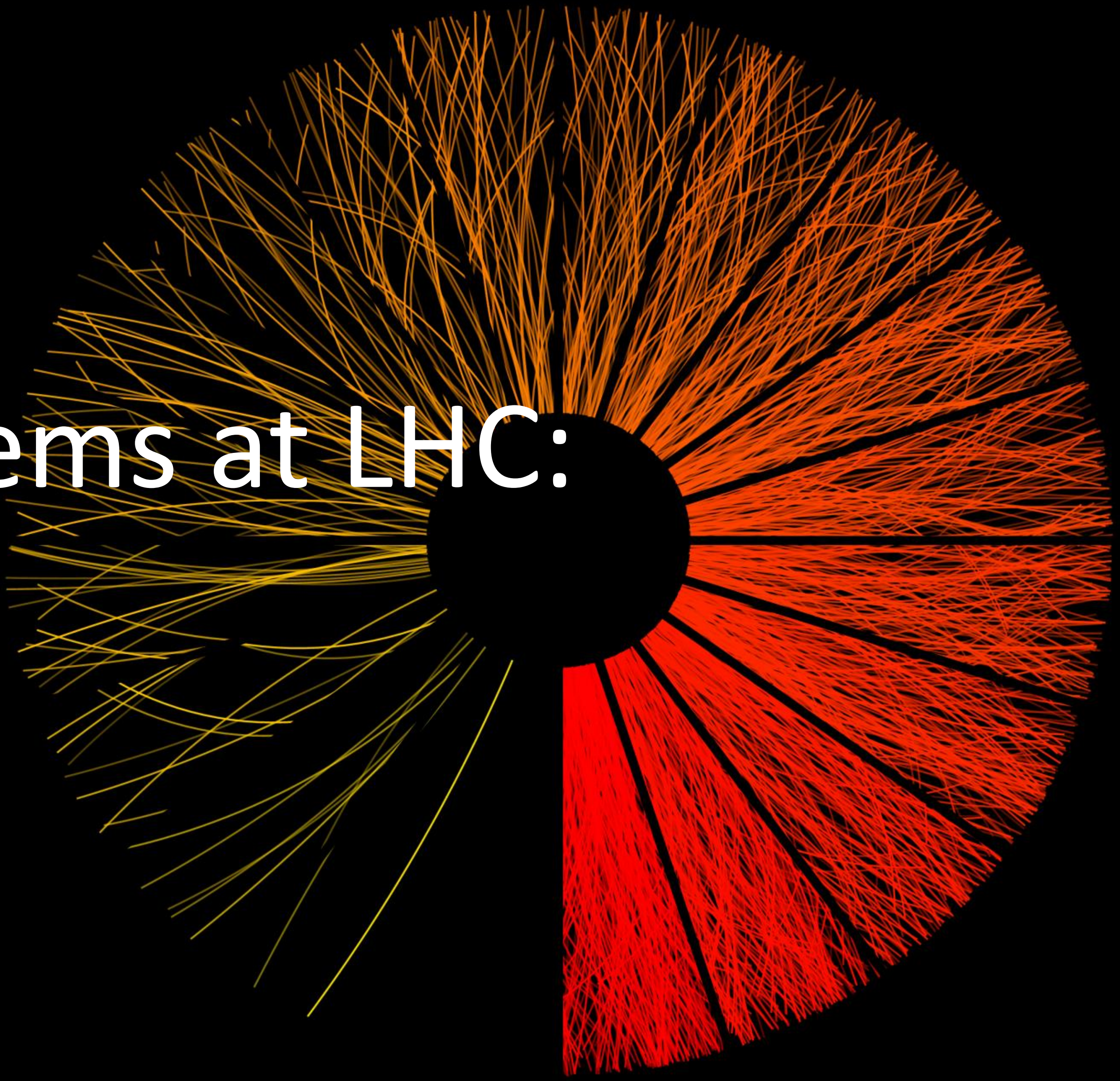
Livio Bianchi *
Università & INFN Torino

QGP in small systems at LHC: overview



35th Winter Workshop on Nuclear Dynamics
Beaver Creek Resort
6-12 January 2019

* *Livio.Bianchi@cern.ch*

1 question: why?

During the last 5 days we've been talking about small systems very extensively…

…but this is the topic I've been working on in the last 5 years...

…mostly thanks to Rene's money…

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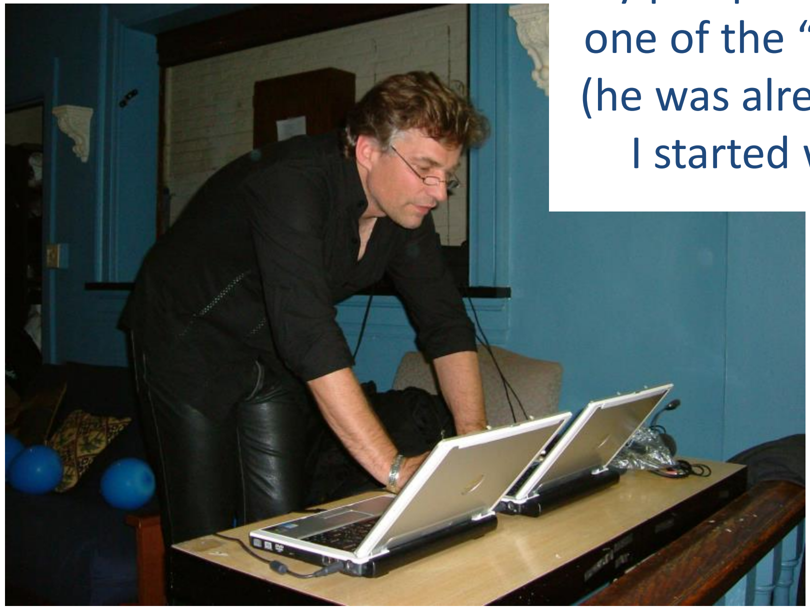

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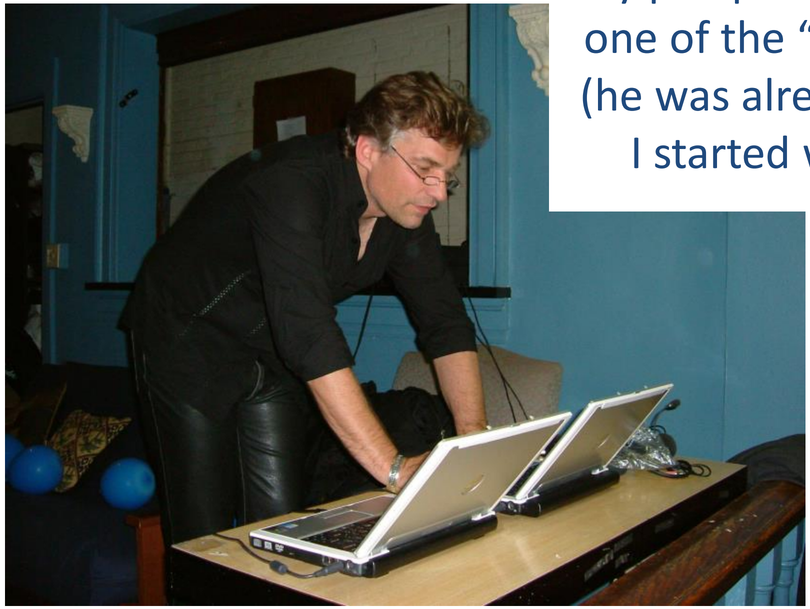

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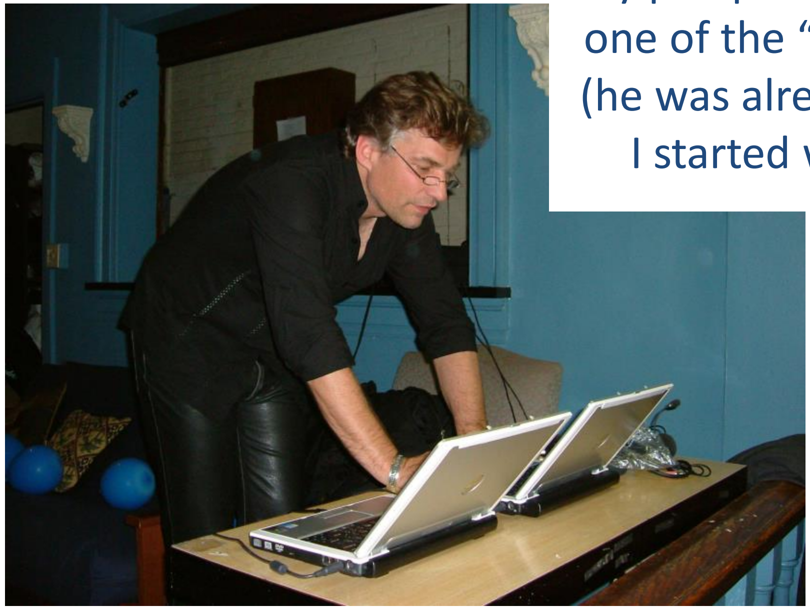

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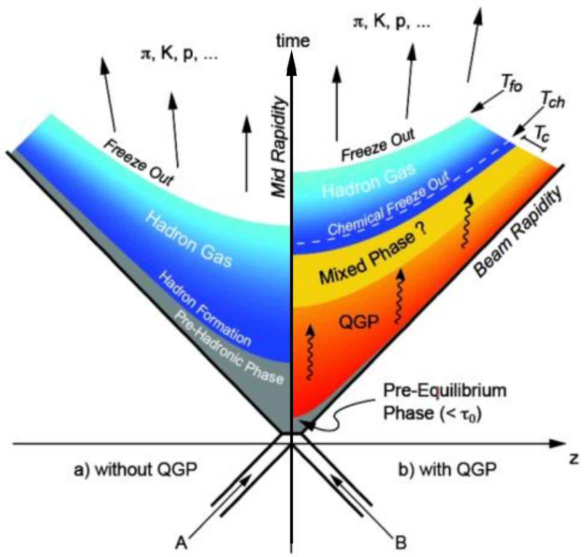
Assumption-1: QGP is formed in Heavy-ion collisions



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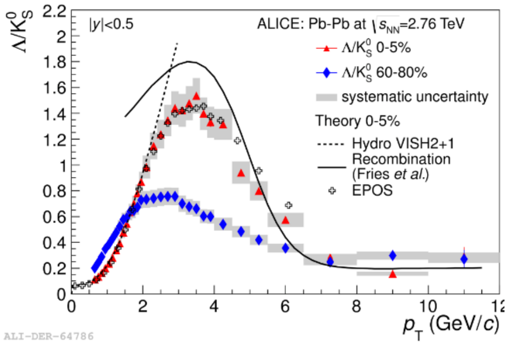
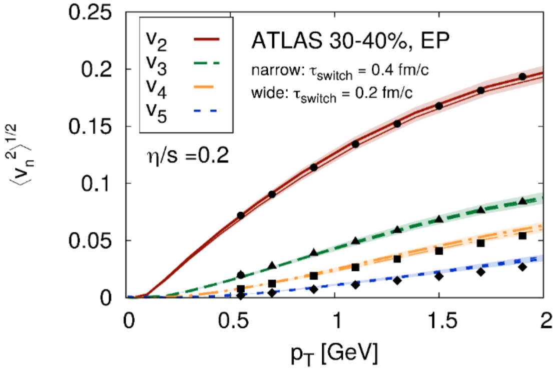
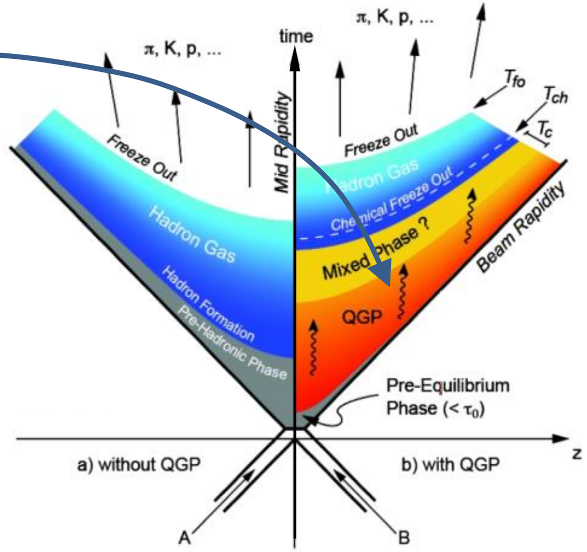
Collectivity: radial and anisotropic flow described by hydro. Global fits to bulk observables start appearing. η/s being measured more and more precisely.







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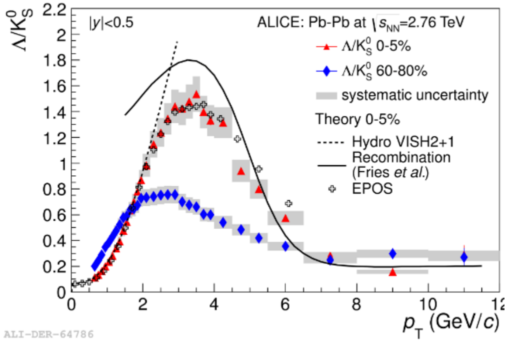
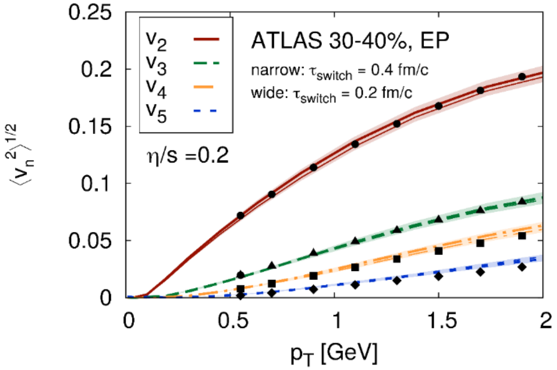
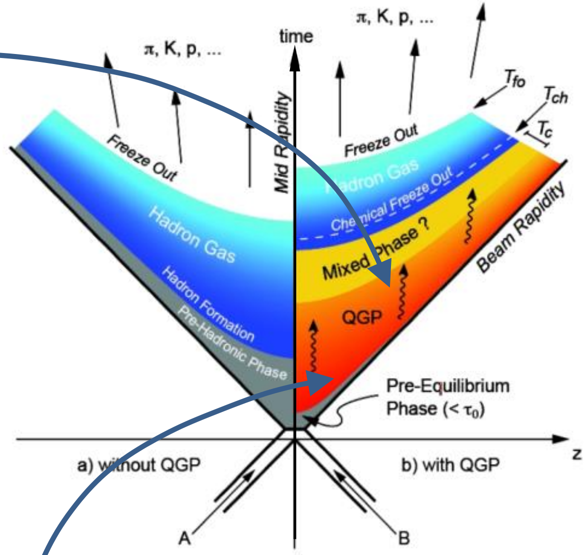
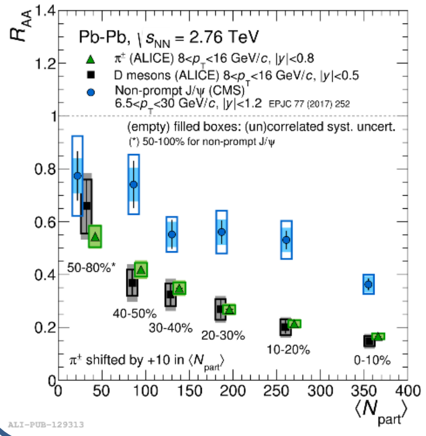
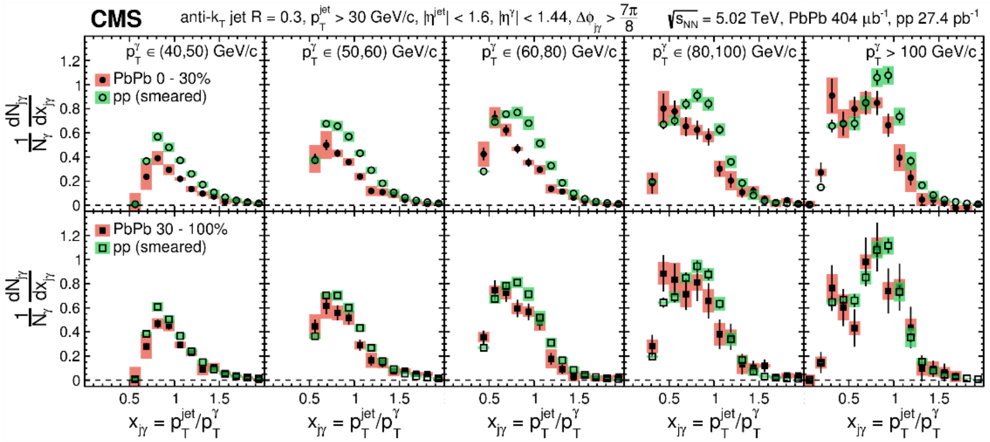






Partonic energy loss: jet quenching and hierarchy $R_{AA}^{B} > R_{AA}^{D}$ confirmed at the LHC. First estimates of $\hat{q}$





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35th WWND
11 Jan. 2019

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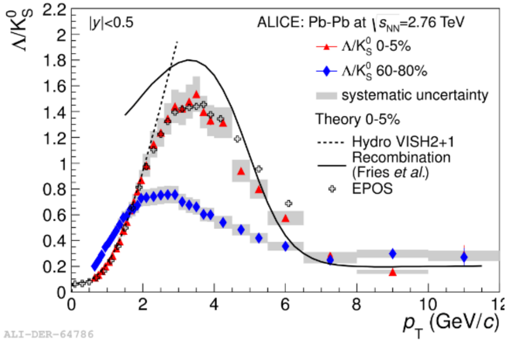
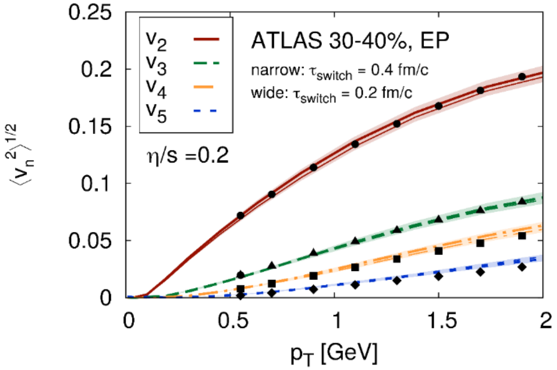
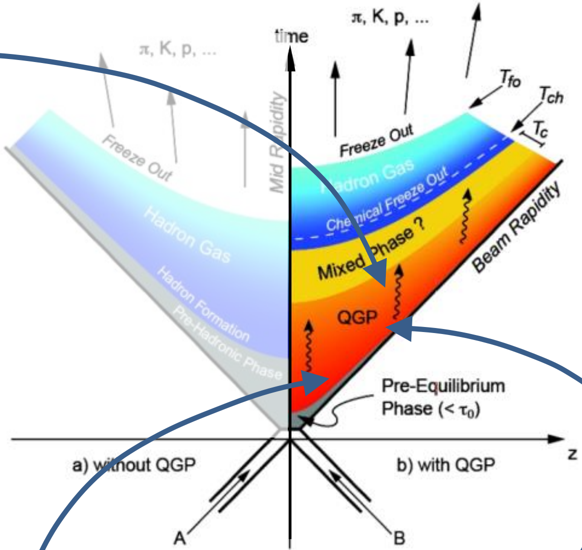


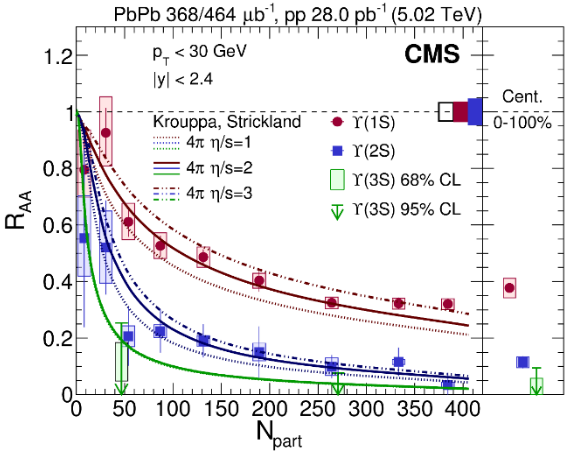




Compelling evidence of QGP formation putting together SPS, RHIC and LHC results

QGP studies @LHC are entering the quantitative era

Quarkonium suppression: first full exploitation of bottomonium thermometer at the LHC



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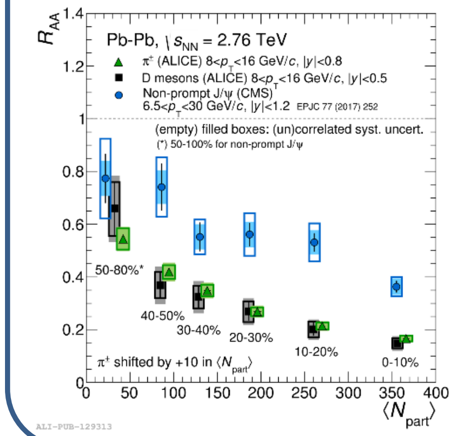

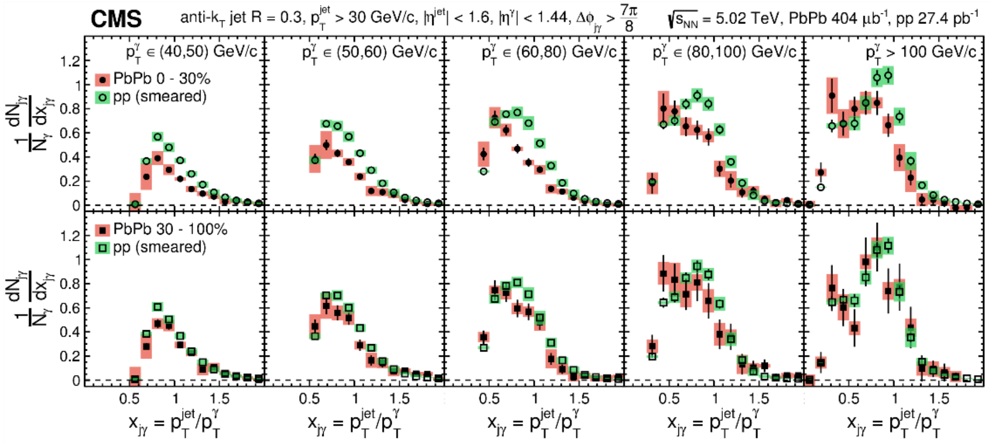

+ SEVERAL OTHER (LESS CLEAN) OBSERVATIONS POINTING TO THE SAME CONCLUSION

Assumption-2: technicalities related to small systems…

… are ordinary business for experimentalists
and theorists are also aware about!

- Geometrical bias
- Multiplicity estimation in small systems
- …

… if that is not the case, let's discuss
(and check backup)

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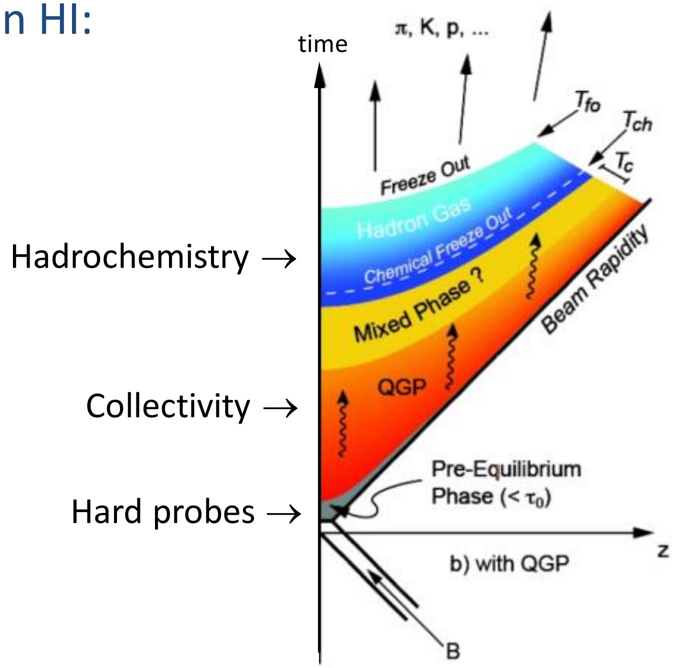
Results in small systems

…from latest to earlier stages of the evolution in HI:



Results in small systems

…from latest to earlier stages of the evolution in HI:

Hadrochemistry →

Collectivity →

Hard probes →

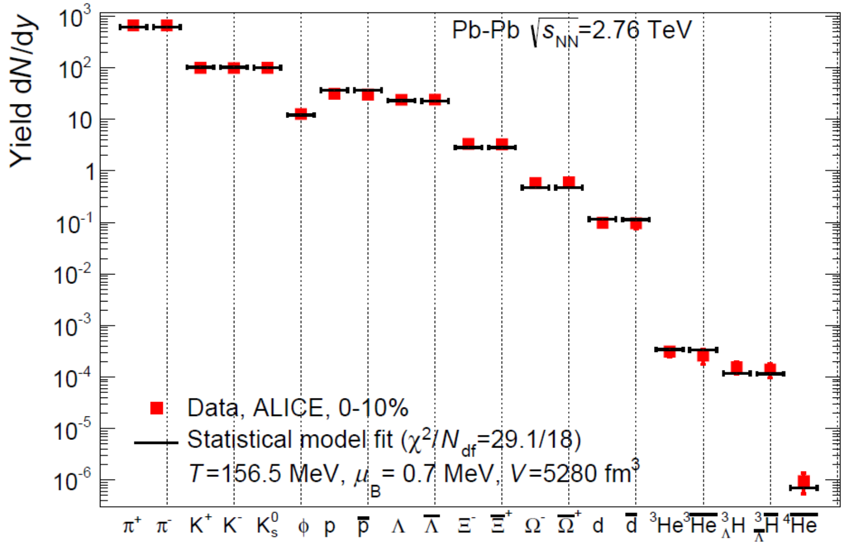
Hadrochemistry: a long debated (non) probe of QGP formation

Measurement of **relative abundances of** different particle **species**

Light hadrons (composed by *u* and *d*) abundantly produced in elementary collisions, but **strange hadrons suppressed**!

What happens in heavy-ion collisions?

- **1982 (Rafelski, Muller)**: **Strangeness enhancement** relative to elementary collisions proposed as smoking gun for **QGP formation**
- **Statistical Hadronization Model** (SHM): reproduce particle yields in HI by means of a Hadron-Resonance Gas in thermal equilibrium



A.Andronic SQM2016, J.Phys.Conf.Ser. 668 (2016)

QGP

⇓ ⇑̸

altered chemical composition

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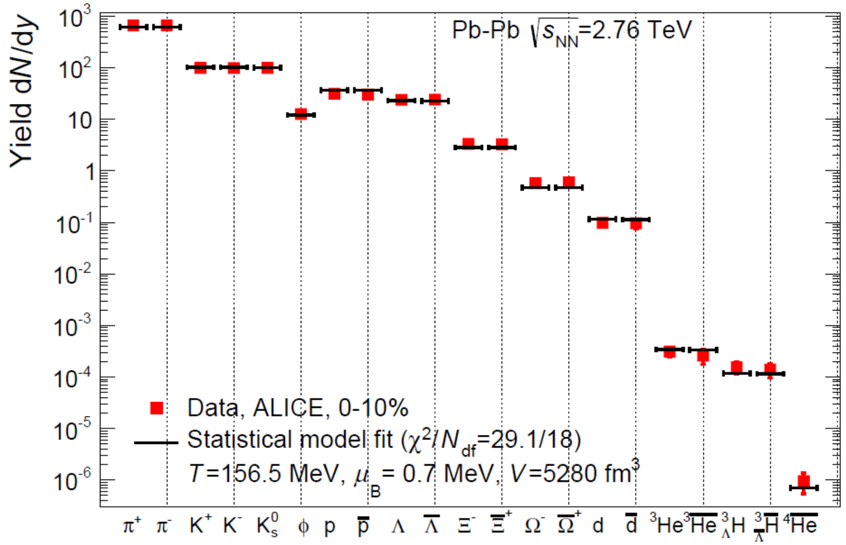

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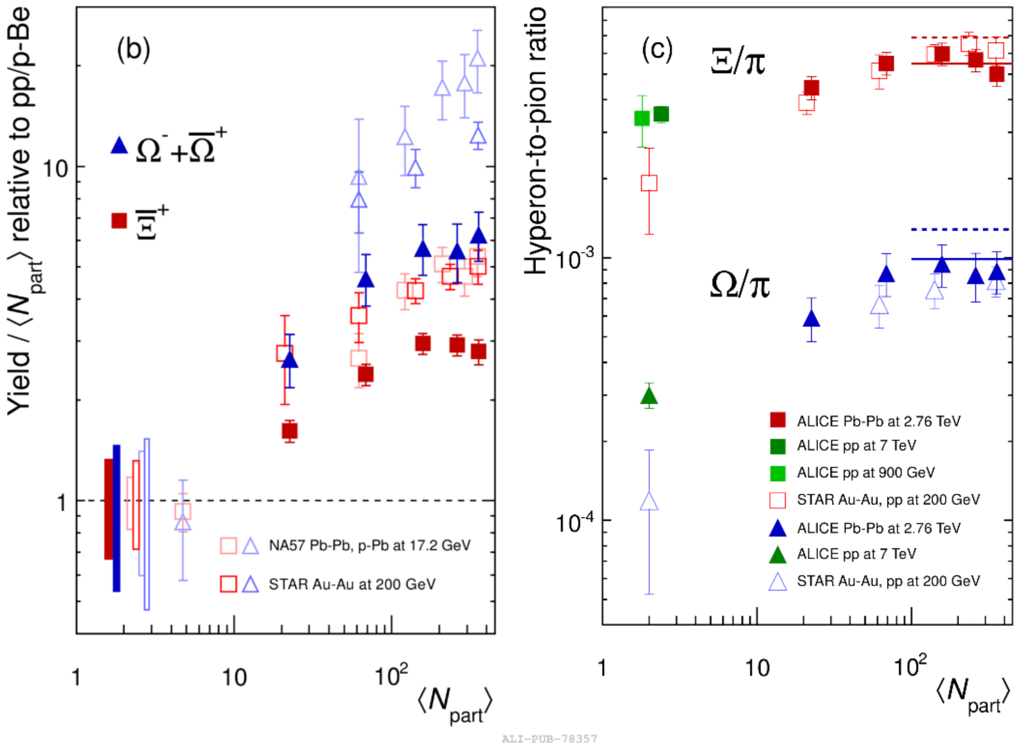


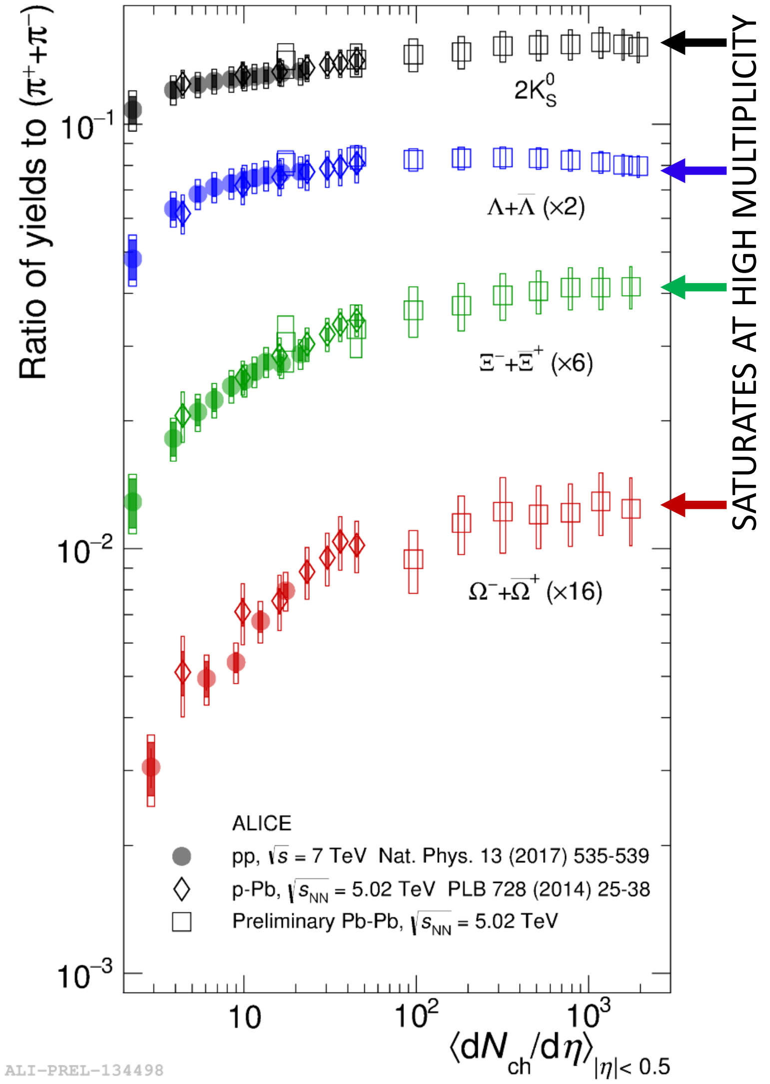
Experimental evidence: strange hadrons more abundant in HI than in pp(p-Be)

MIND THE REFERENCE: strangeness production depends on √s in small systems!

