Status Report

105th LHCC Meeting - Open Session

Mateusz Ploskon

on behalf of the ALICE Collaboration

Outline

- Activities during 2010/2011 shutdown
- Proton-proton collisions: summary of results and new measurements
- Overview of the first publications in Pb-Pb
- Performance and new physics results from heavy-ion collisions
- Outlook

ALICE Christmas break schedule

ALICE performed a very busy shutdown program that was concluded successfully on time.
The EMCAL system was finalized (6 supermodules) and 3 TRD modules were installed.

	Dec				Jan					Feb	
Wk	49	50	51	52	1	2	3	4	5	6	7
Mo	6	13	20	27	Close L3 I-side door 3	10	17	24	31	7	14
Tu											
We	Open Experiment		TRD		EMCal		Close L3 O-side door	Close Experiment			
Th											
Fr											
Sa		Open L3 doors	Xmas Day	NY Day							
Su											

Many other maintenance activities of detectors, infrastructure and central systems e.g.

TPC: Replacement of damaged frontend cards, change of TPC gas to improve stability, laser system upgrade.

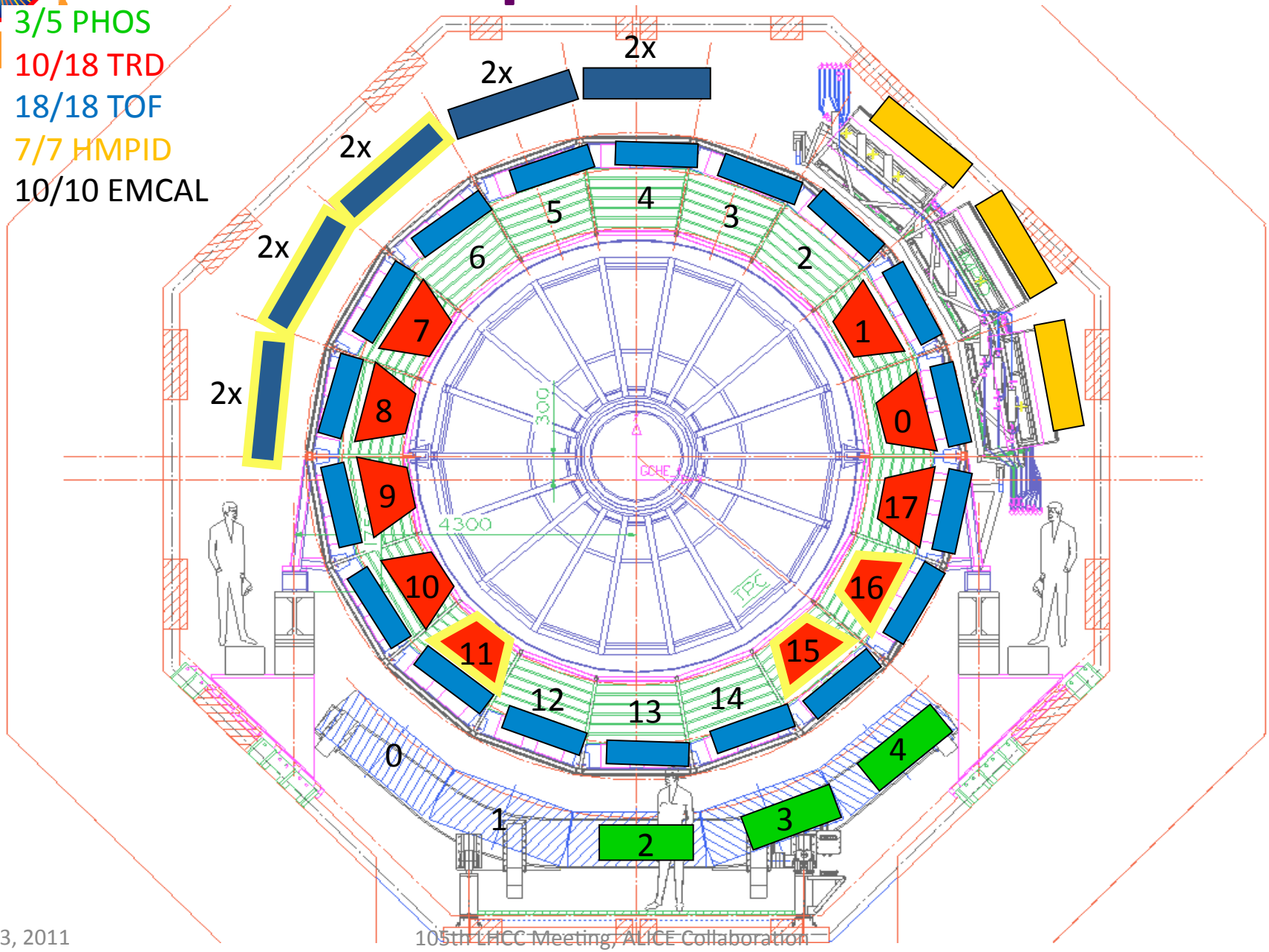
PMD: New re-circulating ventilation system for more efficient cooling.

Muon Tracking: Repairs of LV bus patches to improve pedestal stability.

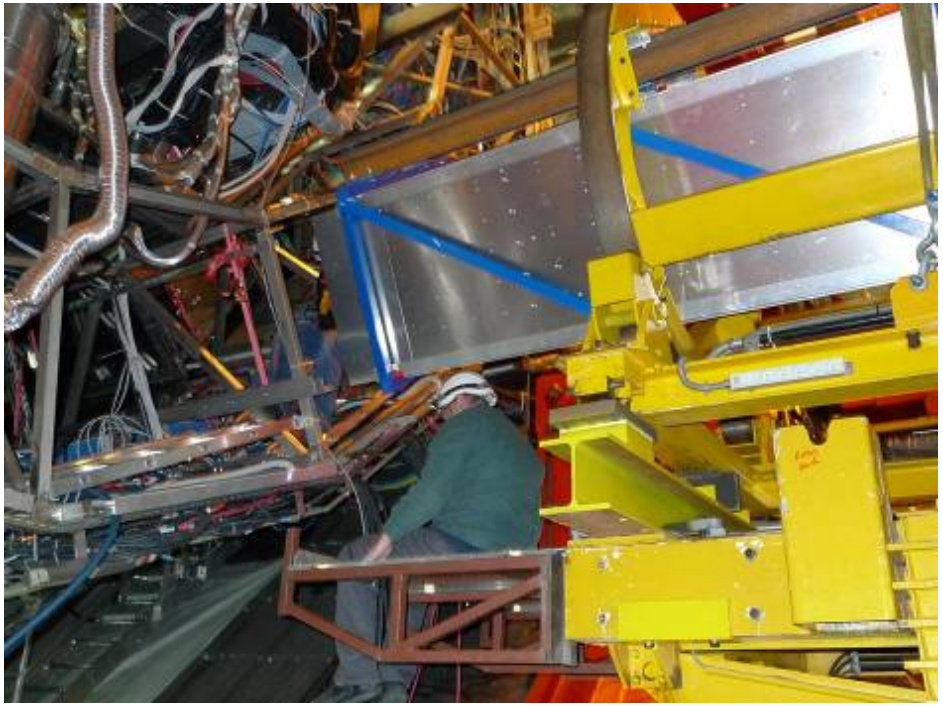
DAQ: Major upgrade including move from SLC 4.8 to SLC 5.5 & 32 bit to 64 bit architecture.

ALICE present status

3/5 PHOS
10/18 TRD
18/18 TOF
7/7 HMPID
10/10 EMCAL

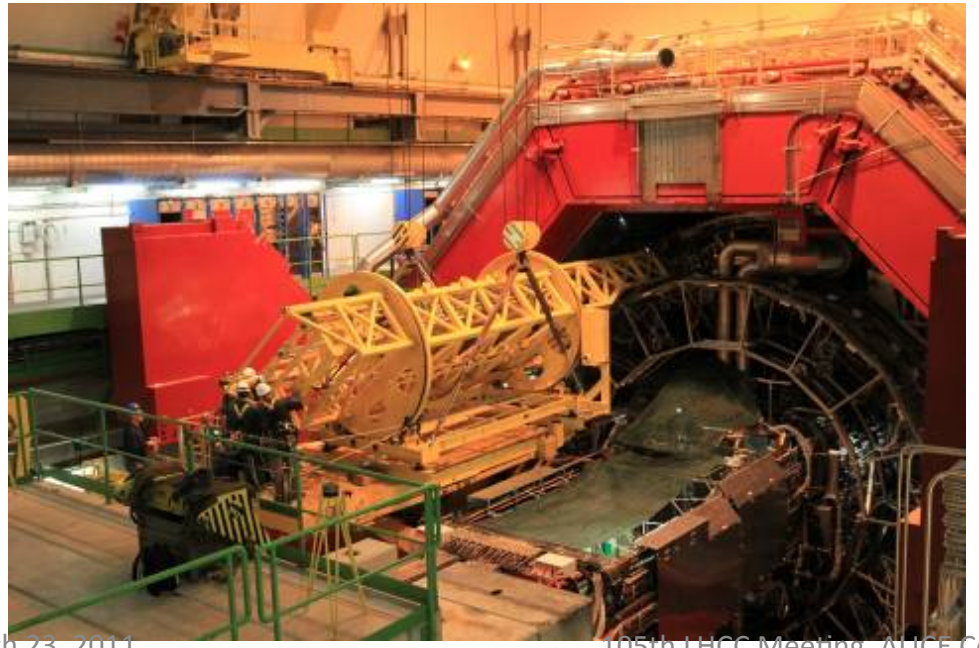


TRD installation



TRD module before insertion

EMCal installation



ALICE publications from p-p collisions

- Multiplicity & distributions
  - 900 GeV: EPJC: Vol. 65 (2010) 111
  - 900 GeV, 2.36 TeV: EPJC: Vol. 68 (2010) 89
  - 7 TeV: EPJC: Vol. 68 (2010) 345
- pbar/p ratio (900 GeV & 7 TeV) PRL: Vol. 105 (2010) 072002
- Momentum distributions(900 GeV) PLB: Vol. 693 (2010) 53
- Bose-Einstein correlations (900 GeV) PRD: Vol. 82 (2010) 052001

NEW since the last LHCC :

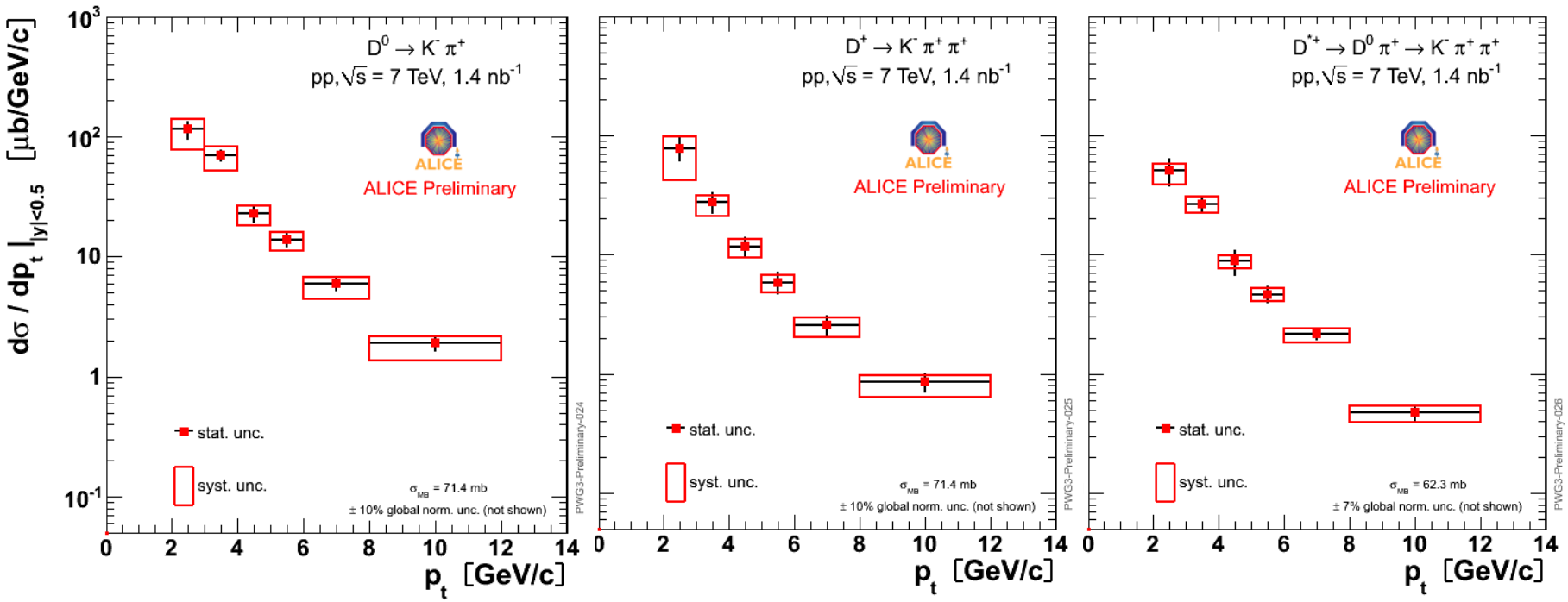
- Strangeness (K_0,Λ,Ξ,Ω,ϕ)
  - http://arxiv.org/abs/1012.3257 **accepted by EPJC**
- Identified charged particle spectra in pp at 900 GeV
  - http://arxiv.org/abs/1101.4110 **accepted by EPJC**
- Pion Bose-Einstein correlations in pp at 0.9 TeV and 7 TeV
  - http://arxiv.org/abs/1101.3665 submitted to Phys.Rev.D
- J/ψ production – under Collaboration review

In this talk we focus on material that has not been discussed earlier

HEAVY FLAVOR AND QUARKONIA IN PROTON-PROTON COLLISIONS

D meson production in p-p

Preliminary cross sections (with 10^8 m.b. events): D^0, D^+, D^*



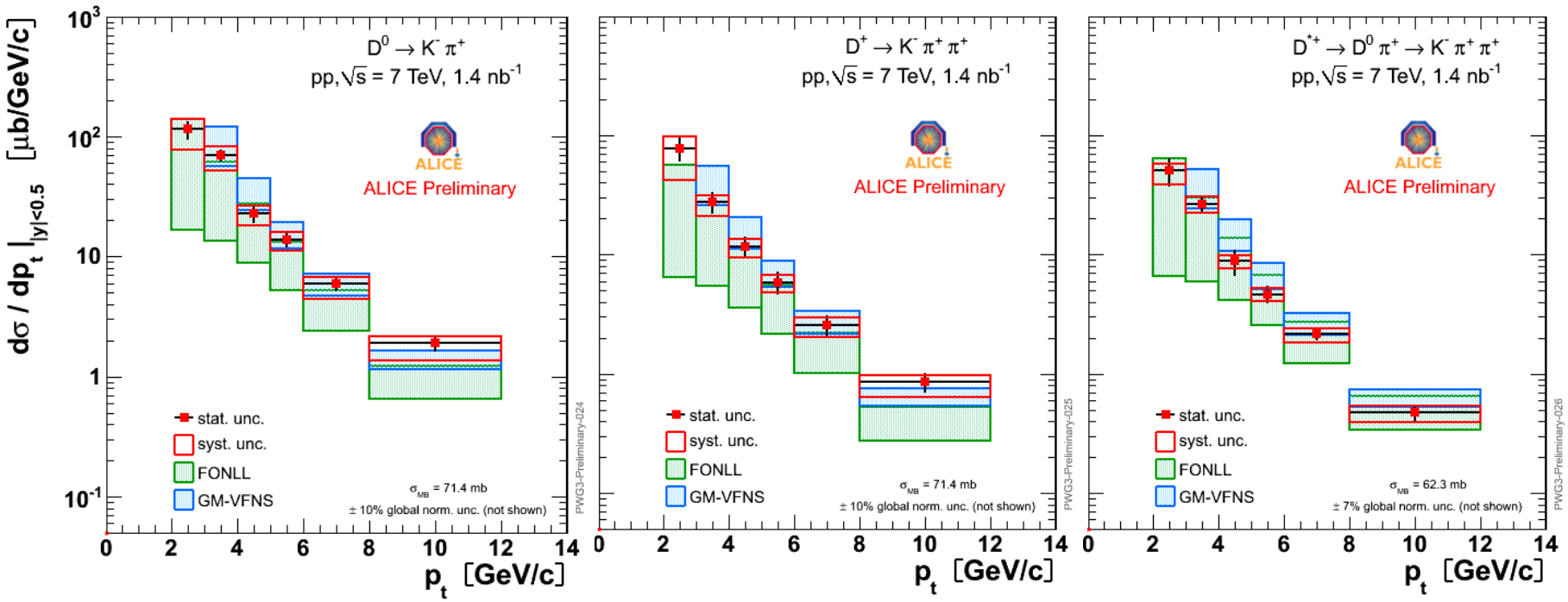
Feed-down from B mesons (after cuts ~10-15% for D^0, D^+, 5% for D^*) subtracted based on FONLL b cross section

Will be done based on data (displaced D mesons) with full 2010 sample (5x more statistics)

In addition: extended reach towards p_t=0 and p_t=20-25 GeV possible

D meson production in p-p

Preliminary cross sections (with 10^8 m.b. events): D^0, D^+, D^*

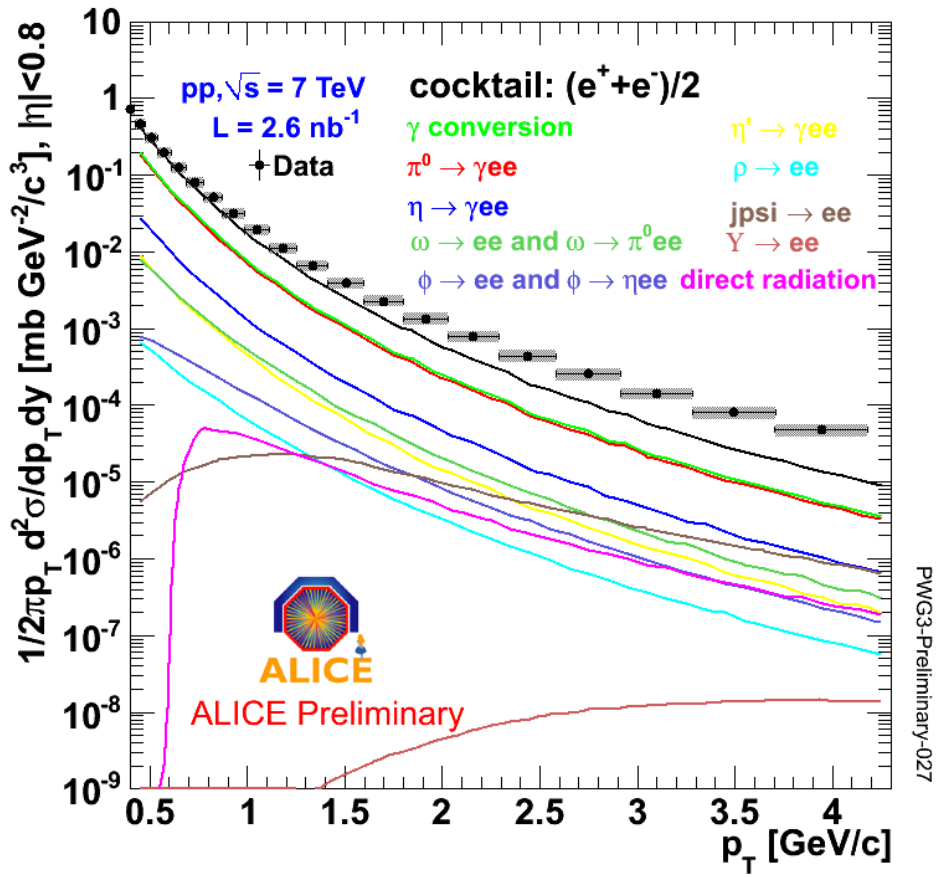


pQCD predictions (FONLL and VFNS) consistent with the data

FONLL: Cacciari et al. in preparation,
GMVFNS, Kniehl et al. in preparation

Electrons from HF decay in p-p

- High quality tracks in TPC and ITS
  - Hit in innermost pixel layer to reduce γ conversions (beam pipe + ~1/3 inner pixel = 0.5% X_0)
- **Electron identification: TOF + TPC-dE/dx**
- Two procedures to extract heavy flavor cross section:
  1. **subtract cocktail of "photonic" electron sources, based on measured π^0 cross section**
  2. select electrons with large displacement to primary vertex → beauty dominance (in progress)



