LHCC Poster Session - CERN, 13 March 2013

Photon Identification Efficiency in ATLAS

Variables based on EMC for photon identification

- Discriminating variables, based on three layers of EM calorimeter
  - provide information of candidates
    - energy deposit ratios
    - shower widths
    - shower shapes
- 9 discriminating variables distributions
  - photons are narrow objects
  - fake photons tend to have broader profile and deposit sizable energy beyond calorimeter
  - strips can distinguish the 2 peaks in a π^0 decay

Variables and Position

	Strips	2nd	Had.
Ratios	f_1, f_{side}	R_η*, R_ϕ	$R_{Had.}$*
Widths	$w_{s,3}$, $w_{s,tot}$	$w_{\eta,2}$*	-
Shapes	ΔE, E_{ratio}		

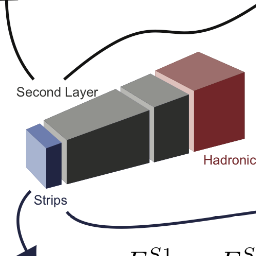
* Used in PhotonLoose.

Energy Ratios

$$R_\eta = \frac{E^{S2}_{3\times7}}{E^{S2}_{7\times7}} \qquad R_\phi = \frac{E^{S2}_{3\times3}}{E^{S2}_{3\times7}}$$

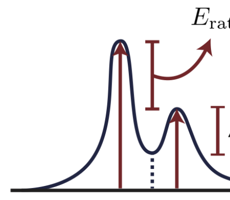
$$R_{Had} = \frac{E_T^{Had}}{E_T}$$

$$f_1 = \frac{E_{S1}}{E_{Tot.}} \qquad f_{side} = \frac{E^{S1}_{7\times1} - E^{S1}_{3\times1}}{E^{S1}_{3\times1}}$$



Shower Shapes

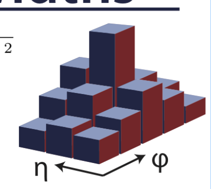
$$E_{ratio} = \frac{E^{S1}_{max,1} - E^{S1}_{max,2}}{E^{S1}_{max,1} + E^{S1}_{max,2}} \qquad \Delta E = E^{S1}_{max,2} - E^{S1}_{min}$$



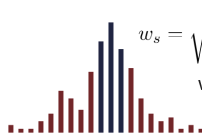
Widths

$$w_{\eta,2} = \sqrt{\frac{\sum E_i \eta_i^2}{\sum E_i} - \left(\frac{\sum E_i \eta_i}{\sum E_i}\right)^2}$$

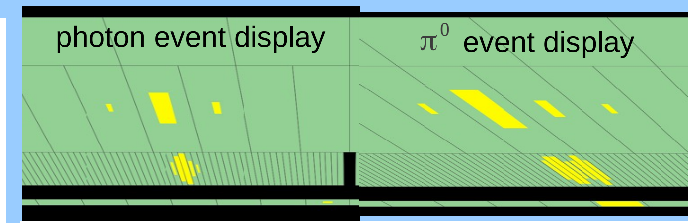
Width in a 3x5 (Δη×Δφ) region of cells in the second layer.

