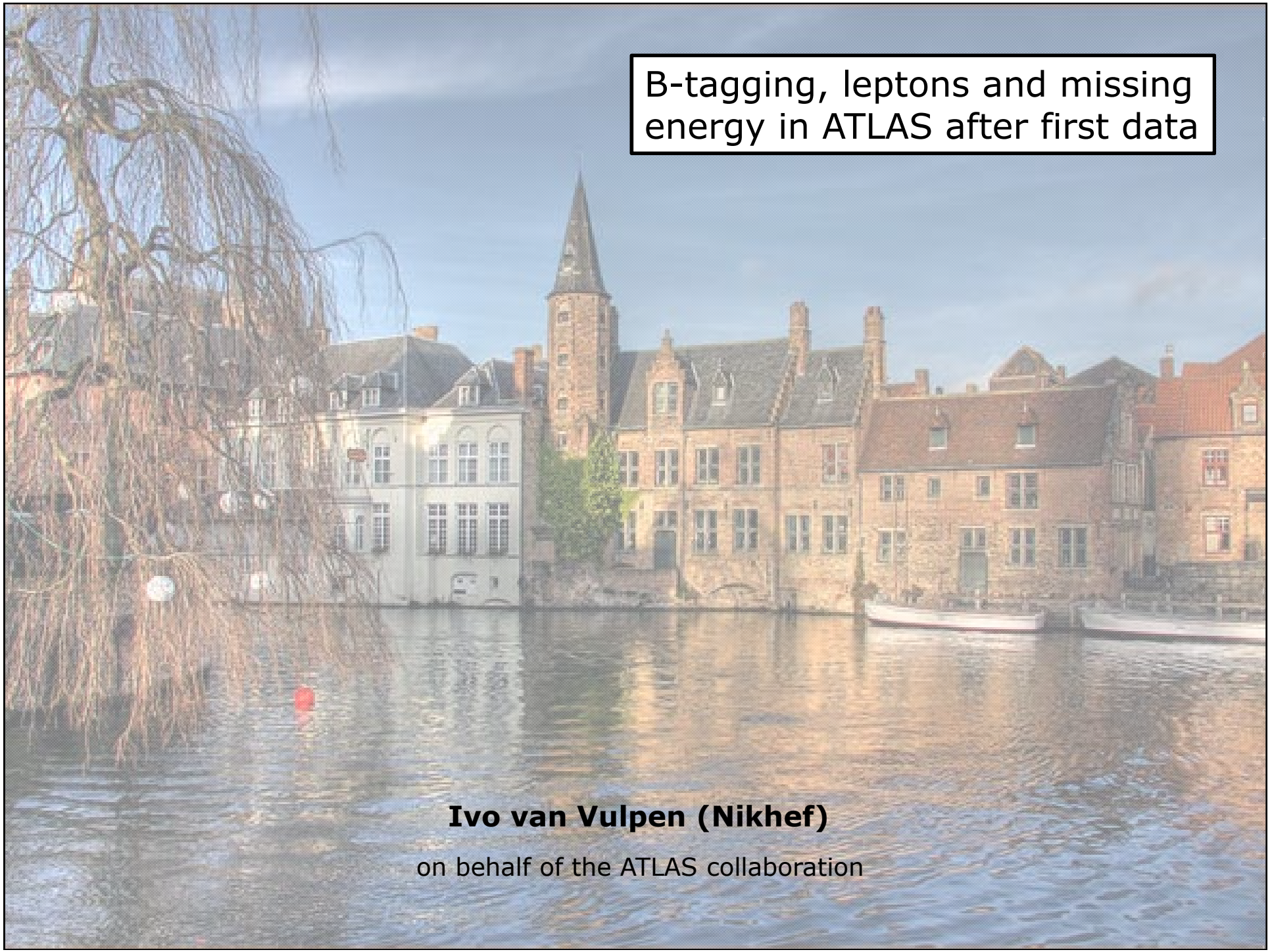
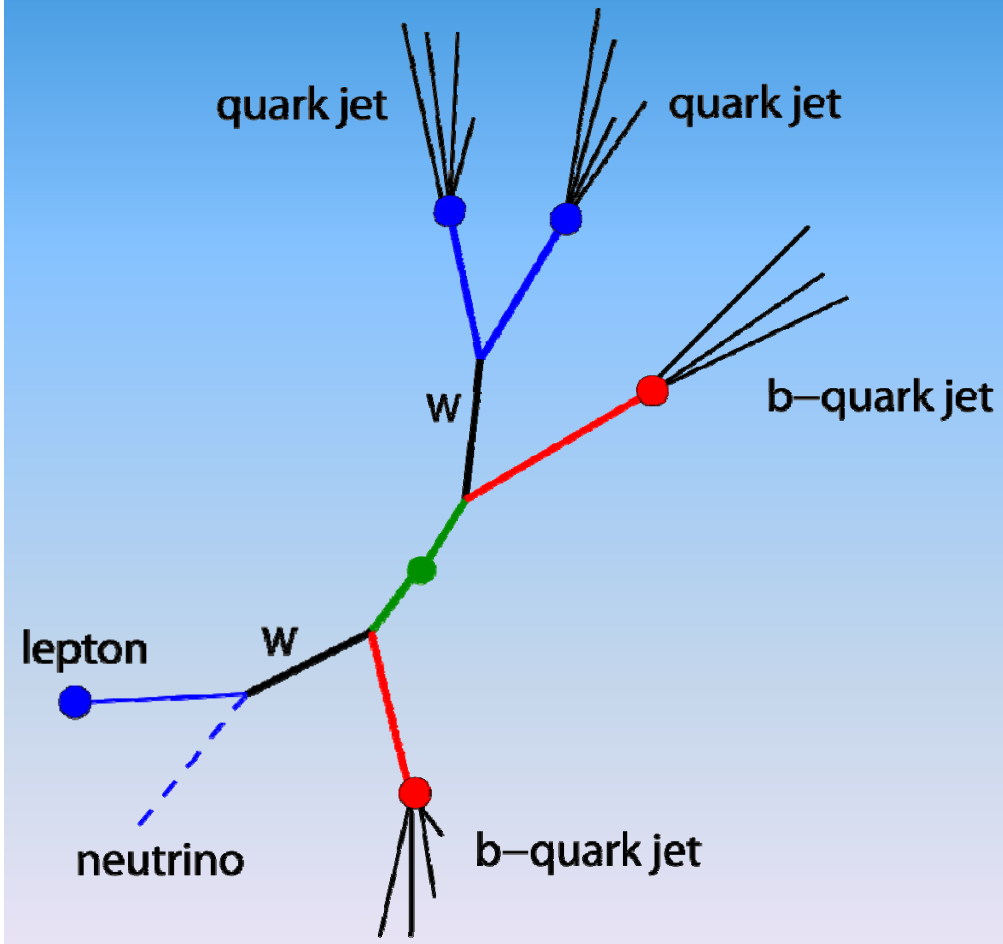


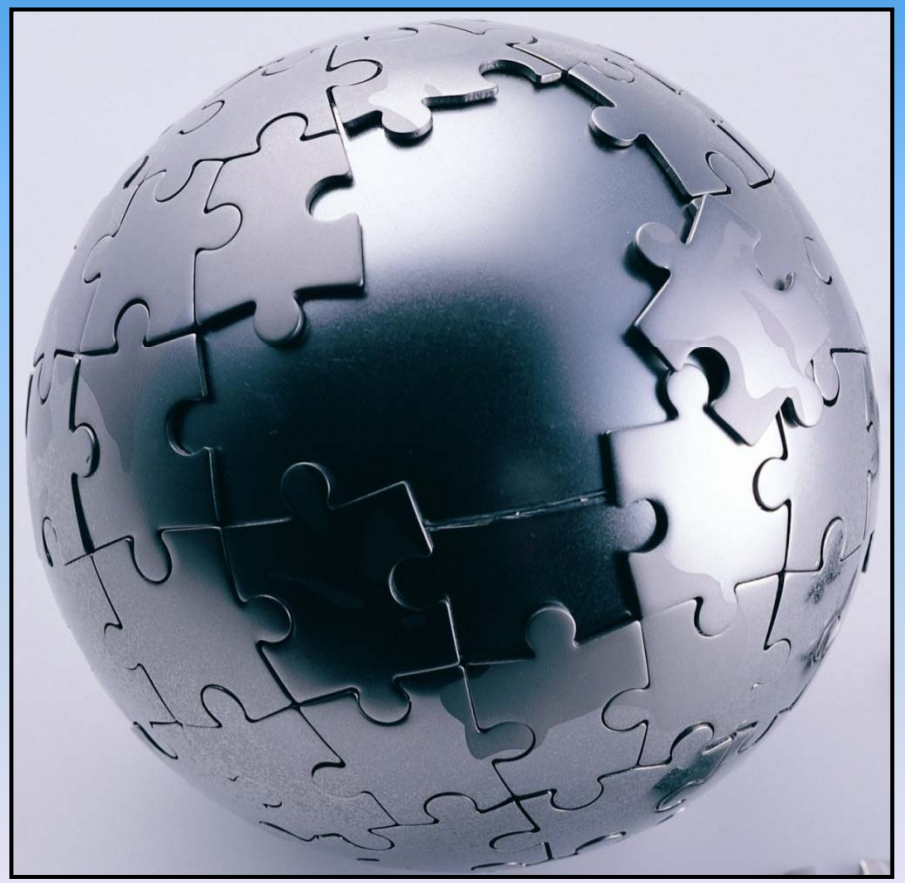
B-tagging, leptons and missing energy in ATLAS after first data

Ivo van Vulpen (Nikhef)

on behalf of the ATLAS collaboration

Studying top quarks pairs – the building blocks





Jets are discussed in a separate talk

ATLAS data-sets

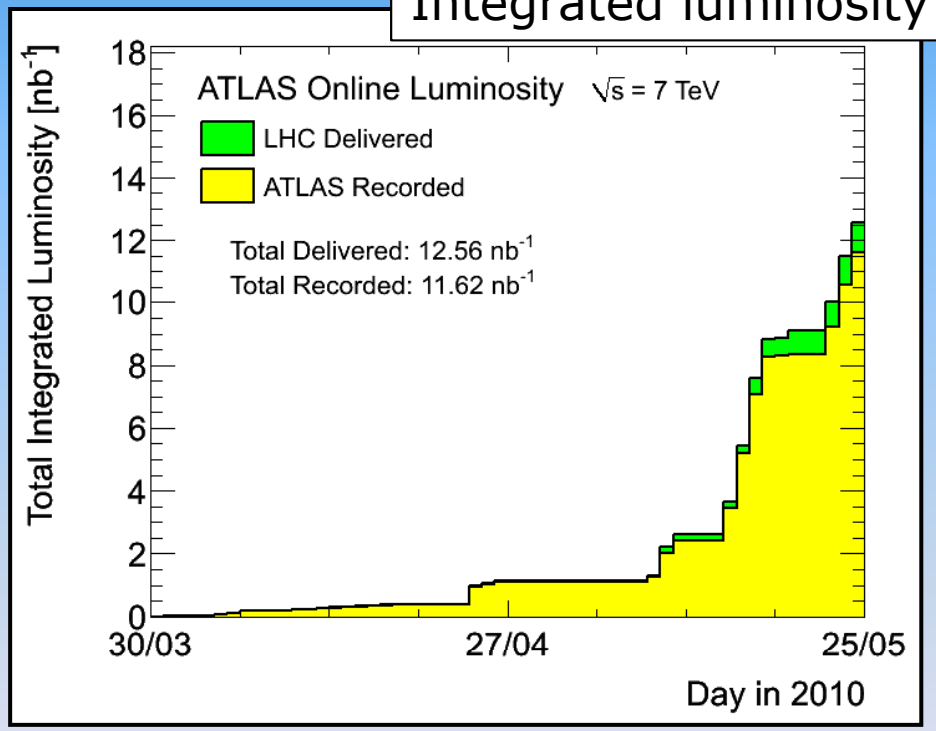
2009: $\sqrt{s}$ = 900 GeV

2010: $\sqrt{s}$ = 7 TeV

Lumi = 12 μb^{-1} (stable beams)
→ 538,000 collision candidates

Main focus of this talk is on this data-set

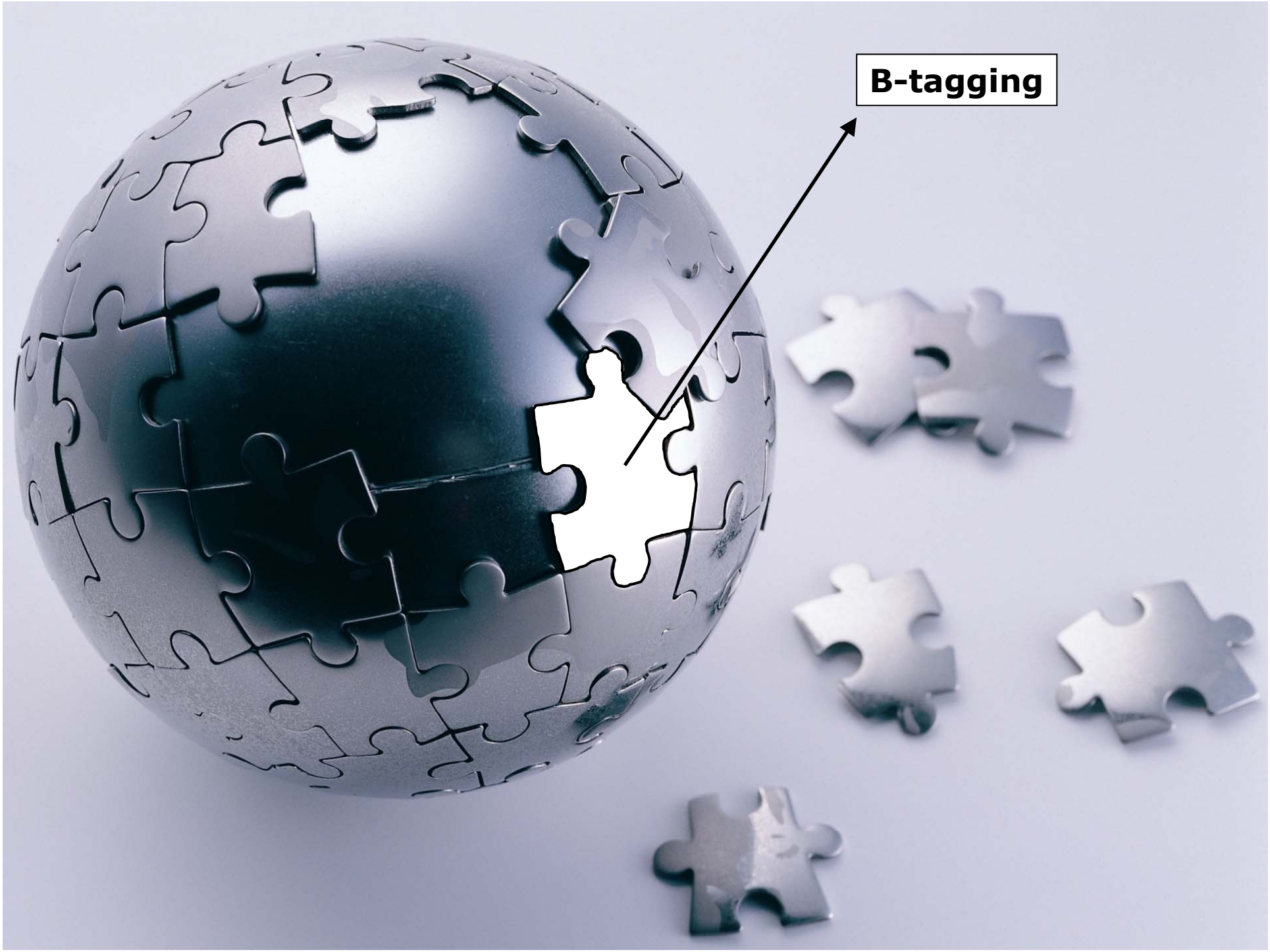
Integrated luminosity



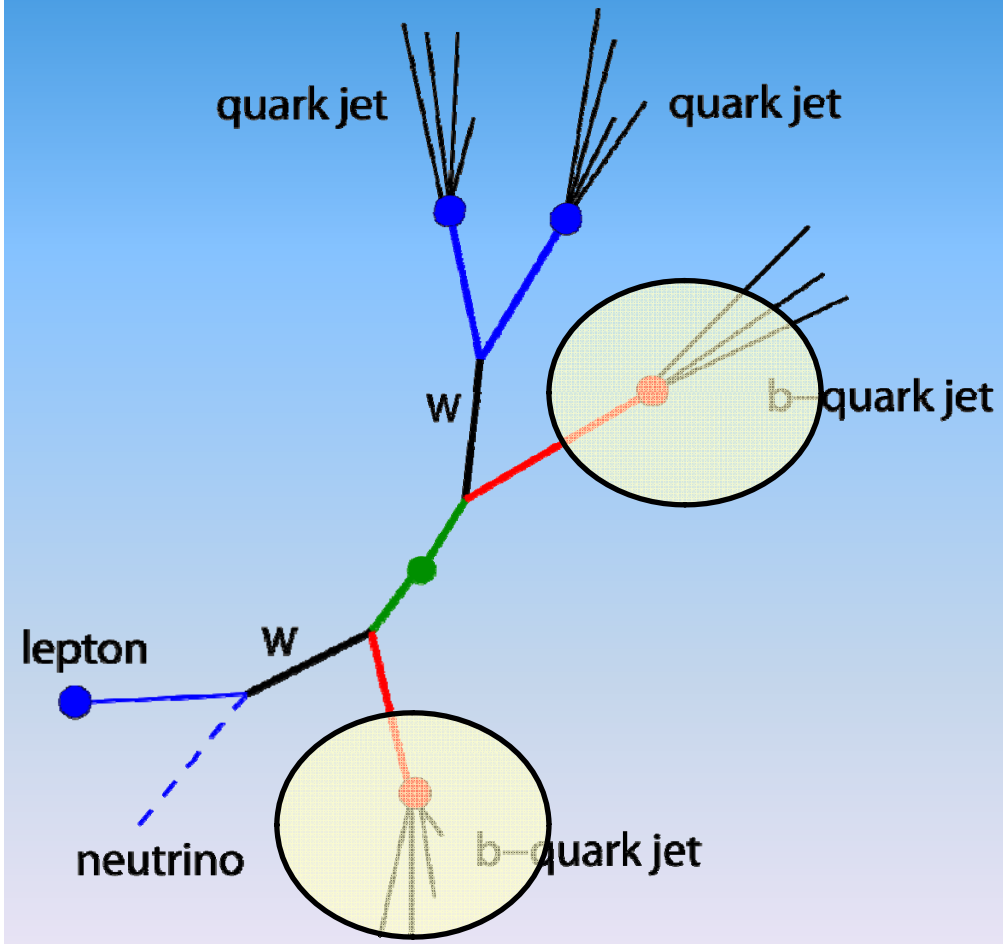
Public ATLAS results:

https://twiki.cern.ch/twiki/bin/view/Atlas/AtlasResults


Upcoming
ATLAS results
You are here


B-tagging

B-tagging in top analyses



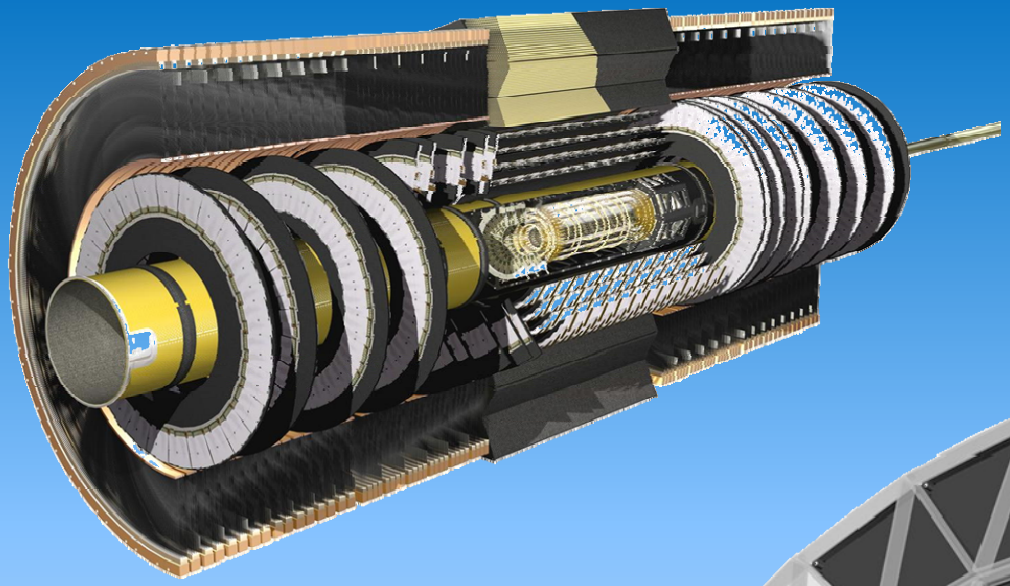
B-tagging in top analyses

- Reduce W+jets & QCD bckg.
- Reduce jet-combinatorics

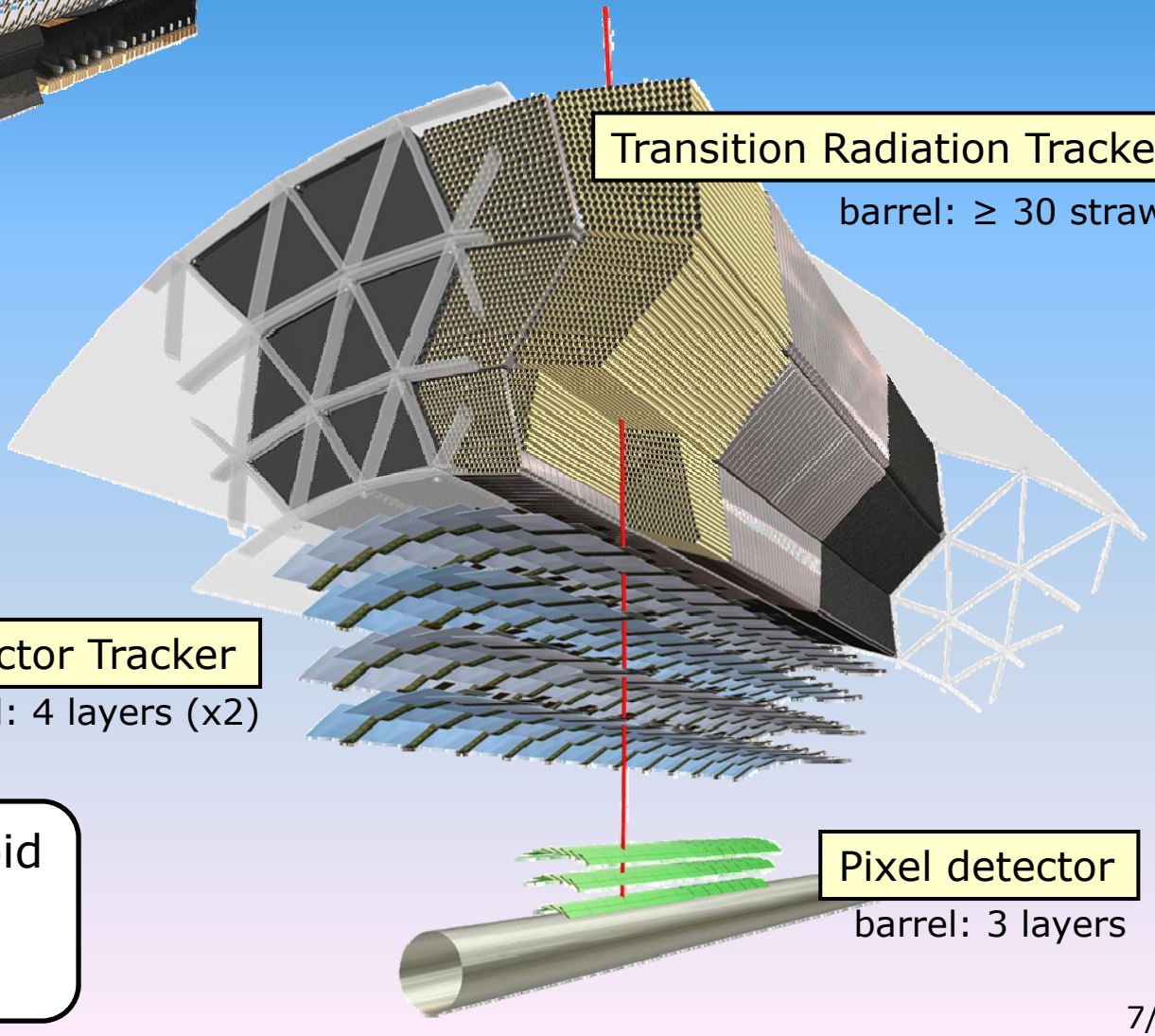
Complications:

- $JES_{b\text{-jet}}$ difficult (vital for M_{top})
- multi-jet environment

Inner detector



ATLAS inner detector



Transition Radiation Tracker

barrel: ≥ 30 straws

SemiConductor Tracker

barrel: 4 layers (x2)

Pixel detector

barrel: 3 layers

3 systems in 2 T solenoid

$|\eta| < 2.5$

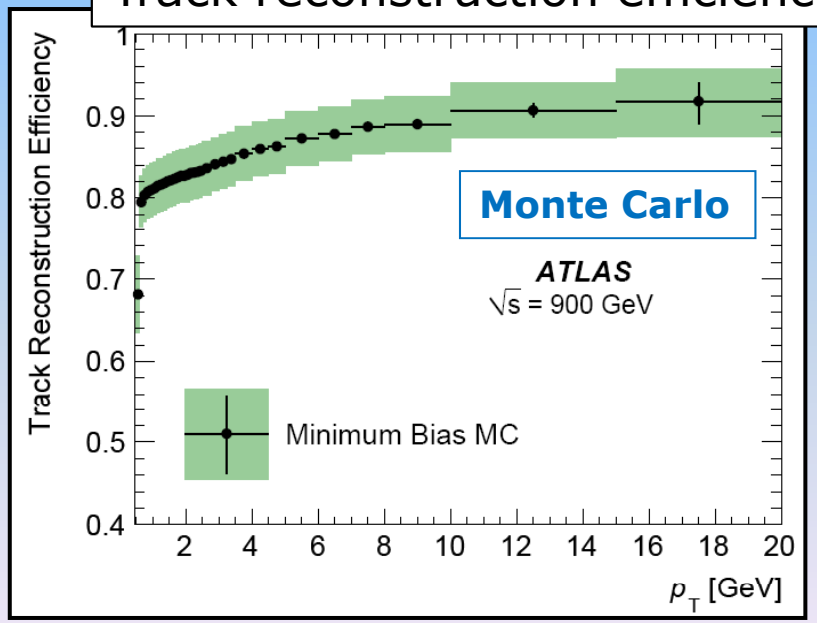
$\sigma_{p_T}/p_T = 0.05\% p_T \oplus 1\%$

Tracking performance

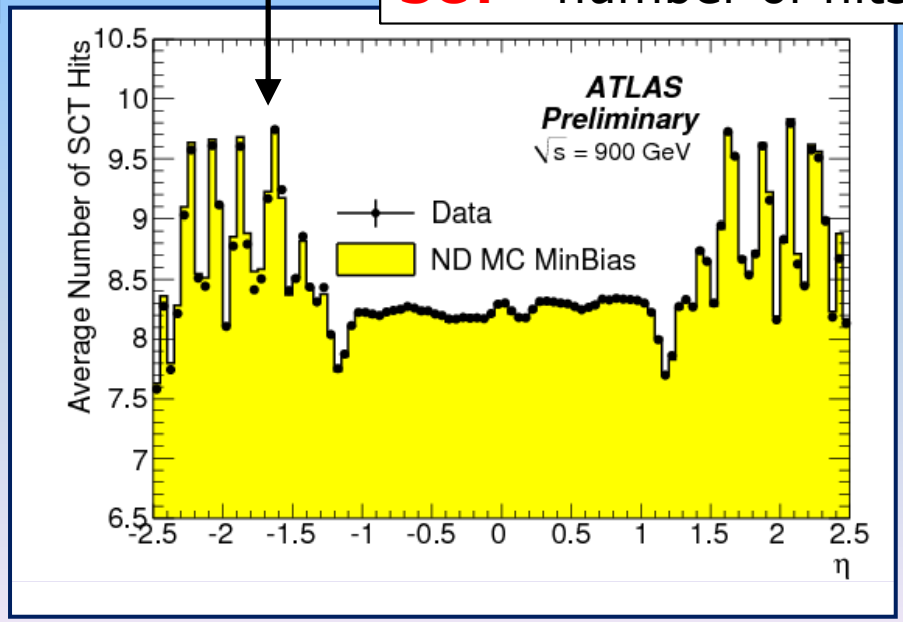
Minimum bias events at √s=900 GeV

Events with:
- Minimum bias trigger, primary vertex ≥ 3 tracks
- Tracks with: P_T > 0.5 GeV, $N_{pixel} \geq 1$, $N_{SCT} \geq 6$, $|d_0|<1.5$ mm, $|z_0 \sin\theta|<1.5$ mm
- Simulation: reweighted beamspot and corrections for disabled modules in data

Track reconstruction efficiency



SCT - number of hits

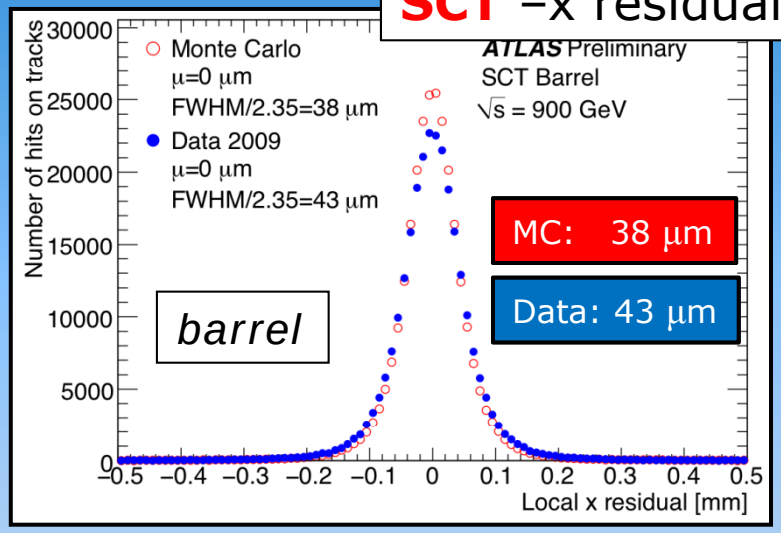


Excellent agreement:
simulation reproduces track properties

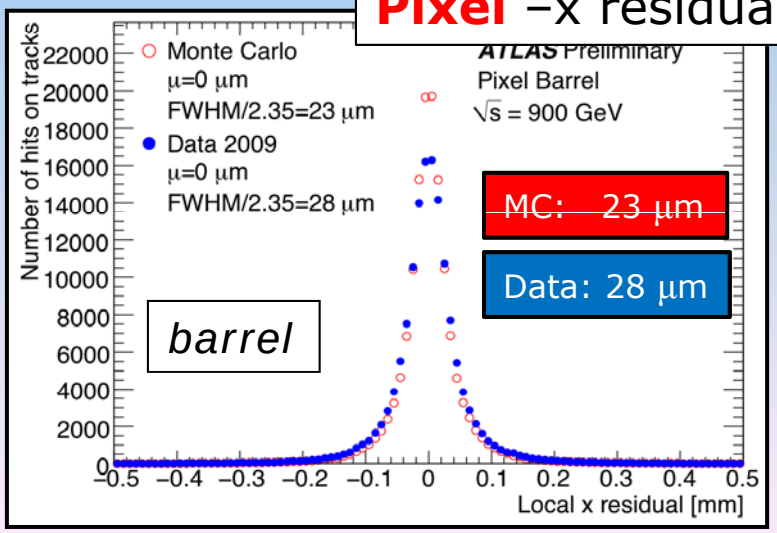
Alignment tracking detectors

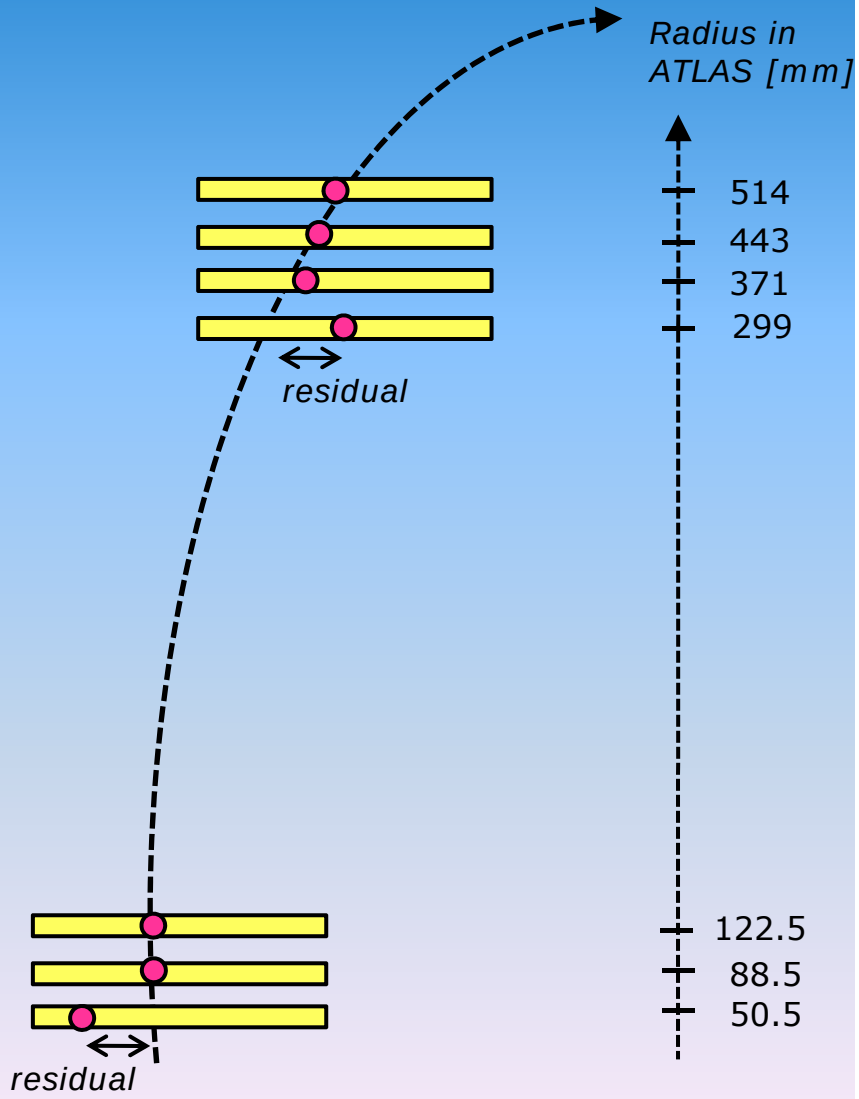
Tracks with: P_T > 2 GeV, $N_{silicon} \geq 6$, $|d_0|$<10 mm

