# Expected Performance for Electron and Photon in ATLAS

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- Electron/photon performance の重要性
- Reconstruction
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# Electron/Photon Performance の重要性 (1/3)

- 多くの bench mark physics channel で、high $p_T$ electron と photon は重要な signal である
  - Higgs search

    $H \rightarrow \gamma\gamma$, $H \rightarrow Z^{(*)}Z \rightarrow 4e$, $2e2\mu$
  - BSM search

    e/γ signatures in SUSY, extra gauge bosons ($Z' \rightarrow ee$ etc.)
  - SM physics

    $Z \rightarrow ee$, $W \rightarrow e\nu$, $\gamma$+jet

# Electron/Photon Performance の重要性 (2/3)

- 検出器（subsystemでは主に内部飛跡検出器と電磁カロリメータ）の性能を data-driven で理解する in-situ tool として、electron/photon を final state に持つ SM process は重要（特にresonance）
  - Electron

    W →eν, Z →ee, J/ψ→ee, Υ→ee
  - Photon

    γ+jet, γγ+jet

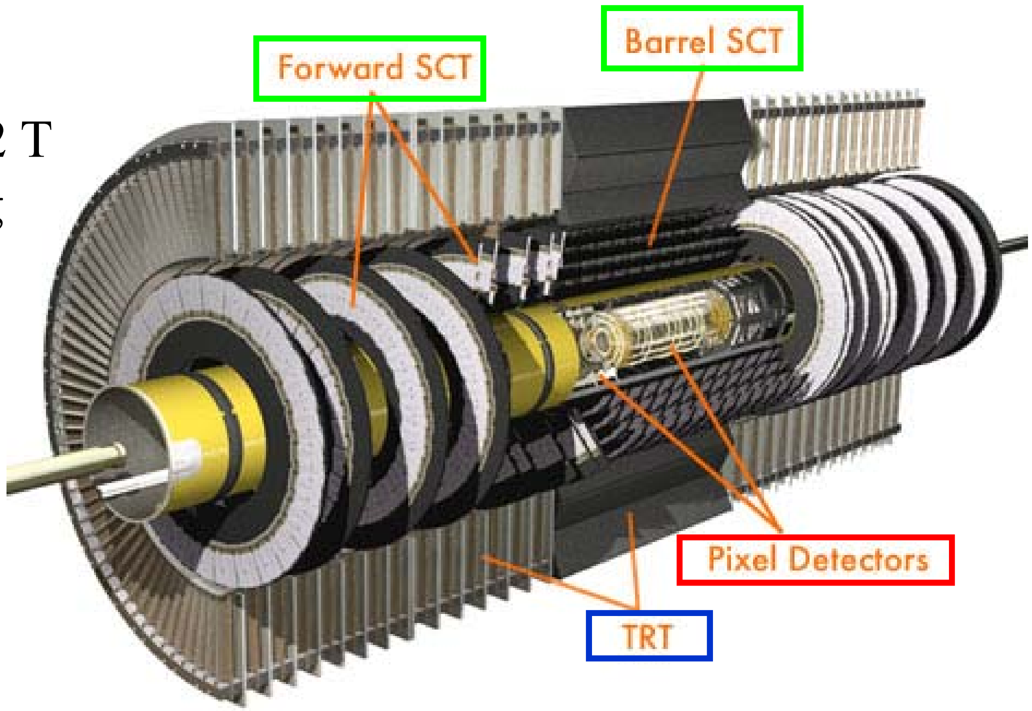
    Note : high pT photon を重い resonance はない

# 内部飛跡検出器

SemiConductor Tracker (SCT)
- Silicon strip detector
- Barrel : 4 cylindrical layers
- End-cap : 9 disks per side

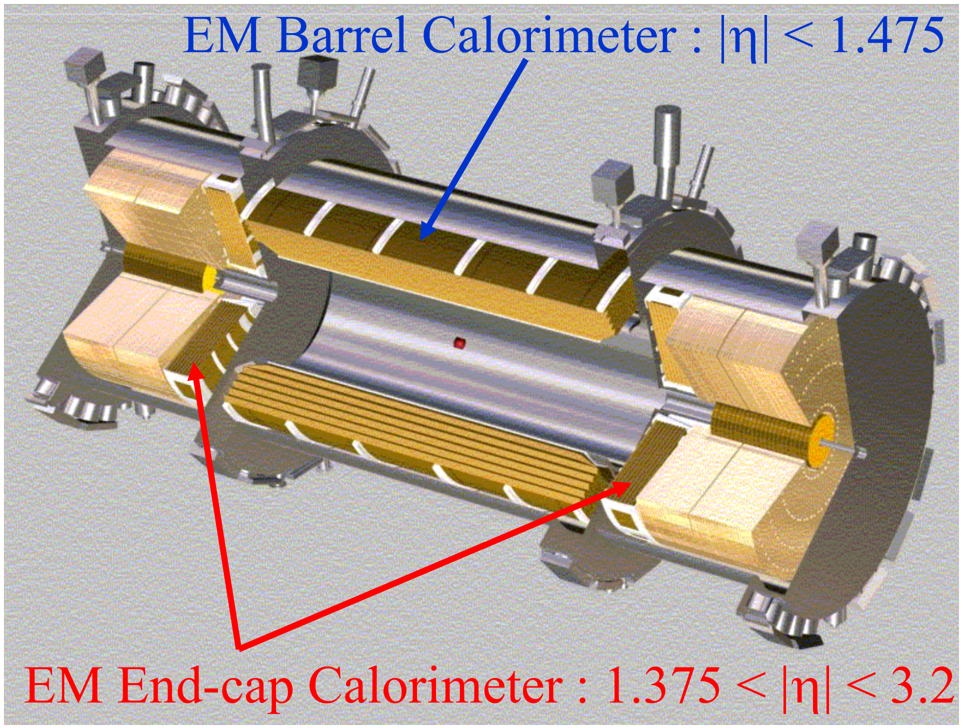
Pixel Detector
- Hybrid silicon pixel detector
- Barrel : innermost cylindrical layer (B-layer) and 2 outer cylindrical layers
- End-cap : 3 disks per side

