First measurement of ɣ+b production cross sections in pp collisions using the ATLAS detector

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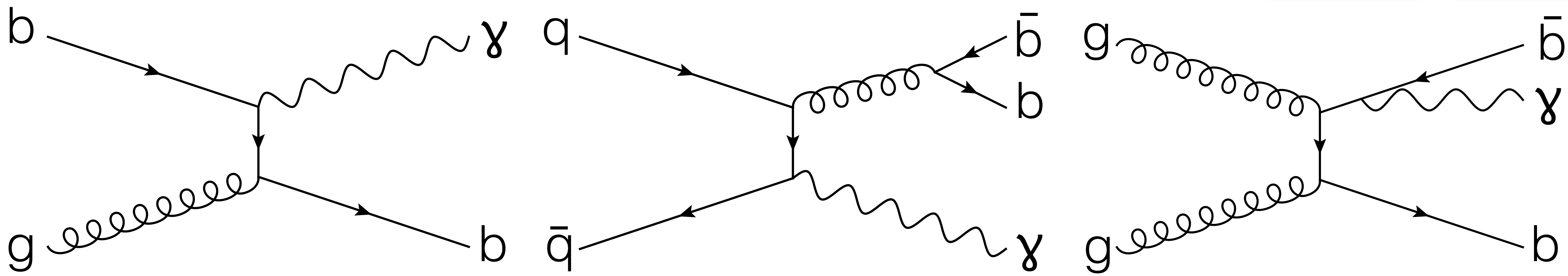
WNPPC 2018

15-18 February 2018

Physics Motivation



- The photon does not hadronize
  - Unique probe to test perturbative QCD predictions
- γ+b production
  - Sensitive to b quark content of the proton
  - Test modelling of b quarks in Monte Carlo generators
- D0 and CDF at Tevatron have measured differential cross sections of γ+b as a function of photon E_T^{γ}
  - Tevatron is a $p\bar{p}$ collider (valence antiquarks present)
  - Higher sensitivity to the b quark content of the proton at LHC

Tevatron γ+b Measurements

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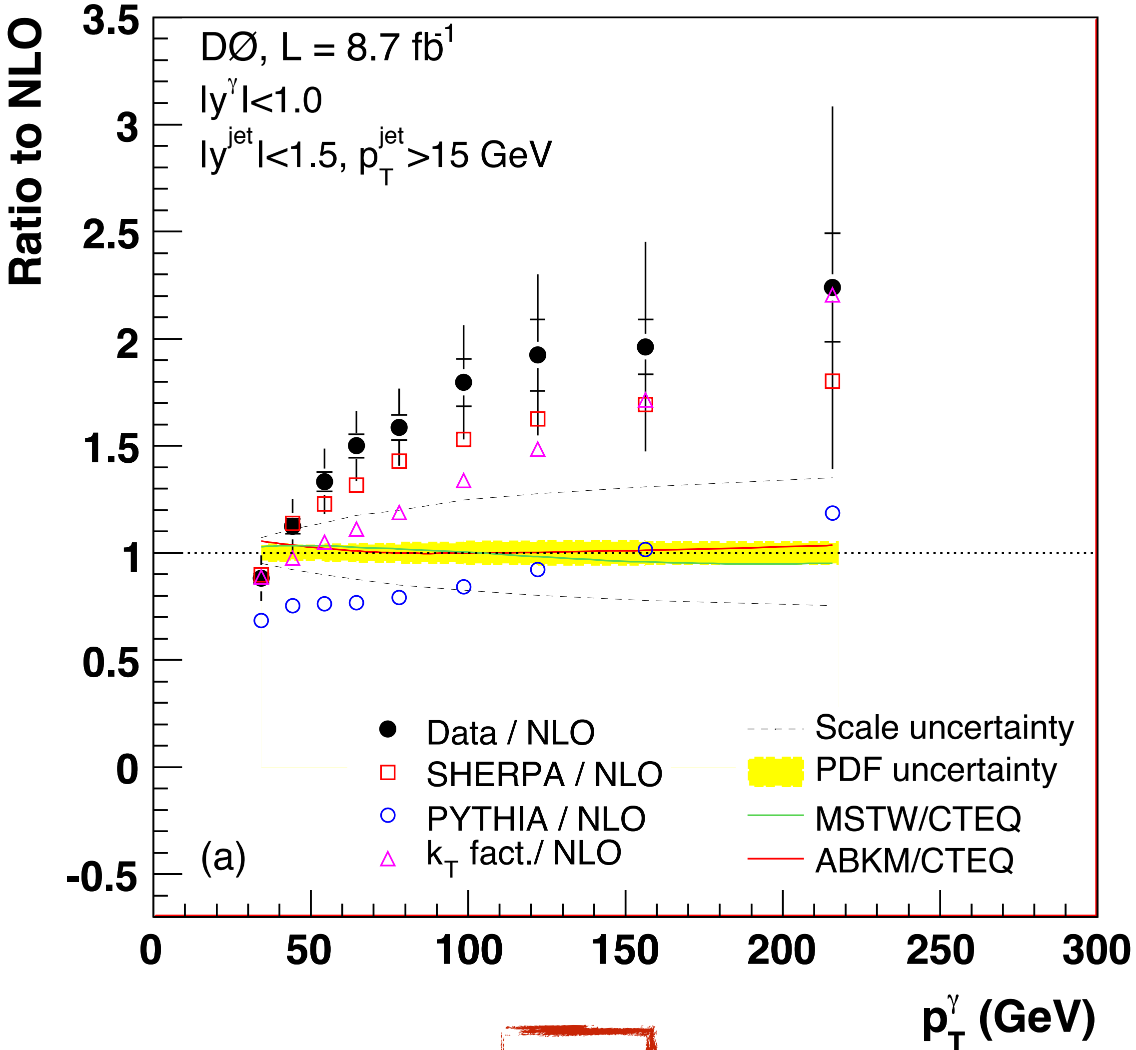
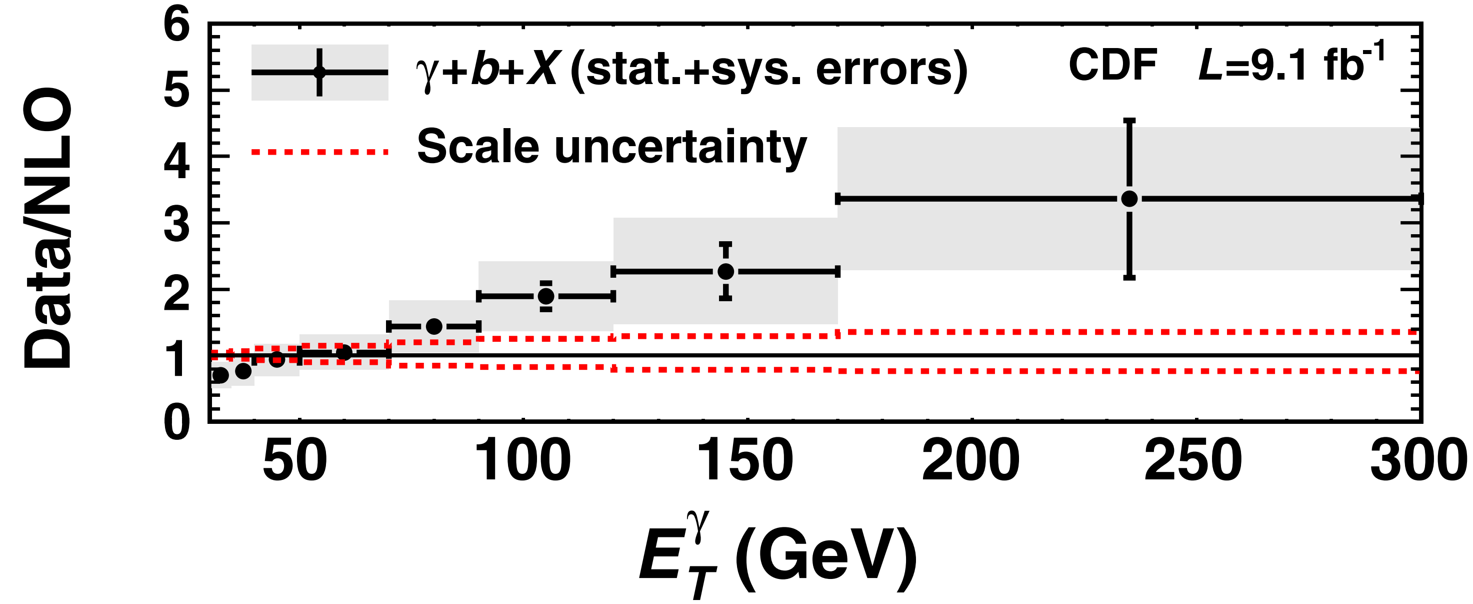


