ATLAS Level 1 Trigger Study

b-Jet Efficiency

David W. Miller

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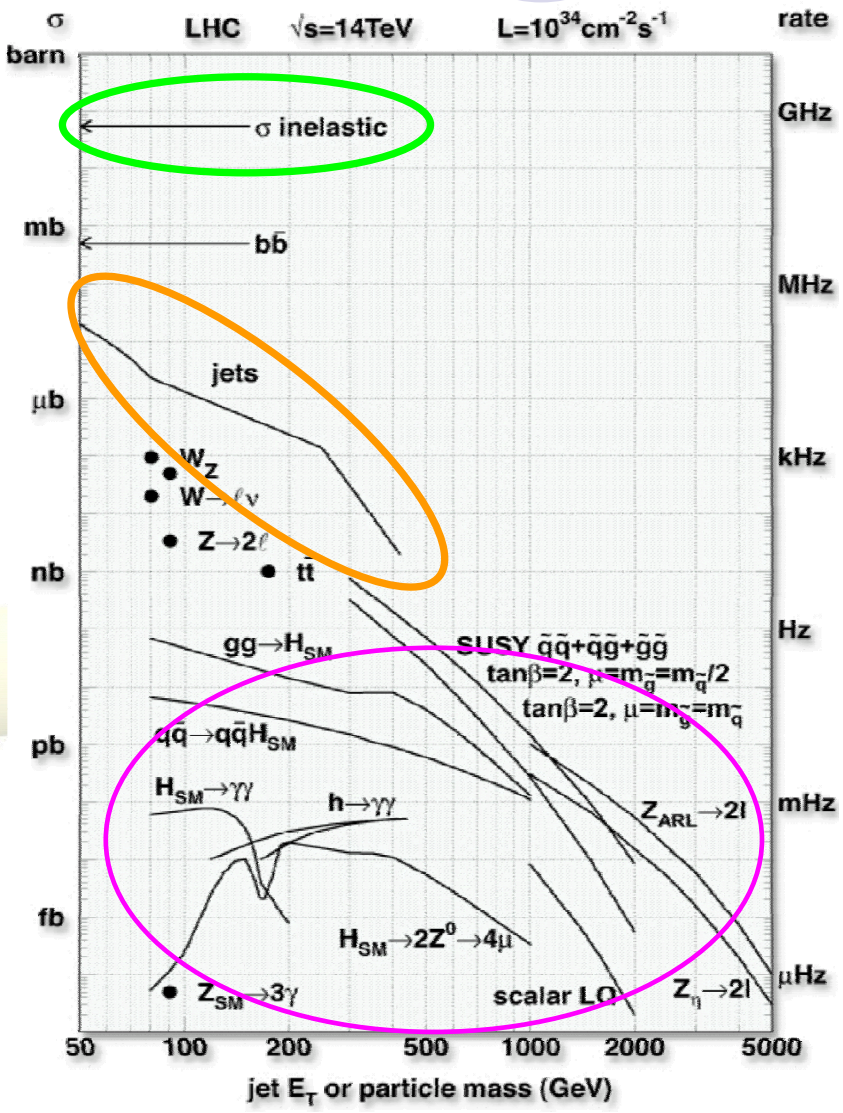
The aim of this study

- Understand simulated detector performance to jet kinematics relevant at the LVL1 trigger
  - Jet energy reconstruction at LVL1
  - Jet position resolution w.r.t truth jet at LVL1
  - Variation of response vs. η and E_T
- Generate and use a data sample of relevant physics events:
  - *bbA, A→bb (m_A=200 GeV, tanβ=20)*
  - Expect 4 b-jets in the detector
- Study the actual LVL1 Jet trigger efficiency and "turn-on" curve for this sample using the standard ATLAS ATHENA framework.
- Allow for a future parameterization of the LVL1 trigger efficiencies directly from event-generator level physics samples.