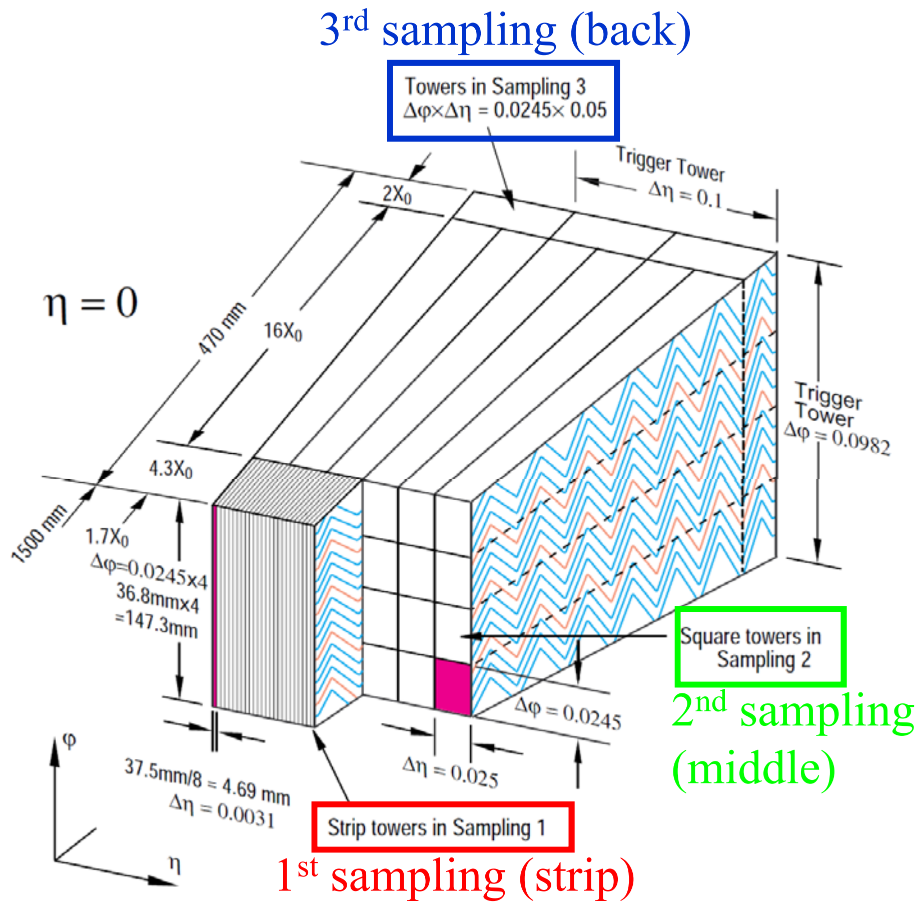
- Surrounded by 2 T super-conducting solenoid magnet
- $|\eta| < 2.5$




Transition Radiation Tracker (TRT)
- Straw-tube tracking chamber w/ transition radiation capability.
- Straws run in axial direction in barrel and radial direction in end-caps.

# LAr 電磁カロリメータ




- Pb/LAr sampling calorimeter w/ accordion-shaped electrodes
- Three longitudinal segmentation
- Cell size in $\Delta\eta \times \Delta\phi$
  1st (strip) : $0.003 \times 0.1$, 2nd (middel) : $0.025 \times 0.025$, 3rd (back) : $0.05 \times 0.025$
- Presampler in front of calorimeter in $|\eta| < 1.8$ : $\Delta\eta \times \Delta\phi \sim 0.025 \times 0.1$

# Electron/Photon Performance の重要性 (3/3)

- LHC 環境下での Severe な検出性能の要求
  - Energy resolution : $\sigma_E/E \sim 10\%/\sqrt{E} \oplus 0.7\%$
  - Energy linearlity : < 0.5% up to 300 GeV
  - EM cluster pointing resolution : $\sigma_{R\phi} \sim 9\text{mm}/\sqrt{E}$, $\sigma_z \sim 3\text{mm}/\sqrt{E}$
  - Electron identification

    Rejection factor $\sim 10^5$ for $p_T > 20$ GeV/c

    ( Note : electron rate / jet rate $\sim 10^{-5}$)
  - Photon identification

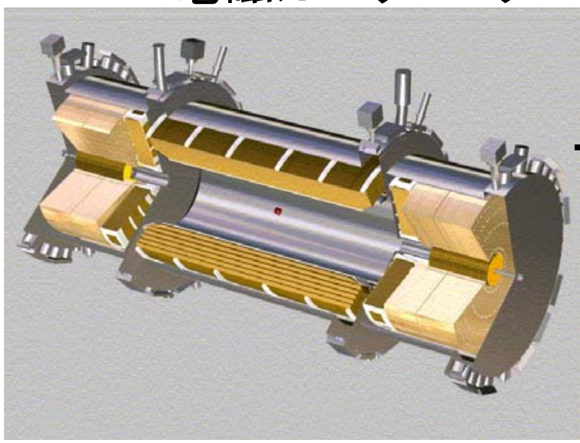
    Rejection factor $\sim 5 \times 10^3$ for $p_T > 20$ GeV/c

# Reconstruction of Electron and Photon (1/2)

System-level reconstruction

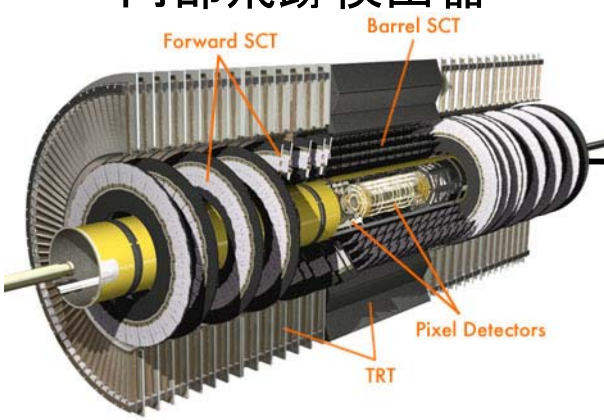
e/γ combined reconstruction

LAr 電磁カロリメータ



cluster (seed)

内部飛跡検出器




track

cluster-track matching

electron/photon candidate

correction & calibration

electron/photon candidate

identification

Identified electron/photon

# Reconstruction of Electron and Photon (2/2)

- e/γ combined reconstruction の algorithm flow
  1. Cluster seed

     Cluster (fixed-size window $\Delta\eta \times \Delta\phi = 5 \times 5$ in cell) を seed とする
  2. Cluster-Track matching (in $\Delta\eta \times \Delta\phi = 0.05 \times 0.1$ at calorimeter position)
     - Match する track あり → electron or converted photon candidate
     - Match する track なし → un-converted photon candidate
  3. Correction

     Electron, converted photon, un-converted photon candidate 別に、cluster の re-build と calibration
  4. Identification
     - Cut-based identification (default)
     - Multivariate discriminants : Likelihood etc.

# Correction and Calibration (1/3)

- Cluster re-build と position correction

  Electron, converted photon, un-converted photon ごとに

  別々のsizeのwindow

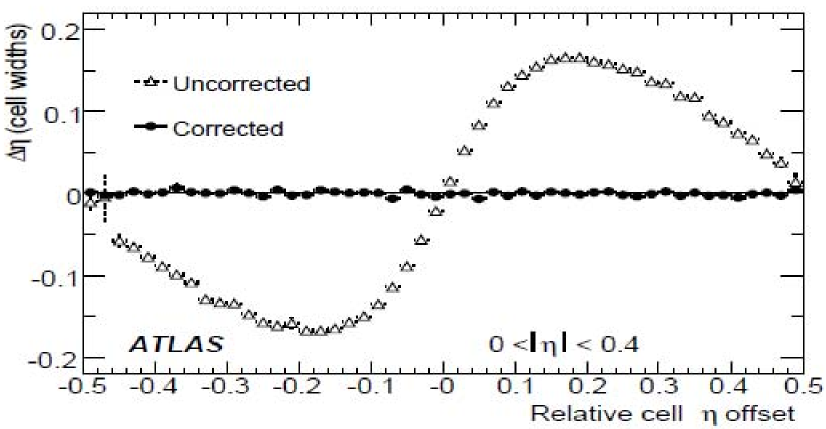
  – Barrel

| | electron | converted photon | un-converted photon |
|---|---|---|---|
| Δη×Δϕ in cell | 3×7 | 3×7 | 3×5 |