Electrons from HF decay in p-p

1.6×10^8 m.b. events

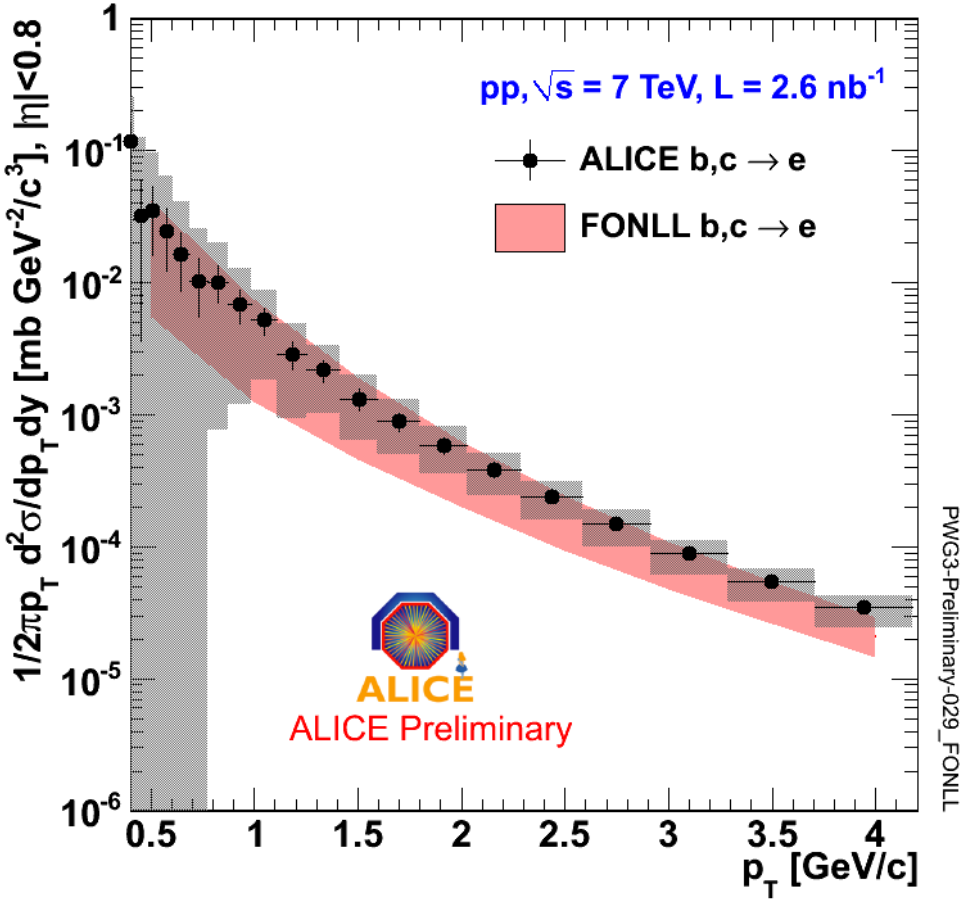
Cocktail of background electron sources subtracted from the data

Cross section of electrons from charm and beauty decays in $|\eta|<0.8$

Good agreement with pQCD FONLL

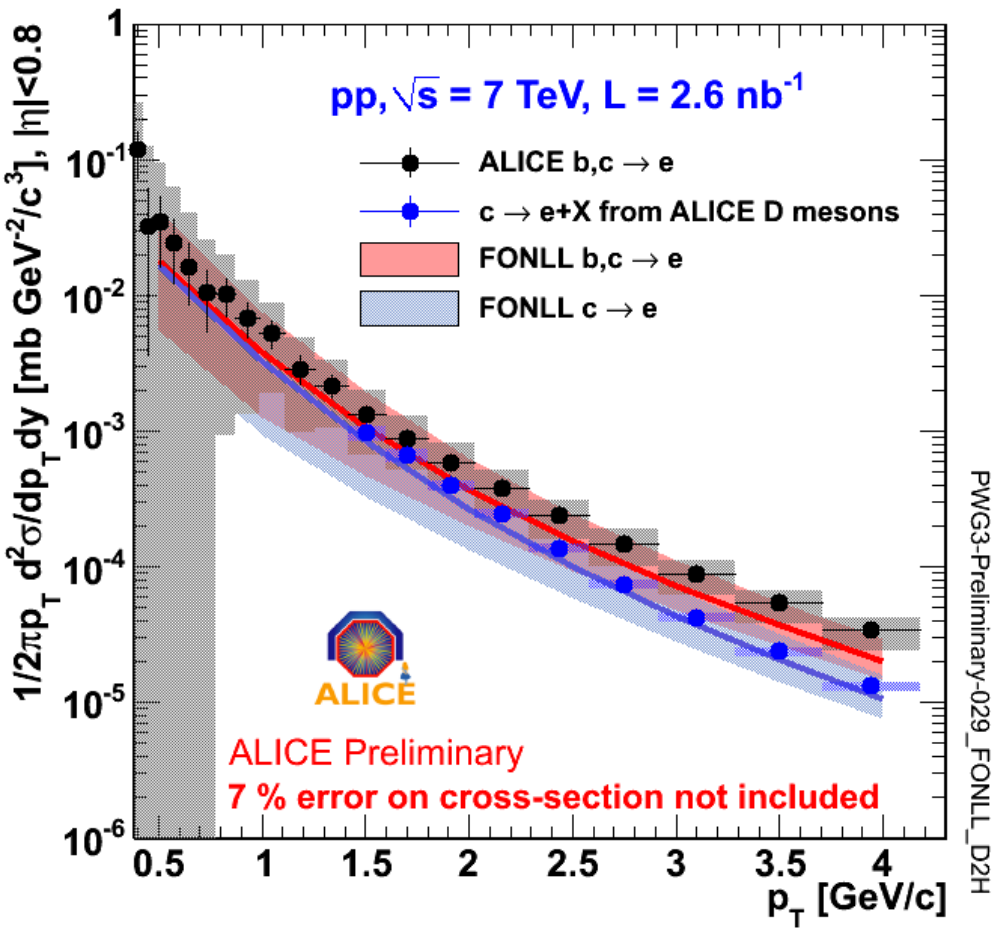
Outlook: extend to higher p_t beyond 10 GeV/c

electron ID in TRD and EMCal



ALICE's charm and beauty, p-p

Good agreement at low p_t (charm dominant) between electrons from **HF and electrons obtained by "decaying" the D meson** cross sections



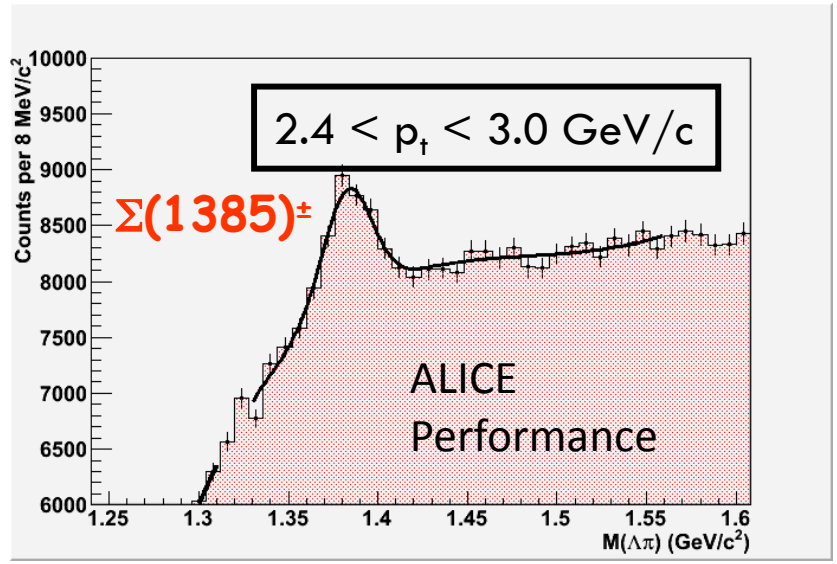
More! Particle production in p-p

Already measured and reported:

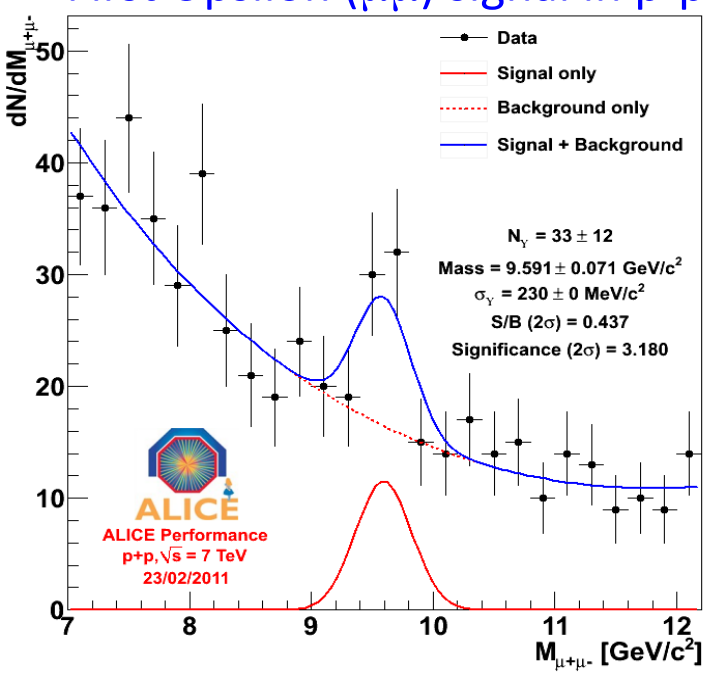
$\phi \rightarrow K^+K^-$, $\Sigma^* \rightarrow \Lambda\pi$,

$\Omega \rightarrow \Lambda K$, $K^* \rightarrow K\pi$, $\Xi \rightarrow \Lambda\pi$

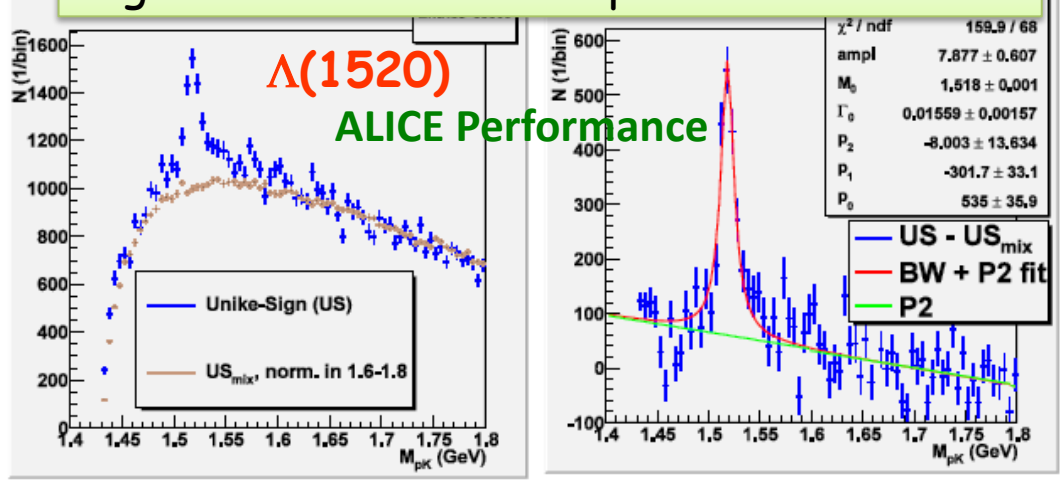
... and more on the way!



First Upsilon (μμ) signal in p-p



Signal ~2000 Λ* →1 Λ* per 10^4 events



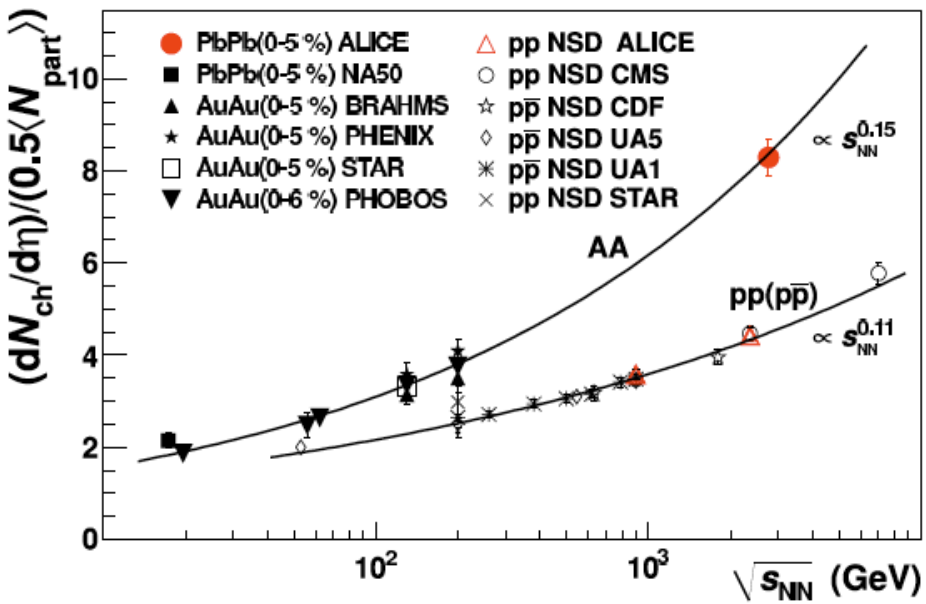
ALICE MEASUREMENTS IN PB-PB

First measurements in heavy-ion collisions at at LHC

- Particle production
  - **Multiplicities – how does the particle production depends on energy and impact parameter of the collisions? Are we able to describe it?**
- Emission of particles – collectivity – dynamical evolution
  - **Azimuthal anisotropy – how the initial spatial anisotropy manifests itself in final momentum anisotropy? – Collective flow at LHC?**
  - **Collectivity? How do the source dimensions evolve with energy?**
- Parton energy loss
  - **Is QCD medium at LHC opaque to high energy partons?**
  - **Evolution of jet quenching with energy?**

Particle production in Pb-Pb

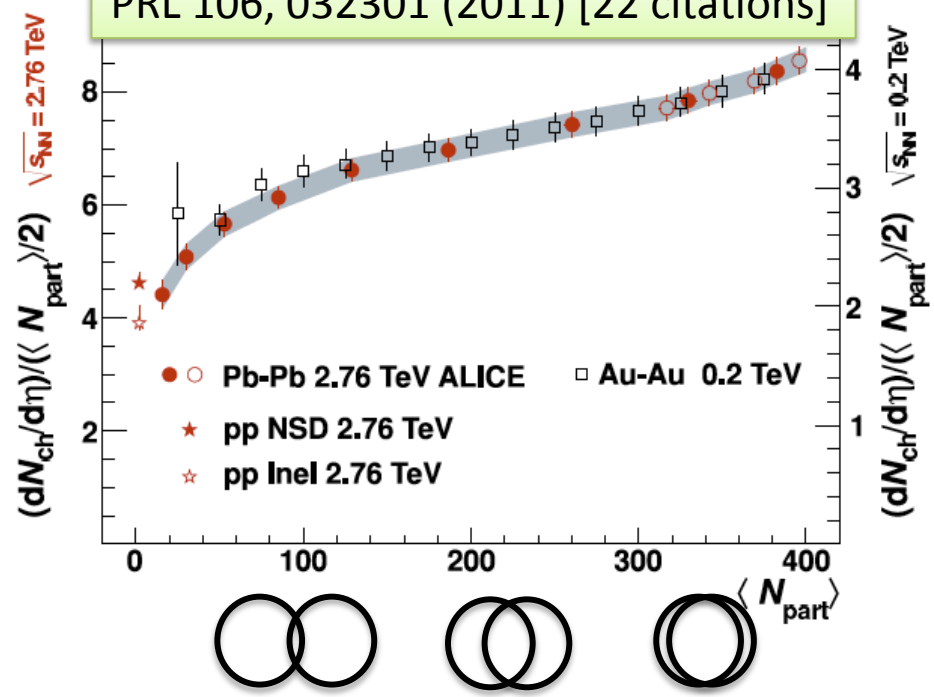
Energy dependence



PRL 105, 252301 (2010) [36 citations]

Centrality dependence

PRL 106, 032301 (2011) [22 citations]



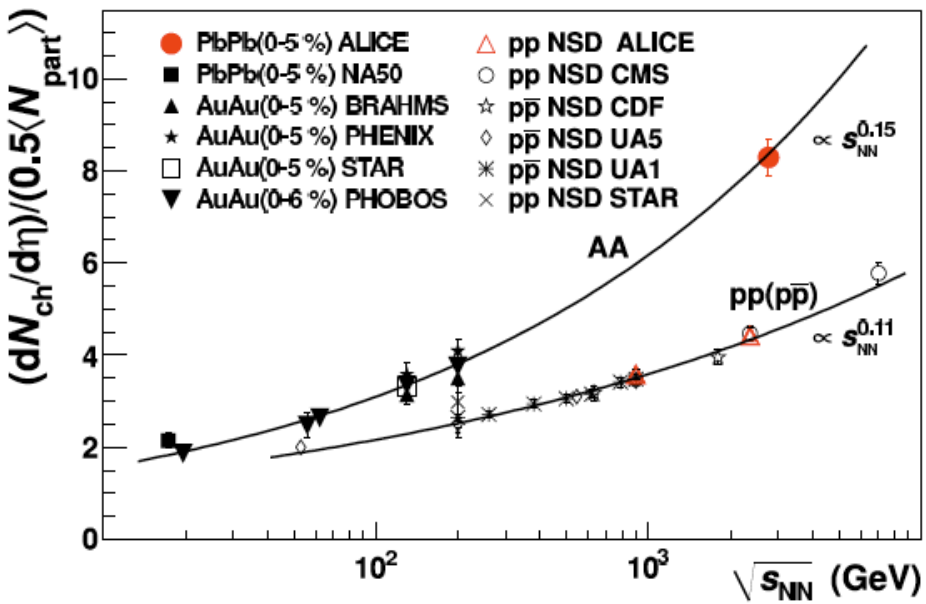
Energy dependence

- p-p ~ $s_{NN}^{0.11}$
- A-A ~ $s_{NN}^{0.15}$ (most central)

Multiplicity dependence on centrality: similar trend as at RHIC

Particle production in Pb-Pb

Energy dependence



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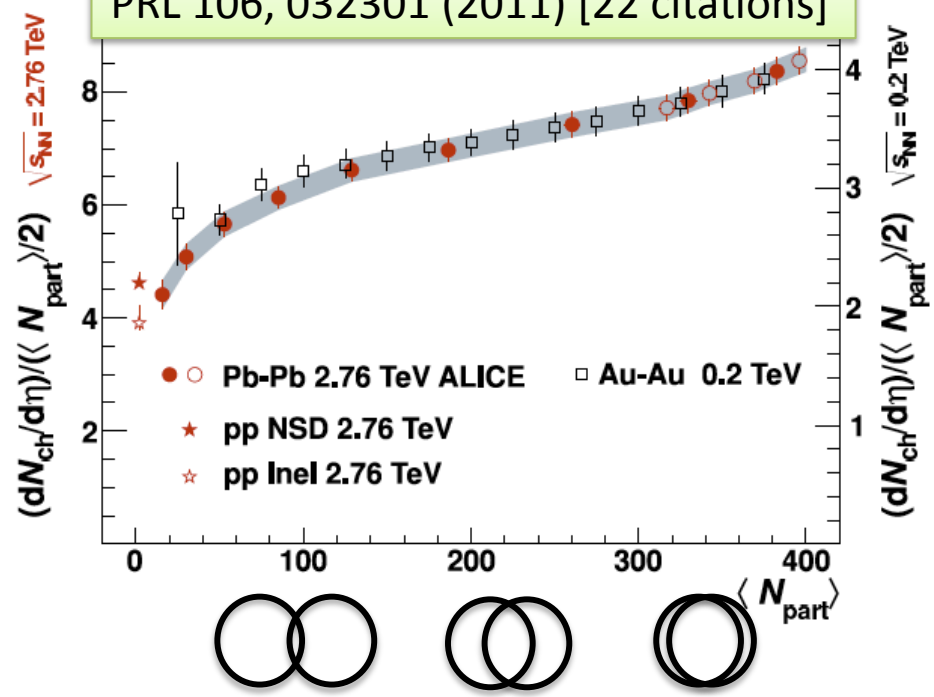
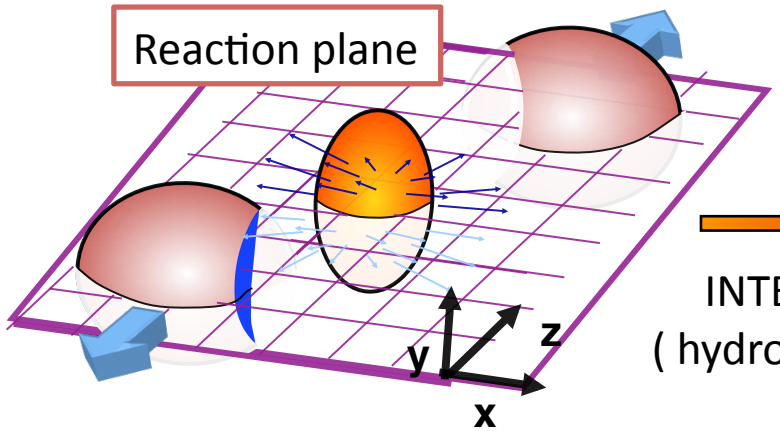


