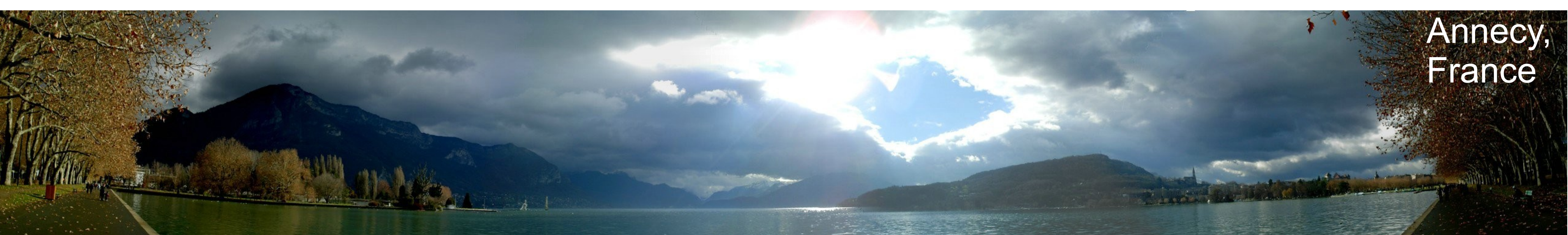
Charged-particle multiplicity, centrality and the Glauber model at 2.76 TeV with ALICE

Constantin Loizides for the ALICE collaboration

23 May 2011

XII International Conference on Ultrarelativistic Nucleus-Nucleus collisions



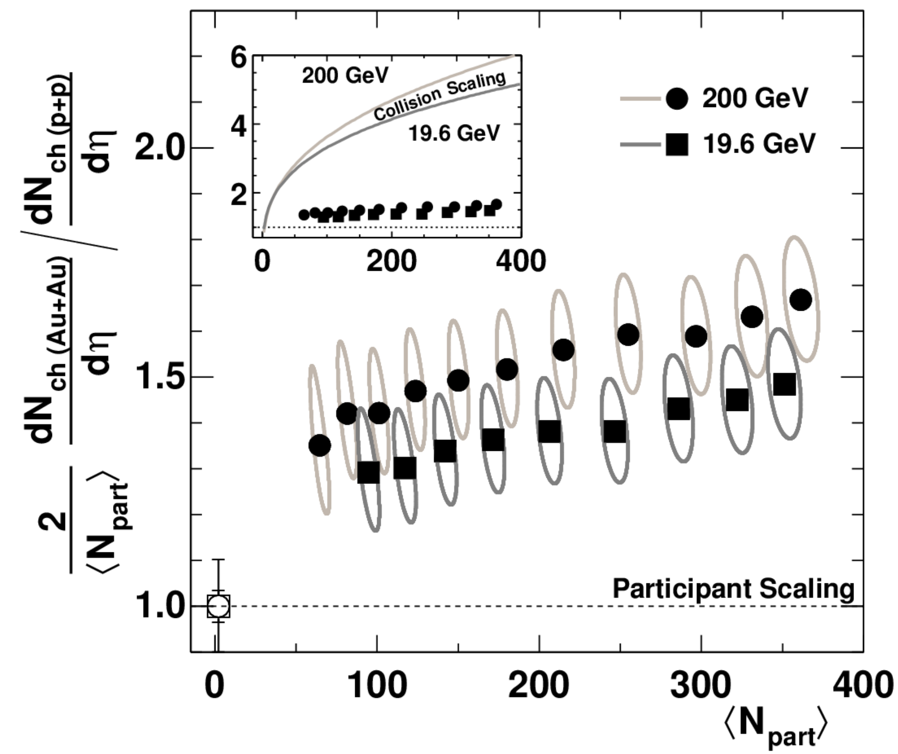
Why measure multiplicity?

- "Easy", day-1 observable determines
  - Density of system
  - Initial conditions
  - Background for hard-probe signals
- "Difficult", convoluted for theory
  - Perturbative vs Non-perturbative,
  - Various scales, hadronization
  - Application of factorization schemes
- Naive parametrization (Npart ~ A, Ncoll ~ $A^{4/3}$):

$$\left.\frac{dN_{ch}^{AA}}{d\eta}\right|_{\eta=0} = \left.\frac{dN_{ch}^{NN}}{d\eta}\right|_{\eta=0}\left[\frac{1-x}{2}N_{part} + xN_{coll}\right]$$

  - Ncoll scaling (x=1) for Collinear factorization
  - Npart scaling (x->0) for shadowing, non-linear QCD dynamics, saturation, collectivity

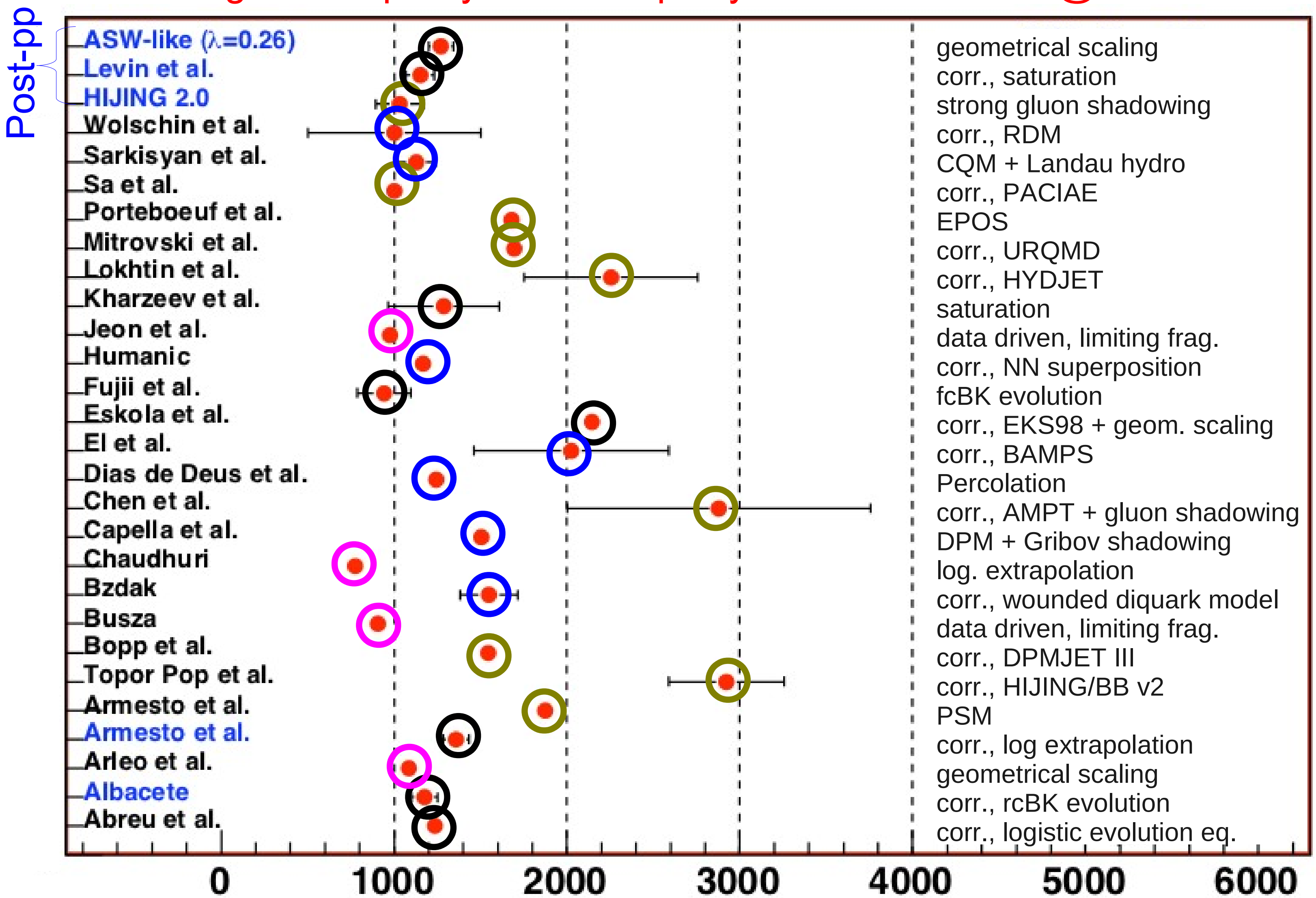
PHOBOS, PRC 70, 021902(R) (2004)



At RHIC, approximate participant scaling and factorization of energy +centrality was found

Predicted multiplicities for LHC energies

Charged multiplicity for mid-rapidity in central Pb+Pb @ 2.76 TeV



Monte Carlo, coherence via collectivity, strong gluon saturation

Saturation ideas

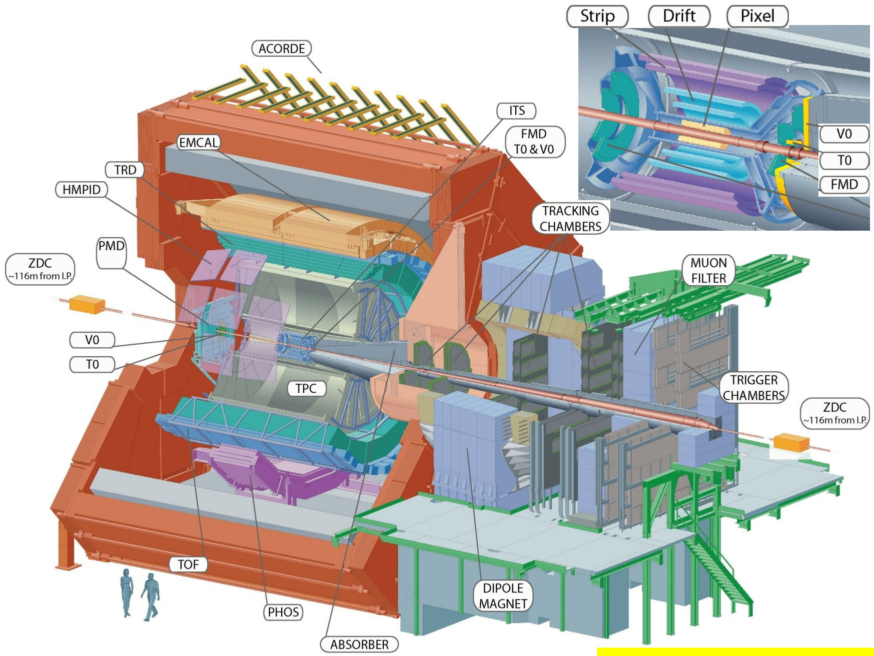
Data driven, limiting frag.