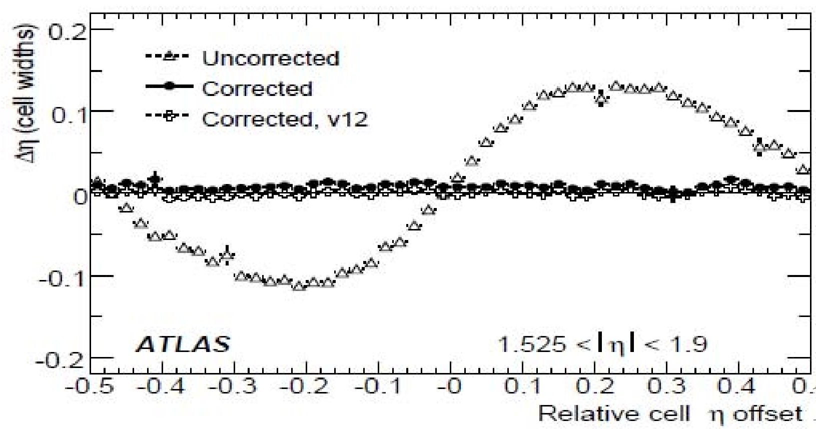
  – Endcap : Δη×Δϕ = 5×5

- η/ϕ position correction

Electron 100 GeV

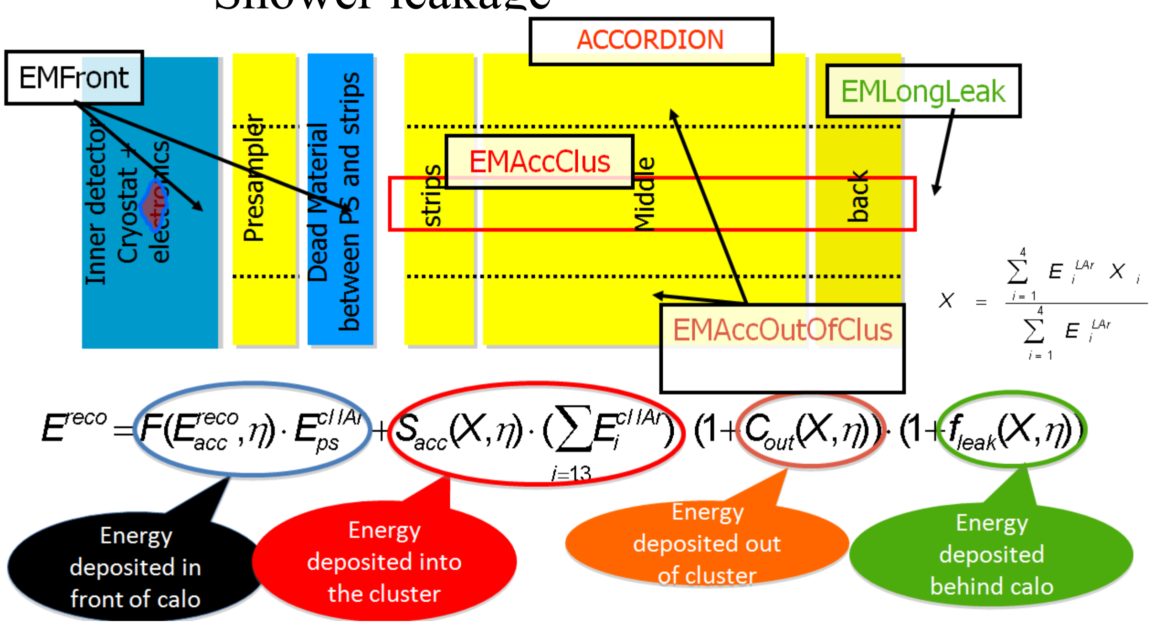



Electron 100 GeV

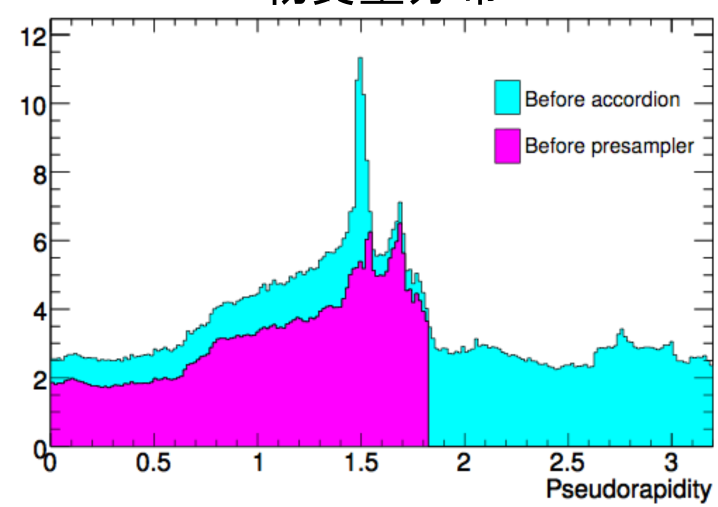


# Correction and Calibration (2/3)

- Energy calibration と correction の実験前初期値として、single-particle (electron と photon) MC の Geant4 の情報（Calibration Hit）を用いて、energy を再構成
  - Active layer (pre-sampler, layer1(strip), layer2(middle), layer3(back)) へのenergy deposit
  - Inactive layer (material in front of pre-sampler and LAr ) へのenergy deposit
  - Out-of cluster energy
  - Shower leakage



