A Large Ion Collider Experiment

ALICE

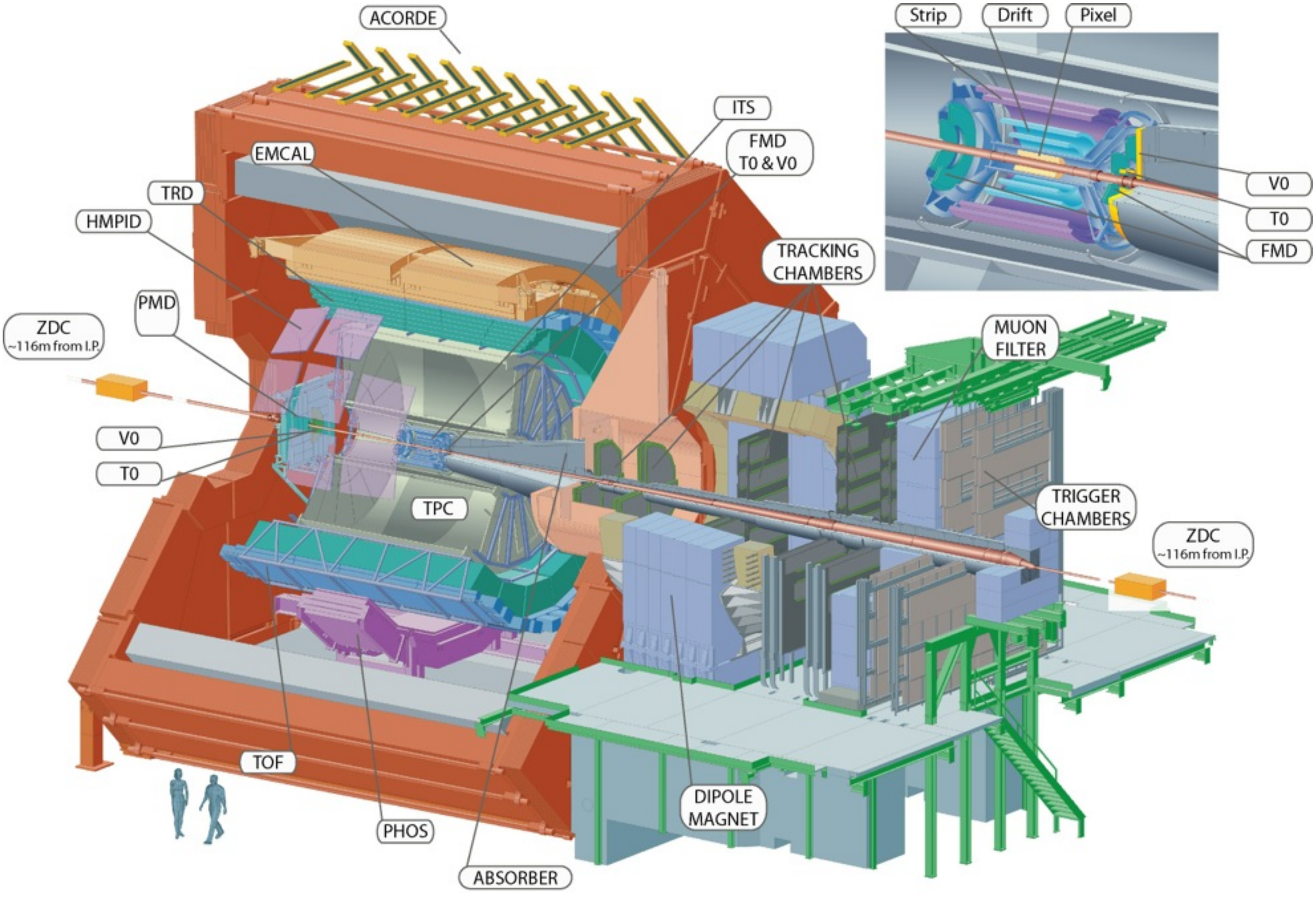
Recent results* from the ALICE experiment

Lee Barnby, University of Birmingham
for the ALICE Collaboration

* a biased selection

@leebarnby

UNIVERSITY OF BIRMINGHAM


ACORDE
ITS
FMD
T0 & V0
EMCAL
TRD
HMPID
TRACKING
CHAMBERS
PMD
ZDC
~116m from I.P.
MUON
FILTER
V0
T0
TPC
TRIGGER
CHAMBERS
ZDC
~116m from I.P.
TOF
PHOS
DIPOLE
MAGNET
ABSORBER
Strip
Drift
Pixel
V0
T0
FMD

ALICE overview

- Design considerations
  - High multiplicity environment
    - see next picture
  - Particle identification (PID)
  - Low p_T coverage (B = 0.5 T)
- Datasets

Pb-Pb (2010)	2.76 TeV	10 μb
Pb-Pb (2011)	2.76 TeV	0.1 nb
pp (2010)	7 TeV	11 nb-1
pp (2011)	2.76 TeV	1.1 nb-1
pp (2011)	7 TeV	4.8 pb-1
pp (2012)	8 TeV	9.7 pb-1
p-Pb (2013)	5.02 TeV	15 nb
Pb-p (2013)	5.02 TeV	15 nb

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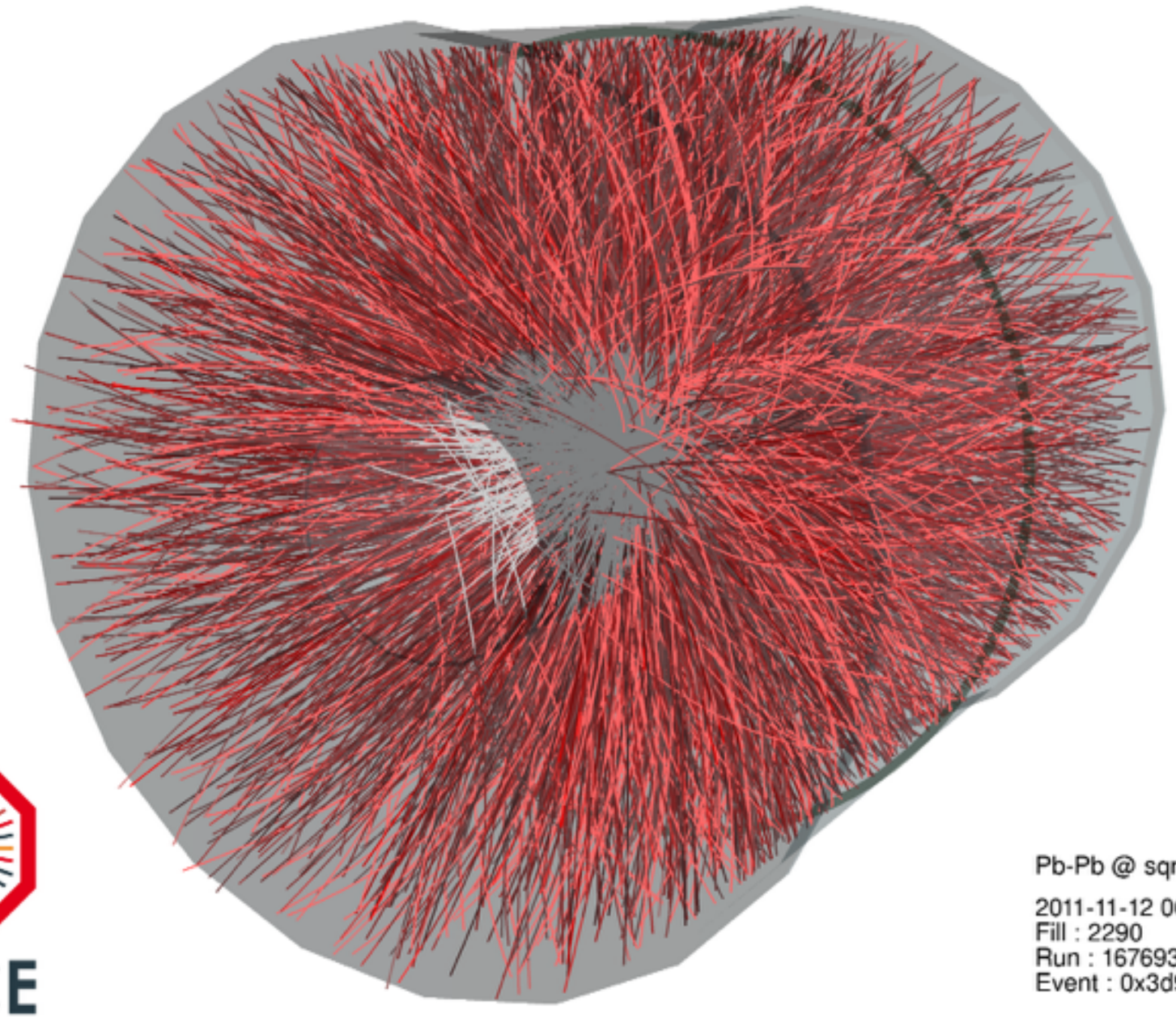

Pb-Pb @ sqrt(s) = 2.76 ATeV

2011-11-12 06:51:12
Fill : 2290
Run : 167693
Event : 0x3d94315a

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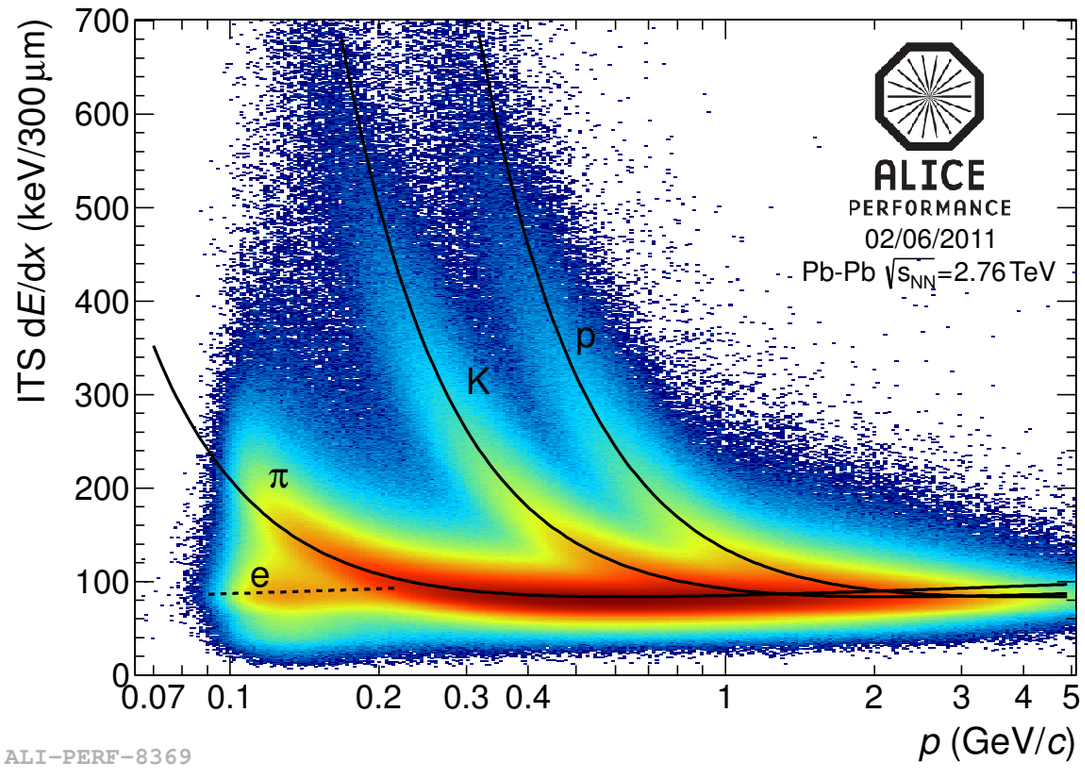
A JOURNEY OF DISCOVERY



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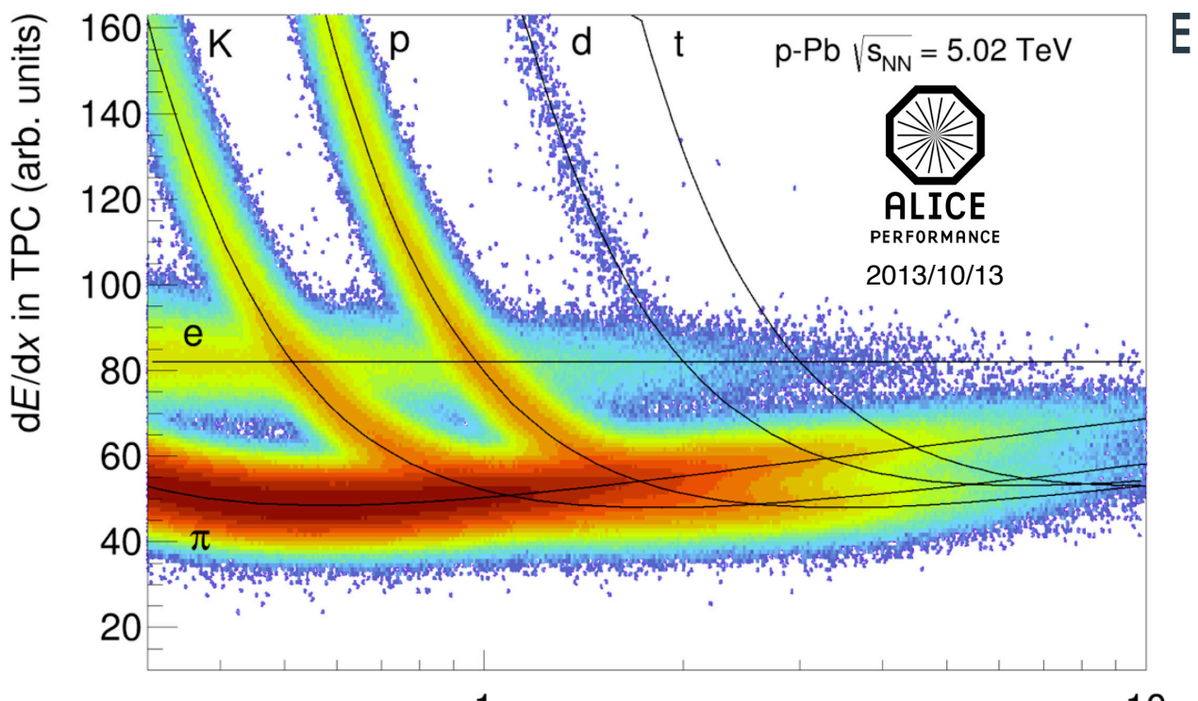

