Electron and Photon Production at ATLAS in 7TeV Collision Data

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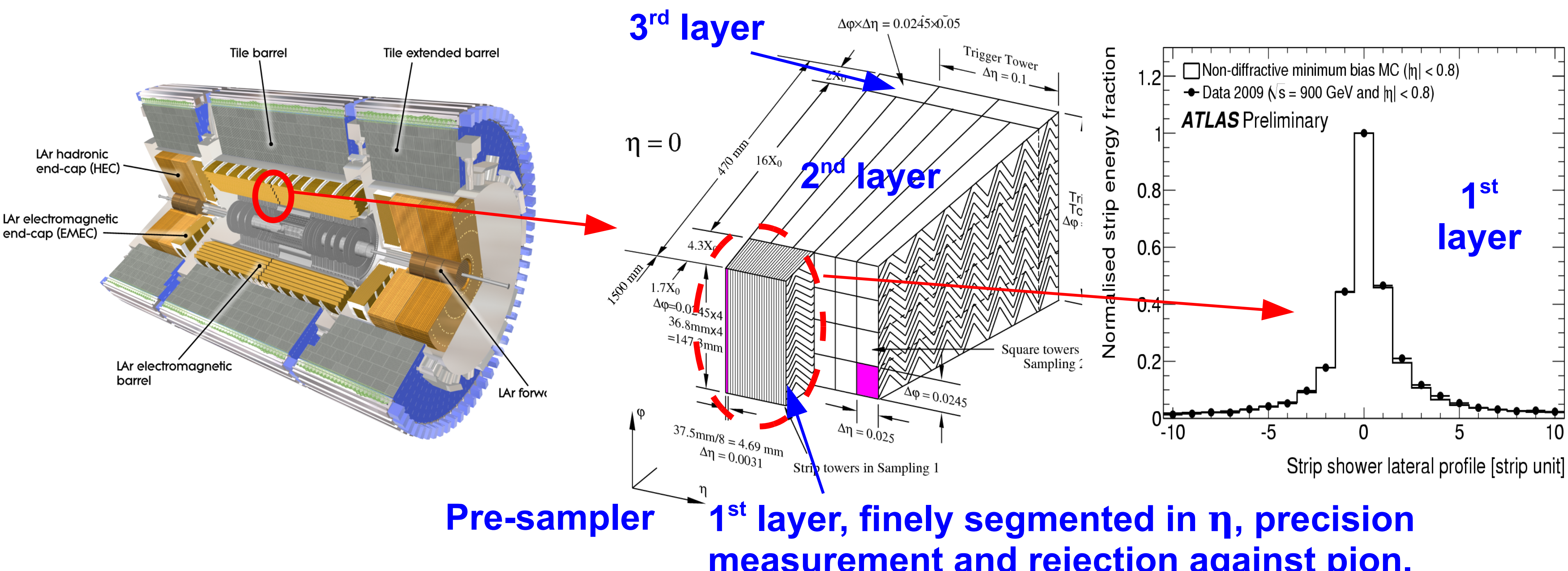
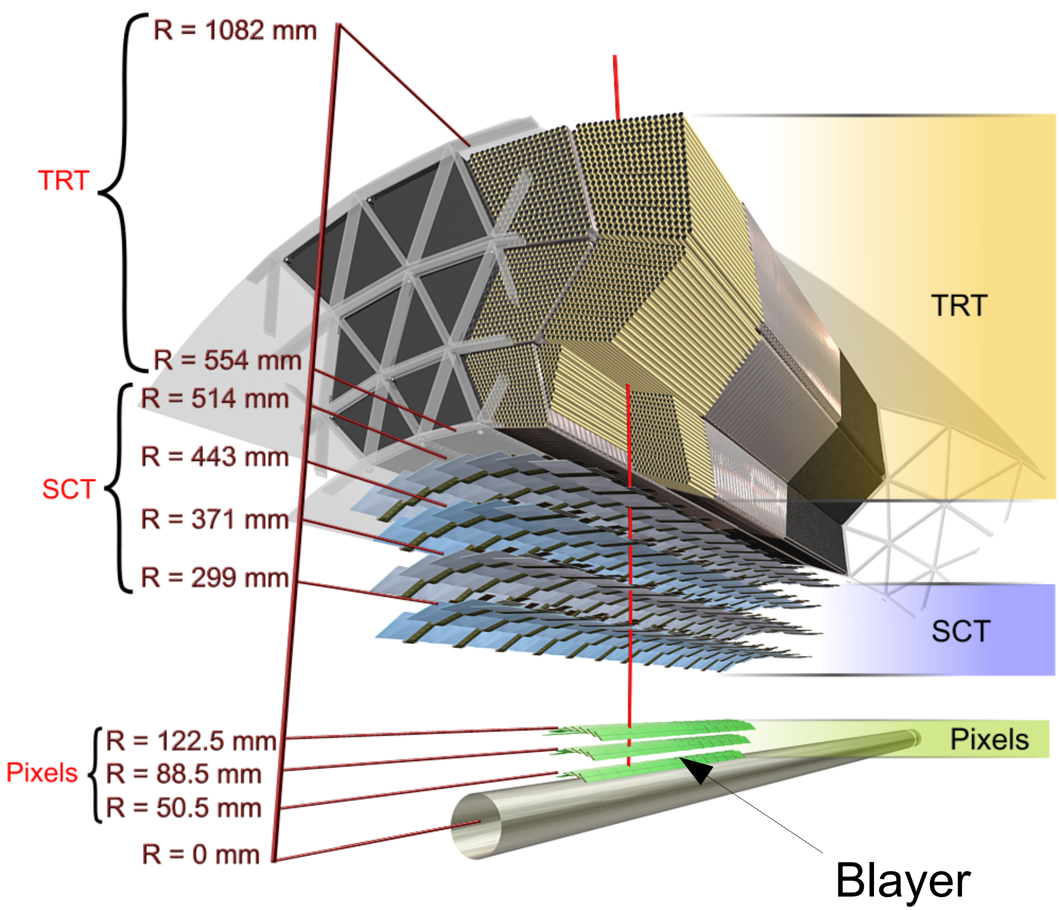
ATLAS EM Calorimeter

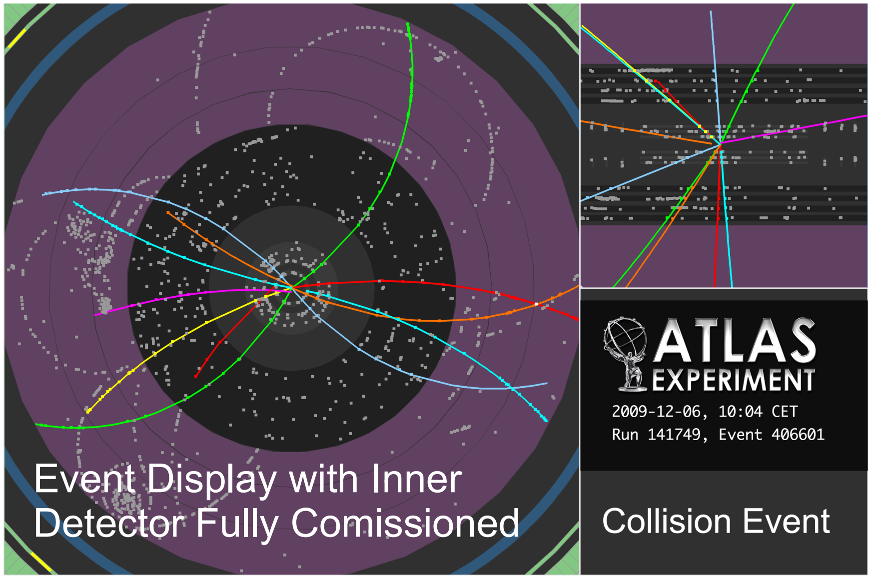
- Liquid Argon EM Calorimeter with accordion geometery covers |η|< 3.2. The fine granularity for |η|< 2.5 allows precision measurements of EM objects.
- Four layers perform energy/position measurements and provide information for particle identification.