Miscellaneous: superposition, WNM, diffusion eqs., DPM + shadowing/ percolation

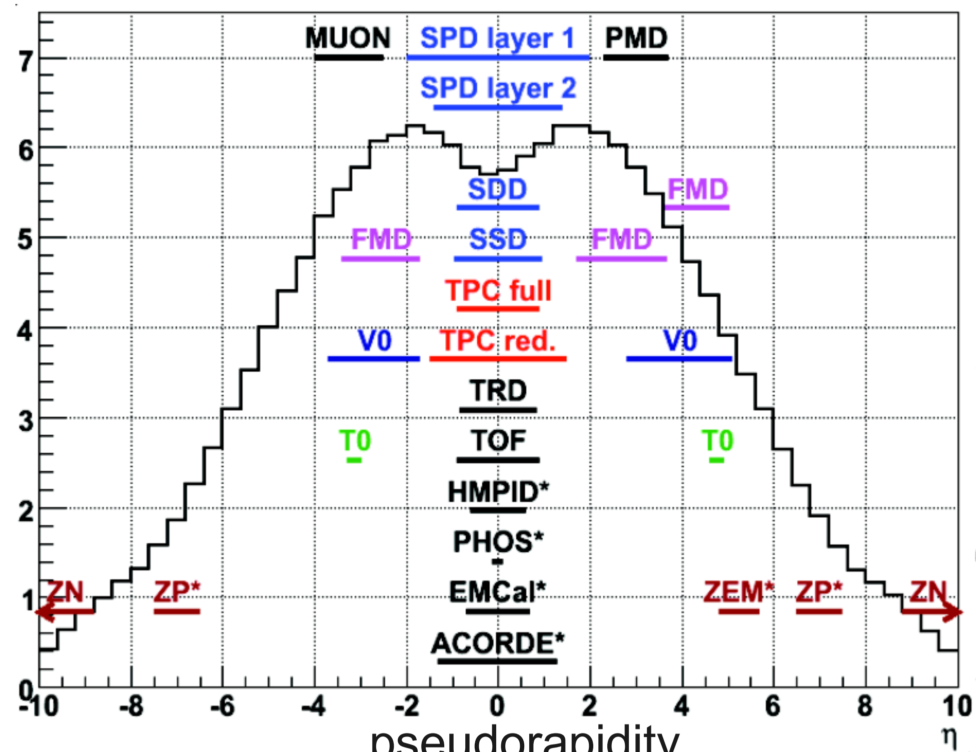
Compilation from N.Armesto (Talk@CERN, 03 Sep 2010)

Blue are unscaled model results

ALICE detector and trigger setup



J.Schukraft talk

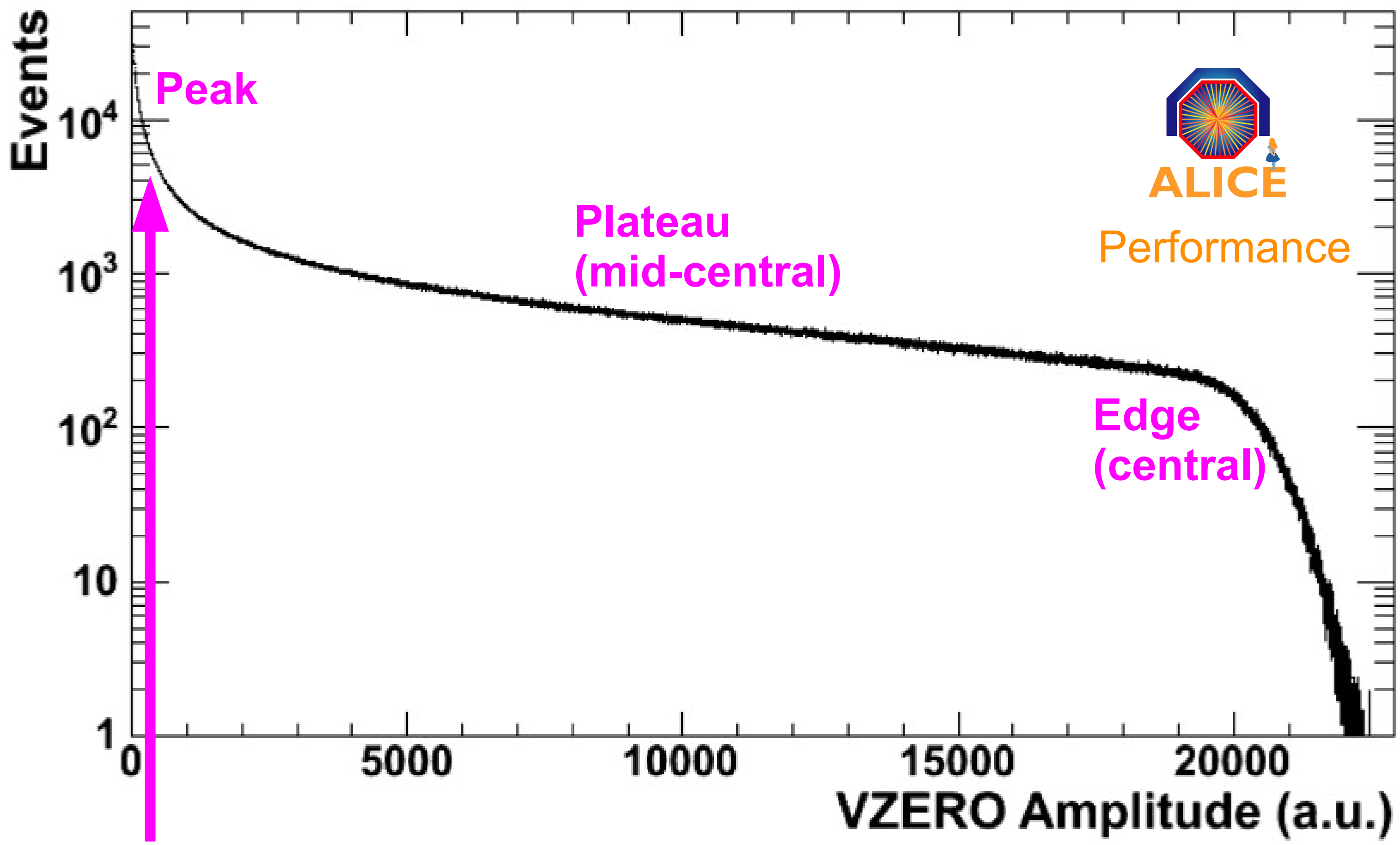


- Minbias triggers: Coincidences of
  - SPD (≥2 pixel hit)
  - V0 (A side)
  - V0 (C side)
- Trigger requirements tightened throughout the run period
  - “2-out-of-3”, “V0AND”, “3-out-of-3”

Relevant for this talk:

- VZERO scintillator hodoscopes $(2.8<\eta<5.1)$ and $(-3.7<\eta<1.7)$
- nZDC (beam rapidity)
- ITS (SPD): First layer $(|\eta|<2)$
  Second layer $(|\eta|<1.4)$
- TPC $(|\eta|<0.9)$

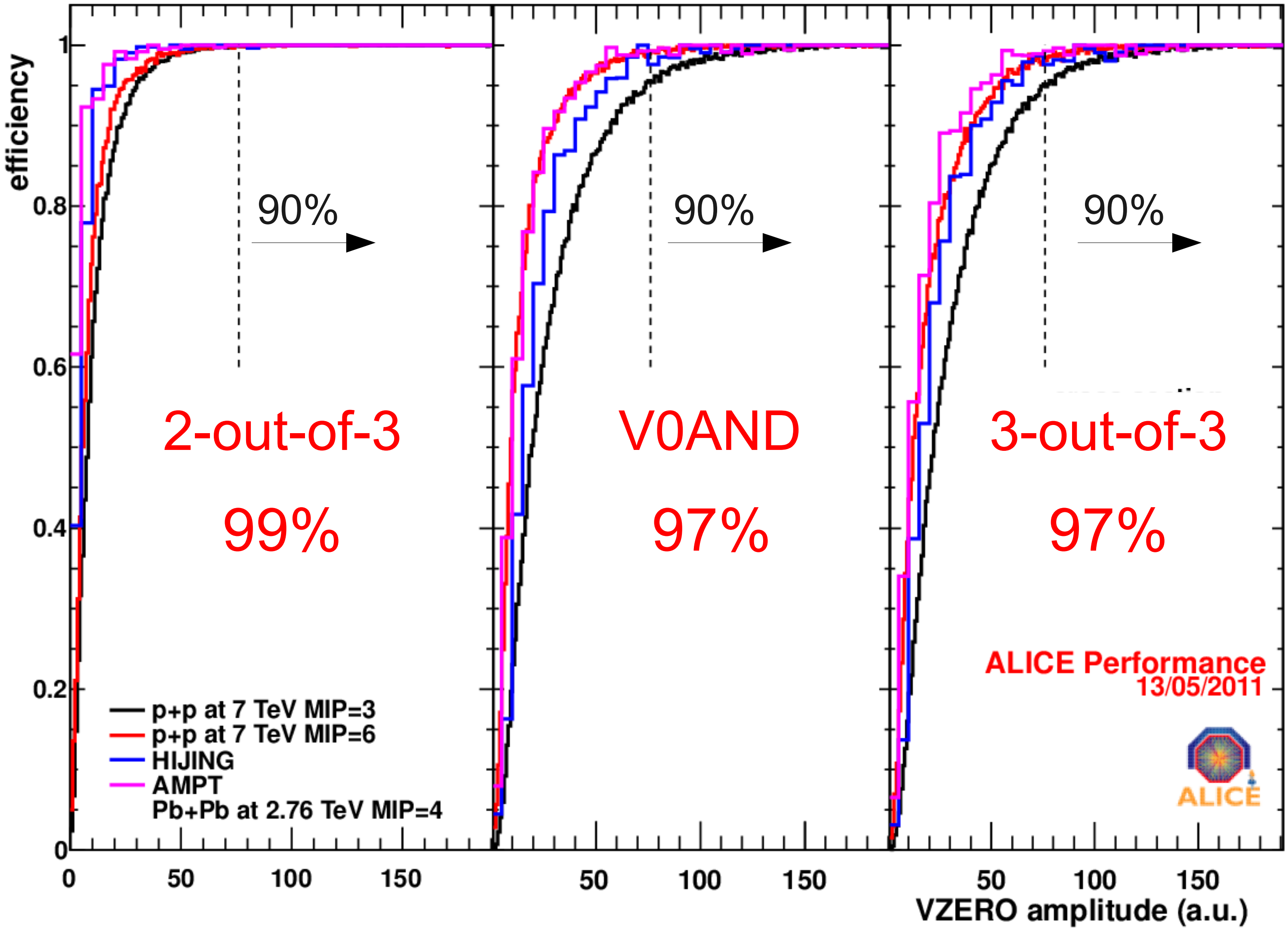
Example VZERO amplitude distribution



Peak:
Very peripheral collisions
Trigger/data selection inefficiency
Background contributions

Cleanup+Centrality
classification needed

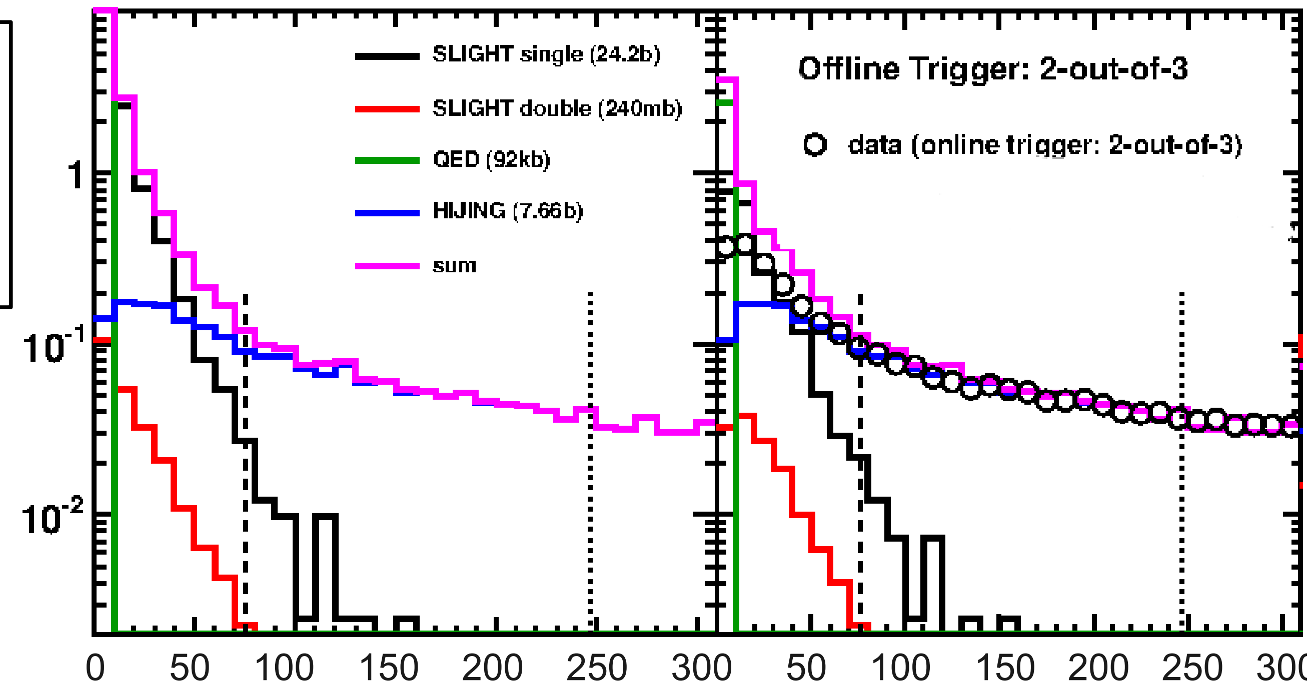
Trigger efficiency



Efficiency estimated with pp data and HIJING/AMPT

Background (simulated cocktail)