DOES IT?

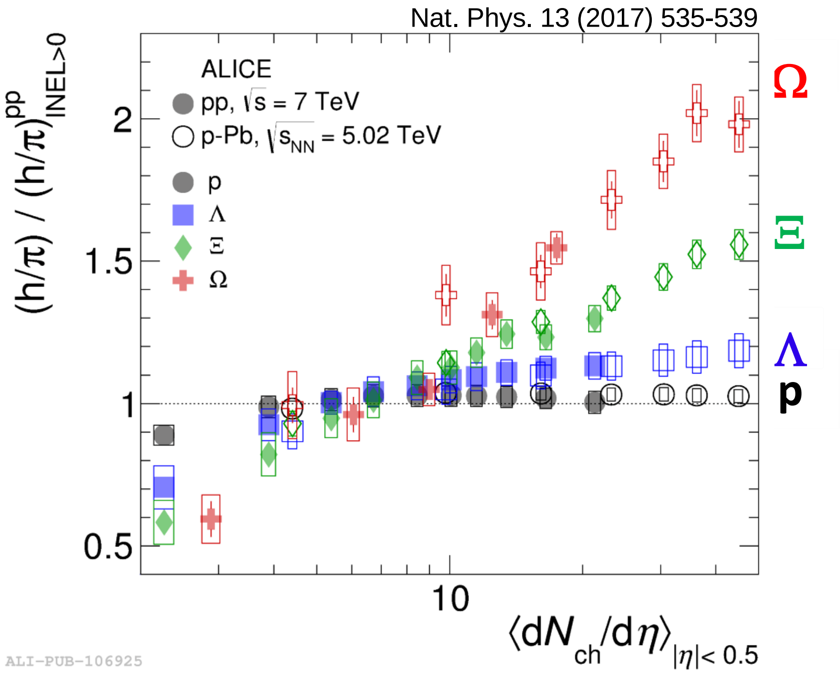
↓

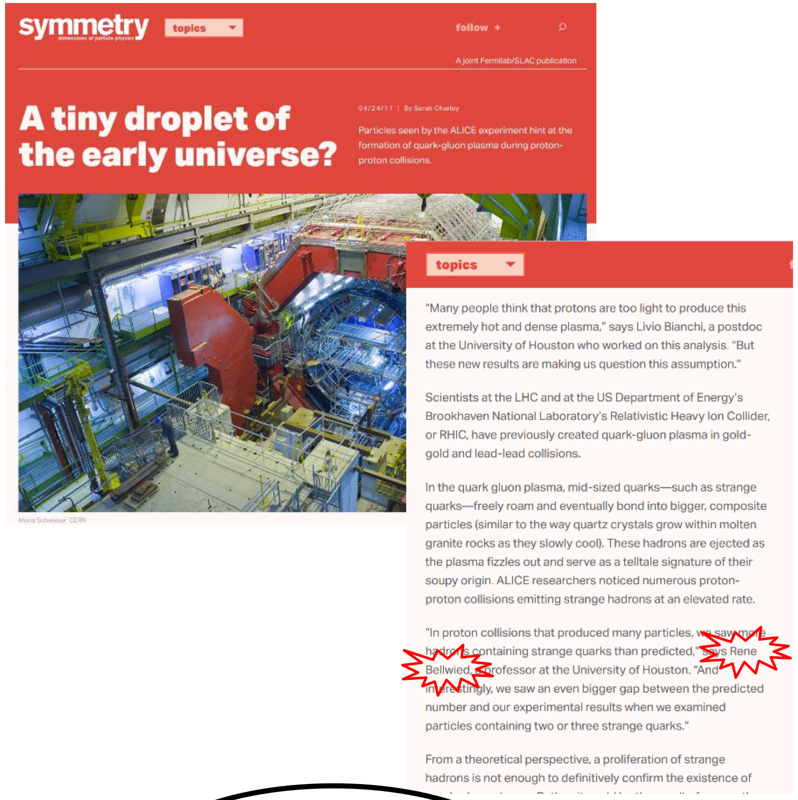
Strangeness enhancement in small systems



Strangeness enhancement in small collision systems (pp and p-Pb)

The larger the content in strangeness of the hadron, the steeper the increase is




symmetry
topics
follow +
A joint Fermilab/SLAC publication

A tiny droplet of the early universe?

04/24/17 | By Sarah Charley

Particles seen by the ALICE experiment hint at the formation of quark-gluon plasma during proton-proton collisions.

"Many people think that protons are too light to produce this extremely hot and dense plasma," says Livio Bianchi, a postdoc at the University of Houston who worked on this analysis. "But these new results are making us question this assumption."

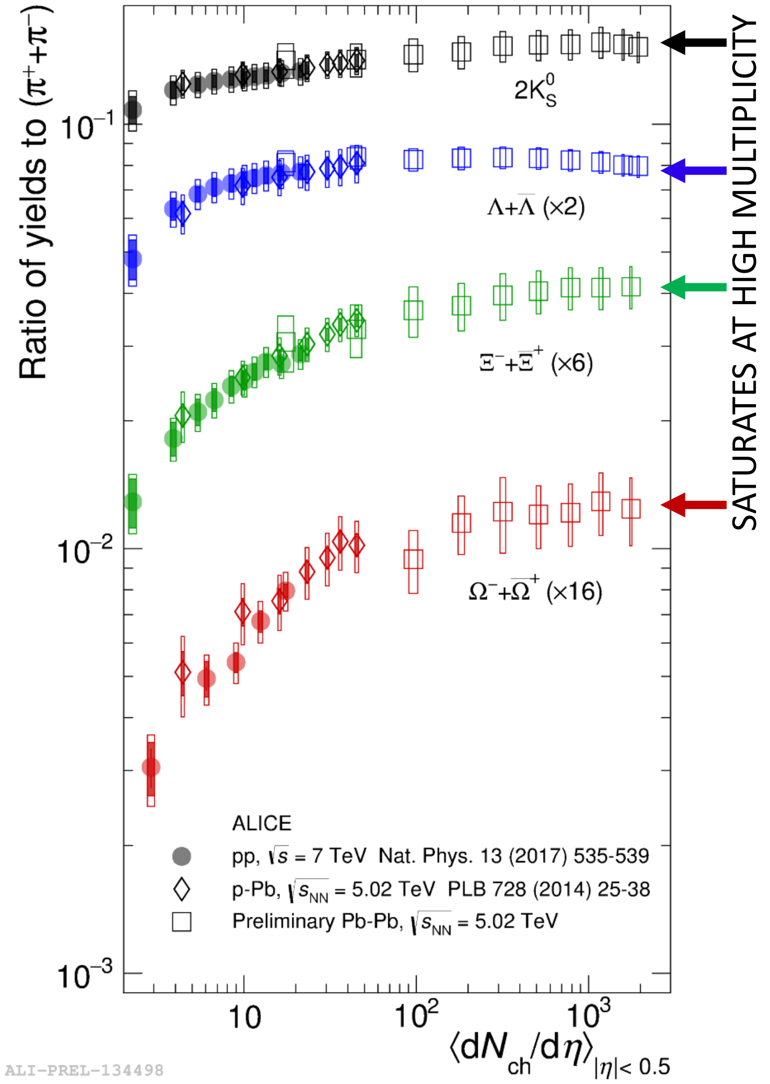
Scientists at the LHC and at the US Department of Energy's Brookhaven National Laboratory's Relativistic Heavy Ion Collider, or RHIC, have previously created quark-gluon plasma in gold-gold and lead-lead collisions.

In the quark gluon plasma, mid-sized quarks—such as strange quarks—freely roam and eventually bond into bigger, composite particles (similar to the way quartz crystals grow within molten granite rocks as they slowly cool). These hadrons are ejected as the plasma fizzles out and serve as a telltale signature of their soupy origin. ALICE researchers noticed numerous proton-proton collisions emitting strange hadrons at an elevated rate.

"In proton collisions that produced many particles, we saw more hadrons containing strange quarks than predicted," says Rene Bellwied, a professor at the University of Houston. "And interestingly, we saw an even bigger gap between the predicted number and our experimental results when we examined particles containing two or three strange quarks."

From a theoretical perspective, a proliferation of strange hadrons is not enough to definitively confirm the existence of

Strangeness enhancement in small systems



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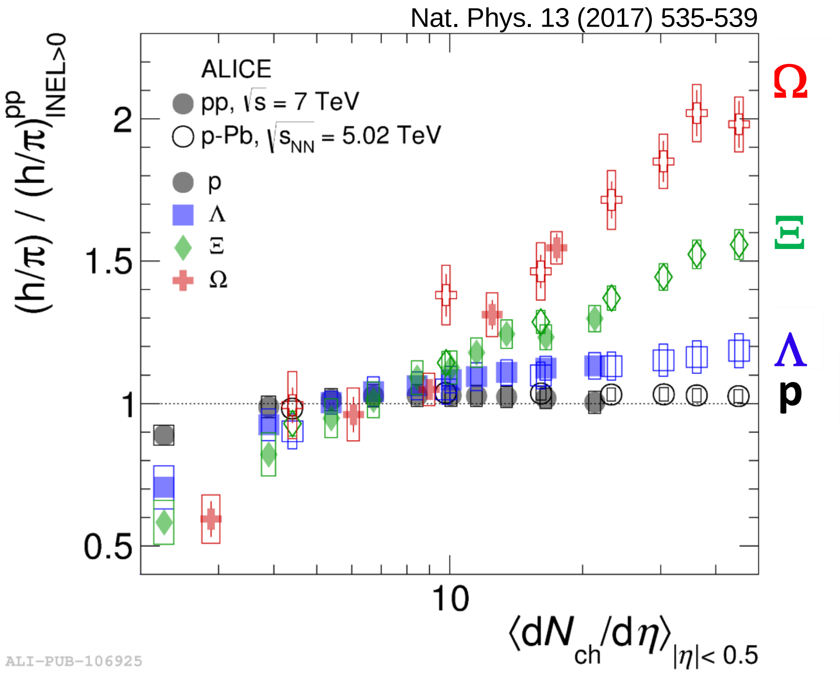
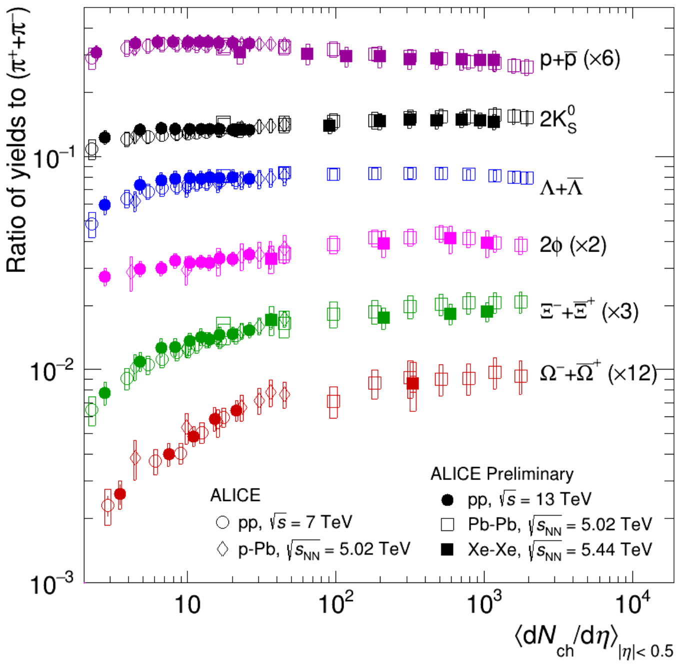
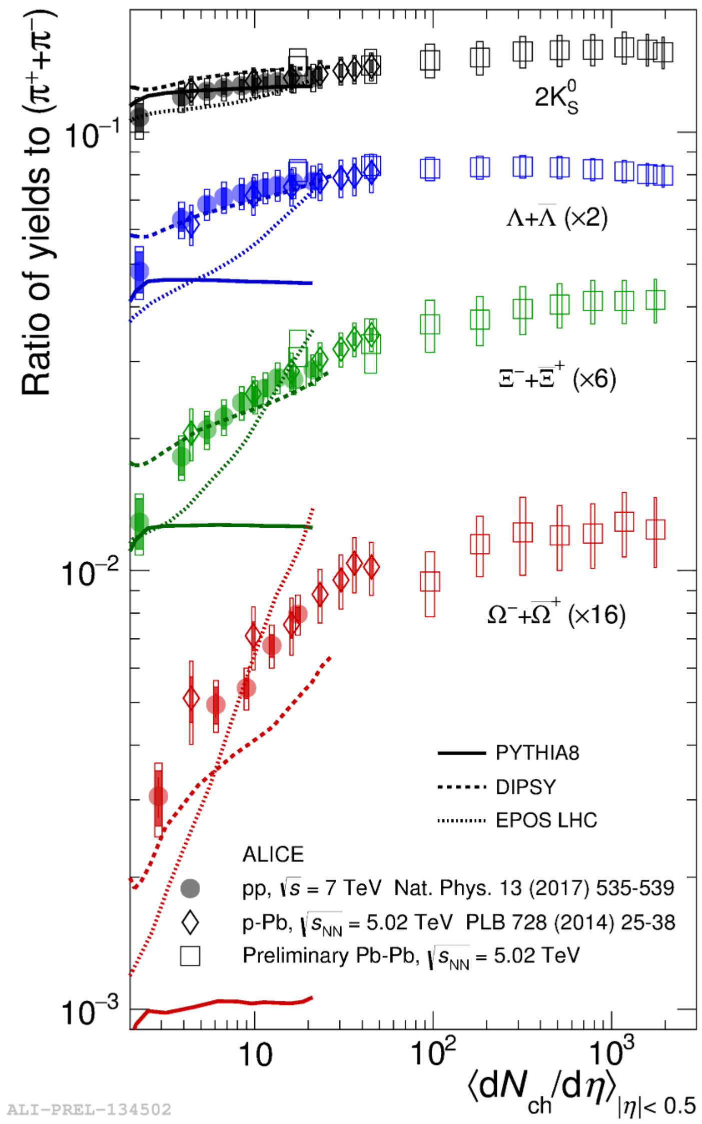


Multiplicity drives strangeness enhancement across different collision systems/energies



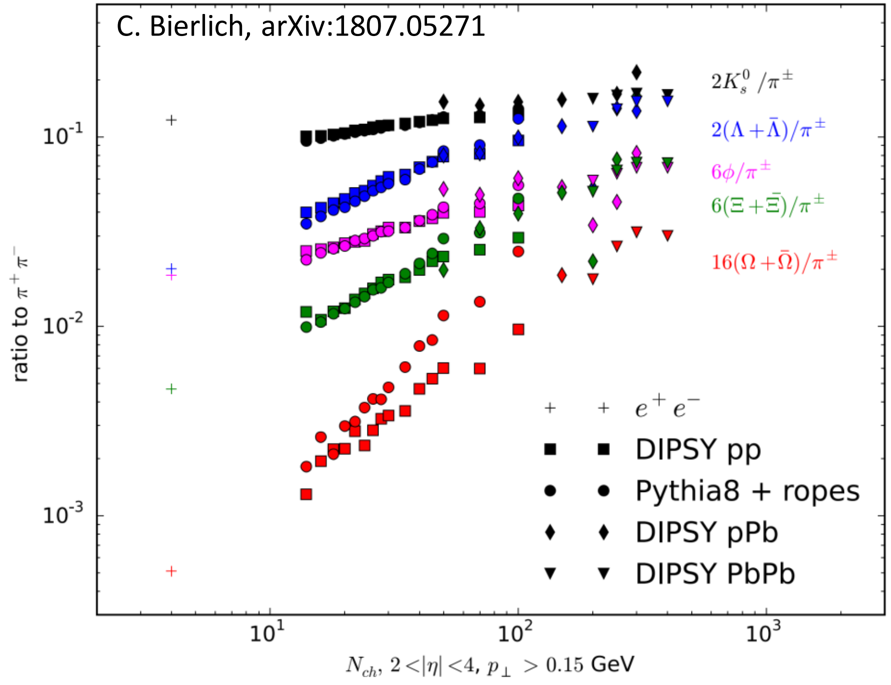
…and this is true for all "soft" particles



- **PYTHIA** (Lund string model):
  - Hadrons come from string (κ = 1 GeV/fm) breaking. s/u fit on data
  - At high energies need MPI to describe multiplicity and re-connection of colour strings to describe <p_T> VS multiplicity

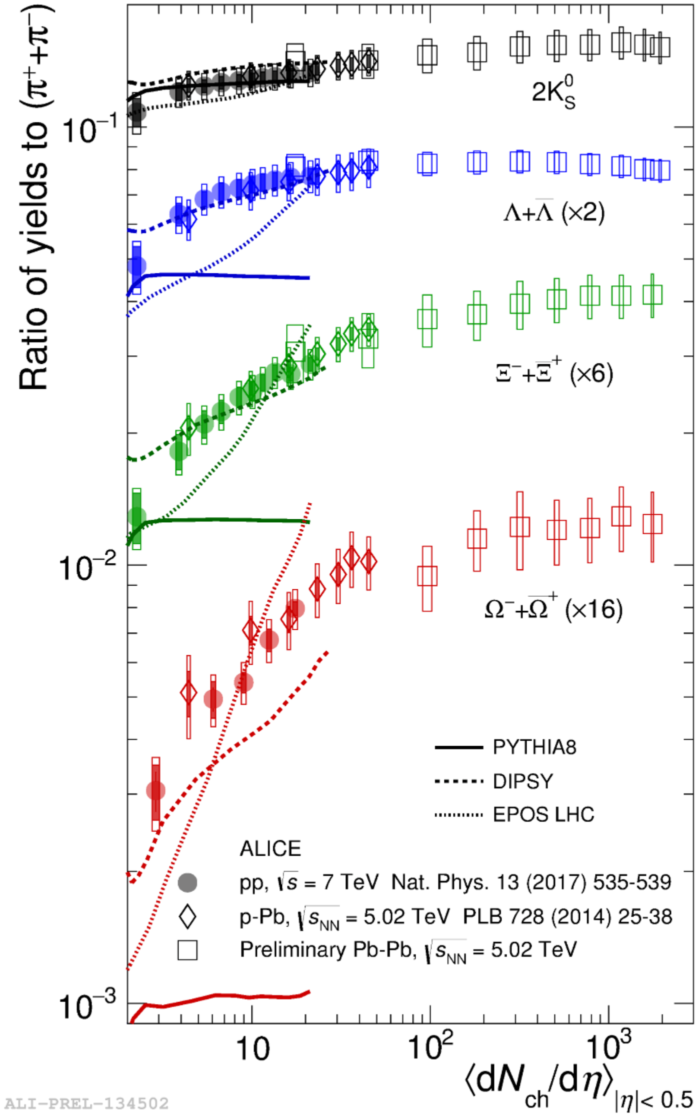
  dramatically fails

  - Recently introduced:
    - Colour **ropes**: packing of strings increase κ
    - p-A and A-A environments
- **DIPSY** (**D**ipole evolution in **I**mpact **P**arameter **S**pace and rapidit**Y**)
  - Evolution of initial state and collision described in impact parameter space.
  - Strings which overlap in impact parameter space form **ropes**



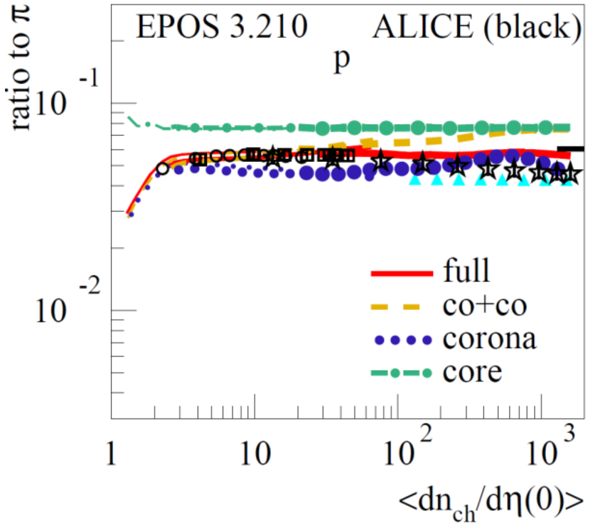
CAVEAT: ropes favor baryons wrt mesons. No flavour preference!

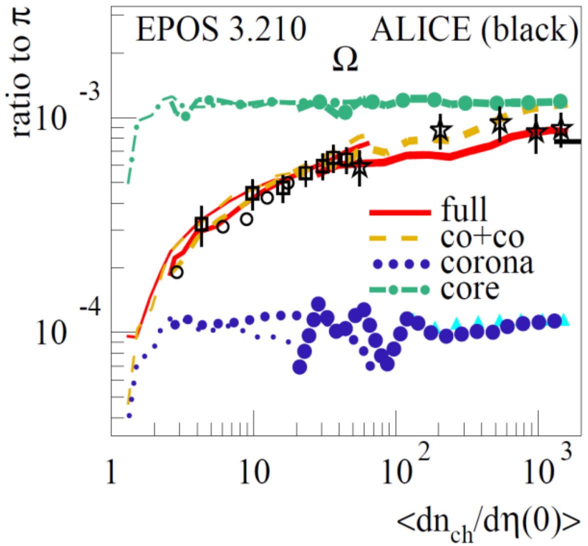
Hadrochemistry as seen by EPOS



- **EPOS**:
  - Hard scattering: parton "ladders" + CGC-inspired saturation scale
  - At time τ_0 (before hadronization) strings divided into fluid (CORE) and escaping (CORONA) according to momenta and local density
    - ❑ **CORONA**: strings can hadronize as in the Lund approach
    - ❑ **CORE**: from time τ_0 evolves as a viscous hydrodynamic system. Hadronization happens statistically at a common T_H
  - After hadronization → afterburner (e.g. UrQMD)

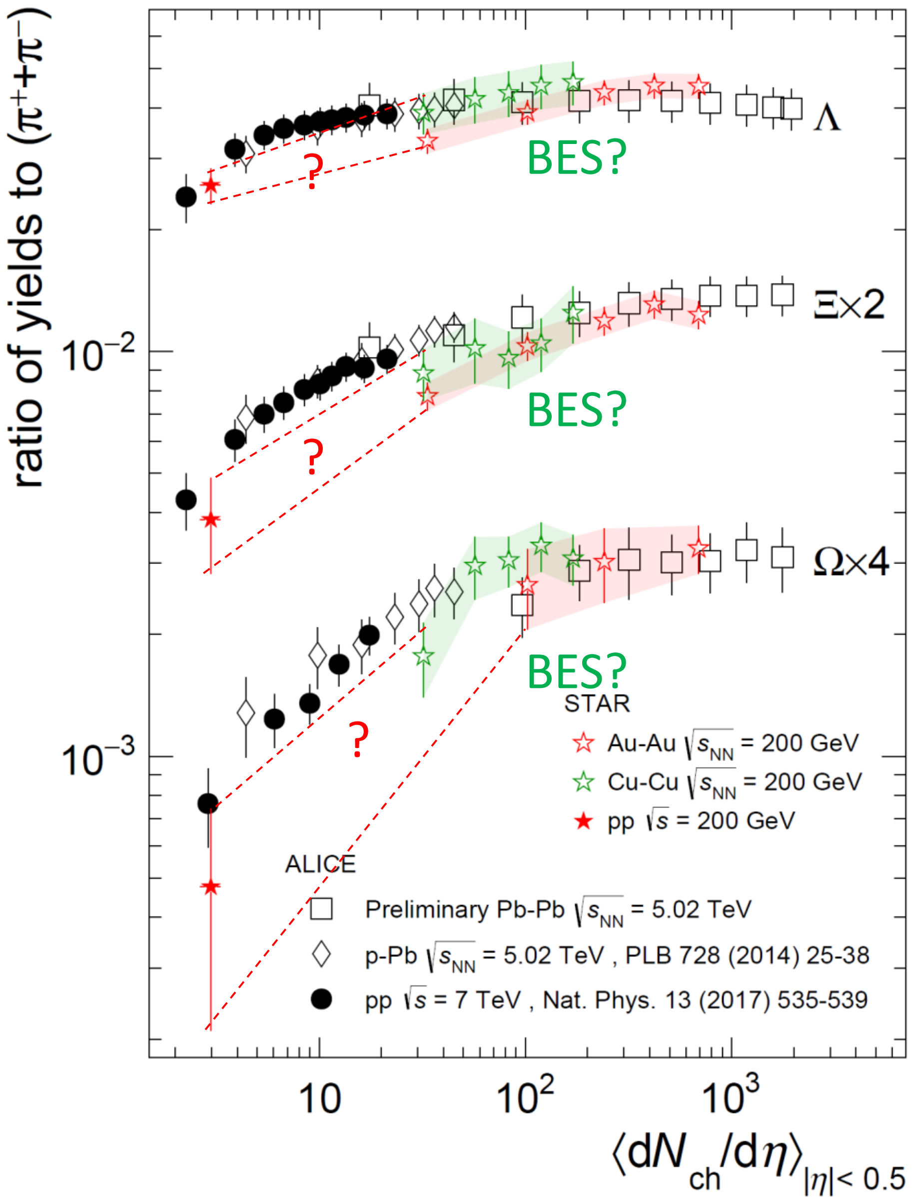
Good job with version 3 of the generator! Hints to the need of "core" part in pp collisions?





K. Werner, http://www.ectstar.eu/files/talks/Klaus.pdf

Hadrochemistry: perspectives?



High precision data from the LHC suggest that the production of strangeness is driven by the final-state multiplicity of the collision

Independence on the collision energy

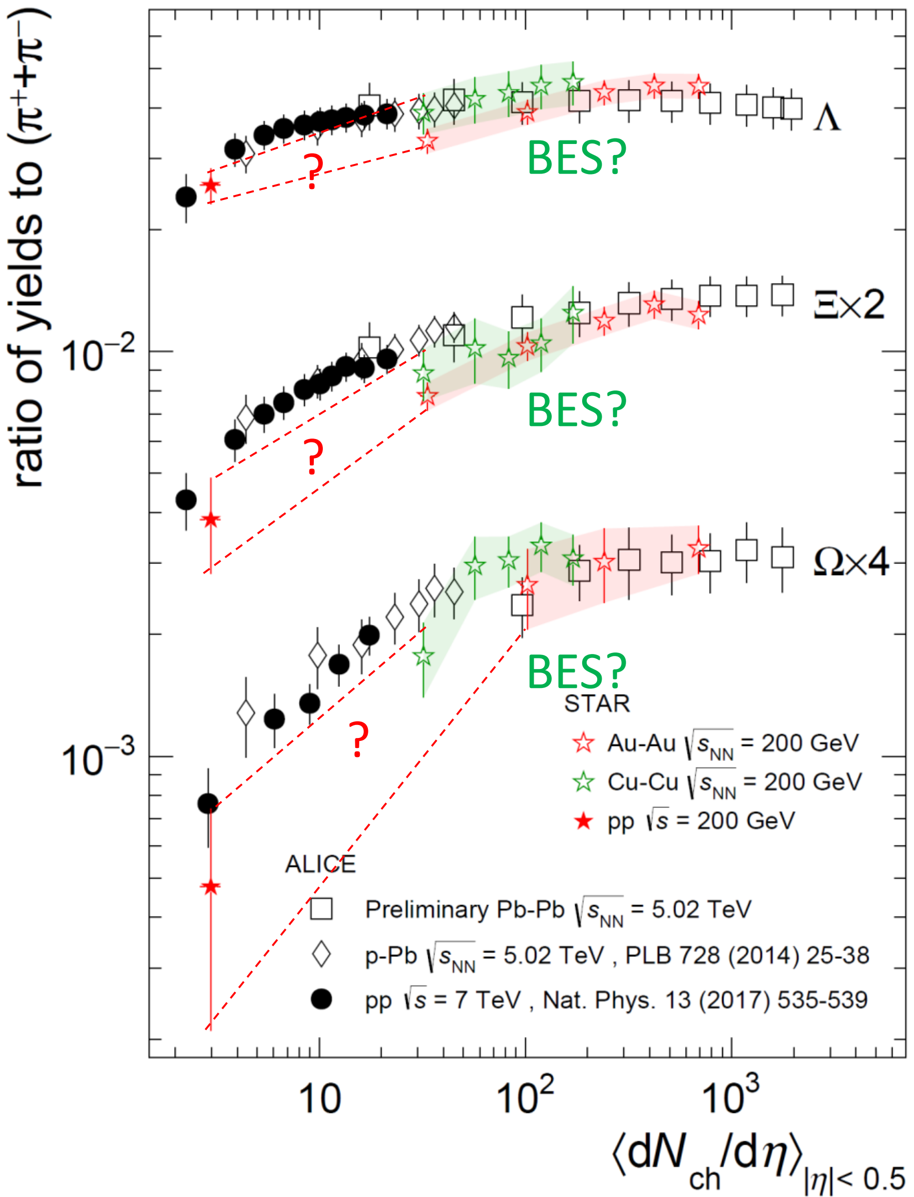
Can we extend this observation to lower energies?

High multiplicity STAR results superimpose to ALICE's points

Can we infer something looking at the trend at lower multiplicity?

Would be interesting to complement with smaller systems results @RHIC!!