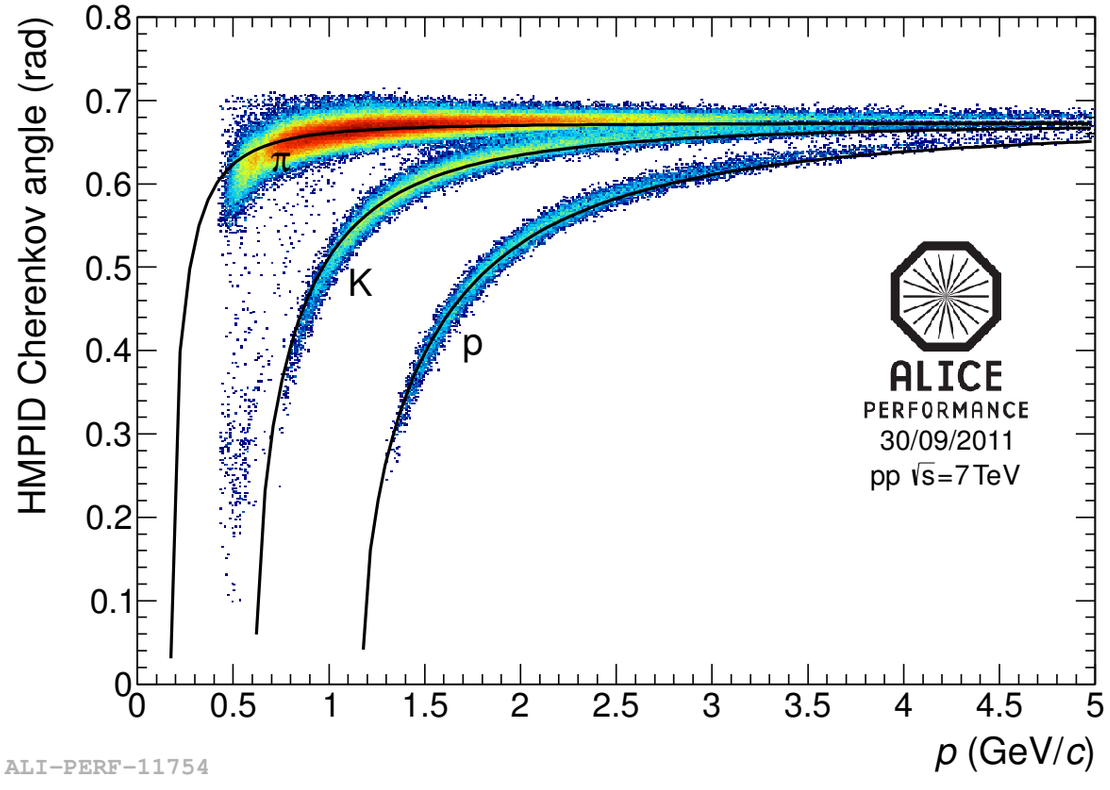

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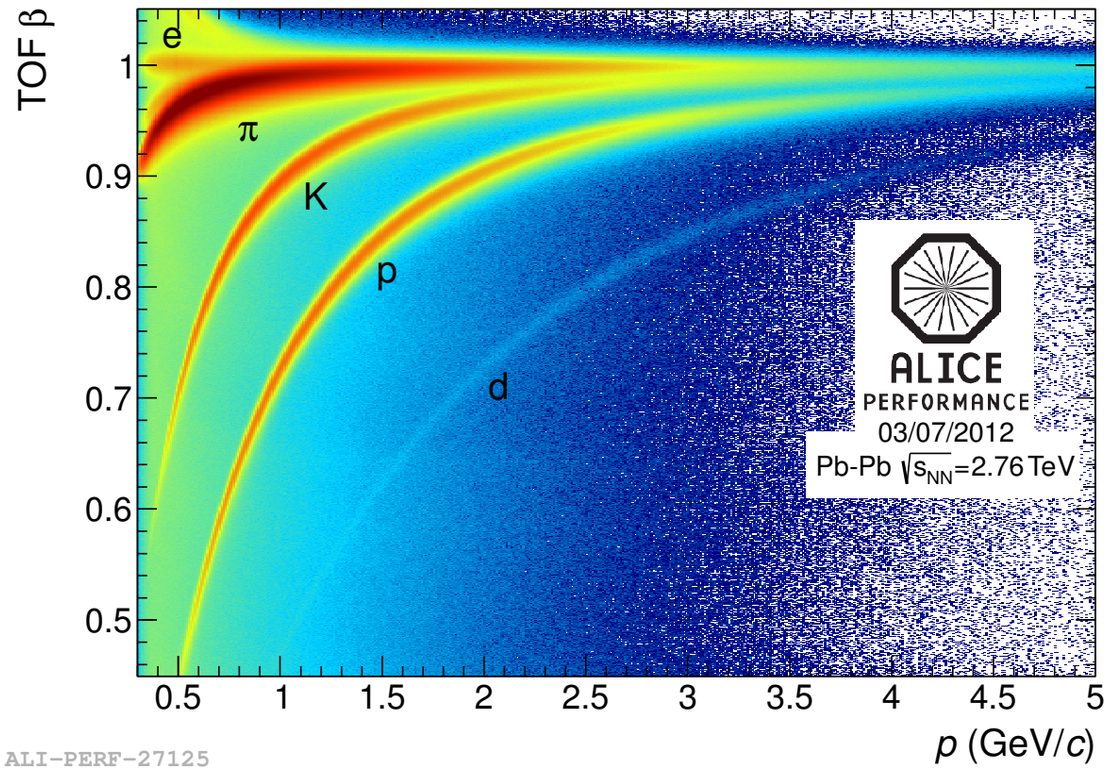

ALI-PERF-27125

A Large Ion Collider Experiment

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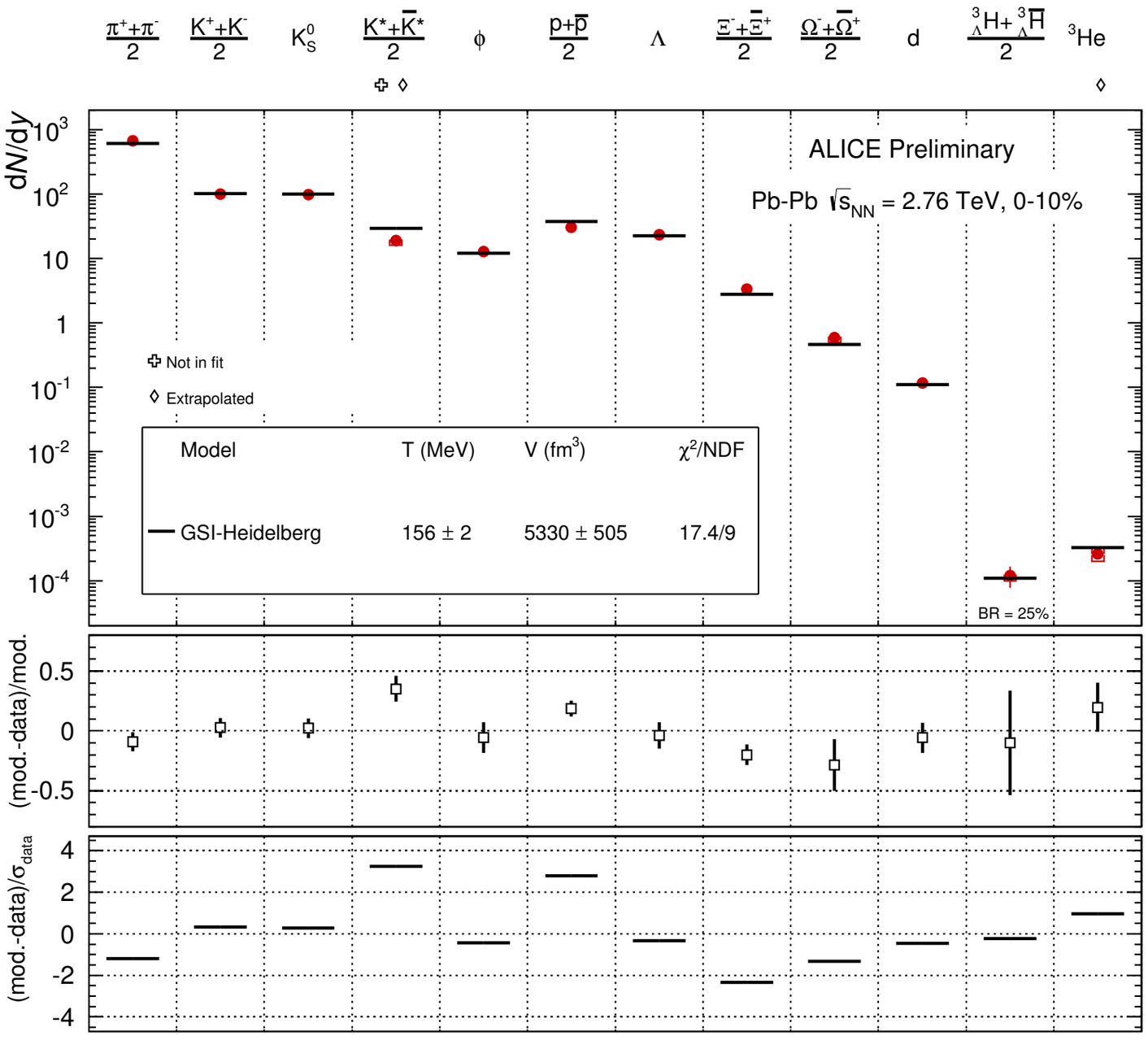
Light flavour hadrons and (anti-)nuclei

Production of light flavour hadrons

- Thermal model fits
- Measurements of Nuclei
  - ^{3}He and hypertriton ($^{3}_{\Lambda}$H)
  - $\bar{\alpha}$ observation
  - Limits on exotic di-baryon particle production

Statistical model for particle yields

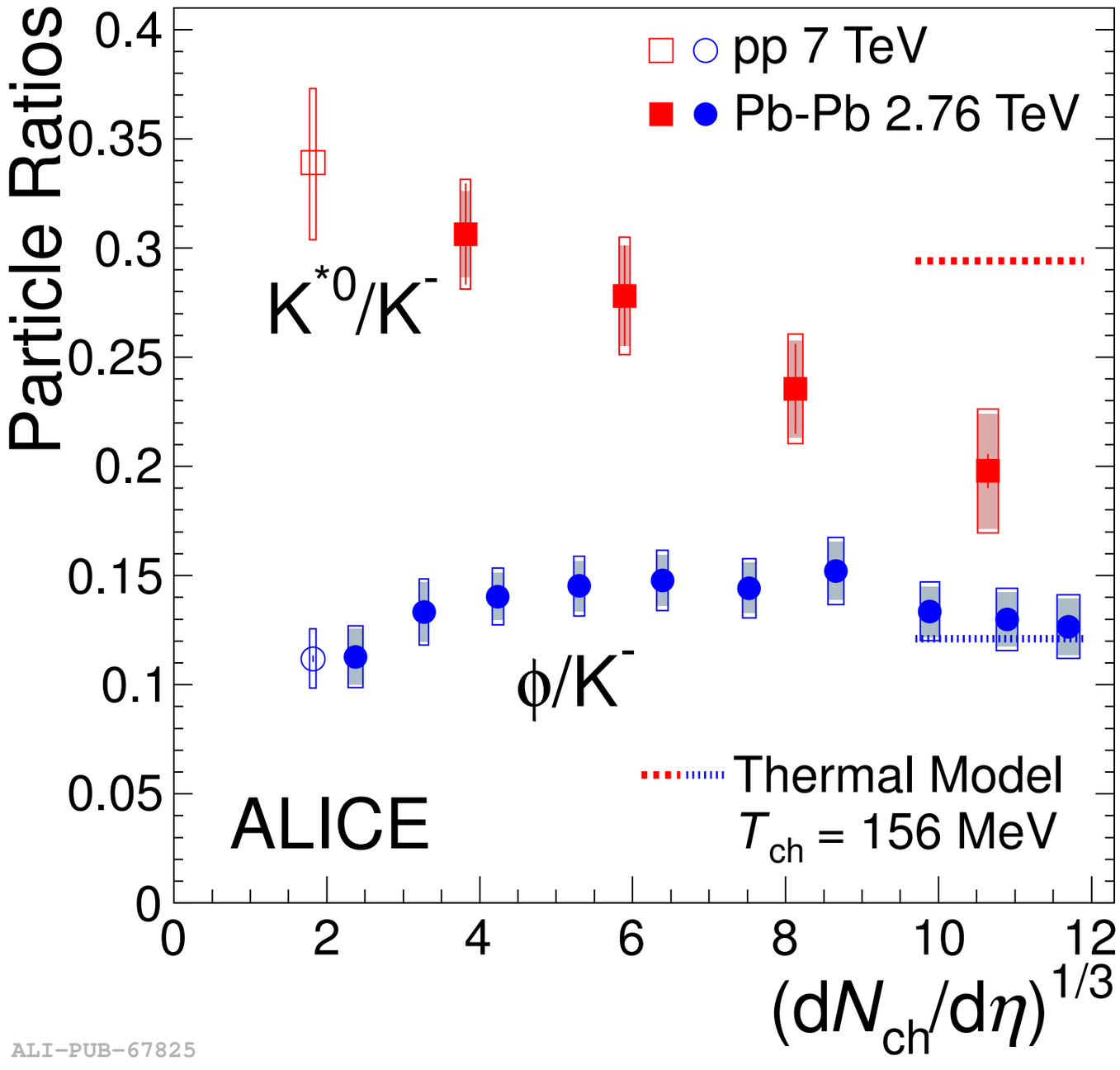


ALI-PREL-75448

- dN/dy of particle species well described in Pb-Pb
- Single temperature ~156 MeV
- Discrepancy K* and p
  - evidence for interactions with final hadronic stage

