Study of hard processes in heavy ion collisions at ATLAS

IMPRS EPP Selection Workshop

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Quark-Gluon Plasma (QGP)

- Exotic phase of matter with quarks and gluons as relevant degrees of freedom
- Existed in very early stages of our Universe ($\approx \mu\mathrm{s}$ after Big Bang)
- Opportunity to study the strong nuclear interaction in extreme conditions
- Very high temperatures and energies needed ($\approx 10^{12}\ \mathrm{K}$)

How to create these conditions in terrestrial laboratory?

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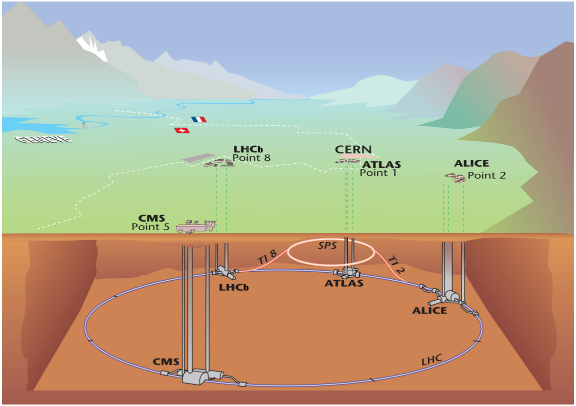
Heavy ion collisions at particle accelerators

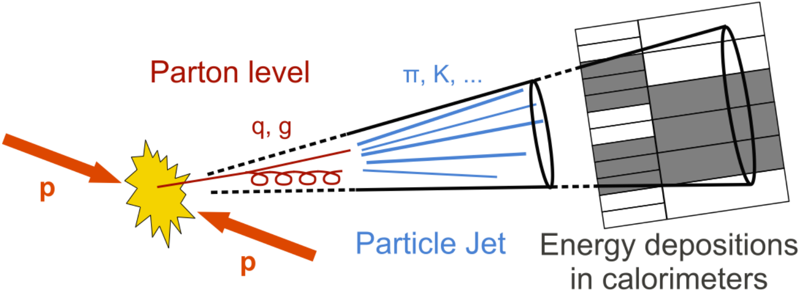
Large Hadron Collider



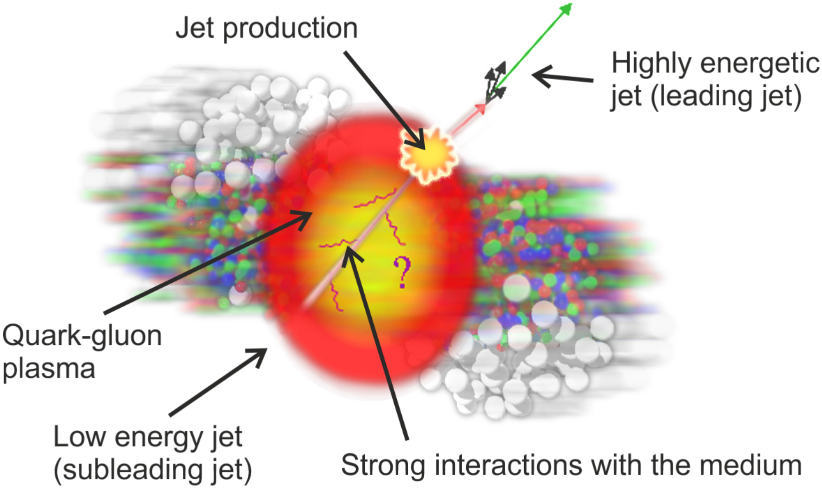
- 4 main detectors at interaction points (ATLAS, CMS, ALICE, LHCb)
- Mainly p+p collisions but couple of weeks per year also p+Pb, Pb+Pb

Study of QGP

- Heavy ion collisions
  - conditions to create QGP
  - tools to study QGP
- Jets - cone shaped streams of particles emerging from collisions at high energies (usually two jets with $\Delta\phi = 180^{\circ}$)

