Probing QCD with the ALICE experiment at the LHC

A.Andronic – GSI Darmstadt

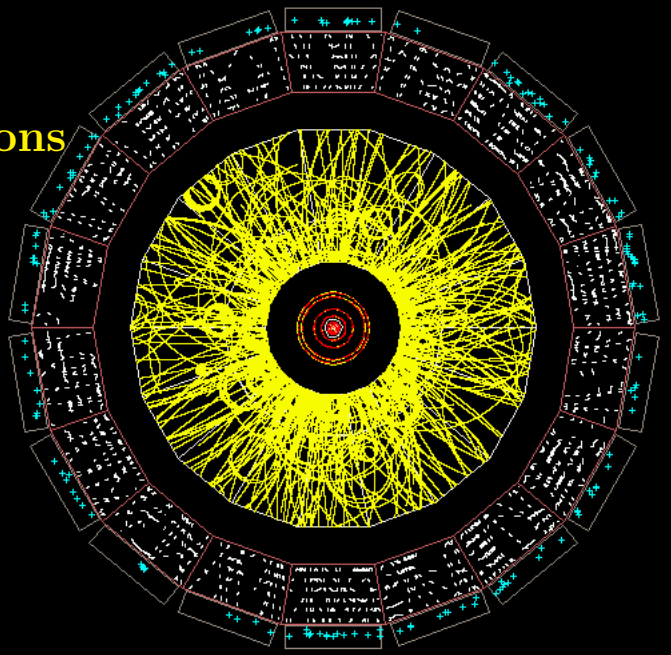
on behalf of the ALICE Collaboration

- The ALICE experiment and its performance
- Selected results in pp collisions ($\sqrt{s}$=900 GeV, 7 TeV)
- Outlook for Pb-Pb collisions

QCD@Work, Martina Franca, 20-23 June, 2010

ALICE detector @ LHC

ALICE Collaboration: 31 countries, 111 institutes, >1000 persons



1% of a central Pb+Pb at LHC

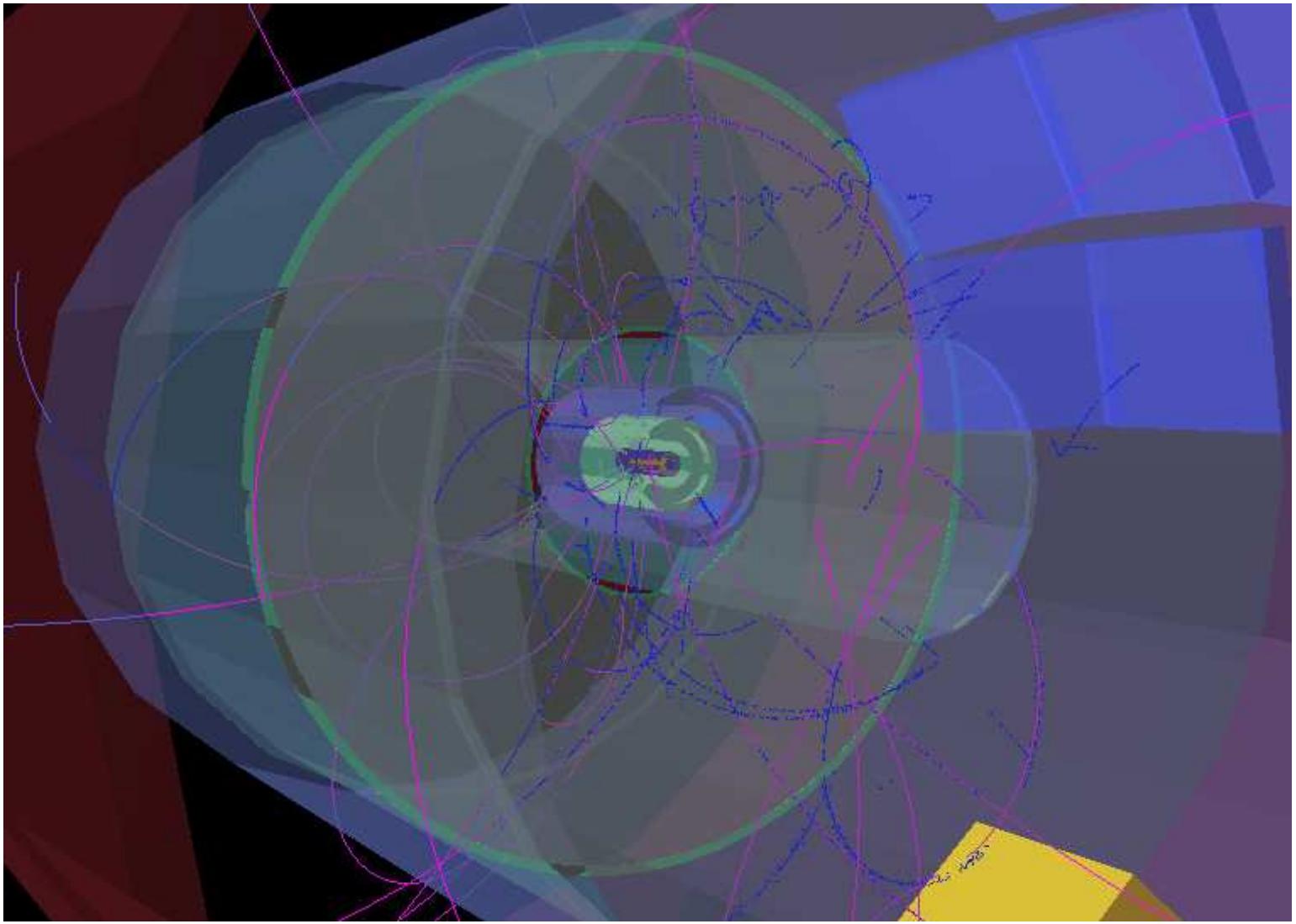
01. *I.T.S.*
02. *F.M.D.*
03. *T.P.C.*
04. *T.R.D.*
05. T.O.F.
06. *H.M.P.I.D.*
07. *P.H.O.S. C.P.V.*
08. *L3 MAGNET*
09. *ABSORBER*
10. *TRACKING CHAMBERS*
11. *MUON FILTER*
12. *TRIGGER CHAMBERS*
13. *DIPOLE MAGNET*
14. *P.M.D.*
15. *COMPENSATOR MAGNET*
16. *C.A.S.T.O.R.*

Measures: all hadrons, e, μ, γ

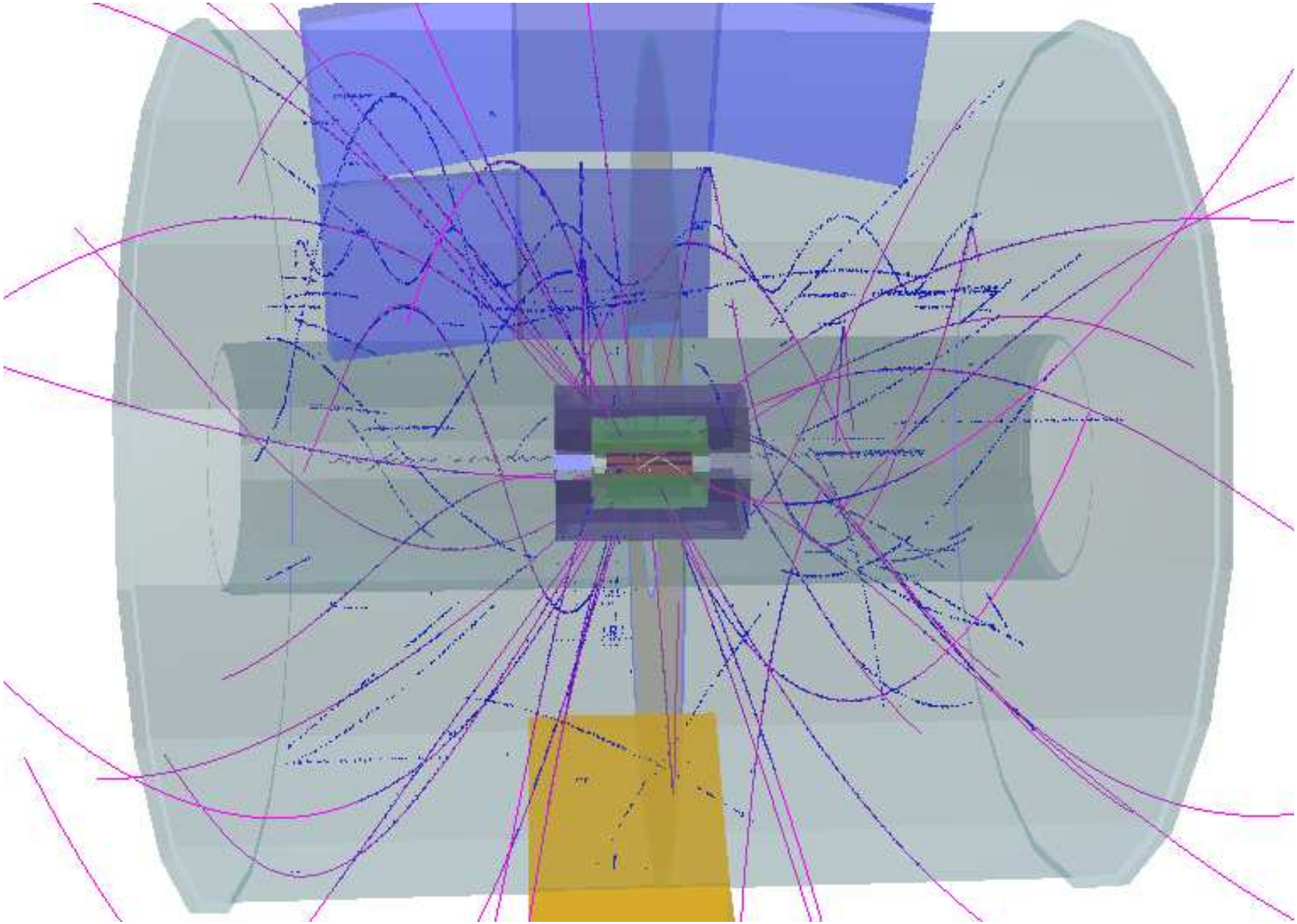
Tracking, dE/dx, TR, ToF, RICH, Calorimetry ... 1 PB/year data

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

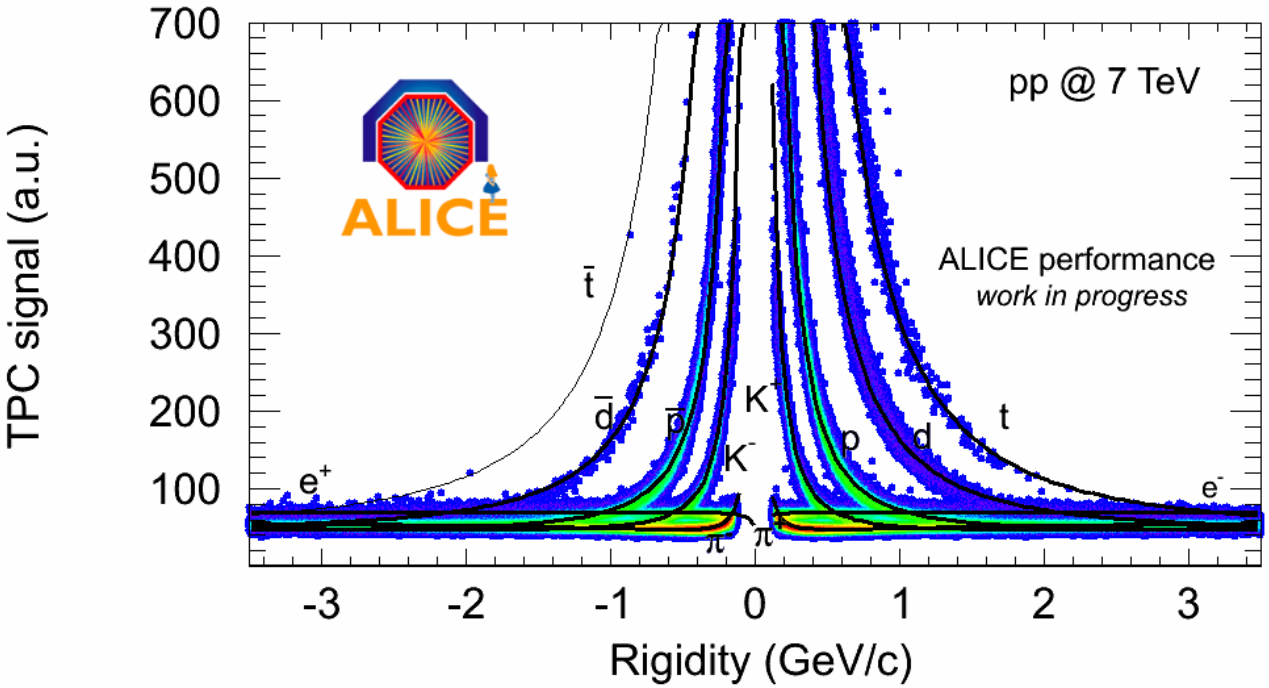
...picture called FANTASTIC.gif (©A.Kalweit:)



Another Fantastic event (Mail subject, Sun, 6 Dec 2009 08:38)

