ALICE

First pp results ... from the AA physics perspective

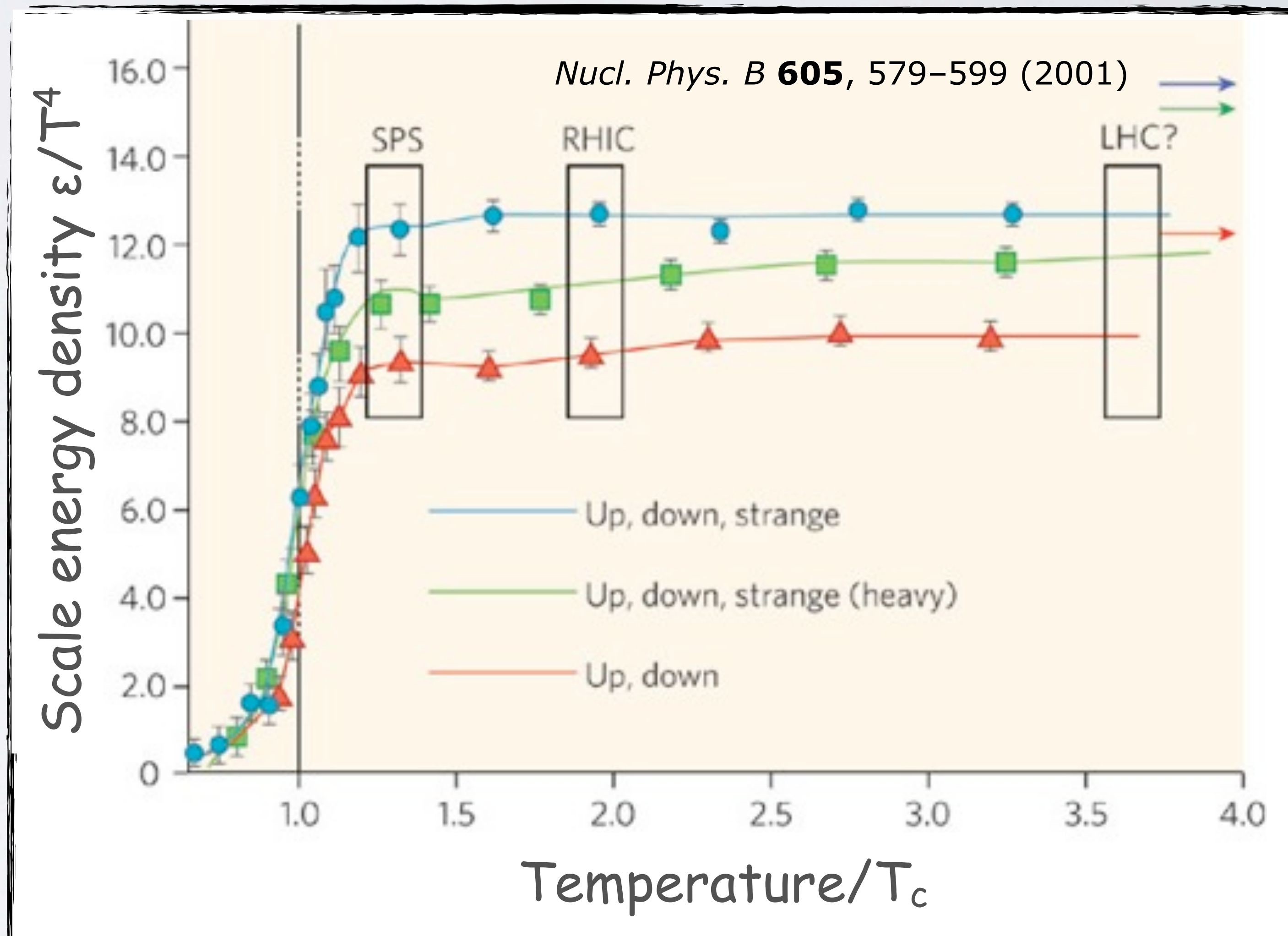
22ème Rencontres de Blois 2010

Yves Schutz

GENERAL REMARK

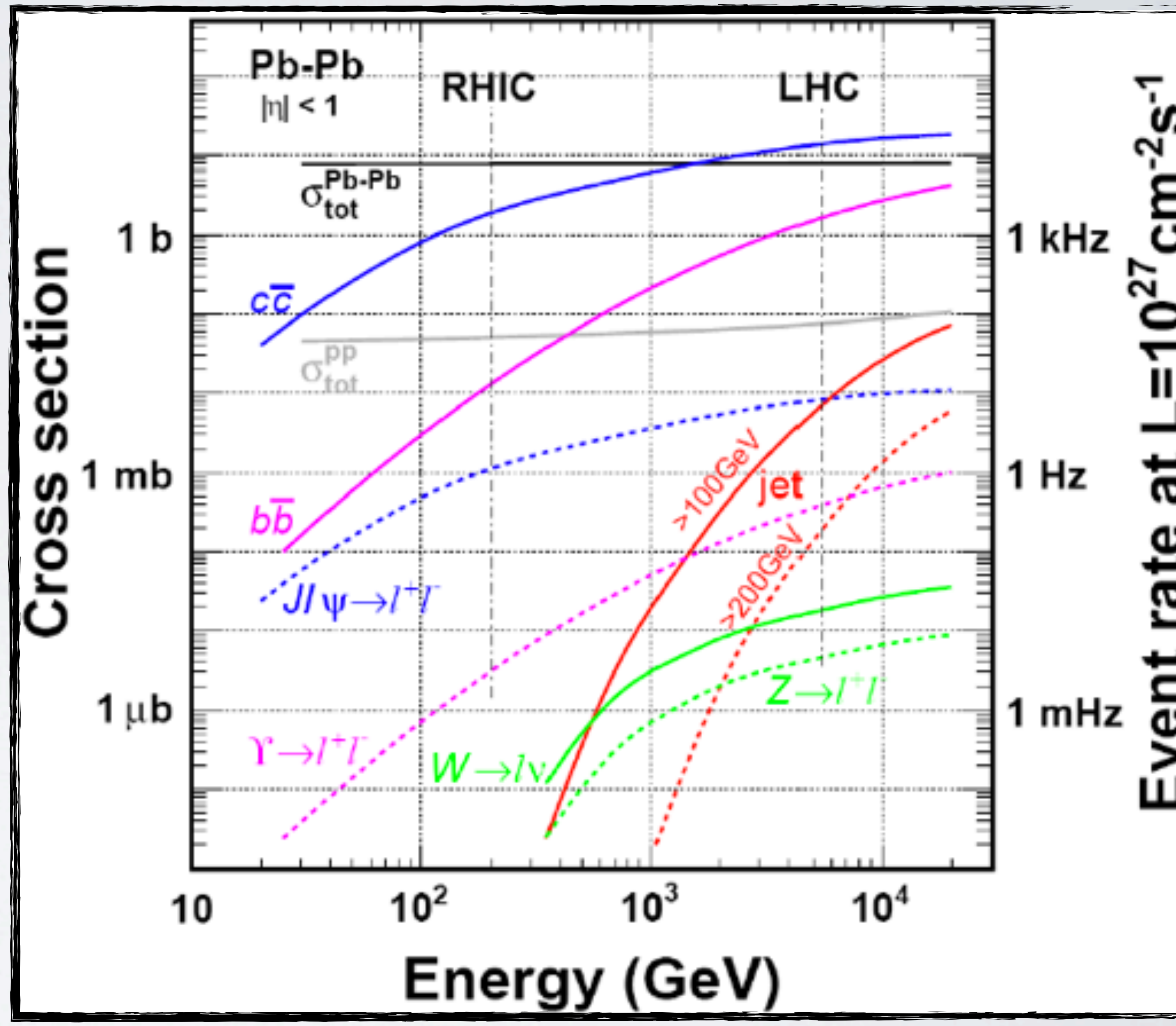
With a factor of 30 increase in $\sqrt{s_{NN}}$ compared to RHIC, the LHC will open a new avenue for the study of QCD matter at extreme high energy densities exploiting hard probes in an ultra-high multiplicity environment

Phases of strongly interacting matter from lattice QCD



QCD MATTER AT LHC

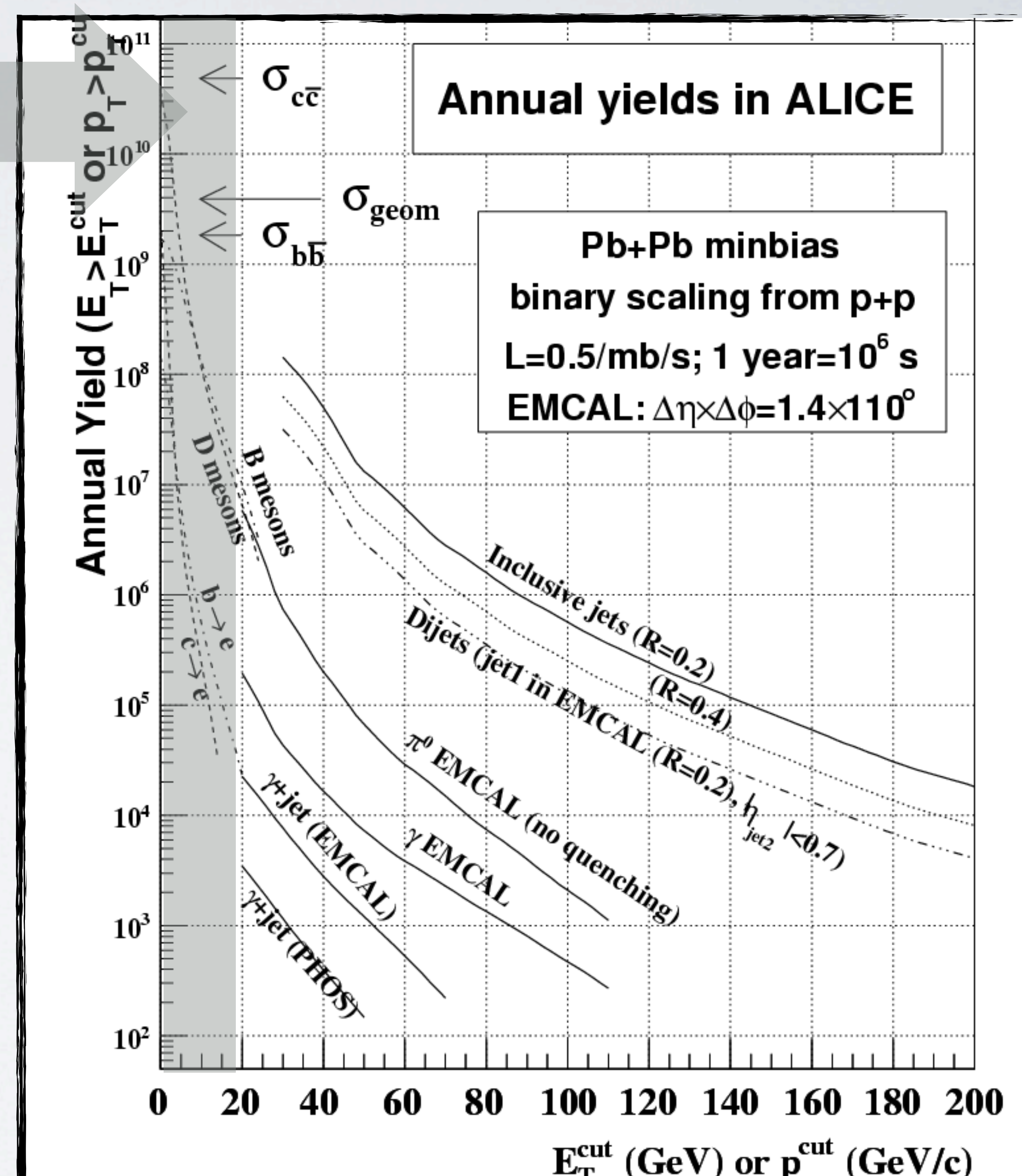
- Characterized through its
  - Equation of state, number of degrees of freedom, transport coefficient, parton energy loss and opacity, velocity of sound ...
- With in particular the help of new hard probes
  - a new era for heavy flavors: c, b, c/b jets, $c\bar{c}$, $b\bar{b}$
  - Jets and photons



THE ULTIMATE HARD PROBES MACHINE

Studied in detail at RHIC

- Inclusive jets: more than 10^4 jets with E_T > 150 GeV in one year with ALICE
- π^0 and γ tagged jets for E_T 20-50 GeV



ALICE PHYSICS OBJECTIVES WITH pp COLLISIONS

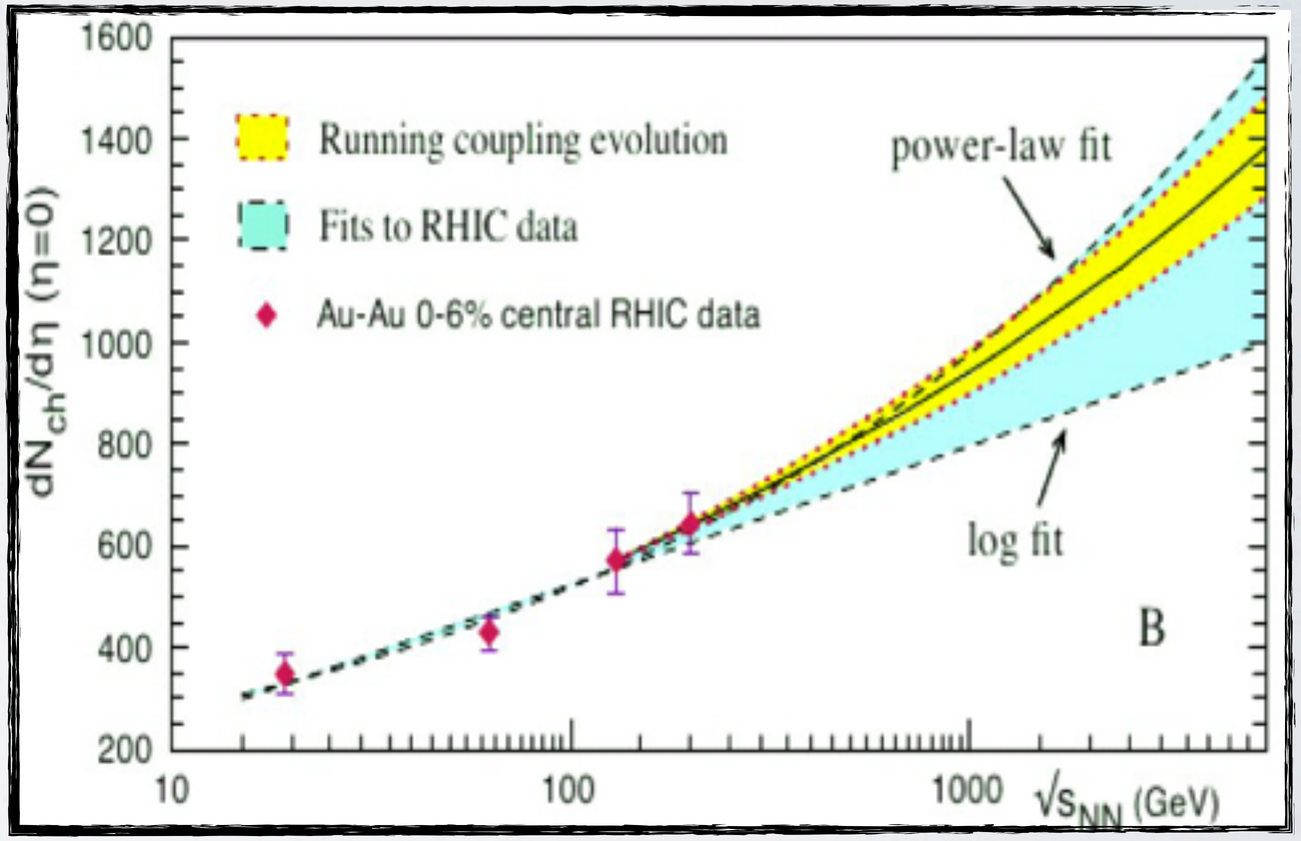
- pp data provide the necessary reference data for the heavy-ion program ... preferably at the same collision energy $\sqrt{s_{NN}}$
- Unique capabilities (very low p_T threshold, PID) for a unique physics potential
  - collective effects in high multiplicity pp
  - baryon transport
  - c, b cross sections down to very low p_T

FIRST RESULTS FROM pp AND RELEVANCE TO AA

- **Multiplicity density and distribution**
- Collective dynamics
- Particle composition
- Jet production
- Heavy quark production ➔ See contribution by G. Batigne

