Electron and photon performance and electron p_T spectrum measurement with ATLAS in pp collisions at $\sqrt{s} = 7\,\text{TeV}$

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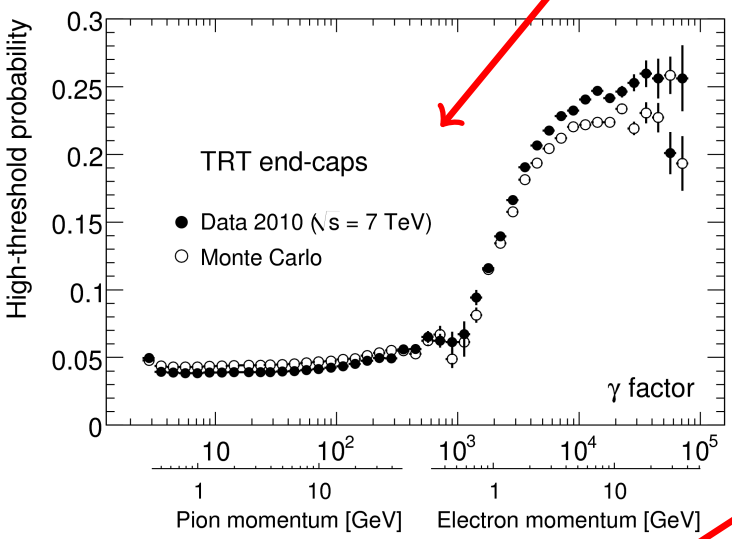
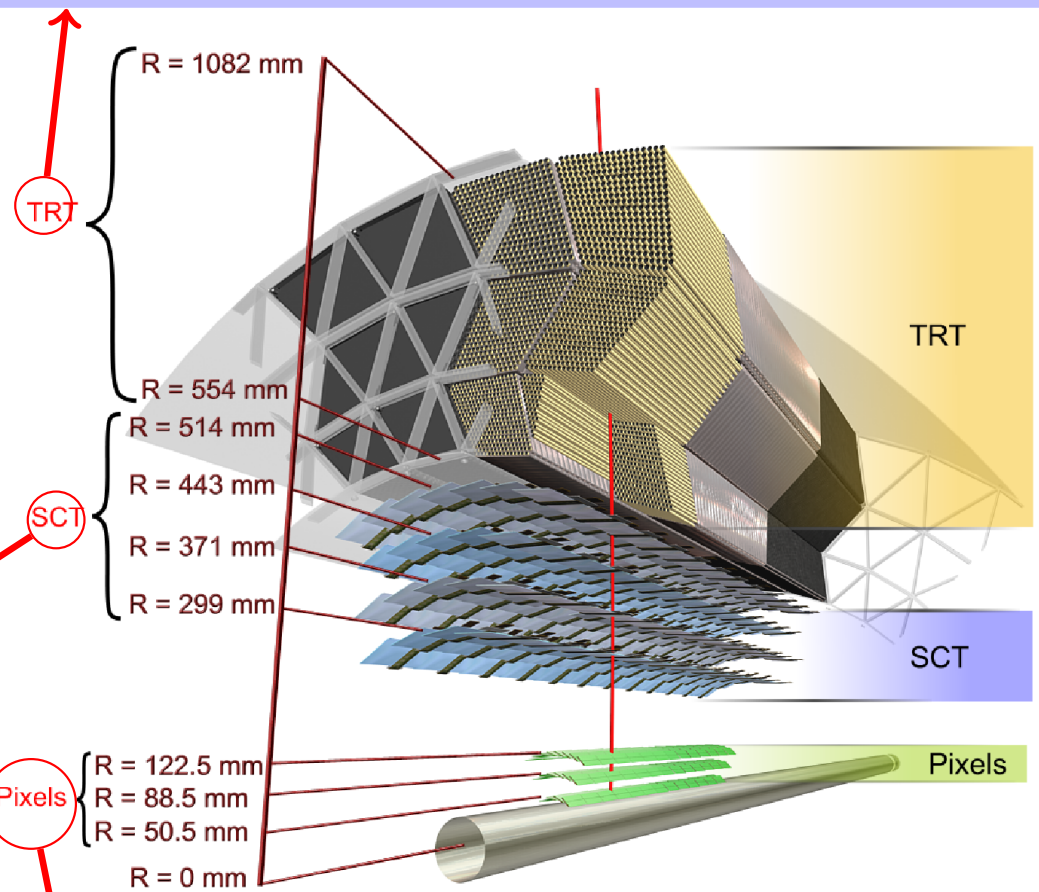
- Electromagnetic object detection at ATLAS.
- Inclusive electron E_T spectrum.
- Direct photon observation.
- J/ψ observation.

Electromagnetic object detection at ATLAS

ATLAS tracking detectors

Transition Radiation Tracker: Straw tubes interleaved with polypropylene radiator. Discriminates e/π from 1–200 GeV.



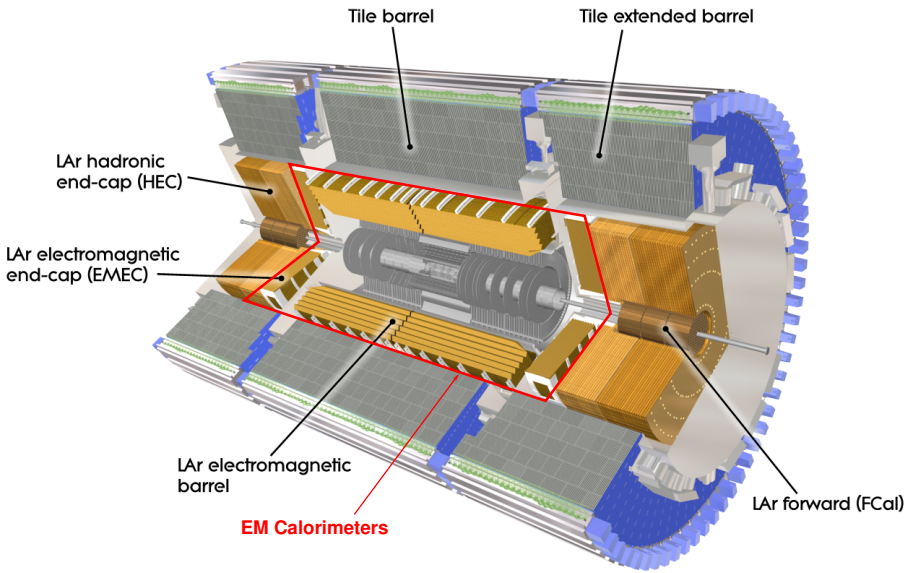


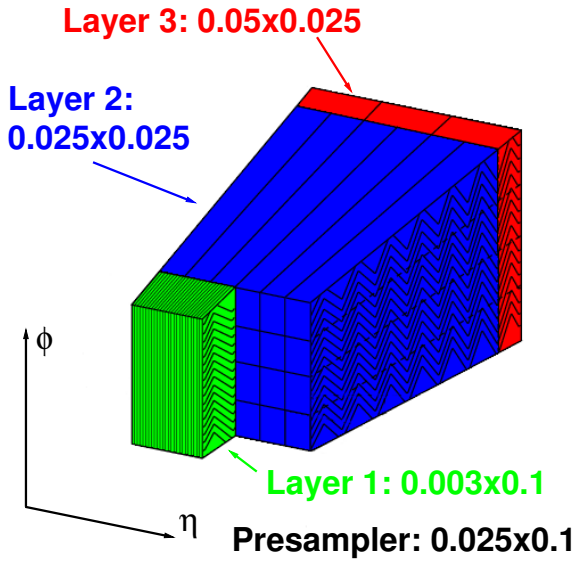
Silicon microstrips.

