Fragmentation of J/ψ in jets in pp and PbPb collisions with CMS

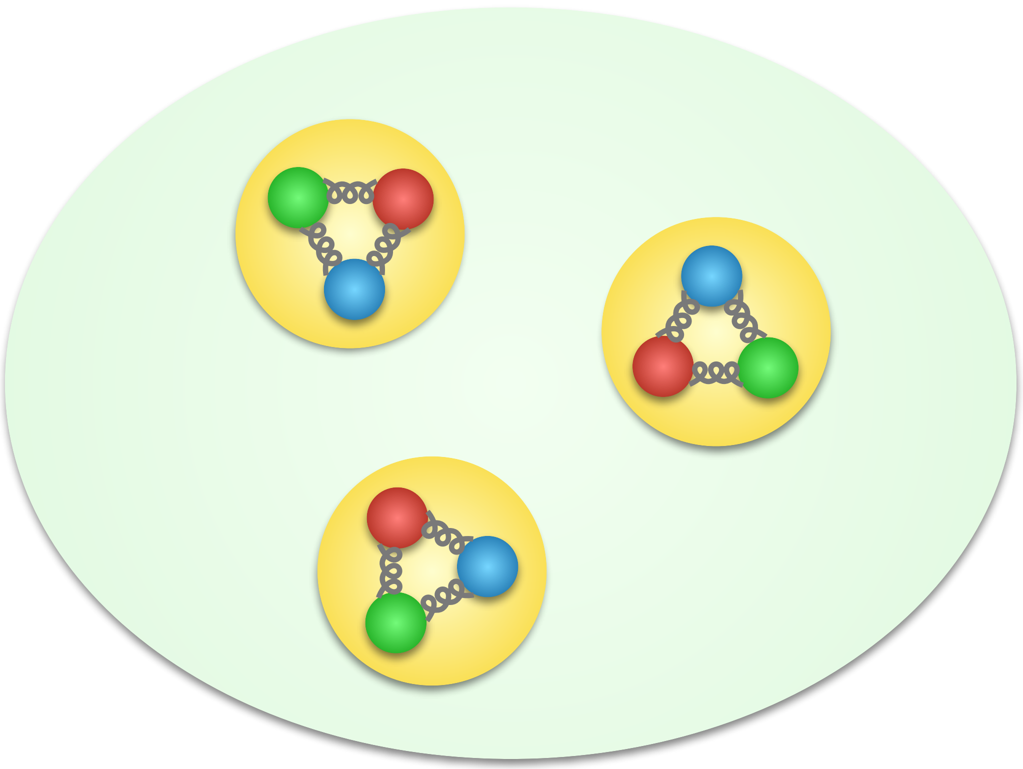
GDR-InF Annual Workshop 2022

Batoul Diab

02/11/2022

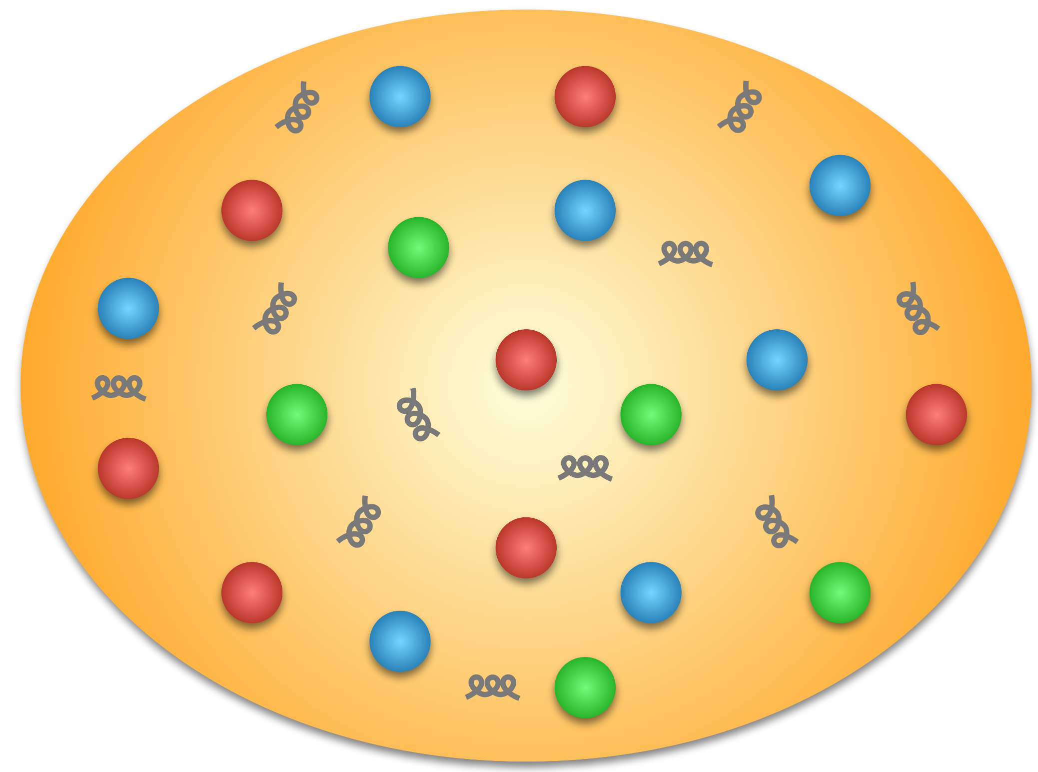
Different states of matter

Normal matter



Quarks and gluons are confined in hadrons

High density/temperature systems



Deconfined state of matter: The Quark Gluon Plasma

Different states of matter

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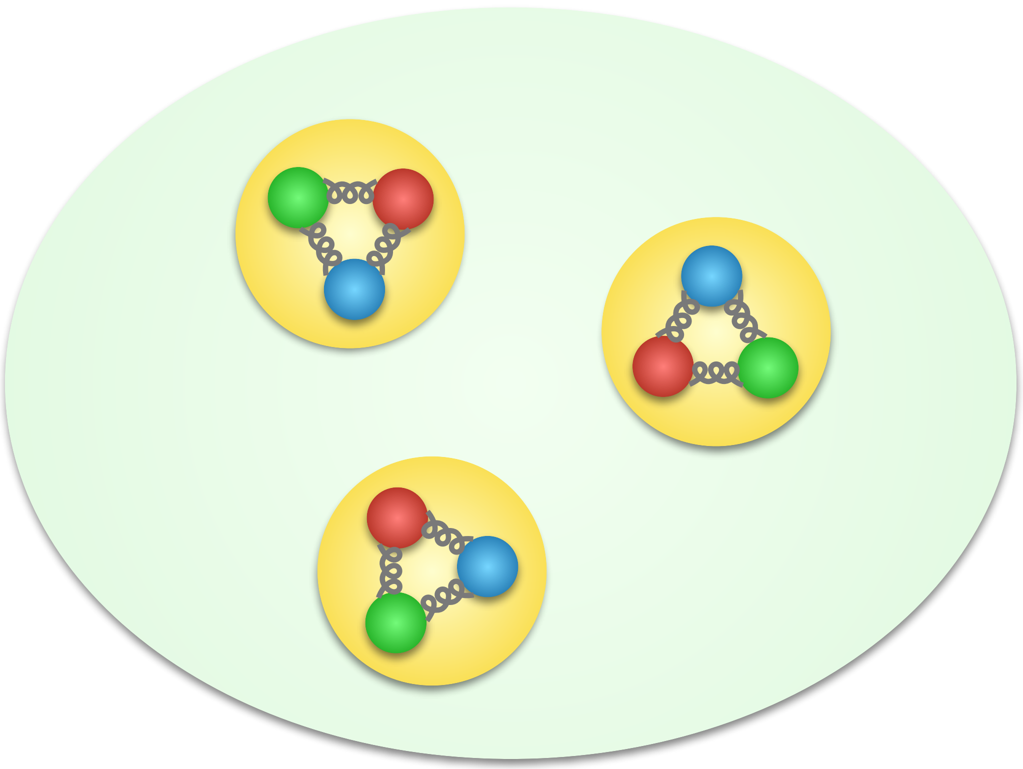

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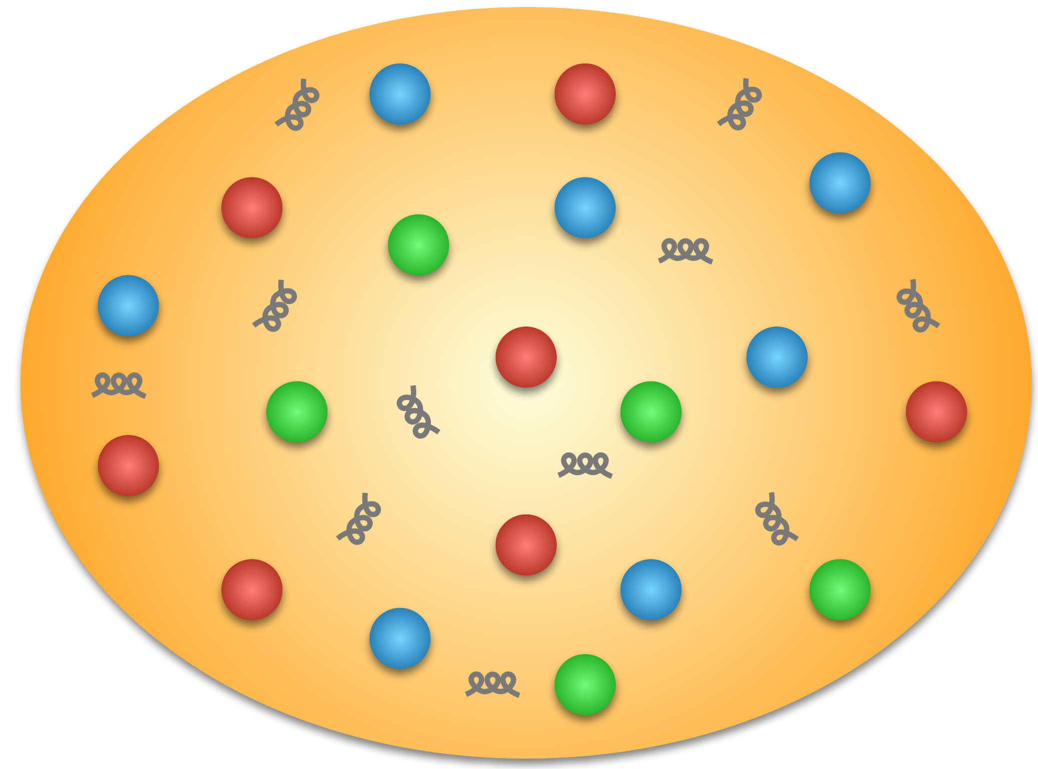
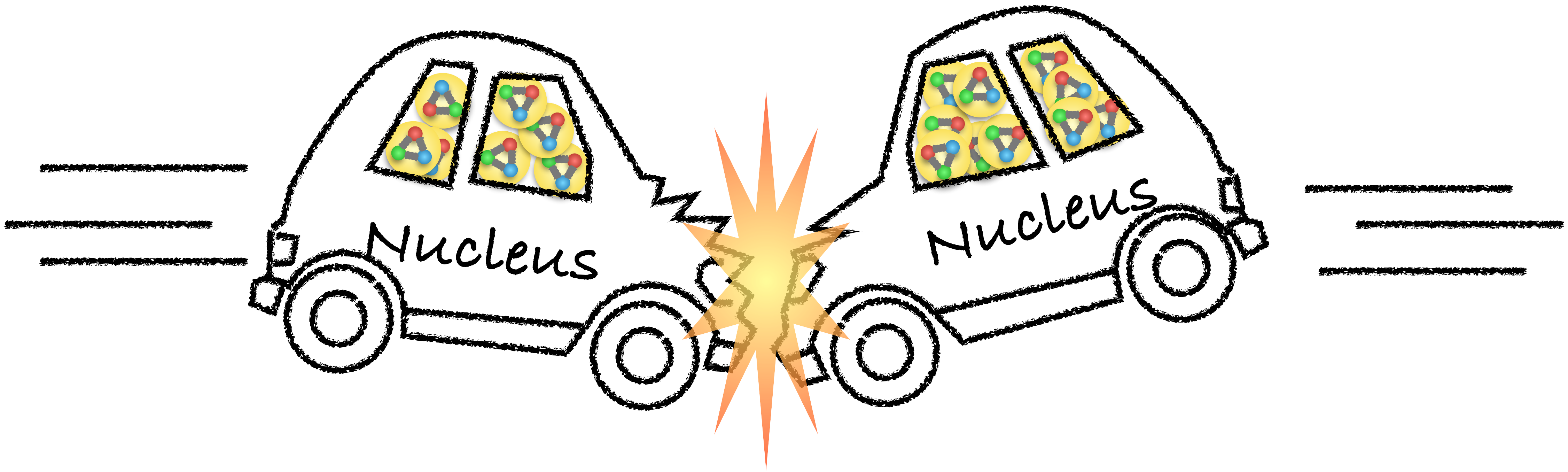
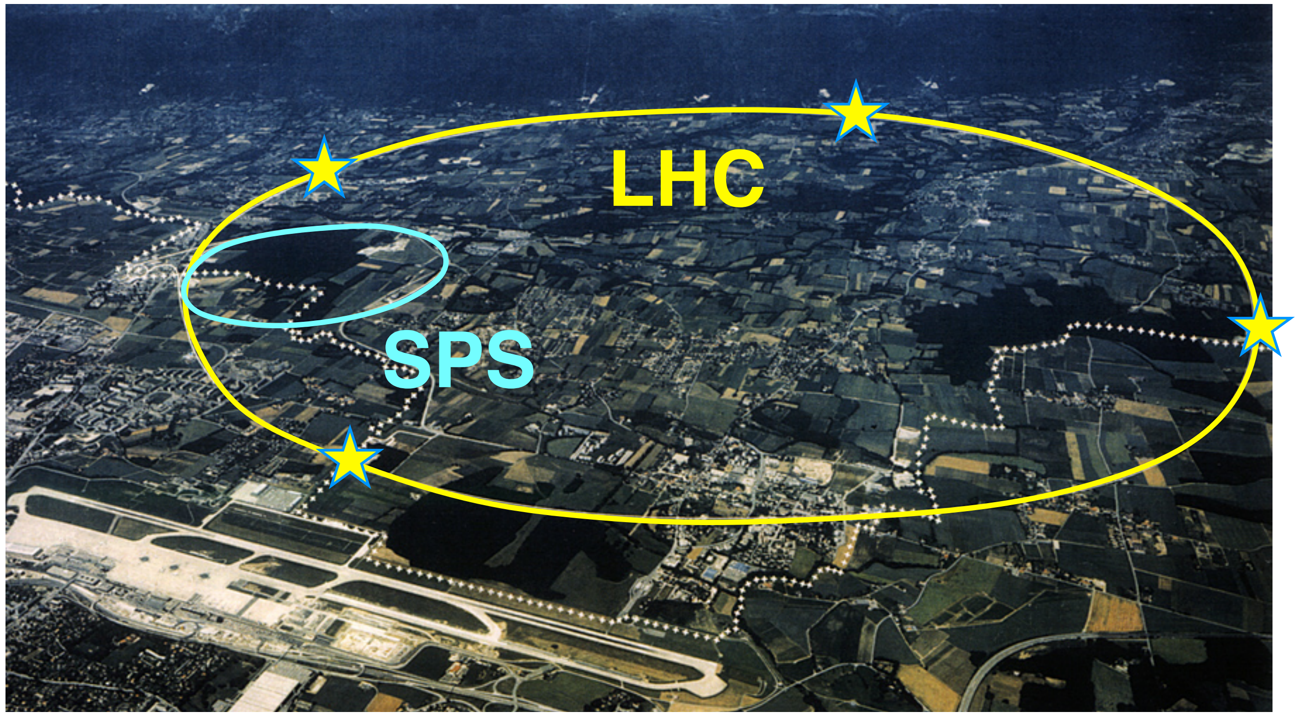
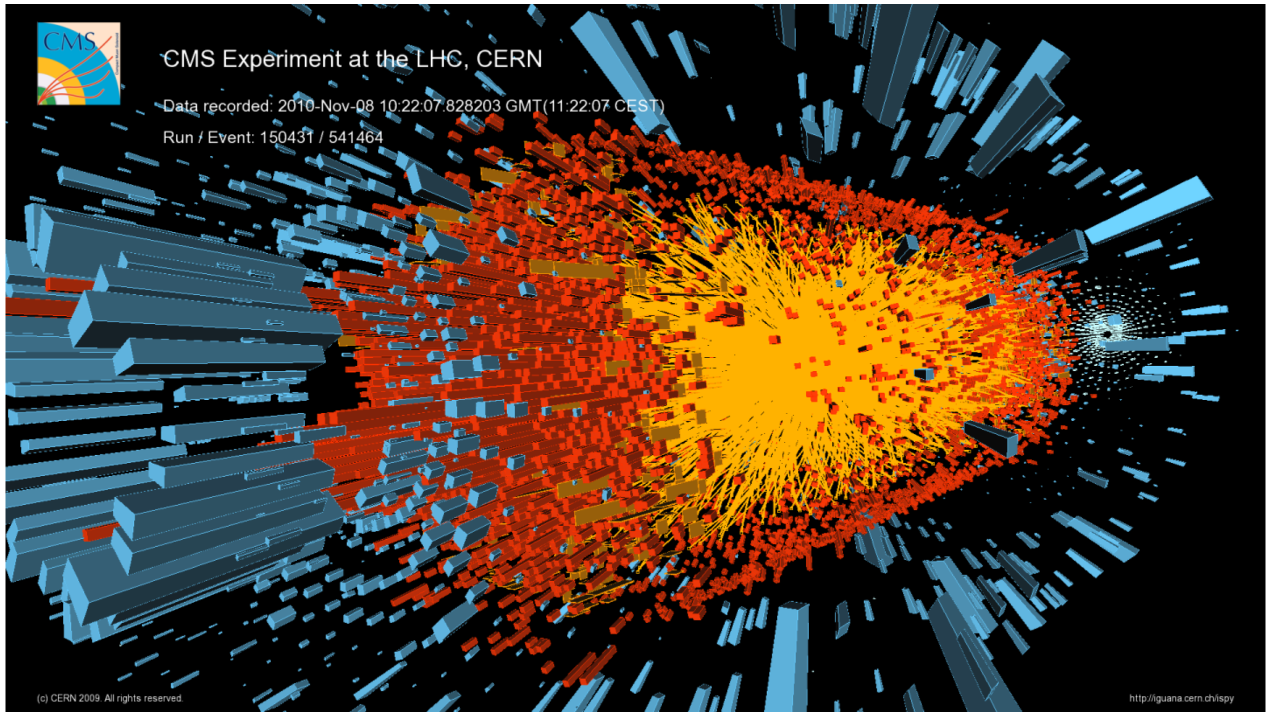


