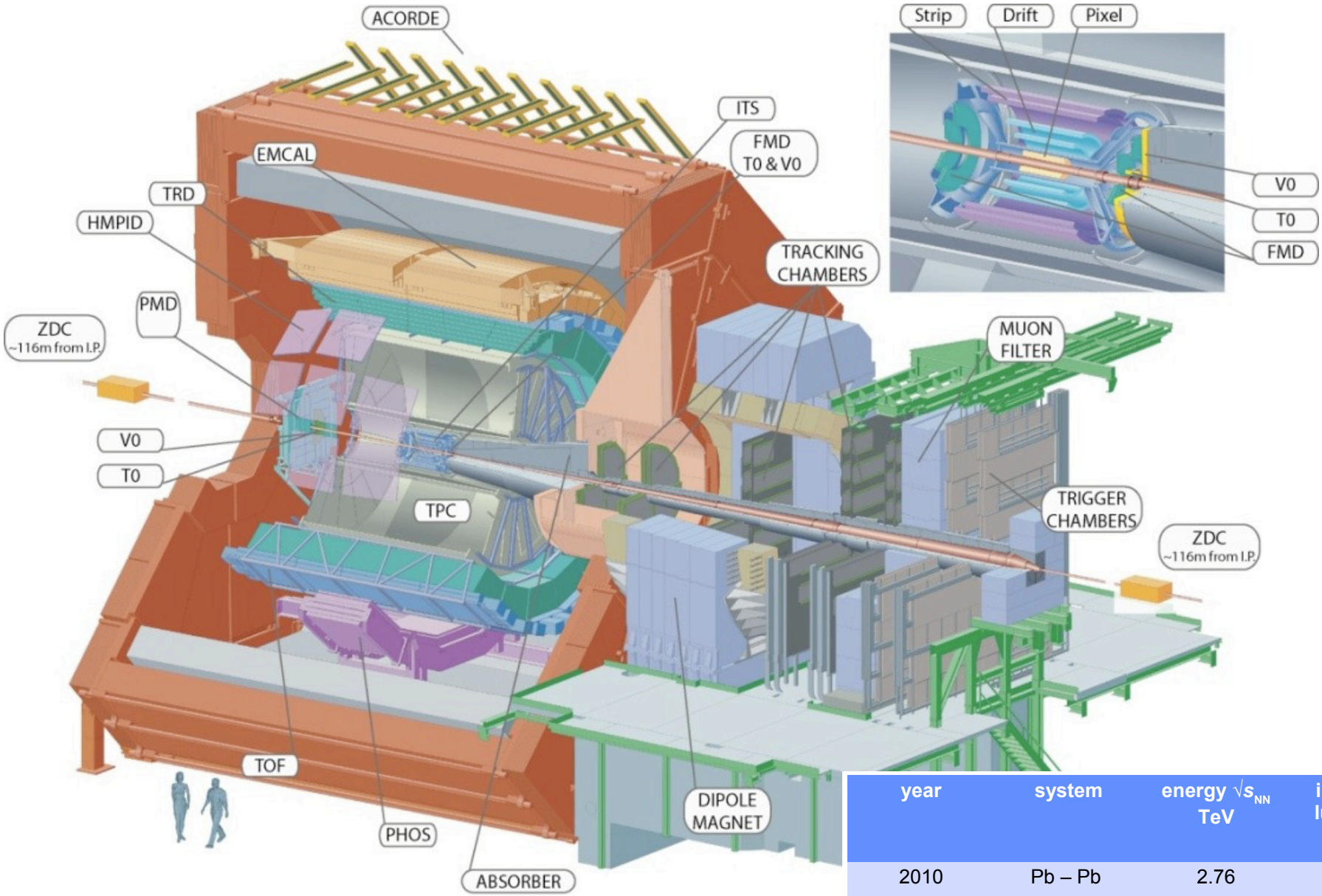
Recent Heavy-Ion Results with the ALICE Detector

Jörn Putschke

On behalf of the

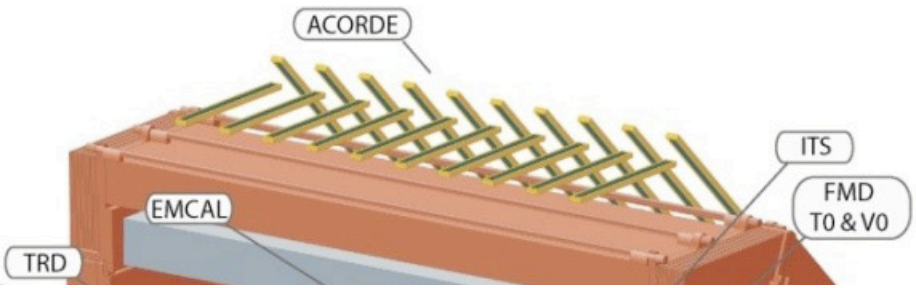
ALICE Collaboration

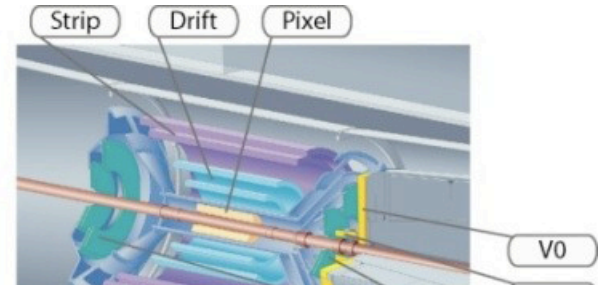
The ALICE Experiment

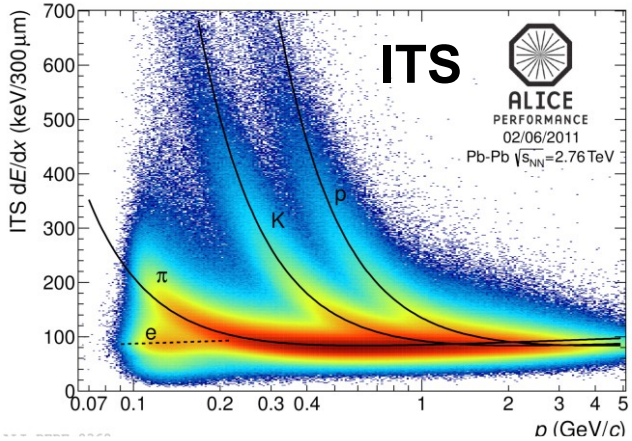


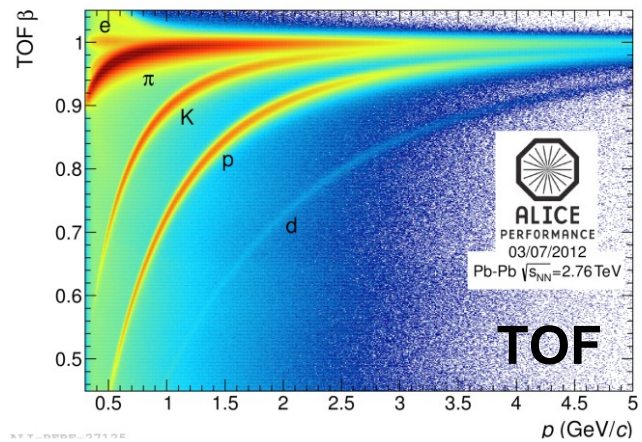
year	system	energy $\sqrt{s_{NN}}$ TeV	integrated luminosity
2010	Pb – Pb	2.76	~ 10 μb^{-1}
2011	Pb – Pb	2.76	~ 0.1 nb^{-1}
2013	p – Pb	5.02	~ 30 nb^{-1}