Pixel detector: high-resolution space points.
Inner $r \sim 5$ cm layer rejects conversions.

Electromagnetic calorimeters

- Lead-LAr calorimeters with accordion geometry and fine segmentation.
- Precision measurements to $|\eta| < 2.5$: three longitudinal samplings.
- Presampler to $|\eta| < 1.8$.
- First sampling very finely segmented in η: precision η measurements and π^0 rejection.

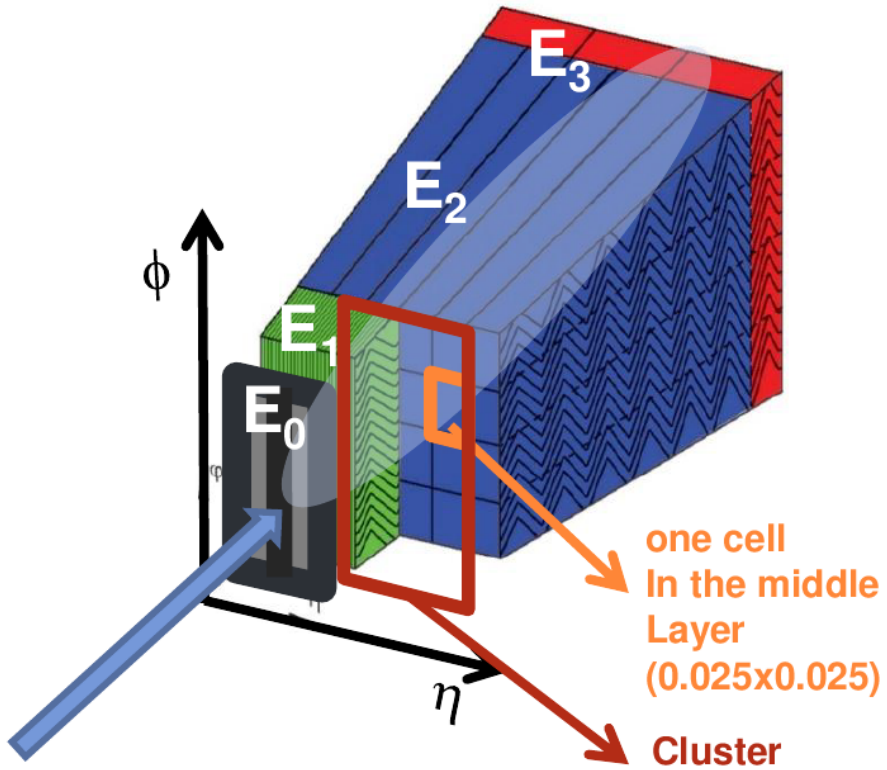




Electron/photon reconstruction

- Search for seed energy clusters in the EM calorimeter with significant energy. (Seed clusters can be either a rectangular window or the result of a nearest-neighbor clustering algorithm.)
- Match cluster with tracks. Classify as electron, photon, or converted photon.

- Form a cluster from cells in a rectangular region around the seed. (Size depends on location in detector and classification.)
- Calculate energy and direction.
  - Energy a weighted sum of layer energies, with corrections for detector effects.



Inclusive electron analysis

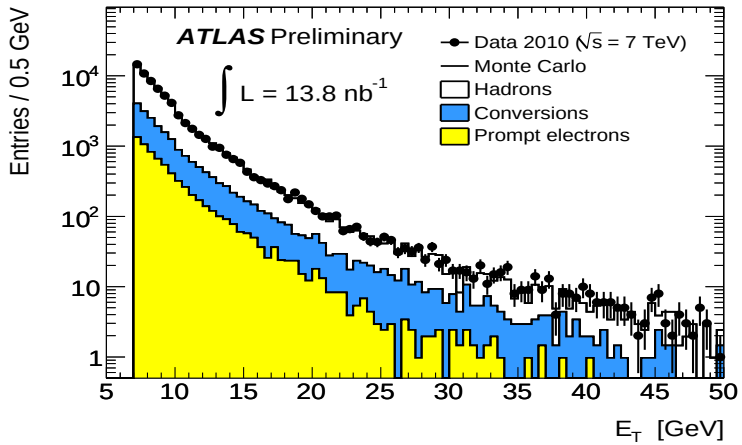
[ATLAS-CONF-2010-073]

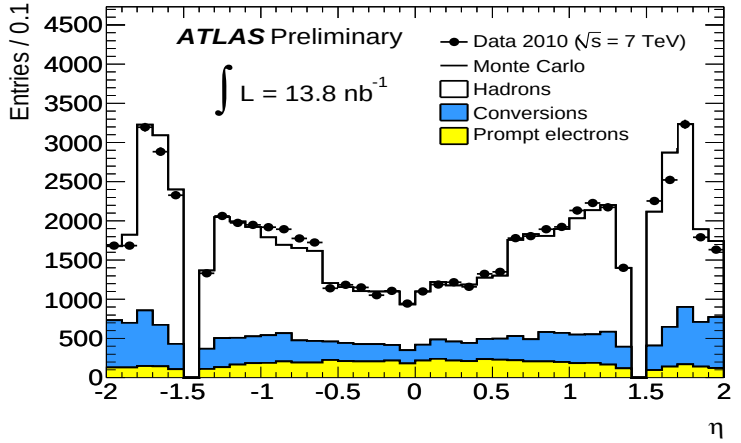
- Goal: Decompose E_T spectrum of electron candidates by source ($b/c \to e$ [Q], conversions [γ], hadrons [h]).

(MC normalized to data.)

Candidate selection variables:

- $E_T > 7\,\text{GeV}$, $|\eta| < 2.0$; exclude cracks between calorimeters.
- f_1: Fractional energy in layer 1.
- Shower width+shape in layer 1.
- Number of hits in tracking detectors.
- Track transverse impact parameter wrt. vertex.
- $\Delta\eta(\text{track}, \text{cluster})$.





