Glauber model calculations and centrality determinations (at LHC)

HonexComb meeting

Shengquan Tuo
Vanderbilt University
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Goals of the presentation:

1. Share past communication experience on Glauber/Centrality among ALICE/ATLAS/CMS
2. Point out issues and possible topics in need of communication

Outline

- Glauber model and centrality determinations
  - Basic quantities, how to estimate centrality, …
- Past communication between experiments
  - Agree on model parameters/method of determining centrality
- Issues and possible topics in need of communication
  - Parameters for future collisions, O-O, p-O, …
  - Centrality in pPb collisions, Glauber Gribov, ZDC, …
  - Bias study in peripheral PbPb

Monte Carlo Glauber model

Simulate the initial state of the collisions and calculate the geometrical quantities: impact parameter (b), number of participating nucleons (N_{part}), the number of binary collisions (N_{coll}), and initial state anisotropies.

ments [3]. The nuclear charge density is usually parameterized by a Fermi distribution with three parameters:

$$\rho(r) = \rho_0 \frac{1 + w(r/R)^2}{1 + exp(\frac{r-R}{a})}, \quad (1)$$

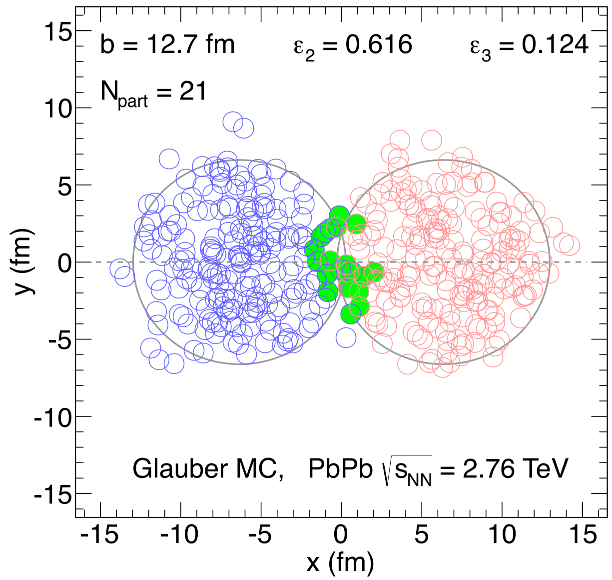
where ρ_0 is the nucleon density, R is the nuclear radius, a is the skin depth and w corresponds to deviations from a spherical shape. The overall normalization (ρ_0) is not relevant for this calculation. Values of the other param-

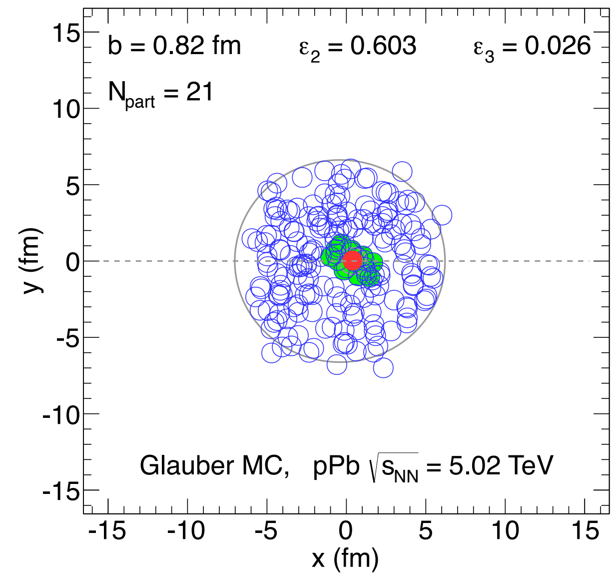
arXiv:0805.4411

Ball diameter:

$$D = \sqrt{\sigma_{NN}/\pi}. \quad (4)$$

Two nucleons from different nuclei are assumed to collide if their relative transverse distance is less than the ball diameter. If no such nucleon–nucleon collision is regis-