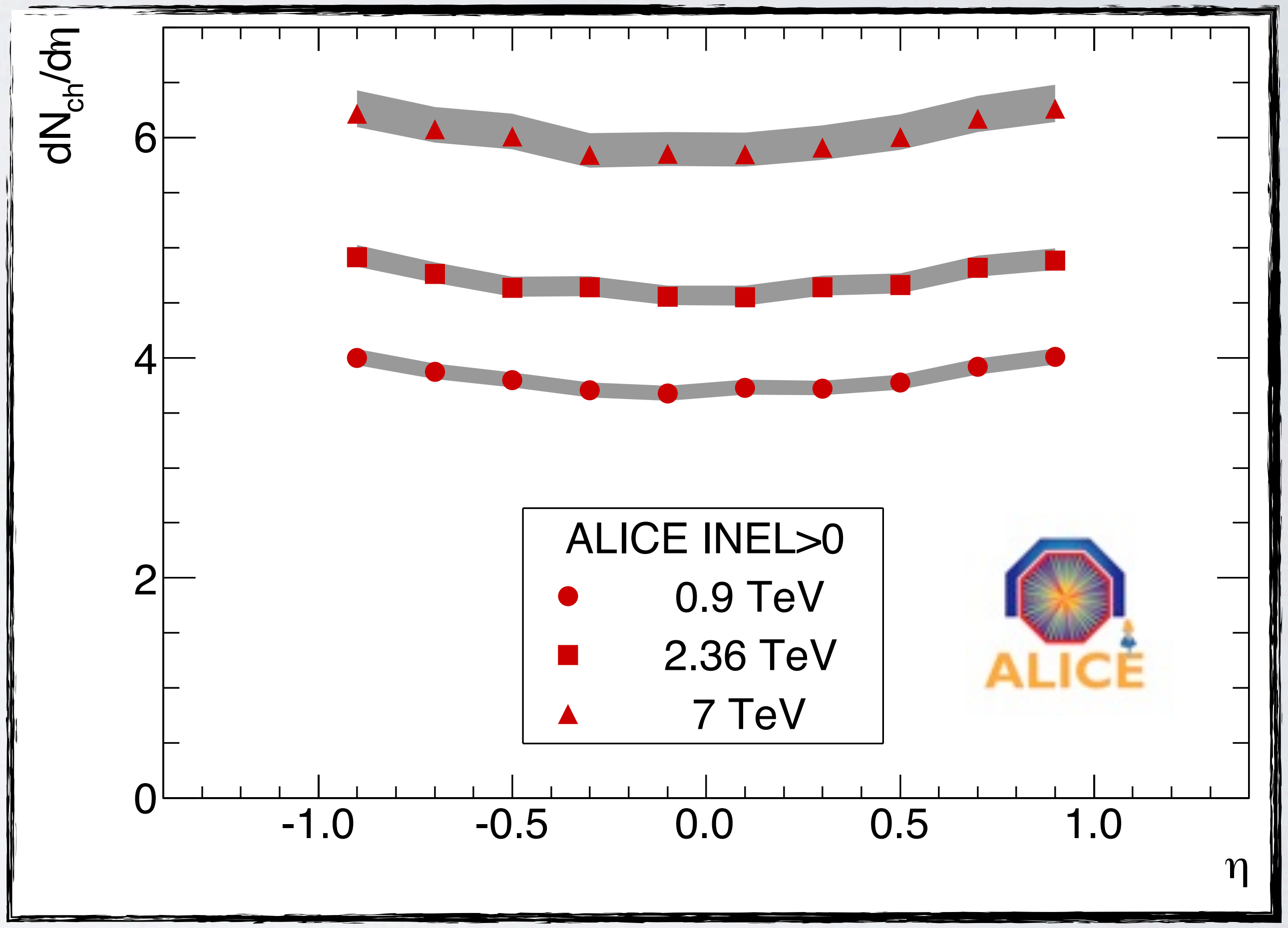
CHARGED PARTICLES MULTIPLICITY

- In AA at LHC
  - the multiplicity density is strongly sensitive to the structure of the initial state (gluon saturation, Color Glass Condensate, shadowing)
  - Because of the wide energy gap, no safe extrapolation from RHIC data



CHARGED PARTICLES MULTIPLICITY

- In pp at LHC
  - Charged particle density
    - $dN_{ch}/d\eta$ pp@900 GeV (EPJC 65 (2010) 111)
    - $dN_{ch}/d\eta$ pp@2.36 TeV (hep-ex:1004:3034 (2010))
    - $dN_{ch}/d\eta$ pp@7 TeV (hep-ex:1004:3514 (2010))



✓ALICE measurements in agreement with earlier measurements (UA5, Tevatron)

✓Other LHC measurements agree with ALICE ones

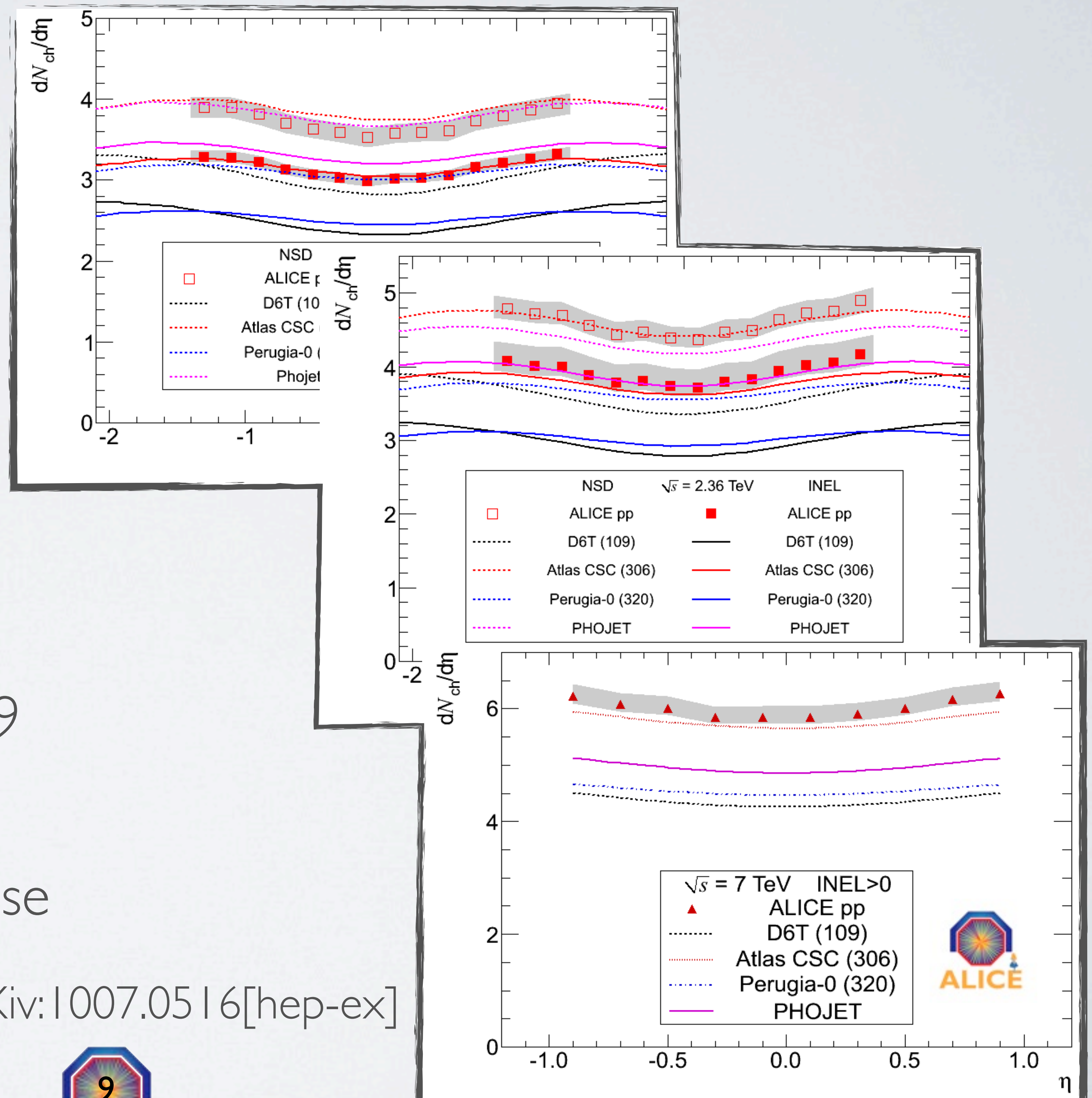
CHARGED PARTICLES MULTIPLICITY

- In pp at LHC
  - Comparison with MC

✓Pythia D6T and Perugia miss the data points

✓Pythia ATLAS CSC and PHOJET come closer to the data points at 0.9 and 2.36 TeV

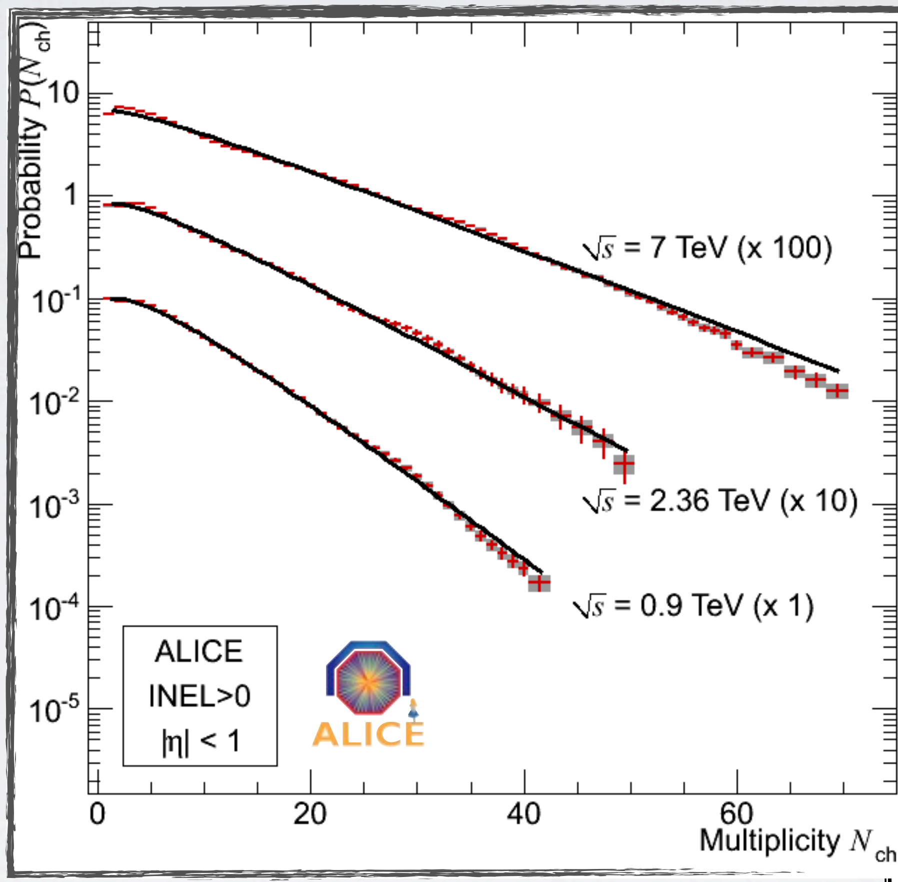
✓Only Pythia ATLAS CSC come close to the data points at 7 TeV



arXiv:1007.0516[hep-ex]

CHARGED PARTICLES MULTIPLICITY

- In pp at LHC
  - Distribution

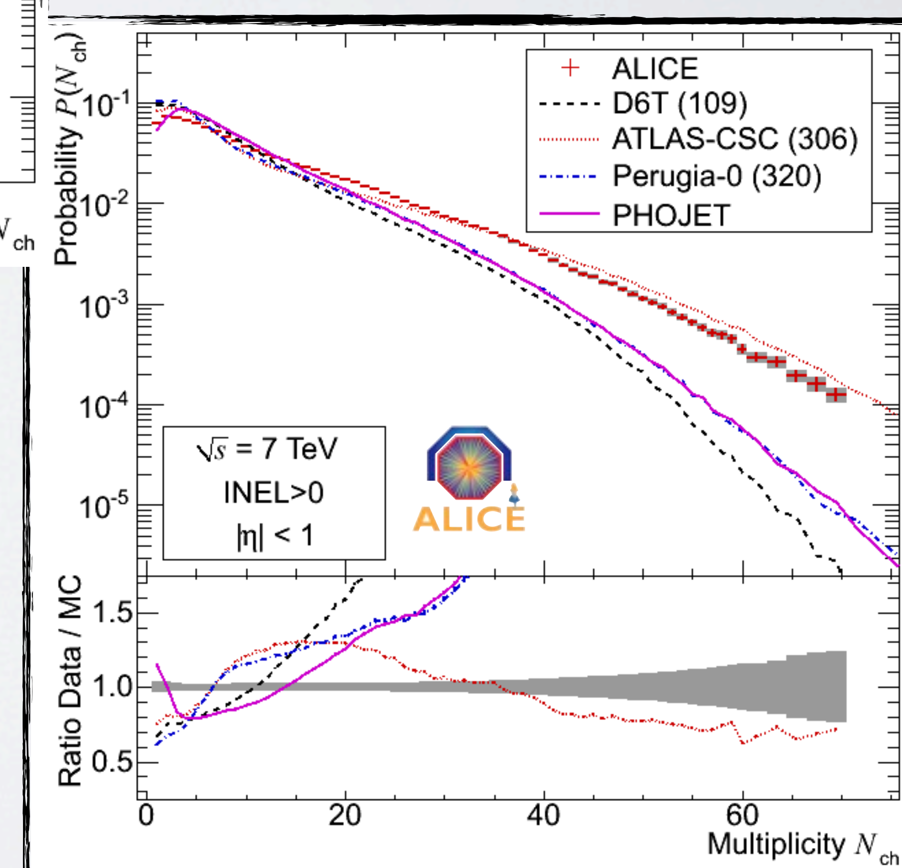


arXiv:1004.3034[hep-ex]

✓Well described by Negative Binomial Distribution

✓Shape not described by any MC model

✓Most models fail at high p_T (Pythia ATLAS CSC)



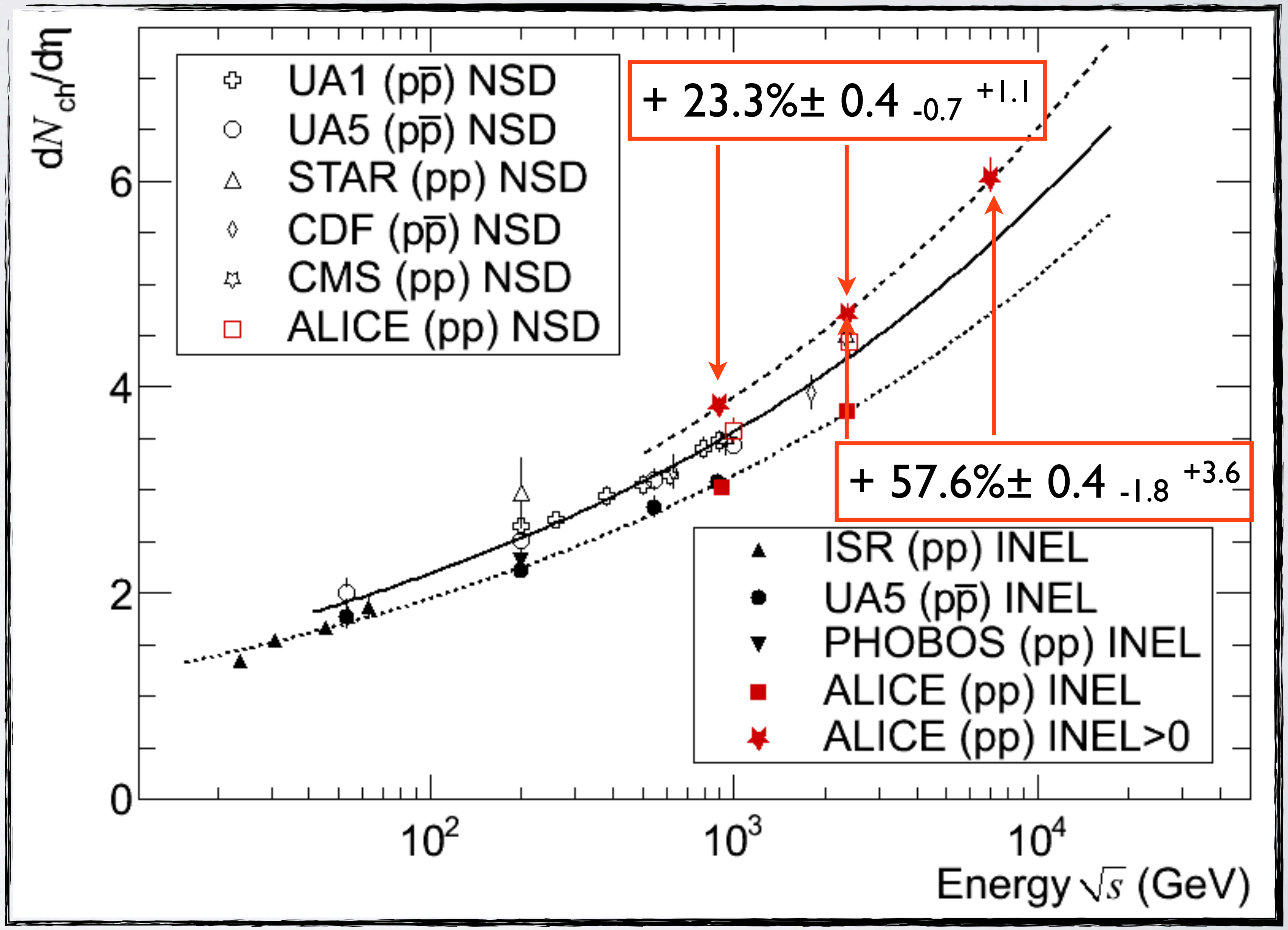
CHARGED PARTICLES MULTIPLICITY

- In pp at LHC
  - Evolution with √s

✓Well described by power law scaling

✓Significantly larger increase from 0.9 to 7 TeV (in |η| < 1) than in any MC model