K* suppression with centrality

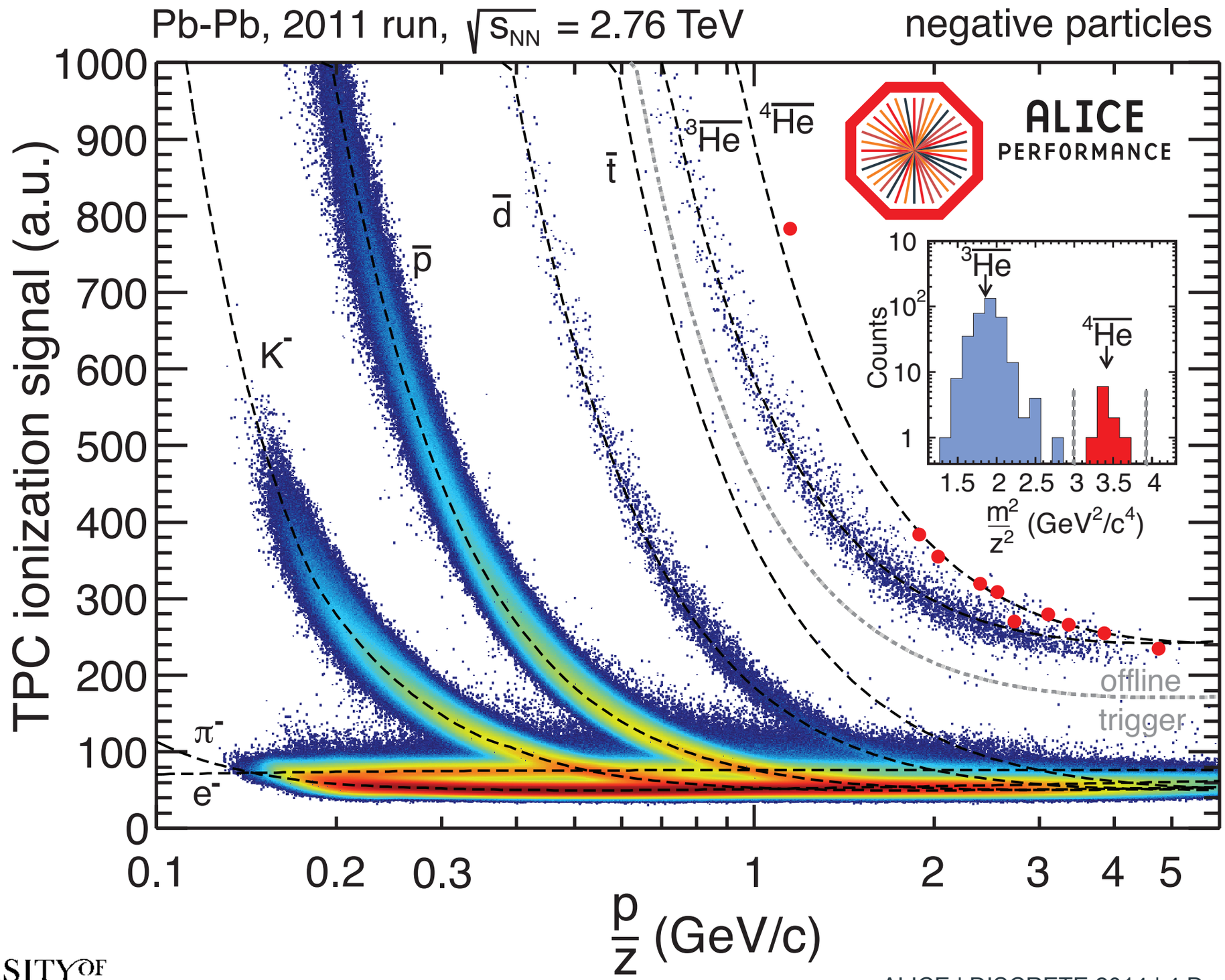
arXiv1404.0495



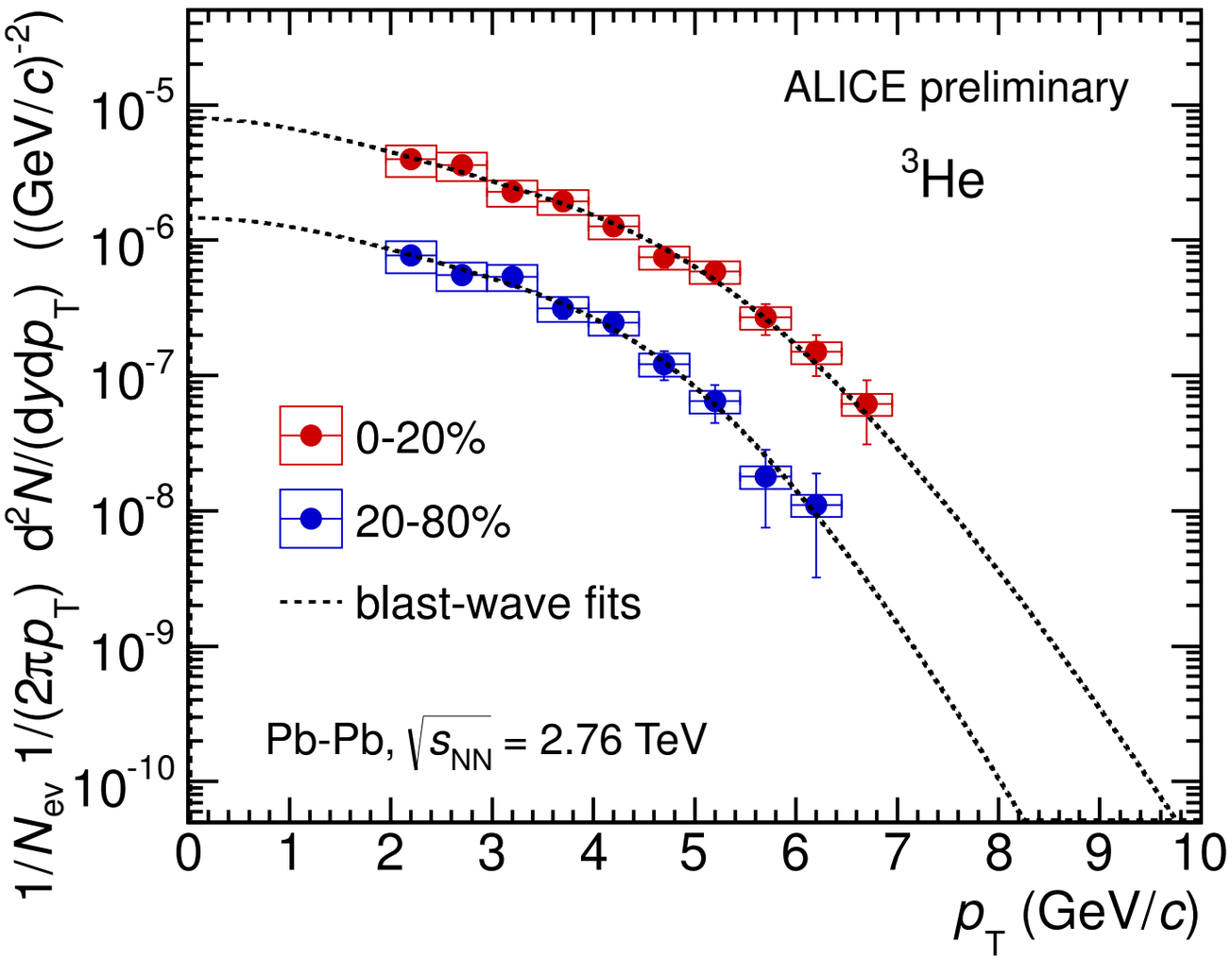
ALI-PUB-67825

- K*/K ratio shows clear suppression going from peripheral and pp collisions to central Pb-Pb
- ϕ/K does not show this
  - also others not shown
- Favoured explanation is re-scattering of decay daughters with final state hadrons
  - $\tau_{K^*} \sim 4$ fm/c

Light nuclei measurements



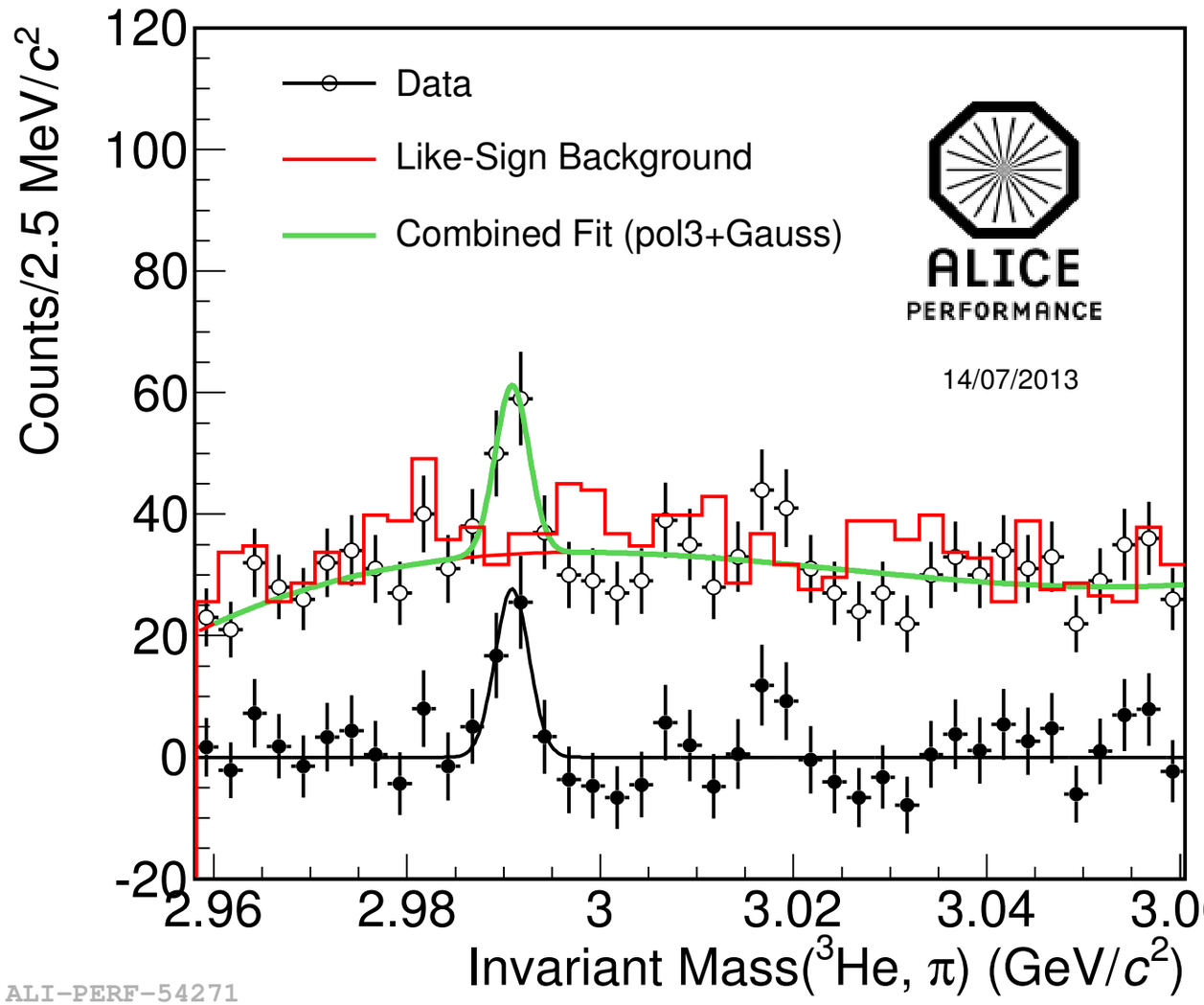
^{3}He measurement



ALI-PREL-74476

- Measurements over large p range
- Fits with overall model of hydrodynamic expansion

Hypertriton measurement



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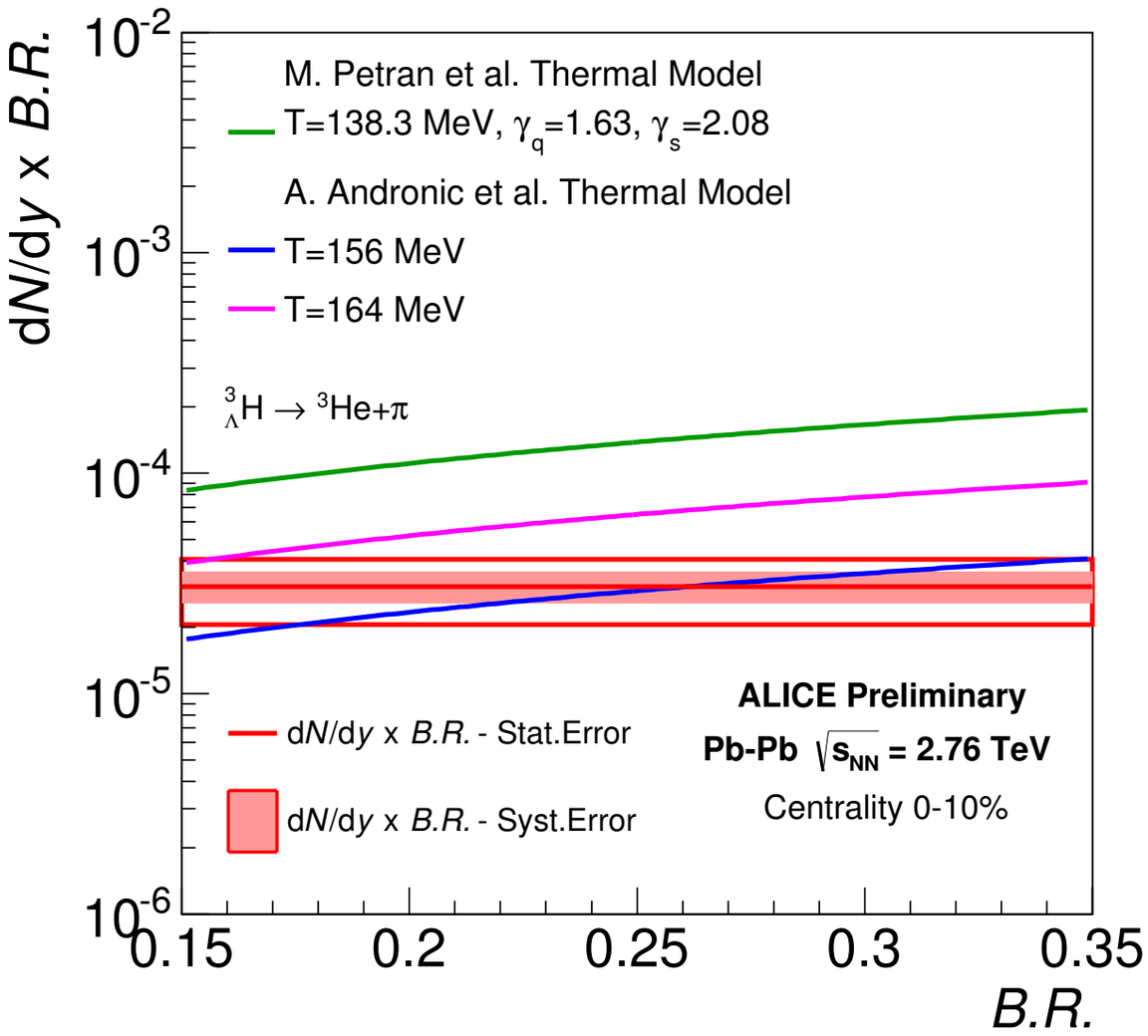
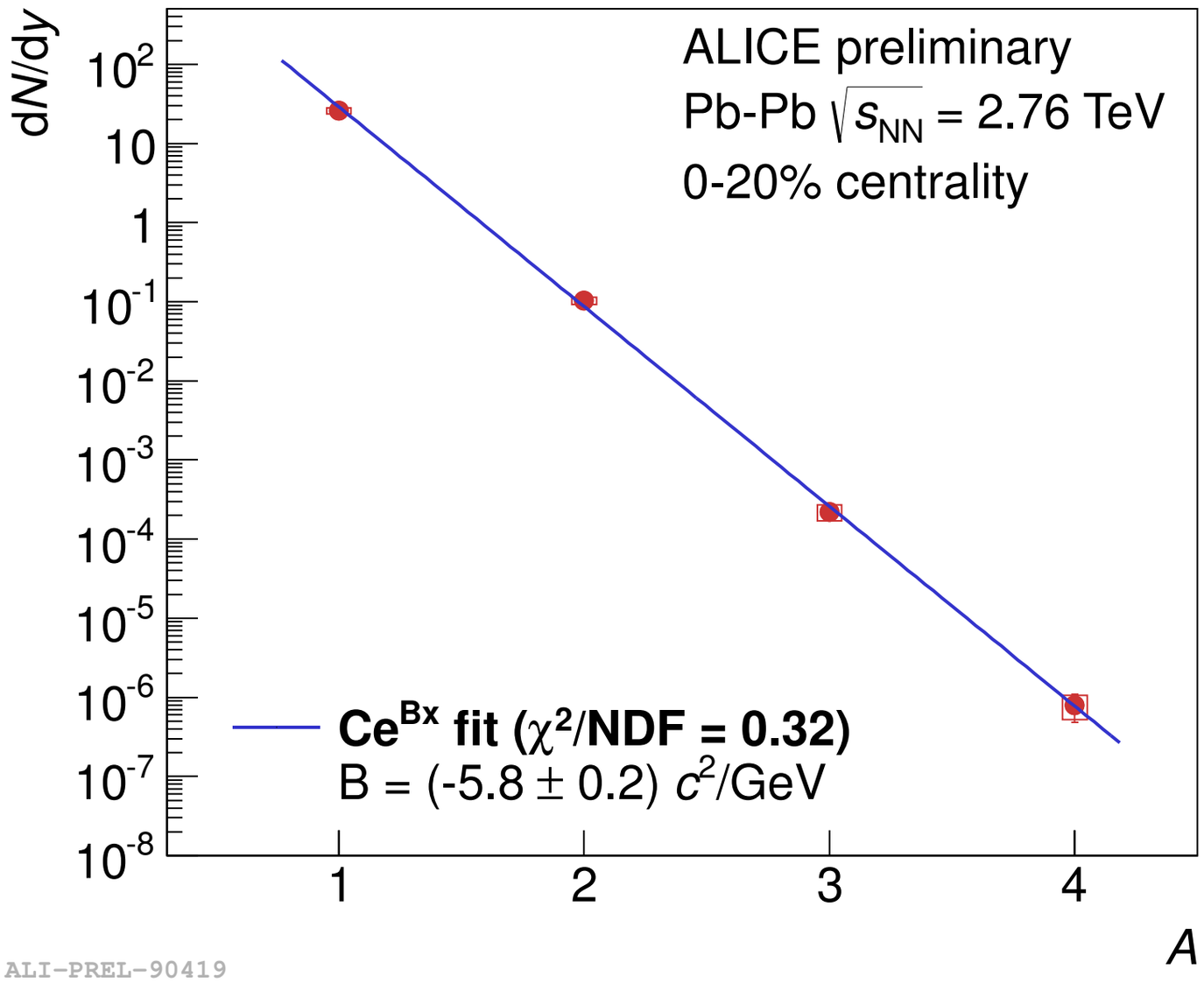