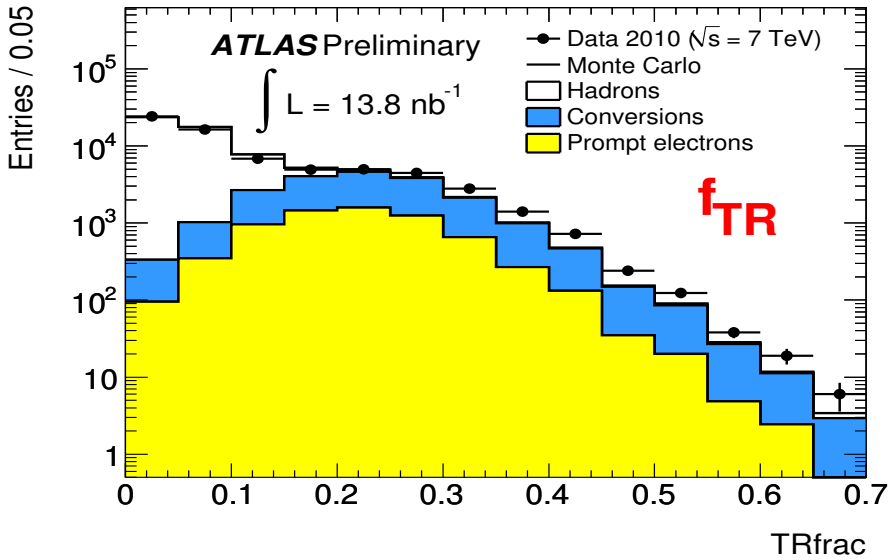
Yields 67124 candidates in $13.8\,\text{nb}^{-1}$.

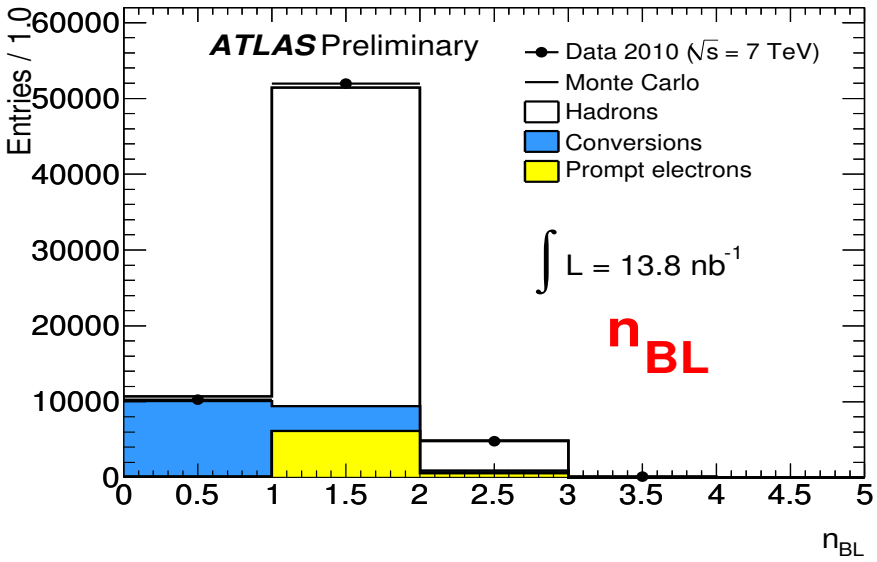
Discriminating variables

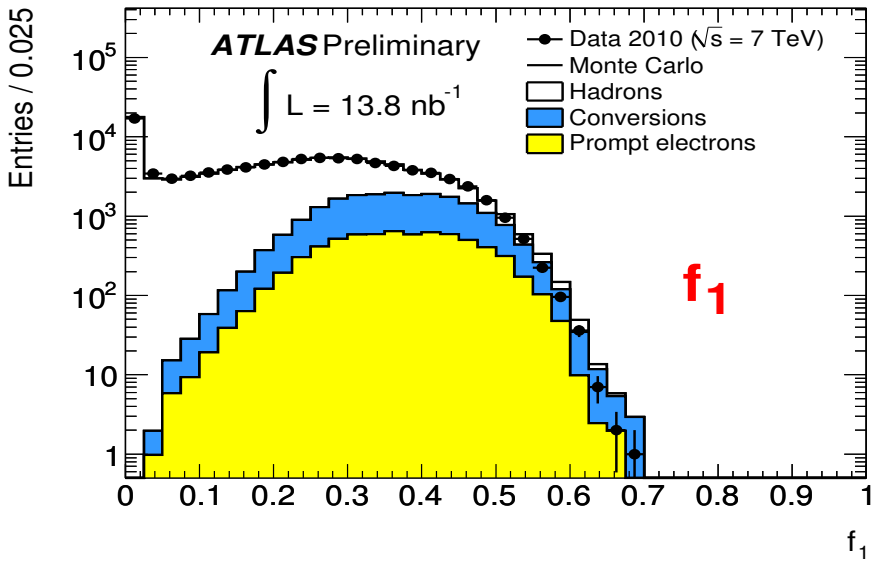
[ATLAS-CONF-2010-073]

Need variables to discriminate between different candidate sources.

- Electrons vs. hadrons:
  - f_{TR}: Fraction of high-threshold TR hits.
  - f_1: Energy fraction in layer 1.
- Electrons vs. conversions:
  - n_{BL}: Number of hits in innermost (B) pixel layer.







Component extraction results

[ATLAS-CONF-2010-073]

Decompose into components using "matrix method".
Efficiencies: ε^Q, ε^γ from MC; ε^h from sample with inverted f_1 selection.

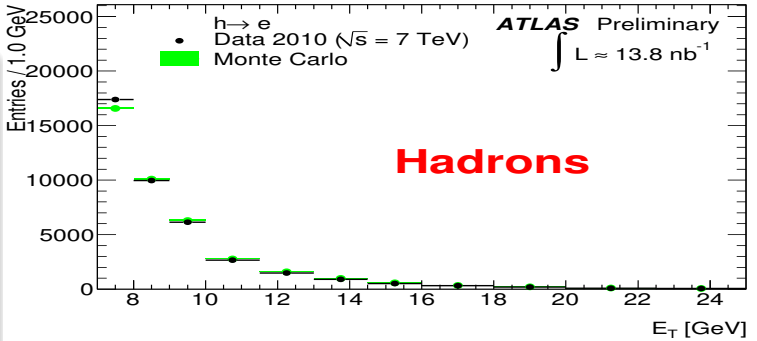
Numbers of extracted events:

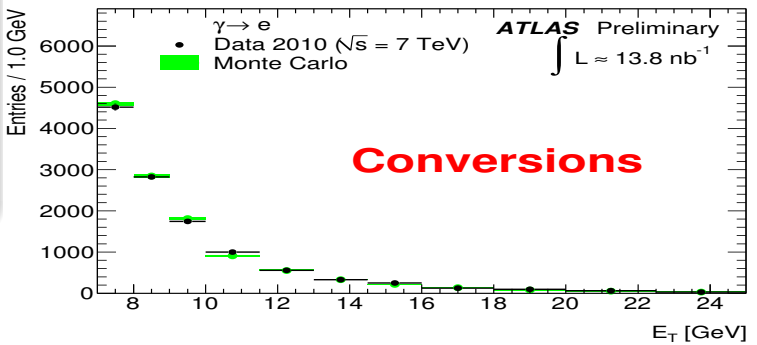
	Data	MC
h	43470 ± 240	46730 ± 150
γ	13160 ± 150	13580 ± 80
Q	9920 ± 160	6890 ± 60
Total	67124	

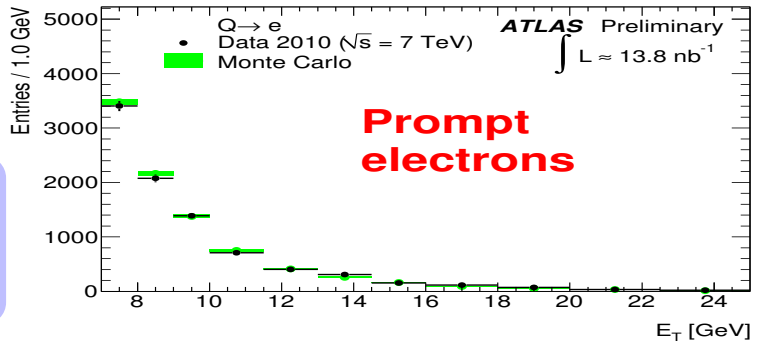
(Statistical uncertainties only.)

