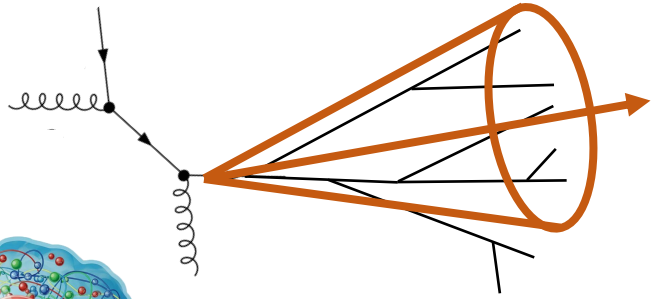
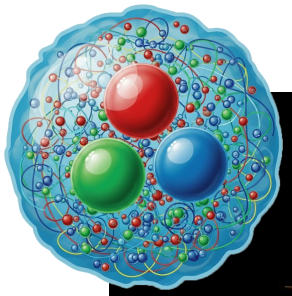
Unraveling QCD using hard probes in proton-proton and heavy-ion data

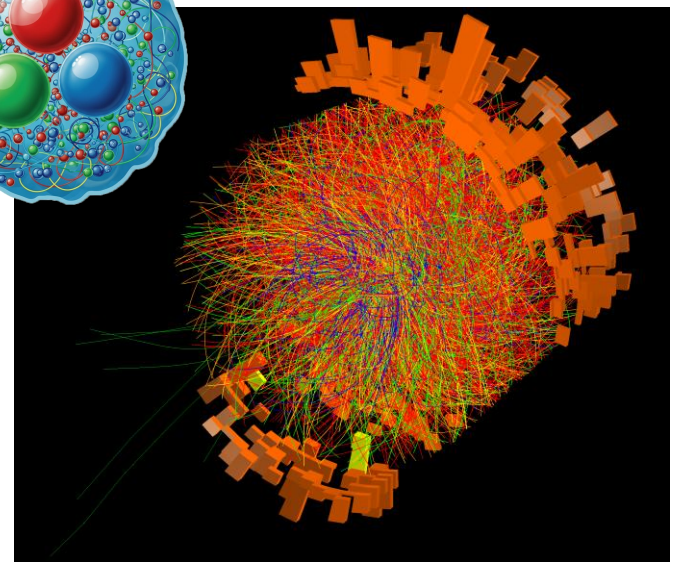


Ezra D. Lesser (LANL)

18 May 2026

Seminar – LLR (CNRS)
Paris, France





Quantum ChromoDynamics

- **QCD** is the theory of the **strong nuclear interactions**

Quantum ChromoDynamics

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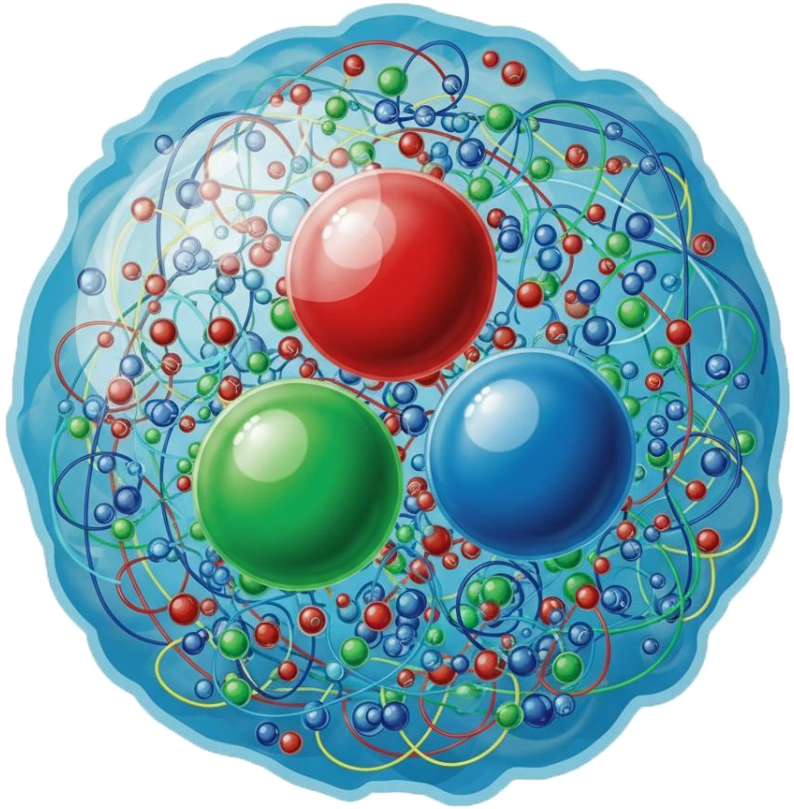

Formation of nucleons and their structure

Quantum ChromoDynamics

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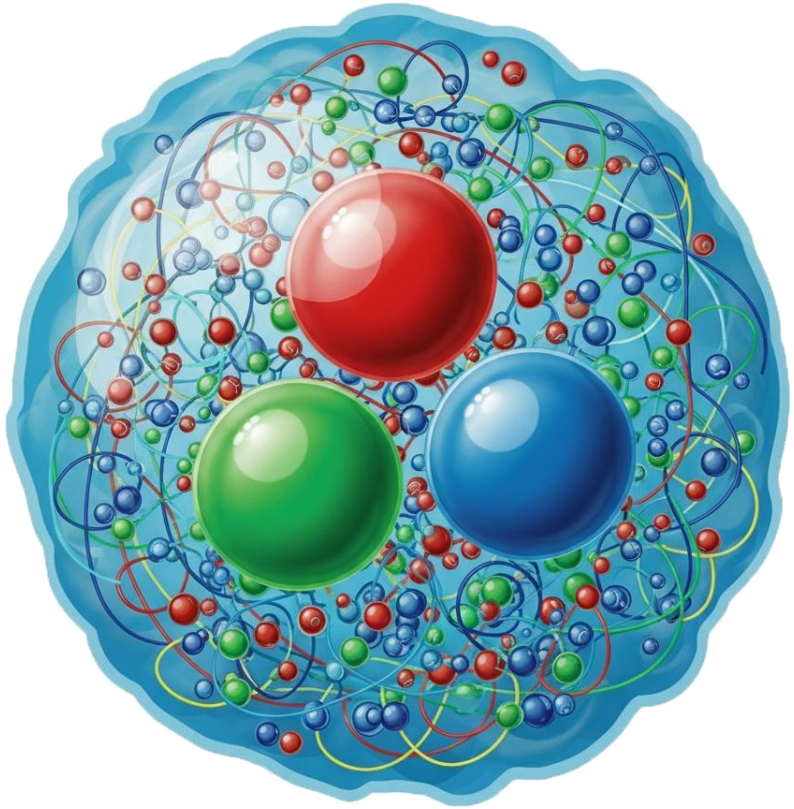

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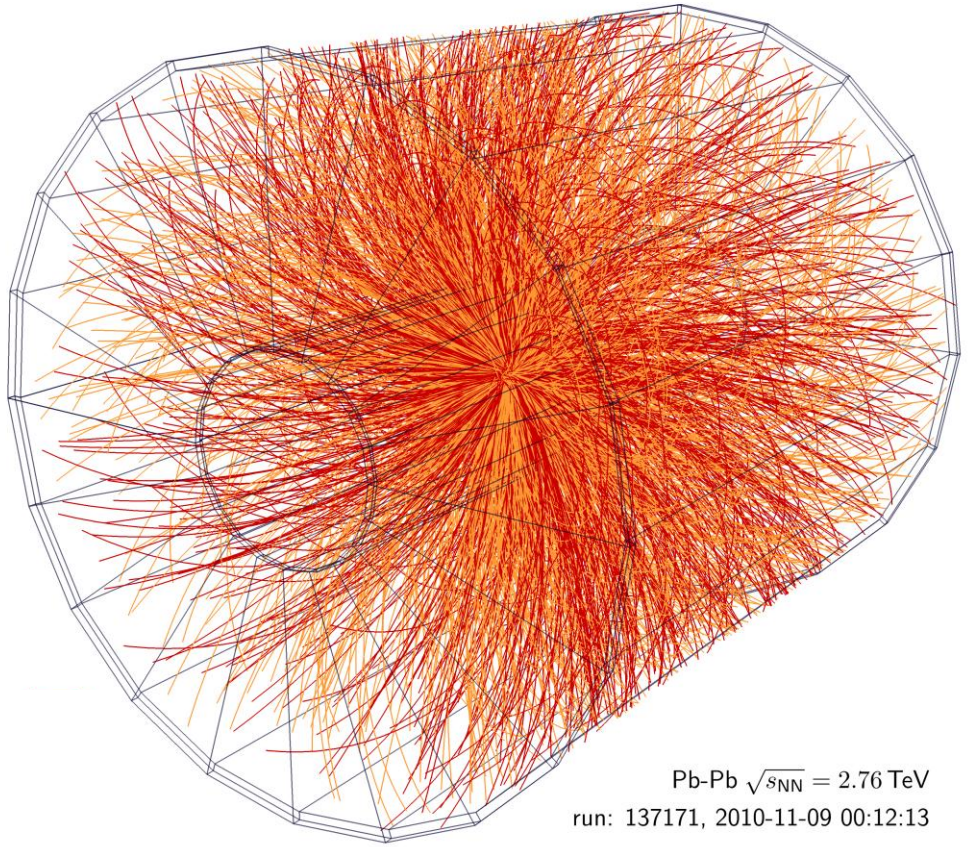

Hot, dense conditions of the early universe

Quantum ChromoDynamics

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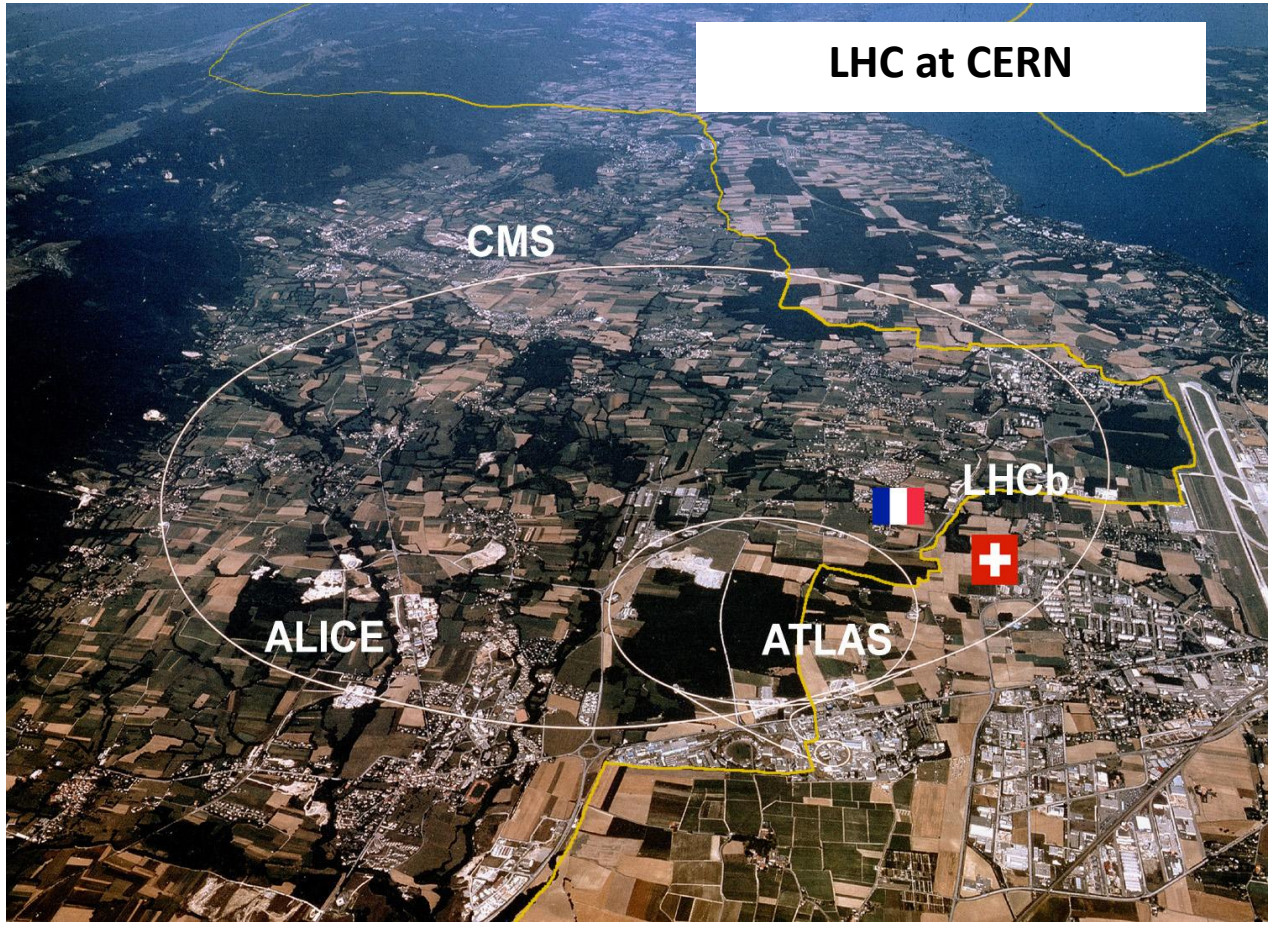
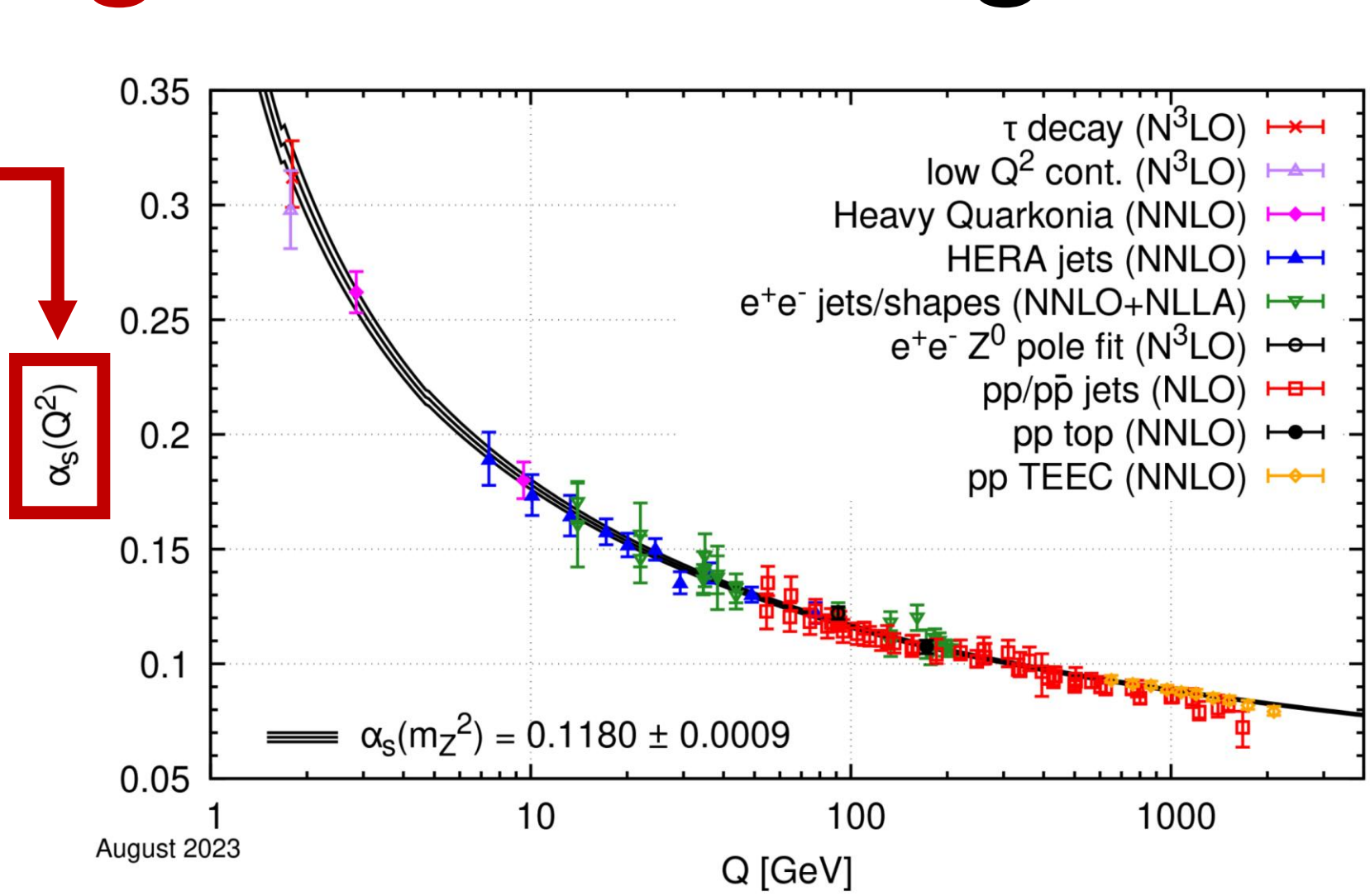


- We study **QCD** using particle colliders like the **Large Hadron Collider (LHC) at CERN**

- **Extreme energies** produce **hard probes** of the theory

Strength of the strong force

Strength of the strong force



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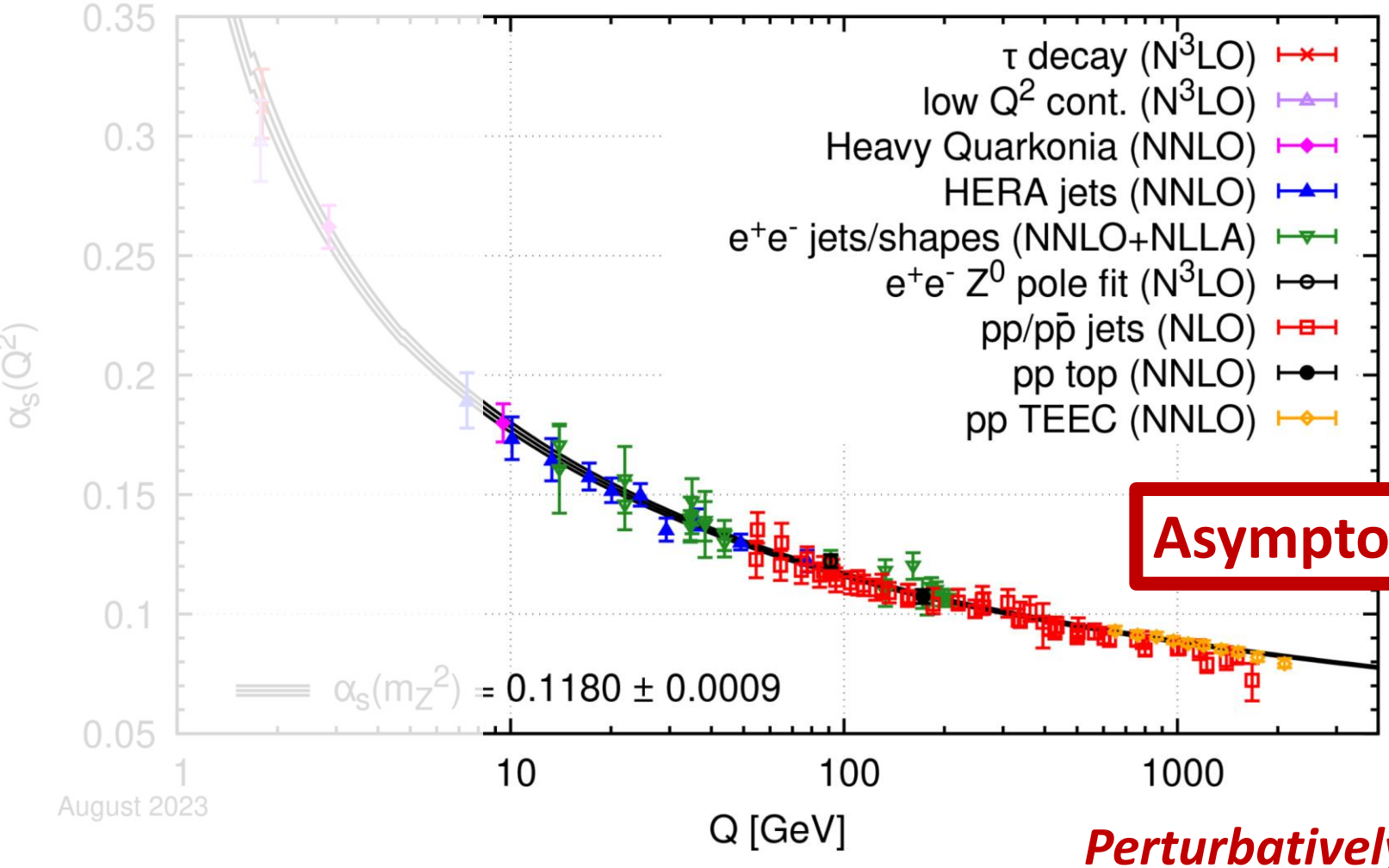
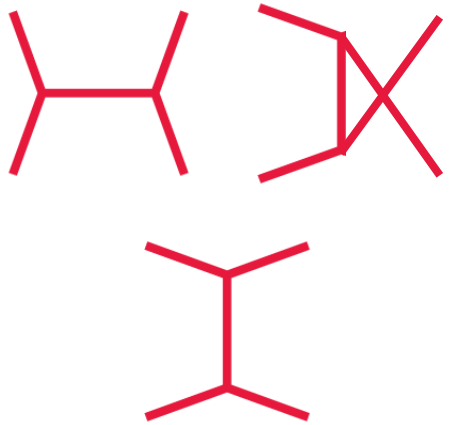
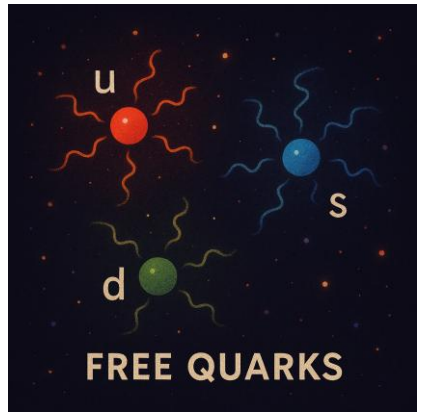
Strength of the strong force





Asymptotic freedom



Perturbatively calculable

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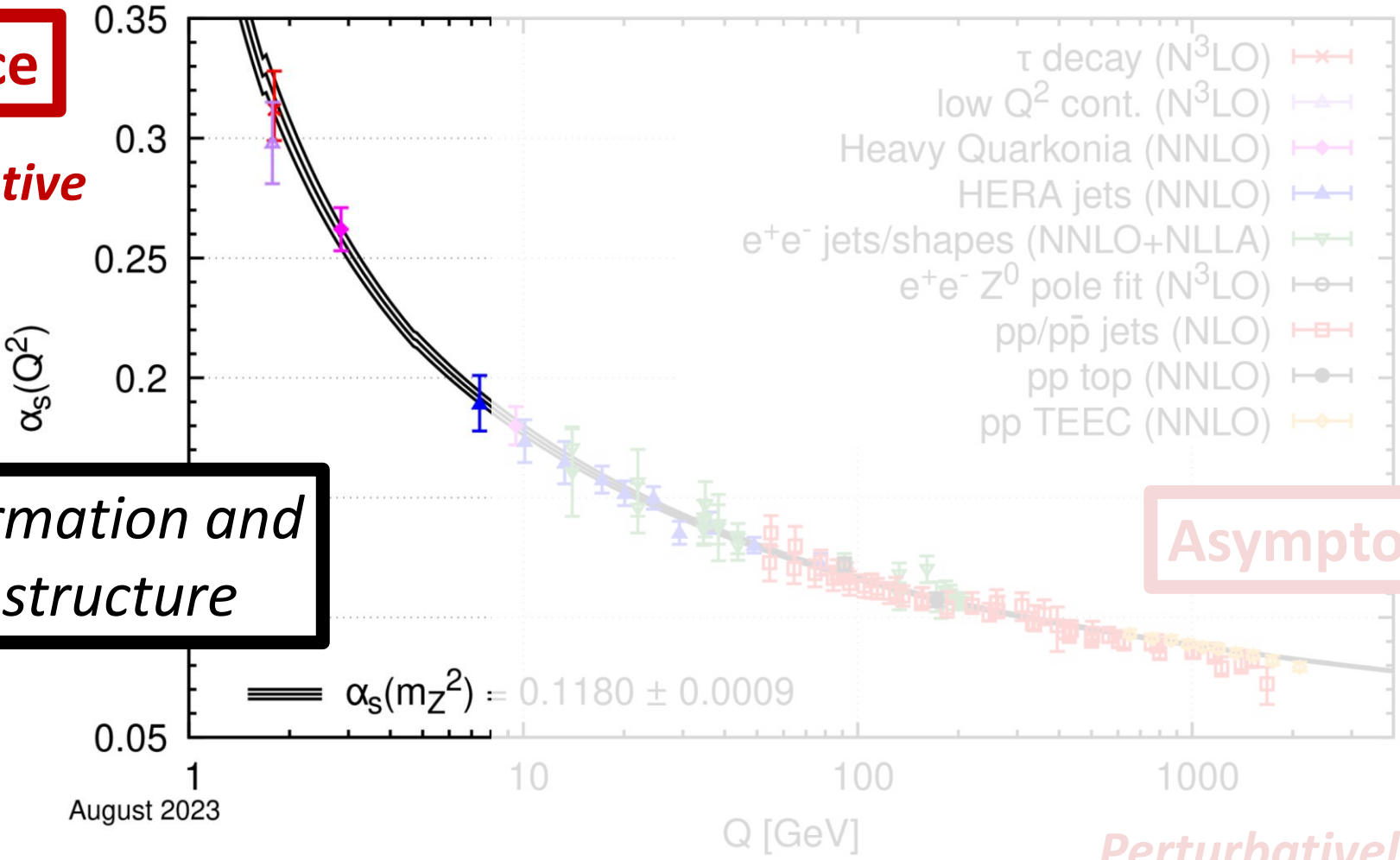
Strength of the strong force

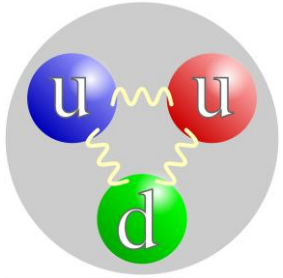
Divergence

Nonperturbative



Hadron formation and internal structure

Asymptotic freedom



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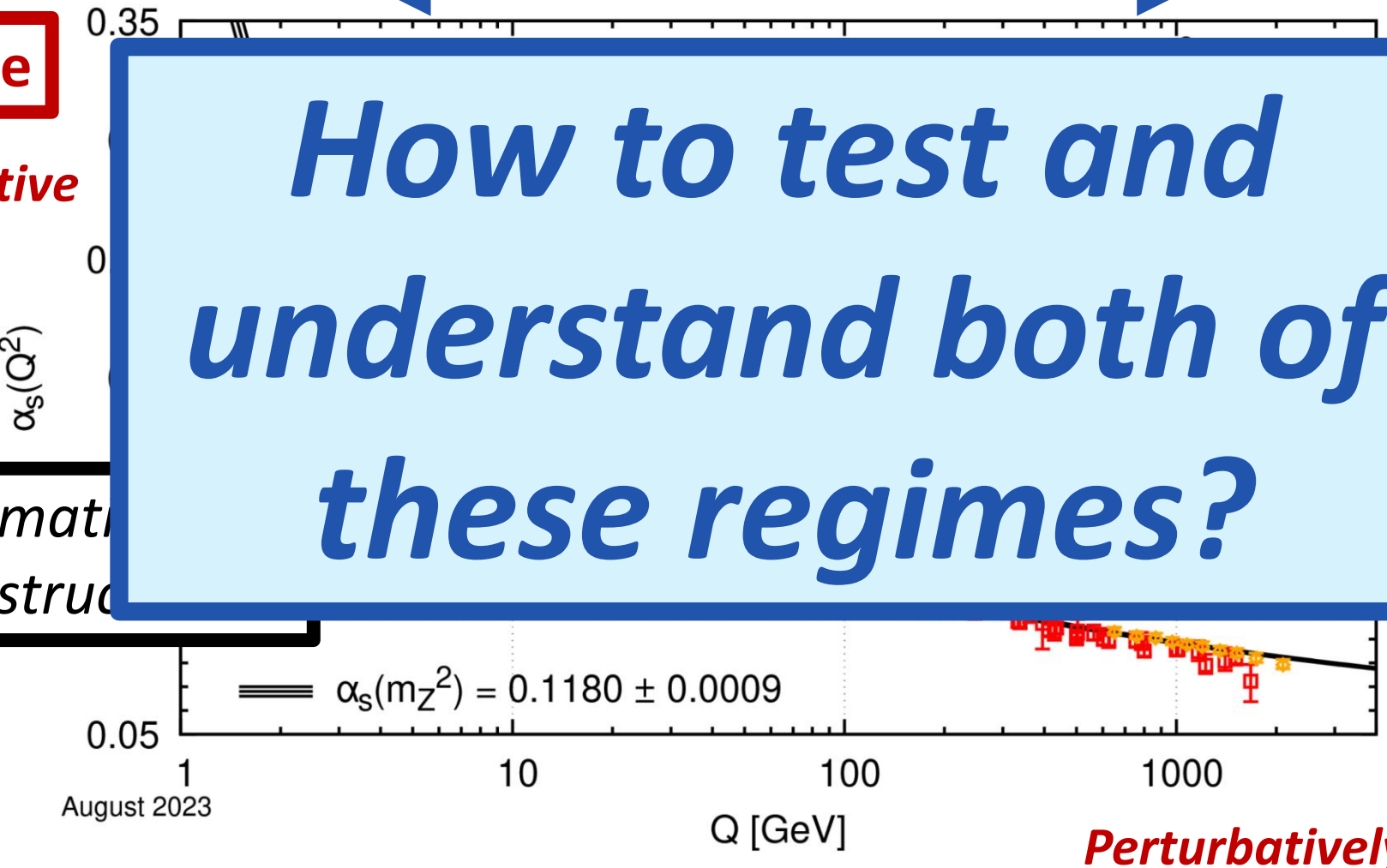
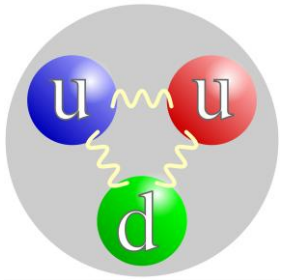
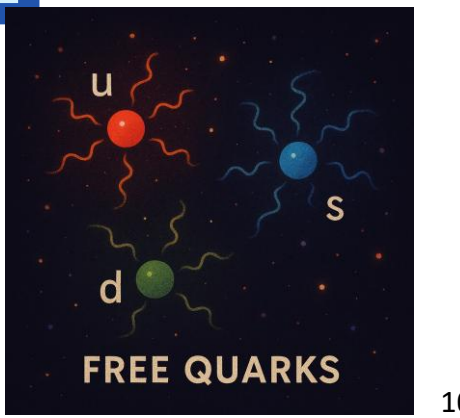


How to test and understand both of these regimes?





freedom

Perturbatively calculable

Hard probes of QCD

- Produced by **high momentum-transfer processes**

Hard probes of QCD

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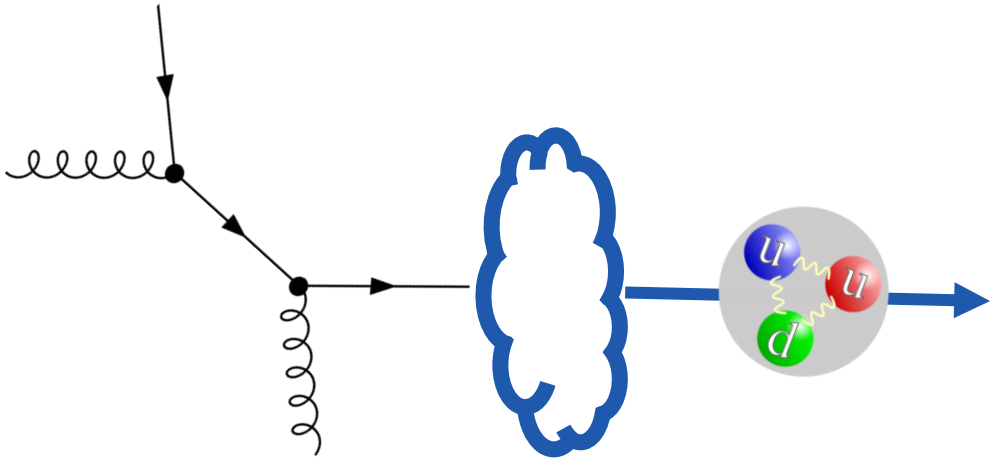
  - **High-p_{T} hadrons,** initiated by a hard scattering;



Hard probes of QCD

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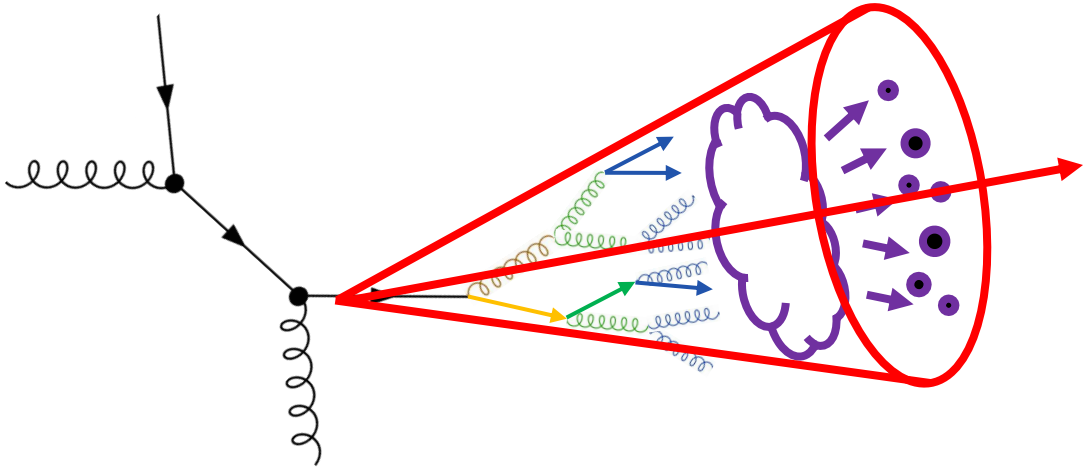

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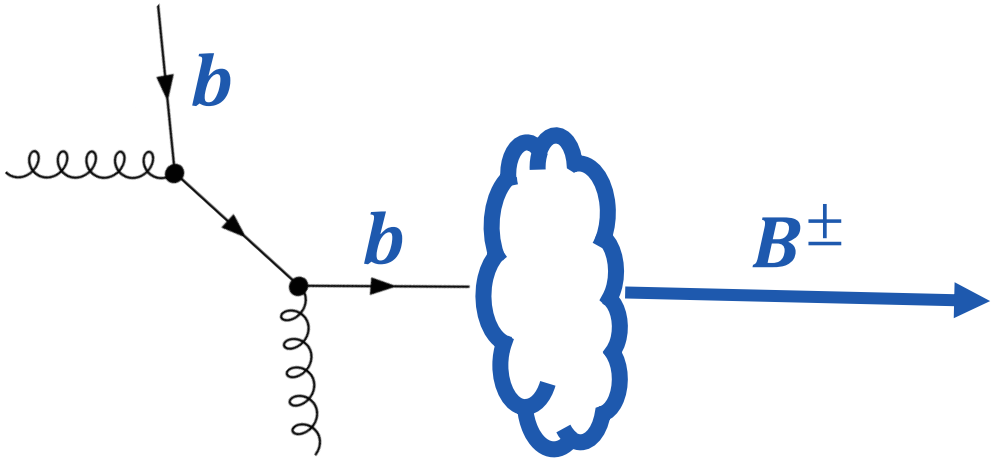


  - **Heavy flavor (HF) hadrons**: particles with large masses, not found in ordinary nuclear matter

Hard probes of QCD

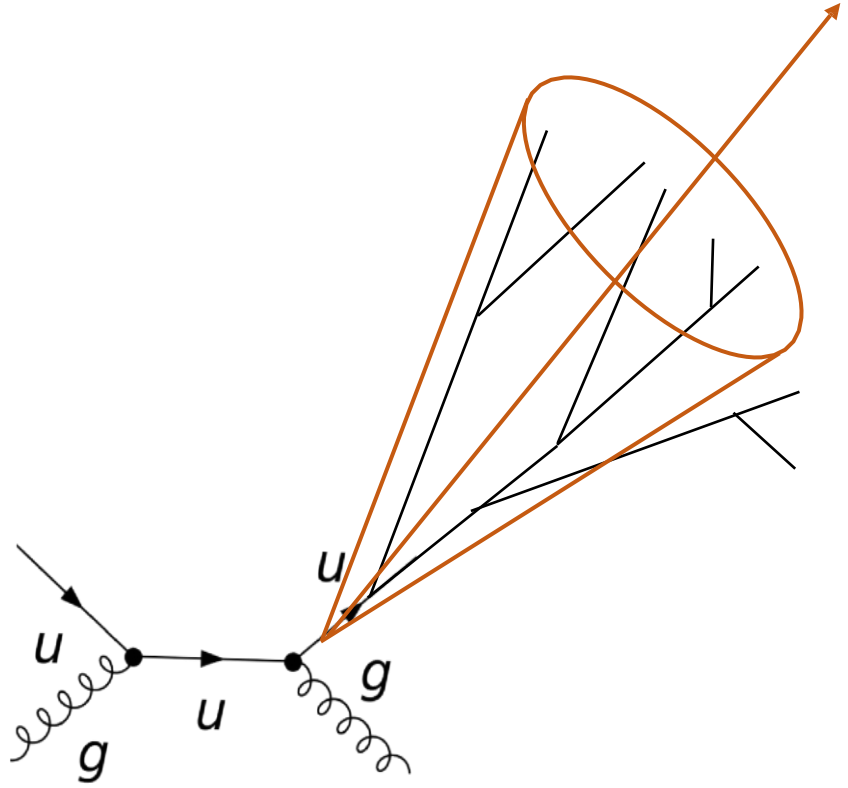
- P

These probes – and combinations of them – allow insight into QCD across different energy scales

found in ordinary nuclear matter

This talk: probing QCD in …

- **“vacuum” (proton-proton collisions)**



This talk: probing QCD in …

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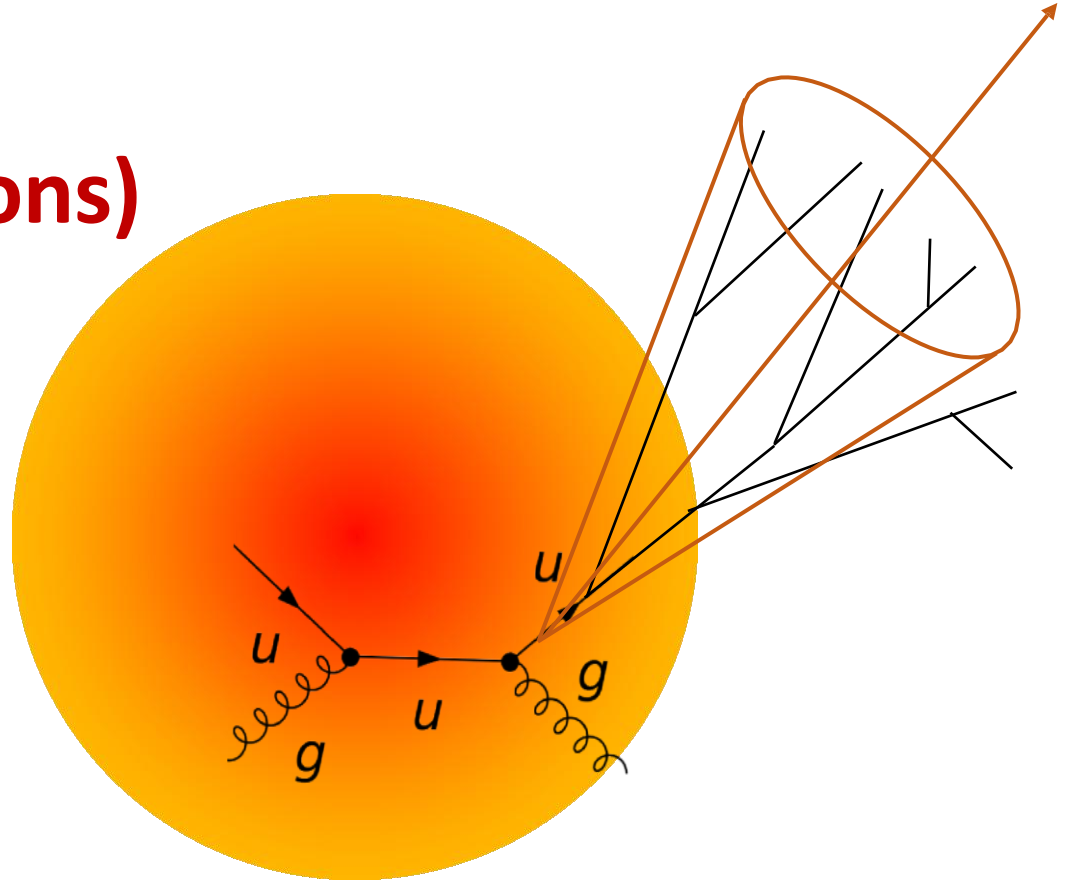

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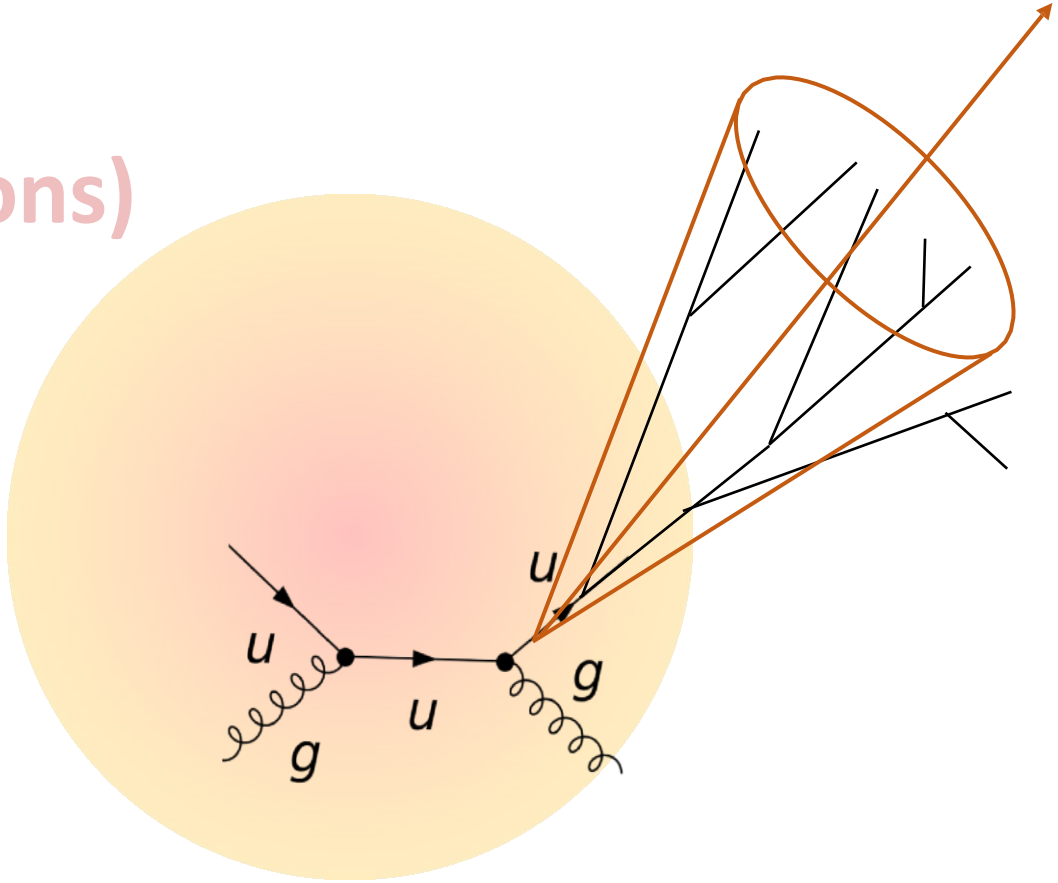

Breaking down a QCD event

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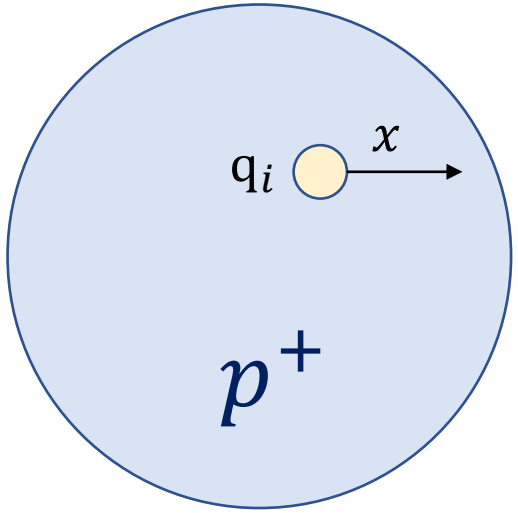
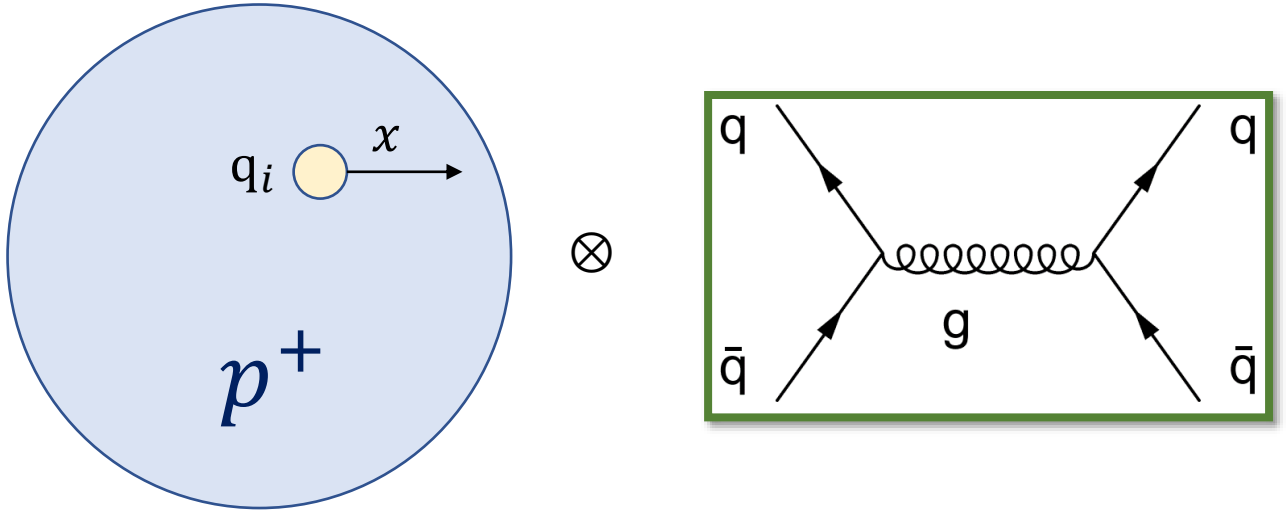
Parton Distribution Functions (PDFs)



Breaking down a QCD event

Parton Distribution Functions (PDFs)

Hard scattering process



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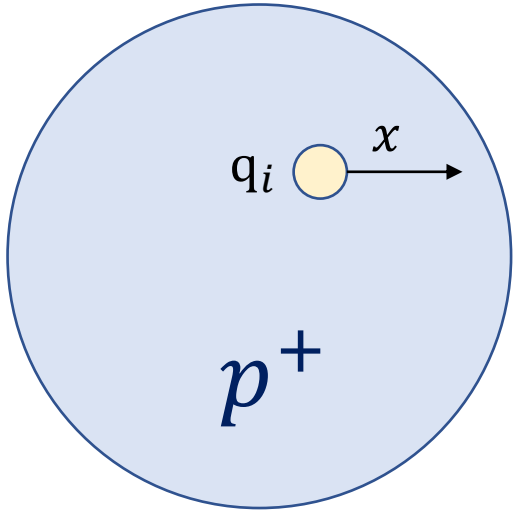

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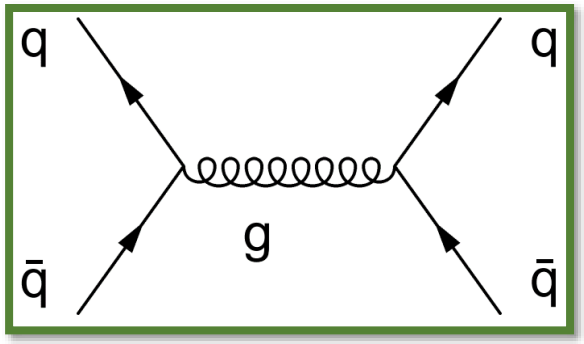

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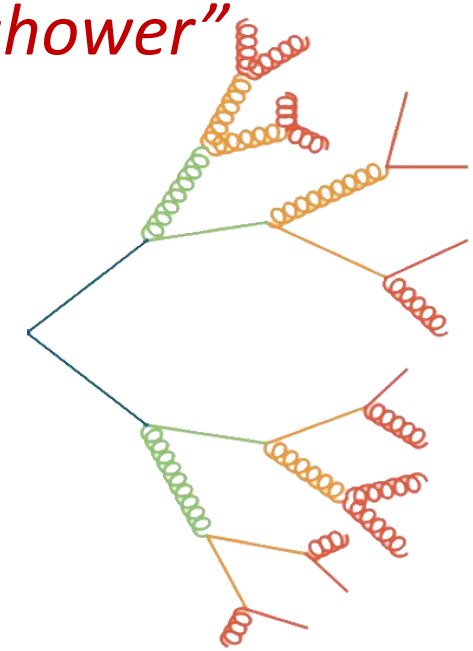
"Parton shower"



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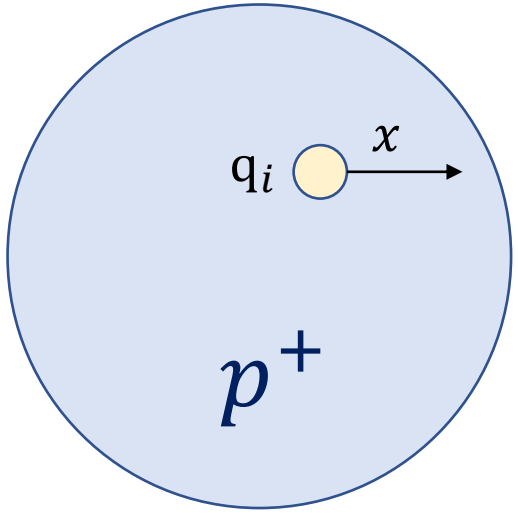

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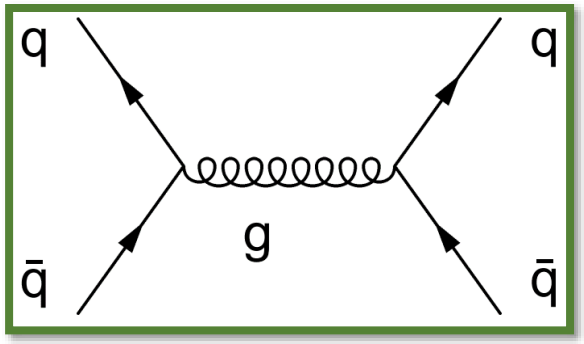

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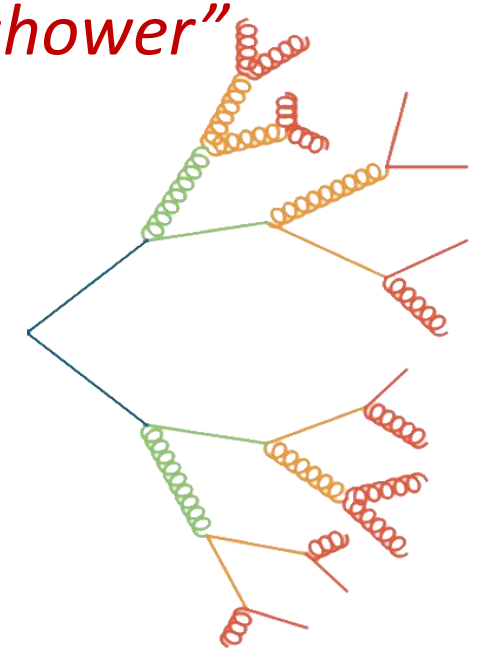

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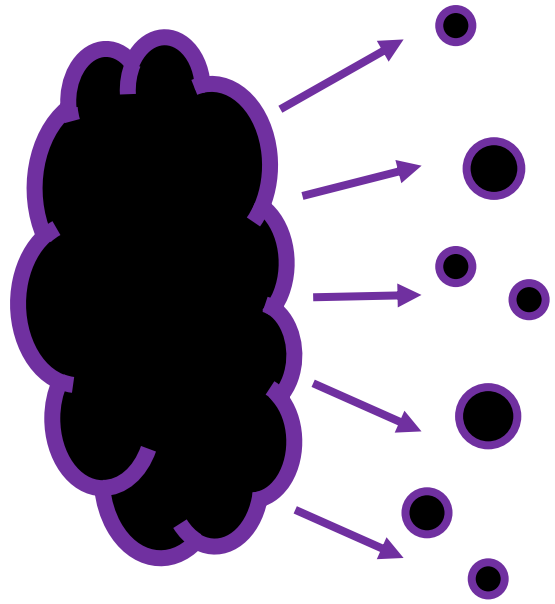
Hadronization



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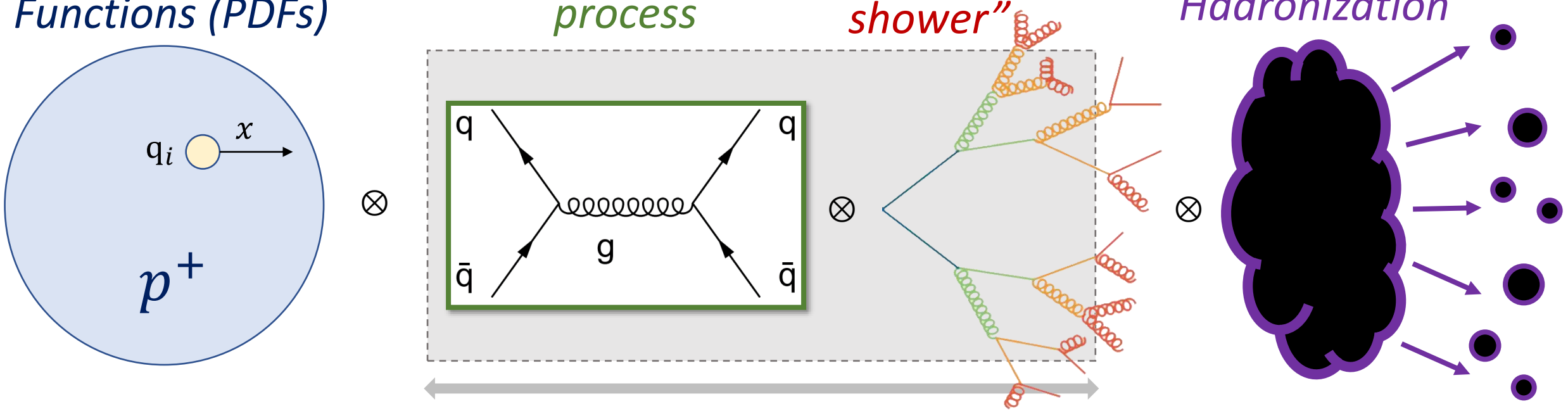

Described by perturbative QCD

Breaking down a QCD event

Parton Distribution Functions (PDFs)

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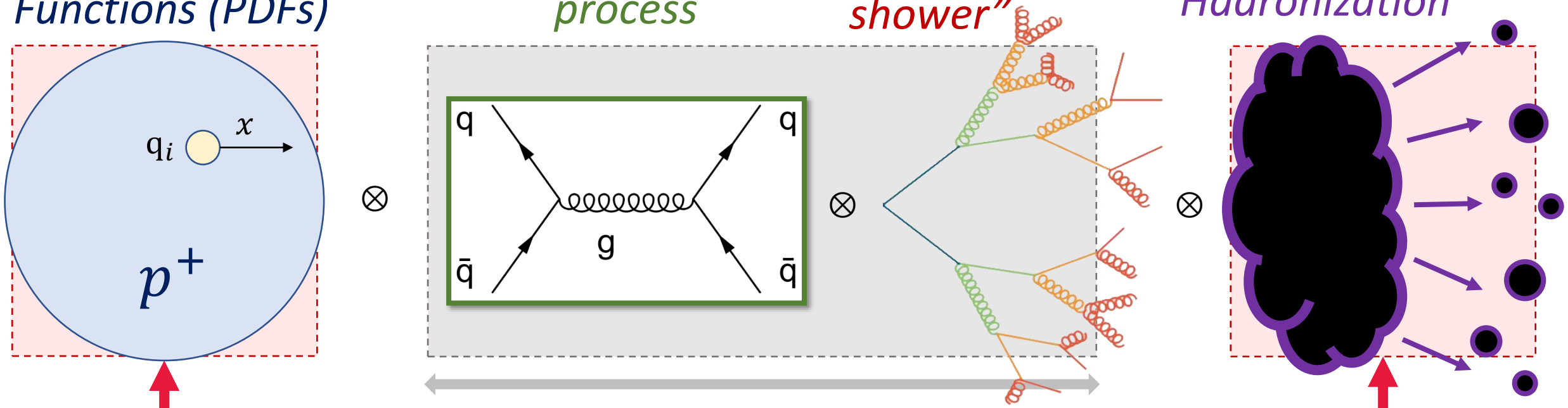
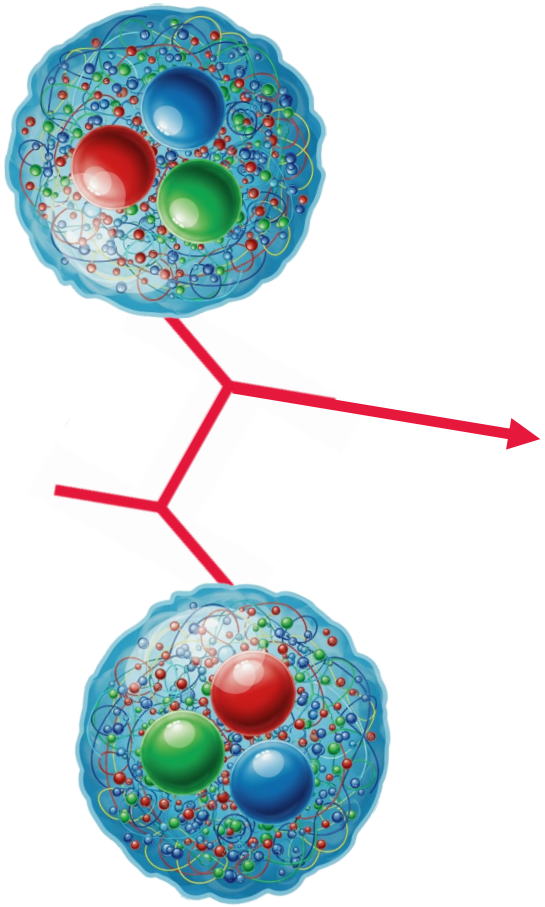


Described by perturbative QCD

Nonperturbative QCD: extracted from experimental data

Jets as a QCD hard probe



Energy scale Q: **High**

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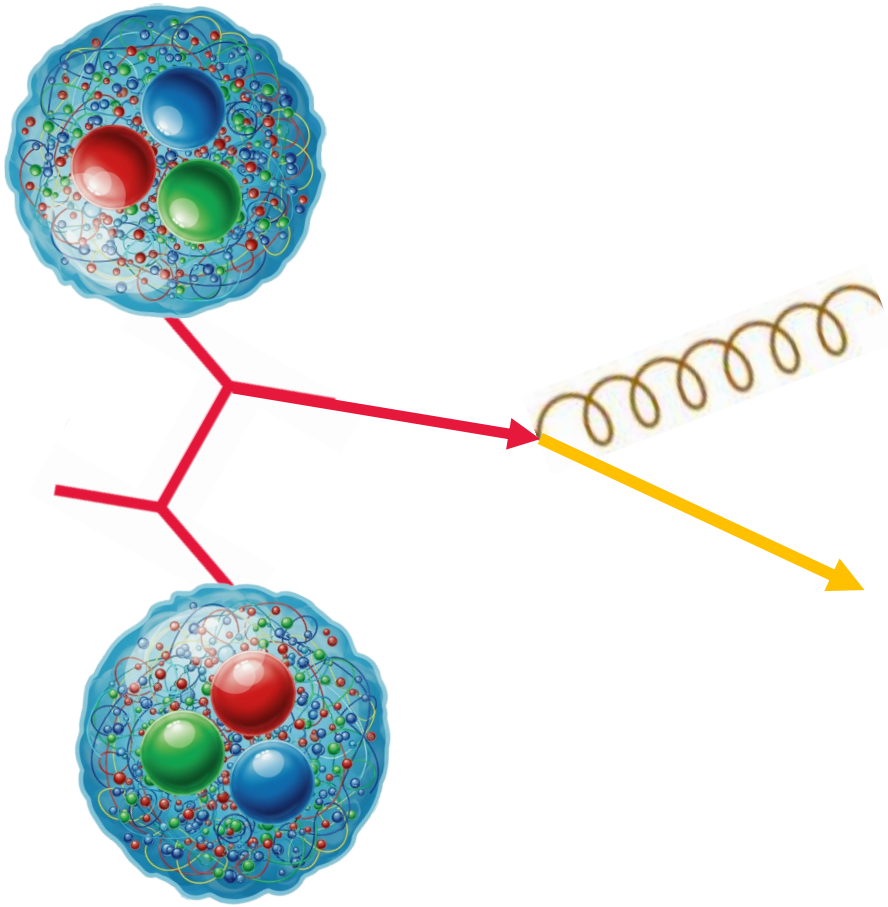

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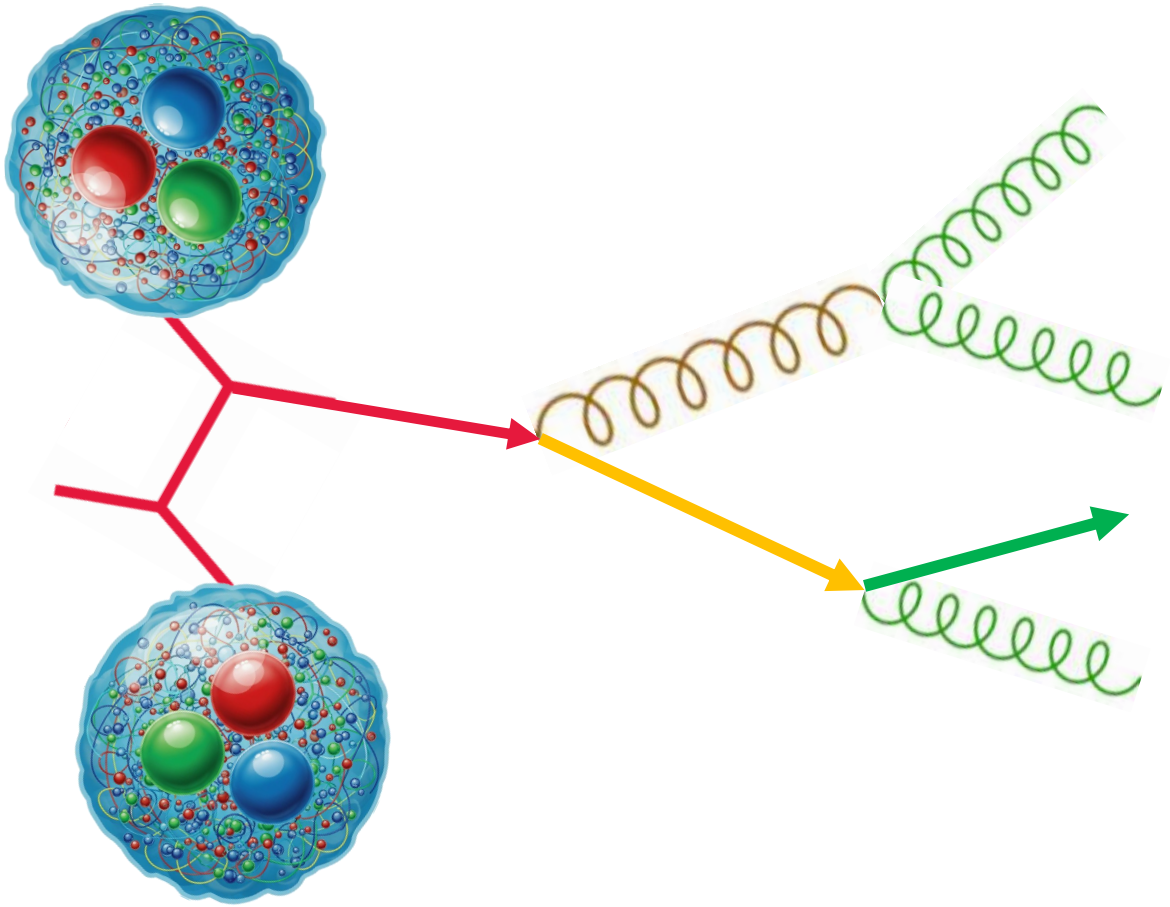

Energy scale Q: **High** →

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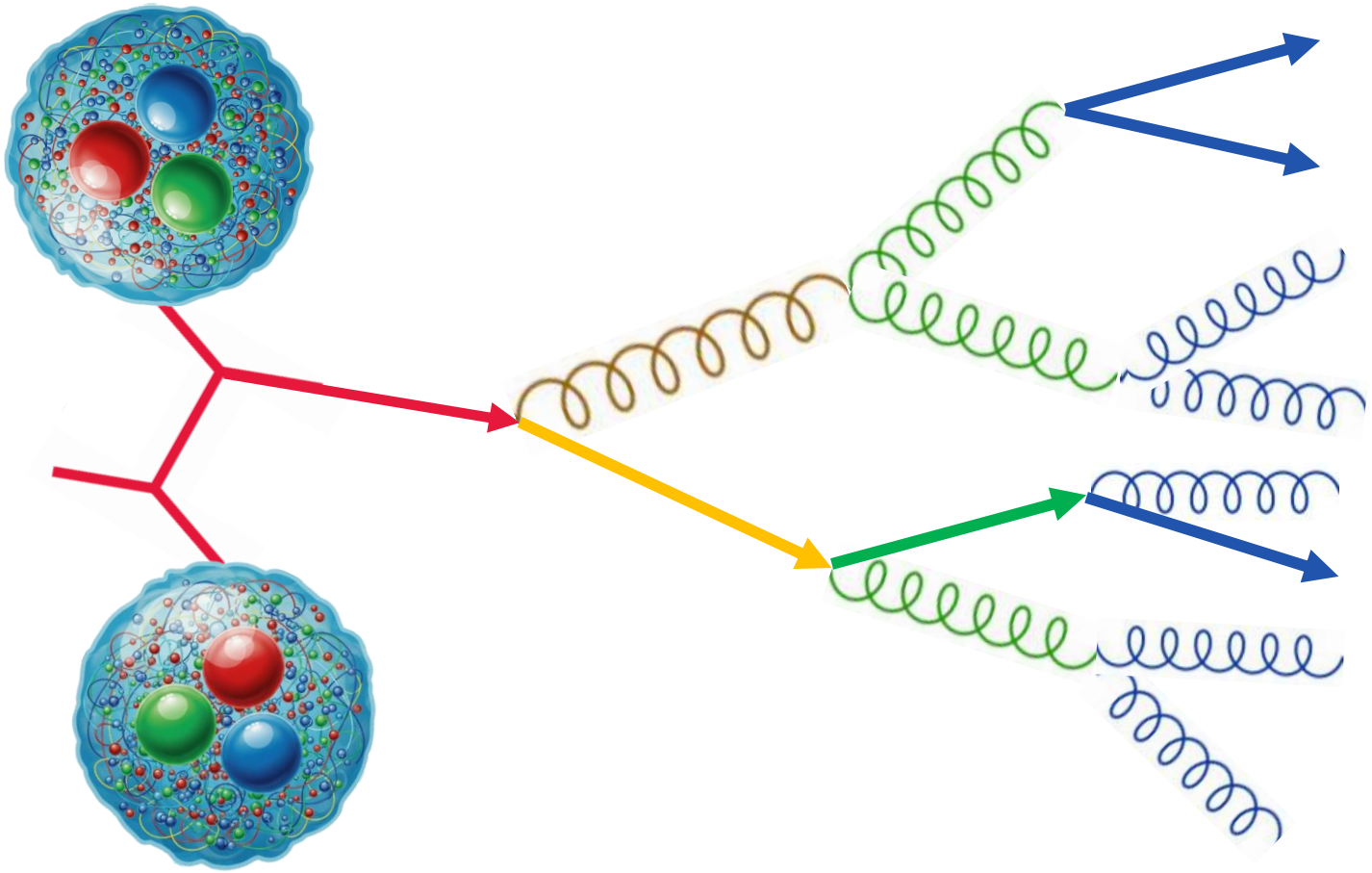
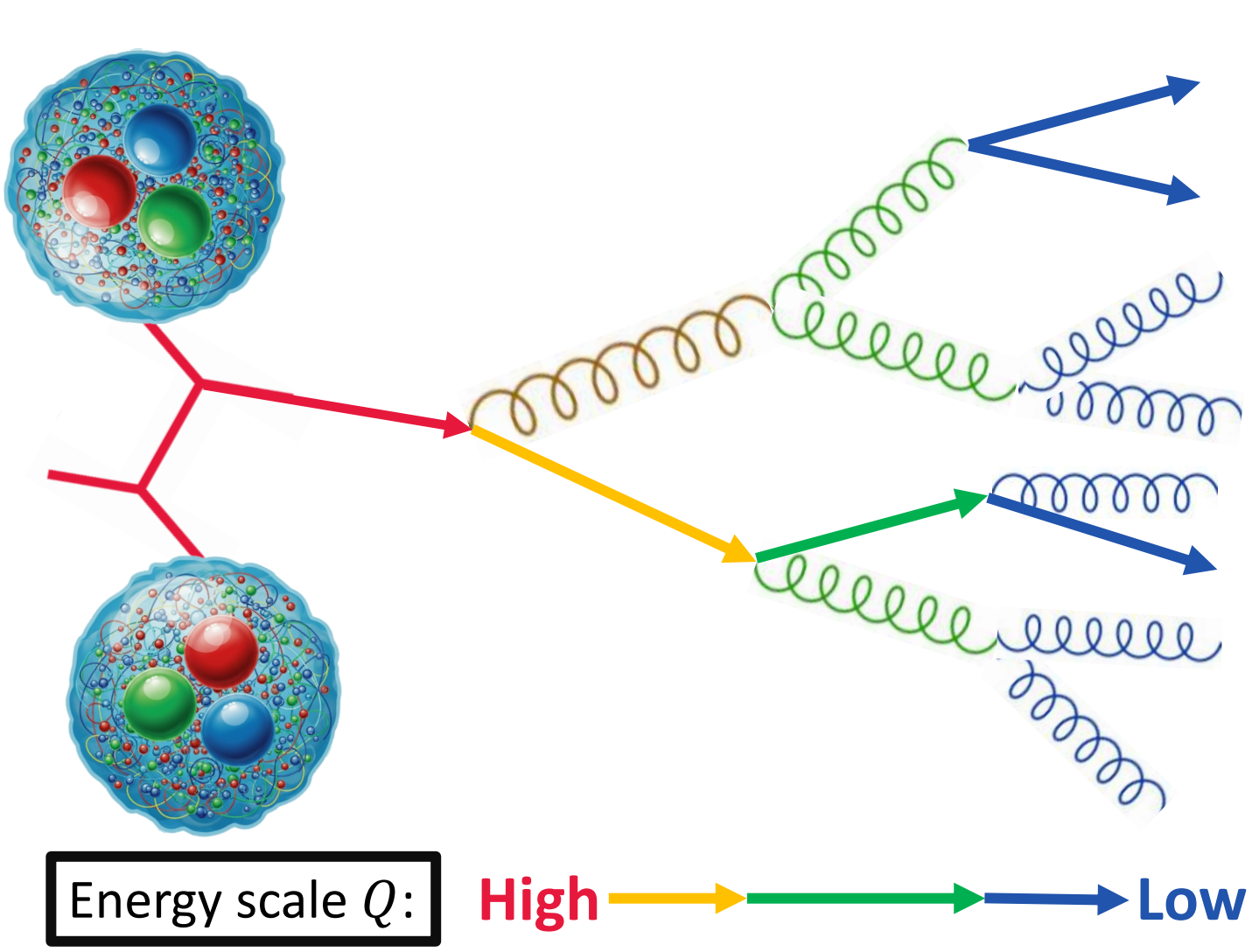


