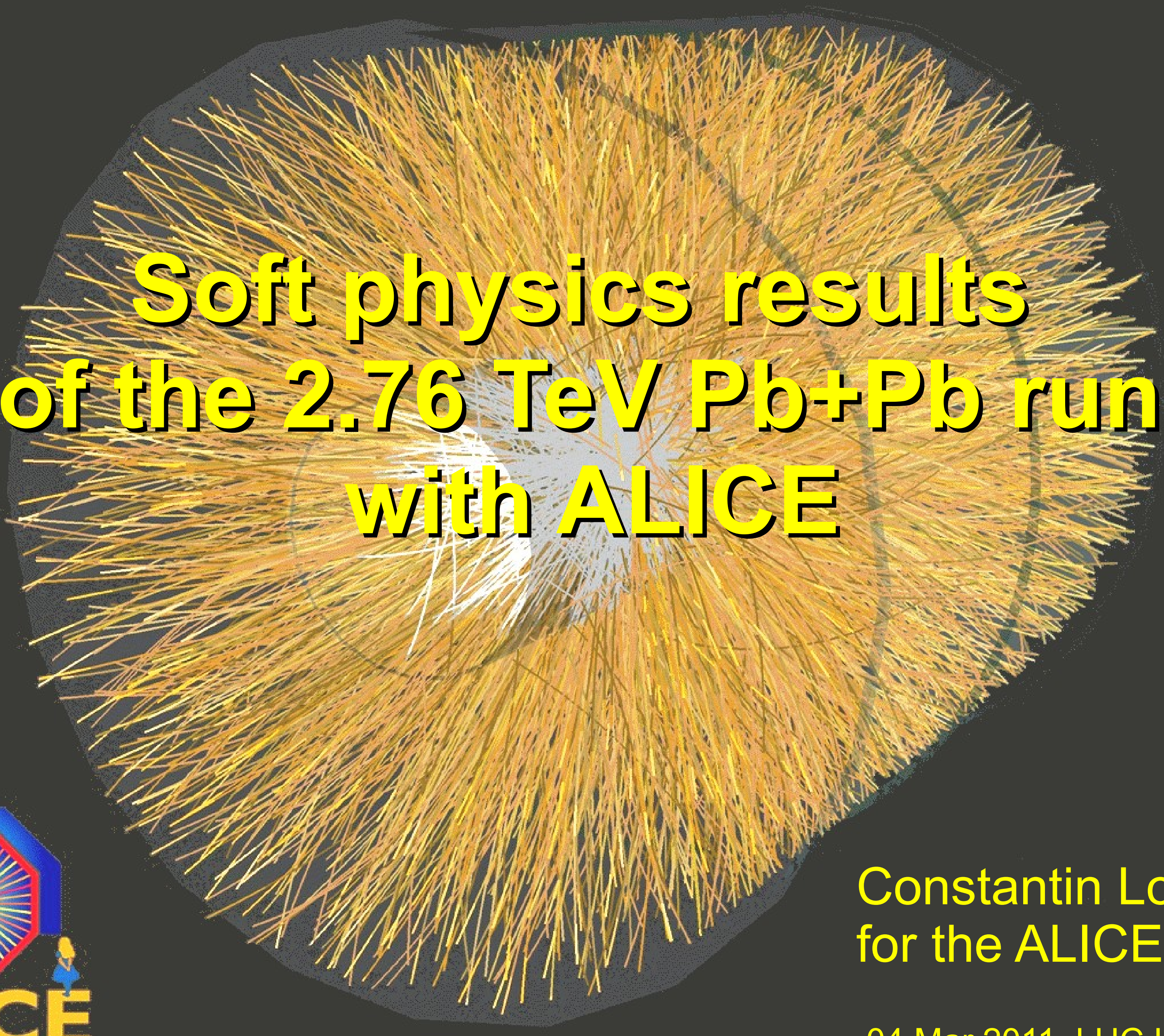
Soft physics results of the 2.76 TeV Pb+Pb run with ALICE



Constantin Loizides
for the ALICE collaboration

04 Mar 2011, LHC HI day

ALICE Pb+Pb results

- Initial Conditions
  - What is the extent of shadowing, saturation, CGC?
    - Particle multiplicity and its centrality dependence
- Time scales & reaction dynamics & transport properties (vs RHIC)
  - What is the space time evolution of the system? Decoupling size/time?
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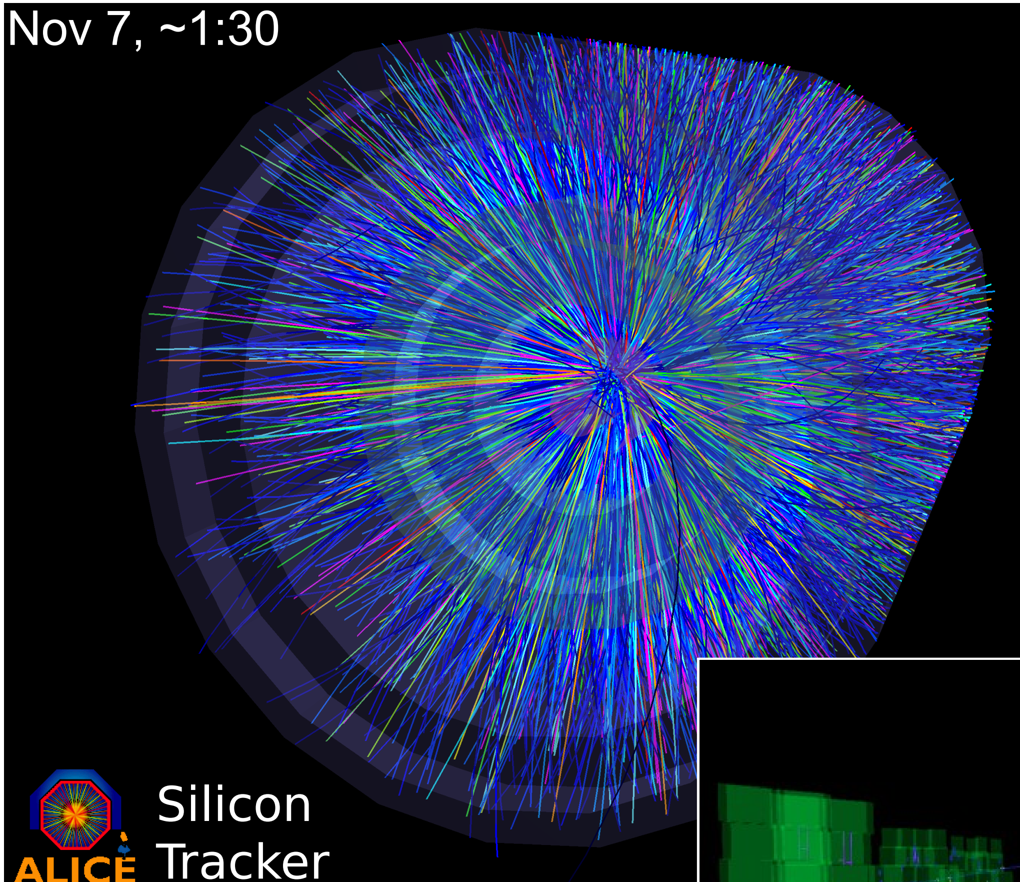
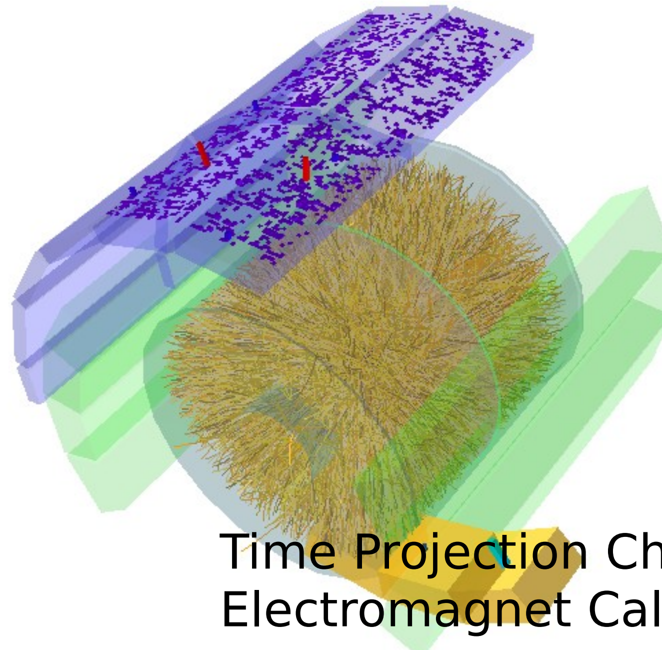
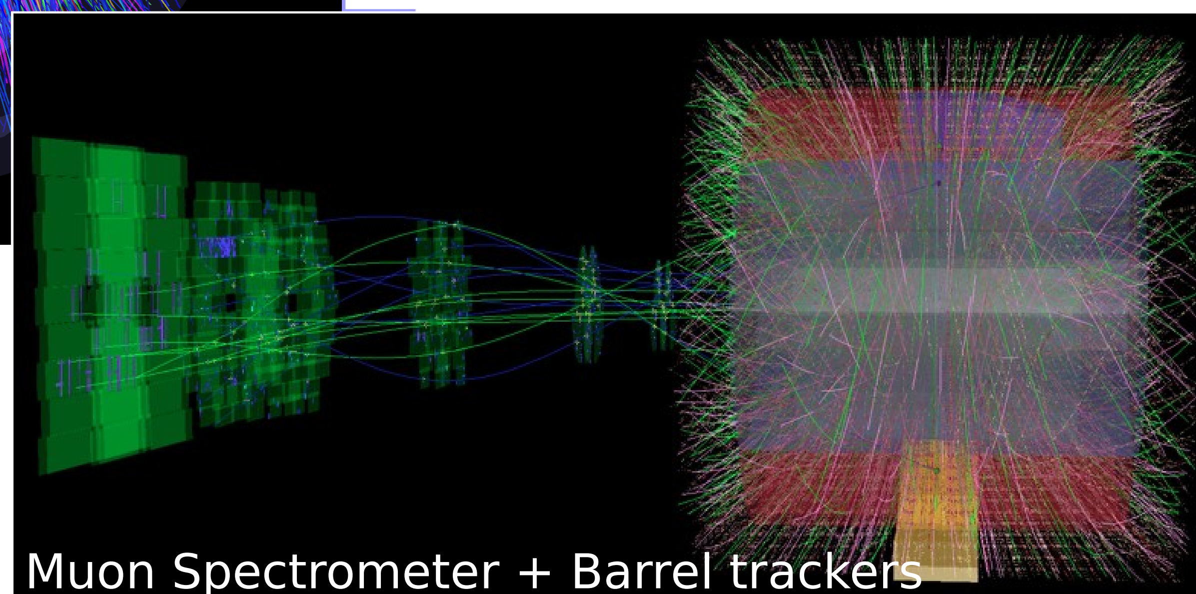
    - Quarkonium yields