Hadrochemistry: perspectives?



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GIVE ME 2 F-O TEMP!!

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Selected results

…from latest to earlier stages of the evolution:

Hadrochemistry →

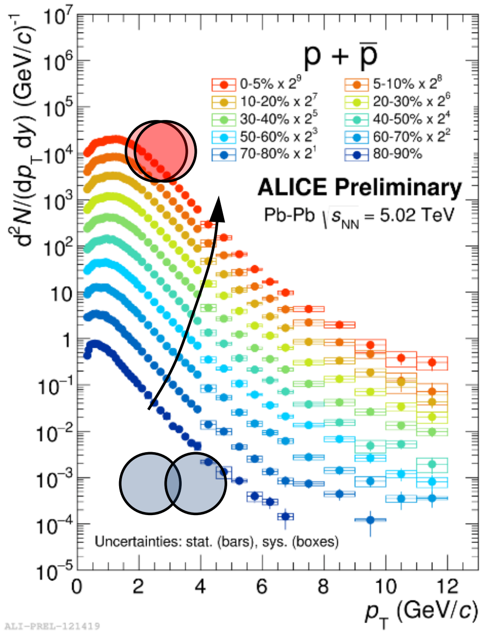
Collectivity →

Hard probes →

Collectivity in a nutshell

According to the hydro picture, in HI the QGP is expected to develop:

- **Radial flow** (important in central collisions):
  - Common expansion velocity of partons
  - Translates into p_T spectra modification
  - Baryon/meson anomaly



p_T spectrum gets harder as the collision gets more central

Common β → larger p-boost to higher-mass particles ($p=m\gamma\beta$)

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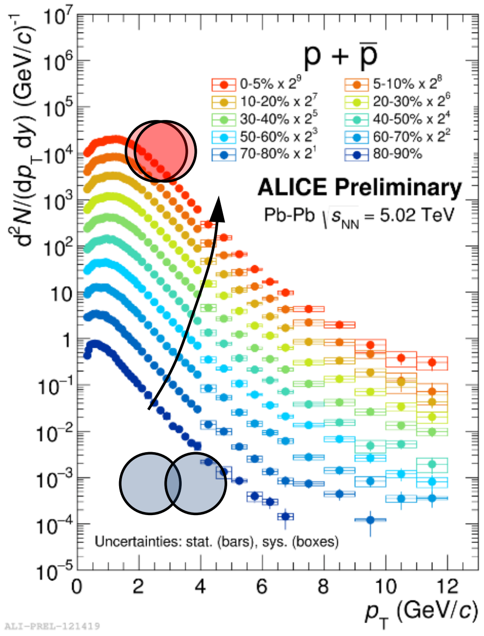
- **Anisotropic flow** (important in semi-peripheral collisions):
  - Initial spatial anisotropy translates into final momentum anisotropy (pressure gradients)
  - Measured through angular anisotropies in the momentum distribution



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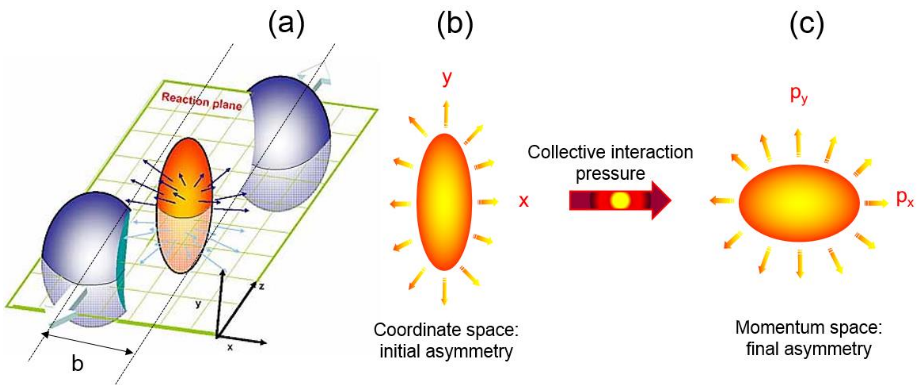
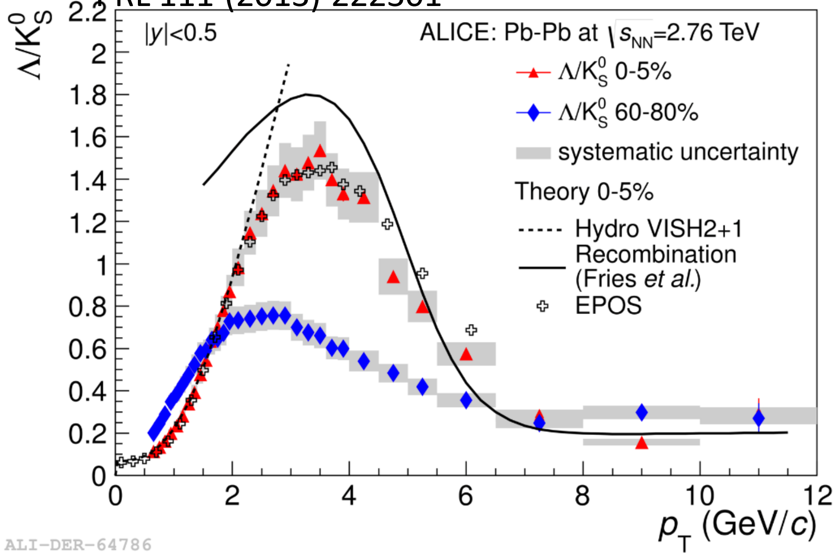


$$v_n = \langle \cos[n(\phi - \Psi_n)] \rangle$$

$$E\frac{d^3N}{dp^3} \approx \frac{1}{2\pi}\frac{d^2N}{p_T\,dp_T\,d\eta}\left[1 + 2\sum_{n=1}^{\infty} v_n \cos[n(\phi - \Psi_n)]\right]$$

~~baryon/meson~~ (high/low mass) ratio: from HI…

PRL 111 (2013) 222301



Increase at mid-p_T in all centrality classes.

Peak shifting towards the right when going more central (higher radial boost in central collisions?)

Evolution can be described by hydro at low-p_T

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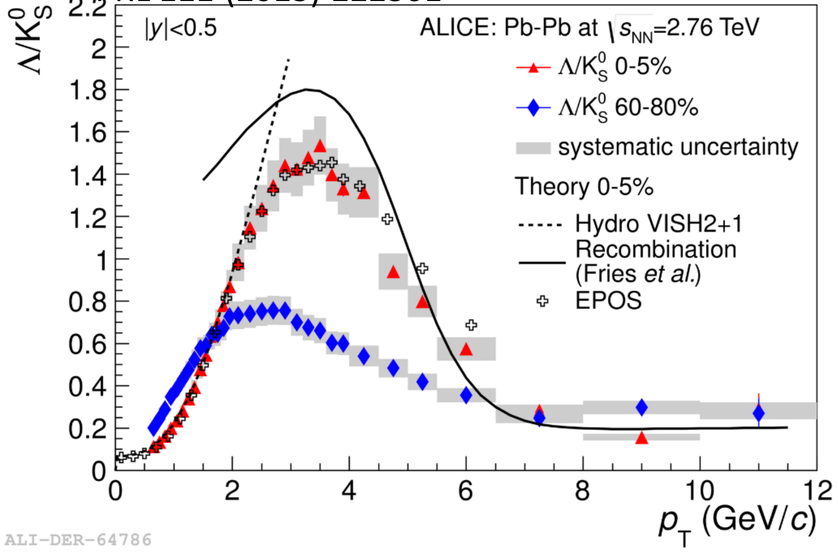

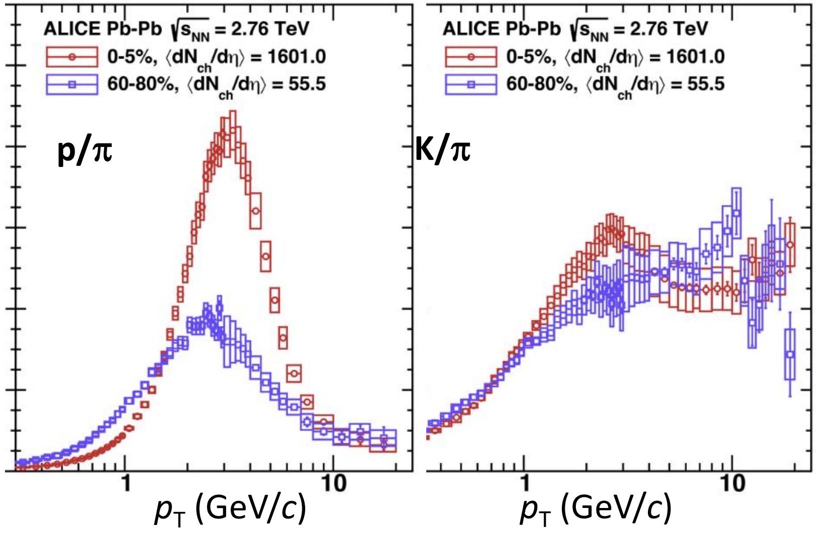

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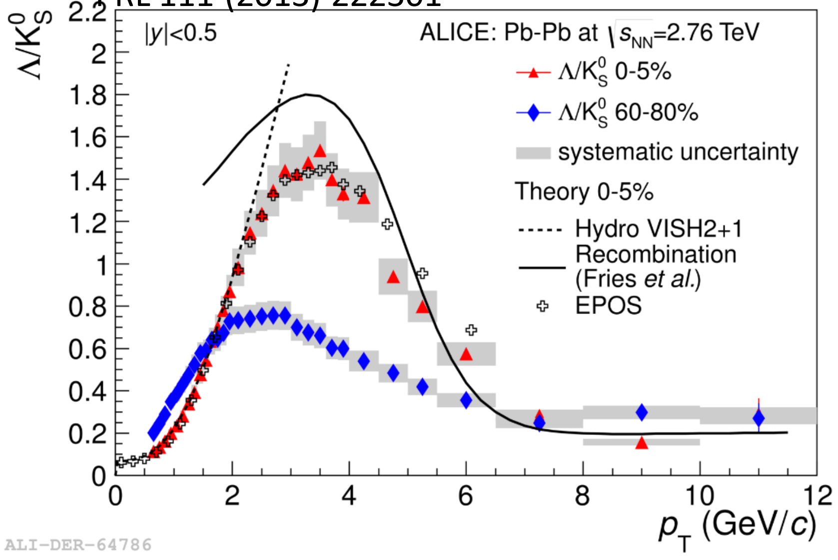
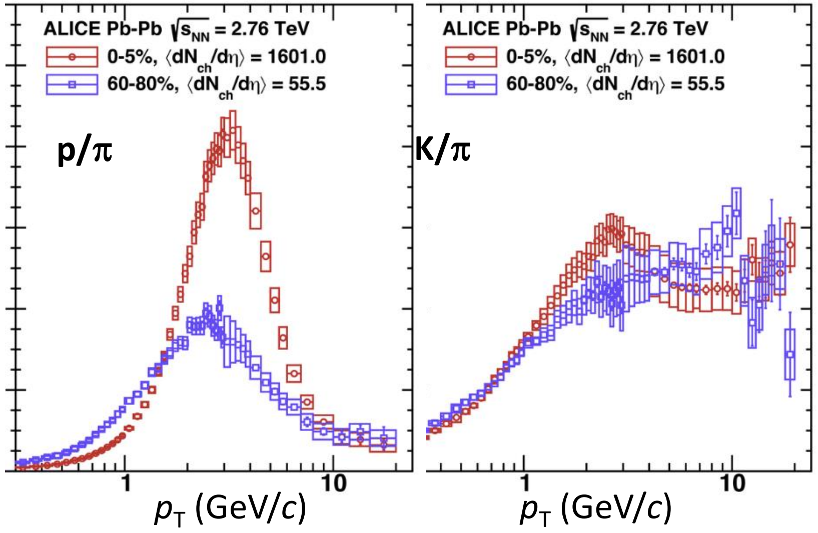
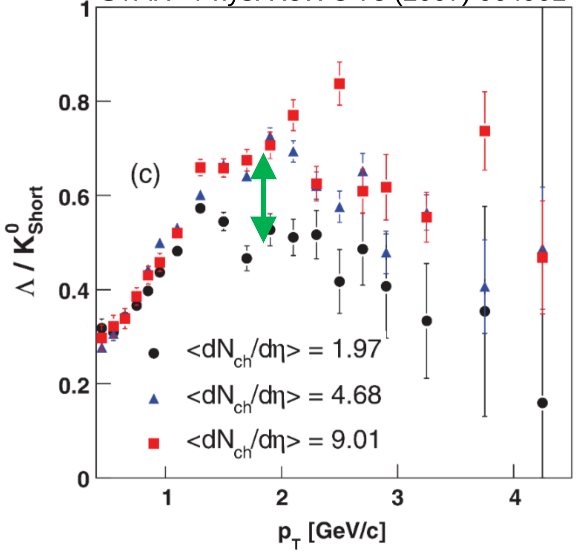




STAR - Phys. Rev. C 75 (2007) 064901



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Hint for a similar evolution in pp from STAR?

Extensively studied in small systems at the LHC:

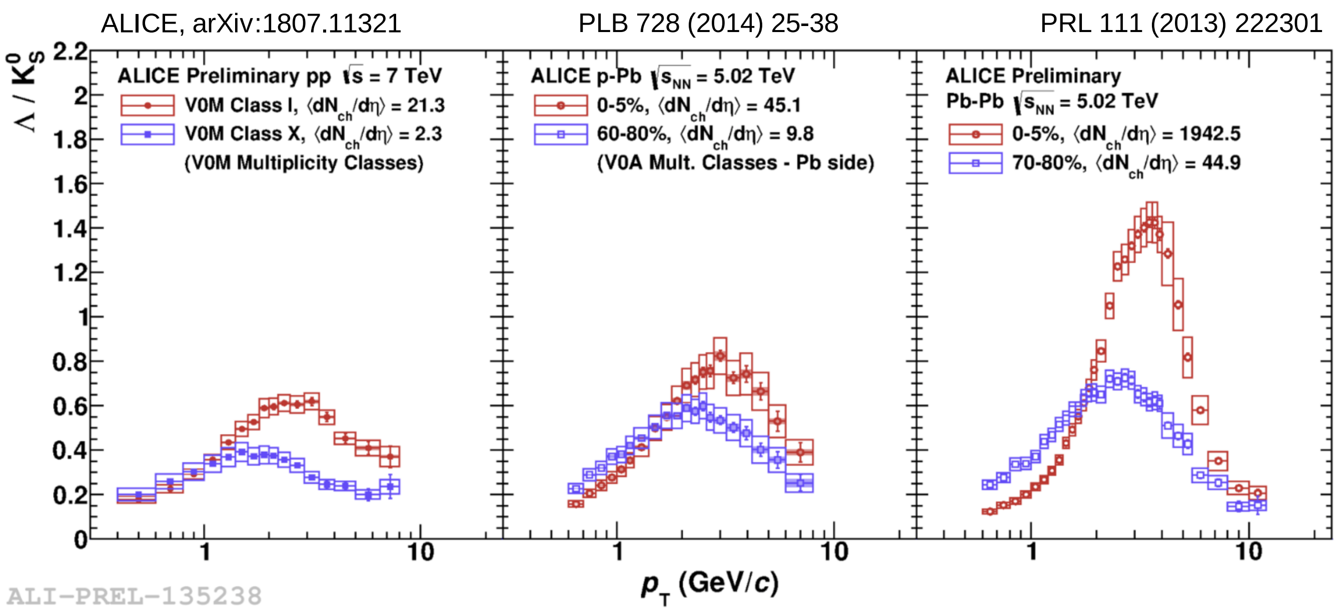
ALICE, Nat. Phys. 13 (2017) 535-539

ALICE, arXiv:1807.11321

ALICE, PLB 728 (2014) 25-38

CMS, PLB 768 (2017) 103

Spectra modification: baryon/meson ratio (small systems)

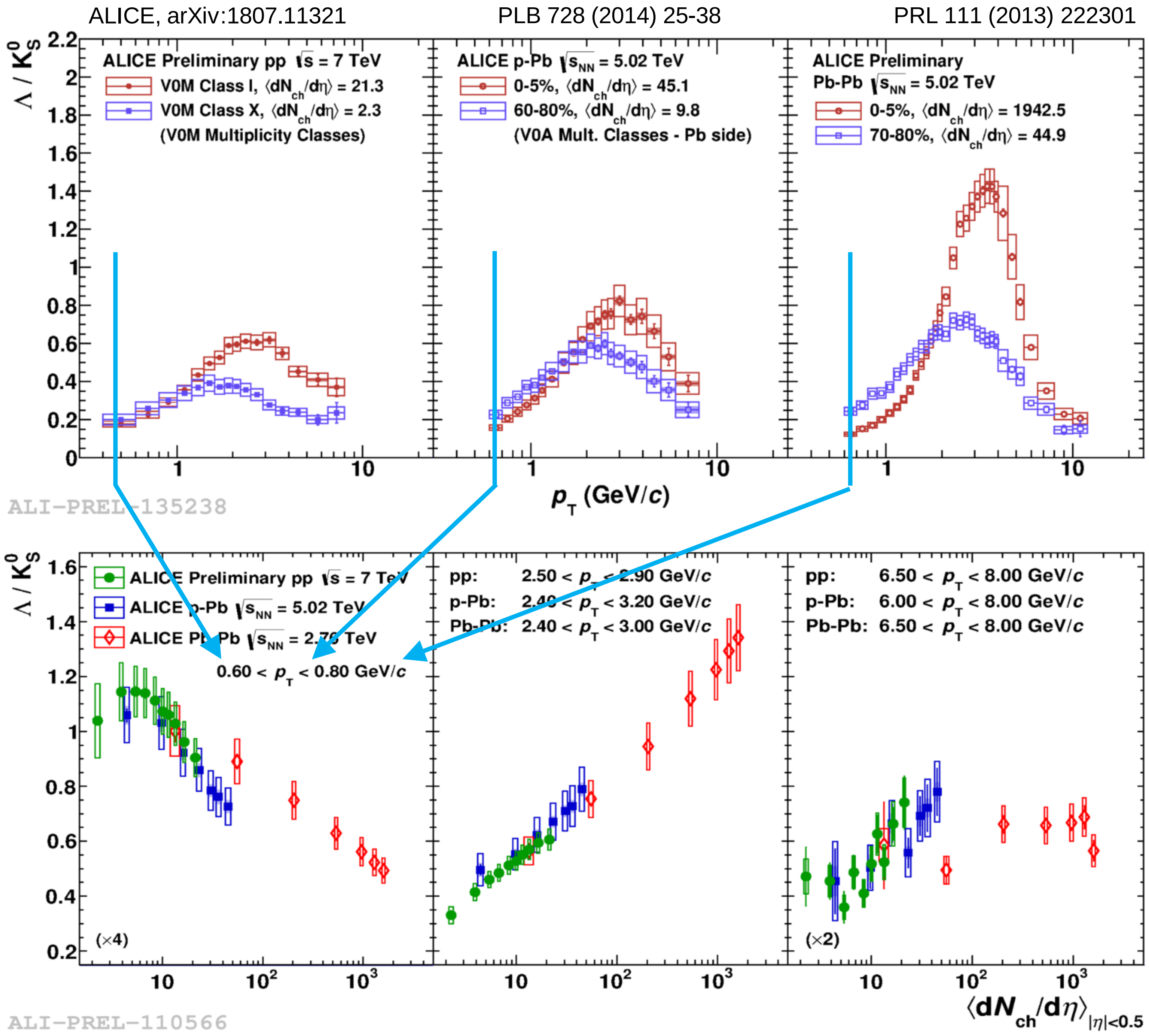


Same pattern in the Λ/K^0_S measured in small systems, with different magnitude…

…but…

MIND THE MULTIPLICITY SPAN!

Spectra modification: baryon/meson ratio (small systems)

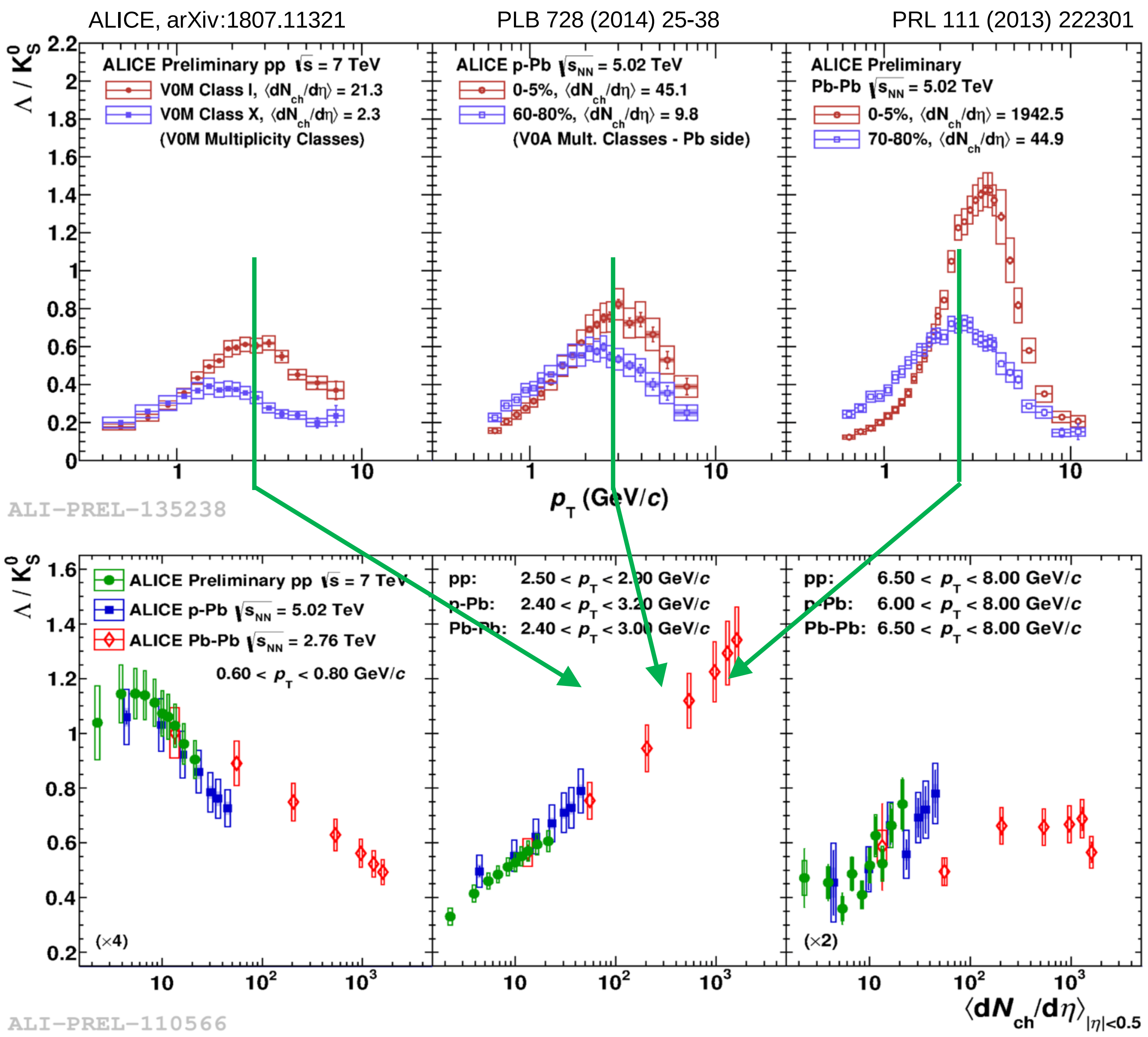


Same pattern in the Λ/K^0_S measured in small systems, with different magnitude…

…but…

MIND THE MULTIPLICITY SPAN!

In order to make proper comparison, one can select p_T ranges and look at multiplicity dependence



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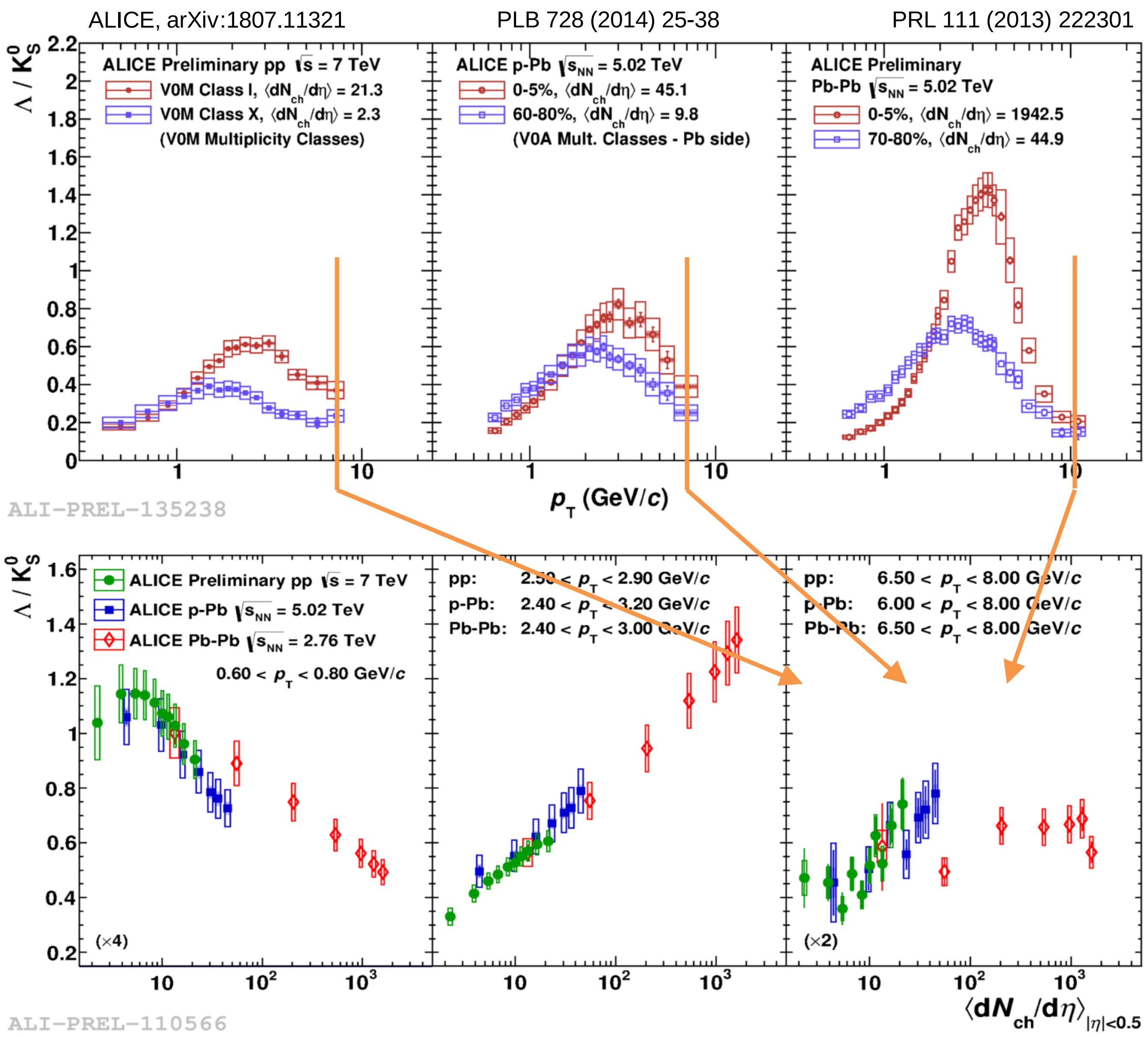

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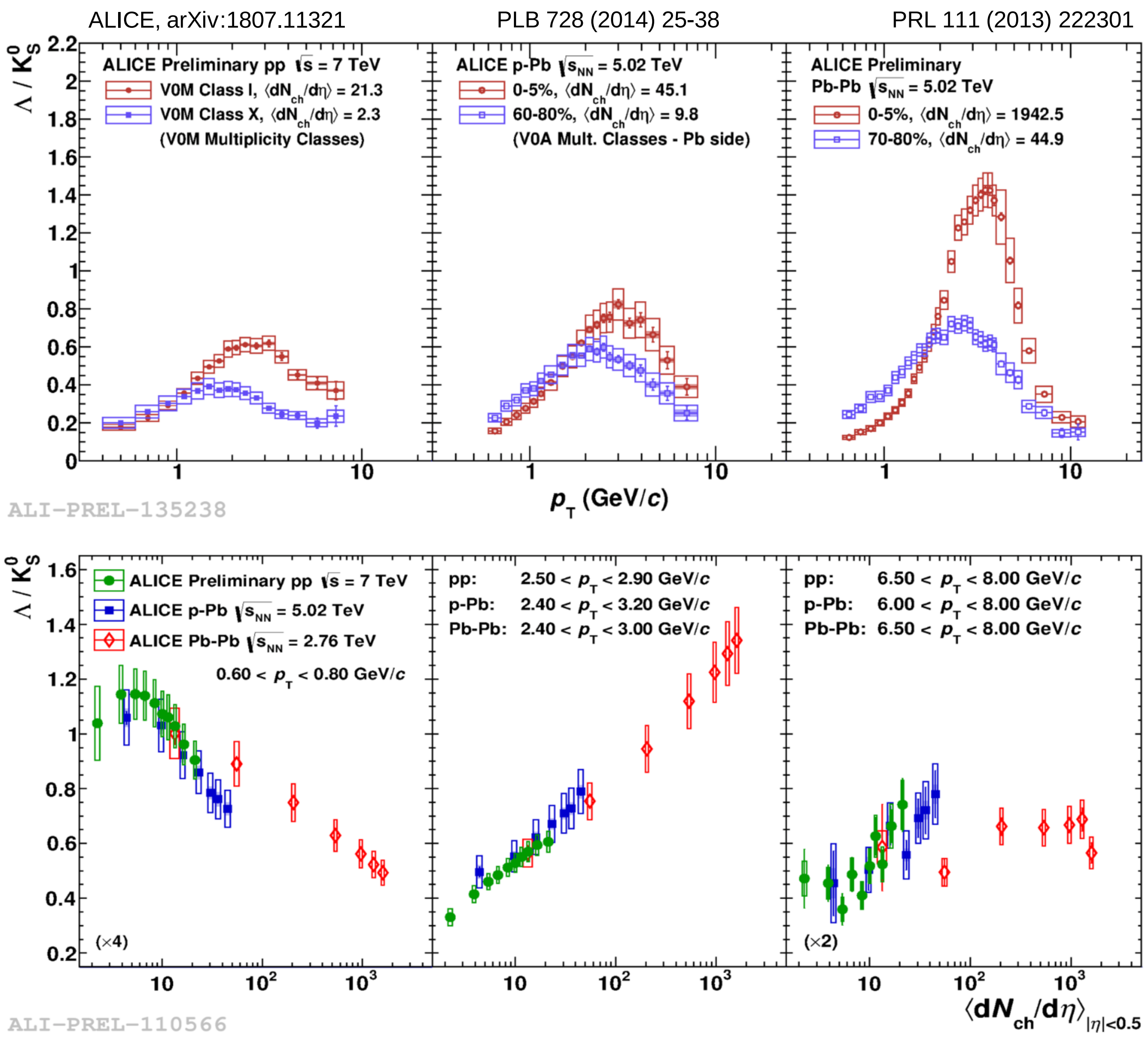
Livio Bianchi
35^{th} WWND
11 Jan. 2019



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MIND THE MULTIPLICITY SPAN!

