Reminder of experimental results* (discussion session)

Initial Stages 2023, June 22nd, 2023

Katarína Křížková Gajdošová
(CERN)

* I don't cover all the results ever measured, I made a (most likely biased) selection of most relevant measurements suited for the discussion.

Signatures of quark-gluon plasma

Collectively expanding

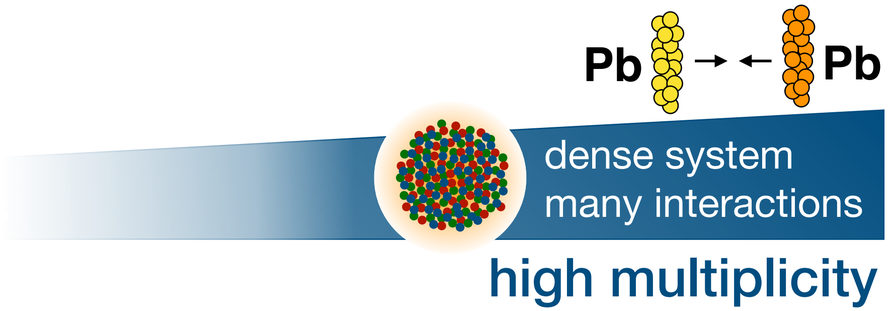
Signatures:
modification of momentum and angular distributions

Thermalised medium

Signatures:
modification of hadronisation
thermal photon radiation

Dense & deconfined medium

Signatures:
parton energy loss
quarkonia dissociation



What causes “flow” in small and/or dilute systems, and what can we learn from it?

Collectively expanding

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modification of momentum and angular distributions

Thermalised medium

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modification of hadronisation
thermal photon radiation

Dense & deconfined medium

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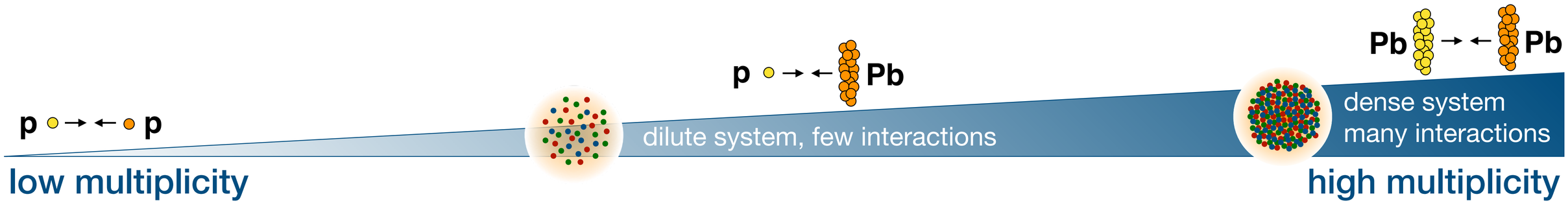
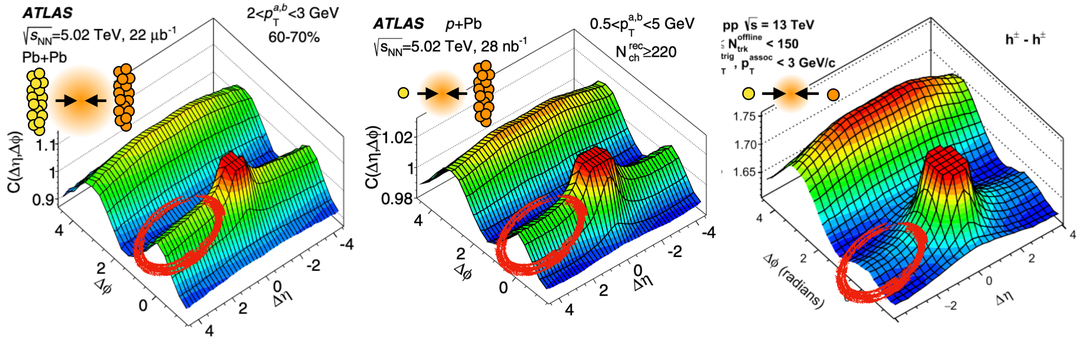


Many similarities with large collision systems

Similar features across collision systems of different sizes

Near-side long-range ridge, only different magnitude



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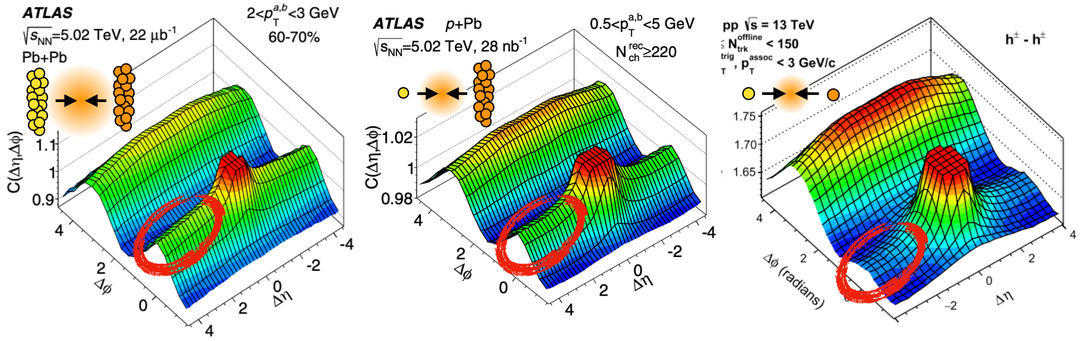
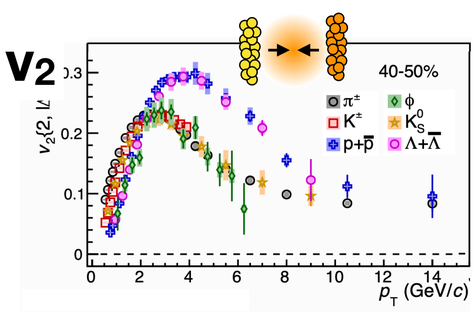
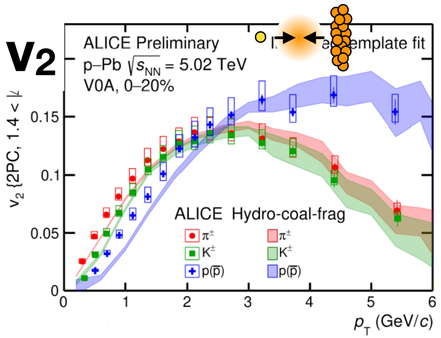
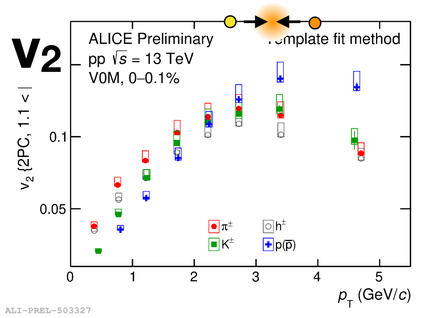