Energy scale Q: **High** → **Low**

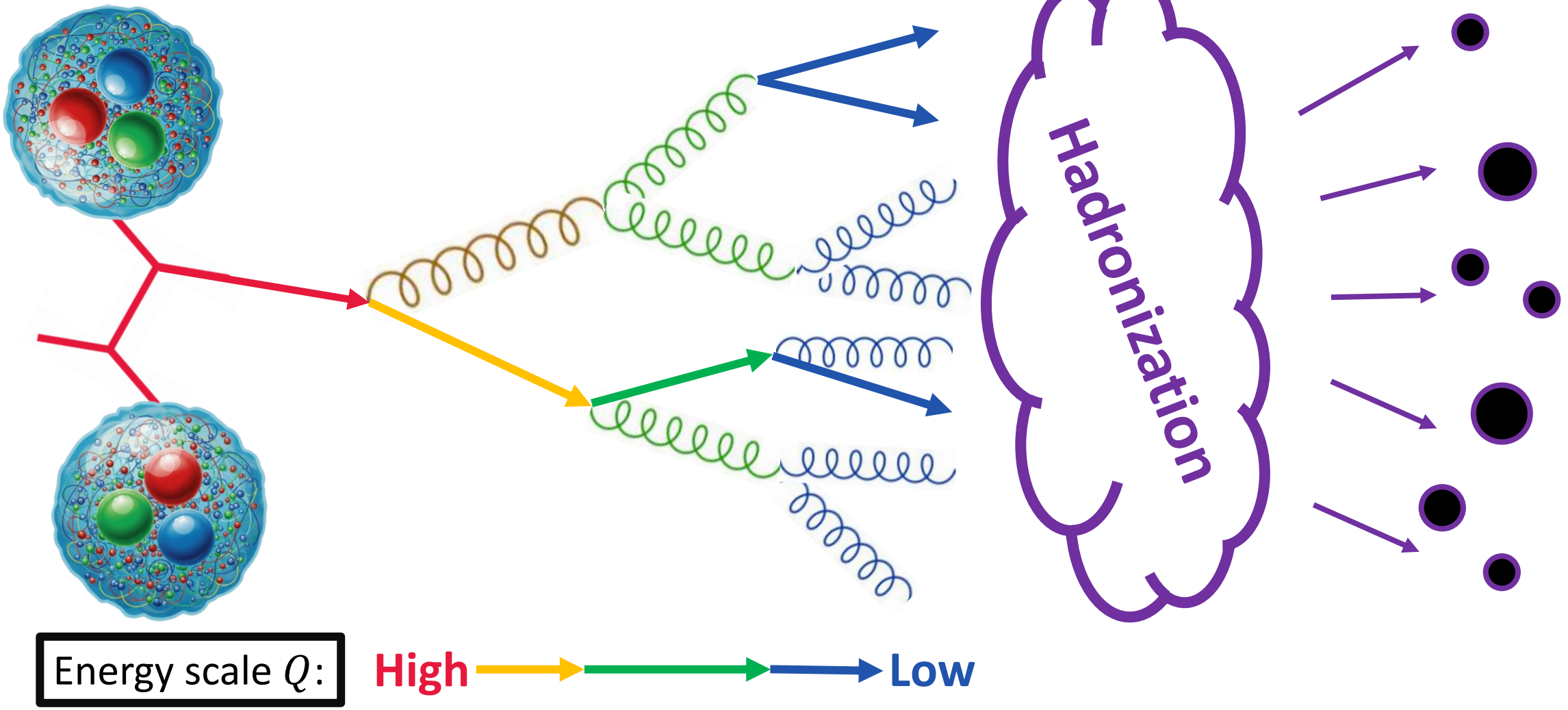
Jets as a QCD hard probe



Connect partons back into hadrons

→ **nonperturbative QCD**

Jets as a QCD hard probe



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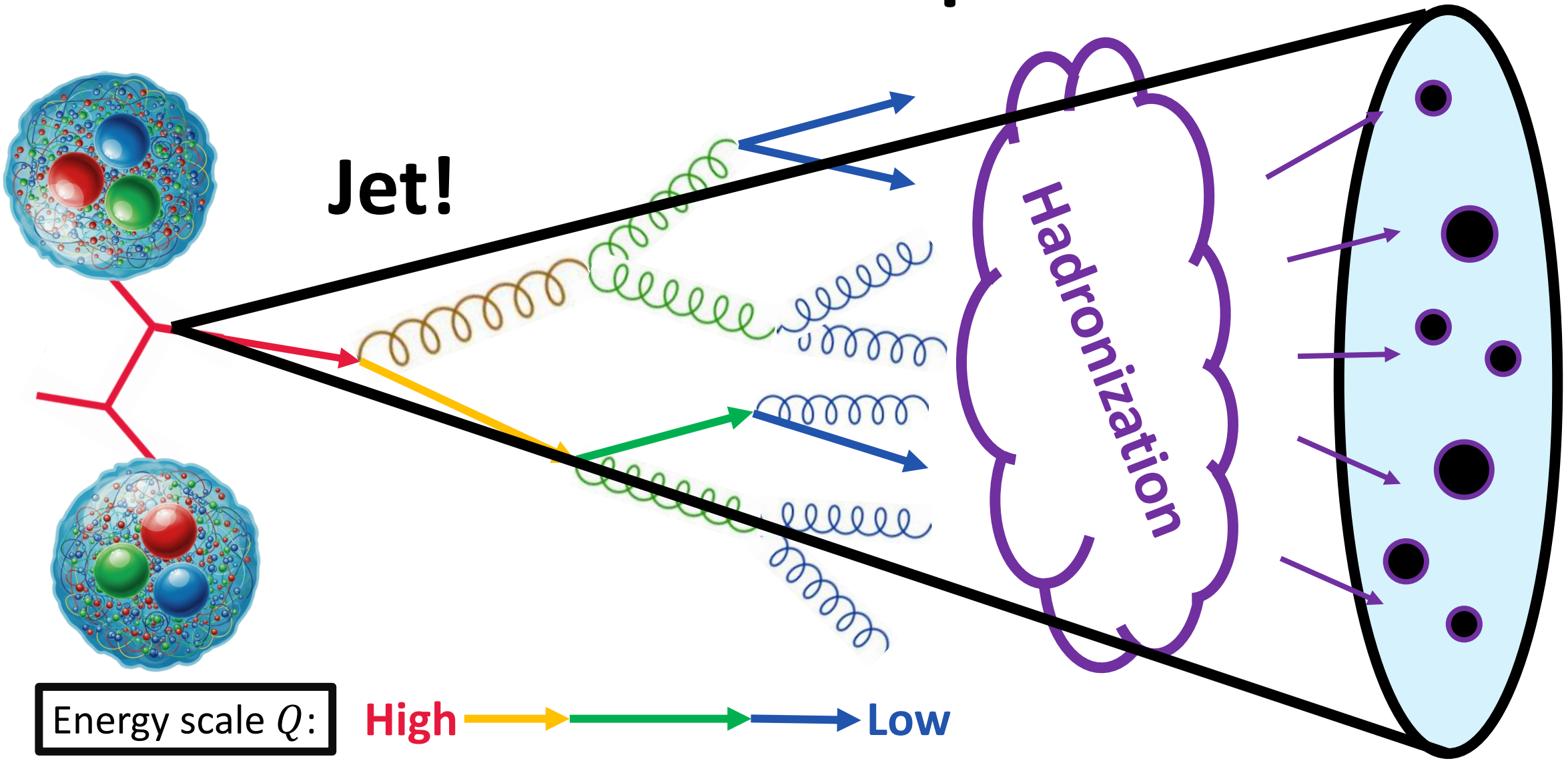

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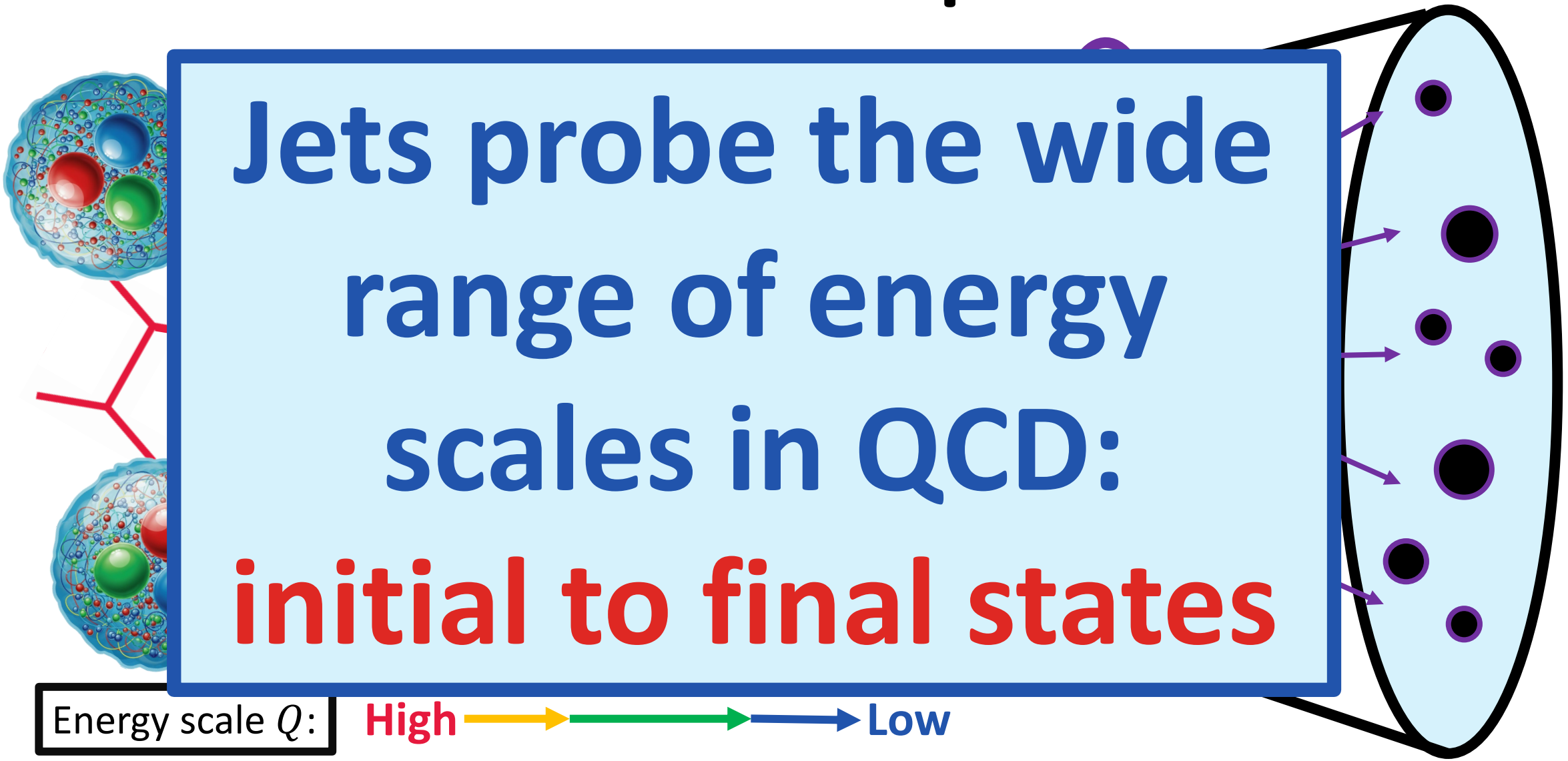
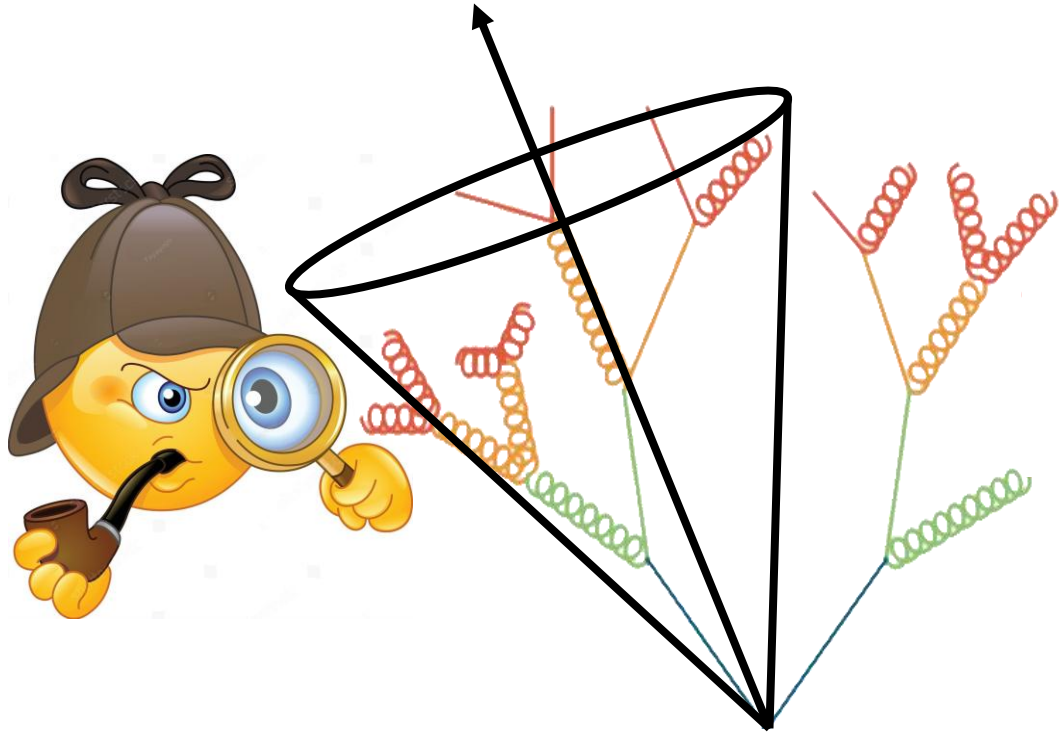


A flexible probe of QCD

- Jets and **jet substructure observables** can therefore be "tuned" to study specific processes of QCD



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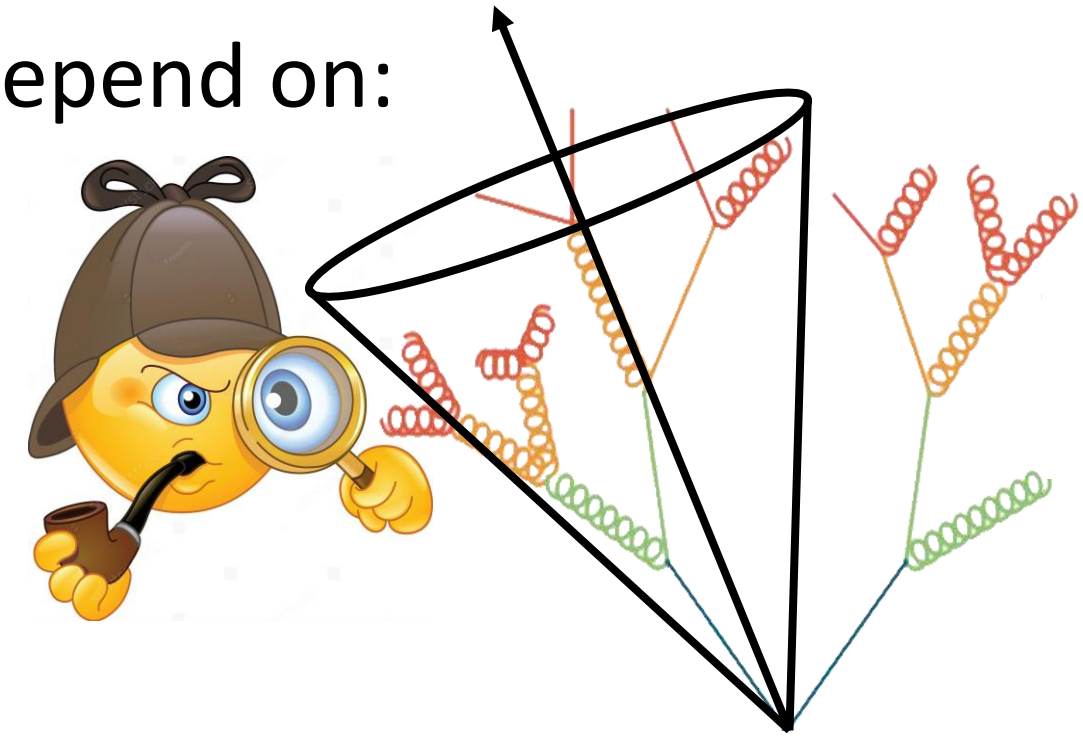

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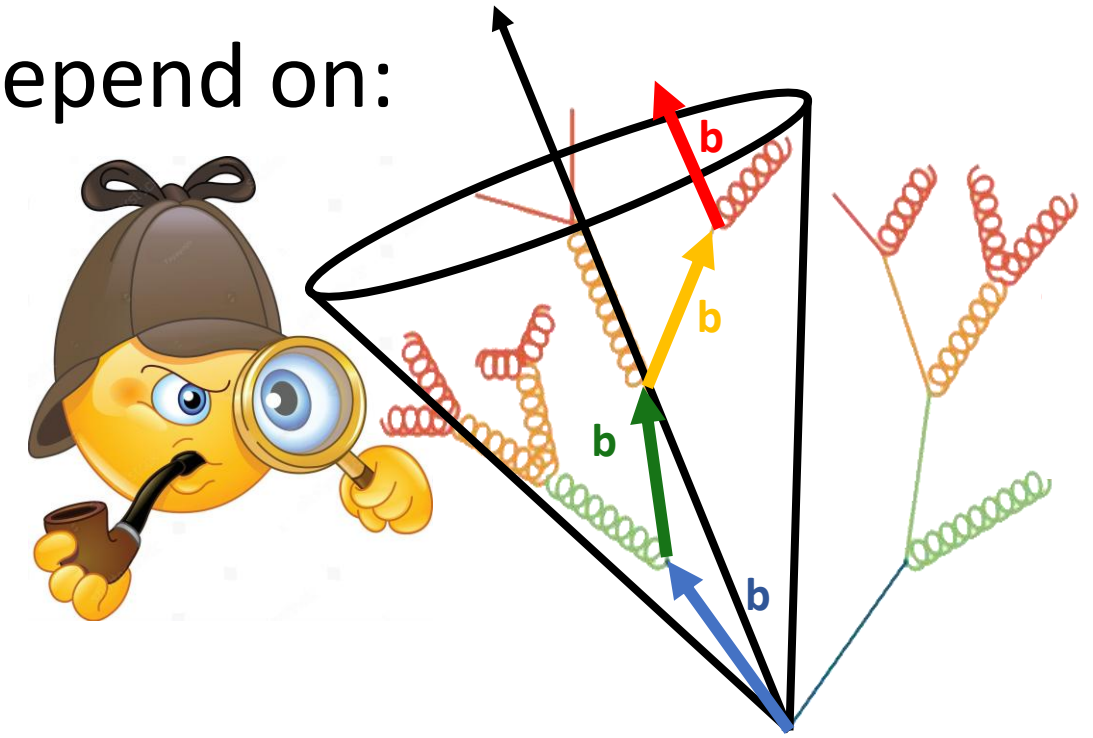

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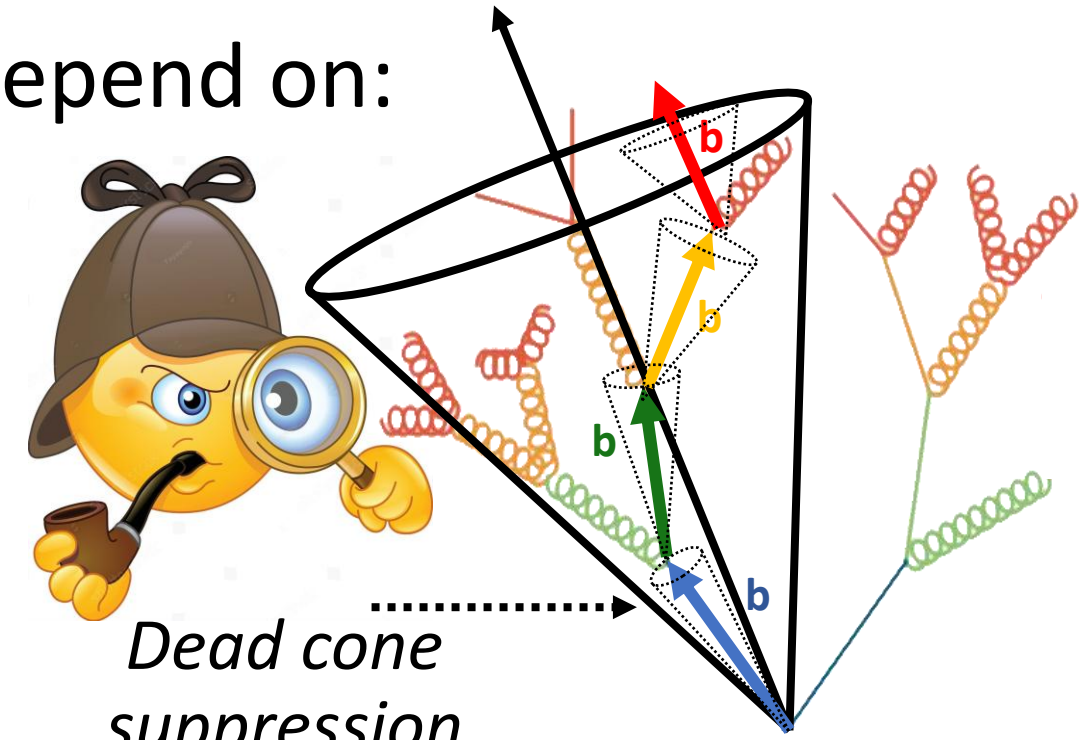

Dead cone suppression

J. Phys. **G17** (1991) 1602

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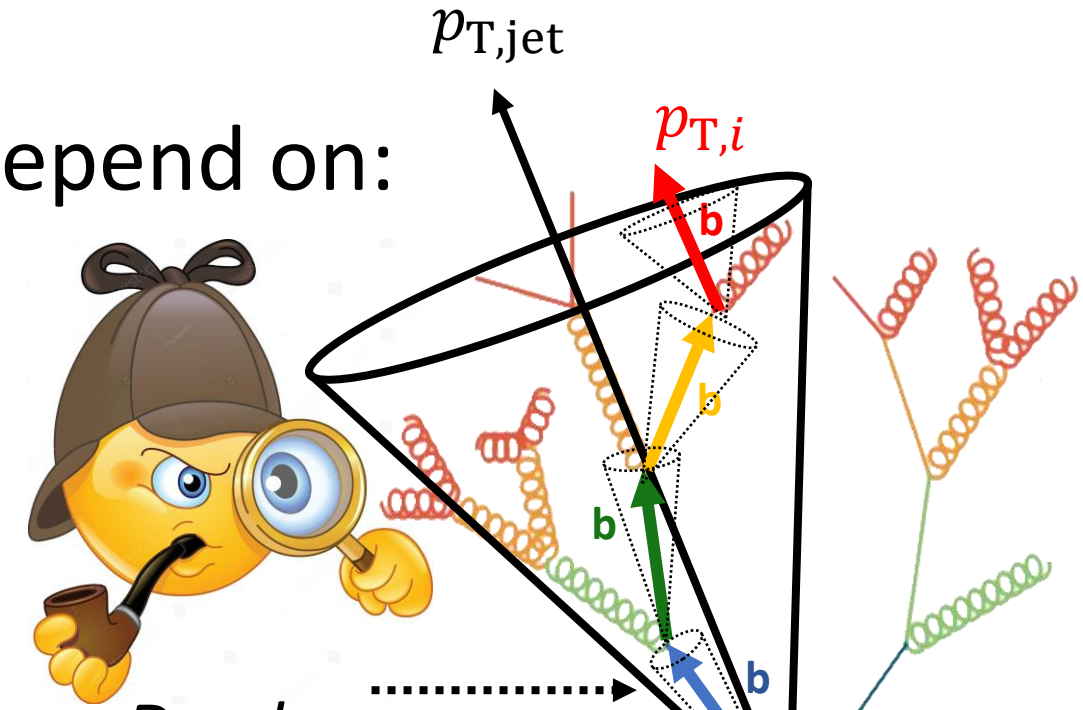

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$$Q^2 = E^2 - p^2$$

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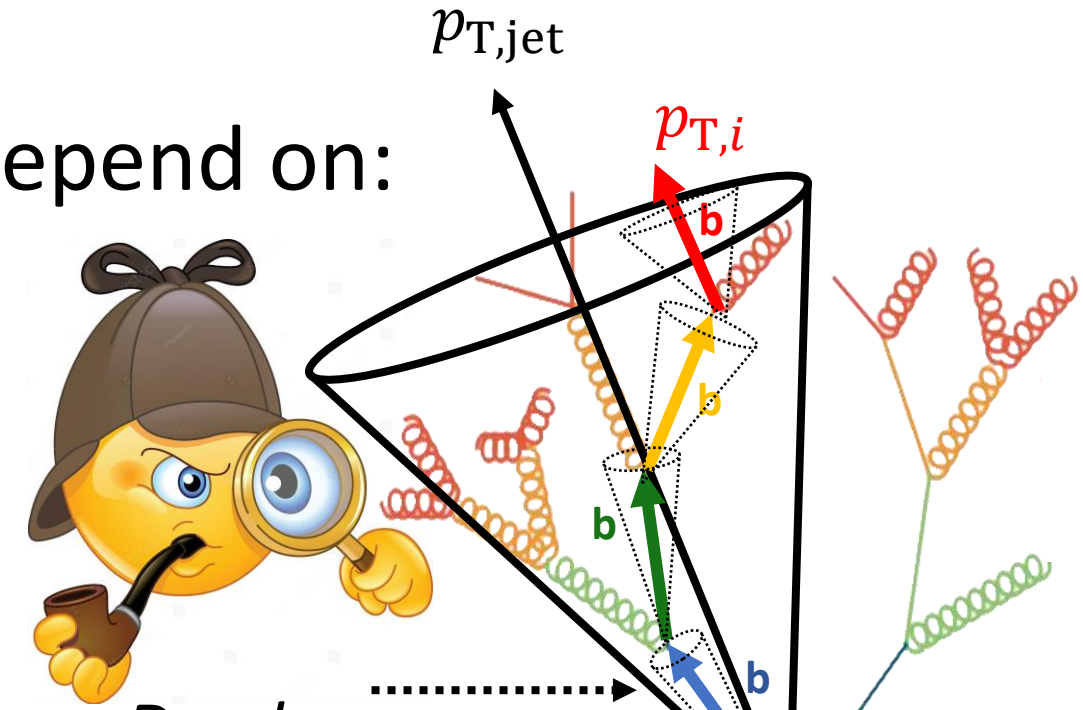
- **How well can QCD predict these effects in data?**



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Criteria for calculability

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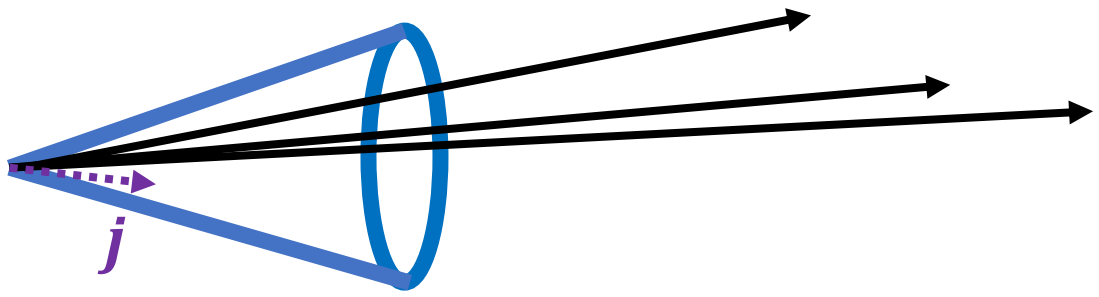
the jet/observable should not change if **a low-momentum ($p \approx 0$) particle j** is added to the event/jet



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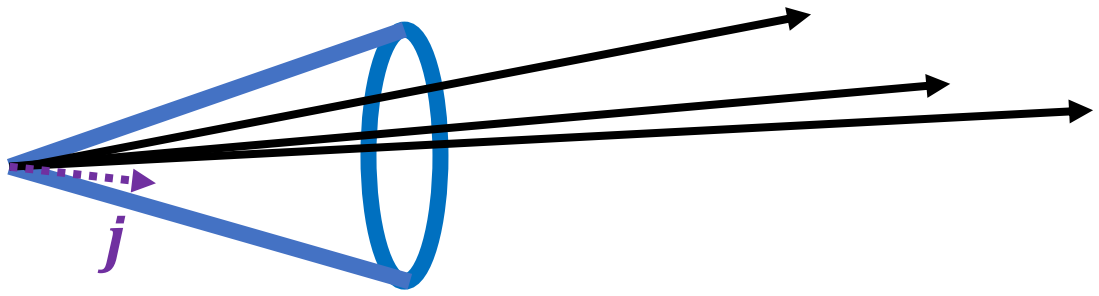
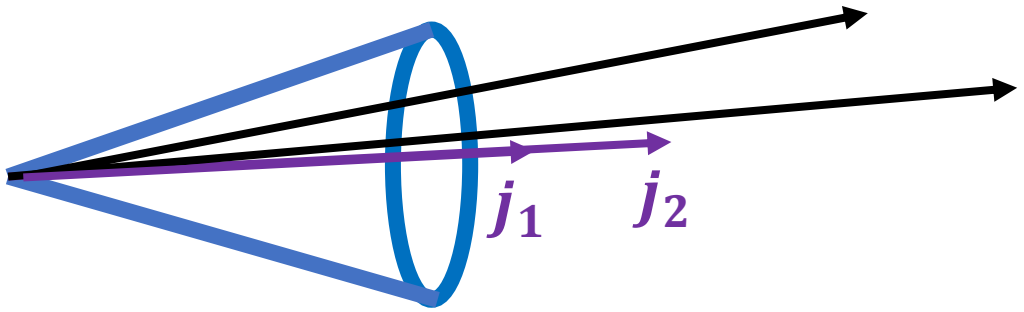


Collinear safety:
the jet/observable should not change if one particle **splits into two collinear particles (j_1, j_2)**



Criteria for calculability

Infra-Red safety:
the jet/observable should not change if **a low-momentum ($p \approx 0$) particle j** is added to the event/jet

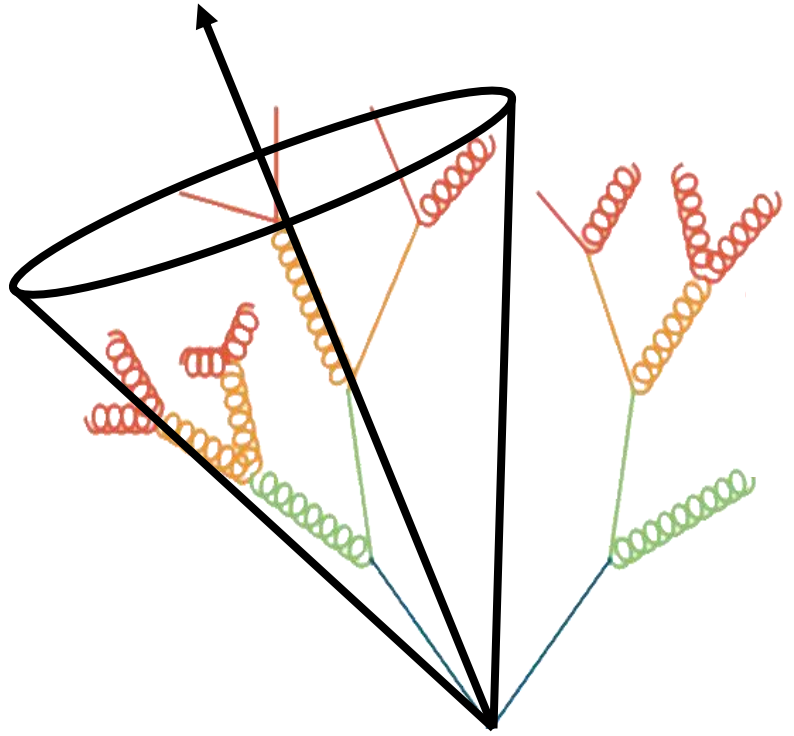
Collinear safety:
the jet/observable should not change if one particle **splits into two collinear particles (j_1, j_2)**

IRC-safe → well-defined path to calculation

Generalized jet angularities

- **IRC-safe jet observables** dependent on constituent p_T and **angle**

$$\lambda_\alpha = \sum_{i \in \text{jet}} \ldots$$



Generalized jet angularities

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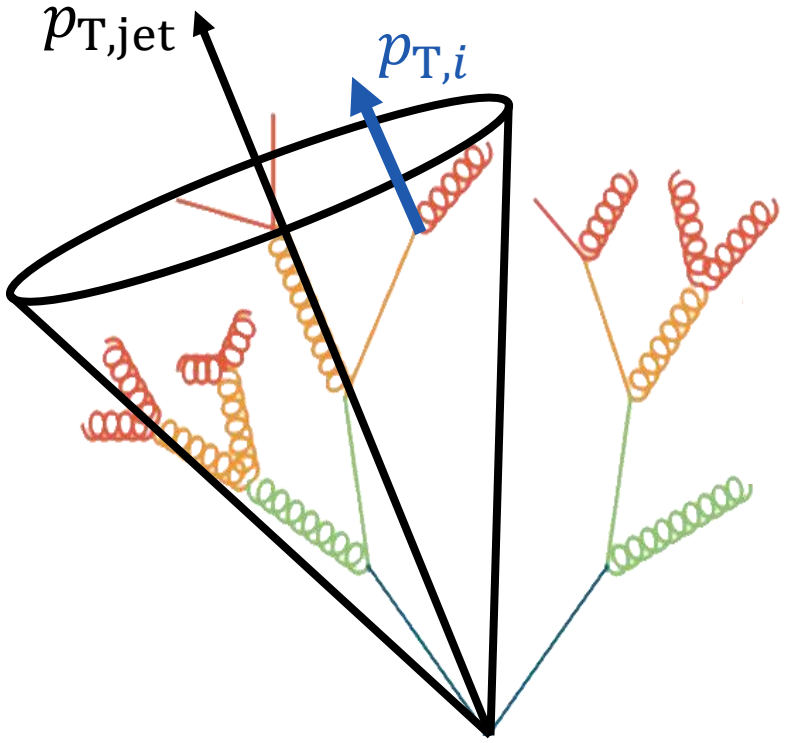
$$\lambda_\alpha = \sum_{i \in \mathrm{jet}} \frac{p_{\mathrm{T},i}}{p_{\mathrm{T,jet}}} \quad \ldots$$



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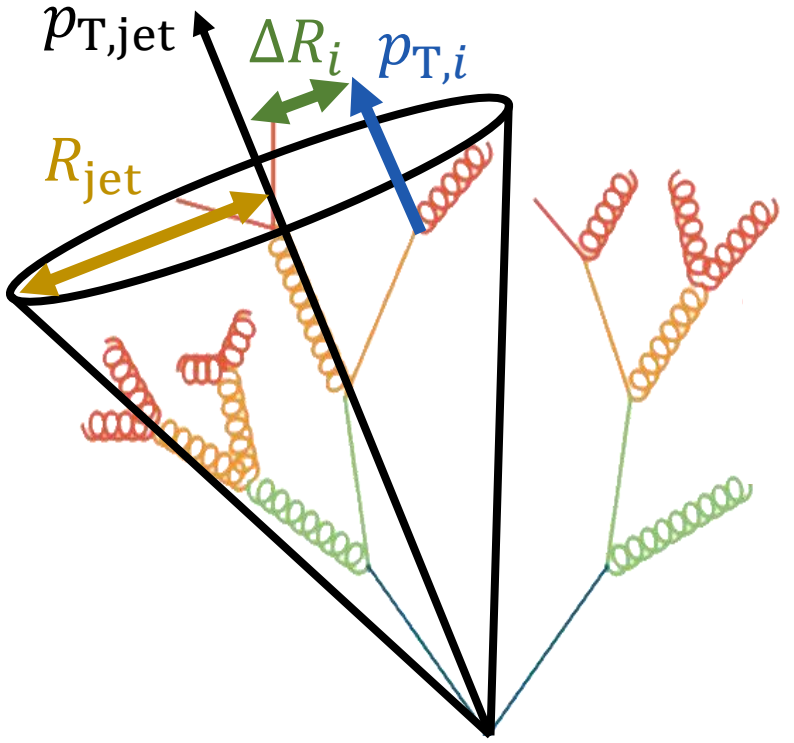

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free parameter

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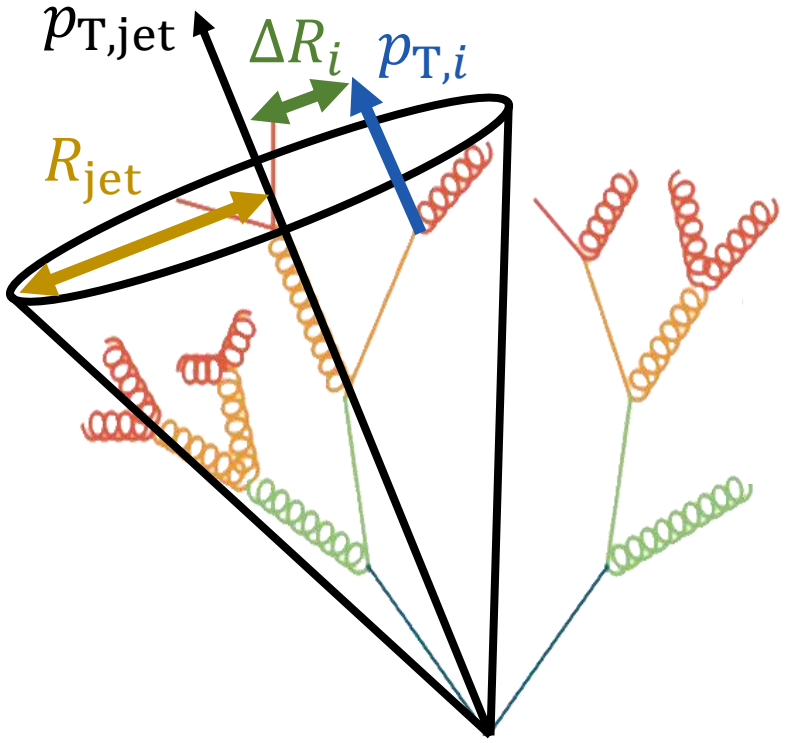

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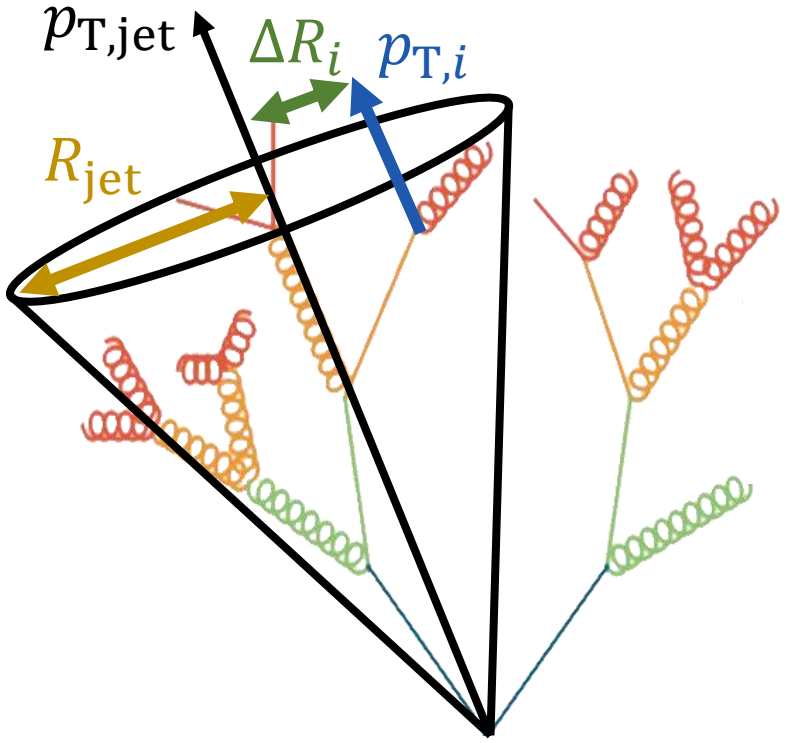
"Where is the p_{T} inside the jet?"



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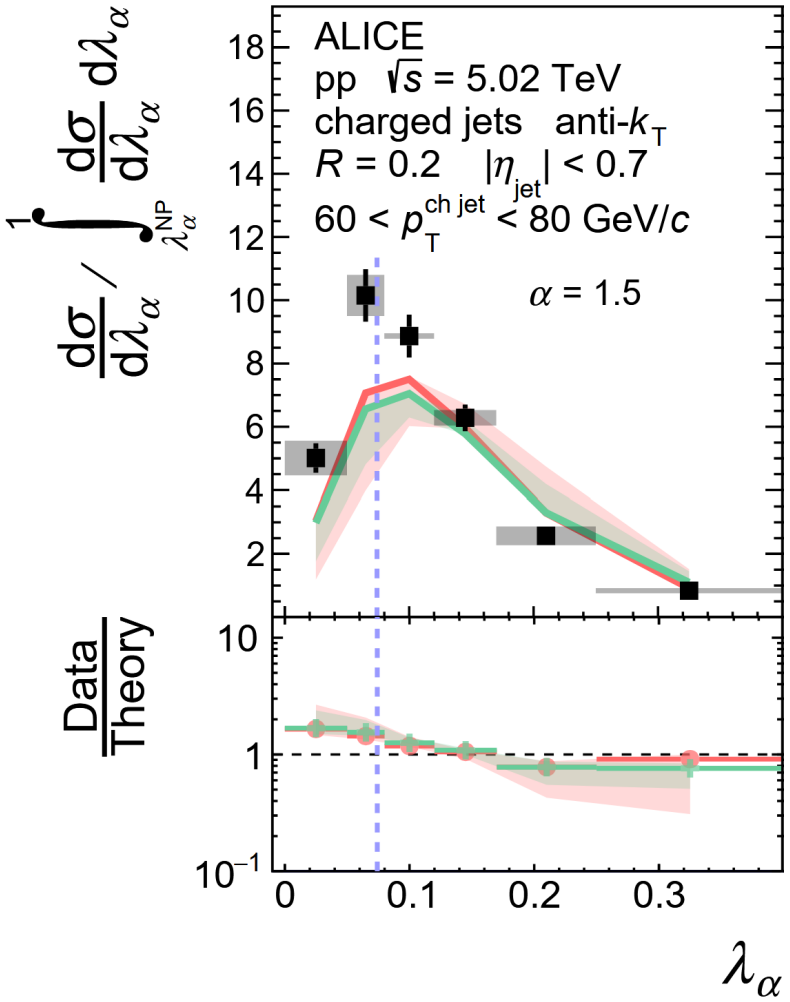

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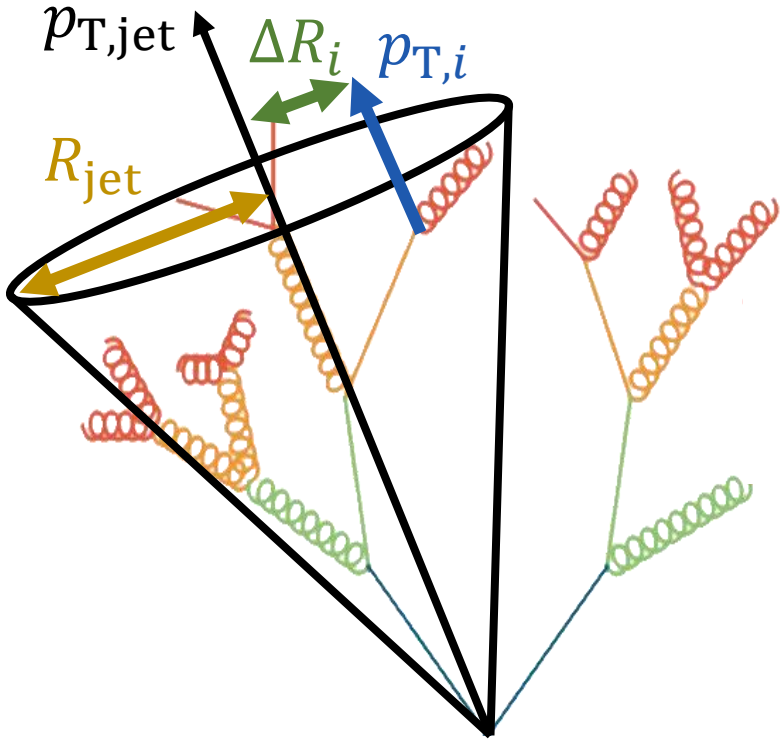

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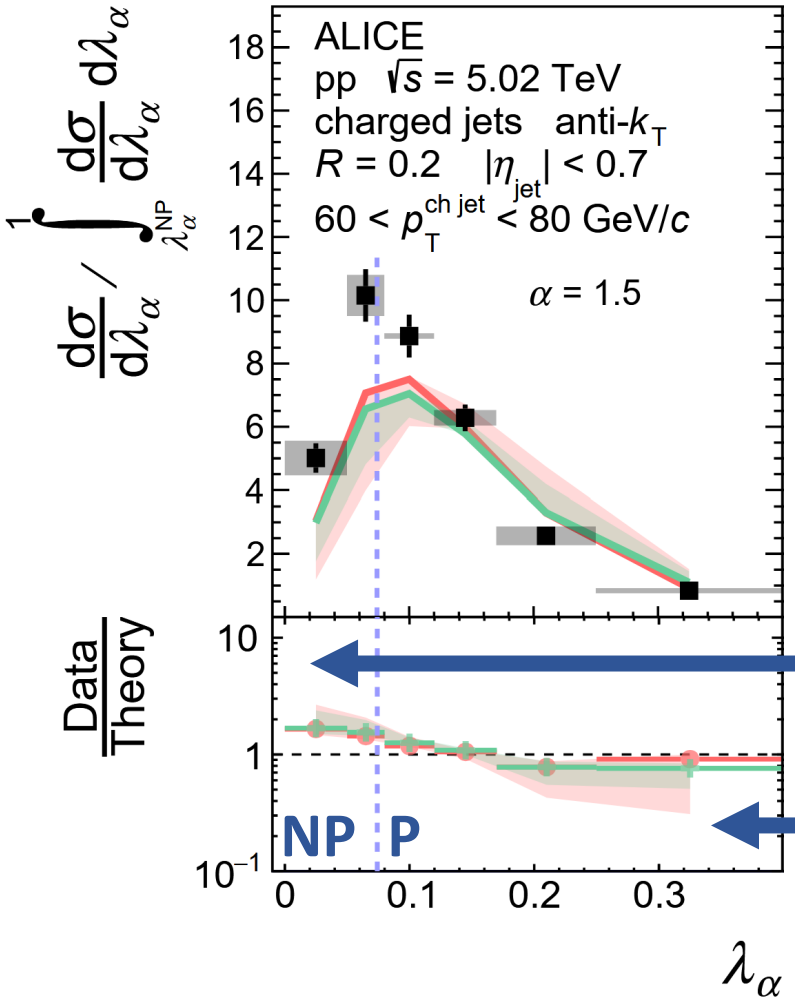

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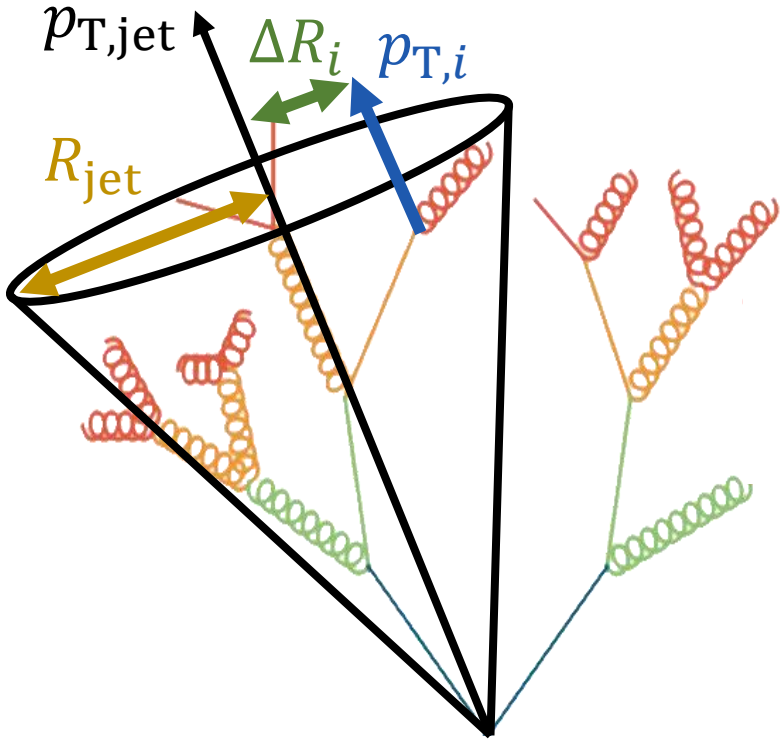

Nonperturbative region

Perturbative region

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Generalized jet angularities

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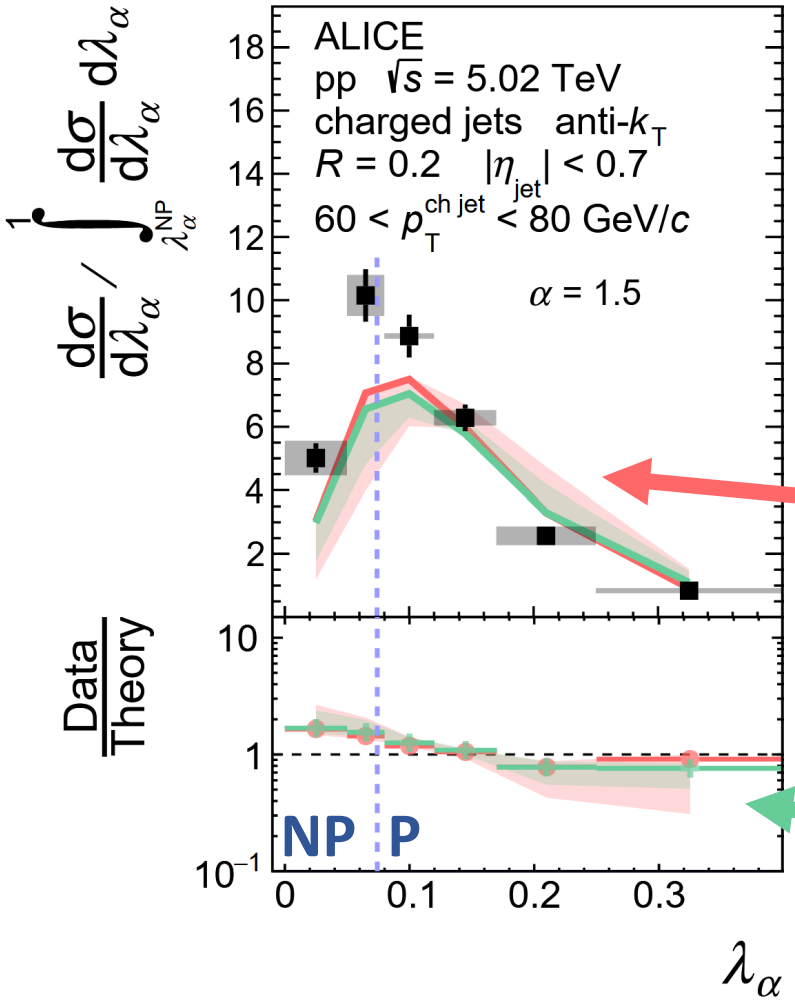

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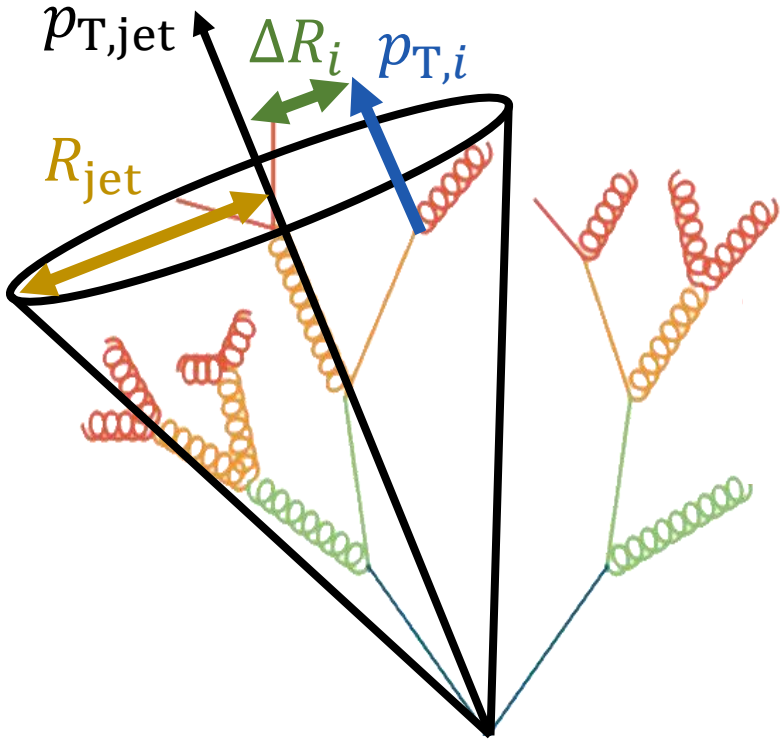

Direct QCD predictions

Reasonable agreement with experimental data

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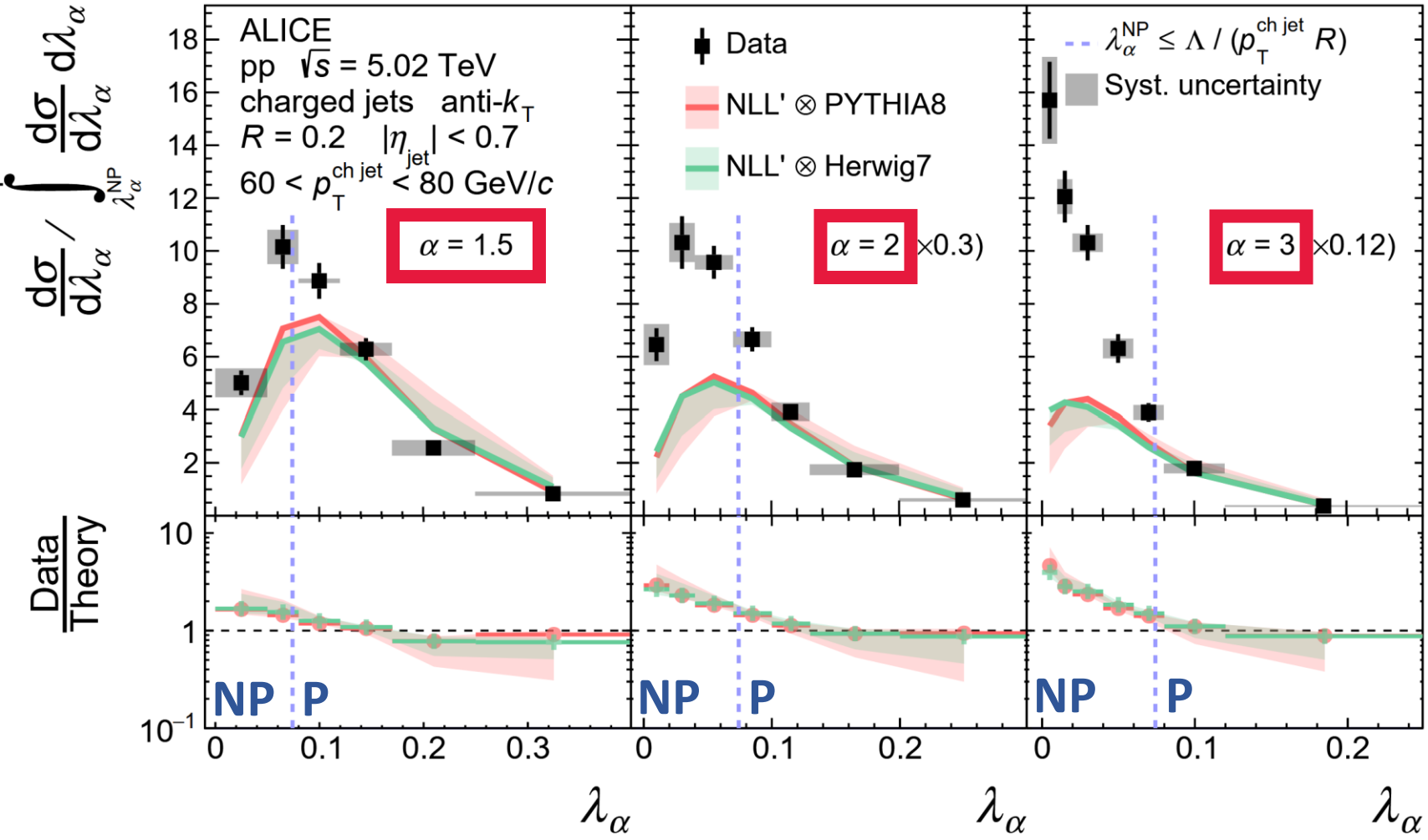

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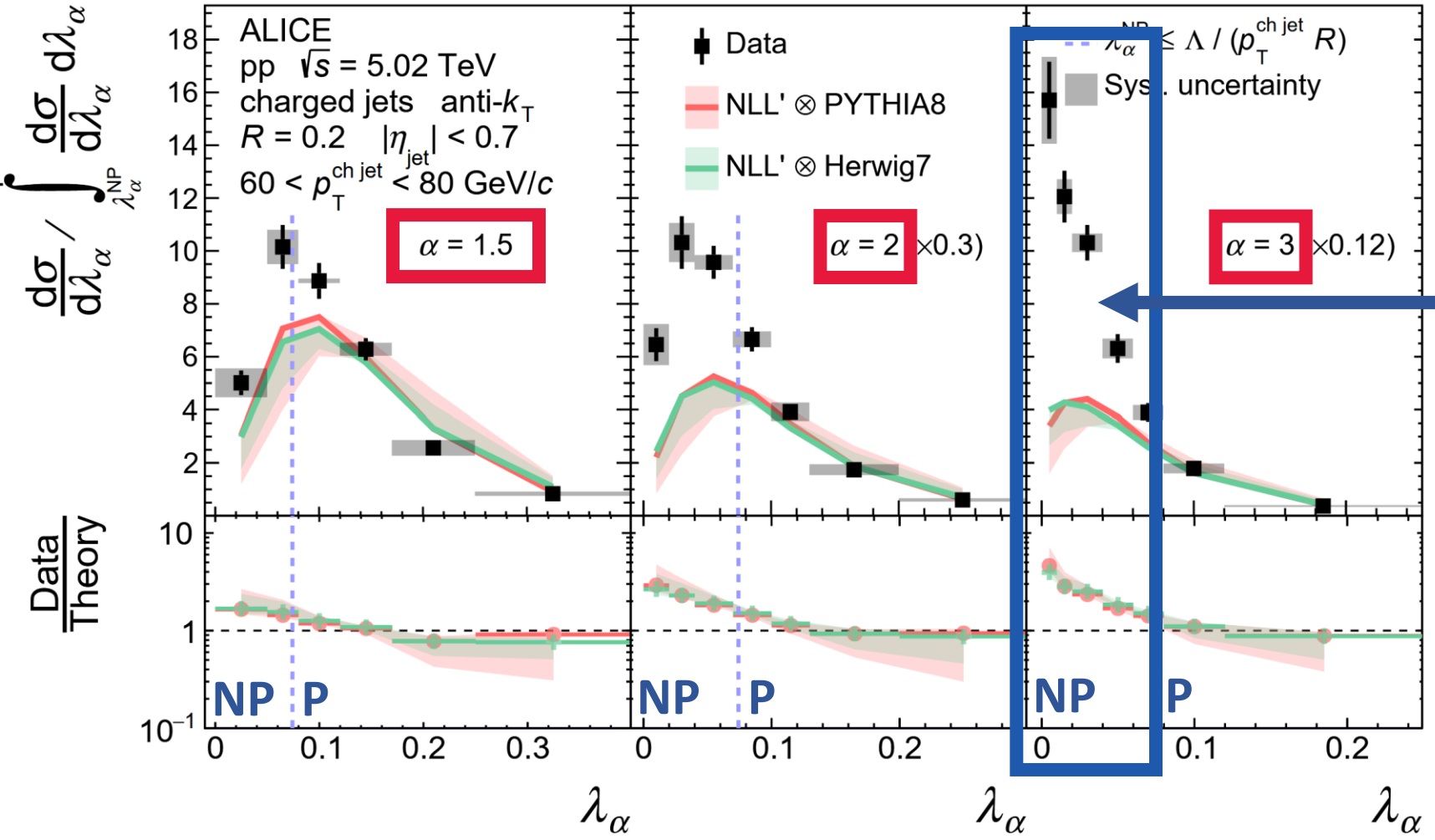

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Breakdown of predictions at larger values of α

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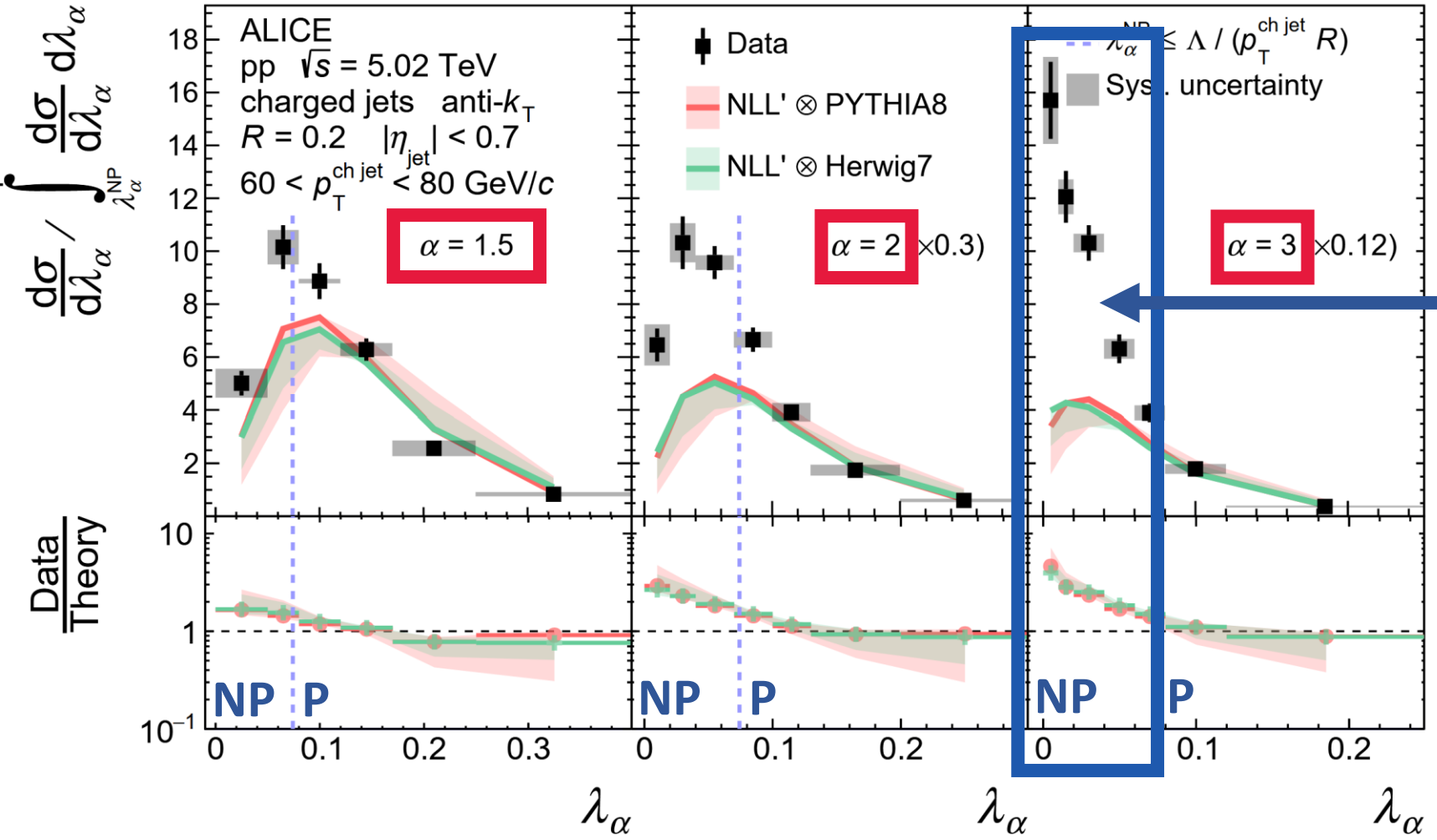

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Breakdown of predictions at larger values of α

Soft, wide angle radiation is more difficult to predict

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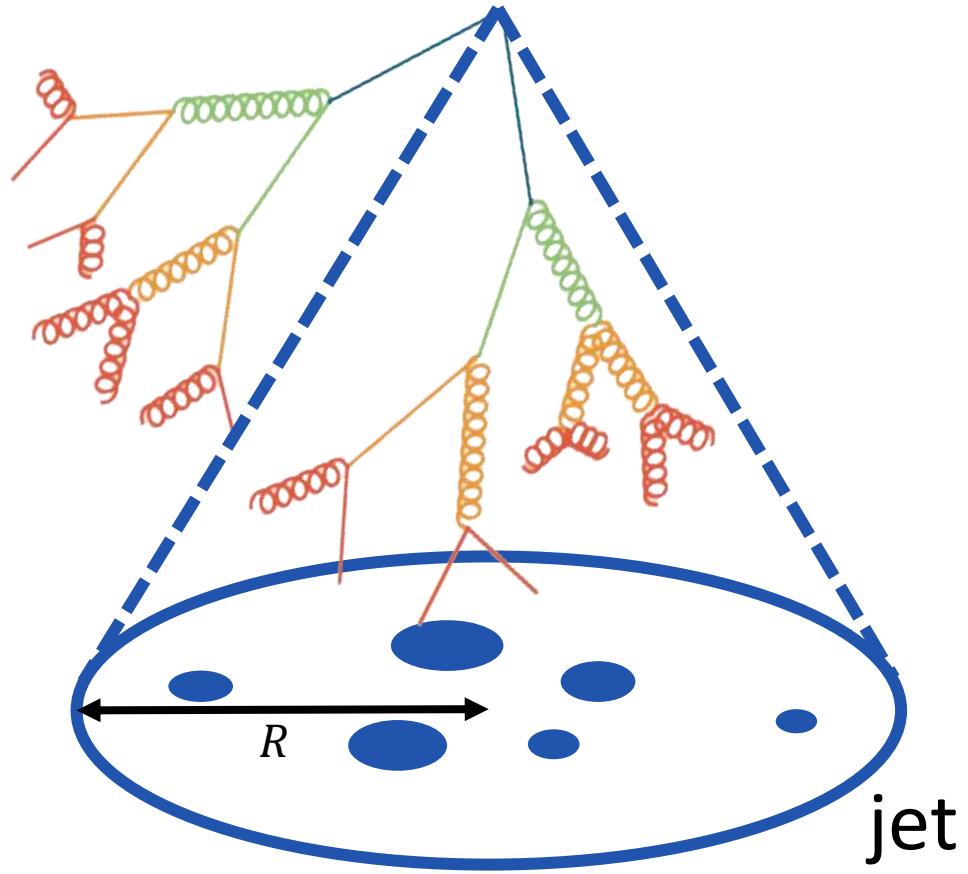
Going deeper: jet grooming



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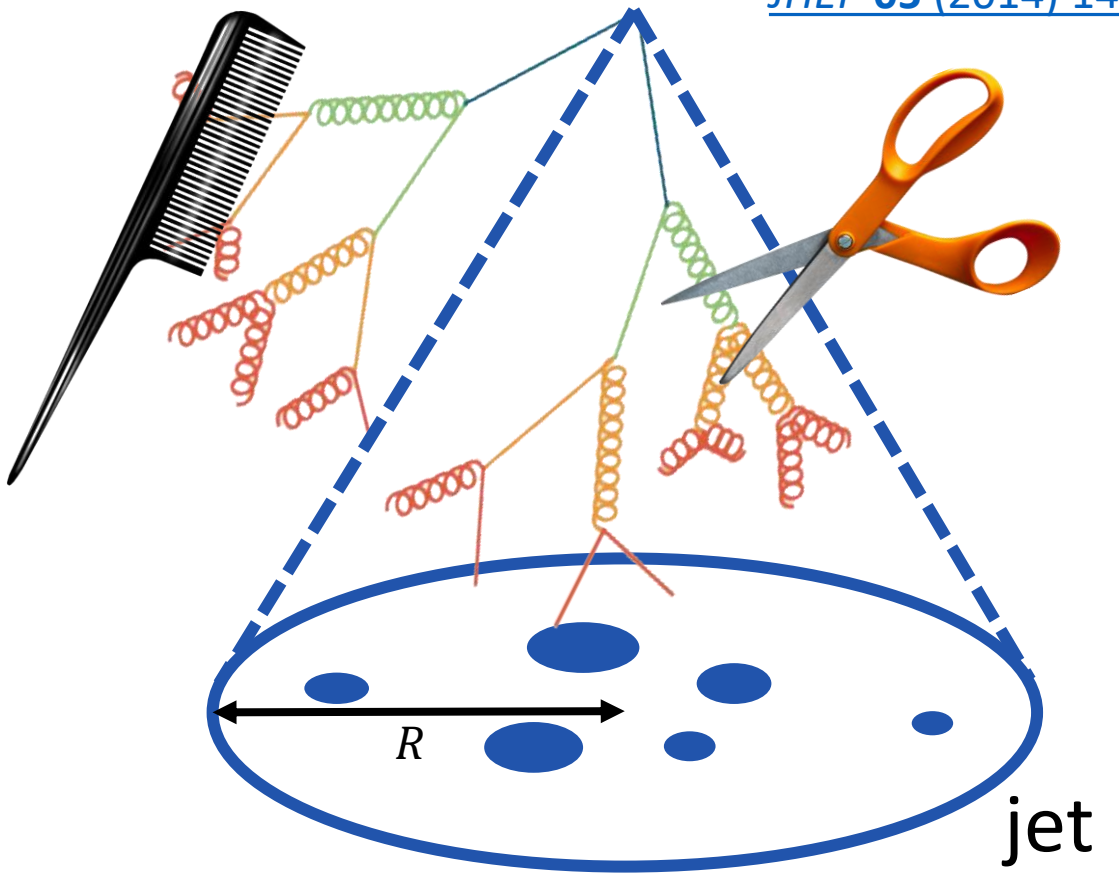
Larkoski, Marzani, Soyez, Thaler
JHEP **05** (2014) 146



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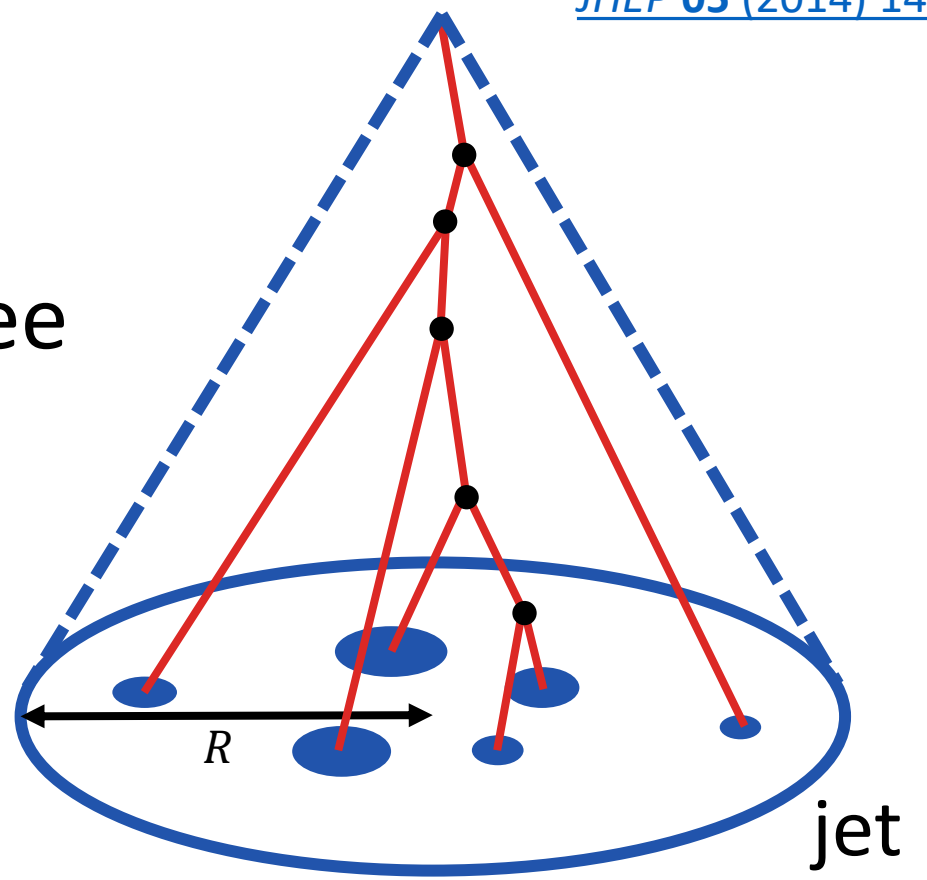

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- Trim branches until the **Soft Drop condition** is satisfied:

$$\frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}} \overset{?}{>} z_{\text{cut}} \left(\frac{\Delta R_{12}}{R}\right)^{\beta}$$

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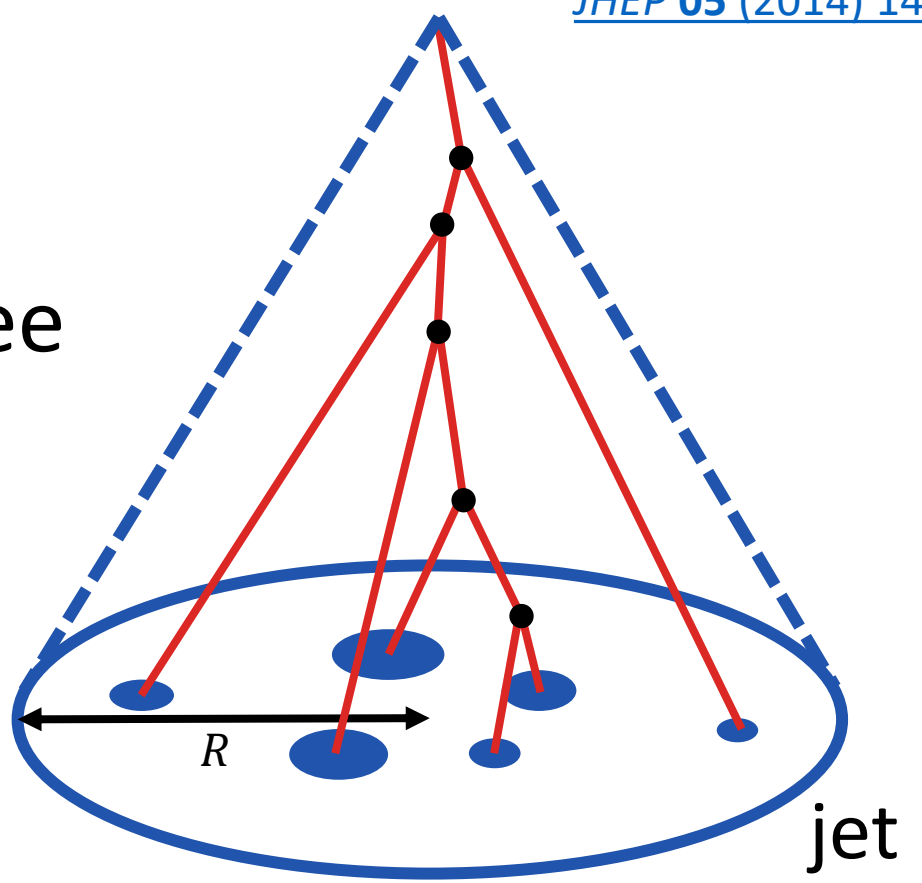

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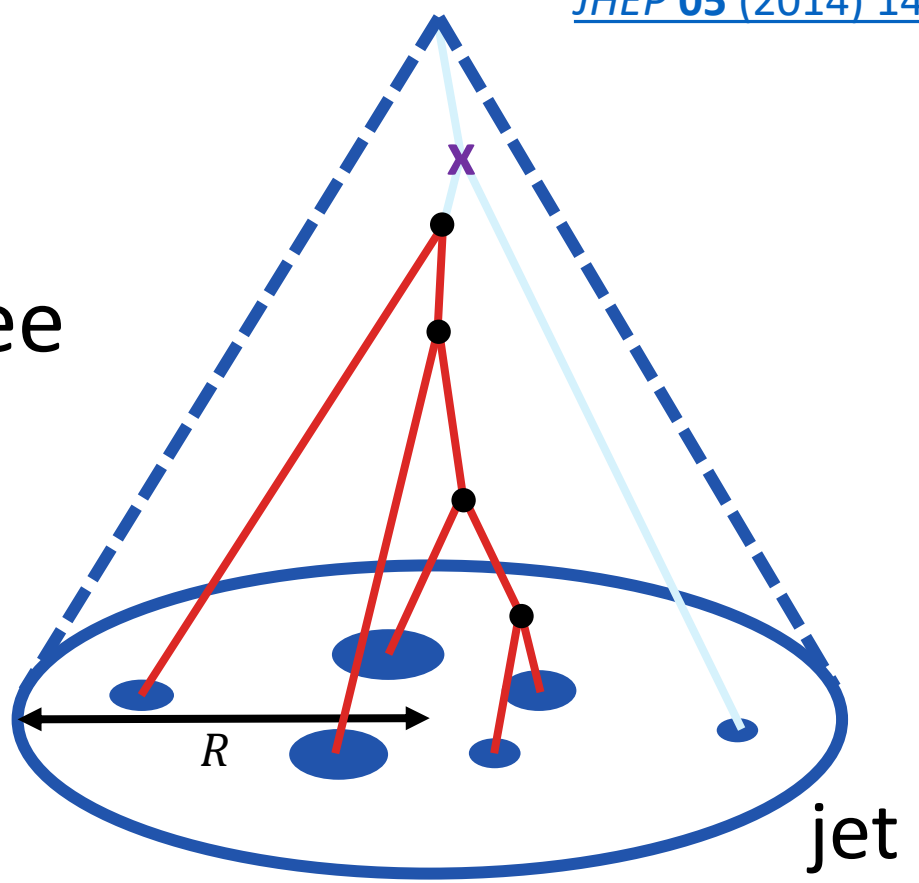

