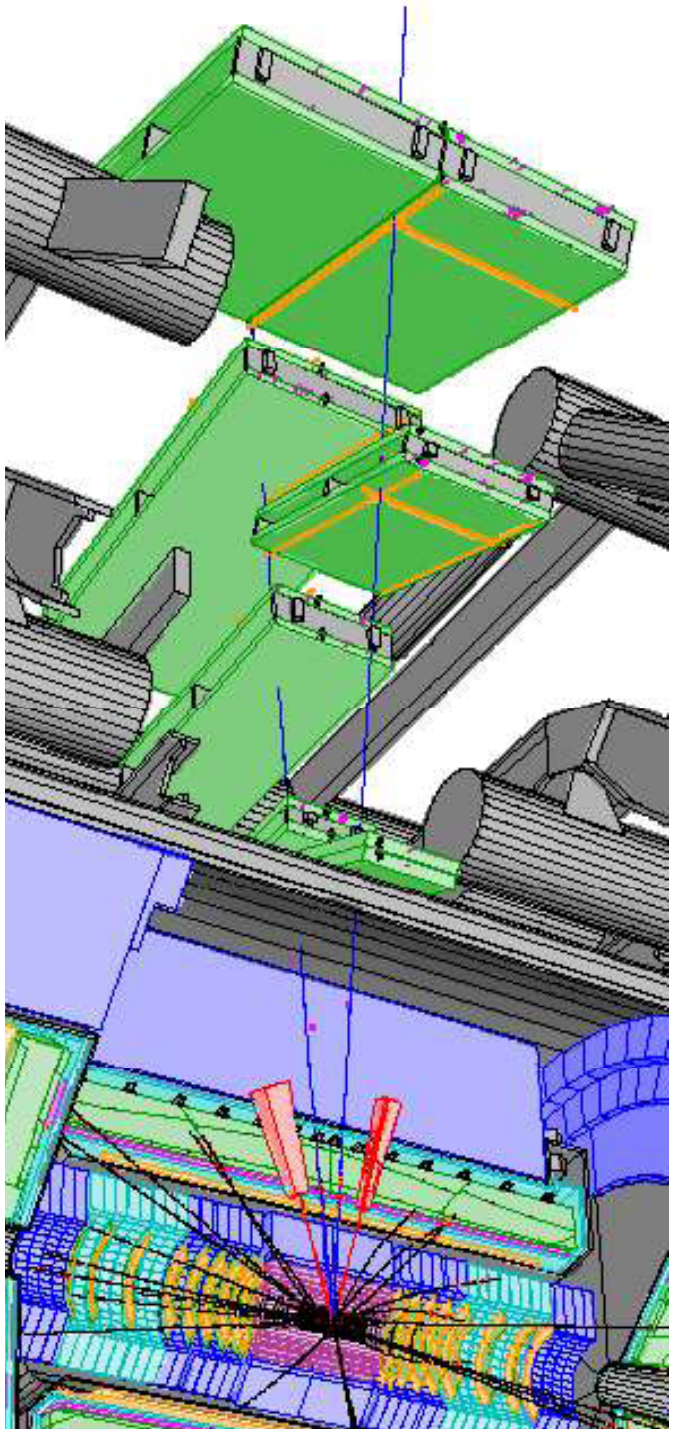


Trigger Algorithms and Performance

Ricardo Gonçalo, Royal Holloway
ATLAS Overview Week - CERN 10 October 2007

- Introduction
- Trigger Algorithms
- Trigger Performance
- Online running
- Conclusions

Introduction

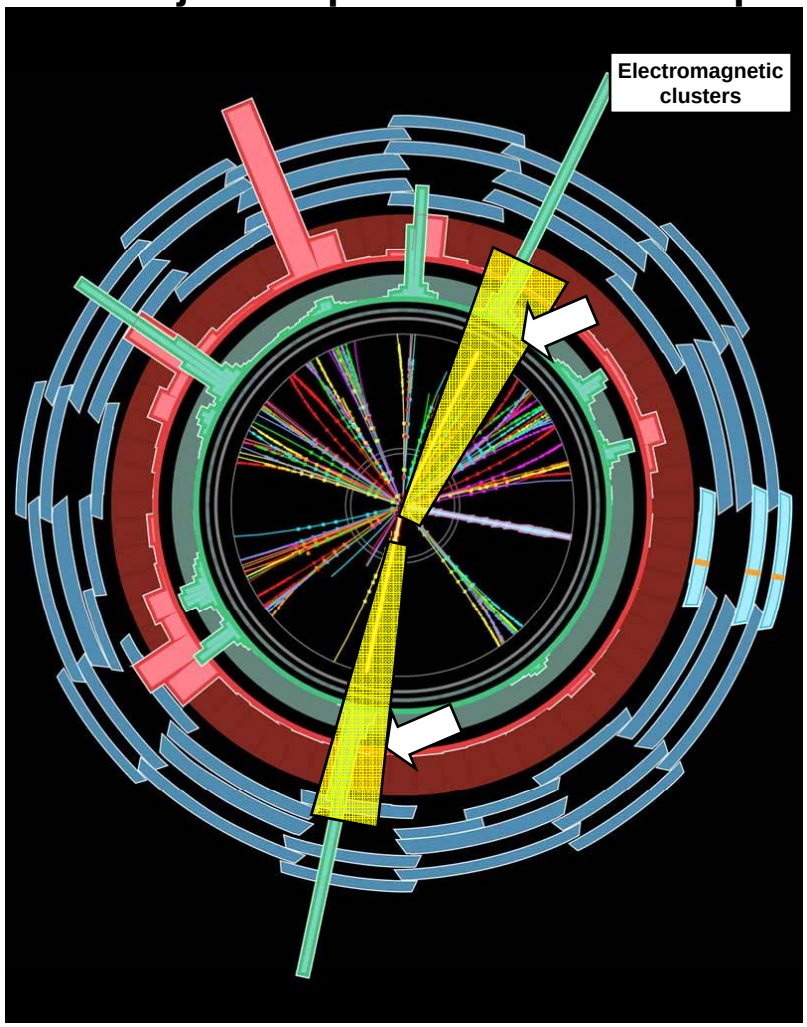
A lot happening since the Glasgow ATLAS Week in July:

- New trigger menus – see Takanori's talk
  - Major effort to produce a realistic trigger menu for $L=10^{31}cm^{-2}s^{-1}$
  - Work started for the $L=10^{32}cm^{-2}s^{-1}$ trigger menu
- Migration to new trigger configuration scripts
- Online – see Imma's talk
  - M4 cosmic-ray run in August
  - Technical run in September
- The final push started towards the end of release 13
  - Release 14 will be used with LHC data

Trigger Algorithms

Selection method

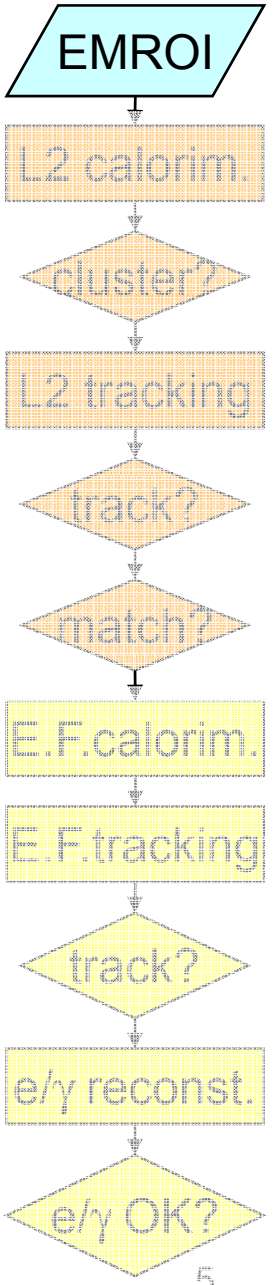
Event rejection possible at each step



Level1 **Region of Interest** is found and position in EM calorimeter is passed to Level 2

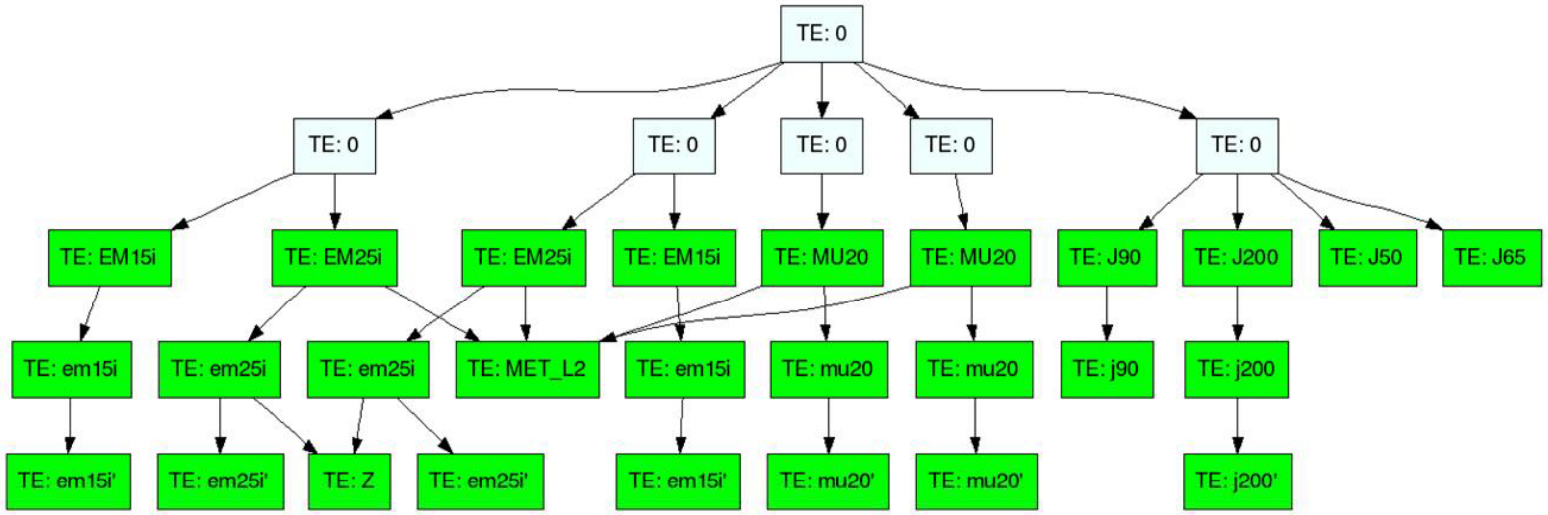
Level 2 seeded by Level 1
Fast reconstruction algorithms
Reconstruction within RoI

Ev.Filter seeded by Level 2
Offline reconstruction algorithms
Refined alignment and calibration



Trigger Algorithms

- Algorithms run by Steering top Algorithm (see talk by Tomasz)
- High-Level Trigger algorithms organised in groups (“slices”):
  - Minimum bias, e/γ, τ, μ, jets, B physics, B tagging, E_T^{miss}, cosmics, plus combined-slice algorithms
- Level 2 : specialized (simplified) algorithms and EDM
  - Time budget is ~40ms
- Event Filter : offline algorithms (wrapped to run on RoIs) and offline EDM
  - Time budget is ~4s