S. Tuo thesis

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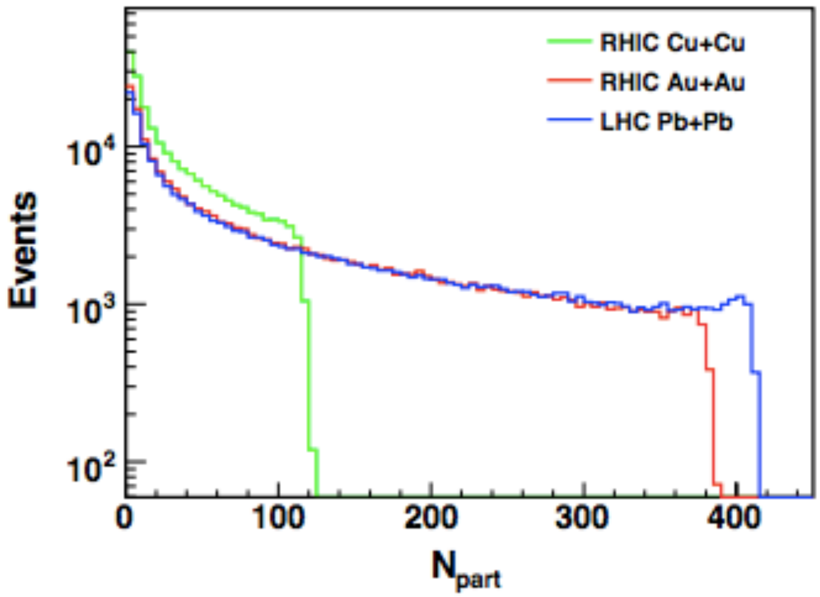
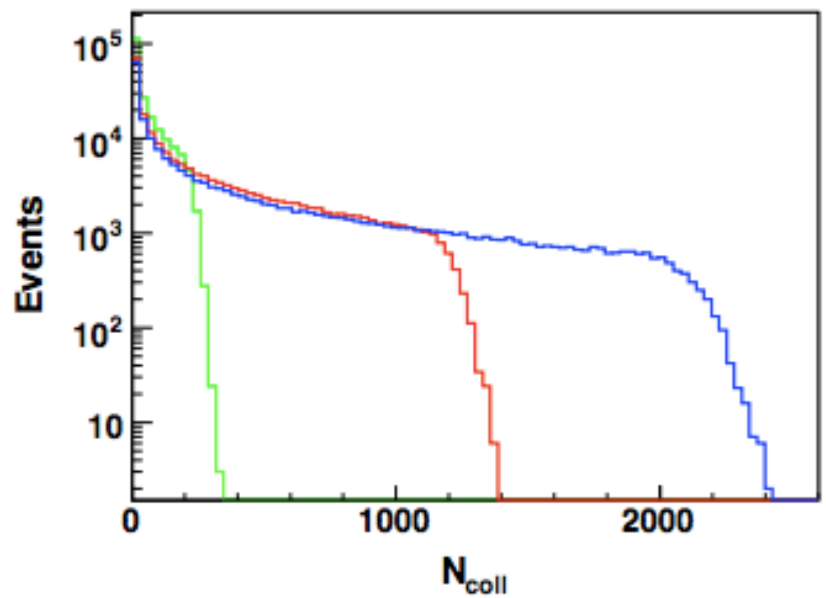
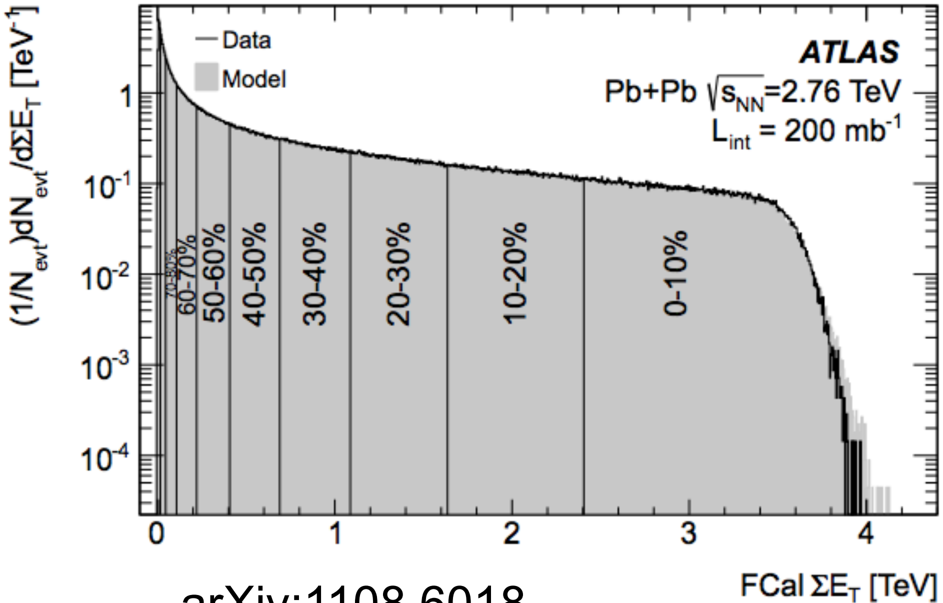


