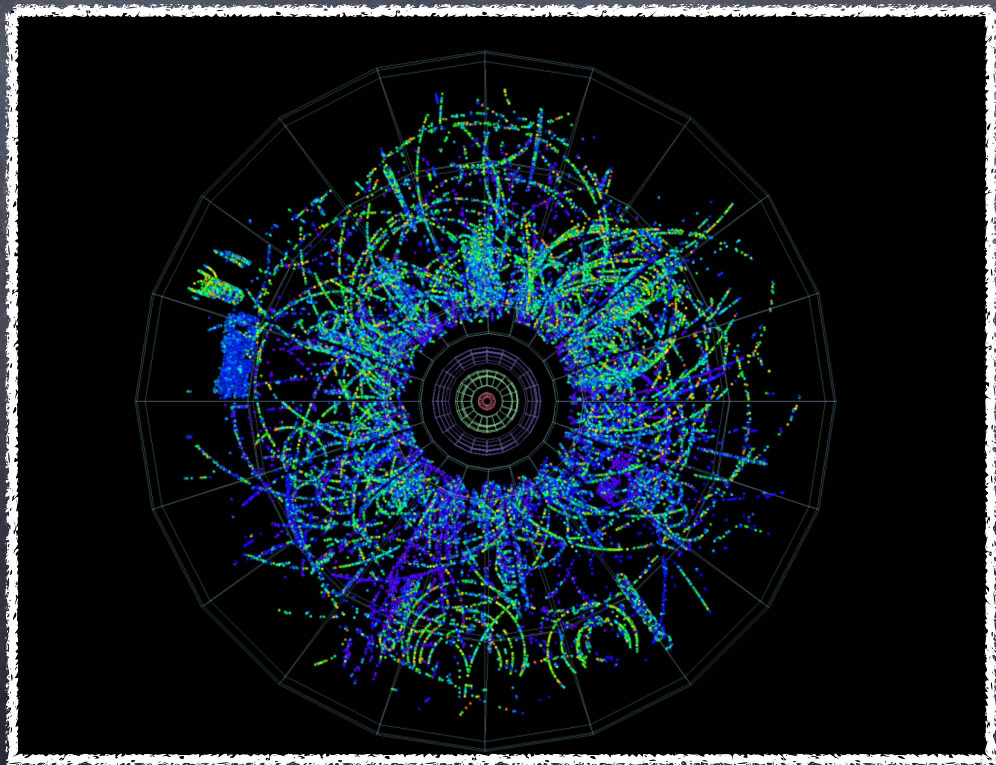
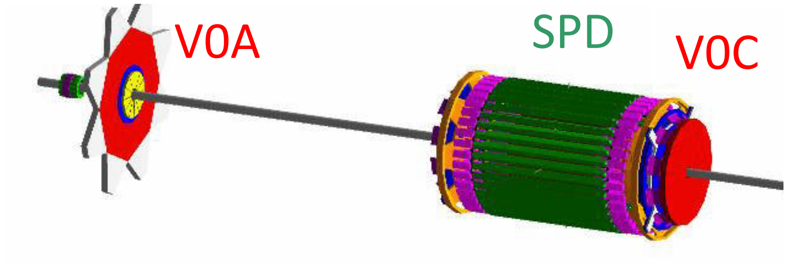
p-Pb centrality in ALICE



ALICE centrality estimators

MULTIPLICITY



MIDRAPIDITY

2 innermost ITS layers (pixel)

$|\eta|< 2$, $|\eta|<1.4$

FORWARD RAPIDITY

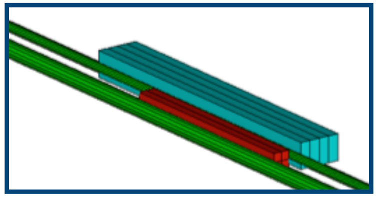
V0 scintillator hodoscopes

V0A z = 3.4 m $2.0<\eta<5.1$

V0C z = -0.9 m $-3.7<\eta<-1.7$

VERY FORWARD ENERGY

ZERO DEGREE



Zero Degree Calorimeters (ZDC) ±112.6 m

neutron ZDC (ZN) $|\eta|>8.7$

proton ZDC (ZP)

- CL1 ➡ clusters in 2nd pixel layer
- V0M ➡ total (V0A+V0C) multiplicity
- V0A ➡ V0 multiplicity (Pb-remnant side)

Estimators sensitive to particle production

- ZNA ➡ ZN energy (Pb-remnant side)
- ZPA ➡ ZP energy (Pb-remnant side)

Estimators sensitive to slow nucleon emission

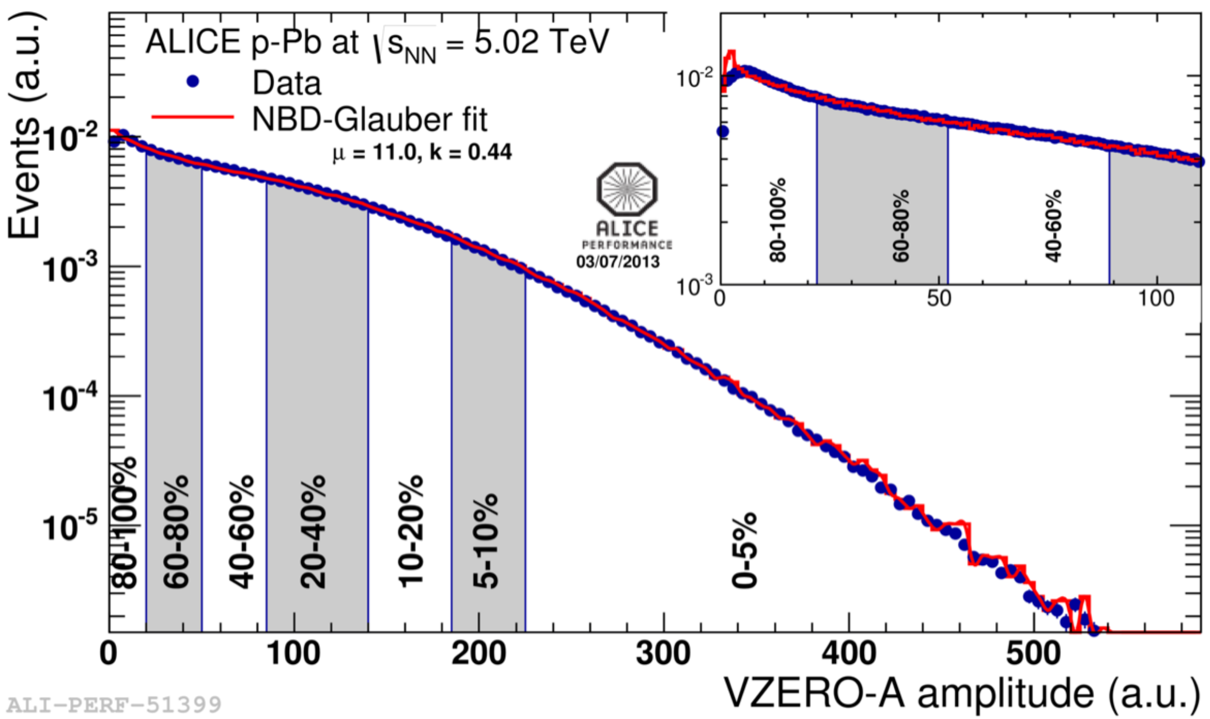
Glauber fit

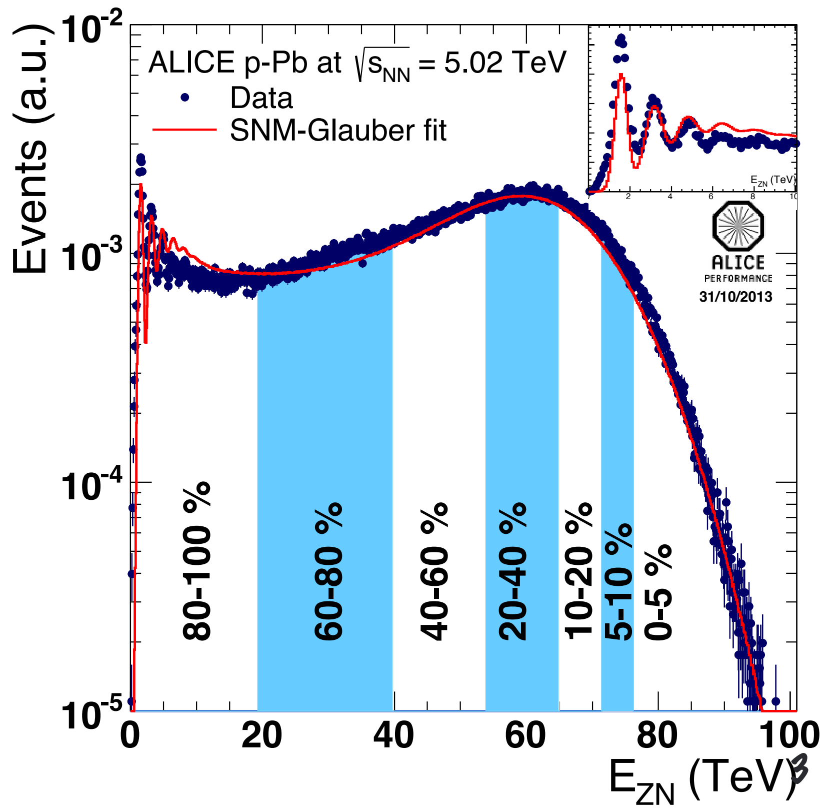
ALICE Collaboration, Phys. Rev. C 88, 044909 (2013)

