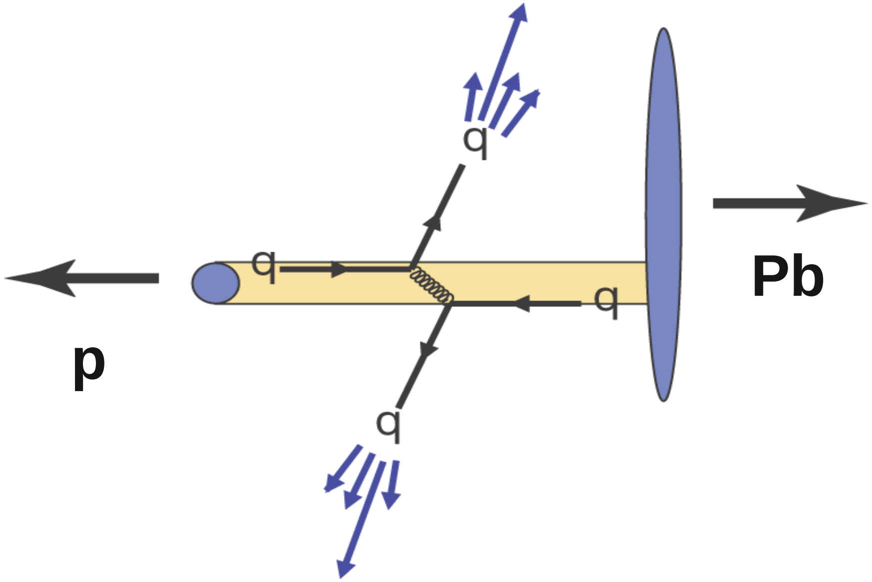
Centrality in pA collisions with ALICE

Alberica Toia

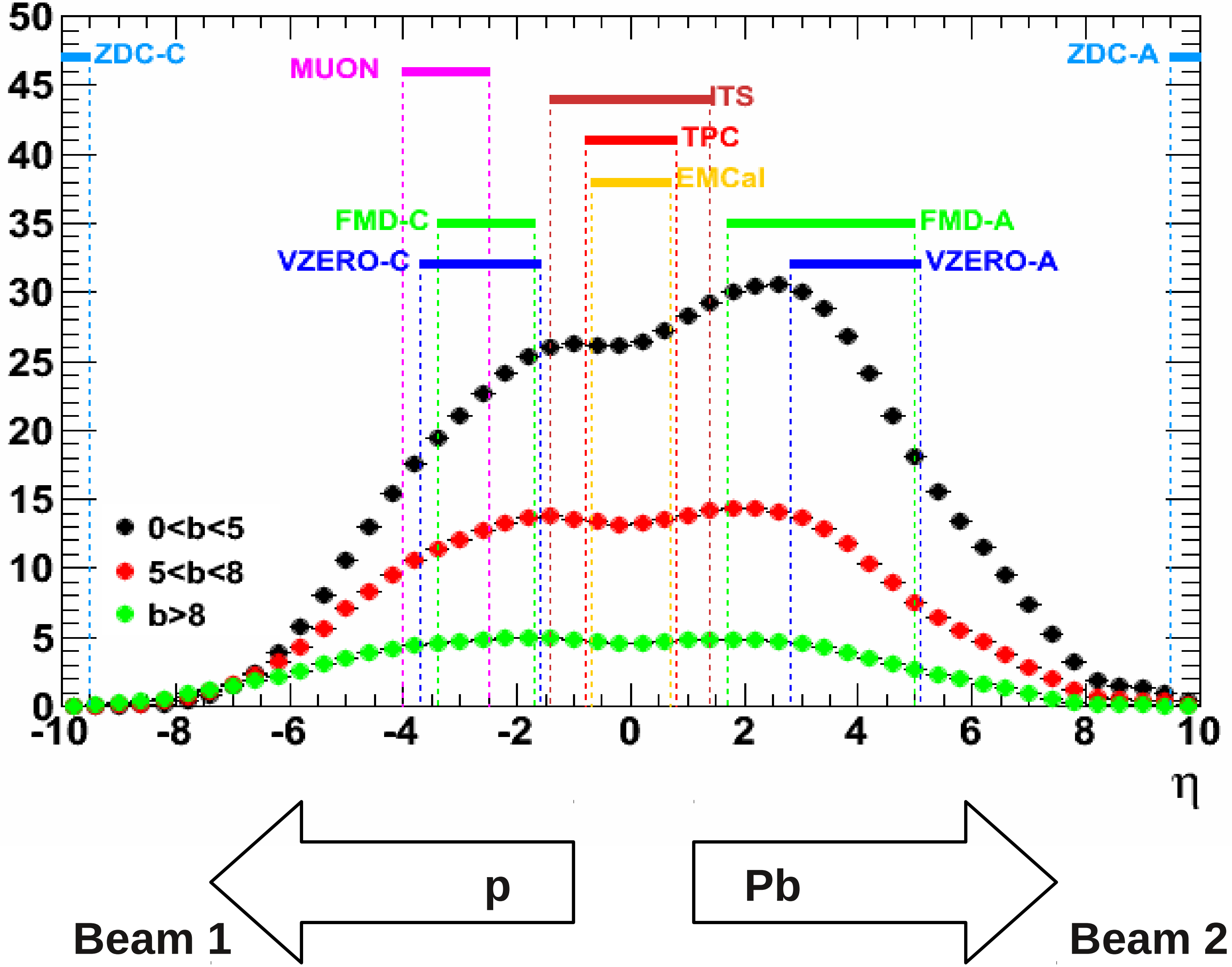
