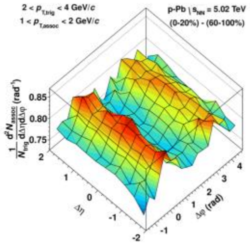
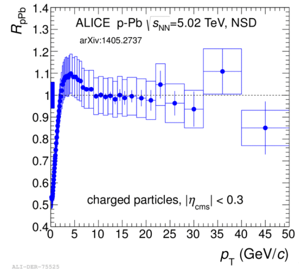
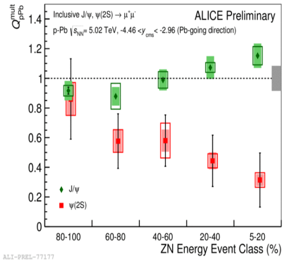
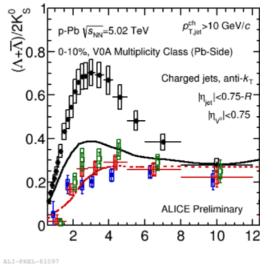
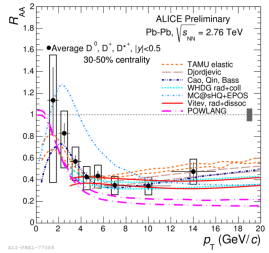
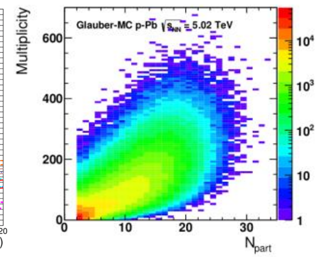












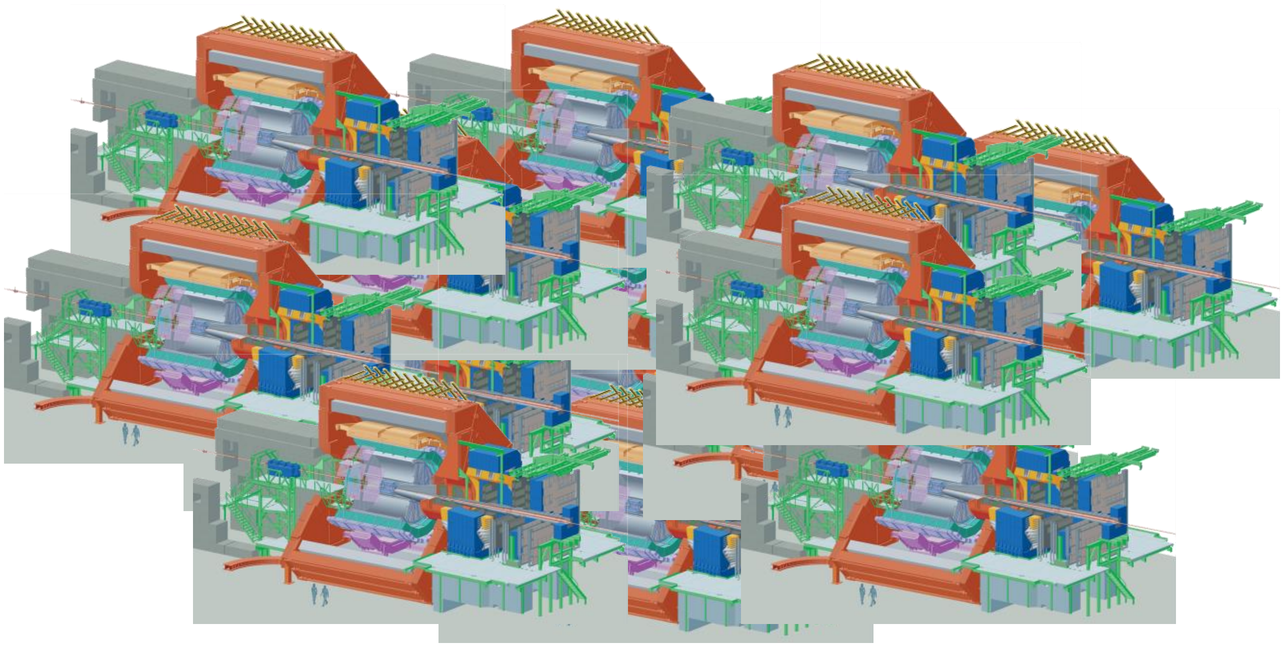
ALICE Overview

Jan Fiete Grosse-Oetringhaus (CERN)

for the ALICE Collaboration

Quark Matter 2014, Darmstadt

A Large Ion Collider Experiment

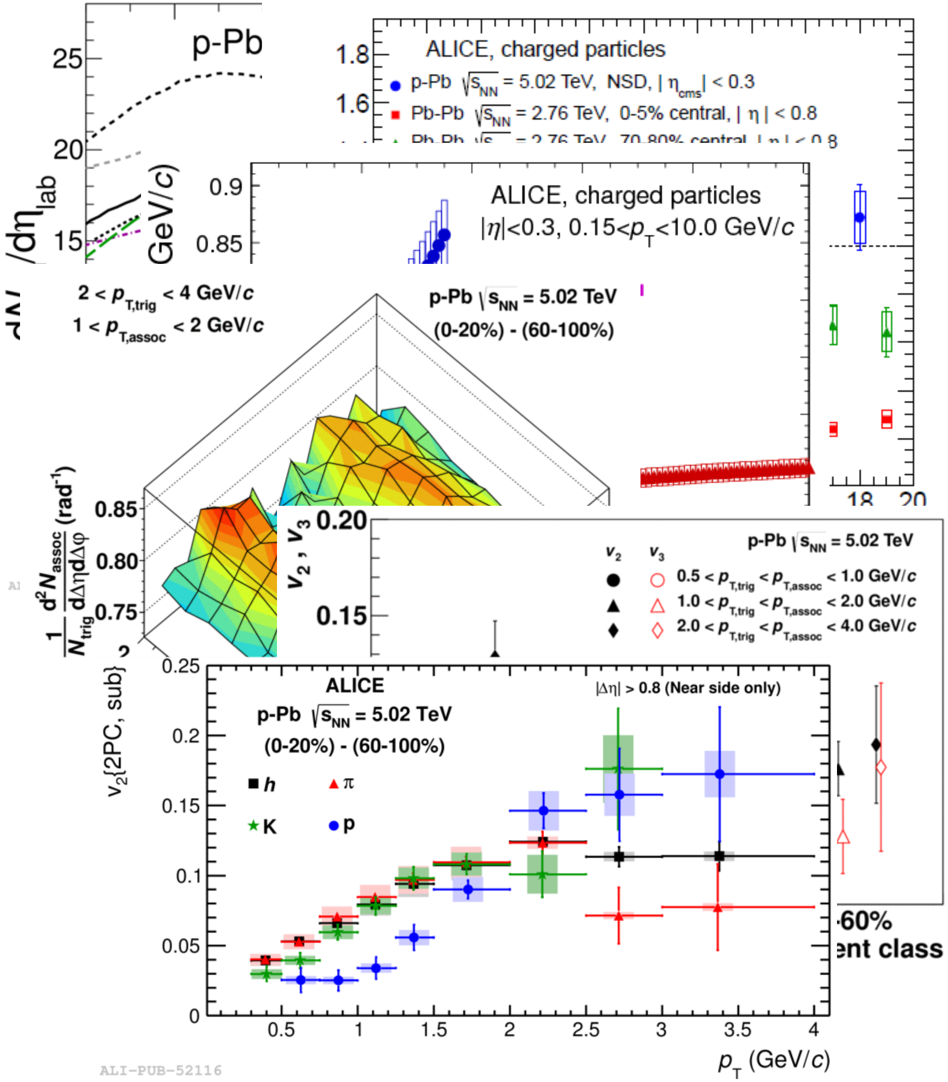


although you may know it after
31 parallel talks and 80±5 posters

PRL110 (2013) 032301
PRL110 (2013) 082302
PLB719 (2013) 29
PLB726 (2013) 164
PLB727 (2013) 371

Pandora's Box…

- p-Pb was meant as a reference run…
- … so we started measuring …
- … at the beginning things looked fine …
- … then things looked interesting …
- … and then it got very interesting …



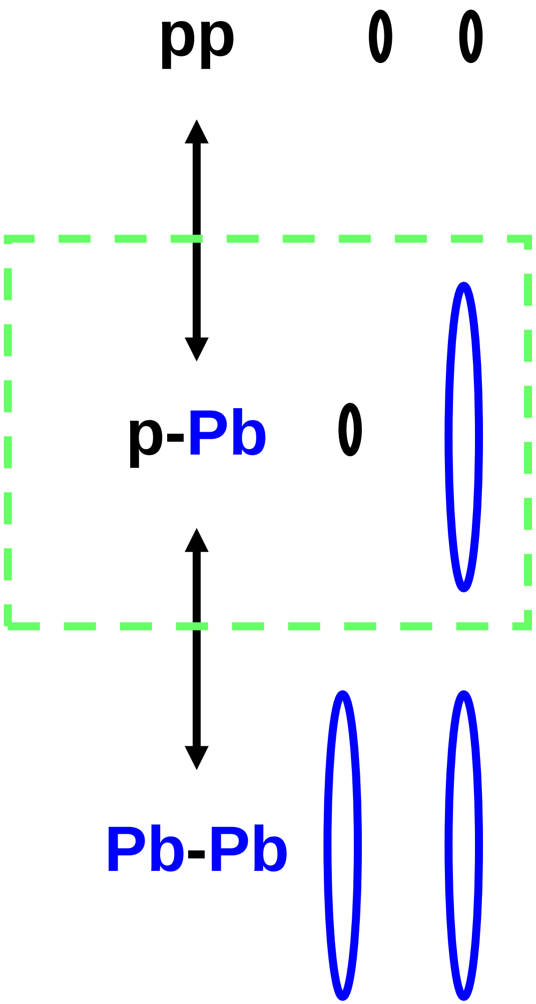
p-Pb

p-Pb Physics

- p-Pb physics more than pp physics?
- p-Pb physics contains Pb-Pb physics?
- High-multiplicity pp already special?

- Many of us started being puzzled…
  - Initial vs final state?
  - How cold is cold nuclear matter?
  - How hot is the fireball?
- So…
  - pA a reference for AA?
  - pp for pA?

- Let's try to solve some puzzles …
- … and add some new ones



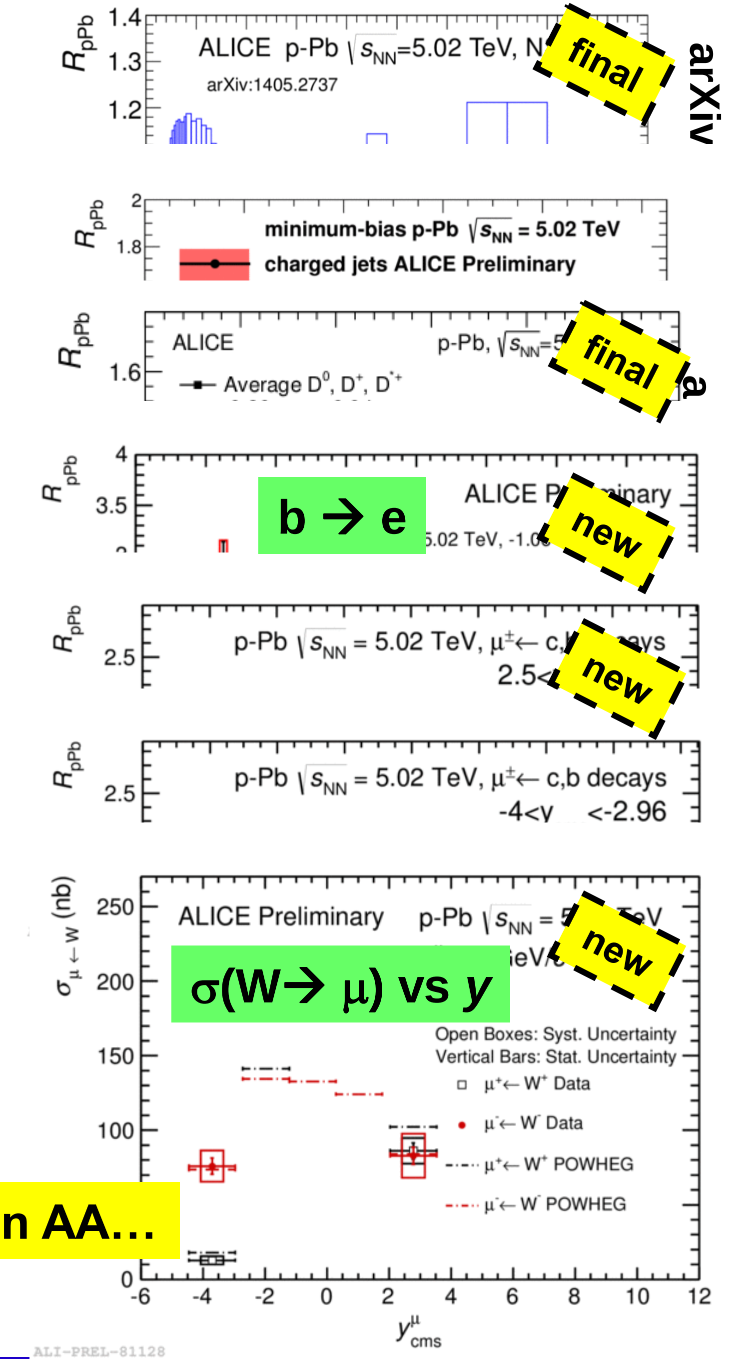
Nuclear Modification Factor

p-Pb

- Study medium-modification of probes expected to scale with N_{coll}

$$R_{pA} = \frac{dN_{pA}/dp_T}{\langle N_{coll}\rangle dN_{pp}/dp_T}$$

- No modifications* observed at high p_T
  - for charged particles above 10 GeV/c (up to 50 GeV/c)
  - for charged jets up to 100 GeV/c
  - for D^0, D^+, D^{*+} mesons (mid rapidity)
  - for b → e decays (mid rapidity)
  - for c, b → μ decays (forward)
  - for W → μ (first measurement in p-Pb!)



