Top Event Search with the early data in ATLAS

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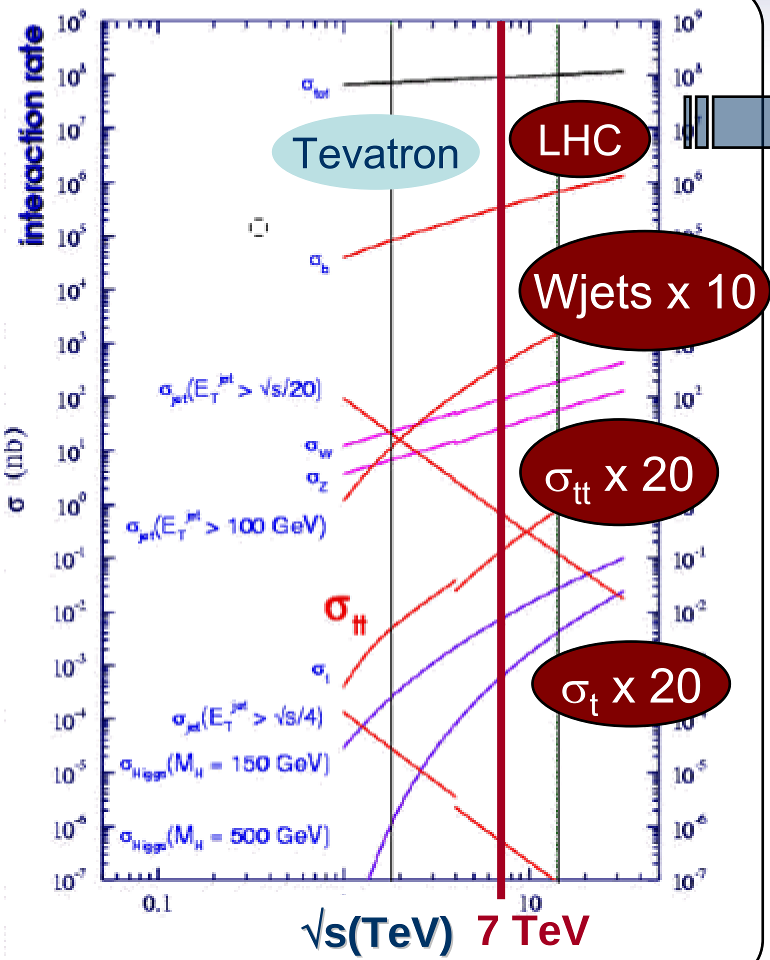
1. Context & Top quark search strategy with the early data
2. Towards the reconstruction of top quark decays
3. First Top event candidates

Top Physics with the early LHC data …



Expectations with 280 nb^{-1}

Assuming 100% efficiency, we expect

Lepton+jets:

~14 in l+jets with l=e,μ

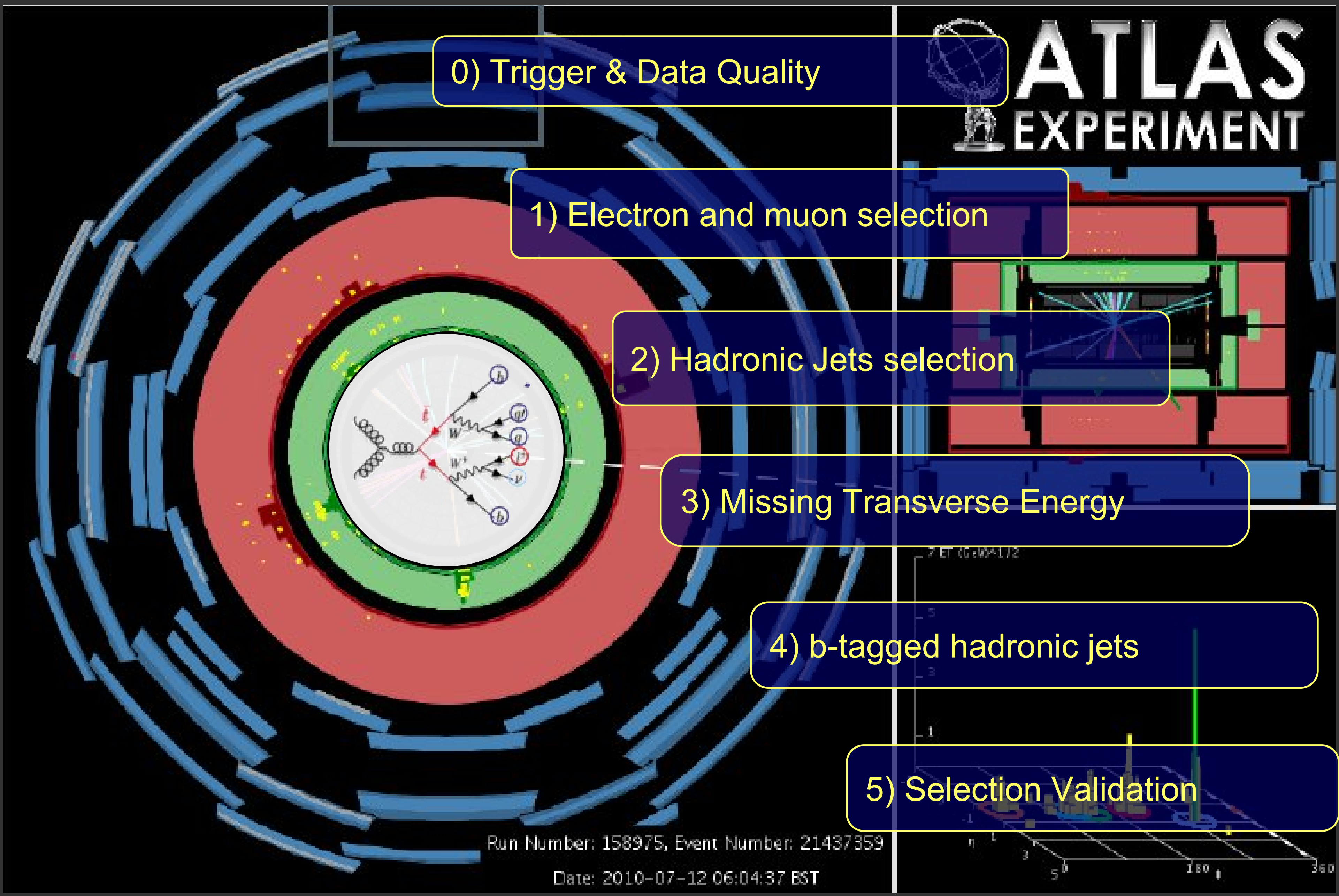
Di-lepton :

~2 events in (ee,$\mu\mu$,eμ)

Strategy with the early data…

- Validate/Calibrate Object reconstruction
  - Quality, Trigger, Reconstruction, Calibration
  - Validate MonteCarlo descriptions
- Understand QCD & W/Z+jets background
  - Determine/Monitor multi-jet events
  - Measure W+(HF)jets background
  - Data Driven vs Simulation
- Select final state for top candidates
  - Define/ validate loose selections
  - Constitute control sample for bkgd and signal
  - Optimize selection for specific measurements

Strategy for top quark search…



0) Trigger & Data Quality

1) Electron and muon selection

2) Hadronic Jets selection

3) Missing Transverse Energy

4) b-tagged hadronic jets

5) Selection Validation

1a) Electron

See S. Snyder's talk

Electron Sources

W/Z boson electron : W(Z) → e(e)
Heavy flavour electron : b(→c)→e
Conversion electron : γ →ee
Fake from charged hadron : h→ e

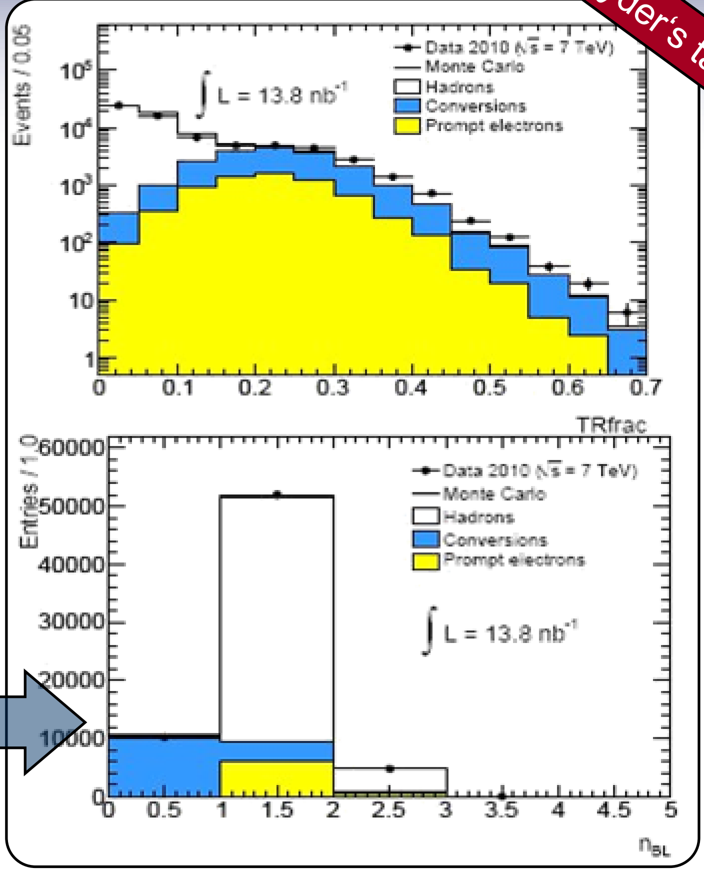
Electron Identification Tools

« Medium electron»

