ALICE at ICHEP
Paris, July 2010

for the ALICE collaboration

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using presentations
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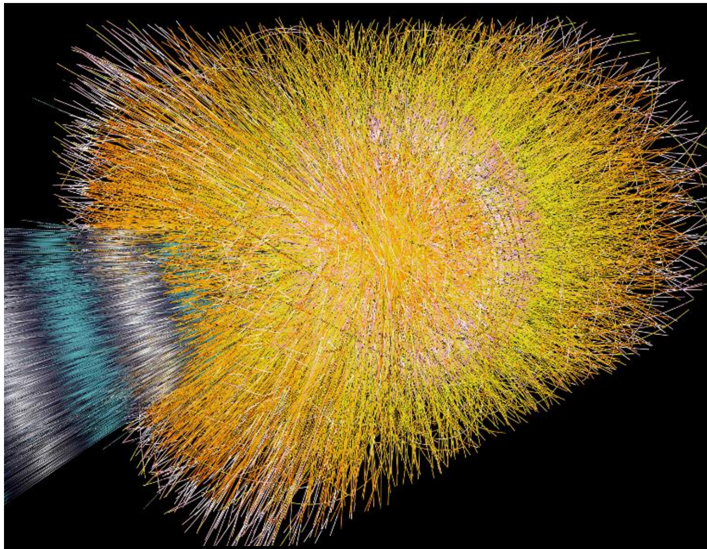
J. Castillo, G. Bruno, J. Rak

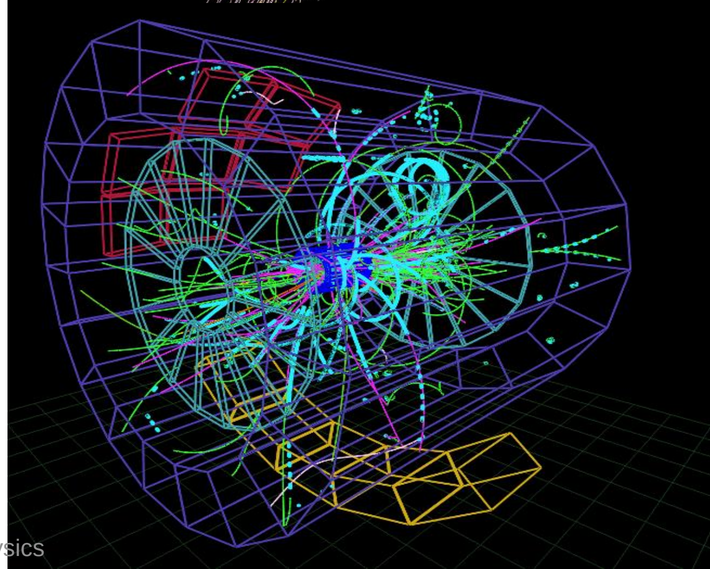
- **Detector status, performance and data taking**
- **Results on minimum bias**
- **Ongoing analyses**

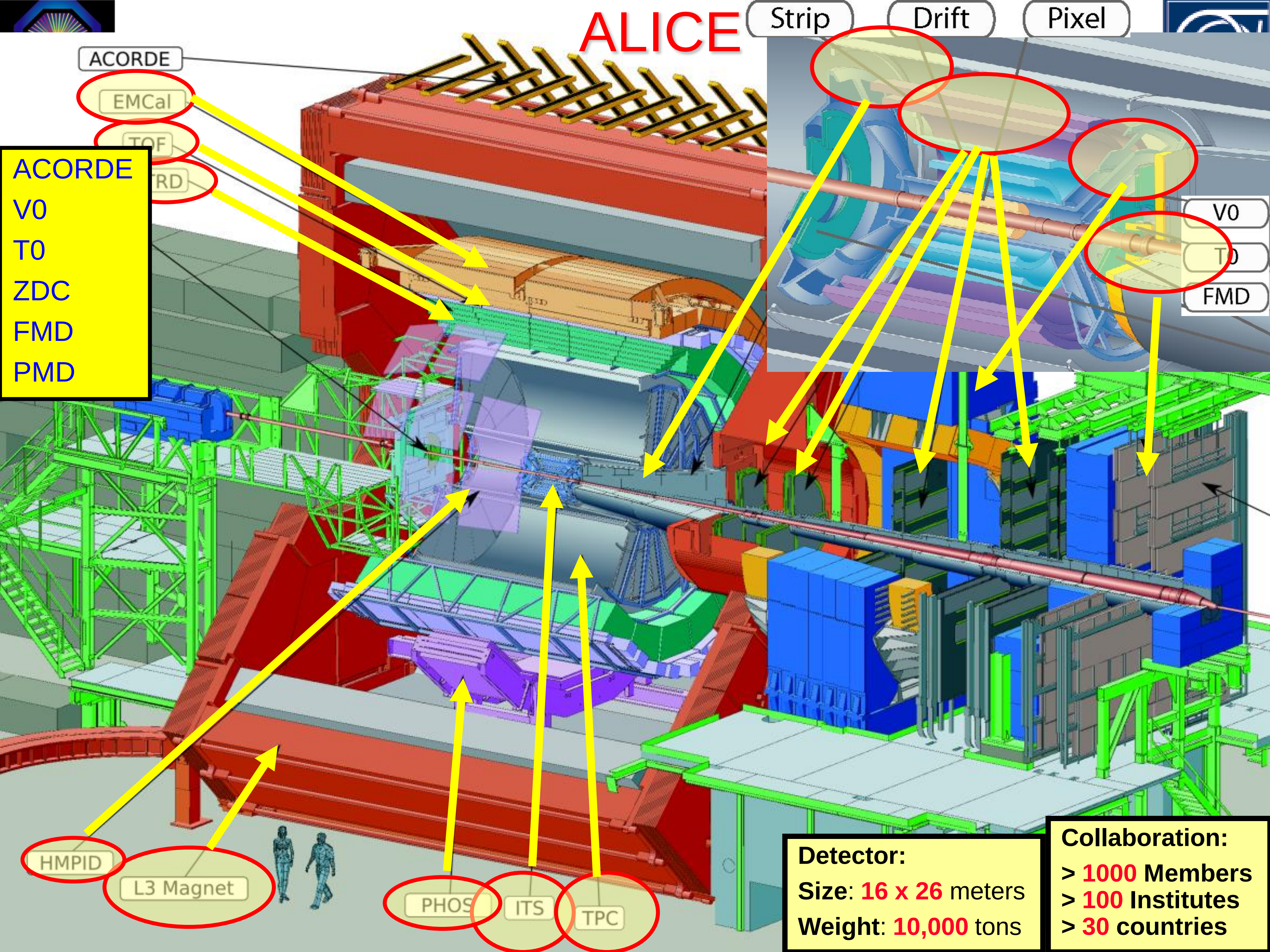
ALICE experiment

- **Dedicated heavy ion experiment at LHC:**
  - ⇨ **study 'state of matter' at high temperature & energy density:** 'The QGP'
    - ✪ **'Standard Model': QCD@finite temperature**
  - ⇨ **LHC:** 30 x energy **of RHIC**
    - ✪ **expect very different type of 'QGP' (T, τ, V, ..)**
    - ✪ **'hard signals' to probe QGP (jets, Υ, heavy Q)**
    - ✪ **first Pb-Pb collisions Nov. 2010**



- **Physics with pp**
  - ⇨ **collect 'comparison data' for heavy-ion program**
    - ✪ **many signals measured 'relative' to pp**
    - ✪ **requires ~ 10^9 MinBias events**
  - ⇨ **comprehensive study of MB@LHC**
    - ✪ **tuning of Monte Carlo (background to BSM)**
  - ⇨ **soft & semi-hard QCD**
    - ✪ **very complementary to other LHC expts**
    - ✪ **address specific issues of QCD**




ALICE
Strip
Drift
Pixel
ACORDE
EMCal
TOF
TRD
ACORDE
V0
T0
ZDC
FMD
PMD
V0
T0
FMD
HMPID
L3 Magnet
PHOS
ITS
TPC
Detector:
Size: 16 x 26 meters
Weight: 10,000 tons
Collaboration:
> 1000 Members
> 100 Institutes
> 30 countries

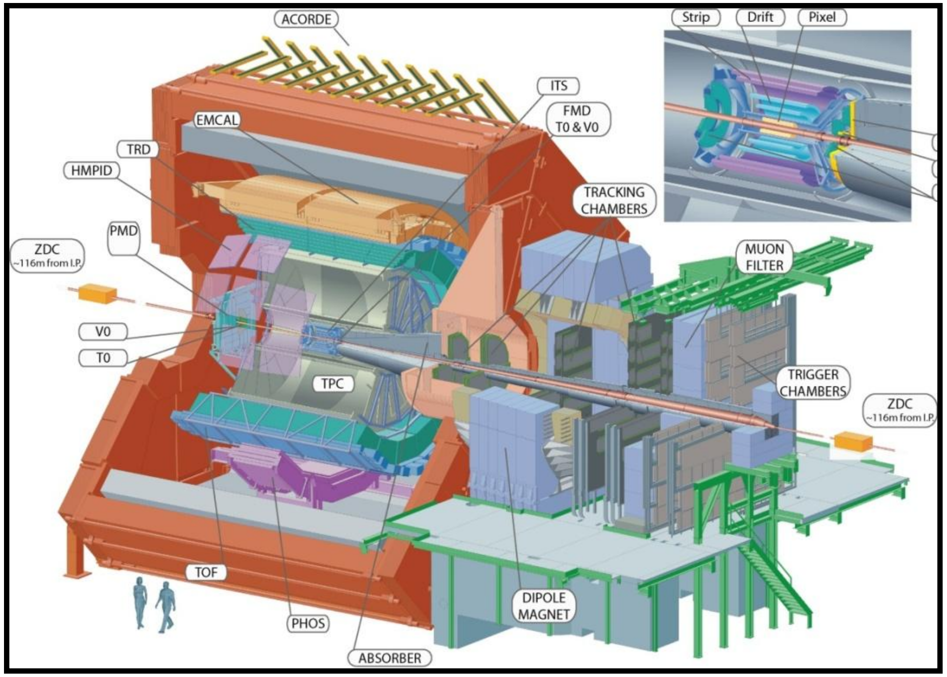
Detector configuration 2010

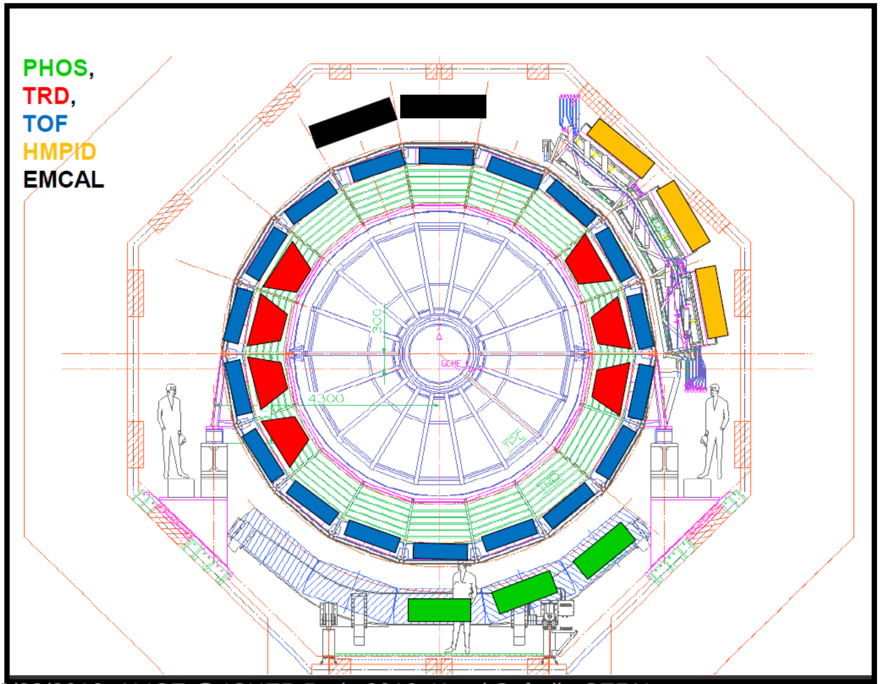
- ITS, TPC, TOF, HMPID, MUON, V0, T0, FMD, PMD, ZDC (100%)
- TRD (7/18)
- EMCAL (4/12)
- PHOS (3/5)
- HLT (60%)