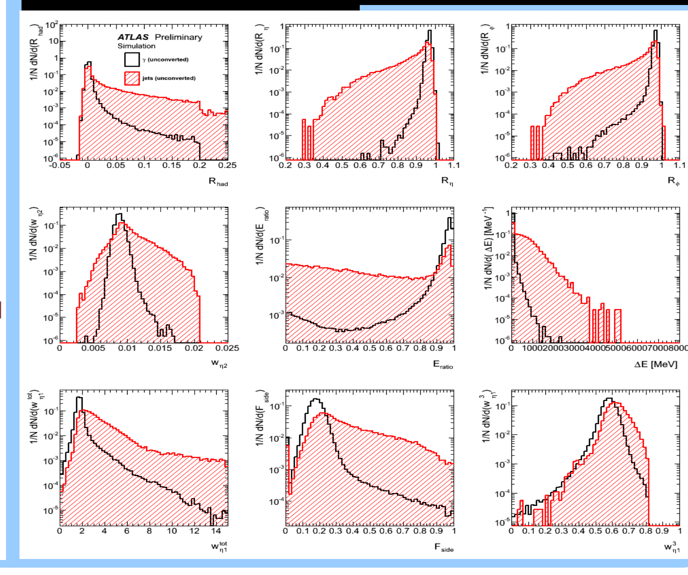


$$w_s = \sqrt{\frac{\sum E_i (i - i_{max})^2}{\sum E_i}}$$



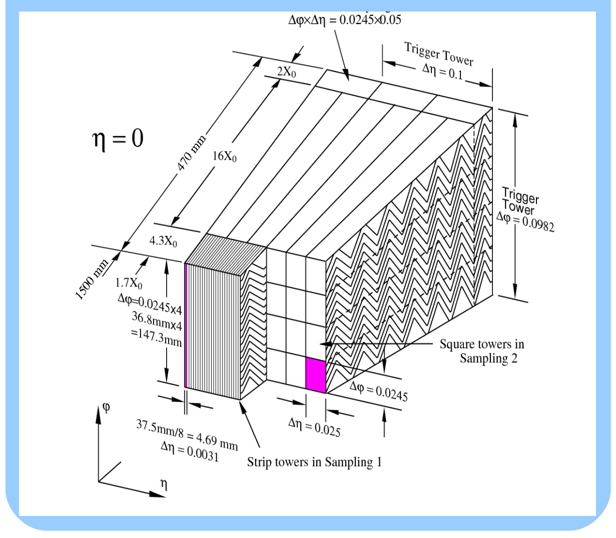
ws3 = w₁ uses ±1 strips (three total); wstot is defined similarly, but uses 20×2 strips.





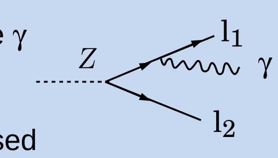
ATLAS Electromagnetic Calorimeter

- Three-fold granularity in depth and with an η x ϕ granularity
- Excellent for separating direct photons from photons associated to the decay of neutral hadrons in QCD jets

