WG1 GDR-QCD – Kick off meeting: Simple and Multiple interactions between Partons

Online

Collective behaviour in small systems

An experimental overview

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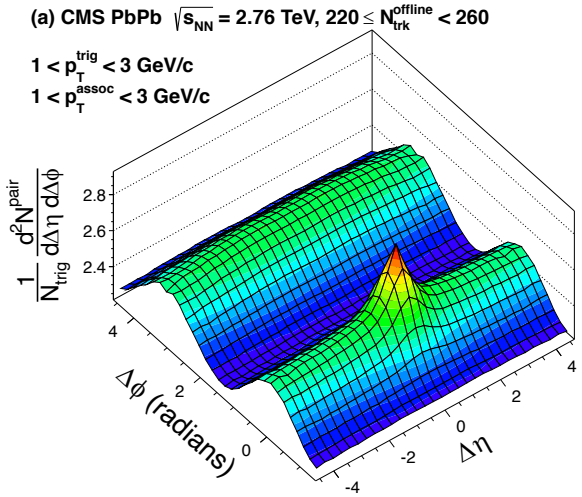
21/06/21

Discovery of the "Ridge"

- Discovery of the ridge
  - Long range correlation
  - Signature of collective flow!



PLB (2013) 06, 028

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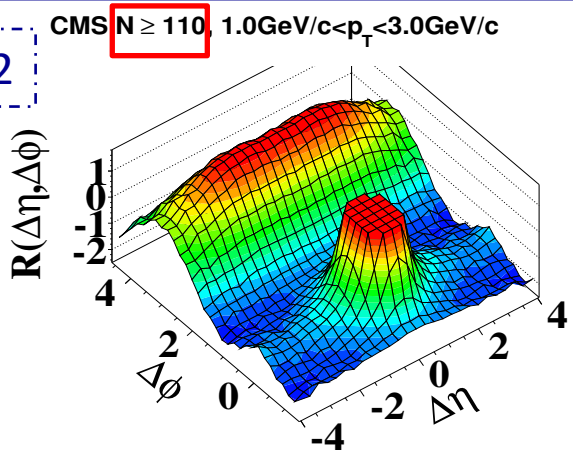
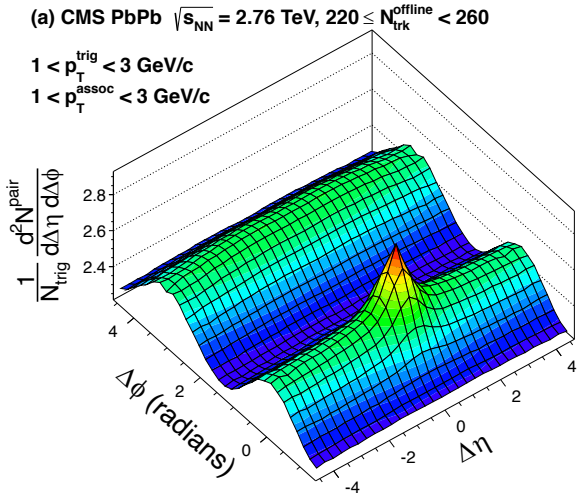
PRL (2016)116, 172302

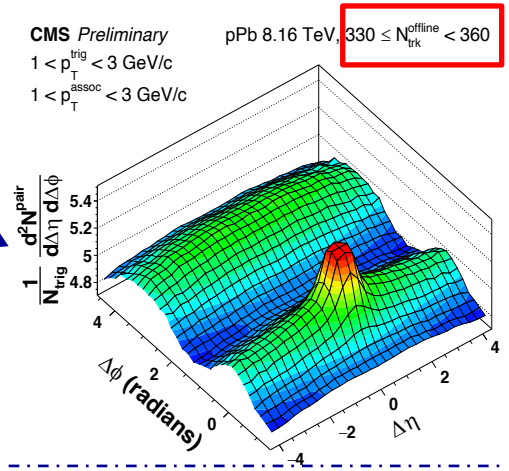
PLB (2016) 12, 009





PLB (2013) 06, 028

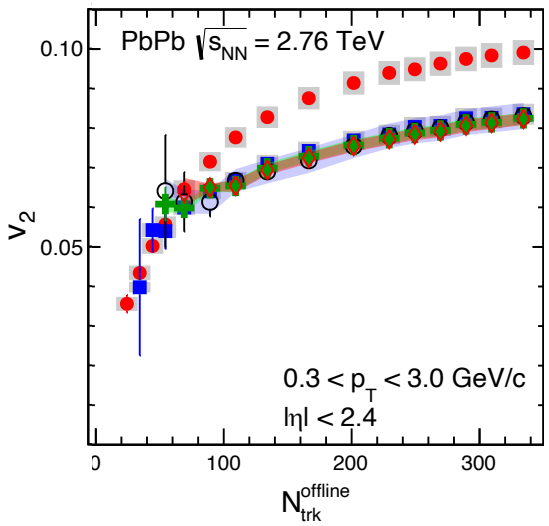
Ridge observed in high multiplicity events for small colliding systems



PRL (2018)120, 092301

Nature of the "Ridge"

- $v_2^{sub}\{2, |\Delta\eta|>2\}$
- $v_2\{4\}$
- $v_2\{6\}$
- $v_2\{8\}$
- $v_2\{LYZ\}$



PLB (2016) 12, 009

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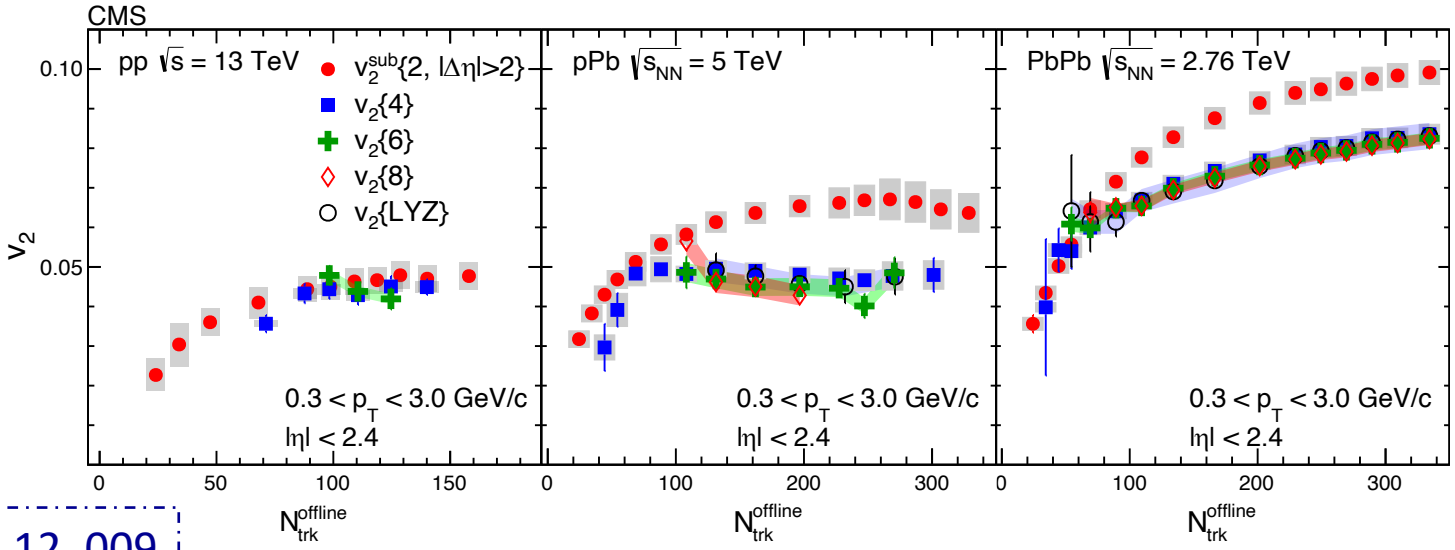
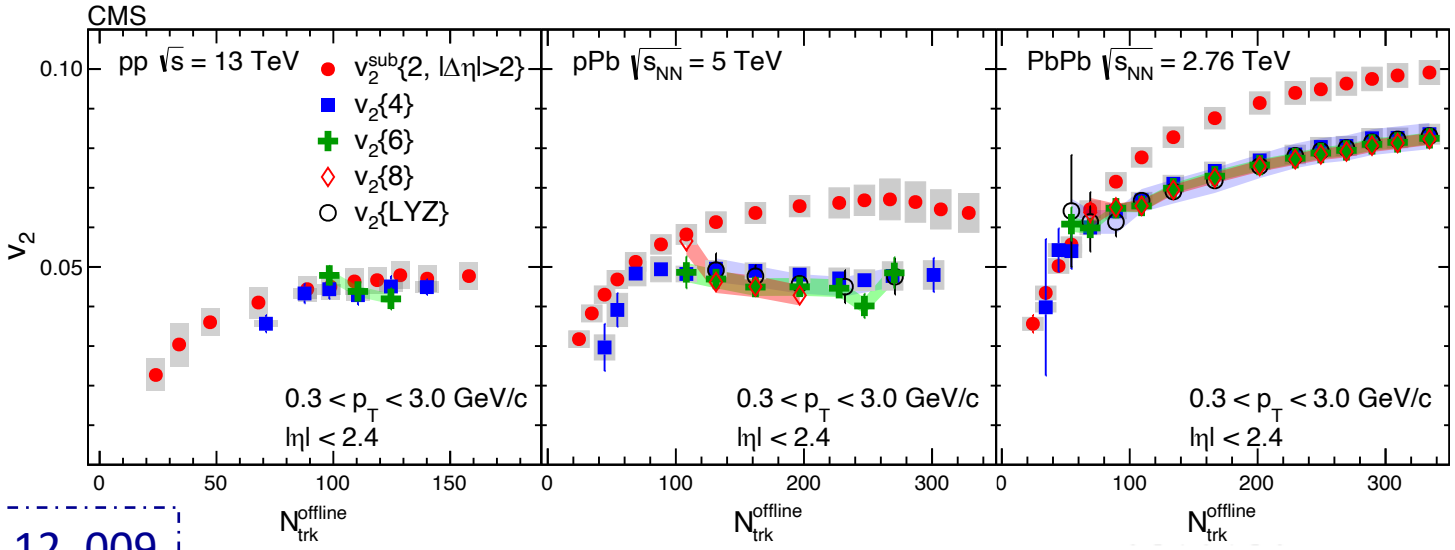