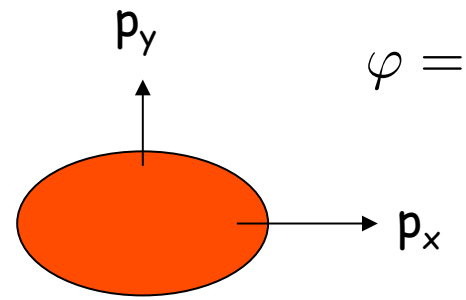
Feedback within the heavy-ion community:

1. **Multiplicity is crucial [input] for modeling**
2. **Saturation models tend to predict lower multiplicity**
3. **Data driven extrapolations did not seem to anticipate the results**

Particle production in Pb-Pb: Azimuthal anisotropy



INTERATIONS
(hydrodynamics?)



$$\varphi = \arctan \frac{p_y}{px}$$

$$\varepsilon = \frac{\langle y^2 \rangle - \langle x^2 \rangle}{\langle y^2 \rangle + \langle x^2 \rangle}$$

Initial spatial anisotropy

$$v_2 = \frac{\langle p_x^2 \rangle - \langle p_y^2 \rangle}{\langle p_x^2 \rangle + \langle p_y^2 \rangle}$$

Final momentum anisotropy

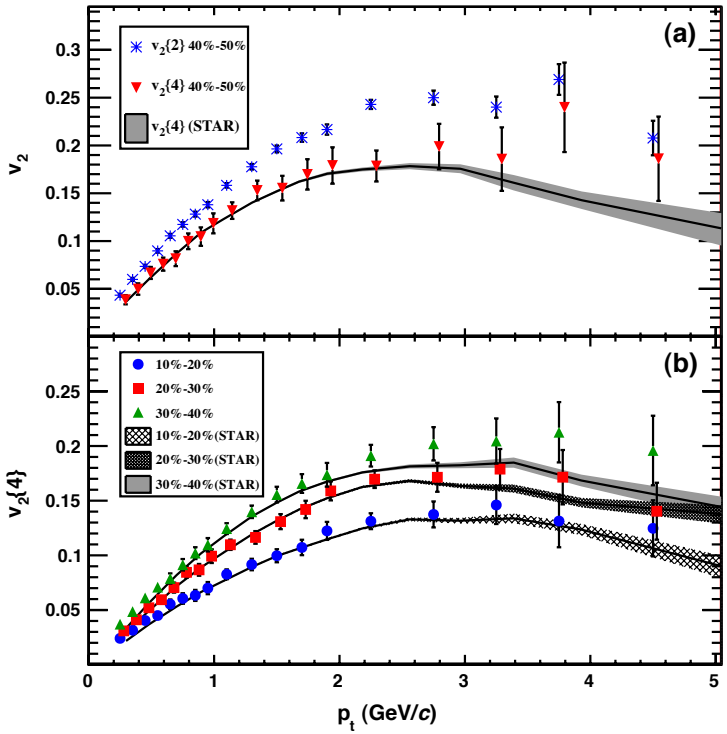
Reaction plane defined by "soft" (low p_T) particles

$$\Delta\varphi = \varphi - \varphi^{Reaction\ Plane}$$

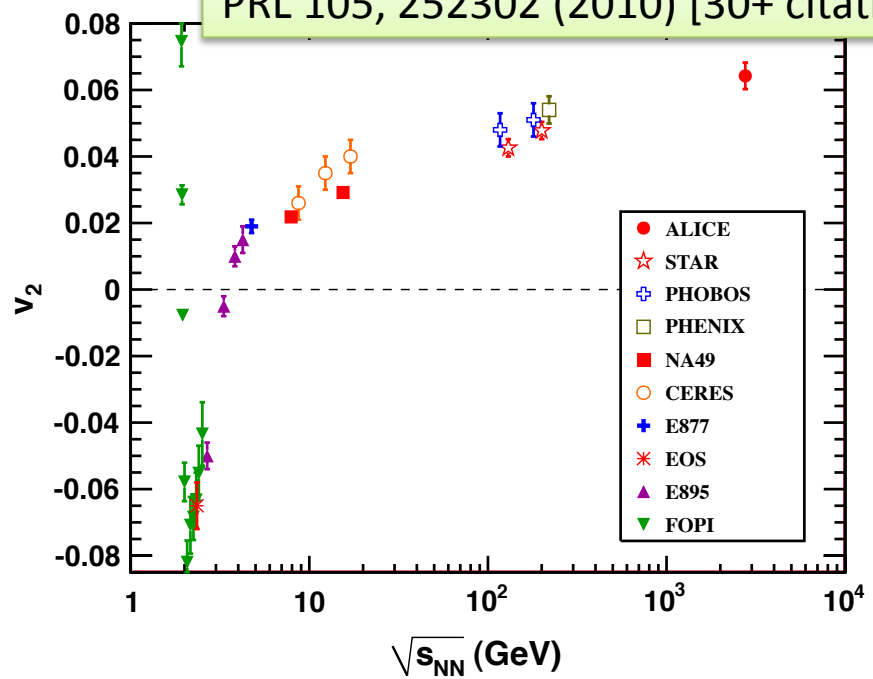
Elliptic flow

$$\frac{dN}{d\Delta\varphi} \propto 1 + 2v_2 \cos(2\Delta\varphi)$$

Particle production in Pb-Pb: Azimuthal anisotropy



PRL 105, 252302 (2010) [30+ citations]



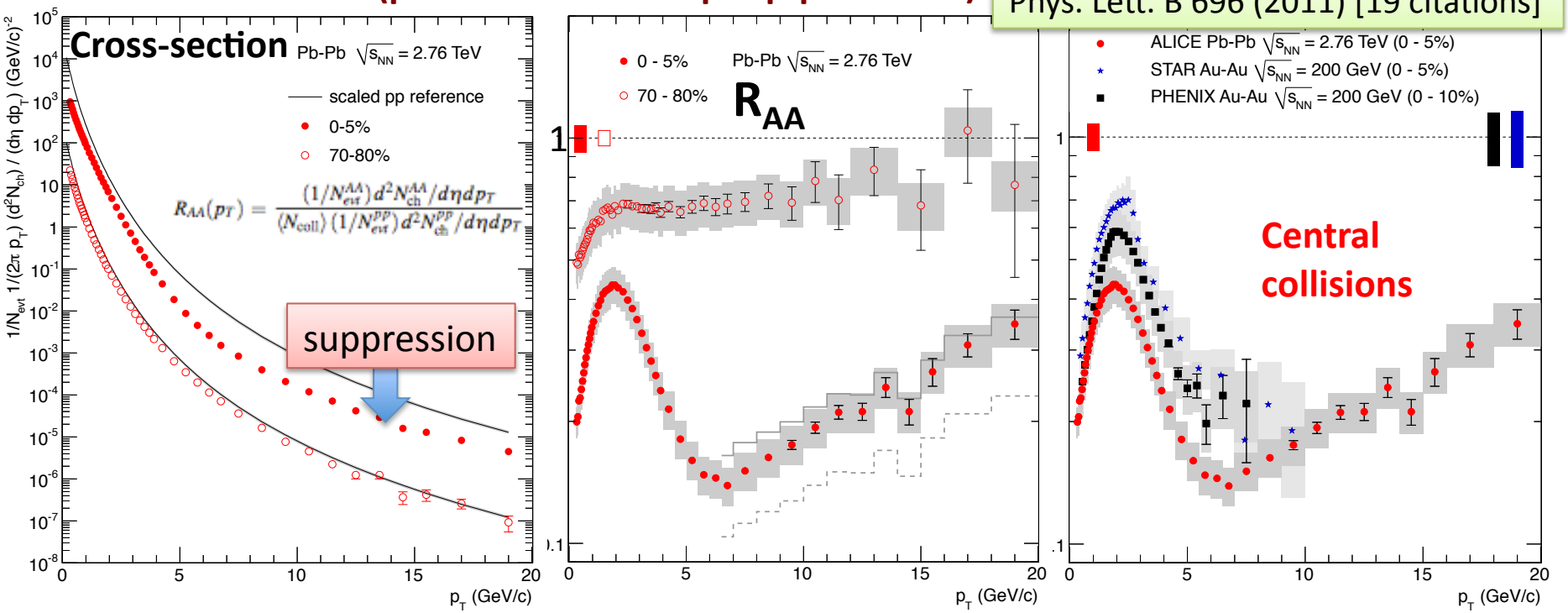
APS Viewpoint: A "Little Bang" arrives at the LHC by Edward Shuryak

1. **Collective behavior observed in Pb-Pb collisions at LHC (+0.3 v_2^{RHIC}) $v_2(p_T)$ similar to RHIC – almost ideal fluid at LHC ?**
2. **New input to the energy dependence of collective flow**
3. **Additional constraints on Eq-Of-State and transport properties**

Jet quenching via hadron suppression

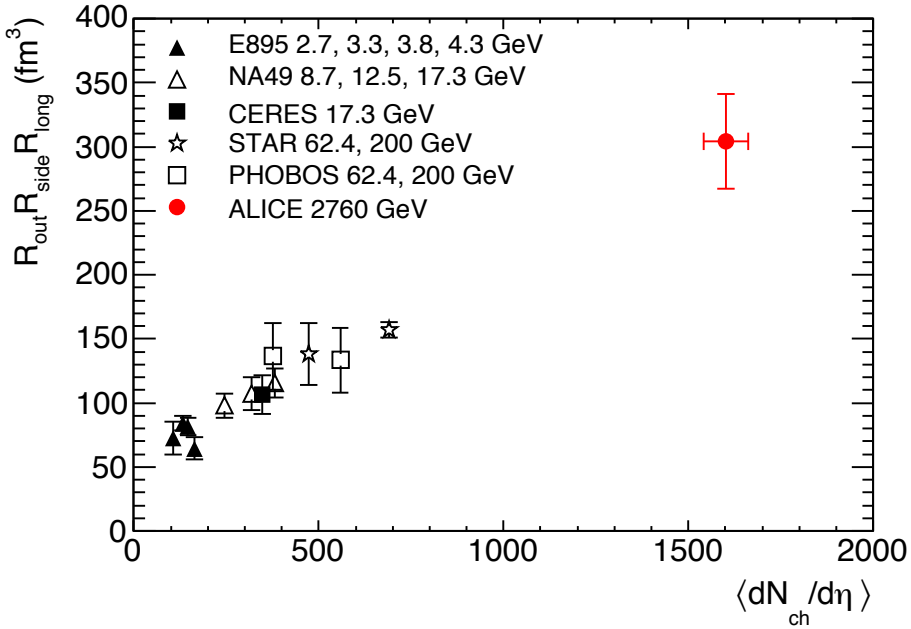
$$\text{Ratio} = \frac{\#(\text{particles observed in AA collision per N-N (binary) collision})}{\#(\text{particles observed per p-p collision})}$$

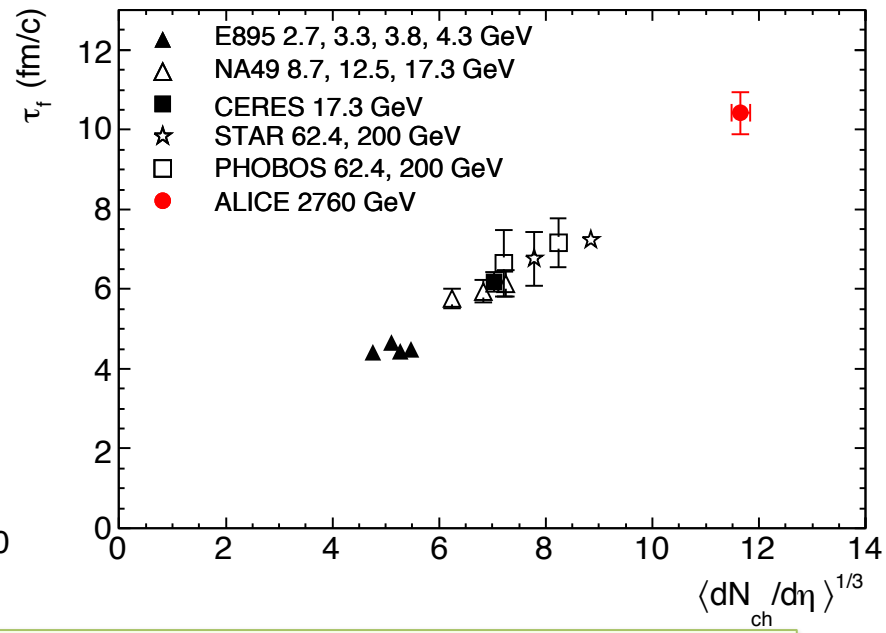
Phys. Lett. B 696 (2011) [19 citations]



1. Strong depletion of high-pT hadrons in A-A collisions – consistent with parton energy loss (jet quenching)
2. Qualitatively new feature : evolution of R_{AA} as a function of p_T
3. New, much anticipated constraint for parton energy-loss models

Particle production in Pb-Pb: Measurements of source dimensions





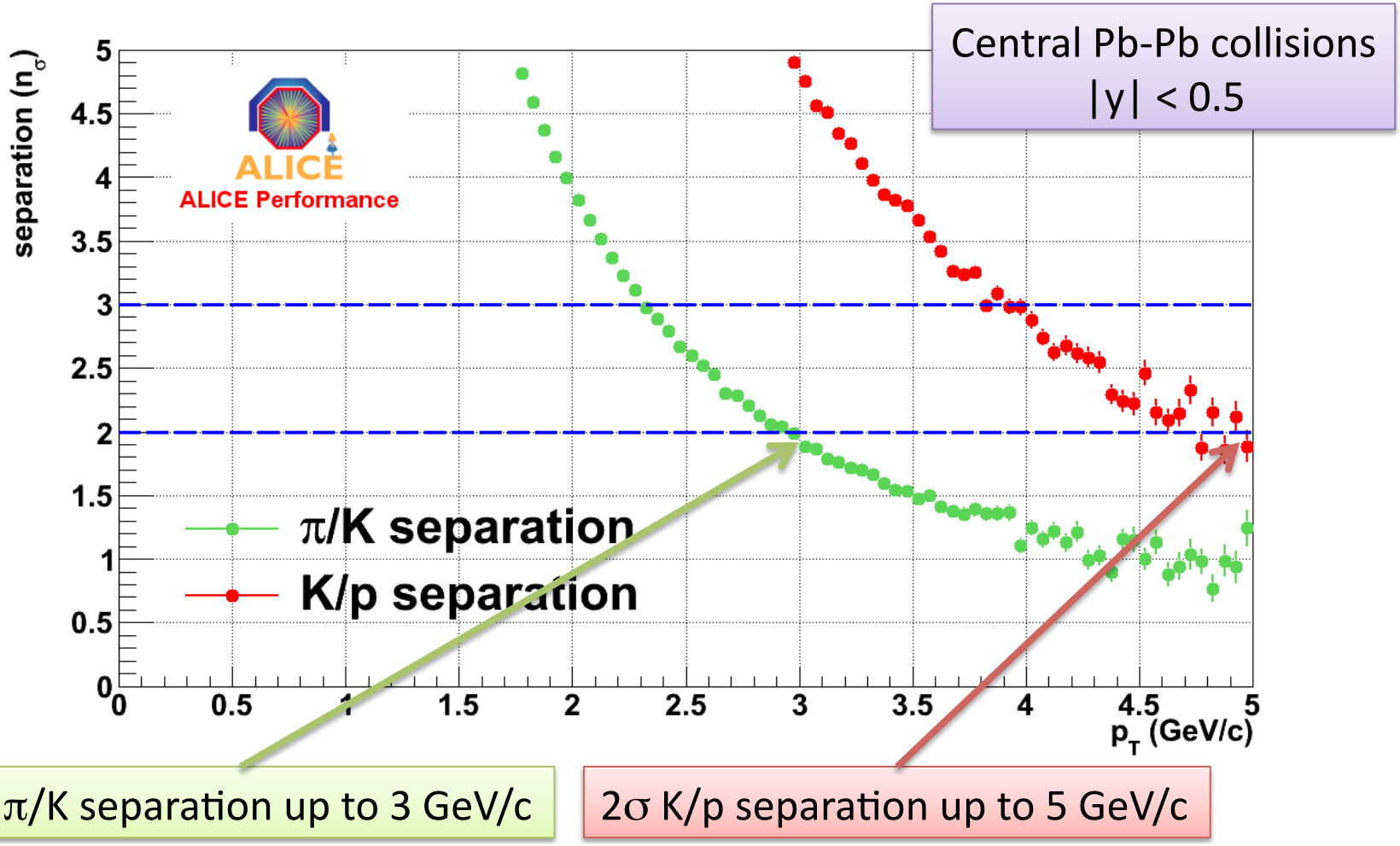
Phys.Lett.B 696:328-337,2011 [5 citations]

1. Energy dependence:
   - system with larger (30%) volume and lifetime (w.r.t RHIC); follows the trend of multiplicity; faster expansion <=> larger collective flow
2. Pair momentum dependence:
   - larger radii, strong dependence on kT; Rout/Rside smaller than at RHIC; overall agreement with extrapolations
3. Important constrains to [hydrodynamical] modelling

Obtaining a more detailed view…

PARTICLE PRODUCTION IN PB-PB

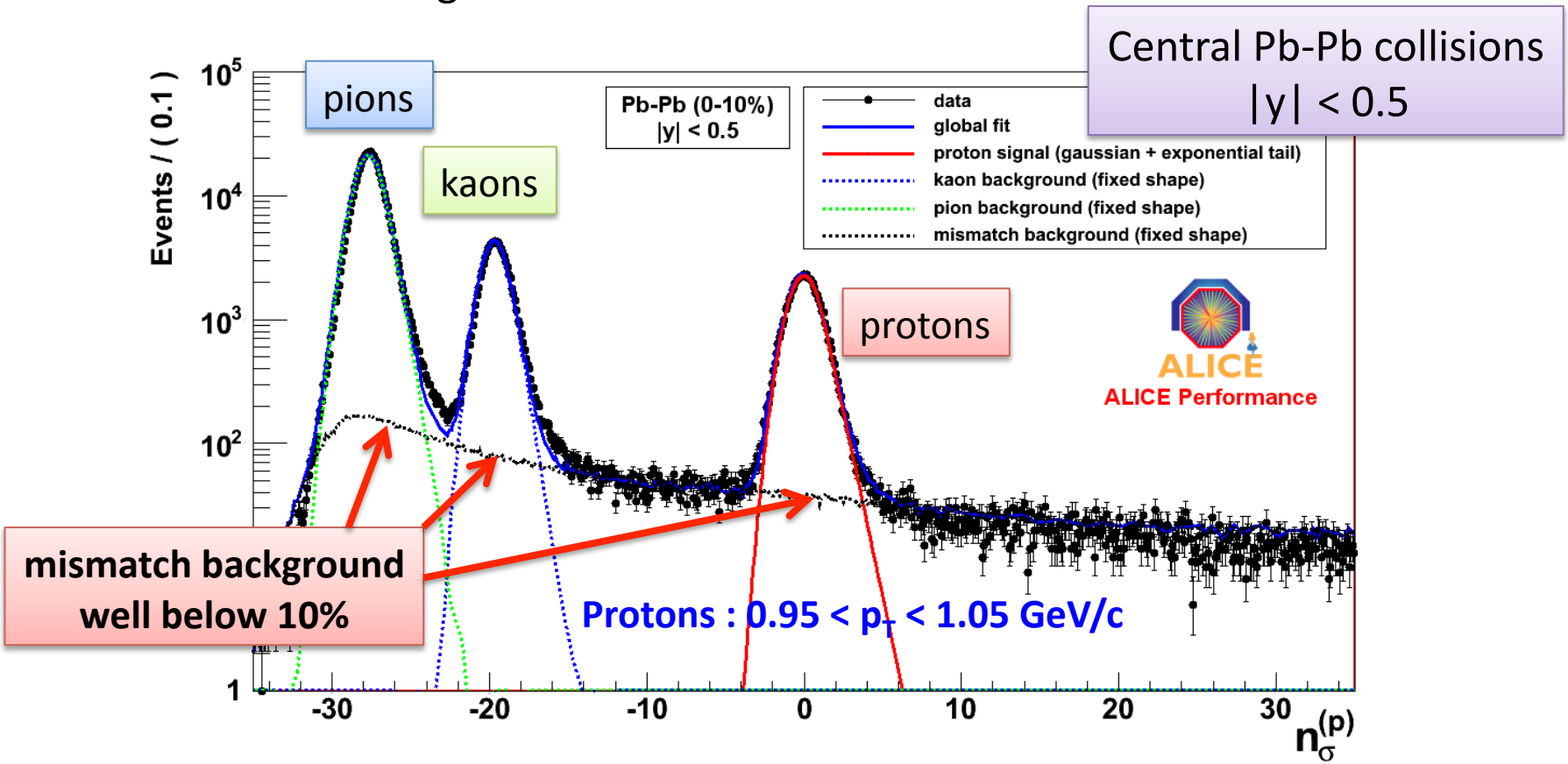
Particle ID separation with TOF



Note: time resolution in Pb-Pb ~90ps – better than in p-p (~110ps)

