Jets and photon + jets measurements with ATLAS and CMS experiment

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Introduction

- Motivation:
  - Jets and photons:
    - Testing ground for perturbative QCD.
    - Good probes for the content of the proton
    - Could lead to new physics / help constrain model
  - Measurements presented in this talk:
    - Jets:
      - Transverse energy decorrelation and strong coupling constant determination with multijet event (8 TeV) ATLAS
      - Dijet azimuthal decorrelation (8 TeV) ATLAS
      - Azimuthal correlation for 2-,4-jets (13 TeV) CMS
      - Azimuthal separation in back to back multijet topologies (13 TeV) CMS
    - Photon + jet:
      - Photon + jet (13 TeV) ATLAS and CMS
      - $Z^{\pm jet}$ (8 TeV) CMS
      - $\gamma + jet$ (7 TeV) CMS
      - Photon + heavy flavour jet ATLAS
Reconstruction performances: Jets

Jet energy resolution (JER) from CMS (left) and ATLAS (right)

- Both resolution $\rightarrow \approx 10\%$ for 100 GeV jets.
- Uncertainties on calibration: from 2\% to sub-percent level for ATLAS and CMS

Reconstruction performances: Photons

- Photon energy resolution from CMS (left) and ATLAS (right)
- Energy resolution at percent level.
Measurement to particle level: unfolding

- Measurement are corrected back to particle level.
- Matrix iterative or inversion based methods. (Tunfold, d'Agostini iteration ...)
- Transfer matrix from particle level to reconstructed level is used.
- Uncertainties obtained from different MC
Determination of $\alpha_s$ from transverse energy correlations in multijet events $8\text{ TeV}$: ATLAS (Eur.Phys.J. C77 (2017) no.12, 872)

- Use of quality jets
- Cut and count analysis
- TEEC function distribution
- Good description from Pythia and Sherpa
- Disagreement from Herwig++
Determination of $\alpha_s$ from transverse energy correlations in multijet events 8 TeV: ATLAS

- ATEEC function distribution
- Good description from Pythia and Sherpa
- Disagreement from Herwig++
Determination of $\alpha_s$ from transverse energy correlations in multijet events: ATLAS

- Value of $\alpha_s$ obtained with TEEC and ATEEC functions.
- Good agreement with world average.
- Measurement limited by theoretical scale uncertainties (TEEC $\approx 6\%$, ATEEC $\approx 4\%$)
Dijet azimuthal decorrelation and determination of $\alpha_s$: ATLAS (Phys.Rev. D98 (2018) no.9, 092004)

- Use of quality jets
- Cut and count analysis
- Good description of $R_{\Delta \phi}$ with NLO pQCD
Dijet azimuthal decorrelation and determination of $\alpha_s$: ATLAS (arXiv:1805.04691 [hep-ex])

$\alpha_s$ from a $\chi^2(\alpha_s)$ minimization

Good agreement with world average.
Azimuthal correlation for 2jets: CMS (arXiv:1902.04374 [hep-ex])

- Tight jet selection
- Cut and count analysis
- Double differential measurement vs $y$ and $p_T$
- Data / MC ratios depend on generators
- Best agreement for Madgraph
Azimuthal correlation for 4-jets : CMS

Best agreement for Madgraph
Azimuthal separation in back to back 2-jets topologies: CMS (arXiv:1712.05471 [hep-ex])

- Cut and count analysis on Multijet events.
- Good agreement with Madgraph
- Deviations up to 10% for other generators
Azimuthal separation in back to back 3-jets topologies: CMS (arXiv:1712.05471 [hep-ex])

- Good agreement with Pythia and Herwig
- Deviations up to 10% for MadGraph
$\gamma + jet$ differential cross section measurement (13 TeV)

