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Photon ID Efficiency measurement with radiative Z boson decays using ATLAS data

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Ilaria LUISE

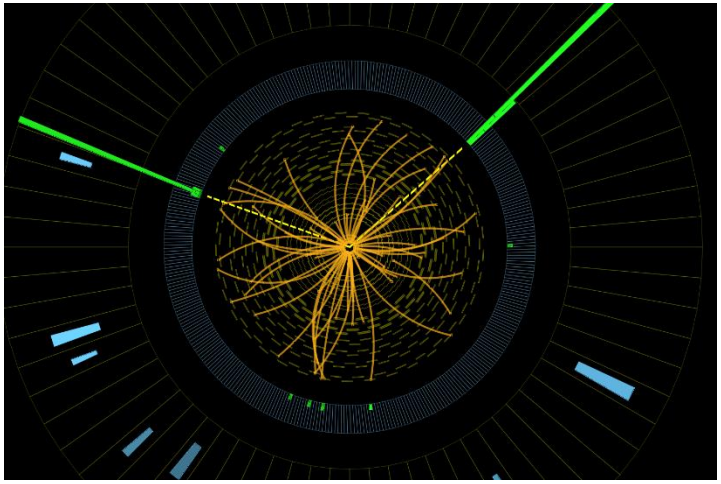
Supervisors:
G. BERNARDI
G. MARCHIORI

Introduction

Photons @ LHC are important signatures in many analyses:

- Higgs Boson Physics (*H→γγ, 2012)*
- *BSM: SUSY or extra dimension models*

Possible H→γγ event

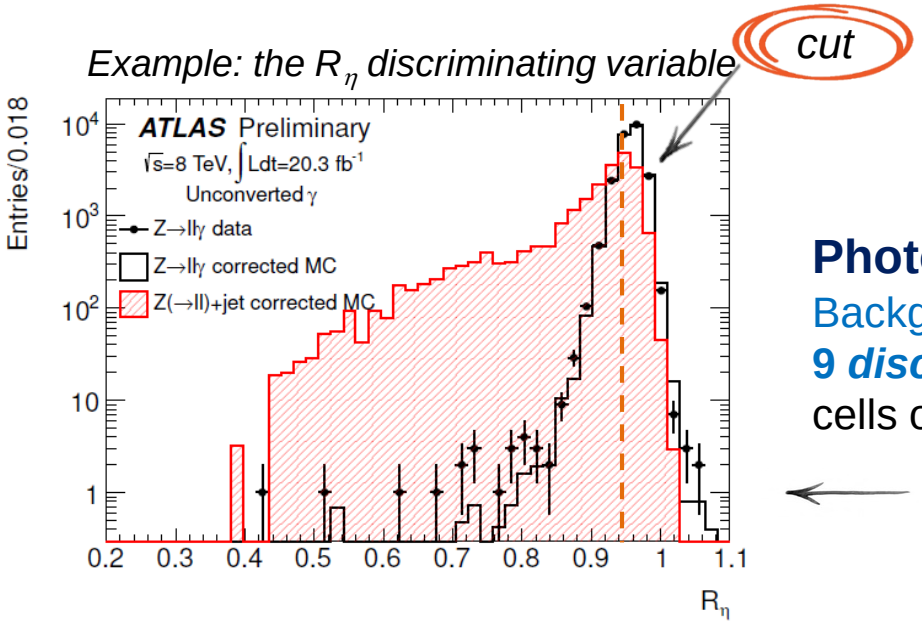


How photons are detected @ LHC?

Reconstruction → *Select possible γ candidates*

Identification → *Reject Background (from jets)*

Example: the R_η discriminating variable



Photon Identification in ATLAS:

Background rejection using cut-based selection on **9 *discriminating variables*** based on energy in cells of ECAL and leakage in HCAL.