– Strip layer information --against π^0's
fraction of energy, shower lateral size,
– Cluster-Track Matching : $\Delta\eta<0.1$
– Track Quality
hits in pixel, pixel+SCT,d0,fiducial B-layer

«Tight electron»

– Hadronic Leakage
ratio of E_T^{HAD}/E_T^{EM} in 1st (all) Had sampling
– Middle layer (Max. shower)
ratio in η of cell energies in 3x7 vs 7x7
– Cluster-Track Matching : *Ratio E/p (vs hadron)*
– B-layer hit (vs conversion)
– Transition Radiation Tracker
nb of hits, ratio of High/Low threshold (vs π's)



Validation of ID tools

Using data driven techniques
→ Derive components using Matrix Method

1b) Electron

Electron in W and Z selection

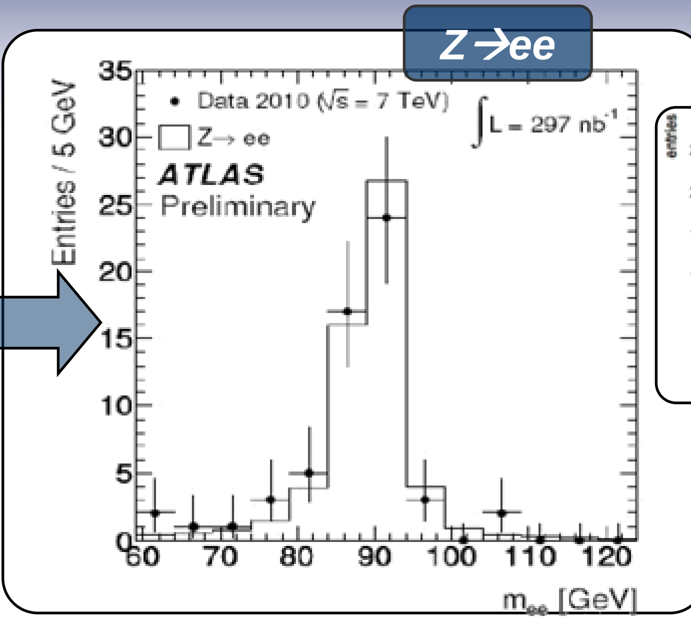
Trigger efficiency of 99.8±0.2% in data

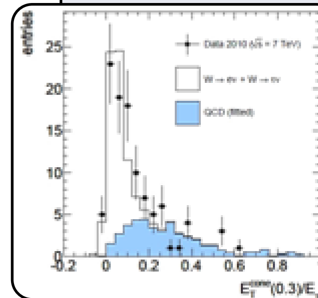
Select electron with p_T>20 GeV

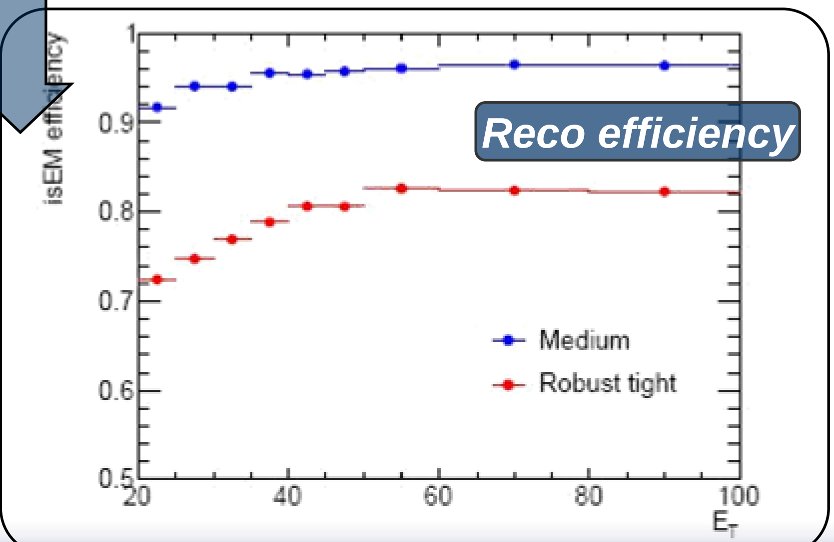
- $|\eta|$ < *2.47 excluding Barrel-EC region*
- *Medium or Tight quality*
- *Isolated electron (calorimeter based)*

Measure relative efficiency in data/MC

- Ratio Loose/Medium and Medium/Tight
- Validate variable description one by one
- → Agreement at the level of 3% (tight)







Energy scale and resolution

Energy scale & resolution dominated by EM

- Uncertainty (abs) is ±3% from TB,$\pi^0 \to \gamma\gamma$

Next: Trigger/Reco efficiency from data

- Via resonnances Z→ee, J/ψ,Υ→ee
- *Tag* e : *tight isolated electron*
- *Probe* : *looser candidate*
  - $|M_{ee}-M_Z|$< *10 GeV*

1c) Muon

Muon Identification

Two main sub-systems:

Muon Spectrometer

Inner Detectors: pixel/SCT **($|\eta|<2.5$)**,TRT **($|\eta|<2$)**

→*Form « Combined Muon » by χ^2 matching*

[chain1] Refit of the ID+MS track

[chain2] Stat. combination of MS & ID meas.

Efficiency in MonteCarlo

99% of W→μ are « combined muons »

MS adds 0.6% and calo-tag muon 0.4%

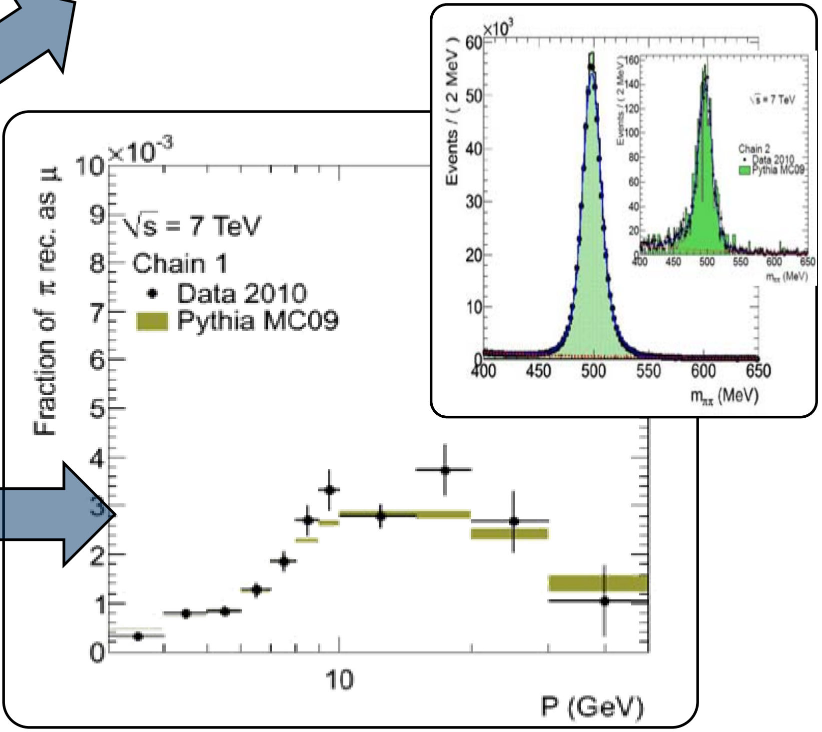
Measurement of relative efficiency at the dca

Use *ID+calorimeter tagged* muon

→ Measure relative efficiencies in data / MC

→ *Validation of MC at the ~3% level*

Muon Identification relative efficiency		
$p_T(\mu)\geq 6$ GeV	DATA ε_{ID}	MC ε_{ID}
Chain 1	**(94.0±2.0)%**	**(96.8±0.3)%**
Chain 2	**(98.7±0.9)%**	**(97.4±0.2)%**



Muon Fake Estimate

Main sources of non-prompt muon

π/K decays & punch through

Use extra cut on MS p_T and Δp_T(ID-MS)<15 GeV

Constraint π/K rate from data using $K^0_S \rightarrow \pi^+\pi^-$

Select vertex and count tracks seen as μ

1d) Muon

Muon in W and Z selection

Trigger efficiency of ~99.7% in data

Select muon with p_T>20 GeV

Combined muon

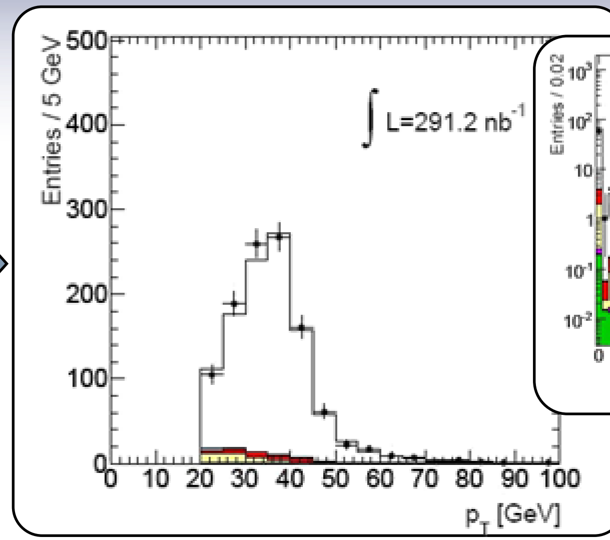
$|\eta|$ < 2.4

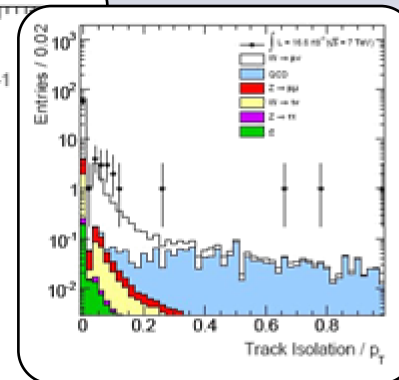
Isolated muon (ΣpT in R=0.3 cone)