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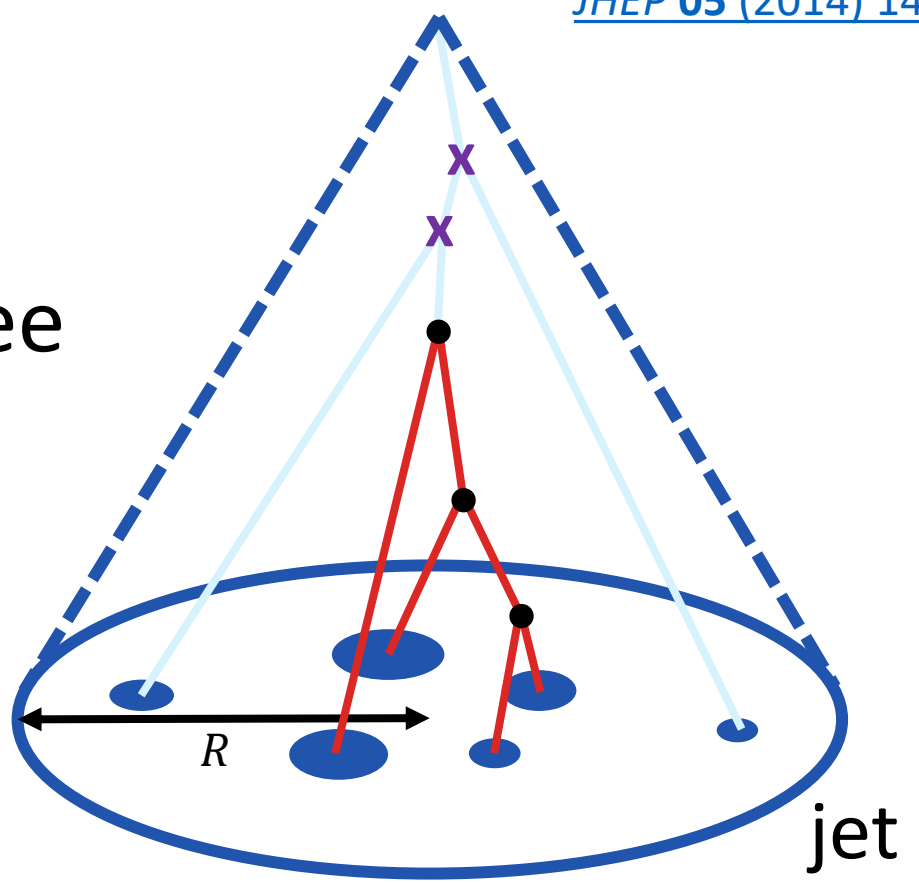

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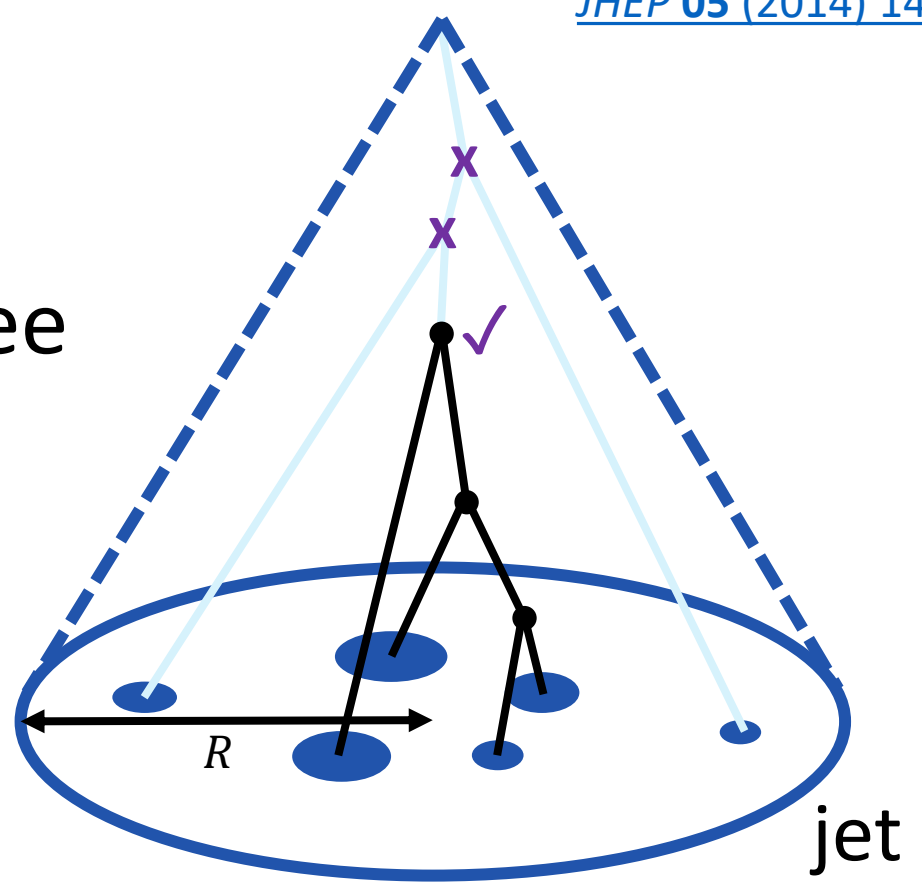
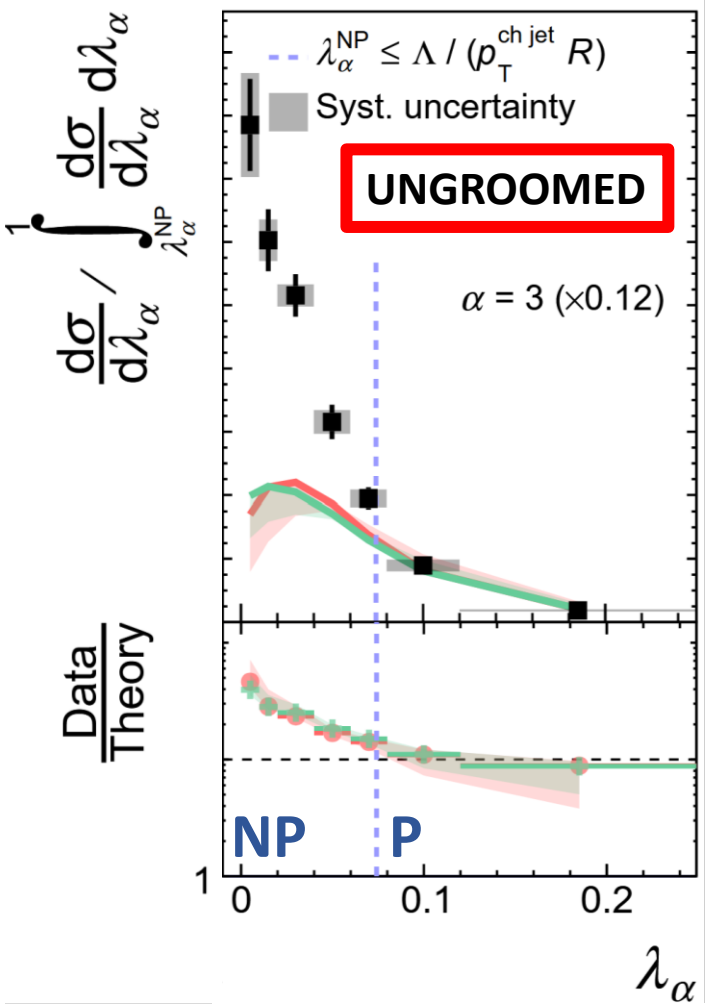
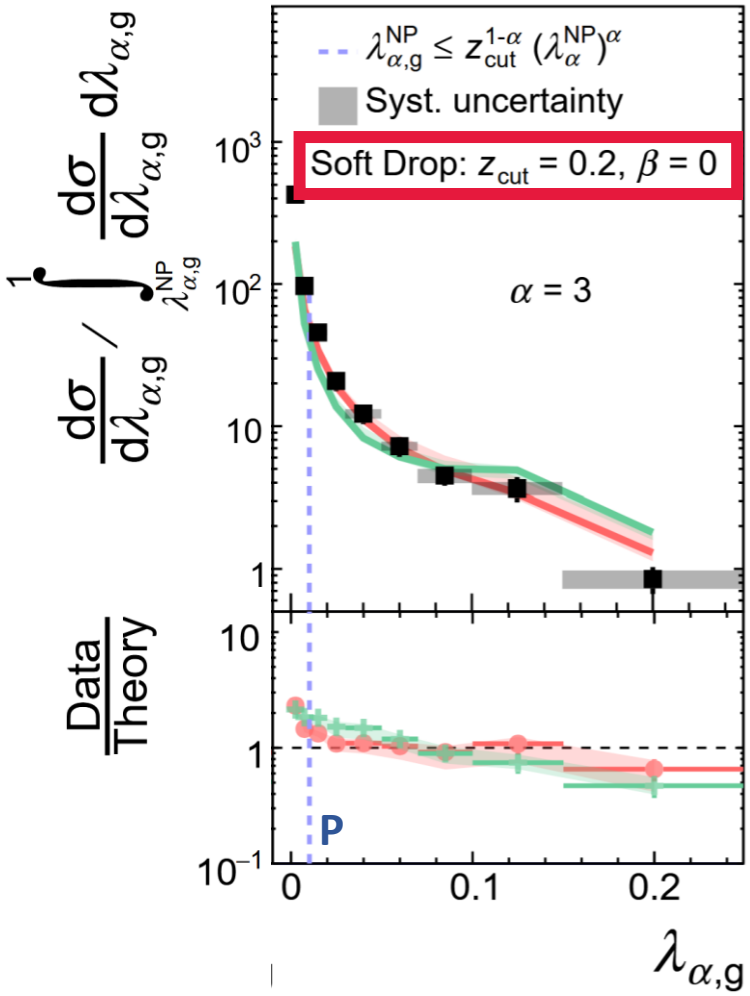


Groomed jet angularities

- **IRC-safe jet observables** dependent on constituent p_{T} and **angle**





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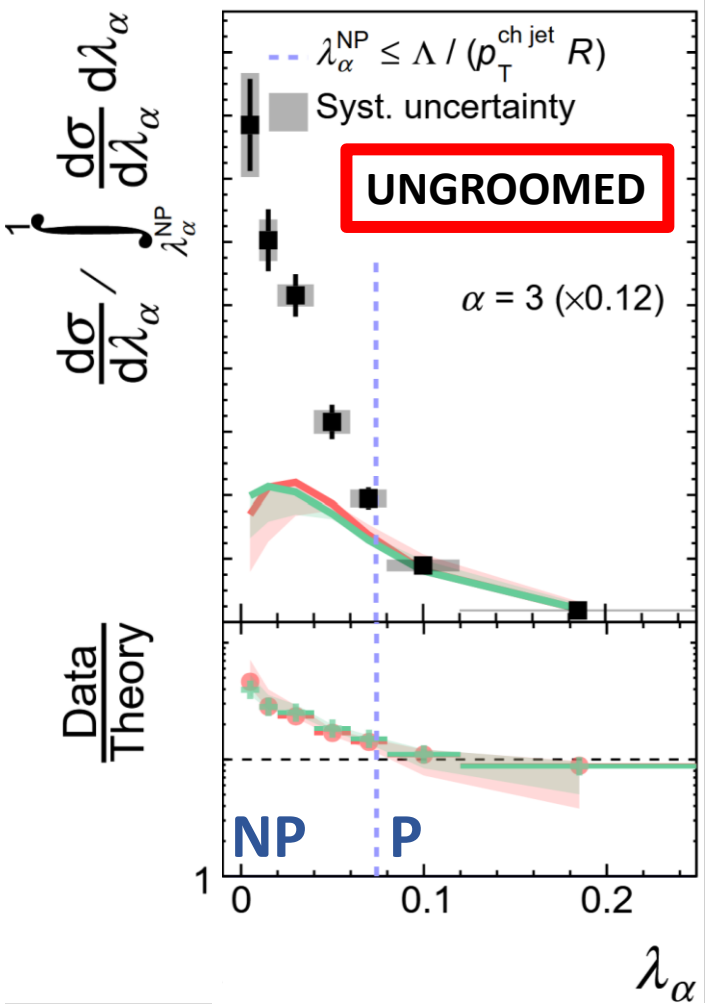

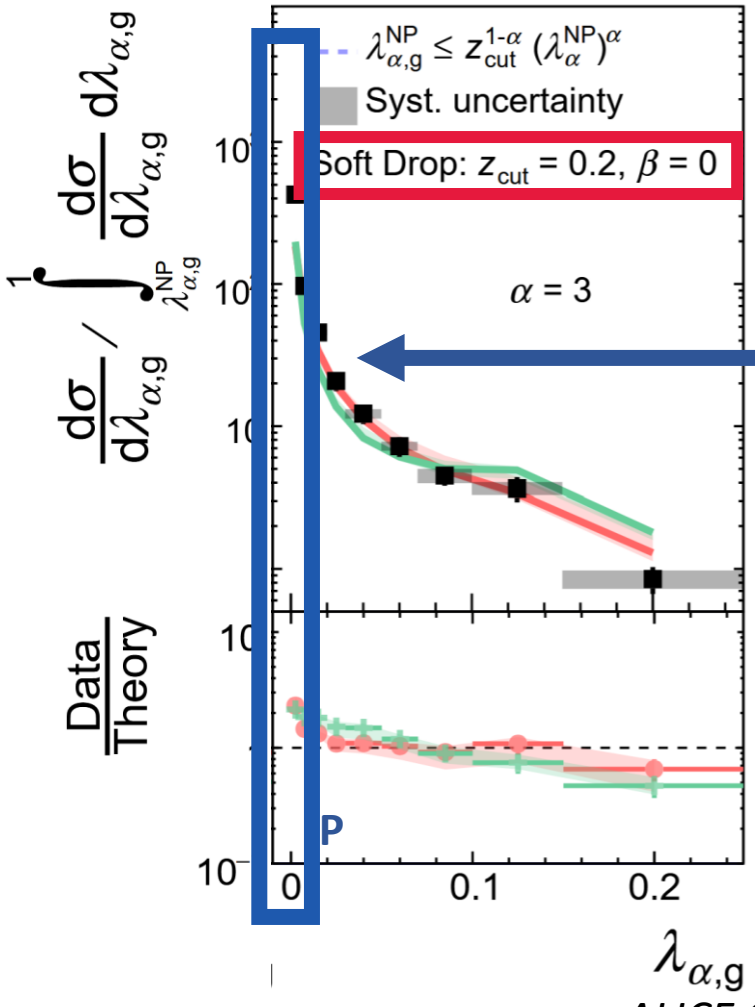

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Nonperturbative region is reduced

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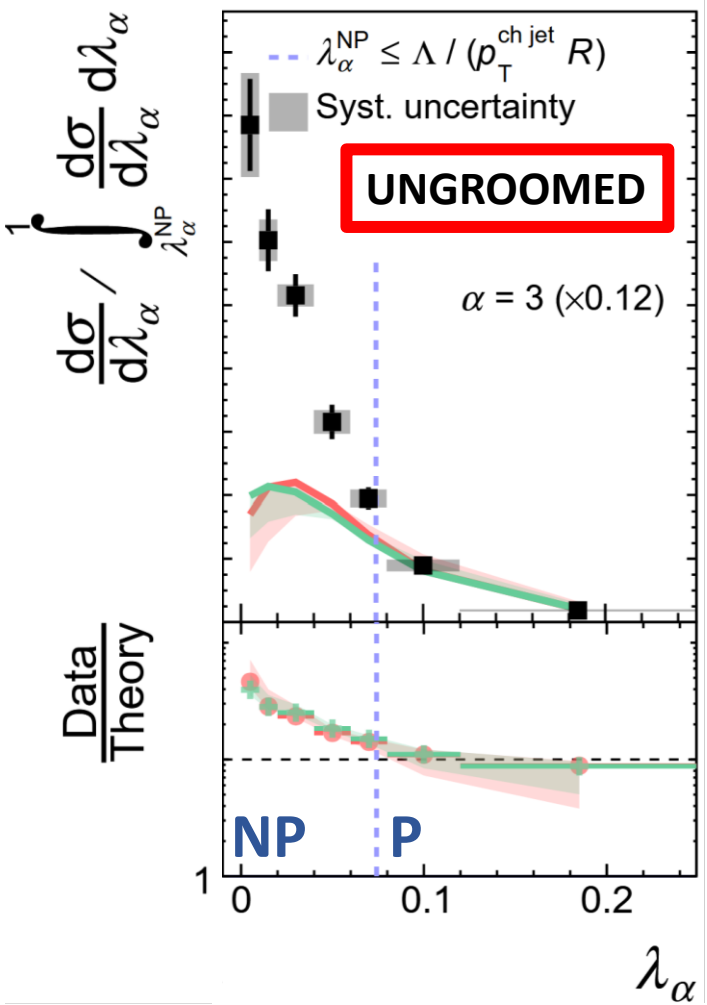

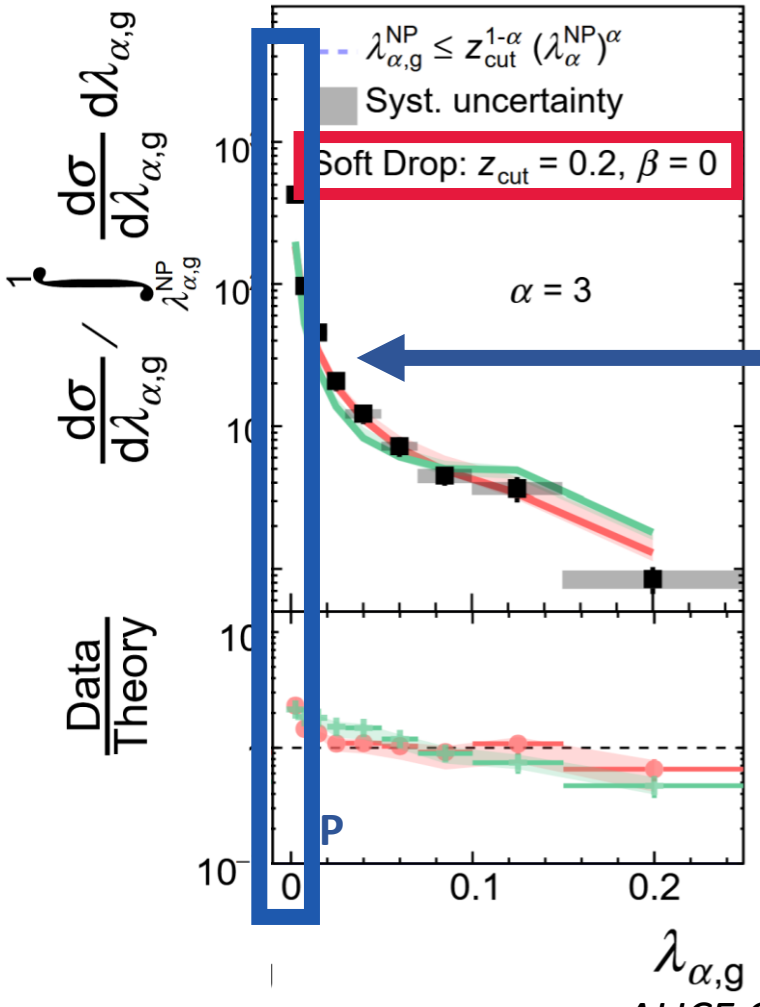

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Nonperturbative region is reduced

Grooming improves constraints on perturbative QCD

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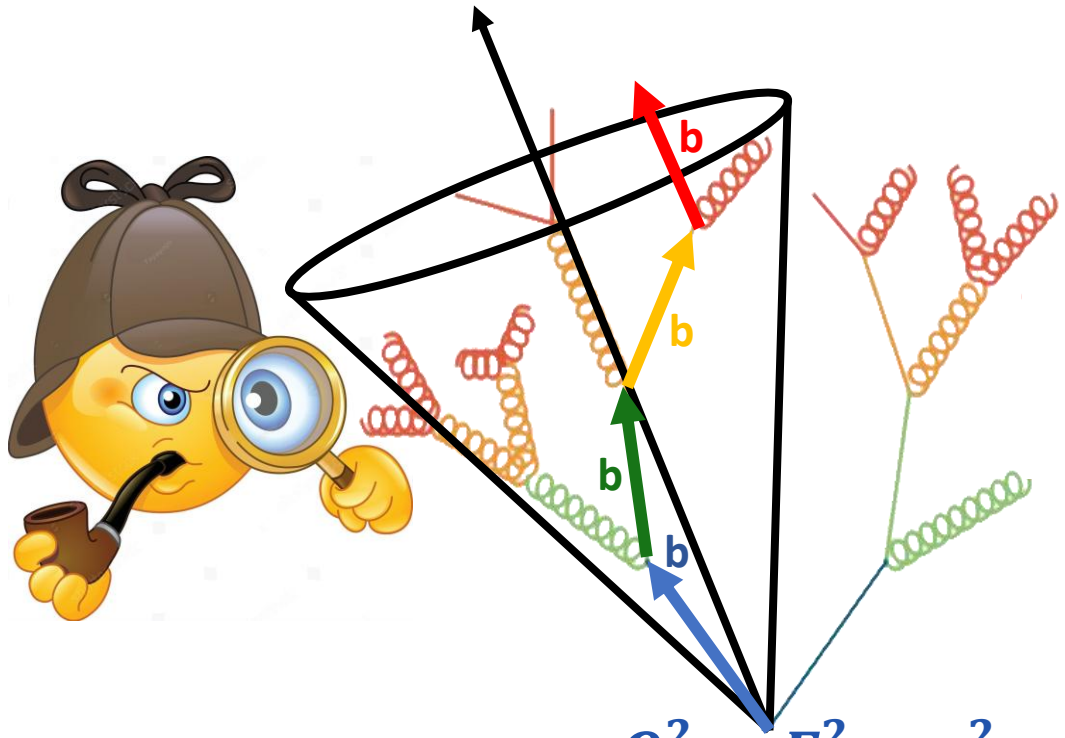
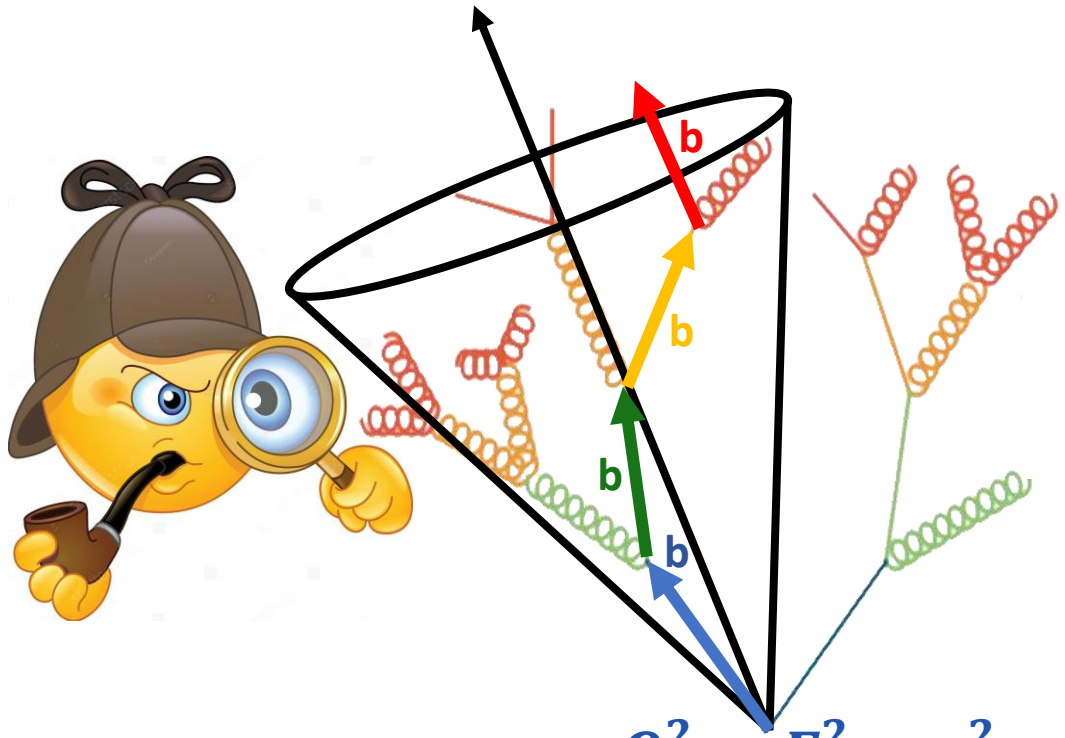
Mass & virtuality dependence



$Q^2 = E^2 - p^2$

Mass & virtuality dependence

- How does the **jet formation** depend on the **mass m_b** and the **virtuality Q^2** of its initiating parton?



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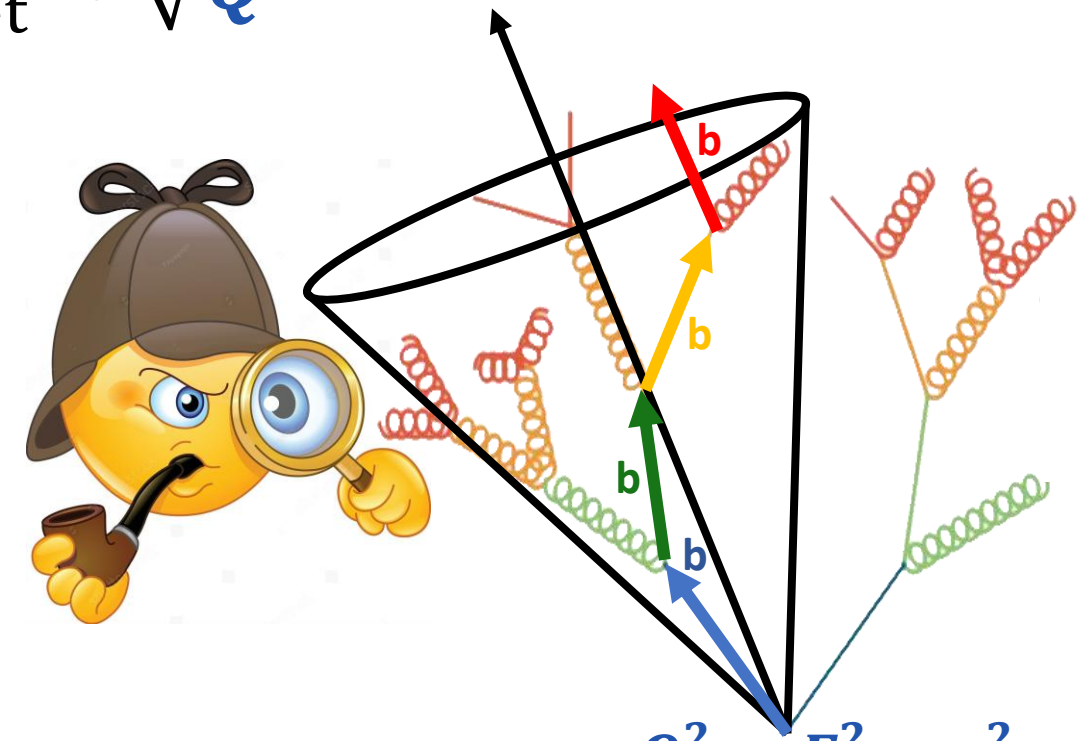

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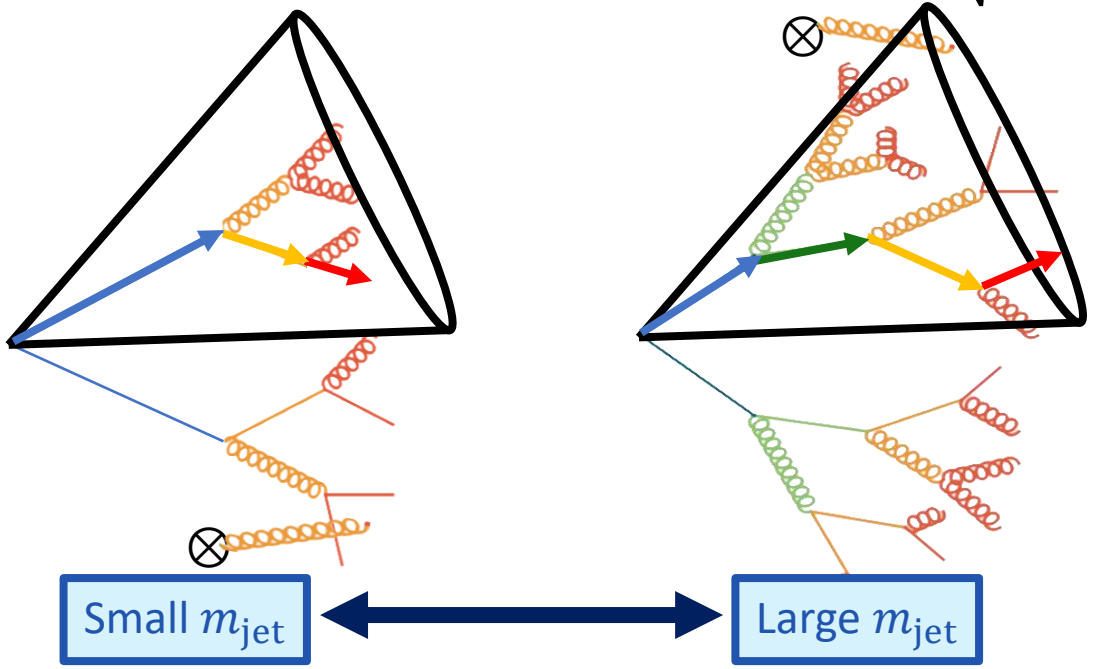

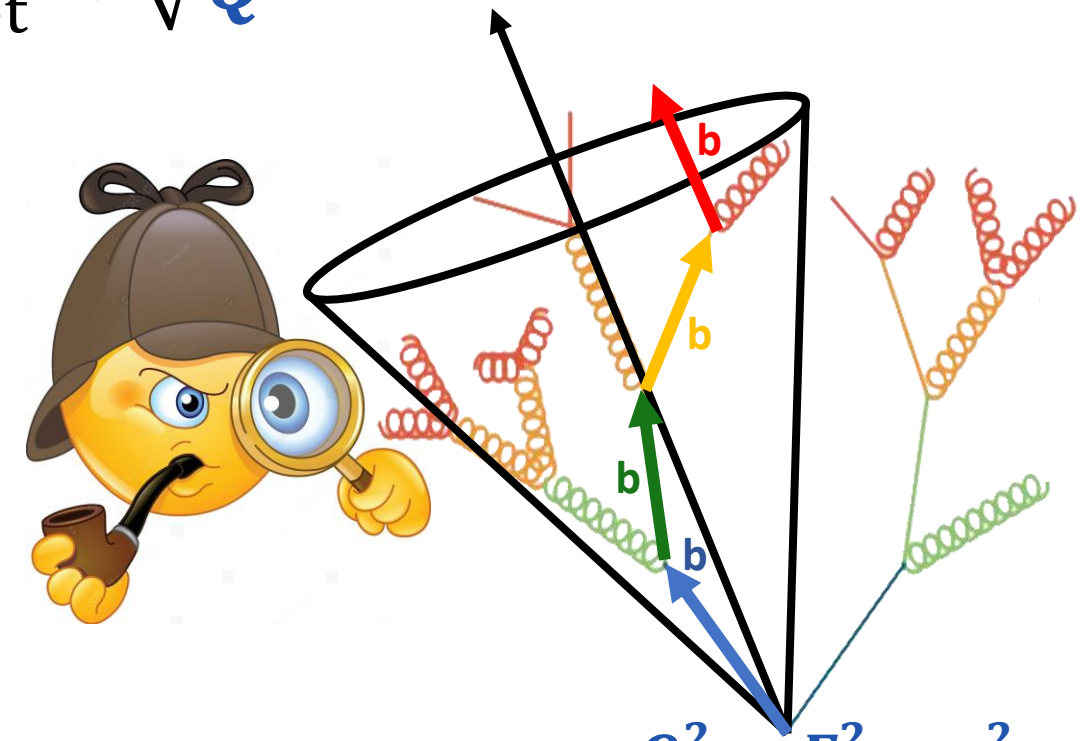

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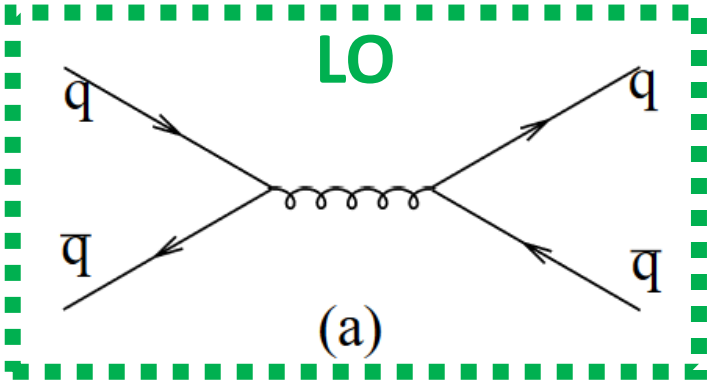
Flavor definition problem



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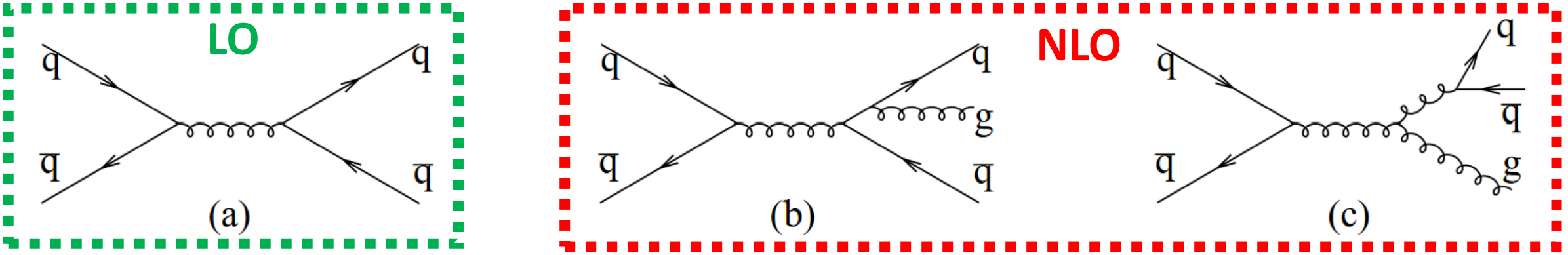
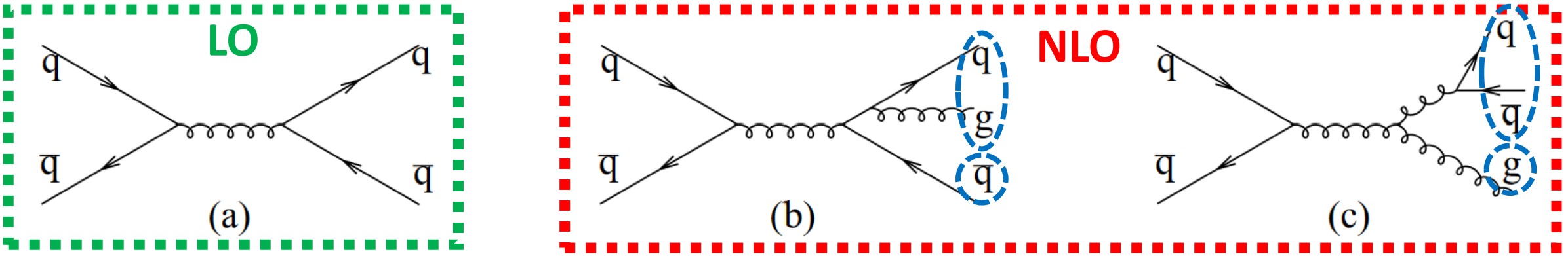


- **Cannot separate $q\bar{q} \to q\bar{q}g$ corrections to gg and $q\bar{q}$ at Born level**

Banfi, Salam, Zanderighi
EPJC 47 (2006) 113-124

Flavor definition problem



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  → **<u>solution</u>**: use an IRC-safe algorithm like anti-k_T to define the flavor

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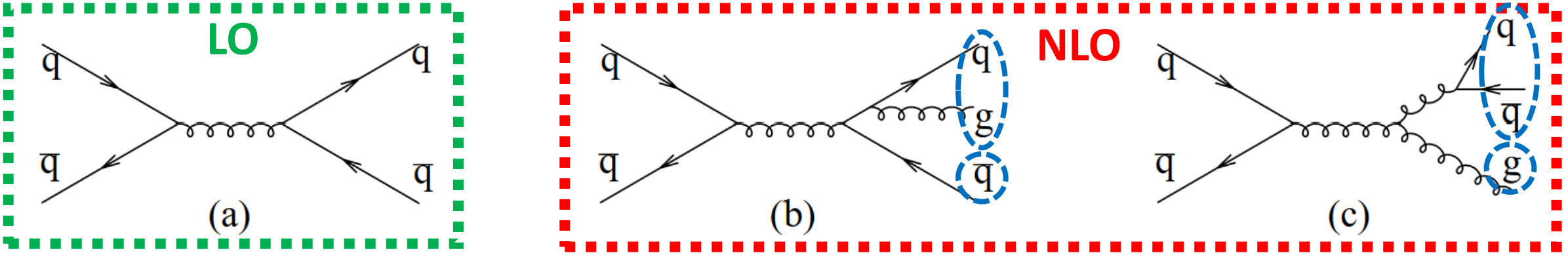

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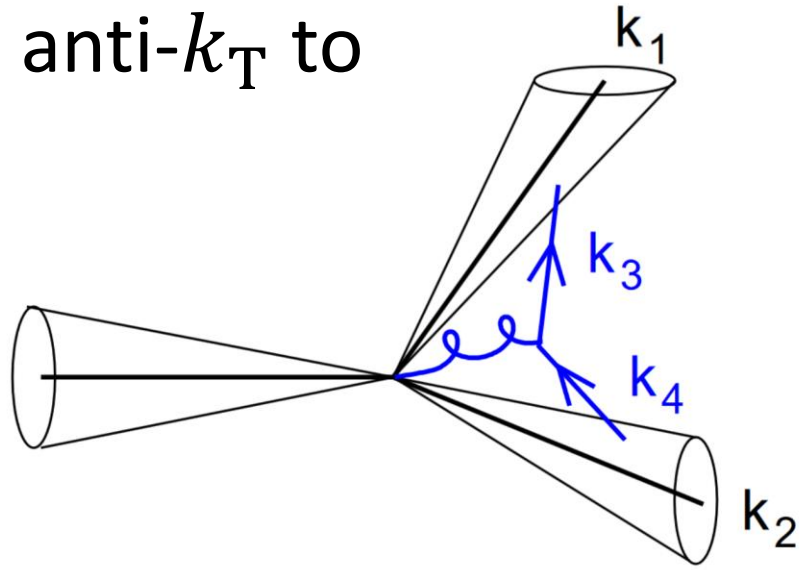

- **But soft gluons ruin this at NNLO**

Banfi, Salam, Zanderighi
EPJC 47 (2006) 113-124

Theoretically safe flavor tagging

- Traditional flavor tagging is **not well-defined past NLO**

Banfi, Salam, Zanderighi
Eur. Phys. J. **C47** (2006) 113-124

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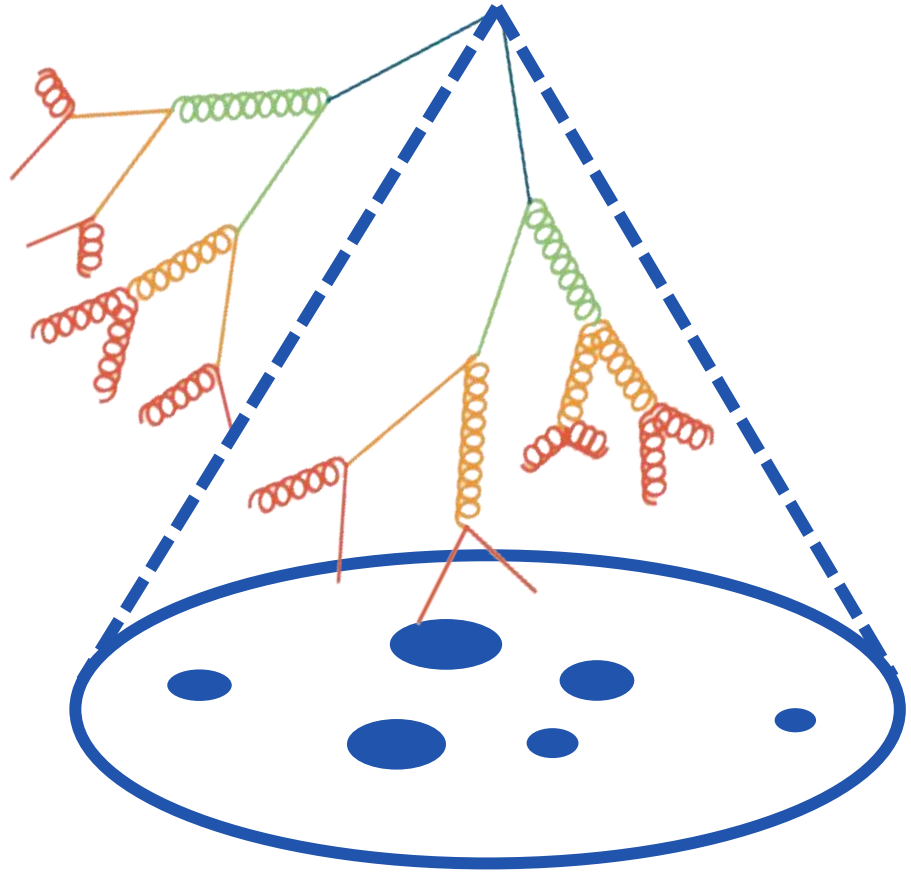
Banfi, Salam, Zanderighi
Eur. Phys. J. **C47** (2006) 113-124



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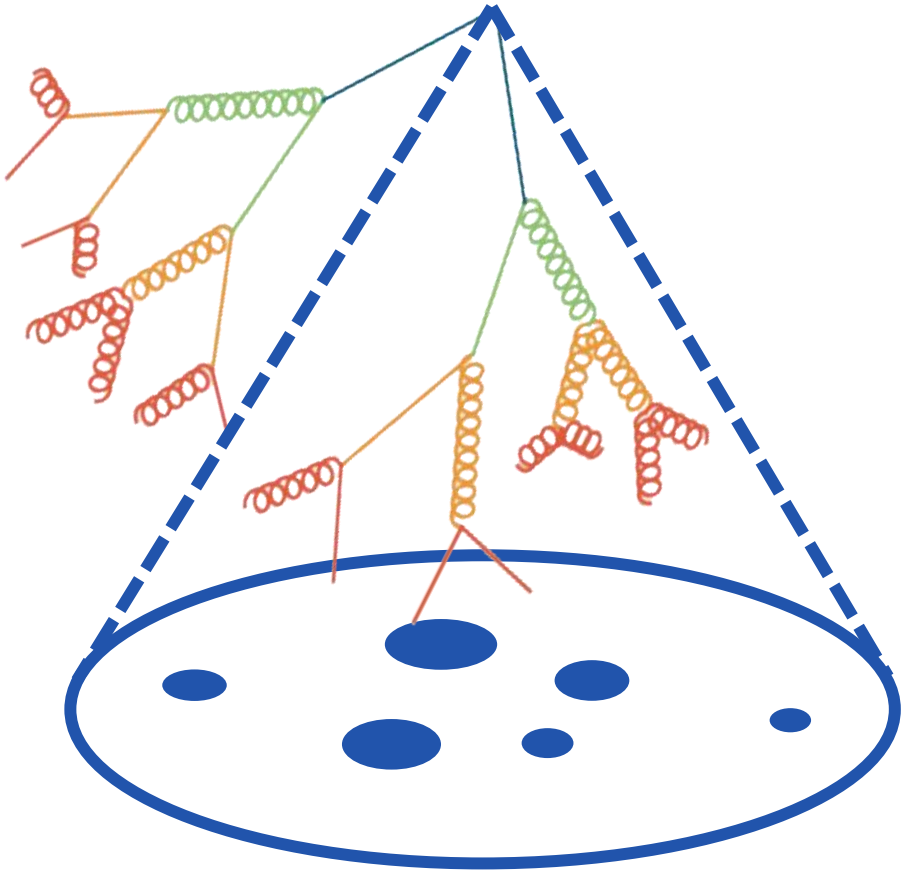
Caletti, Larkoski, Marzani, Reichelt
JHEP **10** (2022) 158



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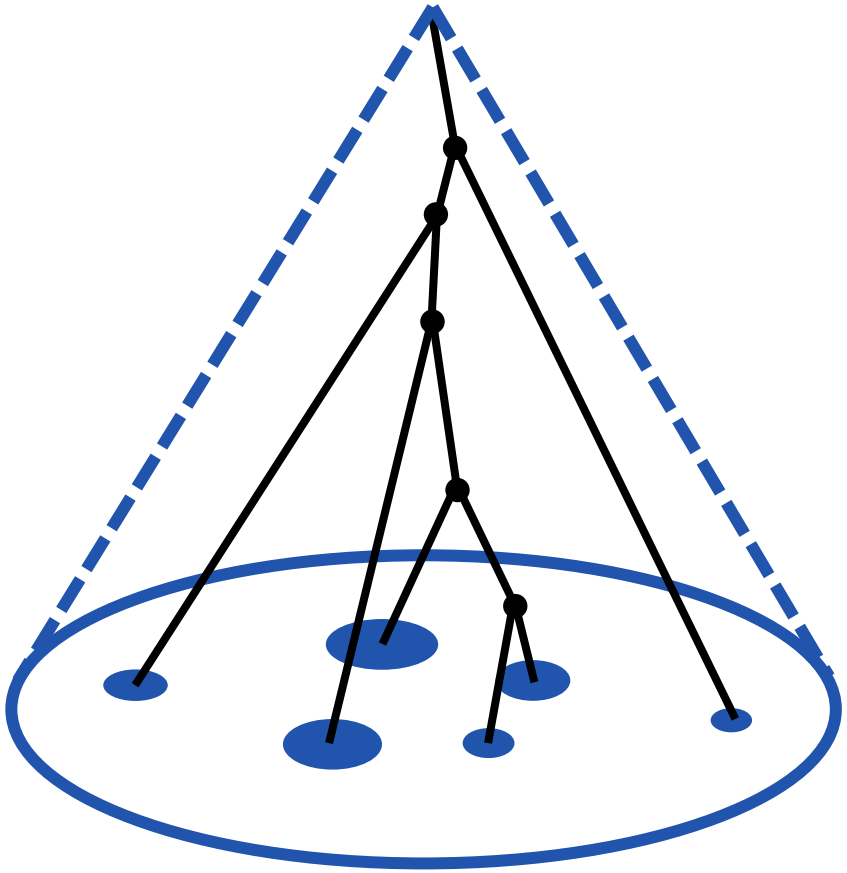
  - **Recluster** into angularly-ordered tree



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JHEP **10** (2022) 158

  - **Recluster** into angularly-ordered tree
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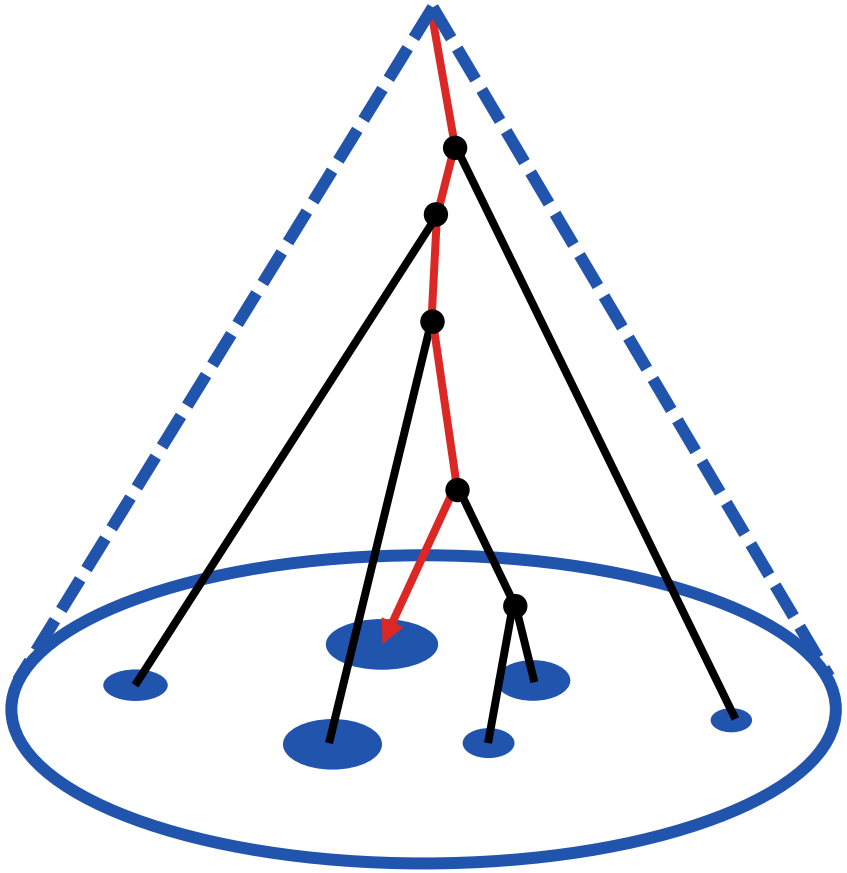

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JHEP **10** (2022) 158

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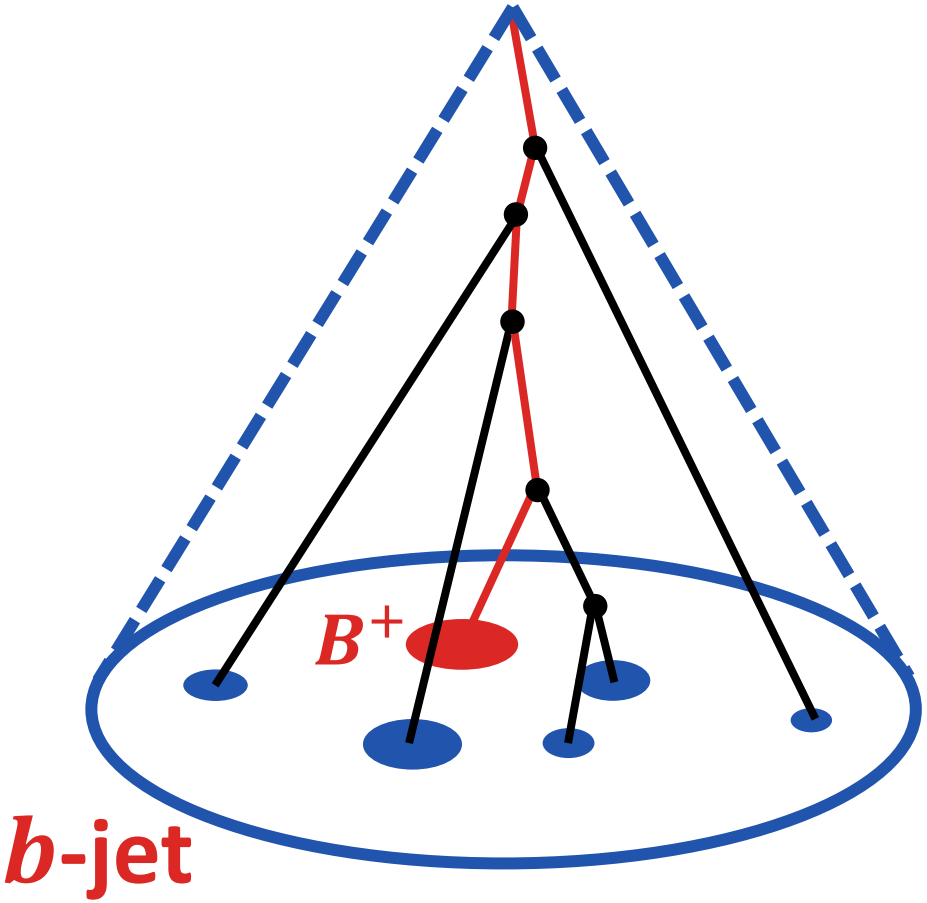
  - **Follow** the hardest branch
  - **Define** flavor by particle along the axis



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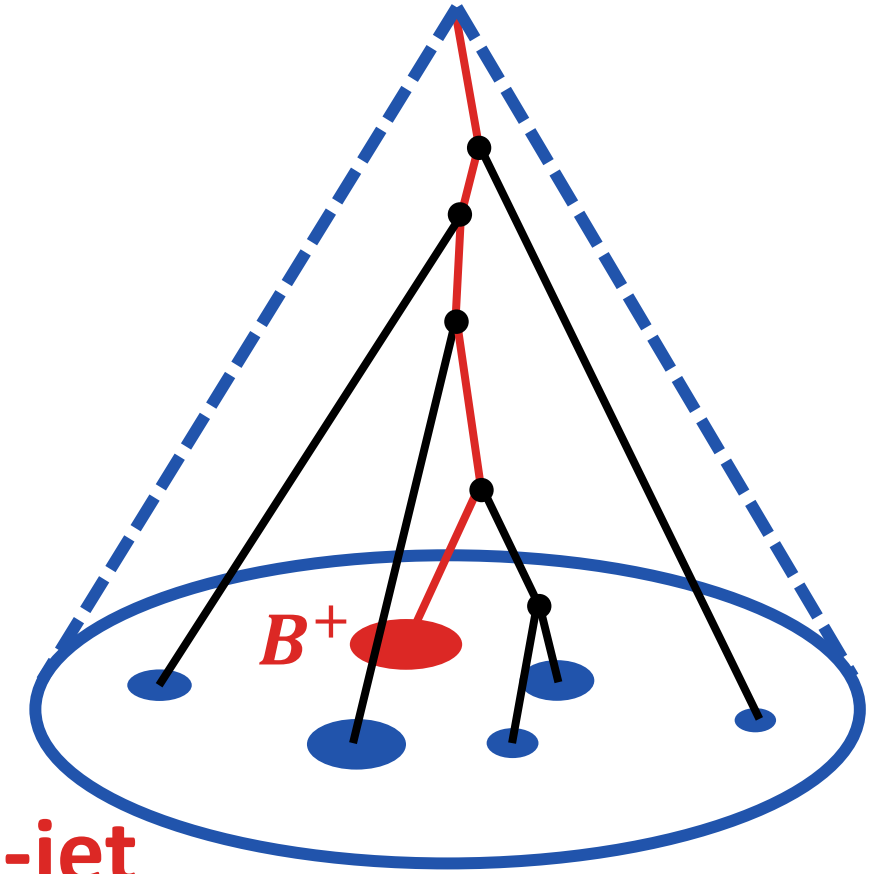
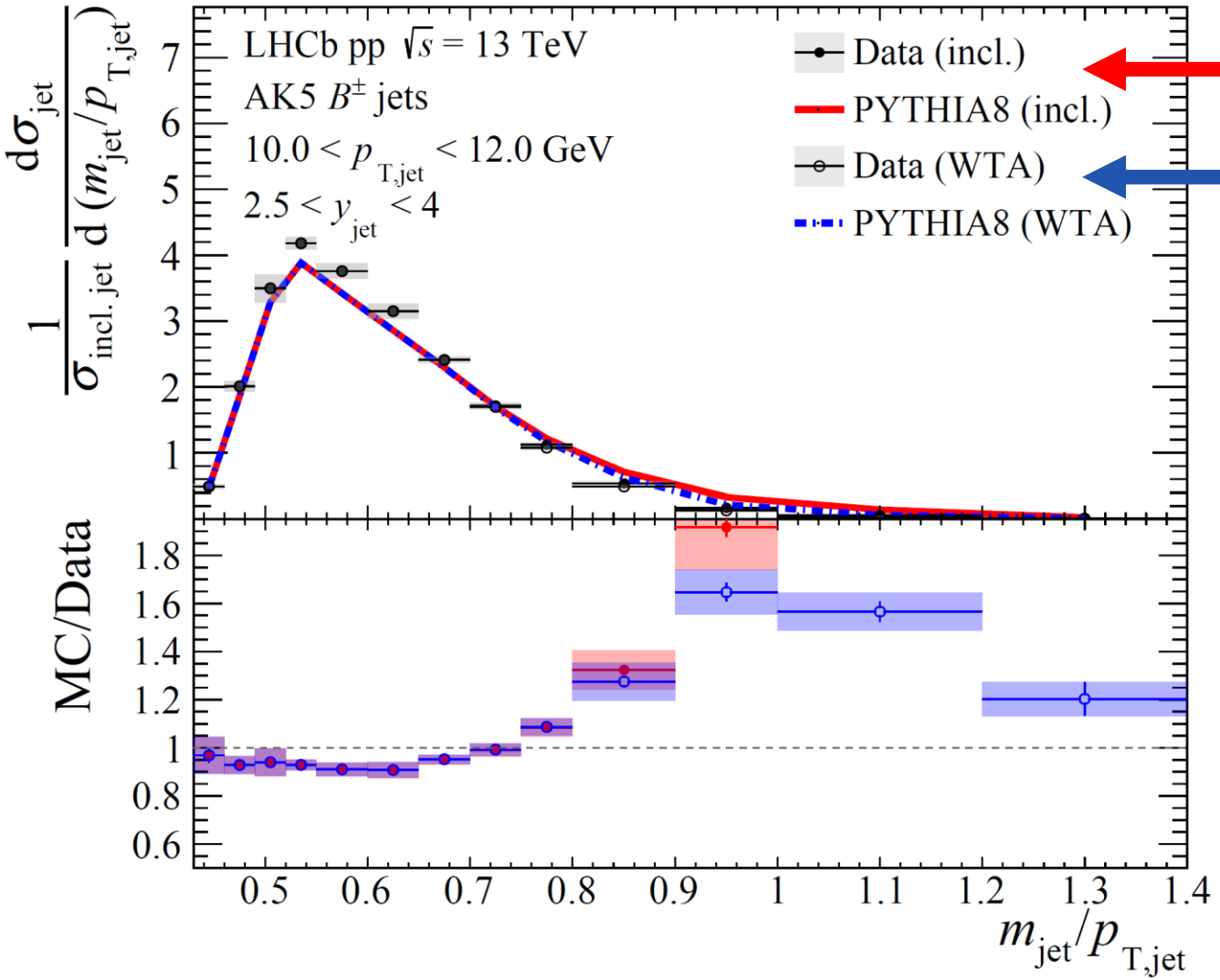
  - **Recluster** into angularly-ordered tree
  - **Follow** the hardest branch
  - **Define** flavor by particle along the axis

- **Calculable to any perturbative order!**



b-jet invariant mass

$$m_{\text{jet}} \approx Q_{\text{parton}}$$



No WTA tagging requirement

WTA tagging required

LHCb Collaboration, [*Phys. Lett.* **B869** (2025) 139854]

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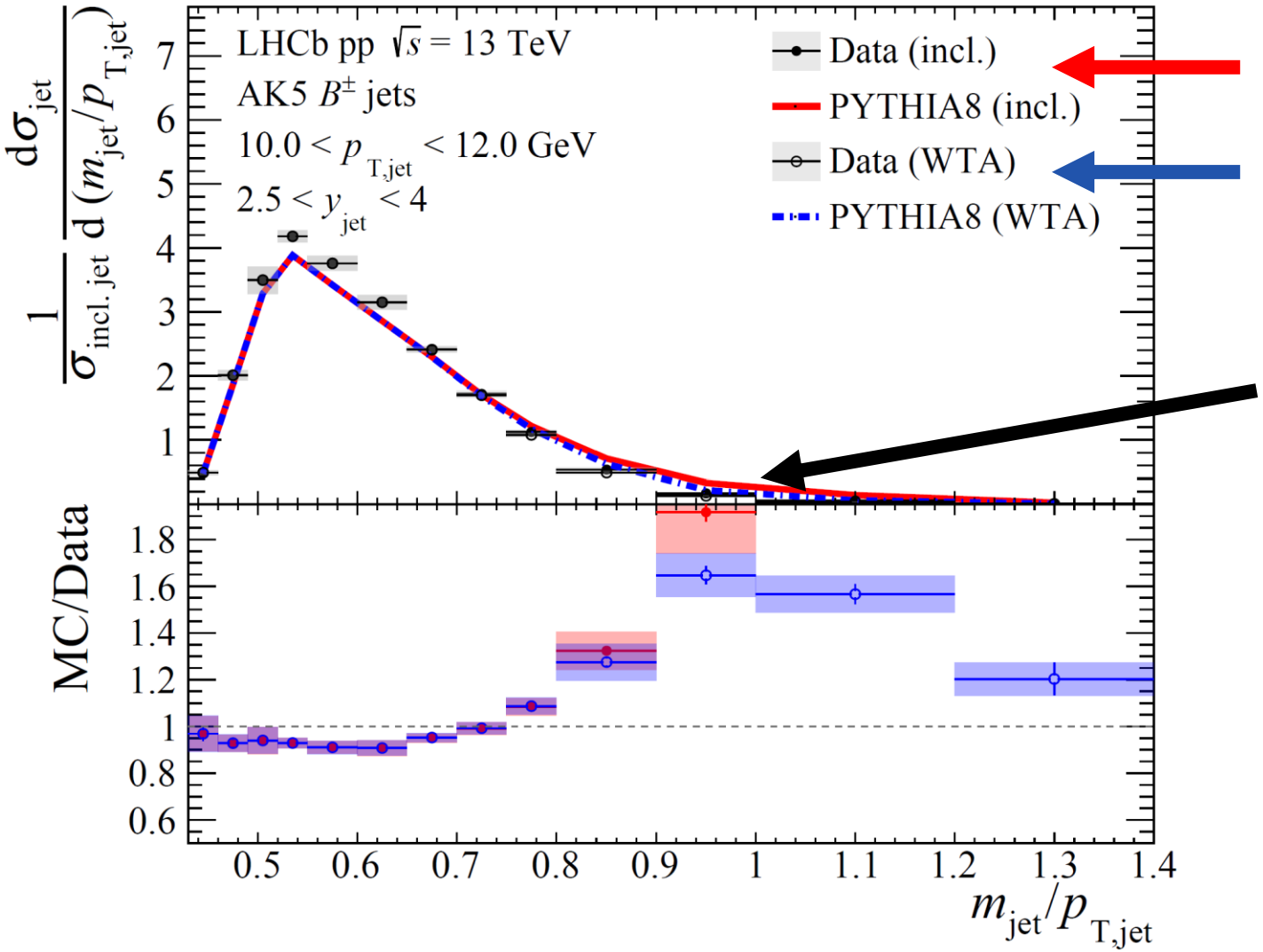

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WTA tagging required

Slight reduction in tails

These entries are coming primarily from $g \to b\bar{b}$

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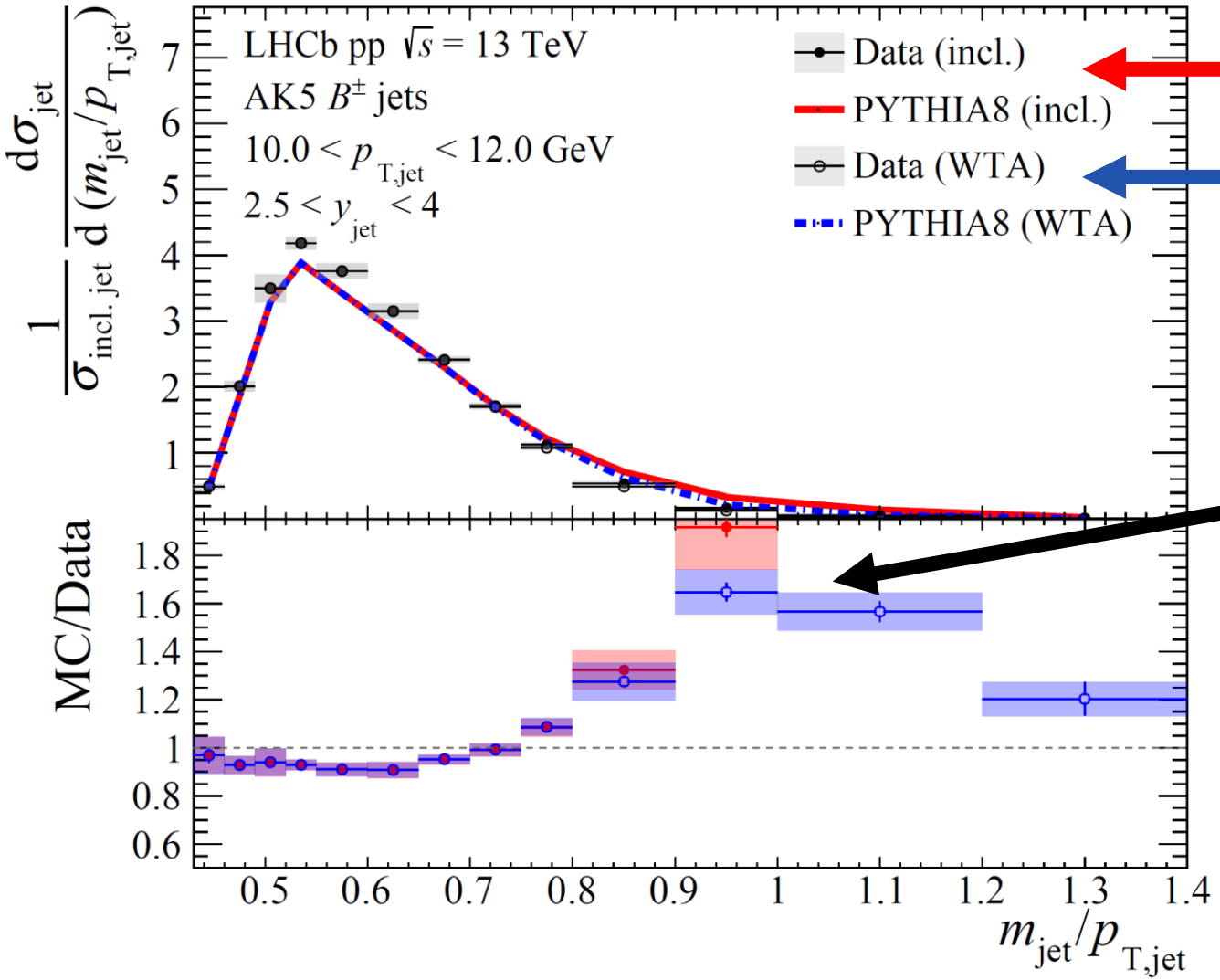

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Significant deviations from Pythia 8.186 MC

Worse for no-WTA: **Pythia splitting function poorly describes $b\bar{b}$ production?**

LHCb Collaboration, Phys. Lett. **B869** (2025) 139854

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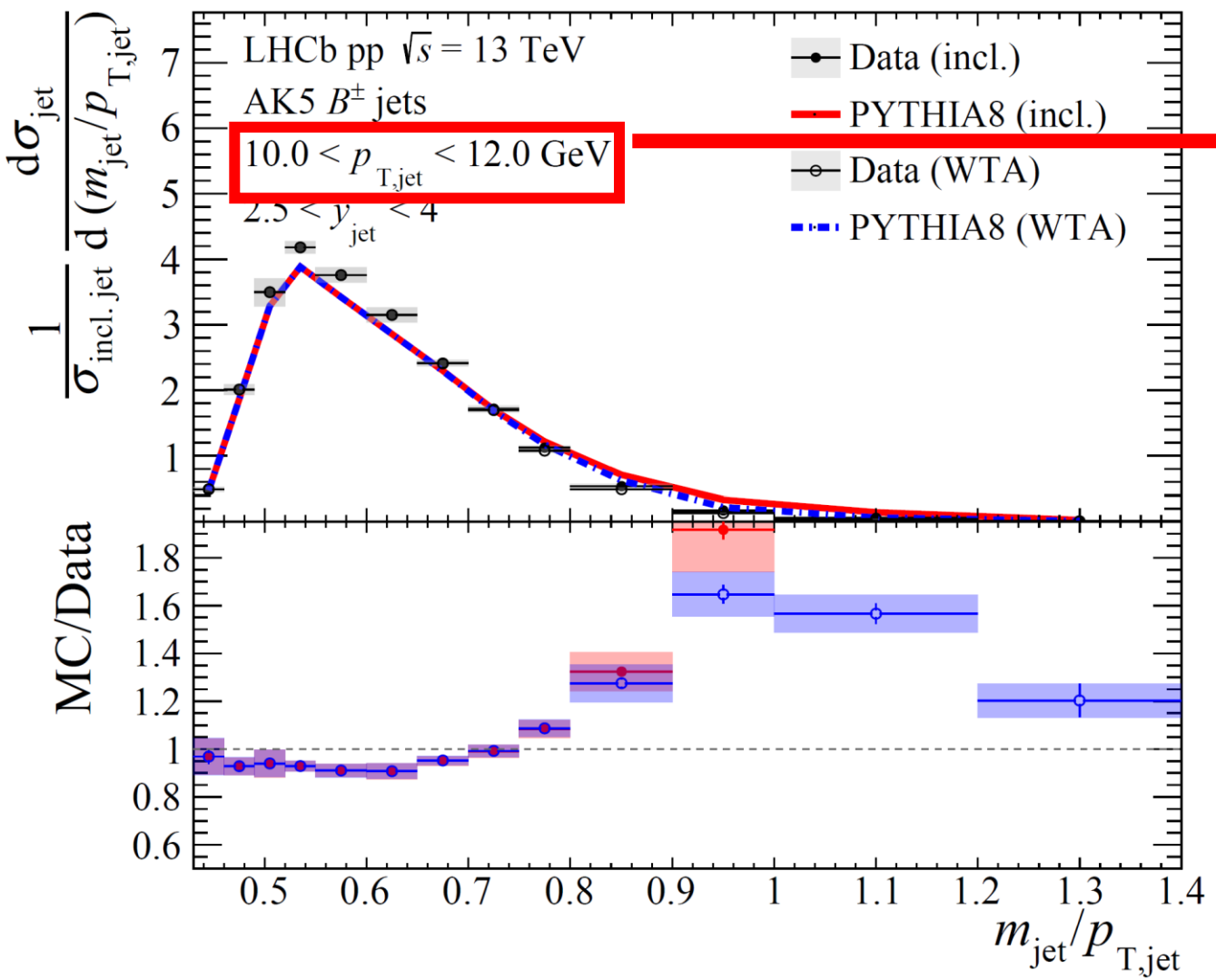

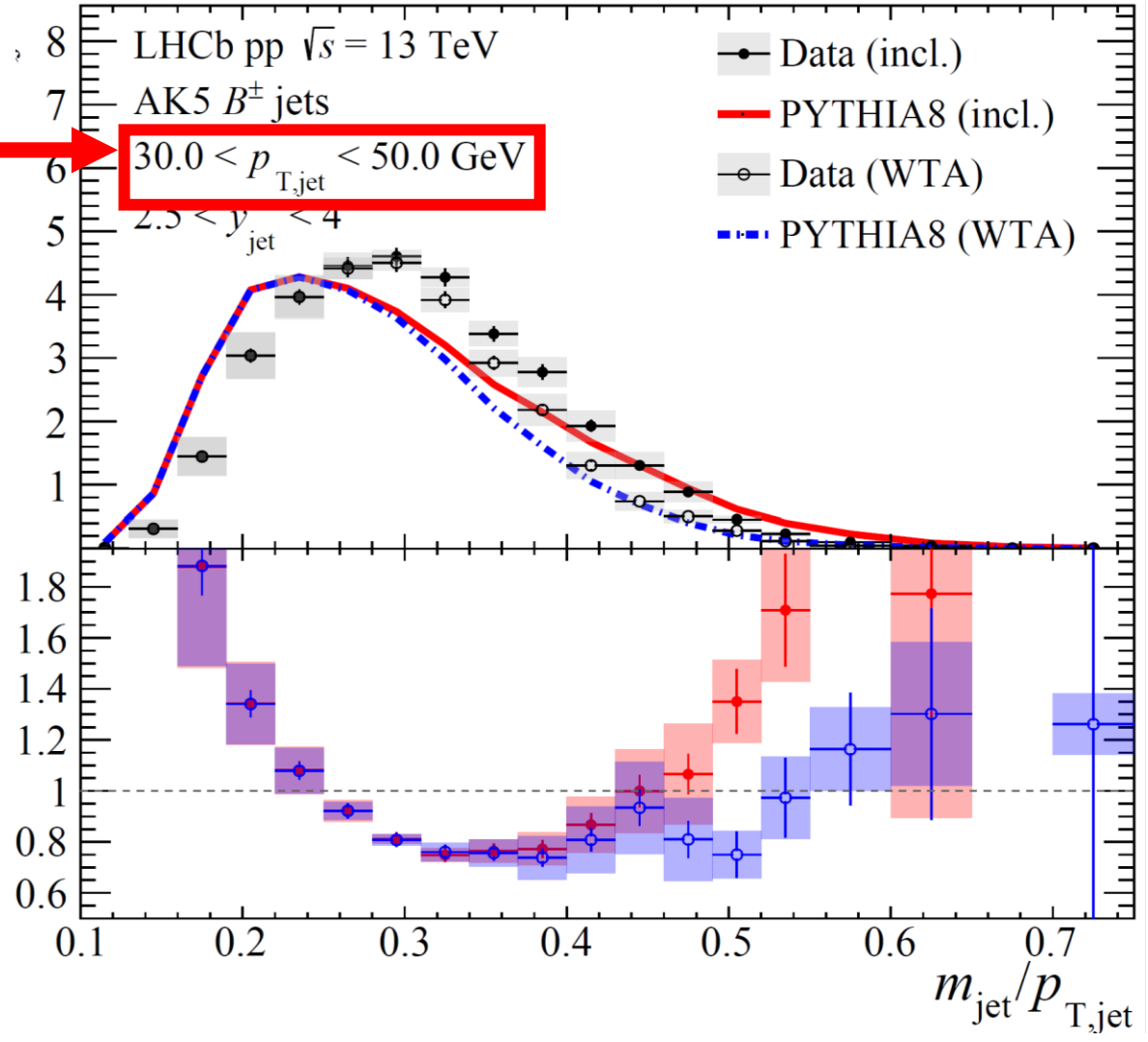

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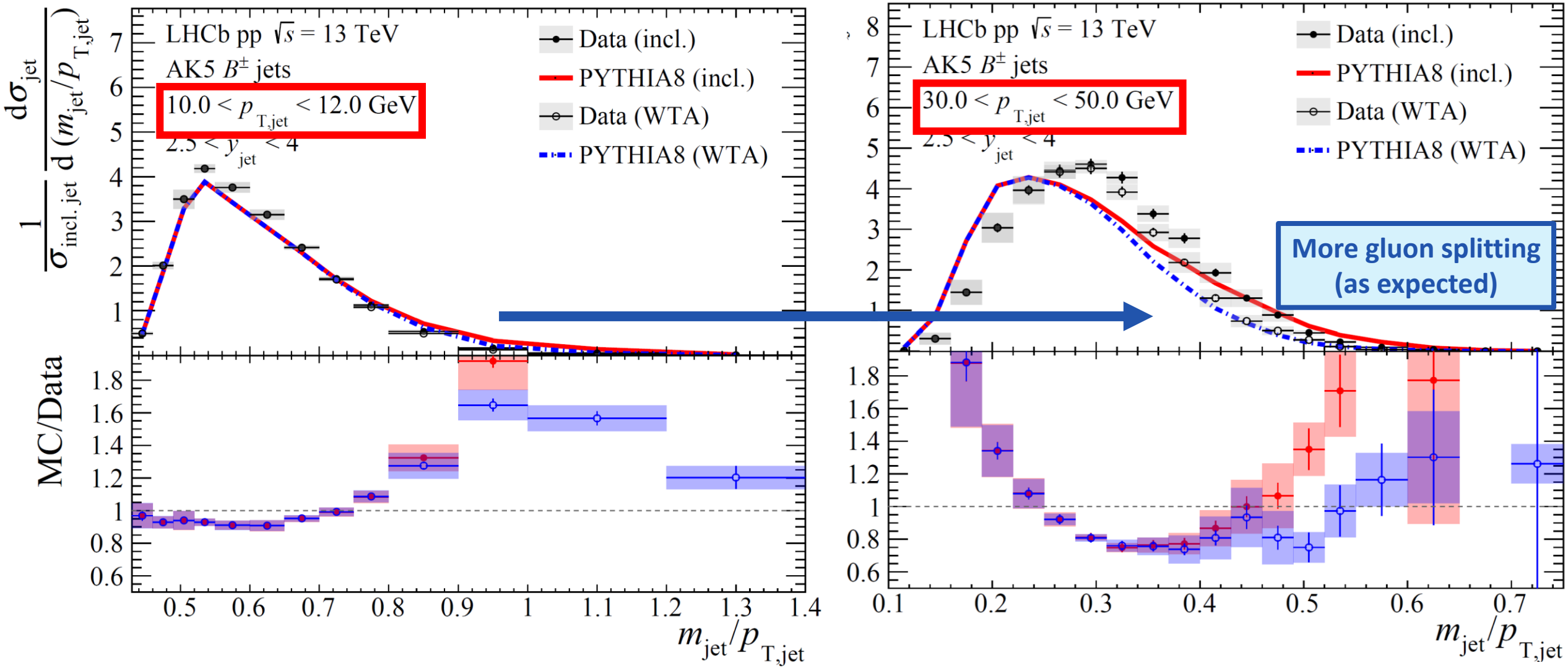

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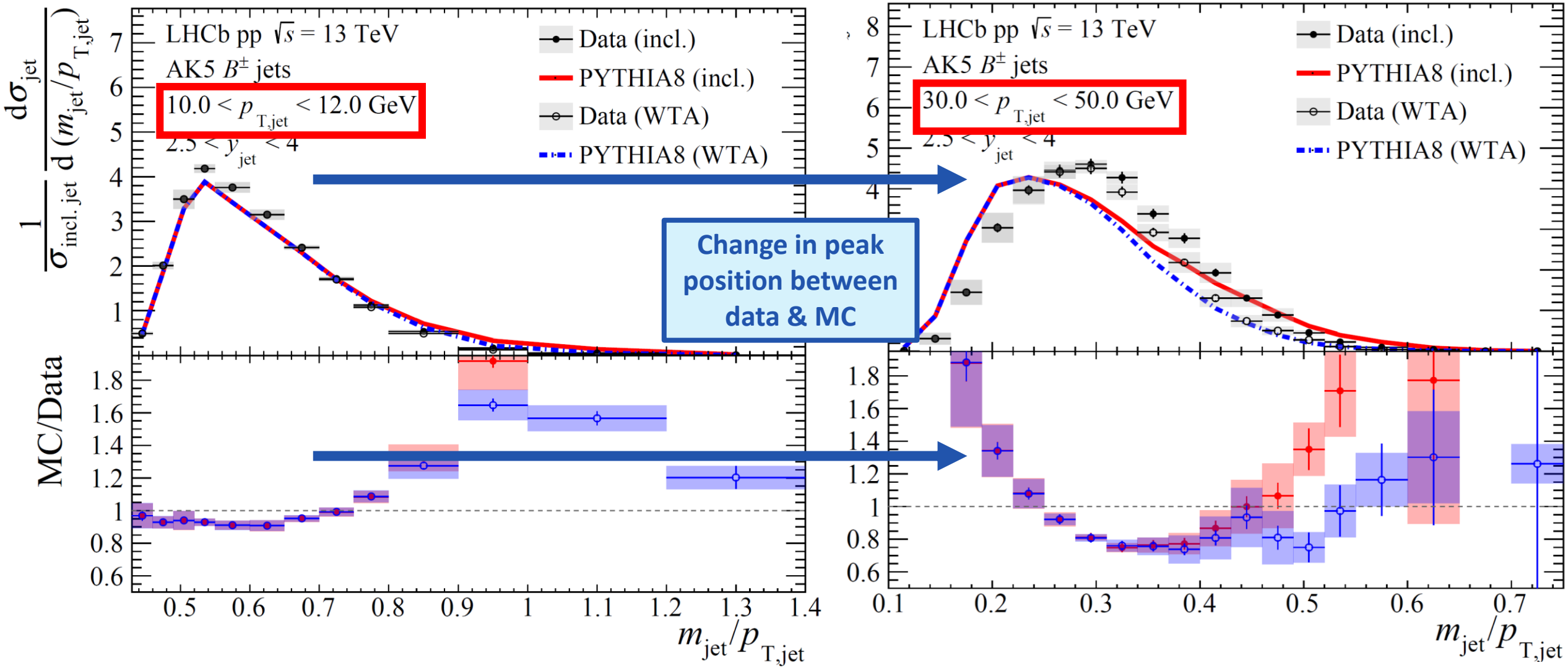

Change in peak position between data & MC

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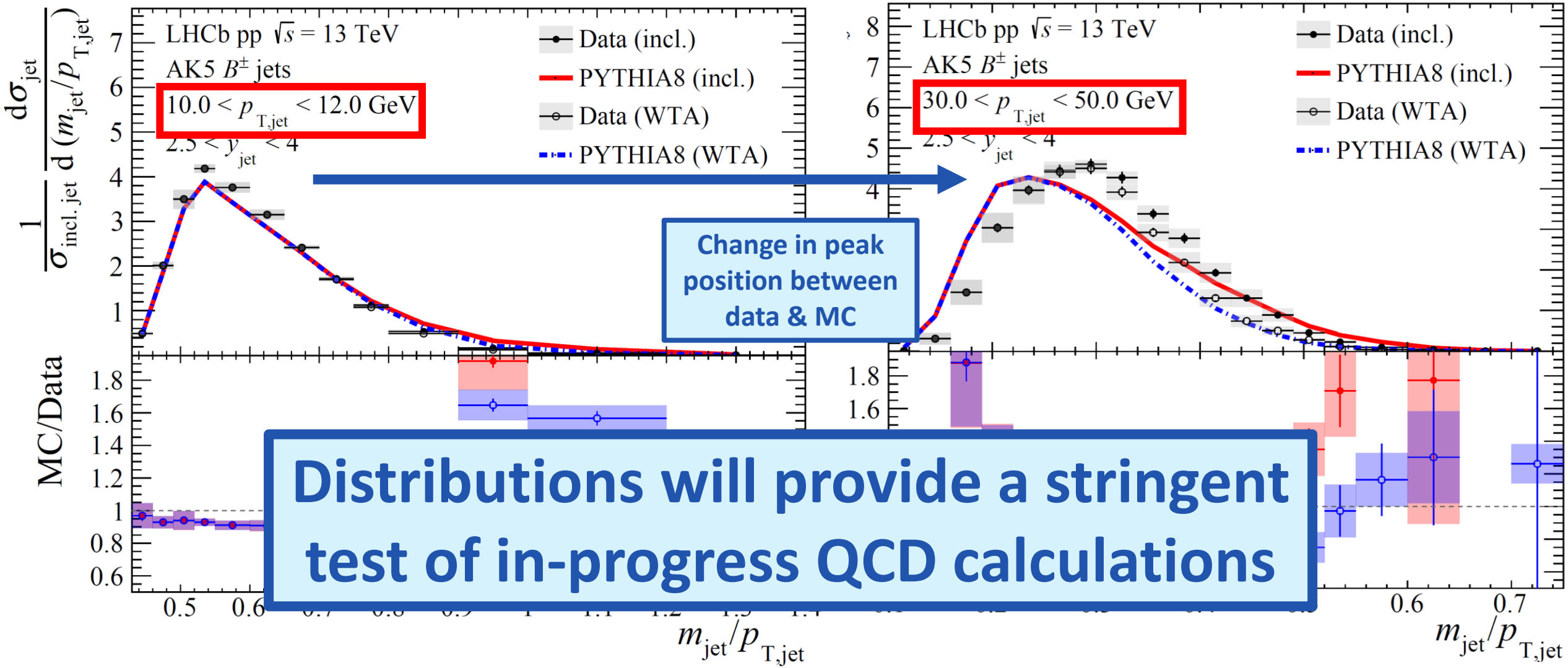
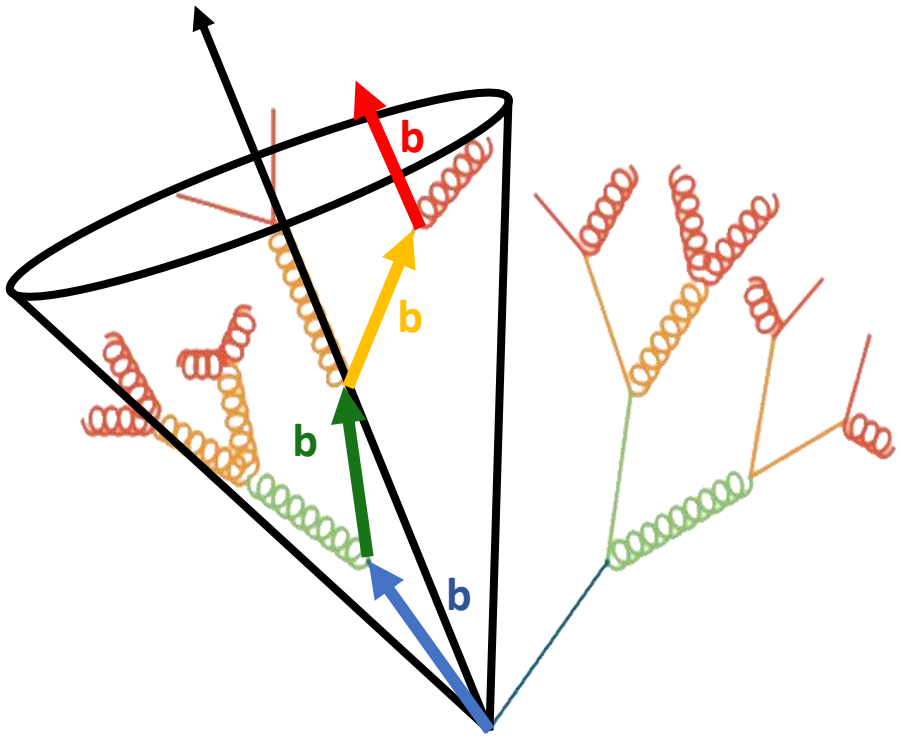


Change in peak position between data & MC

Distributions will provide a stringent test of in-progress QCD calculations

Mass effects on fragmentation?



