Soft Physics of p+Pb and Pb+Pb Collisions from the ATLAS Experiment at the LHC

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- Charged particle centrality, rapidity and p_T distributions in pPb collision data
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- v_2 in the pPb collisions
Phys. Lett. B 725 (2013)
- Event-by-event flow measurements in PbPb
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The ATLAS detector

Inner Detector
 $|\eta| < 2.5$ for the
 charged particles
 reconstruction

Forward
 calorimeters (FCal)
 $3.2 < |\eta| < 4.8$ used
 for the collision
 centrality
 determination

Innermost part of ID, the Pixel detector, most suitable
 for reaching low p_T . Specialized methods developed
 for HI data

- Published result based on pilot pPb run 1ub^{-1} at $\sqrt{s_{NN}}=5.02\text{TeV}$ – September 2012
 - auxiliary pp reference at 2.76 TeV (202 nb^{-1})
 7 TeV (188 nb^{-1}),
 - low luminosity runs
- In multiplicity analysis $p_T \sim 0$ reached thanks to the simplified (efficient at low p_T) two-point tracklets and tracks from the pixel detector
- In spectra full ID tracking used, with very good resolution and efficiency and low fakes used

Centrality determination in pPb

- Centrality determined using FCal ΣE_T in the direction of remnants of the Pb
- All events divided into the classes 1%, 1-5%, .. of events having highest FCal ΣE_T
- Through the model corresponding number of participating nucleons is obtained
 - The Glauber and Glauber-Gribov predictions are compared

In charged particles counting the good control of the efficiencies and fakes is essential

Three independent tracking (with varying efficiency and fakes) used for crosscheck

dN/d η results

The dN/d η grows with centrality, higher on Pb remnant side
 The ratio to the most peripheral removes double peak

dN/dp_T results

- The spectra are measured in the bins of centrality and in the bins of y^* (rapidity in CM)

Nuclear modification factor R_{pPb}

- The pp yields (interpolated from 2.76 and 7TeV pp data) scaled via geometrical models to pPb and used to obtain nuclear modification factor

- The heavy ion collisions are considered to create QGP which manifests itself in azimuthal correlations of charged particles
- Patterns similar to the pp (ridge) and PbPb collisions have been observed in pPb
- Customarily they are characterized by the Fourier expansion:

$$dN = 1 + \sum_{n=1} v_n \cos n(\phi - \Psi_n)$$
- The v_2 of the azimuthal distributions has been measured by ATLAS

- The v_2 is measured using cumulants method
- The cumulants $c_2\{2\} > 0$ and $c_2\{4\} < 0$ allows for calculation of the $v_2\{2\}$ and $v_2\{4\}$

The $v_2(p_T)$ in classes of centrality

As expected the $v_2\{2\} \gg v_2\{4\} \rightarrow$ significant two particle correlations (non-flow)

Stability of the $v_2\{4\}$ with centrality suggests fluctuations as the source of the flow

- The v_n coefficients has important impact on the verification of the hydrodynamic modeling of QGP
- The historically first interpretation of the v_2 as a proxy to the elliptic collision shape $\rightarrow$ v_n are sensitive mainly to the eccentricity fluctuations in PbPb collisions
- In order to shed a light into this subject direct measurements of the $p(v_n)$ are performed by ATLAS experiment

Sufficiently high multiplicity allows “to see” the flow in an event basis

$$\mathbf{p}(\vec{v}_n) \rightarrow \mathbf{p}(v_n) \rightarrow \mathbf{p}_{\text{true}}$$

- For every event the $\vec{v}_n$ can be calculated
 $v_n[\langle \sin n\phi \rangle, \langle \cos n\phi \rangle]$
 - It is smeared around the direction established by the reaction plane in Gaussian manner $\mathbf{p}(\vec{v}_n)$
 - Due to the azimuthal symmetry of the 2D $\rightarrow$ 1D transformation can be made
- Smearing due to limited multiplicity removed by the detector driven unfolding

The fluctuations as a source of the azimuthal anisotropies

The $p(v_n)$ for $n > 3$ consistent with scenario that the fluctuations give raise to these anisotropies

Detailed comparison to MC

The initial eccentricities $p(\epsilon_2)$ from MC (Glauber & MC-KLN) are compared to the $p(v_2)$ – only central collisions are well described - $p(v_3)$ & $p(v_4)$

- The pPb spectra, rapidity and centrality dependences were measured
 - the fluctuations has to be noted as an important component in understanding the relation between centrality and number of participants
- The initial geometry, or fluctuations of thereof, give raise to azimuthal anisotropy of the N_{ch} distribution
- The origin of the flow coefficients in PbPb collisions has been pinpointed to be due to the initial reaction region fluctuations, except v_2 which is sensitive to the average collision geometry
 - none of the tested MC models describes data across centrality range 0-80% neither does tails of the $p(v_n)$

Fluctuations .vs. initial geometry influence

The $\sigma_{v_n}/\langle v_n \rangle$ in the absence of average collision geometry influence ~ 0.52

geometry+

fluctuations

- $p(v_3)$ comparison to MC eccentricities

- $p(v_4)$ comparison to MC eccentricities

- The Glauber-Gribov assumes fluctuations of the σ_{NN} cross-section from event to event, steered by the Ω parameter
- It is inserted into the Glauber simulation and results in different probability of collision involving N participants

Comparison of the pPb and PbPb $v_2(p_T)$

- The comparison is made taking most peripheral and most central PbPb data