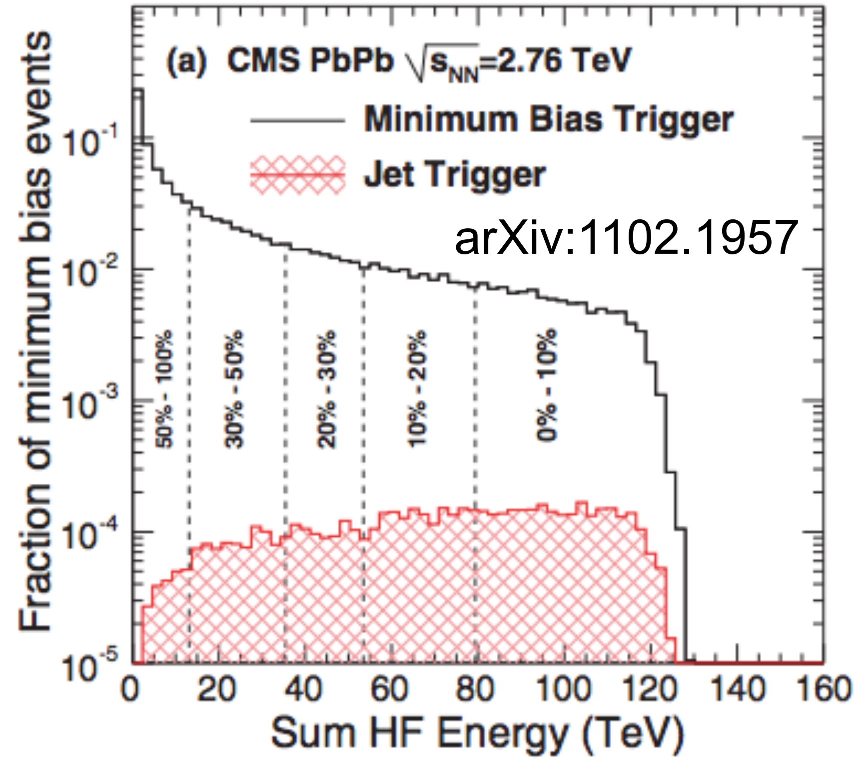


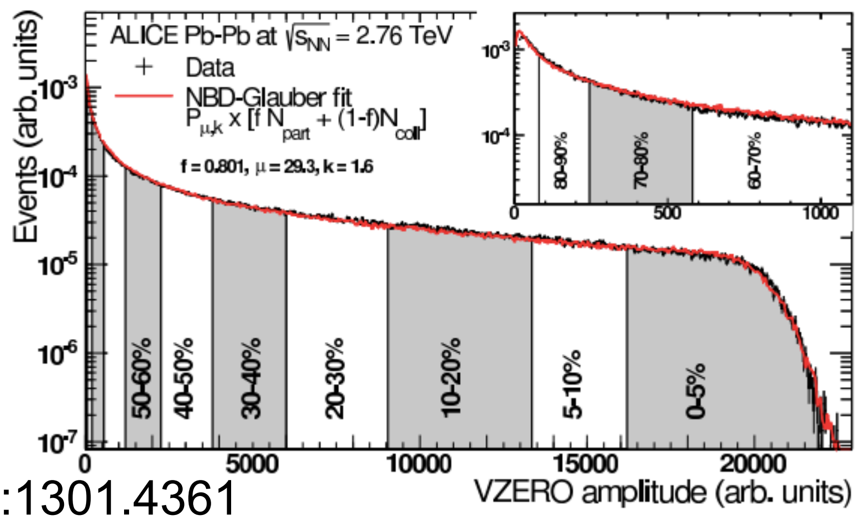
Centrality determinations



arXiv:1108.6018

Figure 1: Measured FCal ΣE_T distribution divided into 10% centrality intervals (black).



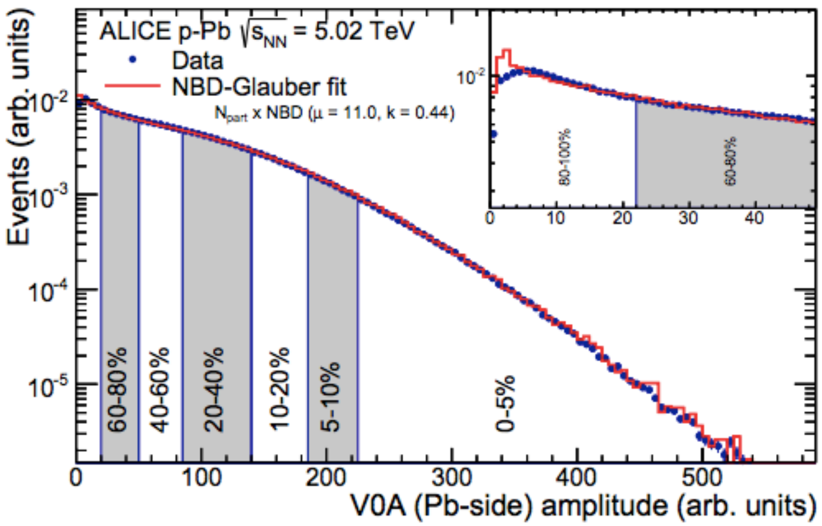


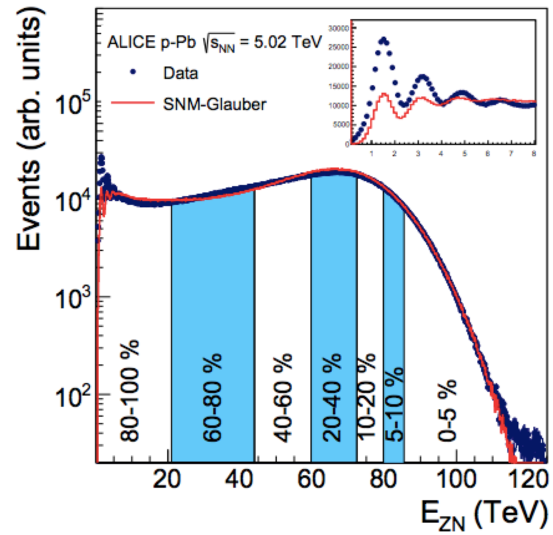
arXiv:1301.4361

Fig. 10: (Color online) Distribution of the sum of amplitudes in the VZERO scintillators. The distribution is fitted with the NBD-Glauber fit (explained in the text) shown as a line. The centrality classes used in the analysis are indicated in the figure. The inset shows a zoom of the most peripheral region.