Workshop pA @ LHC
June 5th 2012



ALICE

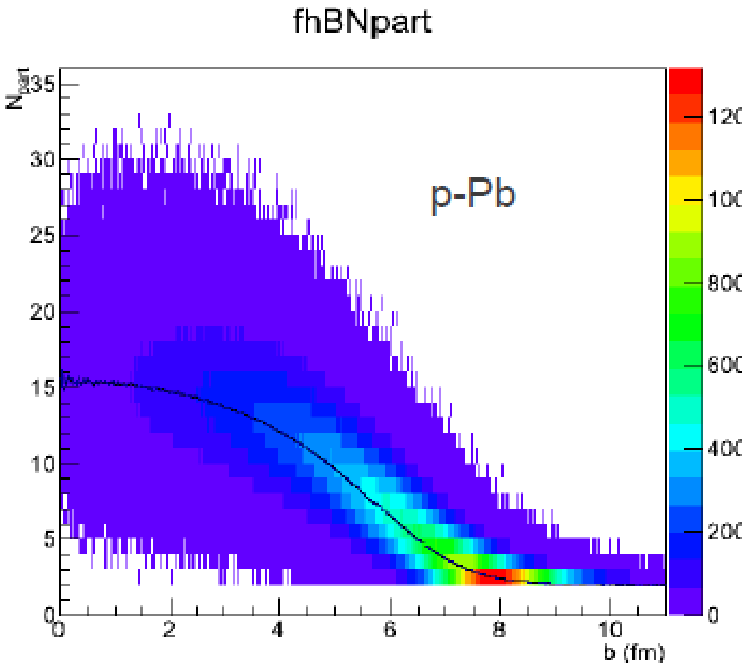
p-Pb

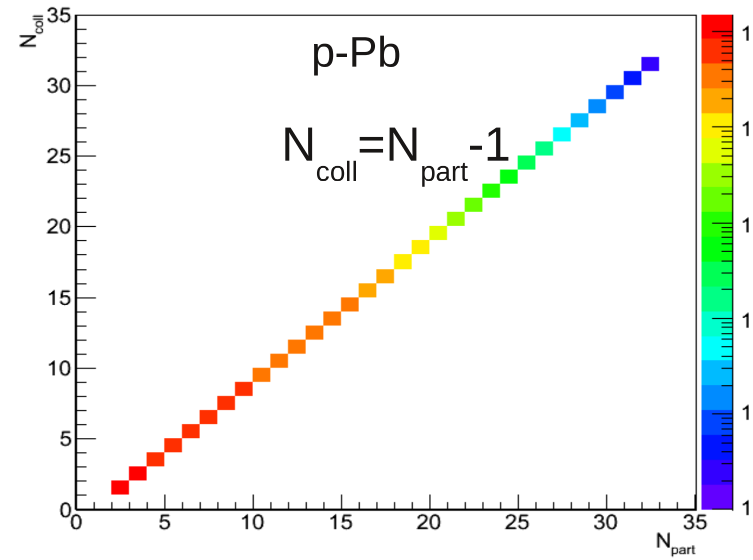
Rapidity distribution