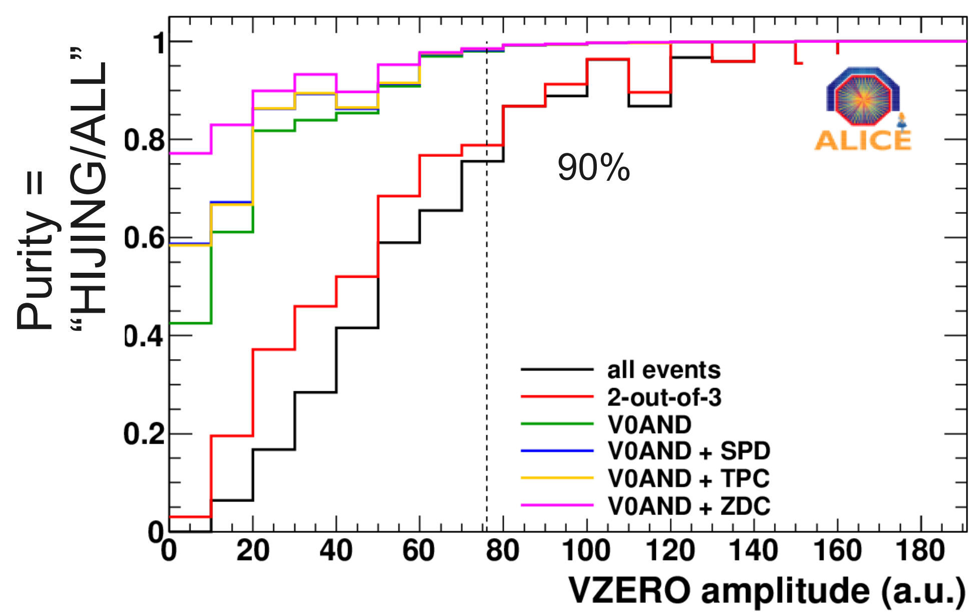
Cocktail (HIIJING, QED, SLIGHT/RELDIS) vs data:
3-out-2: clean from 87%
Others: clean from 90%



- EM processes

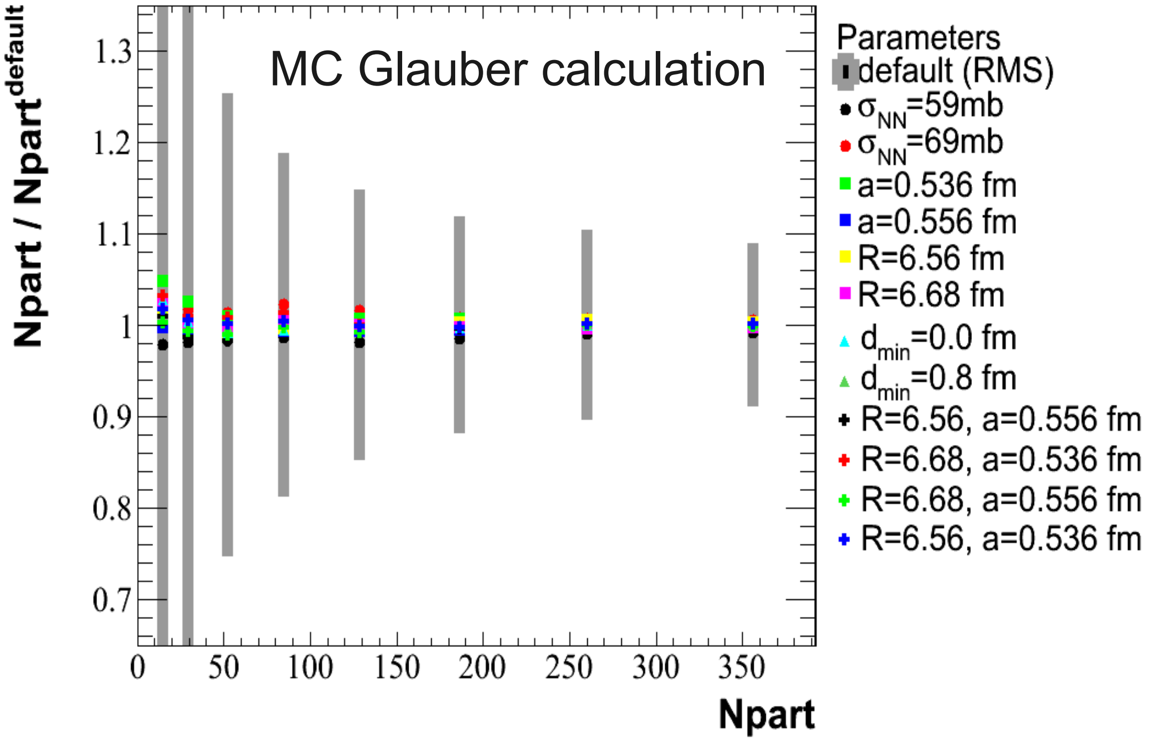
QED
- QED pair production
  - O(100 kbarn)
  - e^+e^- very soft

STARLIGHT/RELDIS
- EM dissociation
  - O(100 barn) C.Oppedisano talk
  - One or few neutrons in ZDC
- Photonuclear interactions
  - O(10 barn) J.Nystrand #533
  - Photon energies O(100 GeV), can produce hadrons at mid-rapidity (Kinematics like pA)



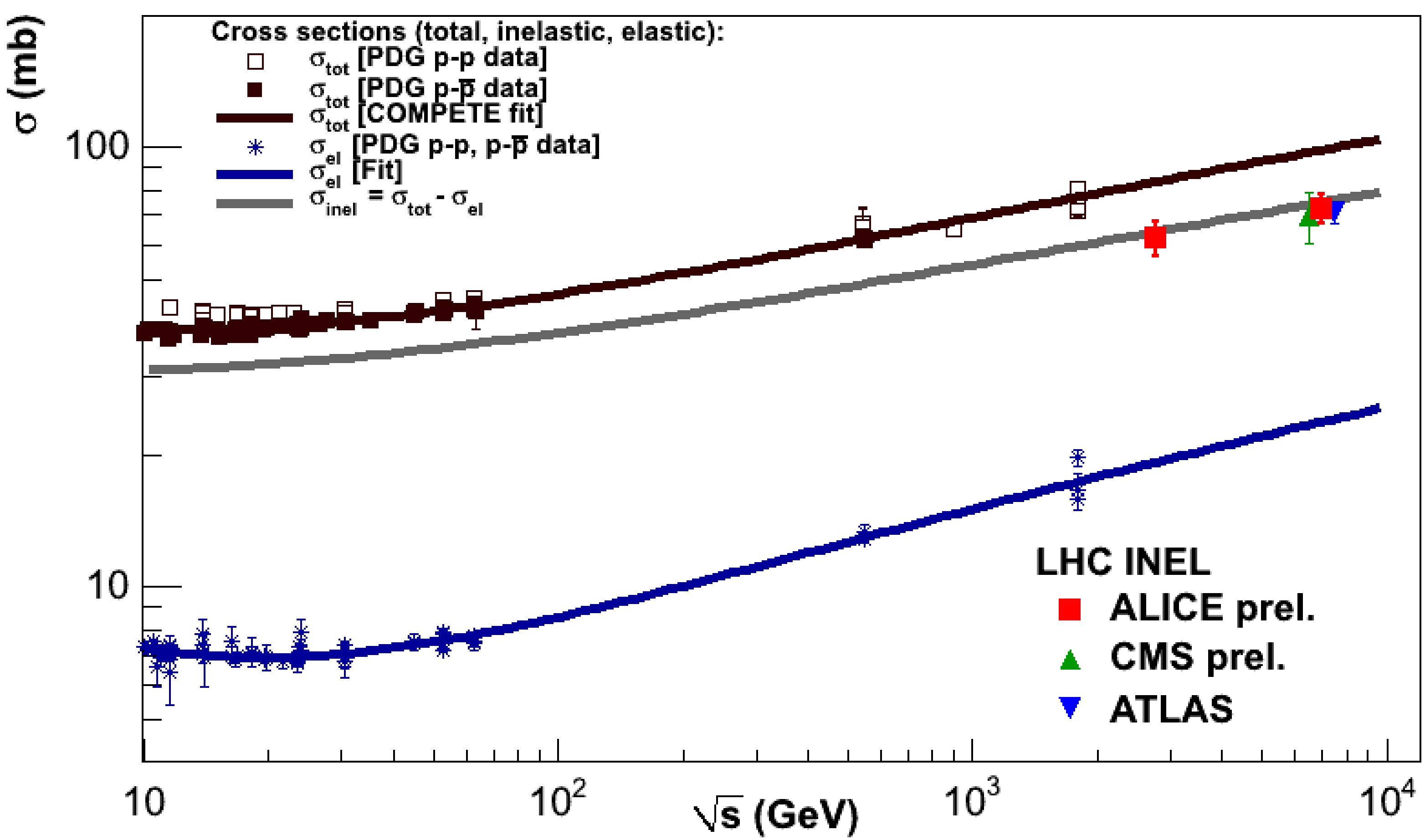
Glauber Monte Carlo

- Geometrical picture of inelastic nucleus+nucleus collision
  - Distribution of nucleons according to Wood-Saxon (2pF)
    - Radius (6.62 ± 6fm), skin depth (0.546 ± 0.01 fm)
    - Inter-nucleon distance (0.4 ± 0.4 fm)
  - Straight-line nucleon trajectories
  - Interaction radius given by σ_{NN}
    - 64 +/- 5 mb used (interp. $p\bar{p}$/pp data)
    - Subsequent interactions equally probably



- Systematic uncertainties by varying model parameters
  - Small effect on <Npart>
  - Uncertainty in σ_{NN} dominant for <Ncoll>

Measured cross-sections



σ^{pp}_{inel} @ 7 TeV

ATLAS:
69.4 ± 2.4 ± 6.9 mb
(arXiv:1104.0326)

CMS (Prel.):
70.4 ± 1.1 ± 3.5 mb
(M.Marone, DIS'11)