Consistent results from using f_1 instead of f_{TR} and using likelihood fit instead of matrix method.

MC predictions for hadronic backgrounds not expected to be accurate at this point.







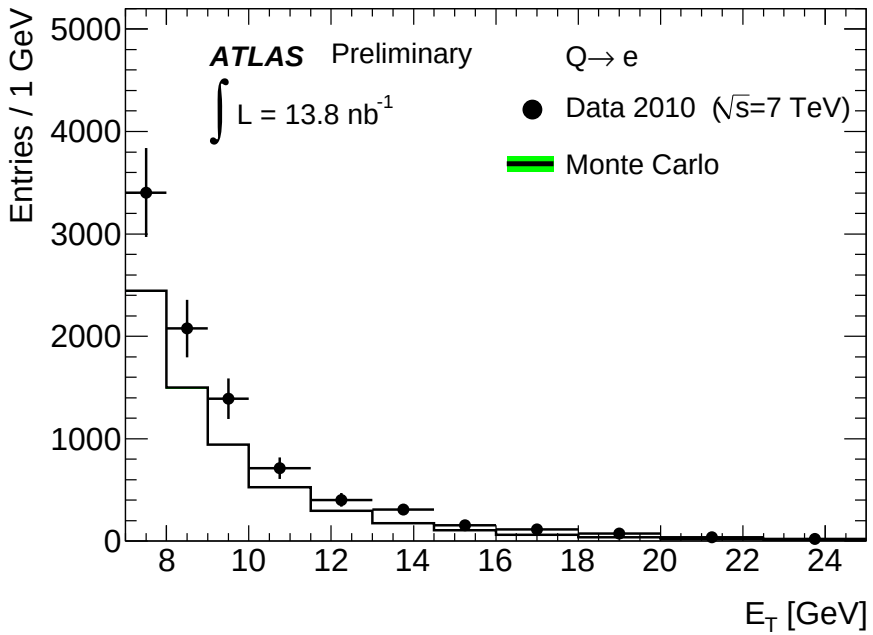
(MC plots normalized to data.)

Systematic uncertainties

[ATLAS-CONF-2010-073]

Method	$\pm 0.9\%$
Hadron discrimination	$\pm 3.3\%$
$\varepsilon_{\mathrm{TR}}^{Q}$	$\pm 5.4\%$
$\varepsilon_{\mathrm{BL}}^{\gamma}$	$\pm 6.6\%$
Other ε	$< 1\%$
MC statistics	$\pm 1.2\%$
Binning	$\pm 1.5\%$
EM energy scale	$< 0.5\%$

Extracted prompt electron signal compared to PYTHIA MC.



MC normalized to total number of electron candidates.

Observed prompt electron signal: 9920 ± 160 (stat.) ± 990 (syst.)

Tight selection

[ATLAS-CONF-2010-073]

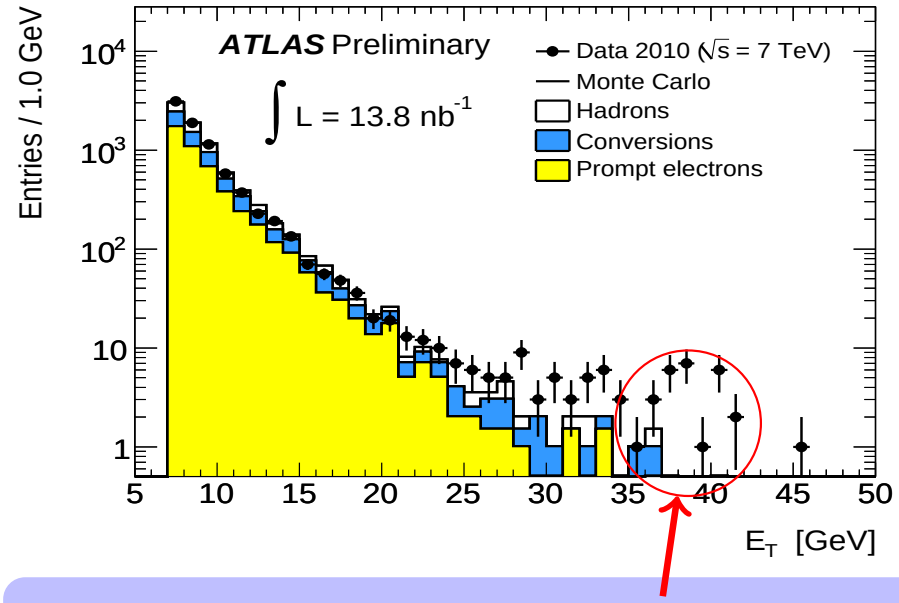
Additional selection variables:

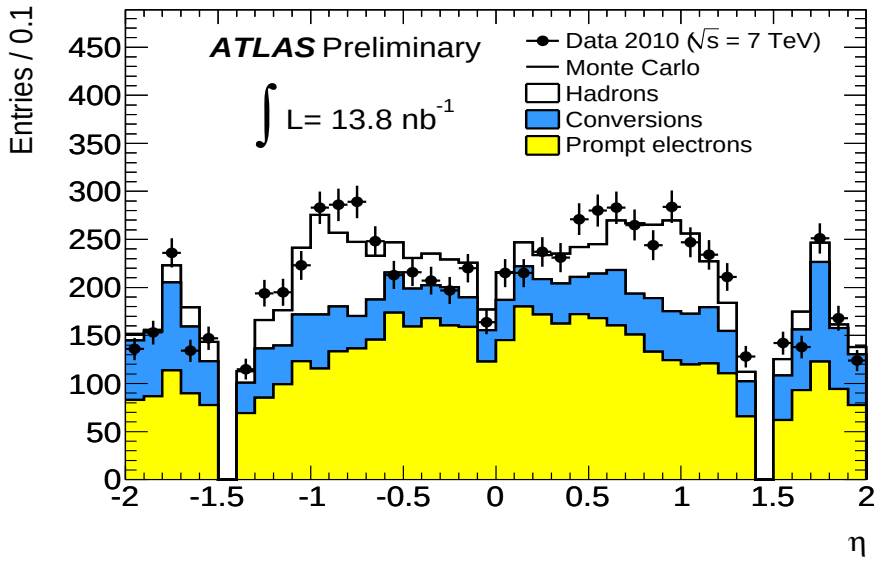
- Hadronic leakage.
- $R_\eta = E(3\times 7)/E(7\times 7)$.
- Cluster/track E/p.
- n_{BL} and f_{TR}.