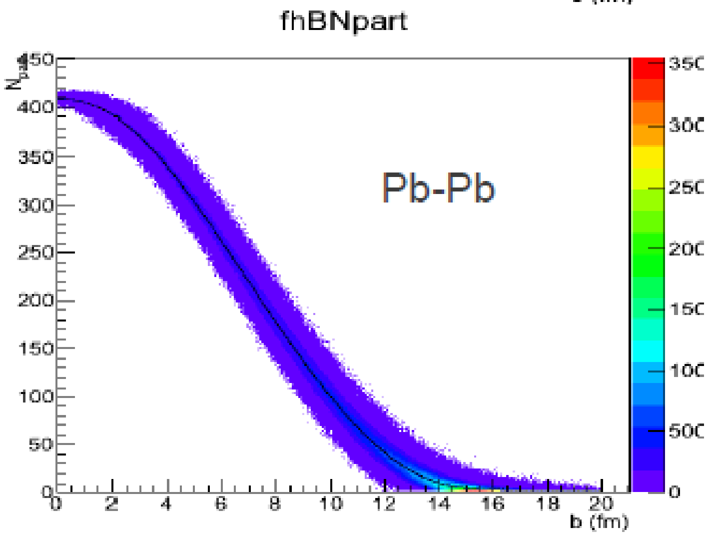


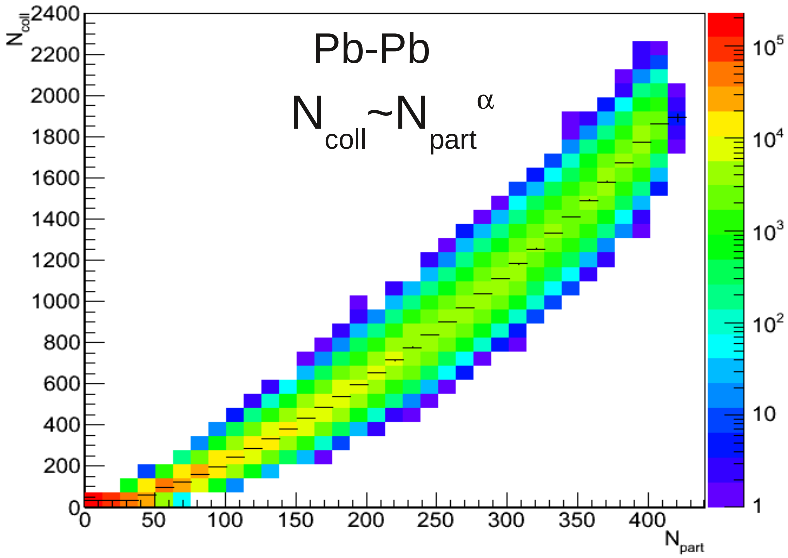
HIJING
Primary charged particles
p_T > 150 MeV