ALI-PREL-54321

- Extracted $^3_\Lambda$H signal)
- Branching ratio not well known

- Described in thermal model even though weakly bound B_Λ = 130 keV
- Favours equilibrium model

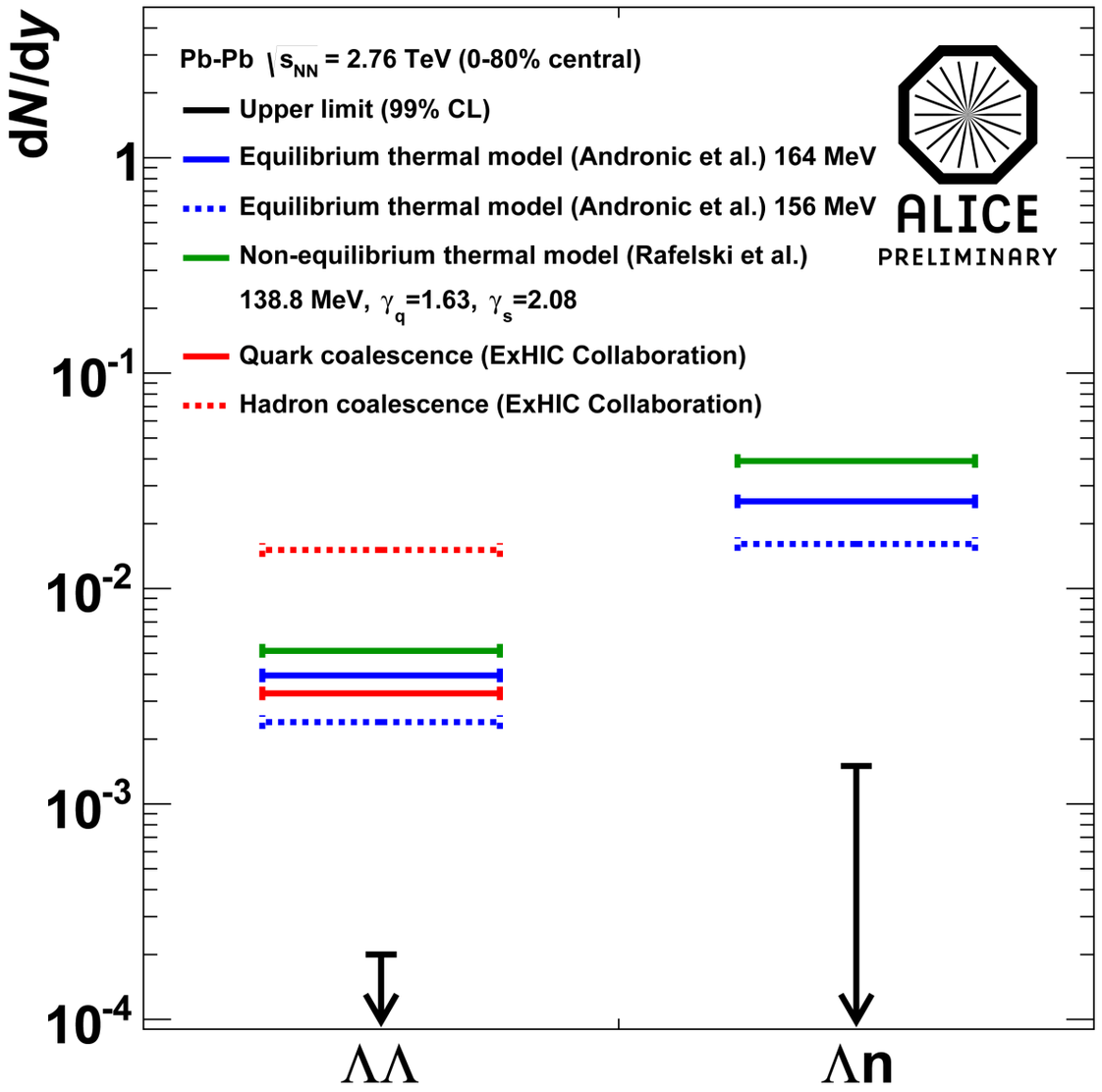
$\bar{\alpha}$ production



ALI-PREL-90419

- First observed in heavy-ion collisions at RHIC
  - STAR, *Nature* **473**, 353–356 (2011)
- ALICE measures in defined centrality interval to compare to other light nuclei

Exotic di-baryon limits



- Success of thermal model encouraged searches for other states
  - H-dibaryon (Λ-Λ)
  - Bound state (Λ-N)
  - Weak decay modes
  - 99% limits are factor of ~10 below the predictions

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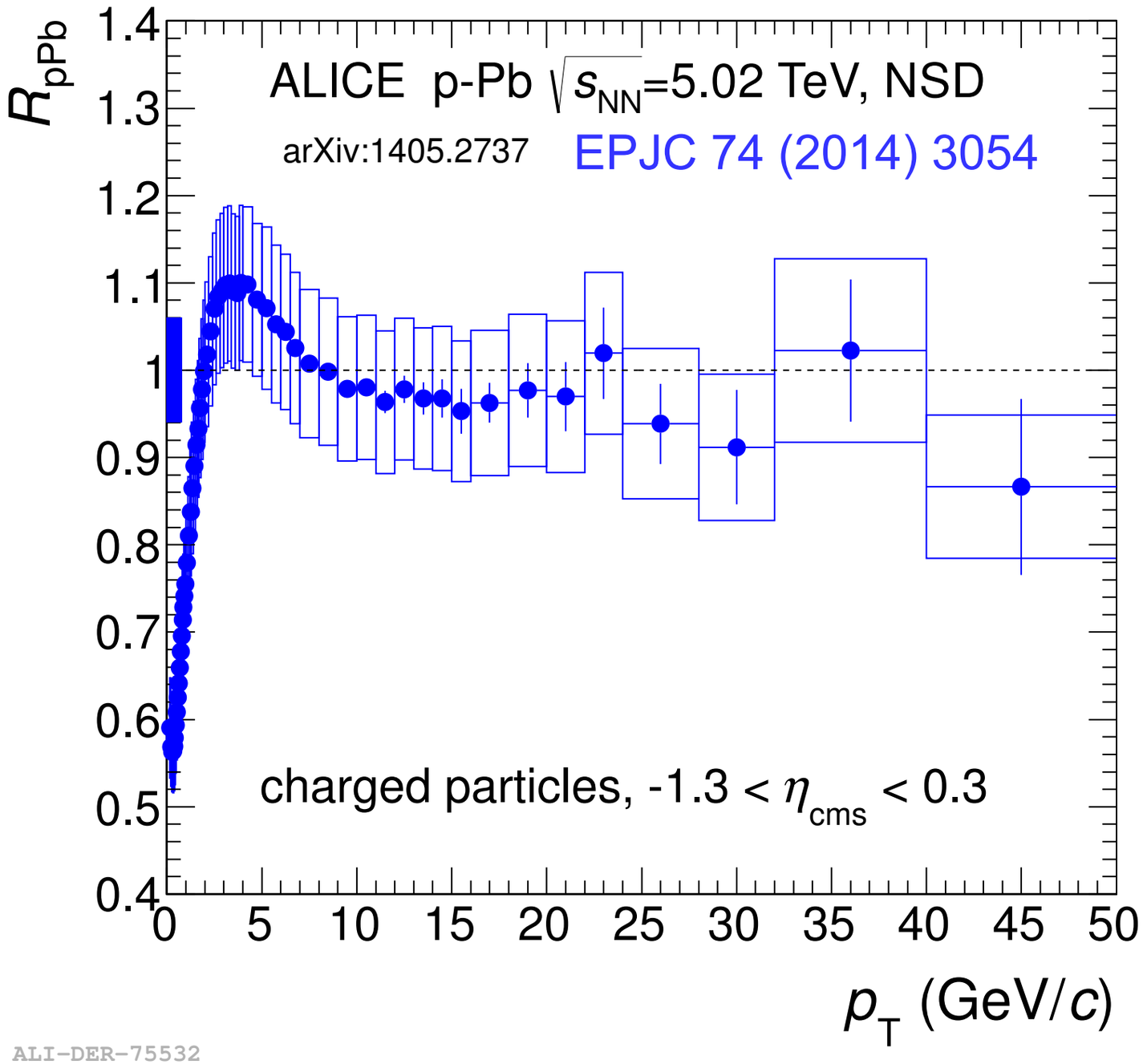
Momentum spectra, nuclear modification factors and p_T-dependent

Momentum spectra

- Pb-Pb and p-Pb compared
- low-p_T
- mid- to high-p_T
- R_{pPb}, Cronin, no high-p_T enhancement
- ie no effects from nuclear p.d.f2