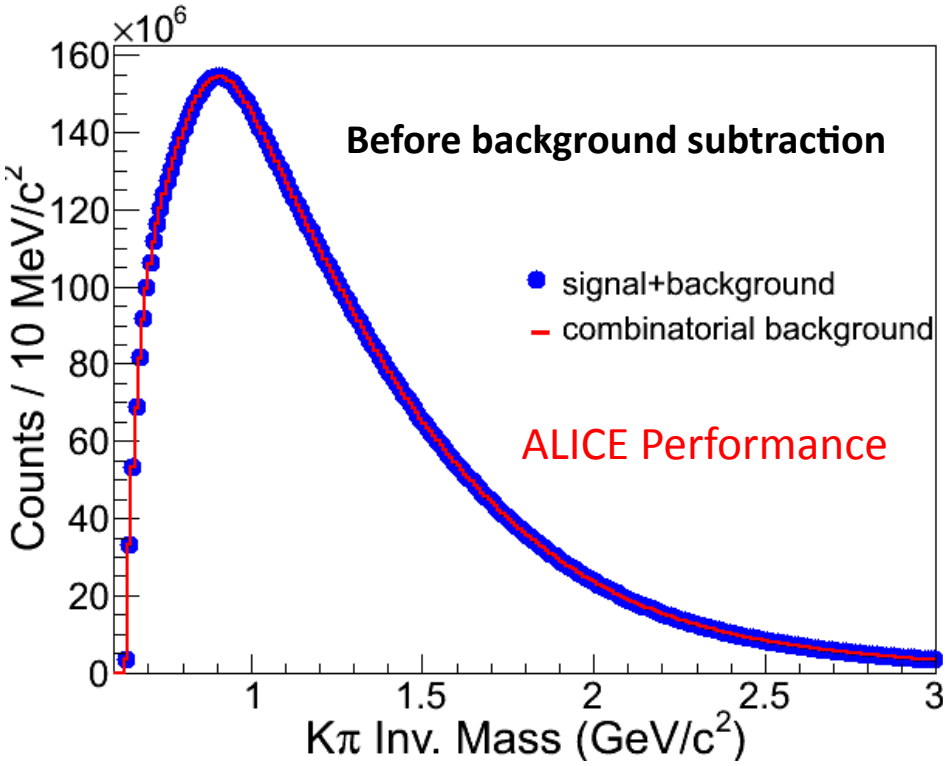
Particle identification in Pb-Pb

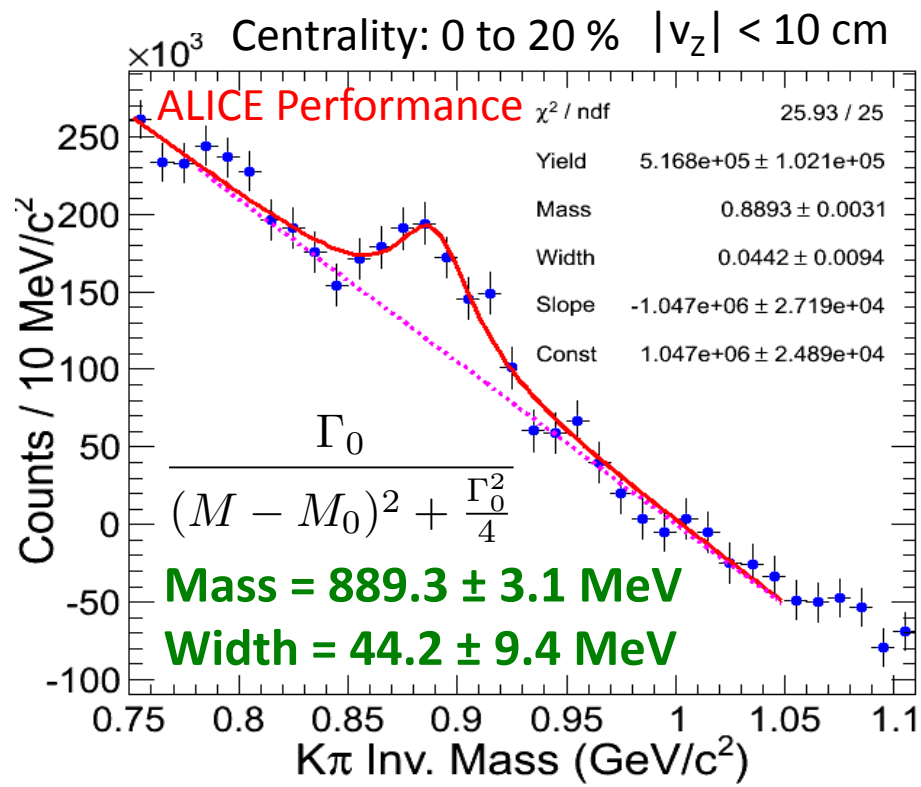
Raw yields: a global fit of **Time-Of-Flight** signal - **mass hypotesis *i* (π, K, p)** constrains the integral of the fit to the total number of entries in the TOF PID



Gaussian (μ=0, σ=1) PID response with a small exponential tail - fit the actual signal of particle type *i*

$K^*(892)^0$ in Pb-Pb





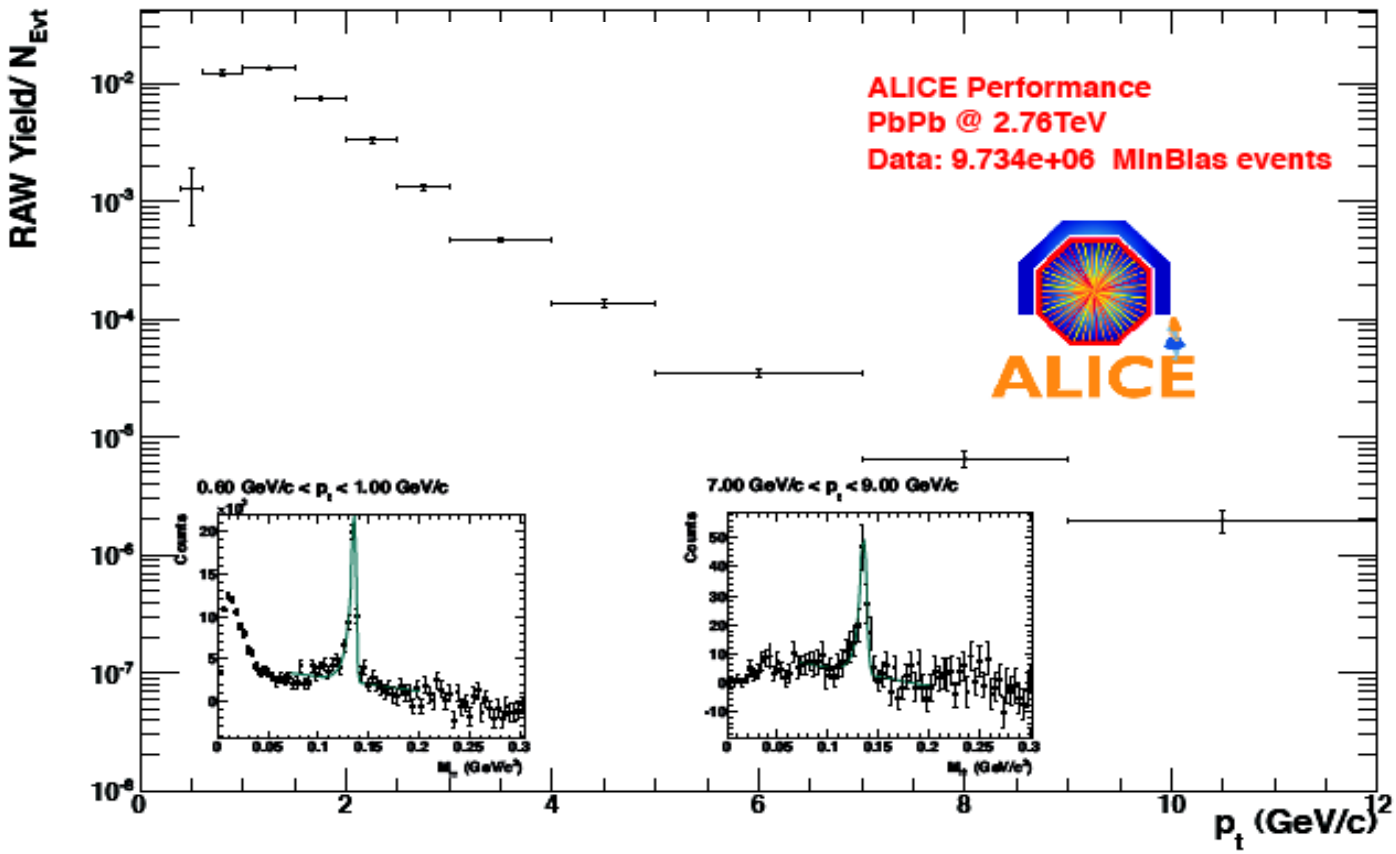
Combinatorial background :

mixed events from the kaon-pion invariant mass distribution.

Good agreement with PDG (M_{PDG} = 895.94 ± 0.22 MeV; W_{PDG} = 48.7 ± 0.8 MeV)

π^0 reconstruction from converted photons in Pb-Pb

$$\pi^0 \rightarrow \gamma\gamma \rightarrow e^+e^-e^+e^-$$

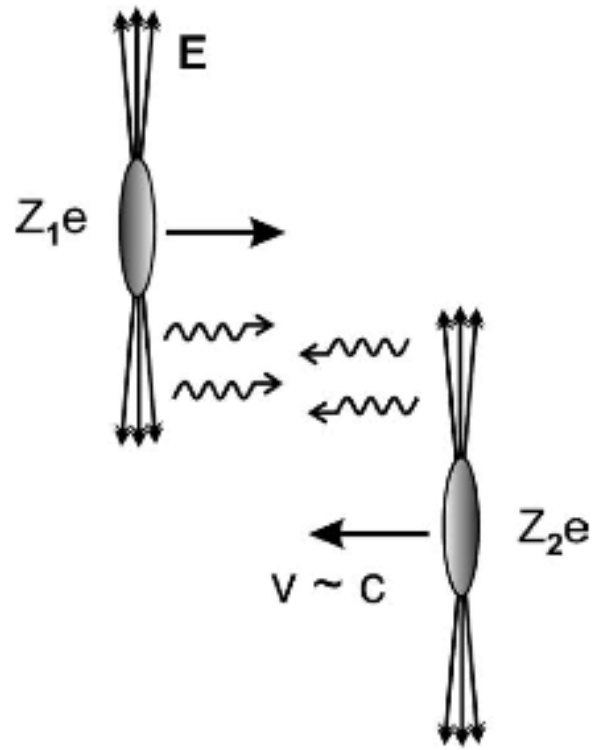


Similar mass resolution as in p-p

Particle production in ultra-peripheral Pb-Pb collisions

$$Pb + Pb \rightarrow Pb + Pb + \rho^0$$

- Invariant mass of **unlike sign** (2-track) events with **event p_T<0.15 GeV/c**
- Pion mass is assumed.
- **Trigger: both tracks with hits in Silicon-Pixel-Detector and Time-Of-Flight**
- **Expect a low mean p_T**



Particle production in ultra-peripheral Pb-Pb collisions

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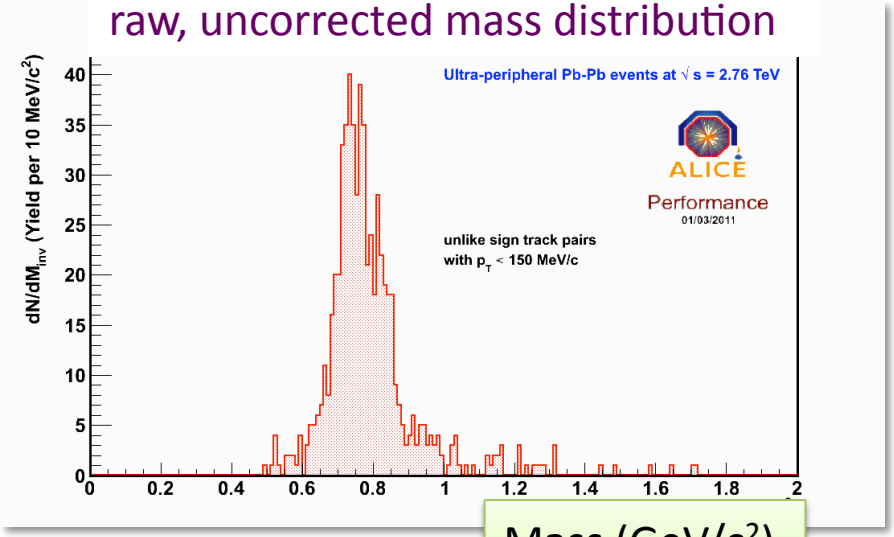
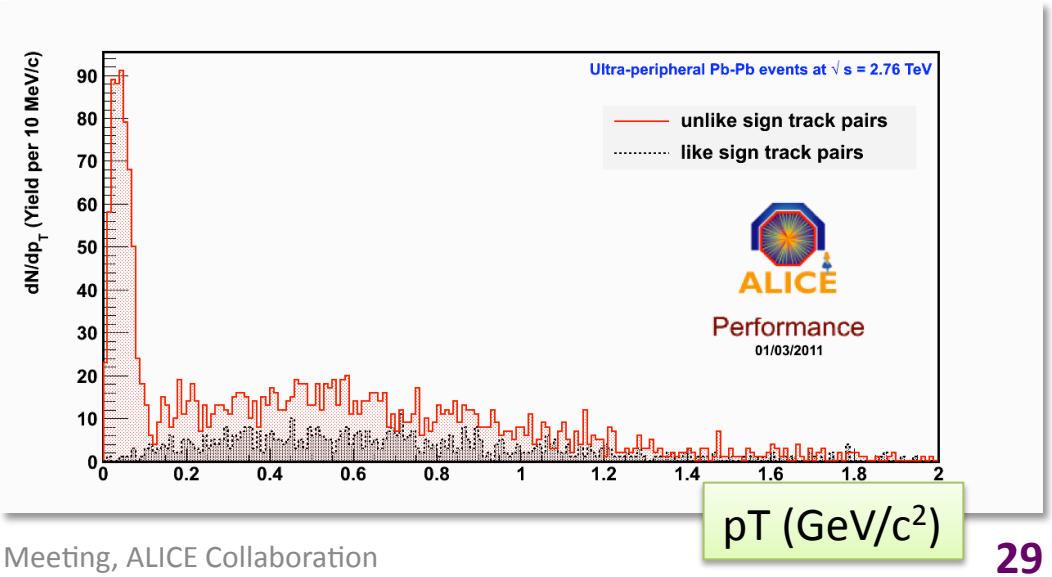
- Invariant mass of **unlike sign** (2-track) events with **event p_T<0.15 GeV/c**
- Pion mass is assumed.
- **Trigger: both tracks with hits in Silicon-Pixel-Detector and Time-Of-Flight**
- **Mean p_T ~ 0.05 GeV/c**

raw, uncorrected mass distribution





Electromagnetic dissociation (EMD) with ALICE ZDC's

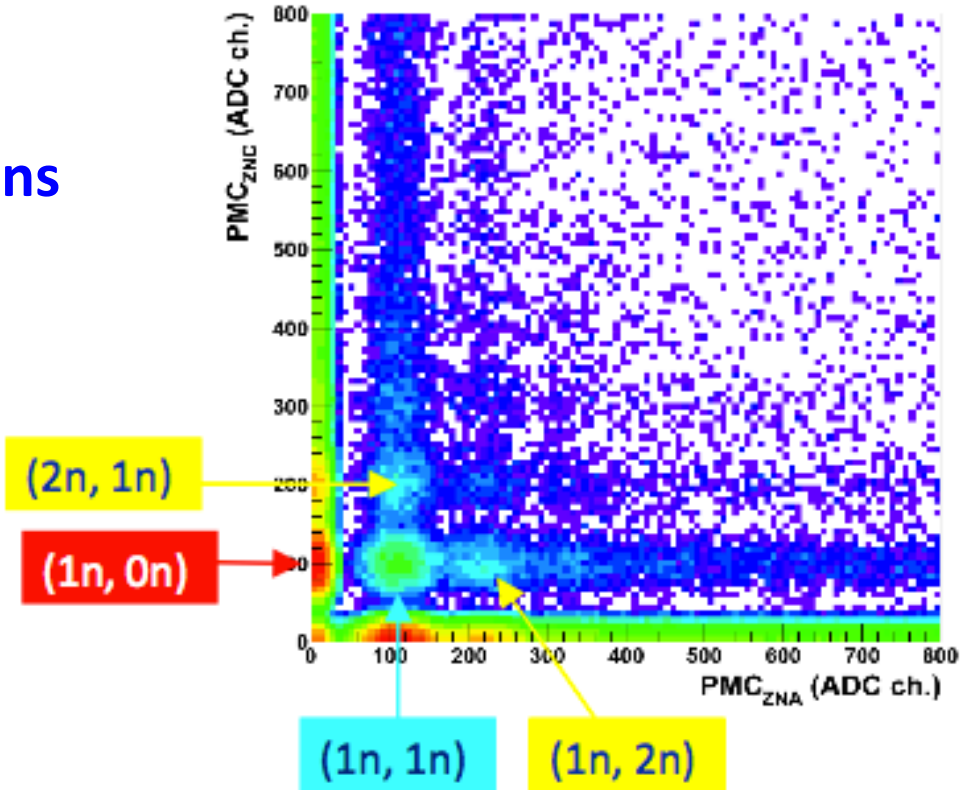
Ultra-peripheral heavy-ion interaction -> EMD of nuclei

Most probable channel:
GDR followed by neutron emission

ZDCs: 115 meters away from IP2 on both (A,C) sides,

Model QED description: RELDIS
– EMD events and cross-sections
Pshenichnov, I.A., et al.
- Phys.Rev. C60 (1999) 044901
- Phys.Rev. C64 (2001) 024903

Trigger ZNA || ZNC selects:
single EMD (~185b);
mutual EMD (~5.9 b)
nuclear (7.8 b)