full hadron and muon capabilities

partial electron and photon

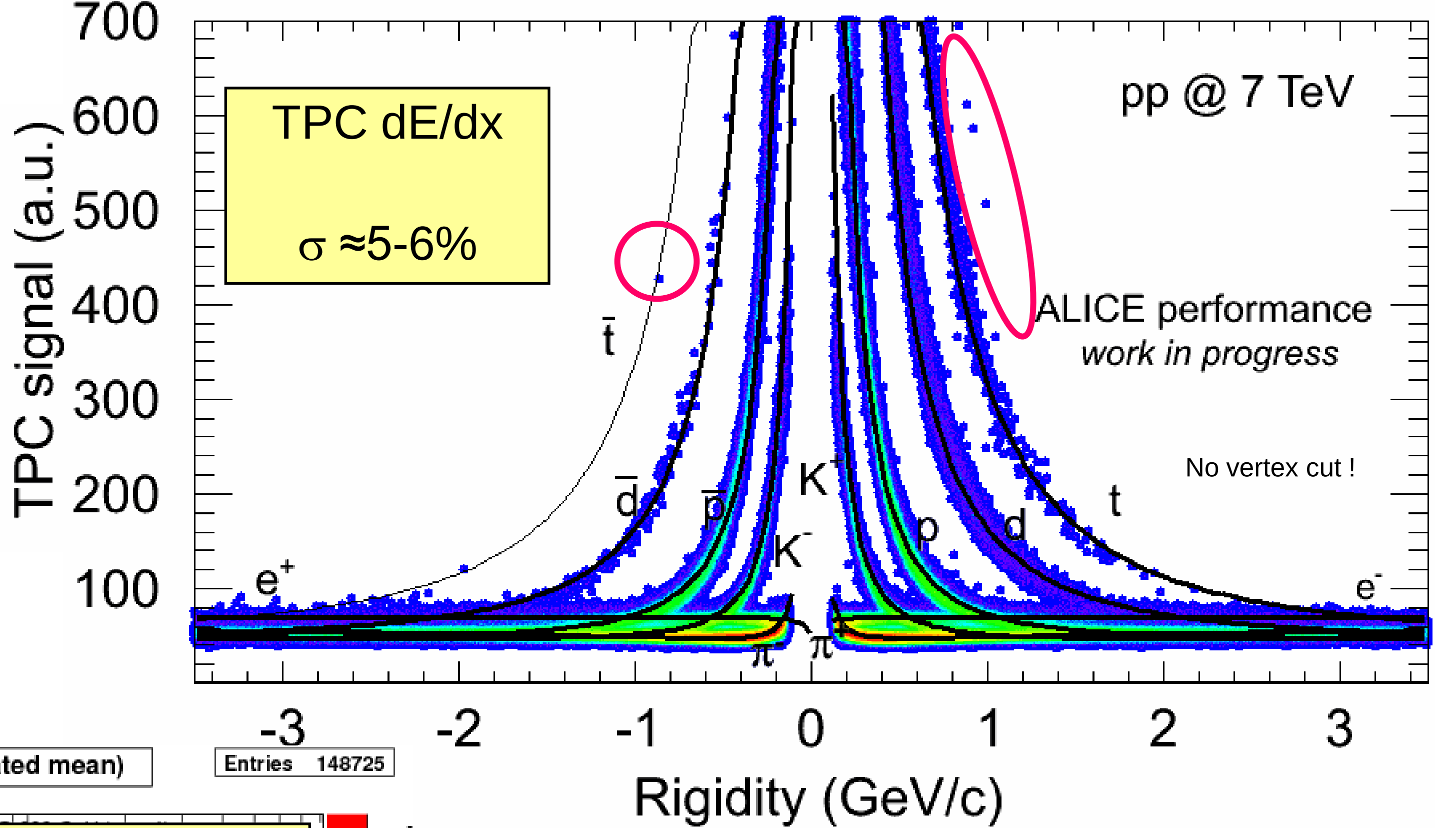
no change with respect to 2009 run

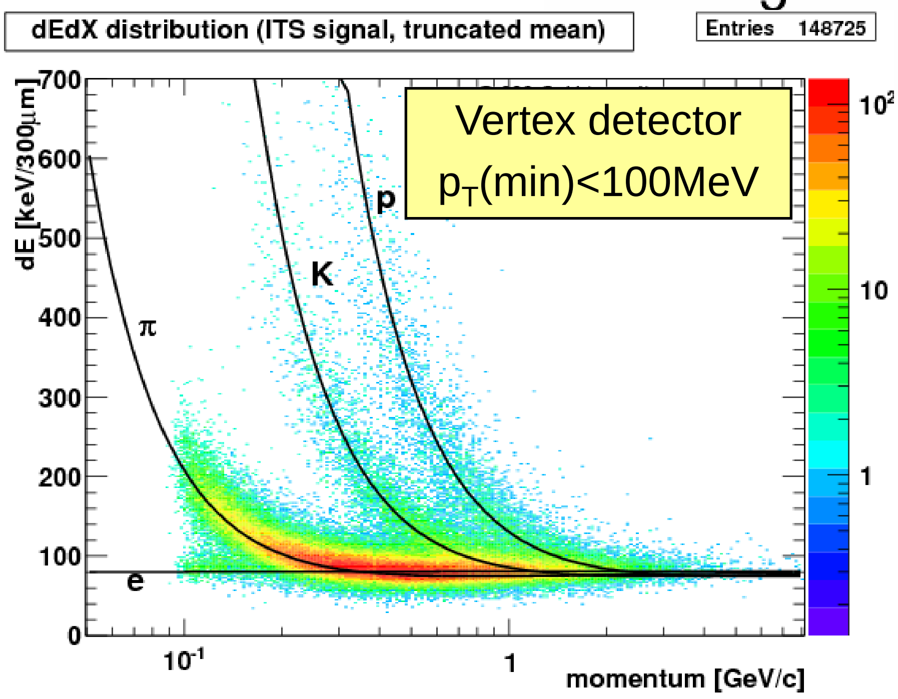


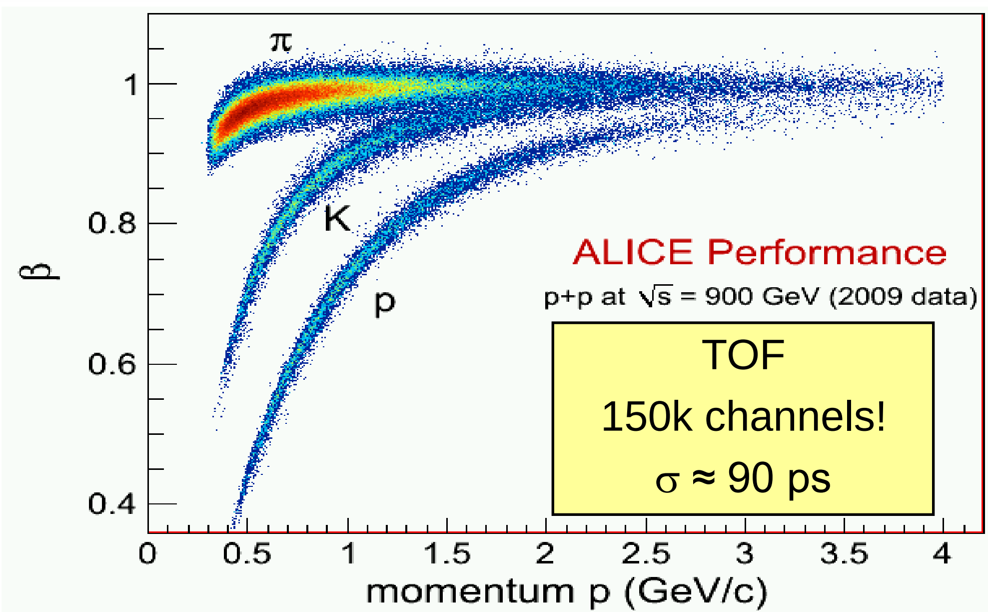


Short Status:
All systems fully operational

PID detectors

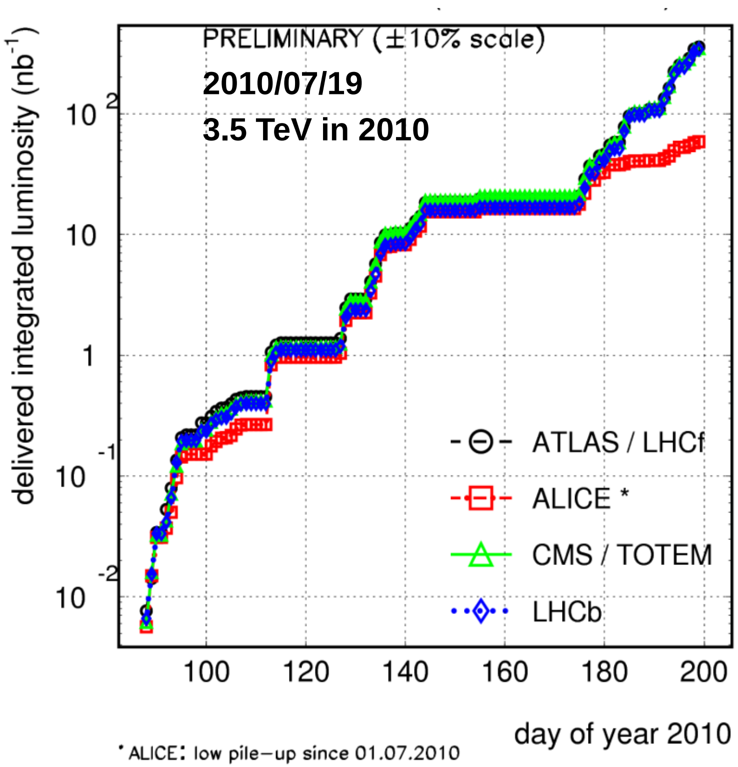


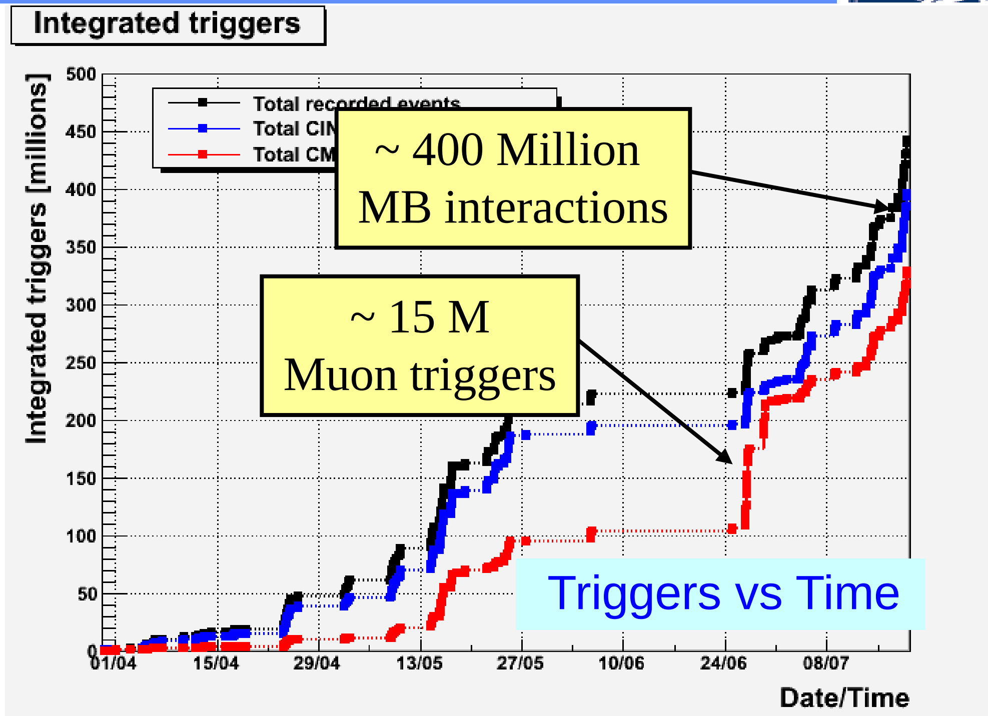


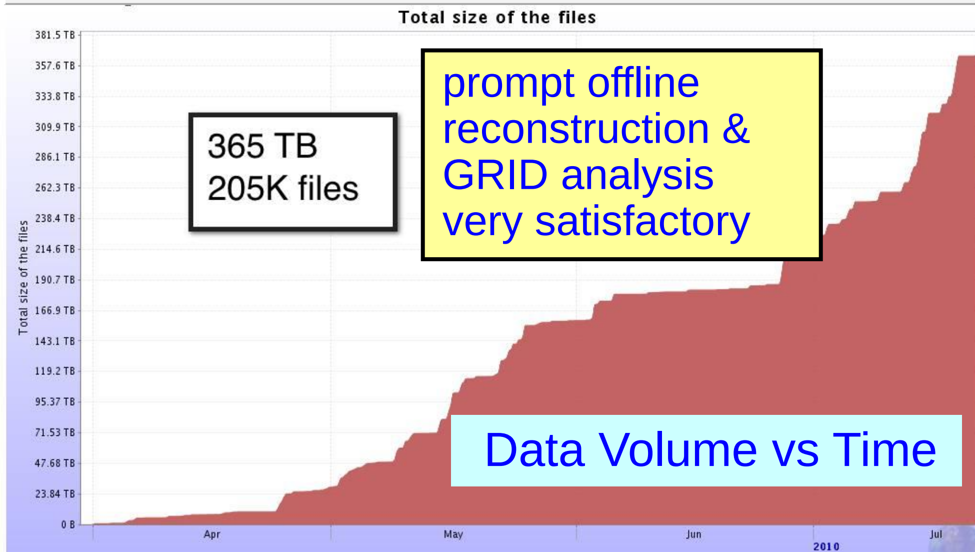


Data taking

Delivered Luminosity







Emphasis so far on MinBias triggers (need ~ 10^9)

since June reduced $\mathcal{L}$ to keep pile-up < 5%

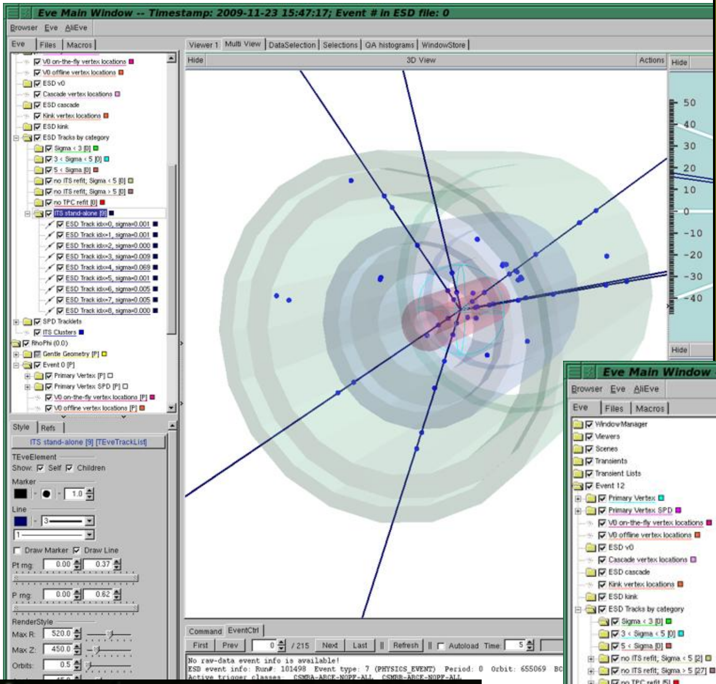
Physics results

- **Final Results**
  - N_{ch} **multiplicity & distributions**
    - **900 GeV:** — EPJC**: Vol.** 65 **(2010) 111**
    - 900 **GeV,** 2.36 **TeV:** — EPJC**: Vol.** 68 **(2011) 89**
    - 7 **TeV:** — arXiv:**1004.3514, accepted by EPJC**
  - **Momentum distributions(**900 **GeV)** — arXiv:**1007.0719**
  - **Bose Einstein correlations (**900 **GeV)** — arXiv:**1007.0516**
  - **pbar/p ratio (**900 **GeV &** 7 **TeV)** — arXiv:**1006.5432, accepted by PRL**

- **Ongoing analysis**
  - **Identified particles** (π,K,p,K^0,Λ,Ξ,Ω,ϕ)
  - **Heavy Flavor: charm** (D^0,D^+, D*), c,b –> μ, e^-
  - **J/Ψ** –> $\mu\mu$, e^+e^-
  - **pQCD: Event topology, 2-particle correlations, jet fragmentation, …**

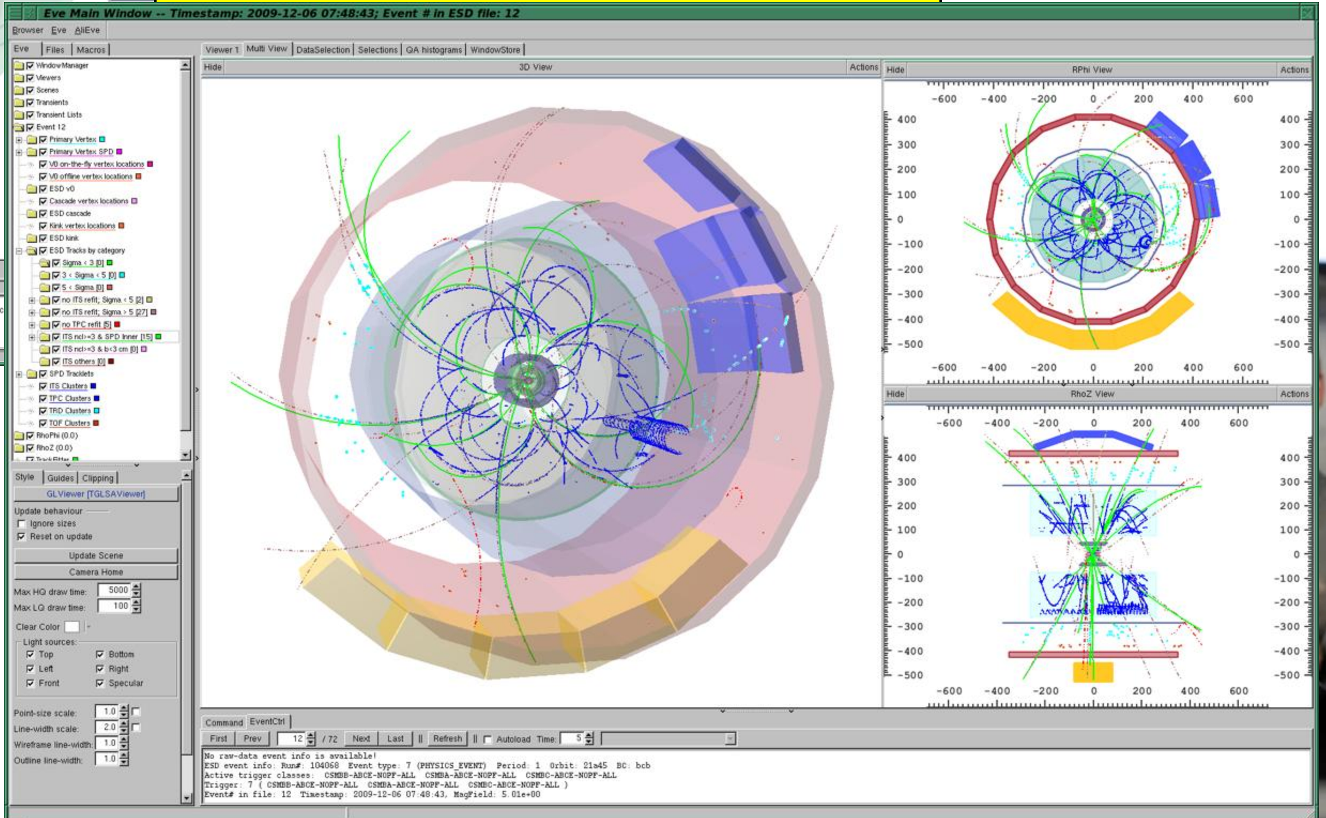
Events…

ALICE first event at 0.9 TeV …

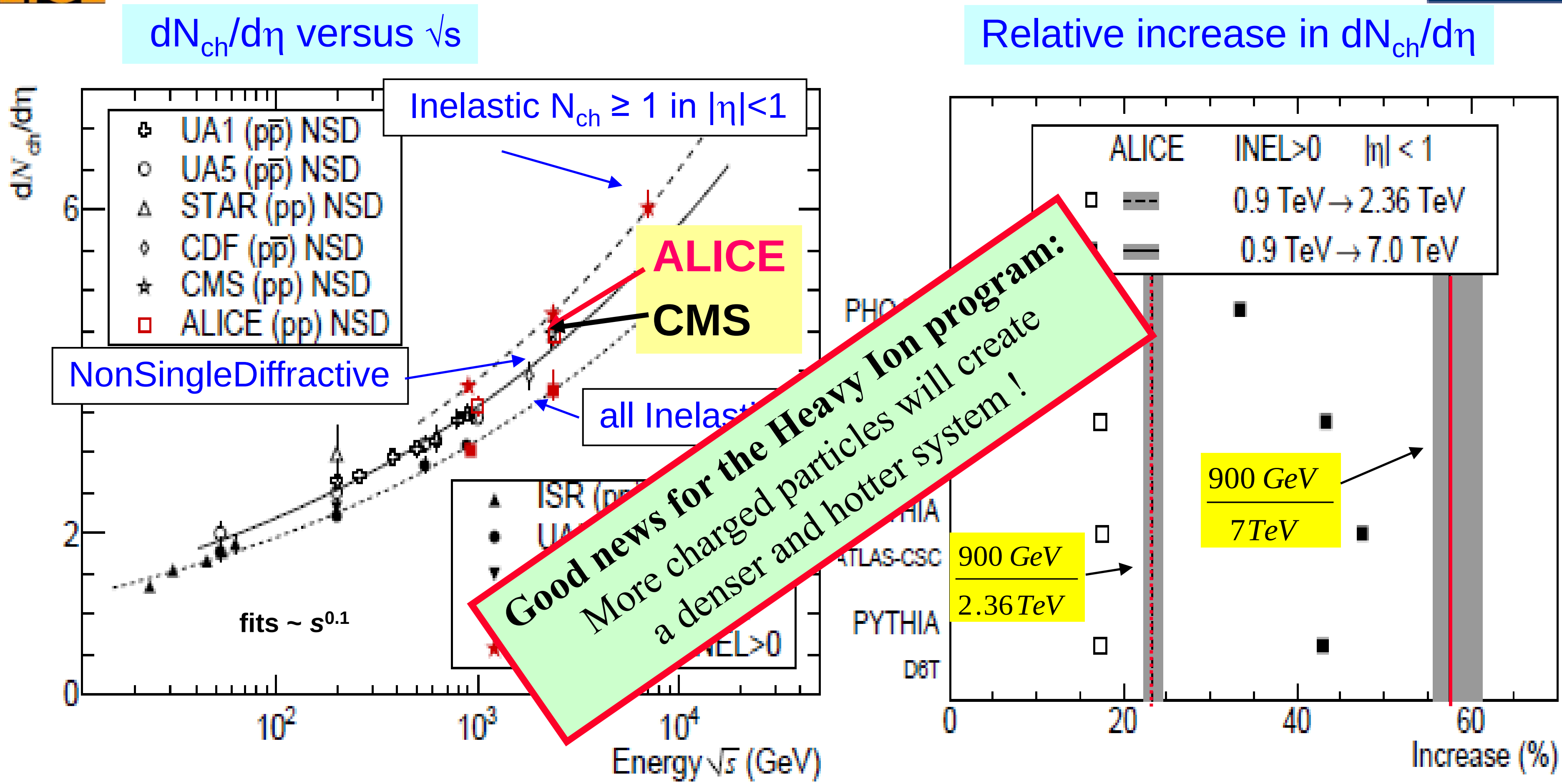


days after submitting our first paper
(28 Nov, 2009; ~3 authors/event !)
National Geographic News (4 Dec.)
'….a machine called ALICE....
found that **a** (!) proton-proton collision
recorded on November 23
created the precise ratio
of matter and antimatter particles

… and at 7 TeV



$dN_{ch}/d\eta$ versus $\sqrt{s}$

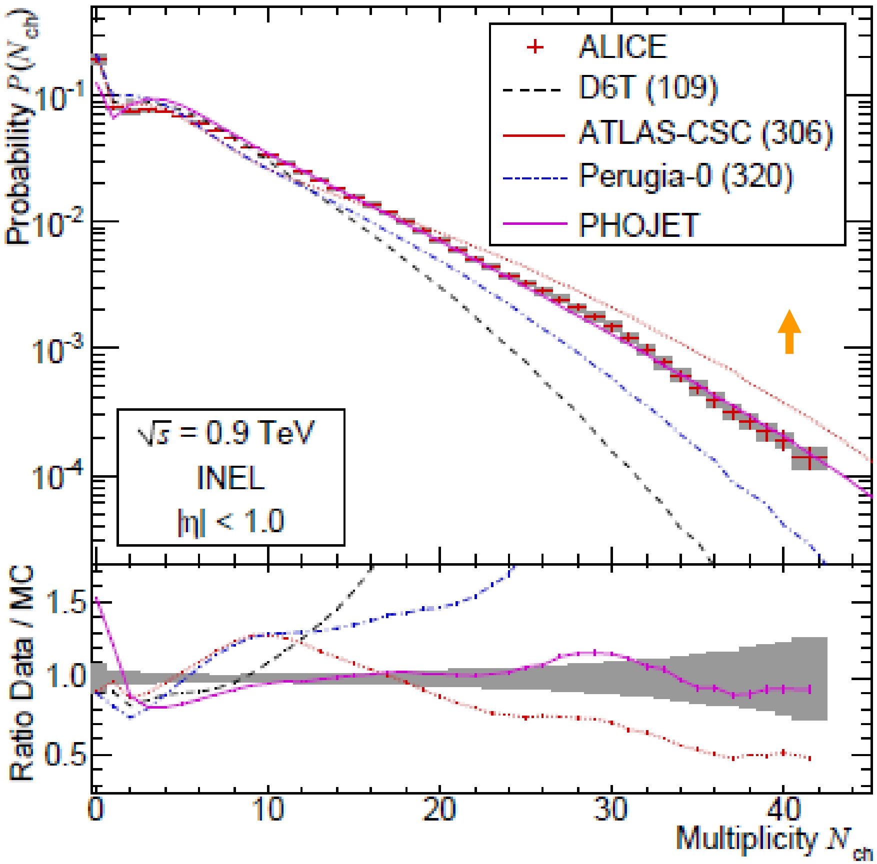


Results:

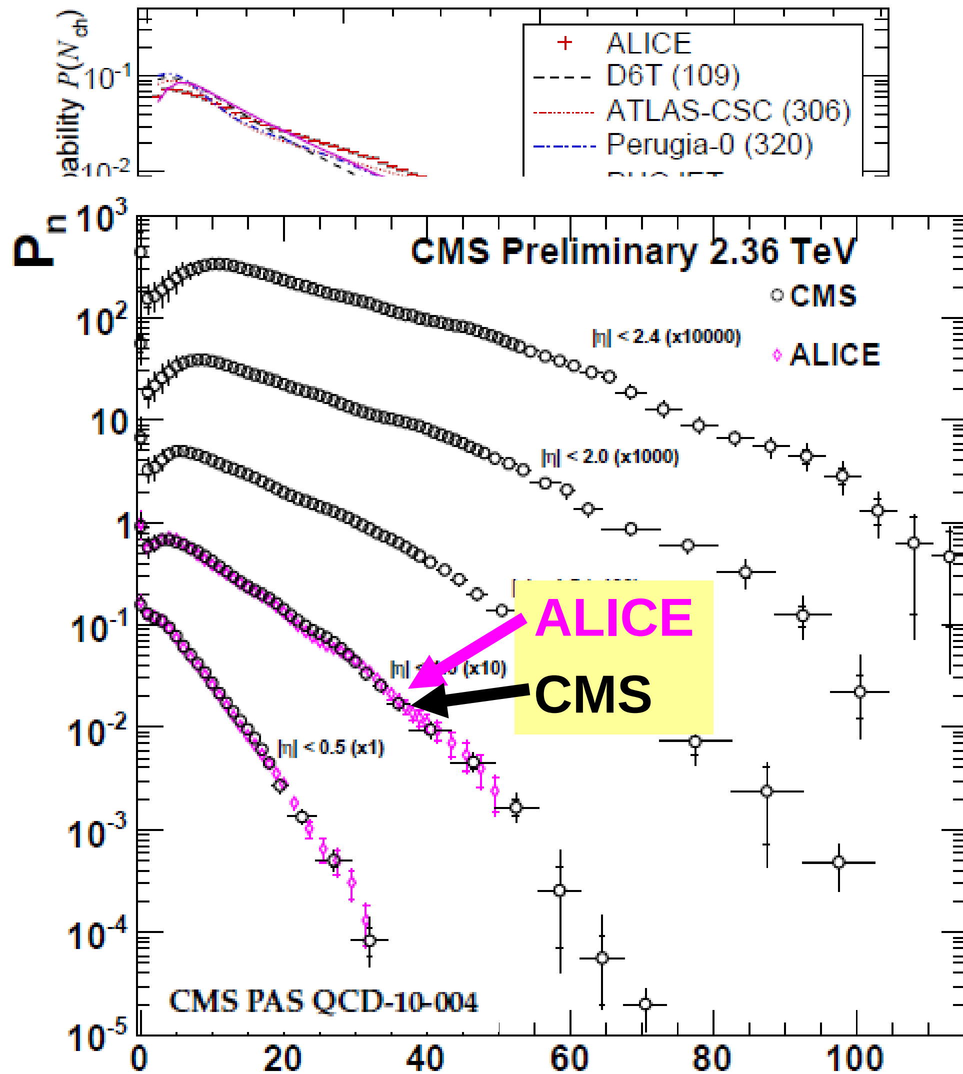
- $dN_{ch}/d\eta$ well described by power law $(\sqrt{s})^{0.2}$
- increase with energy significantly stronger in data than MC's
- Alice & CMS agree to within 1 σ (< 3%)

