Determination of the nuclear modification factor for charged particles at LHCb

Óscar Boente García
Universidade de Santiago de Compostela

2nd Red LHC - Madrid 9/5/2018

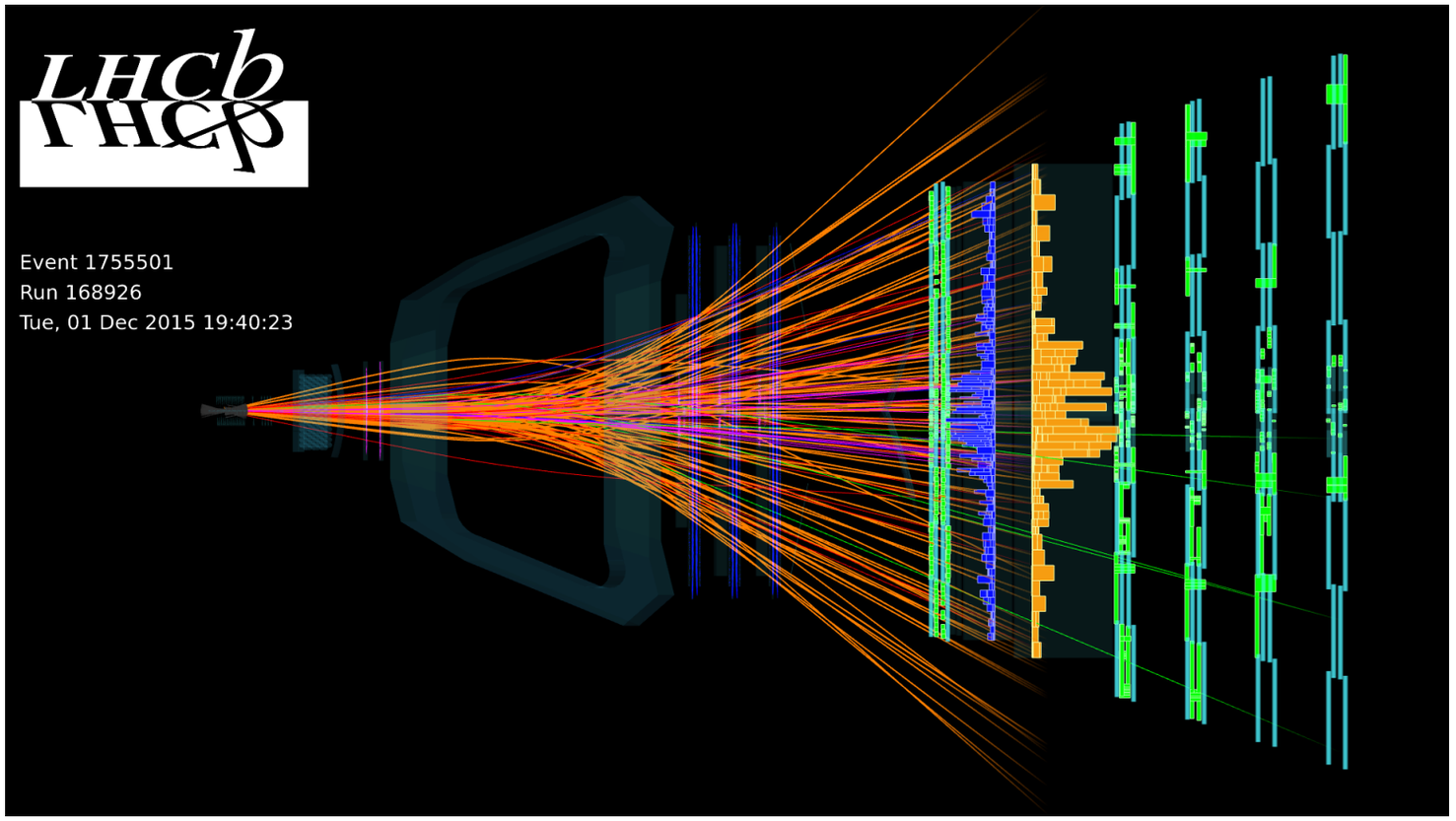
Heavy Ions in LHCb

- LHCb is the only LHC experiment fully instrumented in $2 < \eta < 5$
- p-Pb collisions for two periods:

  2013: $\sqrt{s} = 5\,\mathrm{TeV},\ \mathcal{L} \sim 1.5\,\mathrm{nb}^{-1}$
  2016: $\sqrt{s} = 8\,\mathrm{TeV},\ \mathcal{L} \sim 30\,\mathrm{nb}^{-1}$

- Initial purpose: heavy flavour physics
- Contribution to heavy ion physics
- Remarkable tracking system:
  - Vertex Locator (VELO)
  - Silicon Tracker
  - Outer Tracker
  - Muon System

Event display of a Pb-Pb collision in LHCb



Can characterize charged particles tracks with excellent momentum and impact parameter (IP) resolution:

p: $\Delta p/p = 0.5 - 1.0\%,\ \ \text{for } 0 < p < 200\,\mathrm{GeV}$

IP: $(15 + \frac{29}{p_T\,[\mathrm{GeV}]})\,\mu\mathrm{m}$

for tracks with $p > 2\,\mathrm{GeV}$

Observables

- Nuclear modification factor:

$$\mathrm{R}_{p\mathrm{Pb}} = \frac{\frac{d^2\sigma_{p\mathrm{Pb}}}{dp_T d\eta}}{A\frac{d^2\sigma_{pp}}{dp_T d\eta}}$$

- Incoherent superposition of nucleon-nucleon collisions ⟶ $\mathrm{R}_{p\mathrm{Pb}} = 1$
- In this analysis, prompt charged particle production is studied
- Nucleon-nucleon center of mass system boosted by $y_{cms} = 0.465$
  - Three different observables can be measured in different ranges:

$$\mathrm{R}_{p\mathrm{Pb}}, \quad 1.5 < \eta < 4.5$$

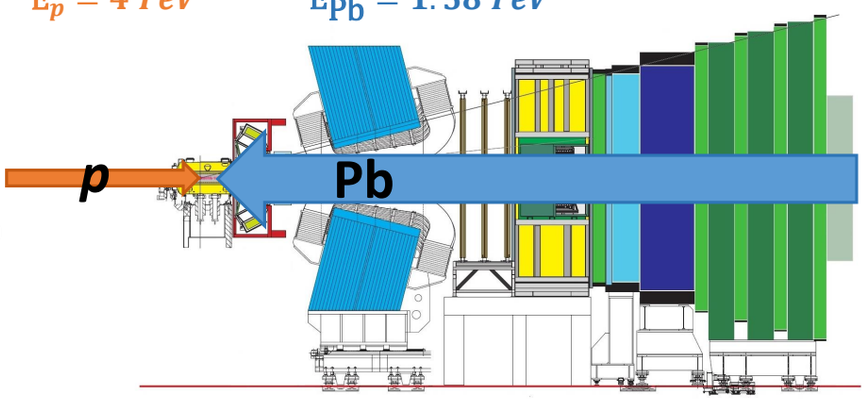
$$\mathrm{R}_{\mathrm{Pb}p}, \quad 2.5 < \eta < 5.5$$

$$\mathrm{R}_{\mathrm{FB}} = \frac{\mathrm{R}_{p\mathrm{Pb}}}{\mathrm{R}_{\mathrm{Pb}p}}, \quad 2.5 < \eta < 4.5$$