Summary of what lies ahead

- Brief introduction to ATLAS trigger system
  - Trigger design and architecture
  - Comments on implementation and expectations
- The physics channel of interest
  - Why pick this one?
- Validation of the simulated events and detector cross-checks
  - General detector performance
- Results of the study and possibilities for improvement
  - Jet trigger efficiency at LVL1

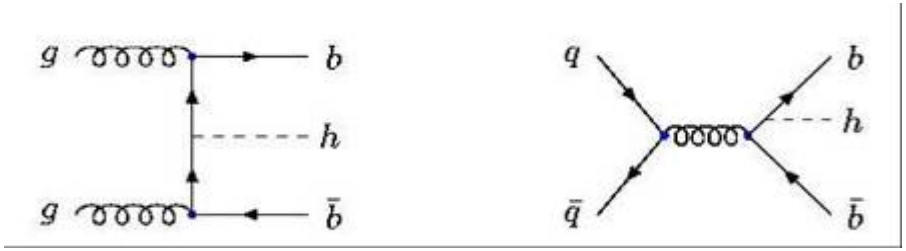
The ATLAS Environment



- Much of this is "not interesting"
  - But need to know what is being "thrown away"
- Jets will then dominate over all other interesting events….
- We must understand trigger biases on these events to get to the ones we REALLY want!
- *However, one person's signal is another person's background*
- More importantly, what's **NOT interesting today**, might be a graduate student's thesis **tomorrow**!

The physics: MSSM bbH/A, H/A→bb

- ATLAS TDR: "*Final states containing four b-jets have been proposed as signatures with a substantial discovery potential for heavy Higgs bosons in supersymmetric models*."

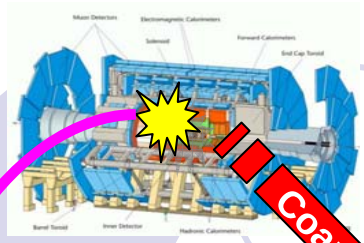


- Phase space at large tanβ remaining / favored
- Large tanβ sees enhancement of bbH/A relative to SM
  - Extremely active pursuit of this channel at Tevatron
- QCD background is extremely high, need very good understanding of trigger efficiency and fake rates

- LVL1 trigger study of this physics channel will draw conclusions not limited only to bbH/A
- Develop important tools for understanding efficiencies for many types of events

- Knowing well what the efficiencies of the LVL1 trigger are as a function of truth jet or quark initiator energies will allow us to quickly study the parameter space for models such as this one.

3-Level Trigger System:



Fully Digitized Data

Coarse Data

="MIGHT BE INTERESTING"

Memory

L1 Accept

LVL1 Trigger Processor

FPGA's

ROI

Full Data, from ROI

ROS

L2 Accept

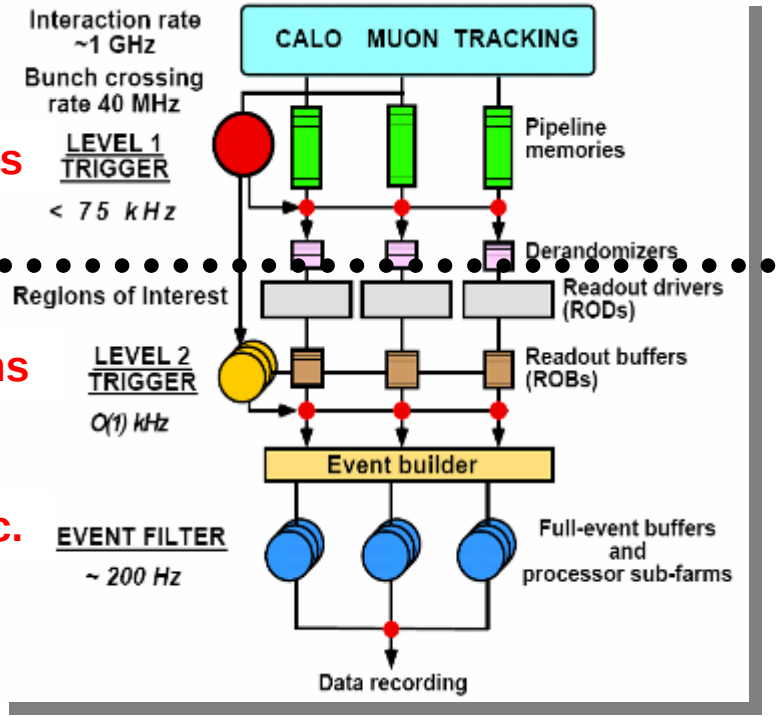
="IS INTERESTING"