Multiplicity distribution

Multiplicity distribution 900 GeV



Multiplicity distribution 7 TeV

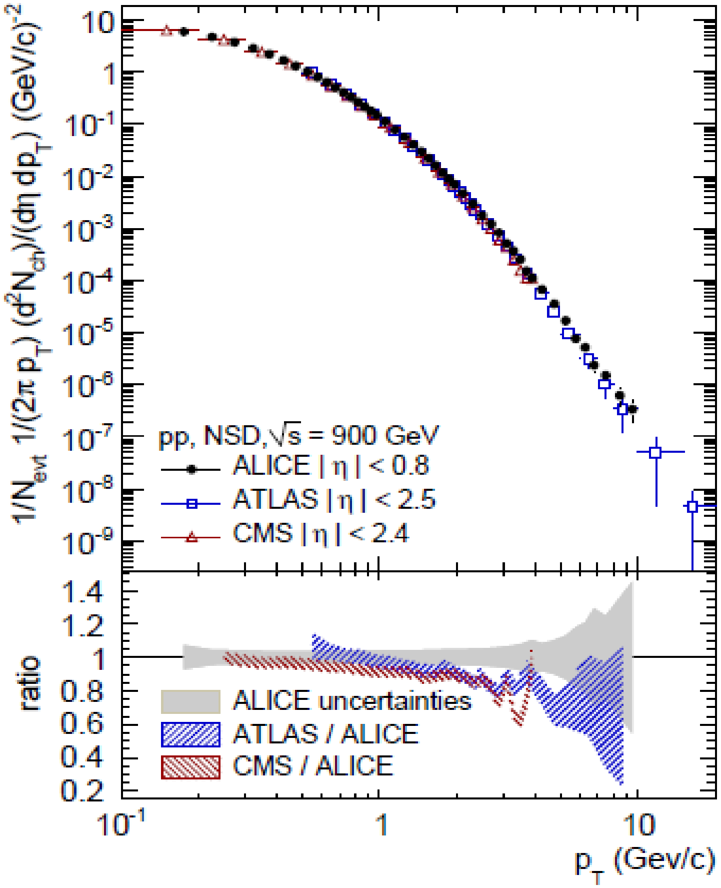


Results:

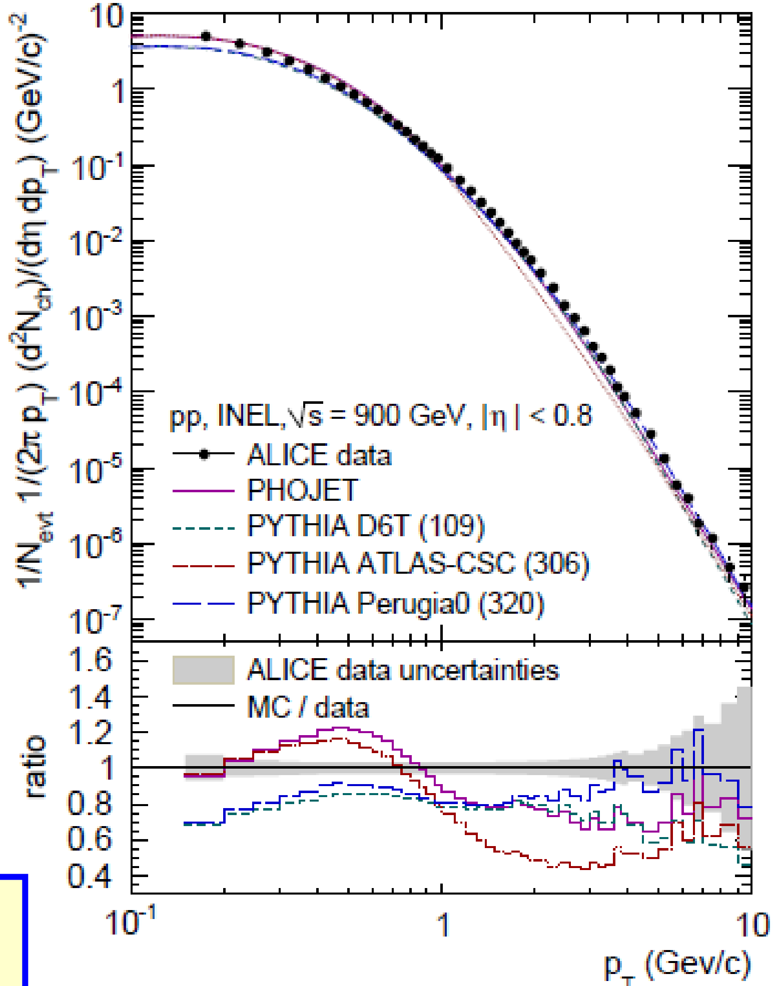
- most of the 'stronger increase' is in the tail of N_{ch}
- ALICE & CMS still agree perfectly !

Momentum distribution 900 GeV

p_T distribution



Comparison to MC's

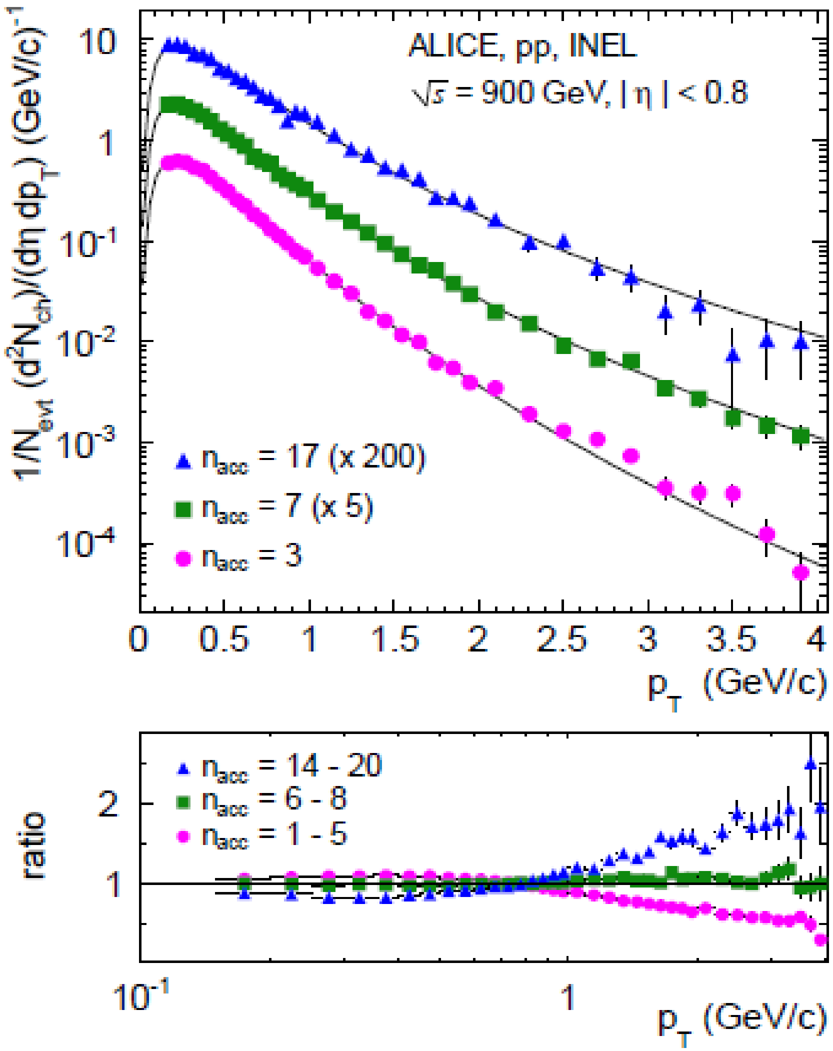


Results:

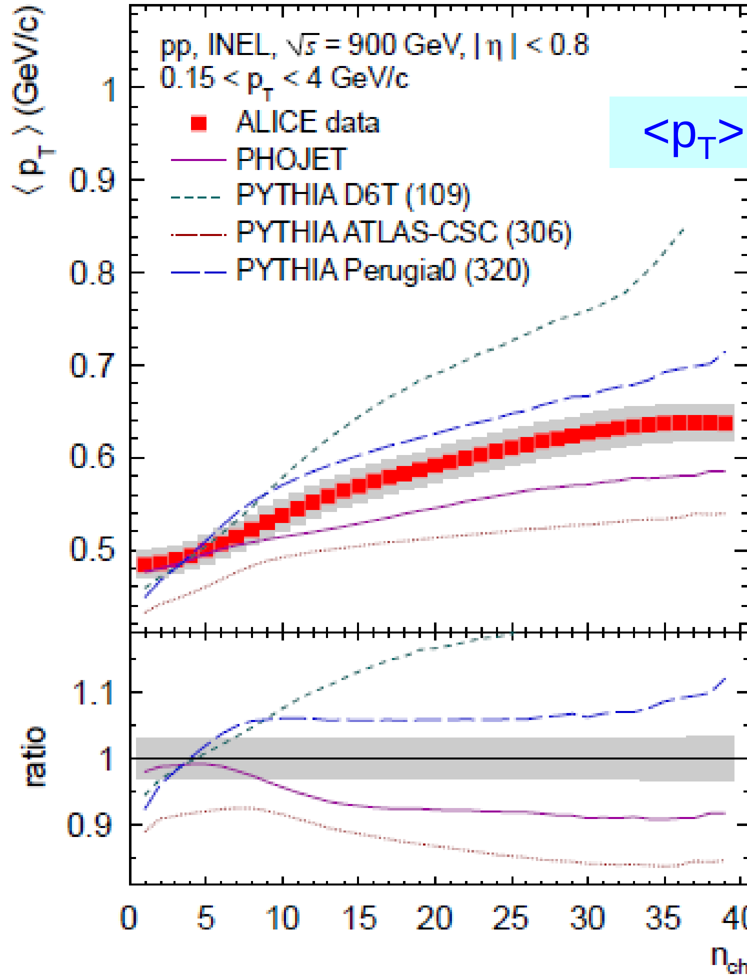
- Finally some (slight) difference !
- Spectrum seems to get harder towards midrapidity
- MC's have hard time to describe the full spectrum

$<p_T>$ versus multiplicity

p_T for different multiplicities



$<p_T>$ vs N_{ch}



Results:

- Change concentrated at pt > 1 GeV (pQCD)
  (surprisingly little change below)
- MC's have hard time…

MC scoreboard

Energy	MC/TUNE	D6T	Perugia0	CSC	PHOJET
0.9 TeV	$dN_{ch}/d\eta$	-20%	-17%	+3%	-2%
0.9 TeV	N_{ch}	N_{ch}>10	N_{ch}>5	N[illegible]>15	N_{ch}>10
0.9 TeV	p_t			[illegible]eV	p_t>1GeV
0.9 TeV	$<p_t>$				
2.36 TeV	η	-24%	-2[illegible]	-2%	-8%
2.36 TeV	N_{ch}	N_{ch}>10	N_{ch}>5	N_{ch} >20	N_{ch}>15
7 TeV	η	-27%	-24%	-4%	-17%
7 TeV	N_{ch}			N_{ch} >30	

Stay tuned !

- MC << data
- MC >> data
- MC ≈ data

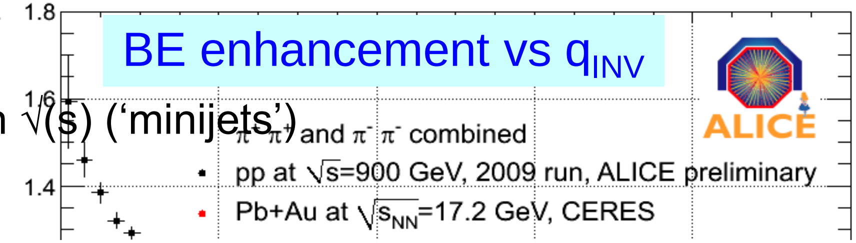
Conclusion:

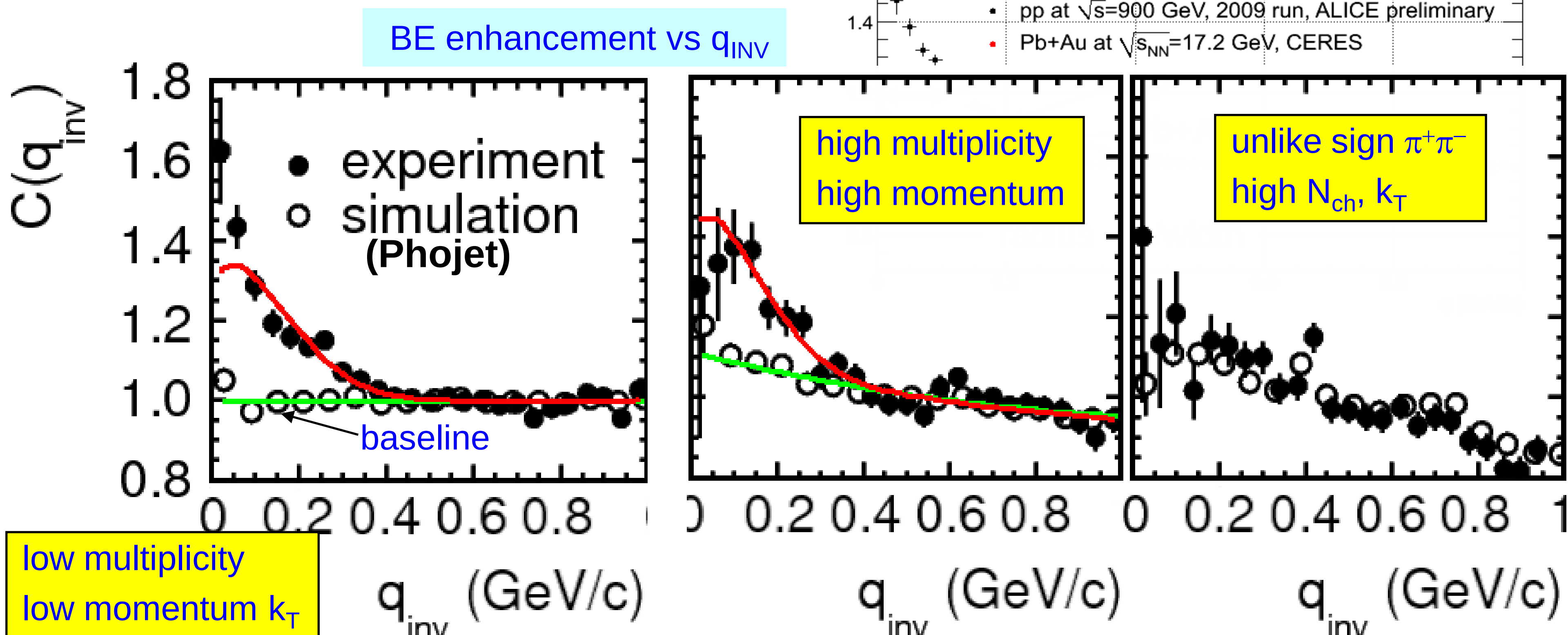
- none of the tested MC's (adjusted at lower energy) does really well
- tuning one or two results is easy, getting everything right will require more effort

(and may, with some luck, actually teach us something on soft QCD rather than only turning knobs)

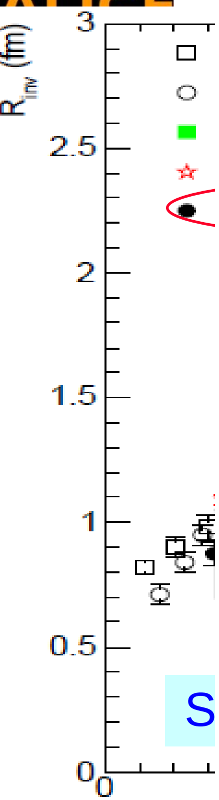
Bose–Einstein correlations (HBT)

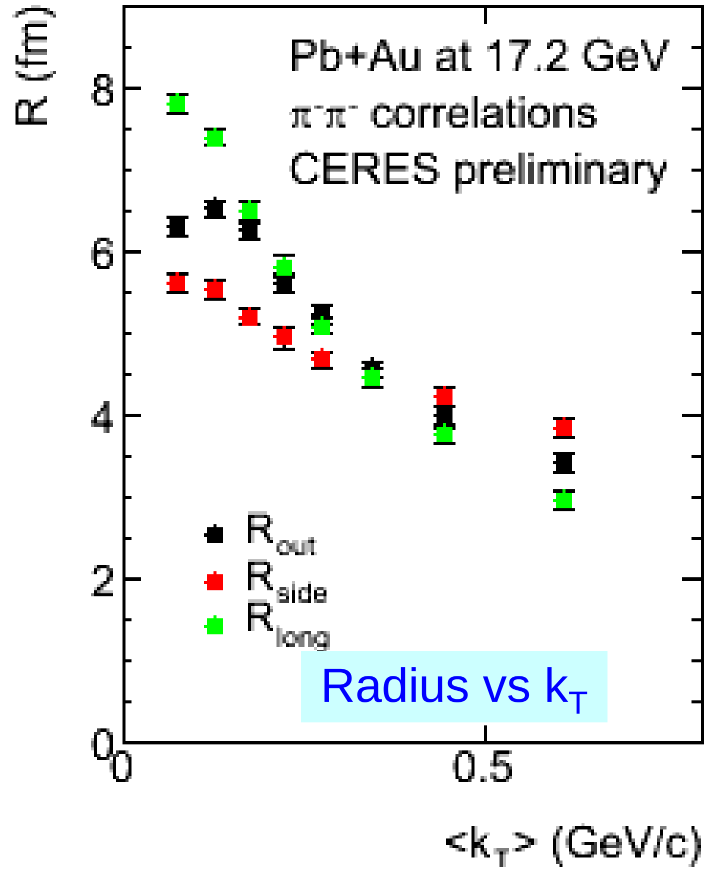
- QM enhancement of identical Bosons at small momentum difference
  - ⇨ enhancement of e.g. like-sign pions at low momentum difference $q_{inv}=|p_1-p_2|$, as function of multiplicity and pair momentum $k_T = |p_{T1}+p_{T2}|/2$
  - ⇨ measure Space-Time evolution of the 'dense matter' system in heavy ions coll.
    - ✪ interpretation in 'small systems' (pp, e^+e^-) is less obvious..
  - ⇨ 'enhancement' rel. to phase-space and any non-BE correlations ('baseline')
    - ✪ non-BE correlations important at high √(s) ('minijets')





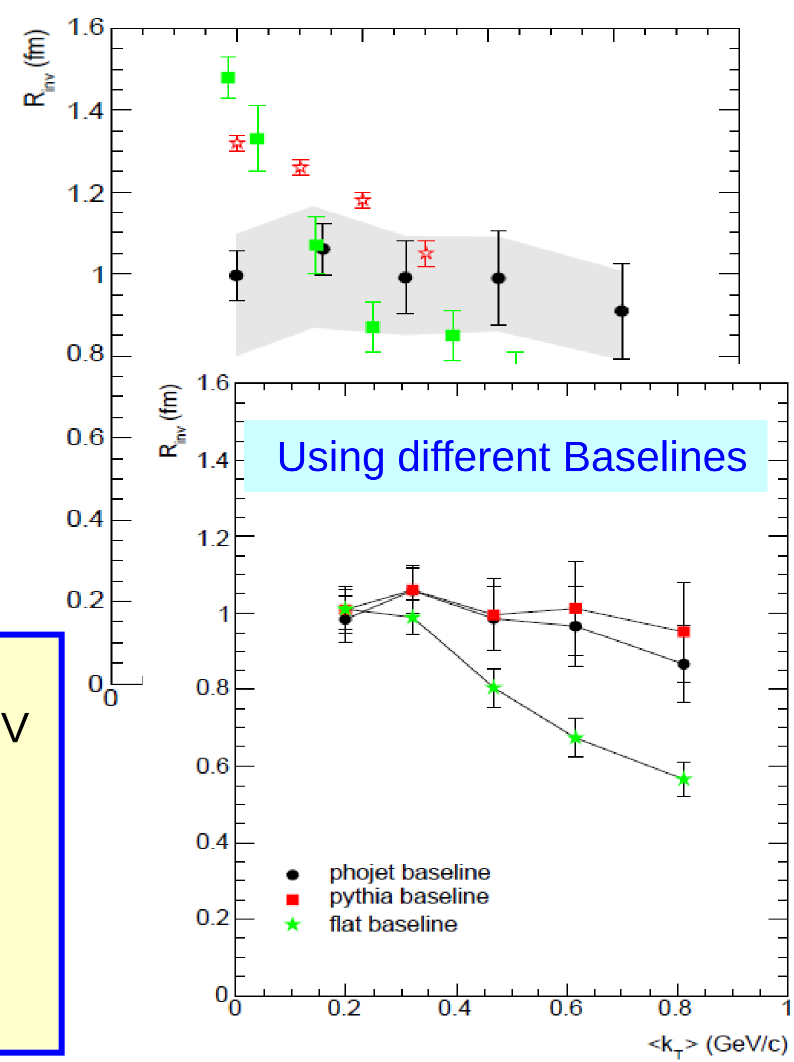
HBT @ 900 GeV





Radius vs k_T

Source Radius vs pair momentum



Using different Baselines

Results:

- Radius increases with N_{ch}, comparable to ISR, RHIC, TeV
- rather constant vs $<k_T>$!

  sign. systematic uncertainty from 'baseline' shape

  dependence usually interpreted as sign of 'flow' in heavy ions
- neglecting non-BE correlations ('flat baseline') can cause k_T dependence (at high $\sqrt{s}$)!

$\bar{p}$/p ratio

- Can one stop a proton 'on its track' at LHC ?
  - ⇨ where does the conserved baryon number reappear after the pp collision ?
  - ⇨ fragmentation function f(z) of baryon number
    - ✪ Di-quark qq: z^2 => $\alpha = -1$, small Δy
    - ✪ single q: $\sqrt{z}$ => $\alpha = 0.5$, medium Δy
    - ✪ no valence q: α = ??; large Δy ??