* J/ψ and ψ(2S) come later…

rather different in AA…

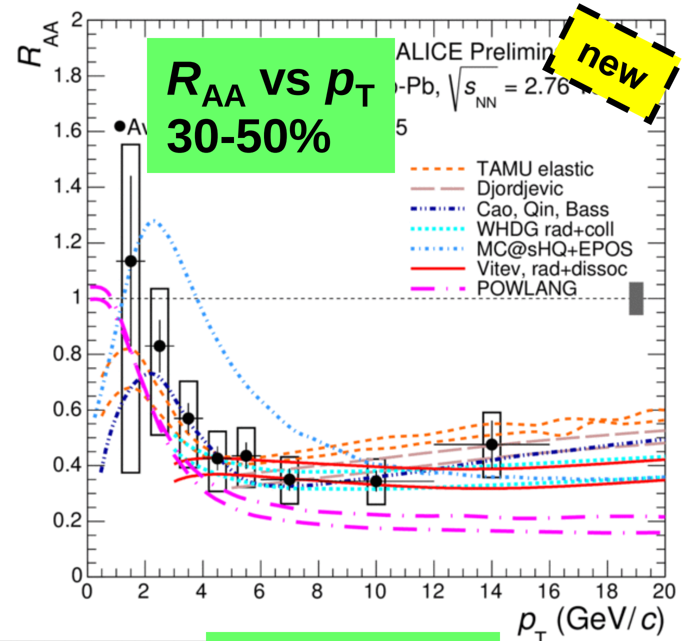
→ Monday PM: M. Knichel | S. Li | R. Russo

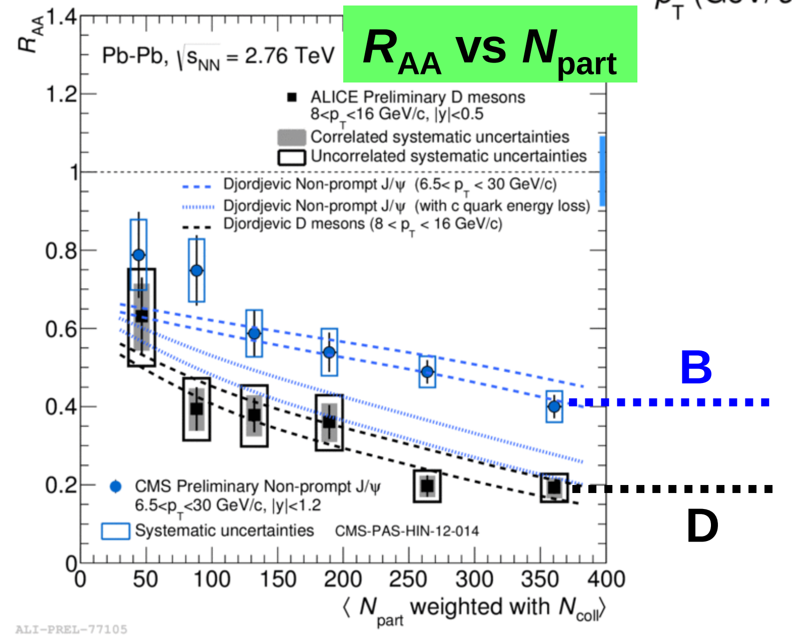
Pb-Pb

D Meson R_{AA} and v_2

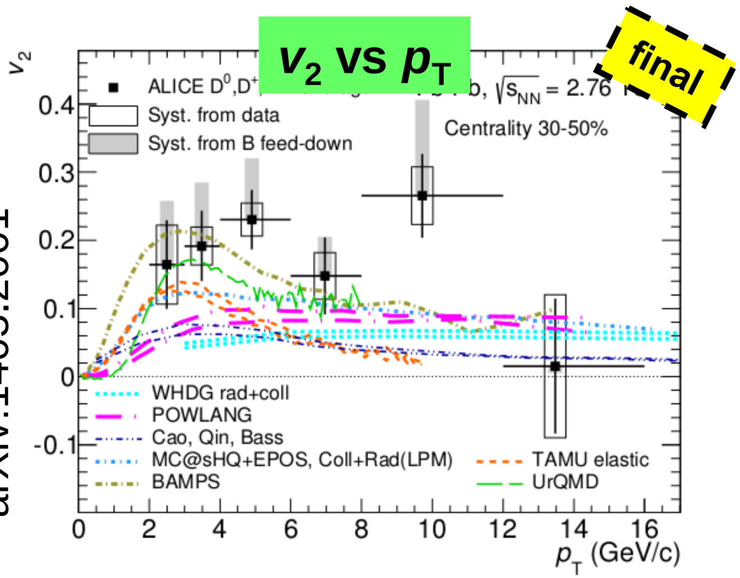
- D^0, D^+, D^{*+} centrality and p_T dependence
- Significant suppression at high p_T
- Sign of quark mass dependence

- Significant non-zero v_2
- Significant interactions with medium
- Simultaneous model comparisons





arXiv:1405.2001



→ Monday AM: A. Festanti | R. Bailhache

Pb-Pb

J/ψ and Υ R_{AA}

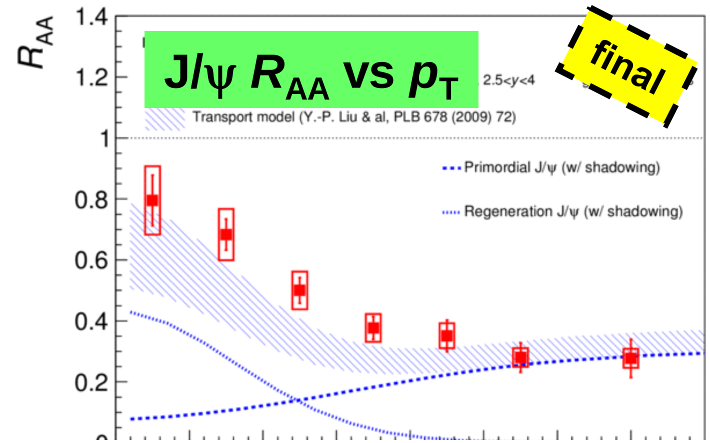
- J/ψ R_{AA} shows strong p_T dependence
  - Contrary to RHIC
  - Suggests contribution from (re)combination
  - p-Pb (R_{pA} x R_{Ap}) (anti)shadowing expectation

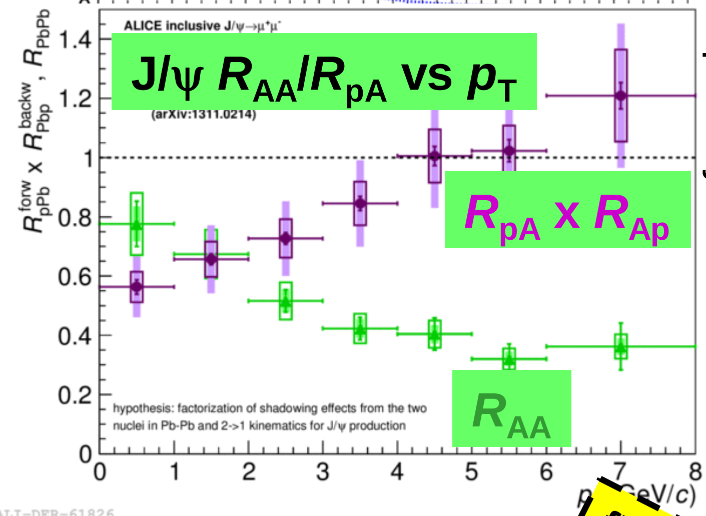
  → **J. Book (Tue AM)**

- Υ(1S) R_{AA}
  - R_{AA} with LHCb reference about 50% smaller wrt interpolated reference
  - More suppression in data than in transport models (Emerick et al., suppression + regeneration)

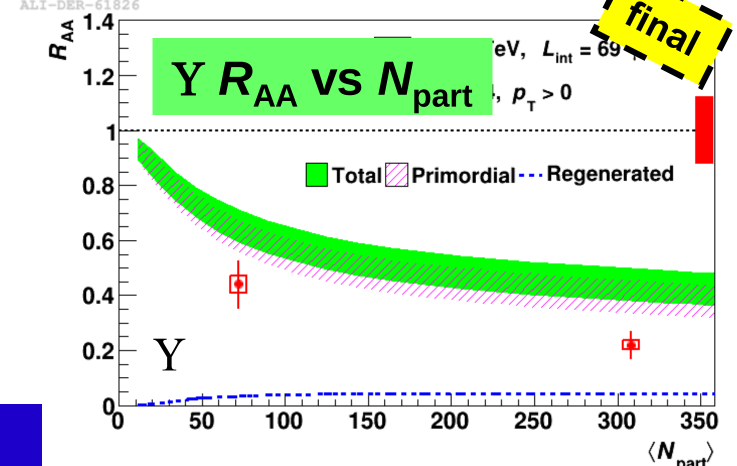
  → **J. Castillo (Wed AM)**

but we were talking about p-Pb…





arXiv:1311.0214, accepted by PLB



arXiv:1405.4493

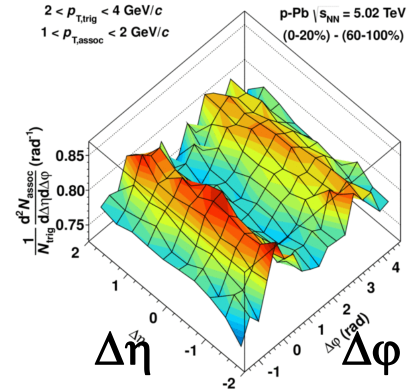
p-Pb

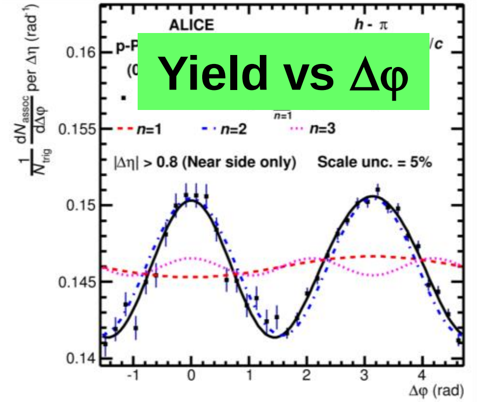
Double Ridge

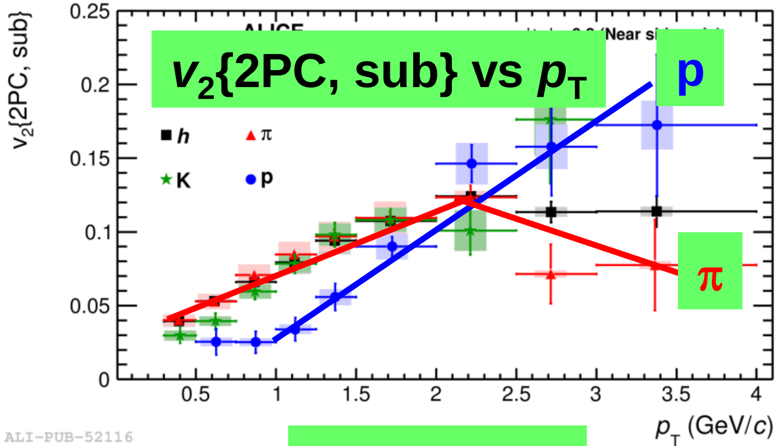
- Double ridge structure in high-multiplicity p-Pb collisions (below the jet)
- Quantified with Fourier components
  - Dominated by v_2 and v_3
- Reminiscent of v_2 in Pb-Pb
  - Mass ordering & crossing
- Also observed in h-e from c,b
- Higher order multi-particle correlations
  - $c_2\{4\} < 0$ above $N_{ch} > 80$

→ L. Milano (Tue PM)
→ A. Timmins (Mon PM)