✓Favorable for QGP studies

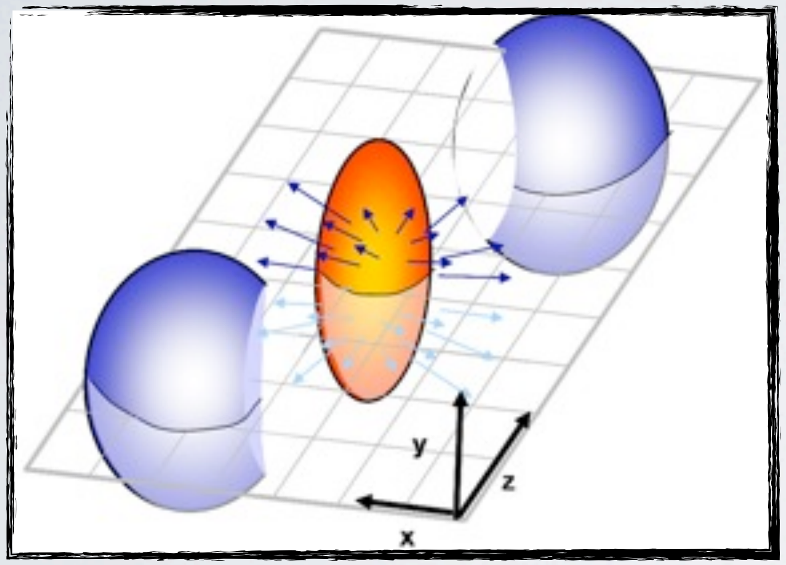


arXiv:1004.3514[hep-ex]

FIRST RESULTS FROM pp AND RELEVANCE TO AA

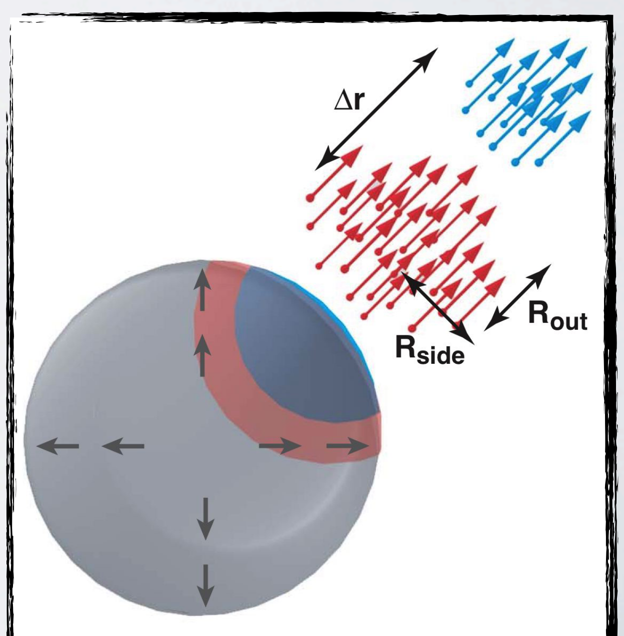
- Multiplicity density and distribution
- **Collective dynamics**
- Particle composition
- Jet production
- Heavy quark production ➔ See contribution by G. Batigne

COLLECTIVE FLOW IN AA



- Momentum anisotropy of particles reflecting initial spatial anisotropy
  - generated in early, equilibrated and partonic phase of collision
  - strength sensitive to thermalisation time scale, EOS, speed of sound, viscosity

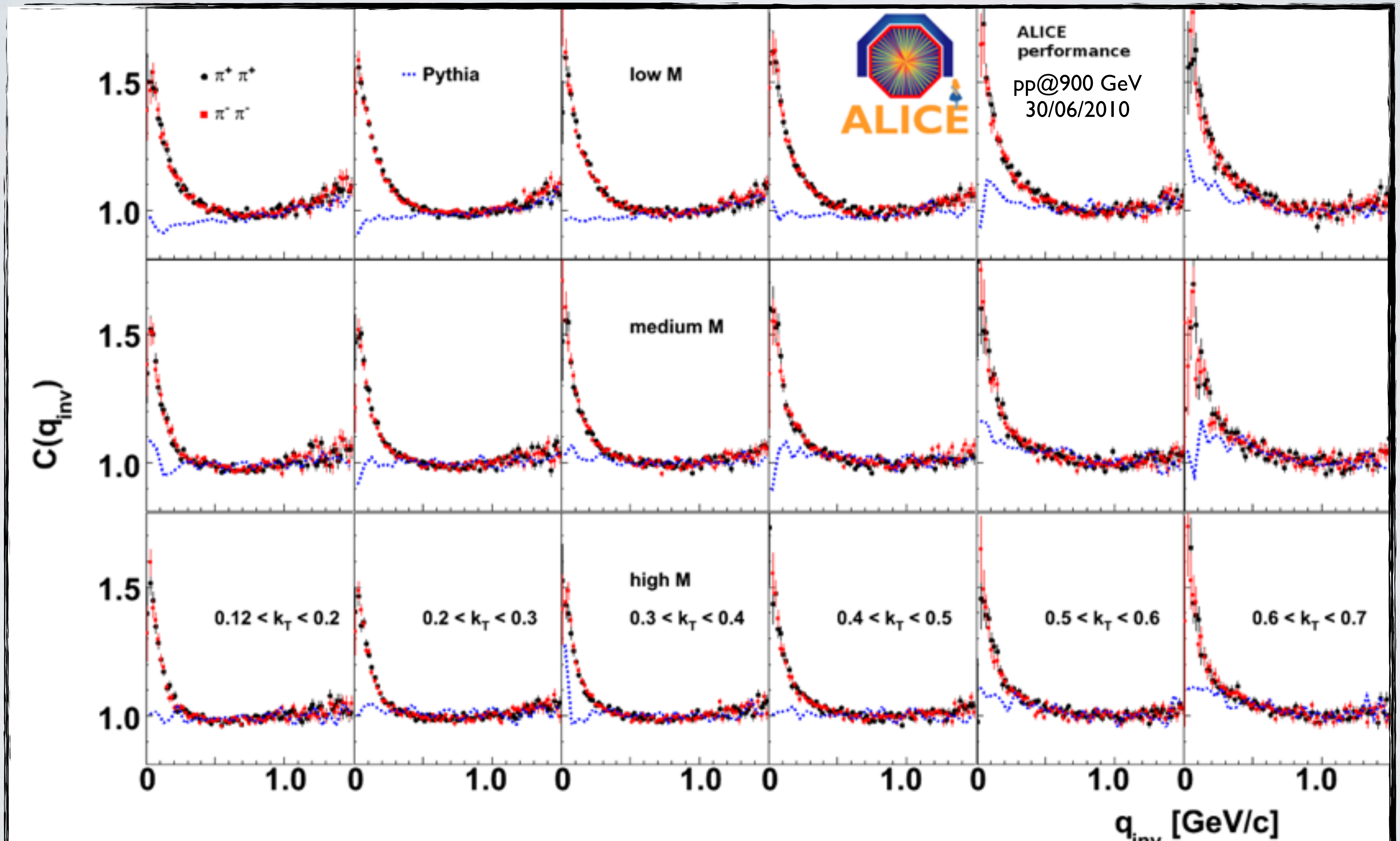
- Spatio-temporal information of the freeze out volume from 2-particle correlations at small relative momentum (HBT, femtoscopy, BE...)
  - Flow generates a fall-off of source radii with k_T



2-PARTICLE CORRELATIONS IN pp

$k_T = |\vec{p}_{T1} + \vec{p}_{T2}|$

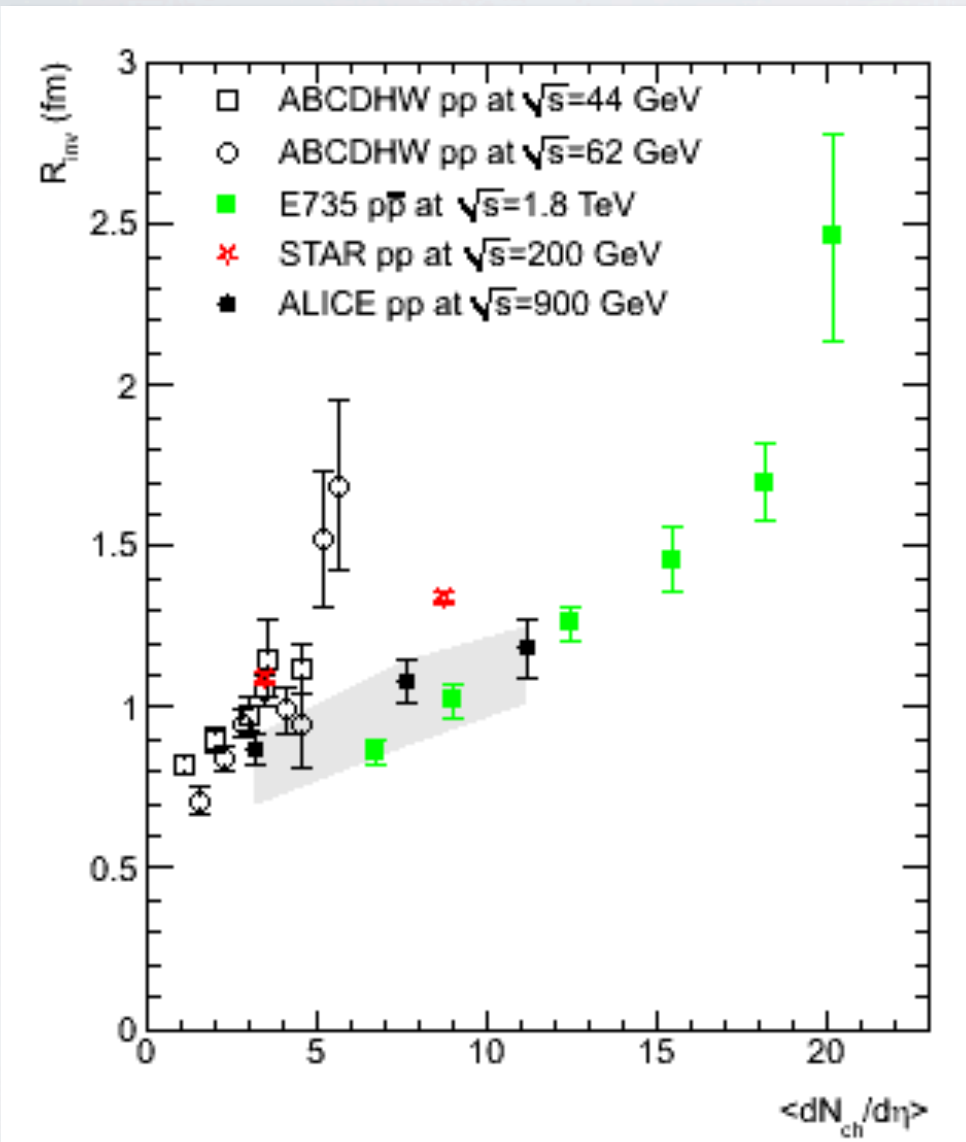
Multiplicity

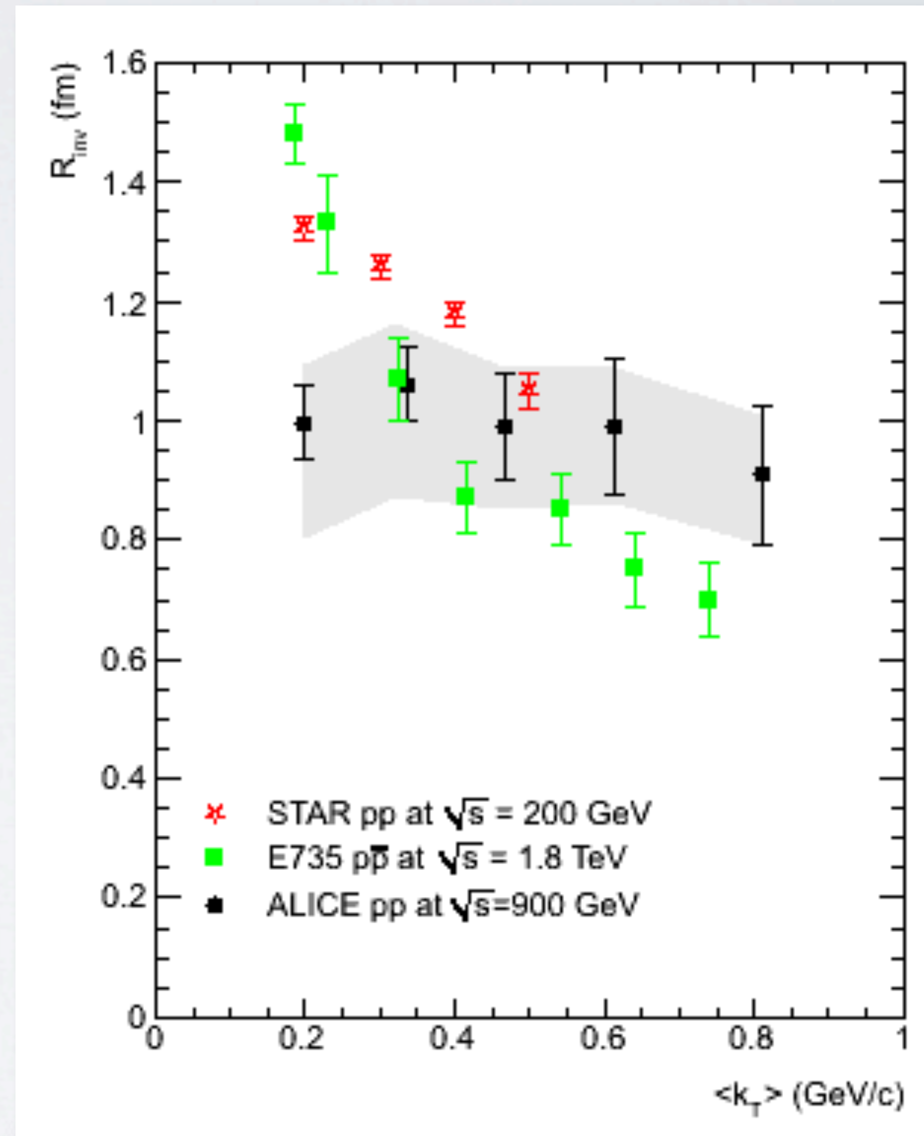


arXiv:1007.0516[hep-ex]

IN pp

- Radius grows with multiplicity
- No k_T dependence of radius

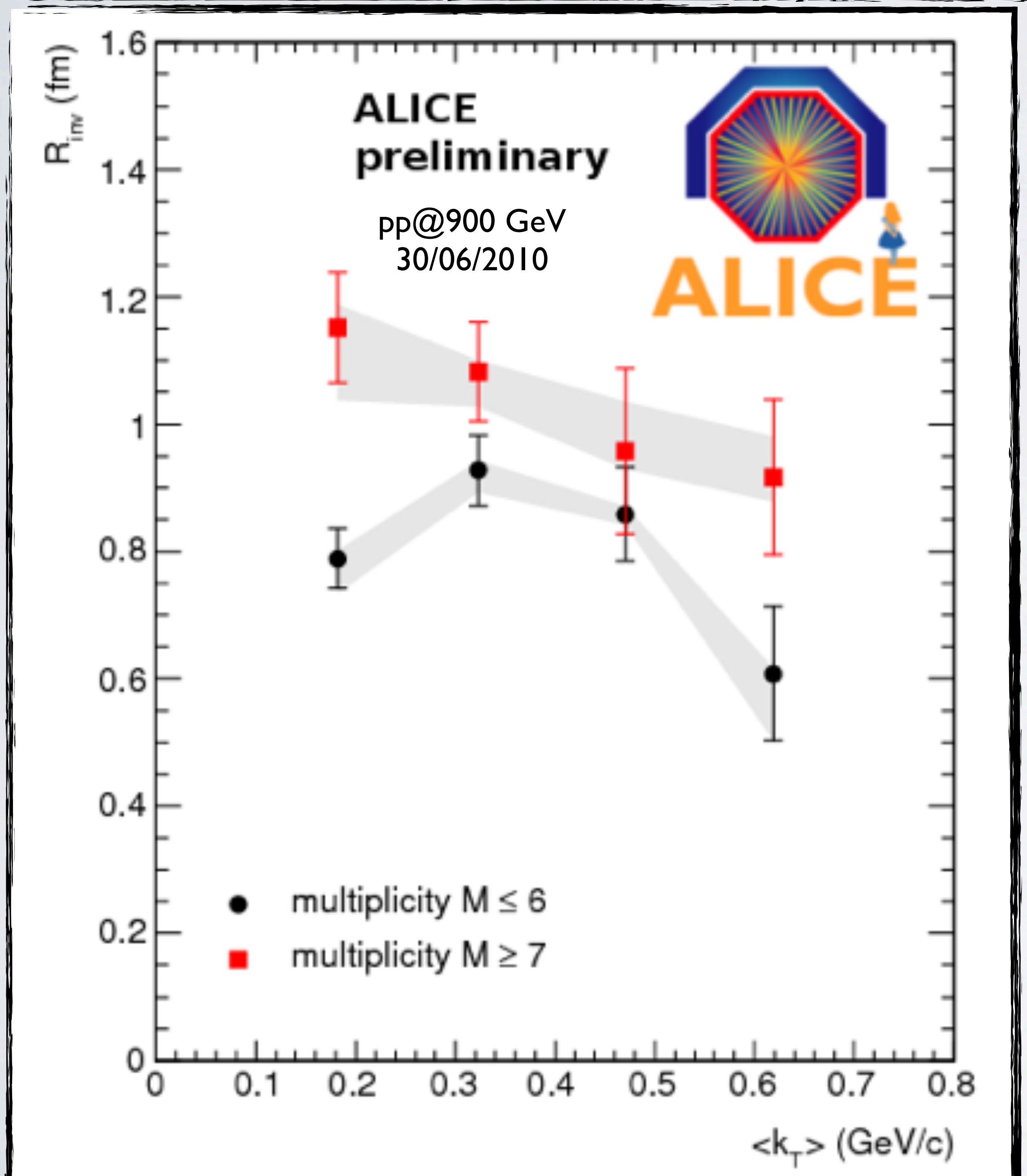




arXiv:1007.0516[hep-ex]

2-PARTICLE CORRELATIONS IN pp

$$C(q_{inv}) = ((1-\lambda) + \lambda K(q_{inv}) [1 + \exp(-R^2_{inv} q^2_{inv})]) \; B(q_{inv})$$



- Gaussian source radius + MC base line:
  - radius scales with multiplicity, consistent with world systematics for hadron-hadron collisions $\sqrt{s} \geq 50$ GeV
  - k_T dependence different (!) for low and high multiplicity
  - do pp collisions with high multiplicity develop a bulk collective dynamic ?