In order to make proper comparison, one can select p_T ranges and look at multiplicity dependence

Clear continuity among different systems!

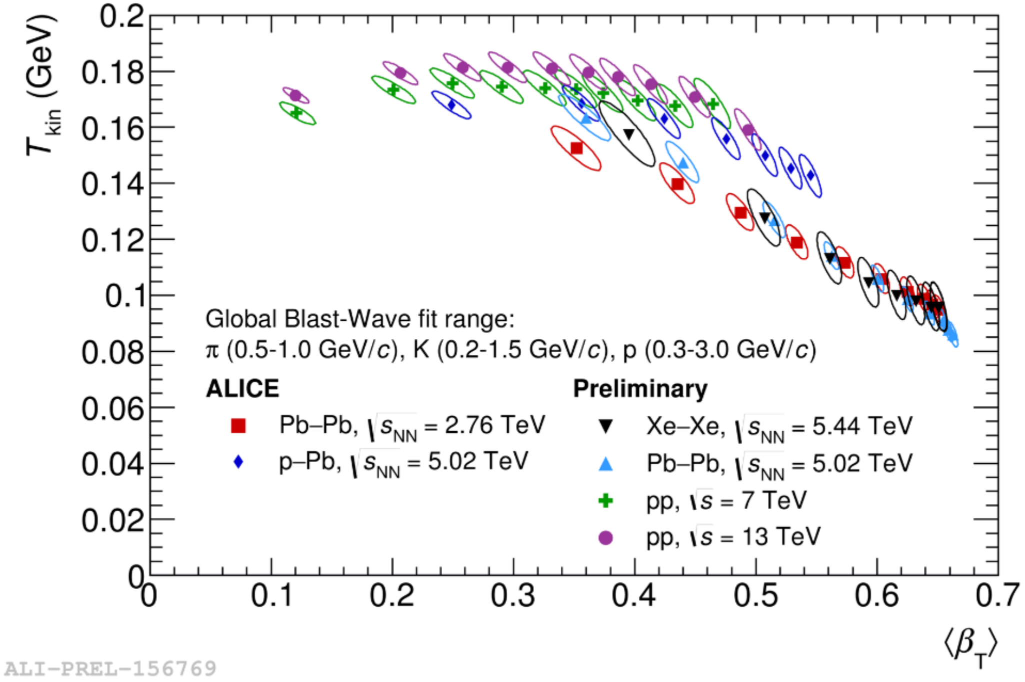
Is the underlying mechanism the same here?

Need to compare p_T spectra to hydro

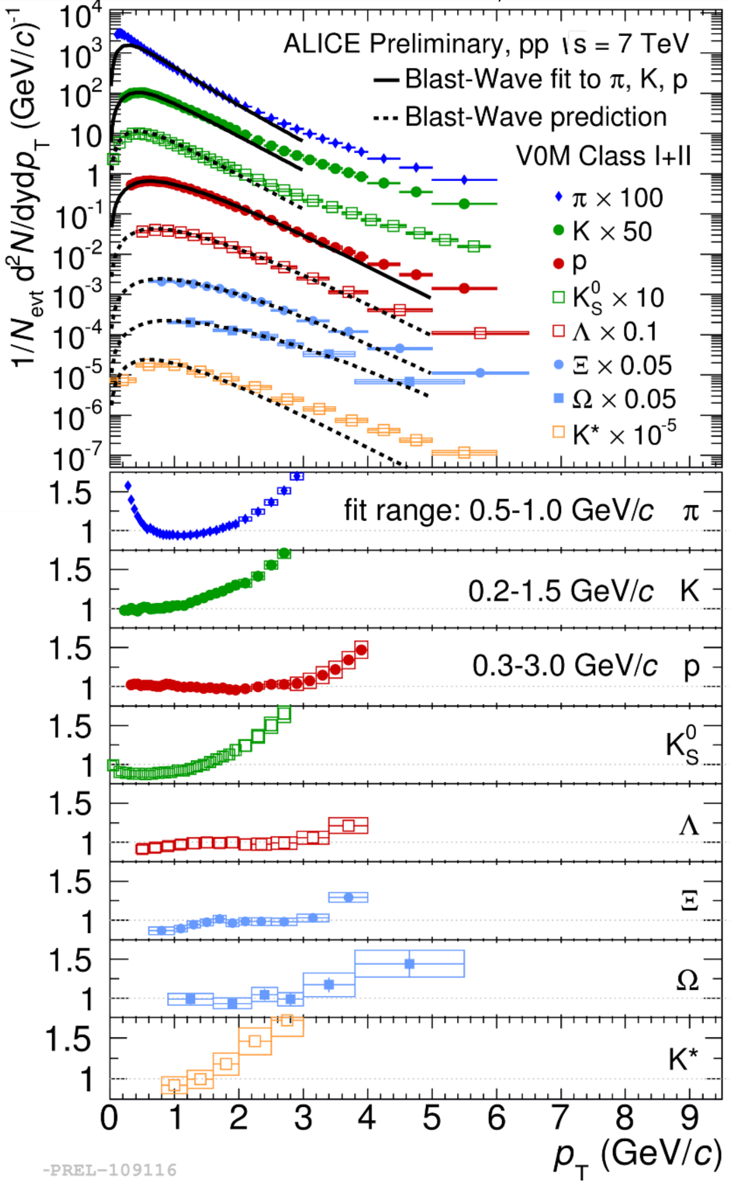
↓

Blast wave - simplified hydro model:

- Assumes common particle expansion with β_T and T_{kin}
- If assumption ok: fit (e.g.) π,K,p $\rightarrow$ predict p_T shape of other particles
- Assumption ~ok for all collision systems
- pp and p-Pb: similar T_{kin}-β_T progression



ALICE, arXiv:1807.11321



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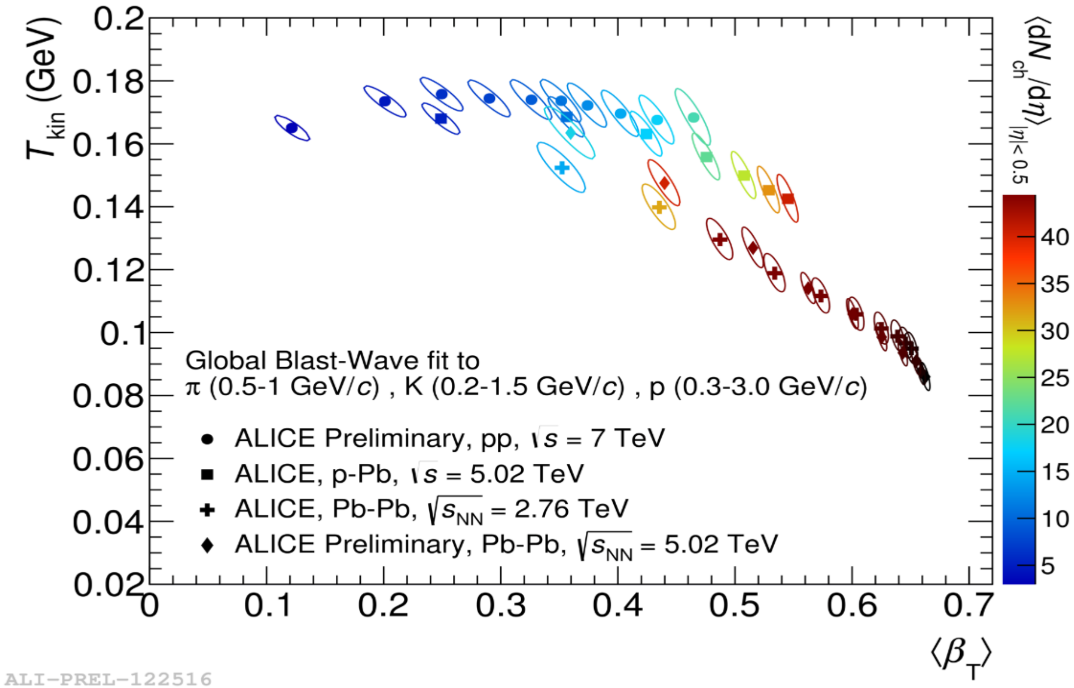
Soft particles p_T spectra in small systems are well reproduced by a symplified hydro model.



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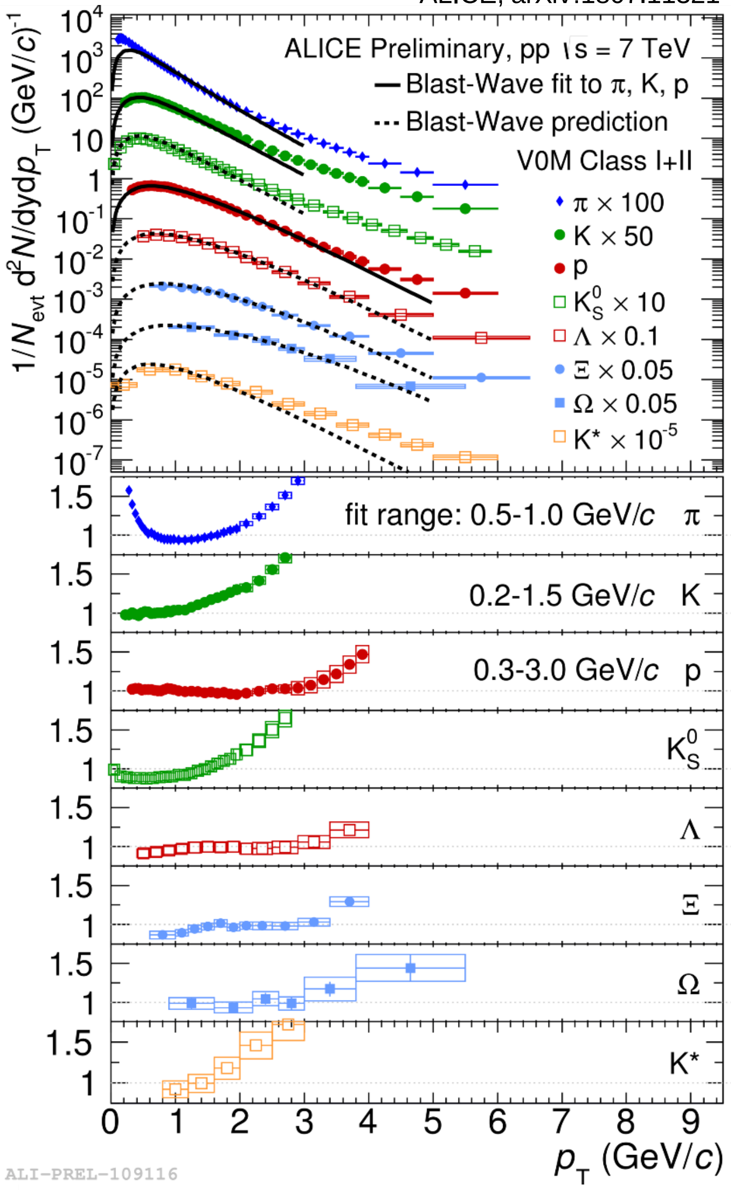

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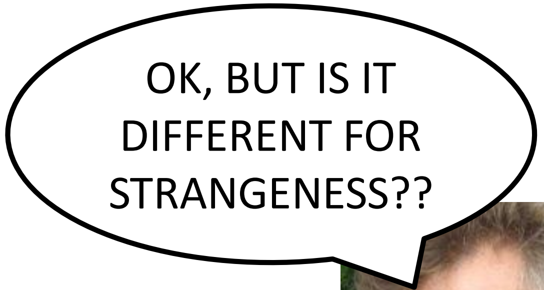

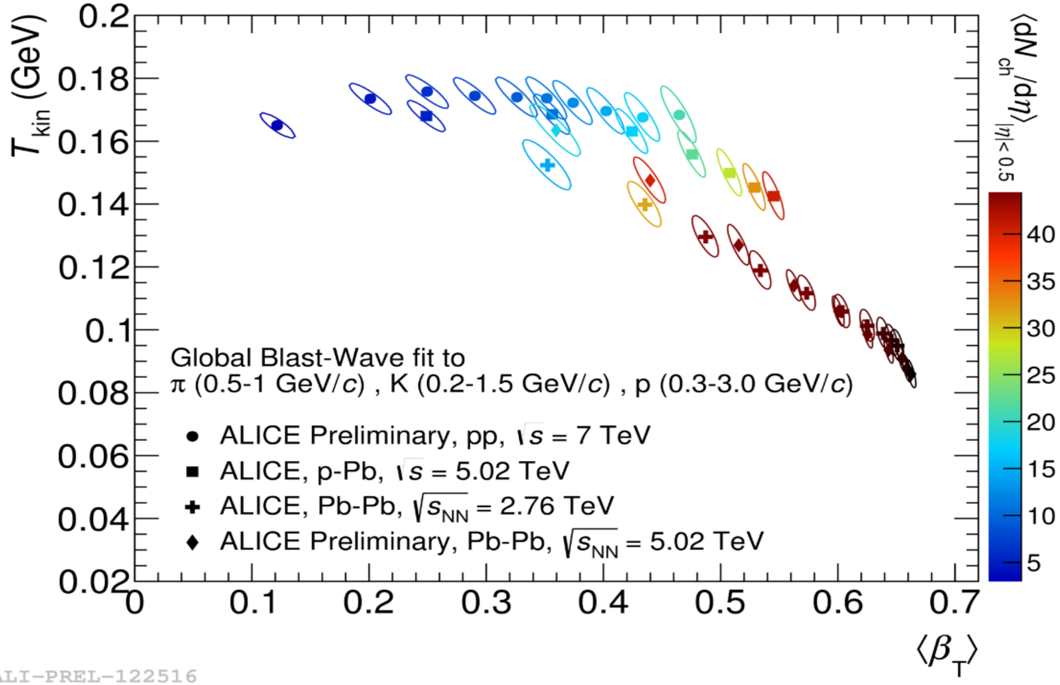

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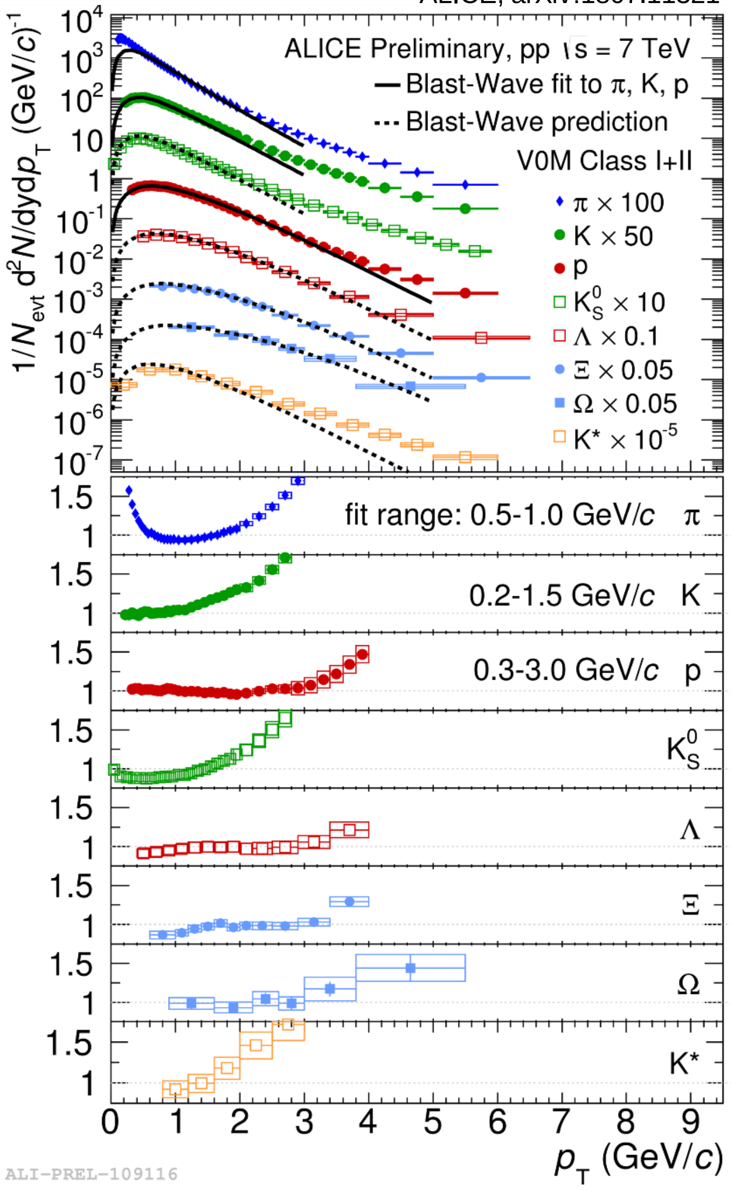
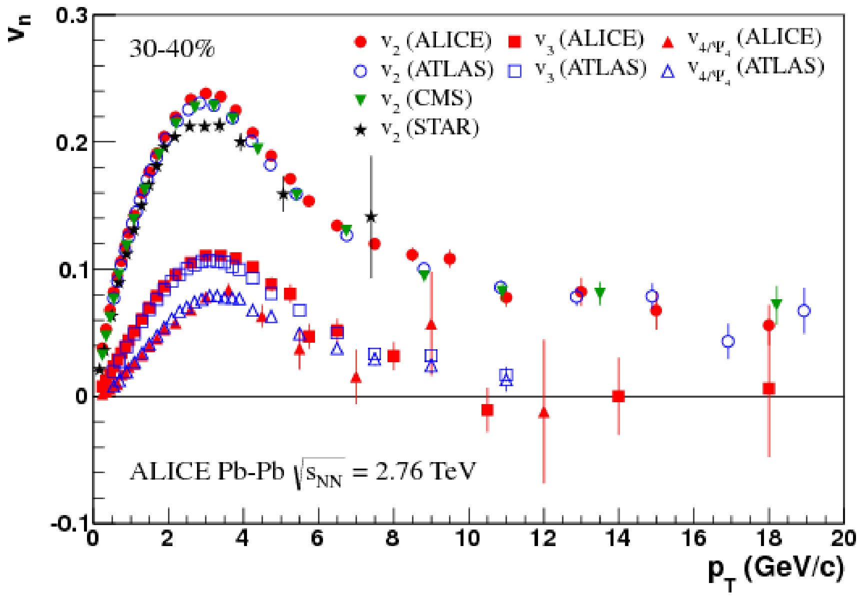


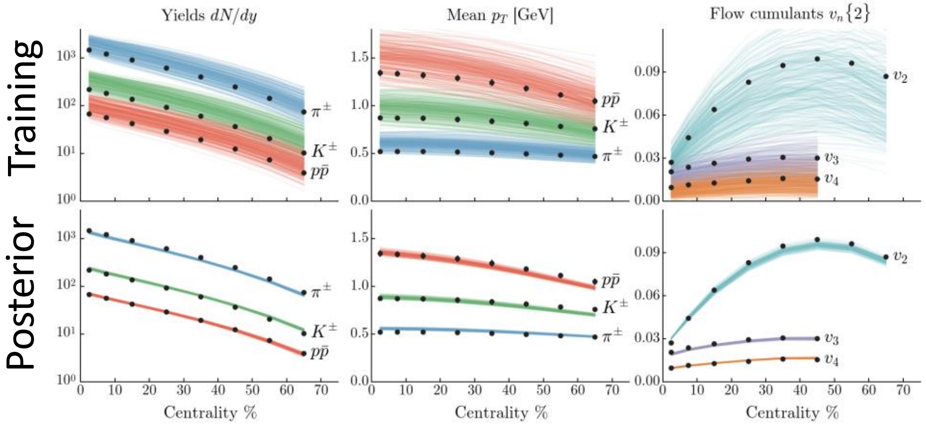
$v_n \neq 0$ observed in HI at RHIC and LHC



What about small collision systems?

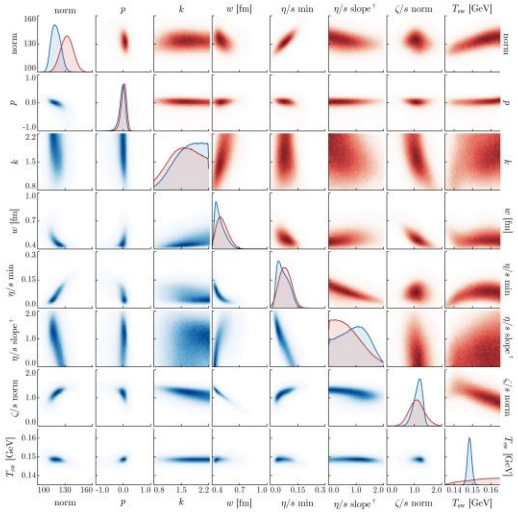
↓

Global hydro fits to several bulk observables start appearing:



THE MODEL

- Initian entropy-density anisotropies + Bulk/shear viscosity + normalization
- ↓ Hydro code (VISH2+1) + EoS (from lattice)
- ↓ At T_{switch}: transition
- ↓ Hadron afterburner (UrQMD)
- → Output



J. E. Bernhard at al., Phys. Rev. C 94, 024907 (2016)

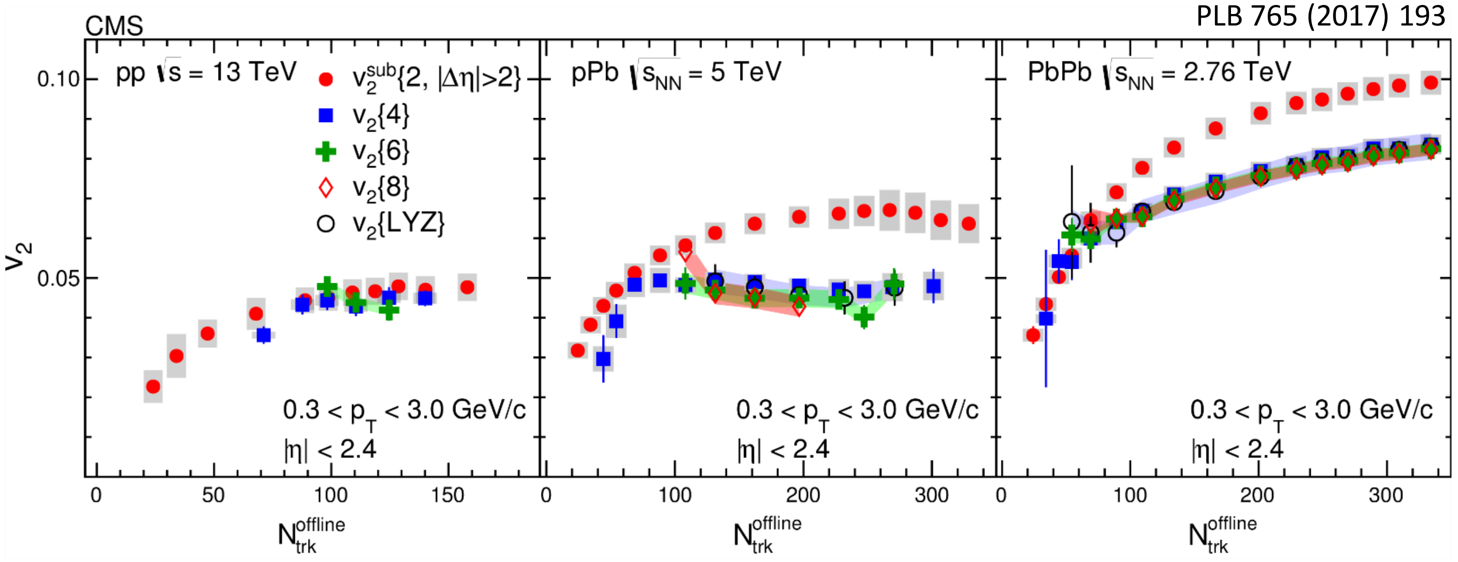
Anisotropic flow: small systems?

$v_2 \neq 0$ observed in all collision systems

NOTE: contribution of non-flow not easy to estimate in pp (and p-Pb)

…but does this make sense at all?
Can hydro develop in so small systems?

PLB 765 (2017) 193



Naïve expectation: need "large enough" and "live long enough" medium to reach thermal equilibrium and apply hydro (several interactions needed)

- $R > \lambda$
- $\tau > \lambda/v$

MEAN FREE PATH

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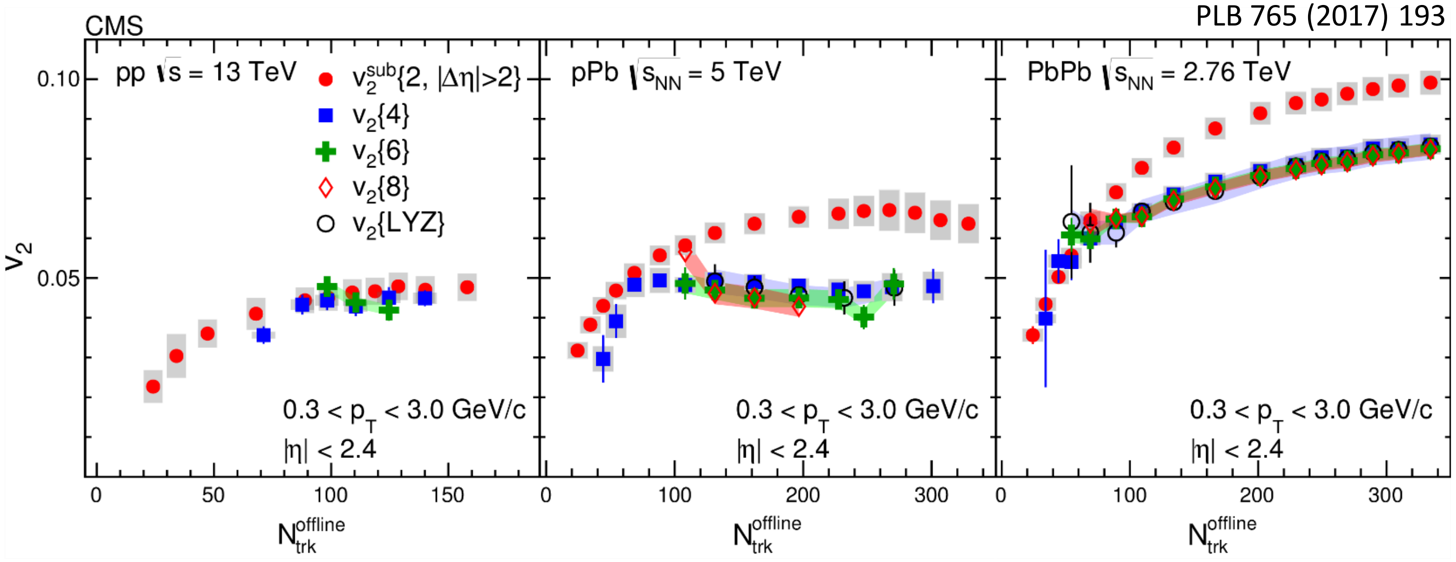

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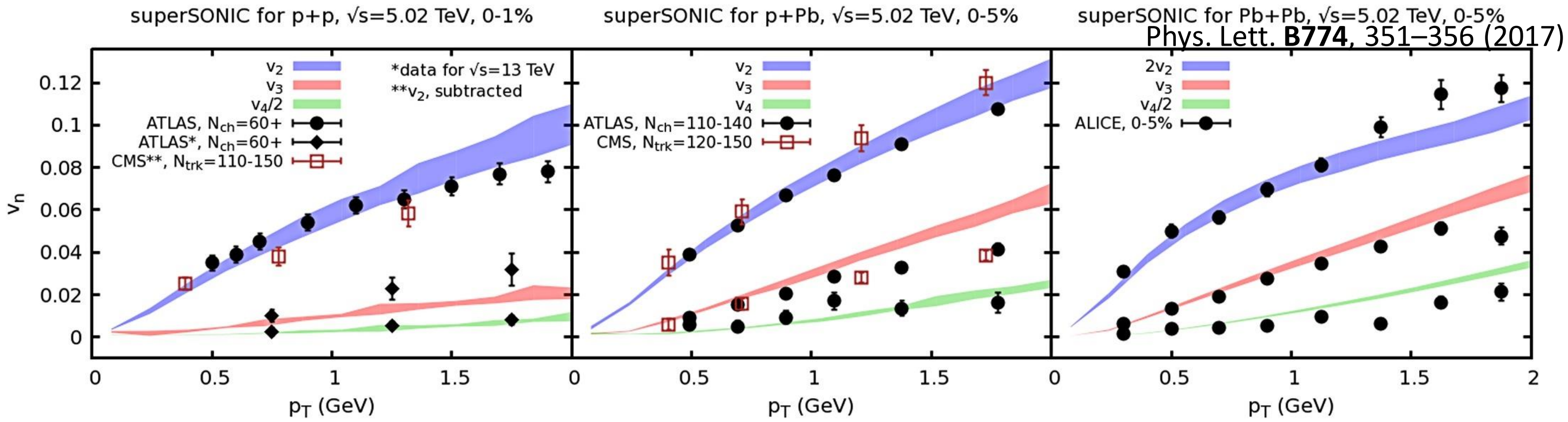
- ~~$R > \lambda$~~
- ~~$\tau > \lambda/v$~~

Too restrictive: hydro can be applied far from thermalization!

W. Li, arXiv: 1704.03576



First theoretical calculations involving hydro expansion of a single fluid in all collisional systems start appearing.