Deconfined state of matter: The Quark Gluon Plasma

Heavy ion collisions



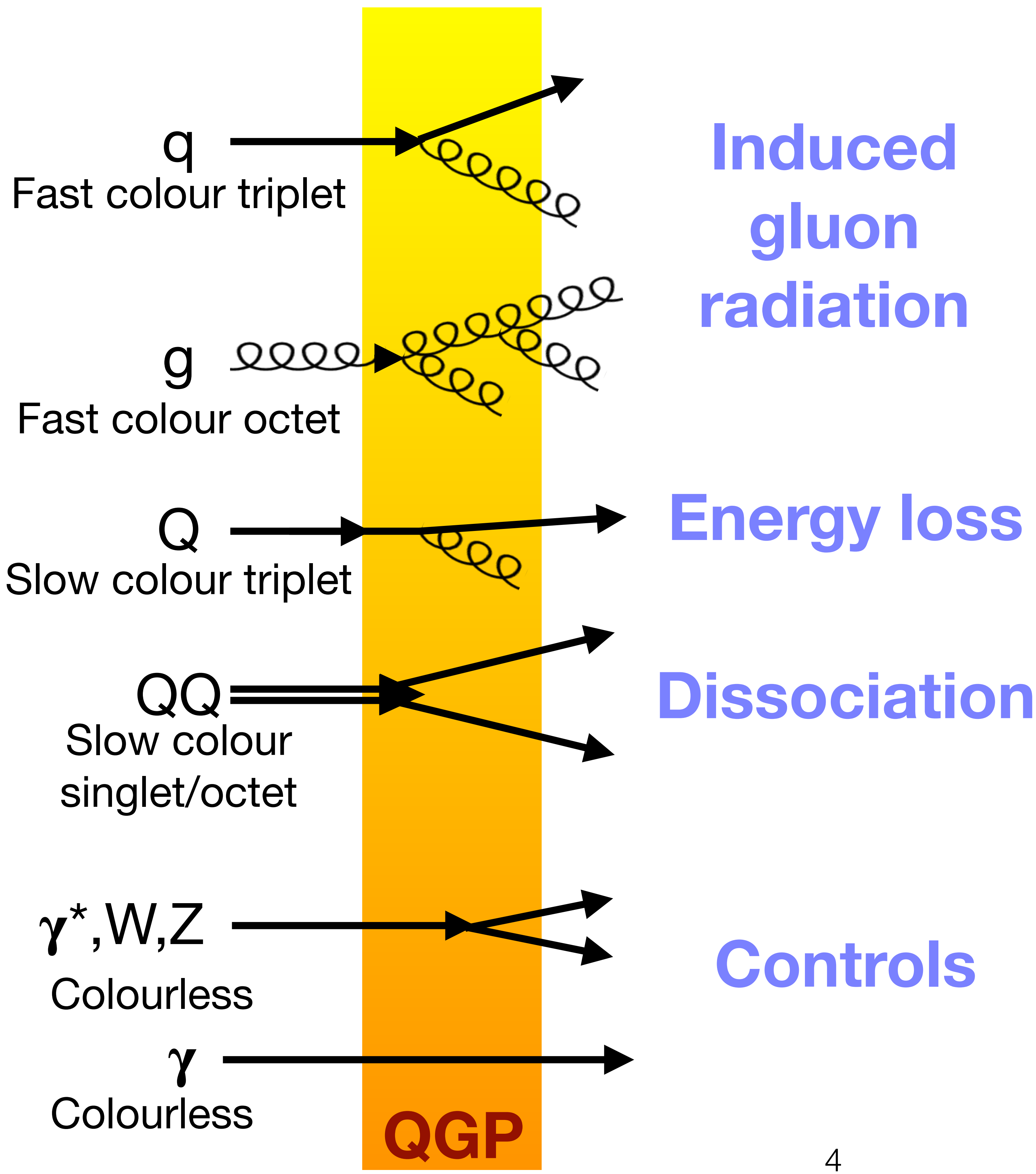




Smash particles at high energies

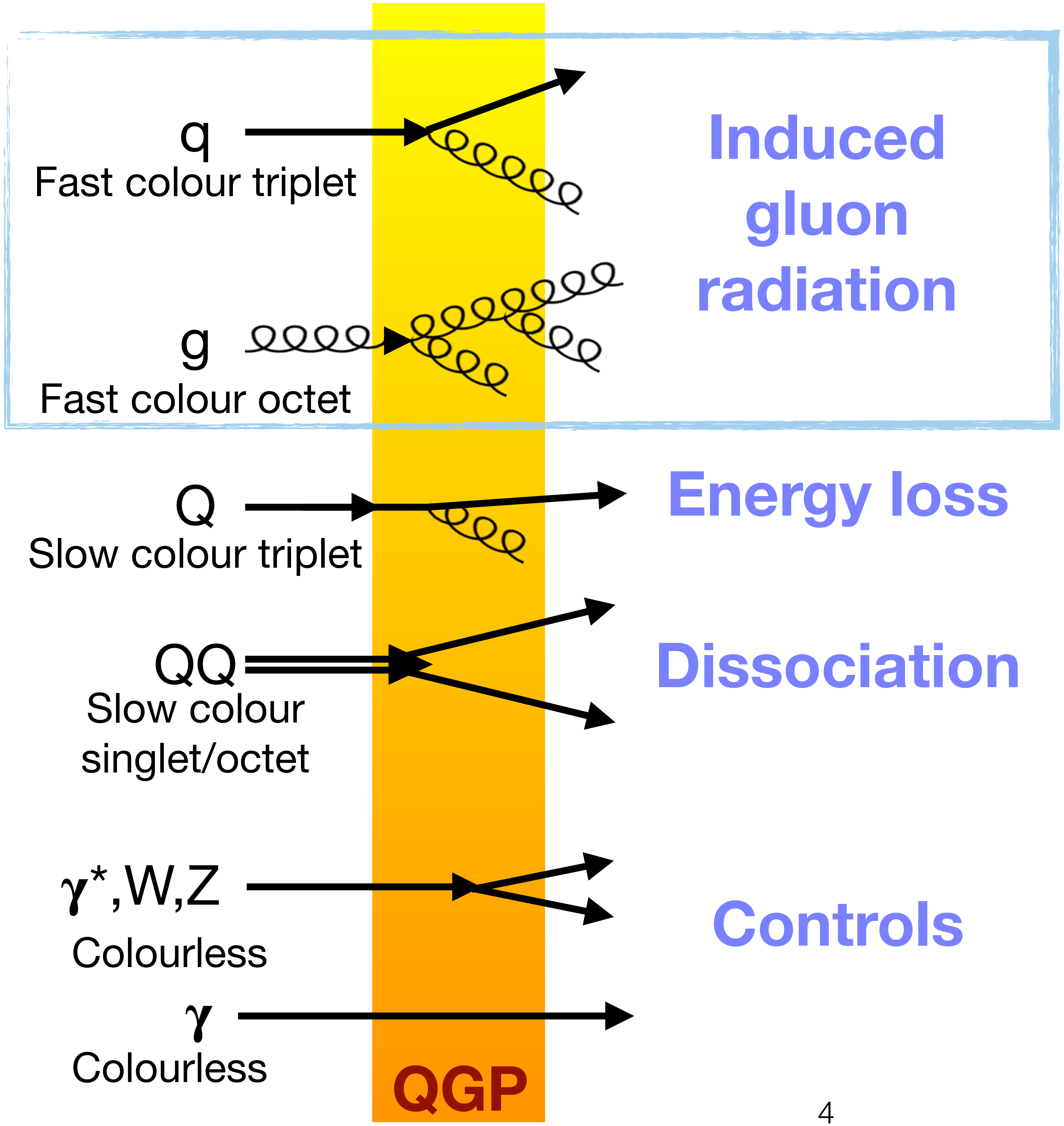
Detect and study the outcome

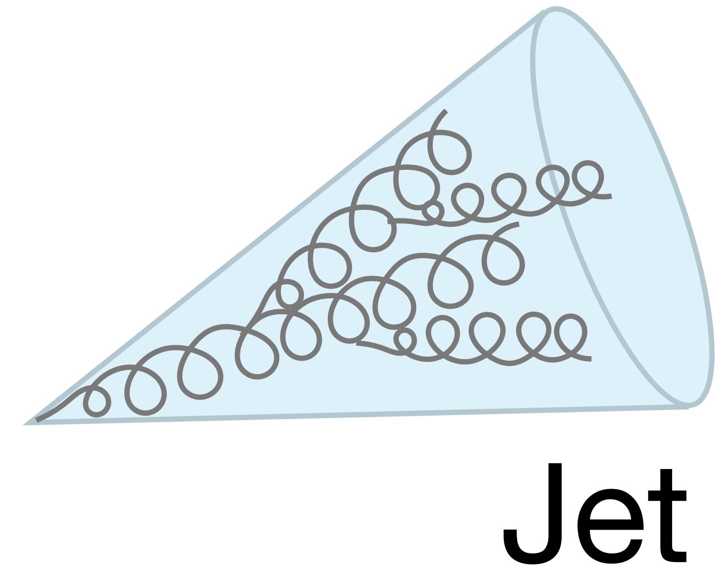
Probes of the Quark Gluon Plasma



Adapted from D. d'Enterria, Landolt-Bornstein 23 (2010) 471

Probes of the Quark Gluon Plasma





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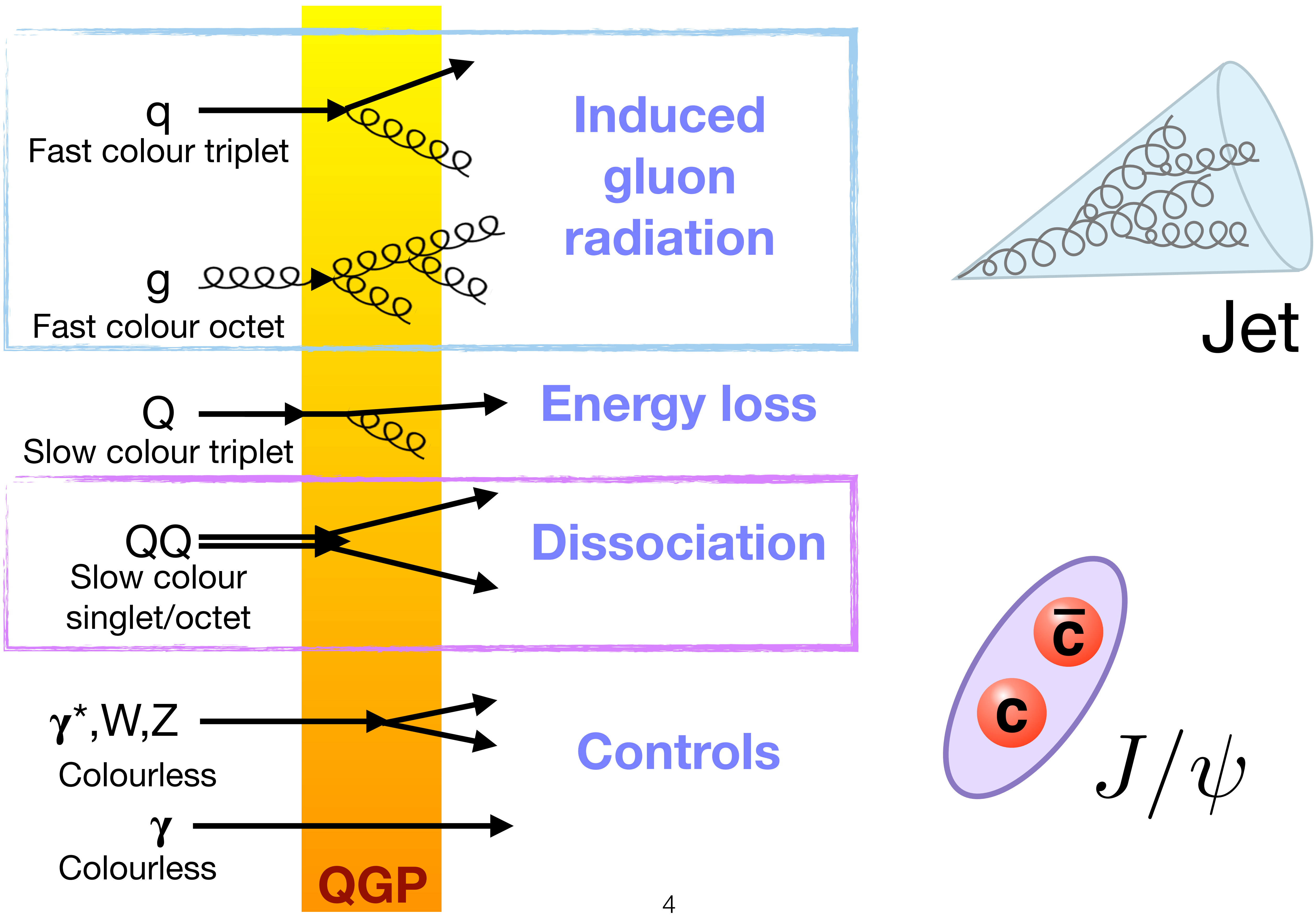

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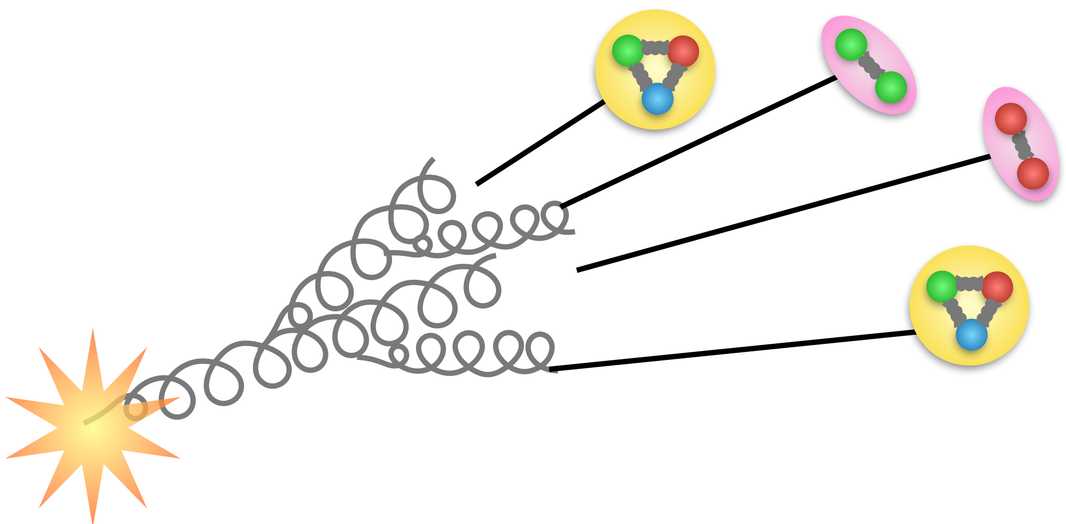
Jets in hadronic collisions



