Results on identified particle spectra from ALICE

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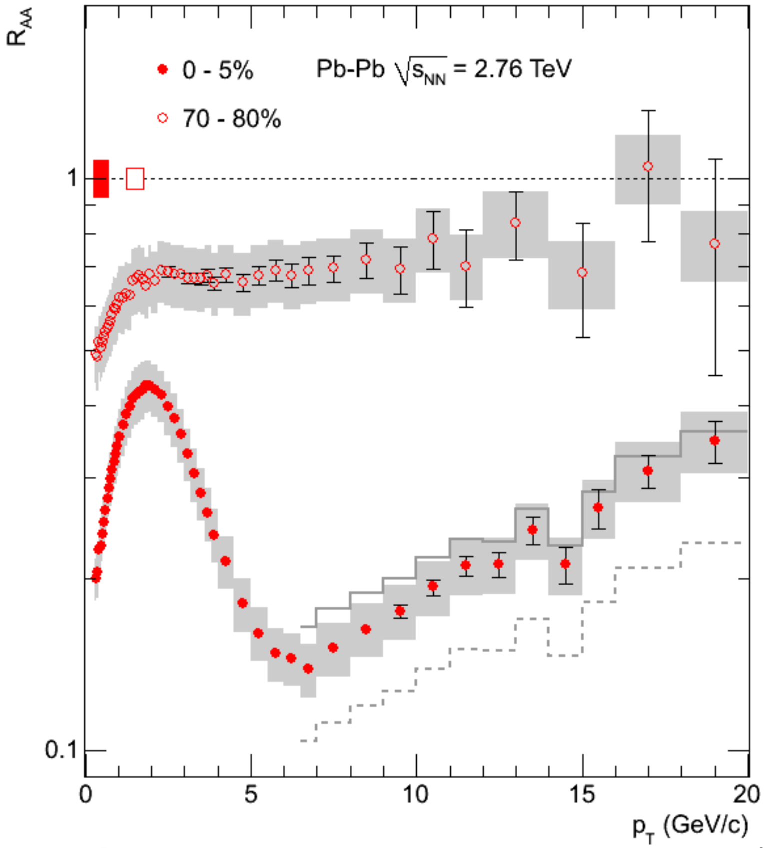
GSI Helmholtzzentrum für Schwerionenforschung GmbH

Outline

- Particle Identification (PID) and tracking capabilities of the ALICE central barrel
- Selected recent physics results at low p_T
- Towards jet quenching with PID
- Conclusions

Motivation



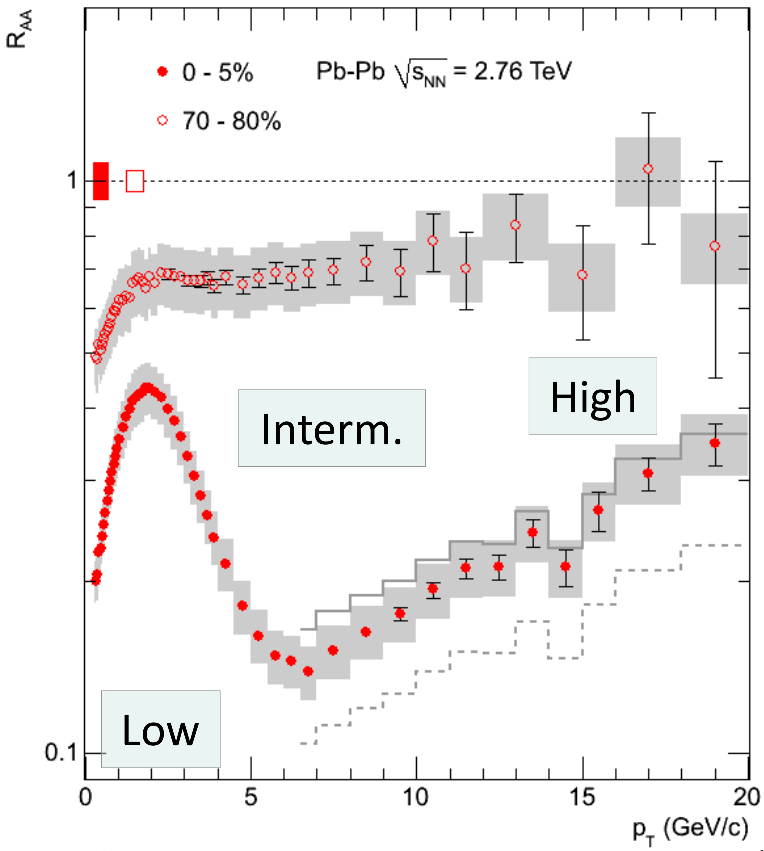
[ALICE Collaboration, *Phys. Lett. B696* (2011) 30]

Very first results of ALICE in Pb-Pb collisions in a limited p_T range and without Particle Identification (PID) produced interesting physics.
Example: R_{AA} as function of p_T

Next step is to provide PID over an extended p_T range

Motivation

3 regimes of p_T and their particle species dependence:



[ALICE Collaboration, Phys. Lett. B696 (2011) 30]

Low: p_T **< 3-4 GeV/*c***

Bulk properties and flow

Intermediate: 3 < p_T **< 7 GeV/*c***

Test of valence quark scaling

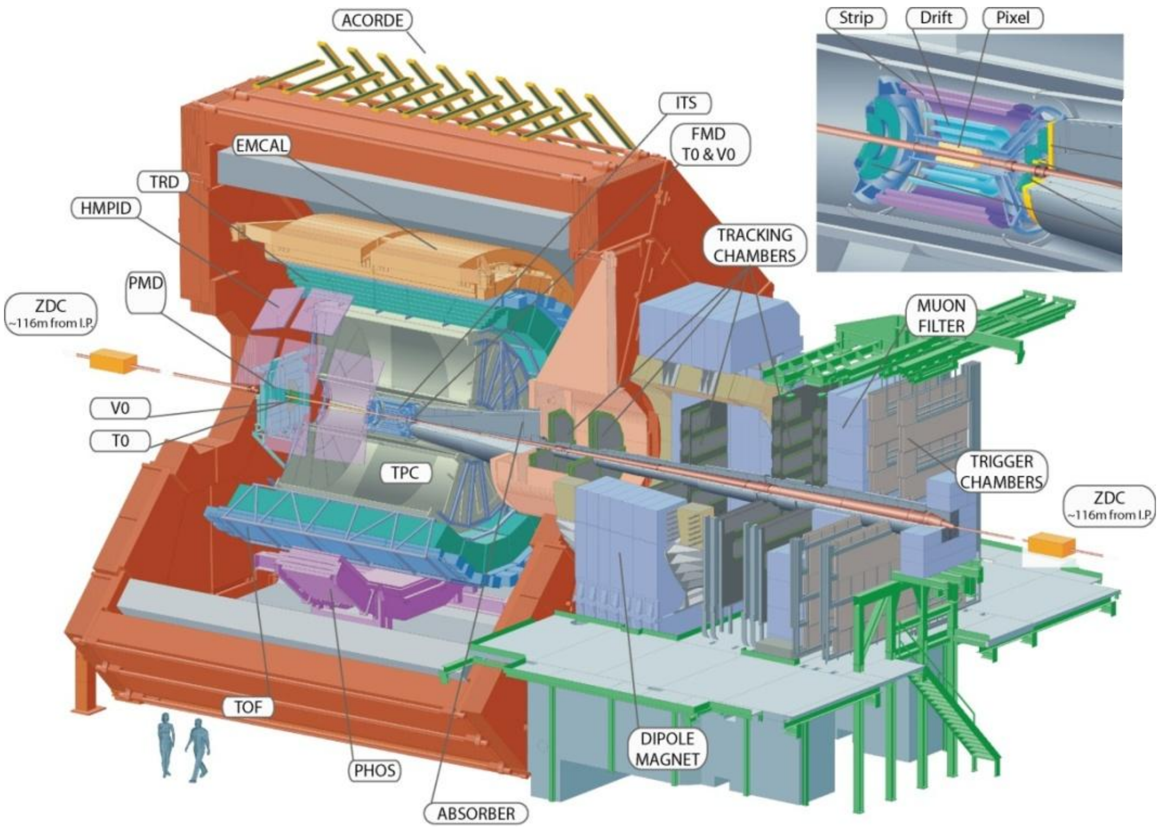
Anomalous baryon enhancement and coalescence

High: p_T **> 7 GeV/*c***

Search for medium modification of fragmentation functions

ALICE provides precision tracking and PID over a broad momentum range **from 100 MeV/*c* to 20-50 GeV/*c***

ALICE setup



Central Detectors:
Inner Tracking System (ITS)
Time Projection Chamber (TPC)
Transition Radiation Detector (TRD)
Time-of-Flight (TOF)
High Momentum PID (HMPID)

Spectrometers:
Photon Multiplicity
Forward Multiplicity
Muon Spectrometer

Calorimeters:
EM Calorimeter (EMCAL)
Photon Spectrometer (PHOS)
Zero Degree Calorimeter (ZDC)

[ALICE Collaboration, JINST 3 (2008) S08002]

PID in ALICE: Charged particles

Inner Tracking System (ITS)

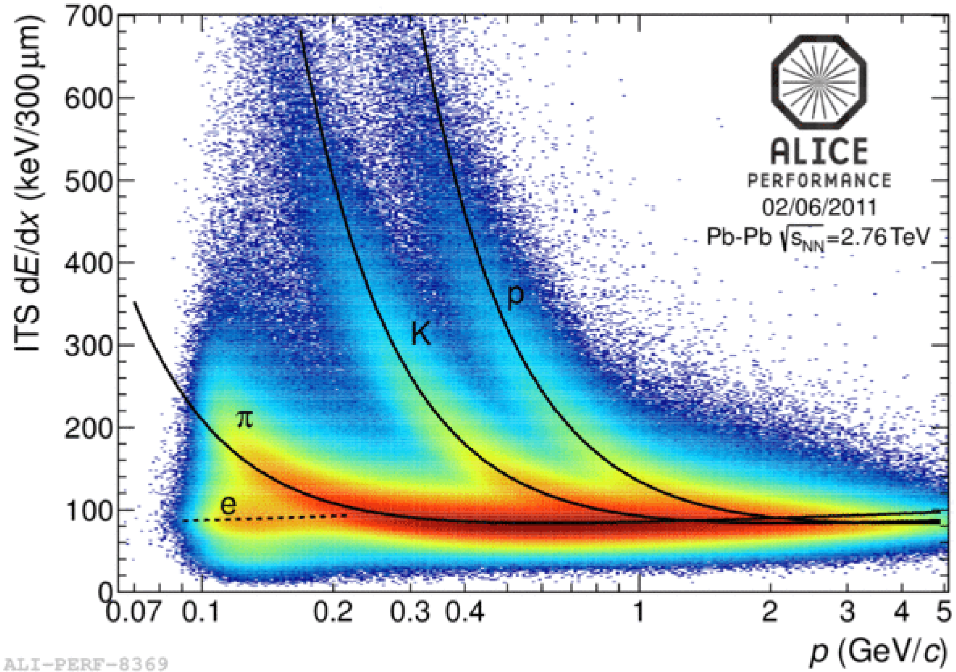
standalone tracker, extends low p_T reach

PID - energy loss in the silicon

Light charged hadrons ($\pi^{\pm}$, $K^{\pm}$, (anti)-proton) and electrons in broad range:

100 MeV/*c* < p_T < 20 - (50) GeV/*c*

Overlap of the momentum reach for several detectors allows for crosschecks



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main tracking system

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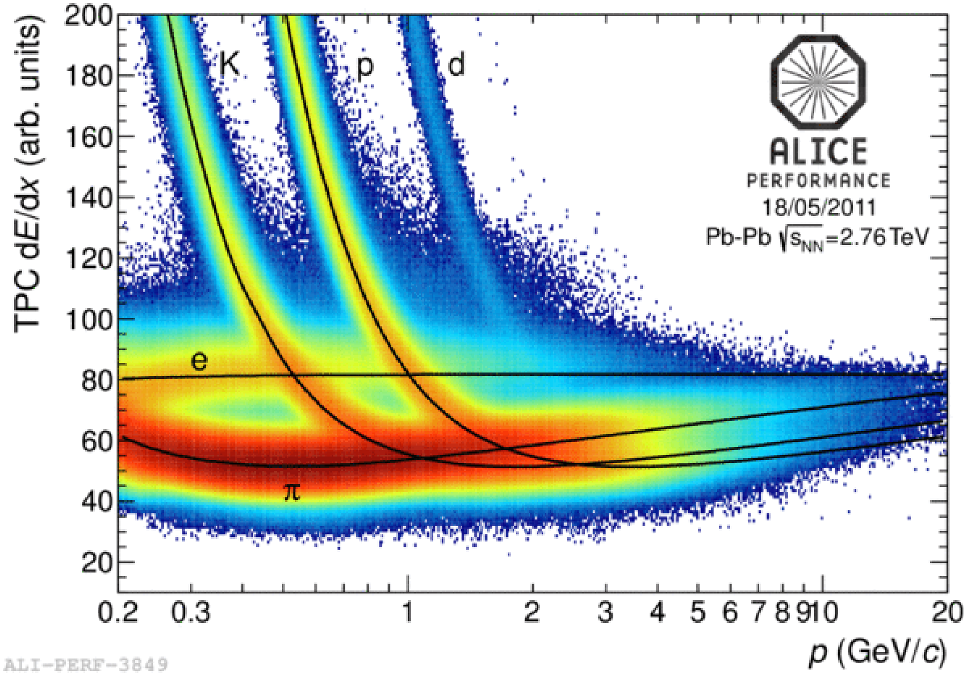

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tracks extrapolated from ITS-TPC

resolution ~85 ps (Pb-Pb)

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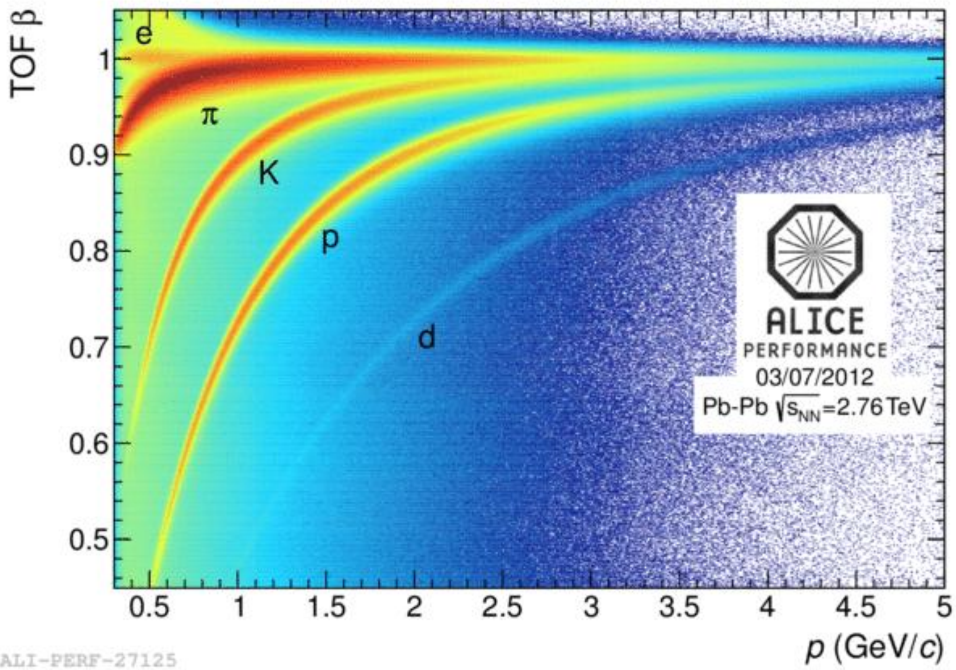