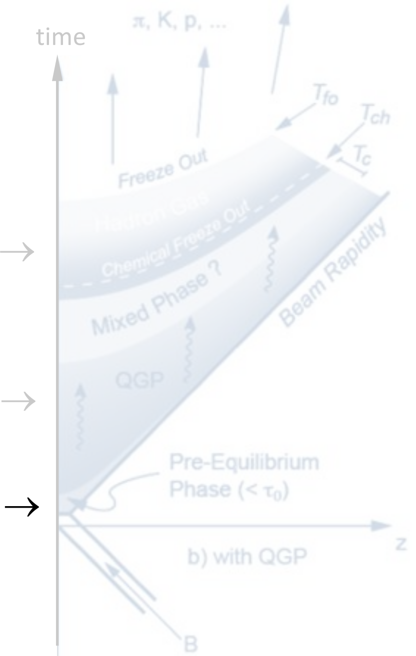
Selected results

…from latest to earlier stages of the evolution:

Hadrochemistry →

Collectivity →

Hard probes →

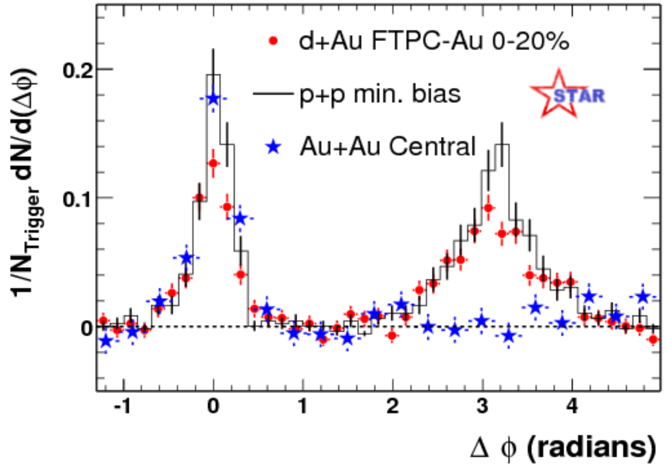


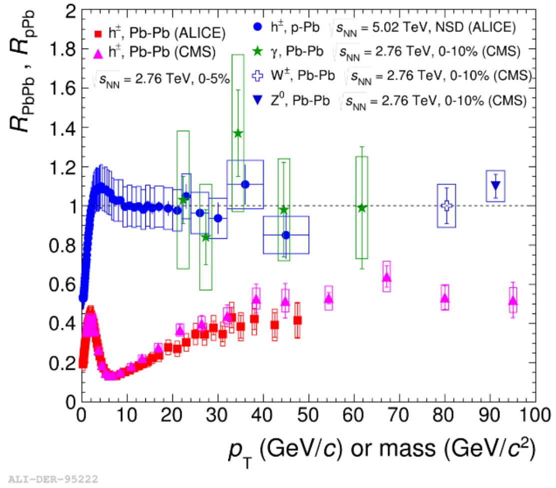
Partonic energy loss

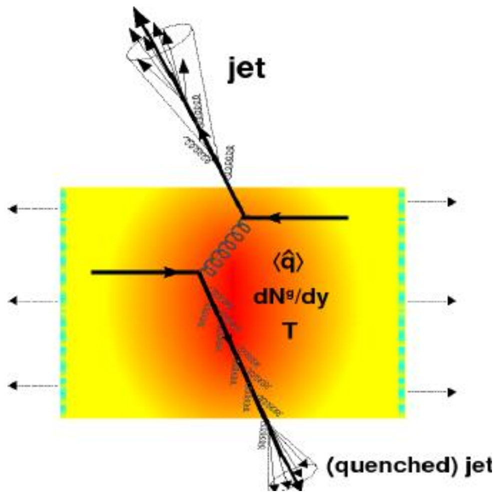
- High-p_T partons produced in the early stages of the collisions (τ<<1fm)
- Loose energy in the medium through:
  - elastic scattering
  - Induced gluon radiation (dominant at high-p_T)
- Simple prediction (dead-cone effect):

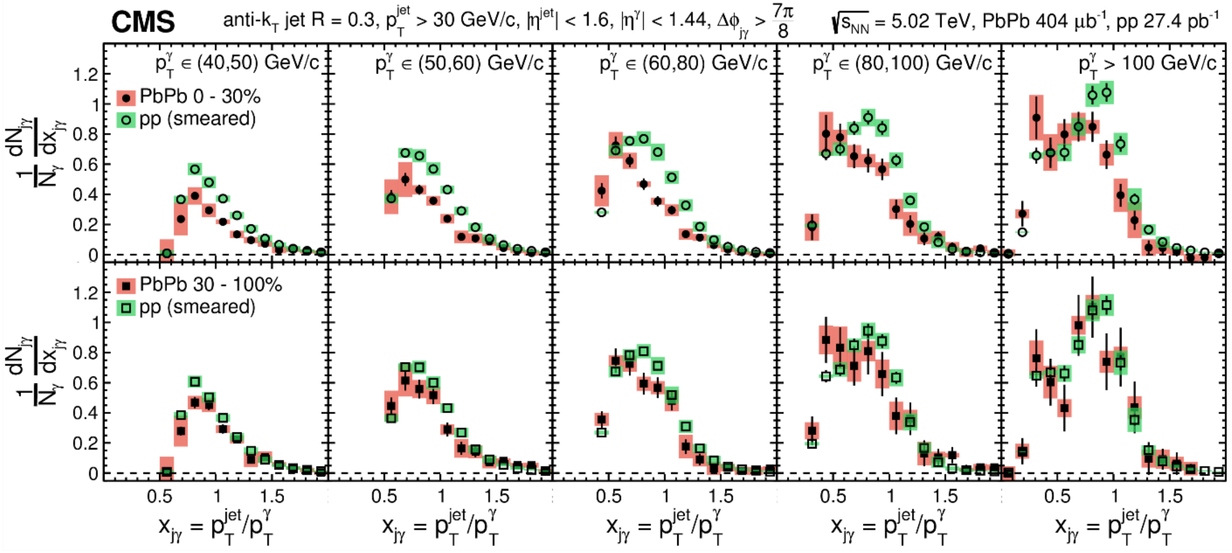
$$\Delta E_g > \Delta E_{light-quark} > \Delta E_{heavy-quark}$$

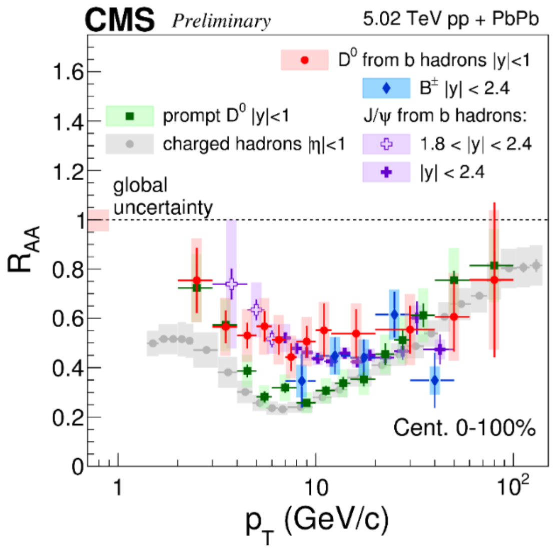
STAR, PRL 91 (2003) 072304





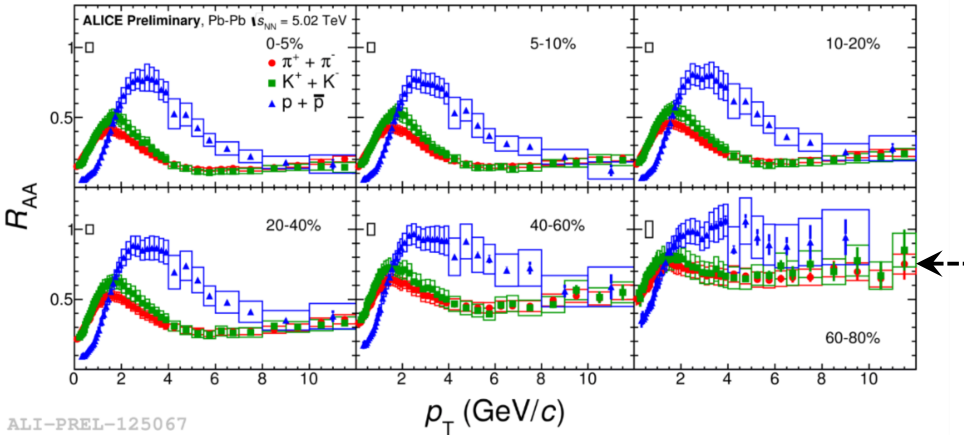


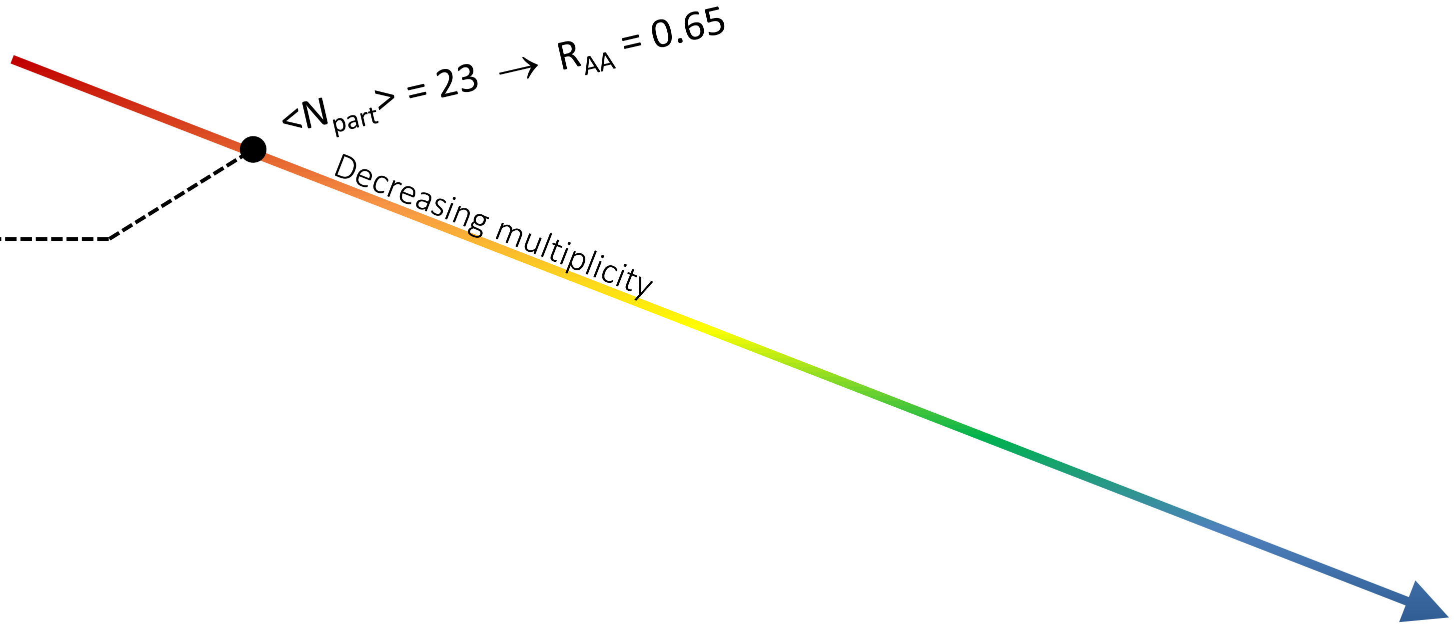




CMS, arXiv:1711.09738

Hard probes: going “smaller”





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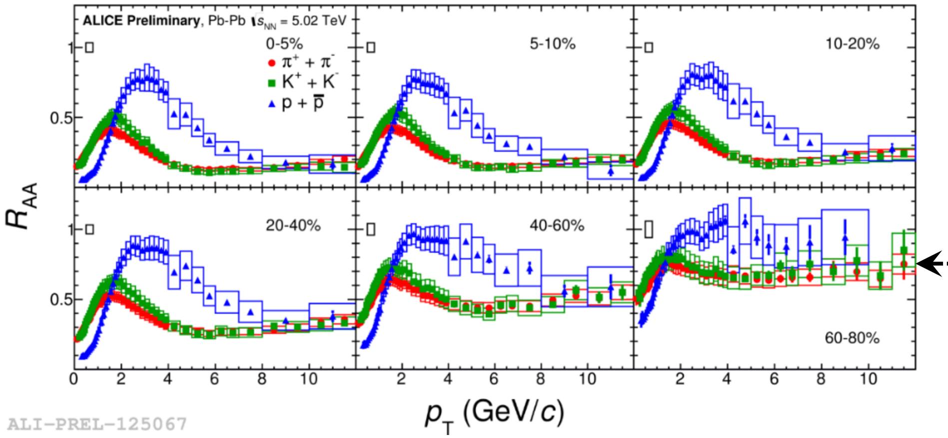

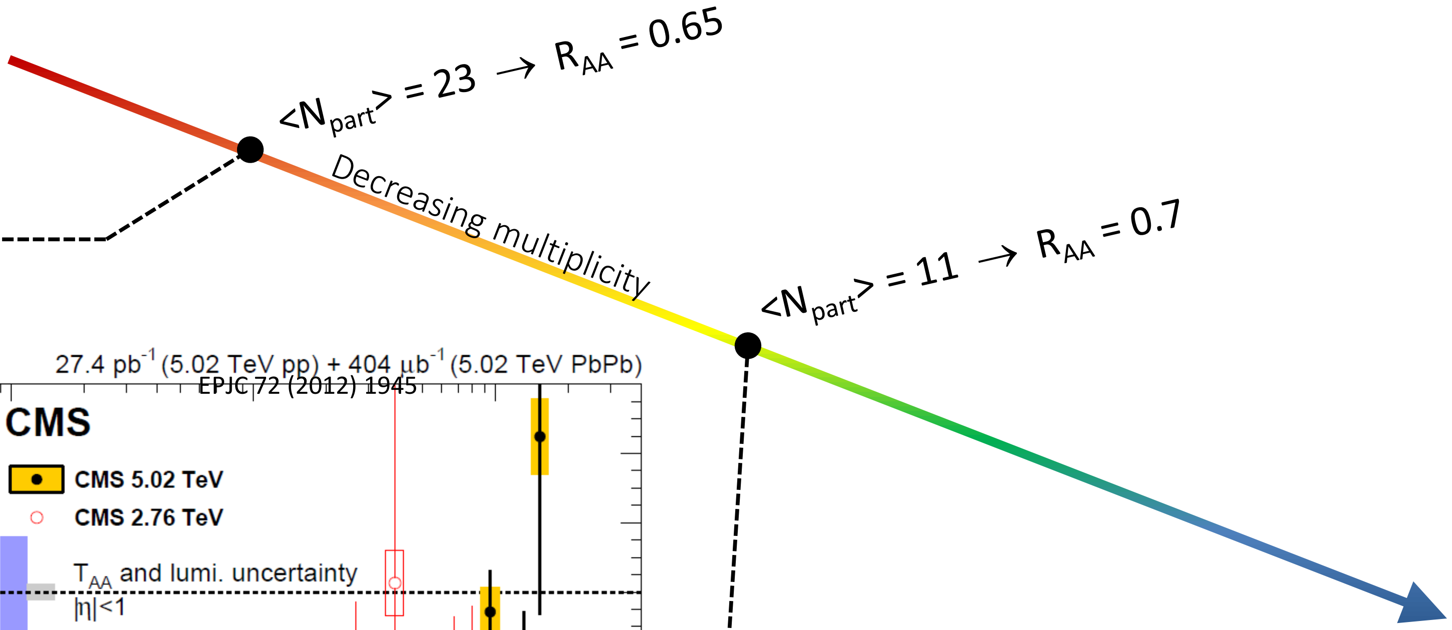

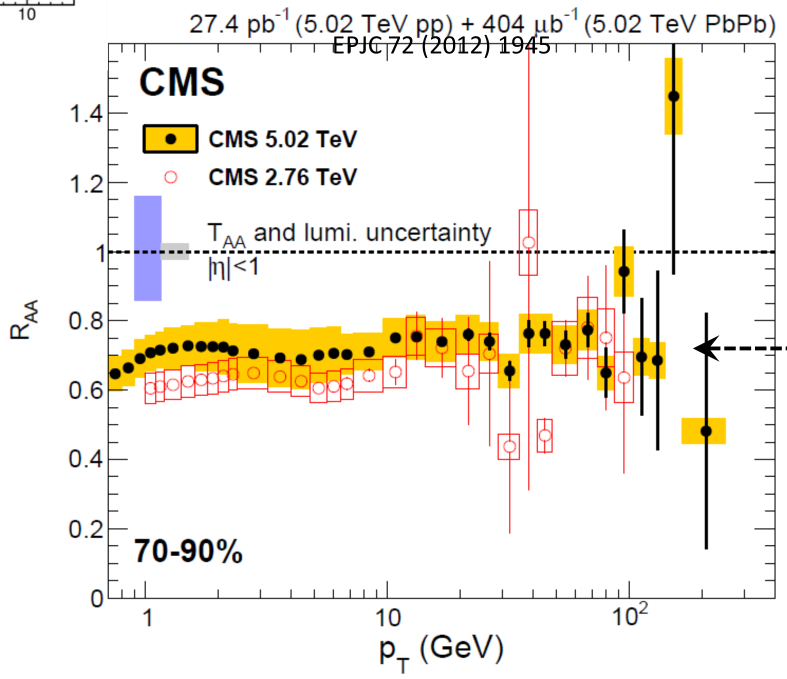

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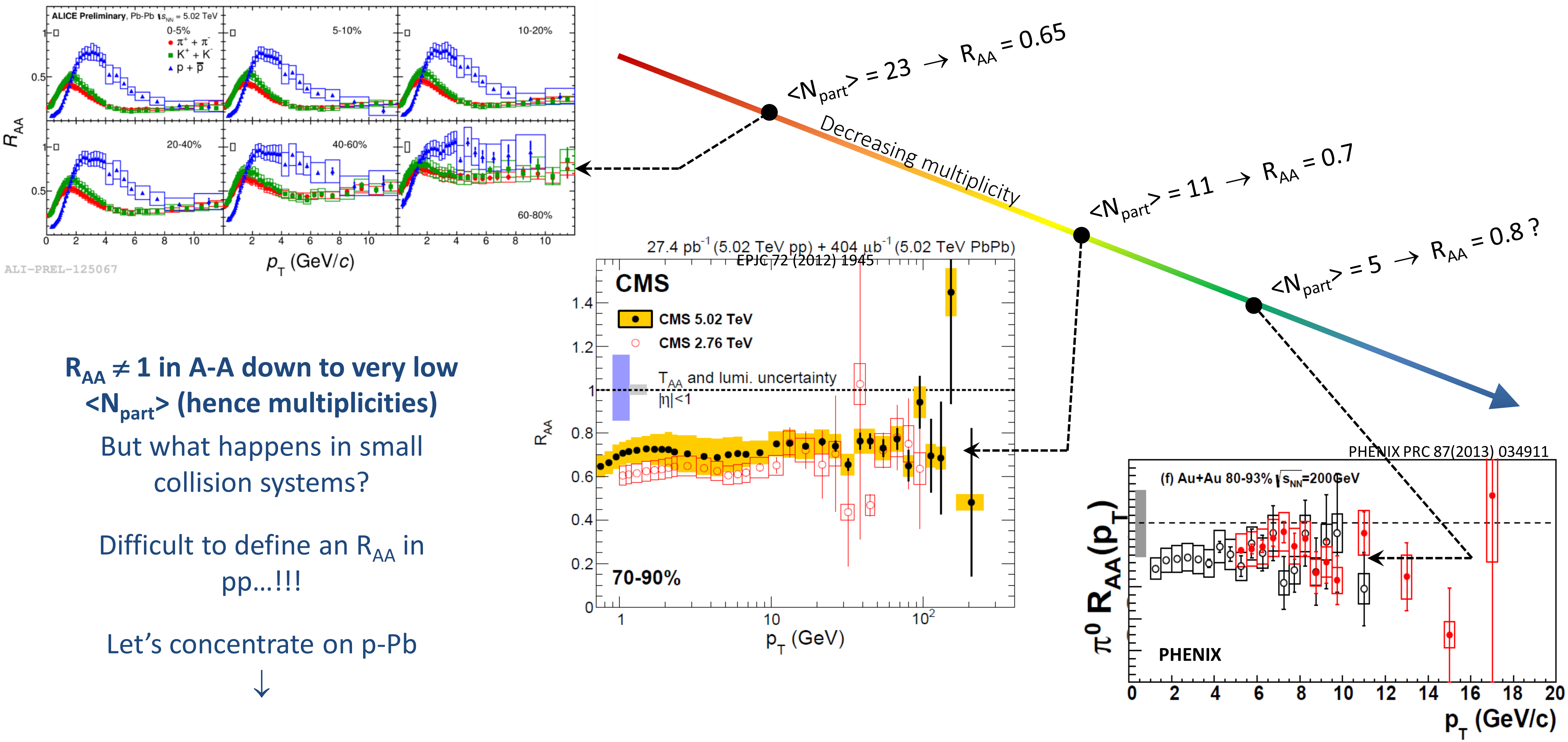

$R_{AA} \neq 1$ in A-A down to very low $\langle N_{part} \rangle$ (hence multiplicities)

But what happens in small collision systems?

Difficult to define an R_{AA} in pp…!!!

Let’s concentrate on p-Pb

↓

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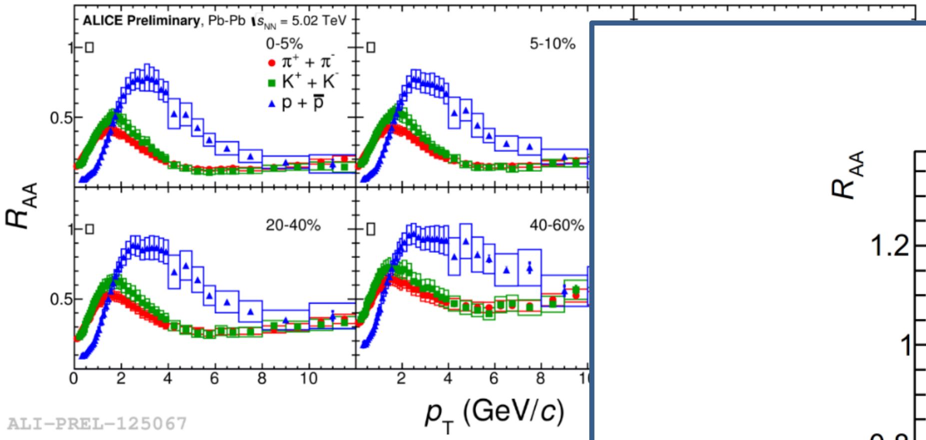

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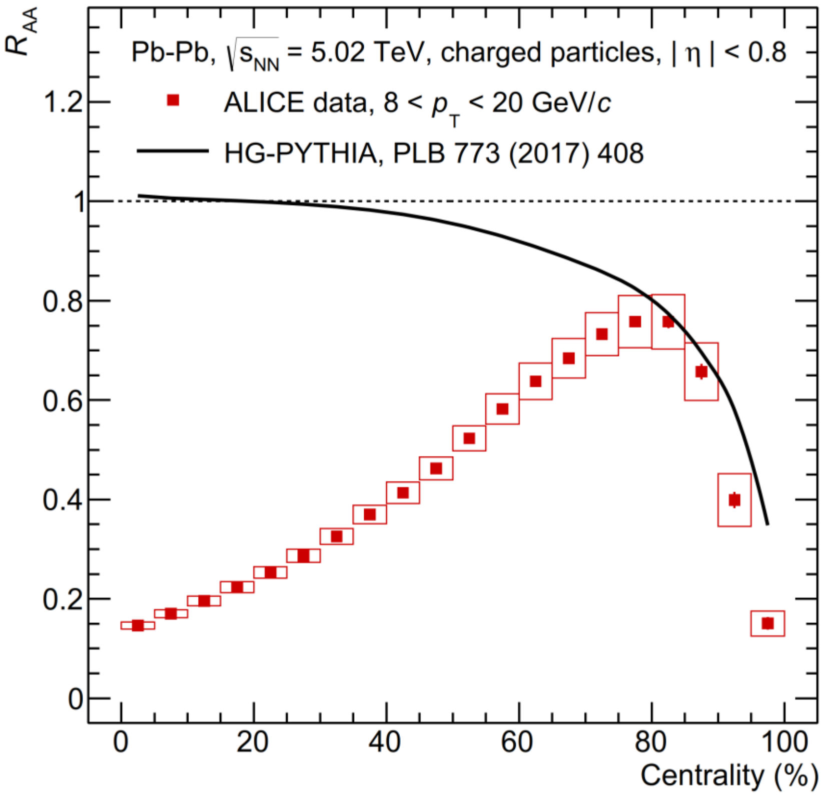
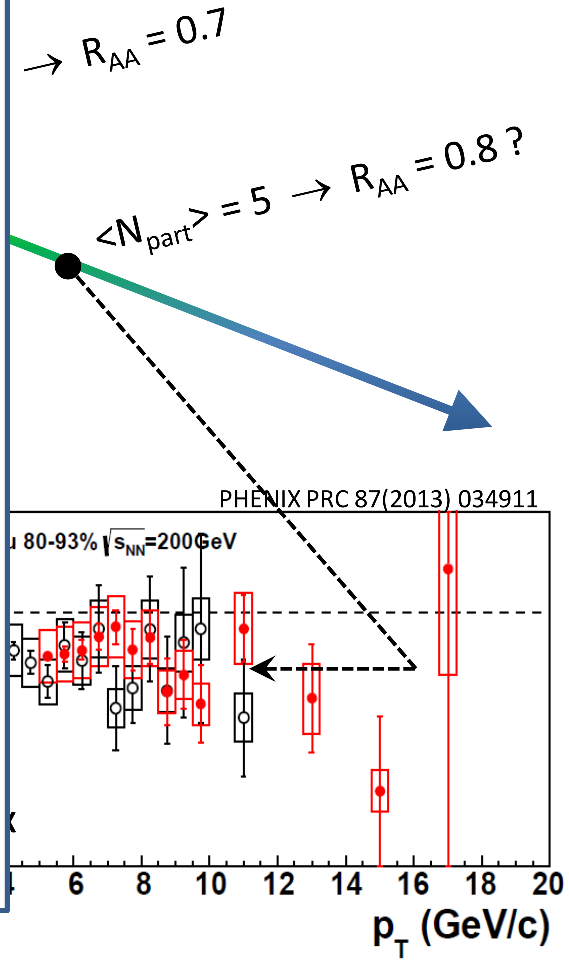


PYTHIA (with no energy loss)
~describes R_{AA} in very peripheral
Pb-Pb collisions from ALICE!

ALICE, arXiv:1805.05212



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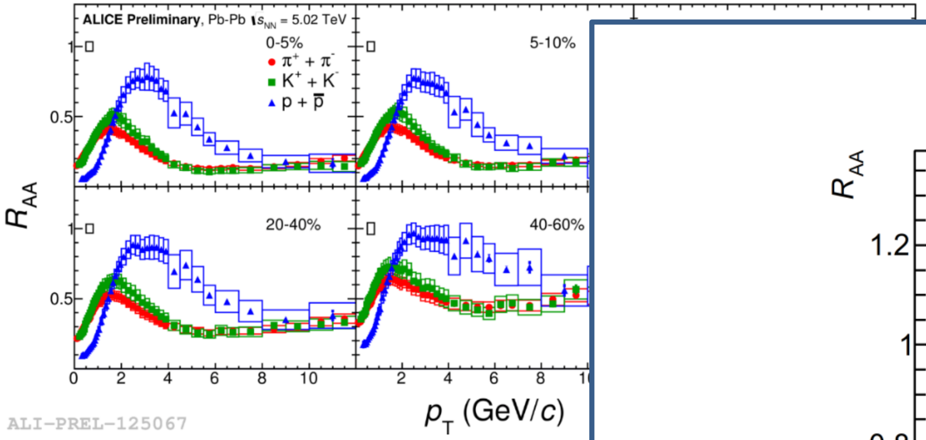

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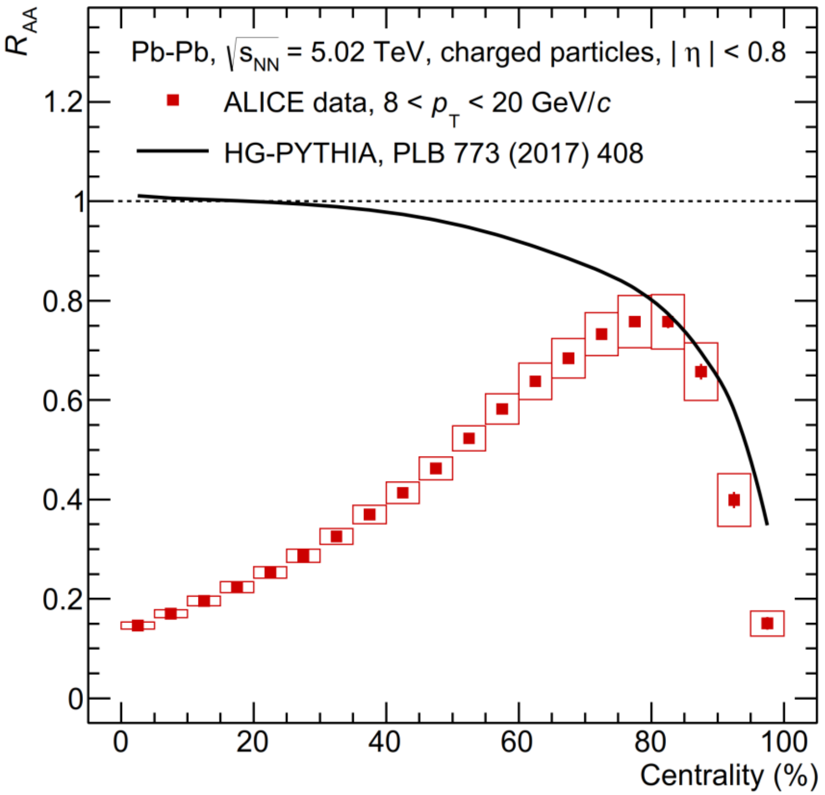

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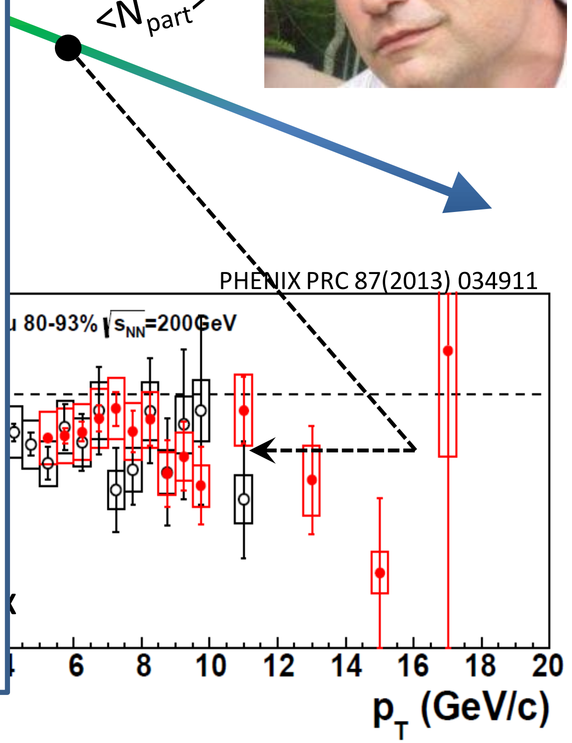
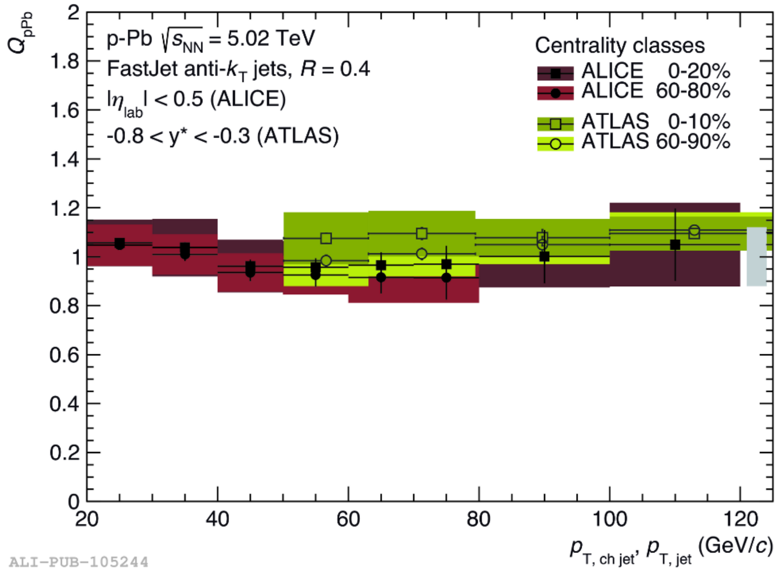
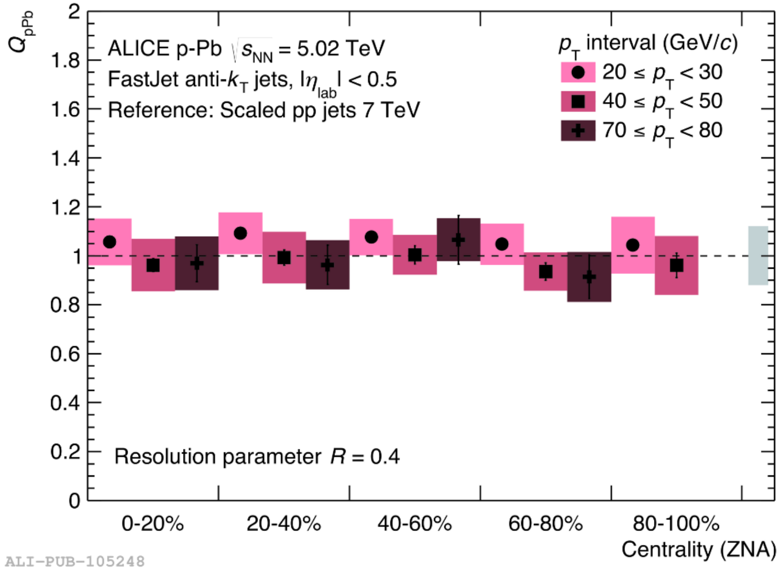


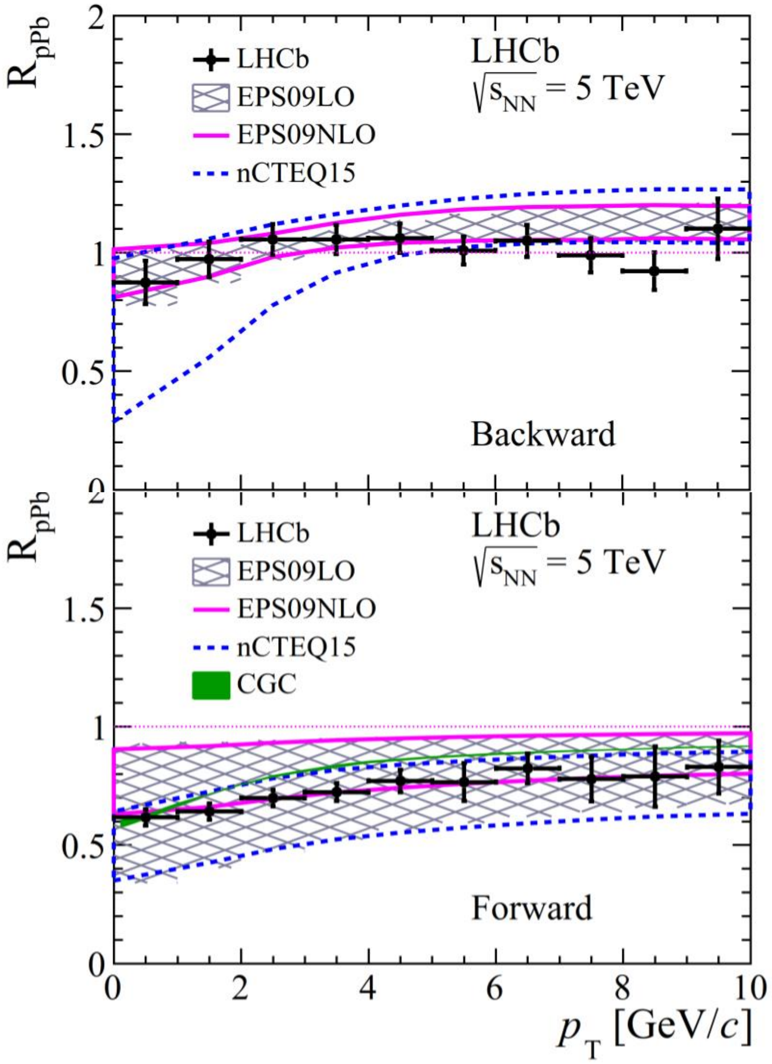
Energy loss in small systems?