} Next talk by Christian Klein-Boesing

Nov 7: First Pb+Pb collisions







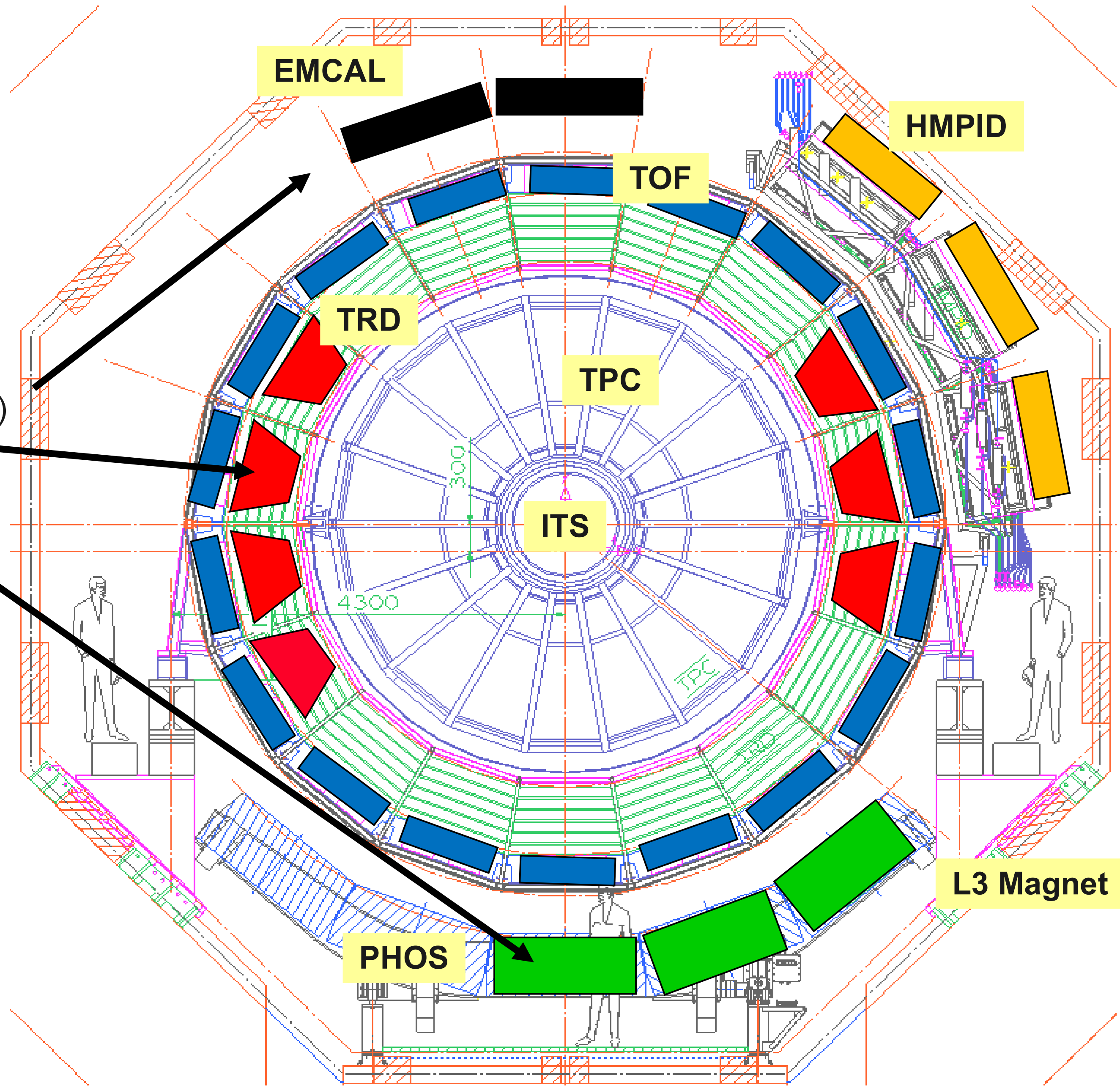
ALICE detector configuration in 2010

Complete since 2008:
ITS, TPC, TOF, HMPID, FMD, T0, V0, ZDC, Muon arm, Acorde, PMD, DAQ

Partial installation:
4/10 EMCAL (approved 2009)
7/18 TRD (approved 2002)
3/5 PHOS (funding)

~ 60% HLT (High Level Trigger)

Short Status:
All systems fully operational



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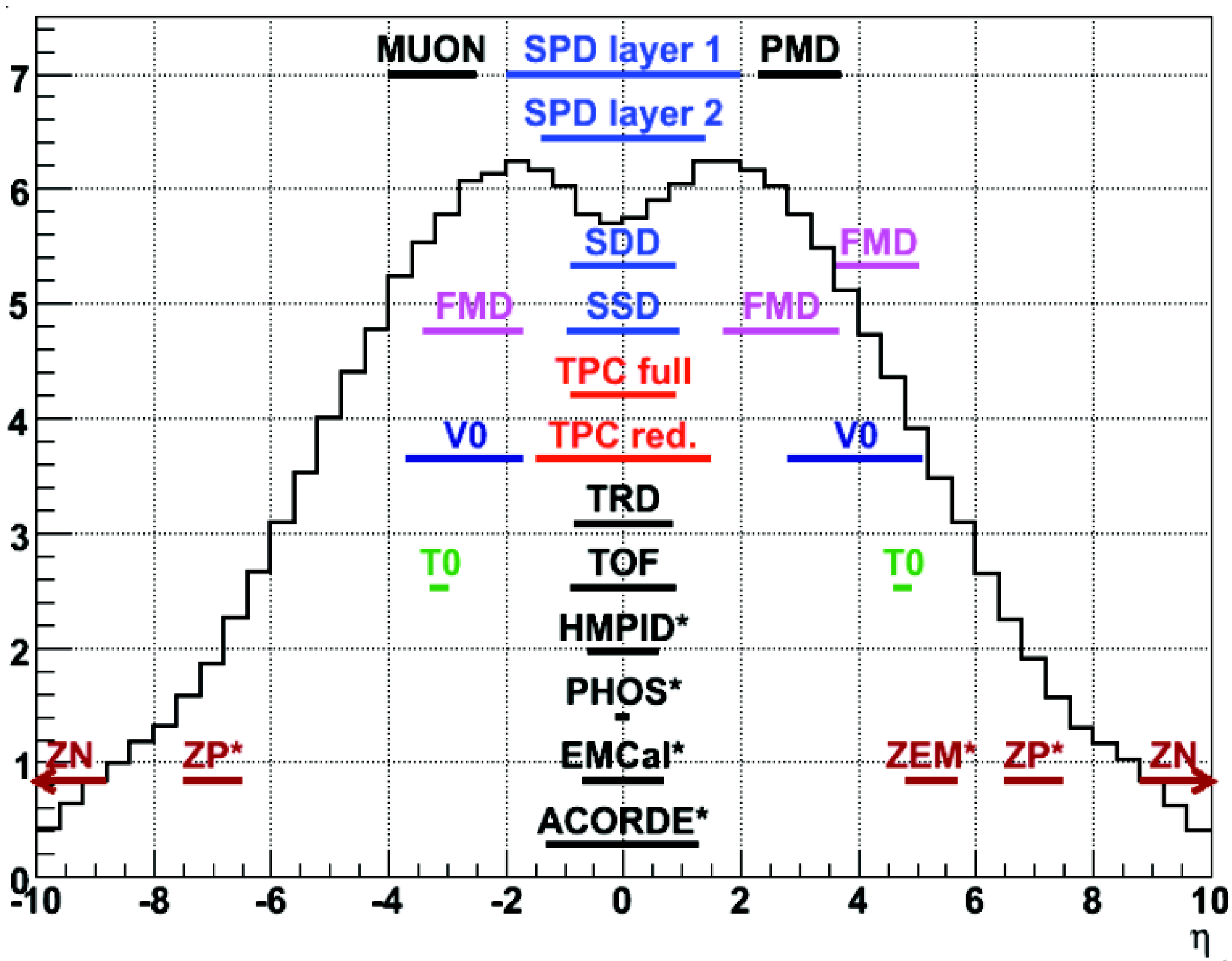
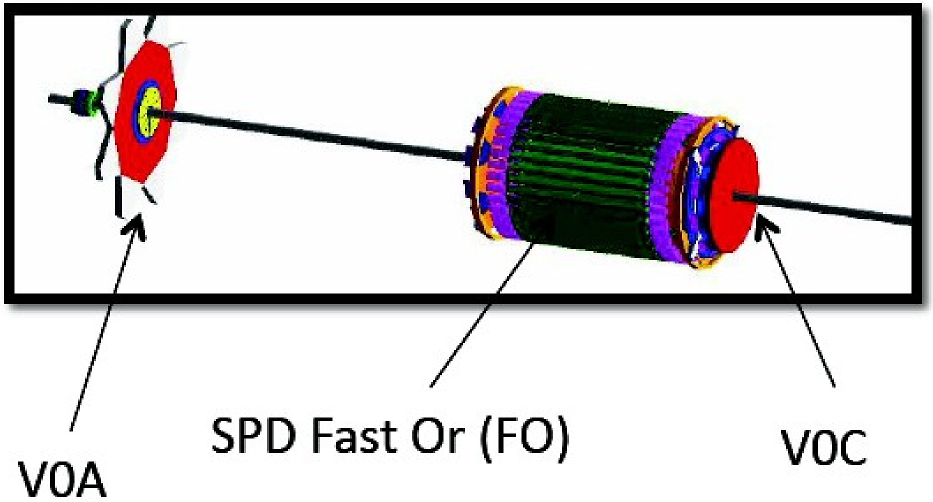


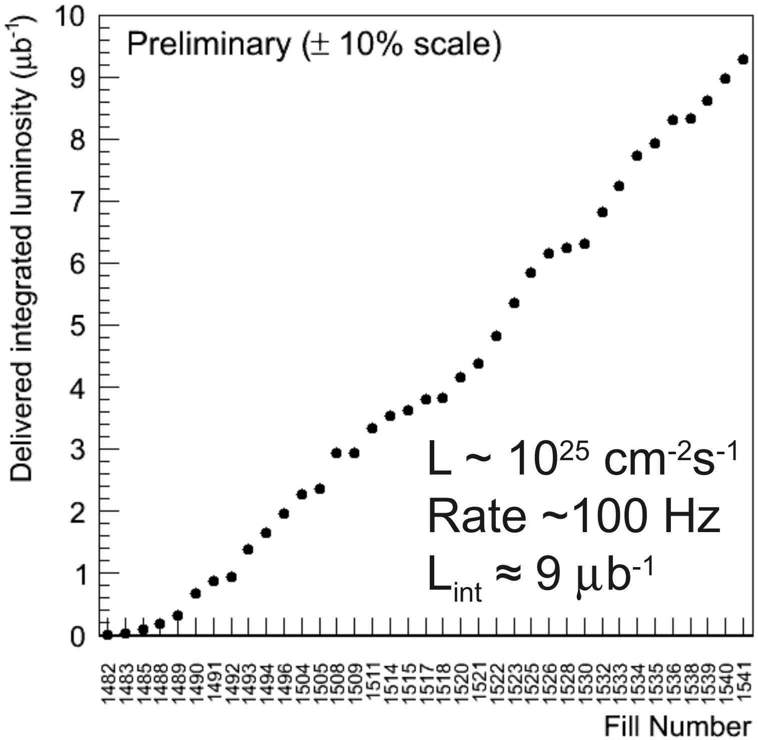
pseudorapidity

Short Status:
All systems fully operational

Trigger conditions

- Open trigger conditions for minimum bias interaction
  - Catches ≈98% of Pb+Pb inelastic cross section
- Zerobias and ultraperipheral triggers also used