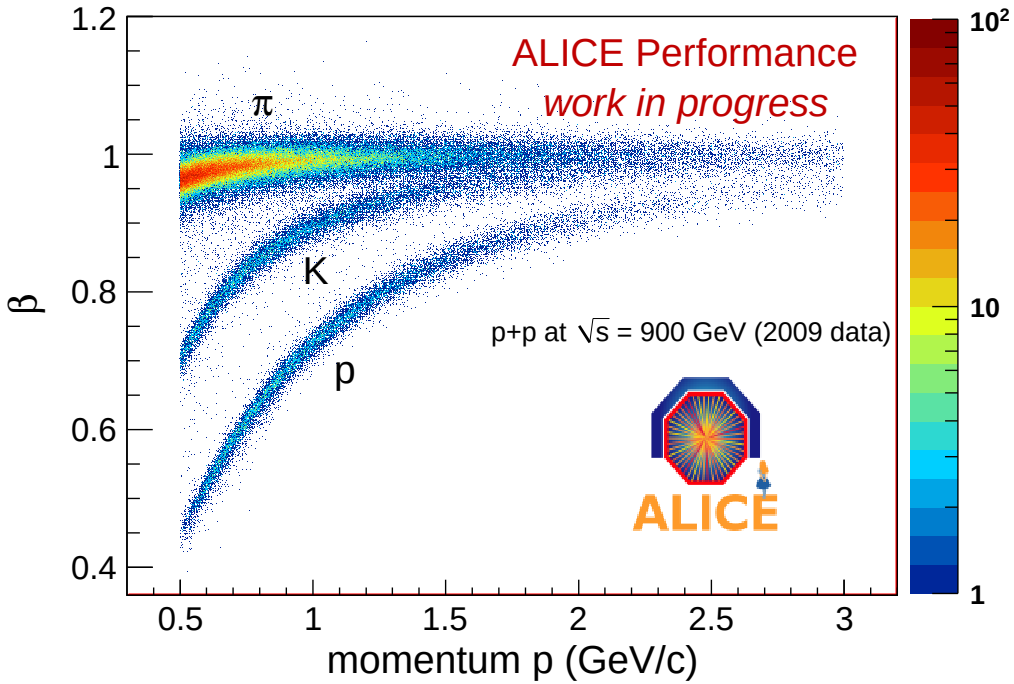


The strength of ALICE: particle identification



Time Projection Chamber

90 m^3 active volume
500 million "pixels"

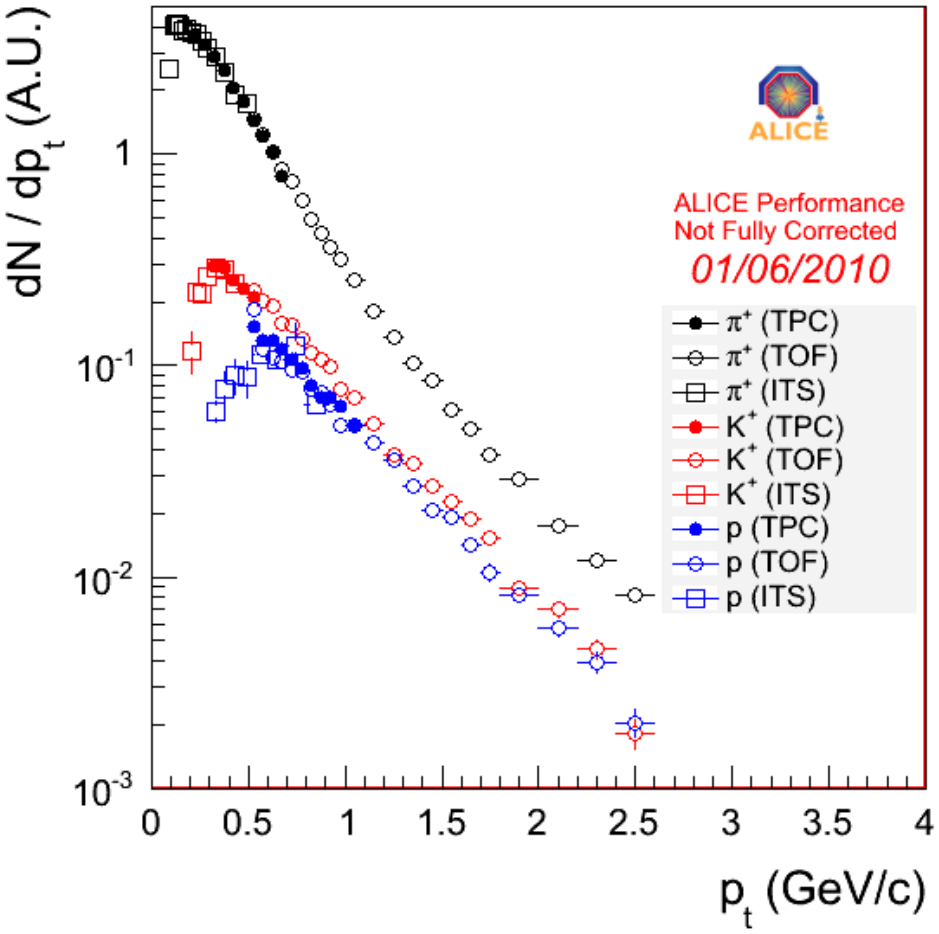


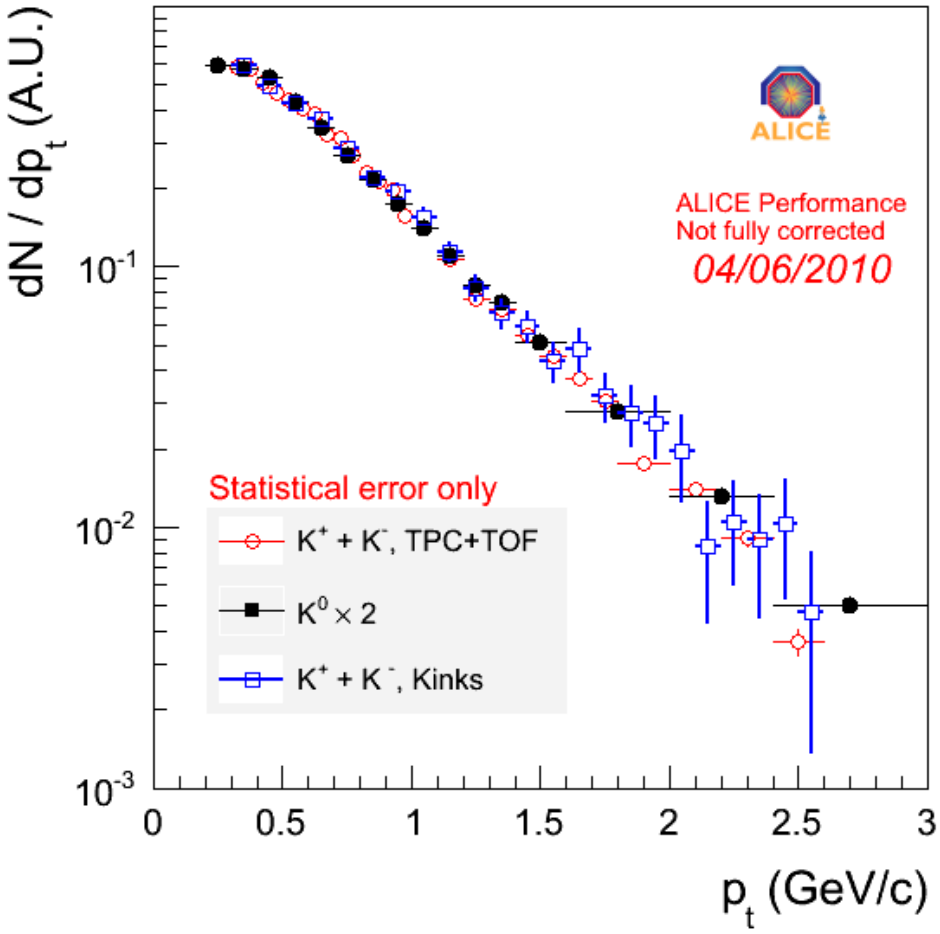
Time of Flight

141 m^2 active area
<100 ps resolution

Identified particle spectra

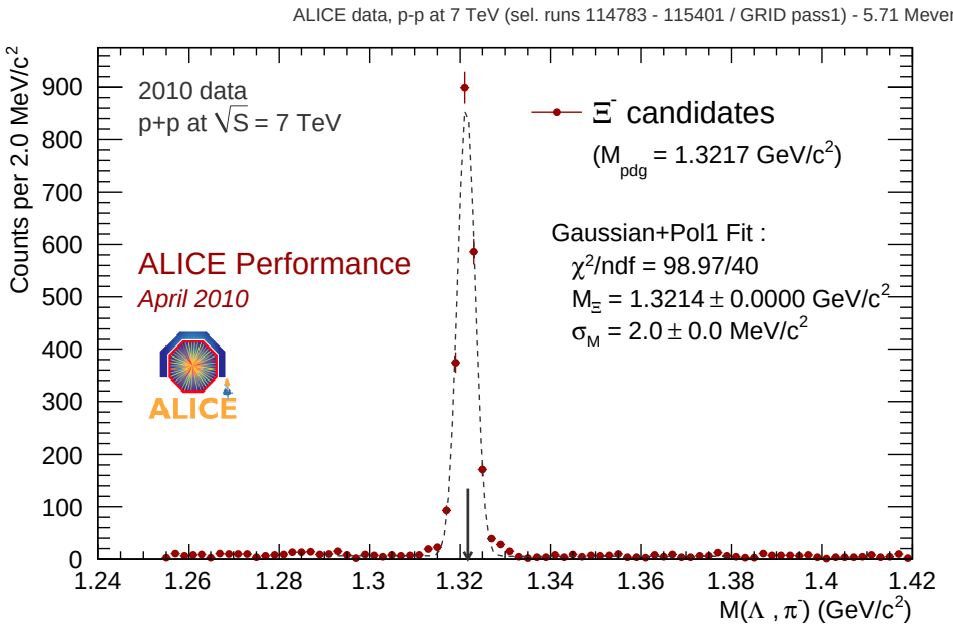
paper in preparation

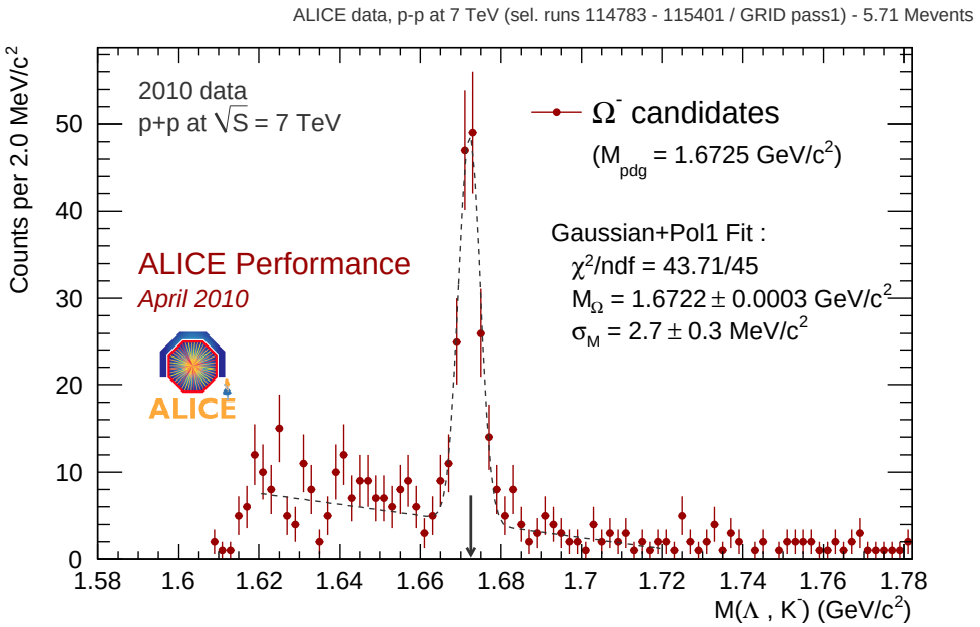




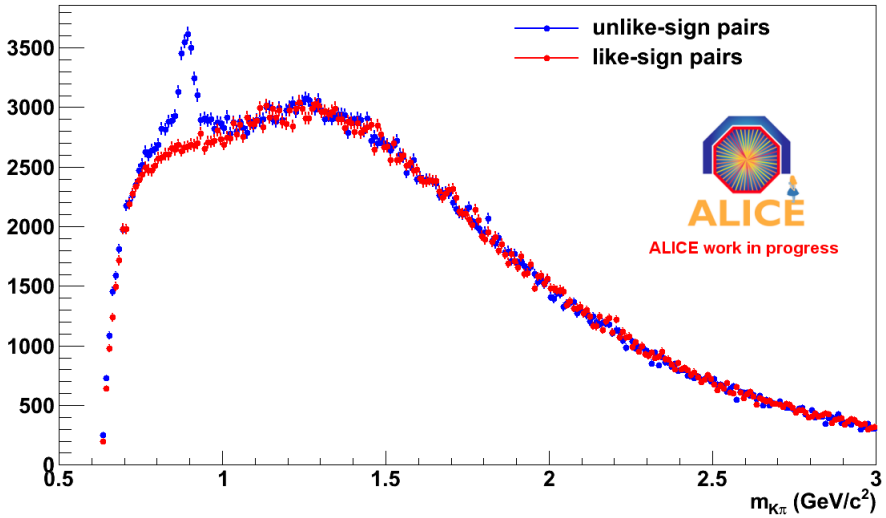
a perfect agreement of 3 systems (ITS, TPC, TOF) and 3 methods