Collision Geometry

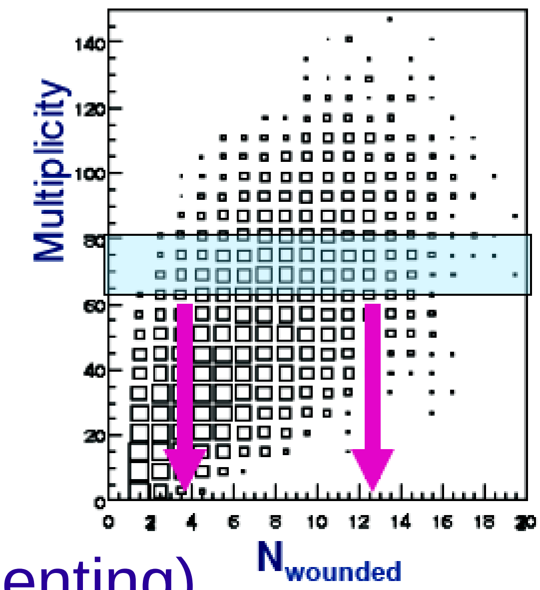








How to determine centrality in p-A



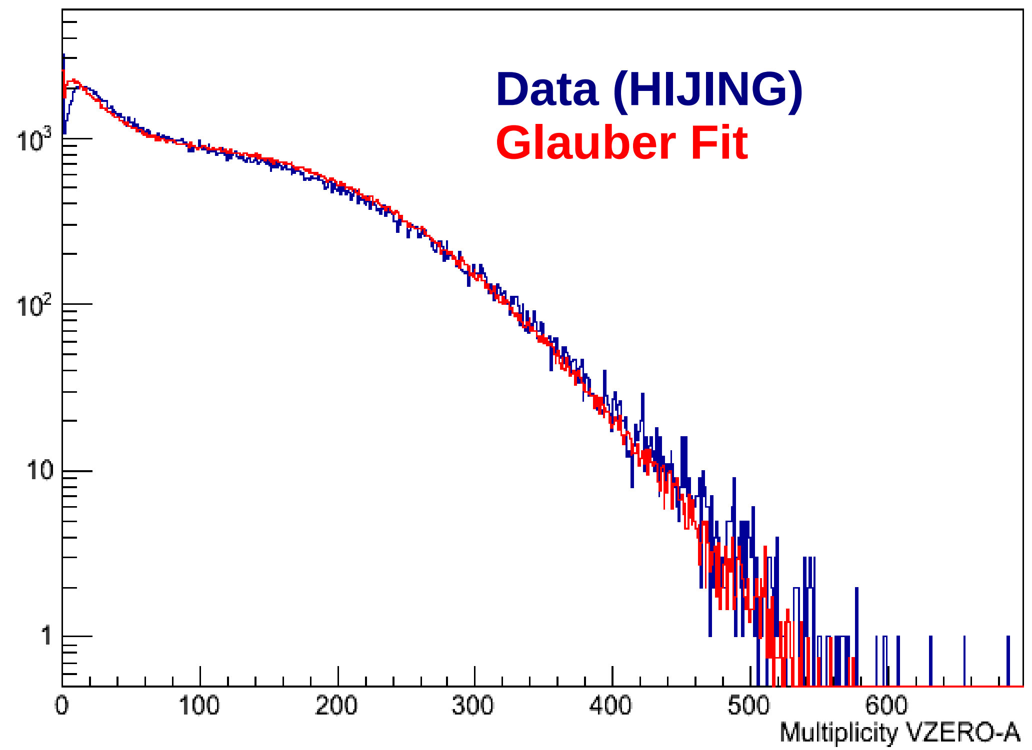
- Ideally the physics used to determine the centrality class would be completely independent from the physics signal we are interested in.
- N_{ch} poorly correlated with N_{coll}
- In earlier fixed target p-A experiments, one often categorized "centrality" via gray tracks (lower momentum particles from the nucleus fragmenting)
- At RHIC, centrality calculated with forward rapidity BBC
- Looking at recoil nucleons from the Pb nucleus may be a possible observable for doing this.
  - ZDC: detect slow nucleons → C.Oppedisano
  - VZERO: detect high p_T particles from the nucleus breaking up

Centrality with VZERO

- Looking at recoil nucleons from the Pb nucleus may be a possible observable to measure gray tracks.
- The idea of using just the VZERO in backward (Pb-going) direction is that this is the direction of the high momentum particles from the nucleus breaking up (of course not really nuclear fragments at this pseudorapidity though).
- It is expected that the number of charged particles in the Pb-going direction should be roughly proportional to the number of participating nucleons in the Pb nucleus.

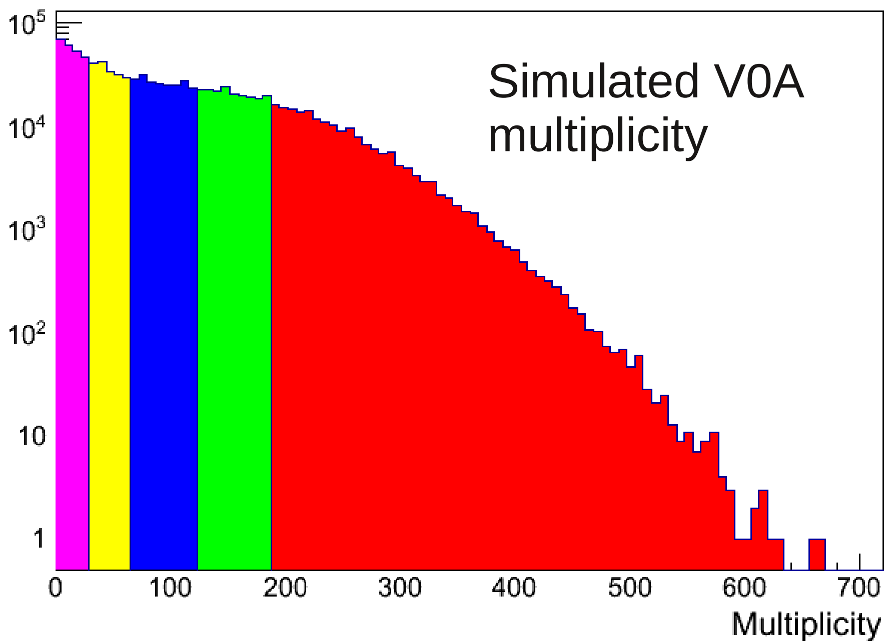
Glauber Fit: VZERO-A

- Glauber Model:
  - 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} = 68.6 mb extrapolated for $\sqrt{s}$=4.4 TeV