ALICE, Eur. Phys. J. C76 (2016) 271





LHCb, arXiv:1707.02750



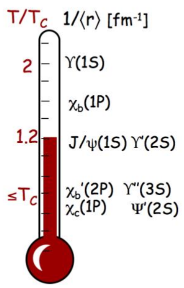
No evidence of **jet quenching in p-Pb** collisions at the LHC

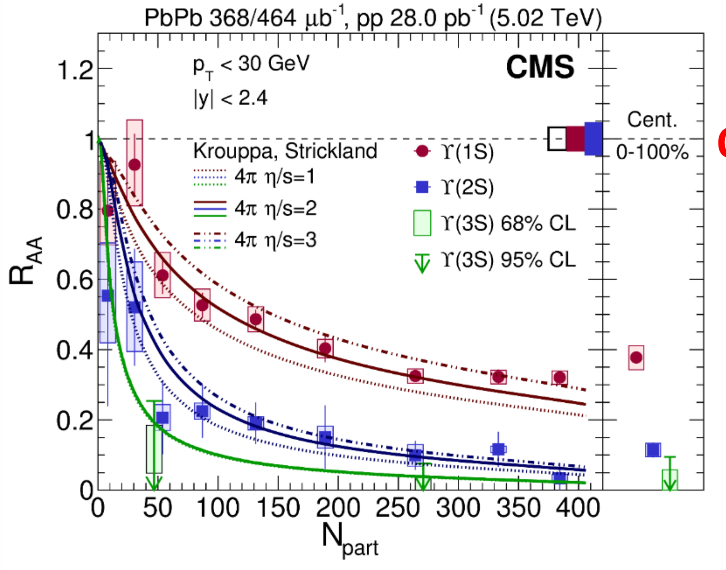
High-p_T hadrons do also not show any suppression

Quarkonia

- **the original idea:**
  quarkonium production suppressed via color screening in the QGP

T.Matsui and H.Satz, Phys.Lett.B178 (1986) 416





Quantitative use of quarkonium as thermometer!!

CMS, arXiv:1805.09215
Krouppa and Strickland, Universe 2016, 2(3), 16

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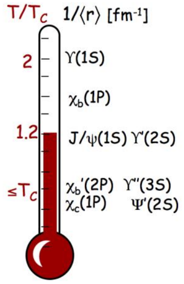
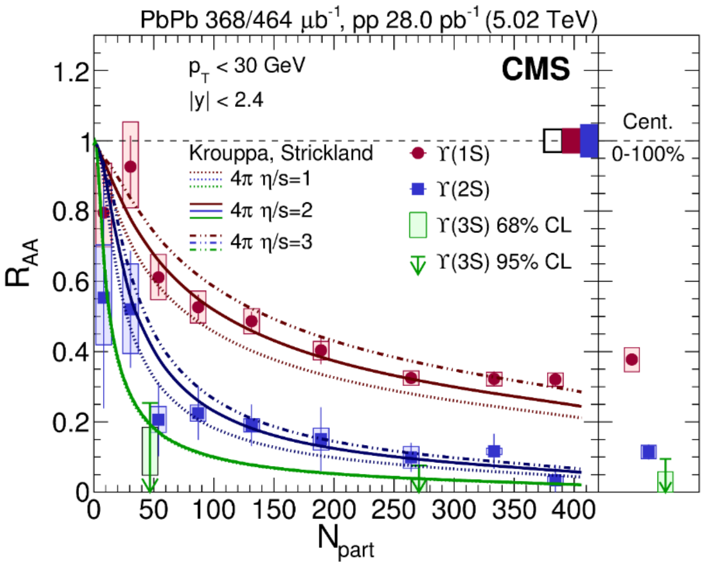




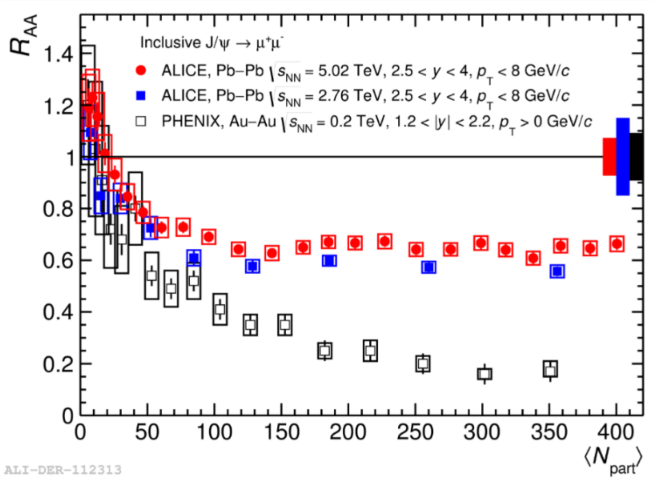
Quantitative use of quarkonium as thermometer!!

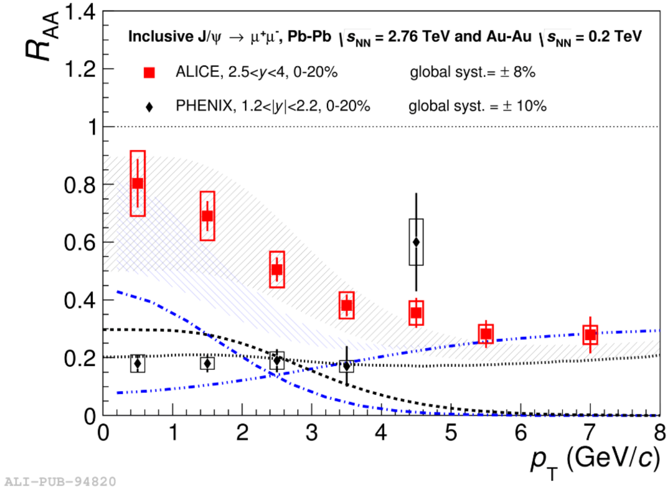
CMS, arXiv:1805.09215
Krouppa and Strickland, Universe 2016, 2(3), 16

- **(re)combination**
  enhanced quarkonium production via (re)combination during QGP phase or at hadronization

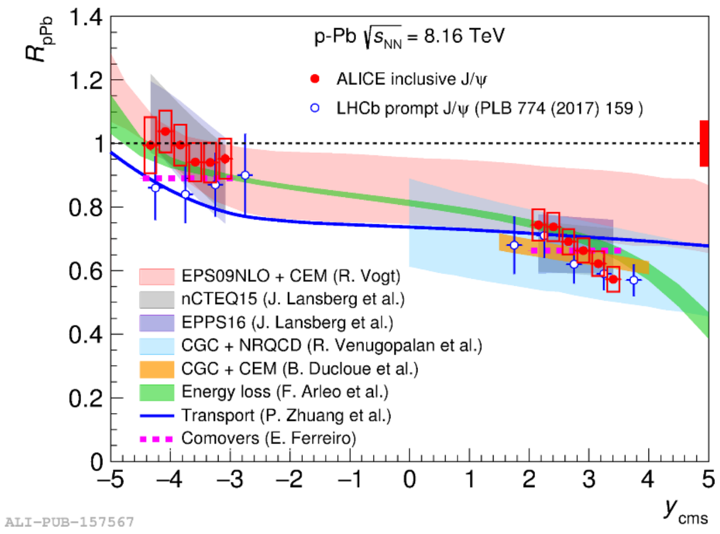
Central AA collisions	SPS 20 GeV	RHIC 200 GeV	LHC 2.76TeV	LHC 5.02TeV
N_{ccbar}/event	~0.2	~10	~85	~115

P. Braun-Muzinger,J. Stachel, PLB 490(2000) 196
R. Thews et al, Phys.Rev.C63:054905(2001)





Quarkonia melting in small systems?



No F.S. suppression for J/ψ in p-Pb collisions

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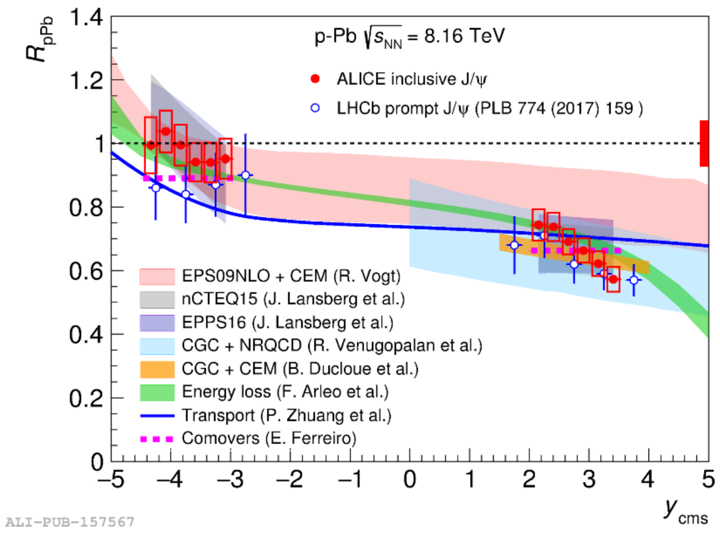
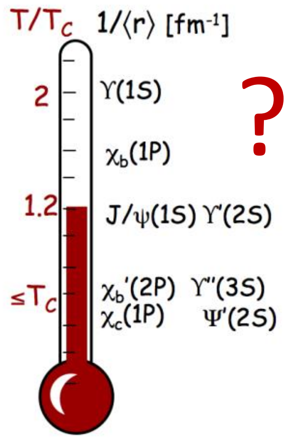
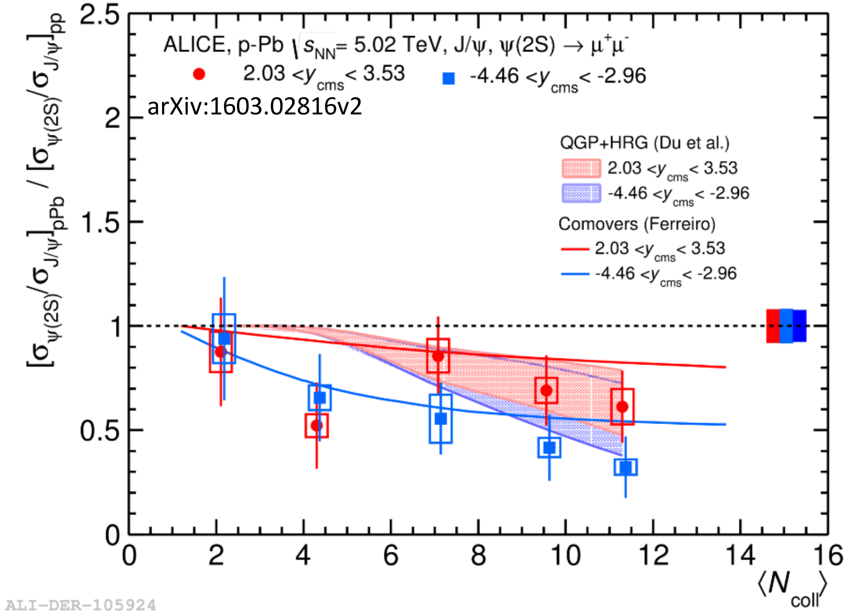


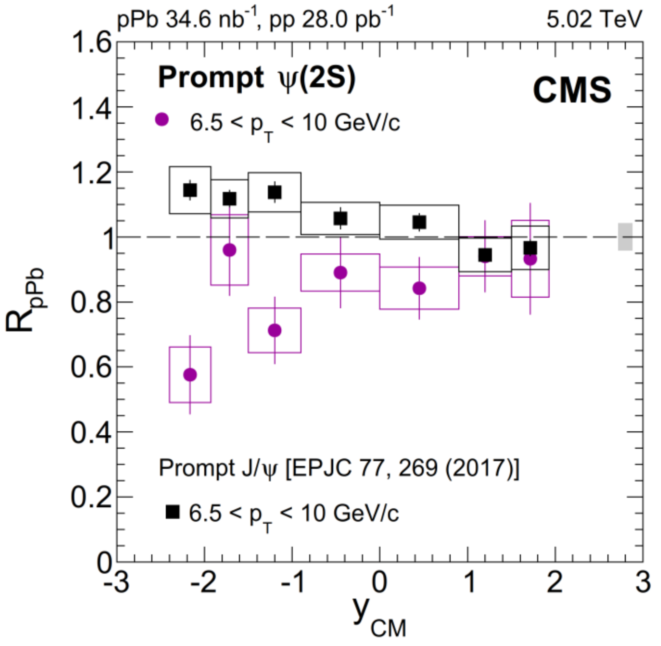
No F.S. suppression for J/ψ in p-Pb collisions

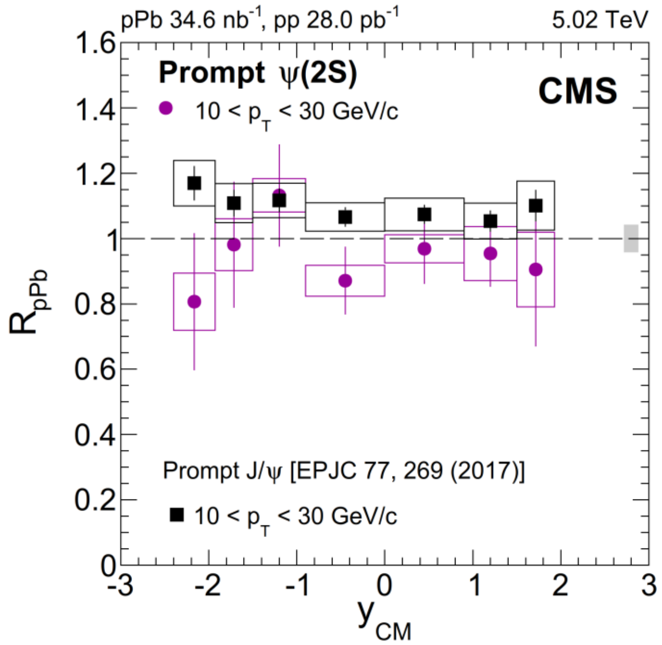
…but ratio ψ(2S)/J/ψ significantly lower than 1 at large N_{coll}!!

Makes sense in the “sequential suppression scenario”: ψ(2S) should dissociate at lower T









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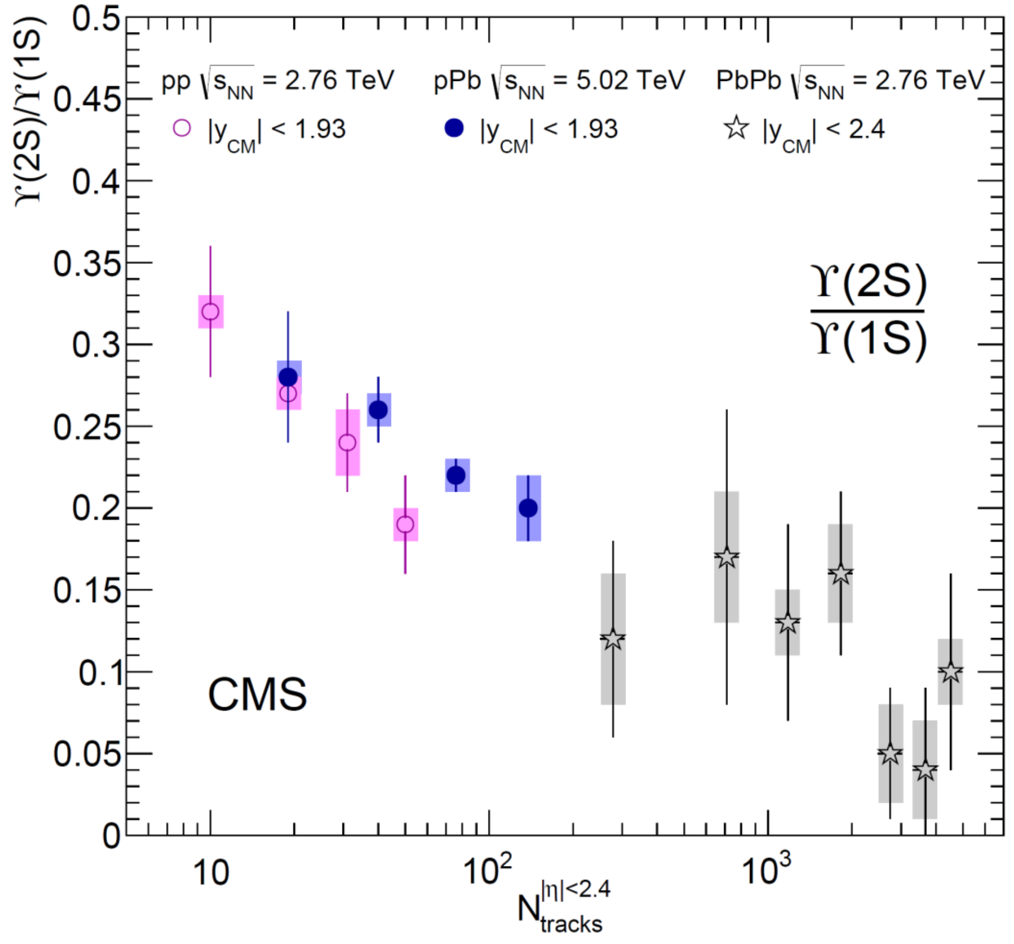
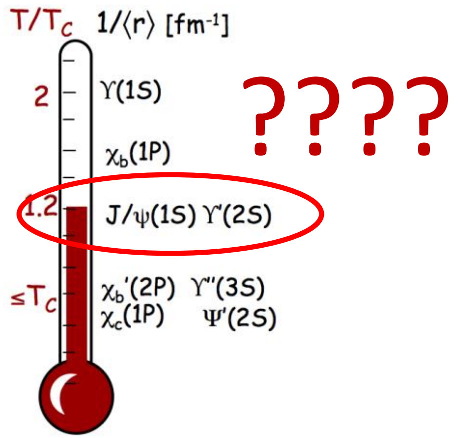


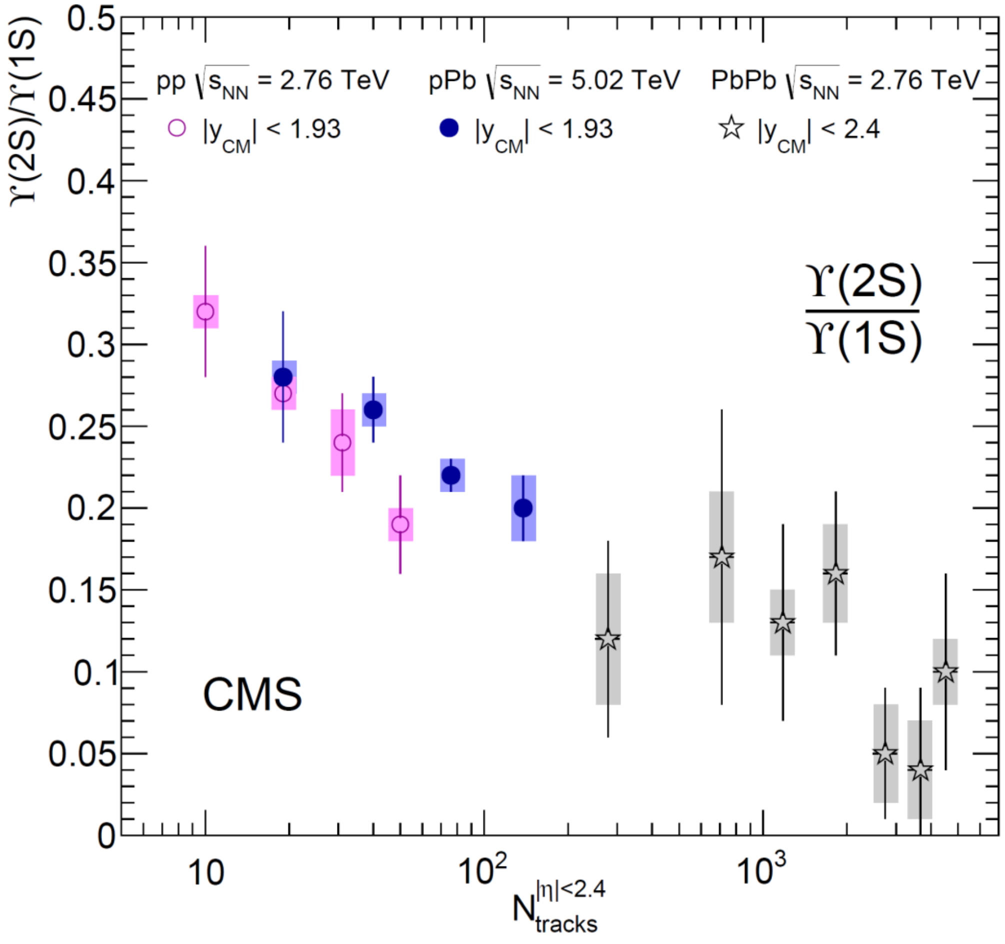


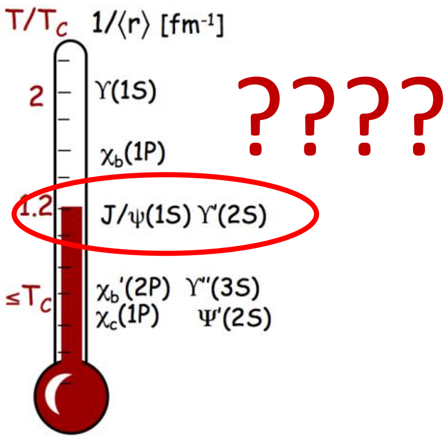
…but then, why ϒ(2S) is suppressed in p-Pb and even pp high-multiplicity events?

Perspective:

ψ(2S)/J/ψ versus multiplicity in pp collisions?

Quarkonia melting in small systems?





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Conclusions

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“small systems” path the way to a possibly deeper (microscopic) understanding of QGP phenomena :

- Final state multiplicity drives light flavours observables across systems and energies.
- Strangeness enhancement in pp collisions. In highest multiplicity, hadrochemistry ≈ to the one in the QGP
- $v_2 \neq 0$ in pp and p-Pb collisions at the LHC.
- No parton energy loss observed in pp and p-A
- Intriguing (and unclear) results on quarkonium suppression in p-A (and pp!) collisions

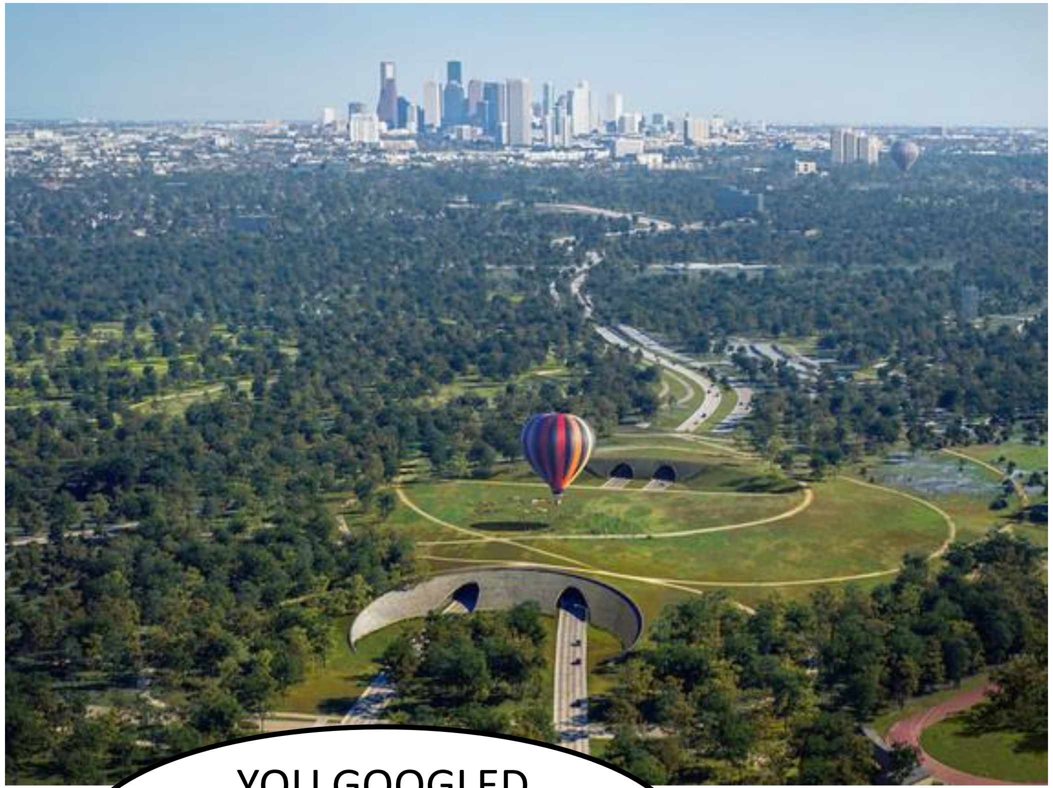
Thank you

Livio Bianchi
35th WWND
11 Jan. 2019

Huston is a great city:

My experience in an US research group

Huston is a great city:



YOU GOOGLED IT…YOU'VE NEVER BEEN THERE!!

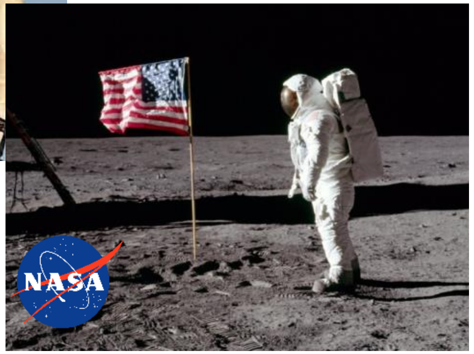
Livio Bianchi
35th WWND
11 Jan. 2019

The dream :

The dream :

Expectations VS Reality

The dream :



The reality :

Loano: the saddest sea place in Italy (sorry Claudia)

Expectations VS Reality

The dream :



The reality :



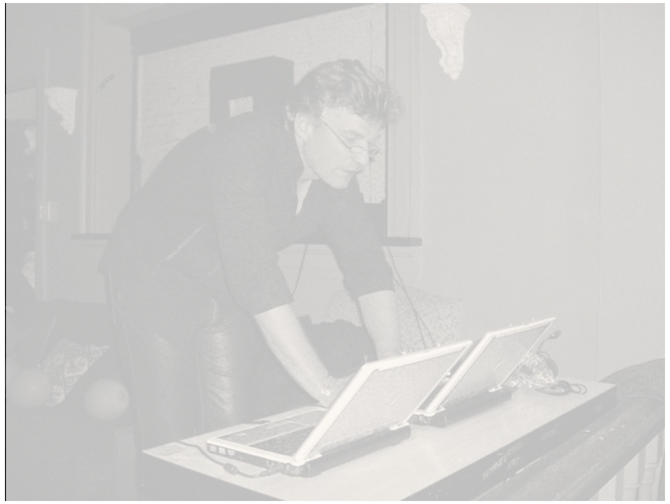
Expectations VS Reality

The dream :

The reality :

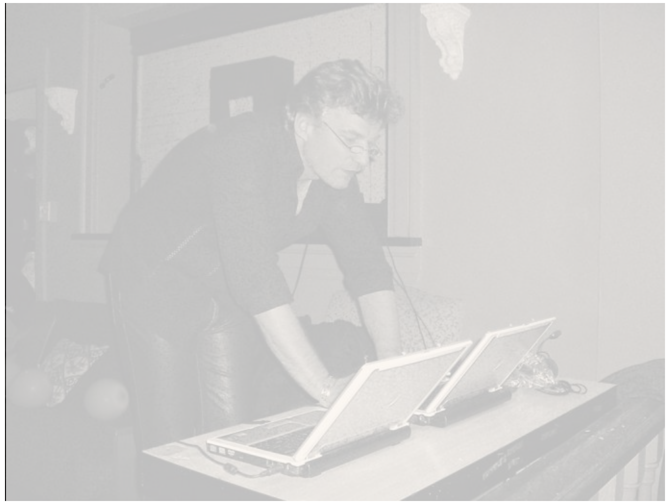
Enjoy your **ies!!