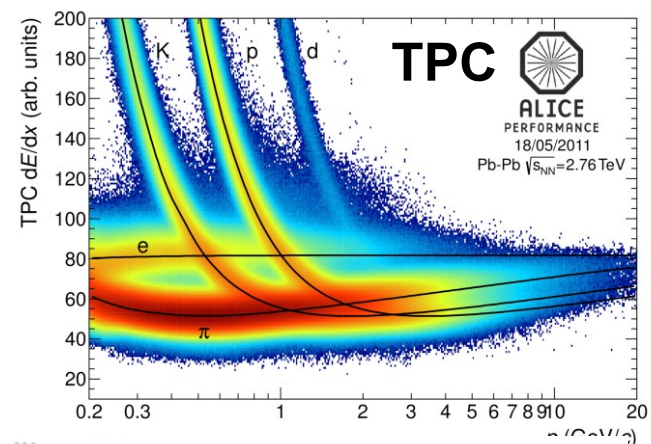
The ALICE Experiment

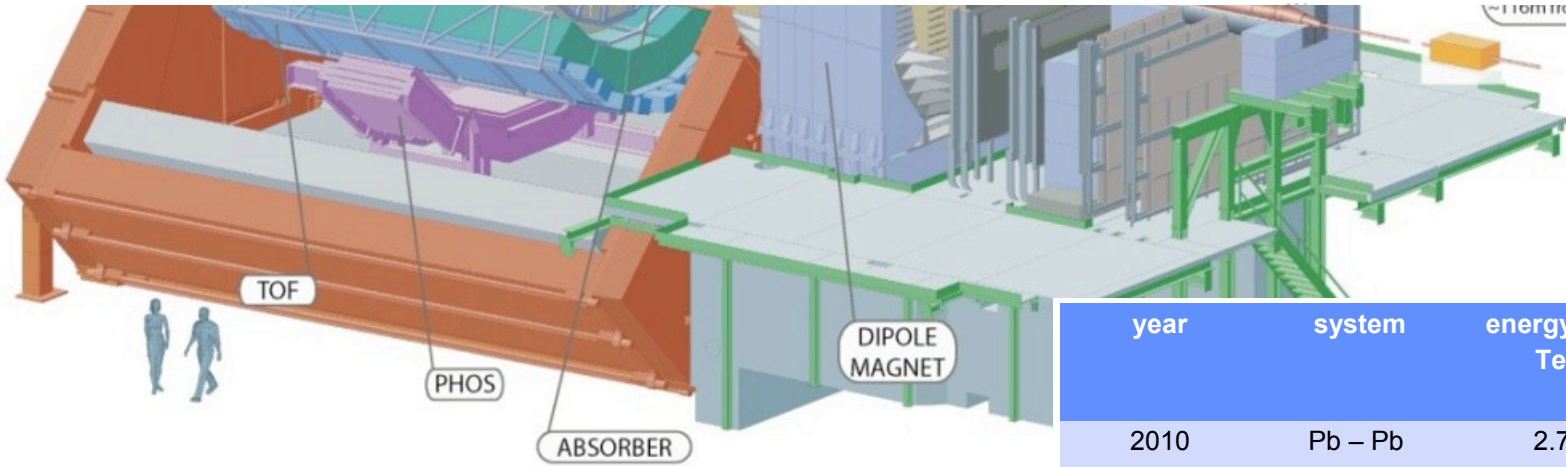












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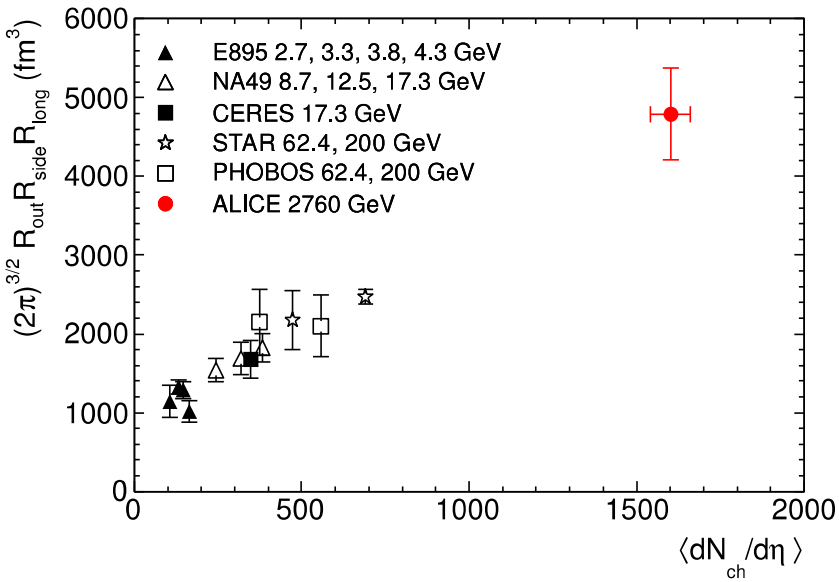
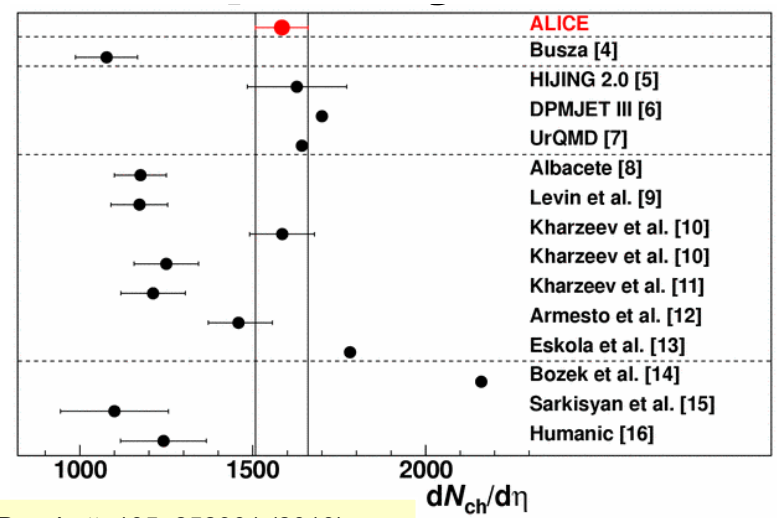
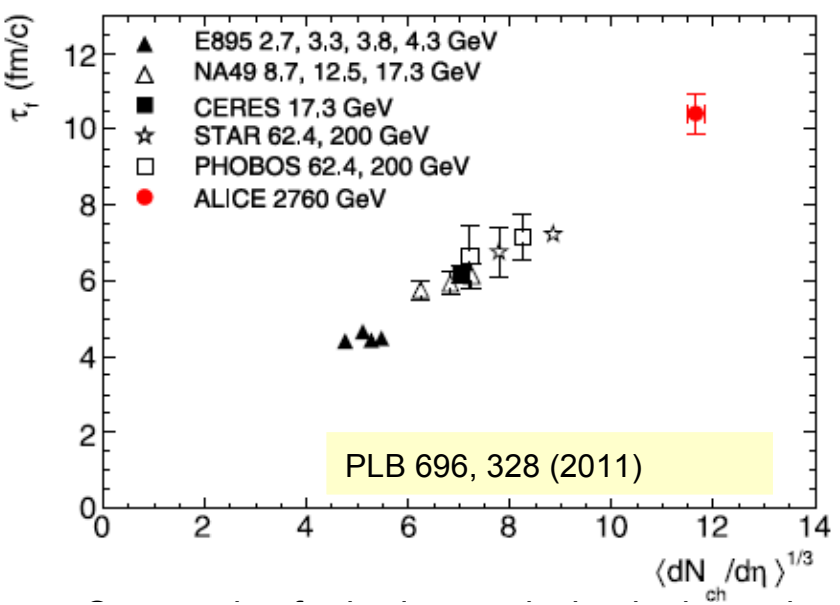
The QGP at the LHC



PbPb



Phys. Rev. Lett. 105, 252301 (2010)



PLB 696, 328 (2011)

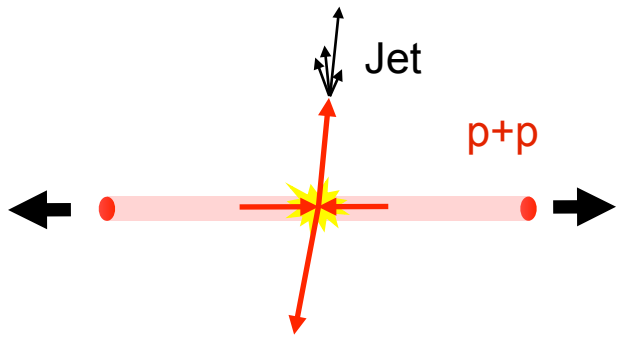
Hotter, denser (x2.5), bigger (x2) and longer lifetime (30%) as compared to RHIC!

Focus on hard probes:

Before we can utilize hard probes/jets (and their modifications/tomography) to probe the medium in heavy-ion collisions we first have to establish that:

1) The probe is calibrated:

Comparison of pQCD calculations with p-p measurements



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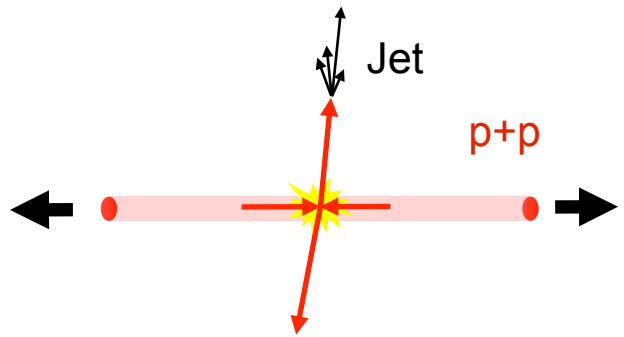
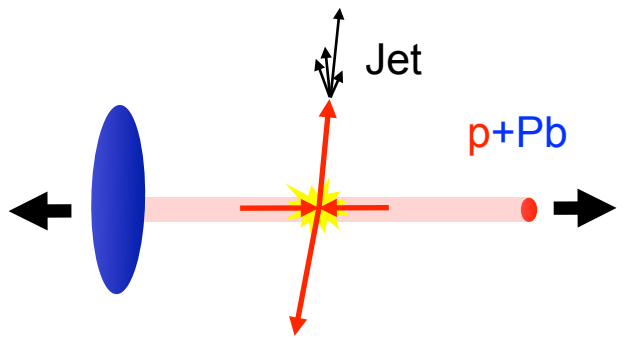


2) Control experiment:

Measure initial state/Cold Nuclear Matter (CNM) effects;

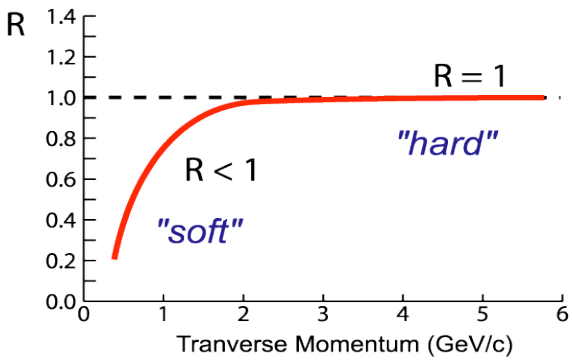
Probe the "cold medium" via p-Pb collisions (compare to p-p)