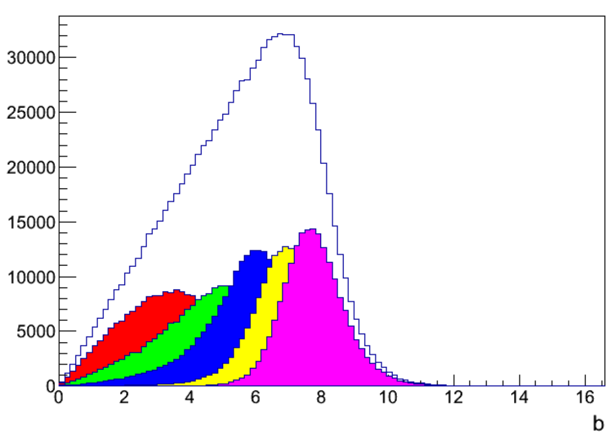


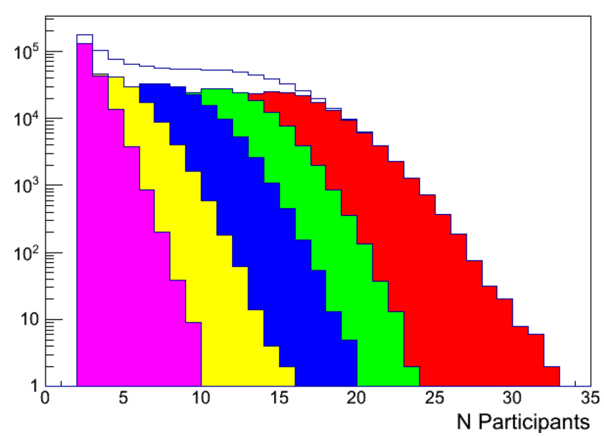
- VZERO Multiplicity proportional to N_{coll}
- For each Ncoll: VZERO multiplicity is related to a negative binomial distribution (NBD) with parameters μ and k
- Minimize chi2 for fit parameters

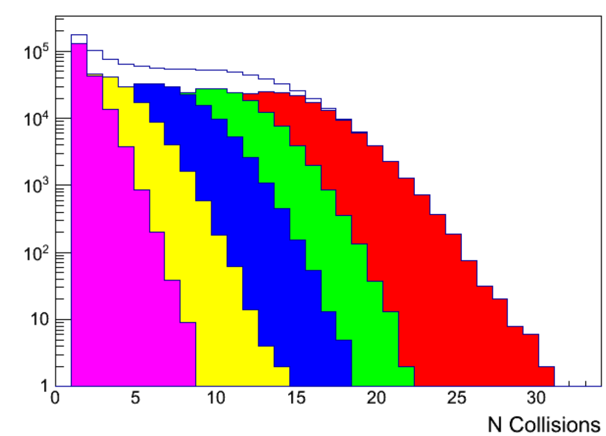
Glauber MC: extract Npart, Ncoll



Cent	Npart	RMS	Ncoll	RMS
00-20:	14.7	3.2	13.7	3.2
20-40:	10.6	2.7	9.6	2.7
40-60	7.1	2.4	6.1	2.7
60-80:	4.1	1.6	3.1	1.6
80-100:	2.4	0.8	1.4	0.8

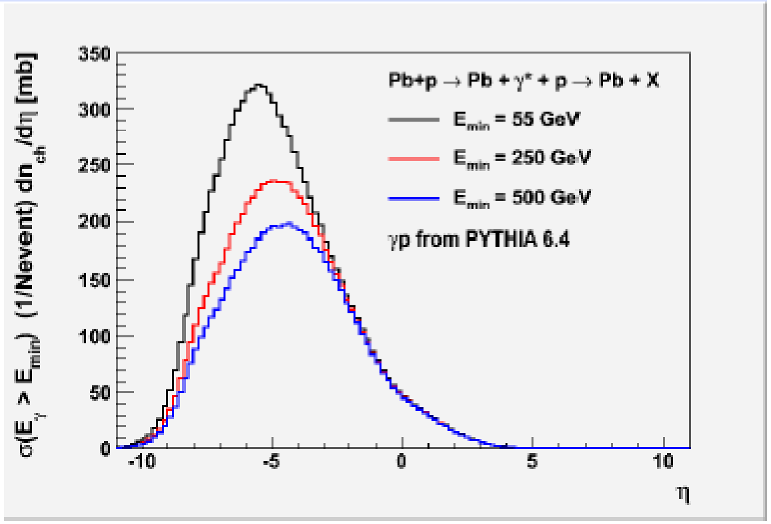






EM Background

- Photoproduction is dominated by photon emission from the Pb nucleus. But the opposite is also possible, i.e. that the proton emits a photon that interacts with the Pb-nucleus.
- The photon flux scale as Z^2. The size of the target scales as $A^{2/3}$.