Patterns of partonic collectivity







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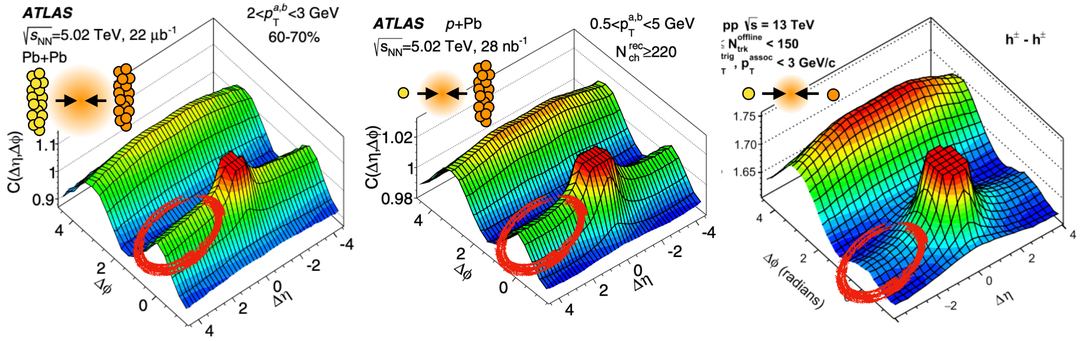

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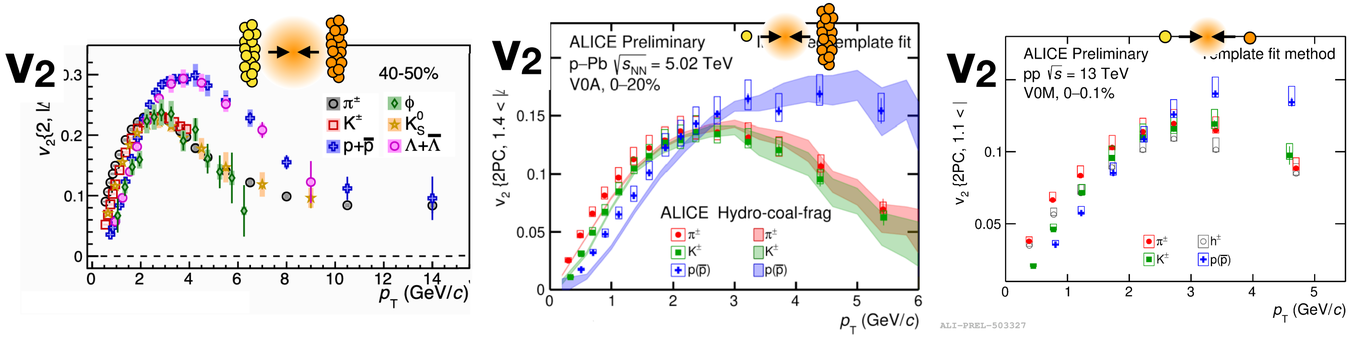
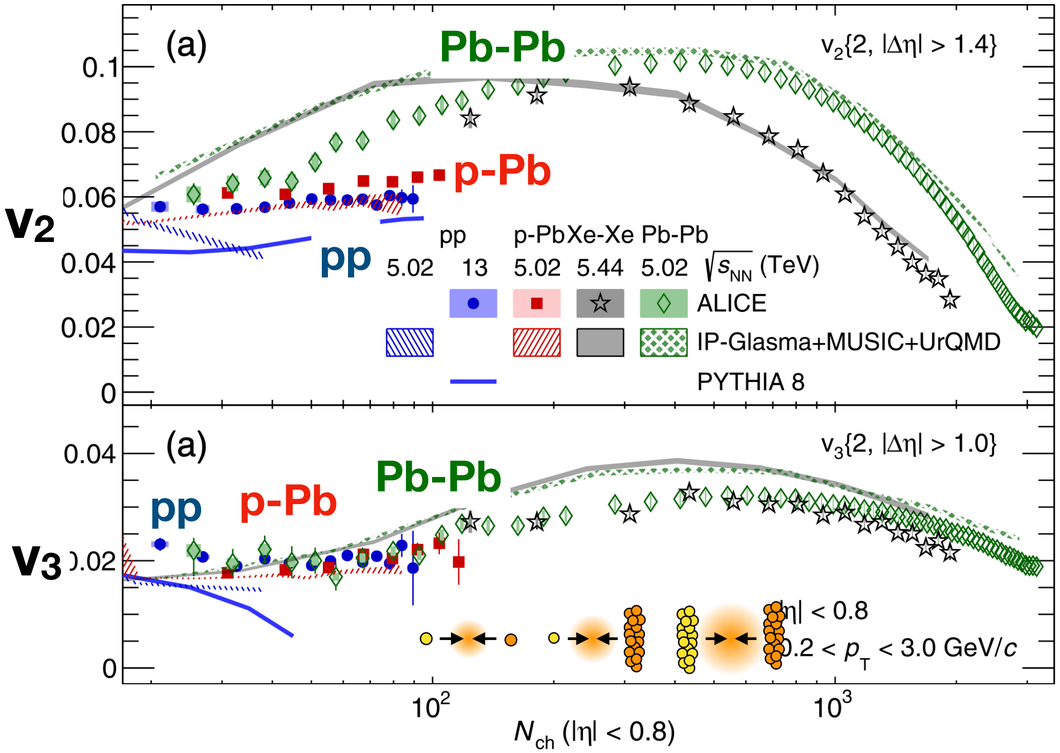