ALICE (Prel.):
72.7 ± 1.1 ± 5.1 mb

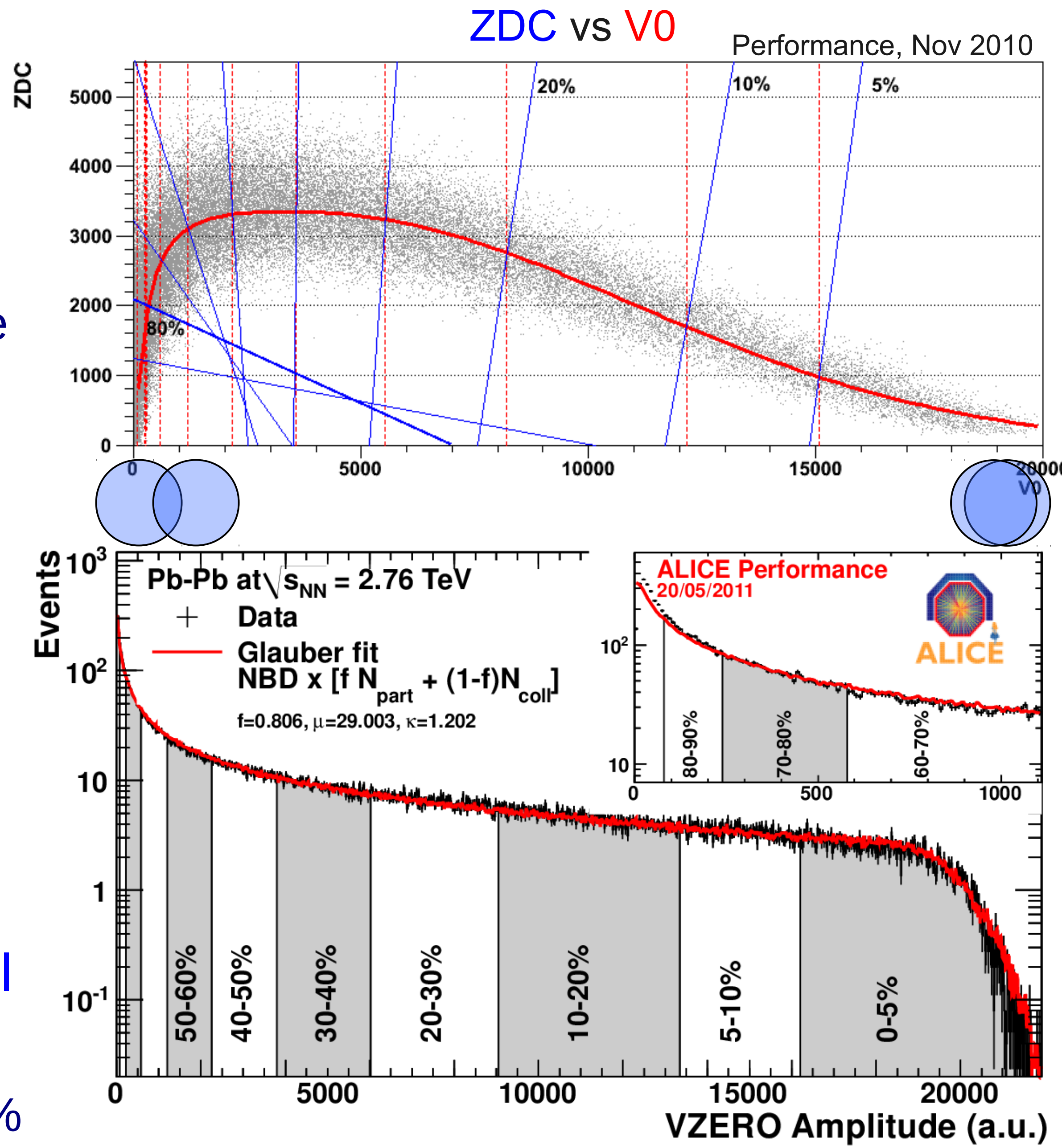
Inel. pp cross section at 2.76 TeV:

- ALICE preliminary: 62.1 ± 1.6 ± 4.3 mb
- Pre-LHC interpolation: 64 mb ± 5 mb (K.Reygers/D.d'Enterria)

K.Oyama talk
M.Poghosyan talk

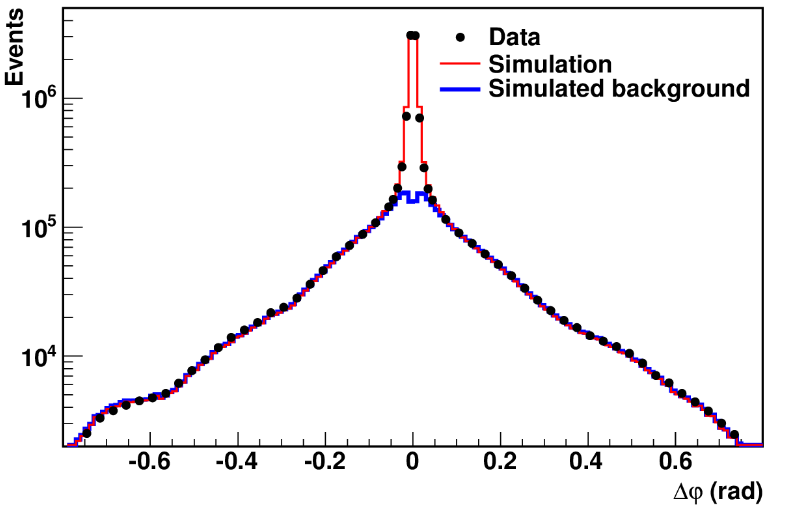
Centrality definition

- Anchor point with Glauber fits
  - Source distributed by f Npart + (1-f) Ncoll
  - Typically f ~ 0.8
  - Particle production per source modeled via NBD
  - Robust results anchoring between 30% and 90% percentile bins
    - Region with 100% trigger eff
    - Negligible background
  - Tight correlation between various centrality measures
- Relation to Glauber values (Npart, etc.) values from model
  - Difference in <Npart> is <1%, except for 70-80% with < 3.5%



Multiplicity measurement

- Tracklet based
  - $dN/d\eta \sim \alpha(1-\beta)N_{tracklets}$
  - α: Acceptance and efficiency corrections
    - Dominated by acceptance (varies little with centrality)
  - β: Combinatorial background
    - 3 ways to estimate
    - Varies by 1% to 14%
- Tracks with zero-p_T extrapolation as cross check



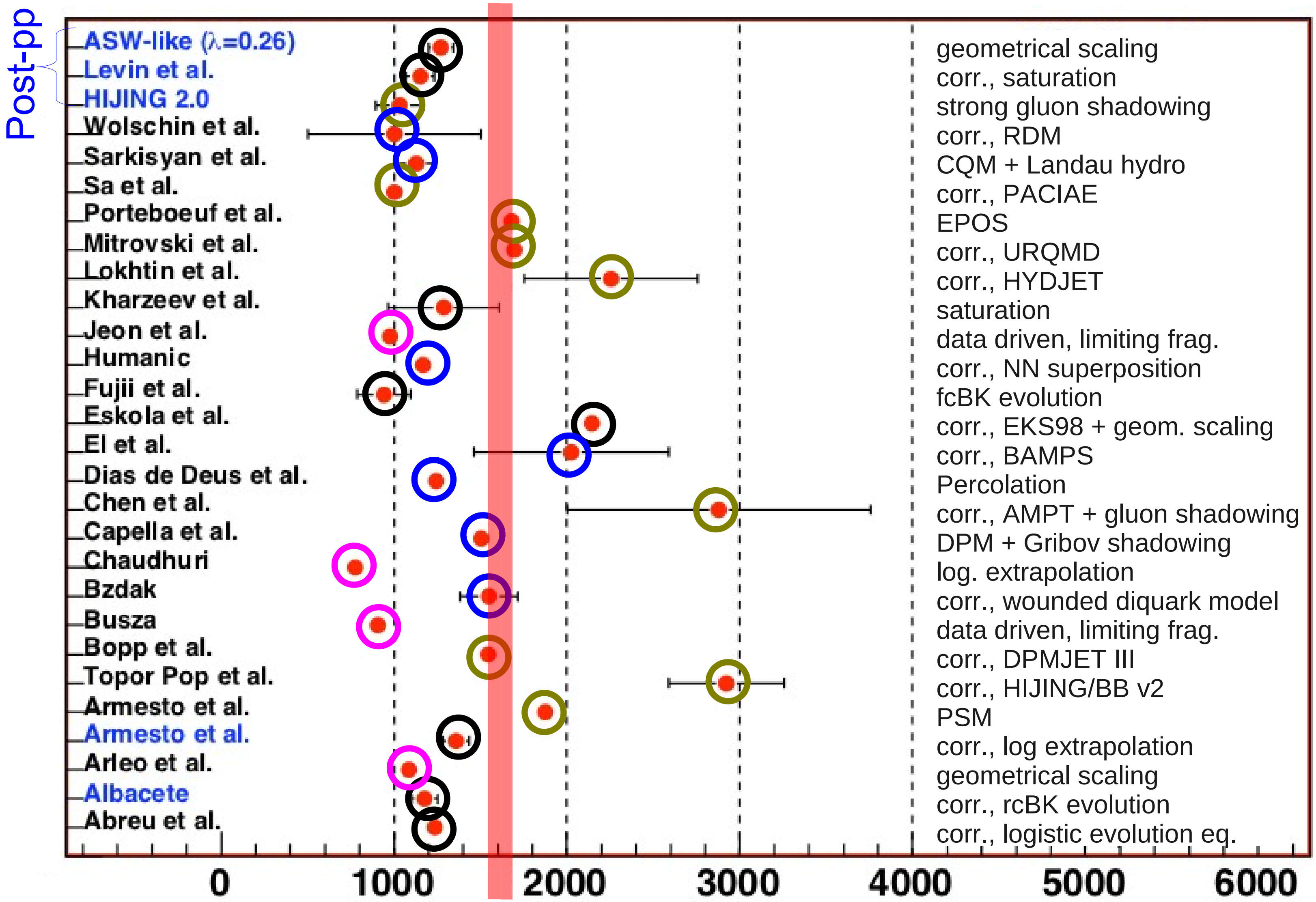
Sources of error	Relative uncertainty
Background subtraction	0.1% to 2.0%
Particle composition	1.0%
Contamination of weak decays	1.0%
Zero-p_t extrapolation	2.0%
Event generator	2.0%
Centrality	6.2% to 0.4%
Tracklet + vertex cuts	negl.
Material budget	negl.
Detector efficiency	negl.
Background events	negl.
Total	7.0% to 3.8%

Centrality	$dN_{ch}/d\eta$	$\langle N_{part}\rangle$	$(dN_{ch}/d\eta)/(\langle N_{part}\rangle/2)$
0–5%	1601 ± 60	382.8 ± 3.1	8.4 ± 0.3
5–10%	1294 ± 49	329.7 ± 4.6	7.9 ± 0.3
10–20%	966 ± 37	260.5 ± 4.4	7.4 ± 0.3
20–30%	649 ± 23	186.4 ± 3.9	7.0 ± 0.3
30–40%	426 ± 15	128.9 ± 3.3	6.6 ± 0.3
40–50%	261 ± 9	85.0 ± 2.6	6.1 ± 0.3
50–60%	149 ± 6	52.8 ± 2.0	5.7 ± 0.3
60–70%	76 ± 4	30.0 ± 1.3	5.1 ± 0.3
70–80%	35 ± 2	15.8 ± 0.6	4.4 ± 0.4

PRL, 105, 252301 (2010)
PRL, 106, 032301 (2011)

Multiplicity in central Pb+Pb@2.76 TeV

Measured dNch/dη = 1584 ± 76 (sys.) PRL, 105, 252301 (2010)



Monte Carlo, coherence via collectivity, strong gluon saturation

Saturation ideas

Data driven, limiting frag.