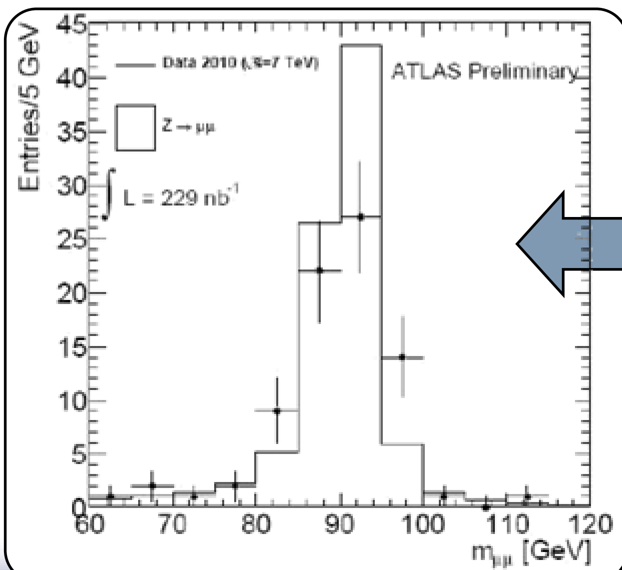
$|p_T^{ID}-p_T^{MS}|$< 15 GeV

Measure relative efficiency in data/MC

Validate variable description







High p_T Muon scale and resolution

Select $p_T(\mu)$> 20 GeV/c

Momentum scale known at a level <2%

Momentum resolution

Known at 5% (Barrel) and 8.5%(EC)

Next: Trigger/Reco efficiency from data

Tag & Probe using Z→$\mu\mu$, J/ψ,Υ→$\mu\mu$

Tag : « tight » isolated muon

Probe: « medium » muon

2) Jet Reconstruction and calibration

See A. Schwartzman's talk

Jet Reconstruction

Anti-KT algorithm with radius of 0.4-0.6

Start from cells regrouped in 3D clusters

Jet Calibration from MC

Several calibration schemes tested vs data

– JES+EM scale (EM+JES)

Corrections from MC truth as $f(p_T^{EM})$

– Global Sequential (GS)

Add jet-by-jet information (shower shape)

– Global Cell energy-density Weighting (GCW)

use cell weights based on energy density distribution wrt MC

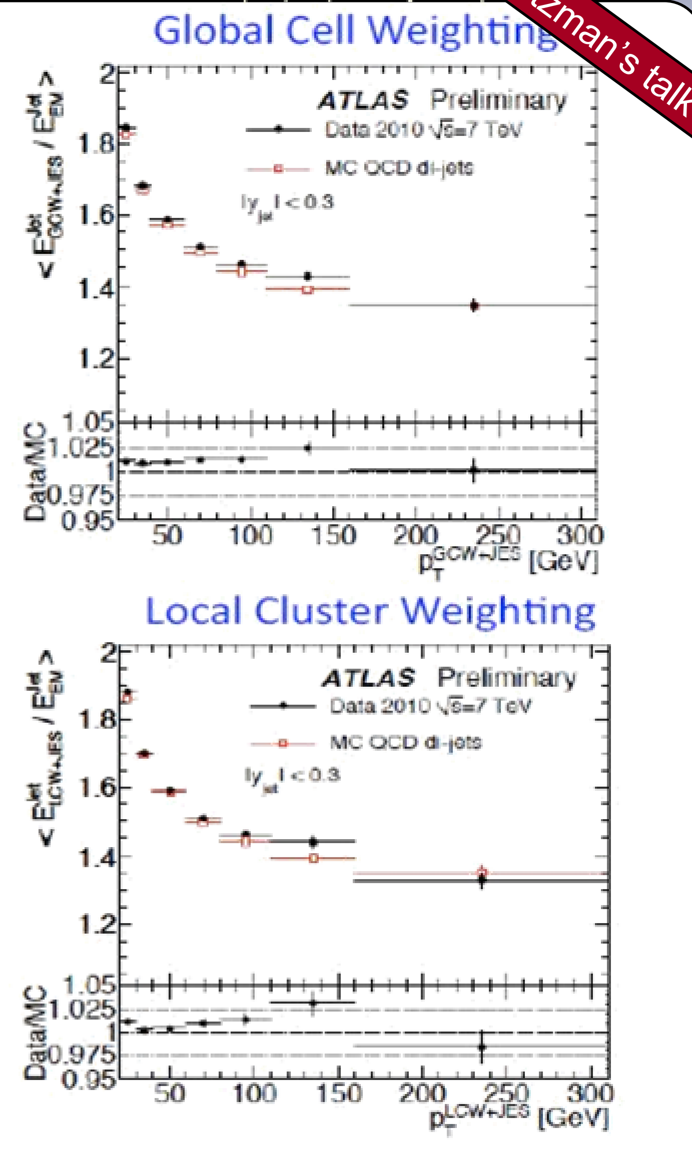
– Local Cluster Weighting (LCW)

use topo-cluster properties for an individual calibration derived from MC of single π's

Performance

Same average corrections over uncalibrated jets

Agreement between data and MC at the ~2%



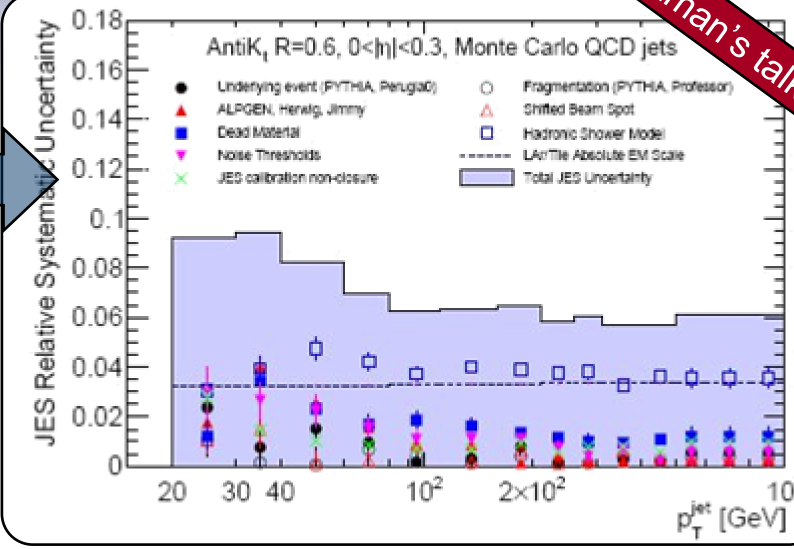
2) Jet Energy Scale and Resolution

See A. Schwartzman's talk

Jet Energy Scale Uncertainty

Dominant sources of systematic uncertainties

- Dead material (5%)
- Hadronic shower model (5%)
- Electronic Noise (3%)
- LAr/Tile absolute EM scale (3%)
  - 9.4% (10%) for p_T^{jet}<60 GeV Barrel (EC)
  - 7.0% (7.6%) for p_T^{jet}>60 GeV Barrel (EC)



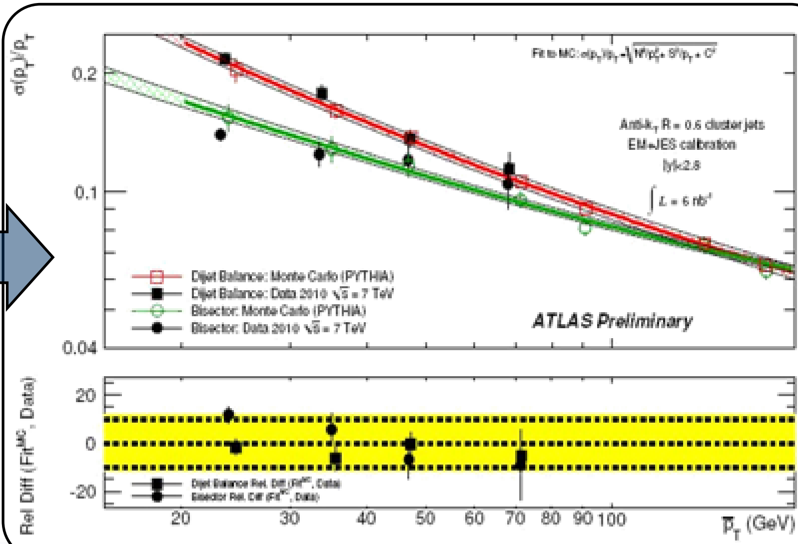
Jet Resolution

Use dijet balance method & Bisector method

- *Select back-to-back jet events*
- *Measure A = (p_T^{probe}-p_T^{ref}/p_T^{avg})*
- Determination of σ_{pT} / $p_T \cong \sqrt{2}\,\sigma_A$
- *MC and data agree within ~14%*
- *for jet of 20< pT <80 GeV*