- One thus expects the cross section for photon emission from the Pb-nucleus to be larger by a factor $Z^2/A^{2/3}$~200
- There will be a rapidity gap between the nucleus and the produced particles.
- Cross section for having 1 charged particle within |η|<1.0: 32 mb (DMPJET/PHOJET) 31 mb (PYTHIA)

J.Nystrand
EDS Blois Workshop, Qui Nhon, Vietnam, 2011

Trigger bias

- Trigger bias (only relevant in peripheral)
  - you want to measure the real number of produced pions divided by the number of real inclusive inelastic reactions

$$Y_{\pi}^{real} = \frac{N_{\pi}^{real}}{N_{inel.coll}^{real}}$$

  - but you measure the number of pions in events where the trigger fires and the number of inelastic collisions where the trigger fires.

$$Y_{\pi}^{measured} = \frac{N_{\pi}^{measured}}{N_{inel.coll}^{measured}}$$

- $\rightarrow$ trigger bias
  different for hard and inclusive probes
  hard parton-parton reactions that produce high pT pions fire the trigger more easily simply because they produce more charged particles, on average, that can hit the VZERO.

Centrality bin shift

- Centrality selection bias
  - you want to measure the real number of produced pions in a given centrality class *i*

$$Y_{\pi}^{real}(i) = \frac{N_{\pi}^{real}(i)}{N_{coll}^{real}(i)}$$

  - but you measure the number of pions in centrality class *j*

$$Y_{\pi}^{meas}(j) = \frac{N_{\pi}^{meas}(j)}{N_{coll}^{meas}(j)}$$

- → centrality is not necessarily correct
  example: an interaction with Ncoll=3 (peripheral) may have an enhanced probability for larger VZERO if the event contains a high pT pion → land into the next higher centrality
  more pions: peripheral → central
  artificial reduction in $Y^{meas}(j=1)$ relative to $Y^{real}(i=1)$
  (for peripheral: opposite effect to trigger bias)

What defines true centrality (a suggestion)

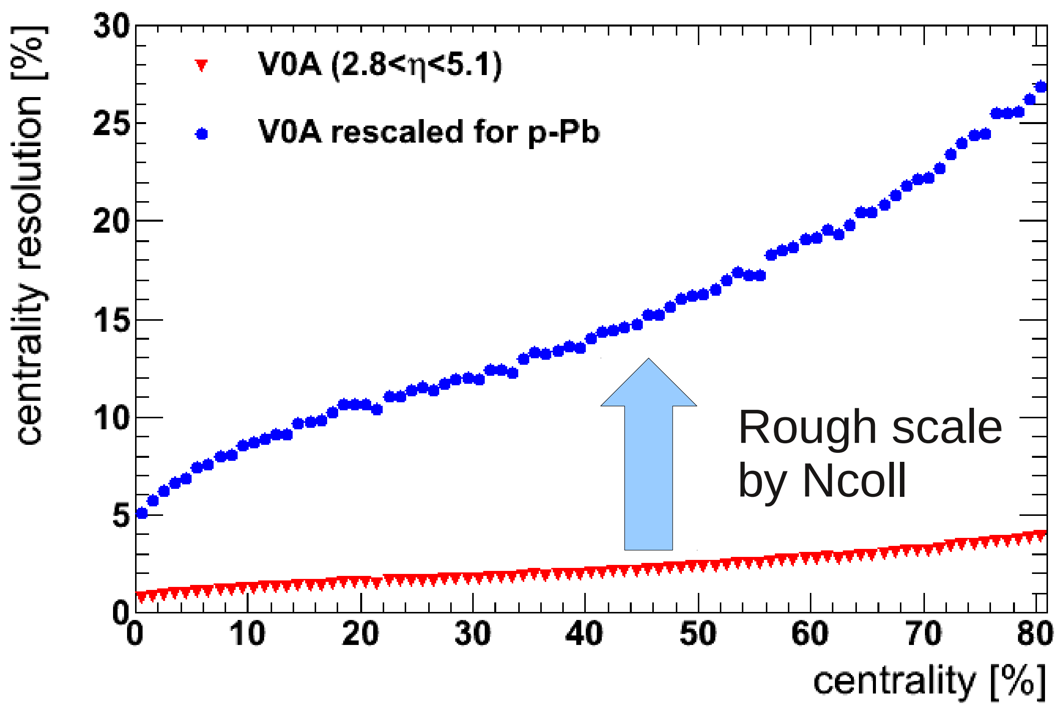
- Real event category defined in terms of true distribution of Ncoll (driven by the detector chosen for centrality determination)
- From Glauber: get the VZERO response
- Knowing the true Ncoll for each event, one can calculate the "real" yield where every event is put exactly correctly into its event category.
- With Glauber: simulate the "measured" yield where every event is not necessarily put into its correct event category
- calculate correction factors to convert our measured yield into the "real" yield.