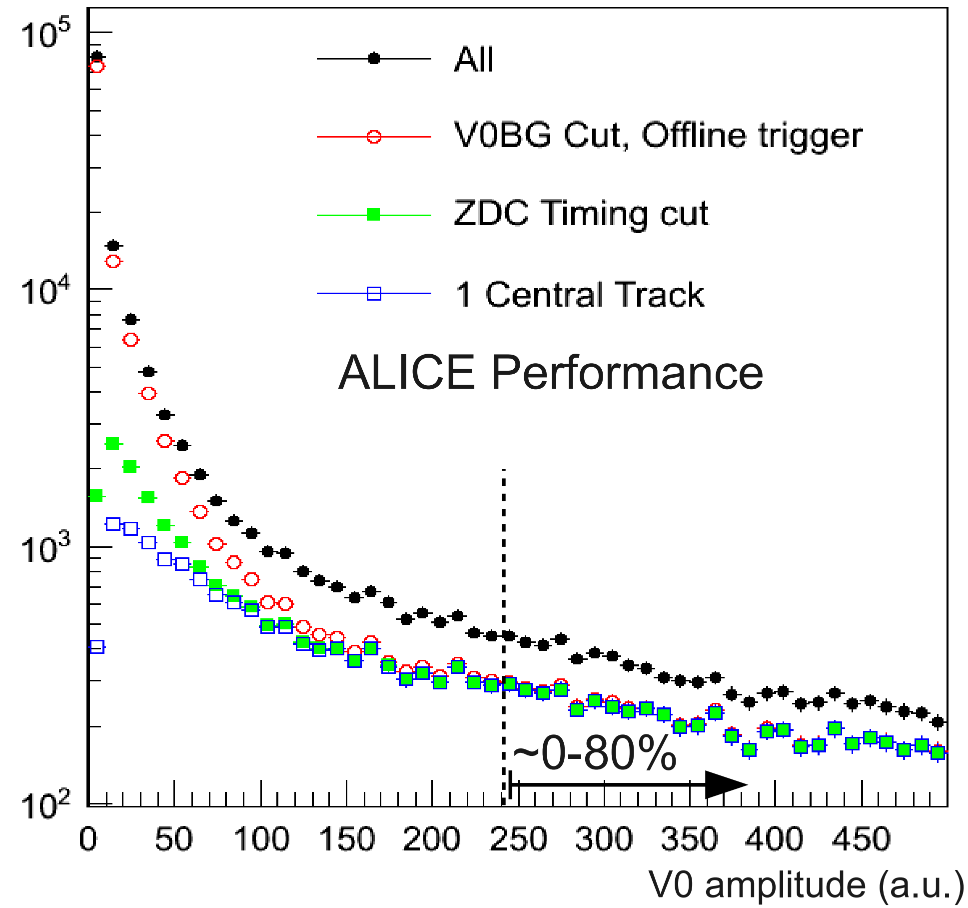


- Minbias triggers: Coincidences between
  - SPD Fast-Or (≥2 chip hits)
  - V0 (A side)
  - V0 (C side)
- Trigger requirements hardened throughout the run period

Recorded ~90 M triggers, so far reconstructed ~30 M inel. collisions

Offline event selection

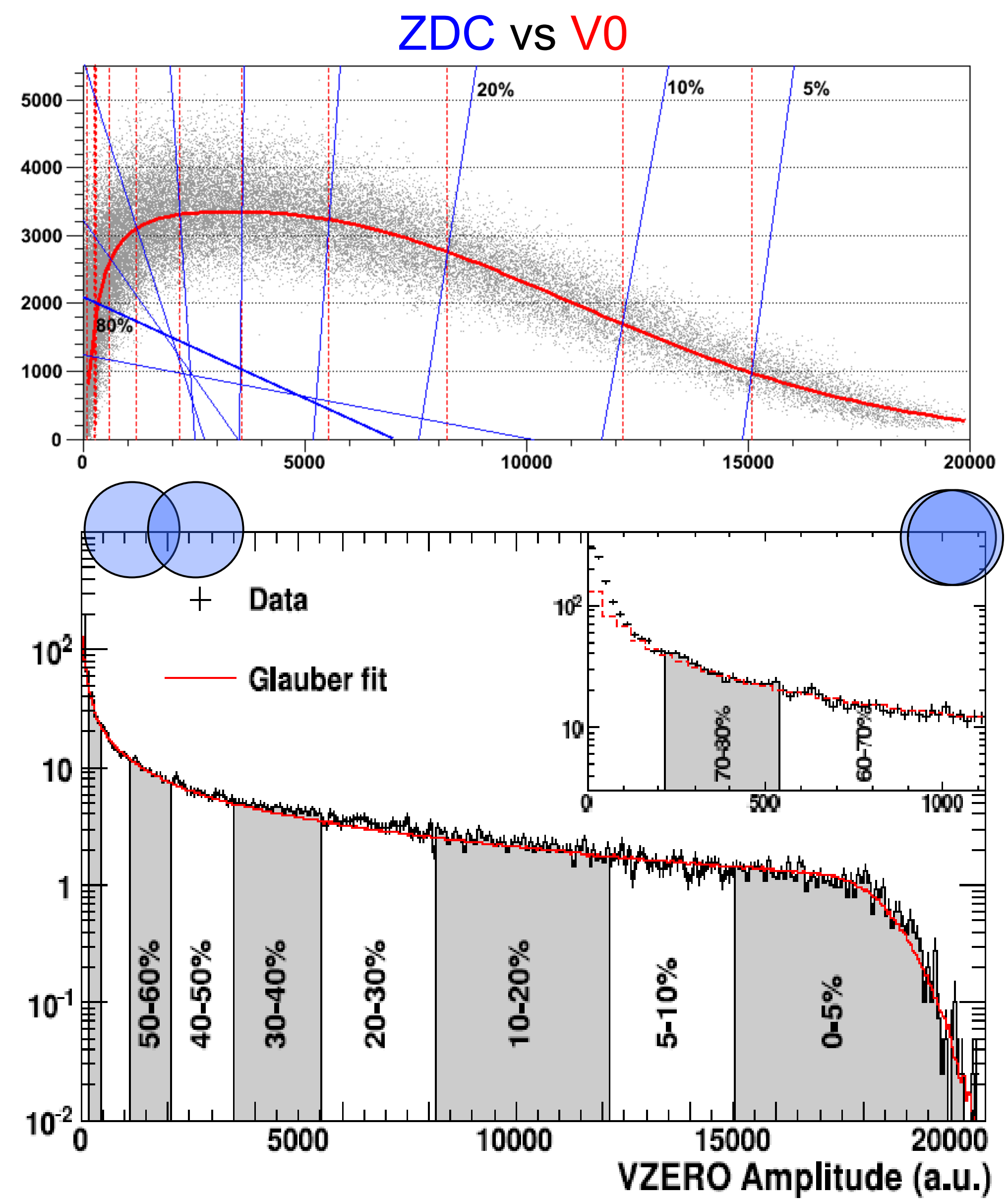
- Offline event selection for inel. collisions required to deal with
  - Beam Background
    - Beam gas and Debunching
  - EM processes
    - QED pair production
      - O(100 kbarn)
      - e^+e^- very soft
    - EM dissociation
      - O(100 barn)
      - One or few neutrons in ZDC
    - Photonuclear interactions
      - O(10 barn)
      - Photon energies O(100 GeV), can produce hadrons at mid-rapidity (Kinematics like pA)



Offline event selection to remove background

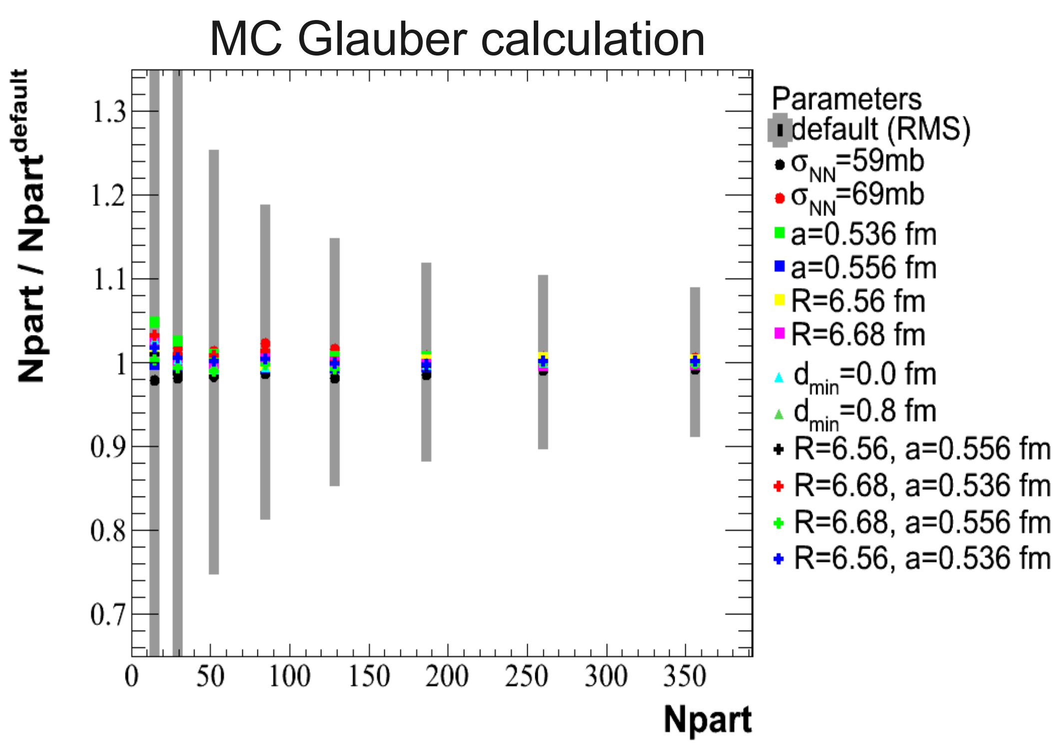
Determination of collision centrality

- Anchor point via Glauber fits
  - Sources distributed by
    f*Npart + (1-f) Ncoll
  - Particle production per source modeled with Negative Binomial
  - Robust results anchoring the fit between 30% to 90% percentile
  - Tight correlation between several centrality measures (V0, tracks, Hits, tracks vs V0, ZDC vs V0)
- Relation of percentile classes to Glauber values (<Npart>, etc) purely geometrical by slicing in impact parameter



Glauber model

- Standard geometrical picture of nucleus+nucleus collision
  - Distribution of nucleons according to Wood-Saxon (2pF)
    - Radius (6.62 fm), skin depth (0.546 fm)
    - Inter-nucleon distance (0.4fm)
  - Nucleons travel on straight lines
  - Interaction radius given by σ_{NN}
    - 64 +/- 5mb used (interp. $\bar{p}p$/pp data)
    - True value probably ~60mb (from ATLAS 7 TeV cross section)
      - Affects Ncoll linearly
    - Measurement@2.76 TeV in April 2011
- Systematic uncertainties by varying model parameters
  - Small effect on <Npart>
  - Uncertainty in σ_{NN} dominant for <Ncoll>