Systematic Uncertainties

- *Difference of two methods*
- *MC Soft radiation correction (3rd jet)*



3) Missing Transverse Energy

Missing ET Definition

– Defined from cells belonging to topo-clusters and from muon contribution

Missing ET Calibration

– Global cell weighting calibration (cell level) or Local cluster calibration (cells w/in cluster level)

– Refined calibration correction from physics objects:

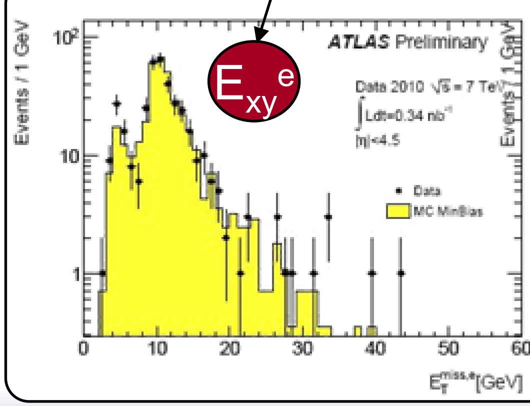
$E_T^{mis,calo,calib}=E_T^{e}+E_T^{\gamma}+E_T^{\tau}+E_T^{jets}+E_T^{calo\mu}+E_T^{cellOut}$

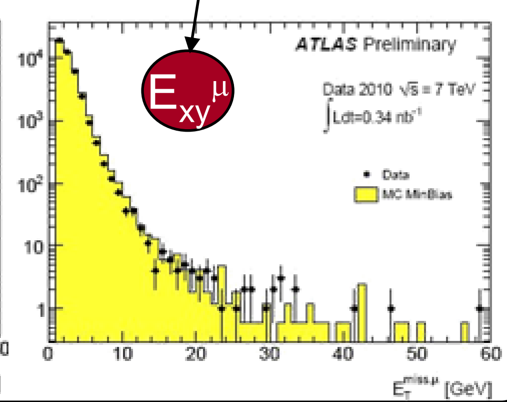
→Calibrated missing E_T is well described by MC

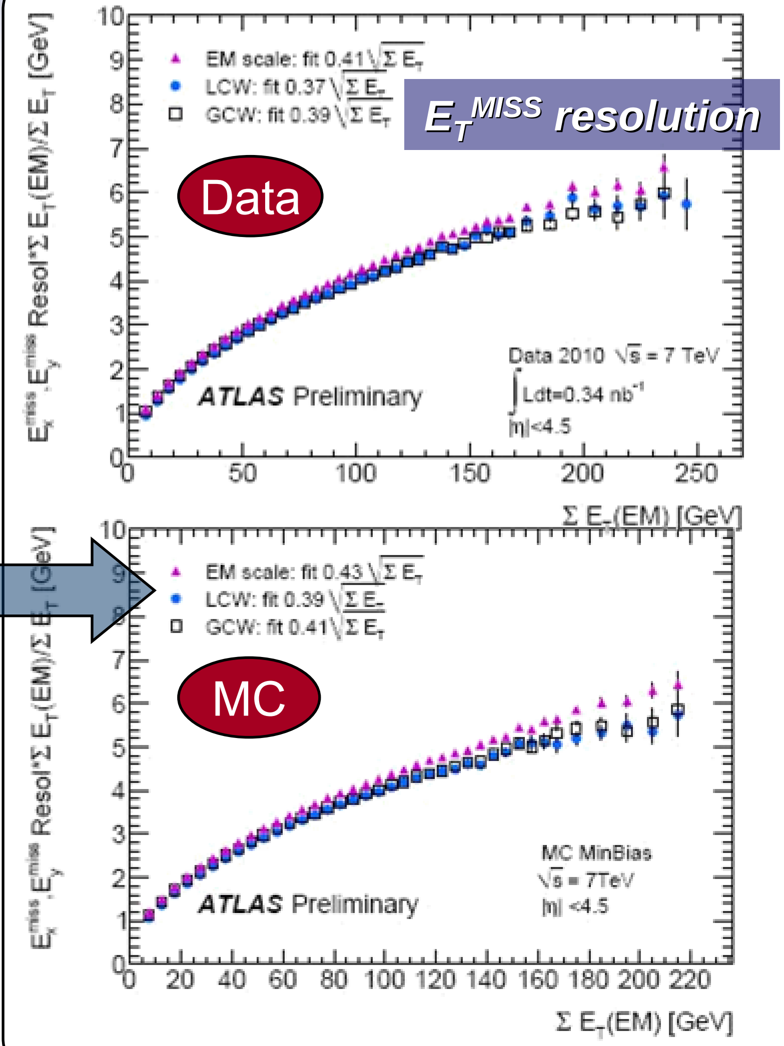
Missing ET Resolution

Overall good agreement / some tails in high jet E_T^{MISS}

Resolution in Data / MC in reasonable agreement







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Resolution in Data / MC in reasonable agreement

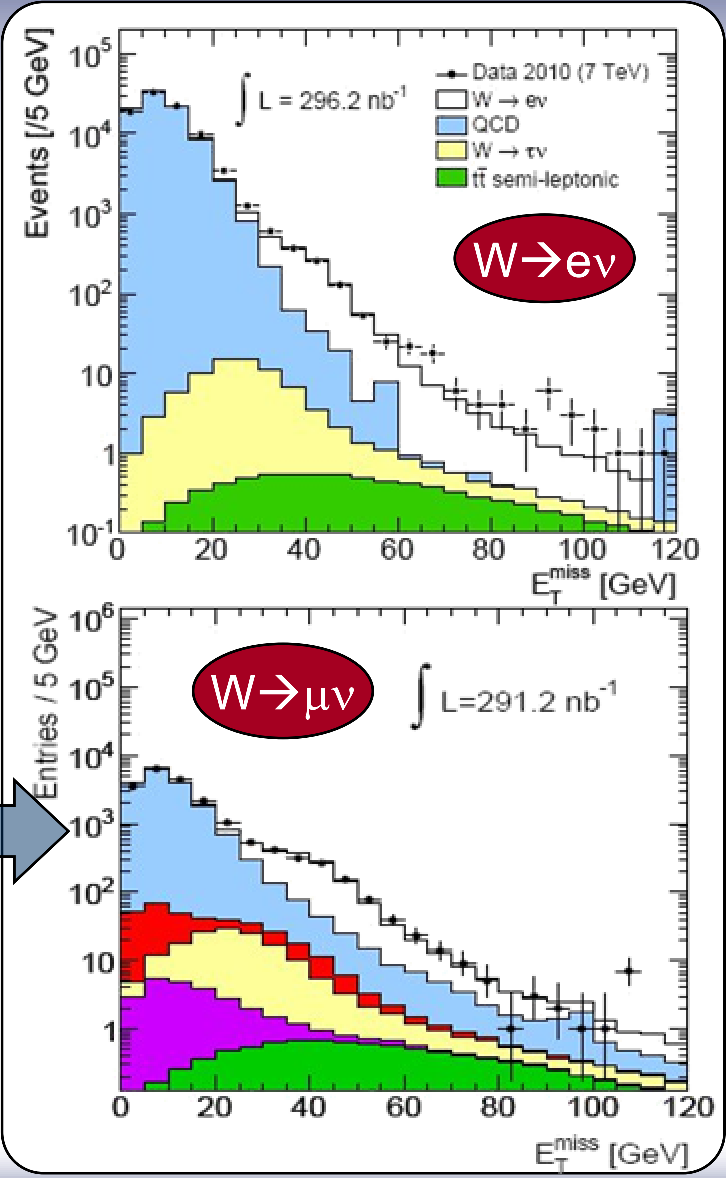
Missing ET in W→lν events

Select events with lepton with p_T>20 GeV

Isolated (remove fake, prompt …)

Extra Missing ET due to presence of neutrino

→E_T^{MISS} Distributions in good agreement with MC



4) Jet Tagging : Impact Parameter Based

See J. Fleckner's talk

Impact parameter based Taggers

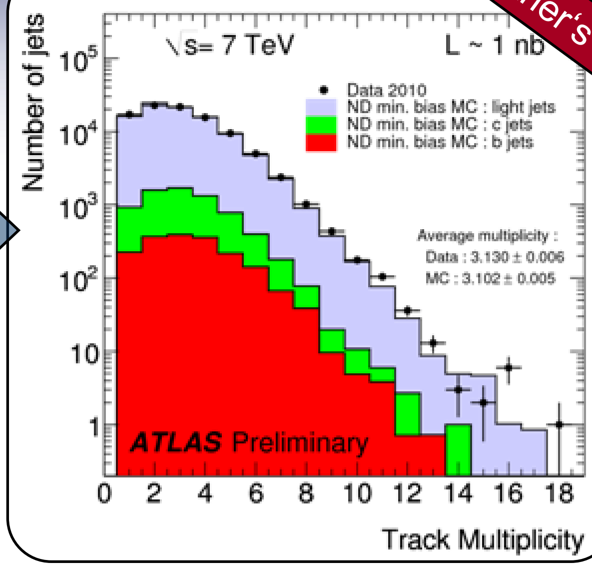
Select quality track in jets

Measure track dca to Primary Vertex

Define significance $S_{d0}=d_0/\sigma_{d0}$

Determine resolution functions

→ Validate MC description



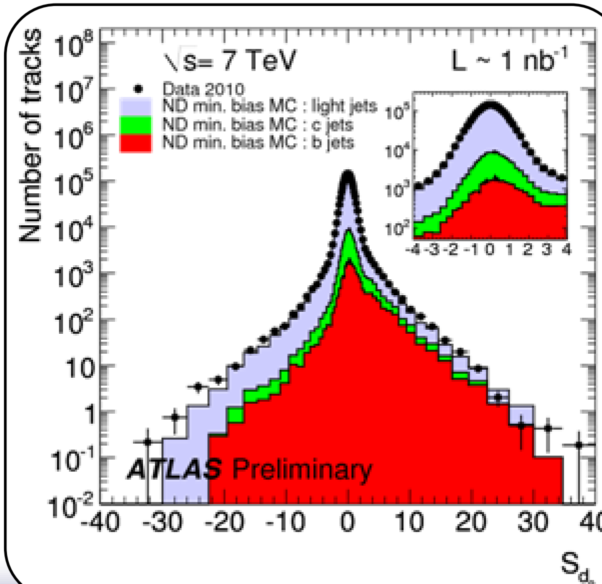
Jet Probability Tagger (Aleph)