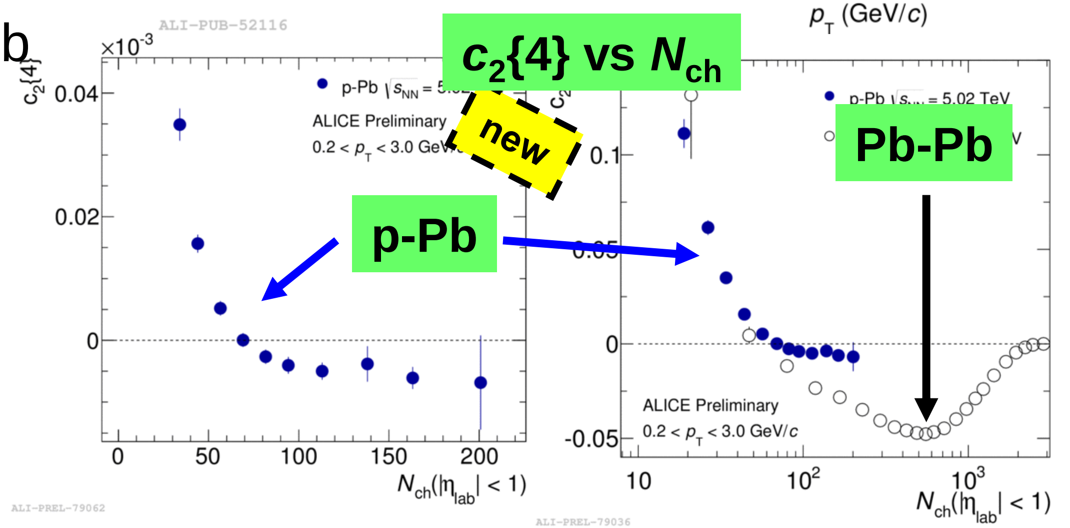
v_2 reminiscent of AA…







PLB719 (2013) 29
PLB726 (2013) 164

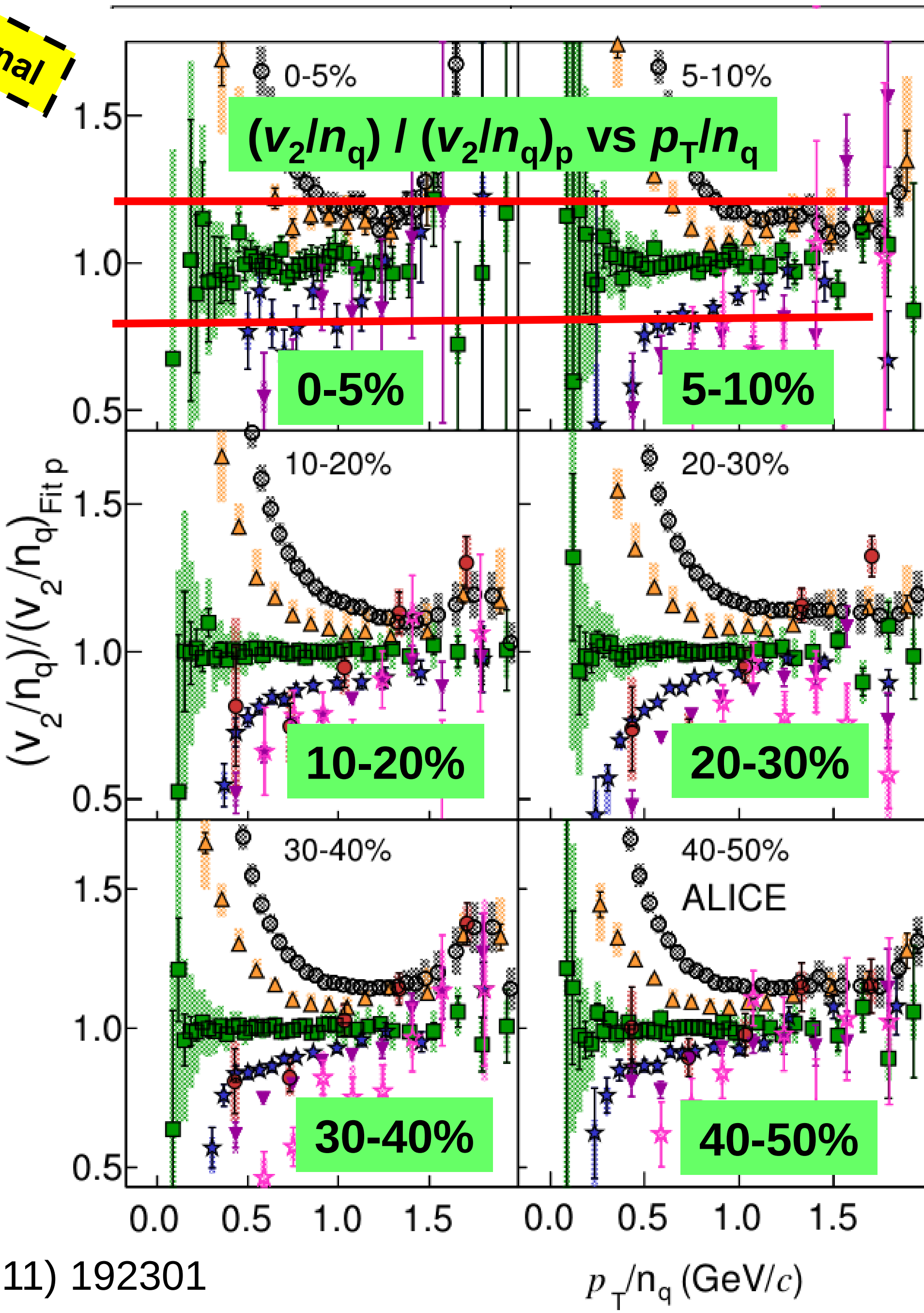


Pb-Pb

Identified v_2 final

- v_2 {SP} measured for π, K, K^0, p, ϕ, Λ, Ξ, Ω
  - Mass ordering (p_T < 2.5 GeV/c)
- Comparison to VISHNU (MC-KLN)
  - Ordering reproduced except Λ
  - π, K good
  - p underestimated; Λ, Ξ overestimated
- Number of quark constituent scaling violated by ~20% in particular in central collisions (p_T/n_q > 1 GeV/c)

→ A. Dobrin (Mon PM)



arXiv:1405.4632

VISHNU: PRL106 (2011) 192301

Pb-Pb

The ϕ…

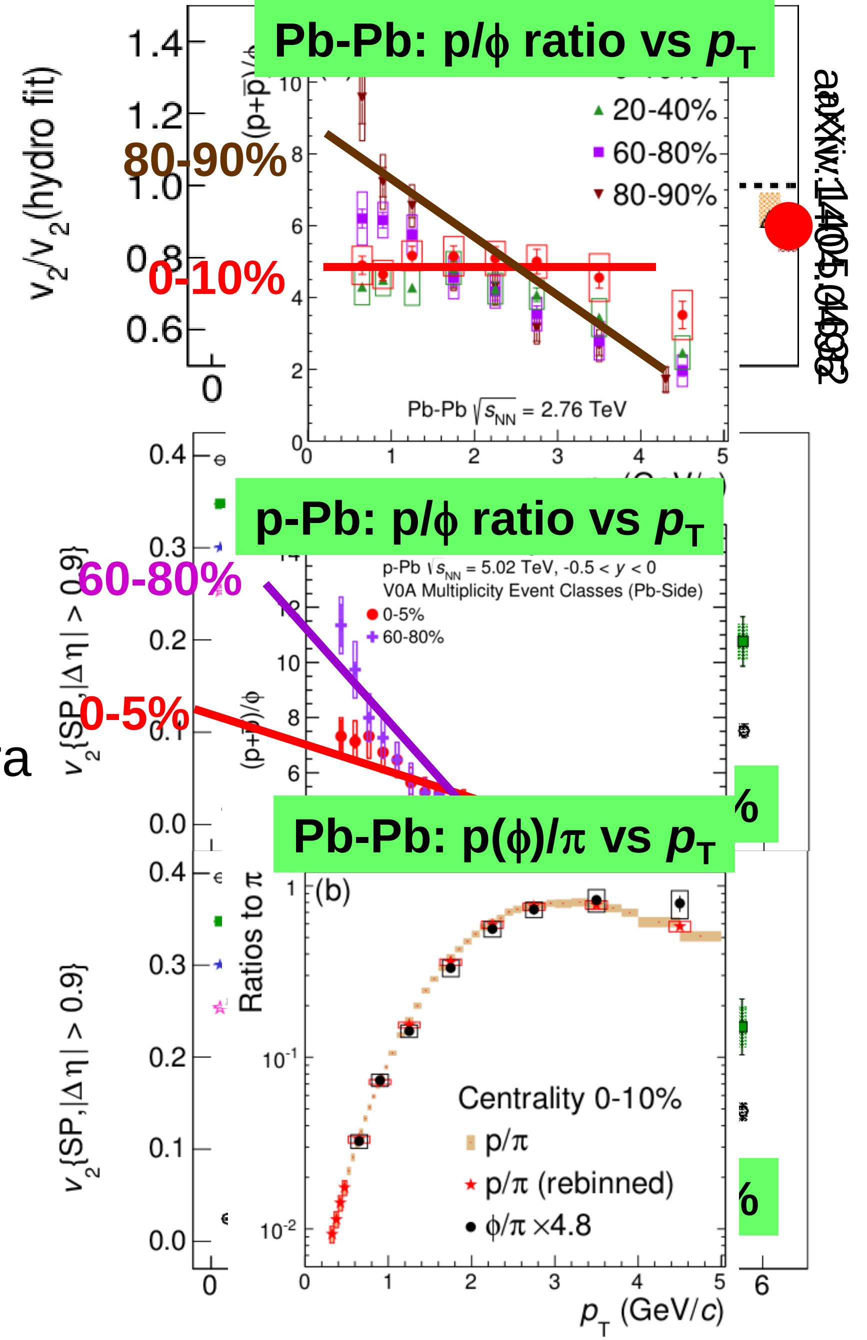
final

- v_2 not reproduced by VISHNU
  - Final-state interactions underestimated?

- v_2 at low p_T follows mass ordering
- v_2 at high p_T close to p in central and close to π in mid-central

- In central collisions p and ϕ p_T spectra have similar shape up to ~4 GeV/c
  - As expected from radial flow
  - Similar in p-Pb?

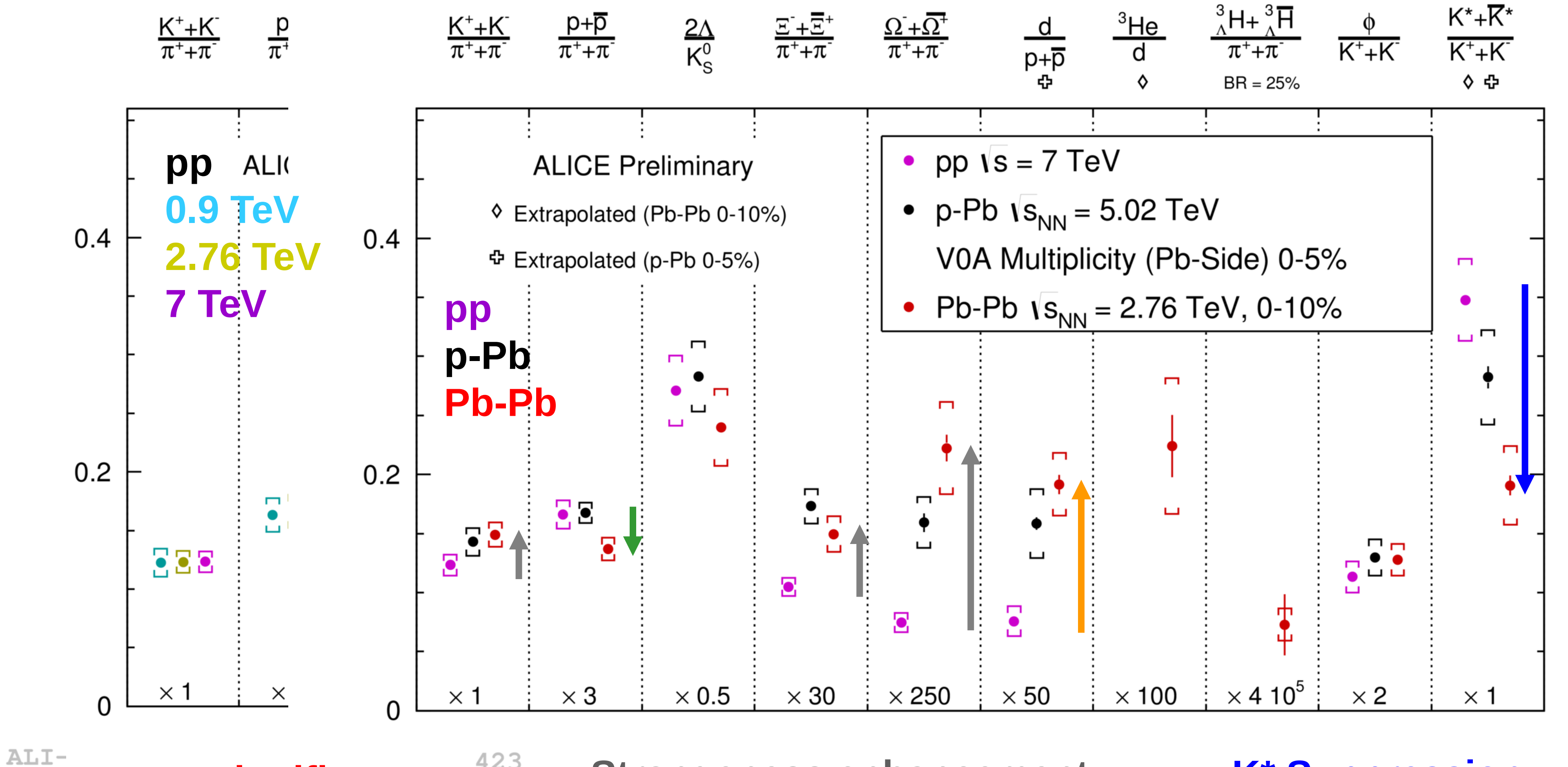
- Mass (and not number of constituent quarks) is main driver of v_2 and spectra in central Pb-Pb collisions



→ F. Bellini (Tue AM)

pp
p-Pb
Pb-Pb

π K K* K^0 p ϕ Λ Ξ Ω d ^{3}He ^{3}H



pp: no significant energy dependence

Strangeness enhancement
Deuteron enhancement

K* Suppression
p ?

Nuclei

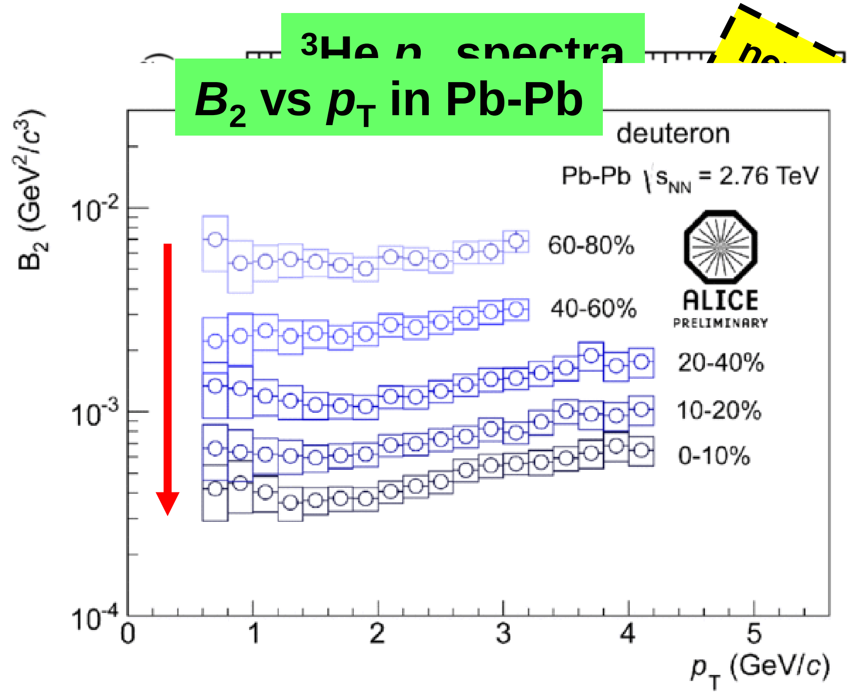
p-Pb
Pb-Pb

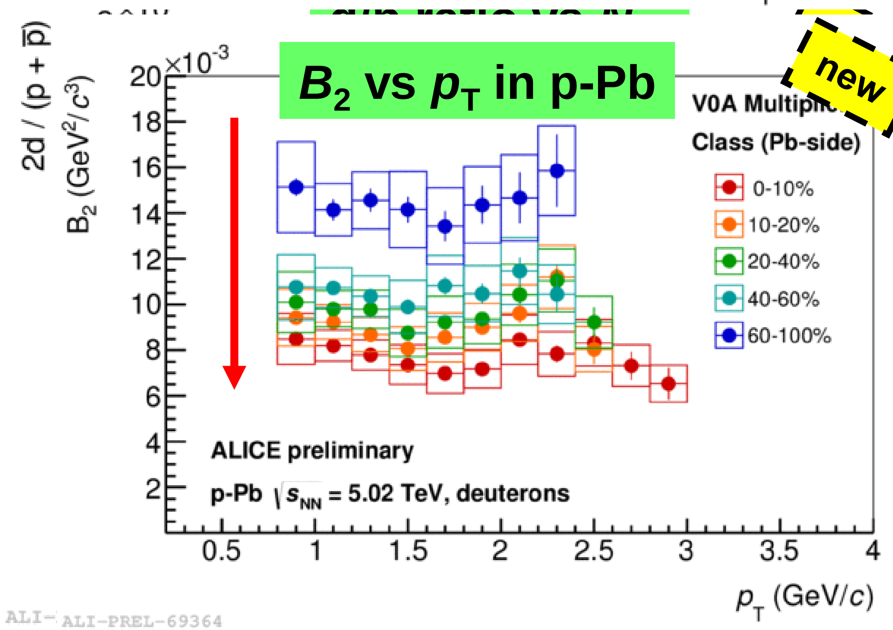
- p_T and centrality dependence of d, ^{3}He
- Smooth increase of d/p ratio from pp over p-Pb to Pb-Pb
  - Ratio increases on N_{ch} in p-Pb
- Coalescence parameter B_2

$$E_i \frac{d^3 N_i}{(dp_i)^3} = B_A \left(E_p \frac{d^3 N_p}{(dp_p)^3} \right)^A$$