No sharp turn-off as a function of multiplicity



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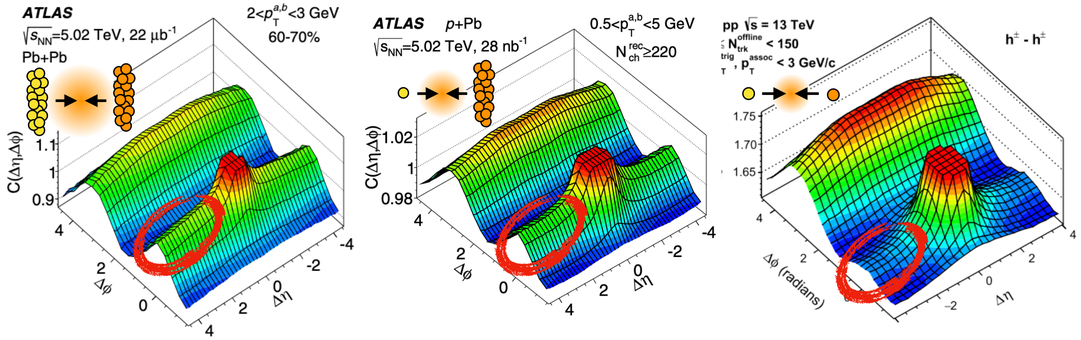

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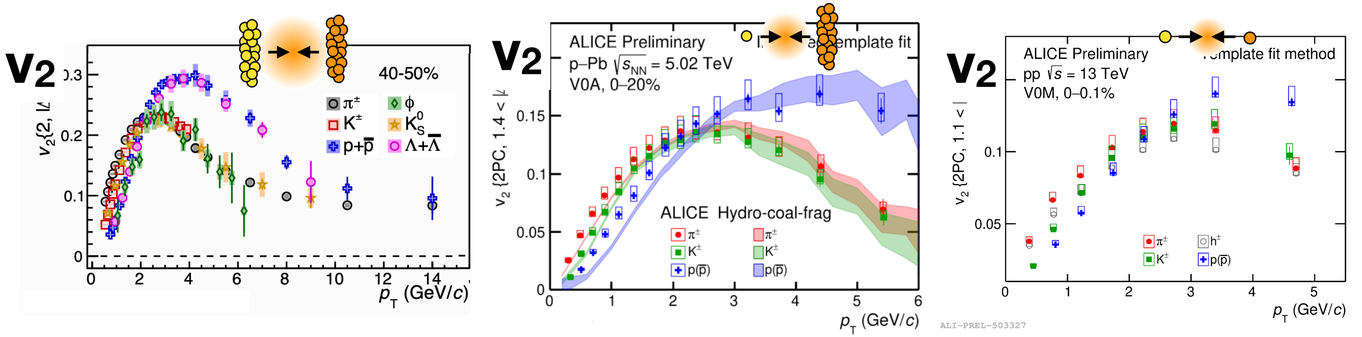
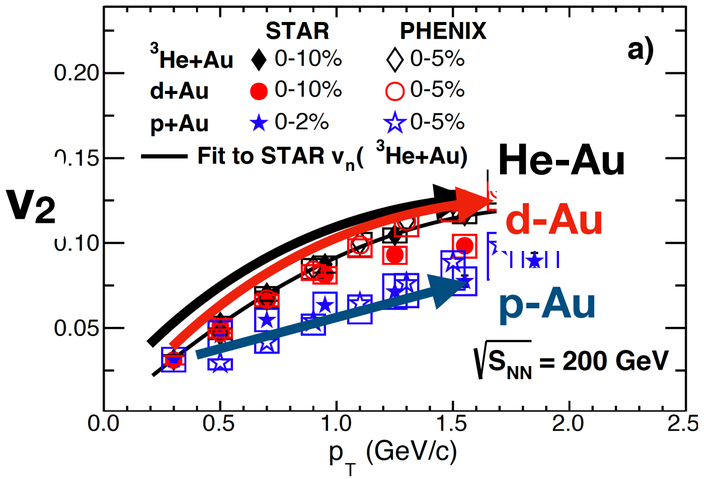
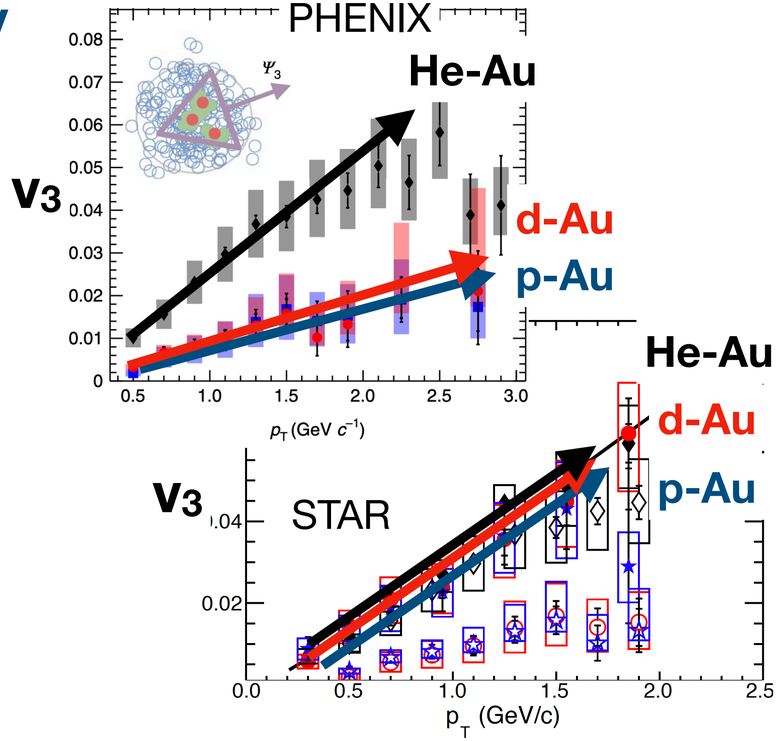