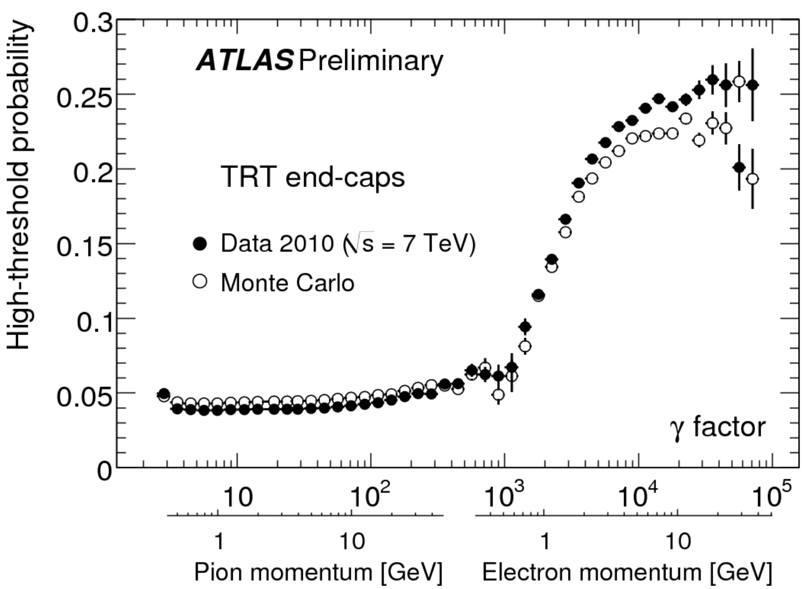
ATLAS Inner Detector Tracking System

- Inner Detector consisting of PIXEL, SCT, and TRT trackers, provides presicion measurements of momentum and direction of tracks with |η|< 2.5, and identification information.





http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

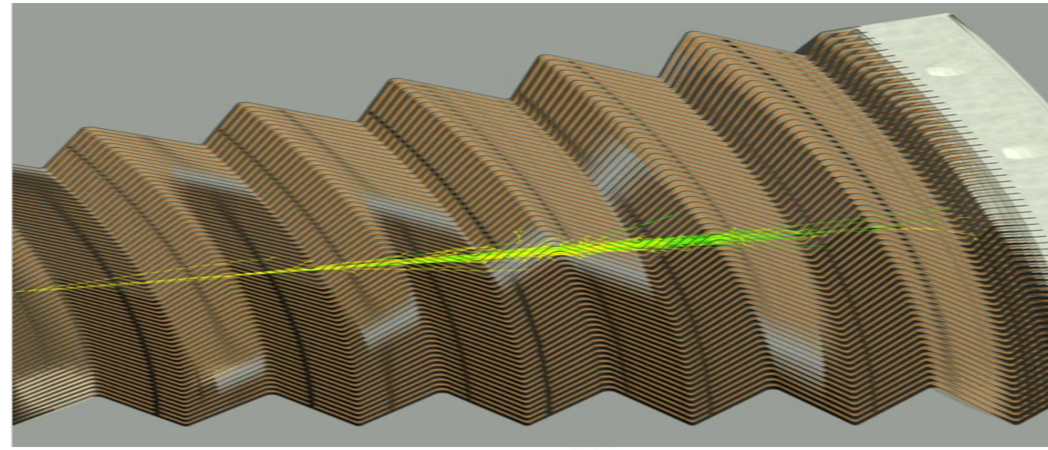


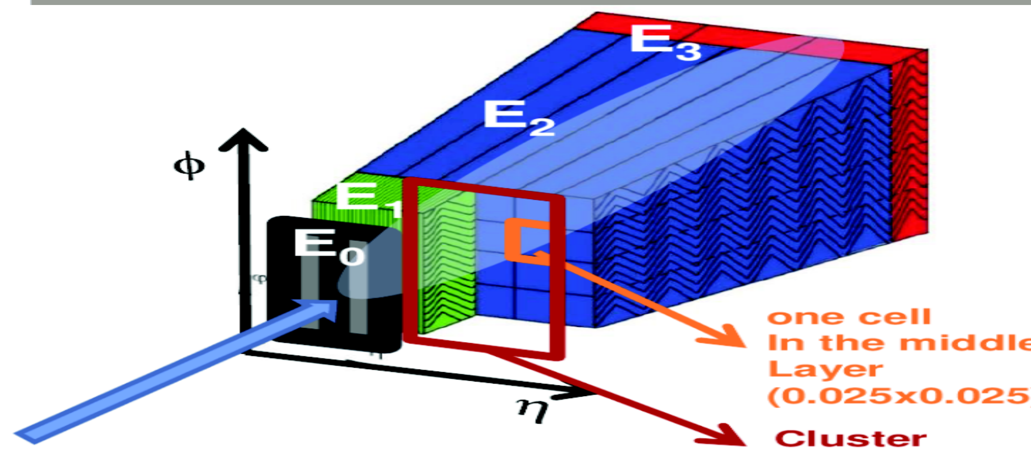
Electron and Photon Reconstruction

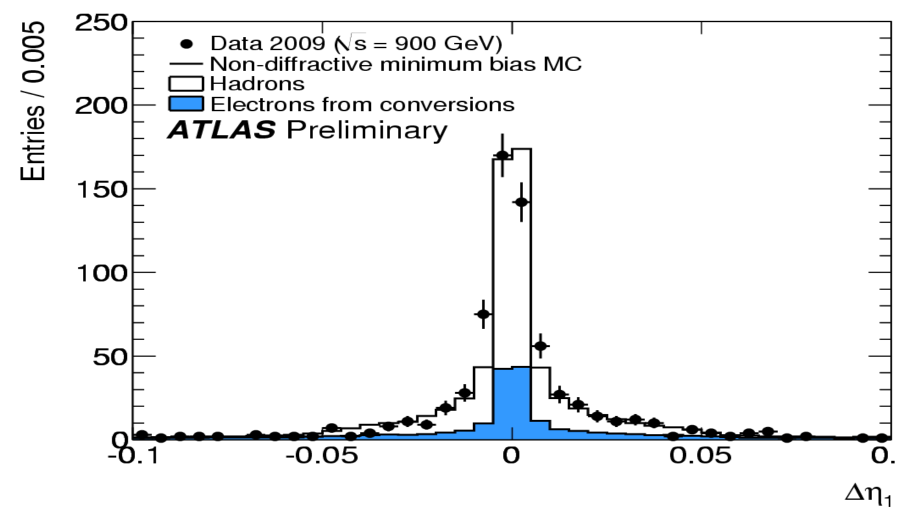
- Clusterization: scan over η-φ plane and find local energy deposit maiximum.
- Track matching: decide whether classify the cluster as an electron candidate or photon candidate.
- Energy measurement: combining energy of each layer taken into account energy lost upstream and laterally.(presampler |η| <1.8)

  Position measurement:

  first 2 layers and tracking in the case of electron.