PLB (2016) 12, 009

- **Collective nature**
  - Multi-particle correlation
    - Rooted in the early stage of the collision
  - Similar patterns

Nature of the "Ridge"



PLB (2016) 12, 009

- **Collective nature**
  - Multi-particle correlation
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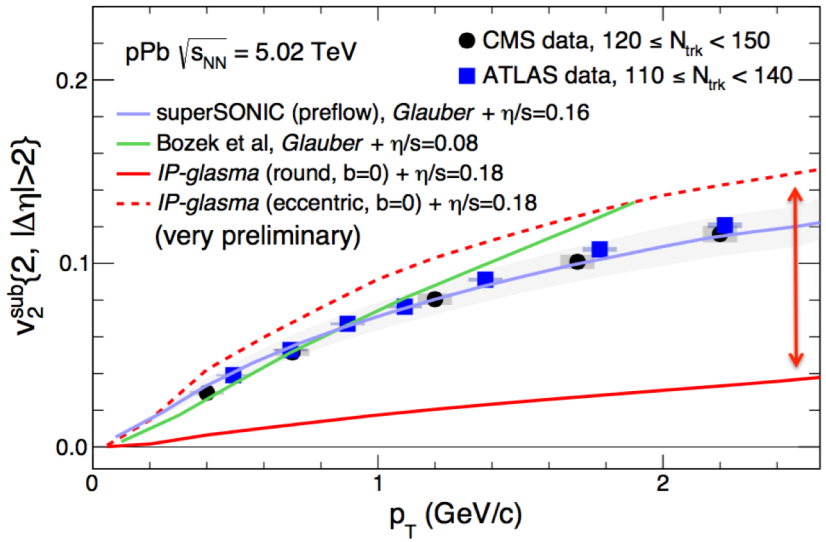
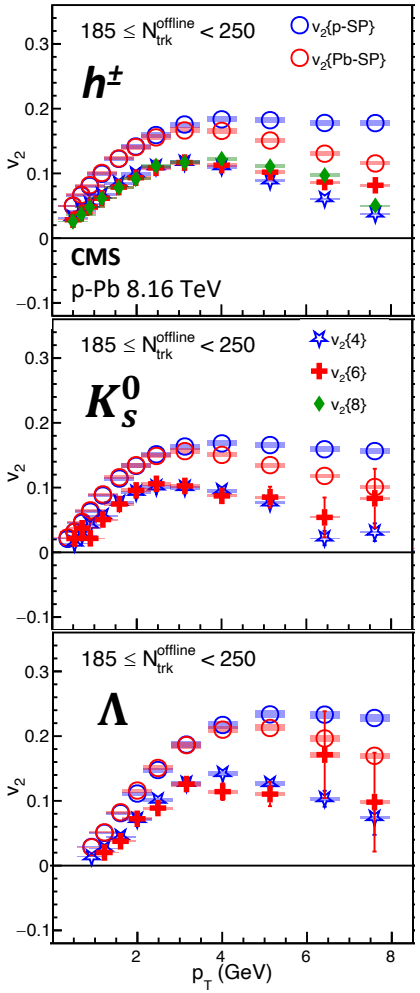
  - Similar patterns
- **Initial State (IS) matters**

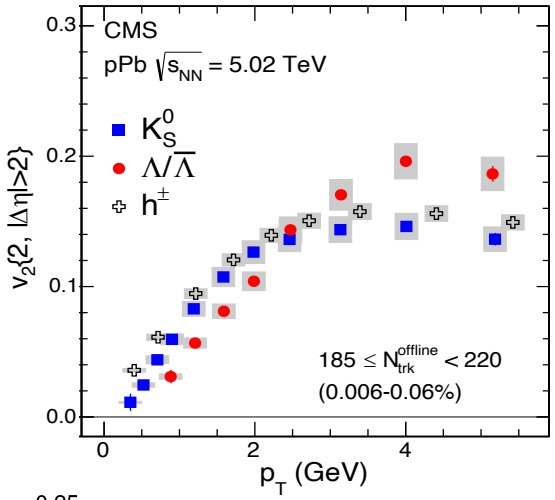


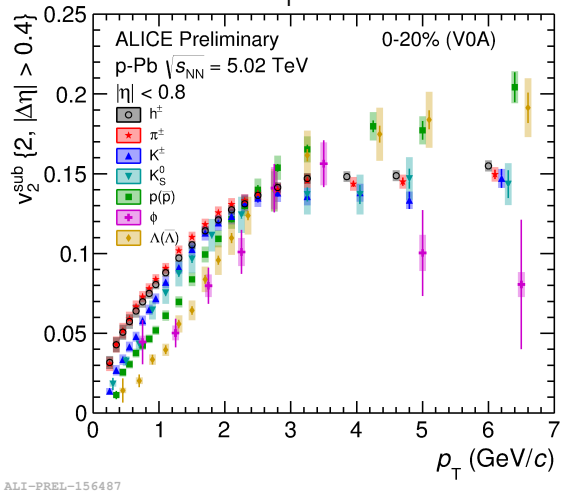
What about PID flow?