Charged particle nuclear modification factor

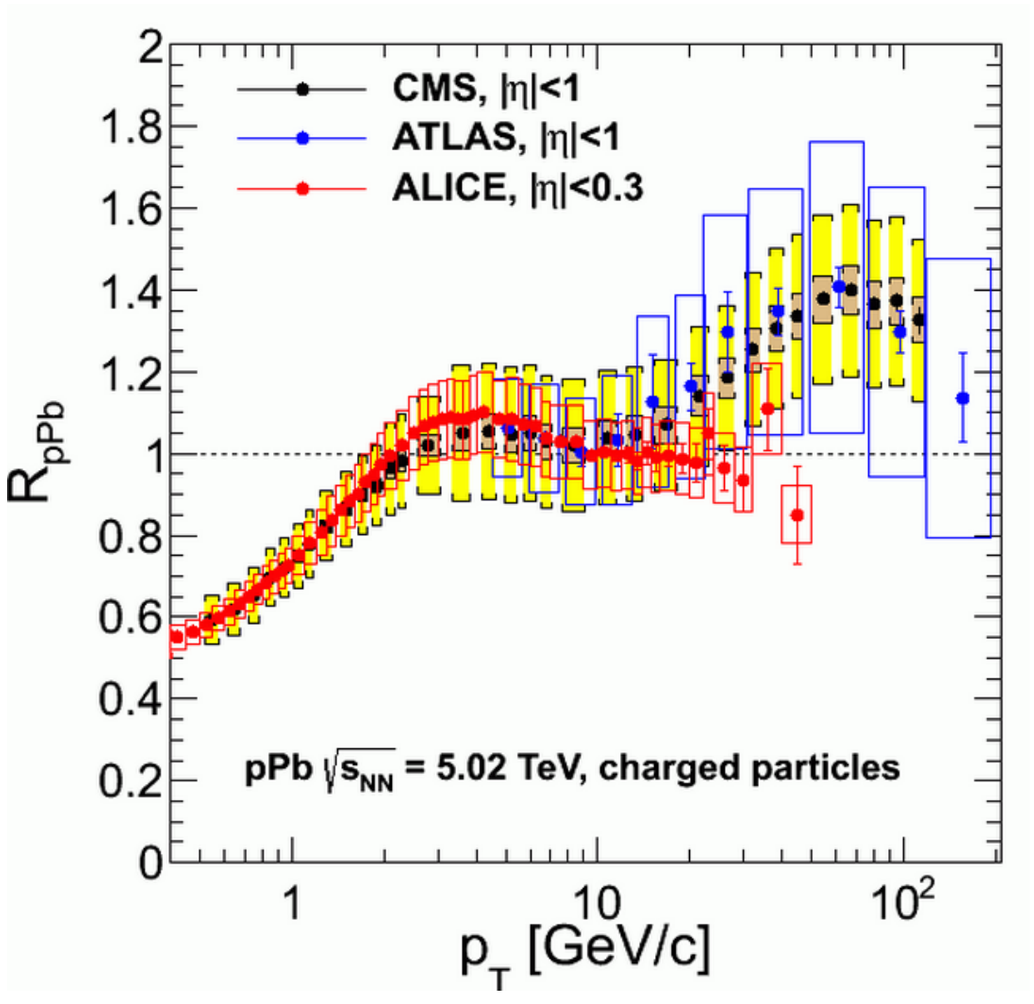


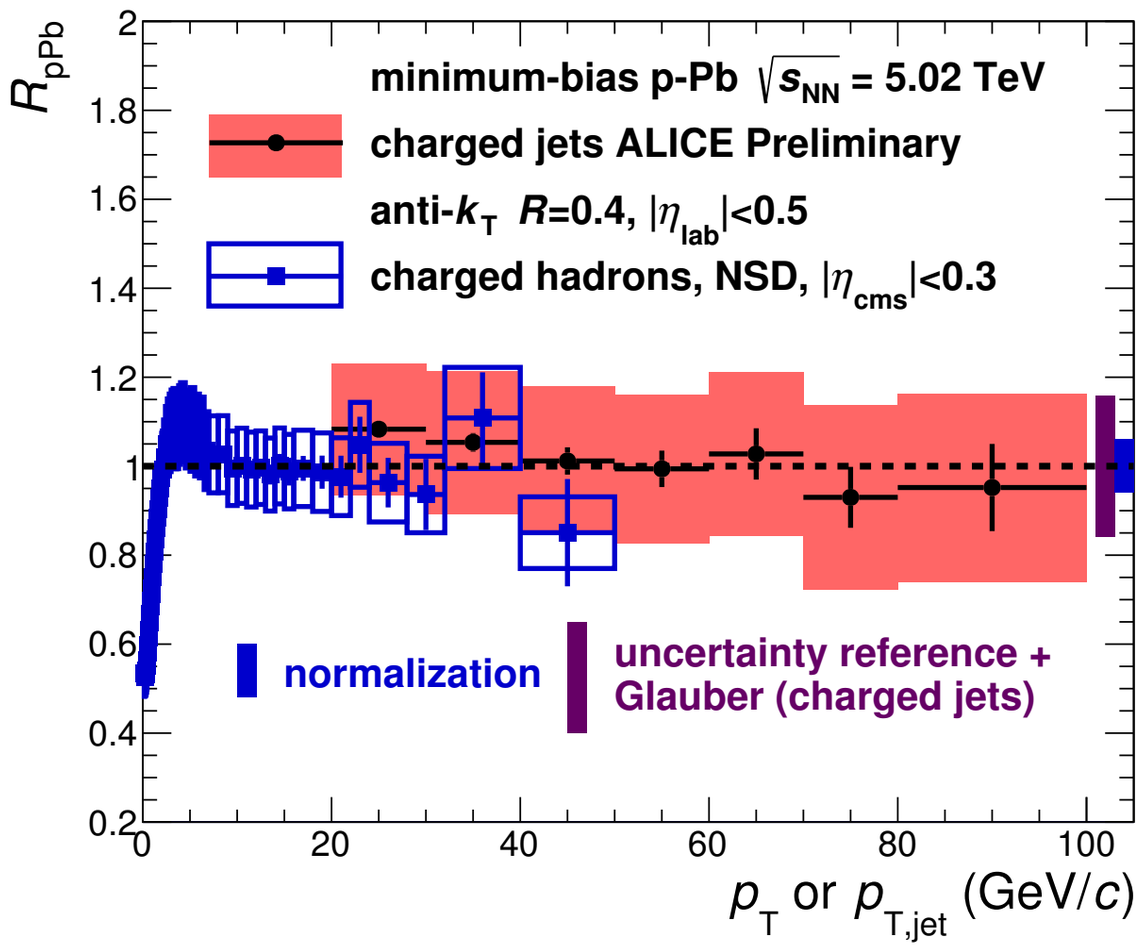
$$R_{\mathrm{pPb}} = \frac{\mathrm{d}N_{pPb}/\mathrm{d}p_{\mathrm{T}}}{N_{\mathrm{coll}}\,\mathrm{d}N_{pp}/\mathrm{d}p_{\mathrm{T}}}$$

- ALICE finds no evidence for $R_{pPb} \neq 1$ at high p_T

ALI-DER-75532

R_{pPb} high-p_T comparisons

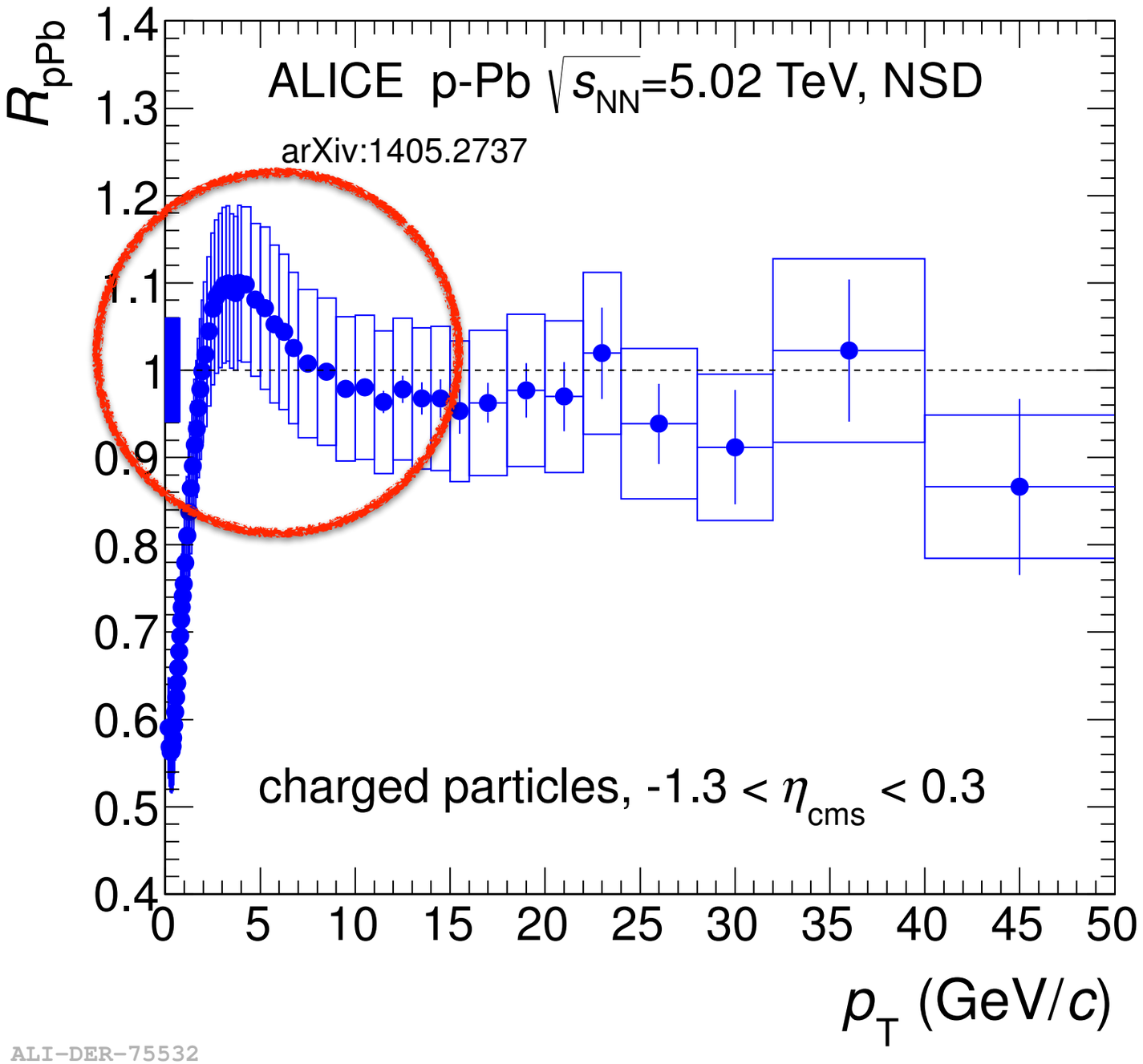




ALI-PREL-80555

- CMS and ATLAS see rise to values > 1
- However jets do not show this rise
- Need more data including √s=5 TeV pp collisions

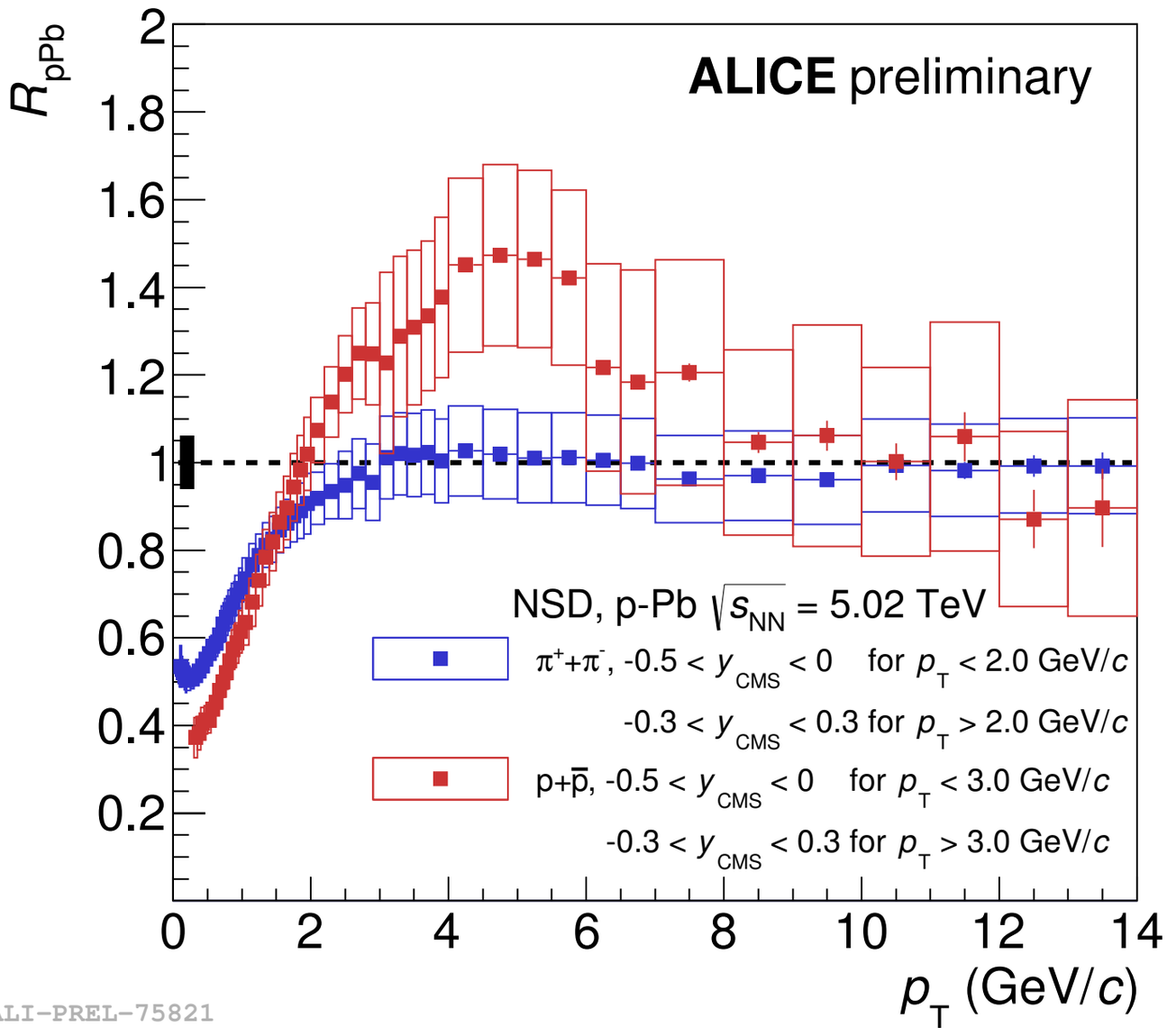
“Cronin” enhancement - identified particles



- Enhanced production at moderate p_T (~3 GeV/c)
- First observed, at lower √s, Cronin et al PRD **11**, 3105 (1975)
- Traditionally explained by multiple soft scattering prior to hard interaction