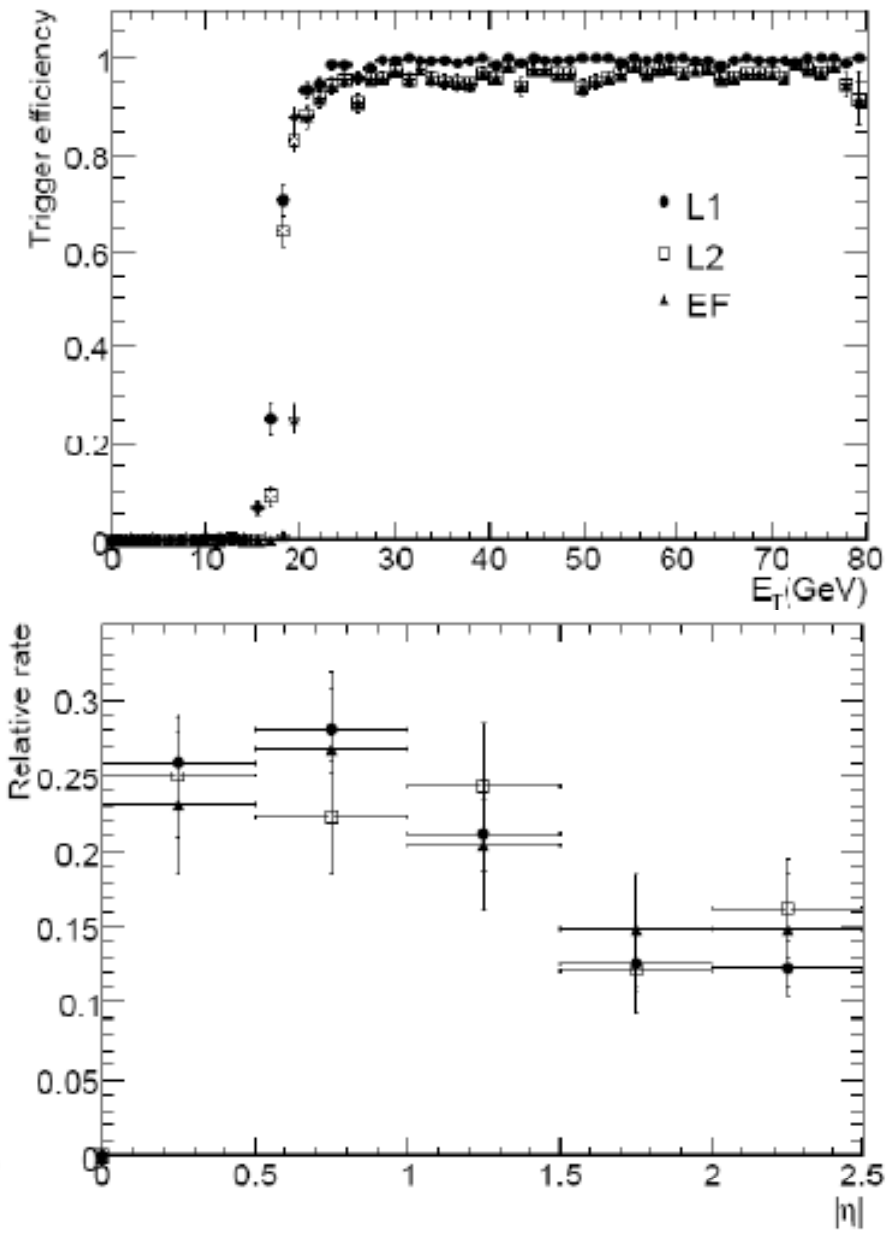


Trigger Performance

Photon slice

Ongoing work:

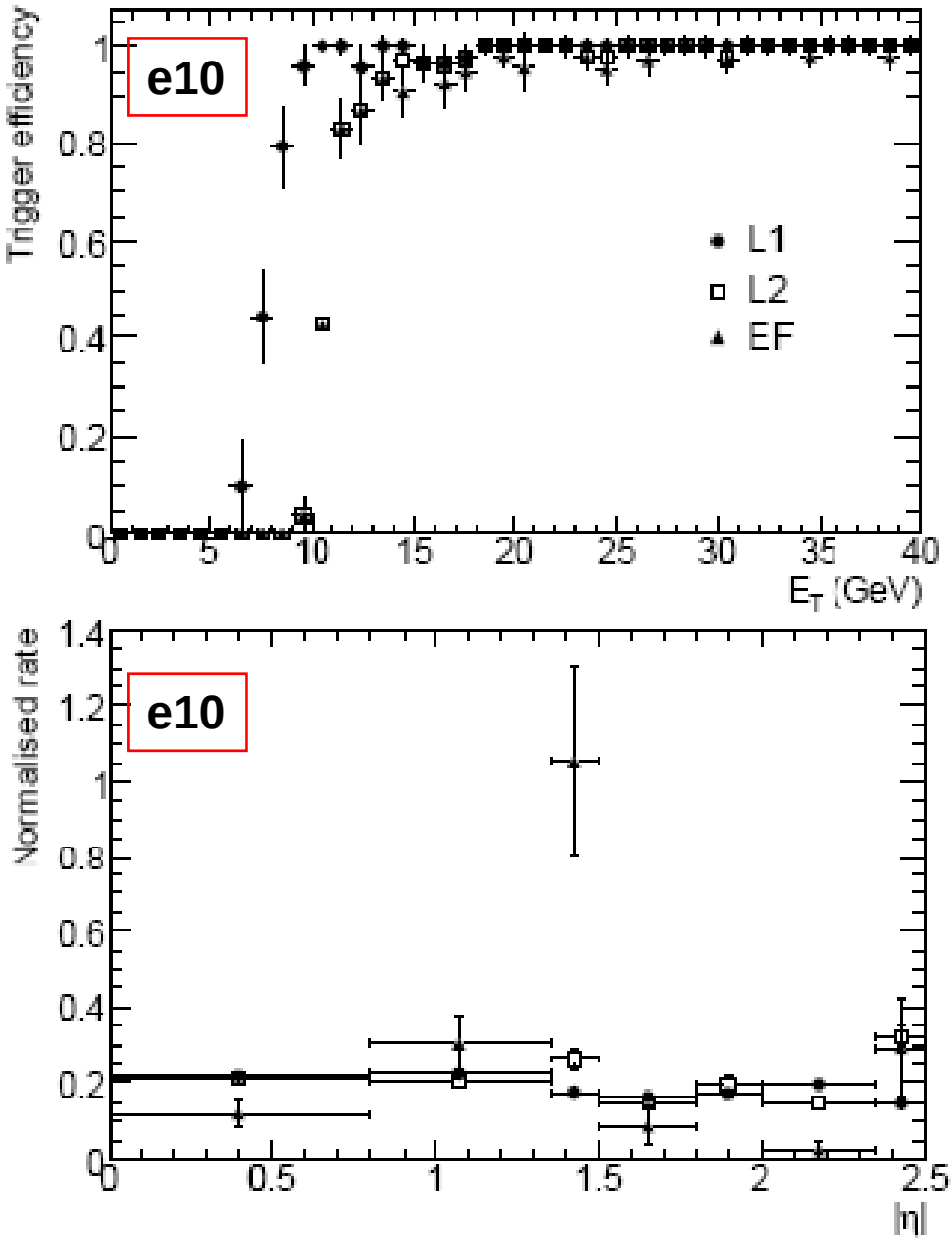
- Just implemented L=10^{31} menu
- Evaluate L=10^{31} menu performance
- Implement L= 10^{32} menu
- Re-evaluate L= 10^{33} menu performance for physics channels



Valeria Perez Reale, Trigger Menus 24 Sep. 2007

Electron slice

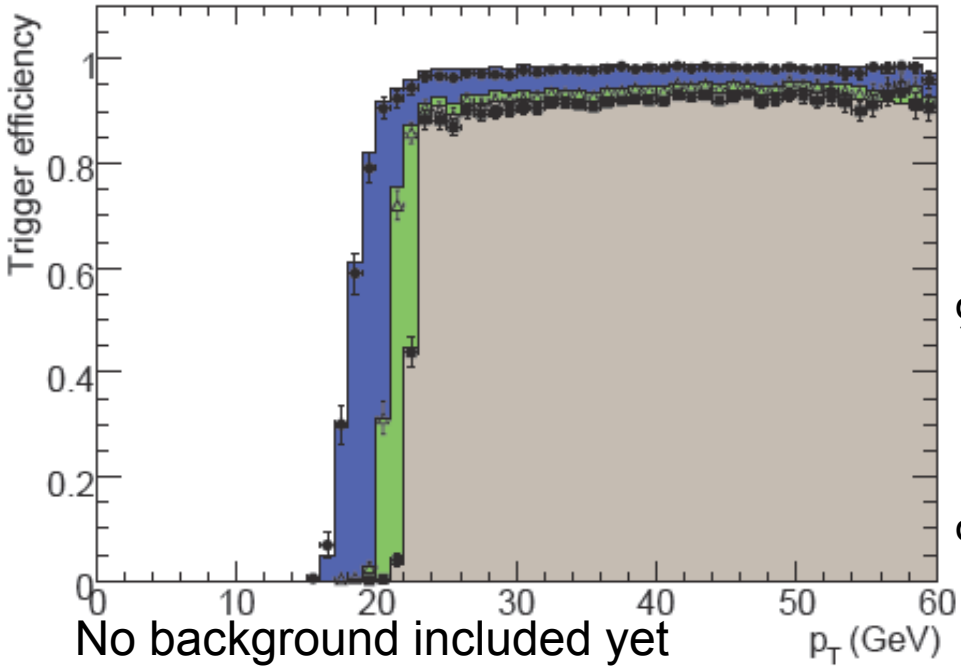
- Performance in general as good in 13.0.30 as it was in 12.0.7
- Will implement $L=10^{32}$ menu soon
- Working on plans for commissioning



Monika Wielers, TAPM 18 September 2007

Efficiency determination

- Trigger efficiency must be determined from real data
- One way to do this is the “tag-and-probe” method:
  - select Z→ee events with single-electron trigger
  - Select (offline) Z→ee sample with good purity
  - Use second electron to find efficiency



No background included yet

$$\varepsilon_{MC} = \frac{\#\ \text{triggered truth matched reco electrons}}{\#\text{all truth matched reco electrons}}$$

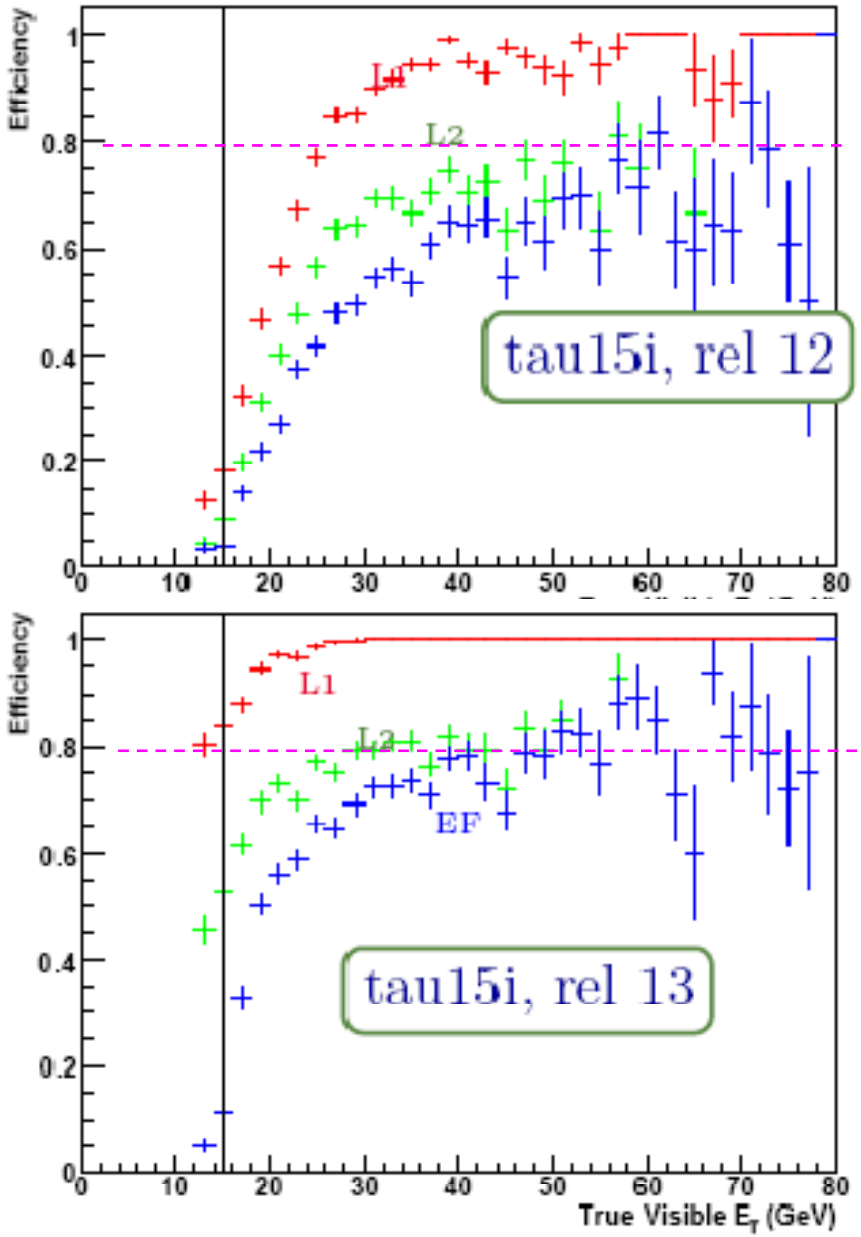
...if event is triggered by the 'tag' electron:

$$\varepsilon_{T\&P} = \frac{\#\ \text{triggered reco 'probe' electrons}}{\#\text{all reco 'probe' electrons}}$$