***p*+Pb configuration (forward)**

Beam 1: protons $\mathrm{E}_p = 4\ TeV$

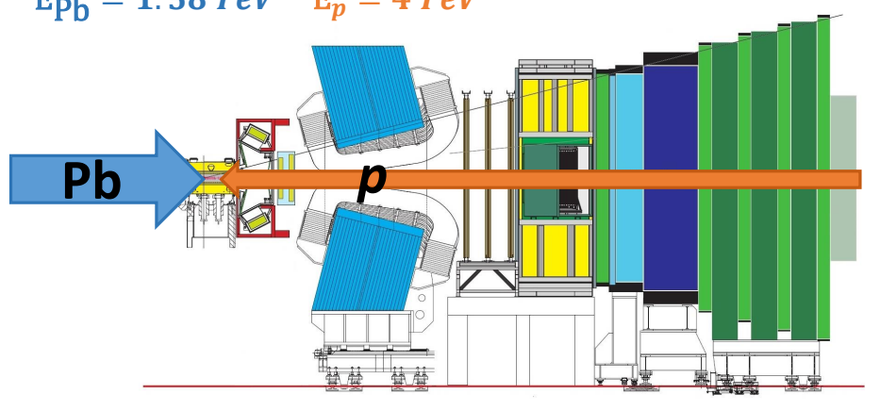
Beam 2: Pb-ions $\mathrm{E}_{\mathrm{Pb}} = 1.58\ TeV$



Pb+*p* configuration (backward)

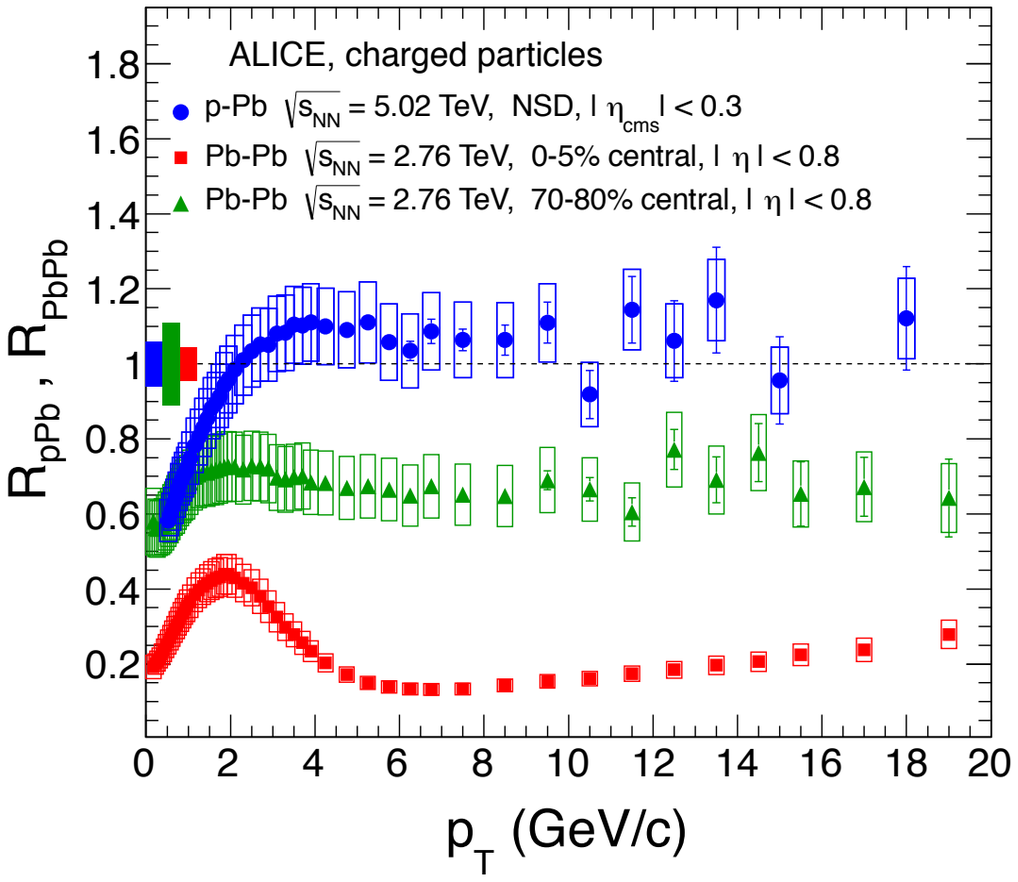
Beam 1: Pb-ions $\mathrm{E}_{\mathrm{Pb}} = 1.58\ TeV$