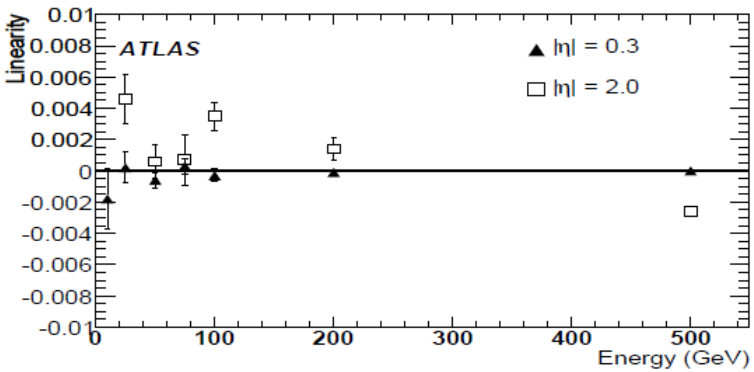

物質量分布

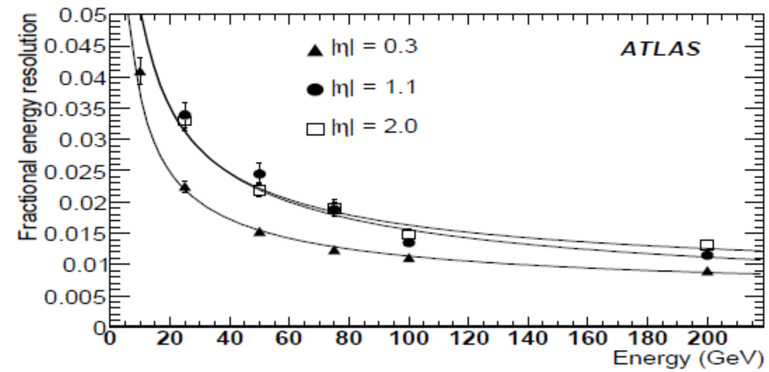


# Correction and Calibration (3/3)

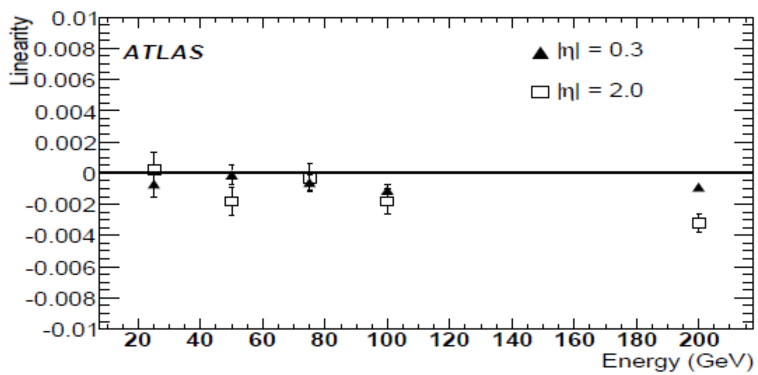
- MC-base correction & calibration 後の energy resolution と linearity

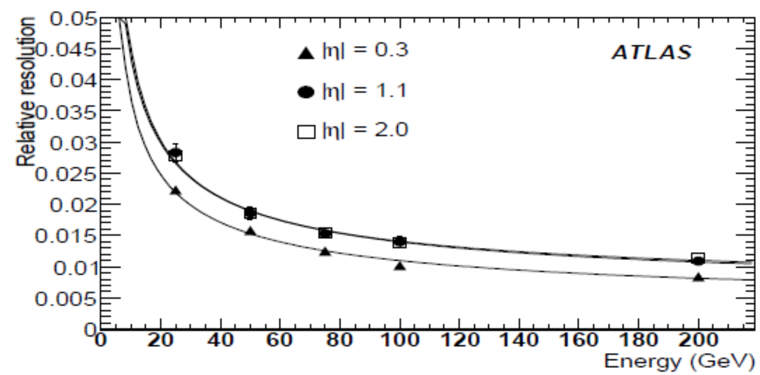
Electron




Photon



# Identification of Electron and Photon (1/3)

- Cut-based method (現在ならびに実験初期のdefault)

  A brief list of cut variables

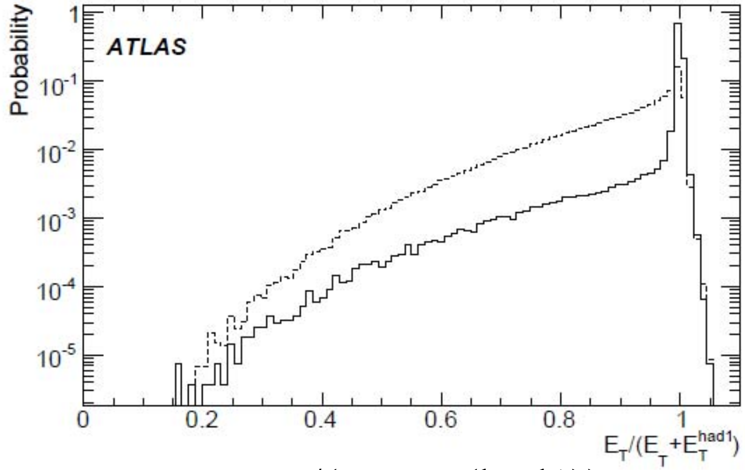
  - Leakage into Hadronic calorimeter
  - Calorimeter shower shapes in 2nd sampling
    - Shower shape in η and ϕ
    - Energy-weighted lateral width
  - Calorimeter shower shapes in 1st sampling
    - Details of energy deposition structure in cells (2nd maximum in energy etc)
    - Shower width
  - Track quality
    - Number of hits in pixel, SCT, TRT
    - Transverse impact parameter
  - Track-cluster matching
    - $\Delta\eta \times \Delta\phi$ position matching at calorimeter, E/p

Red : Calorimeter-related
Blue : ID-related
Green : track-cluster

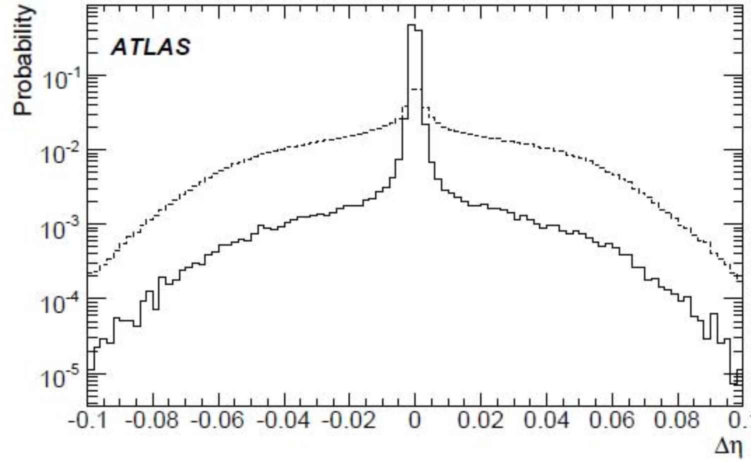
# Identification of Electron and Photon (2/3)