Stefan Maettig, TAPM egamma 4 October 2007

Tau slice

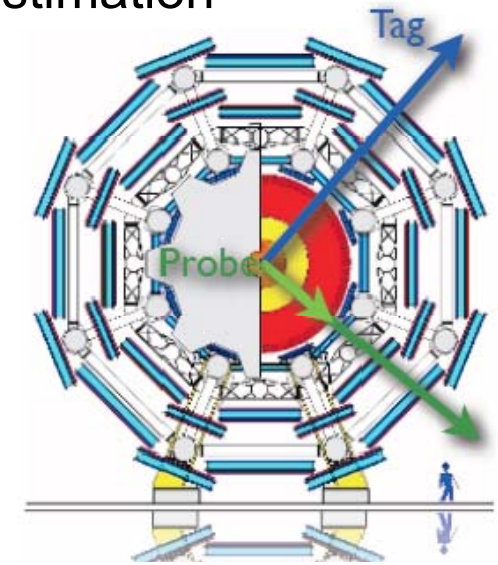
- Many developments since r12
- Massive optimisation effort
  - Aiming for high efficiency wrt offline for true taus above threshold
  - Optimising to have flat efficiency starting from the nominal threshold
- Tau+MET intended for $W \rightarrow \tau\nu$ at low luminosity and $H^{-} \rightarrow \tau\nu$, SUSY, etc at high luminosity
- Looking into L1 tau + EF Missing ET as a “minimum bias” trigger to study tau performance

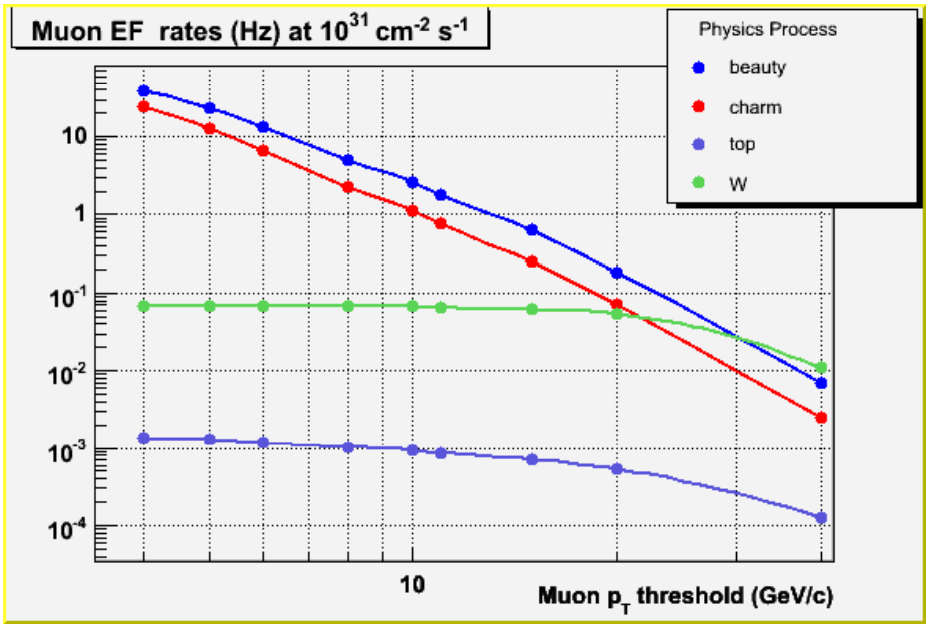


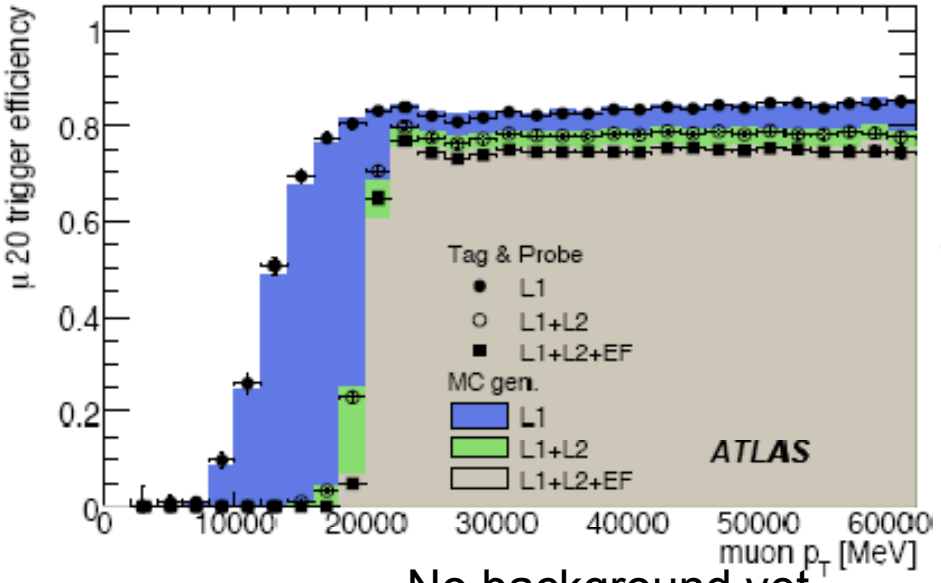
Olga Igonkina – Trigger Menus Workshop, 24 September

Muon slice

- Rates dominated by decays in flight of pions and kaons and heavy-flavour decays
- As in the case of electrons, the tag-and-probe method is being studied to efficiency estimation





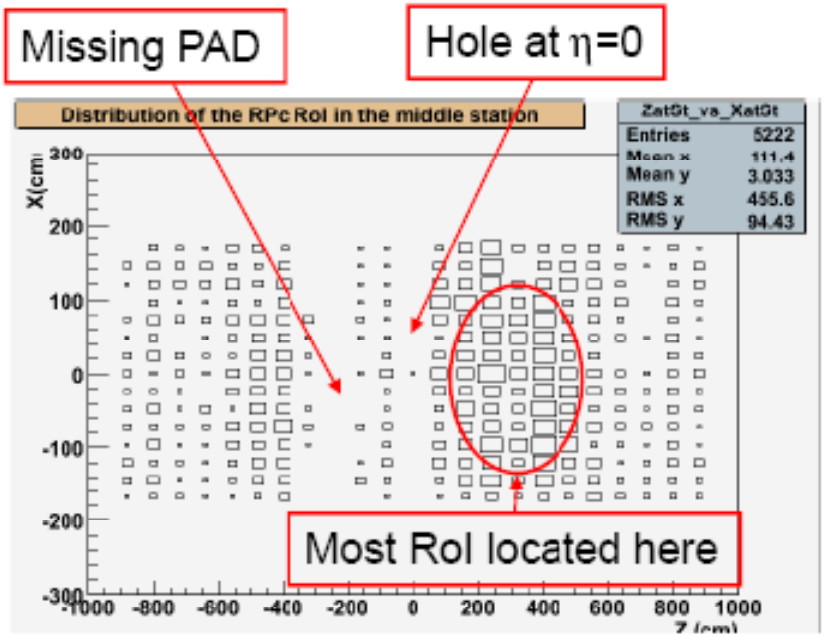


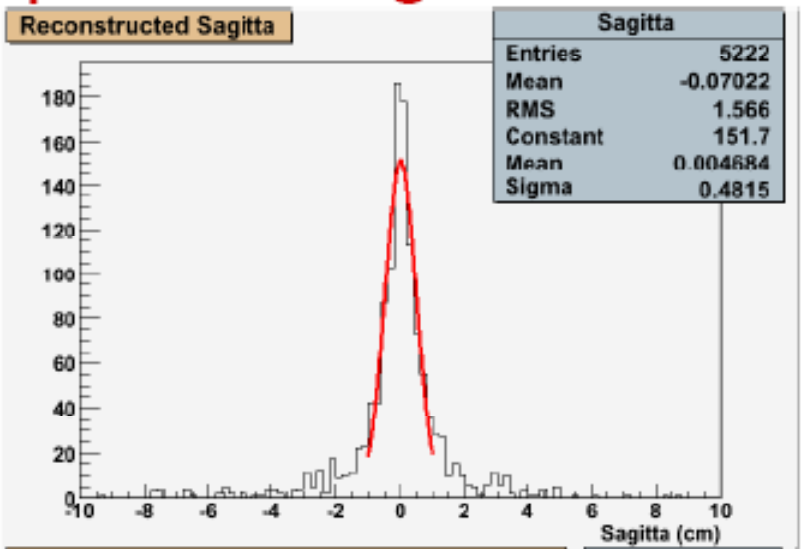
No background yet

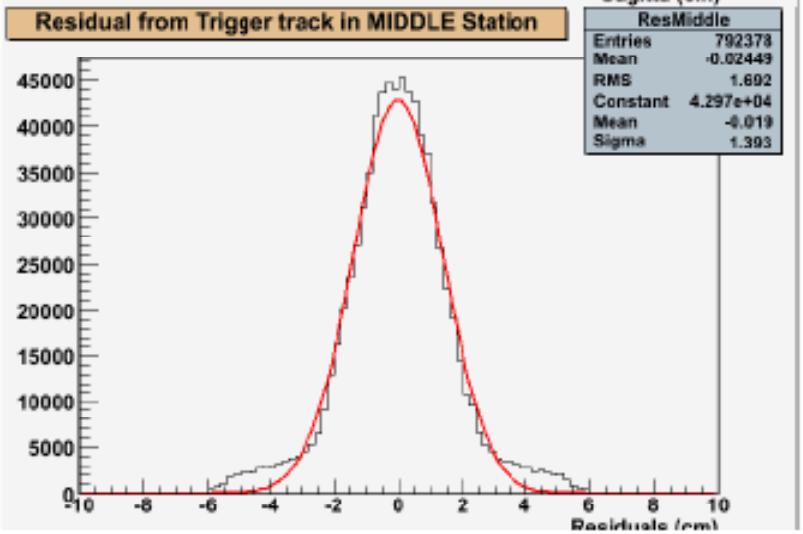
Muon Trigger phone meeting, - note 12 Sep.07 - M.Bellomo,

Example of monitoring histogramming from M4 data processing

- reconstructed sagitta has very large sigma due to misalignment of chambers and use of t0 and MDT calibration constant not tuned for the cosmic experimental setup;
- nice correlation seen in the Middle chamber →no macroscopic effects in the cabling setup