Slice the measured variables (forward usually) to determine the centrality of each event

Centrality determinations in pPb - ALICE





arXiv:1412.6828

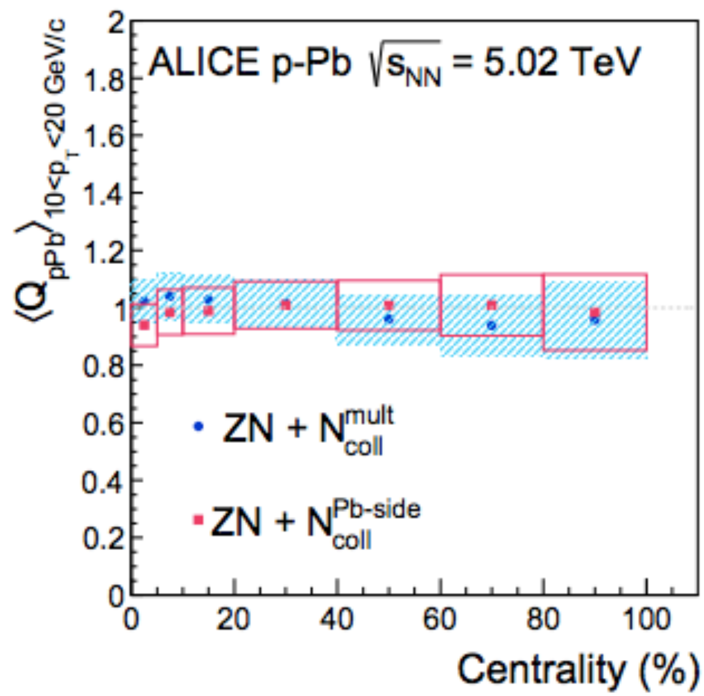
Fig. 1: (color online) Distribution of the sum of amplitudes in the V0A hodoscopes (Pb-going), as well as the NBD-Glauber fit (explained in the text). Centrality classes are indicated by vertical lines. The inset shows a zoom-in on the most peripheral events.

Fig. 5: (color online) Distribution of the neutron energy spectrum measured in the Pb-remnant side ZN calorimeter. The distribution is compared with the corresponding distribution from the SNM-Glauber model (explained in the text) shown as a line. Centrality classes are indicated in the figure. The inset shows a zoom-in on the most peripheral events.

define Q_{pPb} as

$$Q_{pPb}(p_T;\text{cent}) = \frac{dN^{pPb}_{cent}/dp_T}{\langle N^{Glauber}_{coll}\rangle dN^{pp}/dp_T} = \frac{dN^{pPb}_{cent}/dp_T}{\langle T^{Glauber}_{pPb}\rangle d\sigma^{pp}/dp_T} \quad (15)$$

for a given centrality percentile according to a particular centrality estimator. In our notation we distinguish Q_{pPb} from R_{pPb} because the former is influenced by potential biases from the centrality estimator which are not related to nuclear effects. Hence, Q_{pPb} can be different from unity even in the absence of nuclear effects.



Using ZDC and detailed centrality bias was studied in detail

Centrality determination in pPb - ATLAS/CMS

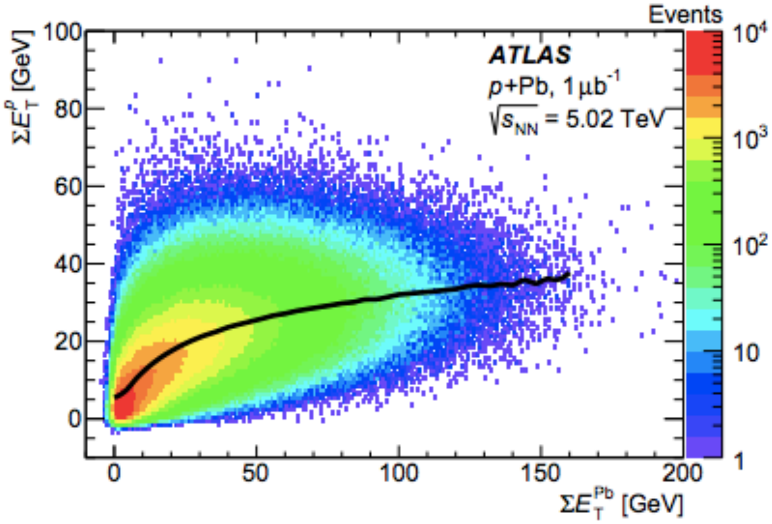
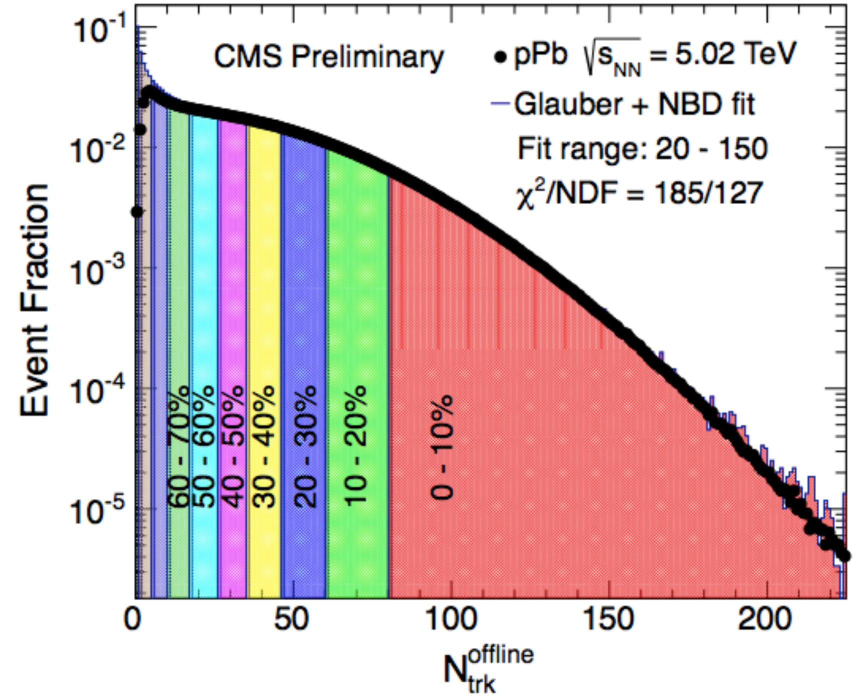