TO PROCESSOR FARMS

LVL2 Trigger Processor

CPU's

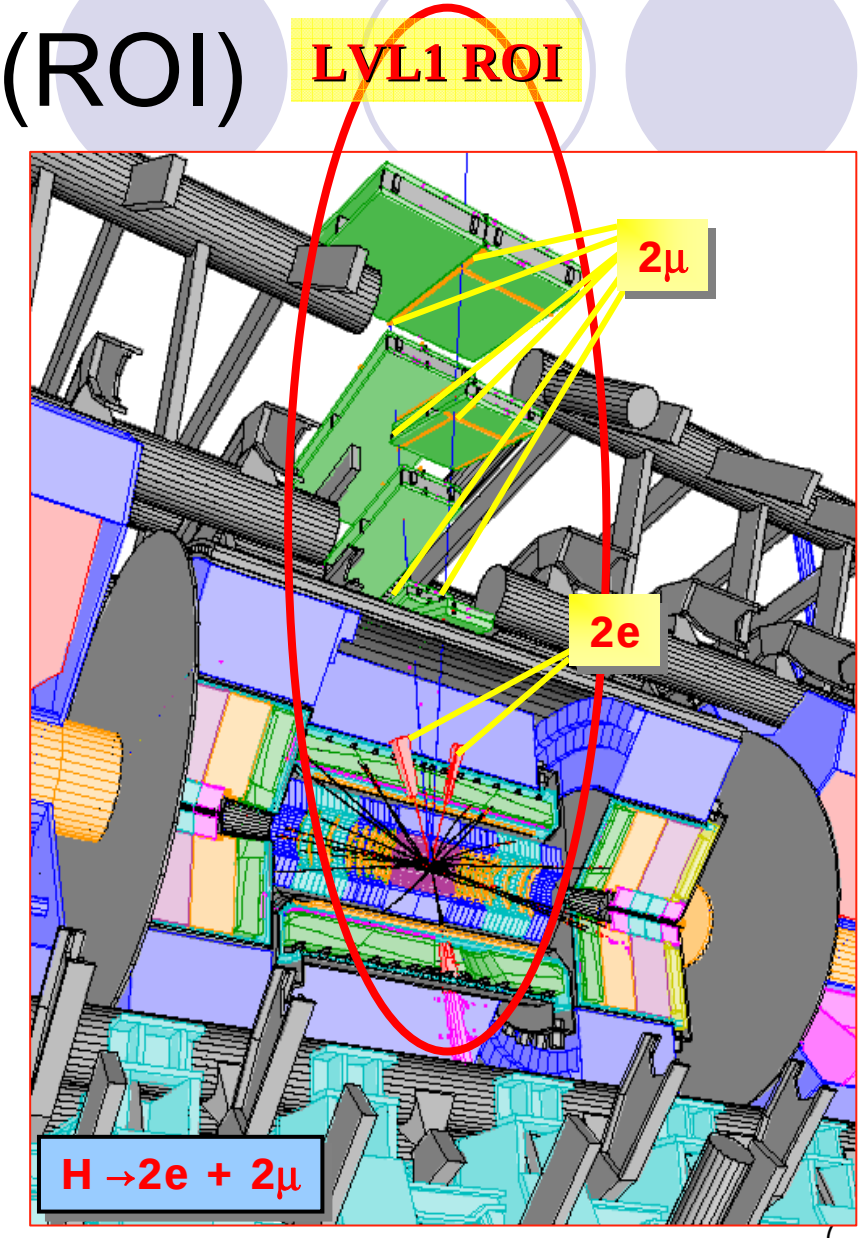
An intuitive picture of the ATLAS Trigger System architecture