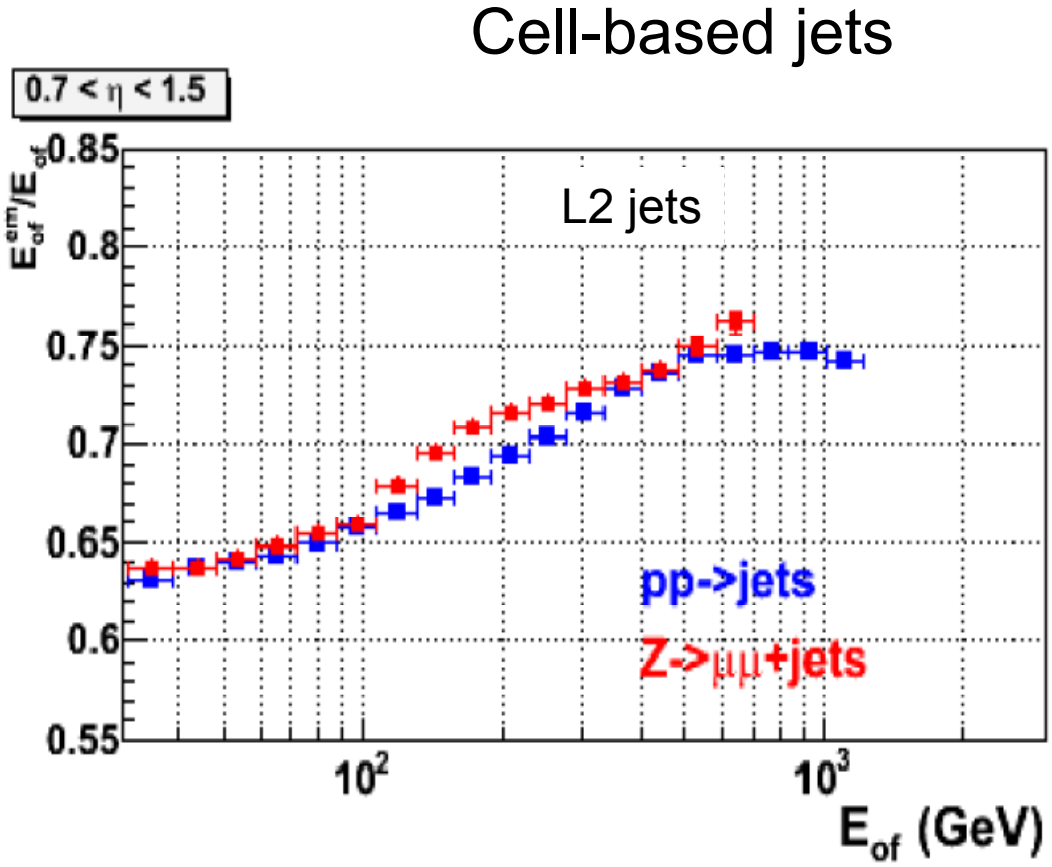




Margherita Primavera, TAPM 18 September 2007

Jets slice

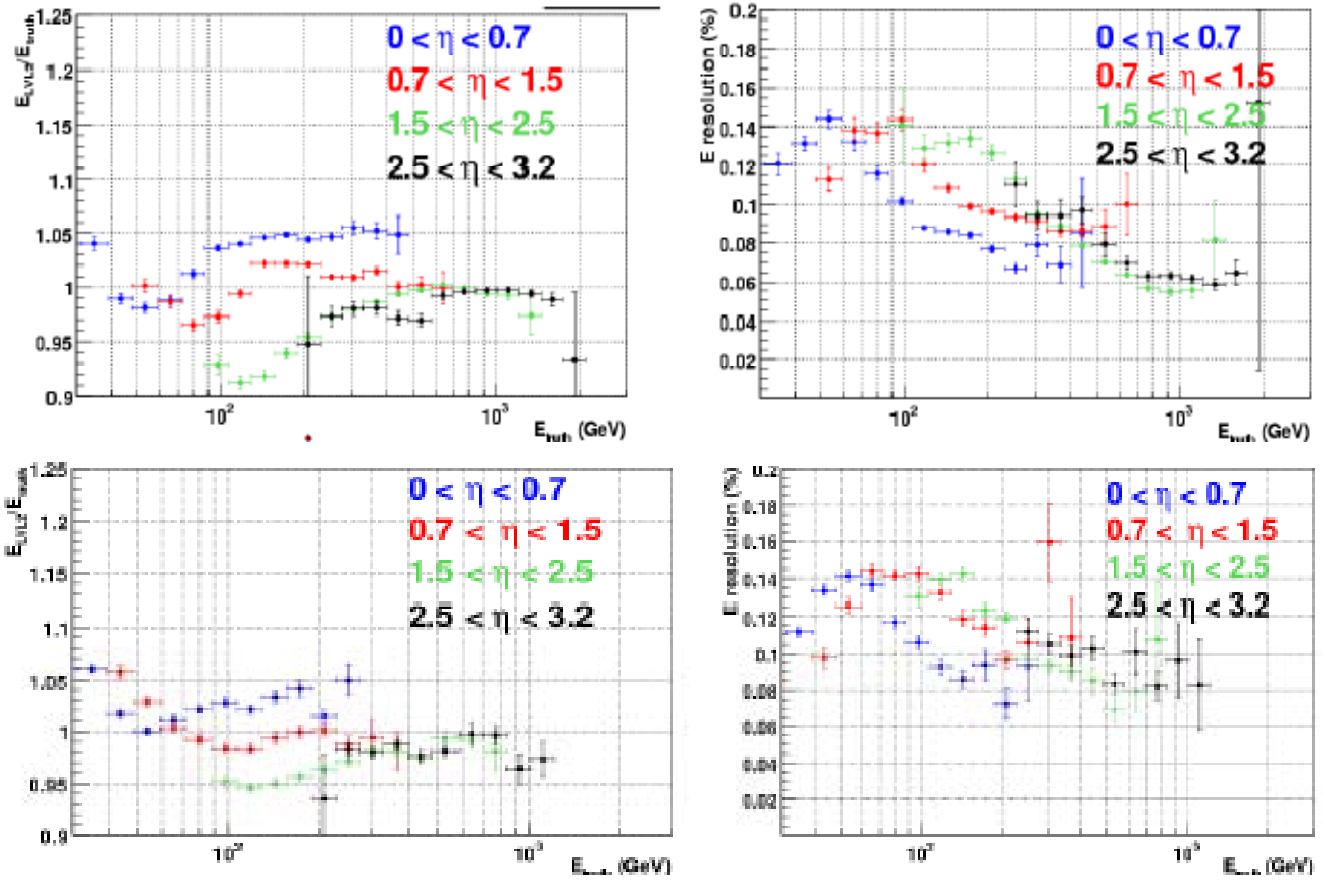
- Ongoing studies of algorithm performance
  - Energy scale
  - Uncertainty due to hadronisation model
  - Dead material effects
- Different electromagnetic content of jets from different channels lead to energy-scale differences
- Looking at a new calibration method to minimize this problem



Patricia Conde, TAPM 2 October 07

- Jet EM fraction depends on
  - Type of parton
  - Mode of production
- Energy scale is average value for range of EM fractions
- Calibration doesn't work well with different types of jets

$Z \rightarrow \mu\mu$ inclusive

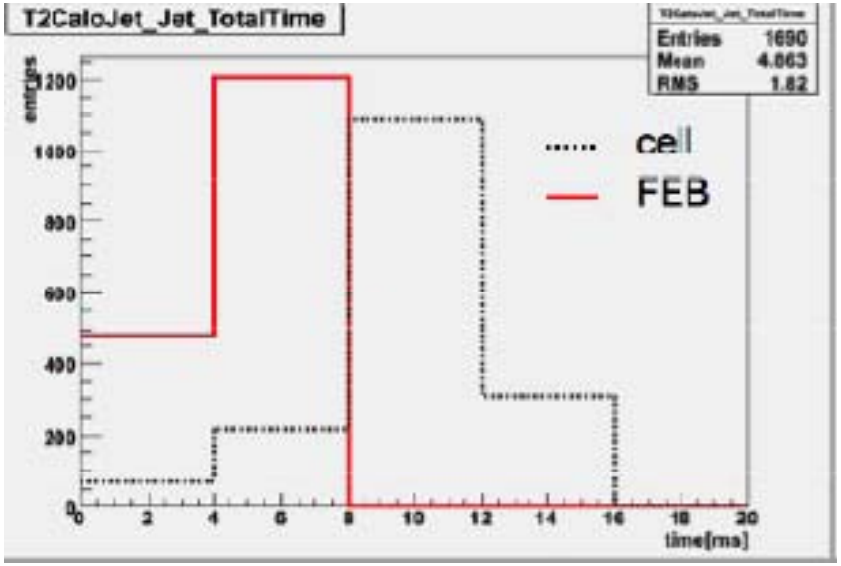


$Z + X \rightarrow \mu\mu$ + jets

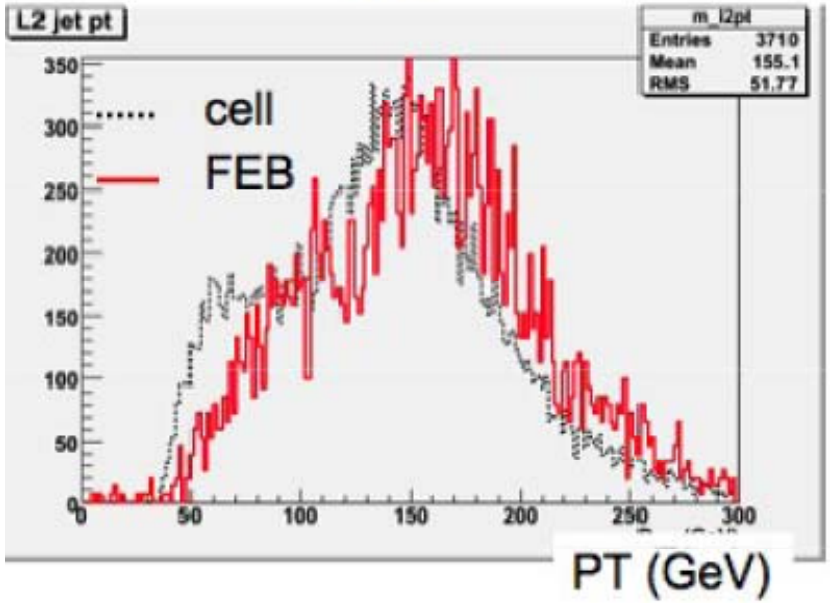
Patricia Conde, TAPM 2 October 07

FEB jets at L2

- Investigating reading Front-End Board (FEB) to build jets at Level 2
- Clear savings in processing time wrt cell-based jet reconstruction
- Different “energy scale”: correction being investigated



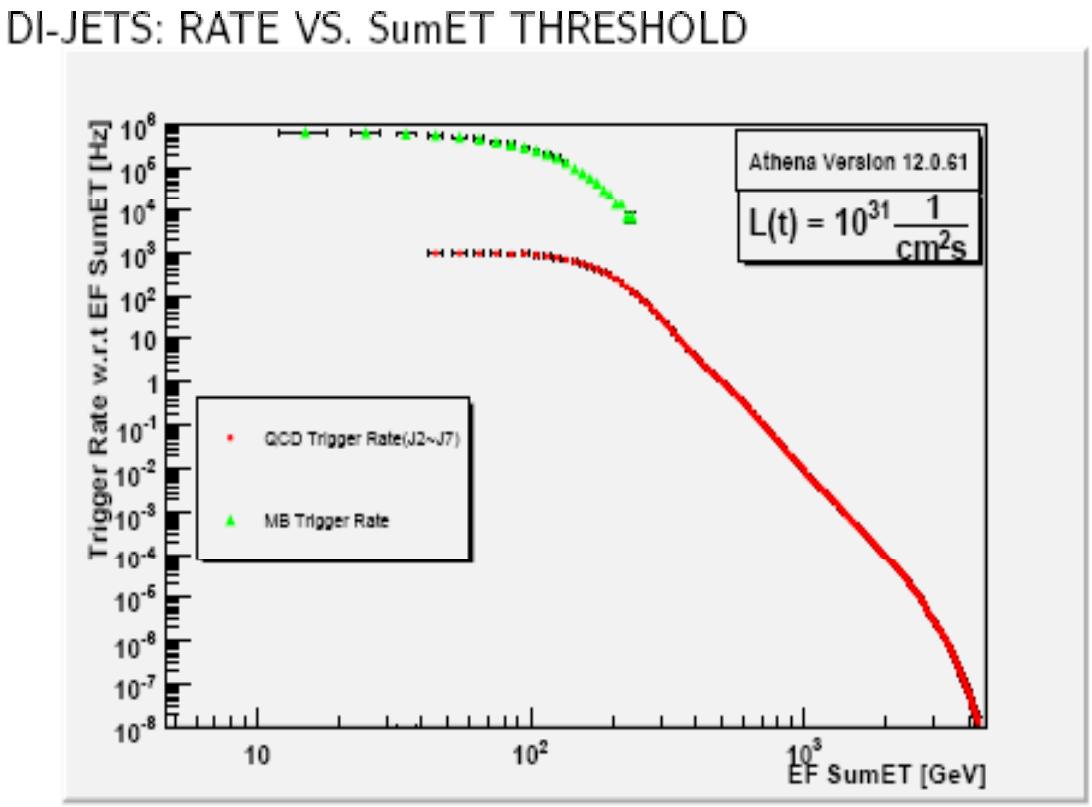
J4



Cibran Santamarina, TAPM 18 September 07

E_T and $\sum E_T$ slice

- Lots of progress adding new code:
  - In June: only one MET or SumET level 1 RoI allowed (not both)
  - No Jet SumET in L2 or EF
  - Today: 8 MET, 4 SumET, 4 Jet Sum ET exist in $L=10^{31}cm^{-2}s^{-1}$ menu plus many combined signatures
  - Performance studies in progress



Diego Casadei, TAPM 17 July 2007

- Work ongoing to improve performance and control detector effects
  - Non-uniformity in phi
  - Parametrise hadronic-scale correction
  - etc