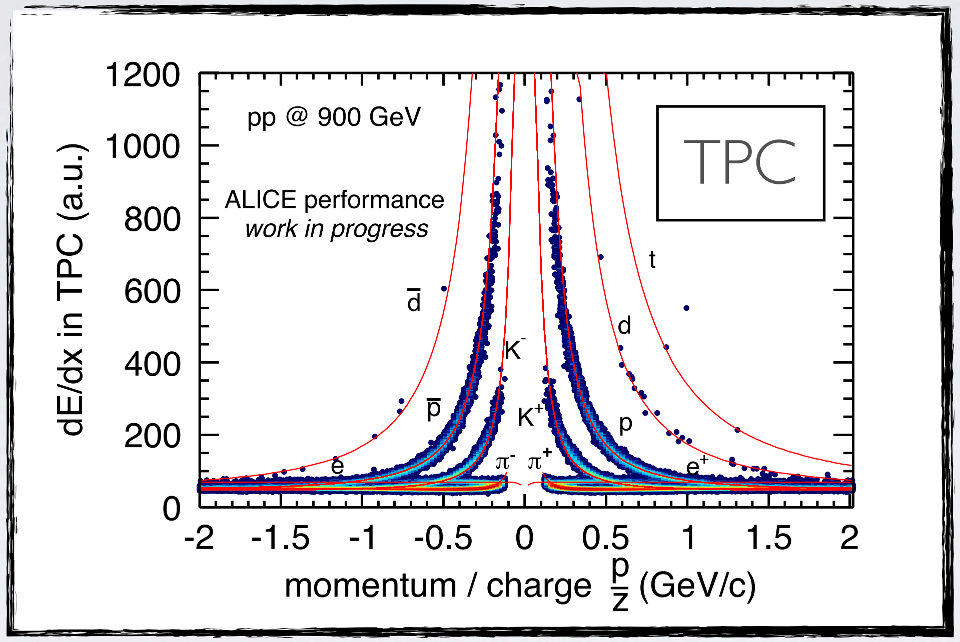
arXiv:1007.0516[hep-ex]

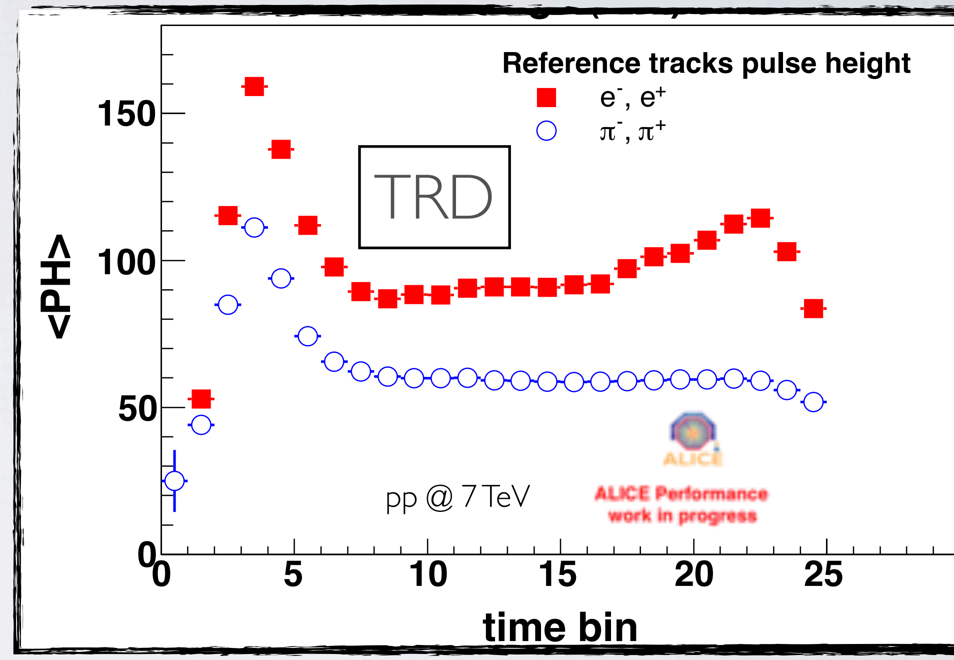
FIRST RESULTS FROM pp AND RELEVANCE TO AA

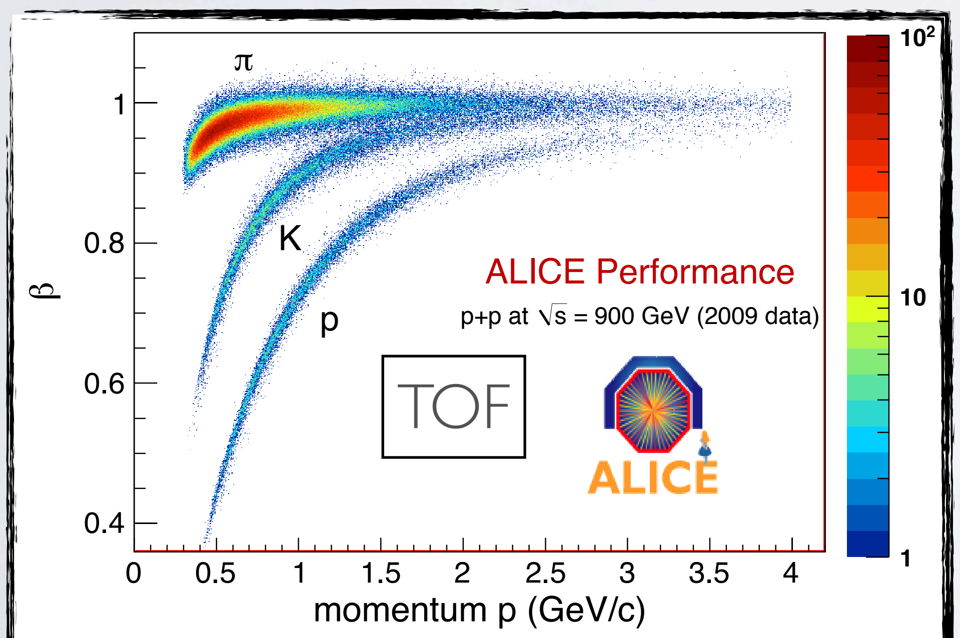
- Multiplicity density and distribution
- Collective dynamics
- **Particle composition**
- Jet production
- Heavy quark production ➔ See contribution by G. Batigne