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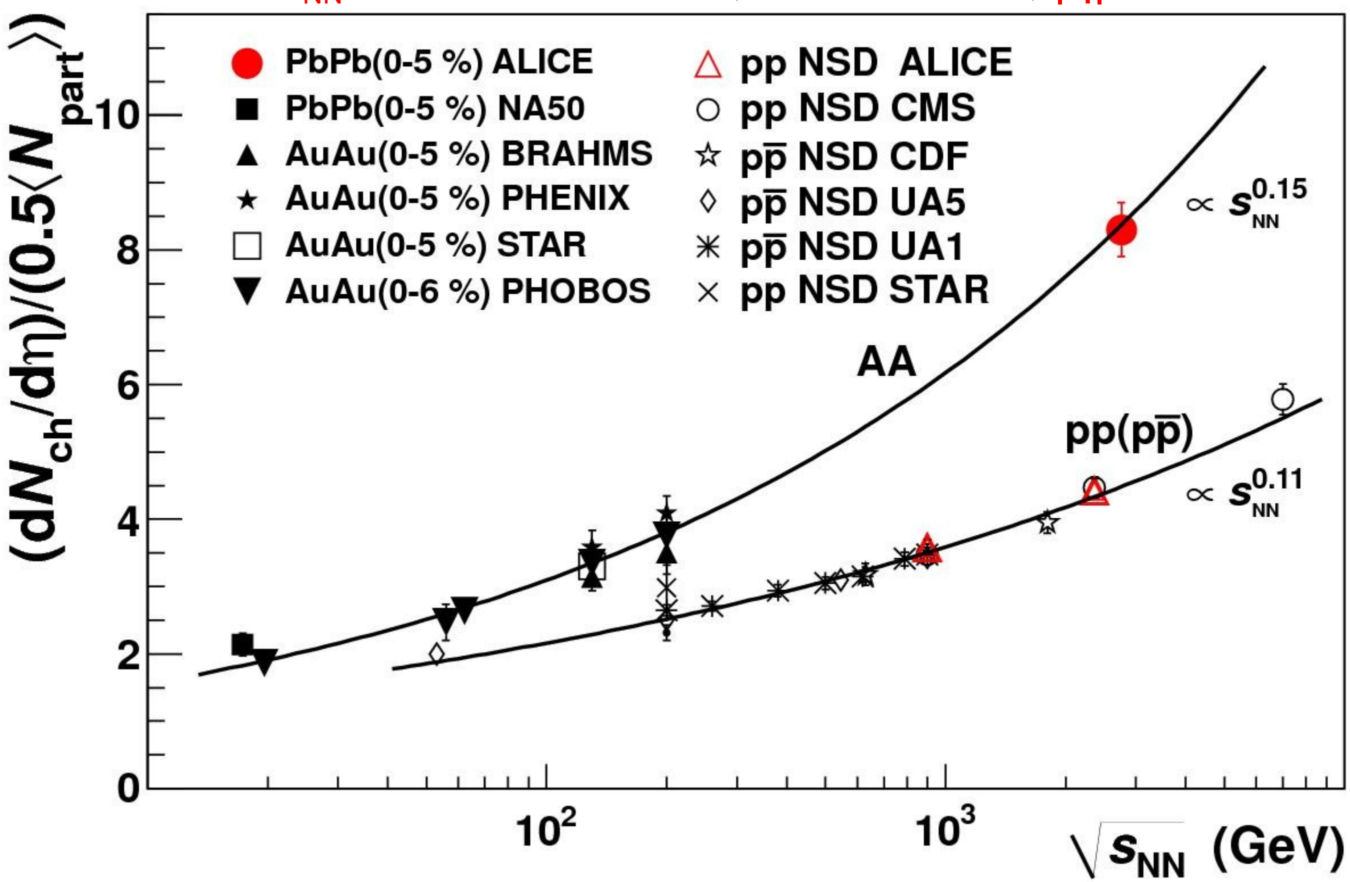
Next talk by Christian Klein-Boesing

Charged particle multiplicity

PRL, 105, 252301 (2010), arXiv:1011.3916

$\sqrt{s_{NN}}$=2.76 TeV Pb+Pb, 0-5% central, |η|<0.5



Pb+Pb ($\sqrt{s_{NN}}$=2.76 TeV)

→ 1.9 x pp (NSD) ($\sqrt{s_{NN}}$=2.36 TeV)

→ 2.2 x central Au+Au ($\sqrt{s_{NN}}$=0.2 TeV)

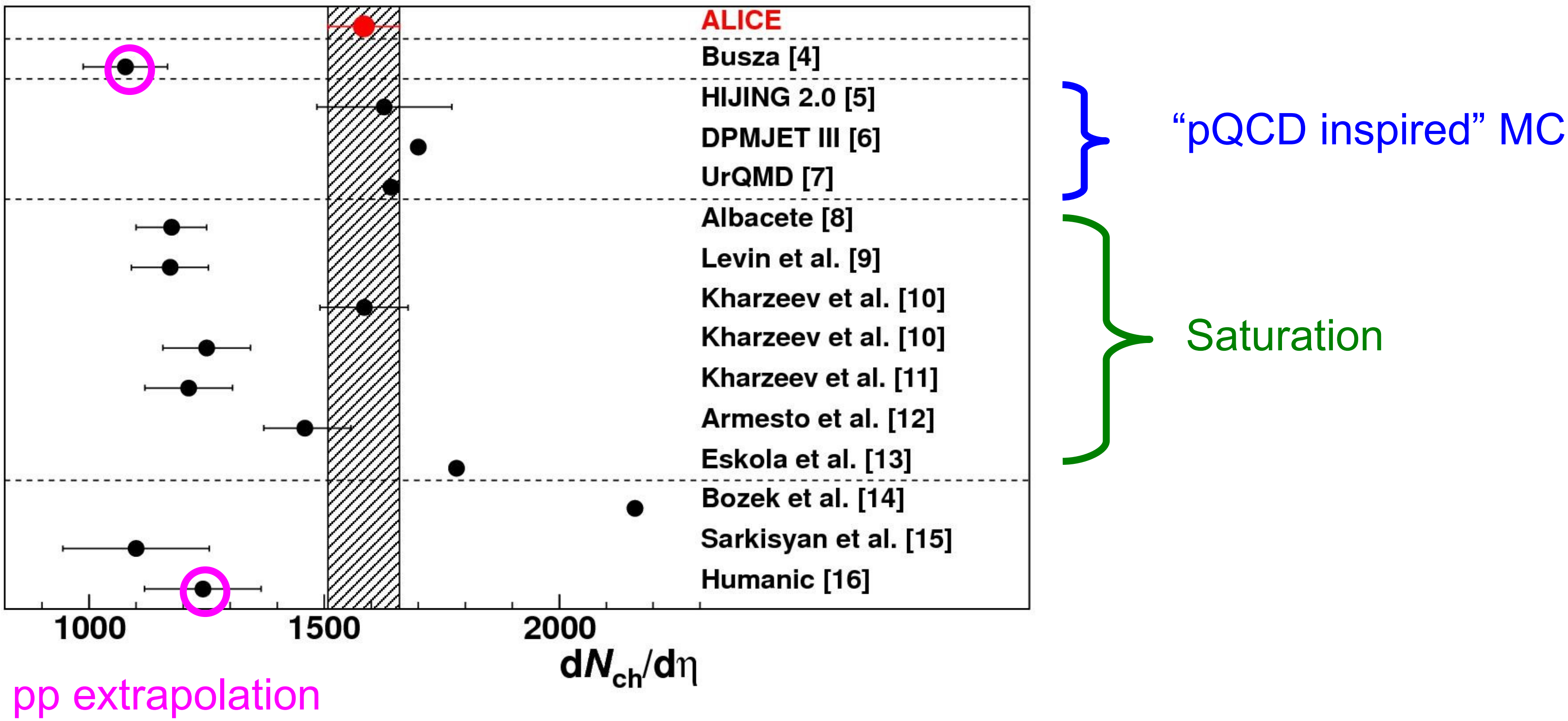
2 dNch/dη / <Npart> = 8.3 ± 0.4 (sys.)

dNch/dη: Comparison to models

PRL, 105, 252301 (2010), arXiv:1011.3916

$\sqrt{s_{NN}}$=2.76 TeV Pb+Pb, 0-5% central, |η|<0.5

dNch/dη = 1584 ± 76 (sys.)



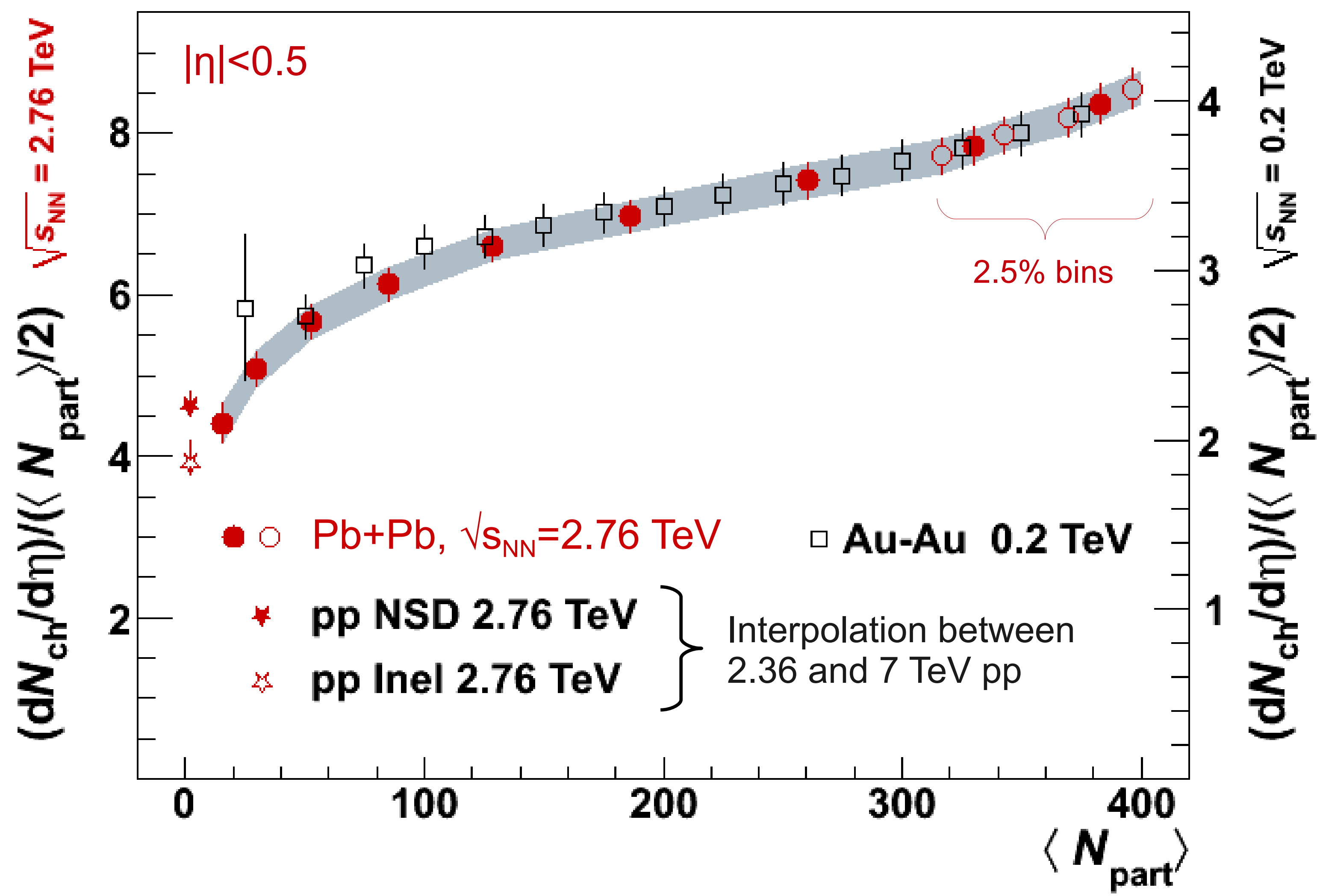
Energy density estimate (Bjorken):

$$\epsilon(\tau) = \frac{E}{V} = \frac{1}{A\tau}\frac{dN}{d\eta}\langle m_T \rangle$$