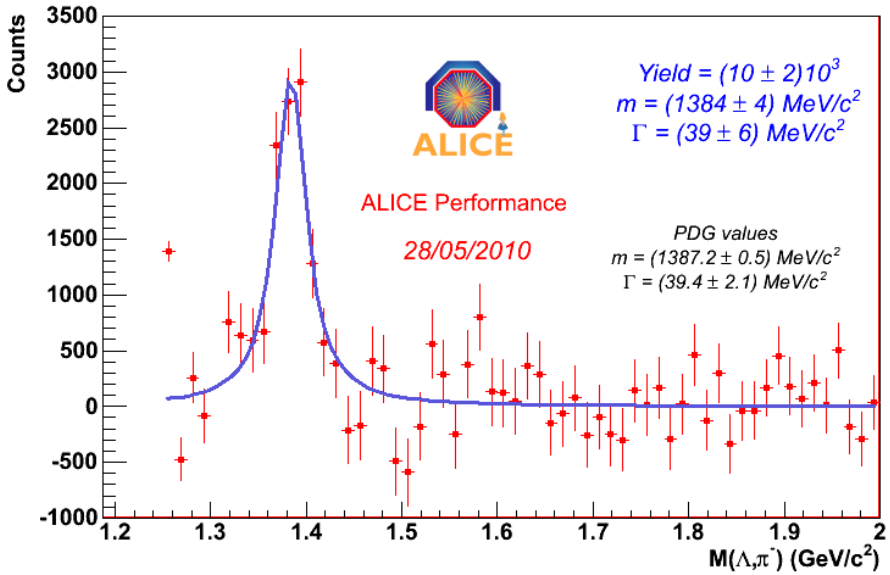
More particle "identification"



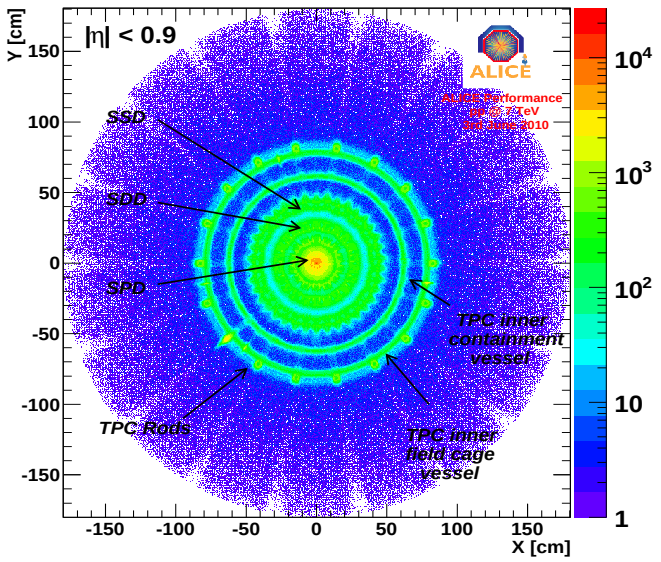


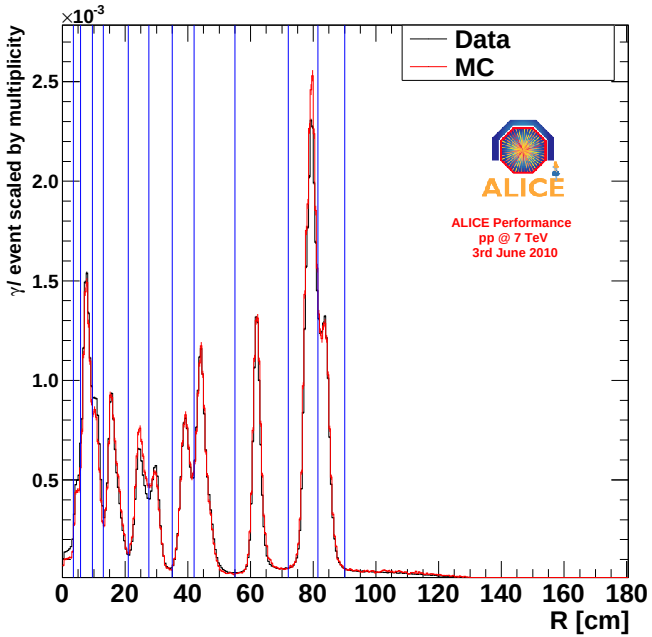
Λ π⁻ invariant mass spectrum (side-bands background subtracted)





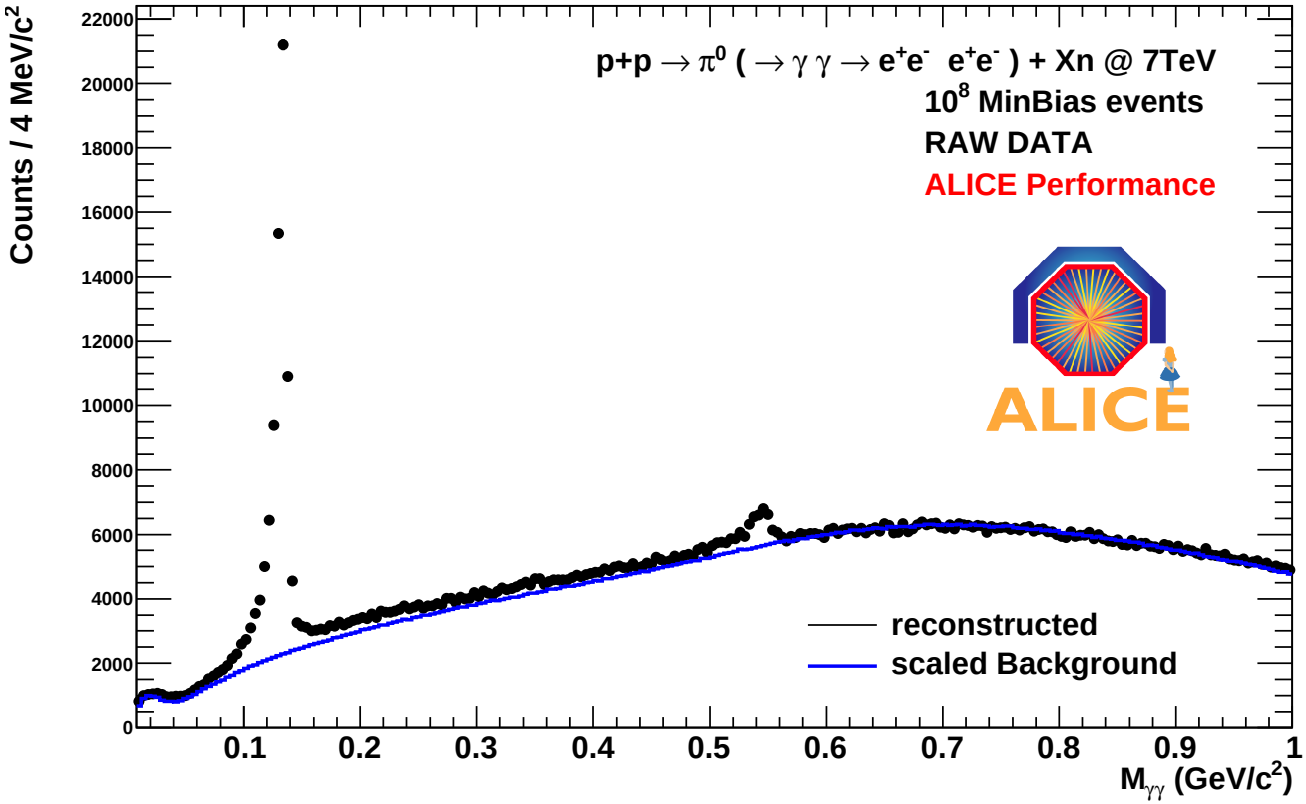
Reconstruction of gamma conversions



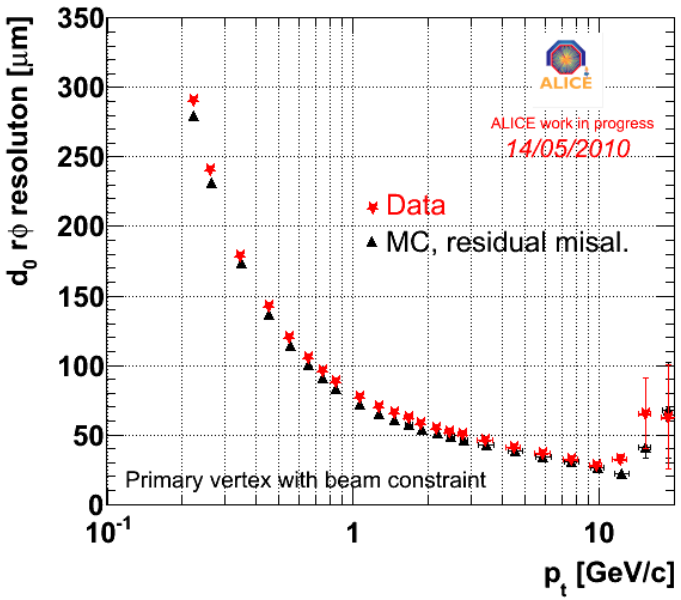


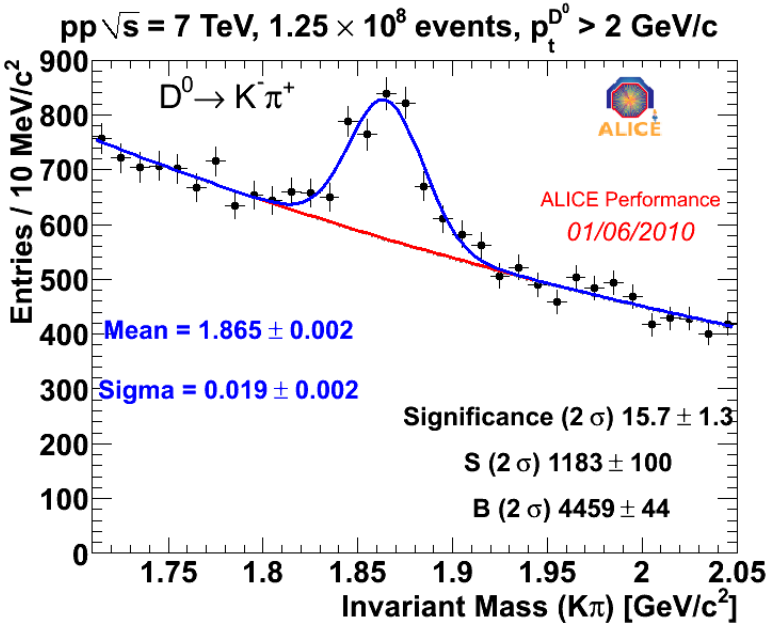
...a tool for detector material "radiography"

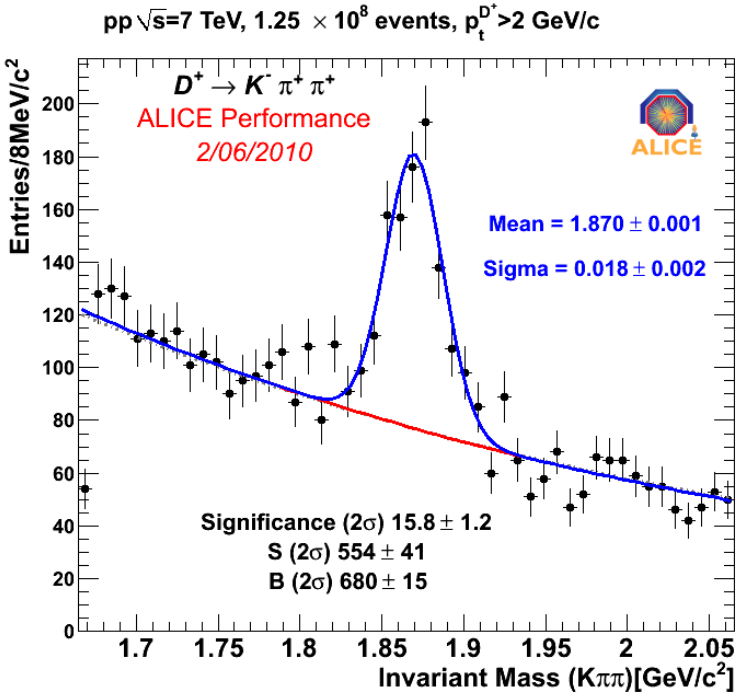
...as well as a powerful tool for physics