Nuclear Modification (R_{AA}) in p-Pb Collisions

$$R_{AA}(p_T) = \frac{Yield(A+A)}{Yield(p+p) \times \langle N_{coll} \rangle}$$

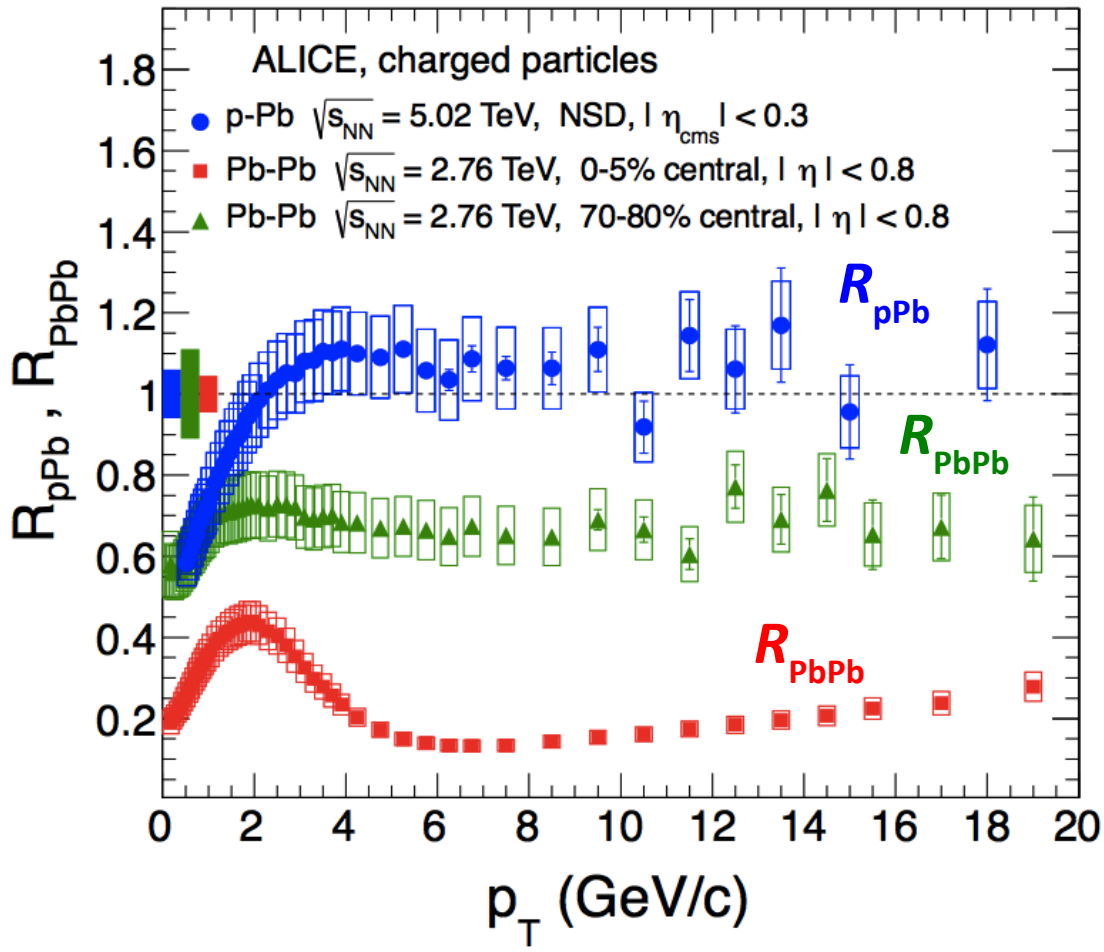
Average number of p-p collision in A-A collision



No "Effect":

- R < 1 at small momenta - production from thermal bath
- R = 1 at higher momenta where hard processes dominate

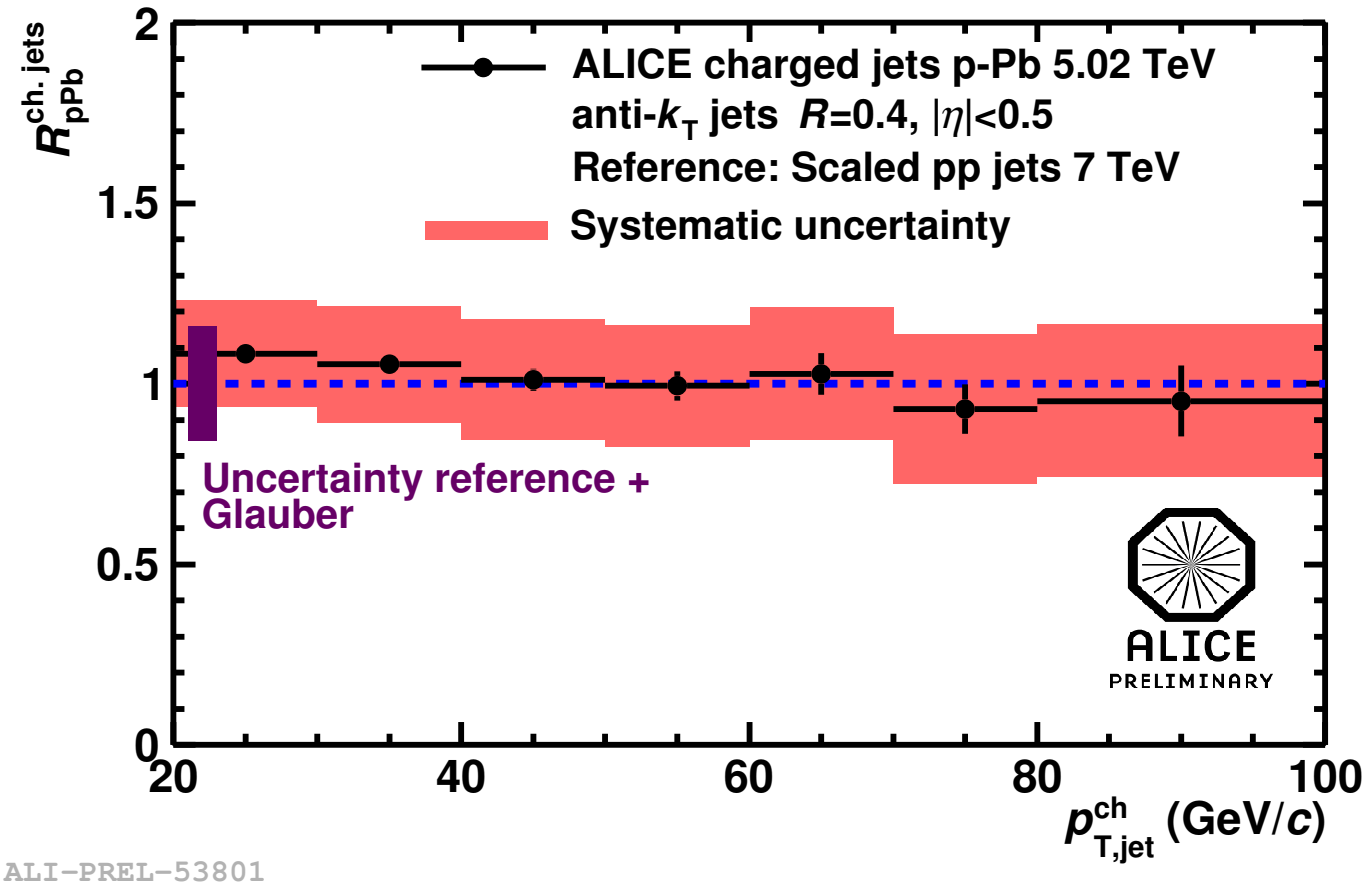
PRL, 110, 082302 (2013)



Strong suppression in central Pb-Pb collisions

R_{pPb} (minbias) consistent with unity in p-Pb collisions

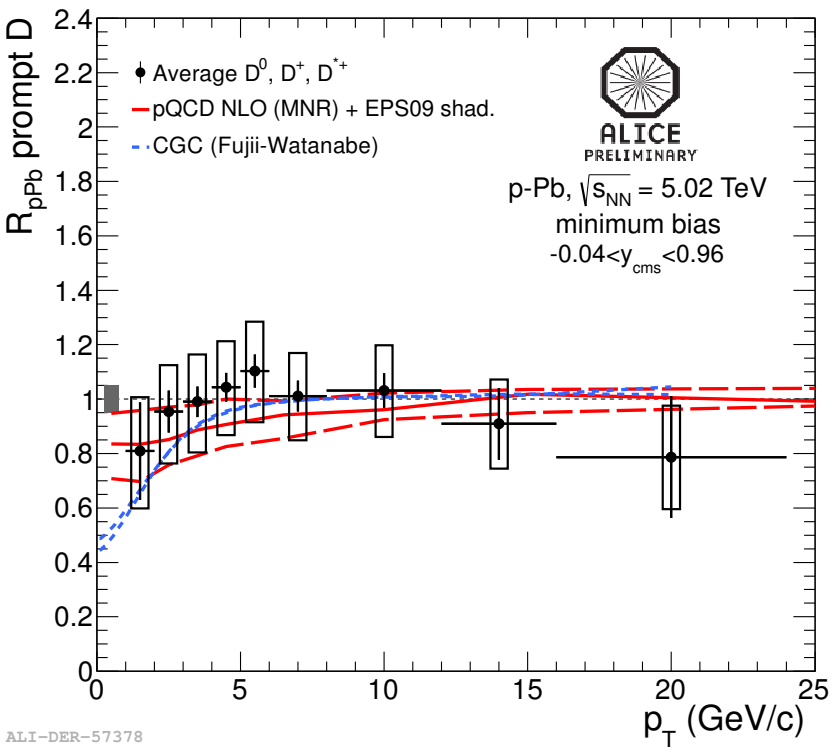
Charged Jet R_{AA} in p-Pb Collisions



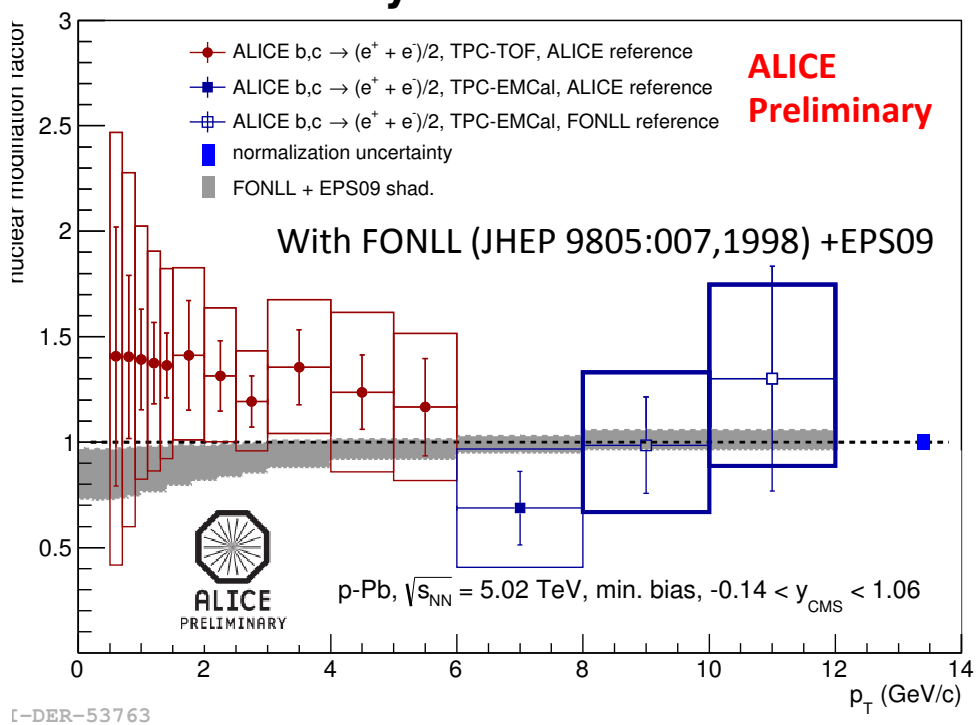
Jet R_{pPb} (minbias) consistent with unity in p-Pb collisions