Modelling the physics to define event category

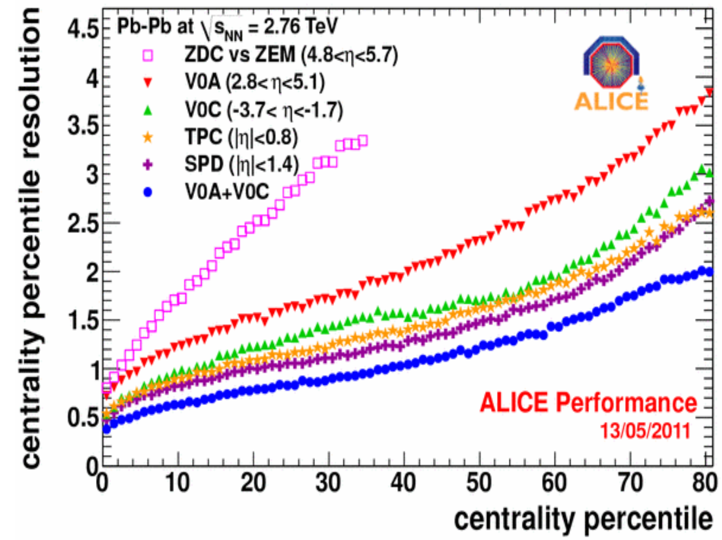
- Study response of VZERO-A in pp collisions
  - In MB events: $V0A_{inclusive}$
  - In events with high pT pion (or high pT muon): $V0A_{hard}$
- Use these distributions in Glauber-biased (instead of NBD)
  - 1 hard scattering from $V0A_{hard}$
  - Ncoll-1 N-N interactions from $V0A_{inclusive}$
- Calculate with Glauber
  - $N_{\pi}^{true}(i)$: centrality determined from Ncoll from Glauber
  - $N_{\pi}^{meas}(i)$: centrality determined from Ncoll from Glauber-biased
- From those derive correction factors for each centrality class
- One can also try Glauber-biased with NBD + scale-up factor

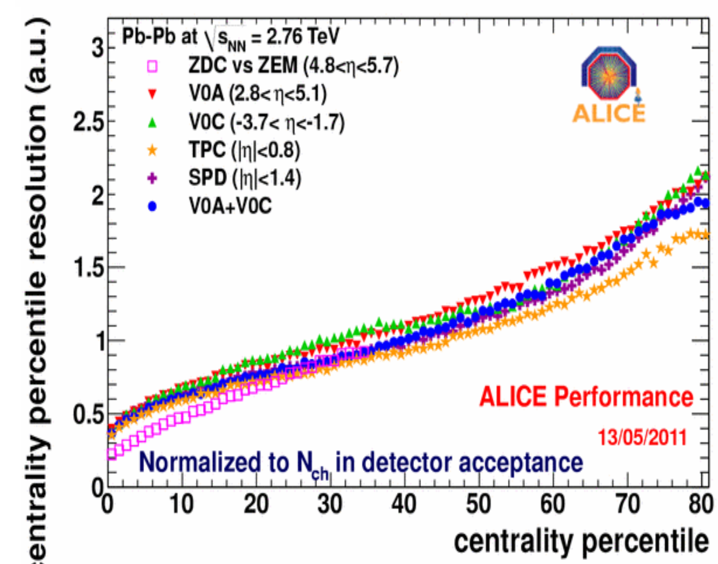
Centrality Resolution

- Scale with $\sqrt{N_{ch}}$ in each detector
- PbPb
  <Npart> = 112
  <Ncoll> = 362
- p-Pb
  <Npart> = <Ncoll> + 1 = 8



Resolution from Pb-Pb





Ignore rapidity distribution or detector settings

Summary

- Problem with centrality measurement:
  - Measurements at mid-rapidity are biased
    - By hard processes
  - At RHIC, measurements @ $|\eta| > 3$ are “safe”
    - Hard processes suppressed by phase space.
  - How far out in η is “safe” at LHC?
  - Applicability of Glauber model in p-A?
- p-A Centrality determination needs careful study
  - Trigger bias
  - Centrality bias
  - Background