8024 candidates in $13.8\,\mathrm{nb}^{-1}$

Expect:

- 59% prompt electrons.
- 23% conversions.
- 18% hadrons.





See electrons from W bosons ! (But that's another talk.)

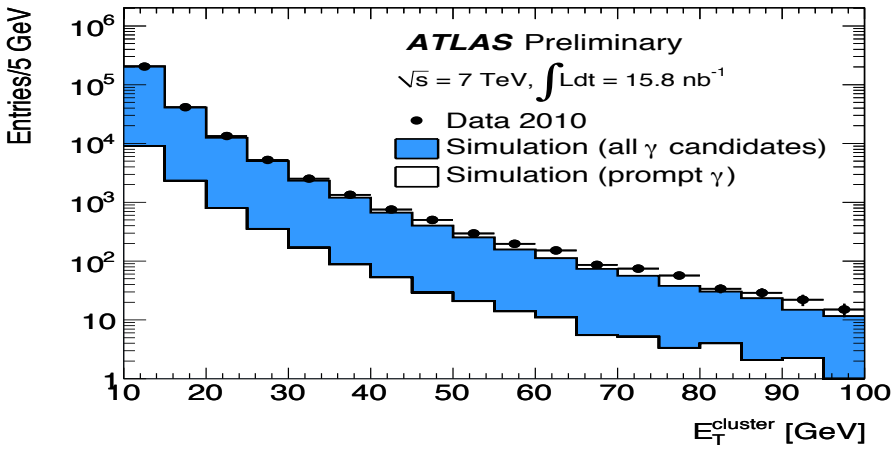
Direct photon analysis

[ATLAS-CONF-2010-077]

Goal: Reconstruct direct, isolated photons with good S/B and measure the purity of the sample.

Initial selection:

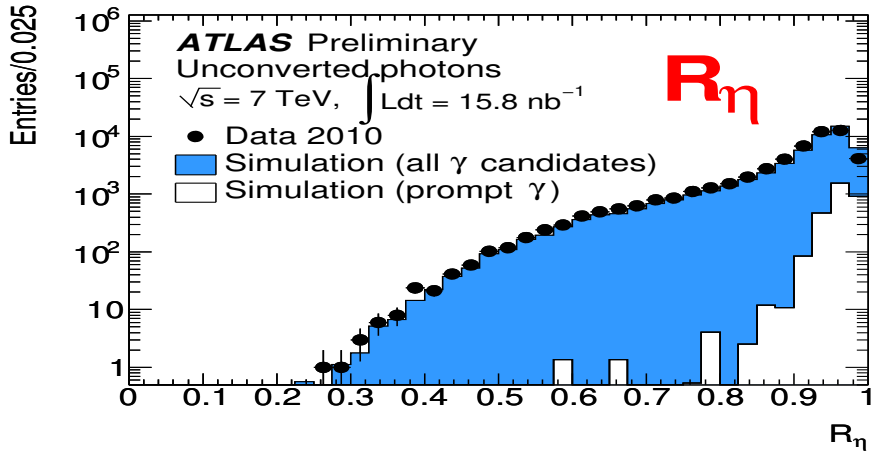
- $E_T > 10\,\text{GeV}$.
- $|\eta| < 2.37$ and exclude the crack region between calorimeters.

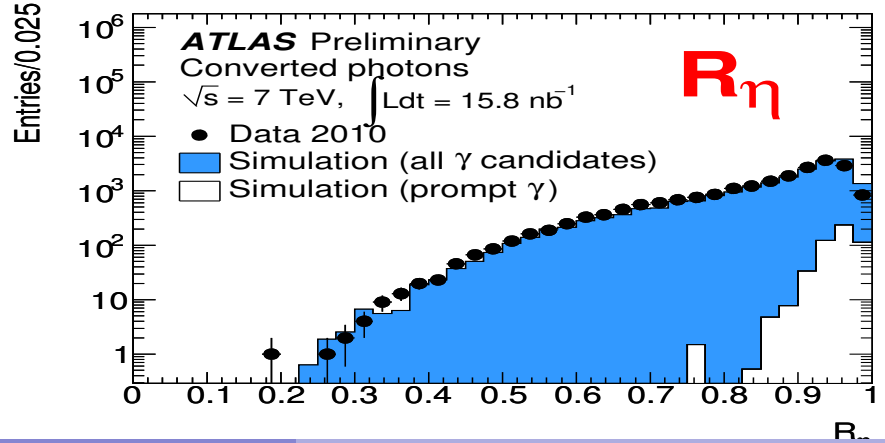


268992 candidates in $15.8\,\text{nb}^{-1}$.

Loose selection variables:

- Hadronic leakage.
- Cluster width in layer 2.
- $R_\eta = E(3\times 7)/E(7\times 7)$.





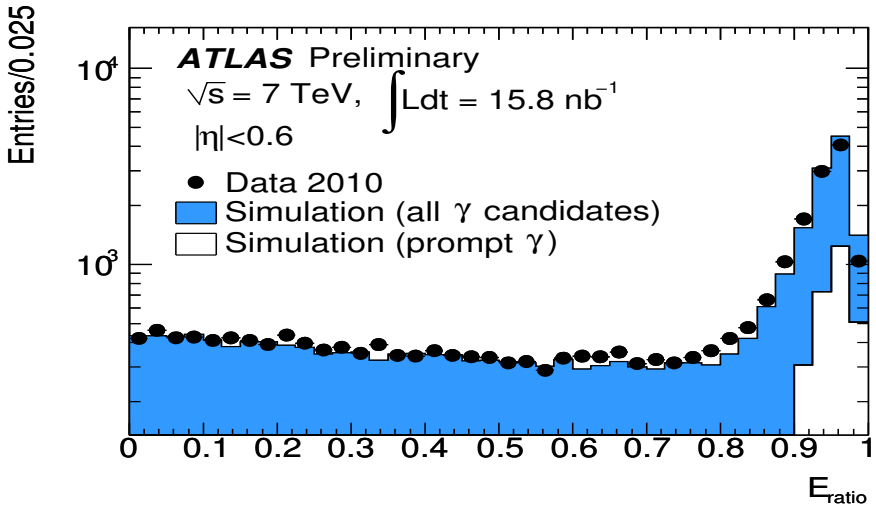
Direct photon analysis

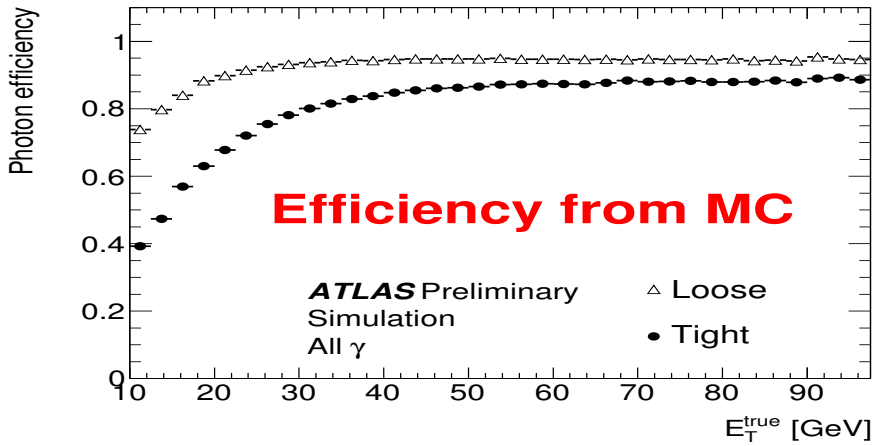
[ATLAS-CONF-2010-077]

Tight selection variables

- Cluster shape/width in layer 1 (π^0 rejection).