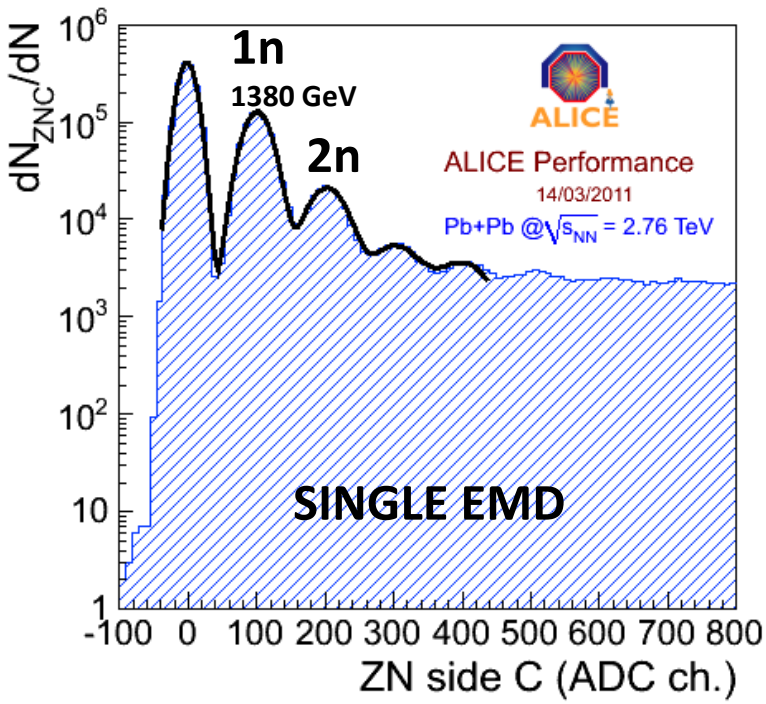
Single and mutual EMD with ZDC

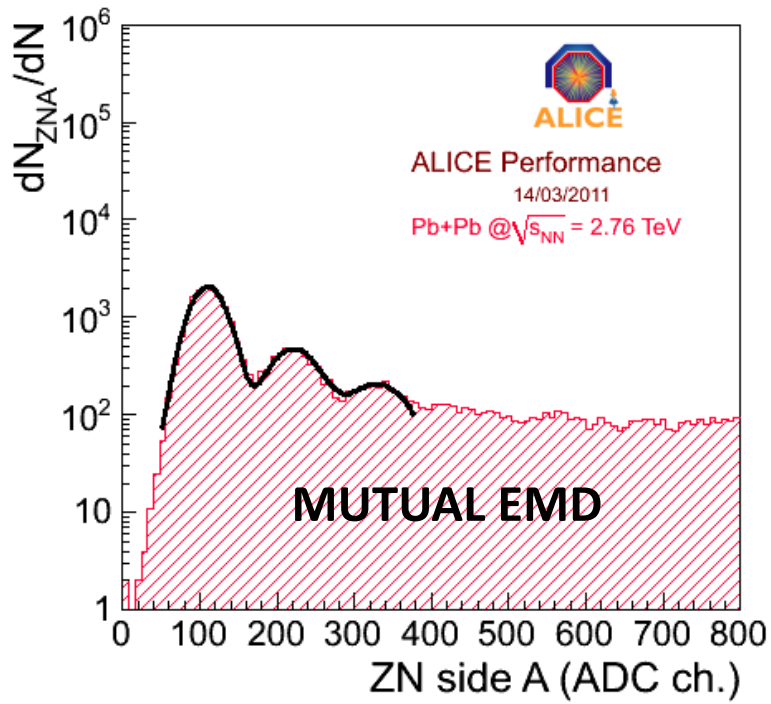
ZDC signal: Single EMD + Mutual EMD + Nuclear effects

Mutual EMD event selection: ZNC && ZNA + ZDC time selection + (ZEM1<10 || ZEM2<10) estimated from simulations to reject nuclear events

Data: 1n peak resolution ~20% consistent with RELDIS calculation

Ratios: 1n/2n; 1n/3n; 2n/3n are under investigation



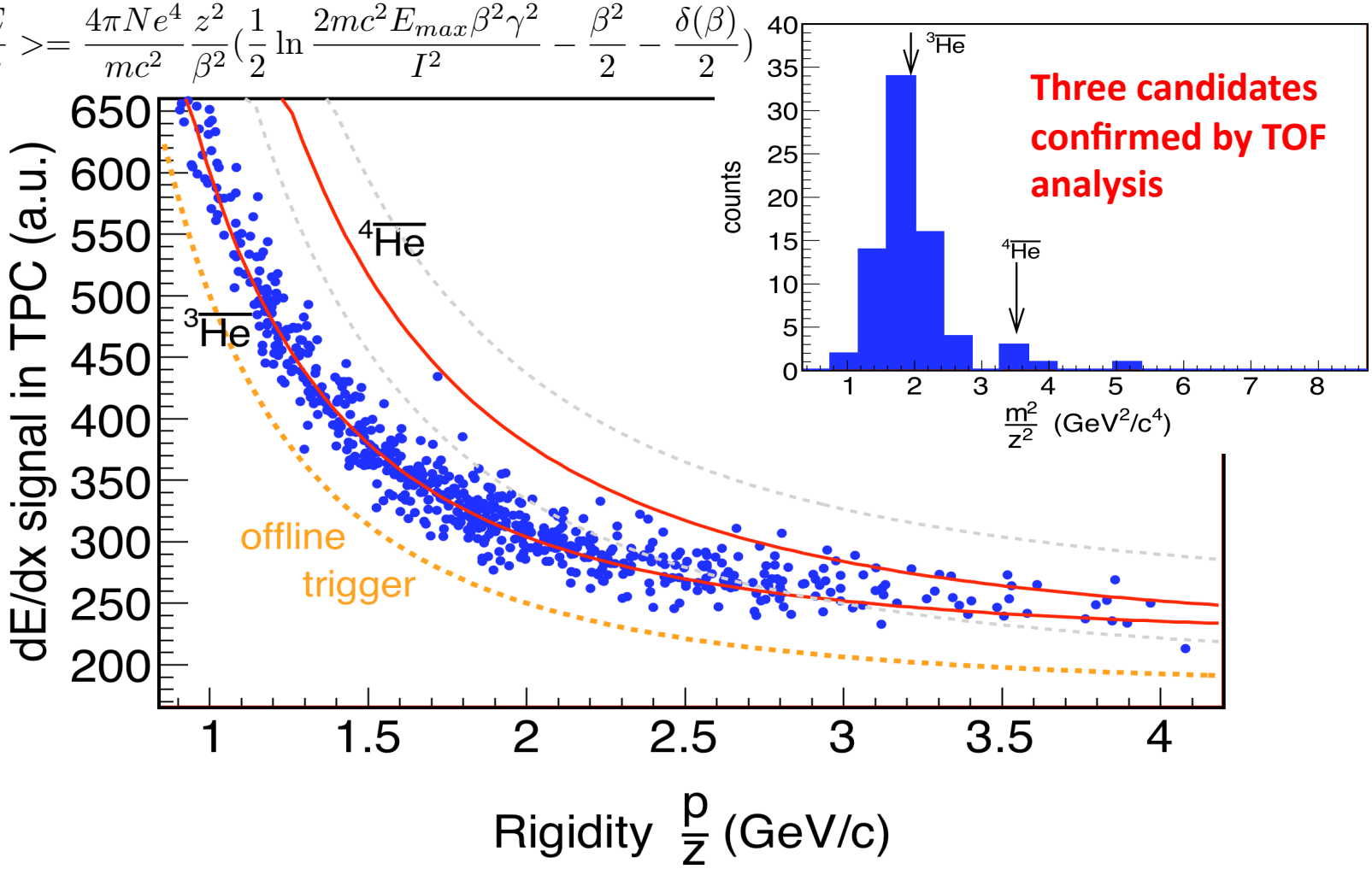


Fit constrains: $\mu_{2n} = 2\mu_{1n};\ \sigma_{2n} = \sqrt{2}\sigma_{1n};\ \mu_{3n} = 3\mu_{1n};\ \sigma_{3n} = \sqrt{3}\sigma_{1n}$

Anti-Alpha candidates in Pb-Pb

Time of flight (sensitive to m/z-ratio): $m = \frac{z \cdot R}{\sqrt{\gamma^2 - 1}}$

$$< \frac{dE}{dx} >= \frac{4\pi N e^4}{mc^2} \frac{z^2}{\beta^2} \left(\frac{1}{2} \ln \frac{2mc^2 E_{max} \beta^2 \gamma^2}{I^2} - \frac{\beta^2}{2} - \frac{\delta(\beta)}{2} \right)$$



HEAVY FLAVOR AND QUARKONIA IN Pb-Pb COLLISIONS

New Signals in PbPb

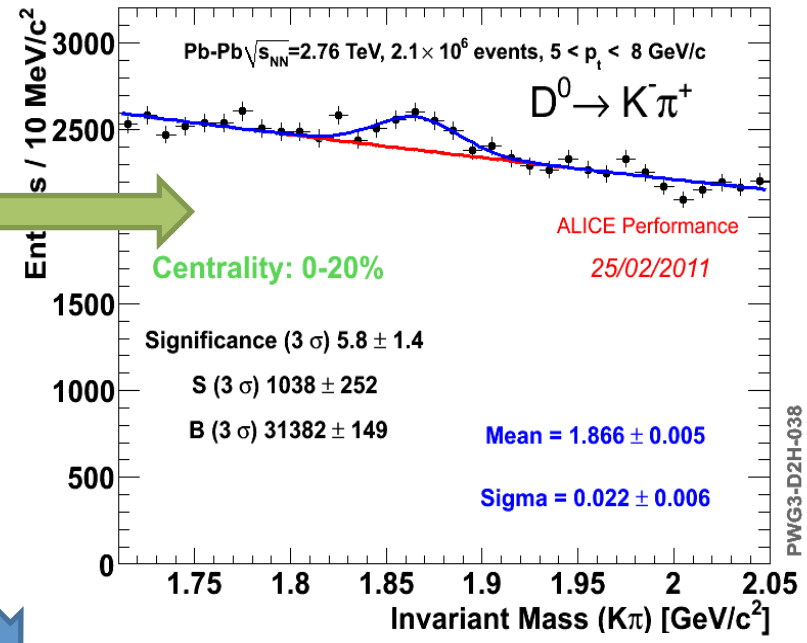
First D0 signal in CENTRAL PbPb.

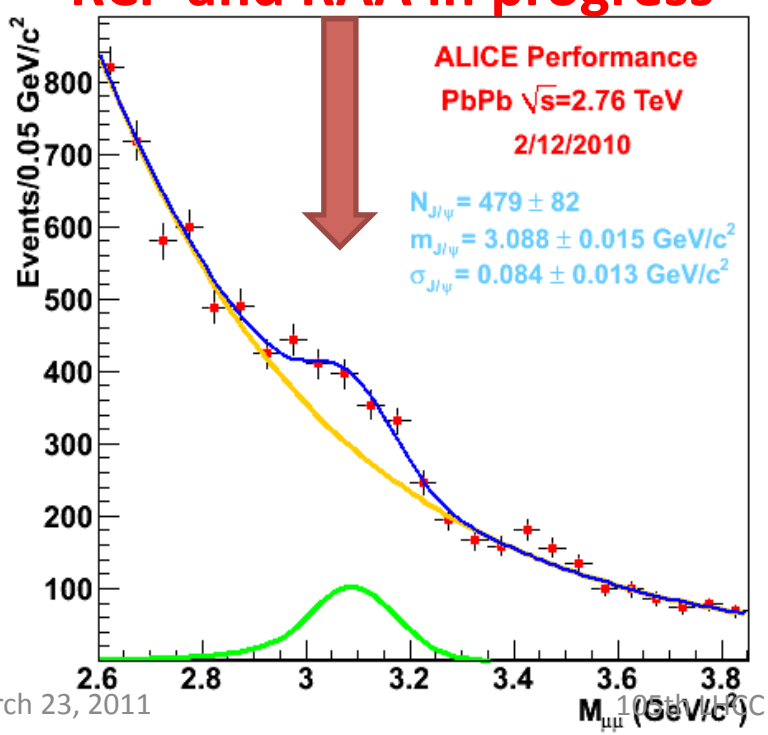
First D+ signal in PbPb

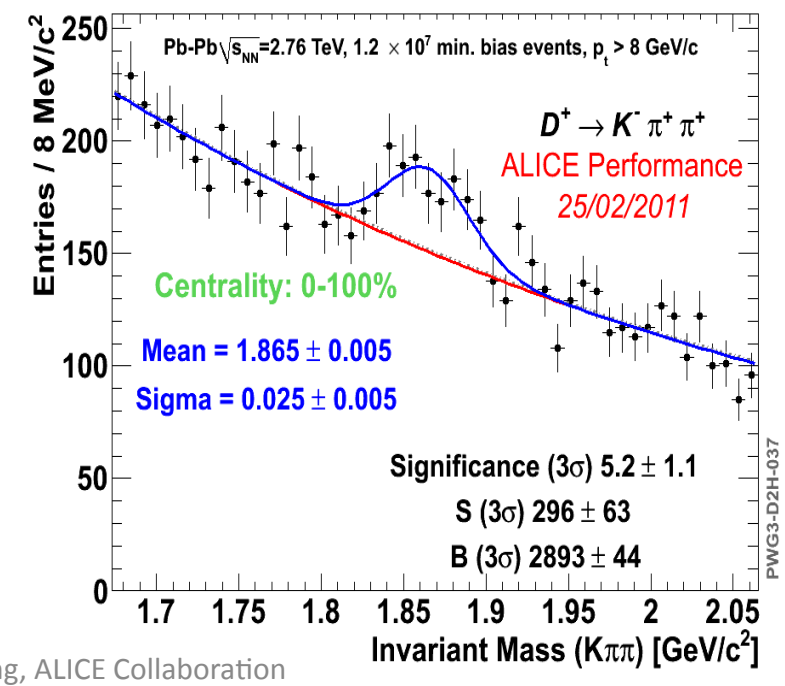
RCP and RAA in progress

First J/psi signal in Pb-Pb

RCP and RAA in progress





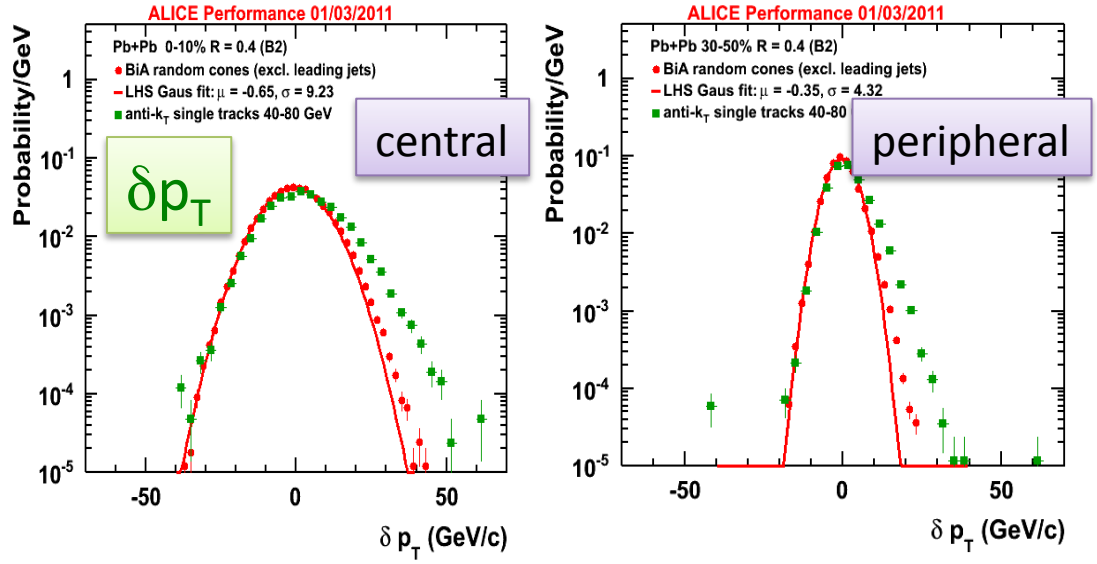


PREPARING FOR COMPLETE JET RECONSTRUCTION

Charged jets and backgrounds in Pb-Pb

Detailed characterization of the background is a prerequisite for jet reconstruction in Pb-Pb

Shown: FastJet Anti-k_T (R=0.4)



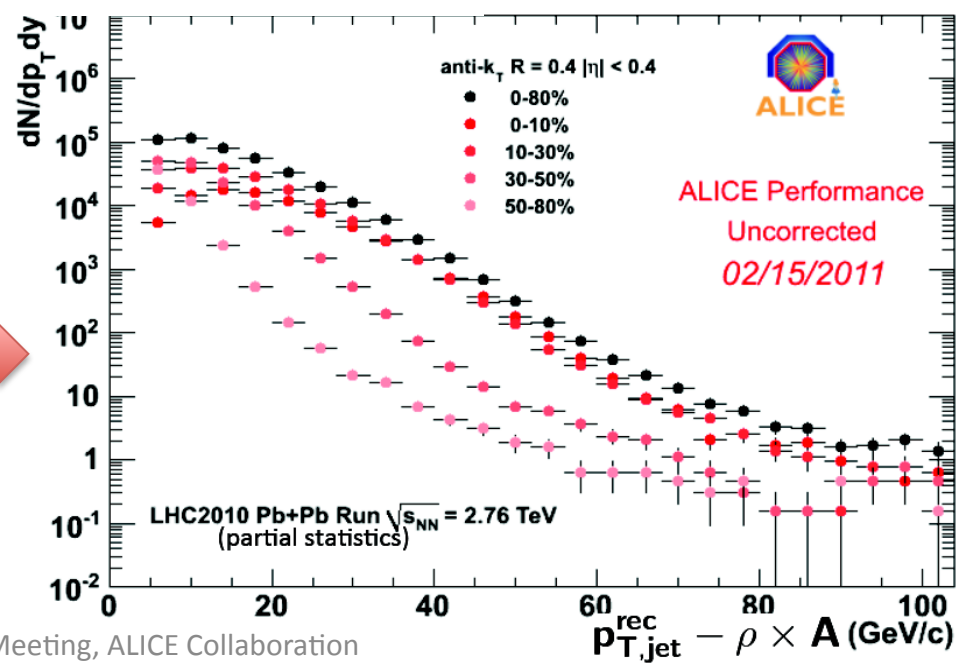
Definition of δp_T:

$$p_T^{rec} = p_T^{true} + \delta p_T$$

Measurement:

$$\delta p_T = p_T^{cluster} - \rho \cdot A - p_T^{probe}$$

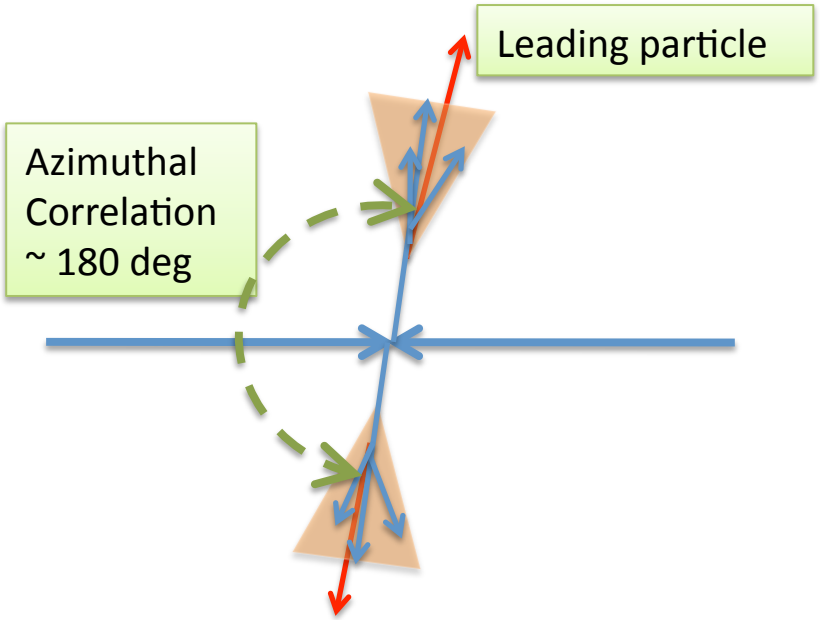
Effect on inclusive spectrum in A-A: Demonstration of the p_T smearing ($f(\delta p_T)$) due to background fluctuations.