Beam 2: protons $\mathrm{E}_p = 4\ TeV$

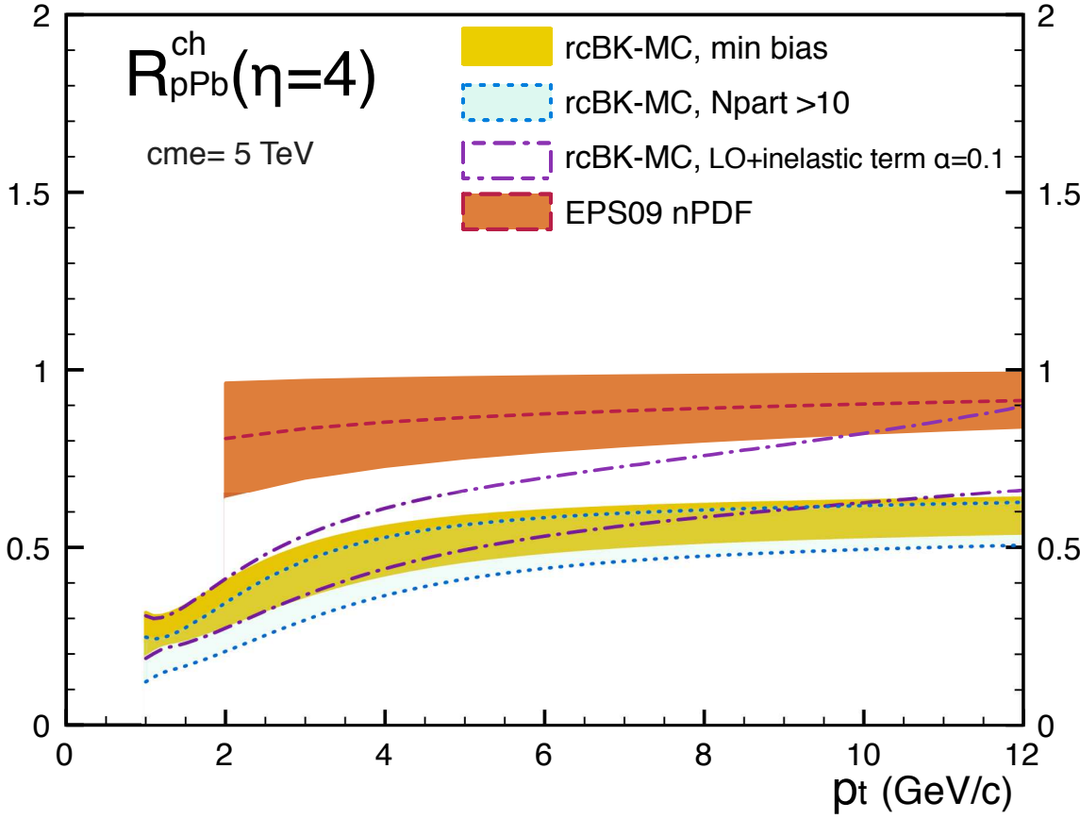


Implications of the analysis

- Charged particle multiplicities can yield information of Cold Nuclear Matter (CNM) effects in p-Pb collisions, revealing the key experimental signatures
- CNM effects are also expected to show in Pb-Pb collisions, thus this measurement acts as baseline
- LHCb can access uncovered phase space regions not accessible by any other experiment