Miscellaneous: superposition, WNM, diffusion eqs., DPM + shadowing/ percolation

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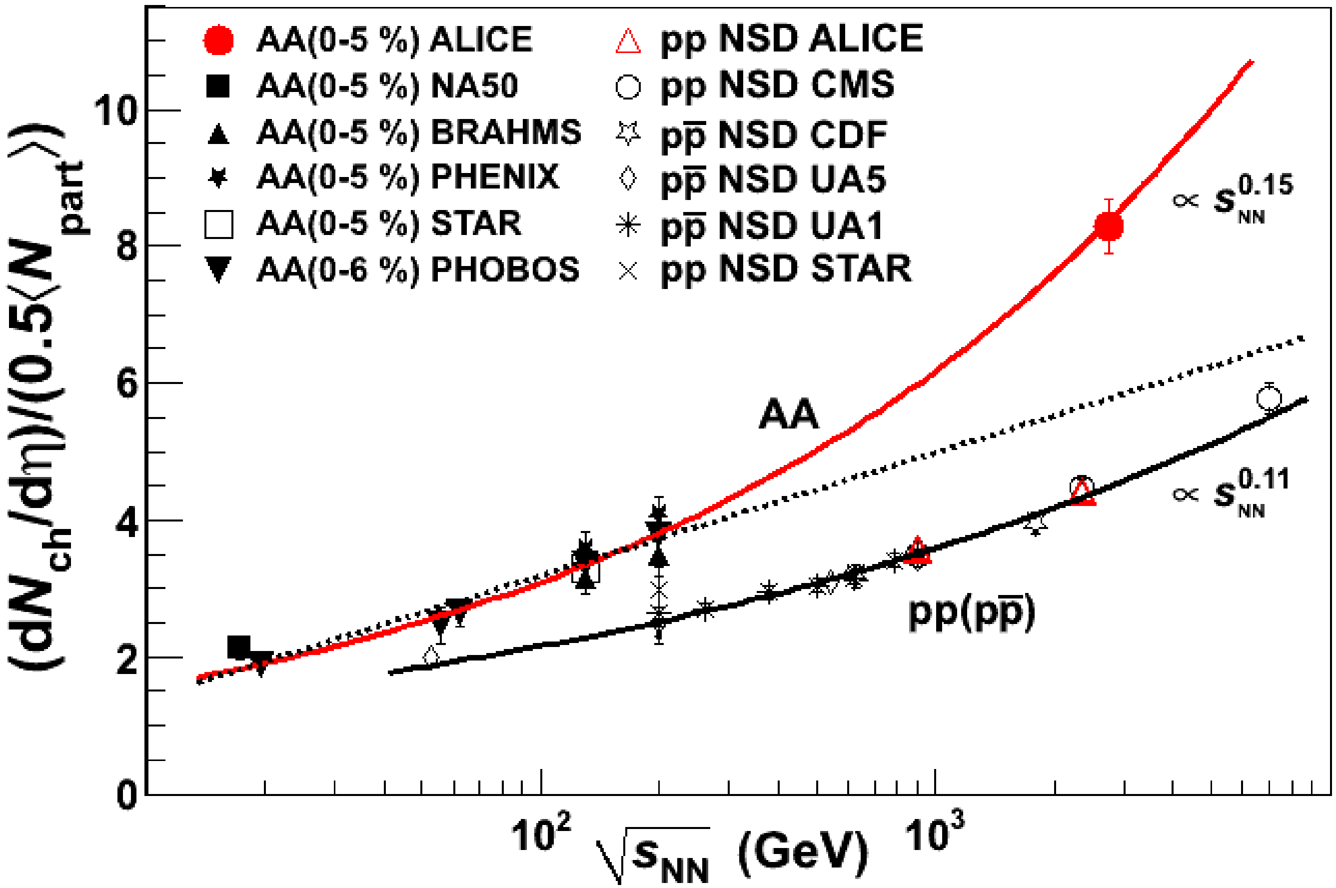
dNch/dη: Energy dependence

Measured dNch/dη = 1584 ± 76 (sys.) PRL, 105, 252301 (2010)



Pre-LHC fit
(~ln s_{NN})

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

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

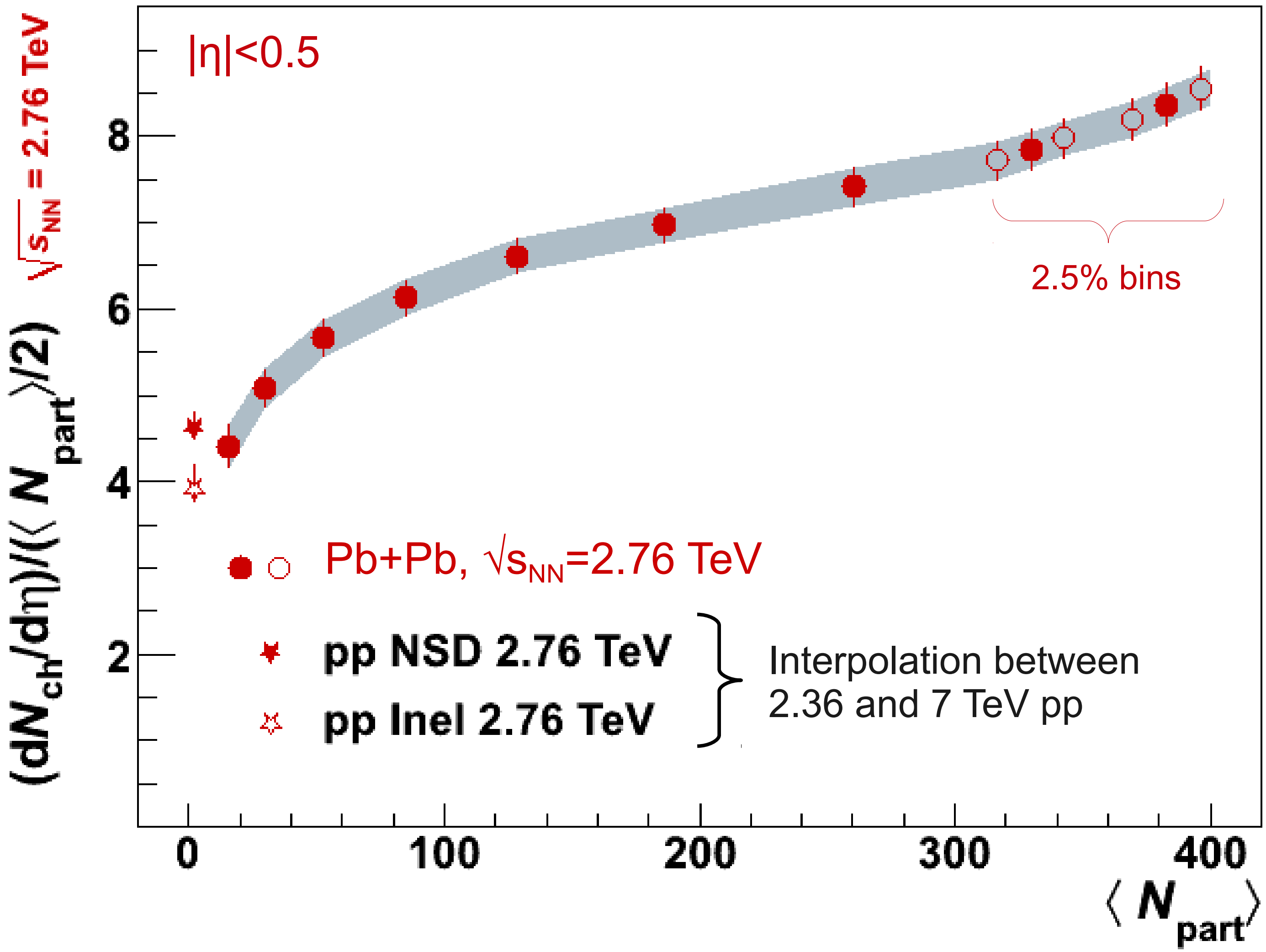
→ 2.2 x central Au+Au
($\sqrt{s_{NN}}$=0.2 TeV)

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

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

dNch/dη: Centrality dependence

PRL, 106, 032301 (2011)



dNch/dη: Centrality dependence

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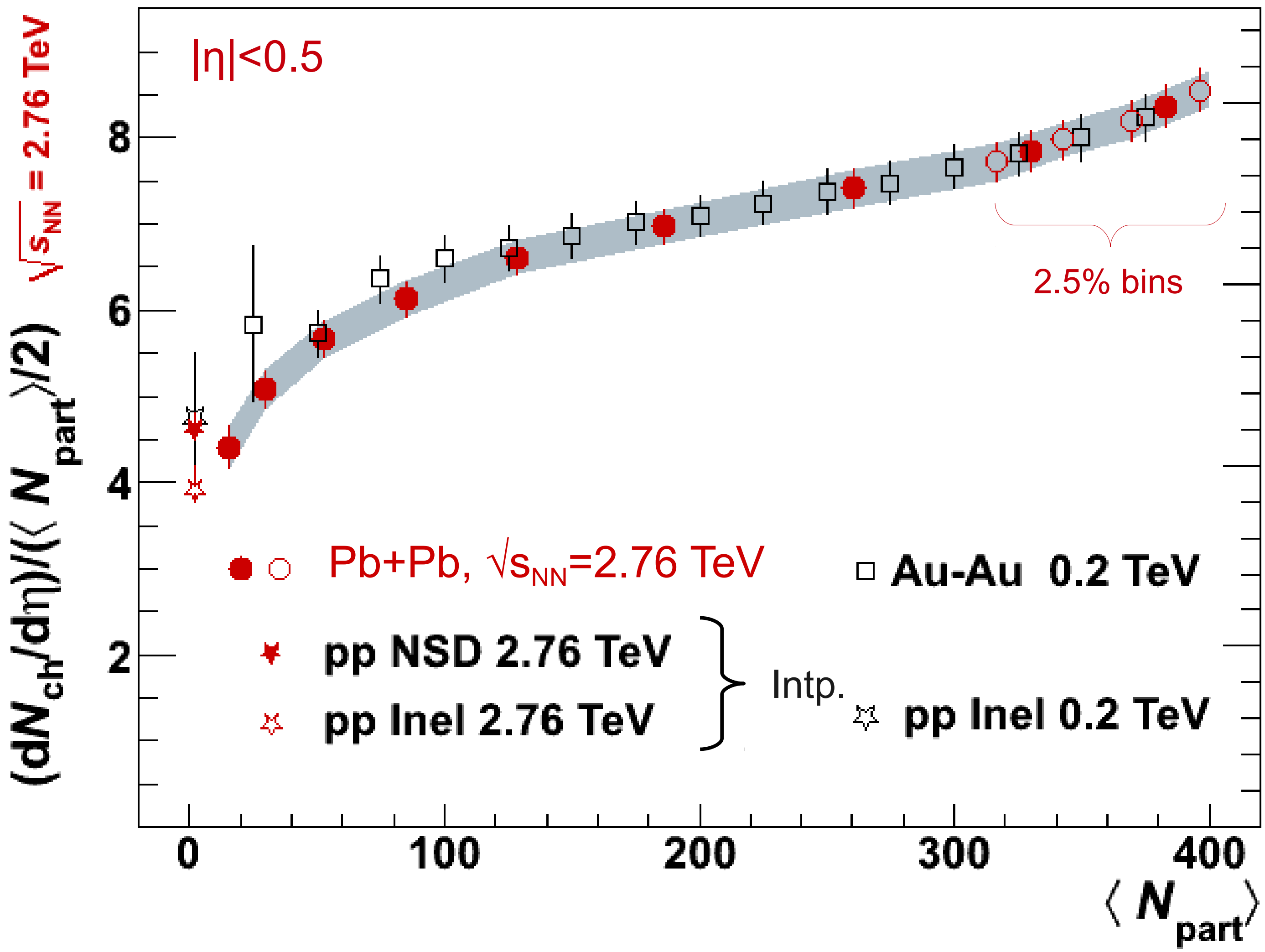