D0

Phys. Rev. Lett. 111, 042003



CDF

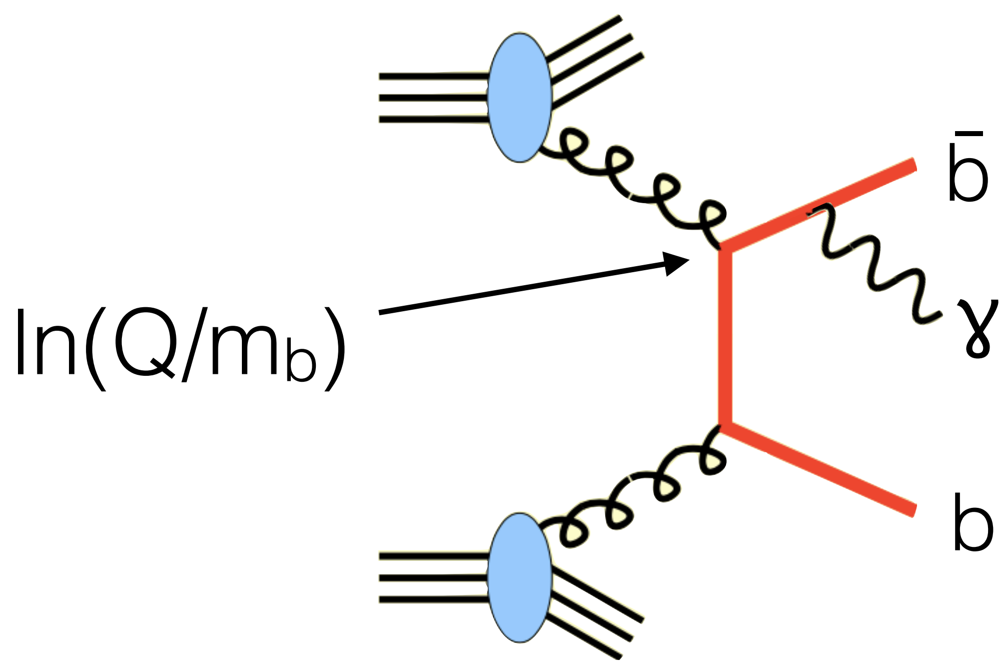
- NLO predictions tend to underestimate data at high E_T^{γ}
  - Data and NLO prediction uncertainties are ~20%
- Level of agreement depends on the modelling of the b quark

Calculation Flavour Schemes

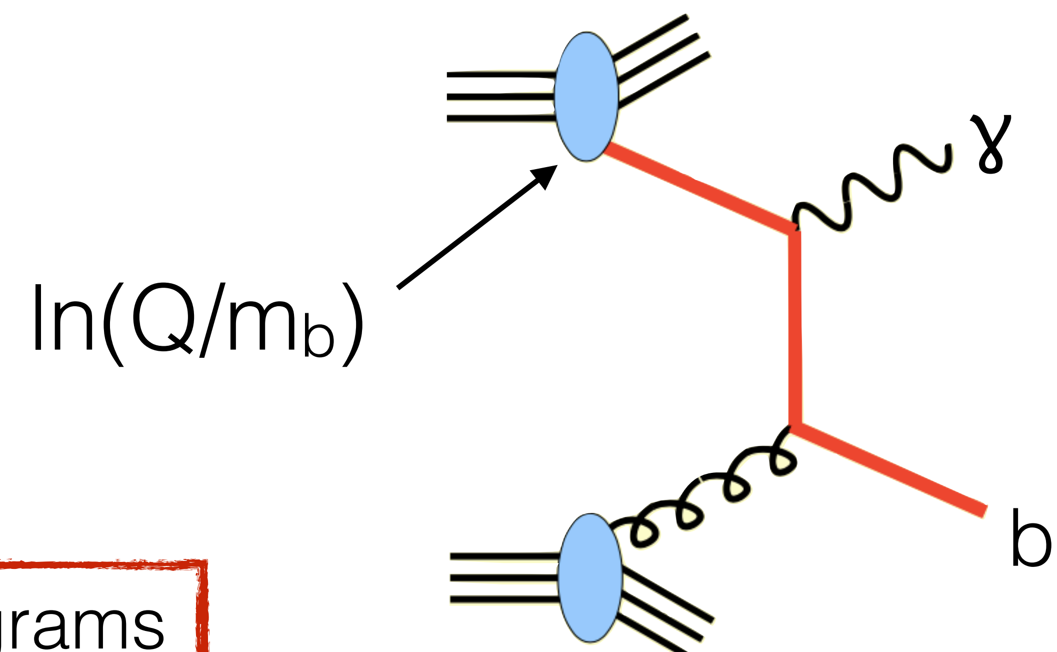
$m_b \gg \Lambda_{QCD}$

⇒ can include m_b in perturbative calculations

- 4-flavour scheme
  - $m_b \neq 0$
  - No b quarks in the proton
  - Logarithms included in the matrix elements
  - A priori good for energies $Q \approx m_b$
- 5-flavour scheme
  - $m_b = 0$
  - b quarks in the proton
  - Logarithms do not affect the matrix elements
  - A priori good for energies $Q \gg m_b$

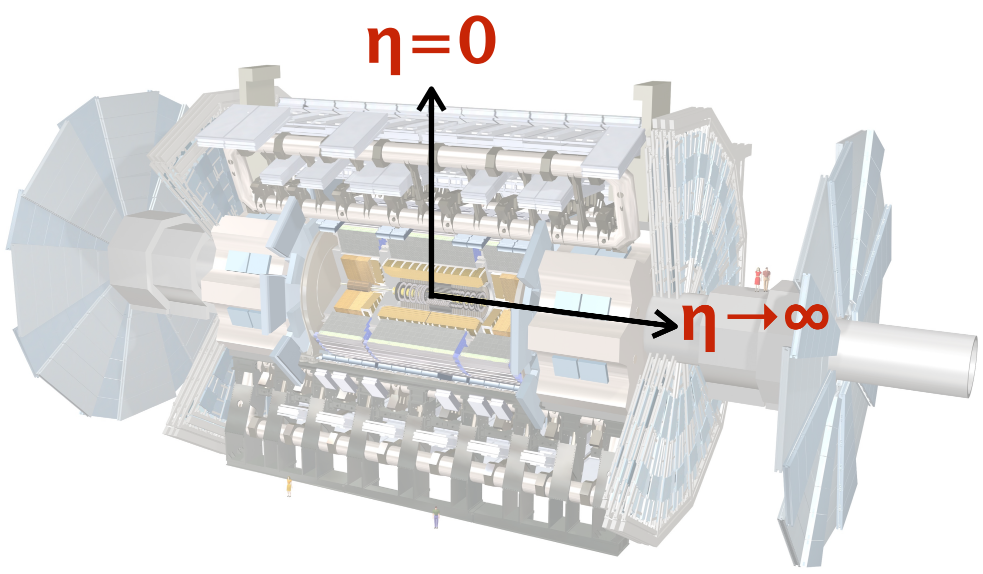


Diagrams at LO



ATLAS Measurement

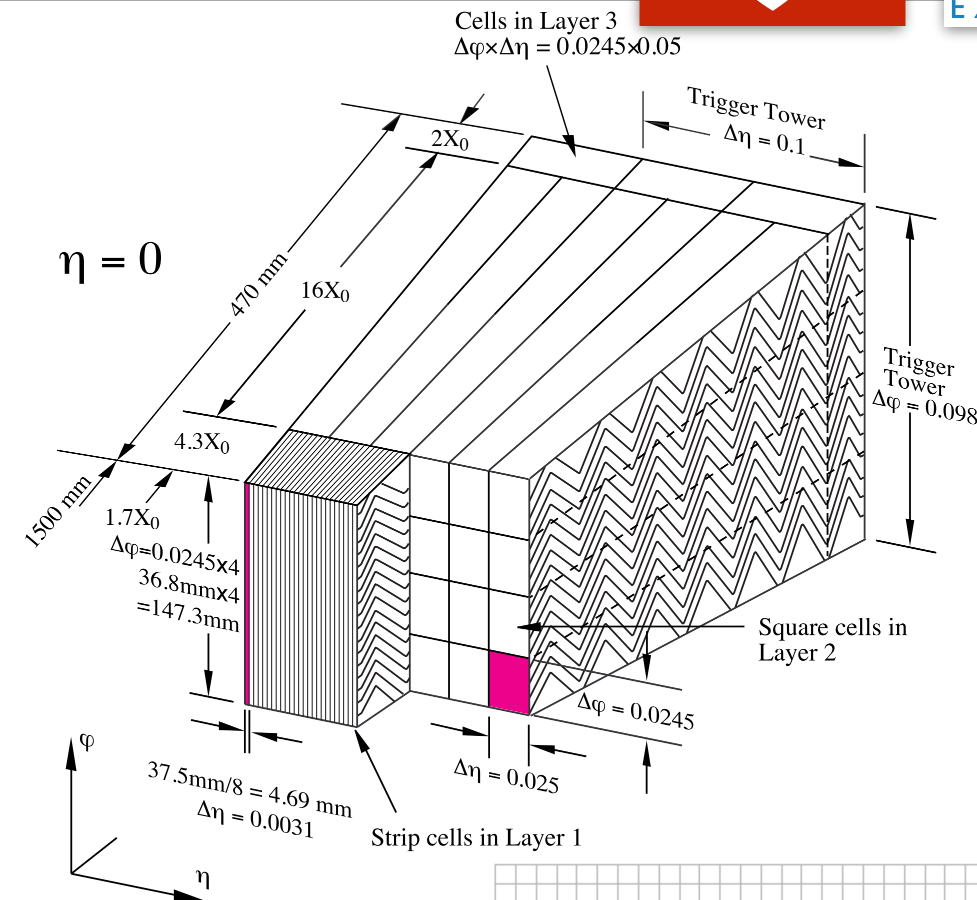
- **Dataset**: 20.2 fb^{-1} of pp collisions at 8 TeV, collected in 2012 with ATLAS
- **Selection**: events with at least one photon and one jet
  - $E_T^{\gamma} > 25$ GeV and either $|\eta^{\gamma}|<1.37$ or $1.56<|\eta^{\gamma}|<2.37$
- **Background subtraction**: photon purity and b-jet fraction
- Unfold detector effects to obtain particle-level distribution to be compared to perturbative QCD predictions