——— $Z \rightarrow ee$

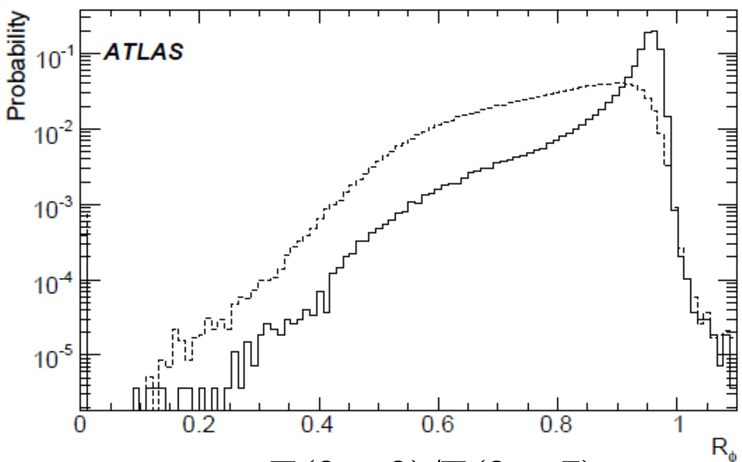
- - - - - - - - dijet



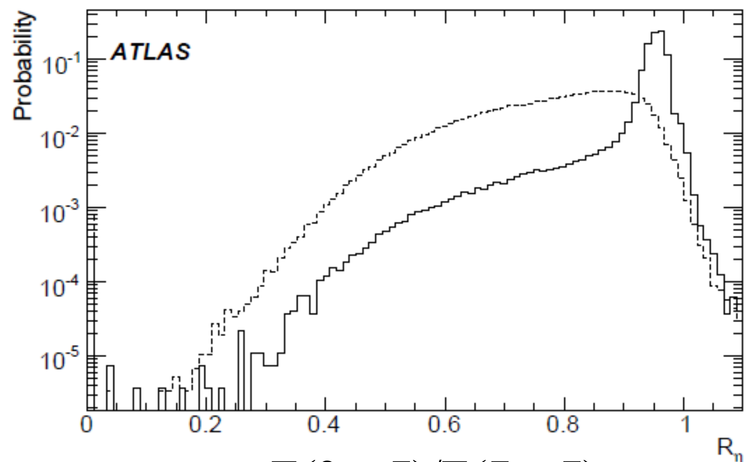

$E_T/(E_T+E_T(\text{had1}))$




$\Delta\eta$(track-cluster)



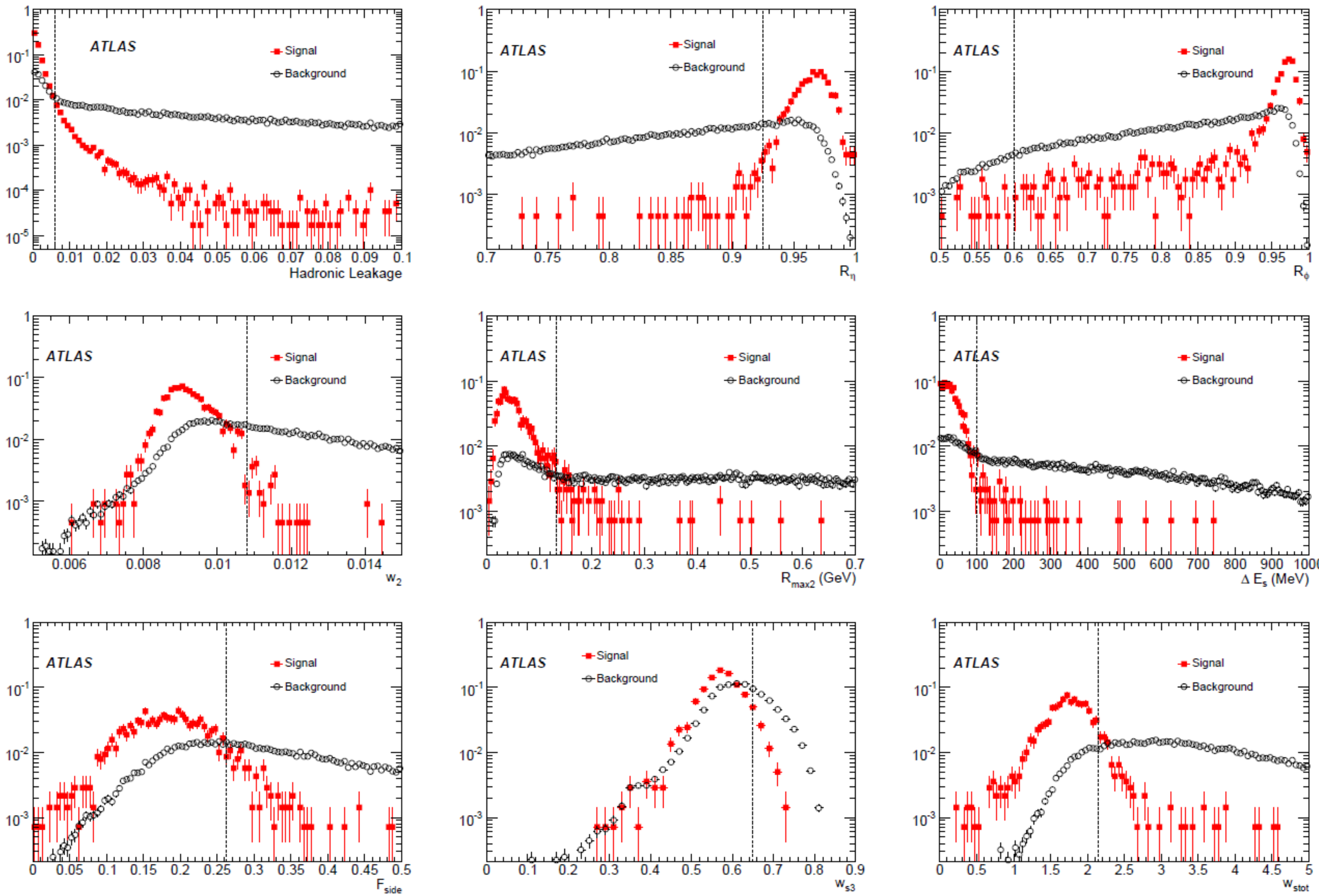

$E(3\times3)/E(3\times7)$




$E(3\times7)/E(7\times7)$

# Identification of Electron and Photon (3/3)

- ● $H \rightarrow \gamma\gamma$
- ○ dijet



# Expected Performance (1/6)

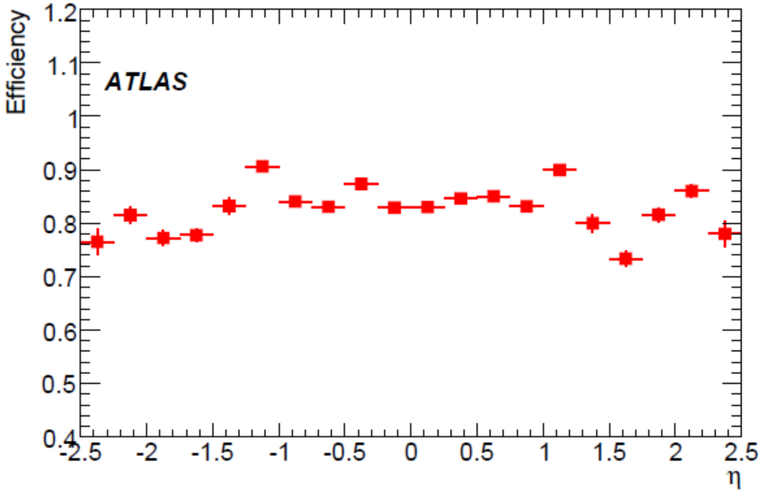
- Efficiency and jet rejection for electron reconstruction/identification
  - Medium cut : efficiency = 77%, rejection = $2.1 \times 10^3$
  - Tight cut : efficiency = 62%, rejection = $8.9 \times 10^4$