  - Flat for pure coalescence
  - Mild p_T dependence in Pb-Pb
  - Decrease with N_{ch} in Pb-Pb, p-Pb
    - Source volume

→ N. Martin (Wed AM)

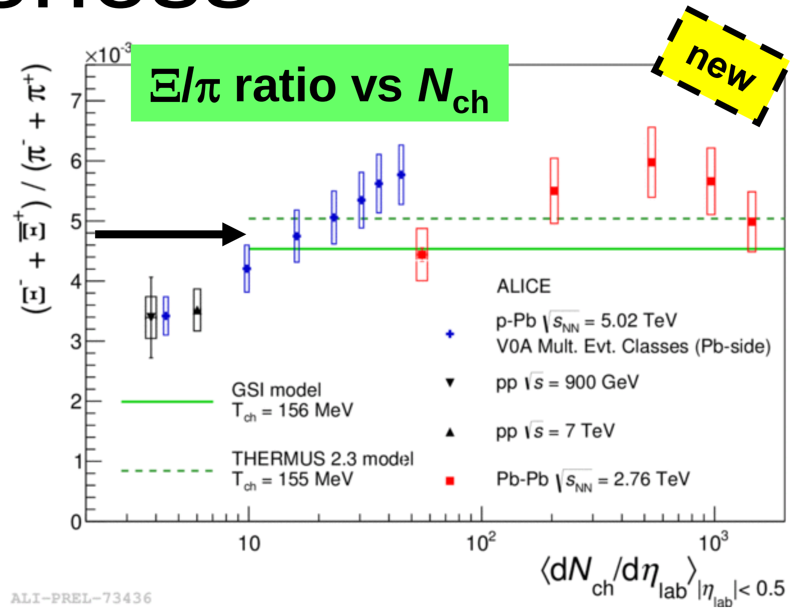


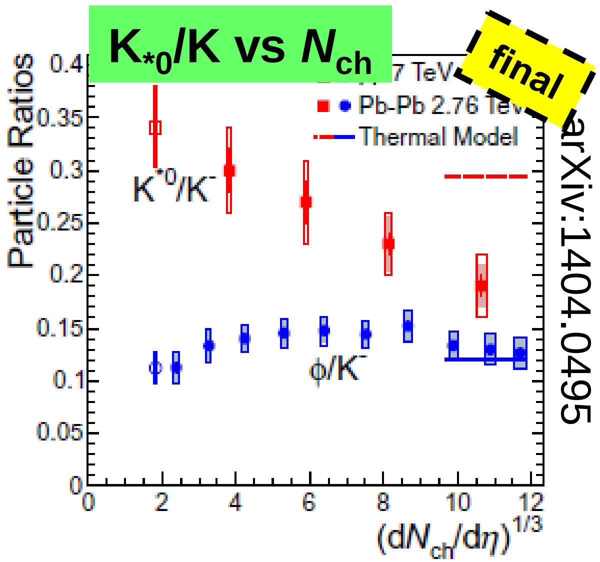


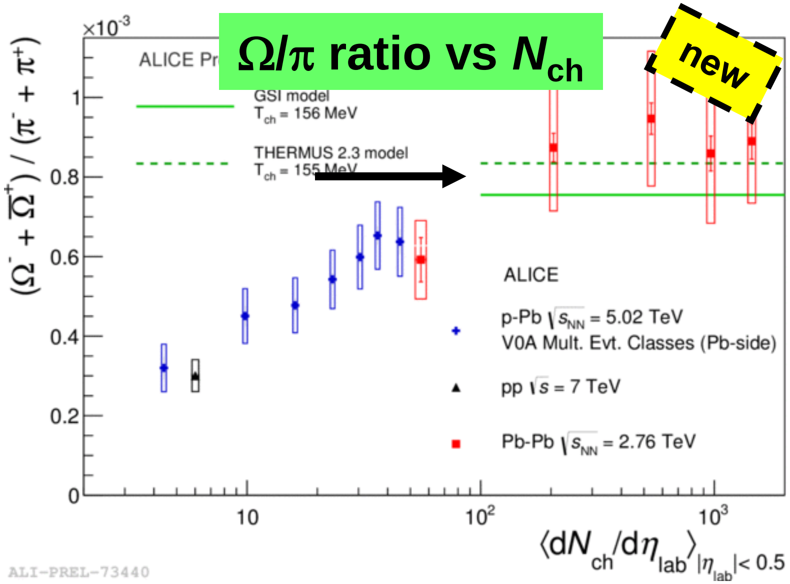
Strangeness

p-Pb
Pb-Pb

- Multi-strange baryons
  - p-Pb bridges pp and Pb-Pb smoothly
  - Ξ/π reach thermal model in p-Pb (so does the Λ/π)
  - Ω/π below thermal model
- K* suppression → rescattering?





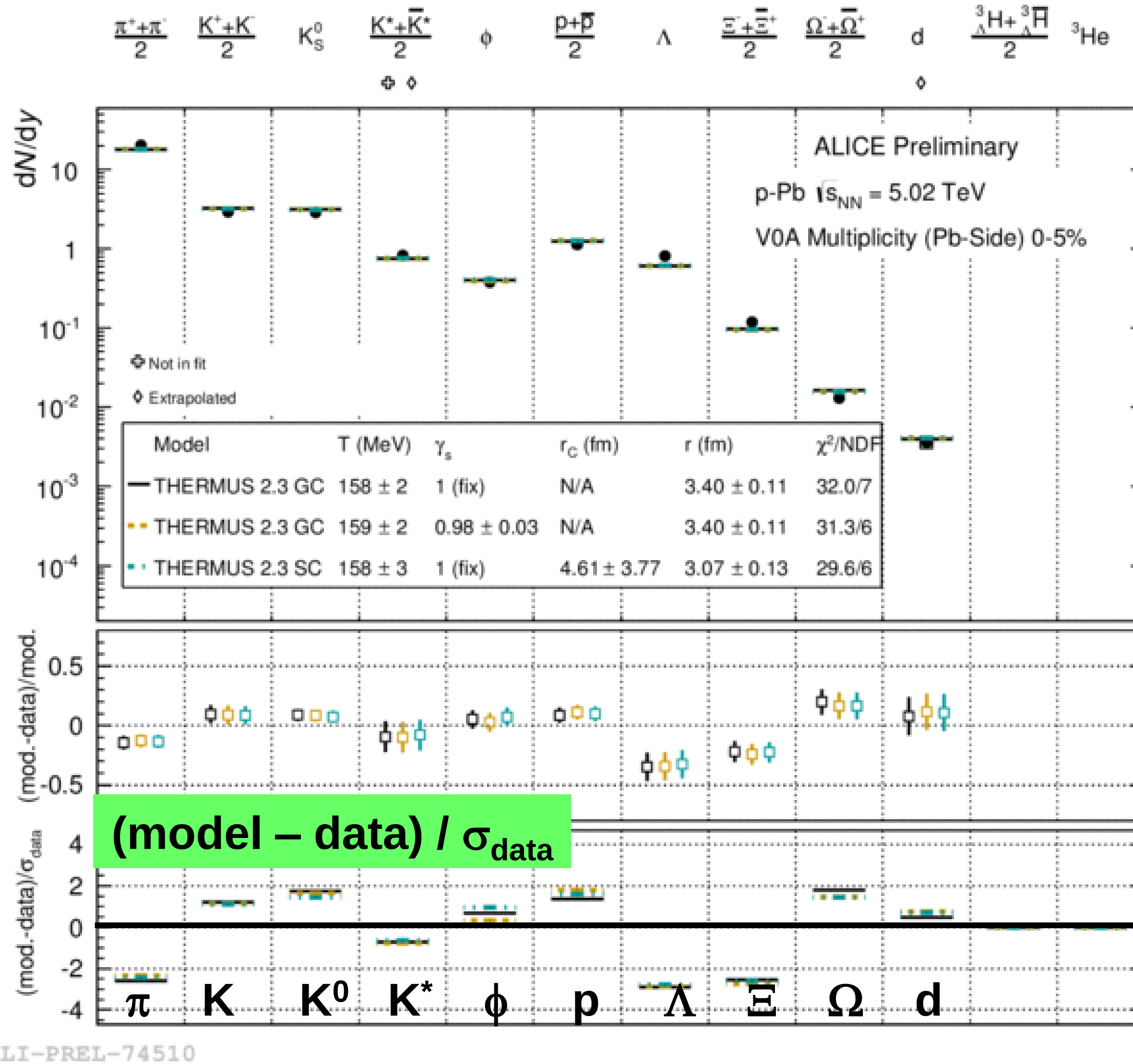


→ D. Alexandre (Wed AM) | F. Bellini (Tue AM)

p-Pb

Thermal Fits p-Pb

- Statistical model fits
  - Freeze-out temperature
  - Volume
  - μ_b
  - Equilibrium? (γ_S, γ_q)
- High-multiplicity p-Pb
  - THERMUS 2.3
  - $\gamma_S = 0.96 \pm 0.04$ → approximate thermal equilibrium
  - χ^2/ndf rather large though (about 5)

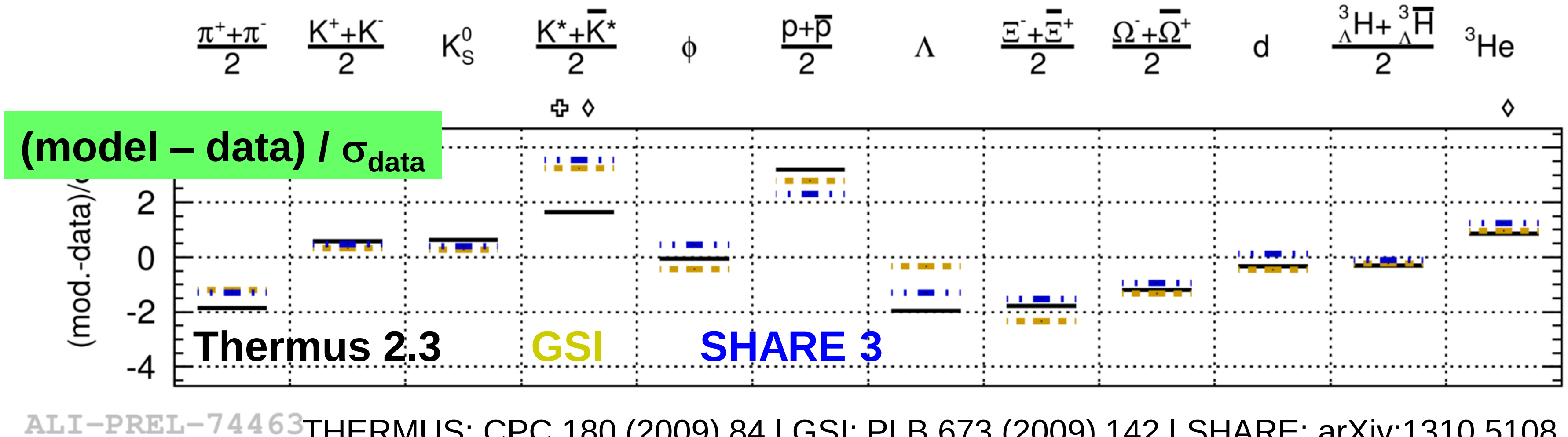


THERMUS: CPC 180 (2009) 84

Thermal Fits Pb-Pb

Pb-Pb

- Equilibrium models yields T = 156-157 MeV
  - But with χ^2/ndf of about 2



THERMUS: CPC 180 (2009) 84 | GSI: PLB 673 (2009) 142 | SHARE: arXiv:1310.5108

- Fits without the proton (and K*)
  - similar T, V but χ^2/ndf drops from about 2 to about 1

→ proton anomaly?

Physics origin?