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Cherenkov angle measurement

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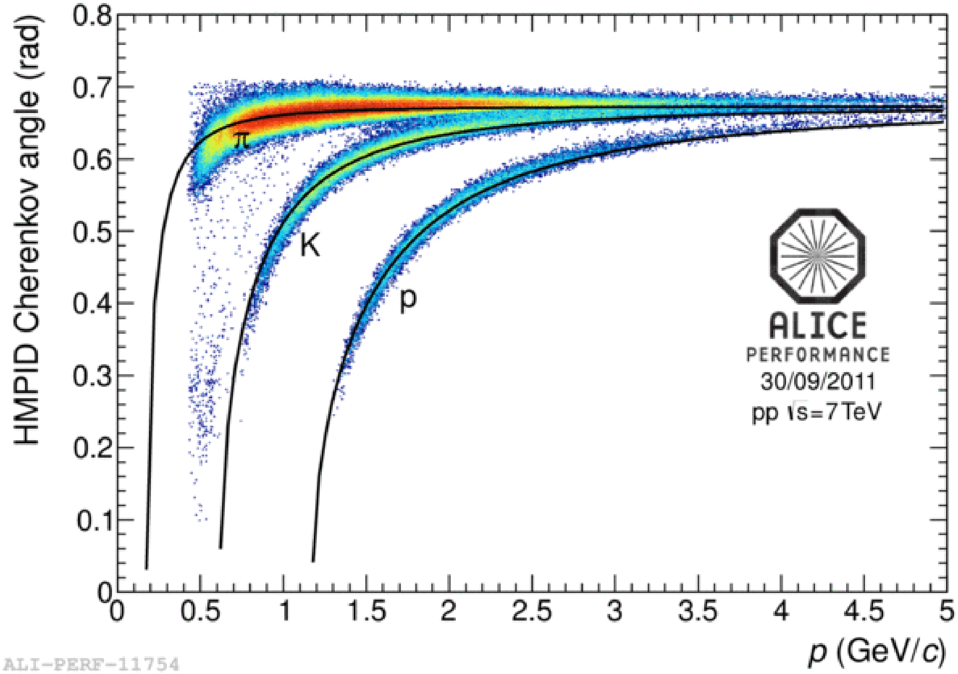

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Electron identification via TR +

Hadron identification - energy loss in the gas

Light charged hadrons ($\pi^{\pm}$, $K^{\pm}$, (anti)-proton) and electrons in broad range:

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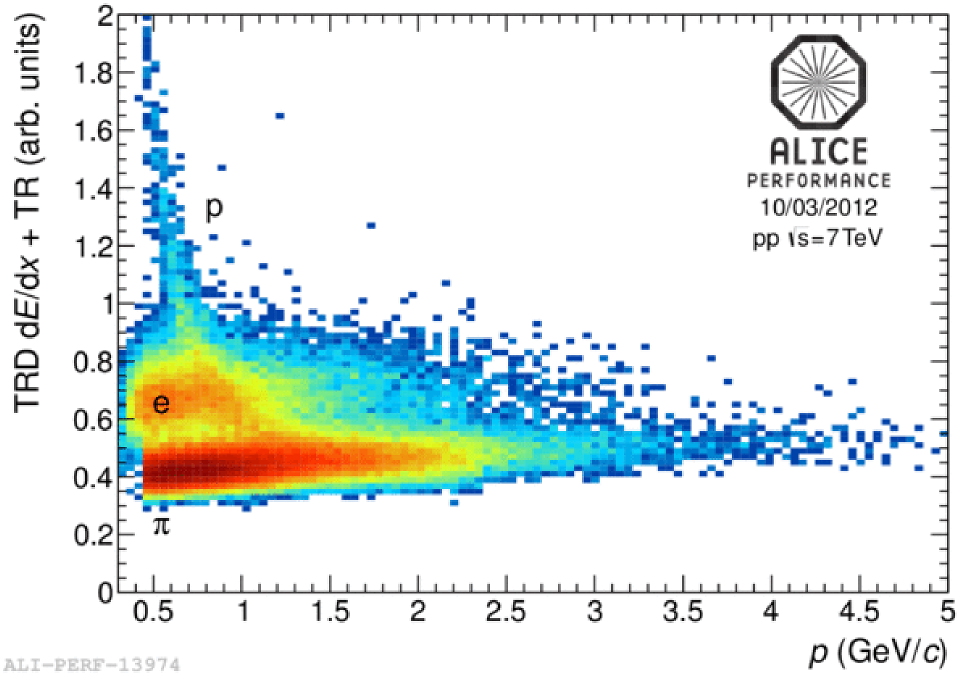

PID in ALICE: Charged particles

Inner Tracking System (ITS)
standalone tracker, extends low p_T reach
PID - energy loss in the silicon

Time Projection Chamber (TPC)
main tracking system
PID - energy loss in the gas

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tracks extrapolated from ITS-TPC
resolution ~85 ps (Pb-Pb)

Cherenkov detector (HMPID)
Cherenkov angle measurement

Transition Radiation Detector (TRD)
Electron identification via TR +
Hadron identification - energy loss in the gas

***E/p* from calorimeters (EMCAL, PHOS)**
Electron identification

Light charged hadrons ($\pi^{\pm}$, $K^{\pm}$, (anti)-proton) and electrons in broad range:

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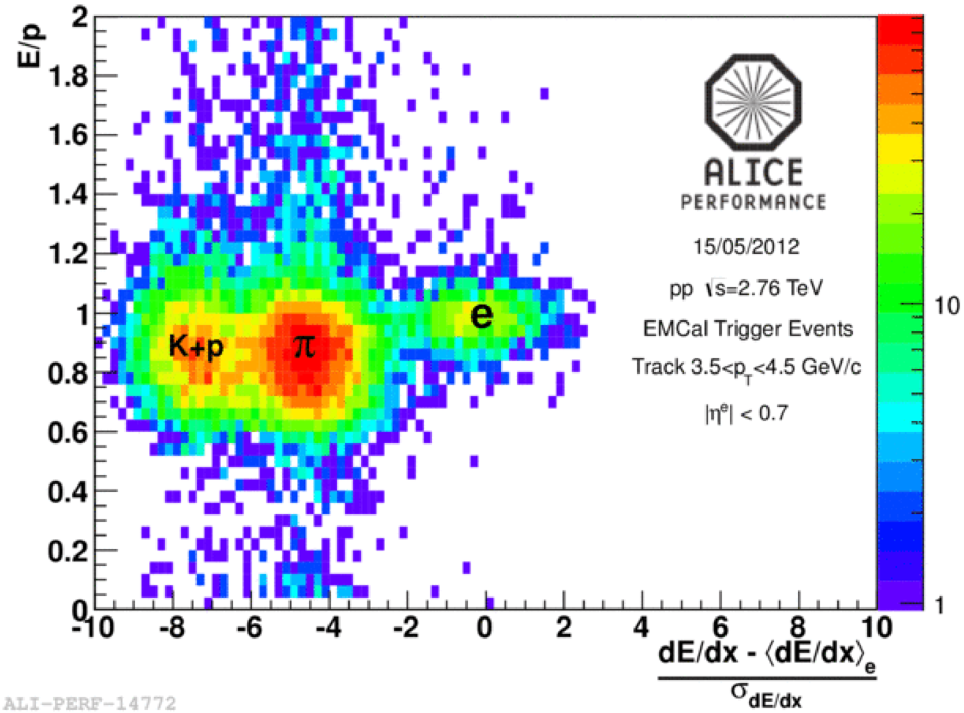
Overlap of the momentum reach for several detectors allows for crosschecks



PID in ALICE: Neutral mesons

π^0, η and ω **identification over a wide p_T range:**

300 MeV/c < p_T < 50 GeV/c

Measurements are performed with complementary subsystems and methods

Talk: D.PERESUNKO on 15 Aug 12:00
Session: Parallel 4B: Jets
Poster: P. GANOTI

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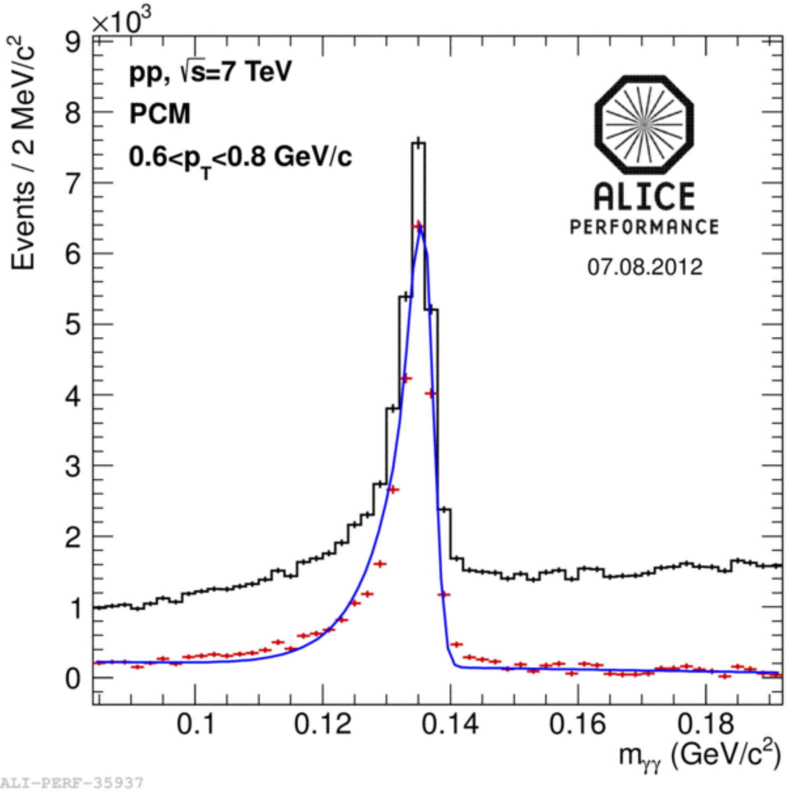
Photon conversion method - PCM

Photon conversion in material of central tracker
π^0 (300 MeV/*c* - 15 GeV/*c*)
p_T range currently statistic limited



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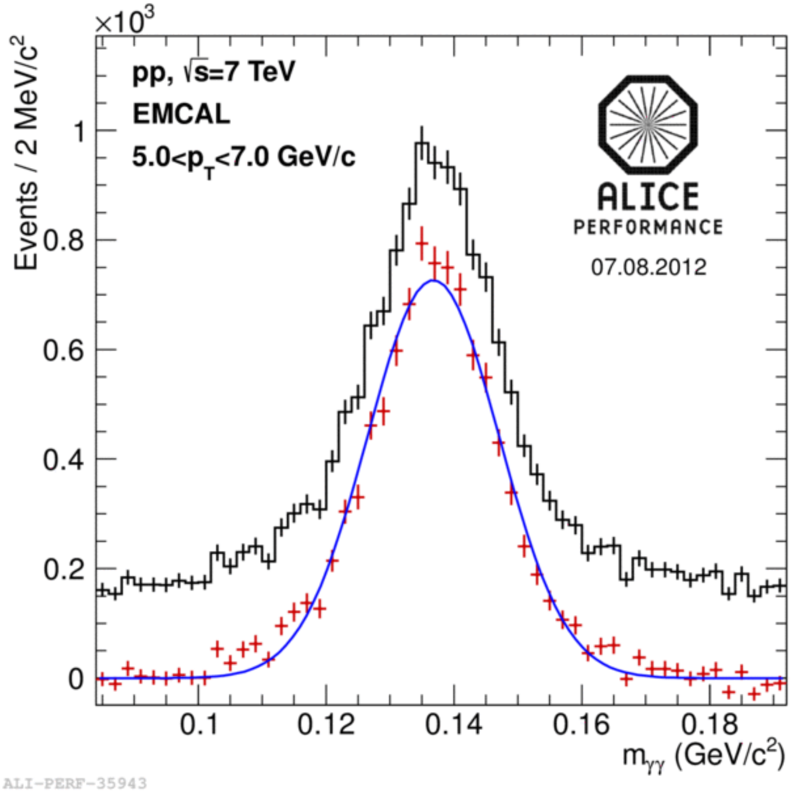
p_T range currently statistic limited

EMCAL

π^0(1 GeV/*c* - 25 GeV/*c*)



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p_T range currently statistic limited

EMCAL

π^0(1 GeV/*c* - 25 GeV/*c*)

PHOS

High granularity

π^0 (500 MeV/*c* - 50 GeV/*c*)

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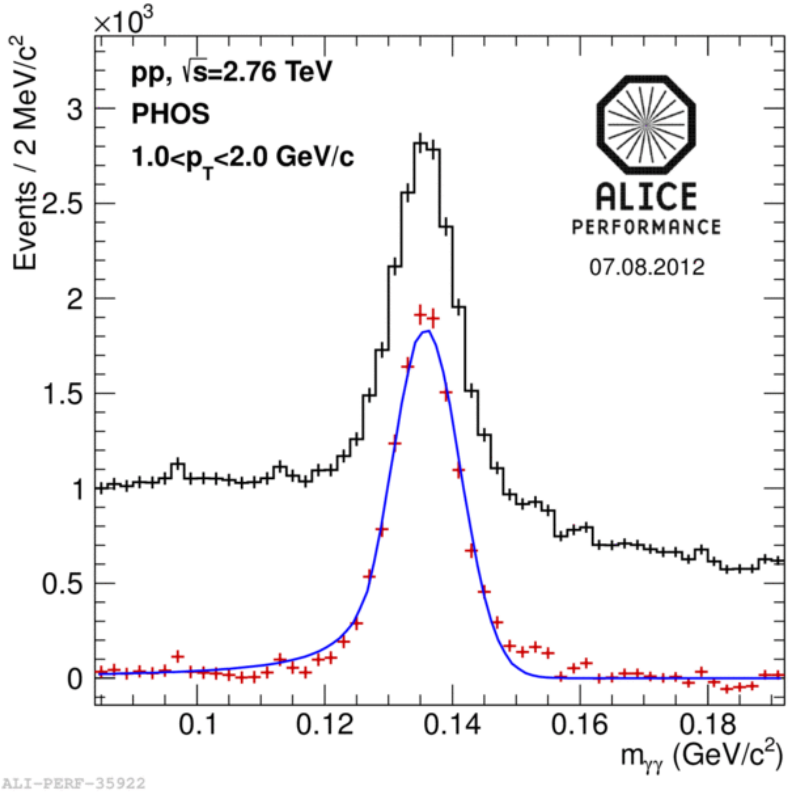


Strange hadrons and resonances:

Ω, Ξ, Λ, ϕ, K*(892), K_S^0

Talk: S. SINGHA on 16 Aug
Parallel 5A: Hadron Thermodynamics and Chemistry

Baryonic resonances:

$\Sigma(1385)$, $\Lambda(1520)$, $\Xi(1530)$, Δ^{++}

Poster: E. FRAGIACOMO on 16 Aug

Quarkonium production:

J/ψ, $\psi(2S)$

Talk: E. SCOMPARIN on 16 Aug
Plenary IVB: Quarkonia, Real & Virtual Photons

Heavy flavor hadrons:

D^0, $D^{\pm}$, D^{*+}, D^+_s

Talk: Z. CONESA on 14 Aug
Plenary IIB: Heavy Flavor

Requirements:

- Pad-by-pad (557k channels) gain calibration using the ^{83}Kr decay.
- Keep gain stable within 0.2 % - frequently updated (15 minutes). Calibration following the change of the pressure, temperature and gas composition.