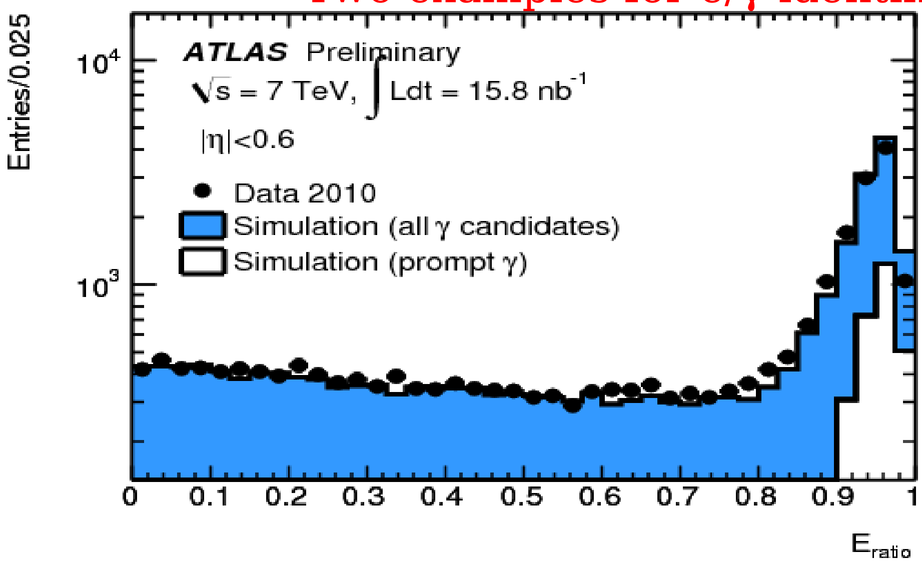




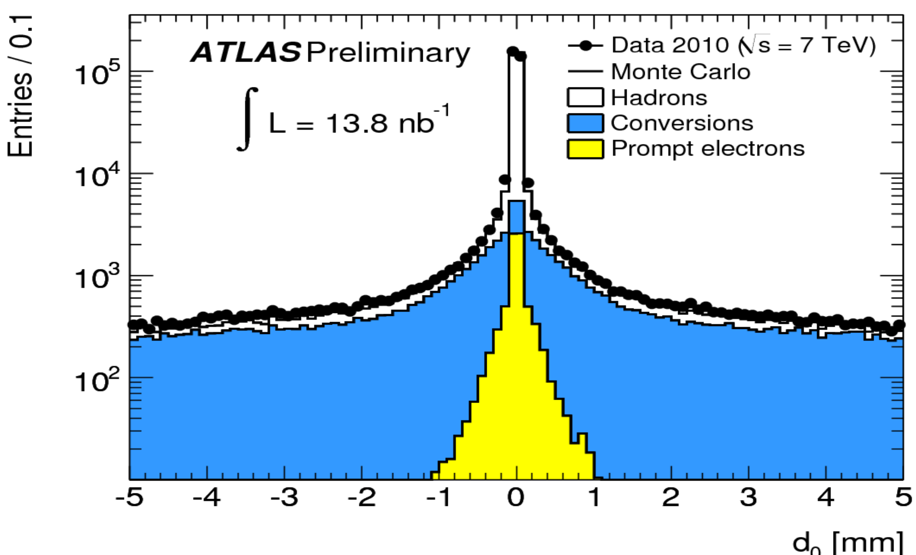
Electron and Photon Identification(1/2)

- Jets also deposit energies in EM calorimeter and have tracks recorded by Inner Detector, leading to fake electrons/photons.
- ATLAS has designed variables using calorimeter information or tracking information to identify electron and photon, and reject fakes from hadronic activities.

Two examples for e/γ identification variables used in ATLAS



$(E1-E2)/(E1+E2)$. E1,E2, two energy maxima in 1st layer



Track impact parameter wrt primary vertex

- Electron: loose / medium / tight selections
- Photon: loose / tight selections
- See backup slides for breakdown of details of these selections.

Electron and Photon Identification(2/2)

$$Efficiency = \frac{N_{e/\gamma\, selected}}{N_{e/\gamma\, produced}}, \quad Rejection = \frac{N_{jet\ produced}}{N_{jet-faking-e/\gamma}}$$

Signal Electron Efficiency and Jet rejection

	Efficiency (%)		Jet rejection (total)
	$Z \to ee$	$b,c \to e$	
Reconstructed	97.56 ± 0.03	-	91.5 ± 0.1
Loose	94.30 ± 0.03	36.8 ± 0.5	1066 ± 4
Medium	89.97 ± 0.03	31.5 ± 0.5	6821 ± 69
Tight	71.52 ± 0.03	25.2 ± 0.5	$(1.38 \pm 0.06) \times 10^5$

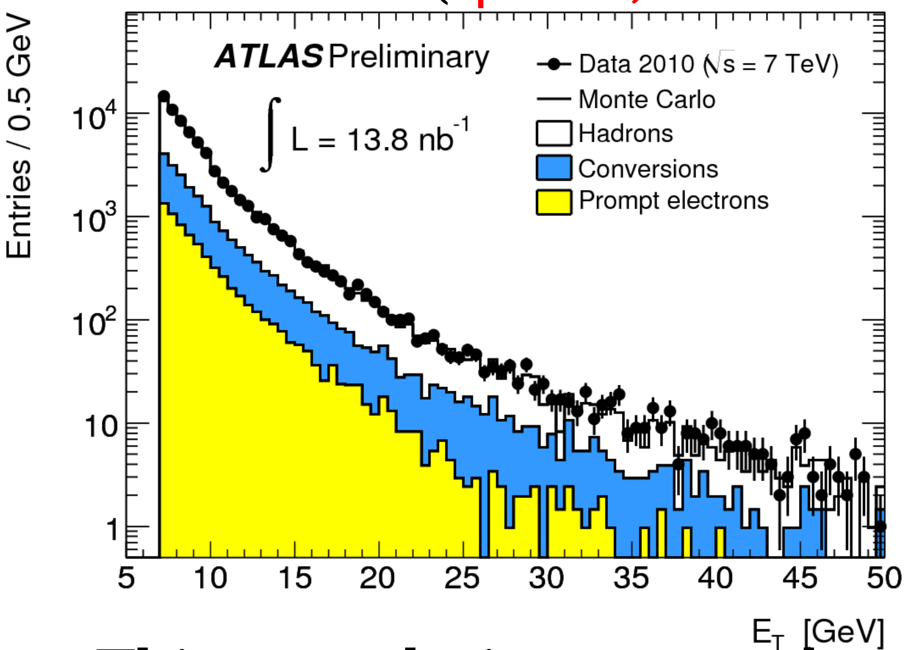
Signal Photon Efficiency and Jet rejection

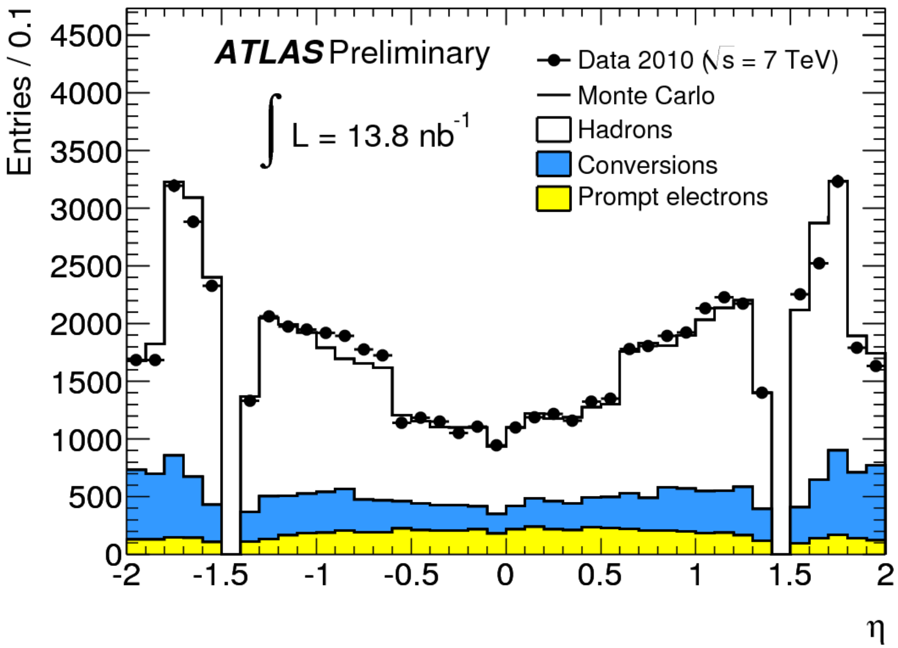
		Efficiency (%)	Jet rejection
Loose	All	95.45 ± 0.01	908 ± 4
	Unconverted	97.80 ± 0.01	
	Converted	91.73 ± 0.01	
Tight	All	82.88 ± 0.02	4770 ± 40
	Unconverted	85.04 ± 0.03	
	Converted	79.44 ± 0.04	

Validation and optimization with data are ongoing.