Enjoy your **ies!!



Looking forward for celebrating in 10 years!!

Enjoy your **ies!!



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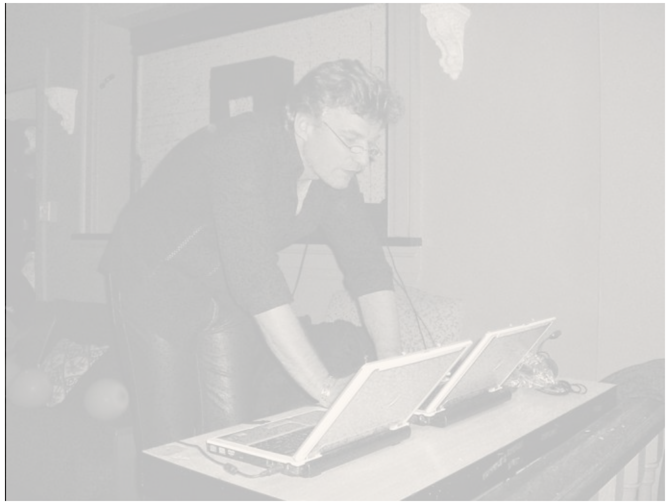

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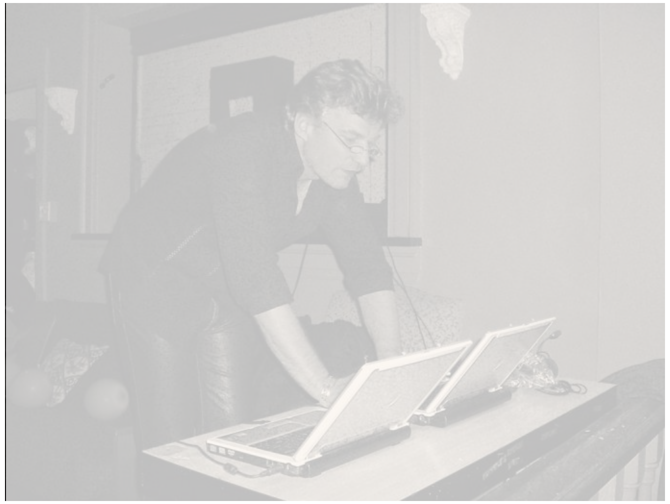
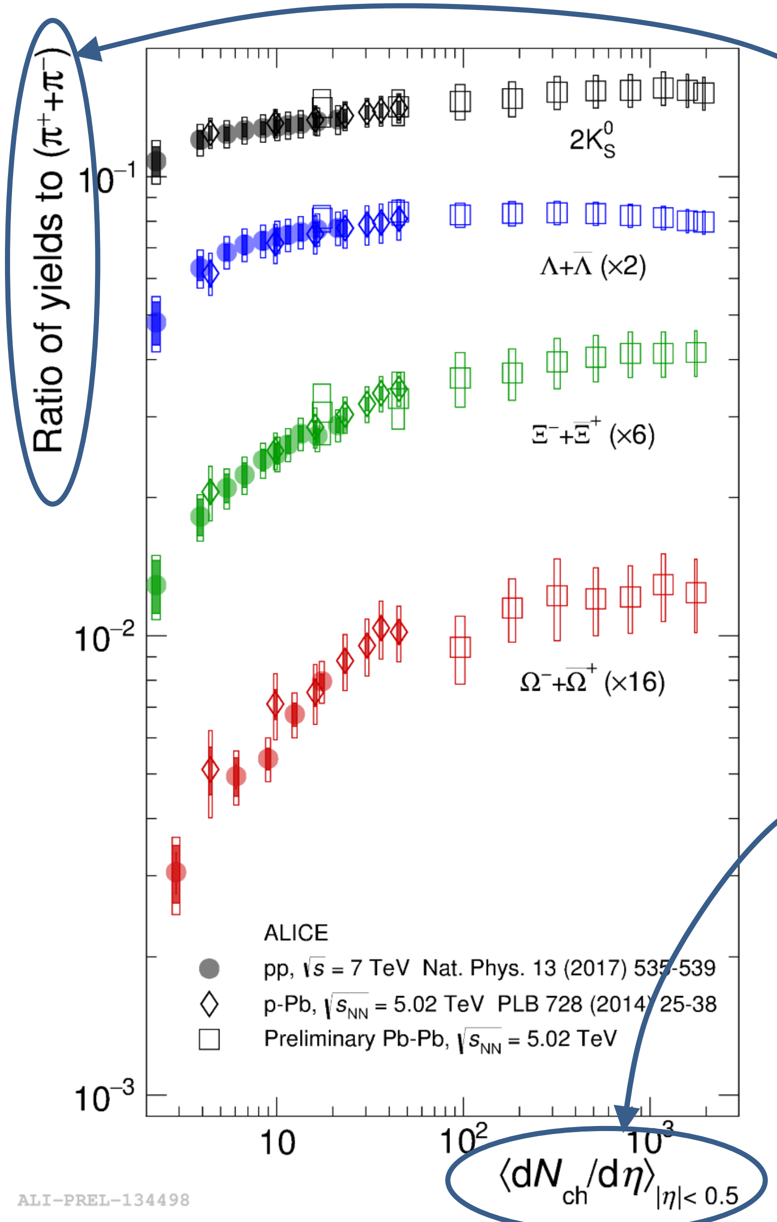


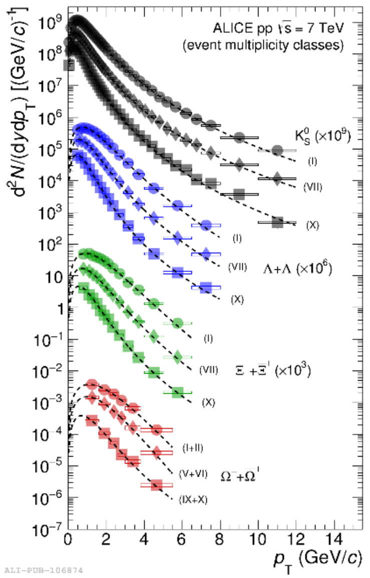
Backup

Multiplicity estimation in small systems



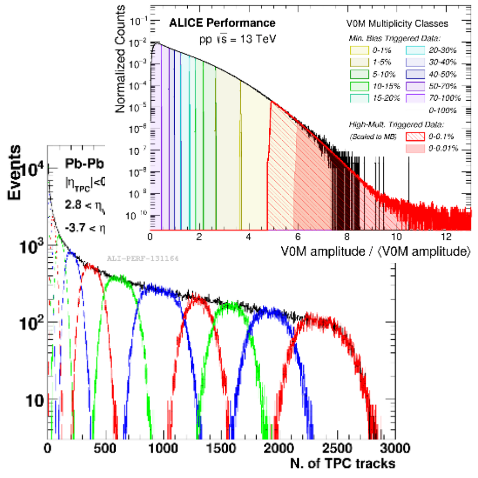
y-values:

- Measure p_T spectra of strange particles and pions in pp events characterized by different multiplicities (fwd-rapidity estimator)
- Integrate spectra extrapolating at low and high p_T with suitable functions.
- Calculate Y^S/Y^π



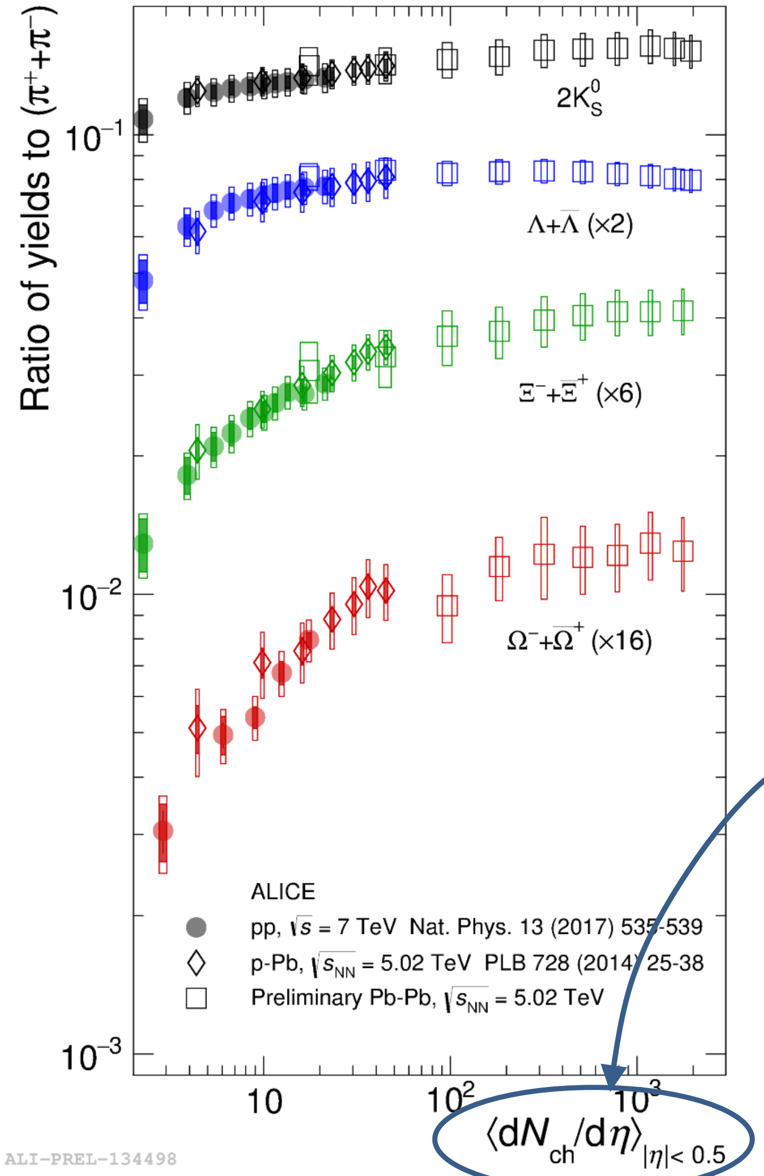
x-values:

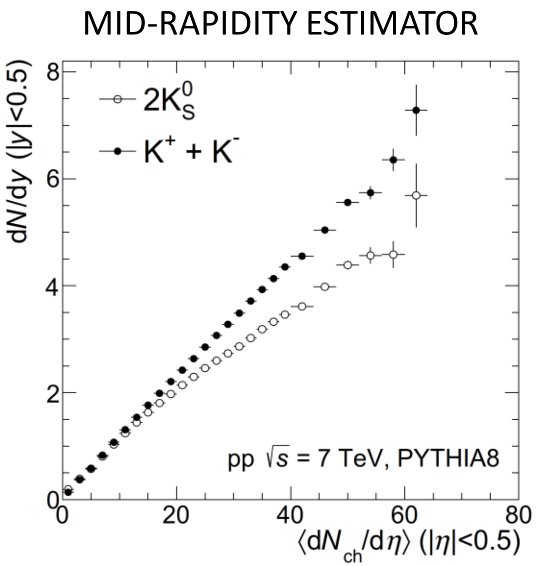
- ∀ multiplicity class (fwd-rapidity estimator), count the number of primary charged particles at central rapidity and build-up $dN_{ch}/d\eta$ distribution
- Take statistical average of every distribution

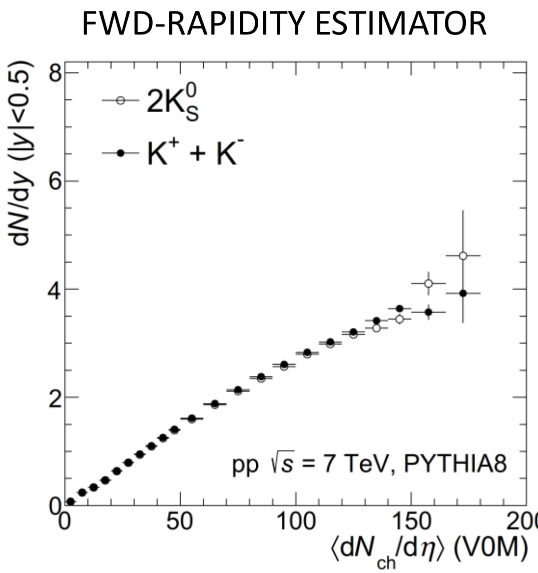


Multiplicity bias in small systems

Livio Bianchi
35th WWND
11 Jan. 2019







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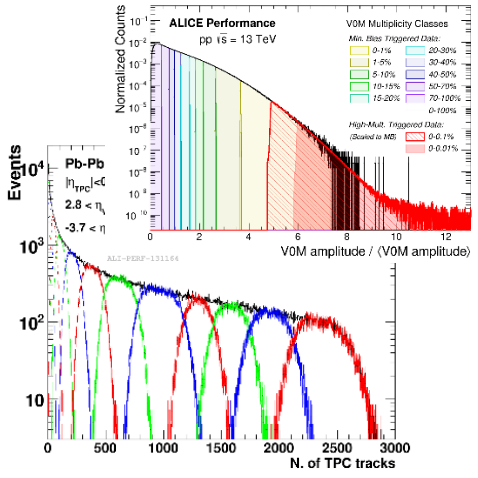
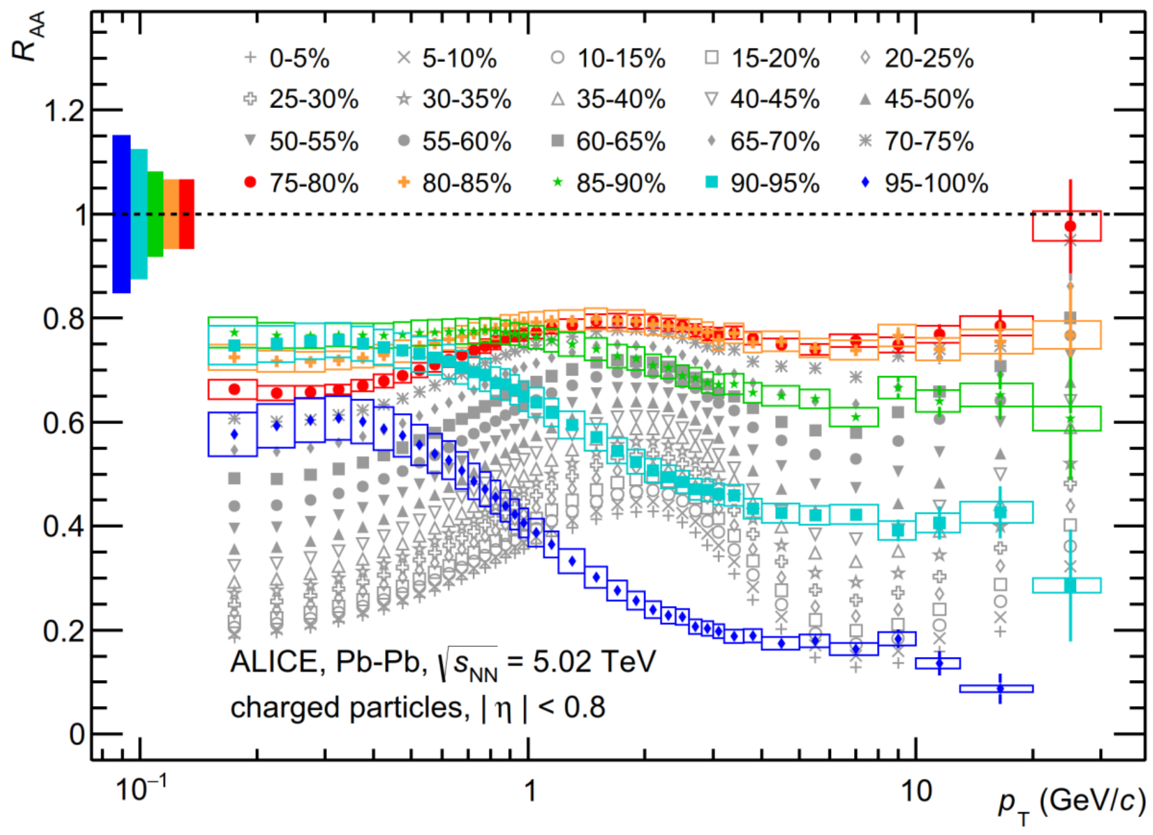
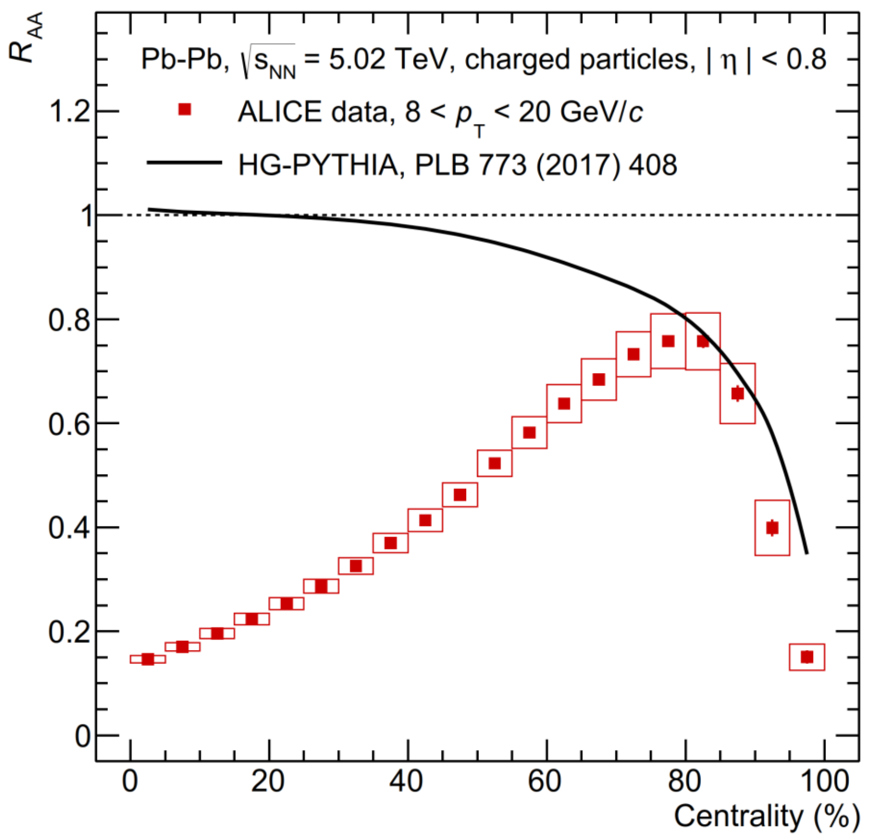


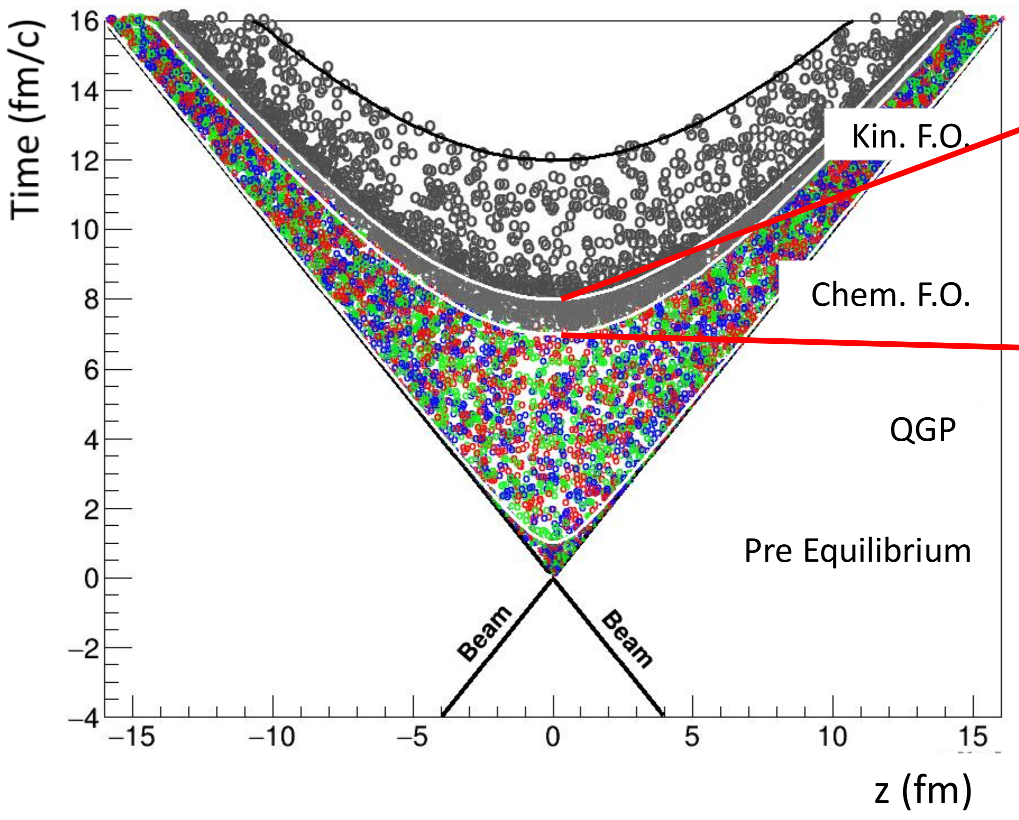
Selection bias and R_{AA} in peripheral collisions at LHC

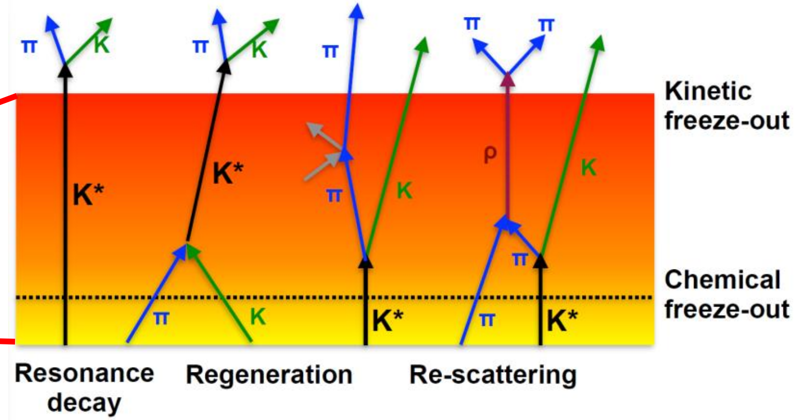




The resonances' story (I)

Resonances are powerful tools to probe the hadronic phase after chemical freeze-out

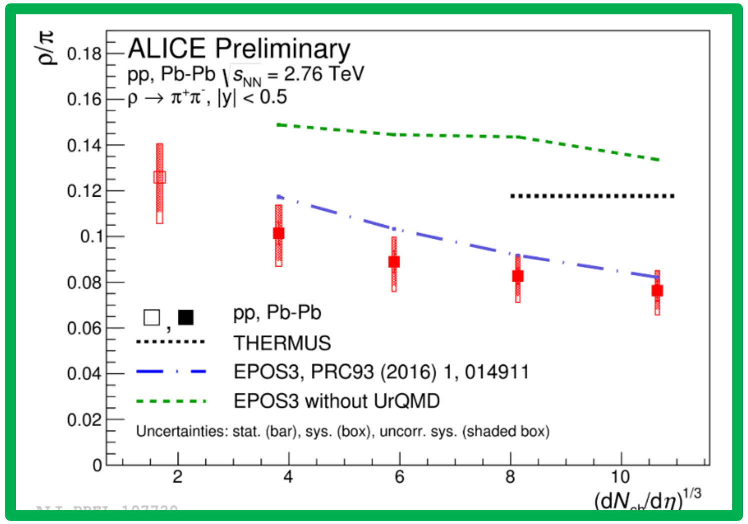


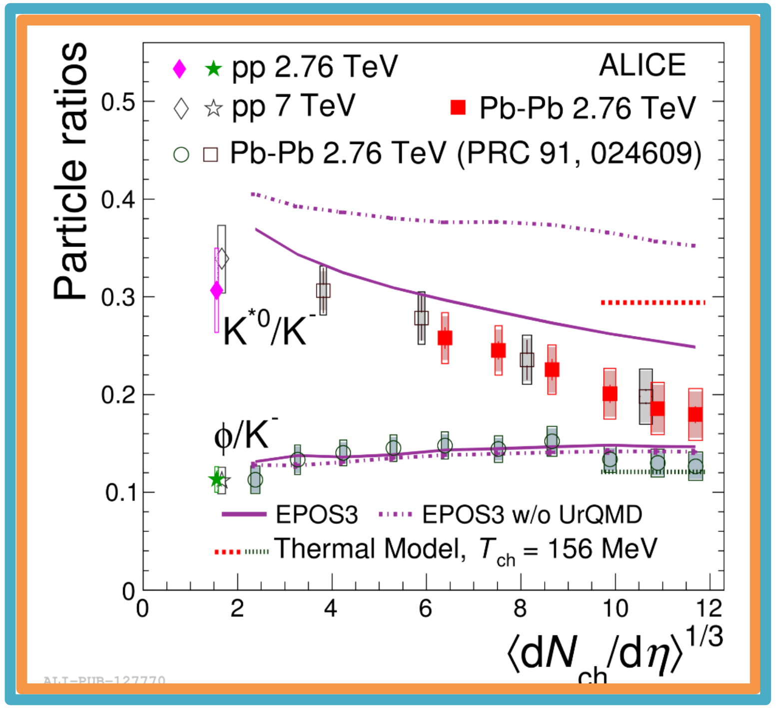


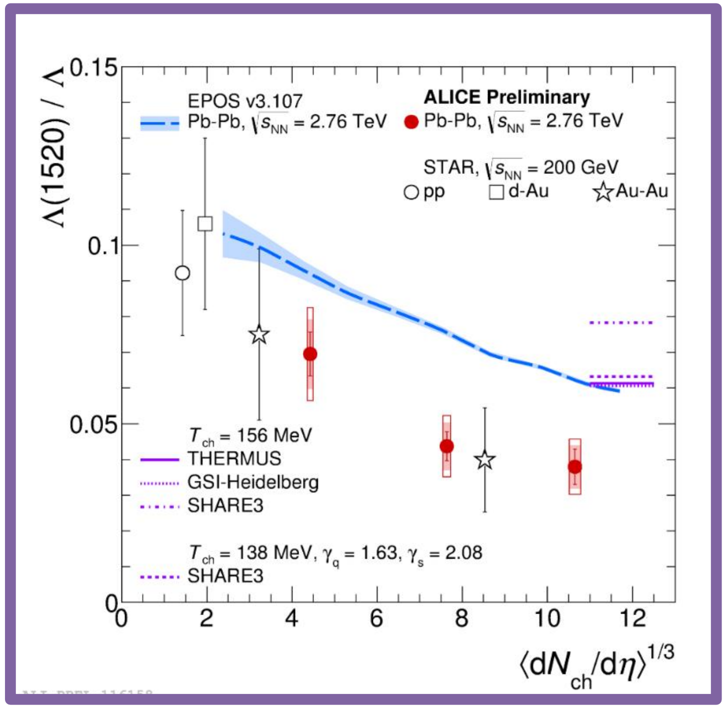
The resonances' story (II)

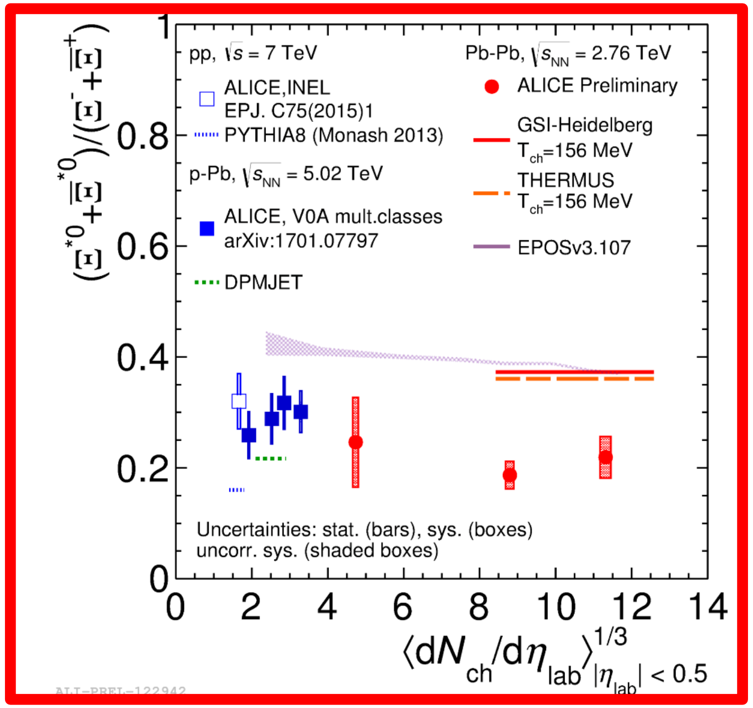
Resonances are powerful tools to probe the hadronic phase after chemical freeze-out

Lifetime [fm/c] :	ρ [1.3]	<	K* [4.2]	<	Λ* [12.6]	<	Ξ⁰* [21.7]	<	ϕ [46.2]

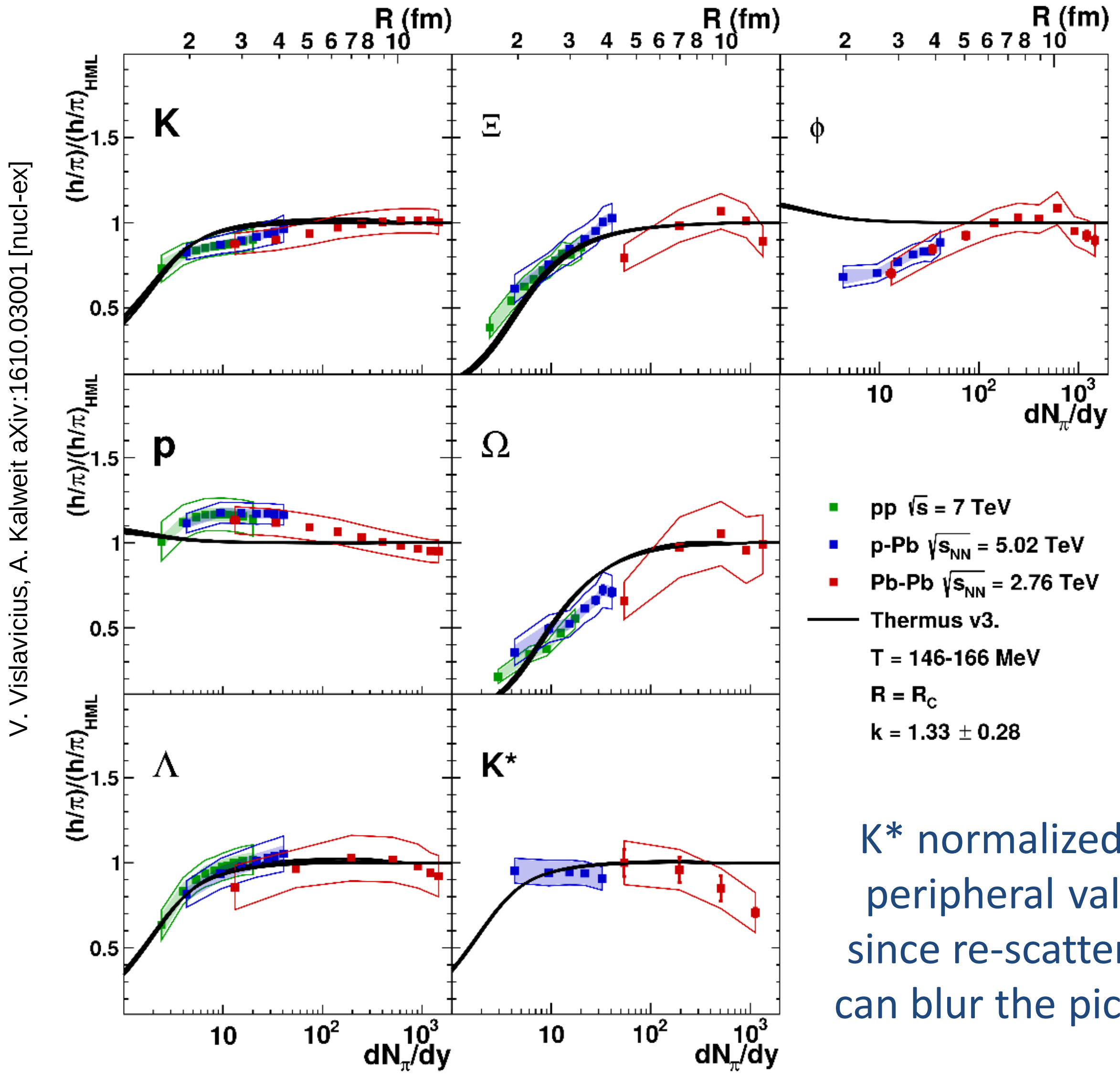








Hadrochemistry: thermal emission in elementary collisions?