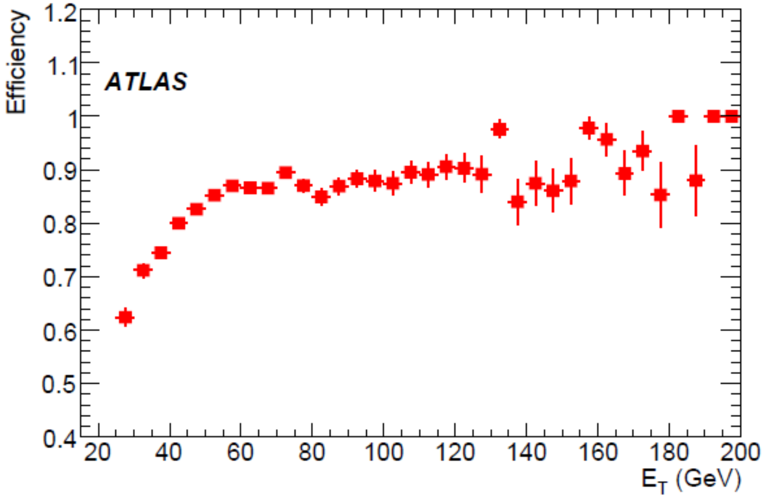
  "Tight" = "medium" & (cut in TRT hits)

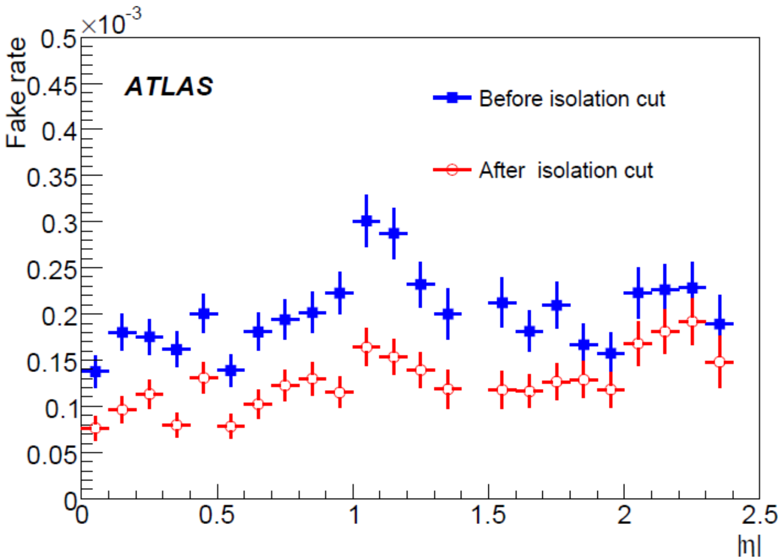
| Cuts | $E_T > 17$ GeV | | | $E_T > 8$ GeV | | |
|---|---|---|---|---|---|---|
| | Efficiency (%) | | Jet rejection | Efficiency (%) | | Jet rejection |
| | $Z \to ee$ | $b,c \to e$ | | Single electrons ($E_T$ =10 GeV) | $b,c \to e$ | |
| Loose | $87.96 \pm 0.07$ | $50.8 \pm 0.5$ | $567 \pm 1$ | $75.8 \pm 0.1$ | $55.8 \pm 0.7$ | $513 \pm 2$ |
| Medium | $77.29 \pm 0.06$ | $30.7 \pm 0.5$ | $2184 \pm 13$ | $64.8 \pm 0.1$ | $41.9 \pm 0.7$ | $1288 \pm 10$ |
| Tight (TRT.) | $61.66 \pm 0.07$ | $22.5 \pm 0.4$ | $(8.9 \pm 0.3)10^4$ | $46.2 \pm 0.1$ | $29.2 \pm 0.6$ | $(6.5 \pm 0.3)10^4$ |
| Tight (isol.) | $64.22 \pm 0.07$ | $17.3 \pm 0.4$ | $(9.8 \pm 0.4)10^4$ | $48.5 \pm 0.1$ | $28.0 \pm 0.6$ | $(5.8 \pm 0.3)10^4$ |
| | Fraction of surviving candidates (%) | | | Fraction of surviving candidates (%) | | |
| | Isolated | Non-isolated | Jets | Non-isolated | | Jets |
| Medium | 1.1 | 7.4 | 91.5 (5.5 + 86.0) | 9.0 | | 91.0 (5.0 + 86.0) |
| Tight (TRT) | 10.5 | 63.3 | 26.2 (8.3 + 17.9) | 77.8 | | 22.2 (7.1 + 15.1) |
| Tight (isol) | 13.0 | 58.3 | 28.6 (8.7 + 19.9) | 75.1 | | 24.9 (6.4 + 18.5) |

# Expected Performance (2/6)

- Efficiency and jet rejection for photon reconstruction/identification
  - Efficiency = 84%, rejection = $5.1 \times 10^3$




Fake rate = 1 / rejection

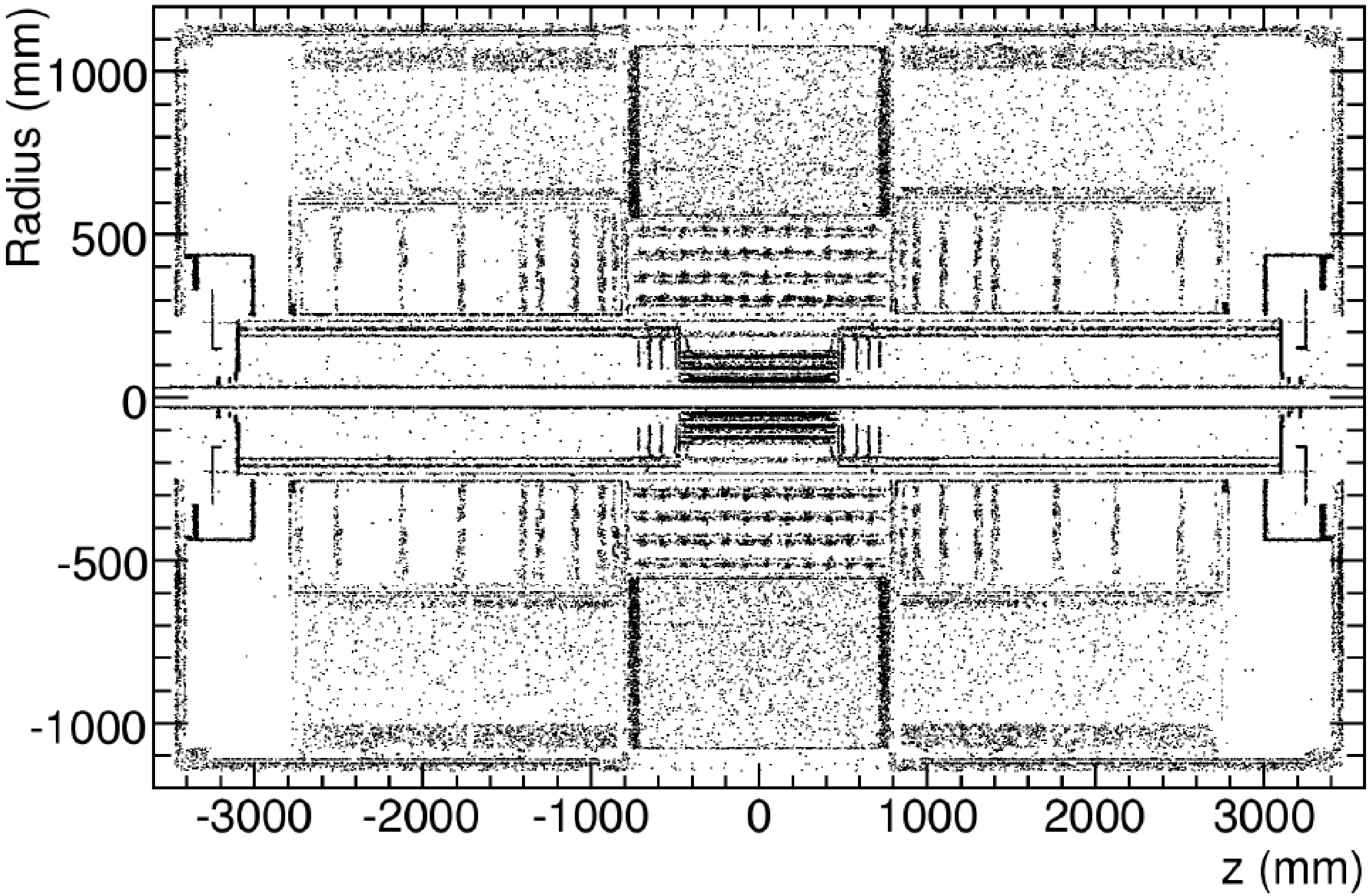
# Expected Performance (3/6)