Same procedure as for Pb-Pb:

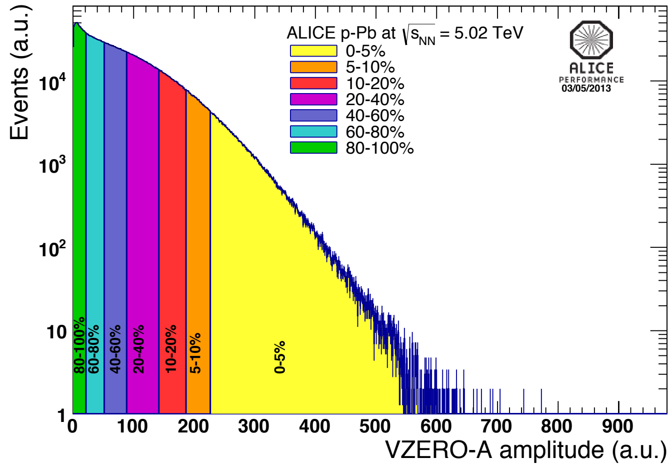
- $P(N_{part})$ from Glauber MC assuming N_{part} = number of particle sources (ancestors)
- multiplicity distribution per ancestor
  - (1) from NBD for charged particle multiplicity
    - pp distribution fitted with convolution of 2 NBDs ➧ $k_{pp} = 2{*}k_{pPb}$ if $N_{ancestors} = N_{part}$
  - (2) from Slow Nucleon Model (SNM) for zero degree energy
- minimization procedure
- centrality classes defined slicing measured observables in percentiles of cross section

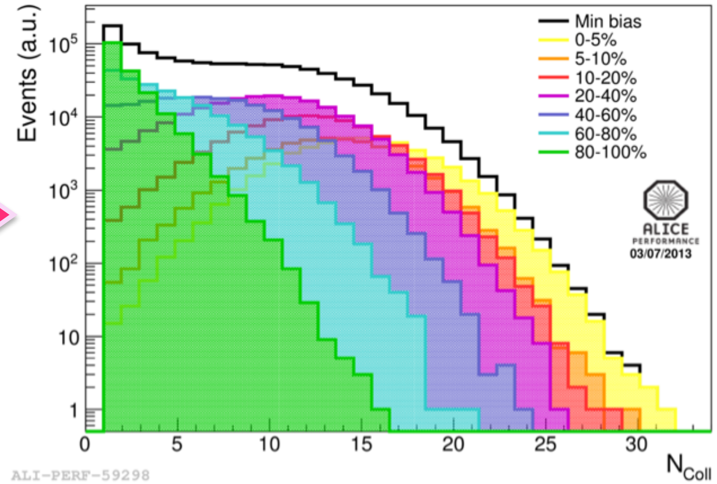
$\langle N_{part}\rangle$, $\langle N_{coll}\rangle$, $\langle T_{pPb}\rangle$ from each defined centrality class from Glauber



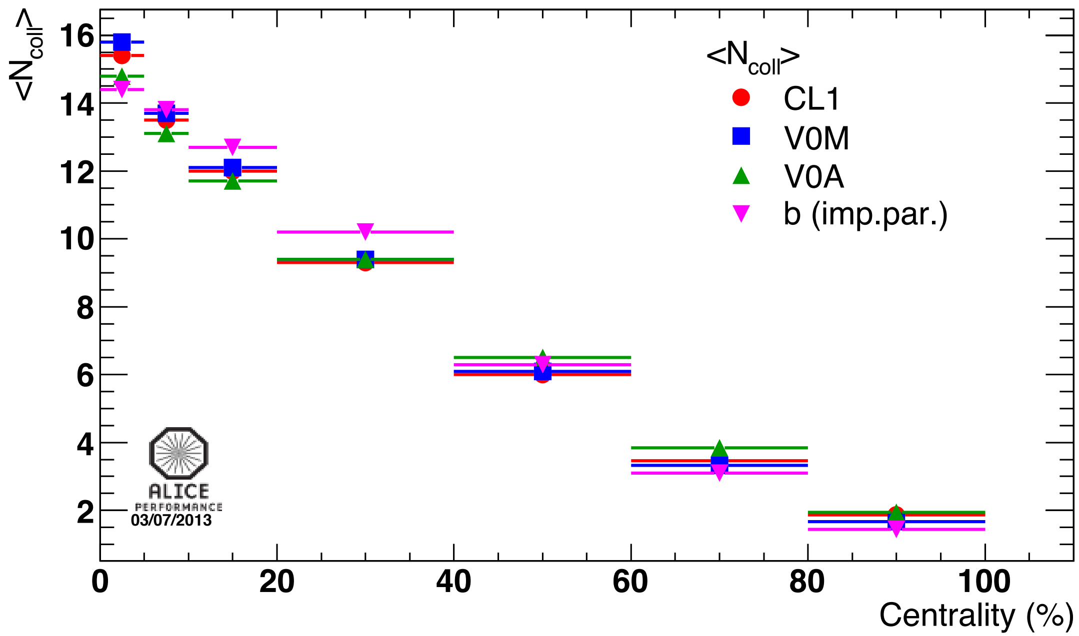


$\langle N_{coll} \rangle$ from Glauber fit





$\langle N_{coll} \rangle$

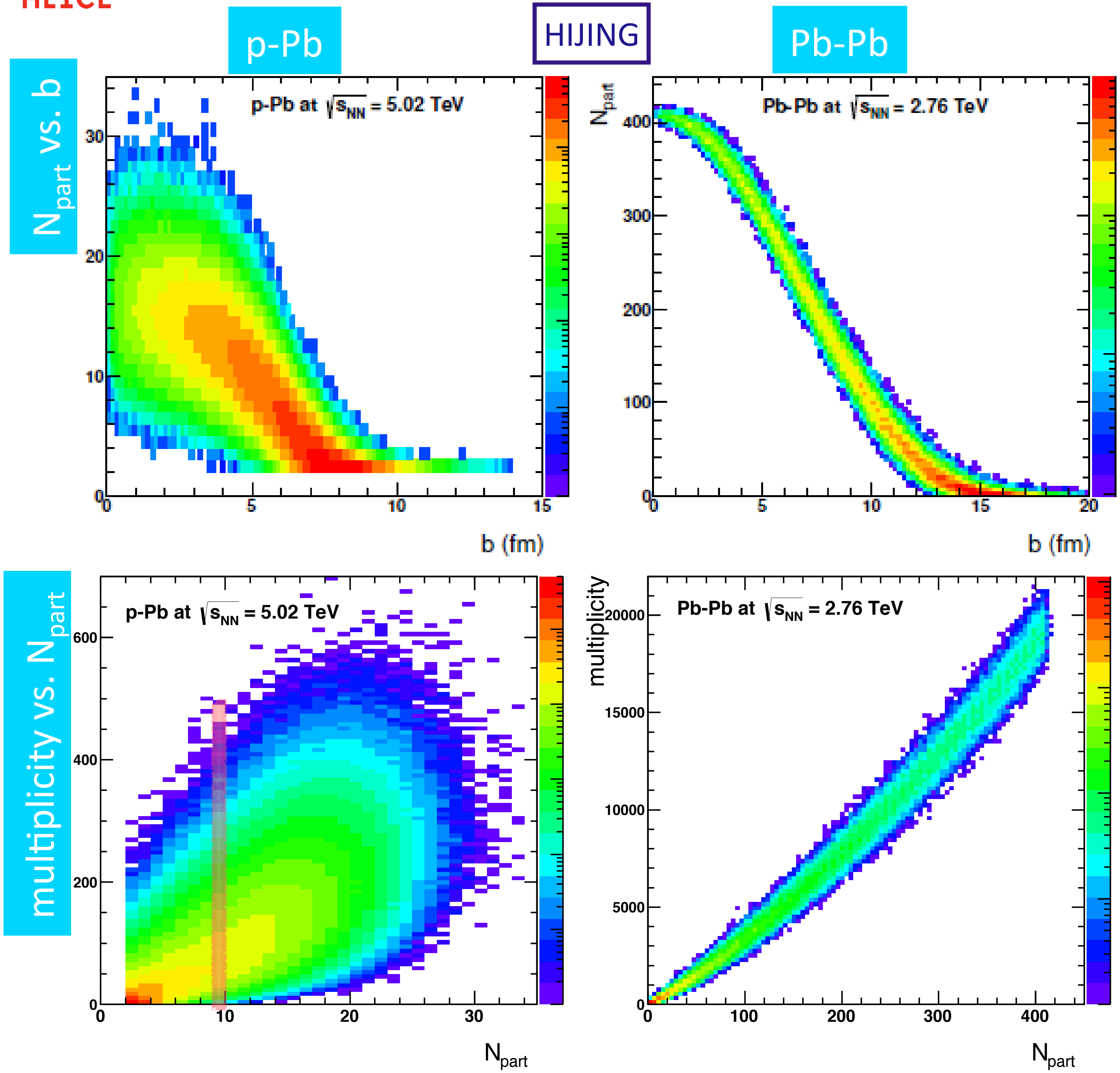


$\langle N_{coll} \rangle$ from different estimators

Systematic error:

- from Glauber, estimated varying input parameters
- MC closure test using HIJING

Bias in p-N collision?



p-A compared to A-A collisions (HIJING)

- looser correlation between N_{part} and impact parameter

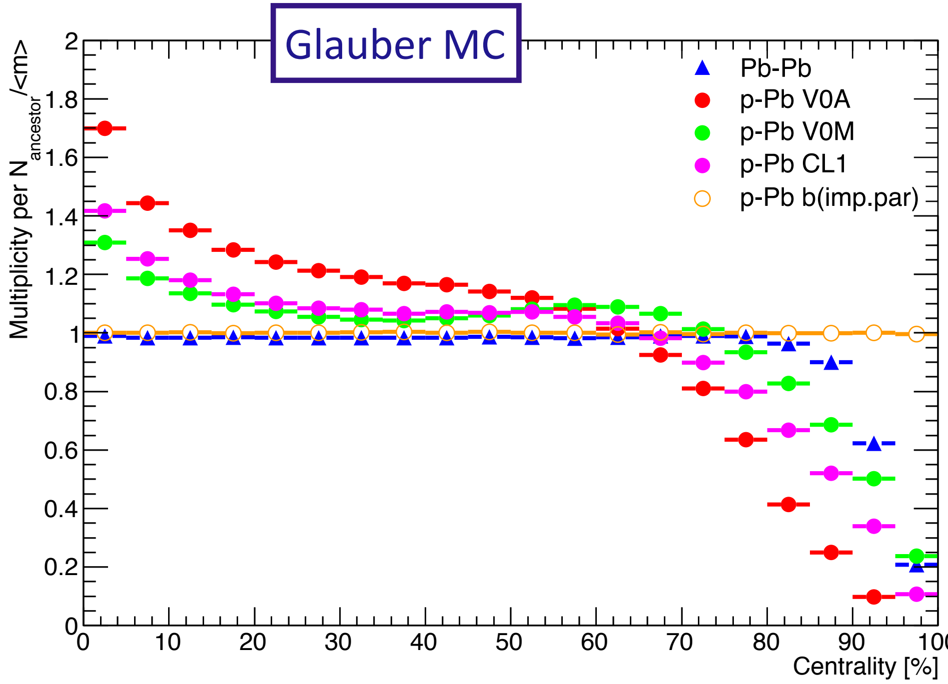
- looser correlation between N_{part} and multiplicity
- limited N_{part} range and large multiplicity fluctuations
- a fixed N_{part} value can contribute to different centrality classes

Bias on multiplicity

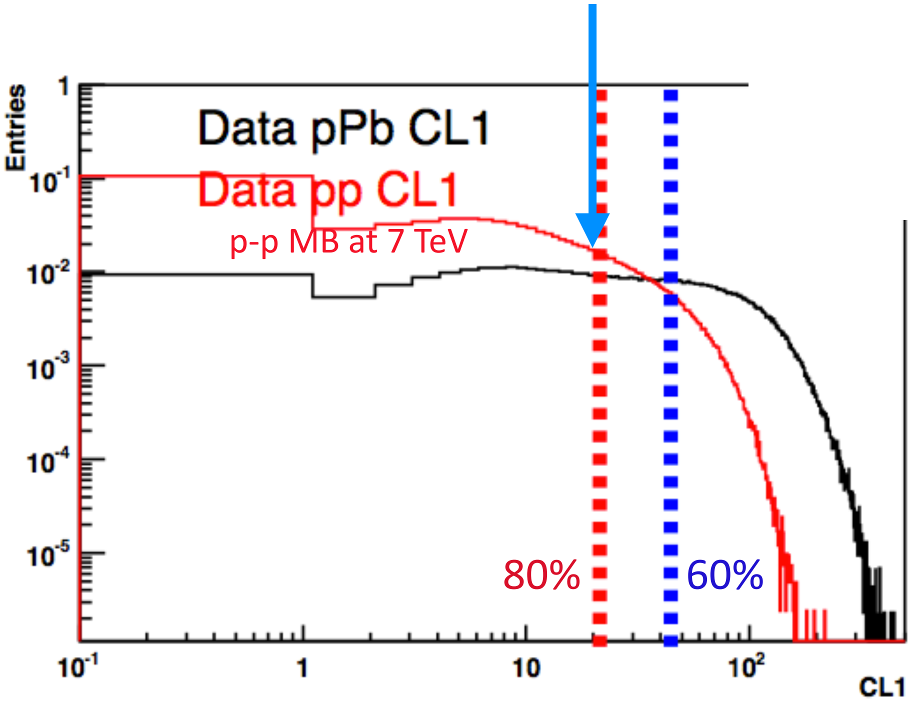
Multiplicity per N_{part} strongly biased for peripheral and central collision

- multiplicity bias much larger than in Pb-Pb
- different estimators show different deviations

- MULTIPLICITY BIAS



Average multiplicity in pp



Multiplicity distributions in p-Pb and in p-p

- 80% cut on p-Pb multiplicity equivalent to cut on the average p-p multiplicity value
- fraction of p-p cross-section selected in 80-100% (60-100%) p-Pb multiplicity is 0.8 (0.97)

- effective veto on large multiplicity events

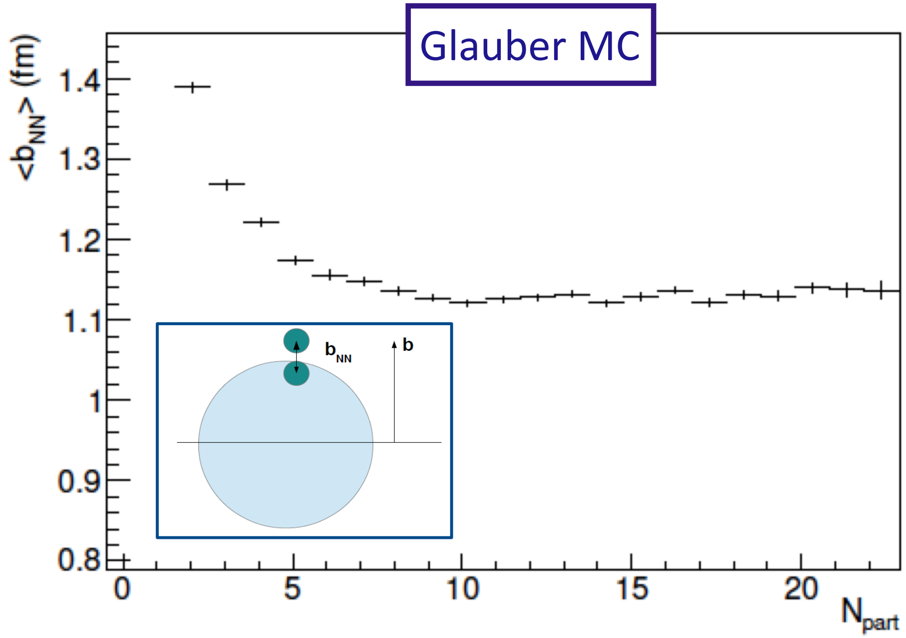
- BIAS ON p-p MULTIPLICITY

Bias on N-N impact parameter

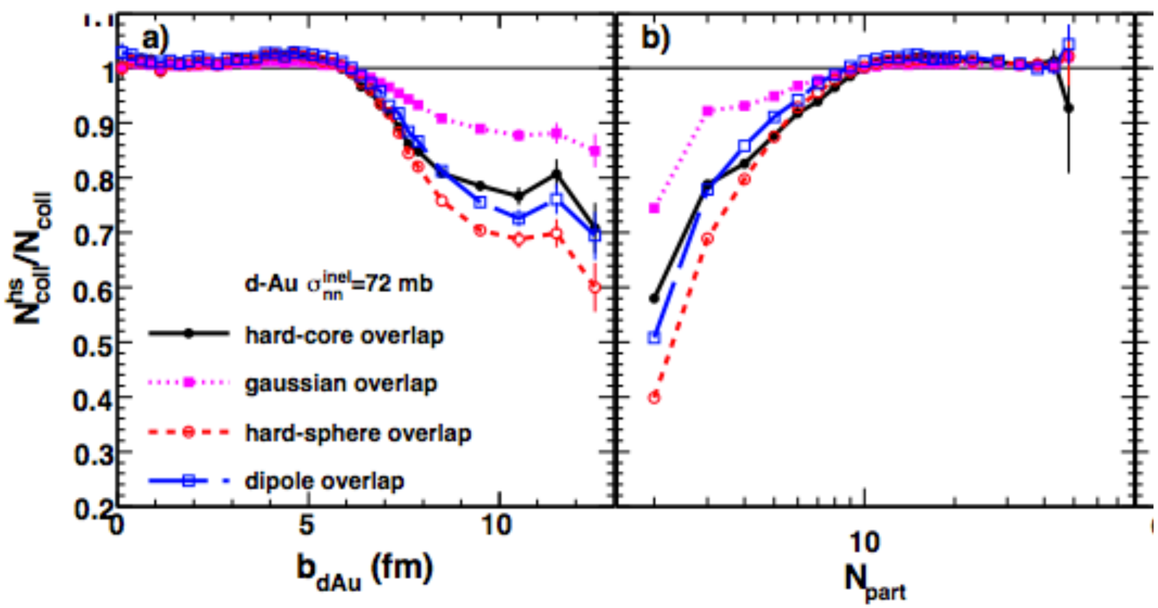
Average N-N impact parameter b_{NN} is larger for peripheral collisions