- Similarities also observed with identified particle



Mass dependence



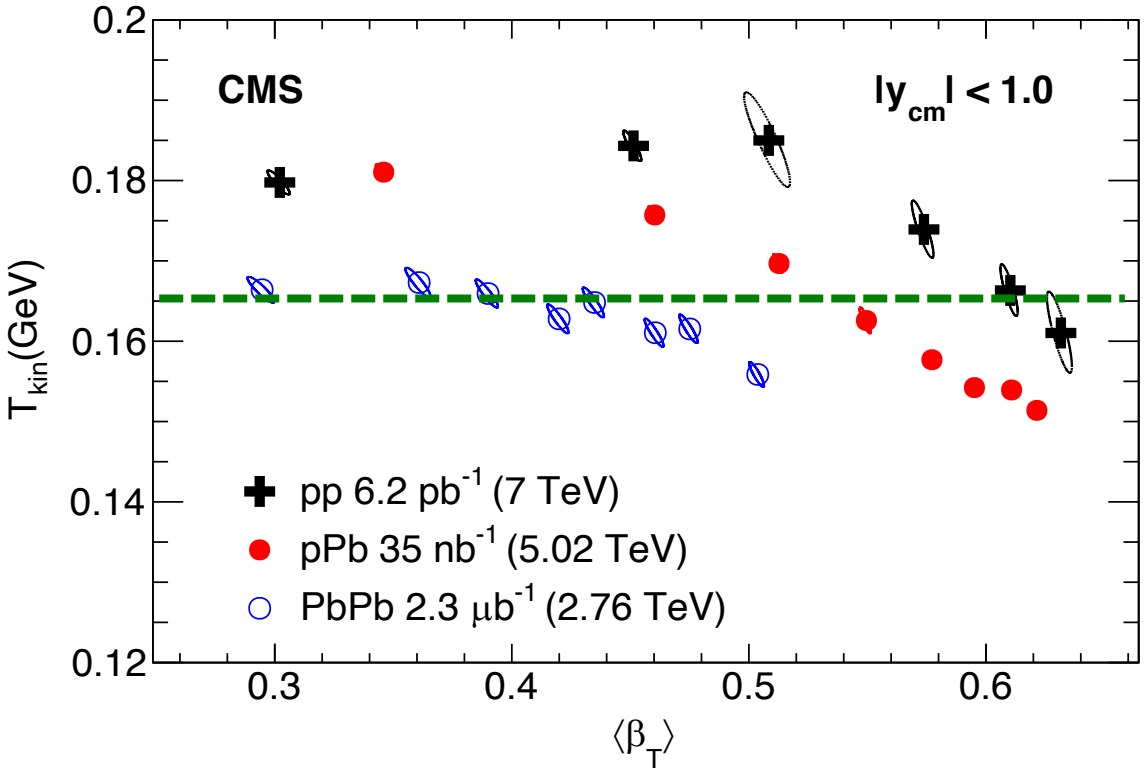


CMS-PAS-HIN-19-004

PLB (2015) 742, 200

Radial flow

- Using V^0
- Heavier particle spectra
  - Steeper as a function of multiplicity
  - Stronger boost
- Quantify with model dep. study
  - Blast wave fit

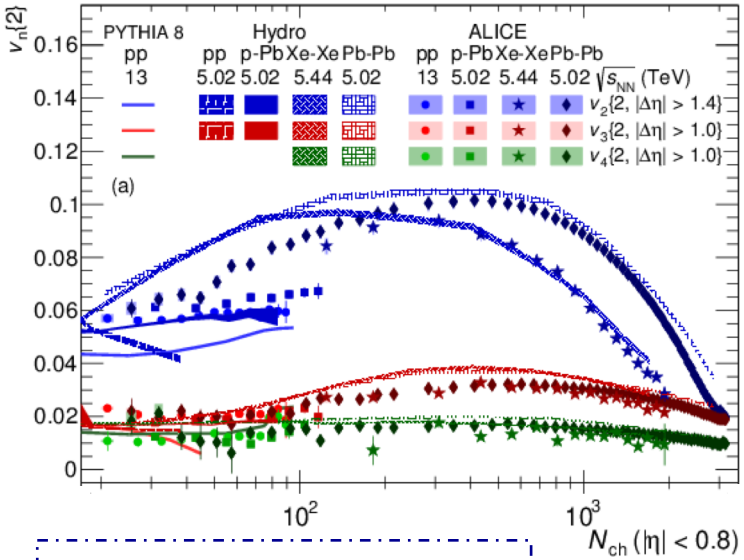


For same multiplicity ⟹ T_{kin} similar and $\langle\beta_T\rangle$ stronger

Smaller system are denser/more explosive

Common paradigm for all?

- Some continuity are observed as a function of multiplicity
  - Flow



PRL (2019)123, 142301

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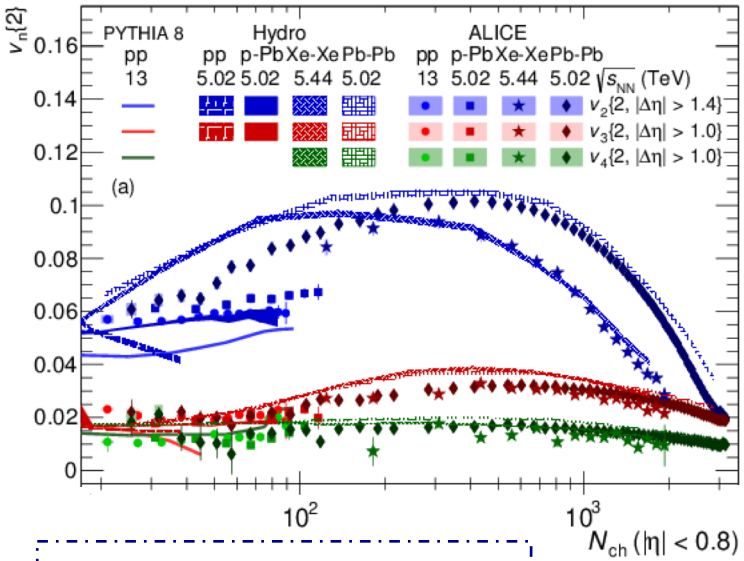
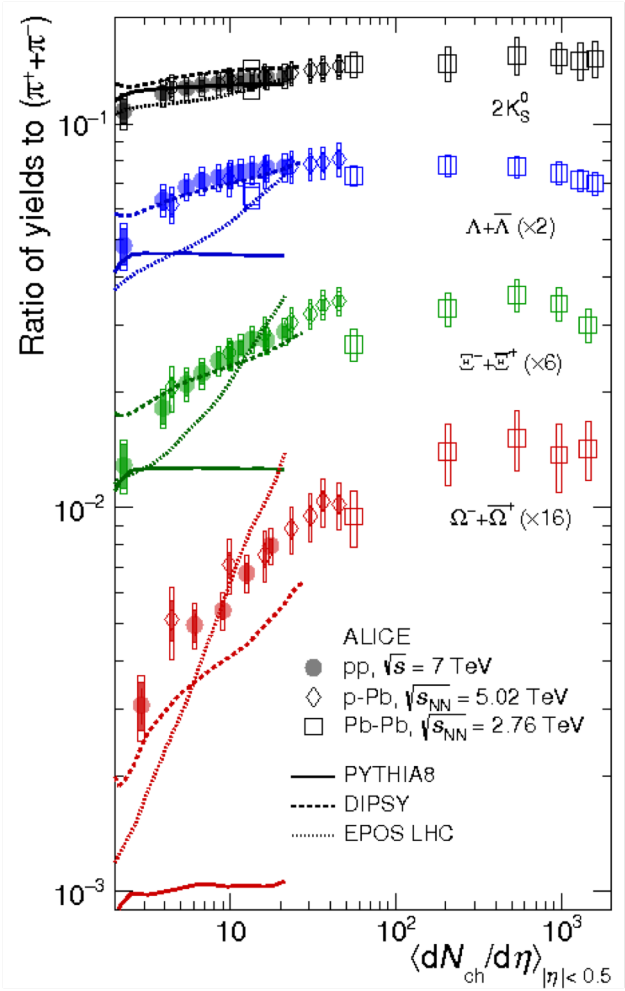


PRL (2019)123, 142301

  - Strangeness enhancement

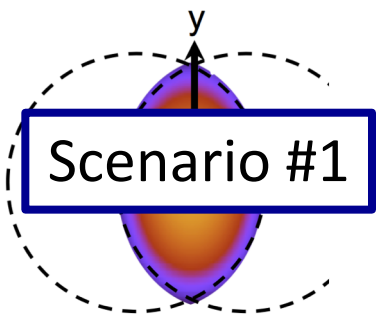


Nature Physics (2017)13, 535-539

How to explain this?

