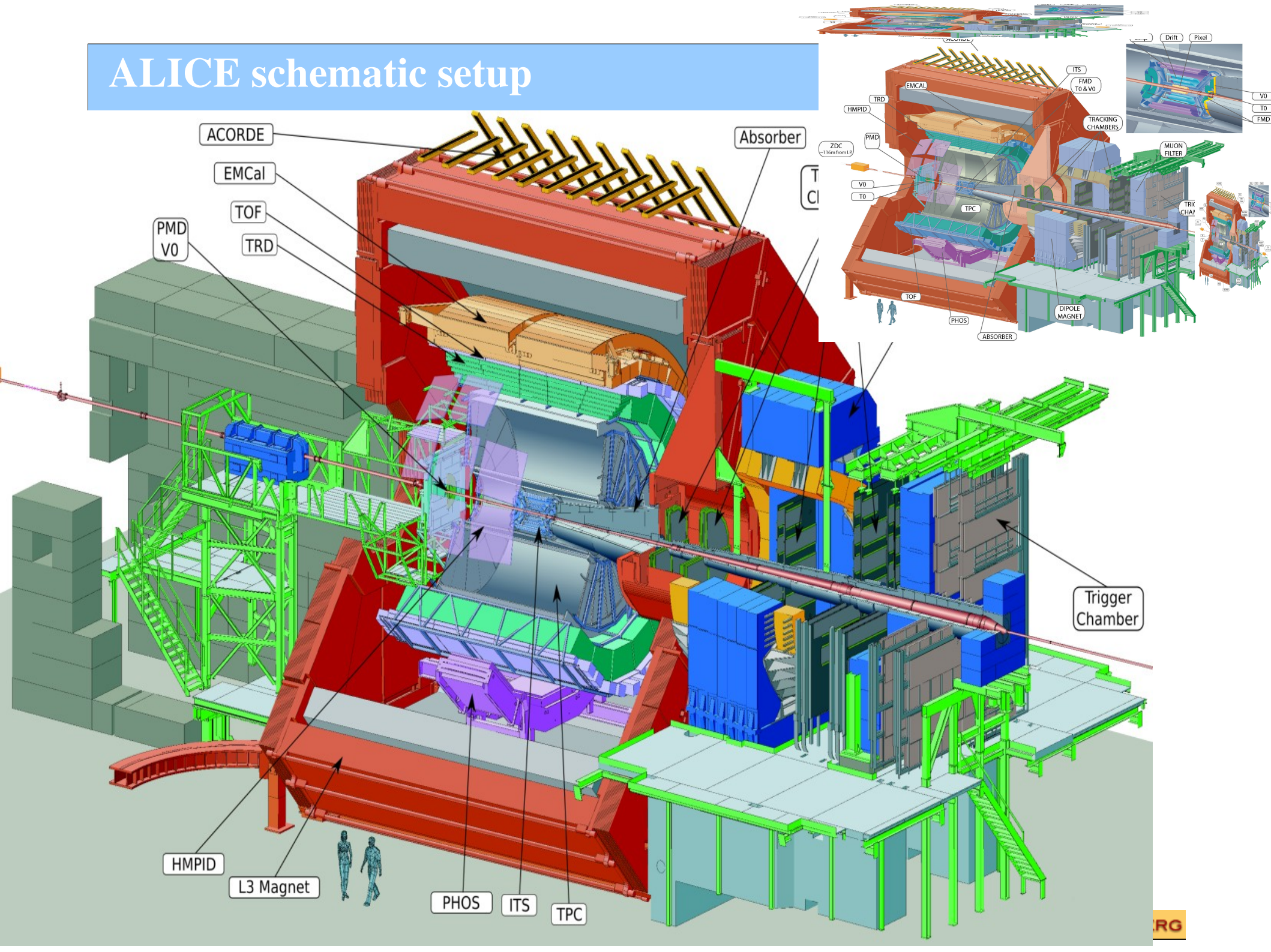
First Physics Results from ALICE at the LHC

detectors used for the measurements
performance in first runs
multiplicity in pp collisions
first results on hadron spectra and strangeness
photon reconstruction using the conversion method
open charm and charmonia

Int. EMMI Workshop „Strongly coupled systems“ in honor of Jochen Wambach
GSI Darmstadt, Nov. 15-17, 2010
Johanna Stachel – Physikalisches Institut – Universität Heidelberg

ALICE schematic setup



ALICE configuration – 2009/2010/2011 physics runs

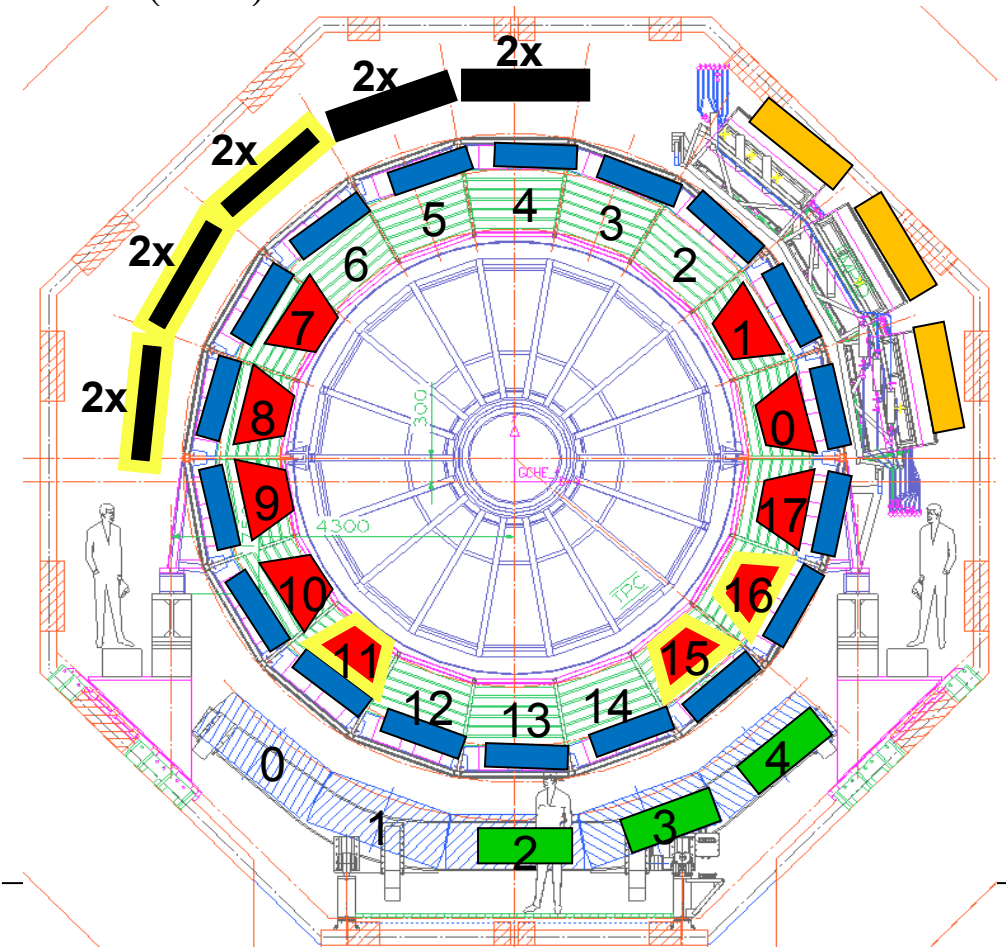
ITS, TPC, TOF, HMPID, MUON, V0, T0, FMD, PMD, ZDC (100%)

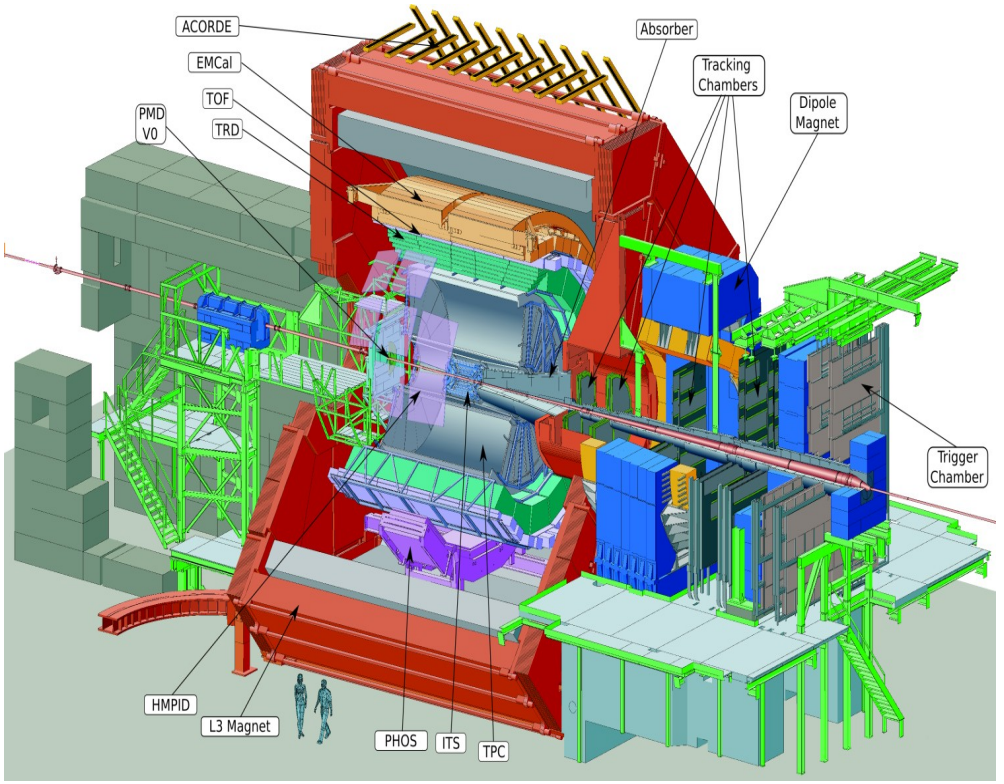
TRD (7/18) [10/18) in Dec 2010

EMCAL (4/10) [/10) in Jan 2011

PHOS (3/5)

HLT (60%)



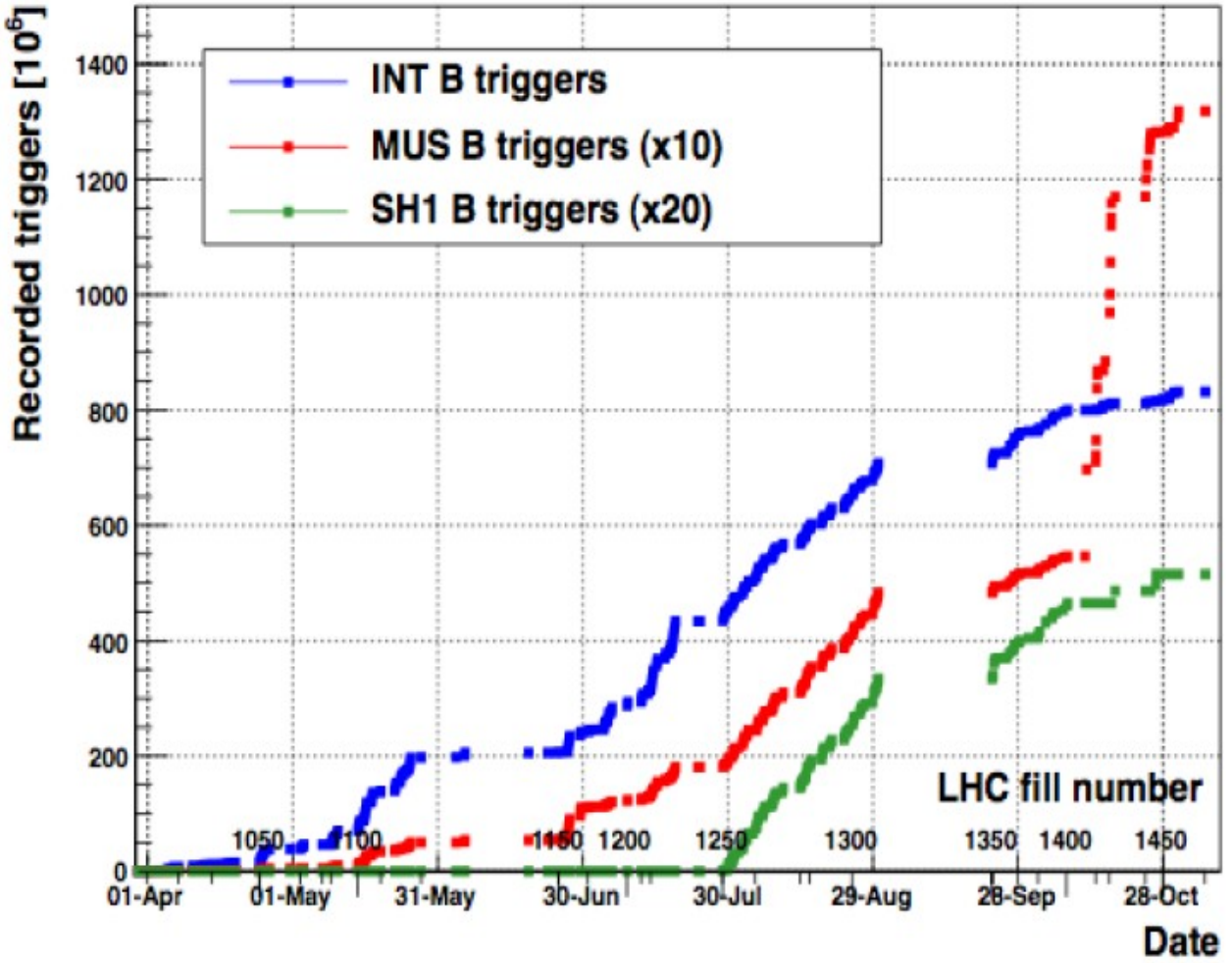


pp running in ALICE

December 2009: 300 k min bias at 900 GeV

similar at 2.36 TeV but no stable beam (only mult measurement)

April – October 2010: mostly 7 TeV plus 3 million 900 GeV



130 million muon triggers

800 million min bias collisions

250 k high mult triggers

tracking in the central barrel of ALICE

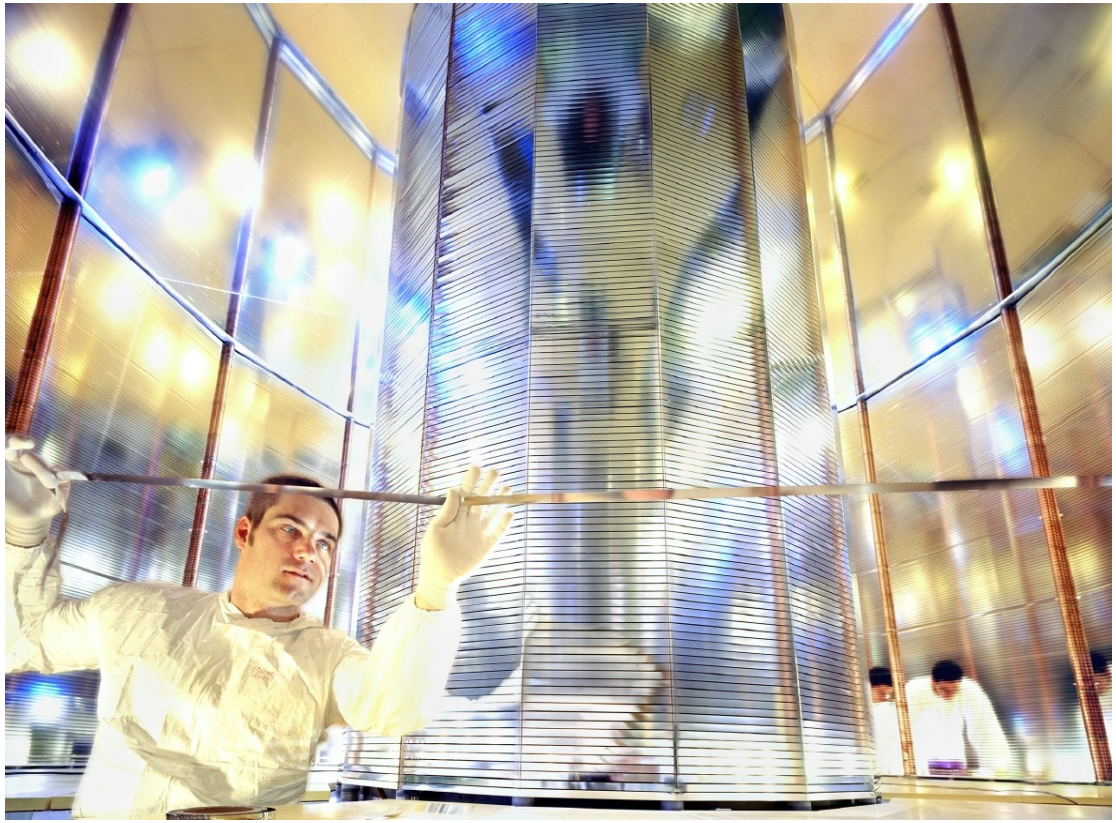
ITS: 6 layers of Si -> 6 space points close to vertex, high resolution
TPC: 150 space points
TRD: about 90 independent space points

all in 0.5 T magnetic field

vertex and tracks can be well reconstructed

the TPC (Time Projection Chamber) - 3D reconstruction of up to 15 000 tracks of charged particles per event

with 95 m^3 the largest TPC ever

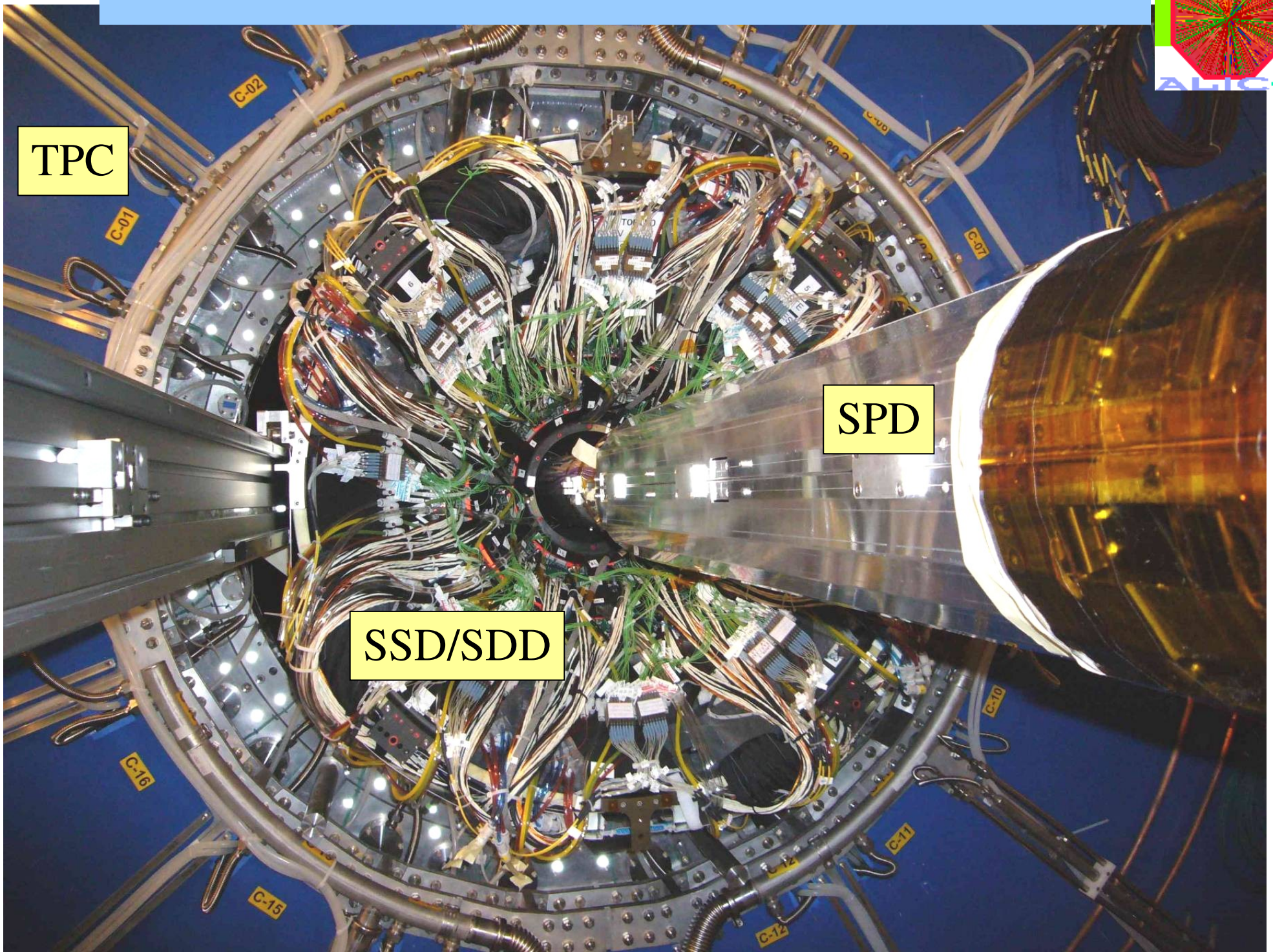


560 million read-out pixels!

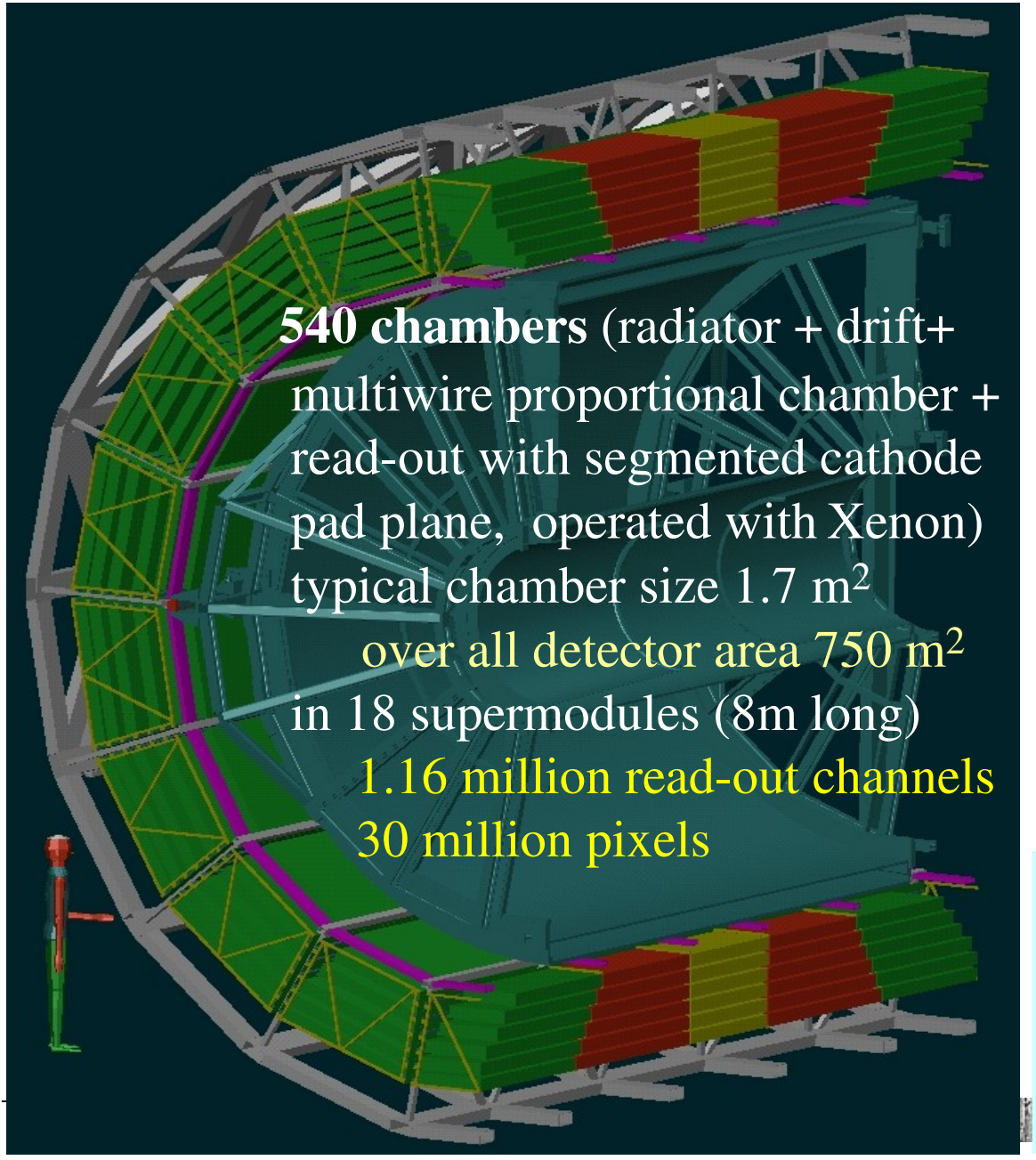
precision better than 500 μm in all 3 dim.

180 space and charge points per track

ITS russian dolls - sliding the SSD/SDD over the SPD



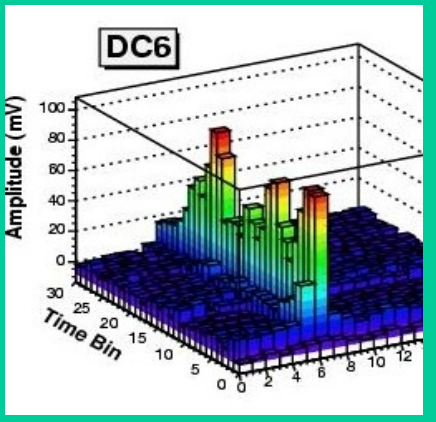
the TRD (Transition Radiation Detector) identifies electrons at the trigger level

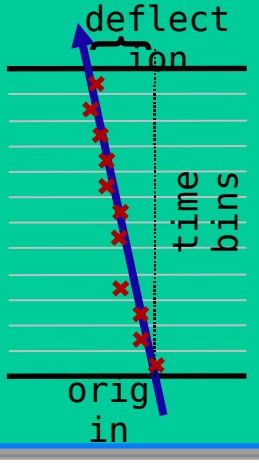


540 chambers (radiator + drift+ multiwire proportional chamber + read-out with segmented cathode pad plane, operated with Xenon)
typical chamber size 1.7 m^2
over all detector area 750 m^2
in 18 supermodules (8m long)
1.16 million read-out channels
30 million pixels

read-out electronics: 2 custom ASICS on multichip modules developed at PI and KIP in Heidelberg

from charge-clustern zu track segments
500 cpu Local Tracking Unit on each chamber:

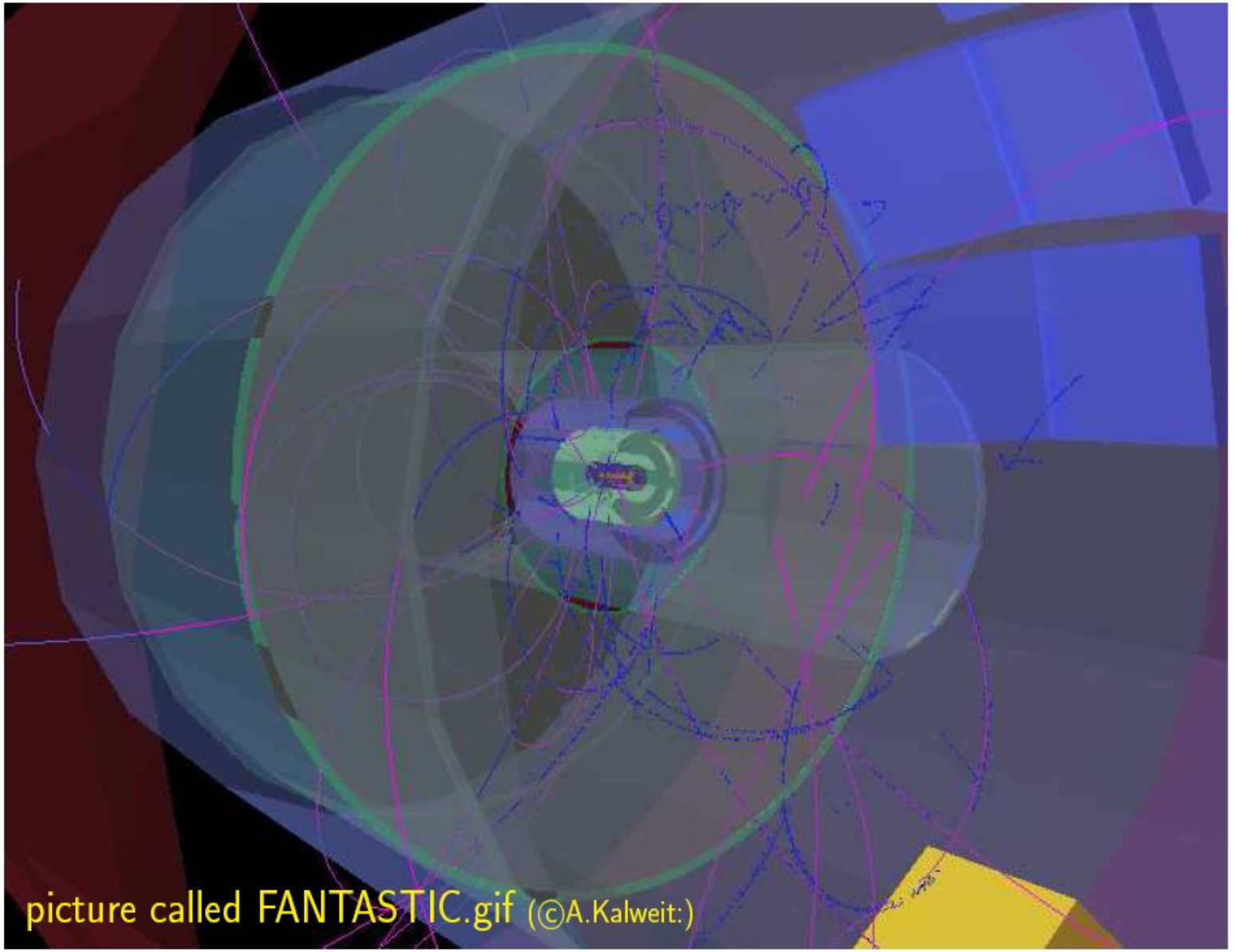




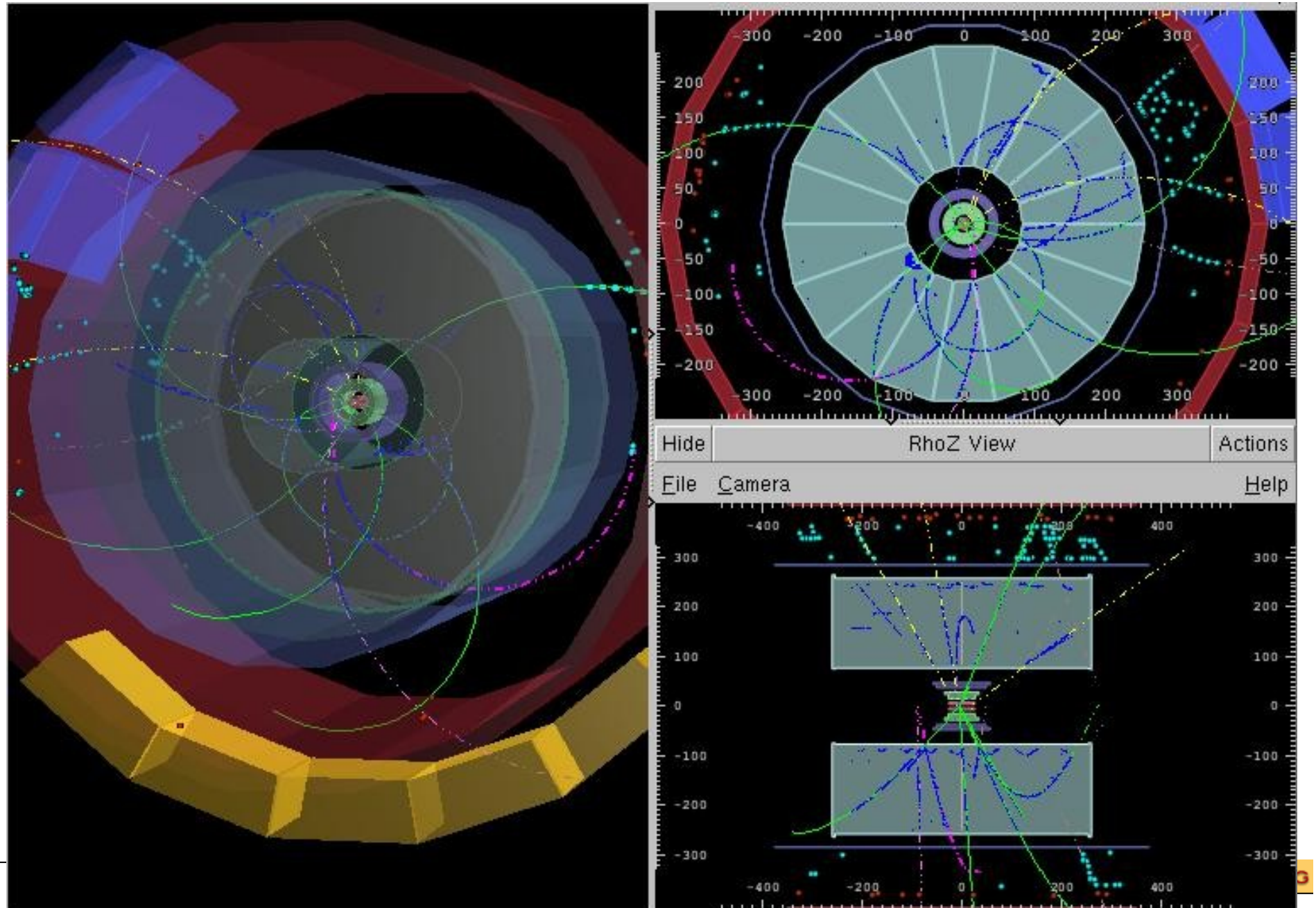
275 000 CPU's process raw data of 65 Mbyte to reconstruct tracks (of 6 segments) in 6.5 µs for trigger decision:
high momentum electron pair

first ALICE event with all detectors turned on

First events (Sun, 6 Dec 2009 08:05)