No sharp turn-off as a function of multiplicity

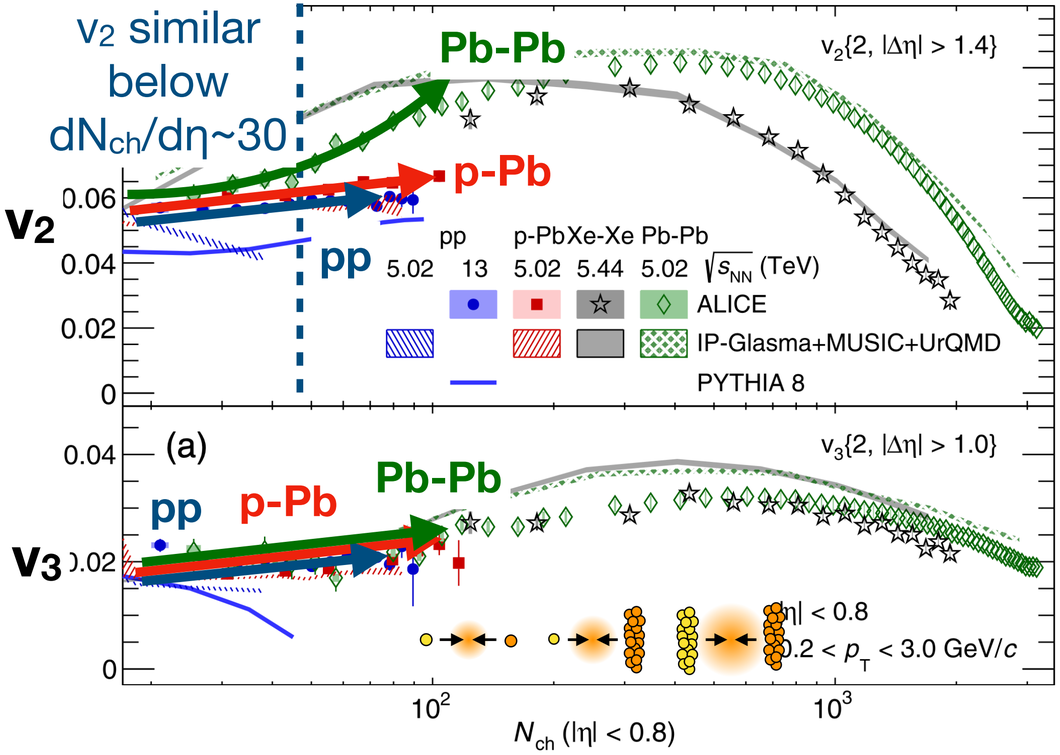
Response to initial geometry

Subnucleon fluctuations important in small systems





v2 similar below dNch/dη~30



Digest of experimental results

measured and similar ✅
measured but different ❌
not measured —

	OBSERVABLES	A—A	p—A (high multiplicity)	pp (high multiplicity)
Long-range correlations	Near-side ridge yield	✅ [1,2]	✅ [30,32,33]	✅ [30,31]
	Anisotropic flow	✅ [3,4]	✅ [36,37,38,39]	✅ [35,37]
Multi-particle correlations	Multiparticle cumulants	✅ [5]	✅ [40-45]	✅ [40,41,45]
Partonic collectivity	Mass ordering	✅ [6]	✅ [47-49]	✅ [46,48]
	Baryon-meson grouping	✅ [6]	✅ [47-49]	✅ [46,48]
Factorisation breaking	Flow decorrelations (p_T)	✅ [7,8]	✅ [50-51]	—
	Flow decorrelations (η)	✅ [9,10]	✅ [52]	✅ [53]
Flow p.d.f.	Event-by-event v_n	✅ [11,12]	—	—
Correlations and fluctuations of V_n	v_n correlations	✅ [13,14]	✅ [54-57]	✅ [54,55,57]
	ψ_n correlations	✅ [15]	—	✅ [58]
	Nonlinear response of V_n	✅ [16-18]	—	✅ [59]
Response to geometry	Event-shape-engineering	✅ [19]	—	—
Role of the IS	rho(v_n^2,[p_T])	✅ [20,21]	✅ [60,61]	✅ [61]
Hard probes	High-p_T flow	✅ [22,23]	✅ [63,65]	✅ [62,64]
	Charm flow	✅ [24-27]	✅ [67,68]	✅ [66,67]
	Bottom flow	✅ [28,29]	✅ [70]	❌ [69]

Caveats

proper nonflow treatment is important

Acceptance and $\Delta\eta$ gap matter

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We see signs of collectivity (almost) everywhere.
Can we ever switch it off ?