Observed long-range correlations in η ⇨ Rooted in **intial/early** stage

PRC (2020) 101 021901

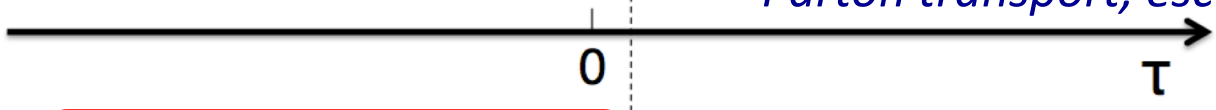


Scenario #1

Initial spatial ε_s **+ final** interactions

Hydrodynamics

Parton transport, escape



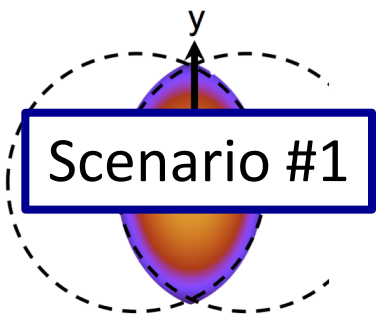
Scenario #2

Initial spatial ε_p
by initial interactions

How to explain this?

Observed long-range correlations in η ⇨ Rooted in **intial/early** stage

PRC (2020) 101 021901



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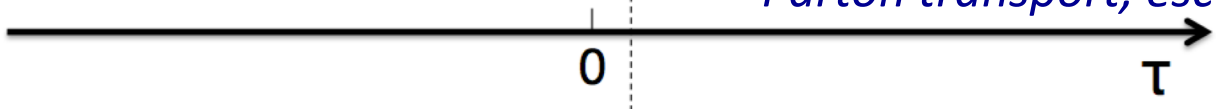


Scenario #2

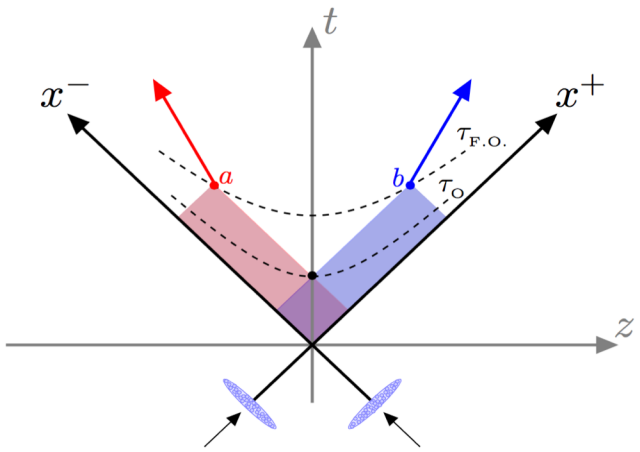
Initial spatial ε_p
by initial interactions

Do we also have a QGP-like scenario in small systems?

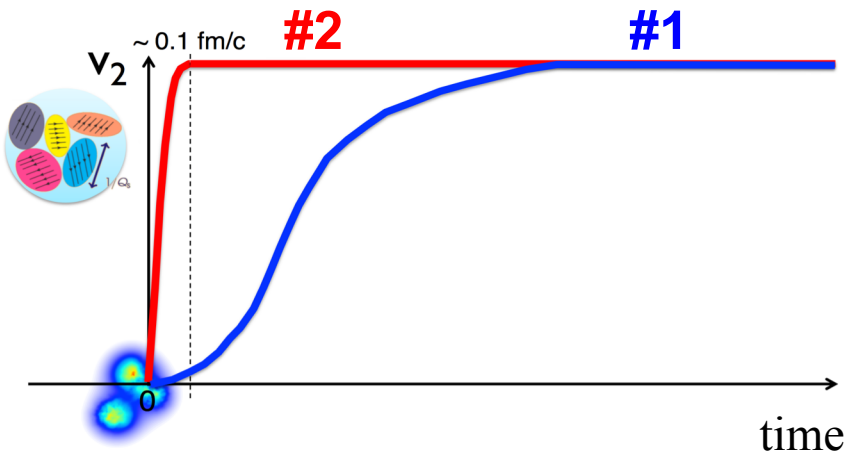
How to disentangle ?

A look at v_n evolution:

- Difference coming from the **birth time** of the correlation
- #1 is driven by geometry #2 **is not**
- In presence of QGP: one would expect #1 and hydro. behaviour



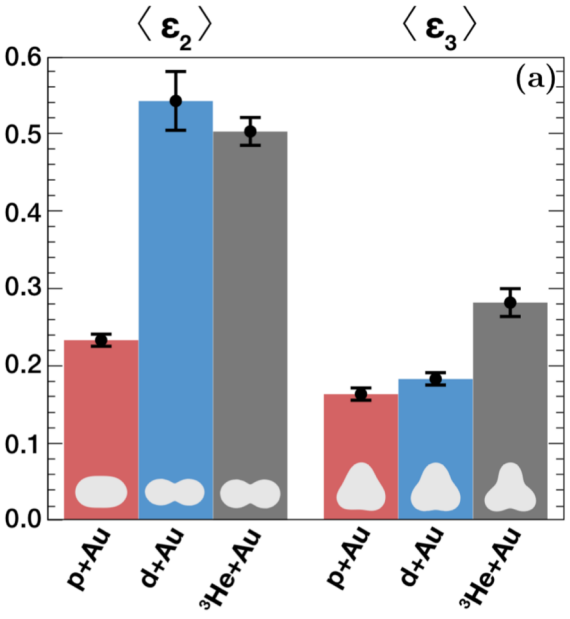
Int.J.Mod.Phys (2016) 01 16390002



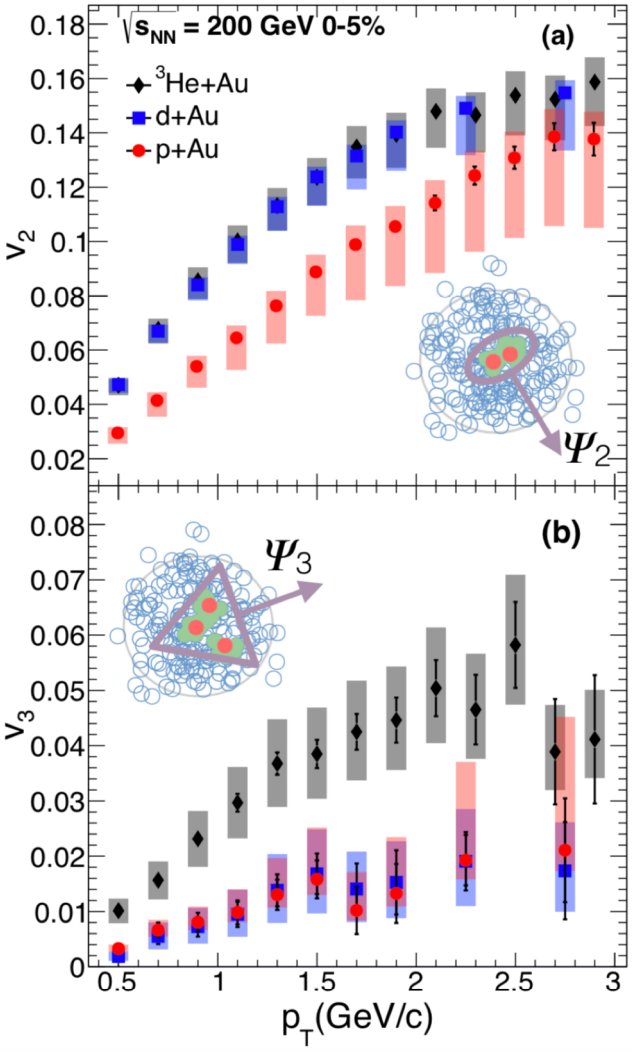
PRC (2020) 101 021901

What do the data tell us?