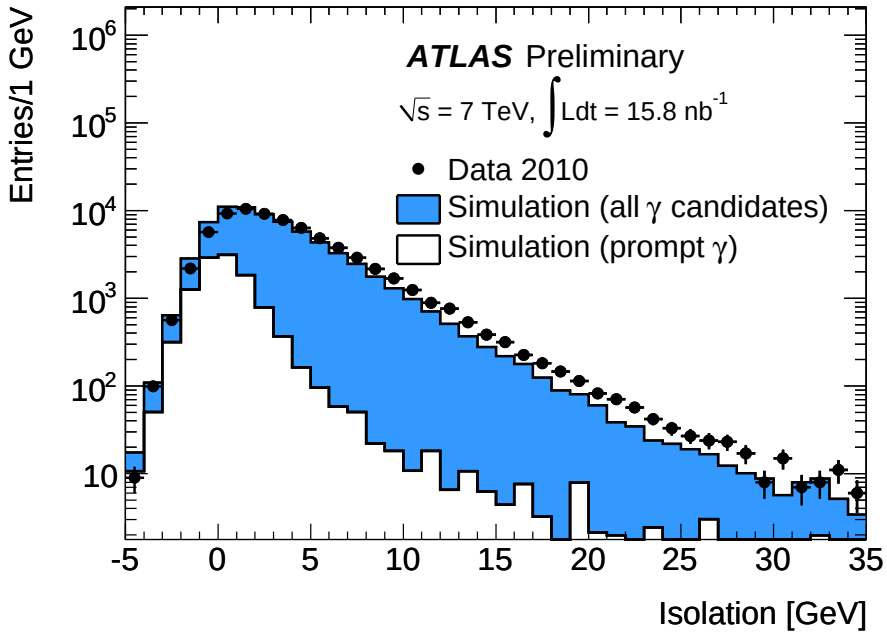
E_{ratio}: asym. btn. first two maxima in layer 1





Isolation:

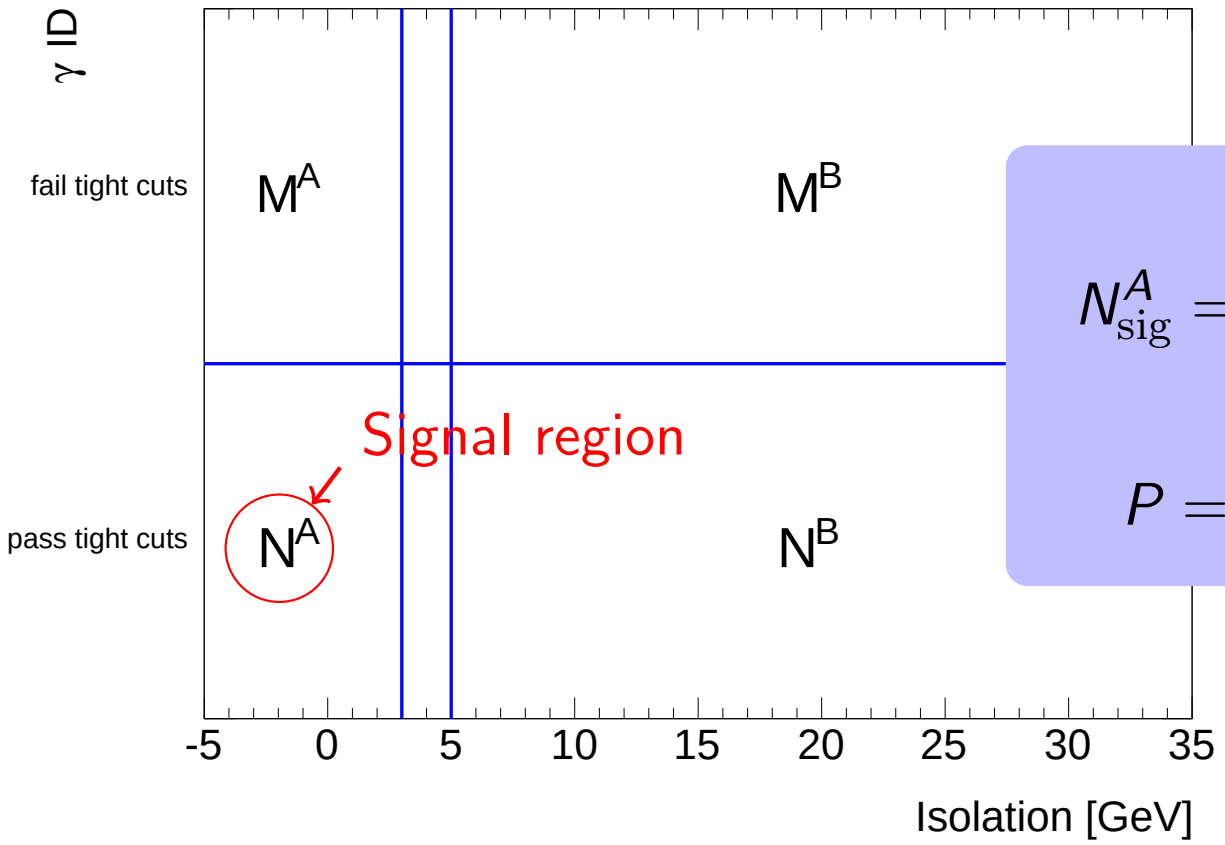
- Sum calorimeter energy within $R < 0.4$ around the candidate.
- Exclude the candidate itself and subtract expected underlying event contribution.
- Signal region: $< 3\,\mathrm{GeV}$.



Purity estimation

[ATLAS-CONF-2010-077]

Assume: Tight (layer 1) selection uncorrelated with isolation, and
Amount of signal in control regions is negligible.