$$\epsilon(\tau_0)_{LHC} \geq 3 \times \epsilon(\tau_0)_{RHIC}$$

dNch/dη: Centrality dependence

PRL, 106, 032301 (2011), arXiv:1012.1657

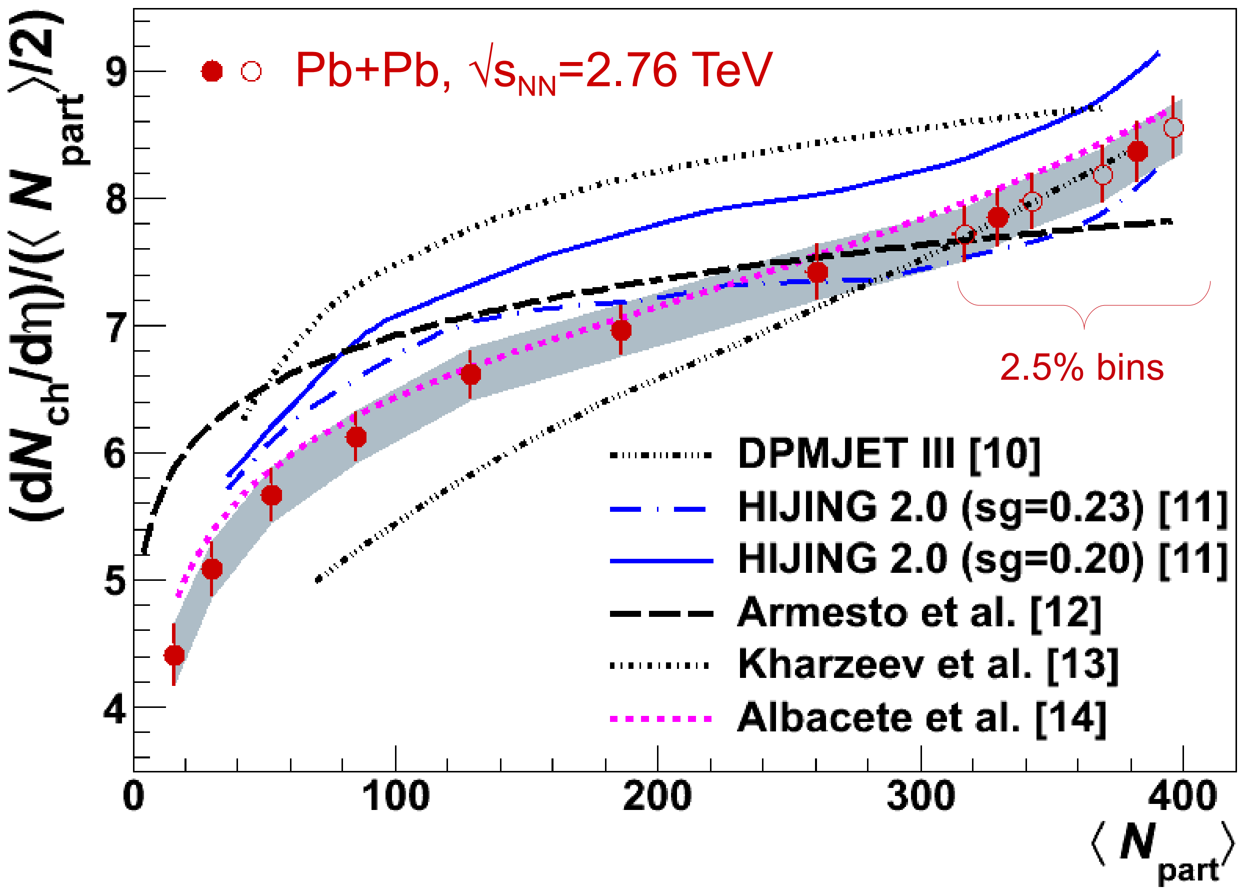


LHC centrality evolution very similar to RHIC

dNch/dη: Centrality vs models

PRL, 106, 032301 (2011), arXiv:1012.1657

- Two-component models
  - Soft (~Npart) and hard (~Ncoll) processes
- Saturation-type models
  - Parametrization of the saturation scale with centrality
- Comparison to data
  - DPMJET (with string fusion) stronger rise than data
  - HIJING 2.0 (no quenching)
    - Strong centrality dependent gluon shadowing
    - Fine-tuned to 0-5% dN/dη
  - Saturation models [12-14]
    - Some tend to saturate too much



Models incorporating a moderation of the multiplicity with centrality are favored by the data (as at RHIC)

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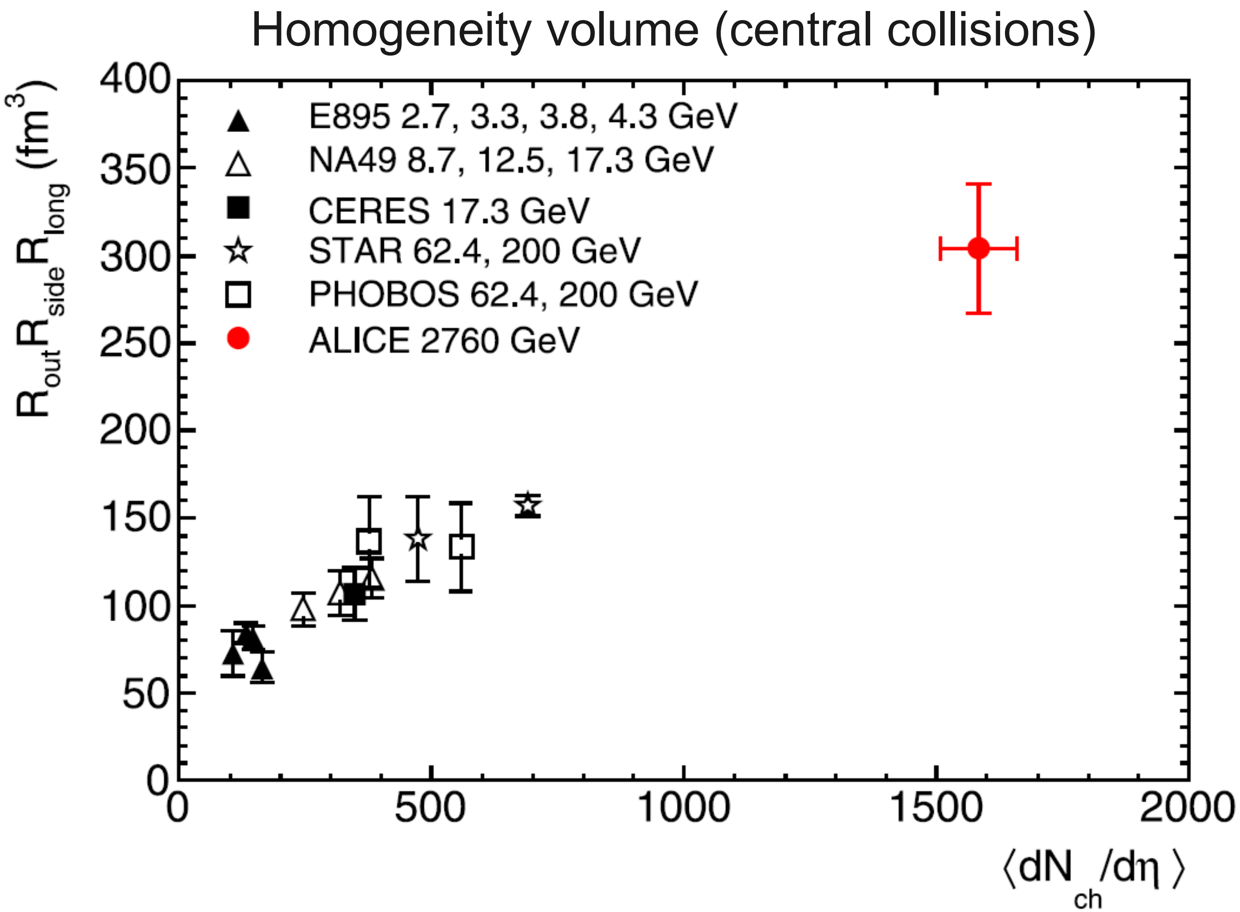
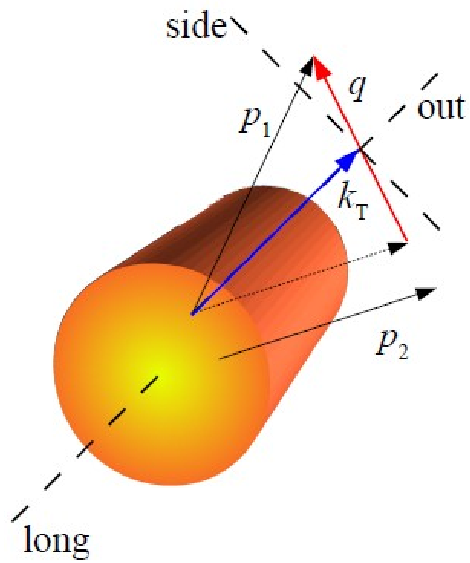
Next talk by Christian Klein-Boesing

Space-time evolution: Freeze-out volume 16

PLB, 696 (2011), 328, arXiv:1012.4035



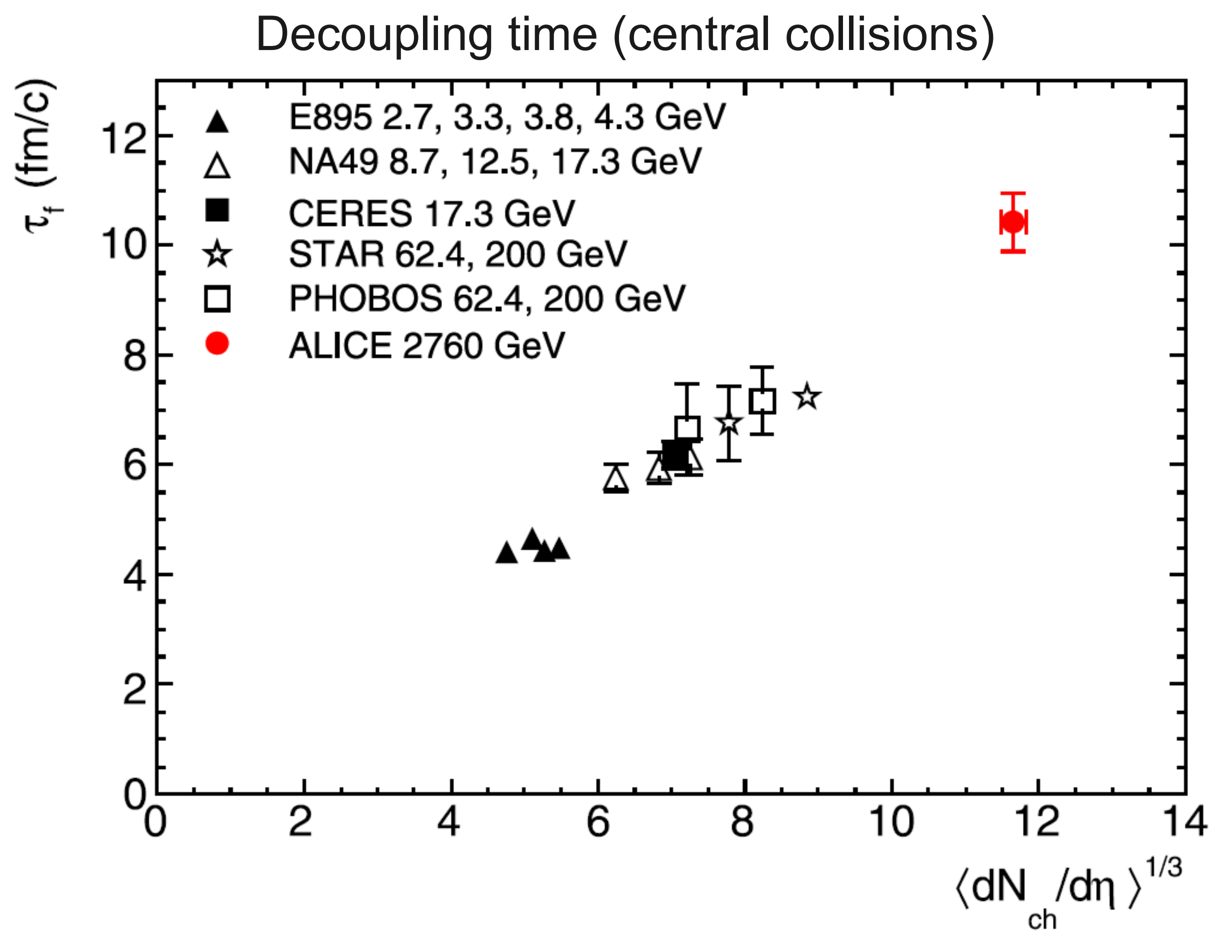


$R_{out}R_{side}R_{long}$ → V(Freeze-out) linear dependence on dNch/dη

V_{LHC} = 300 fm^3 ~ 2 x V_{RHIC}

Space-time evolution: Decoupling time

PLB, 696 (2011), 328, arXiv:1012.4035



R_{long} ⟶ Decoupling time τ_f linear dependence on $dNch/d\eta^{1/3}$

τ_f(LHC) = 10-11 fm/c ~ 1.4 x τ_f(RHIC)