- Compute proba. for a track to originate from PV
- Remove V0, conversions, hadron interactions
- Derive Jet Probability to originate from PV:

$$\mathscr{P}_{\text{jet}} = \mathscr{P}_0 \sum_{k=0}^{N-1} \frac{(-ln\mathscr{P}_0)^k}{k!}, \quad \mathscr{P}_0 = \prod_{i=1}^{N} \mathscr{P}_{\text{trk}_i}$$

TrackCounting Tagger

- Require ≥ 2 good tracks w/ S_{d0} > threshold
- Use a 2nd highest S_{d0} track cut to tag
- Good agreement Data/MC vs p_T and η-ranges



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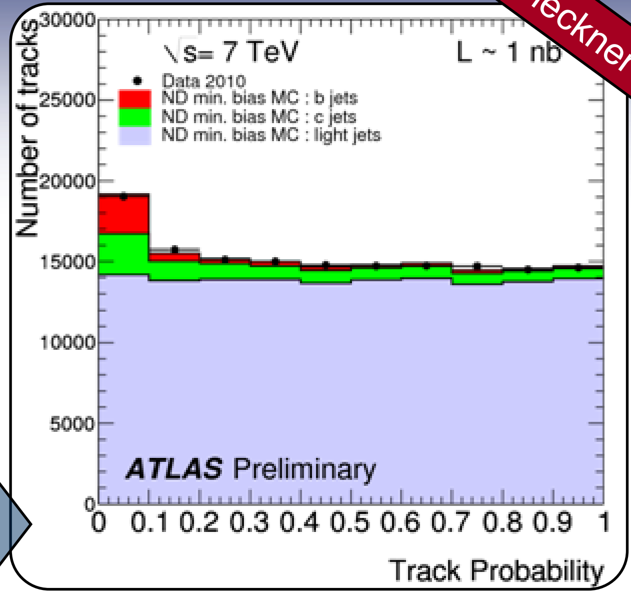

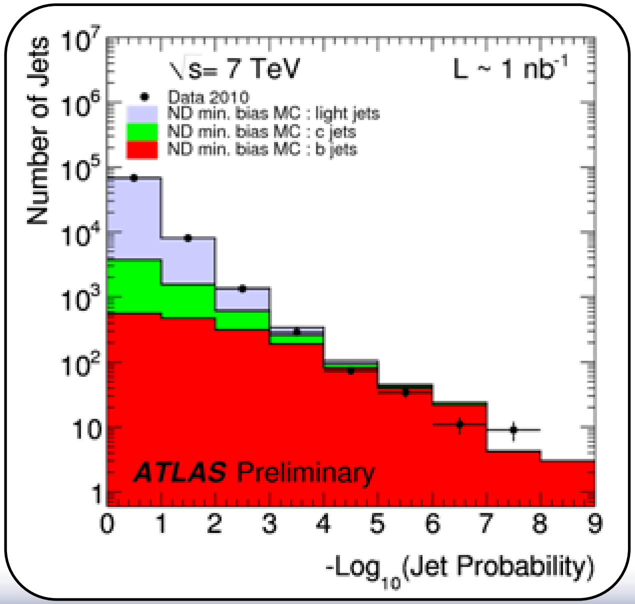

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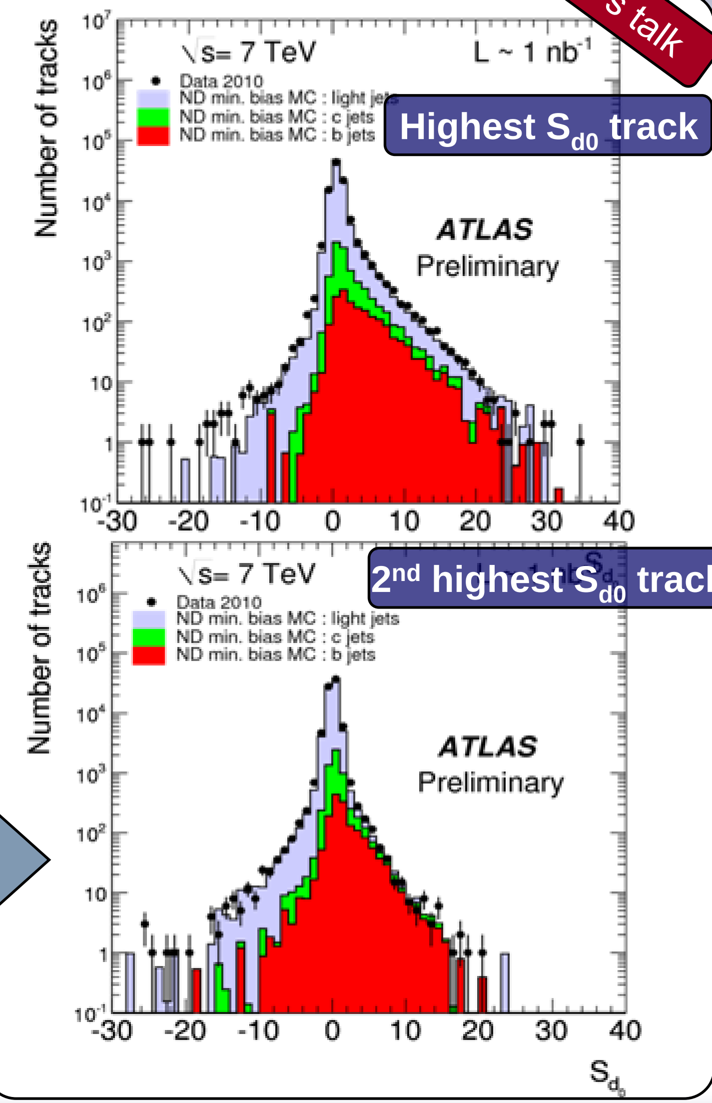


4) Jet Tagging : Soft muon & SV

See J. Fleckner's talk

Soft Muon Tagger

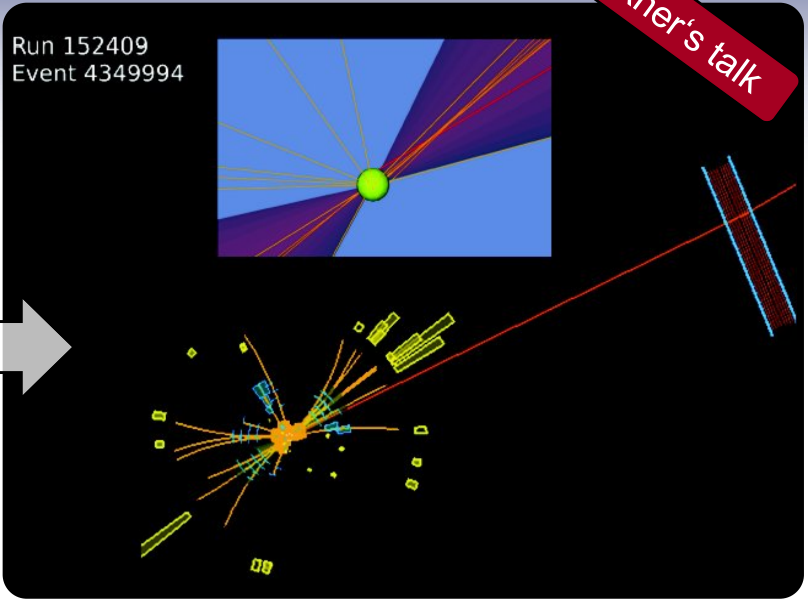
Tag soft muon from b(→c)→μ X [BR~20%]

Select *combined muon* in jets

- Good MS and ID match
- Muon track w/ 7Si+2 pixels+1 BL hits
- $|d_0|$ < 1 mm and $|Z_0 \sin\theta|$< 1.5 mm