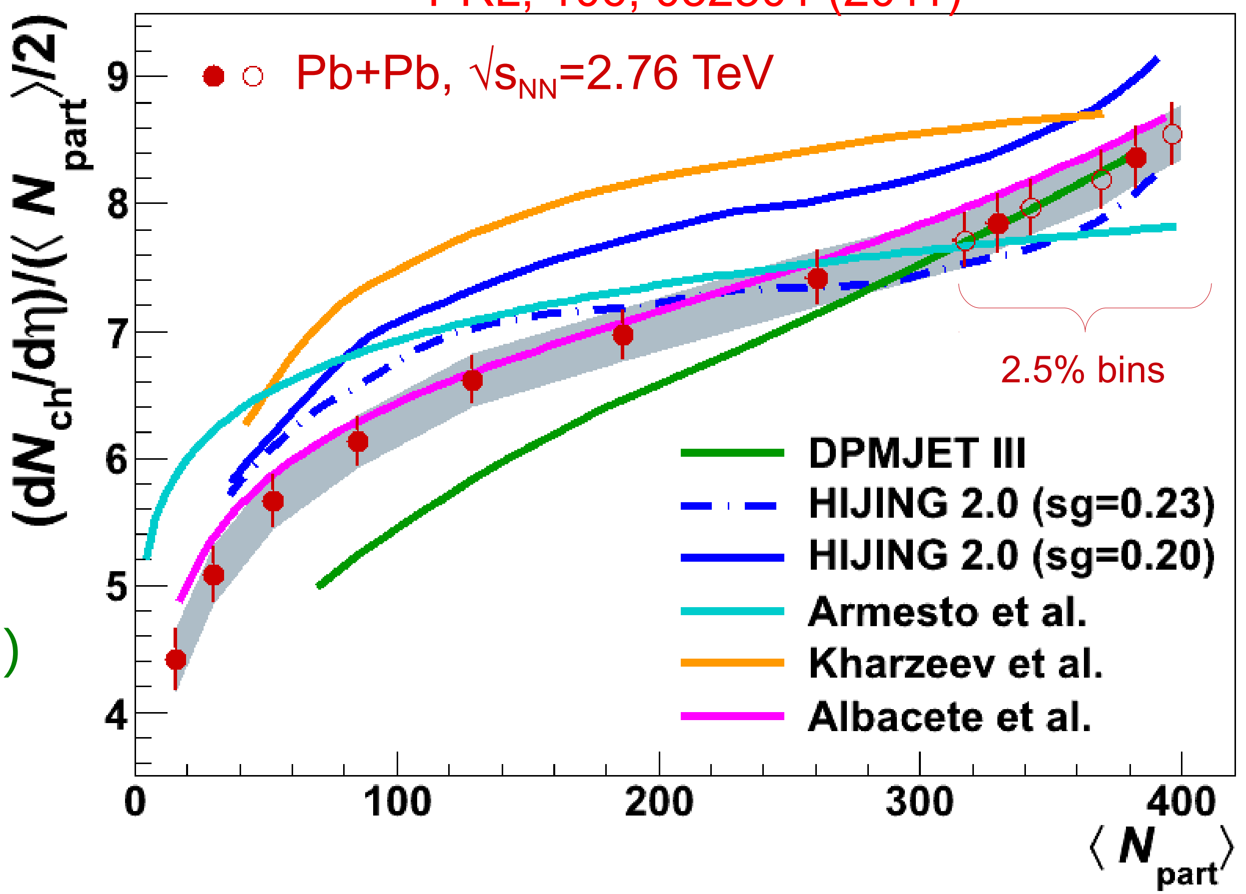
RHIC data scaled by 2.1

LHC centrality evolution very similar to RHIC

dNch/dη: Centrality vs models

- Two-component models
  - Soft (~Npart) and hard (~Ncoll) processes
- Saturation-type models
  - Parametrization of the saturation scale with energy (s) + centrality (A)
- 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
    - Some saturate too much

PRL, 106, 032301 (2011)

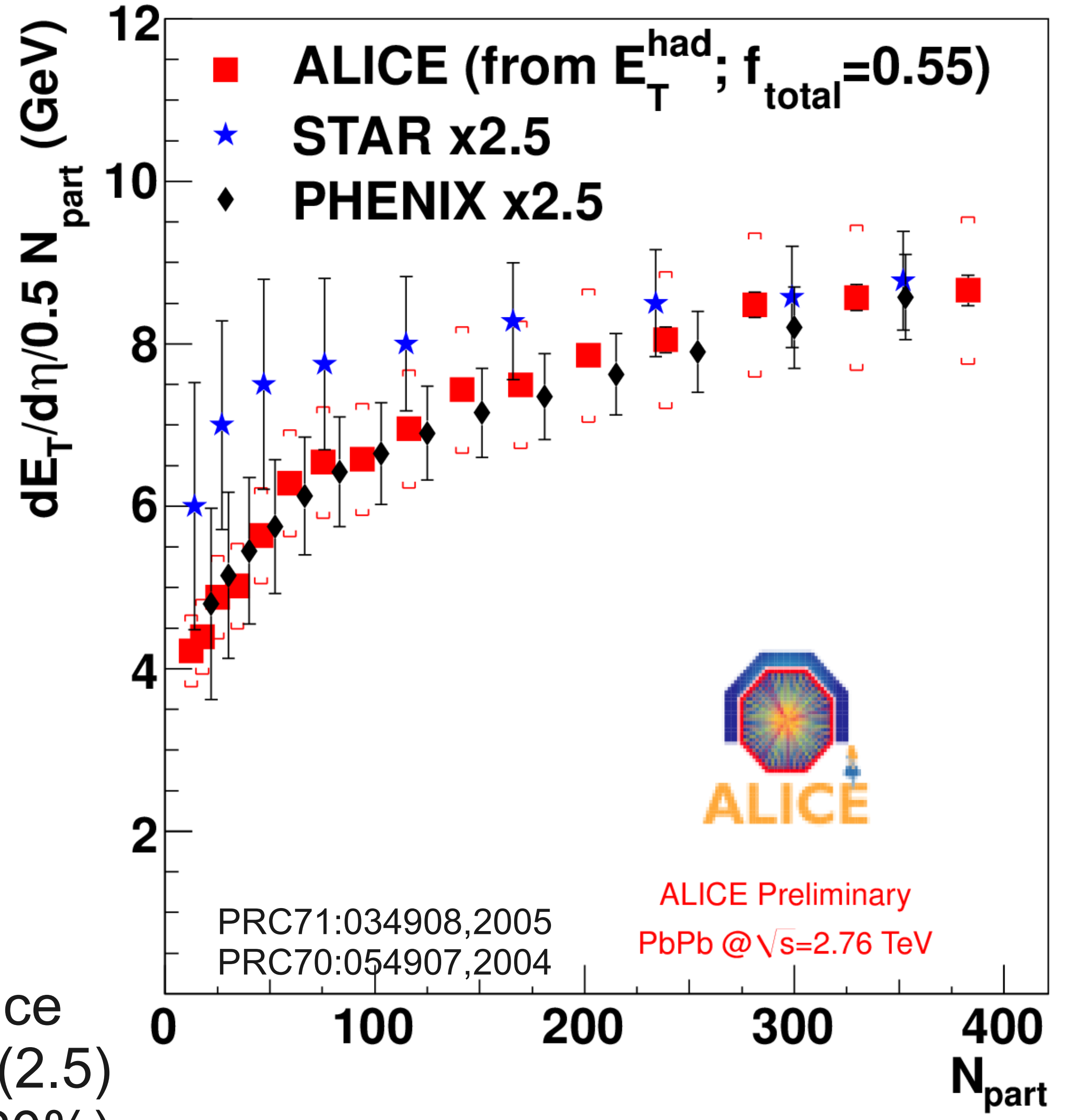


Models incorporating a moderation of the multiplicity with centrality are favored by the data (as at RHIC)

Transverse energy

- Hadronic transverse energy measured with barrel tracking detectors
  - Model dependent correction (f~0.55) to convert into total transverse energy
- From RHIC to LHC
  - ~2.5 increase in 2dEt/dη/Npart
  - ~2.7 increase in dEt/dη
- Energy density estimate

$$\tau\epsilon_{LHC} \geq 3 \times \tau\epsilon_{RHIC}$$



As for dN/dη, centrality dependence similar RHIC. Larger scale factor (2.5) consistent with increase of $\langle p_T \rangle$(20%)

C.Nattrass #630

Summary

- Charged particle multiplicity (transverse E_T) increased from RHIC to LHC by a factor of 2.1 (2.5).
    - Initial energy density is at least 3 times larger
    - Rise with collision energy stronger than expect
    - Centrality dependence found to be similar to RHIC
    - Models have a harder time to describe (predict) the increase in energy than the centrality dependence
- Transverse energy measurement puts additional constraints on models since it is also sensitive to the transverse momentum distribution

Extra

Background and 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
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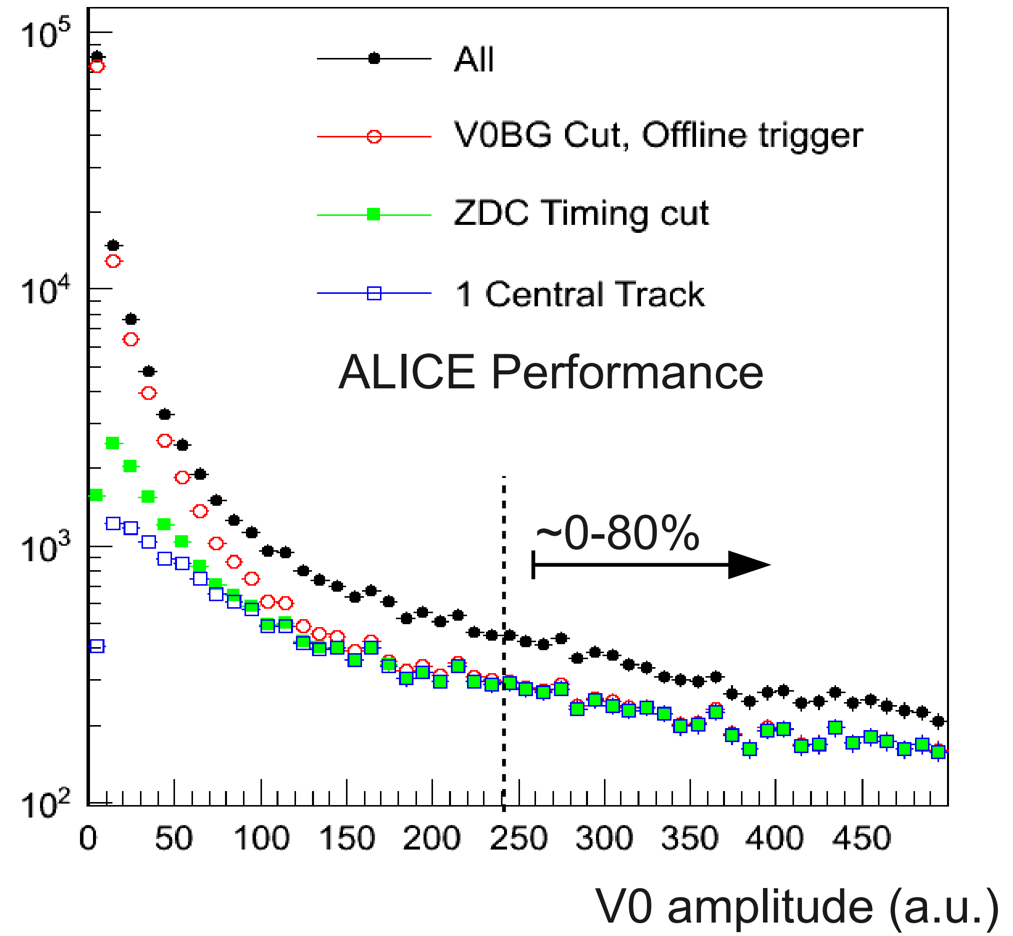
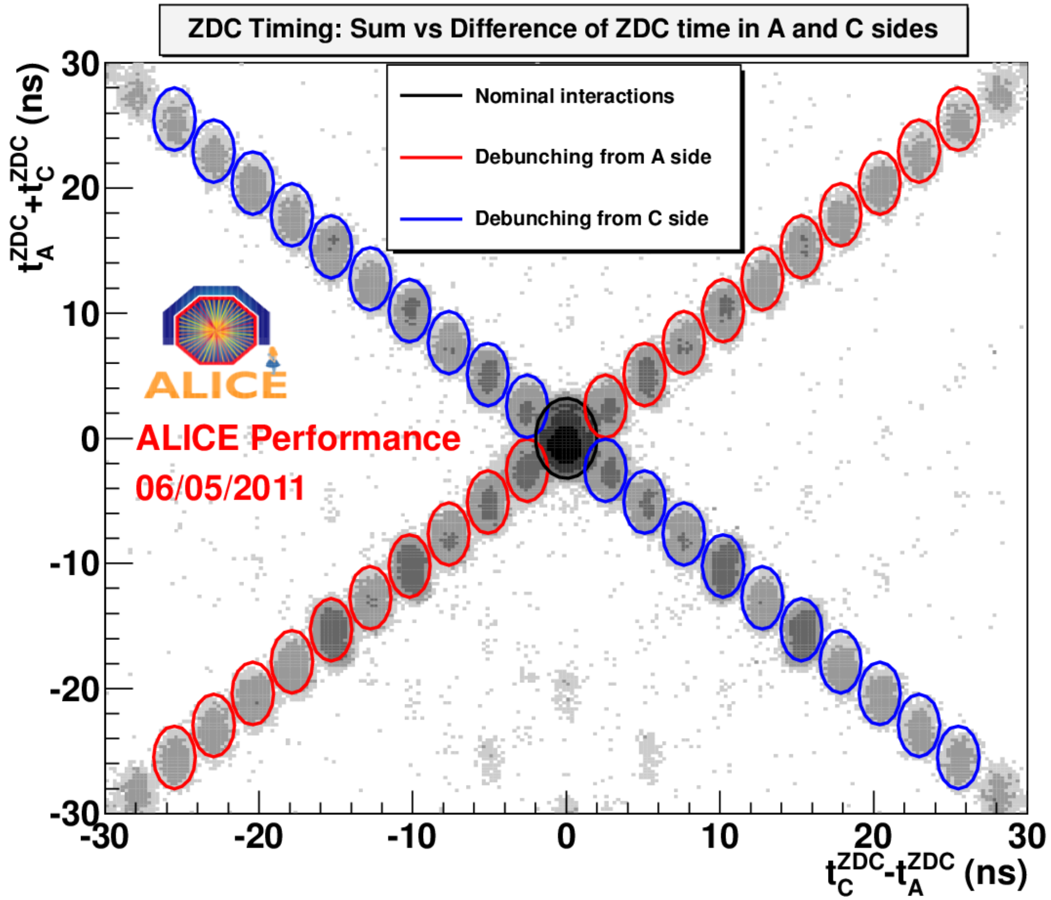