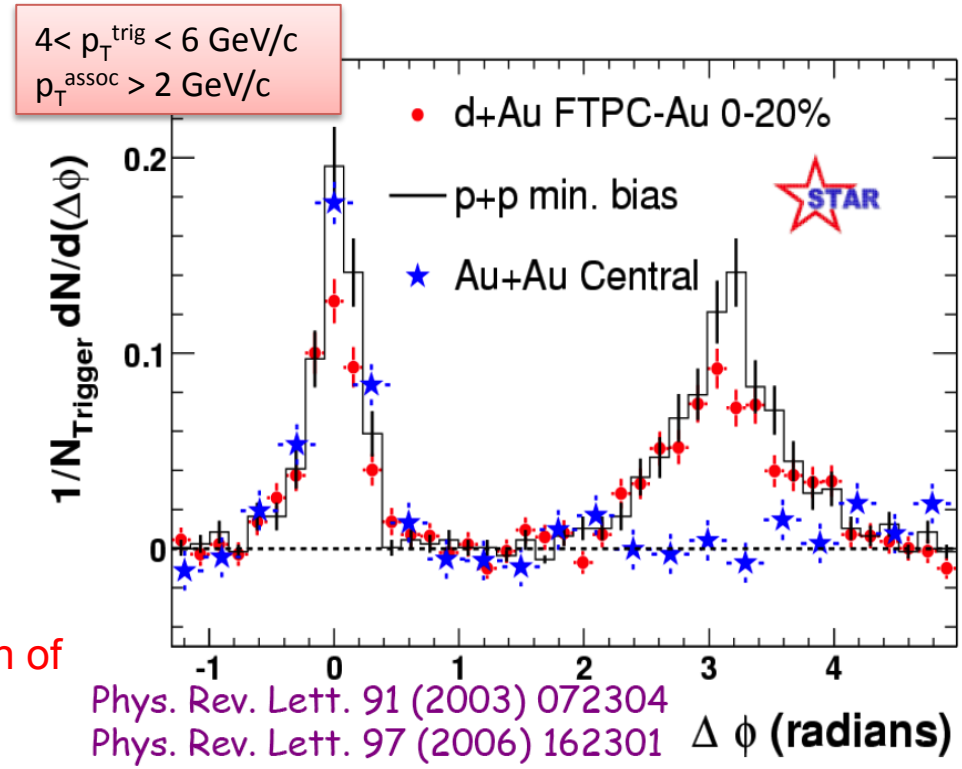


Detailed correction under preparation.

TWO-PARTICLE AZIMUTHAL CORRELATIONS

Jet quenching: recoil jet suppression via leading hadron azimuthal correlations

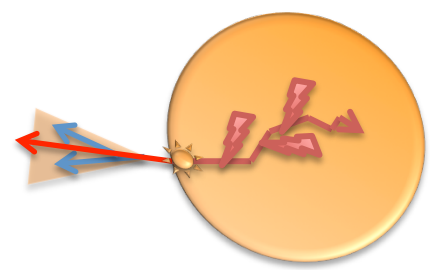




Phys. Rev. Lett. 91 (2003) 072304
Phys. Rev. Lett. 97 (2006) 162301

Intermediate pT di-hadrons: Strong modification of the recoil-jet indicates **substantial partonic interaction within the medium -> quenching**

Near-side: selecting the jets with little interaction; similar conclusion for correlations at high-pT



=> Constraints on jet quenching modelling –

what happens at LHC?

Di-hadron Correlations

Two-particle correlations

- conditional [per-trigger] yields

$$\frac{1}{N_{trig}}\frac{dN_{assoc}}{d\Delta\varphi} \quad \text{and} \quad \frac{1}{N_{trig}}\frac{d^2N_{assoc}}{d\Delta\varphi d\Delta\eta}$$

At Low-p_T :

Ridge

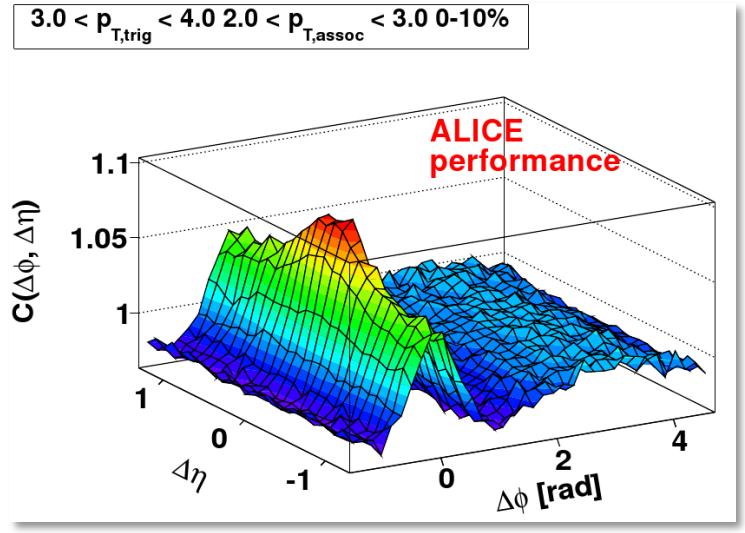
Hydrodynamics, flow

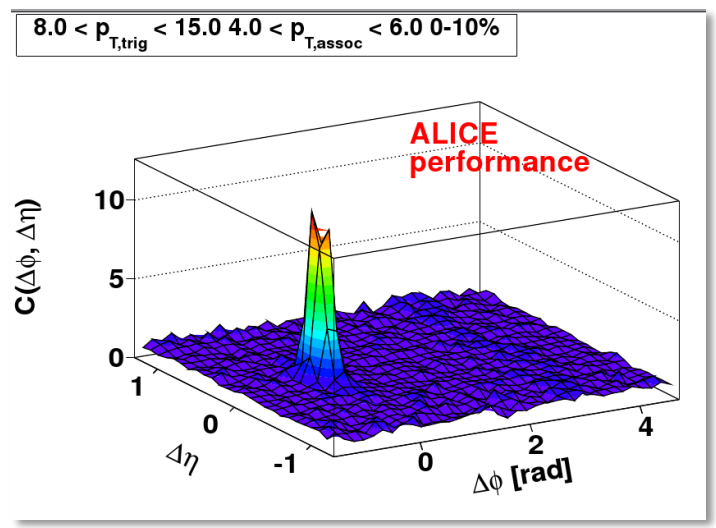
At High-p_T :

Quenching/suppression, broadening

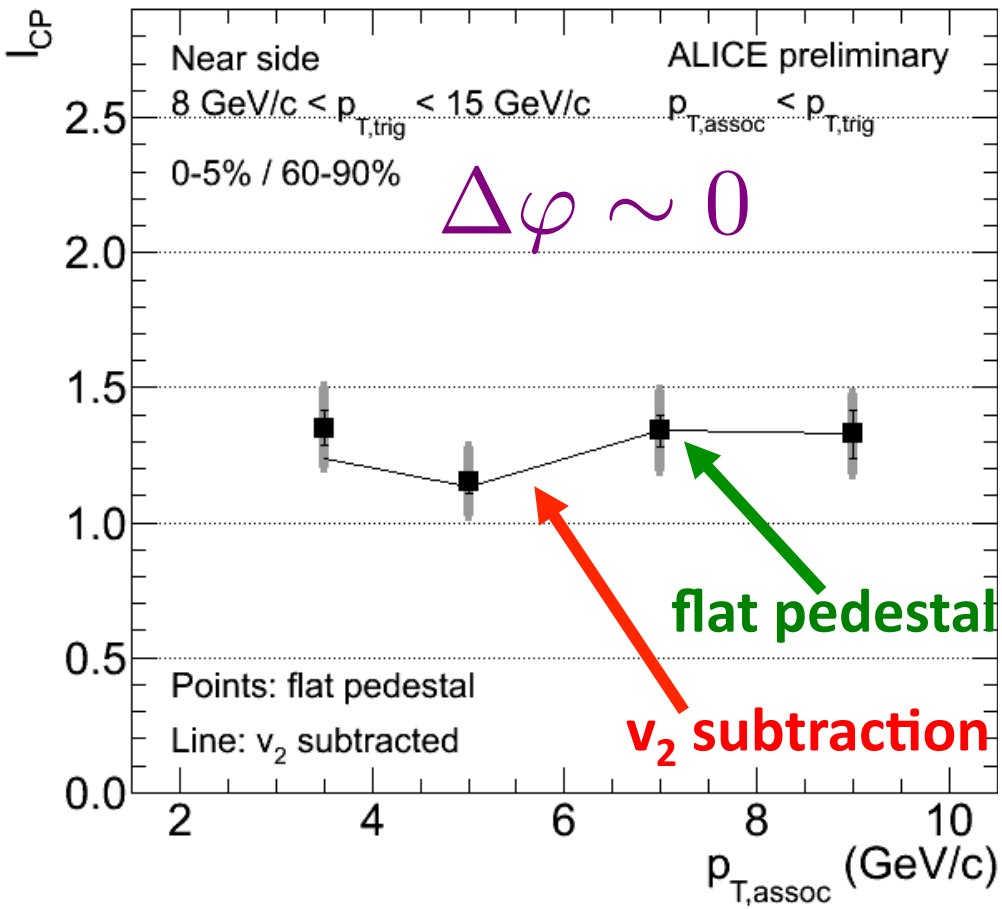
I_{CP}: Yields in central v.s. peripheral collisions

I_{AA}: Yields in A-A compared to p-p



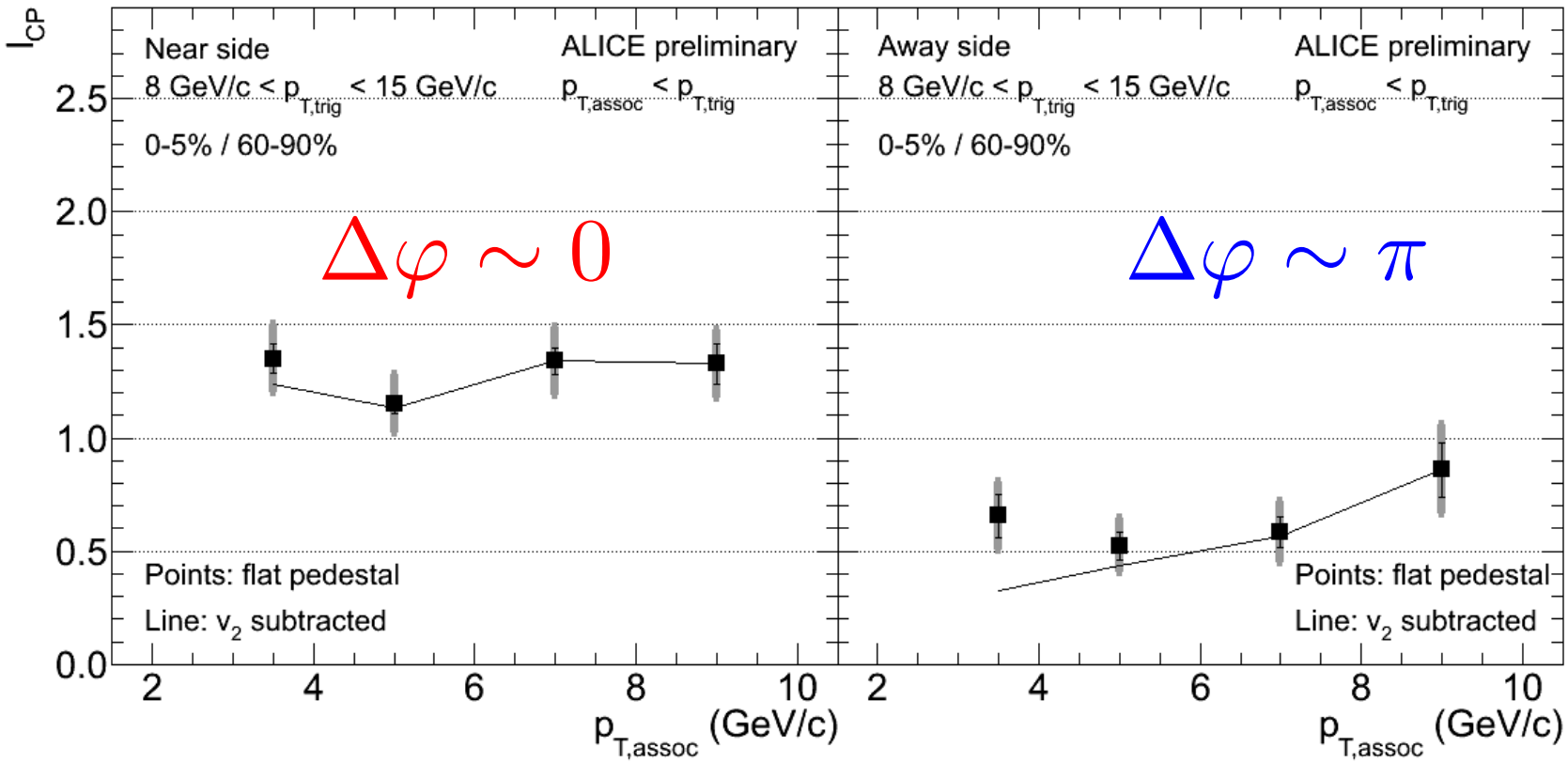


I_{CP} : [yields: central / peripheral]



- Trigger particle:
  - $8 < p_T^T < 15$ (GeV/c)
- Associated particle:
  - $p_T^a < p_T^T$
- **Flat pedestal subtraction → data points**
- **v_2 subtracted → line**
  - **Difference only at low p_T**
- **Statistical and systematic uncertainties shown (shaded area)**

I_{CP} : [yields: central / peripheral]



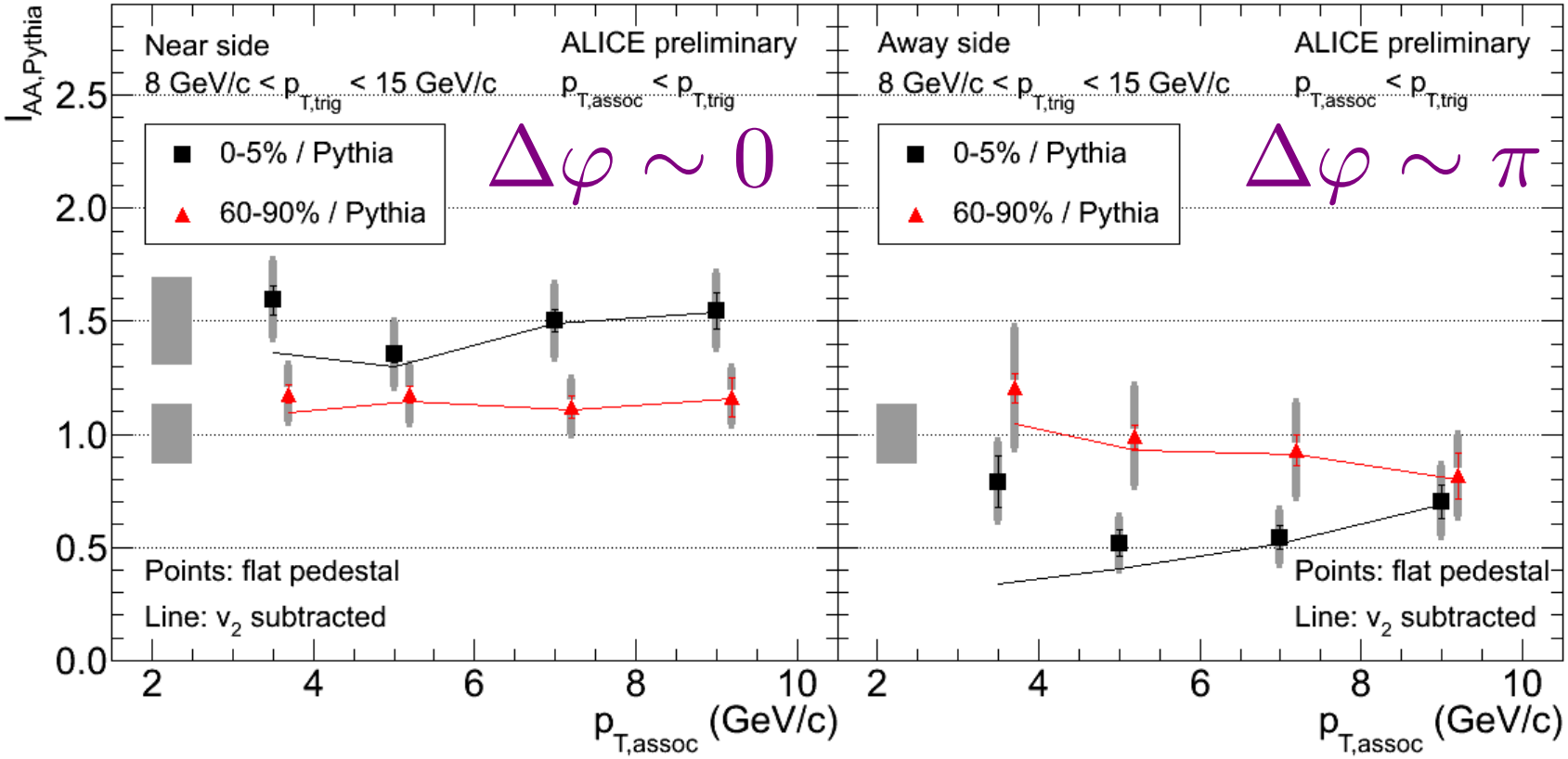
Slightly enhanced near-side: I_{CP} ~ 1.2 … unexpected and interesting

Away side suppressed: I_{CP} ~ 0.6 … consistent with in-medium energy loss

Flow contribution small except in lowest bin. V_3 component not subtracted

$I_{AA,Pythia}$: using Pythia as p-p reference

Pythia6 (Perugia-0) validated with correlations DATA at 0.9 and 7 TeV
Uncertainty from extrapolation shown (shaded single rectangles)



Central events

Near side enhanced $I_{AA,Pythia}$ ~ 1.5

Away side suppressed $I_{AA,Pythia}$ ~ 0.5 – 0.7

Peripheral events

Near side enhanced $I_{AA,Pythia}$ ~ 1.2

Away side $I_{AA,Pythia}$ consistent with 1

Progressing analyses

- p-p exclusive analyses:
  - Resonances in p-p
  - Event shape characterization in p-p
- Pb-Pb exclusive analyses:
  - Indentified particle
    - Including nuclei and anti-anti-nuclei
  - Azimuthal anisotropy – v_n
  - Chiral magnetic effects
  - Event-by-event fluctuation
  - HBT v.s. centrality
- Analyses in both systems:
  - R_{AA} – extend to high p_T
  - J/ψ – p-p under submission, polarization – under study
  - Single electron from heavy-flavor decays
  - Single muons
  - Open charm
  - π^0 production cross-sections
  - Azimuthal correlations
  - Λ / K^0_s
  - Multi-strange particle

ALICE Posters

Valerio Altini : Trigger performance of the ALICE Silicon Pixel Detector

Bruno Alexandre Boyer : Measurement of the J/psi cross section in the dimuon channel with the ALICE experiment at LHC

Davide Caffarri : D0 production in pp collisions at $\sqrt{s_{NN}}$=7 TeV and Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV with the ALICE detector

Veronica Canoa Roman : Diffractive physics studies at ALICE

Gian Michele Innocenti : D+ and D_s production in pp collisions at $\sqrt{s_{NN}}$=7 TeV and Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV in the ALICE experiment

Satyajit Jena : Charge fluctuations in Pb-Pb collisions at $\sqrt{s_{NN}}$= 2.76 TeV

Frederick Kramer, Julian Book : Measurement of the J/psi production cross section in pp collisions at $\sqrt{s_{NN}}$=7 with ALICE at the LHC and perspectives for Pb-Pb collisions

Leonardo Milano : Measurement of identified hadron spectra with the ALICE experiment at the LHC

Igor Lakomov : Mean transverse momentum, multiplicity, and their correlation in pp collisions in string fusion model

Carlos Eugenio Perez Lara : "Anisotropic flow of decaying strange particles in ALICE"