Mass effects on fragmentation?

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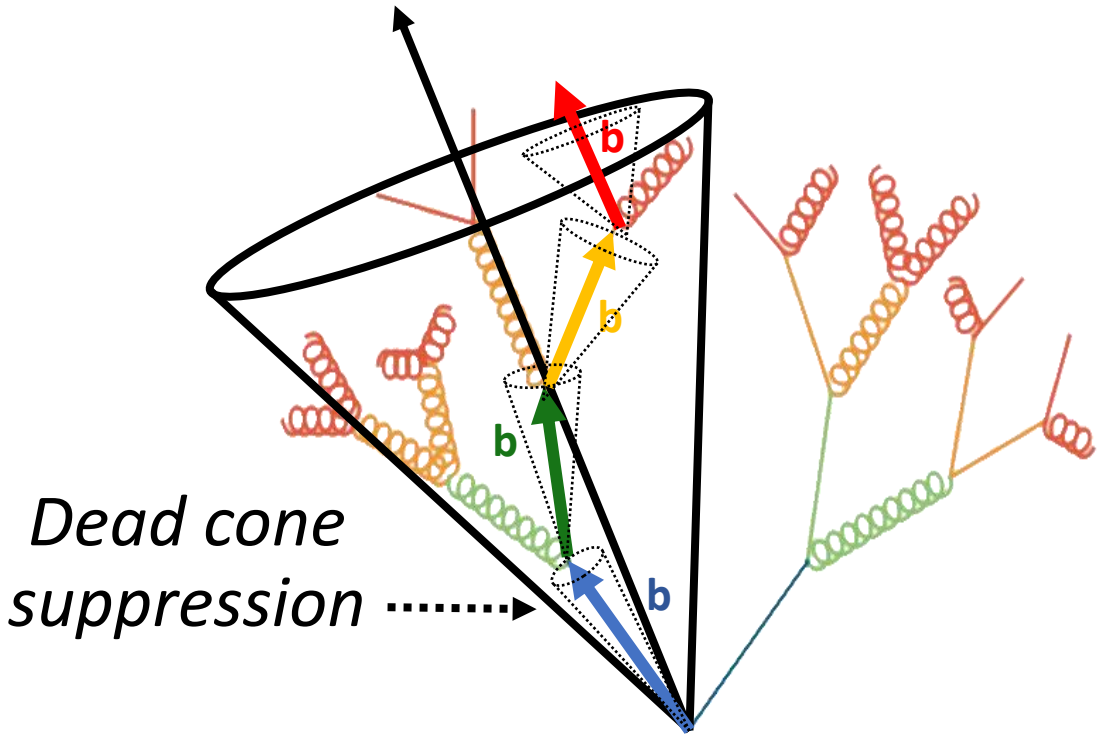
Dokshitzer, Khoze, Troyan
J. Phys. **G17** (1991) 1602



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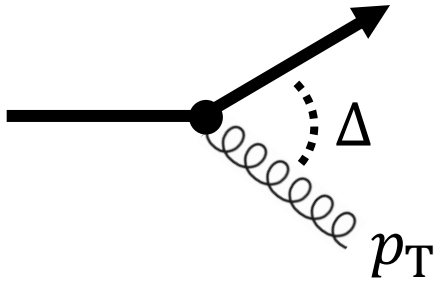

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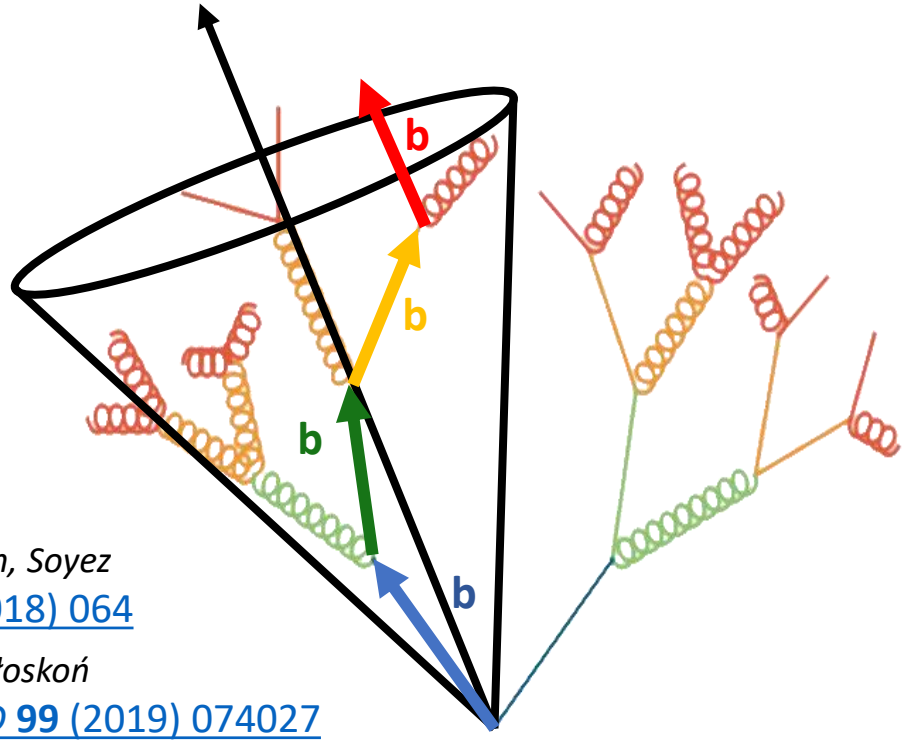

Dreyer, Salam, Soyez
JHEP **12** (2018) 064

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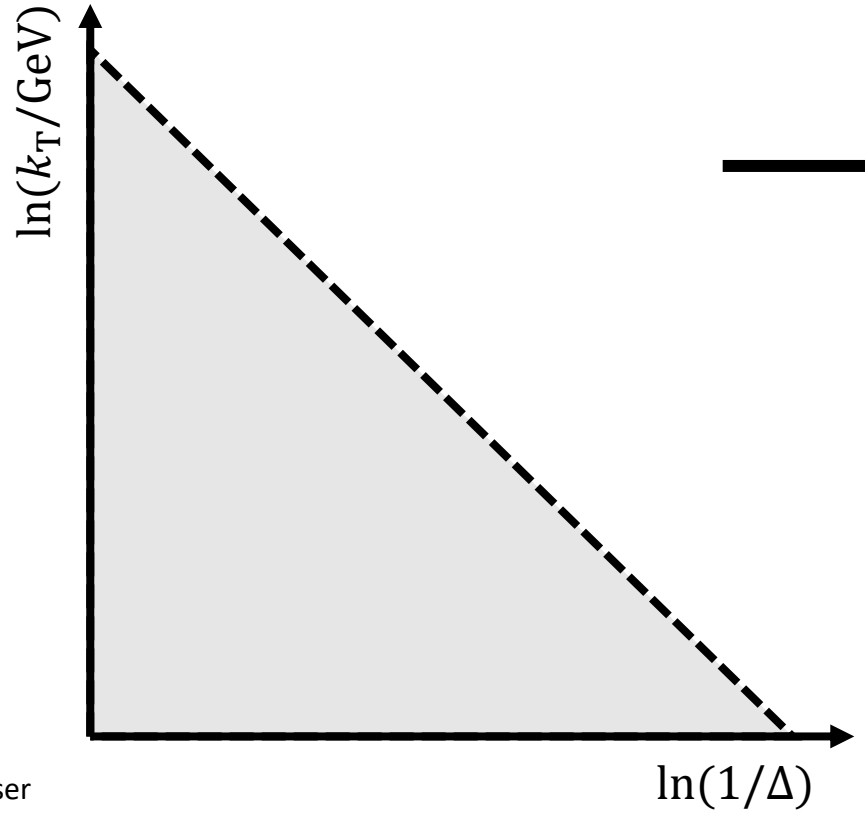

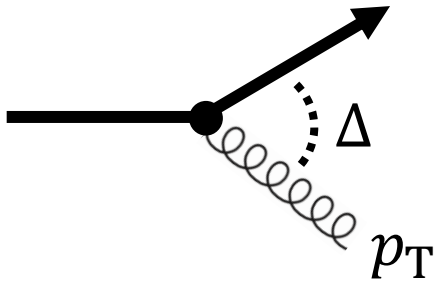

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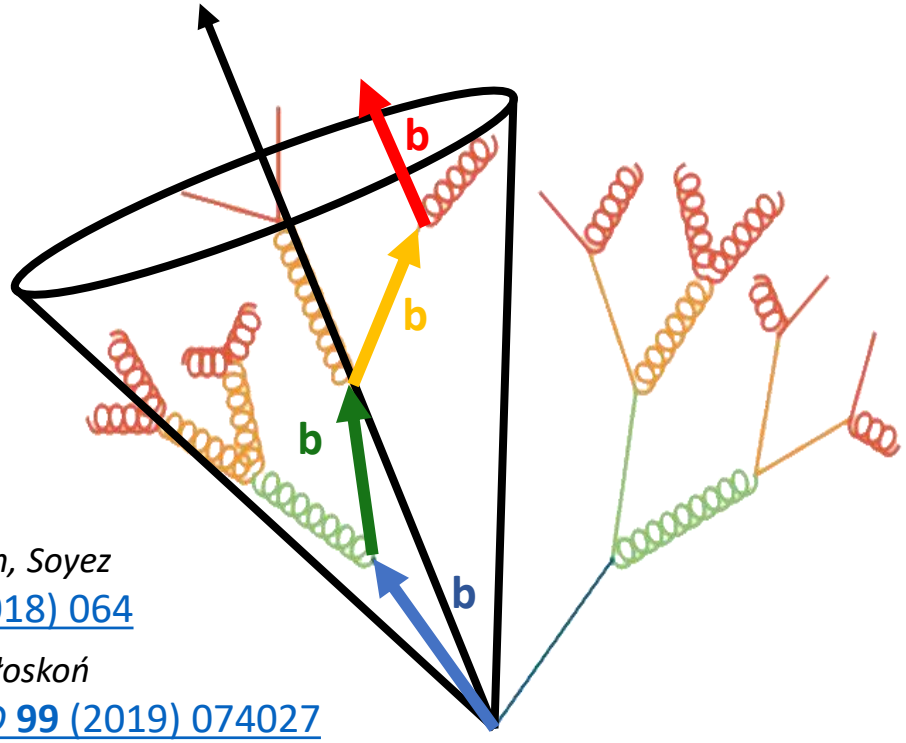

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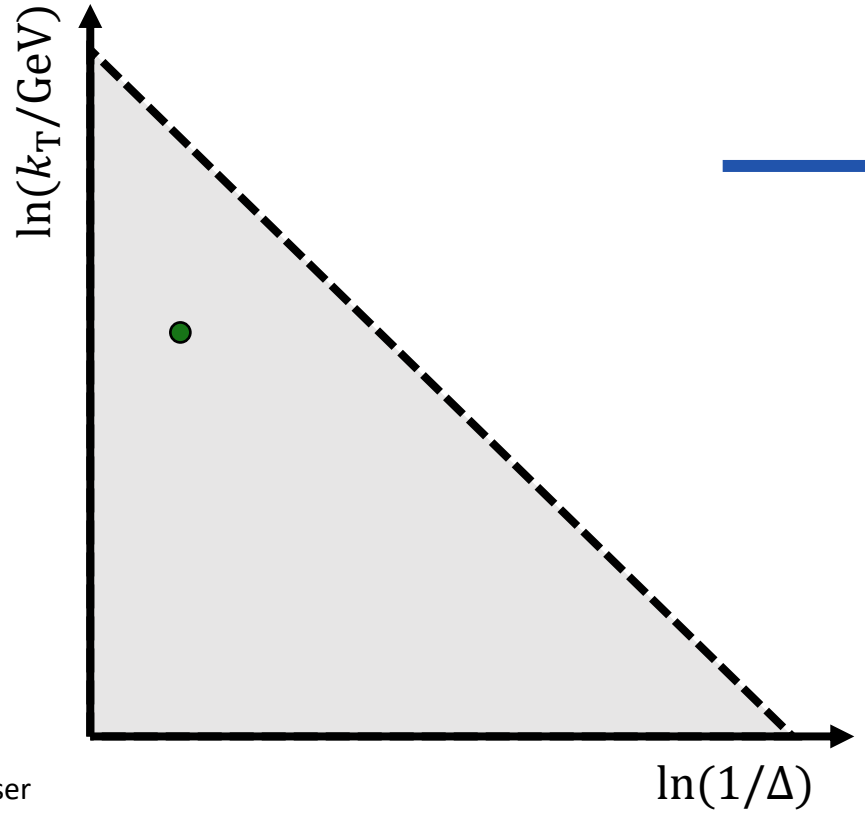

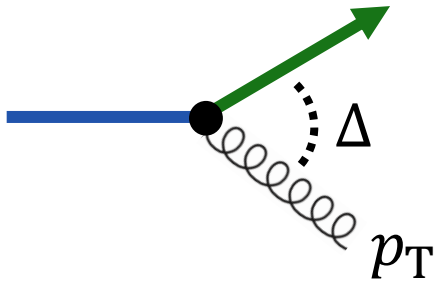

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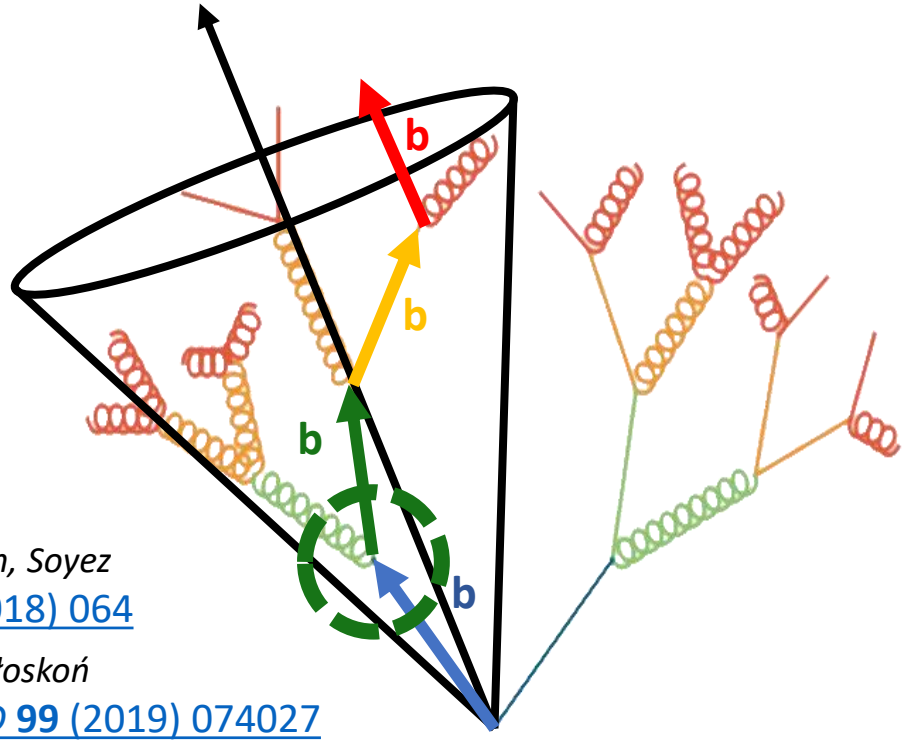

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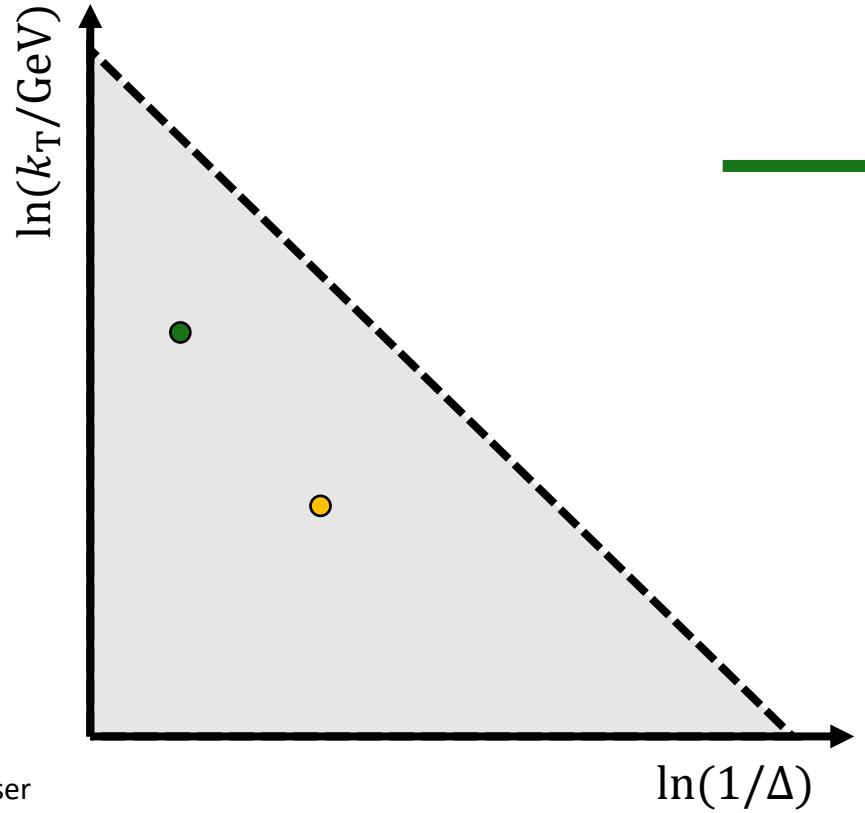

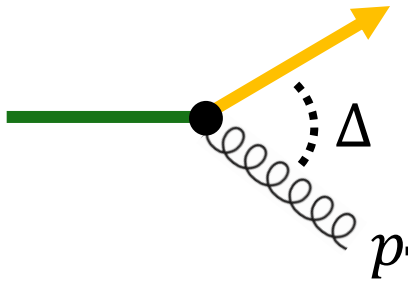

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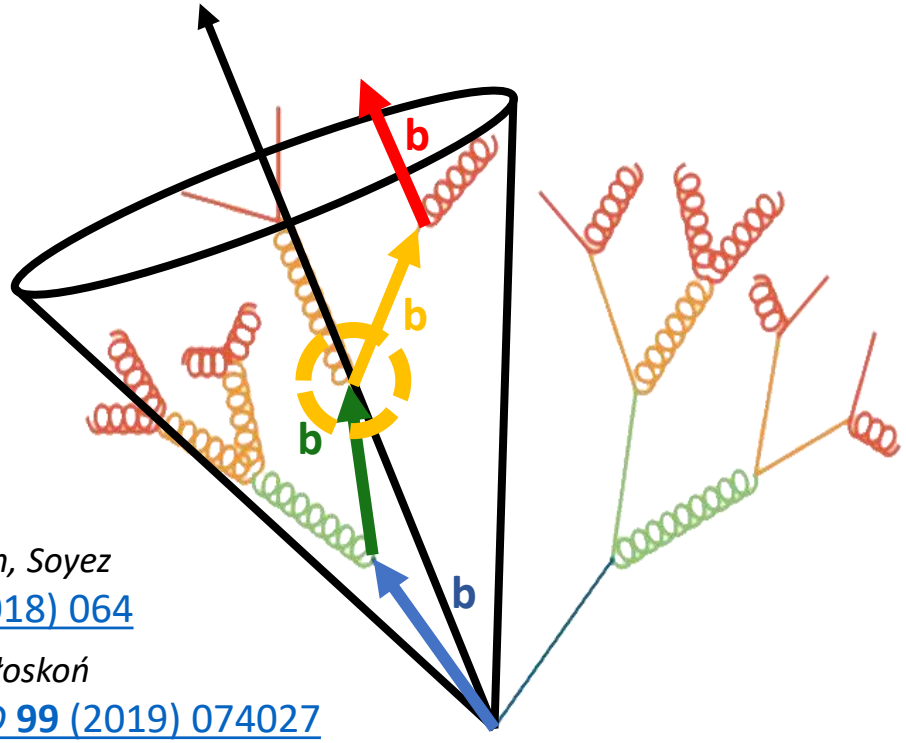

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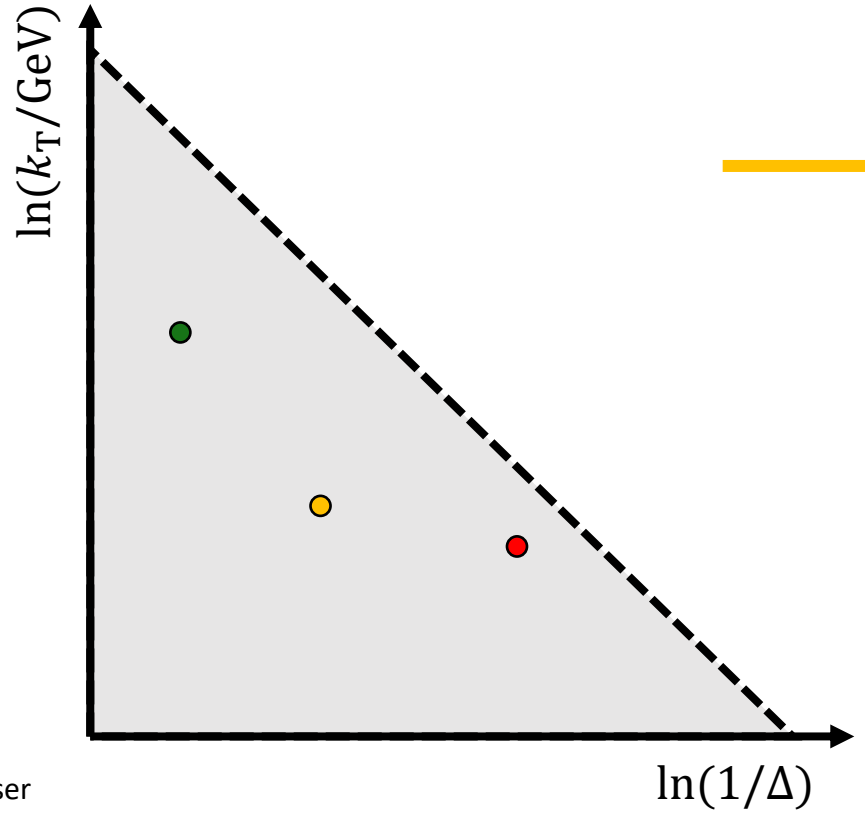

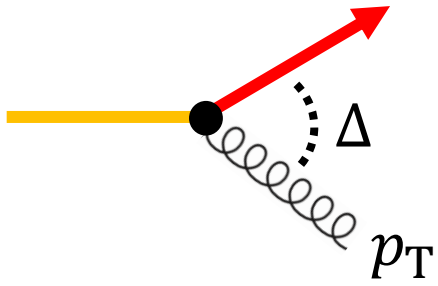

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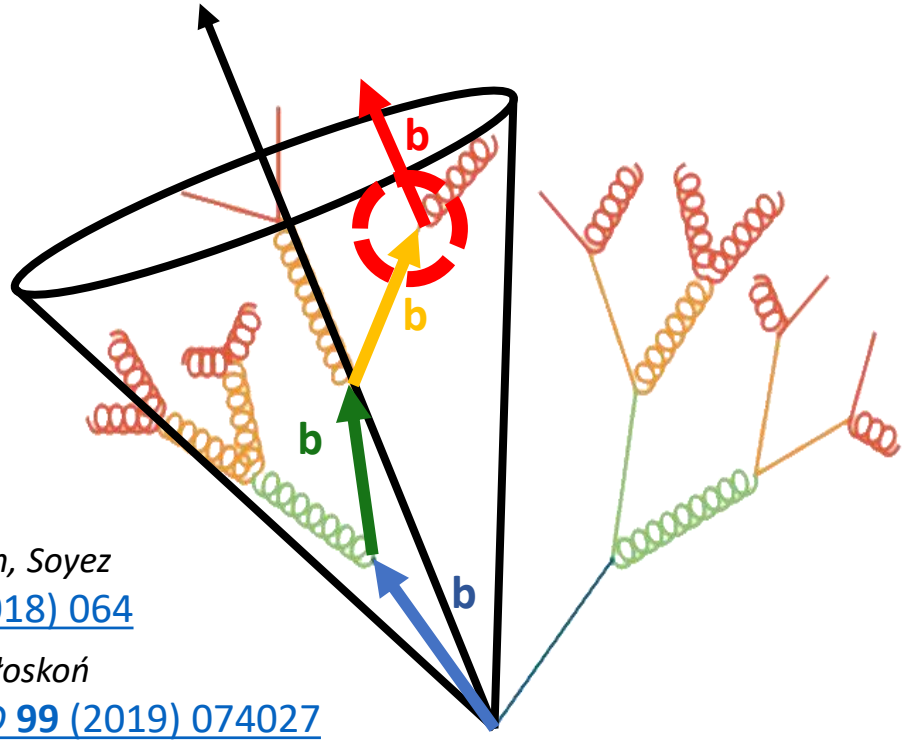

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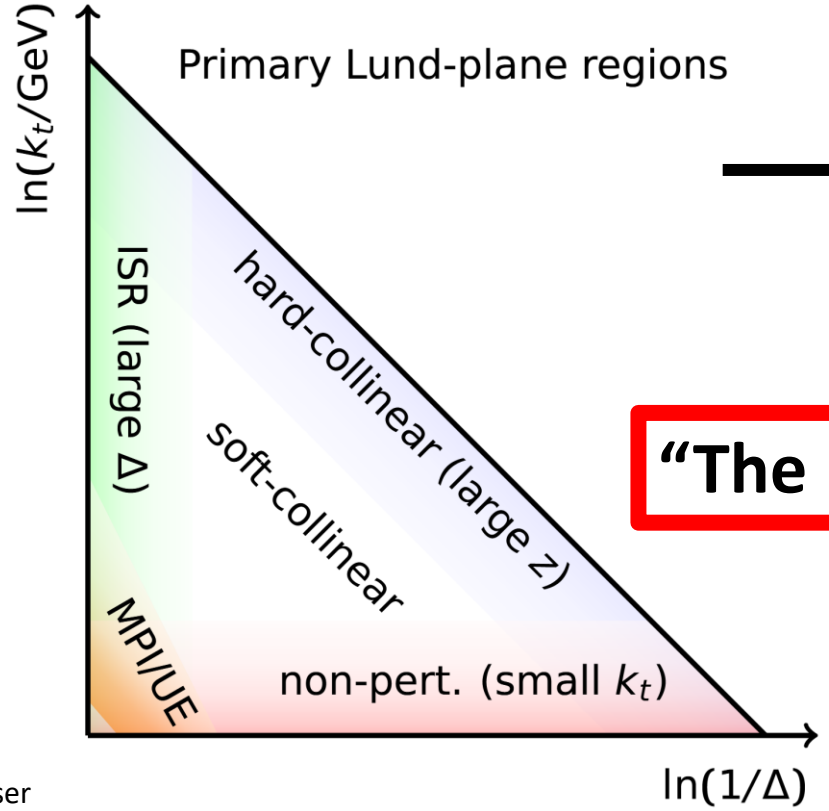

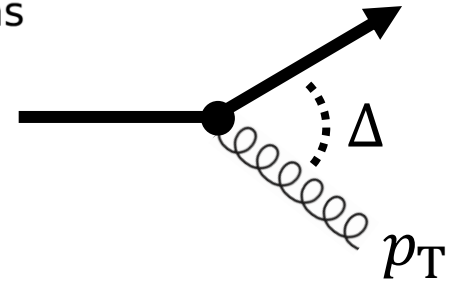

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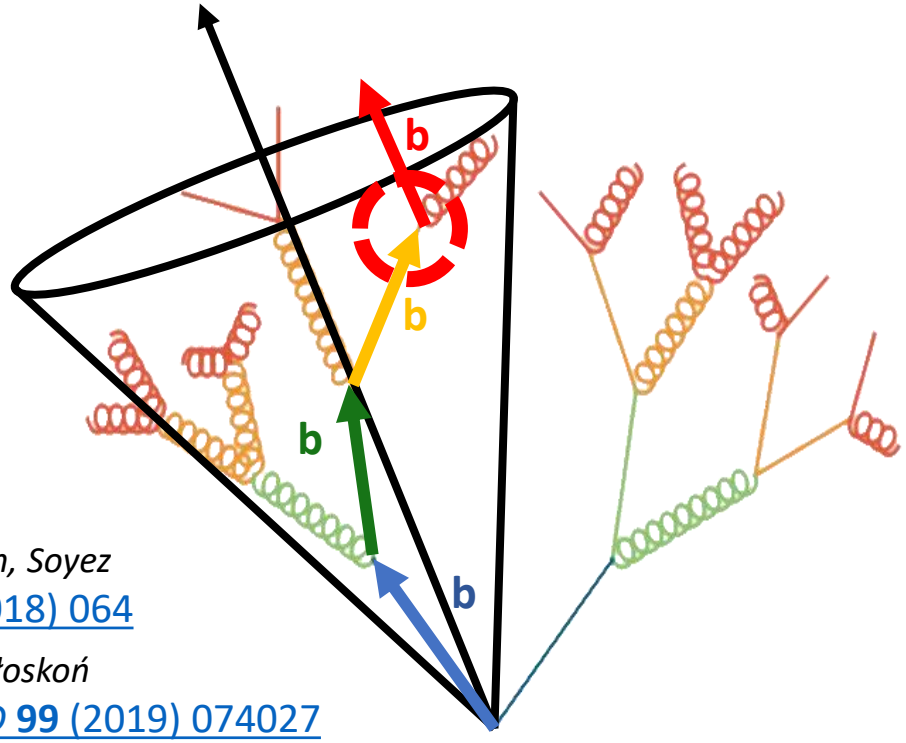
"The Lund jet plane"



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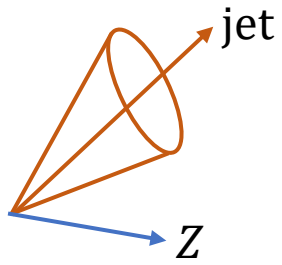
Light **vs. HF** q Lund jet plane

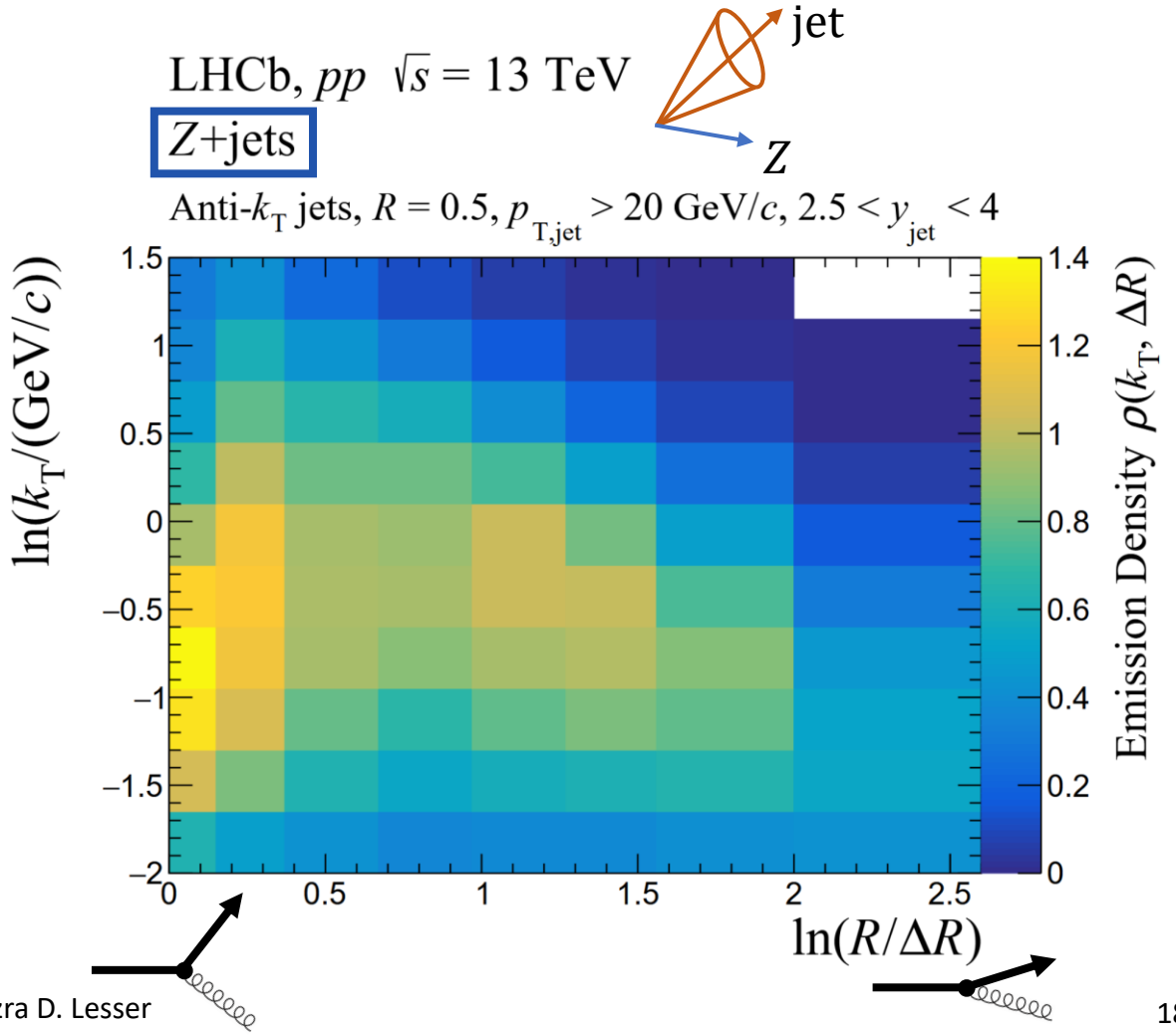
- Light-quark enriched sample obtained using Z + jet sample



Light **vs. HF** q Lund jet plane

LHCb Collaboration,
Phys. Rev. **D112** (2025) 072015

- Light-quark enriched sample: Z + jet events



Light vs. HF q Lund jet plane

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LHCb Collaboration,
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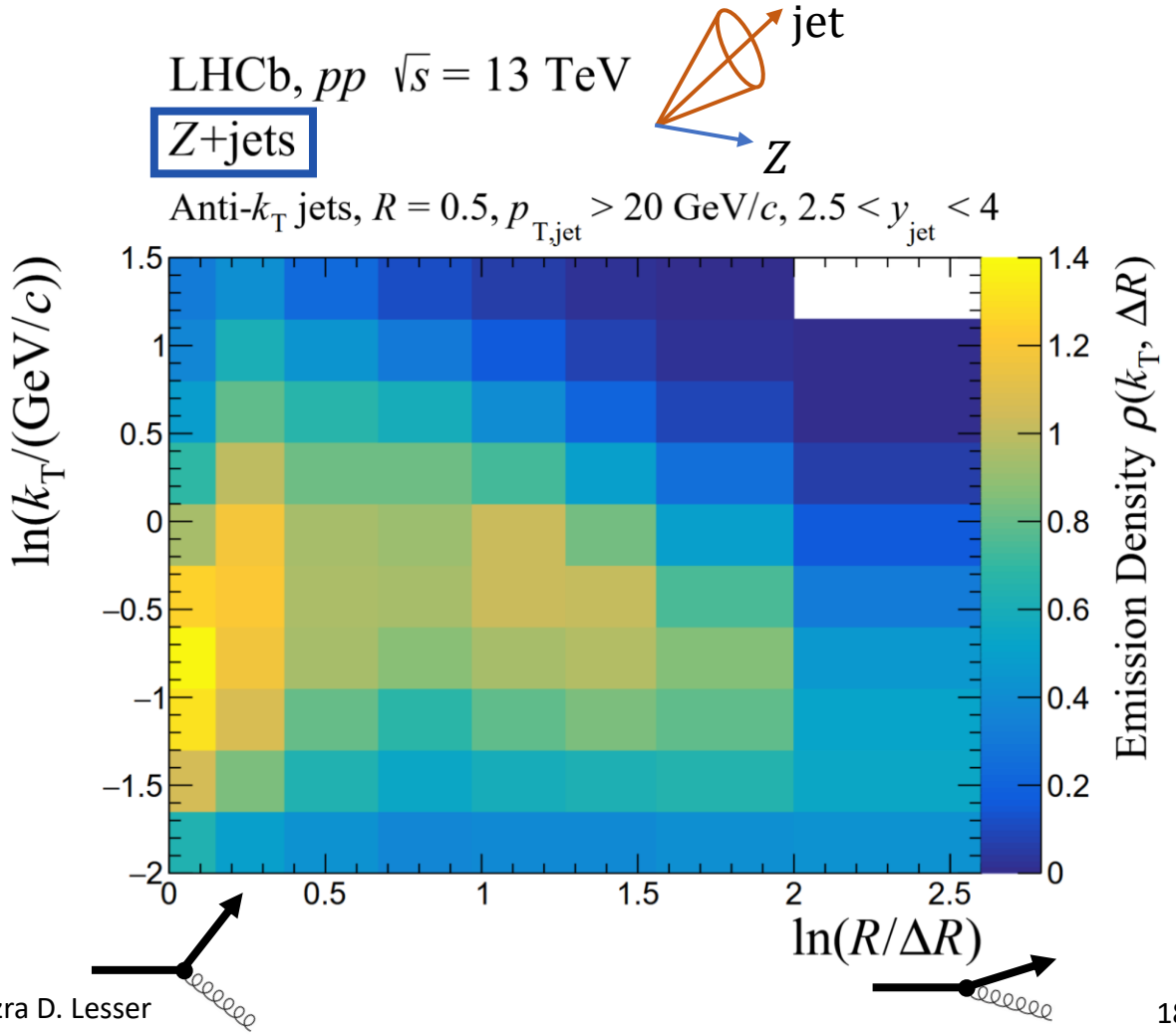
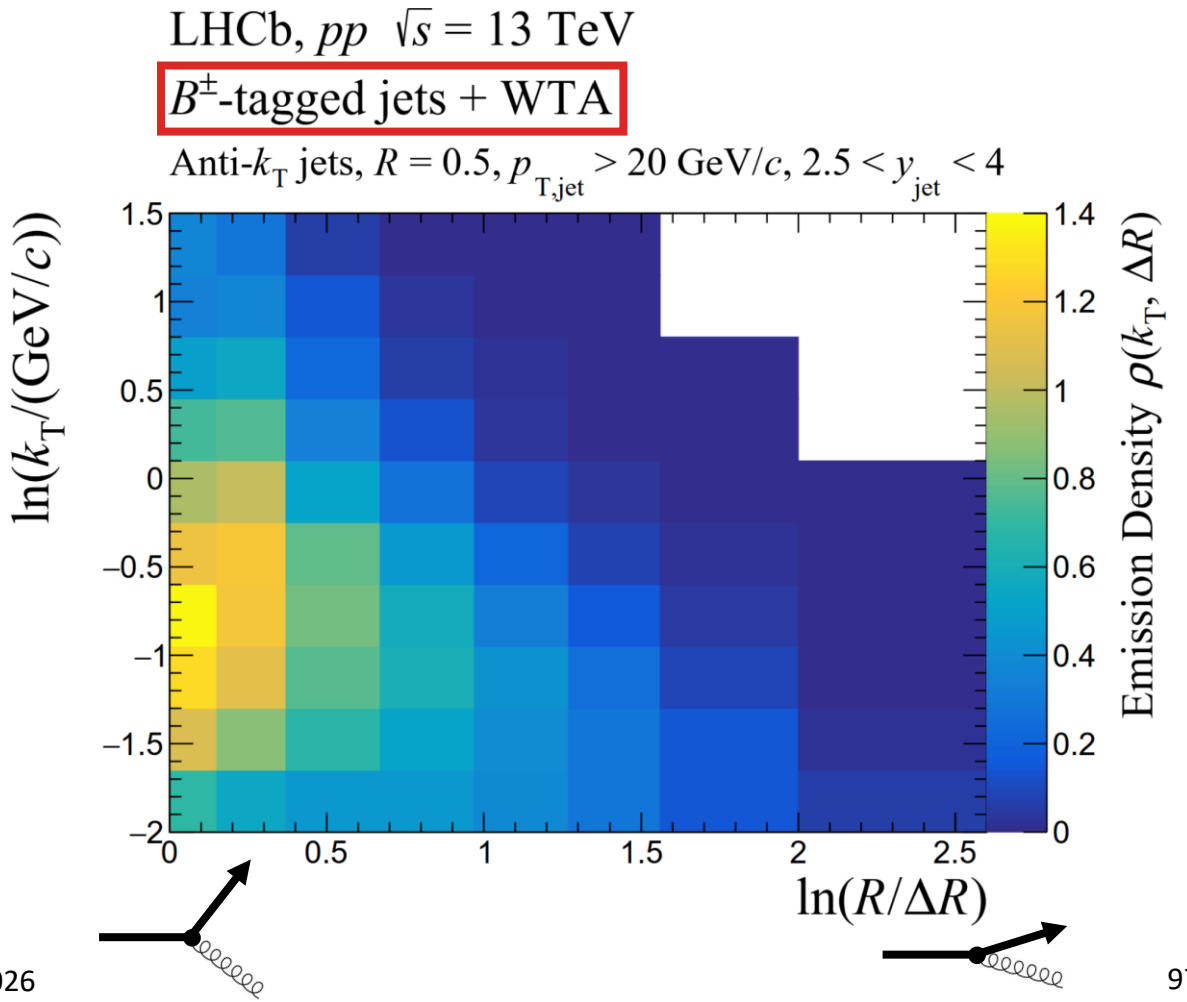


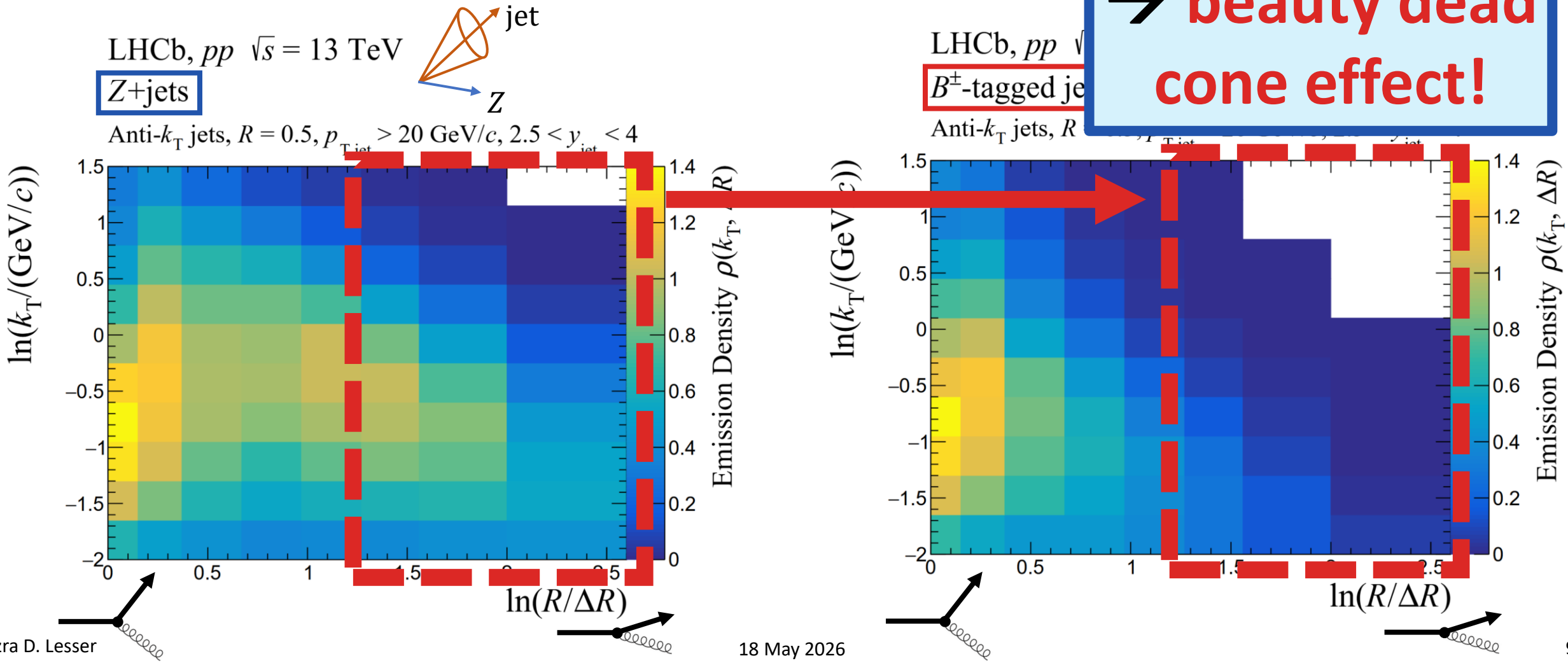


Light vs. HF q Lund jet p

- Heavy flavor distribution from b quarks ($B^{\pm}$ hadrons)

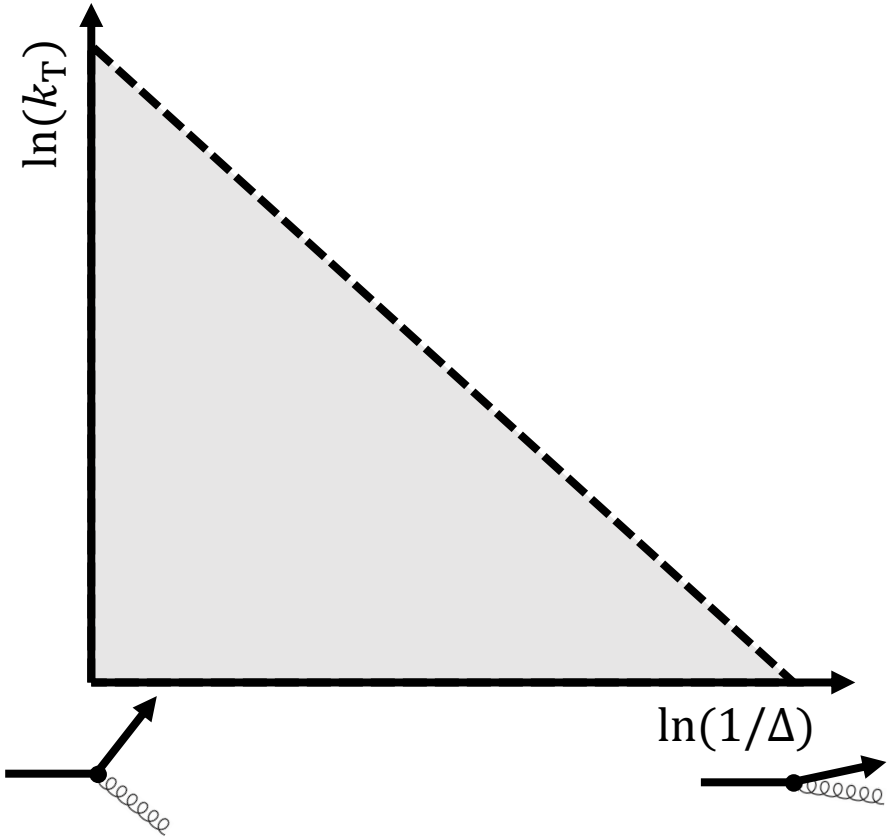
Suppression at small angles

→ beauty dead cone effect!



Slicing the Lund jet plane

LHCb Collaboration,
Phys. Rev. **D112** (2025) 072015



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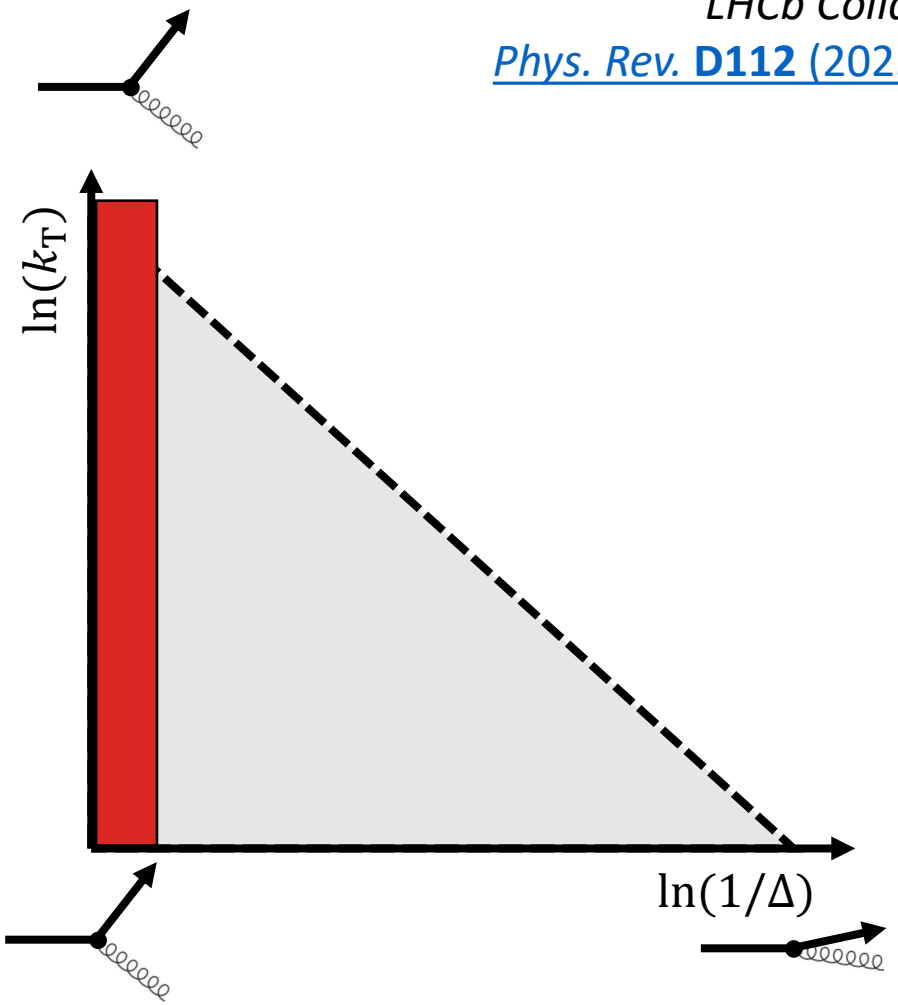

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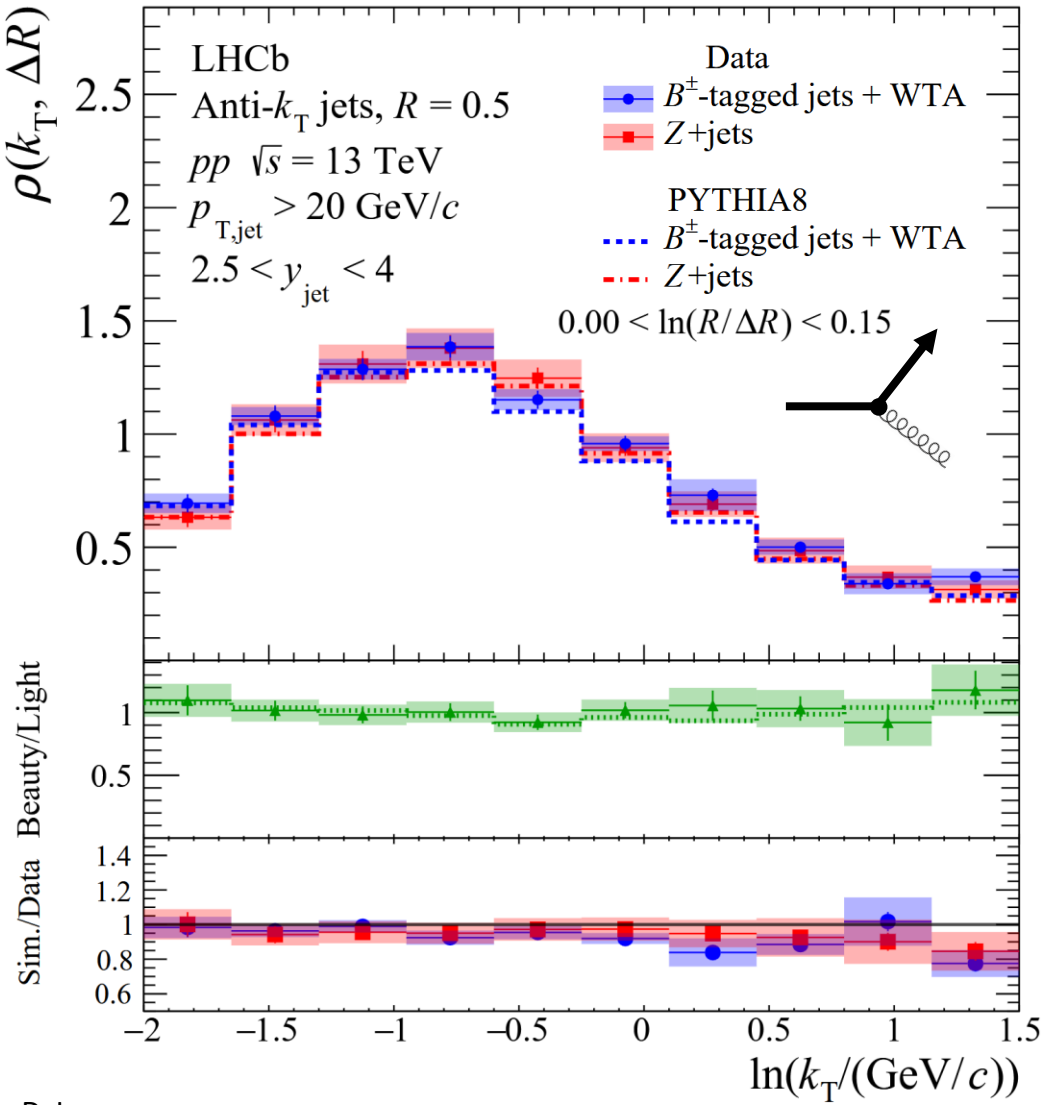
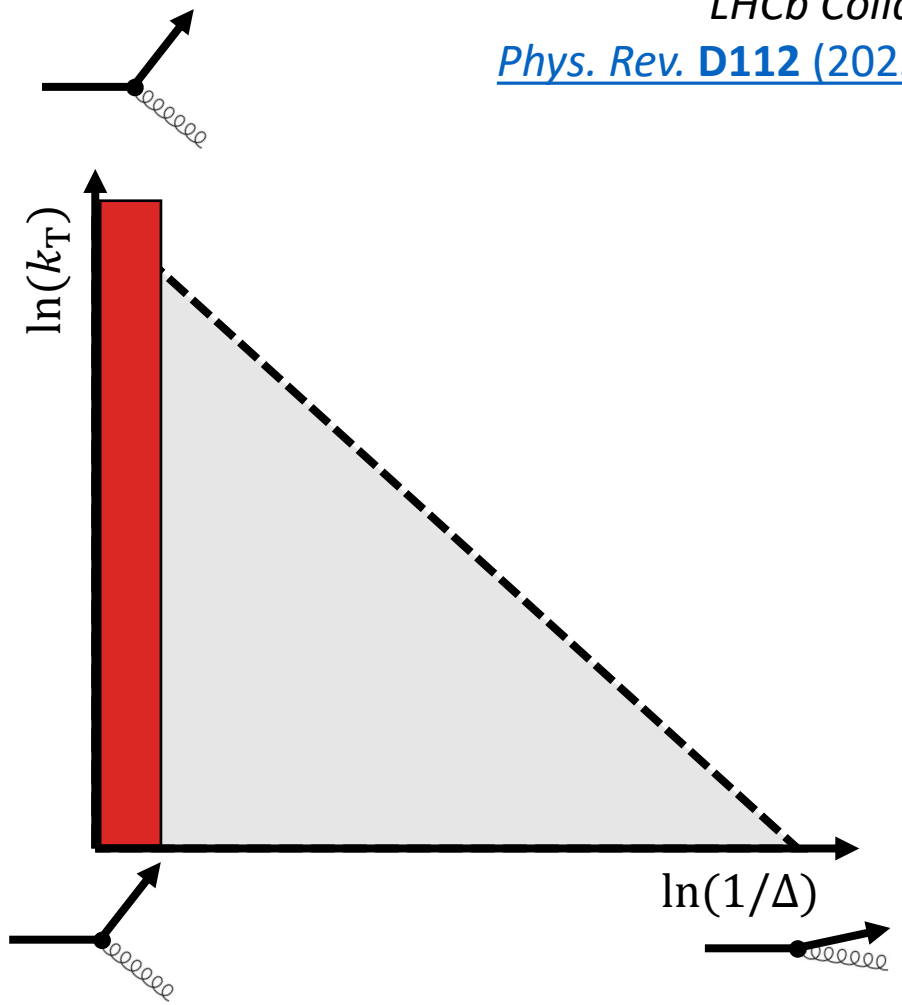


← ***Dead cone modification***

← ***Pythia 8 agreement***



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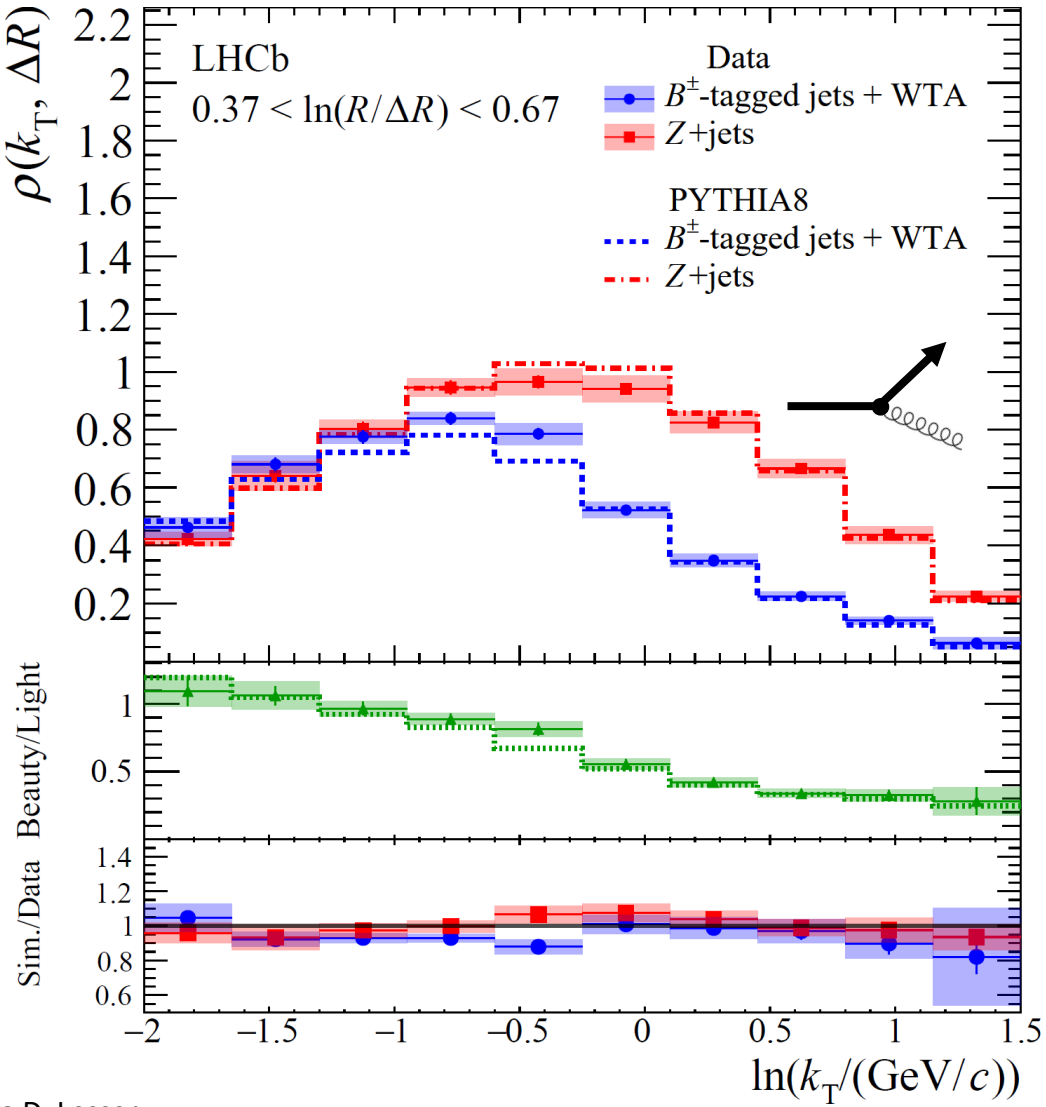

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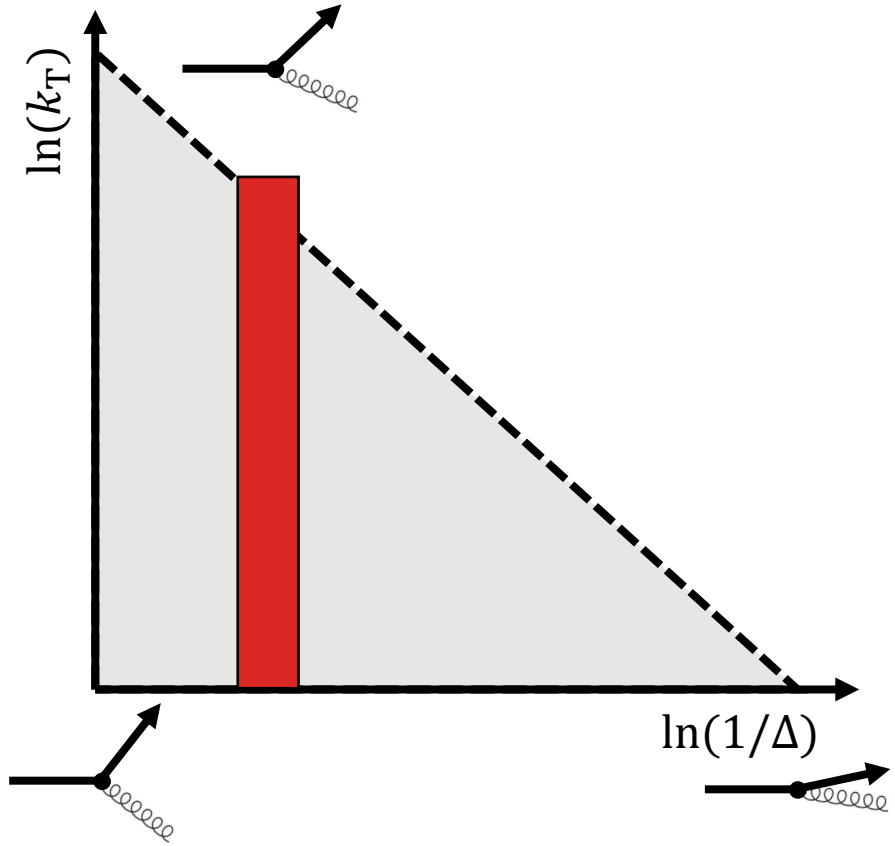
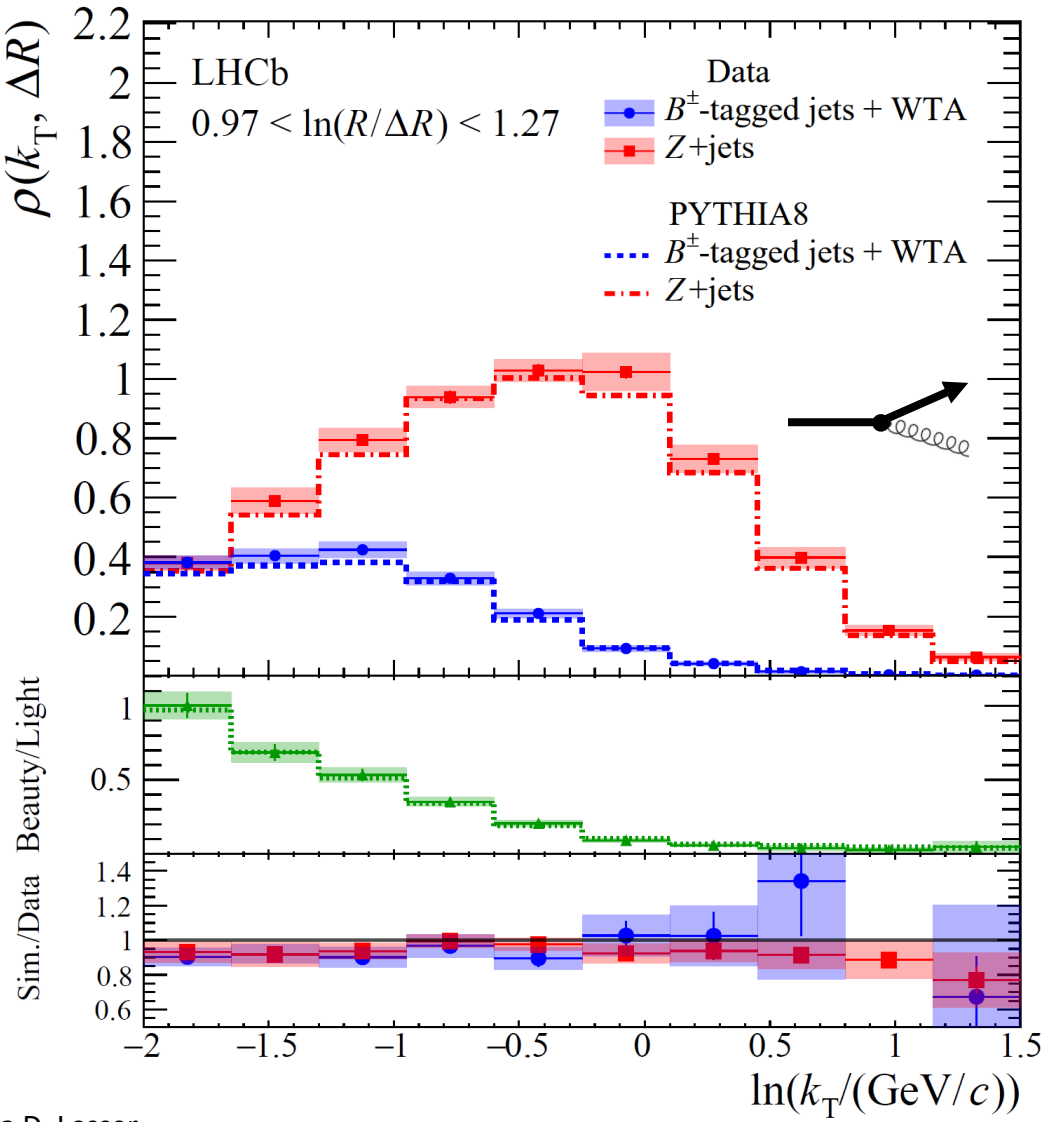