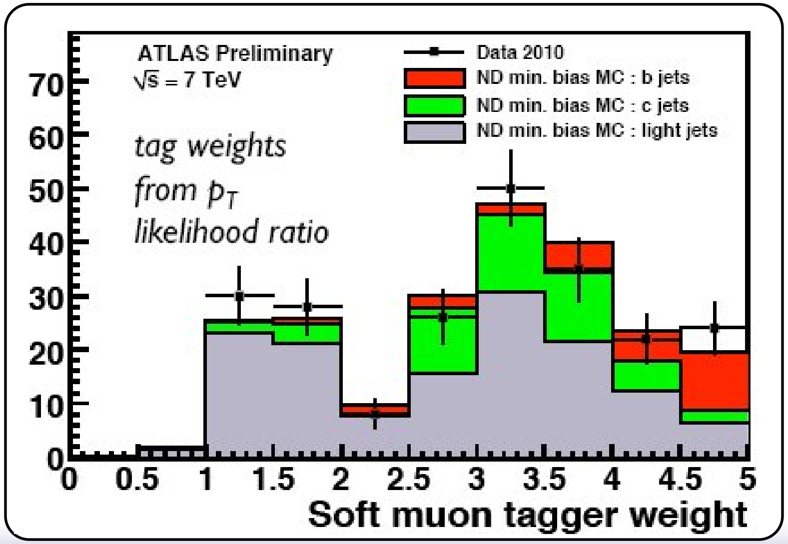
Use $p_T^{rel}(\mu)$ as discriminant variable

- →Fit templates of b, c and light jets



Secondary Vertex Tagger

- Reconstruct vertex from 2-track combinations with dca/σ_{dca} above 2
- Compute 3D decay length significance
  Impose tracks to have 2-track $\Sigma dca/\sigma_{dca}$ > 6
  Cut on χ^2 to ensure bad compatibility w/ PV
- Removal of V0 and γ-conversion
- Removal of vertices in pixel layer (interactions)



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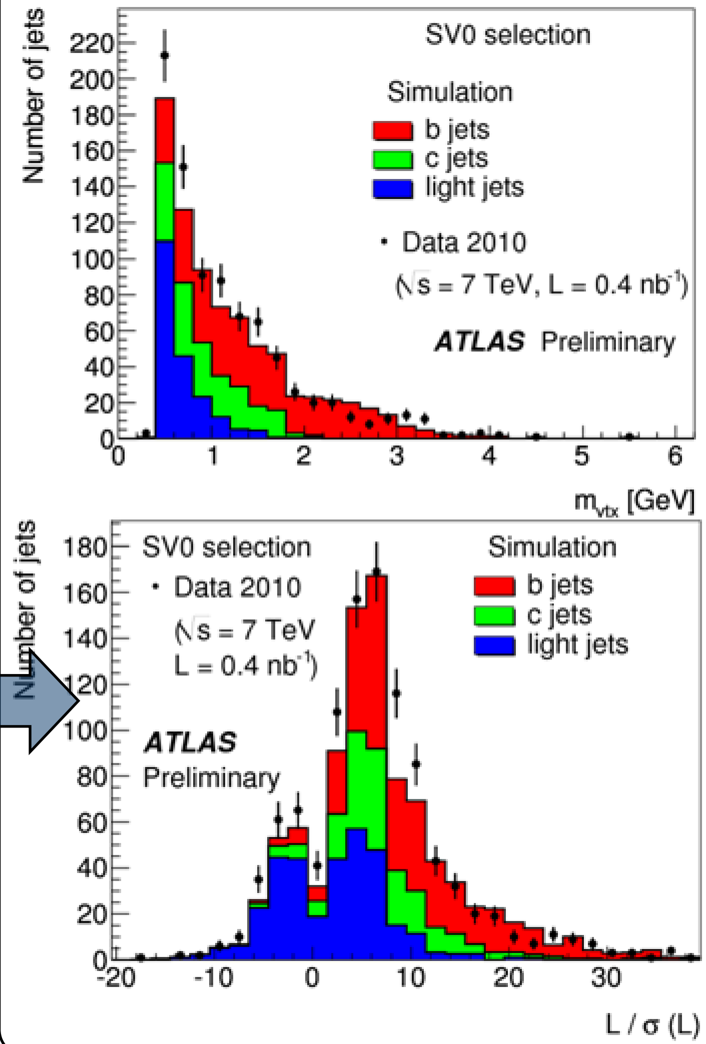


Top quark Candidate Search with 280 nb^{-1}…

Top quark search in « electron+jets »

Electron+jets selection

Primary Vertex with ≥5 tracks

One electron with p_T> 20 GeV

Trigger matched

Medium quality

Track with B-layer hit

Isolated around e-direction

At least 4 jets with p_T>20 GeV

Pseudo rapidity $|\eta| \leq 2.5$

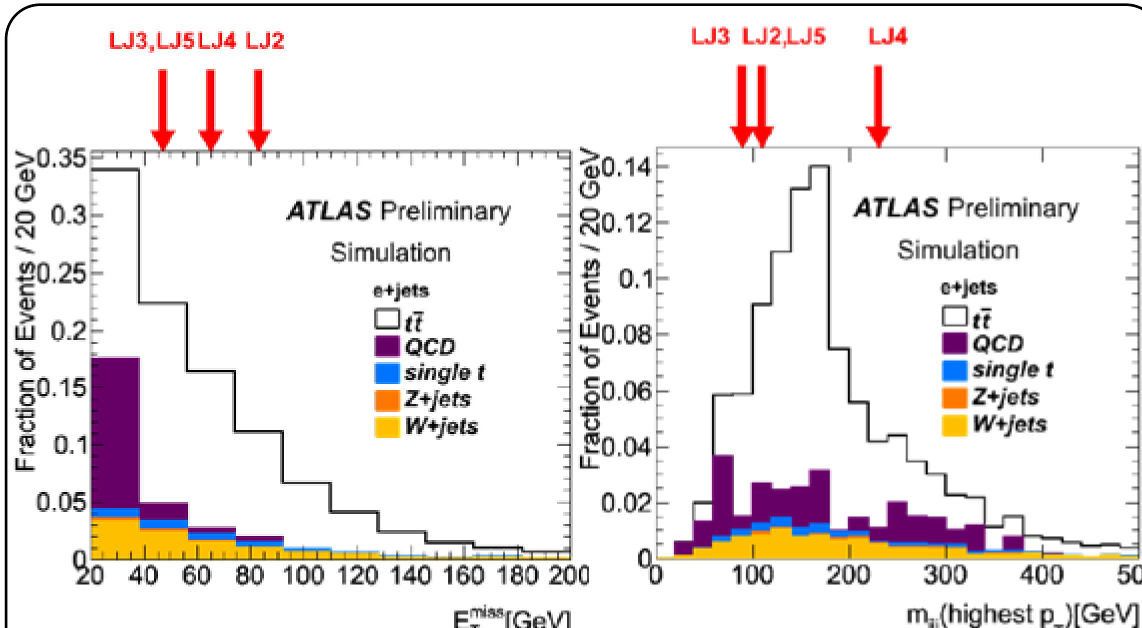
EM scale + JES calibration

≥1 b-tagged jet (SV0)

Missing Transverse Energy

E_T^{MISS} > 20 GeV

	p_T^{lep} (GeV)	N_{jet} (N_{tag})	E_T^{MISS} (GeV)	m_T (GeV)	M_{jjj} (GeV)
LJ2	41.4	4 (1)	89.3	68.7	106
LJ3	26.2	4 (1)	46.1	62.6	94
LJ4	39.1	4 (1)	66.7	102	231
LJ5	79.3	4 (1)	43.4	86.7	122