- If geometry driven, at first order: $v_n = k.\varepsilon_n$
  - ε_n is the eccentricity
- Results from RHIC = **Geometry driven!**



Nature Physics (2019) 15 214-220

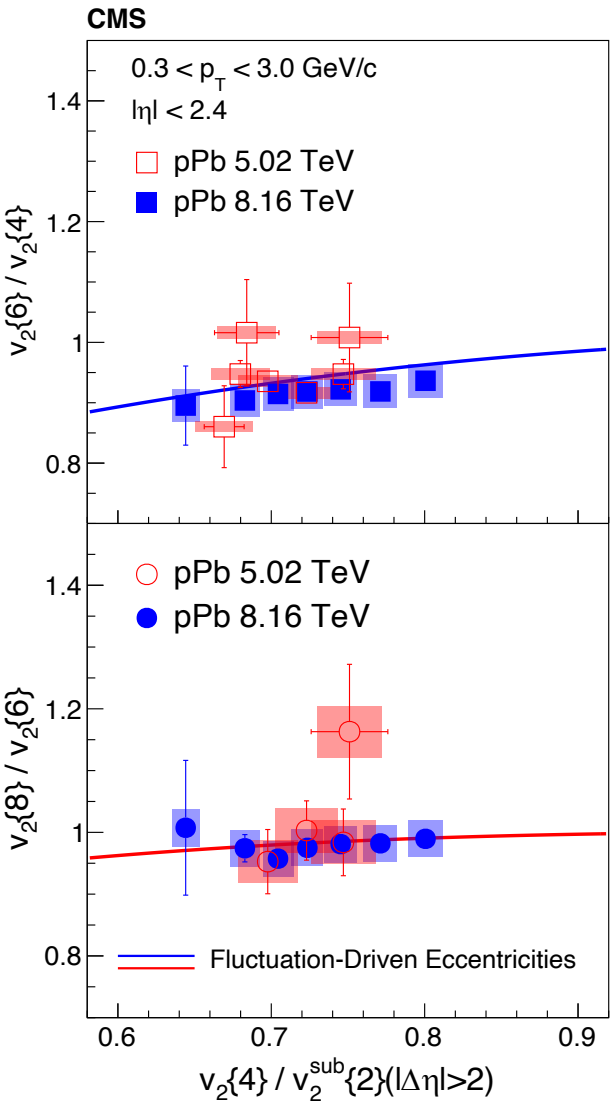


Geometry driven phenomena: LHC

PRC (2020) 101 014912

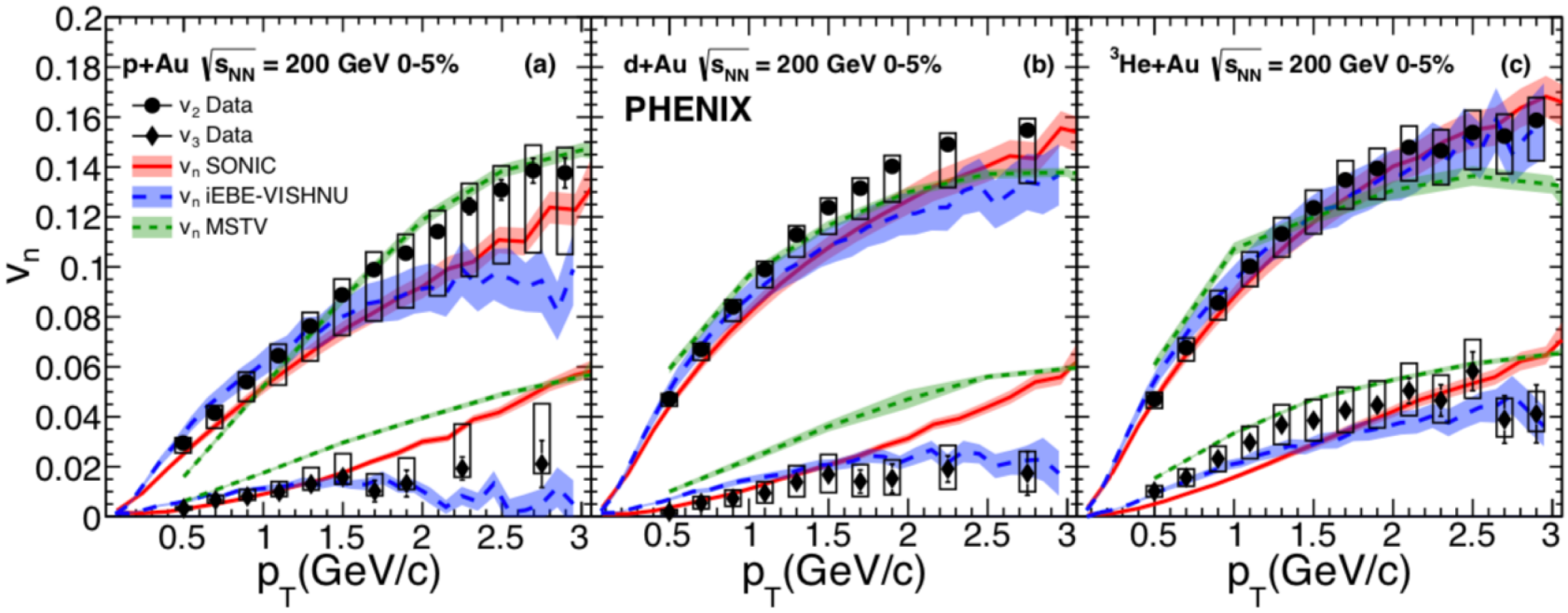
Eccentricity fluctuations are universal

- Geometry driven phenomena
- Consistent with RHIC



Hydro. description in small systems

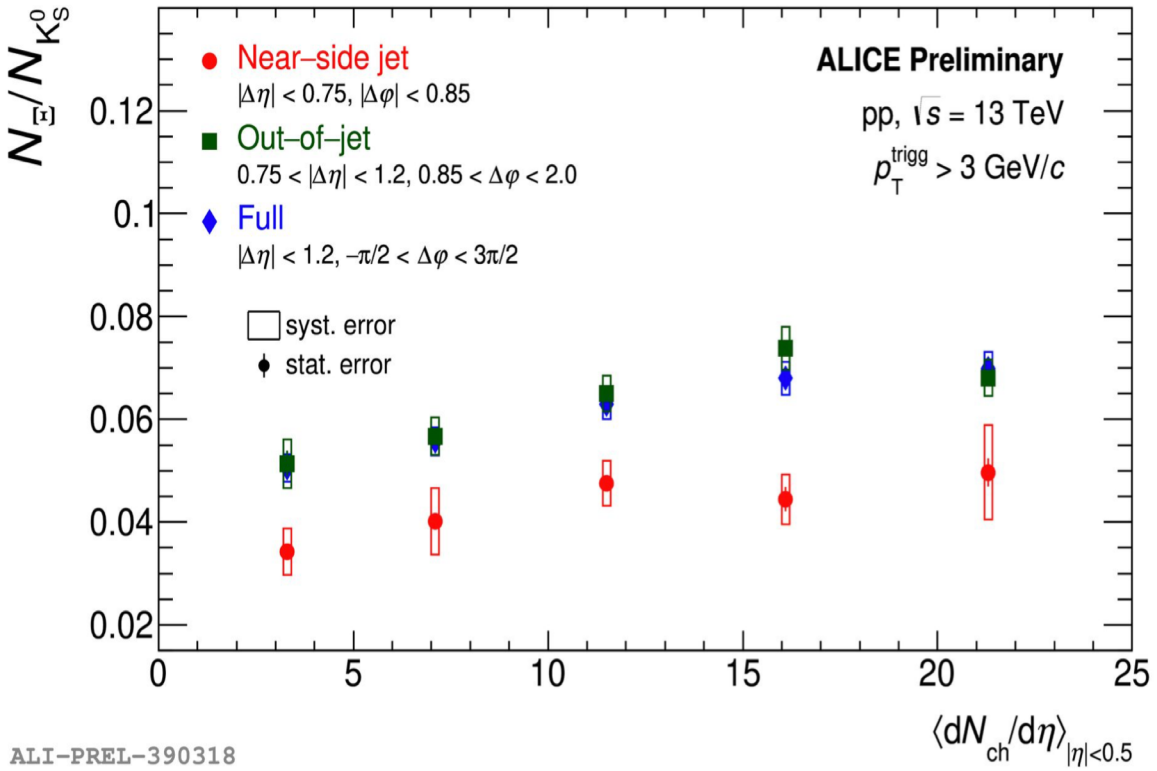
- Hydro. models seems to reproduce the data
  - Favour models which include a droplet of QGP