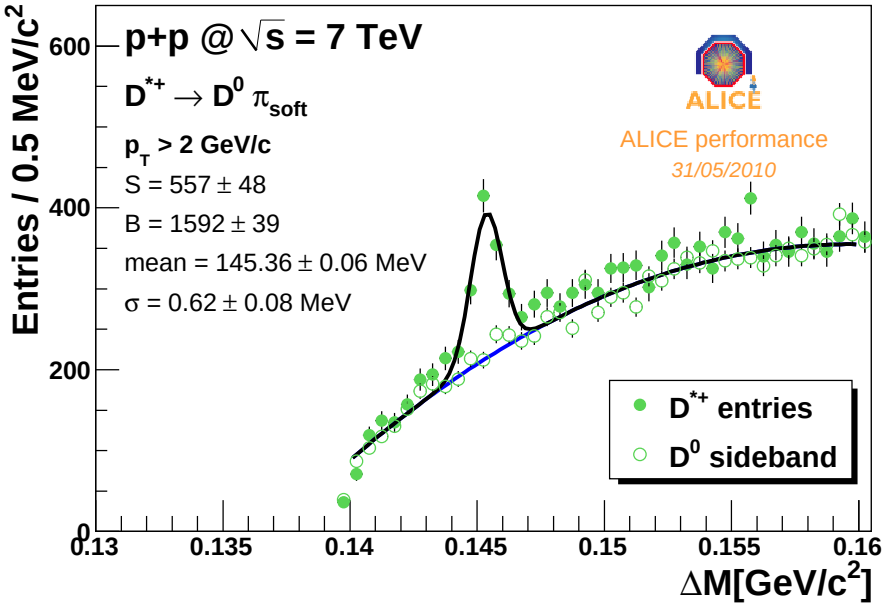


Charm reconstruction performance





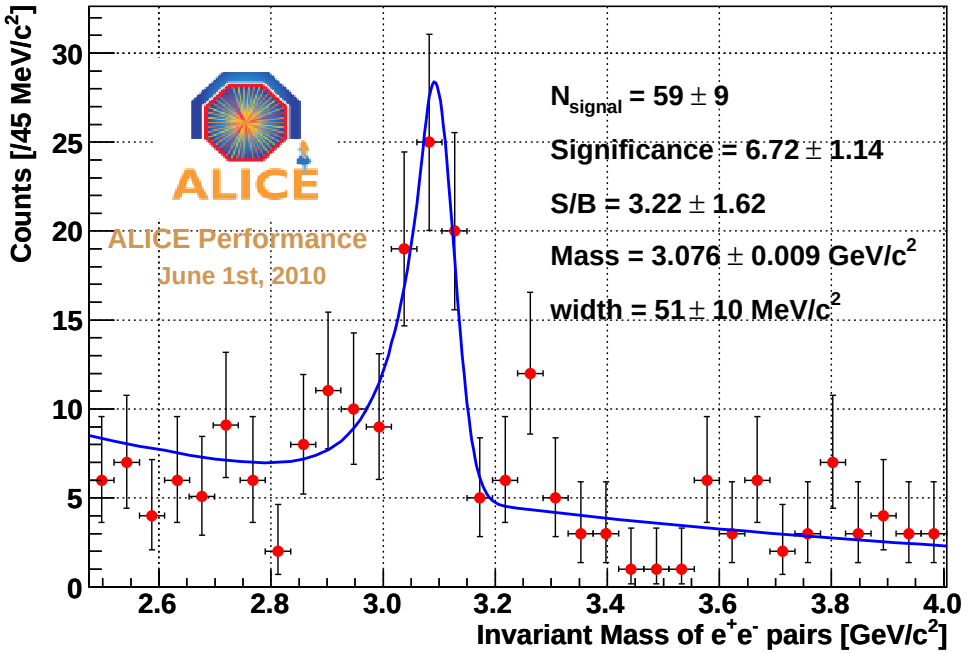


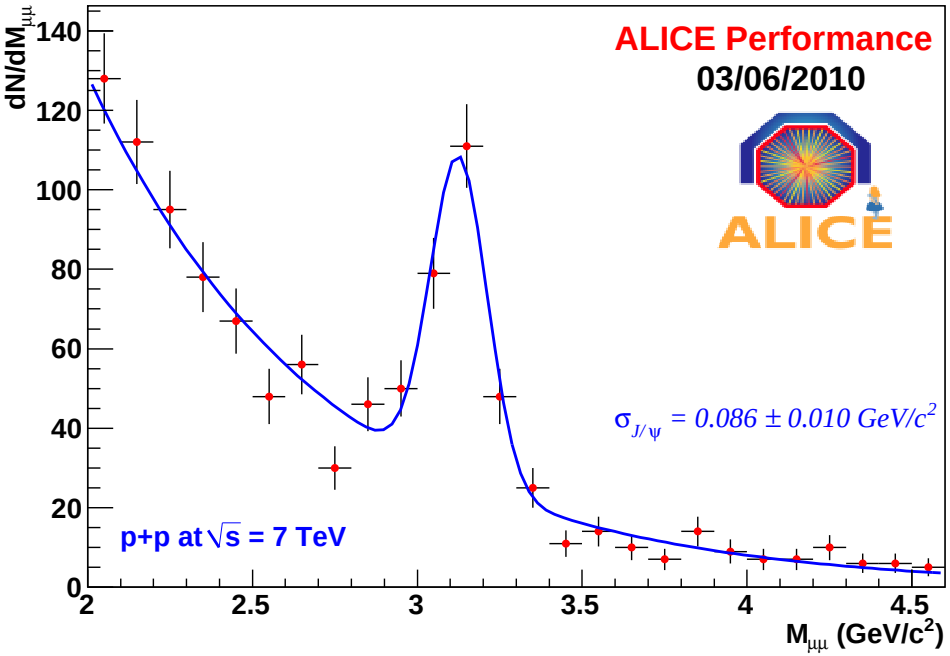


J/ψ reconstruction performance

e^+e^-, $|y|$ <0.8

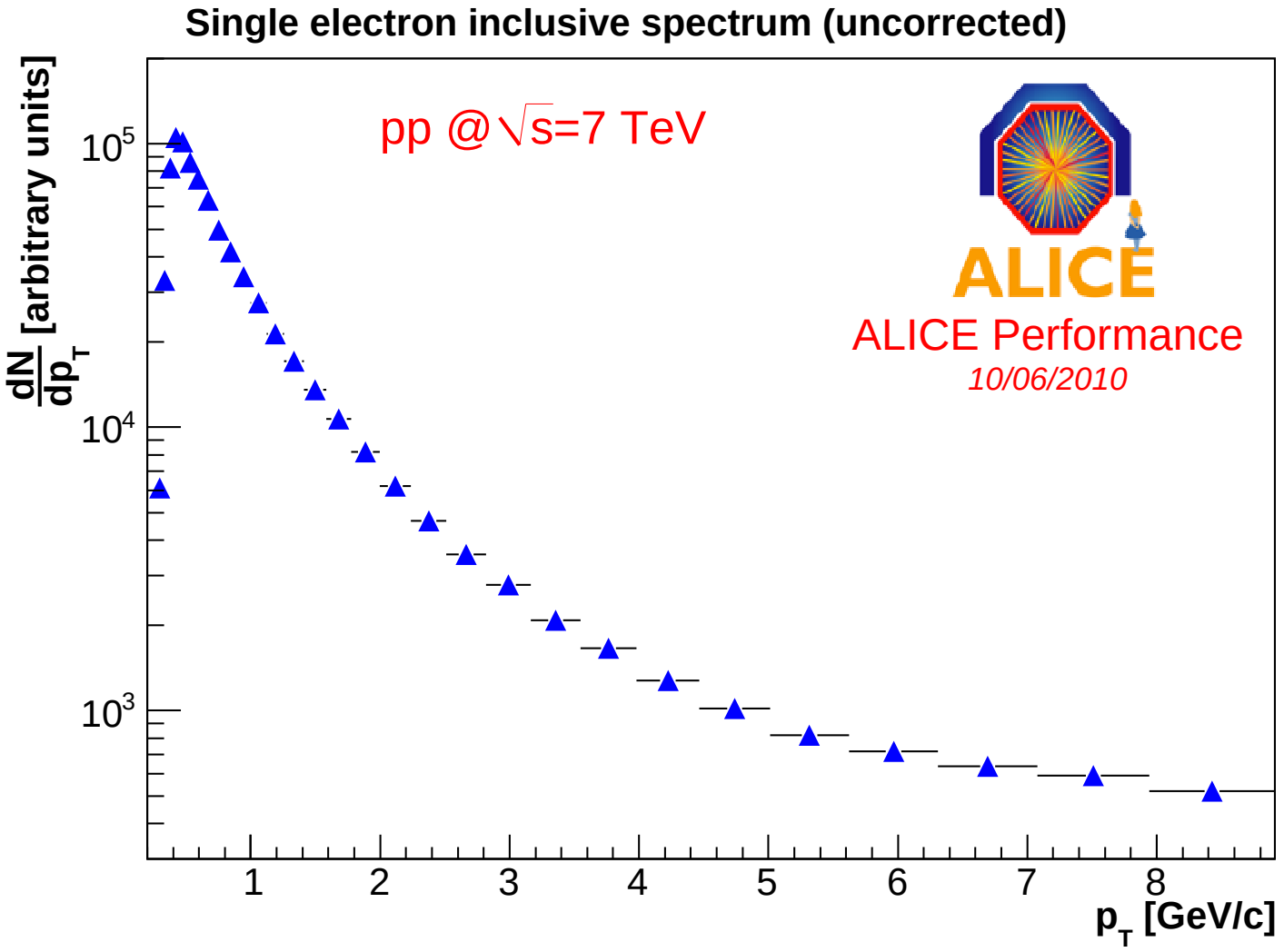
$\mu^+\mu^-$, 2.5< y <4.0





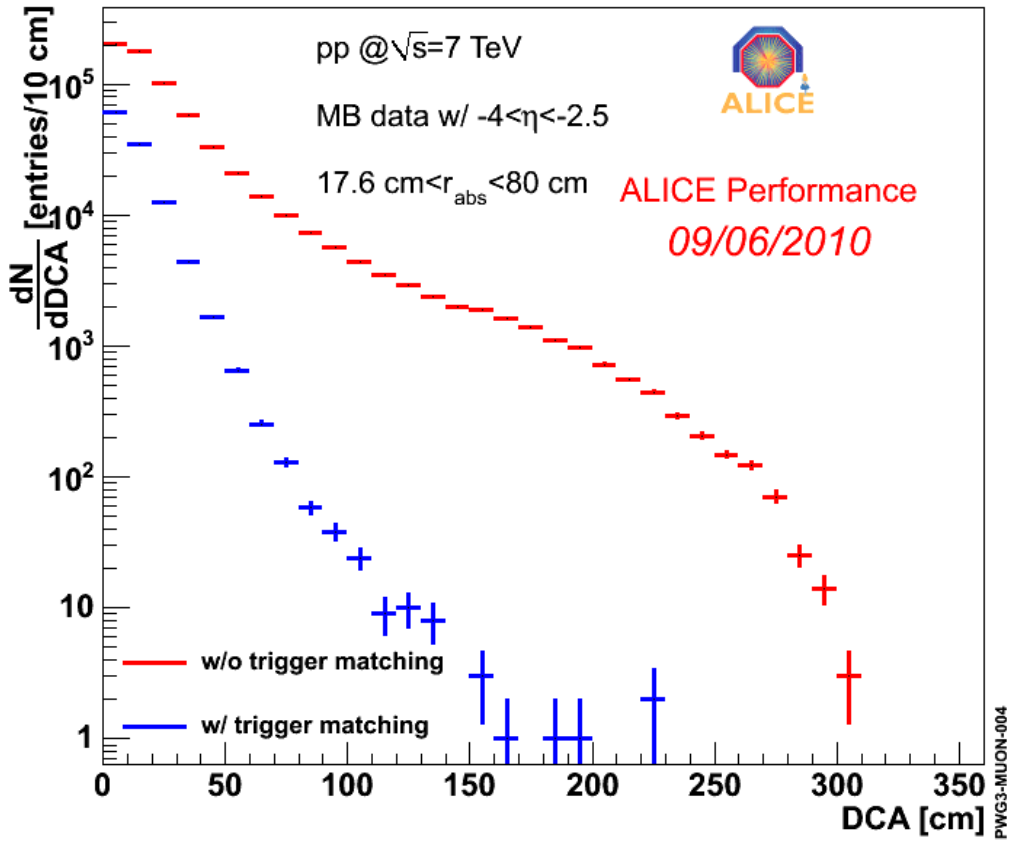
measurement down to p_t=0 in both channels (triggered in $\mu^+\mu^-$)