Figure 1: Distribution of proton-going ($\sum E_T^p$) versus Pb-going ($\sum E_T^{\mathrm{Pb}}$) total transverse energy in the forw
rimeter for p+Pb collisions included in this analysis. The curve shows the average $\sum E_T^p$ as a function of $\sum$

arXiv:1508.00848



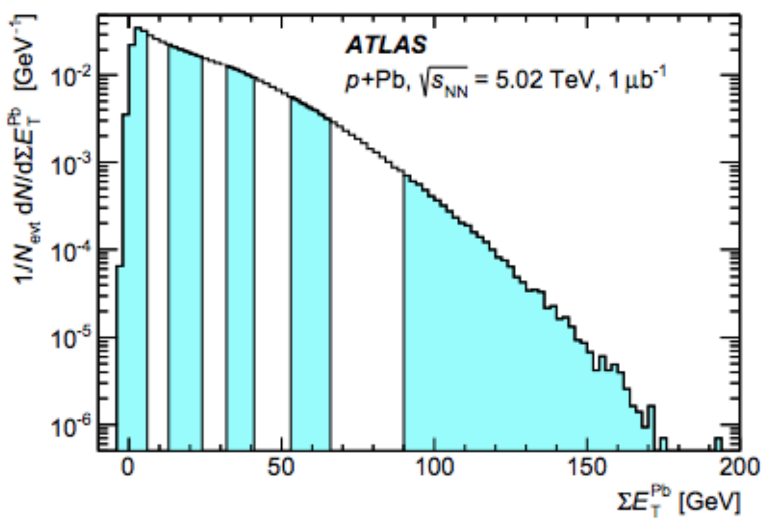


Figure 2: Distribution of the Pb-going total transverse energy in the forward calorimeter $\sum E_T^{\mathrm{Pb}}$ values for events satisfying all analysis cuts including the Pb-going rapidity gap exclusion. The alternating shaded and unshaded bands indicate centrality intervals, from right (central) to left (peripheral), 0–1%, 1–5%, 5–10%, 10–20%, 20–30%, 30–40%, 40–60%, 60–90% and the interval 90–100% that is not used in this analysis.

ZDC was not used.

No detailed centrality bias study.

Past communication between experiments - early PbPb

Short meeting (Nov. 2010) to agree on the input Glauber model parameters

https://twiki.cern.ch/twiki/bin/view/Main/LHCGlauberBaseline

But the systematic uncertainties of these parameters were still not the same, which result in difference of systematics for <Ncoll>. Lots of private emails between experiments trying to find the difference/make the agreement

Glauber Input Parameter	Variation	Variation (%)
Nuclear Radius	6.62 ± 0.13 (fm)	± 2%
Skin Depth	0.546 ± 0.011 (fm)	± 2%
Skin Depth	0.546 ± 0.0546 (fm)	± 10%
d_min	0.4 ± 0.4 (fm)	± 100%
Sigma Inelastic NN	64 ± 5 (mb)	± 7.81%

One of the tables used by CMS early

Past communication between experiments - pPb

Private emails decided the Glauber model input parameters before the run

ATLAS included Glauber-Gribov (fluctuation of NN cross section) later

Special discussion session on centrality in pPb during the Initial Stages 2013 conference (https://indico.cern.ch/event/239958/overview)

Early 2014: Workshop on the determination of centrality in pA collisions at the LHC (https://indico.cern.ch/event/292366/)

Private emails following up …

Past communication between experiments - XeXe

No email discussions before the short run

Big differences on calculated variables between experiments showed up in conferences

Lots of private email discussions later on the Glauber model parameters, including the deformation of Xenon

Past communication between experiments - pPb/PbPb later

Private email discussions in 2016 before the pPb run.
Update on NN cross section and Pb setup.

Glauber values for pPb at 8.16 TeV

D. d'Enterria, C. Loizides, P.Steinberg and S.Tuo

11 Oct 2016

Recommendation of Glauber settings for upcoming pPb@8.16 TeV run based on studies and email exchanges between the authors over the last days.