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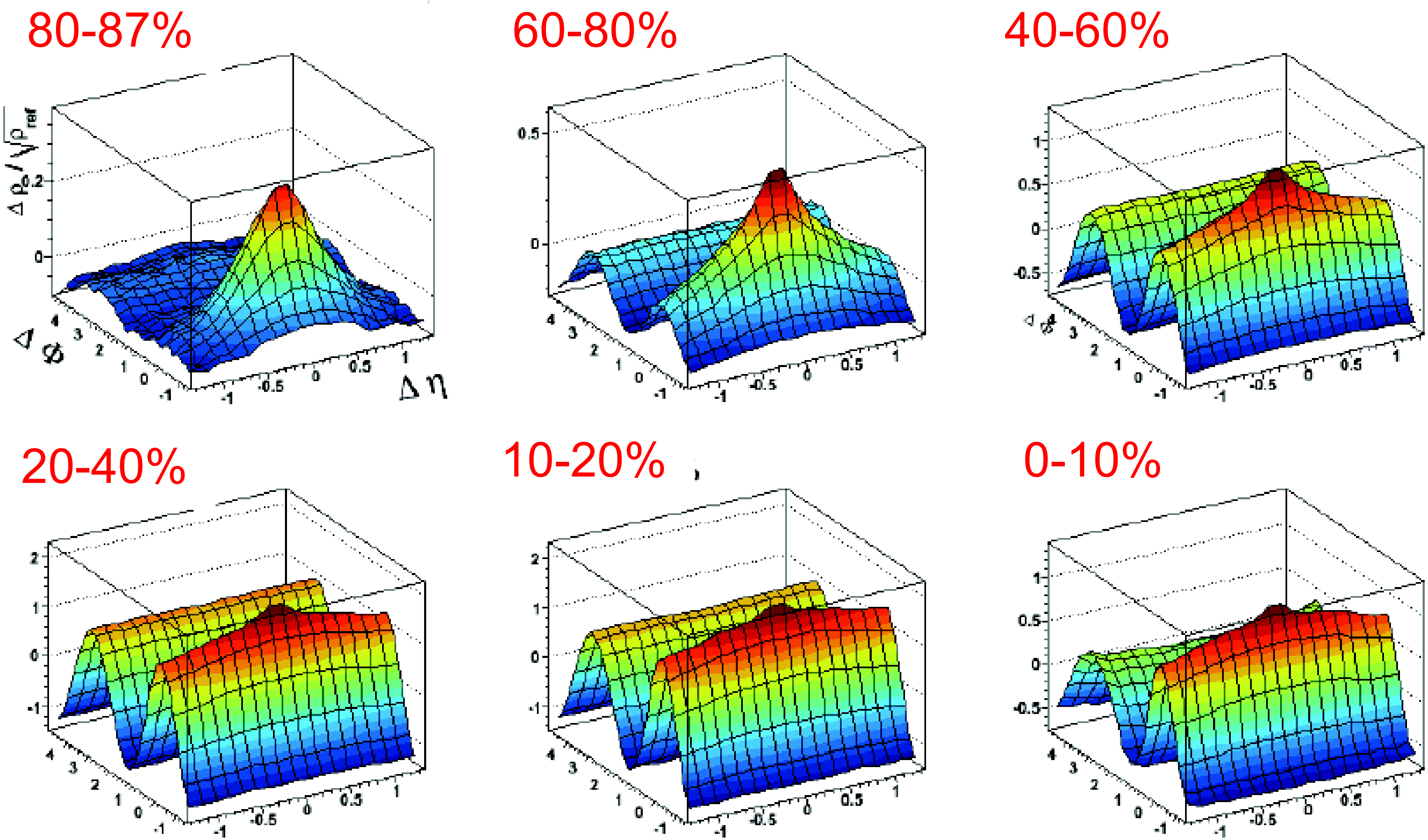
} Next talk by Christian Klein-Boesing

Two-particle angular correlations



ALICE performance

p_T>0.15 GeV/c

$$R(\Delta\eta,\Delta\phi)=\frac{\rho_{sib}-\rho_{ref}}{\sqrt{\rho_{ref}}}=\frac{dN}{d\eta d\phi}\left(\frac{\rho_{sib}}{\rho_{ref}}-1\right)$$

Elliptic flow (but also non flow structures) clearly visible

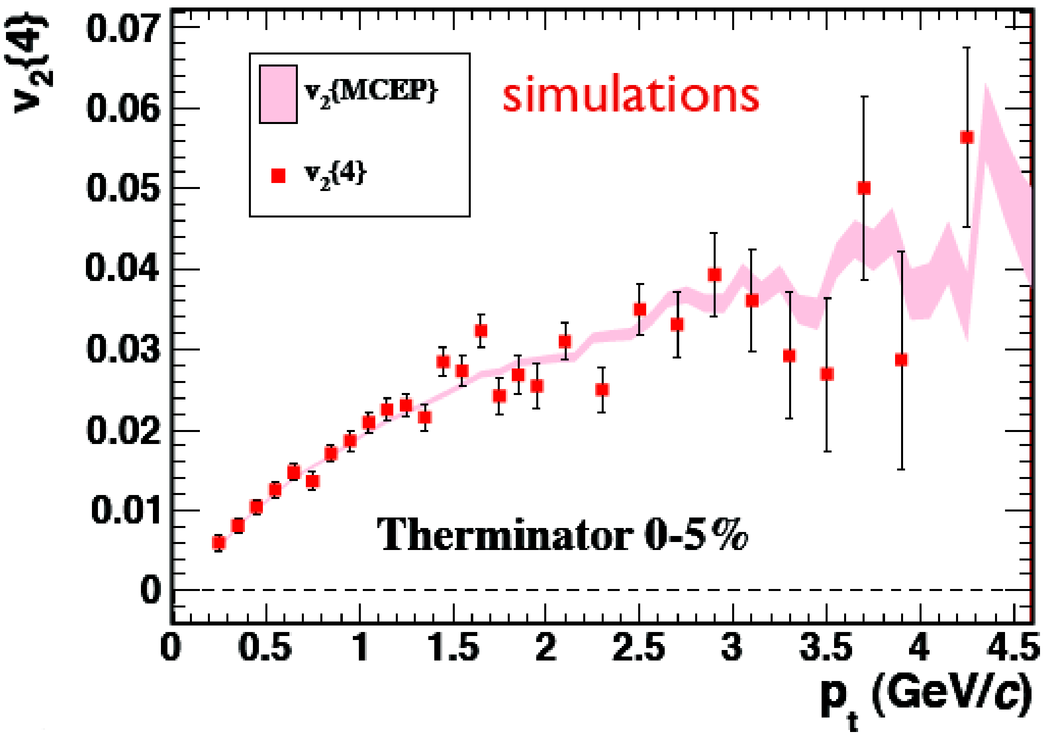
Flow via multi-particle cumulants

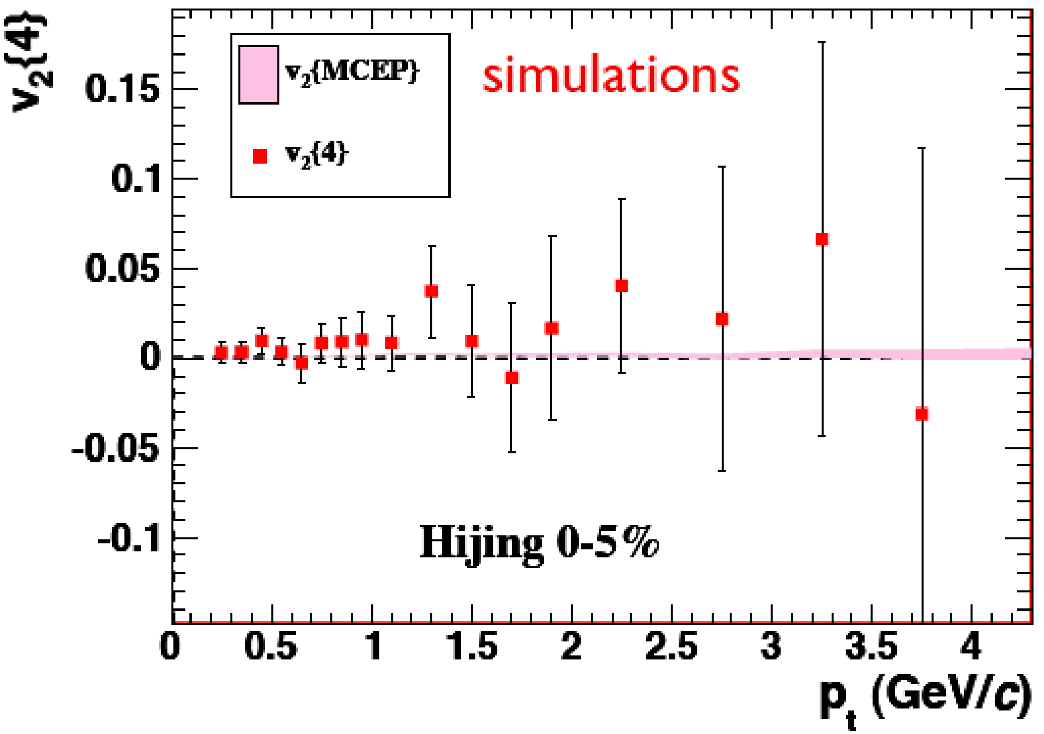
Borghini, Dinh, Ollitrault (2001)

$$v\{2\}^2 \equiv \langle\langle e^{2i(\phi_1-\phi_2)}\rangle\rangle = v_2^2+\delta_2$$

$$v_2\{4\}^4 \equiv \langle\langle e^{2i(\phi_1+\phi_2-\phi_3-\phi_4)}\rangle\rangle - 2\langle\langle e^{2i(\phi_1-\phi_2)}\rangle\rangle = -v_2^4+\delta_4$$