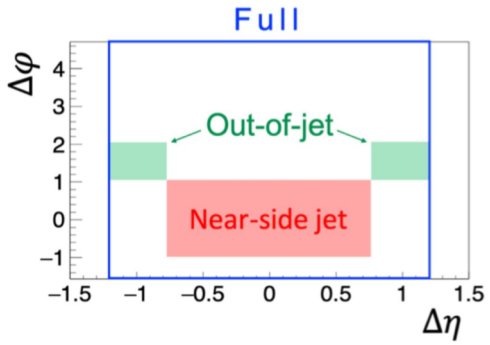


Nature Physics (2019) 15 214-220

Importance of the UE (I)
strangeness enhancement

- Out-of-jet dominant contribution
  - Dominant contribution from soft processes

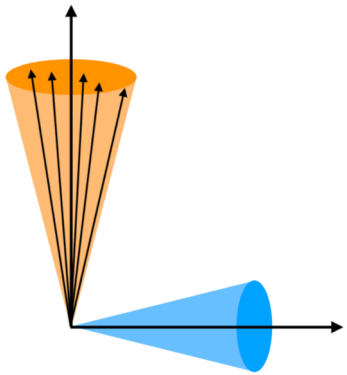




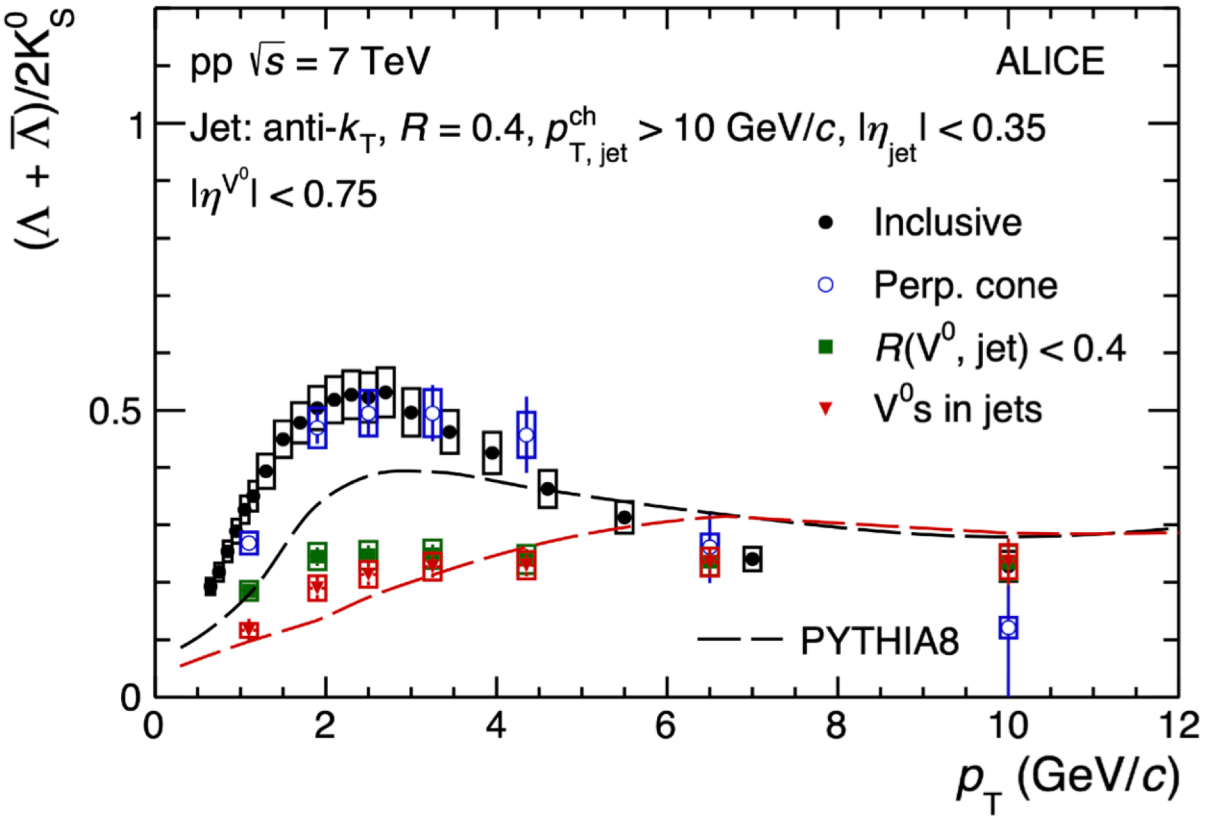
Importance of the UE (II)
strangeness enhancement

- Small relative contribution from jet to strangeness prod.
  - UE dominant – role of MPI?

Jet region:
R ≤ 0.4

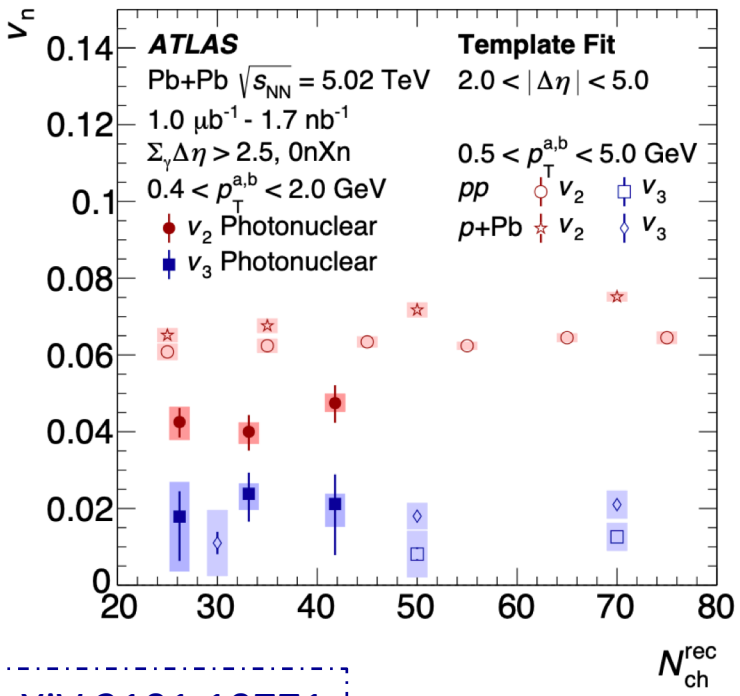


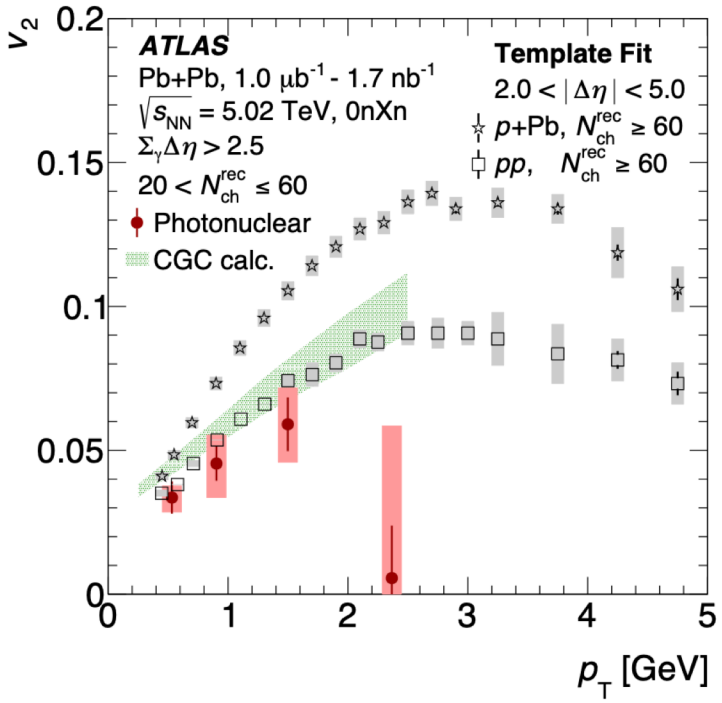
Underlying event:
Perpendicular cone



Toward the smallest colliding system

- Significant flow observed for γ–A collisions
  - Weaker than pp or pA
  - Similar p_T dependence
- γ oscillate into a vector mesons – importance of IS fluctuations