A technical picture of the ATLAS Trigger System architecture

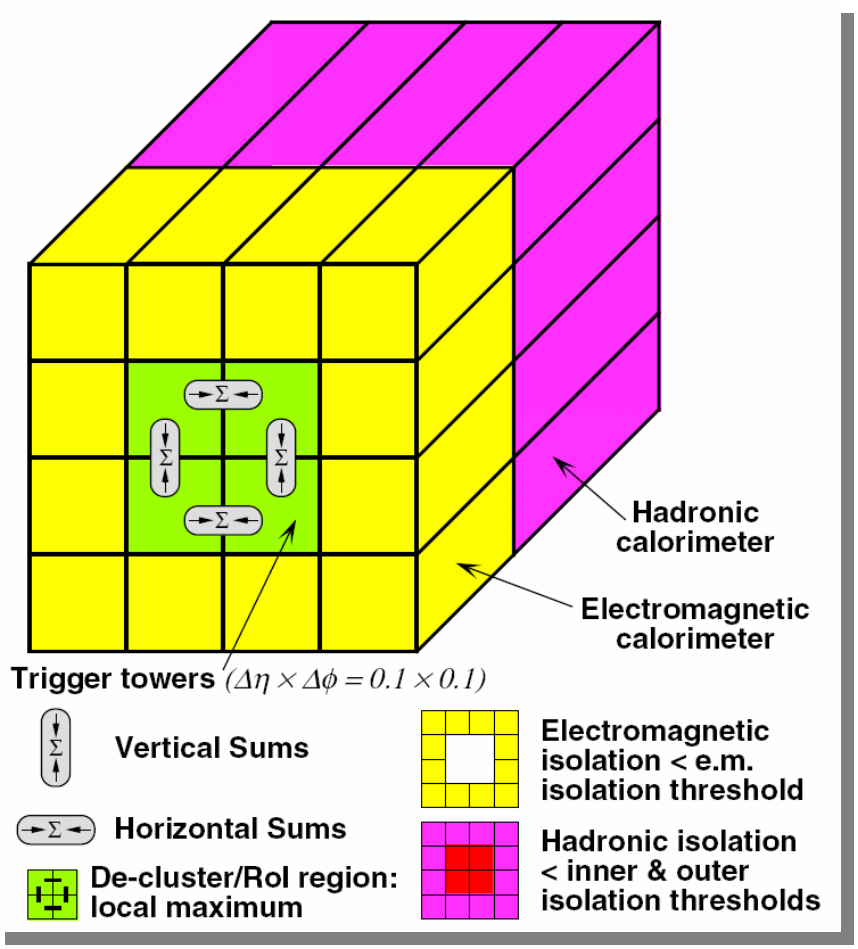
Regions of Interest(ROI)

- Level-2 trigger relies only on regional information from the LVL1 about ***where*** the interesting event occurred
  - LVL1 "seeds" the LVL2 trigger
- Very short time allowed for LVL2 decision
  - Seeding necessary for full granularity to be available at LVL2
- To evaluate the **Jet Trigger Efficiency** we will rely heavily on this fact



Level 1 Jet Triggering

- Sensitivity to these bbH/A(H/A→bb) will derive from our ability to trigger on their jets
- The L1 Jet trigger includes 3 algorithms for jet energy calc:
  - 4x4, 6x6, 8x8 calorimeter cell clusters
- In order to evaluate the L1 performance, we must assess the variation versus cluster size, η range and E_T



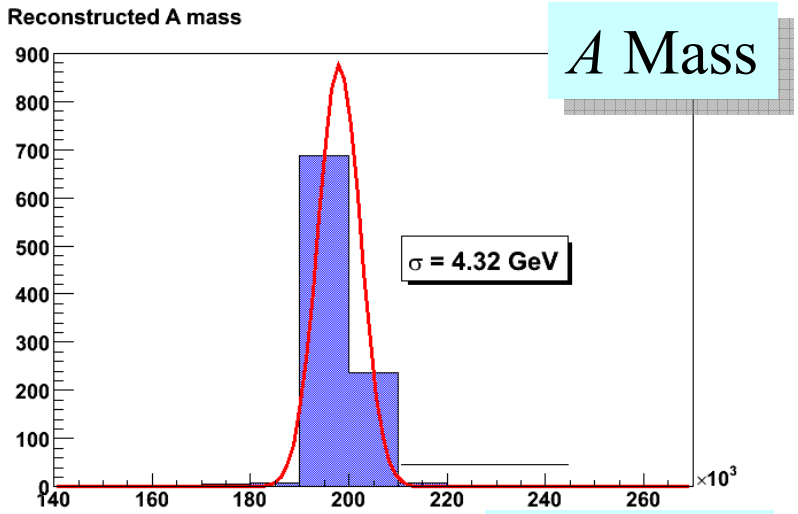
How can we evaluate the LVL1 Trigger performance?

