STATUS OF THE ALICE EXPERIMENT AND FIRST RESULTS ON HEAVY FLAVOR PRODUCTION

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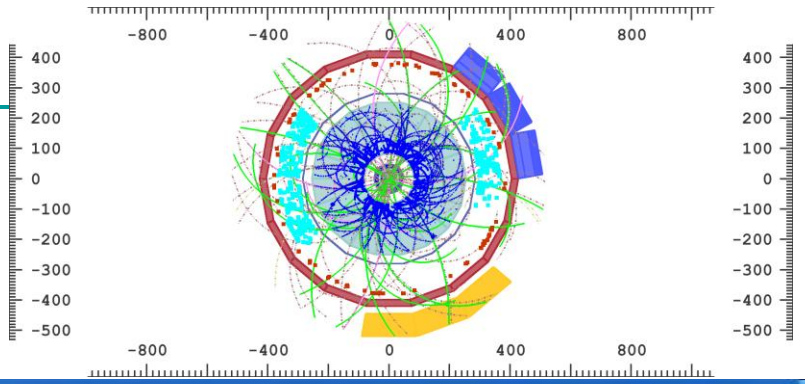
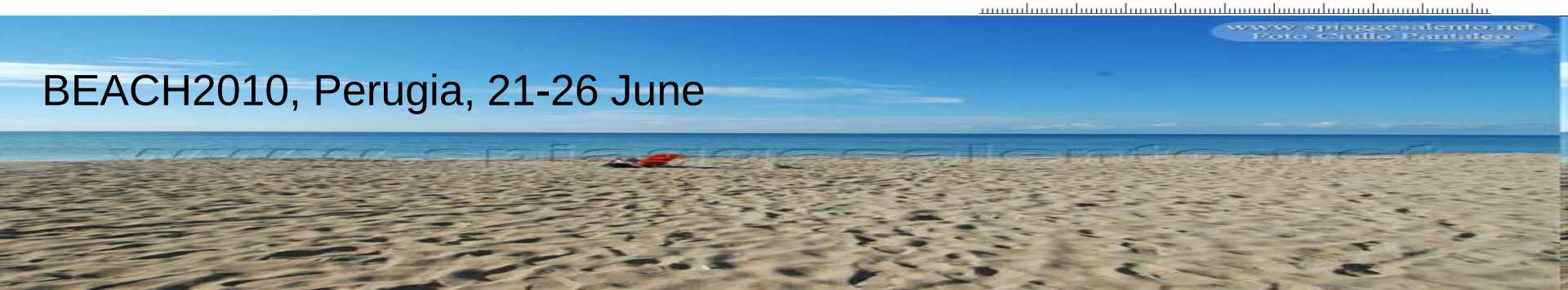




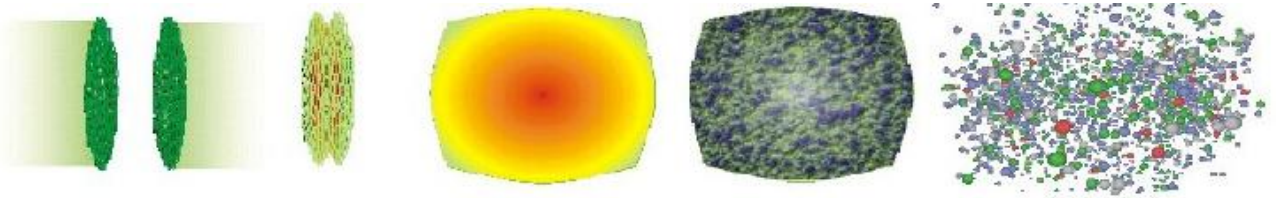
BEACH2010, Perugia, 21-26 June

OUTLINE

- Introduction to ALICE
- Status of the detector and first physics results
  - tracking, vertexing and PID performance
  - multiplicity, p_T, HBT and more
- Heavy flavors at mid rapidity
  - motivations and expectations
  - first results
- Conclusions

A Large Ion Collider Experiment

Dedicated to ***Quark Gluon Plasma*** detection in heavy ion collisions



CHALLENGING!

high particle density, wide p_T range, need to identify particles... all by:
18 detector technologies, several smaller 'special purpose' detectors
central barrel (vertexing, tracking, PID with excellent performance) +
muon arm

NOT ONLY HEAVY ION...

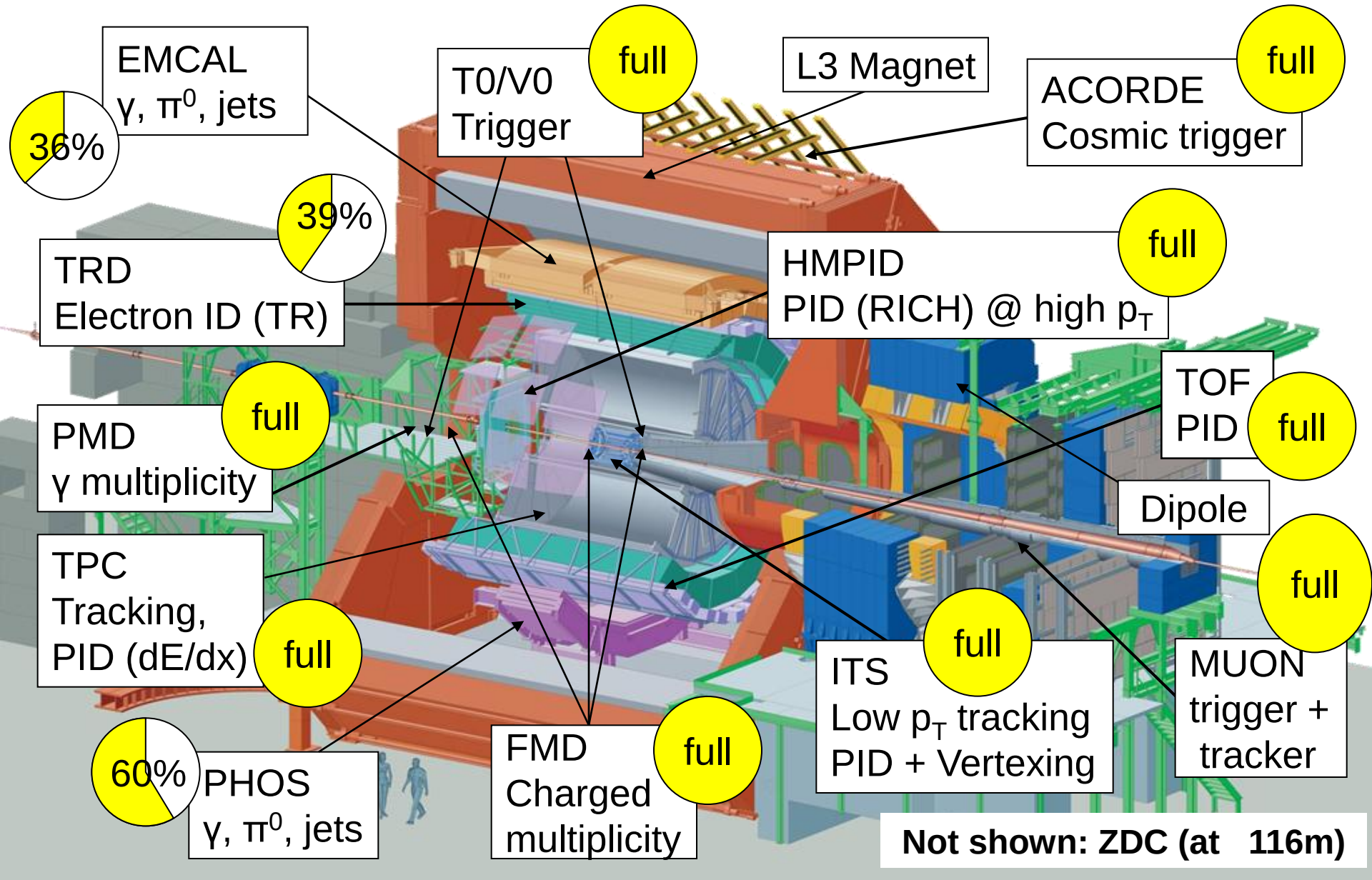
... But also p-p physics!

Among the relevant physics topics:

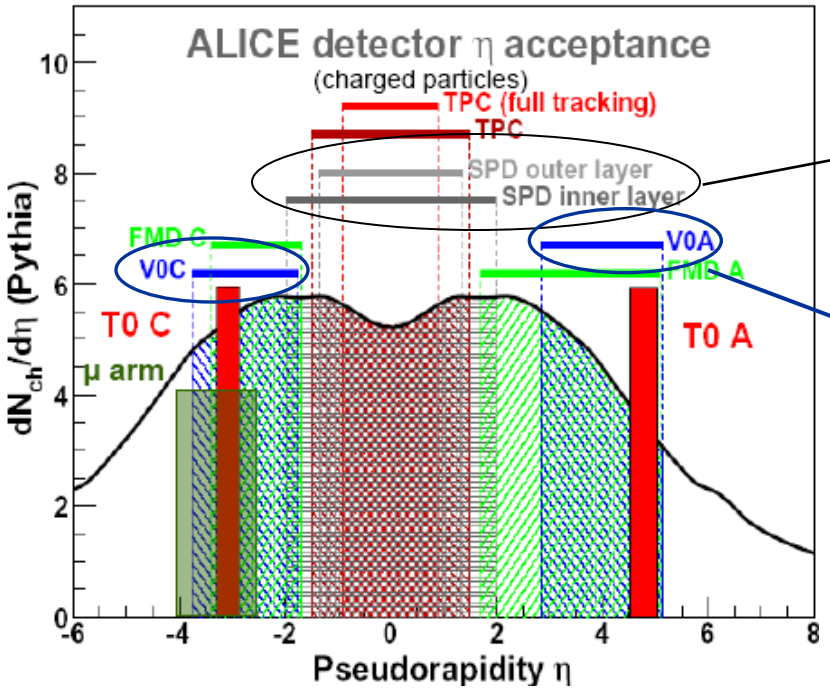
- Physics at high multiplicities: explore possible collective effects, jets, strangeness, etc.
- Systematics of particle production
- Measurement of charm and beauty cross sections, down to low momenta, open charm and quakonia
- Study of underlying event
- Benchmark to Monte Carlo models

- Baseline to Pb-Pb collisions

THE ALICE DETECTOR



MIN BIAS TRIGGER & DATA TAKING



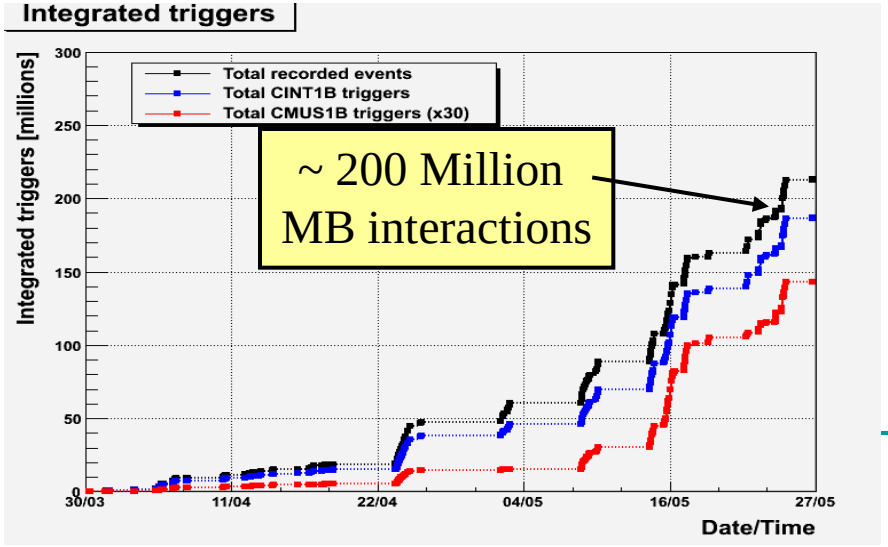
Silicon Pixel Detector
inner: |η|<2 , outer: |η|<1.4

or

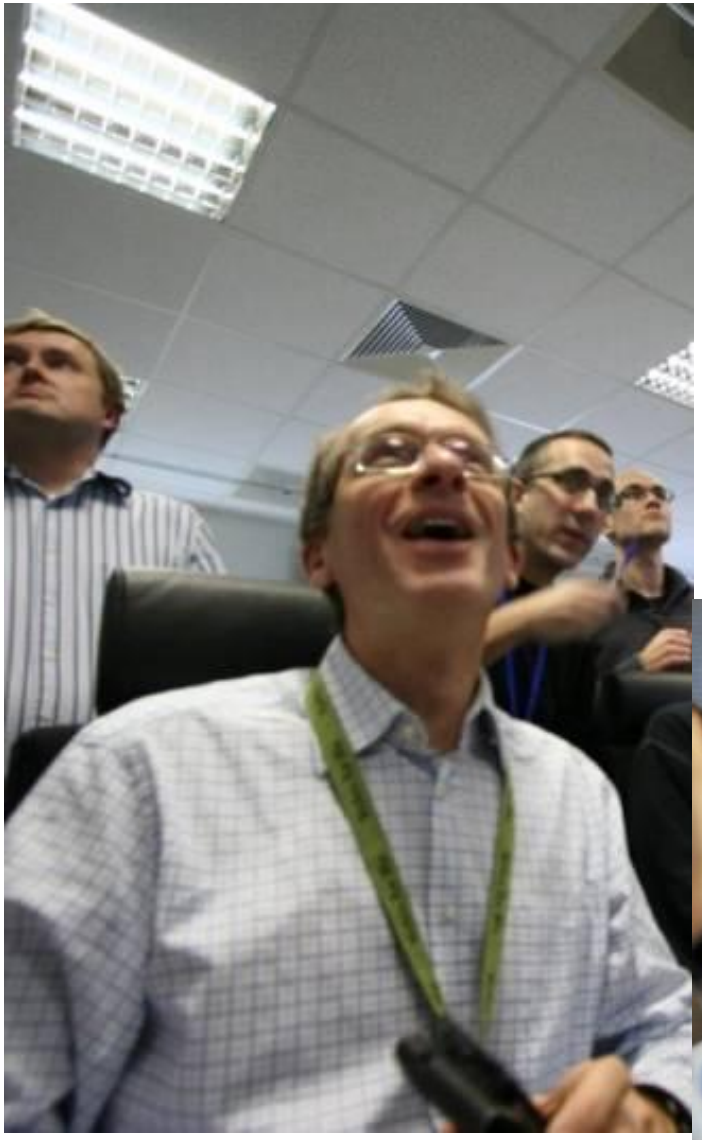
Scintillator hodoscopes
V0A : 2.8 < η < 5.1
V0C : -3.7 < η < -1.7

