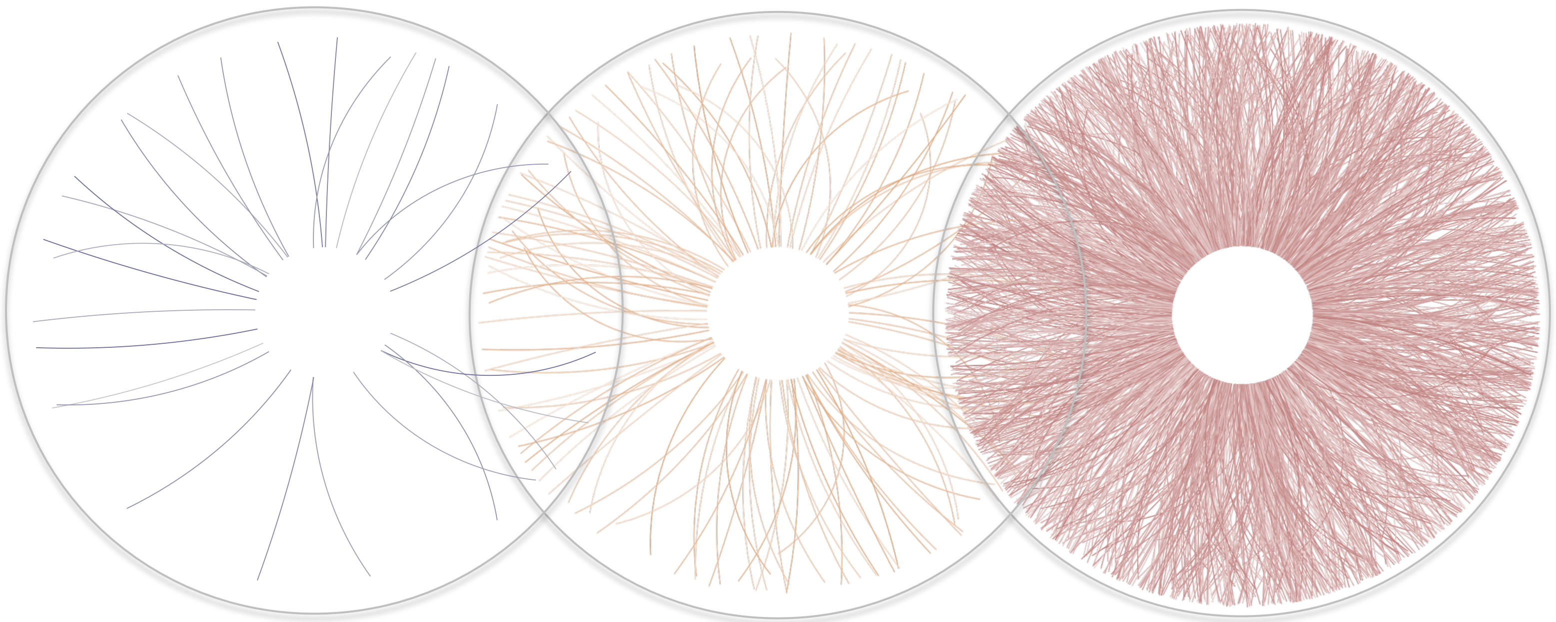


ALICE event activity estimators

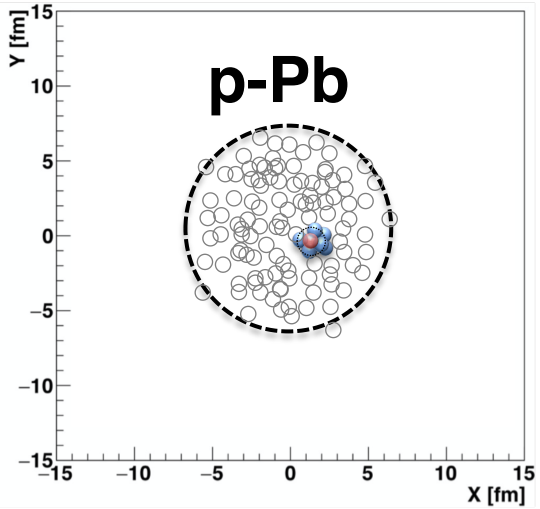
2nd LHC HI WG meeting

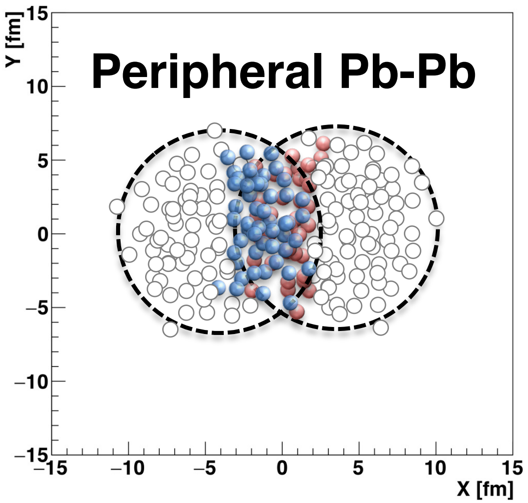
David Dobrigkeit Chinellato for the ALICE Collaboration

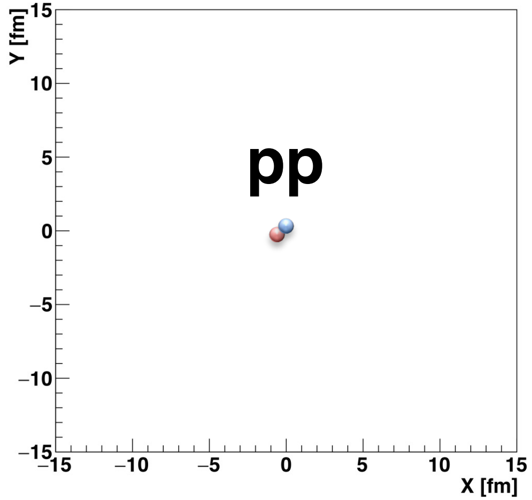
UNICAMP

ALICE

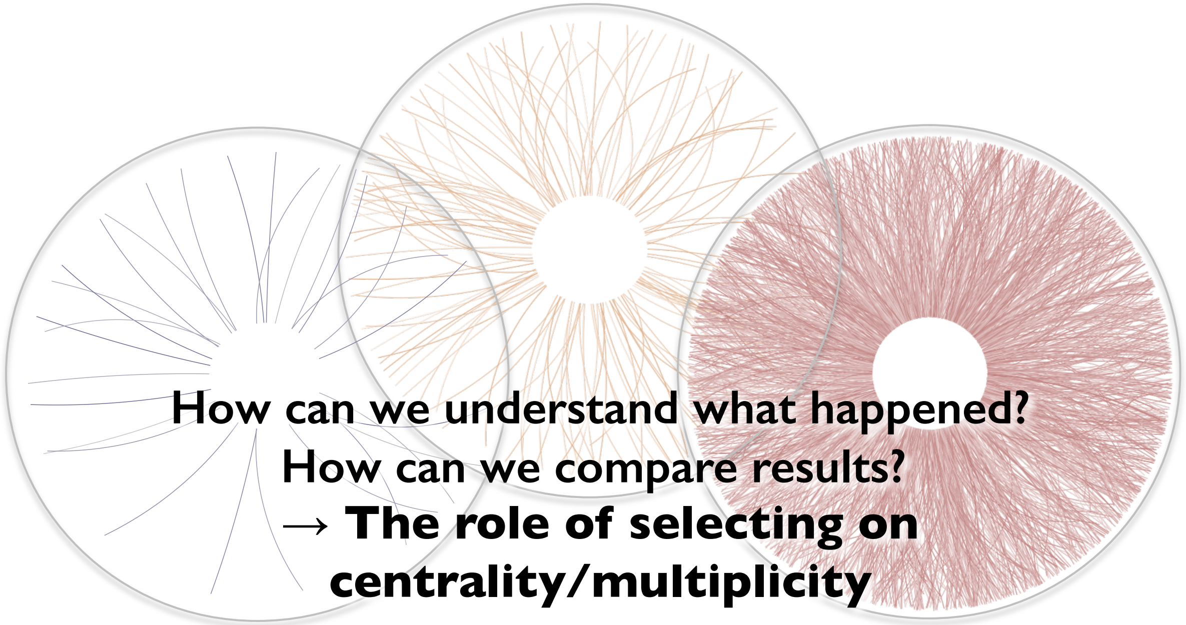
Event activity: why should we care?







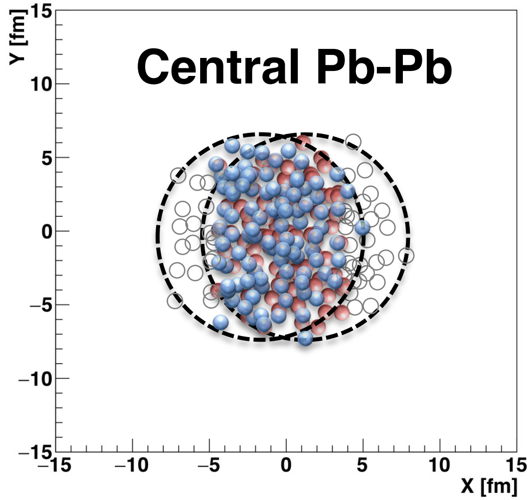
proton-proton (pp) collisions



How can we understand what happened?

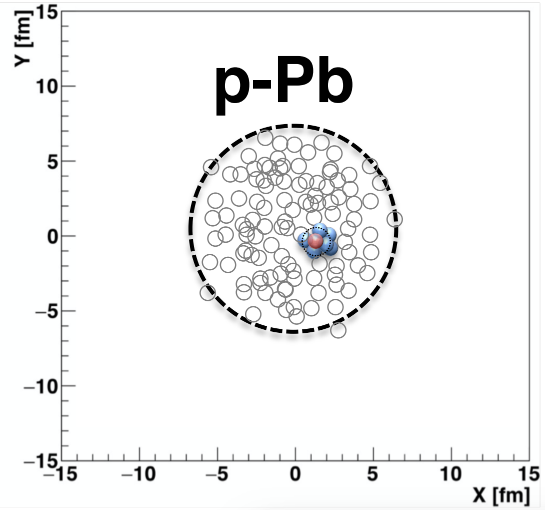
How can we compare results?

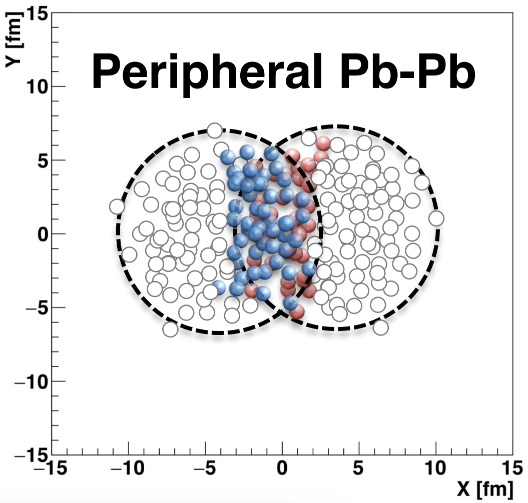
→ **The role of selecting on centrality/multiplicity**