Caveats

proper nonflow treatment is important

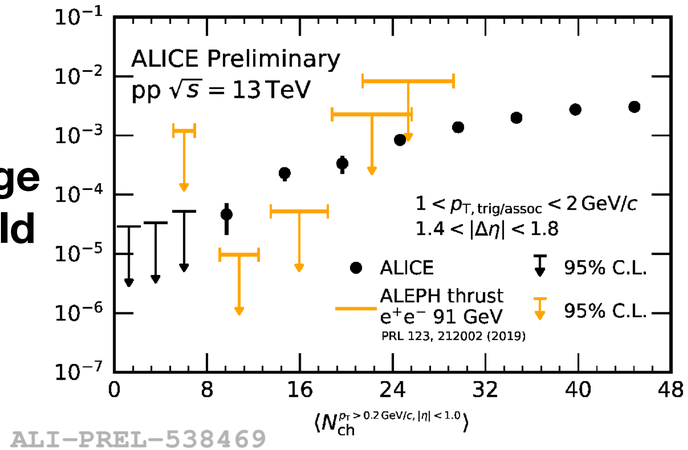
Acceptance and Δη gap matter

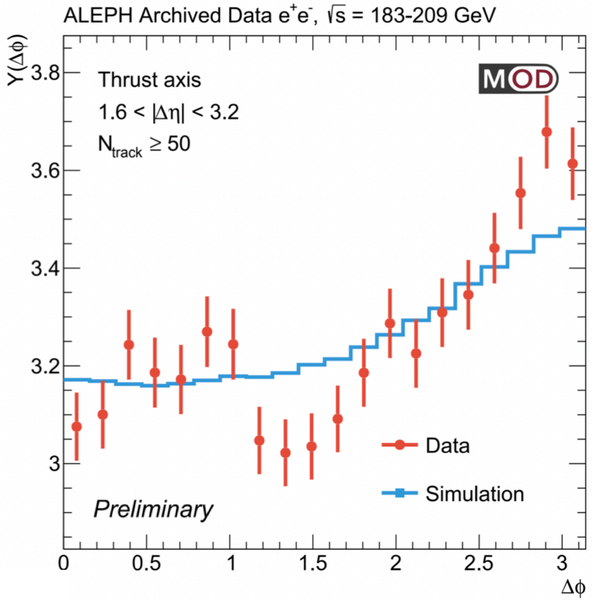
Measurements at the extremes

Near-side long-range ridge yield in pp down to low N_{ch}

Observed in specific $e^+e^- \rightarrow W^+W^-$ high N_{ch} processes?

ridge yield





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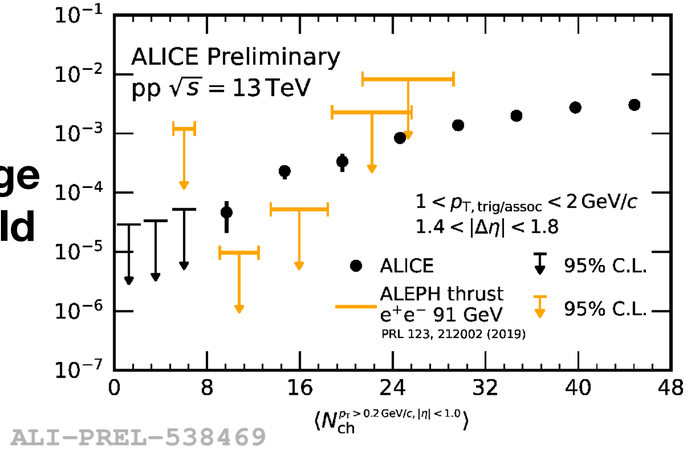
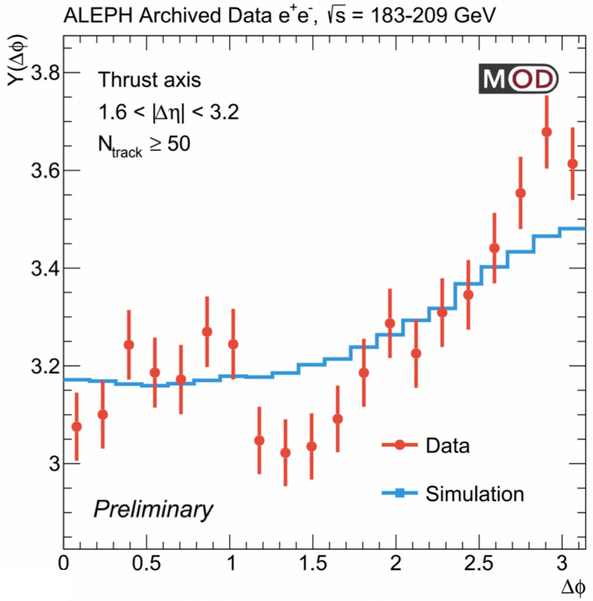
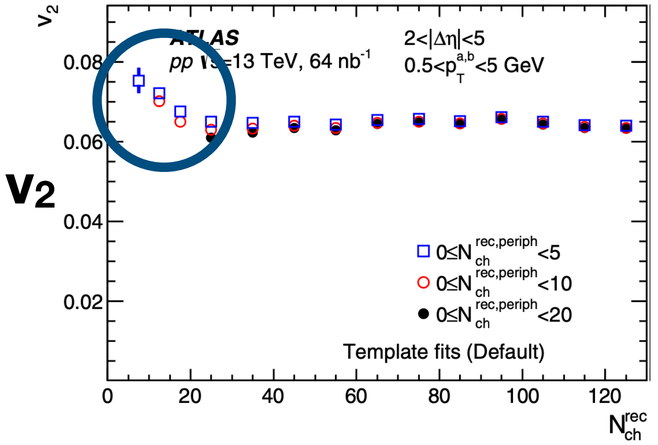




Anisotropic flow down to low multiplicity

Nonzero v_2 below average minimum bias multiplicity

v_2



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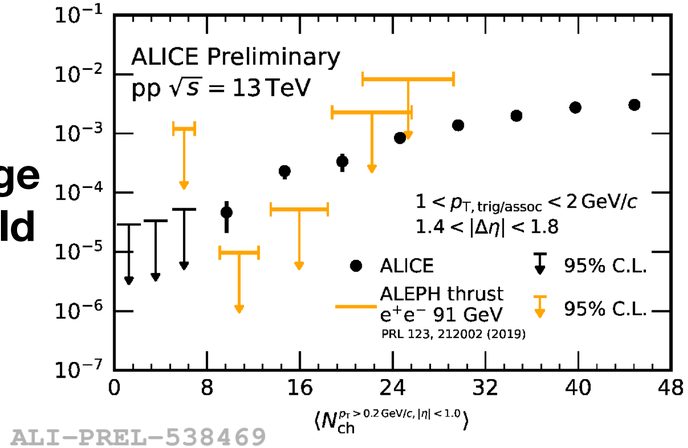

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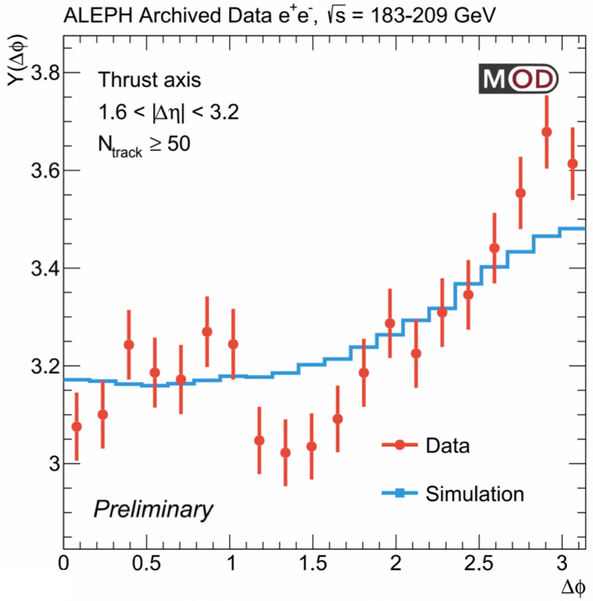