➧ bias towards large b_{NN} value in peripheral events

➧ BIAS FROM b_{NN}



J. Jia, arXiv:0907.4175



➧ For peripheral events N_{coll} for hard processes is smaller than $N_{coll}^{GLAUBER}$

The bias is predicted to increase with $\sigma_{N\text{-}N}^{INEL}$
➧ effect ~60% larger at LHC than at RHIC

Bias on MPI

Models based on multi-parton interactions (MPI) include fluctuations in the number of particle sources (hard scatterings n_{hard})

Poissonian probability for multiple hard interactions ➧ $p_i(b_{NN}) = \frac{\langle n_{hard} \rangle}{i!} \cdot \exp(-\langle n_{hard} \rangle)$

Mean number of scatterings per events depends on b_{NN} ➧ $\langle n_{hard} \rangle (b_{NN}) = \sigma_{hard} T_N(b_{NN})$

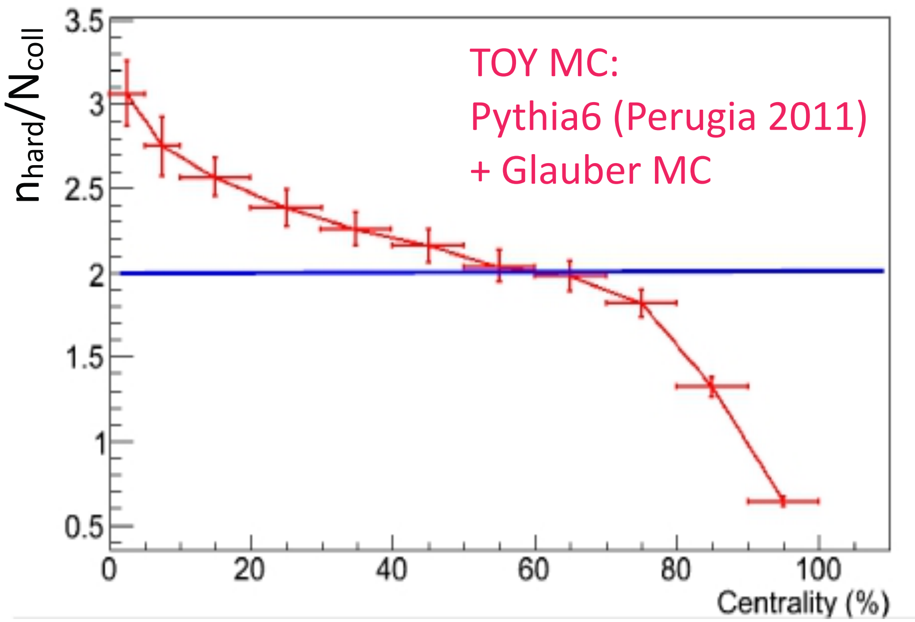
➧ Link between multiplicity fluctuation (bias) and number of hard scatterings

➧ effect enhanced for peripheral collisions where b_{NN} larger than average reduces MPI probability

➧ BIAS ON MPI

At very high p_T multiplicity estimators act as a veto on hard processes for very peripheral collisions

➧ JET-VETO BIAS



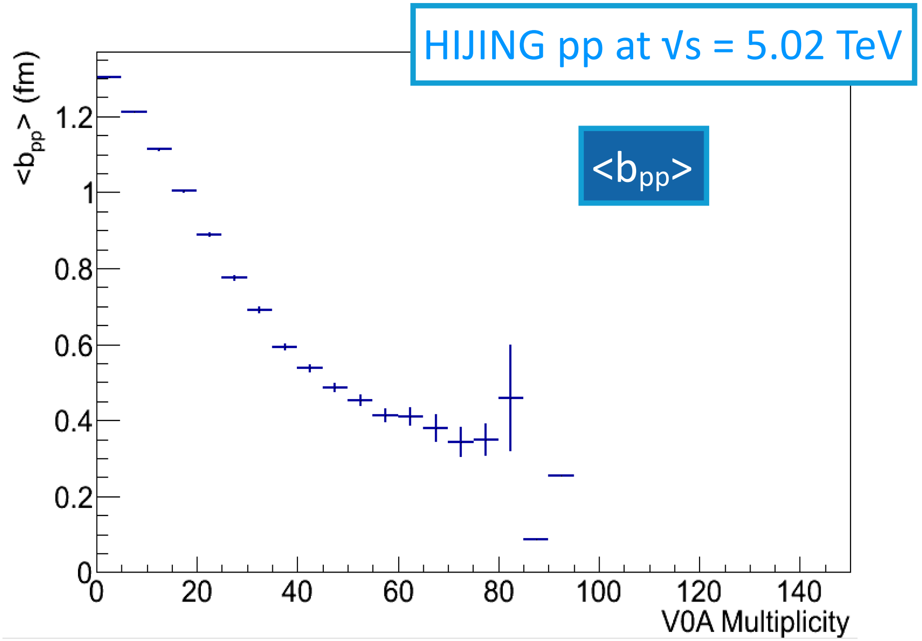
➧ only multiplicity bias (no bias from b_{NN} is included in PYTHIA)

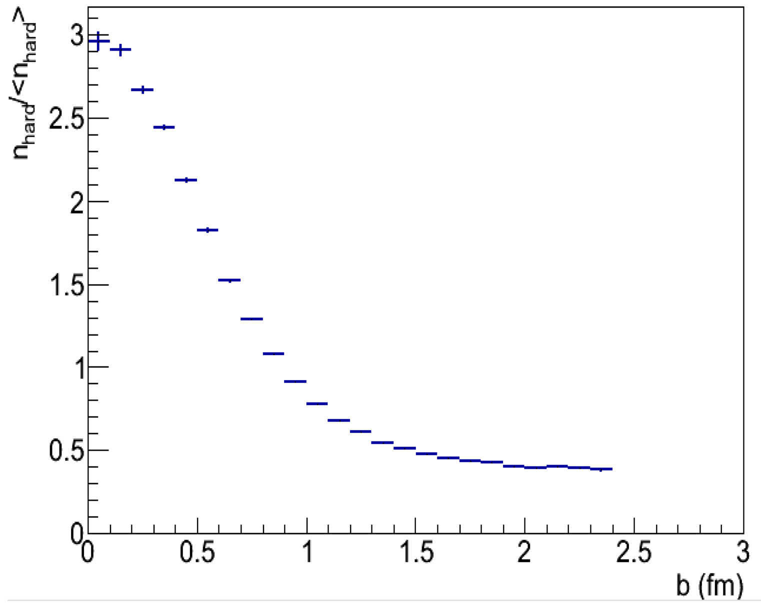
N_{coll} scaling ➧ n_{hard}/N_{coll} = const.

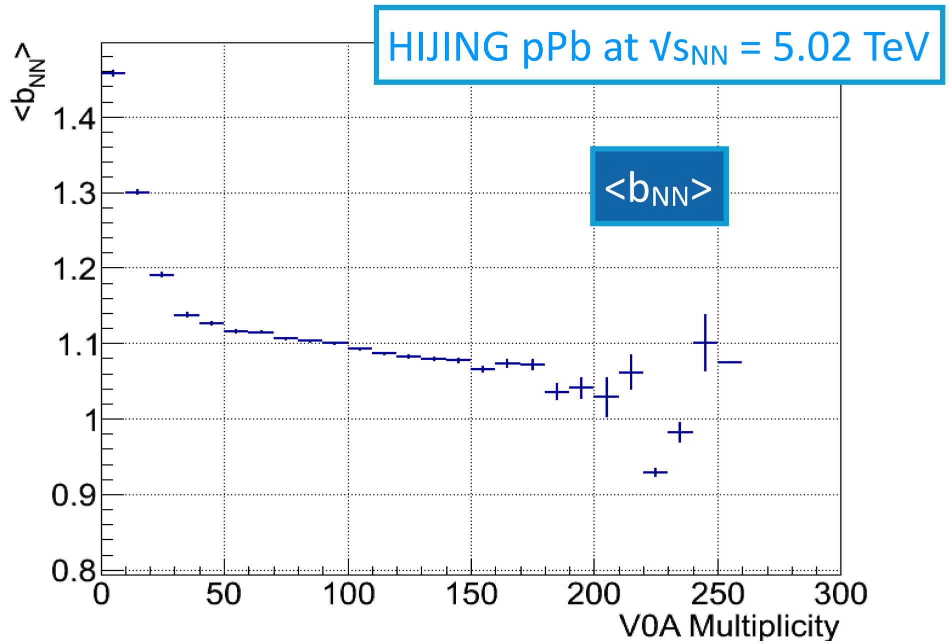
p-A collisions described as incoherent superposition of N-N collisions

➧ strong deviations from N_{coll} scaling at low and high centralities

Long range multiplicity correlation via p-N parameter bias







In p-Pb $\langle b_{NN} \rangle$ instead of b_{pp} contributes to long range correlations.