SCT –x residuals



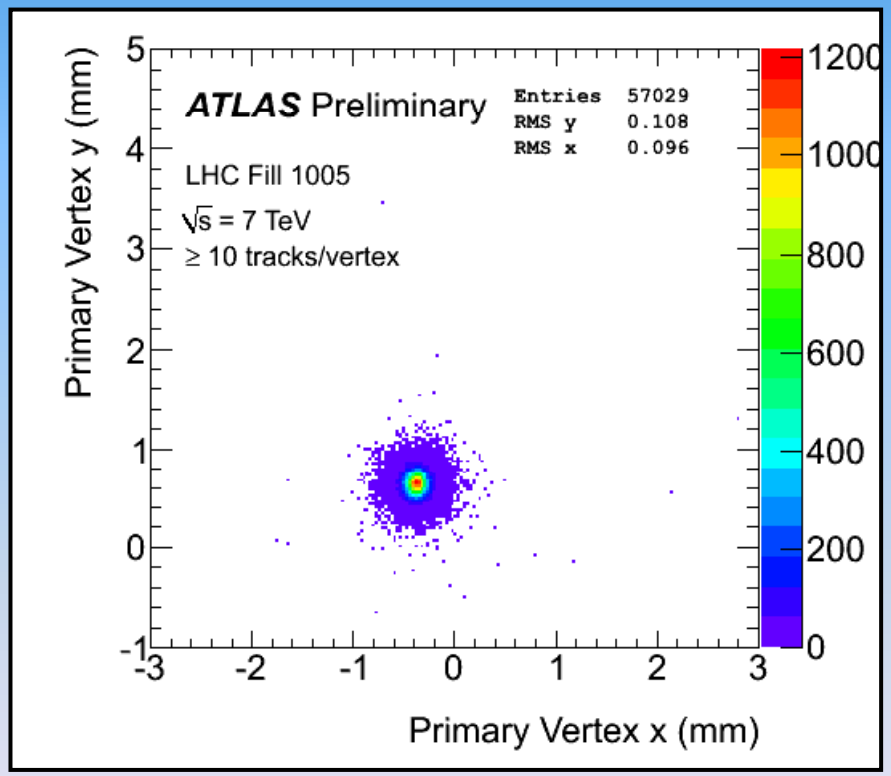
Pixel –x residuals



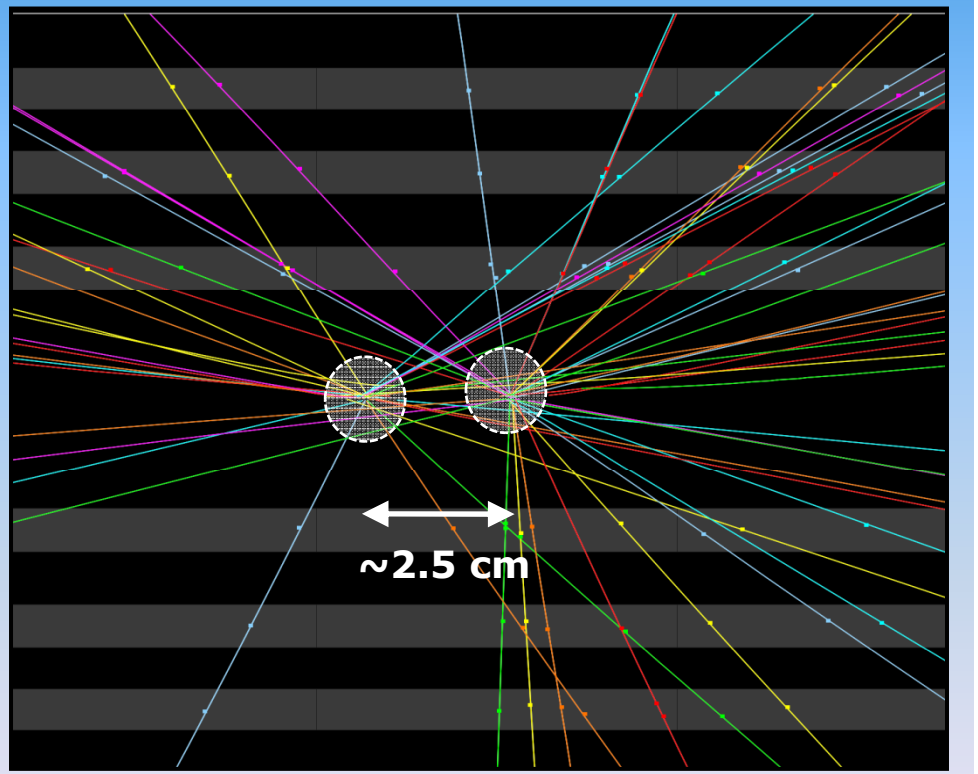


Vertexing

Primary vertices



Pile-up event

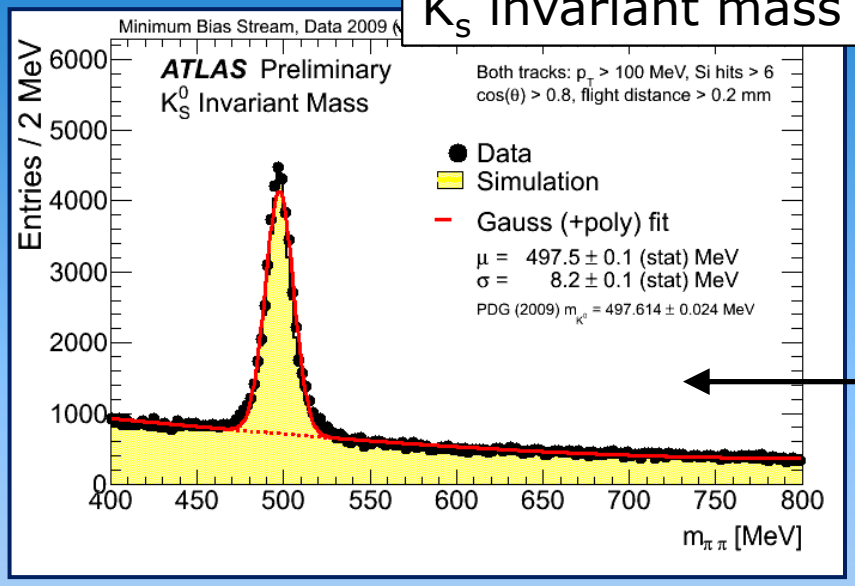


Luminous region: σ_X=45 μm, σ_Y=70 μm

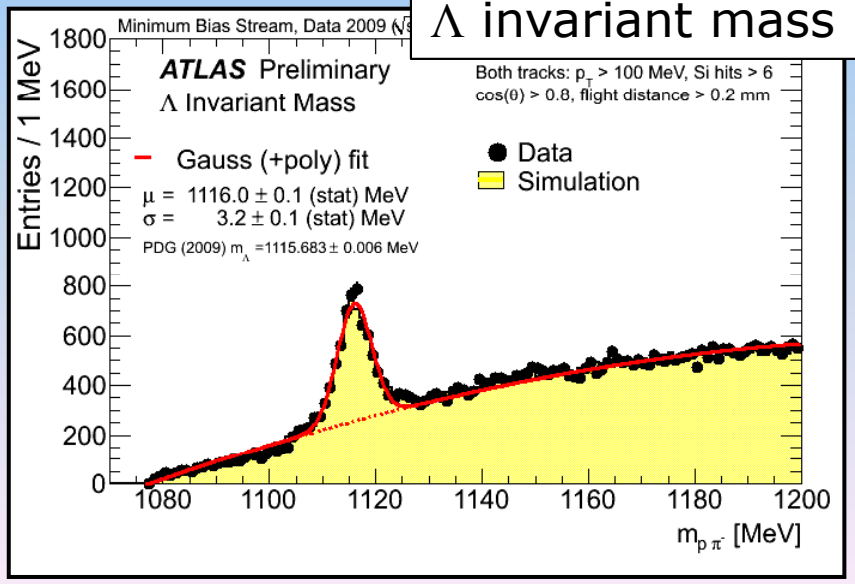
Vertex resolution ~75 μm

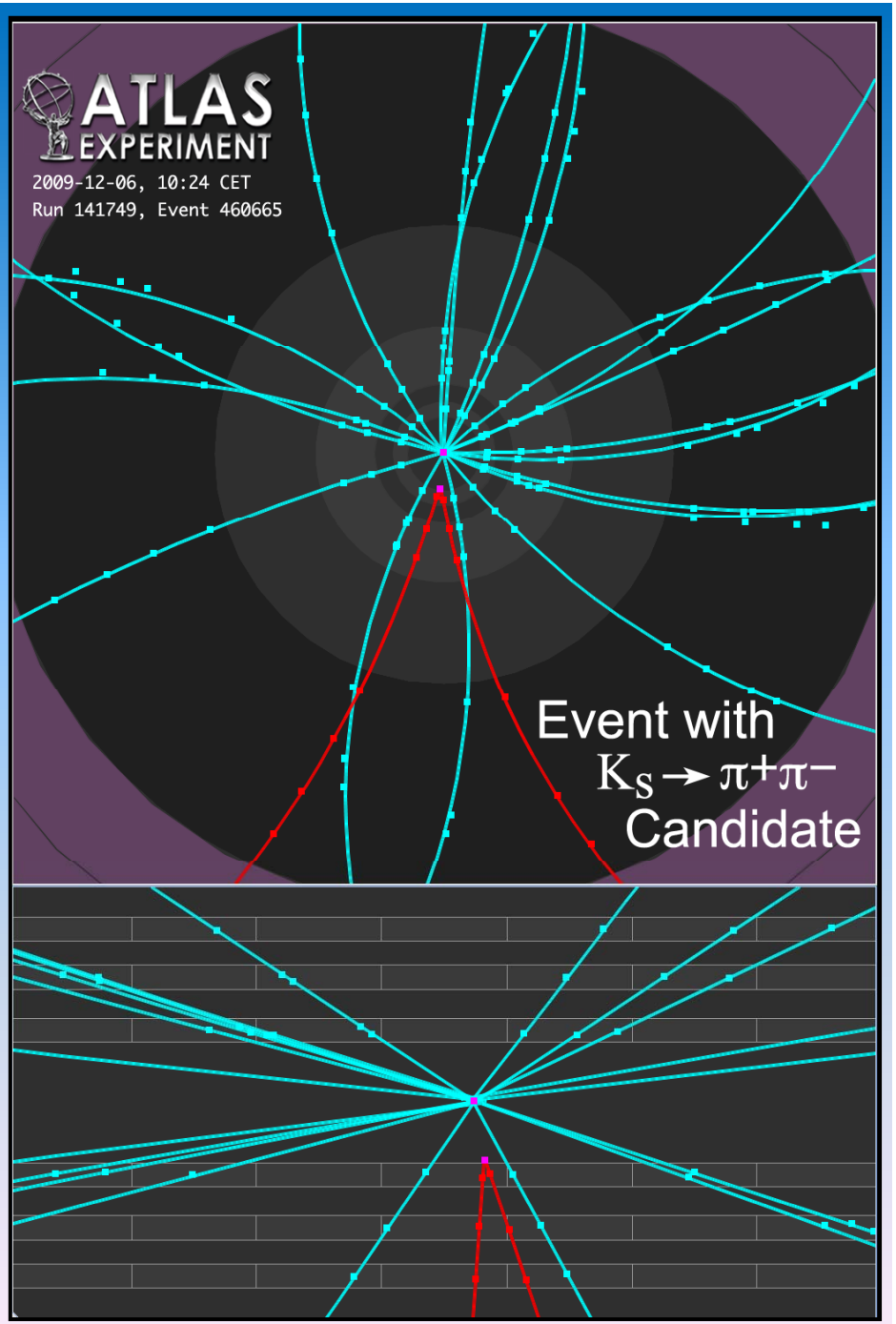
Secondary vertices

K_s invariant mass

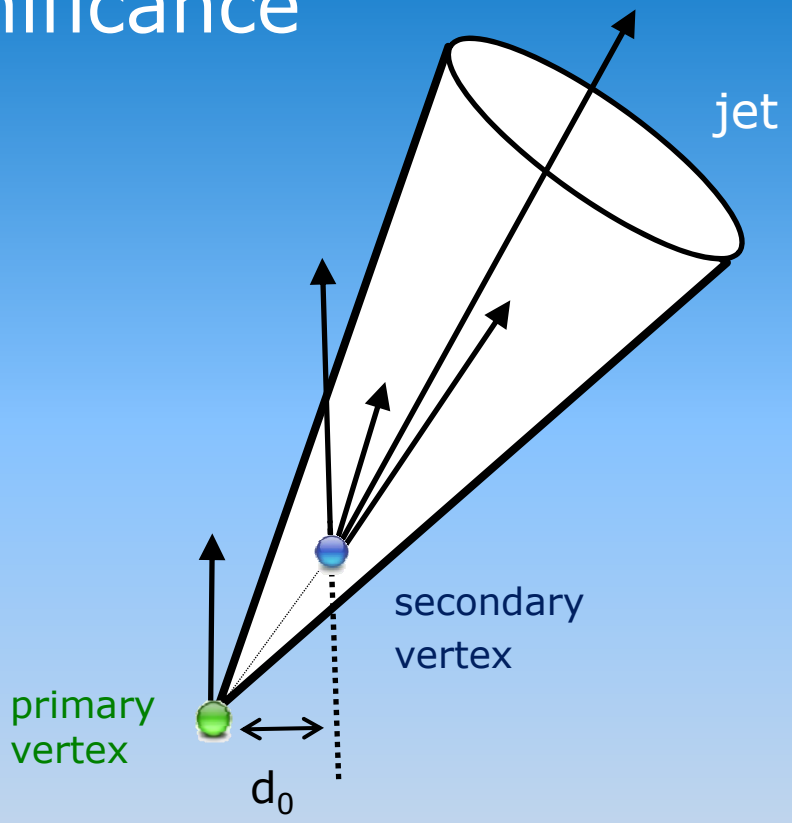


Λ invariant mass





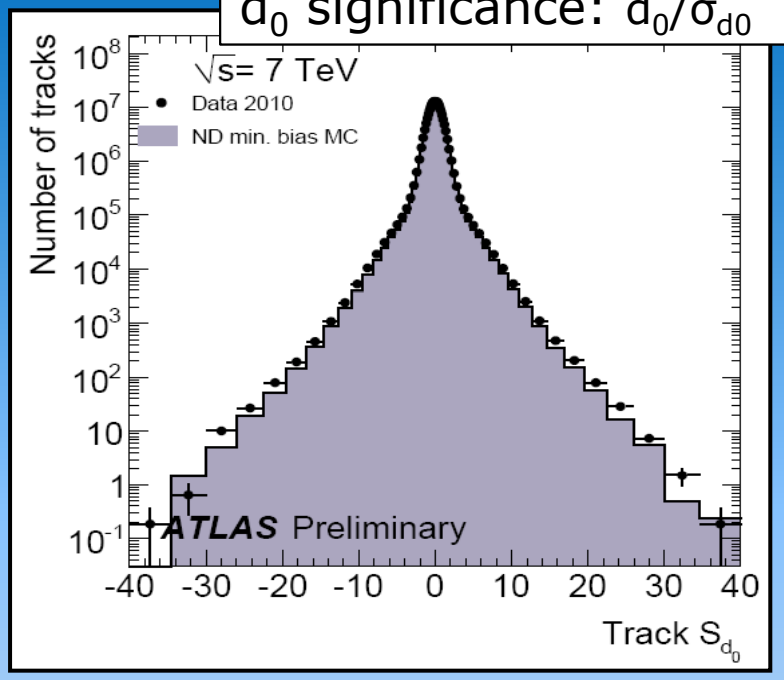
Impact parameter significance



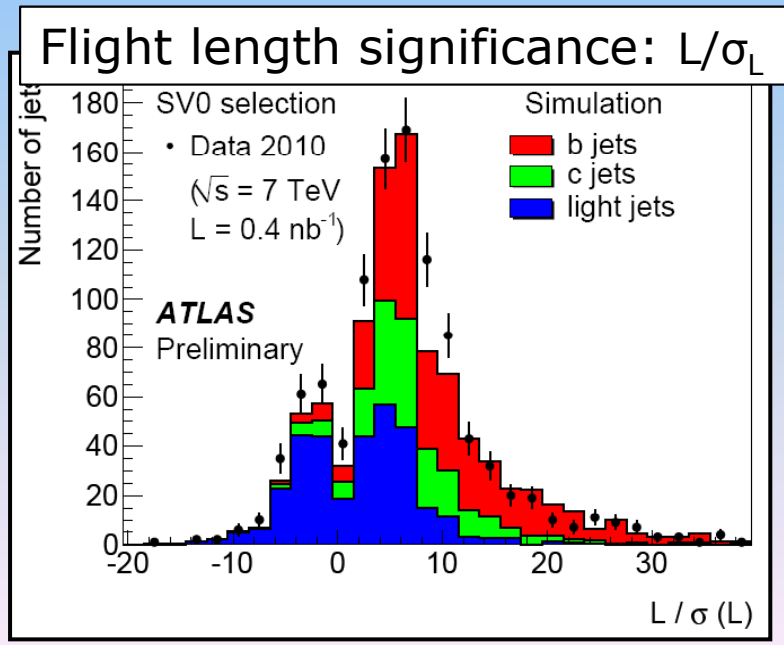
B-tagging algorithms:

- jet tracks (combined) incompatibility with originating from primary vertex
- soft lepton tagging
- secondary vertices & their properties

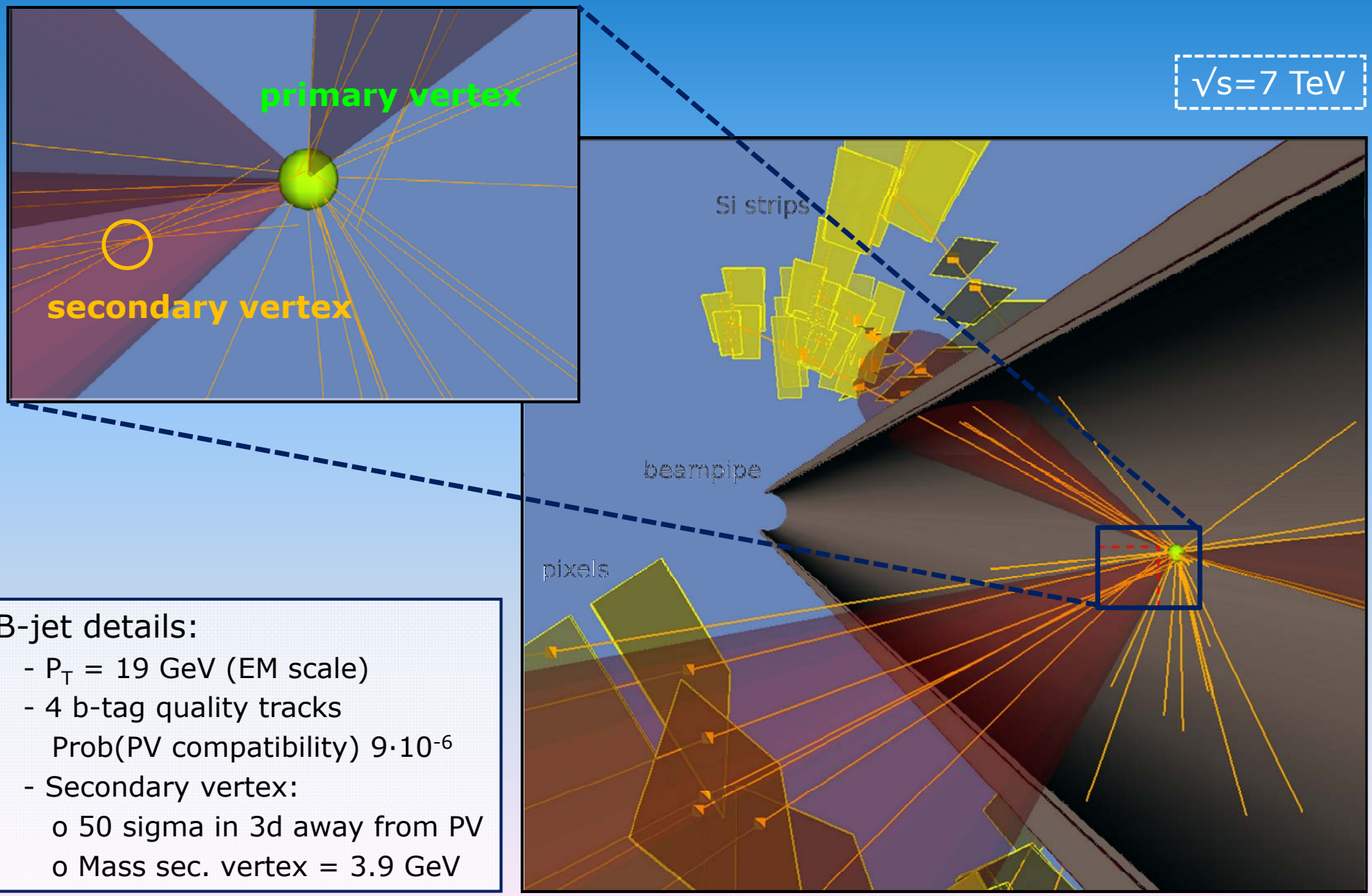
d_0 significance: d_0/σ_{d0}



Flight length significance: L/σ_L

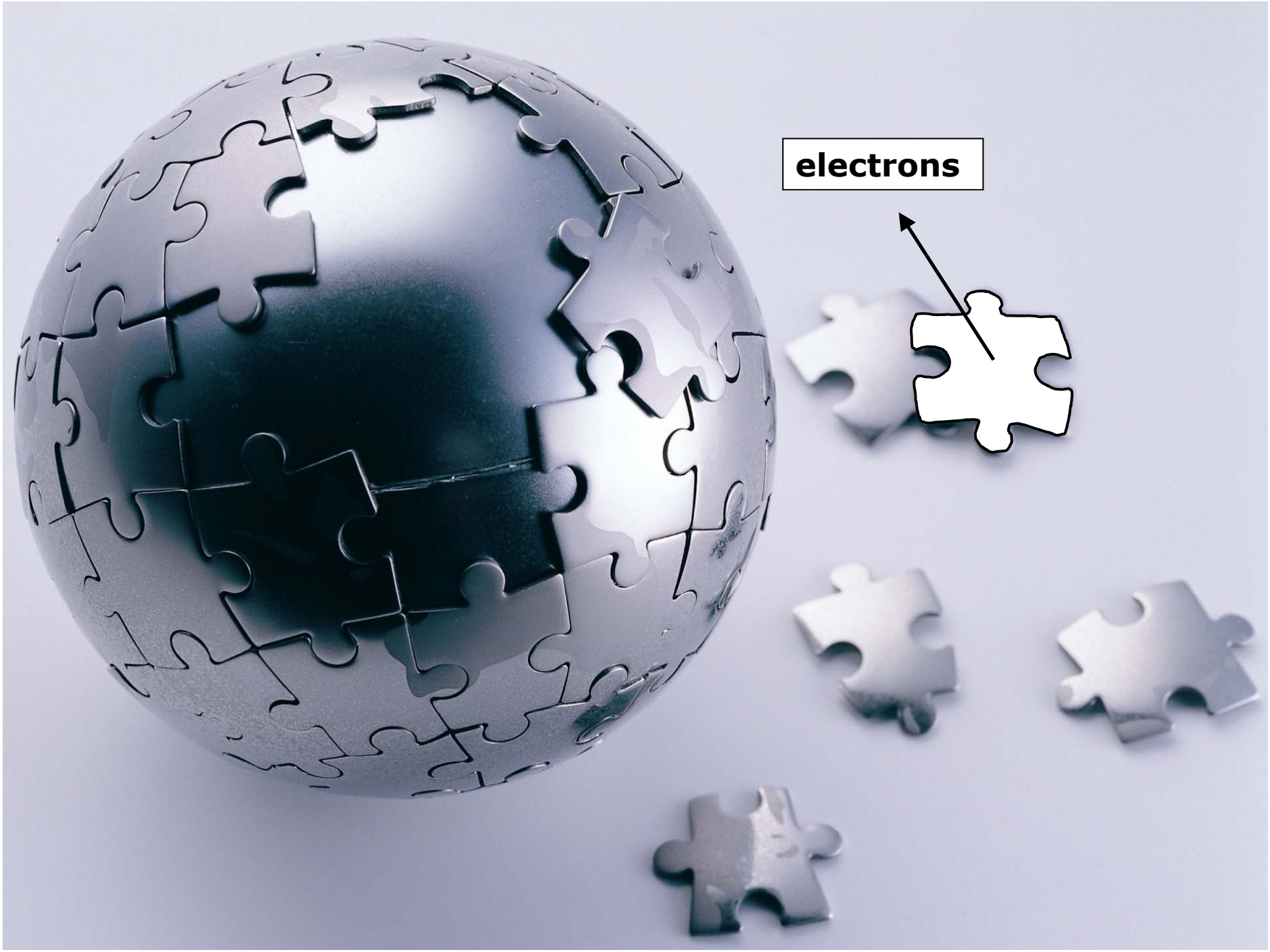


‘Typical’ b-jet candidate

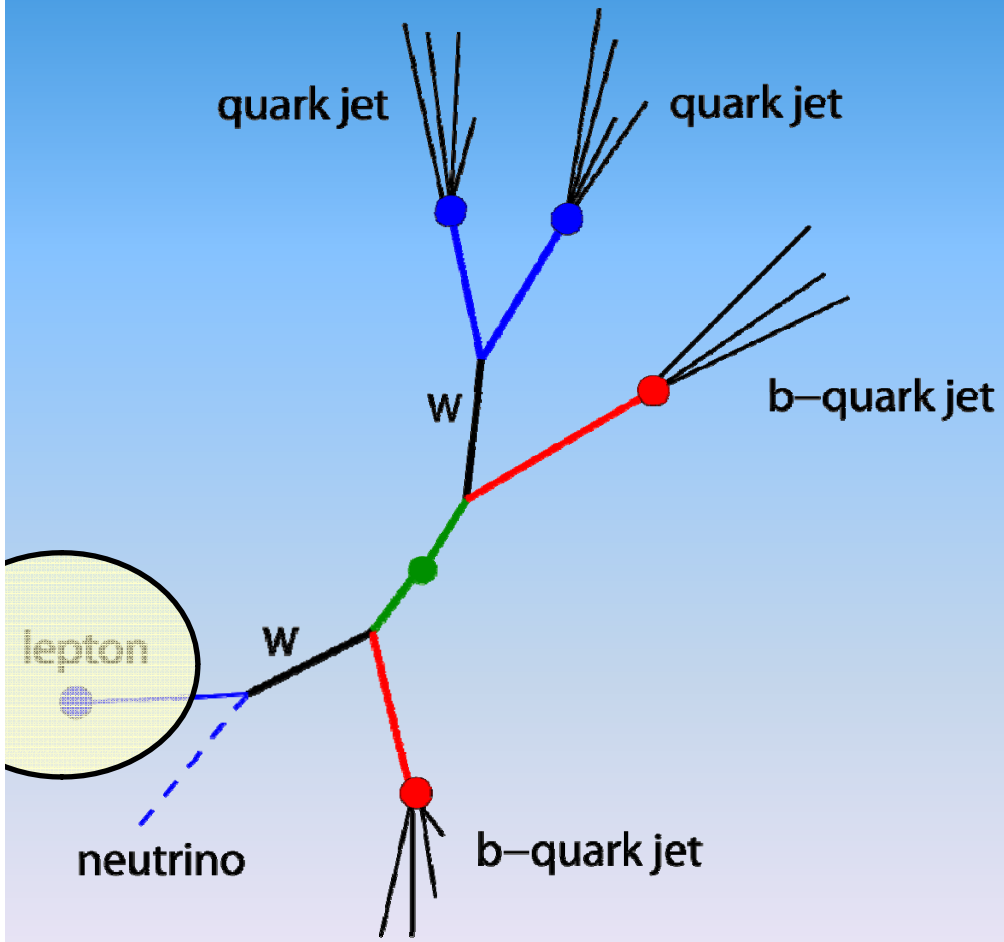


B-jet details:

- P_T = 19 GeV (EM scale)
- 4 b-tag quality tracks
  Prob(PV compatibility) $9 \cdot 10^{-6}$
- Secondary vertex:
  - 50 sigma in 3d away from PV
  - Mass sec. vertex = 3.9 GeV


electrons

Electrons in top analyses



Electrons in top analyses

→ isolated & high-P_T

- dominant trigger stream
- reduce QCD multi-jet bckg.
- handle on leptonic W-boson

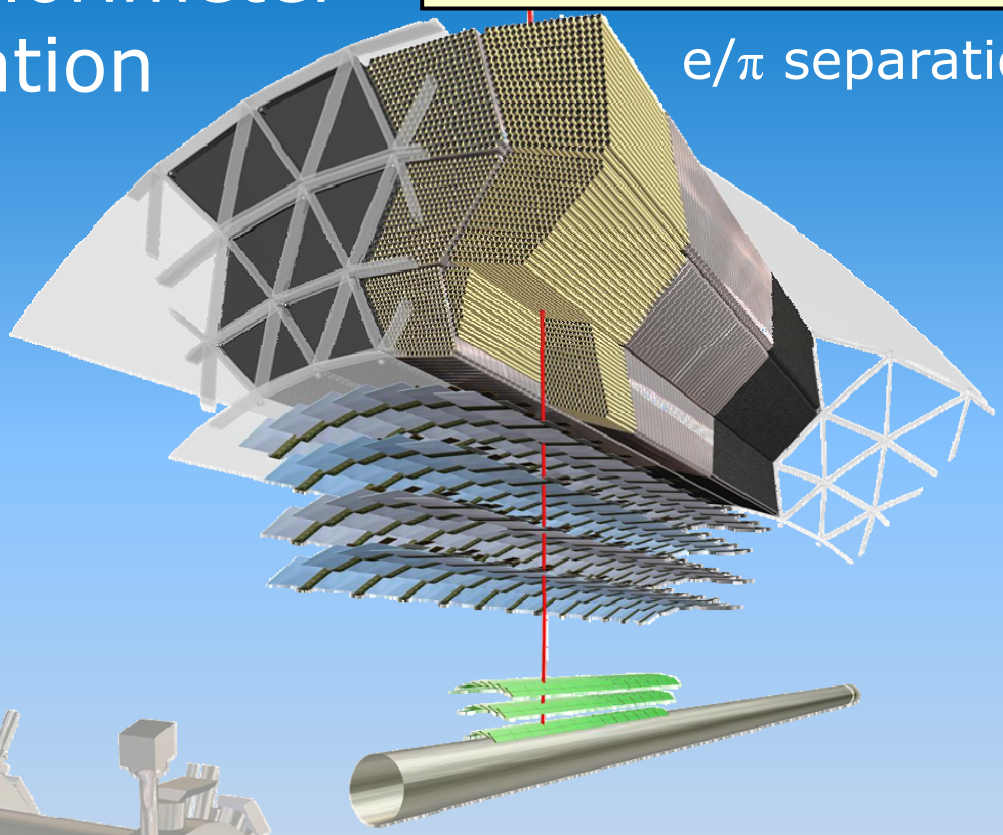
Complications:

- extrapolation from $Z \rightarrow e^+e^-$ to top multi-jet environment
- fake and non-prompt electrons
  - o e/jet ~ 10^{-5} at P_T=40 GeV
  - o identify b/c-decays: isolation

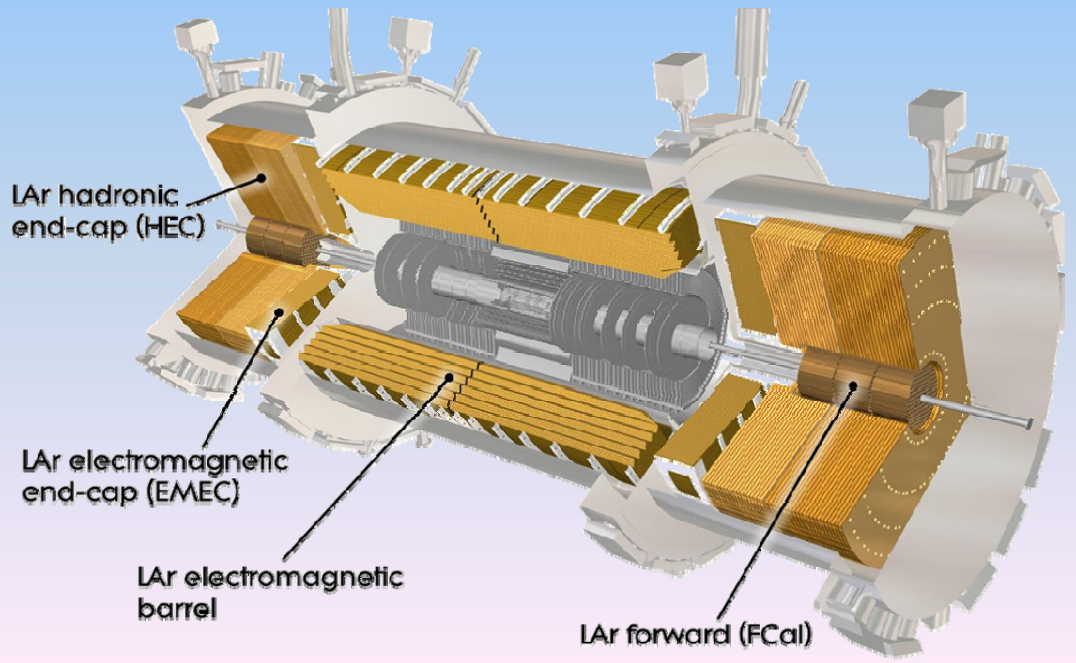
Electromagnetic calorimeter & particle identification

Transition Radiation Tracker

e/π separation



Electromagnetic calorimeter



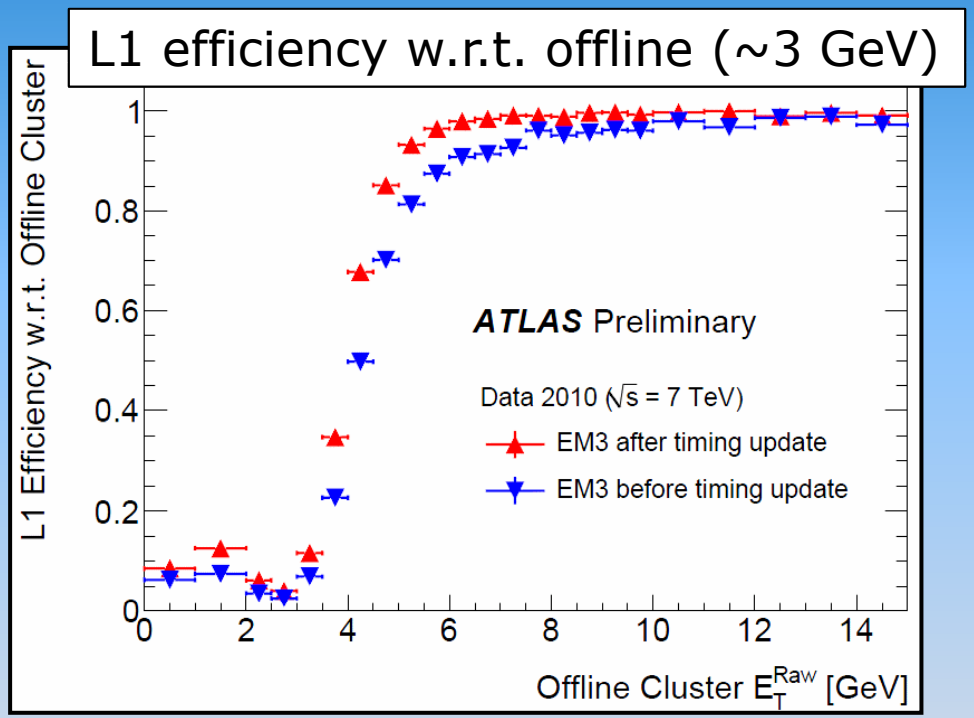
Liquid Argon / Lead

$|\eta| < 3.2$

20-30 X_0

$\sigma_E/E = 10\%/\sqrt{E} \oplus 0.7\%$

EM calorimeter trigger
- level 1 -



L1 rates:
normalised to L=10^{27} $cm^{-2}s^{-1}$

Trigger	Rate (Hz)
EM3	0.515 ± 0.003

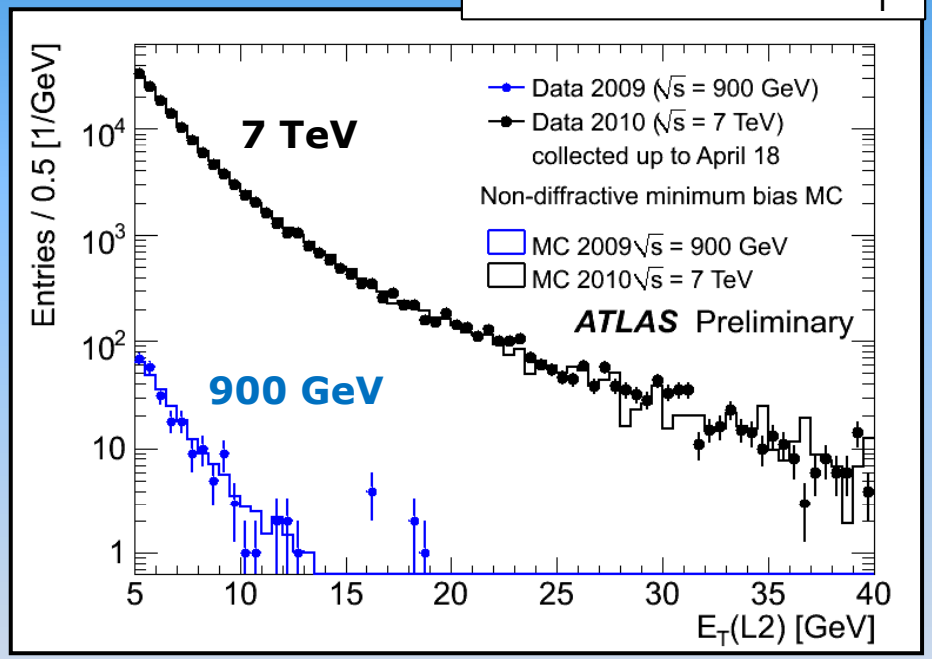
Nominal settings / rates

Signature	Rate (1x10^{31})
L1: e10	5 kHz
EF: e10	21 Hz

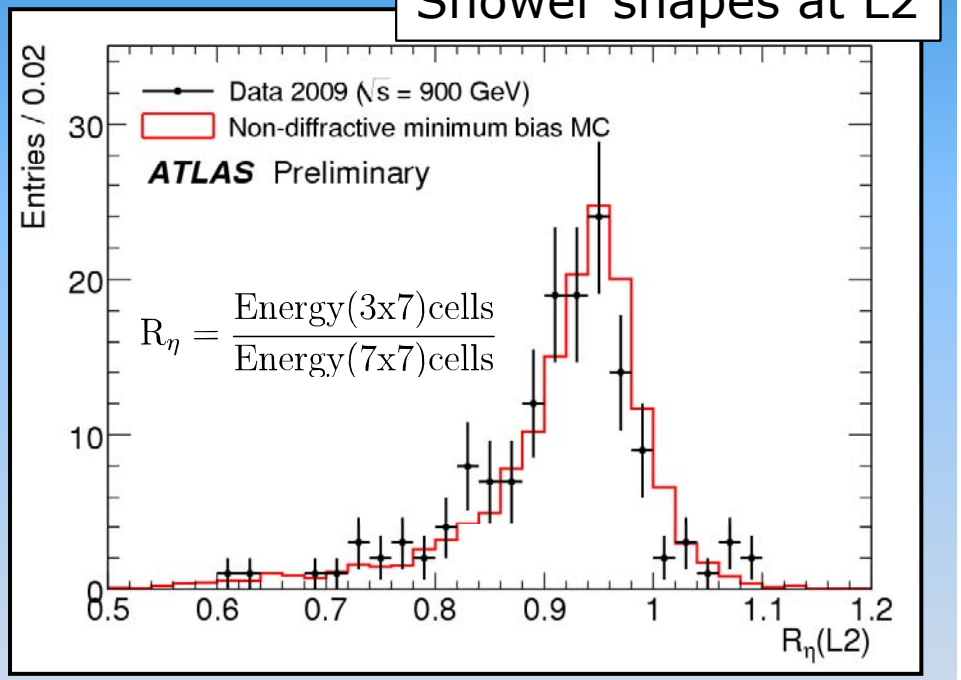
ATLAS detector paper

EM & e/γ trigger
- level 2 and event filter -

L2 rate versus E_T



Shower shapes at L2



Note: - Already at Level 2 fairly good agreement on e/γ specifics
- Highest level (Event Filter) trigger offline - more refined

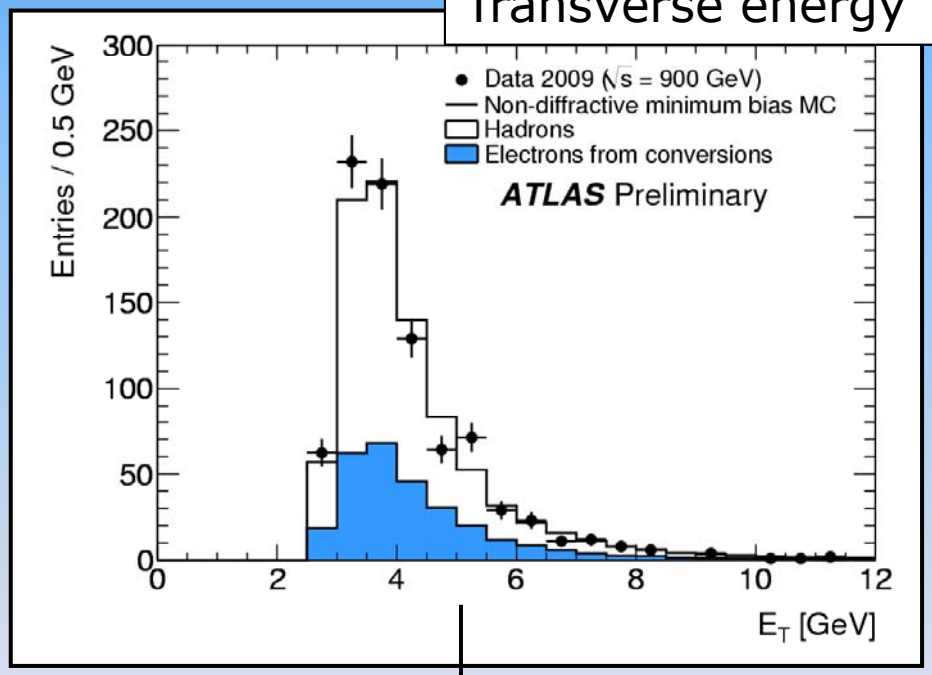
Electrons in 900 GeV data

$\mathcal{L} = 9\ \mu\mathrm{b}^{-1}$

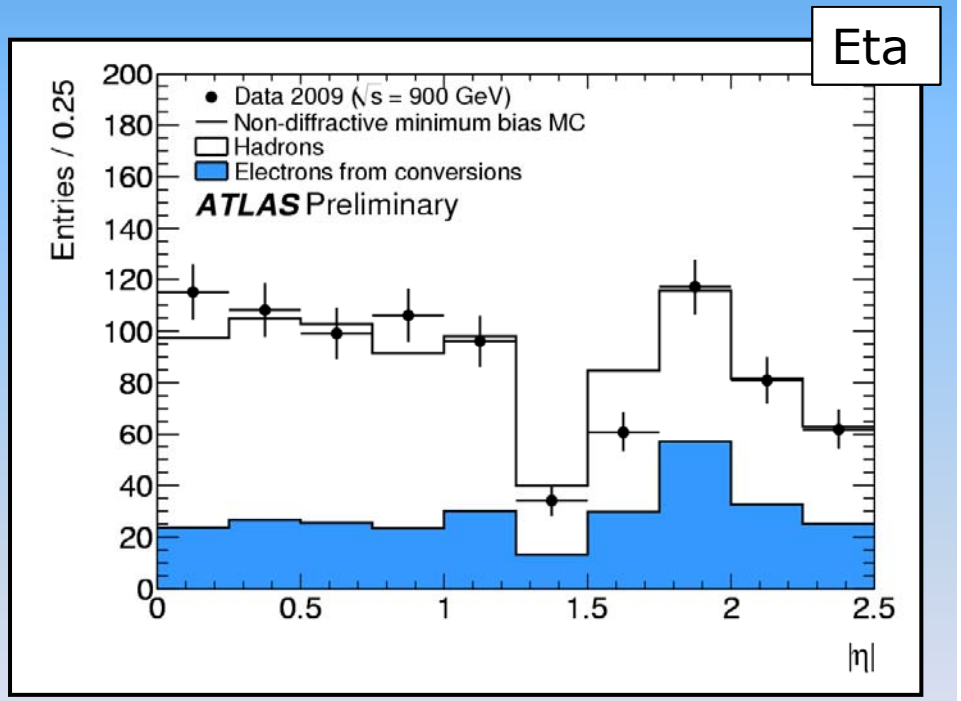
879 electron candidates:

→ electrons from photon conversions and fake electrons (hadrons)

Transverse energy



Eta

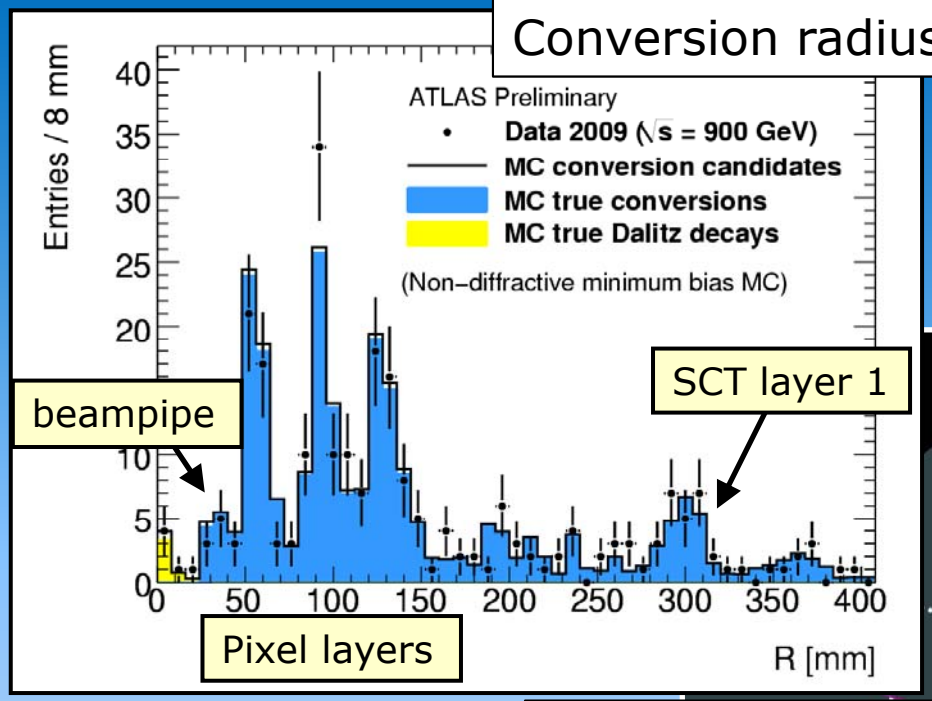


$$\mathrm{E} = s(\eta)\left[c(\eta) + w_0(\eta)\mathrm{E_{PS}} + \mathrm{E_{strips}} + \mathrm{E_{middle}} + w_3(\eta)\mathrm{E_{back}}\right]$$

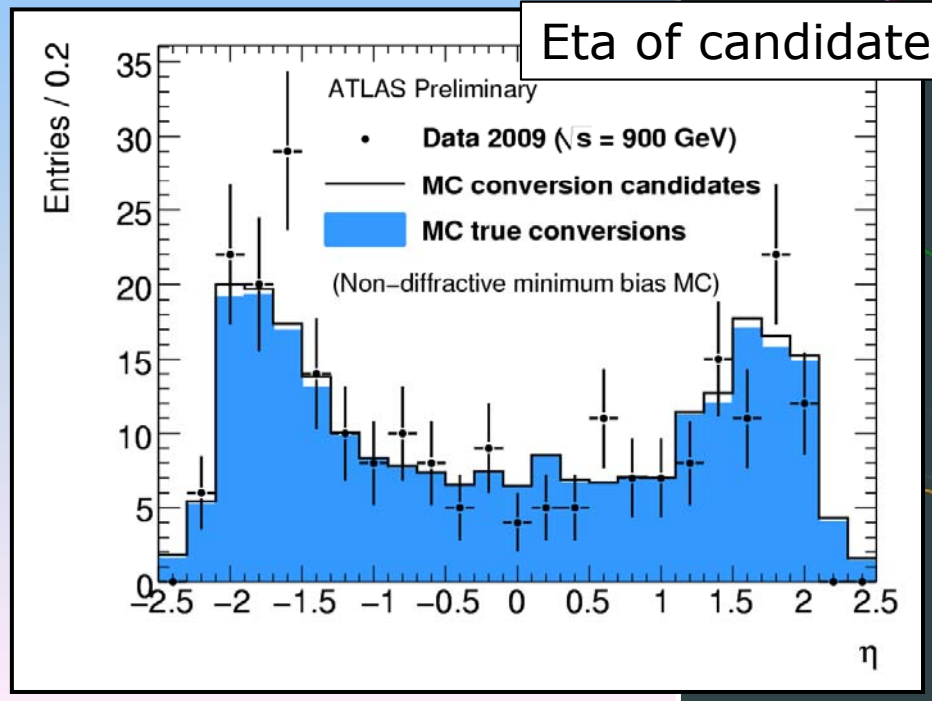
γ/π^0 – separation bulk energy leakage-estimate

Photon conversions

Conversion radius



Eta of candidate



- **Clean electron sample**
- **Good material description in MC**

Electron classifications and data

Loose

ECAL: shower shapes
Track: loose track

Medium

ECAL: strip layer info
Track: tighter quality + matching

Tight

Track: B-layer hit + tight match
TRT: high-threshold hits

Expectations, √s=10 TeV (MC)

	Efficiency ($Z \rightarrow e^+e^-$)	Jet rejection ($\times 10^3$)
Loose	94.3 %	~ 1
Medium:	90.0 %	~ 7
Tight:	71.5 %	~ 140