doi:10.1103/PhysRevLett.110.082302



J. L. Albacete, C. Marquet
doi:10.1016/j.ppnp.2014.01.004

Track and Event selection

Event Selection

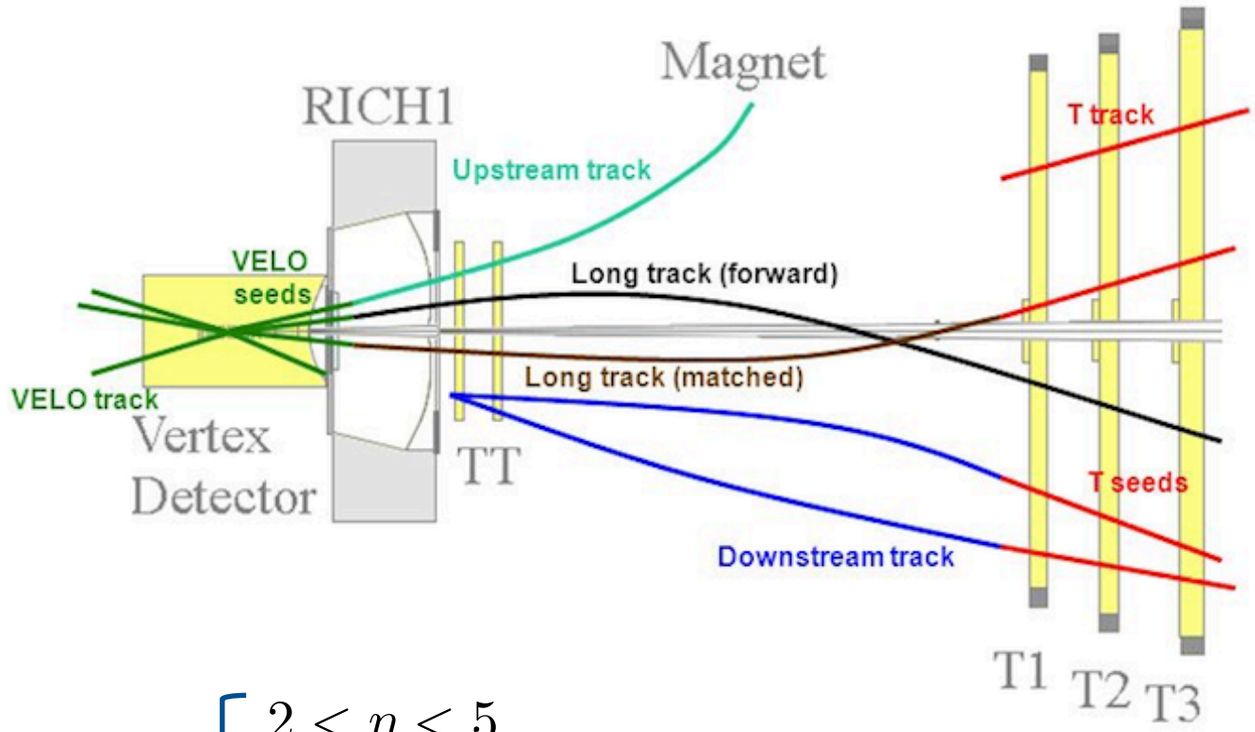
- Minimum bias trigger
- Events with 1 reconstructed Primary Vertex (PV)
- PV position in fiducial luminous region

Track Selection

- Long tracks within fiducial acceptance:

$$2 < \eta < 5$$
$$p > 2\,\mathrm{GeV}$$

- No clone tracks
- Cuts in pseudo impact parameter and ghost probability



Background Sources

- **Fake Tracks**: Not real particles, but reconstruction artifacts
- **Secondary Particles**: Non-prompt particles