Inclusive Electron Analysis

- With the first 13.8nb^{-1} data, ATLAS performed an inclusive electron analysis with a sample of ~67,000 medium electron candidates.(η<2.0, E^T>7GeV)





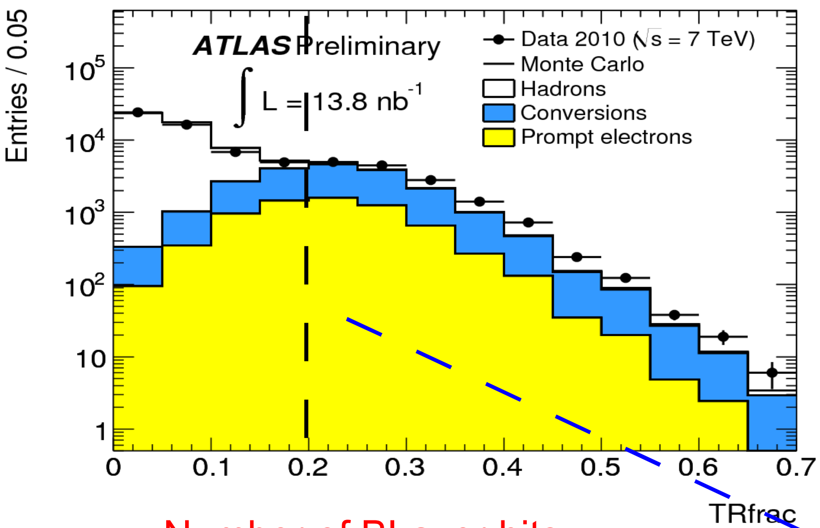
- This sample is expected to be dominated by hadrons, and has a small fraction of electrons from photon conversion. The fraction of prompt electrons (mainly from b/c decays) is about ~10%.

- This analysis is to estimate the fraction of each component, and to extract the distribution for each of them.

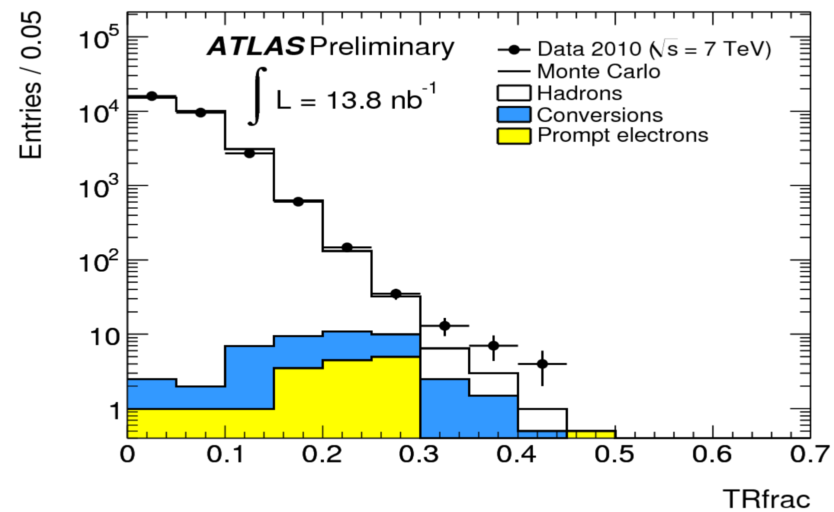
Matrix Method(1/2)

- Use variables that still have discriminating power after medium selection. Need to validate the cut acceptance for each component.

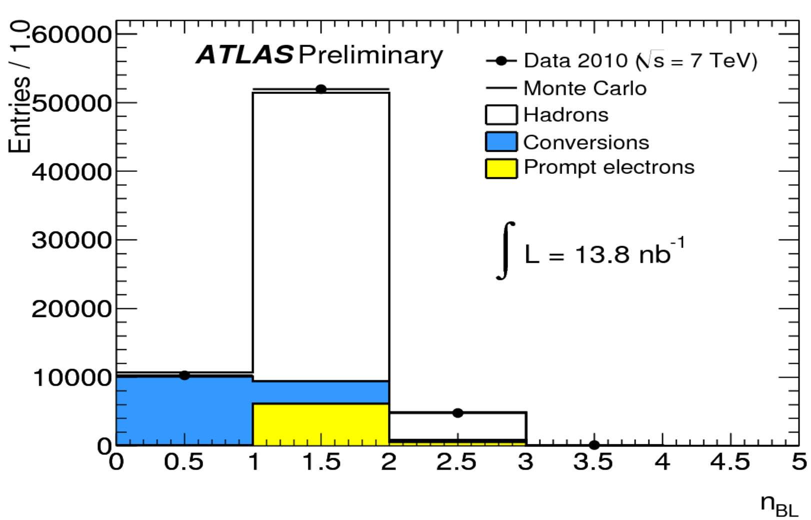
TRfrac: fraction of high-threshold TRT hits over all hits



TRfrac in hadron enriched control sample



Number of BLayer hits



$$N = N^h + N^\gamma + N^Q$$

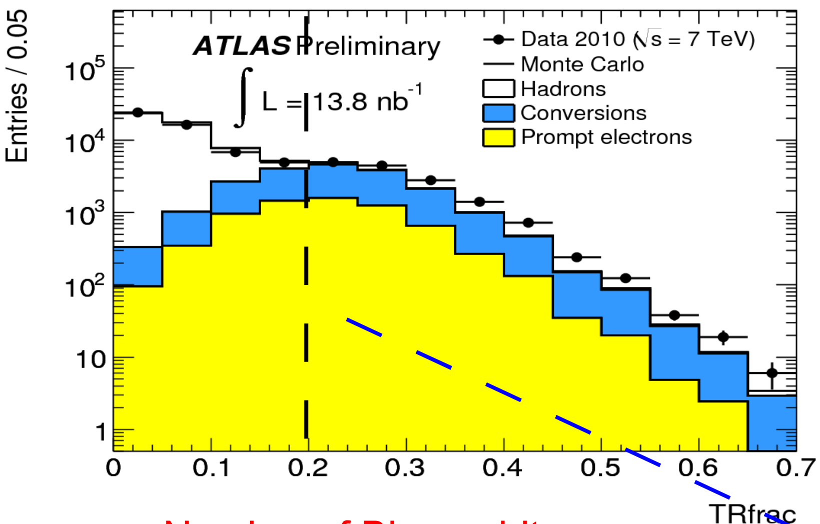
$$N_{TR} = N^h \varepsilon^h_{TR} + N^\gamma \varepsilon^\gamma_{TR} + N^Q \varepsilon^Q_{TR}$$

$$N_{BL,TR} = N^h \varepsilon^h_{BL} \varepsilon^h_{TR} + N^\gamma \varepsilon^\gamma_{BL} \varepsilon^\gamma_{TR} + N^Q \varepsilon^Q_{BL} \varepsilon^Q_{TR},$$

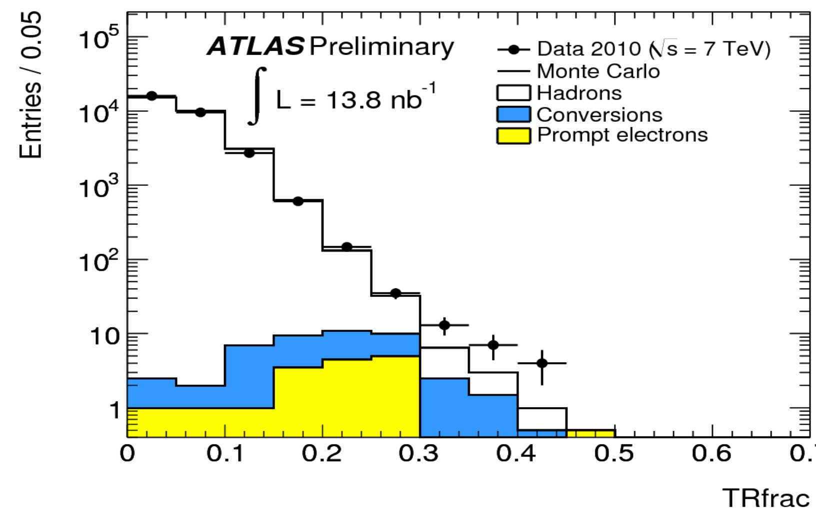
Matrix Method(1/2)

- Use variables that still have discriminating power after medium selection. Need to validate the cut acceptance for each component.