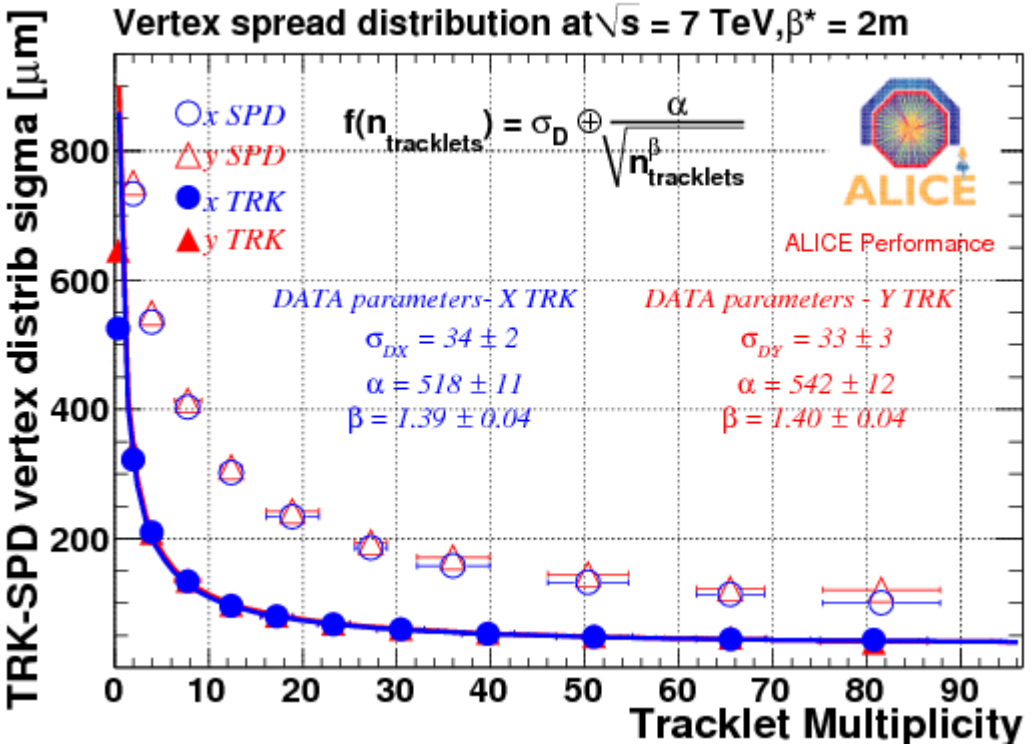


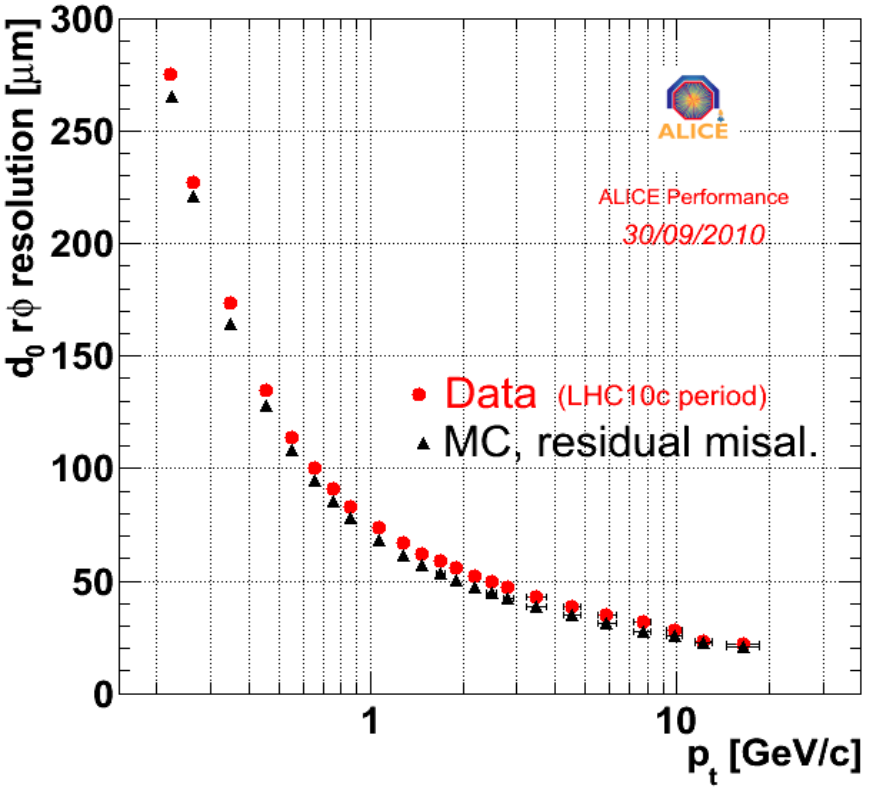
some 7 TeV pp collision event displays



current tracking performance

tracking performance – ITS system

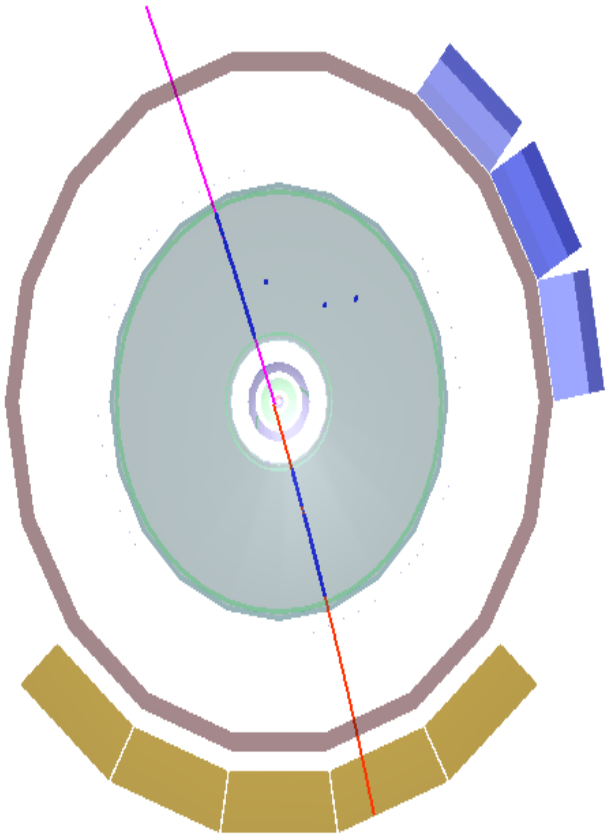




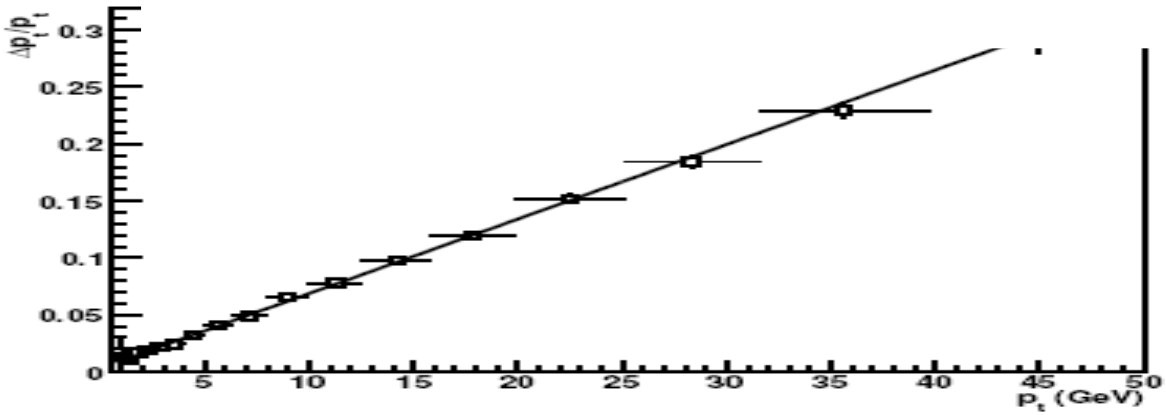
after careful alignment of Silicon Pixel Detectors
expected vertex and impact parameter resolution already nearly reached

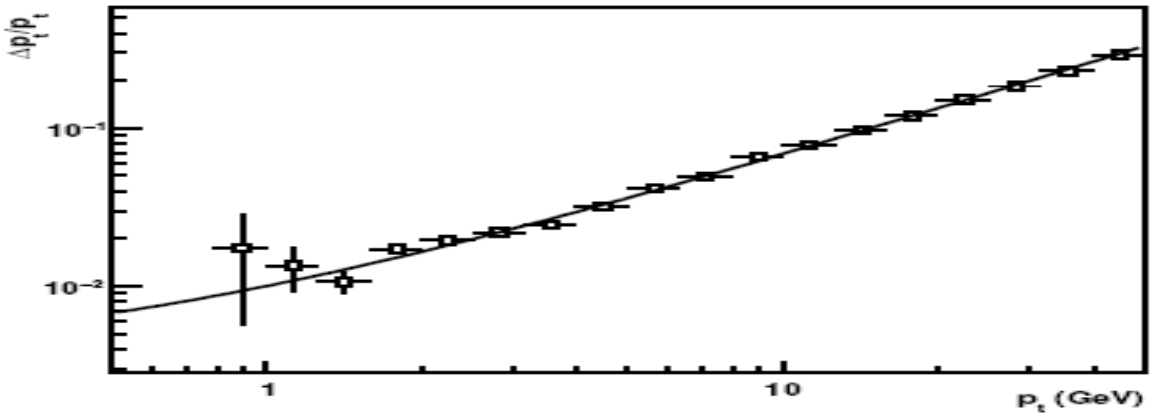
measured TPC stand-alone momentum resolution

tracking cosmic rays in magnetic field



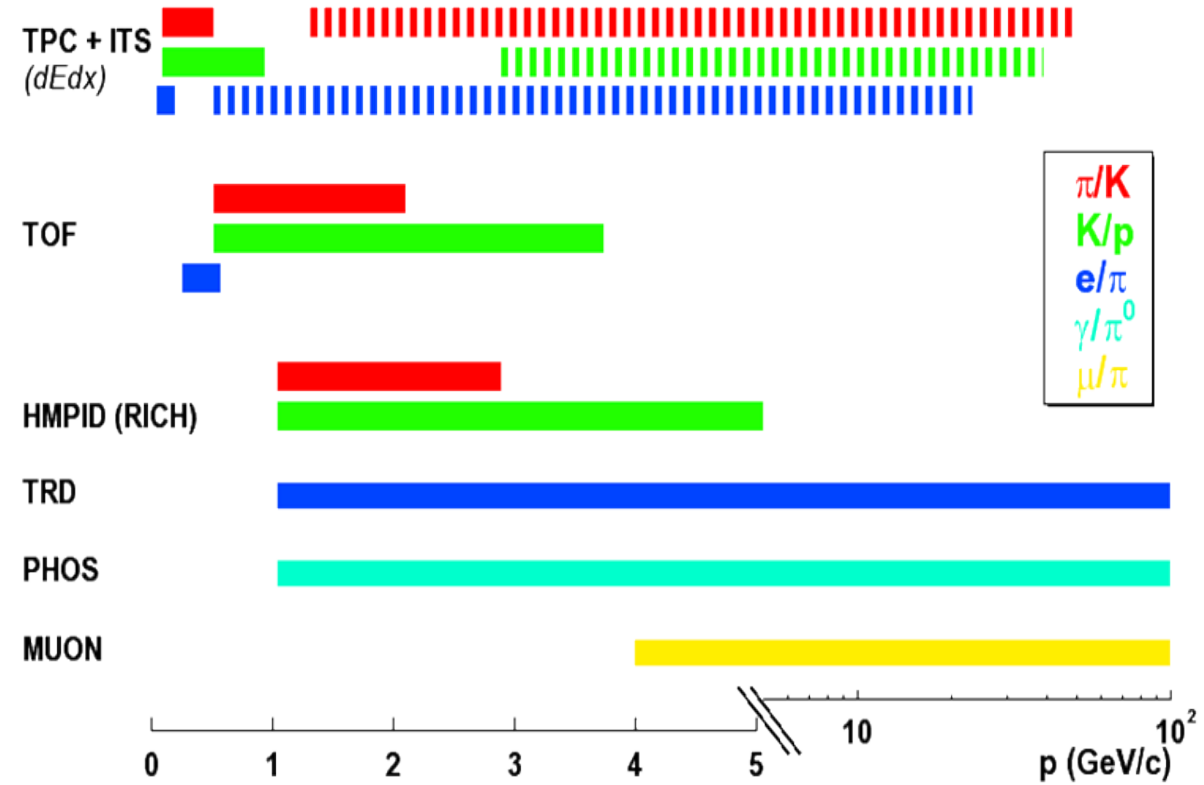
resolution from two halfs of a cosmic ray track: already at this stage 7% at 10 GeV/c





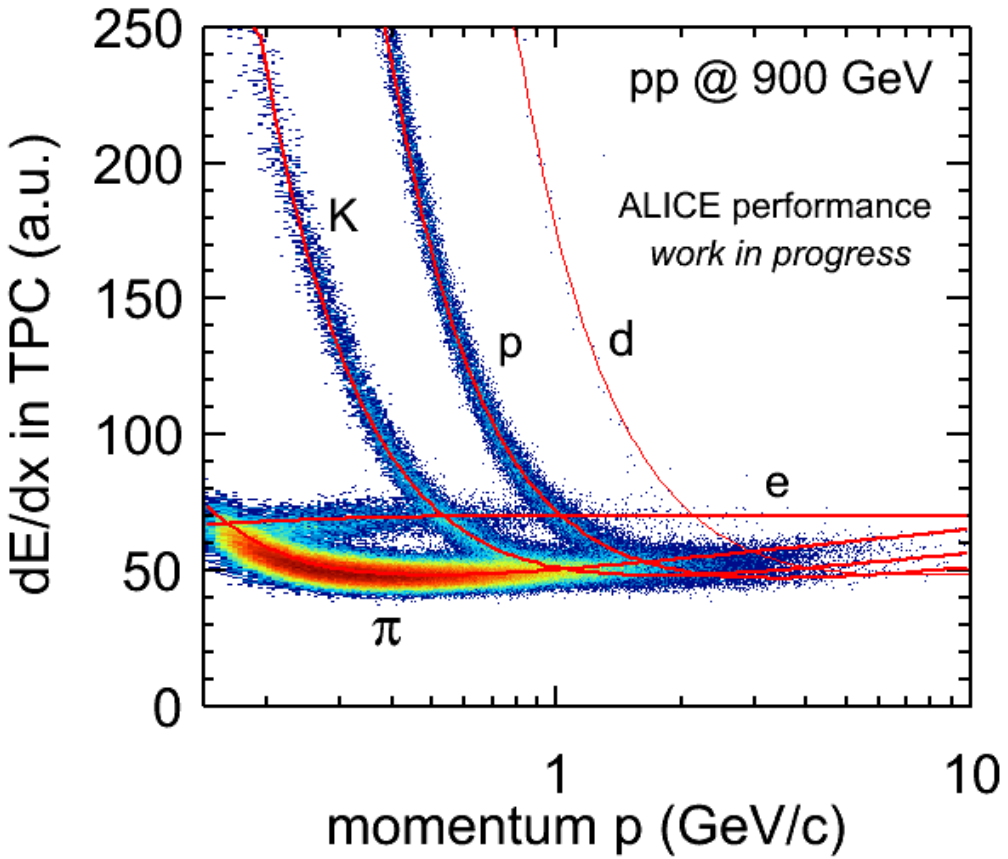
particle identification in ALICE

ALICE has PID over large momentum range

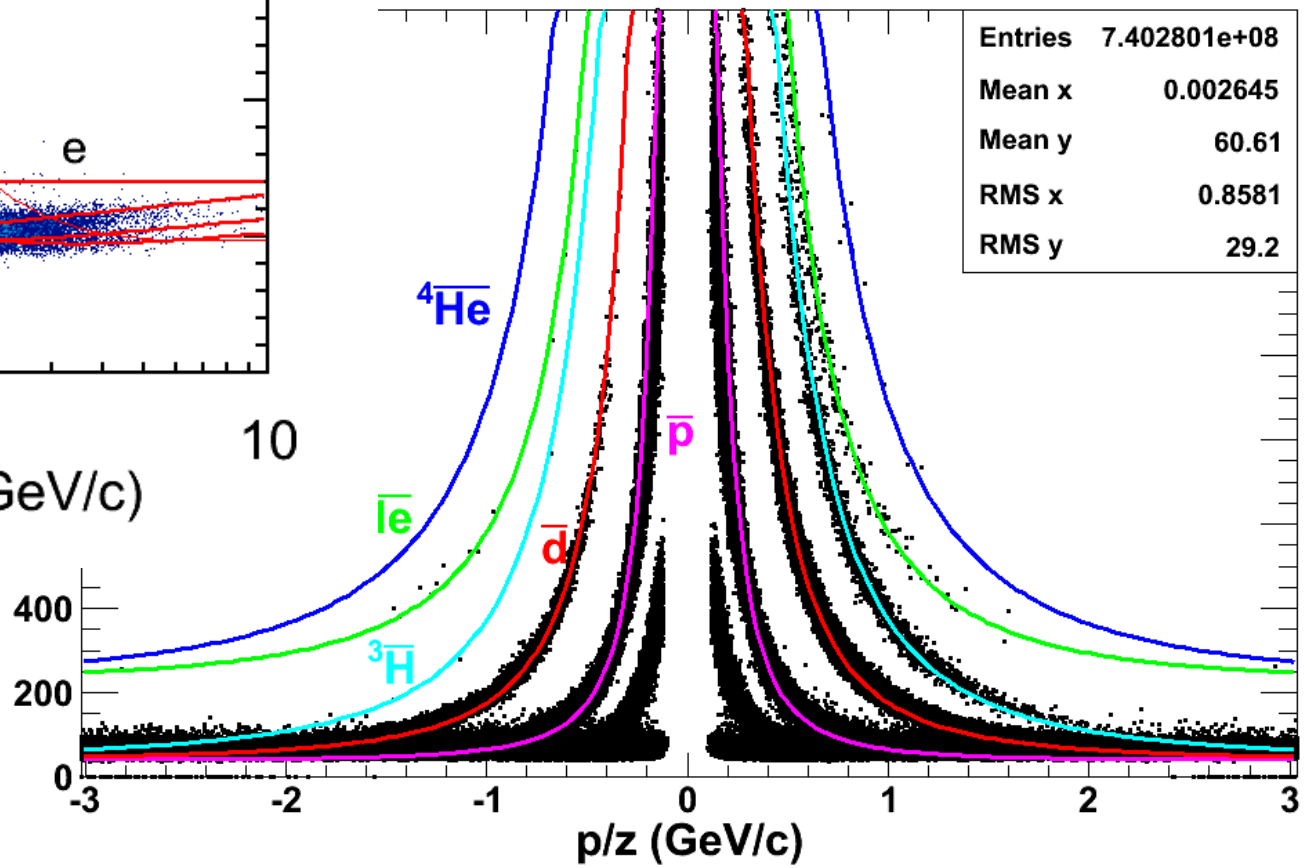


EMCAL adds electron/pion separation via shower shape

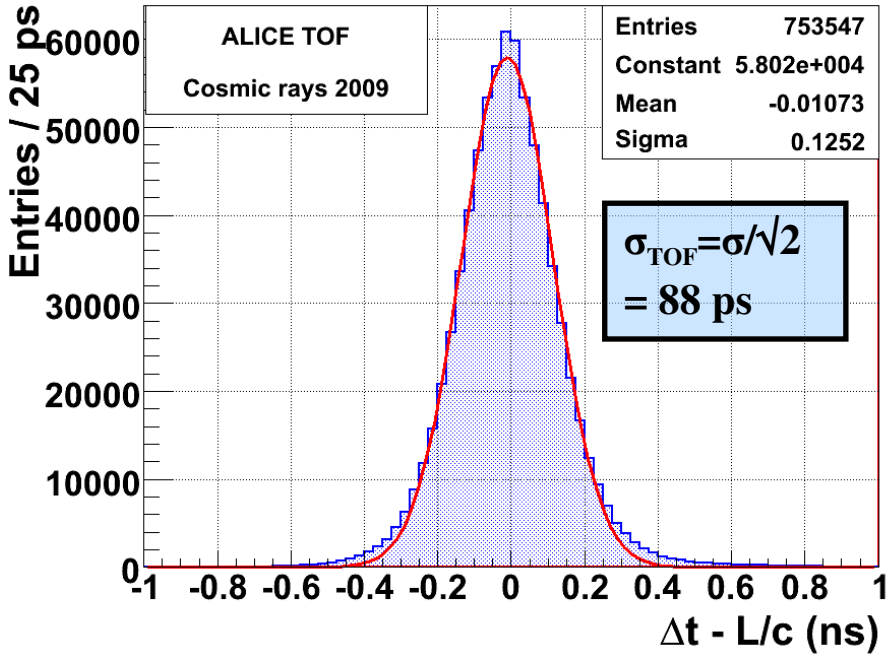
ALICE PID performance 1 – energy loss in TPC

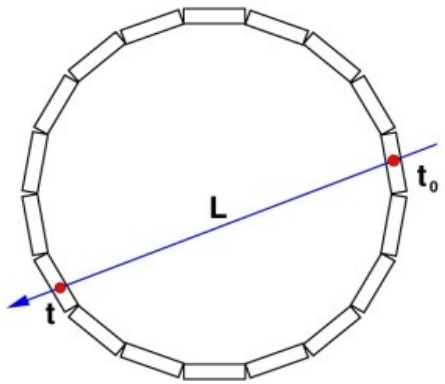


excellent PID with TPC
900 GeV and 7 TeV
dE/dx resolution < 5 %



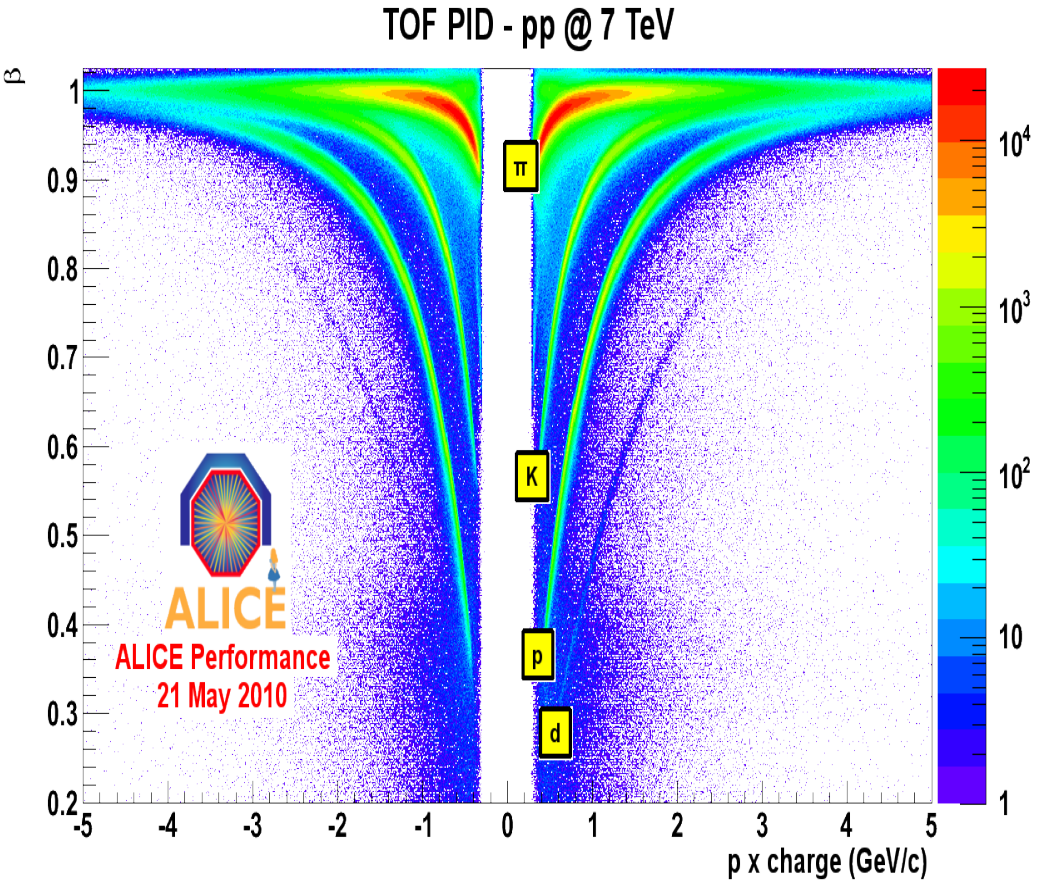
ALICE PID performance 2 – time-of-flight (TOF)