Heavy-flavor R_{AA} in p-Pb Collisions

D meson

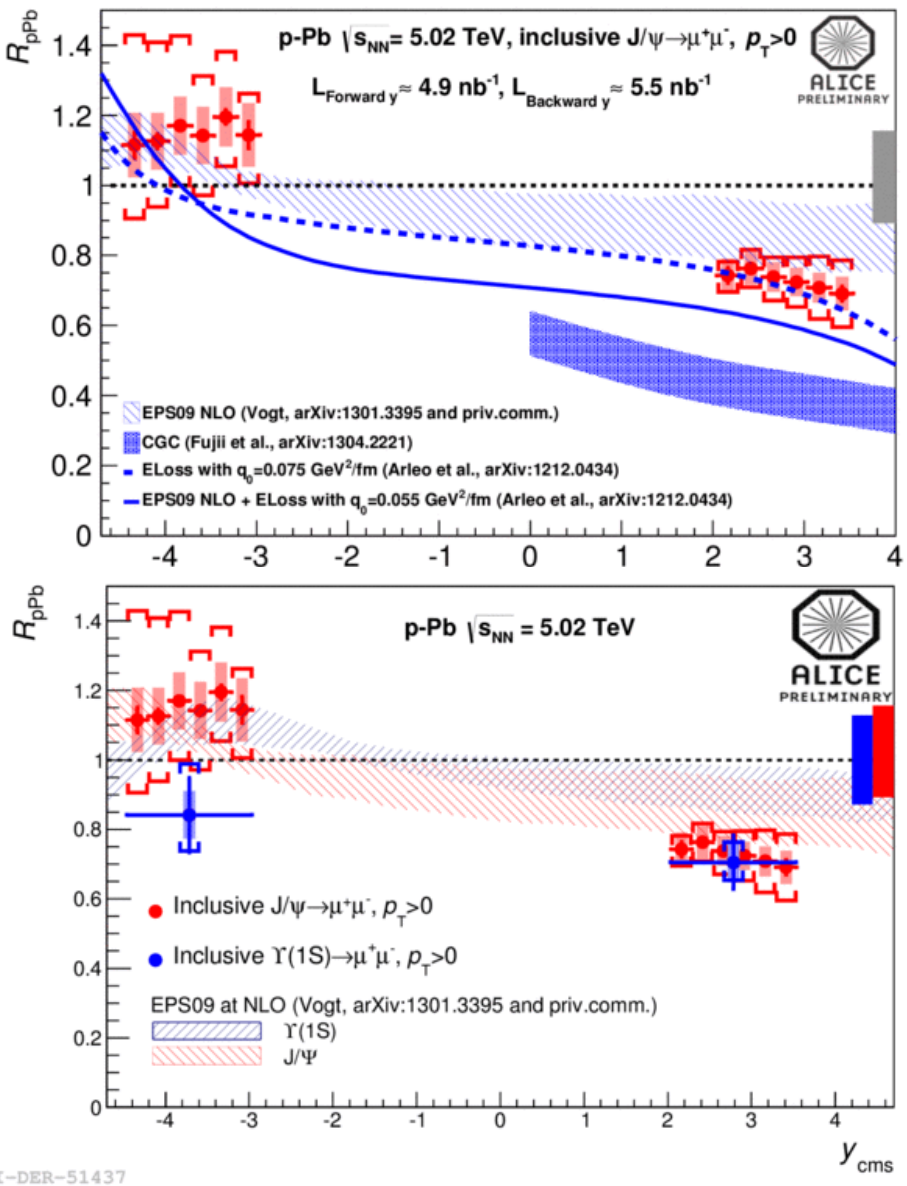


heavy flavor electrons



Heavy-flavor R_{pPb} (minbias) at mid-rapdidity consistent with unity in p-Pb collisions (within uncertainties)

J/ψ and ϒ R_{AA} in p-Pb Collisions



J/ψ R_{pPb}:

- **Described by shadowing**
- **CGC overestimates the suppression at large y**

ϒ R_{pPb}:

- **Consistent with J/ψ (weaker y dep.)**
- **Shadowing alone seems to underestimate the suppression**

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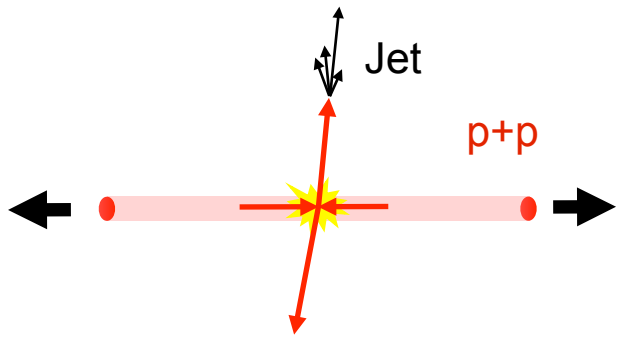

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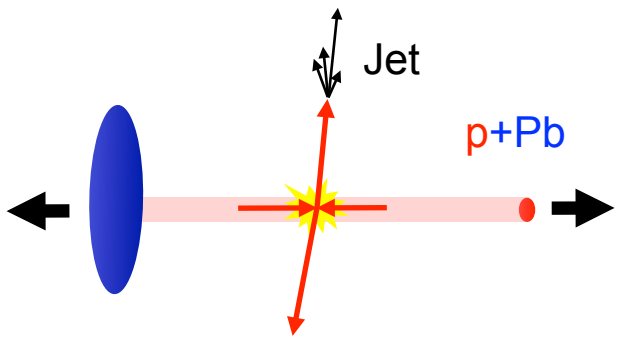
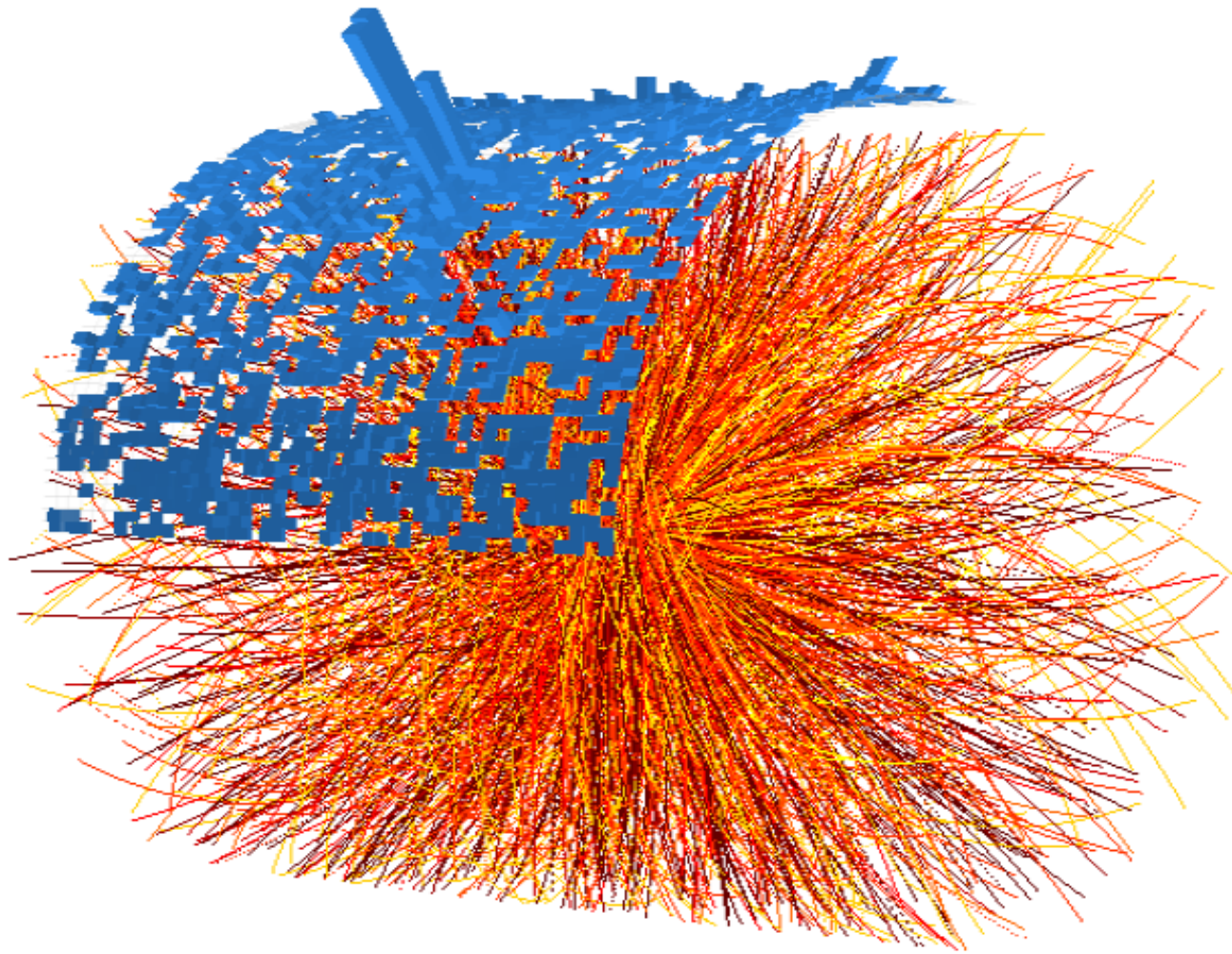
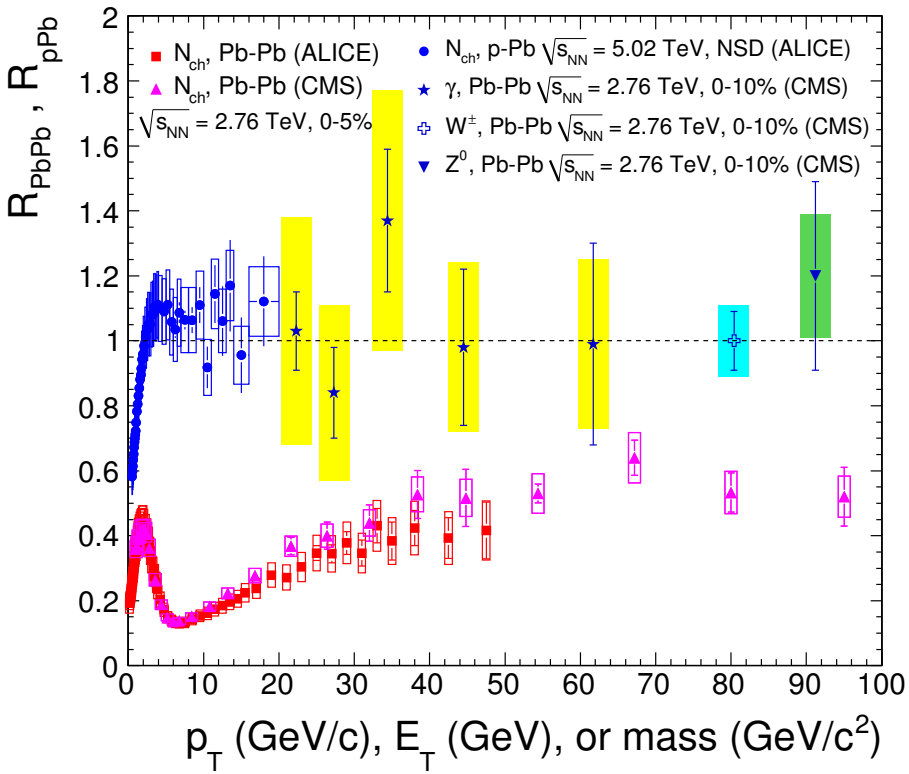