Slicing the Lund jet plane

LHCb Collaboration,
Phys. Rev. **D112** (2025) 072015



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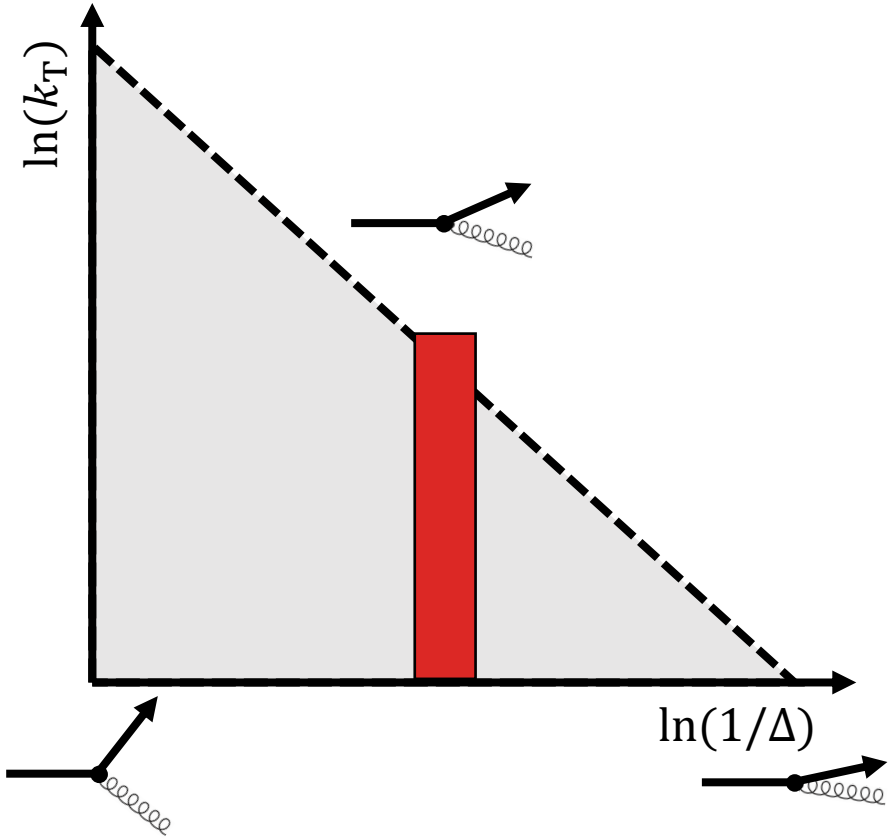

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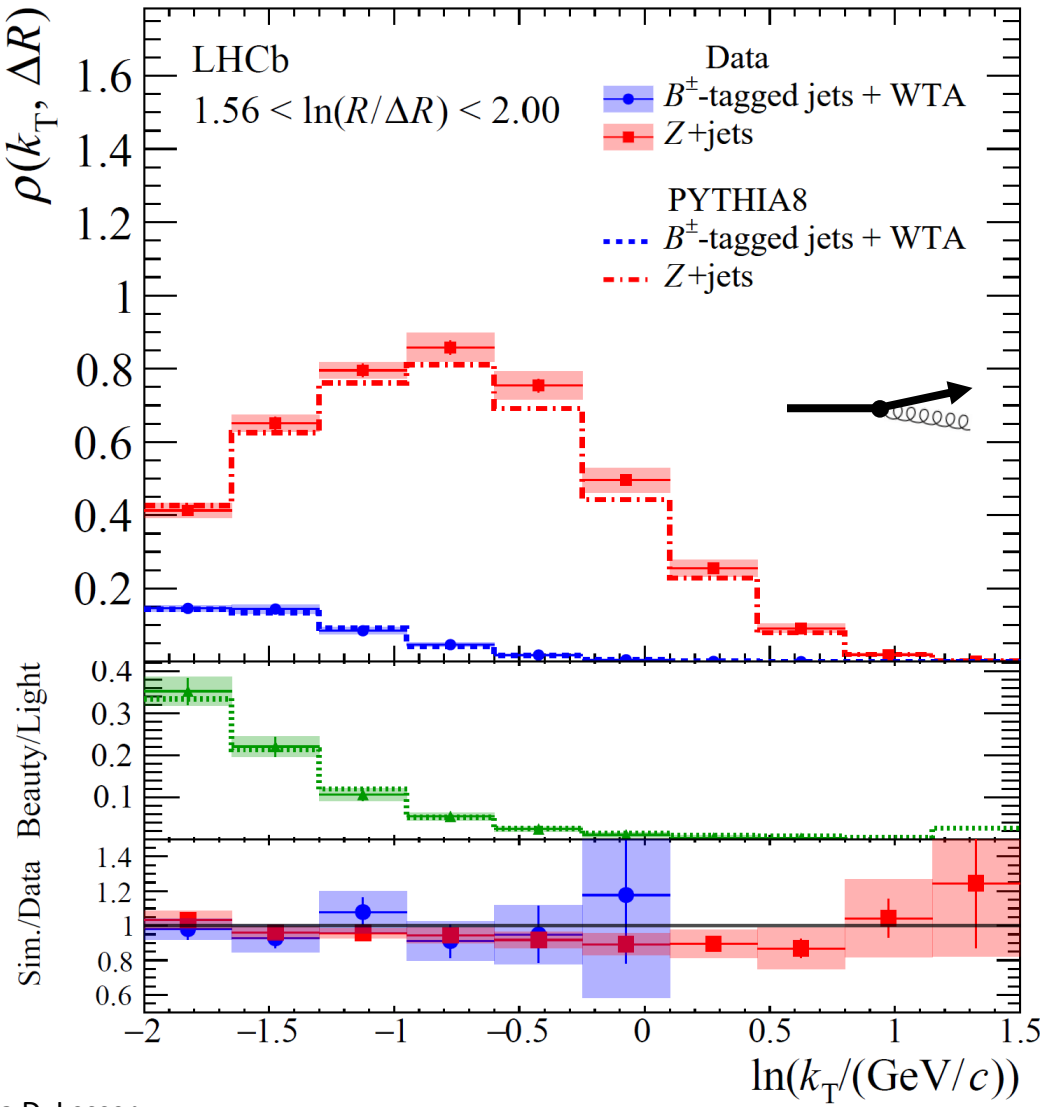

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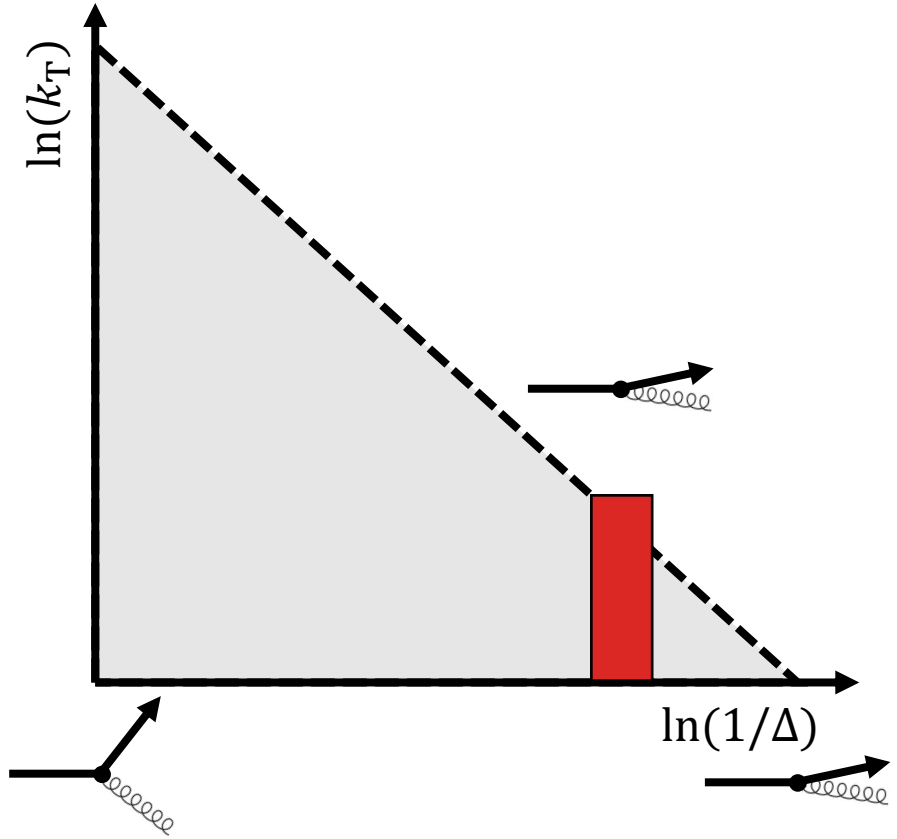
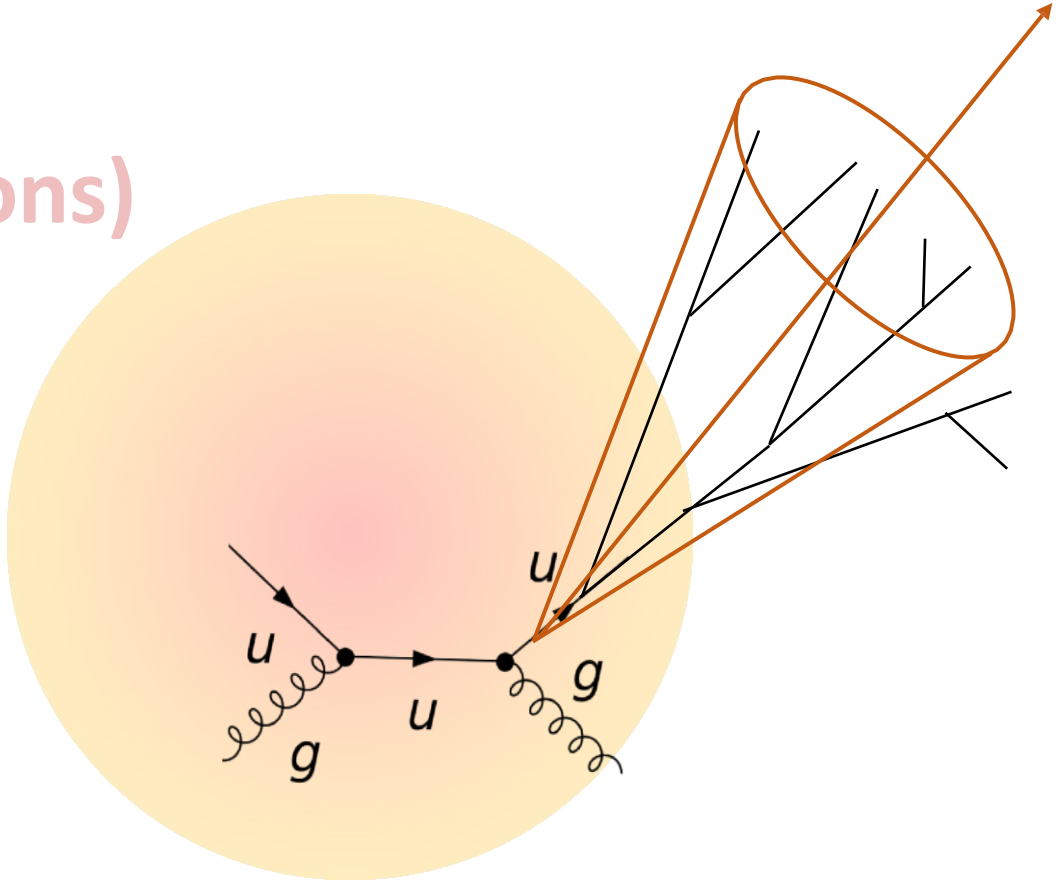


This talk: probing QCD in …

- **“vacuum” (proton-proton collisions)**
- **“medium” (heavy-ion collisions)**



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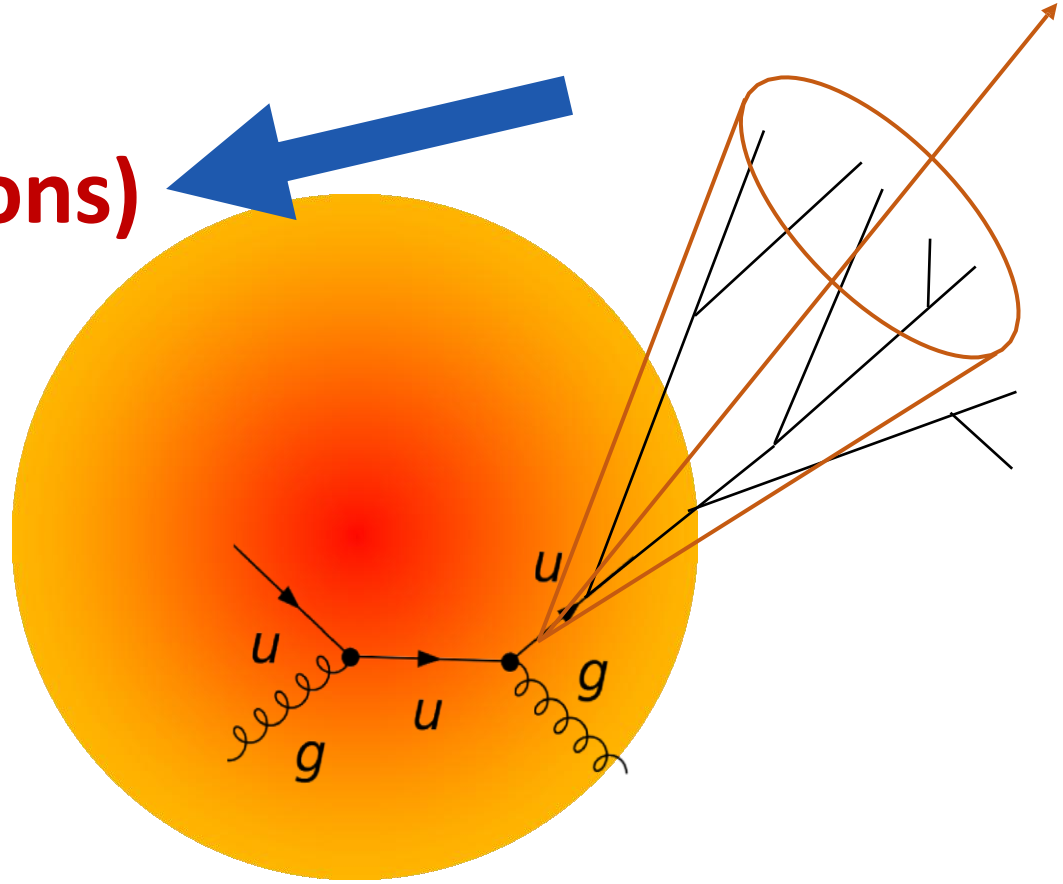
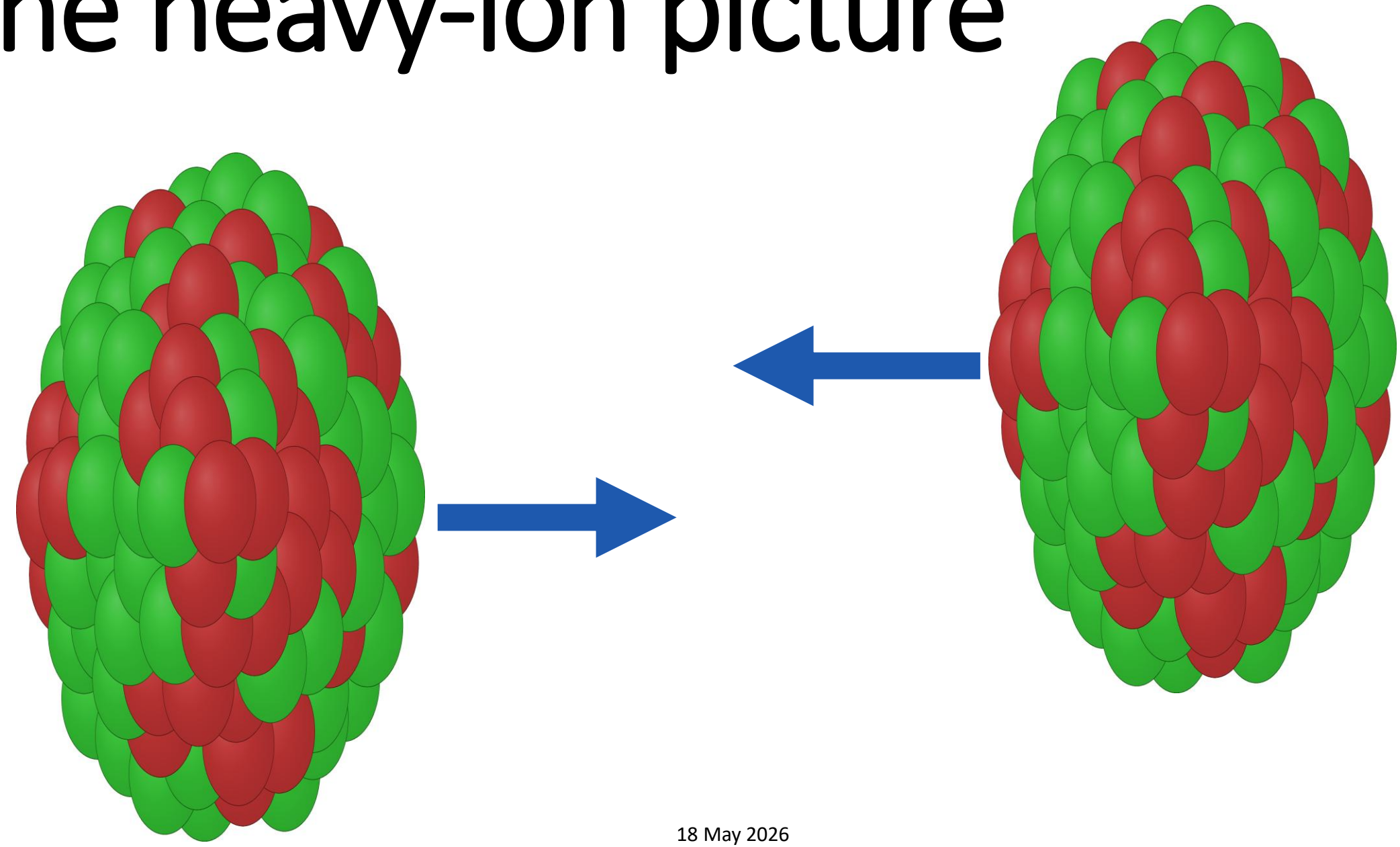


The heavy-ion picture



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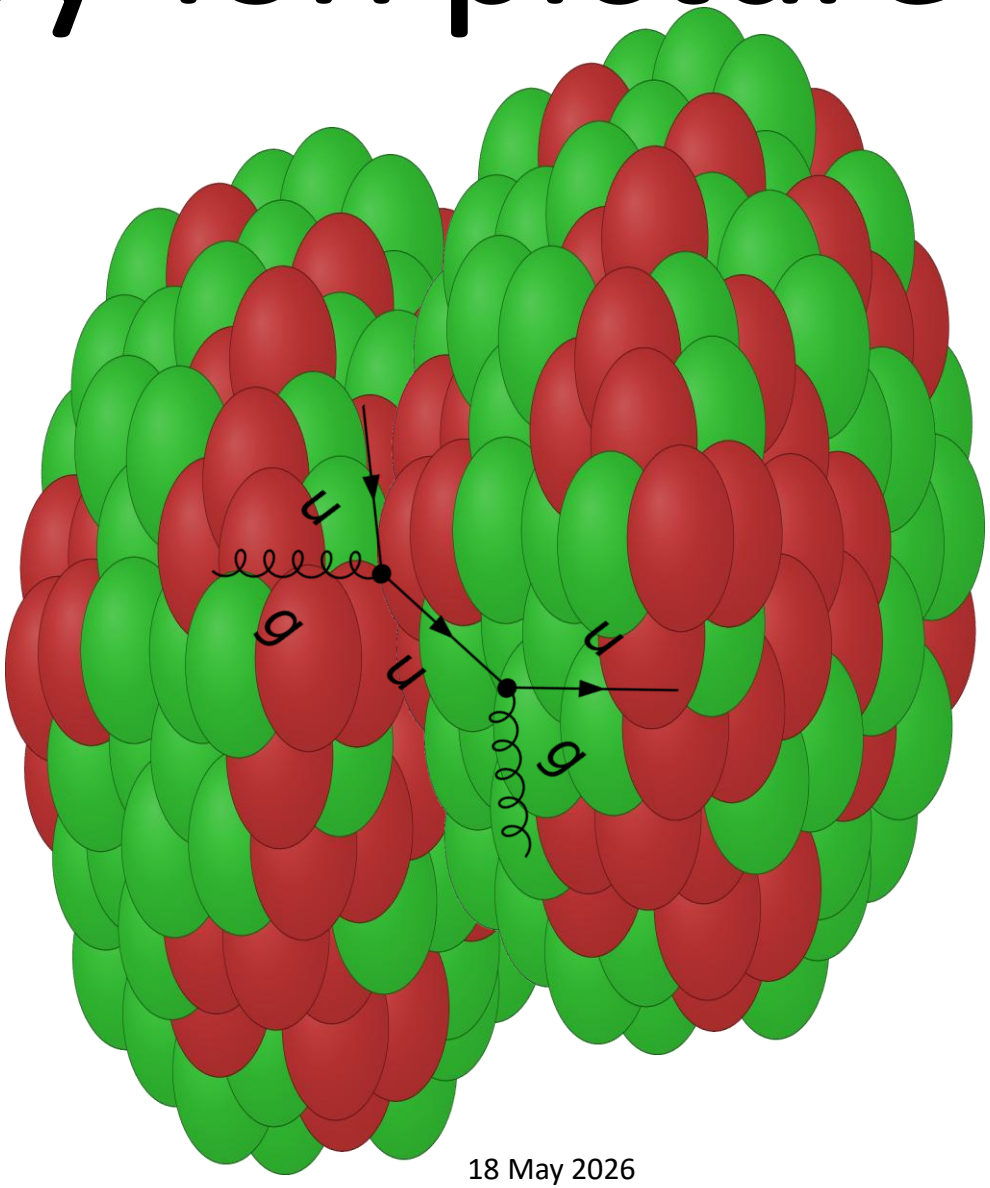

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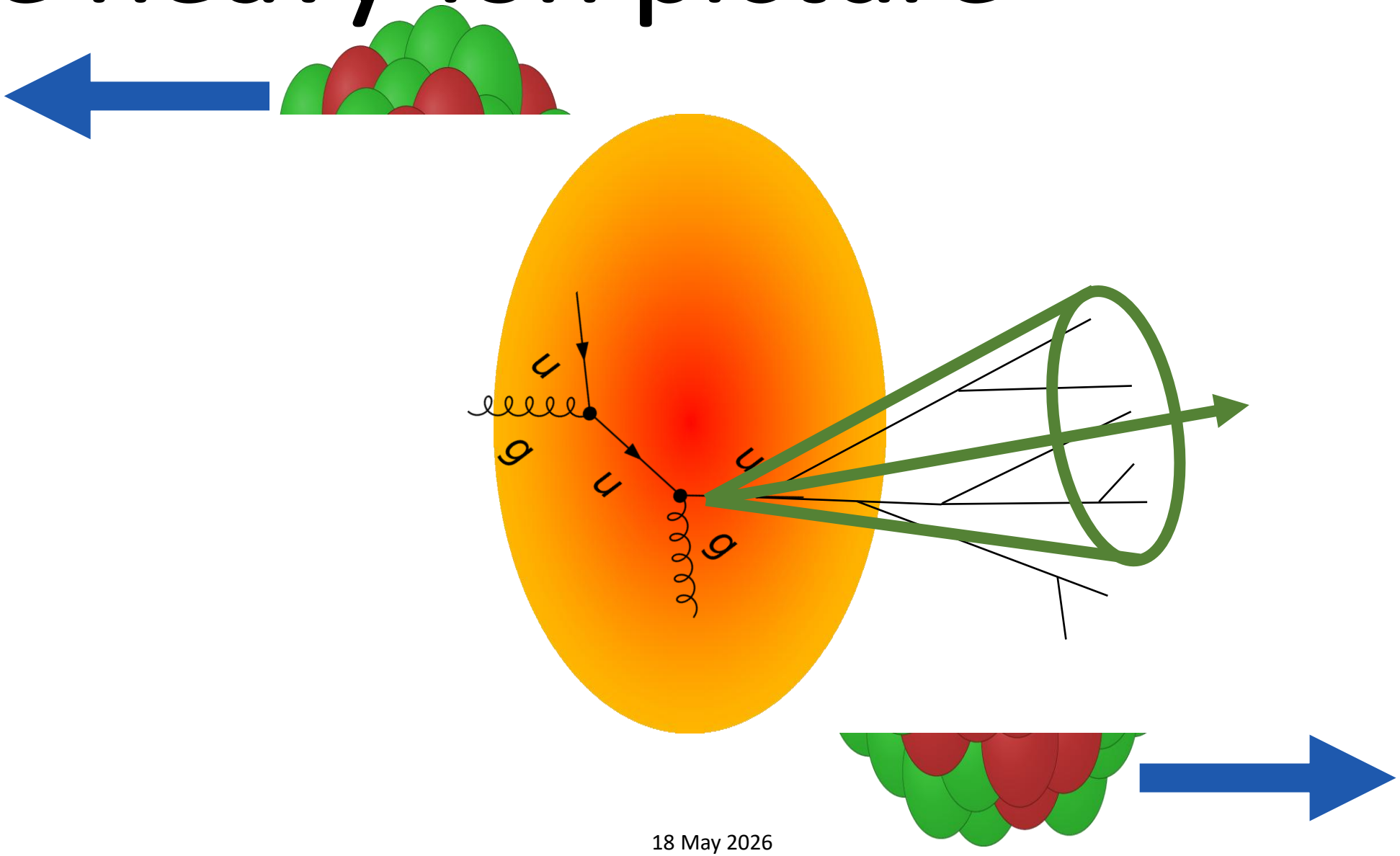

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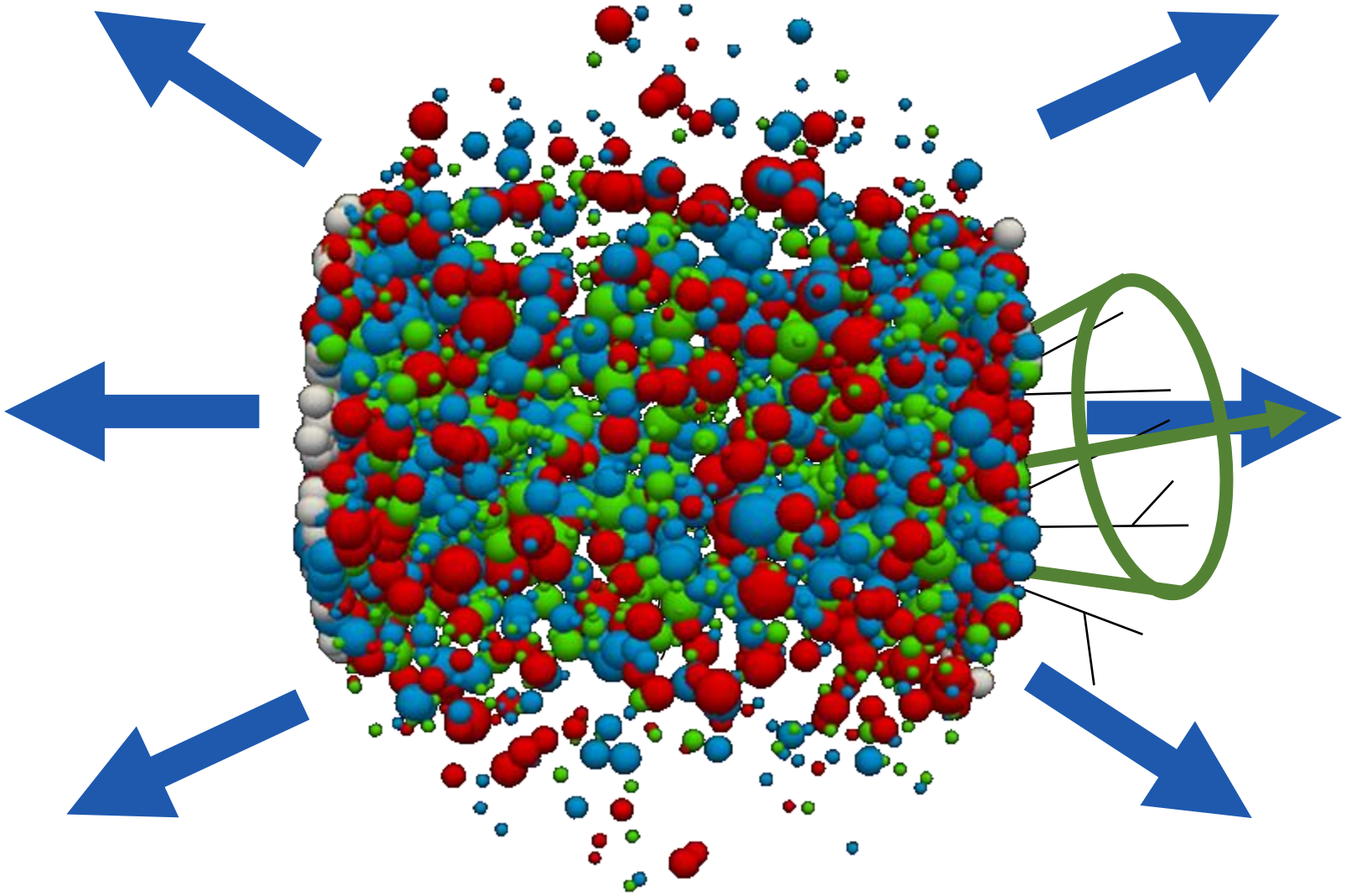

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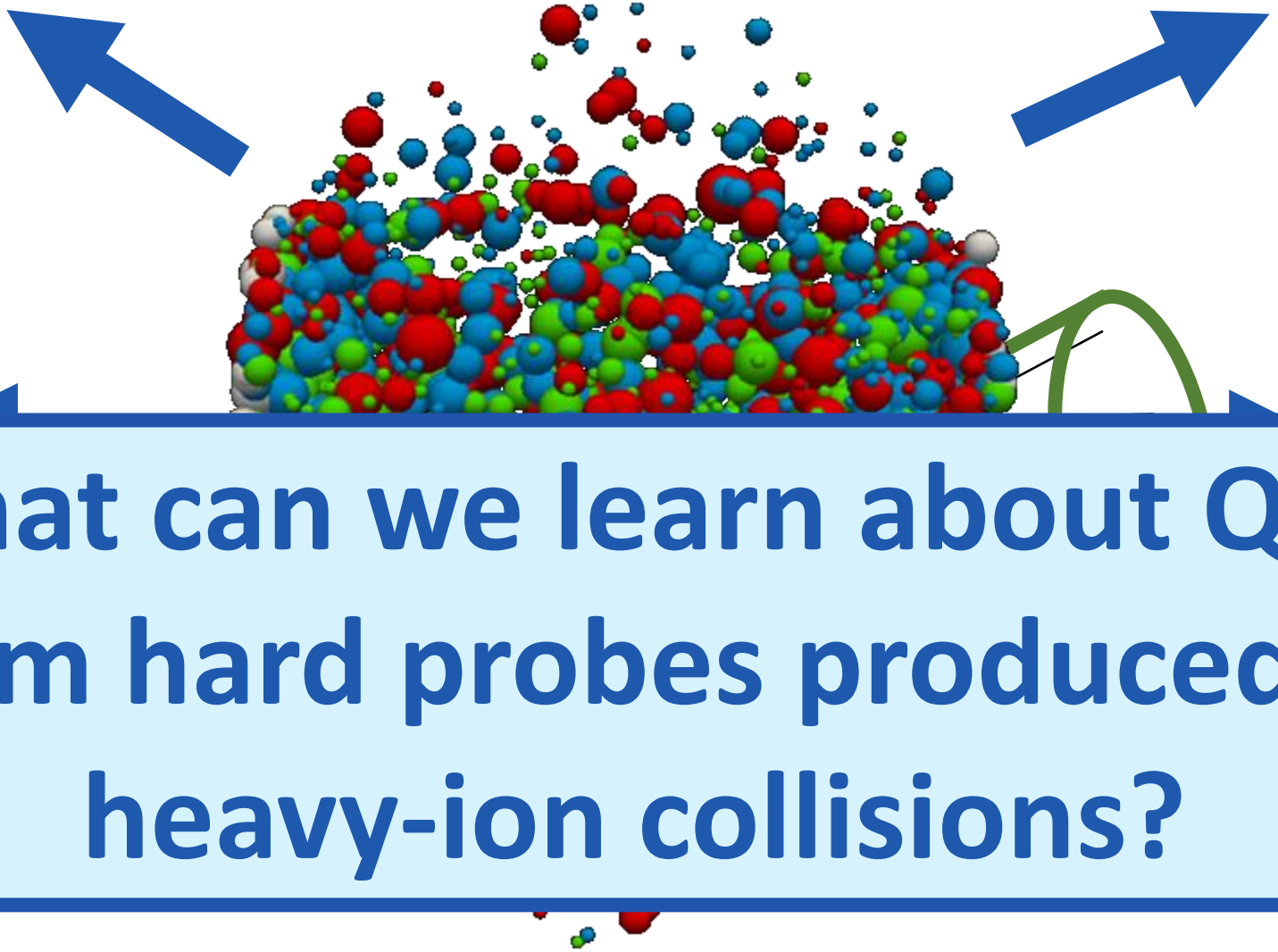
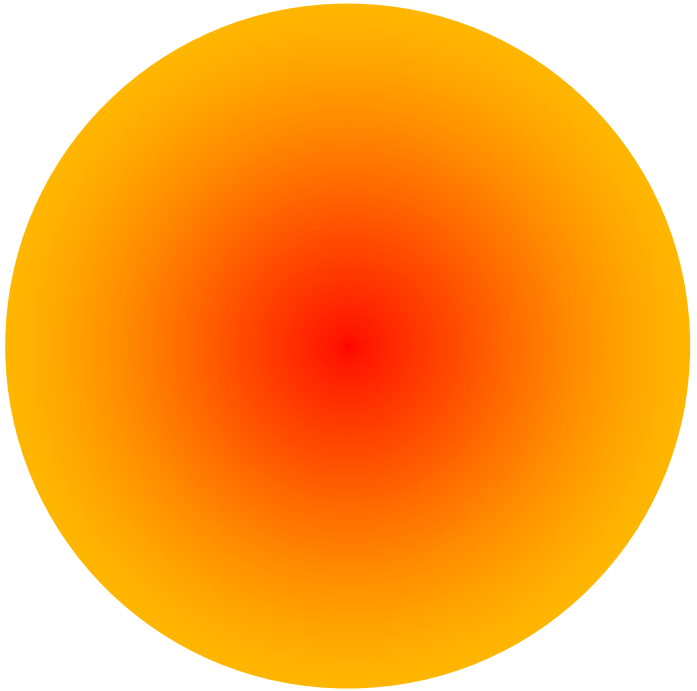


What can we learn about QCD from hard probes produced in heavy-ion collisions?

Many-body QCD in medium

- **Very challenging to study!**
  - Dynamics never (yet) derived from first-principles QCD
  - Competing phenomenological effects



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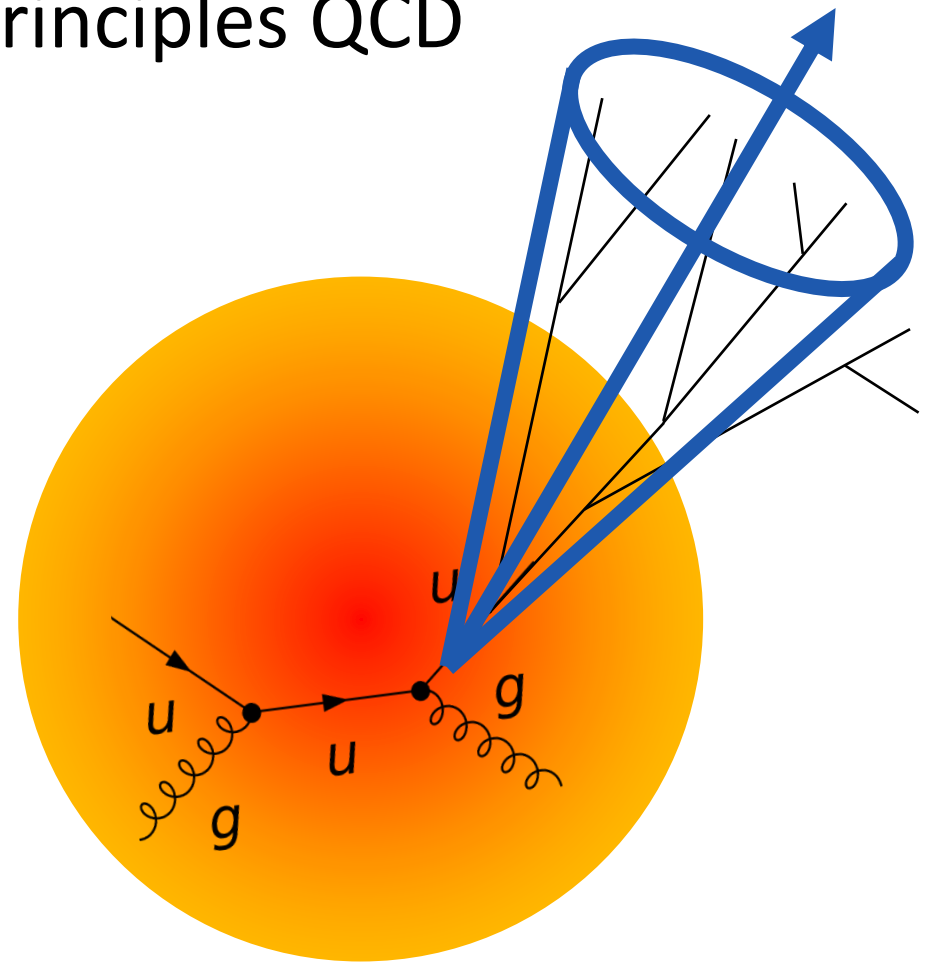

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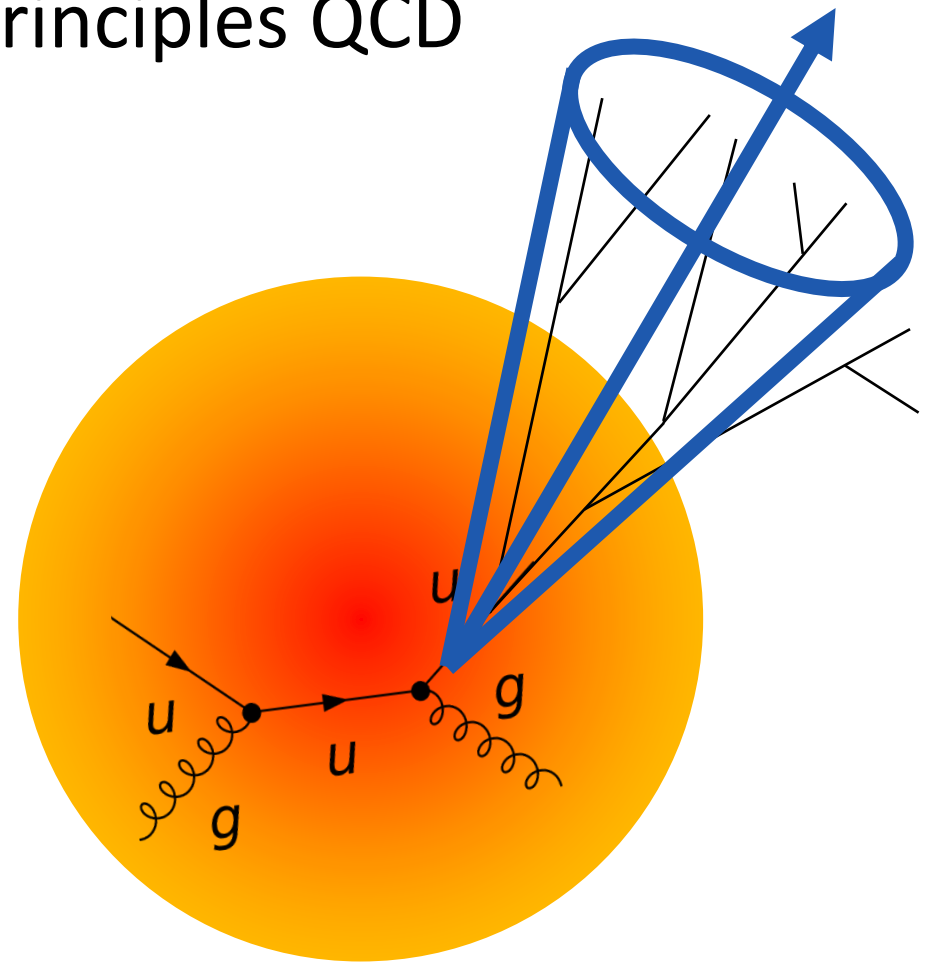

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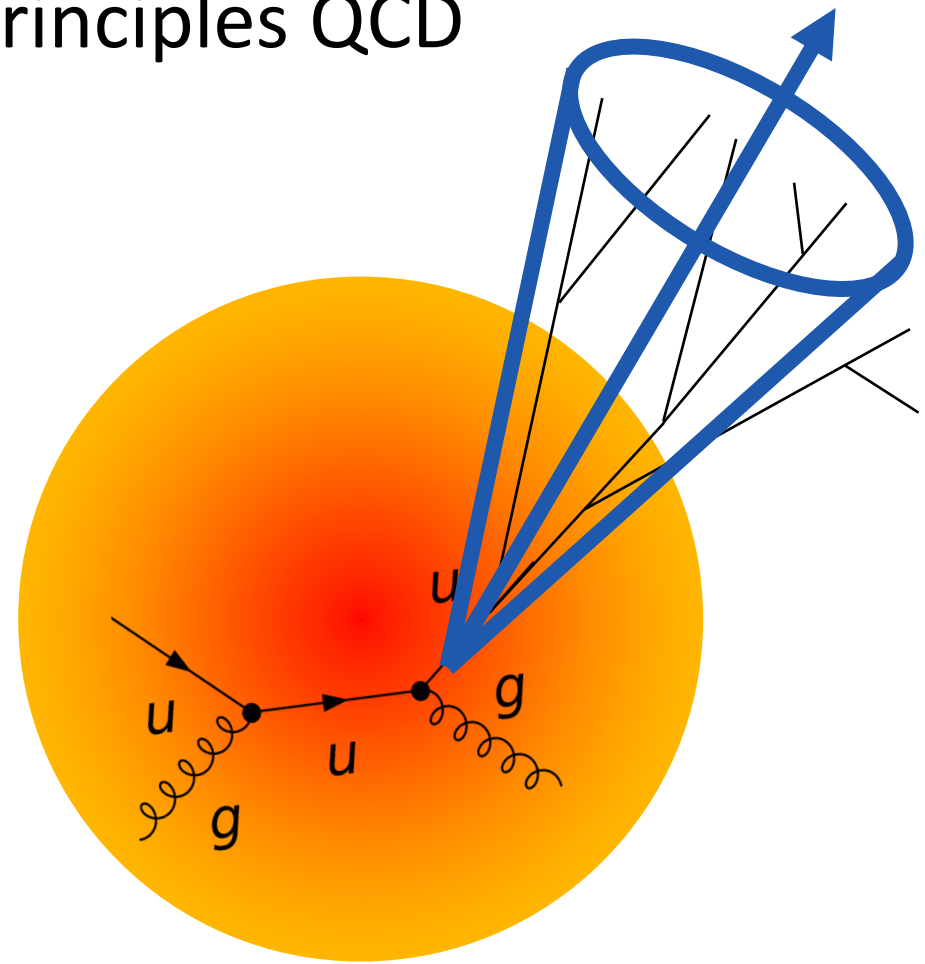

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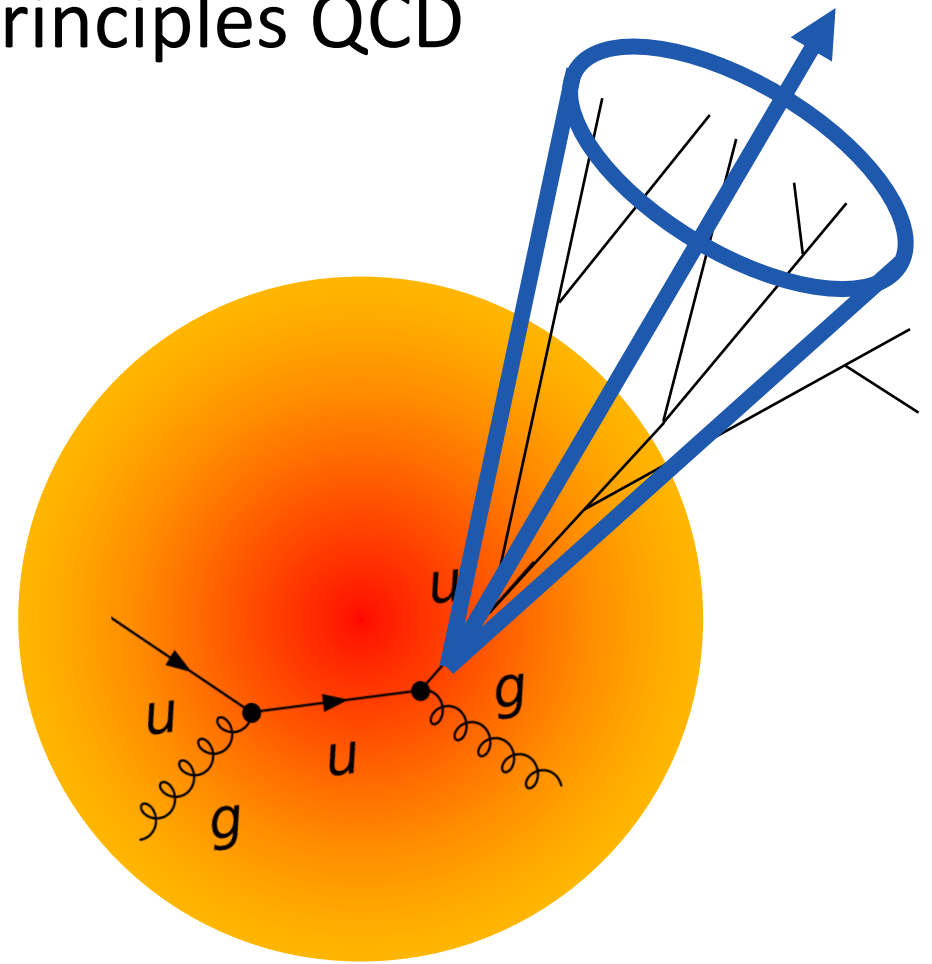

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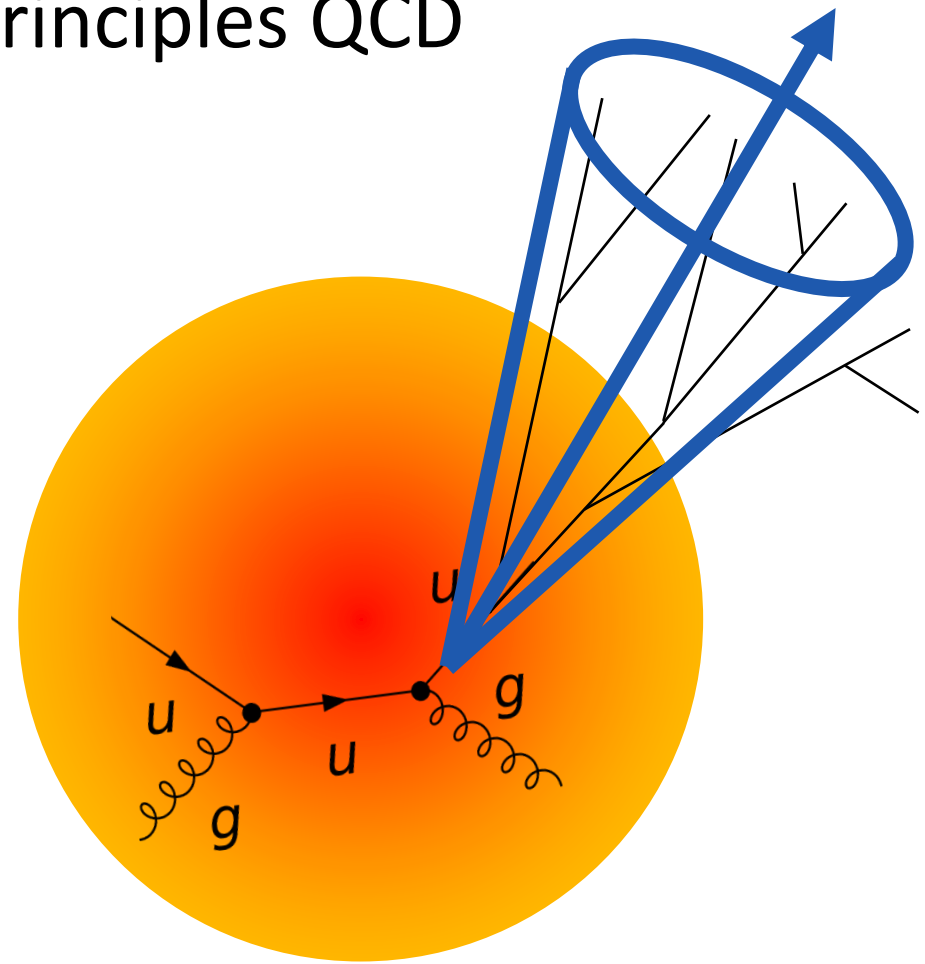

In-medium jet modification

- How does the QCD medium affect jet formation?

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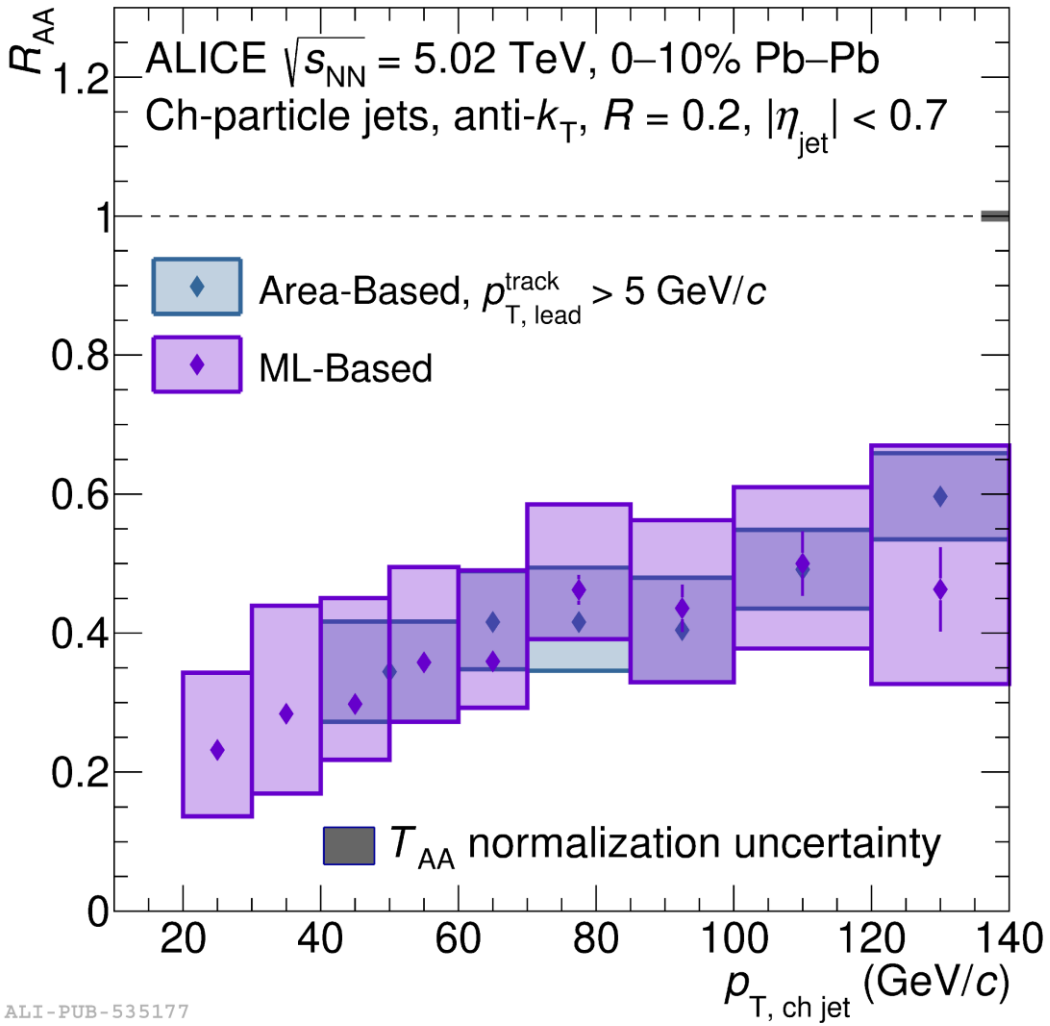

$$R_{AA} \sim \frac{\text{jet yield in AA}}{\text{jet yield in pp}}$$

- $R_{AA} < 1 \quad \rightarrow \quad$ **jets are "quenched"**

ALICE Collaboration,
Phys. Lett. B **849** (2024) 138412

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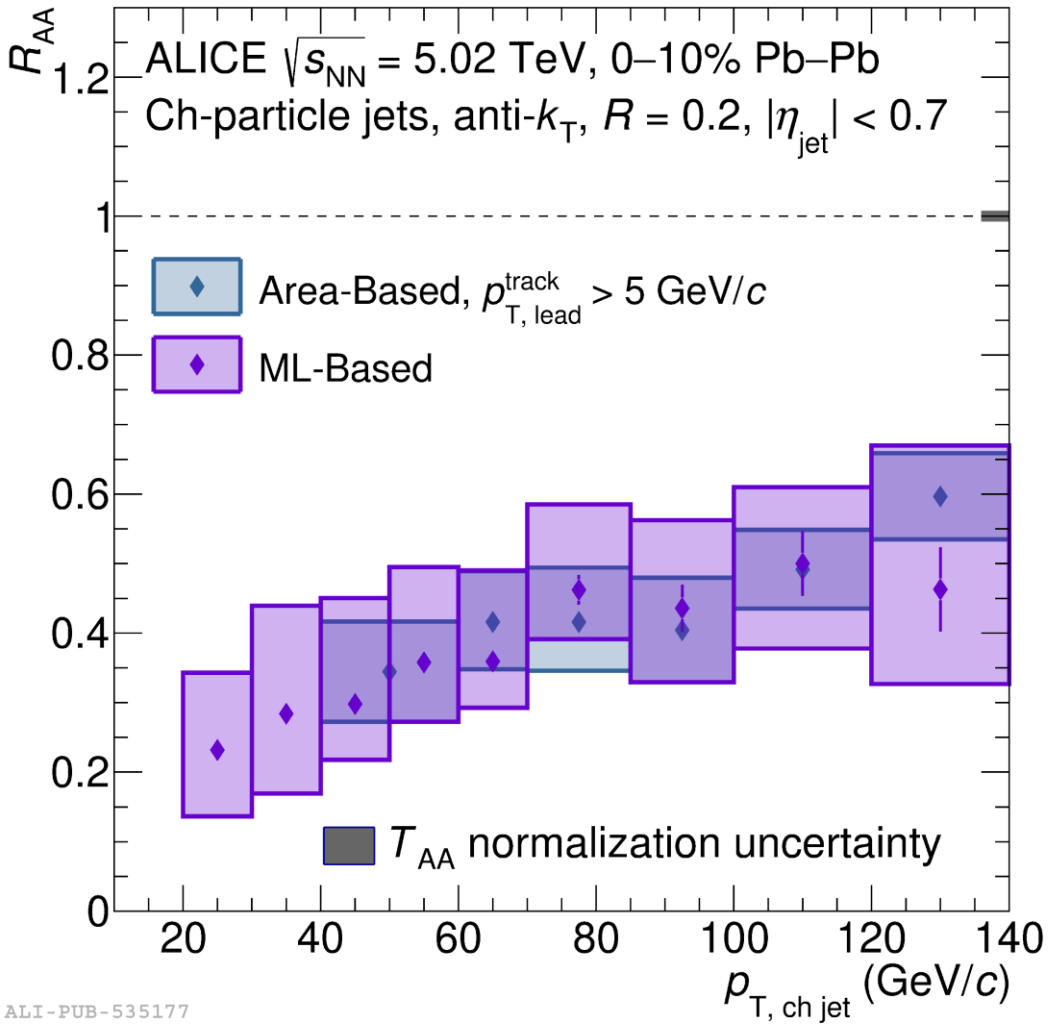

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ALICE Collaboration,
Phys. Lett. B **849** (2024) 138412

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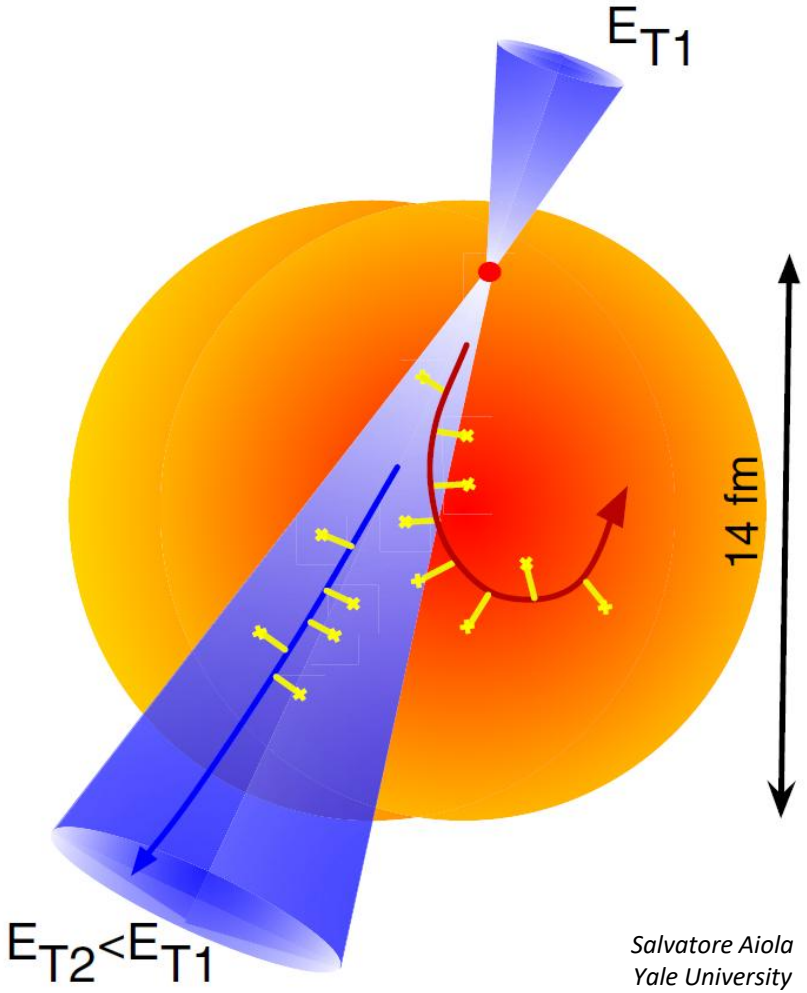

Salvatore Aiola
Yale University

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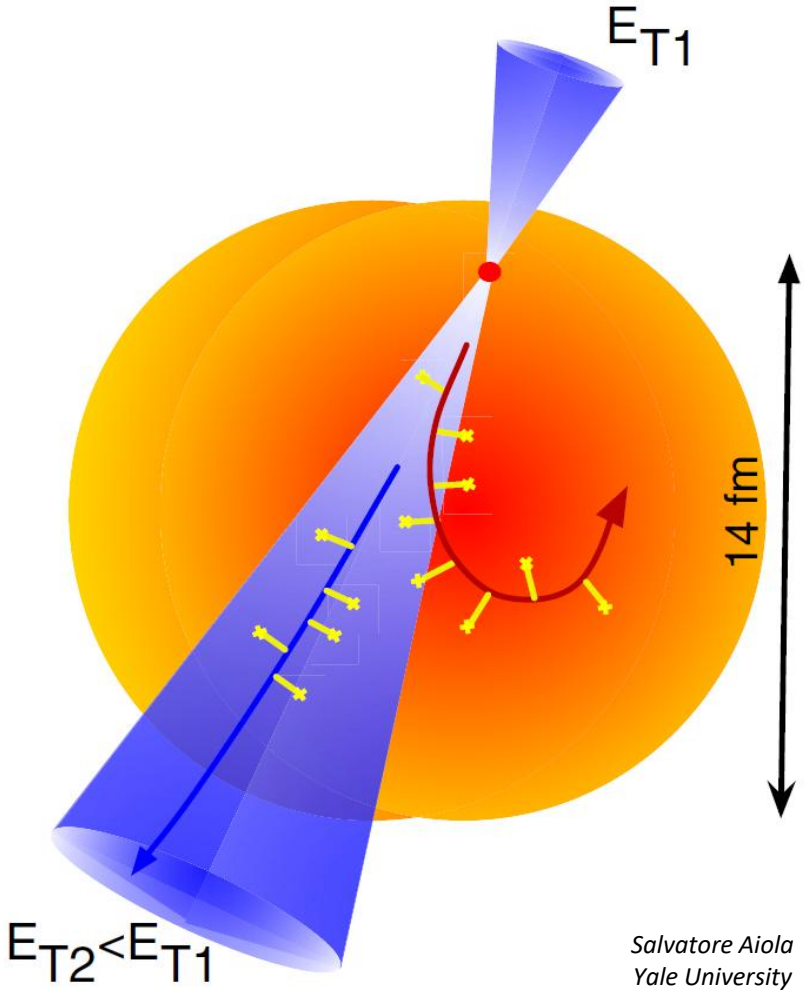
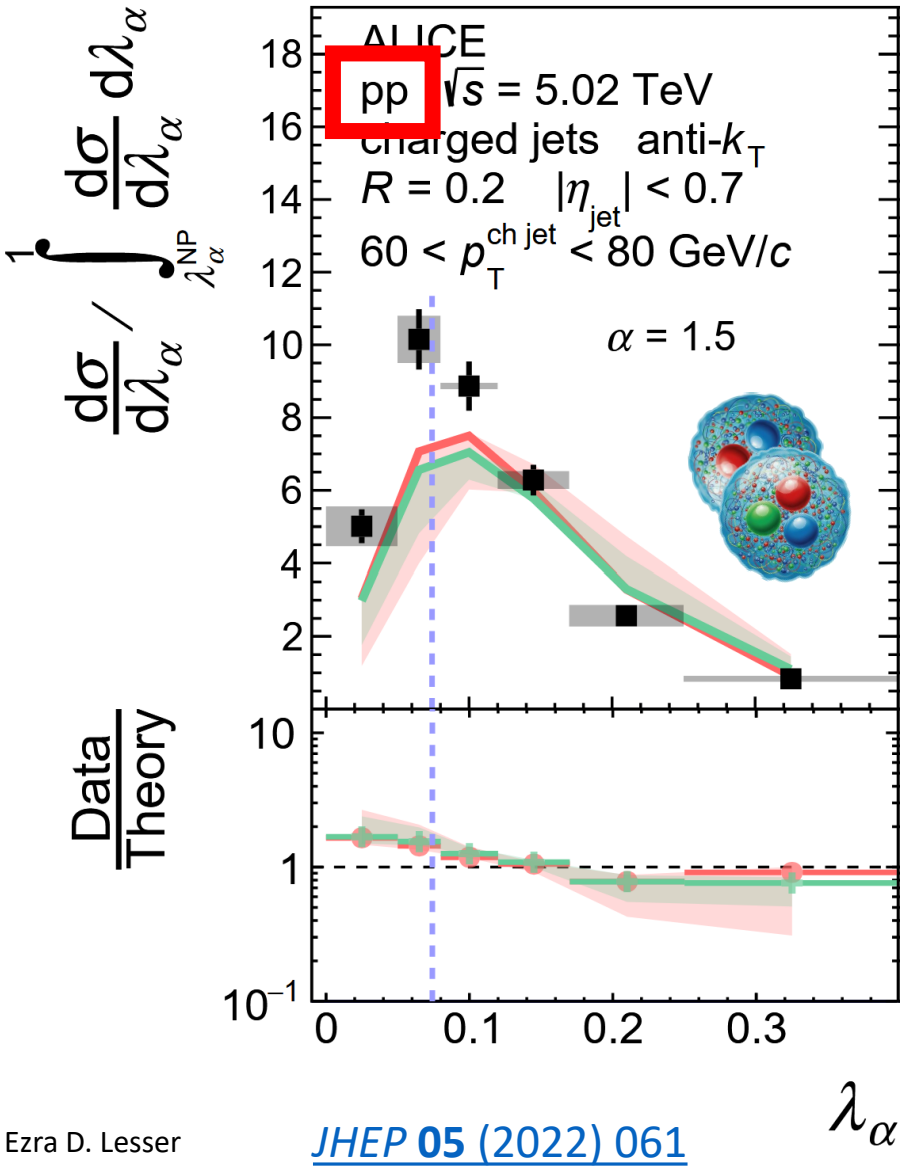


Salvatore Aiola
Yale University

- **Jet substructure** gives insight into the microscopic modification
- Choose jet observables based on the desired physics probe

Jet quenching in angularities



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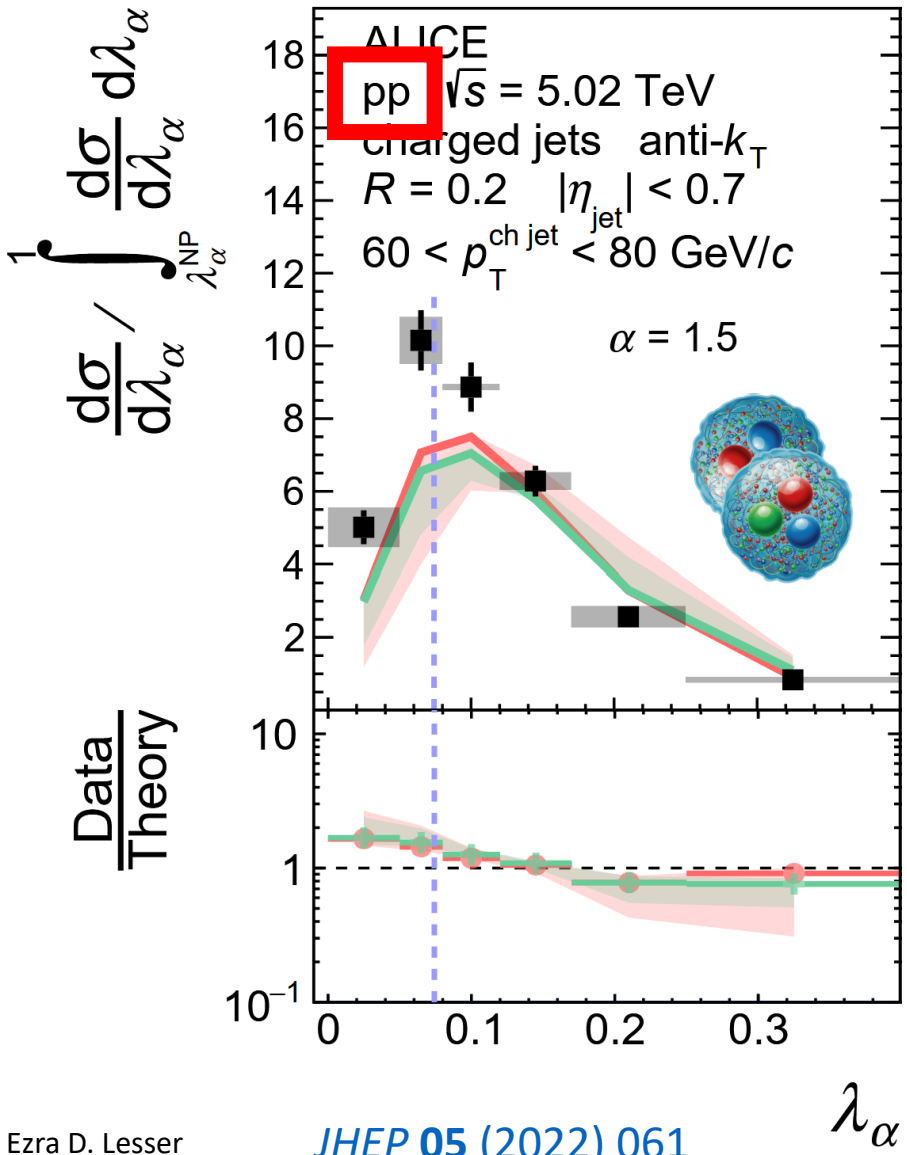

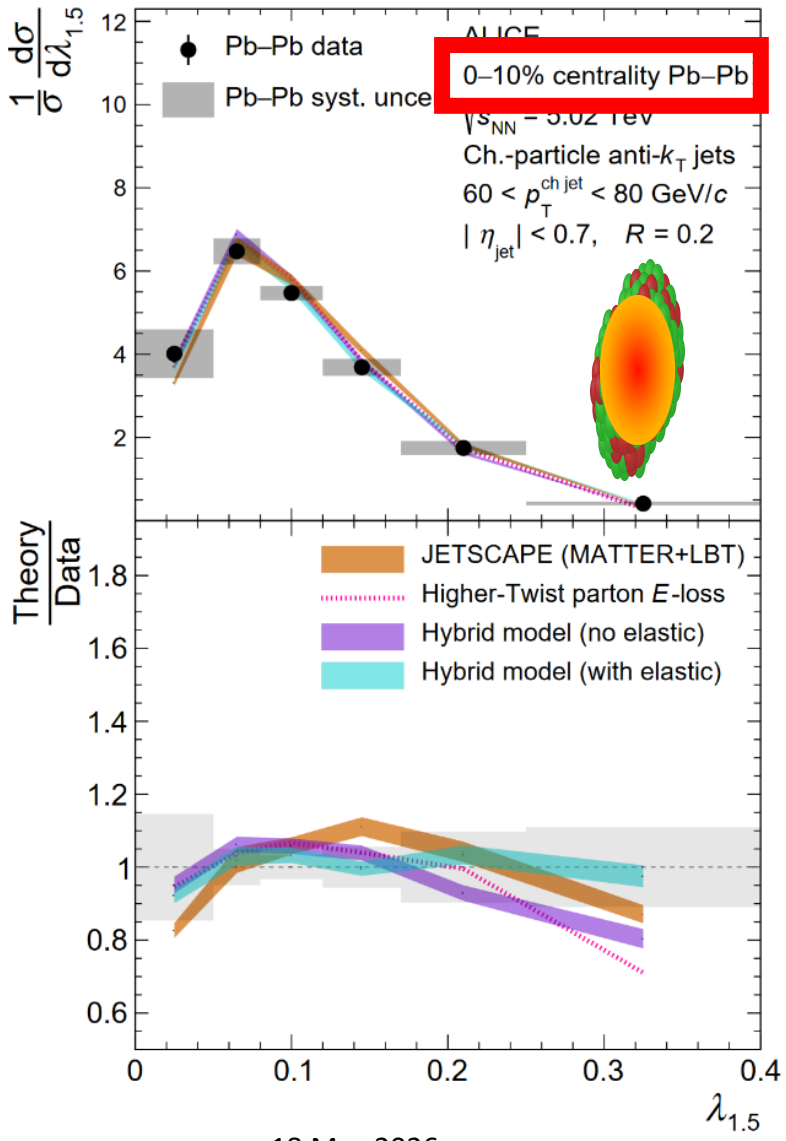

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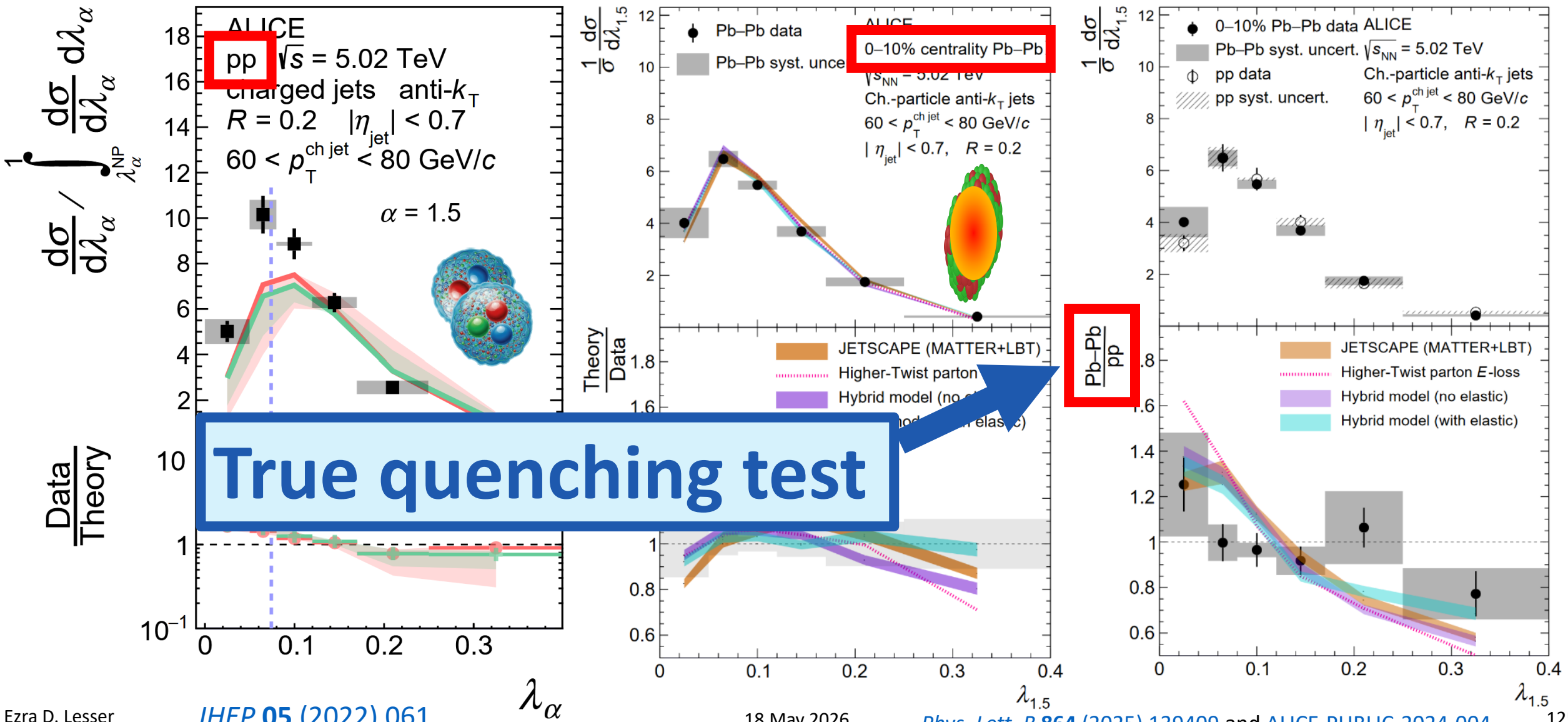
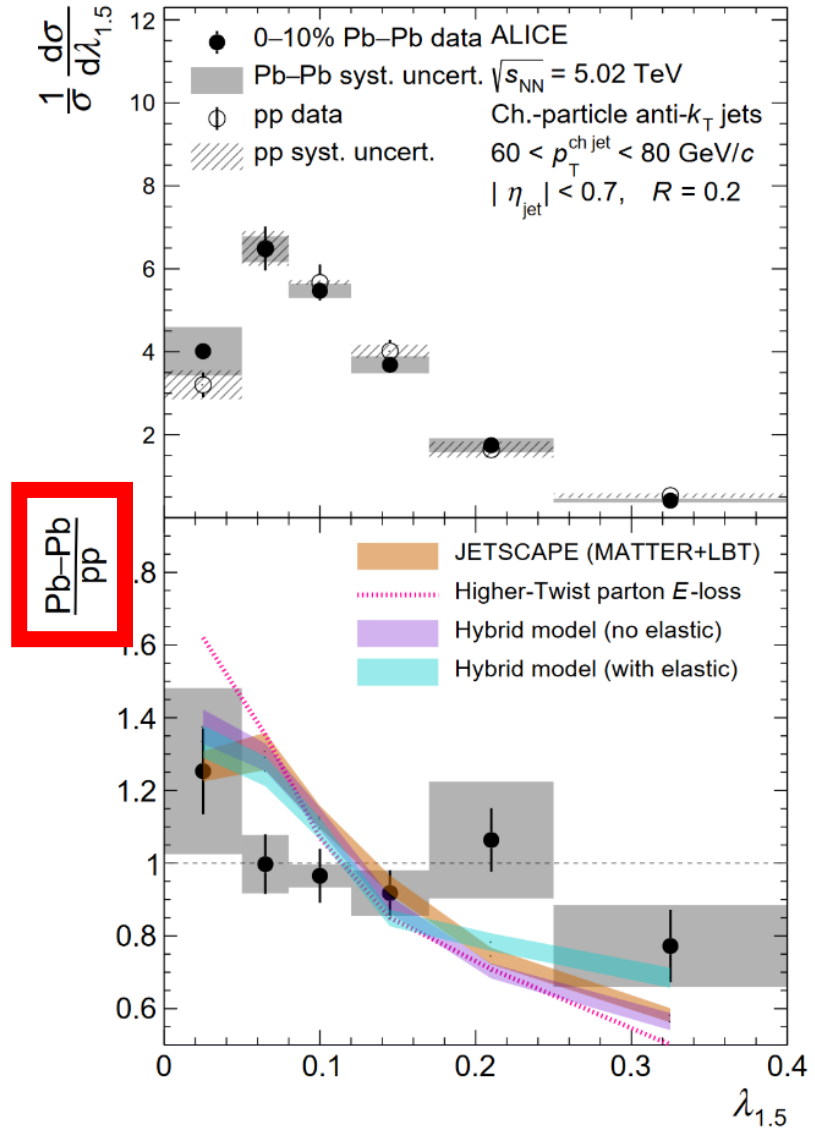