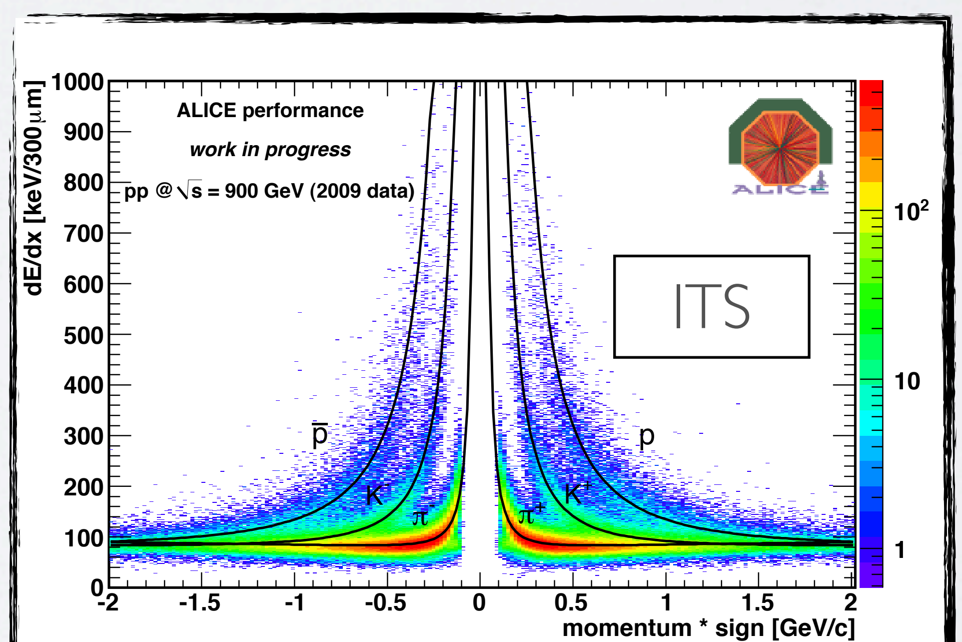
PARTICLE IDENTIFICATION

- ionization energy loss
- time of flight
- transition radiation



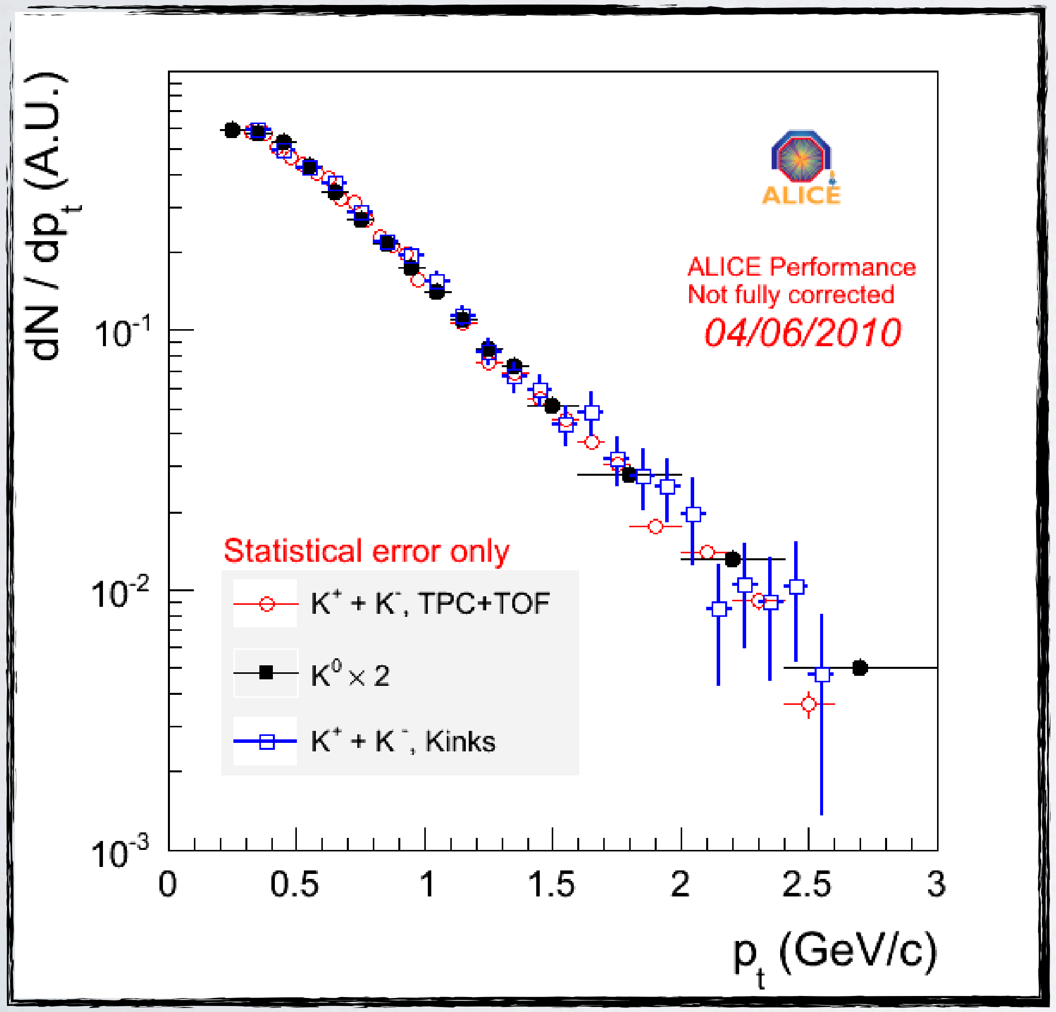


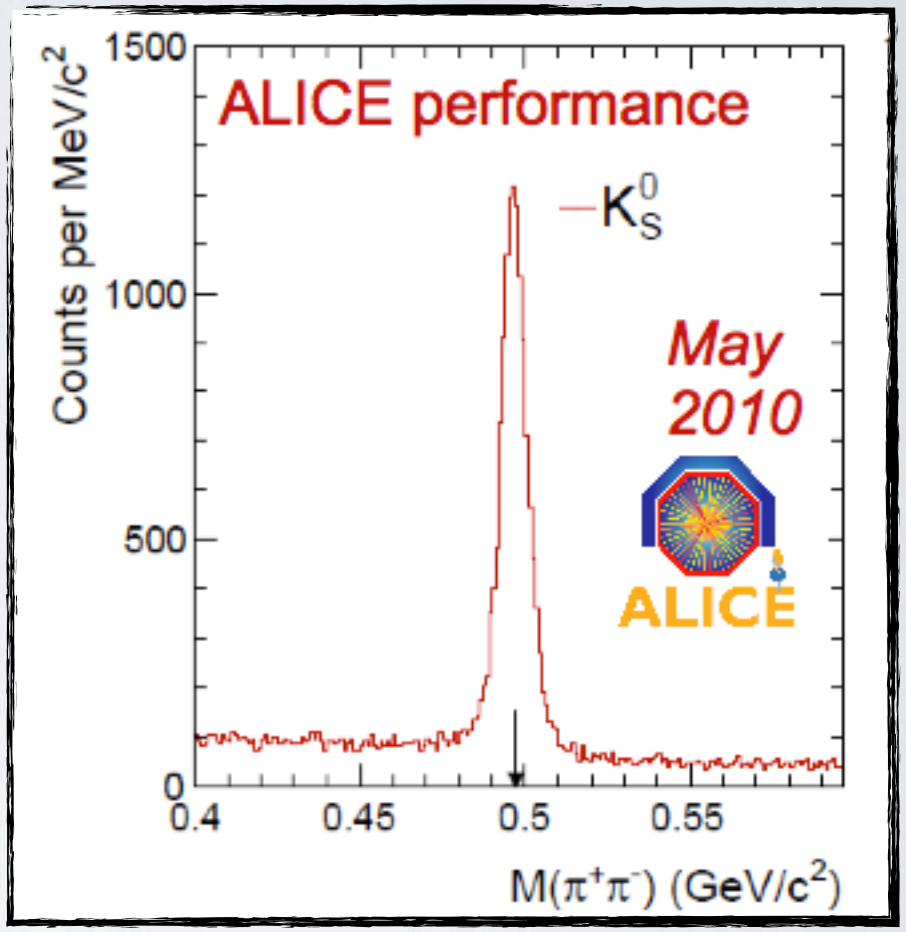




PARTICLE IDENTIFICATION

- Tracking, momentum reconstruction, kink, V0

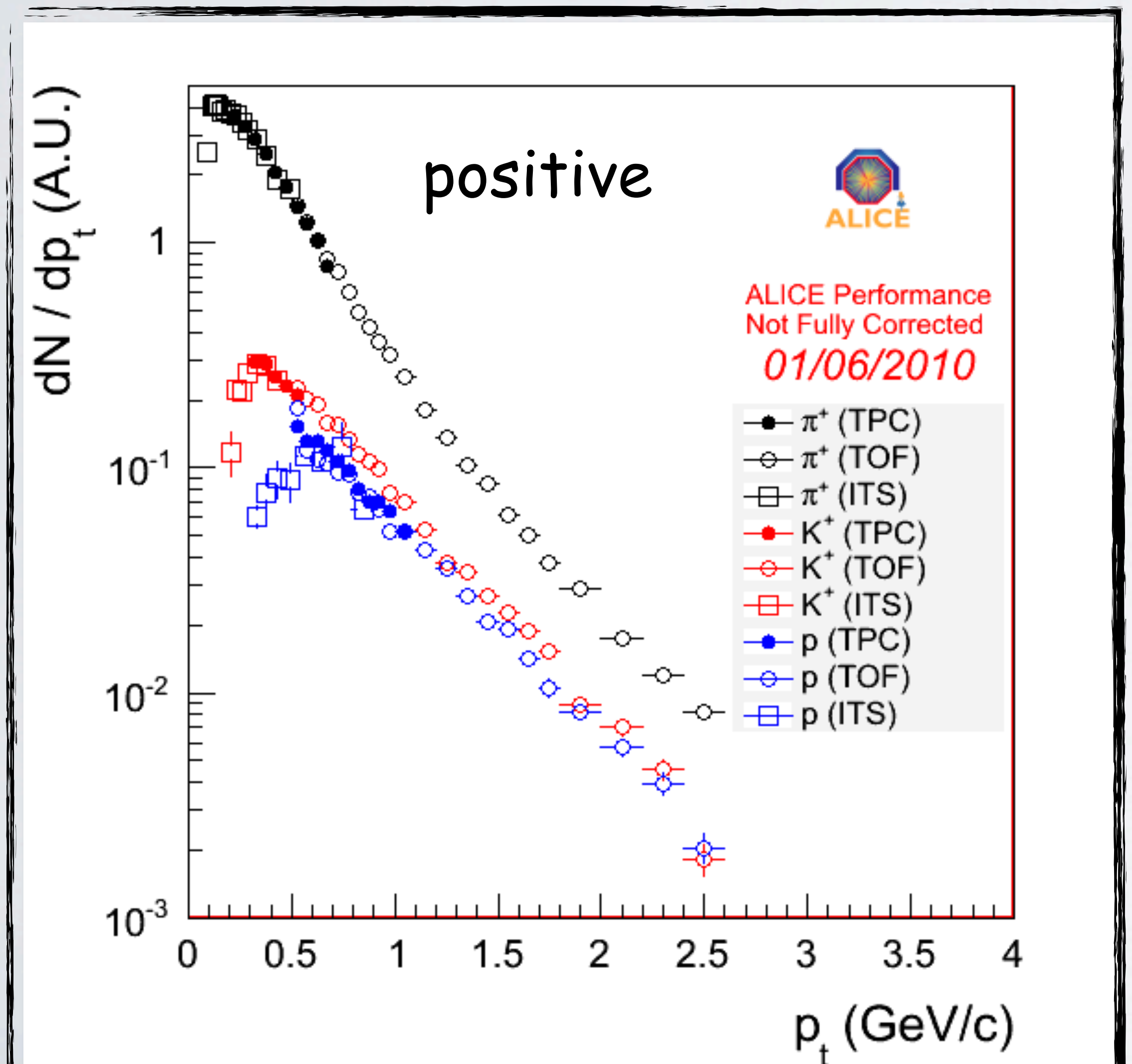


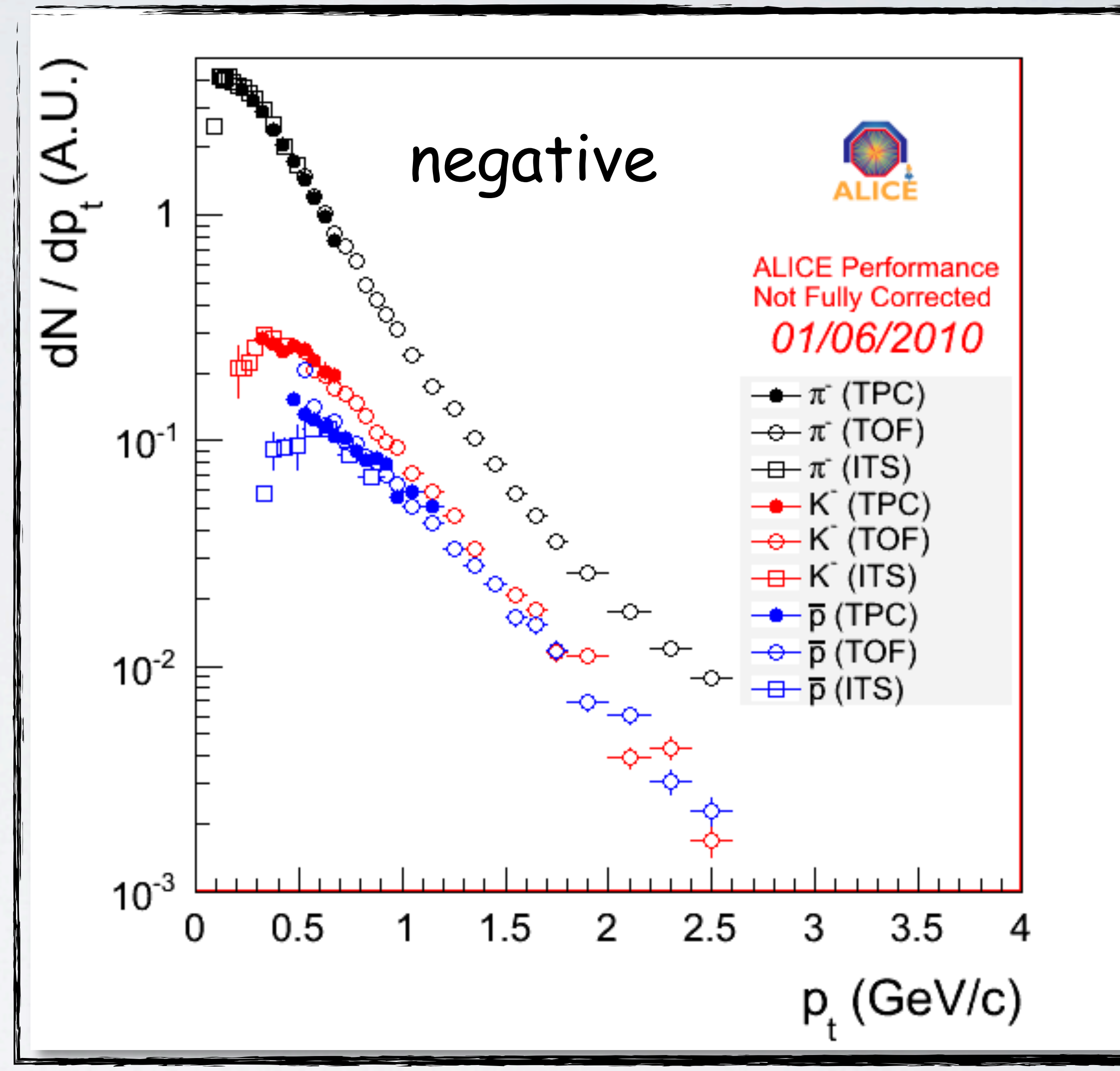


- Various methods lead to the same result

PARTICLE IDENTIFICATION

- ITS, TPC, TOF





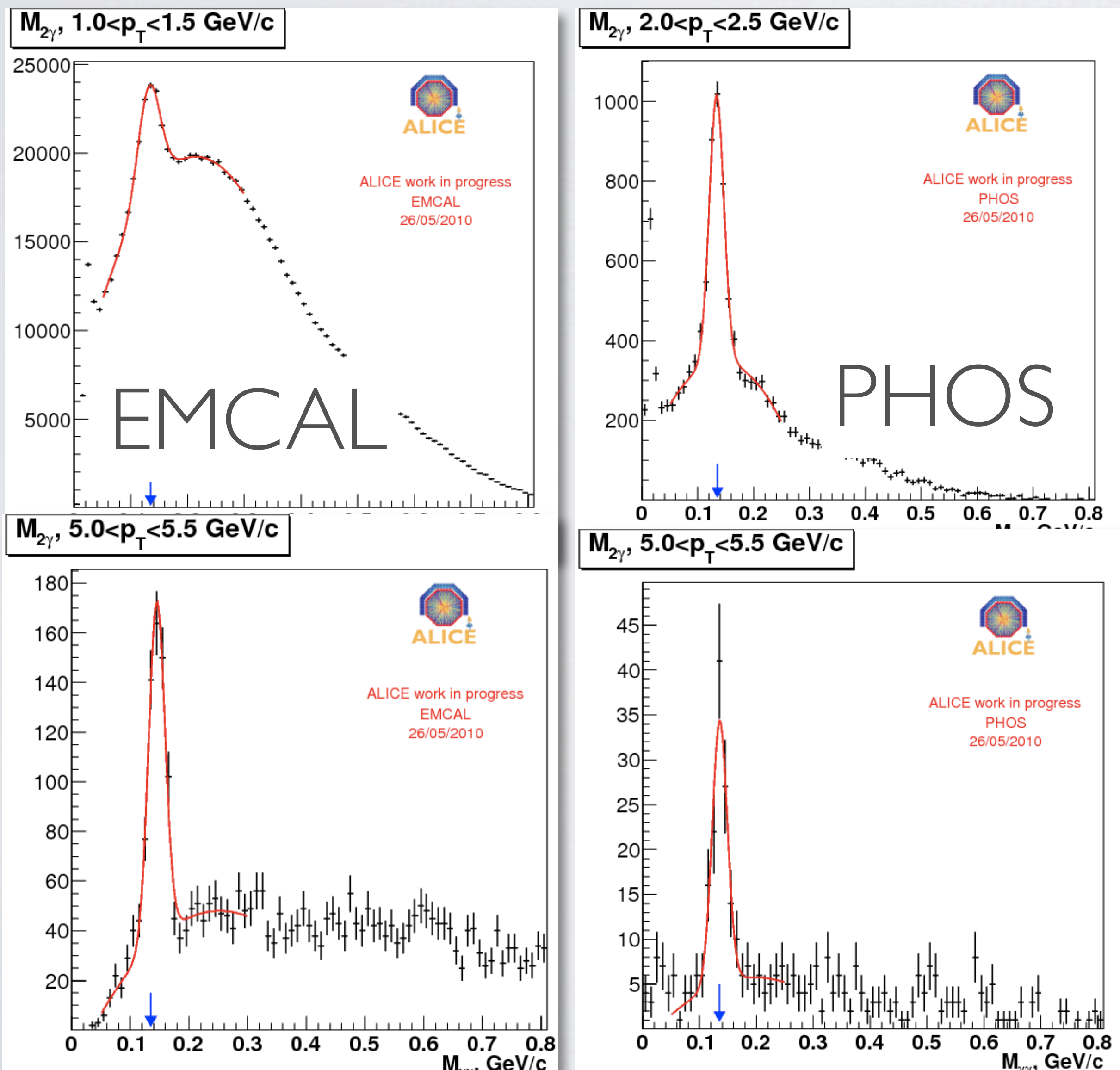
- Different detectors lead to the same result

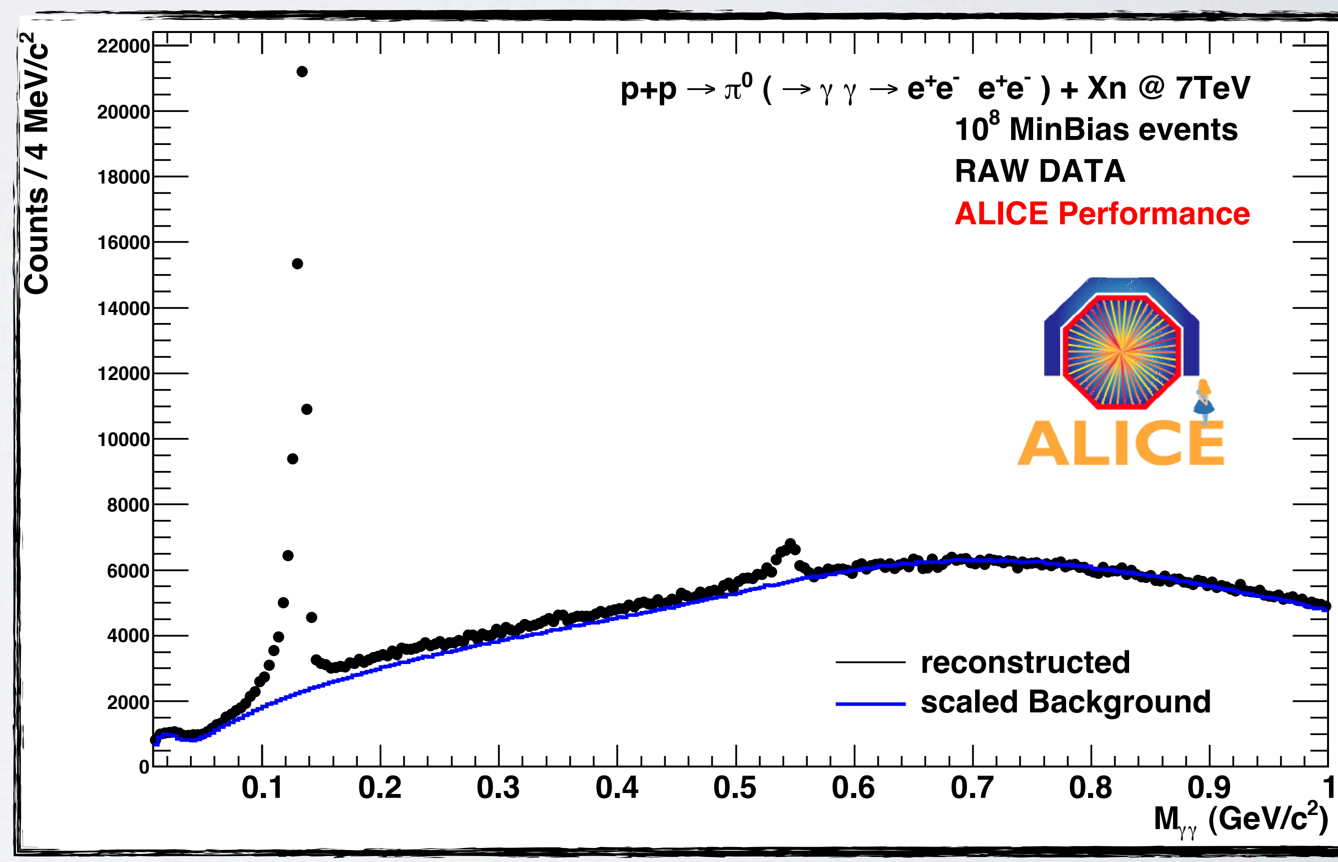
PARTICLE IDENTIFICATION

- Neutral mesons π^0, η, ω^0
  - EM calorimeters
  - tracking: $\pi^0 \rightarrow 4\ e$

1 GeV/c

5 GeV/c

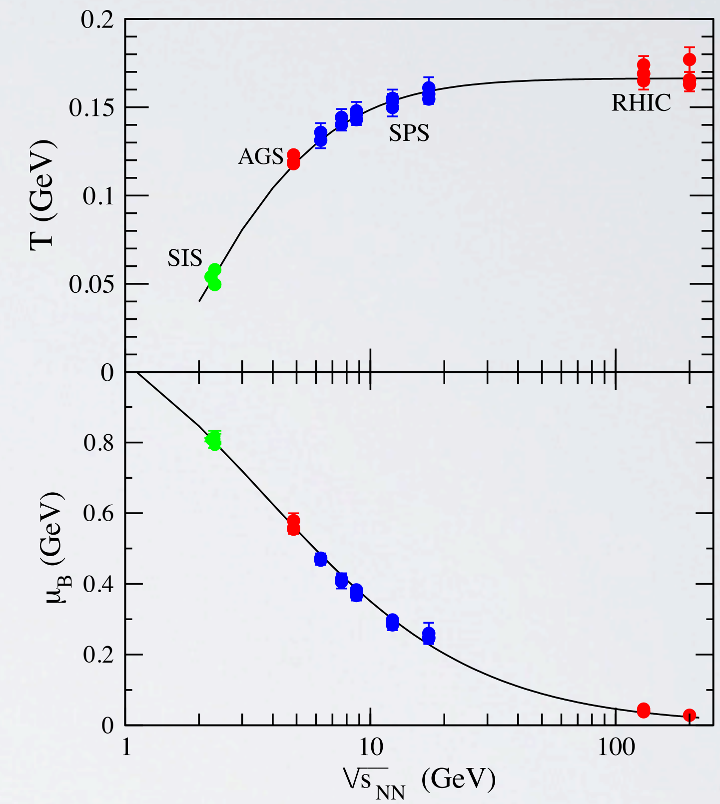




HADROCHEMISTRY

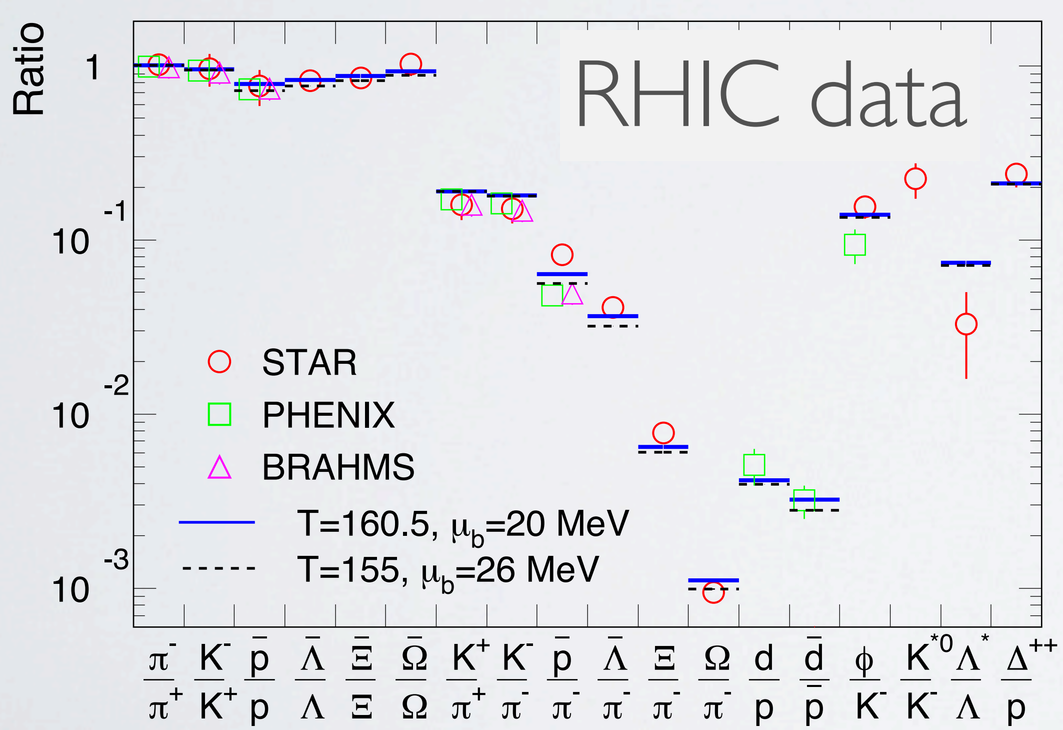
- Relative abundances of hadron species reflect statistical equilibration (grand canonical) → T, μ

Cleymans et al. , hep-th/0511094



$T_{chem} \approx T_C$

Andronic et al. , nucl-th/0511071



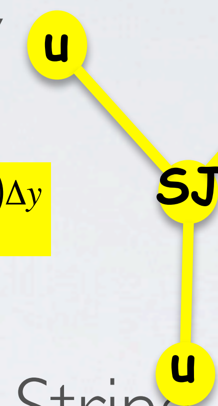
- Limiting temperature established
- Connection to QCD phase boundary
- Does this picture survive at LHC ?