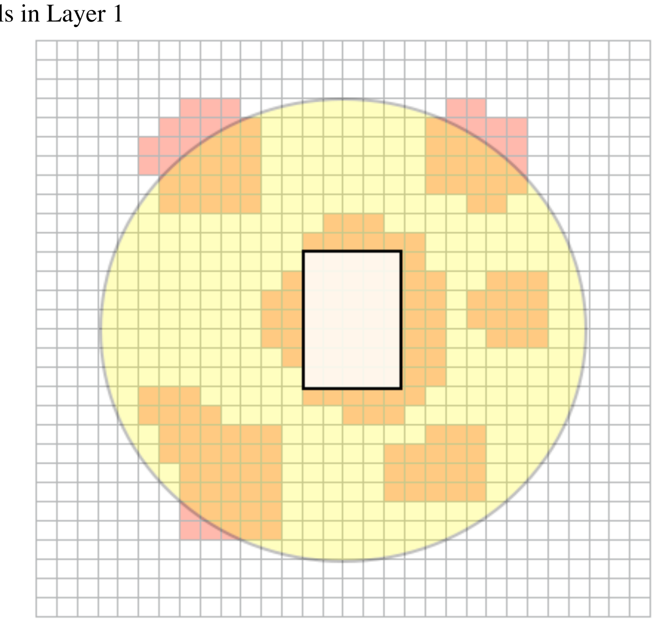


$$\frac{d\sigma}{dE_T^{\gamma}} = \left(\frac{C_{\text{unfold}}}{\Delta E_T^{\gamma}\,\epsilon_{\text{trig}}\mathcal{L}_{\text{int}}}\right) f^{b\text{-jet}} \sum_{i\in\text{MV1c}} p_i^{\gamma\text{-prompt}} N_i^{\gamma+\text{jet}}$$

Signal Photons

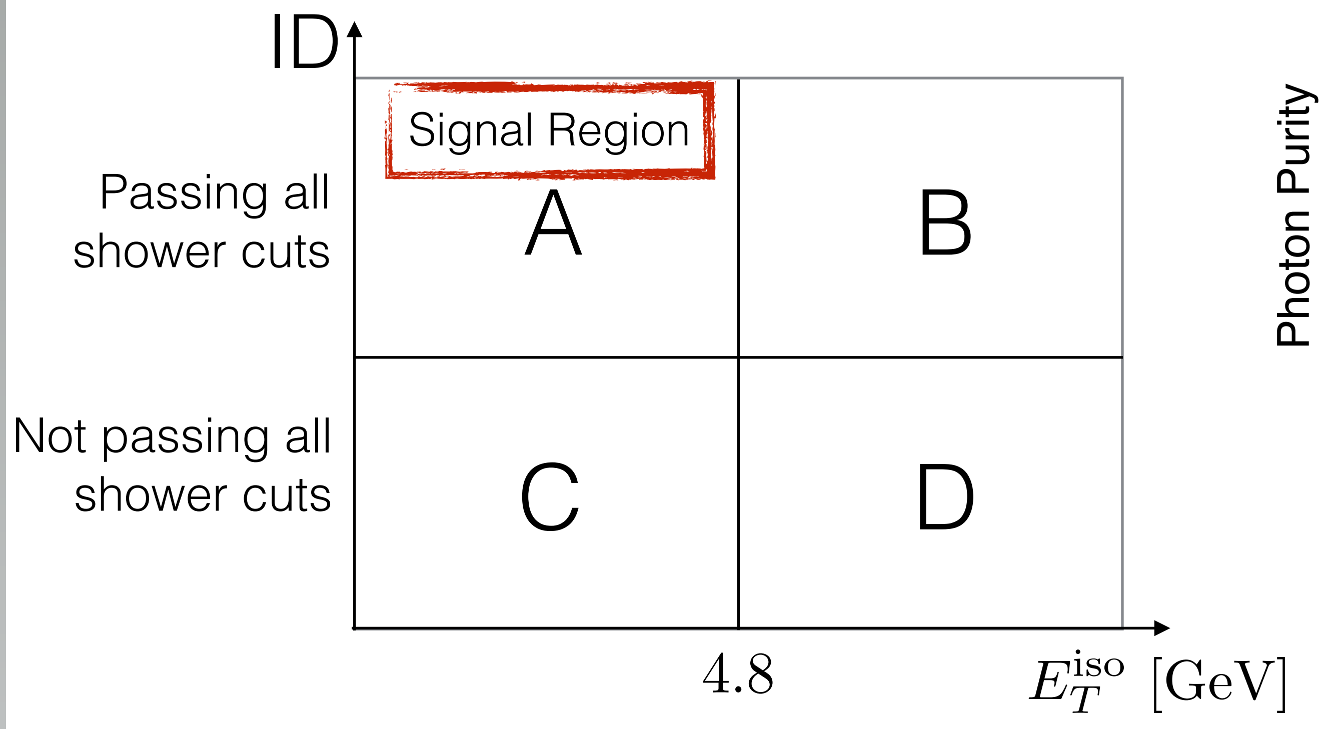
- Signal photons:
  - Identified photons
    - Nine variables quantifying the **shower development**
  - Isolated photons
    - Low amount of **energy around** the photon





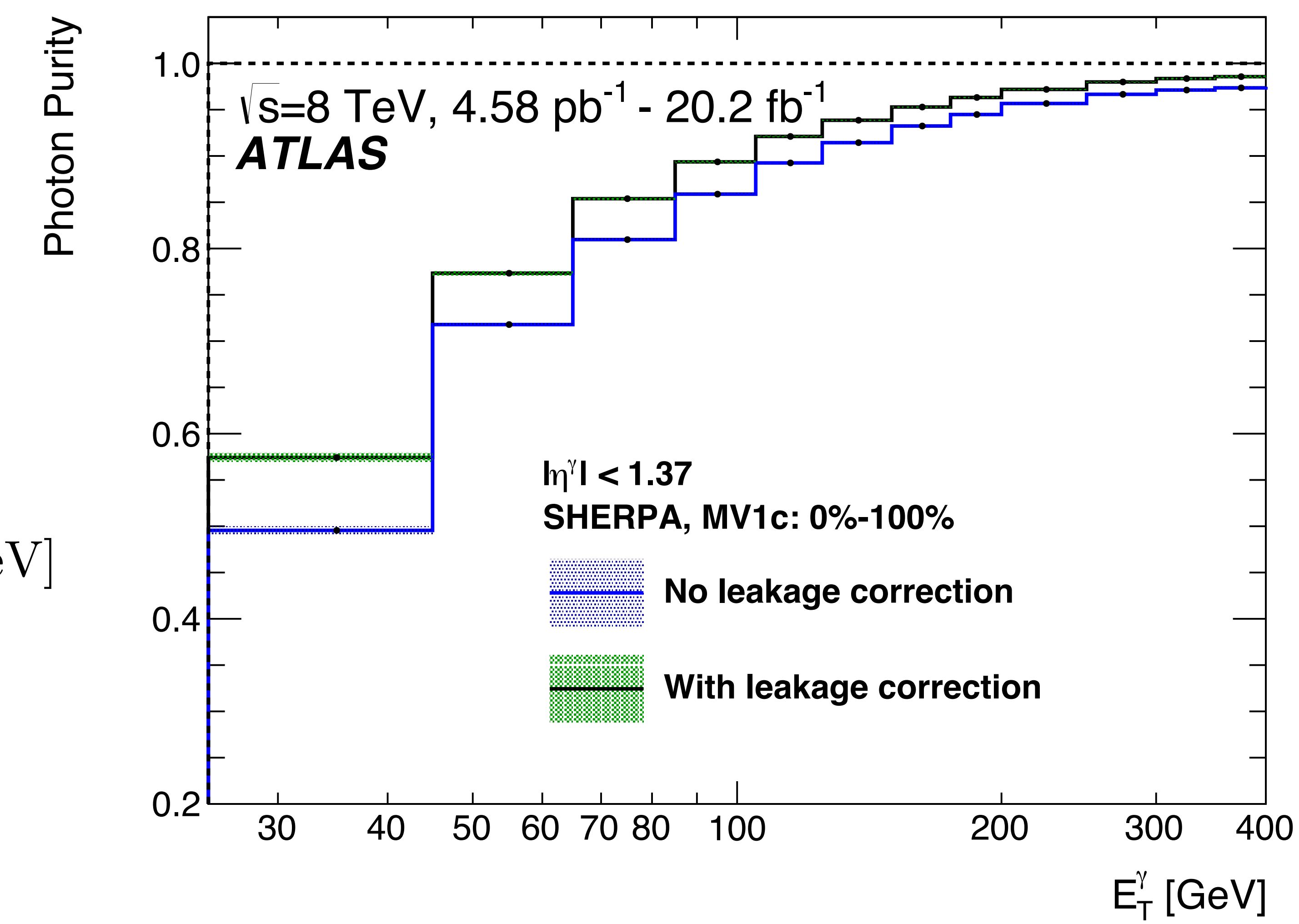
$$\frac{d\sigma}{dE_T^\gamma} = \left(\frac{C_{\text{unfold}}}{\Delta E_T^\gamma\, \epsilon_{\text{trig}} \mathcal{L}_{\text{int}}}\right) f^{b\text{-jet}} \sum_{i \in \text{MV1c}} p_i^{\gamma\text{-prompt}} N_i^{\gamma+\text{jet}}$$