True quenching test

Jet quenching in angularities

- Models generally well-describe a **“narrowing” of the jet shape** in heavy-ion collisions with respect to pp



Phys. Lett. B **864** (2025) 139409 and ALICE-PUBLIC-2024-004

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  S.-Y. Chen, B.-W. Zhang, et al. Chin. Phys. C **45** (2021) 2, 024102

  - **MATTER + LBT** (also using higher-Twist) may perform slightly better

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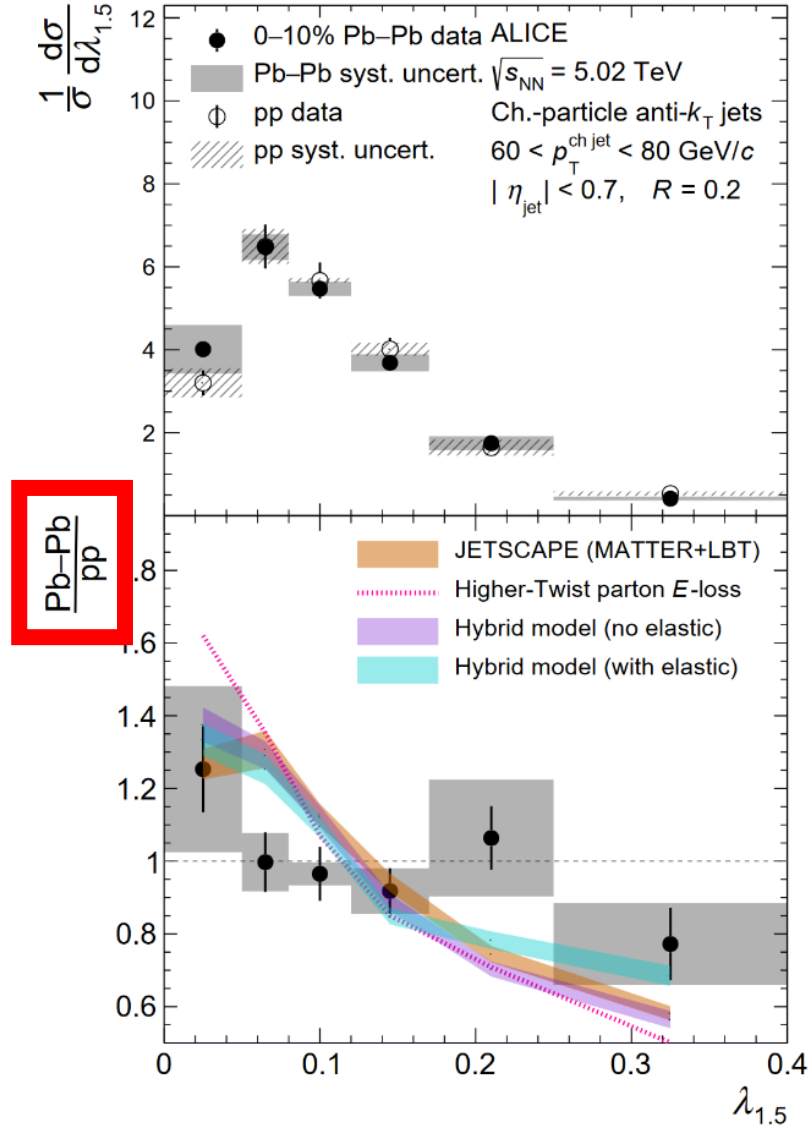

Phys. Lett. B **864** (2025) 139409 and ALICE-PUBLIC-2024-004

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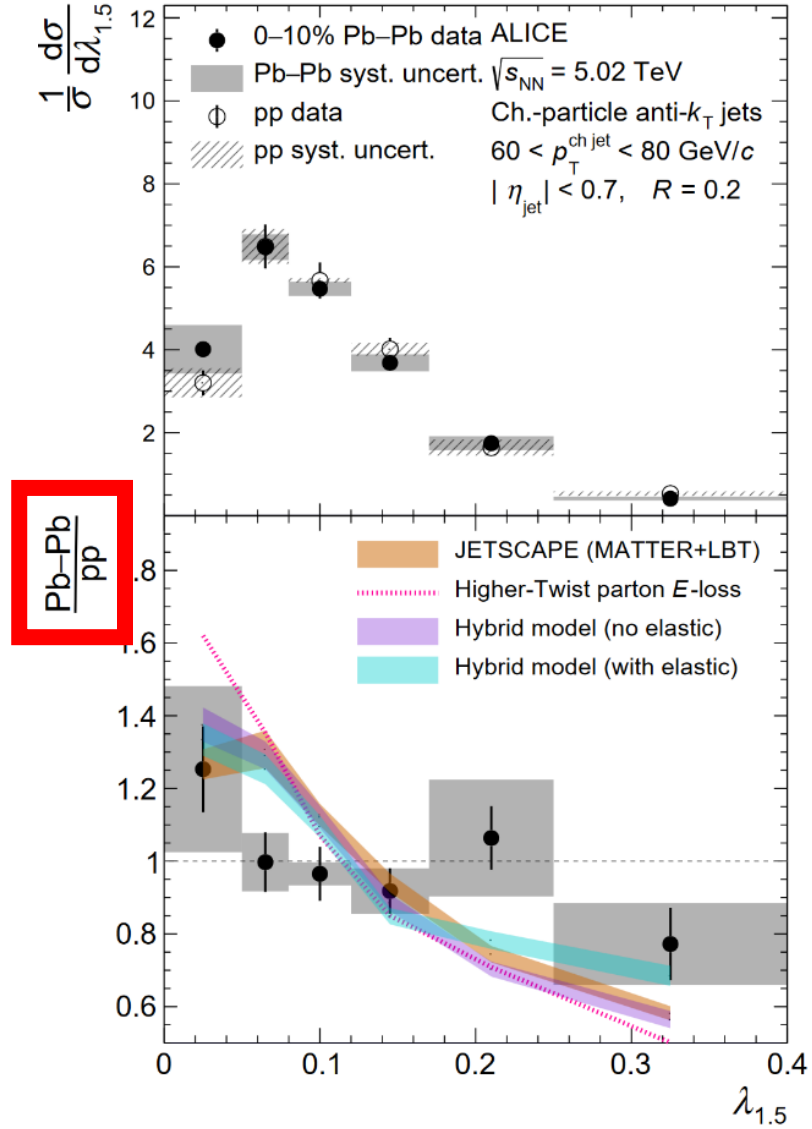
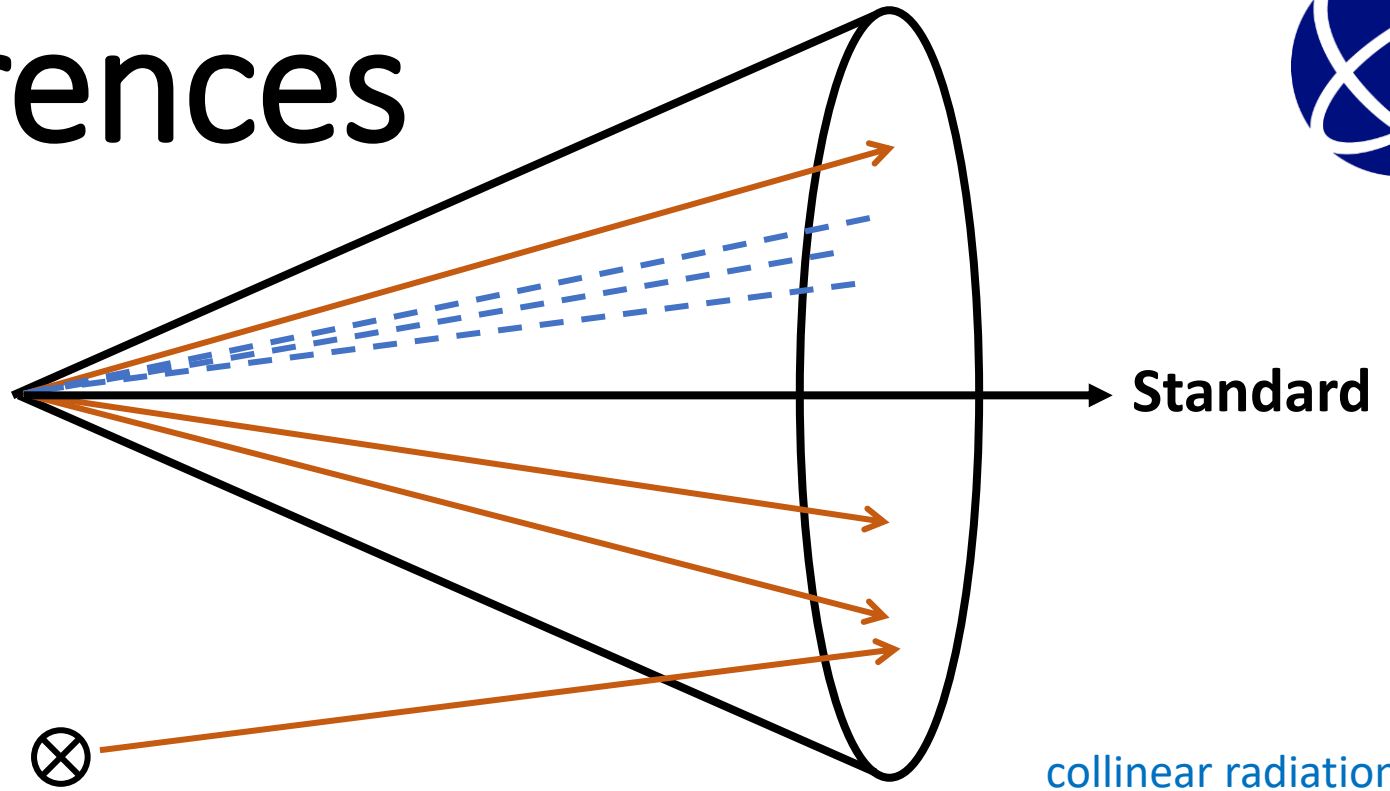


Phys. Lett. B **864** (2025) 139409 and ALICE-PUBLIC-2024-004

Jet-axis differences

- **Standard**: anti-k_{T} jet with E-scheme recombination



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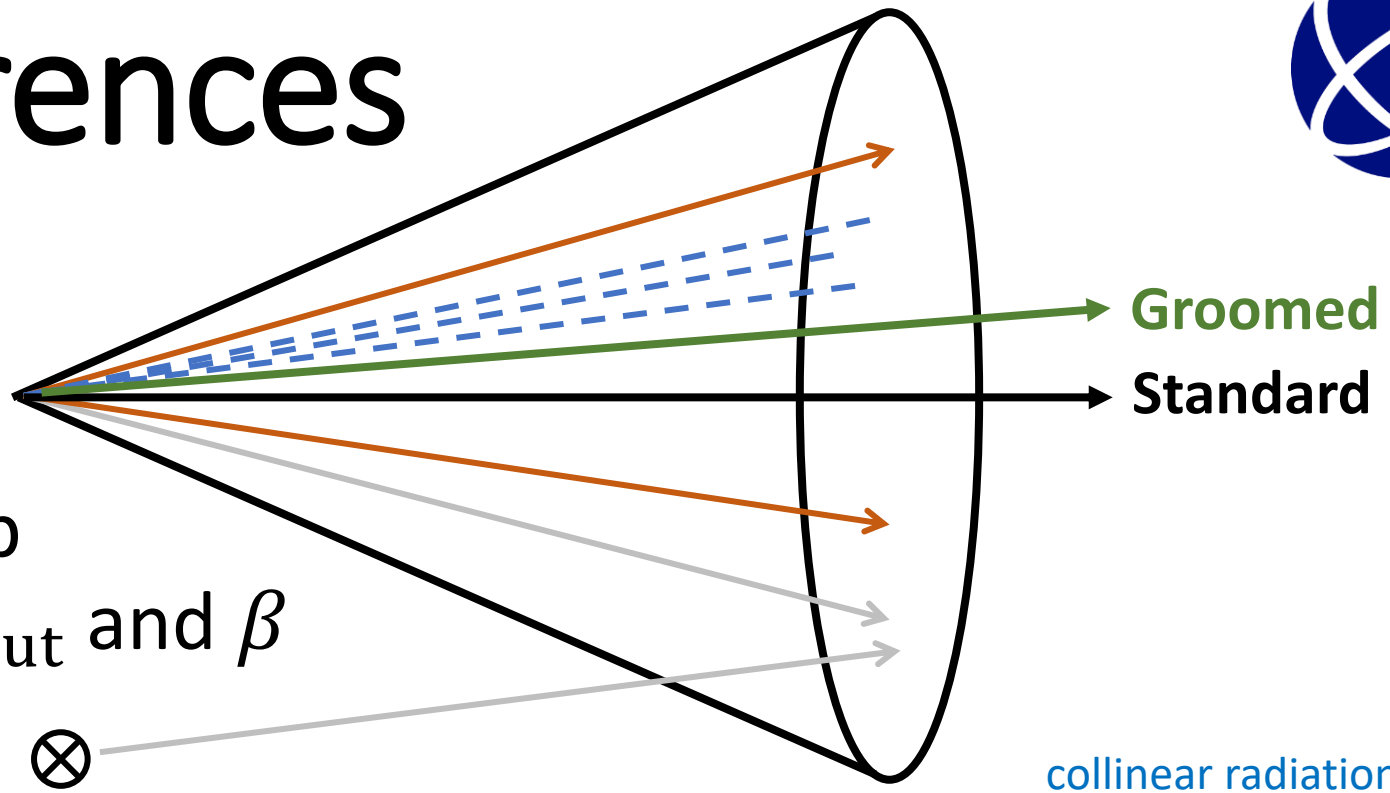

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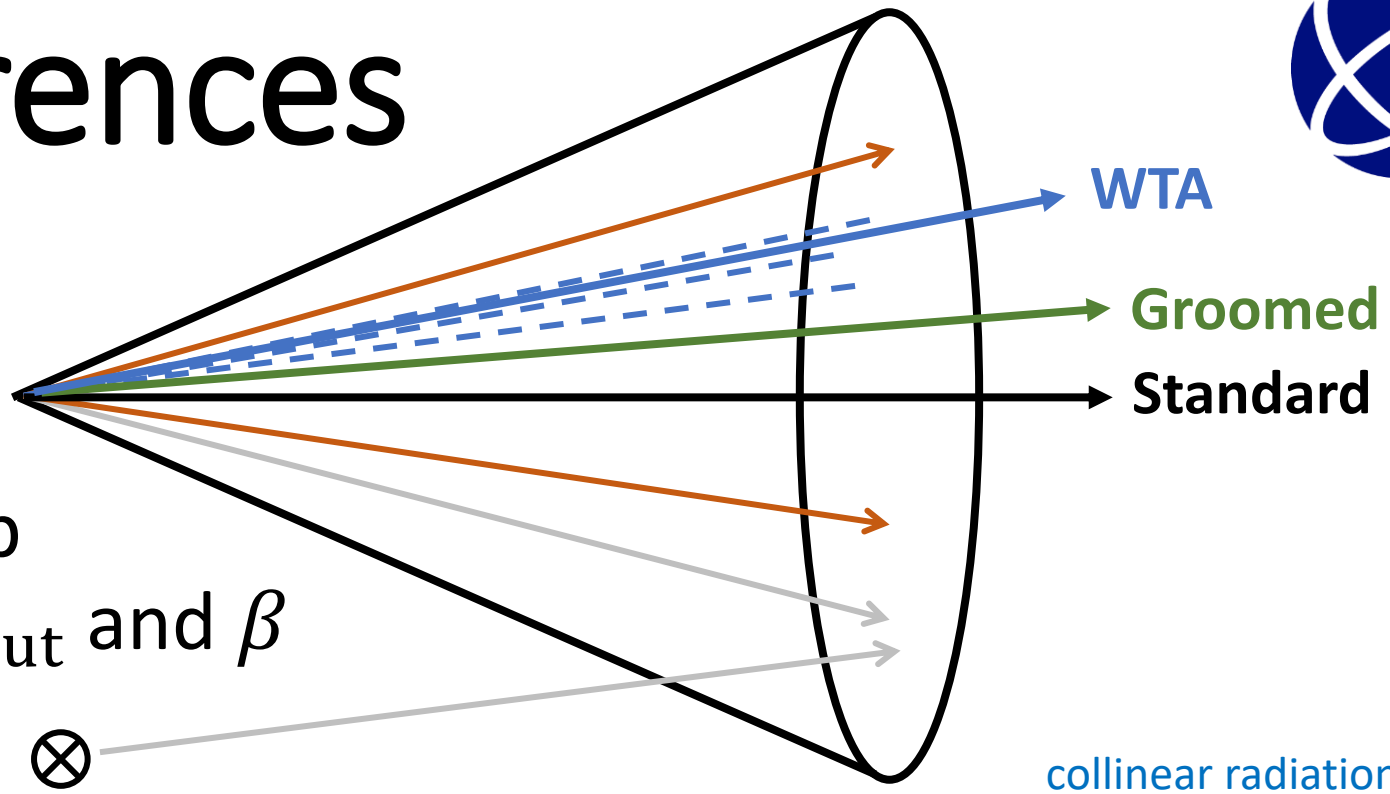

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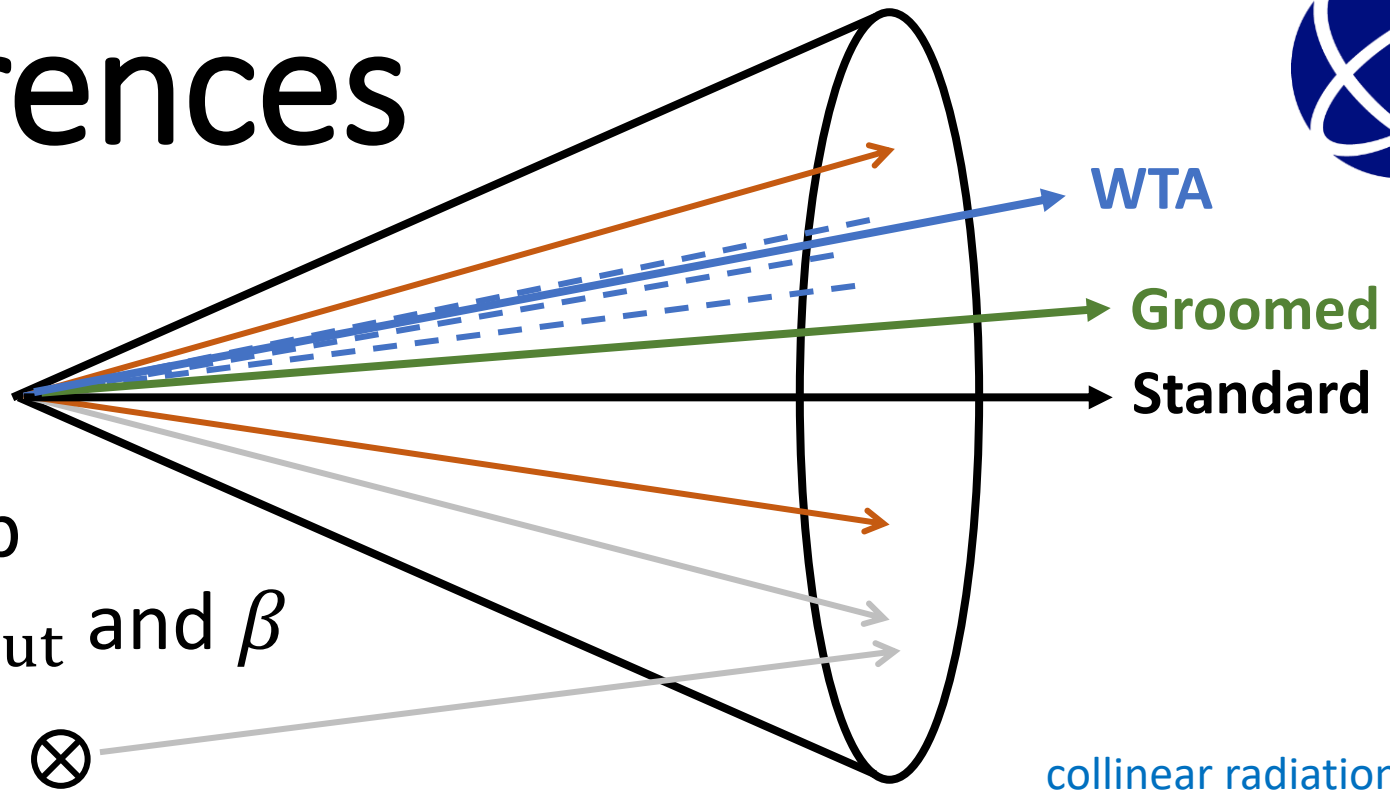
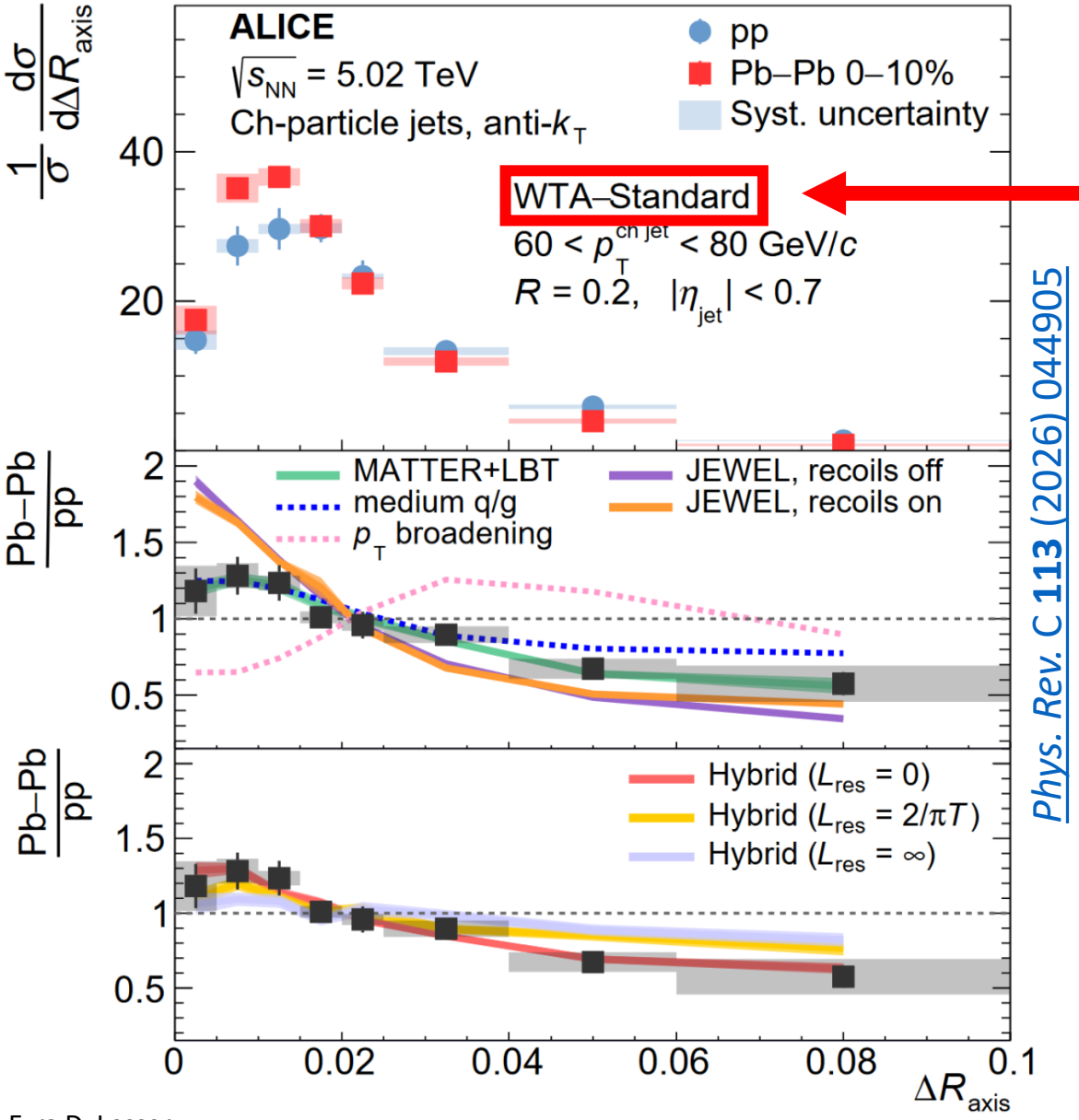


- Calculate the angular separation: $\Delta R_{\mathrm{axis}} = \sqrt{\Delta y^2 + \Delta \phi^2}$
- IRC-safe observable sensitive to **soft radiation, TMDs, and PDFs**

Cal, Neill, Ringer, Waalewijn, JHEP **04** (2020) 211

Jet axis differences in Pb-Pb vs. pp



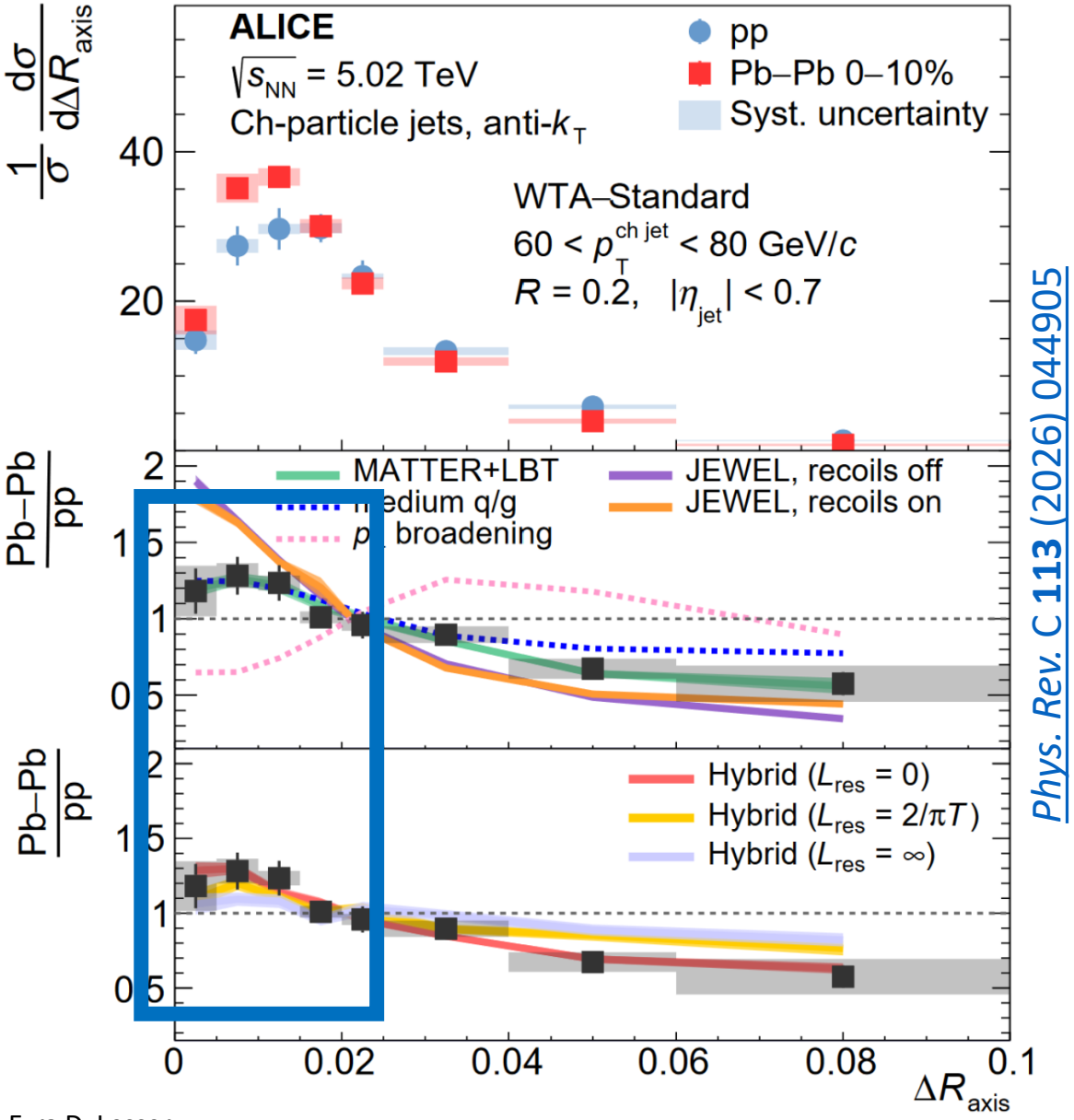
Phys. Rev. C **113** (2026) 044905

Standard (E-scheme)

vs.

Winner-Take-All

Jet axis differences in Pb-Pb vs. pp



Phys. Rev. C **113** (2026) 044905

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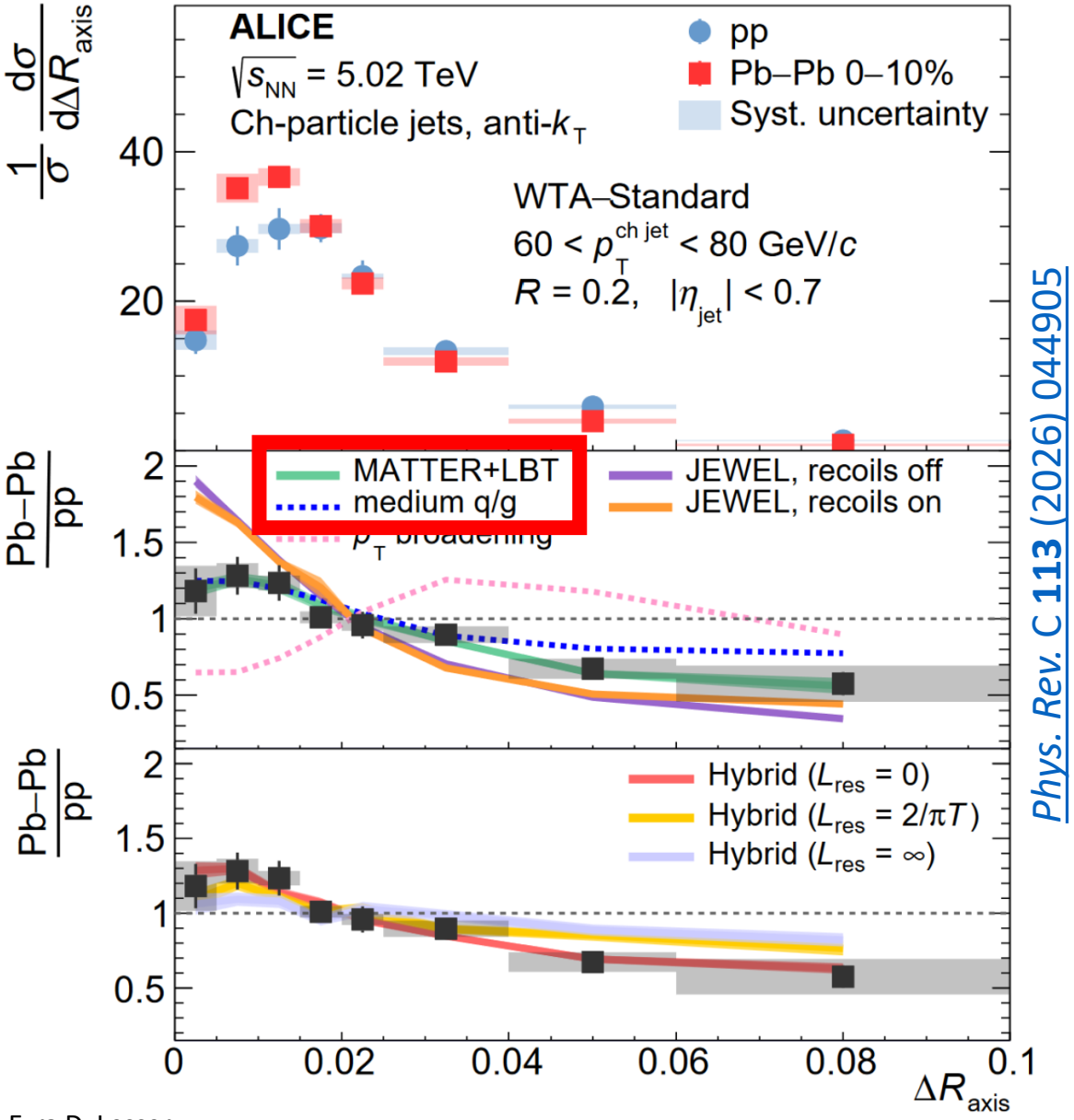

Phys. Rev. C **113** (2026) 044905

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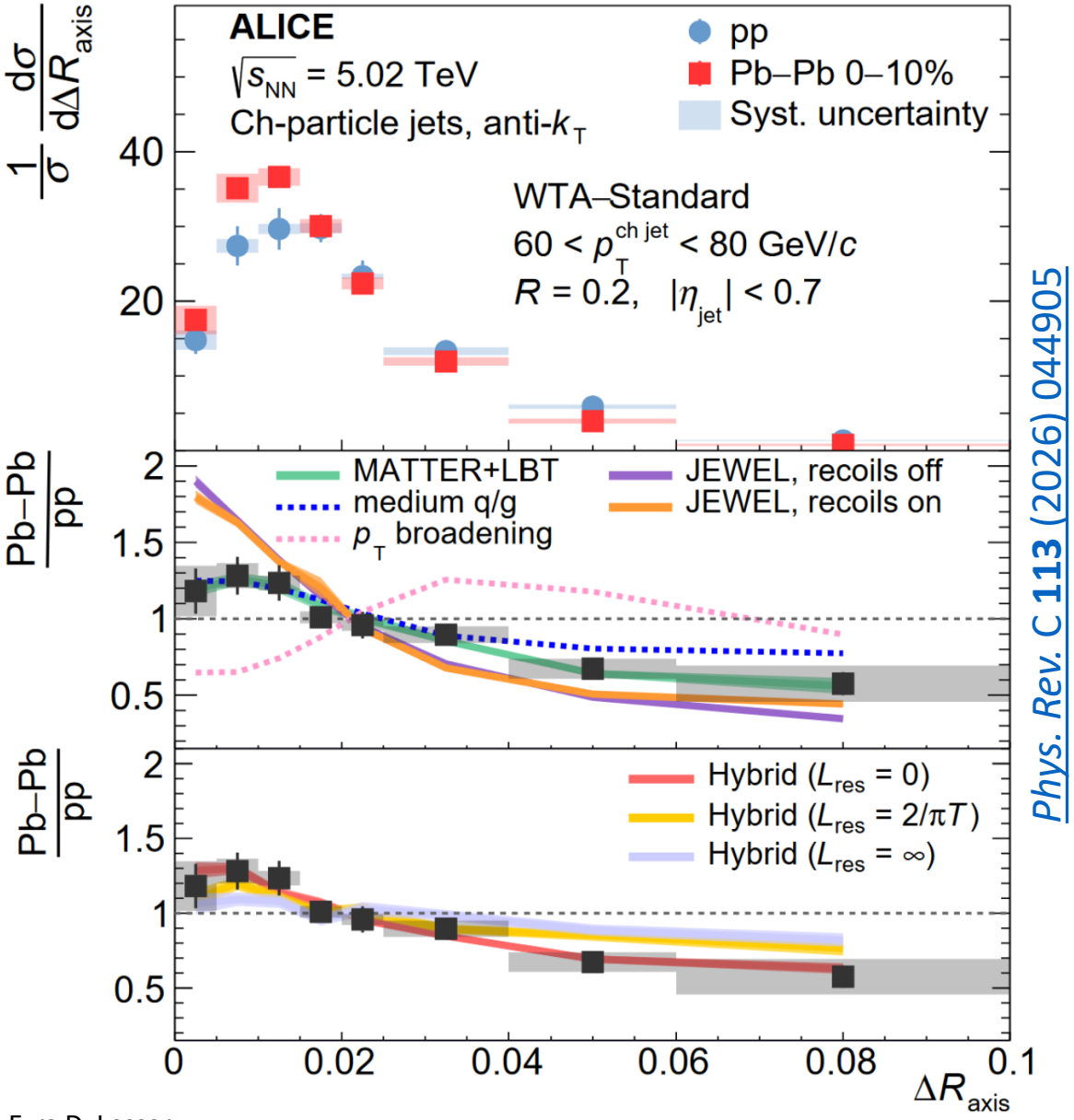

Phys. Rev. C **113** (2026) 044905

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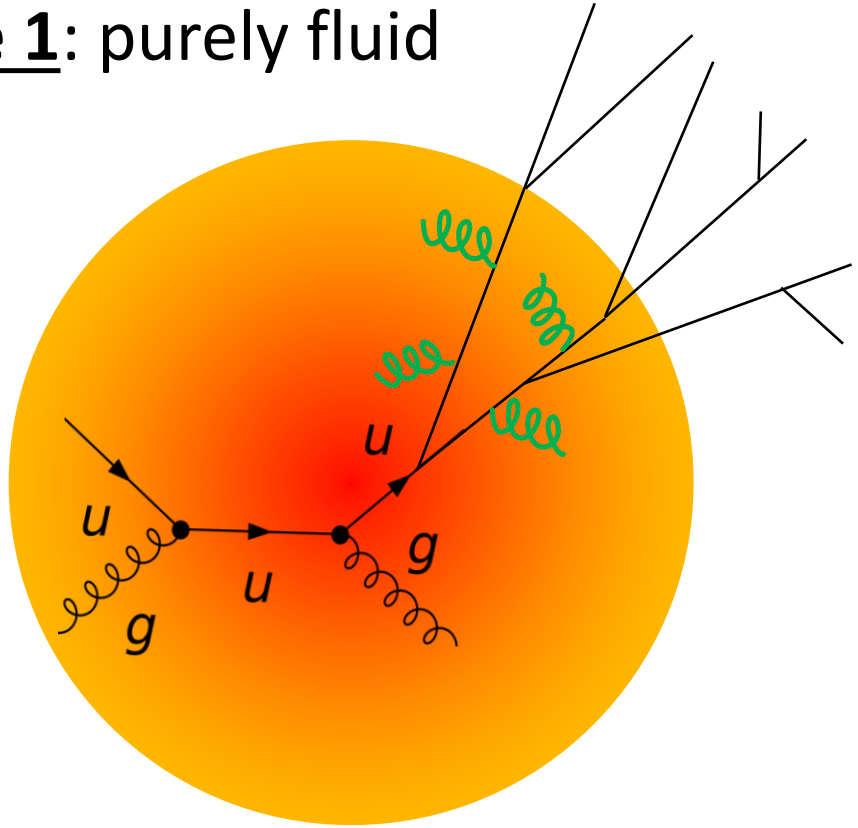
  - *Consistent with "narrowing"*
- Agreement with **JETSCAPE (MATTER+LBT)** and **medium q/g modification** calculations
- Preference towards **zero resolution length of the medium** in Hybrid model

→ **Consistent with other models?**

Multiple hard interactions in QGP?

Picture 1: purely fluid

D'Eramo, Rajagopal, Yin
JHEP **01** (2019) 172



Jet fragmentation
+ medium-induced emissions

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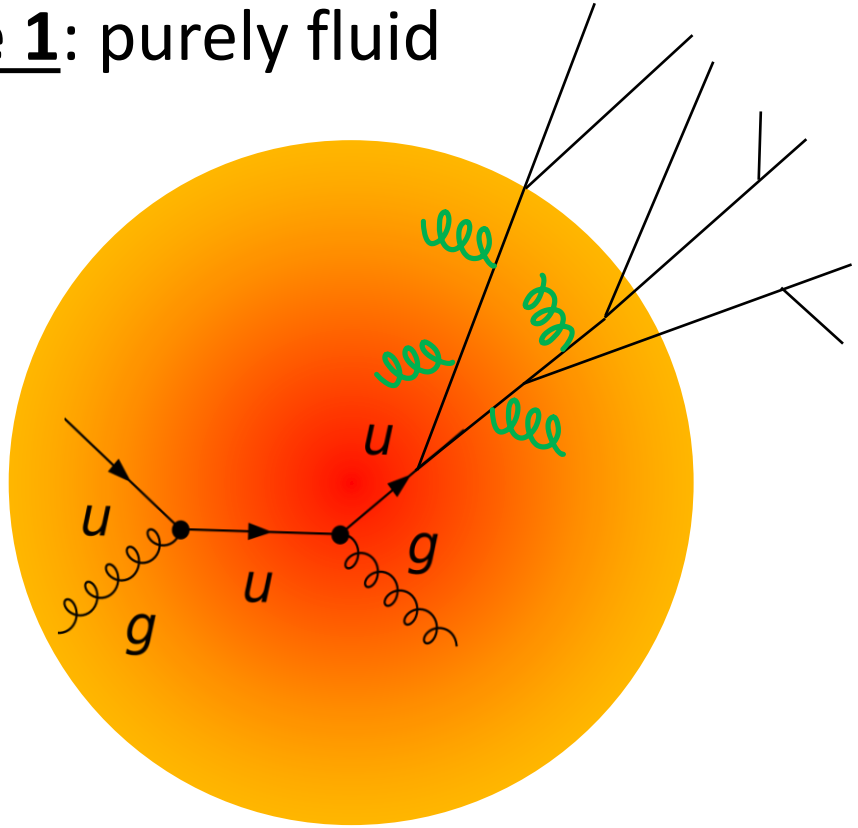

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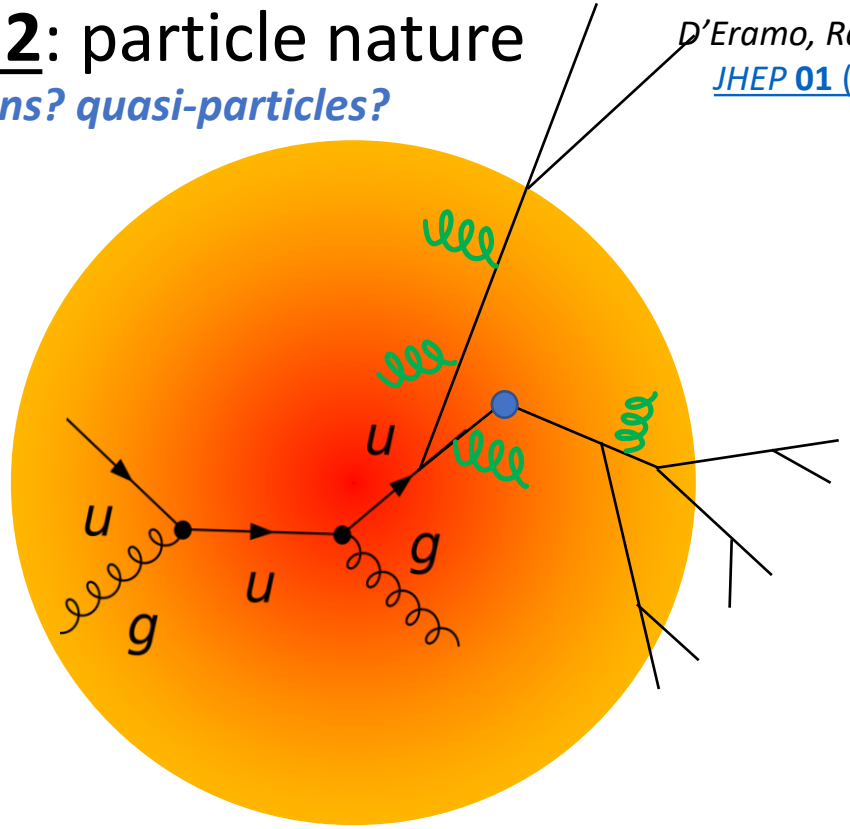
Picture 2: particle nature

partons? quasi-particles?

D'Eramo, Rajagopal, Yin
JHEP **01** (2019) 172



Jet fragmentation
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+ elastic Molière scattering?

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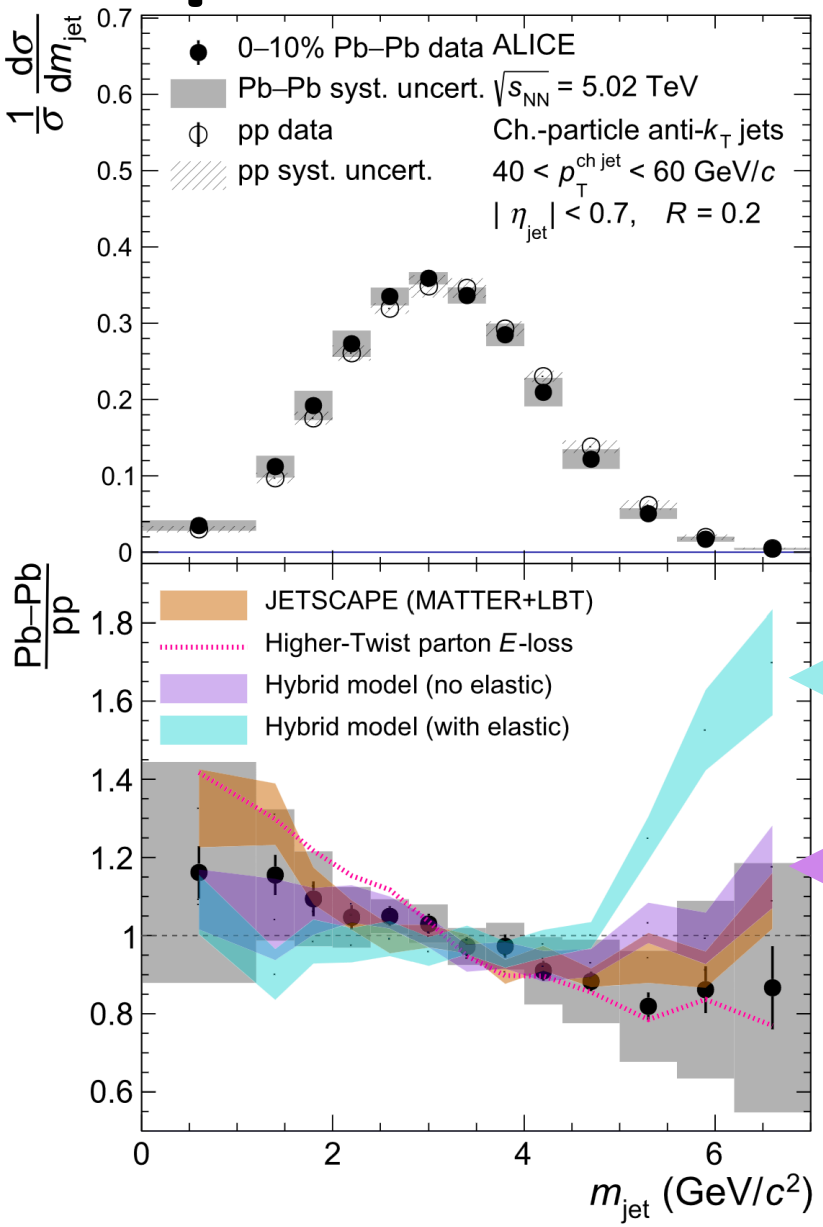
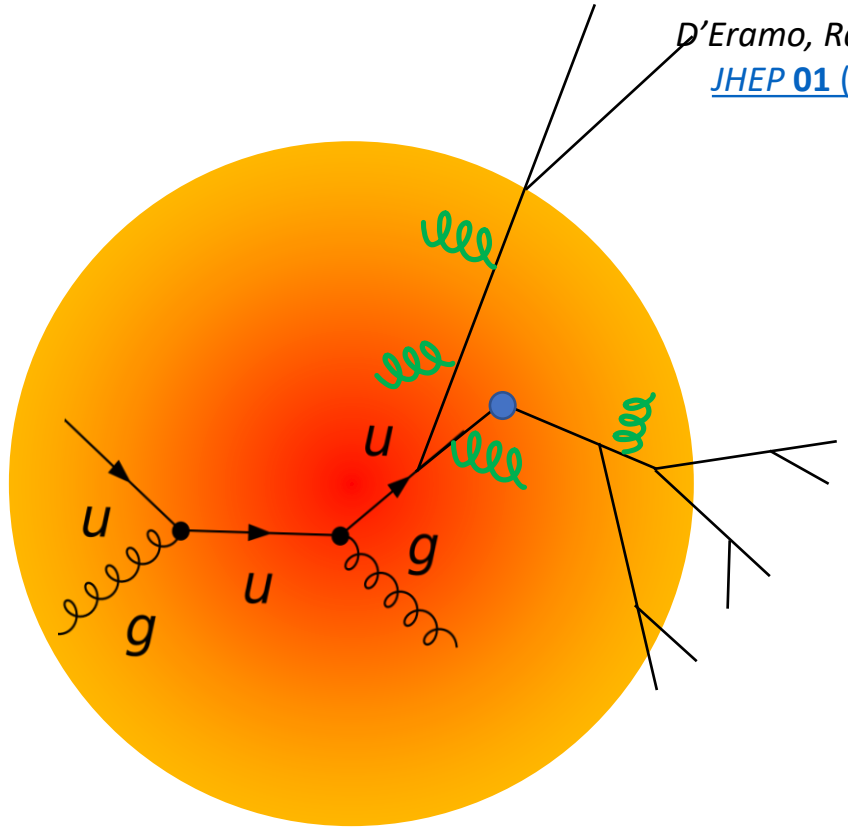


With Molière

No Molière



D'Eramo, Rajagopal, Yin
JHEP **01** (2019) 172

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Phys. Lett. B **864** (2025) 139409 and ALICE-PUBLIC-2024-004

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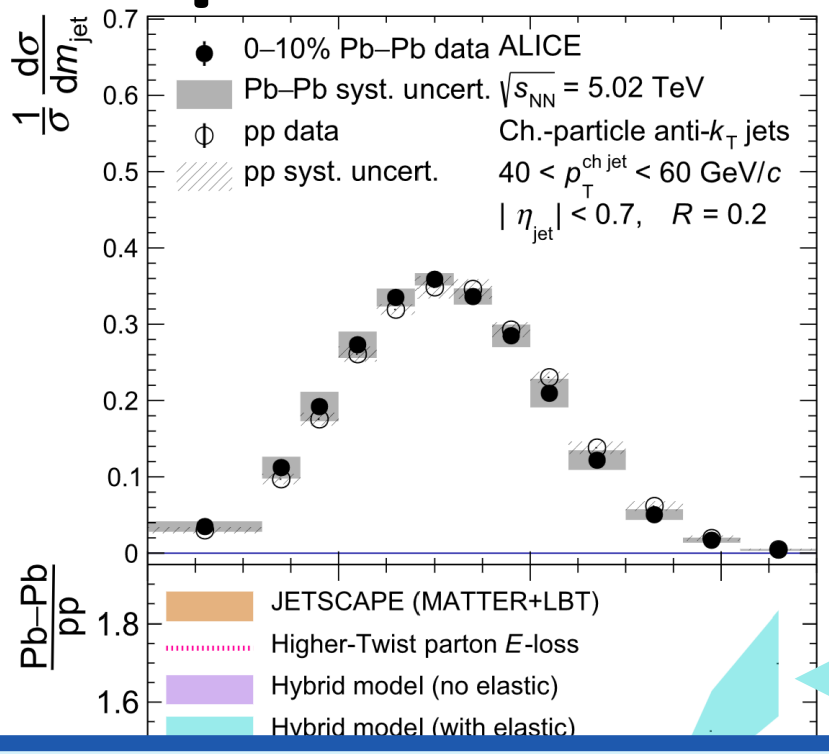

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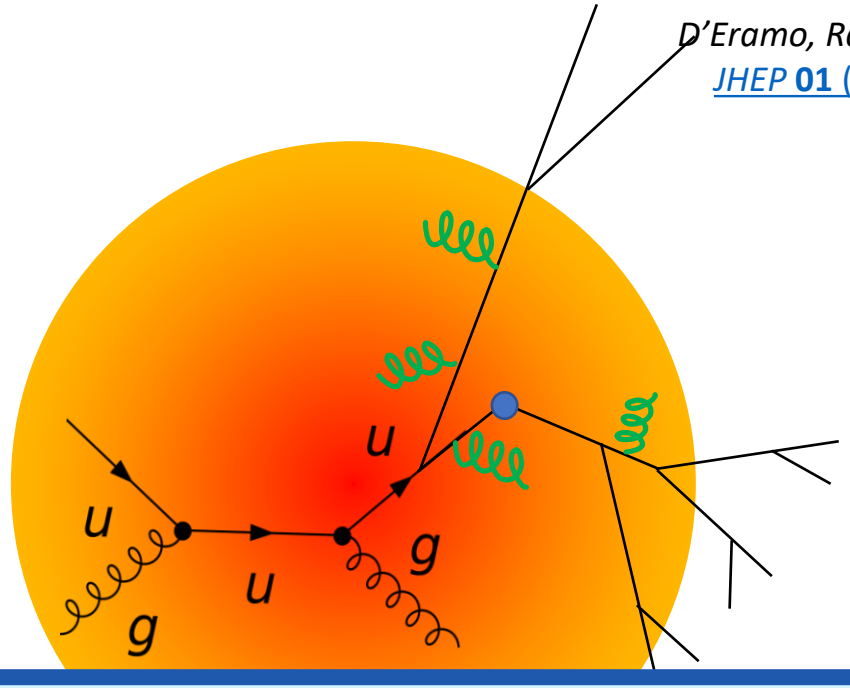


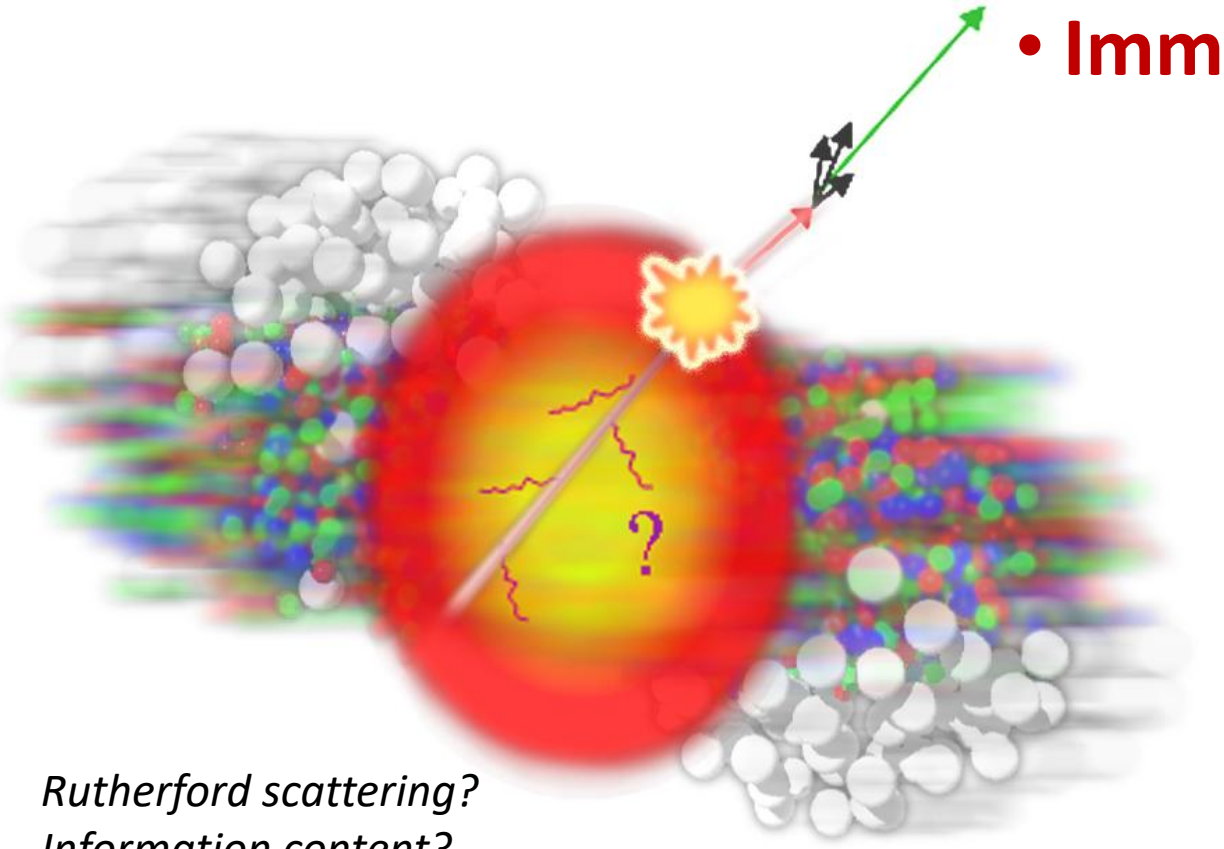
D'Eramo, Rajagopal, Yin
JHEP **01** (2019) 172

No evidence for in-medium Molière scattering in this model

Phys. Lett. B **864** (2025) 139409 and ALICE-PUBLIC-2024-004

How hard must a probe be?

- Low-p_{T} jets (< 40 GeV/c) **challenging in QGP**
  - **Immense uncorrelated background**



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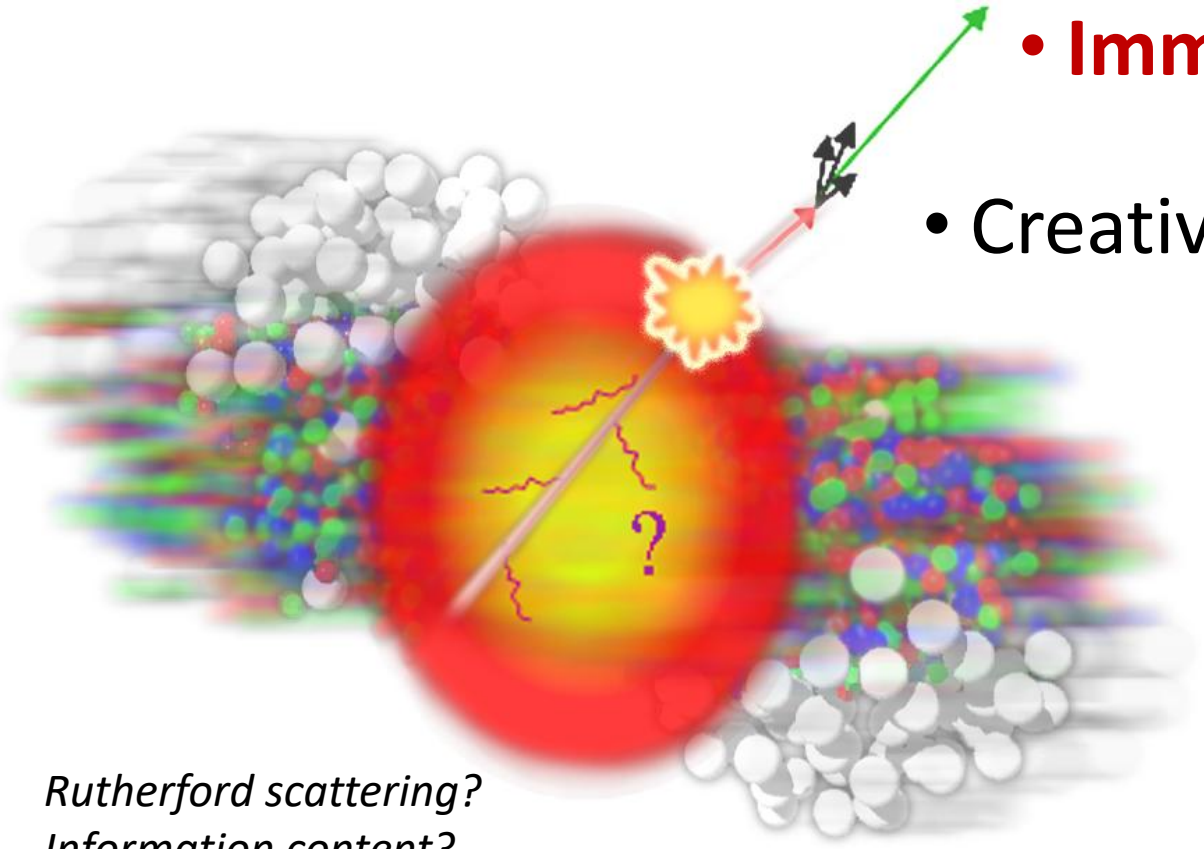
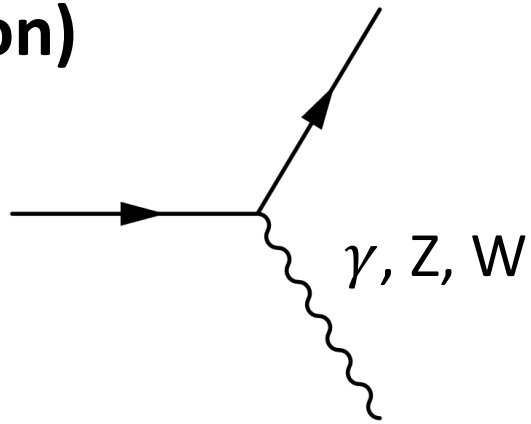


- *Rutherford scattering?*
- *Information content?*

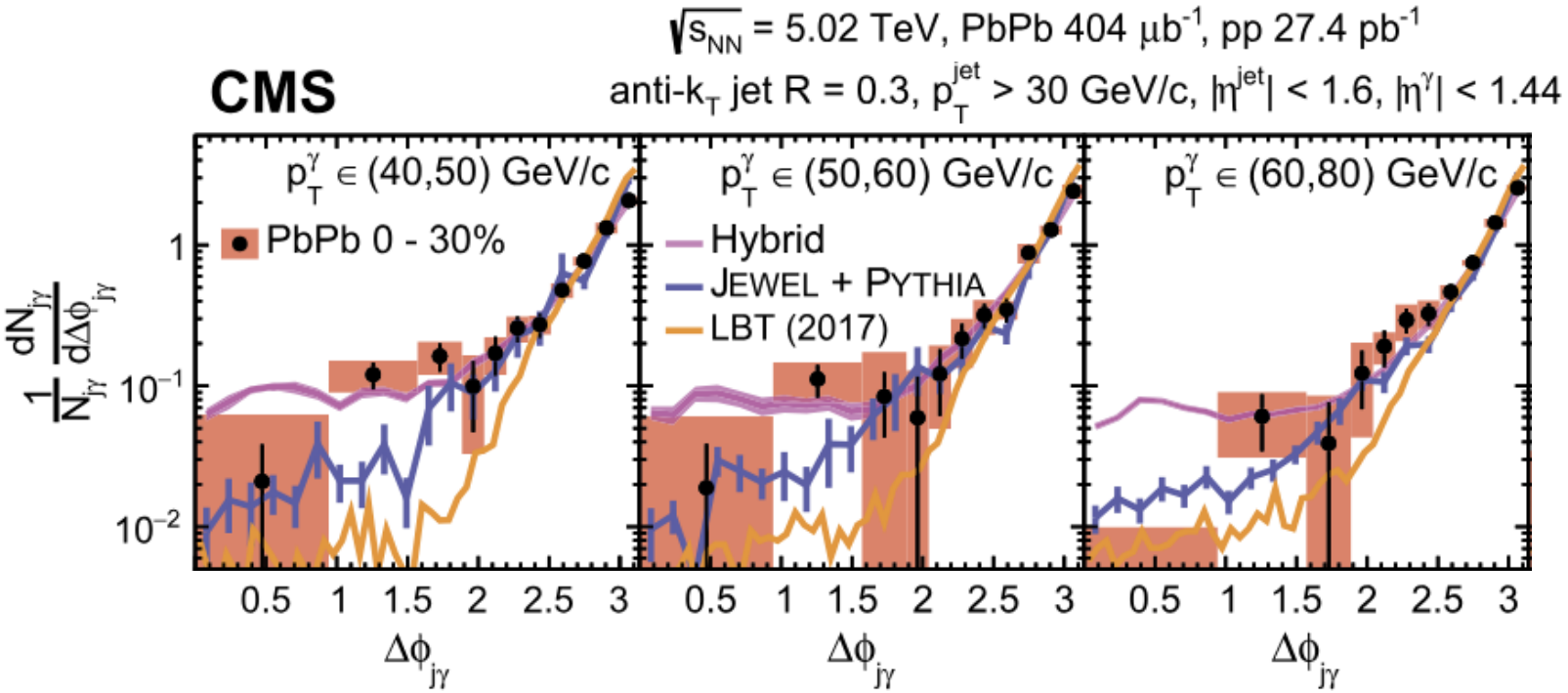
- Creative solution:

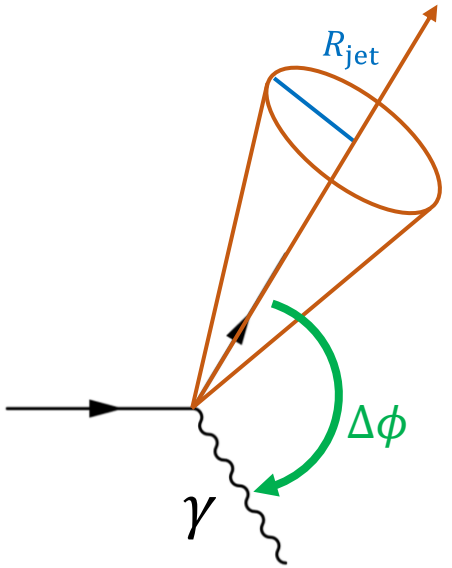
  Tagging jets using a **transverse probe (e.g. EW boson)**



... or another **semi-hard hadron**

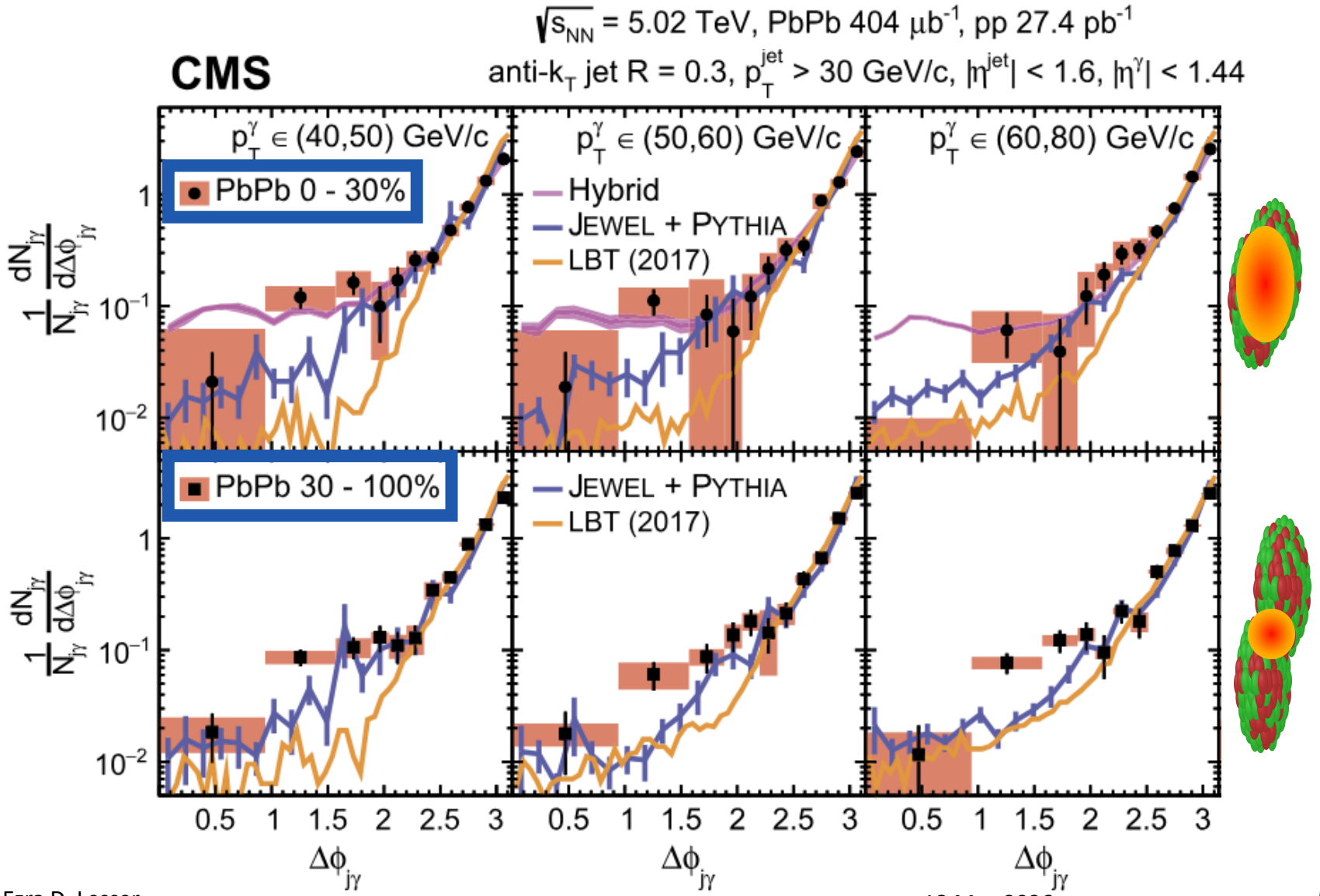
Photon-tagged jet correlations

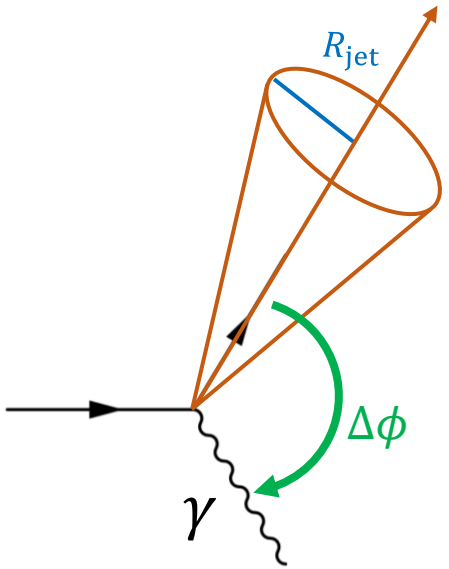




Phys. Lett. B **785** (2018) 14-39

Photon-tagged jet correlations





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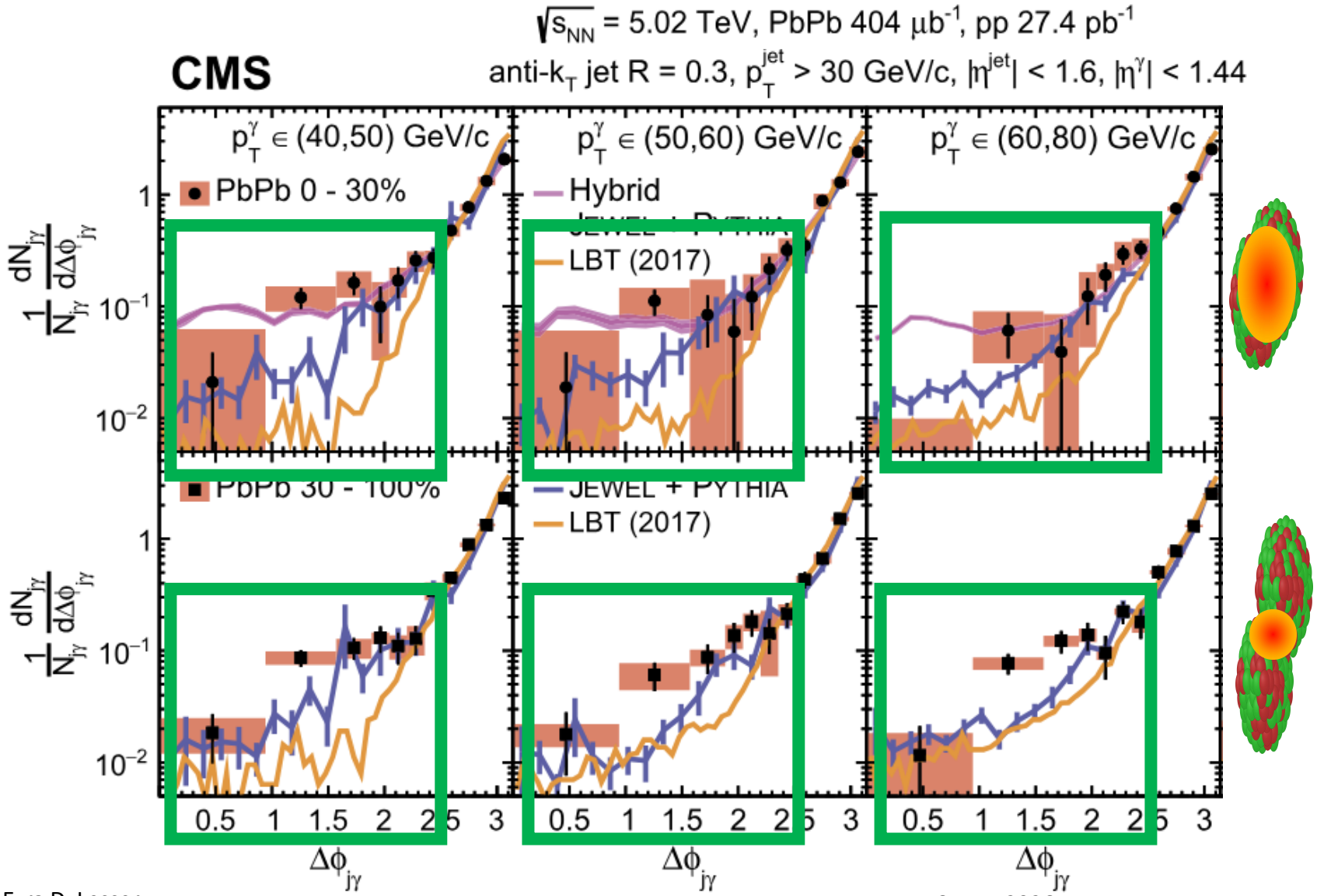
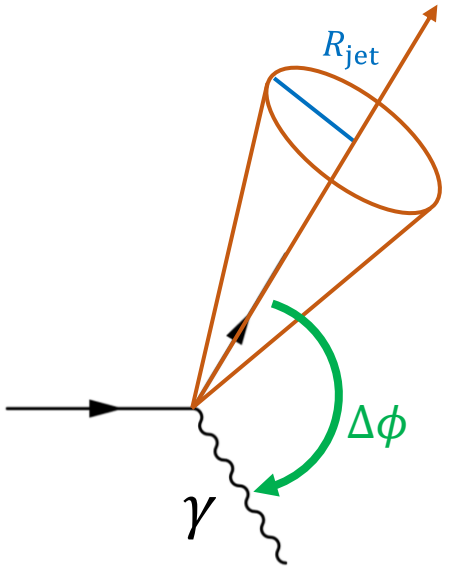
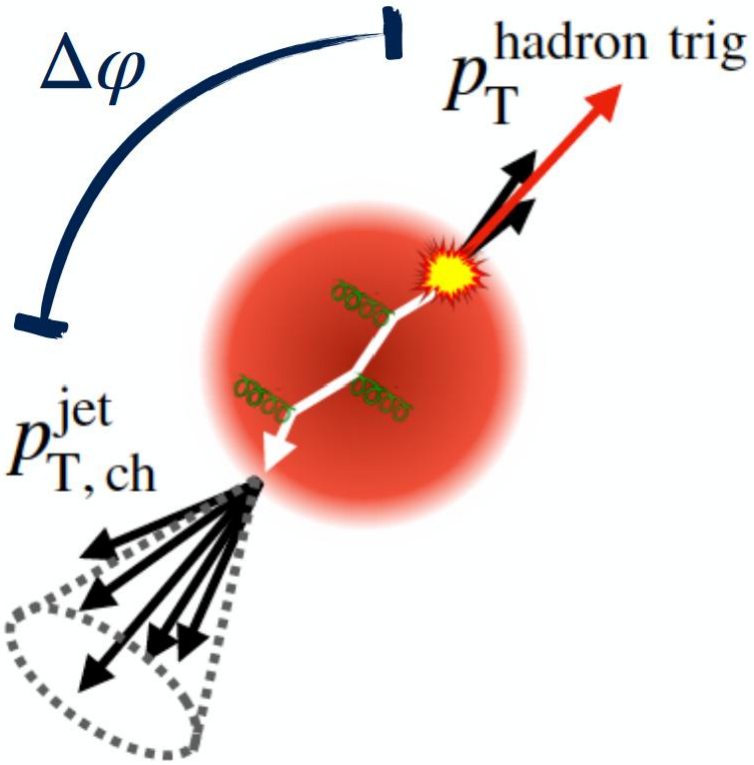




- **Hint of second peak at smaller $\Delta\phi$?**
- Tension with models → scattering effect?