Data recorded in 2009 – 2010:

- 0.9 TeV : 7M events
- 2.36 TeV: 30k events
- 7 TeV: 200M events

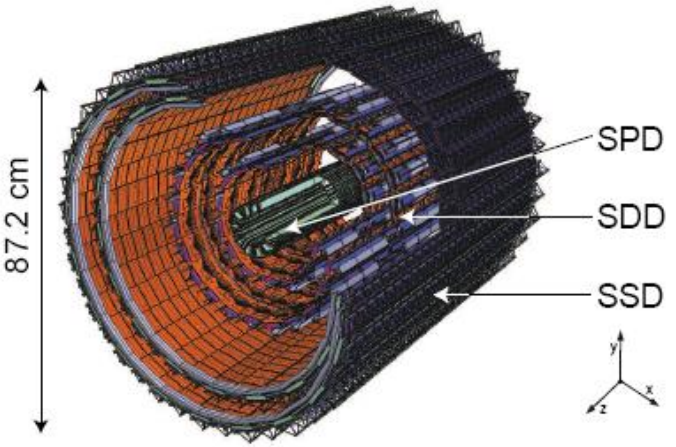


THE FIRST DATA TAKING! (23/11/2009)



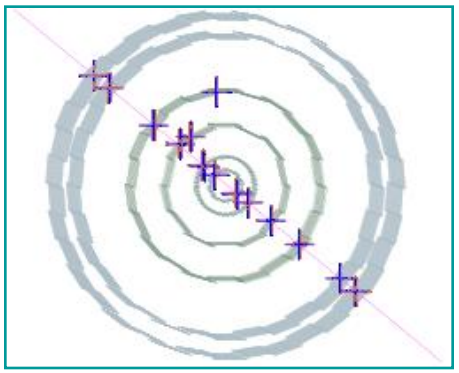
Inner Tracking System

- 3 different technologies used:
  - Silicon Pixel Detector
  - Silicon Drift Detector
  - Silicon Strip Detector

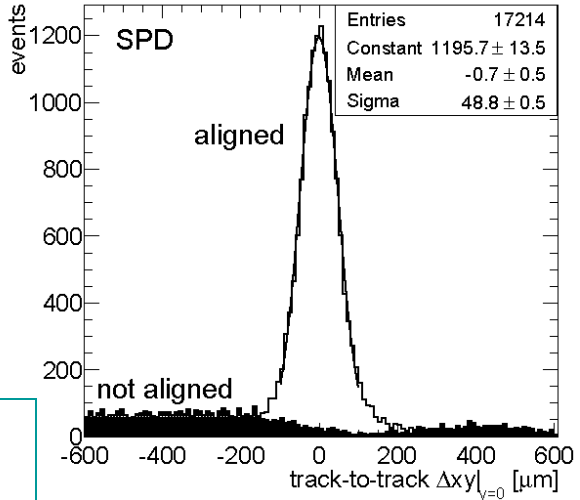


Good alignment is needed to get excellent tracking and vertexing!

For example : SPD Alignment



Δ_{xy} → distance between 2 half tracks in the xy plane at y=0



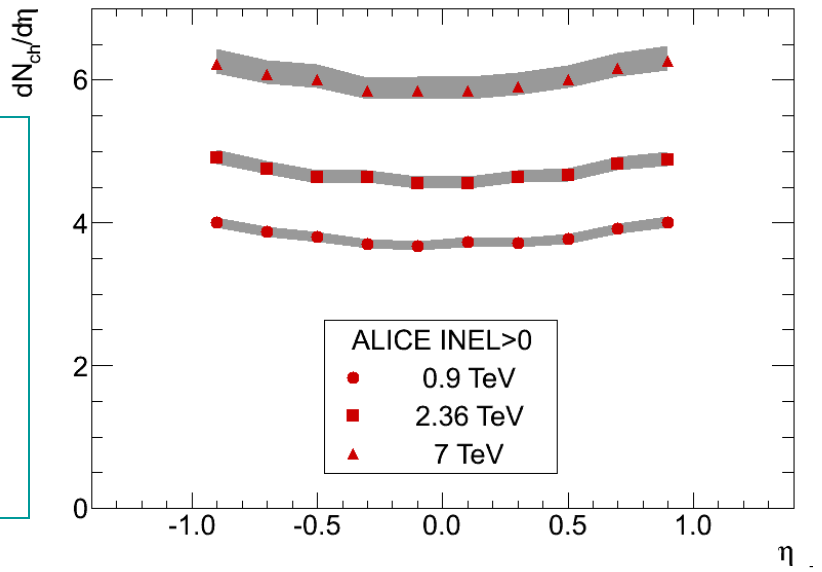
- $\sigma_{r\varphi}$ ≈14 μm
- misalignment < 10 μm

→close to design values

2010 JINST P03003

MULTIPLICITY MEASUREMENTS (I)

- Measure in a new energy domain!
  - Global characteristic of p-p collisions
  - Constraint to theorethical models / input for simulations



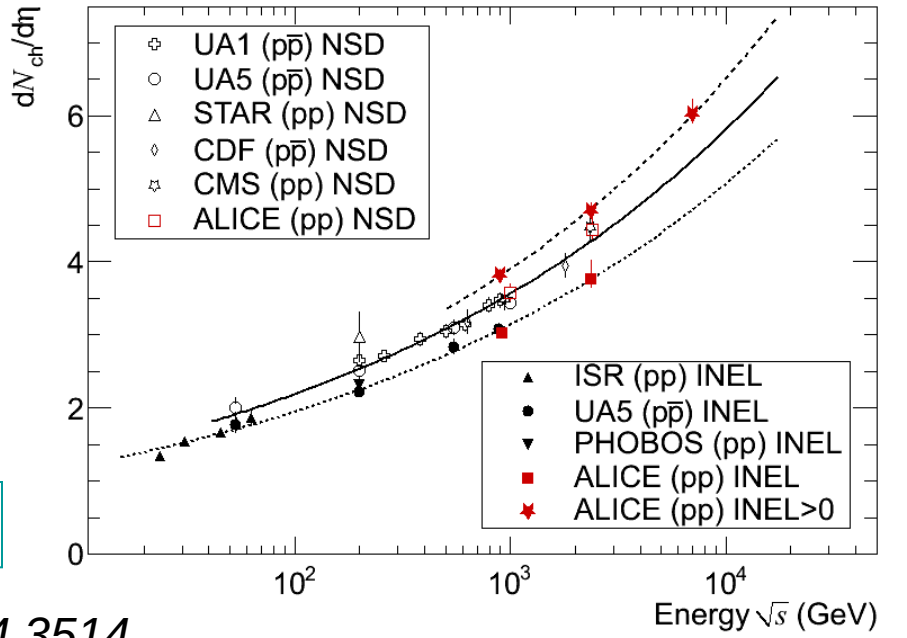
Event classes:

NSD = Non Single Diffractive

INEL = ND + SD + DD

INEL > 0 = INEL with at least 1 track in $-1 < \eta < 1$

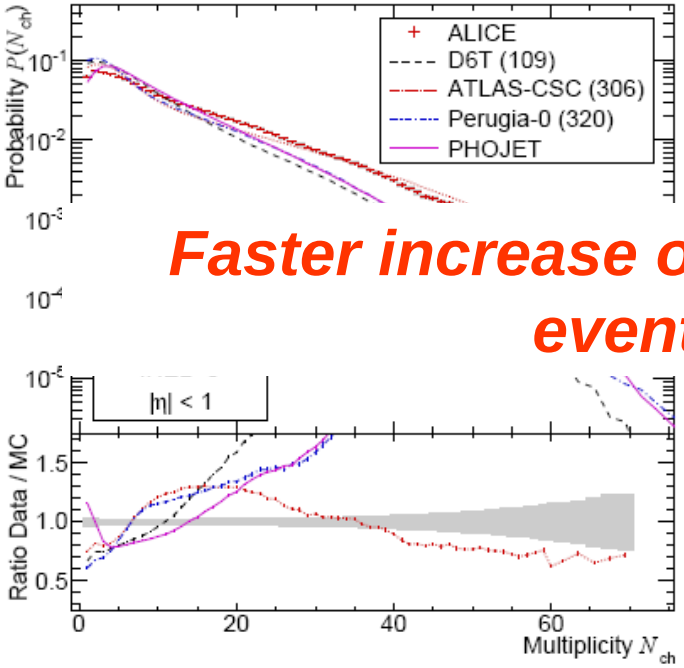
Fits well with a power law



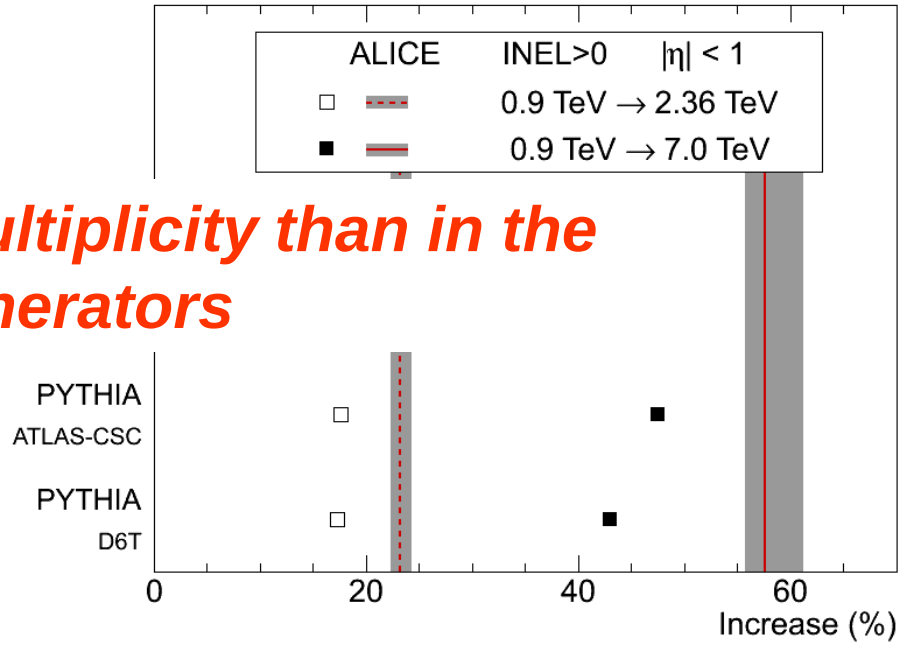
arXiv:1004.3514

MULTIPLICITY MEASUREMENTS (II)

Comparison with event generators



Faster increase of multiplicity than in the event generators



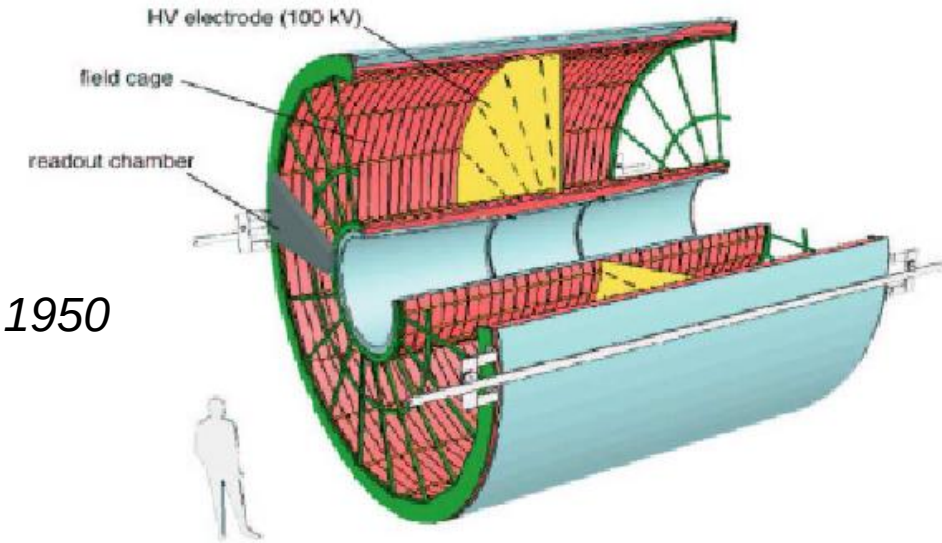
Increase in $dN_{ch}/d\eta$ in $|\eta| < 1$ for INEL > 0 arXiv:1004.3514	**√s**	**ALICE (%)**	**MCs (%)**
	0.9 → 2.36 TeV	**23.3 0.4 $_{-0.7}^{+1.1}$**	**15 – 18**
	0.9 → 7 TeV	**57.6 0.4 $_{-1.8}^{+3.6}$**	**33 – 48**