Calorimeter information

Loose

ECAL: shower shapes
Track: loose track

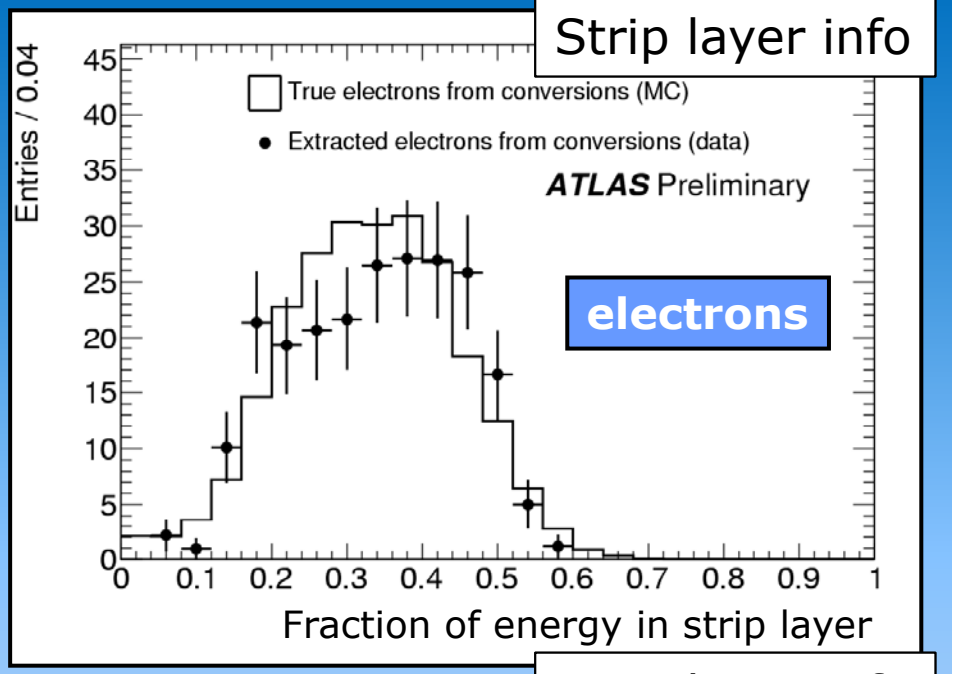
Medium

ECAL: strip layer info
Track: tighter quality + matching

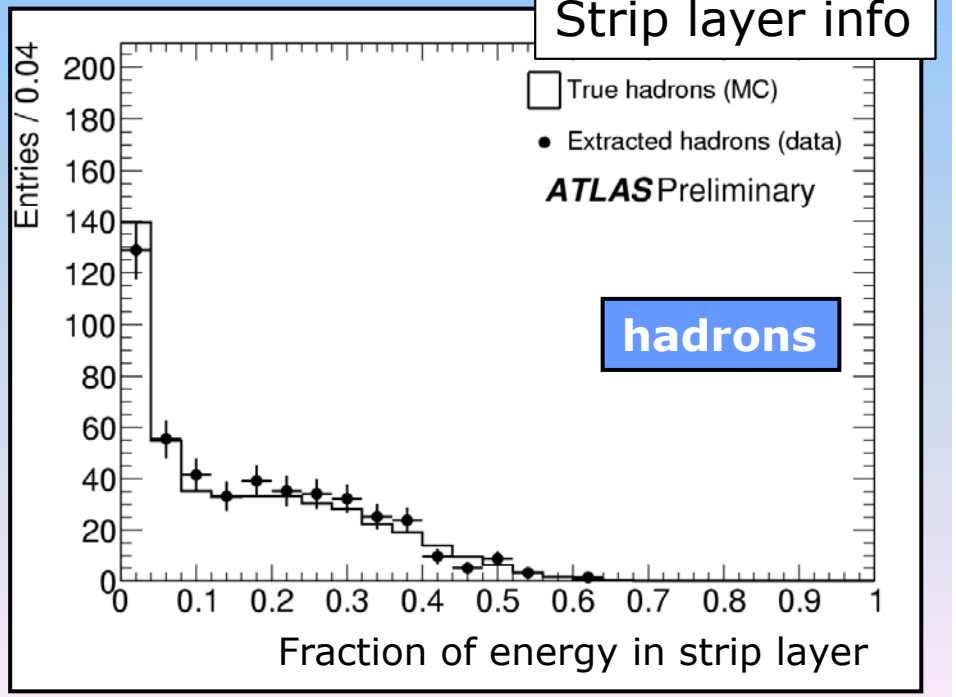
Tight

Track: B-layer hit + tight match
TRT: high-threshold hits

Strip layer info



Strip layer info



Tight electrons

Loose

ECAL: shower shapes
Track: loose track

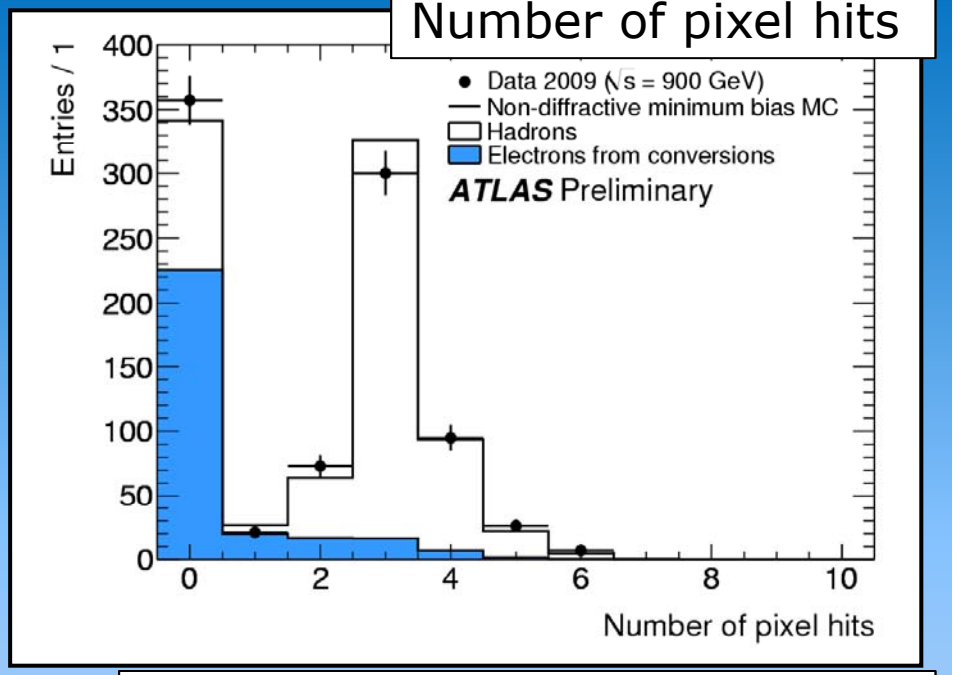
Medium

ECAL: strip layer info
Track: tighter quality + matching

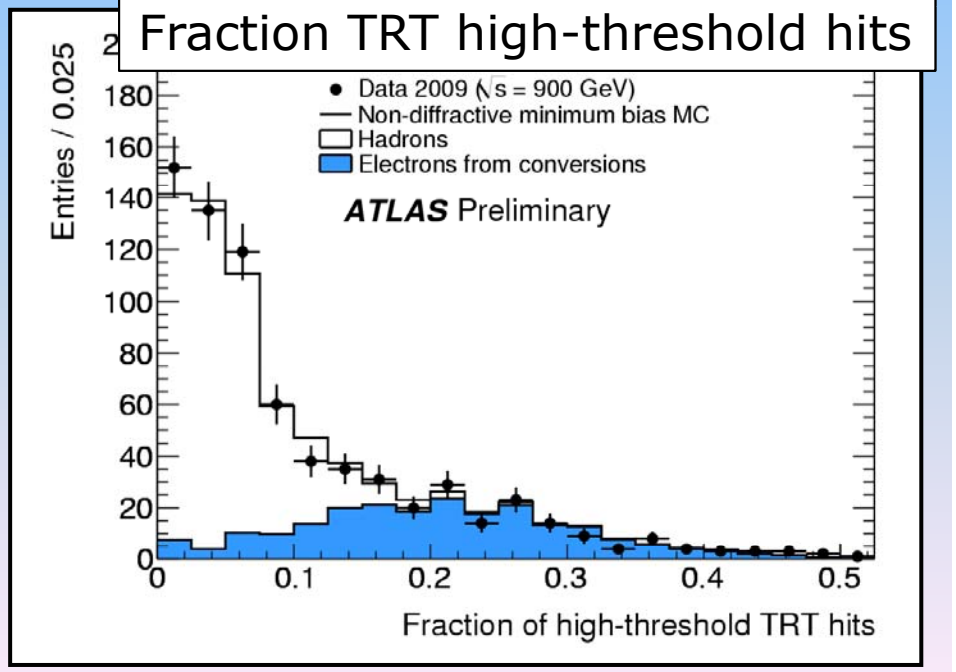
Tight

Track: B-layer hit + tight match
TRT: high-threshold hits

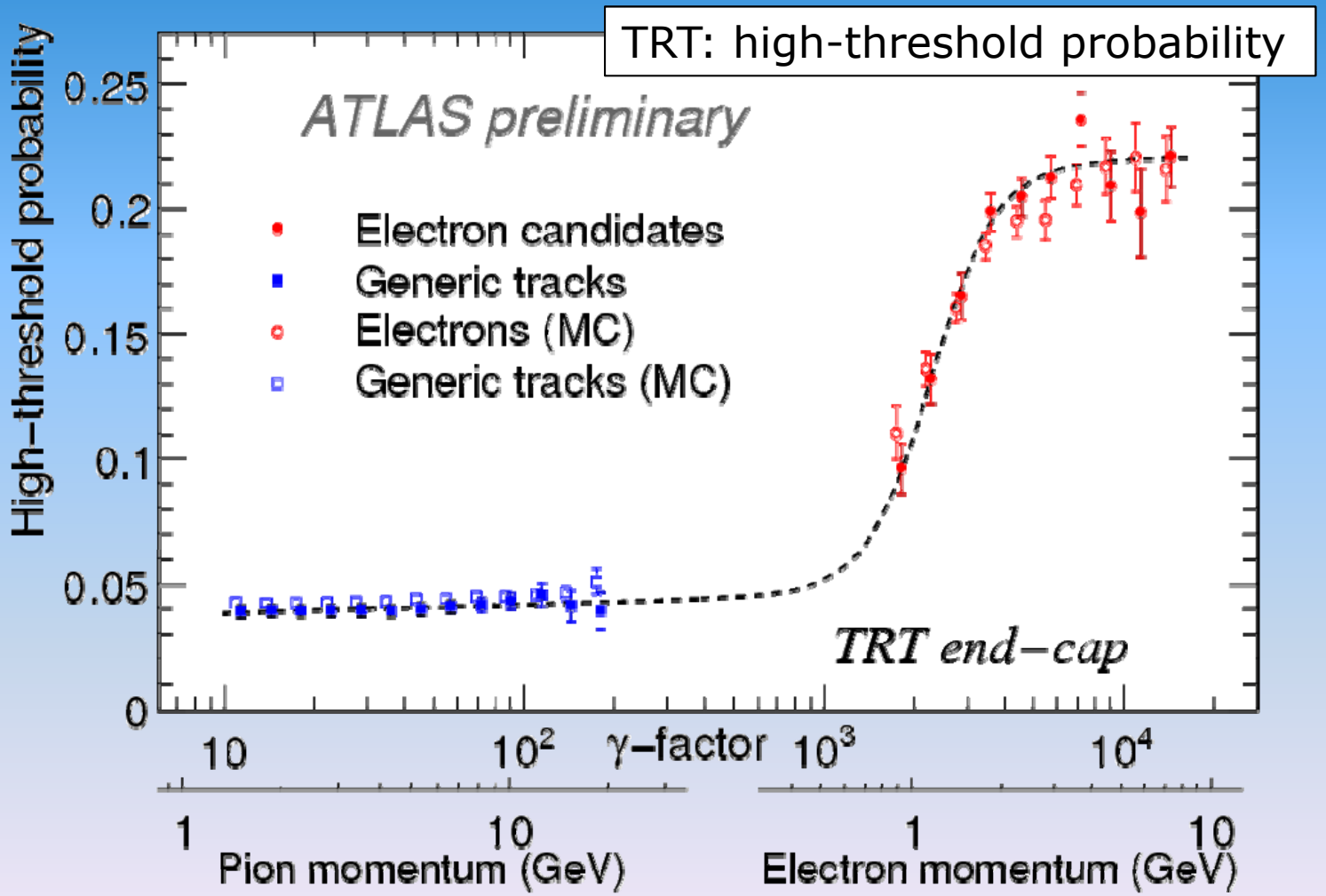
Number of pixel hits



Fraction TRT high-threshold hits

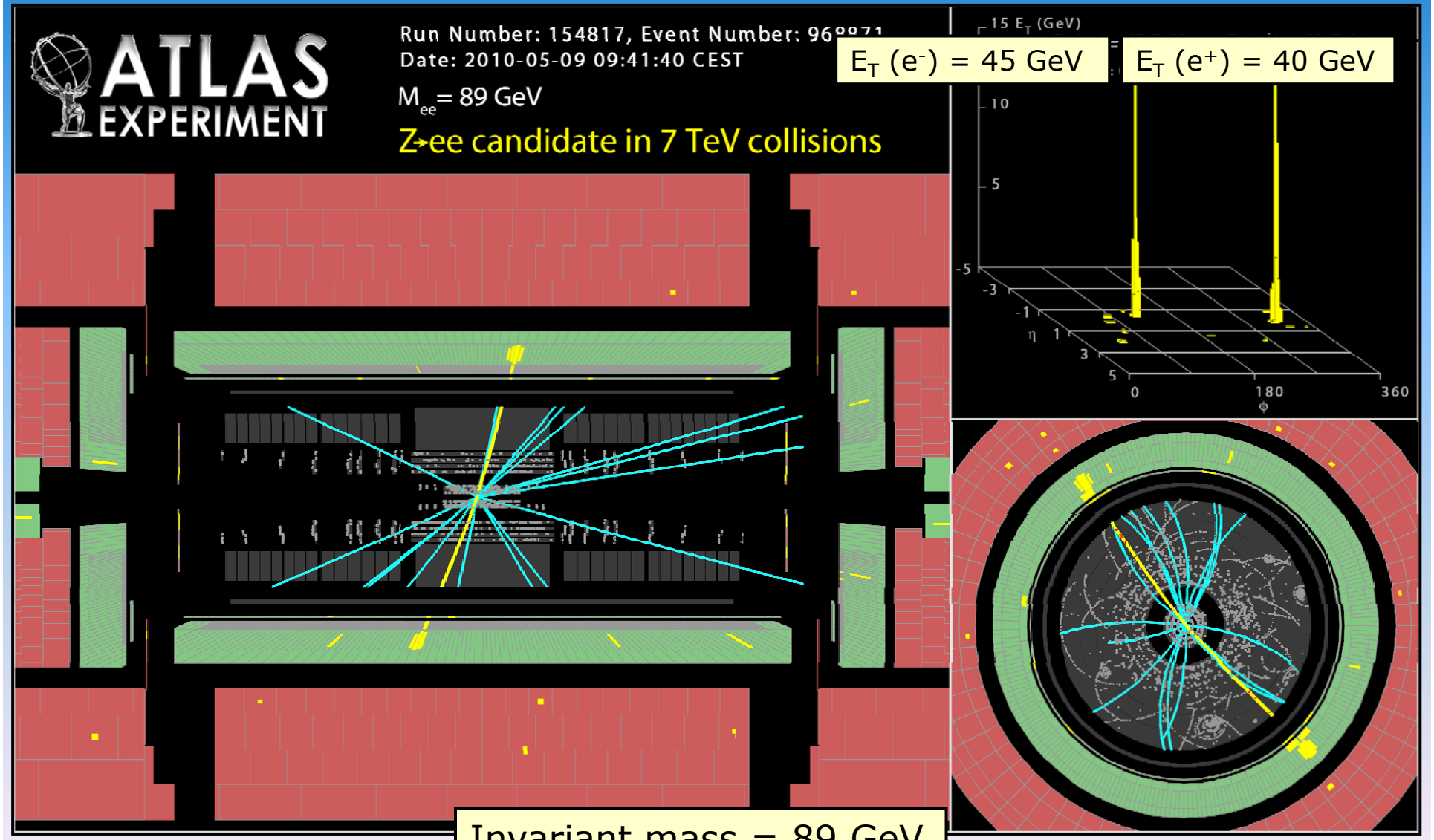


Transition Radiation Tracker (e/π separation)

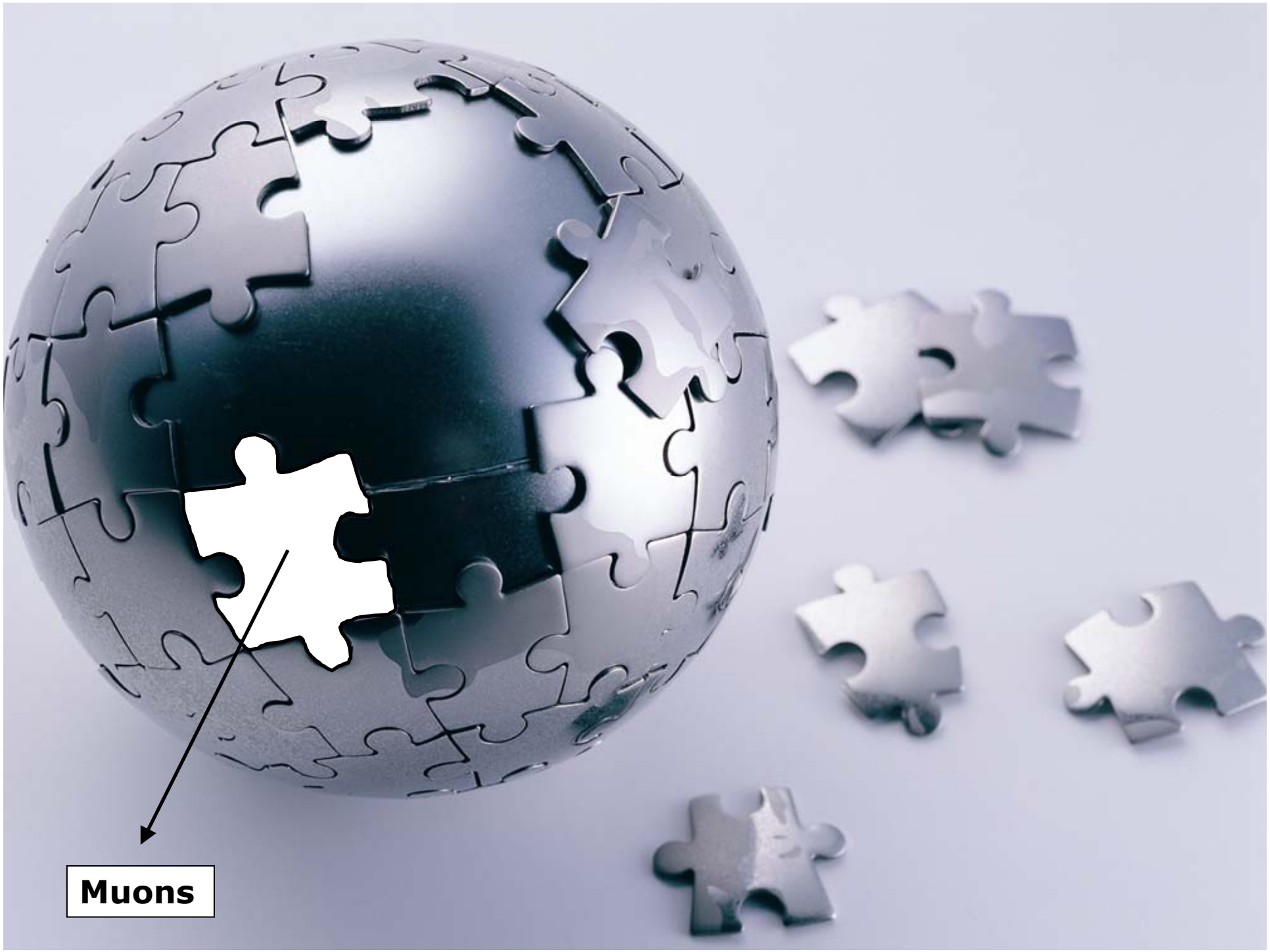


Note: also tested using high-energy muons in the cosmic runs

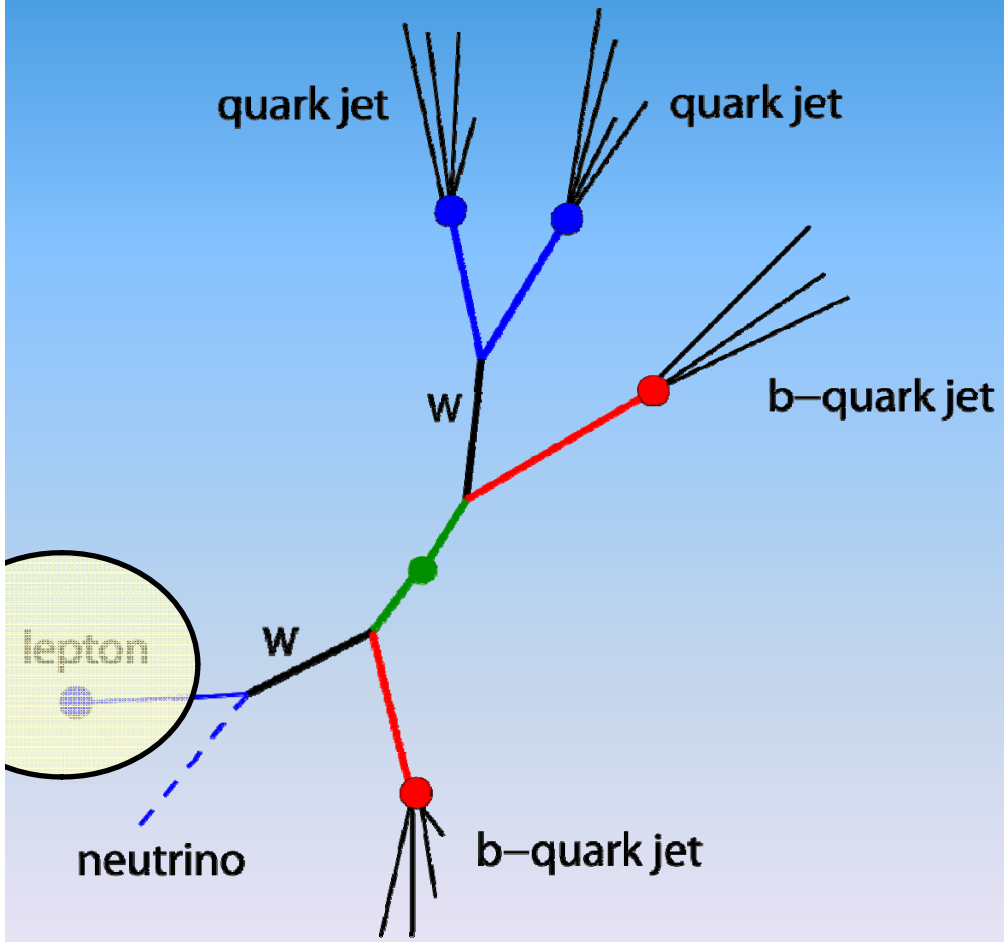
$Z \rightarrow e^+e^-$ candidate at $\sqrt{s}=7$ TeV