Removes 2particle non-flow contribution

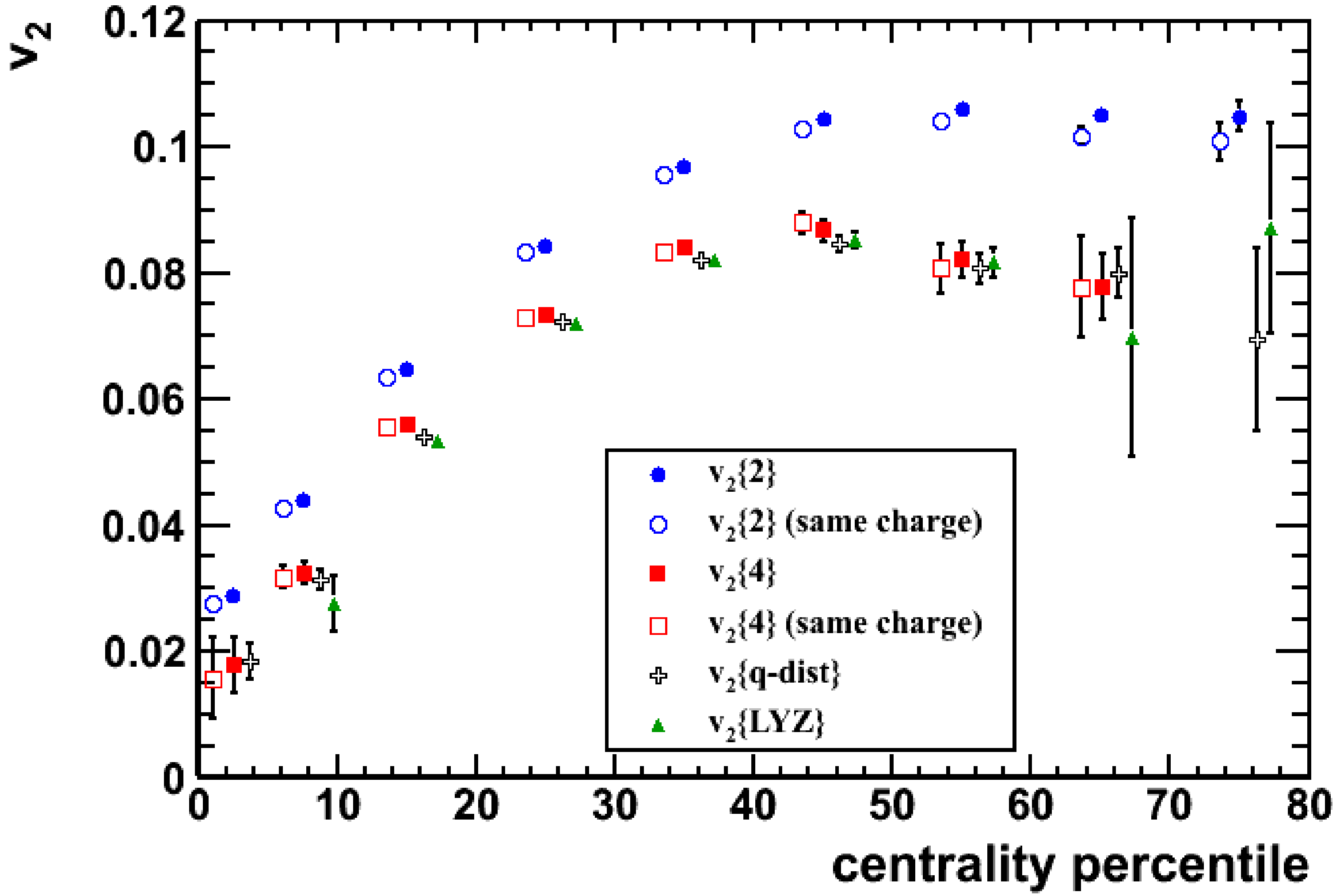




Due to high multiplicity, non flow contributions at LHC become less important

Elliptic flow: centrality dependence

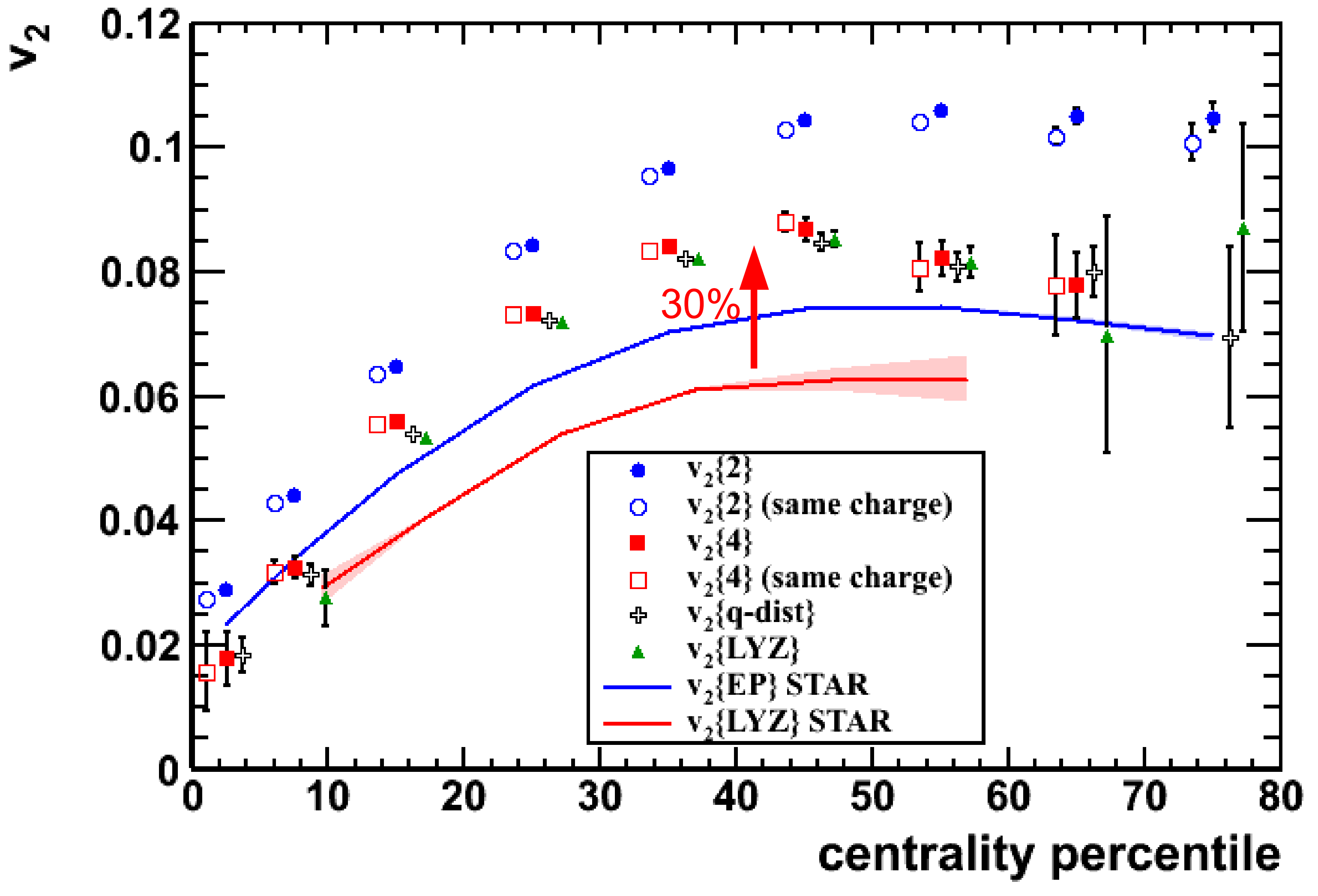
PRL, 105, 252302 (2010), arXiv:1011.3914



Integrated v_2: Comparison of two- and multi-particle methods as expected

Elliptic flow: centrality dependence

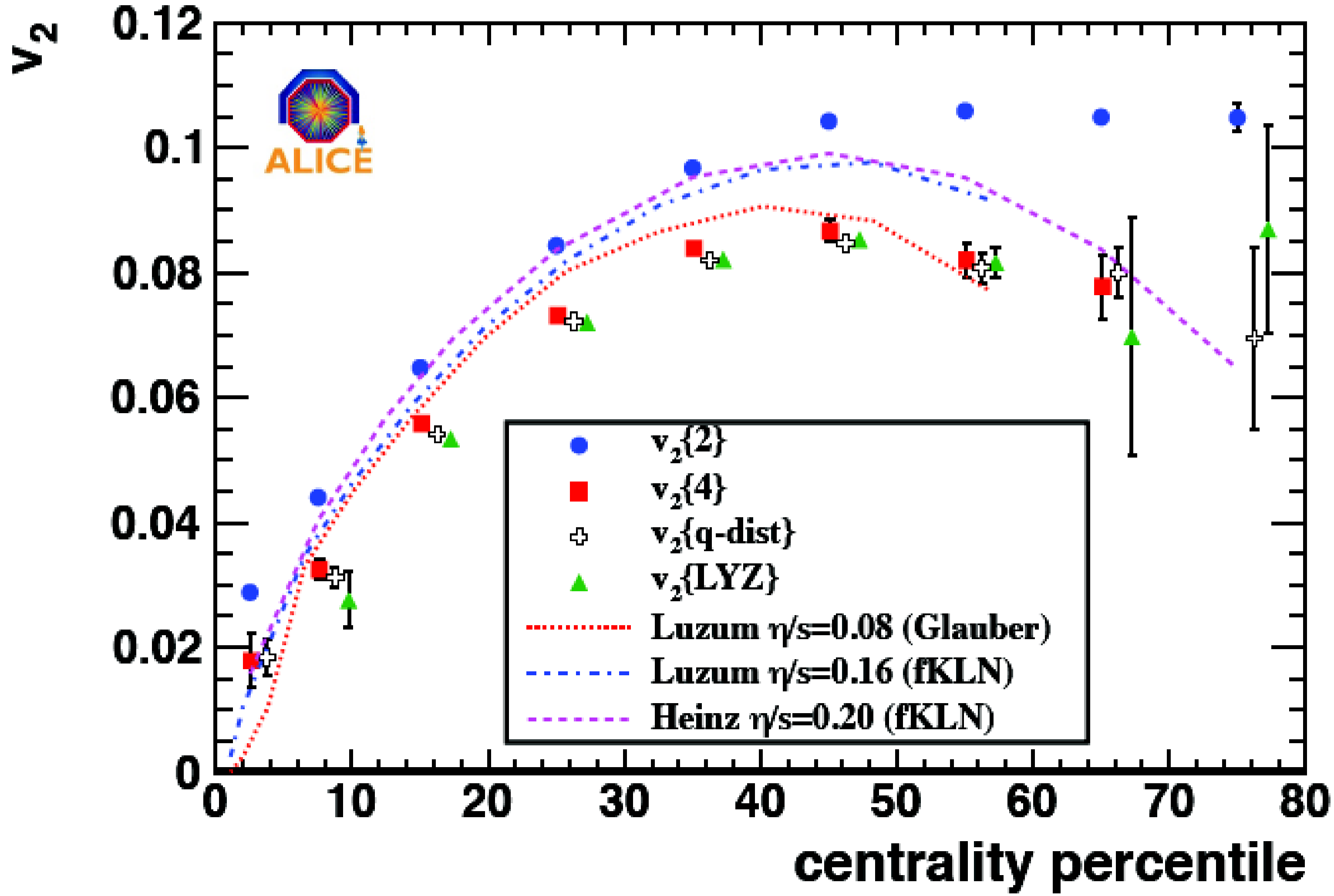
PRL, 105, 252302 (2010), arXiv:1011.3914



Integrated v_2: 30% increase from 0.2 TeV (STAR) to 2.76 TeV (ALICE)