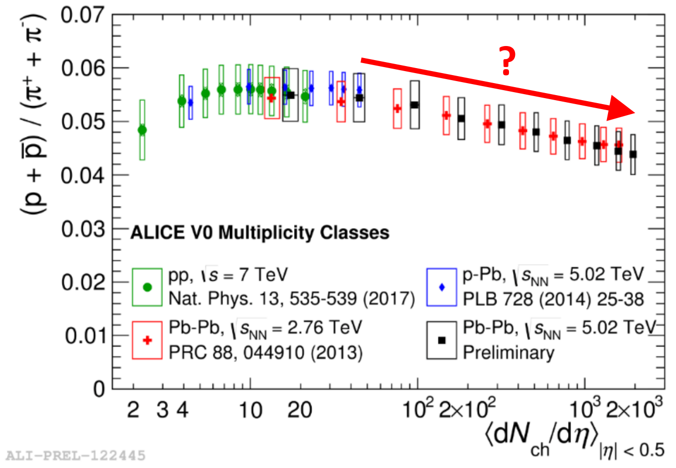
K* normalized to peripheral value since re-scattering can blur the picture

Fix yield's ratio to saturation limit. Check the evolution when decreasing the volume (multiplicity)

Qualitatively the thermal fit describes K,Λ,Ξ,Ω

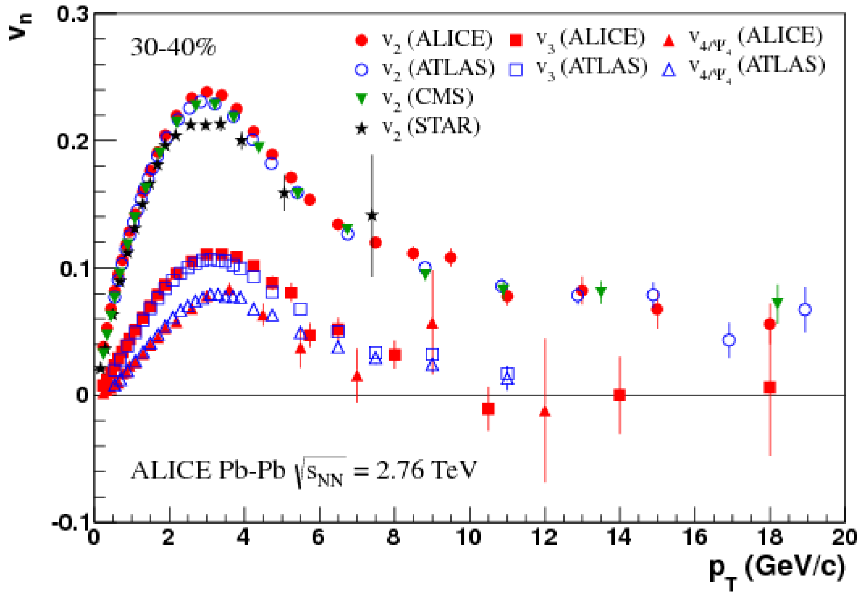
Notable exception is the ϕ!

Slightly decreasing protons
Hint for hadronic re-scattering?
Need to evaluate degree of correlation on systematics across multiplicity!



If interested in re-scattering in the hadronic phase, more in the backup!

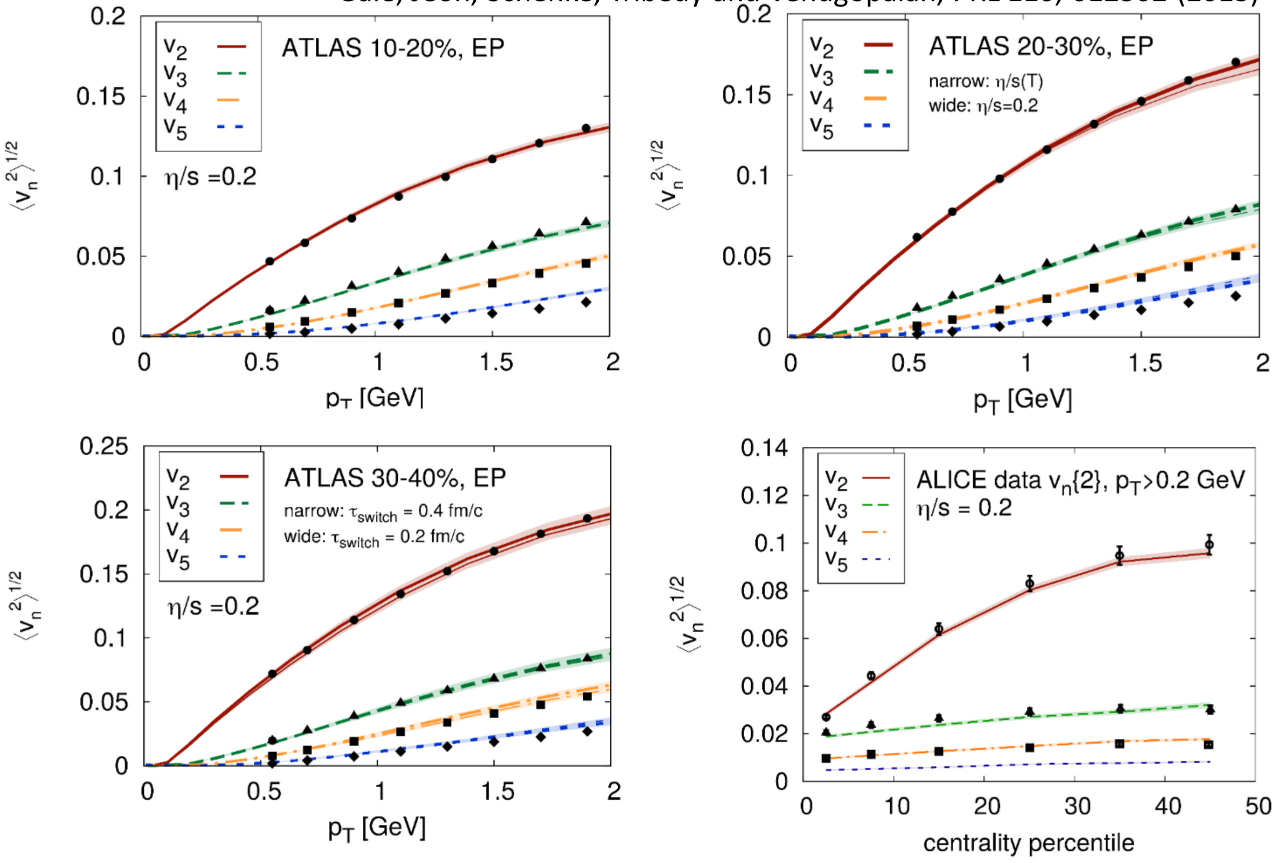
Anisotropic flow in heavy ions



$\mathbf{v_n \neq 0}$ observed at RHIC and LHC: means that in semi-central collisions the p_T distribution of particles is anisotropic wrt the event plane…

does this mean we have flow?

Gale, Jeon, Schenke, Tribedy and Venugopalan, PRL 110, 012302 (2013)



Hydrodynamic models reproduce v_n in all centralities by means of an "almost" perfect fluid: $\eta/s=0.2$

The Lund string model: basics

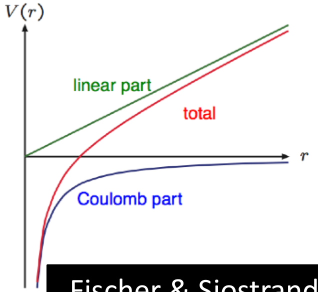
- Linear confinement potential for large distances (confirmed by lattice QCD). For short distances perturbation theory holds

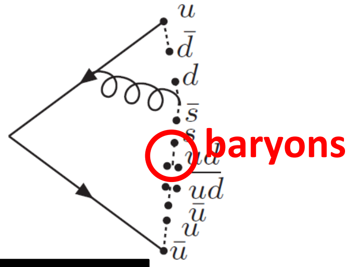
- Confined colour fields described as strings with tension κ = 1 GeV/fm

- Breaking of strings (tunneling) give hadrons

$$P \propto e^{-\frac{\pi m_T^2}{\kappa}} = e^{-\frac{\pi m_q^2}{\kappa}} \cdot e^{-\frac{\pi p_{Tq}^2}{\kappa}}$$

- Flavour of hadrons determined by the Gaussian mass suppression term (which mass to put? If current → less s-suppression than observed. If constituent → too much s-suppression. s/u empirical number to be tuned on data)



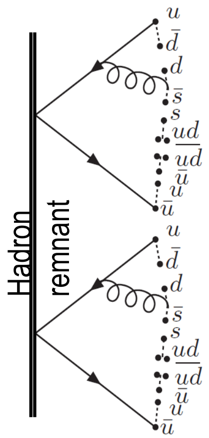


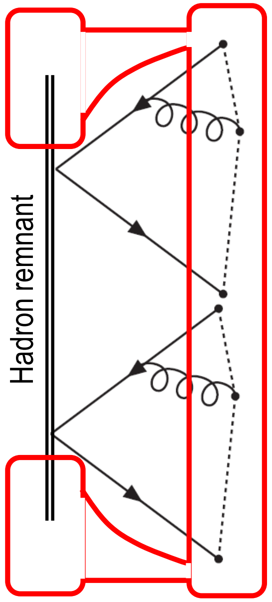
Fischer & Sjostrand, arXiv:1610.09818 (2017)

- In **hadronic collisions** multiple strings needed to describe multiplicity distribution (**MPI**)

- In the LC Lund model each string hadronizes separately with respect to the others

- The multiplicity increases, but not the $\langle p_T \rangle$ nor the relative flavor abundancies!





- Multiple strings are close in space-time. Dynamical interaction not implemented in this model, but **colour re-arrangement** can happen: **Colour Reconnection** (CR)

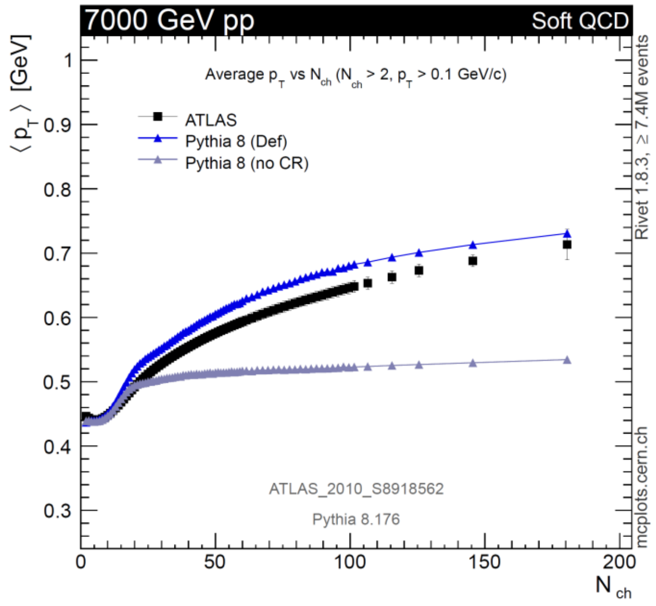
- Takes place after parton shower and takes into account all SU(3) permitted configurations. **Selection parameter: minimum total string length**

- After re-arrangement of strings, hadronization takes place

- Correctly takes into account colour re-arrangement in remnant

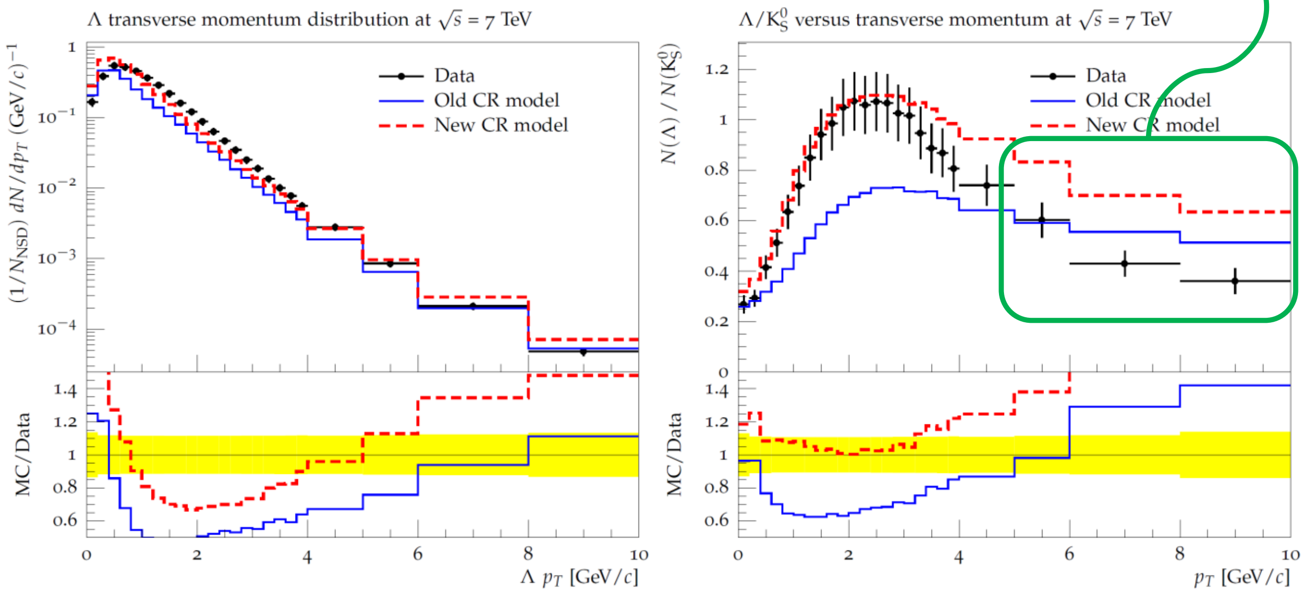
Christiansen & Skands, arXiv:1505.01681 (2015)

PYTHIA: effect of CR



- 3 main parameters tuned on data: c_{time} ($\langle p_T \rangle$), c_j (Λ/K^0_S) and p_T^{ref} ($dN_{ch}/d\eta$).
- The presence of **junctions increases baryon production** at intermediate p_T, but not sufficient to reproduce data
- Λ/K^0_S shape (magnitude is tuned!) reproduces data up to 3 GeV/c → problem in spectra common to baryons and mesons?

Leading Colour strings dominate: can't be attributed to CR



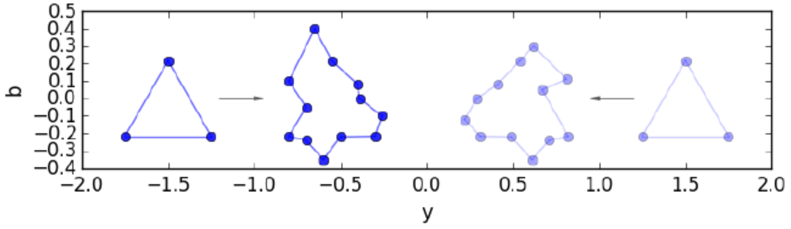
TAKE HOME

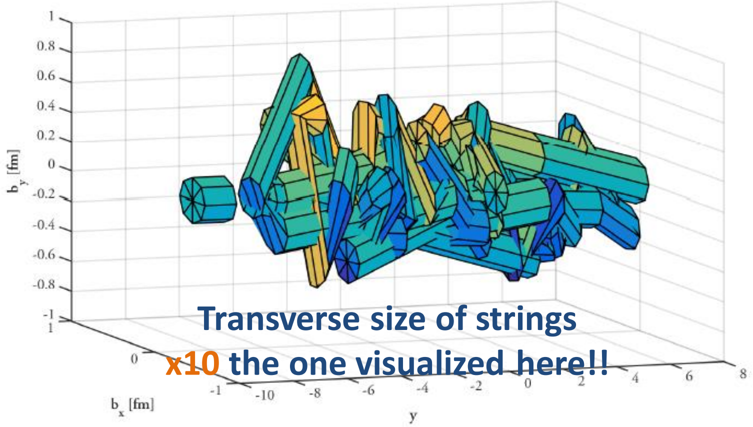
CR mimics features that we traditionally attribute to collective flow, but something more is needed. Tuning?

Christiansen & Skands, arXiv:1505.01681 (2015)

The DIPSY model: basics & ropes

- Partonic model in impact parameter space and rapidity (**D**ipole evolution in **I**mpact **P**arameter **S**pace and rapidit**Y**)
- Mueller dipole model (LL-BFKL)
- Proton/Nucleus structure built up dynamically from dipole splittings
- Builds-up initial state + collision in impact parameter space. Naturally treats saturation and MPI





Transverse size of strings
x10 the one visualized here!!

To the question "Which are the strings that can interact?" the DIPSY model answers following the evolution of colour strings during the whole parton shower

How do strings interact?

Stack of colour strings close in the IP-y space: can form colour singlets or multiplets according to the summing rules of SU(3)
Singlets correspond to simple re-arrangement of single strings,
Multiplets correspond to **ROPES**.

Hadronizing a rope means fragmenting string-by-string with an **effective string tension $\kappa > \kappa_0$**

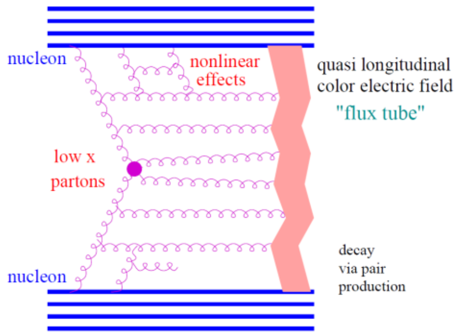
As we know from previous works, **higher string tension $\Rightarrow$ more baryons and more flavours$\neq$(*u,d*)**

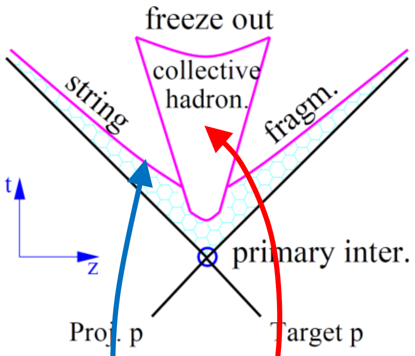
Before hadronizing a string a "swing" mechanism further allow colour re-arrangements
(in analogy with colour re-connection)

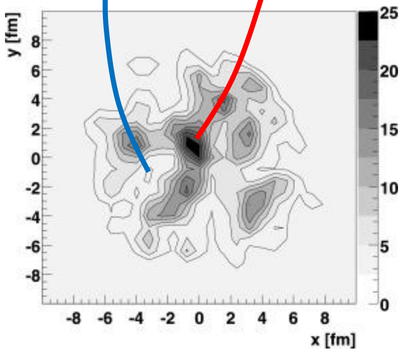
Flensburg et al. arXiv:1103.4321

Bierlich & Christiansen, arXiv:1507.02091

EPOS: the melting pot





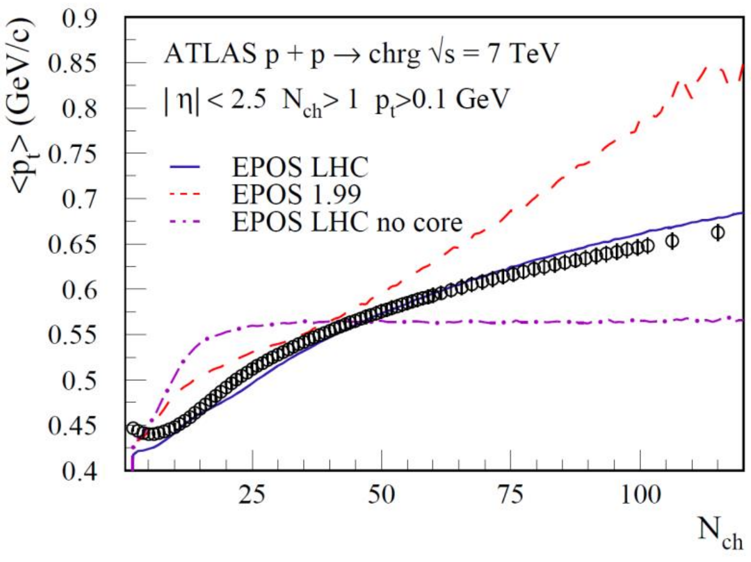


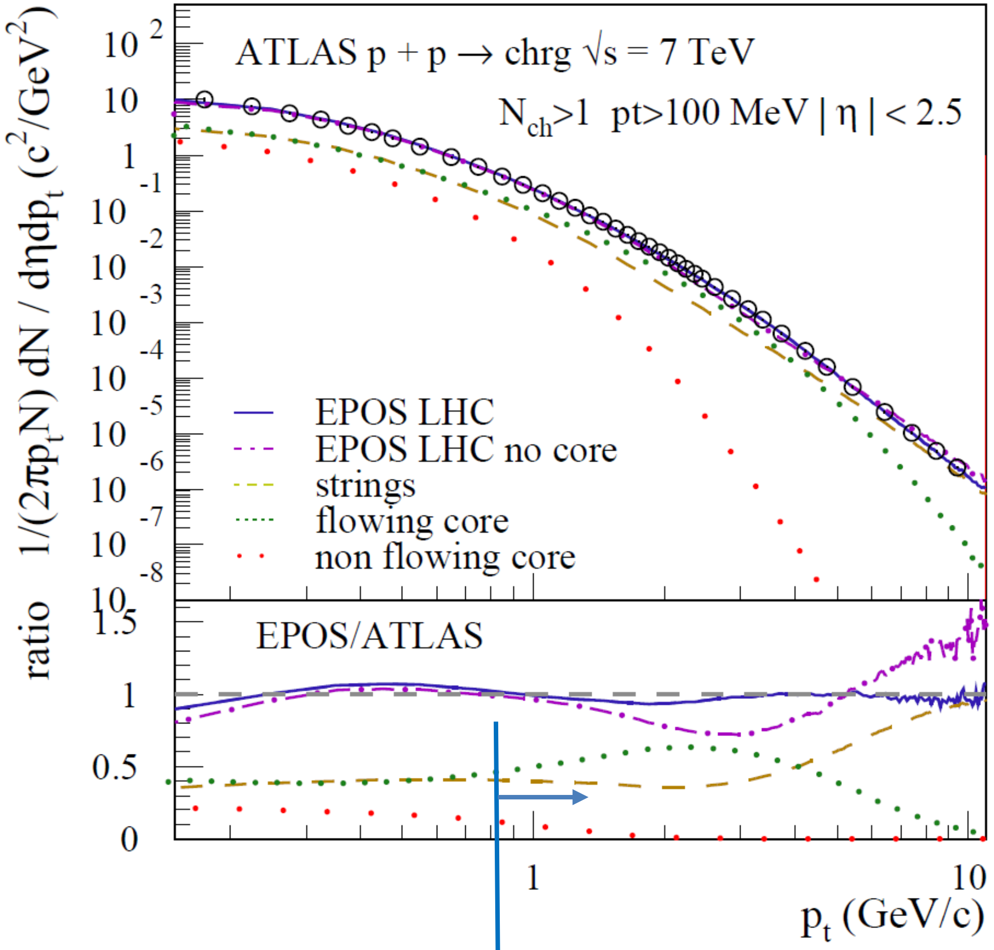
- Hard scattering treated with the addition of several DGLAP parton "ladders" (pomerons) + a CGC-inspired saturation scale
- Parton ladders are then considered as relativistic strings, conveniently treated in a string fragmentation approach (a-la Lund)
- At time τ_0 (well before hadronization) strings are divided into: fluid (CORE) and escaping (CORONA) according to their momenta and density of the string segments
  - ❑ **CORONA**: strings can hadronize as in the Lund approach
  - ❑ **CORE**: from the time τ_0 evolves as a viscous hydrodynamic system. Hadronization happens statistically at a common T_H
- After hadronization hadron-hadron rescattering can be considered, making use of an afterburner (e.g. UrQMD)

NOTE: parameters governing the core-only part are 6 (τ_0, ρ_0, ε_{FO}, y_{rad}, f_{ecc}, γ_s), to be tuned on data!!

Werner, PRL 98, 152301 (2007)

EPOS: effects of Core-Corona (I)



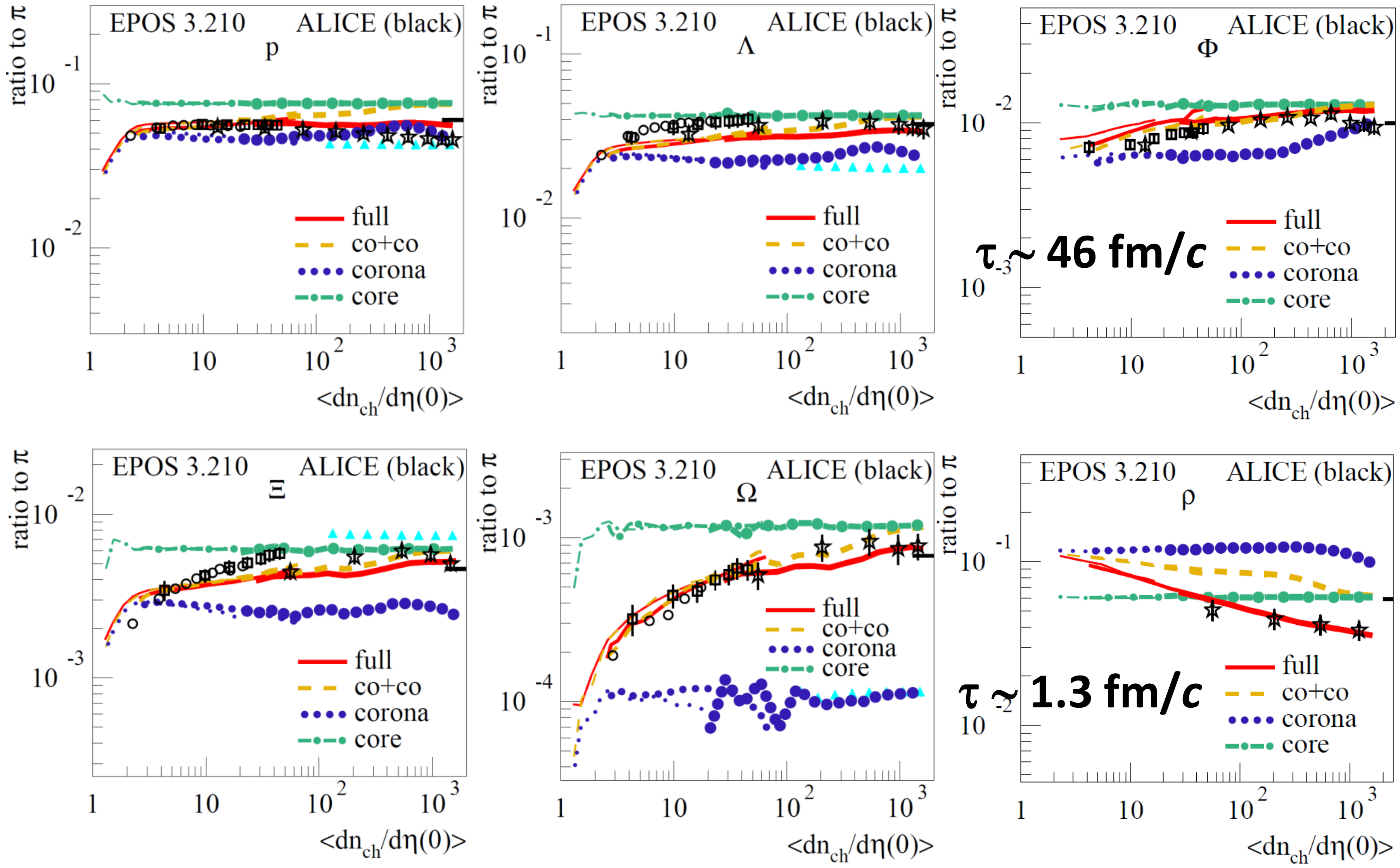


- $\langle p_T \rangle$ increases only when introducing a flowing core
- **Radial flow** of the core also **dominates** the **intermediate** region of the p_T spectrum
- High p_T is dominated by escaping fragmenting strings

NOTE: the exact onset of the effect depends on tuning (p_T cut-off for escaping strings)

Pierog & Karpenko & Katzy & Yatsenko & Werner, arXiv:1306.0121

EPOS: effects of Core-Corona (II)



Observed trends of relative particle yields **reproduced** thanks to **interplay** between **core** and **corona** (+ UrQMD)

TAKE HOME

Spectra + yields described in EPOS through evolution with multiplicity of relative importance of CORE and CORONA

NOTE: Does this imply QGP in small systems? NO! May or may not be.

- Relative importance of CORE/CORONA in the yields for long and short living resonances is strikingly different
- Mild Φ enhancement with multiplicity observed in EPOS