← **Overlap** = ID Algorithm not 100% efficient

We need a *pure* control sample of γ to **test the efficiency** of this algorithm

The Radiative Z method

Use photons from $Z \to ll\gamma$ decays

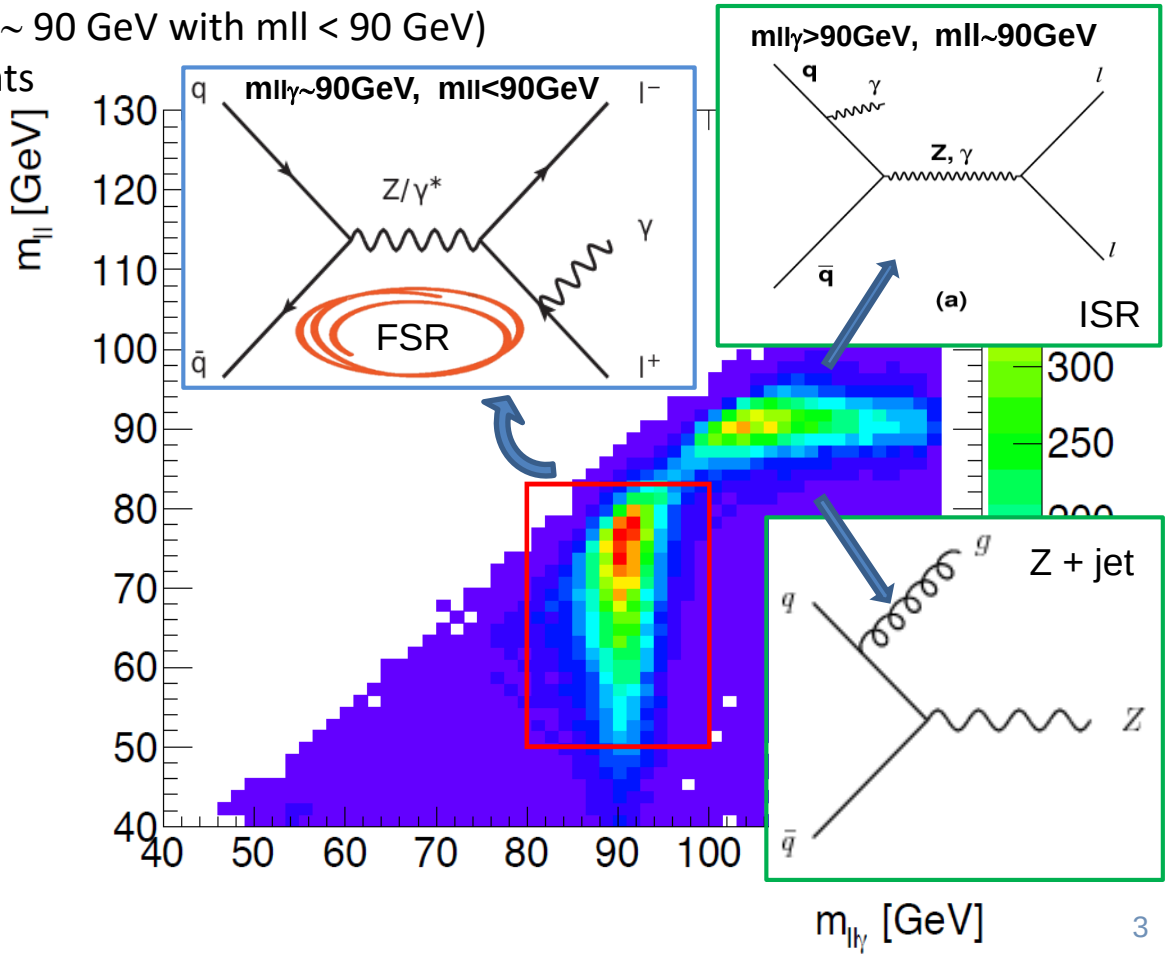
14.8 fb^{-1} 13 TeV ATLAS data

- **Procedure:**
  - **Select** pure sample of $Z \to ll\gamma$ (e, μ) events (before applying tight ID cut to γ)
  - Selection based **ONLY on kinematic cuts**, no cuts on the discriminating variables (invariant mass of the system: $m_{ll\gamma} \sim 90$ GeV with $m_{ll} < 90$ GeV)
  - **Count the fraction** of selected events in which the ***photon*** **passes** the ID requirements

- **Selection:**
  - **2 opposite charge leptons** (e or μ)
  - **1 photon** with p_T **> 10 GeV**
  - **$ll\gamma$ invariant mass** in [80,100] GeV
  - **ll invariant mass** in [50, 83] GeV