DI-JETS: SumET RESOLUTION

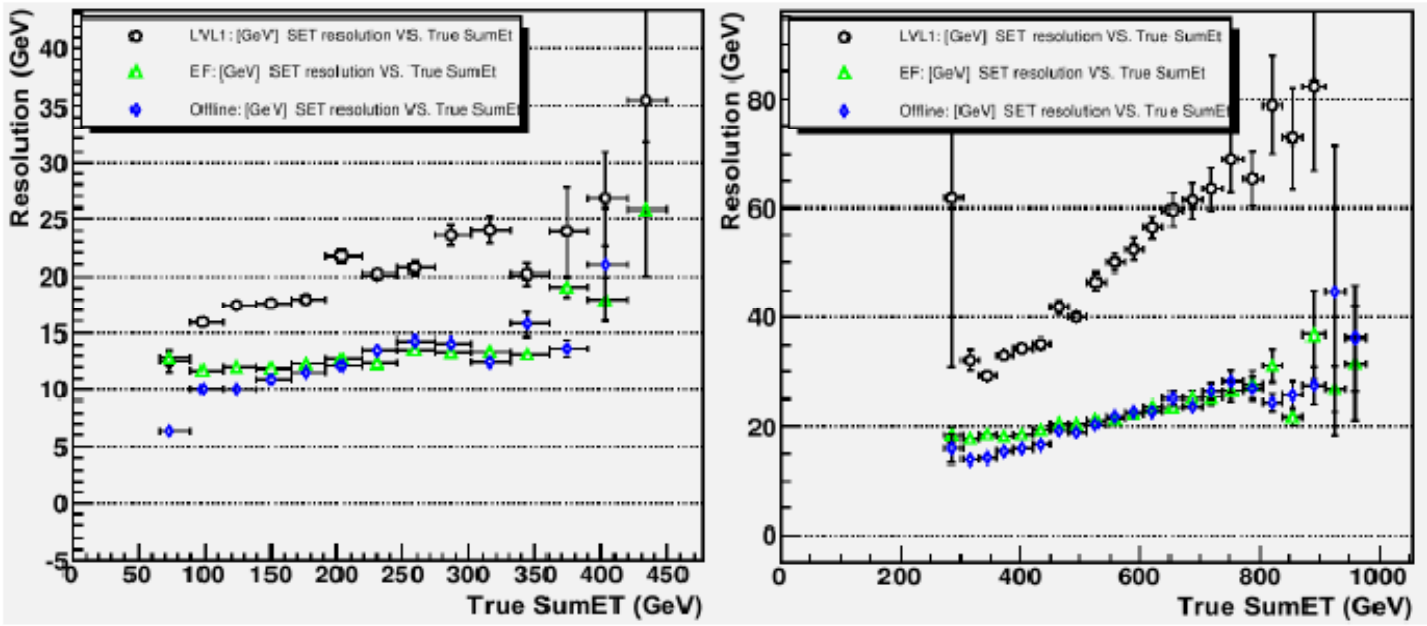
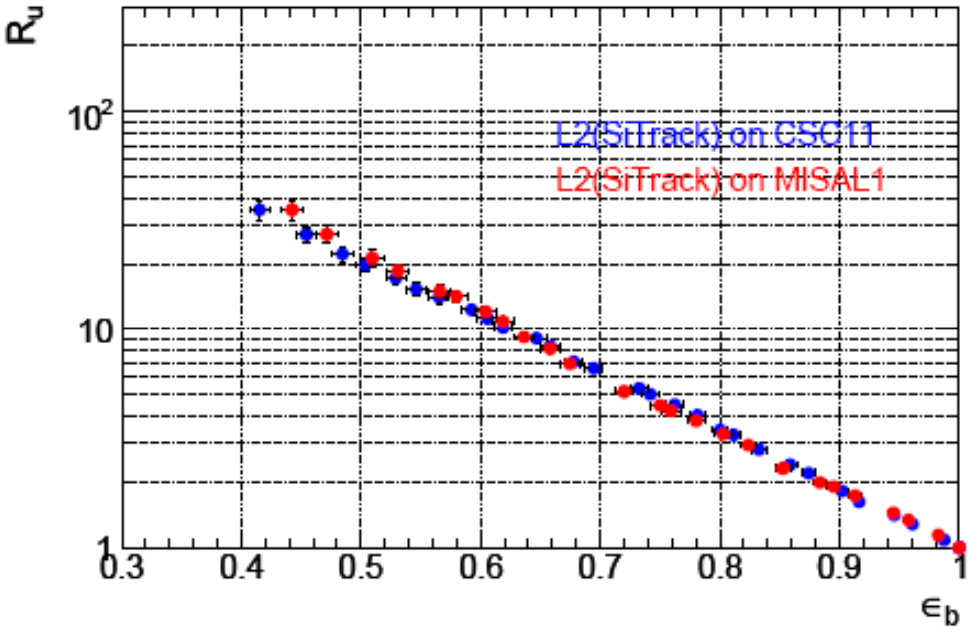


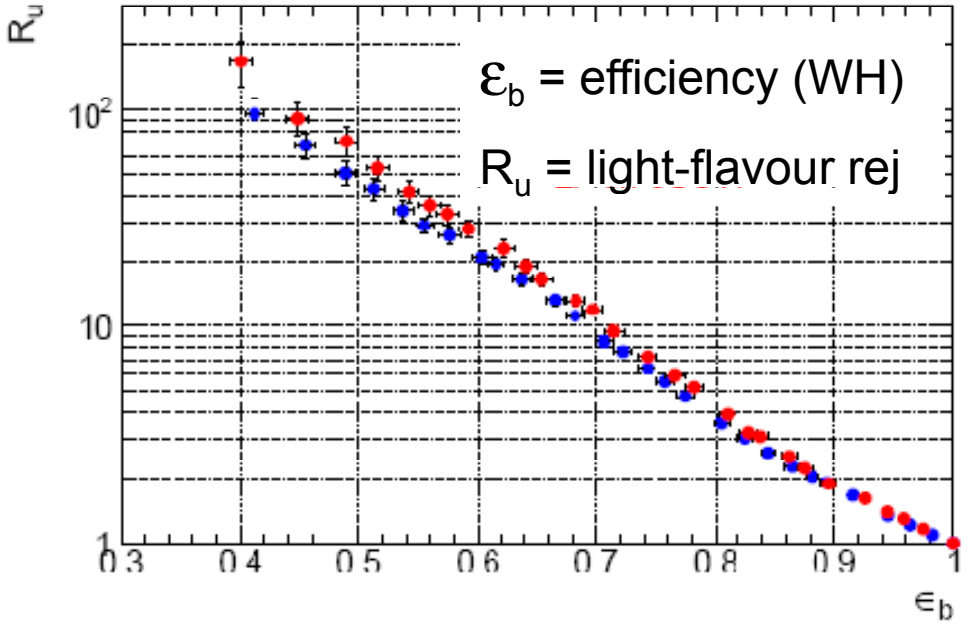
Figure: SumET resolution for J2 (left) and J4 (right) as function of the True SumET.

Diego Casadei, TAPM 17 July 2007

B-jet slice

- B-jet trigger to address multi b-jet final states
- Based on track impact parameter likelihood
- For 10^{31} : test signatures (very useful for searches)
  - 2 b-tag at HLT starting from 3 L1 jets
  - 3 b-tag at HLT starting from 4 L1 jets
- Plan to :
  - Optimise b-tag menu for high luminosities
  - Explore different methods based on secondary vertexing, signed impact parameter etc





B physics slice

- Many exclusive signatures to keep rate low
- Planning menu for various luminosities

- B-Physics group considering various luminosity scenarios for CSC notes:
- 10^{31} : ~100 pb^{-1} – Mainly for understanding the detector using J/ψ(μμ), J/ψ(ee), Υ(μμ), plus start to look at B->μμ, B->μμK*/φ and B->K*/φ γ. Use fullscan to find K*/φ
- 10^{32}: ~1 fb^{-1}: B->μμ(X) and B->K*/φ γ, B–>J/ψ, B->K*/φ γ
- 10^{33}: ~10fb^{-1}/yr Bs->D_sφπ/a1, B->J/ψK, B–>μμX, B->K*/φ γ etc.

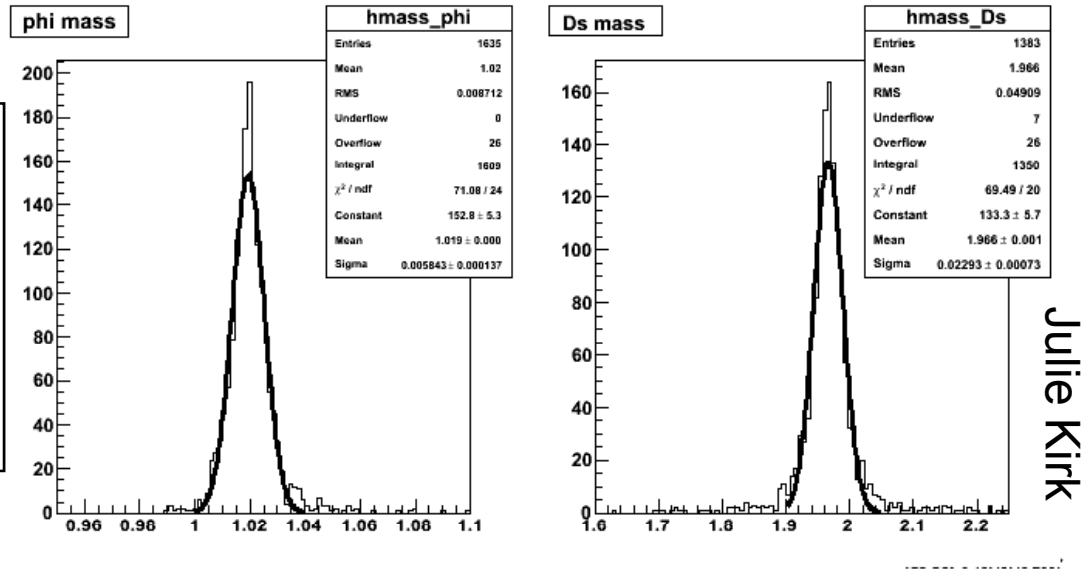
mu4 and fullscan based

mu6 and RoI based

John Baines, TAPM 18 Sep.07

L2
Φ mass 1019 +/- 6 MeV
Ds mass 1966 +/- 23 MeV

Widths in 12.0.6:
5 MeV and 22 MeV



Julie Kirk

Cosmics slice

- Level 2:
  - **TrigL2CosmicMuon** (RPC, MDT, TGC)
  - **TrigSegFinder** (TRT)
  - **IDSCAN** and **SiTrack** – not tested in real data yet, need SCT/Pixel
  - **TrigT2Calo** (LAr, Tile)
  - **TrigTileMuId**, **TrigTileRodMuAlg** (Tile)
- Event Filter:
  - **TrigEFIDCosmic**
  - **TrigMoore** (technical run)

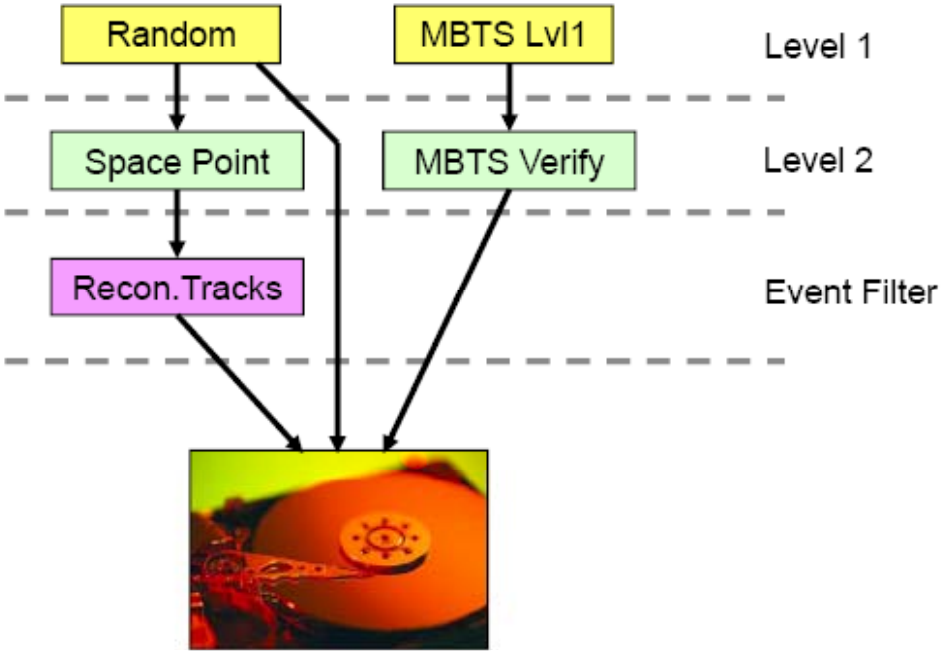
Algorithms have been tested:

- Offline on simulated cosmics and M3 data
- On the “preseries” using the real DAQ infrastructure
- Online in M4 (EF run for the first time!)
- During technical run

The HLT will run by default in M5 cosmic run

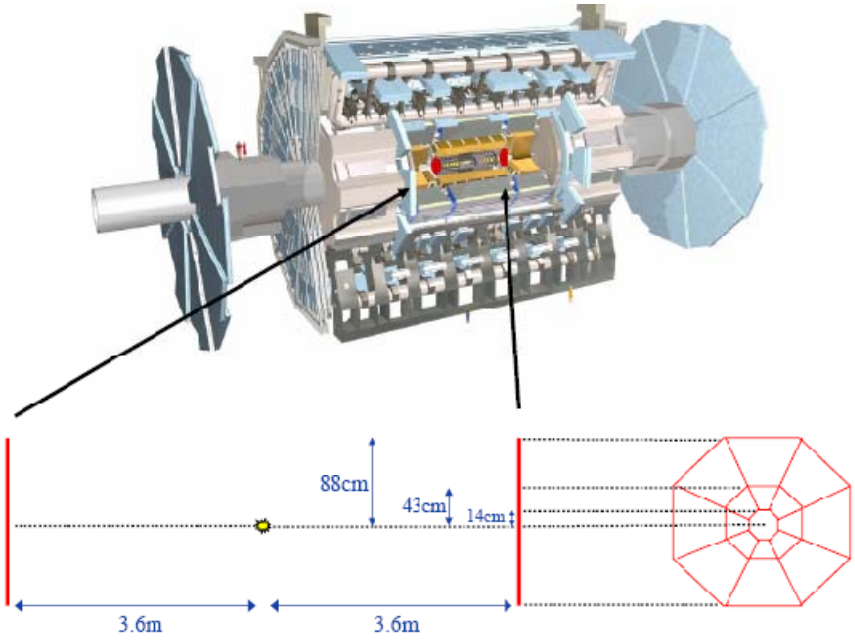
Minimum bias

- Essential for commissioning of trigger itself
- Too many empty bunch crossings during initial running for random trigger alone
  - ~10% interaction probability per bunch x-ing at $10^{31}cm^{-2}s^{-1}$
- For higher luminosity, essentially all bunch-crossings will produce detector activity
- Two triggers being studied:
  - Minimum Bias Trigger Scintillators (MBTS)
  - Track trigger



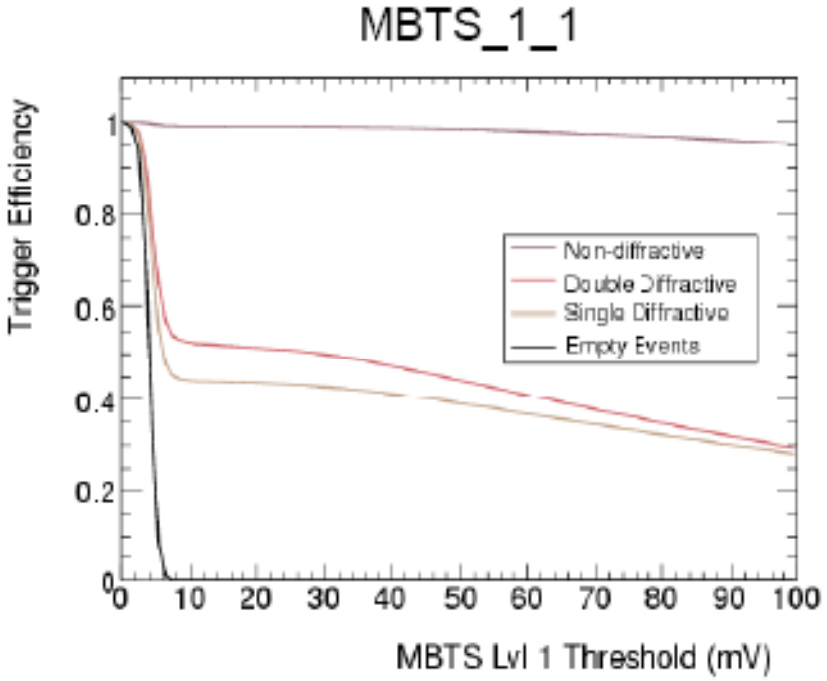
MBTS

Scintillators placed in front of the forward LAr calorimeters



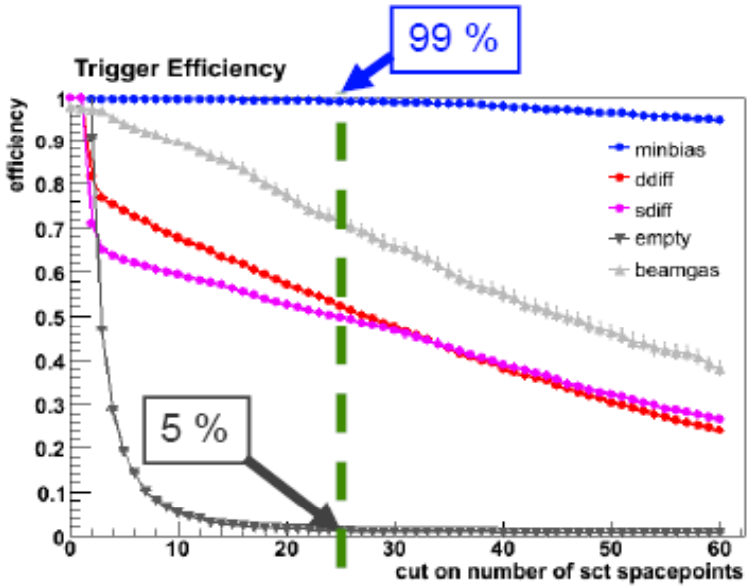
MBTS_2: ≥2 MBTSs fired
MBTS_1_1: ≥1 MBTS fired on each side

	MBTS_2	MBTS_1_1
Noise	0.05%	0.05%
Single Diffractive	68%	45%
Double Diffractive	82%	54%
Non-Diffractive	100%	99%

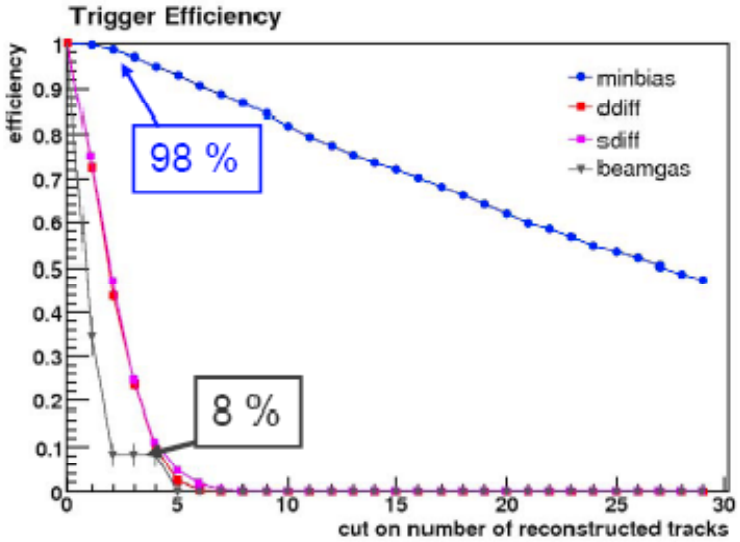


Track trigger

- Reject empty events by cutting on number of SCT space points
- Implemented in level 2 or event filter
- Reject beam-gas by requesting reconstructed tracks consistent with nominal vertex



Cut @ 25

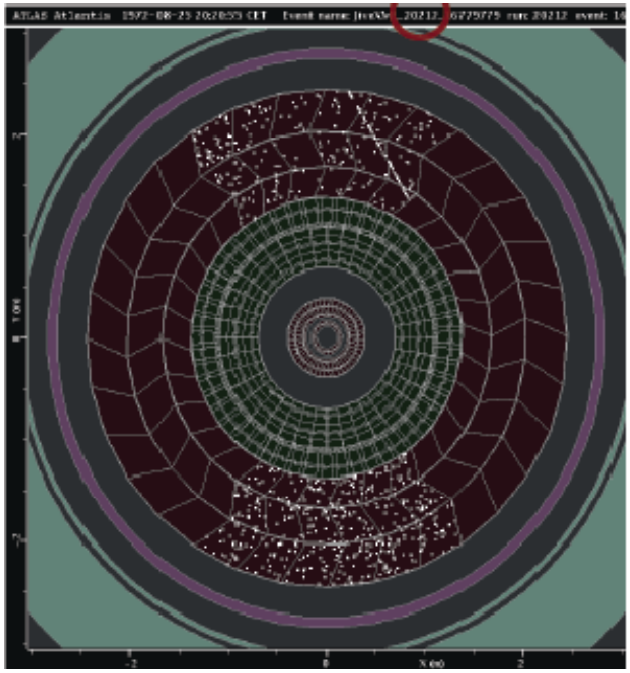


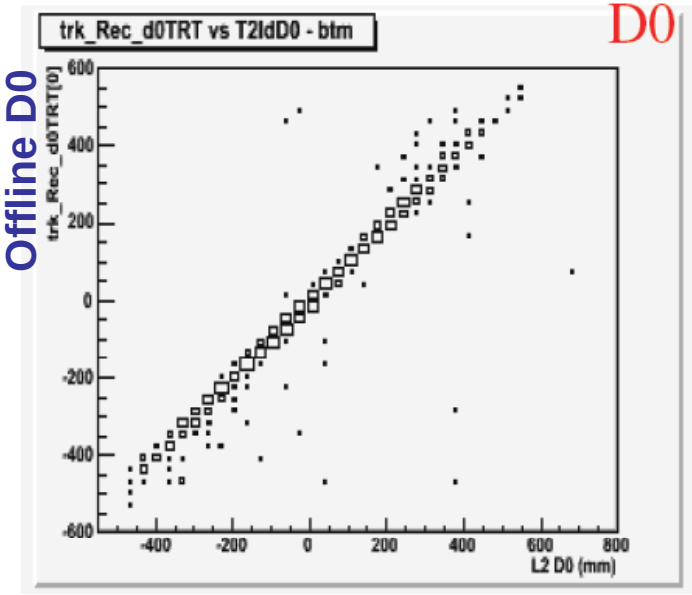
cut on 2 tracks with |z0|<250 mm

Online Algorithms

Cosmics run

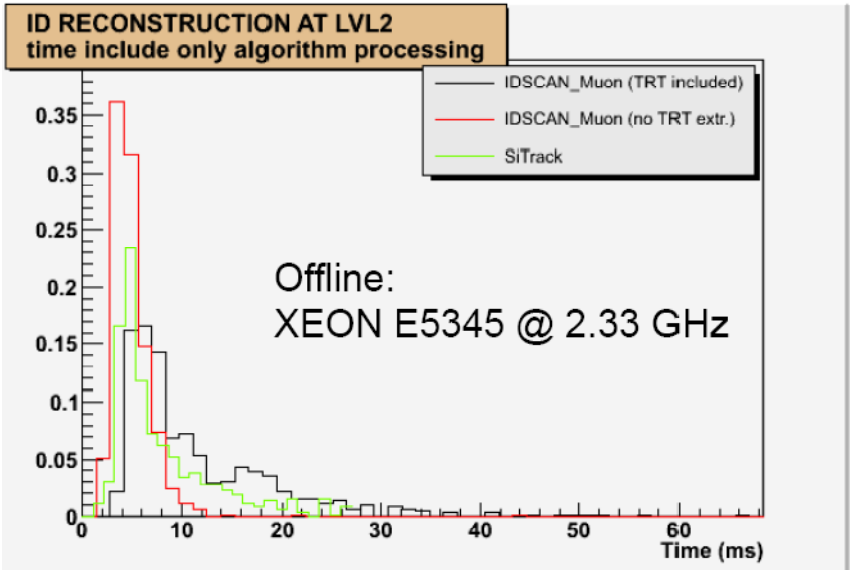
- See Imma's talk for more details
- M4 cosmic-ray run (August)
  - Trigger and DAQ systems ran on real data from:
    - Muons (RPC, MDT, TGC)
    - Calorimeter (LAr, Tile)
    - Inner Detector (TRT)
- Level 2 tracking algorithm (TrigSegFinder) run online for the first time
- Event Filter algorithms run online for the first time