Corrected Photon Purity



$$p^{\gamma\text{-prompt}} = 1 - \frac{N_B}{N_A}\frac{N_C}{N_D}$$

[Phys. Lett. B 776 (2018) 295](https://doi.org/10.1016/j.physletb.2017.11.054)

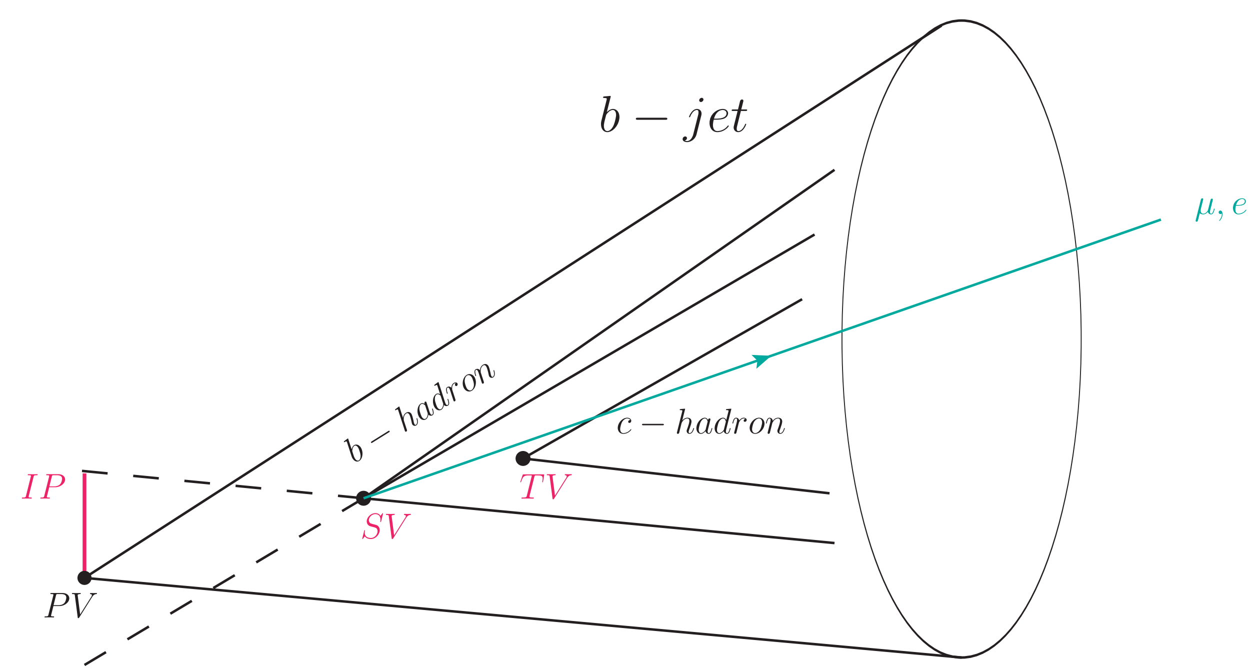


Correct data-driven purity for signal leakage into background regions with MC simulation

$$\frac{d\sigma}{dE_T^\gamma} = \left(\frac{C_{\text{unfold}}}{\Delta E_T^\gamma\, \epsilon_{\text{trig}} \mathcal{L}_{\text{int}}}\right) f^{b\text{-jet}} \sum_{i \in \text{MV1c}} p_i^{\gamma\text{-prompt}} N_i^{\gamma+\text{jet}}$$

b-jet identification

- MV1c neural network trained to differentiate b-jets from c-jet and light jets
  - Takes as input three types of parameters
    - **Impact parameter** information
    - **Secondary vertex** information
    - **Decay chain path** information, up to tertiary vertex



$$\frac{d\sigma}{dE_T^\gamma} = \left(\frac{C_{\mathrm{unfold}}}{\Delta E_T^\gamma\, \epsilon_{\mathrm{trig}} \mathcal{L}_{\mathrm{int}}}\right) f^{b\text{-jet}} \sum_{i \in \mathrm{MV1c}} p_i^{\gamma\text{-prompt}} N_i^{\gamma+\mathrm{jet}}$$

b-jet Fraction

- Maximum likelihood fit to MV1c efficiency
  - Shape of templates taken from MC
  - b-jet fraction is the relative normalization of the template

$$f^{b\text{-jet}} = \frac{\text{green area}}{\text{total area}}$$

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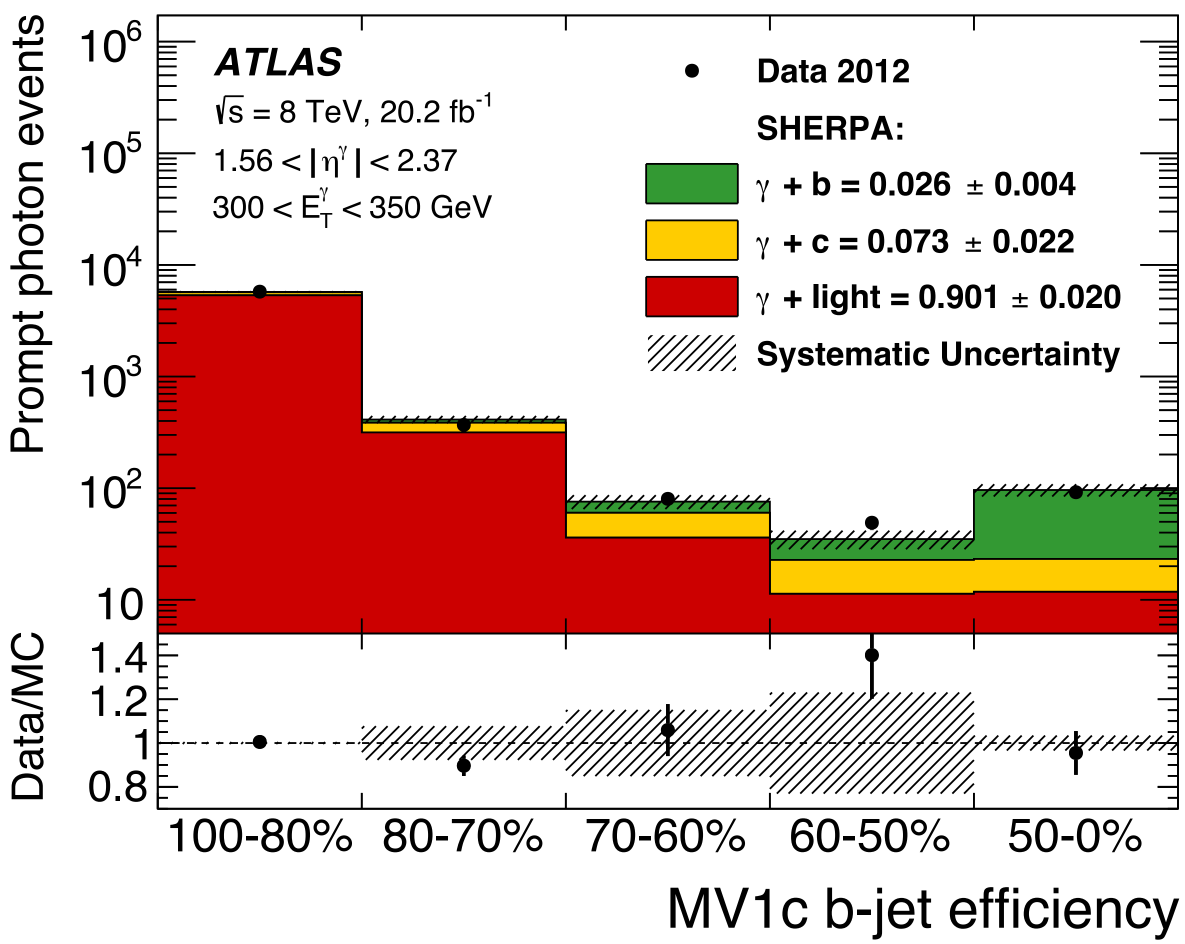