Should we also adjust settings for Pb? 3

- So far we use following our PRL (https://arxiv.org/abs/1210.3615).
  - Radius: 6.62+/- 0.06fm
  - Skin depth: 0.546+/-0.010fm
  - Min-distance: 0.4+/-0.4fm
- However there are updated results from PRL 112 (2014) 242502
  - Proton
    - Radius: 6.680
    - Skin: 0.447
  - Neutron
    - Radius 6.70 +/- 0.03
    - Skin: 0.55 +/- 0.03

Treat the proton and neutron radius/skin depth differently inside Pb

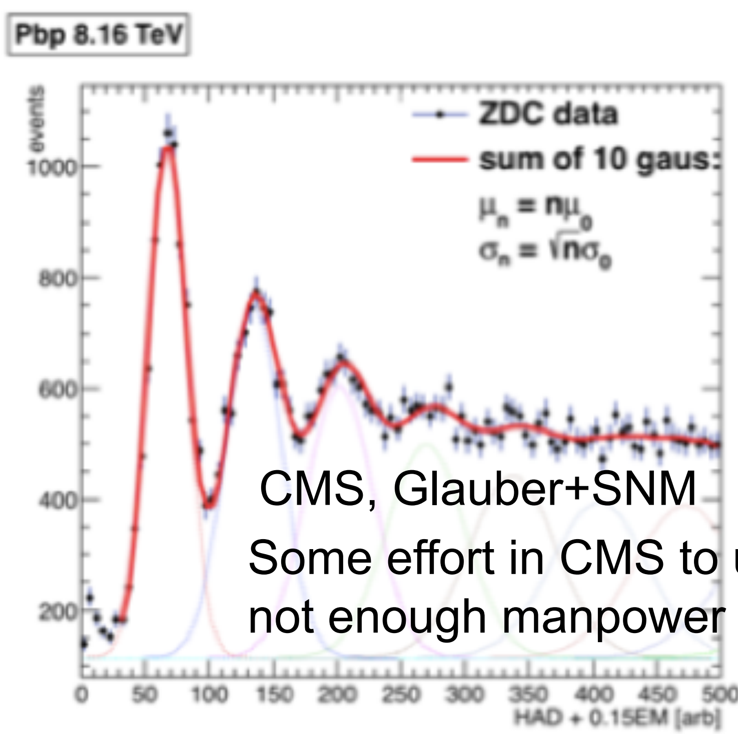
One follow up publication between several of them: arXiv:1710.07098

Latest private email discussions were about Glauber fit parameters for the peripheral PbPb bias study

Topics that need cross-collaboration discussions

1. Need discussions before a heavy ion run with new setup:
   - New energy for PbPb/pPb
   - New setup for O-O, p-O, …

2. pPb Centrality is much better understood in ALICE compare to CMS (ATLAS?)



CMS, Glauber+SNM

Some effort in CMS to use ZDC, but not enough manpower + experience

arXiv:1412.4092

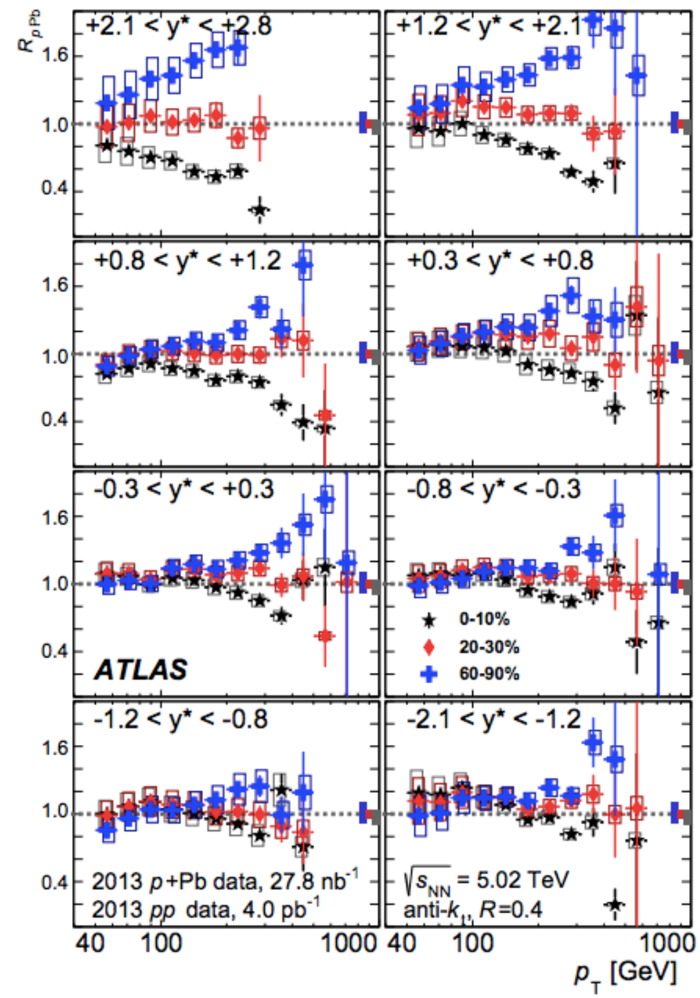


Fig. 5: Measured R_{pPb} values for $R = 0.4$ jets in p+Pb collisions in central (stars), mid-central (diamonds) and peripheral (crosses) events. Each panel shows the jet R_{pPb} in a different rapidity range. Vertical error bars represent the