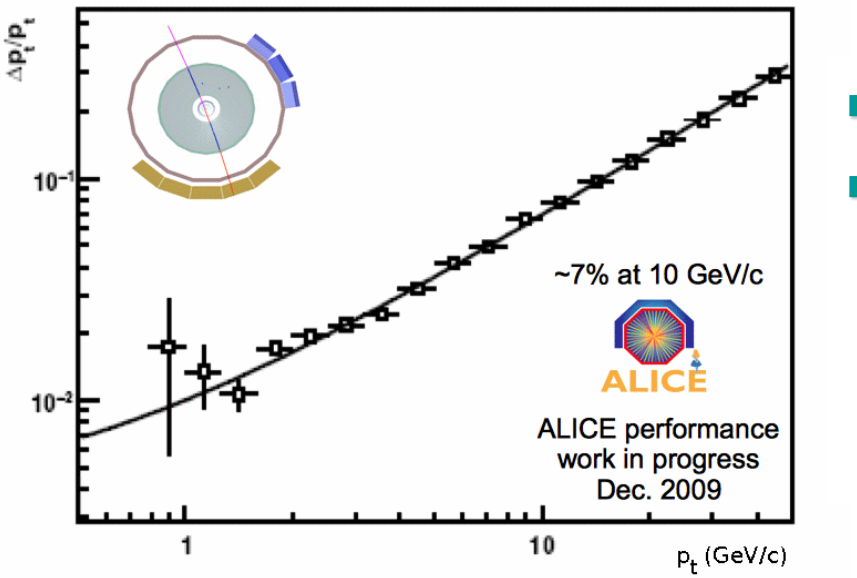
arXiv:1004.3514

Time Projection Chamber

Challenge: reconstruct 15000 primary tracks in heavy ion collisions!

- biggest ever built!
- minimal material budget *arXiv:1001.1950*
- first calibration completed before data taking!

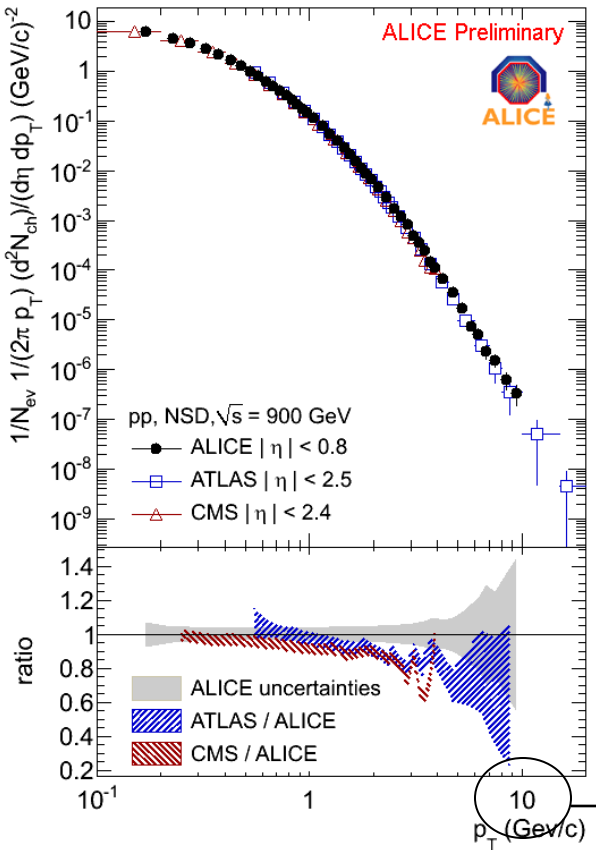




- match two segments of cosmic tracks
- momentum resolution very close to detector design:
  - 7% at 10 GeV/c
  - < 1% at p_T< 1 GeV/c confirmed from K^0_s measurement

P_T DISTRIBUTIONS (900 GeV)

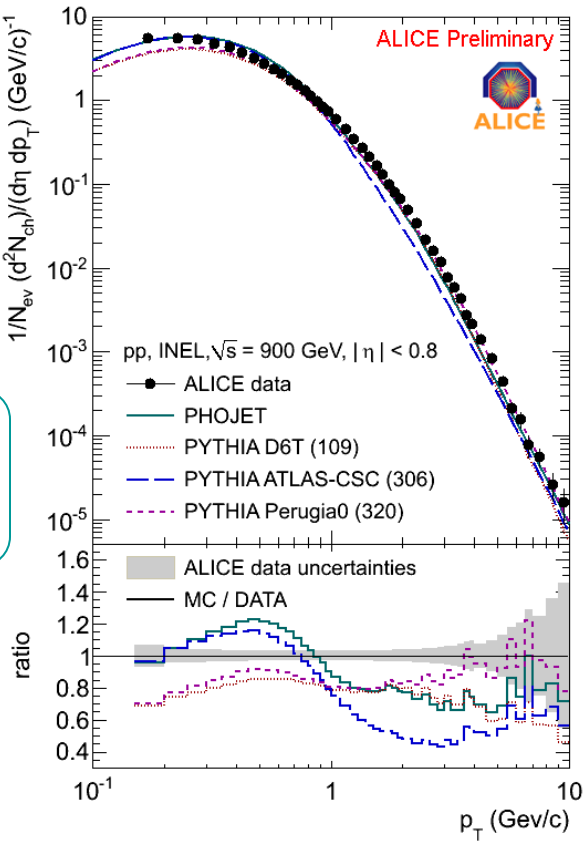
Test for soft QCD, reference for Pb-Pb, collective flow in p-p



comparison with other experiments

comparison with models

tracking under control up to 10 GeV/c

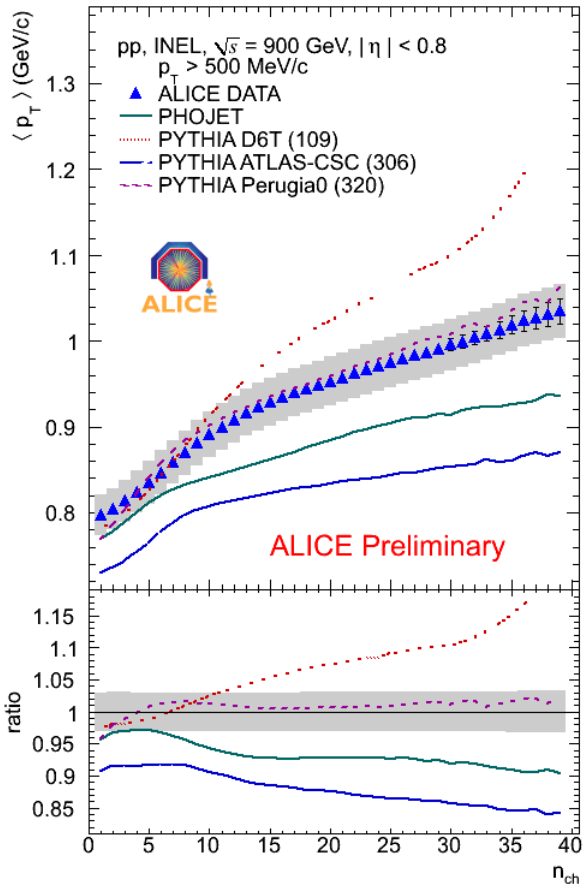


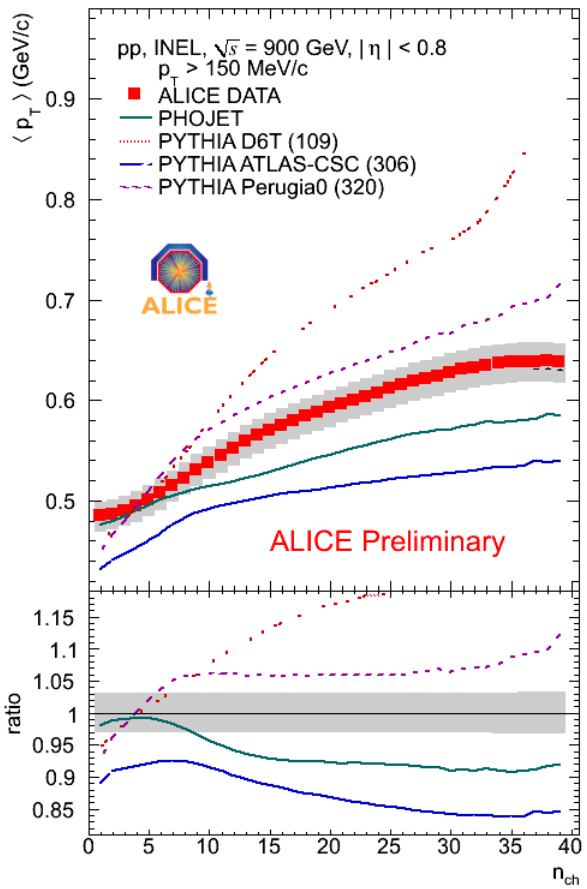
- good agreement at p_T<1 GeV/c
- ALICE spectrum harder at higher p_T (η<0.8)
- PYTHIA D6T and Perugia0 more or less OK
- PHOJET and ATLAS-CSC are off

<p_T> Vs MULTIPLICITY (900 GeV)

- p_T>500 MeV/c:
  - weighted average over data points 0.5<p_T<4 GeV/c
- PYTHIA Perugia0 gives good description of the data

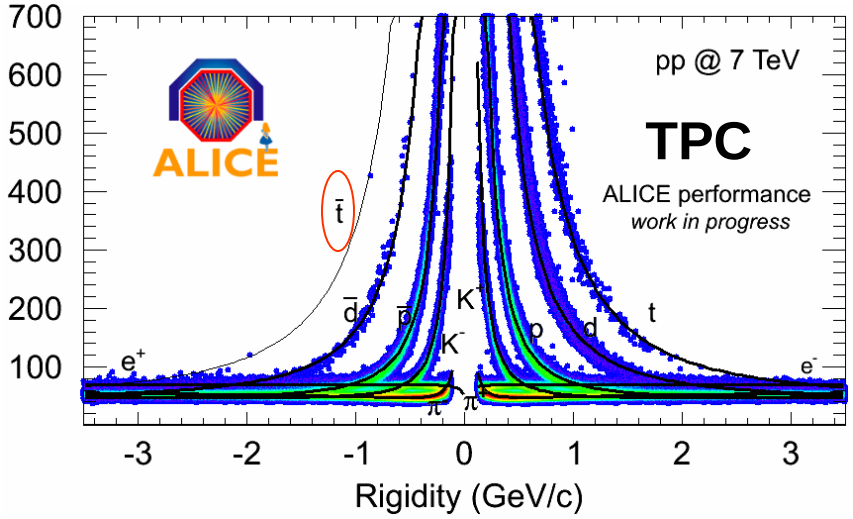
- p_T>150 MeV/c:
  - weighted average over data points 0.15<p_T<4 GeV/c
  - the models don't reproduce the data! (Perugia0 is the one that gets closer..)

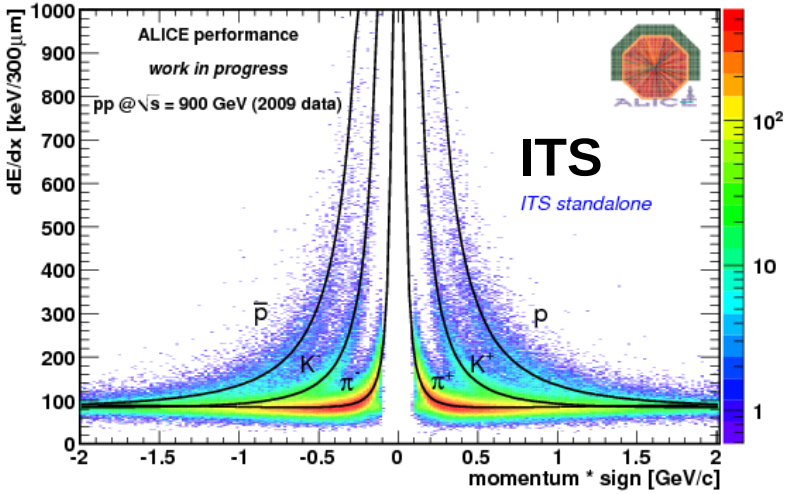




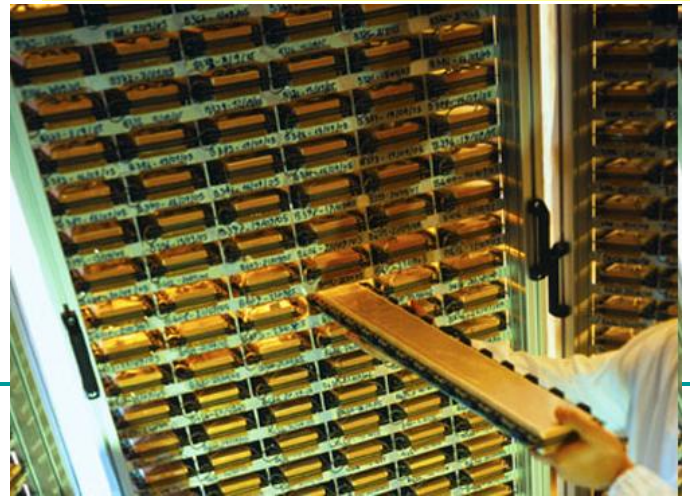
Low p_T and high multiplicity behaviour is not reproduced by models

ONE OF THE ALICE SPECIALTIES: Particle IDentification!