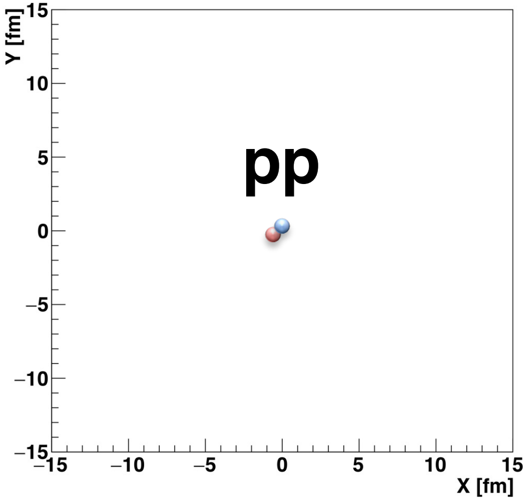


Central lead-lead (Pb-Pb) collisions

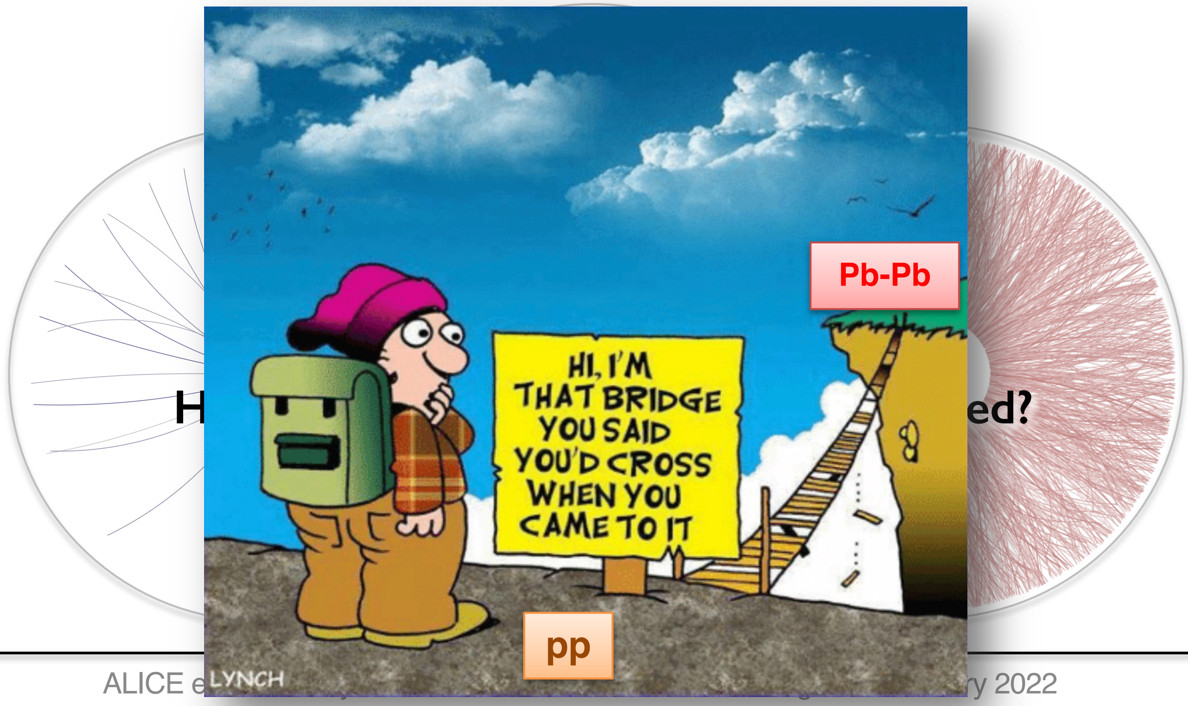
Event activity: why should we care?

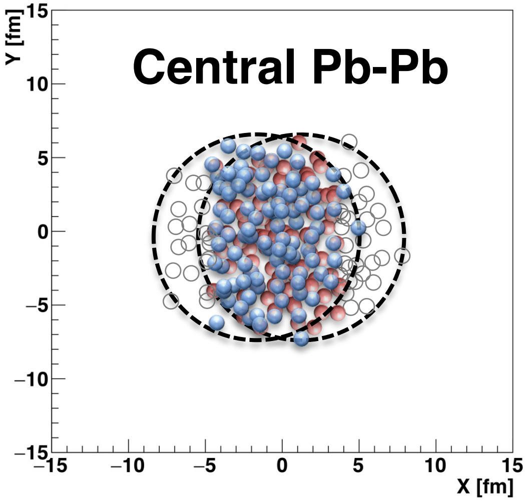






proton-proton (pp) collisions

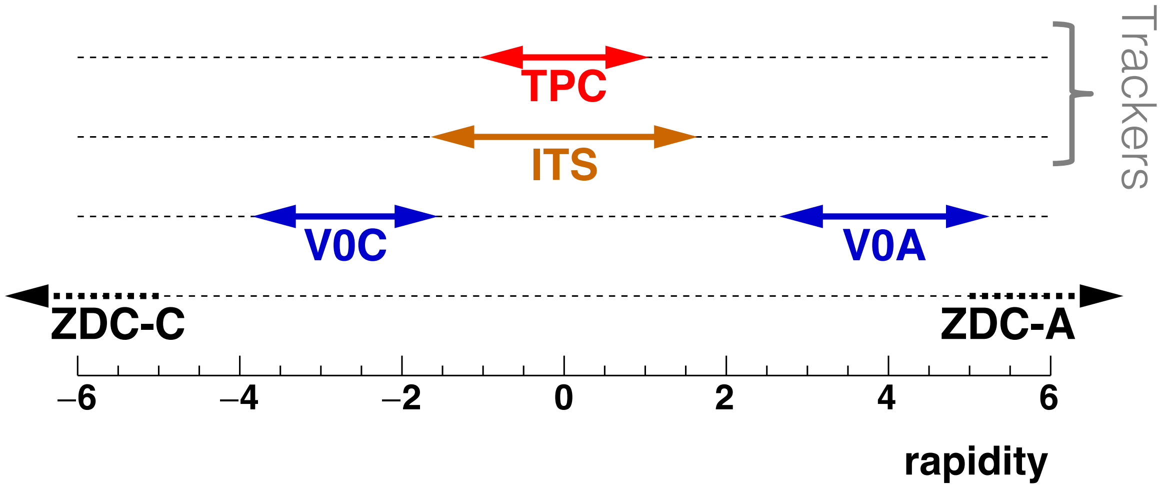




Central lead-lead (Pb-Pb) collisions

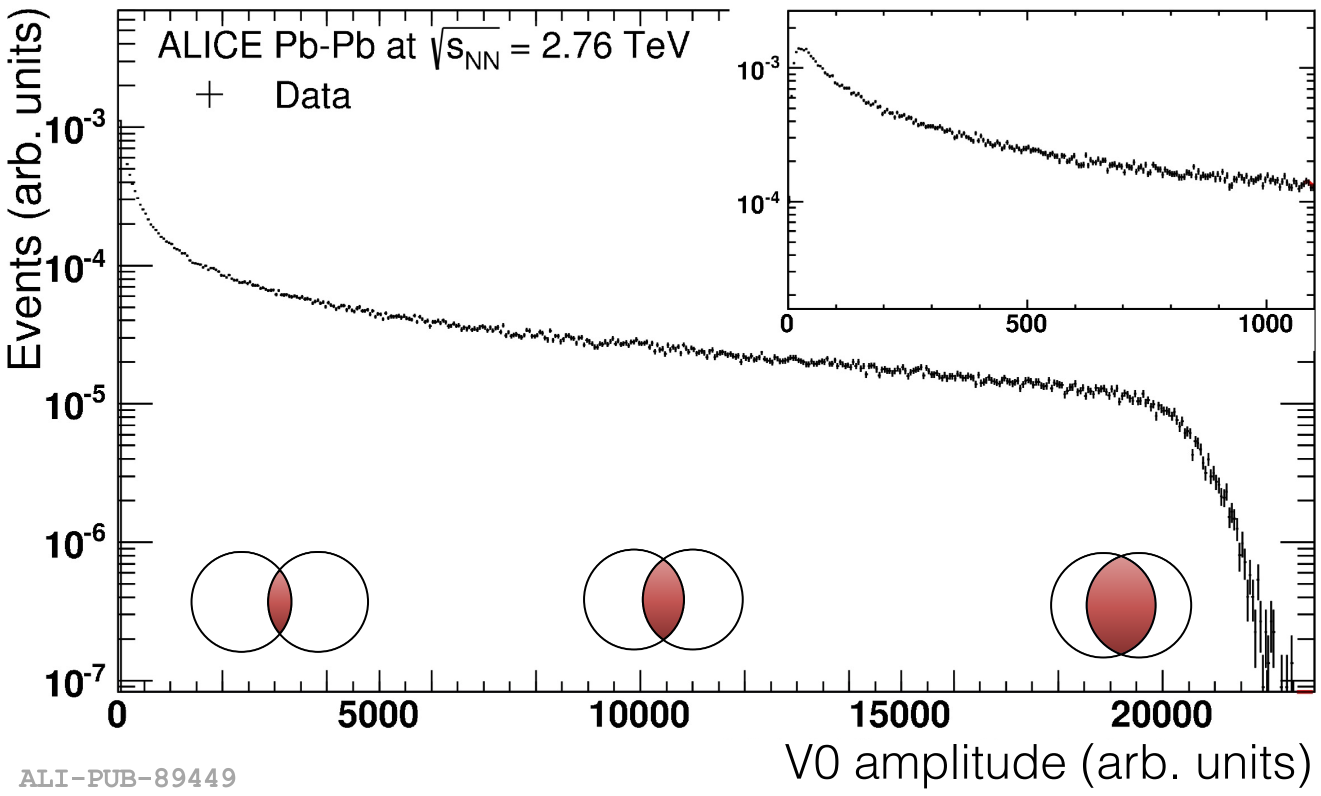
Event activity in Runs 1 and 2: a digest

Ansatz (for now):
"Activity" ≈ charged particle multiplicity



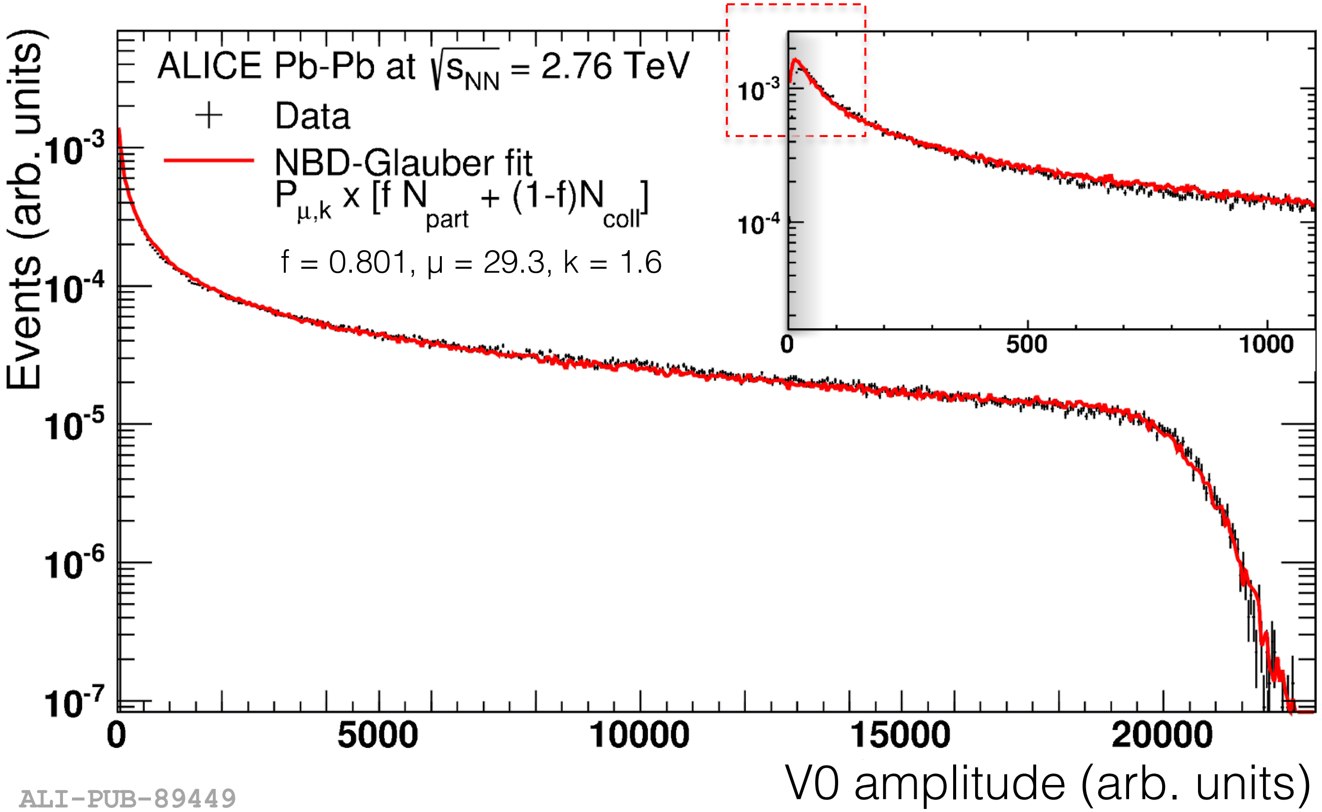
- **TPC: time projection chamber**
  - Number of tracks or similar rarely used
  - Correlation with measurement leads to interpretation difficulties
  - Very high availability: included in most data
- **ITS: inner tracking system**
  - Typical signal: clusters in first layer
  - Very high availability: included in most data
- **'V0M': the sum of V0A and V0C signals**
  - Most used selection in pp, p-Pb, Pb-Pb
  - Used in triggering: signal always present
- **ZDC: zero degree calorimeter signal**
  - No direct correlation with measurement region
  - Used in p-Pb + effective energy in pp
  - Available for part of data