Averaging leads to smaller dynamic range
However, important bias on n_{hard}

Bias and rapidity

Centrality based on multiplicity measurements deviation from binary scaling

Effect reduced increasing the rapidity gap between tracking and centrality measurements

BIAS

- CL1 ➡ strong bias (full overlap with tracking region
  + additional bias in peripheral events from jet veto effect)
- V0M ➡ reduced bias (outside tracking region)
- V0A ➡ small bias (contribution from Pb fragmentation region)
- ZNA ➡ smallest bias (slow nucleon emission independent from hard processes)

New features to be addresses in p-A centrality:

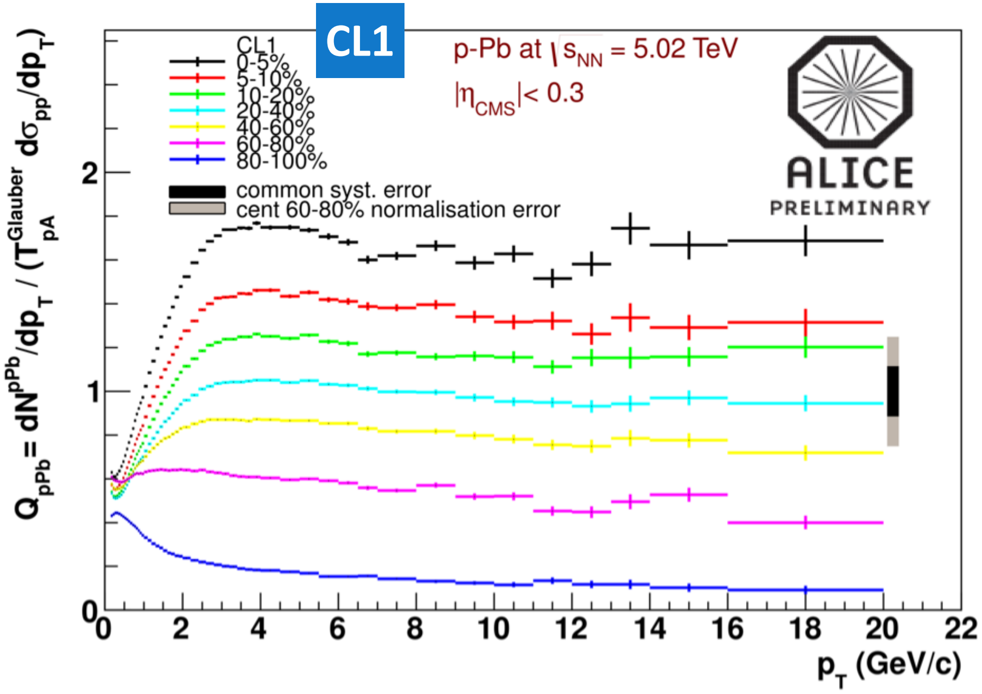
✘ for fixed centrality hard processes scale with $\langle N_{coll}^{Glauber} \rangle * \langle n_{hard} \rangle_{pN}^{i} / \langle n_{hard} \rangle_{pp}$

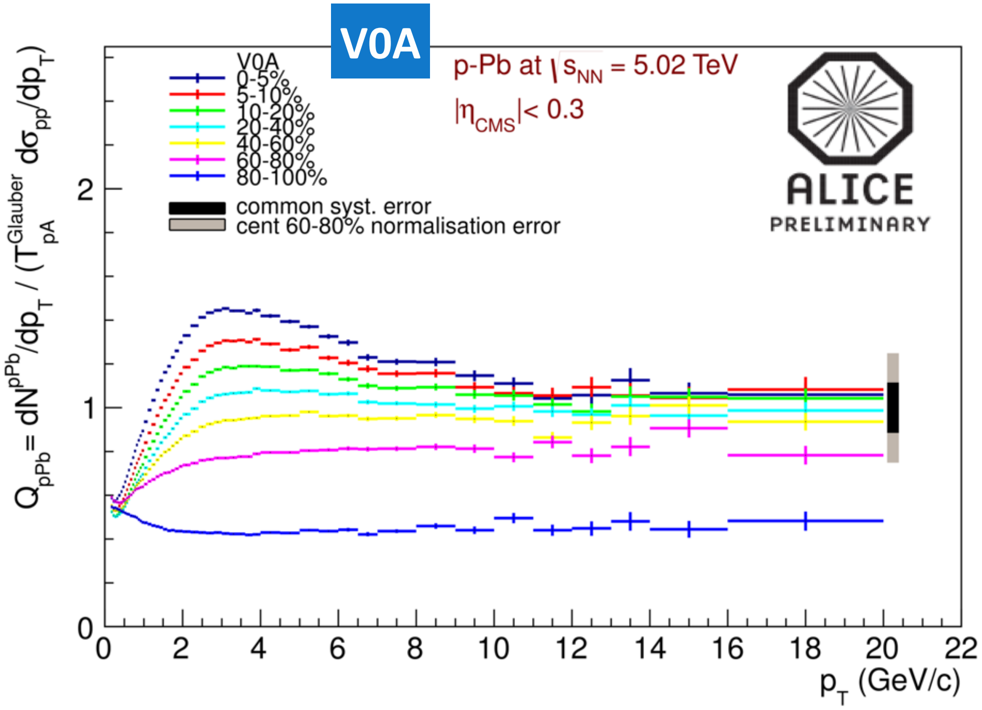
✘ for fixed impact parameter b, $\langle n_{hard} \rangle$ depends on the average p-N impact parameter $\langle b_{NN} \rangle$

- $\langle N_{coll}^{GLAUBER} \rangle$ ($\langle T_{pPb} \rangle$) can't be used to rescale pp data
- Q_{pPb} defined as "biased" R_{pPb}

$$Q_{pPb} = \frac{dN_{pPb}/dp_T}{N_{coll}^{Glauber}\, dN_{pp}/dp_T} = \frac{dN_{pPb}/dp_T}{T_{pPb}^{Glauber}\, d\sigma_{pp}/dp_T}$$