    Veneziano: $\alpha \approx 0.5$ others: $\alpha \approx 1$ (pQCD estimates, σ(p-pbar annihilation), 'odderon')

    $\alpha \approx 1$ => f(y) = constant, pbar/p < 1 at all energies (< 0.93 at LHC)

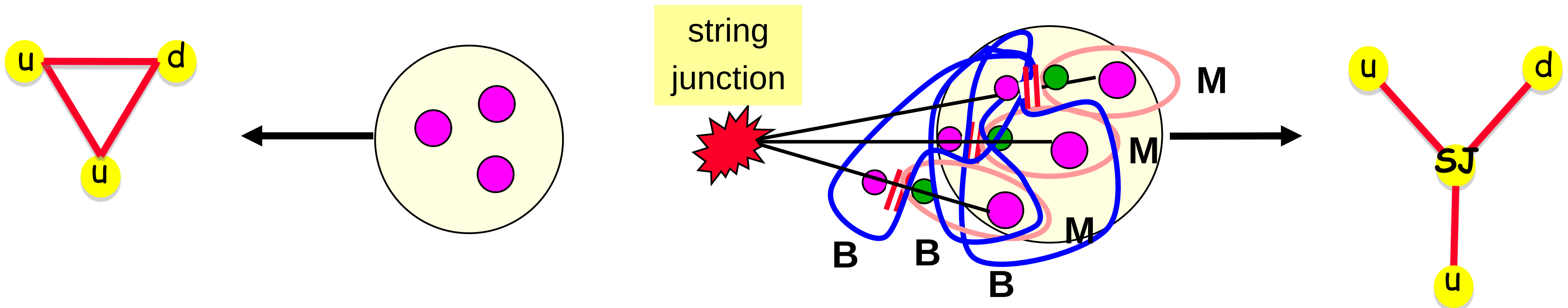
$z^a \sim e^{-a\Delta y} = e^{-(1-\alpha)\Delta y}$ (Δy »1)

α = intercept of relevant Regge trajectory

$\Delta y = y_{beam} - y_{baryon}$ = 'rapidity loss'

G.C. Rossi and G. Veneziano, Nucl. Phys. B123, (1977) 507

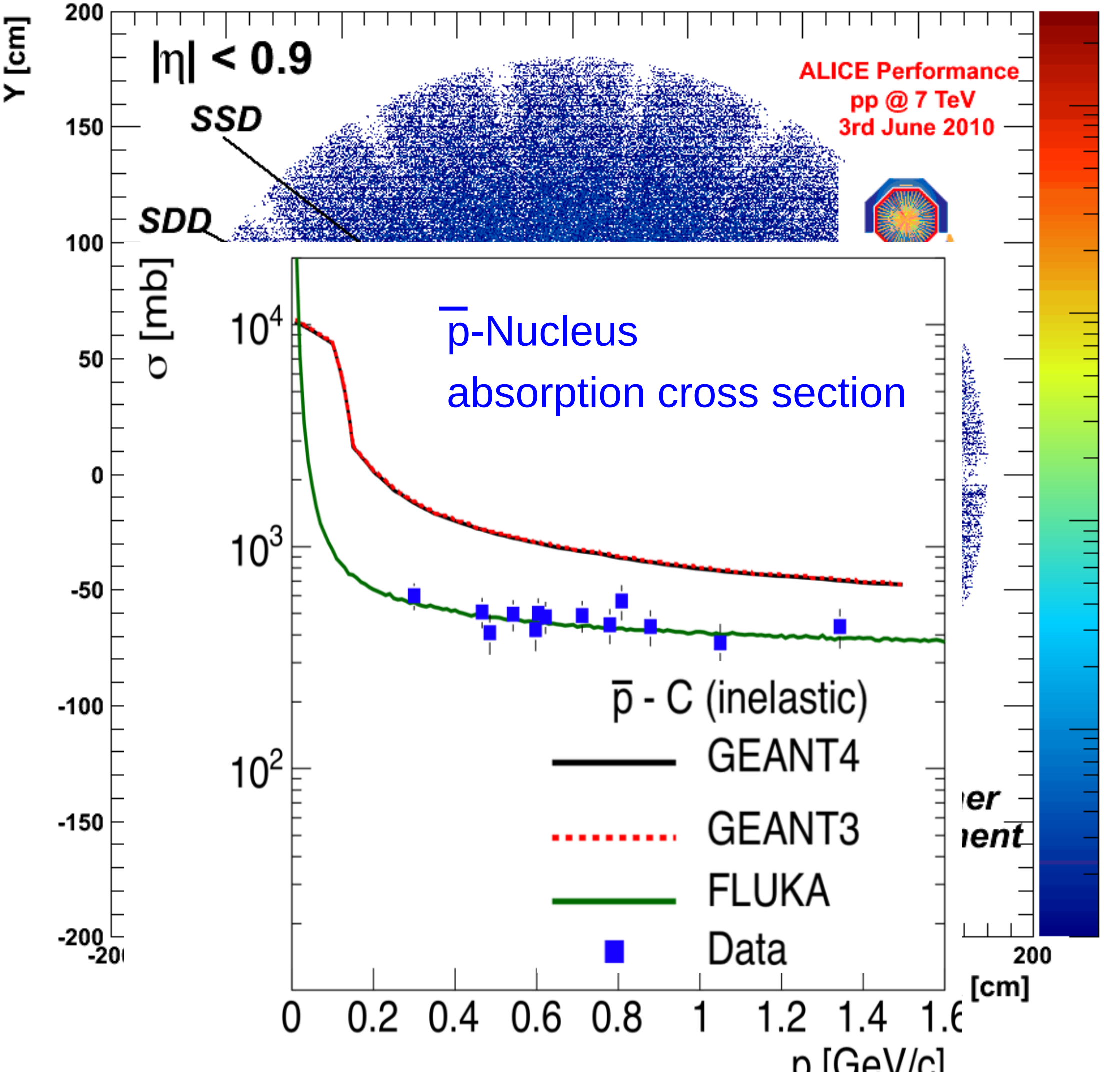
B.Z. Kopeliovich, Sov. J. Nucl. Phys. 45, 1078 (1987)

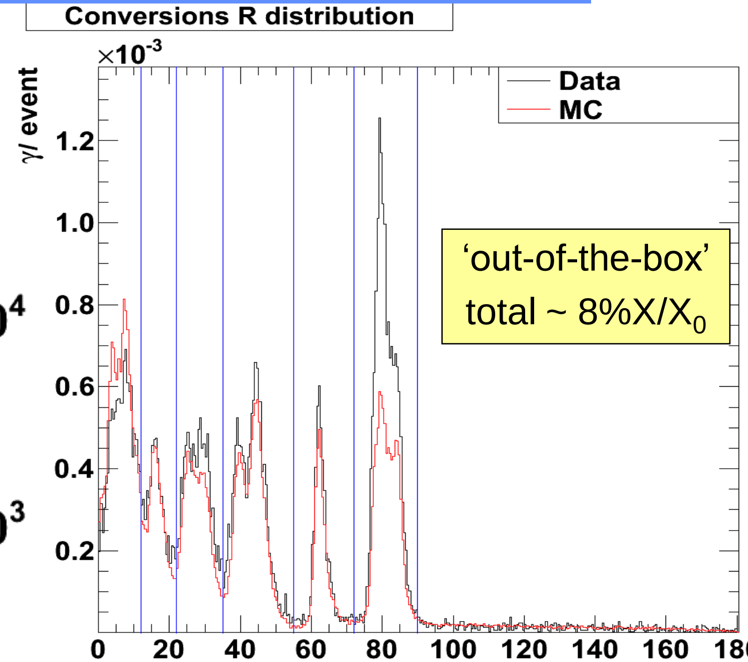


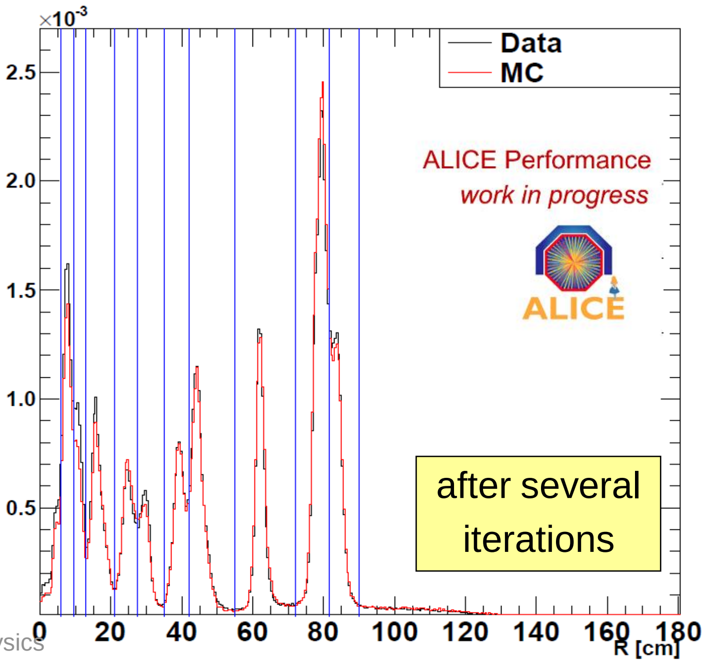
- **Intermezzo: How to measure pbar/p to O(1%) ?**
  - ⇨ **ratio => most instrumental effects cancel**
  - ⇨ **σ(pbar-Nucleus) » σ(p-Nucleus) => absorption/el. scattering correction of O(10%)**

Material budget (what did we actually built ?)

γ-ray image of ALICE
photon conversion vertices

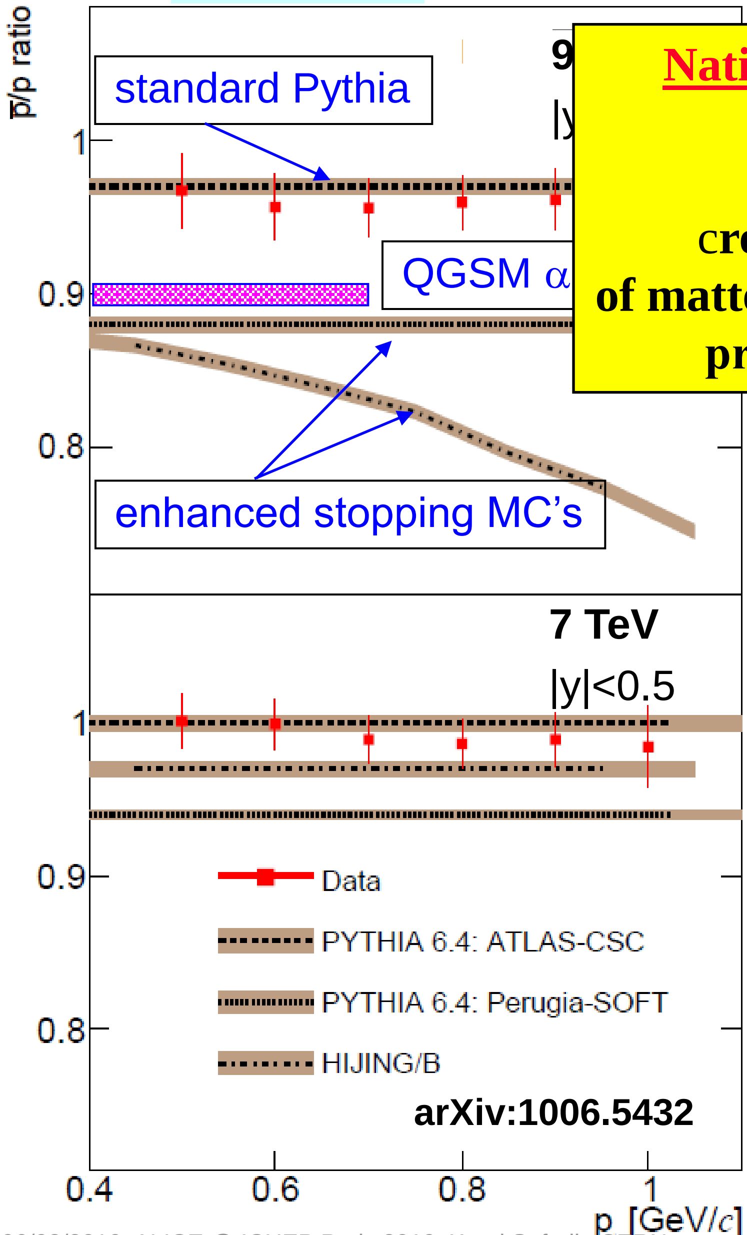




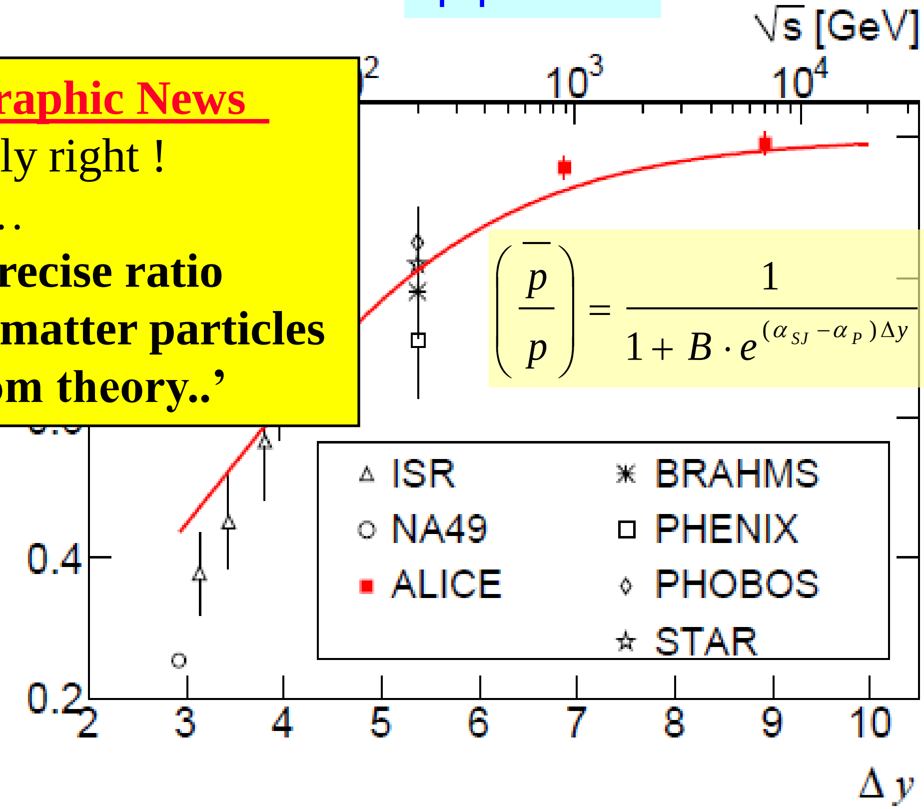


p̄/p ratio @ LHC

p̄/p vs p_T



p̄/p vs √s



National Geographic News
was actually right !
……
created the precise ratio of matter and antimatter particles predicted from theory..'

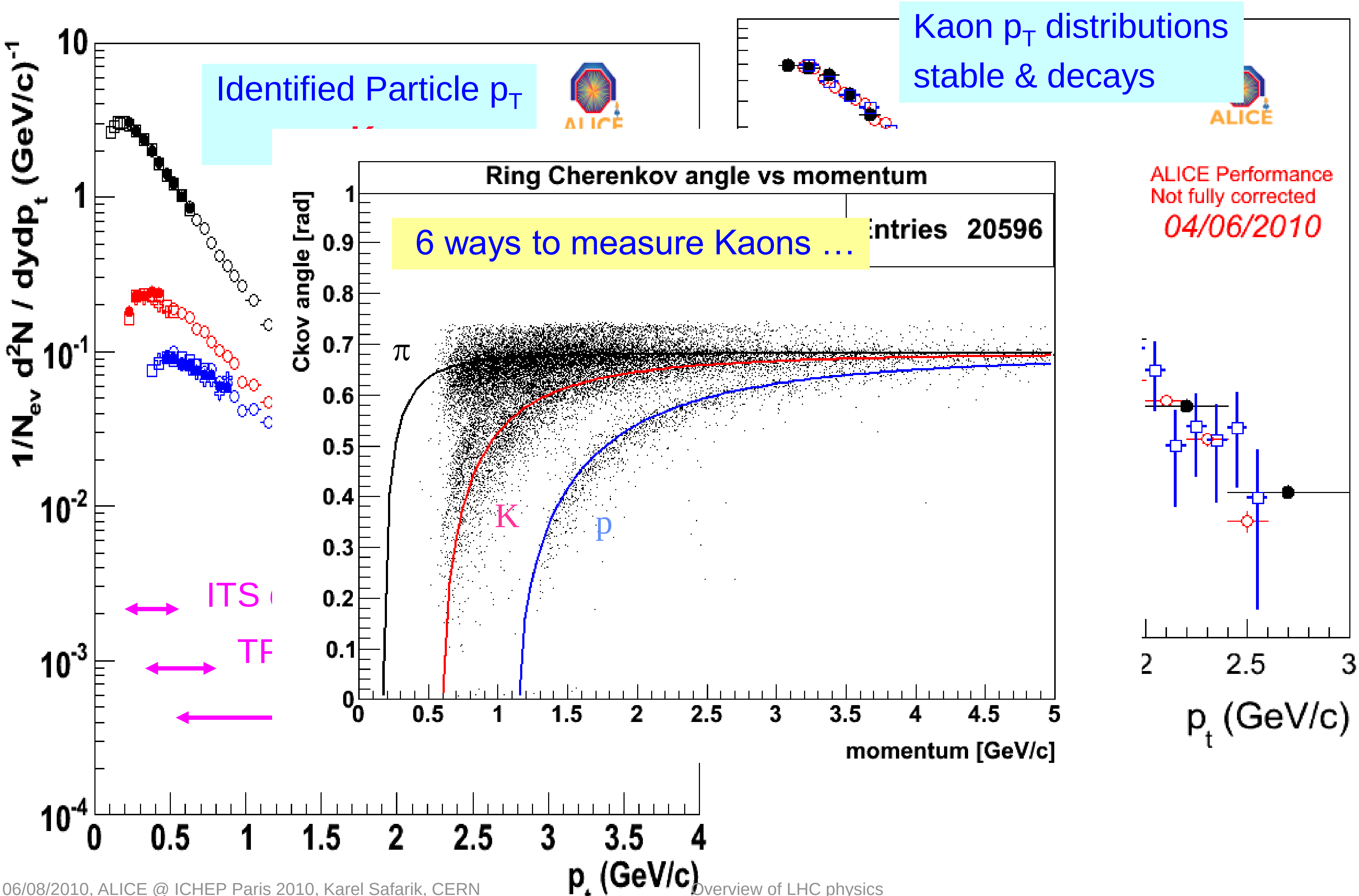
Results:

- you can't stop a proton on its track (at least not at LHC)
- 'string junction' picture: $\alpha_{SJ} \approx 0.5$ (G.V. was right !)
- little room for **any** additional diagrams which transport baryon number over large rapidity gaps

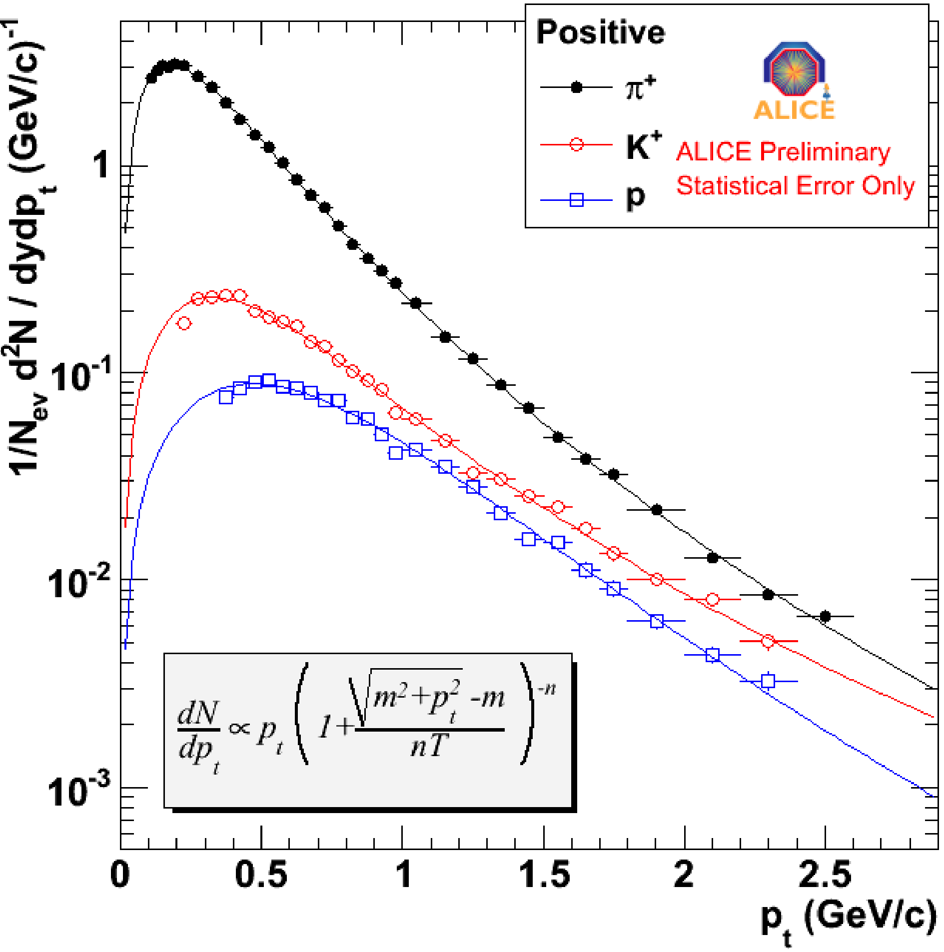
0.9 TeV: p̄/p = **0.957**±0.006(stat) ±0.014(syst)