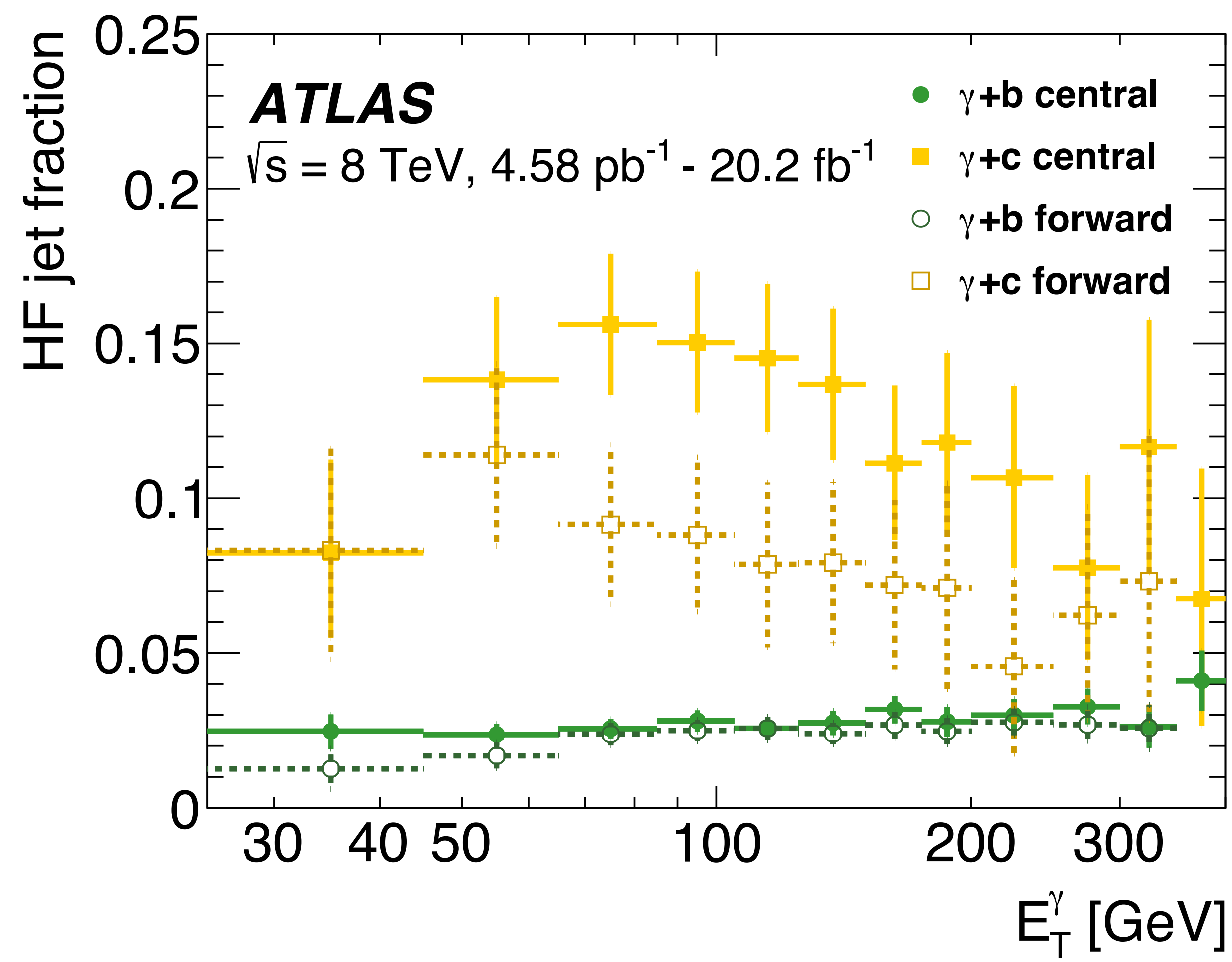

$$\frac{d\sigma}{dE_T^\gamma} = \left(\frac{C_{\text{unfold}}}{\Delta E_T^\gamma\, \epsilon_{\text{trig}} \mathcal{L}_{\text{int}}}\right) f^{b\text{-jet}} \sum_{i \in \text{MV1c}} p_i^{\gamma\text{-prompt}} N_i^{\gamma+\text{jet}}$$

Cross sections

- NLO predictions describe data better than for Tevatron but still underestimate it at high E_T^γ

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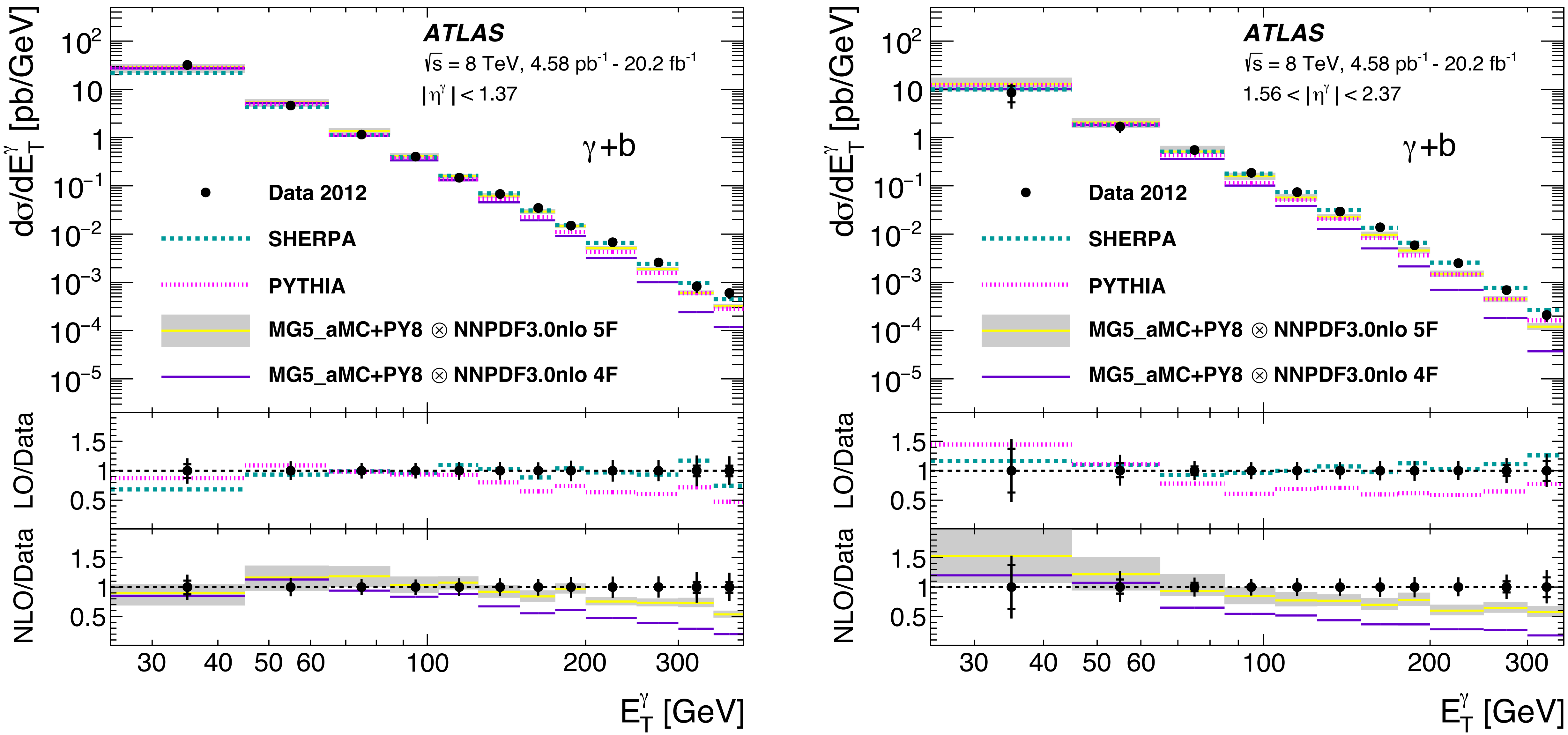