- Generate a sample of interesting physics events and relevant to the LVL1 trigger
- Assess the response of the trigger simulation to simulated events
- Generalize the result in an effort allow fast evaluation of trigger efficiency for physics

1. Attempt to match all jets (reco and truth) to final state b-quarks
2. Take closest jet to b (cut $\Delta R < 0.5$) then count this as a jet representing a b, and should have triggered
   - R ≡ 3D angular separation in η,φ
3. Access the LVL1 ROI information and see if this jet did, indeed, trigger an ROI
4. Define the efficiency as:

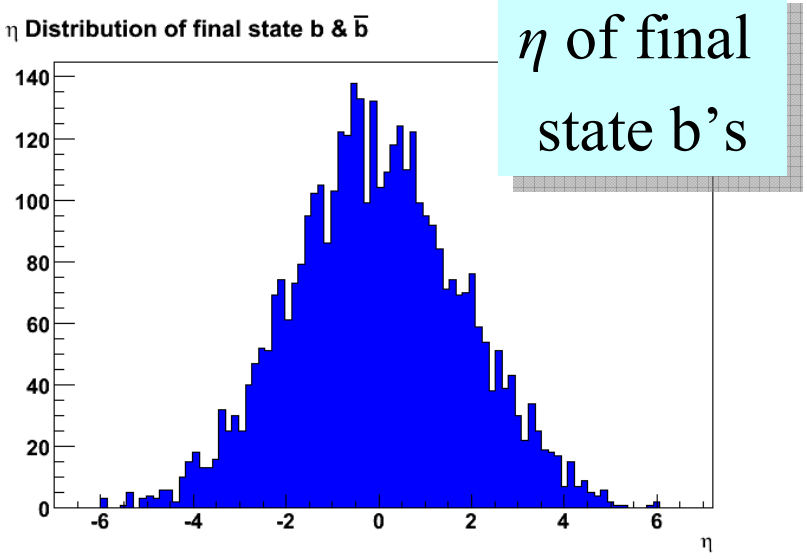
$$Eff = \frac{\#\,\text{b-Jets with matching LVL1 ROI}}{\#\,\text{Jets matched to b-quarks} (\equiv \text{b-Jets})}$$

Kinematics of the final state b-quarks

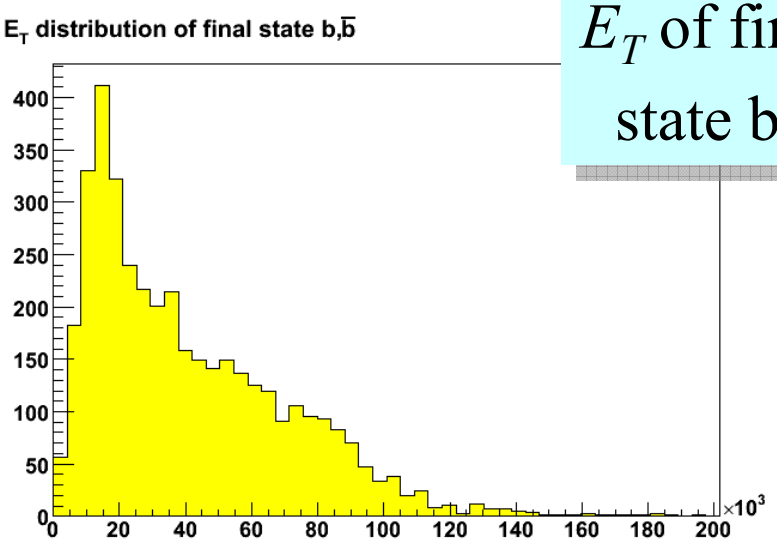


A Mass

- 950 bbA (A→bb) produced (m_A=200 GeV)
- Reconstructed mass from truth particles as expected
- ~6% include extra b's from gluon decay to bb