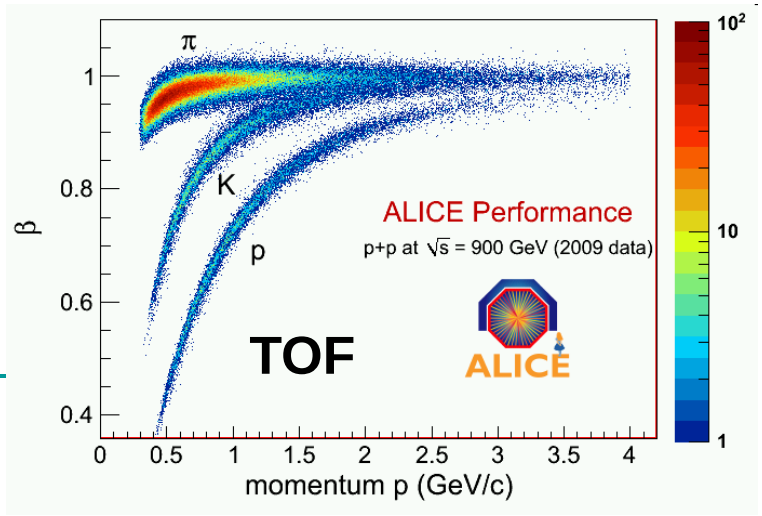




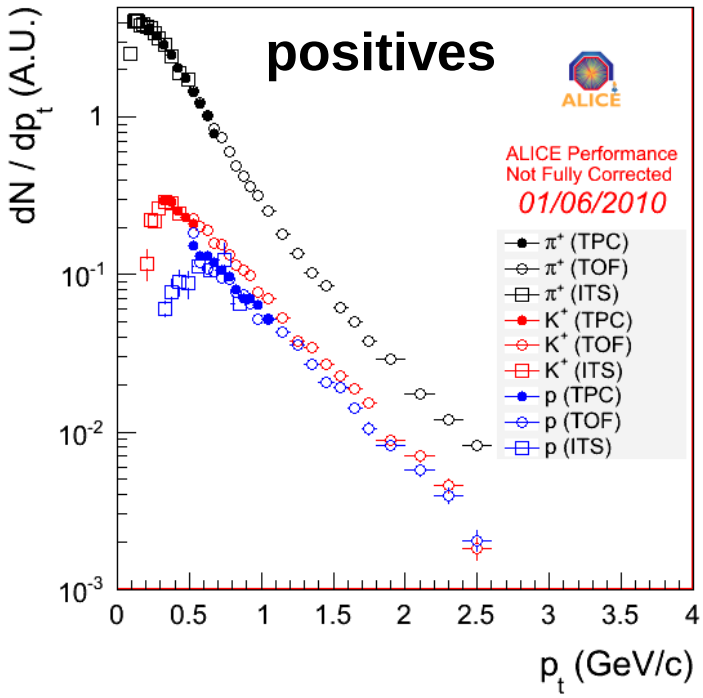
The detectors are complementary and cover the whole p_T range

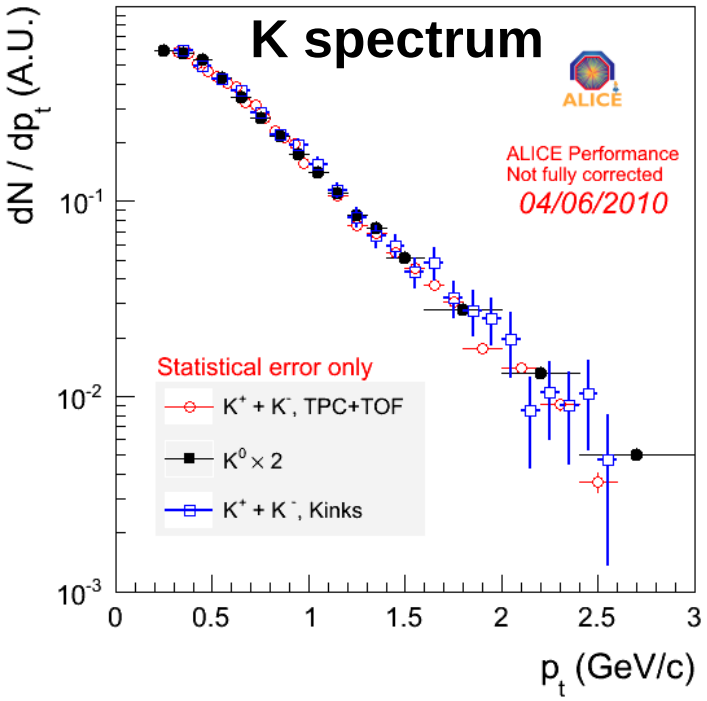


TOF



IDENTIFIED PARTICLE SPECTRA





- Good agreement between the three detectors, both for positives and negatives
- The calibration and understanding of the detectors is good

3 ways of identifying Kaons:

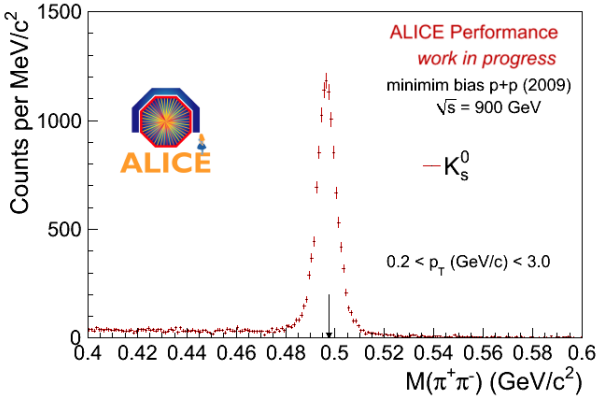
1. TPC + TOF PID
2. K^0
3. Kinks

→ good internal consistency!

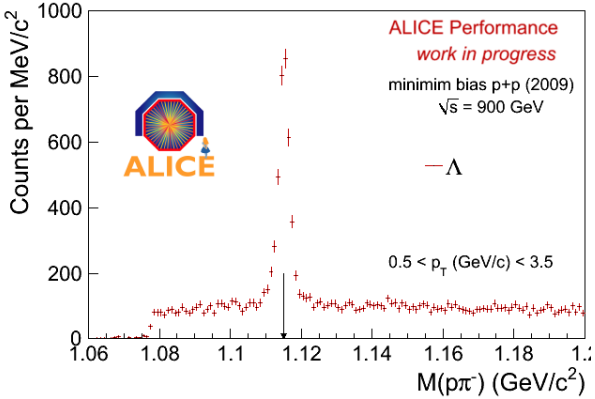
STRANGENESS

See R. Vernet

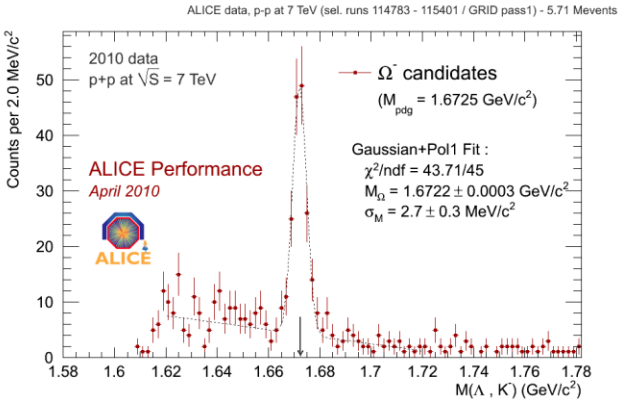
$K^0_s \rightarrow \pi\pi$



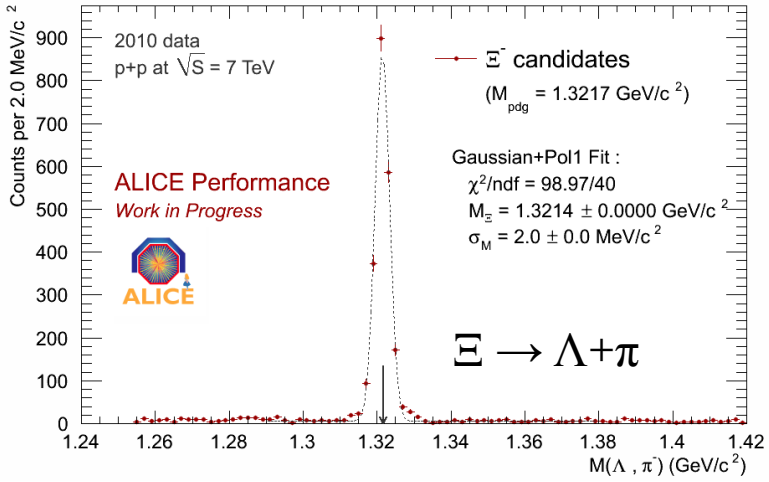
$\Lambda \rightarrow p\pi$

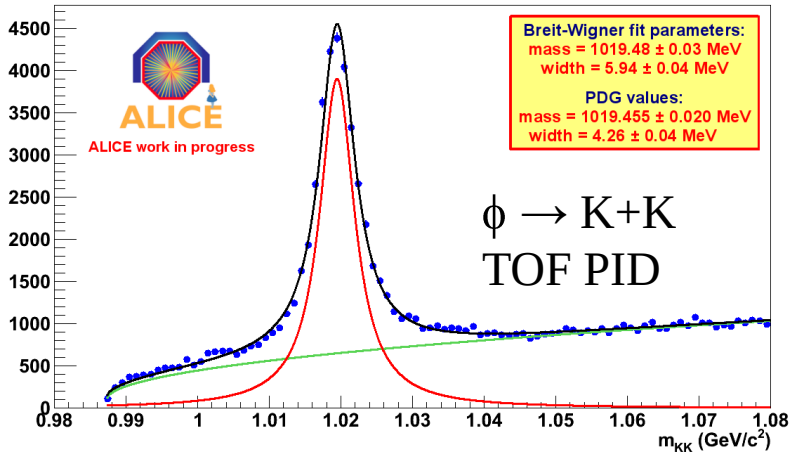


$\Omega^- \rightarrow \Lambda K$



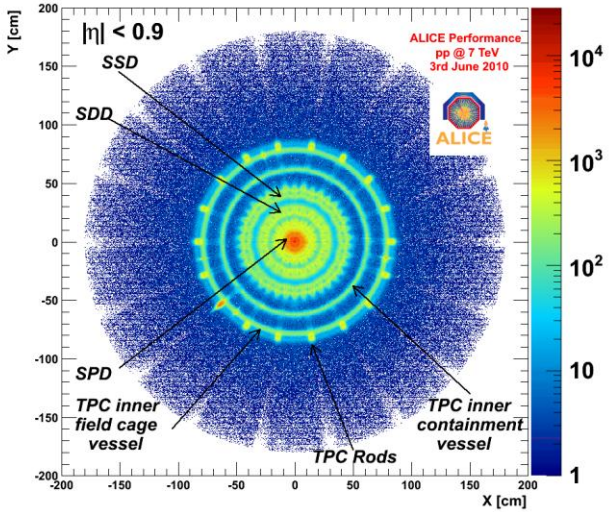
Strange and multistrange particles well reconstructed @900 GeV , 7 TeV



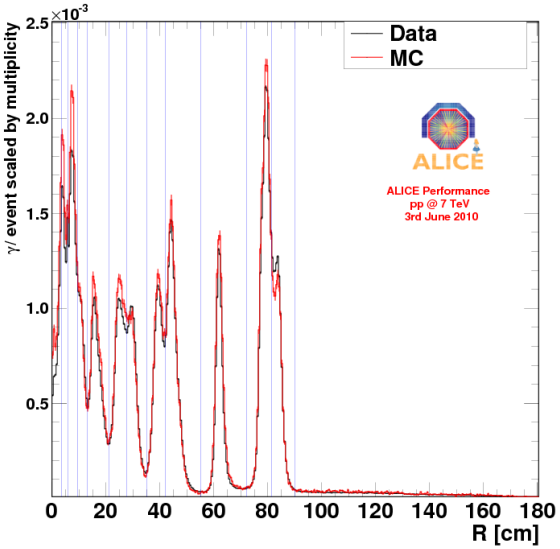


γ CONVERSIONS AND π^0

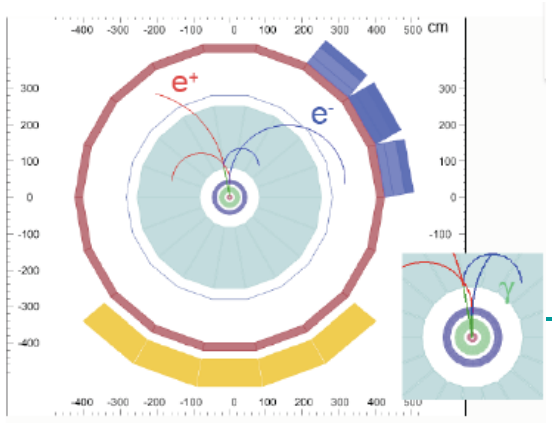
- Interesting measurement: material budget studies + per se
- Electron ID in the TPC
- conversion reconstruction in ITS + TPC