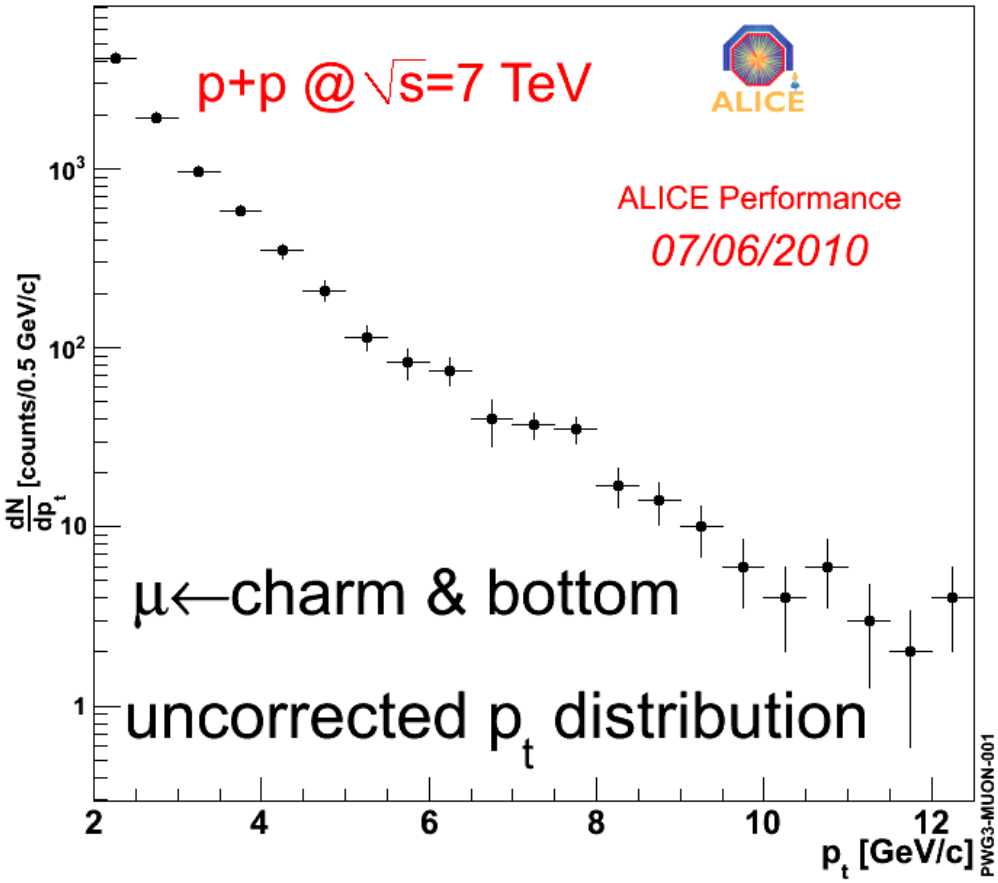
Single-electron spectrum



...measurement of charm and beauty cross section
(after lighter "cocktail" subtraction)

Muons from charm and bottom

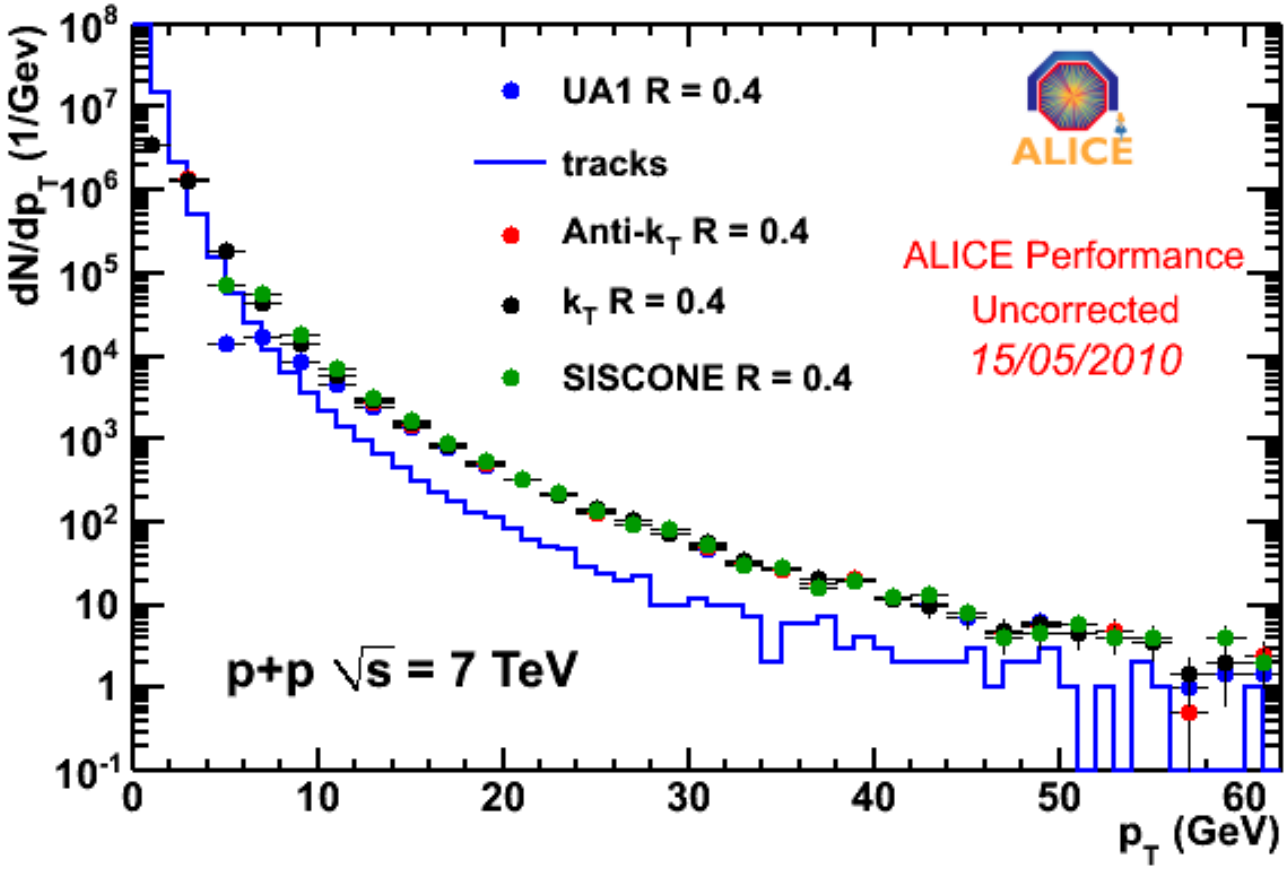




trigger chamber matching removes background (leads to cleaner Distance-of-Closest-Approach) ...remainder subtracted based on Pythia

Jet reconstruction

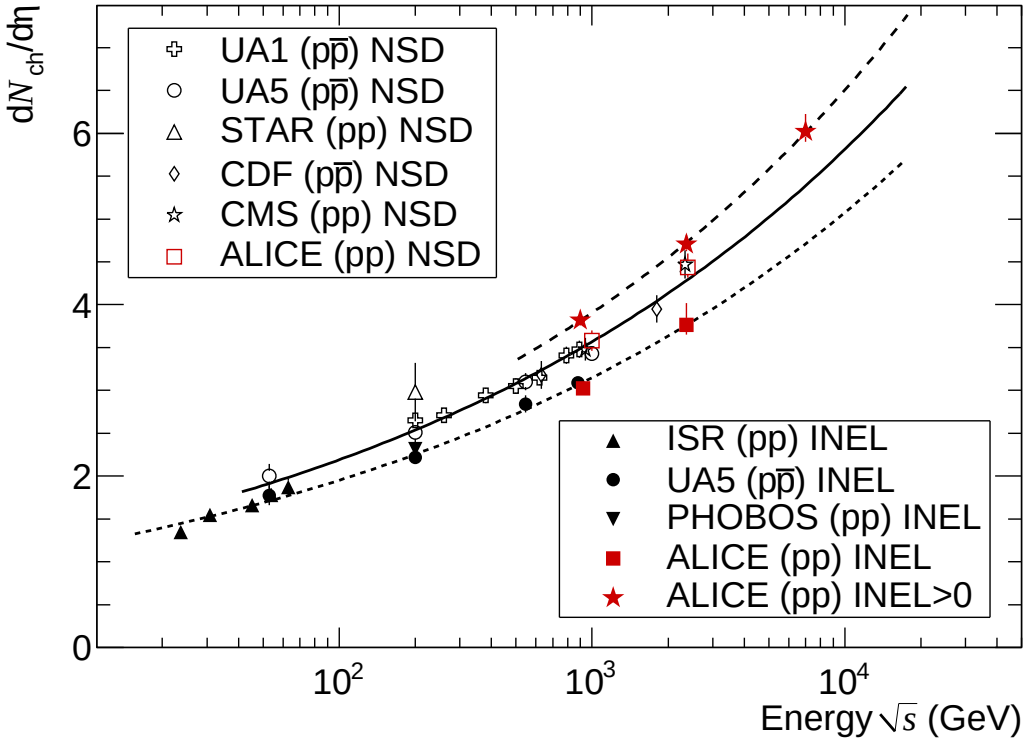
charged-track jets, $|\eta| < 0.5$: uncorrected spectrum

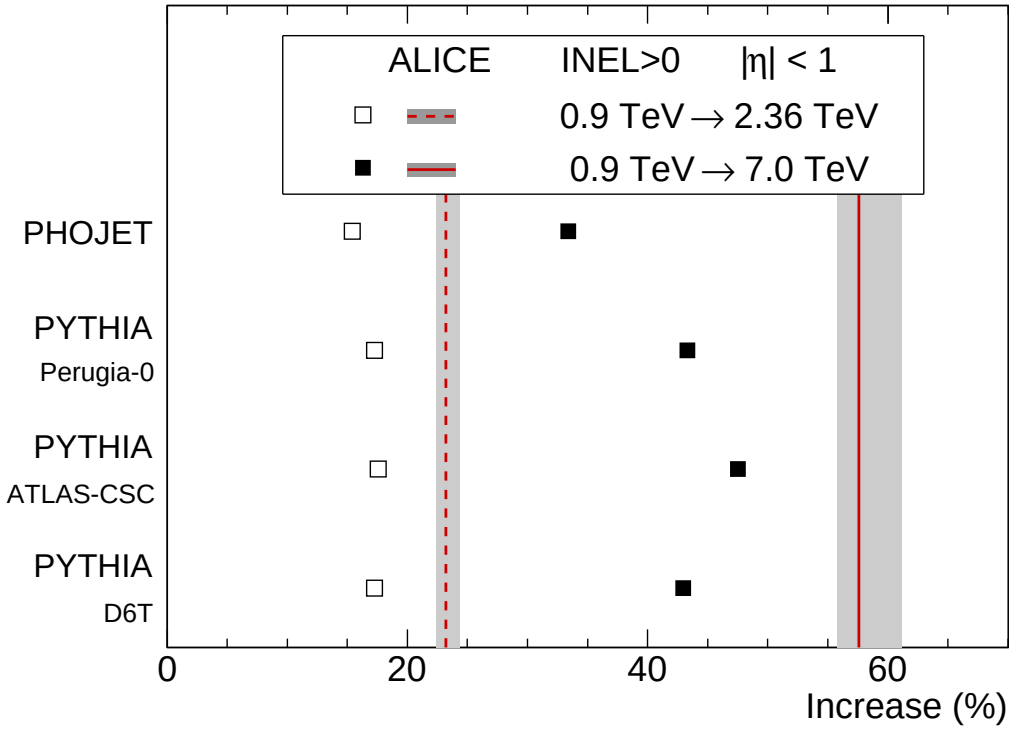


4 jet algorithms compared ...good agreement

First measurement, first surprise...