Centrality determination in Pb-Pb using V0M



Phys. Rev. C 88 (2013) 044909

Centrality determination in Pb-Pb using V0M

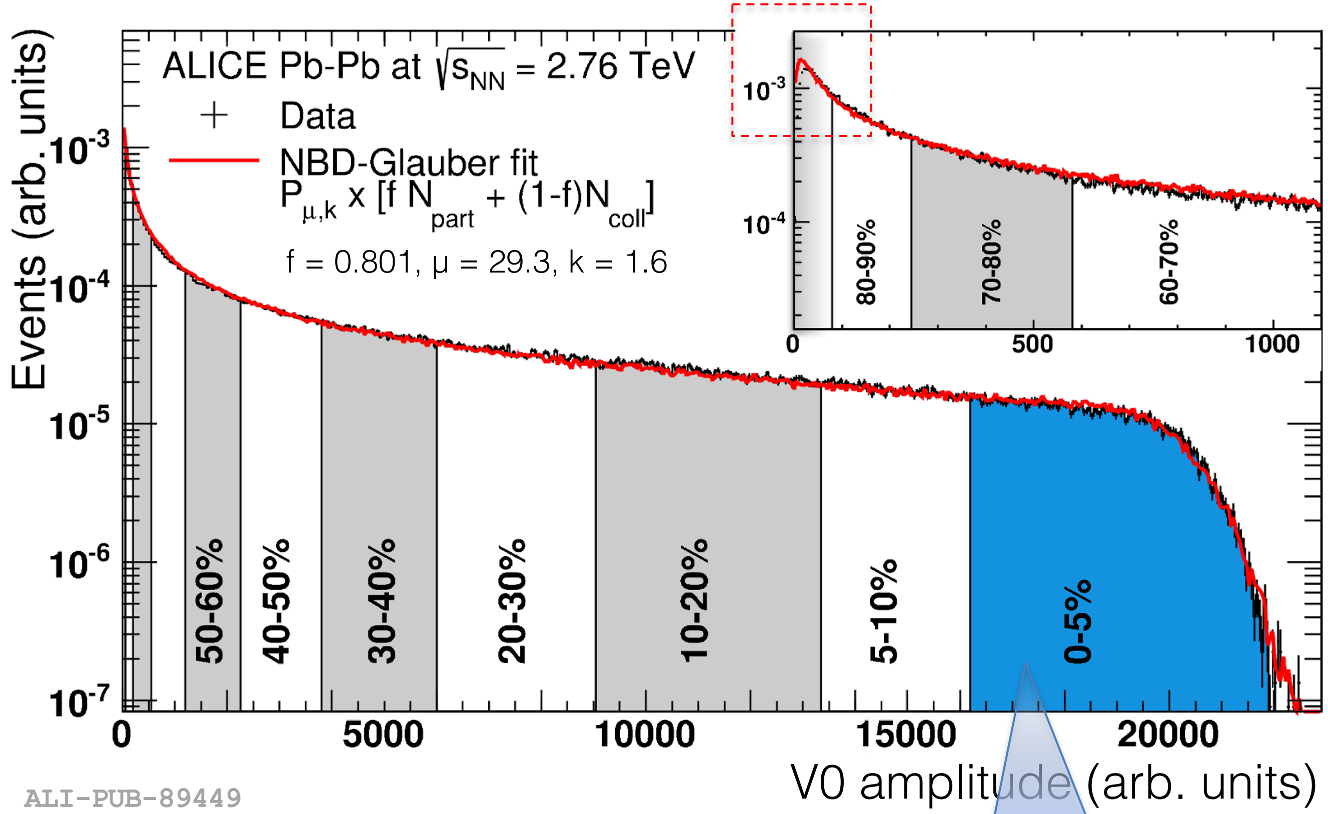


ALI-PUB-89449

Phys. Rev. C 88 (2013) 044909

- Description of V0 signal distribution:
  - Glauber $N_{\text{ancestors}}$: combination of N_{part}, N_{coll}
    - N_{part}: number of participant nucleons
    - N_{coll}: number of NN interactions
  - Convoluted with Neg. Bin. Distribution

Centrality determination in Pb-Pb using V0M

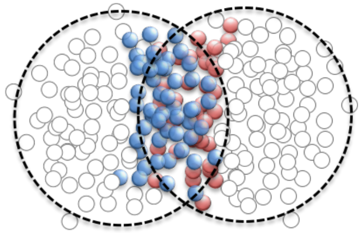


ALI-PUB-89449

Phys. Rev. C 88 (2013) 044909

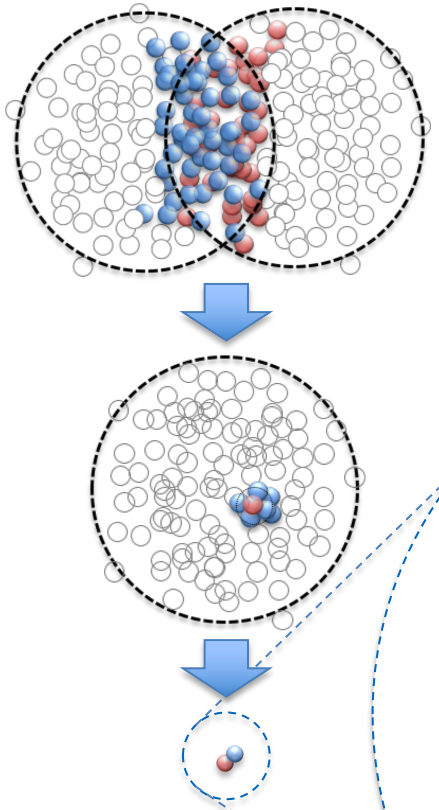
$\langle N_{part} \rangle$ = 381.6
$\langle N_{coll} \rangle$ = 1619

- Description of V0 signal distribution:
  - Glauber $N_{ancestors}$: combination of N_{part}, N_{coll}
    - N_{part}: number of participant nucleons
    - N_{coll}: number of NN interactions
  - Convoluted with Neg. Bin. Distribution
- Lowest multiplicity range discarded
- 90% of hadronic cross section analysed



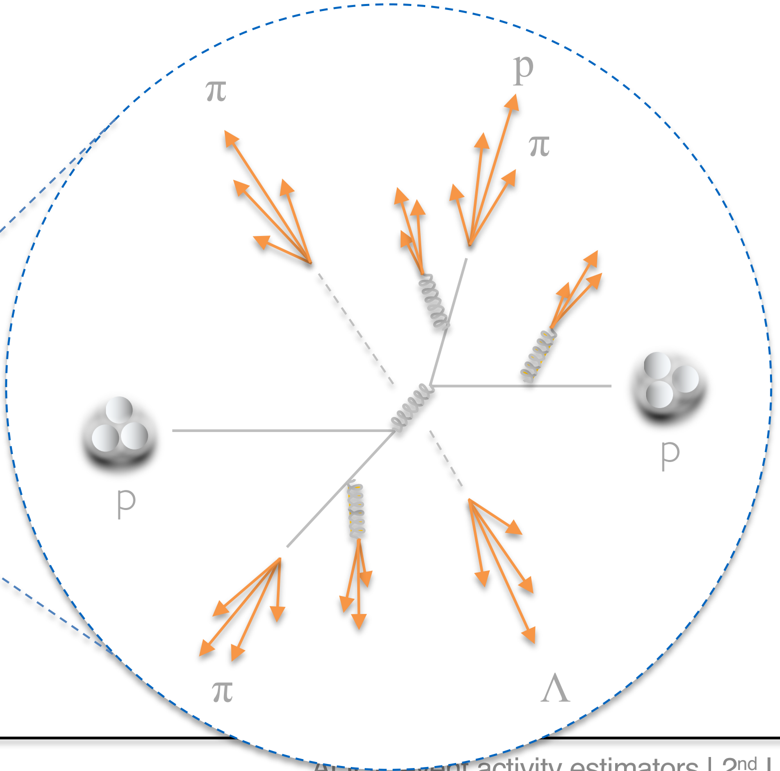
No strong ambiguity in parameters!
$\langle N_{part} \rangle$, $\langle N_{coll} \rangle$ used to interpret Pb-Pb results

The pp limit: going towards low multiplicity



Proton-proton collisions: fluctuations even more significant

- Multiplicity described well via multi-parton interactions (MPI) in QCD-inspired models such as PYTHIA
- MPI → the relevant particle-emitting source

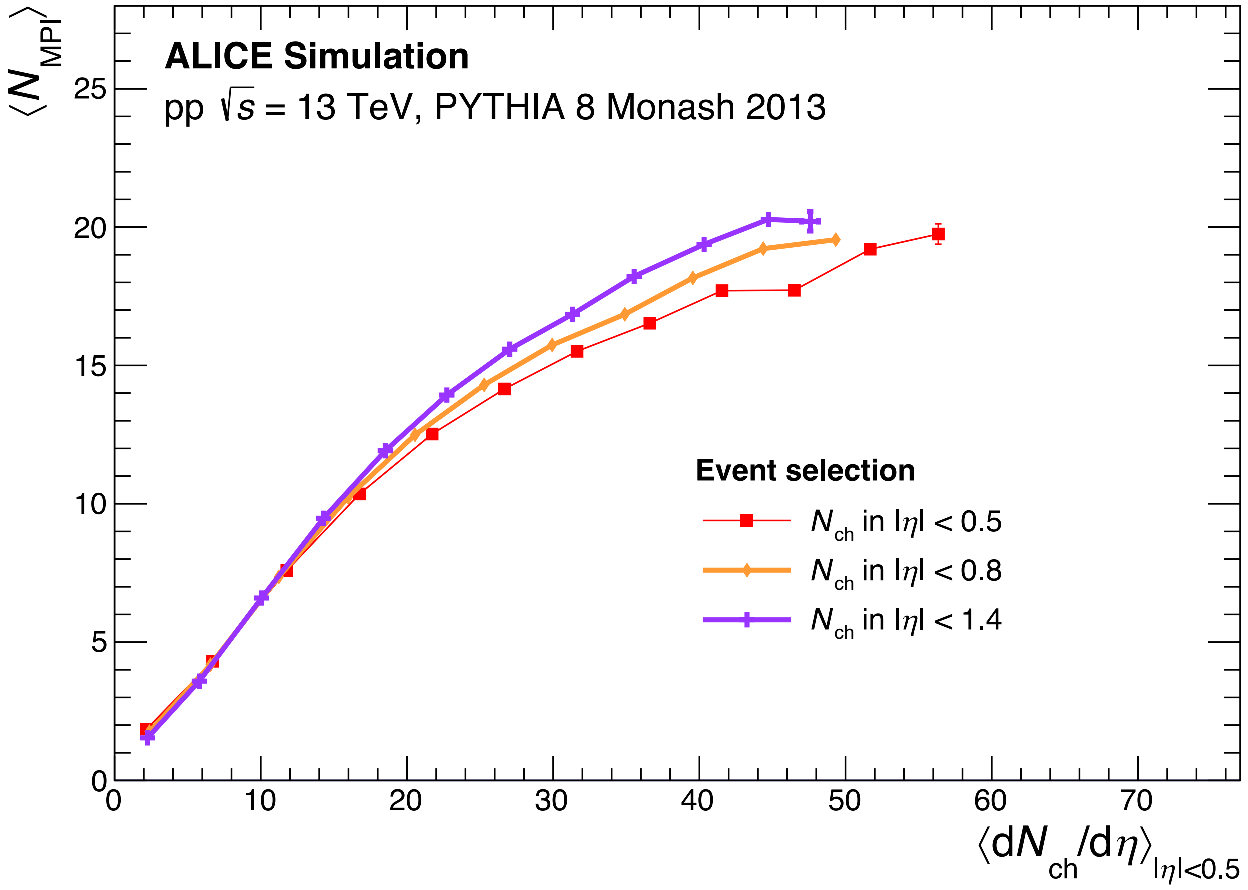


The ideal scenario would be to select on number of partonic interactions (“N_{MPI}”)

…which is of course impossible!