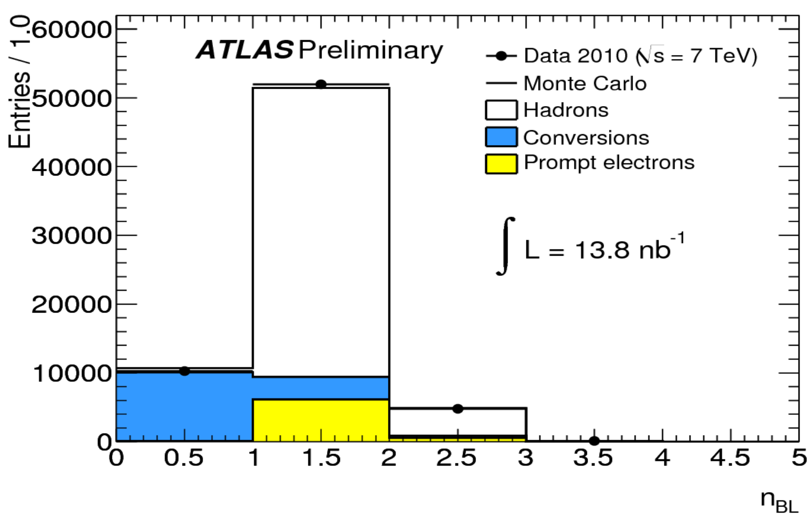
TRfrac: fraction of high-threshold TRT hits over all TRT hits



TRfrac in hadron enriched control sample



Number of BLayer hits



$$\begin{pmatrix} N \\ N_{TR} \\ N_{BL,TR} \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 \\ \varepsilon^{h}_{TR} & \varepsilon^{\gamma}_{TR} & \varepsilon^{Q}_{TR} \\ \varepsilon^{h}_{BL}\varepsilon^{h}_{TR} & \varepsilon^{\gamma}_{BL}\varepsilon^{\gamma}_{TR} & \varepsilon^{Q}_{BL}\varepsilon^{Q}_{TR} \end{pmatrix} \begin{pmatrix} N^{h} \\ N^{\gamma} \\ N^{Q} \end{pmatrix}$$

Solve the equation by inversion.

Matrix Method(2/2)

- Use variables that still have discriminating power after medium selection. Need to validate the cut acceptance for each component.

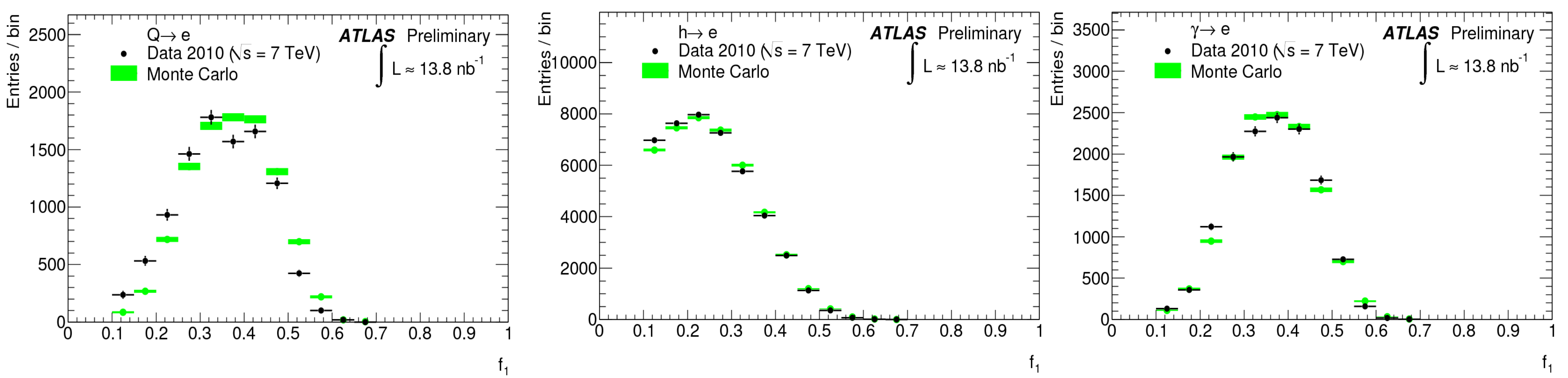
Breakdown of the compositions of the medium electron candidates in the first 13.8nb^{-1}

	Data	MC
Q→e	9920±160	6890±60
h→e	43470±240	46730±150
γ→e	13160±150	13580±80

Only statistical error is shown.

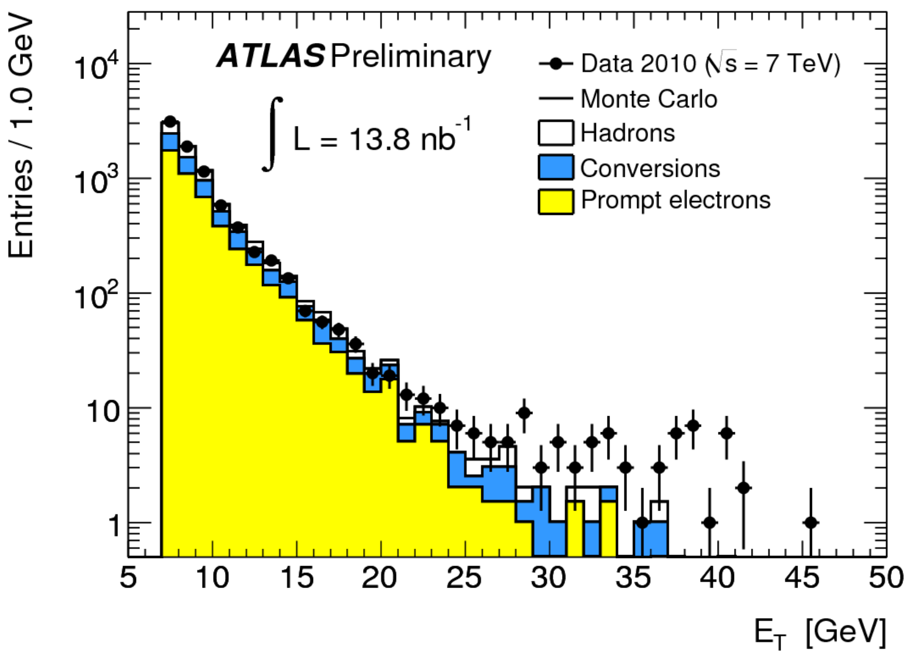
Source	Method used	$\Delta N/N$
Method used	Compare matrix with likelihood	±0.9%
Hadron discrimination	Replace $TRfrac$ by f_1 Vary cut on f_1 Vary electron contamination	±3.3%
$\varepsilon^{\gamma}_{TR}$	Replace Monte Carlo by data	±0.6%
ε^{Q}_{TR}	Replace Monte Carlo by data	±5.4%
$\varepsilon^{\gamma}_{BL}$	Vary by ±5% (see text)	±6.6%
ε^{h}_{BL}	Min. bias meas.	$< 0.5\%$
ε^{Q}_{BL}	Brem. in beam-pipe	$< 0.5\%$
MC statistical uncertainty		±1.2%
Binning uncertainties	Vary bin size	±1.5%
Scale of EM energy	Vary by ±3%	$< 0.5\%$

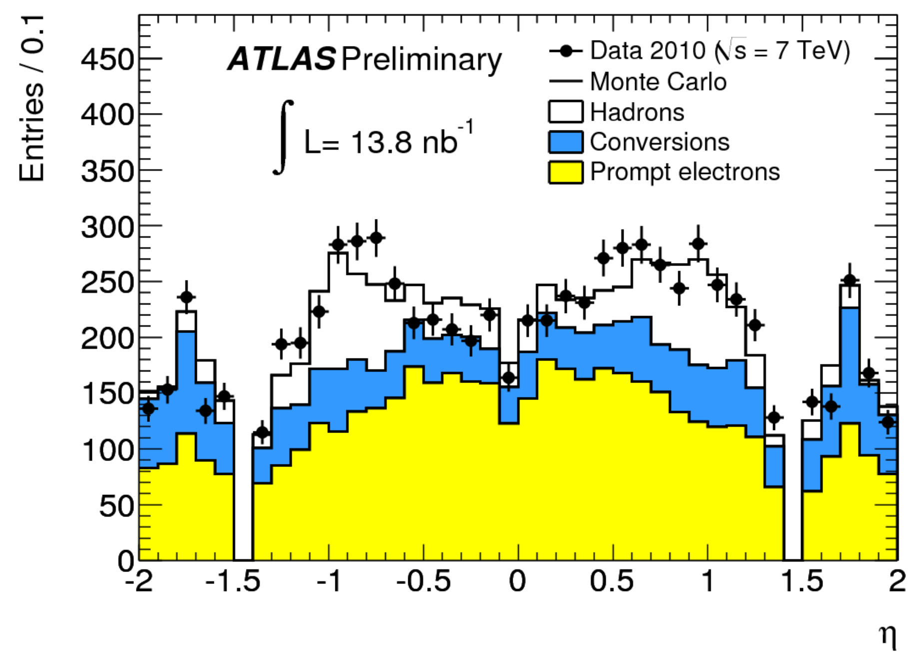
Extracted distributions for three different compositions: the energy fraction for 1st layer



Tight Electron Candidates

- After tight identification cut is applied, 8024 electron candidates are selected.