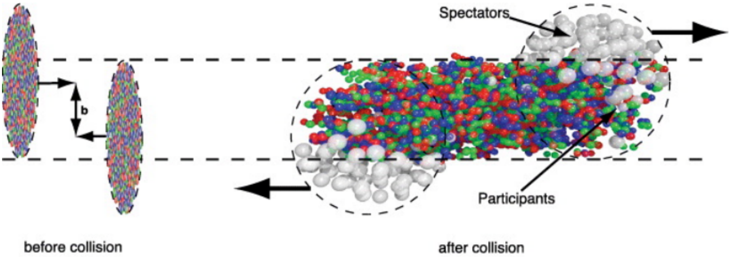


Jet Quenching



Centrality of Pb+Pb Collision

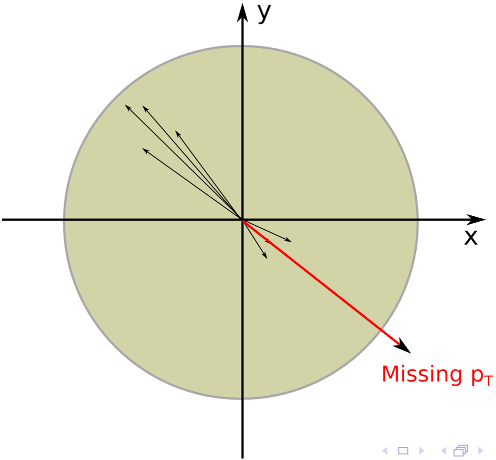
- Impossible to directly measure impact parameter b



- Centrality - measure of overlap of the two colliding nuclei
- More central (head-on) collisions $\rightarrow$ higher probability of QGP creation
- At ATLAS determined according to energy deposited in FCal
- Quoted in terms of percentiles of total Pb-Pb cross section, e.g. $0-10\%$, $10-20\%$, … $90-100\%$.

Missing Transverse Momentum p_{T}

- Conservation of momentum: $\mathbf{p}_{\mathrm{T}} = \sum_{i=0}^{N} \mathbf{p}_{\mathrm{T},i} = \mathbf{0}$
- Missing p_{T}: $\not{\mathbf{p}}_{\mathrm{T}} \equiv -\sum_{i=0}^{N} \mathbf{p}_{\mathrm{T},i} = -\mathbf{p}_{\mathrm{T}}$

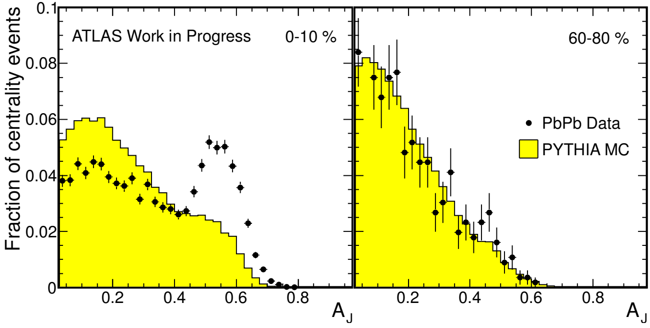


Experimental analysis

- Following samples of data have been analysed
  - Truth Monte Carlo - PYTHIA MC on particle level (no detector)
  - Reconstructed Monte Carlo - PYTHIA MC with Geant4 simulation of ATLAS
  - Real data taken by ATLAS in 2011
- COM energy per nucleon $\sqrt{s_{\mathrm{NN}}} = 2.76\ \mathrm{TeV}$
- Event selection conditions: $E_{\mathrm{T}1} > 100\ \mathrm{GeV}$, $E_{\mathrm{T}2} > 25\ \mathrm{GeV}$, $\Delta\phi > 2/3\pi$
- Effects taken into account
  - Effectivity of tracking detector
  - Fake jets
  - Misindetification LJ $\leftrightarrow$ SJ

Asymmetry Distribution

- Dijet asymmetry – $A_{\mathrm{J}} = \frac{E_{\mathrm{T1}} - E_{\mathrm{T2}}}{E_{\mathrm{T1}} + E_{\mathrm{T2}}}$
- left – high centrality, right – low centrality