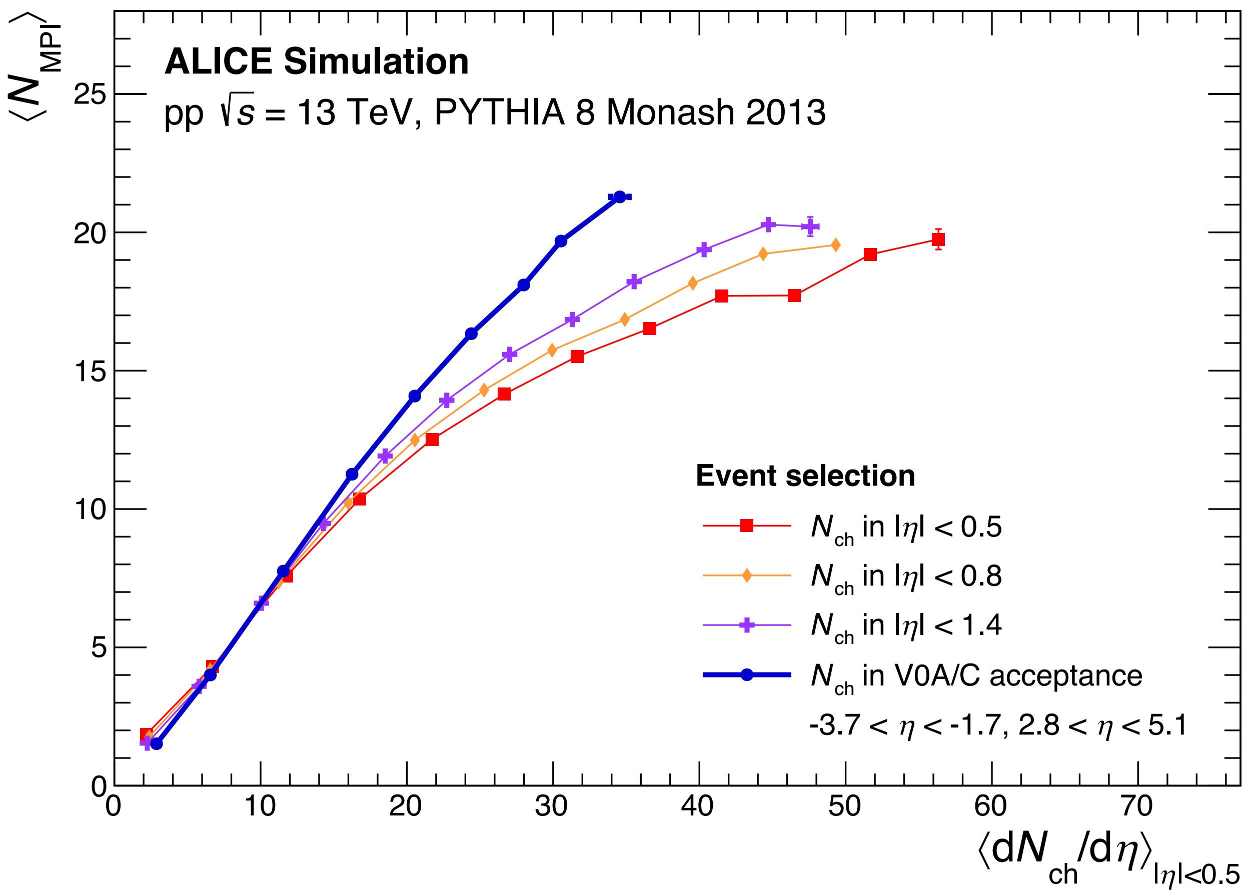
Let’s check our possibilities using **PYTHIA 8** as a diagnostic tool

Progressing in number of partonic interactions



- Selection at mid-rapidity ($|\eta| < 0.5$)
  - X axis biased: You get what you asked for
  - Privileges fluctuations: N_{ch}/N_{MPI} larger
- Wider selection at mid-rapidity ($|\eta| < 0.8$)
  - Smaller bias, smaller N_{ch}/N_{MPI}
- ALICE acceptance at mid-rapidity ($|\eta| < 1.4$)
  - Further reduced N_{ch}/N_{MPI}
  - …but still far from linear

Progressing in number of partonic interactions



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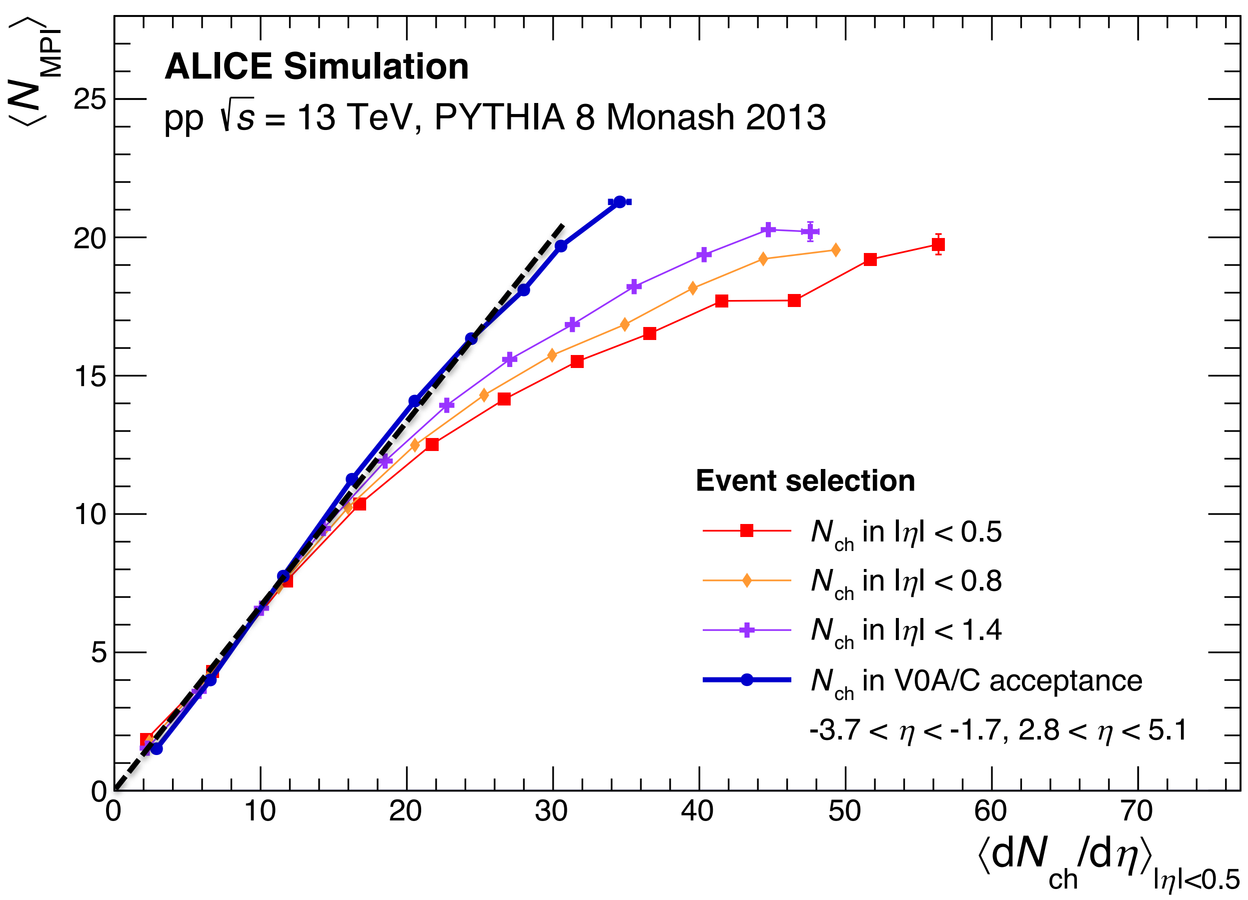
- V0A/C detectors: $-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$
  - Significant reduction of N_{ch}/N_{MPI}

Progressing in number of partonic interactions



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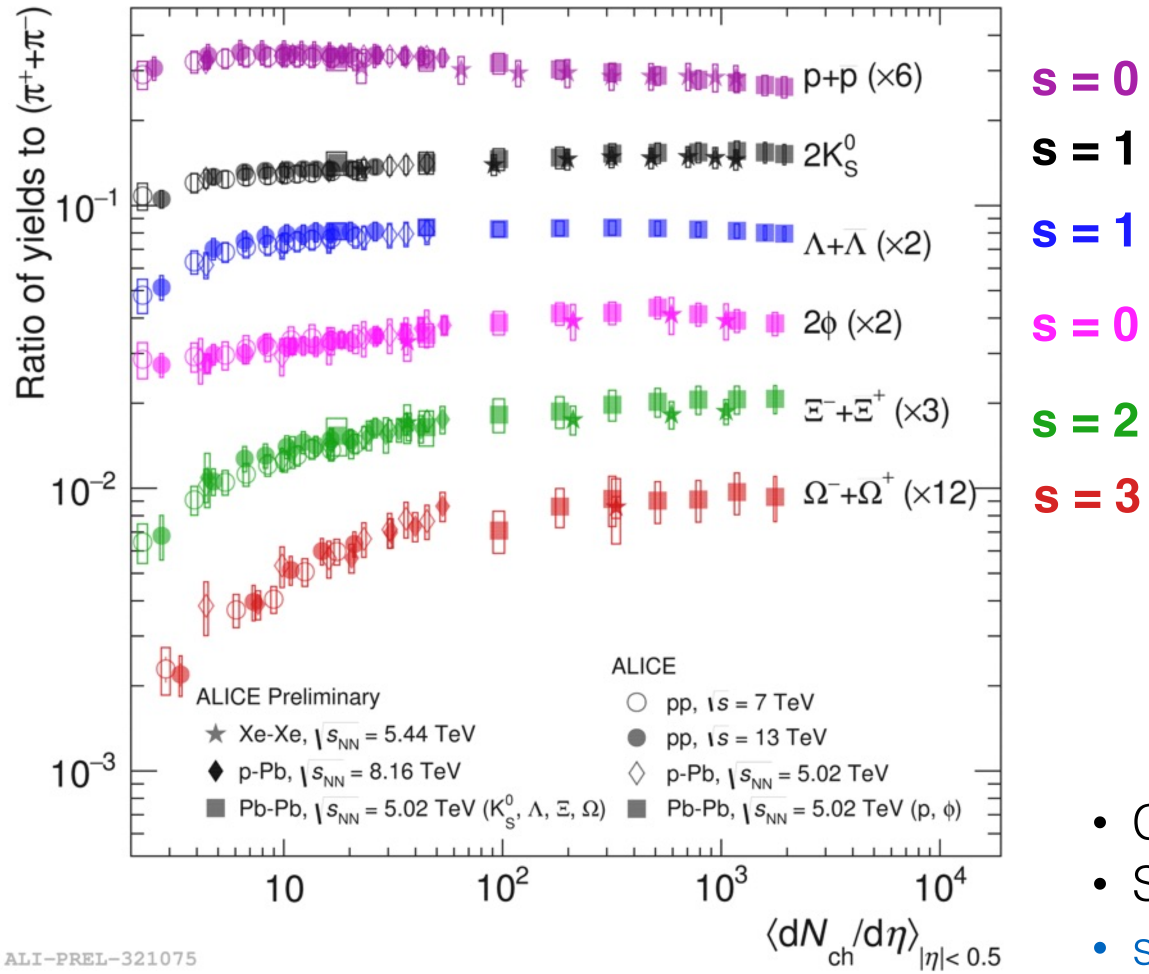
  - Significant reduction of N_{ch}/N_{MPI}

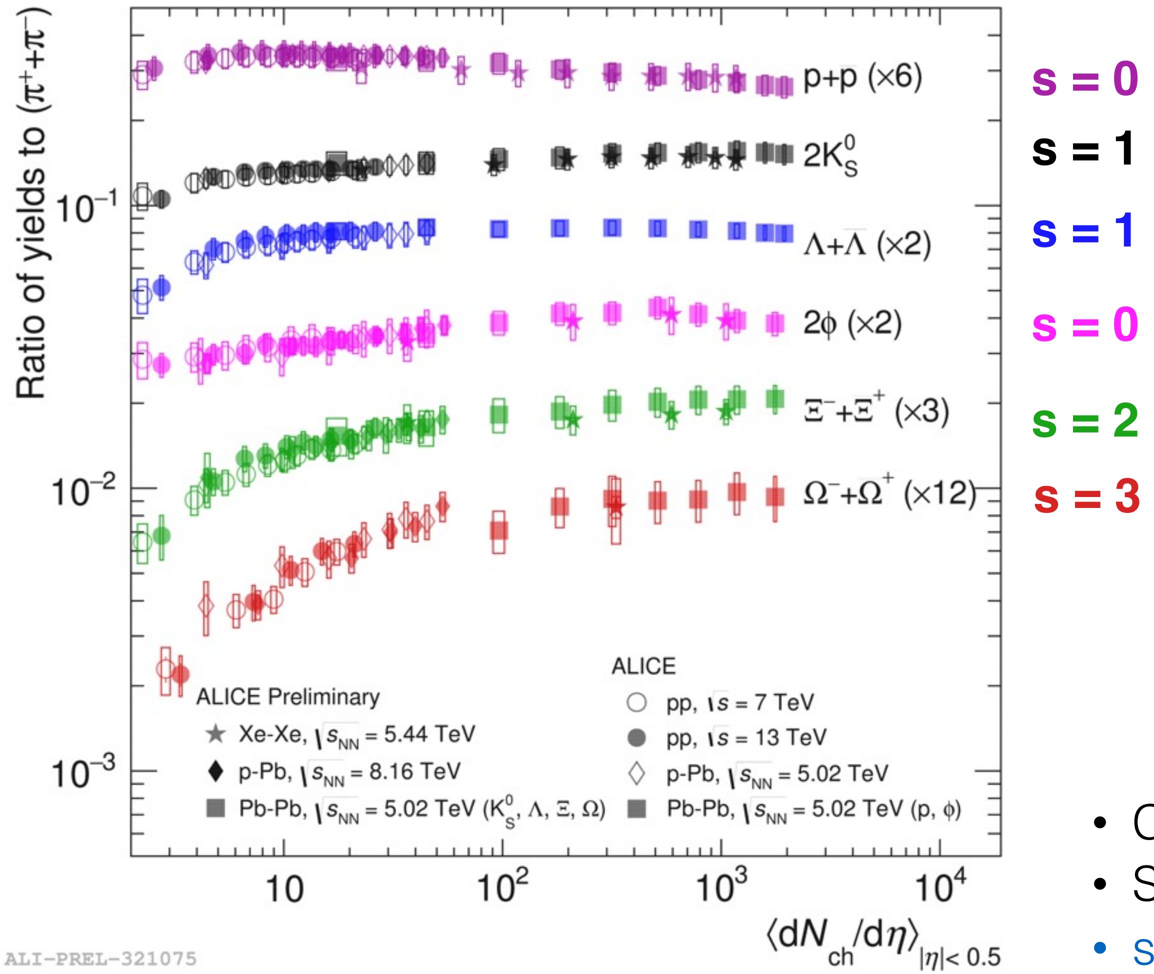
Most importantly:
~linear behaviour between N_{MPI} and N_{ch}!
→ similar notion as before: mid-rapidity multiplicity scales with number of emitting sources