- Measurement performed by ATLAS and CMS
- Include direct photons and fragmentation photons.
- Differential cross section vs kinematic variables is a powerful testing tool.
- Main background: Jet reconstructed as photon in Multijet events.
- Data driven estimation of the background in both analysis: two methods
Event yield obtained by a background subtraction methods on isolation and photon identification areas.
\( \gamma + \text{jet} \) differential cross section measurement: ATLAS (Phys. Lett. B 780 (2018) 578)

- LO prediction: good agreement with Sherpa prediction
\( \gamma + \text{jet} \) differential cross section measurement: ATLAS

Comparison to NLO prediction: reasonable agreement with Jetphox
$\gamma + \text{jet}$ differential cross section measurement: CMS (EPJC 79 (2019) 20)

- Event yield extracted with a fit on BDT discriminant.
\( \gamma + \text{jet} \) differential cross section measurement: CMS

Comparison to NLO prediction: reasonable agreement with Jetphox.
\( \gamma + \text{jet} \) double differential cross section measurement: CMS

-Comparison to NLO prediction: reasonable agreement with Jetphox.
\[ \gamma + jet \] differential cross section measurement : results

- Both measurements are in agreement with JETPHOX predictions.
- NLO prediction describe well data within uncertainties
- PDF set used does not affect a lot data description
\( \frac{Z+\text{jets}}{\gamma+\text{jets}} \) cross section ratio measurement (8 TeV) : CMS (JHEP 1510 (2015) 128)

- Test of SM
- Background in New physics search
- \( Z + \text{jet} \) and \( \gamma + \text{jet} \) treated independently.
- Event yield: \( Z + \text{jet} \) BKG substraction; \( \gamma + \text{jet} \) fit on isolation variable

Results for 1 jet
Cross section ratio measurement (8 TeV): CMS

Results for 2 and 3 jets
\( \frac{Z^{+} \text{jets}}{\gamma^{+} \text{jets}} \) cross section ratio measurement (8 TeV) : CMS

- MADGRAPH + PYTHIA 6 LO generator overestimate data by a factor of 1.21
- BLACKHAT NLO generator overestimate data by a factor of 1.18
- Shapes well modelised
\( \gamma\gamma + \text{jets} \) differential cross section measurement (7 TeV) : CMS (arXiv:1405.7225 [hep-ex])

- Select event with two good photons
- Signal yield extracted from template fit.
- Measurement for 1 or 2 jets
- Good agreement with LO and NLO predictions

- Direct probe of proton flavour composition.
- Select good $\gamma + \text{jet}$ events
- Use MV1 discriminator for selecting events enriched in c- and b-jets
- Background subtraction to access event yield.
γ + HF-jets differential cross section measurement (8 TeV) : ATLAS

- γ + b-jet cross section
- good agreement with SHERPA LO predictions
- NLO best agreement with PDF 5F massive scheme
\( \gamma + \text{HF-jets} \) differential cross section measurement (8 TeV) : ATLAS

- \( \gamma + \text{c-jet} \) cross section
- Similar agreement with LO and NLO predictions.
- Various PDF’s used for comparisons.
Conclusion

- ATLAS and CMS produced numerous SM physic results with jets or photon with jets topologies
- Precious comparisons with various generators and PDF sets
- Intrinsic interest as measurements and needed for other analyses (both precision measurements and NP searches)
- We enter the precision era where more and more data will allow us to reduce statistical uncertainties and probe rarer SM processes.
TEECE function: \[ \frac{1}{\sigma} \frac{d}{dcos\phi} = \frac{1}{N} \sum_{A=1}^{N} \sum_{ij} \frac{E_{T,i}^A E_{T,j}^A}{\sum_{k} E_{T,k}^A} \delta(\cos\phi - \cos\phi_{ij}) \]

ATEECE function: \[ \frac{1}{\sigma} \frac{d}{dcos\phi} \sum_{\text{asym}} = \frac{1}{\sigma} \frac{d}{dcos\phi} |\phi| - \frac{1}{\sigma} \frac{d}{dcos\phi} |\pi - \phi| \]