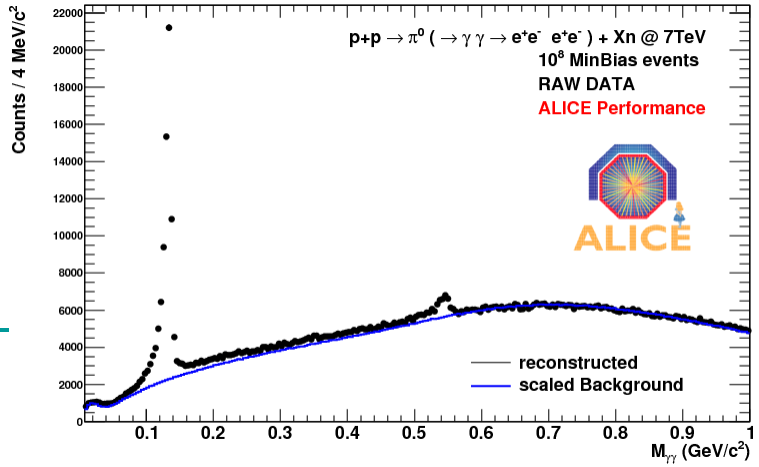


material budget studies are important, especially for heavy flavor measurements



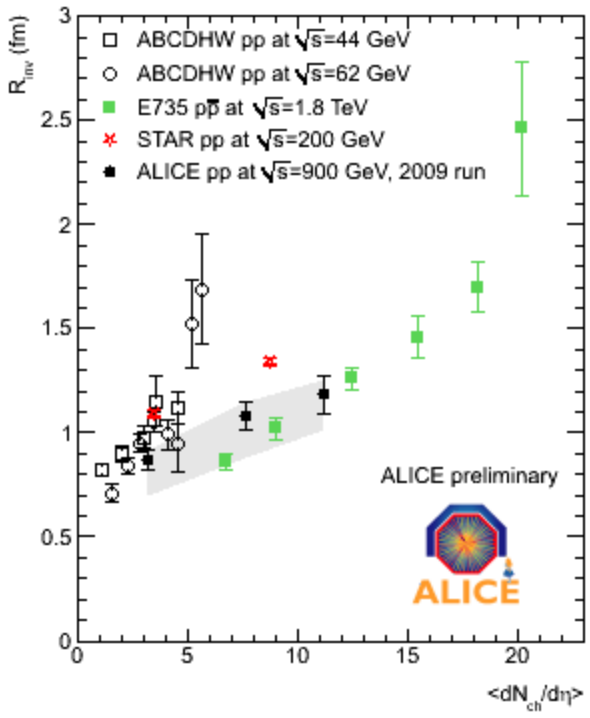
we know well our detector (~7%)!





TWO PIONS CORRELATION (900 GeV)

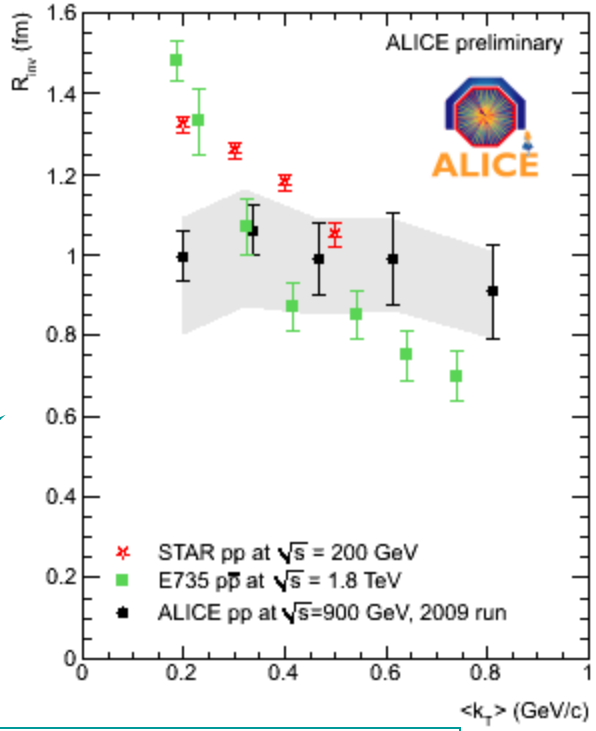
- Get information about space-time evolution of the source emitting the pions (i.e. the colliding system)
- Obtained measuring the Bose-Einstein enhancement of pairs of pions with small momentum difference and fit with a gaussian:



$$C(q_{inv}) = [1 + \lambda \exp(-R_{inv}^2 q_{inv}^2)]$$

increase with multiplicity

no K_T dependence



less K_T dependence than at E735, STAR, Pb-Pb collisions

HEAVY FLAVORS

- In Pb-Pb collisions: probe the properties of the medium
  - created in the hard initial collisions → **experience the whole collision history**
  - possible comparison heavy quarks/light partons

  → **energy loss:**

$$\Delta E_g > \Delta E_{u,d,s} > \Delta E_c > \Delta E_b$$

dead cone effect (mass)

Casimir factor (color charge)

$$R_{AA}^{H}(p_t) = \frac{1}{N_{coll}} \frac{dN_{AA}^{H}/dp_t}{dN_{pp}^{H}/dp_t}$$

medium density and size

$$R_{AA}^{\pi} < R_{AA}^{D} < R_{AA}^{B}$$

- in p-p collisions:
  - baseline for Pb-Pb
  - measure charm and beauty cross section
  - compare to pQCD predictions

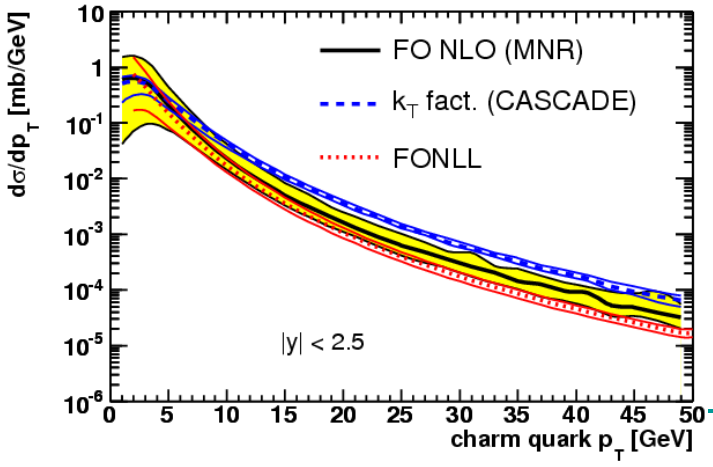
HF PRODUCTION AT LHC

NLO prediction → ALICE baseline for charm and beauty

MNR code (FO NLO): Mangano, Nason, Ridolfi, NBP373 (1992) 295

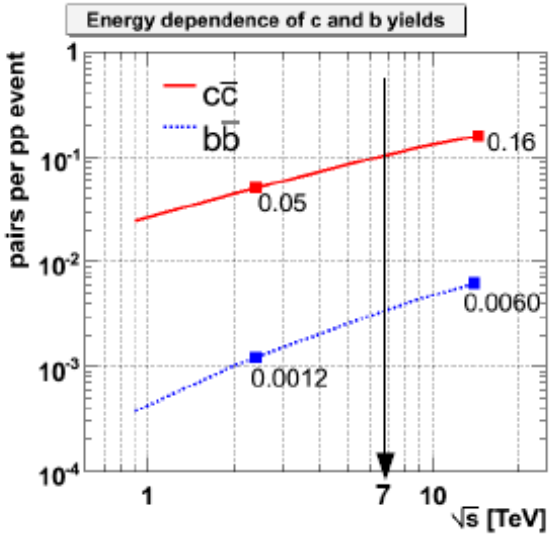
system, √s	pp, 7 TeV	pp, 14 TeV	Pb-Pb (0-5%), 5.5 TeV
$\sigma_{NN}^{Q\bar{Q}}$ [mb]	6.9 / 0.23	11.2 / 0.5	4.3 / 0.2
$N_{\mathrm{tot}}^{Q\bar{Q}}$	0.10 / 0.003	0.16 / 0.006	115 / 4.6

σ_c @LHC goes up by a factor 20 wrt RHIC, σ_b up by a factor 100!



Charm cross section in Pb-Pb

Number of QQ in p-p



MEASUREMENTS IN PREPARATION

✓ ***Open Charm:*** $D^0 \rightarrow K\pi$,
$D^+ \rightarrow K\pi\pi$,
$D_s \rightarrow KK\pi$,
$D^* \rightarrow D^0\pi$,
$D^0 \rightarrow K3\pi$,
$\Lambda_c \rightarrow \pi Kp$

✓ ***Hidden charm:*** $J/\Psi \rightarrow ee$

✓ ***Beauty:*** $B \rightarrow e + X$,
$B \rightarrow X\ J/Psi$

✓ ***charm & beauty → e + X***

✓***measurements with μ:*** *see N. Bastid*

Features	**What is needed to detect them**
"Rare" decays	excellent tracking (TPC + ITS) √
Displaced secondary vertex as signature of heavy-quark decay: cτ = 60μm – 300μm	good vertexing + impact parameter resolution (ITS, see next slide) √
High combinatorial background	good Particle IDentification (TPC, ITS, TOF,TRD) √

→ *The ALICE detector has all we need!*

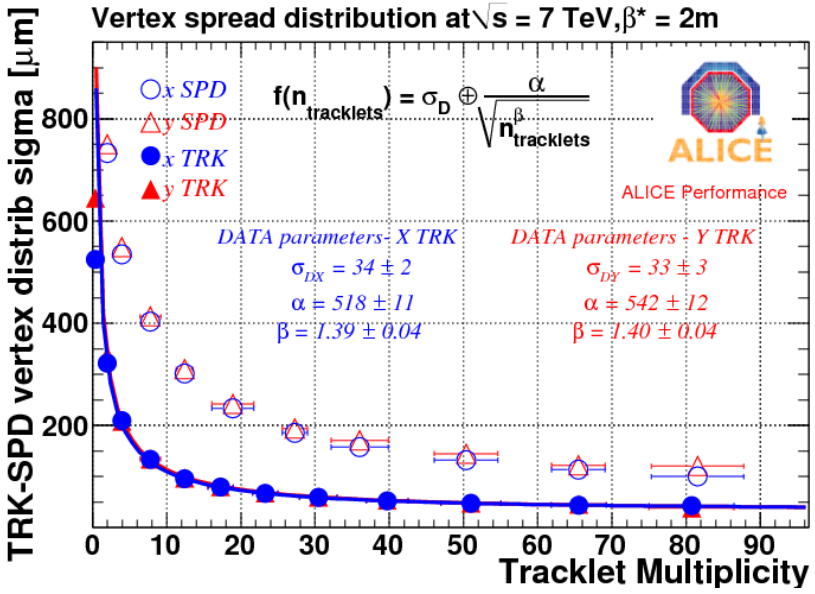
VERTEX RESOLUTION & CO.

- The lifetime of particles with charm / beauty is ~ 100 μm

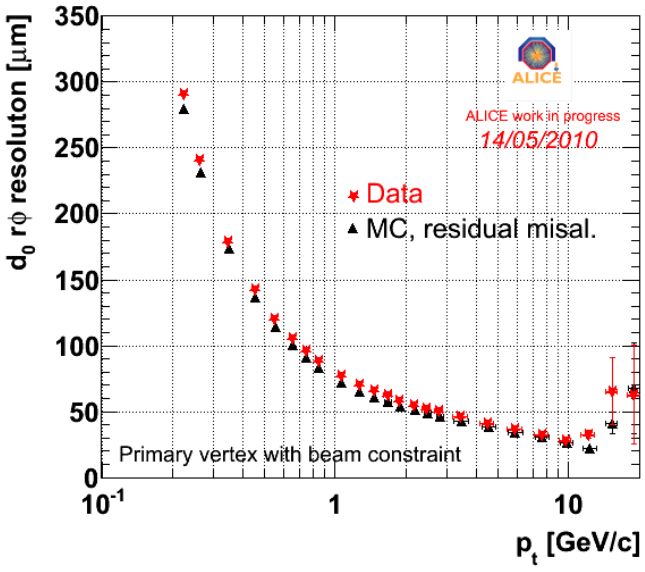
→ to identify their displaced vertices we need a good vertex resolution!