Technical run

- Technical run in September
  - See Imma's talk
  - High-Level Trigger ran in online framework on preloaded event fragments pre-selected by Level 1
  - Used a normal nightly from ~3 days before 13.0.30 build
  - Code running online just a few days later
    - Reflects both integration experience and the health of SW



Menu for technical run:

Electrons: e10, e25i, 2e15i, Zee, Jpsiee
Photons: g10, g60, 2g20i
Jets: jet20, jet160, 2jet120, 3jet65, 4jet50
Muons: mu6i, mu6, mu20i
Taus: tau10, ta10i, tau15, tau20i, tau25i, tau35i
MissingET: xe15, xe20, xe25, xe30, xe40, xe50, xe70, xe80
TotalE: te100, te304, te380
Bjet: b35 (being tested)
Bphyics: being implemented

Imma Riu, TAPM 2 October 2007

Conclusions

- Since release 12, the trigger software has become part of the code that is run in normal Monte Carlo productions; and trigger studies are now commonplace within physics analyses

- Many essential changes were introduced in release 13 (in a rather short time)
  - New steering, including support for online monitoring of algorithms
  - New python configuration
  - New trigger menu for initial running

- Much of this code has also been successfully tested online with the final DAQ infrastructure and with real data

- There is still much to do, of course, but the next year will be very interesting for trigger algorithms

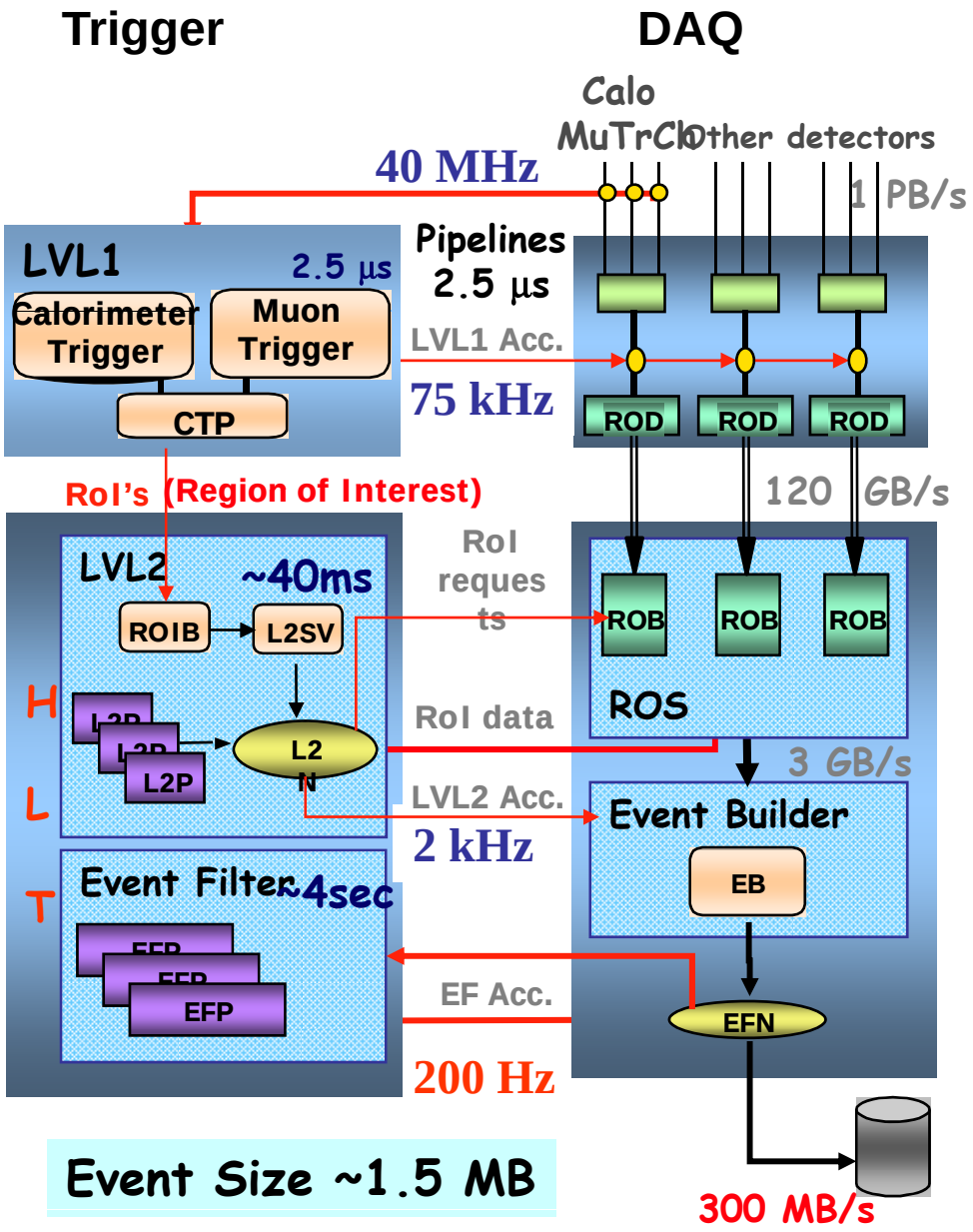
Backup

- Three trigger levels:
- Level 1:
  - Hardware based
  - Calorimeter and muons only
  - Latency 2.5 μs
  - Output rate ~75 kHz

- Level 2: ~500 farm nodes(*)
  - Only detector **"Regions of Interest" (RoI) processed - Seeded by level 1**
  - Fast reconstruction
  - Average execution time ~40 ms(*)
  - Output rate up to ~2 kHz

- Event Builder: ~100 farm nodes(*)

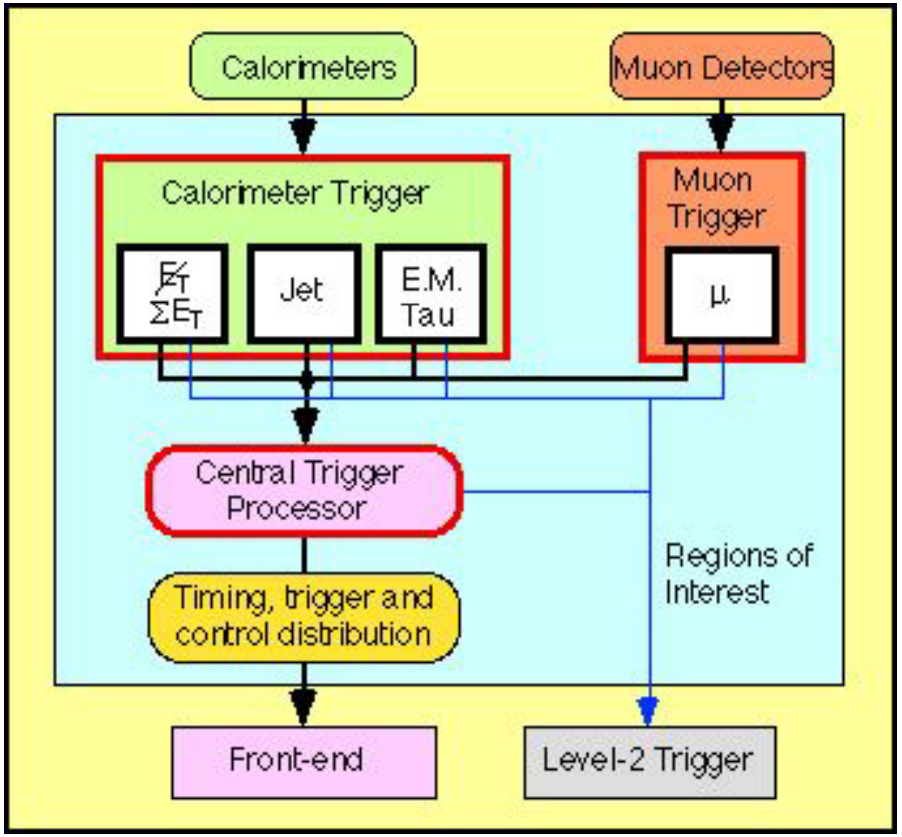
- Event Filter (EF):~1800 farm nodes(*)
  - Seeded by level 2
  - Potential full event access
  - Offline algorithms
  - Average execution time ~4 s(*)
  - Output rate up to ~200 Hz



(*) 8CPU (four-core dual-socket farm nodes at ~2GHz

Level 1 architecture

- Level 1 uses calorimeter and muon systems only
- Muon spectrometer:
  - Dedicated trigger chambers
    - Thin Gap Chambers – TGC
    - Cathode Strip Chambers – CSC
- Calorimeter:
  - Trigger towers group calorimeter cells in coarse granularity: $\Delta\eta\times\Delta\varphi = 0.1\times0.1$ (EM/Tau); $\Delta\eta\times\Delta\varphi = 0.2\times0.2$ (Jets)
- Identify regions of interest (RoI) and classify them as MU, EM/Tau, Jet
- Information passed to level 2:
  - RoI type & threshold passed
  - Location



The response of the level 1 hardware is emulated in Athena.

High Level Trigger architecture

Basic idea:

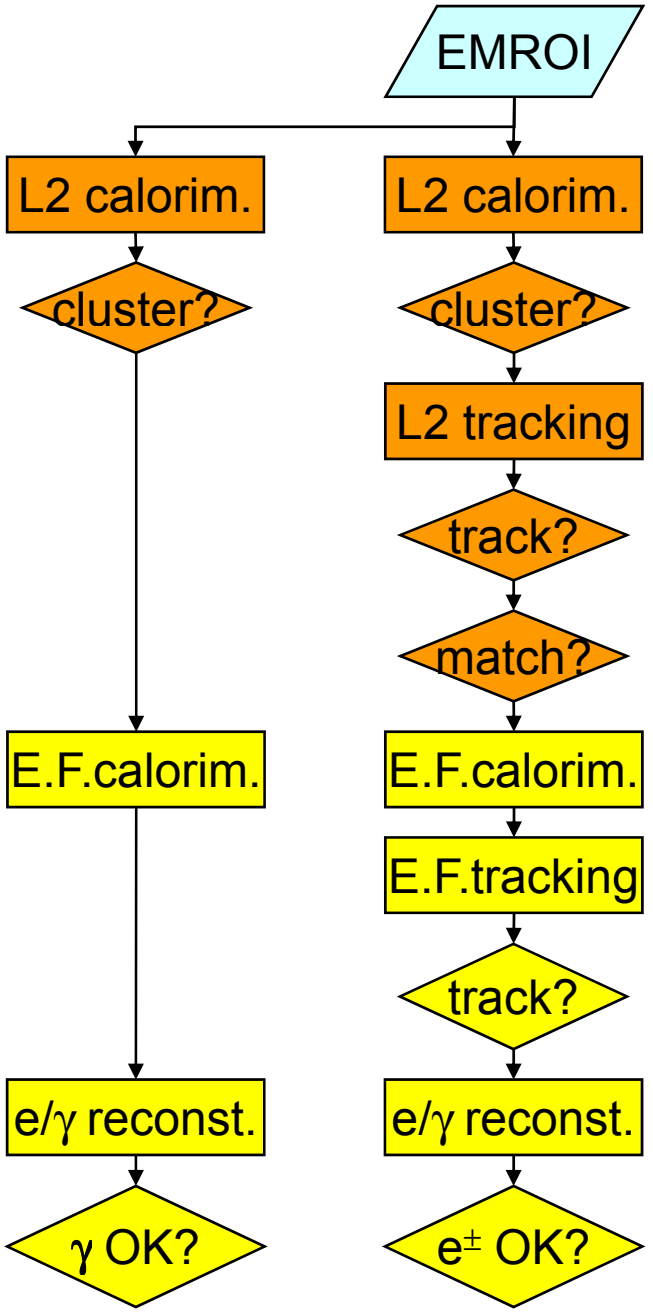
- ***Seeded* and *Stepwise* Reconstruction**
- Regions of Interest (RoI) *"seed"* trigger reconstruction chains
- Reconstruction ("Feature Extraction") in steps
  - One or more algorithms per step
- Validate step-by-step in "Hypothesis" algorithms
  - Check intermediate signatures
- Rejects hypotheses as early as possible to save time

Note:

- Level 2 accesses only a fraction of the full event
  - Only ~2% of event shipped over the network from the Read Out Buffers (ROBs), on average
- Full event building may happen only at Event Filter (EF):
  - EF will be seeded by L2