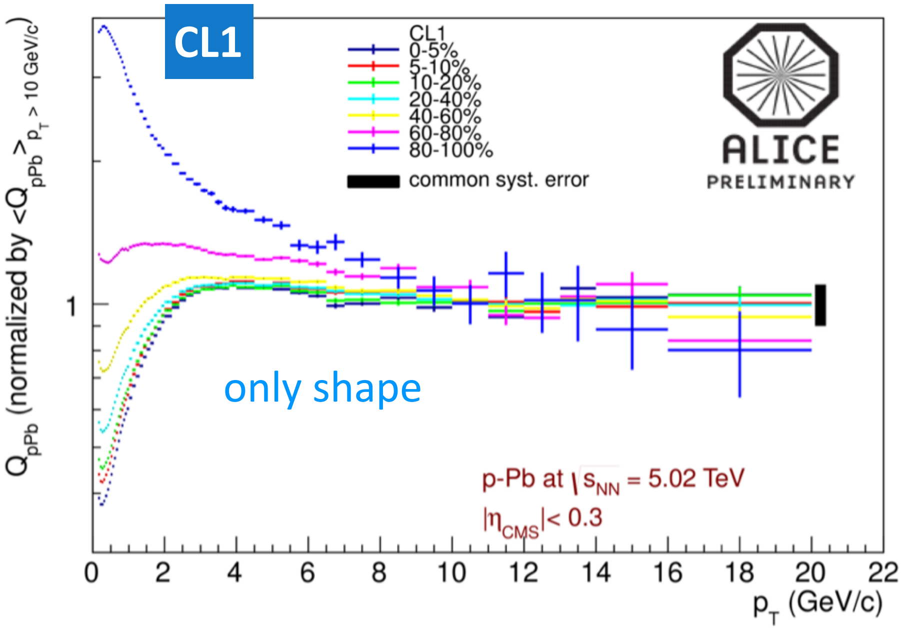
Biased nuclear modification factor



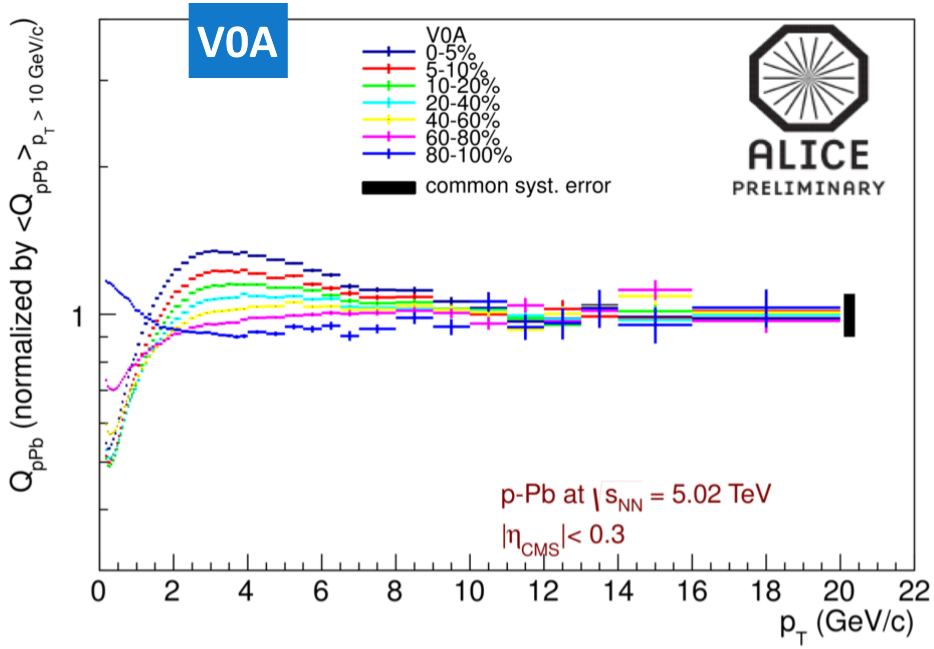


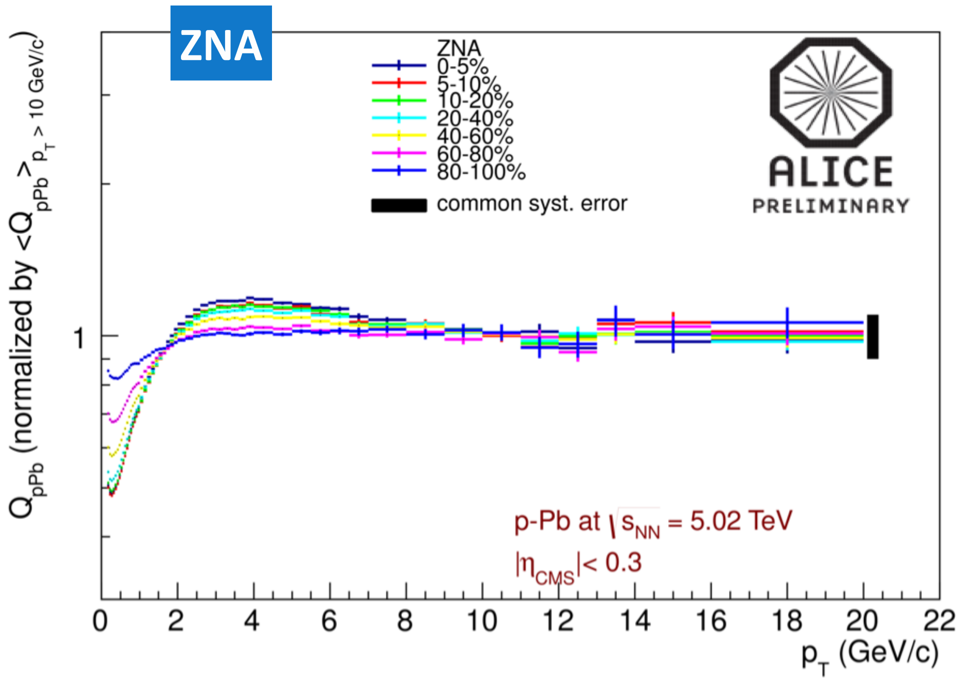
- clear indication of jet-veto bias in most peripheral bin when midrapity multiplicity (CL1) is used
- smaller jet veto bias using V0A (Pb-remnant side)
- Q_{pPb} spread reduced increasing the rapidity gap
- Q_{pPb} from ZNA shows different ordering of the bins ➧ SNM implementation

Q_{pPb} normalized to high p_T



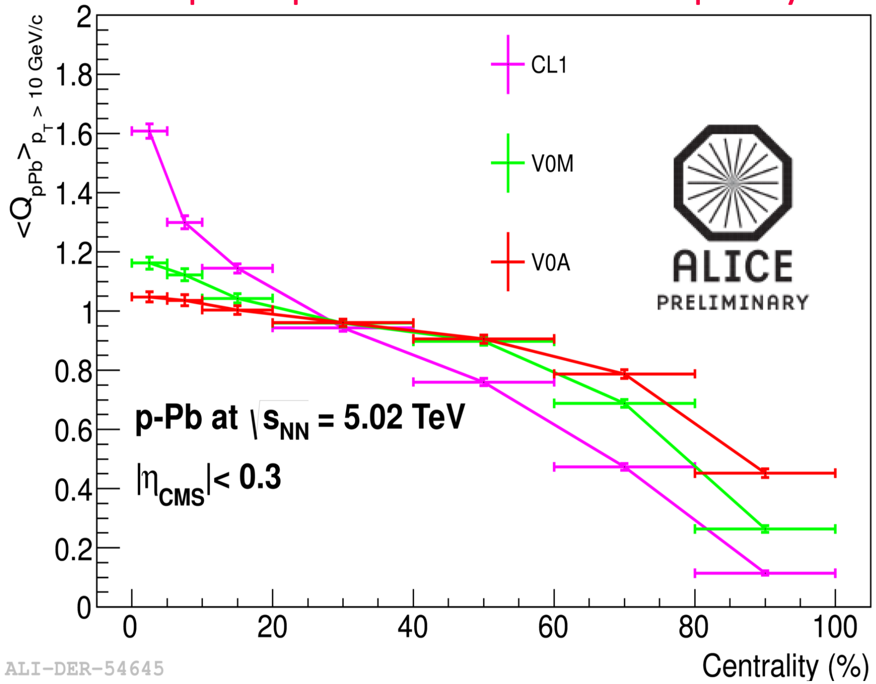
ALI-PREL-53985





ALI-PREL-53997

S-shape dependence as for multiplicity bias

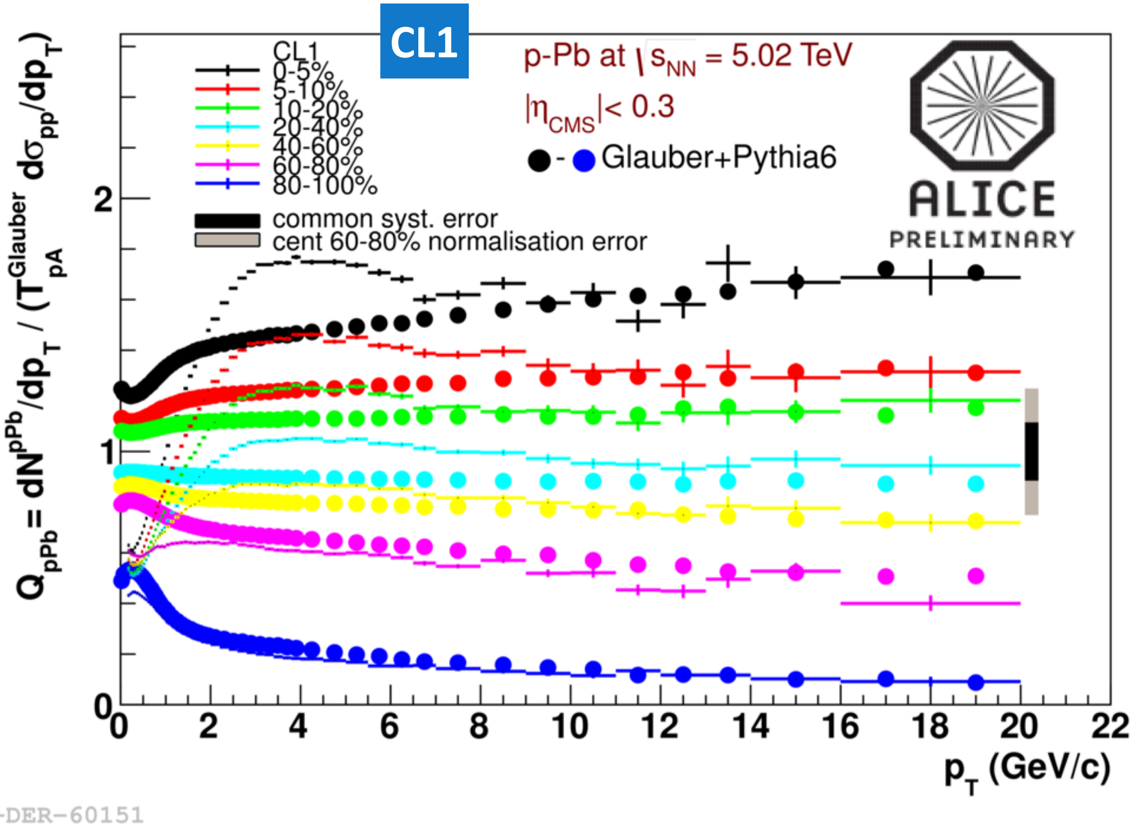


ALI-DER-54645

Scaling at high p_T

PYTHIA6 (Perugia 2011) + Glauber N_{coll} distribution

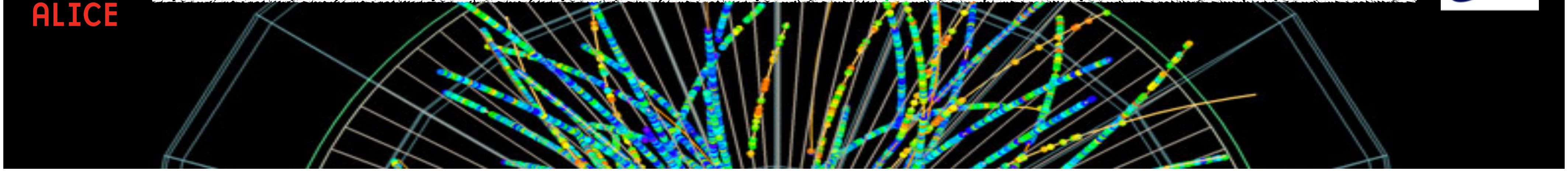
* centrality from multiplicity in $|\eta|<1.4$
* $\langle N_{coll} \rangle$ from Glauber MC