Optimization of d*E*/d*x* algorithm for TPC:

- Signal integration - correction for the signal below threshold
- Consideration of one pad and missing clusters

Ion tail effect correction (for Pb-Pb):

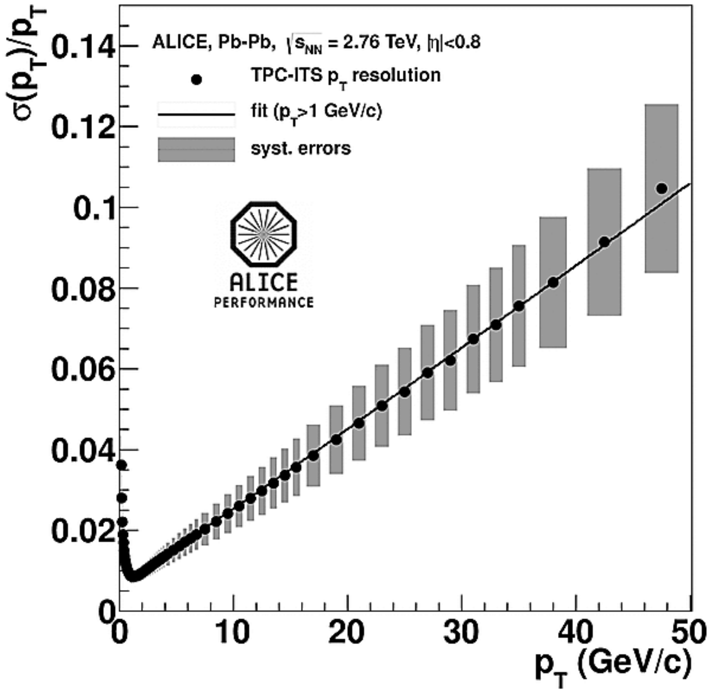
- Correction for the track - multiplicity dependent baseline shift

d*E*/d*x* resolution close to the design value ~ 5.5% at MIP position for low multiplicity and ~ 6.8% for central Pb-Pb collisions

Future improvement: precision ion tail cancellation

Tracking performance – p_T resolution

Combined tracking TPC-ITS **momentum resolution ~10% at 50 GeV/*c****
(Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV from 2010)



ALI-PERF-16396

Small multiplicity dependence

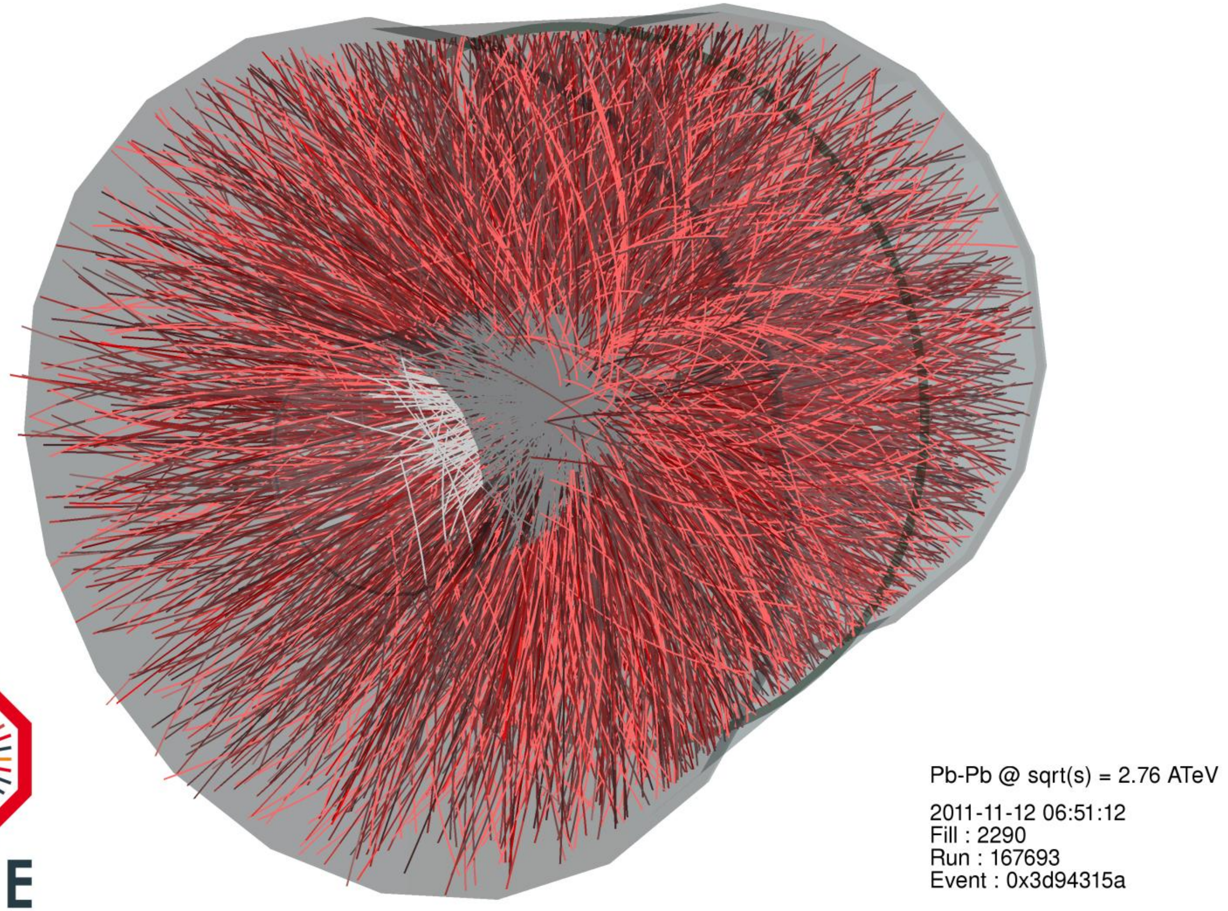
Additional uncertainty due to residual mis-alignment and mis-calibration estimated from track matching residuals

Verified using cosmic tracks and K_S^0 invariant mass distribution - systematic uncertainty: 20%

$\Delta(1/p_T)$ shift monitored run-by-run

*For new ongoing reconstruction production, the momentum resolution improved to ~ 5% at 50 GeV/*c*, as a result of improved TPC-ITS matching.

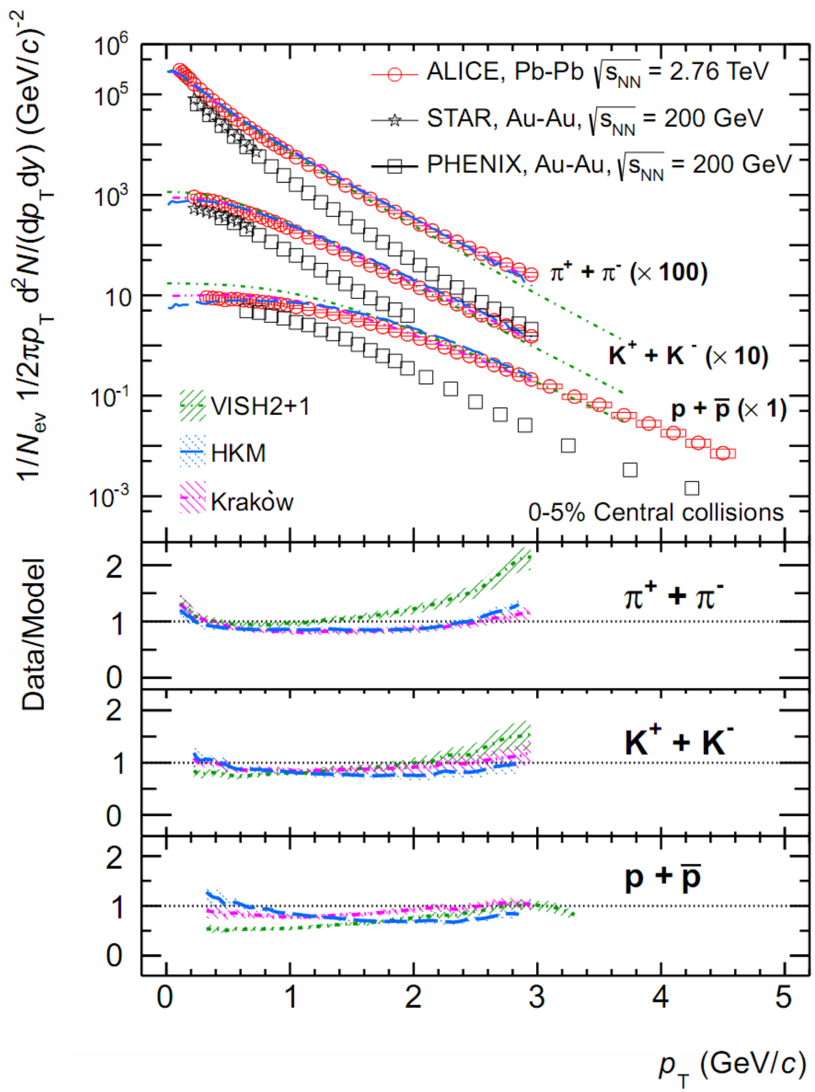
Selected recent physics results at low p_T



ALICE
A JOURNEY OF DISCOVERY

Identified particle spectra in central (0-5%) Pb-Pb collisions

Talk: L. MILANO on 16 Aug
Parallel 5A: Hadron Thermodynamics and Chemistry



Data:

~10% larger radial flow than at RHIC

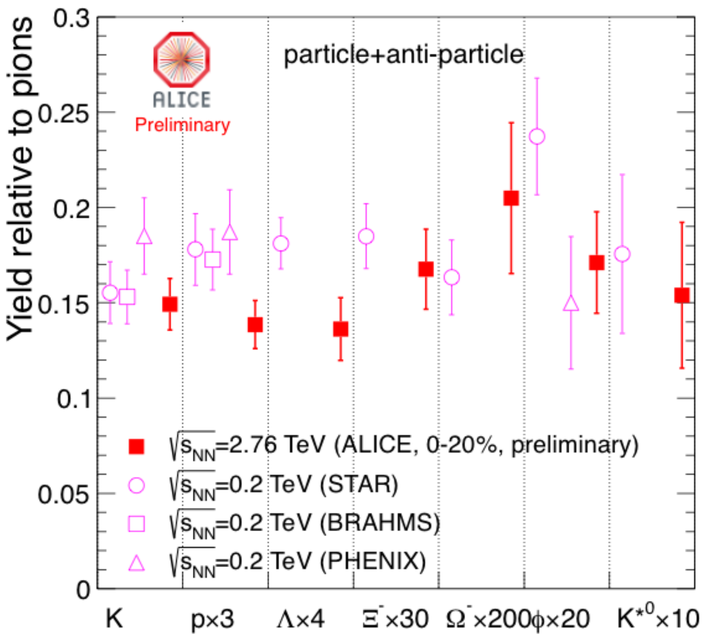
$\langle \beta_T \rangle = 0.65 \pm 0.02$

Model comparison:

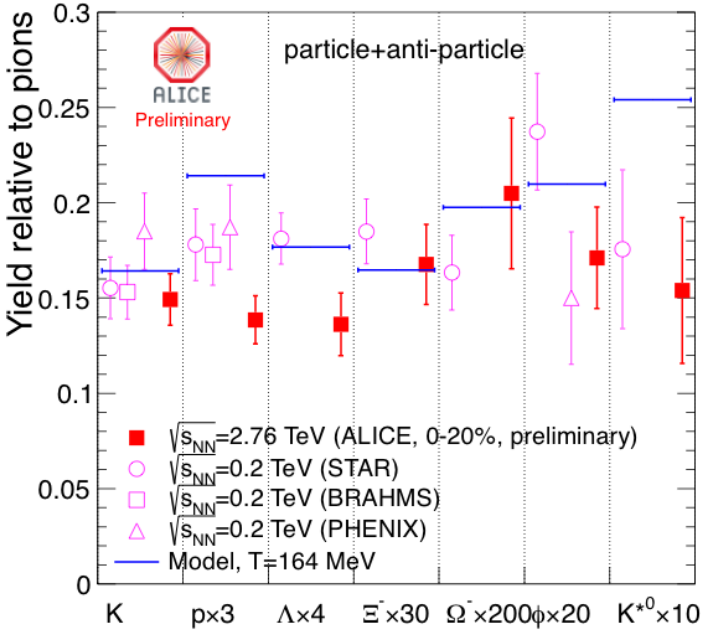
- **VISH2+1** (viscous hydro)
- **HKM** (Hydro+ UrQMD)
- **Krakow** (viscous corrections that lower the effective T_{ch})

(ALICE Collaboration), arXiv:1208.1974
(STAR Collaboration), Phys.Rev. C79,034909 (2009)
(PHENIX Collaboration), Phys.Rev.C69, 034909 (2004)
(VISH2+1) H. Song, S. A. Bass, and U. Heinz, Phys. Rev. C83
(HKM) Y. Karpenko, Y. Sinyukov, and K. Werner, (2012), arXiv:1204.5351[nucl-th]
(Krakow) P. Bozek, Phys. Rev. C85, 034901 (2012)

Thermal fit



- feed-down correction: STAR (proton -37%) , PHENIX (π -10%)
- decreasing ratios at the LHC?
- p/π and Λ/π different at the LHC



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- T_{ch} =164 MeV from lower energies extrapolation