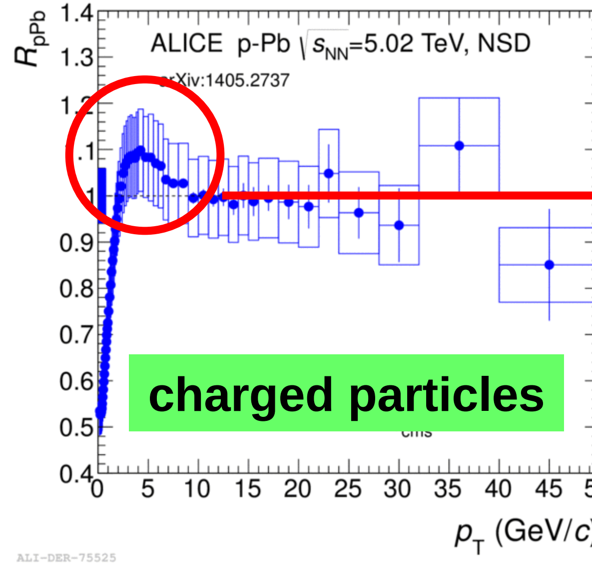
- Non equilibrium thermal model
- Baryon annihilation
- Freeze-out temperature hierarchy
- Incomplete hadron spectrum

→ **Plenary: M. Floris**

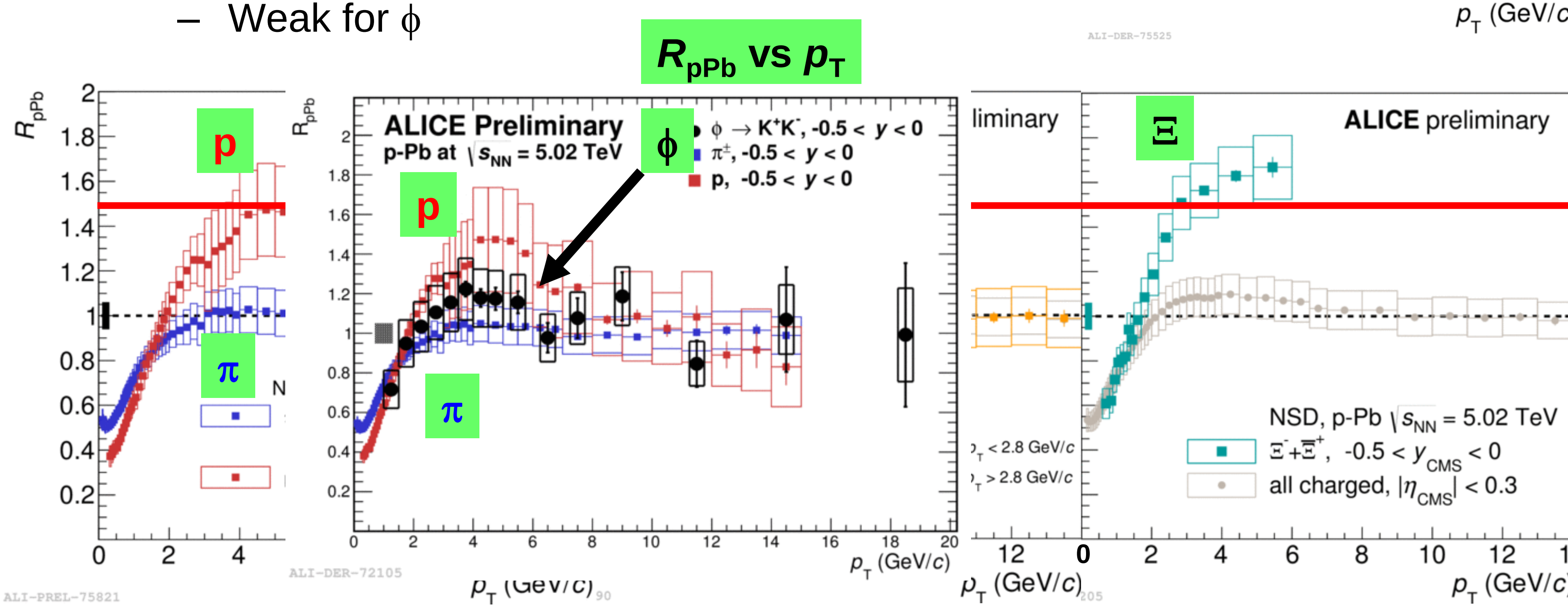
p-Pb

new

Identified R_{pA}



- "Cronin peak" around 3-4 GeV/c
- Shows dependence on particle type
  - No peak for π, K
  - Rather pronounced for p, Ξ
  - Weak for ϕ

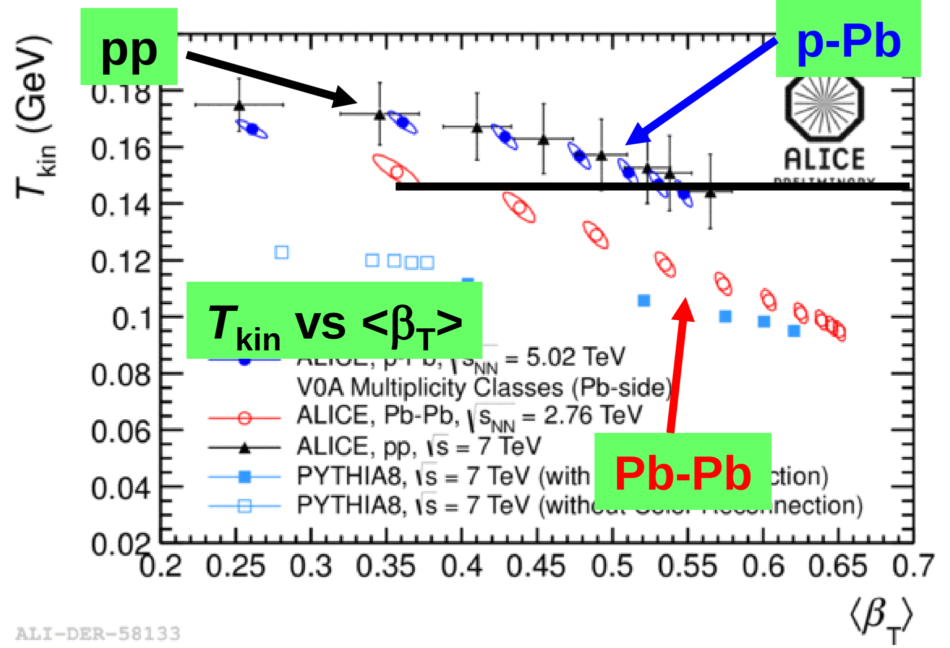


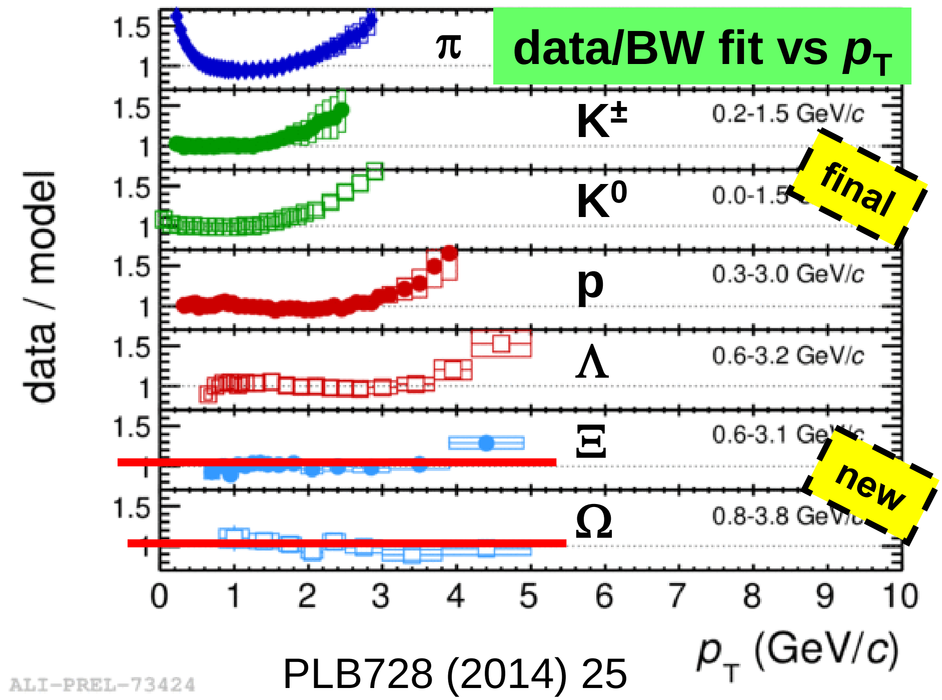
→ M. Knichel (Mon PM)

p-Pb

Radial Flow in p-Pb?

- Blast-wave fits as proxy for hydrodynamic modeling
  - Coherent fit for π, K, p, K^0, Λ, Ξ, Ω
- At same N_{ch}, $<\beta_T>$ larger in p-Pb than in Pb-Pb
  - Larger density gradient
- But… $<\beta_T>$ similarly large in pp and p-Pb (at same N_{ch})





PLB728 (2014) 25

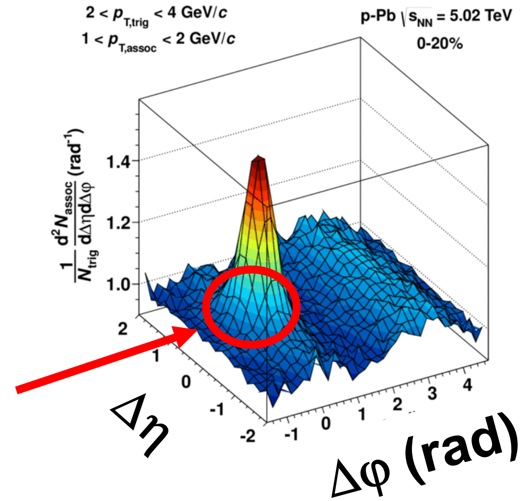
→ C. Andrei (Mon AM)

p-Pb

And the Jet at low p_T?

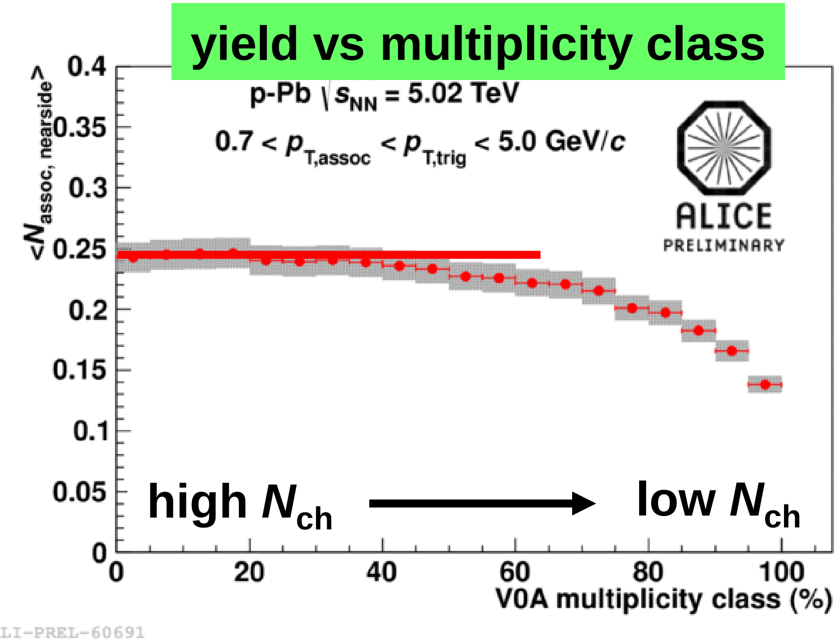
- No modification at high p_T
- Double ridge at low p_T
- Spectra modified at low p_T?

What happens to the "jet" at low p_T?



- Ridge-subtracted jet-like yields
- Ridge and jet seem additive in 2PC
- Constant jet yields for ~60% of p-Pb cross-section → no modification even at low p_T

- Consistent with a picture of minijets in p-Pb collisions from superposition of NN collisions with incoherent fragmentation

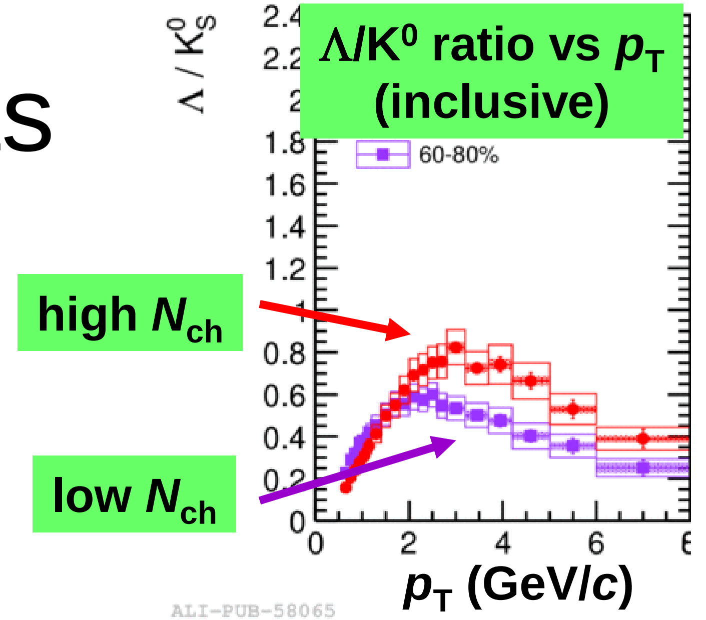


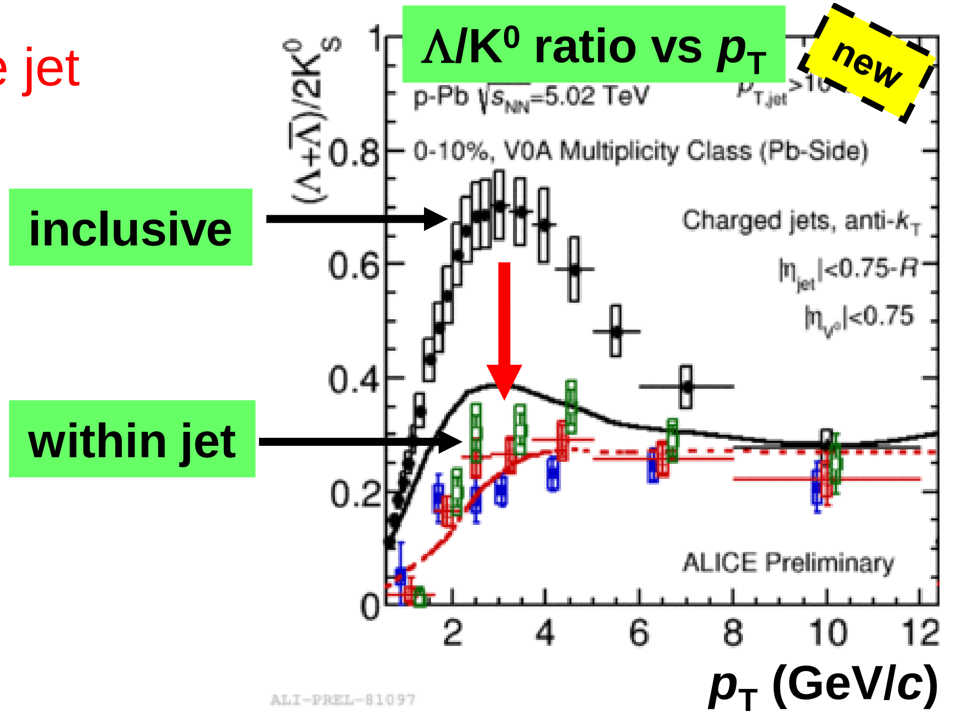
→ L. Milano (Tue PM)

p-Pb

Λ/K^0 Ratio in Jets

- Enhancement of Λ/K^0 ratio within the jet?
- Measure Λ/K^0 within jets
  - Background Λ and K^0 are estimated
    - outside of the cone
    - in events without jet with p_T > 5 GeV/c
- Factor 2-3 smaller ratio within the jet
  - Baryon/meson ratio enhancement is not present within the jet