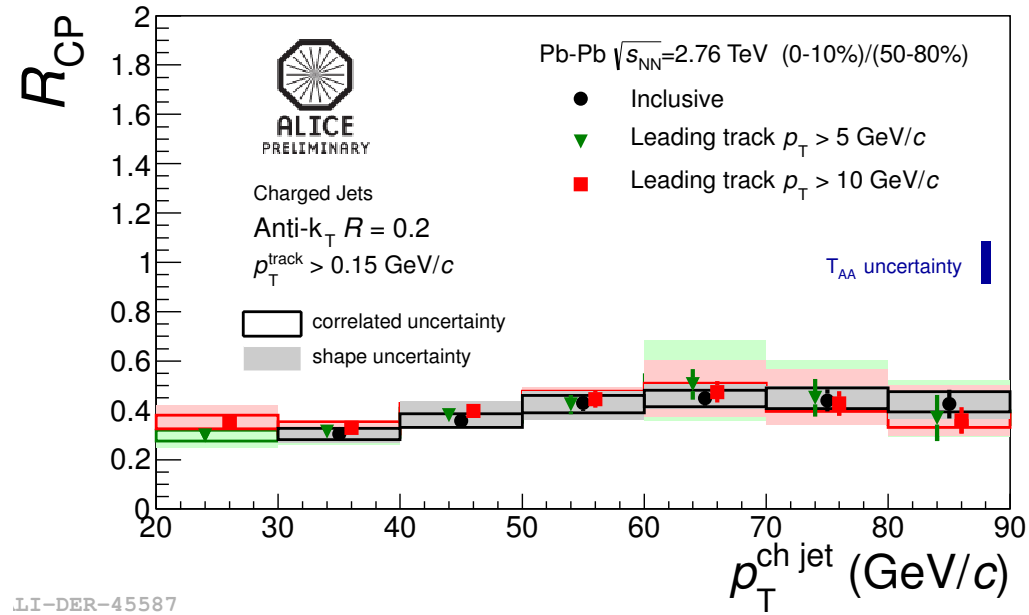
Hard Probes in Pb-Pb Collisions (a small selection ...)



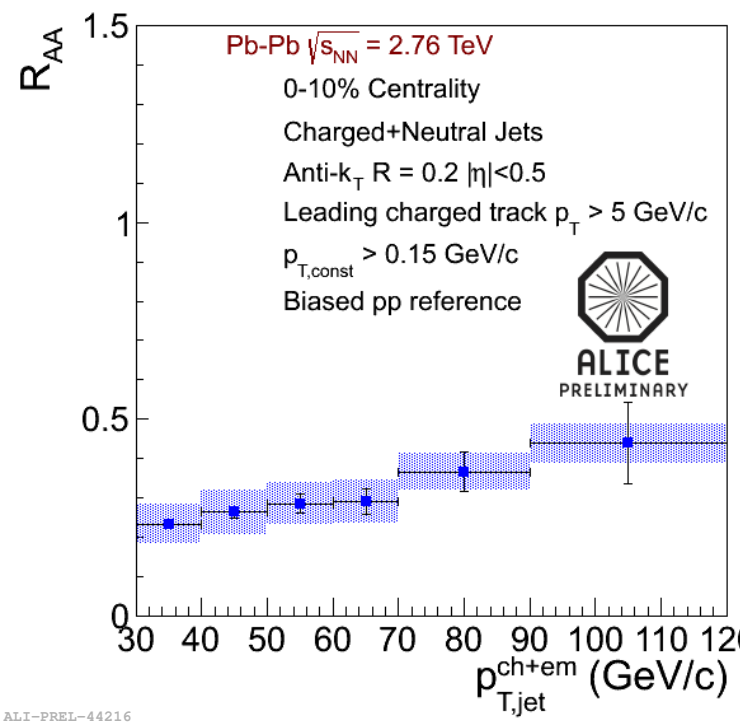
Nuclear Modification in Pb-Pb Collisions



ALI-DER-45646



LI-DER-45587



ALI-PREL-44216

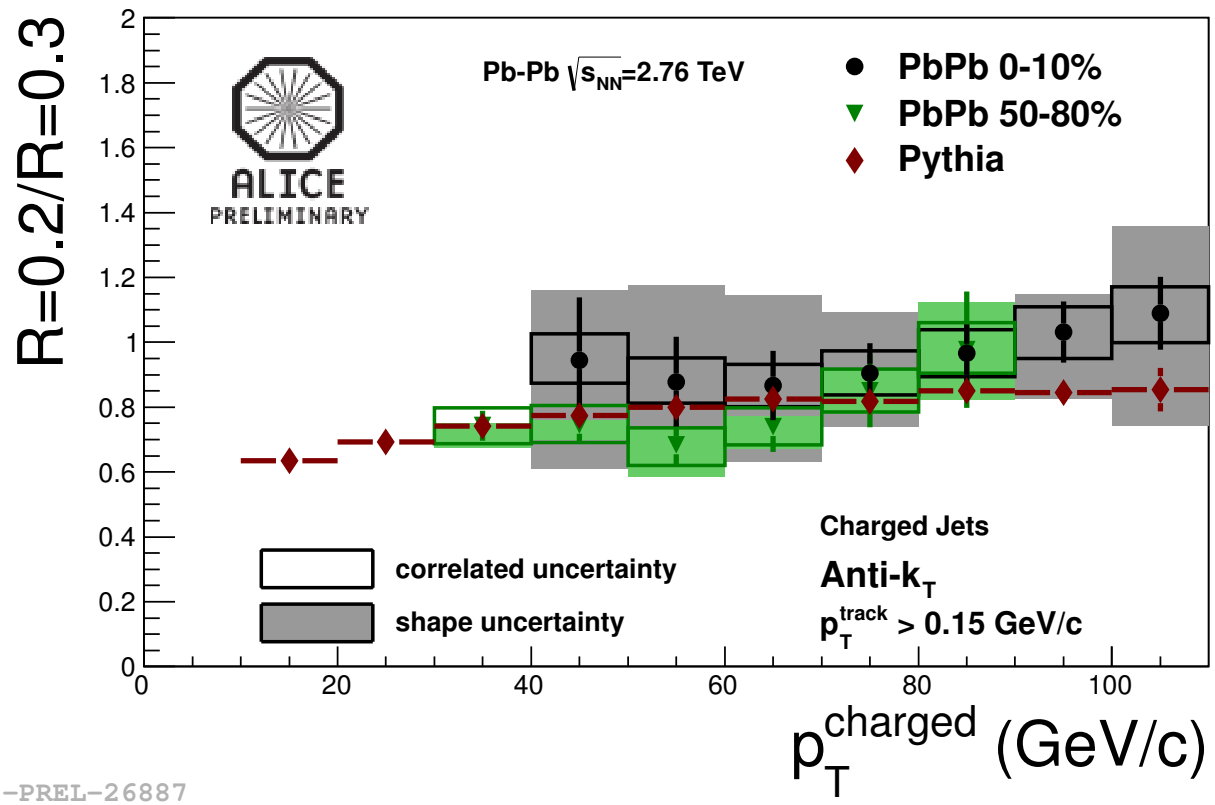
No suppression of hadron yields in p-Pb

No suppression of direct photons, W, Z^0

Strong suppression of hadron yields and in Jet R_{AA} in central Pb-Pb collisions

➜ Energy loss of colored probes in the QGP at the LHC is a final-state effect!