EPJC in press, arXiv:1004.3514



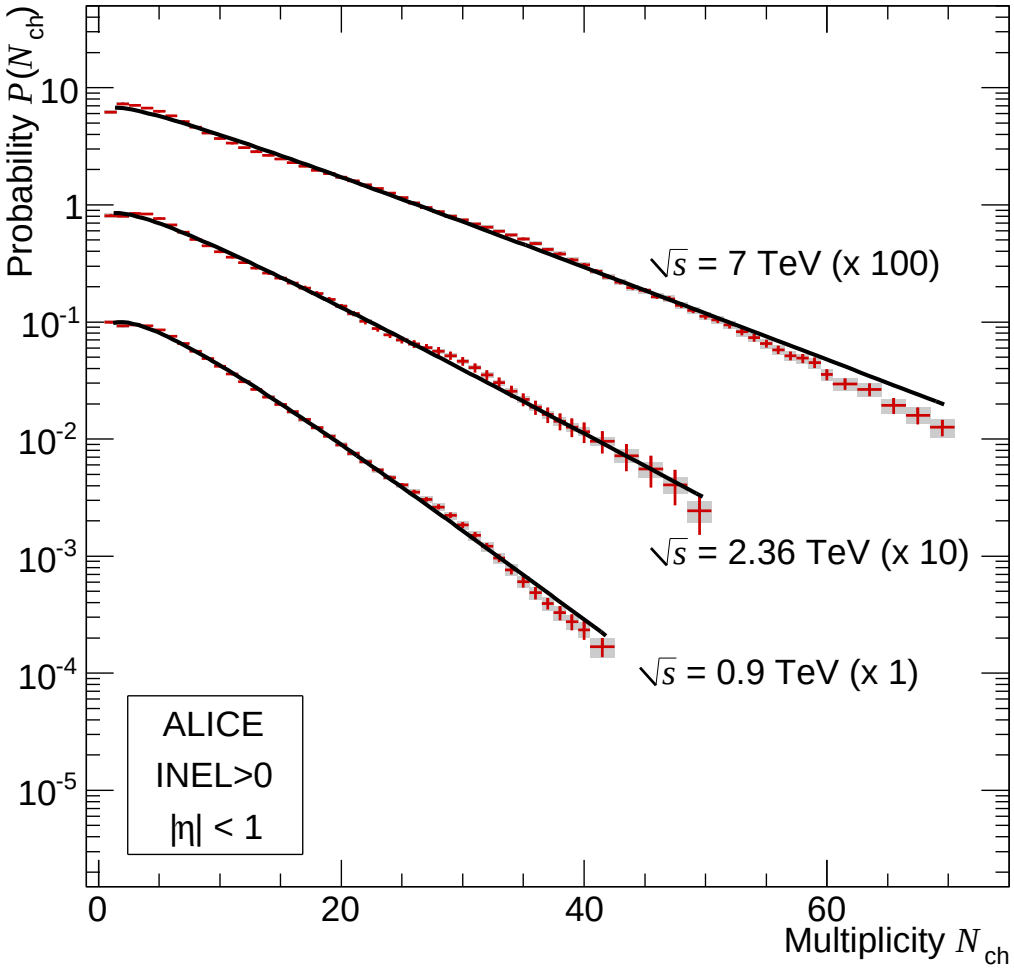


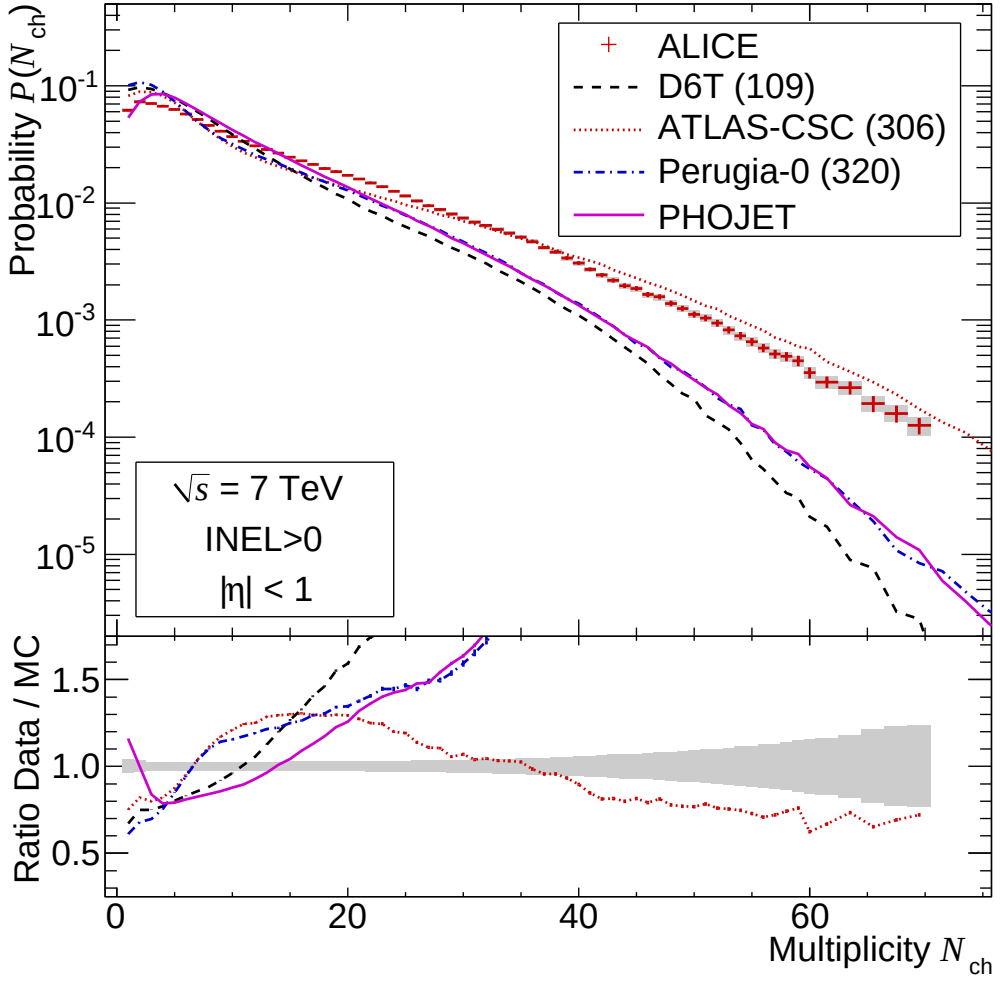
The growth of multiplicity from 0.9 TeV is larger than predicted by models

INEL>0 = triggered events with at least 1 track in acceptance

More multiplicity ...up to 70 per event!

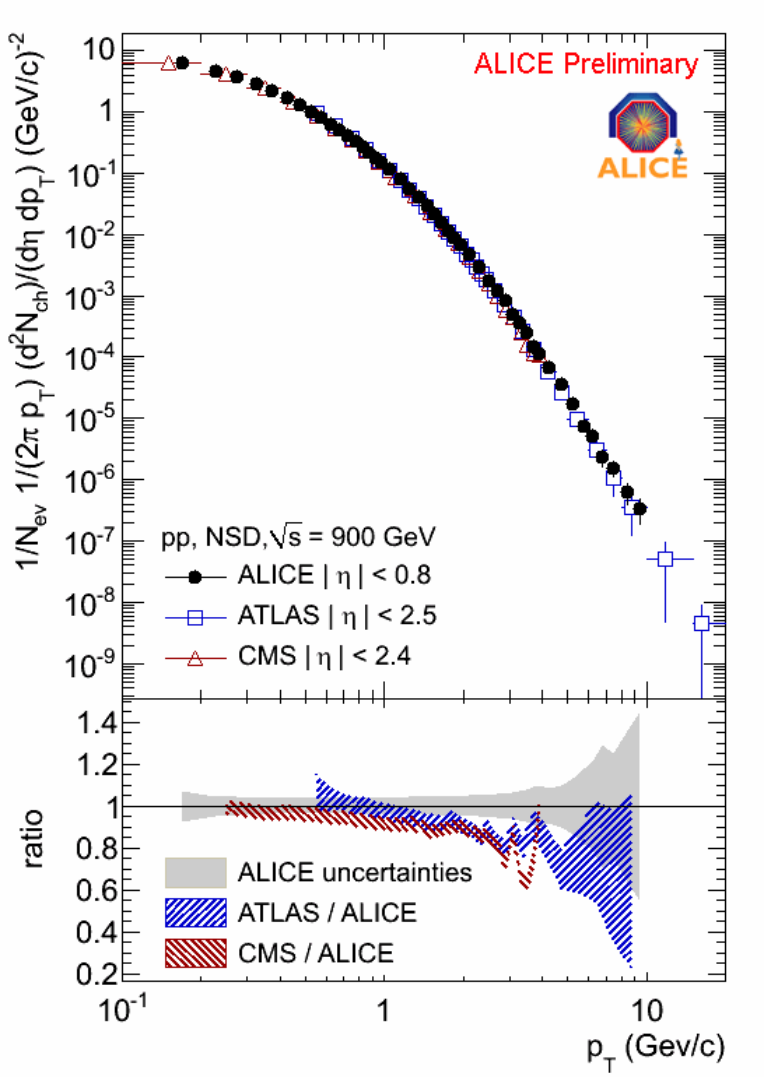
EPJC in press, arXiv:1004.3514

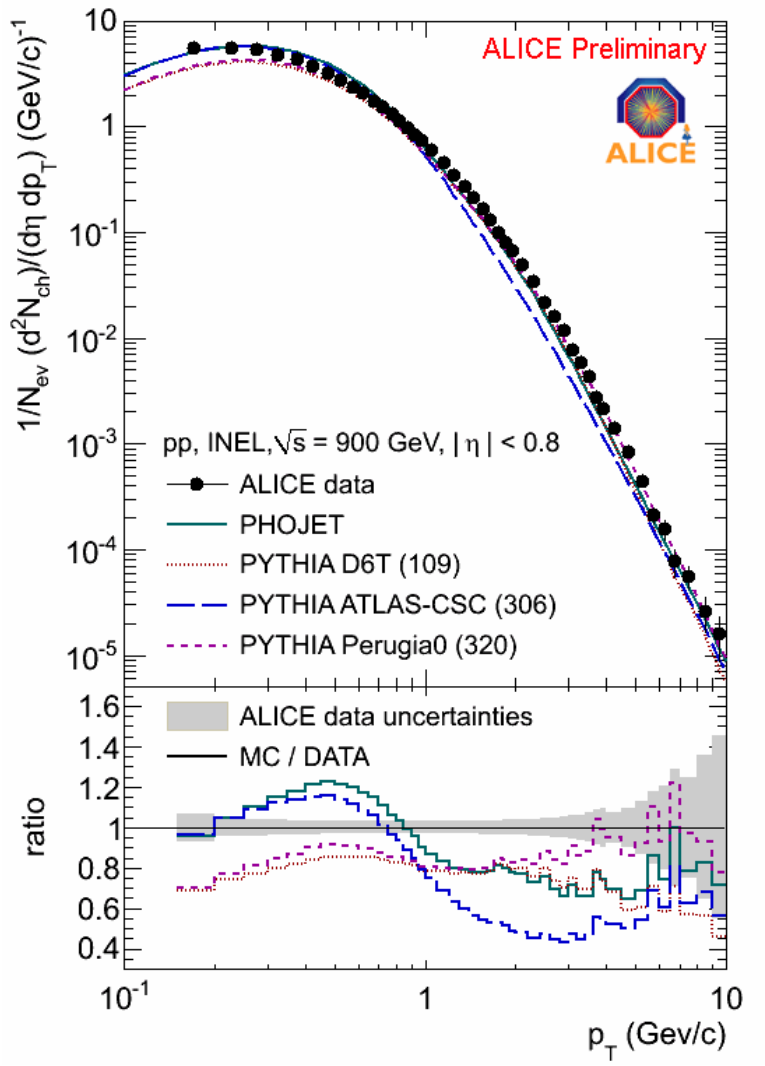




Multiplicity distributions not reproduced by models (ATLAS-CSC tune is close)

Transverse momentum spectrum





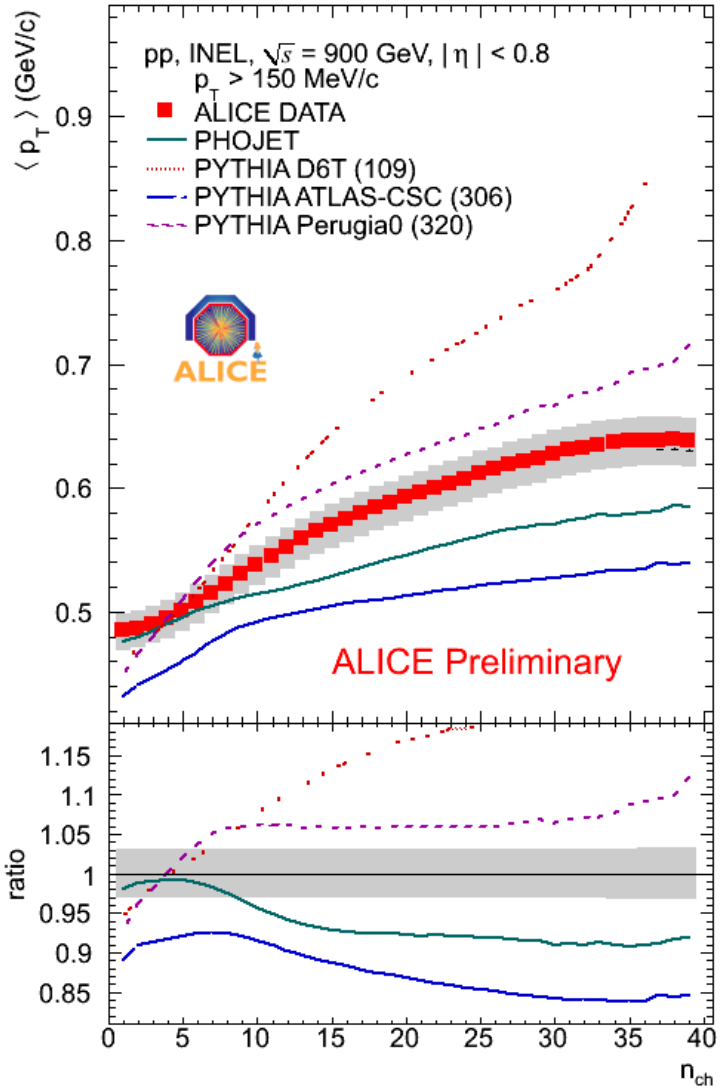
paper in preparation

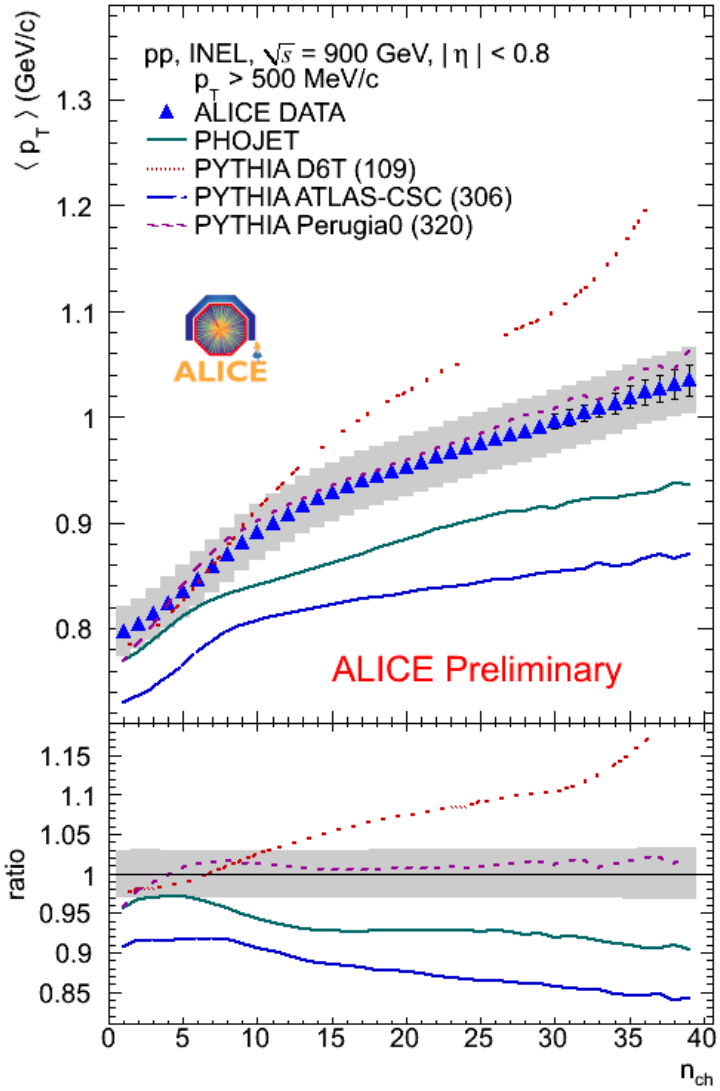
ALICE vs. ATLAS, CMS: harder spectrum (narrower η range)