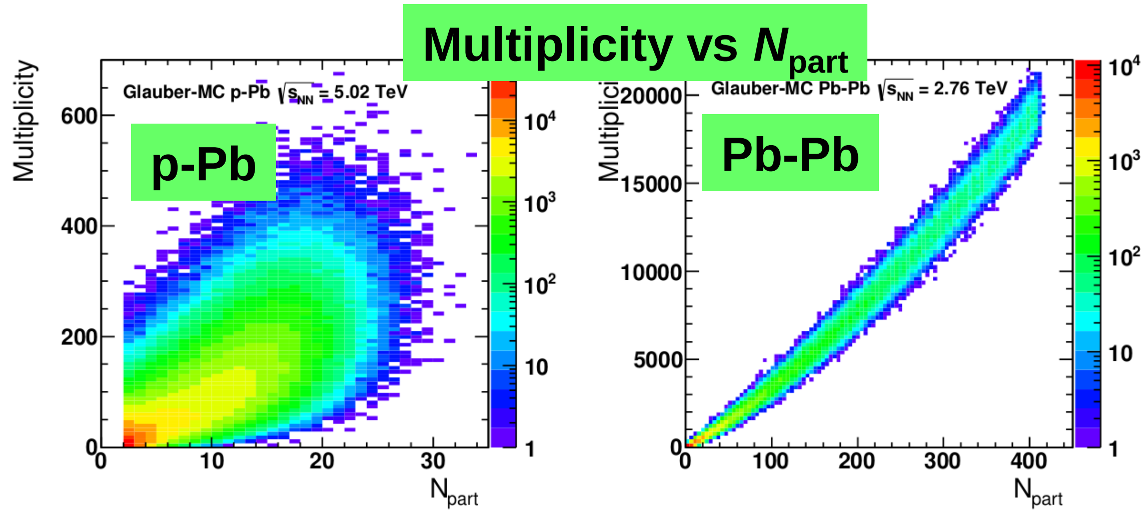
→ X. Zhang (Tue PM)

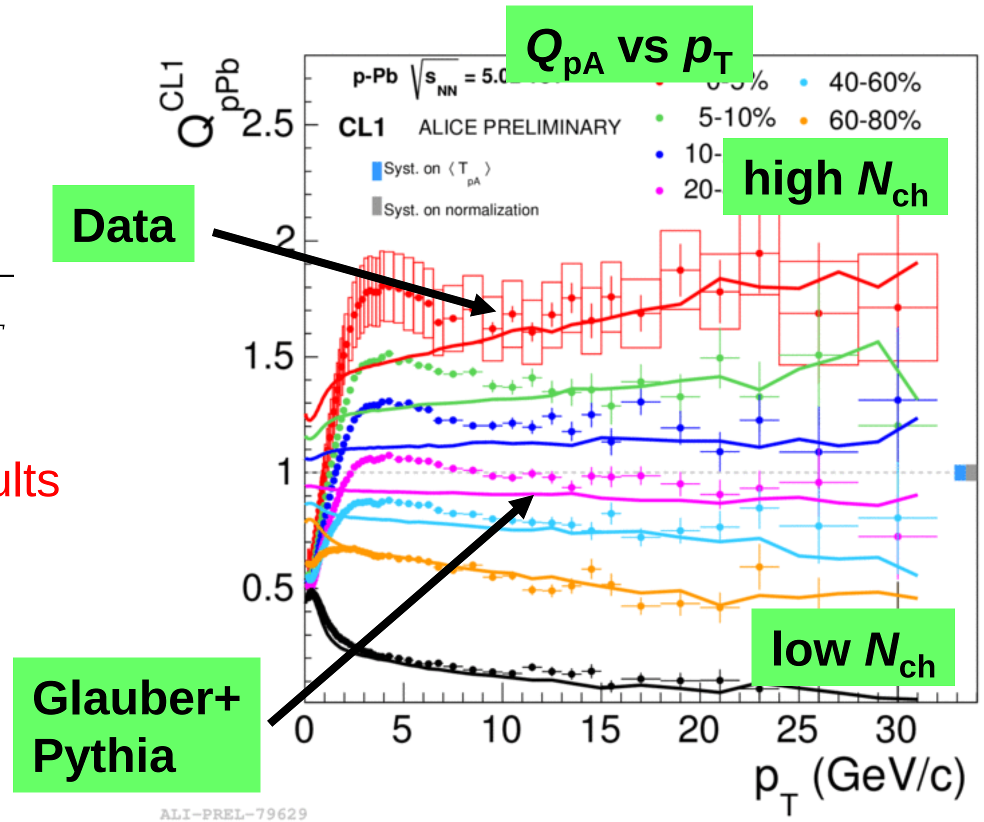
p-Pb

"Centrality" in p-Pb

- Due to the small N_{part}/N_{coll}, several biases are present
  - Multiplicity fluctuations
  - Jet-veto bias
  - Geometric bias

- Example $Q^{i}_{pA} = \dfrac{dN_{pA}/dp_T}{\langle N_{coll} \rangle_i \, dN_{pp}/dp_T}$
  - Standard Glauber fit + event selection (a la AA) leads to results which depends on η-region of "centrality estimator"
  - Therefore not called R_{pA}





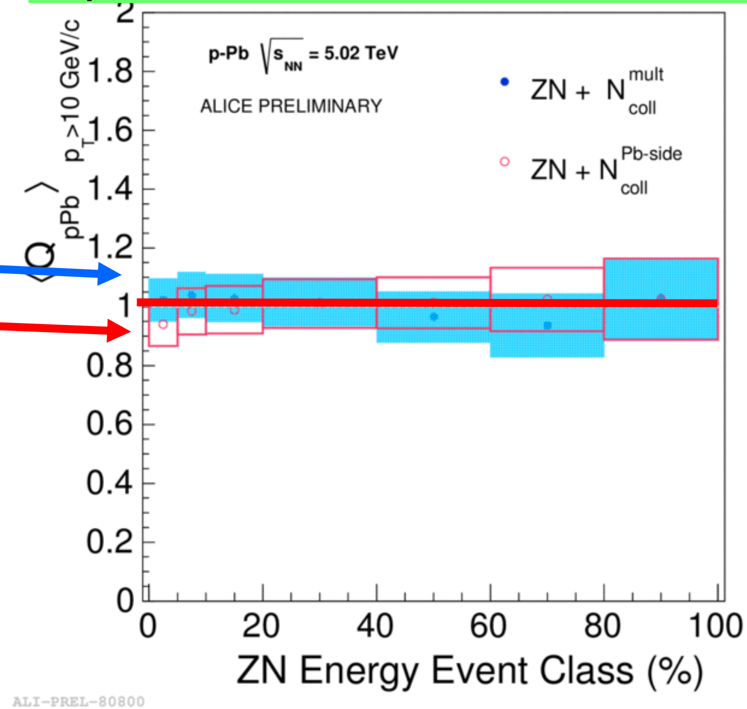
Promising Alternative to Centrality in p-Pb

new

- Forward neutrons cause no selection bias on mid-rapidity bulk production → use to bin events in classes
- N_{coll}/N_{part} by assuming one out of
  - Mid rapidity $dN_{ch}/d\eta \sim N_{part}$
  - Forward $dN_{ch}/d\eta \sim N_{part}^{Pb} = N_{part} - 1$
  - High p_T yield is $\sim N_{coll}$
- Methods reach consistent results
  - N_{coll} consistent within 5-10%
  - High p_T Q_{pA} flat
- "R_{pA}" in event classes depends on the estimator → we measure several Q_{pA}

→ A. Toia (Mon PM)

Q_{pPb} > 10 GeV/*c* vs event class



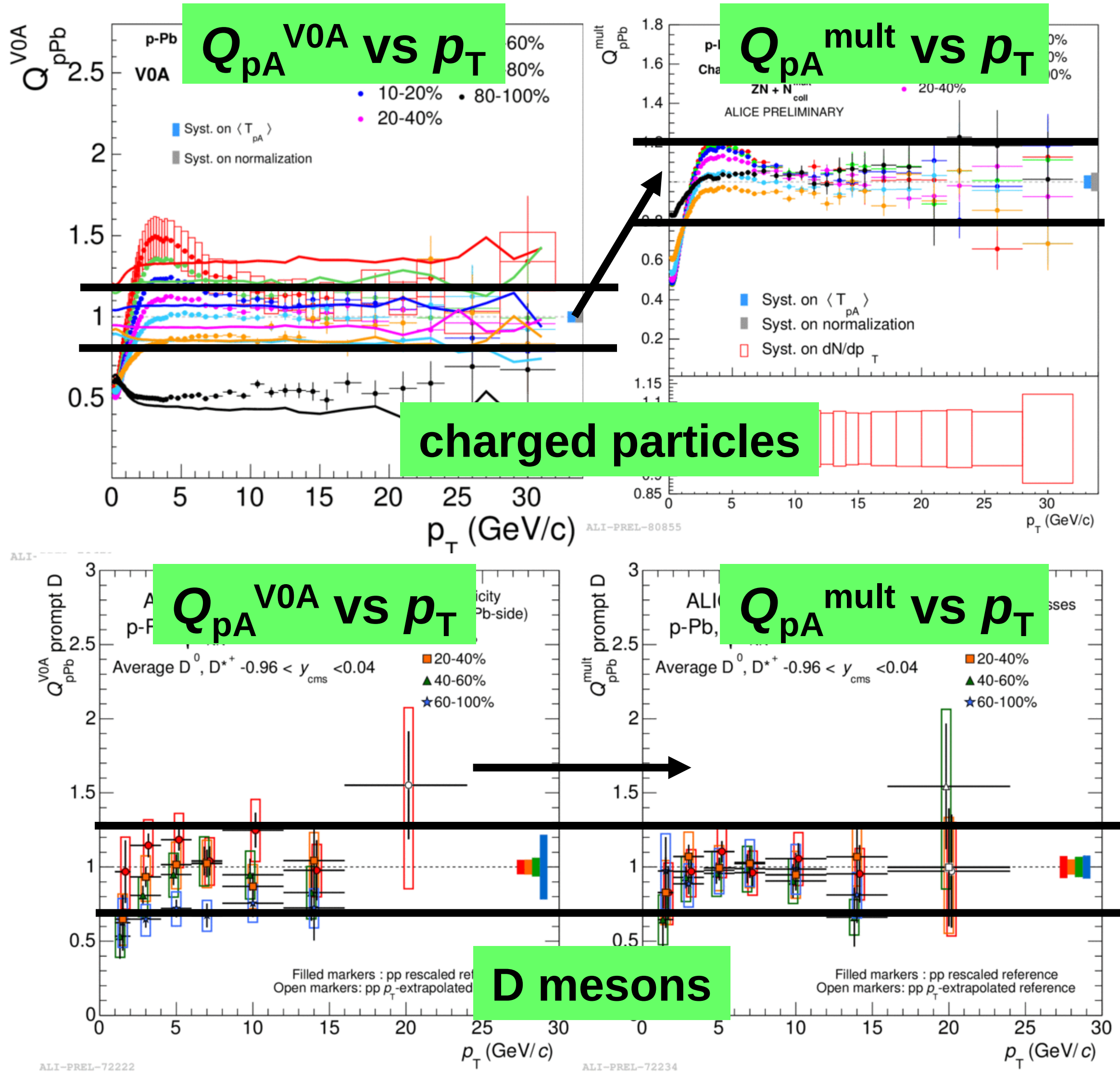
p-Pb

new

New Estimator: Q_{pA}^{mult}

- Charged particle Q_{pA} consistent with unity at high p_T
  - Cronin peak develops with multiplicity
- D meson Q_{pA} independent of p_T above 2 GeV/c
  - Consistent with unity

NB. Estimators have different dynamic range

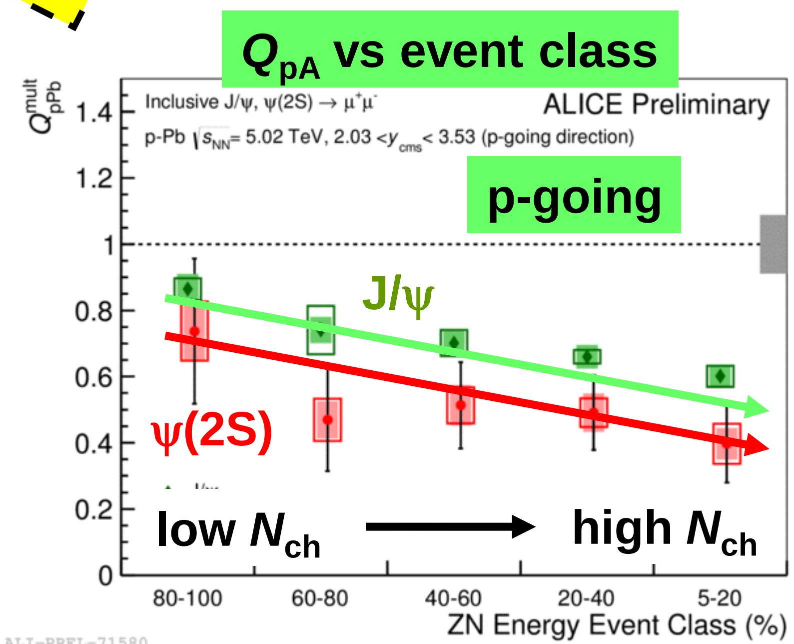


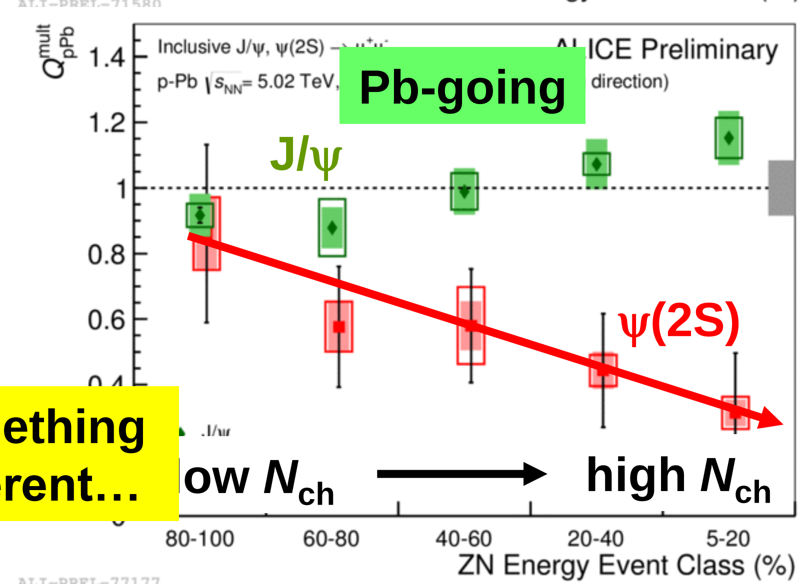
p-Pb

Charmonia Q_{pA}

new

- J/ψ → μμ: Multiplicity dependent suppression in p-going direction
  - Independent of p_T
  - Shadowing region; <x> ~ 10^{-4}
- No suppression in Pb-going direction
  - Antishadowing region; <x> ~ 10^{-2}
- ψ(2S) → μμ: Multiplicity dependent suppression in both directions
- Consistent with RHIC
- J/ψ consistent with shadowing
- ψ(2S) needs additional effects
  → Final state?