Invariant mass = 89 GeV


Muons

Muons in top analyses



Muons in top analyses

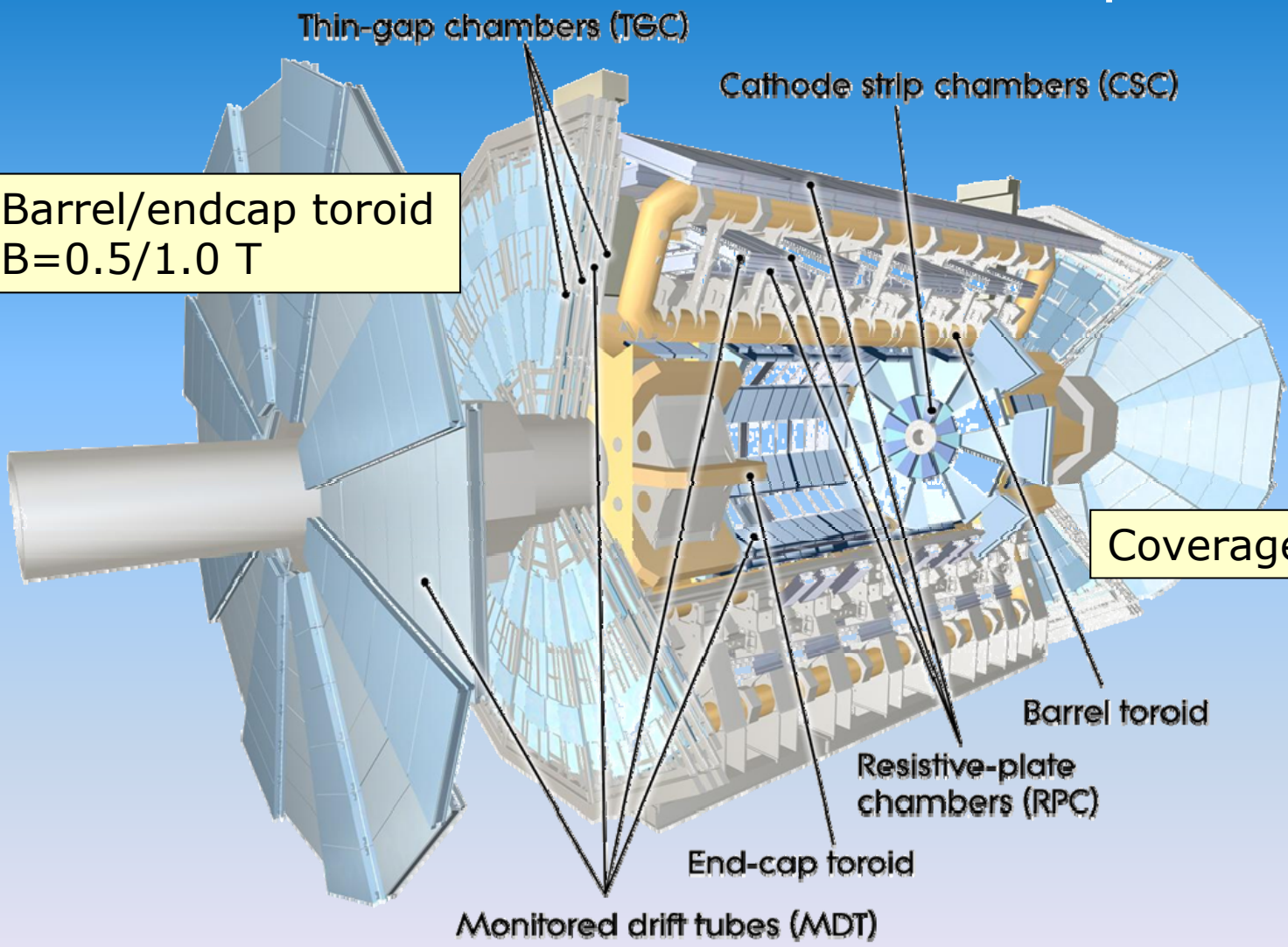
→ isolated & high-P_T

- dominant trigger stream
- reduce QCD multi-jet bckg.
- handle on leptonic W-boson

Complications:

- extrapolation from $Z \rightarrow \mu^+\mu^-$ to top multi-jet environment
- fake and non-prompt muons mainly from b-decays:
  → identify using isolation

Muon Spectrometer

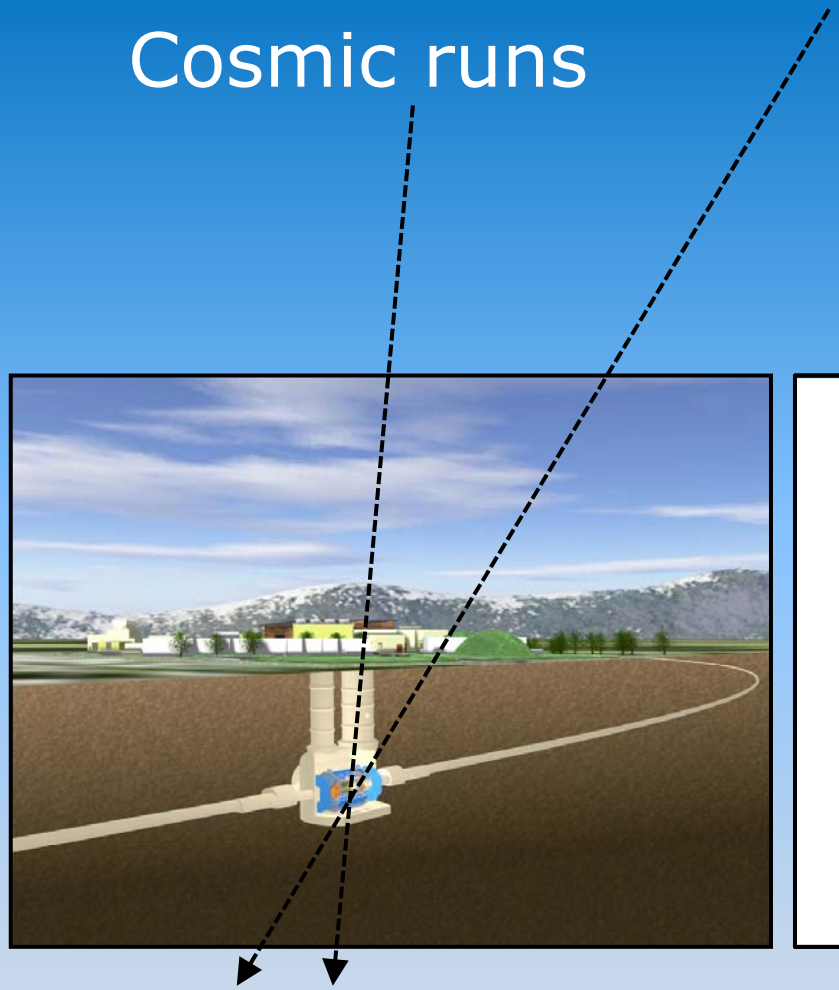


Barrel/endcap toroid
B=0.5/1.0 T

Coverage: $|\eta| < 2.7$

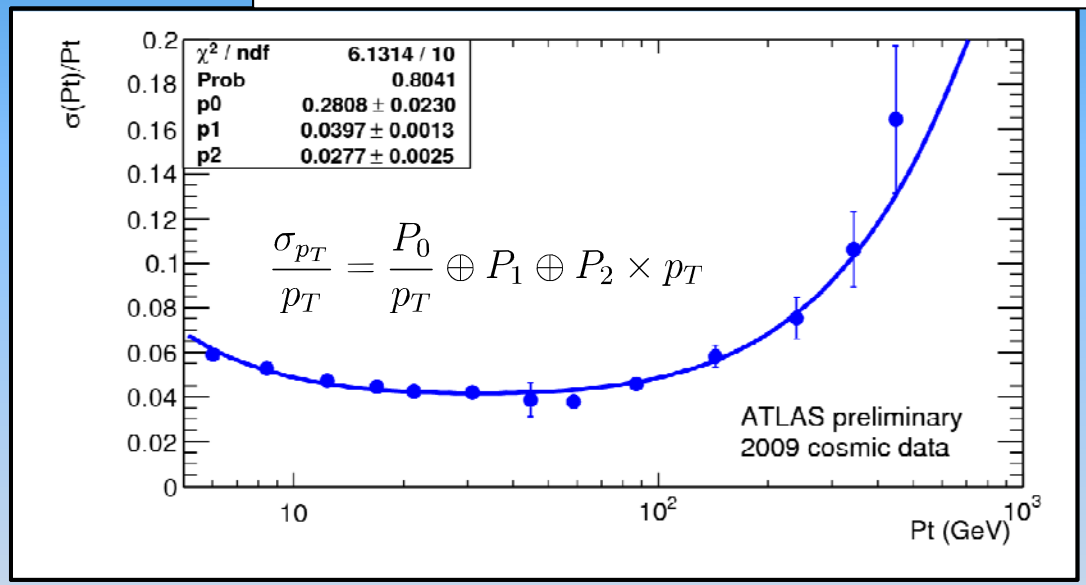
Muon trigger and momentum resolution < 10% up to 1 TeV
standalone or combined with inner detector information

Cosmic runs



Millions and millions of cosmics

Transverse momentum resolution

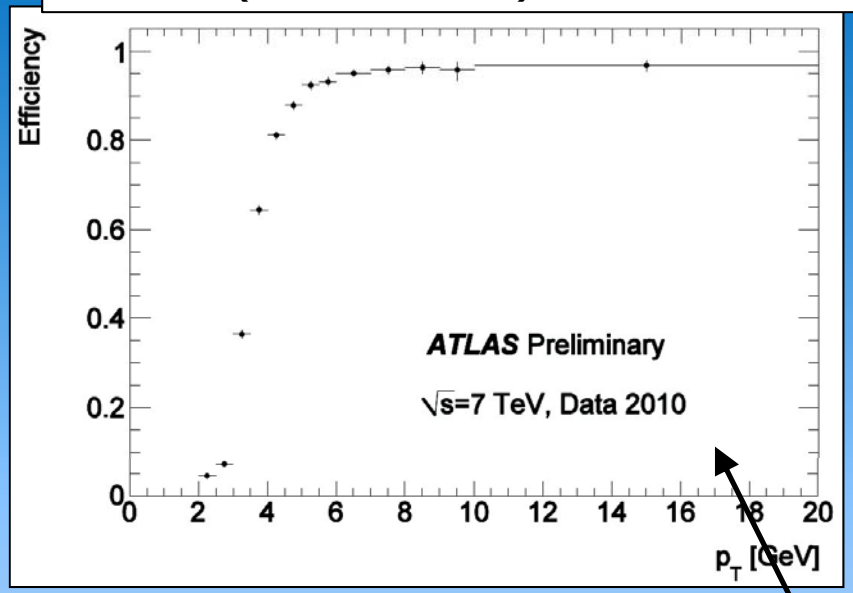


Transverse momentum resolution

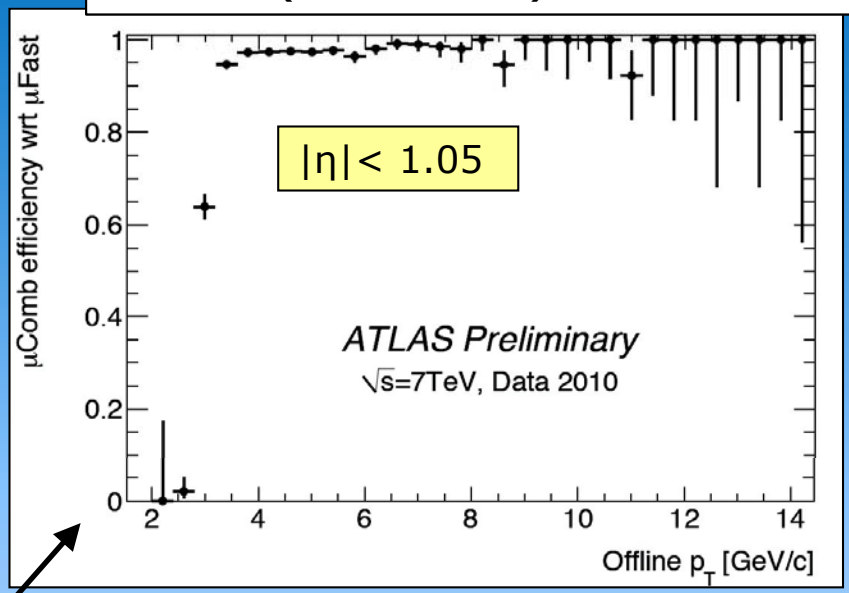
Resolution close to nominal

Ongoing effort on alignment and calibration

L2 eff. (standalone) w.r.t. offline



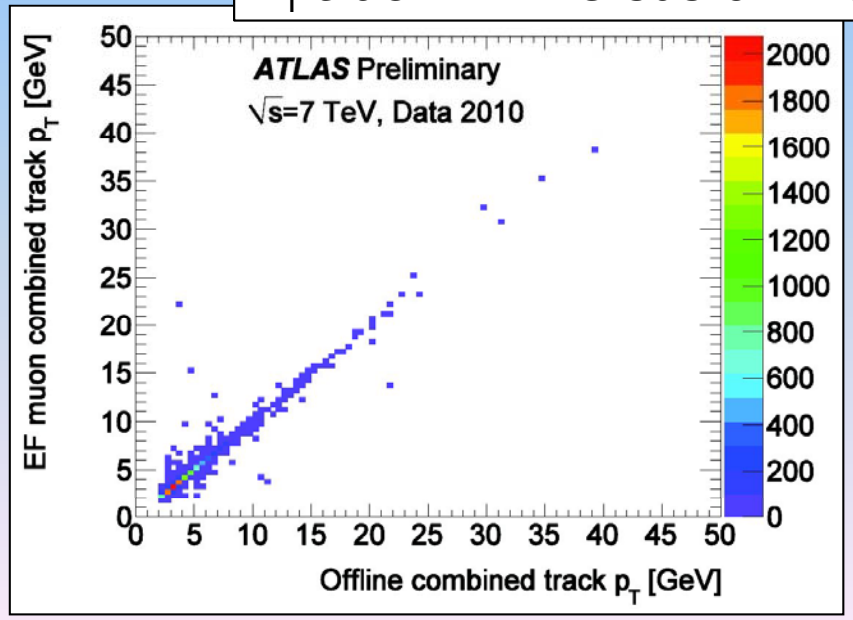
L2 eff. (combined) w.r.t. offline



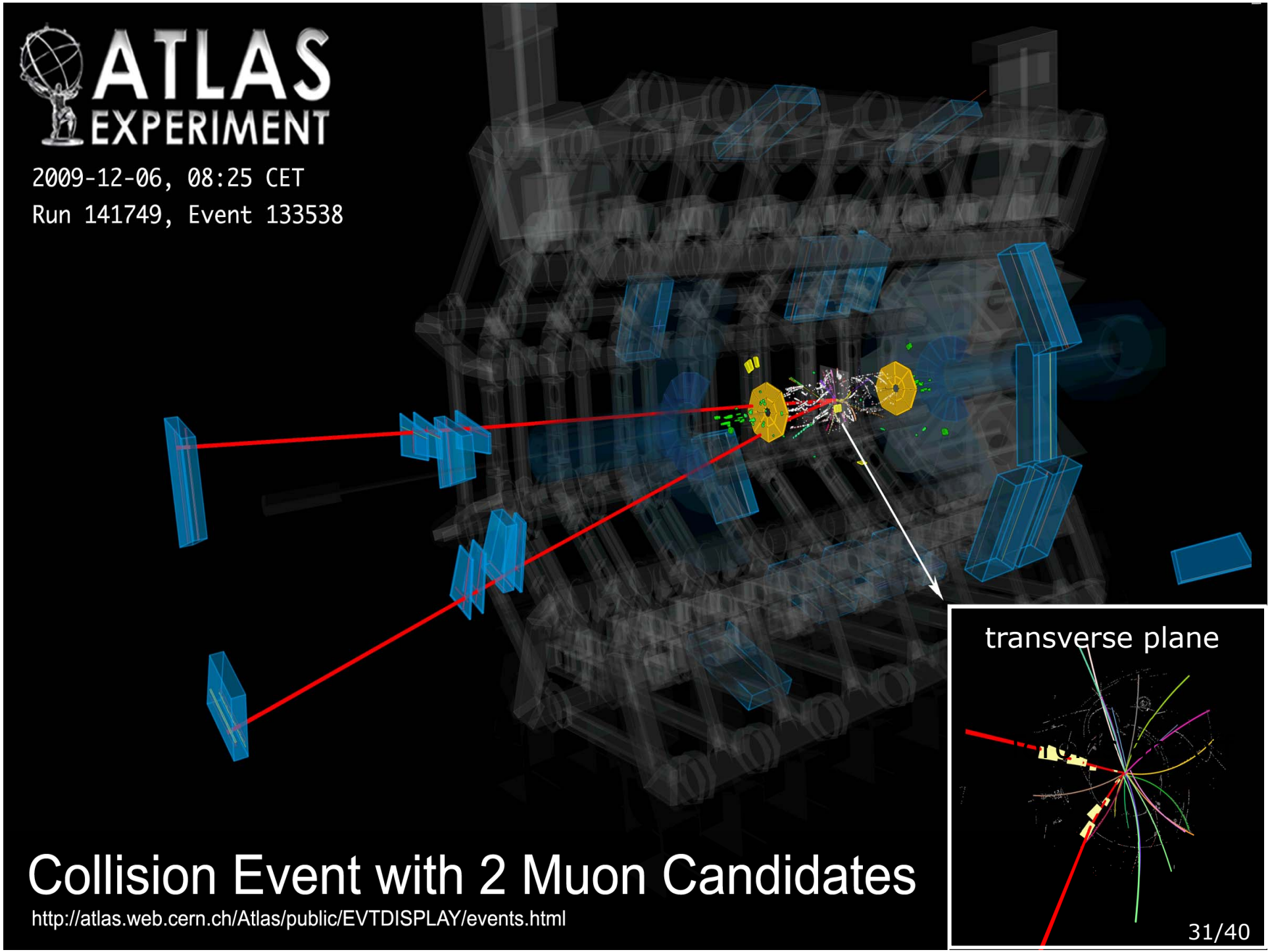
Level 2 plots from events with:

- L1 muon trigger
- offline muon (P_T > 2 GeV, P > 4 GeV)
- $N_{silicon}$ ≥ 6, match L1 ROI in dR<0.5

P_T track: EF versus offline

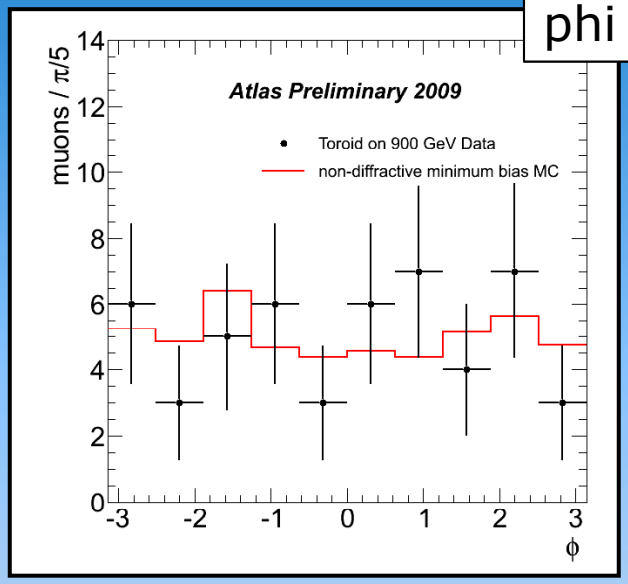


Muon trigger

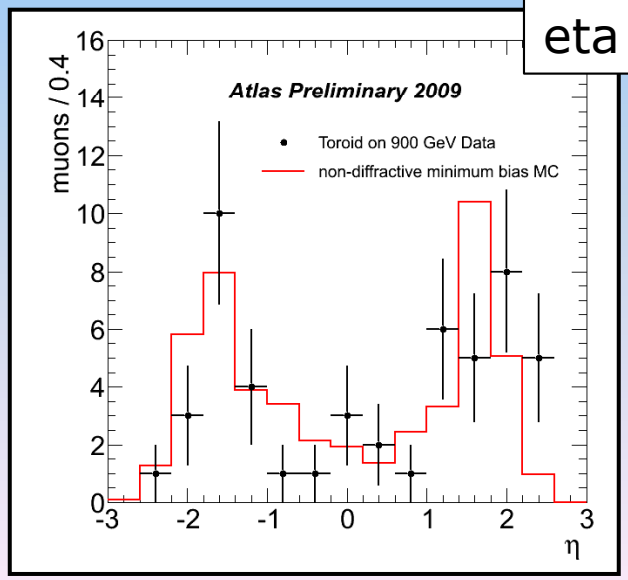

ATLAS
EXPERIMENT
2009-12-06, 08:25 CET
Run 141749, Event 133538
transverse plane
Collision Event with 2 Muon Candidates
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html
31/40