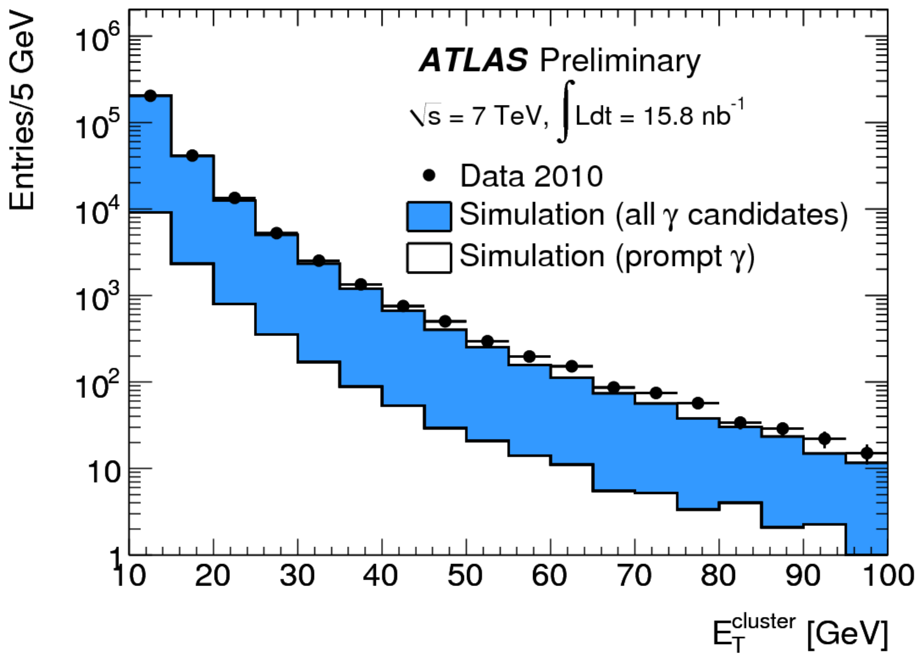


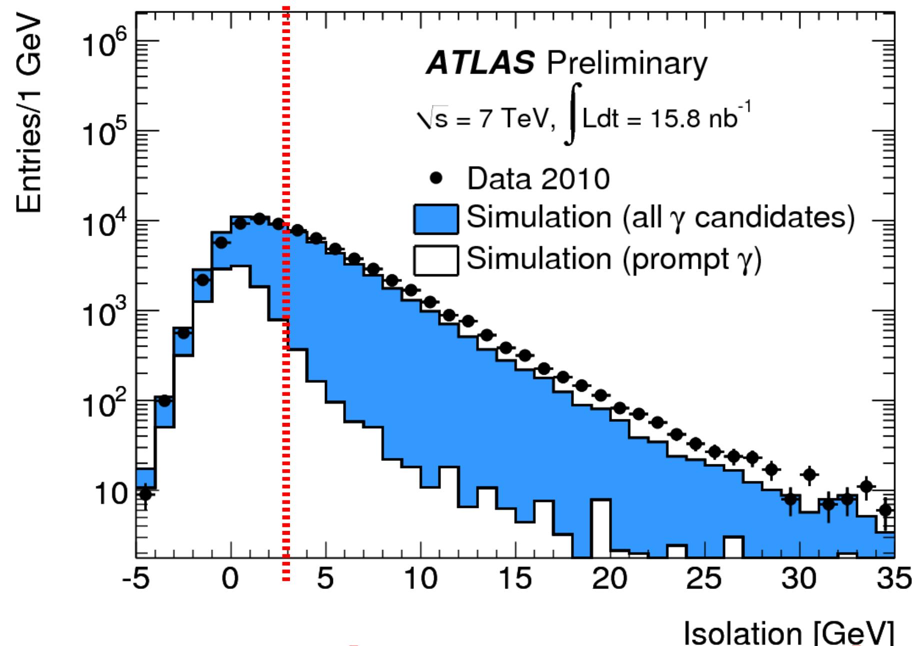


- Isolated prompt electrons from W/Z decays are clearly visible.

Prompt Photon Analysis

- Prompt Photon: γ from hard process, γ from FSR/ISR, and γ from non-perturbative fragmentation of quarks and gluons.





$E_T > 10$GeV, $|\eta|<2.37$, excluding transition region between Barrel and endcap

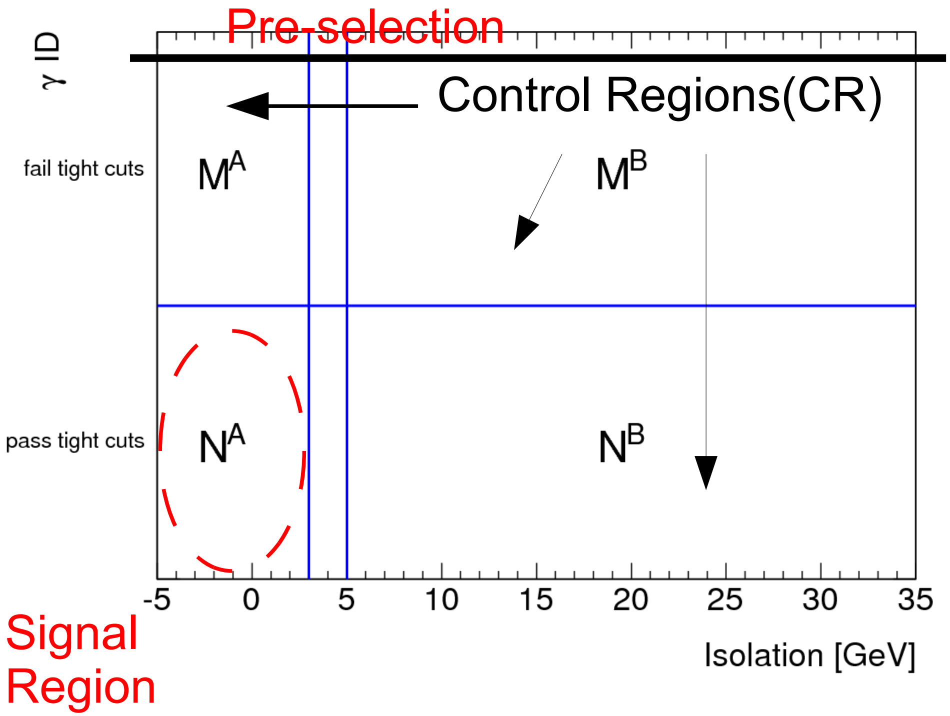
Sum calorimeter energy within R<0.4(in η-φ) around the photon cluster. The energy from underlying event is removed