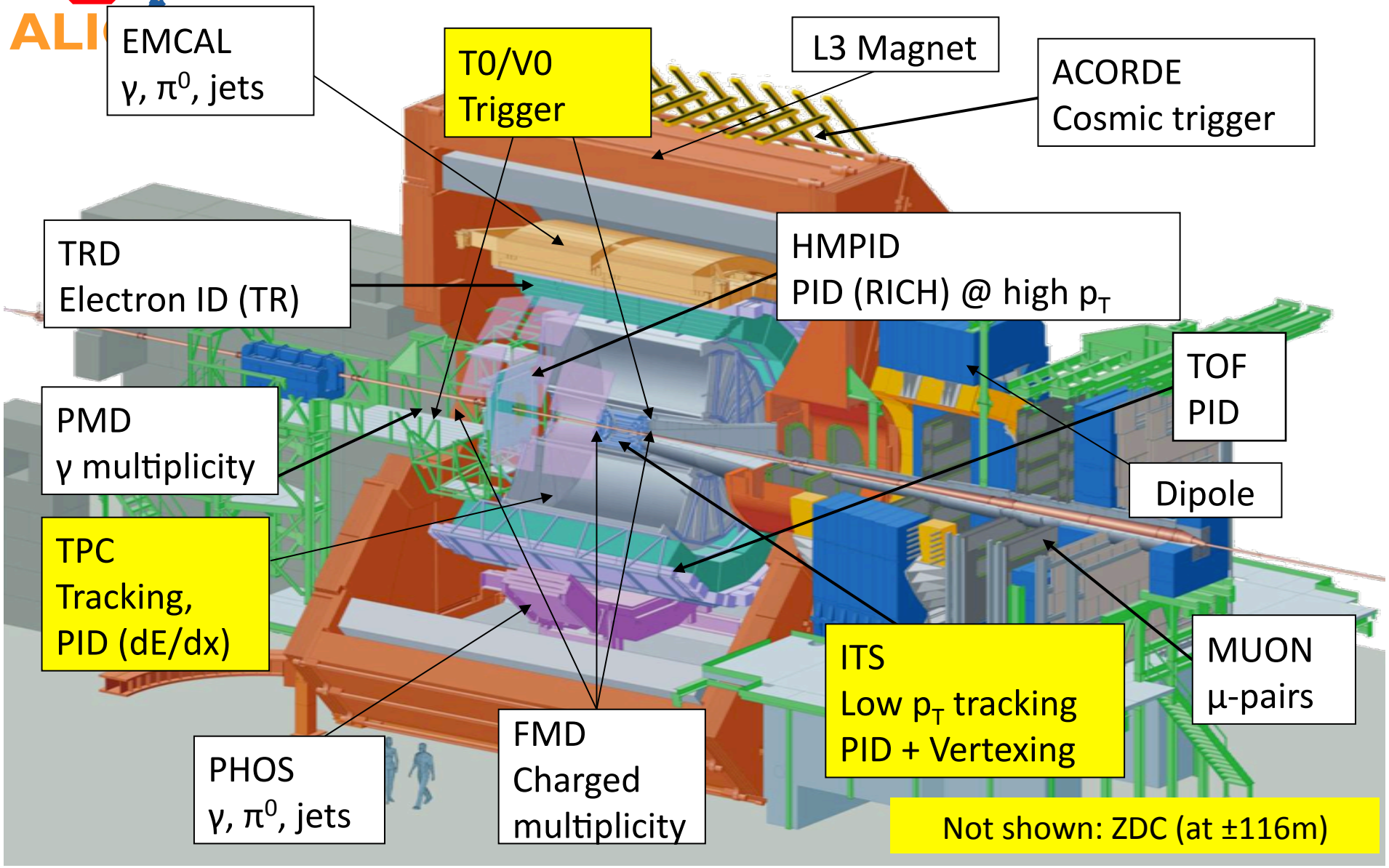
Marta Verweij : Background studies for jet reconstruction in heavy-ion collisions

Natasha Sharma : Antimatter production in pp and PbPb collisions

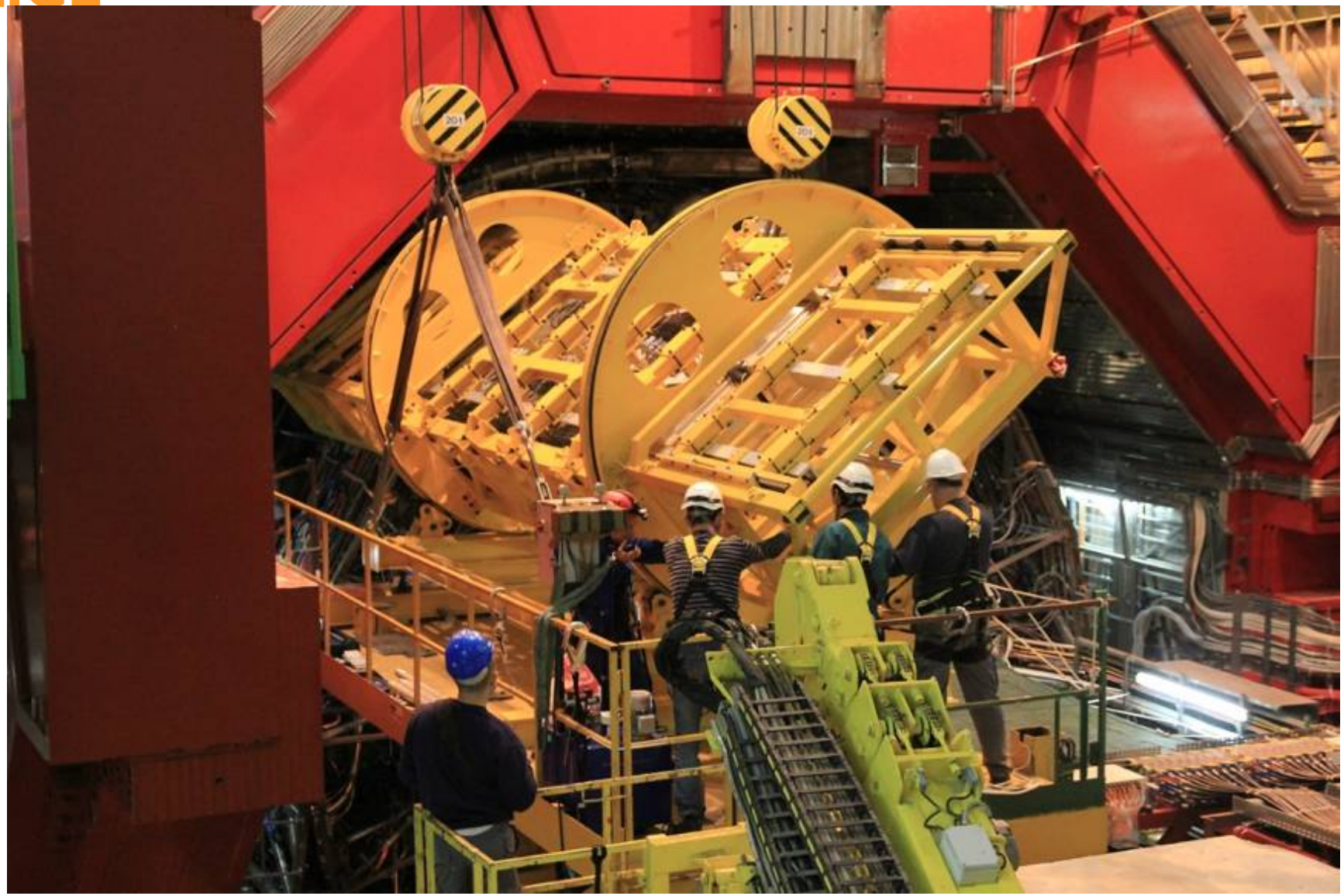
Xiaoming Zhang : Measurement of heavy-flavor production using single muons with ALICE

EXTRA SLIDES

A Large Ion Collider Experiment



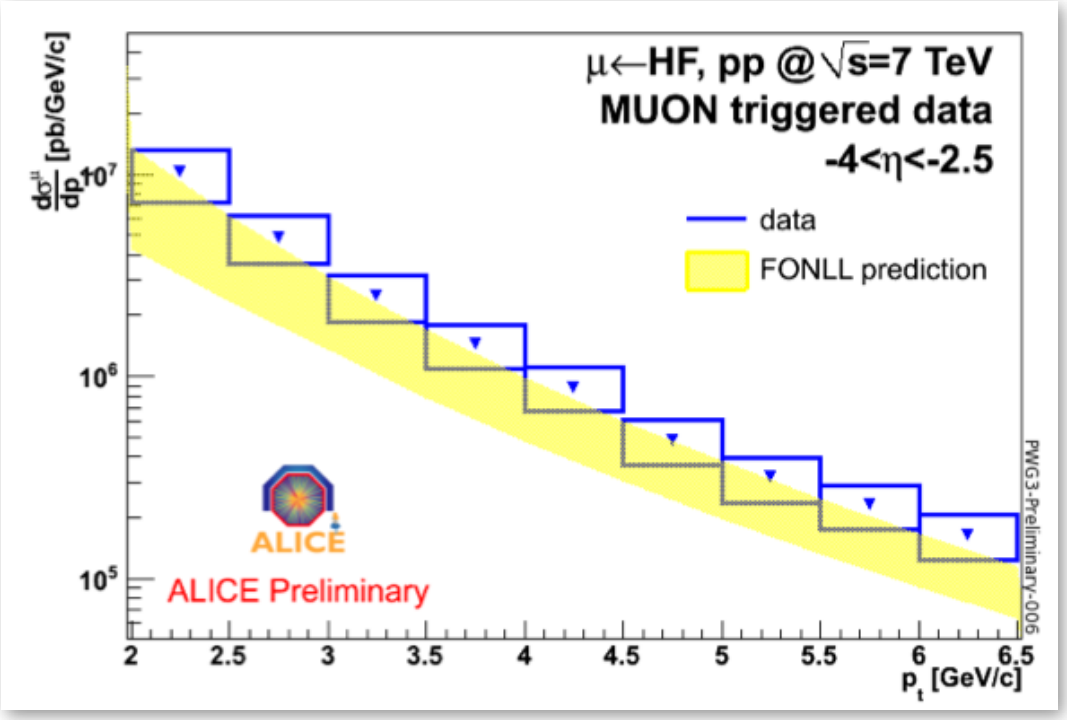
EMCal installation



TRD crew

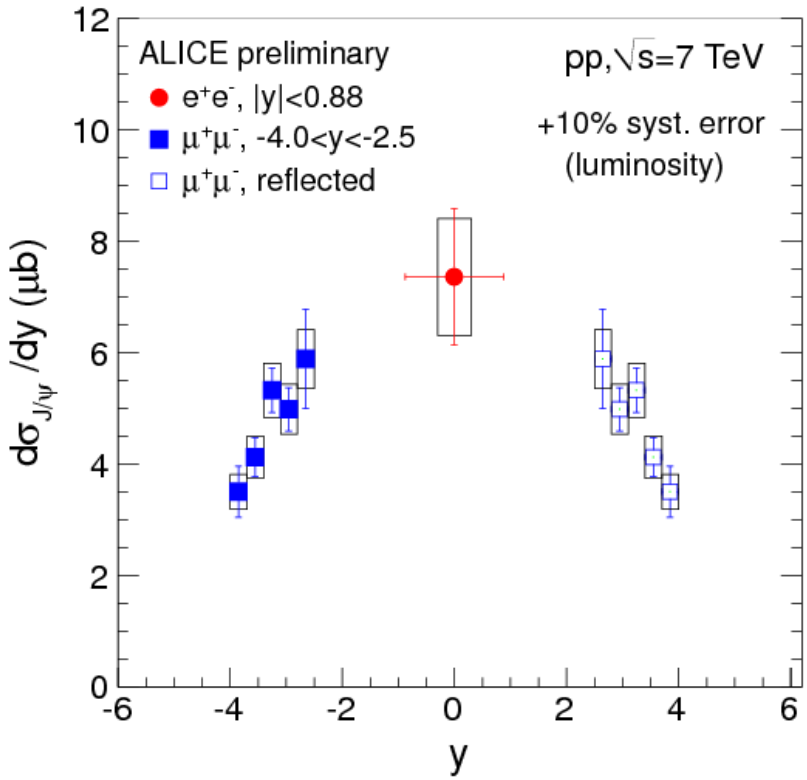
ALICE heavy flavous in the muon channel in pp and PbPb

Muons from heavy flavour also agreed with pQCD FONLL predictions.



- High quality track in the muon tracking system;
- Matching with muon trigger system remove most of secondaries about pT=2 GeV;
- New tracks cut applied (chi2, DCA …);
- **New analysis in pp@7TeV , 15 GeV reach and pT distribution in 5 rapidity bins;**
- **First analysis in PbPb allows for the determination of RCP and RAA of muon from heavy flavours in the pt range 4-8 GeV/c**

Quarkonia in p-p



- Paper released to the ALICE collaboration;
- **Expected submission beginning April;**
- First J/psi wide range rapidity distribution down to pT=0 in pp@ TeV;
- New interesting results from analysis on Jpsi polarization and j/psi in high multiplicity events.

Analysis basics and strategy

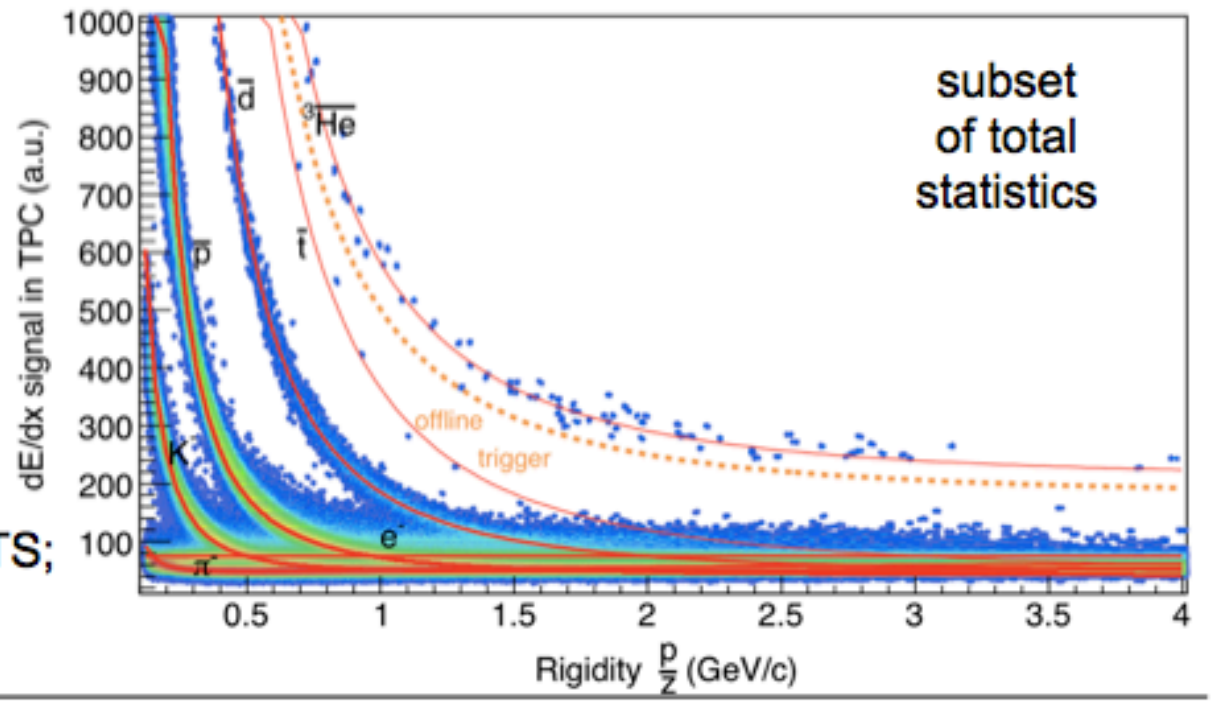
TECHNISCHE UNIVERSITÄT DARMSTADT

- Total available pass1 PbPb statistics was analyzed: 16.1 million nuclear collisions "after physics selection".

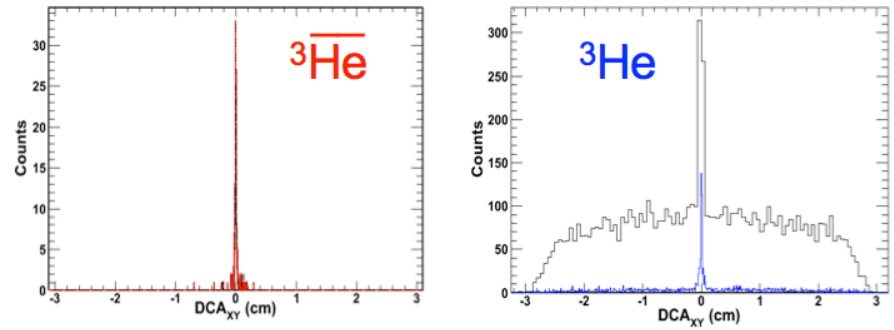
- 10.1 x 1010 tracks inspected and filtered with an offline trigger:

- 768 Anti-He-3 particles after filtering

- Basic track cuts:
  - 80 TPC cls; eta < 0.8; ITS+TPC refit; chi2/cls < 5; 1 Hit in ITS; DCA < 1cm; no Kink



DCA Study



DCA_Z < 1.0 cm cut removes large fraction of background

$^3\overline{He}$ Entries: 328 → 322

^3He Entries: 7162 → 1527

Natasha Sharma, PWG2 Meeting, March 15th, 2011

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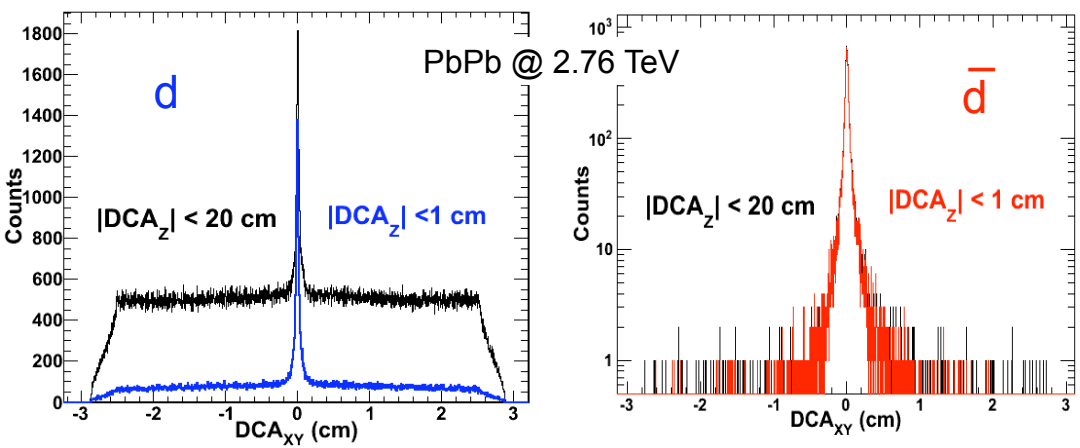
- Nearly 11 M minimum bias events are analyzed for PbPb and over 350 M events are analyzed for pp @ √s = 7 TeV
- Nuclei and anti-nuclei produced in the collisions have Dist Closest Approach (DCA) always near to zero. Nuclei can also be produced by interaction with the material. Their yield is then determined after background subtraction in the DCA_{XY} distribution.