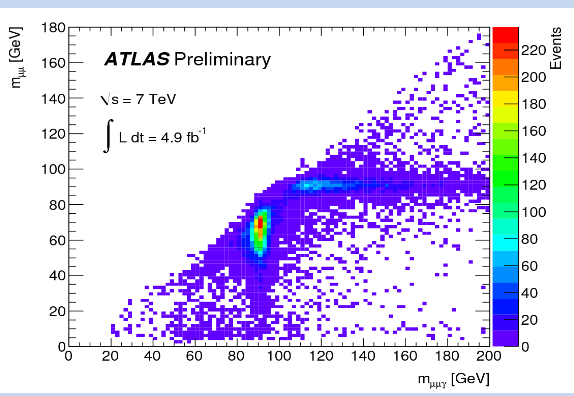


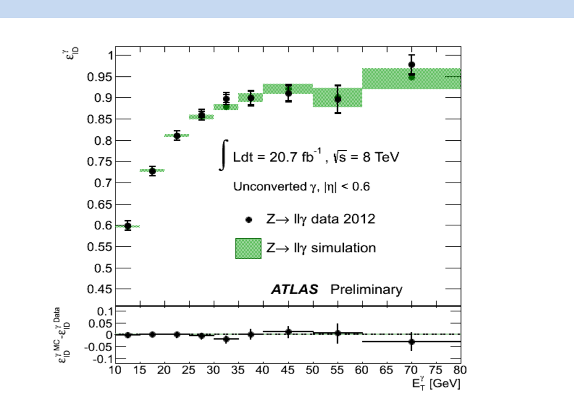
Radiative Z decays

- Final state radiative γ from Z decays

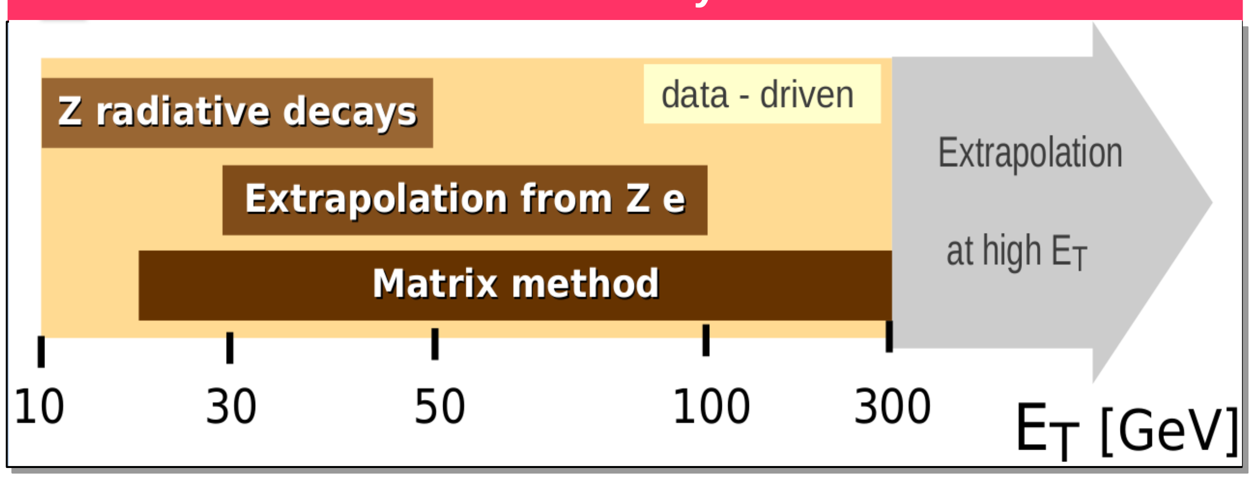


- Event selection based on leptons does not bias γ shower
- Photons have typically low E_T : [10,80] GeV
- The total uncertainty goes from 1% to 5%, dominated by statistical uncertainty





Three data-driven efficiency measurements



Matrix method

- Measurement is available for photon's E_T in [20, 300] GeV
- Photon purity is measured before/after identification, using track isolation as discriminate variable
- Photons and fakes track isolation efficiency as inputs
  - photons track isolation: measured in simulation
  - fakes track isolation : measured in data

Measured sample

Pass ID & Pass track isolation	Fail ID & Pass track isolation
Pass ID & Fail track isolation	Fail ID & Fail track isolation

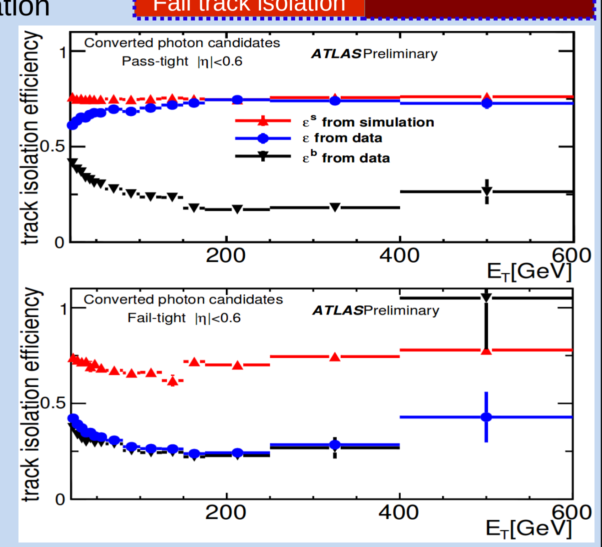
- Purity for photons pass(P) and fail(F) ID

$$P = \frac{\varepsilon_p - \varepsilon_p^b}{\varepsilon_p^s - \varepsilon_p^b} \qquad F = \frac{\varepsilon_f - \varepsilon_f^b}{\varepsilon_f^s - \varepsilon_f^b}$$

- Identification efficiency:

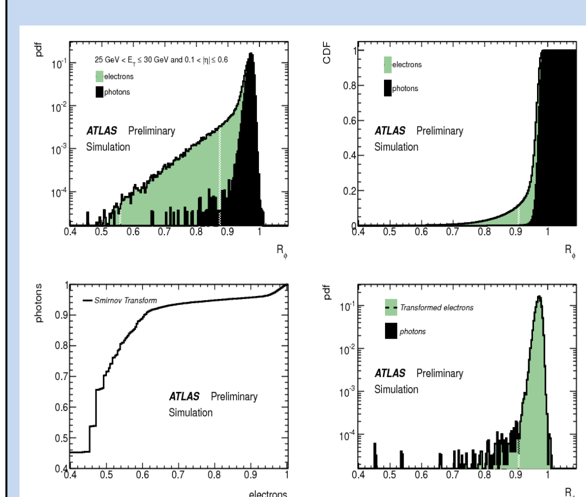
$$\varepsilon_{ID} = \frac{1}{1 + \frac{F * N^T_{fail}}{P * N^T_{pass}}}$$