ITS performance:

Vertex resolution



Impact parameter resolution

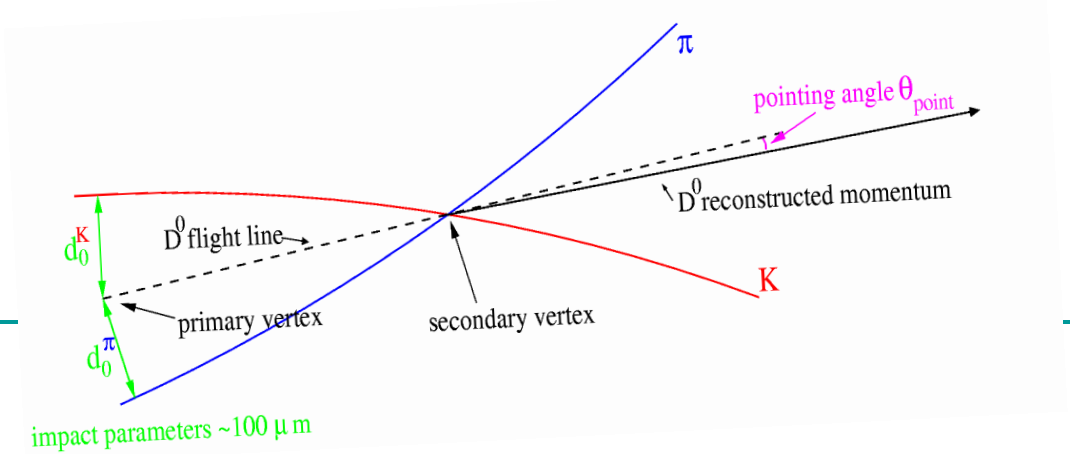


Excellent vertexing and good impact parameter resolution!

OPEN CHARM IN THE BARREL

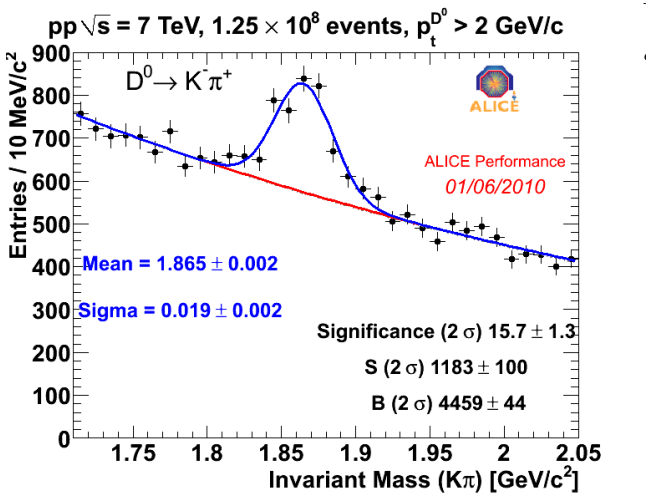
Charm candidates "production" (vertexing) → Raw signal extraction → Corrections (efficiencies, acceptance, feed-down from B)

- Topological cuts to separate signal and background
- Invariant mass analysis to extract the raw signal yield
- Example: $D^0 \rightarrow K^-\pi^+$:
  - good pointing of reconstructed D momentum to the primary vertex
  - pair of opposite-charge tracks with large impact parameters

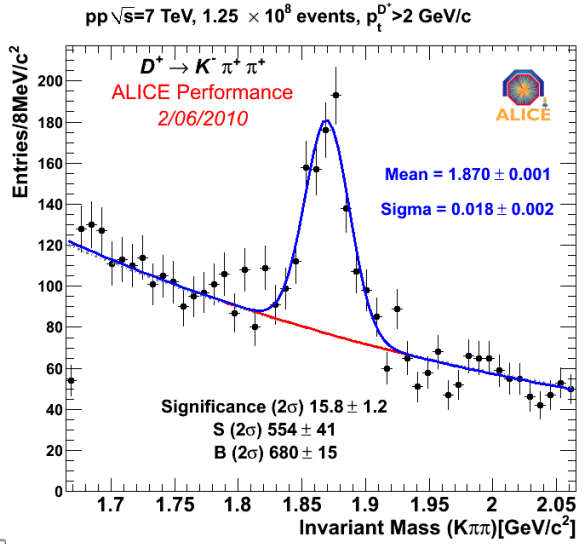


YES, WE SEE THEM!

125 million events pp collisions @ 7 TeV

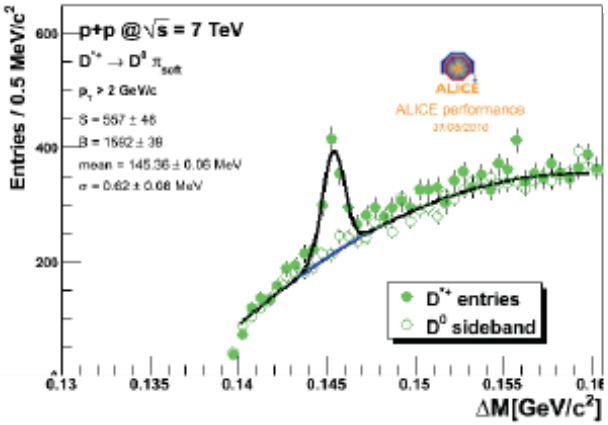


Expected to cover
0.5 < pT <15 GeV/c
with 10^9 events



For more details:

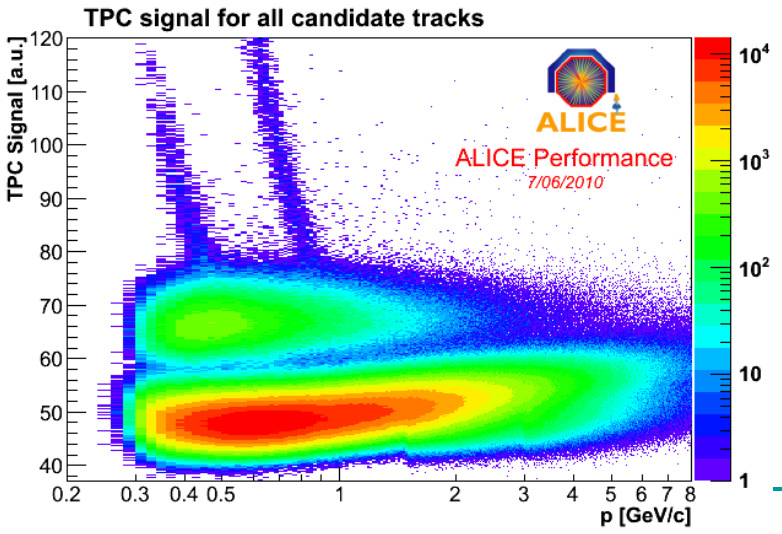
see R. Bala , Y. Wang

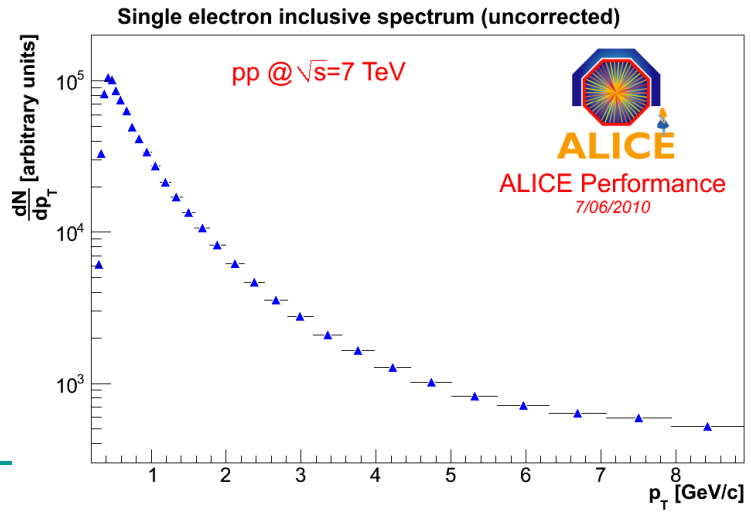


HF ELECTRONS

- Compute the inclusive cross section using electrons
- For high p_T, the contribution from charm and beauty becomes dominant

- Essential ingredient for the analysis: electron ID! For the moment: TPC + TOF, TRD will join soon!

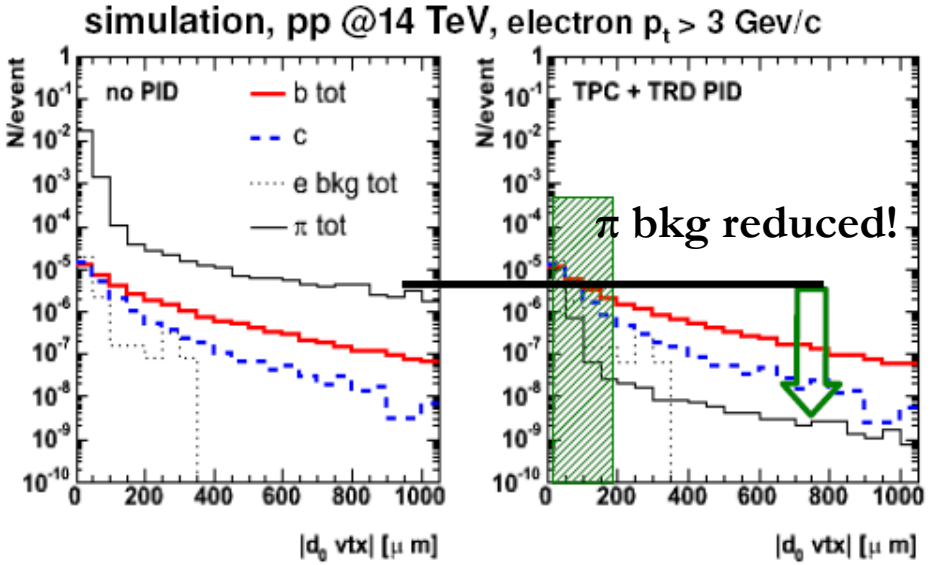




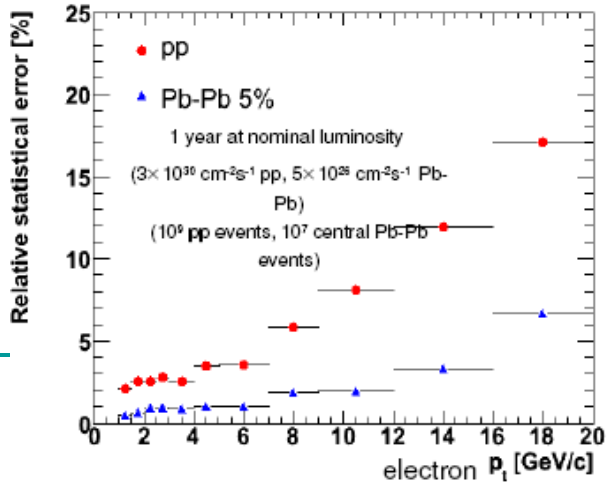
OPEN BEAUTY IN THE BARREL

Analysis strategy:

1. identification of electron candidates
2. Cut on impact parameter to reduce charm, Dalitz, γ conversions
3. Subtract the residual background

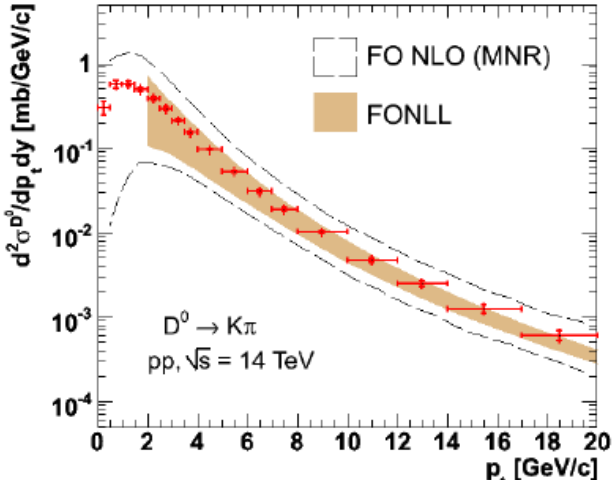


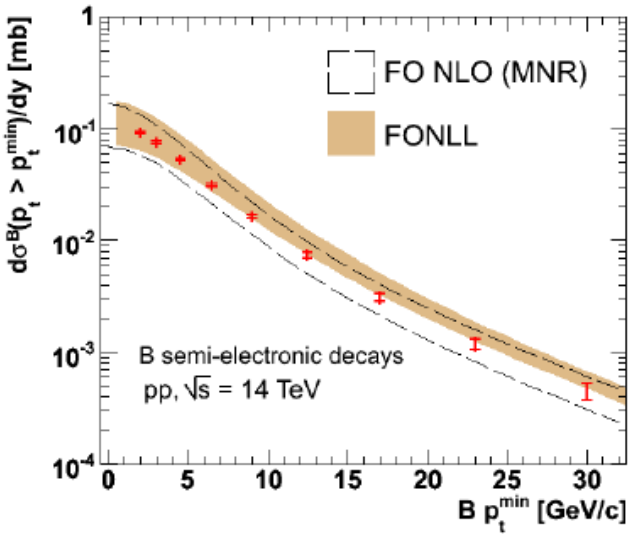
With 10^9 p-p and 10^7 Pb-Pb events , very small statistical error expected!



SOME EXPECTATIONS...