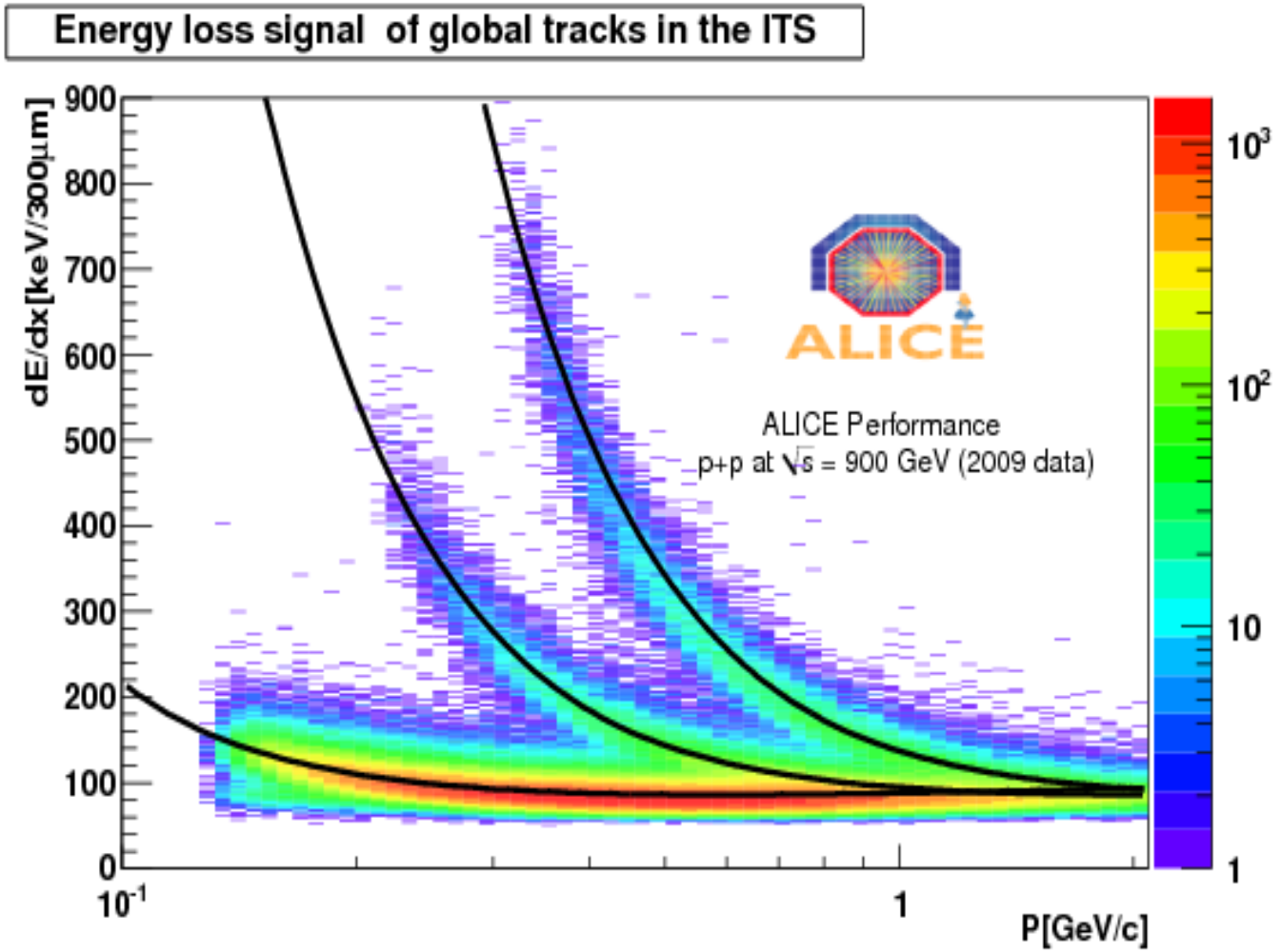


β 1.0

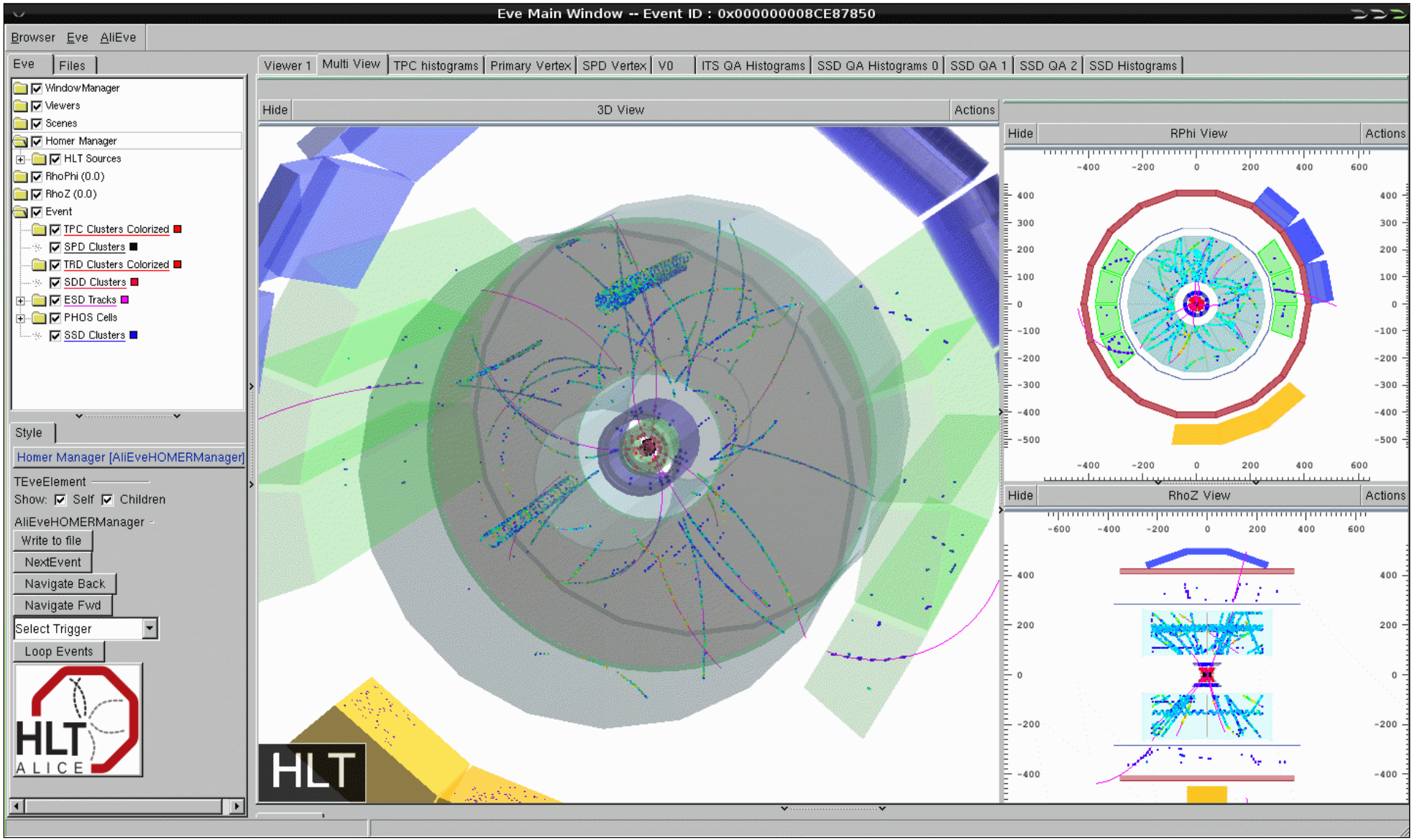
0.2



ALICE PID performance 3 – energy loss in ITS



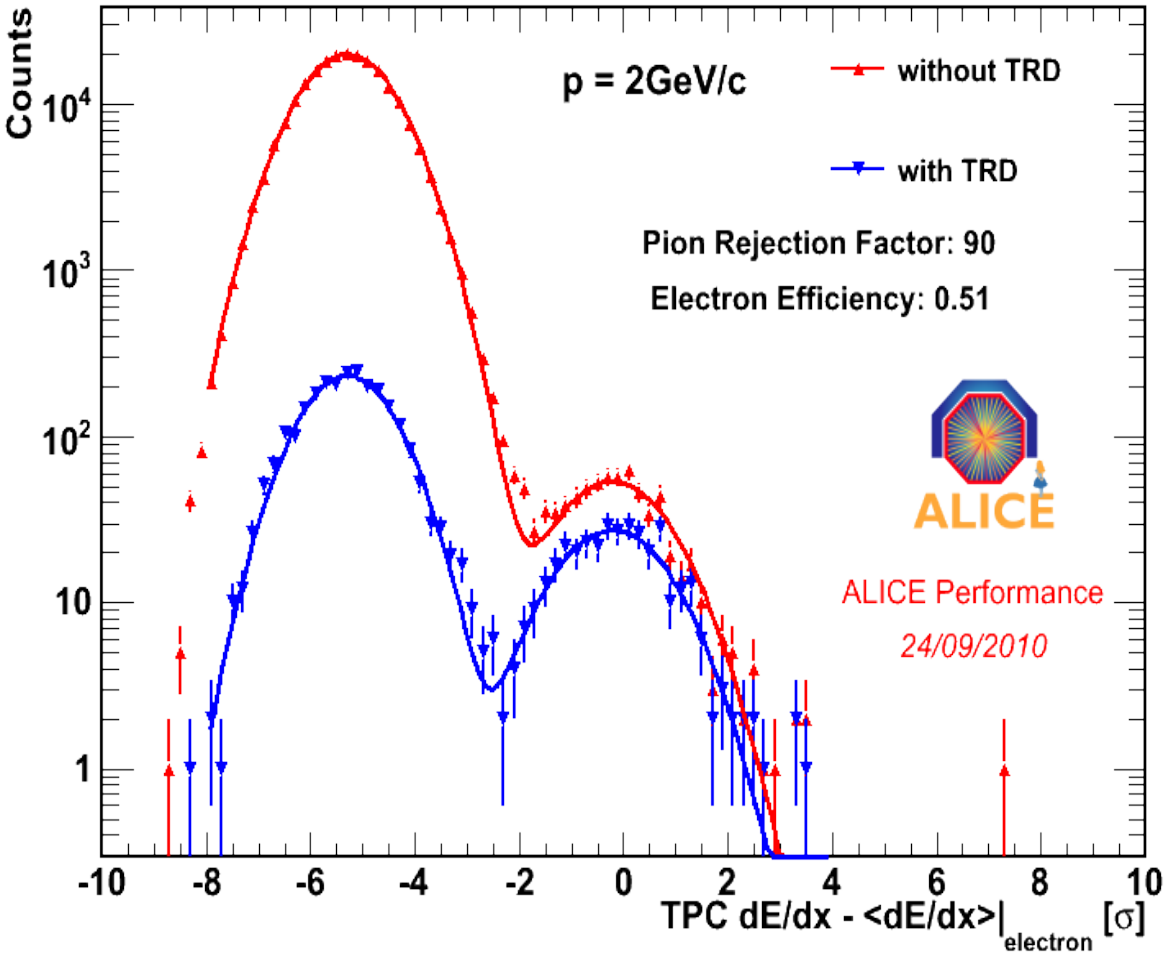
ALICE PID performance 4 - transition radiation in TRD



event display with High Level Trigger (HLT) 900 GeV pp collision

ALICE PID performance 4 - transition radiation in TRD

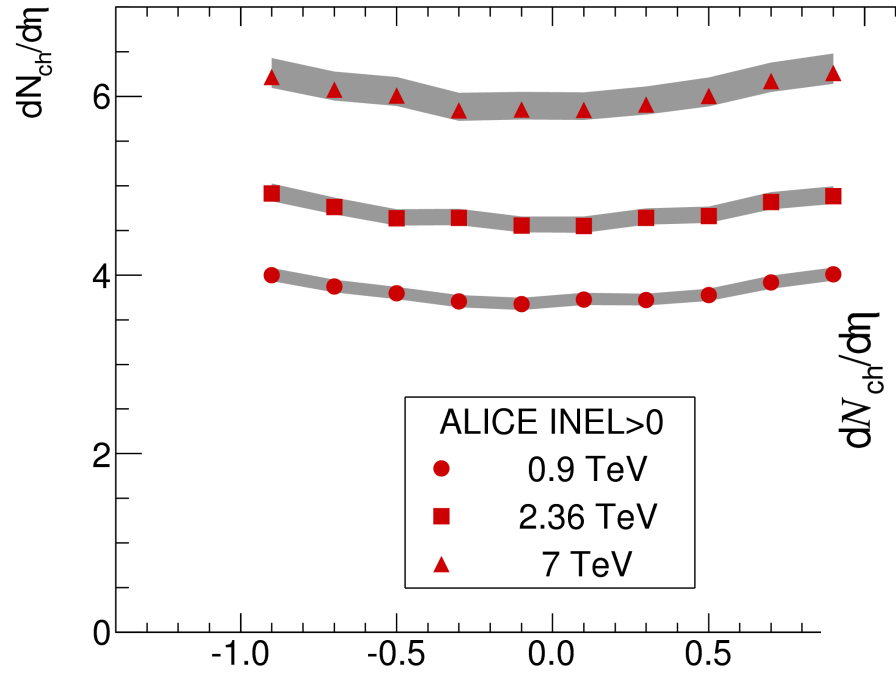
first pion rejection results from TRD

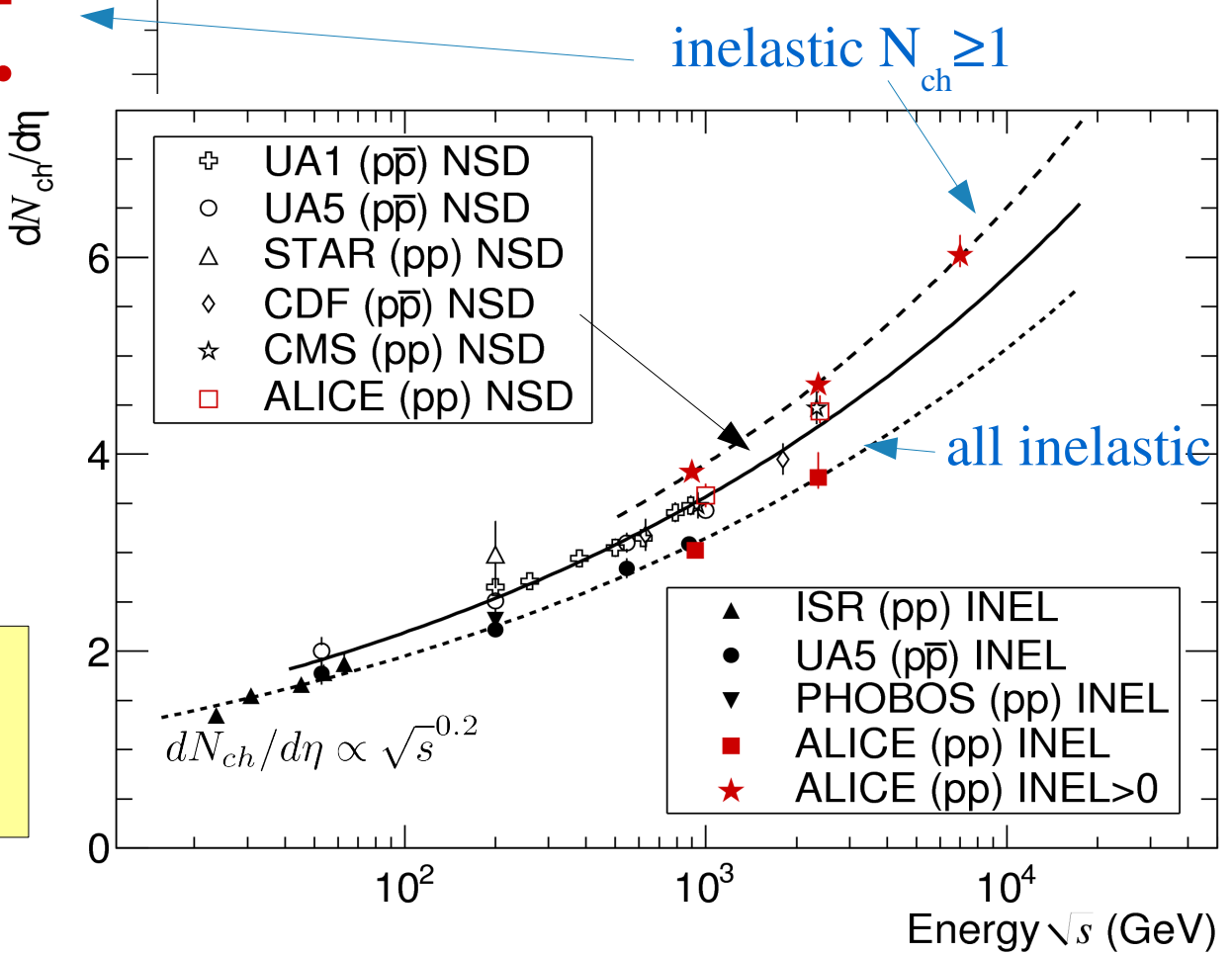


charged particle multiplicity

charged particle multiplicity in pp at 3 beam energies

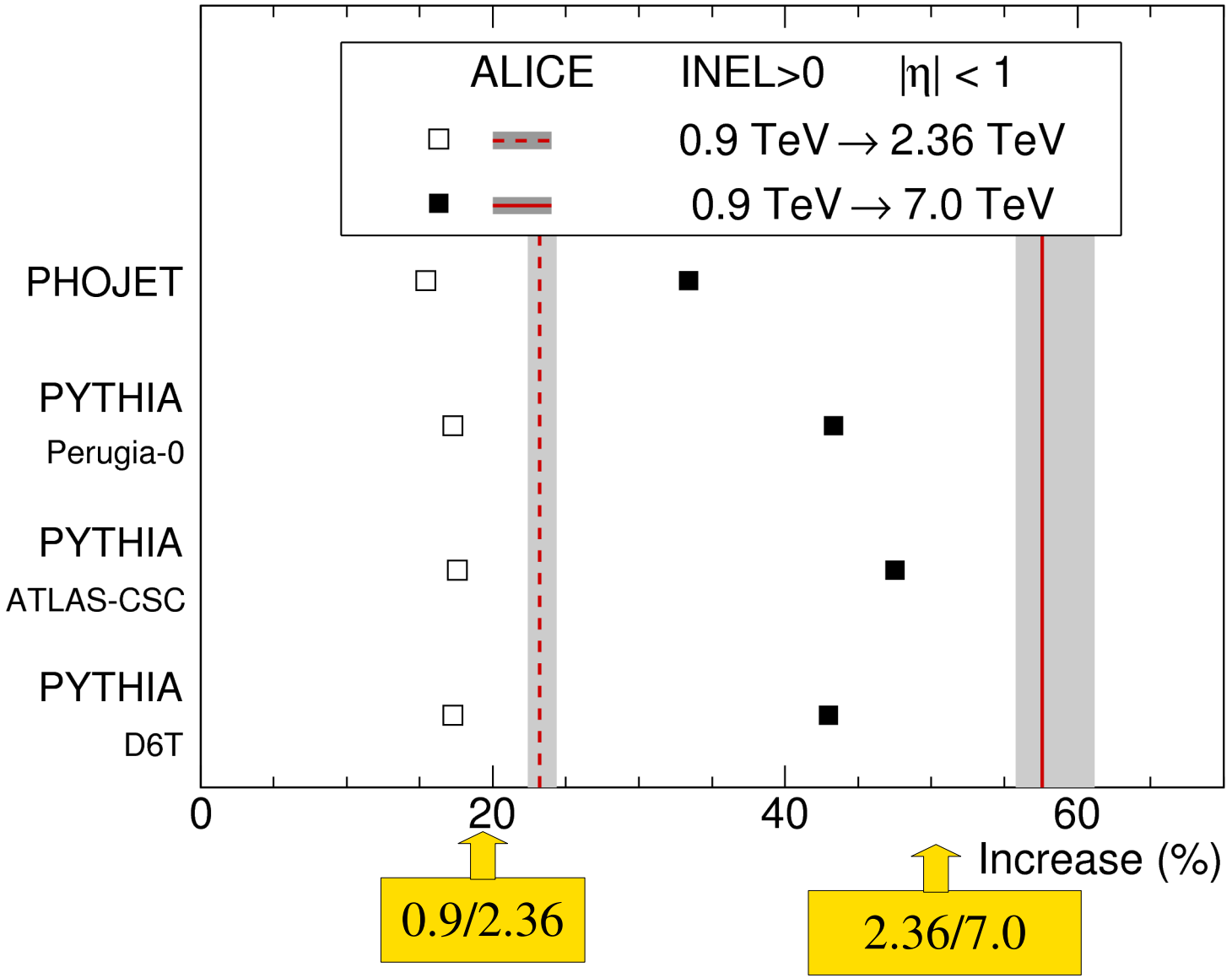
EPJ C65 (2010) 111, EPJ C68 (2010) 89, EPJ C68 (2010) 345





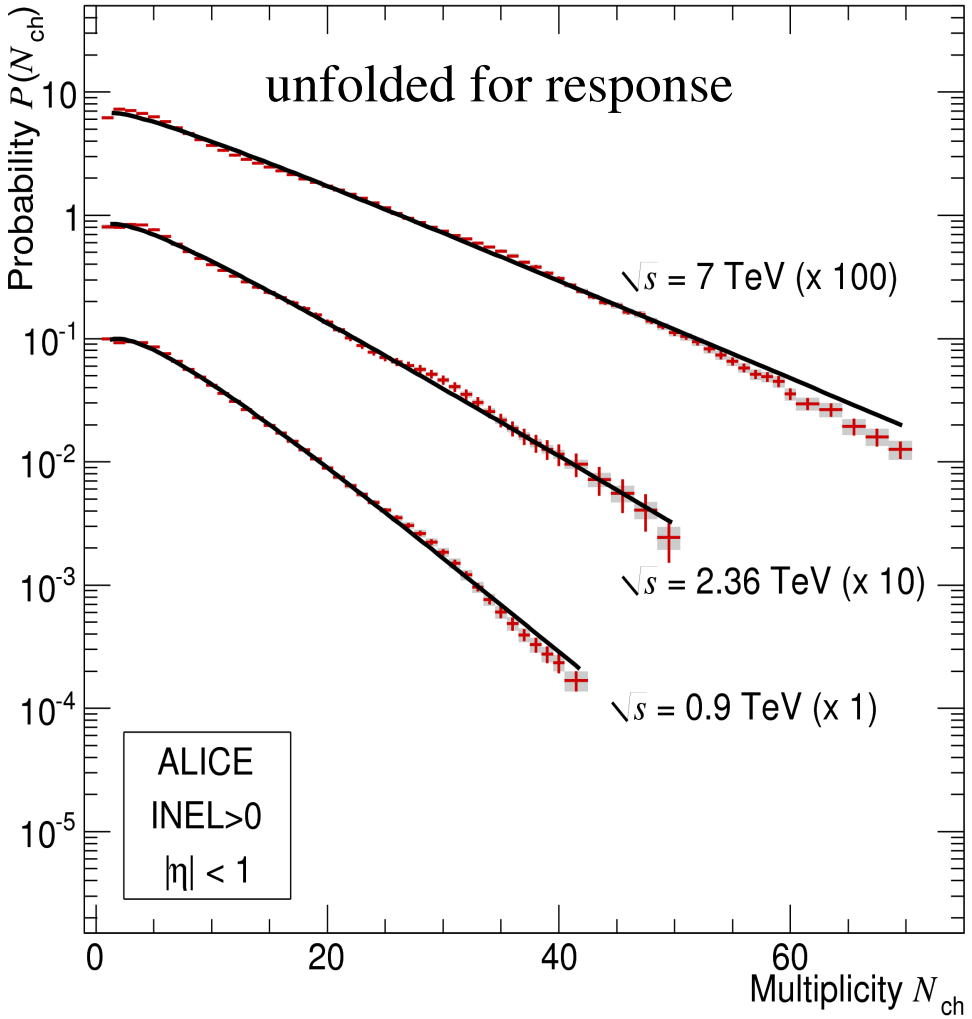
ALICE and CMS agree to 3%
power law describes data well

increase with beam energy compared to MC event generators



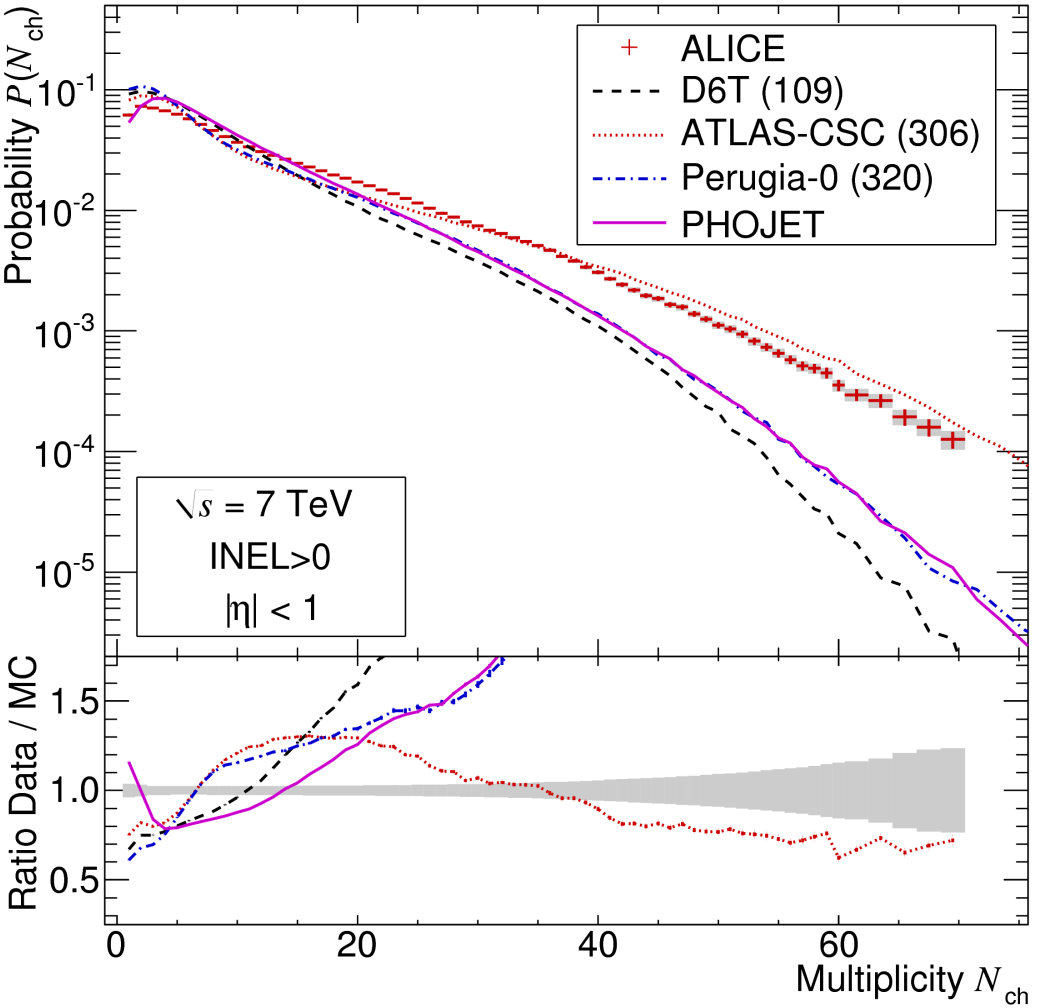
increase in data significantly stronger than in generators tuned up to Tevatron energies

charged particle multiplicity distributions



multiplicity distributions rather well described by negative binomial distr.

most of stronger increase in tail generators will need careful tuning



identified particle spectra and strangeness in ALICE

PID via energy loss and time of flight

(p, π^+, K^+ and antiparticles)

or

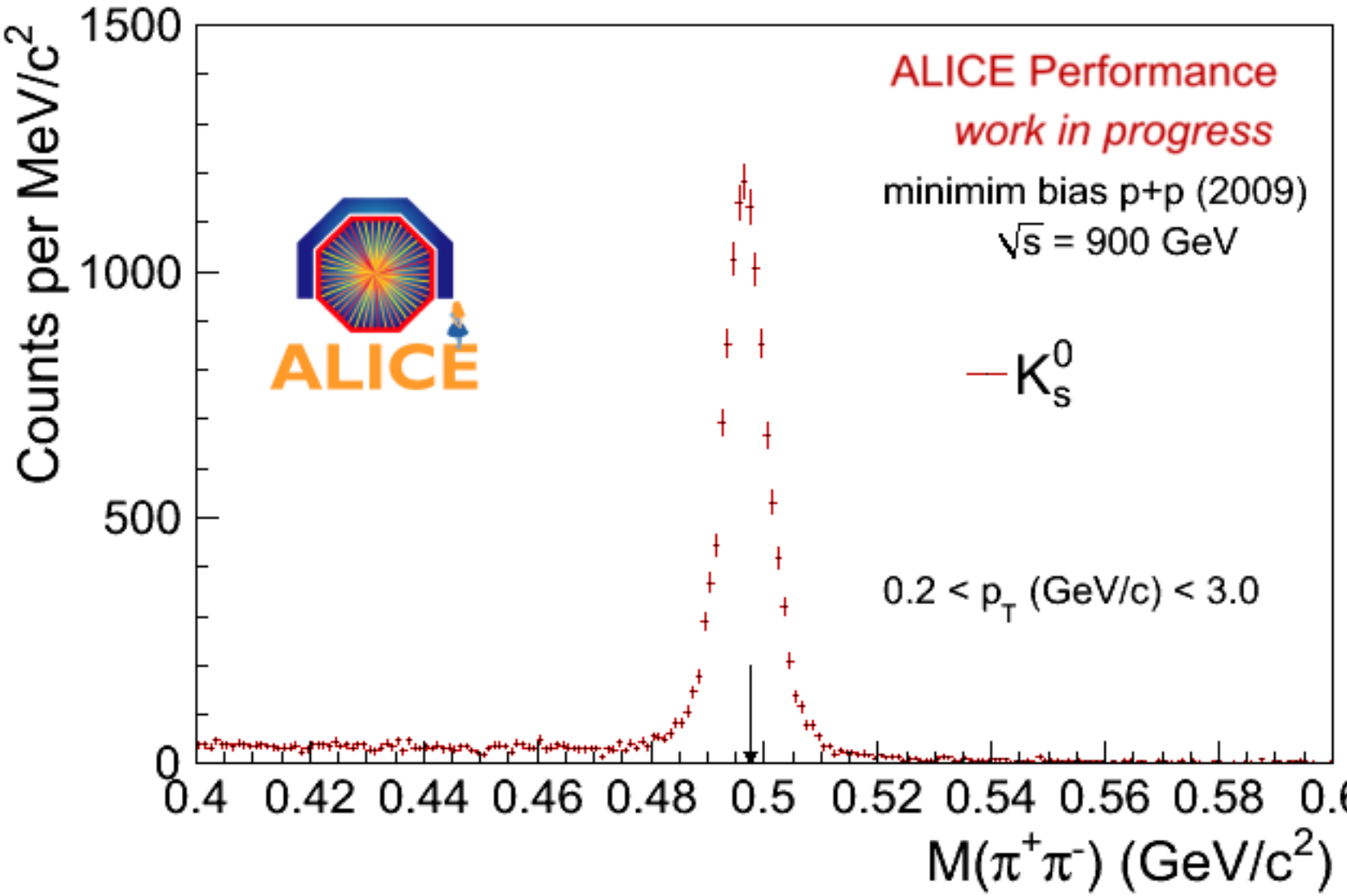
via reconstruction of secondary vertex for weak decays

(K^0, Lambda, Cascade, Omega, ...)

example K^0_s decays

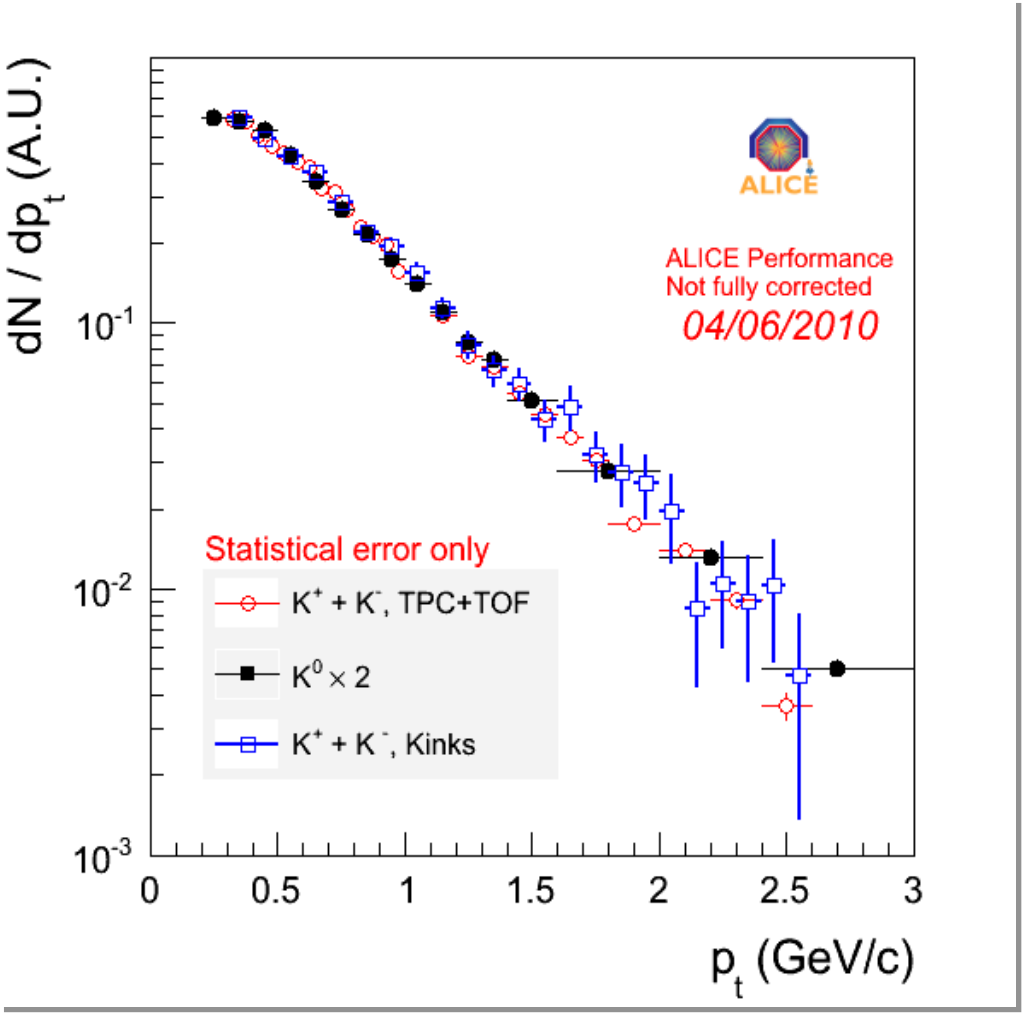
mass: 498.66 ± 0.04 MeV width: 3.83 ± 0.04 MeV