- Efficiency and jet rejection for photon reconstruction/identification
  - Efficiency = 84%, rejection = $5.1 \times 10^3$

| | All | Quark jets | Gluon jets |
|---|---|---|---|
| $N$(jet)/$N$(generated events) | 0.23 | 0.056 | 0.177 |
| | | Before isolation cut | |
| $N$(fake)/$N$(filtered events) | $(5.43\pm0.13).10^{-4}$ | $(3.87\pm0.11).10^{-4}$ | $(1.44\pm0.07).10^{-4}$ |
| Rejection | 5070±120 | 1770±50 | 15000±700 |
| | | After isolation cut | |
| $N$(fake)/$N$(filtered events) | $(3.38\pm0.10).10^{-4}$ | $(2.47\pm0.08).10^{-4}$ | $(0.78\pm0.49).10^{-4}$ |
| Rejection | 8160± 250 | 2760±100 | 27500±2000 |

# Expected Performance (4/6)

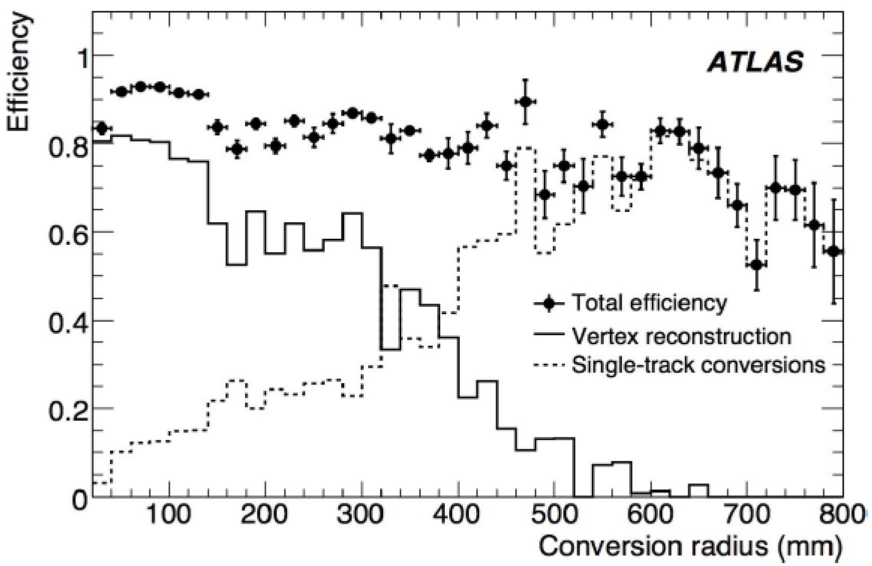
- Photon conversion reconstruction
  - Photon conversion vertex in MC truth for Minimum bias events

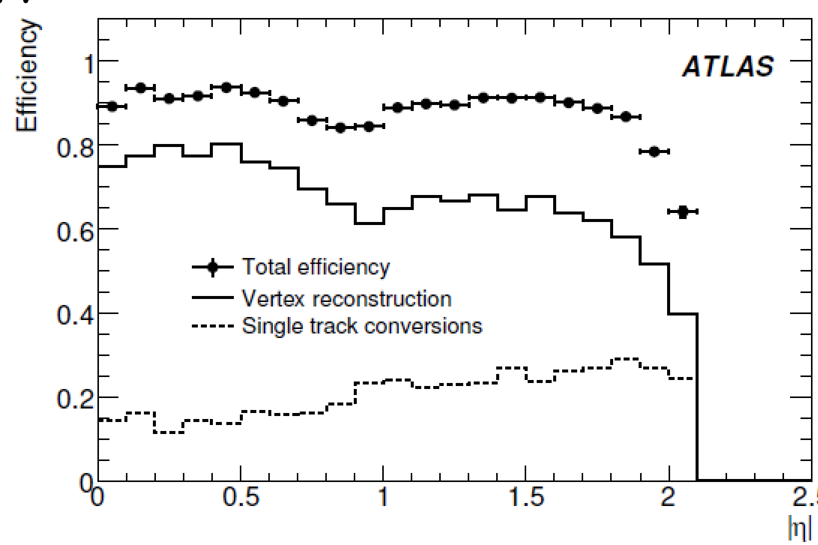


# Expected Performance (5/6)

- Photon conversion reconstruction
  - Track reconstruction
    - Algorithm seeded in silicon detector (smaller radius) or TRT (lager radius)
    - Combine tracks from both categories
  - Conversion vertex fitting assuming electron mass
  - 現在も発展途上