BARYON ASYMMETRY

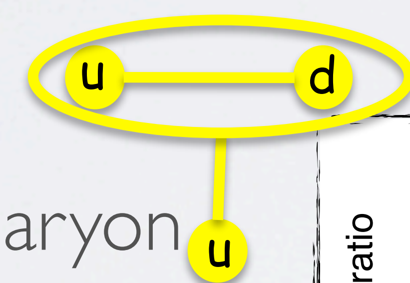
Antiproton to proton ratio at mid rapidity approaches 1

- No p_T and y dependance
- Models with enhanced contributions of String Junction underestimate data
- Data consistent with standard picture of baryon transport

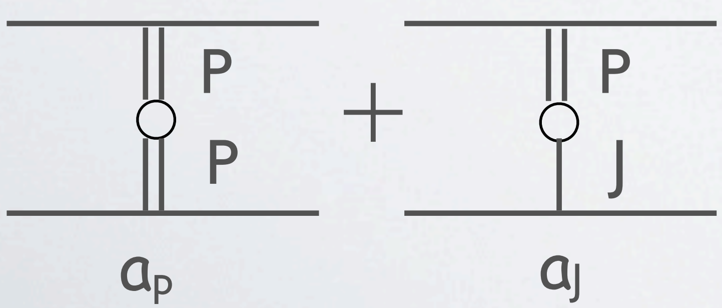
$$P(\Delta y) \sim e^{(\alpha_J - 1)\Delta y}$$

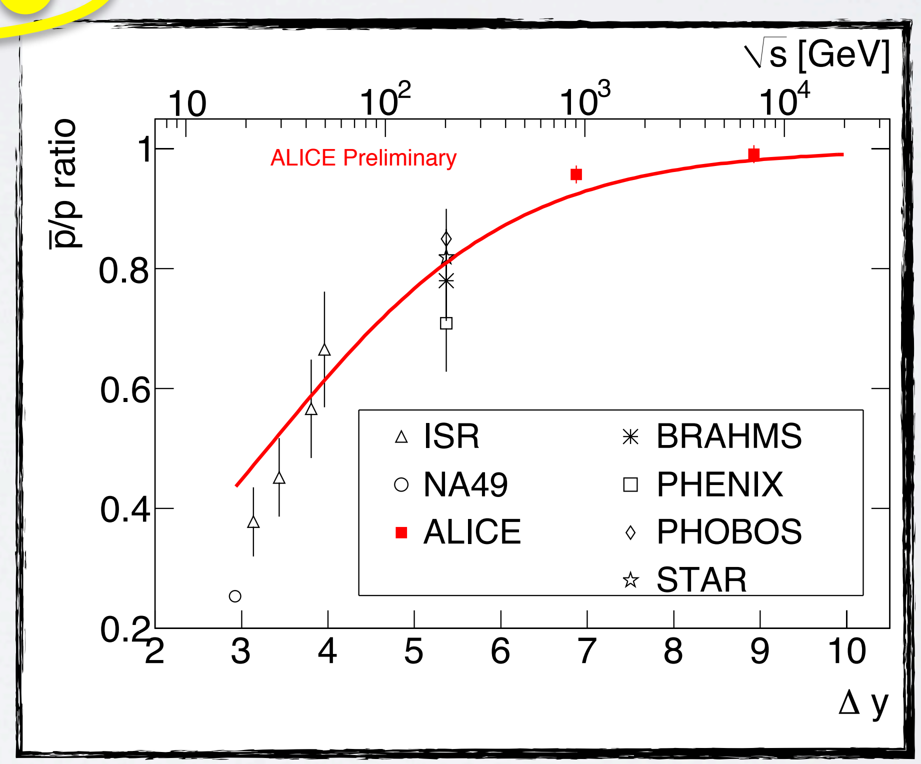


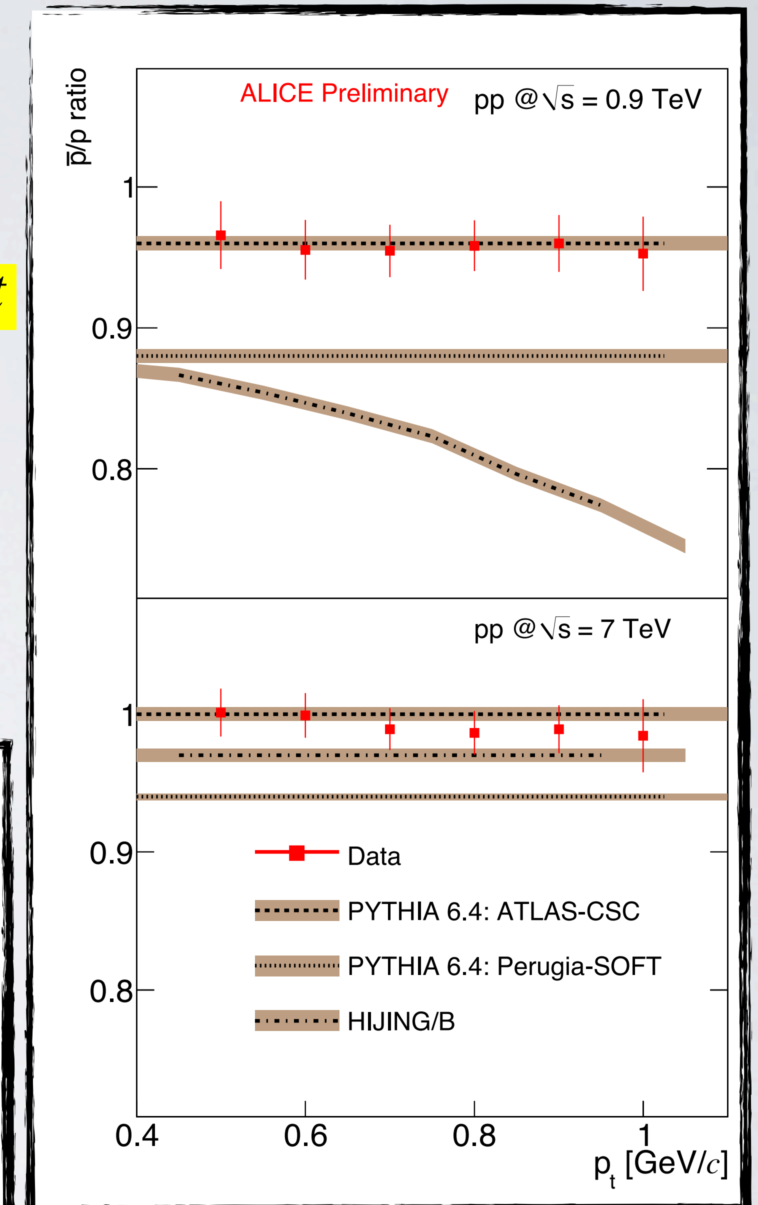
$$P(\Delta y) = const$$



$$\left(\frac{\bar{p}}{p}\right) = \frac{1}{1 + C \cdot e^{(\alpha_J - \alpha_P)\Delta y}} \rightarrow \begin{Bmatrix} a_J = 0.5\ (fixed) \\ a_P = 1.2\ (fixed) \\ C = 10.0 \pm 1.0 \end{Bmatrix}$$







arXiv:1006.5432[hep-ex]

FIRST RESULTS FROM pp AND RELEVANCE TO AA

- Multiplicity density and distribution
- Collective dynamics
- Particle composition
- **Jet production**
- Heavy quark production ➔ See contribution by G. Batigne

PARTON ENERGY LOSS

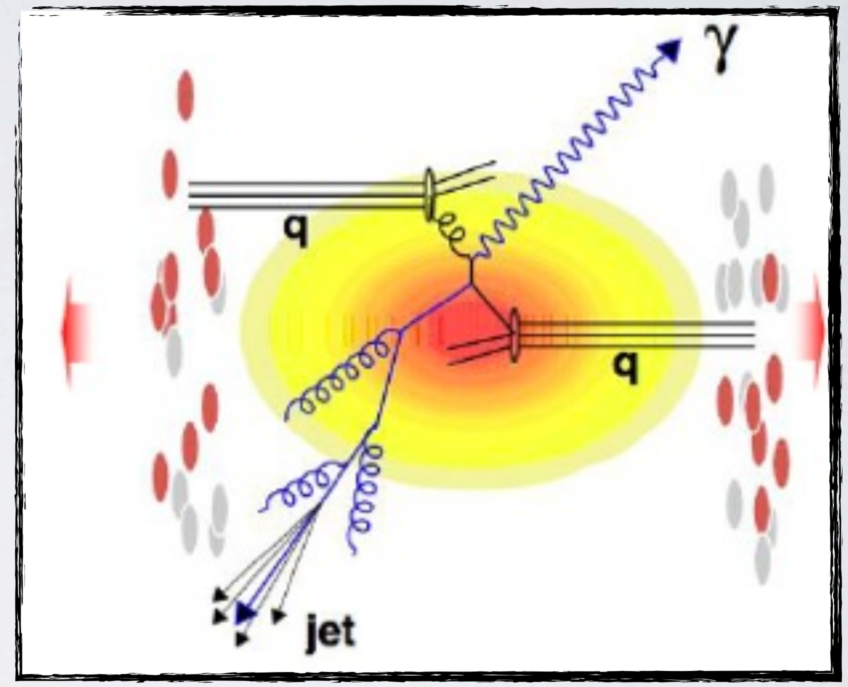
- partons produced in high Q^2 scattering
  - loose energy while traversing the medium through soft gluon radiation and scattering
  - energy loss characteristic of the medium color density

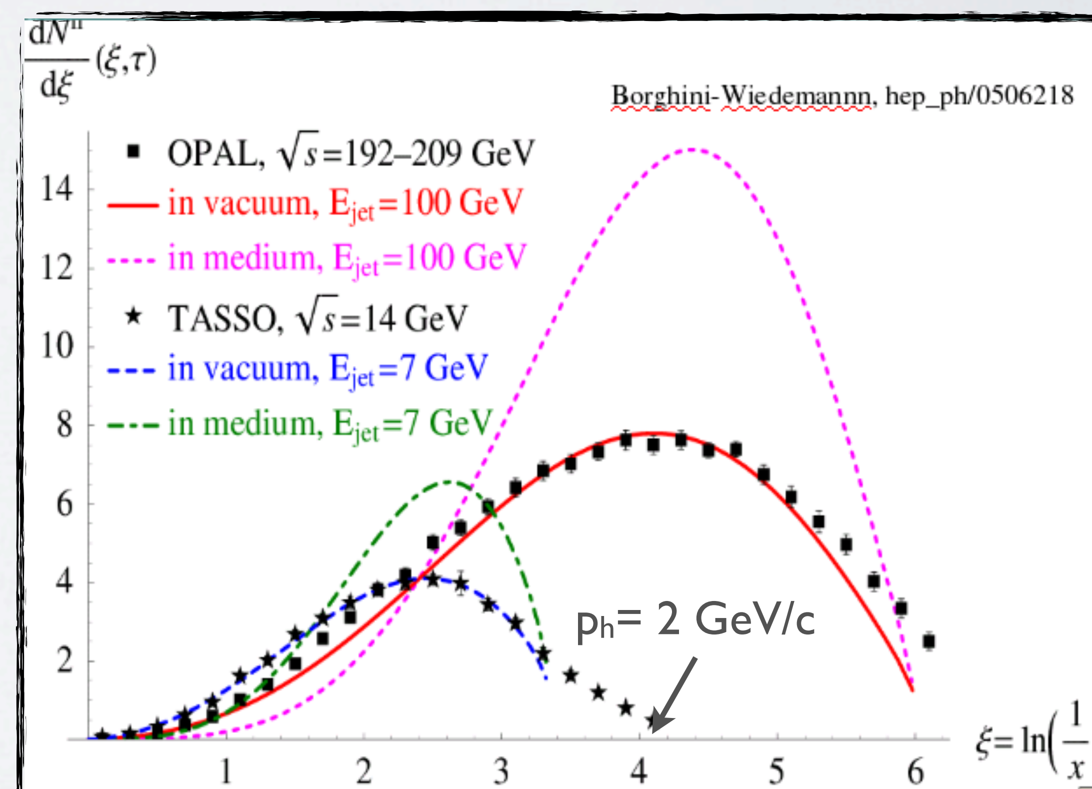
$$\Delta E \propto \alpha_s \hat{q} L^2 ; \hat{q} \equiv \langle p_T^2 \rangle / \lambda \approx \rho_{gluons}$$

  - Measure the effect in the jet fragmentation into hadrons:

$$\xi = \ln(E_{jet}/p_h)$$

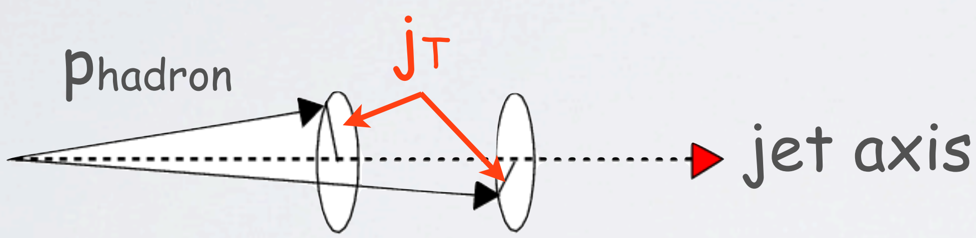
$$E_\gamma$$



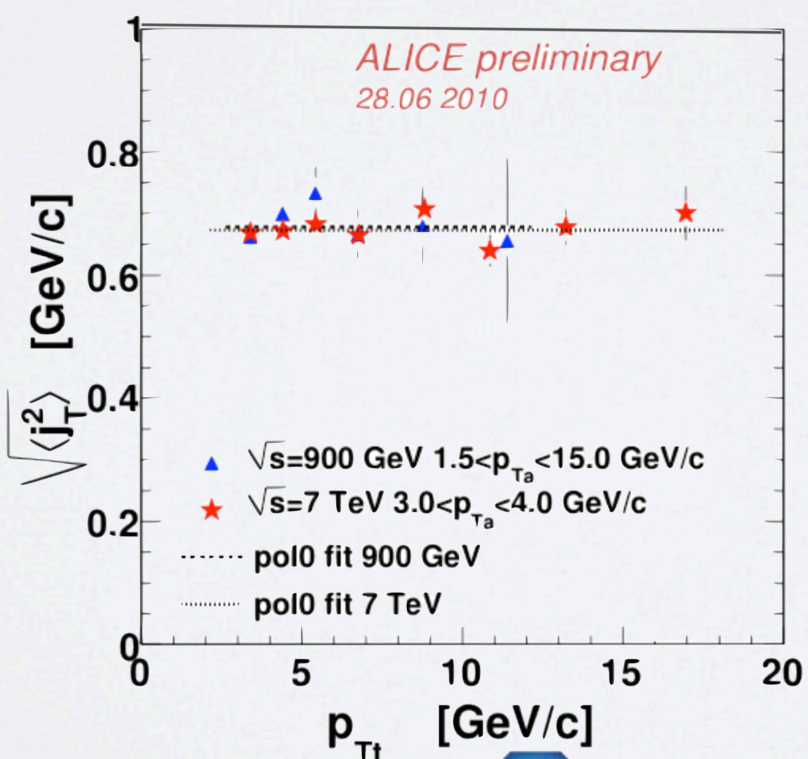


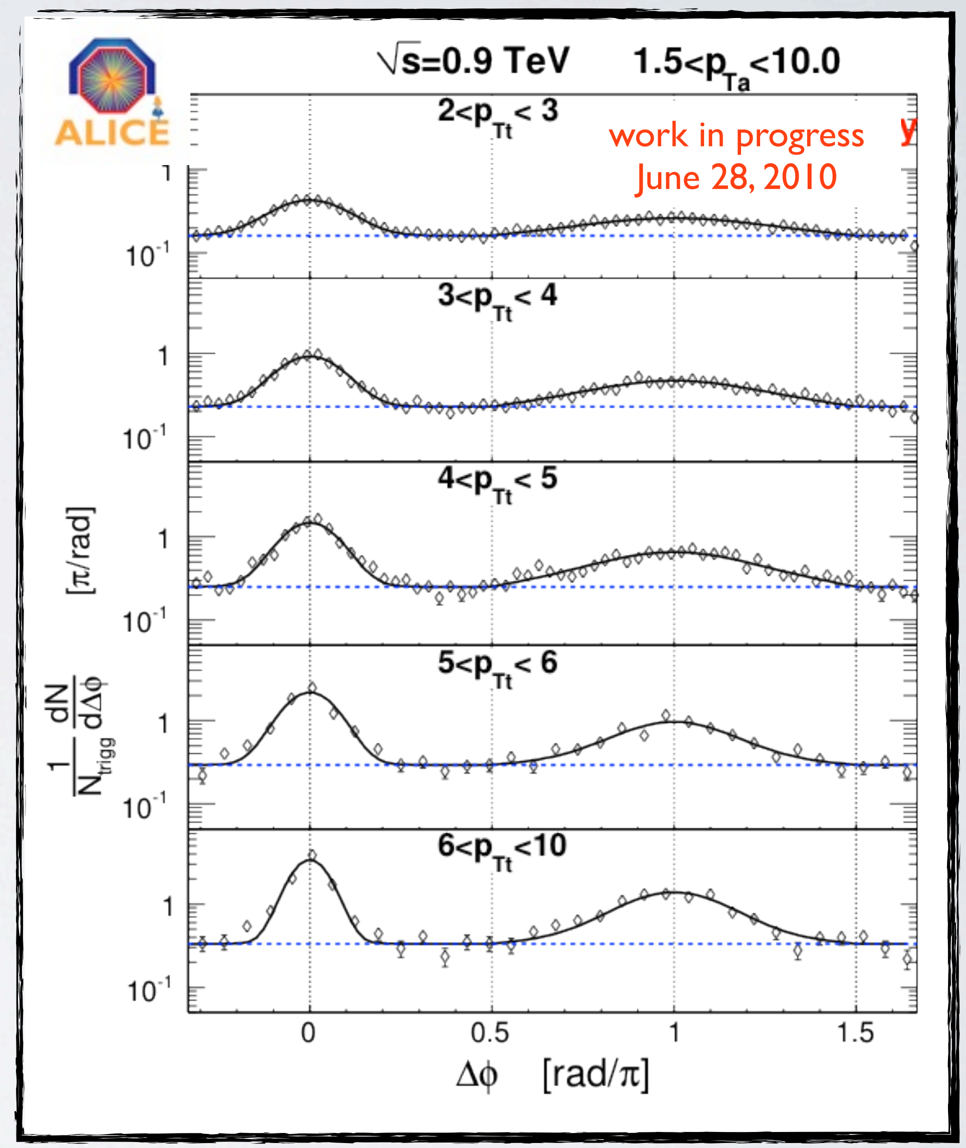
JETINESS

- jet-like structure of the events
- internal structure of the jet



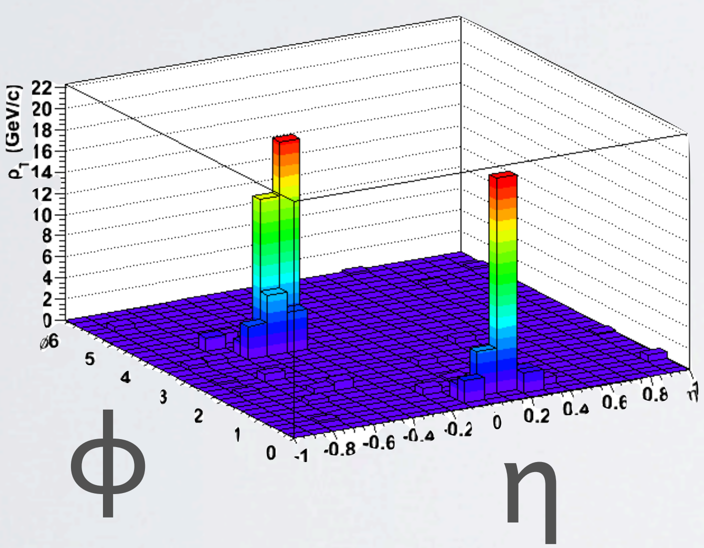
  - remains identical at 0.9 and 7 TeV
  - modification in AA related to the medium properties

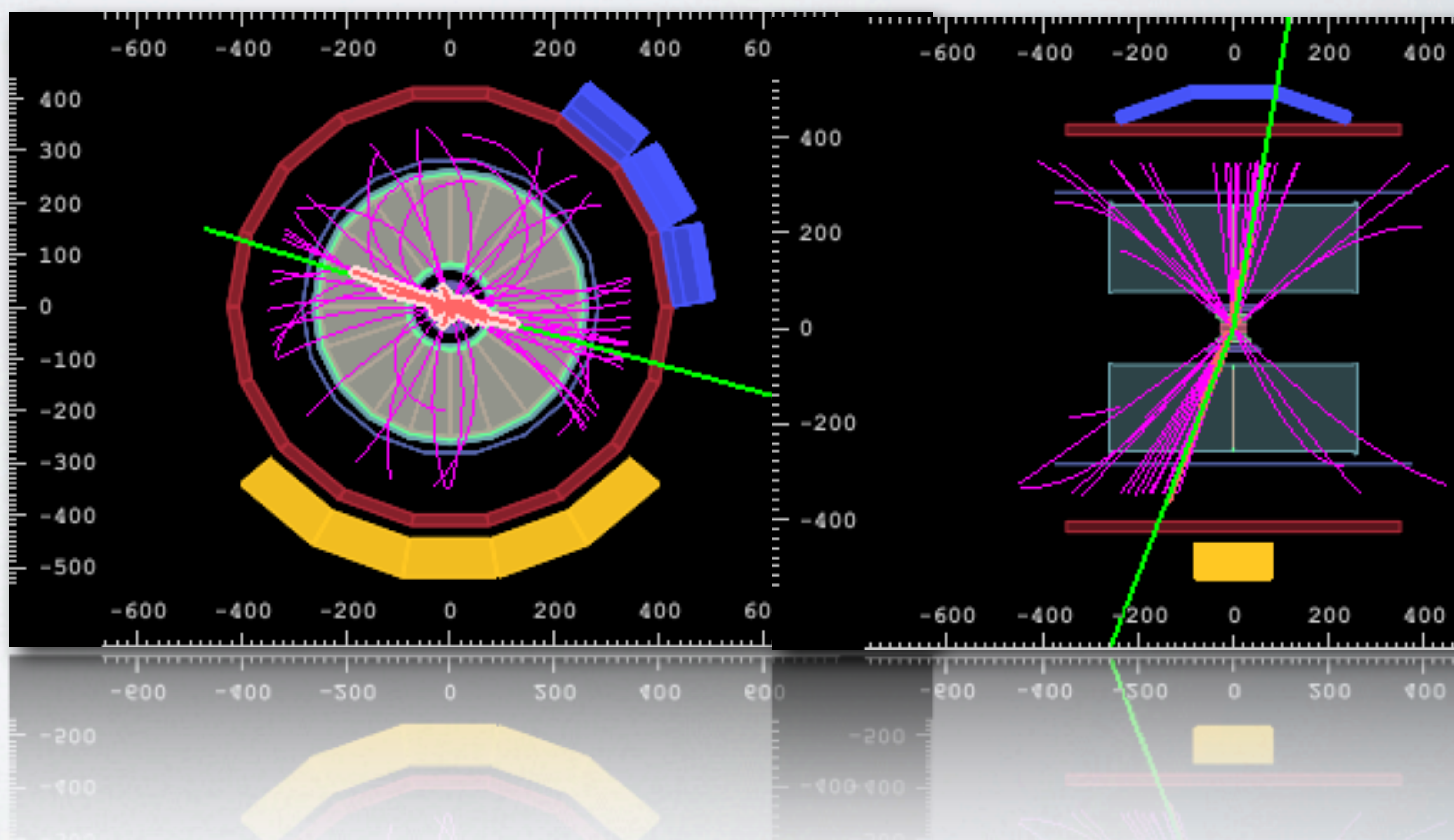




JET RECONSTRUCTION

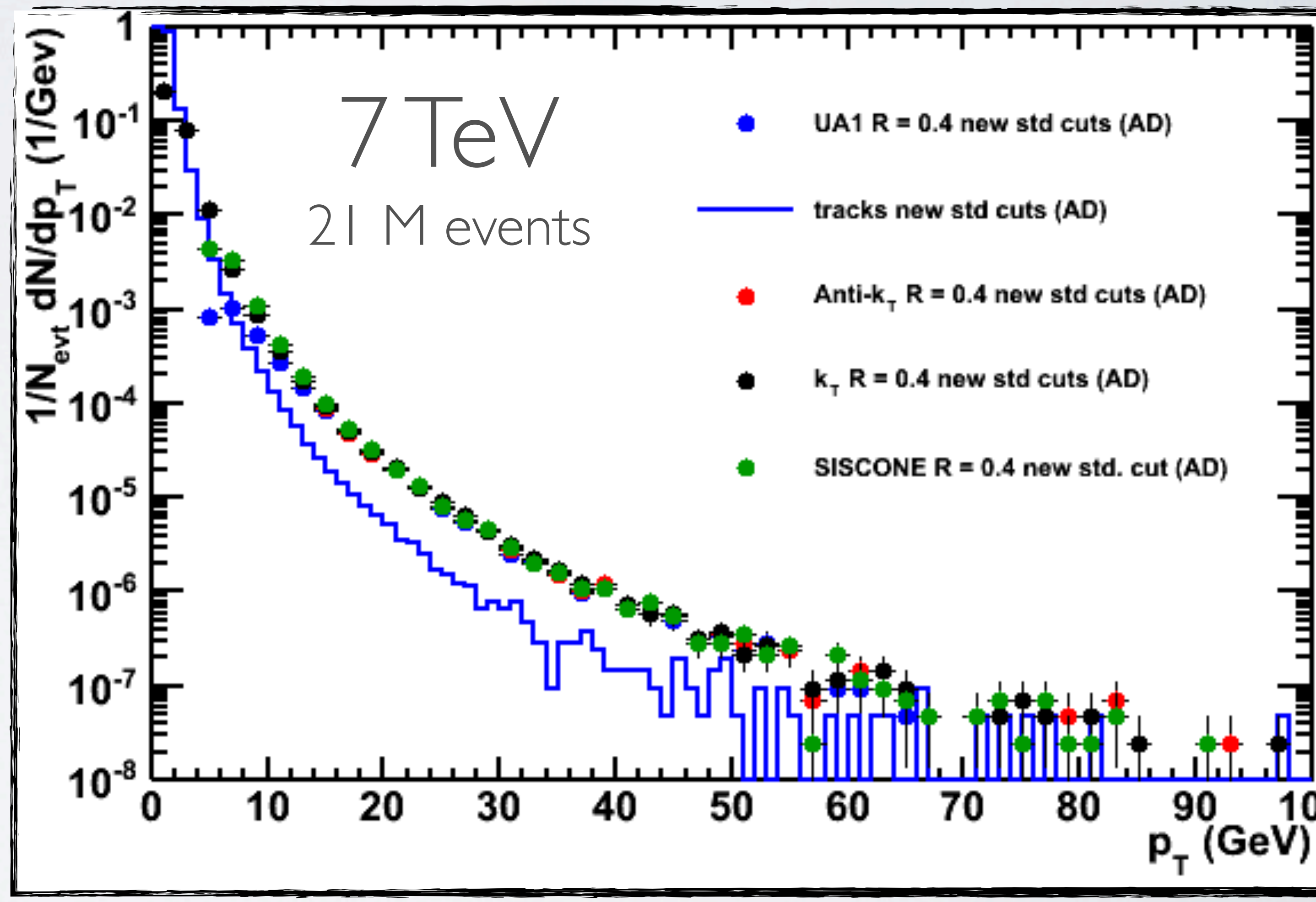
- reconstruction from the charged tracks only





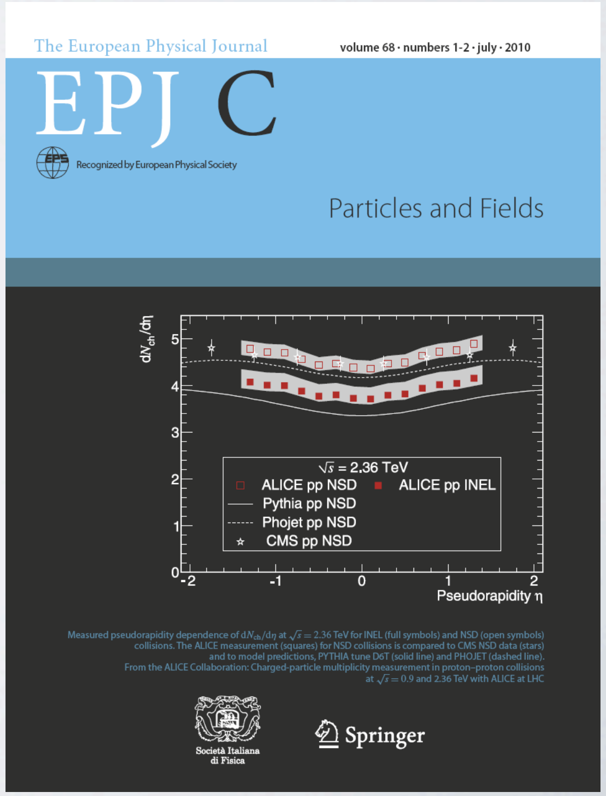
JET RECONSTRUCTION

- **reconstruction from the charged tracks only**
- Compare various algorithms: UA1 jet finder, k_T, anti-k_T, SISCONE
  - jet spectrum safely reconstructed out to 50 GeV
  - very similar results for all jet finders above 15 GeV
  - ready for FF and UE studies



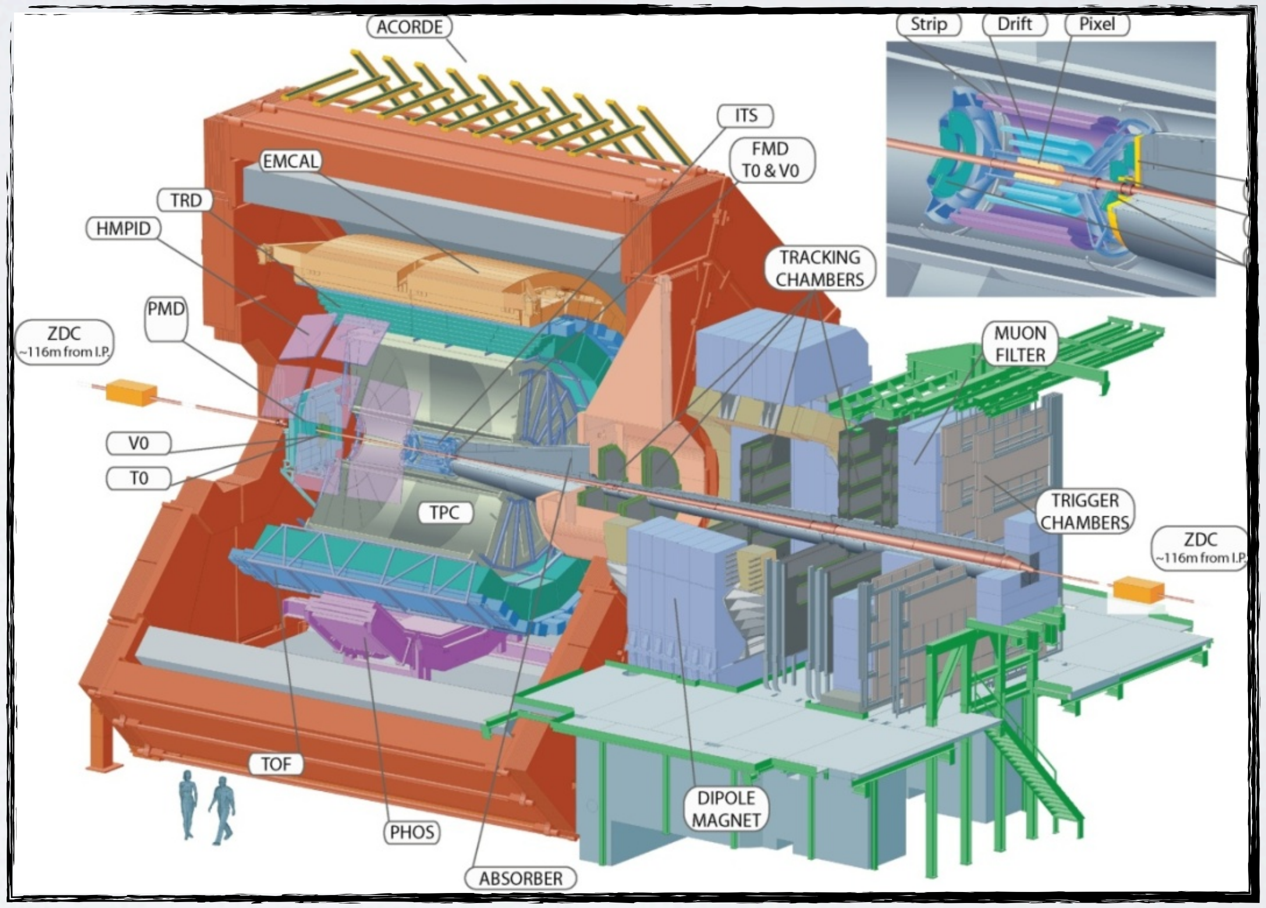
CONCLUSIONS

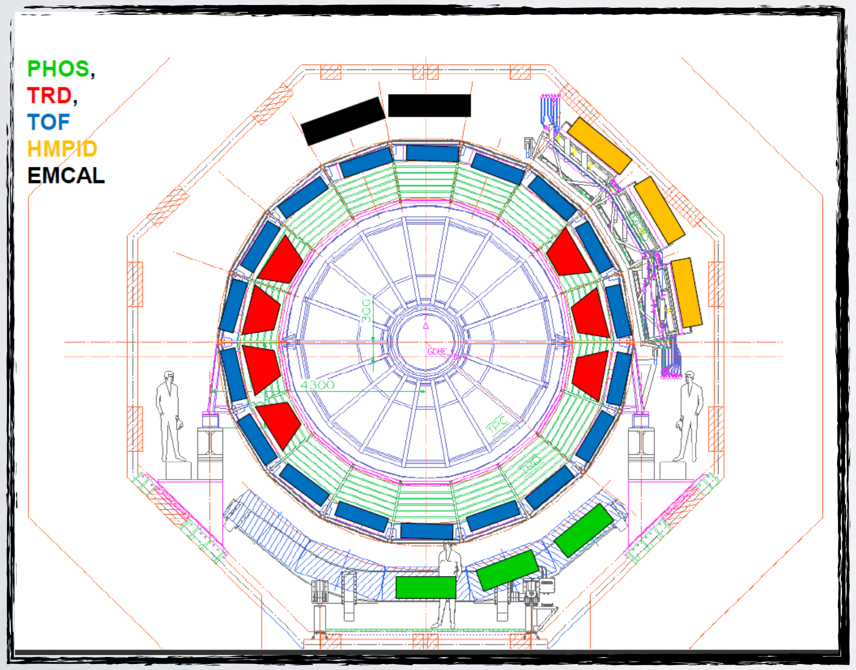
- The ALICE pp physics program
  - do we understand the hadron production in pp ?
  - do high multiplicity pp events exhibit collective behavior ?
  - pave the way for the AA physics program