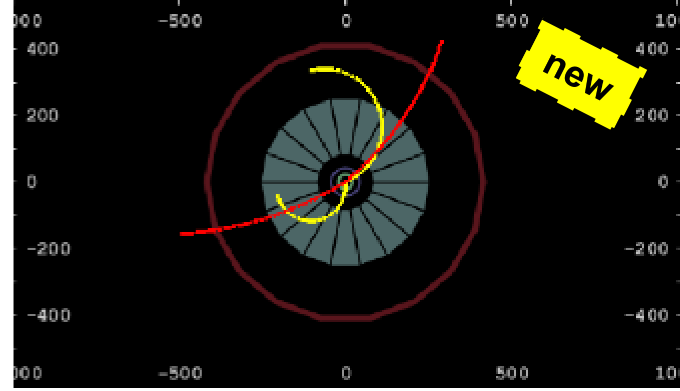


and now to something completely different…

→ Tuesday PM: J. Blanco | R. Arnaldi

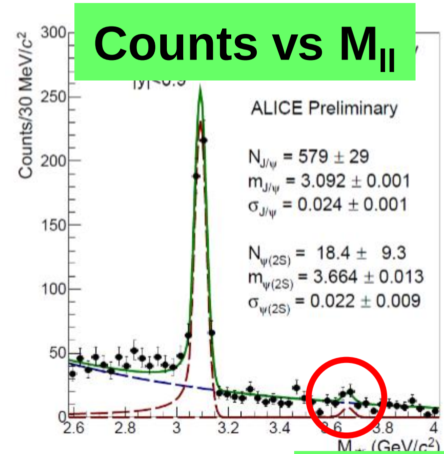
Pb-Pb

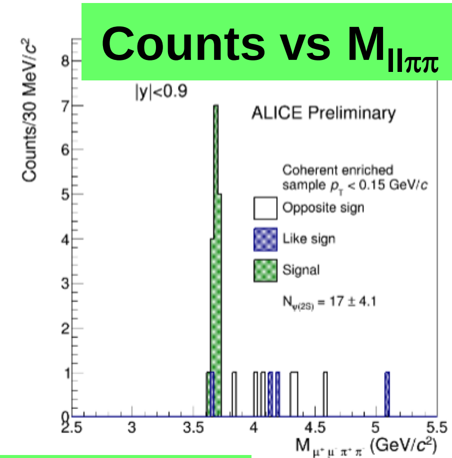
Ultra-Peripheral Collisions

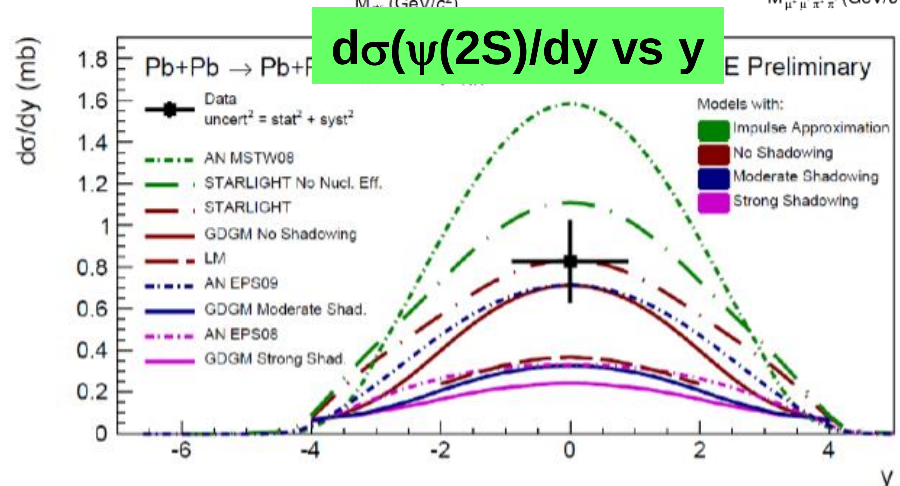


- Coherent J/ψ photo-production published (PLB718 (2013) 1273, EPJC 73 (2013) 2617)
- First measurement of exclusive ρ^0
- First measurement of ψ(2S) photoproduction in a nuclear target
  - $\psi(2S) \rightarrow l^+l^-$
  - $\psi(2S) \rightarrow l^+l^- + \pi^+\pi^-$
- Strong model constraints
  - Strong shadowing disfavored
  - No nuclear effects disfavored

→ J. Nystrand (Mon AM)







Pb-Pb

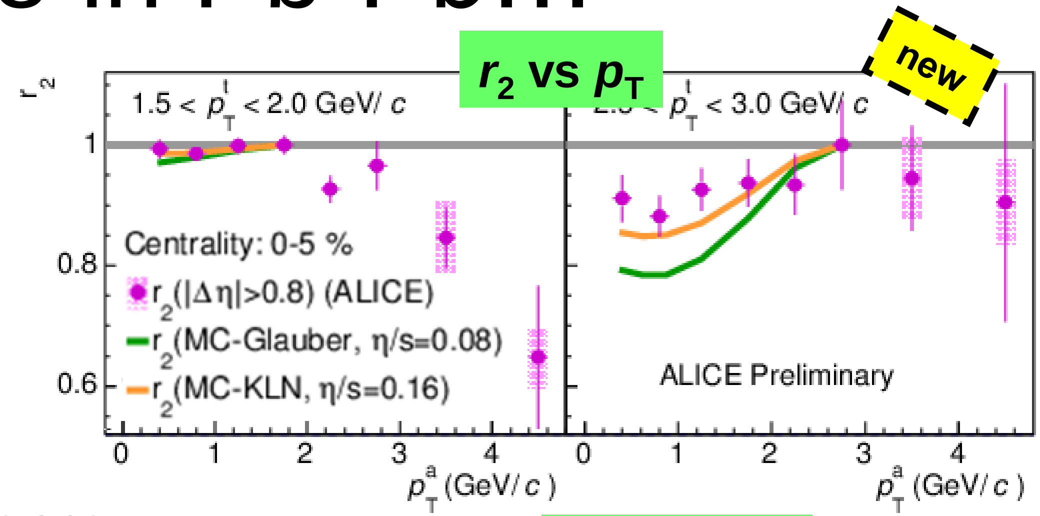
More in Pb-Pb…

- p_T dependent symmetry plane angles

$$r_n \equiv \frac{V_{n\Delta}(p_T^a, p_T^b)}{\sqrt{V_{n\Delta}(p_T^a, p_T^a) \cdot V_{n\Delta}(p_T^b, p_T^b)}}$$

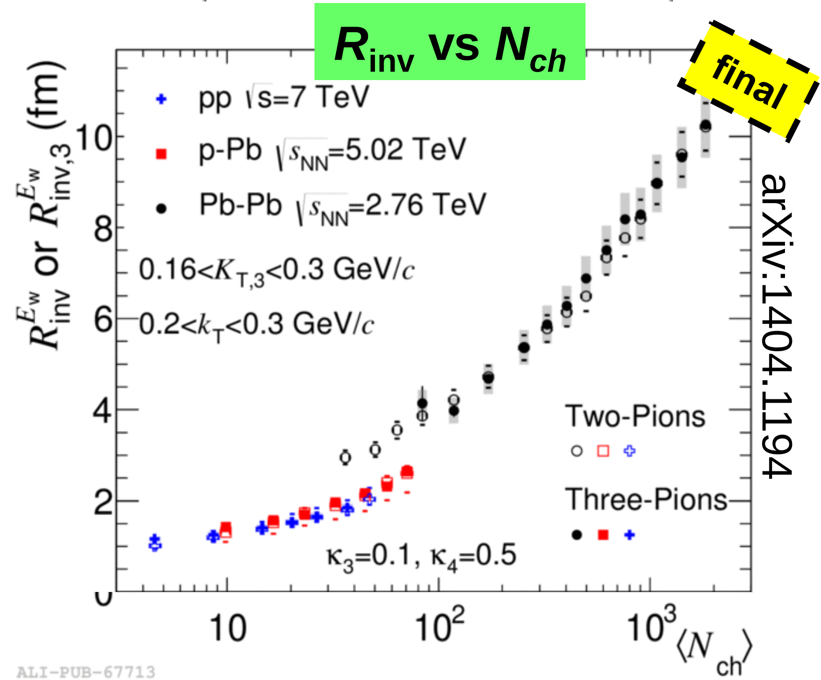
  - r_2 deviates from 1 with increasing $p_{T,a} - p_{T,b}$
  - Largest effect in central collisions
  - Hydro in the right ballpark

→ **Y. Zhou (Tue AM)**



- First extraction of femtoscopic radii with 3 π cumulants
  - Non-femtoscopic effects reduced
  - p-Pb radii 5-15% larger than in pp at same multiplicity
  - Pb-Pb radii 35-45% larger than in p-Pb at same multiplicity

→ **D. Gangadharan (Wed AM)**

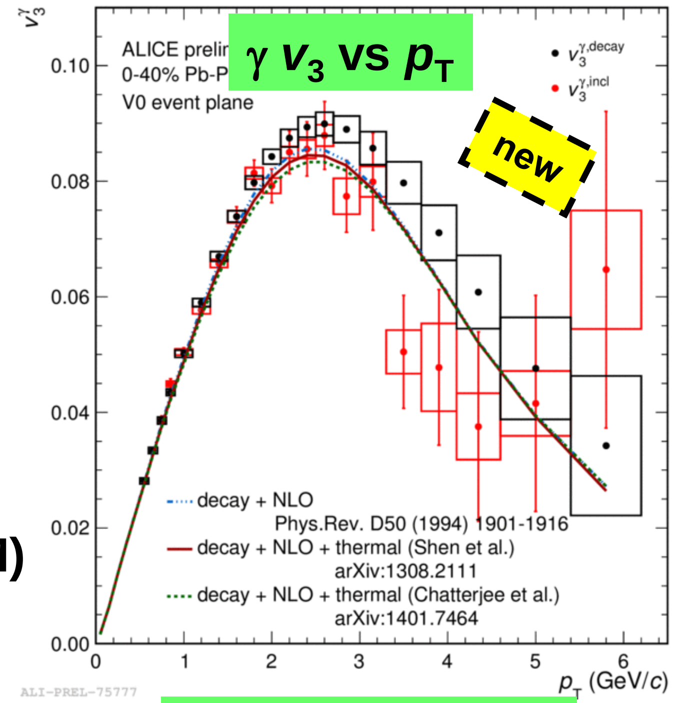


More in Pb-Pb…

Pb-Pb

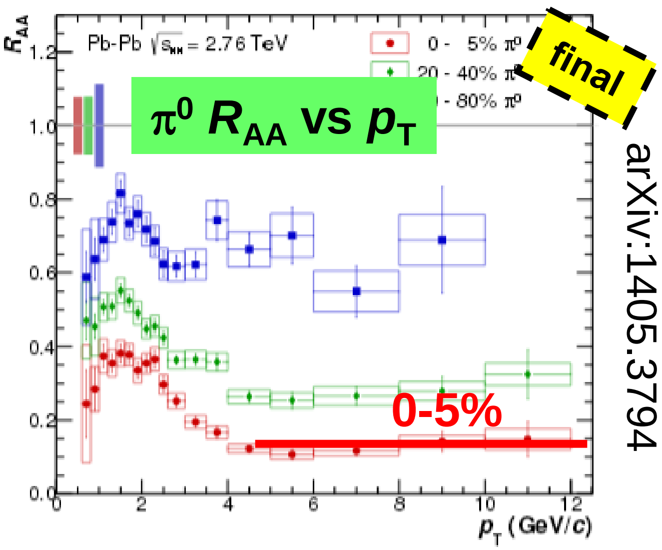
- Direct photons
  - Inclusive photon v_3 compared to cocktail

→ **F. Bock (Mon PM)**



- π^0 R_{AA}
  - Significant suppression

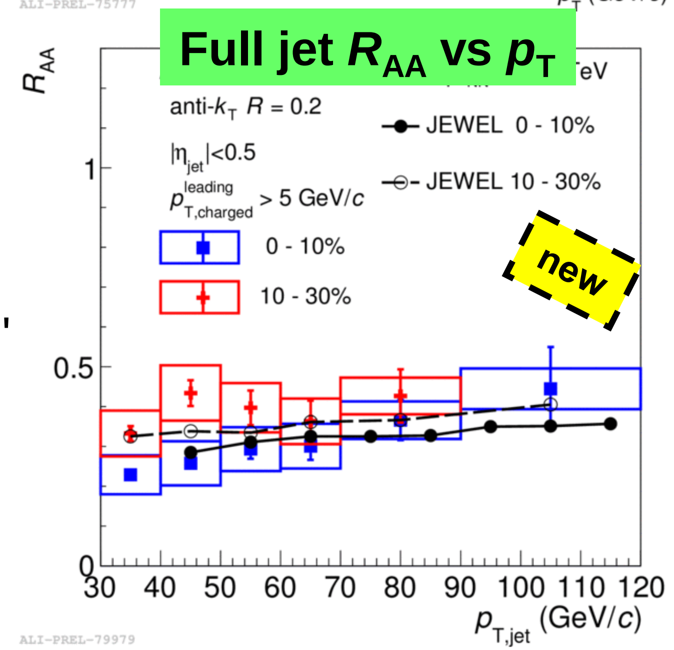
→ **A. Marin (Tue PM)**



arXiv:1405.3794

- Full jet R_{AA}
  - In the "low jet p_T" region (for ATLAS/CMS)