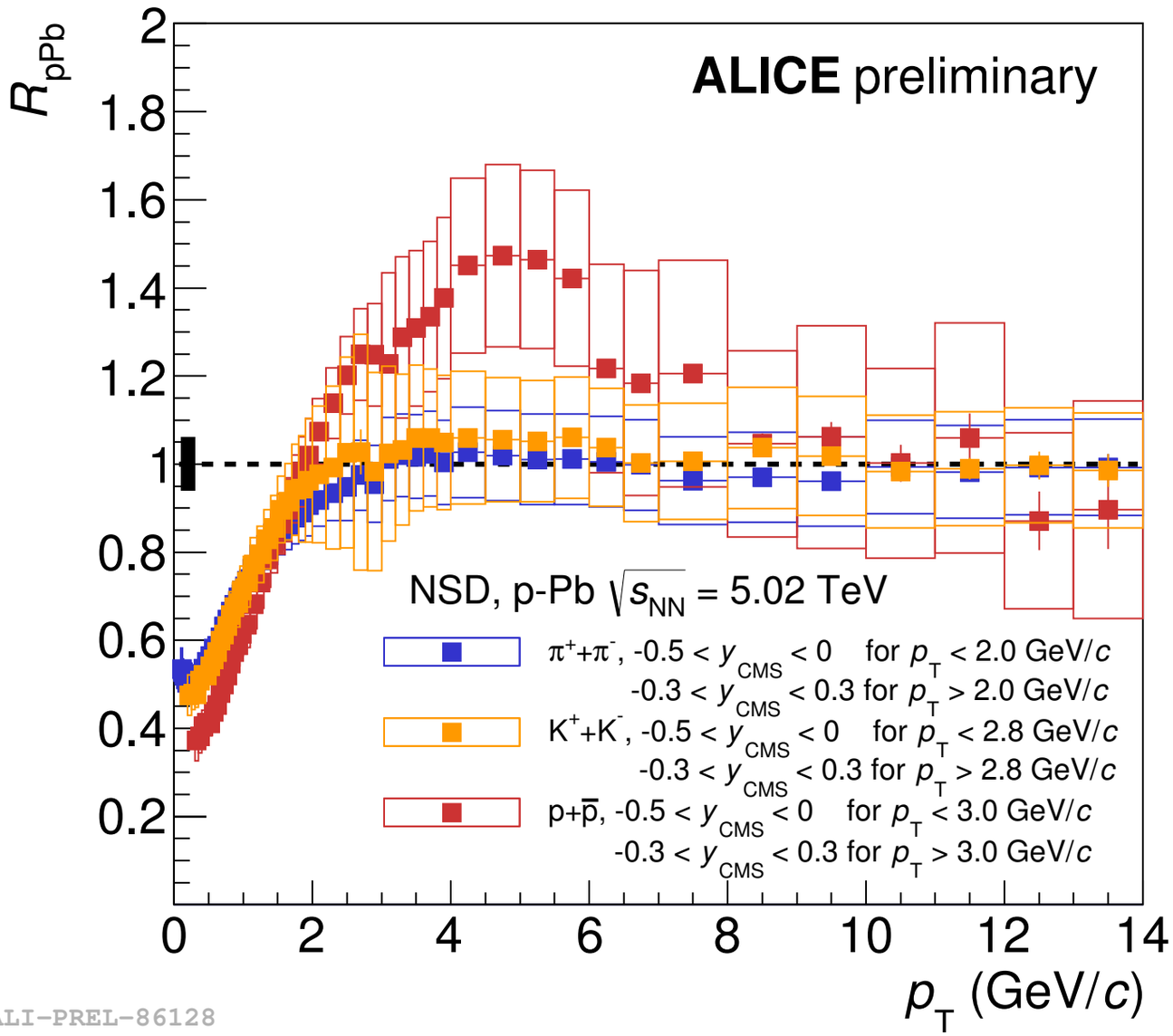
ALI-DER-75532

“Cronin” enhancement - identified particles



- Effect absent for π, larger for p

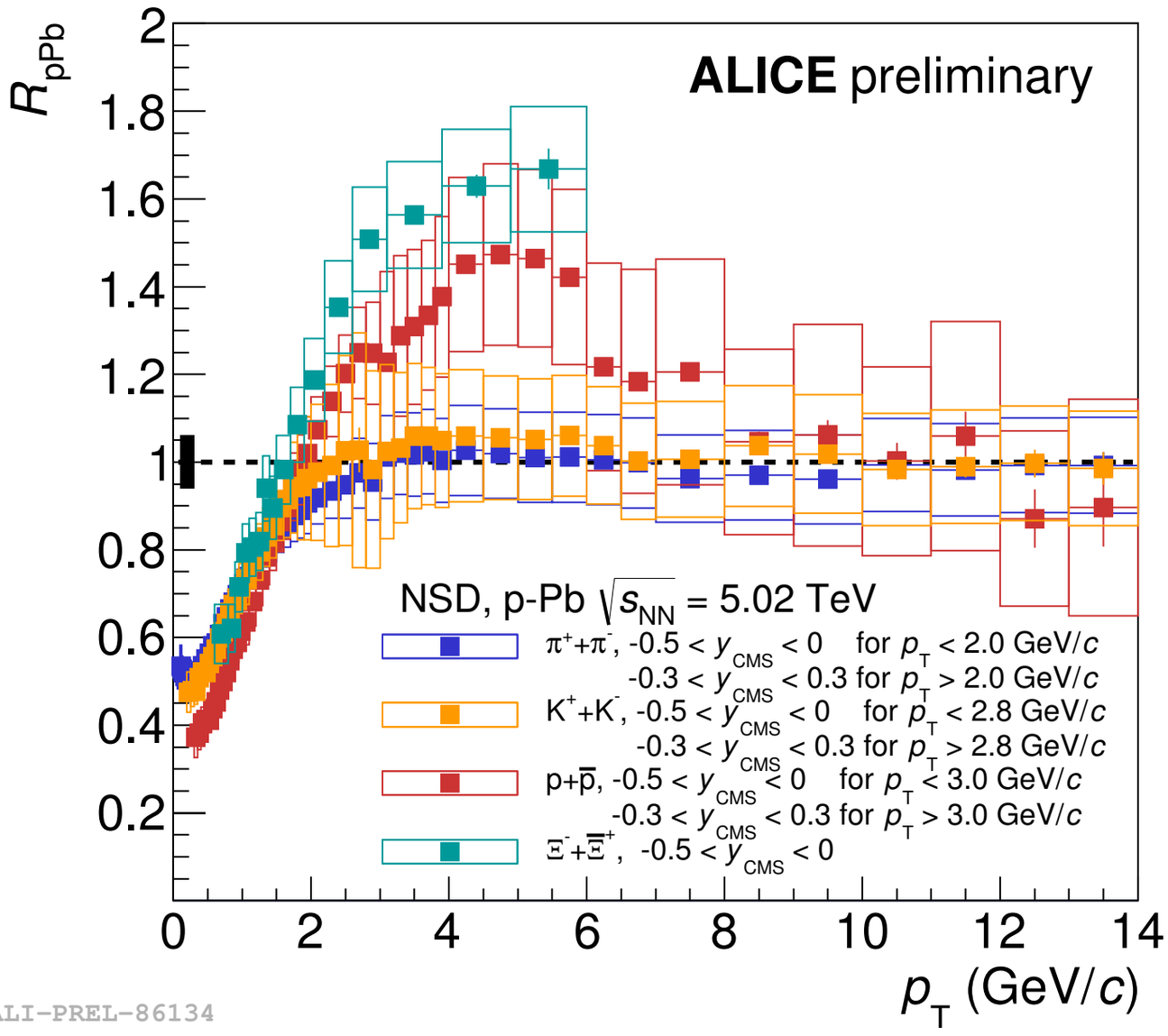
“Cronin” enhancement



ALI-PREL-86128

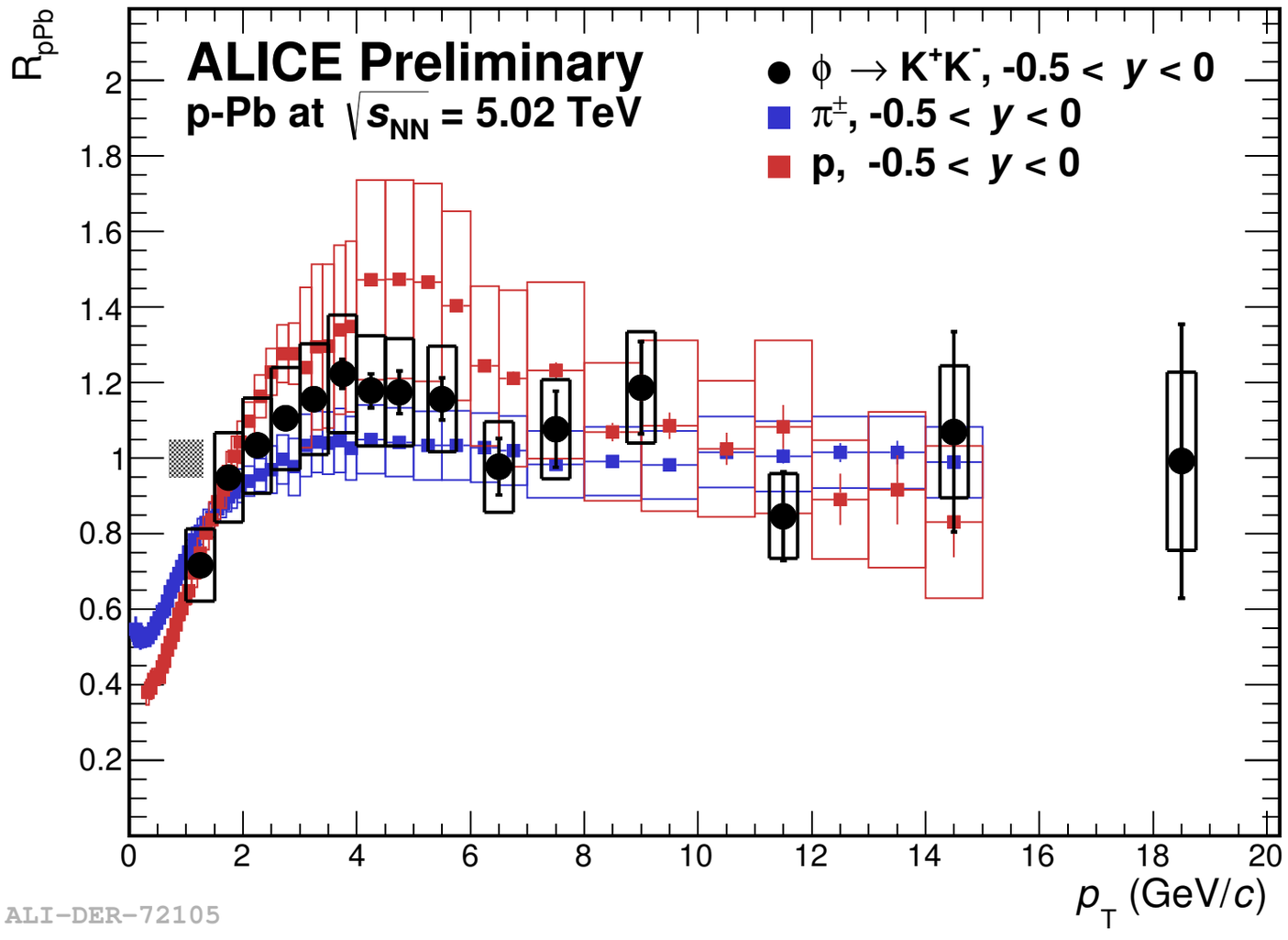
- Effect absent for π, larger for p
- K are very close to π
- Clear mass-dependence to effects

“Cronin” enhancement



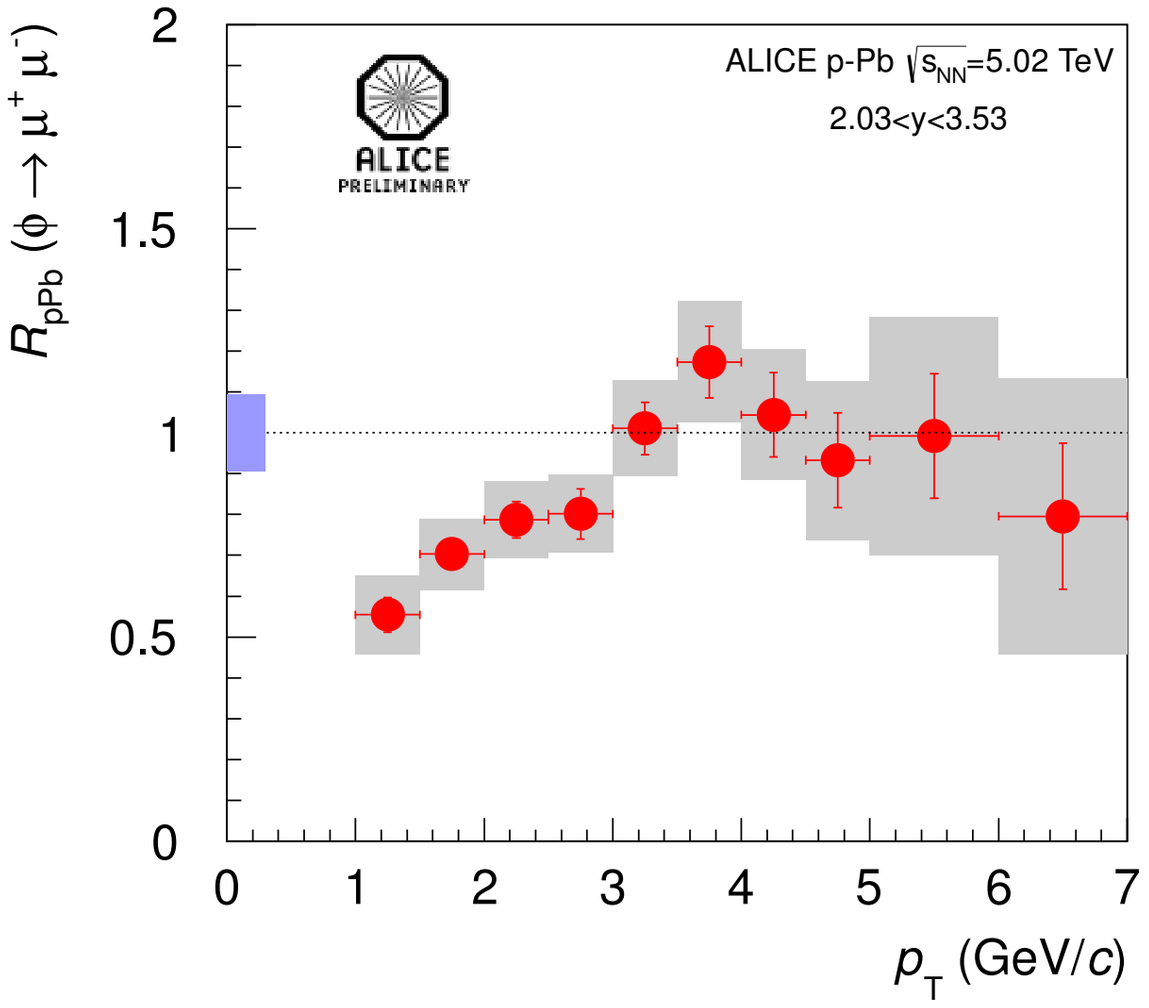
- Apparently reaches even higher values for Ξ
- Mass ordering reminiscent of collective behaviour (hydrodynamics?)