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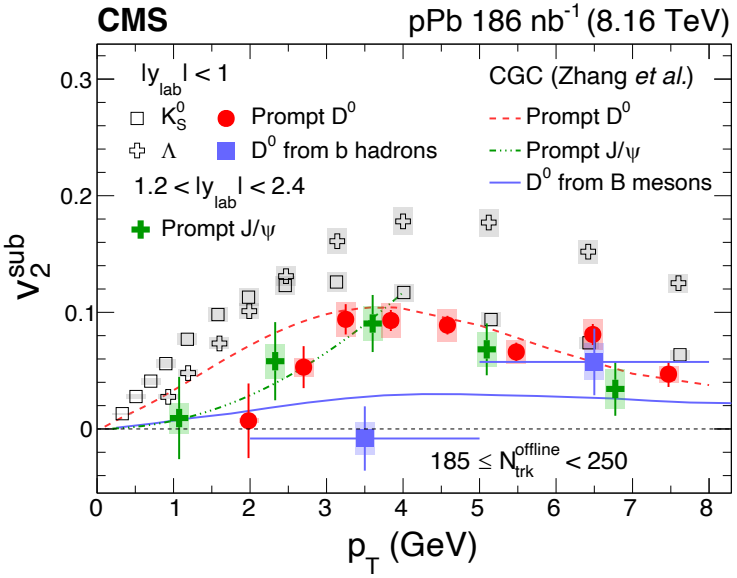
Interplay with the heavy sector

- Collective behaviour observed for heavy quarks
  - Magnitude surprisingly high



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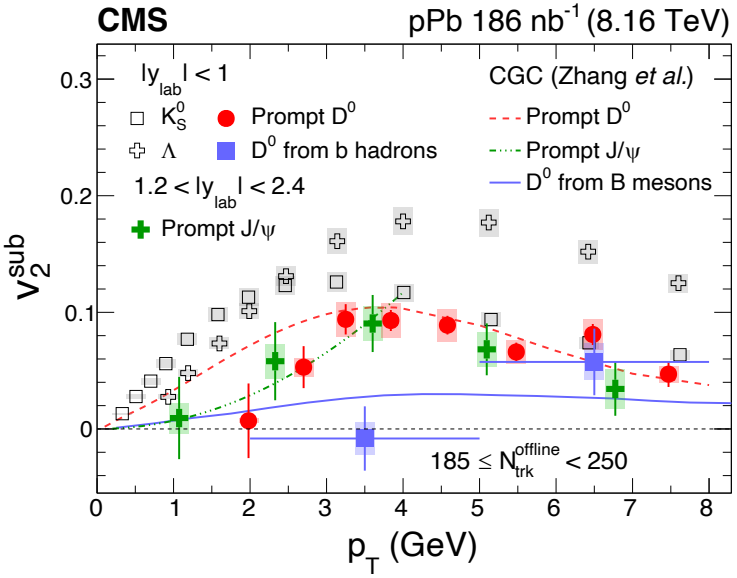

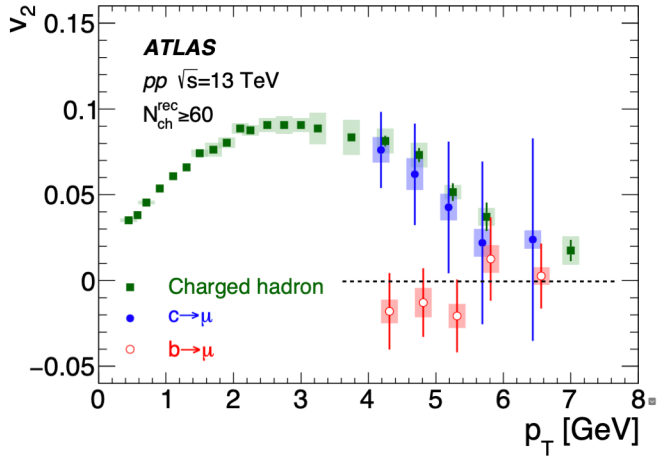

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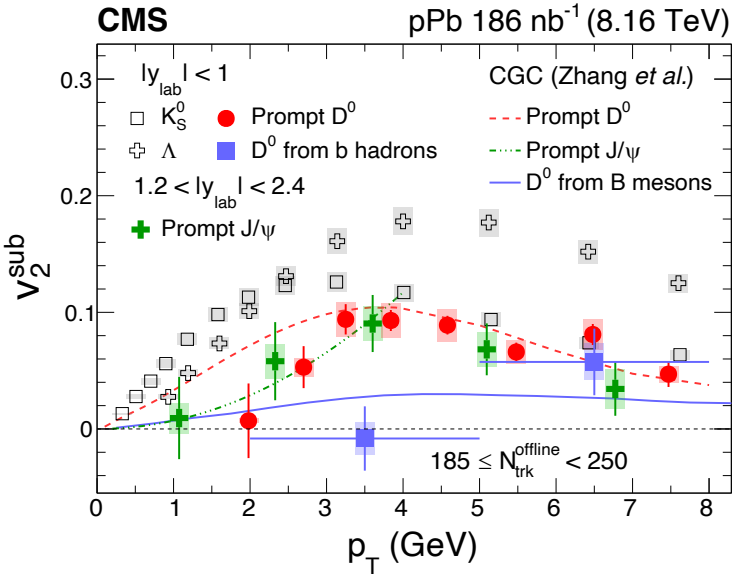

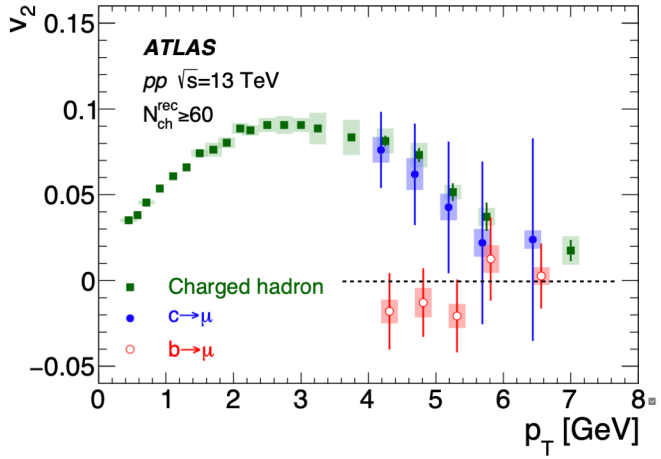

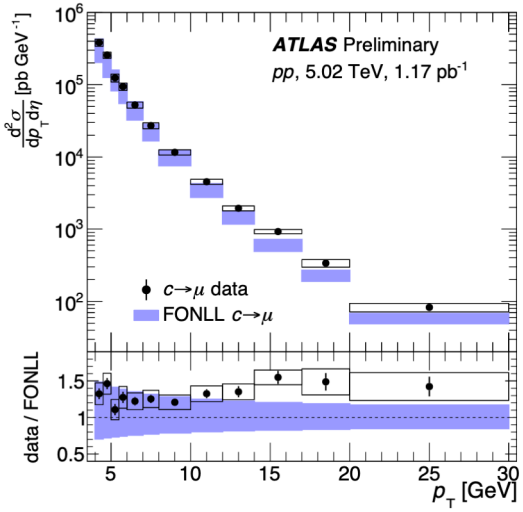

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    - bottom doesn't
  - Strong collectivity w/o p_T spectra modification

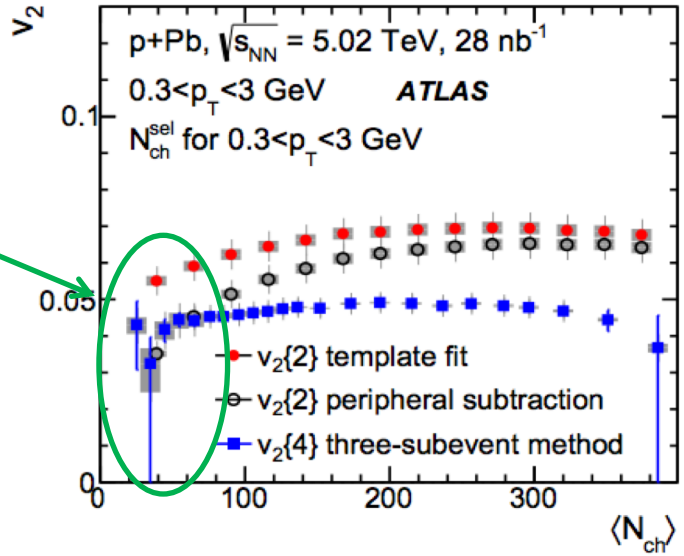
Wrap-up

- Inclusive soft probes can be described with scenario **#1** (using hydro)
  - The IS + fluctuation are important
  - **#2** can still play a role to describe the IS
  - Can we still have a unified picture for all systems?
- From strangeness studies: UE dominate in observed effects
  - Role of MPI
  - Is multiplicity the correct observable to look at?
- The interplay between the soft and hard sector need further investigation
  - Heavy flavour production (see next talk)
  - Energy loss

What's more?