A. Andronic et all J. Phys. G 38 (2011) 124081

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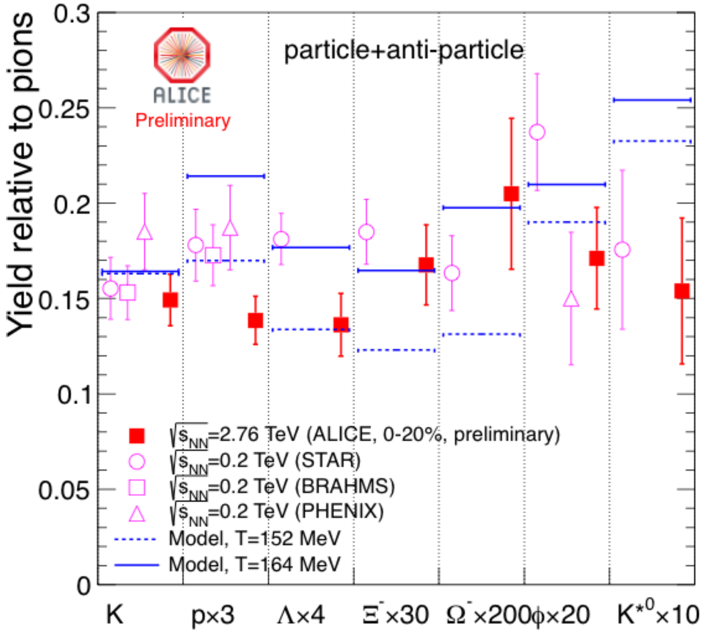
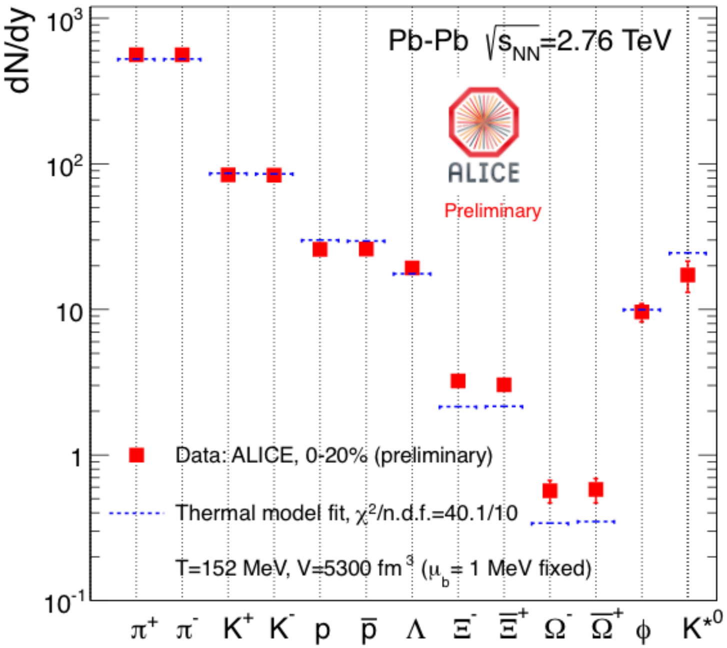




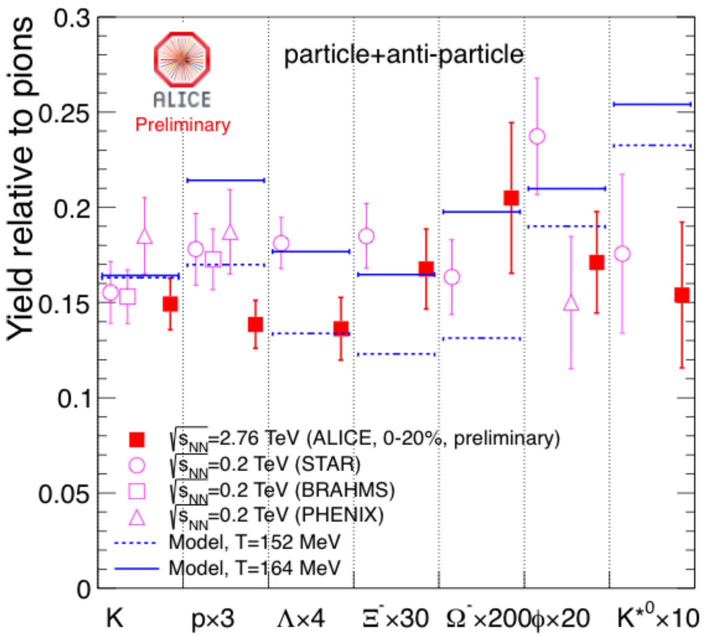
- feed-down correction: STAR (proton -37%) , PHENIX (π -10%)
- decreasing ratios at the LHC?
- p/π and Λ/π different at the LHC

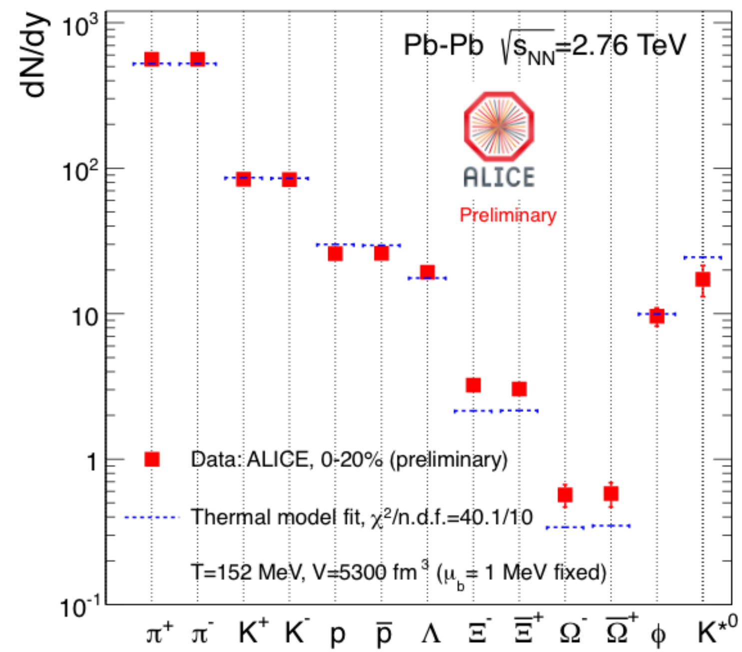
- T_{ch} =164 MeV from lower energies extrapolation
- T_{ch} =152 MeV from fit

A. Andronic et all J. Phys. G 38 (2011) 124081

- ALICE data are feed-down corrected, K*(892) and φ not included in the fit
- lower T_{ch} from fit = 152 MeV

Thermal fit





- feed-down correction: STAR (proton -37%) , PHENIX (π -10%)
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A. Andronic et all J. Phys. G 38 (2011) 124081

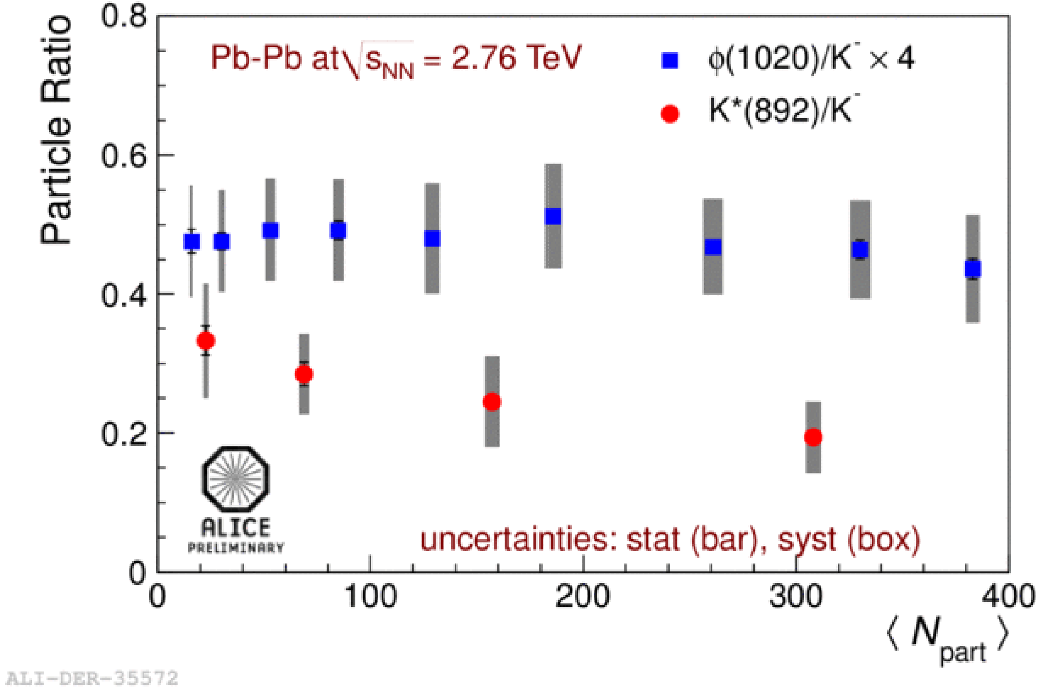
- ALICE data are feed-down corrected, K*(892) and φ not included in the fit
- lower T_{ch} from fit = 152 MeV
- possible explanation*: hadronic interactions

*J. Steinheimer, J. Aichelin, M. Bleicher, arXiv:1203.5302v1 [nucl-th]

*F. Becattini, M. Bleicher, T. Kollegger, M. Mitrovski, T. Schuster, R. Stock, arXiv:1201.6349v1 [nucl-th]

Resonance suppression in central Pb-Pb collisions?

Talk: S. SINGHA on 16 Aug
Parallel 5A: Hadron Thermodynamics and Chemistry



- ϕ/K ~ constant with centrality
- K*(892)/K: hint of decrease with centrality

- Possible explanation:

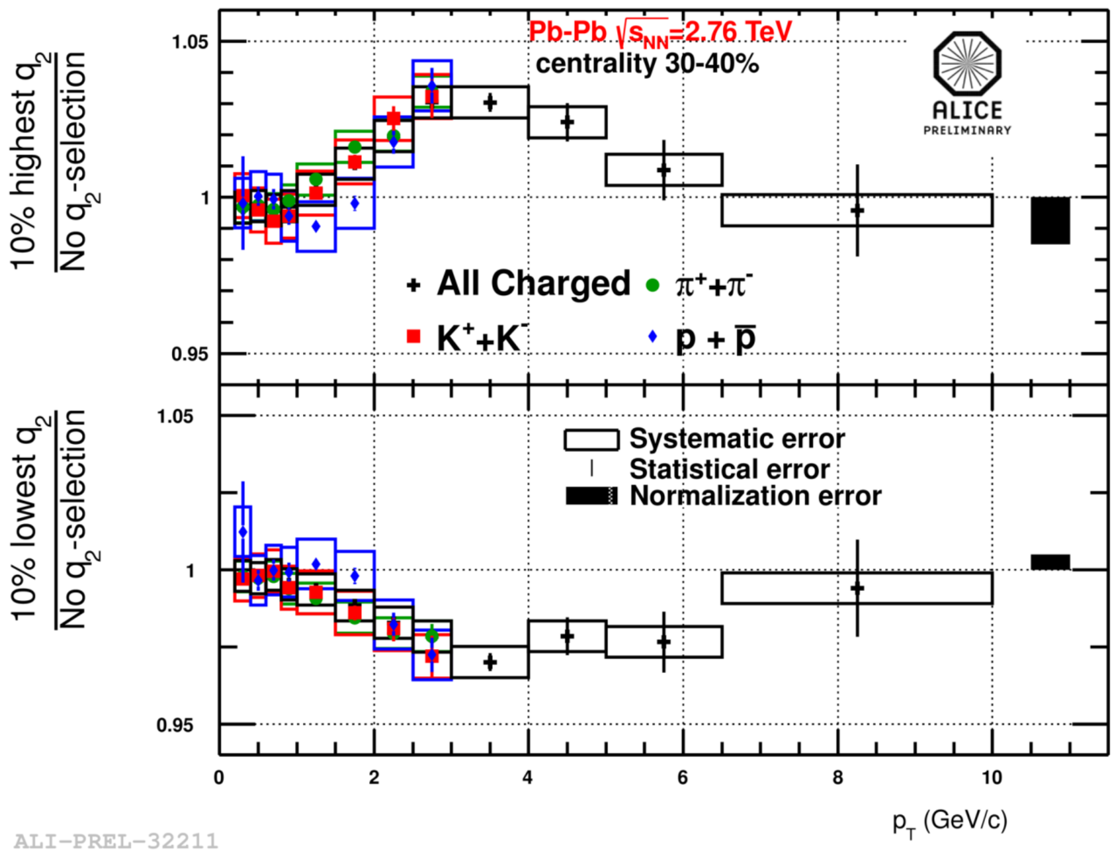
→Re-scattering of decay daughters in hadronic medium. (More effective for short lived resonance $\tau_{K^*} < \tau_{\phi}$)

hadronic interactions

G. Torrieri and J. Rafelski, Phys. Lett. B 509, 239 (2001)
M. Bleicher and J. Aichelin, Phys. Lett. B530 (2002) 81.

	Lifetime (fm/c)
K*(892)	4
ϕ	45

p_T-spectra vs E-by-E flow



More details on
Event shape engineering – ESE

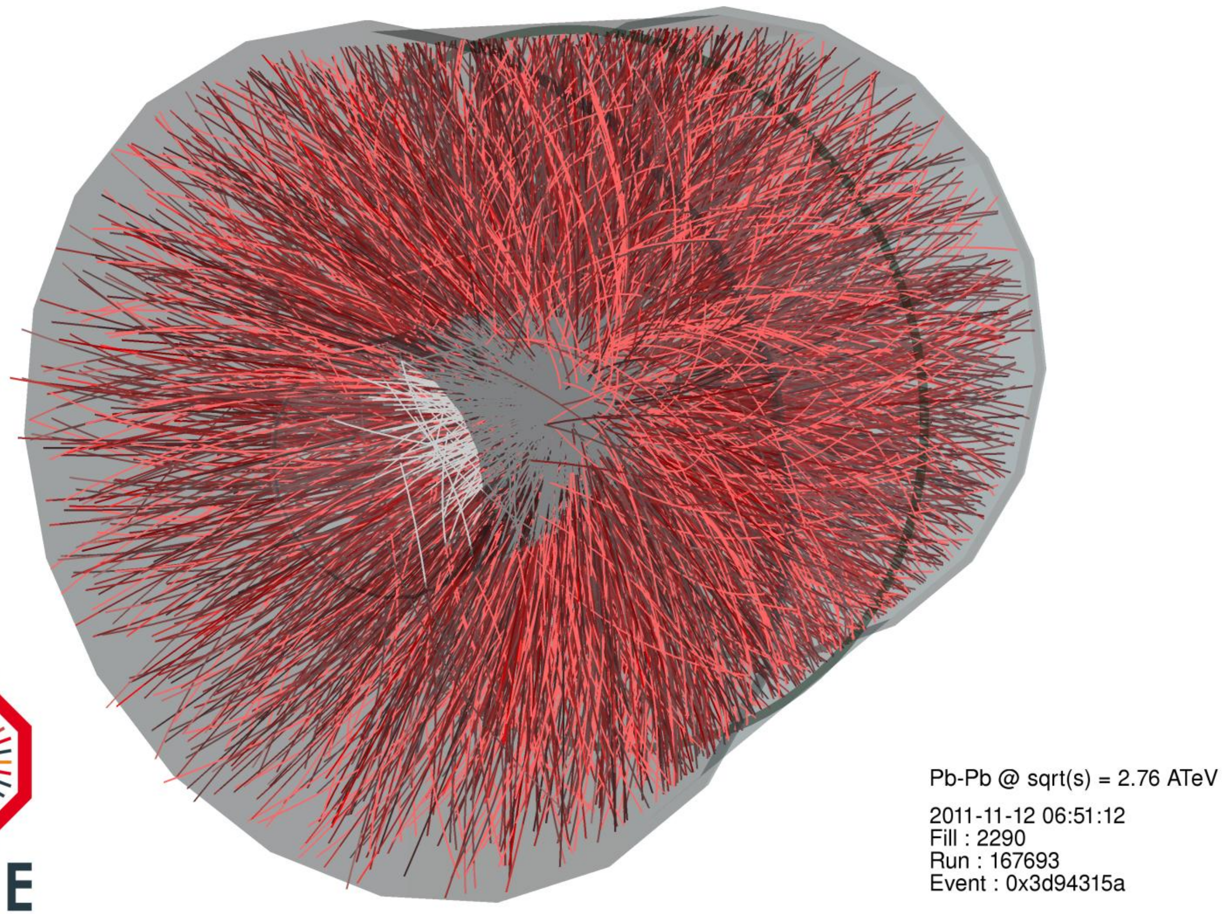
Talk: Prof. S. VOLOSHIN on 13 Aug
Plenary ID: Initial State, Global & Collective Dynamics
Talk: A. DOBRIN on 14 Aug
Parallel 1C: Correlations & Fluctuations