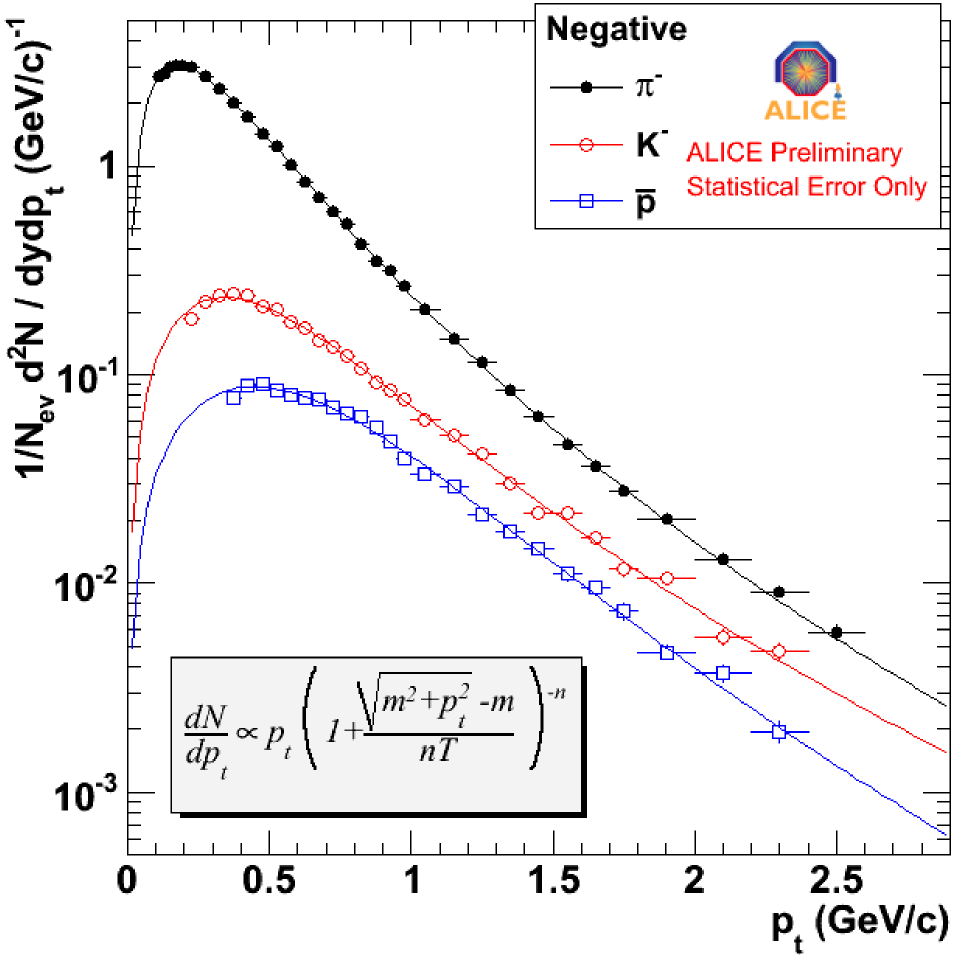
7 TeV: p̄/p = **0.990**±0.006(stat) ±0.014(syst)

Identified particles

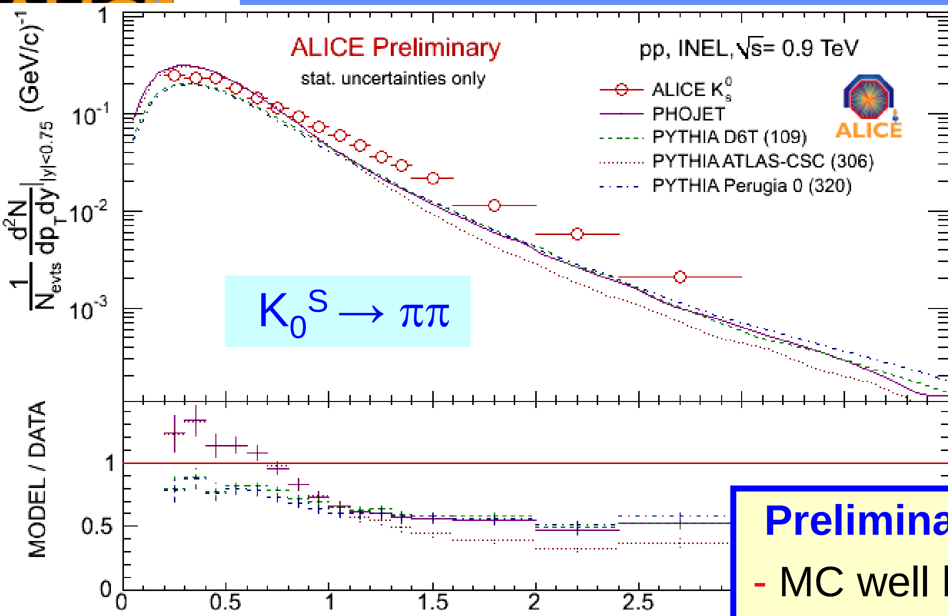


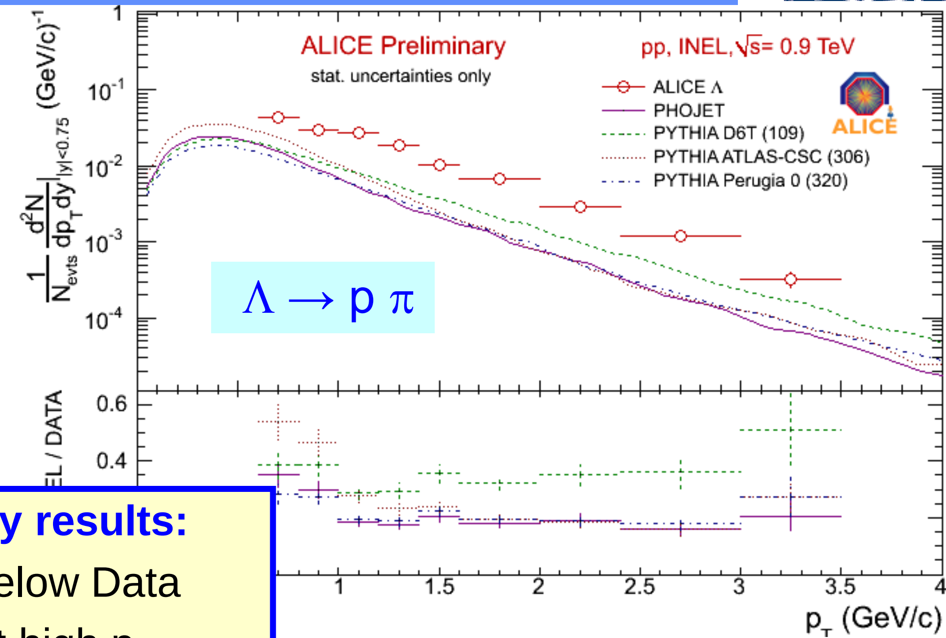
Charged: π, K, p at 900 GeV

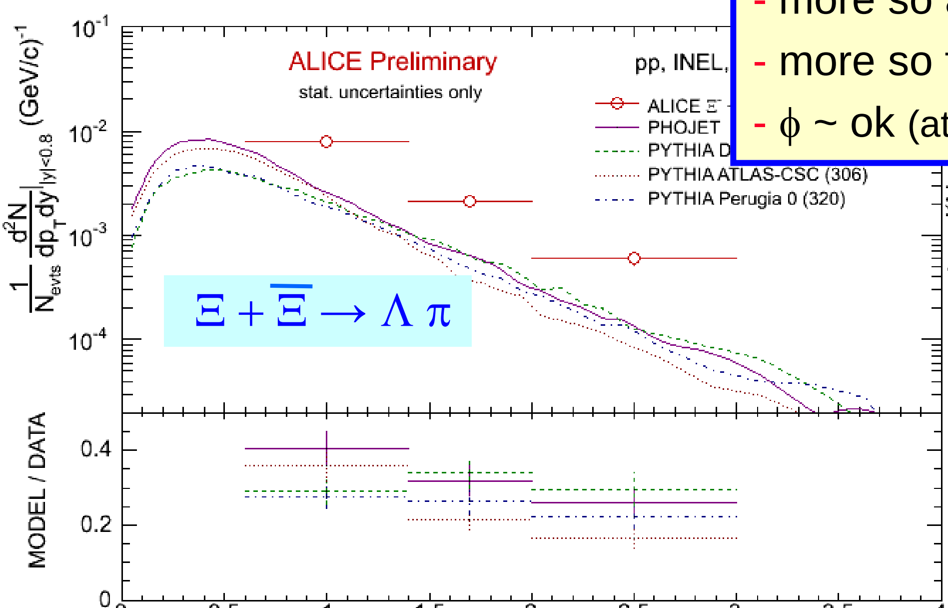


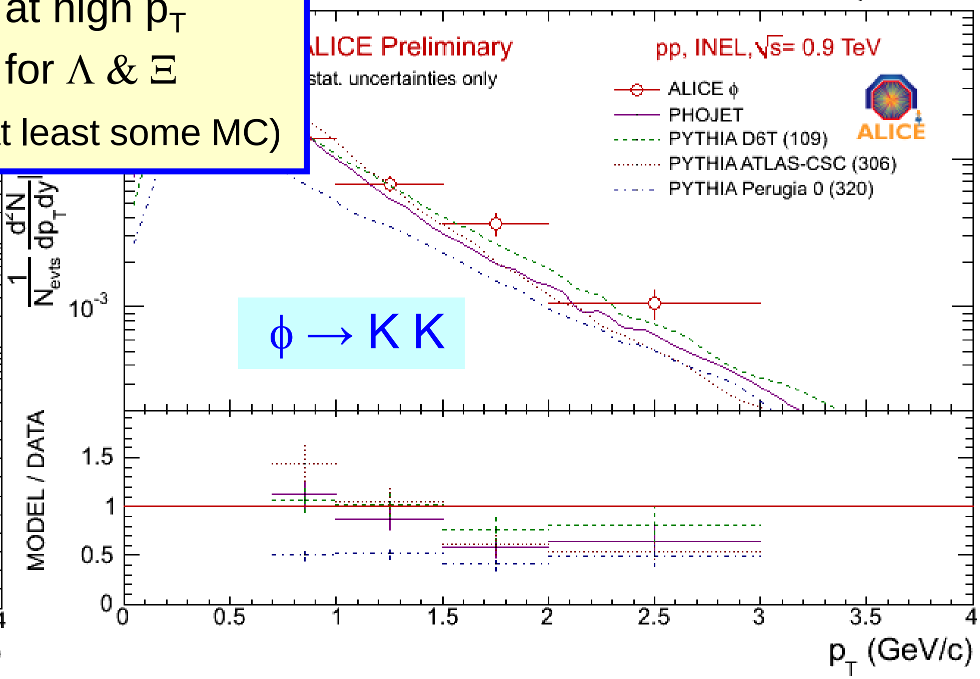


Decays: K_0^S, Λ, Ξ, ϕ at 900 GeV *







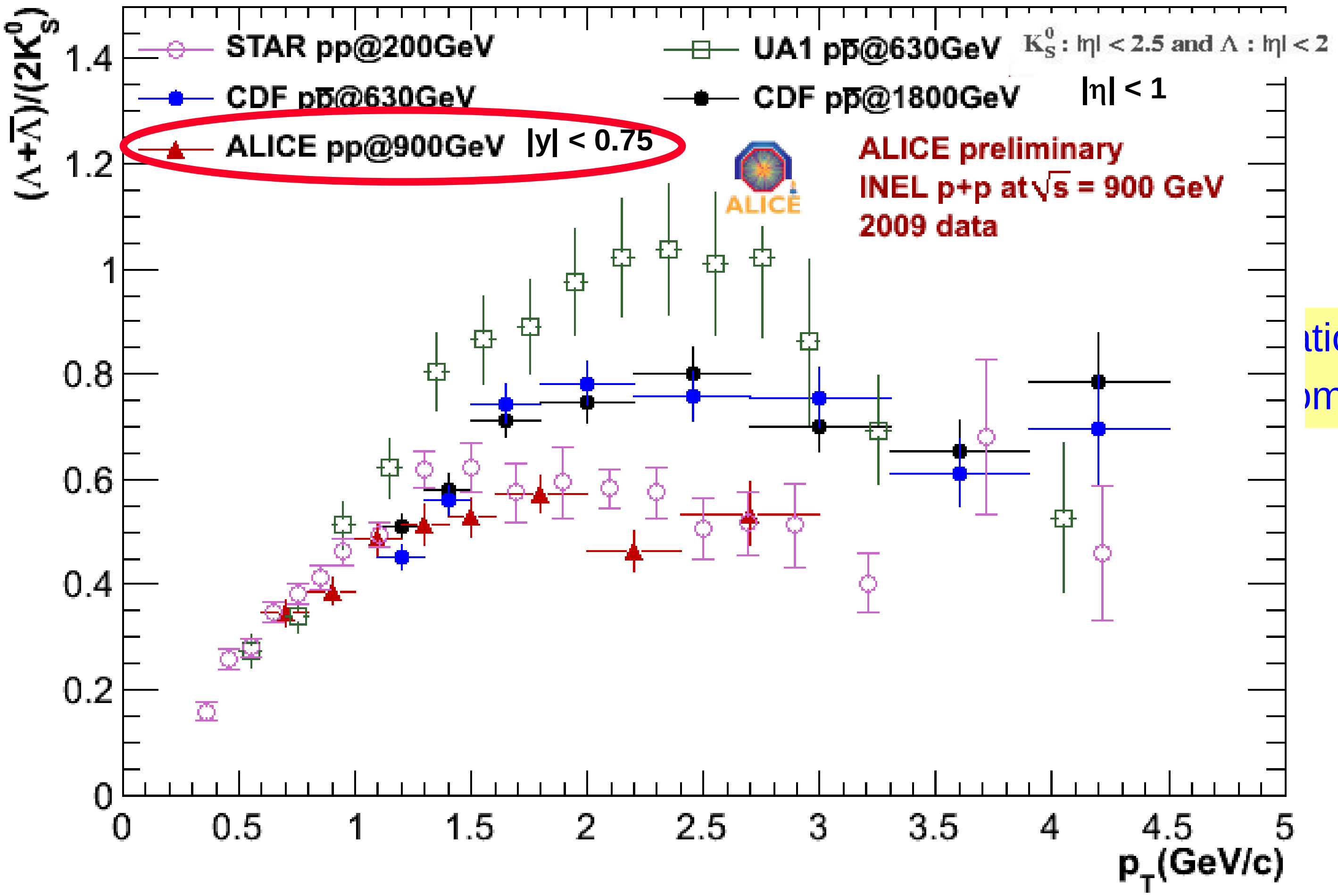


Preliminary results:

- MC well below Data
- more so at high p_T
- more so for Λ & Ξ
- ϕ ~ ok (at least some MC)

* 2009 Data (~300 k events)

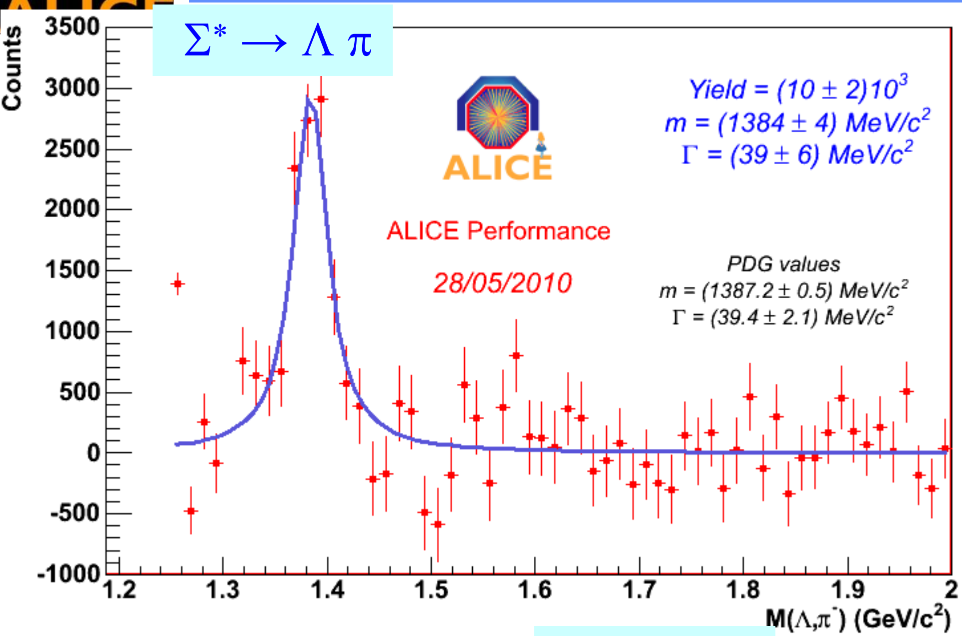
Λ/K_0^S ratio 900 GeV

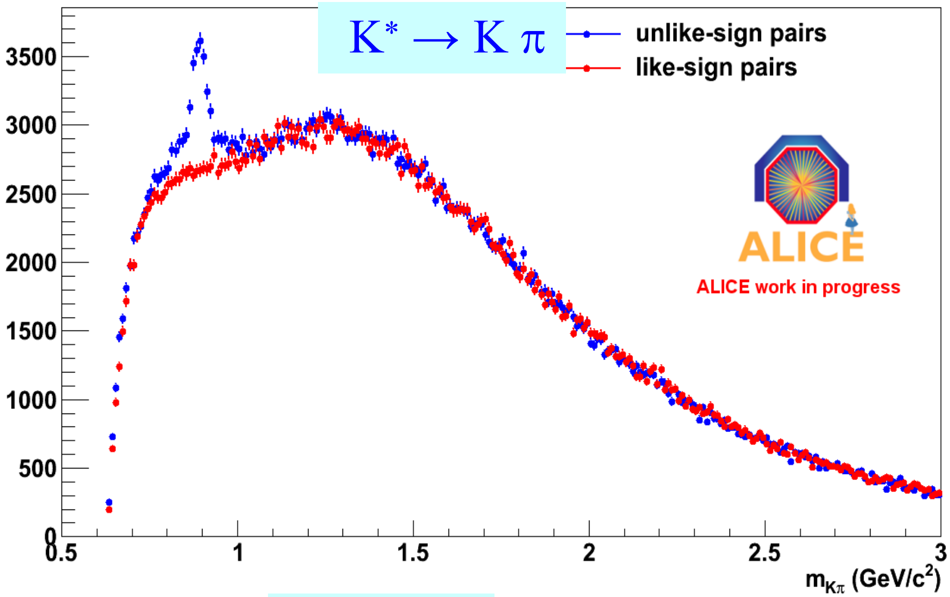


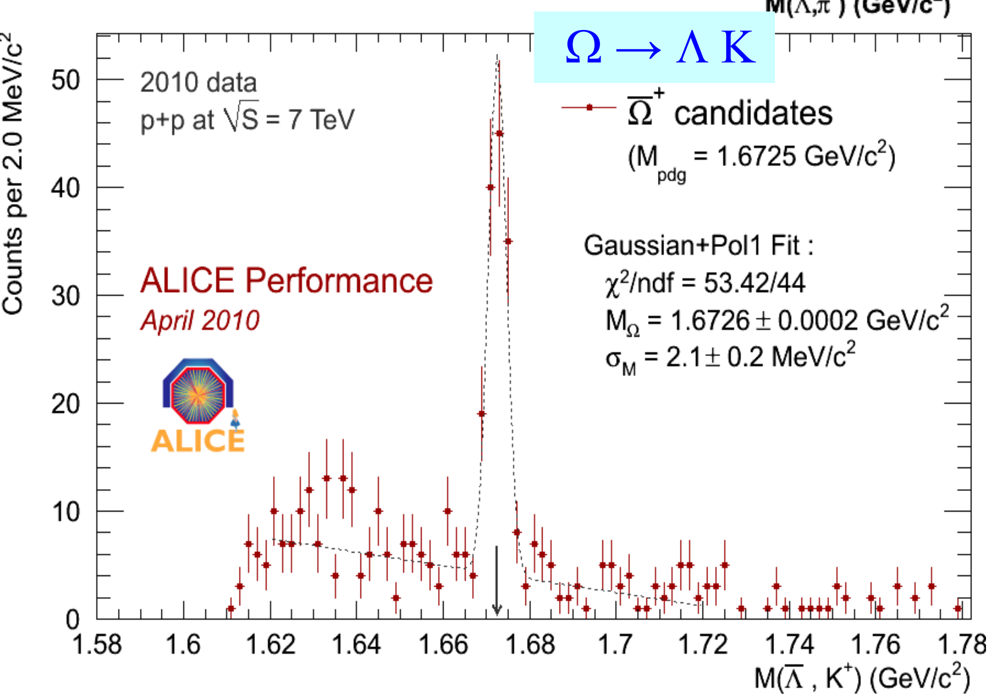
- very good agreement between STAR (200 GeV) and ALICE (900 GeV)
- very different from CDF (630/1800) and UA1 (630) for p_T > 1.5 GeV
- UA1(630) and CDF(630) don't agree either …

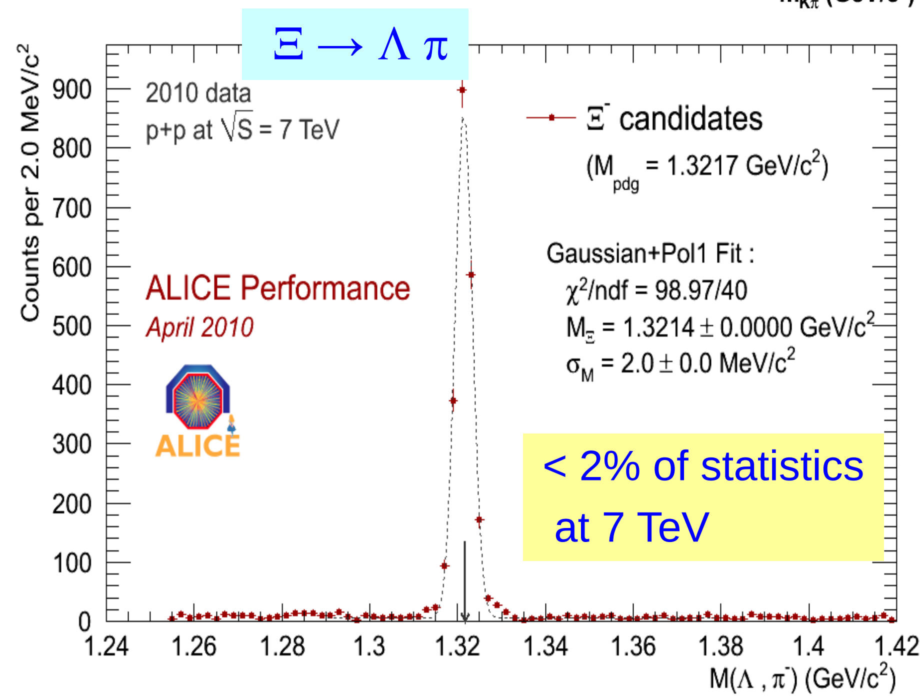
to be further investigated (different triggers, acceptance, feed-down correction ?)