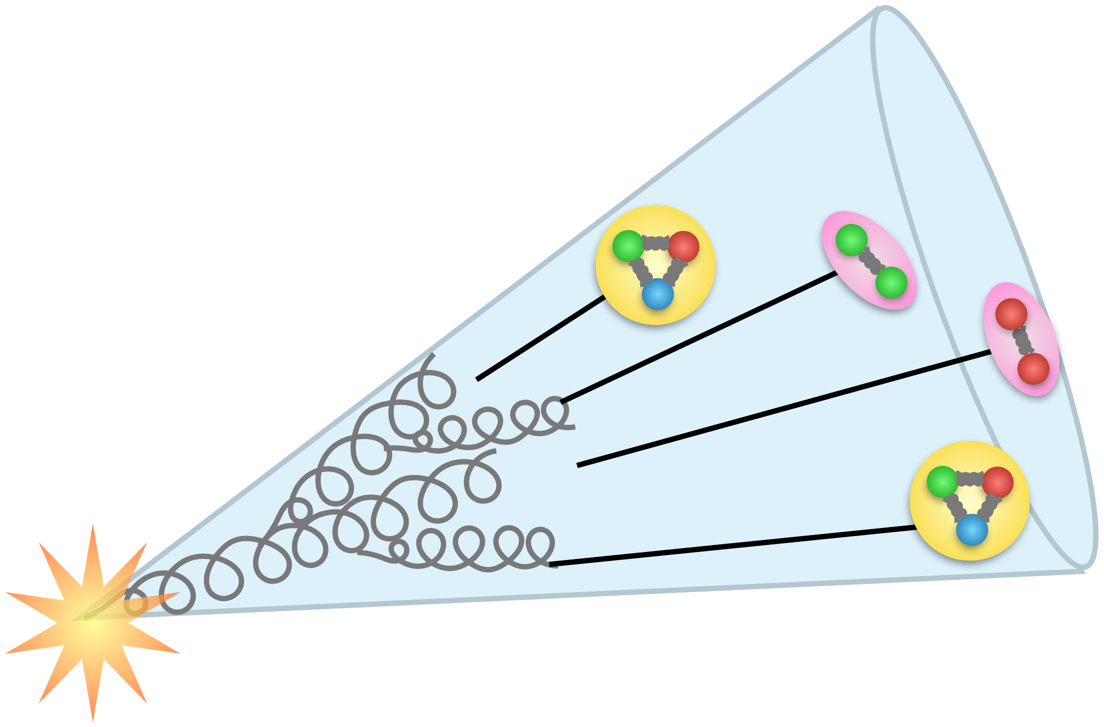
Collision

Partons with large momentum

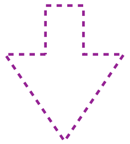
Gluon radiation

Hadrons

Jets in hadronic collisions

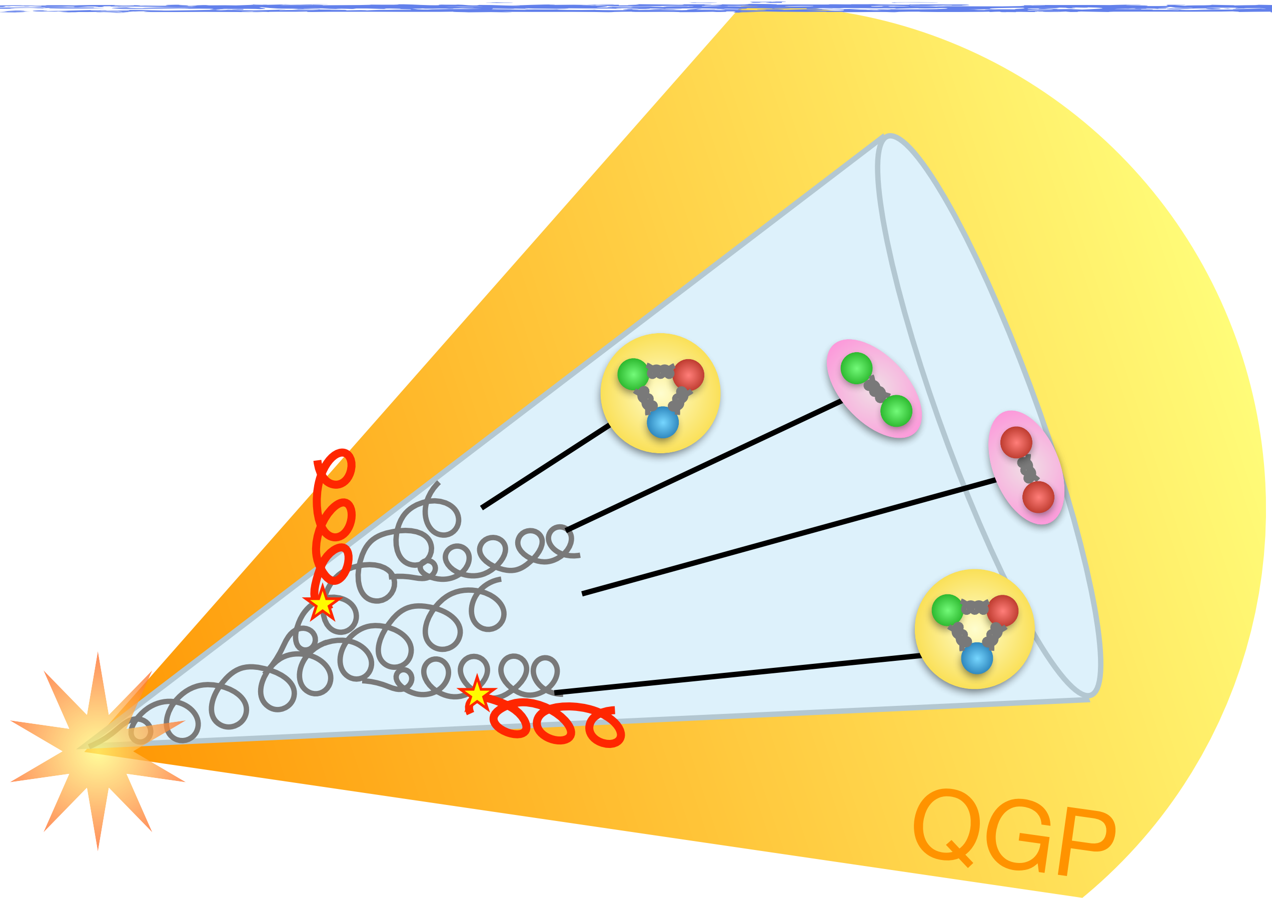


The hadrons move along the same direction



Jets

Jets in heavy ion collisions

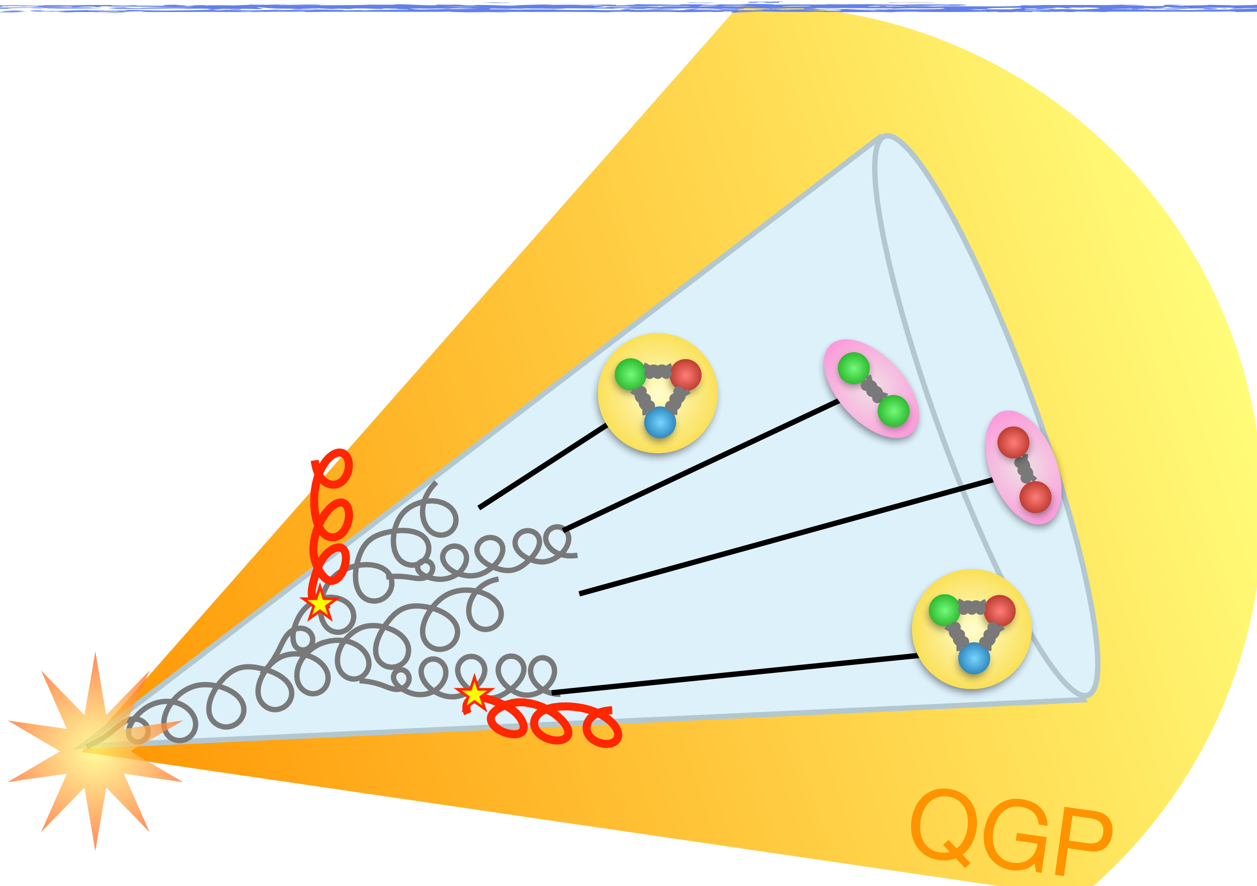


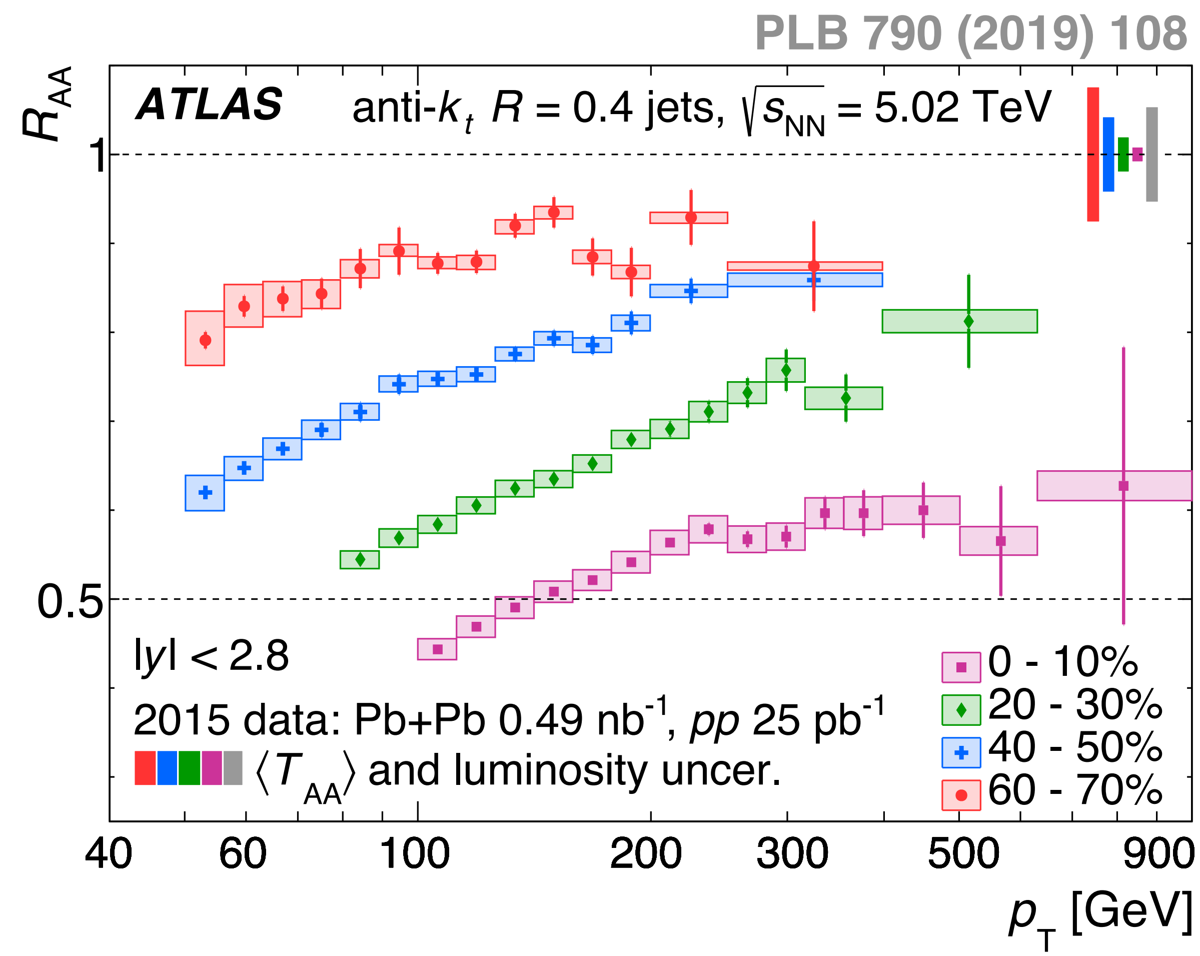
The partons interact with the plasma

jet loses energy

jet quenching

Jets in heavy ion collisions





The partons interact with the plasma

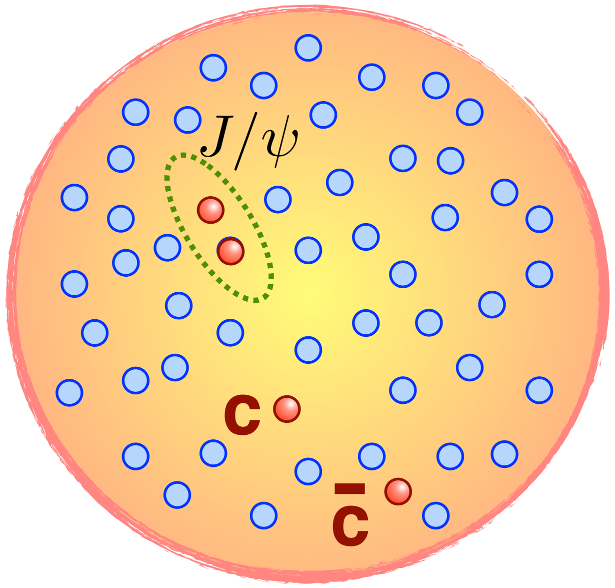
jet loses energy

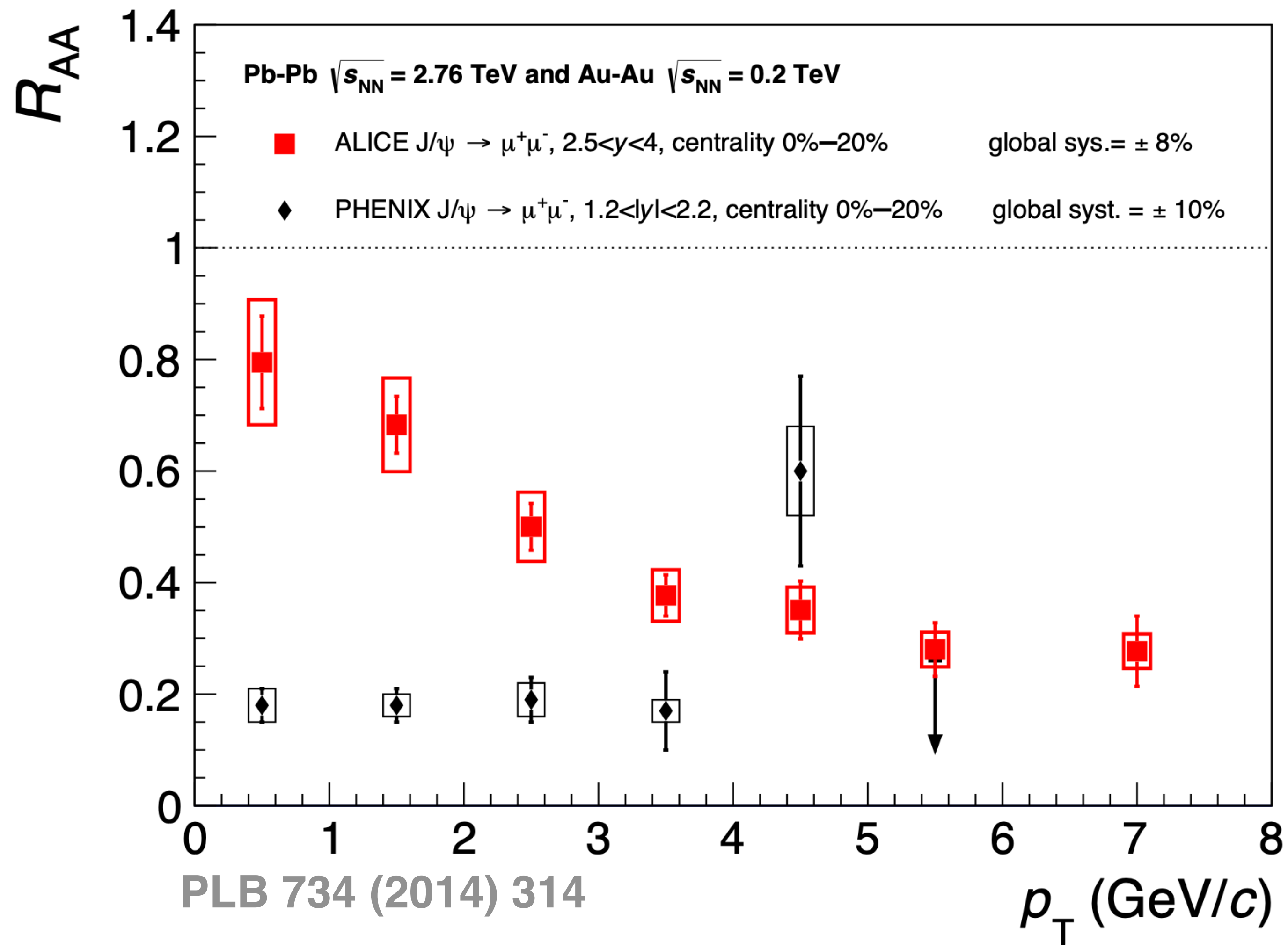
R_{AA} is the yield in PbPb over the expectation from pp

$R_{AA} < 1$

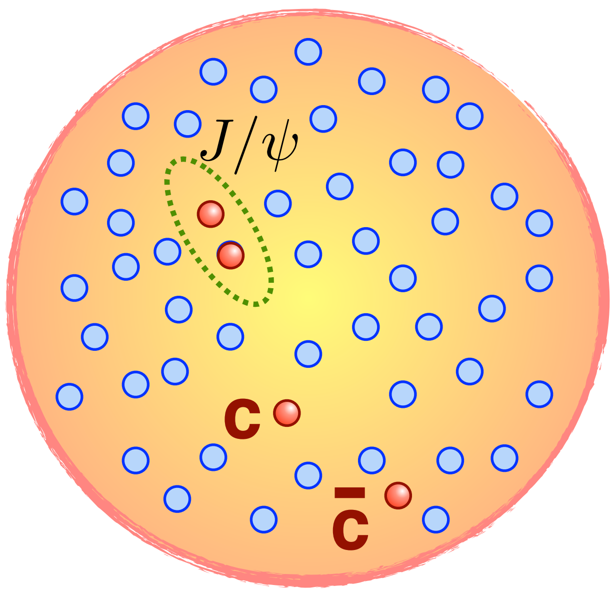
jet quenching

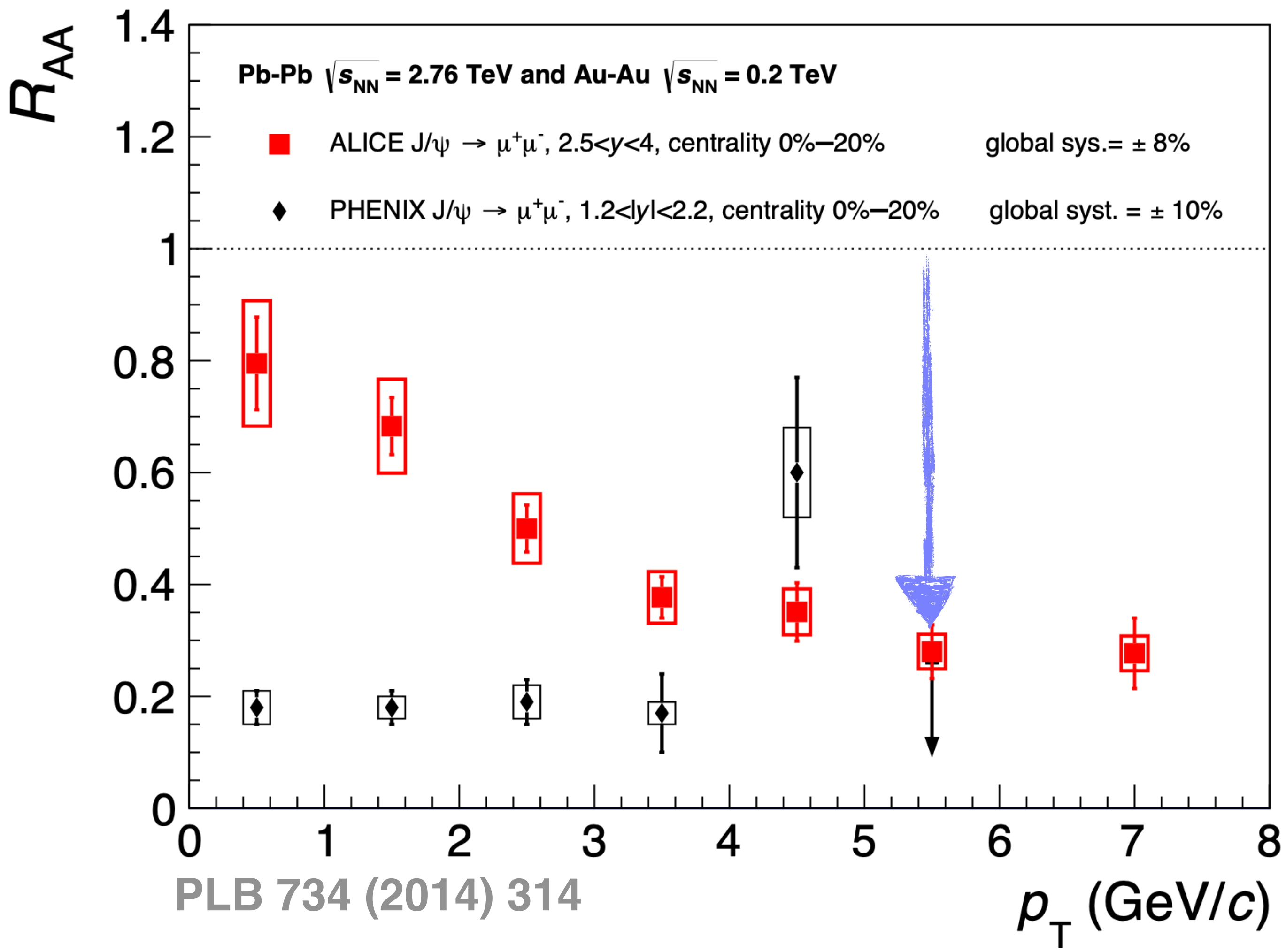
J/ψ in heavy ion collisions





J/ψ in heavy ion collisions



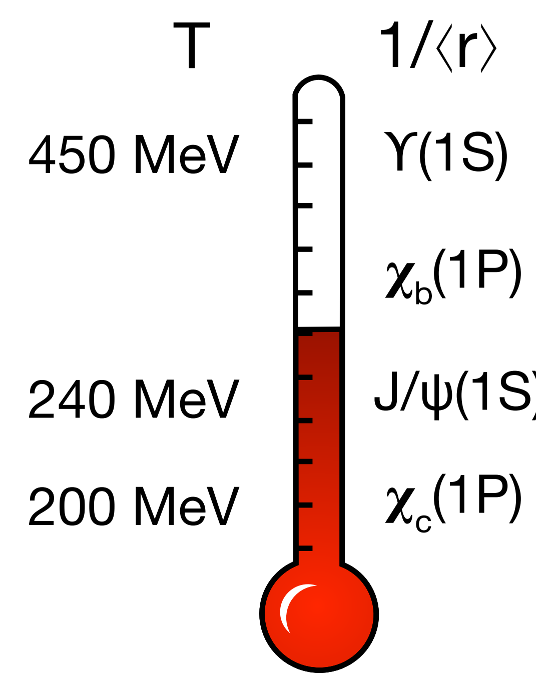


PLB 734 (2014) 314

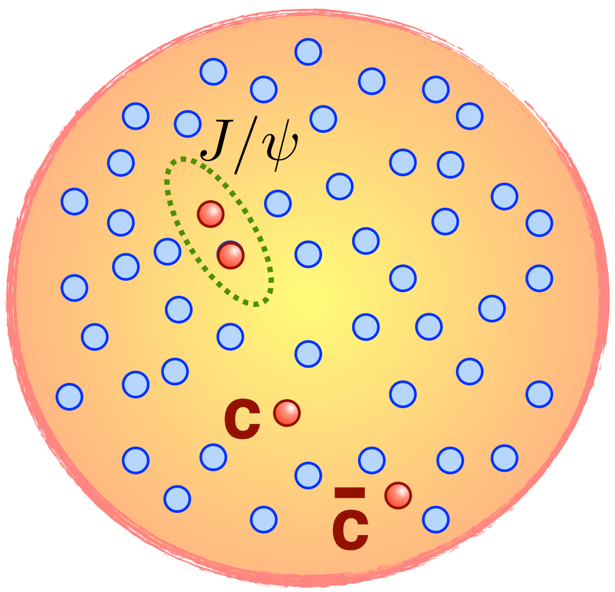
Suppression

↳ Debye screening

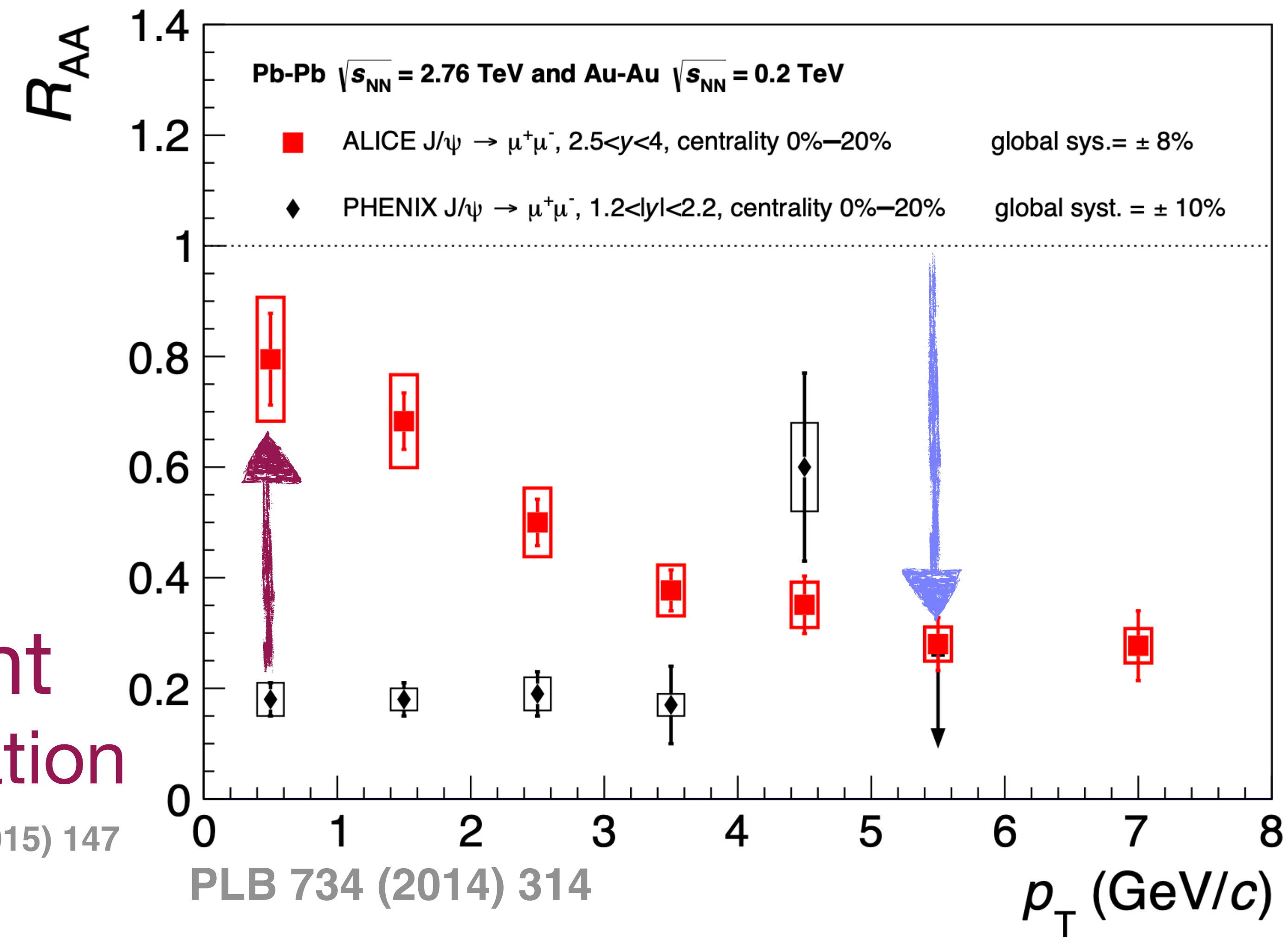
Matsui and Satz, PLB 178 (1986) 416



J/ψ in heavy ion collisions



Enhancement
↳ Recombination
Du and Rapp, NPA 943 (2015) 147



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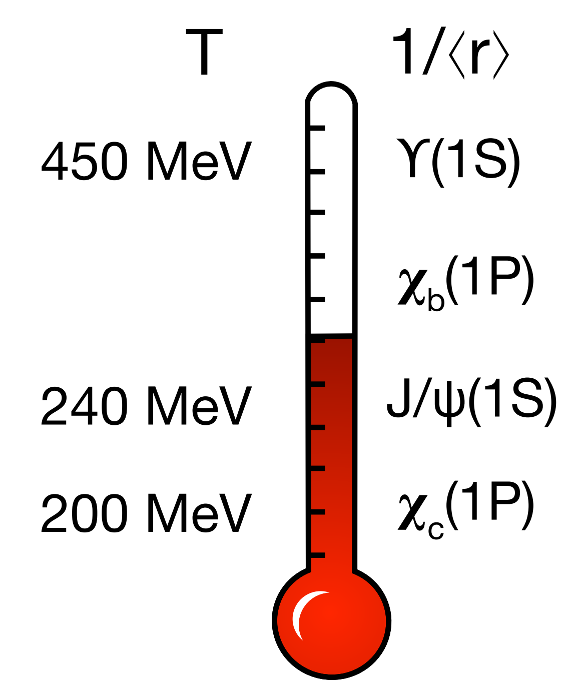
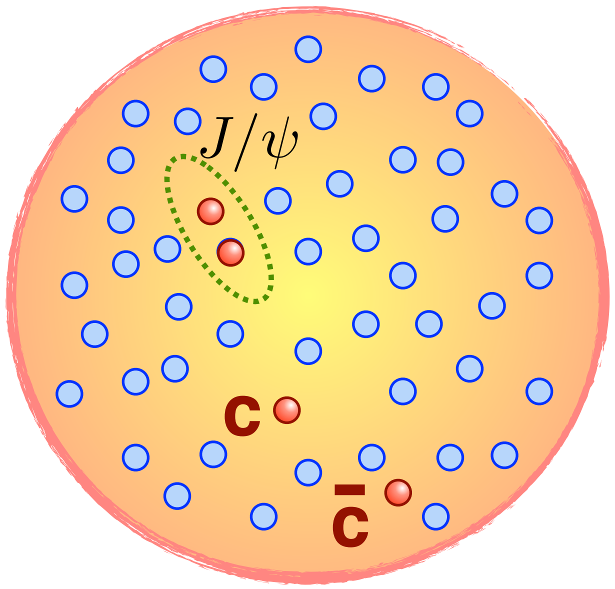
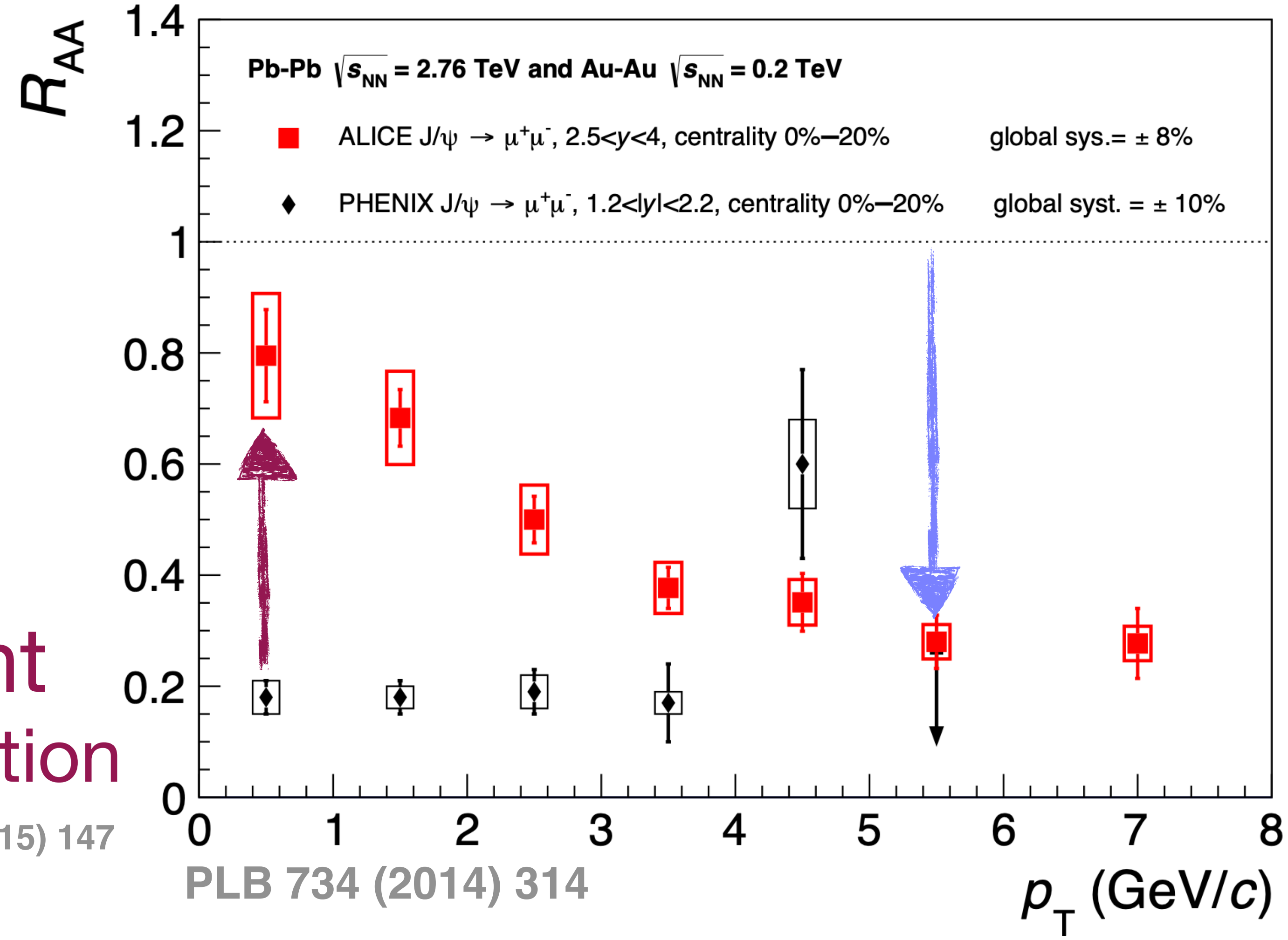