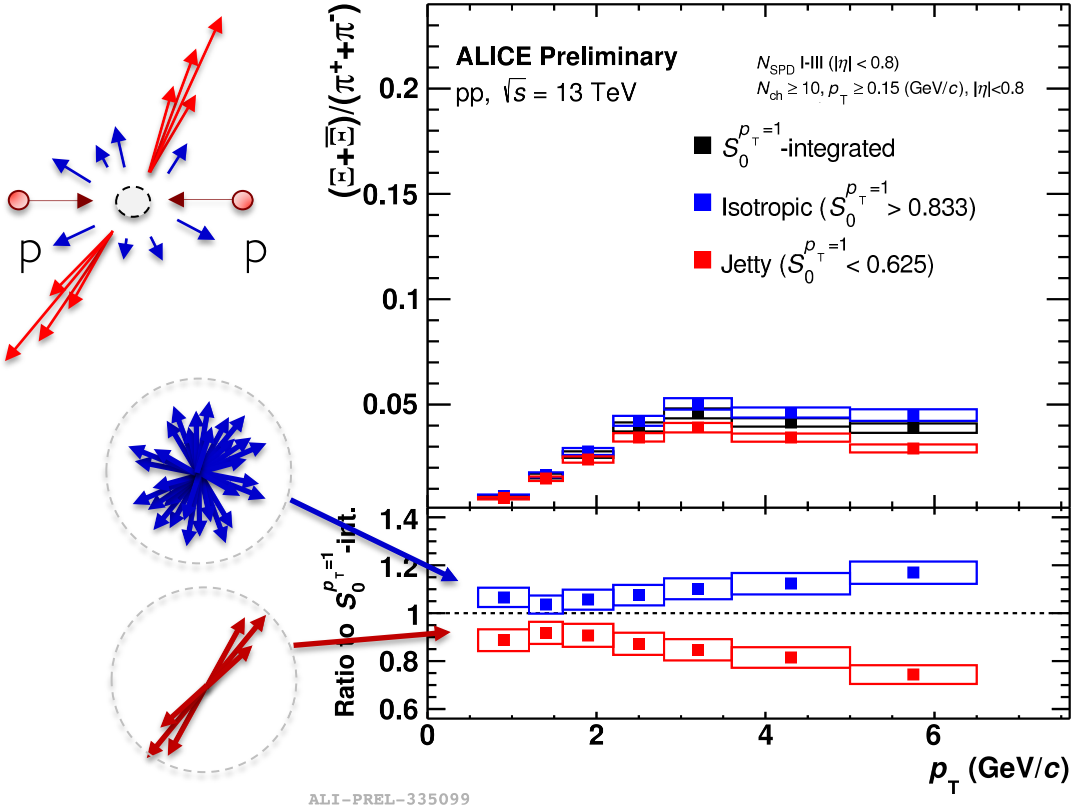
The outcome: a complete picture



- Consistent selection strategy → systematic comparisons
- Smooth evolution of particle ratios with multiplicity
- strangeness enhanced already in high-multiplicity pp, p-Pb

The outcome: a complete picture ... And beyond!





- Consistent selection strategy → systematic comparisons
- Smooth evolution of particle ratios with multiplicity
- strangeness enhanced already in high-multiplicity pp, p-Pb
- And beyond multiplicity:
  - Spherocity selection: isotropic events → extra strangeness

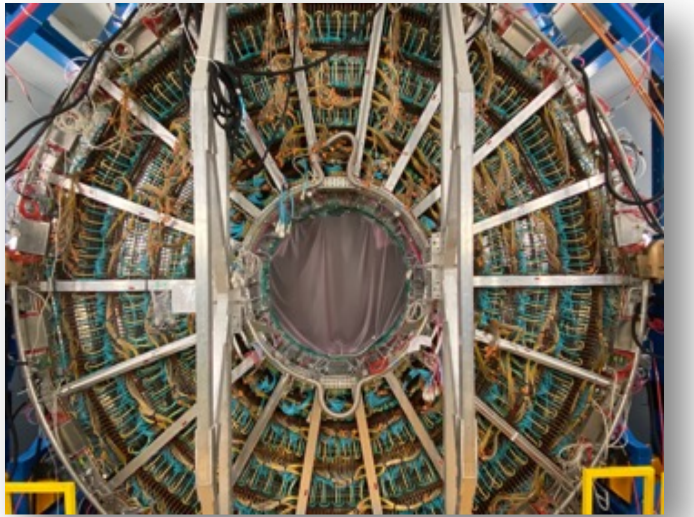
Upgrades: **50x** faster and **3x** more precise data

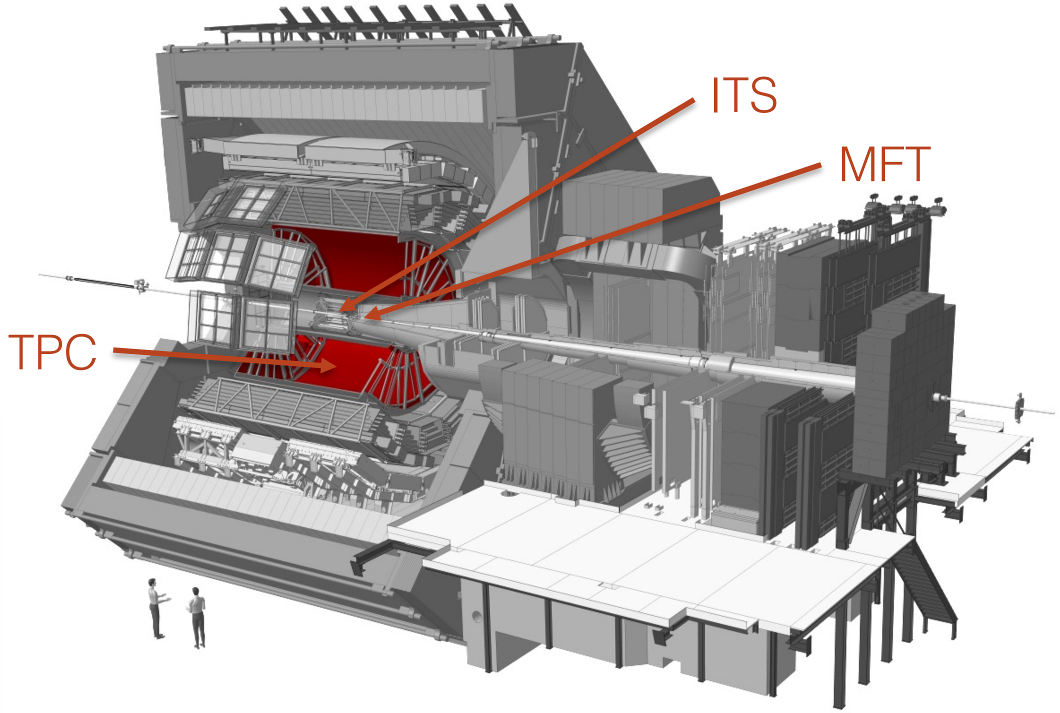
Run 1&2 TPC: MWPC-based
~1 kHz readout

Run 3 TPC: GEM-based
50 kHz readout

50x higher data rate

GEM-based TPC readout



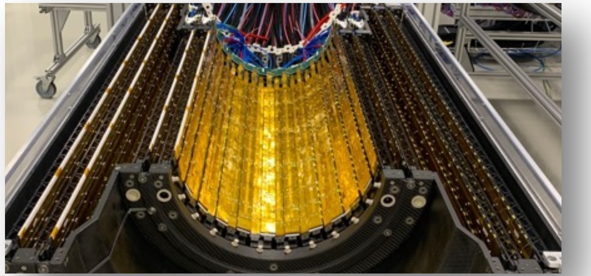


Run 1&2 ITS:
~10^7 channels

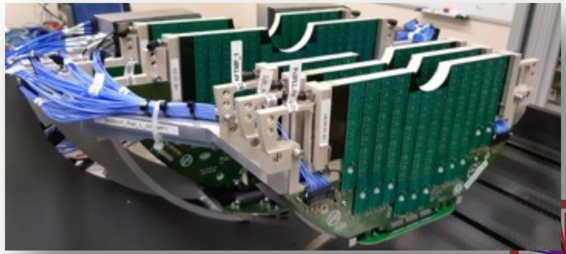
Run 3 ITS2 + MFT:
13×10^9 pixels

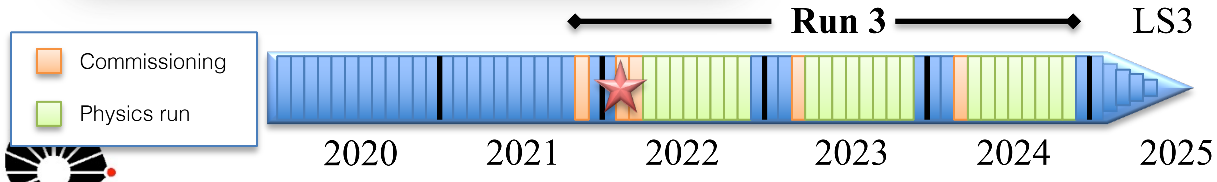
+**3x** in tracking precision

Monolithic-pixel Inner Tracking System: ITS2



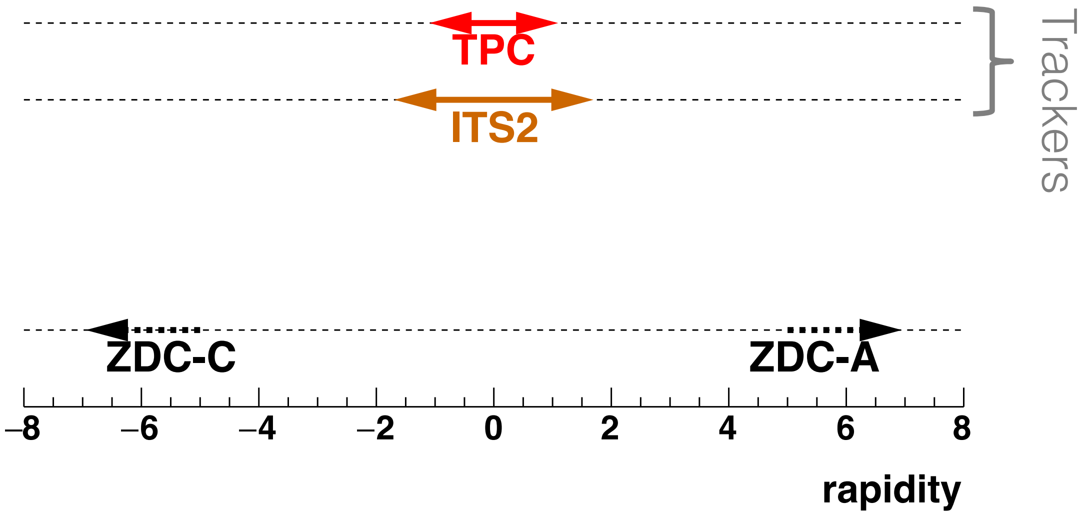
Pixel Muon Forward Tracker (MFT)





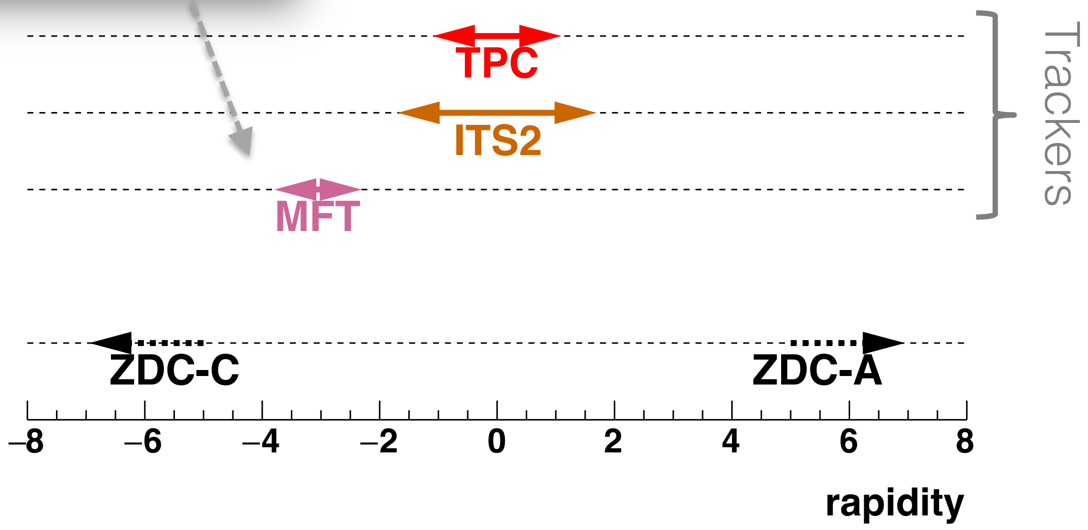
Major upgrade completed:
New experimental tools
ready to be exploited!