consistent with design momentum resolution



provides actually also a nice clear sample of charged pions for PID optimization

identified particle spectra in ALICE - example kaons reconstruced in 3 ways



$K^{\pm}$: PID from TPC and TOF

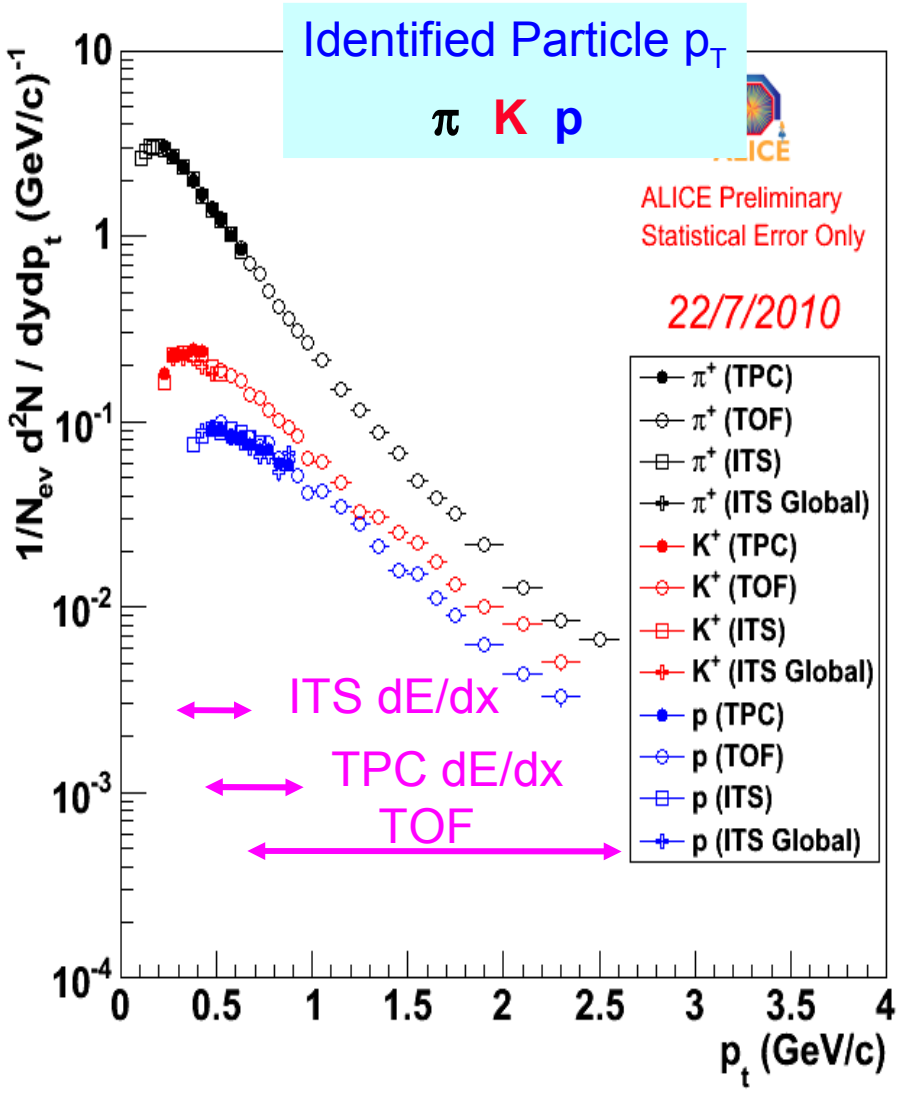
K^0_s: secondary vertex reconstruction

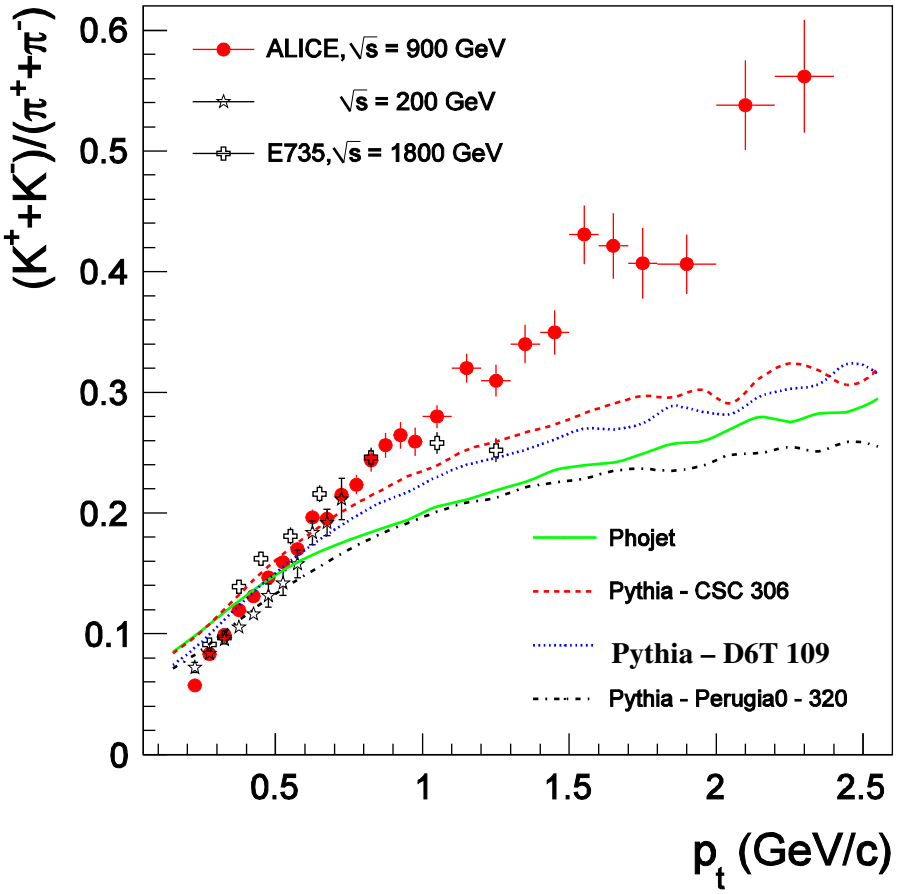
$K^{\pm} \rightarrow \mu\nu$ via kinks

good consistency

corrections being finalized

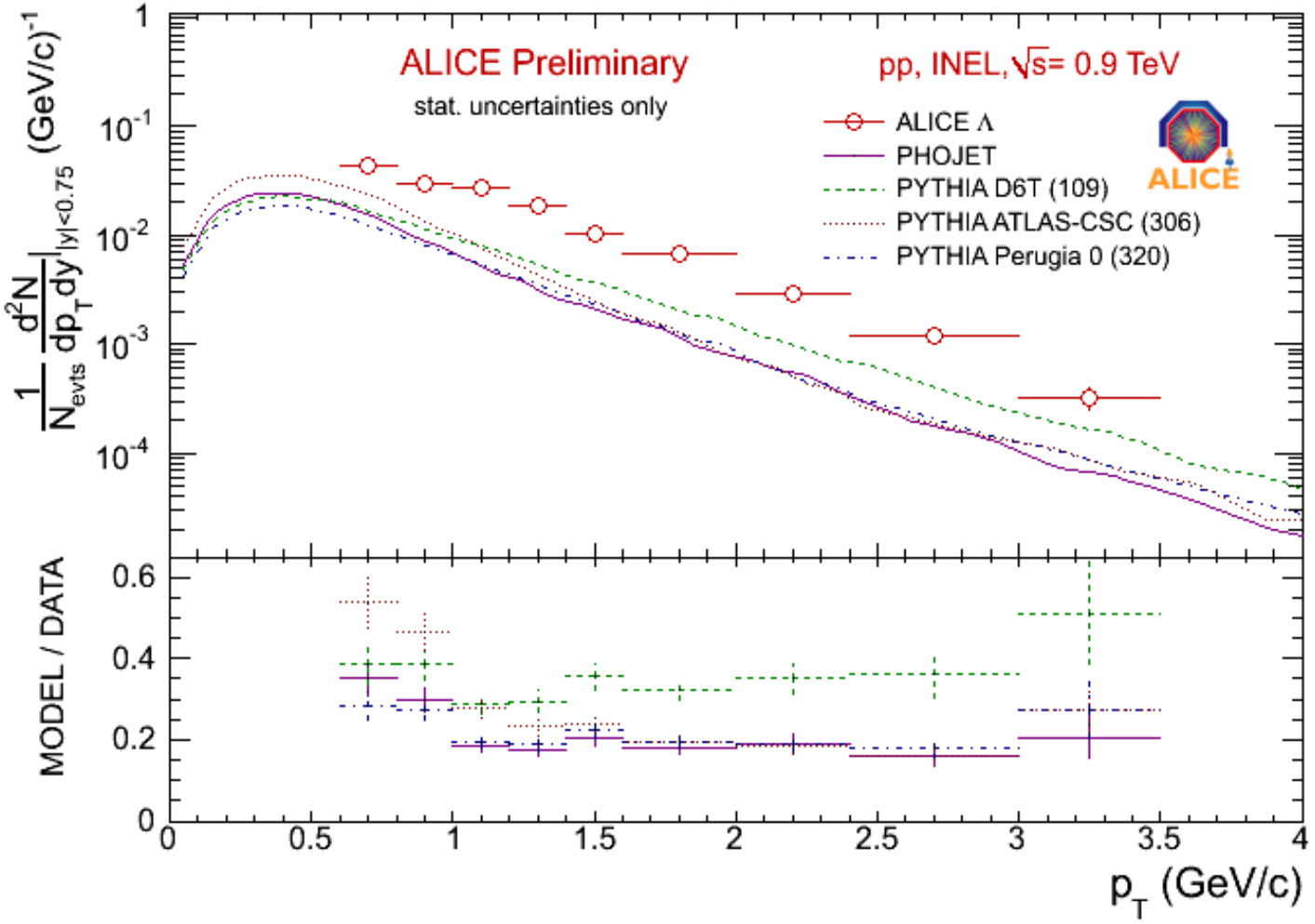
Spectra of charged pion, kaon, proton





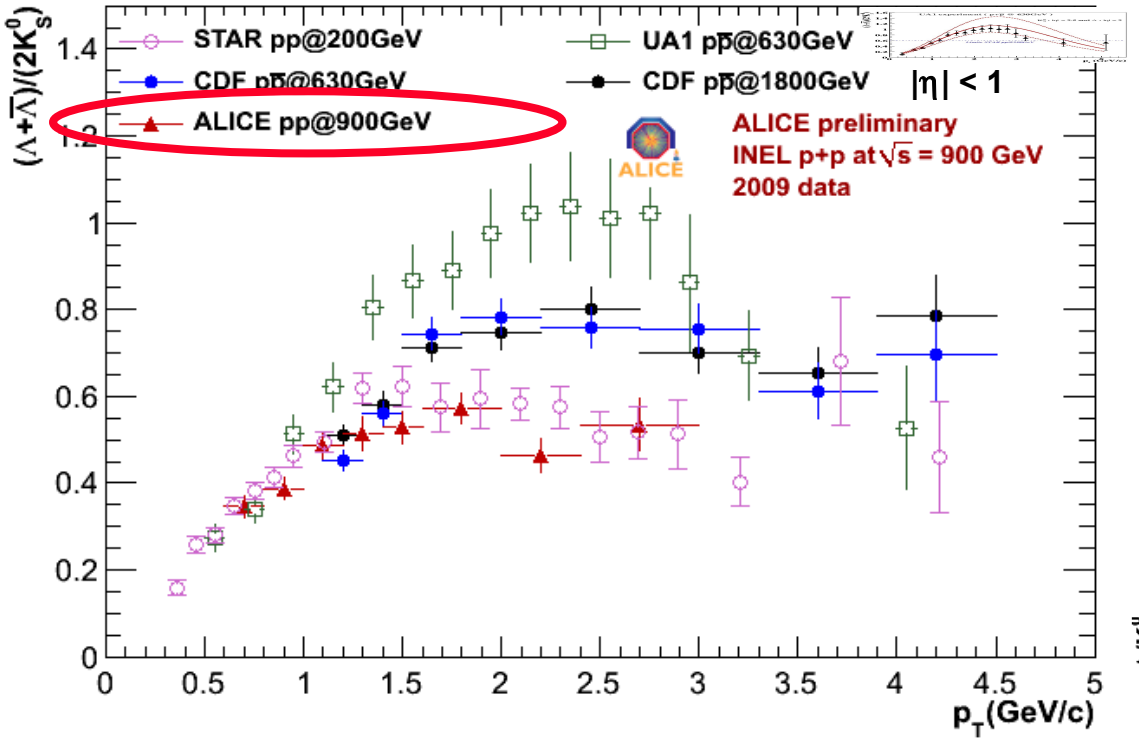
very large K/pi at higher p_t
not reproduced by any generator

Lambda transverse momentum spectrum - 2009 data



Monte Carlo well below data, in particular beyond 1 GeV

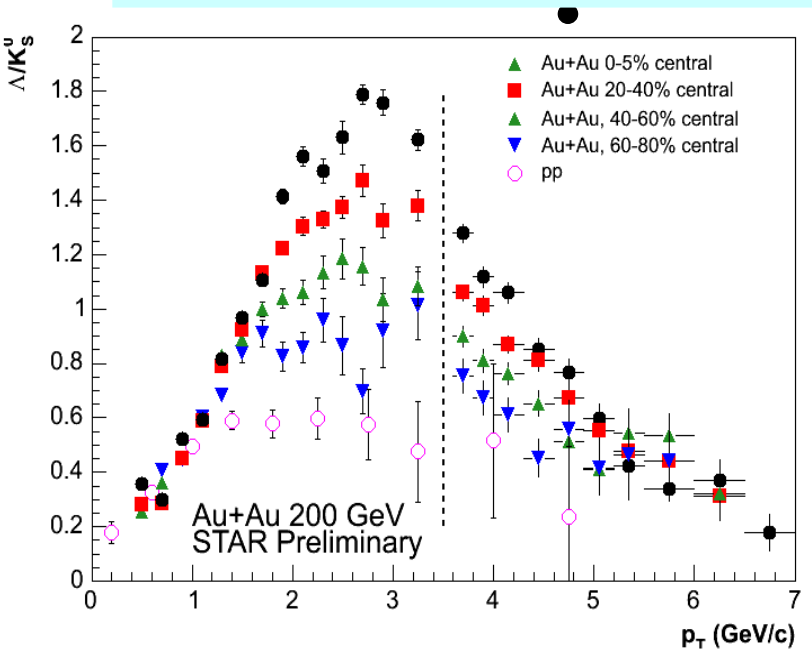
Lambda to kaon ratio



very good agreement between
ALICE (900 GeV) and STAR (200 GeV)
CDF significantly higher and UA1 still more
under investigation (trigger, acceptance, feed-down)

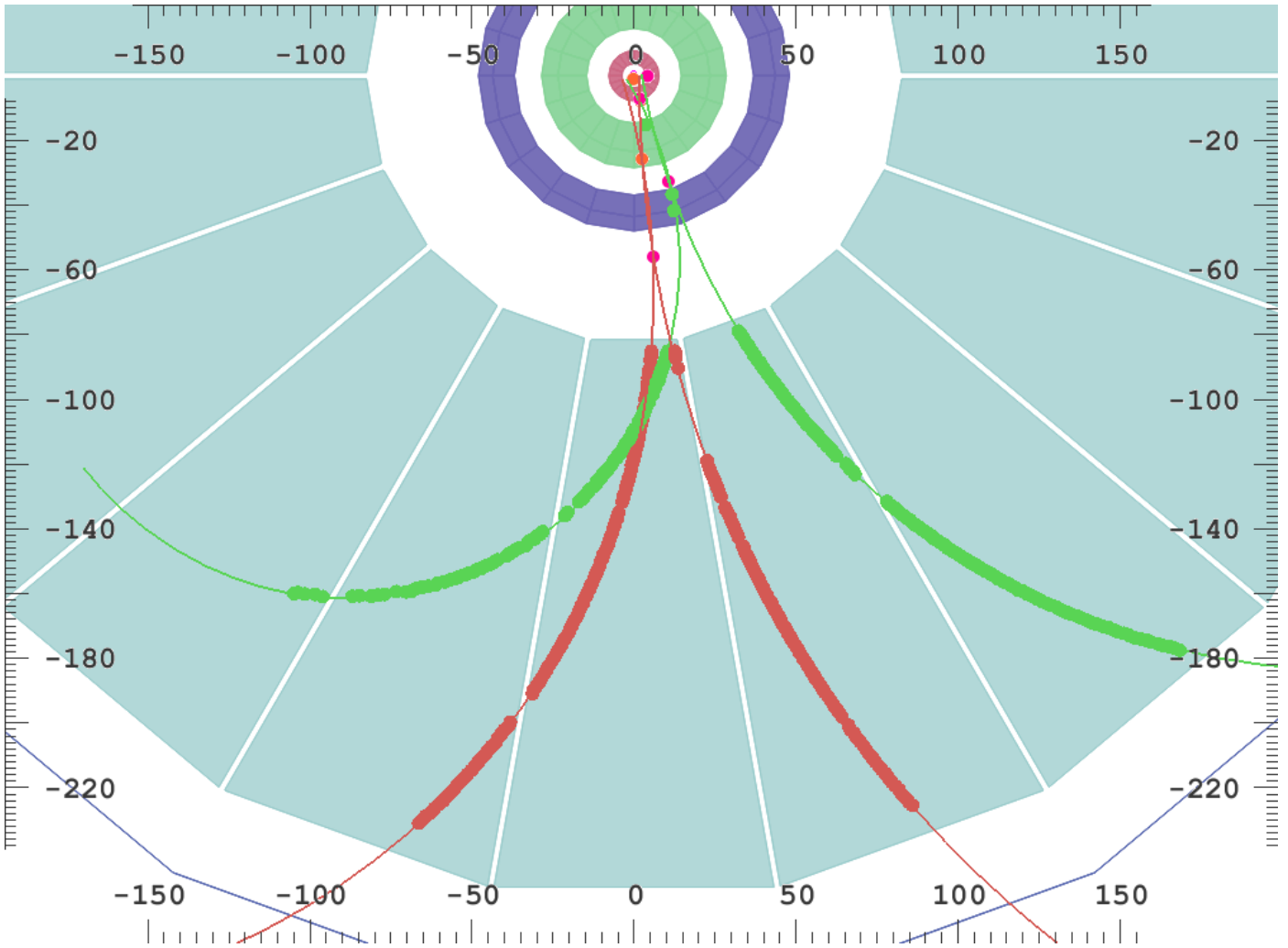
Relevant, because large values for central AA were taken as sign of partons coalescing from QGP

Λ/K^0_S Ratio in Au+Au at RHIC



Reconstruction of photons in TPC via conversions

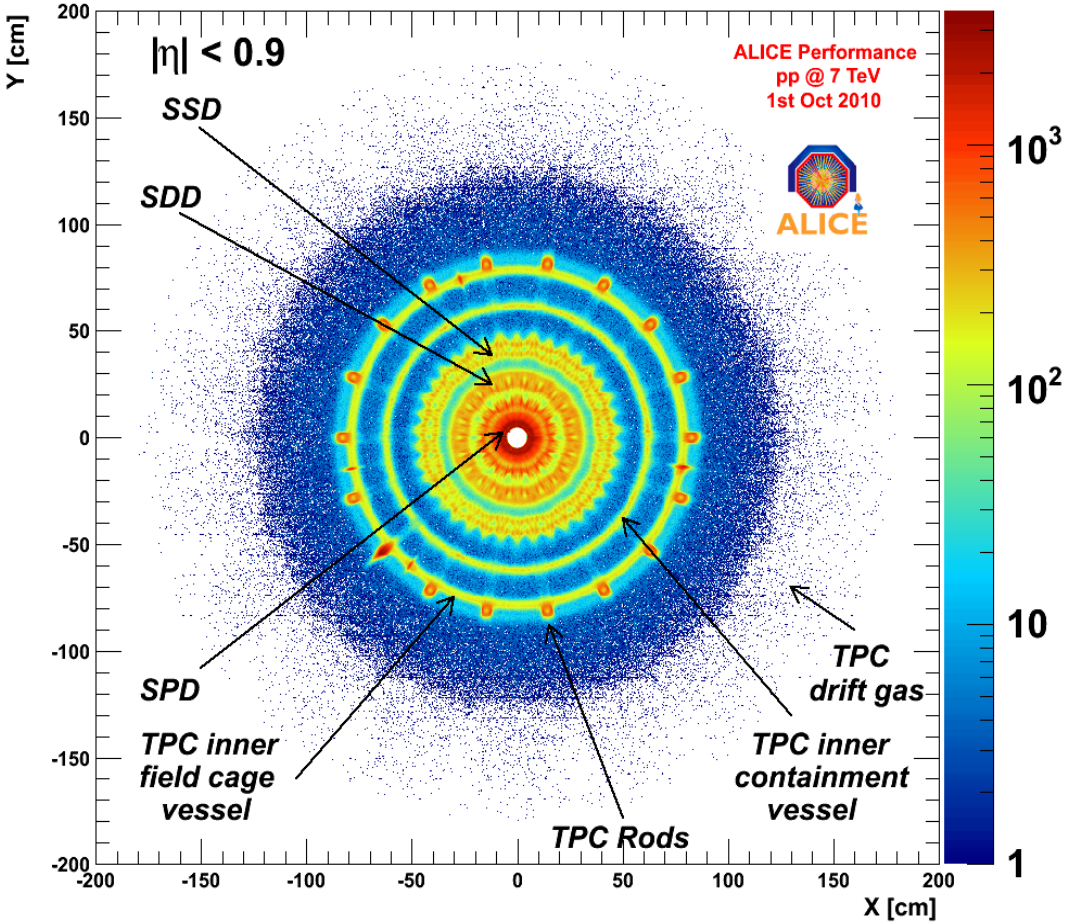
reconstruction of π^0 and η with conversion method

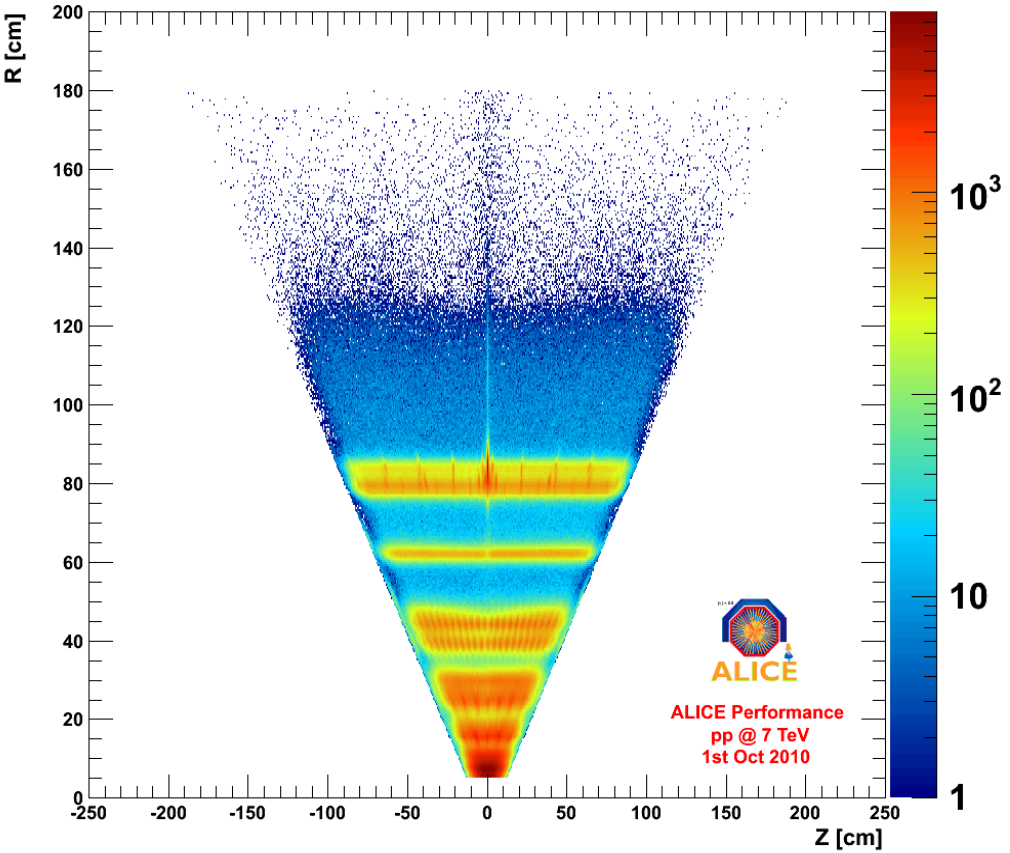


ALICE data (December 2009)

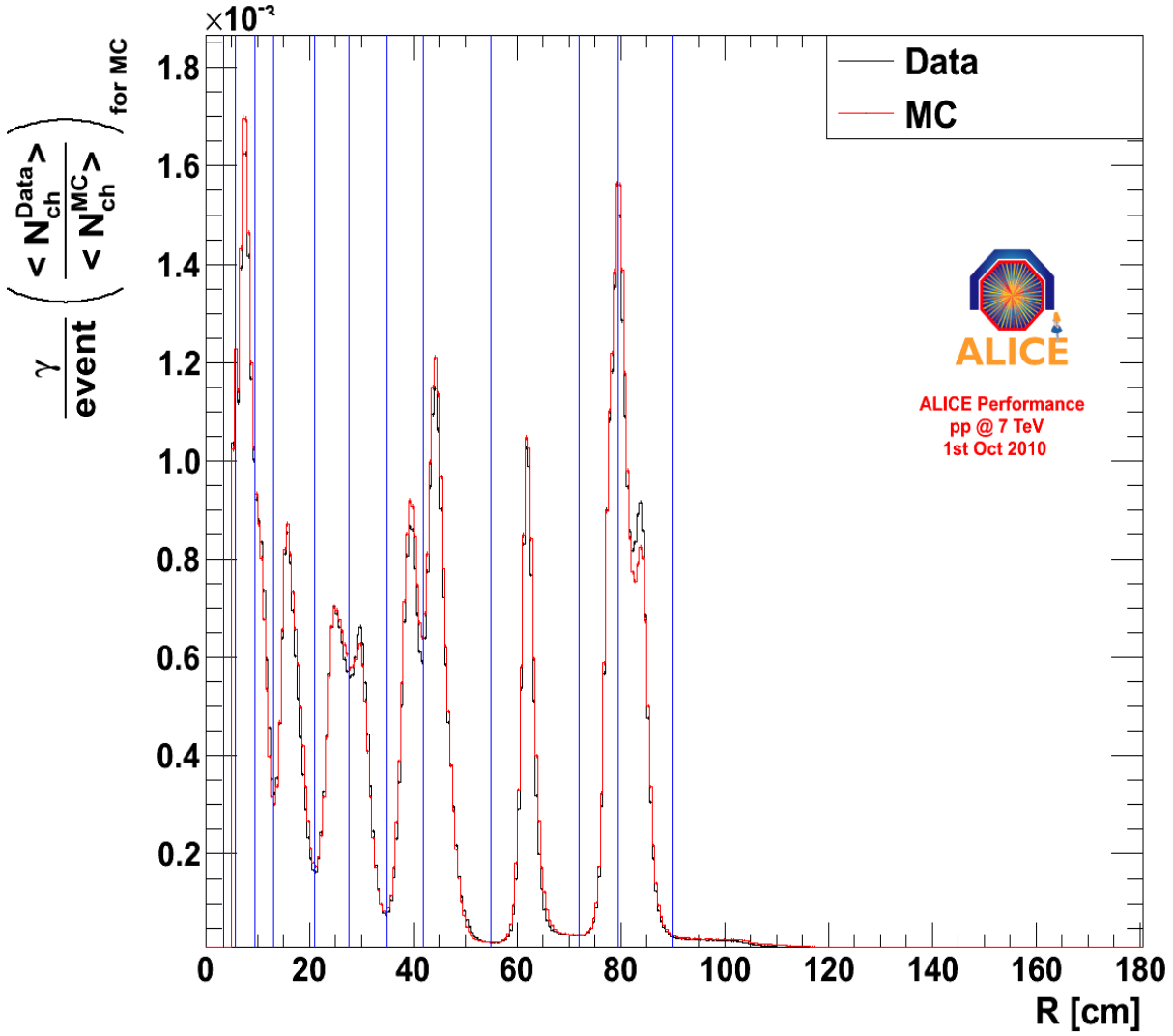
first application: a clean electron sample in 7 TeV pp collisions from pair conversions

tomography of the experiment: xy- and rz-distributions of conversion points



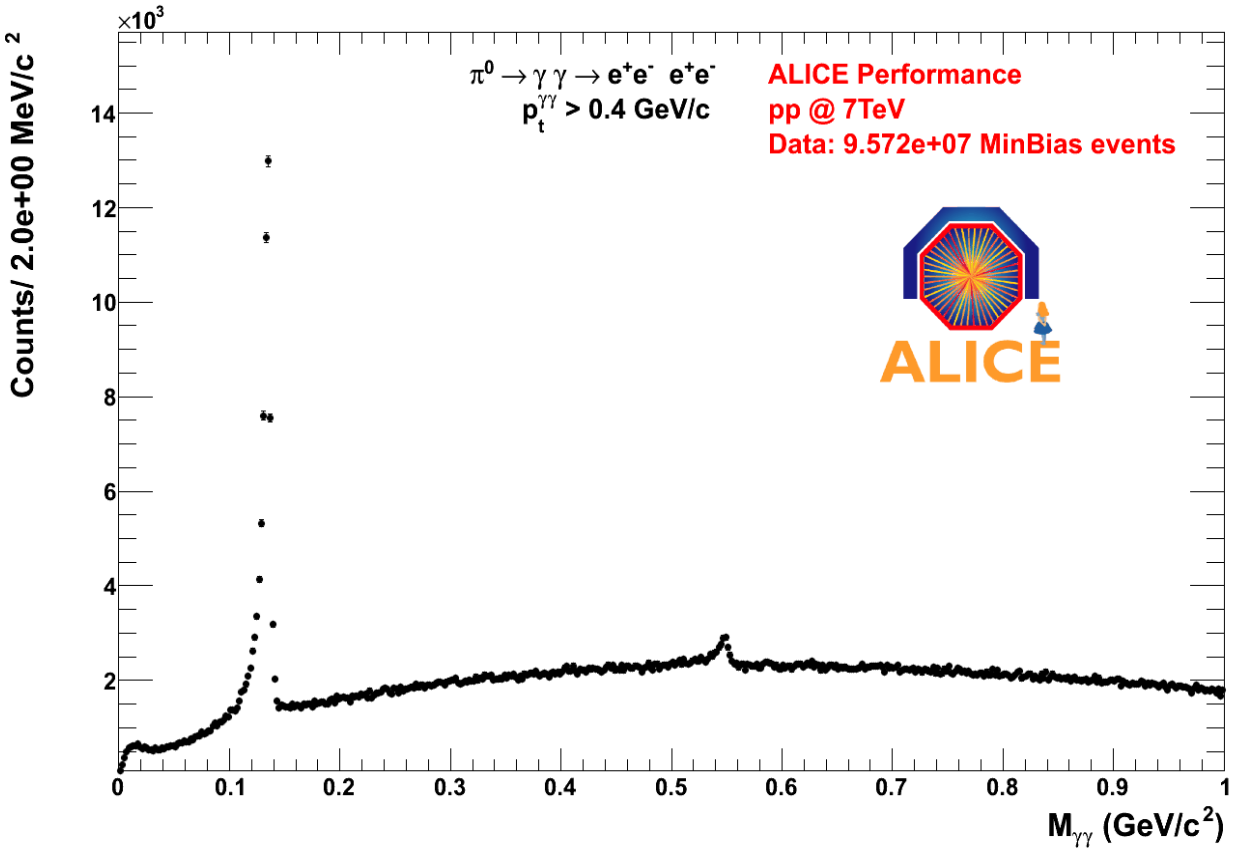


radial distribution of conversion points – data and Monte Carlo



material up to interior of TPC 11 % X_0 known (conservatively) with accuracy of -6.2/+3.5 % further improvements already implemented in simulation of ALICE

photon-photon invariant mass distribution from pair conversion

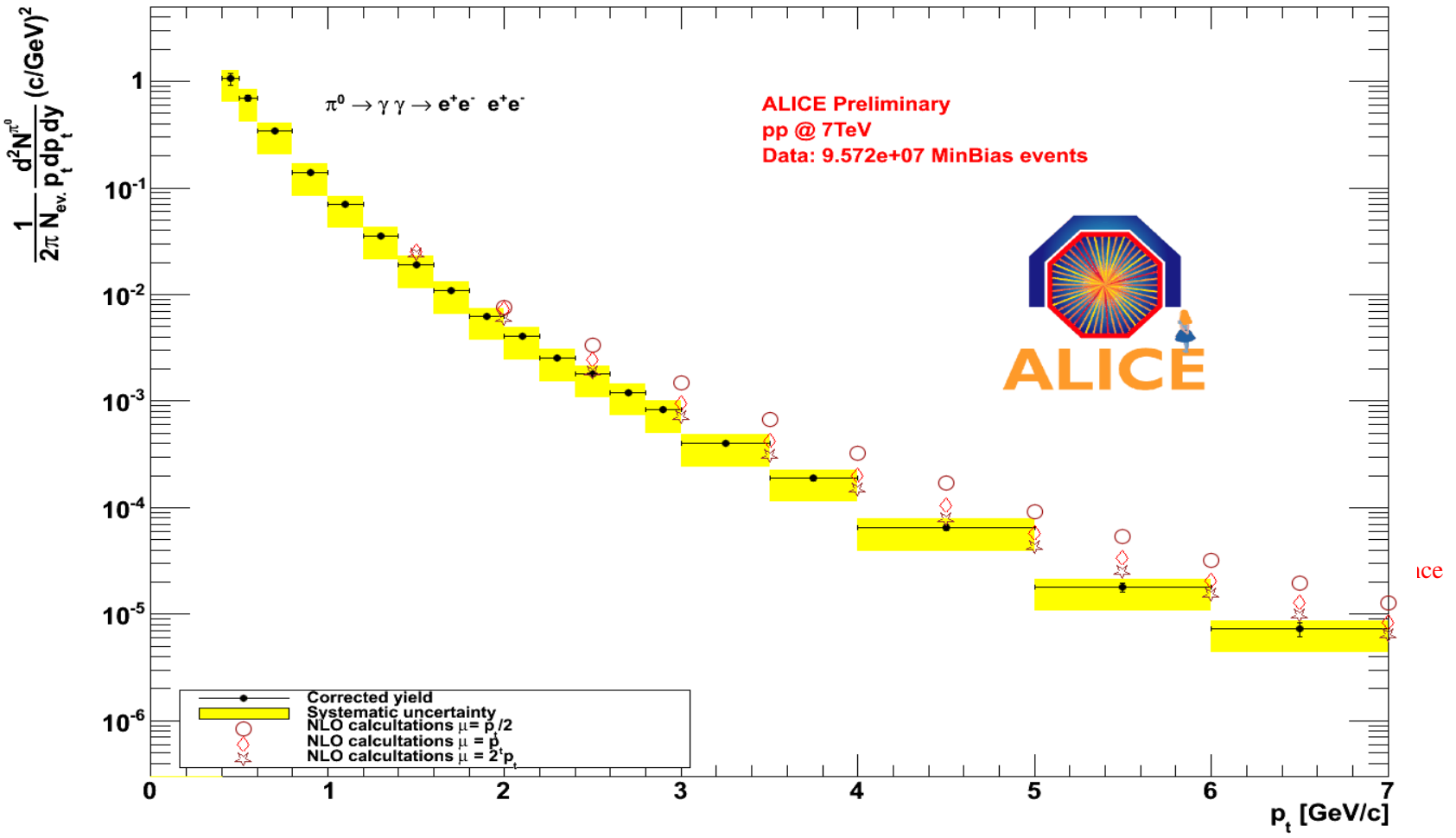


combinatorial background from mixed events and random rotation

excellent mass resolution FWHM/2.36 = 3-6 MeV at pt = 1-7 GeV

reconstruction efficiency including conversion probability:
$7\ 10^{-4}$ at 1 GeV/c
$2\ 10^{-3}$ at 3 GeV/c
very competitive method!