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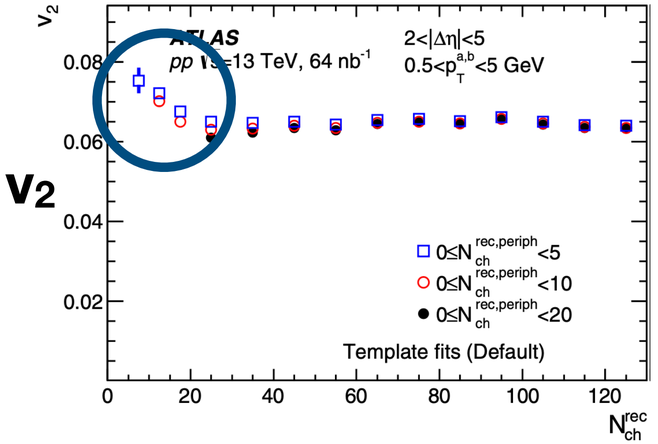
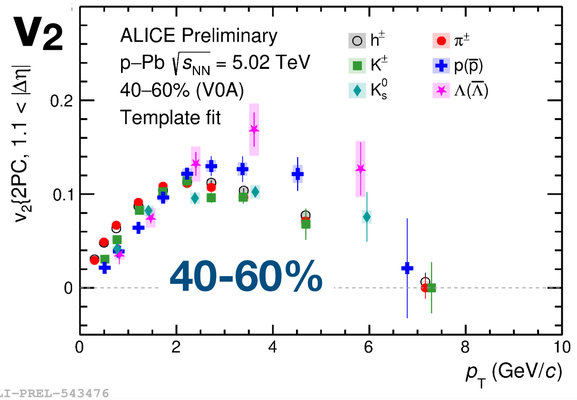


PID flow down to low multiplicity in pPb

Features of partonic collectivity remain at smaller multiplicities

What about pp, e^+e^- ?



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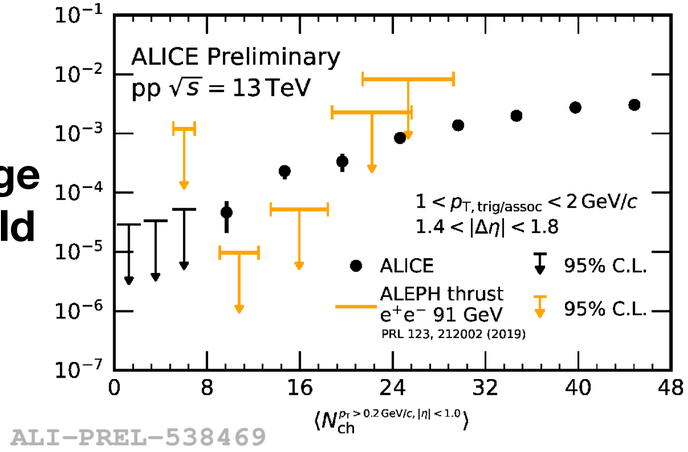

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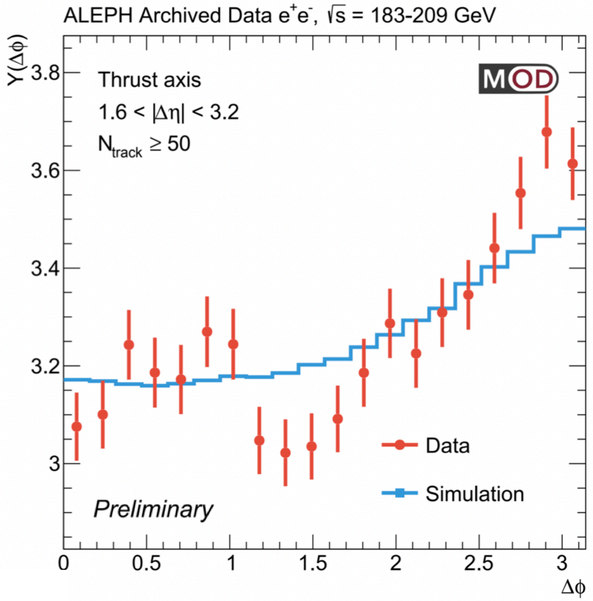

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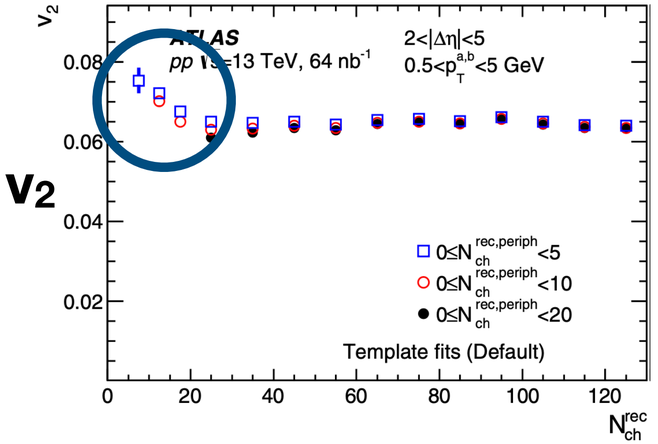

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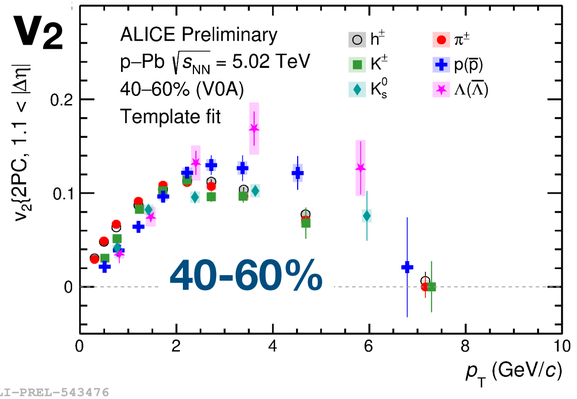