...and much more to come...





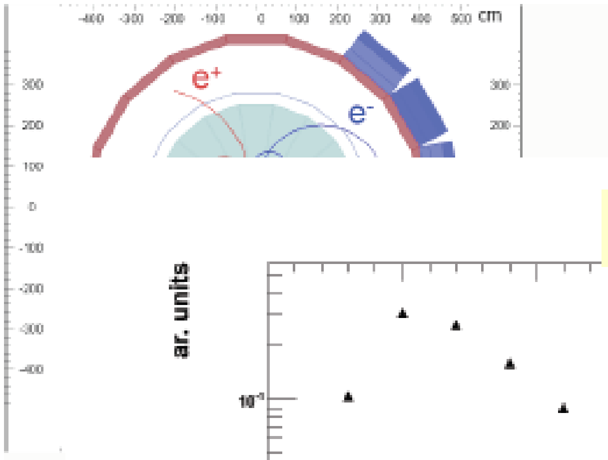




< 2% of statistics at 7 TeV

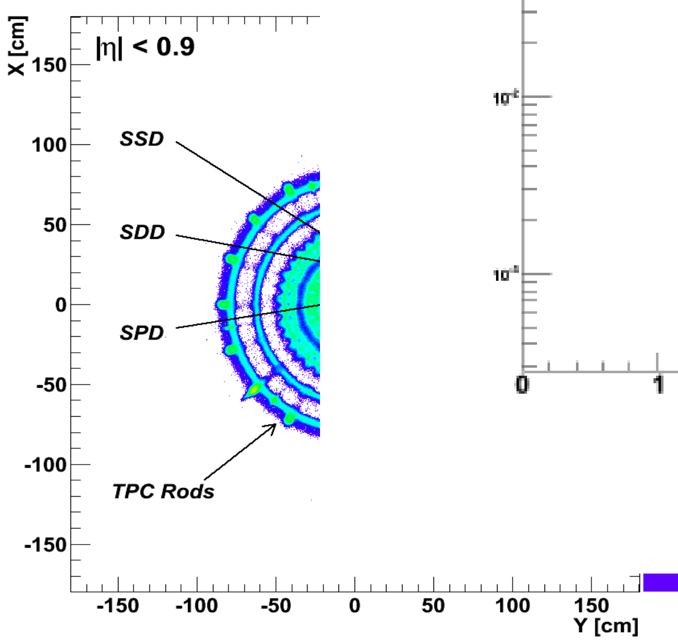
π^0 and η from γ conversion

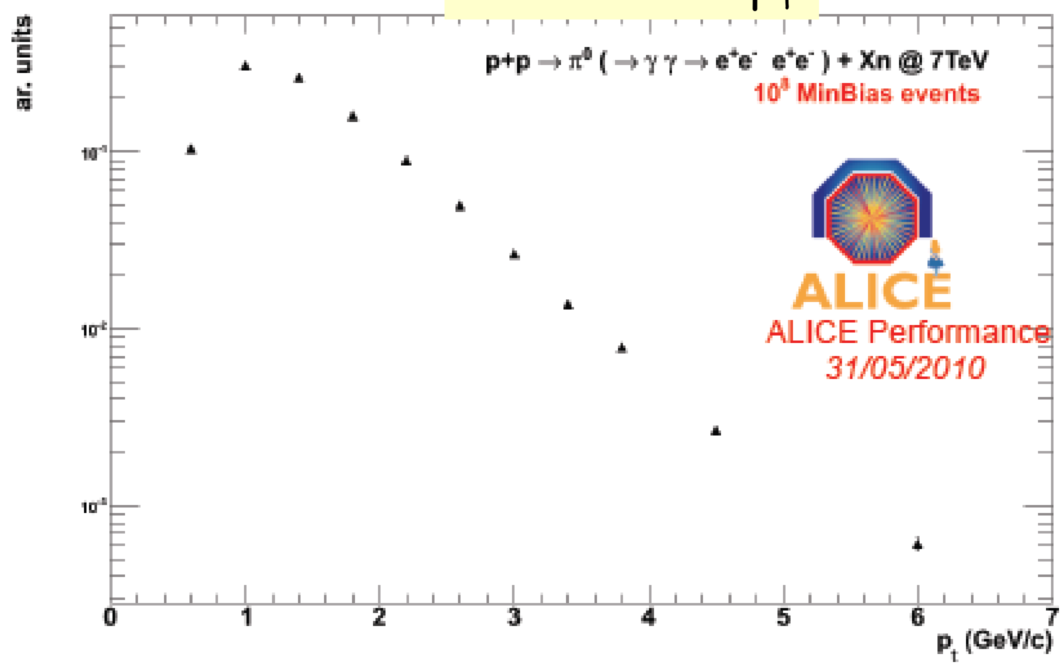
- e identification in TPC (TRD soon)
- study of γ conversion points/material

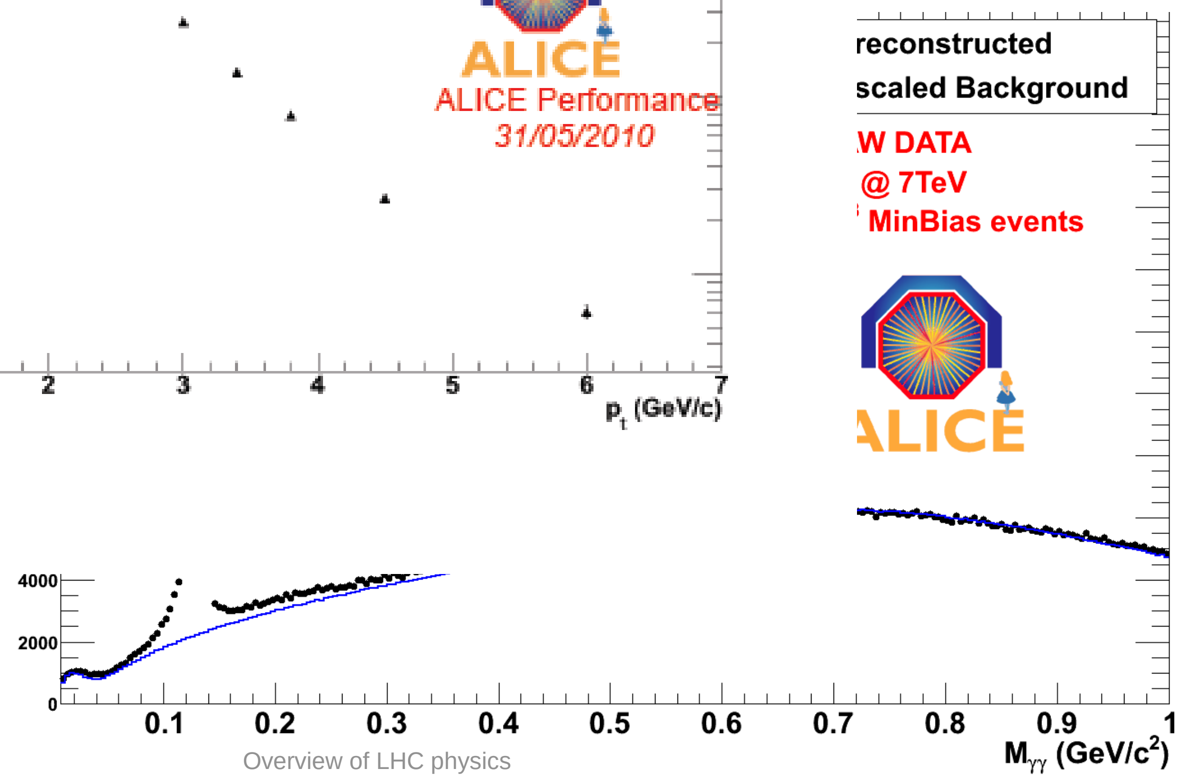


Raw π^0 dN/dp_T

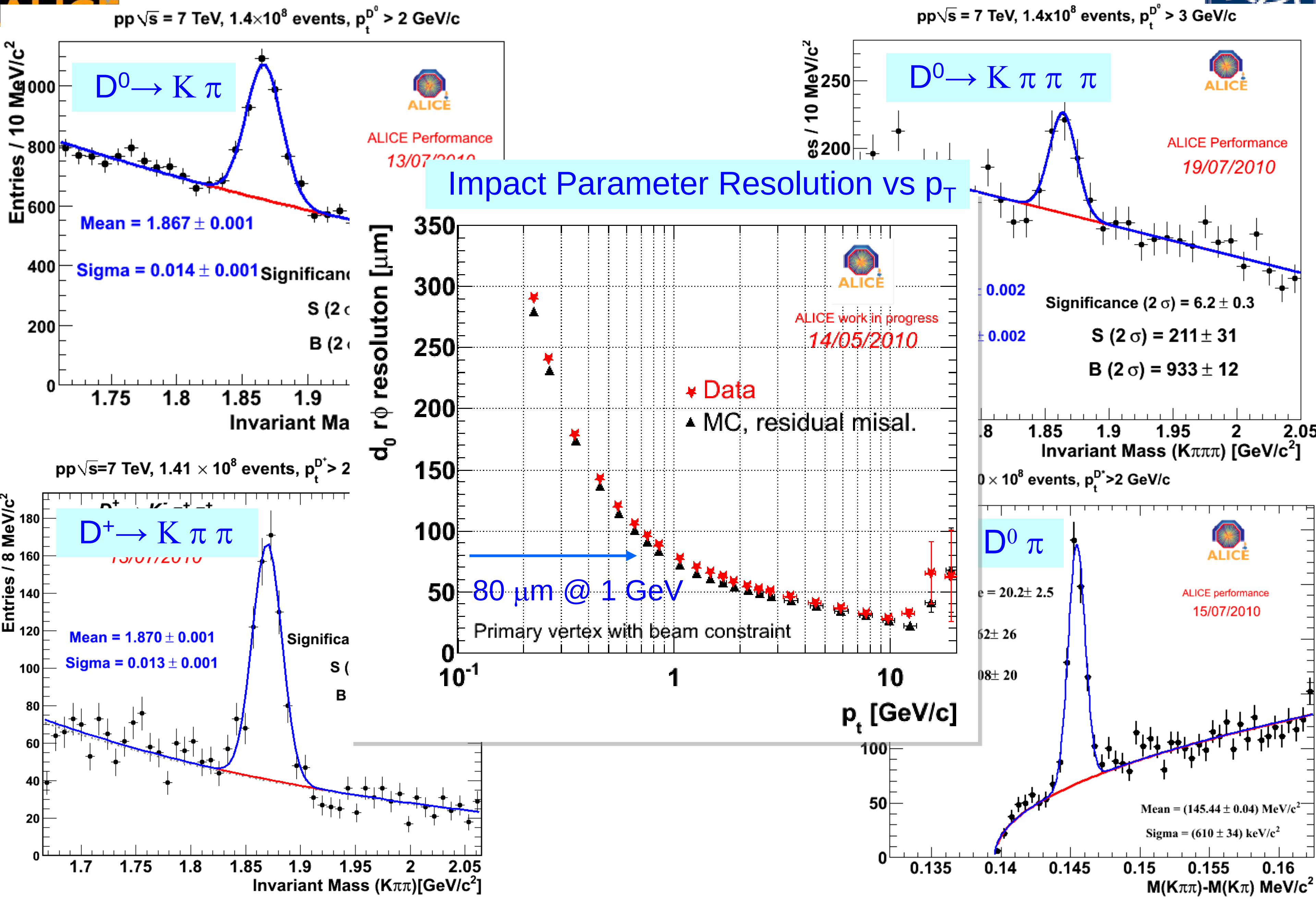
ı in



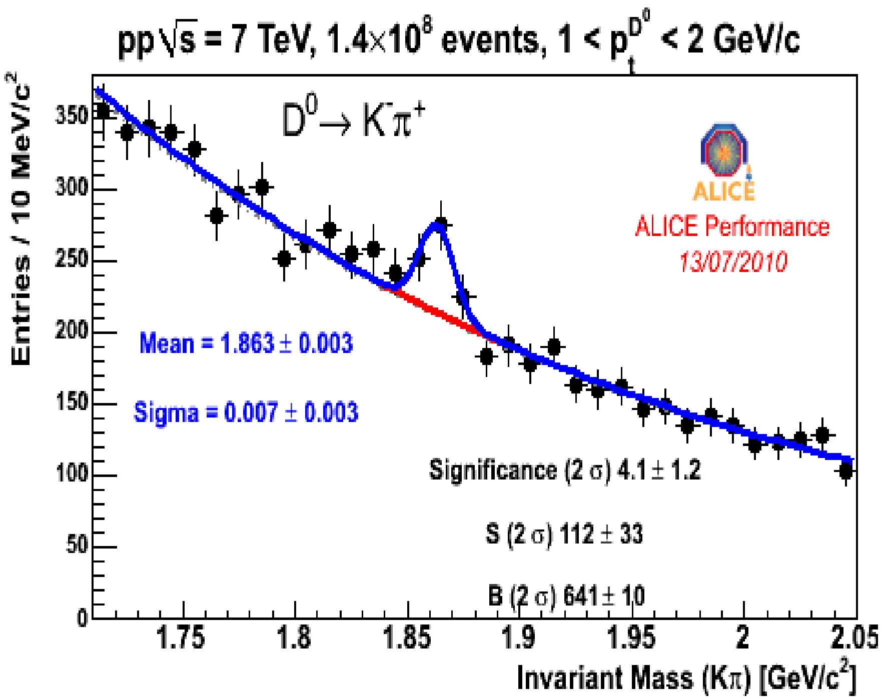


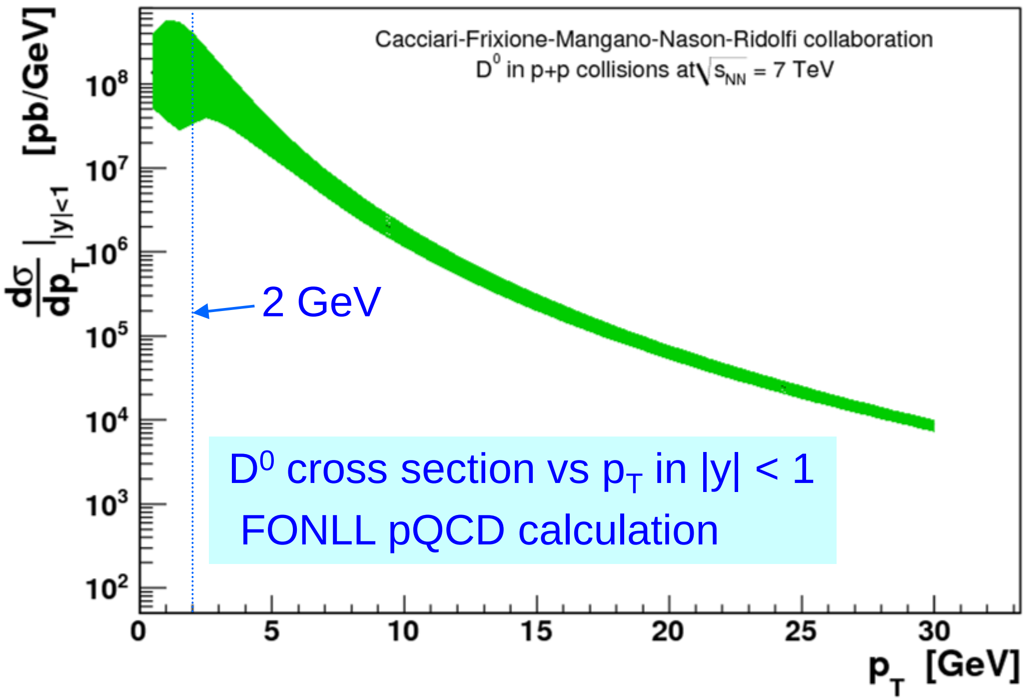


Charm at 7 TeV



Charm at very low p_T



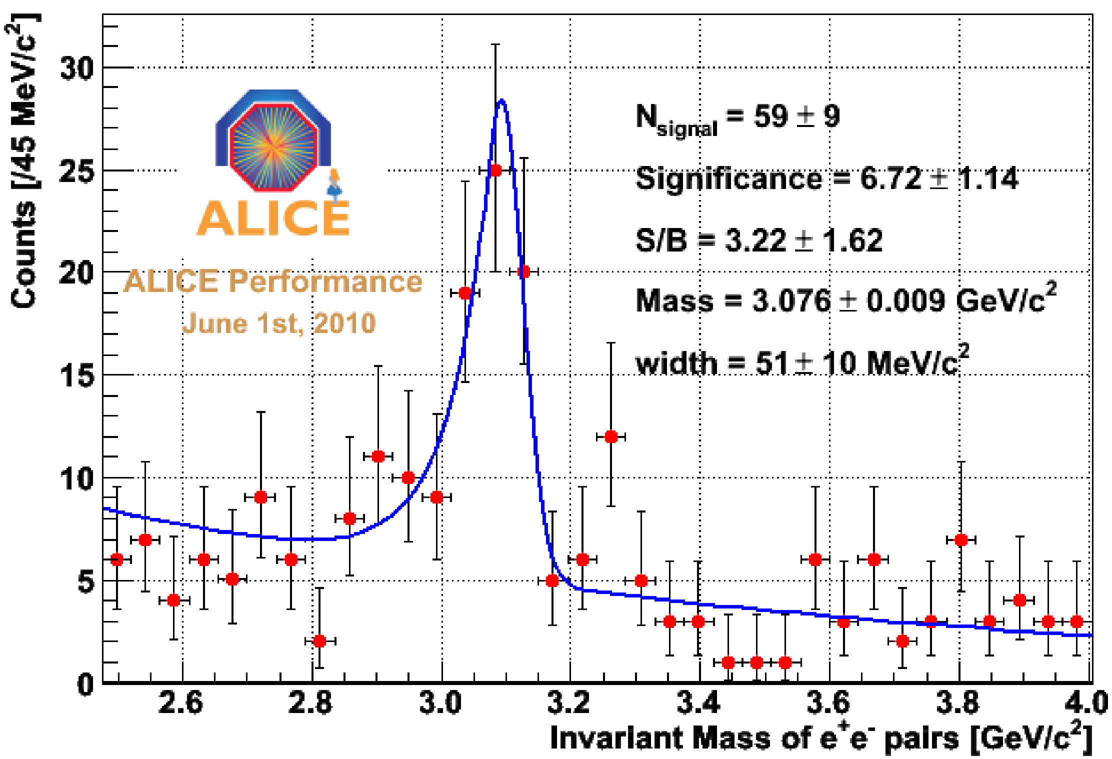


- most of the cross section at low p_T
- shape at low p_T very uncertain
- 10^9 MB events => measure below 1 GeV

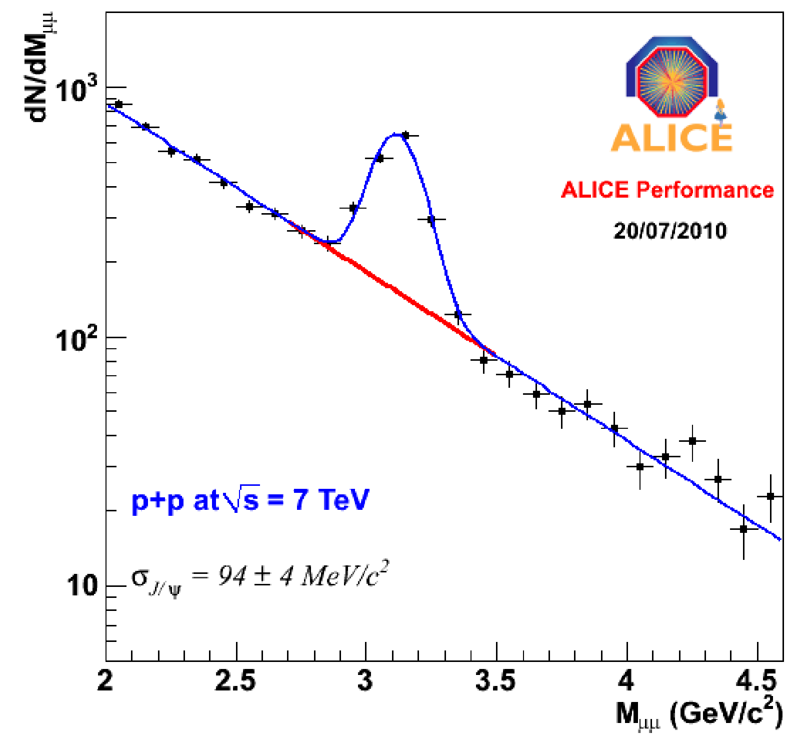
  (PID important at low p_T !)