➡ incoherent superposition of p-p collisions reproduces the bias at high p_T over the whole centrality range

➡ good agreement at low p_T for the most peripheral bin where also the jet-veto effect is reproduced

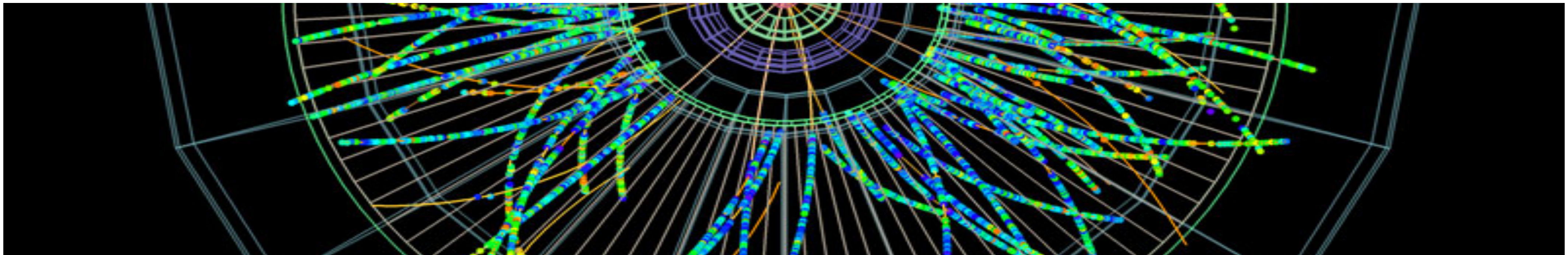
SUMMARY

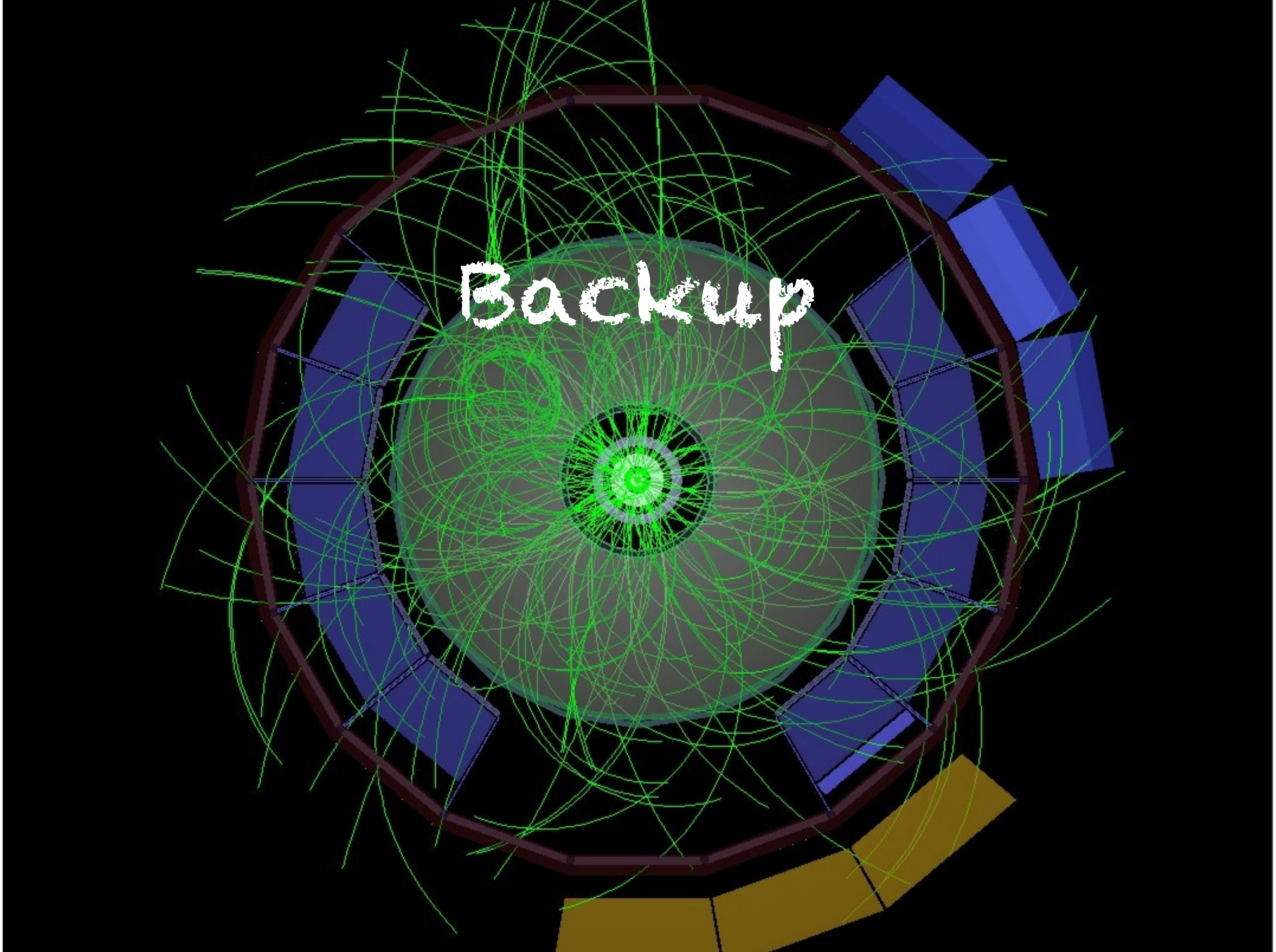


Different biases affect the centrality measurement in p-A

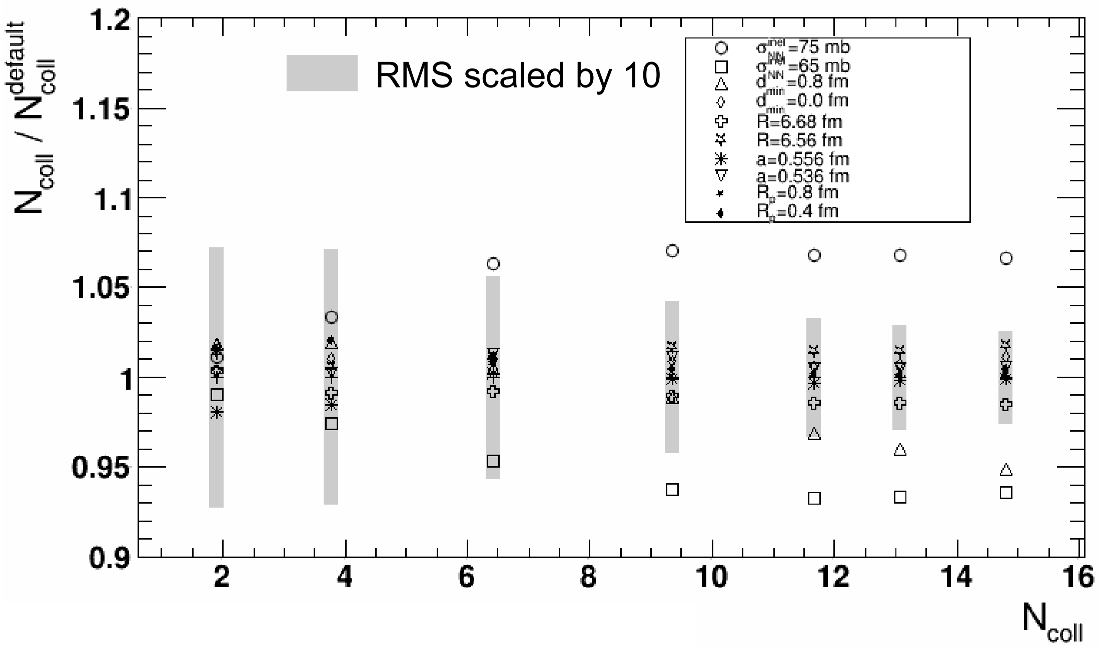
- multiplicity bias
- bias on p-N impact parameter
- dynamical models allow to relate the bias on multiplicity to a bias on the binary scaling of hard processes through multiple parton interactions
- jet-veto bias at high transverse momentum for peripheral events
- biased $\langle N_{coll}^{GLAUBER} \rangle$

- the biases decrease by increasing the η-gap between centrality estimator and momentum/multiplicity measurement




Backup

Systematic on Glauber N_{coll}



Default values varied within known uncertainties

Nuclear density profile: Woods-Saxon (2pF):

- radius = (6.62 ± 0.06) fm
- skin depth = (0.546 ± 0.01) fm
- intra-nucleon distance = (0.4 ± 0.4) fm