PHOJET and PYTHIA ATLAS-CSC tune fail to reproduce data

Transverse momentum vs. multiplicity

paper in preparation

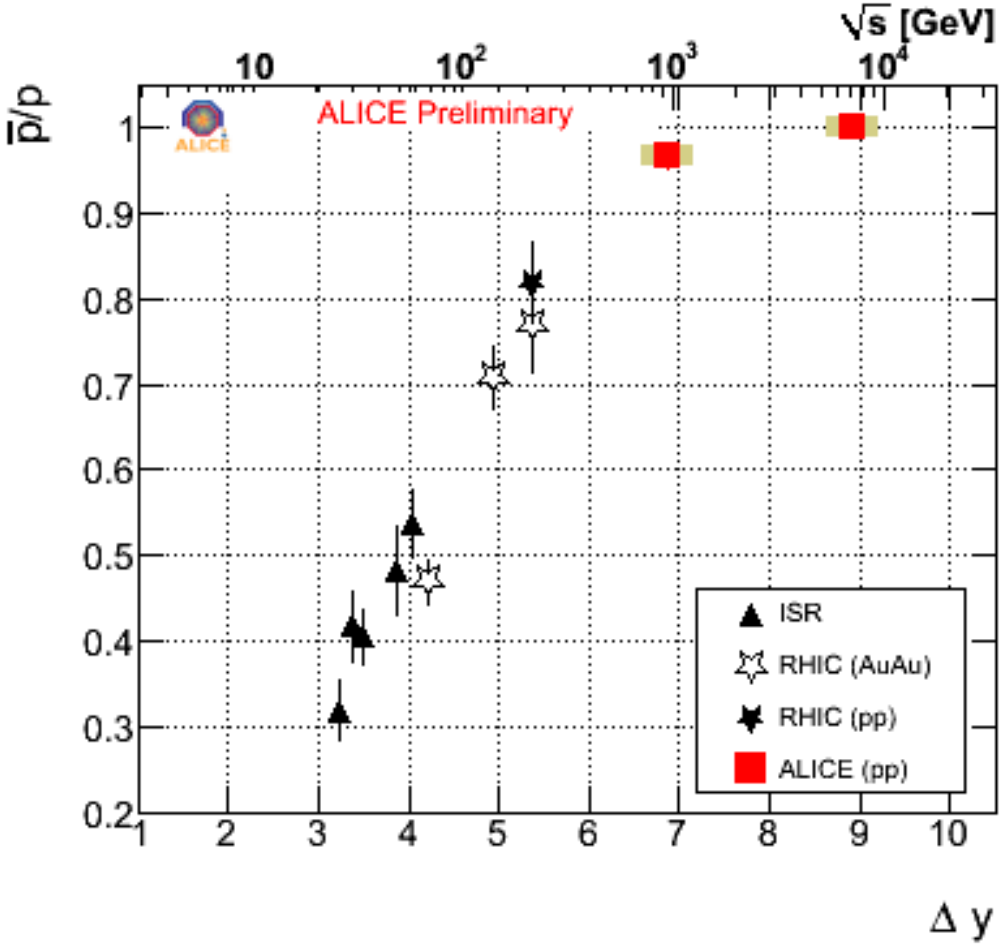


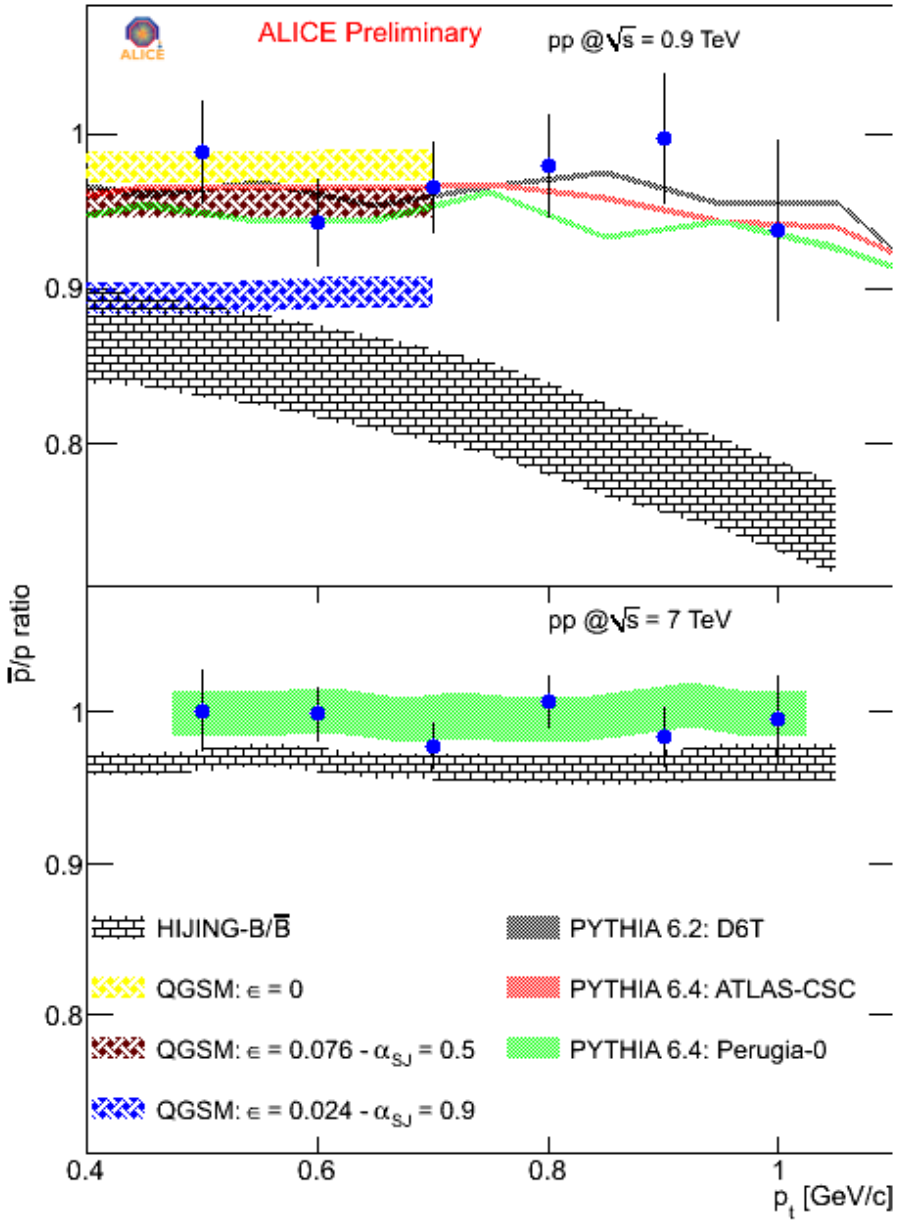


No model can reproduce multiplicity and p_t distributions and $< p_t >$-n_{ch}

$\bar{p}/p$ measurement

paper in preparation

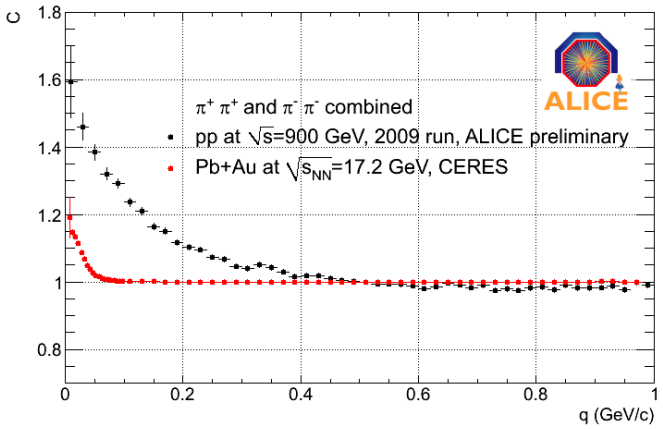




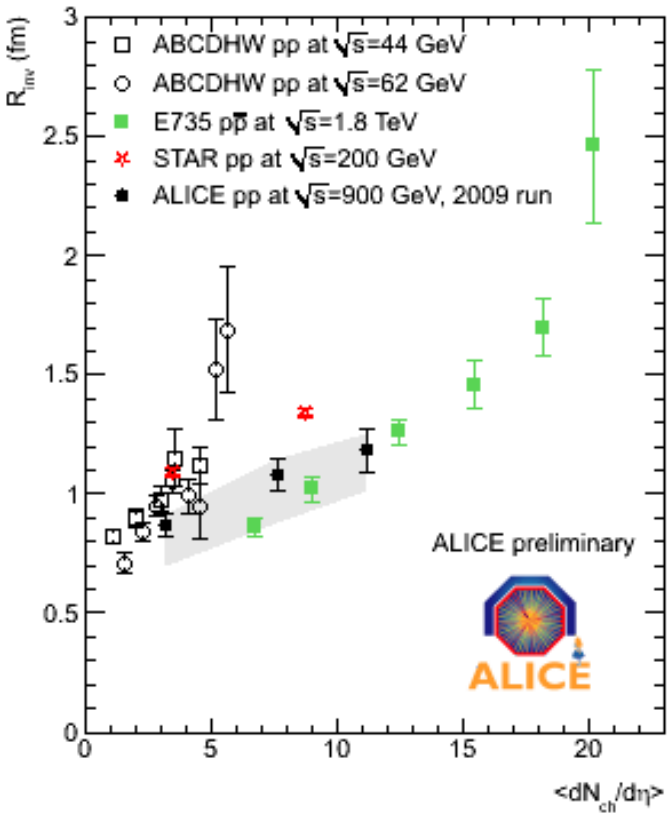
no baryon transport over large rapidity gap ... several models excluded