→ **S. Aiola (Tue AM)**



Pb-Pb

More in Pb-Pb…

- Charged jet v_2
  - Path-length dependence of energy loss

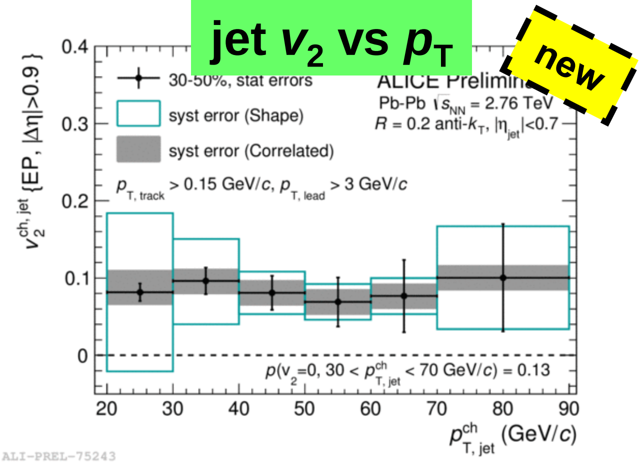
→ **S. Aiola (Tue AM)**

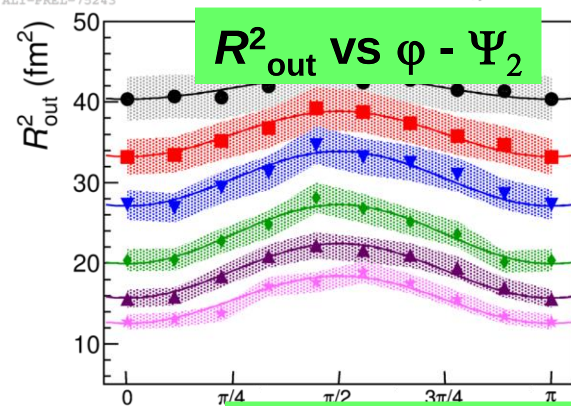
- Azimuthally-sensitive femtoscopy
  - Source out of plane extended (as at RHIC)

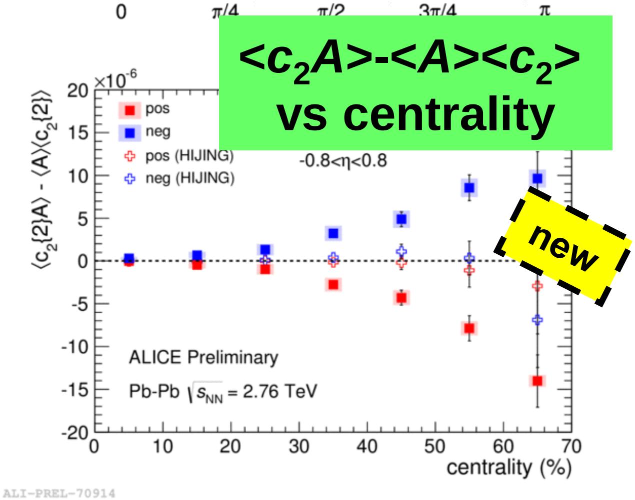
→ **V. Loggins (Wed PM)**

- Measure charge-dependent flow as signal for chiral magnetic wave
  - Signal to be understood in terms of local charge conservation and dilution

→ **R. Belmont (Tue AM)**







p-Pb

More in p-Pb…

- D-hadron correlations
  - Promising for Run II

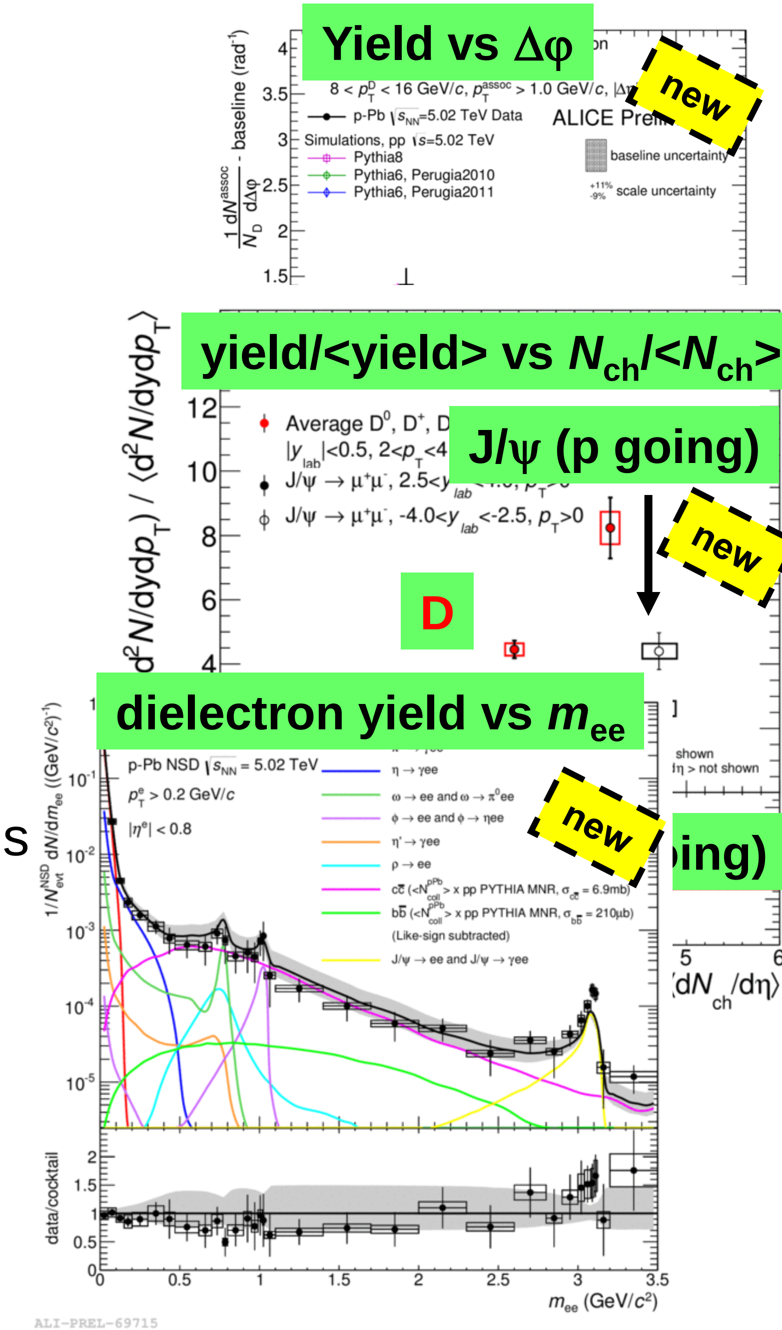
→ **S. Bjelogrlic (Mon PM)**

- N_{ch} dependence of D and J/ψ
  - Self-normalized variables
  - D yield similar in pp and p-Pb
  - D and J/ψ yields show different trends

→ **J. Blanco (Tue PM) | R. Russo (Mon PM)**

- Low-mass dielectrons
  - No enhancement over cocktail (m_{ee} < 3.5 GeV/c^2)

→ **M. Kohler (Mon AM)**

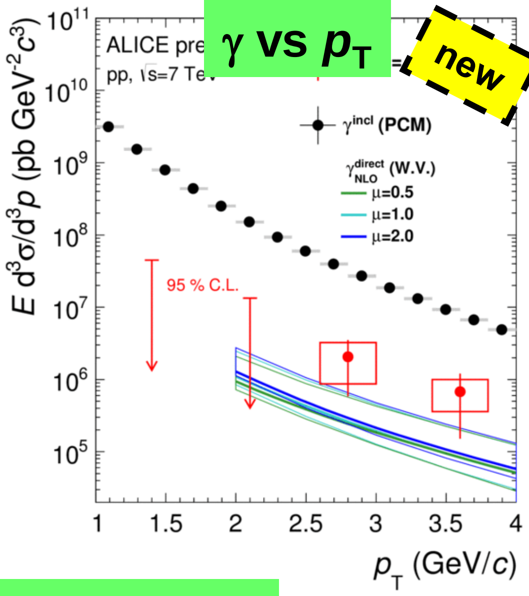


More in pp…

pp

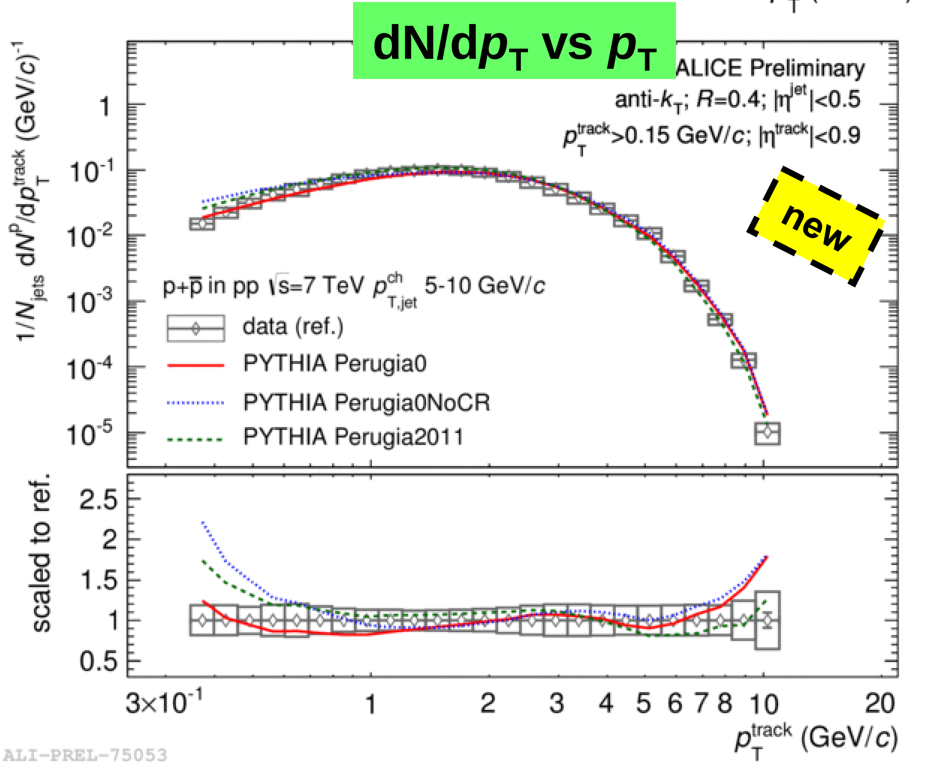
- Direct photons
  - Consistent with pQCD NLO

  → **M. Kohler (Mon AM)**



- PID-dependent (π, K, p) jet fragmentation functions
  - $p_{T,hadron}$ 0.2–20 GeV/c
  - Charged jet p_T: 5–20 GeV/c
  - Large discrepancies to PYTHIA at low p_T

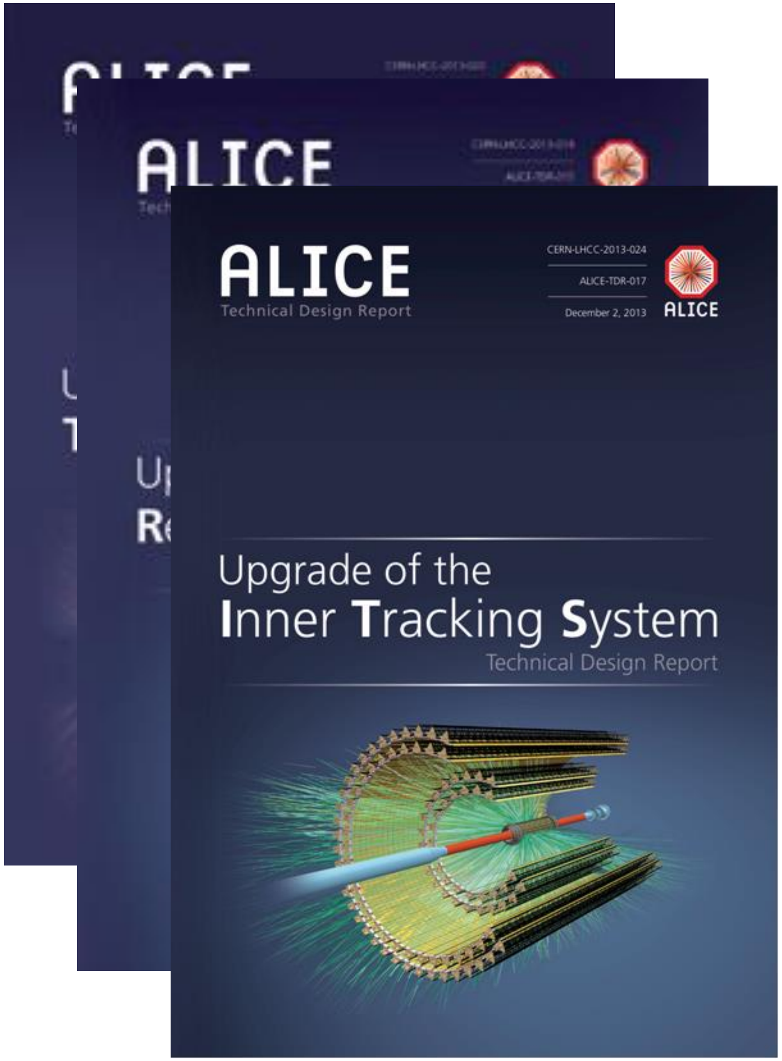
  → **X. Lu (Tue PM)**



Run II and Upgrade

- Run II in 2015 – 2017
  - Updated detectors, readout, trigger
  - LHC energy up to 13 TeV for pp (~5.1 TeV for Pb-Pb)
  - Factor 2-3 to 10 increase in pp, p-Pb and Pb-Pb depending on channel
- ALICE 2.0 well underway for physics in the 2020s
  - New ITS and new TPC readout
  - Increase data-taking rate by factor 100! (→ 50kHz Pb-Pb continuous)
  - Heavy flavor, quarkonia, low-mass dileptons, jets …

→ Wednesday AM: S. Siddhanta | T. Gunji



Summary – ALICE Highlights

Hot QCD – Heavy-ions

- Significant progress in precision (spectra, PID v_2, D, J/ψ, …)
- v_2 mass ordering for light and strange hadrons up to $p_T < 2.5$ GeV/c
- Mass seems to drive spectra and v_2 up to ~ 4 GeV/c in central collisions
- ΔE(beauty) < ΔE(charm) at high p_T

Pb-Pb remains a very hot and interesting system

"Cold" QCD – Proton-lead

- Centrality tricky at LHC
- Pb-Pb-like features at low p_T (radial flow, v_2, thermal fits, …)
- No indications of quenching at high p_T (charged hadrons, jets, open charm, heavy flavor electrons and muons)
- ψ(2S) vs J/ψ R_{pA} suggests significant final-state effects

p-Pb seems hotter than we thought and very interesting