For a fixed centrality flow fluctuates.
p_T spectra for events with 10% highest (lowest) q_2 value (q_2 <-> elliptic flow):

- modification of the p_T-spectra
- larger flow (q_2) ⇒ harder spectra
- increased radial flow ?
- similar effect for all particle species

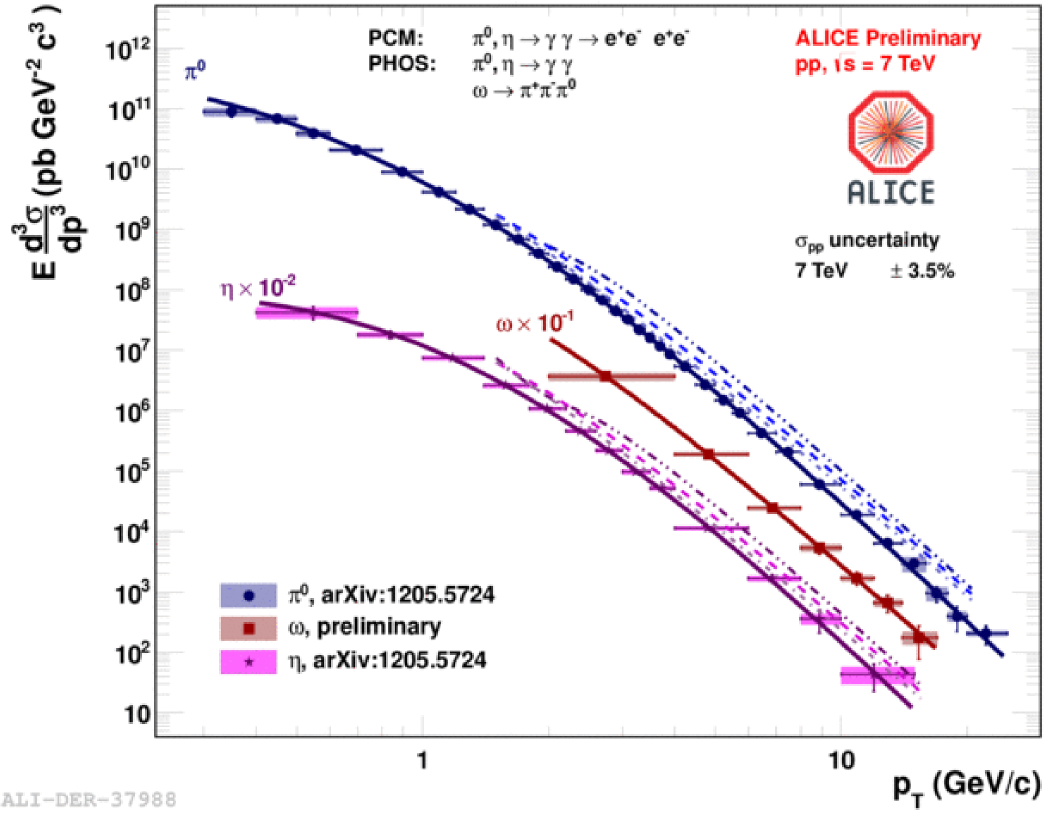
Talk: L. MILANO on 16 Aug
Parallel 5A: Hadron Thermodynamics and Chemistry

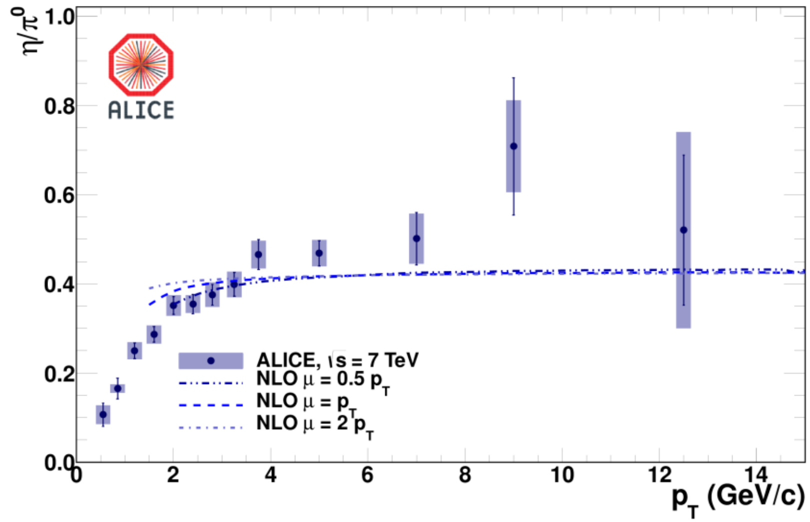
Towards jet quenching with PID



Neutral meson production in pp collisions

ALICE data: CERN-PH-EP-2012-001, arXiv.1205.5724



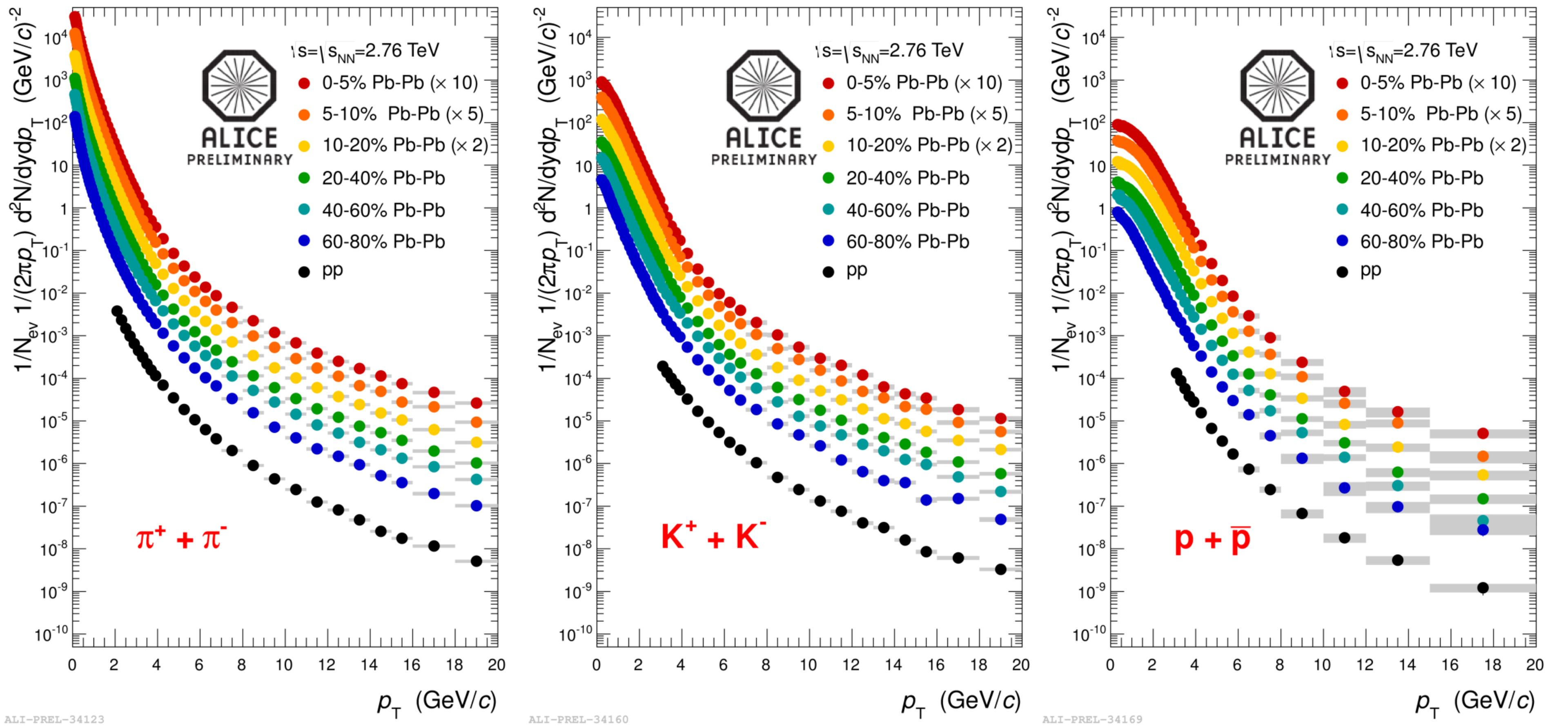


Talk: D.PERESUNKO on 15 Aug 12:00
Session: Parallel 4B: Jets
Poster: S. YANO, P. GANOTI

pQCD NLO calculations [*] reproduce pp data at √s = 900 GeV, but overestimate π^0 and η spectrum at √s = 7 TeV.
At √s= 7 TeV the measured η/π^0 ratio is reproduced by pQCD.
[*] P. Aurenche et al., Eur. Phys. J. C13, 347-355 309 (2000).

Pb-Pb results and R_{AA} are coming soon

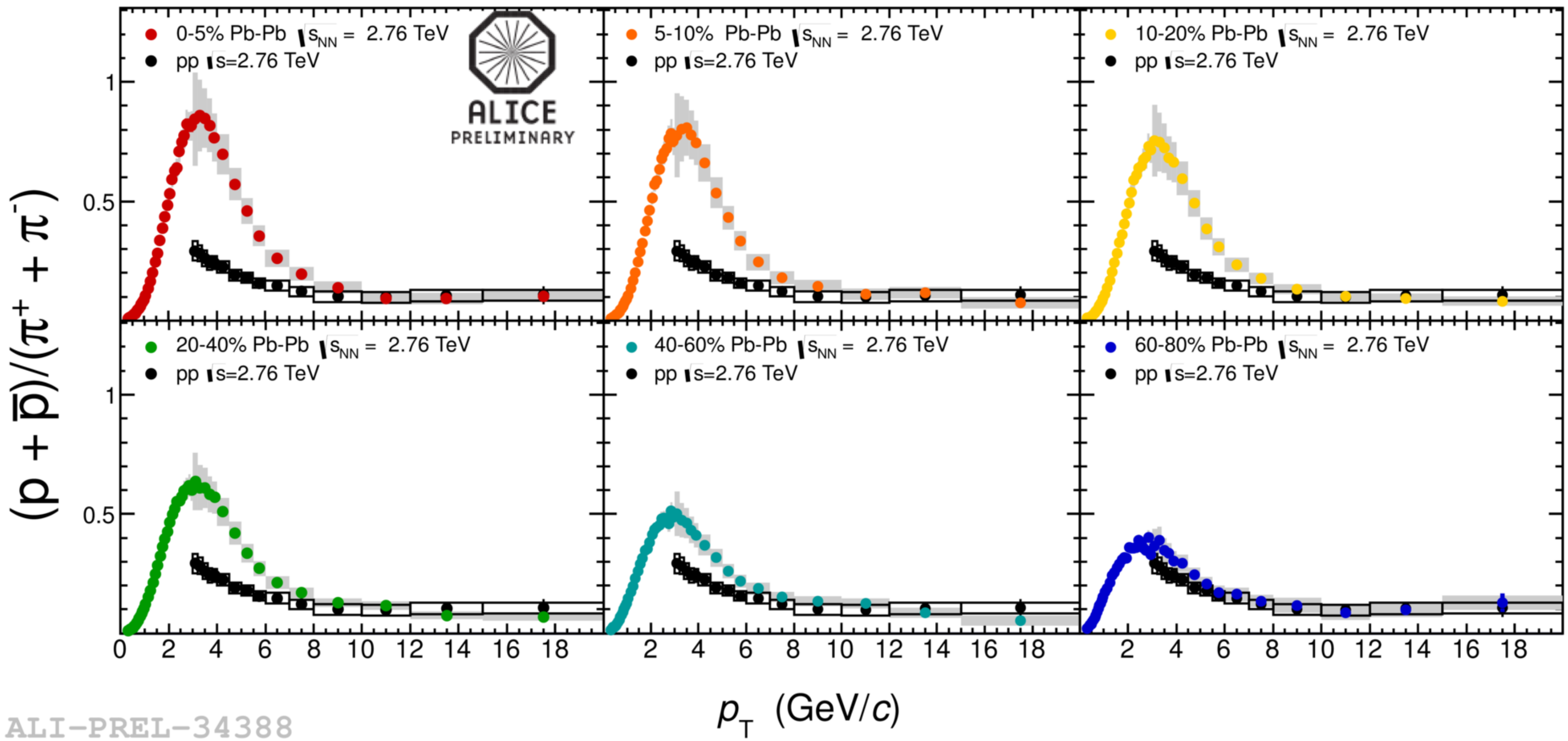
Identified particle spectra



High p_T results - first time PID up to 20 GeV/*c* :
Pions: p_T >2 GeV/*c* Protons and Kaons: p_T> 3 GeV/*c*.

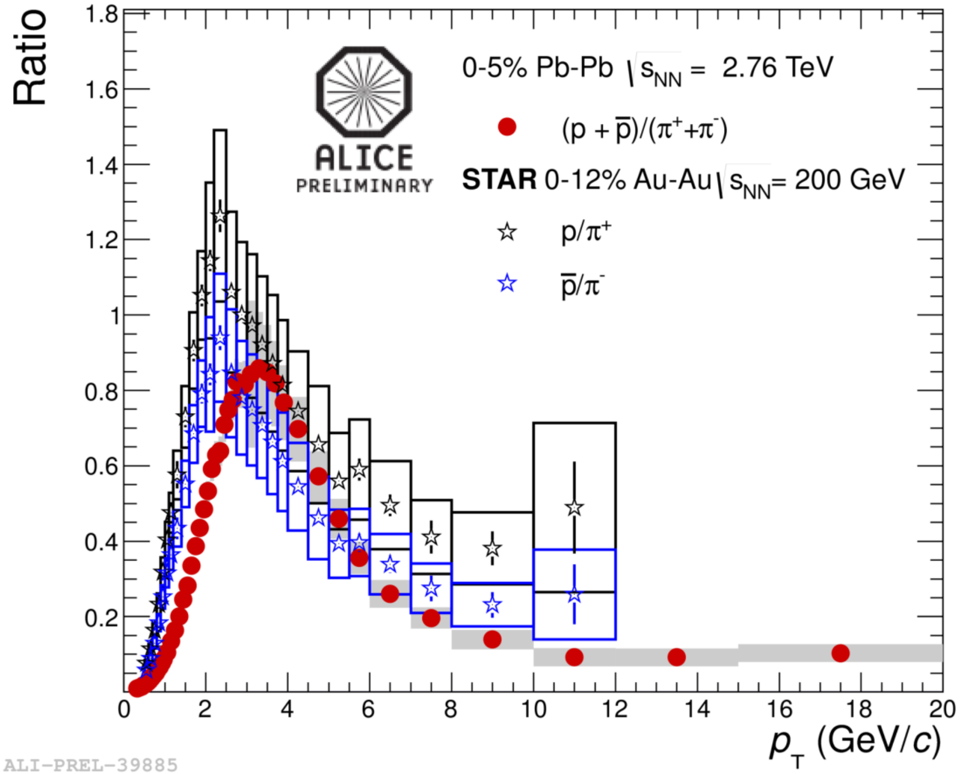
Talk: A. ORTIZ on 16 Aug, 14:20
Parallel 5C: High pt and Jets

Intermediate p_T region: comparison with RHIC



Intermediate p_T: 3-7 GeV/c, enhancement of the baryon to meson ratio.