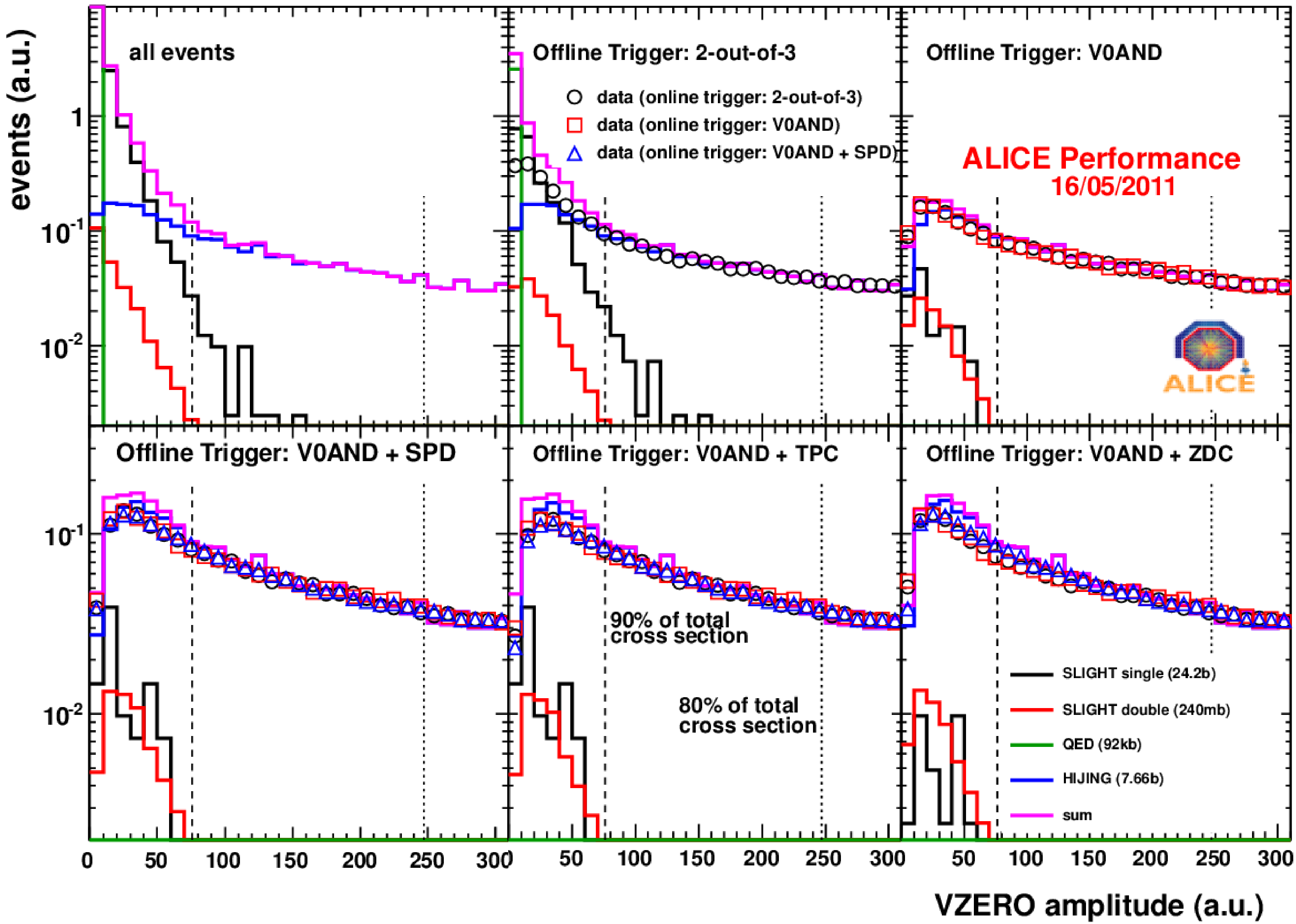
C.Oppedisano talk
J.Nystrand #533

ZDC timing cut

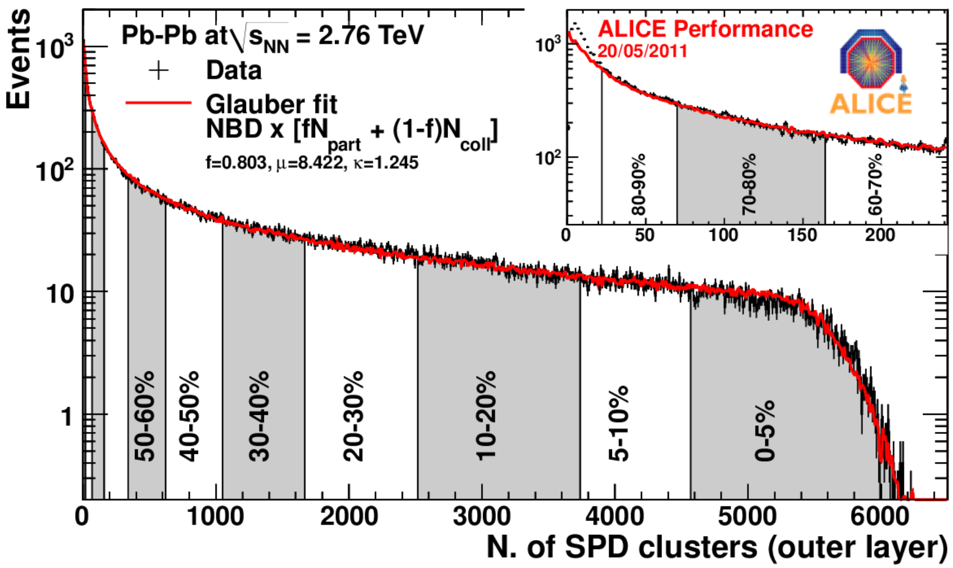


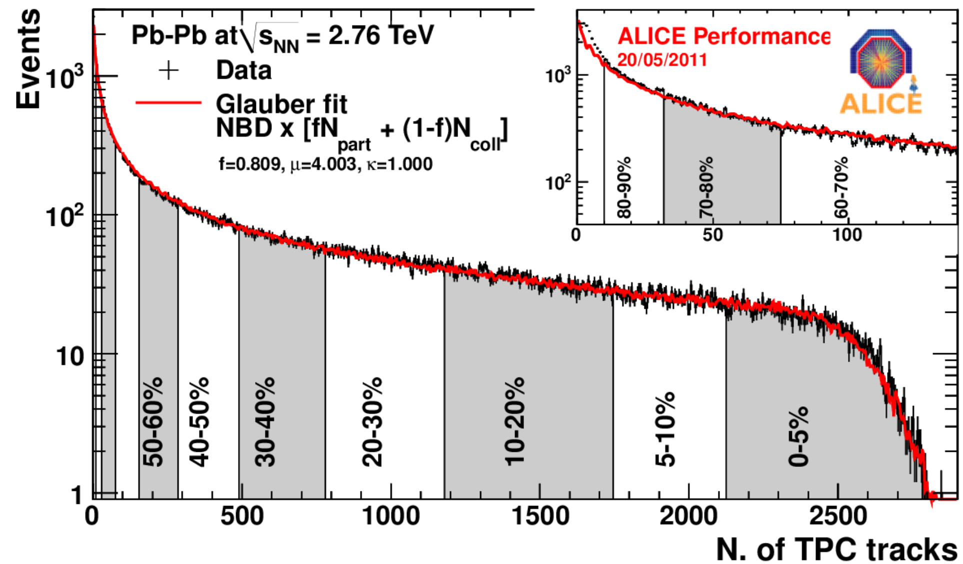
M.Guilbaud #413

Data vs simulation (cocktail)