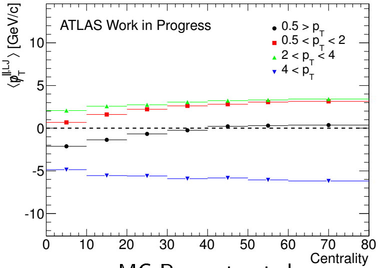


- More central → bigger discrepancy between MC and data

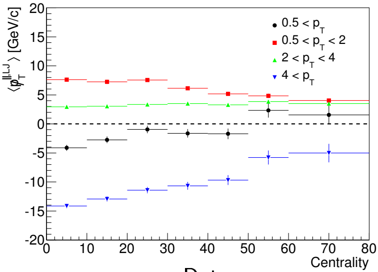
Monte Carlo vs. Data

Projections as a function of centrality

- Mean values of scalar projections of $\not{p}_{\mathrm{T}}$ on LJ axis



MC Reconstructed



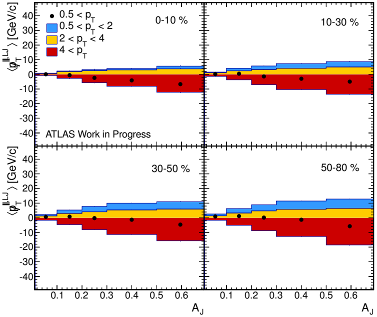
Data

- In data we observe decrease in yield of hard particles in SJ compensated by increased yield of soft particles in SJ
- Effect stronger for central collisions
- In MC only slight centrality dependance (detector and reconstruction effects)

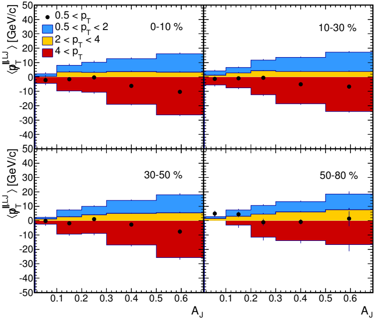
Monte Carlo vs. Data

Projections as a function of A_J

- Dijet asymmetry – $A_J = \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}$



MC Reconstructed

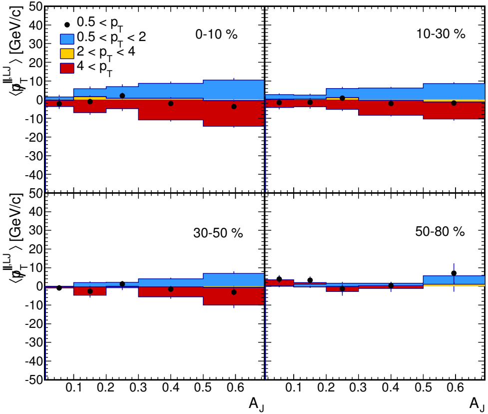


Data

- Imbalance increases with increasing A_J
- To get rid of detector effects – do the difference of Data and MC

Data minus MC Reconstructed

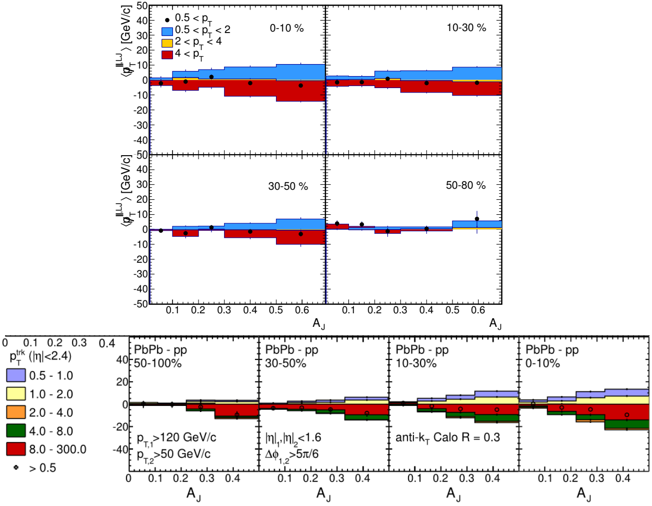
Projections as a function of A_J



- Observed centrality dependance is now coming only from jet quenching
- Central collisions exhibit bigger difference

Comparison With CMS Results

Projections as a function of A_J



CMS PAS HIN-14-010

Conclusions

- A strong increase in the fraction of highly unbalanced jets has been seen in central Pb-Pb collisions compared with peripheral collisions and model calculations
- A strong increase of yields of highly unbalanced dijets has been shown to be correlated with an increase of production of soft particles associated with the strongly quenched subleading jet
- We hope these results will provide a qualitative and quantitative insight into the transport properties of the medium created in heavy-ion collisions
- Good agreement with previously published results by CMS

Presentation

- (Preliminary) results presented at 18th Conference of Czech and Slovak Physicists
- Final results presented to the ATLAS Heavy Ion working group at CERN
- Currently undergoing transformation into ATLAS internal note

Thank you for attention!

Questions?