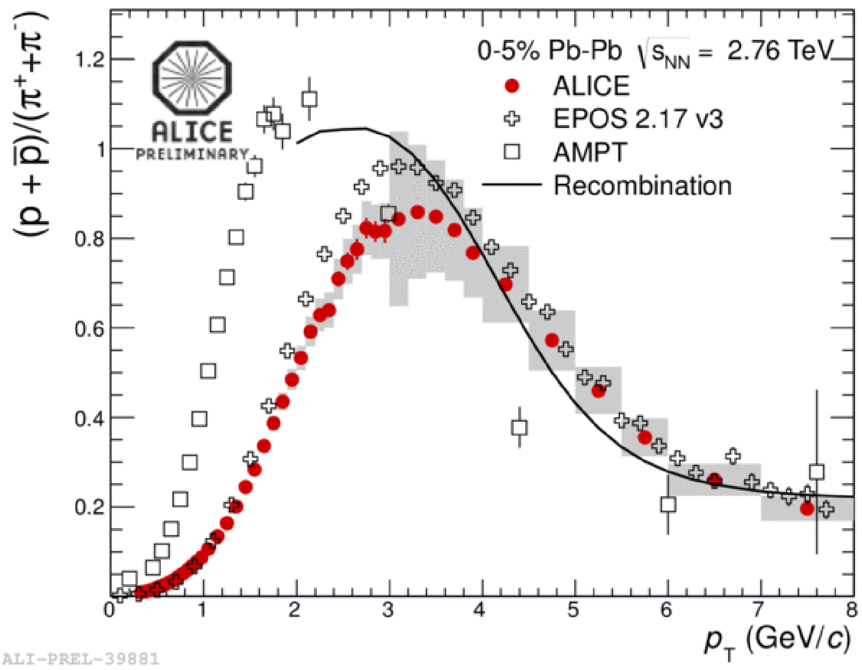
Intermediate p_T region: comparison with RHIC

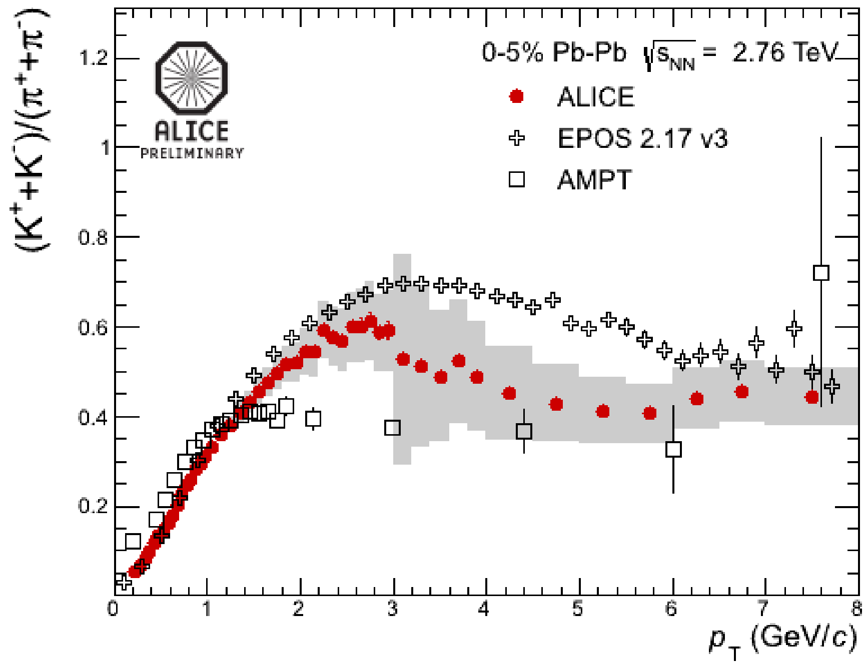


STAR data not feed-down corrected

Intermediate p_T: 3-7 GeV/*c*, enhancement of the baryon to meson ratio. Qualitatively comparable to RHIC results but maximum is shifted.

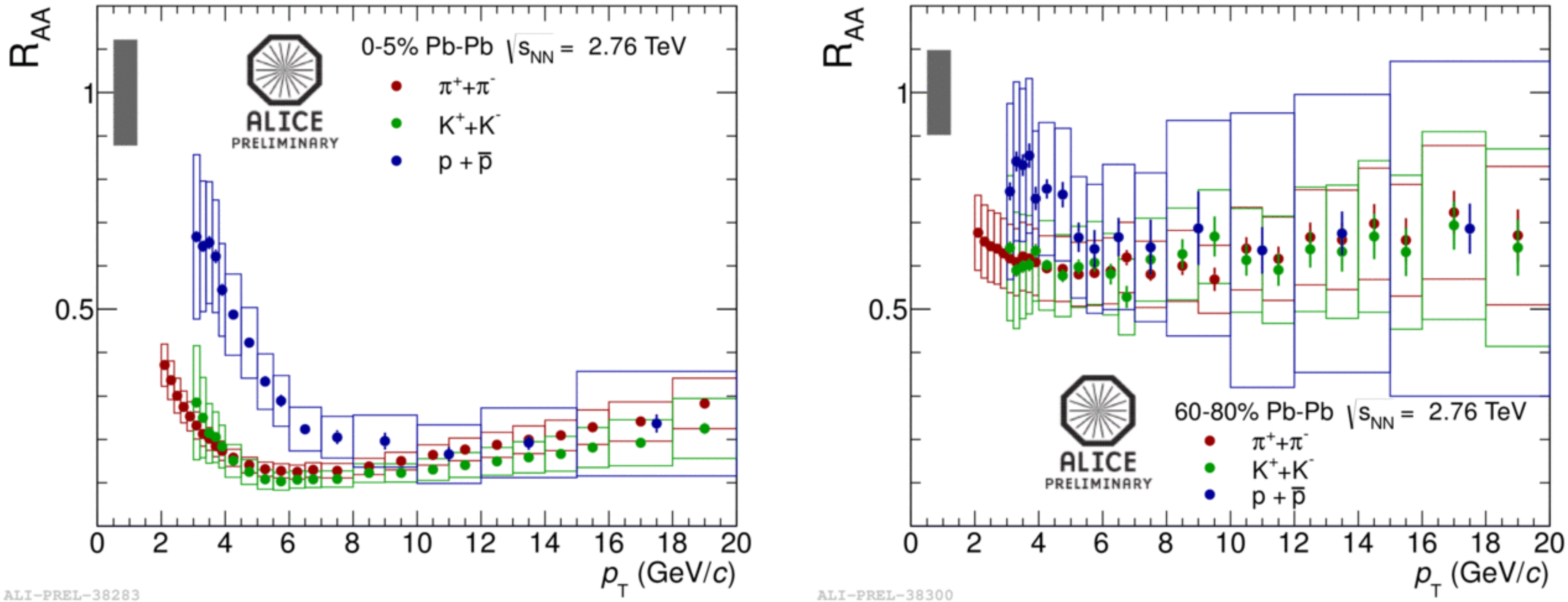
Intermediate p_T region: comparison with theory





EPOS: K. Werner et all, arXiv:1204.1394, arXiv:1205.3379.
AMPT: J. Xu and Che Ming Ko, Phys. Rev. C 83, 034904 (2011).
Recombination: R.J.Fries, B.Muller, C.Nonaka and S.A.Bass, Phys. Rev. C 68, 044902 (2003)

R_{AA} of identified hadrons



For $p_T < 8$ GeV/c: R_{AA} for π and K are compatible and they are smaller than R_{AA} for proton.

At high p_T above 10 GeV/c the R_{AA} for π, K and proton are compatible within systematic error.

This suggest that leading particle jet hadron chemistry effects are small if present, unlike in the jet hadrochemistry model of Sapeta and Wiedemann.

Eur. Phys. J. C. 55, 293-302 (2008)

Conclusion

We presented the measurement of the identified charged hadron spectra. The ALICE central barrel provides precision tracking and PID in the broad momentum range $0.1 < p_T < 50$ GeV/c.

At the low p_T region the data were compared with the hydrodynamic models. Hydrodynamic models with an explicit late fireball description reproduce the experimental data.

The measured particle yields were compared to the prediction of the thermal model based on the RHIC and SPS data.

In the intermediate p_T region, we observe an enhancement of the baryon to meson ratio. The maximum is shifted wrt RHIC measurements.

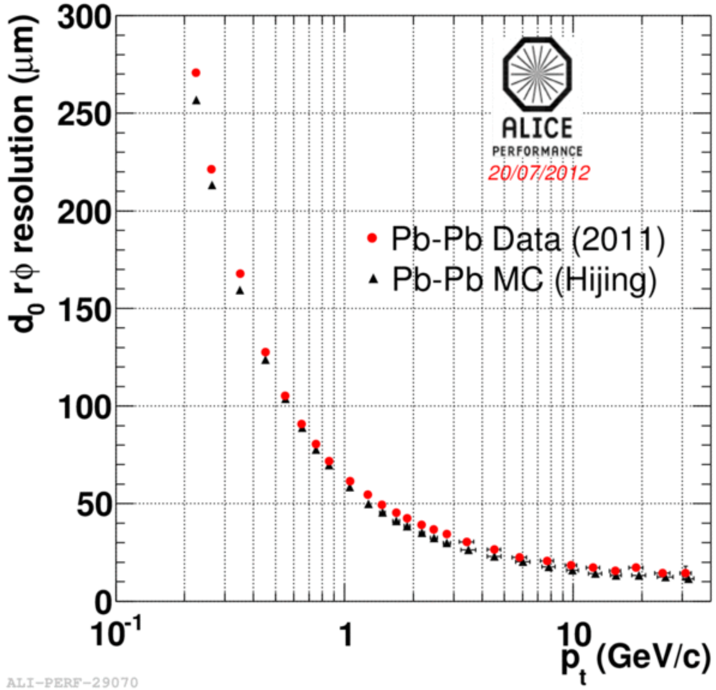
First measurement of (anti-)proton, K and π at high p_T region (>7 GeV/c) presented. The R_{AA} for (anti-)protons, charged π and K are compatible, this suggests that the medium does not affect the fragmentation.

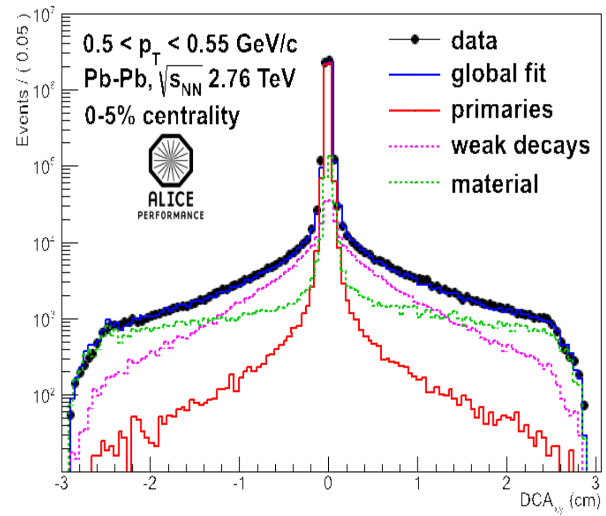
Backup

Tracking performance - Vertexing

*A. Kalweit (ALICE), J. Phys. G38, 124073 (2011)

DCArϕ: Transverse distance-of-closest-approach





Good DCA resolution (~ 20 μm for large momenta)

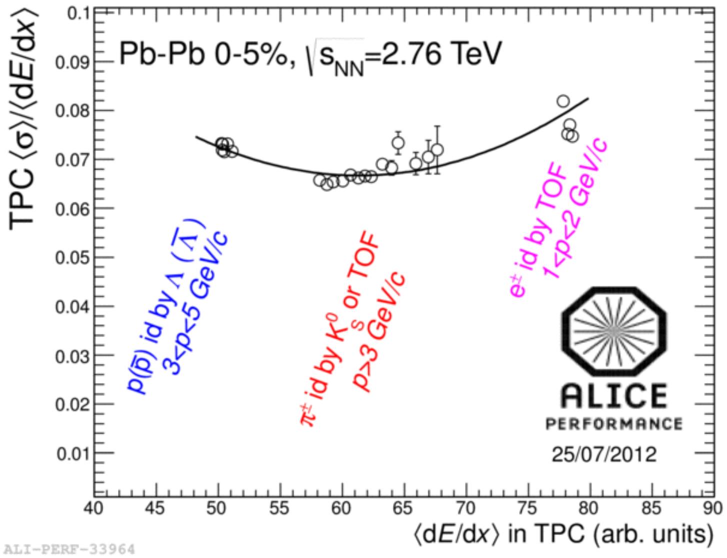
Tool to control contamination from secondaries

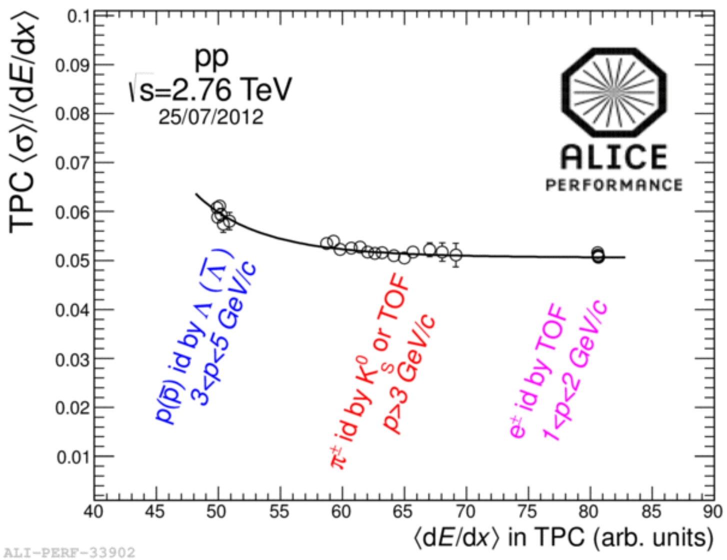
Strict resolution based DCA cut, small contamination