J/ψ in heavy ion collisions





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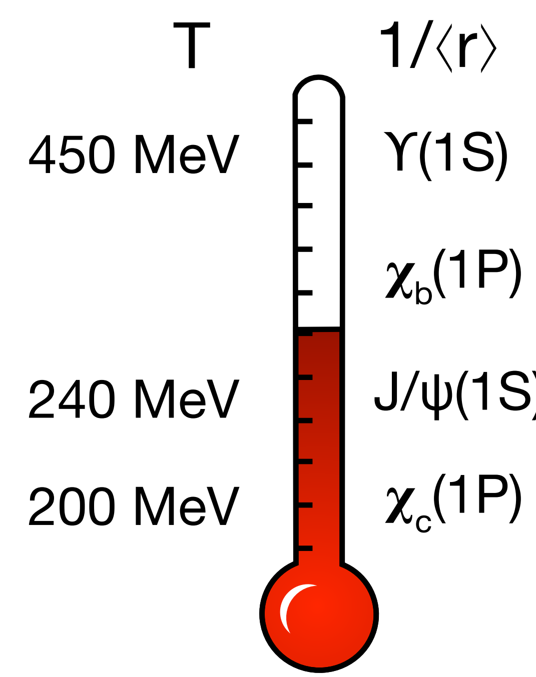
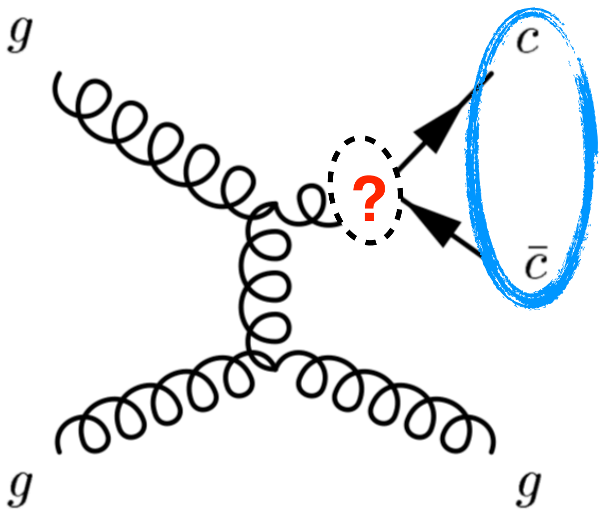
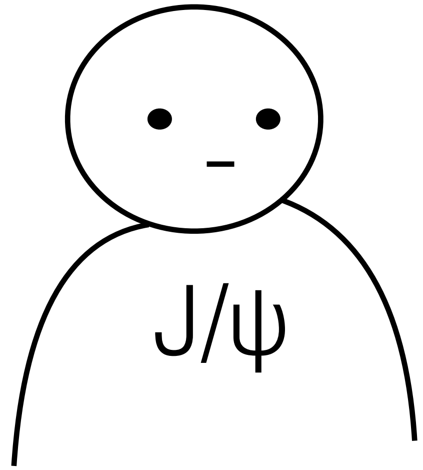


This picture assumes the production of the $c\bar{c}$ pair at early times

J/ψ puzzle

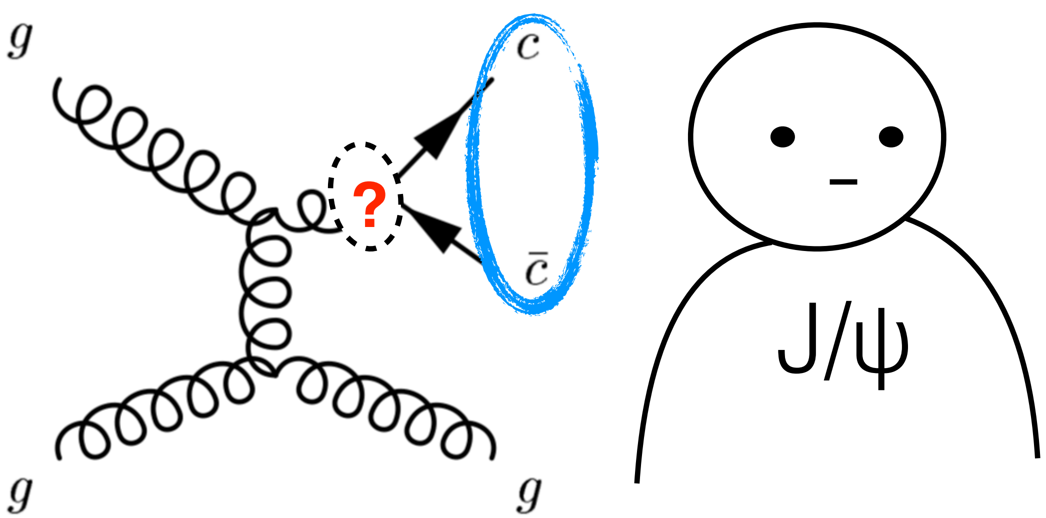




charm formation
➔ bound state

not fully understood

J/ψ puzzle



charm formation
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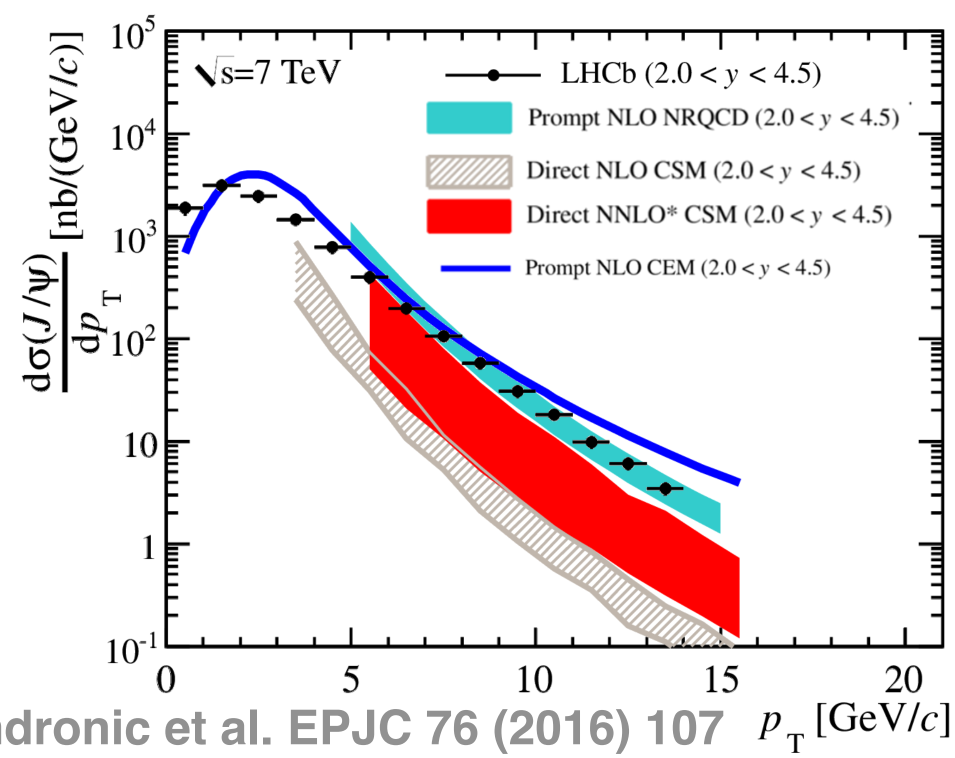
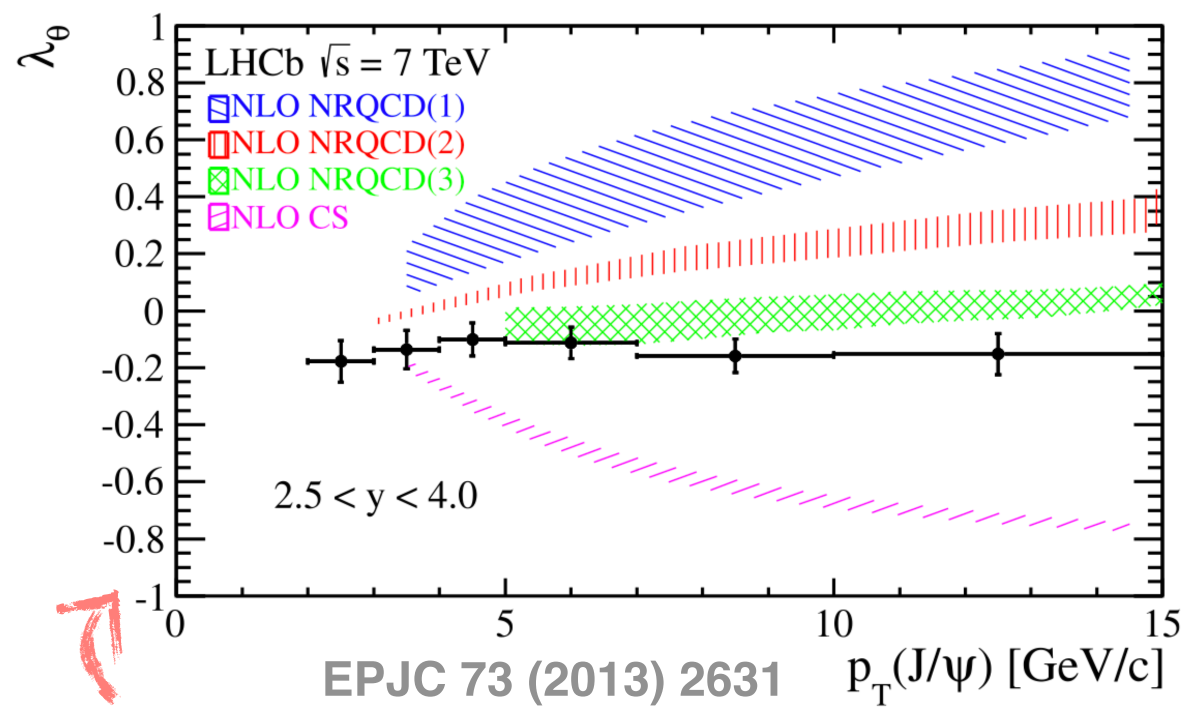
not fully understood

Models can't reproduce both cross section and polarization



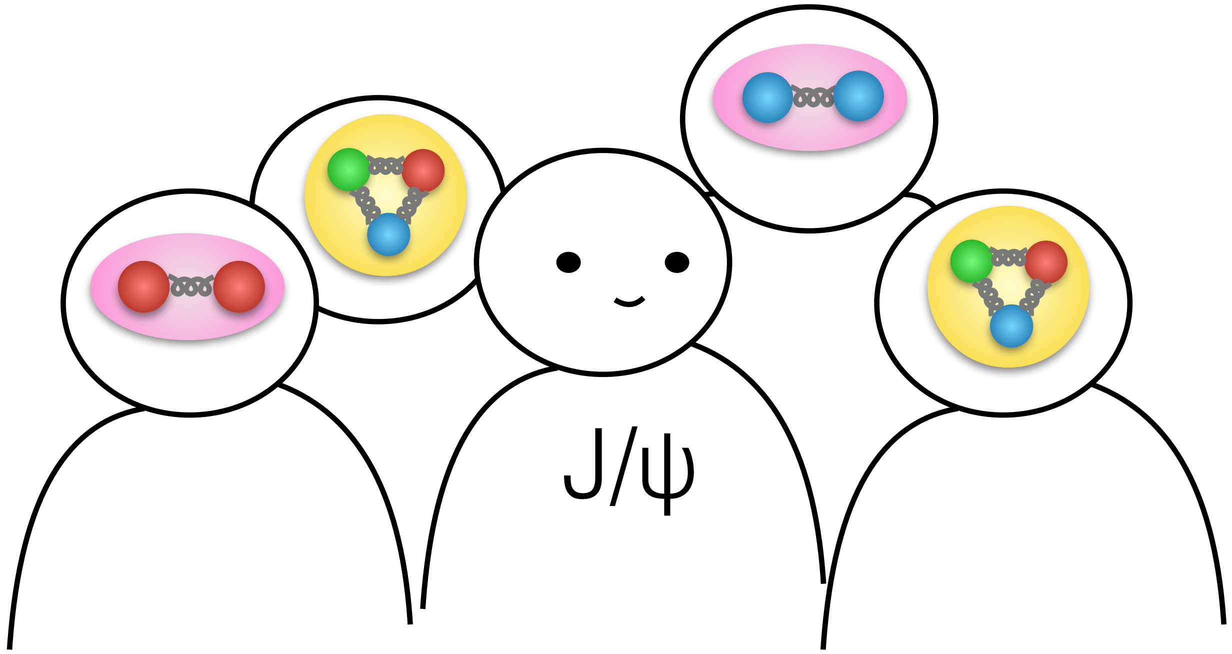
Andronic et al. EPJC 76 (2016) 107

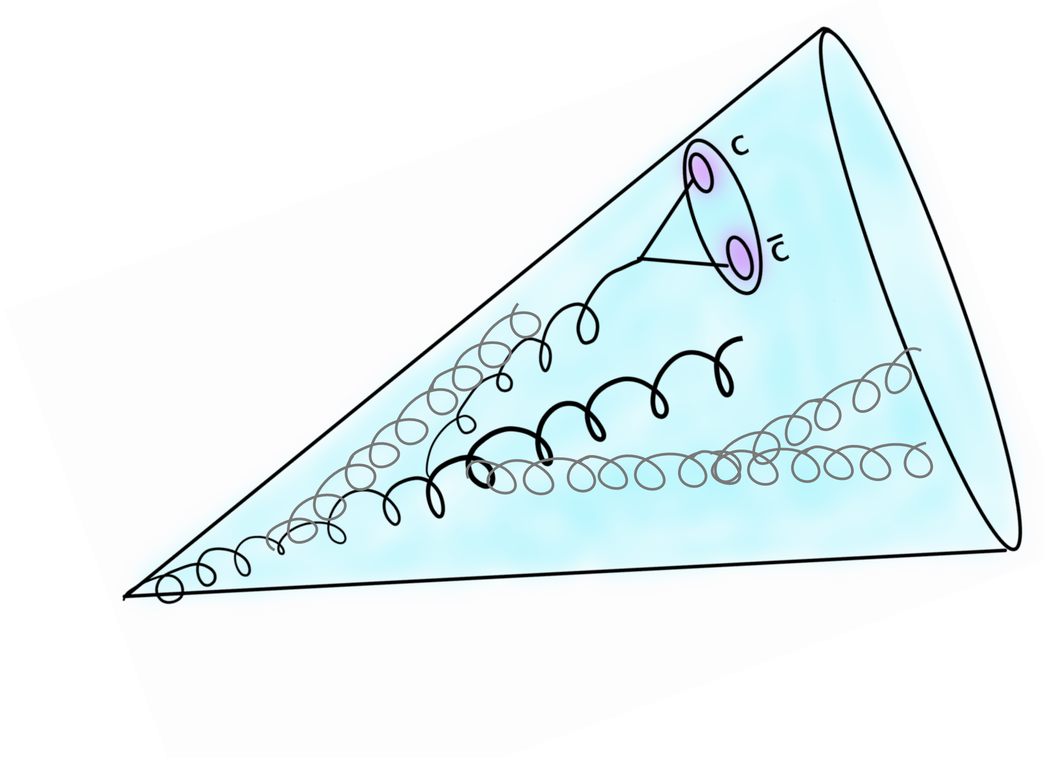


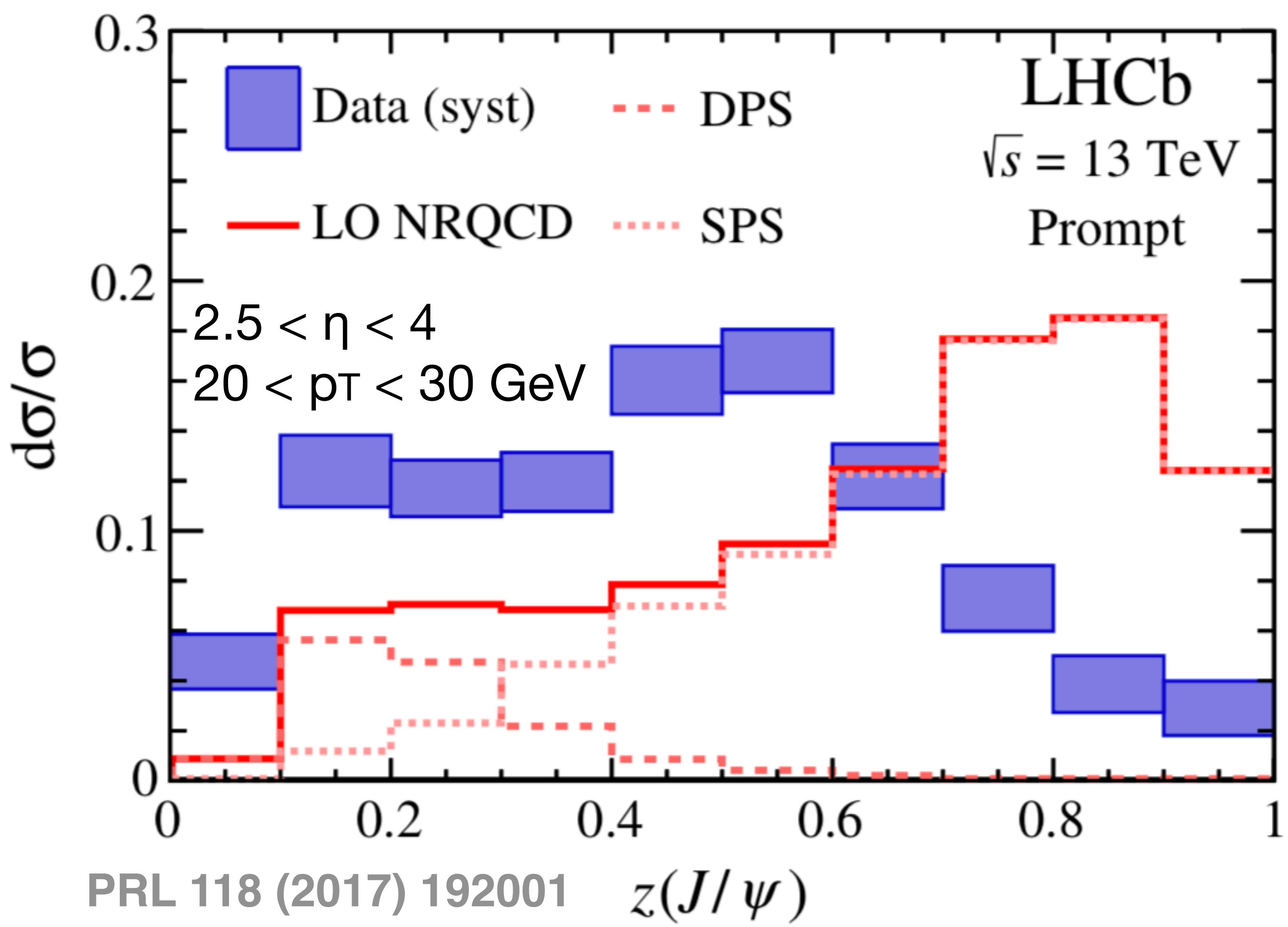
EPJC 73 (2013) 2631

Polarization

J/ψ in jets in pp







PRL 118 (2017) 192001

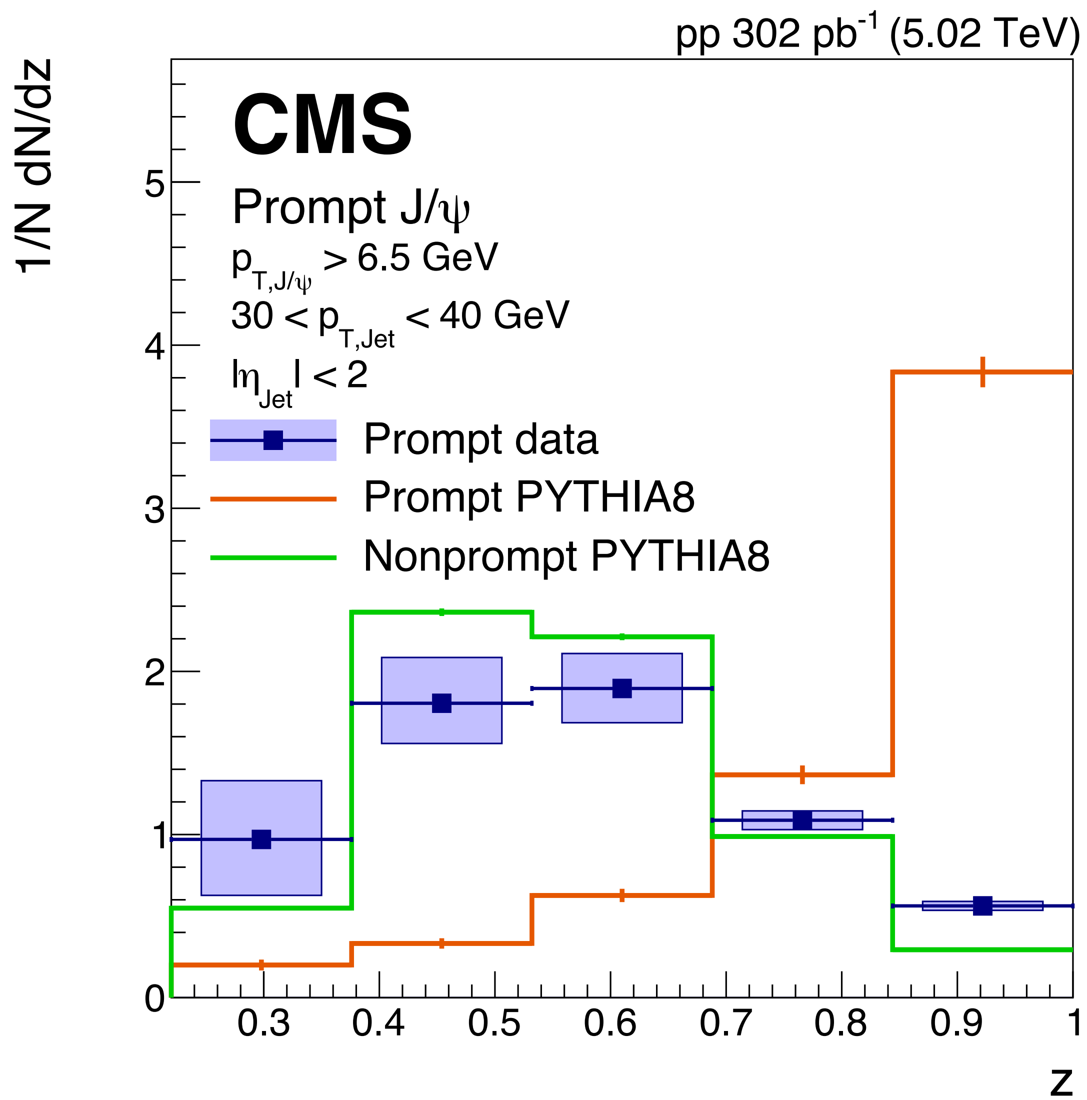
Recent measurement by LHCb: J/ψ in jets

z = J/ψ p_T / jet p_T

prompt J/ψ are produced with far more jet activity than predicted by models

Prompt J/ψ in pp data and MC

Starting point for my thesis in CMS
Start with pp data and then move to PbPb
Different kinematic ranges