Topics that need cross-collaboration discussions

3. Bias study in peripheral AA collisions

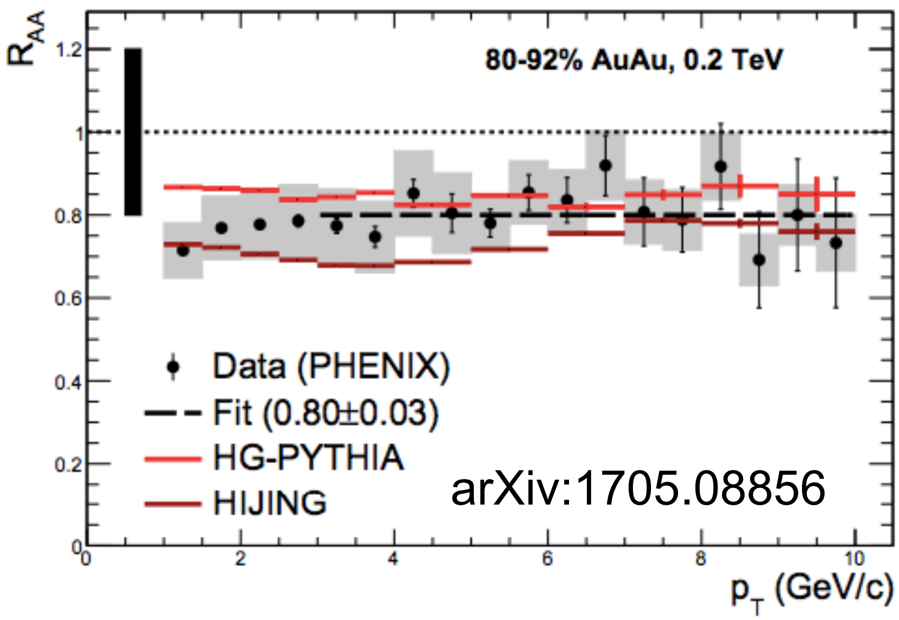
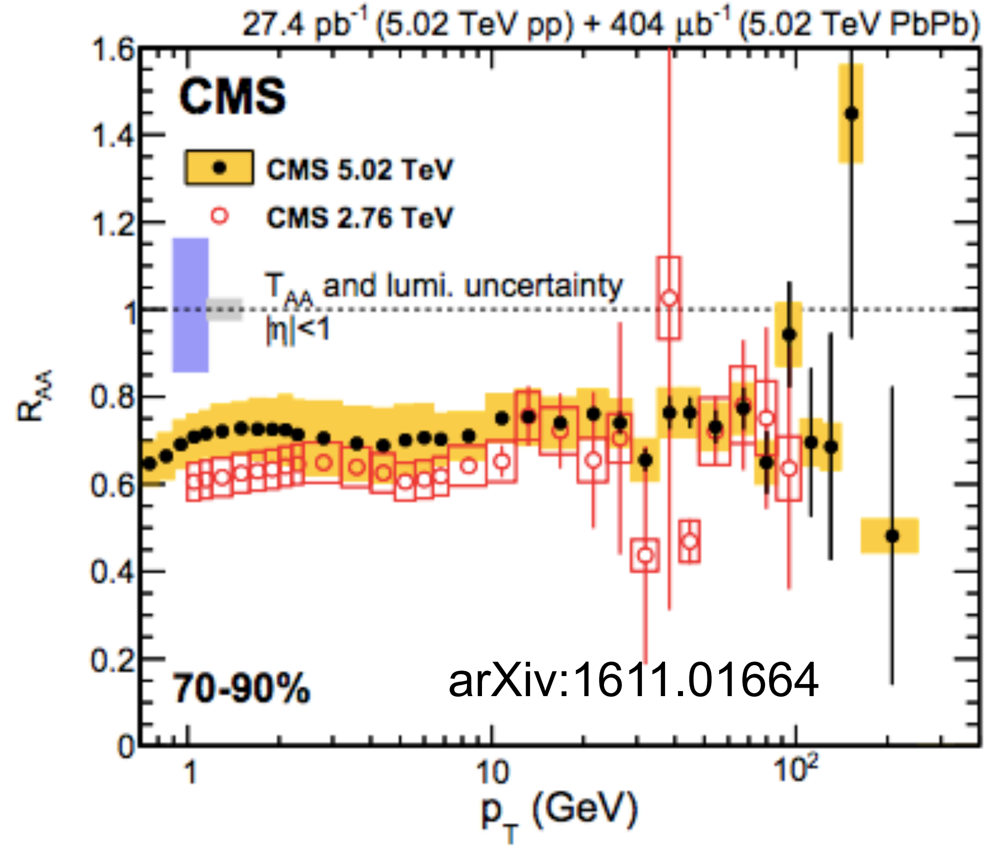


Figure 1: R_{AA} versus p_T in 80–92% central AuAu collisions at $\sqrt{s_{NN}} = 0.2$ TeV. The PHENIX data from [10, 11], which were averaged as explained in the text, are compared to HG-PYTHIA and HIJING calculations. For details, see text.



Quenching in peripheral?

