Hard Probes in PbPb collisions with CMS

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on behalf of the CMS Collaboration

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Hard processes in vacuum:
- Well understood by pQCD
- Measured in pp collisions

What happens to the final state, in the hot and dense medium?

Jets
Photons
Z^0
W^±
Quarkonia (Prompt and Non-Prompt)

Hadrons
arXiv:1202.2554


Jets
Photons
Z^0
W^±
Quarkonia (Prompt and Non-Prompt)

Hard processes in QCD medium
No significant effects on the initial state, by color-neutral probes
Charged hadron production at high-p$_T$ is suppressed → Jets are quenched!
Jet measurements

Calorimeter clusters and tracks are matched and combined to obtain most detailed information of particles in the event (Details: CMS-PAS-HIN-11-004)
Estimated background is subtracted from each calorimeter segmentation
Lessons from 2010 LHC data

- Very asymmetric in energy!
- No angular decorrelation
- Energy distributed over large range


- Fragmentation of jets unmodified

CMS-PAS-HIN-11-004
Data sample of 2011

150 $\mu$b$^{-1}$ ~ 20 times more data than in 2010!!!
Able to perform same measurements differentially in $p_T$

Yetkin Yilmaz (MIT)              Hard Probes in PbPb with CMS
Background fluctuations supersede the recoil jet more often in data.

Correlation peak is the same in data and Pythia across all values of $p_T$.

No significant angular decorrelation of dijets.
At high $p_T$, only very few jets get completely lost on the away side.

- Background amount enhanced with quenching

- However, very little at high $p_T$
Dijets in PbPb are more imbalanced than Pythia at all bins of leading jet $p_T$.
Energy loss apparent at all jet $p_T$.

Reference itself has an increasing trend.

No significant dependence on jet $p_T$.
Conclusions

Enhanced imbalance exists at all $p_T$

No angular decorrelation

The fraction of the energy that a jet loses does not dramatically change with jet $p_T$
Back up
The CMS Detector
Leading jet momentum dependence

Dijets in PbPb are more imbalanced than Pythia at all bins of leading jet $p_T$. 
Fragmentation of jets

Structure of reconstructed jets resemble those that were produced in vacuum
No additional hard radiation inside the jet (CMS-PAS-HIN-11-004)
Jet Measurements

Lots of underlying event activity:

\[ \frac{dN}{d\eta}(\eta=0) \sim 2000 \]

Local fluctuations from semi-hard interactions

Depends on collision centrality
Jet Measurements

Background estimated for each calorimeter ring of constant $\eta$

The background estimation is re-iterated after excluding the jets found in the first iteration
Jet Measurements

After the background subtraction, some higher local fluctuations remain (fake jets)

The fluctuations also deteriorate the jet resolution in central events

→ Important to represent these fluctuations well in simulated reference
PbPb event simulations with Hydjet 1.8

• Hydjet 1.8 default tune successfully reproduces:
  • Charged hadron multiplicity
  • Charged hadron $p_T$ spectrum
  • Azimuthal asymmetry of low-$p_T$ particles (Elliptic Flow)

• Pythia dijet events are mixed with the Hydjet sample at the same vertex

http://lokhtin.web.cern.ch/lokhtin/hydro/plots
Centrality

More peripheral \( \leftarrow 70-100\%, 50-70\%, 30-50\%, 20-30\%, 10-20\%, 0-10\% \rightarrow \) More central

\( N_{\text{part}} \): Number of participating (overlapping) nucleons in event

\( N_{\text{coll}} \): Number of binary interactions in event

Transverse energy in the forward calorimeter is correlated to \( N_{\text{part}} \)

Rare probes exhibit a bias towards central events (\( N_{\text{coll}} \) scaling)
Jet Measurements

Combining various subdetectors provides strong tools for analysis of jets. Low $p_T$ efficiency is important for unbiased measurement.
The global event properties are modified with the existence of quenching.

The missing energy is found at large angles from the jet axis.
Isolated Photons in 2010 data

- Isolation with event by event UE subtraction (R = 0.4)
- Background shower shape estimated from isolation sideband