Muons in √s=900 GeV data

phi



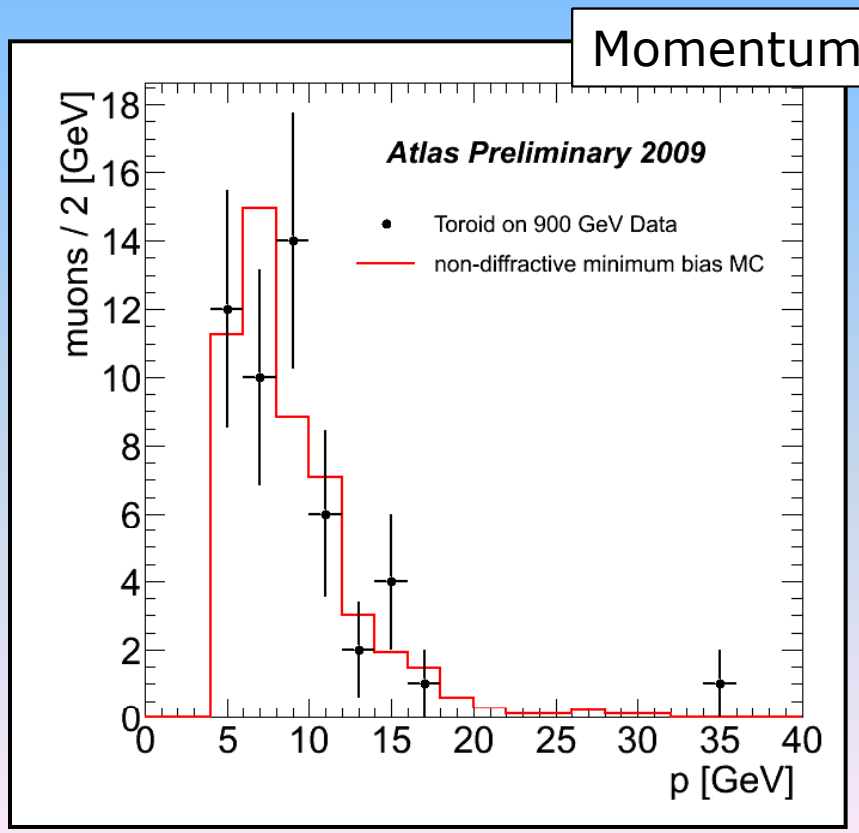
eta



$\mathcal{L} = 6\ \mu\mathrm{b}^{-1}$

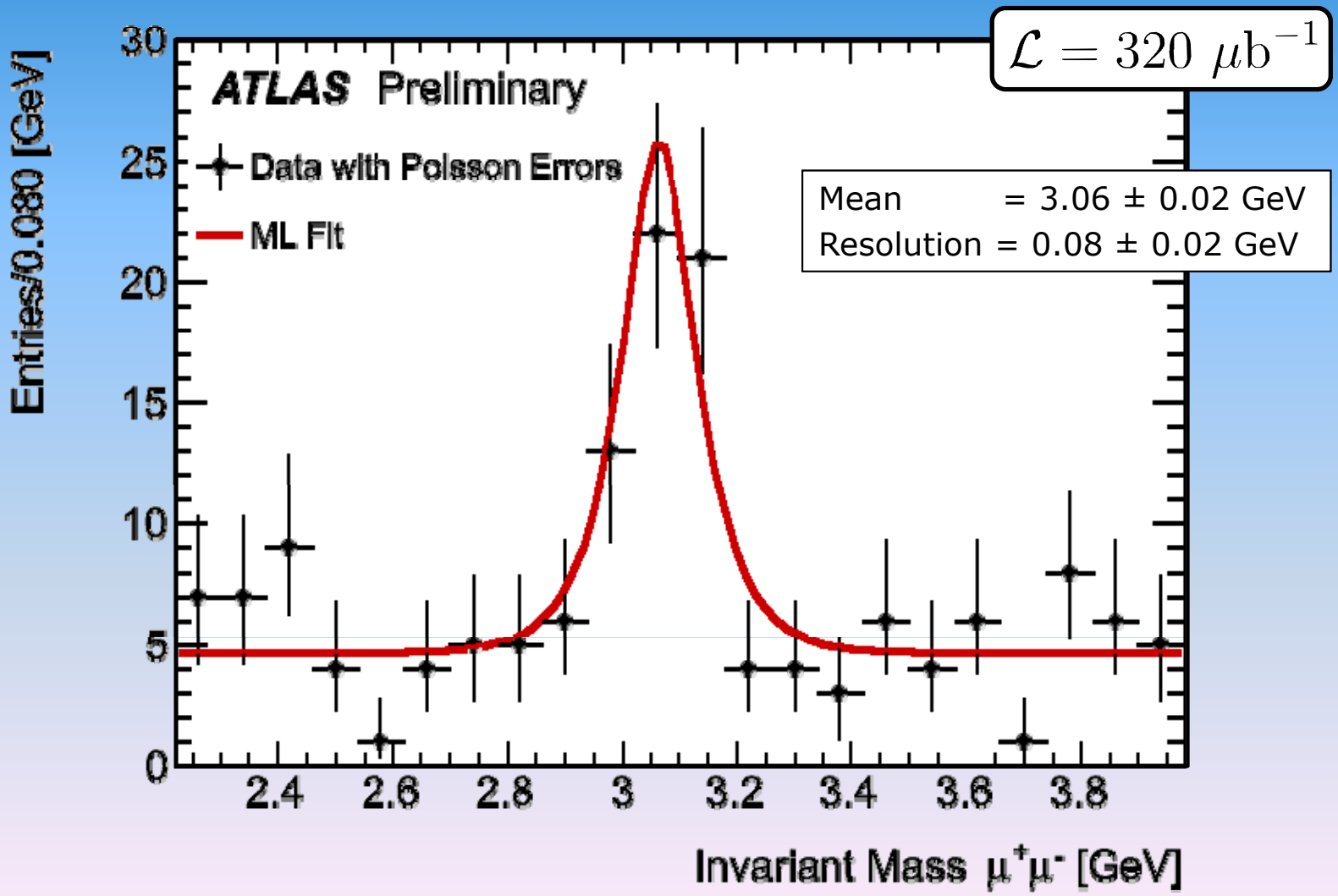
Monte Carlo expectation:
Mainly π/K decays (~25% b/c decays)

Momentum



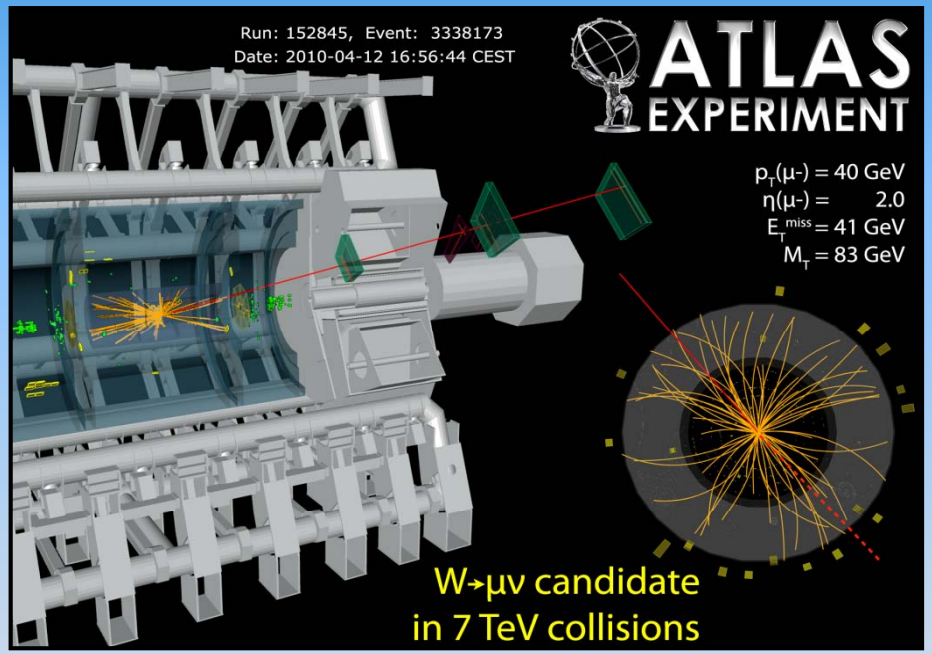
Muons in √s=7 TeV data

J/Ψ peak in di-muon mass (opposite charge with p>3 GeV)



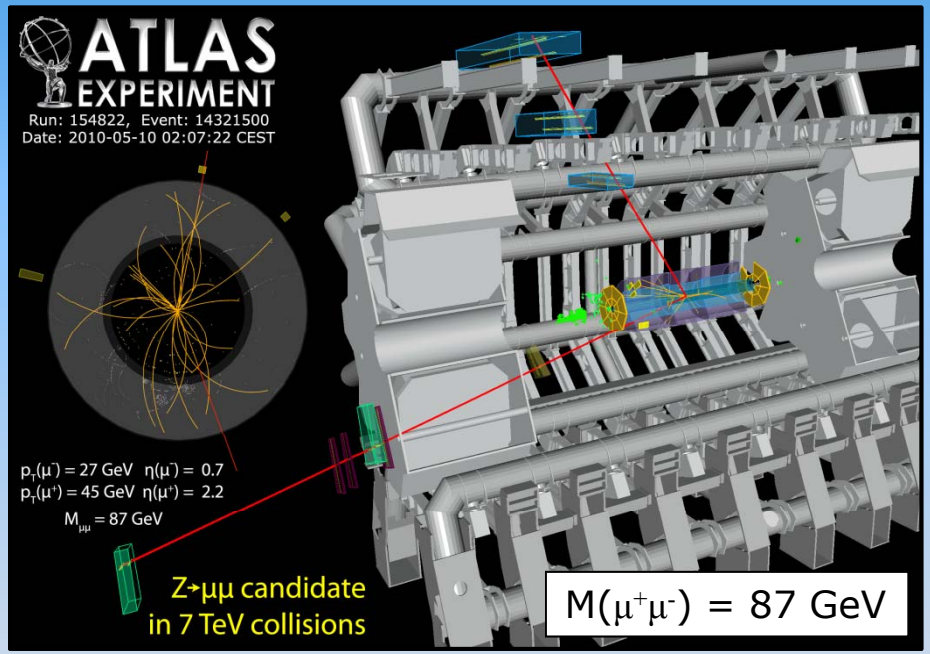
Muons in W- and Z-boson candidates in 7 TeV data

W→μν candidate

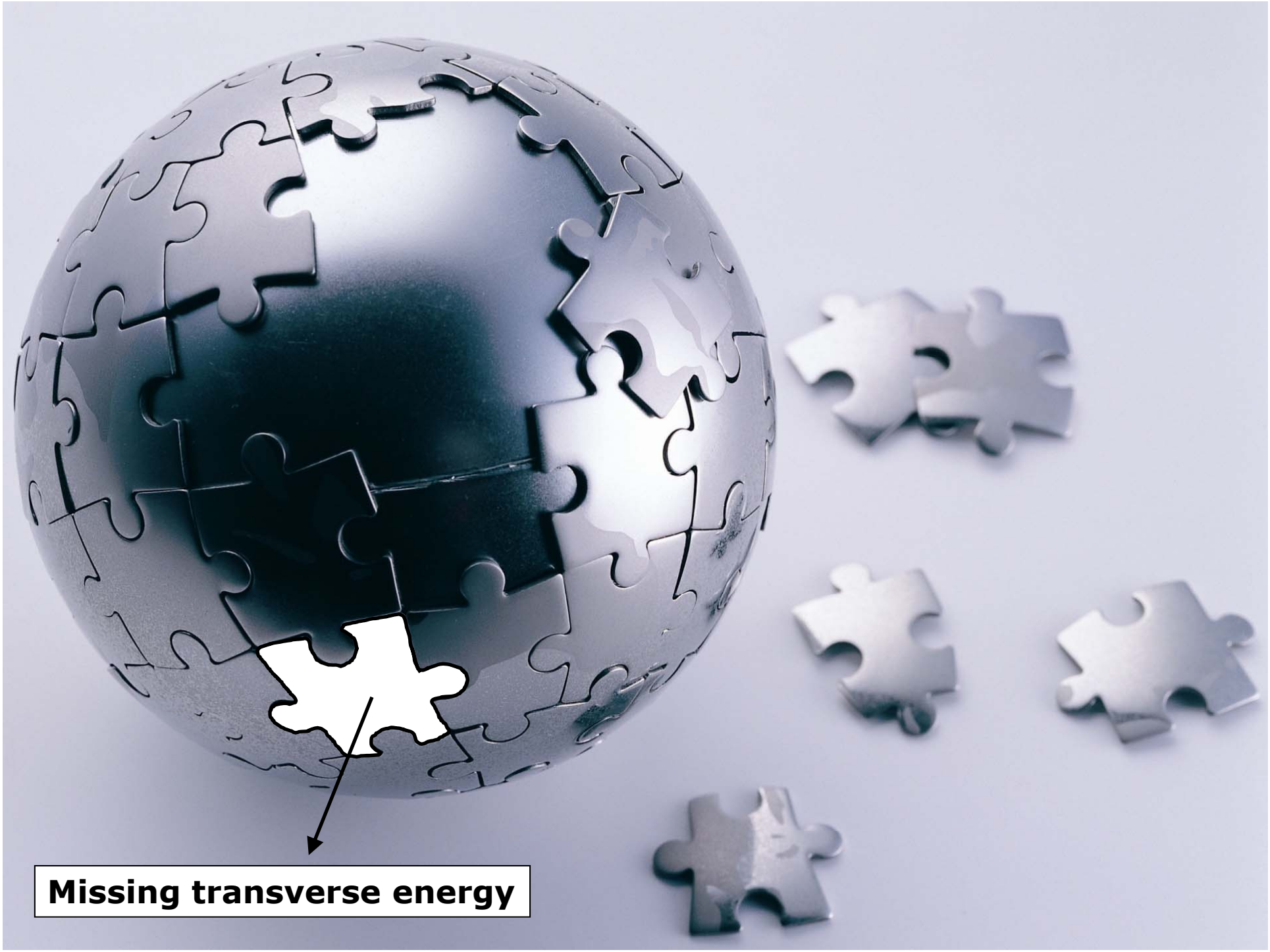


$$
\begin{aligned}
P_T(\mu^-) &= 40 \text{ GeV} \\
\eta(\mu^-) &= 2.0 \\
E_T^{\text{miss}} &= 41 \text{ GeV} \\
M_T &= 83 \text{ GeV}
\end{aligned}
$$

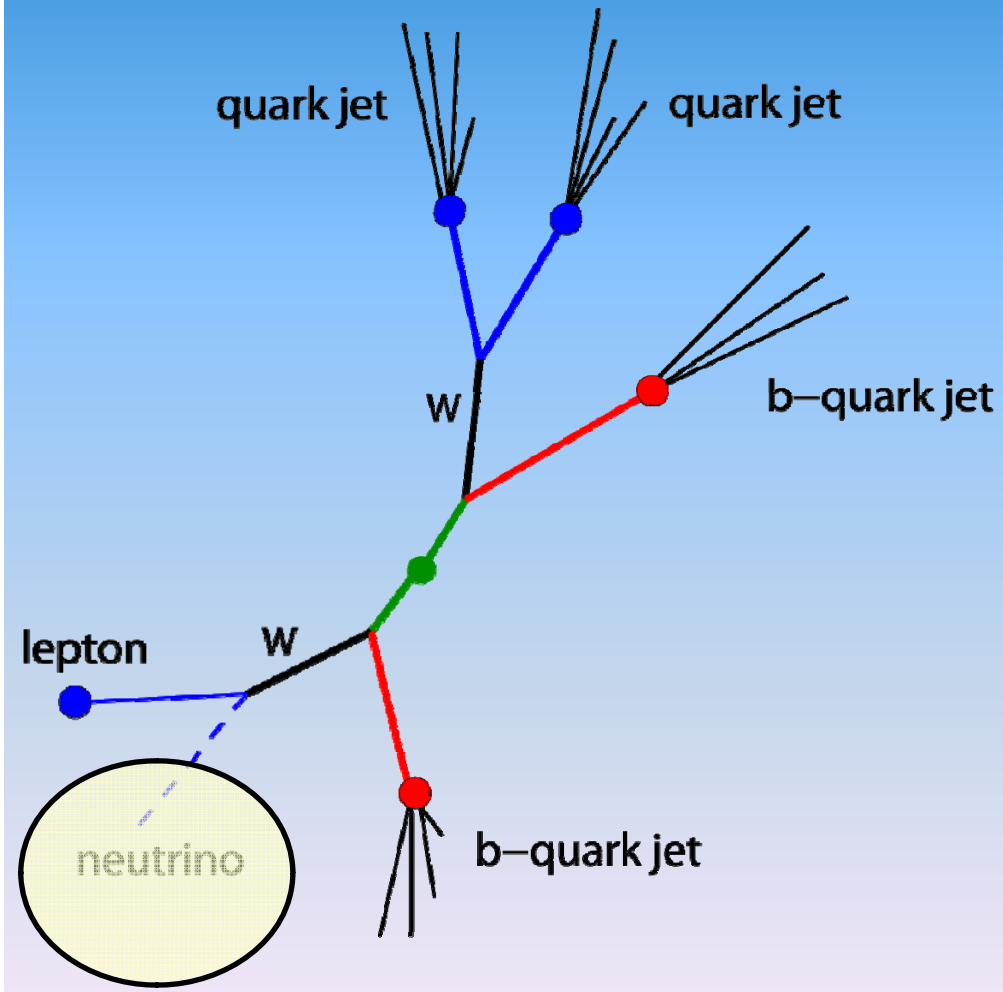
Z→μμ candidate



$$
\begin{aligned}
P_T(\mu^+) &= 45 \text{ GeV} \\
\eta(\mu^+) &= 2.2 \\
P_T(\mu^-) &= 27 \text{ GeV} \\
\eta(\mu^-) &= 0.7
\end{aligned}
$$


Missing transverse energy

E_T-miss in top analyses



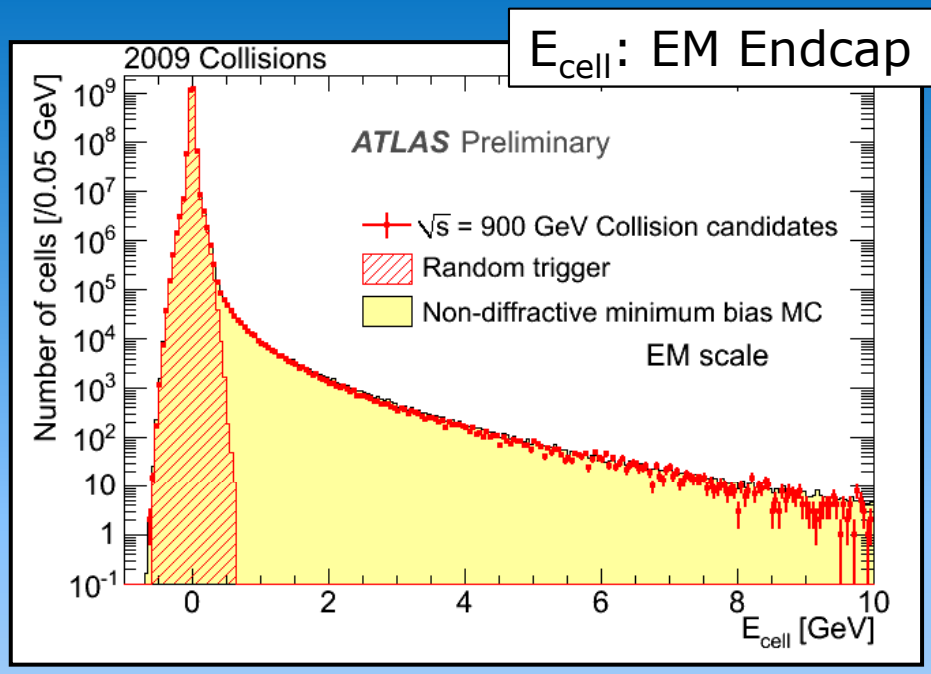
E_T-miss in top analyses

- reduce QCD multi-jet bckg.
  E_T>20 GeV: ε(tt) ~ 90%
  QCD rejec. ~ 10
- handle on leptonic W-boson
- tails important for new physics

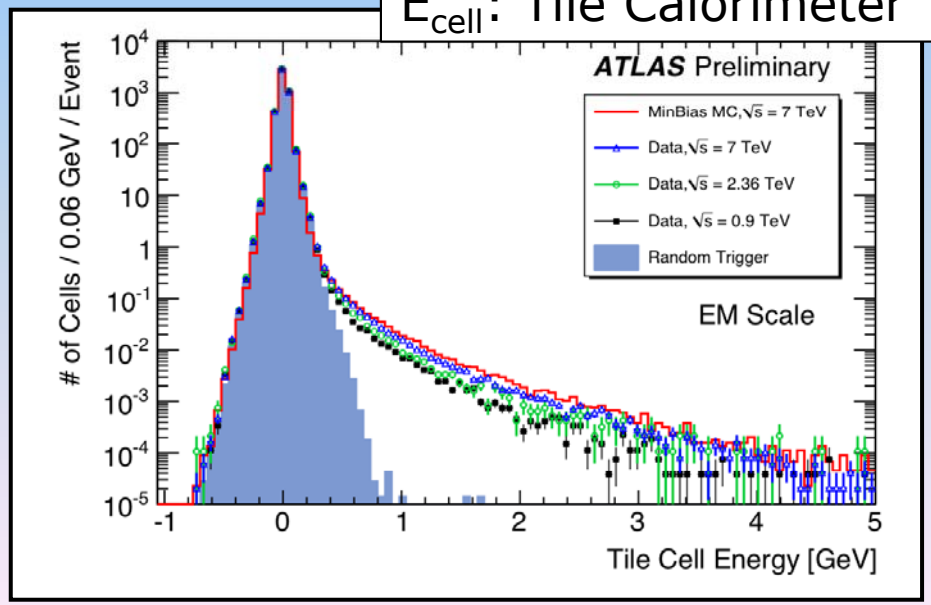
Complications:
- multi-jet topology (2 b-jets)
- high-p_T muons

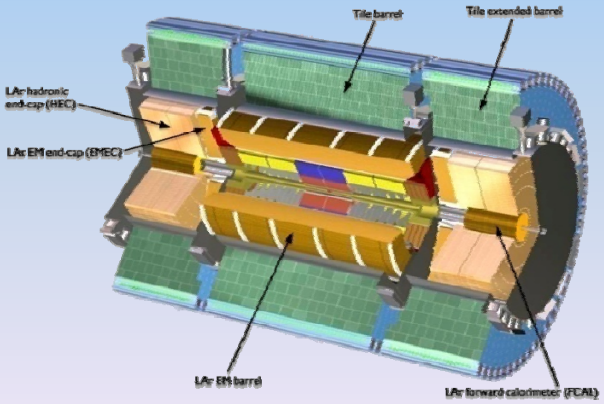
Calorimeter response

E_T-miss= Calorimeter (+cryo+muons)