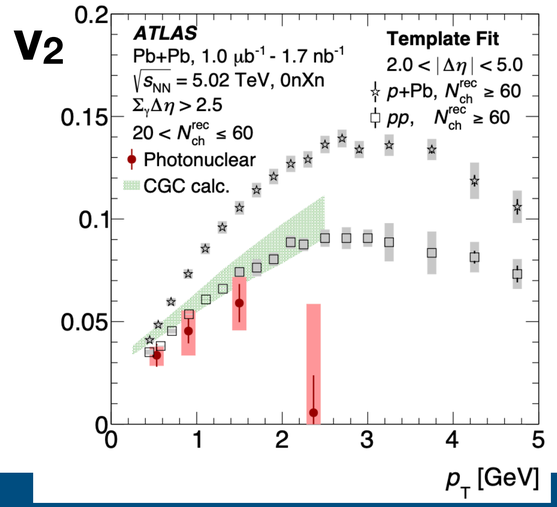

Anisotropic flow in ultraperipheral collisions

Hierarchy of p—Pb, pp, γPb

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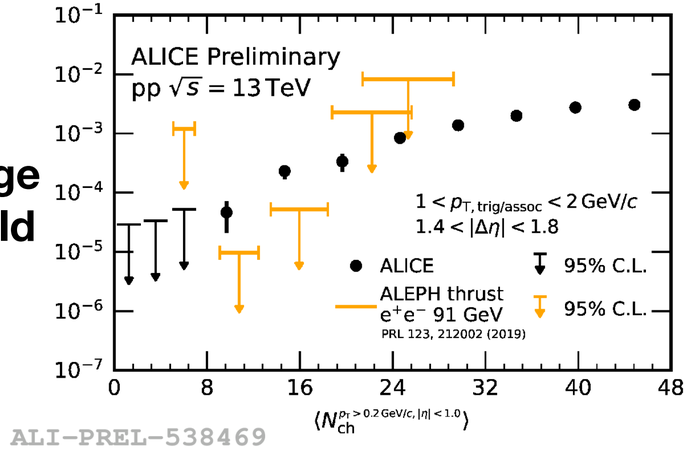

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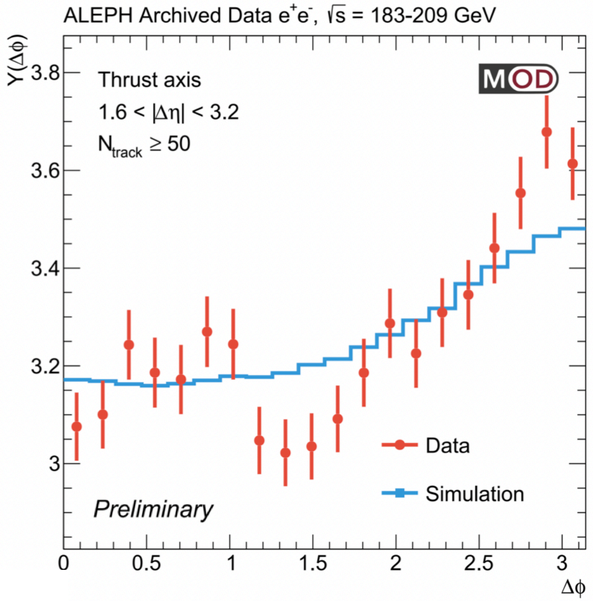

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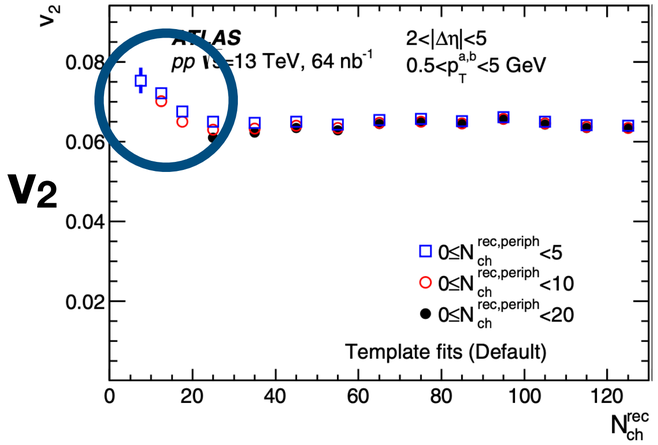

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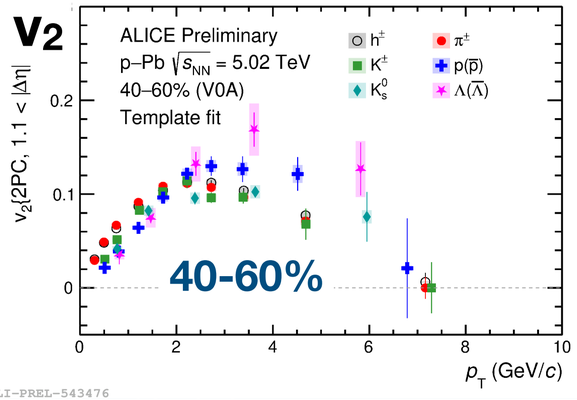
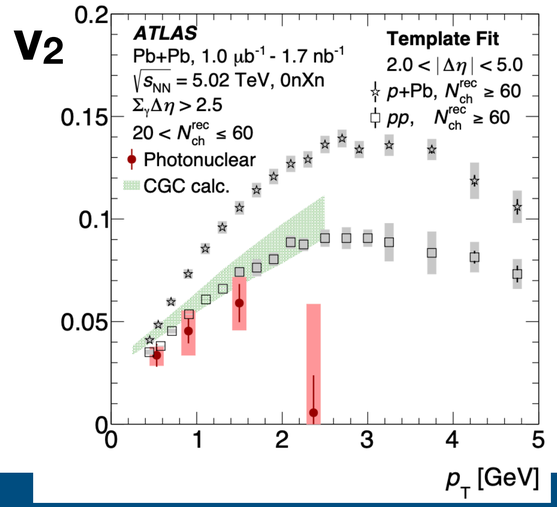
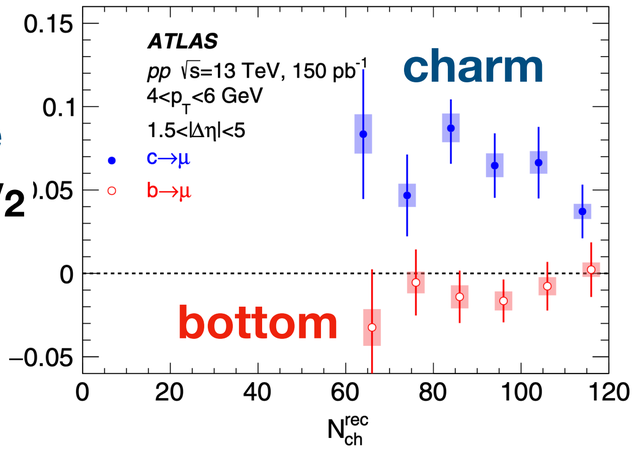