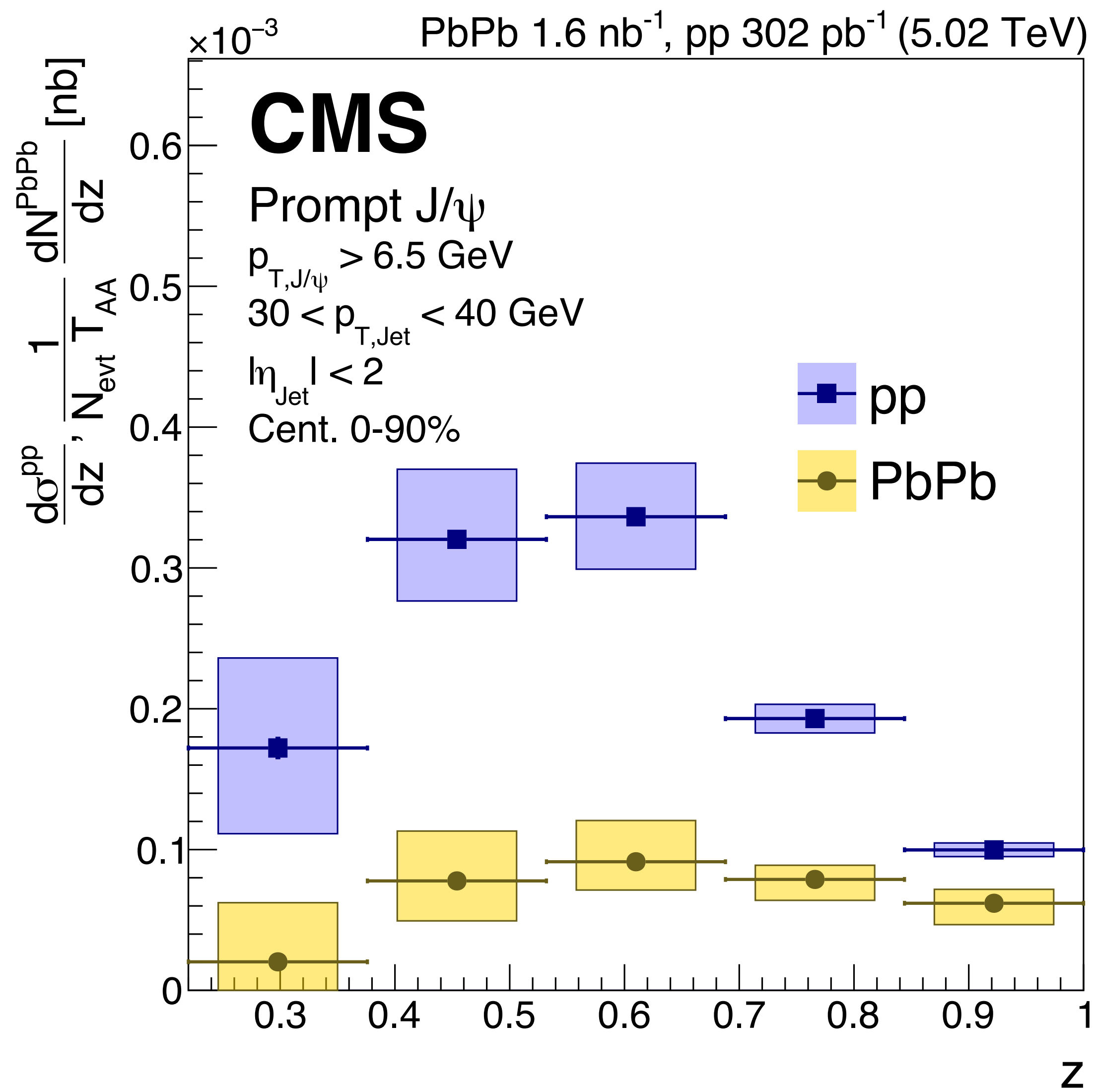


Similar results to LHCb

Prompt data more similar to nonprompt PYTHIA8 than prompt PYTHIA8

z distributions in pp and PbPb

Per-event yield of prompt J/ψ mesons in PbPb collisions scaled by T_{AA} and the cross section in pp collisions, as a function of the fragmentation variable z



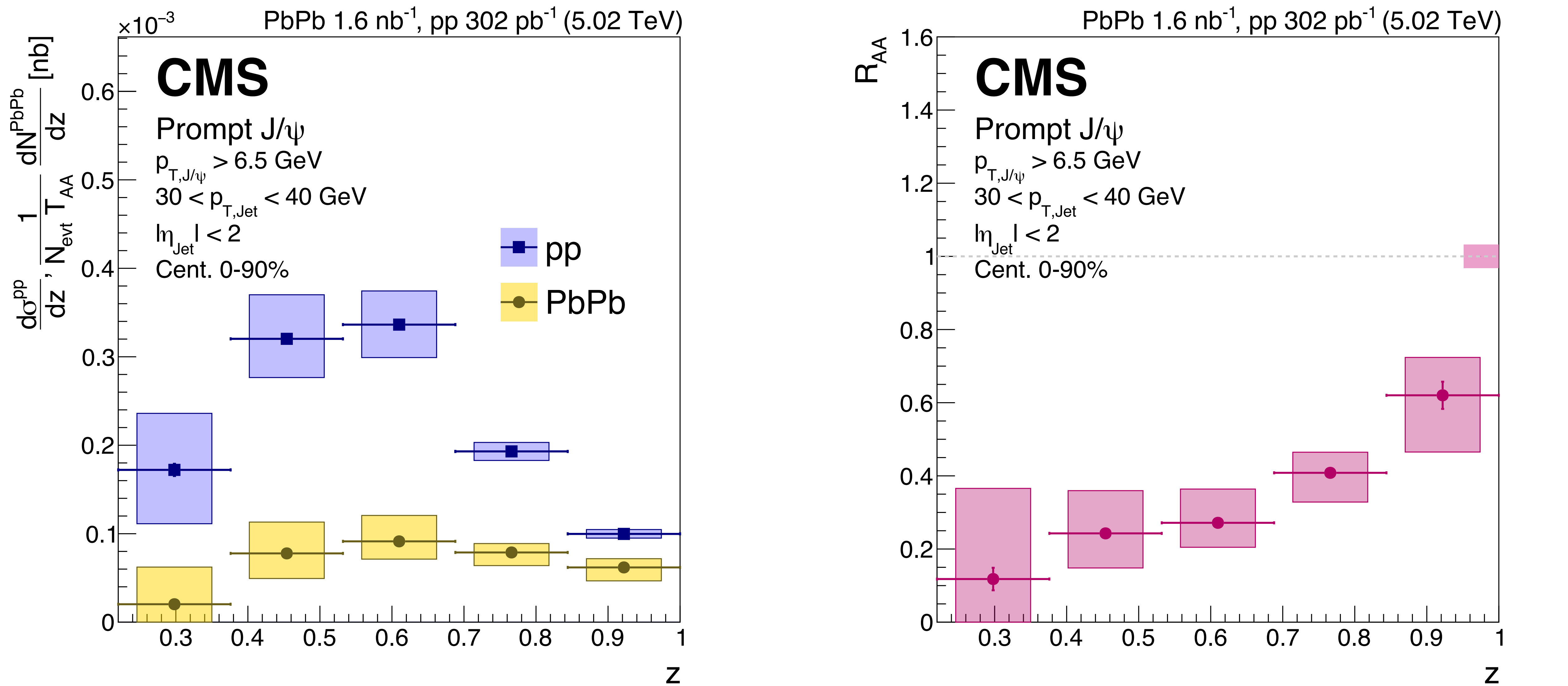
pp and PbPb have similar trends

Suppression in PbPb in all z bins

R_{AA} of J/ψ in jets

Rising trend as a function of z

Less suppression for isolated J/ψ compared to J/ψ with larger jet activity



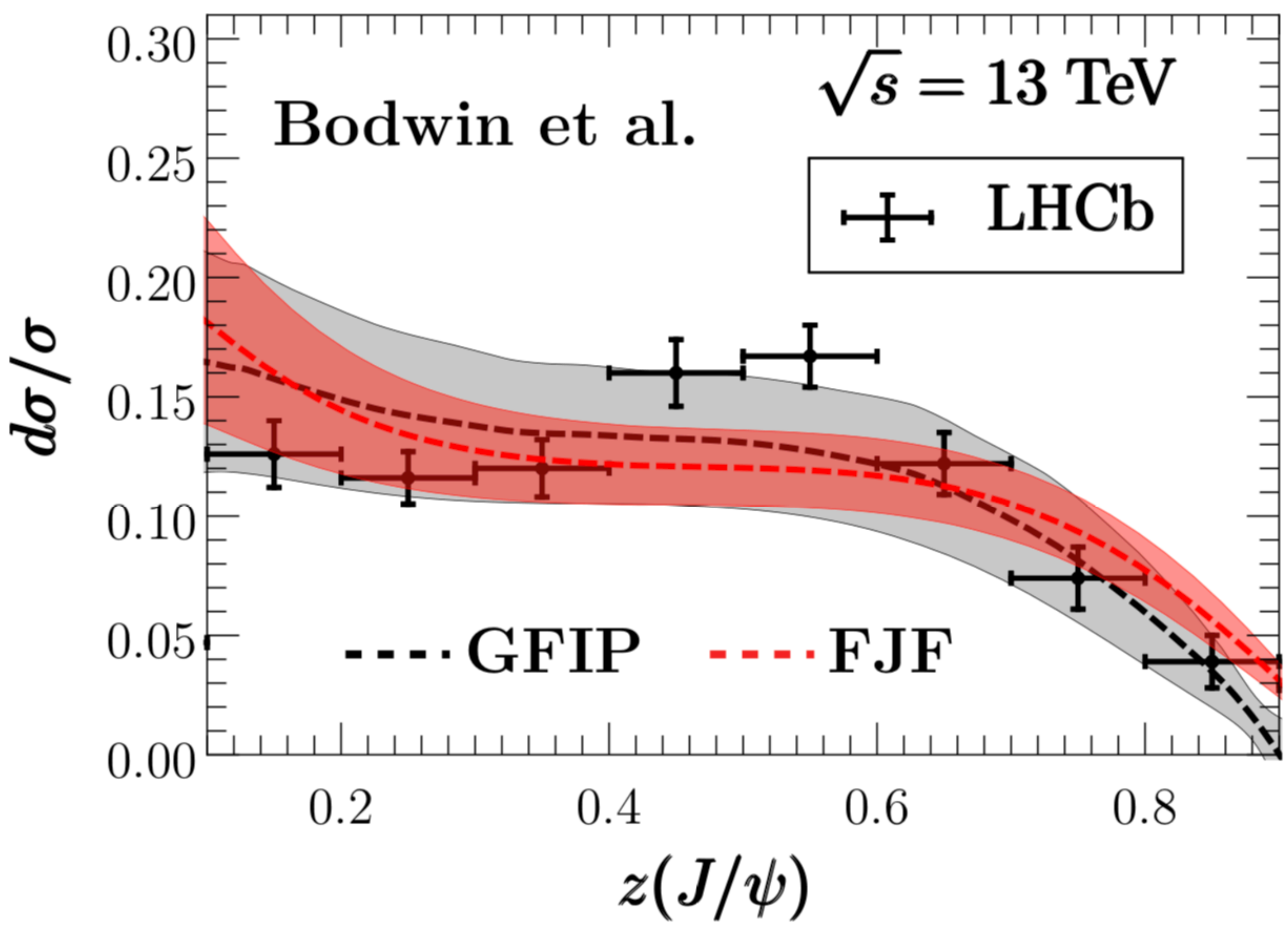
NRQCD vs LHCb

Fixed order calculations are not enough to understand the J/ψ puzzle

J/ψ could be produced in parton showers

→ Later time

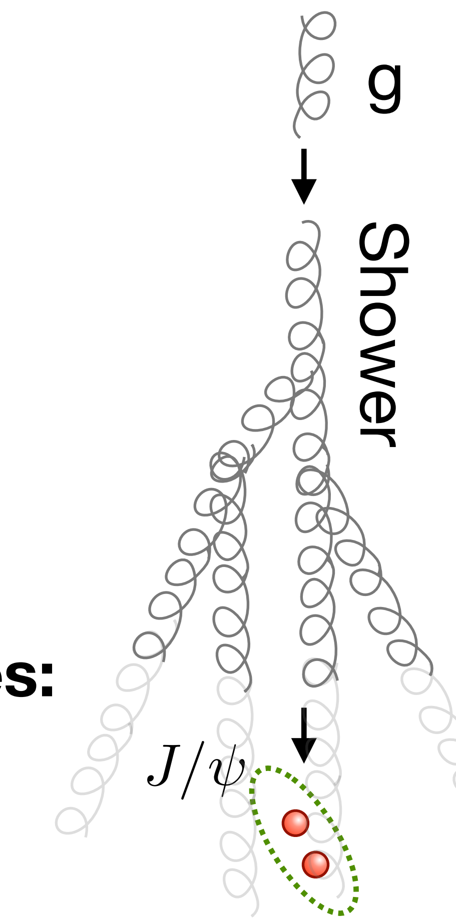
→ Low z



Two comparable approaches:

GFIP: Gluon Fragmentation Improved PYTHIA

FJF: Fragmentation Jet Functions



Better agreement with LHCb results than LO NRQCD

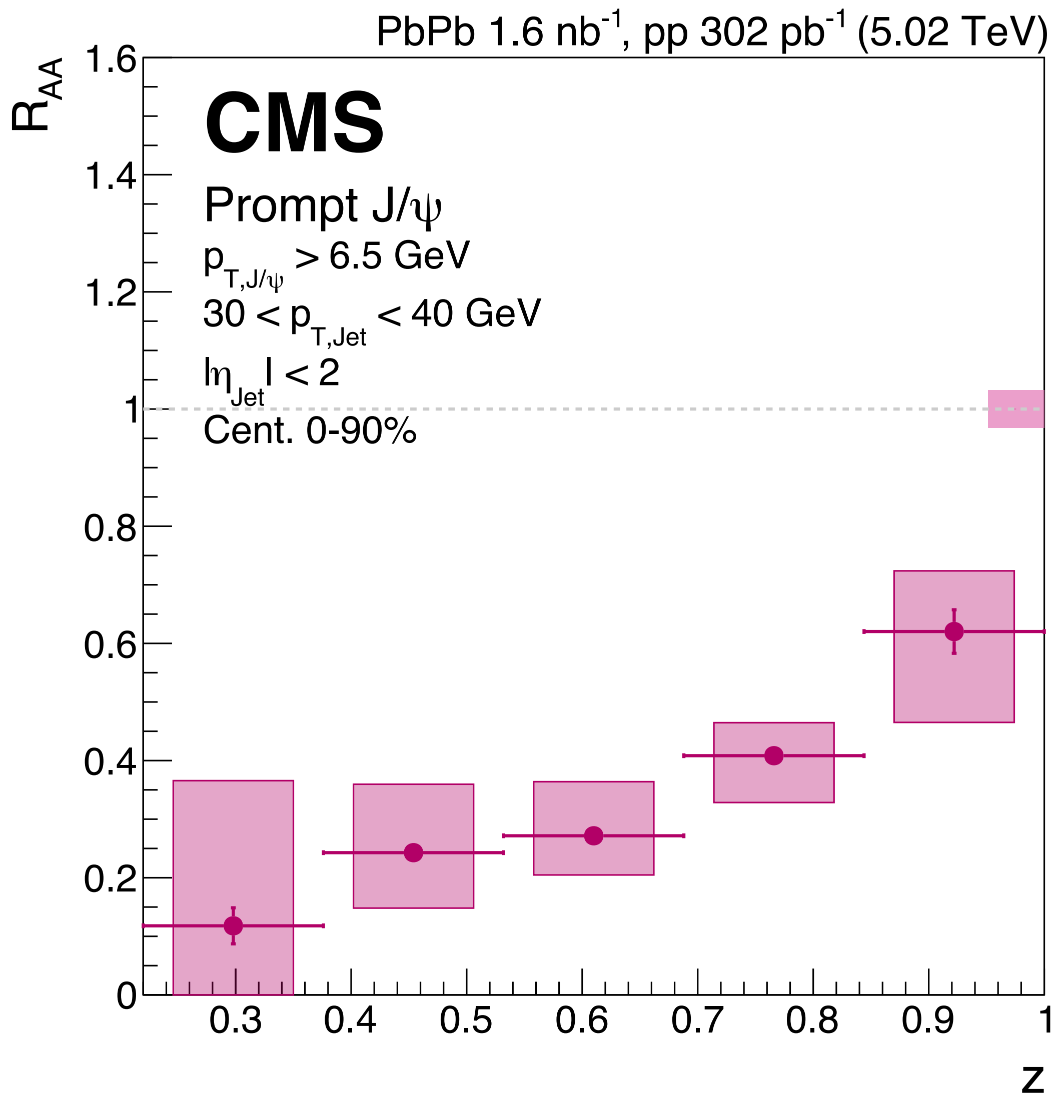
R. Bain et al. PRL 119 (2017) 032002

R_{AA} of J/ψ in jets

Lower z

J/ψ produced later in parton shower

Larger degree of interaction with the QGP

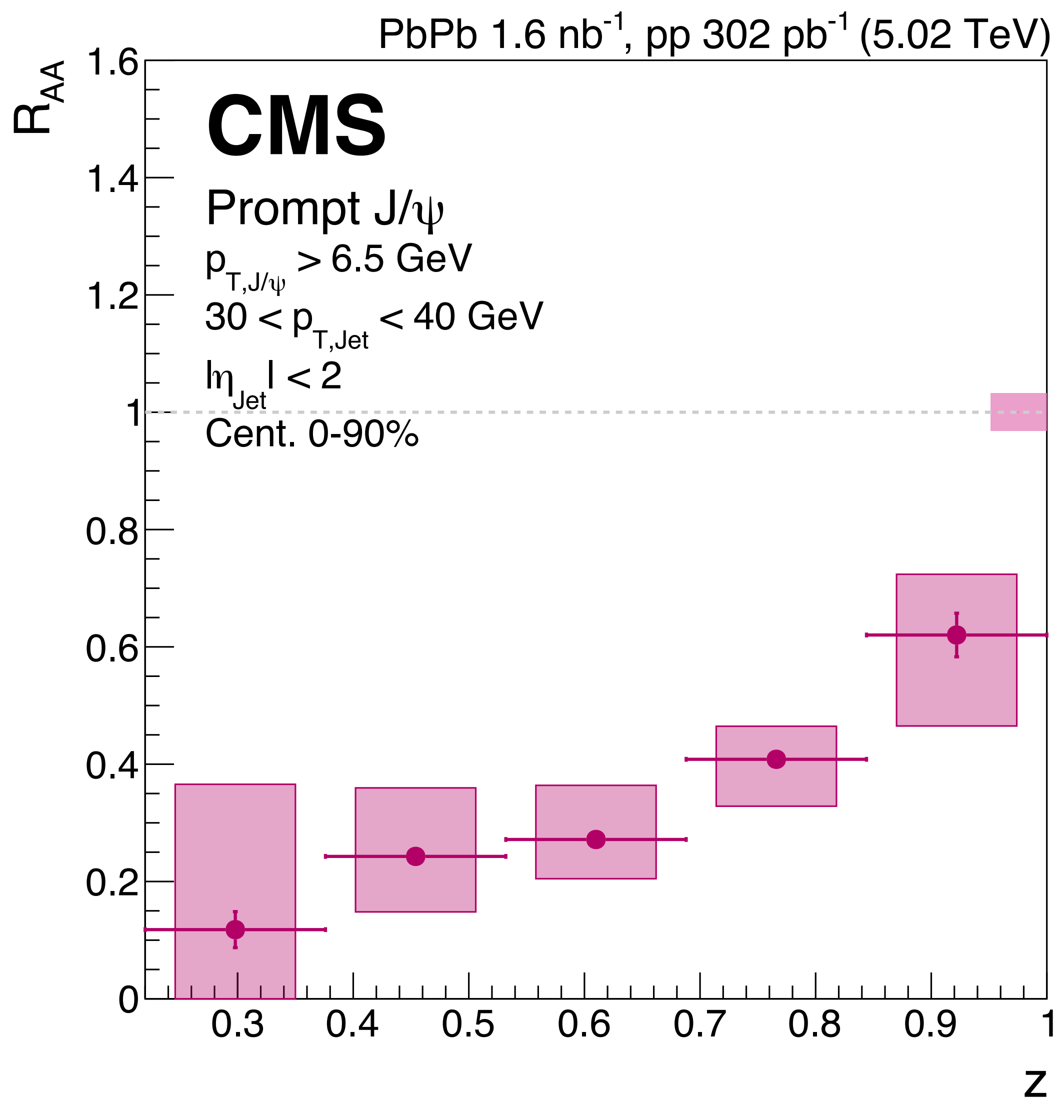


Conclusions

I measured the jet fragmentation function of the J/ψ meson in pp and PbPb collisions

Prompt J/ψ R_{AA} showed a rising trend with z

These results support the interpretation of jet quenching as a relevant mechanism for J/ψ suppression