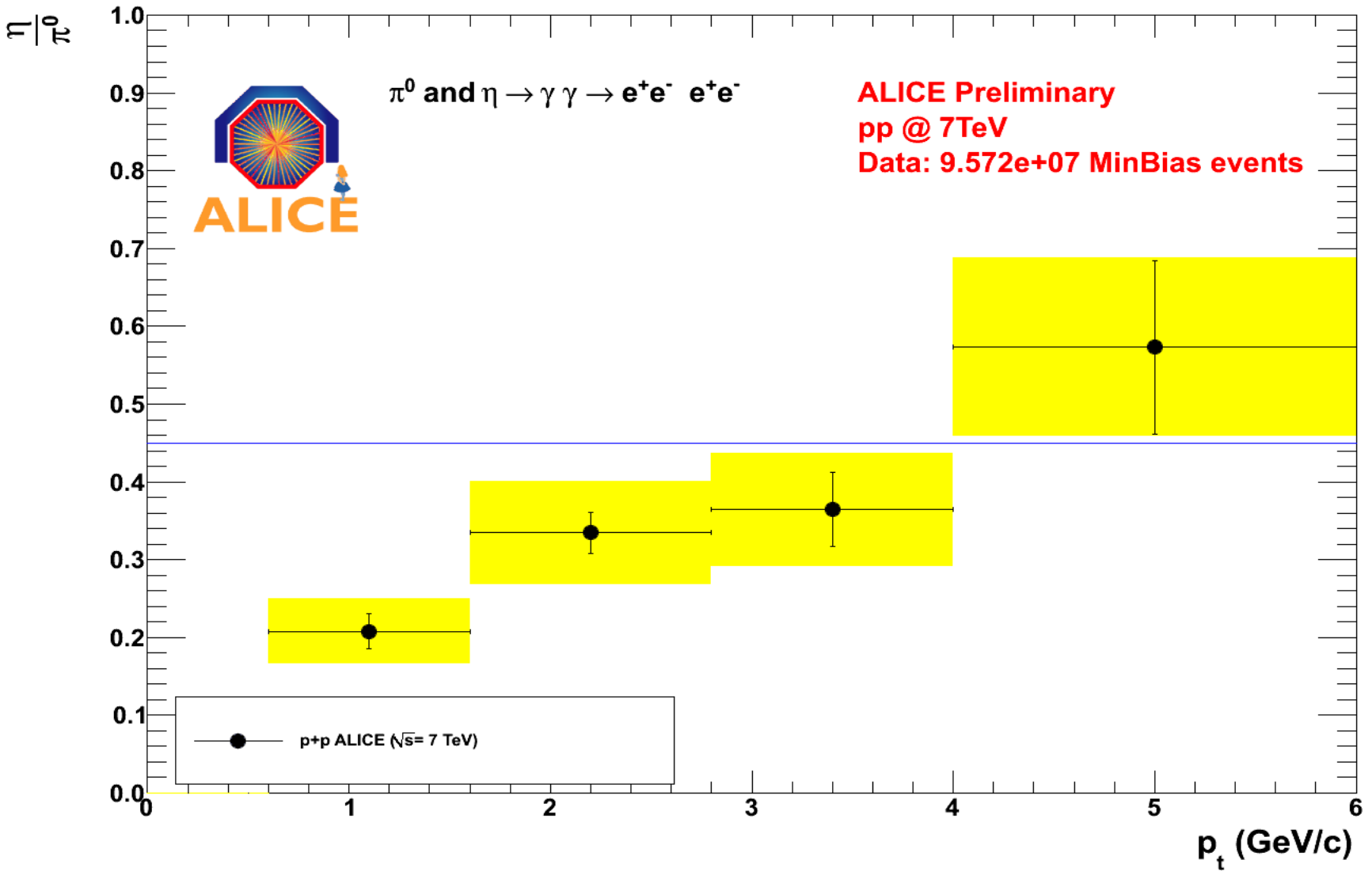
corrected π^0 p_t spectrum



rather good agreement with NLO pQCD prediction for this energy

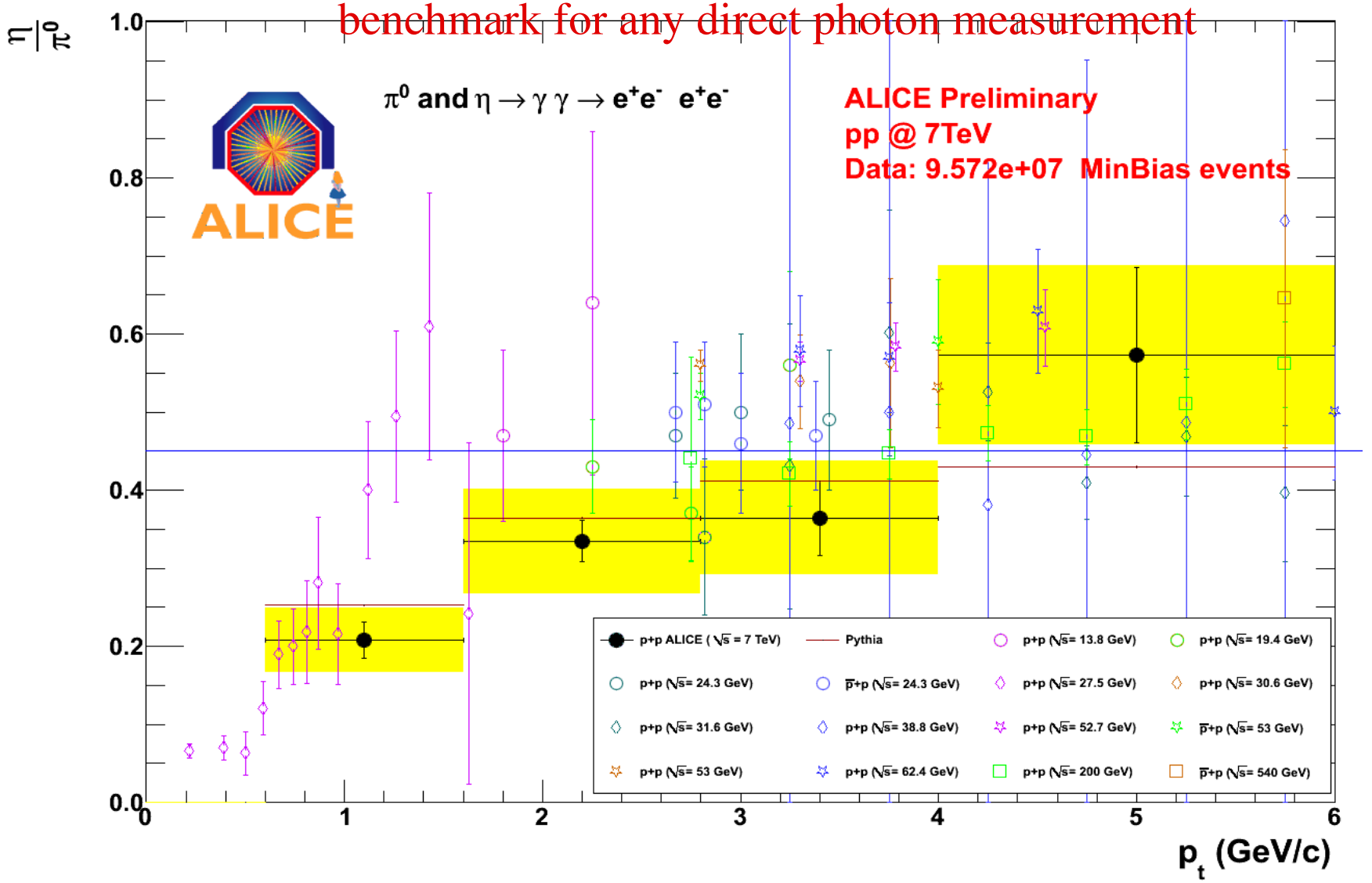
(B.Jager, A. Schaefer, M. Stratmann, W. Vogelsang Phys. Rev. D67 (2003) 054005)

corrected ratio of η to π^0 yield



corrected ratio of η to π^0 compared to world data

already quite competitive, precise knowledge is ~~benchmark for any direct photon measurement~~



open heavy flavor measurements in ALICE

open heavy flavor measurements in ALICE

Hadronic decays: $D^0 \rightarrow K\pi$, $D^{+-} \rightarrow K\pi\pi$, $D^* \rightarrow D^0\pi$, $D_s \rightarrow K\,K^*$, $D_s \rightarrow \phi\pi$, …

Leptonic decays:

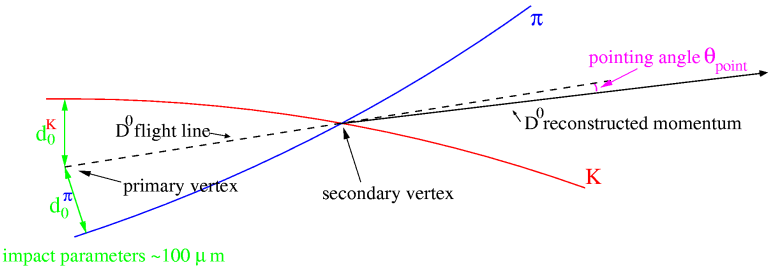
$B \rightarrow l$ (e or μ) + anything

Invariant mass analysis of lepton pairs:

BB, DD, BD_{same}, J/ψ, ψ', ϒ family, $B \rightarrow J/\psi$ + anything

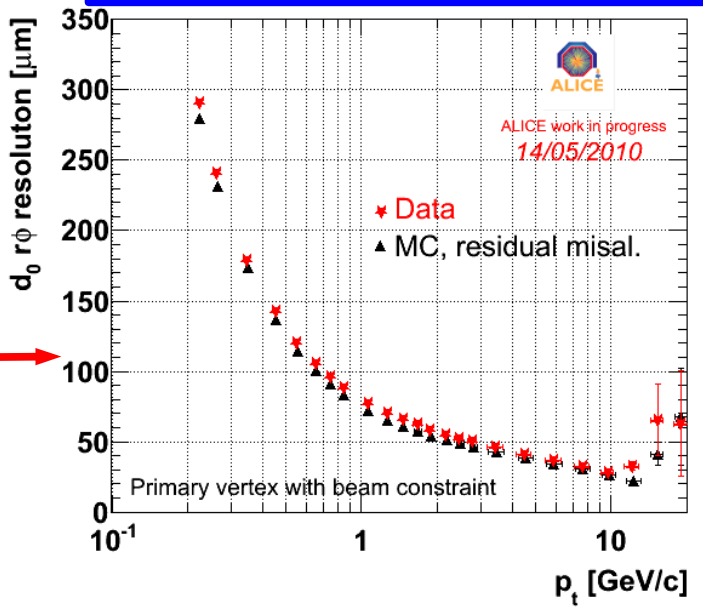
$BB \rightarrow \mu\mu\mu$ (J/ψ μ)

e-μ correlations



current impact parameter resolution close to design goal

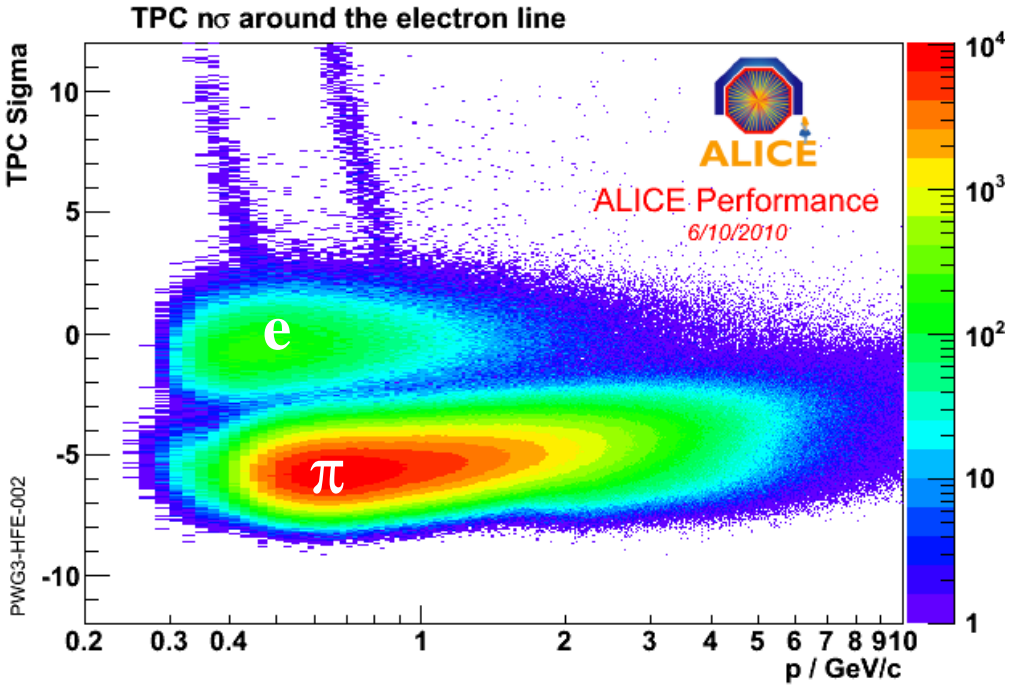
id. hadrons, electrons: -0.9 < y < 0.9
muons: y=2.5-4.0
in central barrel: vertex cut effective for heavy quark identification

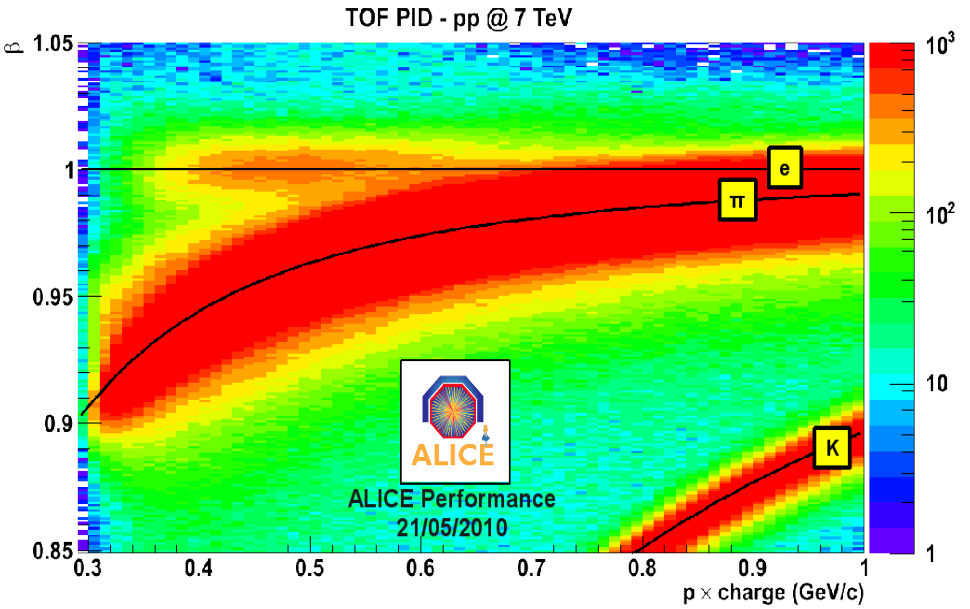


heavy flavor via semi-leptonic decays of D and B mesons

electrons identified via dE/dx in TPC and TOF to cut p and K crossings

require hits in first ITS layer to reduce conversions (1.2% X_0)

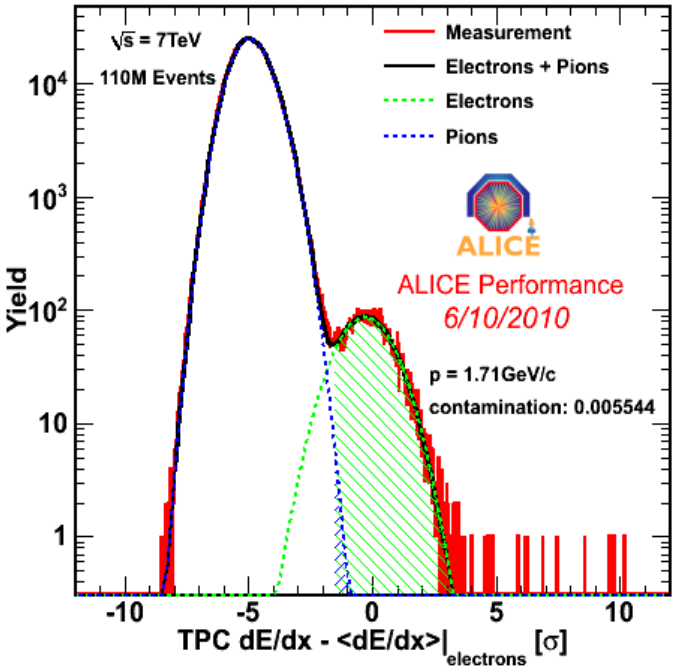


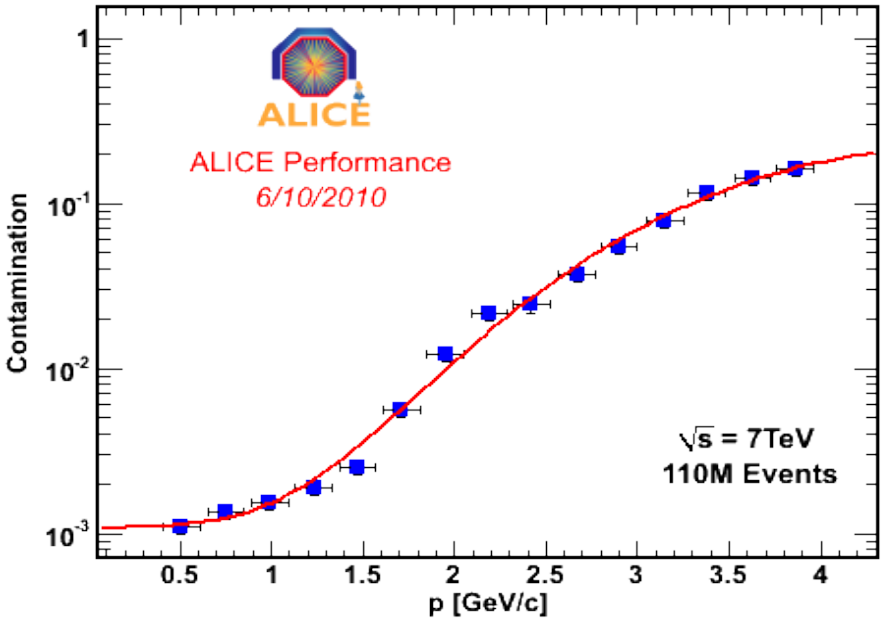


next:
displacement cut
better electron id using TRD

purity of electron sample

cut at fixed p_t to inspect pion contamination:
TPC dE/dx response Gaussian over 5 orders of magnitude!

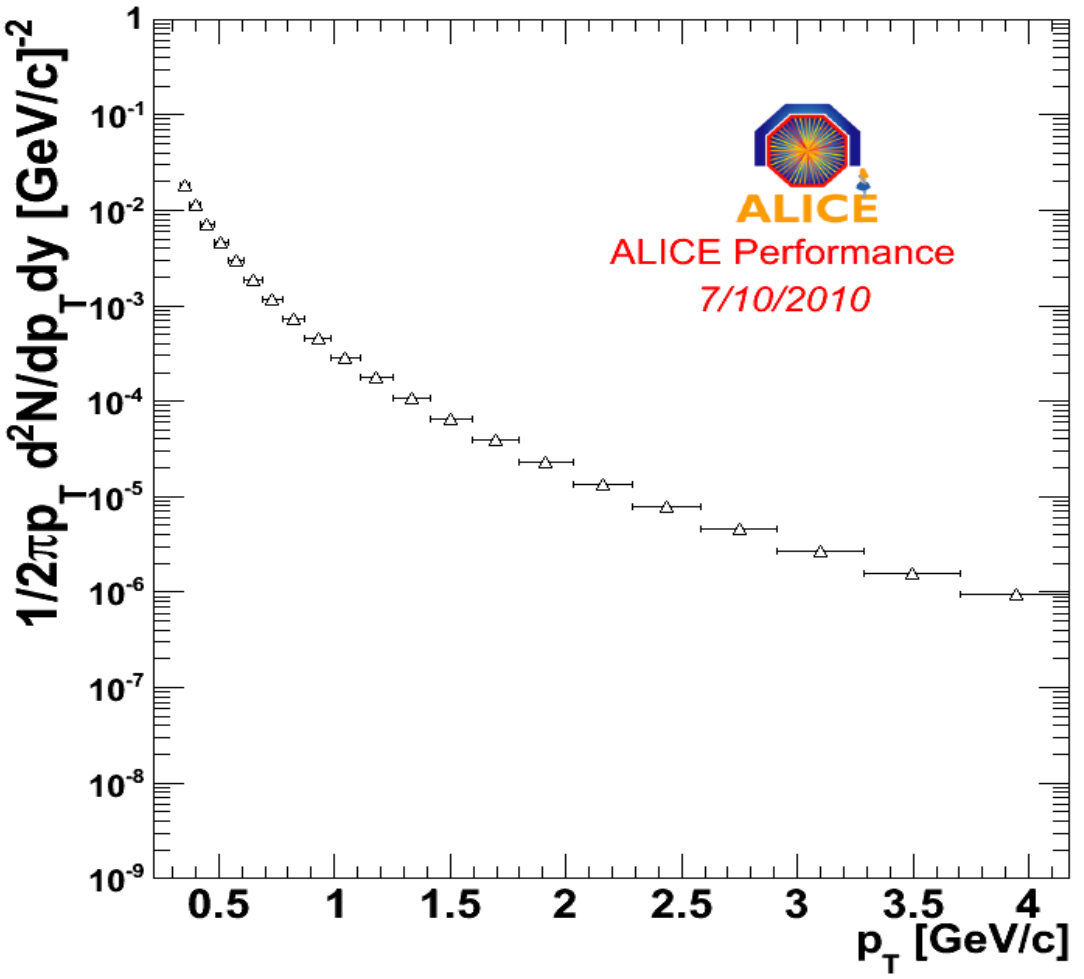




up to 4 GeV/c PID with TPC dE/dx alone feasible; beyond TRD and EMCal will be needed; plus to come: cut on displaced vertex

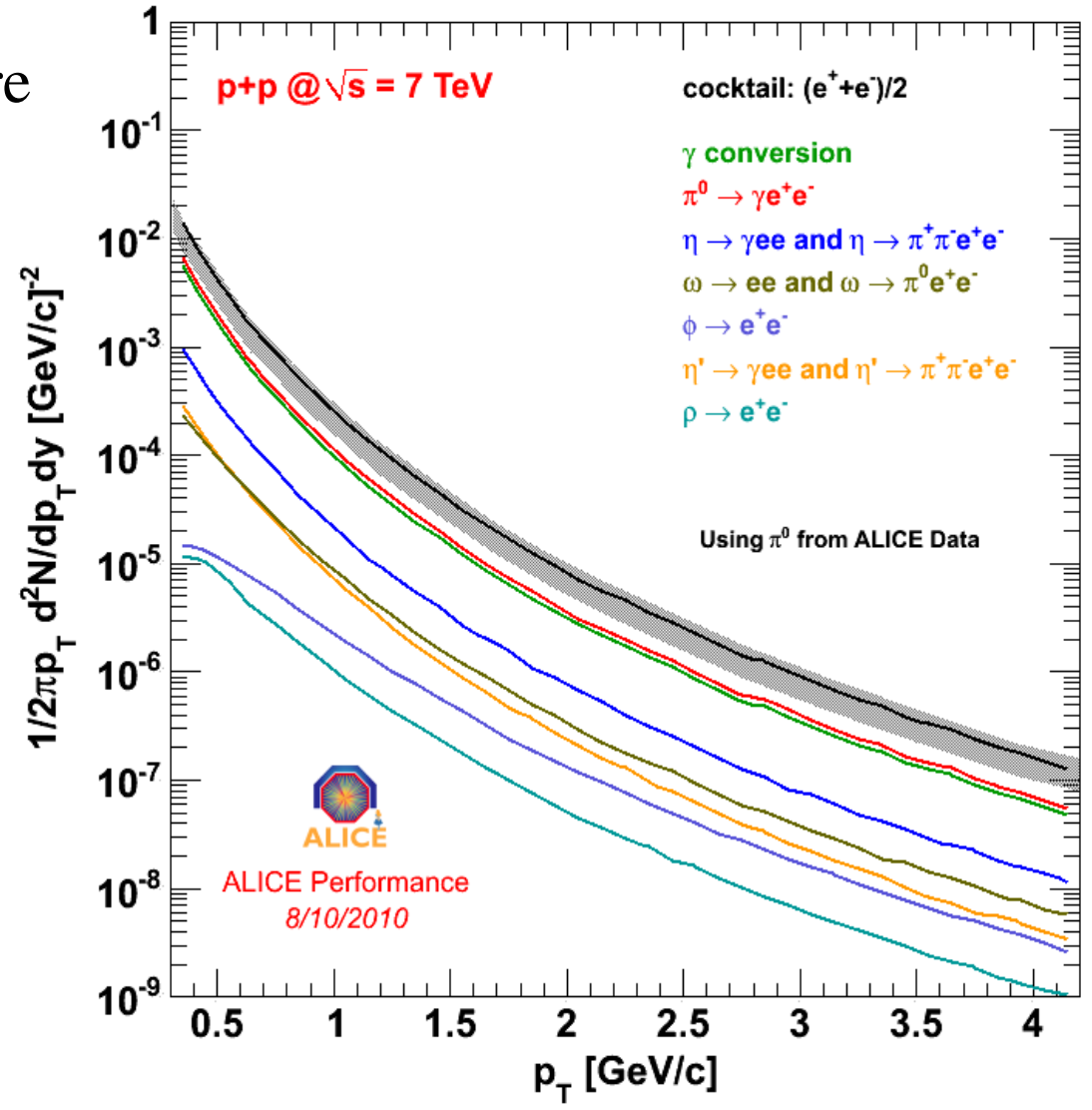
inclusive electron spectrum

Spectrum corrected
- for residual hadronic contribution
- for acceptance and efficienc
- for detector pt resolution
  (bremsstrahlung)

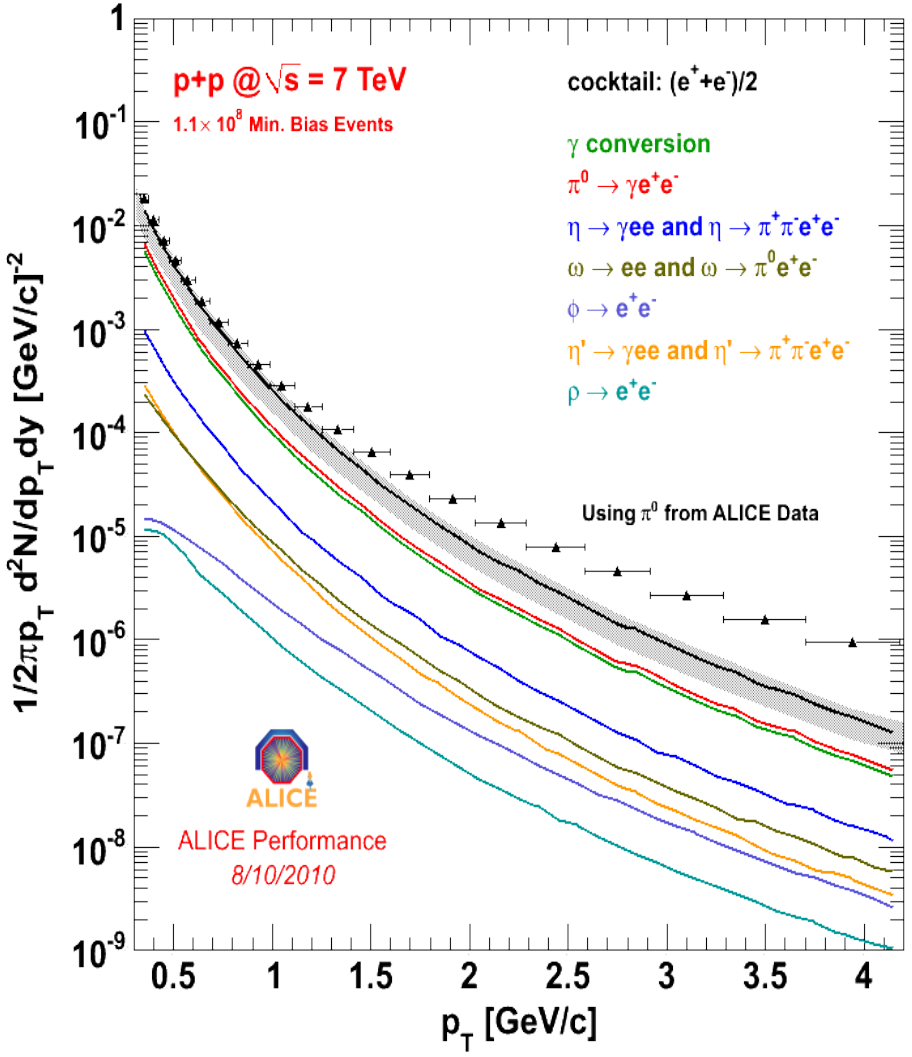


cocktail of contributions to inclusive electron spectrum from hadron decays and conversions