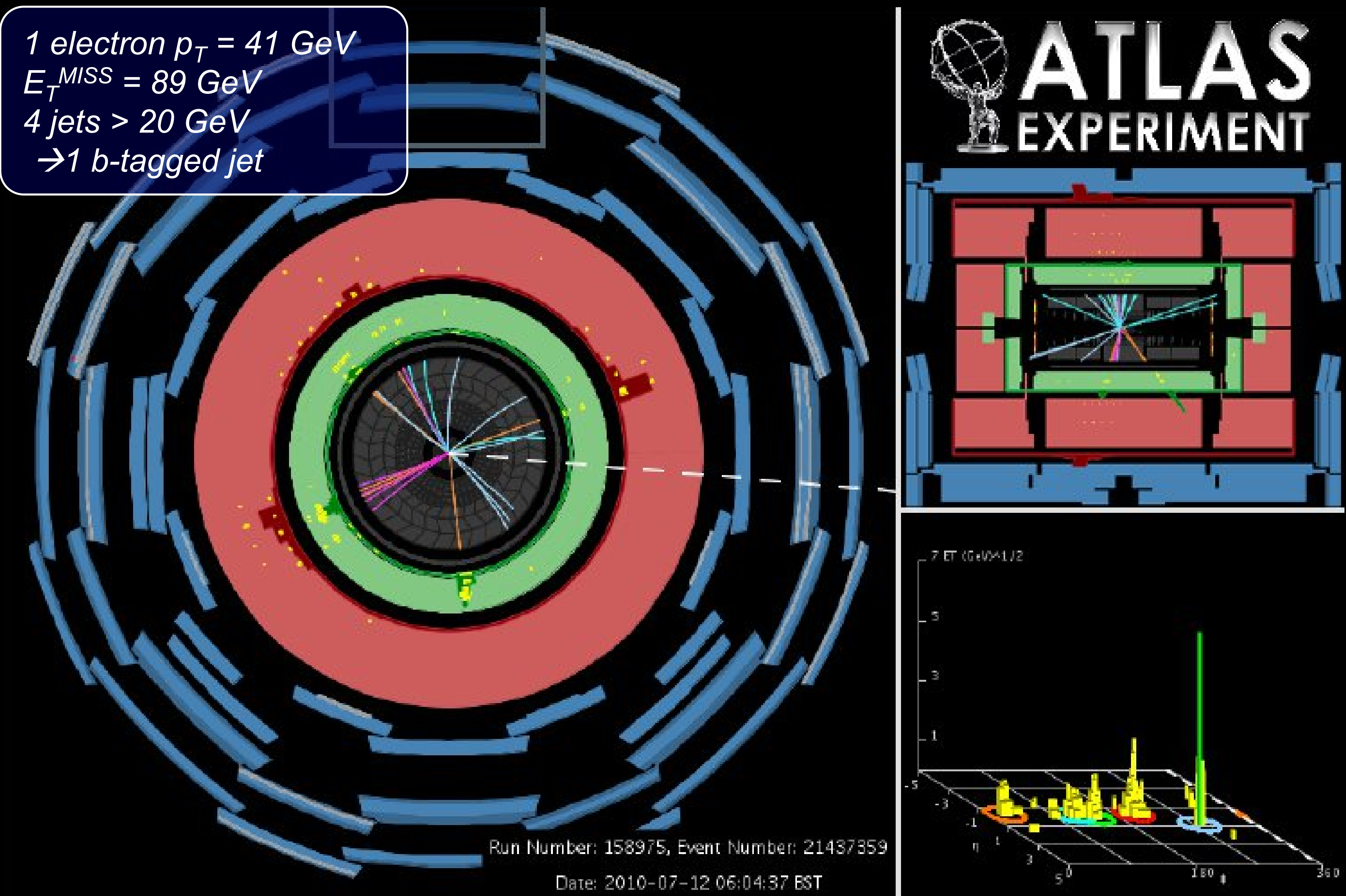
Note on B-tagging

SV0 is the default tagger

Jet by JetProb & TrackCount used as cross-checks

Top pair candidates in « electron+jets »

1 electron p_T = 41 GeV
E_T^{MISS} = 89 GeV
4 jets > 20 GeV
→1 b-tagged jet



Top quark search in « muon+jets »

Muon+jets selection

Primary Vertex with ≥5 tracks

At least 4 jets with p_T>20 GeV

Pseudo rapidity $|\eta| \leq 2.5$

EM scale + JES calibration

≥1 b-tagged jet (SV0)

Missing Transverse Energy

E_T^{MISS} >20 GeV

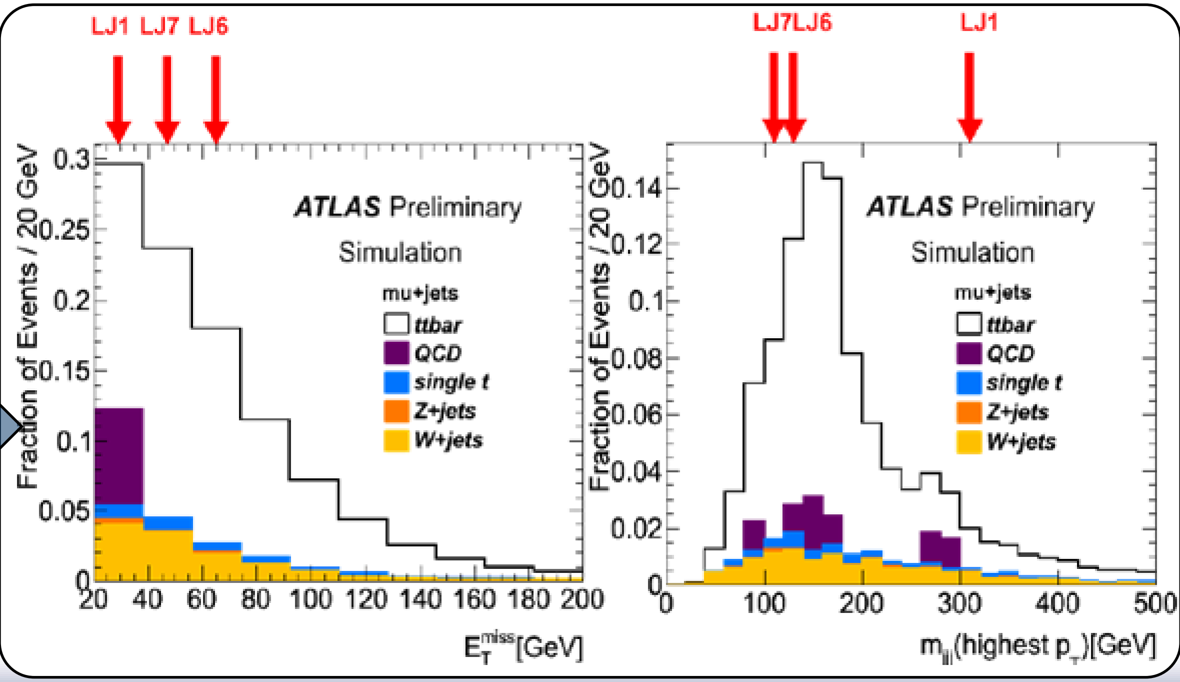
one muon with p_T> 20 GeV

Trigger matched

Combined Tight

Isolated around μ direction

	p_T^{lep} (GeV)	N_{jet} (N_{tag})	E_T^{MISS} (GeV)	m_T (GeV)	M_{jjj} (GeV)
LJ1	42.9	7 (1)	25.1	59.3	314
LJ6	29.4	5 (1)	65.4	64.1	126
LJ7	78.7	4 (1)	40.0	83.7	108

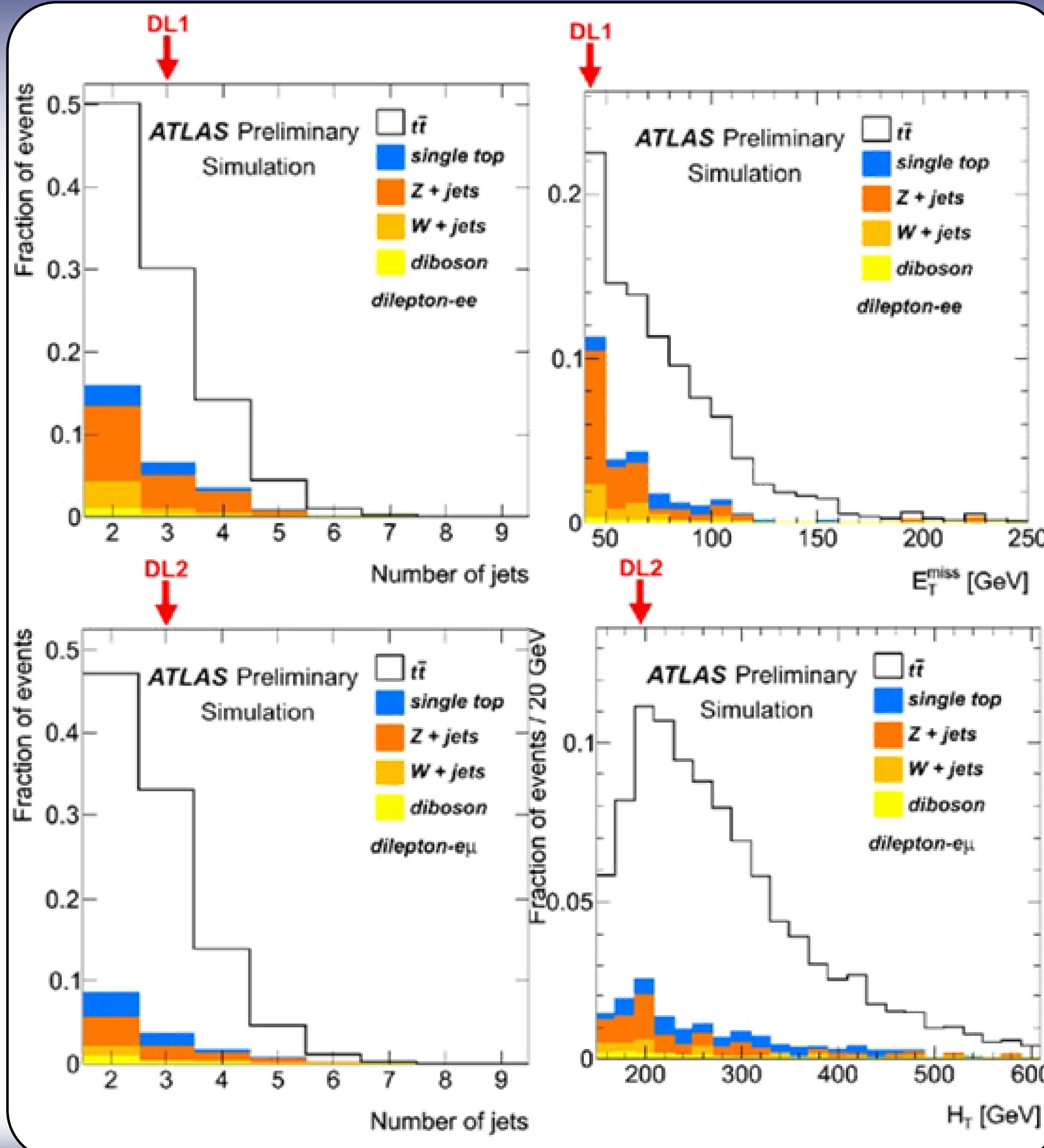


Top quark search in « dilepton channel »