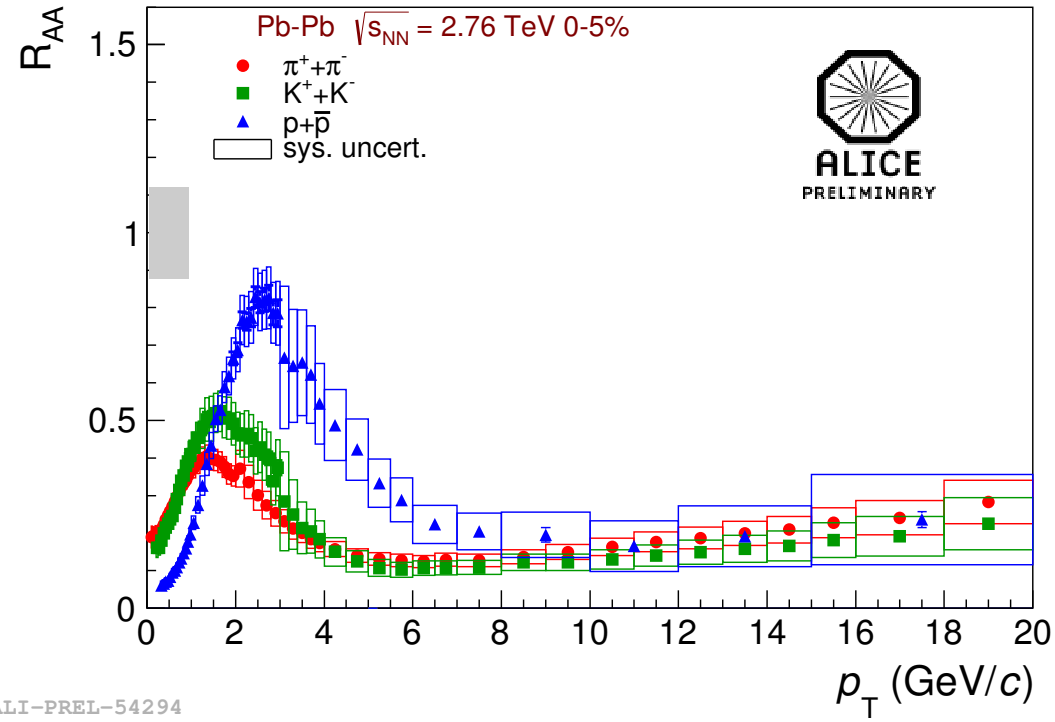
Jet Structure in Pb-Pb Collisions

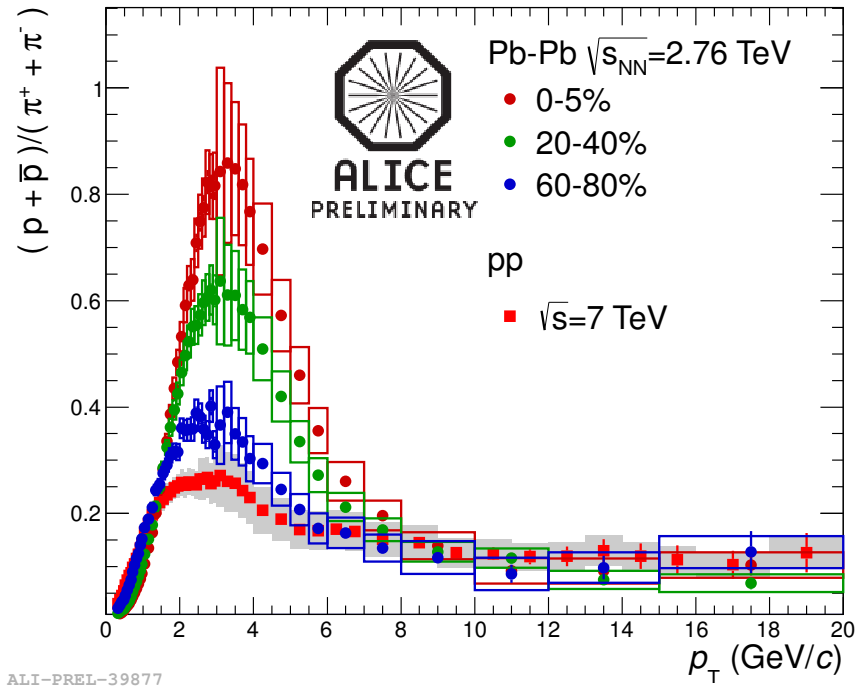


Ratio of jet x-section R=0.2/R=0.3 is sensitive to broadening in the jet structure:

Pb-Pb jet structure consistent with vacuum jets; no jet broadening (within R=0.3) observed!

Hadron PID in Pb-Pb Collisions



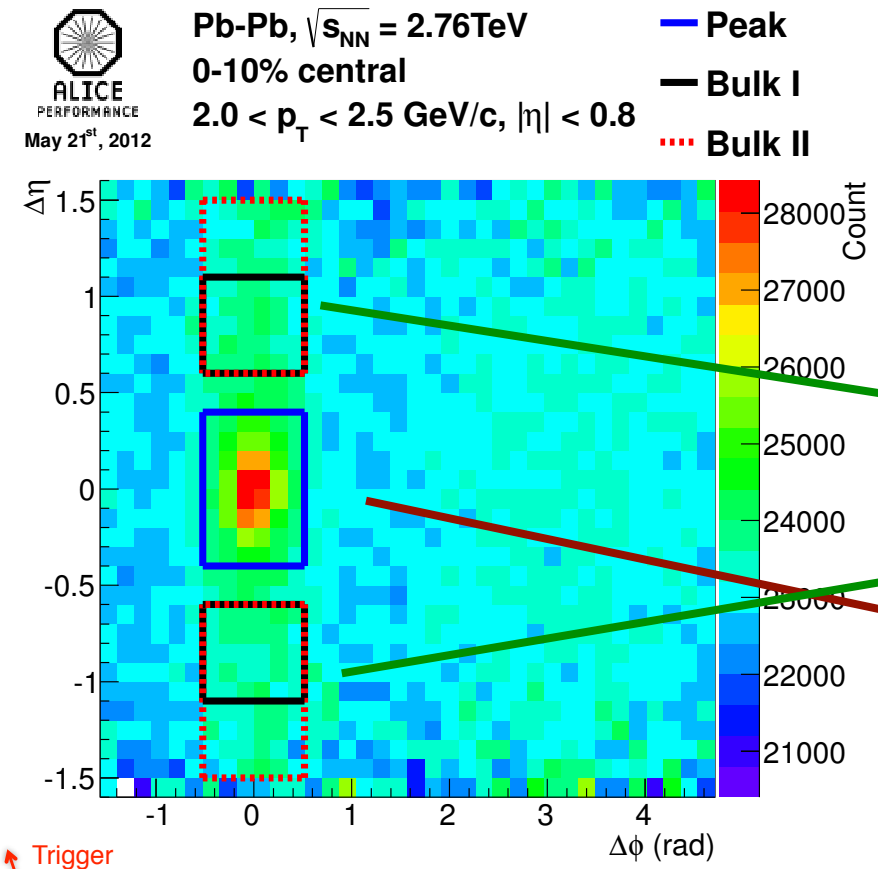


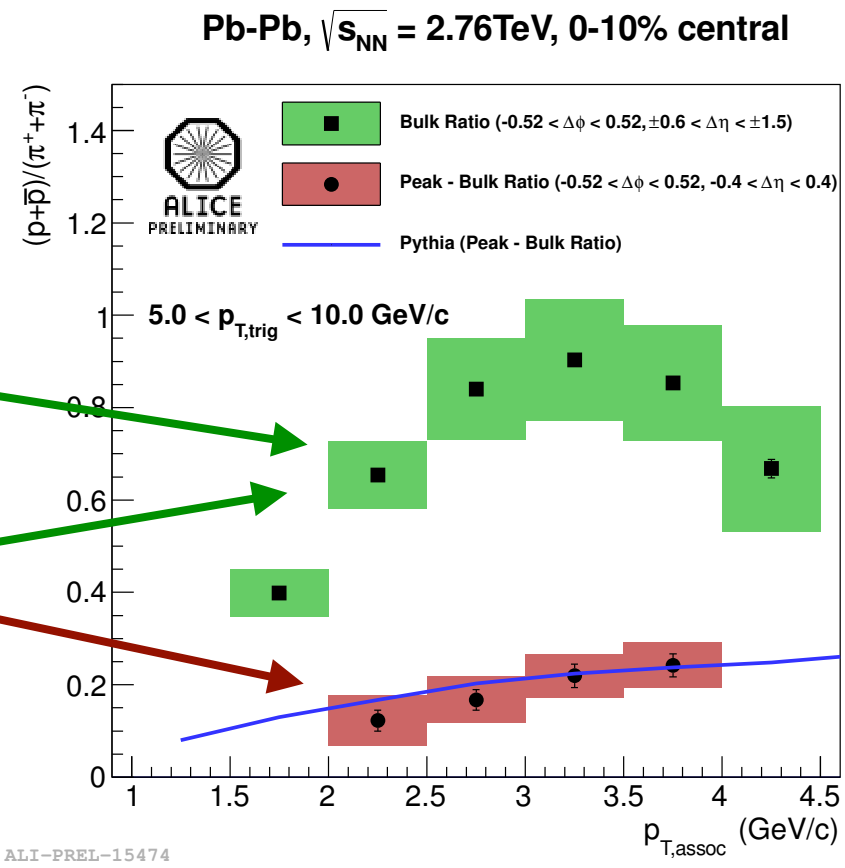
Similar R_{AA} for pions, kaons and protons at high-p_T

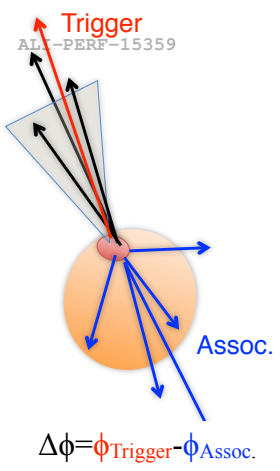
Proton/pion ratio at high-p_T consistent with vacuum

➜ Particle composition unmodified in Pb-Pb collisions!

“Jet PID” in Pb-Pb Collisions





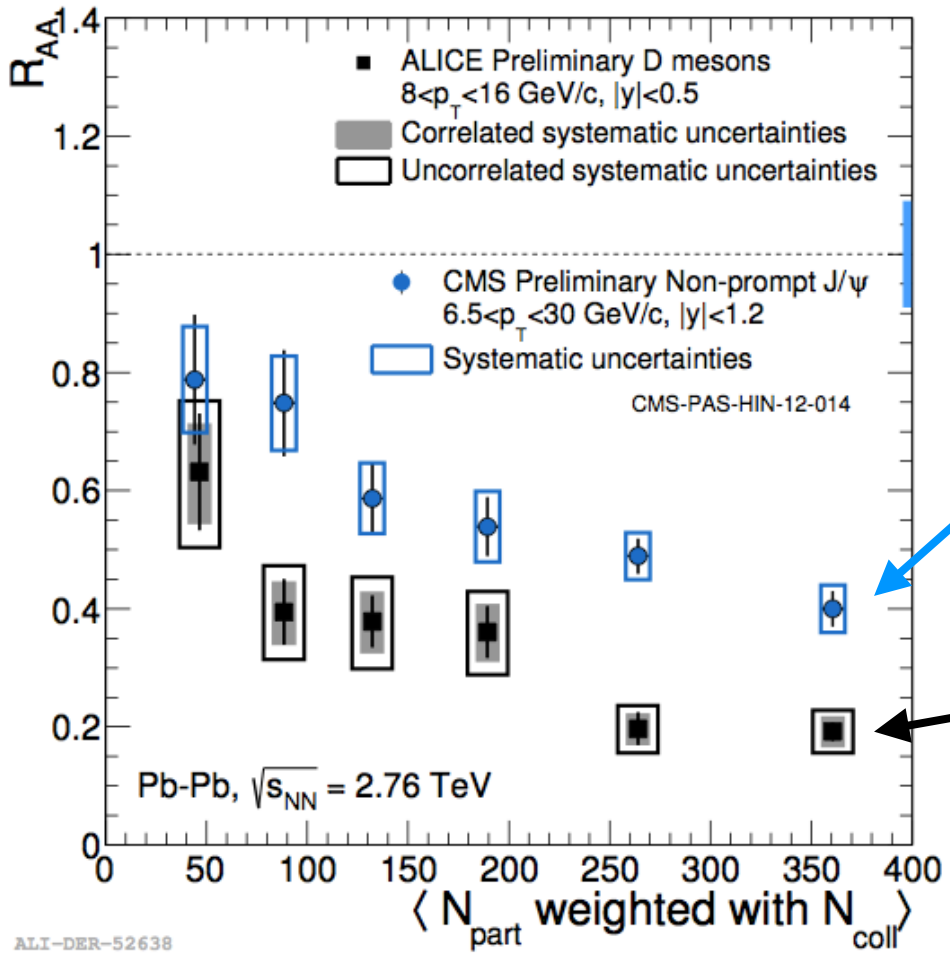


A closer look via two particle ΔηxΔΦ correlations; Isolate jet-like and bulk-like region:

p/π in bulk region consistent with inclusive ratio

p/π in jet consistent with vacuum

D and B R_{AA} vs. centrality



J/ψ from bottom decay (CMS)
B <p_T> ~ 11 GeV

Charm Meson
D <p_T> ~ 10 GeV

First clear indication of mass dependent partonic energy loss in heavy-ion collisions!