Phys. Lett. B **785** (2018) 14-39

Hadron-jet acoplanarity



- Look for a **trigger track (TT)** within some p_T range, and then **study jets in $\Delta\phi$ from TT**

Phys. Rev. Lett. **133** (2024) 022301

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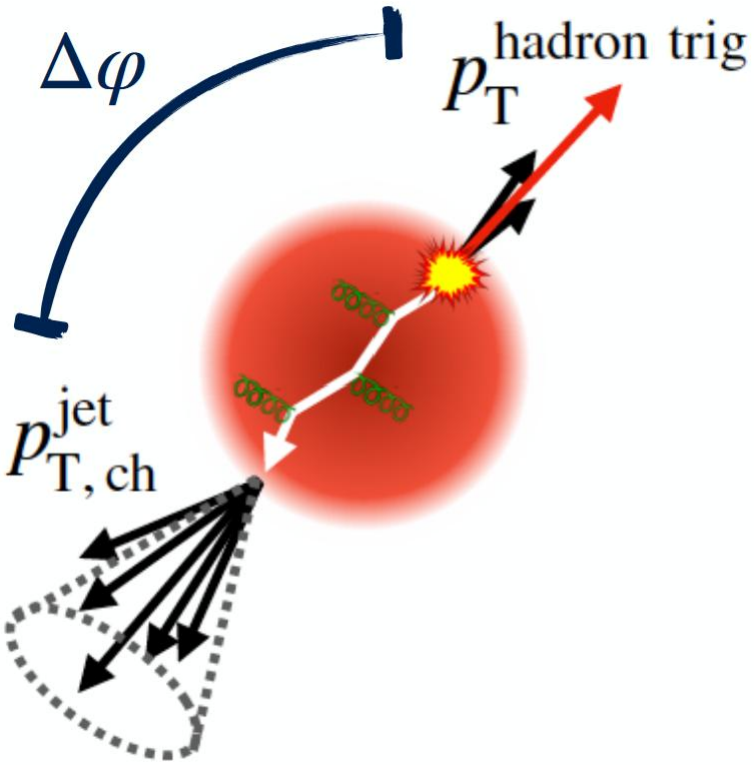

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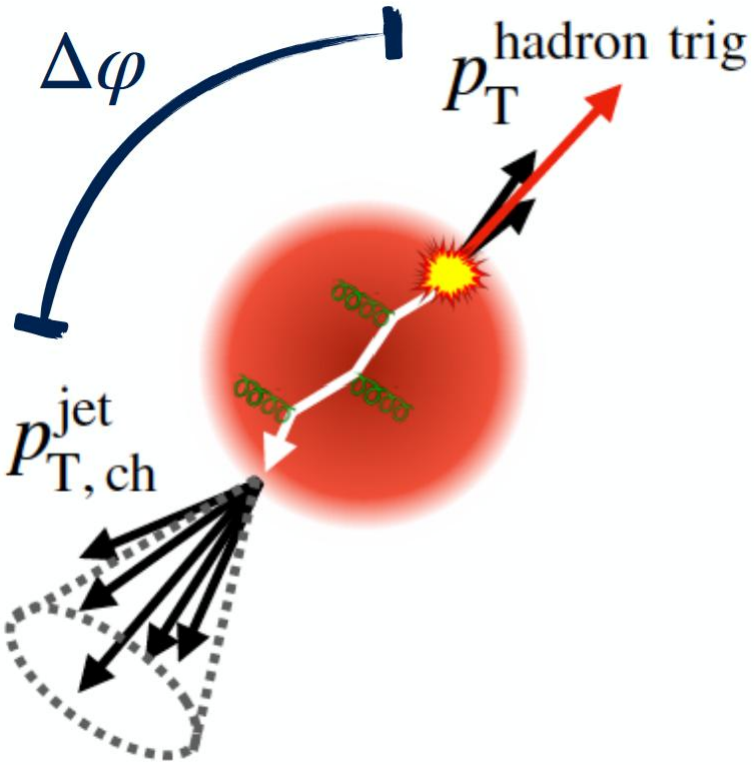

- Look for a **trigger track (TT)** within some p_T range, and then **study jets in $\Delta\phi$ from TT**
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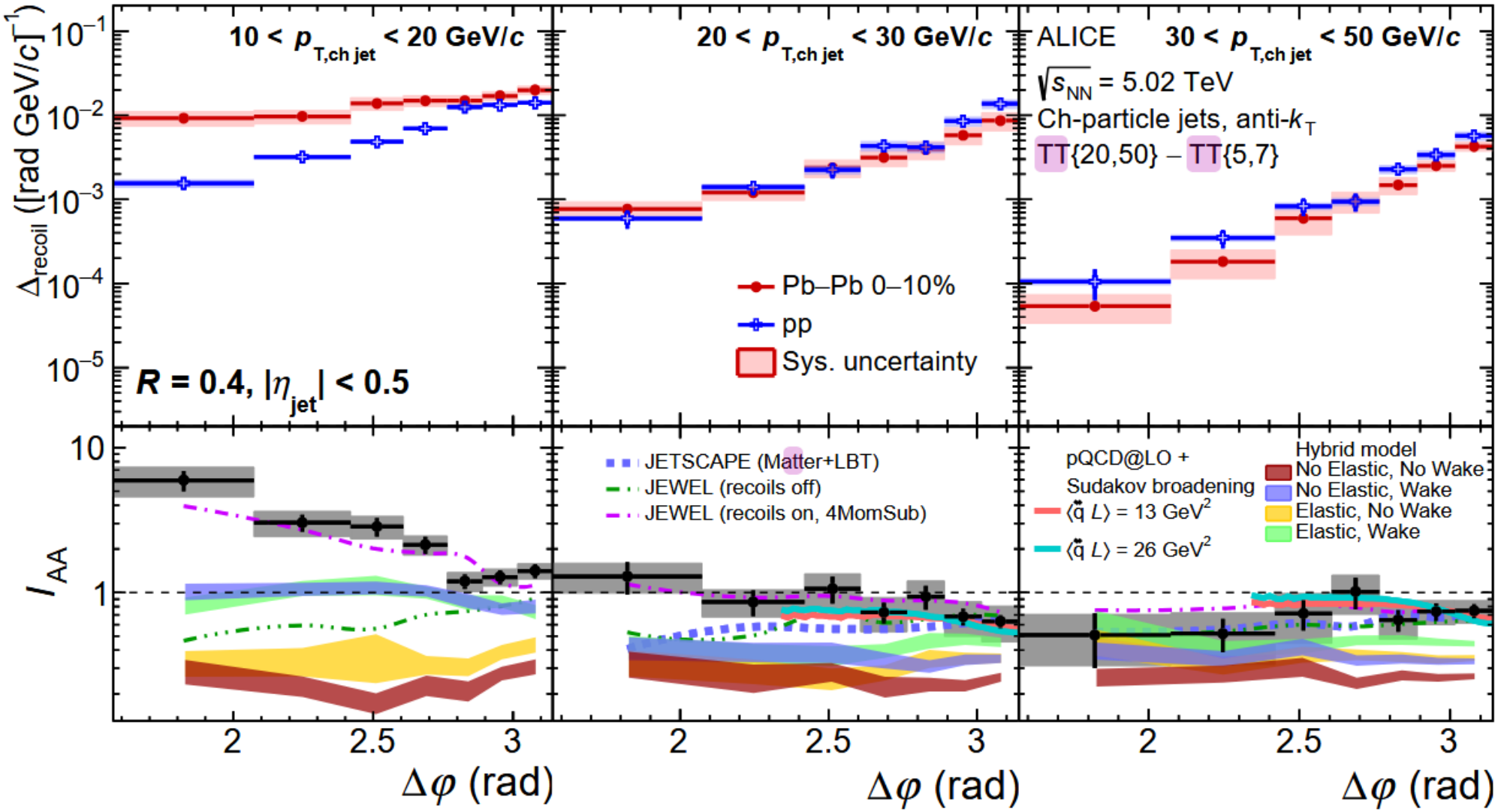
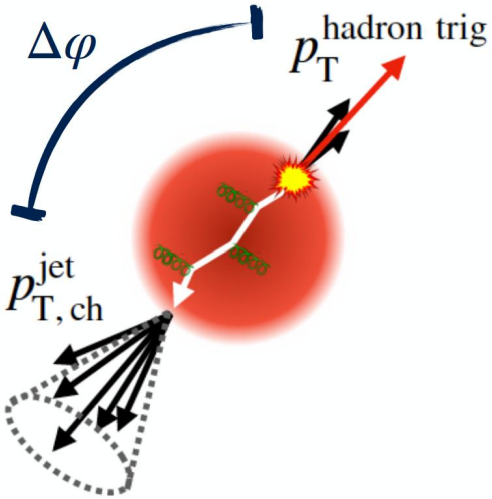
- **Subtract "reference" (low-p_T) TT distribution from "signal" (high-p_T) TT distribution** to correct for uncorrelated effects: left with Δ_{recoil} observable

Phys. Rev. Lett. **133** (2024) 022301

Hadron-jet acoplanarity





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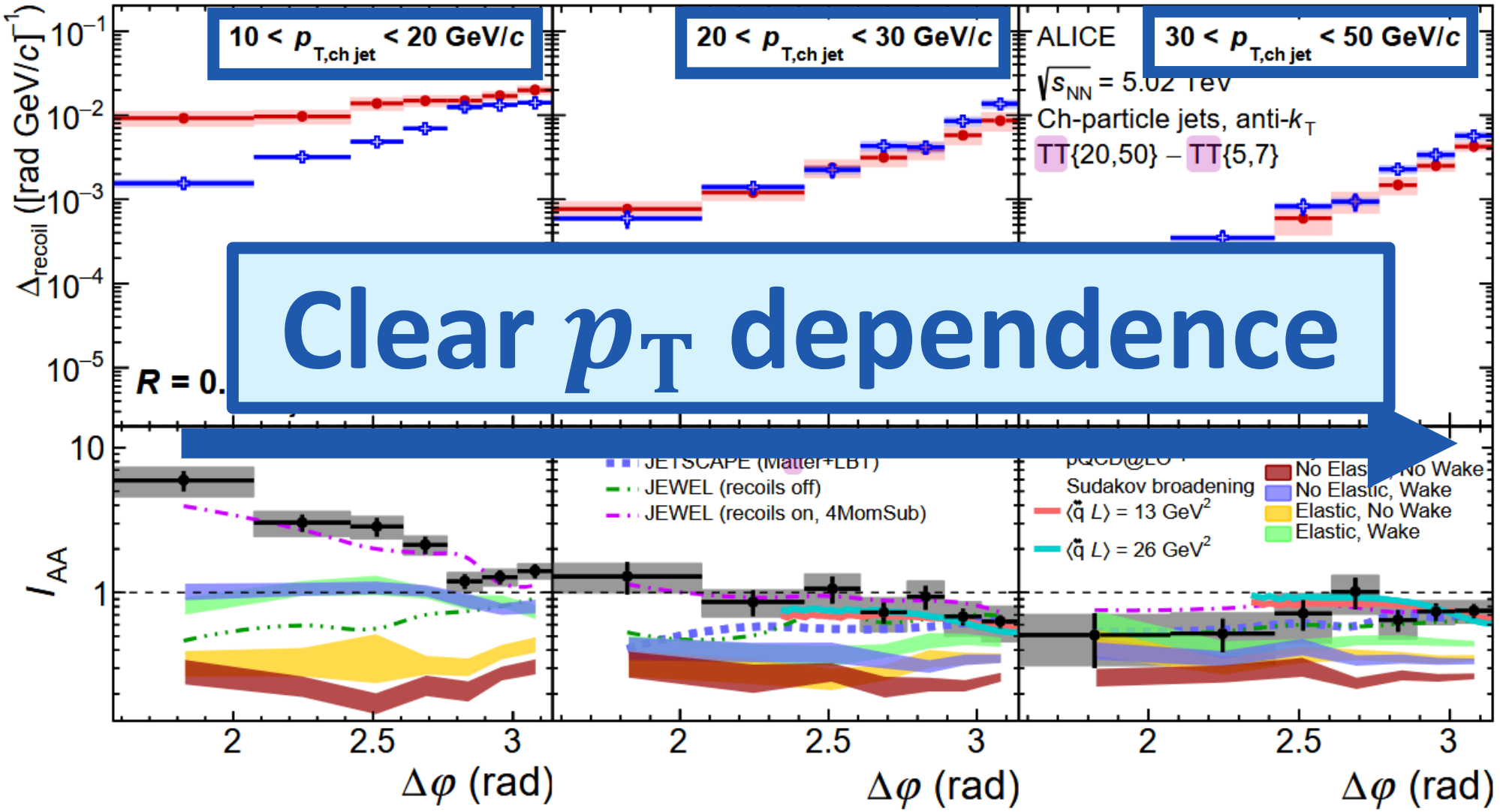
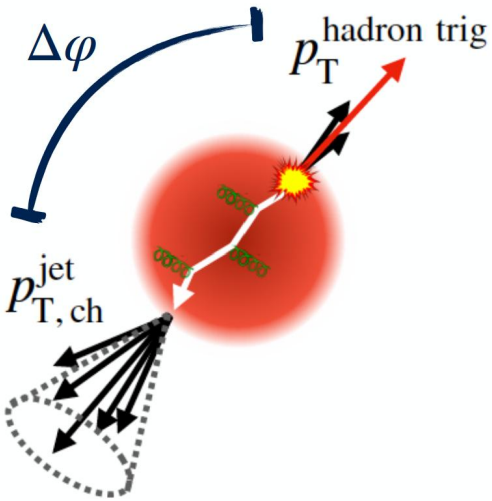


Clear p_T dependence



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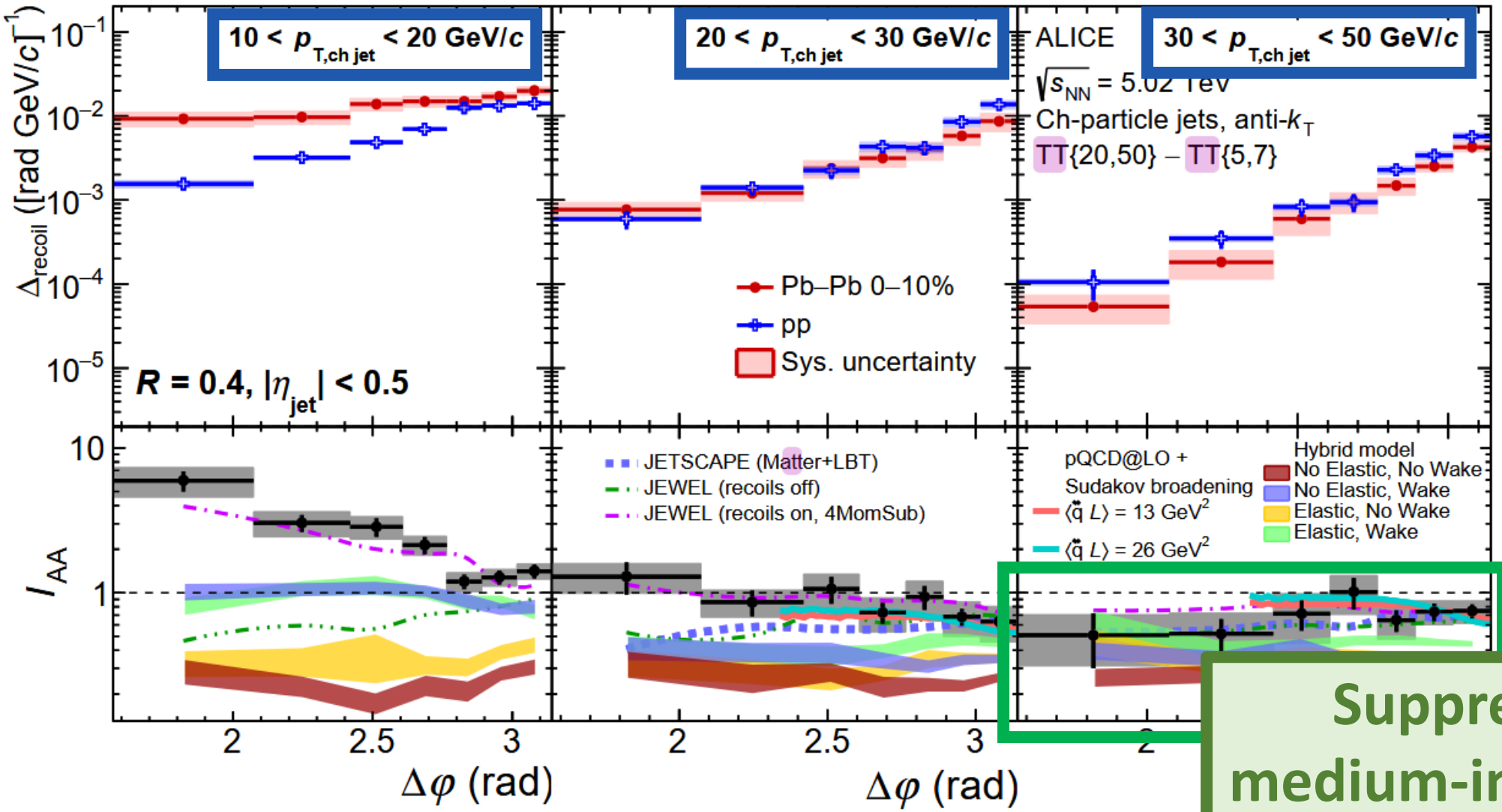

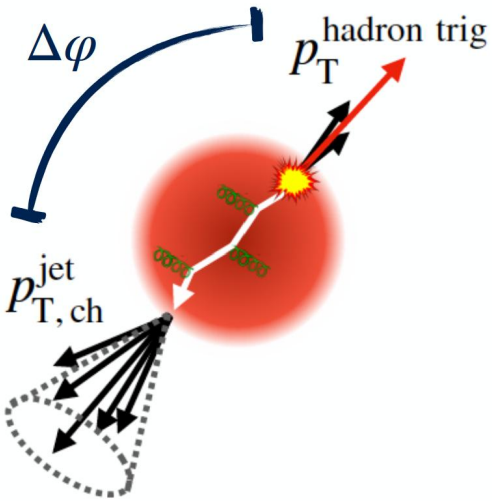

Suppression in medium-induced yield

Phys. Rev. Lett. **133** (2024) 022301

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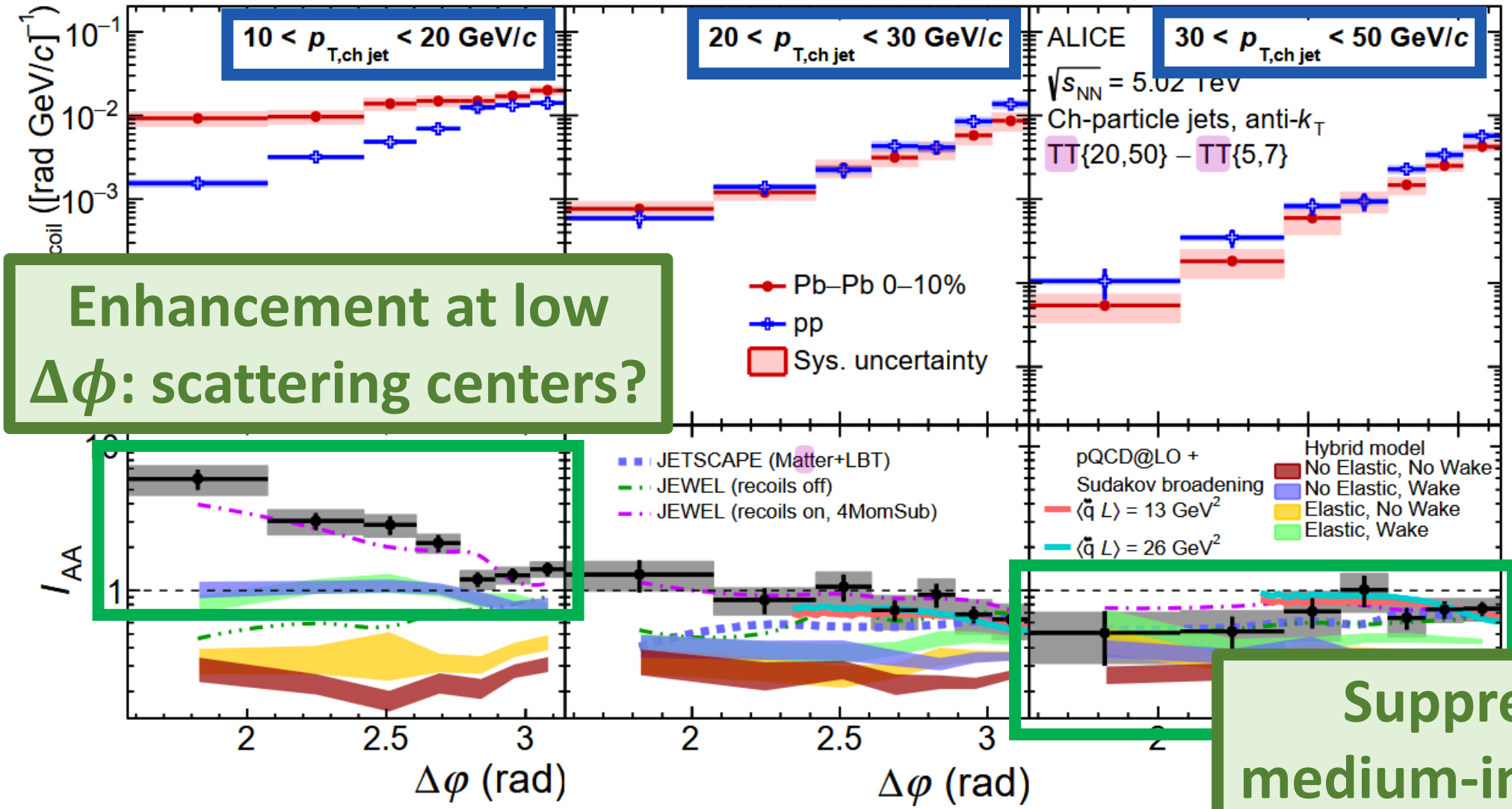

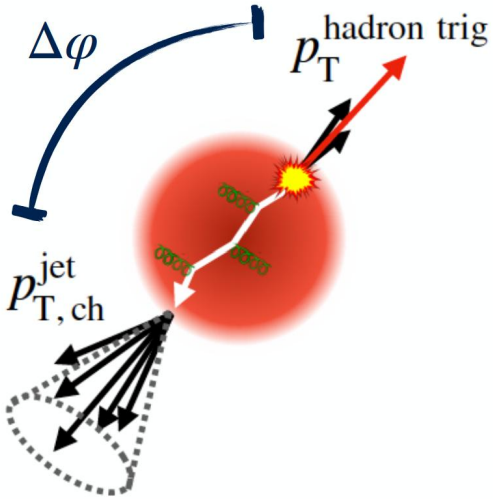

Enhancement at low $\Delta\phi$: scattering centers?

Suppression in medium-induced yield

Phys. Rev. Lett. **133** (2024) 022301

Summary

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- **Diverse and growing opportunities for future LHC measurements!**

Backup

Durham (k_{T}) jet family

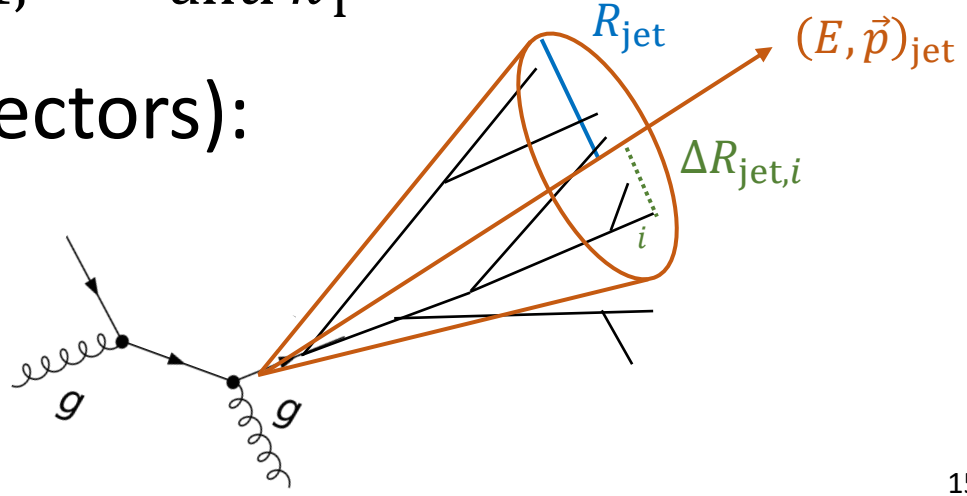
- Jets are reconstructed from **Particle Flow objects** using a sequential recombination algorithm
  - From an **IRC-safe** class of algorithms
  - **Soft-resilient**: shape is not strongly affected by soft, wide-angle radiation

$$d_{ij} = \min\left(k_{\mathrm{T}i}^{2p}, k_{\mathrm{T}j}^{2p}\right)\frac{\Delta_{ij}^2}{R^2}$$
$$d_{i\mathrm{B}} = k_{\mathrm{T}i}^{2p}$$

$$p = \begin{cases} 1, & (\text{"inclusive"})\ k_{\mathrm{T}} \\ 0, & \text{Cambridge/Aachen} \\ -1, & \text{anti } k_{\mathrm{T}} \end{cases}$$

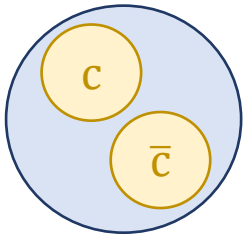
- ***E*-scheme** recombination (adding four vectors):

$$(E, \vec{p})_{\mathrm{jet}} = \sum_{i \in \mathrm{jet}} (E, \vec{p})_i$$



JHEP **04** (2008) 063

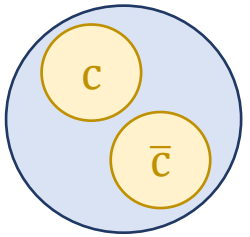
Heavy quarkonium in jets



J/ψ

- How are heavy $q\bar{q}$ pairs (e.g. J/ψ) produced according to QCD?

Heavy quarkonium in jets



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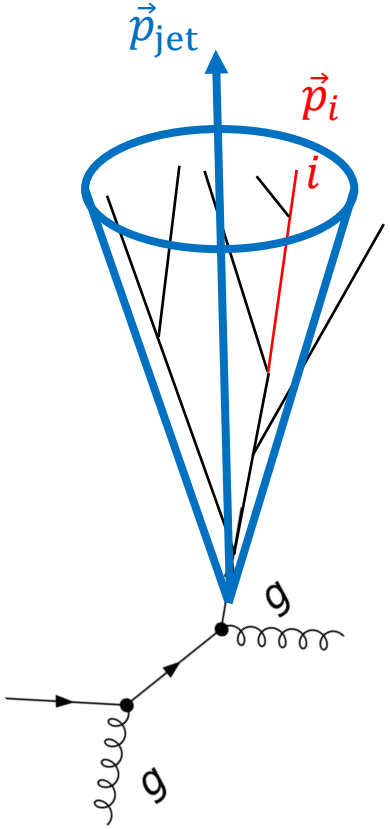
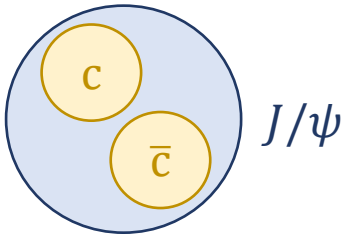


$$z = \frac{p_{\mathrm{T},i}}{p_{\mathrm{T,jet}}}$$

particle momentum fraction

Heavy quarkonium in jets



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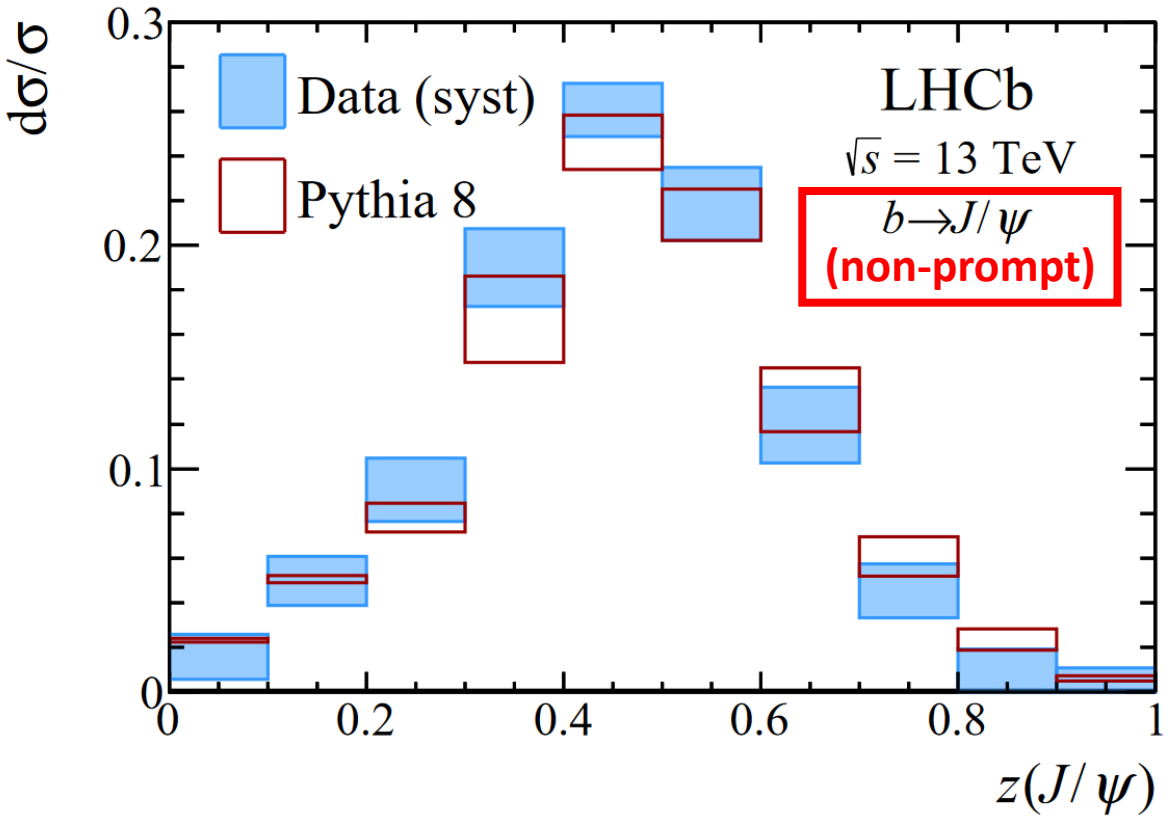
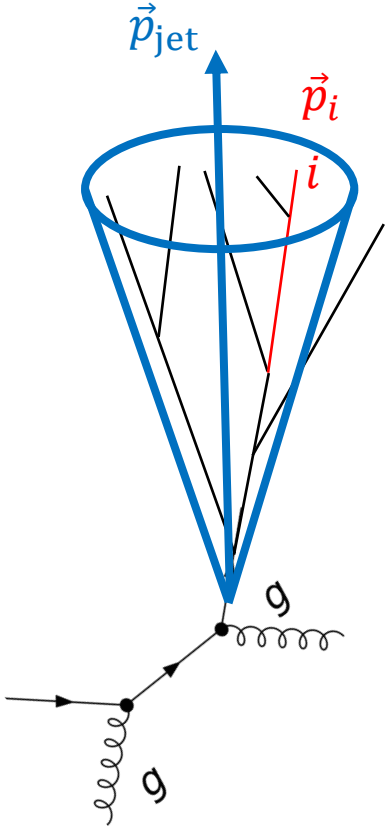


- Both **prompt** and **non-prompt (feed-down)** contributions



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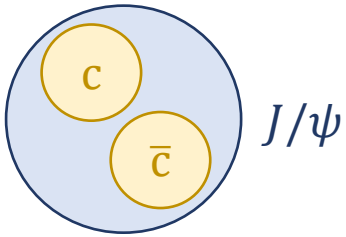
Phys. Rev. Lett. **118** (2017) 192001

Heavy quarkonium in jets



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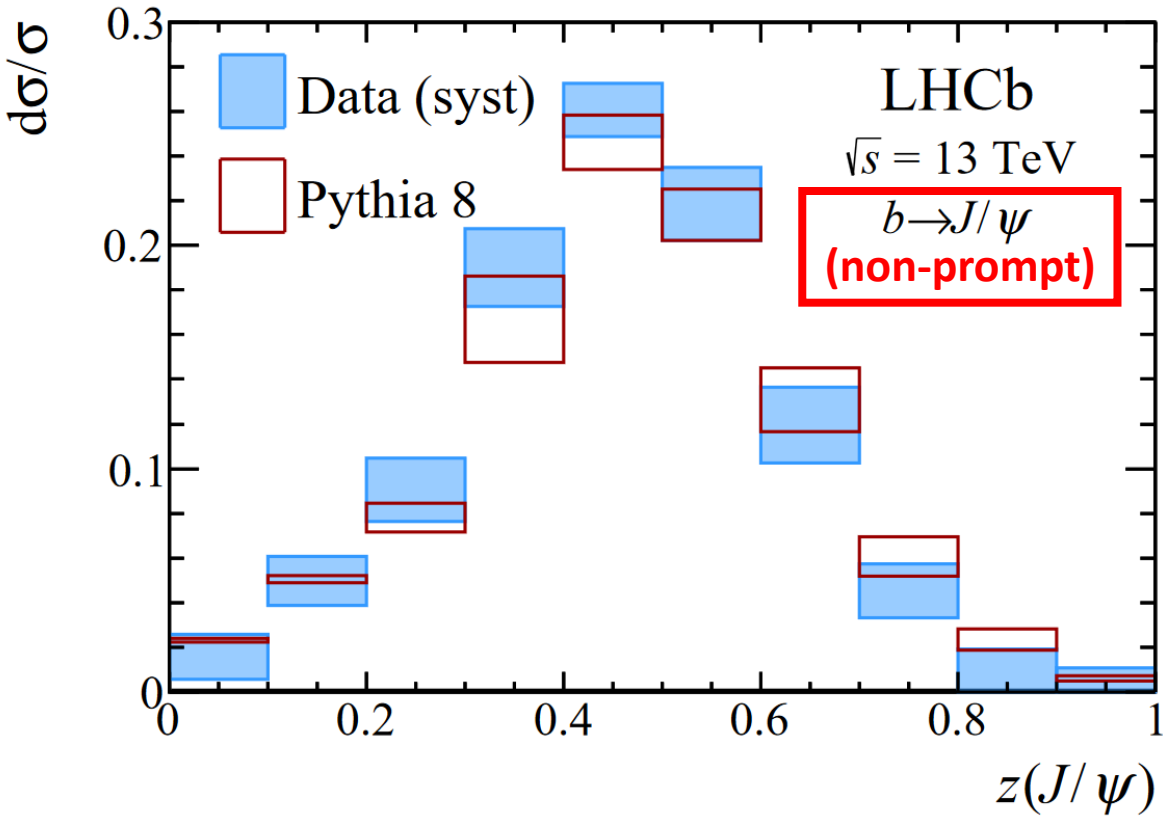
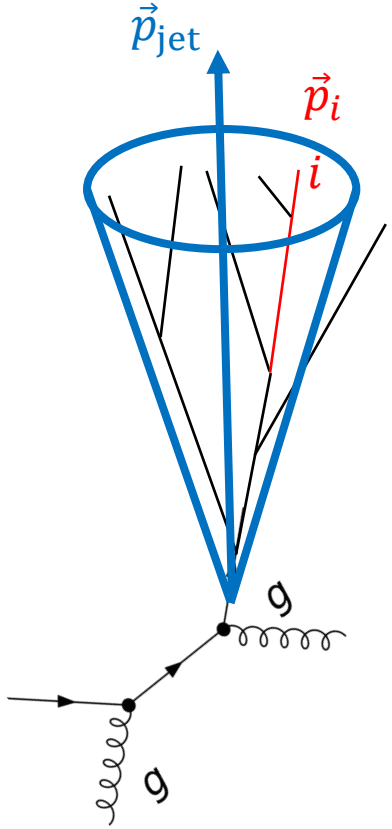


- Both **prompt** and **non-prompt (feed-down)** contributions

- Charmonium from b decays only carries ~50% of jet energy
  → **surrounded by b-jet fragmentation**



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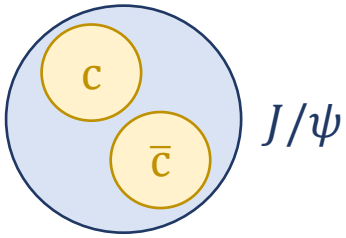

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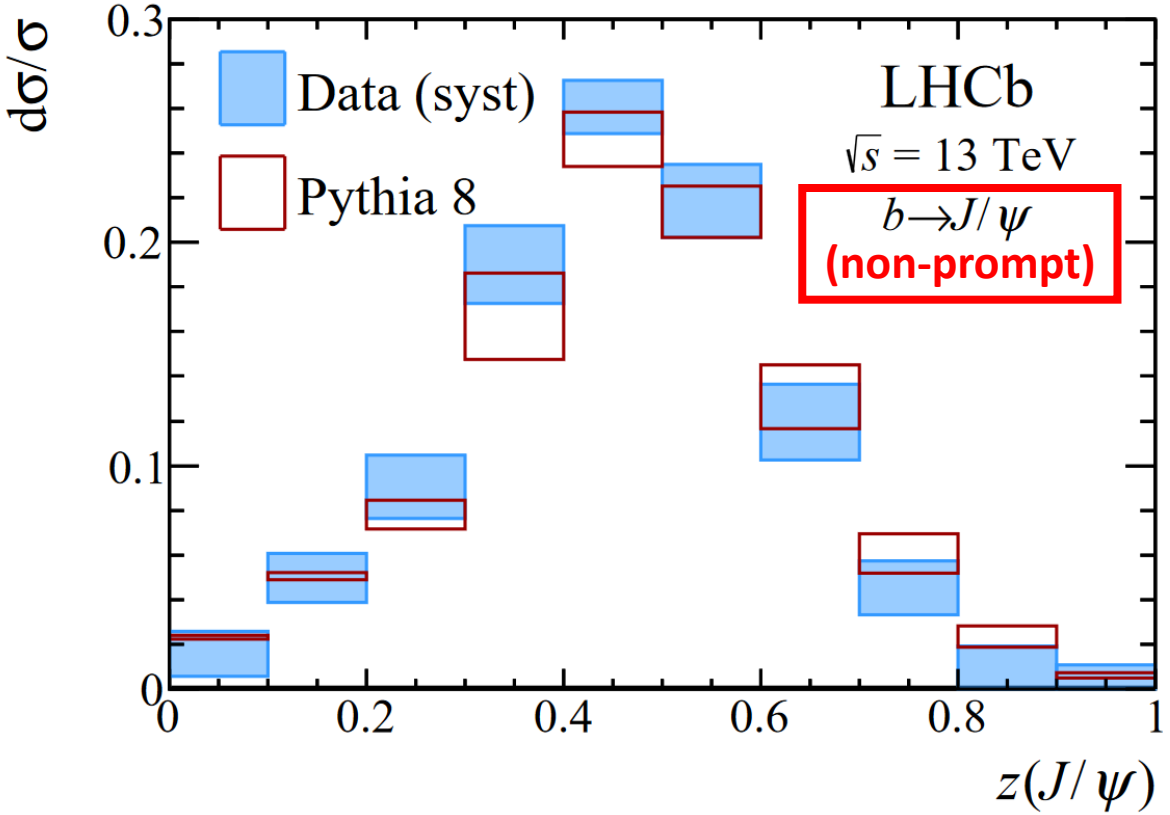

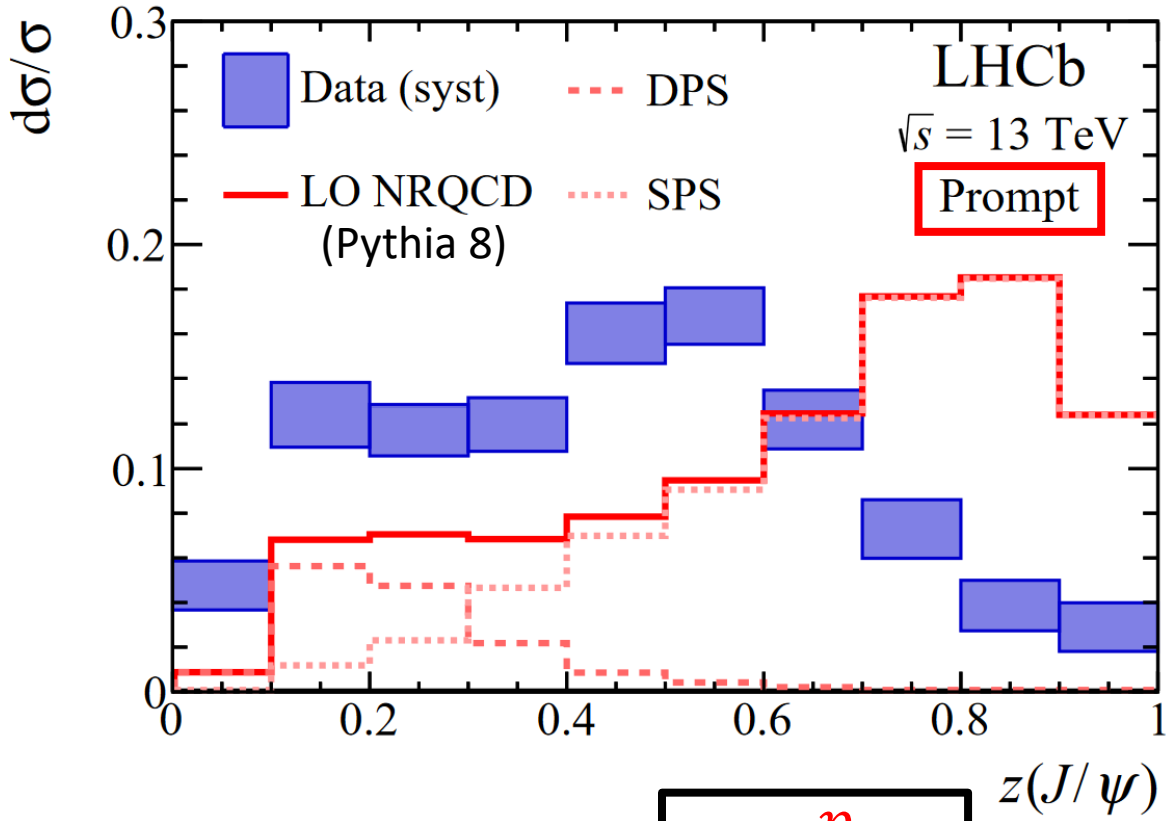

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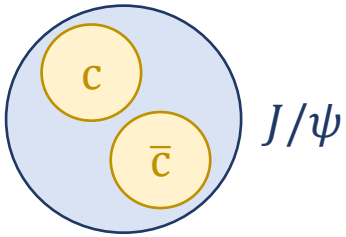

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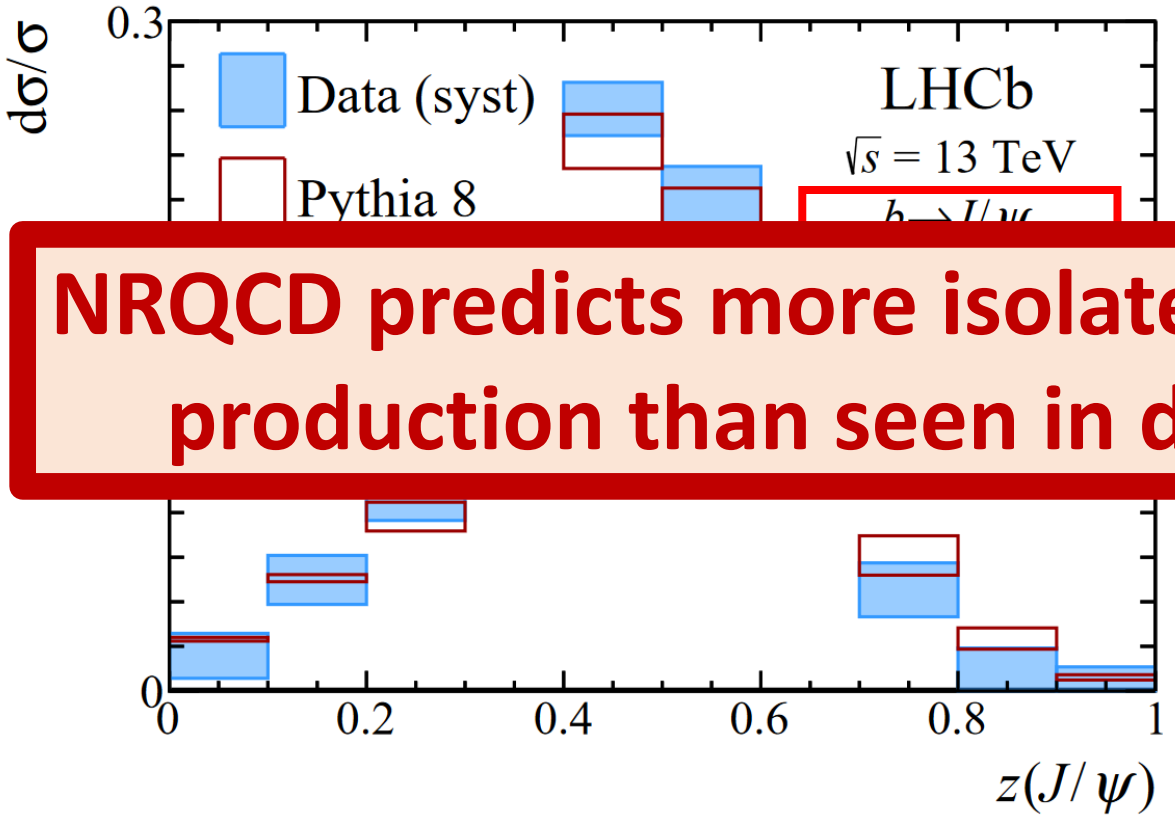

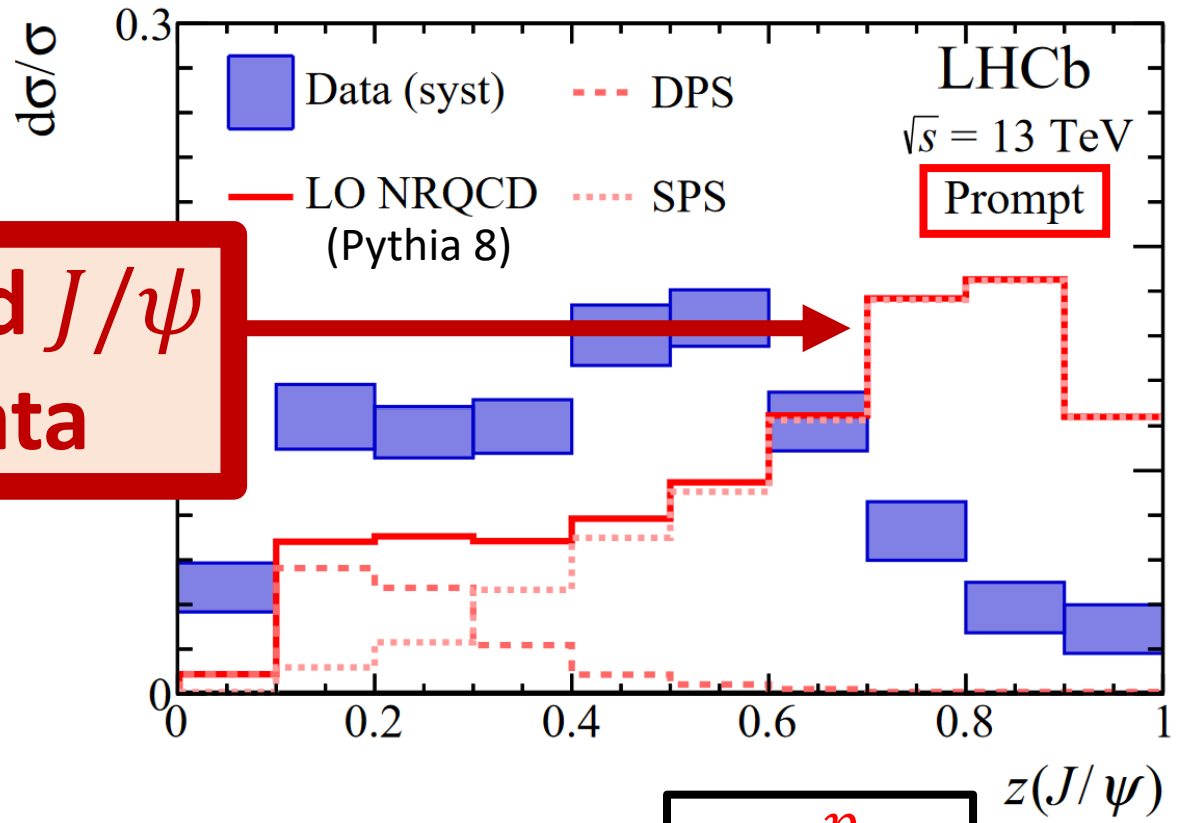

NRQCD predicts more isolated J/ψ production than seen in data

particle momentum fraction $z = \dfrac{p_{T,i}}{p_{T,jet}}$

Phys. Rev. Lett. **118** (2017) 192001

H

- Ho

This *same result* also observed by:

CMS: *Phys. Lett.* **B825** (2021) 136842

ATLAS: *JHEP* **12** (2021) 131

ALICE: arXiv:2602.22889

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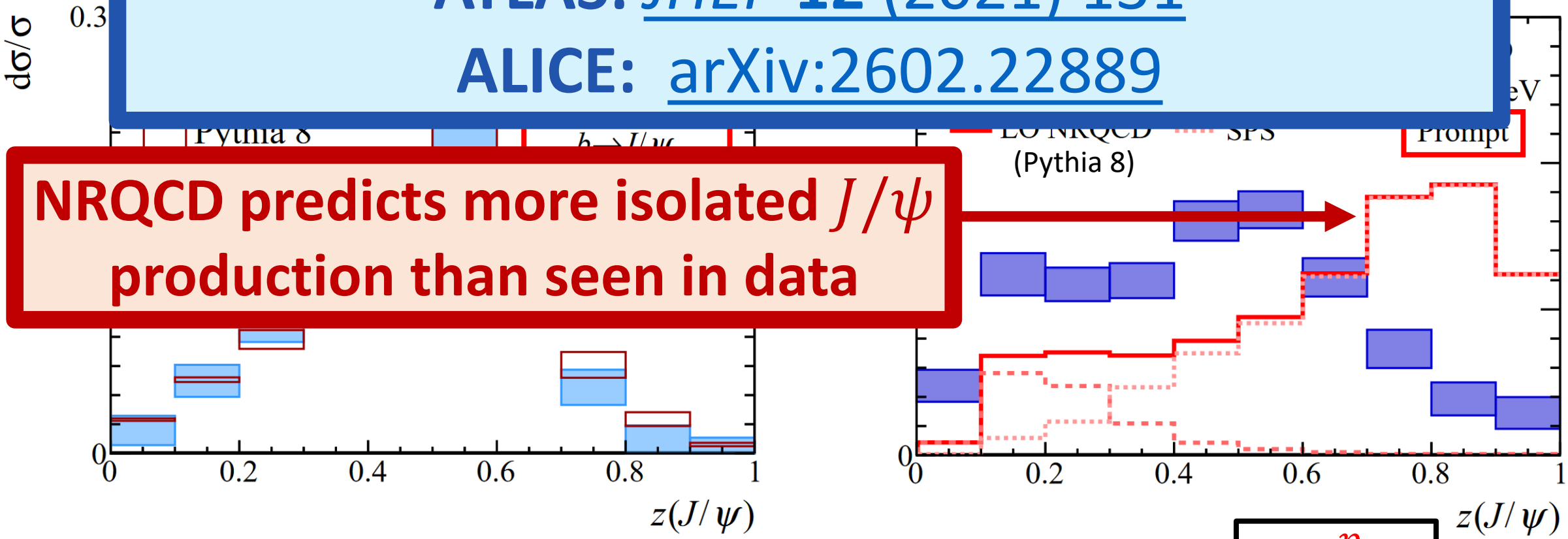

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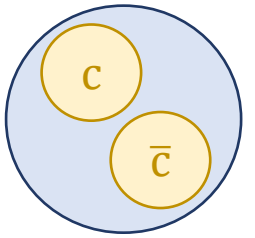
Heavy quarkonia in jets



$\psi(2S)$

- How are heavy $q\bar{q}$ pairs such as $\psi(2S)$ produced according to QCD?

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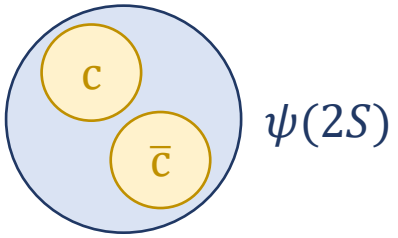

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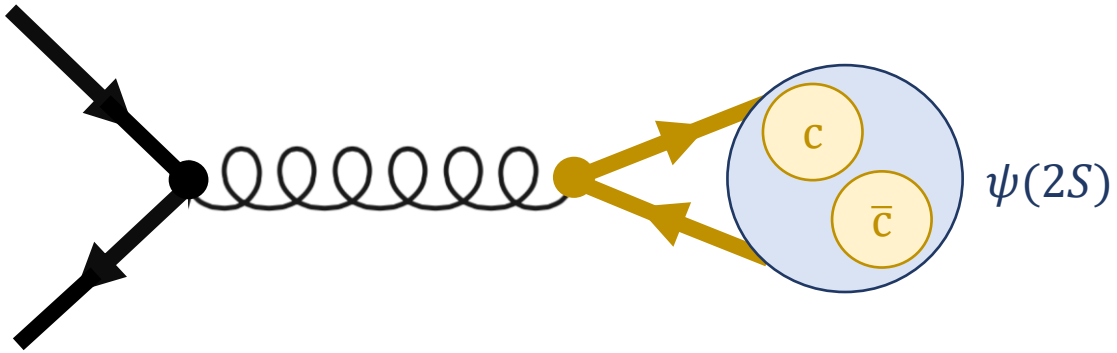
(LO NRQCD picture)



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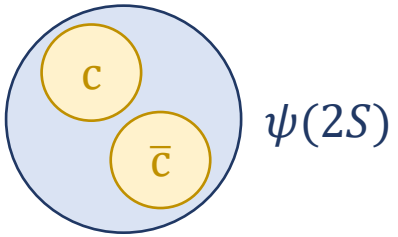

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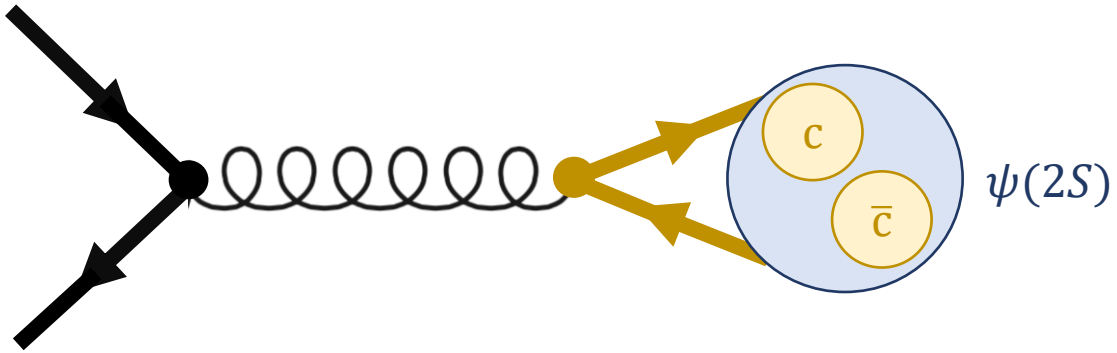

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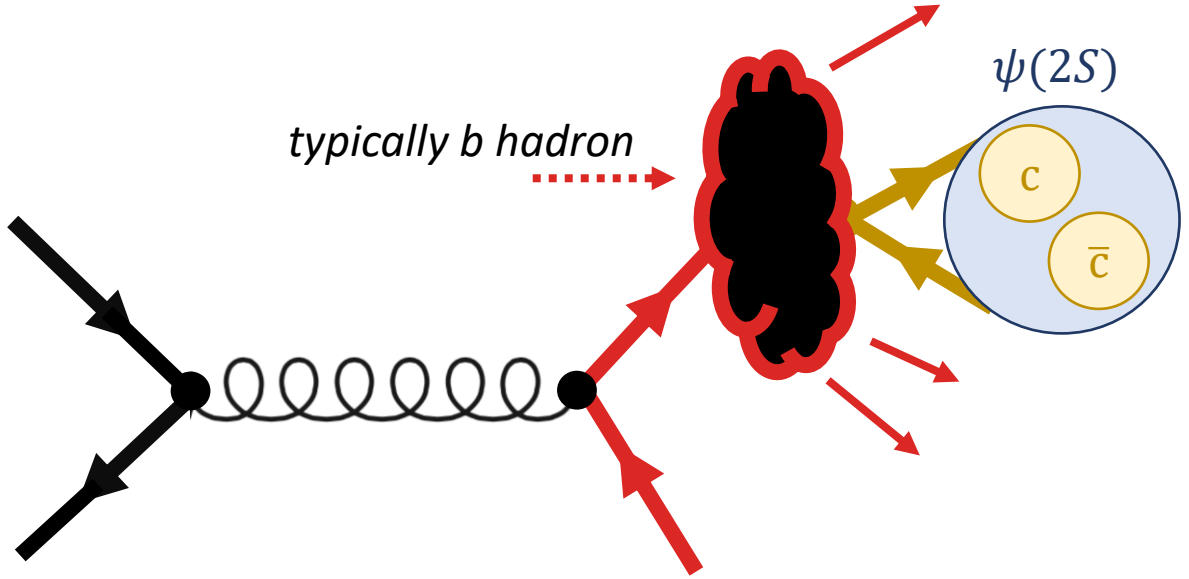

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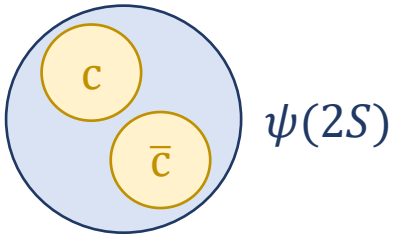

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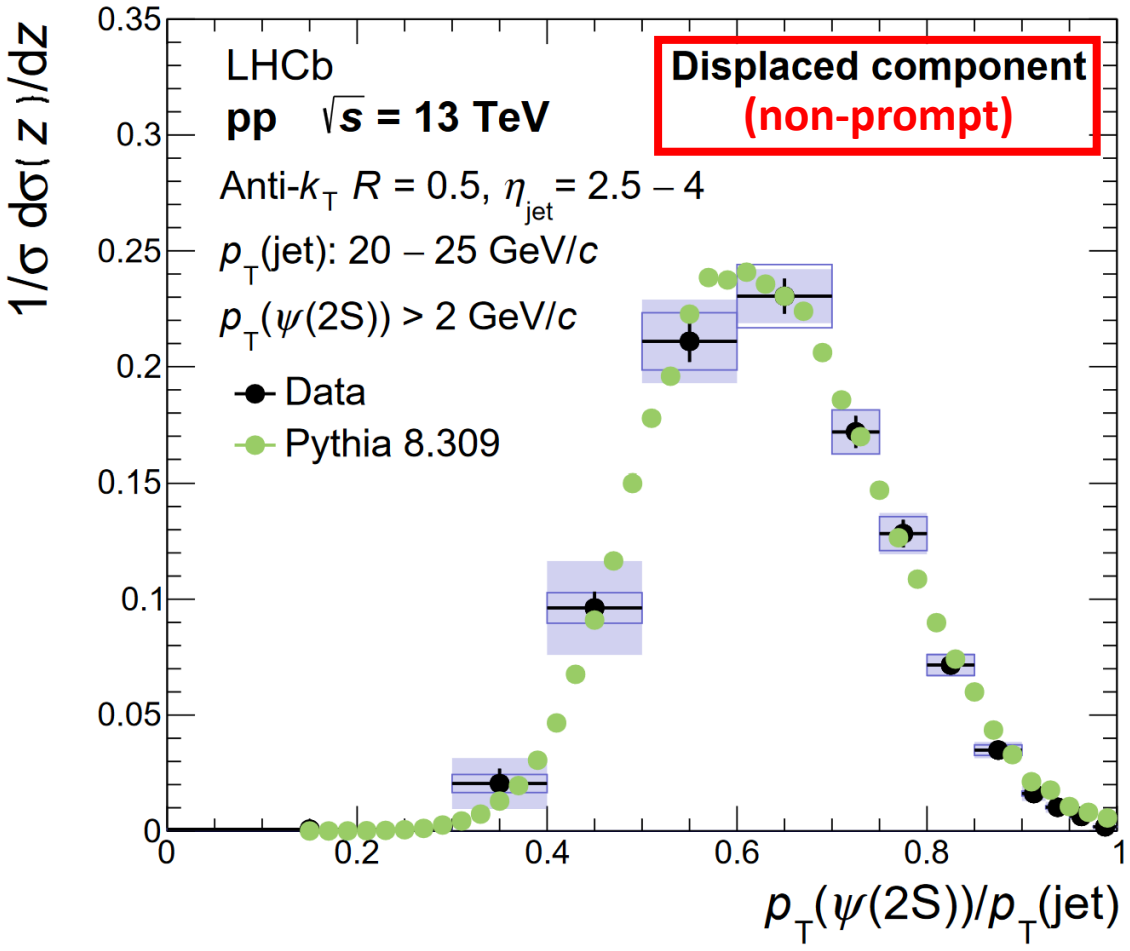
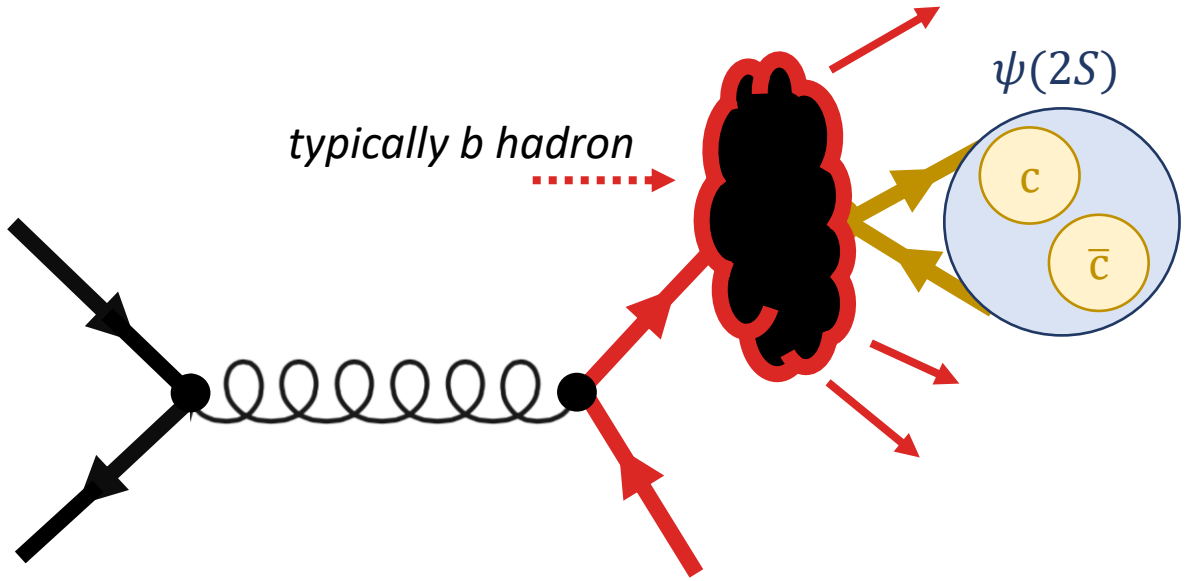
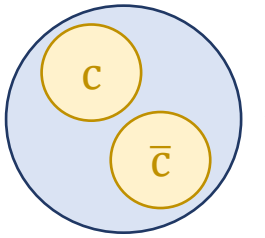


2) Non-prompt production



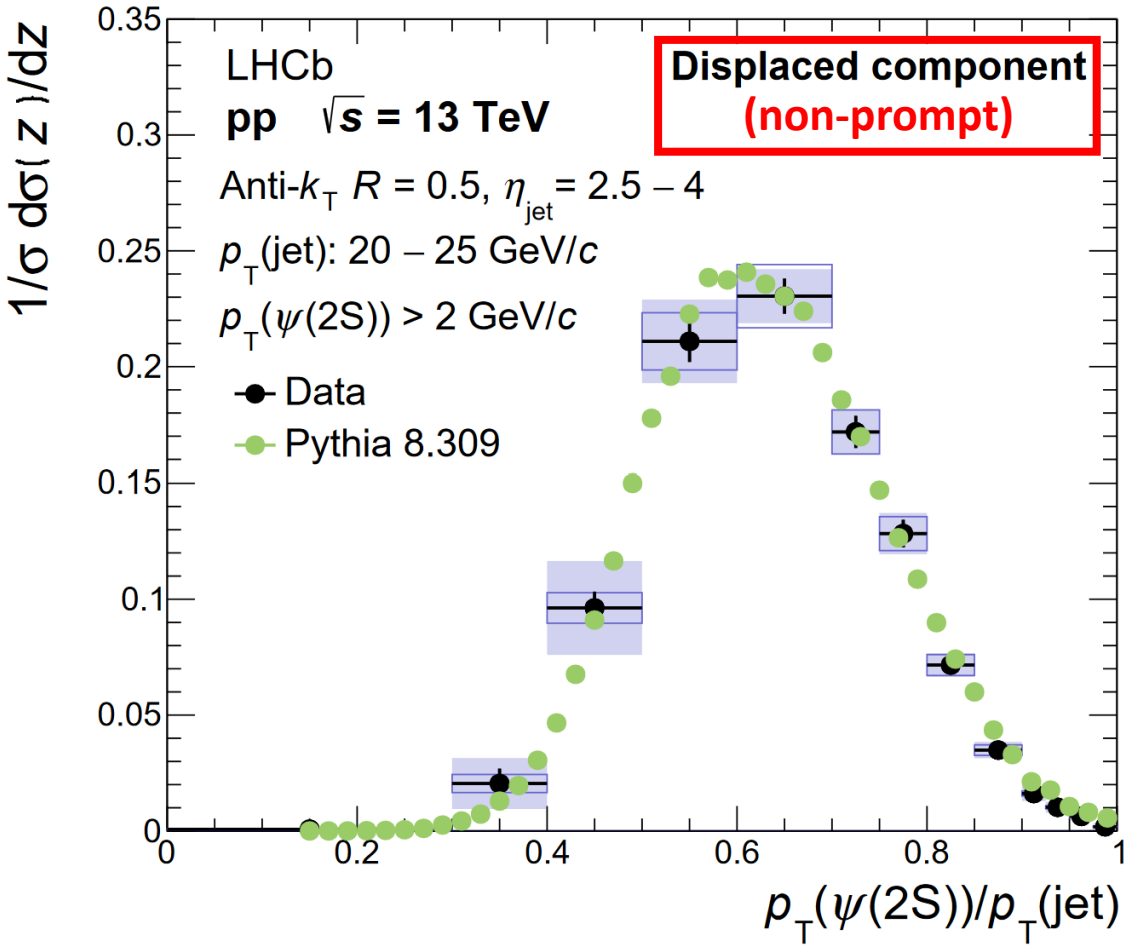
Eur. Phys. J. C **85** (2025) 562

Heavy quarkonia in jets



$\psi(2S)$

- How are heavy $q\bar{q}$ pairs such as $\psi(2S)$ produced according to QCD?