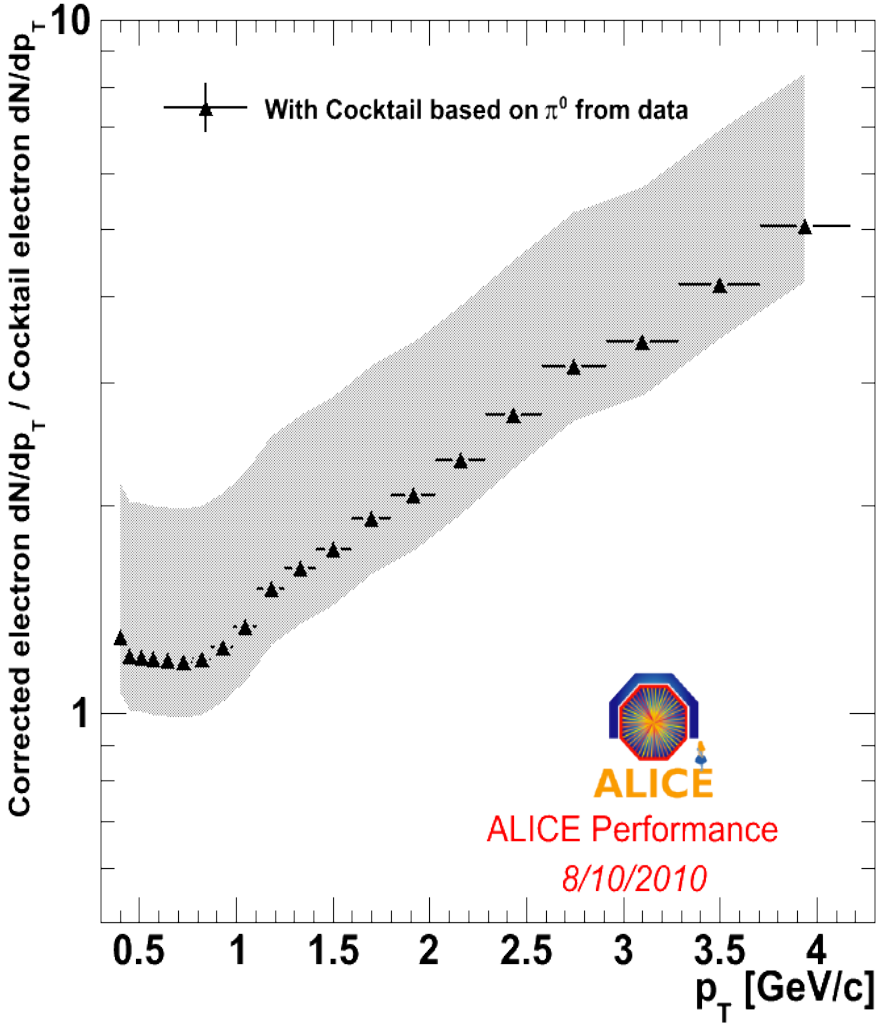
experimental input used where possible
(conversions, pi0 spectrum)



Experimental spectrum compared to cocktail of contributions from hadron decays and conversions



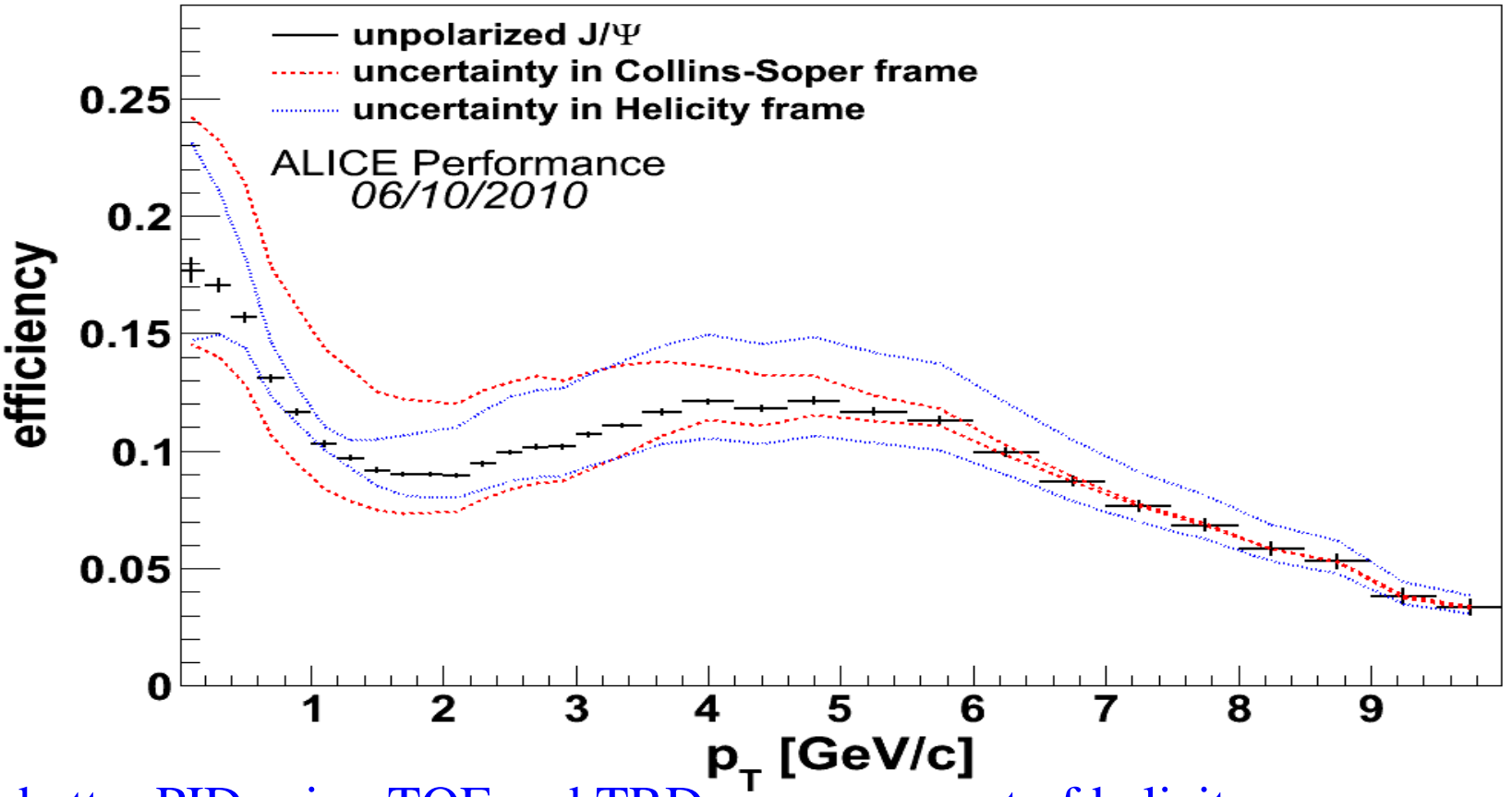
note: at low pt ratio should be 1 (ok within error)
at higher pt a clear contribution from b and c and direct photons



Charmonia

J/ψ cuts and acceptance

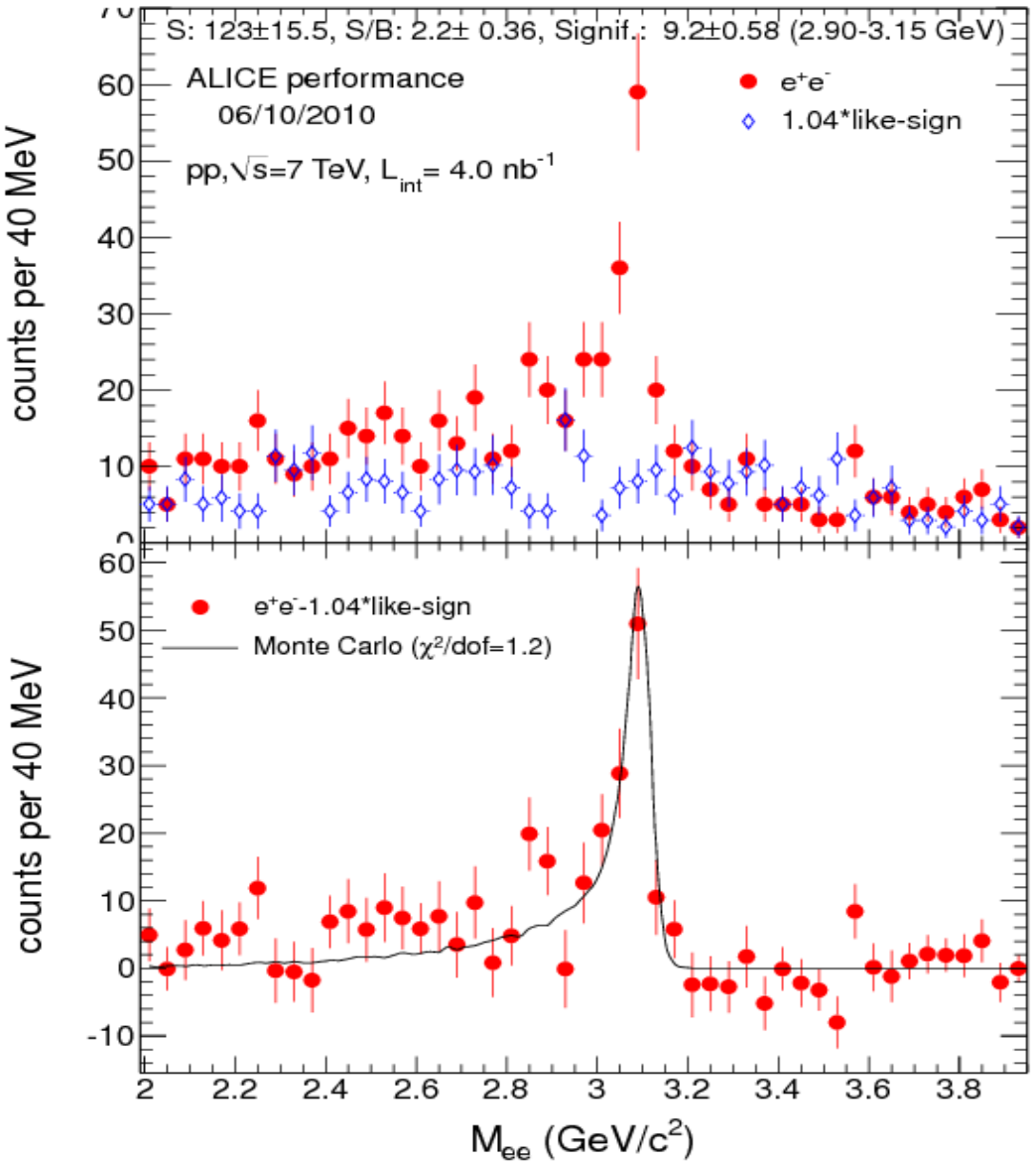
e+ and e- within eta<0.88 and pt > 1 GeV, good tracks in ITS and TPC, not from weak decays, hits in one pixel layer, PID TPC dE/dx 3sigma electron and 3 sigma proton and pion exclusion, signal integrated between 2.9 and 3.15 GeV (69%)

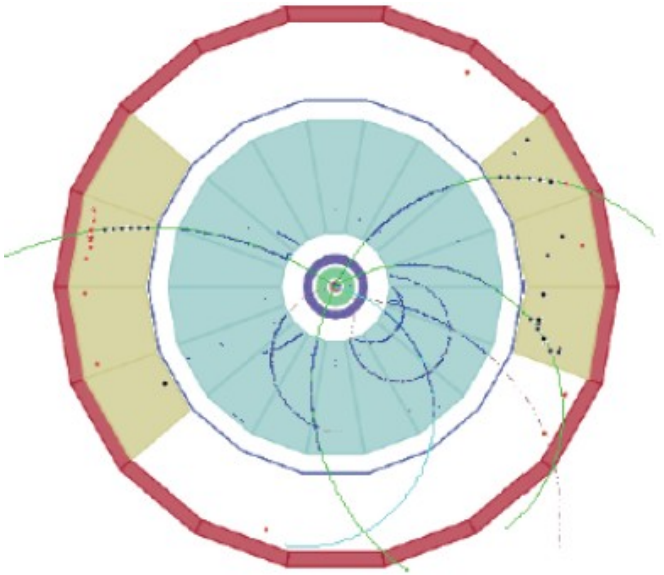


Outlook: better PID using TOF and TRD, measurement of helicity

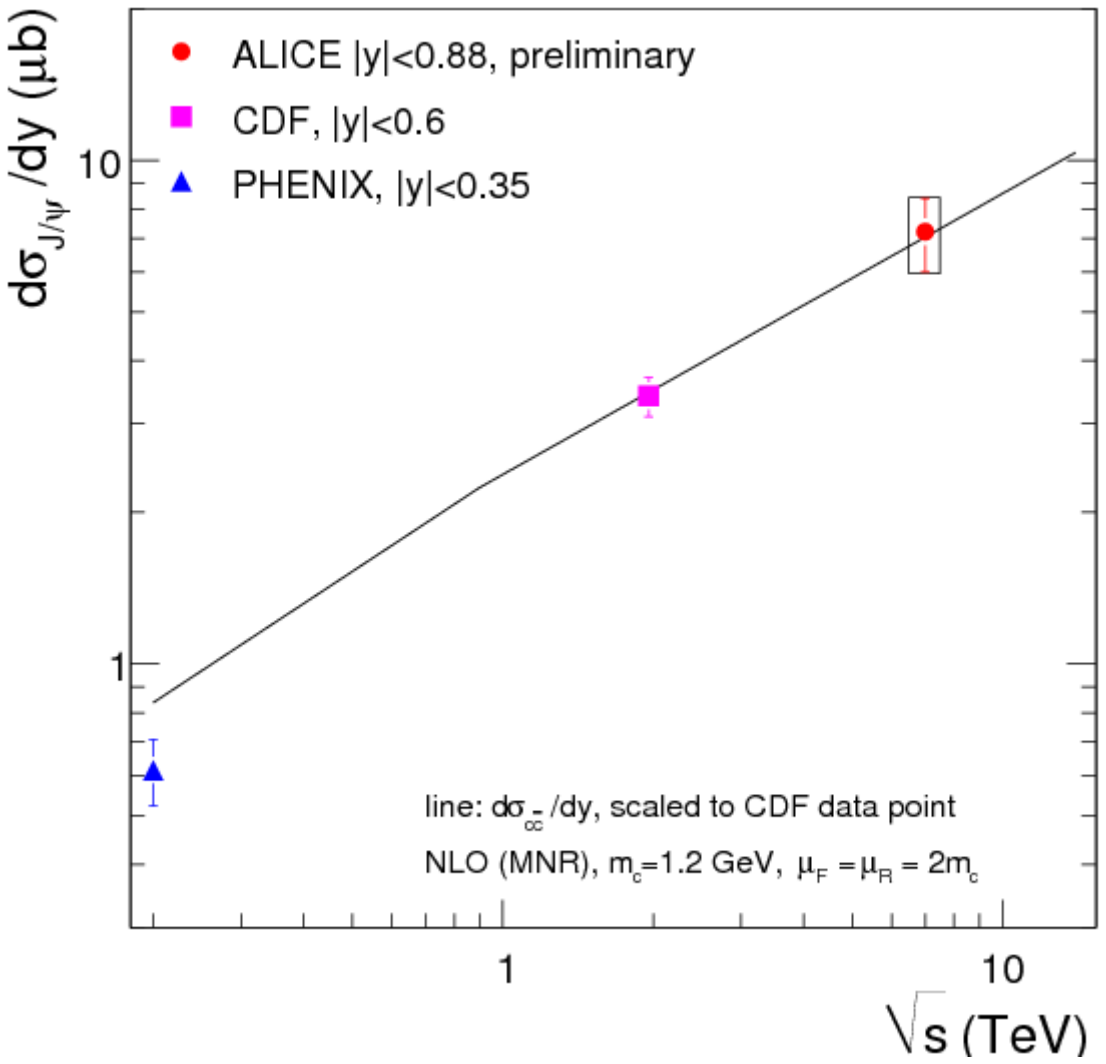
→ reduction of syst. errors

first J/ψ in ALICE central barrel from 280 million pp collisions at 7 TeV





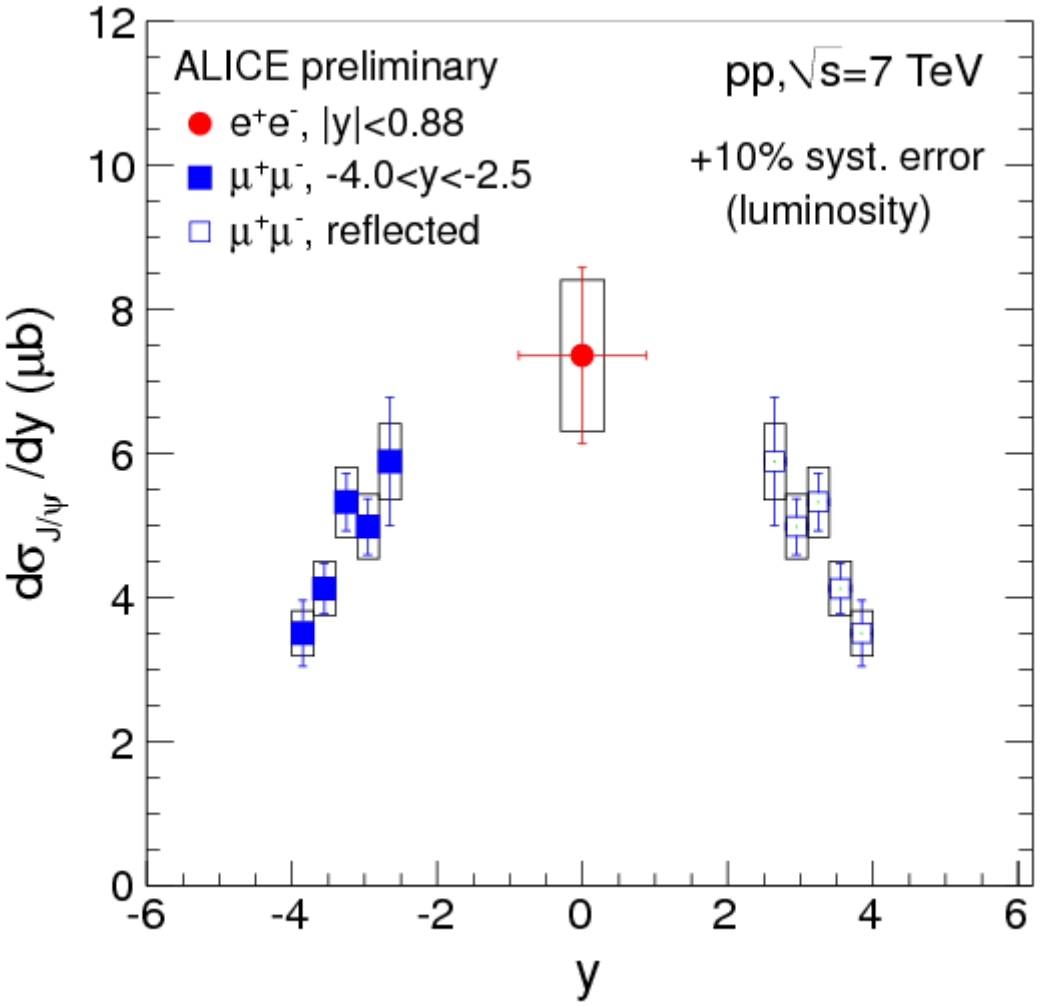
beam energy dependence of J/psi production



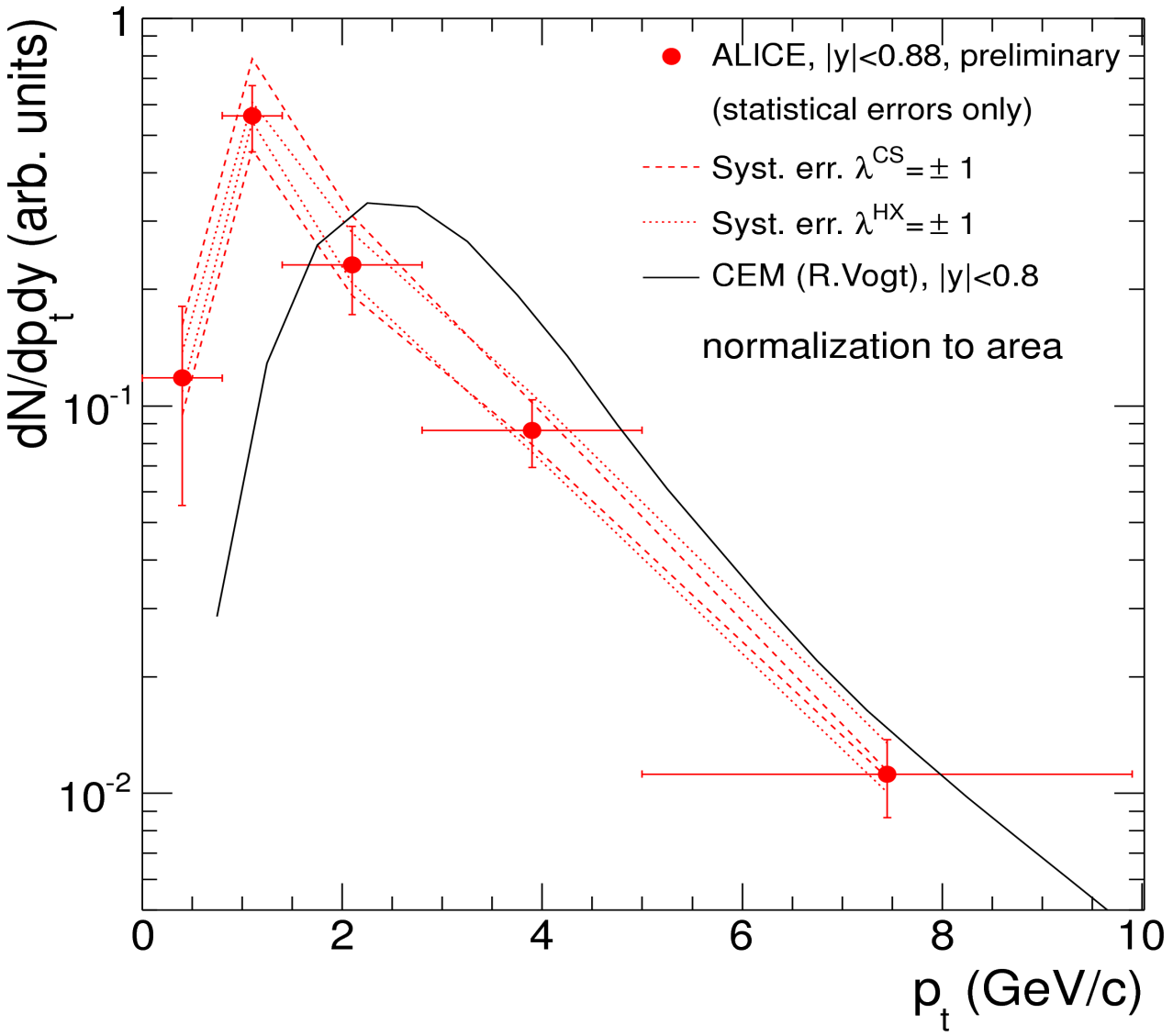
yield at LHC consistent with σ(ccbar) = 640 μb and branching ratio to J/psi 1%

combined results of ALICE muon arm and central barrel

in very good agreement with expected systematics



transverse momentum distribution of J/psi at midrapidity

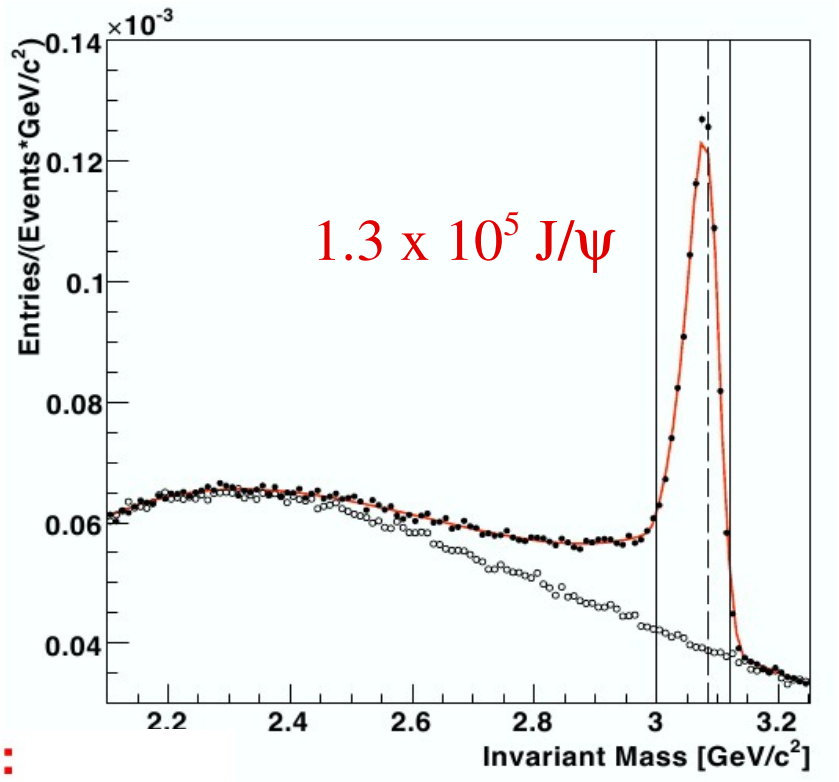


significantly more yield at low p_t as compared to e.g. color evaporation model

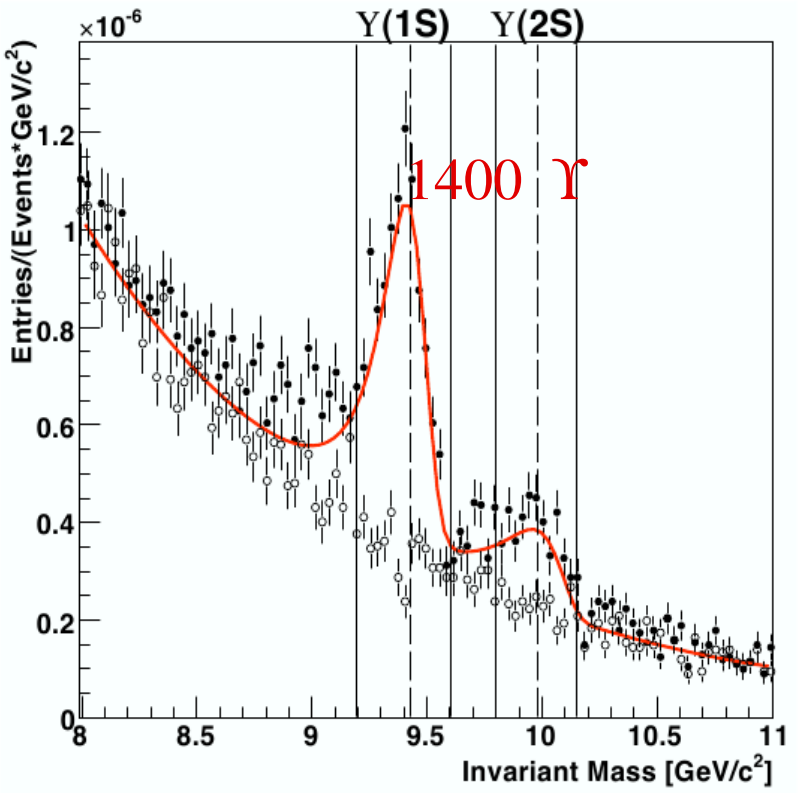
in many experiments this p_t range cannot be measured leading to significant uncertainty in overall J/psi yield

Charmonia in PbPb collisions at 5.4 TeV - full simulation of central barrel performance central collisions

2×10^8 central (10%) events, 10^6 sec (1 year run)



J/ψ:
S/B = 1.47
sgn = 284
signal = 1.3 × 10^5
FWHM = 65 MeV/c^2

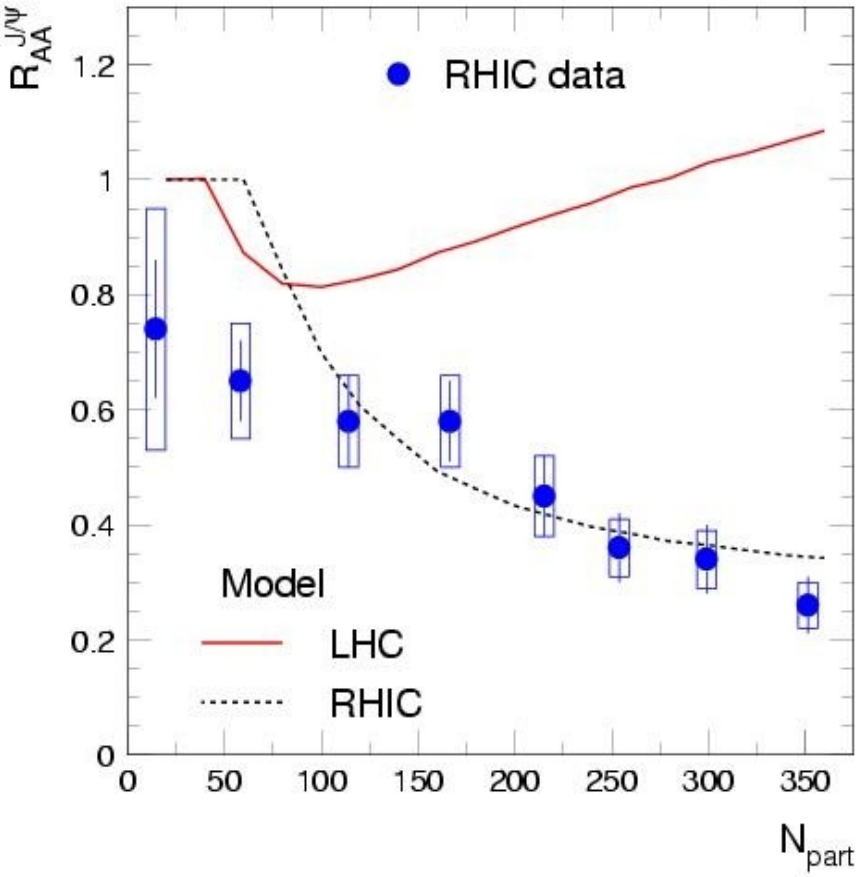


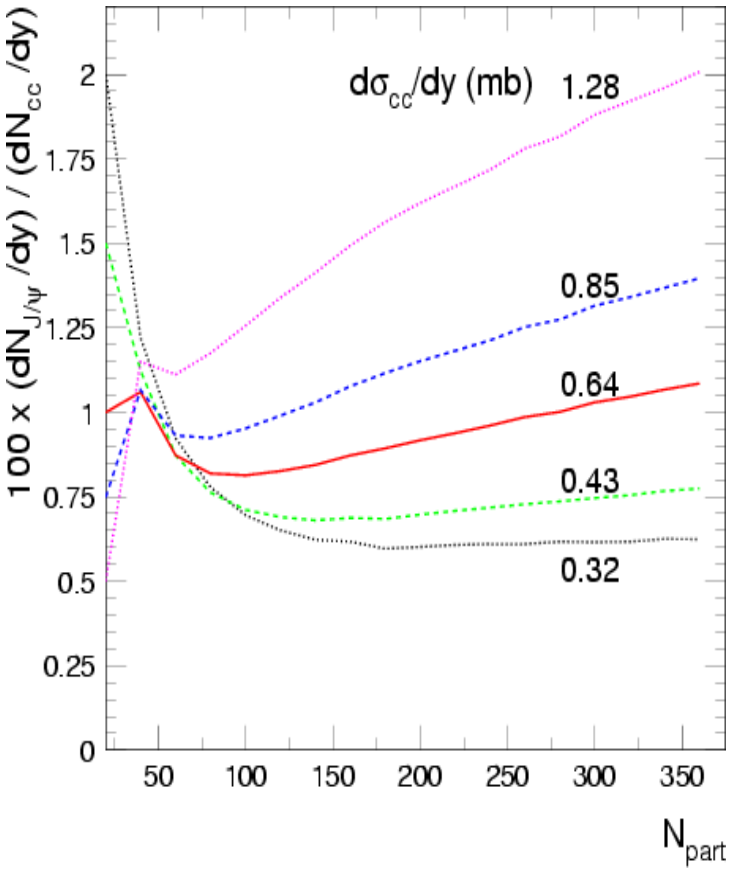
Υ:
S/B = 1.03
sgn = 25.0
signal = 1378
FWHM = 200 MeV/c^2

Expectation 2010: luminosity 10^{25} $cm^{-2}s^{-1}$
can hope for 10^7 min bias collisions
about 500 J/psi

we are on our way to test the energy dependence of quarkonium production between RHIC and LHC