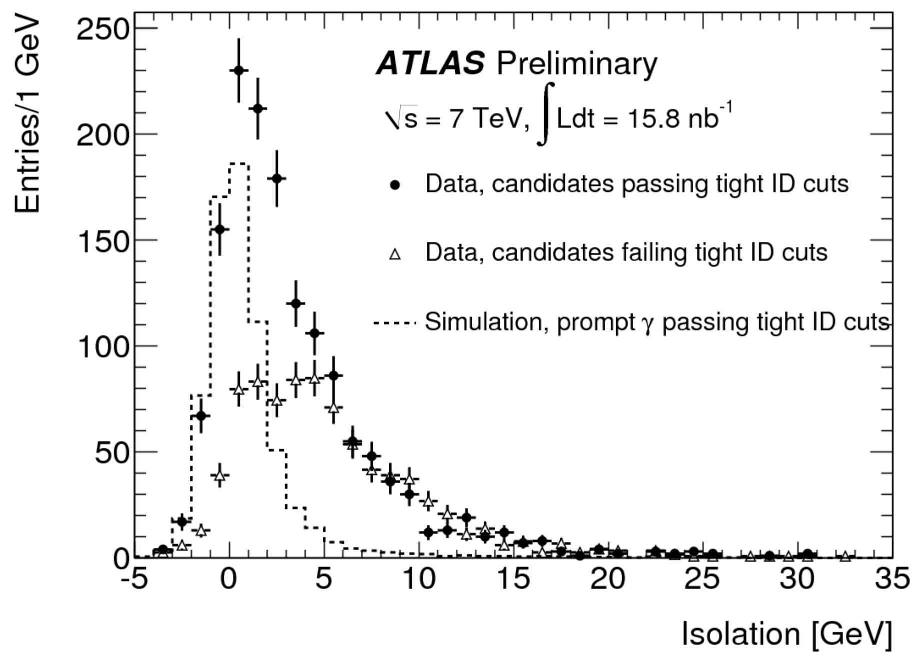
- Isolation: important in the NLO QCD calculation. We've done a lot works to make experimental isolation comparable with parton isolation(removed cluster energy leakage, UE contributions, working on removing pile-up contributions).

- ATLAS performed a data-driven analysis to yield the purity of photon sample in various P_T and η bins.

Photon Purity Measurements

- Tight Photon Candidates Sample: Tight Photon Identification Requirement + isolation energy requirement(<3GeV).



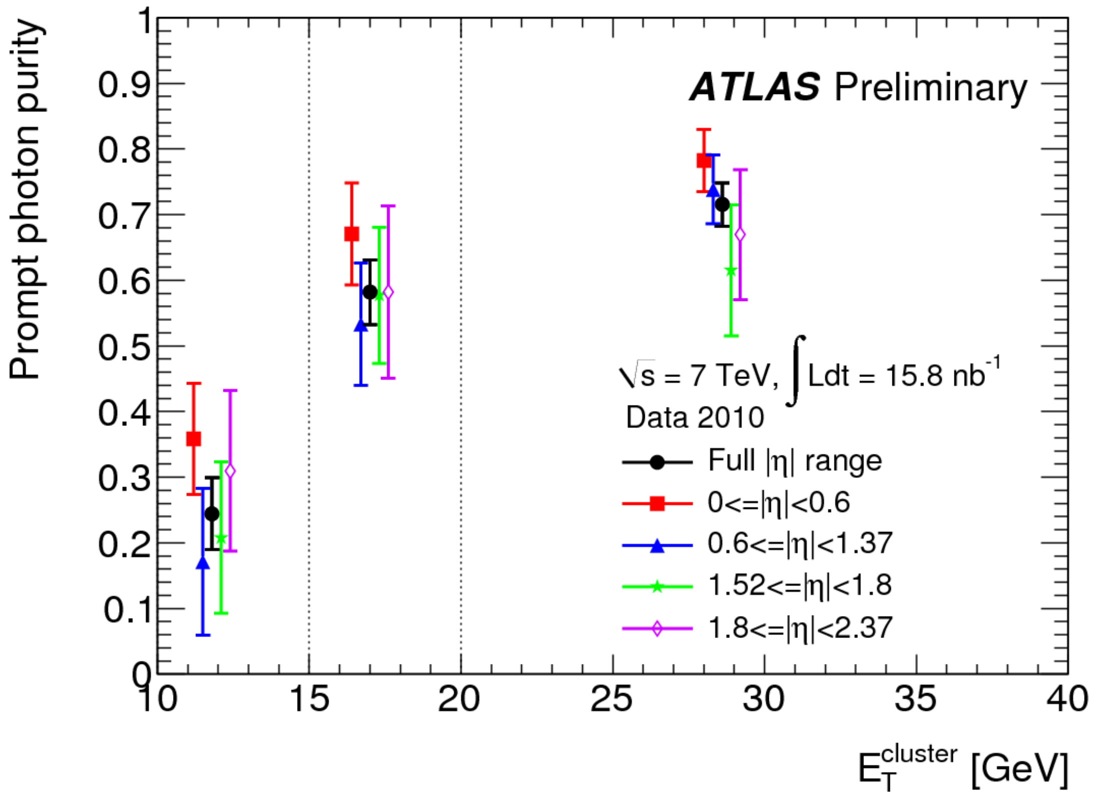


The fake photon candidates in signal regions could be extracted using the acceptance of isolation for fakes obtained from M^A, M^B.

$$N^A_{\text{sig}} = N^A - N^B \frac{M^A}{M^B}$$

$$P = 1 - \frac{N^B}{N^A} \frac{M^A}{M^B}$$

Photon Purity Results



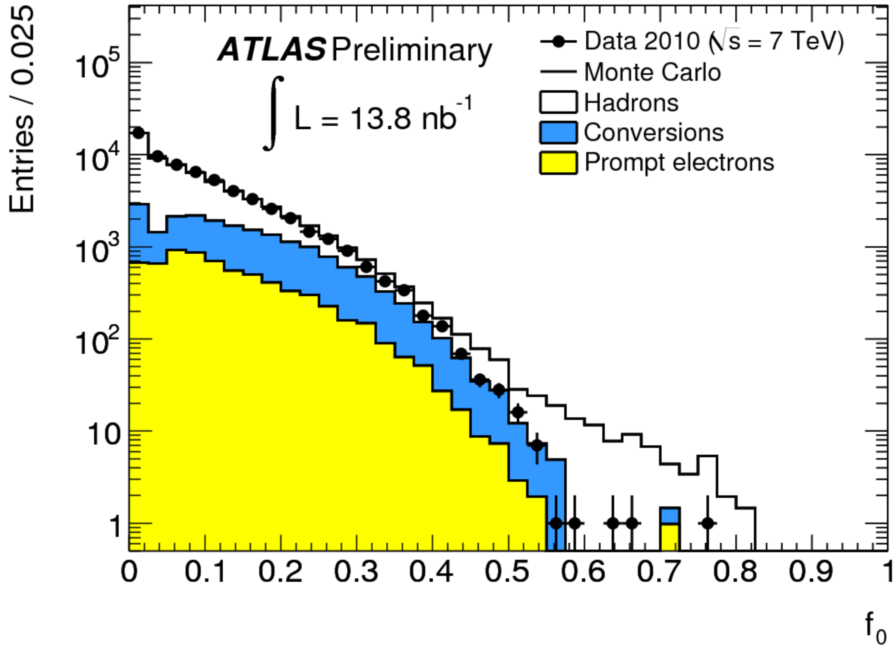
E_T interval [GeV]	$10 \leq E_T < 15$	$15 \leq E_T < 20$	$E_T \geq 20$
Number of candidates	5271	1213	864
Estimated purity P [%]	24 ± 5	58 ± 5	72 ± 3
Systematic uncertainty on P [%]	24	8	6
Estimated signal yield N^A_{sig}	1289 ± 297	706 ± 69	618 ± 42
Systematic uncertainty on N^A_{sig}	1362	86	59