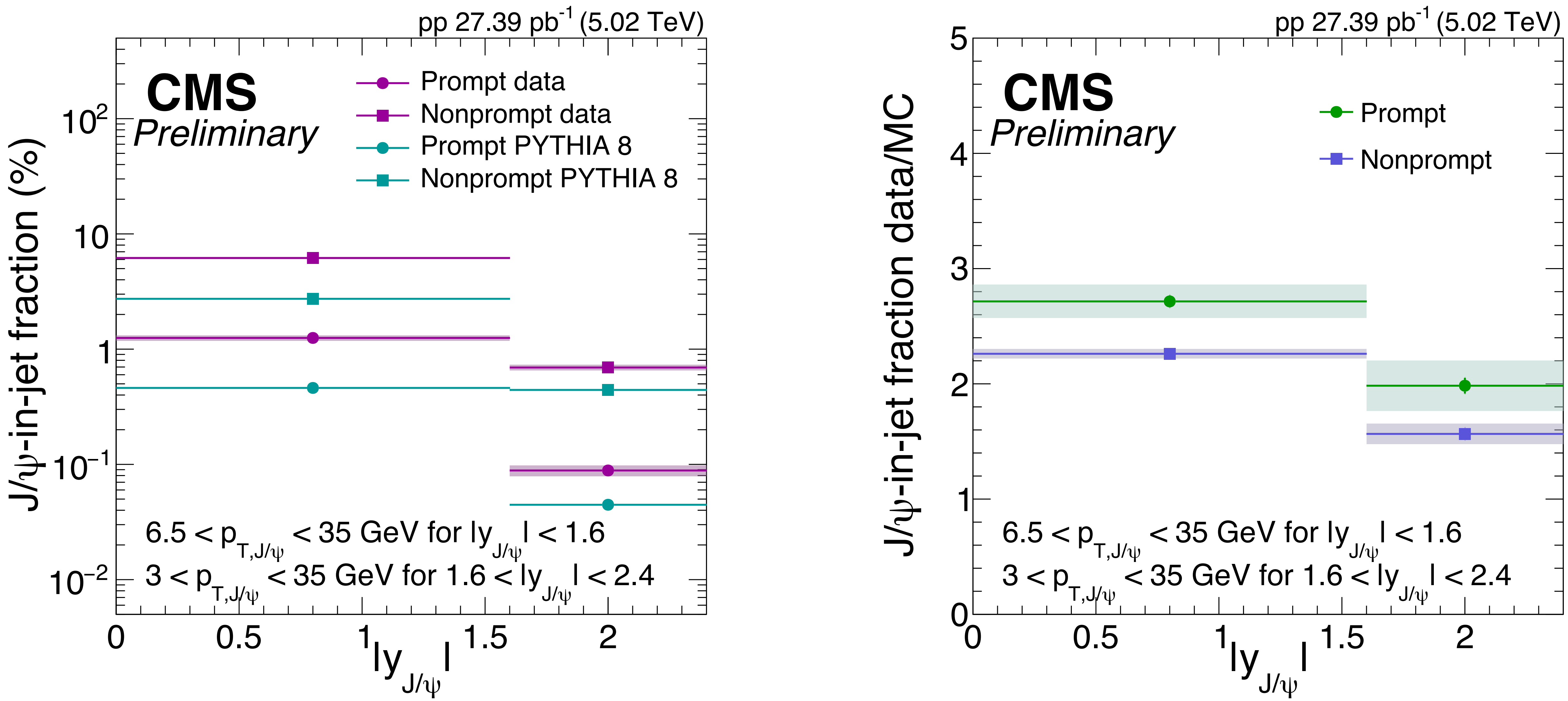
Backup

J/ψ-in-jet fraction

Ratio of J/ψ produced in jets in our selection over the total number of J/ψ

Less than 7% are produced in jets in our selection

Under-predicted in PYTHIA8



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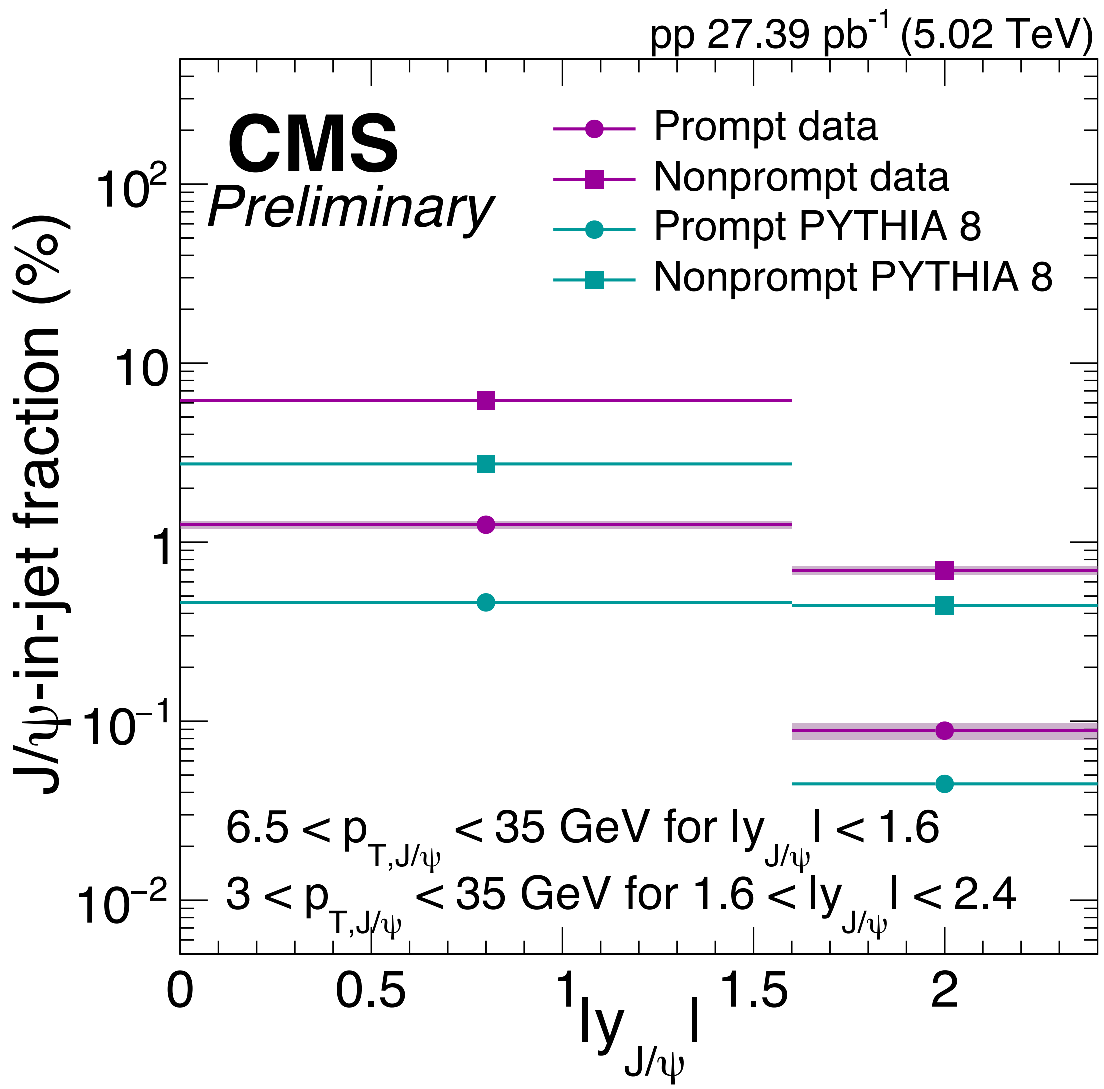
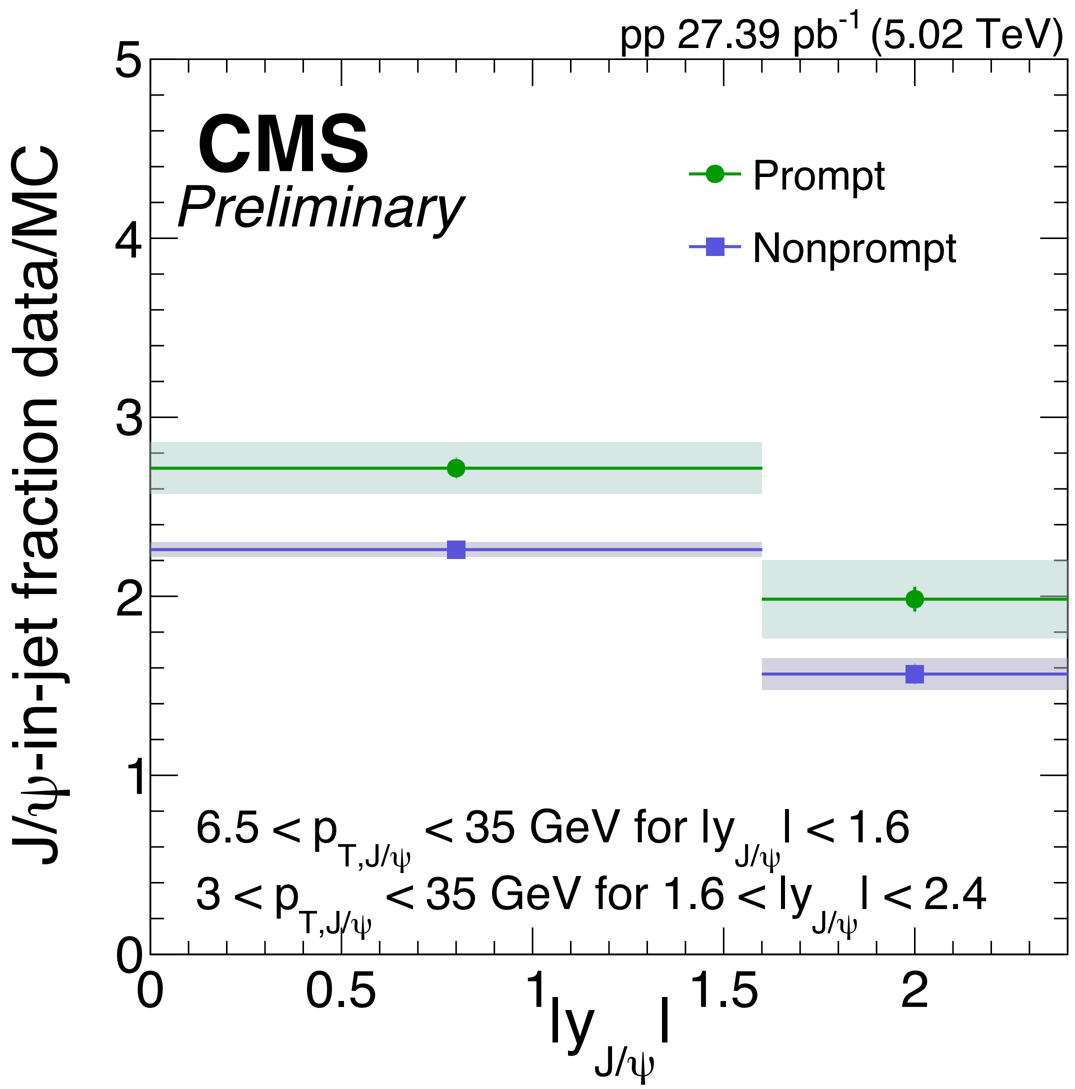


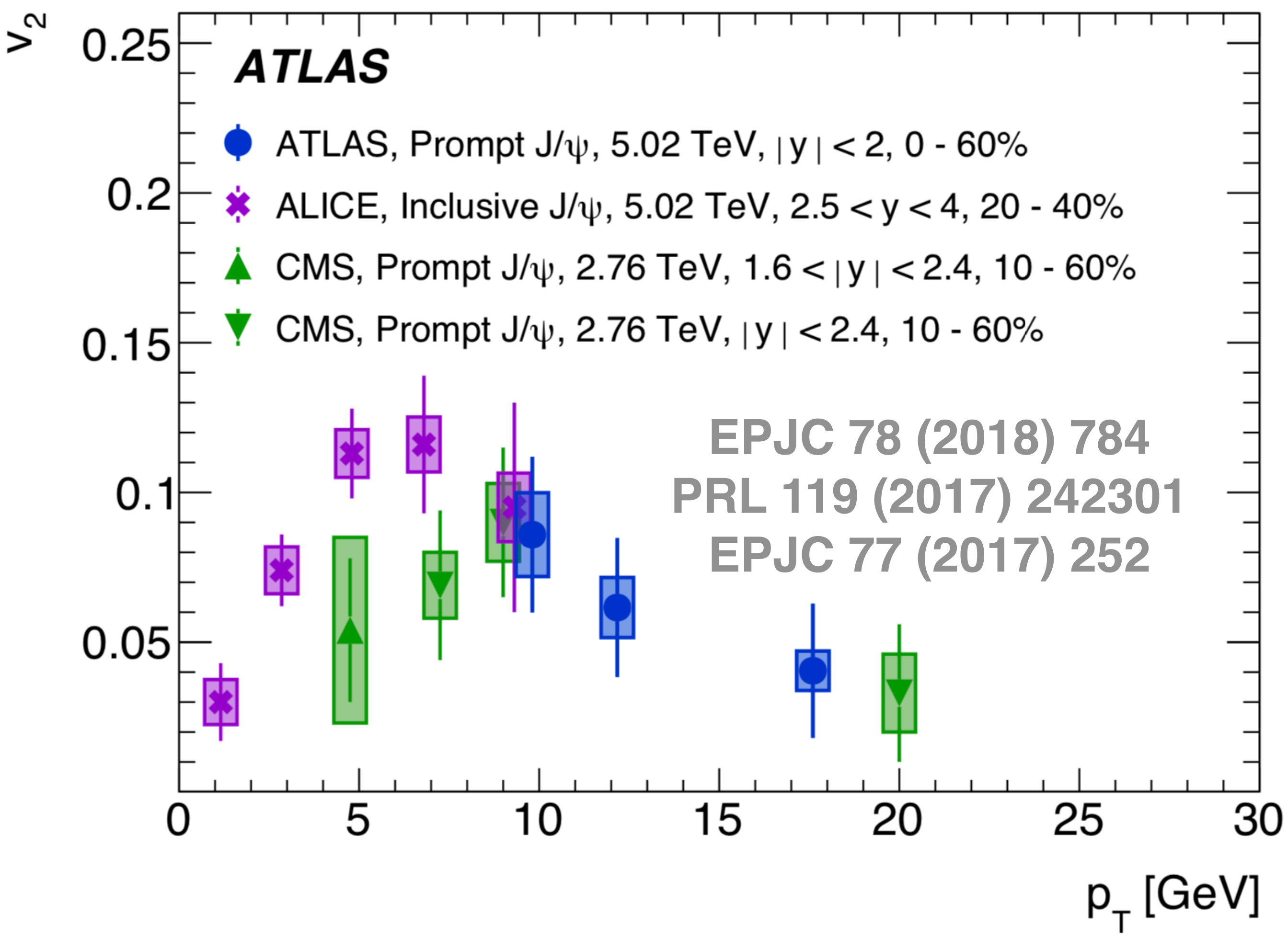


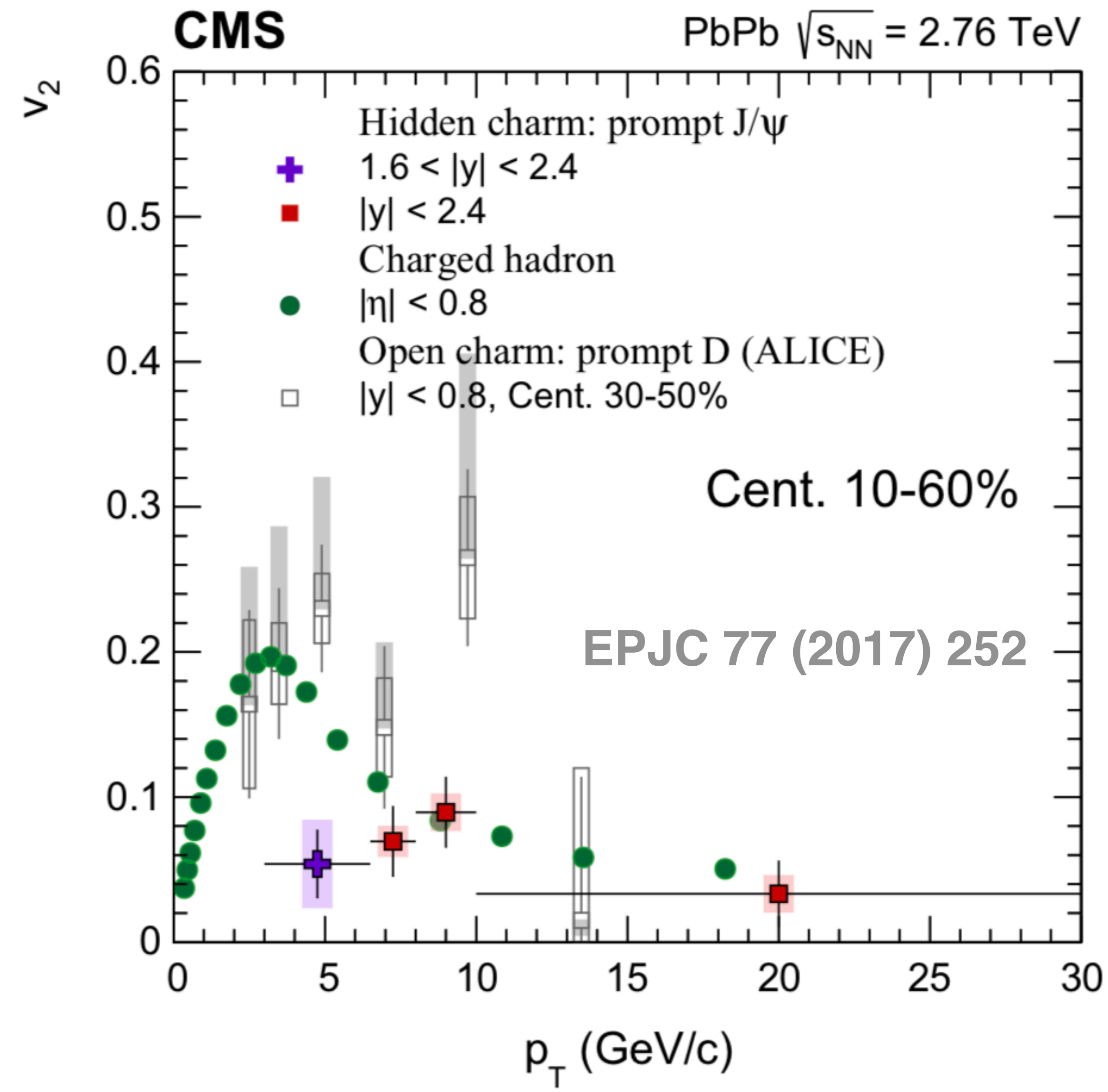
CMS measurement at 8 TeV:

PLB 804 (2020) 135409

(85 ± 3(stat) ± 7(syst))% of J/ψ ($E_{J/\psi}$>15 GeV) are produced with a jet (E_{Jet}>19 GeV)

Elliptic flow in PbPb





Unexpected non zero v_2 for prompt J/ψ at high p_T

Similar to other hadrons at high p_T

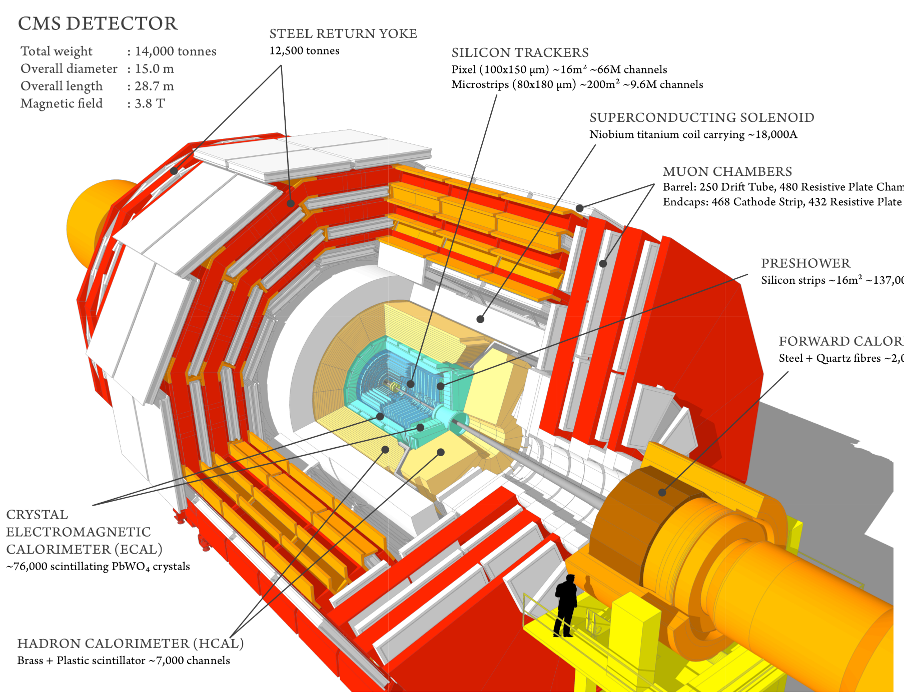
Path-length dependence of energy loss

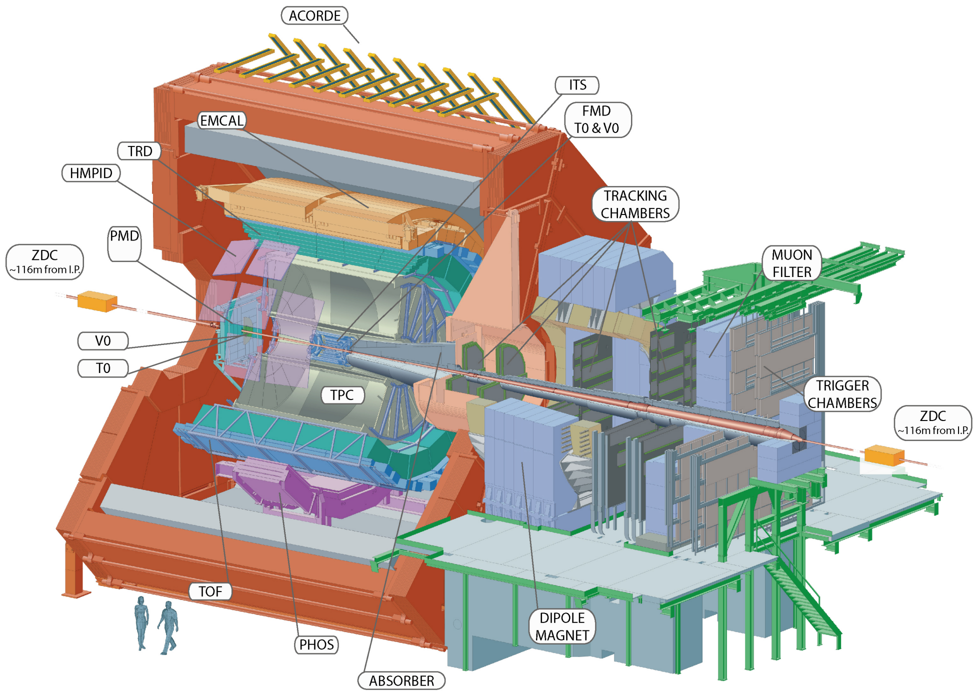
From CMS to ALICE

Moved from CMS to ALICE

$J/\psi \rightarrow \mu\mu$ in jets cannot be done in ALICE

But similar tools can be used in many analyses



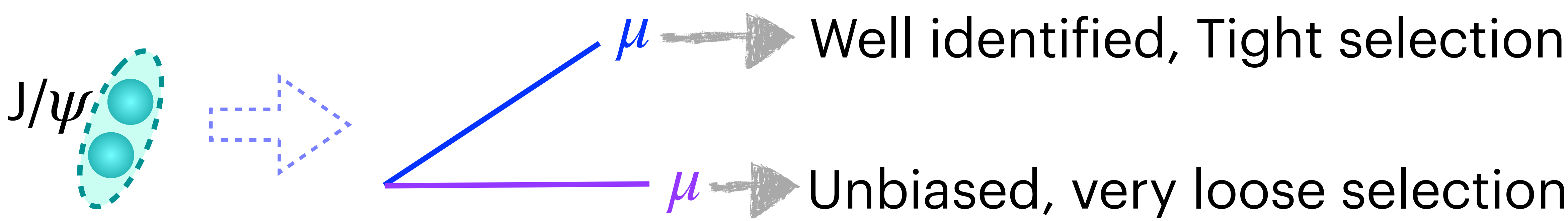


-> seperation of prompt and nonprompt J/ψ

-> efficiency calculation studies

The Tag-and-Probe method

- Tag-and-Probe (T&P) is a data-driven efficiency calculation technique
- Simulations are not ideal → need data calibration
- based on the decays of known resonances, e.g. J/ψ



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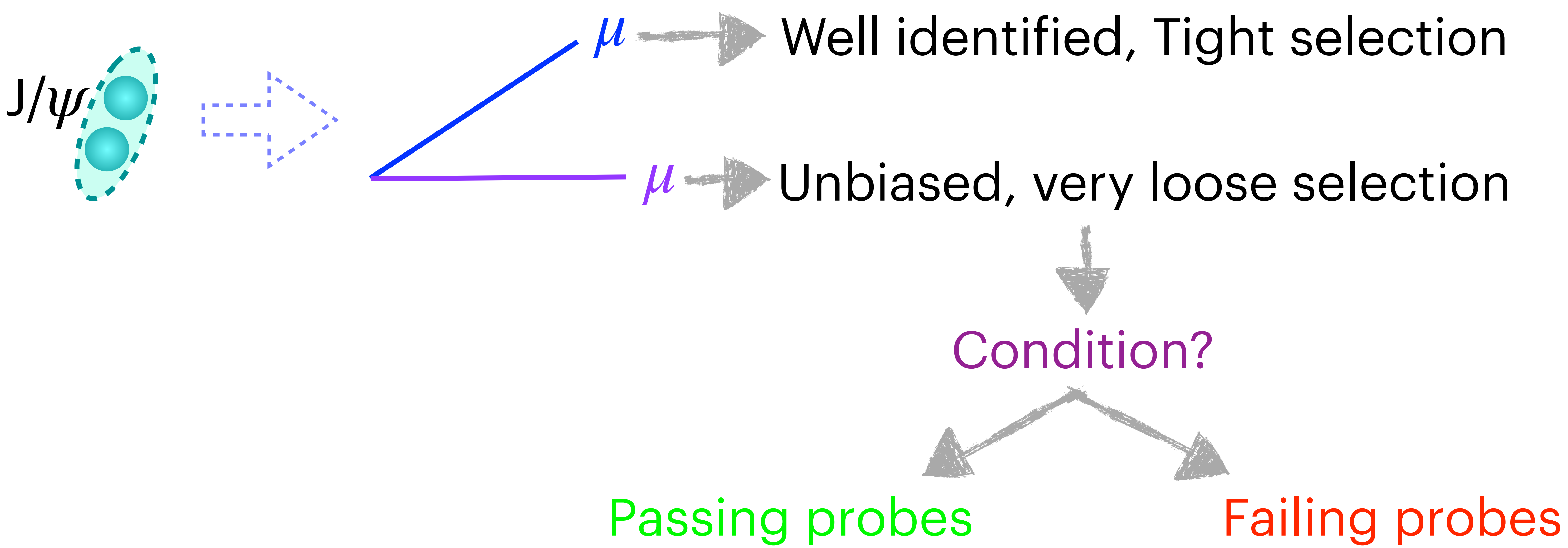

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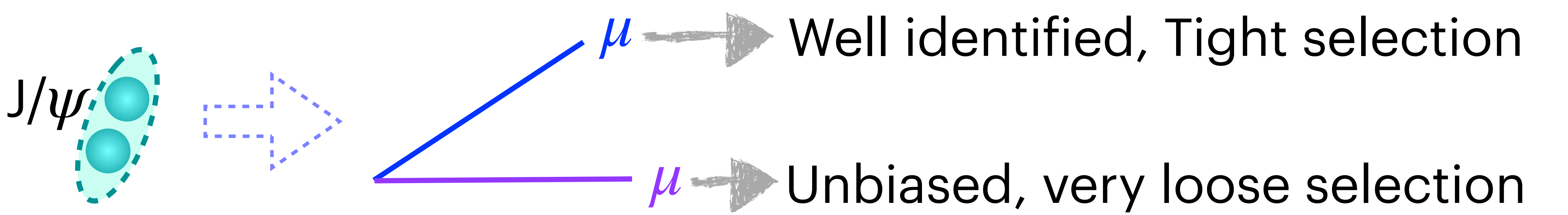