133k events selected

100k *unconverted* photons
33k *converted* photons



Photon ID Efficiency Data vs Simulation

Scale Factors (SFs): *DATA/MC ratios of the efficiencies*

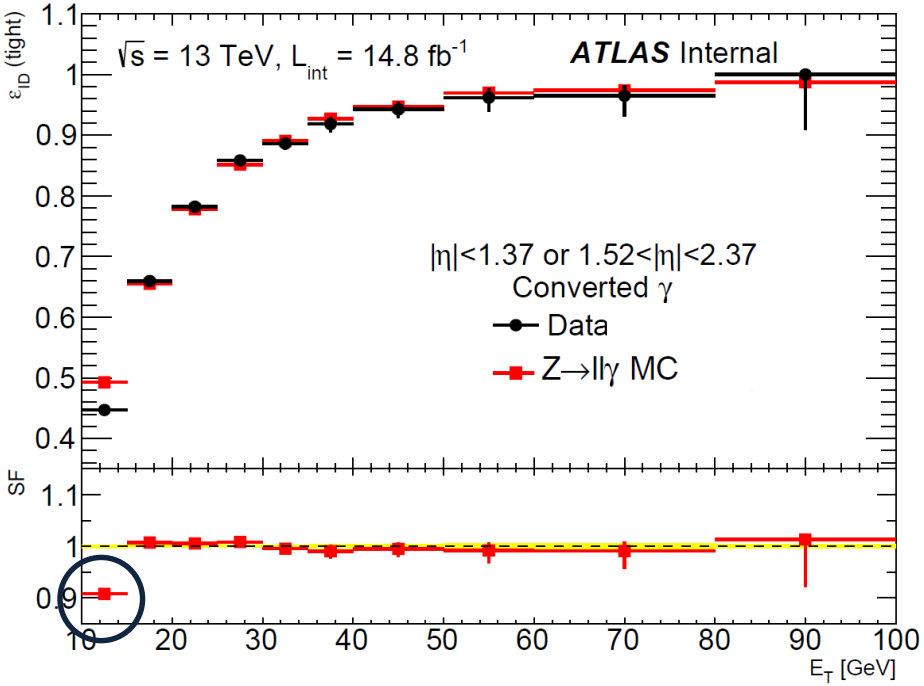
multiply MC to get the scaled efficiency consistent with the efficiency in data

→ SFs are used to correct all the ATLAS photon based analyses

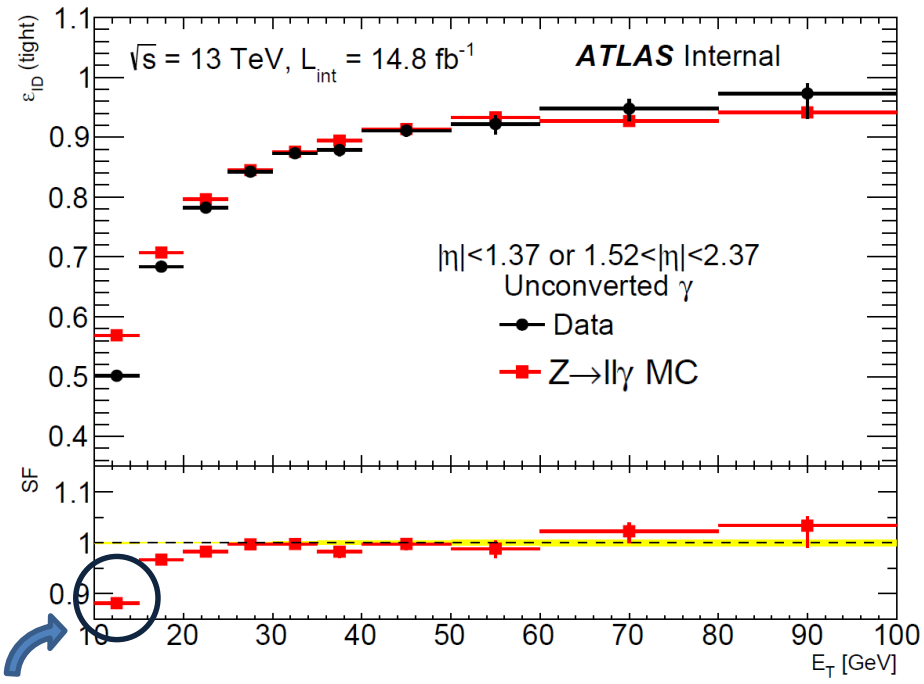
How to extract SFs?