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Conclusion

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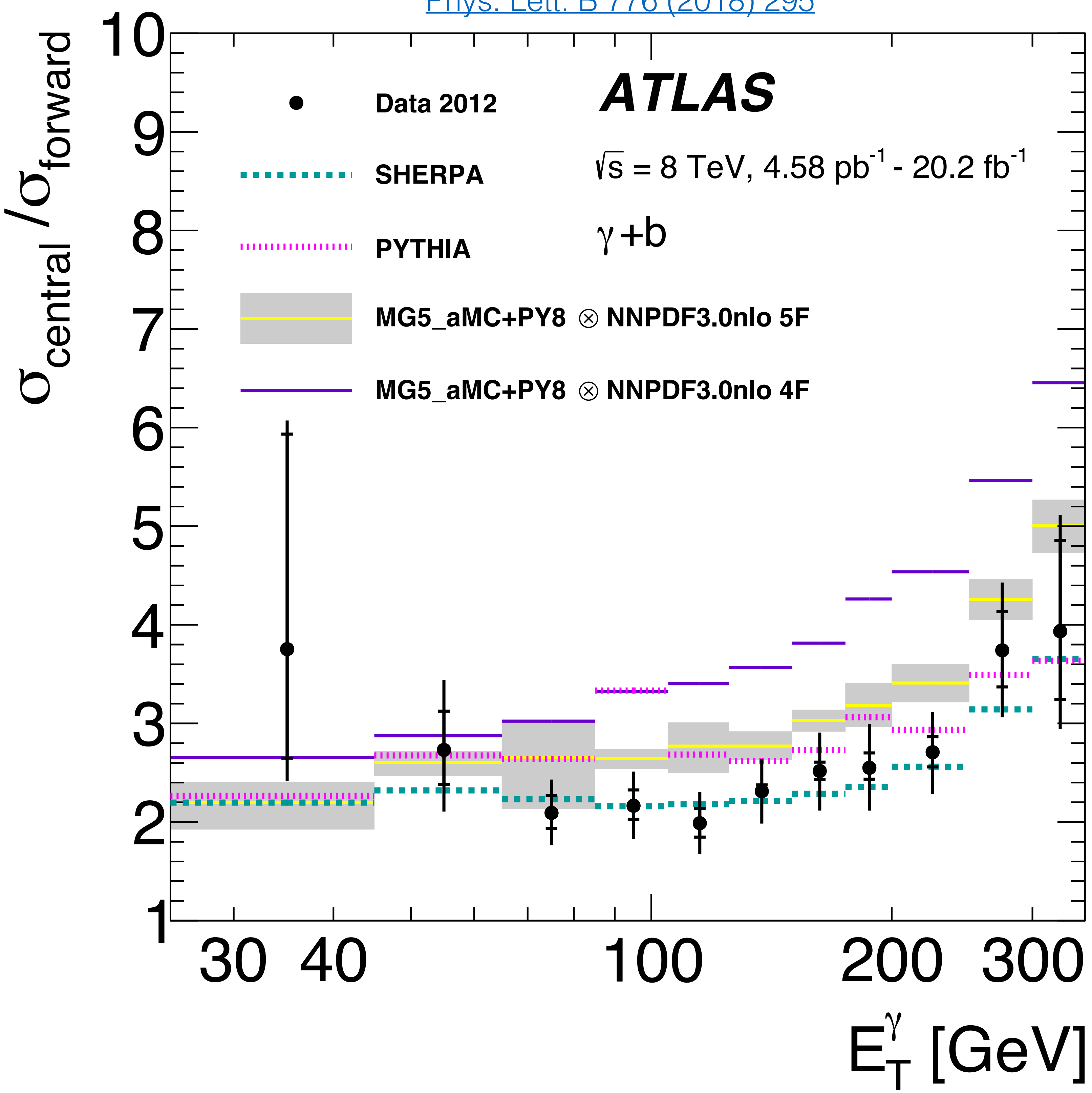

- First measurement γ+b differential cross sections in pp collisions
  - Provide a new test of perturbative QCD
- Measurement can be used to perfect the modelling of b quarks in MC generators
  - Data available at HEPData
  - Rivet analysis available

Backup

Important γ+b contributions

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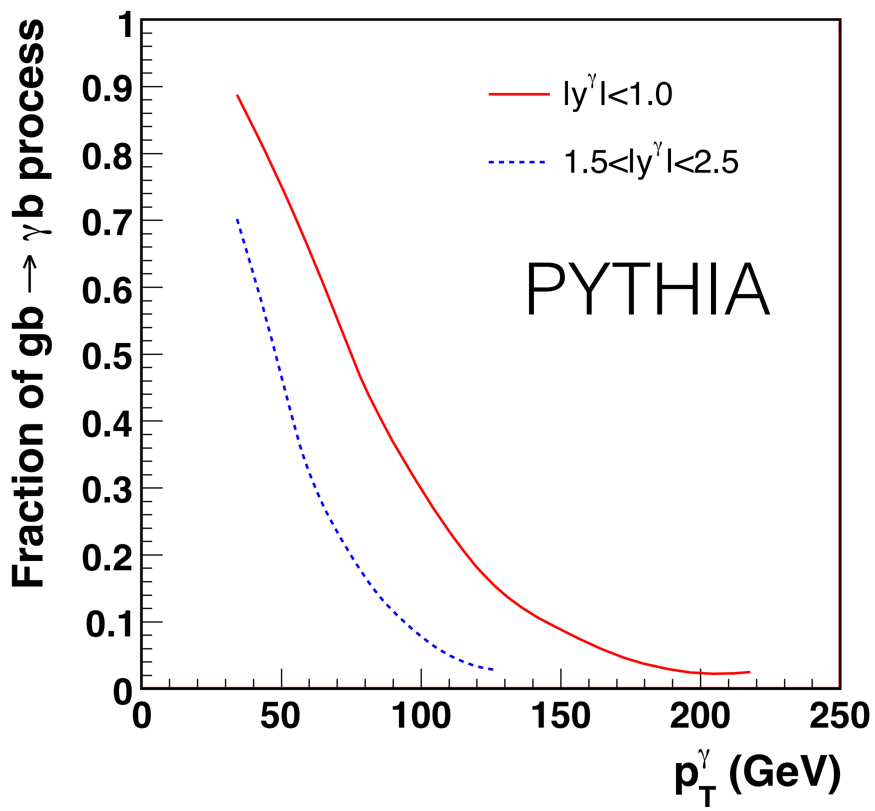
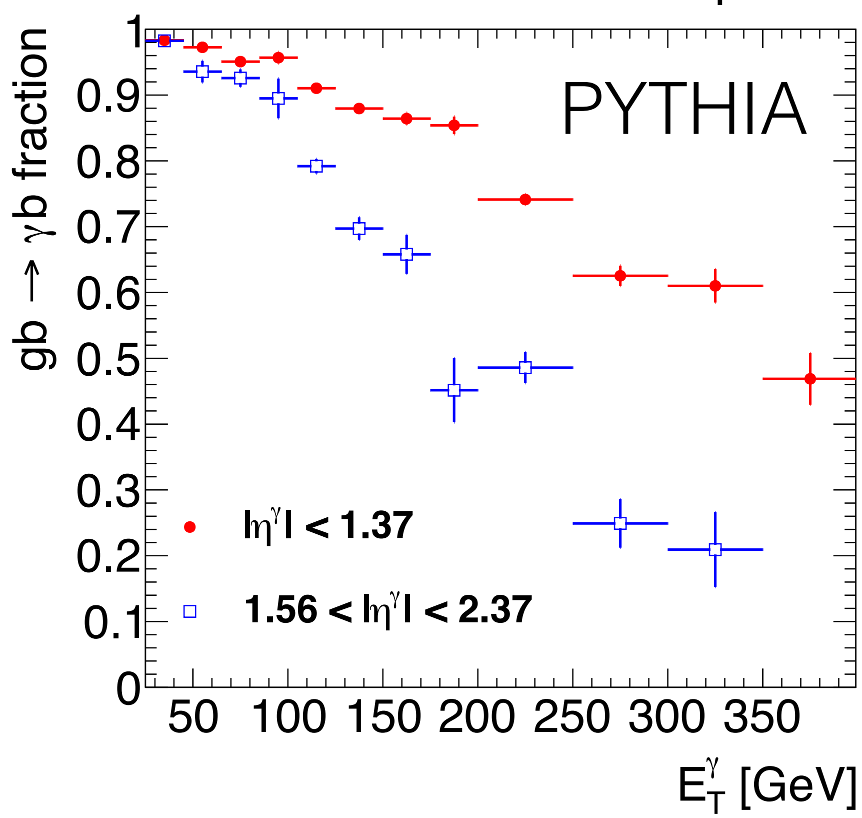
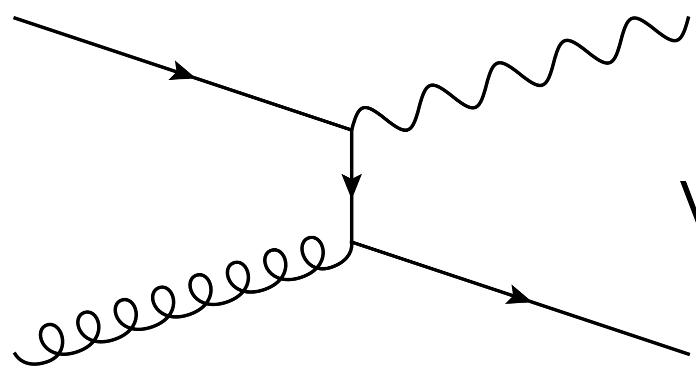


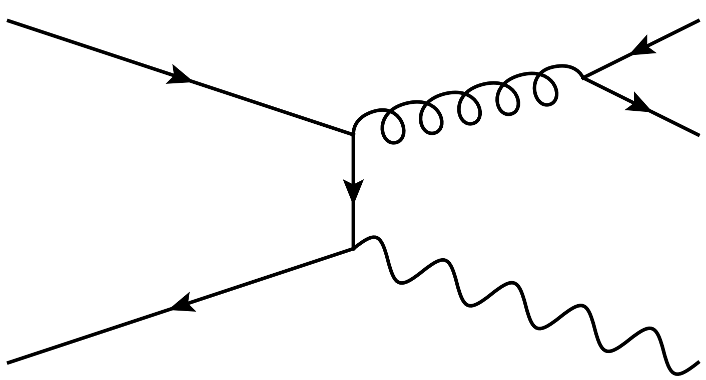


Tevatron

Compton contribution becomes negligible wrt gluon-splitting contribution at high E_T^{γ}