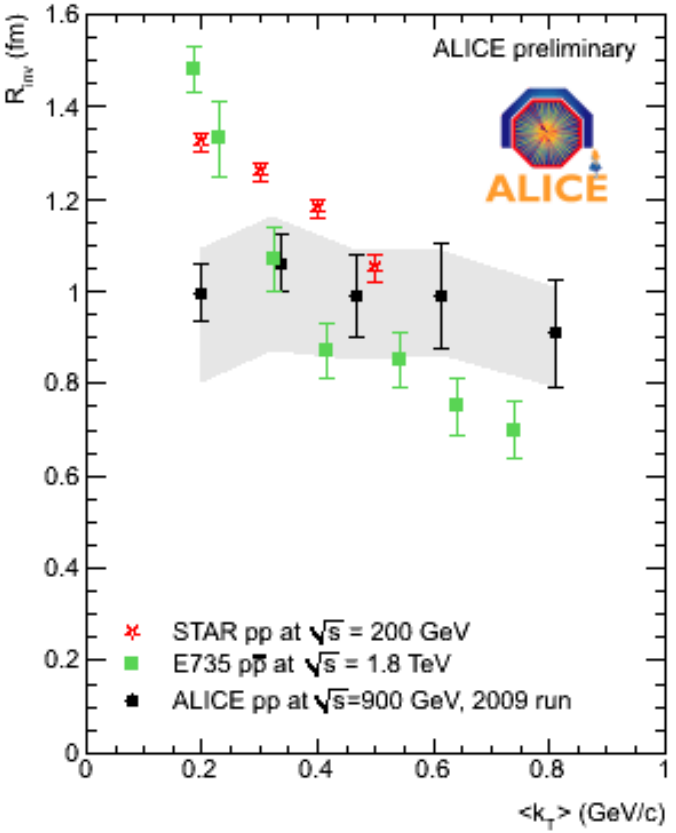
Bose-Einstein correlations (Hanbury Brown and Twiss)

paper in preparation



$$C(q) = 1 + \lambda \exp(-q^2 R^2)$$
$$q = |p1 - p2|$$

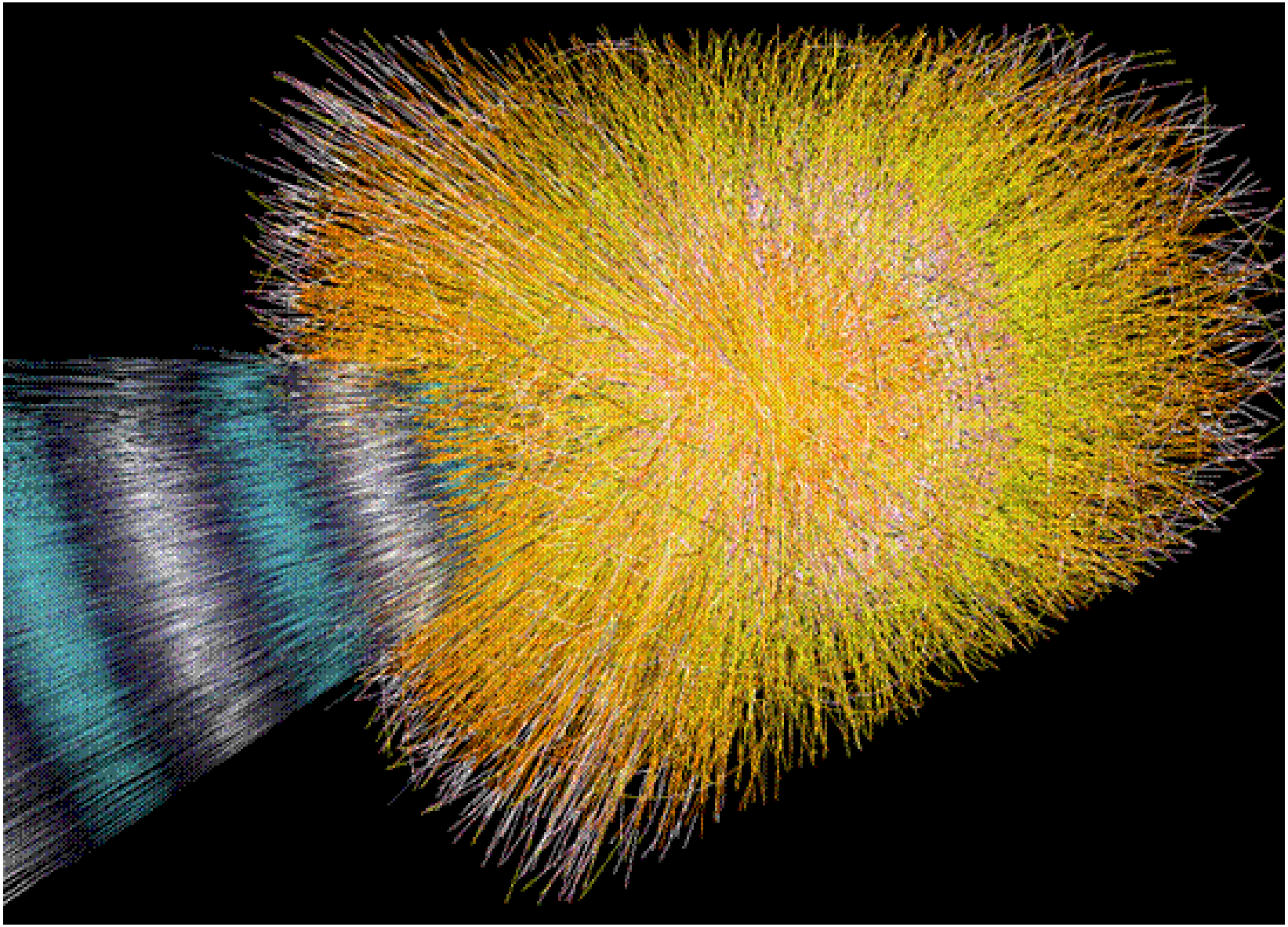




R_{inv} increases with multiplicity

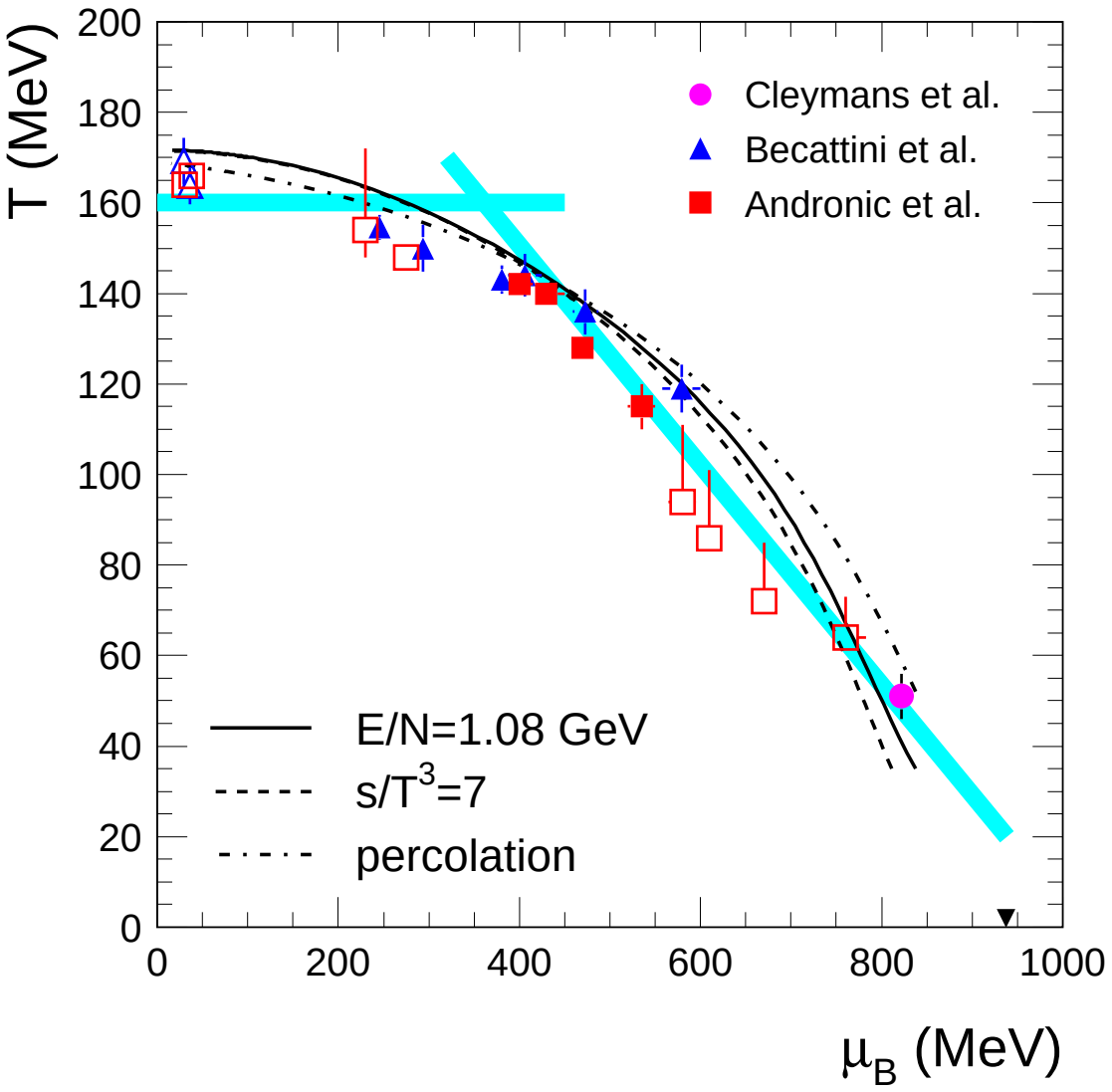
no (or weak?) k_T $(=|p_{t1} + p_{t2}|/2)$ dependence (absence of flow?)

QCD in Pb+Pb collisions



study of (QCD) matter at extremes

The phase diagram of QCD



...established with thermal fits of u,d,s-hadrons in Au+Au/Pb+Pb central collisions at energies $\sqrt{s_{NN}}$=2.3-200 GeV

phase boundary delineated by data ($T_{chem} = T_c \simeq$160-170 MeV)

we believe the matter was in a deconfined stage (for $\sim$10 fm/c)

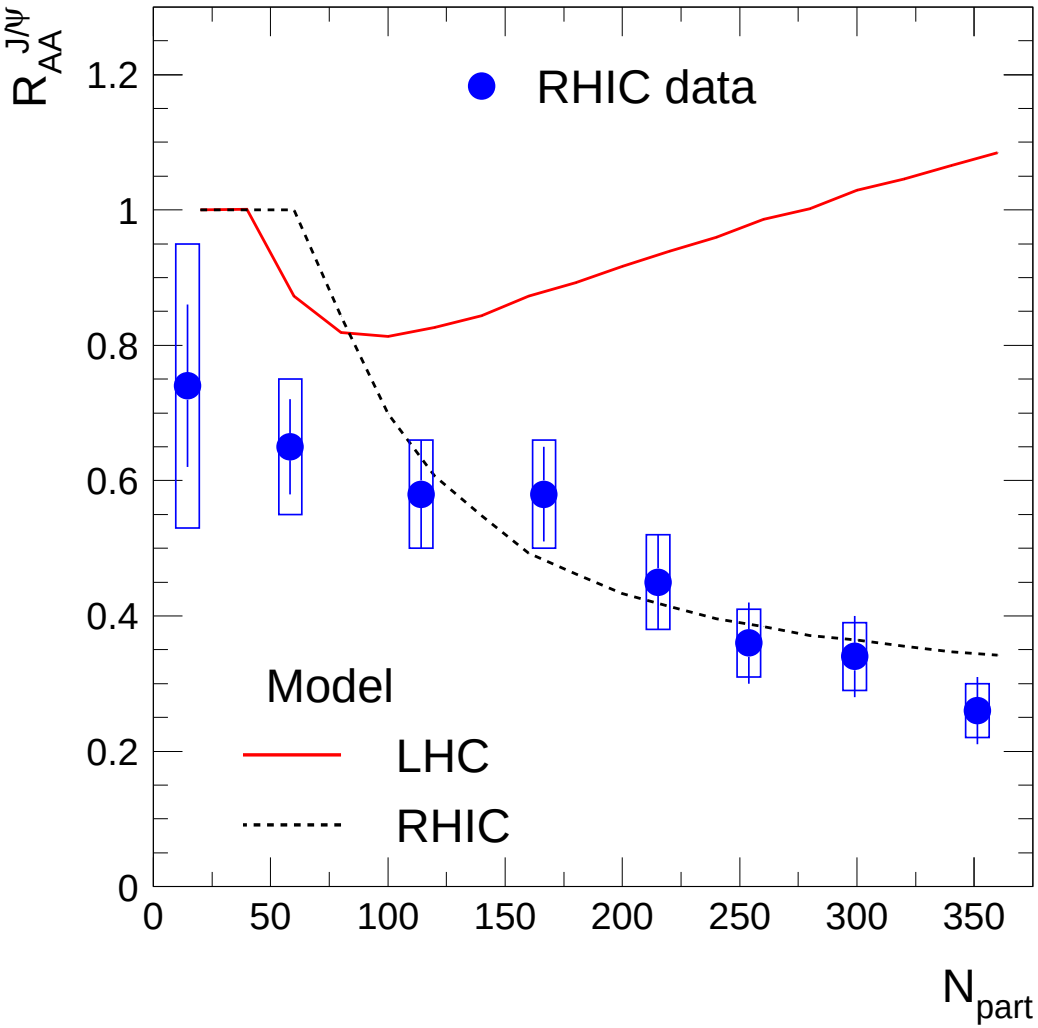
(based on other observables too: collective flow, jet quenching)

Lattice QCD (μ_b=0): $T_d \simeq$170 MeV

The LHC: domain of purely produced matter ($\mu_B \simeq$0), as the Early Universe

A key measurement: Charmonium (J/ψ)

...an ultimate observable to measure the phase boundary (thermal model)
...with the help of charm quarks equilibrating in the deconfined stage



$$R_{AA}^{J/\psi} = (\mathrm{d}N_{J/\psi}^{AuAu}/\mathrm{d}y)/(N_{coll} \cdot \mathrm{d}N_{J/\psi}^{pp}/\mathrm{d}y)$$

R_{AA}=1 if superposition of pp coll.

very different centrality dependence

- "suppression" at RHIC
- "enhancement" at LHC

$N_{J/\psi} \sim (N_{c\bar{c}}^{dir})^2$

What is so different at LHC?

(compared to RHIC)

$\sigma_{c\bar{c}}$: 10x, Volume: 3x

Summary and outlook

- a remarkable startup of the LHC (which deserves our warm thanks)

  ...ALICE collected $2{\cdot}10^8$ events at 7 TeV

- with a remarkable ALICE detector performance (the result of long years of assiduous preparations)

  ...leading to quick physics results

- QCD probed with a wealth of identified particles

  ...offered a first glimpse in the new energy domain ...and first surprises too

- much more to come

  ...in pp and, prominently, in Pb+Pb collisions (the Wonderland of Alice)