Backup

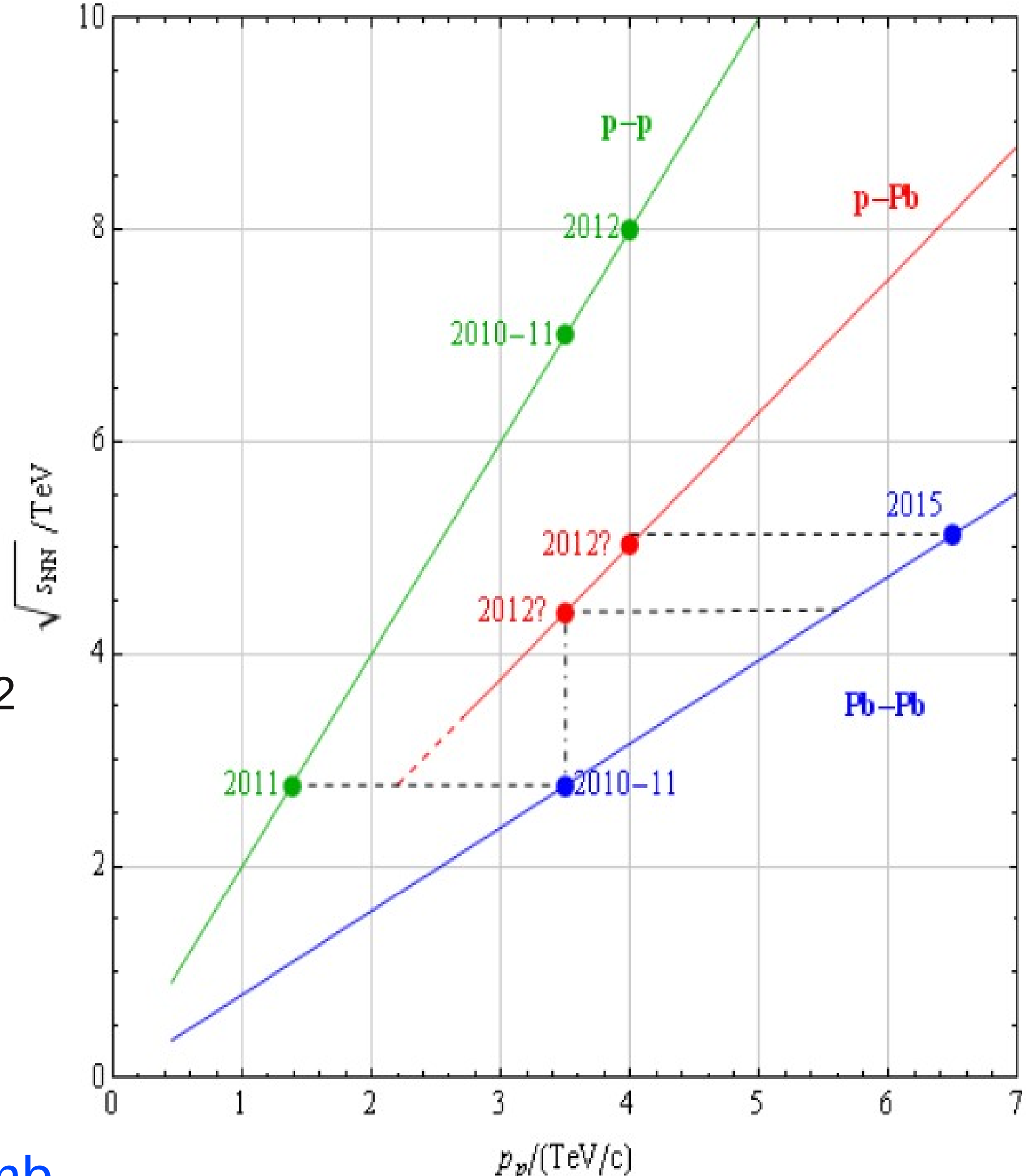
Running condition

Charges Z_1, Z_2 in rings with magnetic field set for protons of momentum p_p

$$\sqrt{s_{NN}} \approx 2c\, p_p \sqrt{\frac{Z_1 Z_2}{A_1 A_2}},$$

$$y_{NN} = \frac{1}{2}\log\frac{Z_1 A_2}{A_1 Z_2}$$

J.M. Jowett
LHC Performance Workshop Chamonix 2012



- $\sqrt{s}$ = 5 TeV for p_p =4 TeV
- $\sqrt{s}$ = 4.4 TeV for p_p =3.5 TeV
- $\sqrt{s}$ = 2.76 TeV for p_p =2.2 TeV

For $\sqrt{s}$=4.4TeV
Extrapolated σ_{NN}=68.6mb