- Displaced $\psi(2S)$ carries ~60% of jet transverse momentum

- **Good agreement** between data and simulation

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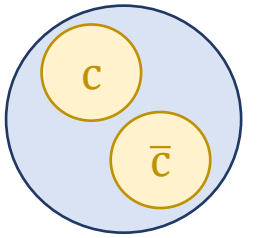
Heavy quarkonia in jets



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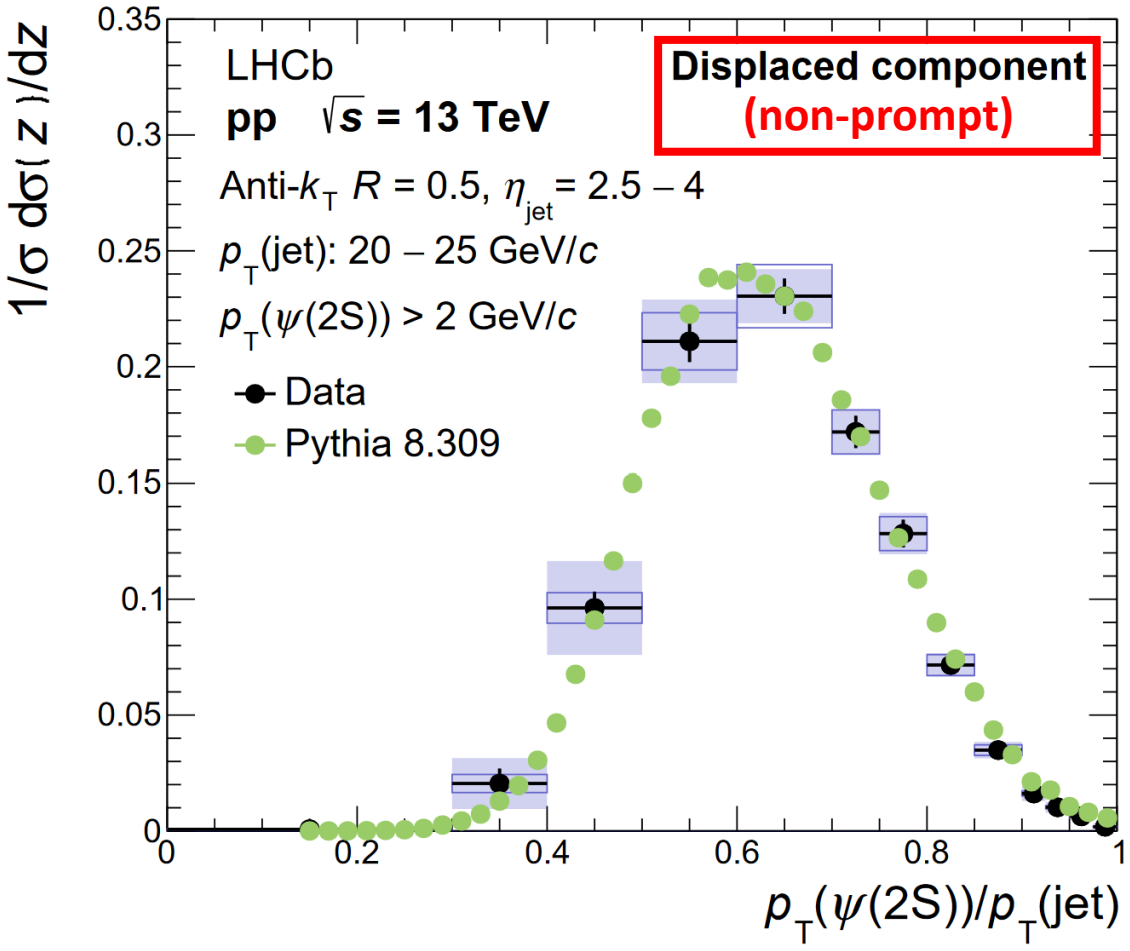
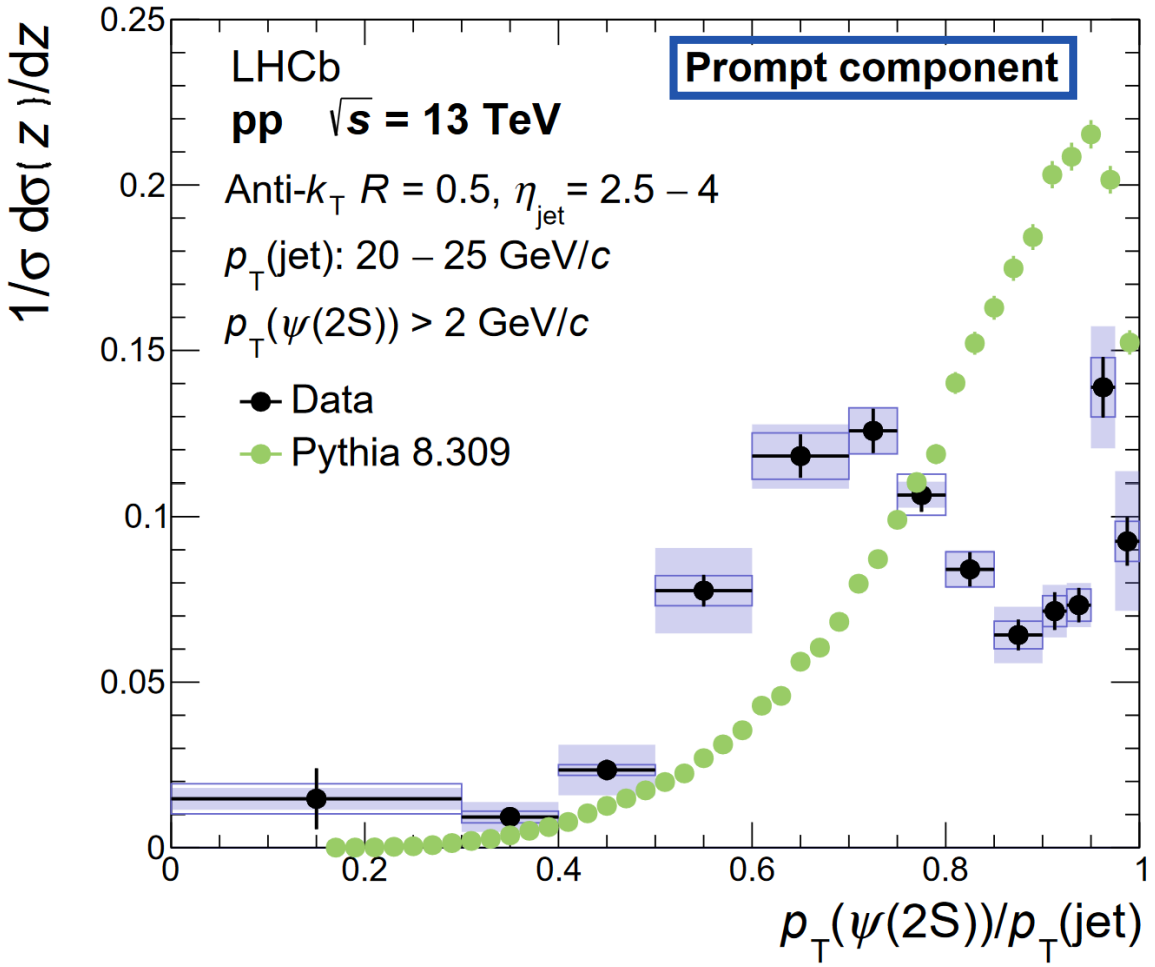
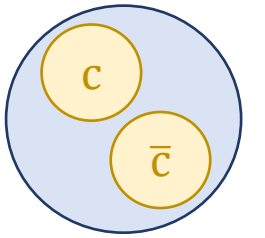




Eur. Phys. J. C **85** (2025) 562

Heavy quarkonia in jets



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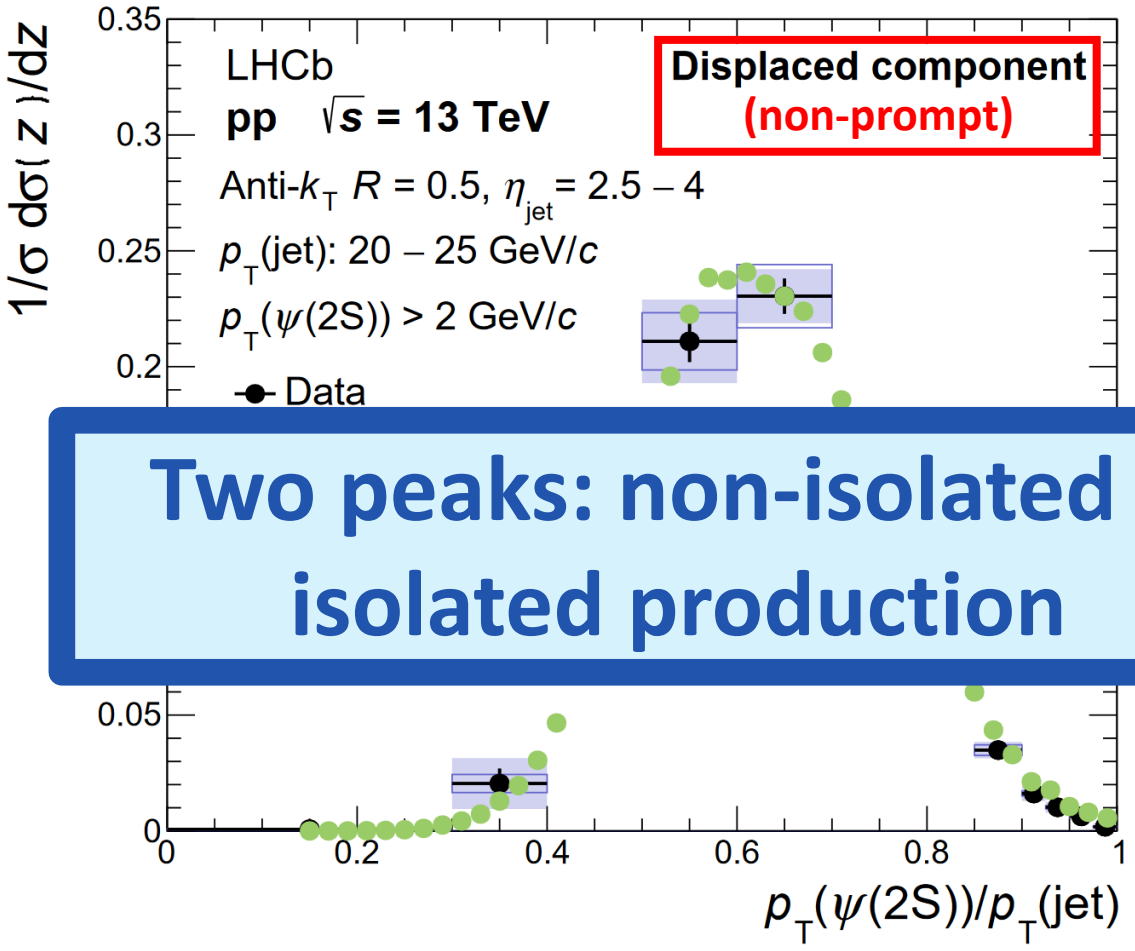
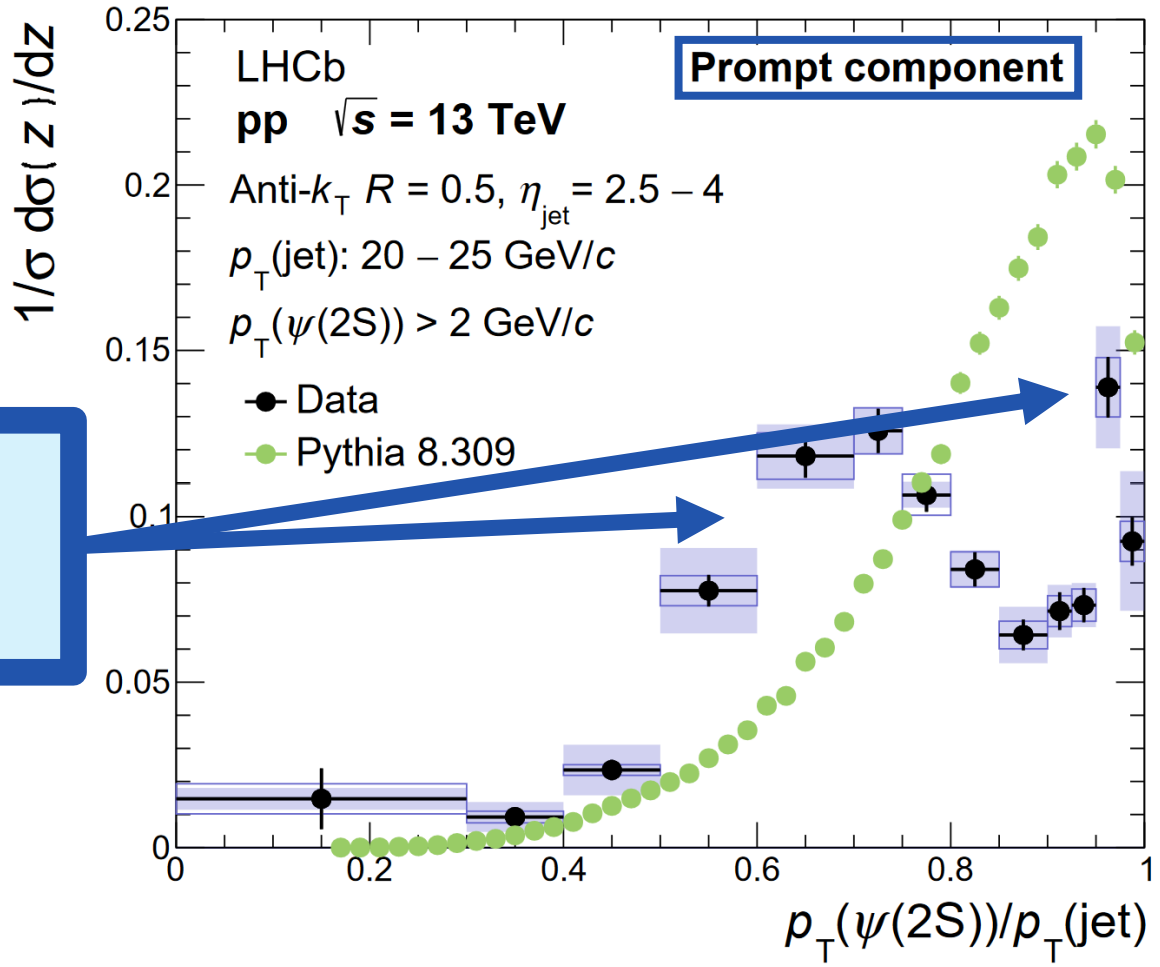
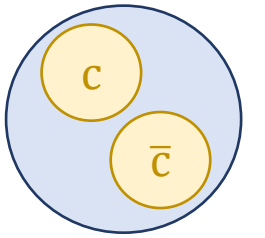




Two peaks: non-isolated & isolated production

Heavy quarkonia in jets



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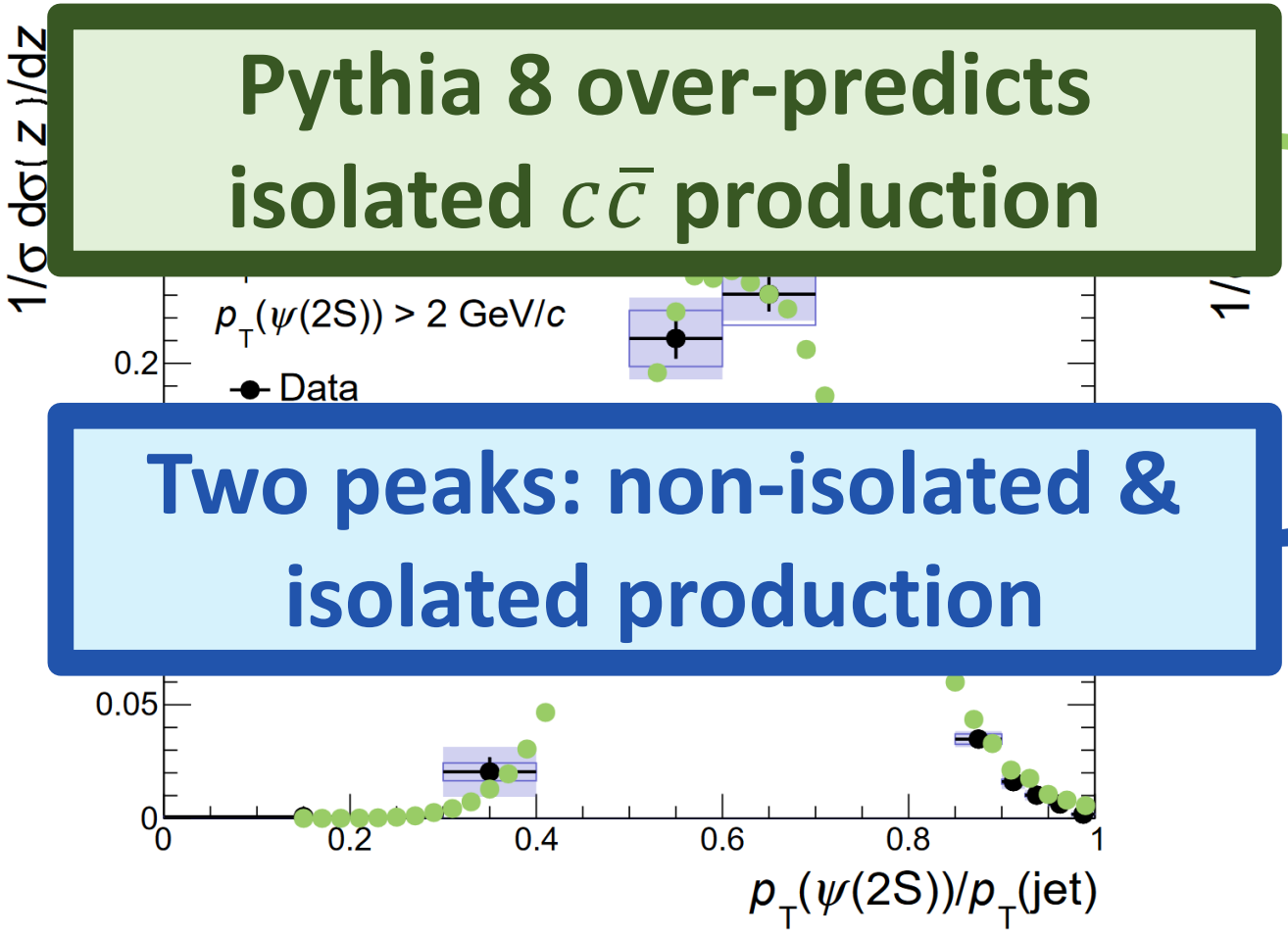
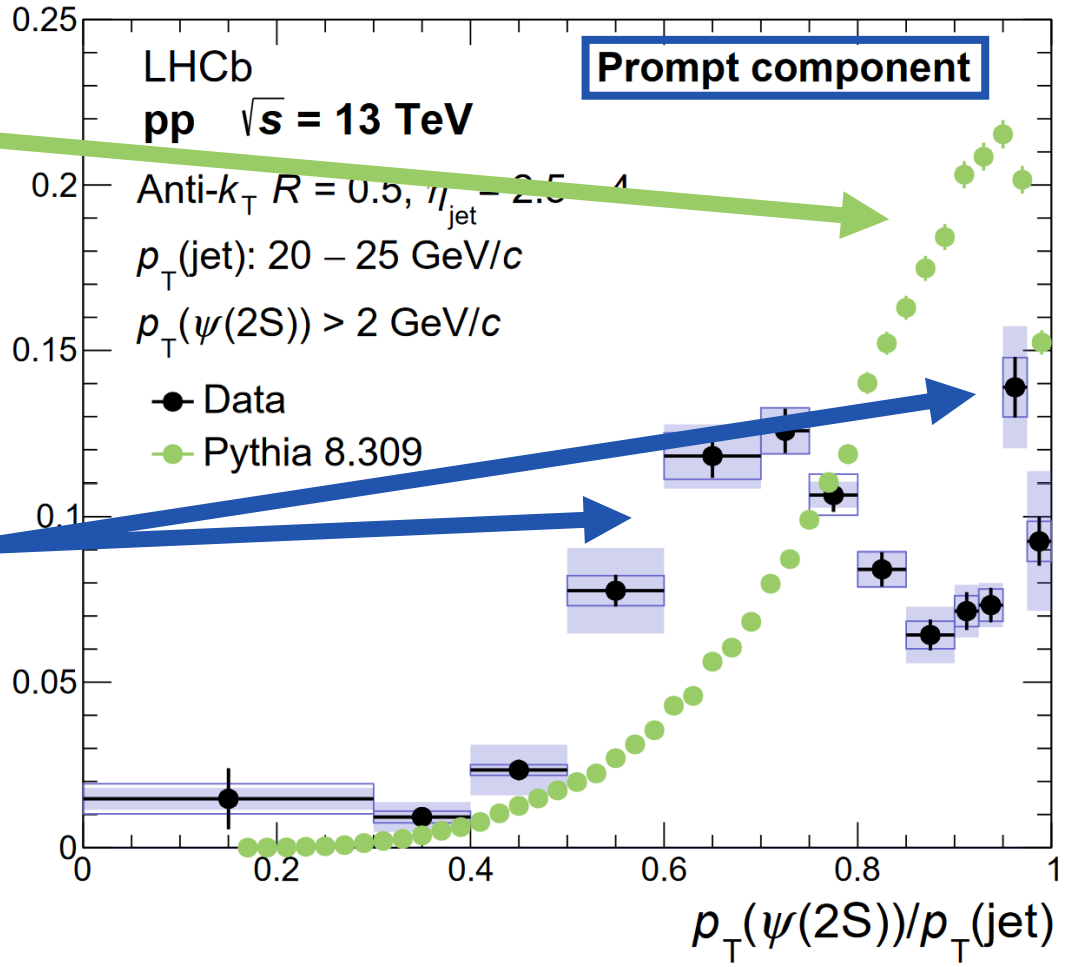
Pythia 8 over-predicts isolated $c\bar{c}$ production

Two peaks: non-isolated & isolated production





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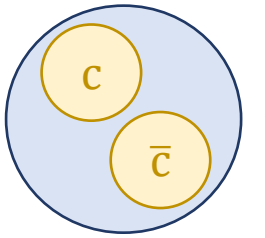

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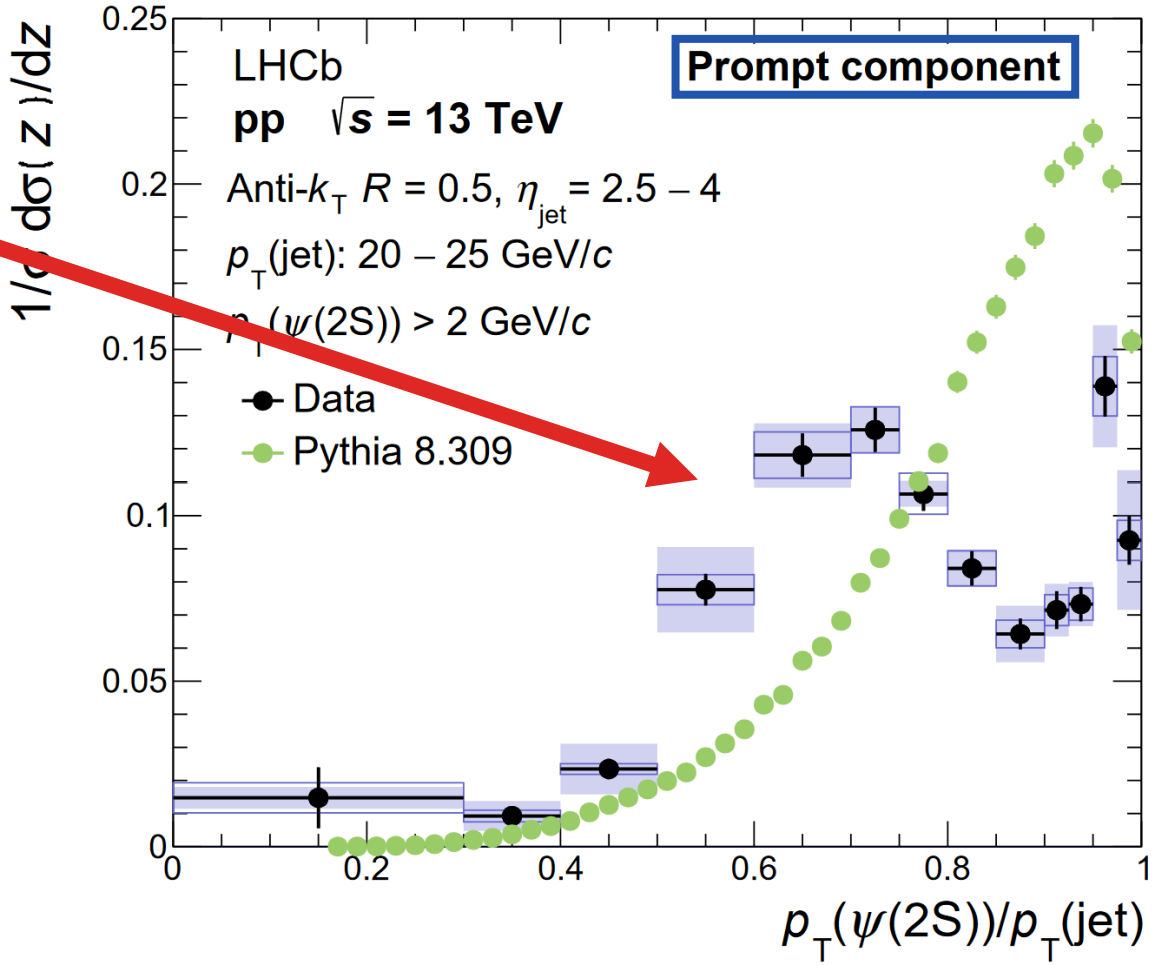

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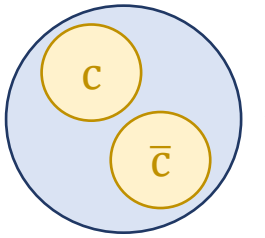
Heavy quarkonia in jets



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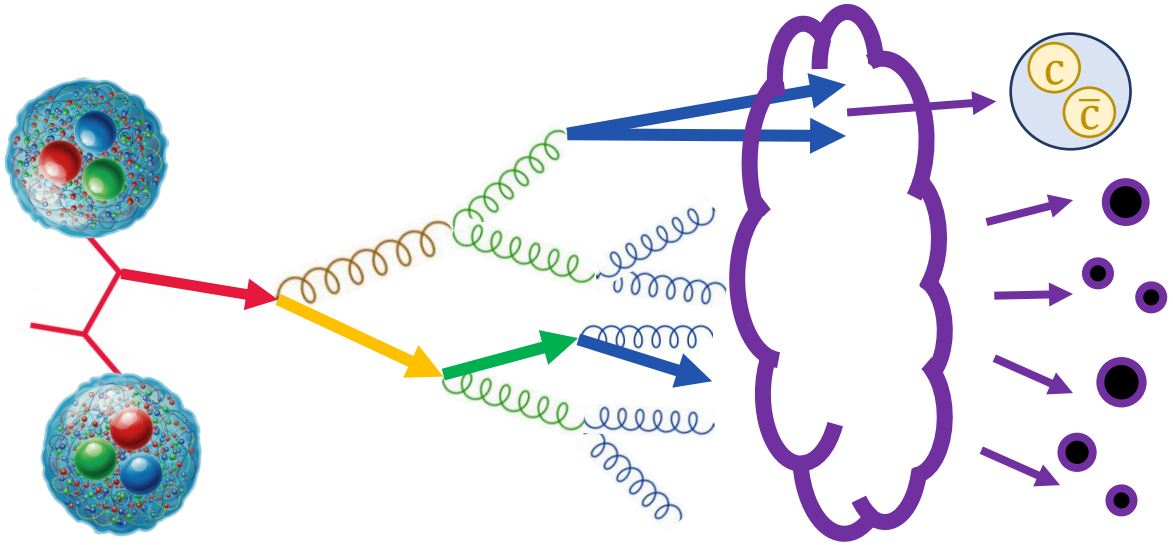

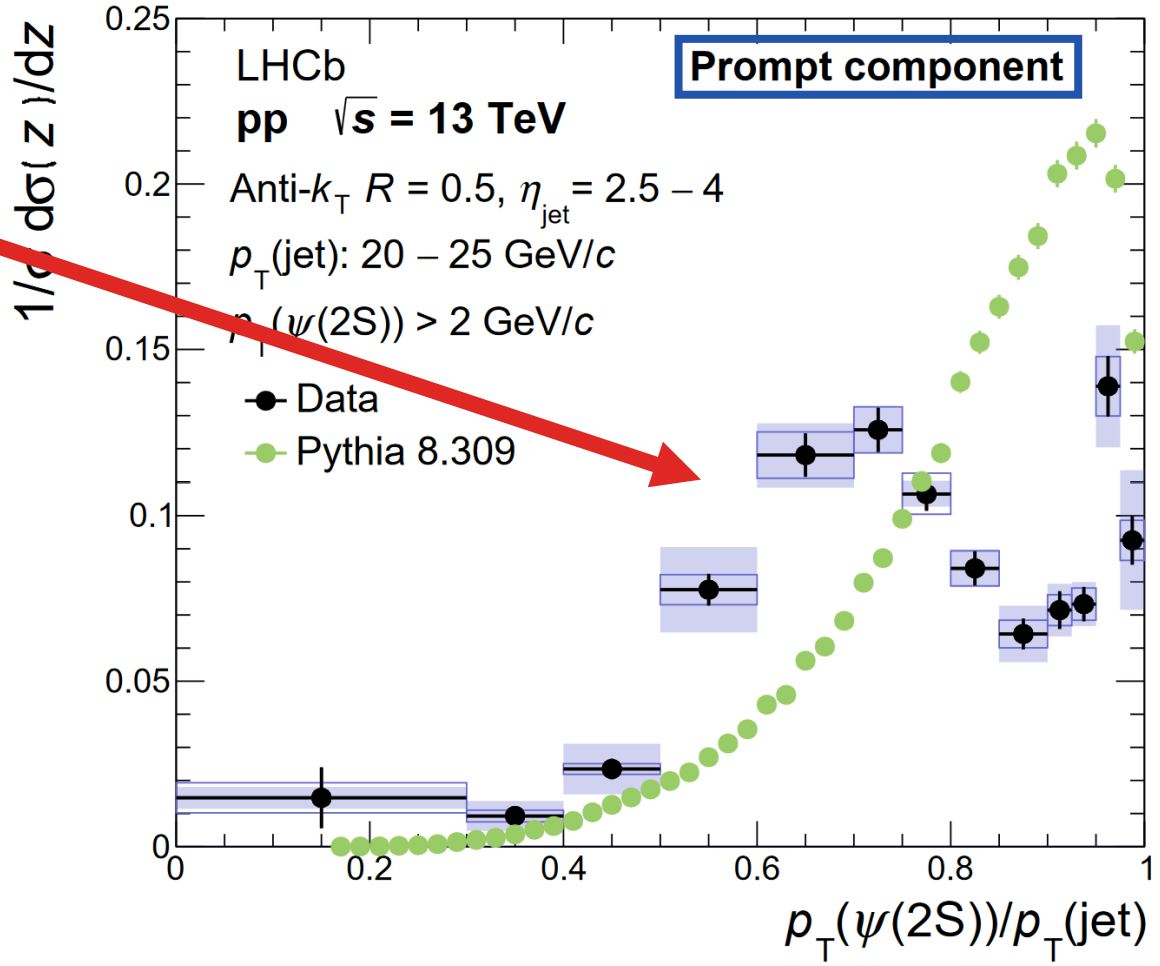

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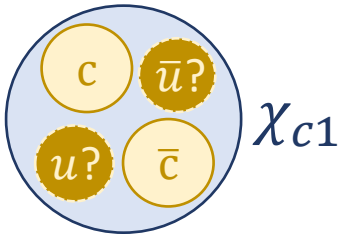
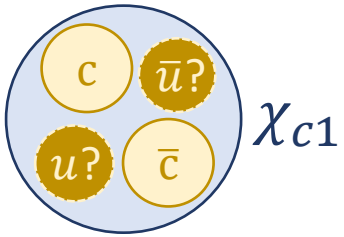
Higher mass states



χ_{c1}

- How is **tetraquark / $D\overline{D}^*$ molecule** candidate $\chi_{c1}(3872)$ produced?

Higher mass states



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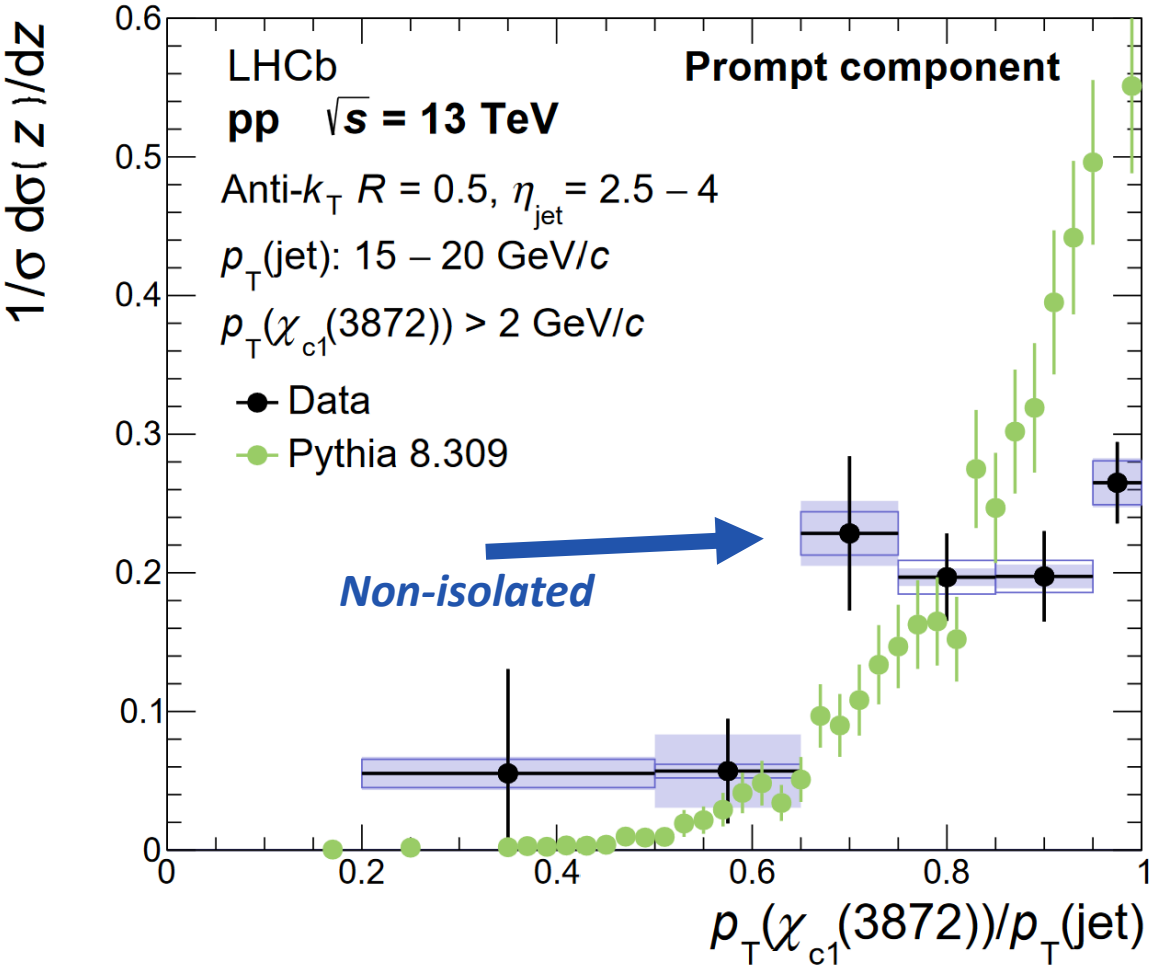

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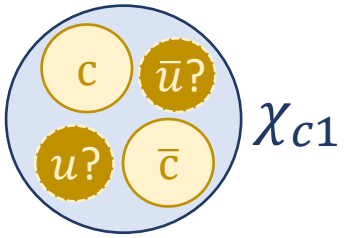

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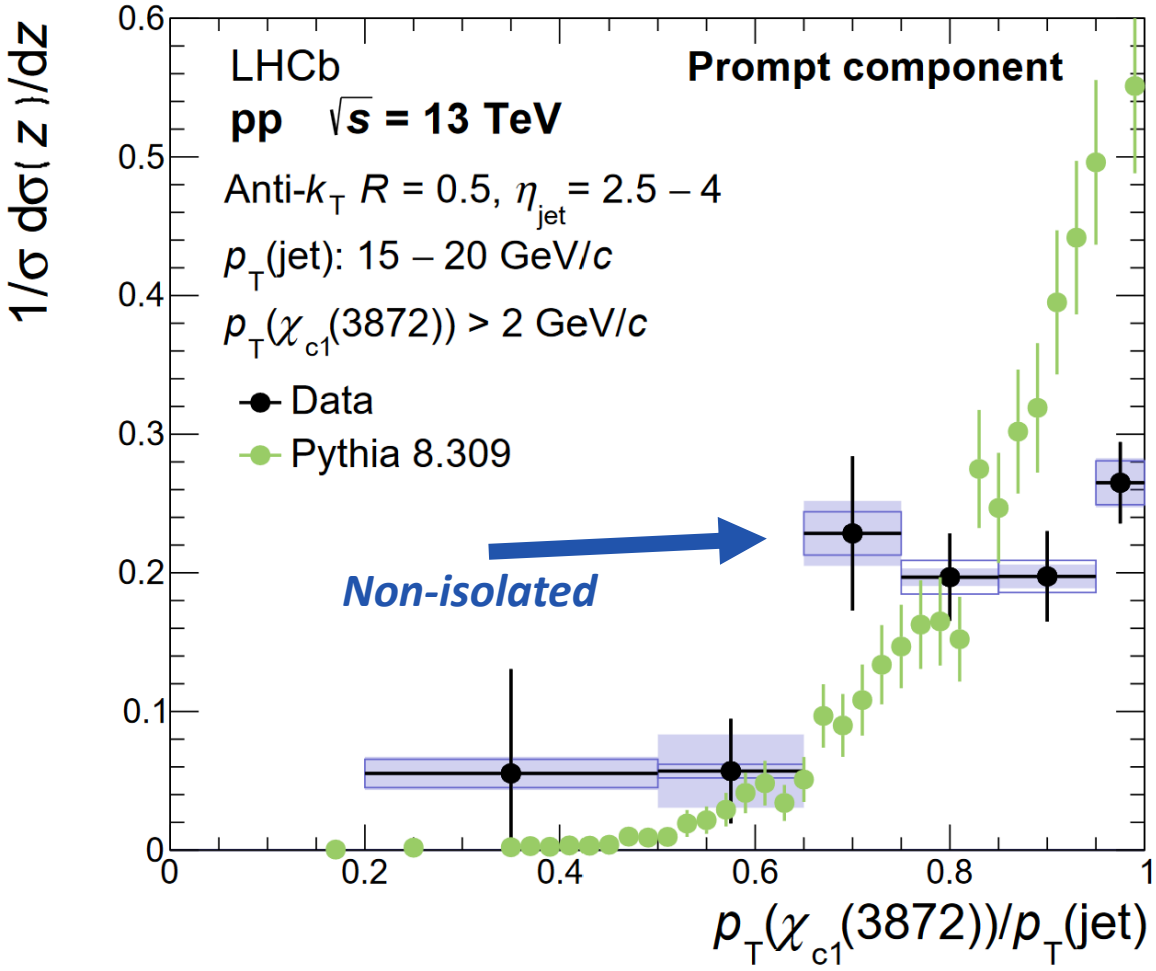

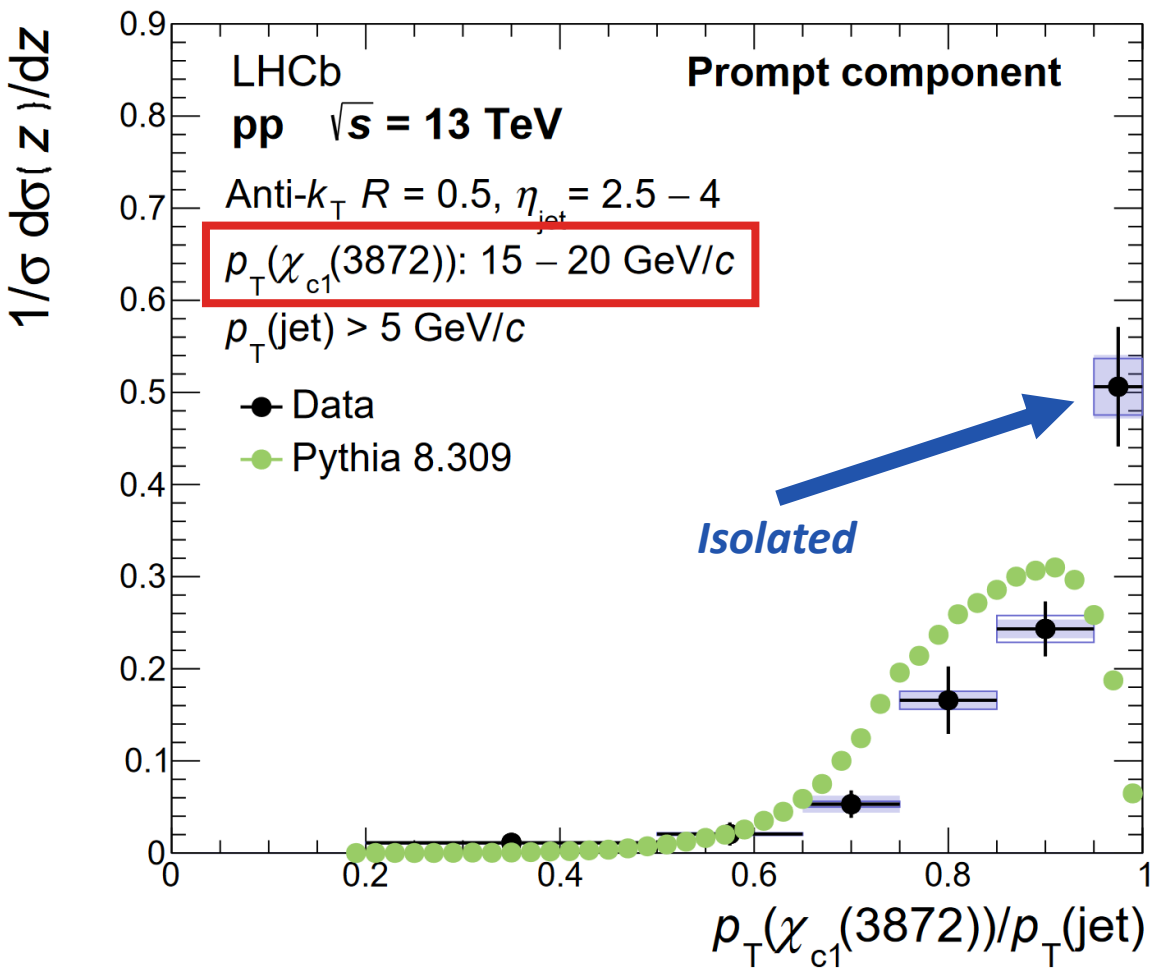

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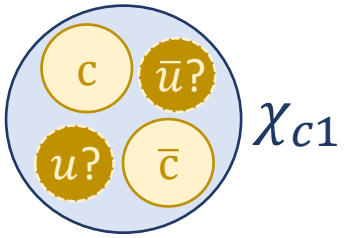

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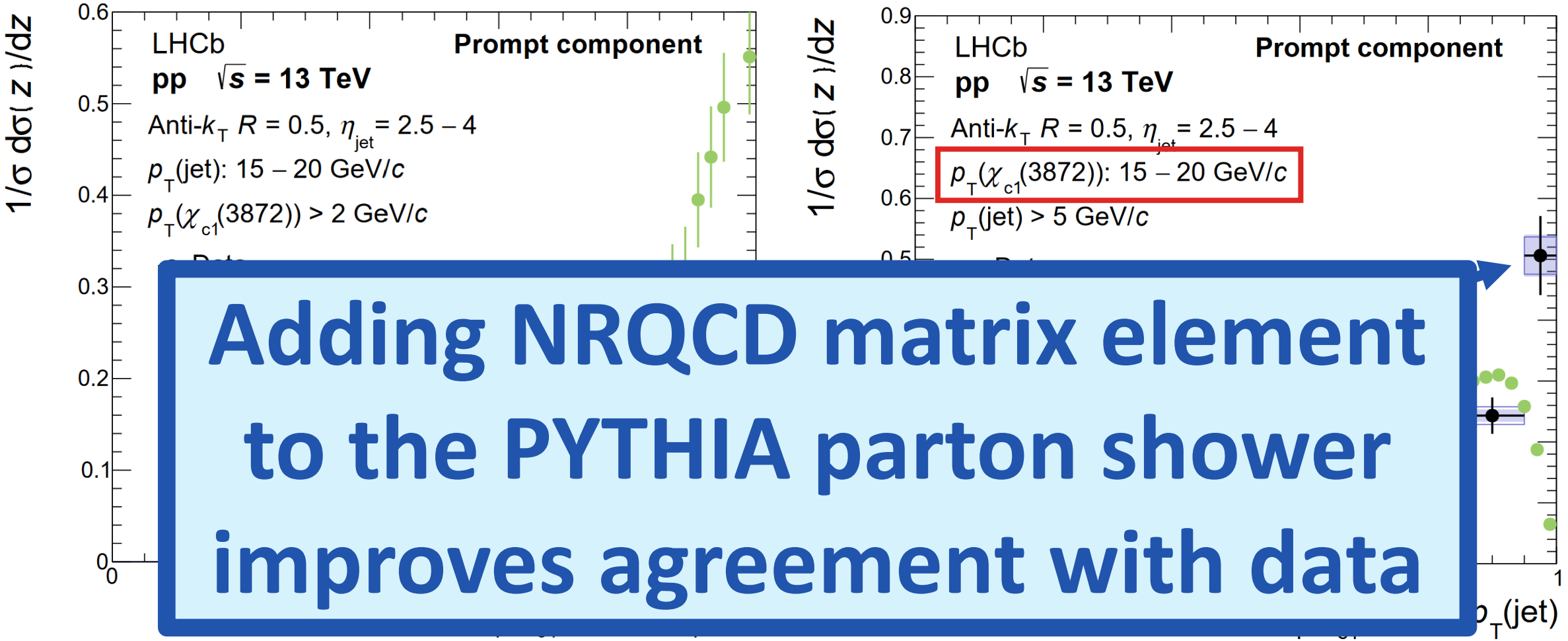
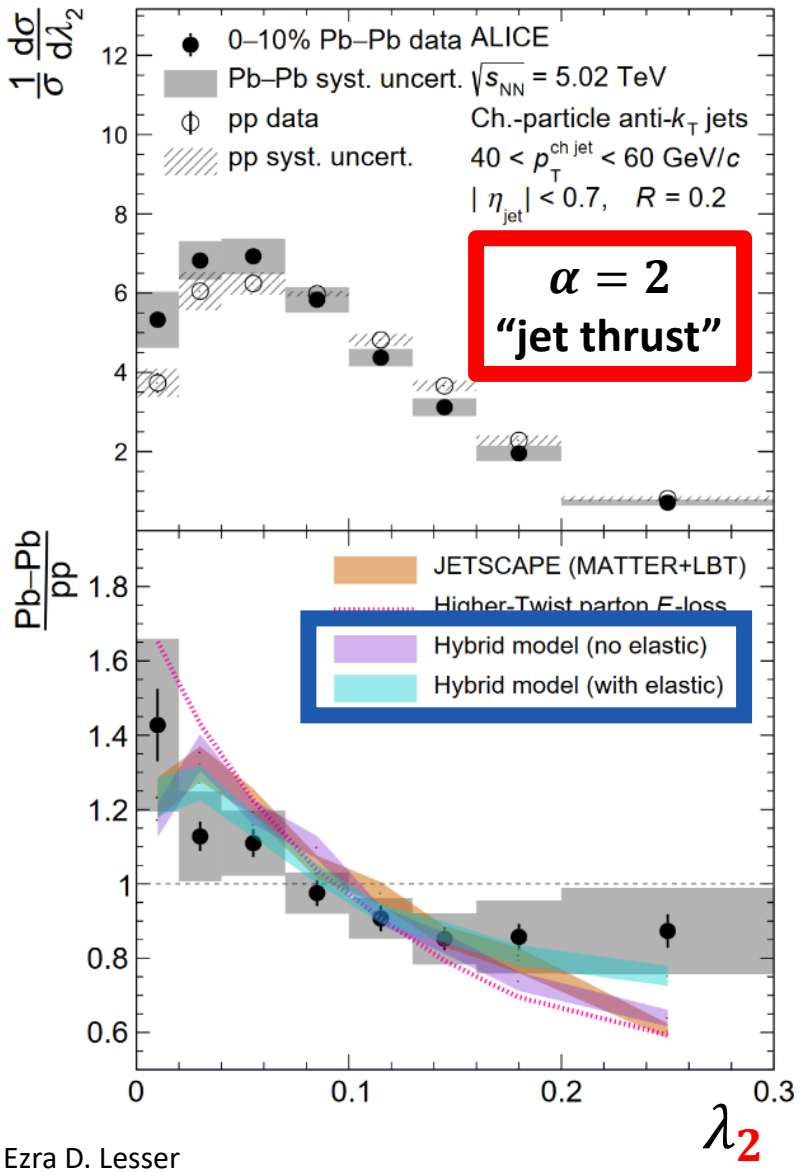


Adding NRQCD matrix element to the PYTHIA parton shower improves agreement with data

Eur. Phys. J. C **85** (2025) 562

Eur. Phys. J. C **84** (2024) 432

Jet quenching in angularities



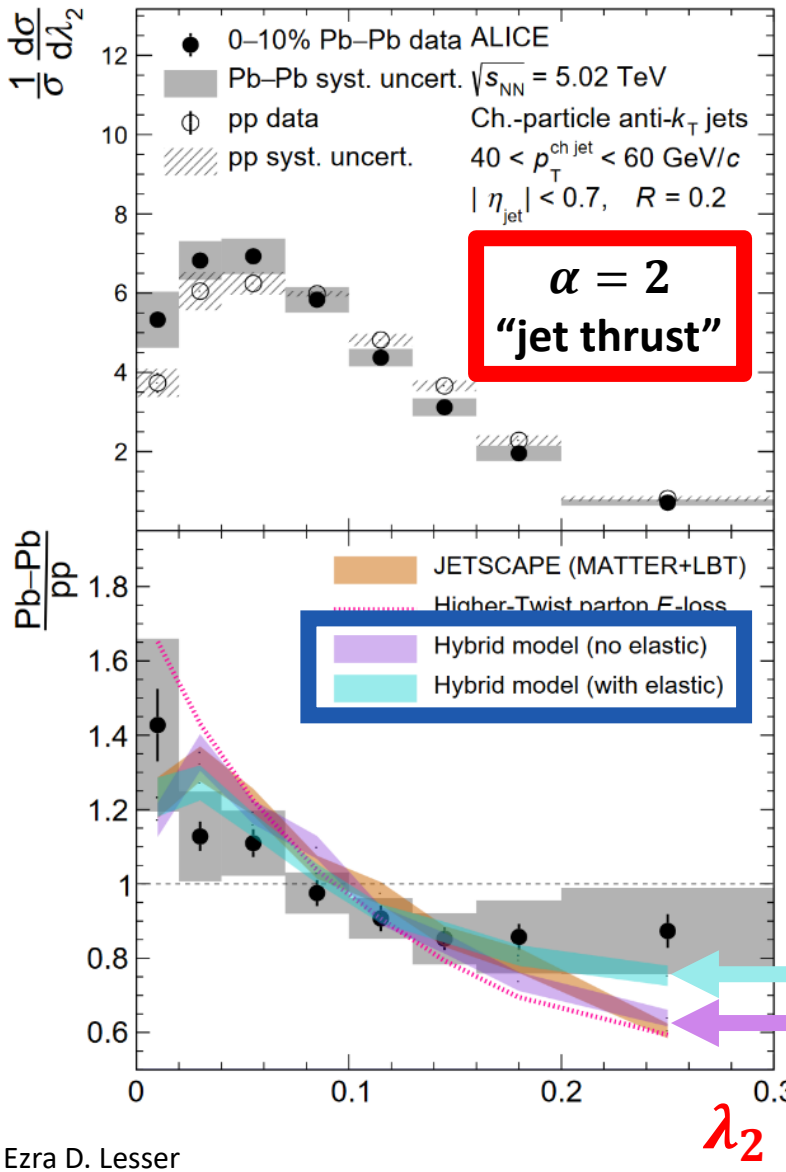
Hybrid model: vacuum predictions + strong QGP modifications based on **AdS/CFT correspondence**

D. Pablos, et al., JHEP **10** (2014) 019

- with / without elastic **Molière scattering**

F. D'Eramo, K. Rajagopal, Y. Yin JHEP **01** (2019) 172

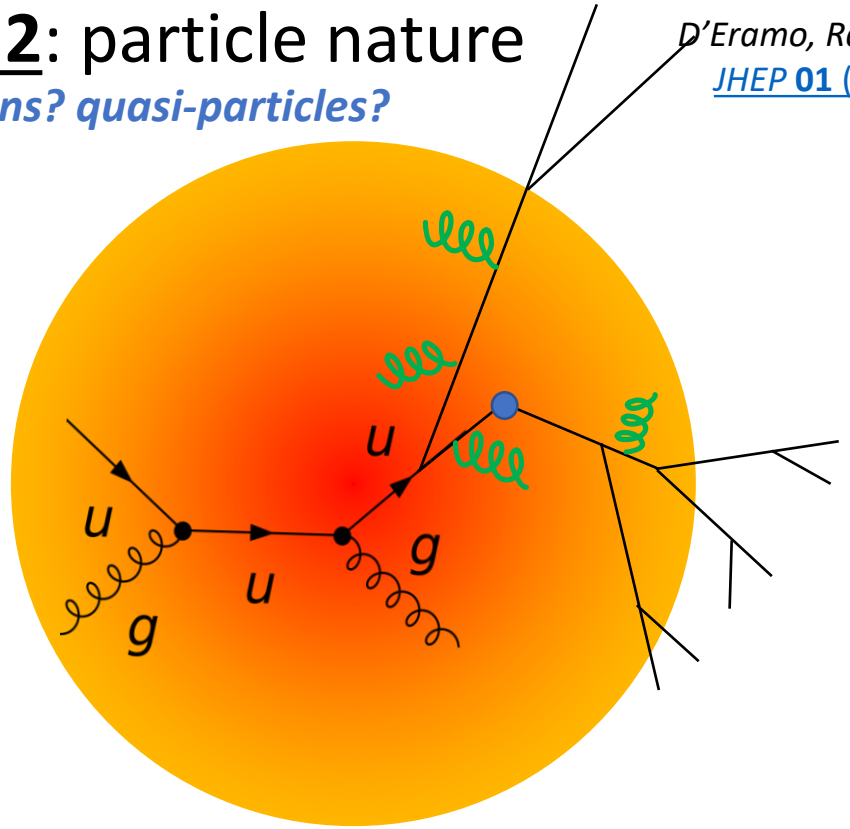
Multiple hard interactions in QGP?



Picture 2: particle nature

partons? quasi-particles?

D'Eramo, Rajagopal, Yin
JHEP **01** (2019) 172

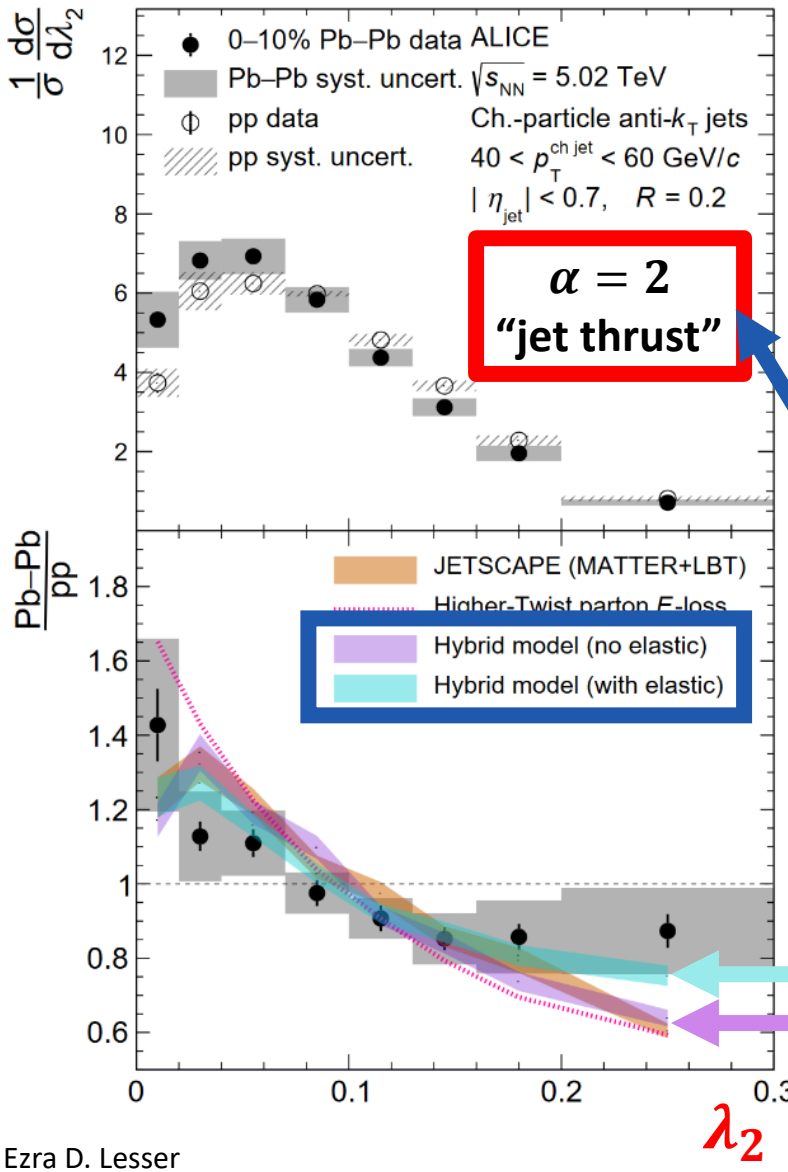


Jet fragmentation

+ medium-induced emissions

+ elastic Molière scattering?

Multiple hard interactions in QGP?

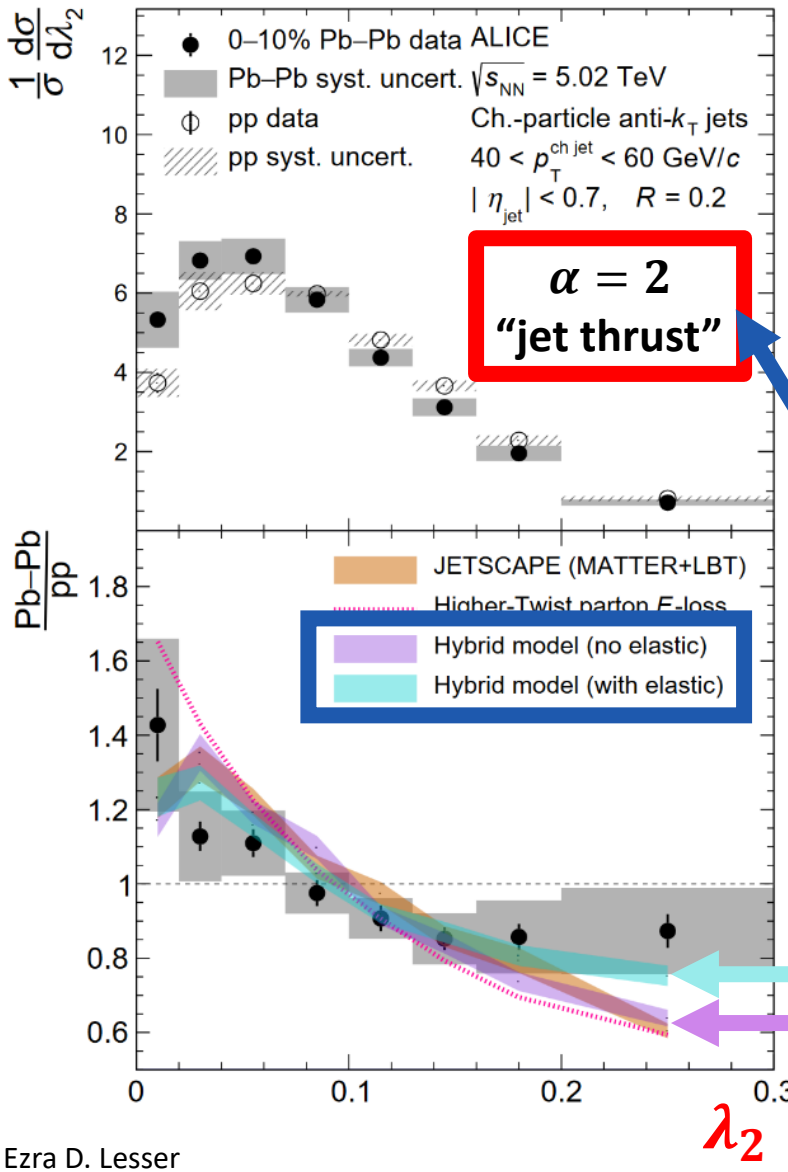


Theoretical correspondence between **jet angularities** and **jet mass:**

$$\lambda_2 = \left(\frac{m}{Rp_T}\right)^2 + O[(\lambda_2)^2]$$

JHEP 1804 (2018) 110

Multiple hard interactions in QGP?



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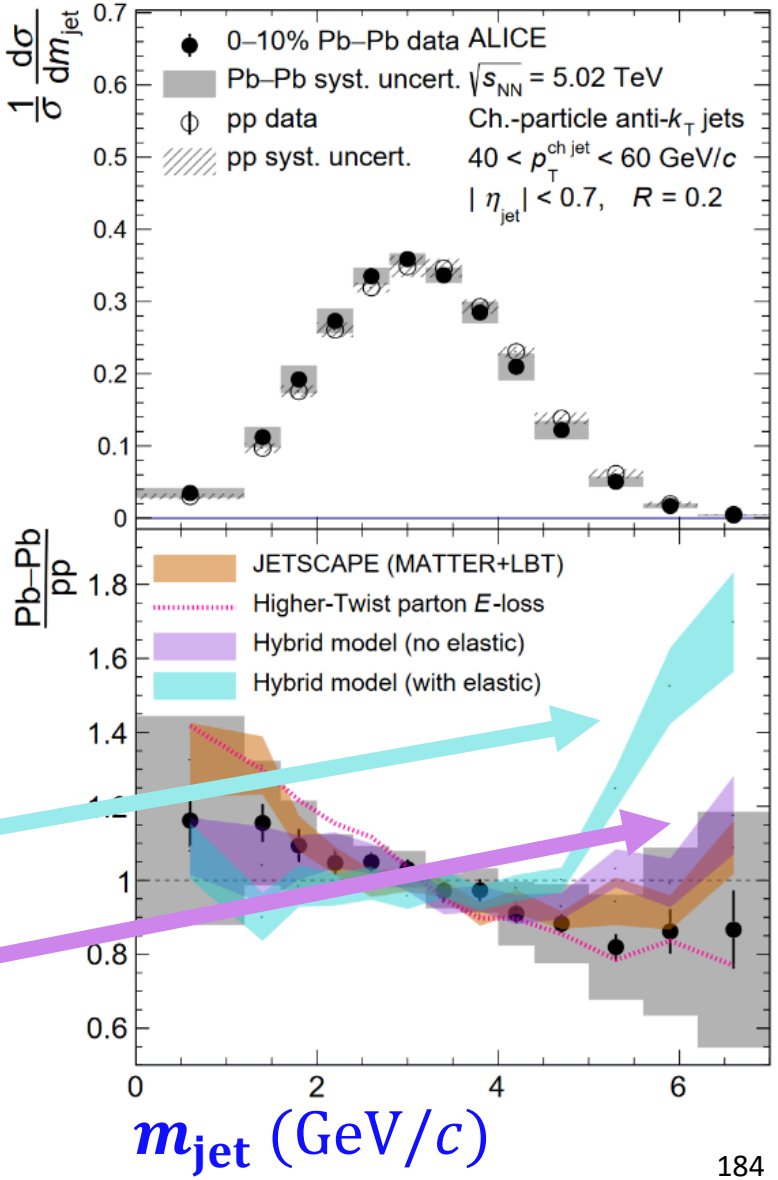
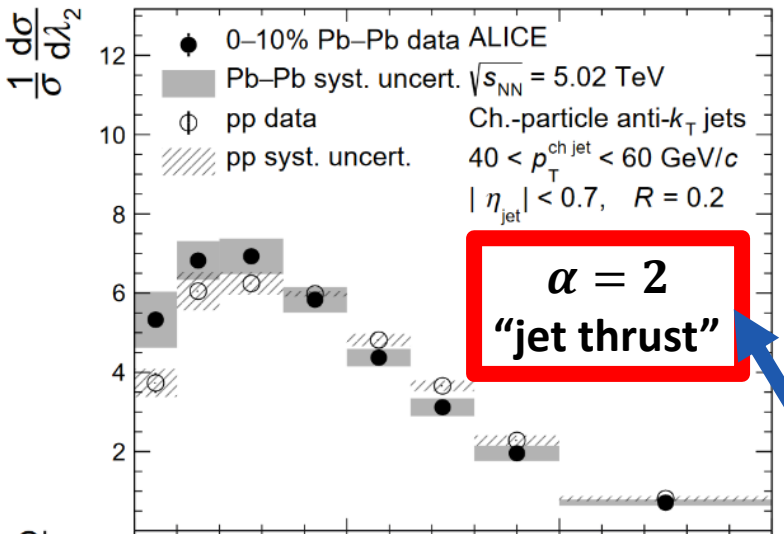
JHEP 1804 (2018) 110



With Molière

No Molière

Multiple hard interactions in QGP?



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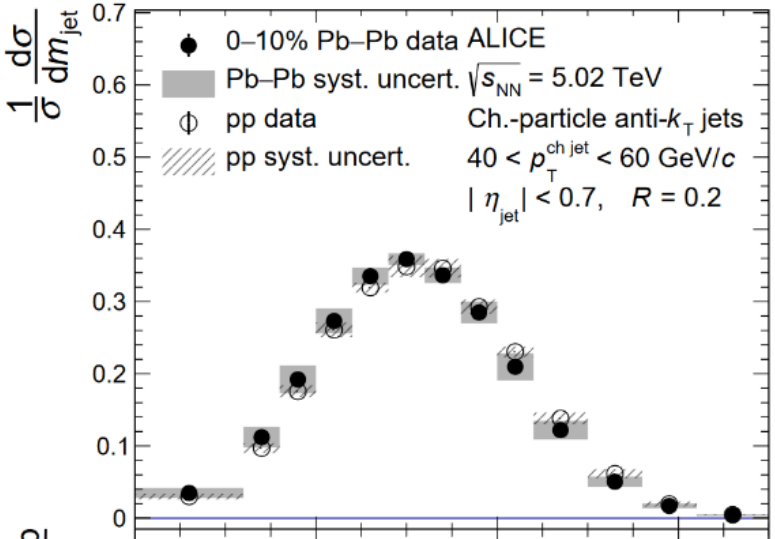
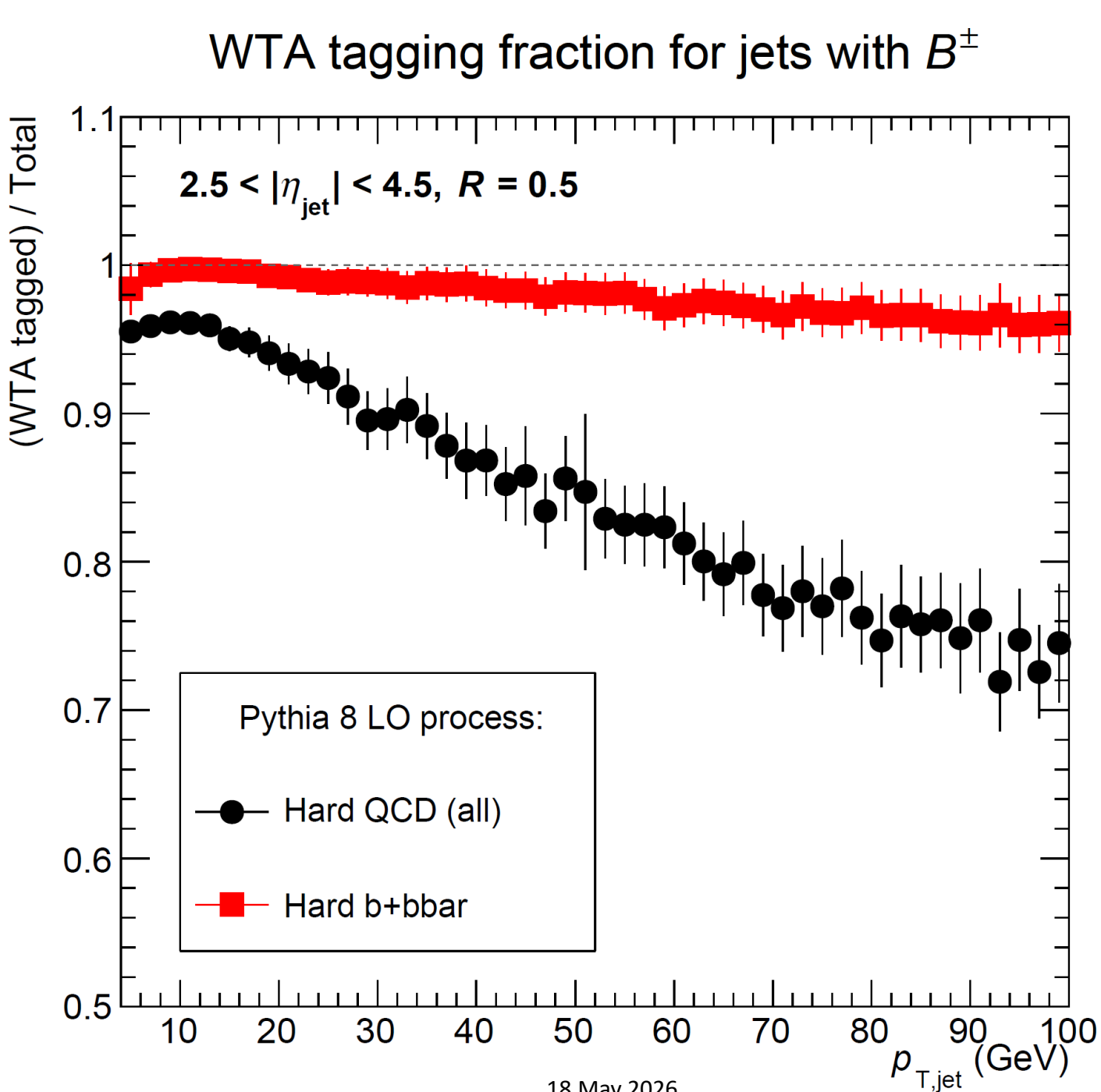
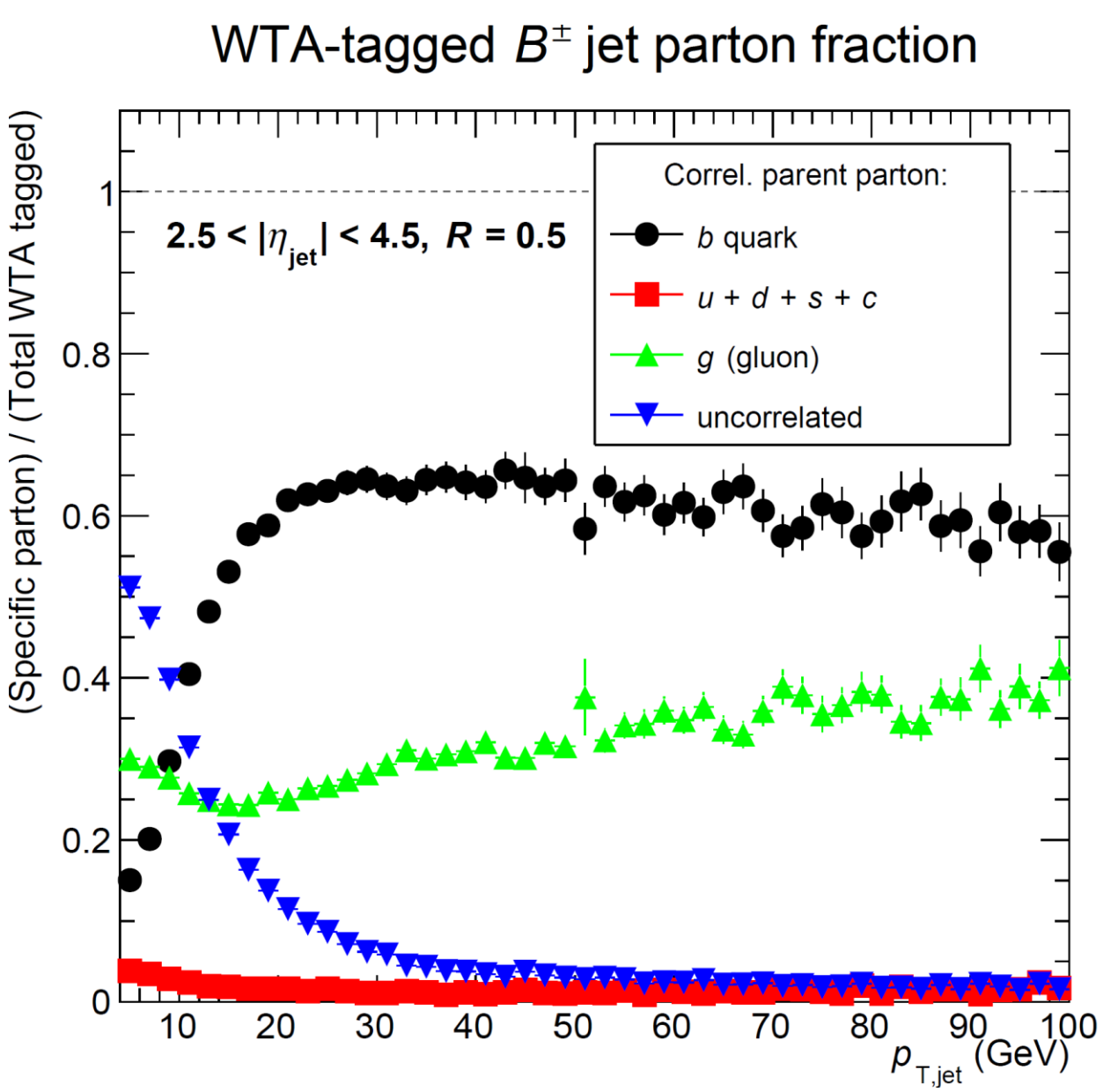
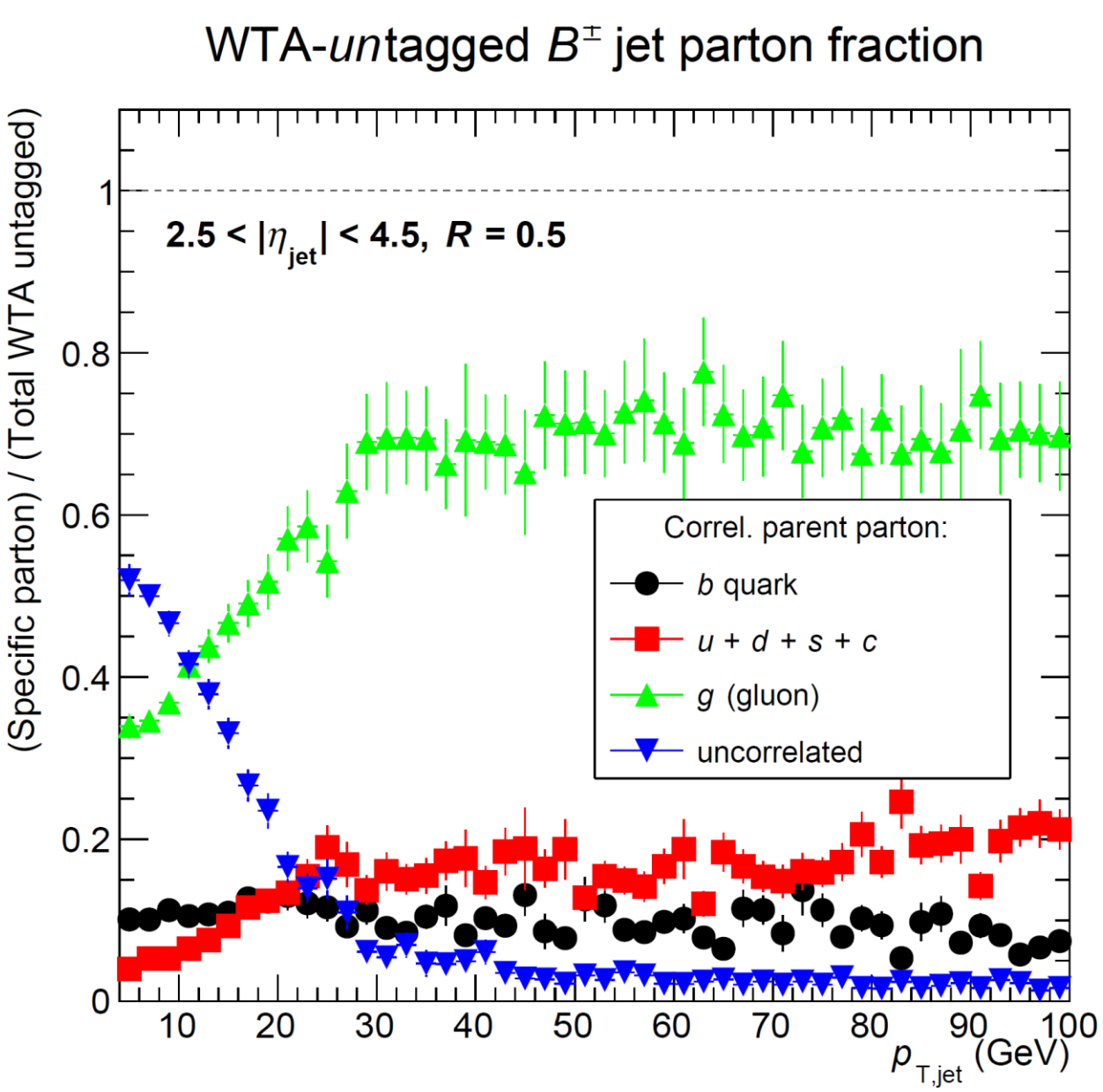
JHEP 1804 (2018) 110

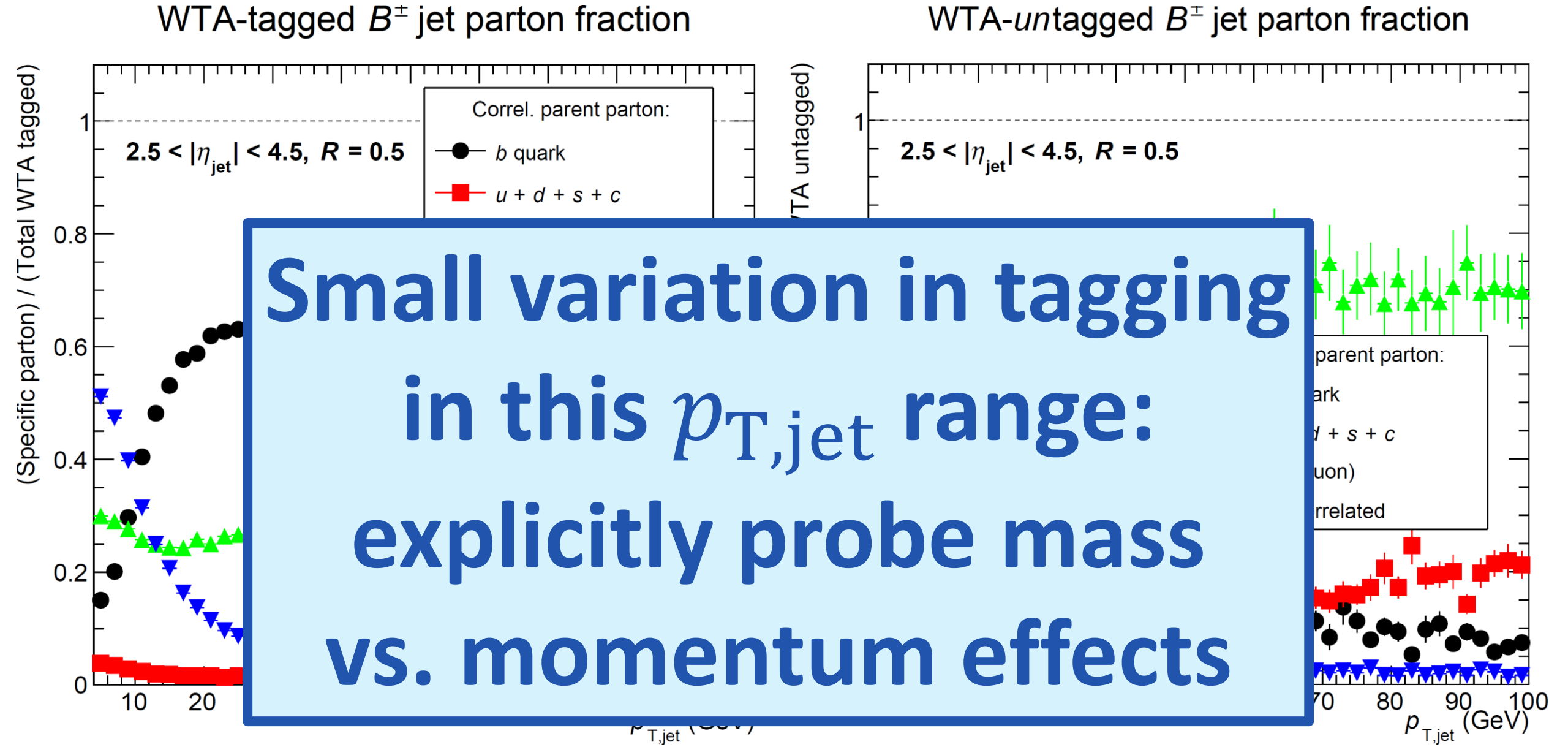


Inconsistency: this correspondence is not useful at low p_T


WTA tagging fraction for jets with $B^{\pm}$
$2.5 < |\eta_{jet}| < 4.5,\ R = 0.5$
(WTA tagged) / Total
1.1
1
0.9
0.8
0.7
0.6
0.5
10
20
30
40
50
60
70
80
90
100
$p_{T,jet}$ (GeV)
Pythia 8 LO process:
Hard QCD (all)
Hard b+bbar


WTA-tagged $B^{\pm}$ jet parton fraction
(Specific parton) / (Total WTA tagged)
$2.5 < |\eta_{jet}| < 4.5,\ R = 0.5$
Correl. parent parton:
b quark
$u + d + s + c$
g (gluon)
uncorrelated
0
0.2
0.4
0.6
0.8
1
10
20
30
40
50
60
70
80
90
100
$p_{T,jet}$ (GeV)


WTA-*un*tagged $B^{\pm}$ jet parton fraction
(Specific parton) / (Total WTA untagged)
$2.5 < |\eta_{jet}| < 4.5,\ R = 0.5$
Correl. parent parton:
b quark
$u + d + s + c$
g (gluon)
uncorrelated
0
0.2
0.4
0.6
0.8
1
10
20
30
40
50
60
70
80
90
100
$p_{T,jet}$ (GeV)



Small variation in tagging in this $p_{\mathrm{T,jet}}$ range: explicitly probe mass vs. momentum effects