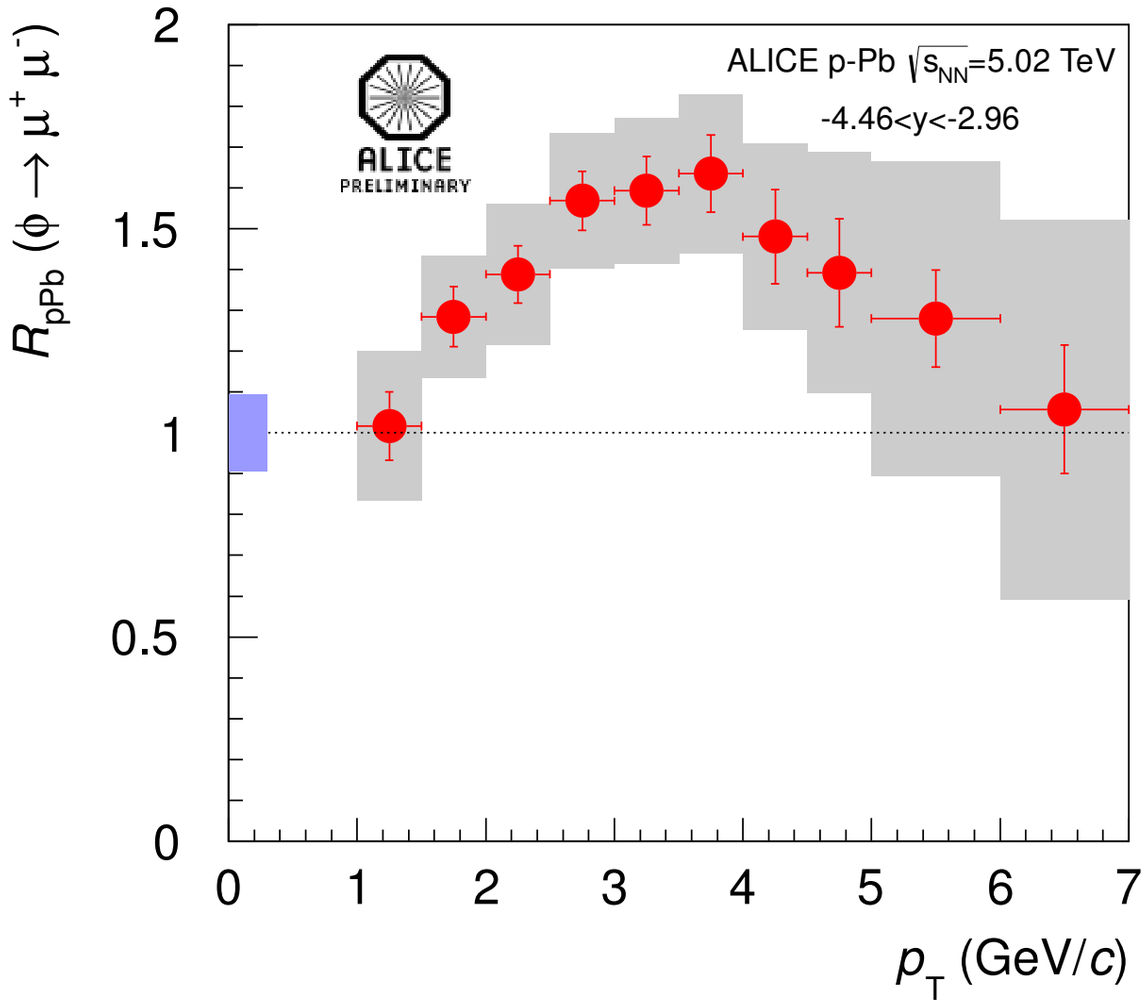
R_{pPb} of ϕ at mid-rapidity



- However…
- $m_\phi > m_p$ so this is not following this trend

R_{pPb} of ϕ away from mid-rapidity

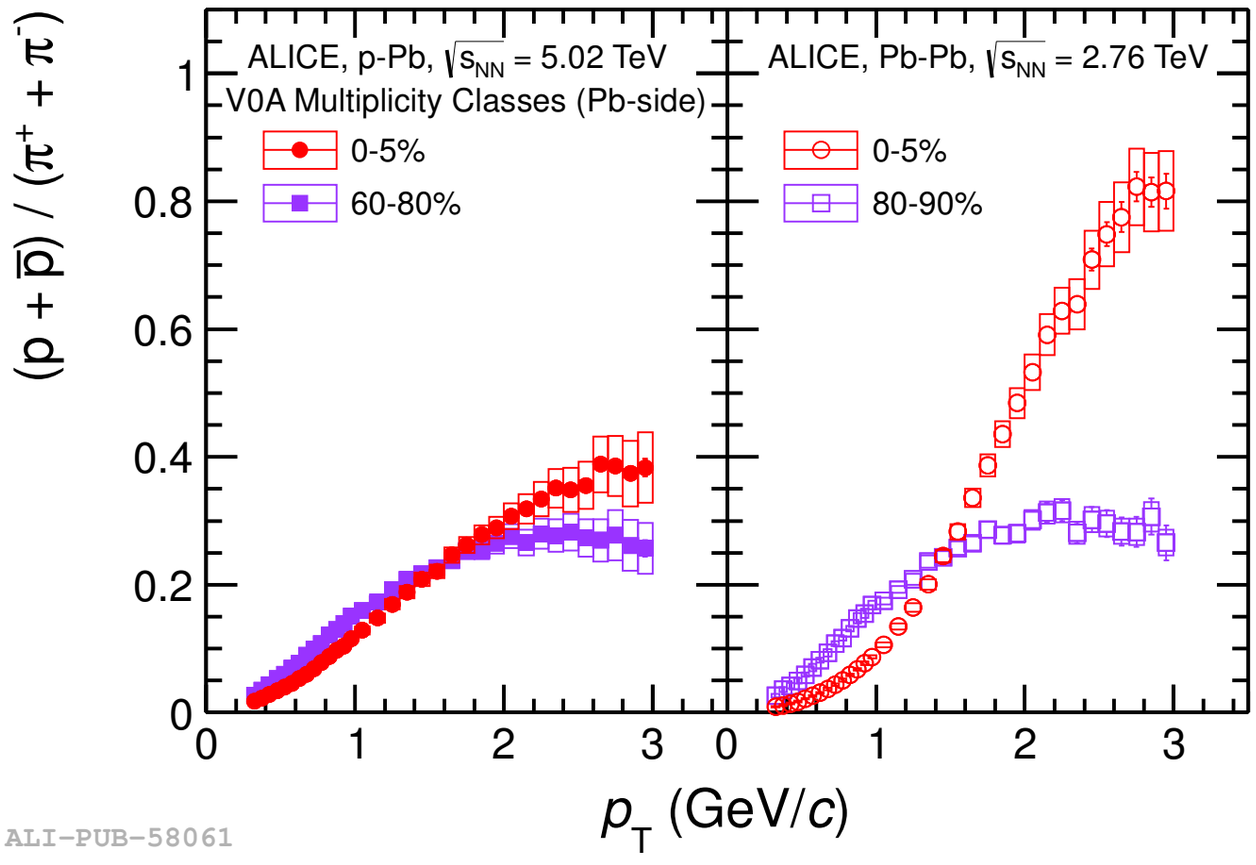




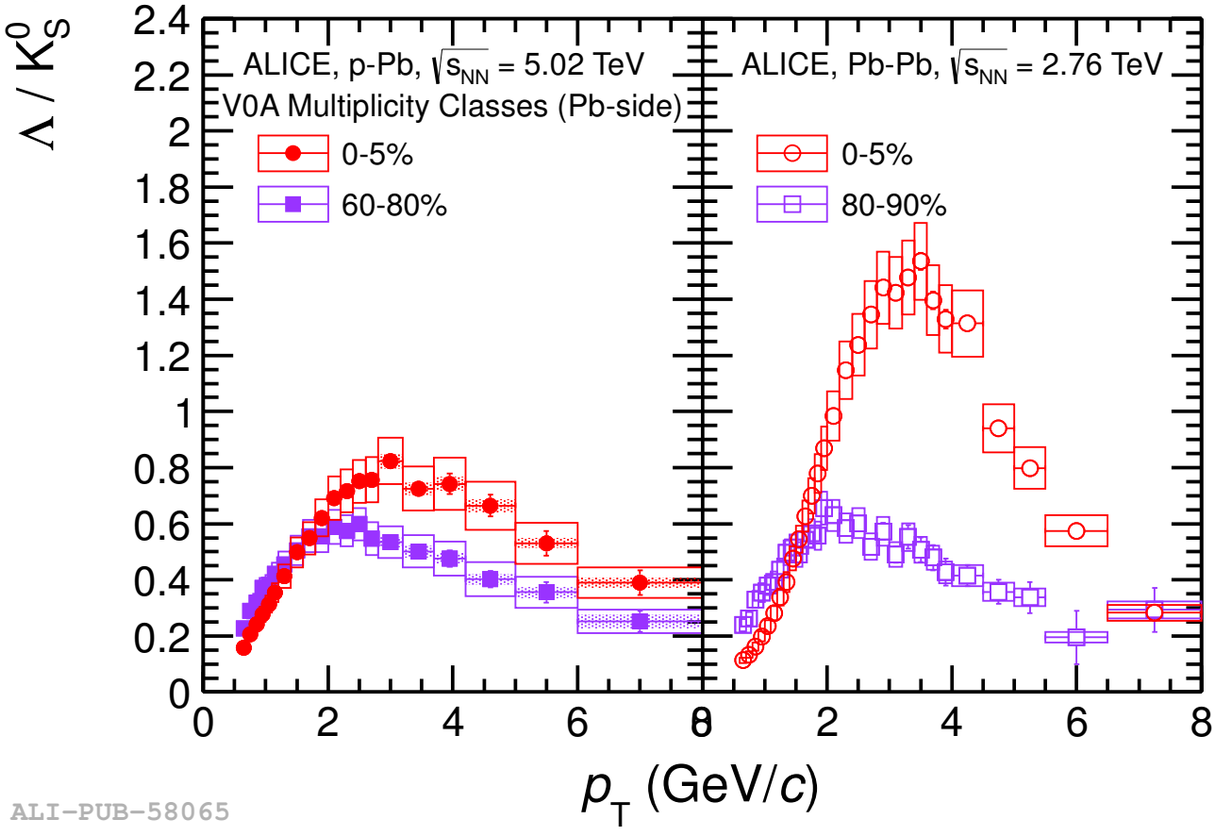
- ϕ is the only particle for which we can perform measurements at different rapidities, via μμ channel
- Picture is obviously more complicated

Possible collective effects

PLB 728 (2014) 25-38



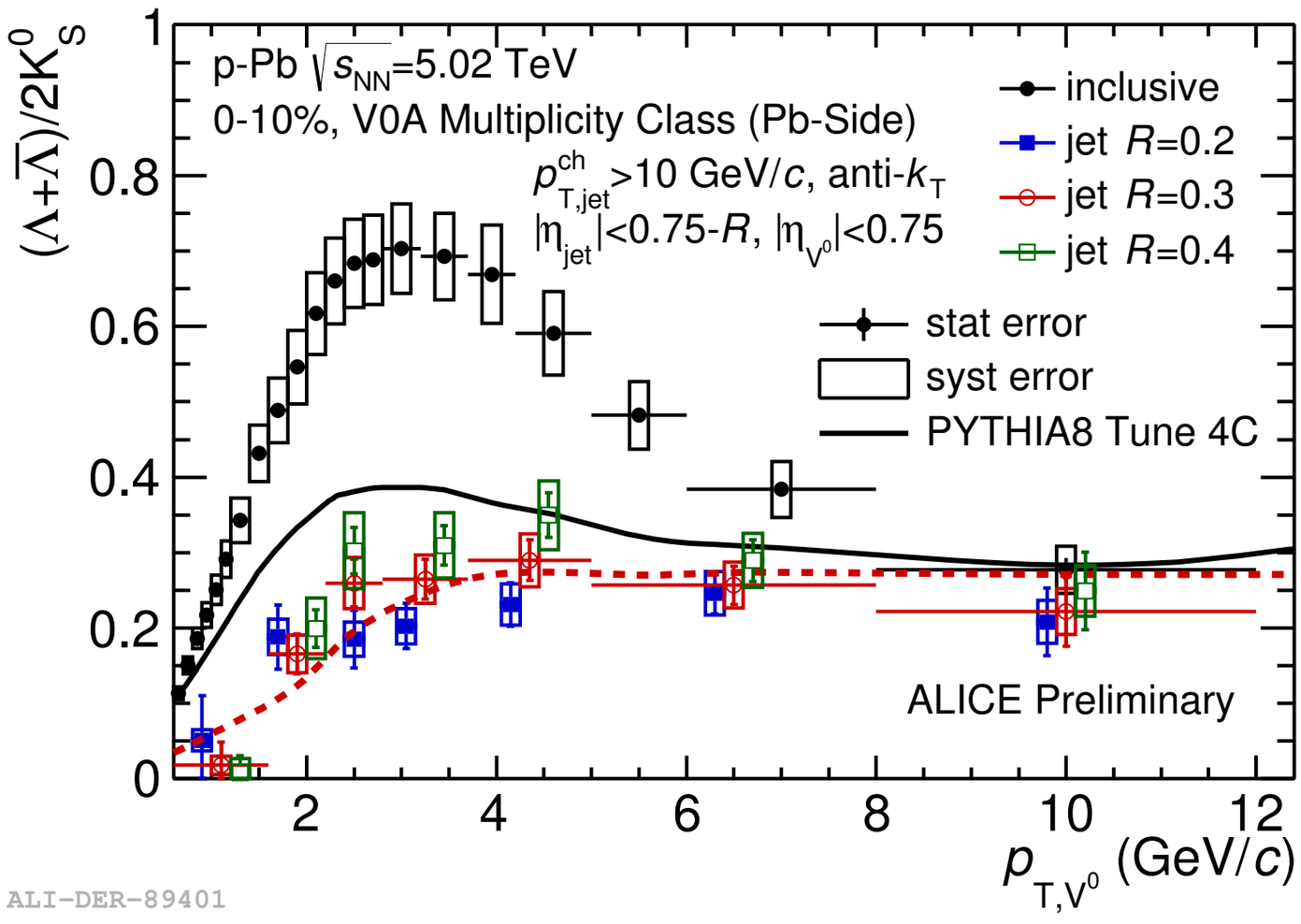
ALI-PUB-58061



ALI-PUB-58065

- Investigate collective effects
- p_T dependent particle ratios have centrality dependence in Pb-Pb …
- … and also a multiplicity dependence in p-Pb

Particle ratio in jets



- Investigate role of hard and soft mechanisms in the enhancement
- Ratio $(\Lambda+\overline{\Lambda})/2K$ measured in jets with $\sum p_T$ charged > 10 GeV/c

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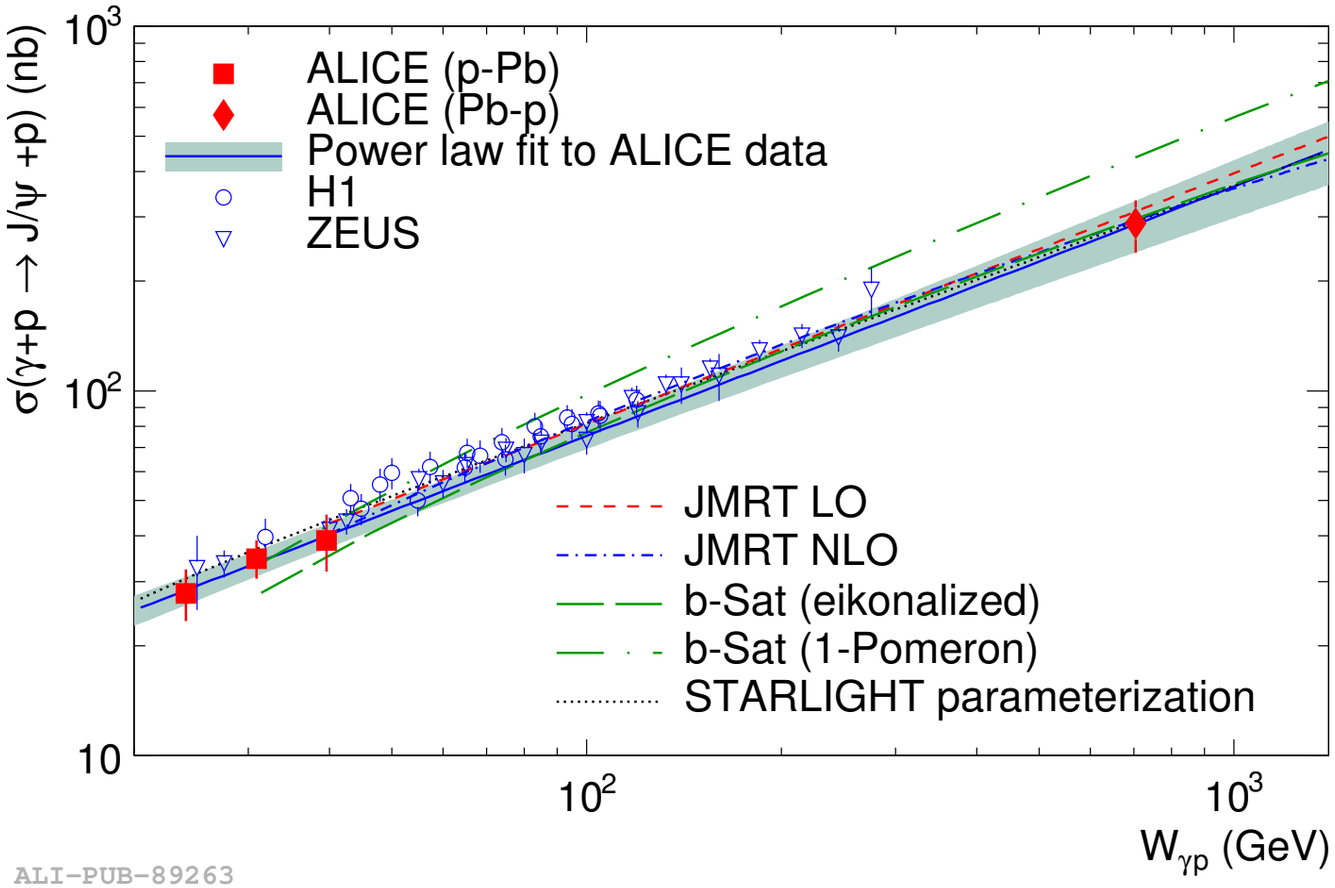
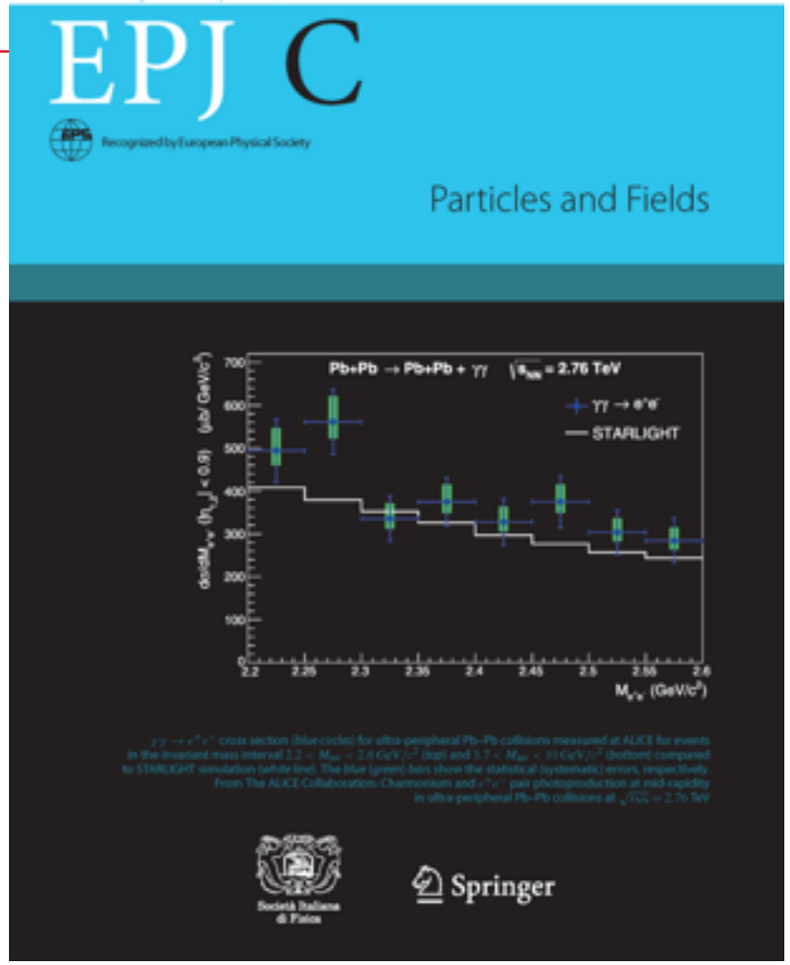
Further interesting results (in brief)