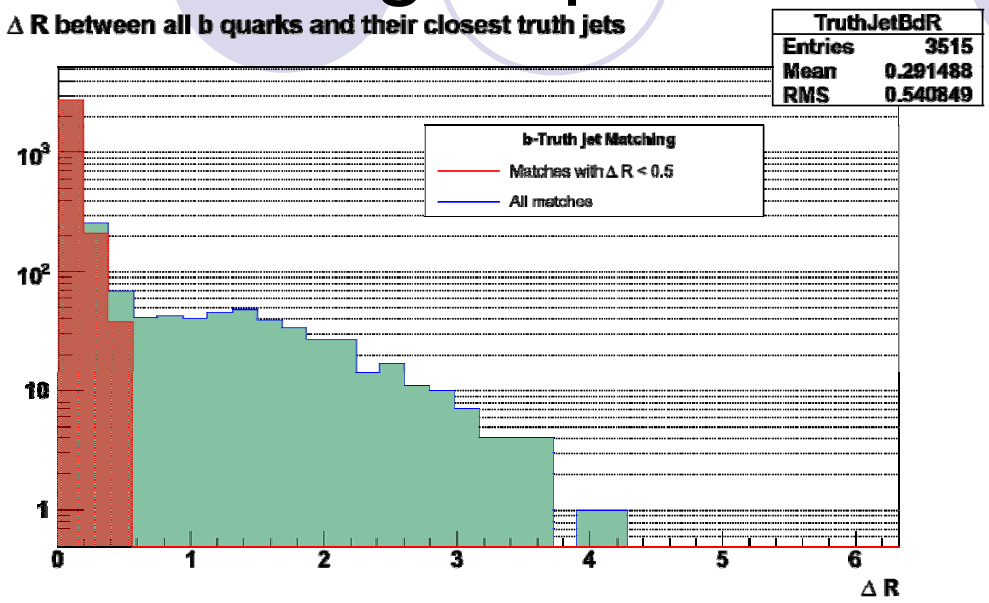


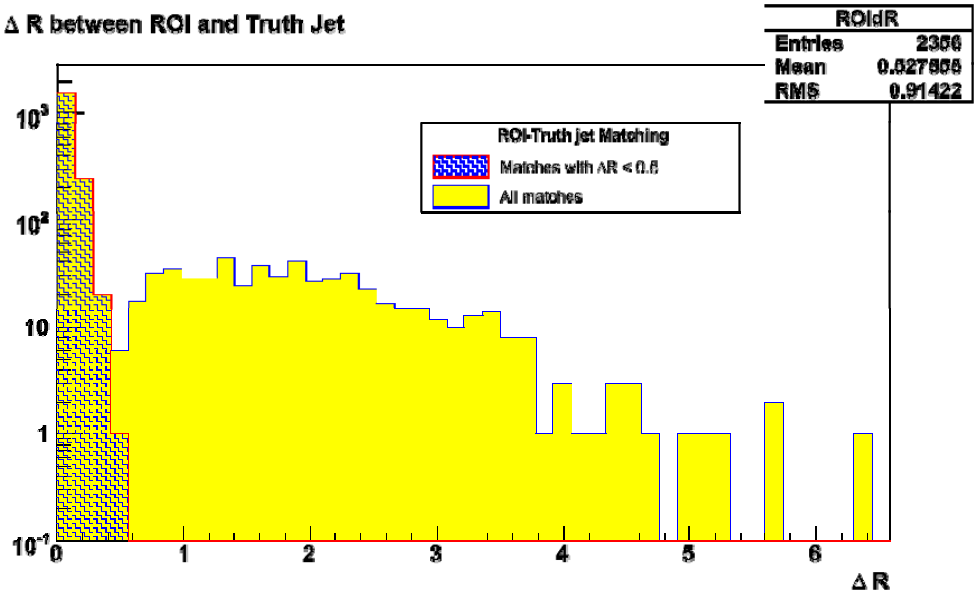
η of final state b's



E_T of final state b's

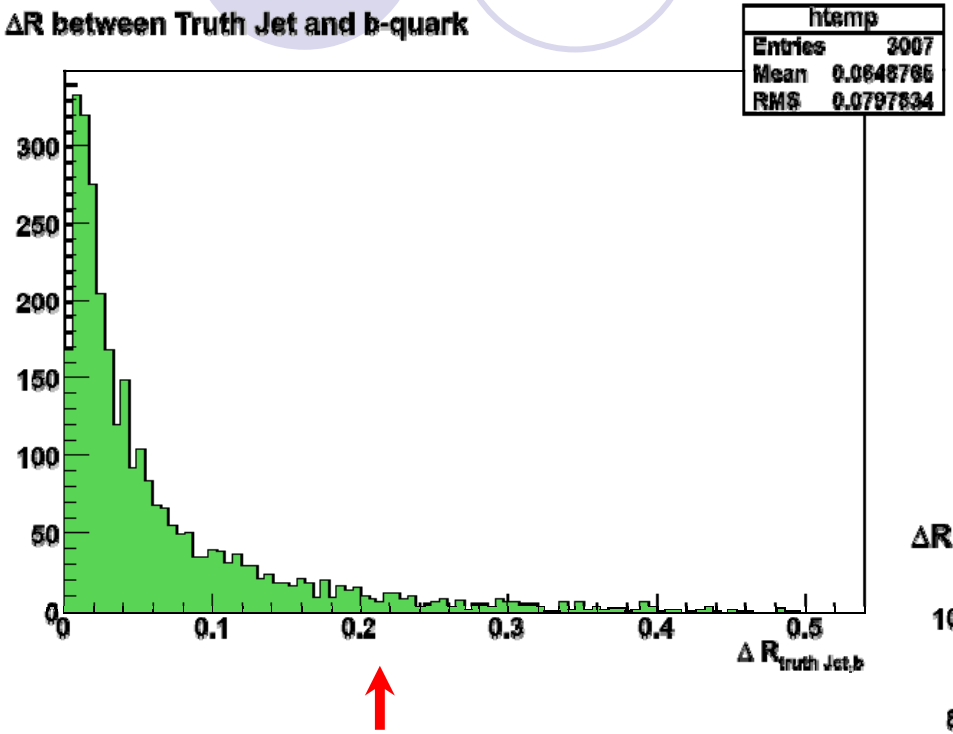
Matching b-quarks → truth jets → L1 ROI





- Jet trigger efficiency *per jet* depends on ability to match the jet to the correct ROI (if it exists).
- Truth Jet matching to final state b's shows ~14% of b's far from closest truth jet