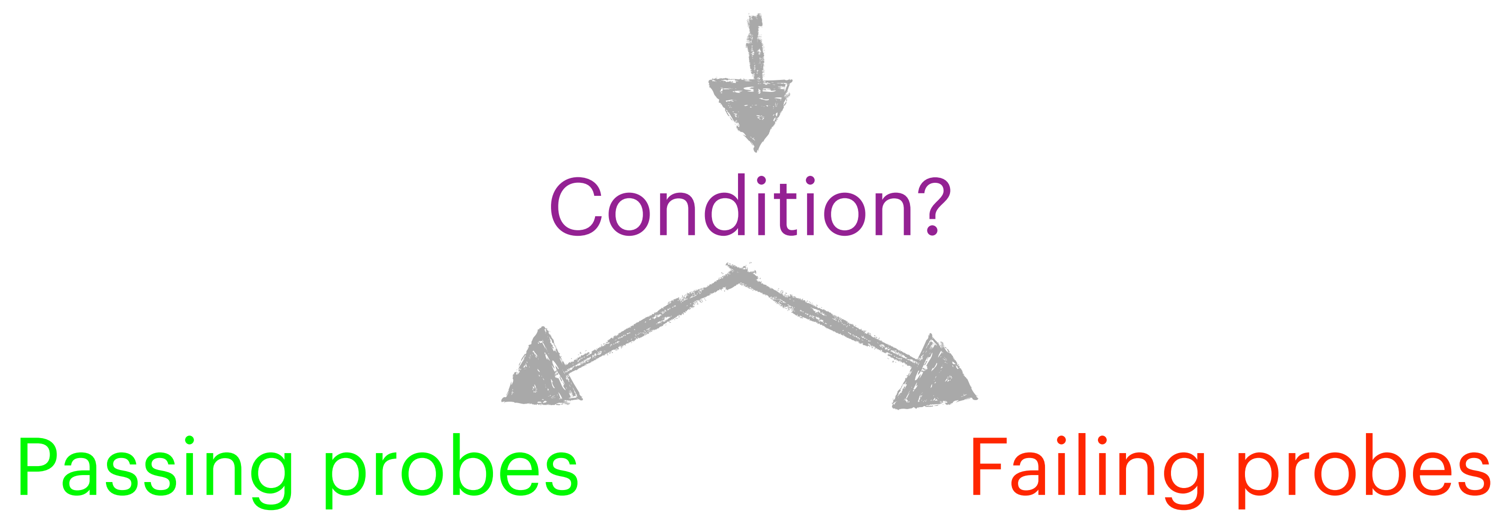

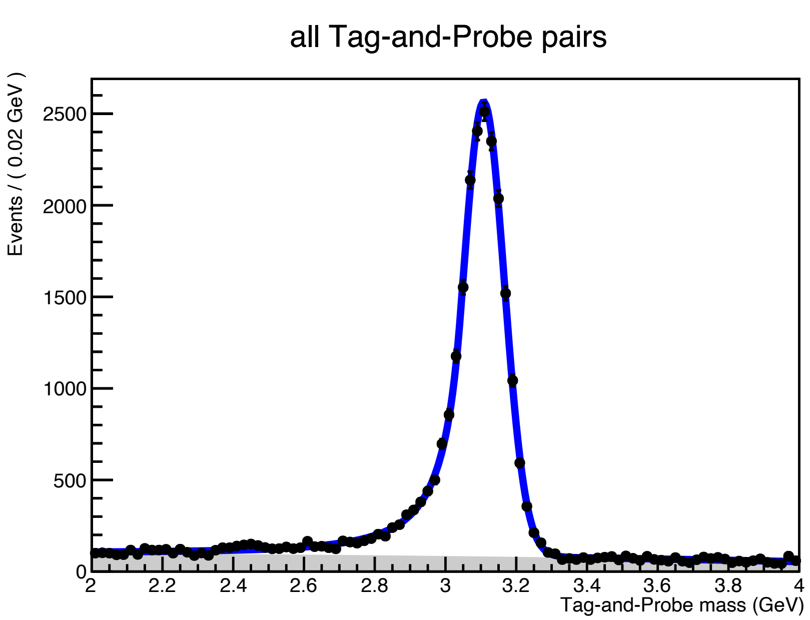

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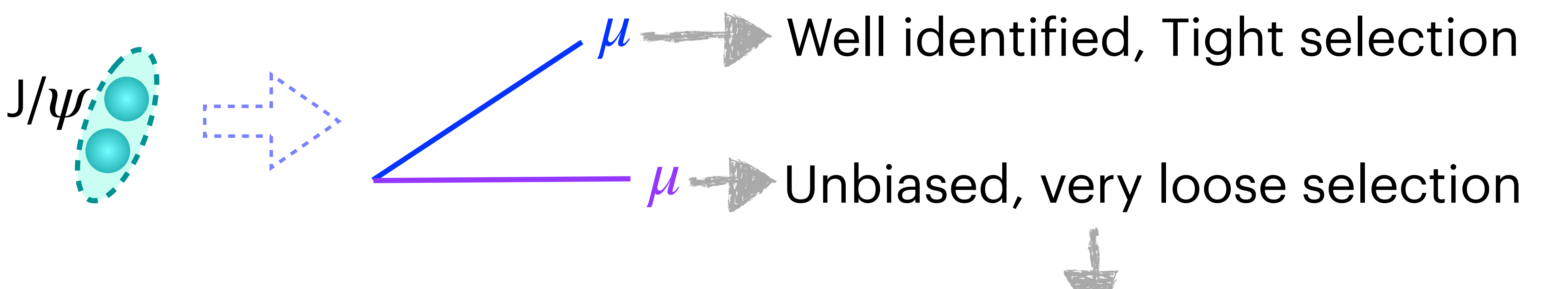
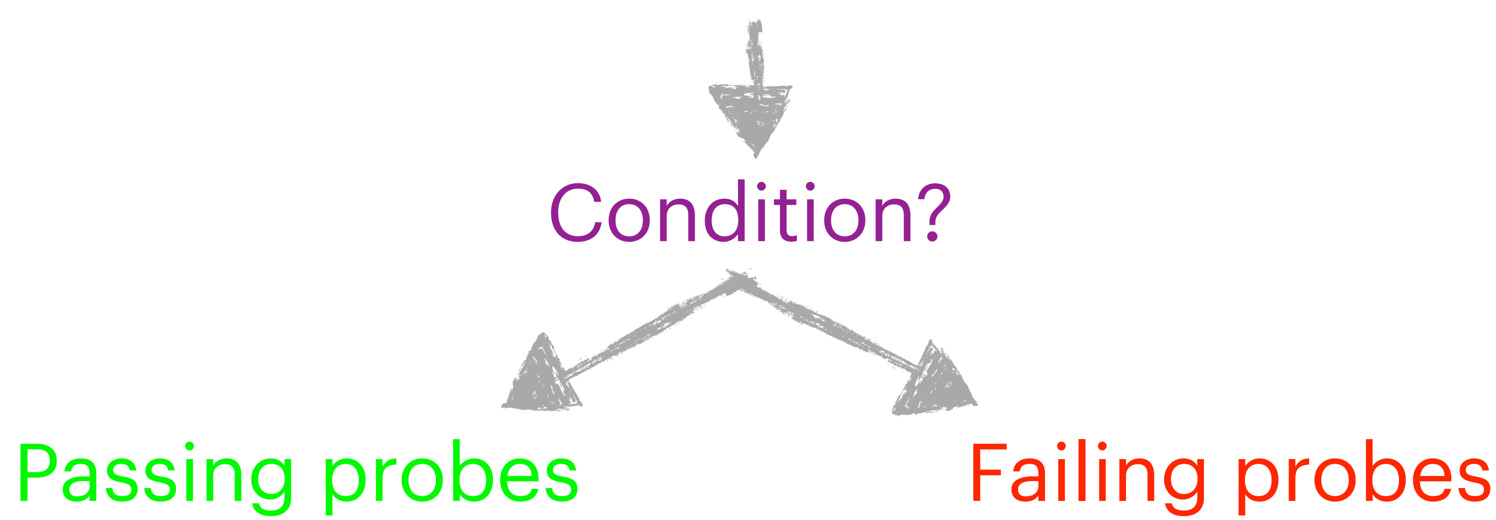
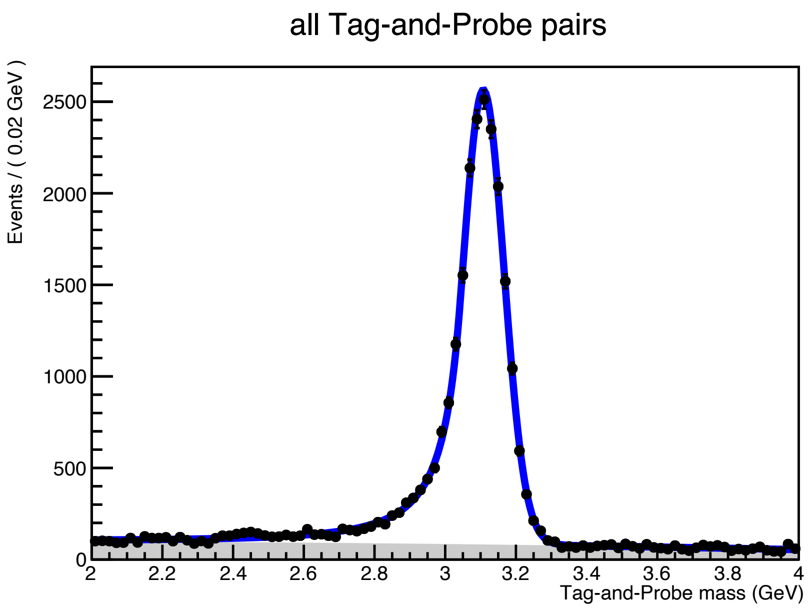


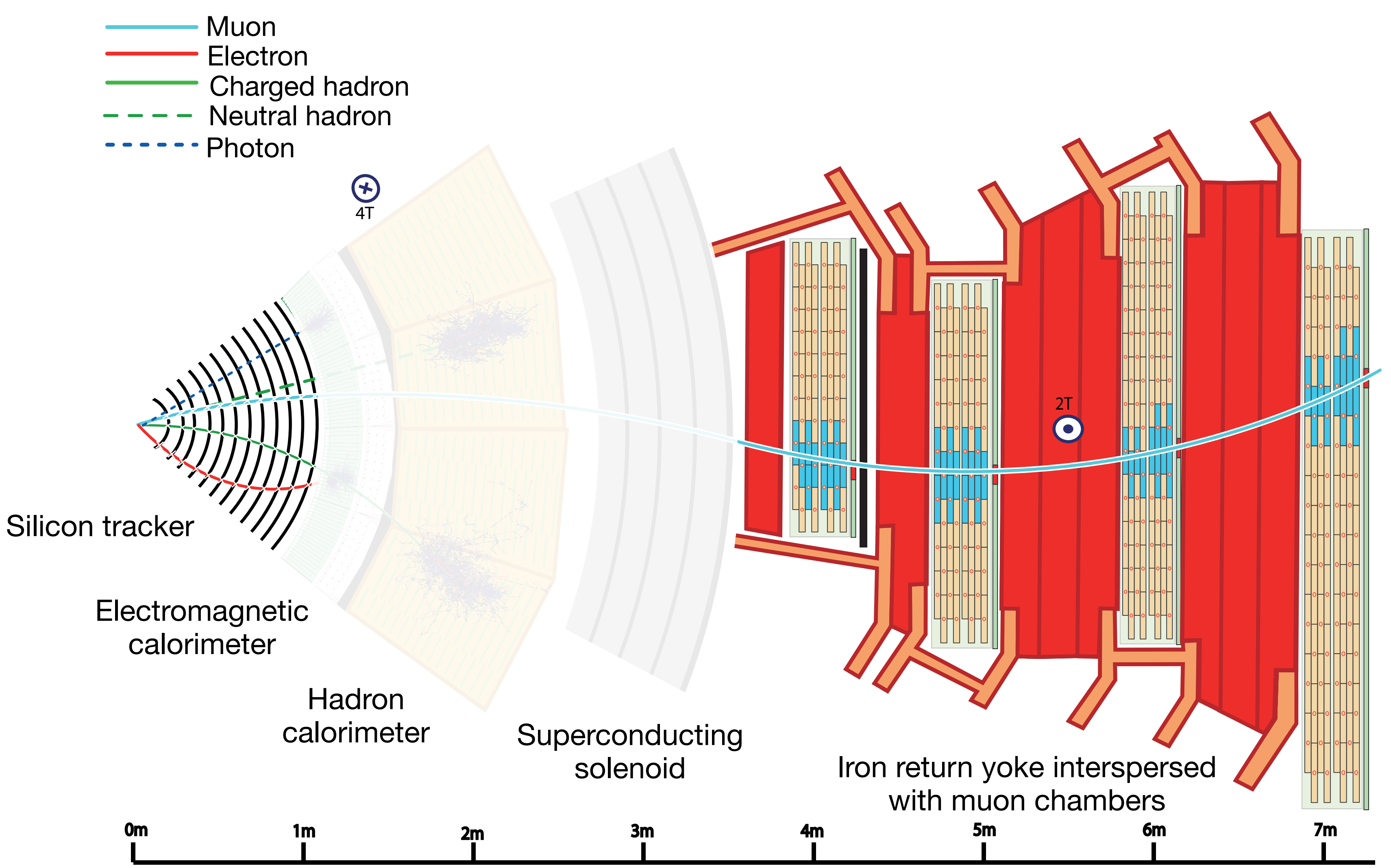




$$\varepsilon = \frac{\text{probes passing condition}}{\text{all probes}}$$

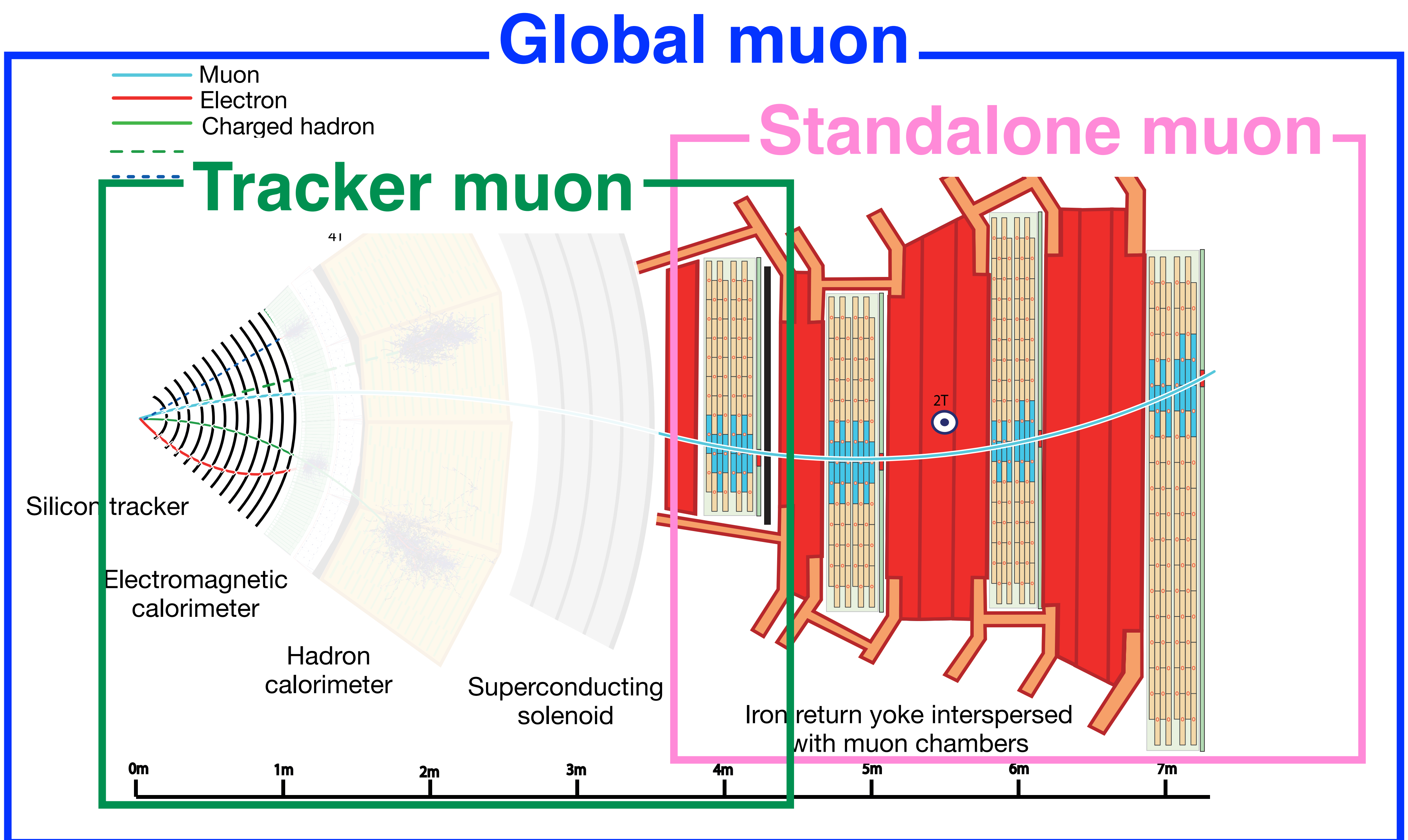
Muon systems in CMS

- Muons are measured in two subsystems in CMS
- The silicon tracker: very precise momentum determination but busy environment
- The muon chambers: very clean signal
- Together they give very precise and clean muon detection
- $p_T > 3$ GeV for $|\eta| < 1.2$, $p_T > 1.5$ GeV for $2.1 < |\eta| < 2.4$



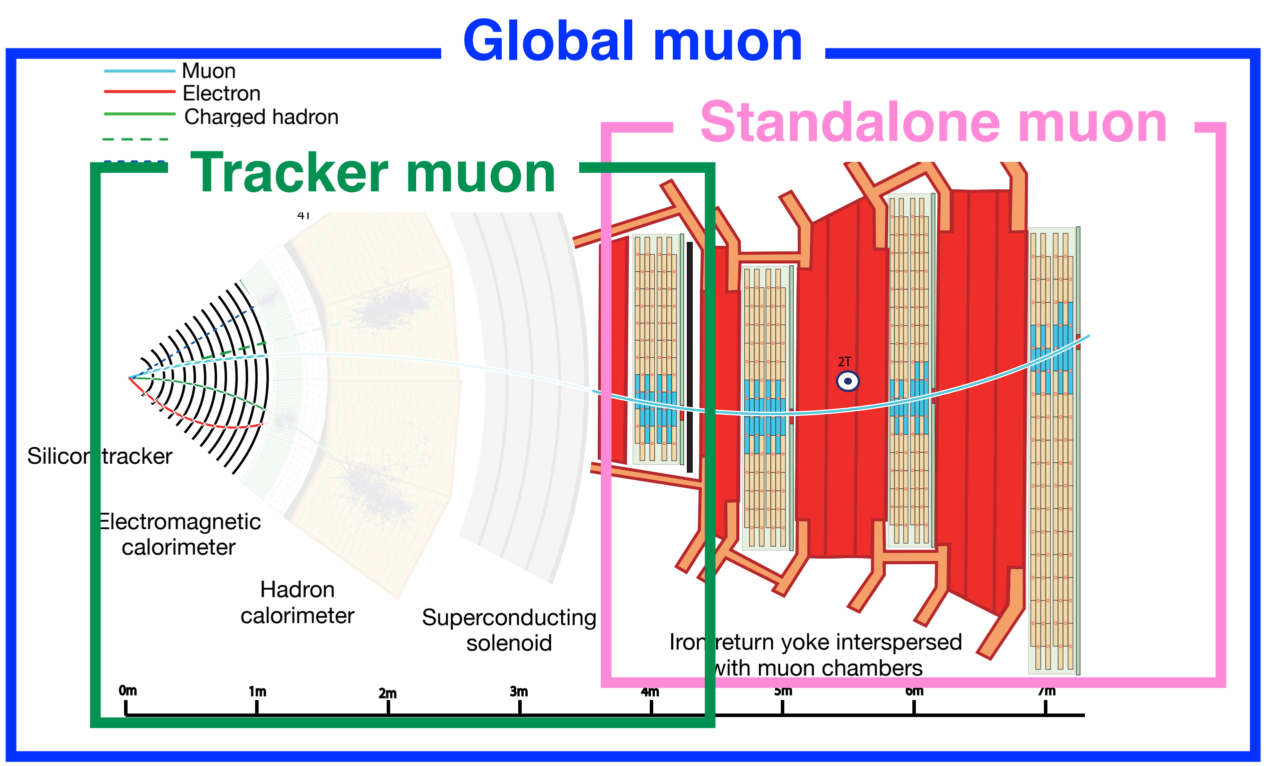
Tag-and-Probe in CMS

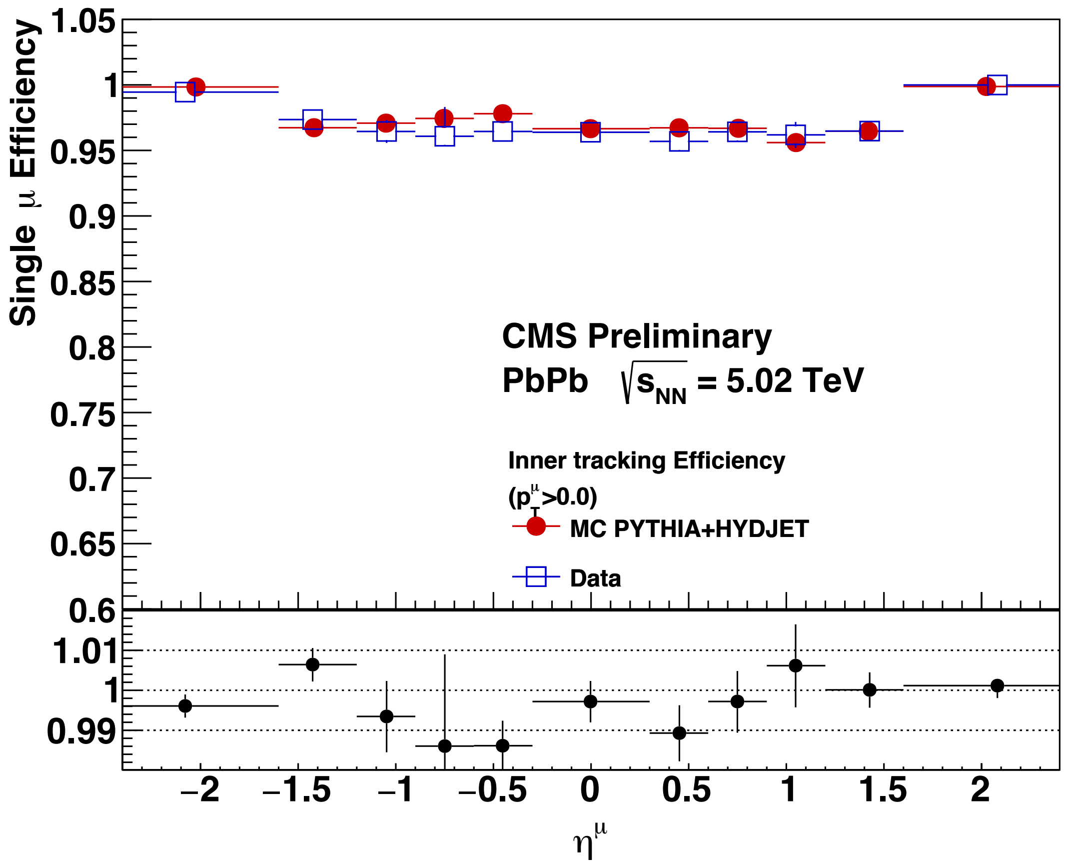
- Three types of muons are defined in CMS
- Standalone muons: reconstructed in the muon chambers
- Tracker muons: tracker + first layer in the muon chambers
- Global Muons: tracker + muon chambers
- Works in favor of efficiency measurements like Tag-and-Probe