Bottom less suppressed than charm and light flavor!

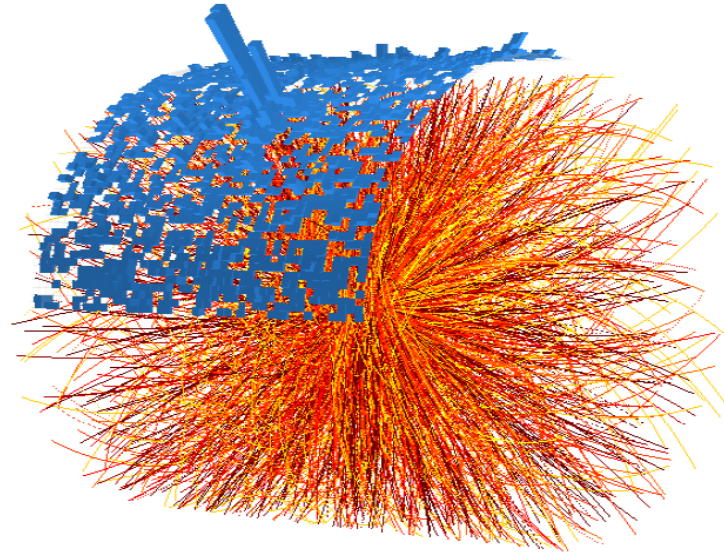
Hard Probes Summary:

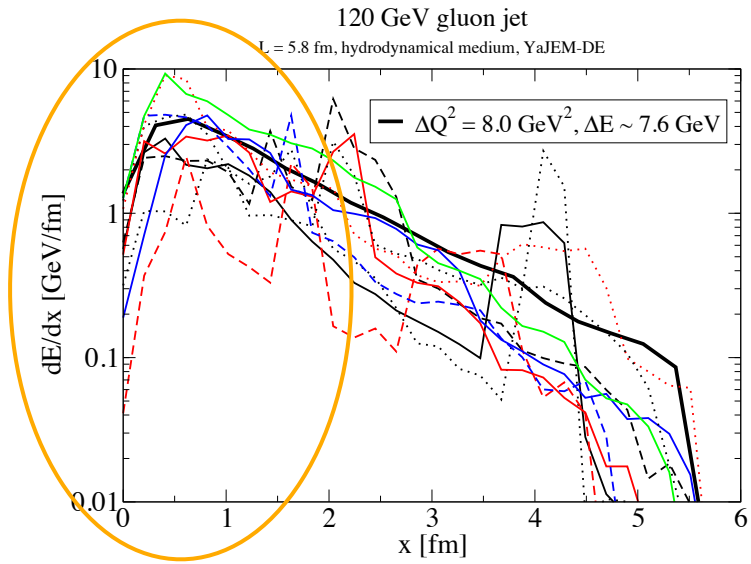
The energy loss of colored probes in the QGP at the LHC is unambiguously a final-state effect!

The hard core of the jet, after energy loss, seems to fragment vacuum like:
No broadening or change in PID is observed!

For the first time:
Mass dependent partonic energy loss is observed (bottom loses less energy than charm and light quarks)

Observations are (qualitatively) consistent with a pQCD-type energy loss picture in which a significant amount of energy loss happens at early times with the "lost" energy thermalized in the medium and the leading parton fragmenting vacuum like!





T. Renk, arXiv:1306.2739

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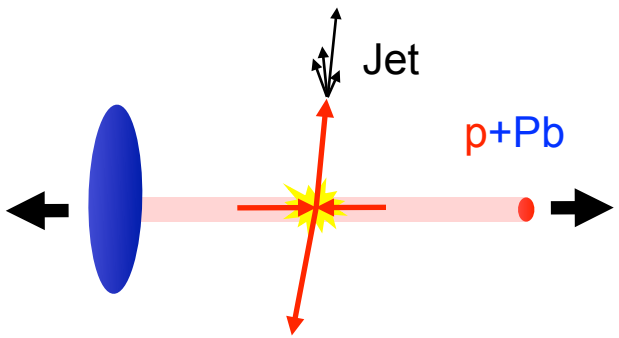

✓

Concerning hard probes!

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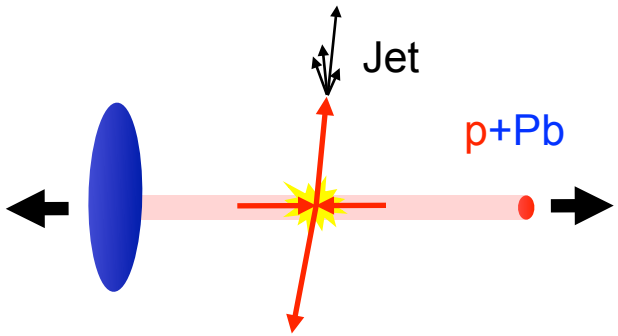


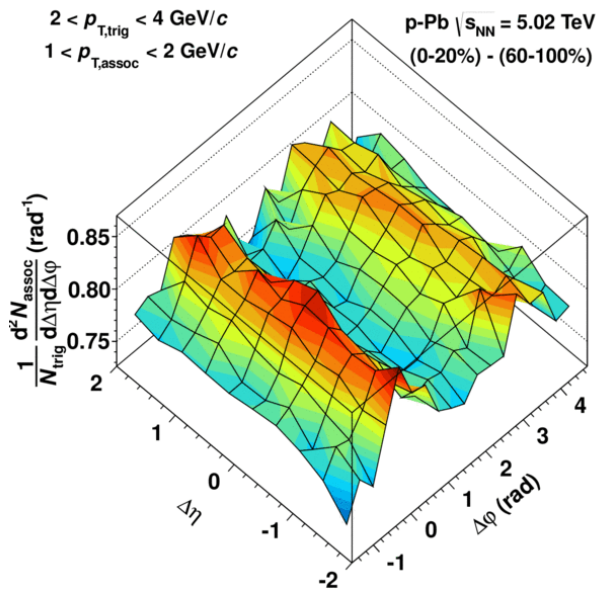
✓

Concerning hard probes!

BUT: Surprise concerning the "bulk" properties in high multiplicity p-Pb collisions:

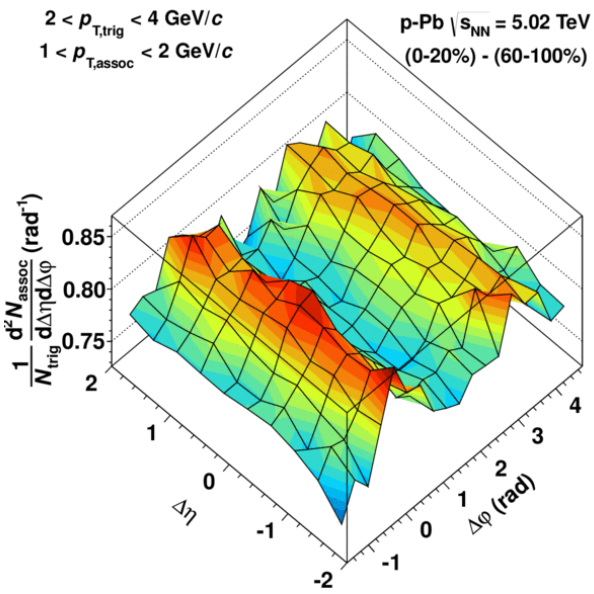
The twin ridge structure!

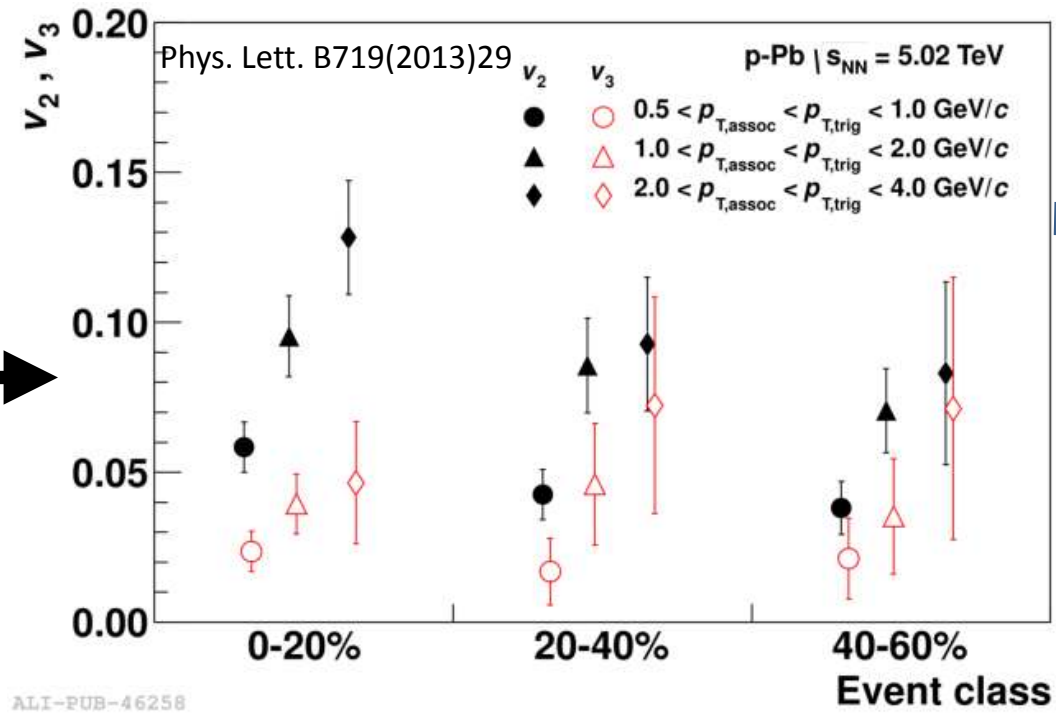
Just a quick look ...

