ALICE event activity estimators

2nd LHC HI WG meeting

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Event activity: why should we care?

How can we understand what happened?
How can we compare results?

→ The role of selecting on centrality/multiplicity

pp
proton-proton (pp) collisions

p-Pb

Peripheral Pb-Pb

Central Pb-Pb

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

- **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

Ansatz (for now):
“Activity” ≈ charged particle multiplicity
Centrality determination in Pb-Pb using V0M

ALICE Pb-Pb at $\sqrt{s_{NN}} = 2.76$ TeV

+ Data

Centrality determination in Pb-Pb using V0M

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

\[ f = 0.801, \mu = 29.3, k = 1.6 \]
Centrality determination in Pb-Pb using V0M

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  - Convoluted with Neg. Bin. Distribution
  - Lowest multiplicity range discarded
  - 90% of hadronic cross section analysed

- Fitted parameters:
  - $f = 0.801$, $\mu = 29.3$, $k = 1.6$
  - $\langle N_{\text{part}} \rangle = 381.6$
  - $\langle N_{\text{coll}} \rangle = 1619$

No strong ambiguity in parameters! $\langle N_{\text{part}} \rangle$, $\langle N_{\text{coll}} \rangle$ 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: $N_{\text{ch}}/N_{\text{MPI}}$ larger

- Wider selection at mid-rapidity ($|\eta| < 0.8$)
  - Smaller bias, smaller $N_{\text{ch}}/N_{\text{MPI}}$

- ALICE acceptance at mid-rapidity ($|\eta| < 1.4$)
  - Further reduced $N_{\text{ch}}/N_{\text{MPI}}$
  - …but still far from linear

ALICE Simulation

pp $\sqrt{s} = 13$ TeV, PYTHIA 8 Monash 2013

Event selection

- $N_{\text{ch}}$ in $|\eta| < 0.5$
- $N_{\text{ch}}$ in $|\eta| < 0.8$
- $N_{\text{ch}}$ in $|\eta| < 1.4$
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- V0A/C detectors: $-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$
  - Significant reduction of $N_{\text{ch}}/N_{\text{MPI}}$
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Most importantly:

~linear behaviour between $N_{\text{MPI}}$ and $N_{\text{ch}}$!

→ similar notion as before: mid-rapidity multiplicity scales with number of emitting sources
The outcome: a complete picture

- Consistent selection strategy $\rightarrow$ 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:
  - Sphericity selection: isotropic events → extra strangeness

\[ s = 0 \]
\[ s = 1 \]
\[ s = 2 \]
\[ s = 3 \]
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: 13x10^9 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 ($|\eta| < 1.5$, three layers: $|\eta| < 2.0$)
  - All-pixel based detector
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  - Opens up **exciting new possibilities**: multiplicity, precise spherocity/event shape selection in decorrelated region, and more
  - High availability

**Trackers**

- TPC
- ITS2
- MFT
- ZDC-C
- ZDC-A

**Rapidity**

-8  -6  -4  -2  0  2  4  6  8
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- **New: FIT: Fast Interaction Trigger**
  - FIT FT0: $-3.3 < \eta < -2.1, 3.5 < \eta < 4.9$
  - FIT FV0: $2.2 < \eta < 5.0$
  - FIT FDD: $-6.9 < \eta < -4.9, 4.7 < \eta < 6.3$
  - 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!

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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

Thank you!

**Pb-Pb @50 kHz IR**
1 ms time frames
TPC reconstructed tracks from different colour-coded events
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 $\eta$)

- Determine if relative $\Xi$ 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)?
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Initial state is unimportant, strangeness production solely dependent on final-state charged-particle density!
Going towards p-Pb


Glauber-MC
Pb-Pb $\sqrt{s}_{NN} = 2.76$ TeV
Going towards p-Pb

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

Could we try the same strategy?
Glauber model meets p-Pb: describing the signal

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

Resort to Pb-Pb experience: The nuclear modification factor

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

Is unity if (Pb-Pb) = $\langle N_{\text{coll}} \rangle \times (\text{pp})$ “$N_{\text{coll}}$ Scaling”

\[ \text{ALI-PUB-100509} \]

The nuclear modification factor in p-Pb

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

$$Q_{pPb} (p_T; cent) = \frac{dN_{pPb}^{cent} / dp_T}{\langle N_{coll}^{Glauber} \rangle dN_{pp} / dp_T}$$

- 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?

The $Q_{pPb}$ using the ZDC and a ‘hybrid’ approach

- **ZDC**: Zero Degree Calorimeter
  - Very forward in rapidity
  - Geometry biased with minimal impact on hadronisation

- **The hybrid approach**:
  - Assume $dN_{ch}/d\eta$ 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:

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

$$\langle N_{coll} \rangle_{i}^{\text{mult}} = \langle N_{part} \rangle_{i}^{\text{mult}} - 1.$$ 

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

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**ZDC-based centrality classes**

- 0-5%
- 5-10%
- 10-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

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