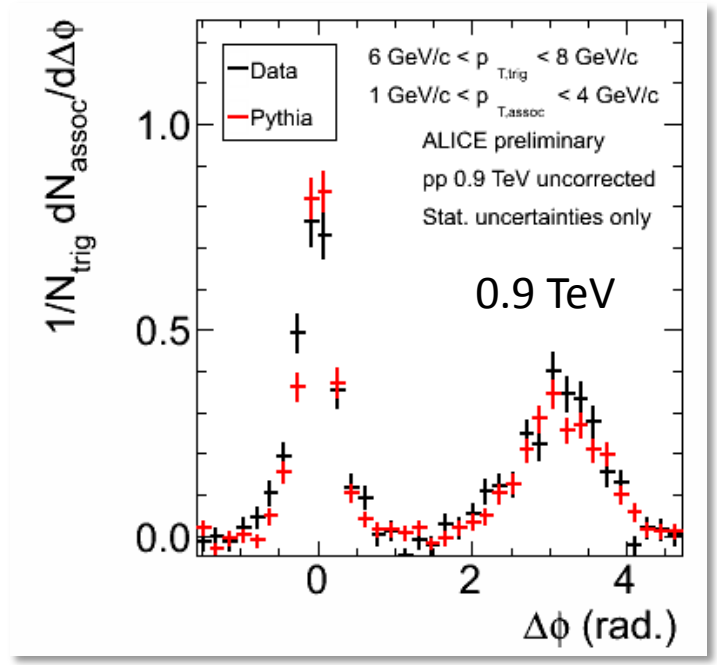


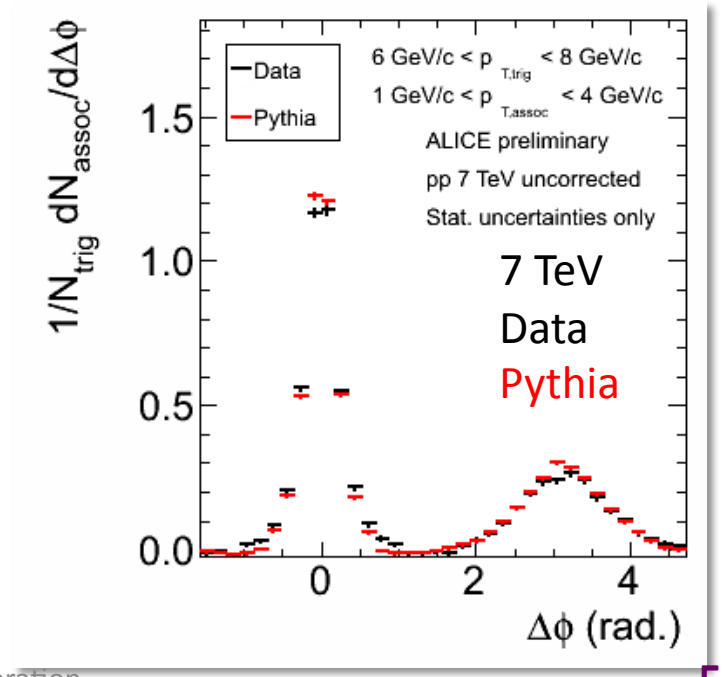
FROM HIGH-PT CORRELATIONS

I_{AA} Reference

- Interesting to **study yield with respect to unquenched (pp)** case
  - No pp data taken at 2.76 TeV, yet
  - Use a MC
- Pythia6 tune Perugia-0 has been found to describe di-hadron correlations at 0.9 and 7 TeV well
  - Using a scaling factor between 0.8 and 1
  - Interpolate to 2.76 TeV
    - Factor 0.93 ± 13% (stat/syst)

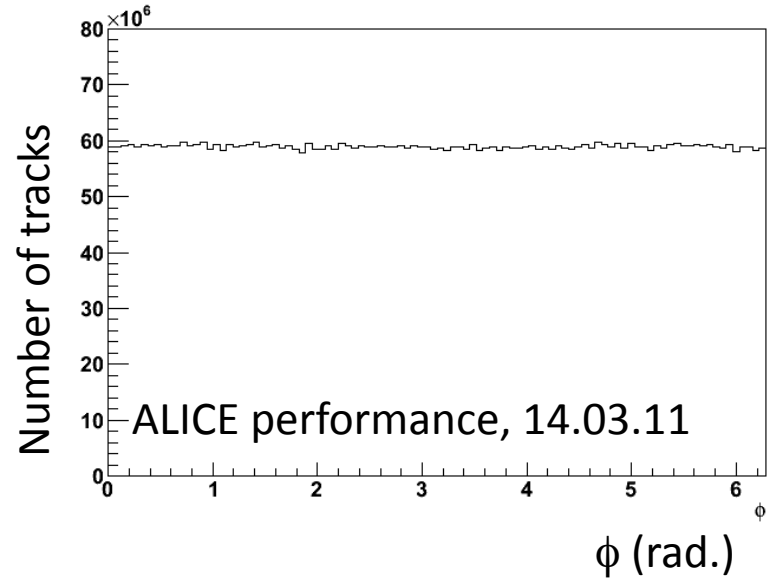
→ Use scaled Pythia reference to calculate $I_{AA,Pythia}$

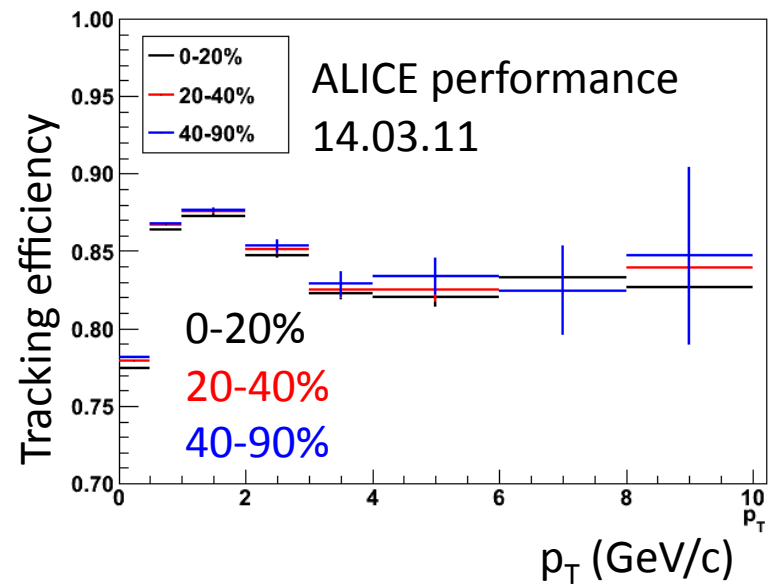




Di-hadron Analysis

- 12M Pb+Pb collisions used
- Tracking with Time Projection Chamber and Inner Tracking System
  - Flat ϕ acceptance → No mixed event background needed for acceptance correction (in ϕ)
- Centrality determination with V0 (forward scintillators) and hits in pixel detector
- Corrections applied for efficiency and contamination
  - Weakly centrality dependent
  - Two-track effects considered



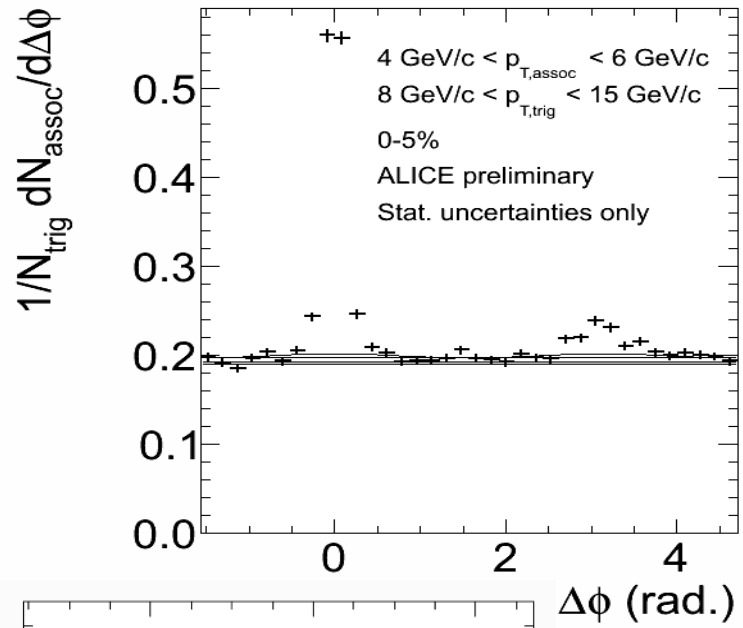


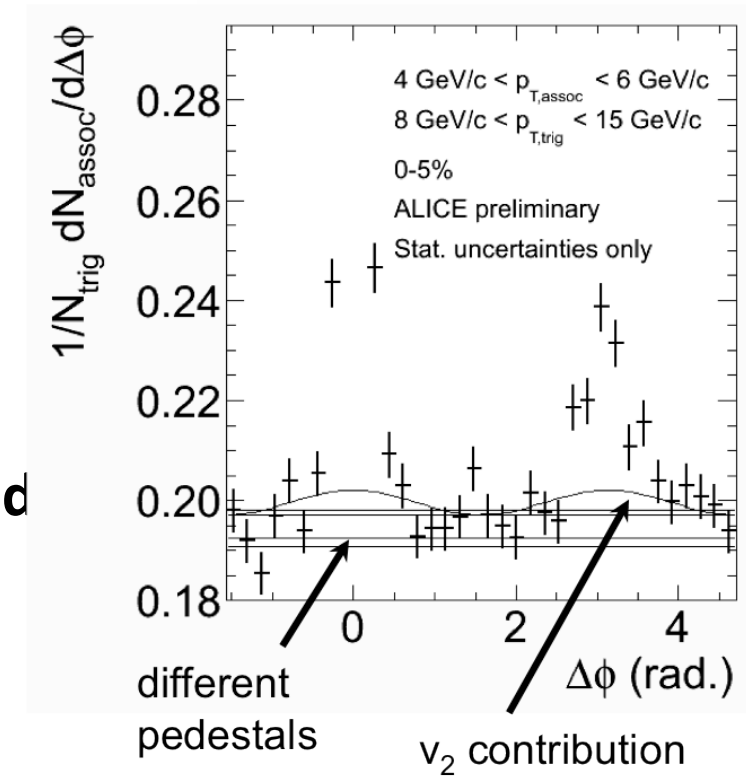
Pedestal and Flow

- Background determination
- Fit in region around $\pi/2$
  - Different ways to estimate uncertainty
- Estimate v_2 contribution using ALICE flow measurement

→ Measure in a region where the signal dominates over pedestal and v_2 modulation ($8\ \text{GeV/c} < p_{T,trig} < 15\ \text{GeV/c}$)

→ **Difference in measurement indicated when v_2 was subtracted**





Yield Extraction

- After pedestal (and optionally v_2) subtraction), integrate to obtain yield Y

  Near side $-0.7 < \phi < 0.7$

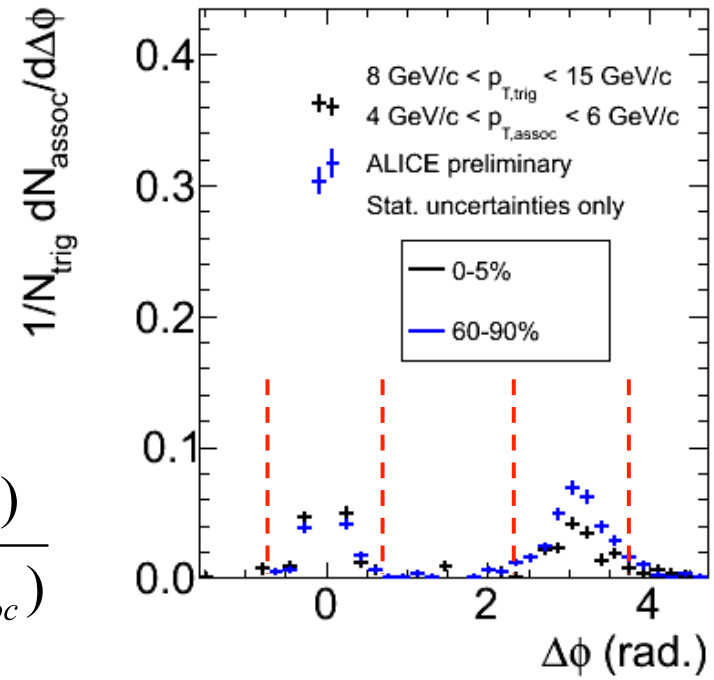
  Away side $-0.7 < \phi - \pi < 0.7$

- In bins of $p_{T,assoc}$
- I_{CP} and I_{AA} obtained with

$$I_{CP}(p_{T,trig};p_{T,assoc}) = \frac{Y^{AA}_{central}(p_{T,trig};p_{T,assoc})}{Y^{AA}_{peripheral}(p_{T,trig};p_{T,assoc})}$$

$$I_{AA}(p_{T,trig};p_{T,assoc}) = \frac{Y^{AA}(p_{T,trig};p_{T,assoc})}{Y^{pp}(p_{T,trig};p_{T,assoc})}$$

0-5%
60-90%



integration windows

Systematic Uncertainties

- Detector efficiency and two-track effects
- Centrality determination
- p_T resolution
  - Fold associated p_T distribution with momentum resolution
- **Different pedestal determination schemes**
  - **Discussed above → 7-20%**
- Variation of the integration window
  - between ±0.5 rad. and ±0.9 rad.

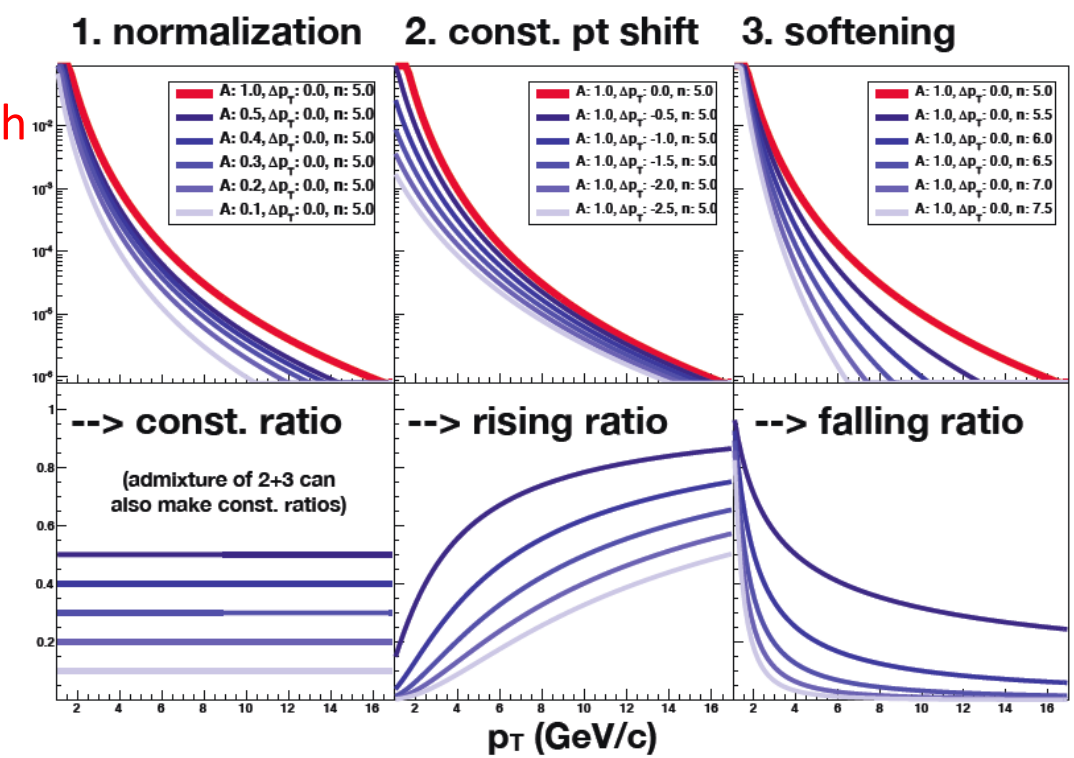
Detector efficiency	**5-8%**
Centrality selection	**2-8%**
p_T resolution	**3%**
Pedestal calculation	**7-20%**
Integration window	**0-3%**

Ranges indicate different values for I_{CP}/I_{AA} and near/away side

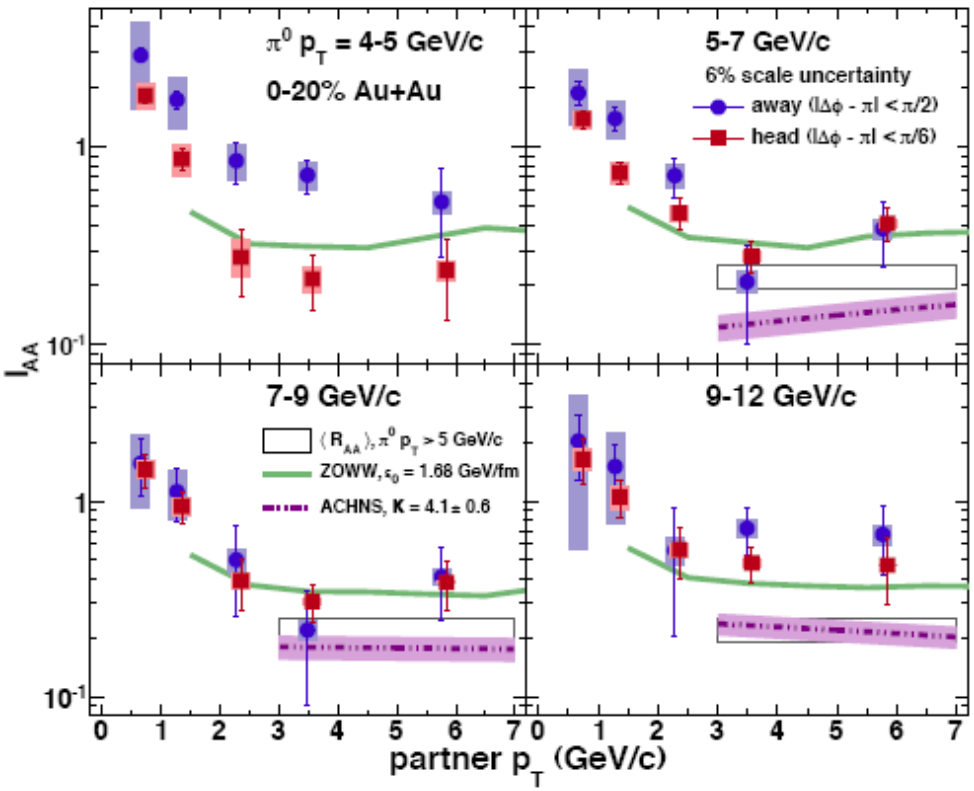
Considerations: Near Side Enhancement (I_{AA} > 1)

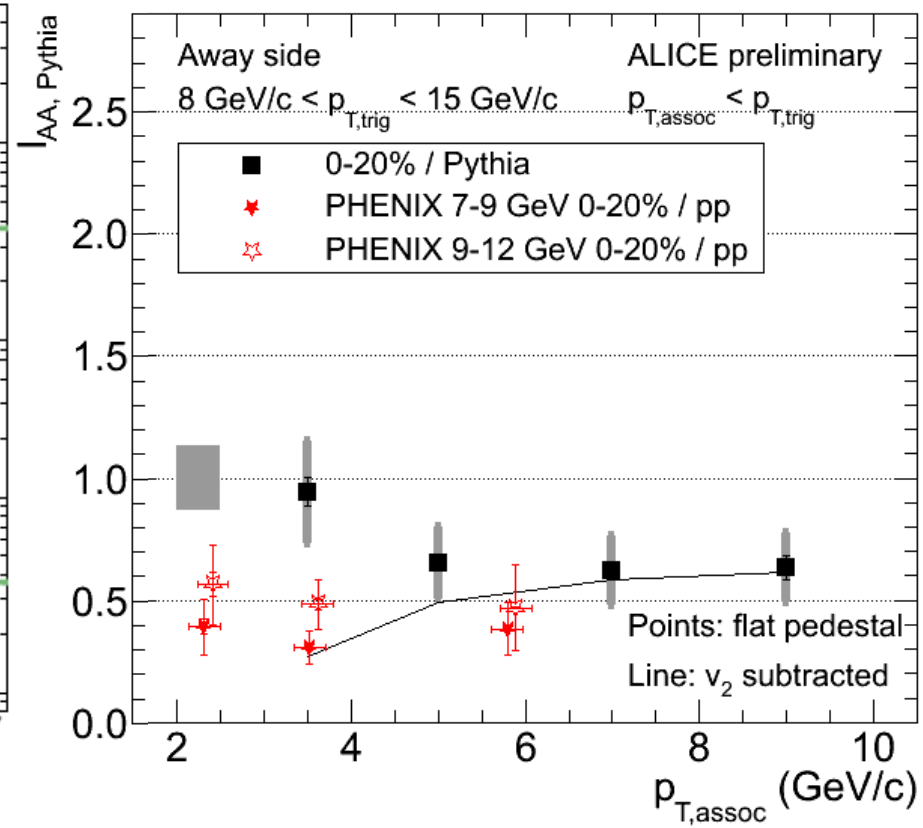
- Near side enhancement in I_{CP} and $I_{AA,Pythia}$ in central events
  - Near side is modified → trigger particle interacts with the medium
- Possible explanation
  - **In the presence of quenching same trigger p_T might probe higher parton p_T**
  - Increased trigger p_T → increased yield → increased $I_{AA,Pythia}/I_{CP}$
  - $I_{AA,Pythia}/I_{CP}$ on away side would be even lower without this effect!

Toy power law example: $A/(p_T - \Delta p_T)^n$



$I_{AA,Pythia}$: ALICE vs. PHENIX





PHENIX, PRL 104, 252301 (2010)

- **PHENIX subtracts v_2 → compare ALICE line with PHENIX**
- **Much larger p_T reach at LHC**
- **Slight increase with $p_{T,assoc}$ → not significant, to be studied further**