Cross section ➡ σ_{NN} = (70 ± 5) mb

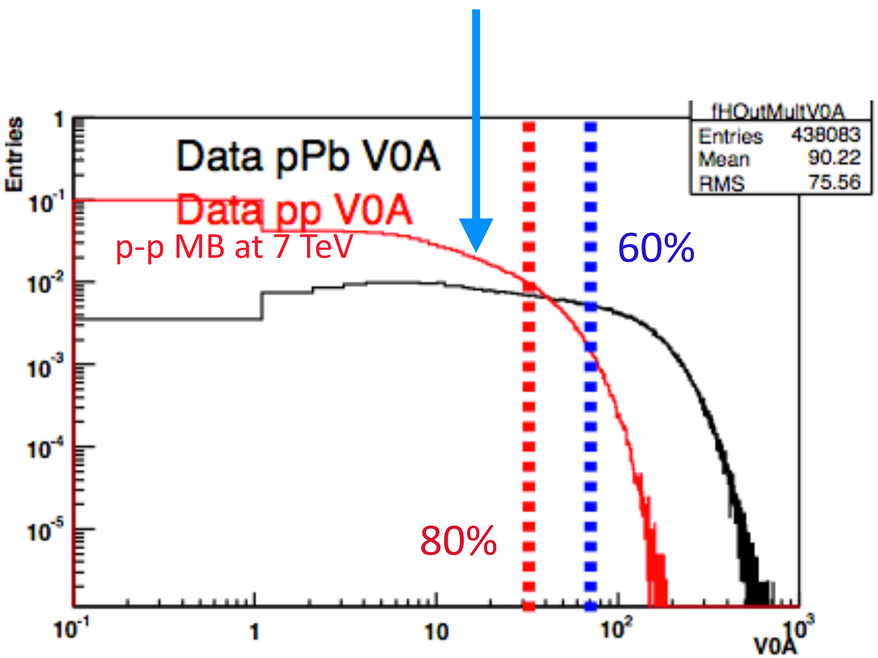
p radius ➡ R_p = (0.6 ± 0.2) fm

Systematic uncertainty:
4-5% in peripheral events
10% in central events

Closure test performed using HIJING

Centrality (%)	HIJING	Glauber + NBD	difference (%)
0-5	14.9	15.3	+2.7
5-10	13.6	13.5	-0.7
10-20	12.1	11.9	+1.7
20-40	9.72	9.51	-2.2
40-60	6.16	6.37	+3.4
60-80	2.97	3.56	+20
80-100	1.45	1.79	+23
MB	6.69	6.9	+3.1

Average multiplicity in pp



Glauber fit + SNM

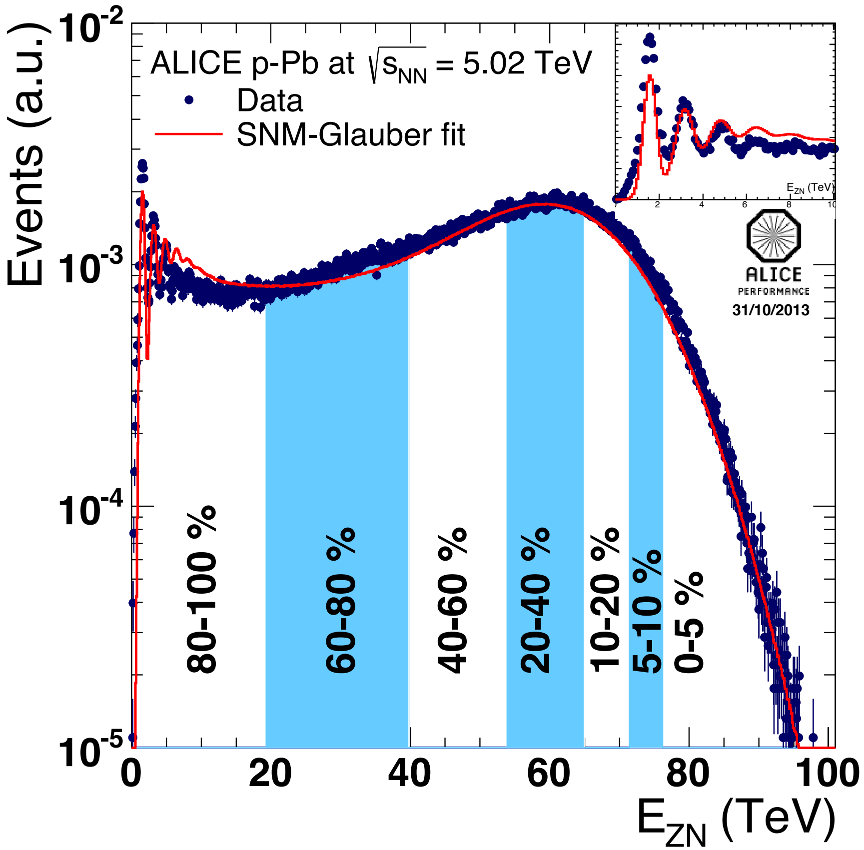
Similar procedure but coupled with a model for slow nucleon emission (SNM)

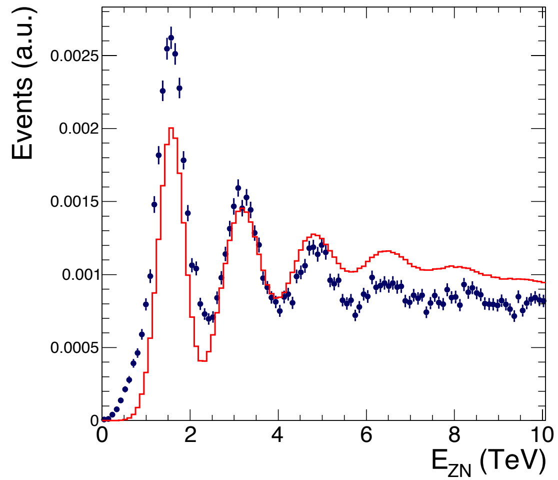
No model is currently available for LHC energies!

F. Sikler, arXiv: 0304.065

Features of emitted nucleons weakly dependent on projectile energy from 1 GeV to 1 TeV

- "Phenomenological" model based on experimental results at lower energies
  - number of protons and neutrons as a function of N_{coll}
  - kinematical properties of emitted slow nucleons
- able to reproduce essential features of the spectrum, still ongoing work!





SNM (I)

➡ At fixed target experiments centrality in p-A determined detecting slow nucleons

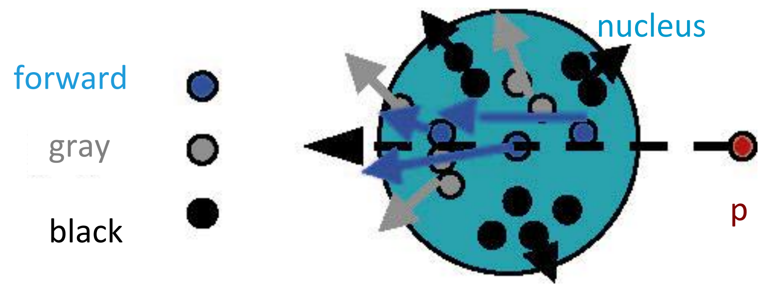
Hadron-nucleus collisions ➡ slow nucleons = gray + black components

(classification from emulsion experiments related to track grain density)

Gray nucleons ➡ soft nucleons knocked out by wounded nucleons

Black nucleons ➡ low energy target fragments from nucleus de-excitation, evaporation

SLOW NUCLEONS	β [c units]	p [MeV/c]	E_{kin} [MeV]
Black	0 ÷ 0.25	0 ÷ 250	0 ÷ 30
Gray	0.25 ÷ 0.70	250 ÷ 1000	30 ÷ 400



Features of slow nucleon emission are weakly dependent on beam energy from 1 GeV to 1 TeV ➡ emission dictated by nuclear geometry

F. Sikler, hep-ph/0304065

➡ kinematical distributions described by independent statistical emission from a moving frame

➡ isotropic emission from a source moving with velocity β

➡ number distribution of black/gray nucleons follows binomial distributions

SNM (II)

PROTONS

I. Chemakin *et al.*, Phys. Rev. C **60** 024902 (1999)

- E910 (p-Au @ 18 GeV/c) fit to N_{gray} vs. N_{coll}
  $<N_{gray\ p}> = (c_0 + c_1\ N_{coll} + c_2\ N_{coll})\ (A_{Pb}/A_{Au})^{2/3}$

A. Letourneau, Nucl. Phys. A 712 (2002) 133

- COSY (p-Au @ 2.5 GeV) measured the fraction of black over gray protons
  $<N_{black\ p}> = 0.65 * <N_{gray}\ p>$

NEUTRONS

- COSY measured Light Charged Particle (Z<=7) vs. total number of protons/neutrons
  $LCP = (<N_{gray\ p}> + <N_{black\ p}>)/\alpha$
  - α free parameter to reproduce n multiplicities at LHC energies (α = 0.585 @ COSY, α = 0.565 for LHC)

  $<N_{slow\ n}> = <N_{black\ n}> + <N_{gray\ n}> = a + b/(c-LCP)$
  - a, b, c obtained from a fit to COSY distribution are finely tuned
- results from p induced spallation reactions (0.1-10 GeV)
  $<N_{black\ n}> = 0.9 * <N_{slow\ n}>$ $<N_{gray\ n}> = 0.1 * <N_{slow\ n}>$

- $N_{gray\ p}$, $N_{black\ p}$, $N_{gray\ n}$, $N_{black\ n}$ from binomial distributions