J/ψ @ 7 TeV

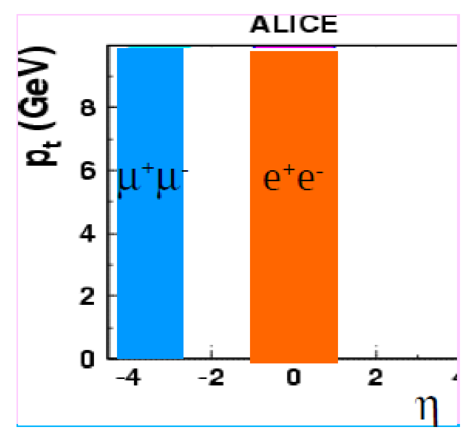
$J/\psi \rightarrow e^+e^-$ $|y| < 1$



$J/\psi \rightarrow \mu^+\mu^-$, y = 2.5–4.1

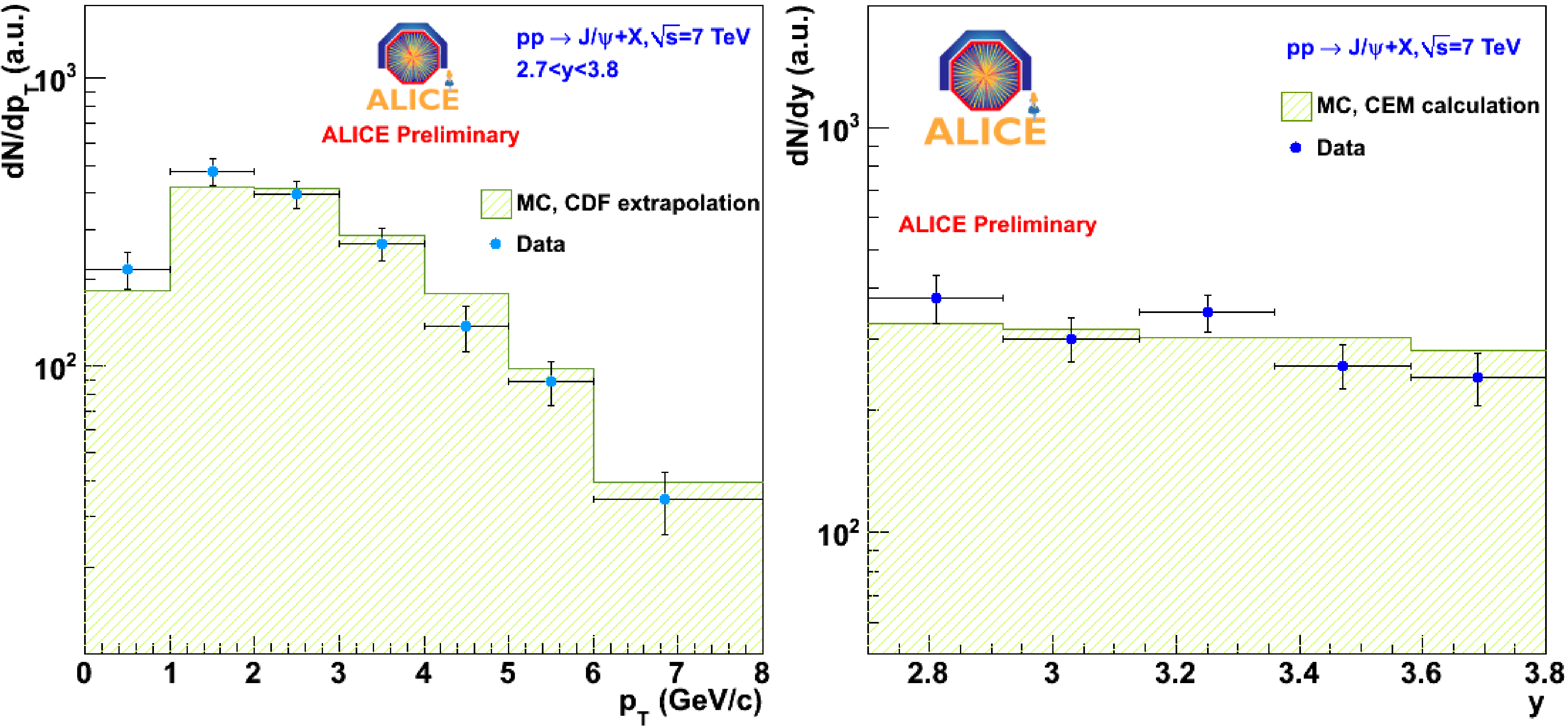


- tough to measure J/ψ with our current low luminosity
  (also 1st year Pb–Pb luminosity will be **very** low -> priority on MB in pp)
- ‘proof of performance’
  higher luminosity later this year and next year



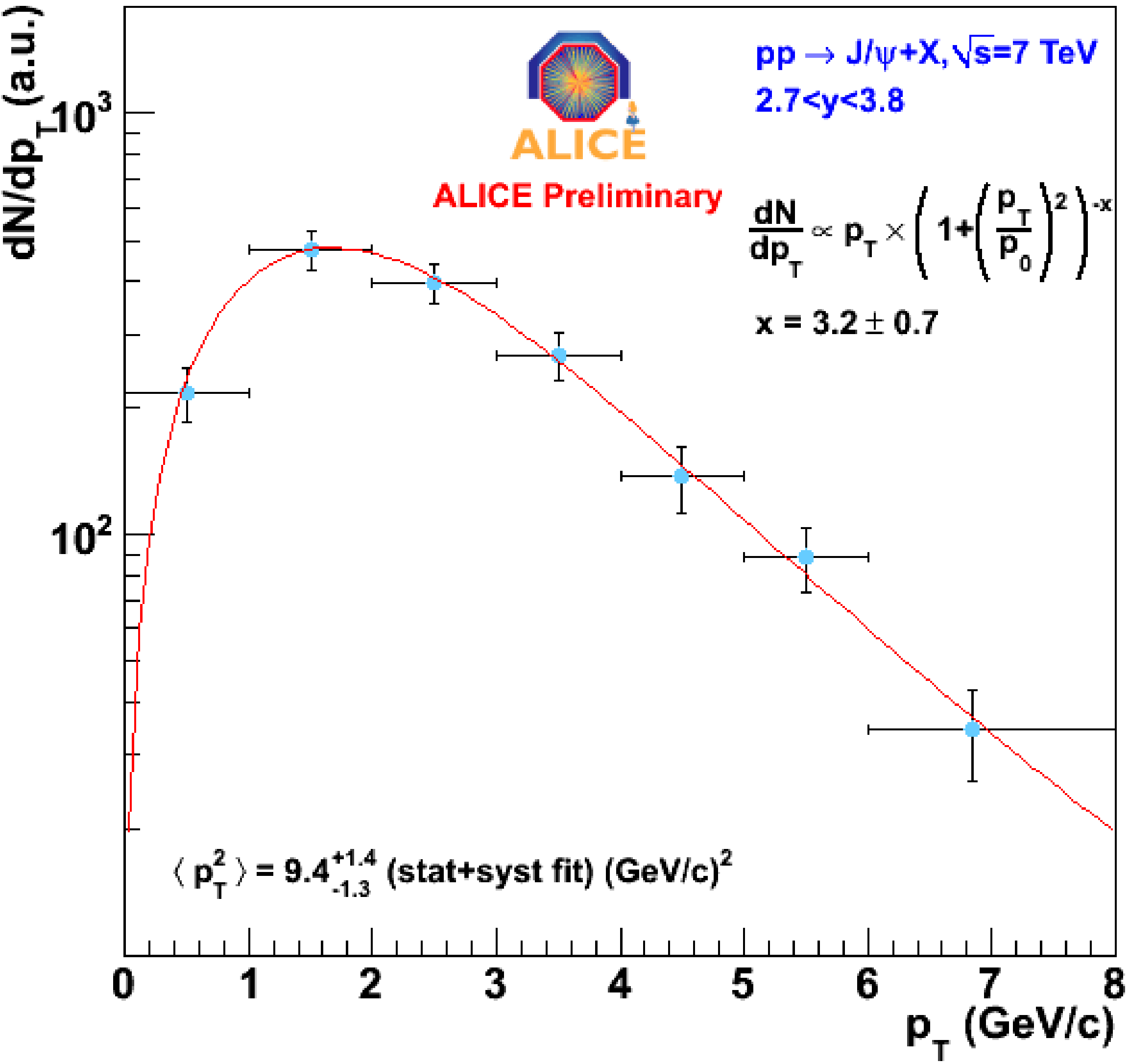
$J/\psi \to \mu^+\mu^-$

The acceptance and efficiency corrected distributions are compared to generated MC distribution

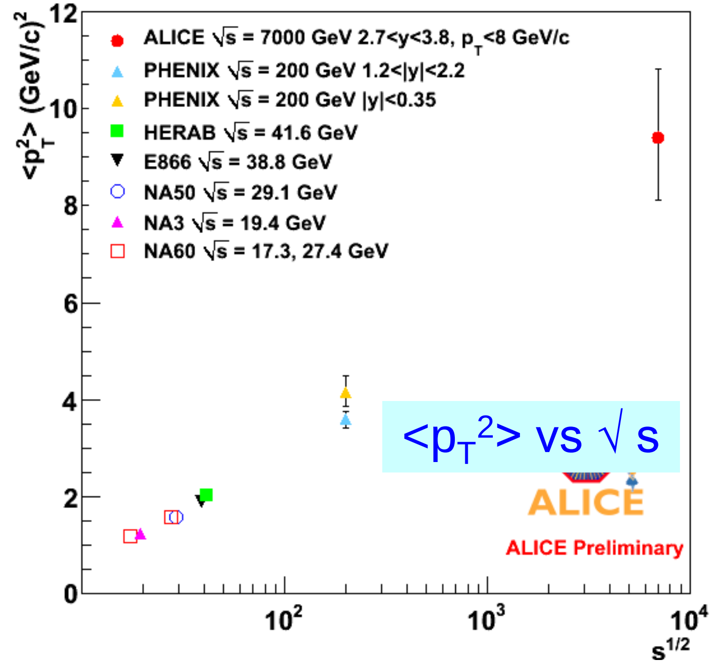


- **“CDF pp 7TeV” parameterization**
  - ⇨ **p_T extrapolated from CDF results**
  - ⇨ **y obtained from CEM calculations**
  - ⇨ **No polarization (λ = 0)**

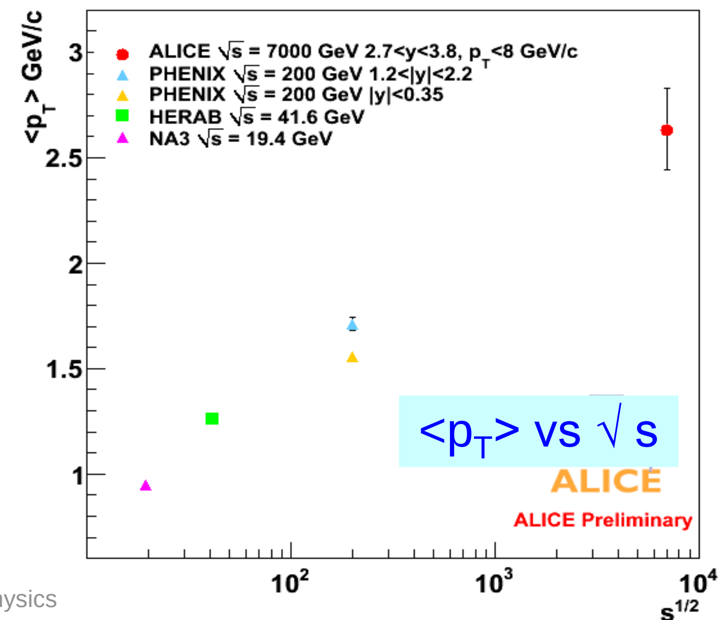
$J/\psi \to \mu^+\mu^-$



ALICE
ALICE Preliminary
pp → J/ψ+X, √s=7 TeV
2.7<y<3.8
$\frac{dN}{dp_T} \propto p_T \times \left(1+\left(\frac{p_T}{p_0}\right)^2\right)^{-x}$
x = 3.2 ± 0.7
$\langle p_T^2 \rangle = 9.4^{+1.4}_{-1.3}$ (stat+syst fit) (GeV/c)^2
dN/dp_T (a.u.)
p_T (GeV/c)



ALICE √s = 7000 GeV 2.7<y<3.8, p_T<8 GeV/c
PHENIX √s = 200 GeV 1.2<|y|<2.2
PHENIX √s = 200 GeV |y|<0.35
HERAB √s = 41.6 GeV
E866 √s = 38.8 GeV
NA50 √s = 29.1 GeV
NA3 √s = 19.4 GeV
NA60 √s = 17.3, 27.4 GeV
<p_T^2> (GeV/c)^2
s^1/2
$<p_T^2>$ vs √ s
ALICE
ALICE Preliminary



ALICE √s = 7000 GeV 2.7<y<3.8, p_T<8 GeV/c
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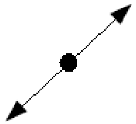
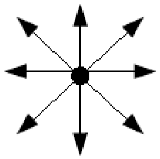
PHENIX √s = 200 GeV |y|<0.35
HERAB √s = 41.6 GeV
NA3 √s = 19.4 GeV
<p_T> GeV/c
s^1/2
$<p_T>$ vs √ s
ALICE
ALICE Preliminary

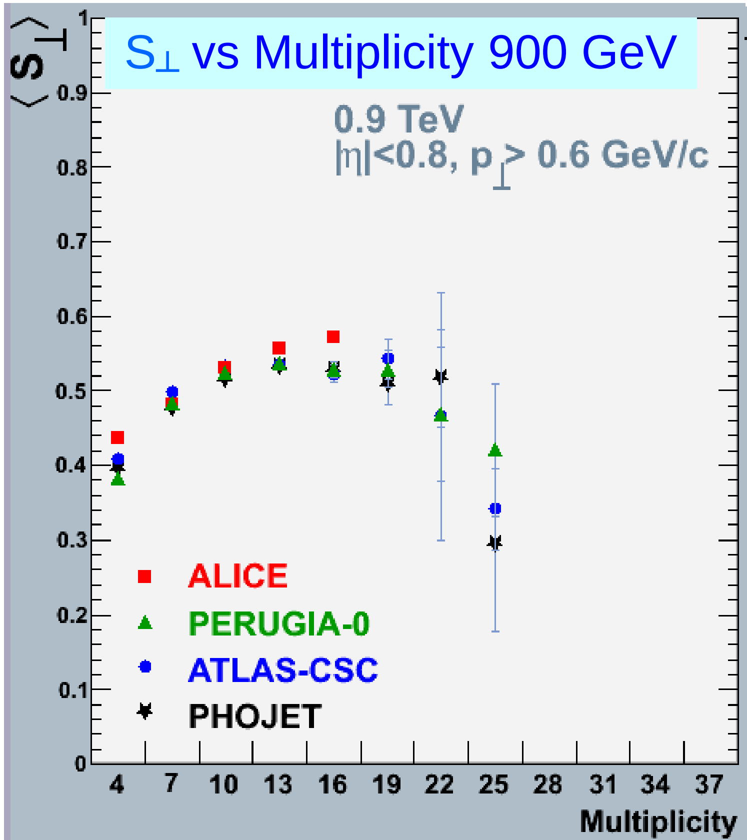
Event shape analysis

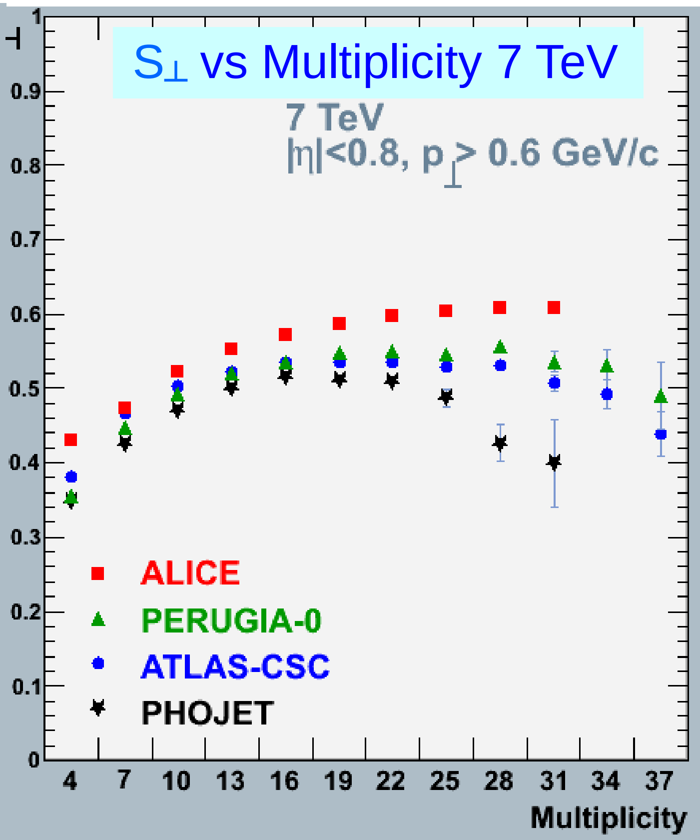
Transverse sphericity $S_\perp$:
eigenvalues of the momentum tensor S_{xy}

$$\mathbf{S_{xy}} = \sum_i \begin{pmatrix} p_x^{(i)\,2} & p_x^{(i)} p_y^{(i)} \\ p_x^{(i)} p_y^{(i)} & p_y^{(i)\,2} \end{pmatrix}$$

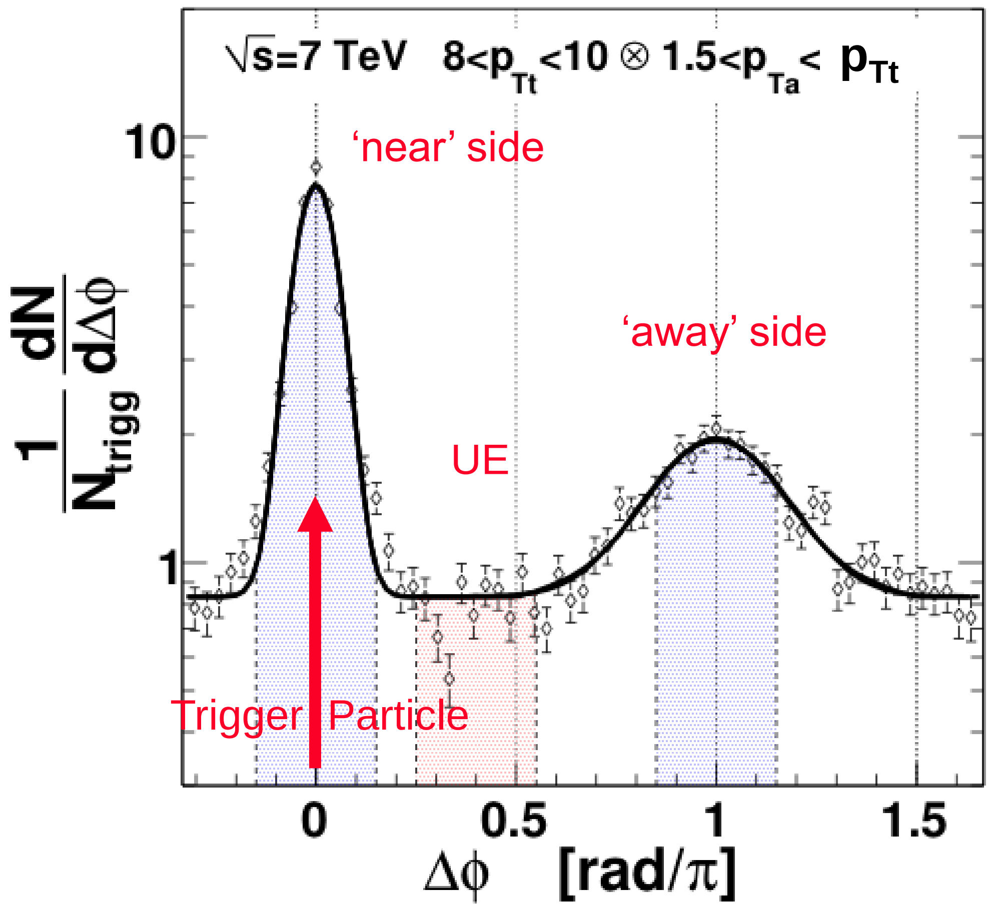
$$S_\perp \equiv \frac{2\lambda_2}{\lambda_2 + \lambda_1}$$