VS



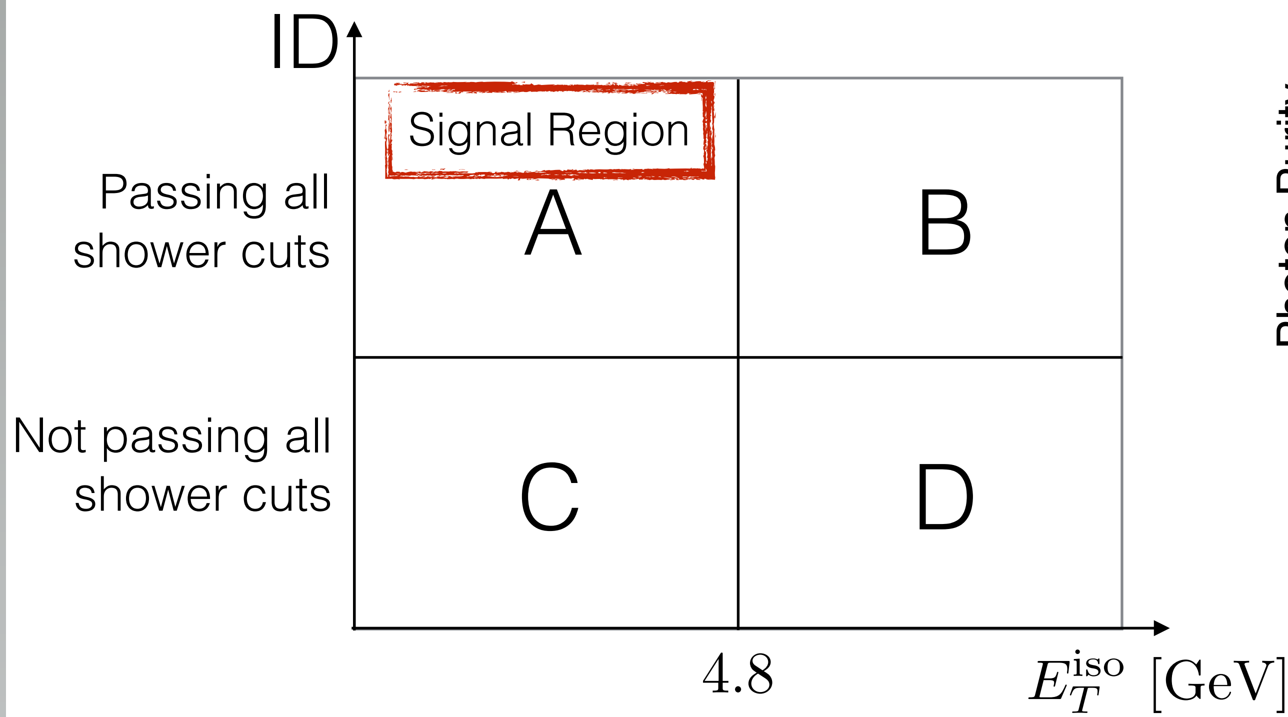
Compton

Gluon splitting

LHC

Absence of valence antiquarks keep the Compton contribution dominant at higher E_T^{γ}

Corrected Photon Purity



$$p^{\gamma\text{-prompt}} = 1 - \frac{N_B}{N_A}\frac{N_C}{N_D}$$

Correct data-driven purity for signal leakage into background regions with MC simulation

$$p^{\gamma\text{-prompt}} = 1 - \frac{N_B - c_B N_A^{\mathrm{sig}}}{N_A}\frac{N_C - c_C N_A^{\mathrm{sig}}}{N_D - c_D N_A^{\mathrm{sig}}}$$

$$c_X = \frac{N_X^{\mathrm{sig}}}{N_A^{\mathrm{sig}}},\ X = \{B, C, D\}$$

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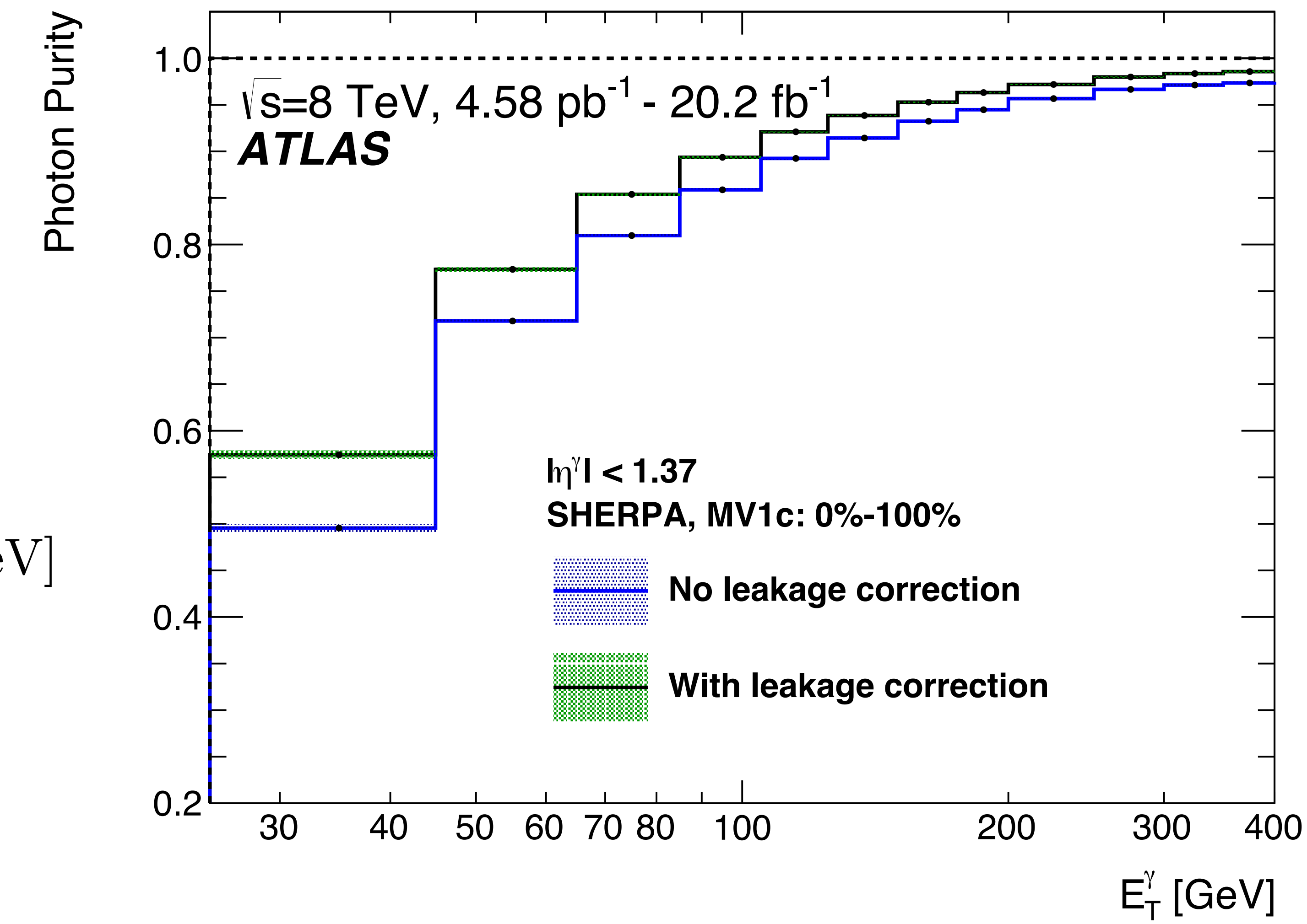