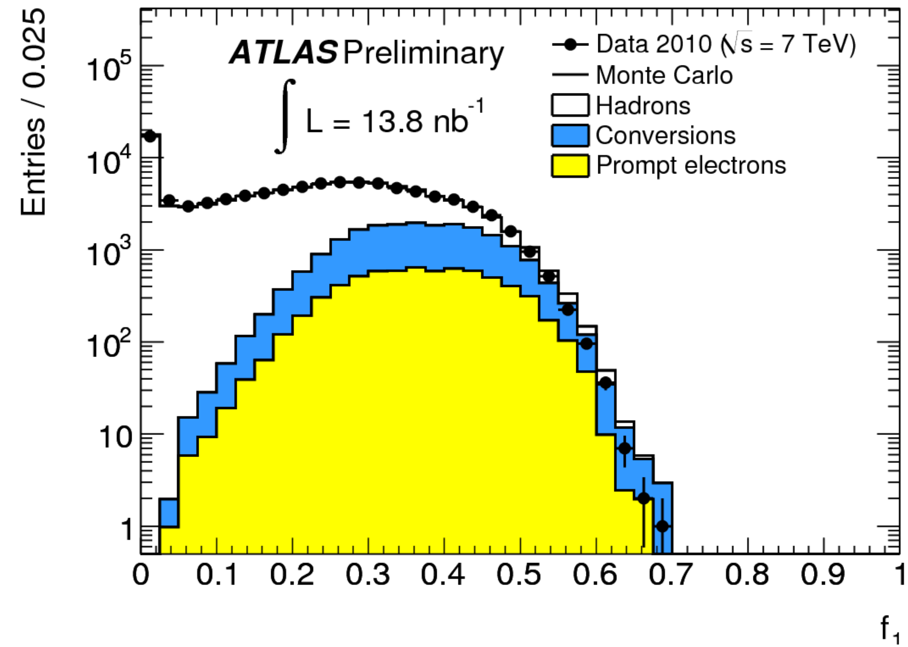
Summary

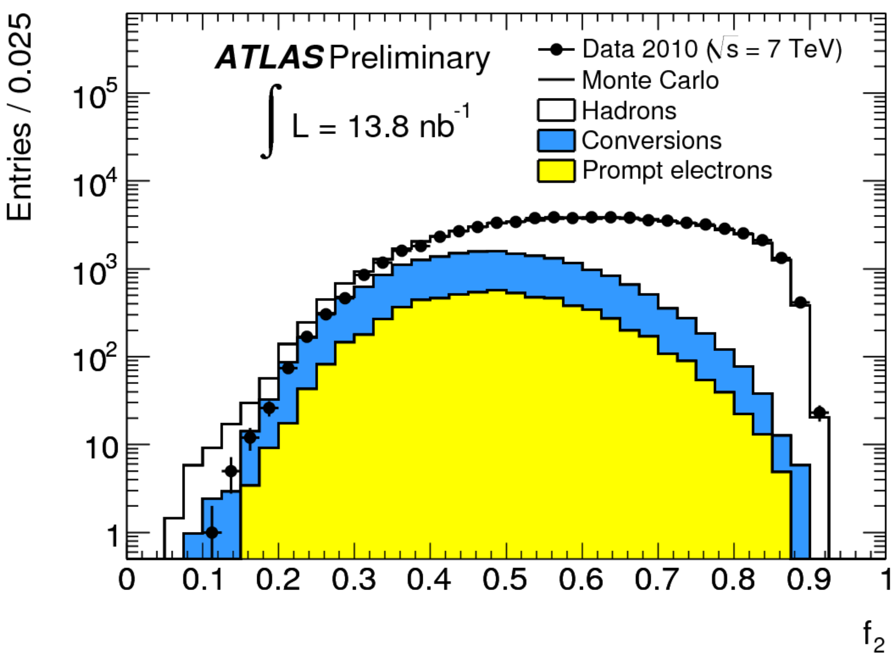
- ATLAS has been performing well with the first data and substantial works have been done to understand the performances of electron and photon.
  - We still have much works to do
    - Will have good constraints from Z and Jpsi decays with enough statistics, which allow us to study the identification and energy scale in a data driven way.
- Both inclusive electron and prompt photon analyses have demonstrated our ability to understand the physics behind the data with the knowledge on the detector.
  - These are important steps towards first cross section measurements of electron and photon.
  - More exciting results with electron/photon are coming soon …

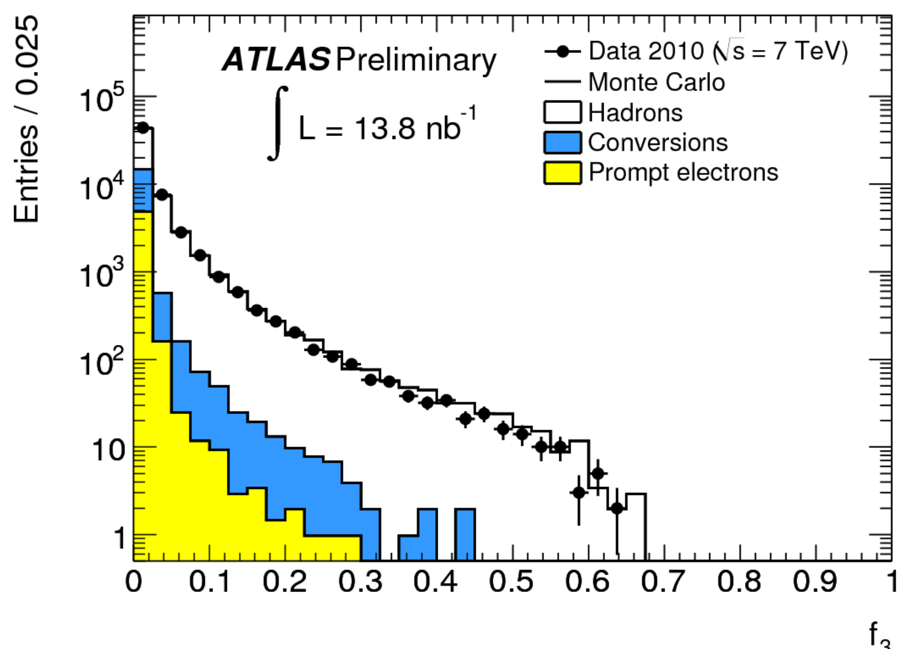
Back Up

Electron Cluster Energy Fractions in 4 layers









Electron and Photon Identification Criteria

Type	Description	Name
Loose electron and photon cuts		
Acceptance of the detector	$\|\eta\| < 2.47$ for electrons, $\|\eta\| < 2.37$ for photons ($1.37 < \|\eta\| < 1.52$ excluded)	-
Hadronic leakage	Ratio of E_T in the 1st sampling of the hadronic calorimeter to E_T of the EM cluster (used over the range $\|\eta\| < 0.8$ and $\|\eta\| > 1.37$)	R_{had1}
	Ratio of E_T in the hadronic calorimeter to E_T of the EM cluster (used over the range $\|\eta\| > 0.8$ and $\|\eta\| < 1.37$)	R_{had}
Middle layer of the EM calorimeter	Ratio in η of cell energies in 3×7 versus 7×7 cells.	R_η
	Lateral width of the shower	w_2
Medium electron cuts (in addition to the loose cuts)		
Strip layer of the EM calorimeter	Total lateral shower width (20 strips)	w_{stot}
	Ratio of the energy difference between the largest and second largest energy deposits over the sum of these energies	E_{ratio}
Track quality	Number of hits in the pixel detector (at least one)	-
	Number of hits in the pixels and SCT (at least seven)	-
	Transverse impact parameter (<5 mm)	d_0
Track matching	$\Delta\eta$ between the cluster and the track in the strip layer of the EM calorimeter	$\Delta\eta_1$
Tight electron cuts (in addition to the medium electron cuts)		
B-layer	Number of hits in the B-layer (at least one)	
Track matching	$\Delta\phi$ between the cluster and the track in the middle layer of the EM calorimeter	$\Delta\phi_2$
	Ratio of the cluster energy to the track momentum	E/p
TRT	Total number of hits in the TRT (used over the acceptance of the TRT, $\|\eta\| < 2.0$)	-
	Ratio of the number of high-threshold hits to the total number of TRT hits (used over the acceptance of the TRT, $\|\eta\| < 2.0$)	-
Tight photon cuts (in addition to the loose cuts, applied with stricter thresholds)		
Middle layer of the EM calorimeter	Ratio in ϕ of cell energies in 3×3 and 3×7 cells	R_ϕ
Strip layer of the EM calorimeter	Shower width for three strips around maximum strip	w_{s3}
	Total lateral shower width	w_{stot}
	Fraction of energy outside core of three central strips but within seven strips	F_{side}
	Difference between the energy of the strip with the second largest energy deposit and the energy of the strip with the smallest energy deposit between the two leading strips	ΔE
	Ratio of the energy difference associated with the largest and second largest energy deposits over the sum of these energies	E_{ratio}