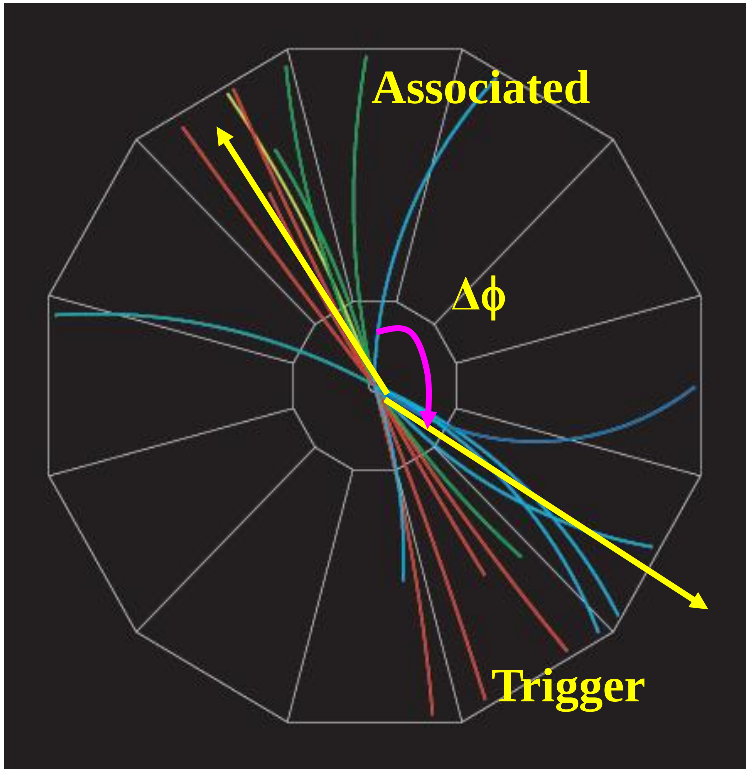
small $S_\perp$:  large $S_\perp$: 





pQCD: High-p_T particle correlations

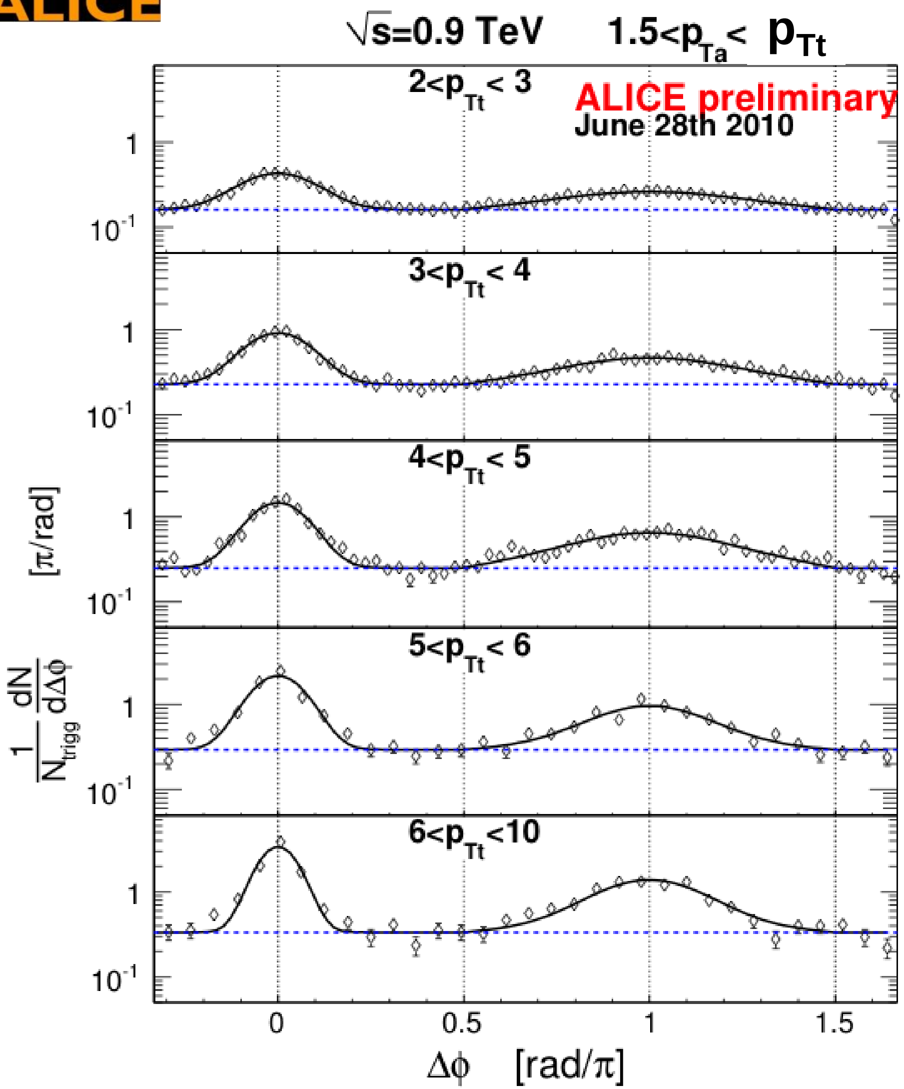


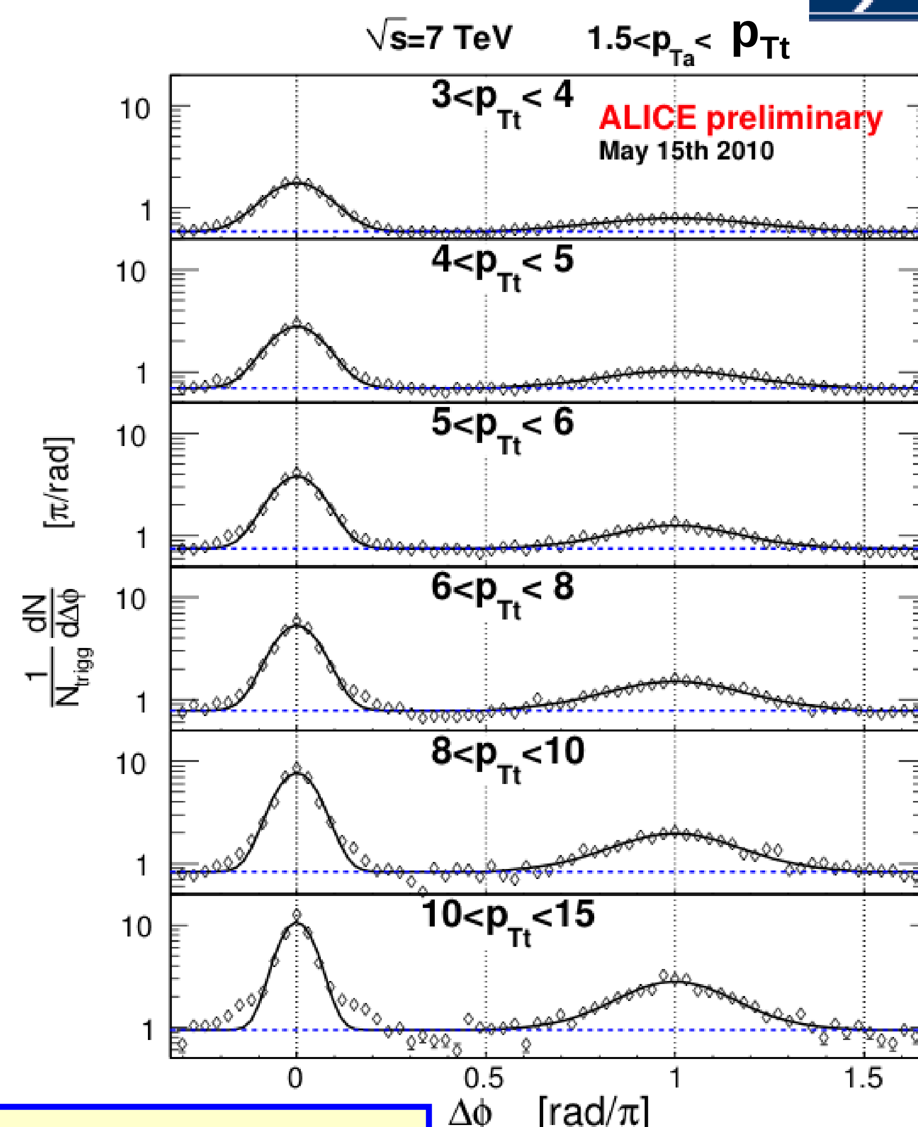


Trigger Particle: highest p_T particle in event (p_{Tt})

Associate Particle: all the others (p_{Ta})

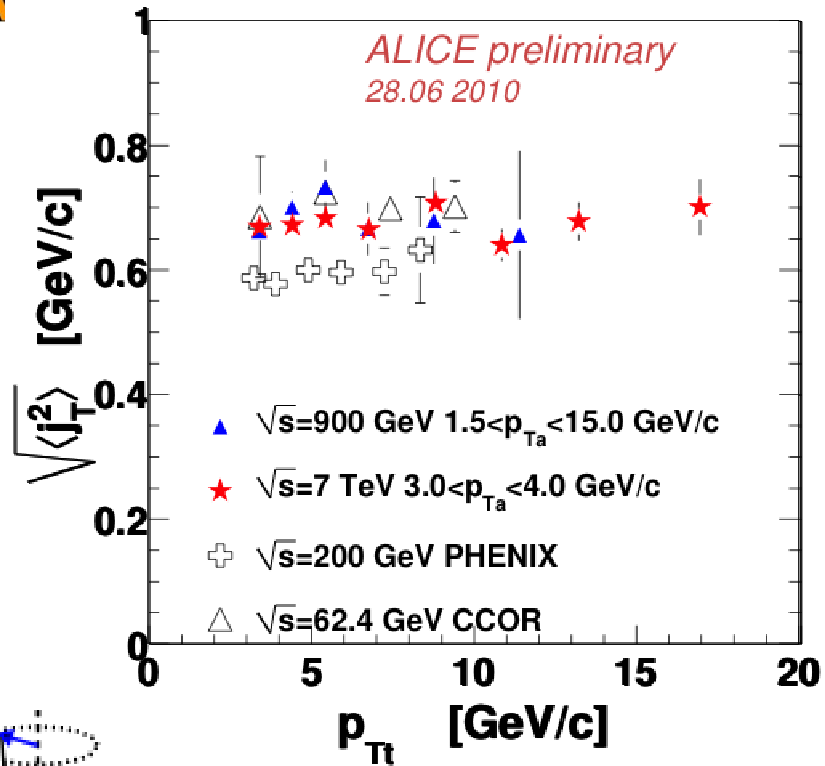
‘High’-p_T particle correlations

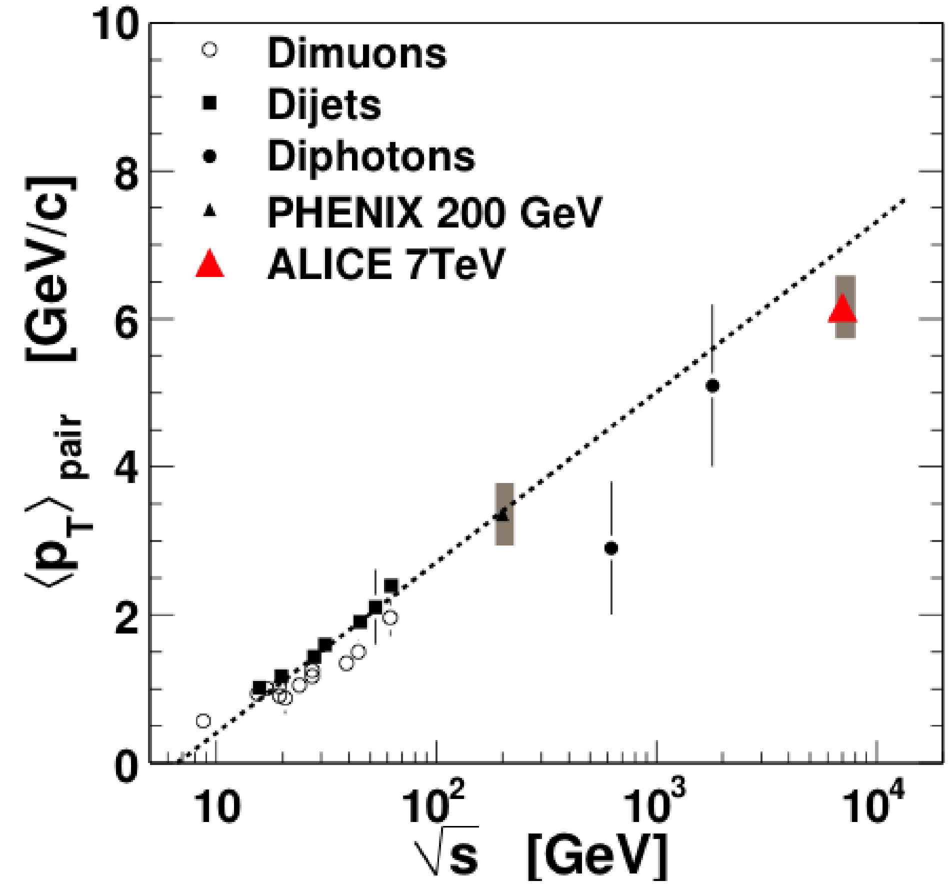


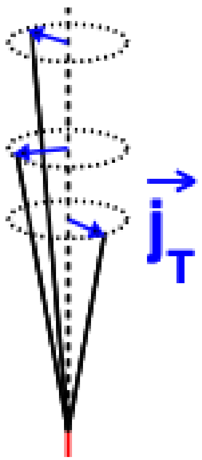


- correlations present down to very low p_T
- study ‘mini-jet region (difficult with fully reconstructed jet ?)

Charged 'mini-jets'







Width of 'near' side correlation => j_T

average transverse momentum
of fragments relative to jet axis

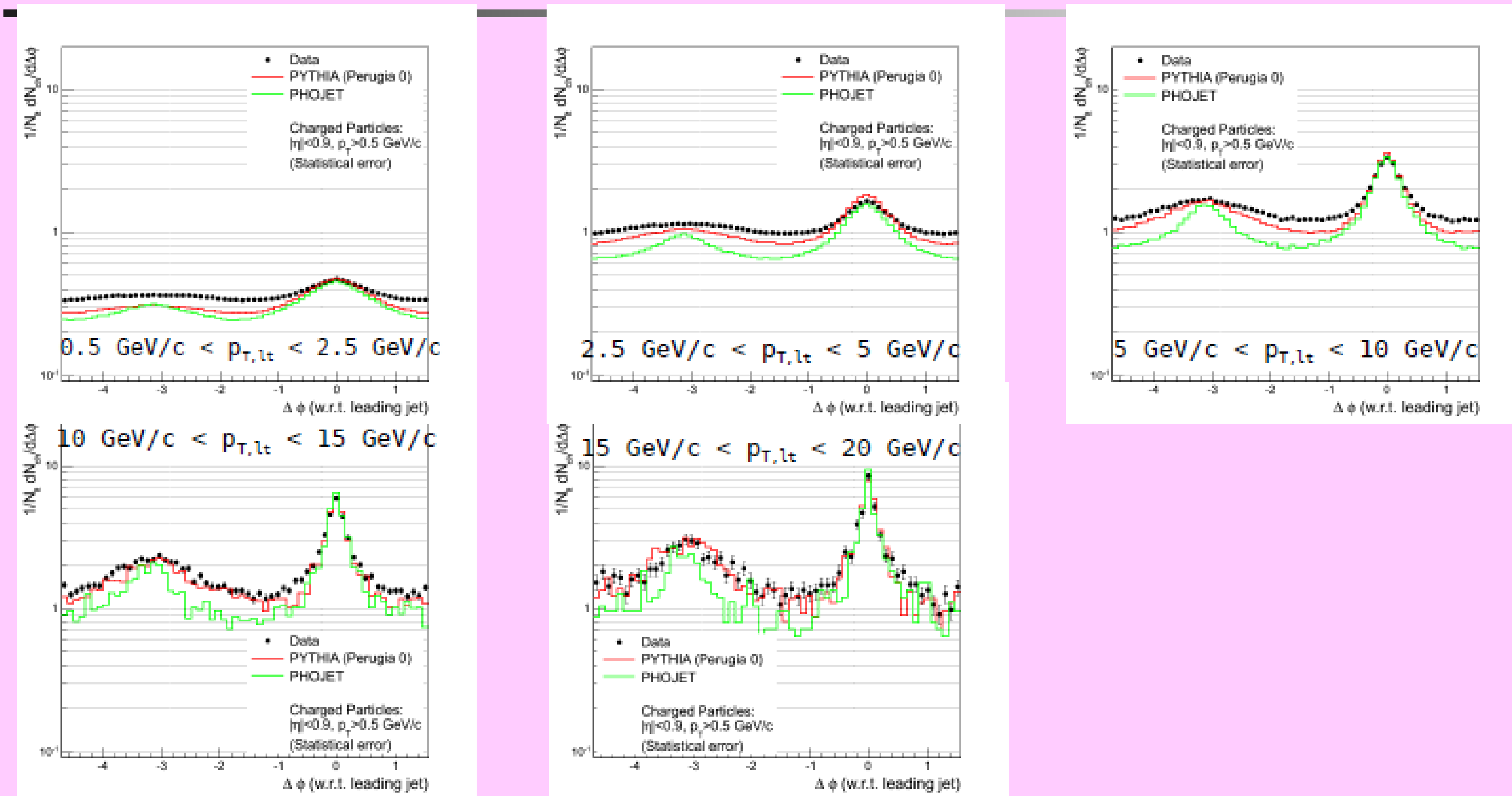
independent of √ s (well known)

Width of 'away' side => $\langle p_T \rangle_{pair}$

~ mean jet acoplanarity (~ k_T)

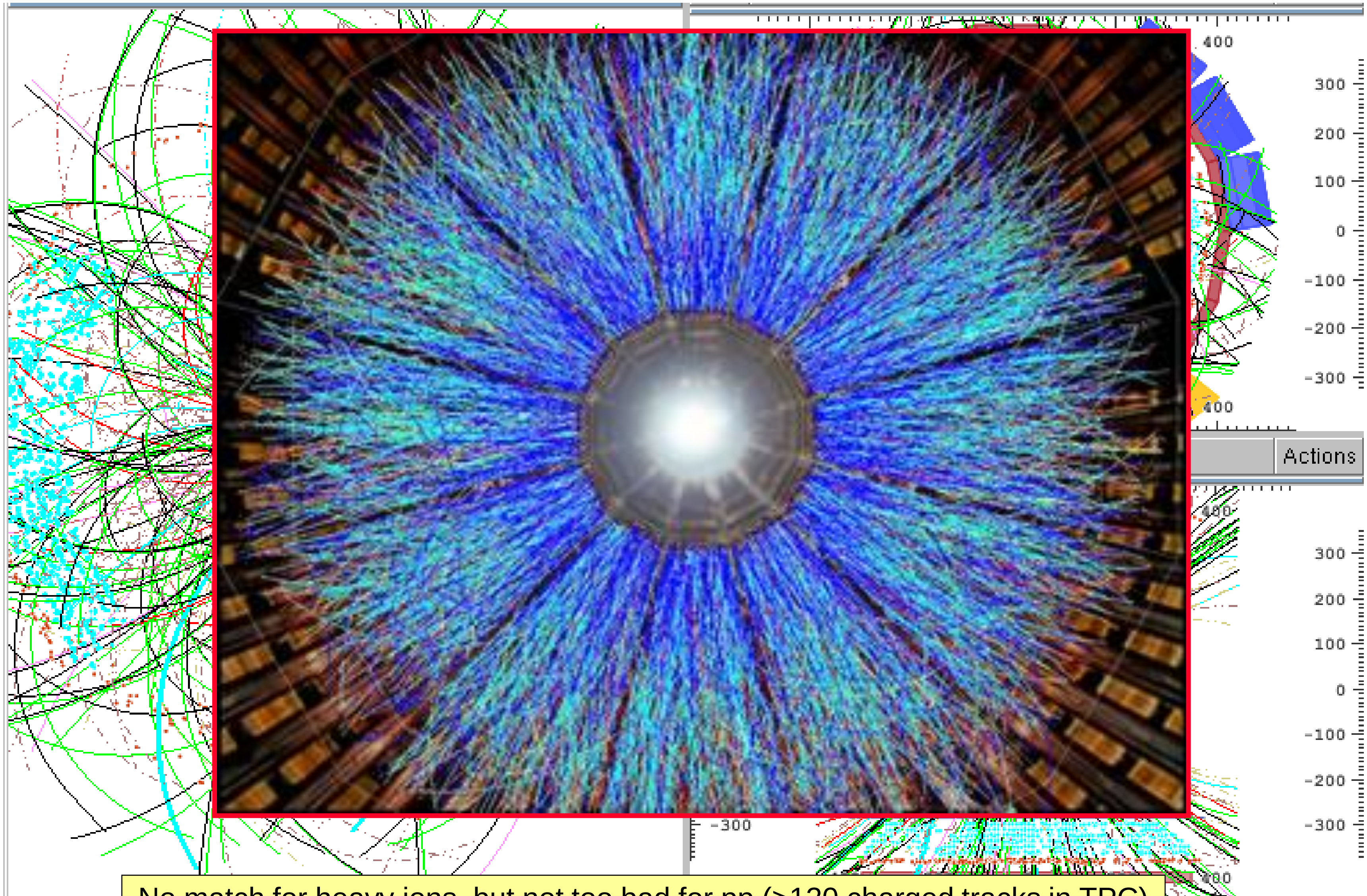
increases with √ s

UE vs. MC



- Inclusive $\Delta\phi$ correlations wrt the leading track
- For p_t<10 GeV/c, the data are less back-to-back-ish than MCs

High-multiplicity event



No match for heavy ions, but not too bad for pp (>120 charged tracks in TPC)

Summary

- **ALICE is in good shape**
  - **most** detectors **perform already at or** close to specifications
  - physics is in full production
    - **heavy ions are our 'core business', starting in November this year**
    - **meanwhile study QCD with pp collisions**
    - **while 'rediscovering' the SM, we can clean up some bits here and there…**
      ($\bar{p}$/p, HBT R vs $<k_T>$, Λ /K^0, …)
- **Looking forward to explore the 'terra incognita' at LHC**

Hic sunt Leones !