Di-lepton selection

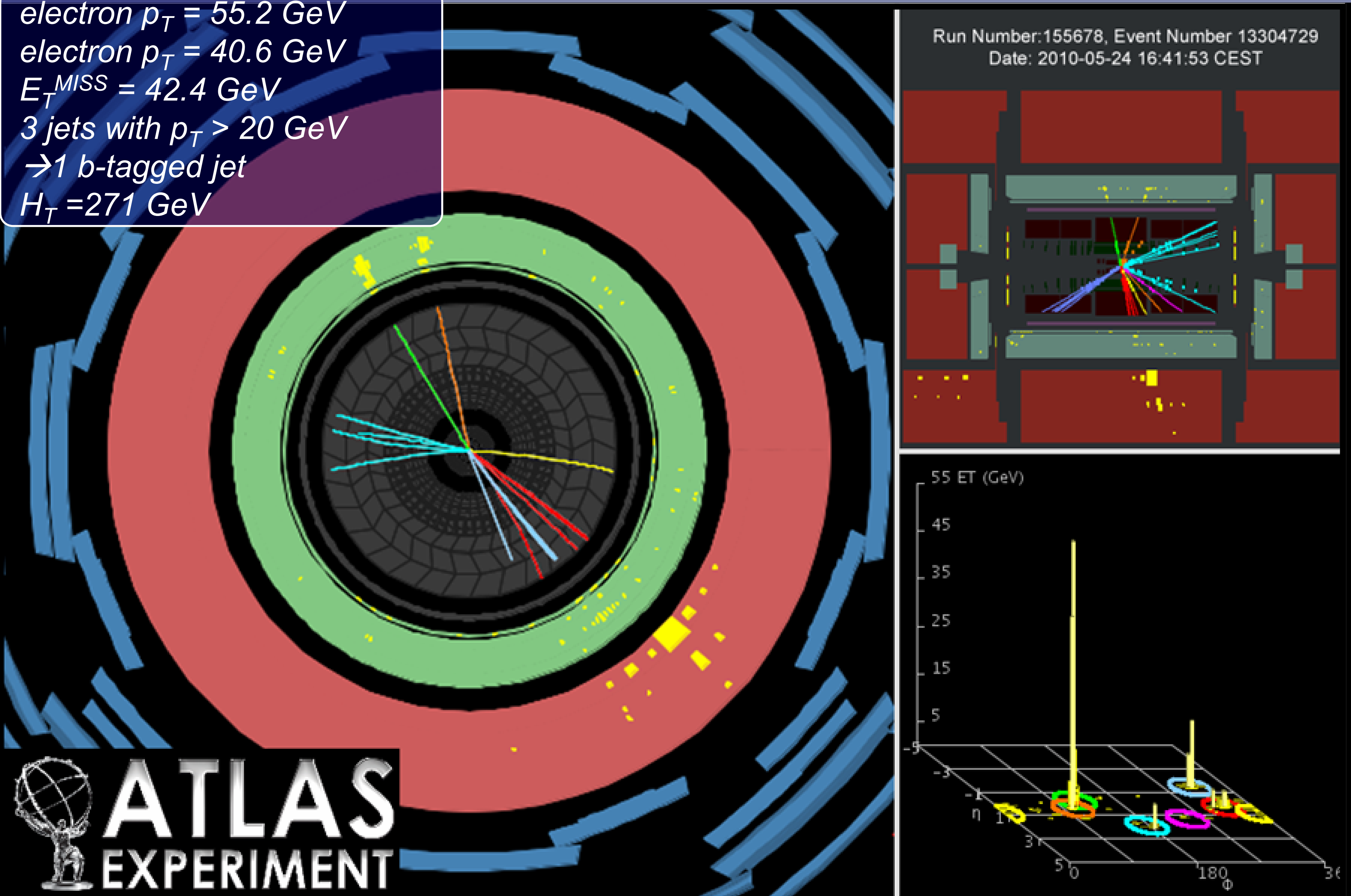
Primary Vertex with ≥5 tracks
2 leptons with p_T > 20 GeV
 Medium electron and/or
 Combined muon
At least 2 jets with p_T > 20 GeV
 No b-tagging required
 [ee] E_T^{MISS} > 40 GeV
 $|M_{ll}-M_Z|$>5 GeV
 [μμ] E_T^{MISS} > 30 GeV
 $|M_{ll}-M_Z|$>10 GeV
 [eμ] H_T(jets,leptons)> 150 GeV

	p_T^{lep} (GeV)	N_{jet} (N_{tag})	E_T^{MISS} (GeV)	H_T (GeV
DL1 ee	55.2/40.6	3 (1)	42.4	271
DL2 eμ	22.7/47.8	3 (1)	76.9	196

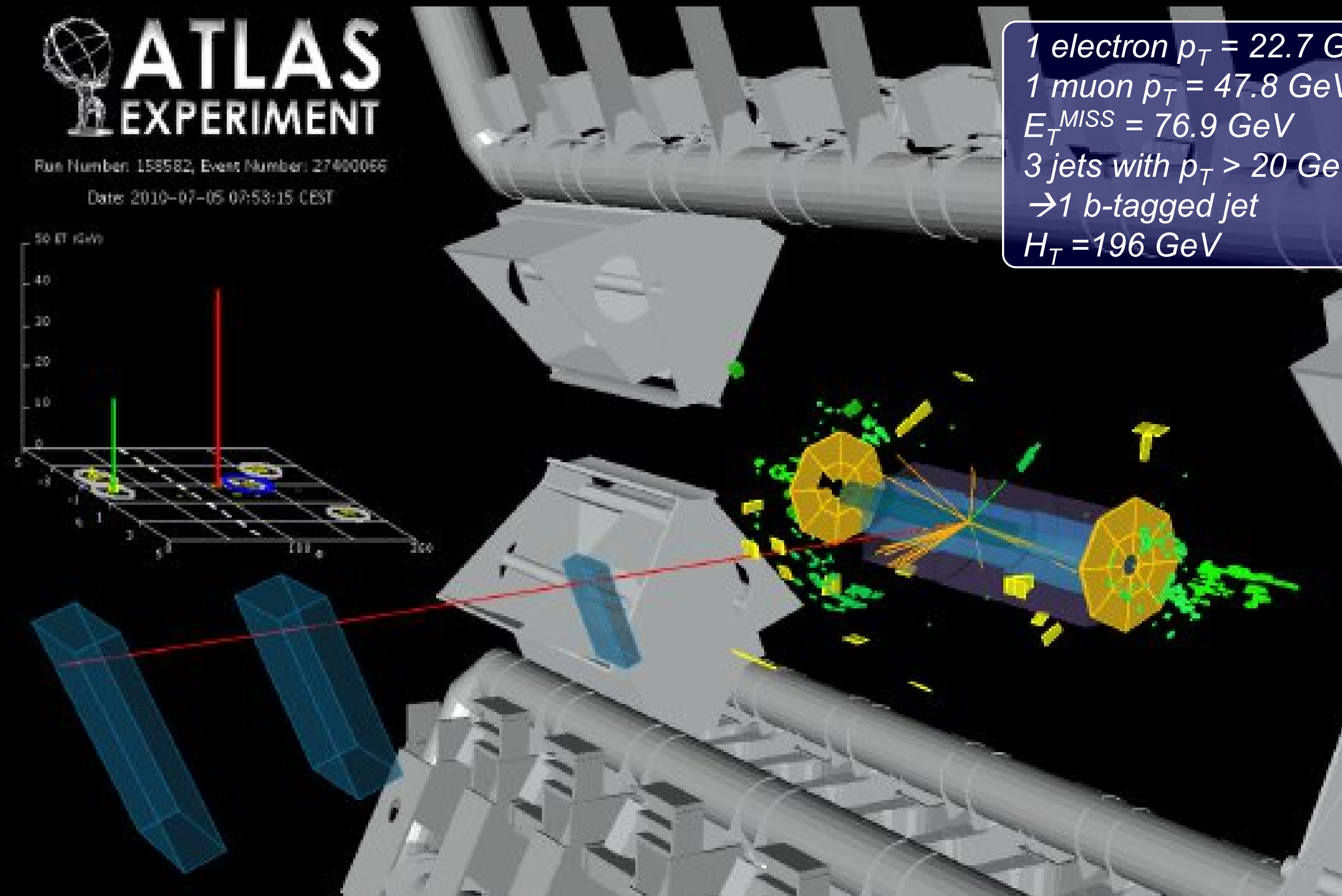


Top pair candidate in **ee** channel

electron p_T = 55.2 GeV
electron p_T = 40.6 GeV
E_T^{MISS} = 42.4 GeV
3 jets with p_T > 20 GeV
→1 b-tagged jet
H_T =271 GeV



Top pair candidate in « eμ channel »



1 electron p_T = 22.7 GeV
1 muon p_T = 47.8 GeV
E_T^{MISS} = 76.9 GeV
3 jets with p_T > 20 GeV
→1 b-tagged jet
H_T =196 GeV

Summary & Perspectives

Top quark physics requires an overall good understanding of the detectors

A lot of progress in understanding most physics objects has already been achieved:

- Leptons reconstruction, ID and resolution performance
- Hadronic jets reconstruction, ID, calibration & resolution
- Missing transverse energy calibration, correction & resolution
- B-tagging tools (several taggers) tested against first data

Still a lot remains to be done:

- Lepton performance calibration with (Z) data
- In situ Jet energy scale calibration, higher statistics in situ resolution measurements
- Validate Background Estimate & Description in data control sample

A search for top quark candidates has been conducted with 280 nb^{-1}

Strategy has been defined to look for top (pair) candidates

- Specific selections developped for top pair in lepton+jets and dilepton channels

Some candidates have been identified

- Number of observed events is compatible with expectations
- Kinematic properties are consistent with top pair expectations

Larger data sample is required to quantify background to a level where it can support a conclusive observation of top quark production in ATLAS
…but a new era for Top Physics is about to begin…