General analysis picture

Data
Simulation

Real Data

2013: *p*+Pb/Pb+*p*
2015: *pp*

Simulation

Event Selection

Track Selection

Corrected 3D Multiplicities

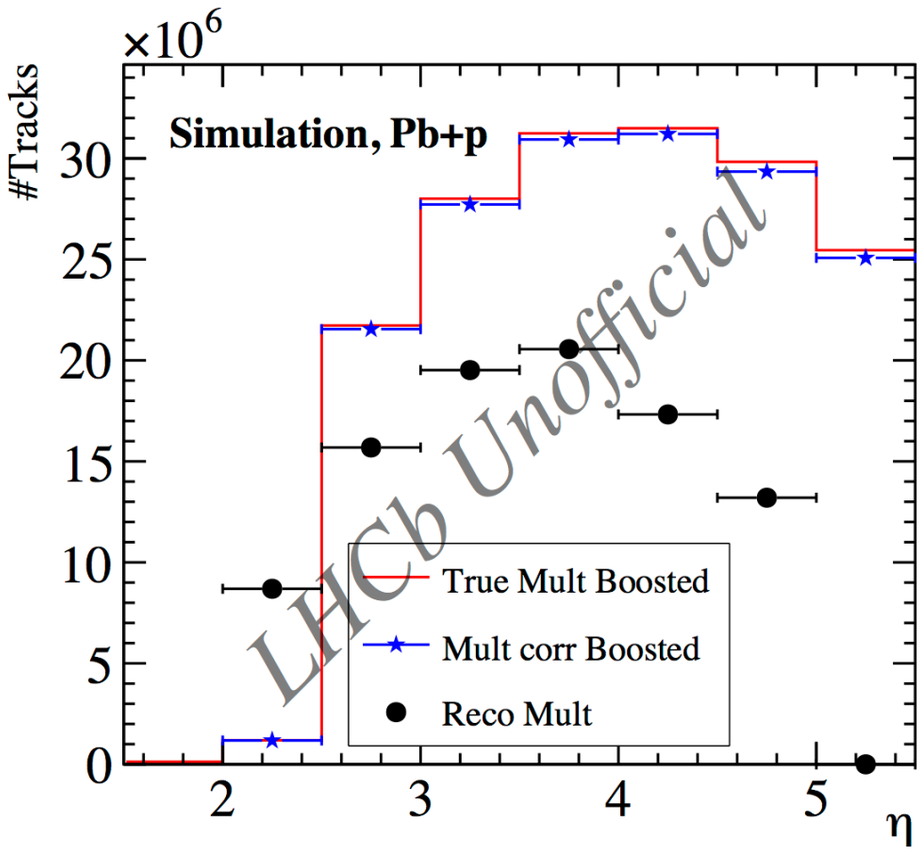
Unfolded Multiplicities

xSection and R_{pPb}

Background estimation
in (p_T, η, #VeloTracks)

Response Matrix
(p_T, η, #VeloTracks)

Boost
y~0.465



Conclusions

- Charged particle multiplicities in p-Pb are essential for the interpretation of CNM effects in Pb-Pb collisions

- The measurement of the R_{pPb} for charged particles is a feasible measurement at LHCb

- We expect to have good impact in the community, considering the unique acceptance covered by the detector

Thanks for your attention!

Backup

Data Samples

Real Data

- Proton-lead data 5 TeV, taken in 2013 in two configurations $\begin{cases} \textit{Backward} & \mathrm{Pb}{+}p;\ \mathcal{L} \sim 0.4\,\mathrm{nb}^{-1} \\ \textit{Forward} & p{+}\mathrm{Pb};\ \mathcal{L} \sim 1.1\,\mathrm{nb}^{-1} \end{cases}$
  - Both samples in two magnet polarities magnet up (MU) and magnet down (MD)
- Proton-proton data 5 TeV , taken in 2015
  - Only MD data

Simulated Data

- Proton-lead
  - Generation with EPOS (Hijing also available)
  - $5{\cdot}10^6$ events/configuration and polarity, fixed to one primary vertex (PV) per event
- Proton-proton
  - Generation with Pythia
  - 10^6 events