A. Andronic, P. Braun-Munzinger, K. Redlich, J. Stachel Phys. Lett. B652 (2007) 259

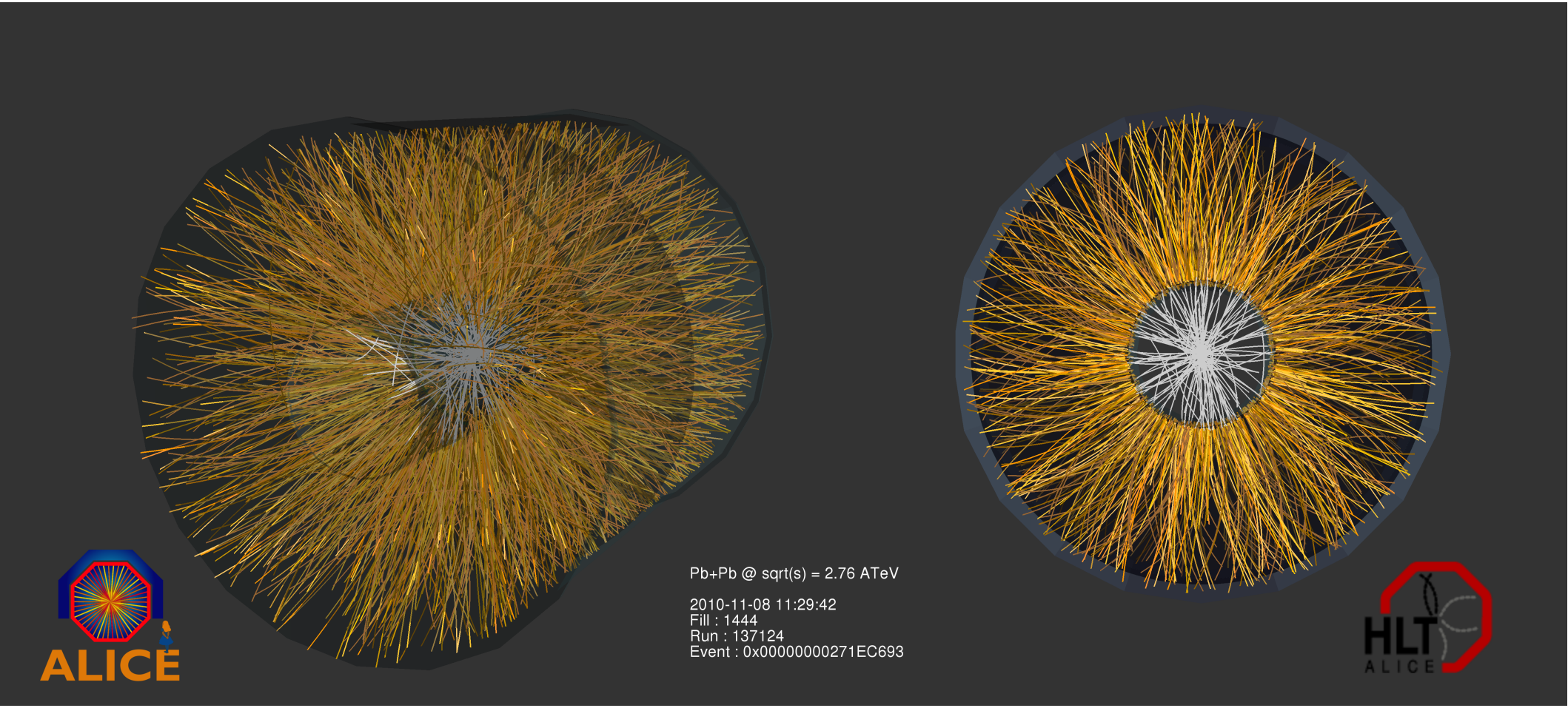




centrality dependence and enhancement beyond pp value will be fingerprint of statistical hadronization at LHC

-> direct signal for deconfinement

first PbPb collisions at LHC at sqrt(s) = 2.76 A TeV



setup for ion collisions: November 4

first collisions: November 7

first collisions with stable beams: November 8, since then increase in lumi by 100

Summary

ALICE had a very good physics start
detectors function as designed
calibration still ongoing but in many respects nearing desired performance

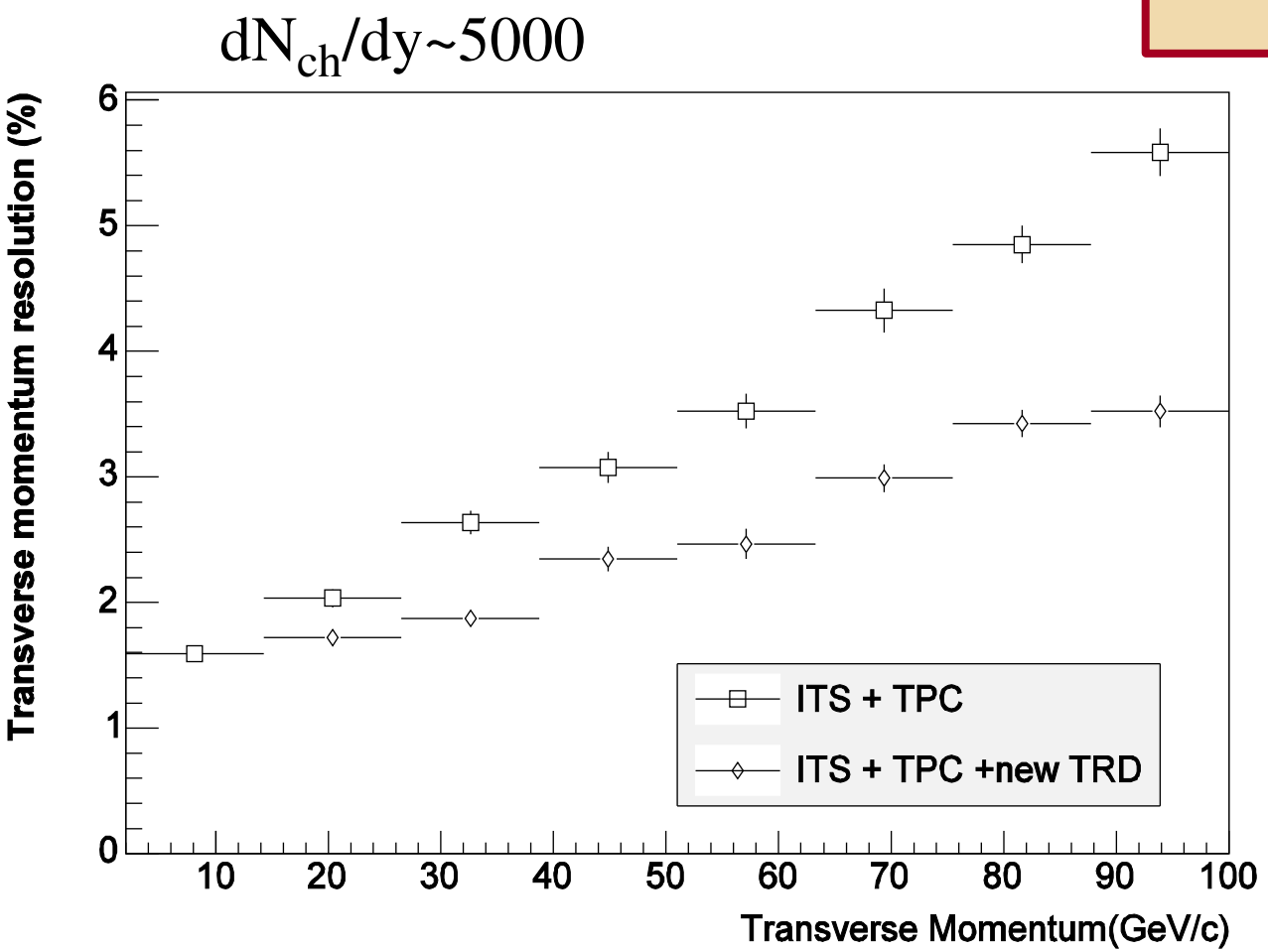
a multitude of physics analyses ongoing
(6 papers published, about 10 currently in preparation)
quantitative results expected soon for 10^9 pp collisions

now taking data for PbPb collisions at sqrt(s_{nn}) = 2.76 TeV

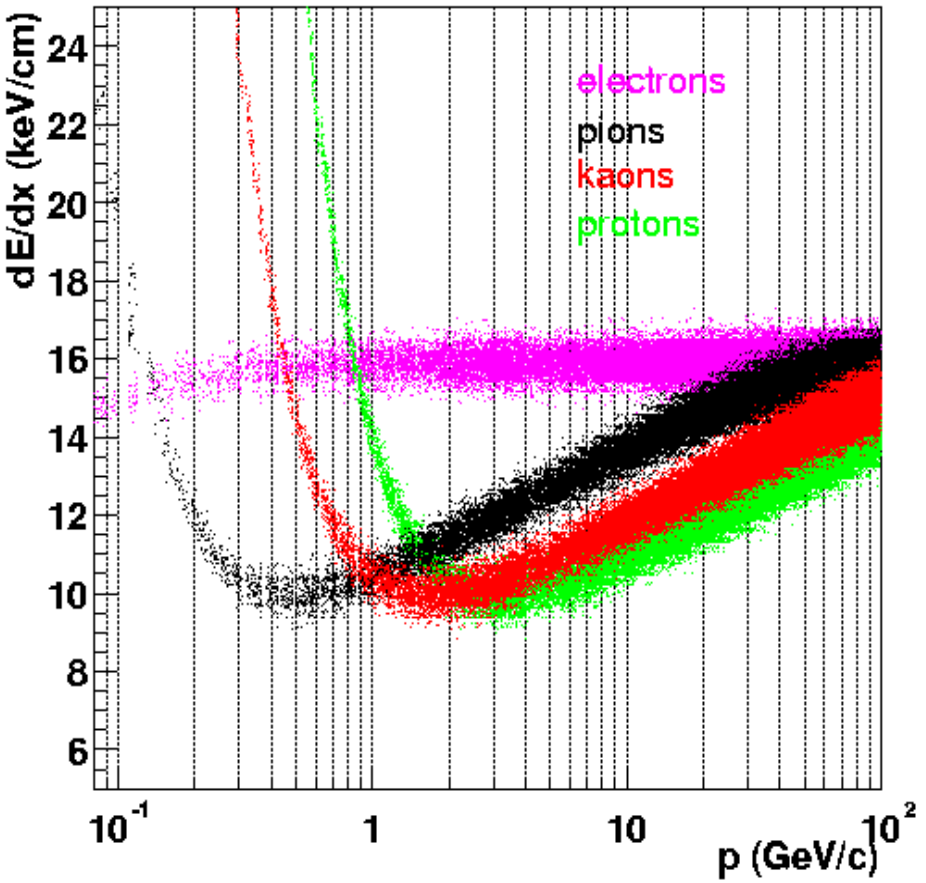
backup

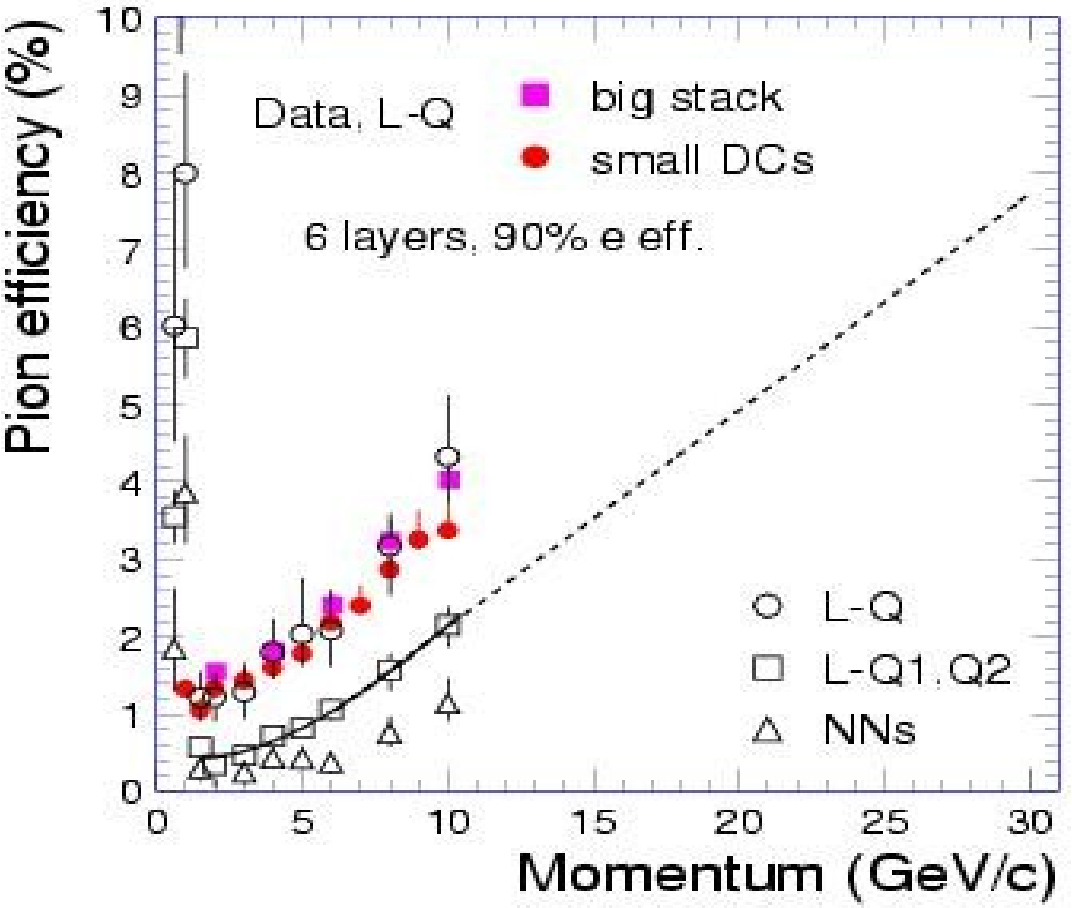
design combined momentum resolution in ALICE central barrel in PbPb collisions

resolution ~ 3% at 100 GeV/c still excellent performance in hard region!



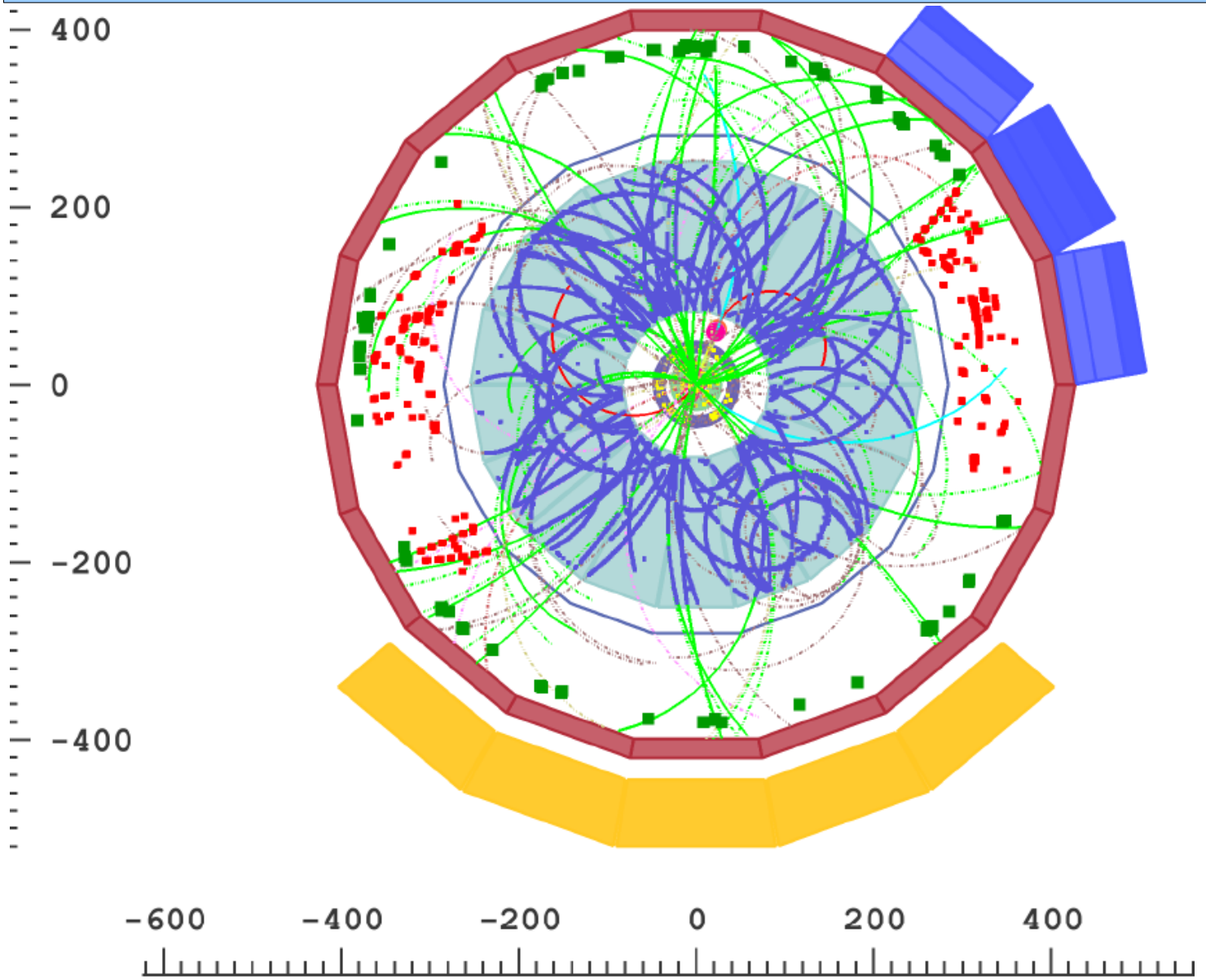
electron identification with TPC and TRD





From test beam data: at 2 GeV and 90 % e eff → 10^5 π rejection

a pretty busy pp collision



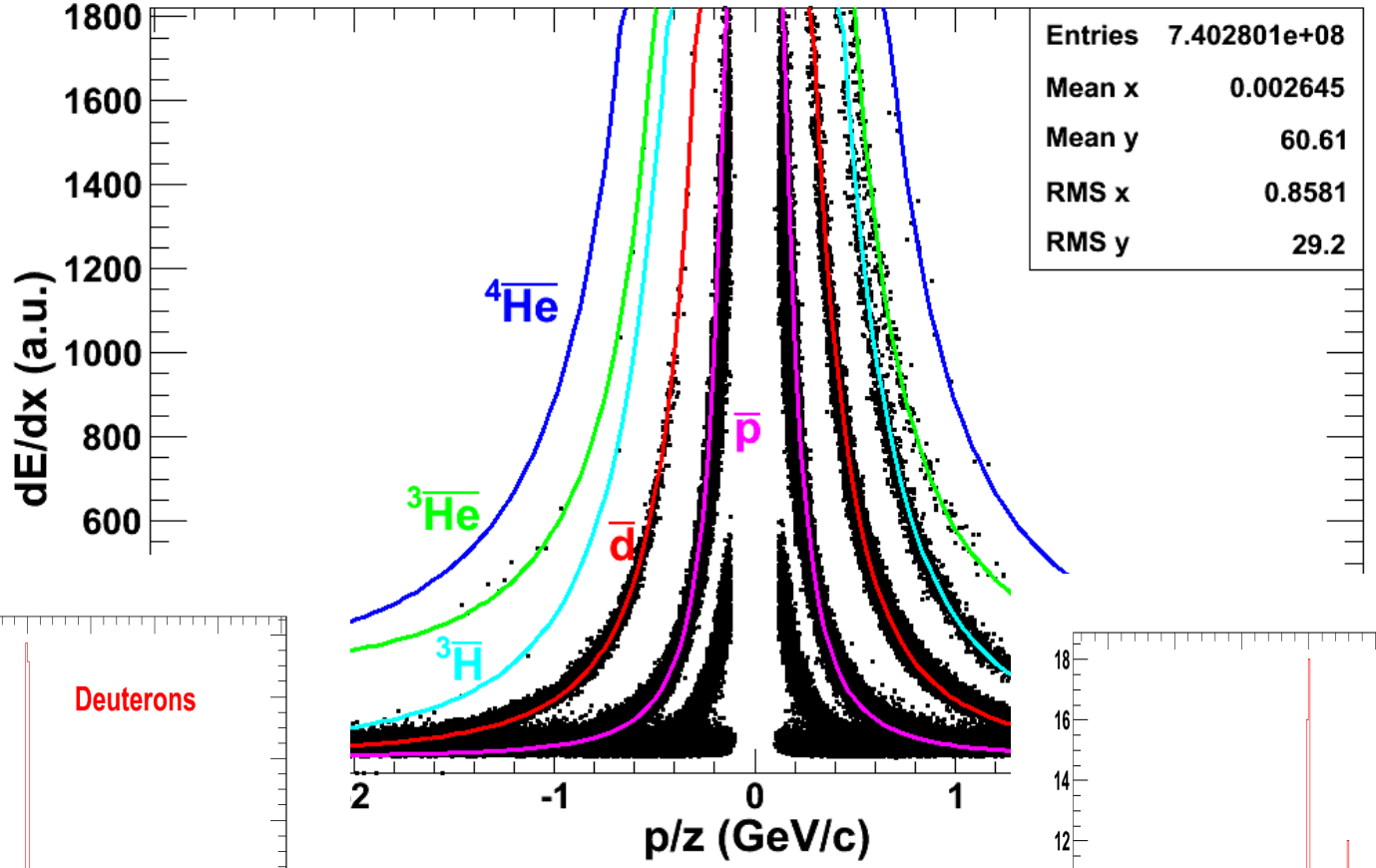
pp results published sofar

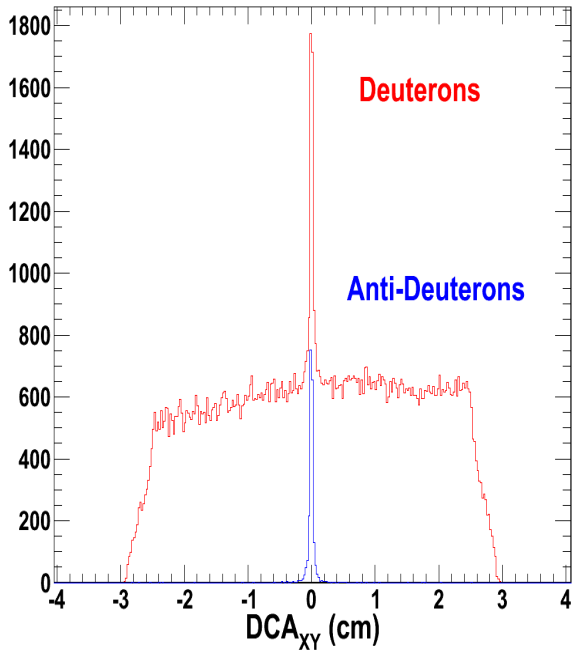
Final published results

N_{ch} multiplicity & distributions

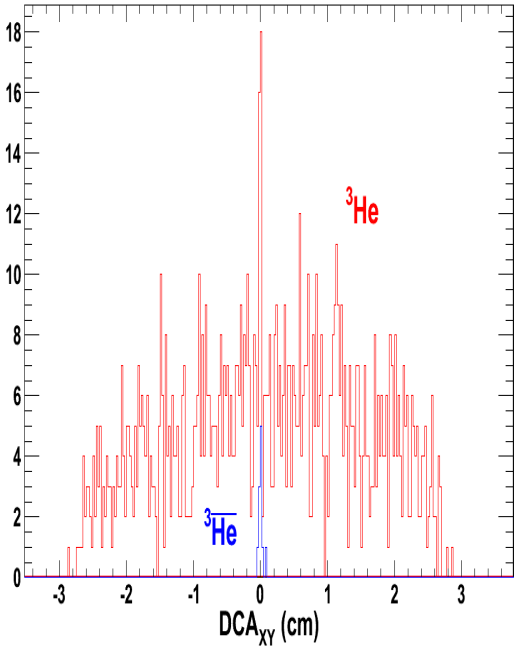
900 GeV:	EPJ C65 (2010) 111
900 GeV, 2.36 TeV:	EPJ C68 (2010) 89
7 TeV:	EPJ C68 (2010) 345
pbar/p ratio (900 GeV & 7 TeV)	PRL 105 (2010) 072002
momentum distributions(900 GeV)	PL B693 (2010) 53
Bose-Einstein correlations (900 GeV)	PR D82 (2010) 052001