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

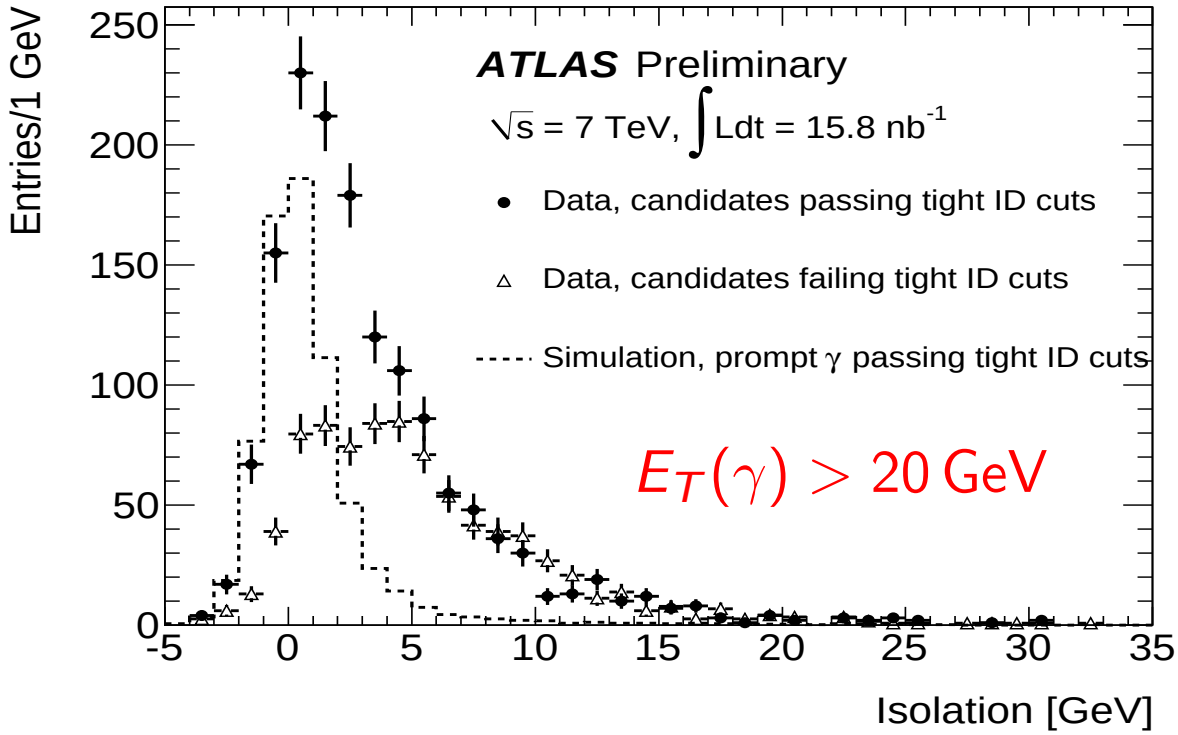
$$P = 1 - \frac{N^B}{N^A}\frac{M^A}{M^B}$$

(Assumptions don't hold exactly; corrections are applied, and uncertainties included in systematics.)

Direct photon analysis results

[ATLAS-CONF-2010-077]

Significant direct photon signal is seen for $E_T > 15\,\text{GeV}$.



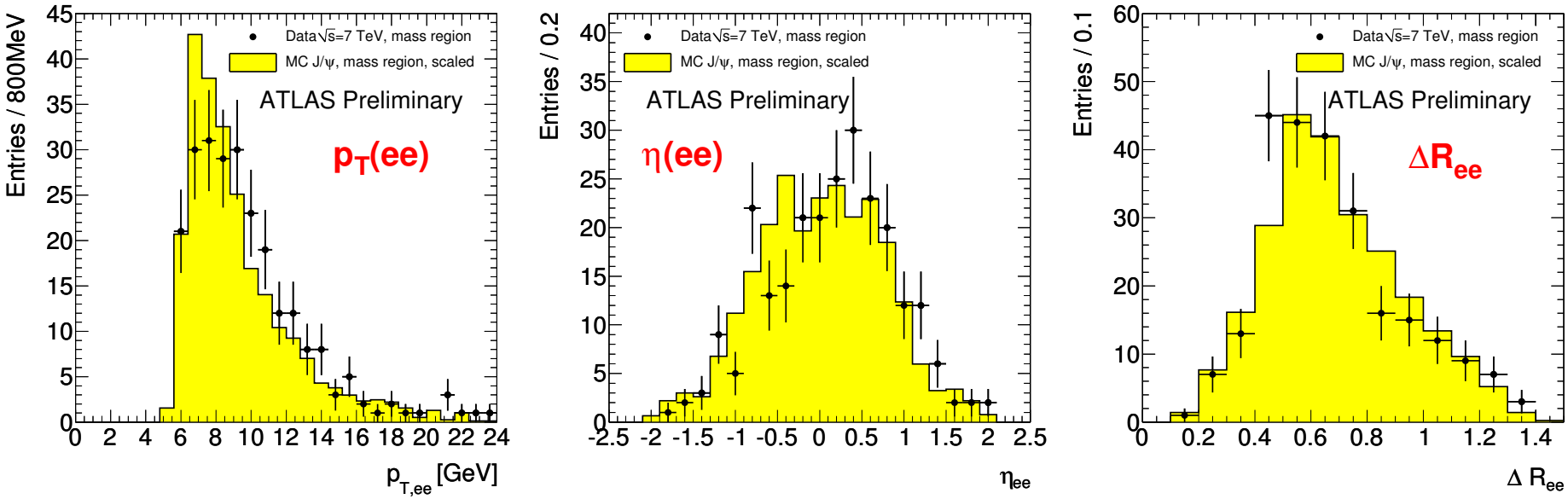
Direct photon results

	N_{cand}	Purity (%)	N^A_{sig}		
$10 \leq E_T \leq 15$	5271	$24 \pm 5 \pm 24$	1289	± 297	± 1362
$15 \leq E_T \leq 20$	1213	$58 \pm 5 \pm 8$	706	± 69	± 86
$20 \leq E_T$	864	$72 \pm 3 \pm 6$	618	± 42	± 59

(Uncertainties are $\pm$ stat. $\pm$ syst.)

J/ψ analysis

- Use sample of $77.8\,\mathrm{nb}^{-1}$.
- Candidate cluster-finding seeded with nearest-neighbor clusters instead of rectangular window. Improves efficiency at low p_T.
- Take opposite-sign pairs of electron candidates, one $> 4\,\mathrm{GeV}$ and one $> 2\,\mathrm{GeV}$.
- Select on R_η, f_1, shape in layer 1, track impact parameter, number of tracker hits, and a strict selection on f_{TR}.



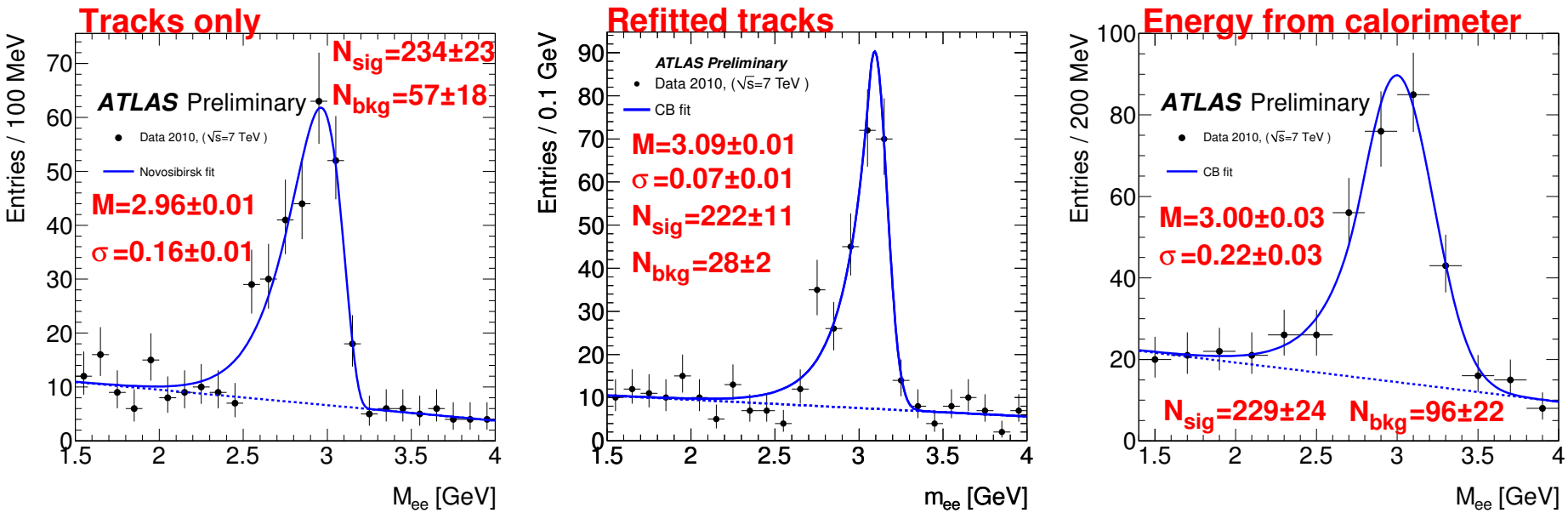
[MC includes J/ψ only; no b-mesons.]