Ultra peripheral collisions (b>2r)

- LHC as γPb, γp and γγ collider to study
  - (Pb-Pb) exclusive vector meson (J/ψ) cross sections to investigate the gluon distribution in the nuclei
  - (Pb-Pb) results agree with EPS09 gluon distribution, favouring the presence of gluon shadowing
  - (Pb-Pb) ψ' vector meson photo-production measured
  - (Pb-Pb) γγ cross section constraints QED processes





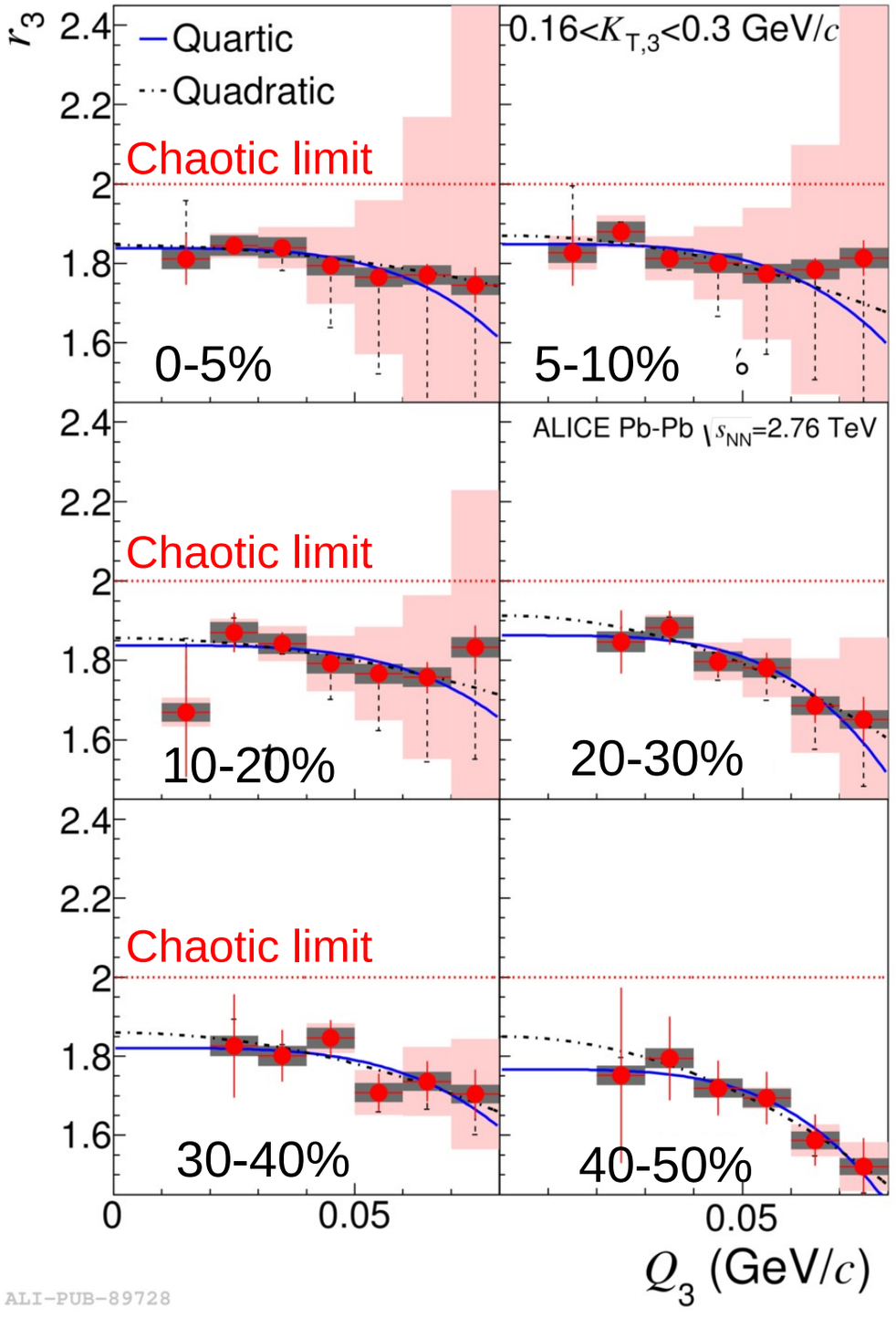
- 3 ALICE papers
  - Phys. Lett. B718 (2013) 1273-1283 (J/ψ at forward rapidity)
  - Eur. J. Phys. C73, 2617 (2013) (J/ψ and γγ at mid-rapidity)
  - arXiv:1406.7819, accepted PRL (J/ψ photo-production off protons in ultra-peripheral p-Pb collisions)

ALI-PUB-89263

Quantum Coherence

PRC 89 (2014) 024911

- Extend ππ interferometry (HBT, aka femtoscopy) to 3- and 4-pion correlations
  - Increased sensitivity to coherent emission
- Measure r_3 ratio of 3π to 2π quantum correlations
- extrapolate Q3→0
- fully chaotic means r_3



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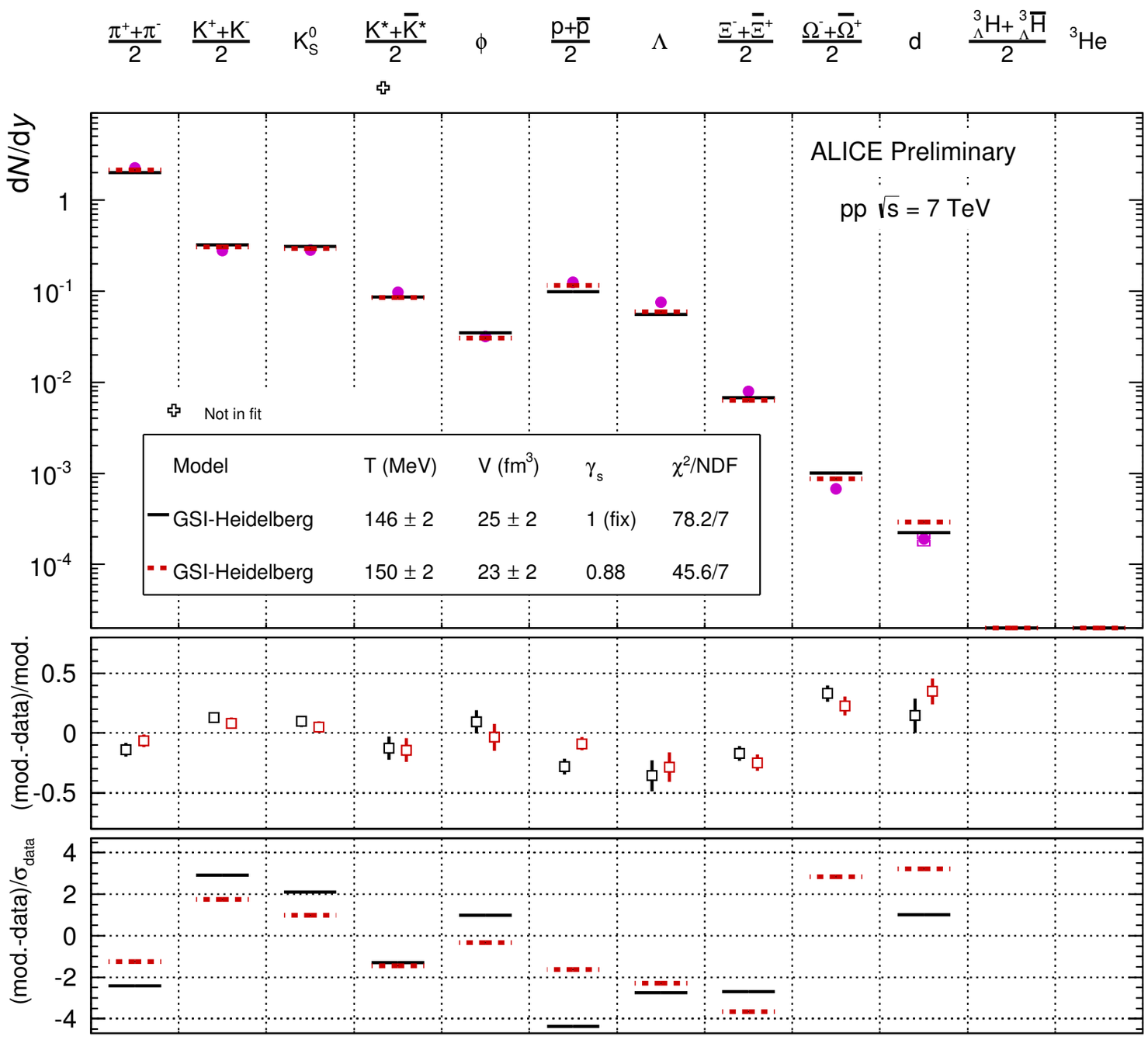
Summary

- ALICE measurements in Pb-Pb imply a picture where:
  - –overall particle yields, even rare ones, closely match statistical thermal model
  - –momentum spectra (and their harmonic decomposition) support collective effects described by hydrodynamics
  - –hadrons at high-p_T from partons fragmentation are suppressed, regardless of colour charge
- p-Pb collisions show several surprising features analogous to Pb-Pb
- Heavy-ion collisions can serve as a laboratory for interesting physics not directly related to the quark gluon plasma

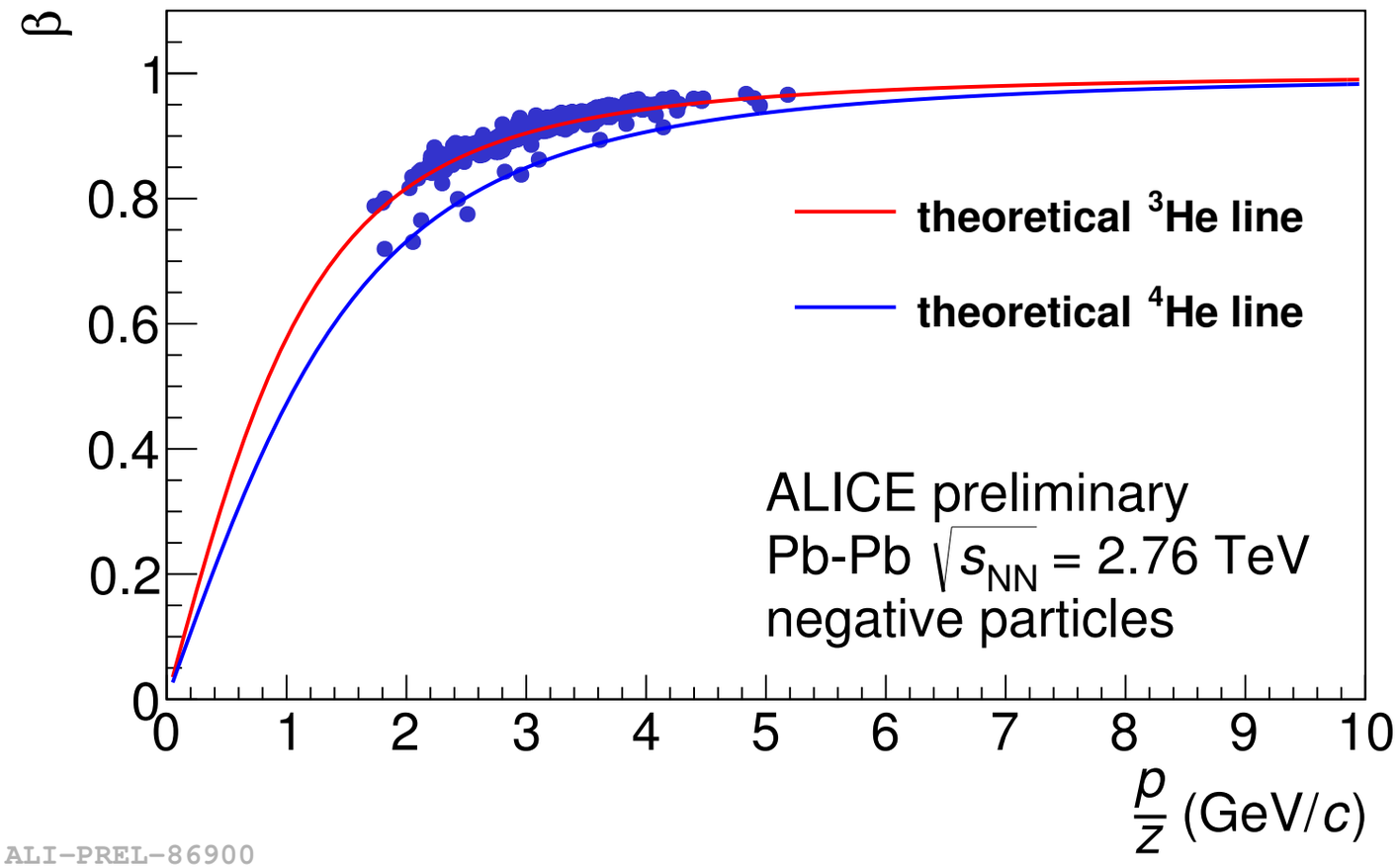
Backup

Statistical model - pp collisions



ALI-PREL-74533

$\bar{\alpha}$ extraction with TOF



ALI-PREL-86900