(anti) nuclei

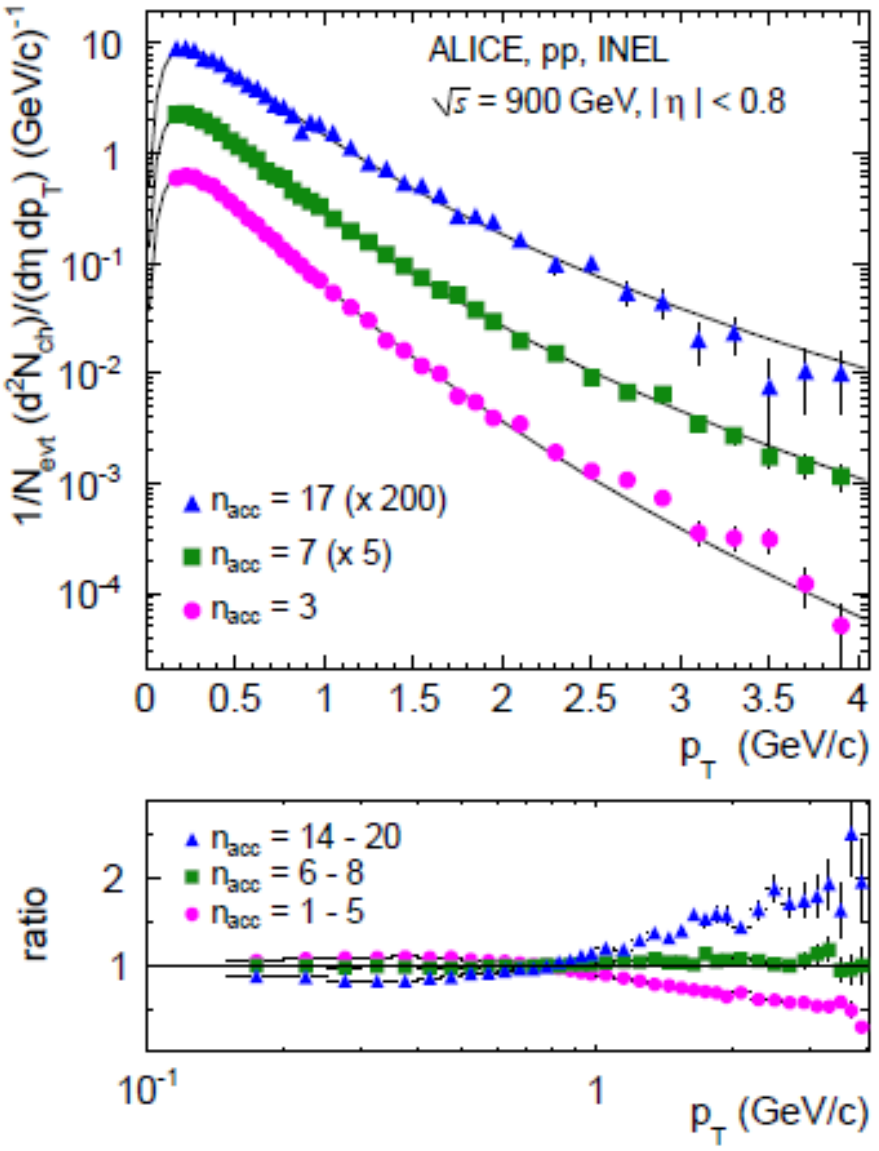


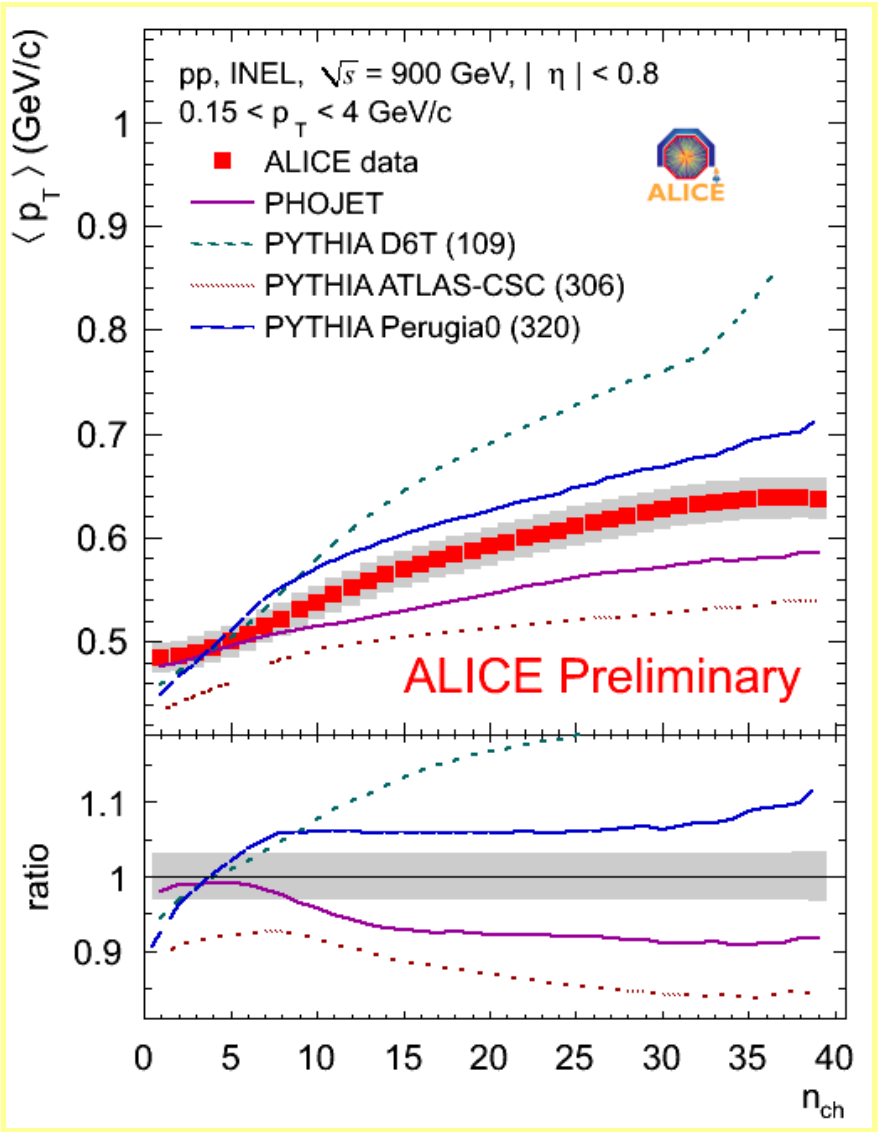


Distance of track to collision vertex



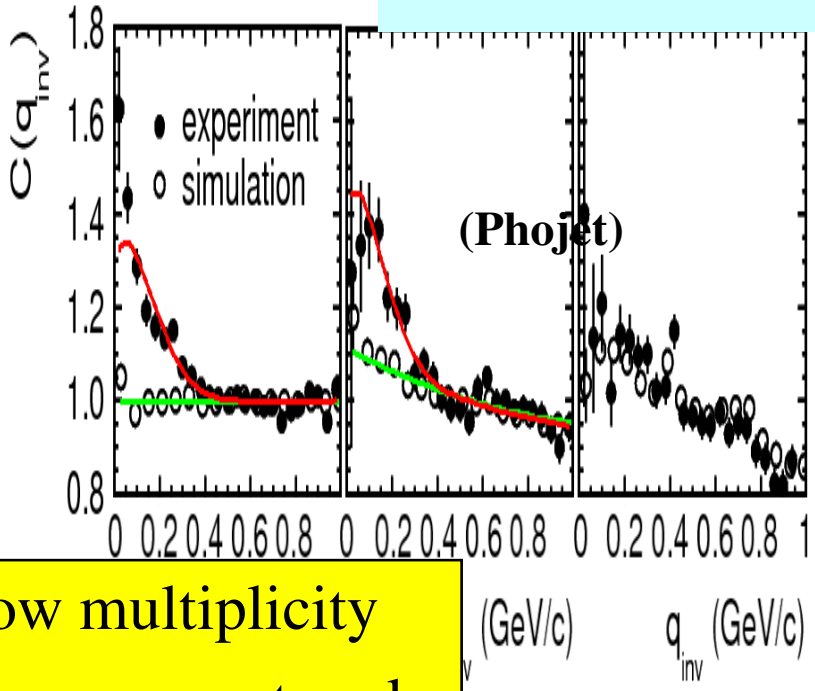
transverse momentum distribution



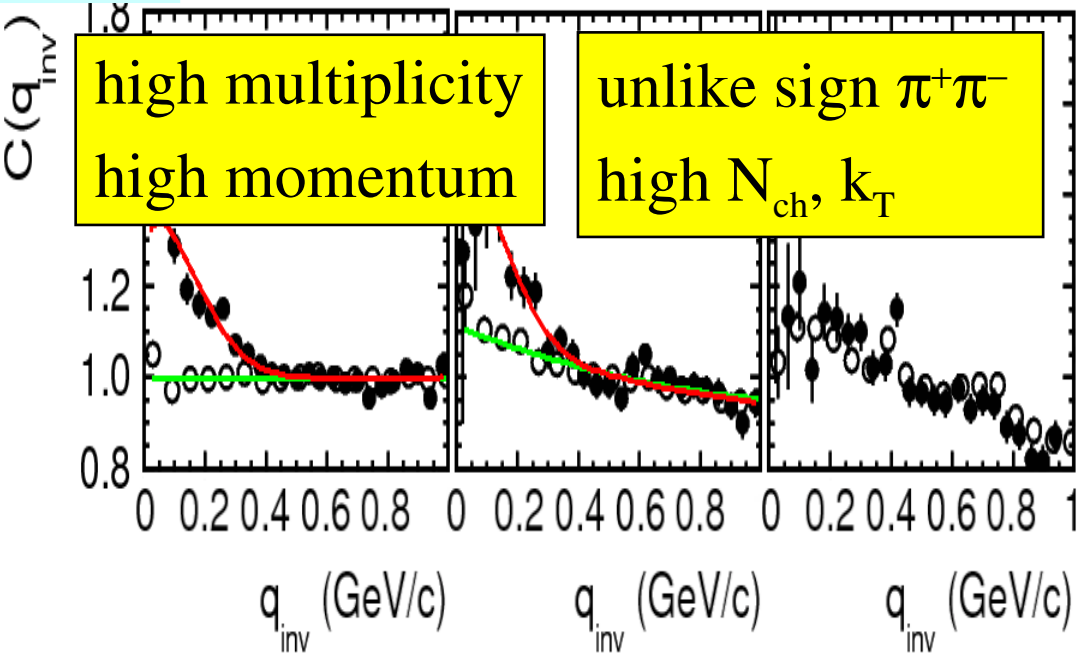


ALICE data: arXiv:1007.0719v3, PLB 693 (2010) 53

BE enhancement vs q_{INV}

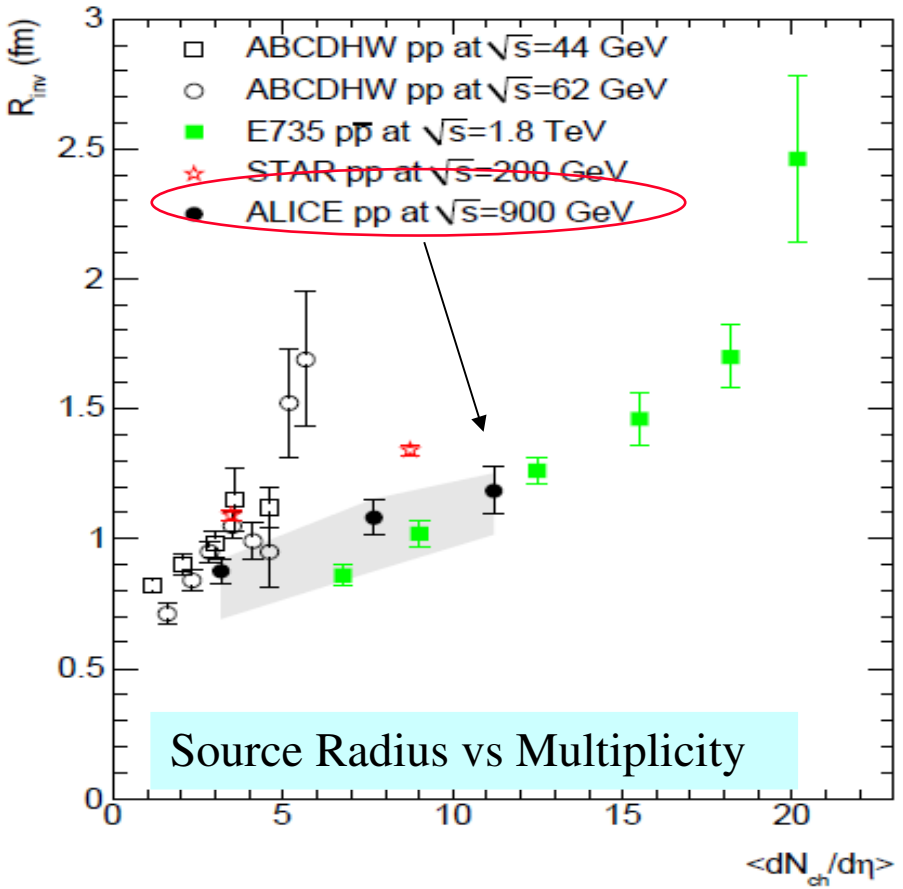


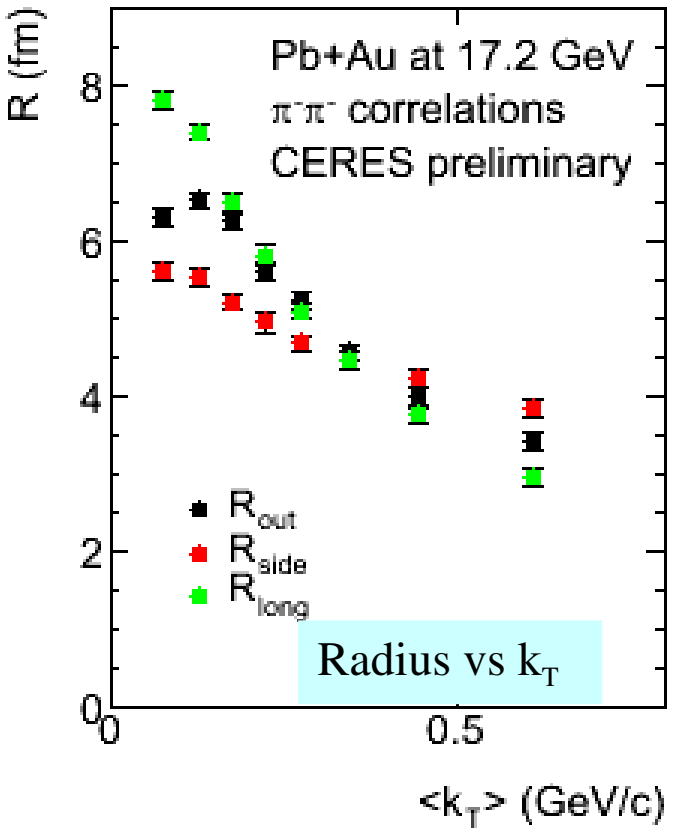
low multiplicity
low momentum k_T

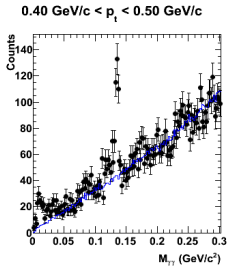


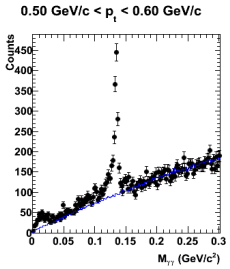
high multiplicity
high momentum

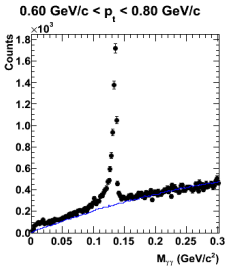
unlike sign $\pi^+\pi^-$
high N_{ch}, k_T

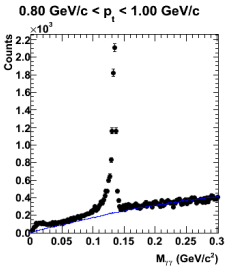

ABCDHW pp at √s=44 GeV
ABCDHW pp at √s=62 GeV
E735 pp̄ at √s=1.8 TeV
STAR pp at √s=200 GeV
ALICE pp at √s=900 GeV
R_inv (fm)
<dN_ch/dη>
Source Radius vs Multiplicity

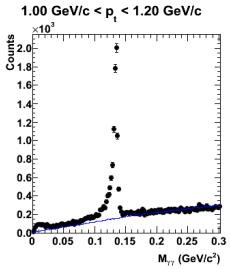

Pb+Au at 17.2 GeV
π⁻π⁻ correlations
CERES preliminary
R_out
R_side
R_long
R (fm)
<k_T> (GeV/c)
Radius vs k_T

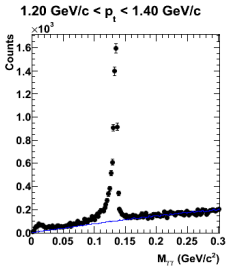










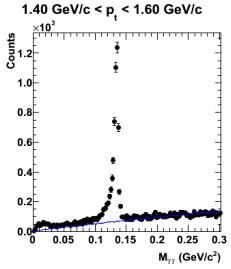


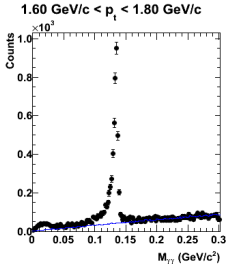
ALICE performance

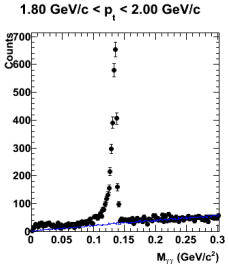
$pp \rightarrow \pi^0 (\rightarrow \gamma\gamma \rightarrow e^+e^- e^+e^-) + X$ @ 7TeV

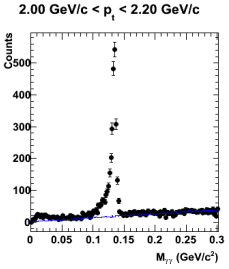
Data: 9.572e+07 MinBias events

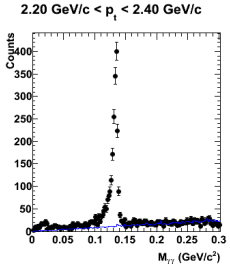
RAW DATA

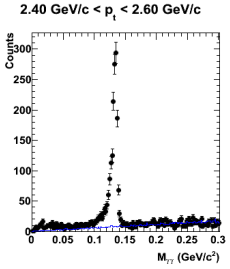


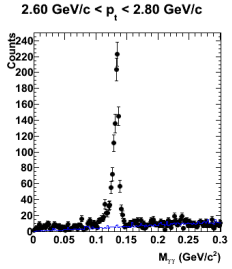


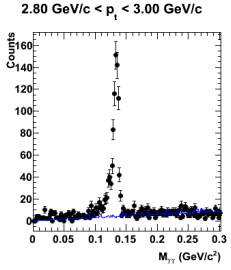


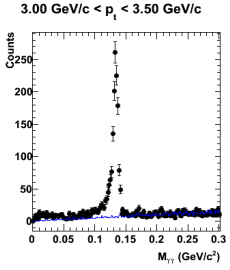


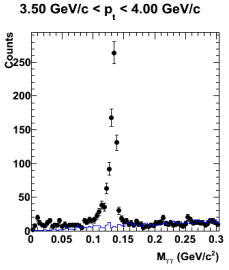


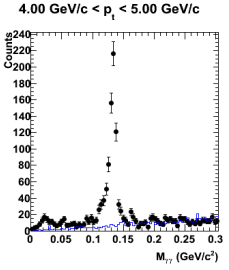


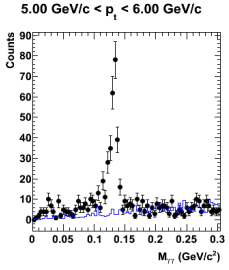


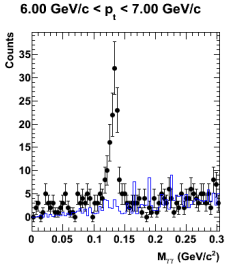


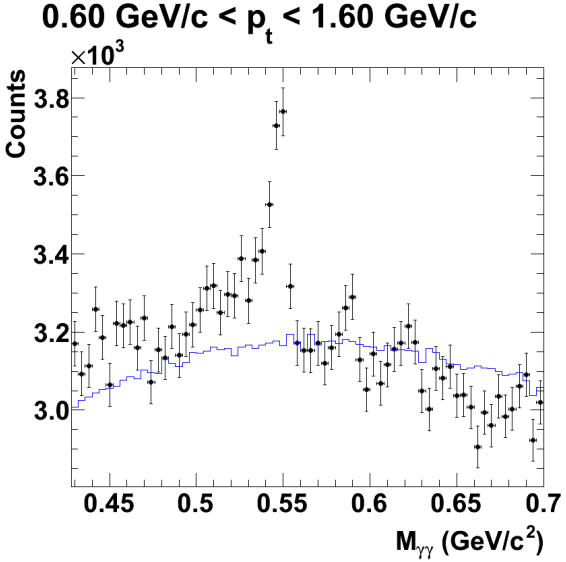


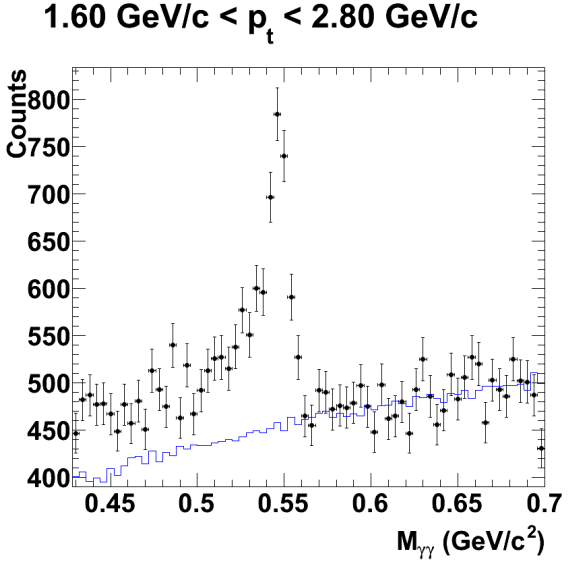


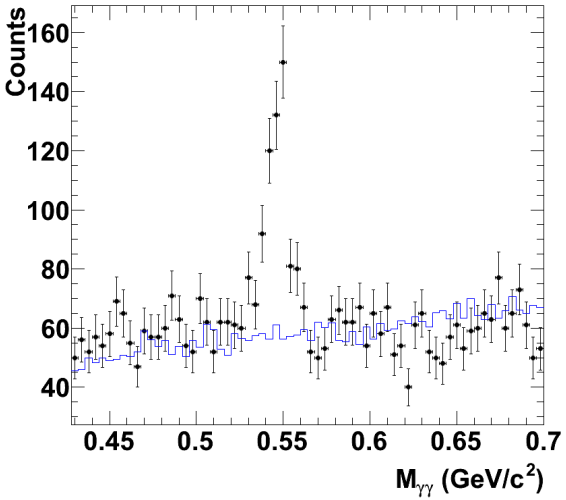


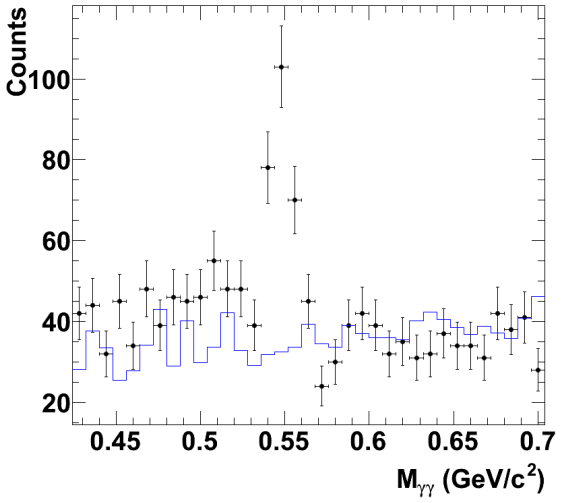










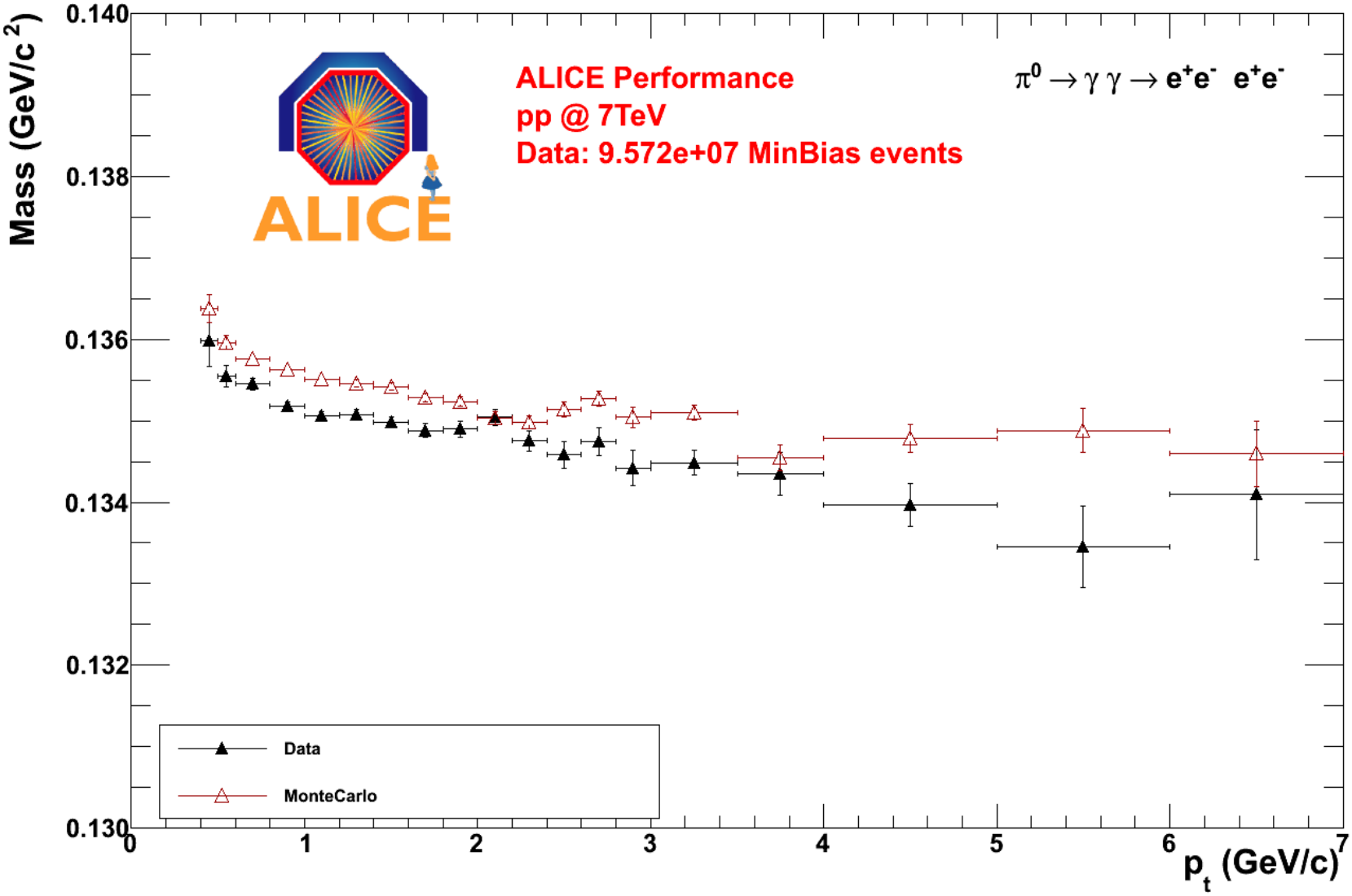


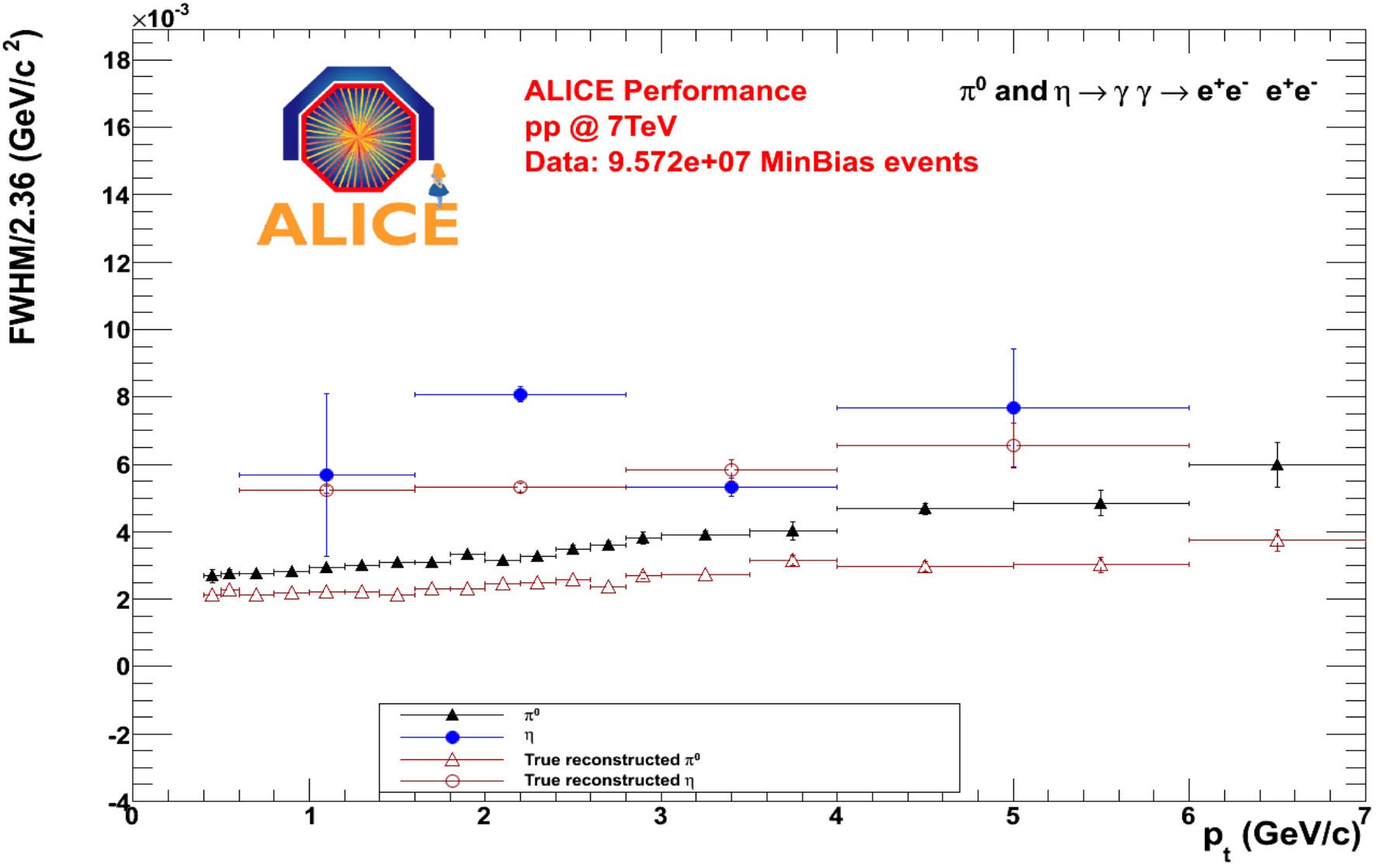
ALICE performance

pp → η (→ γ γ → e^+e^- e^+e^-) + X @ 7TeV

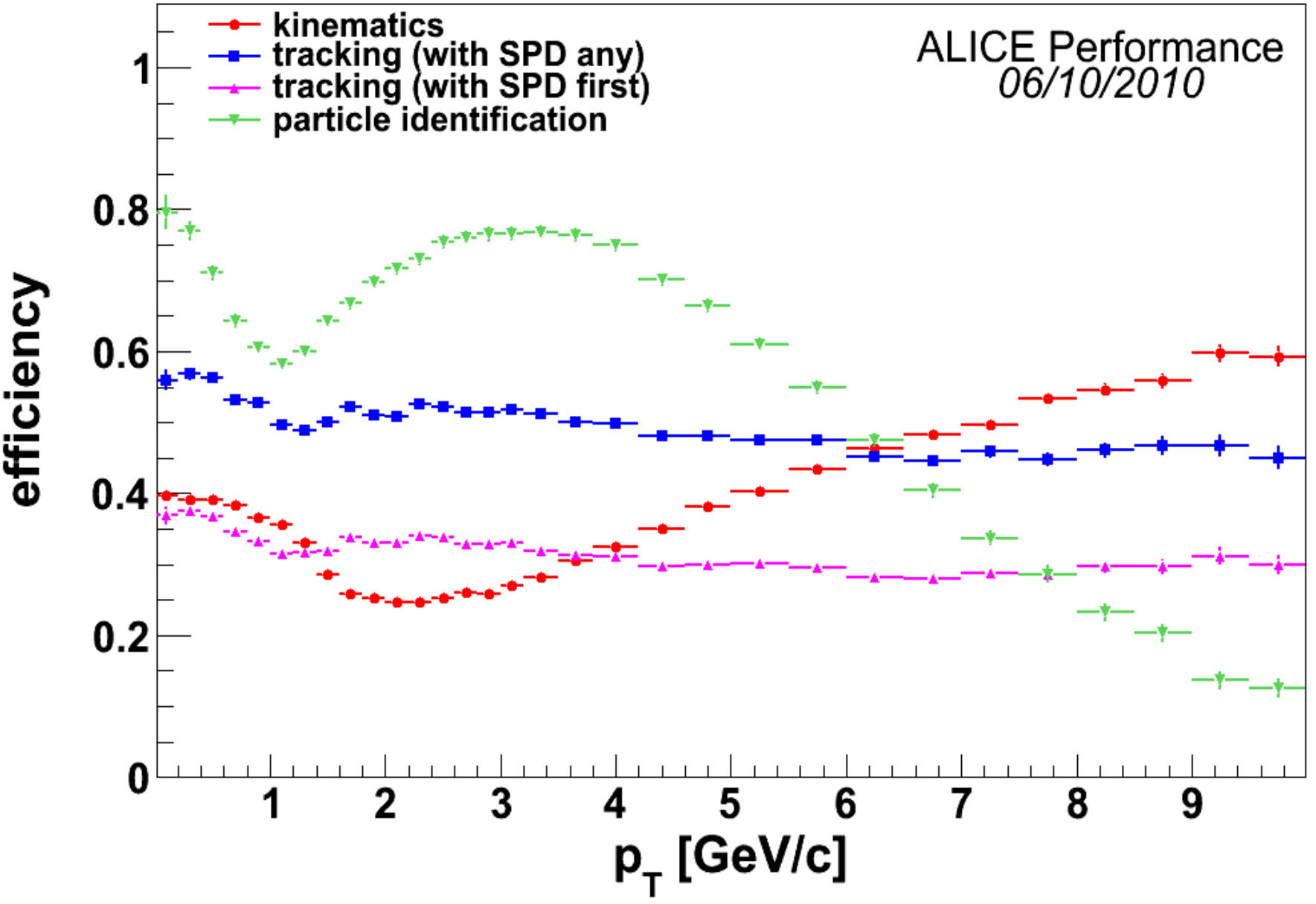
Data: 9.572e+07 MinBias events

RAW DATA


ALICE Performance
pp @ 7TeV
Data: 9.572e+07 MinBias events
$\pi^0 \rightarrow \gamma\,\gamma \rightarrow e^+e^-\ e^+e^-$
ALICE
Mass (GeV/c^2)
0.140
0.138
0.136
0.134
0.132
0.130
0
1
2
3
4
5
6
7
p_t (GeV/c)
Data
MonteCarlo

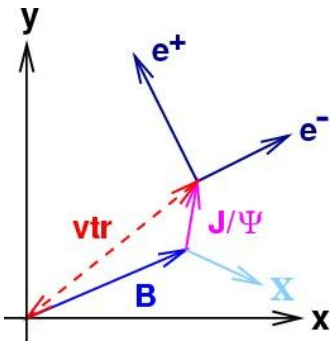

ALICE Performance
pp @ 7TeV
Data: 9.572e+07 MinBias events
π^0 and $\eta \rightarrow \gamma\gamma \rightarrow e^+e^-$ e^+e^-
ALICE
FWHM/2.36 (GeV/c^2)
$\times 10^{-3}$
p_t (GeV/c)
π^0
η
True reconstructed π^0
True reconstructed η

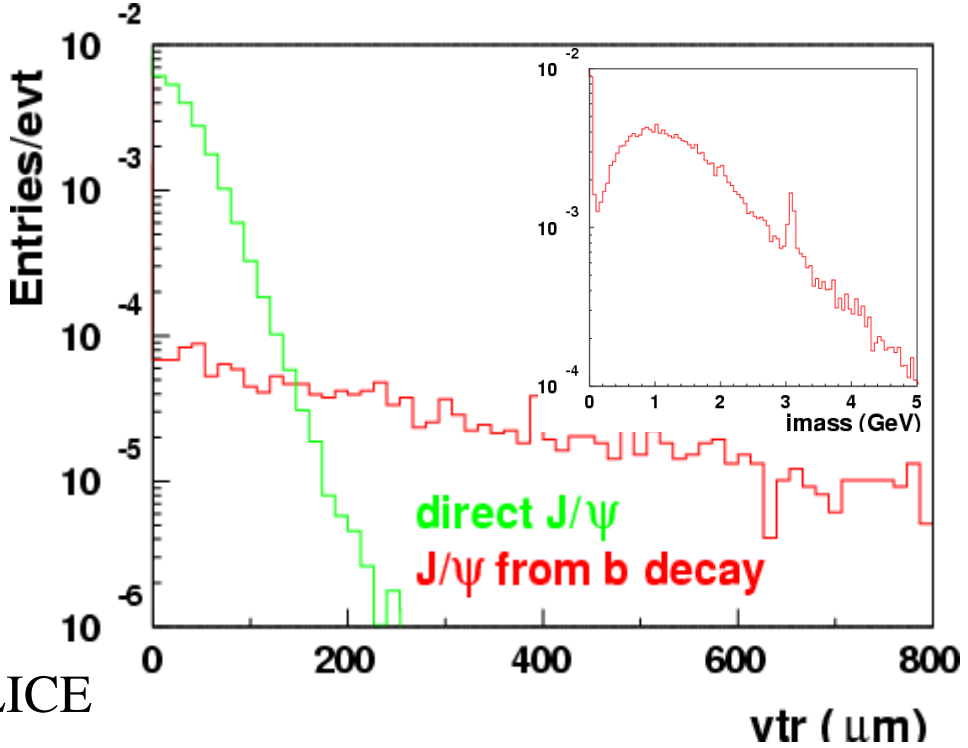
J/psi reconstruction efficiency in central barrel of ALICE



J/ψ from B-decay

N(B → J/ψ) / N(direct J/ψ) ~ 20% in 4π @ LHC





σ (d0) < 50 μm for p_t > 1.5 GeV/c in ALICE

disentangle primary & secondary J/ψ

measure inclusive b cross-section

probe b quark in-medium energy loss