compare Data and Simulated $\ell\ell\gamma$ (ONLY PURE SIGNAL EFFICIENCY, No Jets in the MC)

Converted photons



Unconverted photons



Expected:

~10% Bkg Contamination @ 10-15 GeV

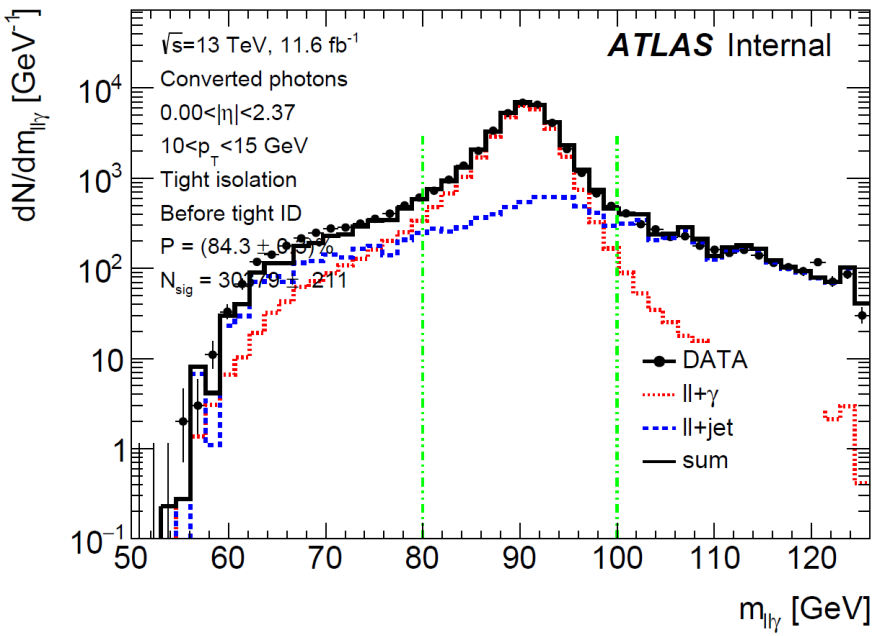
≤ 2% for higher energy regions

Background Subtraction

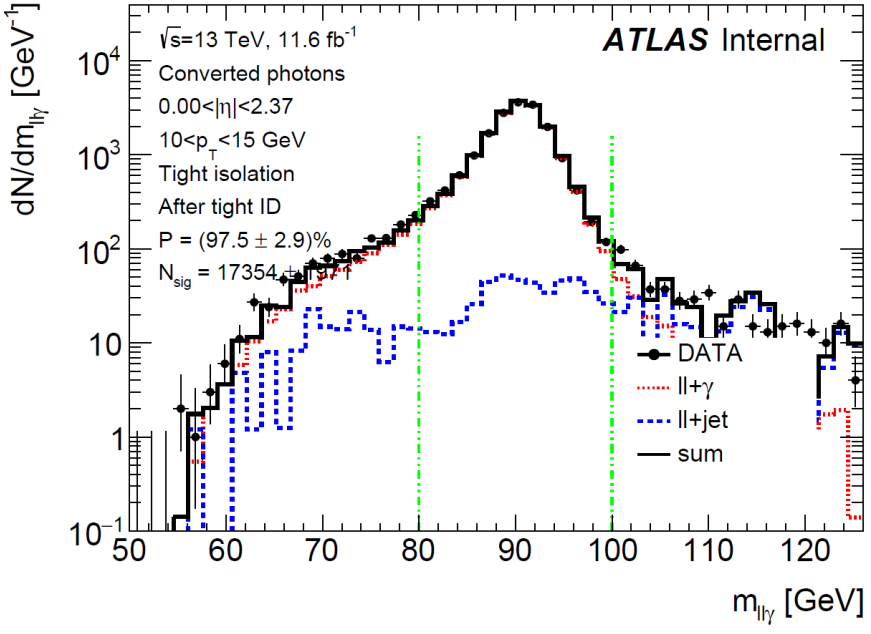
- **Maximum Likelihood fit** to the $m_{ll\gamma}$ distribution in data *after* applying all the other selection criteria
- Estimate Signal and Background yeld for each bin of p_T and eta:
  - ***Signal distribution***: from Sherpa or Powheg MC simulation of **$Z \rightarrow ll\gamma$**
  - ***Bkg distribution***: from Sherpa or Powheg MC simulation of **Z+jet**