Comparison with pQCD





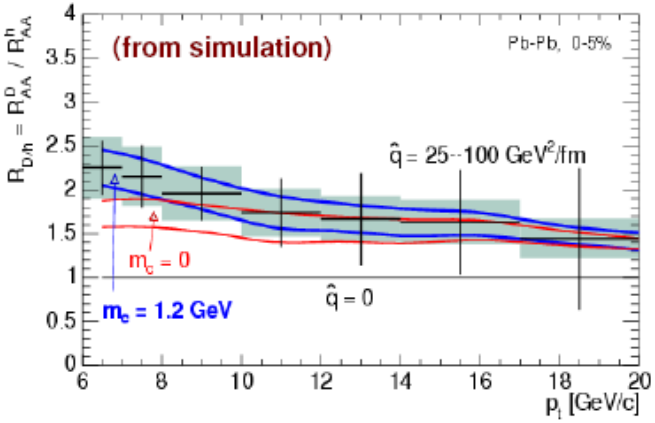
... a forward look

Measure the cross section and compare to pQCD

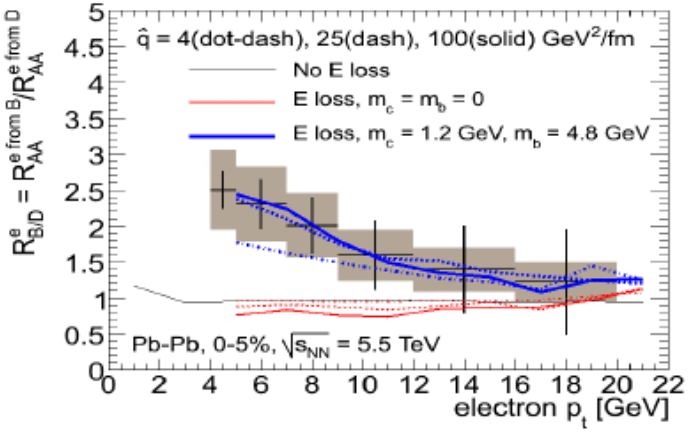
Energy loss studies, using D and B

Energy loss studies

$$R_{D/h}(p_t) = R_{AA}^{D}(p_t) / R_{AA}^{h}(p_t)$$

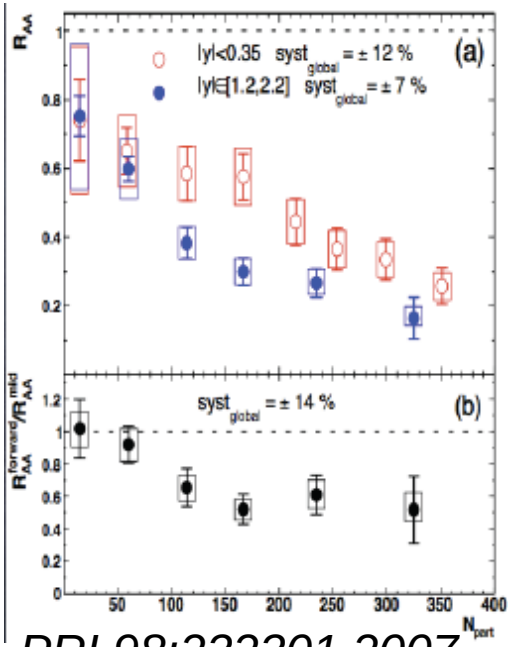


$$R_{B/D}(p_t) = R_{AA}^{e\ from\ B}(p_t) / R_{AA}^{e\ from\ D}(p_t)$$

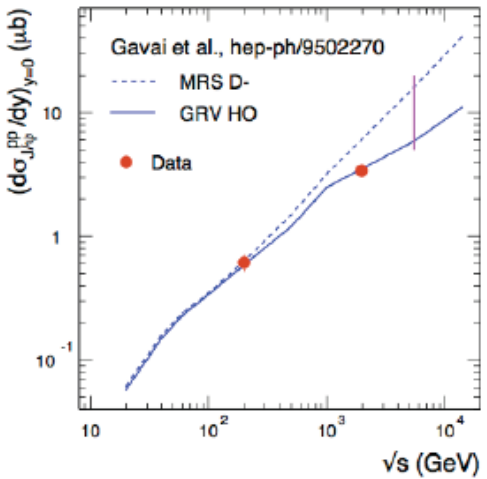


HIDDEN CHARM IN THE BARREL: J/Ψ → e^+e^-

- Why in Pb-Pb:
  - J/Ψ dissociation is a signature of QGP formation
  - J/Ψ suppression at RHIC was expected to be higher than at SPS, but it was the same! Not yet explained...
- Why in p-p:
  - reference to heavy ion data
  - none of the models is able to reproduce both production and polarization
  - measure the total cross section

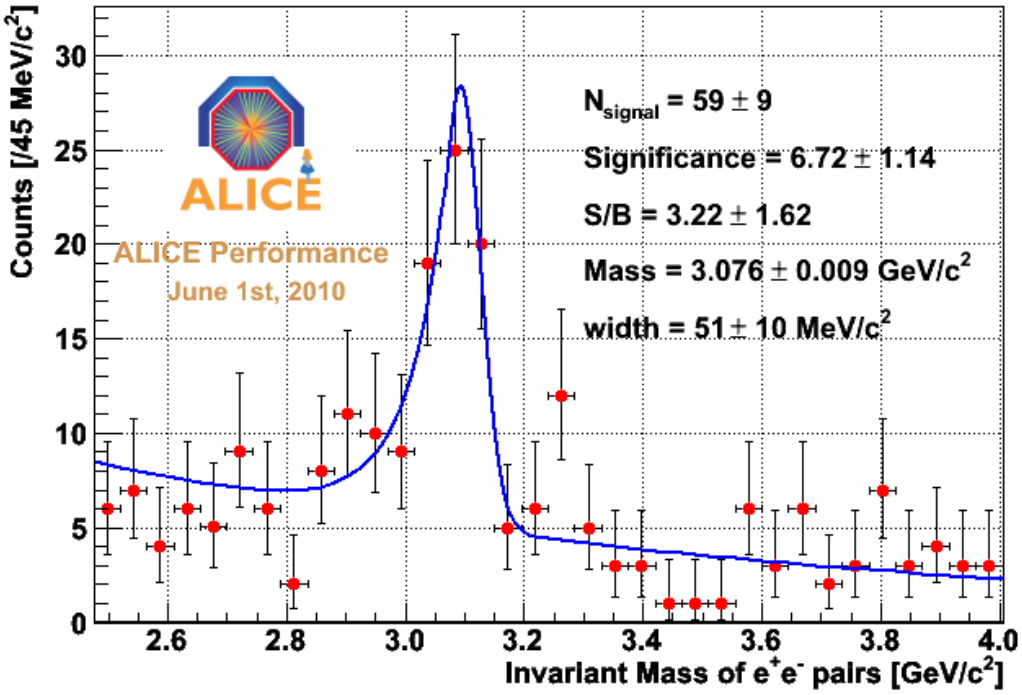


PRL98:232301,2007



$J/\Psi \rightarrow e^+e^-$ @ 7 Tev

- 110M pp events @ 7 TeV
- electrons identified with TPC (TRD will come soon!), pions and protons rejected
- fit with a Cristal Ball function



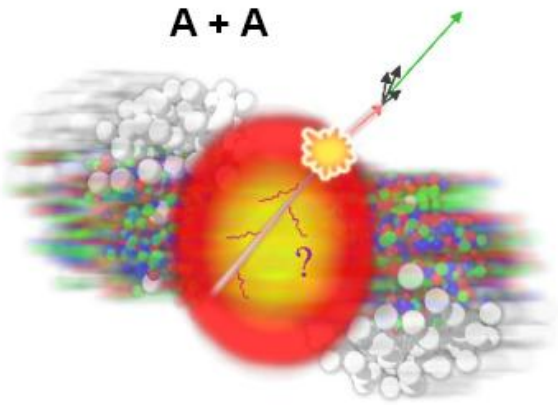
CONCLUSIONS

- ALICE is in a good shape..
  - many detectors already at design specification
  - able to produce the first physics results already with the very first data taking
- ..and is producing a lot of interesting results!
  - multiplicity: increase with energy faster than expected
  - p_T spectra: low p_T and high multiplicity behaviour not described by models
  - HBT measurements: the size of the emitting source increases with multiplicity, but less K_T dependence than expected
- The game has just started..
  - Jets
  - Event shape
  - High multiplicity
  - p / p ratio
  - a very rich heavy flavor program
  - ...

Looking forward to Pb-Pb collisions!

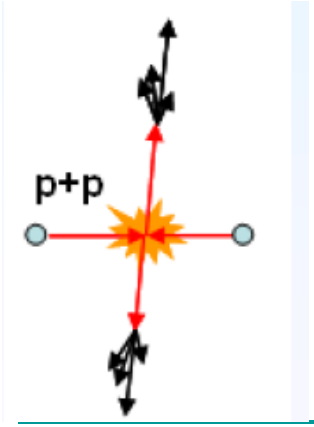
SPARES

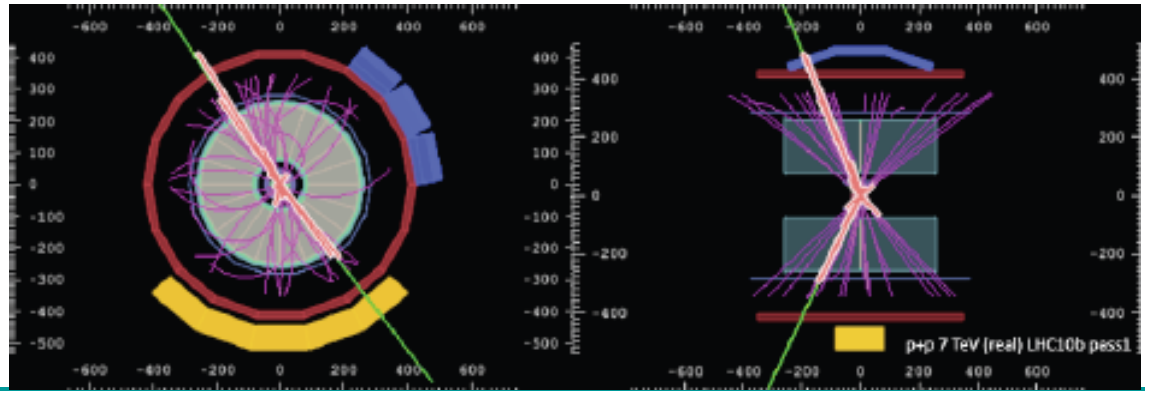
JETS



- The high p_T hadrons in Pb-Pb collisions should be suppressed when crossing the hot and dense medium → observed @RHIC
- Study the energy loss for different flavor

p p collisions: baseline for Pb-Pb!

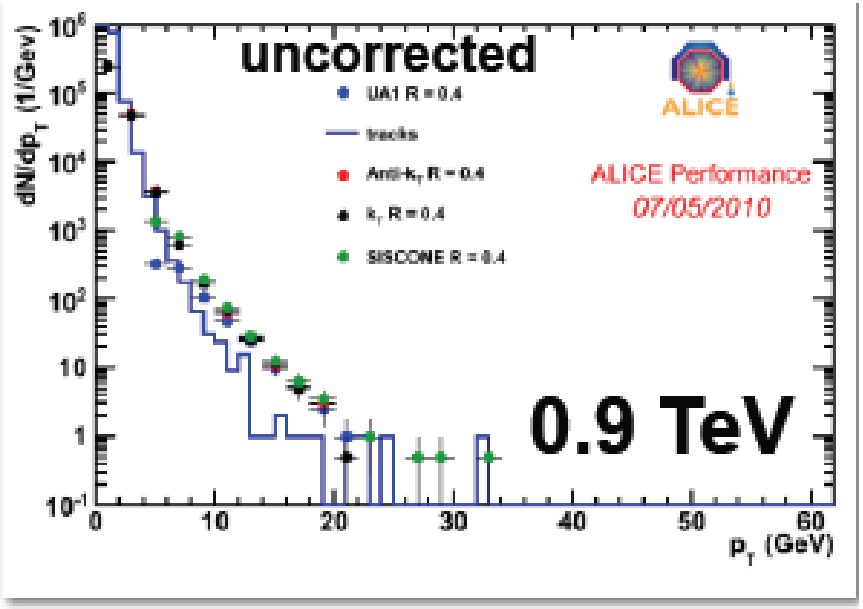


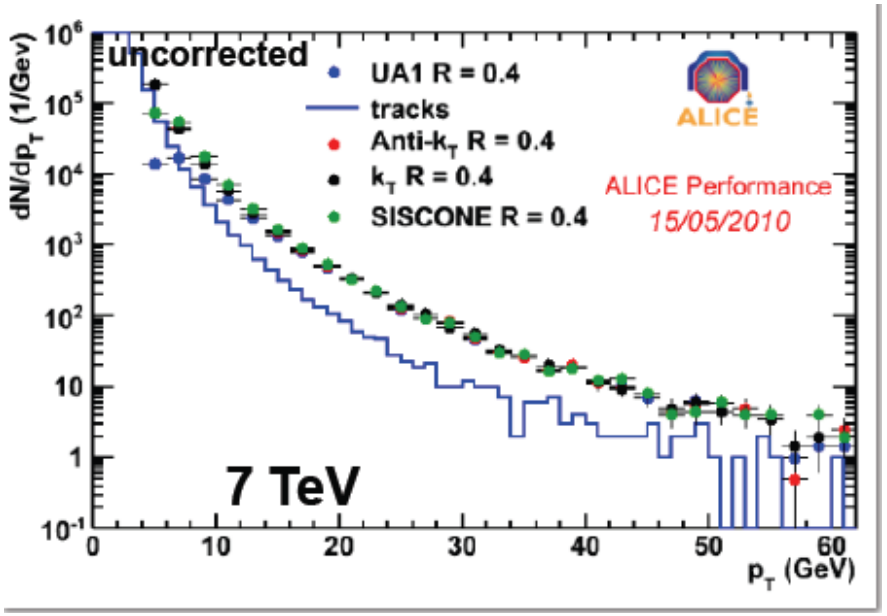


JETS

Uncorrected charged tracks raw spectra

- 4 different algorithms used to identify jets → consistent
- much more to come!