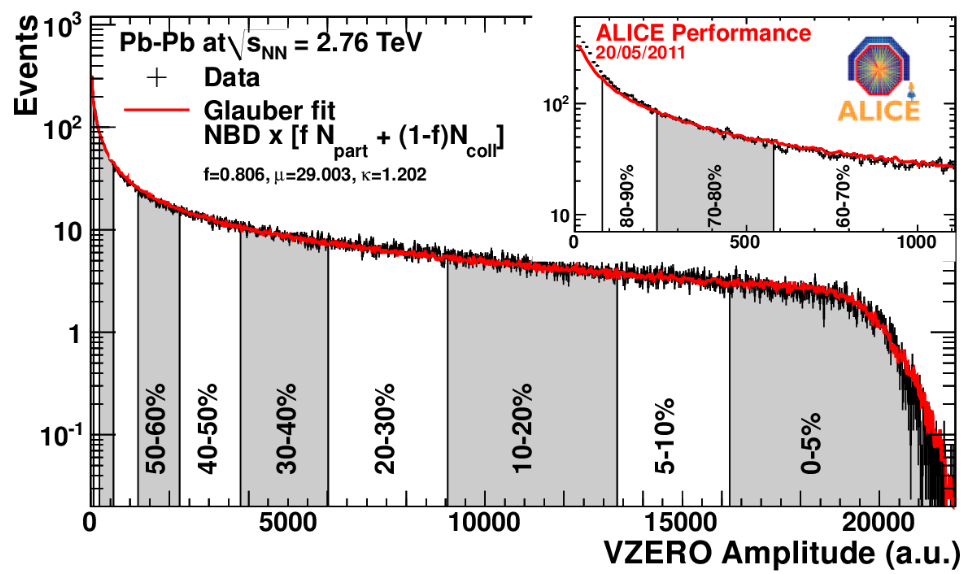


Glauber fits

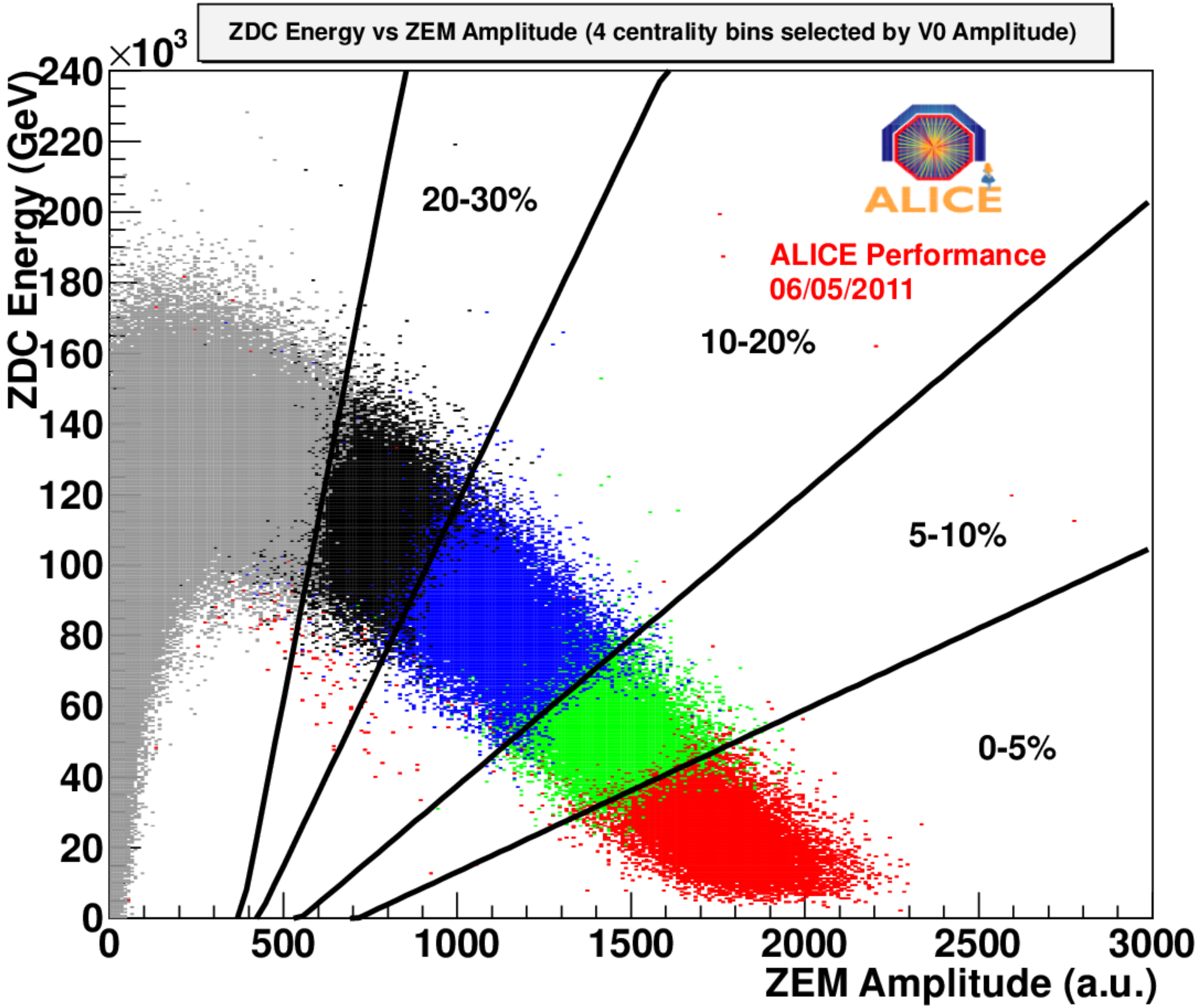




- Glauber fits
  - Using two component ansatz
  - Distribution of particles with NBD
  - Typically (for the tight trigger conditions) fit up to about 90%



ZDC vs ZEM



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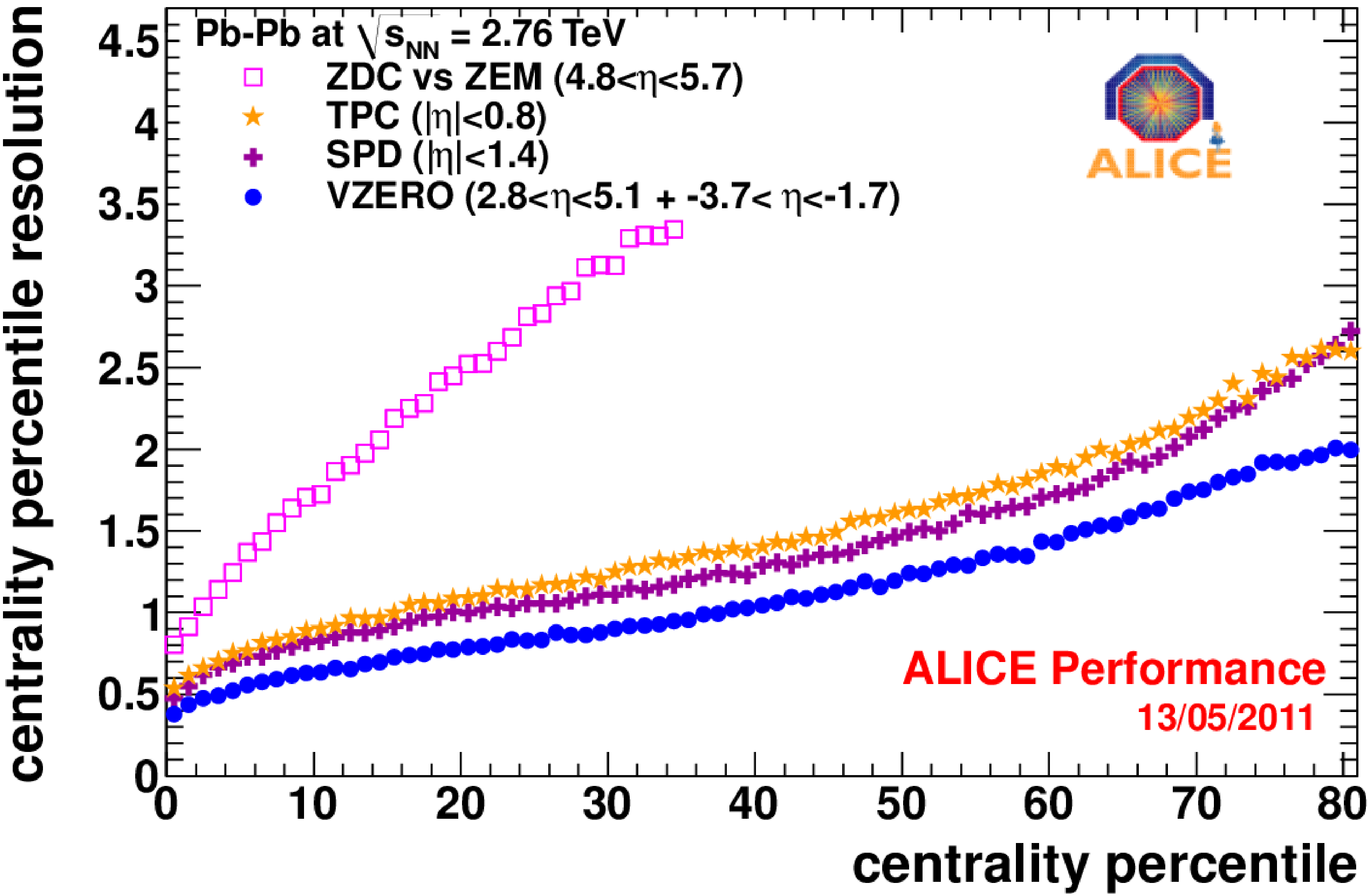
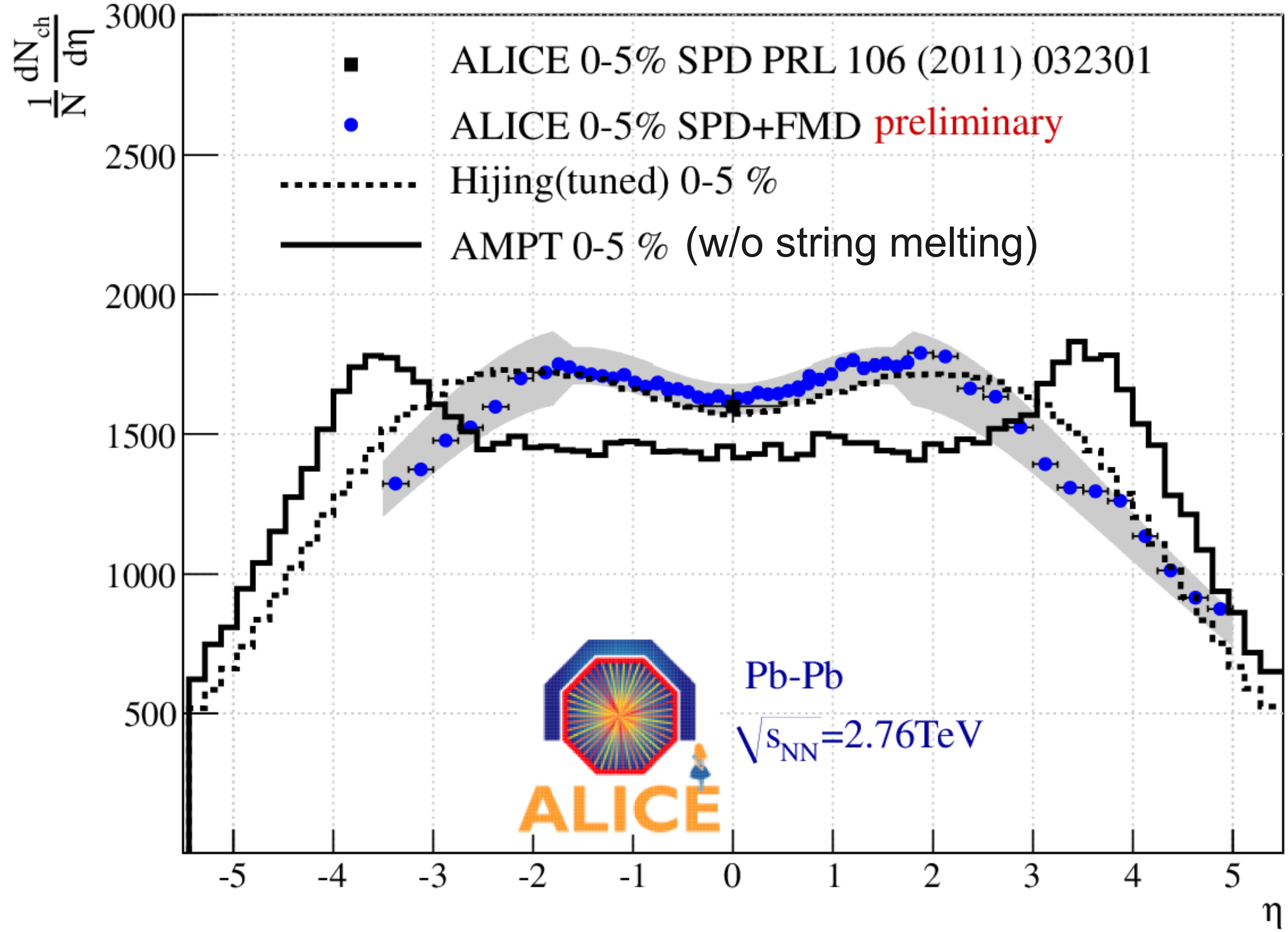
Centrality resolution



Pseudorapidity distribution vs generators



H.Dalsgaard #513

Particle production parametrizations