Direct photon and photon-jet measurement capability of the ATLAS experiment at the LHC

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on behalf of the HI ATLAS collaboration
EM calorimeters of the ATLAS detector

- Jet reconstruction with calorimeters covered full $\phi$ and large $\eta$ domains.
- First finely segmented layer of LAr EM calorimeter together with ID provides photon identification & isolation, other layers also well segmented.

Longitudinally segmented calorimeters provide jets and neutral clusters for $|\eta|<5$.
Photons are identified for $|\eta|<2.4$ with 3 layers strips $\Delta \eta=0.003-0.006$.
Good quality as for energy and spatial resolutions and for linearity (below 0.5% up to 300 GeV) as well.
Direct photons

*Compton*  

*Annihilation*

Prompt photons detected at hadron colliders provide a tool to test pQCD and to constrain parton distribution function.

High transverse momenta photons signal for many signatures: Higgs via $\gamma\gamma$ decays, SUSY and exotic particles searches.

In case of heavy ion collisions at the LHC, analysis of jets tagged by prompt $\gamma$ are a direct tool to learn on jet energy loss in formed QGP.

HI runs will begin next month with PbPb collisions at $\sqrt{s_{NN}}=2.75$ TeV with 4 weeks for physics at luminosity starting at $10^{25}$ toward to max rate of 160 Hz and expected integral luminosity on level of 3 $\mu$b$^{-1}$.

Event rates of process ($\sigma$ around 10 nb) available in the run are expected as few thousands for photon transverse energy above 30 GeV with statistically significant tail around 100 GeV.
Problems to extract prompt photons are caused by presence of huge background coming from $\gamma$ decays of light mesons (mainly, $\pi^0$ and $\eta$) and photons produced during fragmentation. Ability of the ATLAS setup to distinguish direct photons from decayed ones is a fine longitudinal segmentation in first layer of EM calorimeter.
Direct photons identification performance

HIJING events as a background with PYTHIA embedded signal events show that in domain of (40-50) GeV the neutral hadron spectrum falls below direct. S/B ratio depends on choice of $R_{AA}$ for instance, $S/B=5$ ($R_{AA}=0.2$) for 100 GeV photons

Expected photon reconstruction and identification efficiency vs true photon transverse energy, as obtained from simulated prompt photons in $\gamma$-jet events with different selections
Medium of heavy ion collisions is transparent (in term of strong interactions) to photons so produced jets can be calibrated with photon measured. Another feature, (mostly) back-to-back topology, of γ-jet system constrains event selection and is able to suppress a background in jet search algorithm and to increase efficiency as well.

Jet energy scale is derived from photon measurement, appropriate jet algorithm to study internal structure of jets produced in heavy ions - jet energy spectra and resolution, jet shapes, jet quenching etc.

Event-by-event jets in ATLAS are reconstructed over |η|<5 domain with usage of anti-kt jet searching algorithm.
The uncorrected jet shape measured for all jets with $p_T > 60$ GeV, using calorimeter clusters for anti-$k_T$ jets with $R=0.6$

But heavy ion collisions include together with hard-scattered jets a large, fluctuating background coming from underlying interactions.

A procedure has to be developed in order to take background into account when searching for a jet and to reject fakes due to sizeable fluctuations in underlying interactions.

Also the background will influence jet reconstruction efficiency as on energy and spatial resolutions of calorimeters and on tracking devices as well.
EM calorimeters from pp to HI

**ATLAS Preliminary**

\[ \sigma(E) = \frac{p_0}{\sqrt{E}} \oplus \frac{p_1}{E} \oplus p_2 \]

**pp**

***noise term***

**PbPb, b=2fm, dN/d\eta ~2700**

**Permanent and fluctuated UE background leads to “noise” term on level of 15 GeV for most central events**

**More accurate calculations have to be done when first data resolve problem on multiplicities vs centrality and simulation is then tuned**
Jet reconstruction

Jet reconstruction efficiency shows stability under accompaniment of underlying interactions with different centralities of HI collisions.

Energy deposition in 0.1 (\(\Delta \phi\)) \(\times\) 0.1 (\(\Delta \eta\)) towers of electromagnetic and hadron calorimeters.

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Direct \(\gamma\) and \(\gamma\)-jet measurement capability of the ATLAS
Jet shape resolution

ATLAS is able to resolve different jet shapes

Quenching leads to enhancement of small transverse momentum particles (low z) while higher z particles are suppressed
In conclusion, ATLAS is fully operational, ready to take and analyze data, including study of \( \gamma \)-tagged jets in HI collisions.

Thanks for your attention.
EM calorimeters and ID of the ATLAS detector

**LAr/Pb sampling calorimeter w/ accordion geometry**
- 3 longitudinal layers with cell of
  \[ \Delta \eta \times \Delta \phi : (0.003-0.006) \times 0.1 \text{ (1\textsuperscript{st} layer)}, \ 0.025 \times 0.025 \text{ (2\textsuperscript{nd} layer)}, \ 0.050 \times 0.025 \text{ (3\textsuperscript{rd} layer)} \]
- Presampler w/ cell \( \Delta \eta \times \Delta \phi \approx 0.025 \times 0.1 \text{in } |\eta| < 1.52, \ 1.5 < |\eta| < 1.8 \)
- \( \sigma(E)/E = (10-17\%) \ (\eta) / \sqrt{E} \geq \text{(GeV)} + 0.7 \%

**Inner Detector (ID) in 2 T solenoidal B-field**
- Pixel: 3 barrels + 2 x 3 disks
  \[ \sigma_{r\phi} \approx 10 \ \mu\text{m, } \sigma_z \approx 115 \ \mu\text{m} \]
- SCT: 4 barrels + 2 x 9 disks
  \[ \sigma_{r\phi} \approx 17 \ \mu\text{m, } \sigma_z \approx 580 \ \mu\text{m} \]
- TRT: 73 layers (barrel) + 2 x 160 layers (endcap)
  \[ \sigma_{r\phi} \approx 130 \ \mu\text{m (barrel)} \]

\( |\eta| < 2.5 \) (TRT: \( |\eta| < 2.0 \))