- **Correct the efficiency:** using the estimated signal yeld before and after tight photon identification criteria

Before Tight ID (Purity 84.3%)

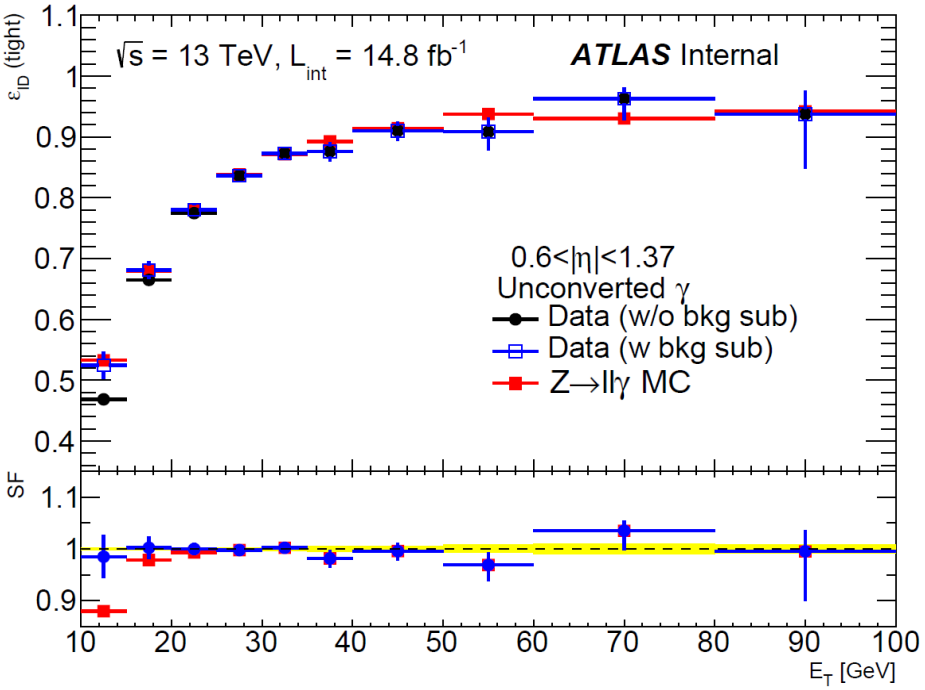


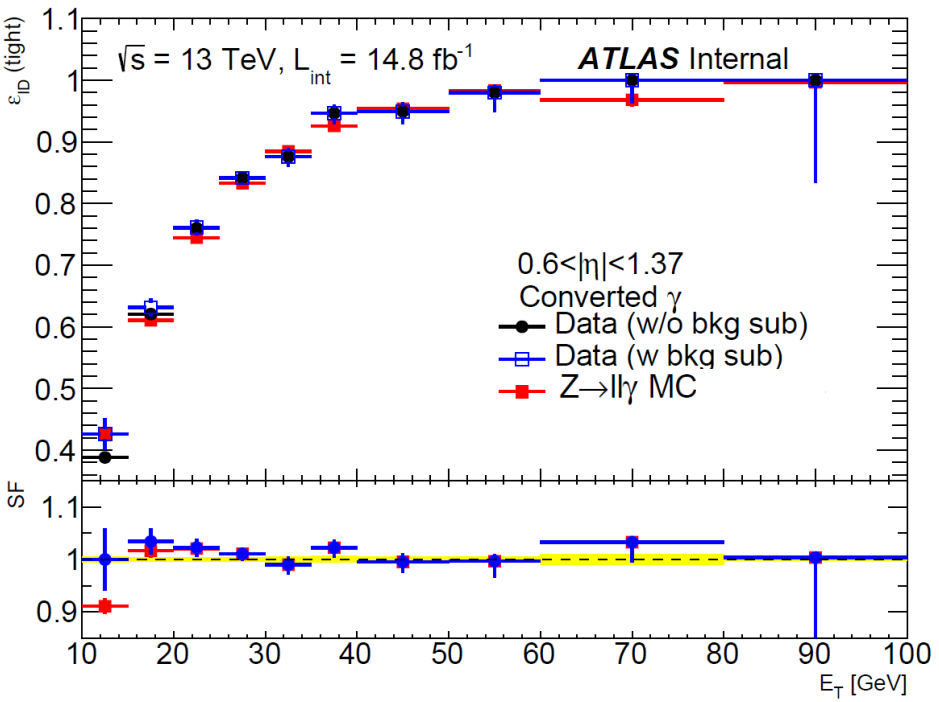
After Tight ID (Purity 97.5%)