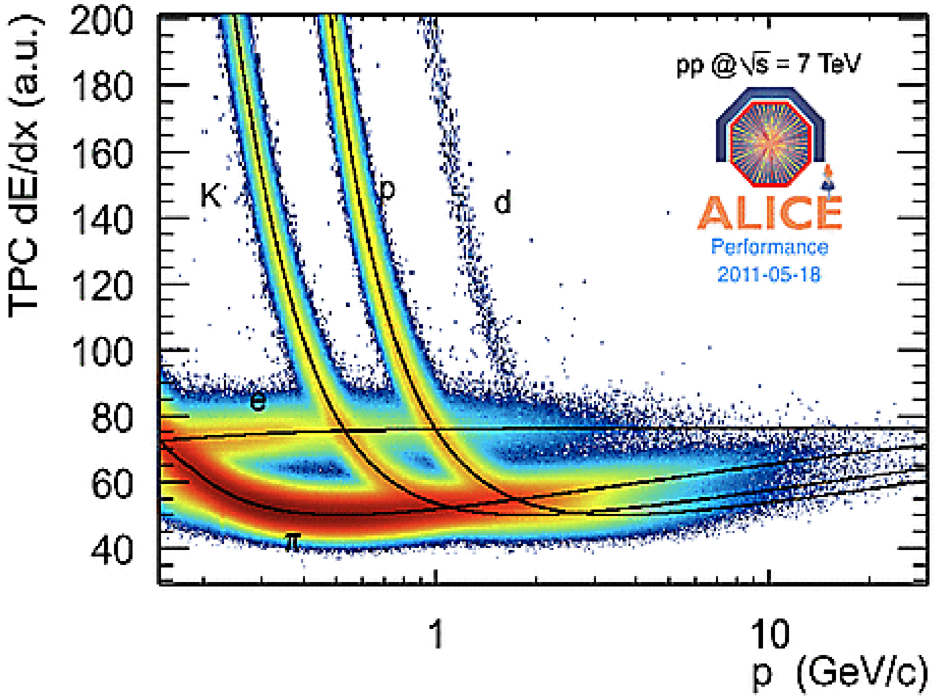
Residual contamination: MC + DCArϕ fits

Less than 1% for pt > 4 GeV/c

Getting the ultimate TPC dE/dx - PID at high p_T

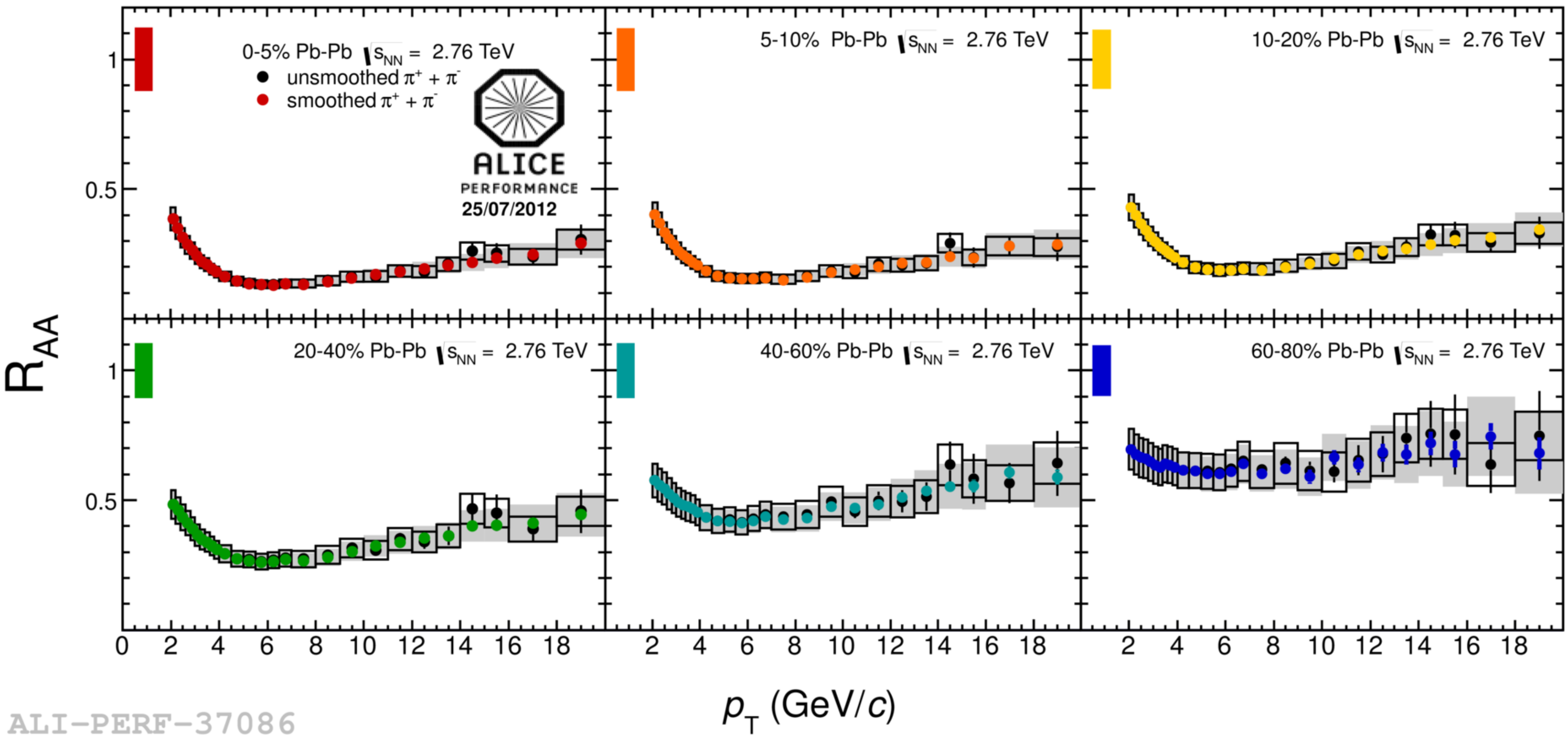






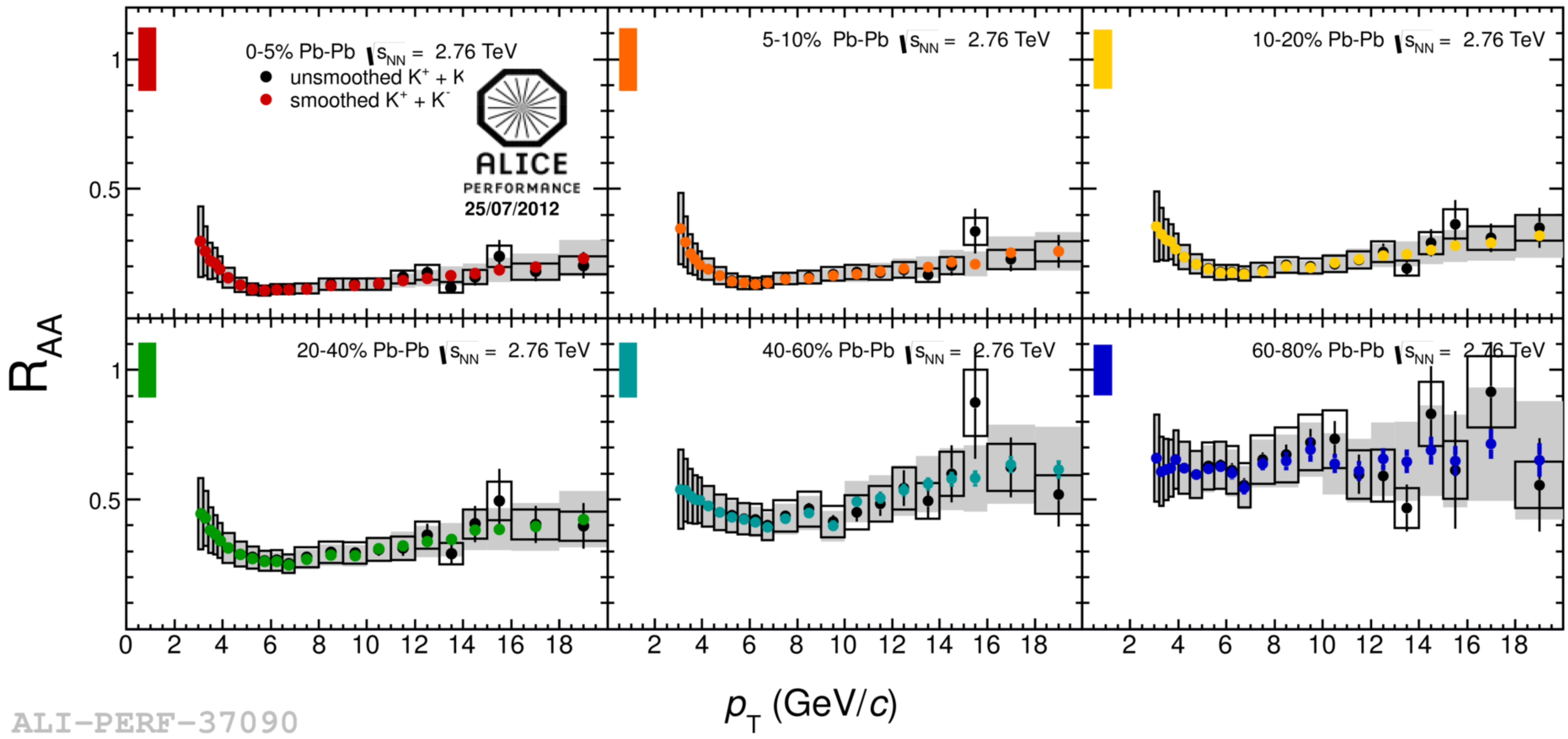
Performance close to the design value ~ 5.5 % at MIP position at low multiplicity and ~ 6.8 % for central Pb-Pb collisions

R_{AA} for charged pions



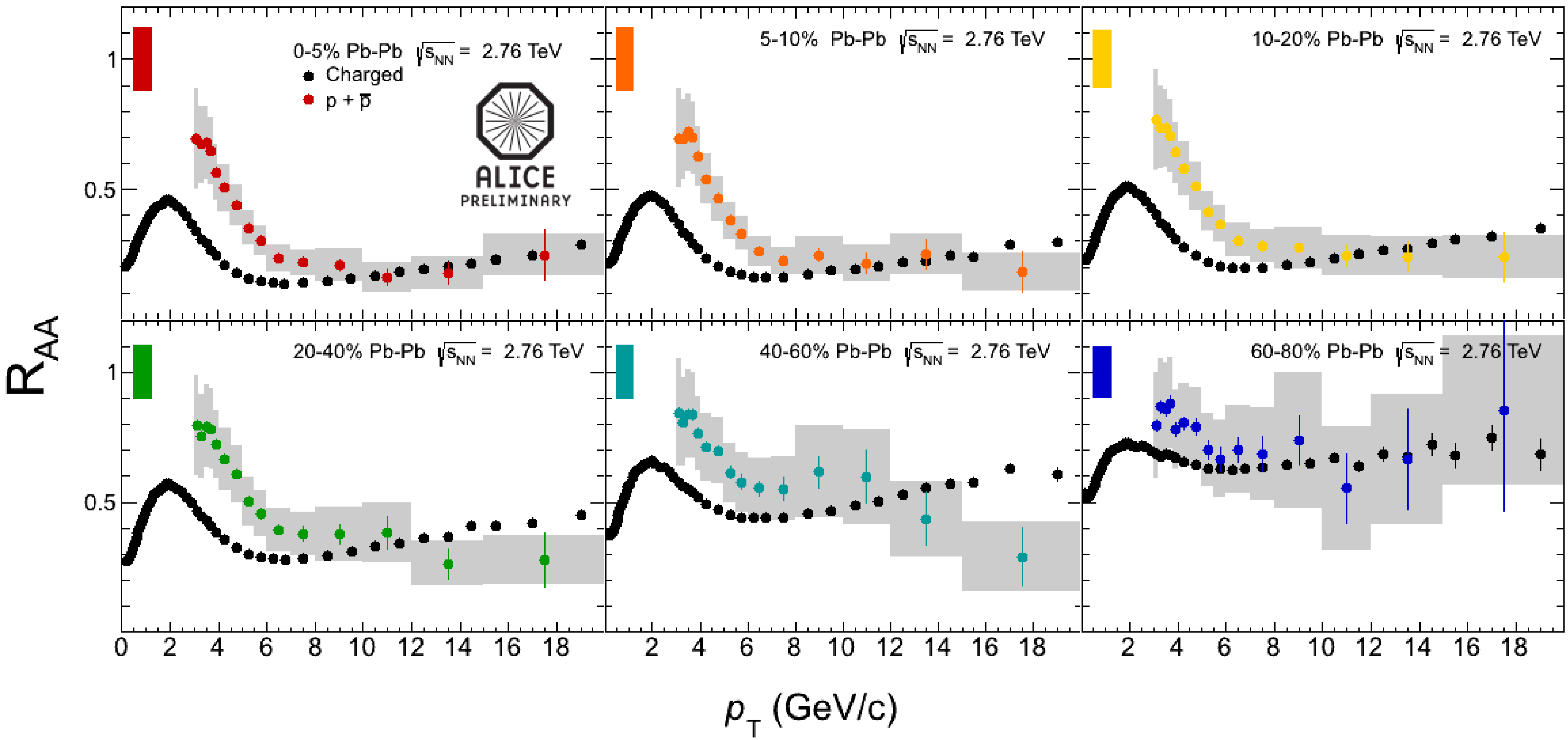
$p_T < 7$ GeV/c, R_{AA} for charged pions < R_{AA} for inclusive charged particles
$p_T > 7$ GeV/c, R_{AA} for charged pions ~ R_{AA} for inclusive charged particles

R_{AA} for charged kaons



R_{AA} for charged kaons compatible with R_{AA} for inclusive charged particles

R_{AA} for (anti-)protons



$p_T < 7$ GeV/c, R_{AA} for (anti-)protons > R_{AA} for charged pions
$p_T > 7$ GeV/c, R_{AA} for (anti-)protons compatible with R_{AA} for inclusive charged particles

Getting the ultimate TPC dE/dx - PID at high p_T

Requirements:

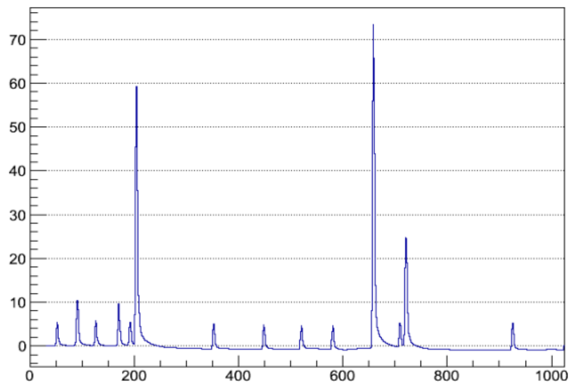
- Pad-by-pad (550,000 channels) gain calibration using the ^{83}Kr decay.
- Keep gain stable within 0.2 % - frequently updated (15 minutes). Calibration following the change of the pressure, temperature and gas composition.