H→γγ

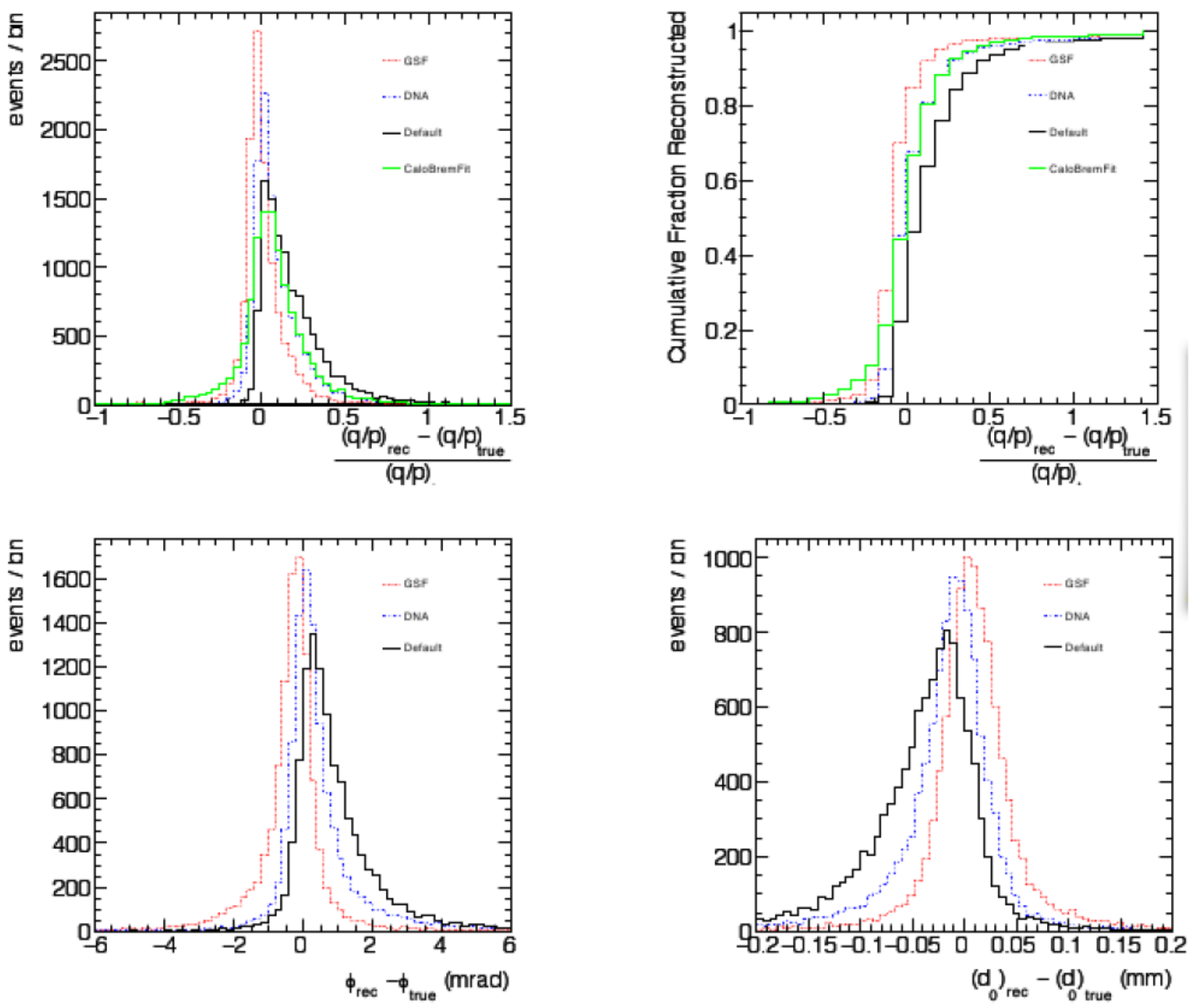


# Expected Performance (6/6)

- Brems recovery
  - 現在も発展途上

Electron 25 GeV




３つのalgorithmを検討中

- GSF (Gaussian Sum Filter)
- DNA (Dynamic Noise Adjustment)
- CaloBremFit

# Performance in Early Data (1/4)

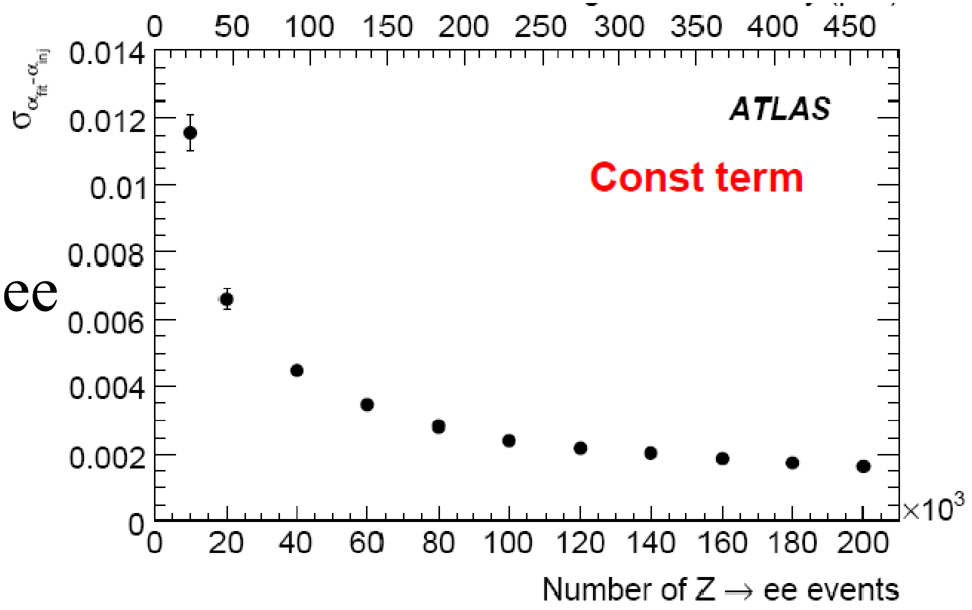
- 現在の LHC プラン
  - 2009年9月末 : 1st beam, 2009年10末 : 1st collision
  - 11 months (44 weeks) running at 5 TeV + 5 TeV
  - 期待される delivered luminosity : ~200 $pb^{-1}$
    - 1st 100 days : ~100 pb-1
    - 2nd 100 days : ~200 pb-1
    - Last 5 weeks : Heavy ion run
  - 200 $pb^{-1}$でのプランを策定中

# Performance in Early Data (2/4)

- $1^{st}$ beam – $1^{st}$ collision at 10 TeV
  - 900 GeV (injection energy) か 10 TeV より low energy の run があると予想
  - Start to look at Minimum bias
  - $\pi^0 \rightarrow \gamma\gamma$, energy flow, photon conversion を使って、カロリメータの response の（非）一様性、内部飛跡検出器の物質量の評価を行う
  - 物質量評価は特に重要
    - 初期は 5% $X_0$ の精度、ゴールは 1-2% $X_0$ 精度

# Performance in Early Data (3/4)

- 1 - 10 pb$^{-1}$
  - Start to use J/ψ→ee, Υ→ee, Z→ee, W→eν, γ+jet
  - 実データに対して、e/γ combined reconstruction の tuning・実用化を目指す
    - Algorithm flow
    - Correction and calibration
    - Cut-based identification
  - Efficiency と fake のstudy
    - 5% 精度
- 10 - 200 pb$^{-1}$
  - In-situ calibration using Z→ee
    - 0.1% 精度
  - Efficiency と fake のstudy
    - 2% 精度(統計＋系統)



# Performance in Early Data (4/4)

- その他議論中の重要な item
  - MC-based calibration
  - MC-based calibration と in-situ calibration の比較・理解
  - 内部飛跡検出器のalignment
  - 内部飛跡検出器 – カロリメータ間のalignmnent
  - Data quality monitoring