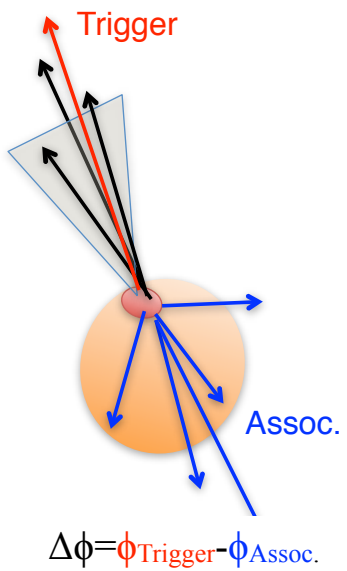


Fourier Decomposition of the twin Ridges

p-Pb: 0-20%-60-100%





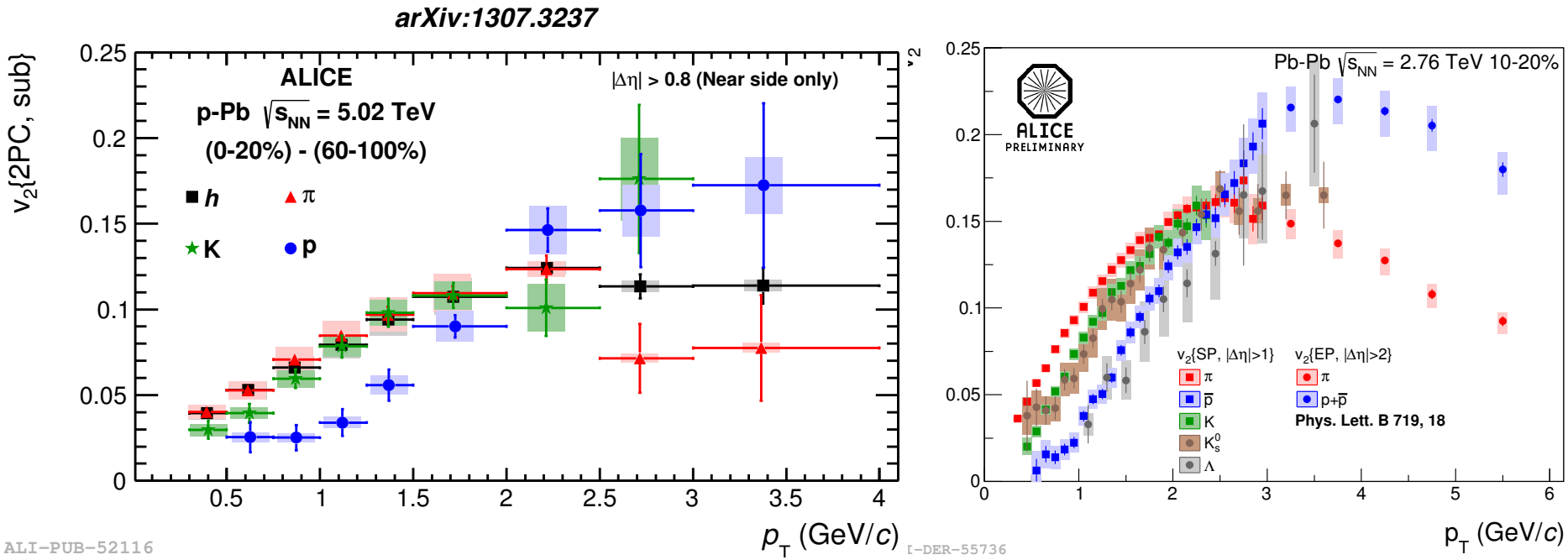


v_2>v_3 in central p-Pb collision

v_n increasing with p_T

centrality dependence visible

PID v_2 in p-Pb and Pb-Pb Collisions

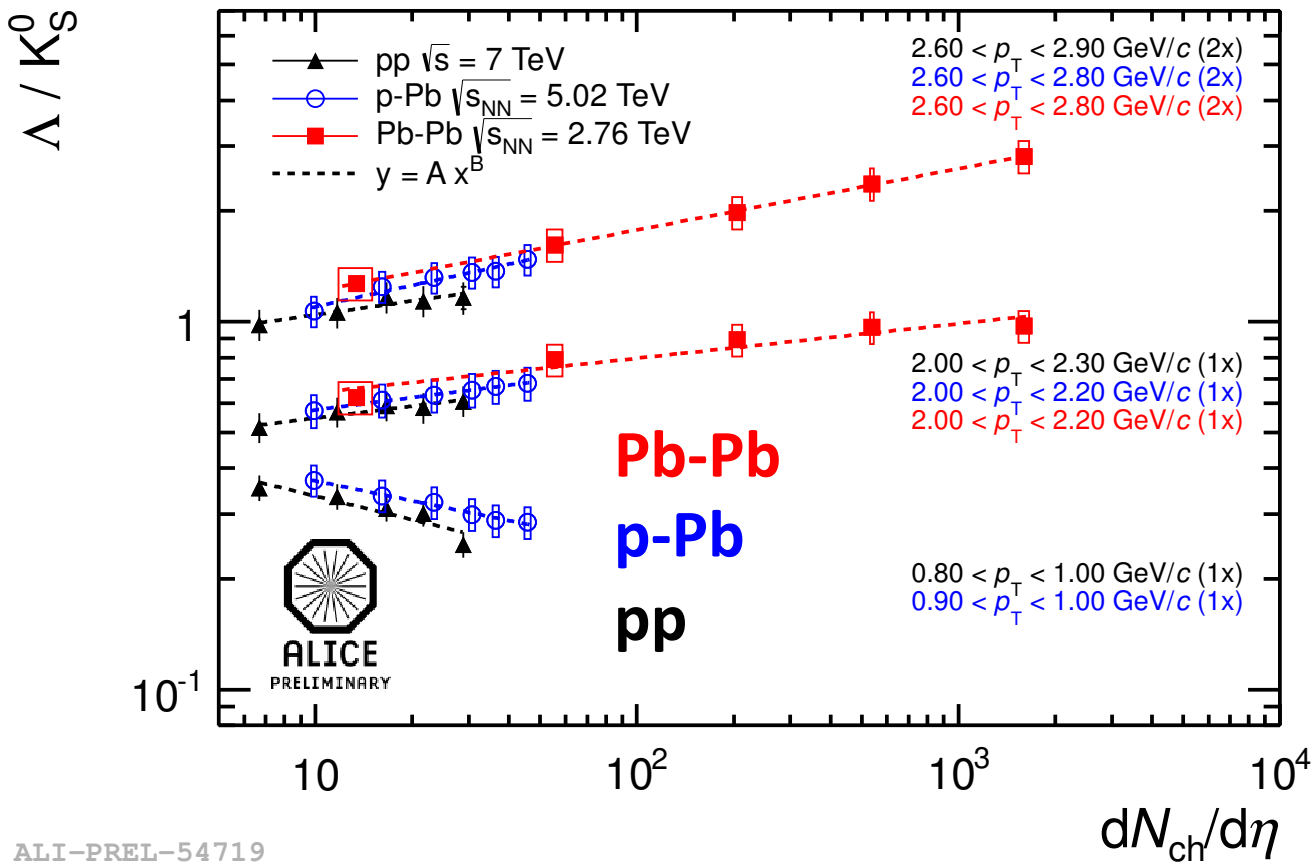


Similar features of $v_2(p_T)$ in p-Pb and PbPb collisions observed:

Mass ordering at low-p_T (in Pb-Pb attributed to hydro behavior)

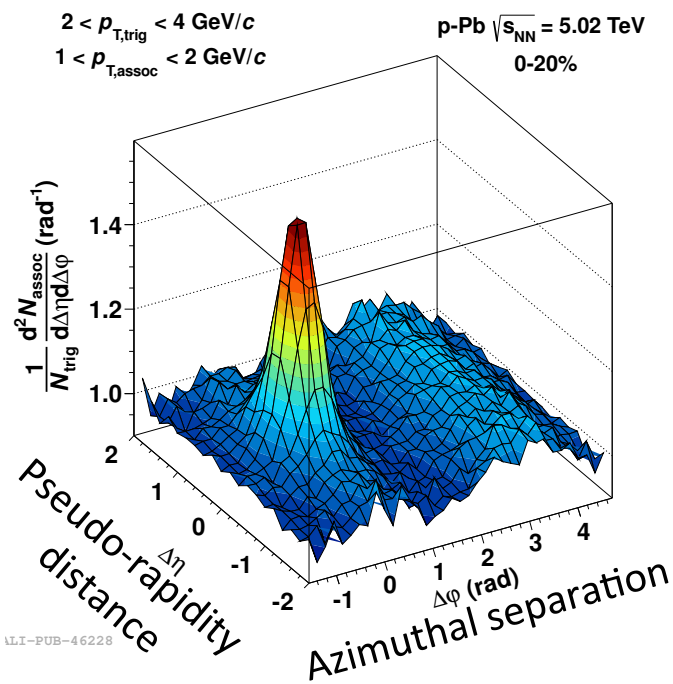
Proton v_2 > pion v_2 for p_T>2 GeV (constituent quark scaling in p-Pb!?)

PID in p-Pb Collisions



Similar trend in p-Pb and p-p collisions compared to Pb-Pb collisions as function of $dN_{ch}/d\eta$ (although smaller in p-Pb)

The “bulk” in p-Pb Collisions ...



The control experiment p-Pb revealed surprising results in high-multiplicity p-Pb collision:

Mass ordering of v_2 at low-p_T is observed, as well as similar trends in particle ratios as function of $dN_{ch}/d\eta$!

Are we seeing hydrodynamical behavior in p-Pb collision or is it the CGC!?

Very Interesting observations and more to come ...