DETECTOR CONFIGURATION

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





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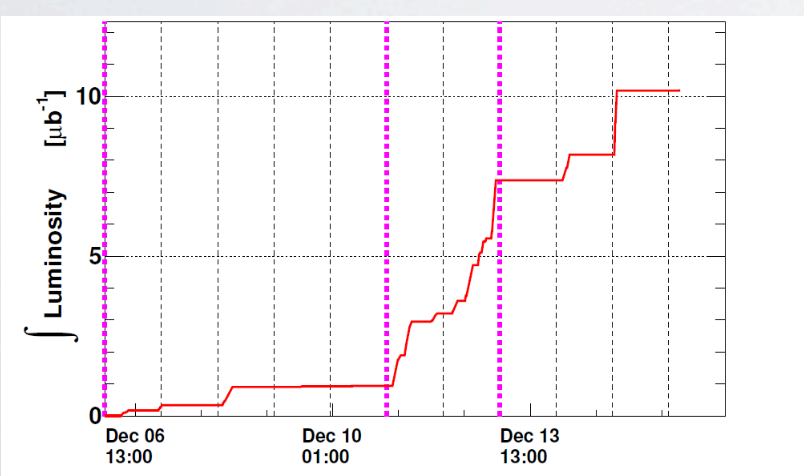
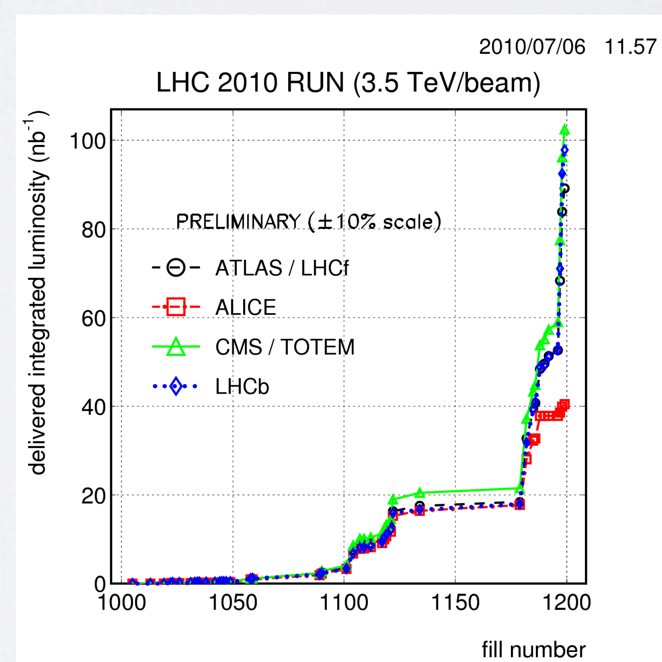
TRIGGER & DATA SAMPLES

- Minimum bias from interaction trigger
  - SPD OR V0-A OR V0-B (at least one charged particle in 8η)
  - Readout all ALICE detectors
- Single μ trigger
  - forward μ AND MinBias
  - Readout MUON, SPD, V0, FMD, ZDC
- In coincidence with beam pickups: bunch crossing with bunches from both sides



2009: 0.9 and 2.36 TeV
~10.4μb^{-1} (5×10^{5} MinBias)



2010: 0.9 and 7 TeV
~40nb^{-1} (350×10^{6} MinBias)

PYTHIA vs. PHOJET (1)

PYTHIA:

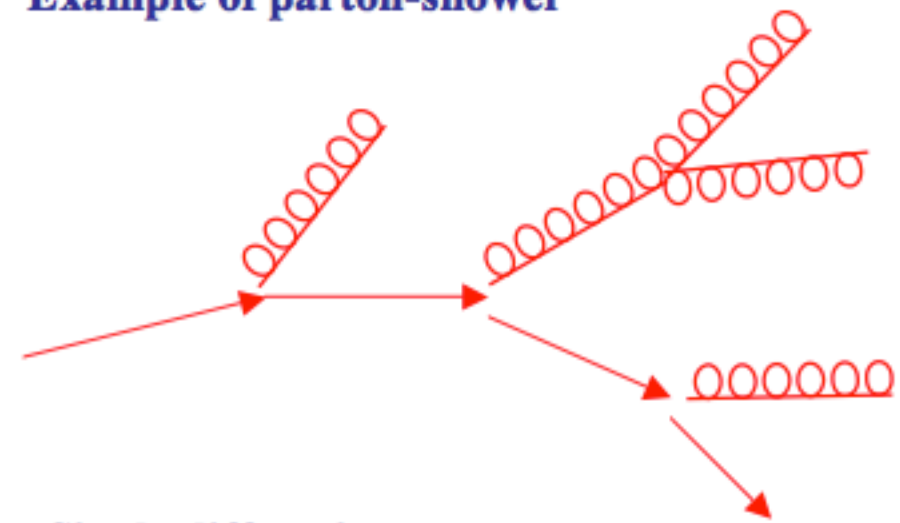
- pQCD cross-section
- multi-partonic-interactions
- cut-off parameter $p_{T,min}$ to cure divergences (simple/complex scenario)
- NLO processes: parton-shower formalism
- Donnachie/Lanshoff parameterization for soft (diffractive) processes

PHOJET

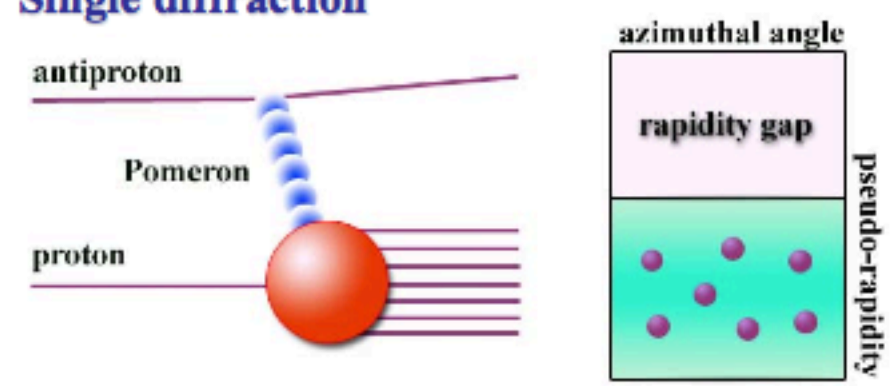
- Leading contribution to multi-particle-production via Pomeron exchange (Donnachie/Lanshoff)
- pQCD for the hard component

Both models implement String Fragmentation.

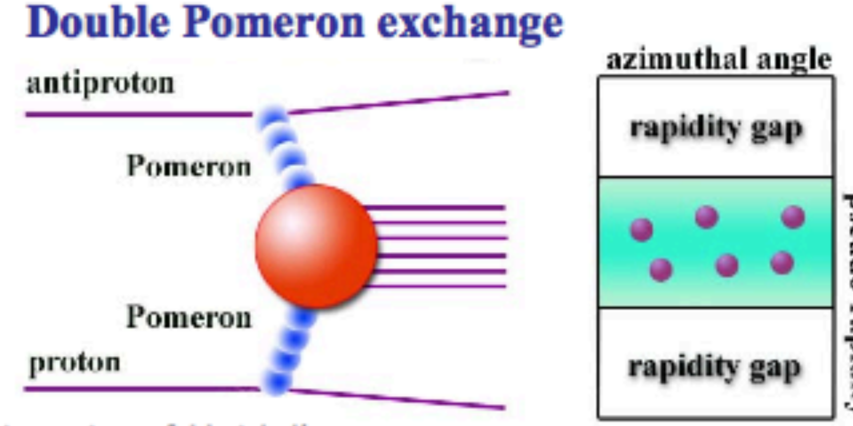
Example of parton-shower



Single diffraction

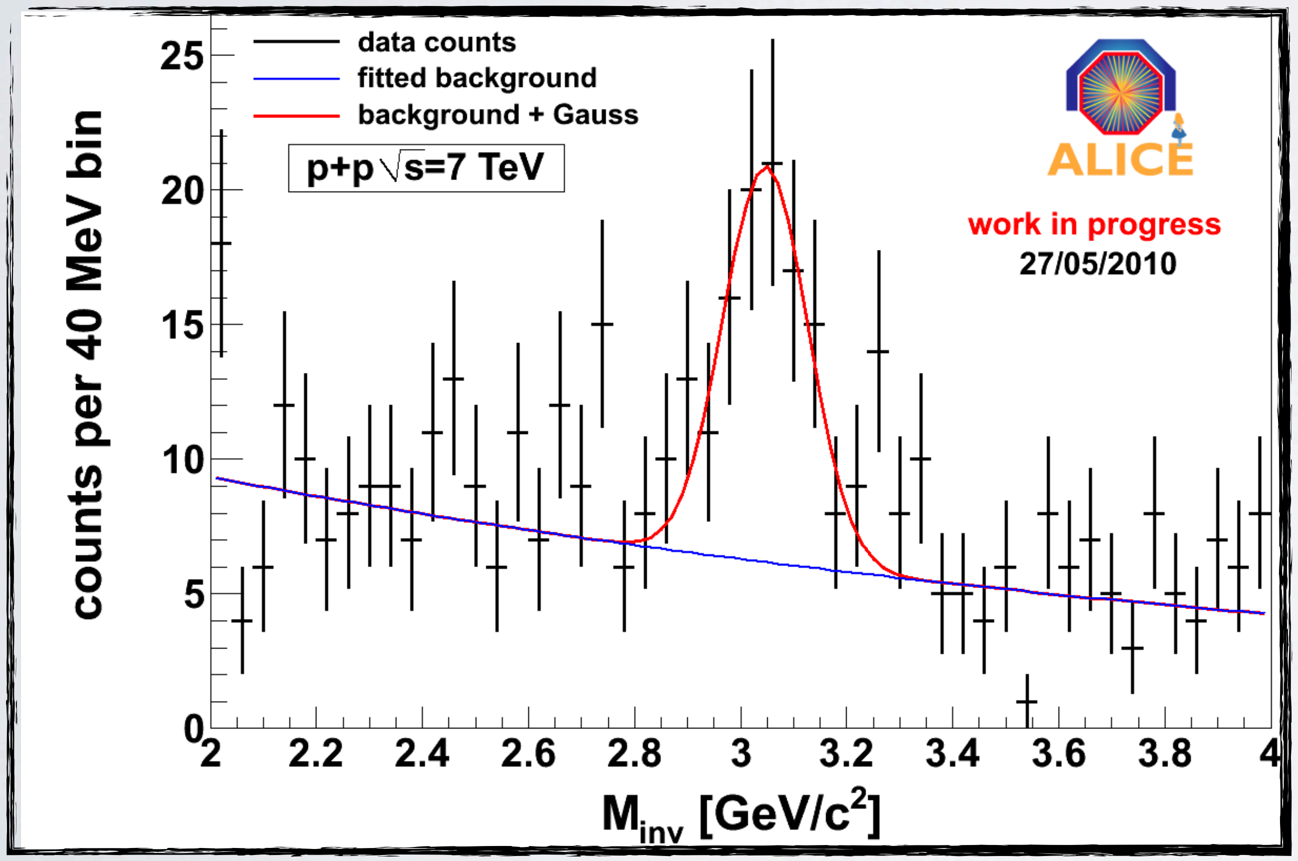


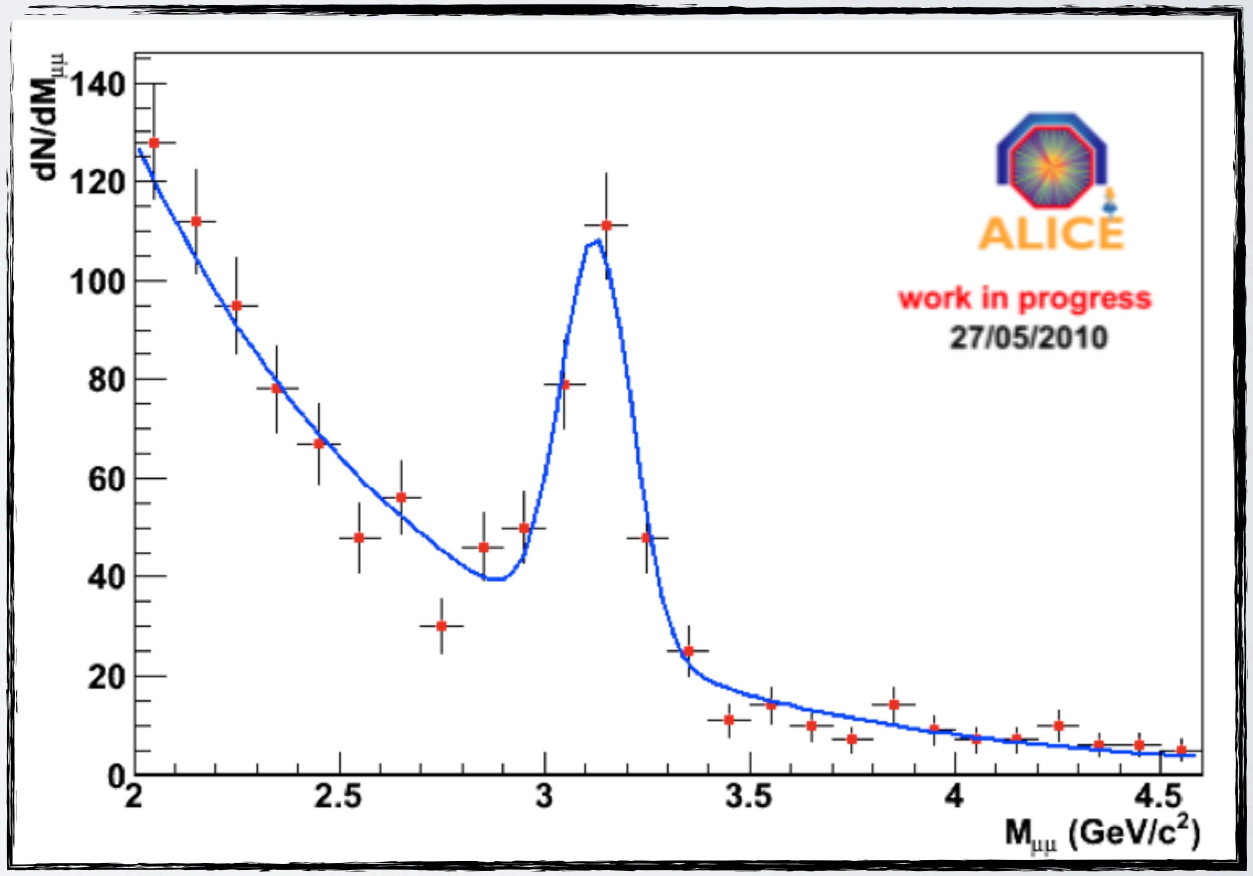
Double Pomeron exchange



CHARMONIA

- $J/\psi \rightarrow e^+e^-$ $|\eta| < 0.9$
- $J/\psi \rightarrow \mu^+\mu^-$ $-4.0 < \eta < -2.5$





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