Steering

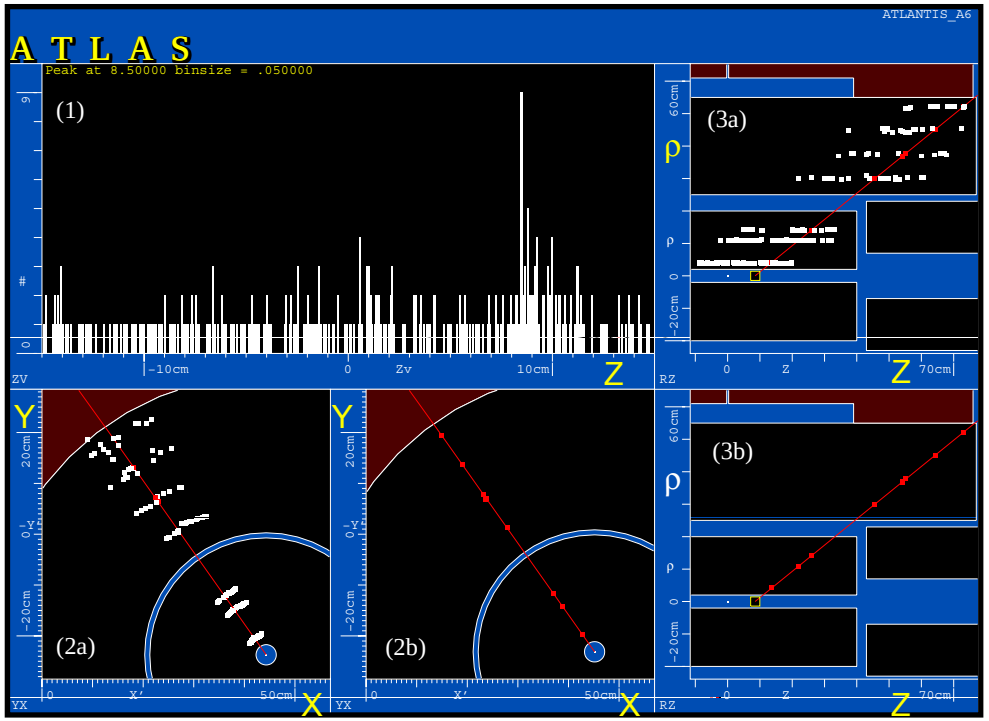
- Algorithm execution managed by Steering
  - Based on static trigger configuration
  - And dynamic event data (RoIs, thresholds)
- Step-wise processing and early rejection
  - Chains stopped as soon as a step fails
  - Reconstruction step done only if earlier step successful
  - Event passes if at least one chain is successful
- Prescale (1 in N successful events allowed to pass) applied at end of each level
- Specialized algorithm classes:
  - Topological: e.g. 2 μ with $m_{\mu\mu} \sim m_Z$
  - Multi-objects: e.g. 4-jet trigger
  - etc…



Example: level 2 tracking algorithm

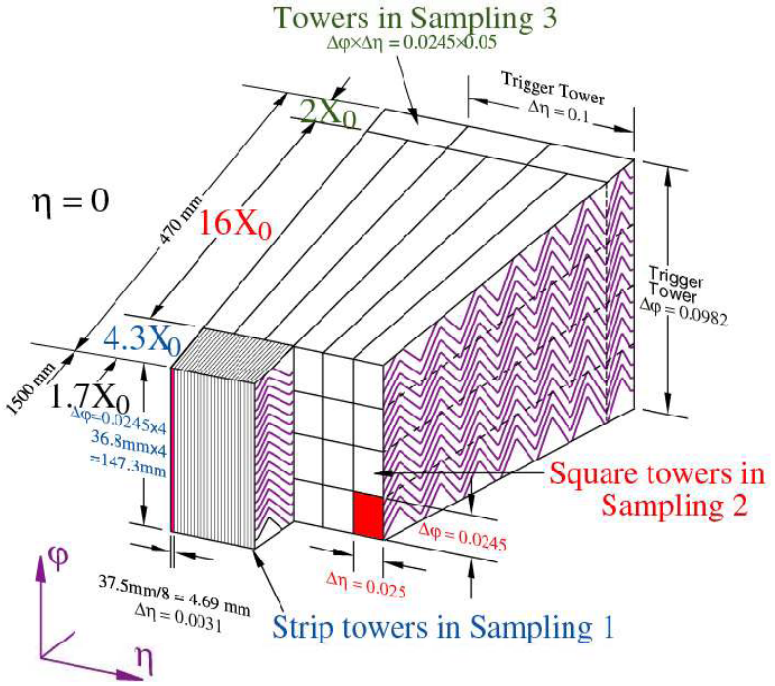
1. Form pairs of hits in Pixel and SCT in thin ϕ slices;
   - extrapolate inwards to find Z_{vtx} from a 1D histogram
2. Using Z_{vtx}, make 2D histogram of hits in η-ϕ plane;
   - remove bins with hits in too few layers
3. Do 2D histogram using space point triplets in $1/p_T$-ϕ plane;
   - Form tracks from bins with hits in >4 layers
4. Use Kalman technique on the space points obtained in previous steps
   - Start from already estimated parameters: Z_{vtx}, $1/p_T$, η, ϕ

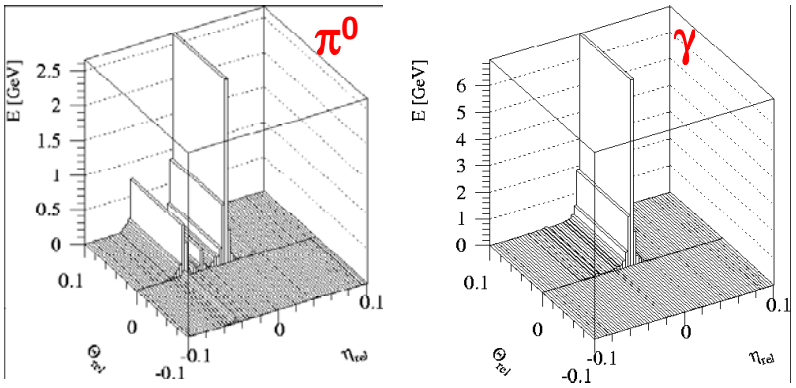
- Full granularity but short time
- Algorithms optimised for execution speed, including data access time
- Produce level 2 tracks

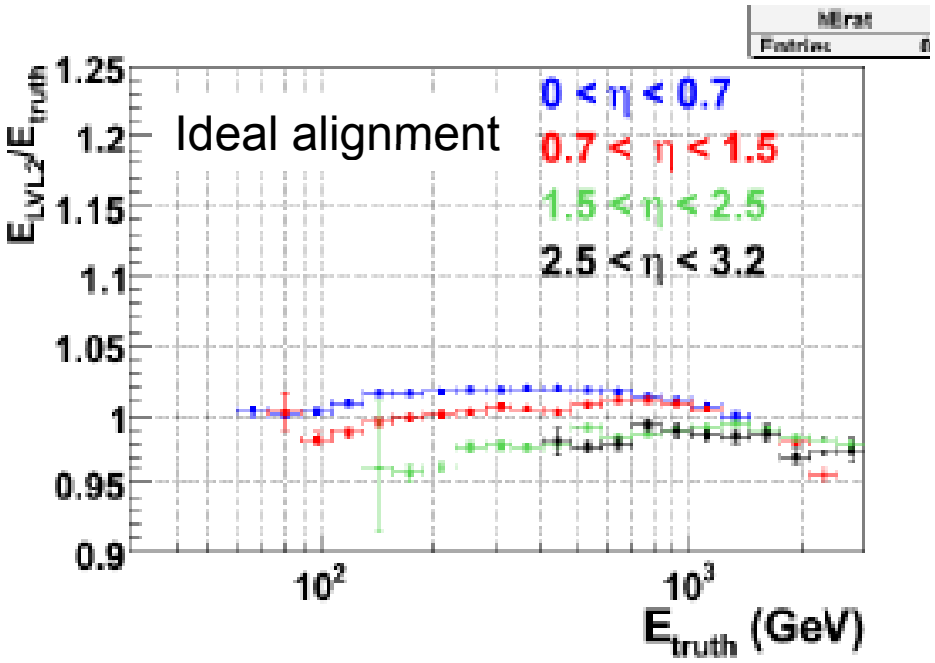


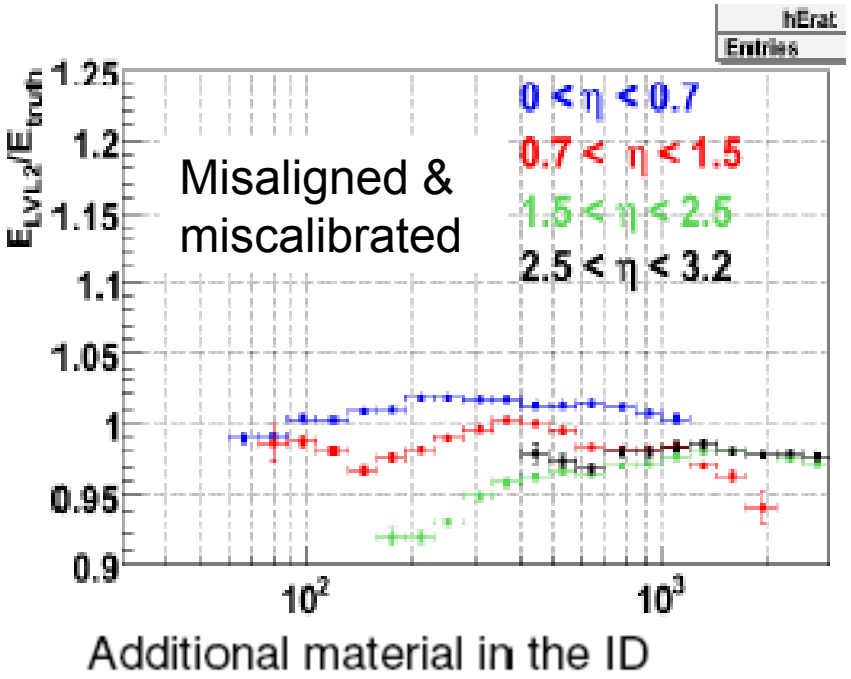
Example: level 2 e/γ calorimeter reconstruction

- Full granularity but short time and only rough calibration
- Reconstruction steps:
  1. LAr sample 2; cluster position and size (E in 3x3 cells/E in 7x7 cells)
  2. LAr sample 1; look for second maxima in strip couples (most likely from $\pi^0 \rightarrow \gamma\gamma$, etc)
  3. Total cluster energy measured in all samplings; include calibration
  4. Longitudinal isolation (leakage into hadronic calorimeter)
- Produce a level 2 EM cluster object (note EDM different from offline)





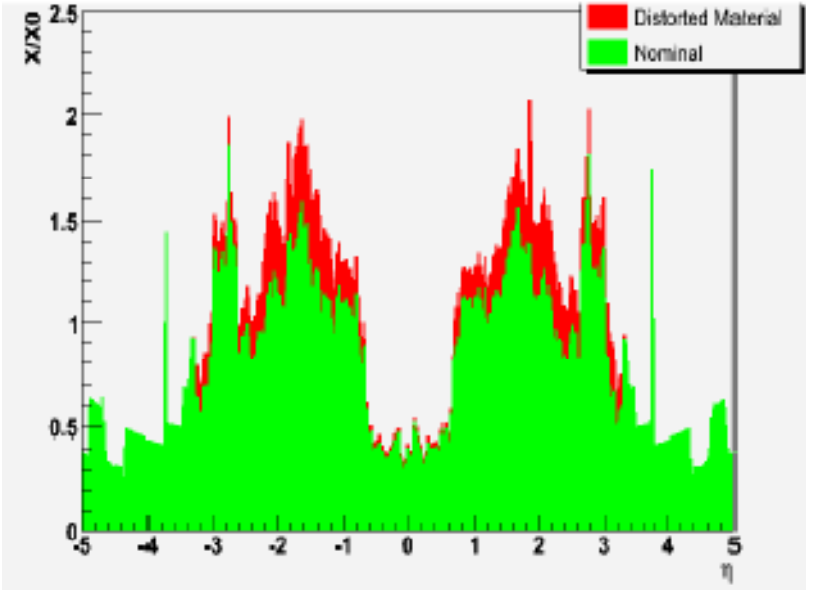




L2 Jets:

- Misaligned data also includes extra material
- This distorts the Energy scale wrt ideal geometry
- Overall, jet energy scale at L2 within ~5%

Additional material in the ID



Patricia Conde, TAPM 2 October 07