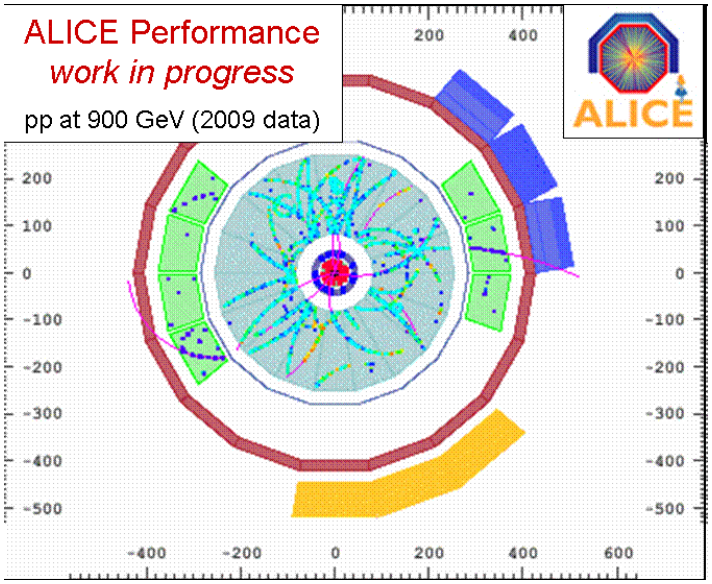




ELECTRON PID

The detector dedicated to electron PID is the

Transition Radiation Detector:



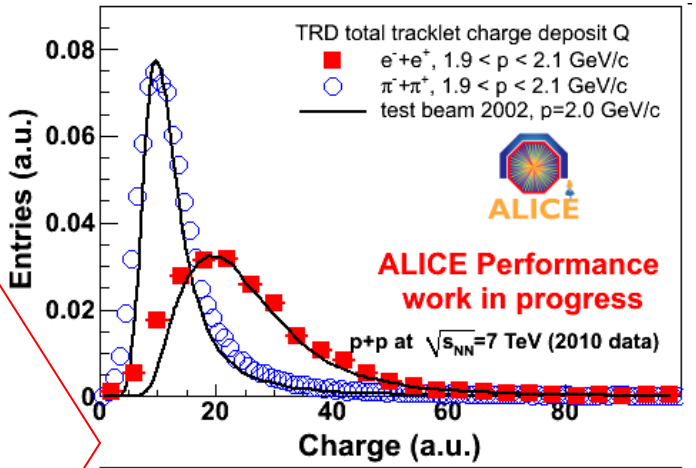
- Distinguish e from π → rejection factor 100
- Electron trigger

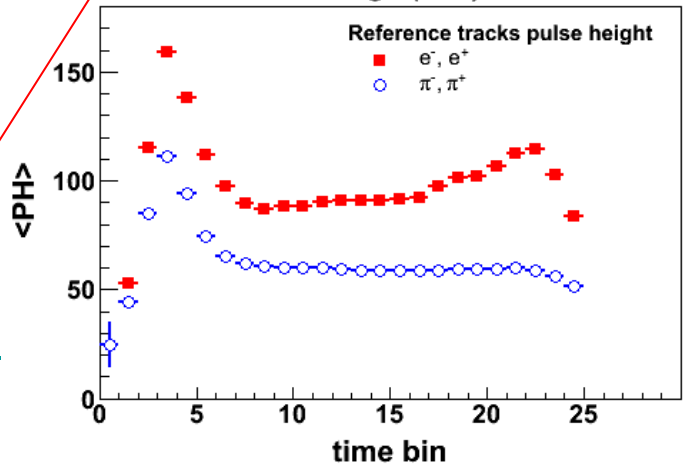
Electrons and pions from:

$\gamma \rightarrow ee$

$K^0 \rightarrow \pi\pi$

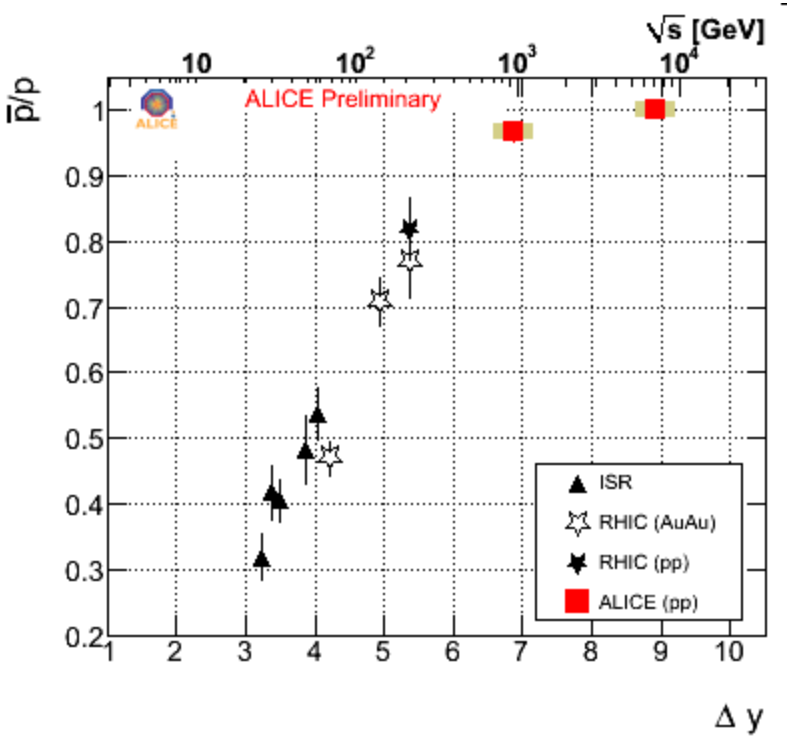
Good agreement with test beam



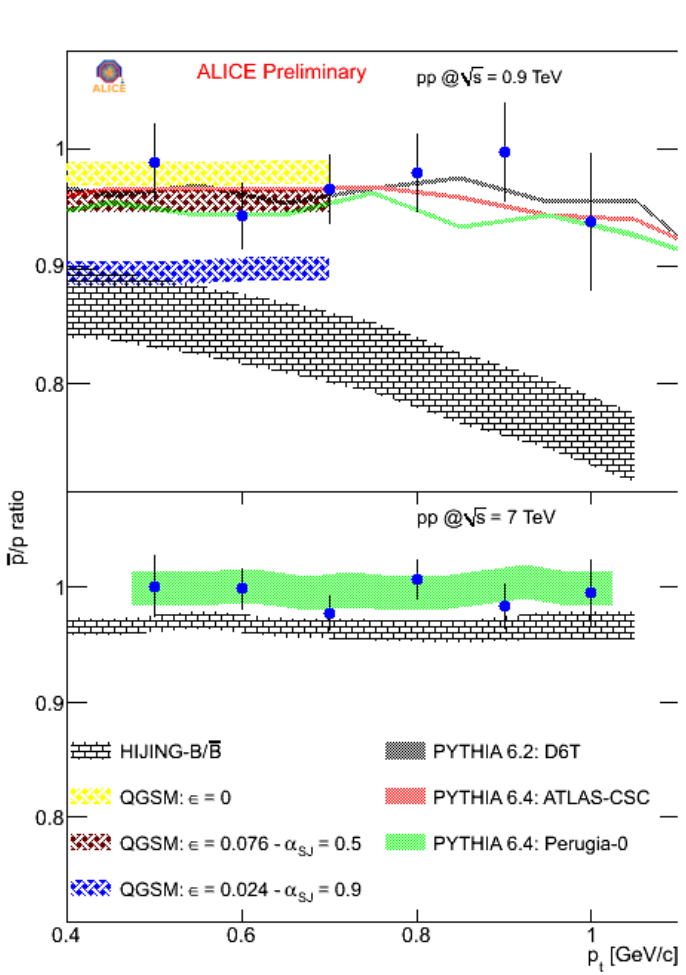


P/P RATIO

- Protons identified by TPC
- special care for secondaries and absorption correction

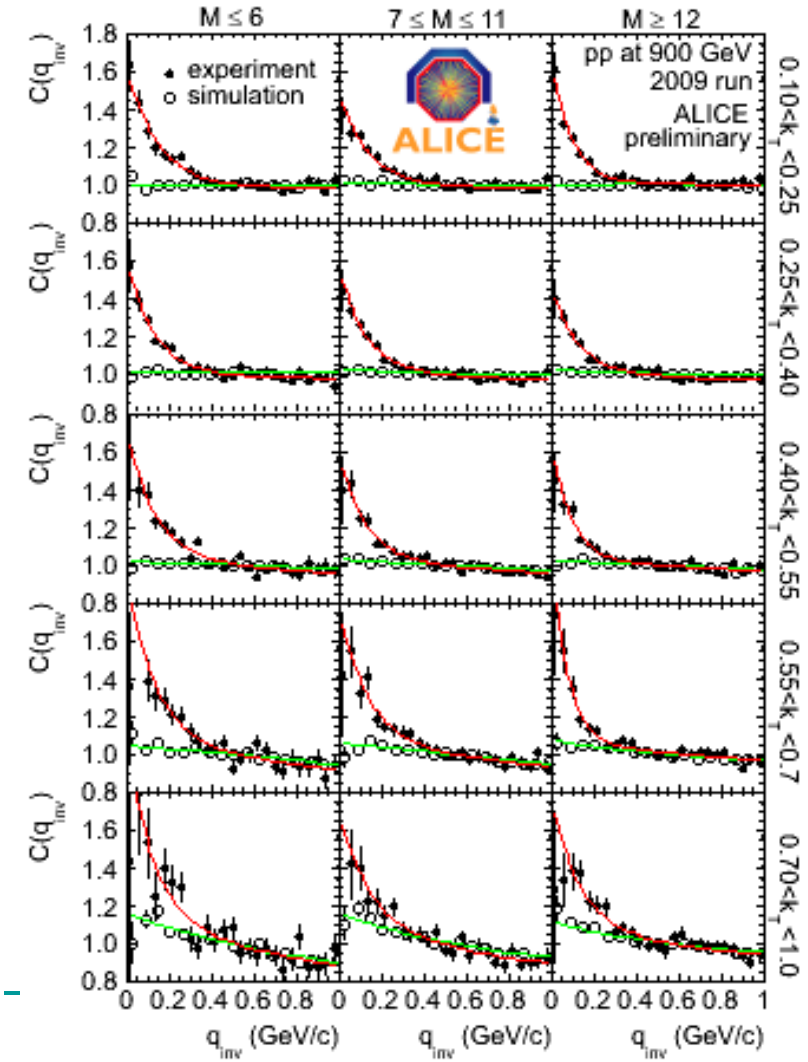


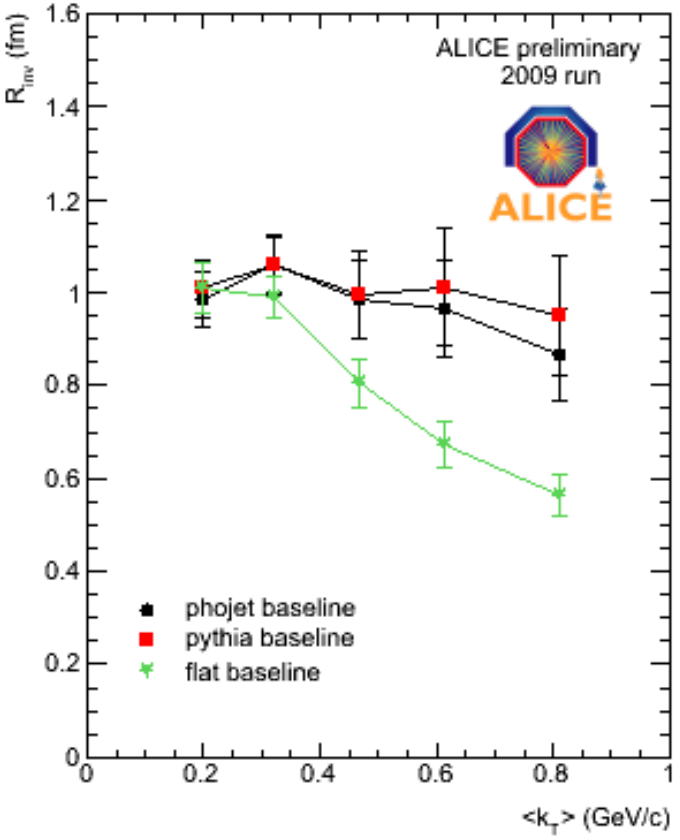
Baryon stopping at low Δy vanishes at LHC energies



☺ PYTHIA reproduces the data

X all the models with anomalous barion trasport don't !





$$C(q_{inv}) = \left[1 + \lambda \exp(-R_{inv}^2 q_{inv}^2)\right] B(q_{inv})$$