There are still questions to answer at RHIC/LHC

- Rise and fall of collectivity
  - Onset?
    - multiplicity: down to 0?
    - system size: smaller than γ–A?
    - c.o.m energy: any minimun?
  - Behaviour at high multiplicity?



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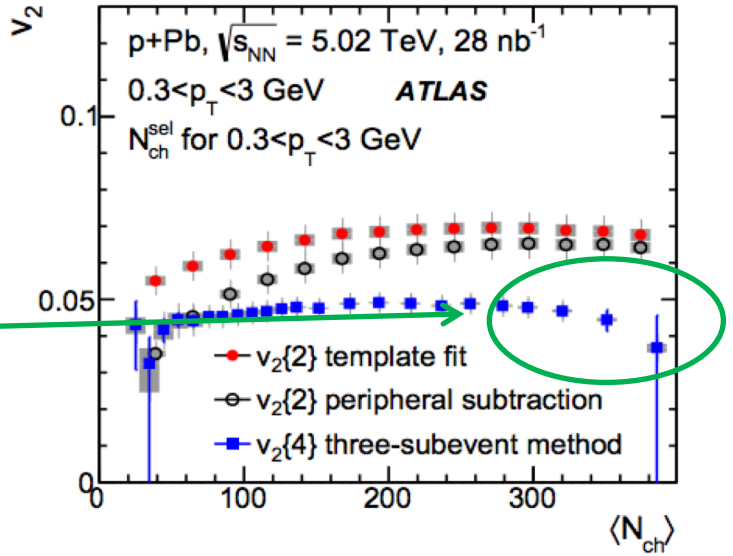

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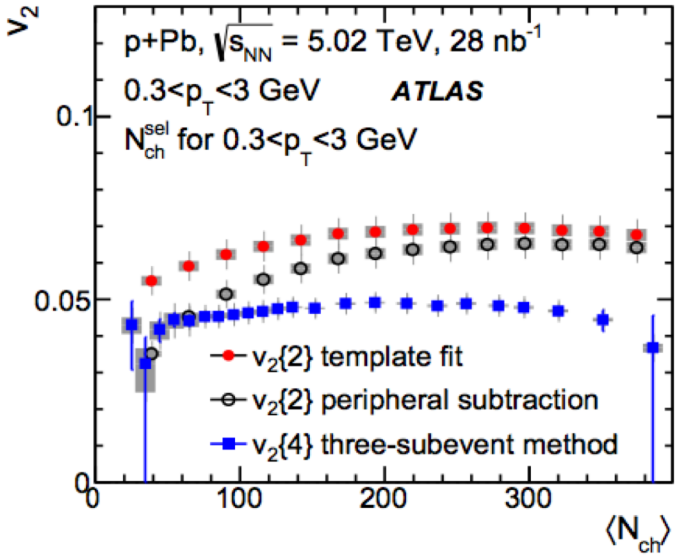


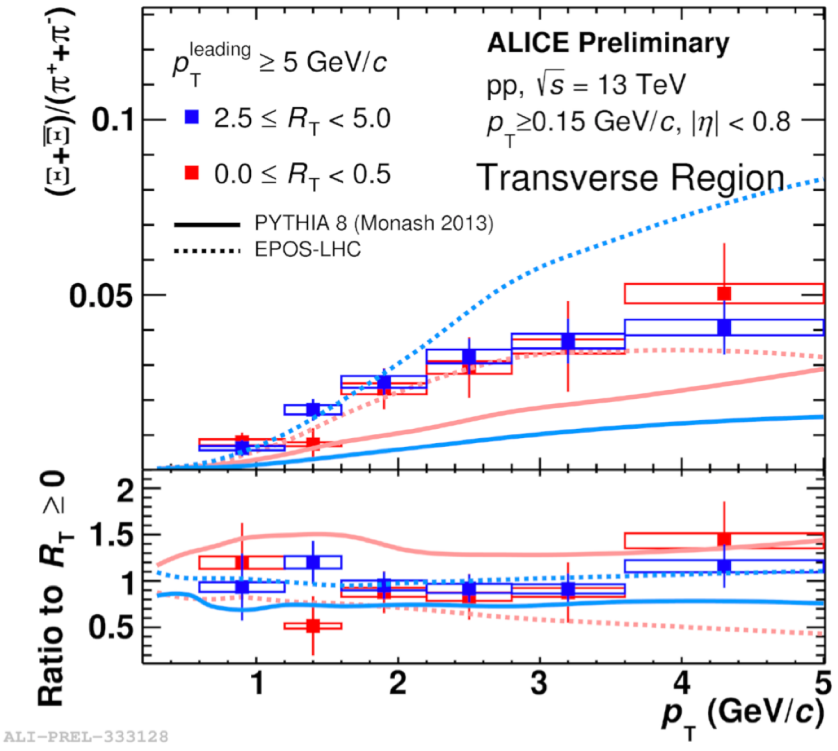
- Study the transition from p-p to A-A in details: intermediate ion size run (O-O)

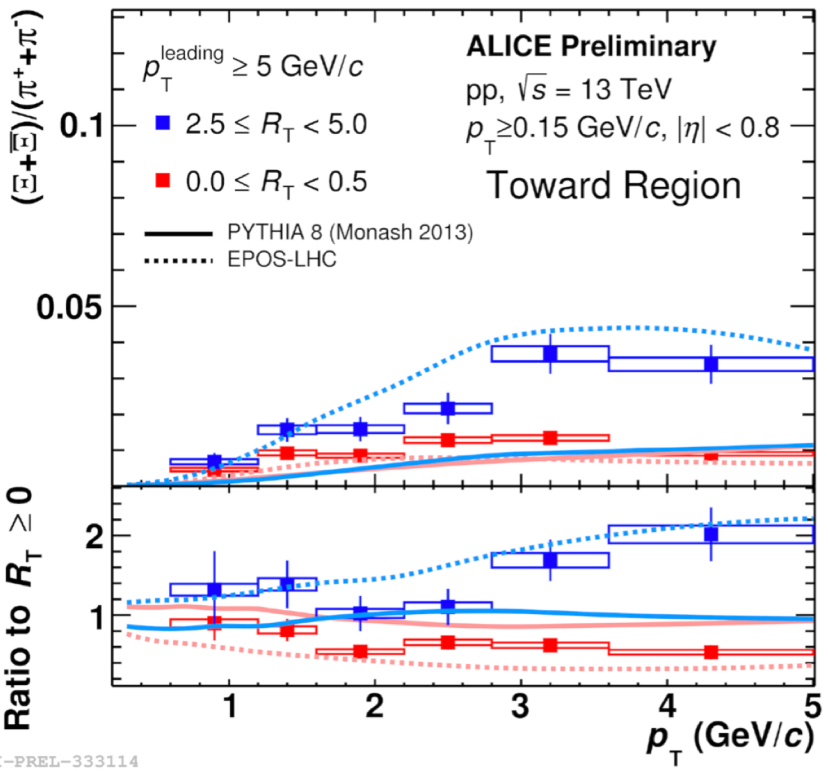
Outlook

- **Run-3 is coming**
  - More statistics and more differential measurements
  - O-O and p-O run should help to bridge the gap

- **Future accelerator and experiments**
  - FCC
  - EIC

Back-up


ALICE Preliminary
pp, $\sqrt{s}$ = 13 TeV
p_T≥0.15 GeV/c, $|\eta| < 0.8$
$p_T^{leading} \geq 5$ GeV/c
$2.5 \leq R_T < 5.0$
$0.0 \leq R_T < 0.5$
Transverse Region
PYTHIA 8 (Monash 2013)
EPOS-LHC
$(\Xi+\bar{\Xi})/(\pi^+ + \pi^-)$
Ratio to $R_T \geq 0$
p_T (GeV/c)
ALI-PREL-333128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