Over all centrality classes, due to the increase of $\langle p_T \rangle$

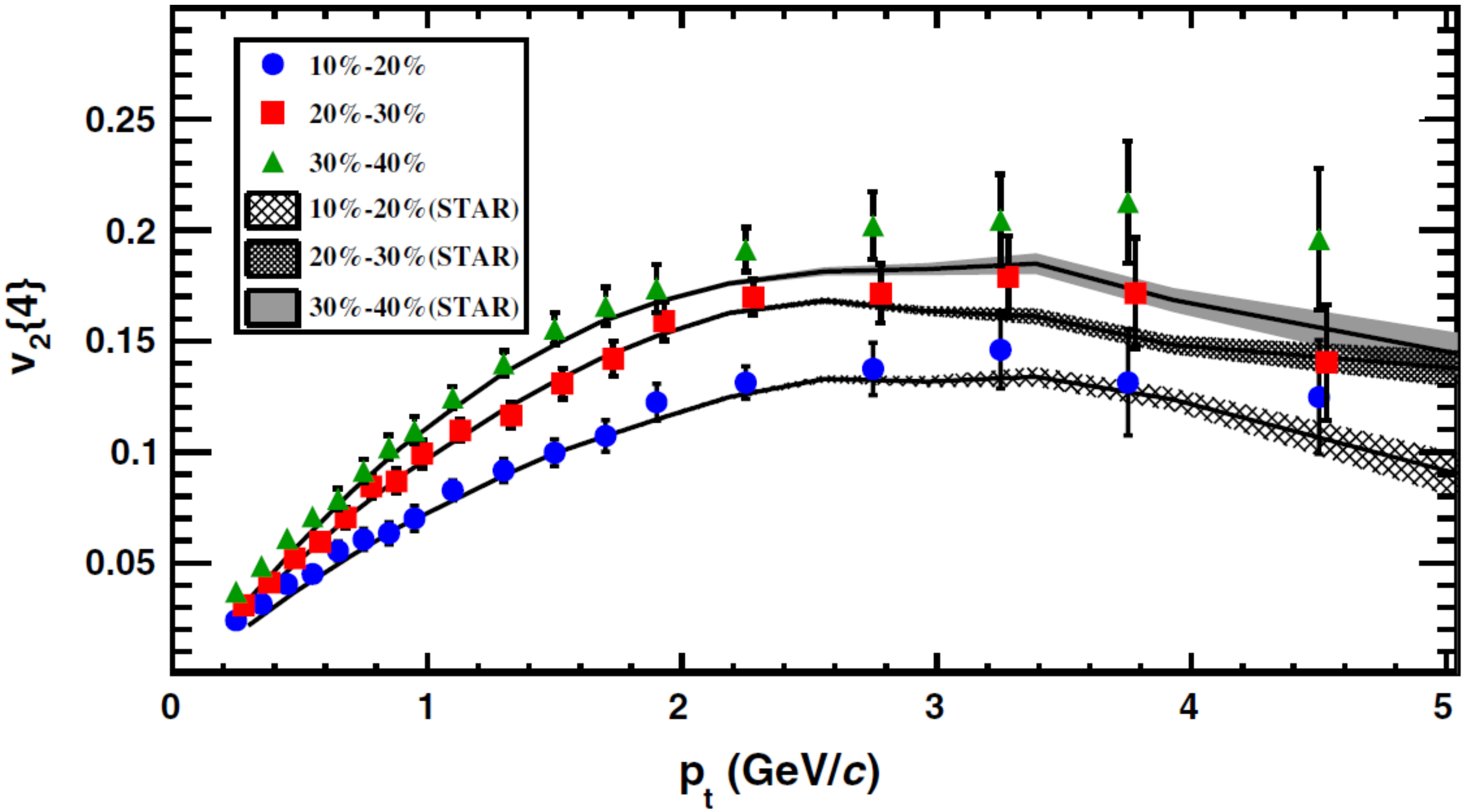
Elliptic flow: centrality dependence



Increase well within the range of viscous hydro predictions

Elliptic flow: p_t - dependence

PRL, 105, 252302 (2010), arXiv:1011.3914



Little change between 0.2 TeV (STAR) and 2.76 TeV (ALICE)
Consistent with expectations from ideal hydro (Eskola, Heinz).

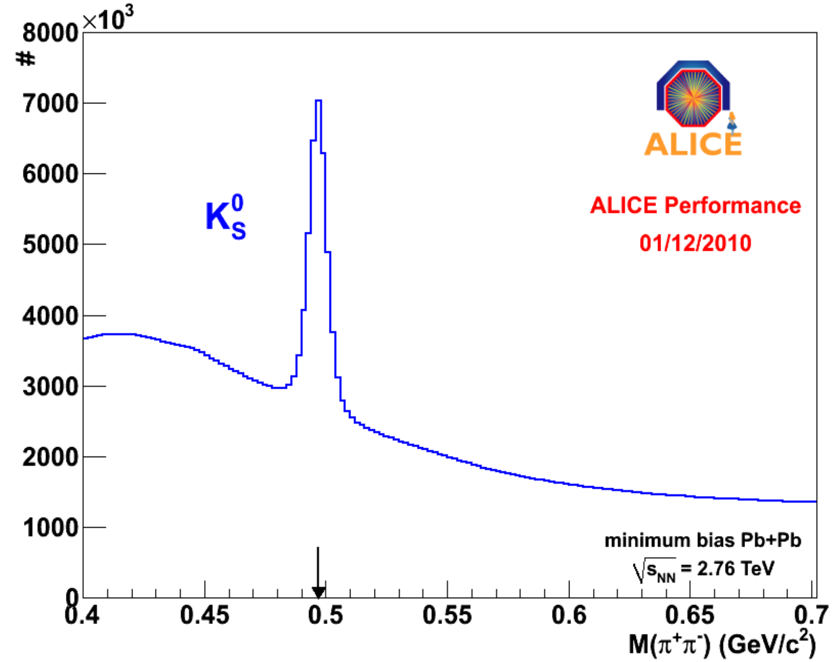
Conclusions & Summary

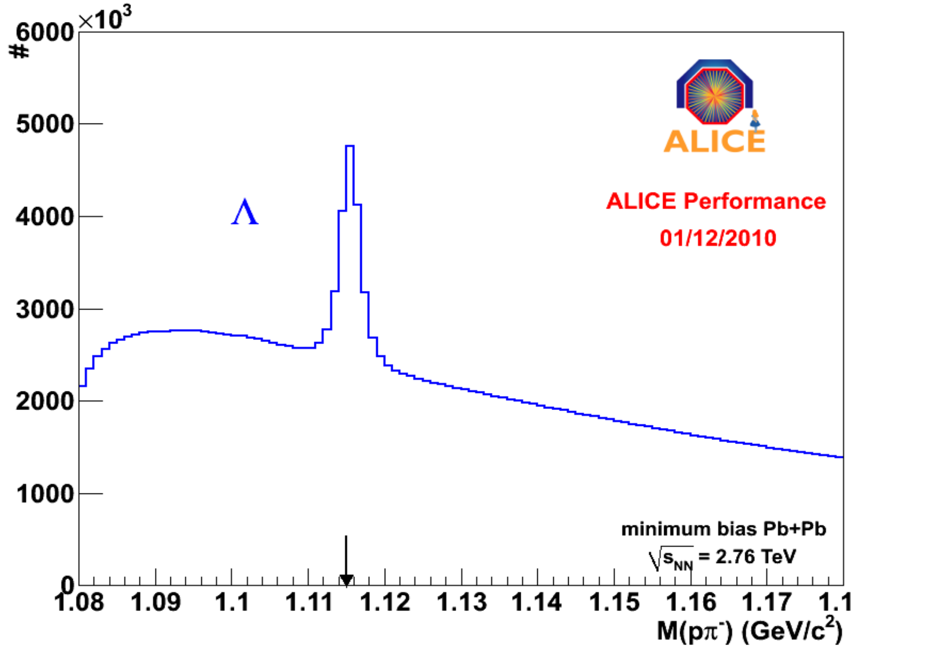
- Charged particle multiplicity increased over RHIC by about a factor 2
  - Energy density is at least 3 times larger
  - Centrality dependence is very similar
    - Constrains models
  - Saturation models tend to be too low
    - Initial state gluon saturation weaker than expected?
- Freeze-out volume (central): V(LHC) ~ 300fm^3 ~ 2 x V(RHIC)
- Decoupling time (central): τ_f(LHC) ~ 10-11 fm/c ~ 1.4 x τ_f(RHIC)
- Elliptic flow
  - p_t-dependence: Same for all centrality classes studied
  - Integrated v_2: 30% increase over RHIC
    - Can by caused by radial flow in ideal hydro (needs PID test)
    - Can be accommodated by viscous hydro

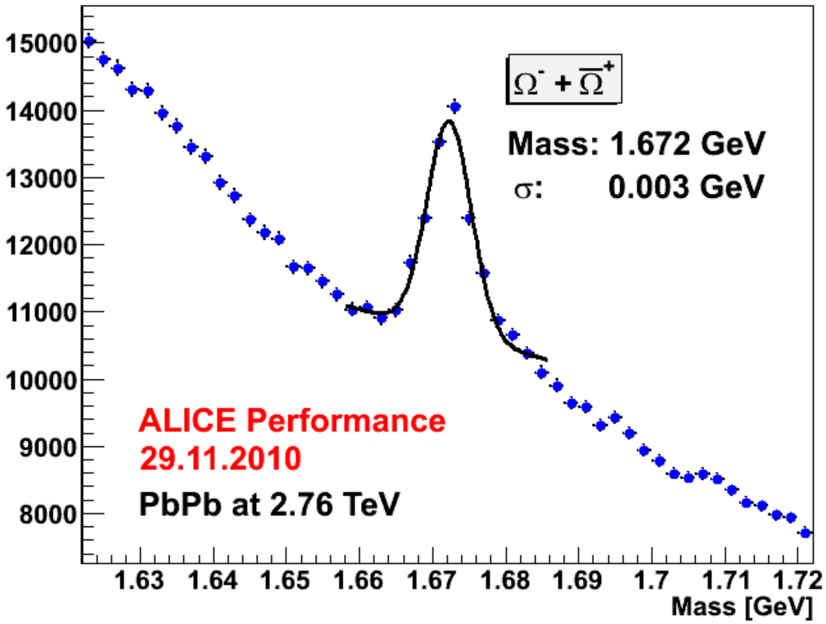
Outlook

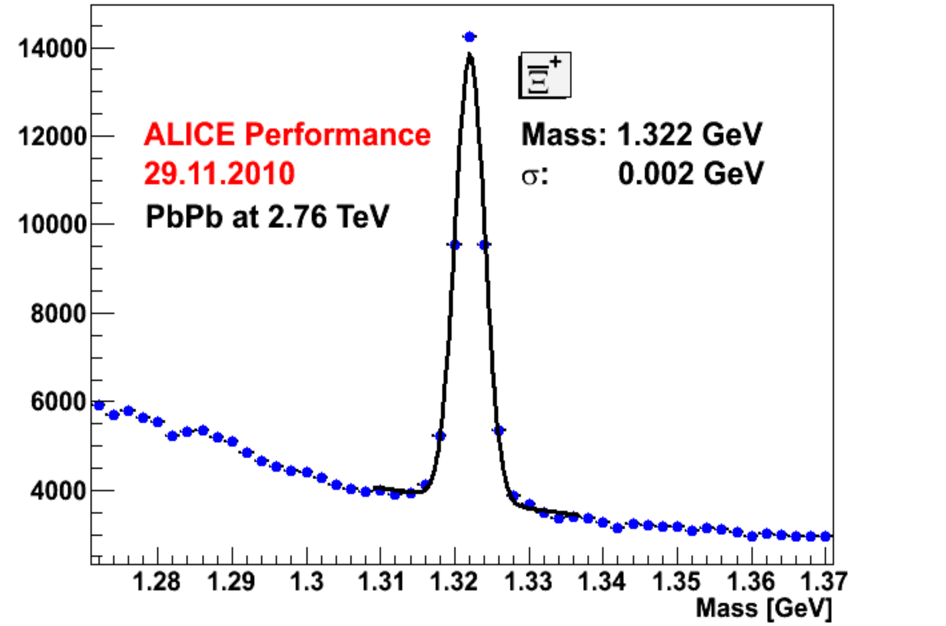
- Ongoing (related) analyzes
  - Detailed studies of flow/non-flow (yes, still more methods)
  - Flow at high p_t
  - Directed flow and other harmonics
  - Event characterization using two-particle correlations
  - E-by-E fluctuations
  - Chiral magnetic effect studies
  - Centrality dependence of pion HBT
  - ...

PID, PID, PID, PID









The end

Publications

- Published physics results in Pb+Pb
  - Multiplicity
    - 0-5% central: PRL, 105, 252301 (2010), arXiv:1011.3916
    - Centrality dependence: PRL, 106, 032301 (2011), arXiv:1012.1657
  - Bose Einstein correlations
    - 0-5% central: PLB, 696 (2011), 328, arXiv:1012.4035
  - Elliptic flow
    - Centrality and p_T dependence: PRL, 105, 252302 (2010), arXiv:1011.3914
  - High pt charged hadron suppression
    - Central + peripheral R_{AA} with constructed reference:
      PLB, 696 (2010), 30, arXiv:1012.1004