J/ψ mass fits

$\int \mathcal{L}\, dt = 77.8\,\text{nb}^{-1}$

J/ψ mass can be calculated in three ways:

- Information from the tracks only. (Slightly low: ignoring Bremstrahlung.)
- Tracks only, but refitting tracks to take into account Bremsstrahlung (Gaussian sum filter[1]). (Corrected to remove bias from GSF.)
- Energies from the calorimeter clusters and directions from the tracks. (Slightly low: calorimeter calibrations incomplete for very low energies.)



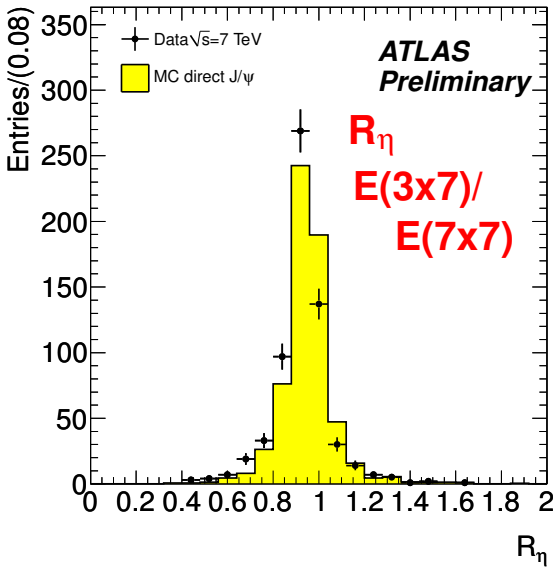
PDG average $m(J/\psi) = 3.097\,\text{GeV}$.

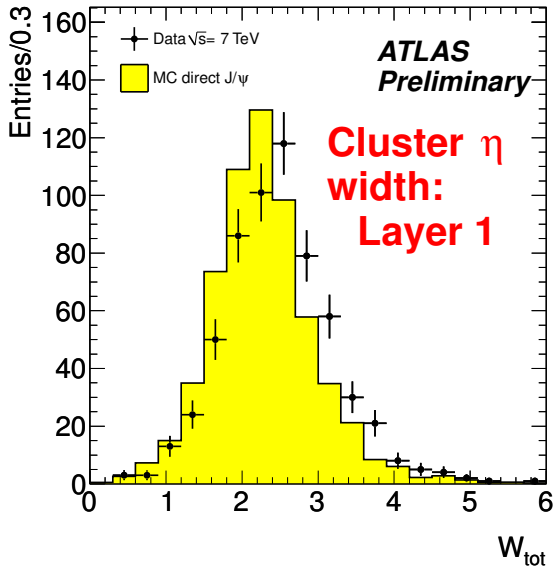
[1] R. Frühwirth, Comp. Phys. Comm. **100** (97); T. Atkinson, PhD thesis, U. Melbourne (06).

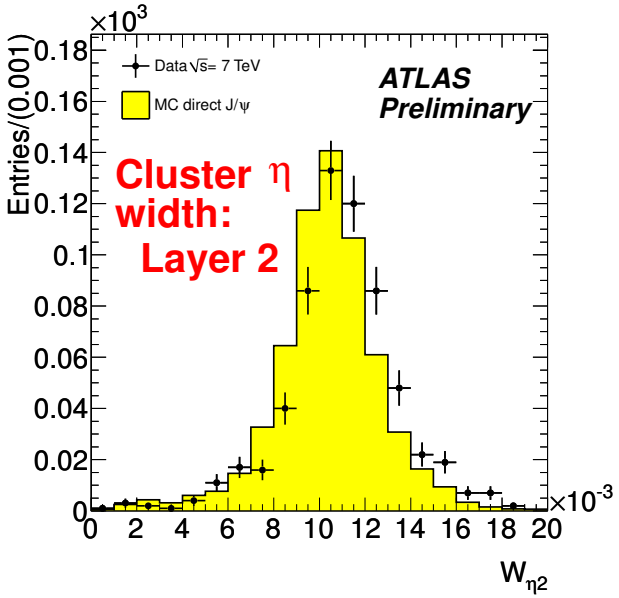
Shower shapes from J/ψ

$\int \mathcal{L}\, dt = 77.8\,\text{nb}^{-1}$

- The J/ψ peak provides a sample of real electrons to use to check the modeling of electron discrimination variables by the detector simulation. Important for evaluating systematics on electron identification.
- Tag-and-probe analysis: Maintain tight selection on one *tag* e, remove shower shape selections from the other *probe* e.
- Select candidates within $2.7 < m(ee) < 3.2\,\text{GeV}$, $f_1 > 0.15$.
- Starting to see small systematic differences between data and MC.







Summary

- ATLAS and the LHC are performing well!
- Early analyses of 7 TeV data are encouraging, with observation of prompt electrons, direct photons, and J/ψ.
- Luminosity is increasing rapidly: we will soon have large samples of electrons from J/ψ and Z.
- Work in progress:
  - Detailed understanding of variables used in electron identification.
  - Measurement of identification efficiency.
  - Calibration of the energy scale.
  - Calorimeter uniformity measurements.
  - Measurement of the material inside the calorimeter.

Leading towards physics measurements and new discoveries in electron/photon channels!

Backup

Matrix method to extract components [ATLAS-CONF-2010-073]

- Bin in f_{TR} and n_{BL}. Within each bin:
- N, N_{TR}, $N_{\mathrm{BL,TR}}$: Counts of events passing cuts for this bin.
- ε^h, ε^γ, ε^Q: Efficiencies for hadrons/conversions/electrons to pass.

Then

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

- Can use this to get distributions for h, γ, Q components for any variable independent of f_{TR} and n_{BL}.
- ε^γ, ε^Q from Monte Carlo.
- ε^h from a hadron sample obtained by inverting f_1 selection

Events binned in η/p; method carried out separately for each bin.