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2D Photon Purity

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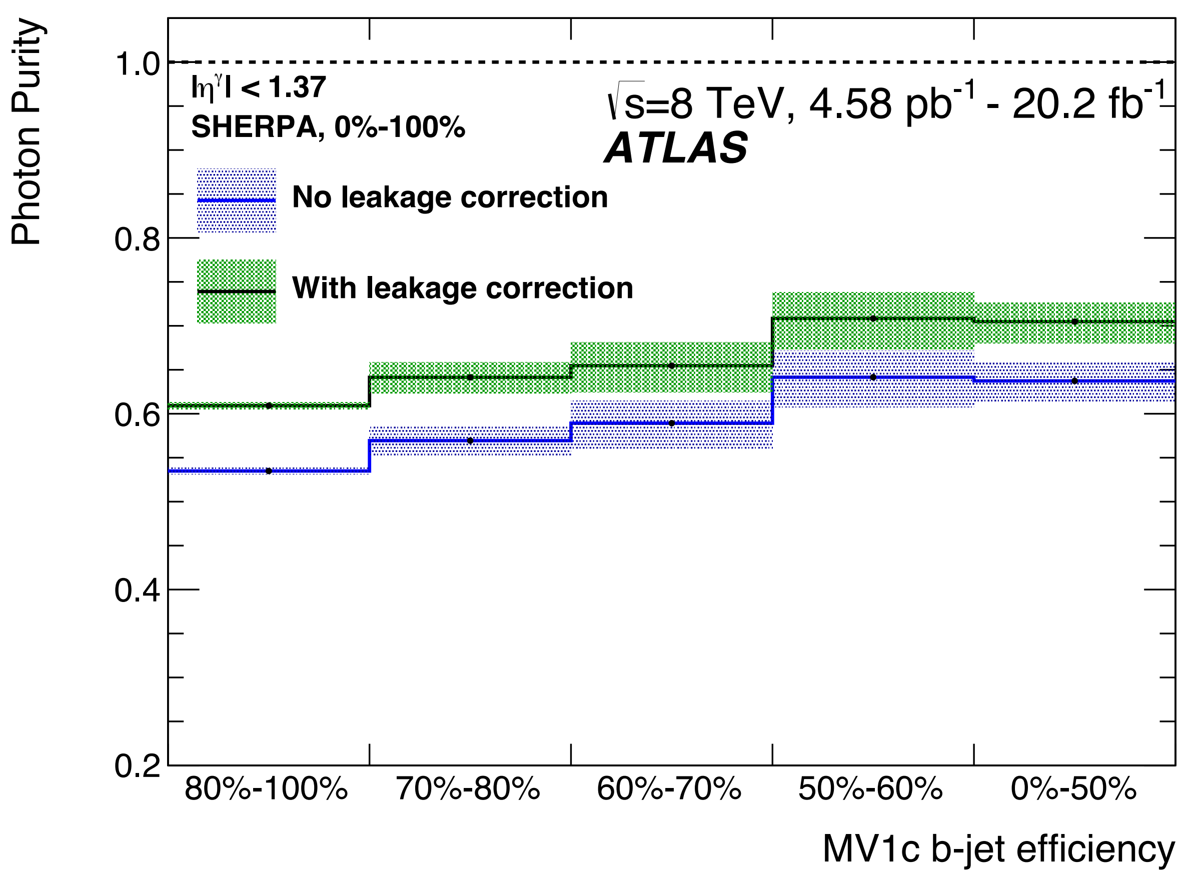
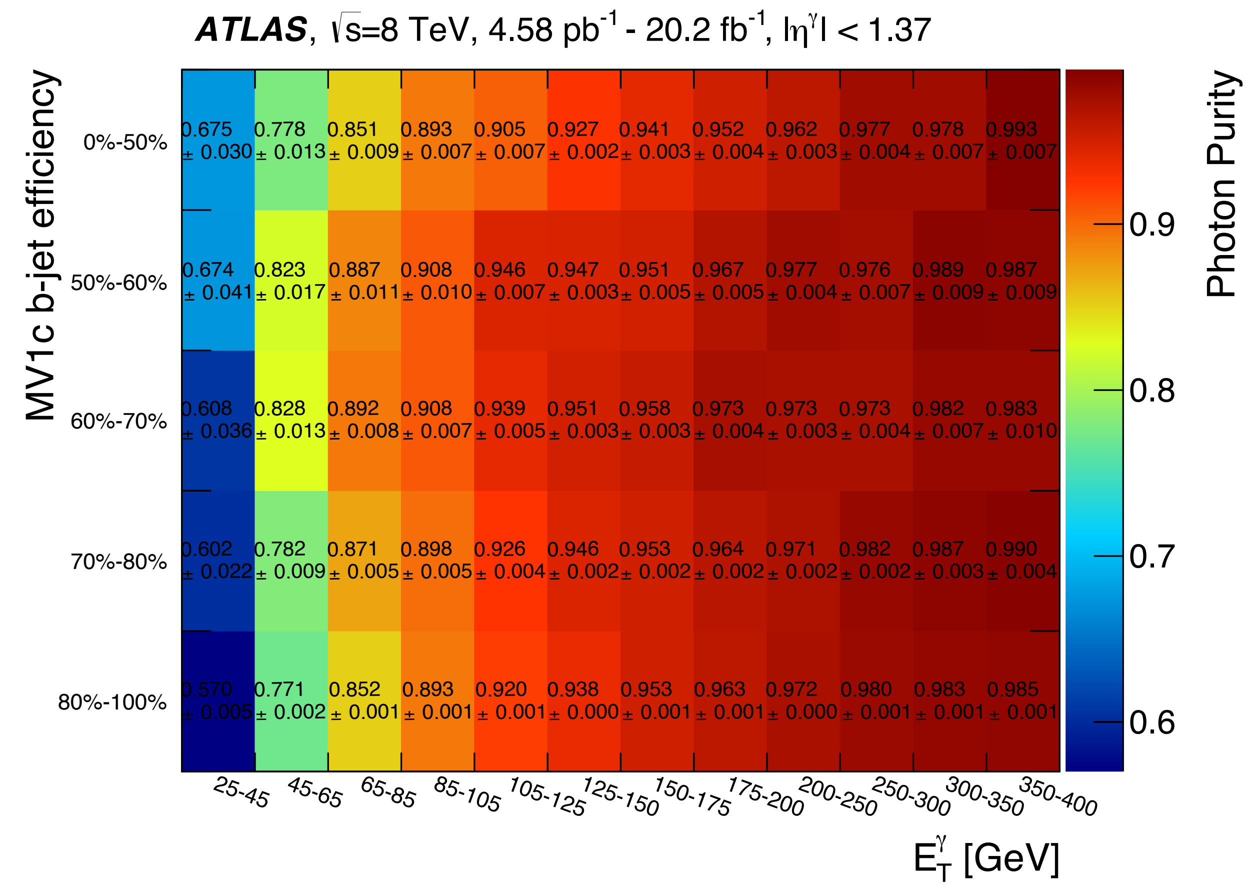
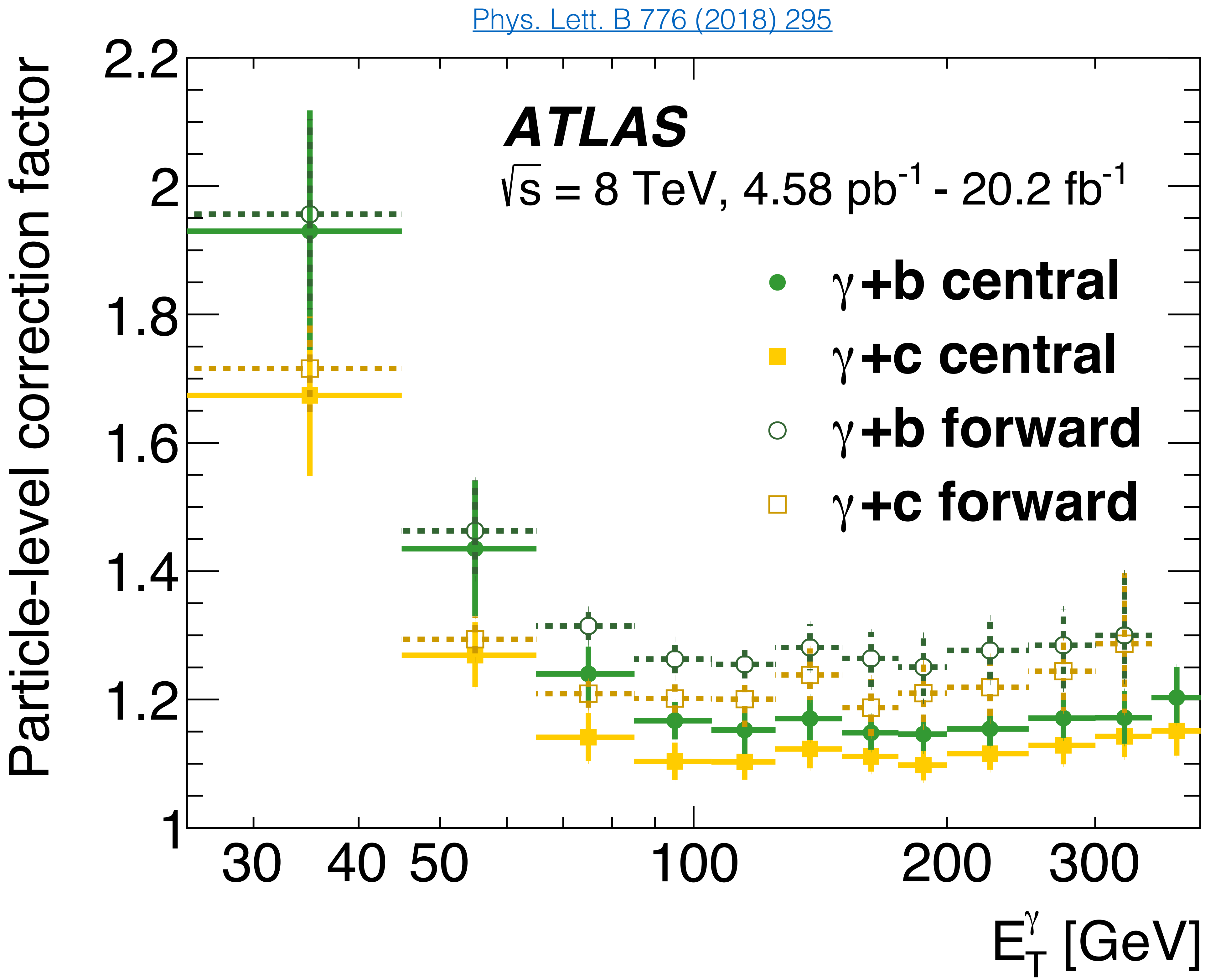




Purity depends on the MV1c efficiency
⇒ Take into account that correlation by measuring the purity in 2D

$$\frac{d\sigma}{dE_T^\gamma} = \left(\frac{C_{\text{unfold}}}{\Delta E_T^\gamma \, \epsilon_{\text{trig}} \mathcal{L}_{\text{int}}} \right) f^{b\text{-jet}} \sum_{i \in \text{MV1c}} p_i^{\gamma\text{-prompt}} N_i^{\gamma+\text{jet}}$$

Unfolding Correction Factor



Jet-related Uncertainties

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