Tag-and-Probe tracking efficiency

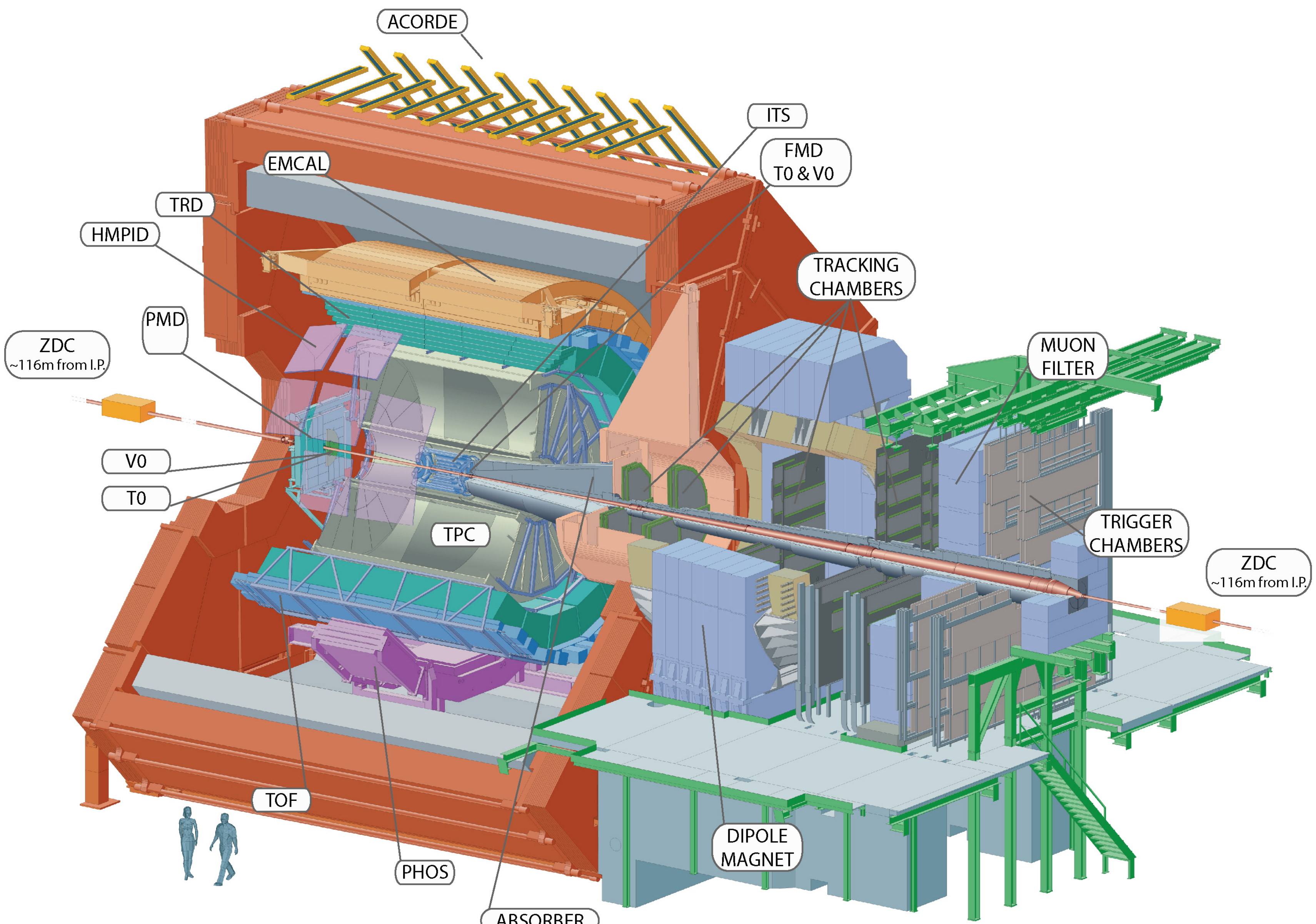
- For the tracking efficiency we can look at standalone muons and check if they are reconstructed in the tracker as well (Global muons)
- For 2018 PbPb run: very good efficiency that only depends on rapidity
- Small differences between data and simulation





The ALICE detector

- A Large Ion Collider Experiment optimized for collisions of heavy nuclei at ultra-relativistic energies
- Goal: studying the physical properties of the Quark-Gluon Plasma
- Made of many detectors: ensemble of cylindrical detectors in the barrel + a muon spectrometer in the forward region



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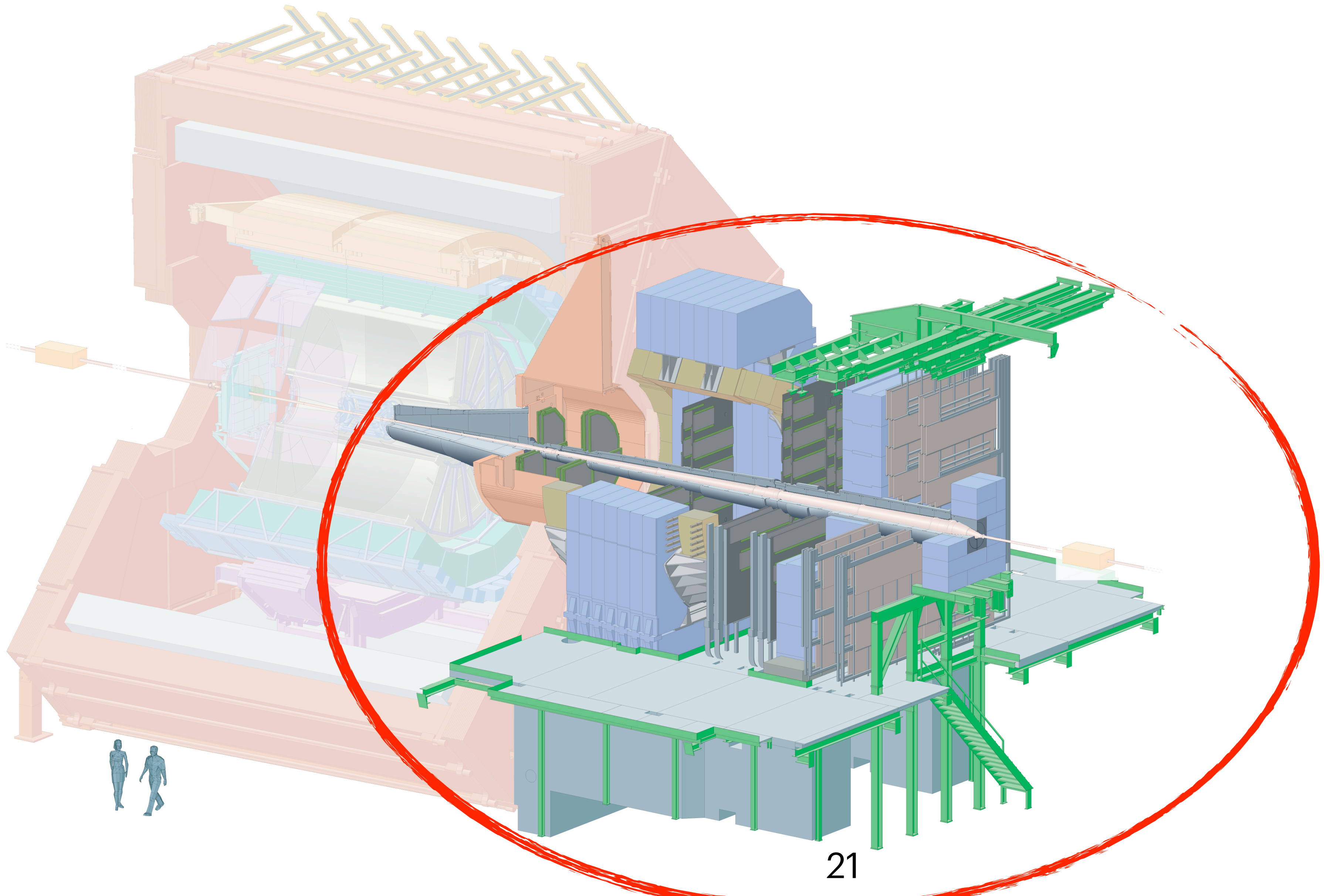
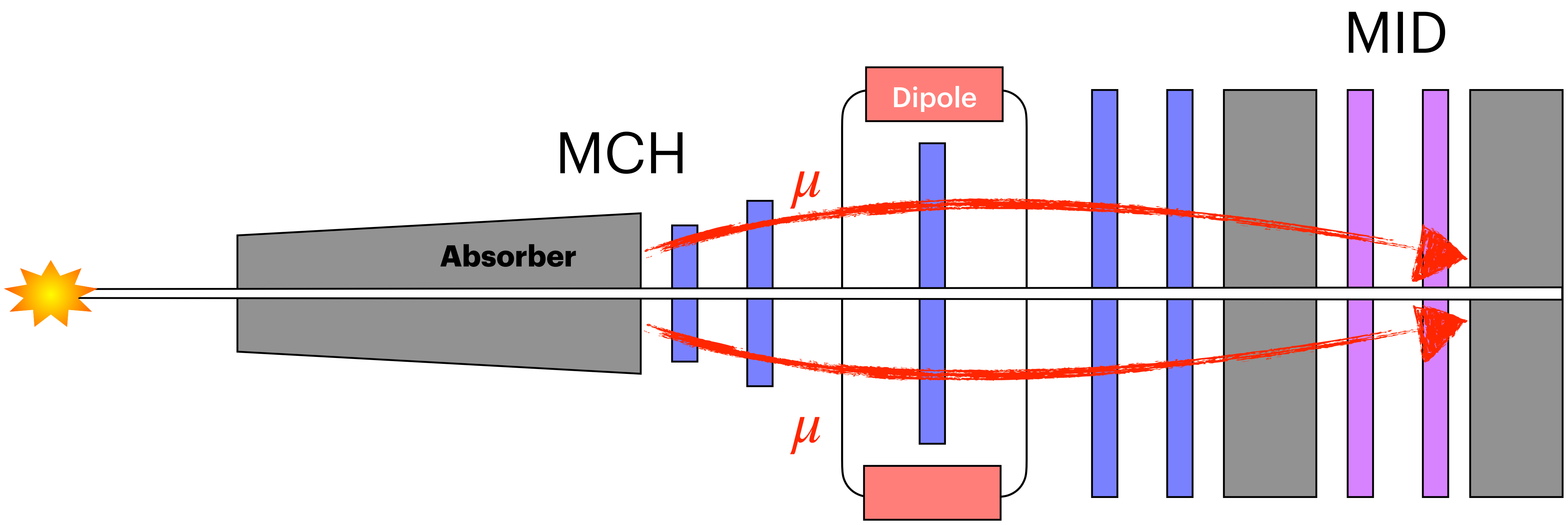


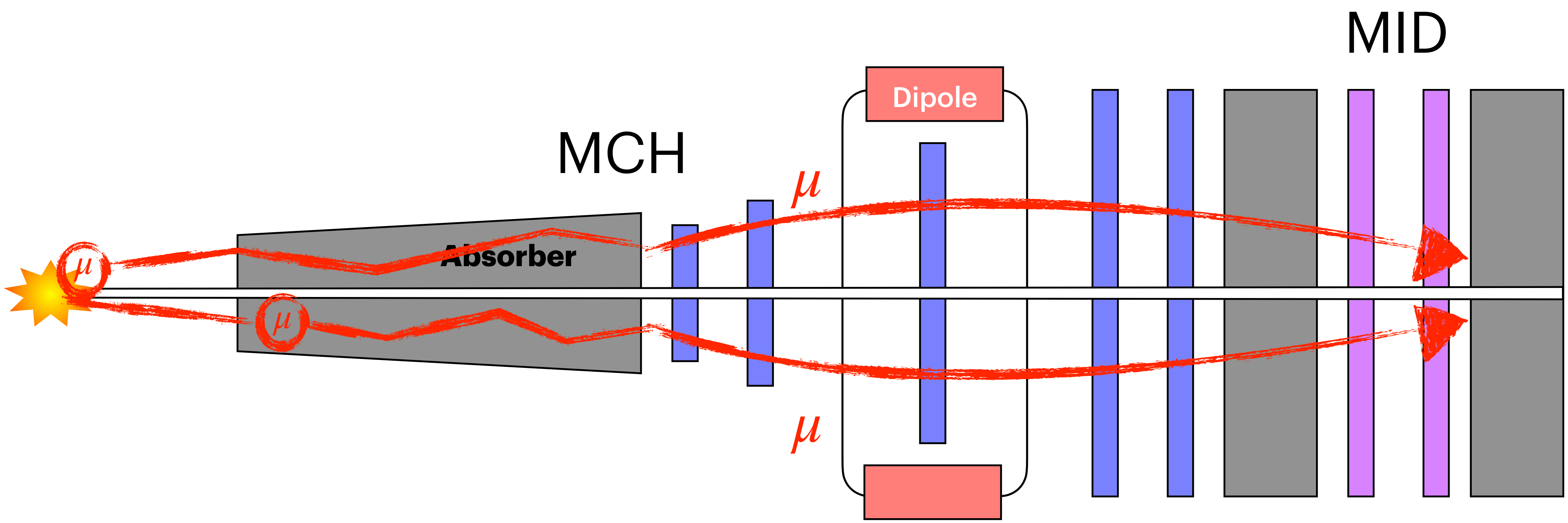
Muons in ALICE Run 2

- MCH: Muon CHambers, tracking stations
- MID: Muon ID, trigger stations
- Front absorber: suppresses particles except for muons
- Muon measurements in -4 < η < -2.5
- Resonances can be detected down to zero transverse momentum



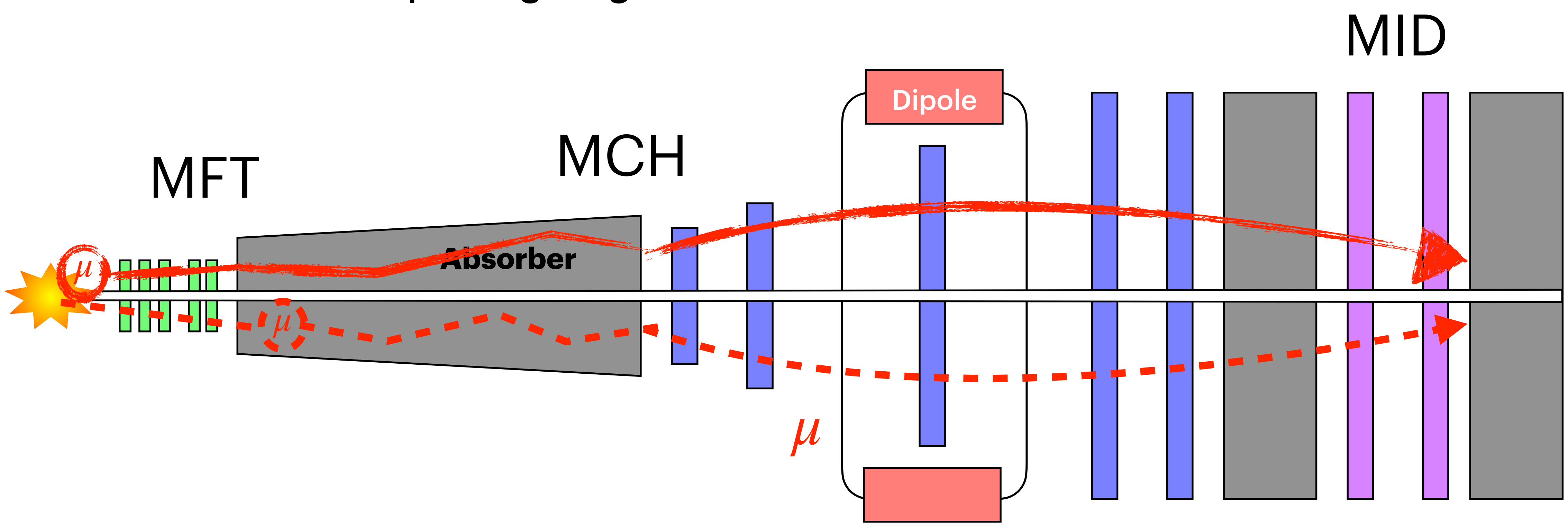
Muons in ALICE Run 2

- Muons can come from the interaction point or from decay in flight
- Limitations of the muon spectrometer:
  - High background from π/K decays
  - No secondary vertex reconstruction
  - Limited mass resolution



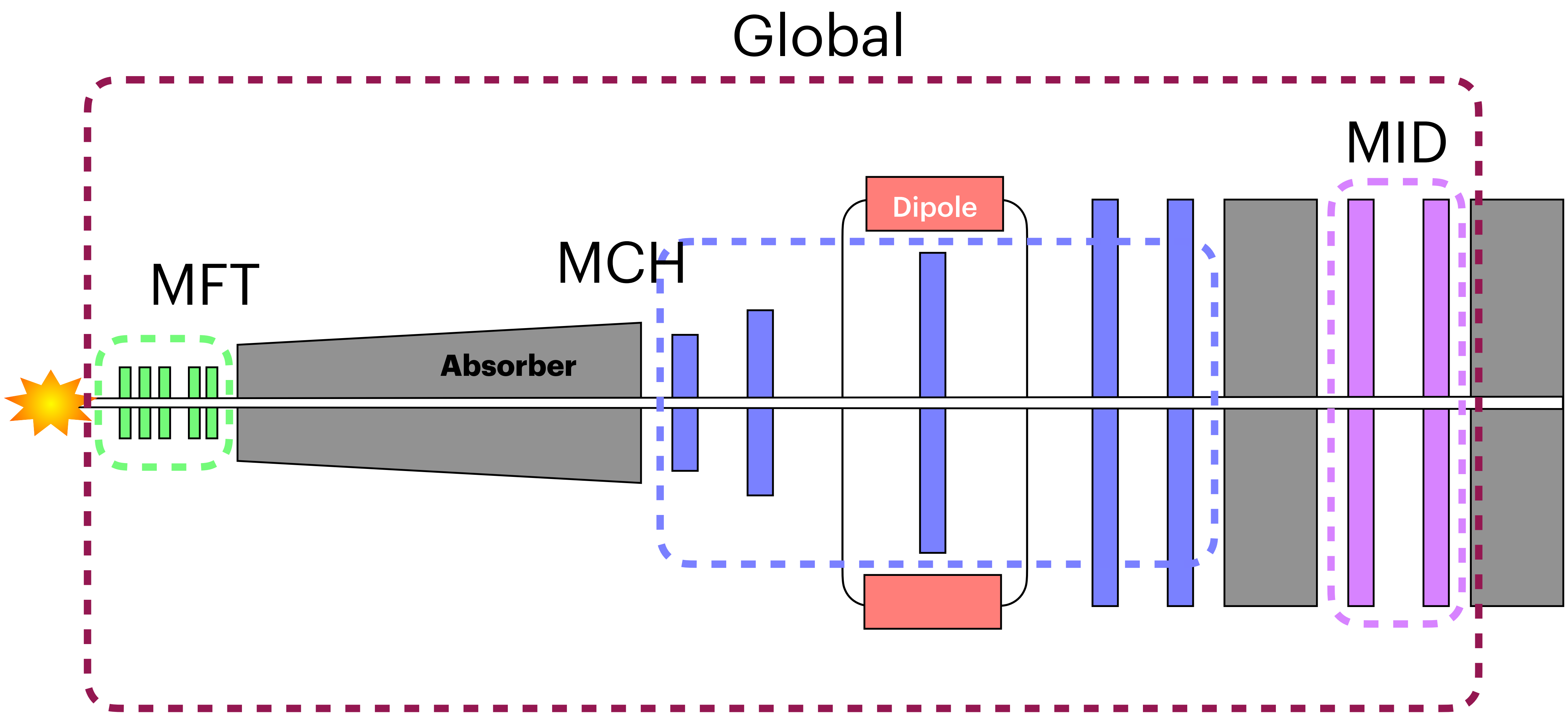
Muons in ALICE Run 3

- The Muon Forward Tracker is added for run 3
- Granular silicon detector placed in front of the absorber at 40 cm from the interaction point
- Improvements:
  - The S/B ratio
  - Precise determination of production vertex
  - Better dimuon opening angle resolution



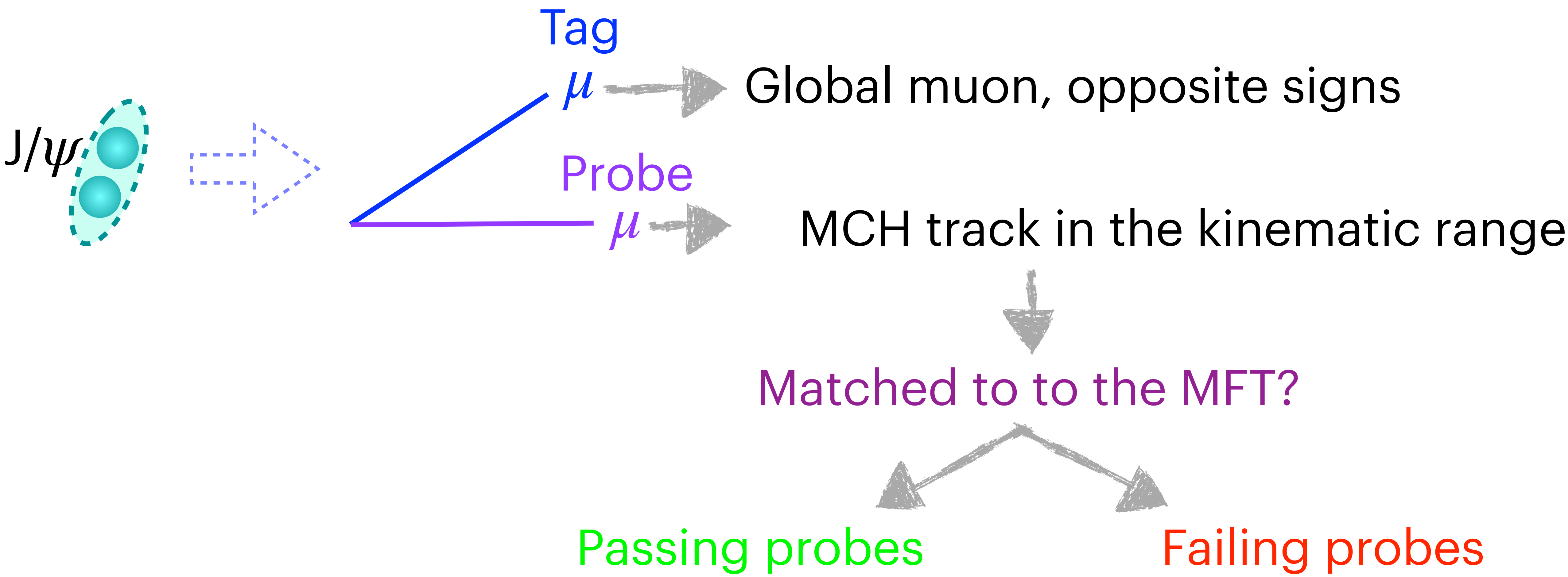
Tag-and-Probe in ALICE

- In Run 3 analyses will use global muons: reconstructed in the three subsystems (MFT, MCH and MID)
- An important part of the reconstruction: matching between MCH and MFT
- The efficiency is going to be calculated in simulation
- T&P studies are needed for calibration



The starting point

- For now we only have MC simulation
- Using the nonprompt J/ψ simulations in pp and PbPb



- The efficiencies are still very preliminary and need some work that affects muon measurements in general
- Main issue: fake matches between MFT and MCH detectors