Electromagnetic calorimeter

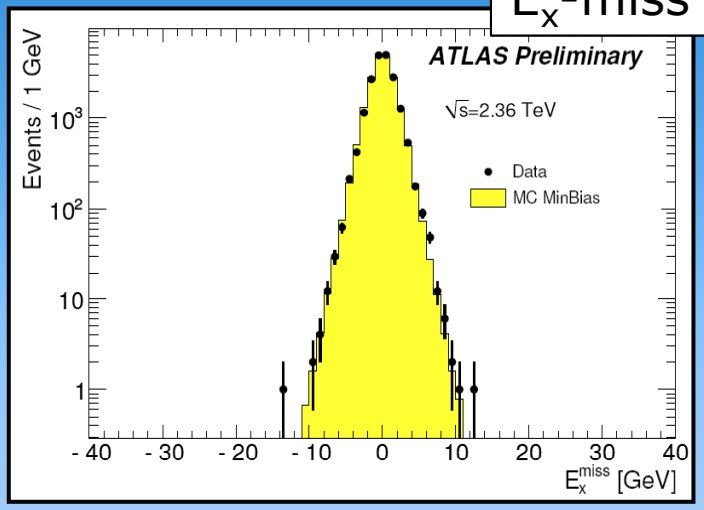




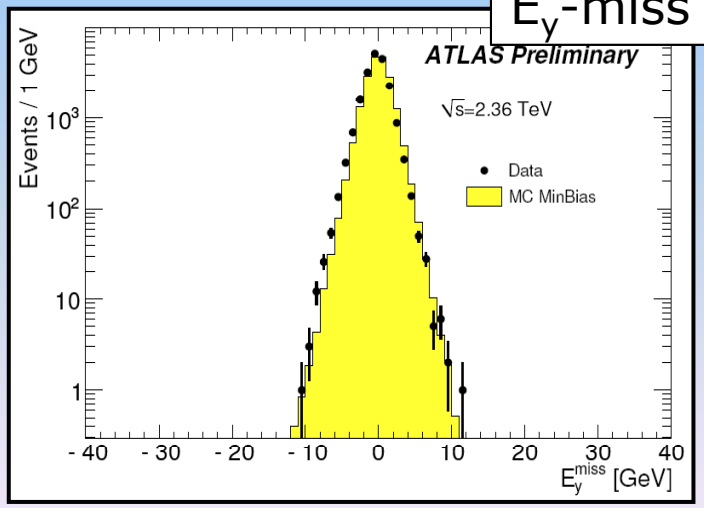
Hadronic calorimeter

Missing transverse energy and resolution

E_x-miss



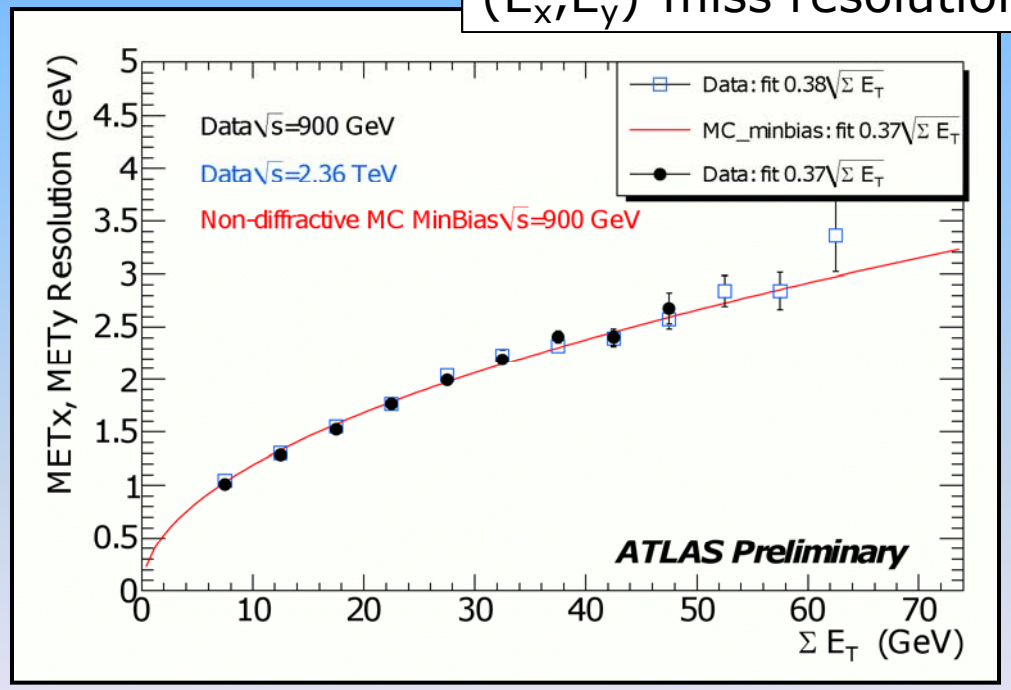
E_y-miss



RMS ~ 1.8 GeV

Minimum bias events at 900 GeV and 2.36 TeV

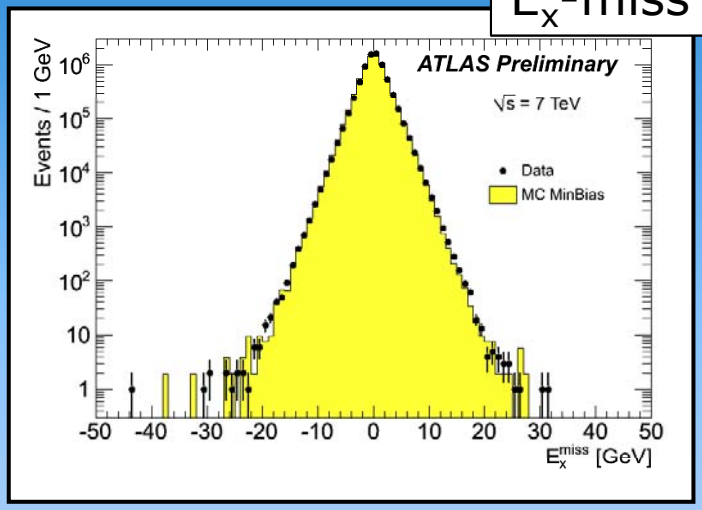
(E_x,E_y)-miss resolution



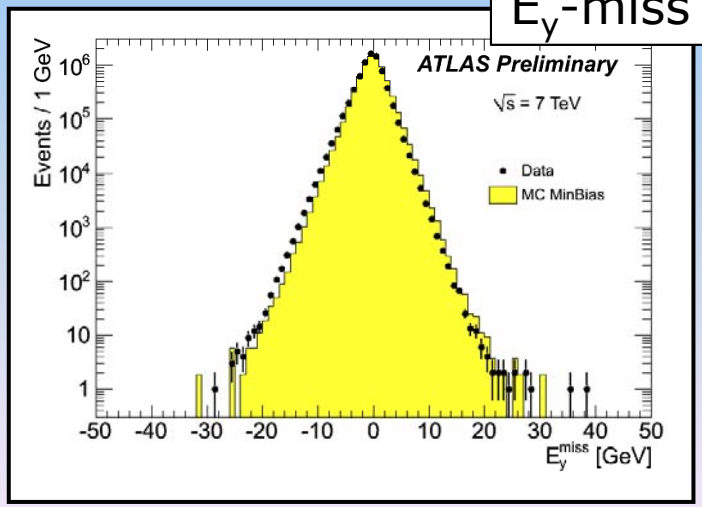
$$\text{resolution (fit)}: = 0.37\sqrt{\Sigma E_T}$$

Missing transverse energy: 7 TeV data

E_x-miss



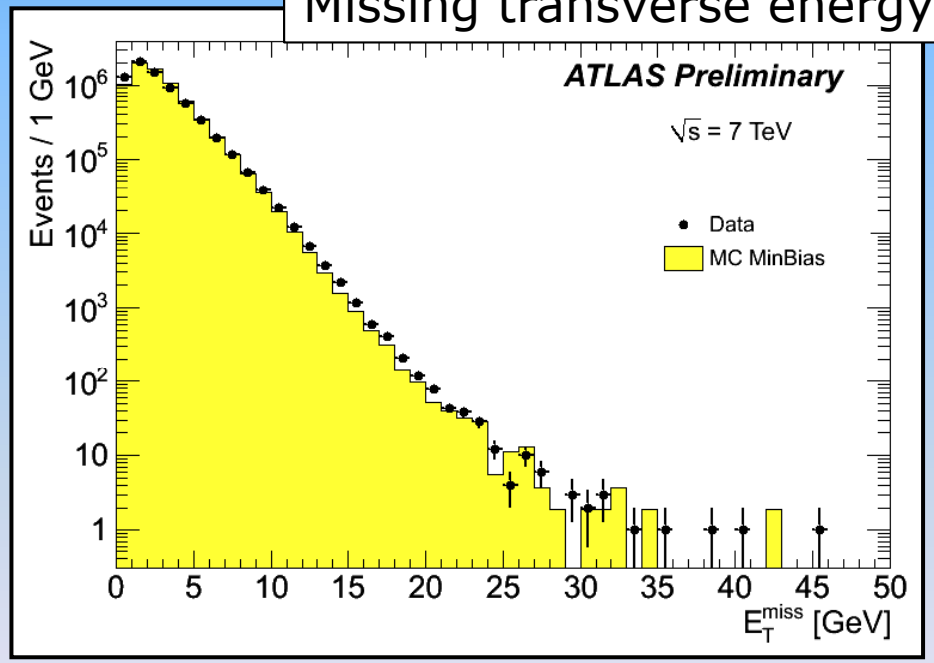
E_y-miss



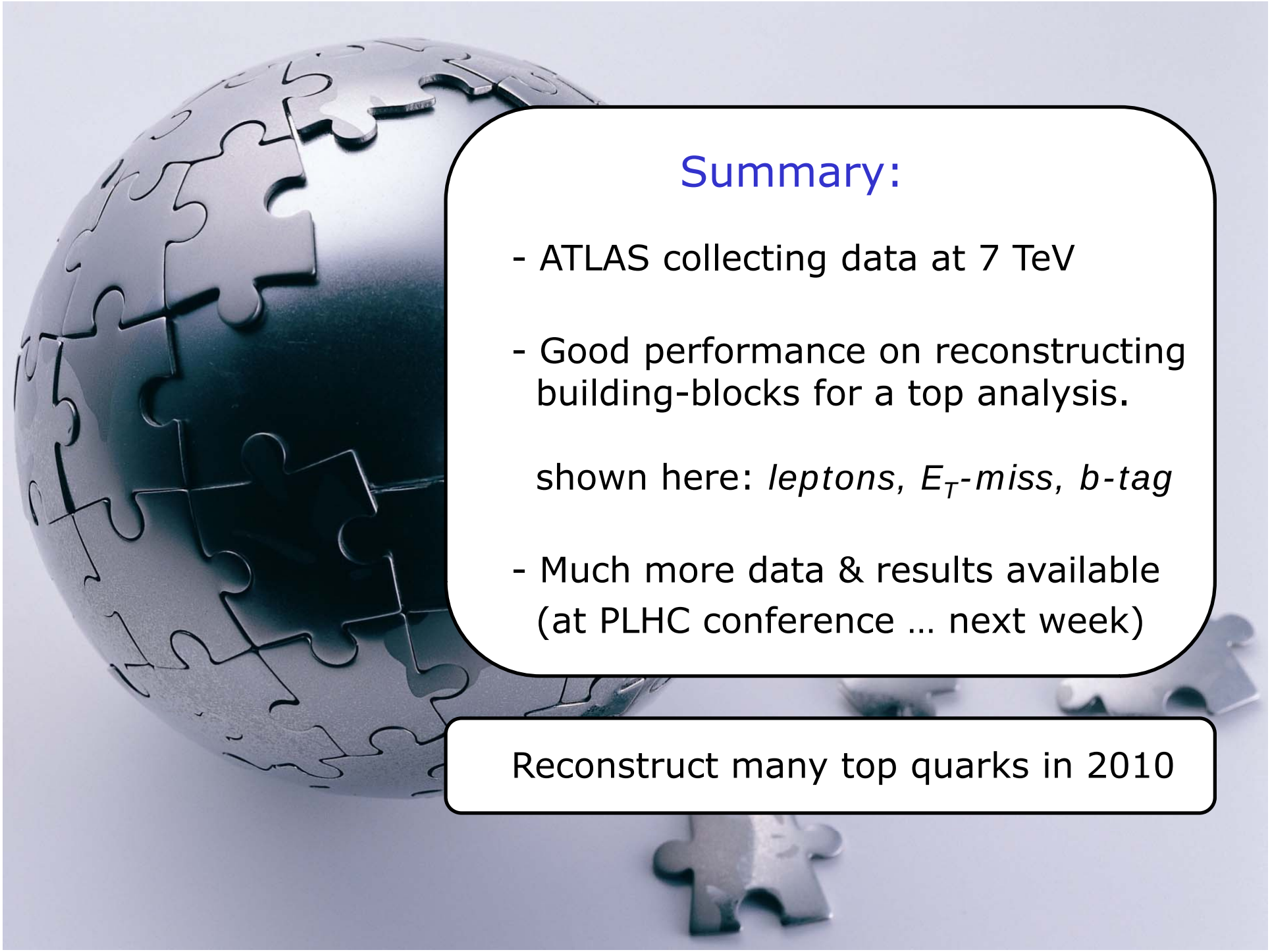
Collision data at √s = 7 TeV

$\mathcal{L} = 110\ \mu\mathrm{b}^{-1}$

Missing transverse energy



Note: - tails under control
- cells from topo-clusters (EM-scale)



Summary:

- ATLAS collecting data at 7 TeV

- Good performance on reconstructing building-blocks for a top analysis.

  shown here: *leptons*, E_T*-miss*, *b-tag*

- Much more data & results available (at PLHC conference … next week)

Reconstruct many top quarks in 2010

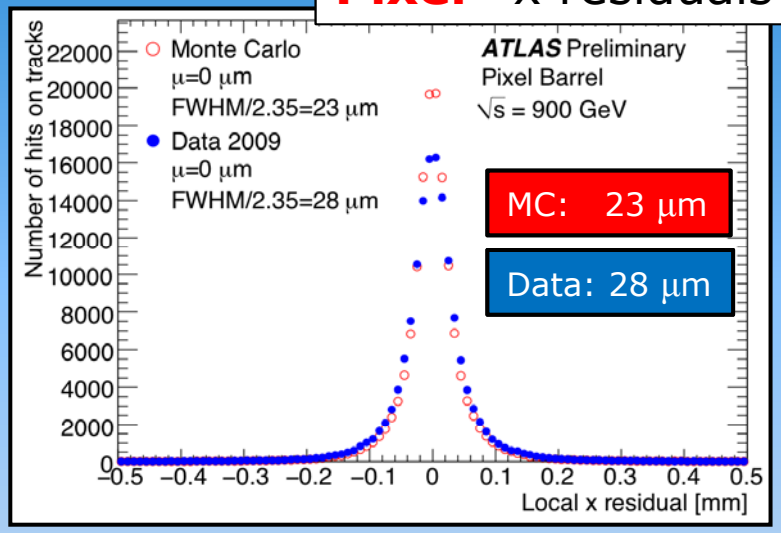
Backup slides

Alignment tracking detectors

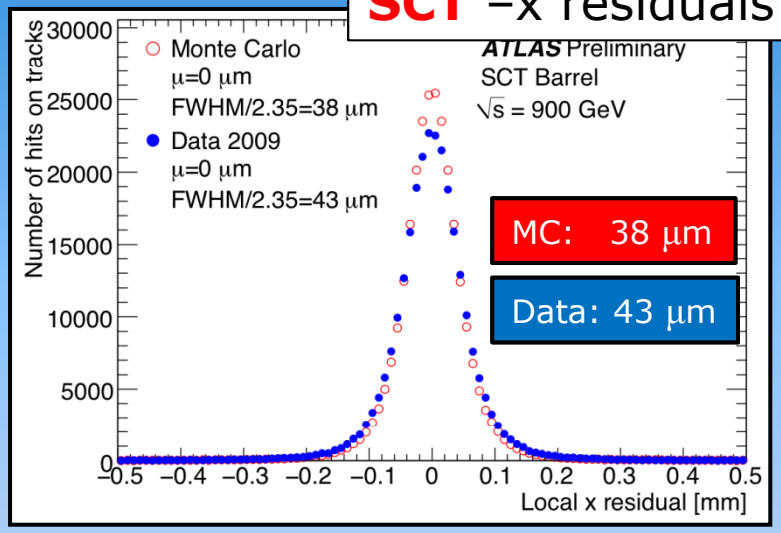
Tracks with: $P_T > 2$ GeV, $N_{silicon} \geq 6$, $|d_0| < 10$ mm

Barrel

Pixel –x residuals

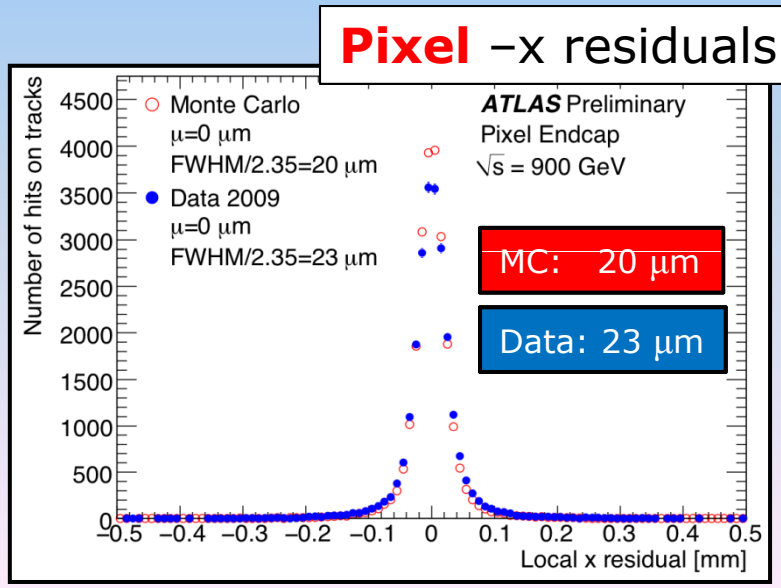


SCT –x residuals

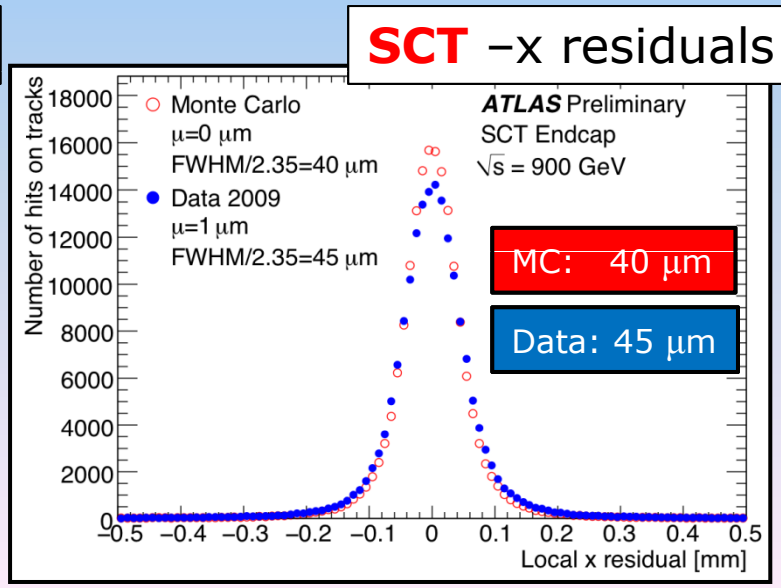


Endcap

Pixel –x residuals

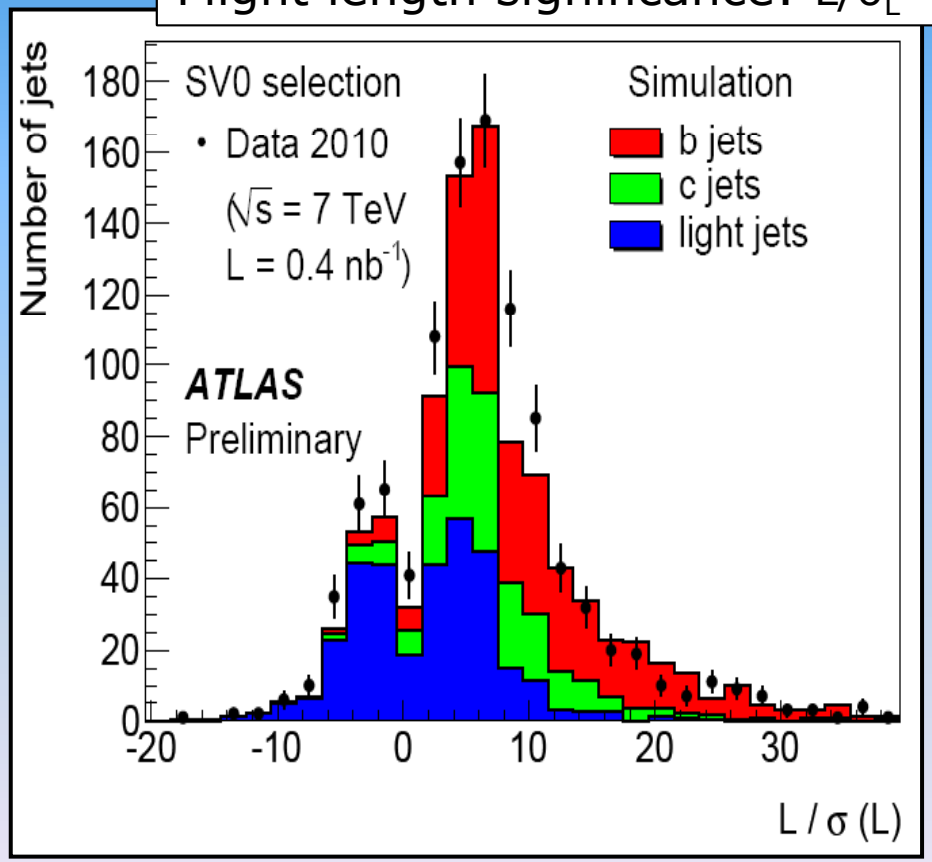


SCT –x residuals



B-tag distributions in √s=7 TeV data

Flight length significance: L/σ_L



Jet probabillity