No. Both $<N_{coll}>$ (T_{AA}) and selected events (in the centrality) are biased in peripheral

Topics that need cross-collaboration discussions

3. Bias study in peripheral AA collisions

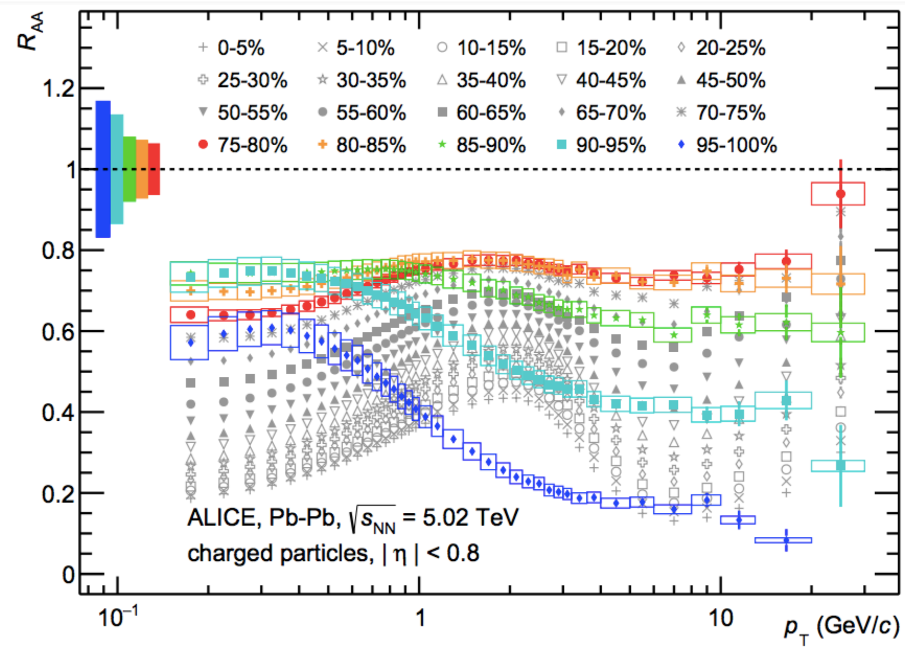
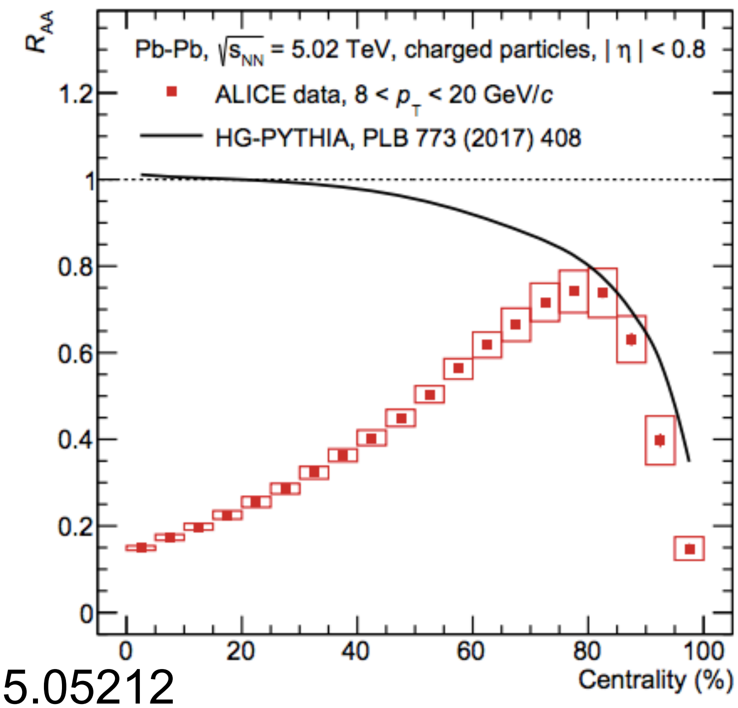
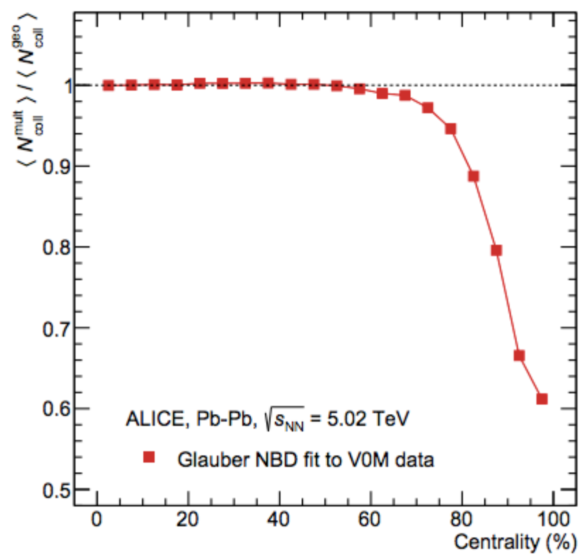


Fig. 2: Nuclear-modification factor versus p_T for charged particles at midrapidity in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV for 5%-wide centrality classes. The filled, coloured markers are for the five most peripheral classes, with the corresponding global uncertainties denoted close to $p_T = 0.1$ GeV/c. Vertical error bars denote statistical uncertainties, while the boxes denote the systematic uncertainties. For visibility, the uncertainties are only drawn for the peripheral classes.



arXiv:1805.05212

Fig. 3: Average R_{AA} for $8 < p_T < 20$ GeV/c versus centrality percentile in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV compared to predictions from HG-PYTHIA [38]. Vertical error bars denote statistical uncertainties, while the boxes denote the systematic uncertainties.



These biases are similar but could be different in ALICE/ATLAS/CMS

Summary

Clearly, cross-collaboration discussions are needed for the Glauber model calculations and centrality determinations