Detector coverage in Run 3 and beyond



- **New: ITS2 (|η| < 1.5, three layers: |η| < 2.0)**
  - All-pixel based detector
  - More flexible for event selection

Detector coverage in Run 3 and beyond



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  - Instead of a counter, a full tracker!
  - Opens up exciting new possibilities: multiplicity, precise spherocity/event shape selection in decorrelated region, and more
  - High availability

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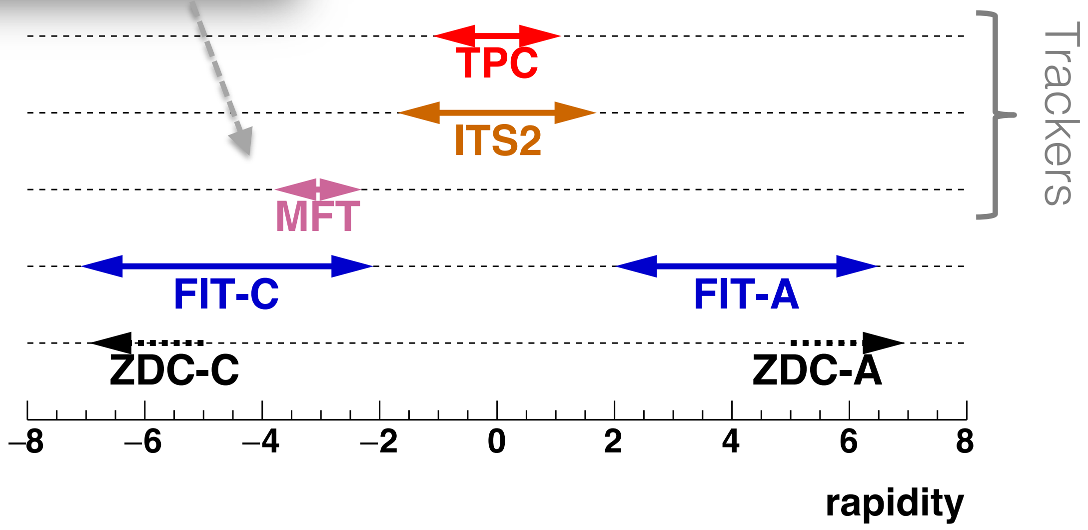

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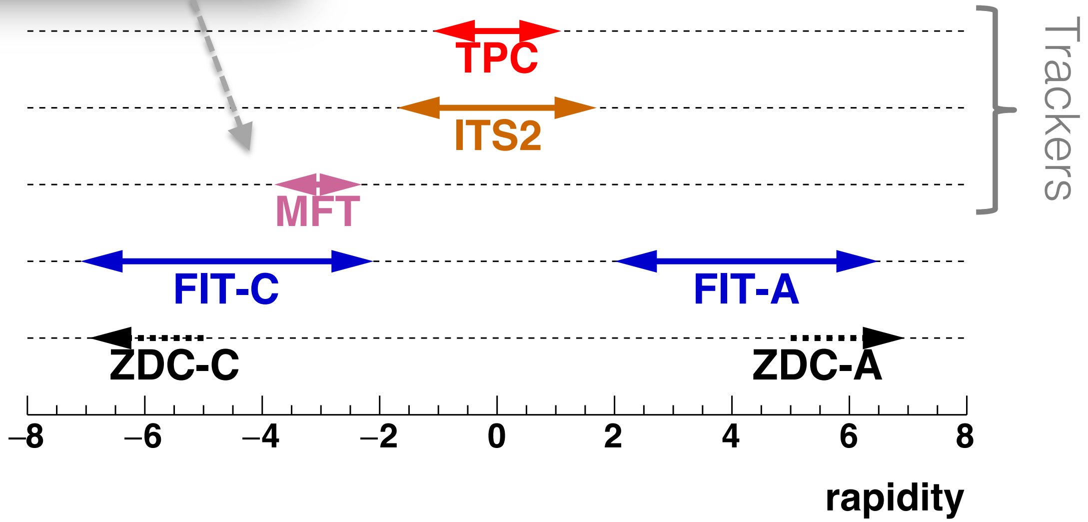
- **New: FIT: Fast Interaction Trigger**
  - FIT FT0: **-3.3 < η < -2.1, 3.5 < η < 4.9**
  - FIT FV0: **2.2 < η < 5.0**
  - FIT FDD: **-6.9 < η < -4.9, 4.7 < η < 6.3**
  - Replaces V0 scintillators

Detector coverage in Run 3 and beyond



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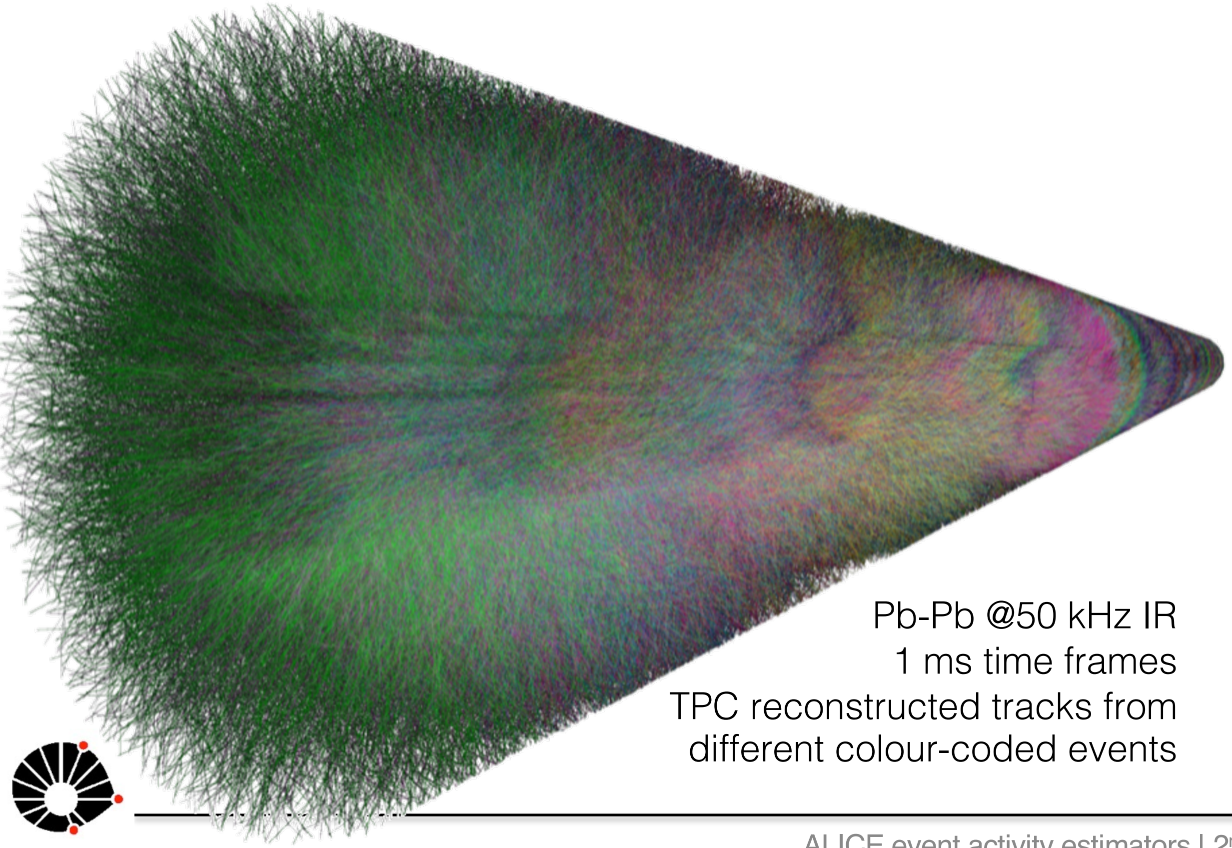
  - Replaces V0 scintillators

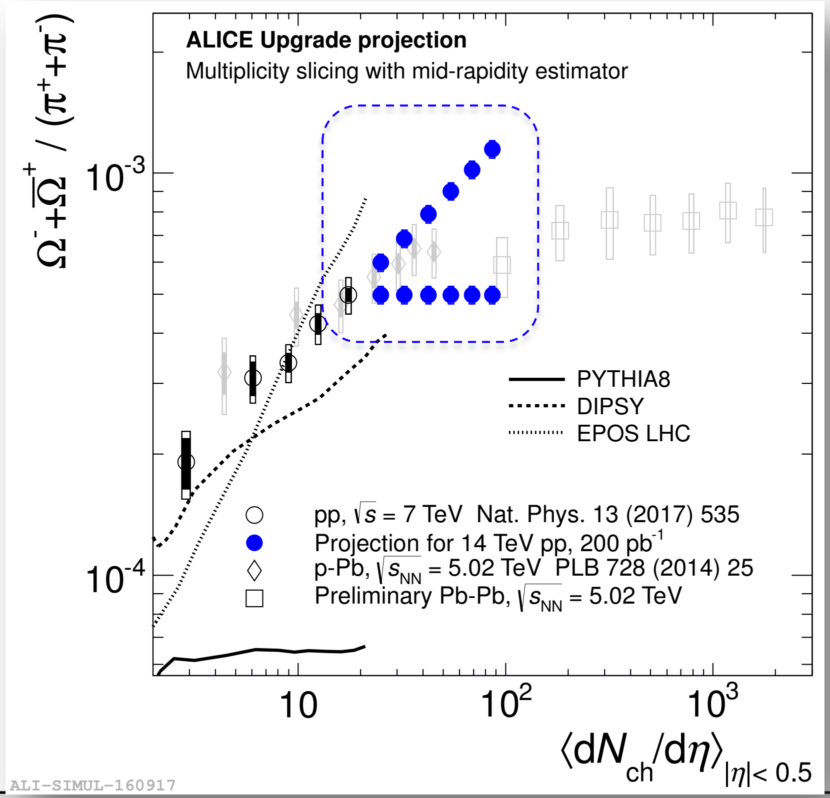
The new ALICE datataking scheme:
- Continuous readout + much more data (**50x**)
- Software trigger for selecting events
- Flexibility: trigger on high event activity, specific event shape, presence of particle of interest → new measurements viable!

Outlook: the (imminent) future

- Plenty of exciting opportunities through new hardware, high luminosities, innovative analyses
- Today: combine efforts in brainstorming about event selection and characterization



Pb-Pb @50 kHz IR
1 ms time frames
TPC reconstructed tracks from
different colour-coded events



Thank you!