Photon ID Efficiency *after* Bkg subtraction

Bkg subtraction only in the first three E_T bins: 10-15 GeV, 15-20 GeV and 20-25 GeV





Better Data/MC agreement @ low E_T → scale factor for first E_T bin compatible with 1.

… Study of possible systematics (i.e. pile-up and isolation)

Conclusions

- **Measurement of Photon ID Efficiency** performed on ATLAS **data**:
  - using **14.8 fb^{-1}** Run2 data: 3.2 from 2015 + 11.6 from 2016
  - with **Radiative Z method**, using $Z \rightarrow \mu\mu\gamma$ and $Z \rightarrow ee\gamma$ channels combined.
- Improvement of DATA/MC agreement @ low pT using template based **Bkg subtraction** on data
- Contribution to the measurement of the **scale factors Data/MC** for the ATLAS analyses
- Study of possible sources of **systematic uncertainties** on SFs (not shown):
  - Isolation pre-selection
  - Pile-up

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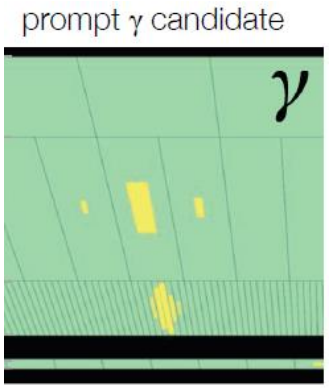
Backup Slides

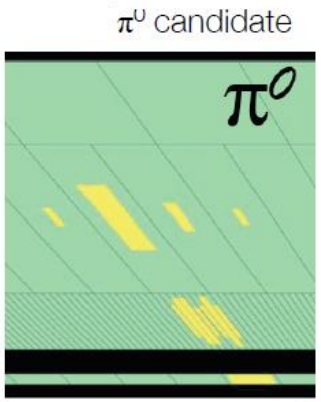
Photons Identification

Many sources of Background:

- **neutral meson decays** inside hadronic **jets** → huge xsection

Background rejection using cut-based selection on ***9*** *discriminating variables* based on energy in cells of layers 1, 2 of ECAL and leakage in HCAL





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.	

Shower Shapes

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

$$\Delta E = E^{S1}_{max,2} - E^{S1}_{min}$$

Energy Ratios

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

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

$$f_1 = \frac{E_{S1}}{E_{Tot.}}$$

$$f_{side} = \frac{E^{S1}_7 - E^{S1}_3}{E^{S1}_3}$$

Second Layer, Hadronic, Strips

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 3×5 (Δη×Δφ) region of cells in the second layer.

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

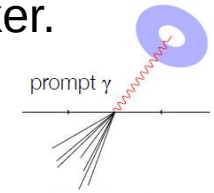
ws3 = w_1 uses 3 strips in η; wstot is defined similarly, but uses 20 strips.

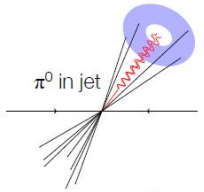
ATL-COM-PHYS-2013-600

- *tight photon-id:* ε~85% for E_T>20 GeV, R_{jet}~5000 ;

Photon Isolation

Isolation: measure the activity around the photon in ECAL and tracker.
Reduce neutral meson Bkg.





Calorimeter isolation:

- sum of ET of clusters in cone $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 4$, excluding a rectangle (0.125x0.175) around photon
- larger ΔR = better S/B separation, larger sensitivity to *pileup*

Track isolation:

- number or sum of pT of tracks in cone of radius ΔR (<0.2, 0.3)
- pileup robust (only tracks from Primary Verteces)
- less discriminating (*only charged particles – i.e. conv* γ)

- *loose iso*: 99% calo iso ; 99% track iso ; 99% combined iso
- *tight iso: 96% calo iso ; 99% track iso ; 95% combined iso*