Optimization of d*E*/d*x* algorithm for TPC:

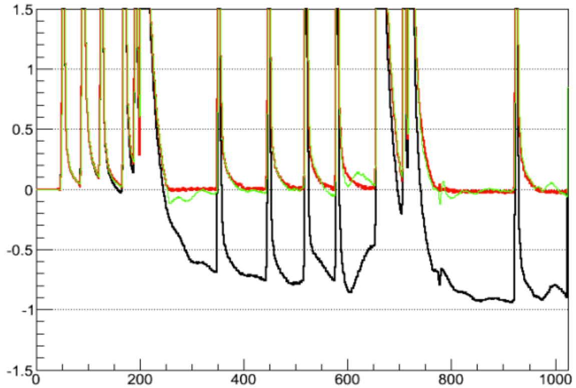
- Signal integration - Correction for the signal below threshold
- Consideration of one pad and missing clusters

Ion tail effect correction (for Pb-Pb):

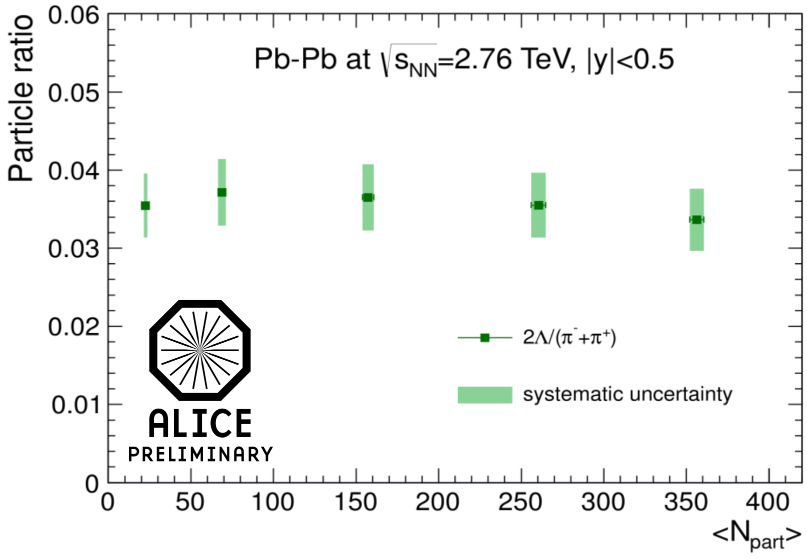
- Effective correction for the track- multiplicity dependent baseline shift ()
- Future improvement - preprocessing of signal shape

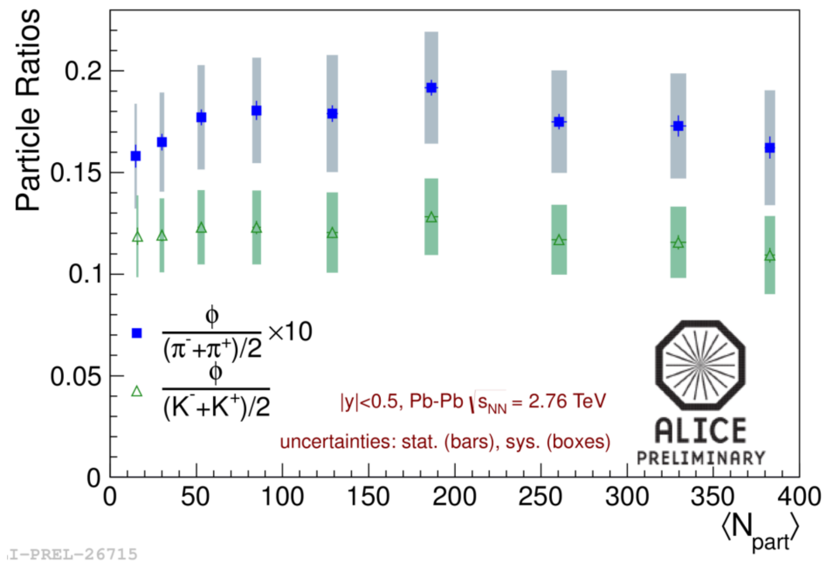


Unfold



Particle ratios : centrality dependence





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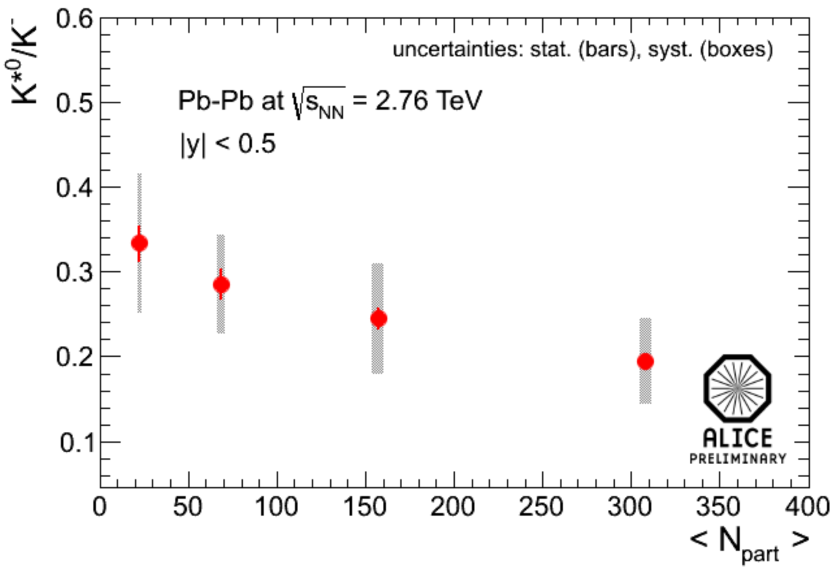
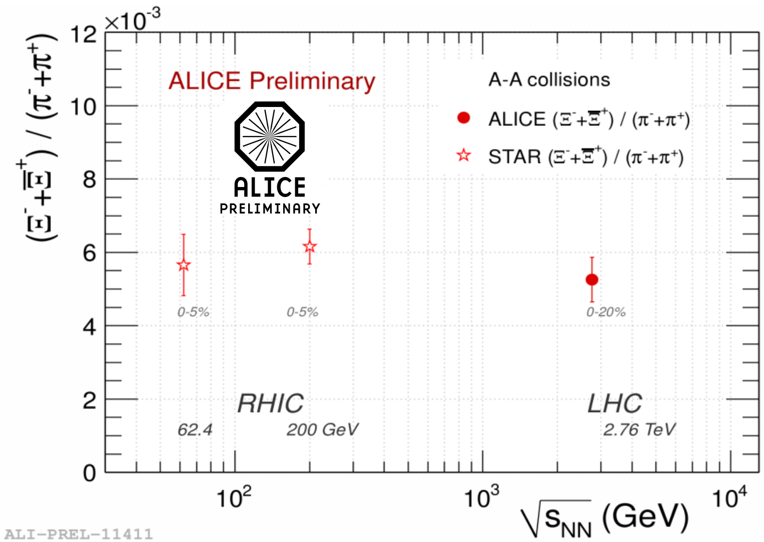


Λ/π → independent of collision centrality.

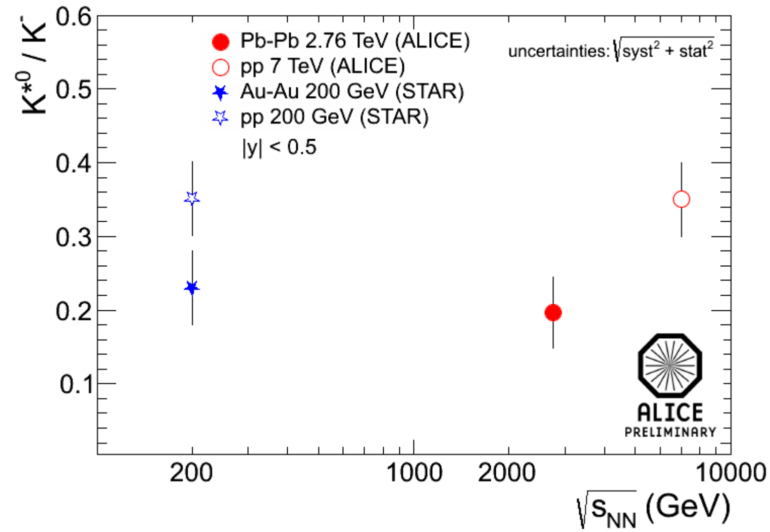
ϕ/K , ϕ/π → independent of collision centrality → rules out ϕ production through Kaon coalescence.

K^{*0}/K^- weak dependence on collision centrality.
Decreasing trend in K^{*0}/K^- seems to suggest a possible increase in re-scattering effects for central collisions

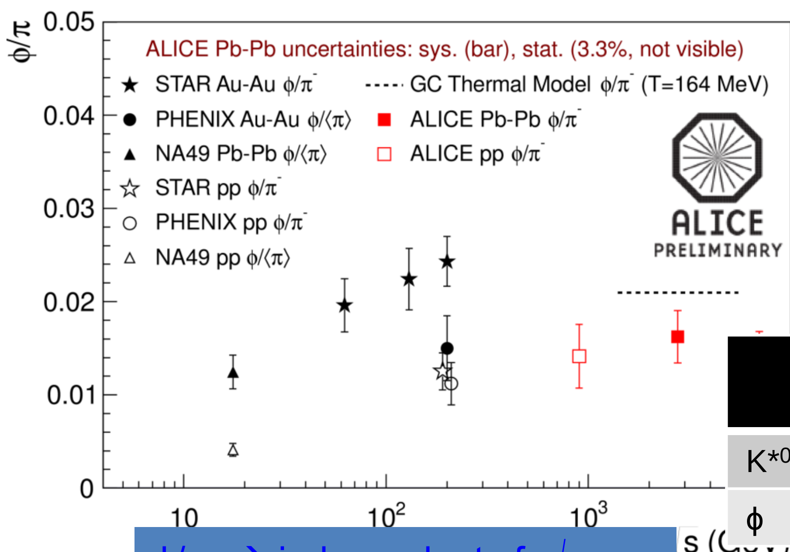
Particle ratios : energy dependence



Ξ/π → independent of $\sqrt{s}$

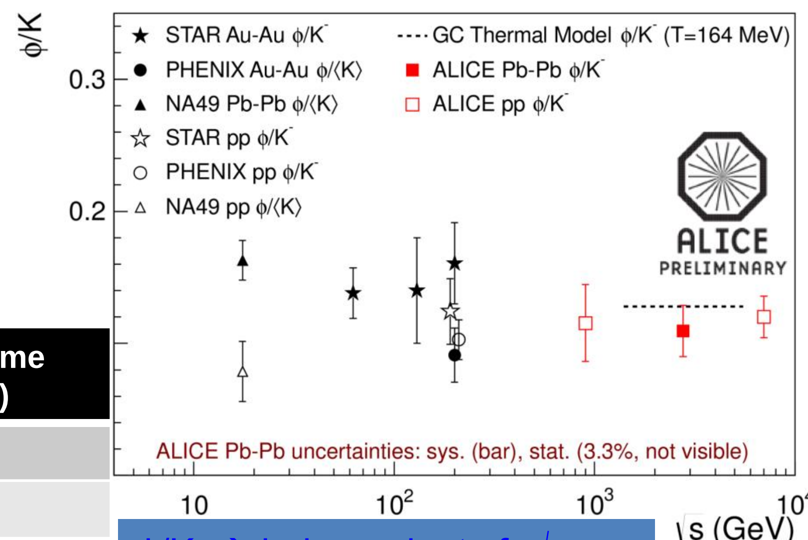


$(K^*/K)_{AA} < (K^*/K)_{pp}$ → re-scattering effects



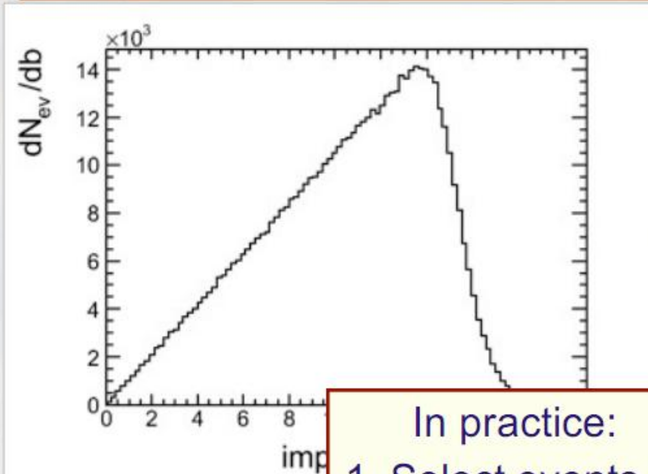
ϕ/π → independent of $\sqrt{s}$

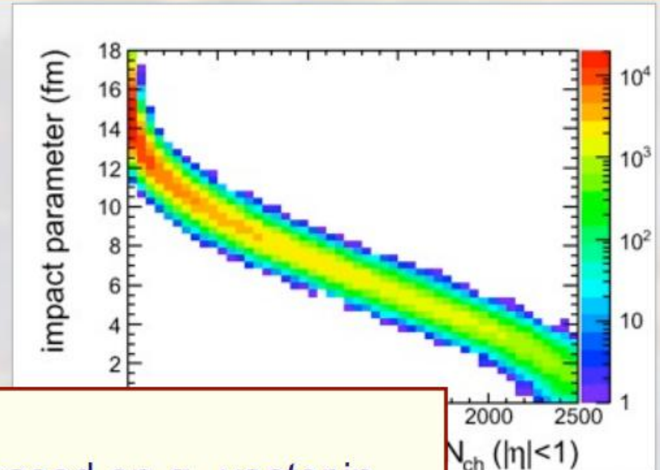
	Lifetime (fm/c)
K^{*0}	4
ϕ	45



ϕ/K → independent of $\sqrt{s}$

ESE: → Events(centrality,shape)



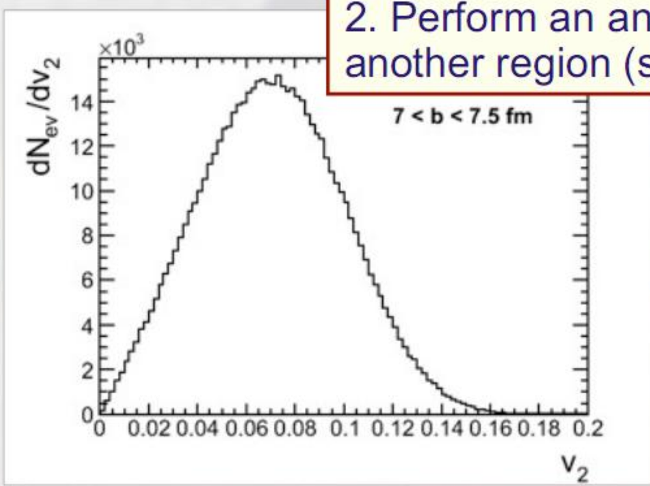


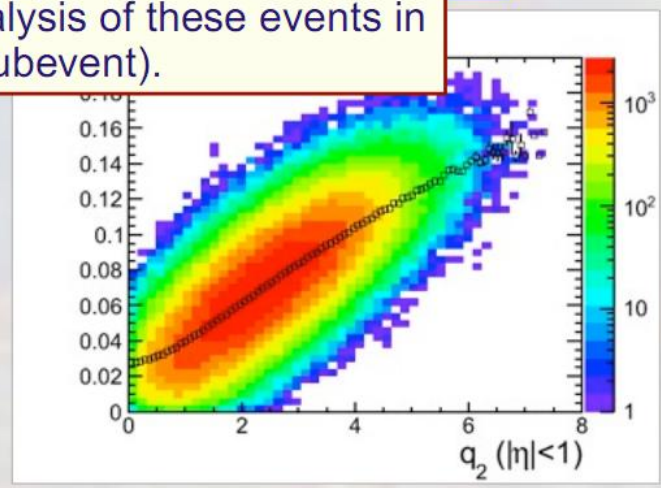
MC Glauber,with parameters tuned to LHC multiplicity and flow

In practice:

1. Select events based on q_n-*vector* in one momentum region ("subevent")
2. Perform an analysis of these events in another region (subevent).

city





$$Q_{n,X} = \sum_{i=1}^{M} \cos(n\phi_i)$$

$$Q_{n,Y} = \sum_{i=1}^{M} \sin(n\phi_i)$$

$$q_n = Q_n/\sqrt{M}$$

For a fixed centrality, flow fluctuates. Can we select events with given v_n?

Yes, e.g. based on the length of flow vector.

Voloshin, PRL **105** 172301 (2010)