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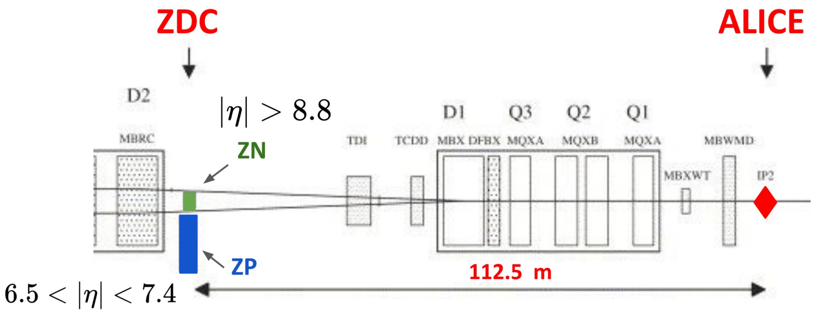
ALICE

Backup

Effective energy analysis in proton-proton collisions



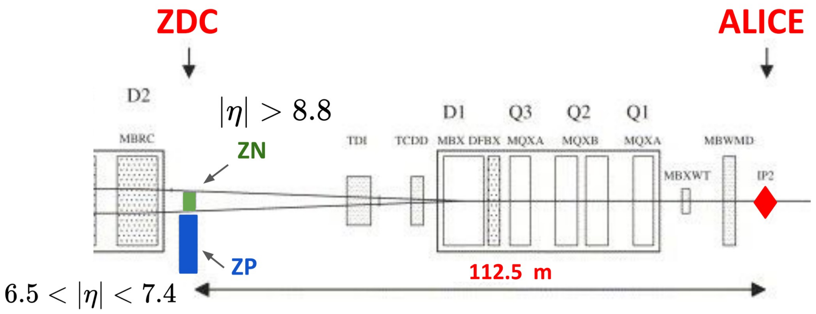
- measure energy available for initial state particle production E_{EFF} as:

$$E_{EFF} = \sqrt{s} - E_{forward}$$

with E_{EFF} measured with the Zero Degree Calorimeter (at very large η)

- Determine if relative Ξ production depends on E_{EFF} in addition to depending on multiplicity
- Is strangeness production associated to the initial state or to the final state (multiplicity)?

Effective energy analysis in proton-proton collisions



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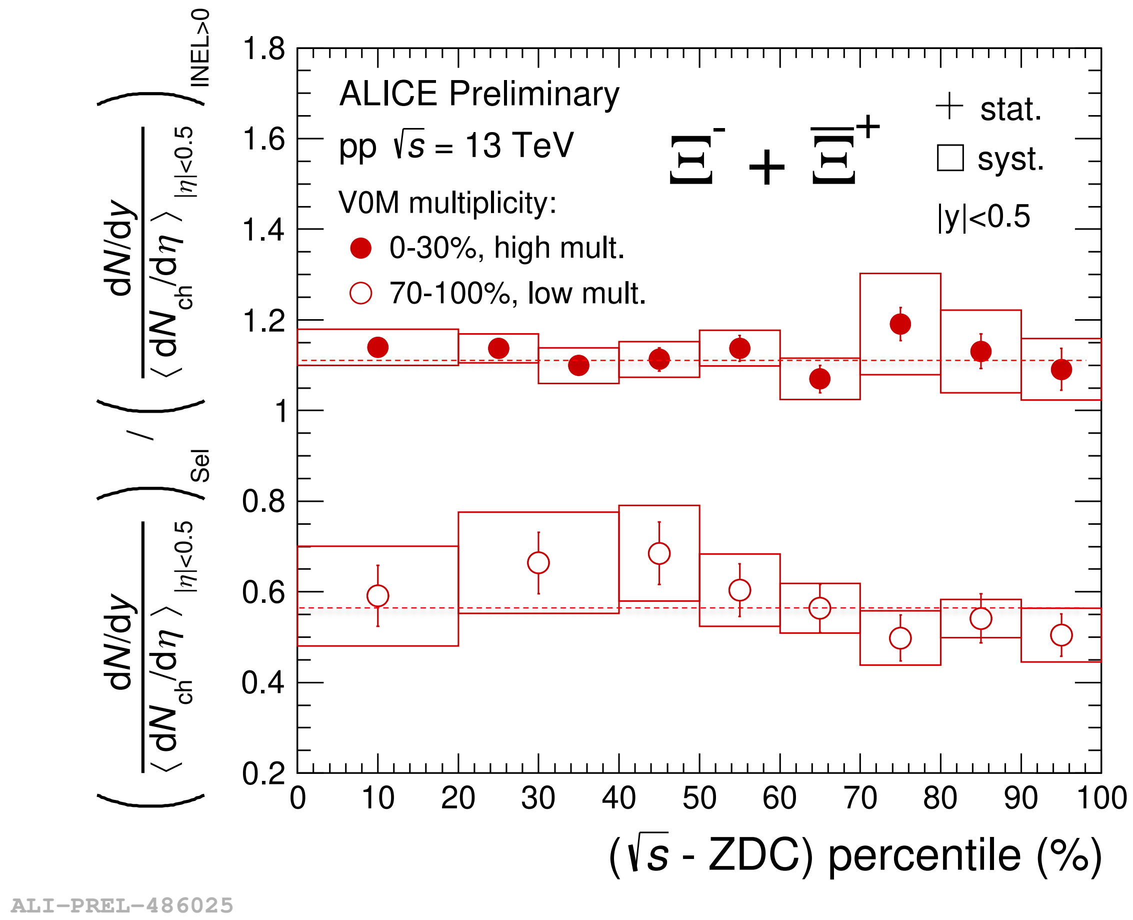
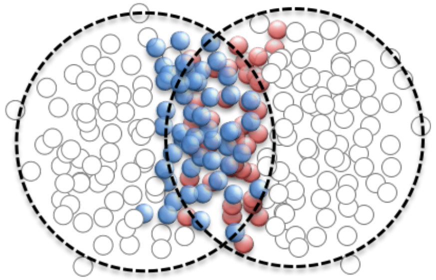


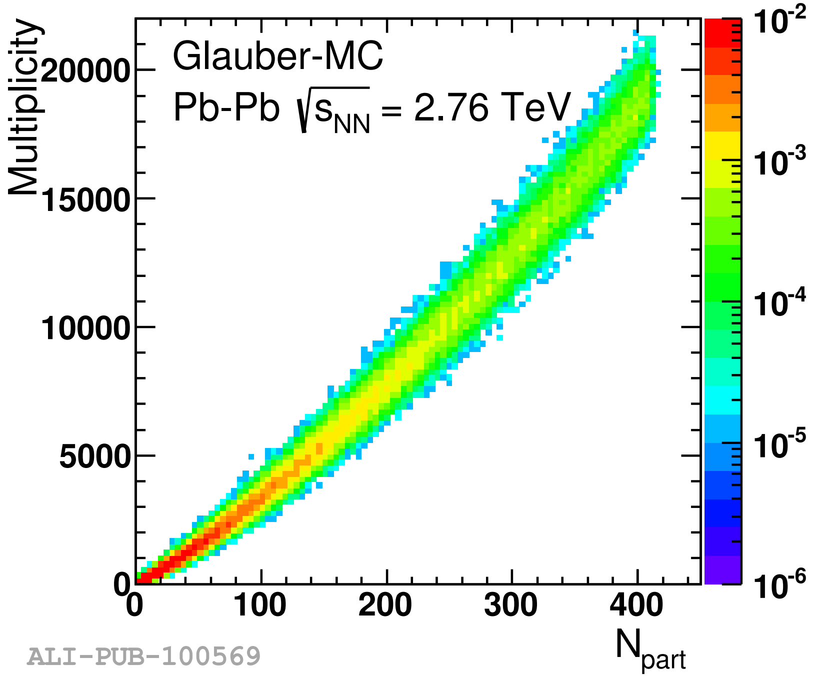
Initial state is unimportant, strangeness production solely dependent on final-state charged-particle density!

Going towards p-Pb

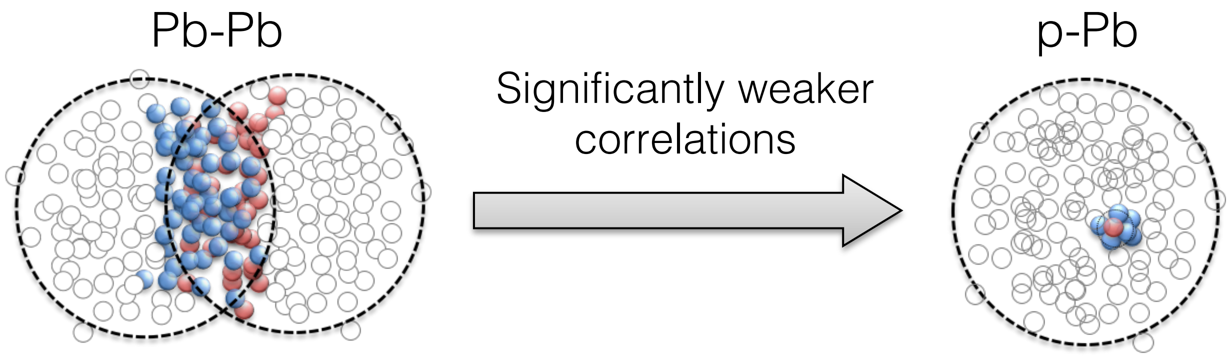
Pb-Pb



Phys. Rev. C 91 (2015) 064905



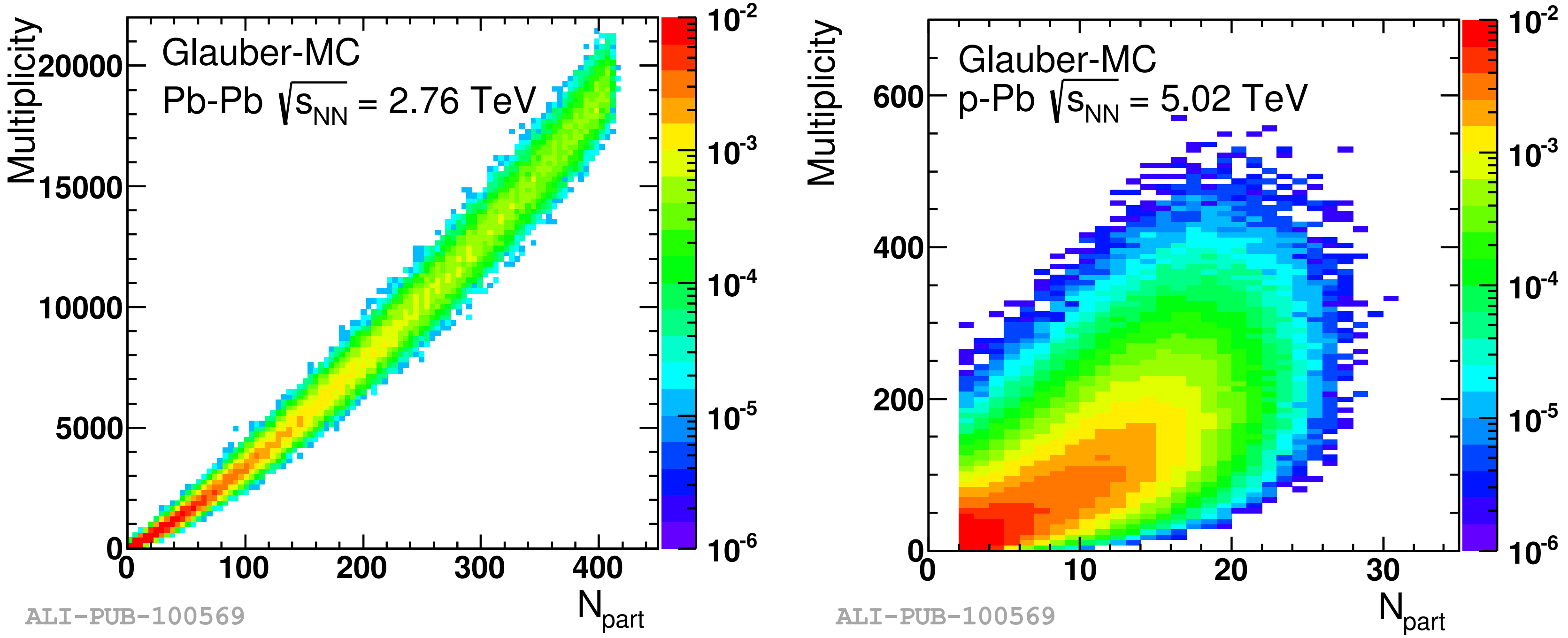
Going towards p-Pb



The challenge:

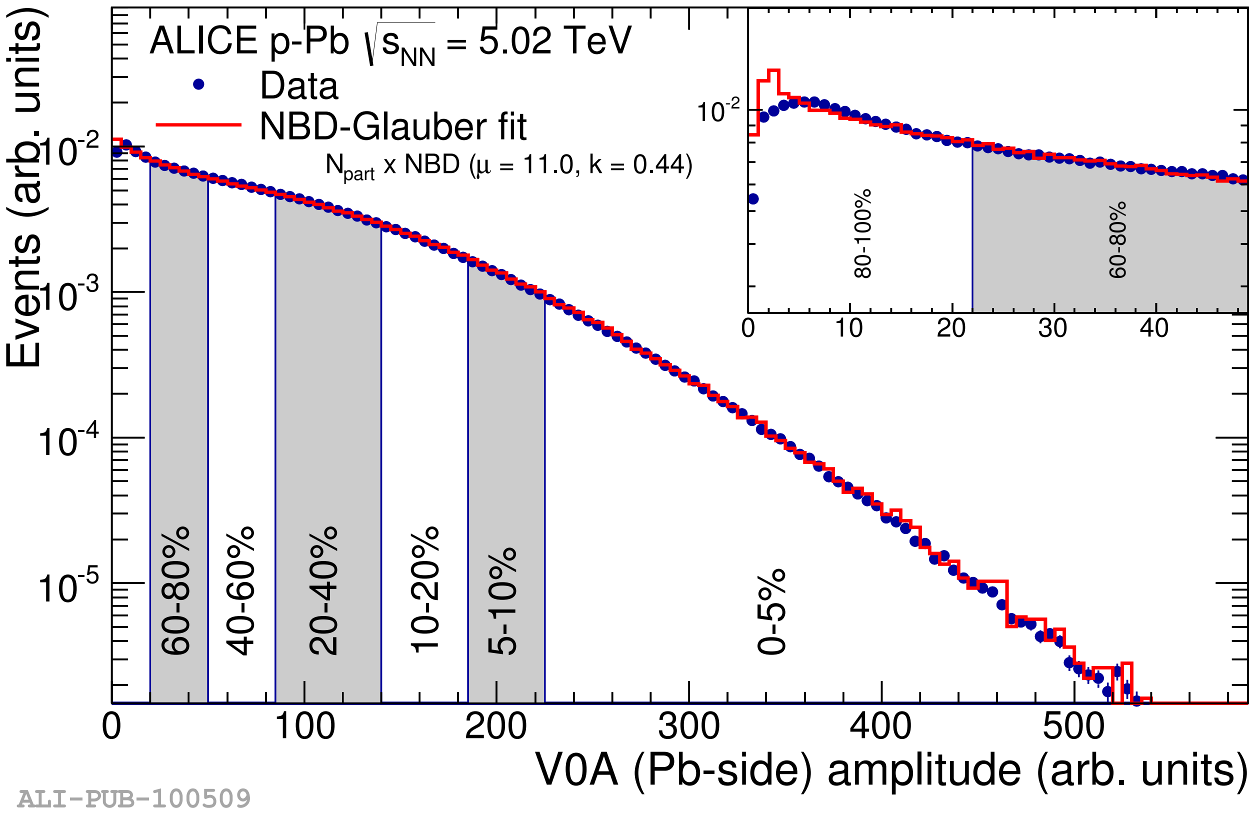
- Multiplicity and Glauber quantities are weakly correlated
- A.k.a.: multiplicity “fluctuates”
- How can we relate variables?

Phys. Rev. C 91 (2015) 064905



Could we try the same strategy?

Glauber model meets p-Pb: describing the signal



Phys. Rev. C 91 (2015) 064905

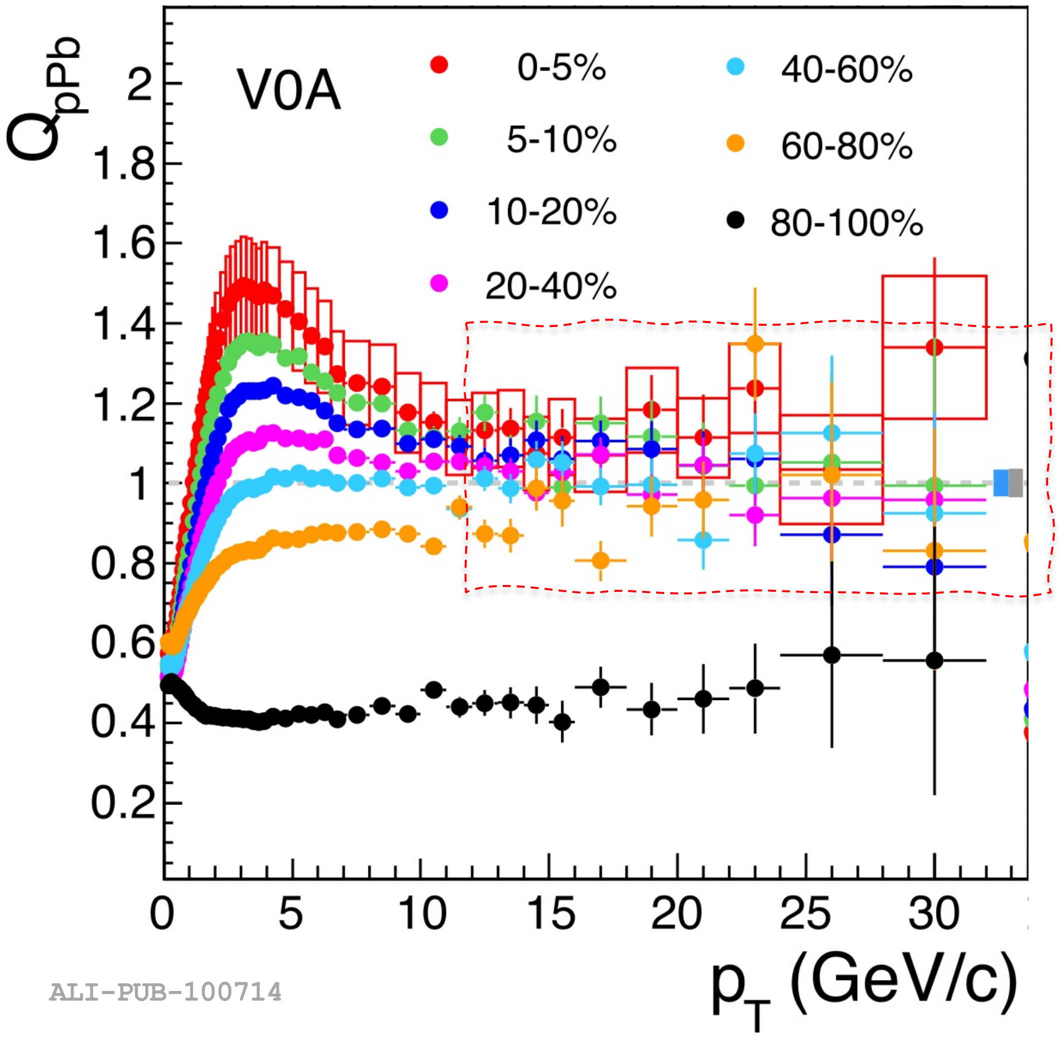
- V0A: in the Pb-going side → expect scaling closer to N_{part} for multiplicity
- Description reasonable except for lowest multiplicity
- N_{part}, N_{coll} obtained slicing the model curve are very broadly distributed
  - $\langle N_{part} \rangle$, $\langle N_{coll} \rangle$ can still be determined
  - Can we check if these are reasonable?

Resort to Pb-Pb experience:
The nuclear modification factor

$$R_{AA} = \frac{\text{Yield in AA}}{\langle N_{coll} \rangle \times \text{Yield in pp}}$$

Is unity if (Pb-Pb) = $\langle N_{coll} \rangle$ × (pp)
"N_{coll} Scaling"

The nuclear modification factor in p-Pb



Phys. Rev. C 91 (2015) 064905

- The Q_{pPb}: the nuclear modification factor in multiplicity classes in p-Pb

$$Q_{\mathrm{pPb}}\,(p_{\mathrm{T}}; cent) = \frac{\mathrm{d}N^{\mathrm{pPb}}_{\mathrm{cent}}/dp_{\mathrm{T}}}{\langle N^{\mathrm{Glauber}}_{\mathrm{coll}}\rangle\,\mathrm{d}N^{\mathrm{pp}}/dp_{\mathrm{T}}}$$

- N.B.: Not called R_{pPb} because multiplicity fluctuation biases may cause unexpected behaviour

- Should be unity in the absence of nuclear modification or biases
- High p_{T}: no modification?
  - Fails for low multiplicity
  - Works reasonably for higher multiplicity

…Can we do better?

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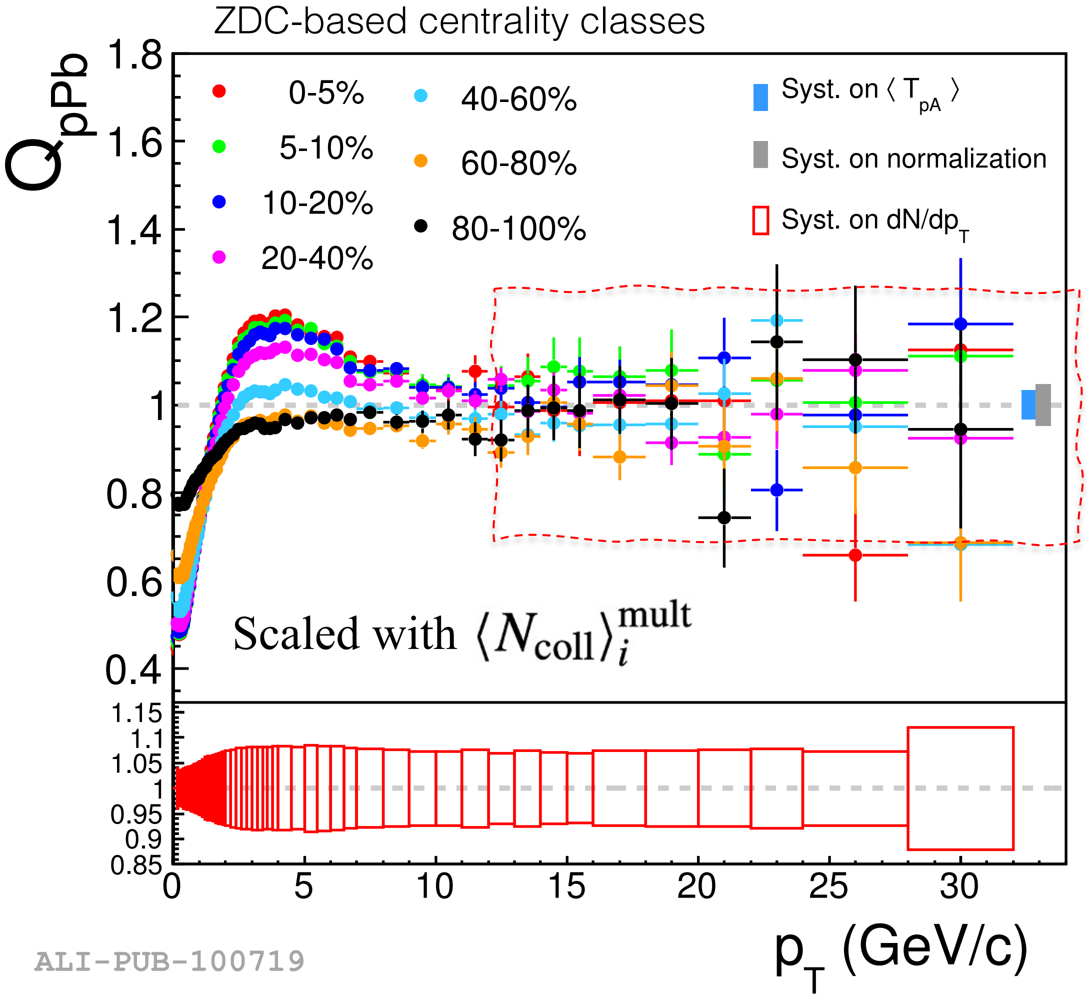
The Q_{pPb} using the ZDC and a 'hybrid' approach



Phys. Rev. C 91 (2015) 064905

- ZDC: Zero Degree Calorimeter
  - Very forward in rapidity
  - Geometry biased with minimal impact on hadronisation
- The hybrid approach:
  - Assume $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$ at mid-rapidity (in CMS) scales with N_{part}
  - Motivated by wounded nucleon model
  - N_{coll} in a given centrality i selected with the ZDC:

$$\langle N_{\mathrm{part}} \rangle_i^{\mathrm{mult}} = \langle N_{\mathrm{part}} \rangle_{\mathrm{MB}} \left(\frac{\langle dN/d\eta \rangle_i}{\langle dN/d\eta \rangle_{\mathrm{MB}}} \right)_{-1<\eta<0}$$

$$\langle N_{\mathrm{coll}} \rangle_i^{\mathrm{mult}} = \langle N_{\mathrm{part}} \rangle_i^{\mathrm{mult}} - 1.$$

Least biased: N_{coll} scaling recovered at high momentum!