Anisotropic flow of charm and bottom

Bottom doesn't flow anymore



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Hierarchy of p—Pb, pp, γPb

Digest of experimental results

measured and similar ✅
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not measured —

OBSERVABLES	A—A	p—A (high mult.)	pp (high mult.)	pp (low mult.)	UPC	ep	e^+e^- (high mult.)	e^+e^-
Near-side ridge yield	✅ [1,2]	✅ [30,32,33]	✅ [30,31]	✅ [34]	—	❌ [74,75]	✅ [77]	❌ [76]
Anisotropic flow	✅ [3,4]	✅ [36,37,38,39]	✅ [35,37]	✅ [30]	✅ [72,73]	❌ [74,75]	✅ [77]	—
Multiparticle cumulants	✅ [5]	✅ [40-45]	✅ [40,41,45]	—	—	—	—	—
Mass ordering	✅ [6]	✅ [47-49]	✅ [46,48]	—	—	—	—	—
Baryon-meson grouping	✅ [6]	✅ [47-49]	✅ [46,48]	—	—	—	—	—
Flow decorrelations (p_T)	✅ [7,8]	✅ [50-51]	—	—	—	—	—	—
Flow decorrelations (η)	✅ [9,10]	✅ [52]	✅ [53]	—	—	—	—	—
Event-by-event v_n	✅ [11,12]	—	—	—	—	—	—	—
v_n correlations	✅ [13,14]	✅ [54-57]	✅ [54,55,57]	—	—	—	—	—
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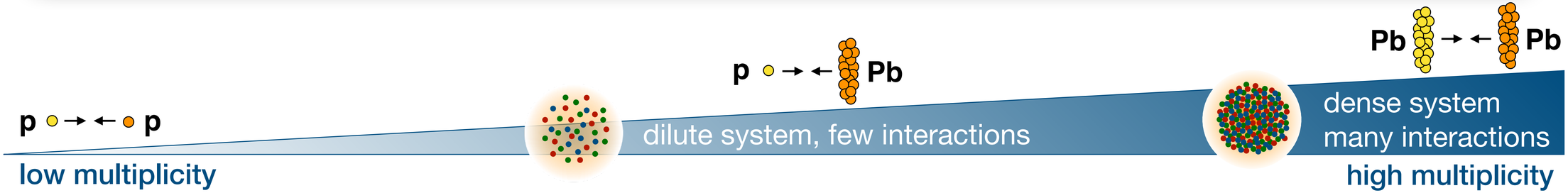
Nonlinear response of V_n	✅ [16-18]	—	✅ [59]	—	—	—	—	—
ESE	✅ [19]	—	—	—	—	—	—	—
rho(v_n^2,[p_T])	✅ [20,21]	✅ [60,61]	✅ [61]	—	—	—	—	—
High-p_T flow	✅ [22,23]	✅ [63,65]	✅ [62,64]	—	—	—	—	—
Charm flow	✅ [24-27]	✅ [67,68]	✅ [66,67]	—	—	—	—	—
Bottom flow	✅ [28,29]	✅ [70]	❌ [69]	—	—	—	—	—

The big picture of **small systems**

Even the smallest (hadronic) system seems to be collective …

… is the underlying physics of *small & dilute* in essence the same as in *large & dense*?



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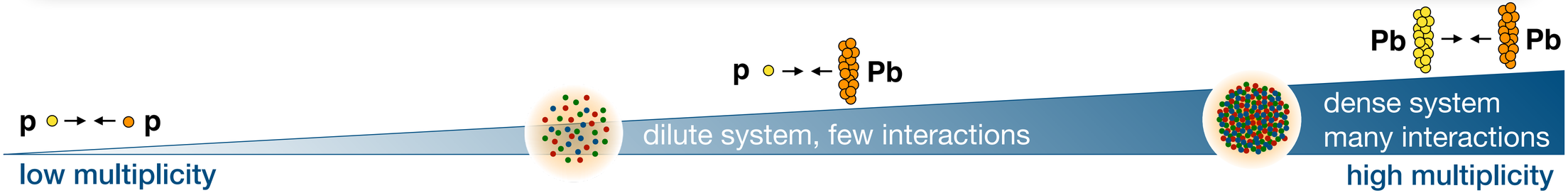

Collectively expanding	Thermalised medium	Dense & deconfined medium
Signatures: modification of momentum and angular distributions	**Signatures:** modification of hadronisation ~~thermal photon radiation~~	**Signatures:** ~~parton energy loss~~ ~~quarkonia dissociation ?~~

Not everything is similar to heavy-ion collisions…

… should we expect jet quenching?

Indication for a 200 MeV energy loss in d-Au collisions

Does the high-p_T flow fit into the picture ?

… should we expect to see any thermal radiation?

… should we expect to see any quarkonia dissociation?

References in heavy-ion collisions

Near-side long-range ridge yield
[1] CMS, Eur. Phys. J. C (2012) 72:2012
[2] ALICE, PLB 708 (2012) 249–264
Anisotropic flow
[3] CMS, JHEP02(2014)088
[4] ALICE, PRL 116, 132302 (2016)
Multiparticle correlations
[5] ALICE, JHEP07(2018)103
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