- Uncertainty in this measurement comes from track isolation efficiency uncertainty
  - dominated by fake photon track isolation efficiency uncertainty



Electron Extrapolation

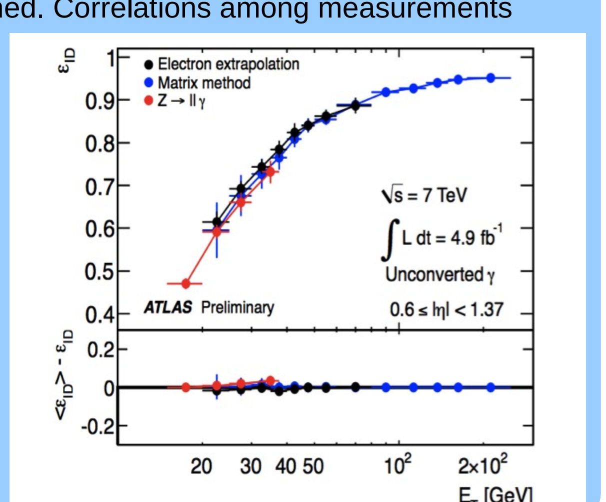
- Transformation is used to map e to γ
- Electron are selected in Z → ee decays
- Measurement is available for photon's E_T in [20, 80] GeV
- Cumulative distribution function of e and γ discriminating variables integrated from probability distribution function $f(x)$ or $g(x)$
  - for electrons $F(x) = \int_{-\infty}^{x} f(t)\,dt$
  - for photons $G(x) = \int_{-\infty}^{x} g(t)\,dt$
- Smirnov transform function maps the electron variable x_e to a transformed photon variable x_γ: $x_\gamma = G^{-1}(F(x_e))$
- Uncertainty of this measurement
  - main uncertainty from material knowledge impacting the transform function
  - are ~3 % for converted photons and up to ~10% in worst region for unconverted photons



Combination of efficiency in three measurements

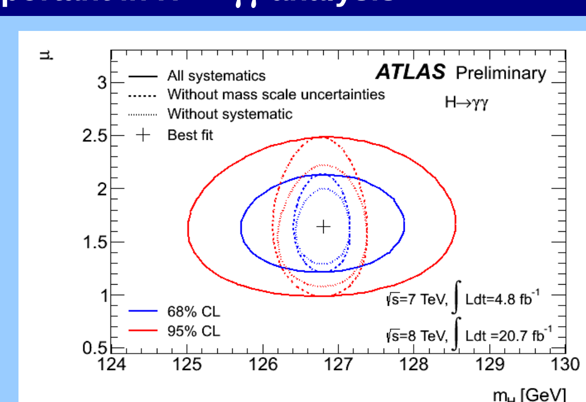
- Three data-driven measurements are combined. Correlations among measurements are taken into account.
- Identification efficiency is measured for photons with E_T in [10, 300] GeV.

- Efficiency uncertainty depends on photon's η, E_T and conversion
  - 2011: ~7.0%(low E_T) to ~1.0%(high E_T)
  - 2012: ~2.5%(low E_T) to ~1.5%(high E_T)



Efficiency uncertainty is important in H → γγ analysis

- Photon identification uncertainty has a direct impact on the signal strength measurement
- Combination of data-driven methods can provide a powerful constrain on this measurement
- Thanks to the combination of three data-driven measurements, the photon identification gives 2.4% level uncertainty on di-photon event in 2012, and can be further improved with additional data-driven studies



$$\mu = 1.65 \pm 0.24(stat)^{+0.25}_{-0.18}(syst)$$

Reference: ATLAS-CONF-2012-123 in https://cds.cern.ch/record/1473426

Kun Liu, for the ATLAS Collaboration

ATLAS EXPERIMENT