  - b ISR causing the jet could explain this
- Correspondingly, ~22% of ROIs are not matched to truth jets from final state b's
  - This will degrade the jet trigger efficiency depending on what we call a match!

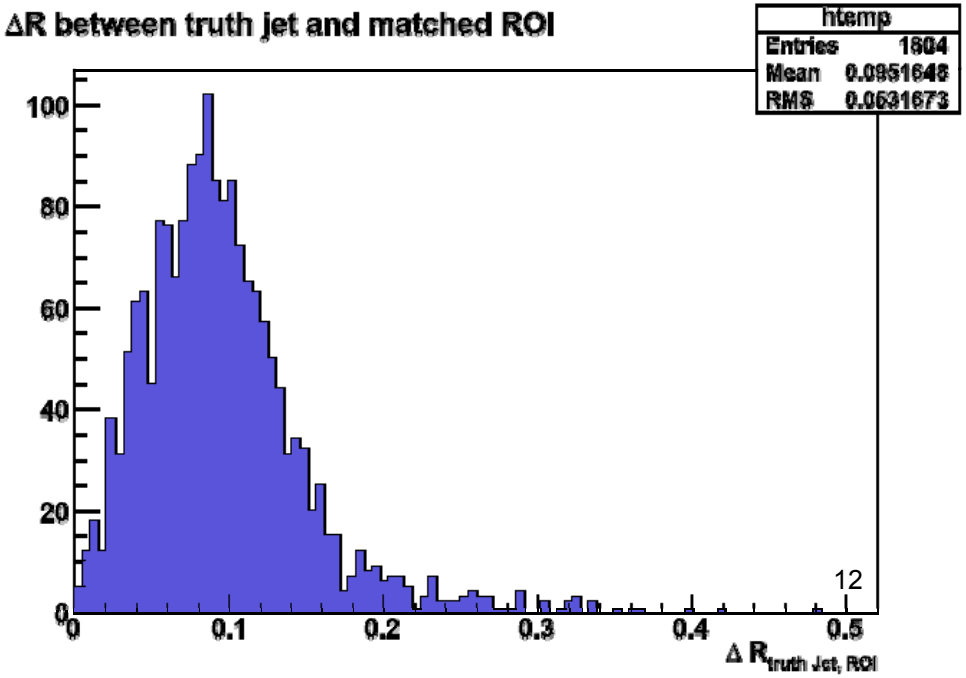
Position Resolution



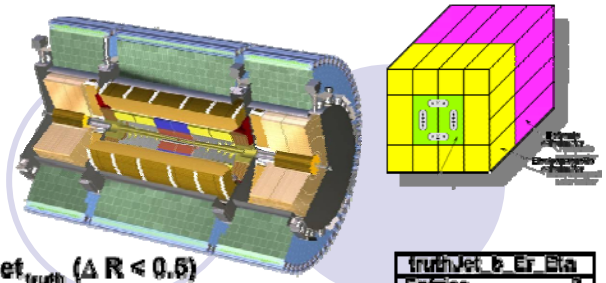
- Assuming a good match, what is the position resolution we can achieve?
  - ΔR < 0.5 between the two objects

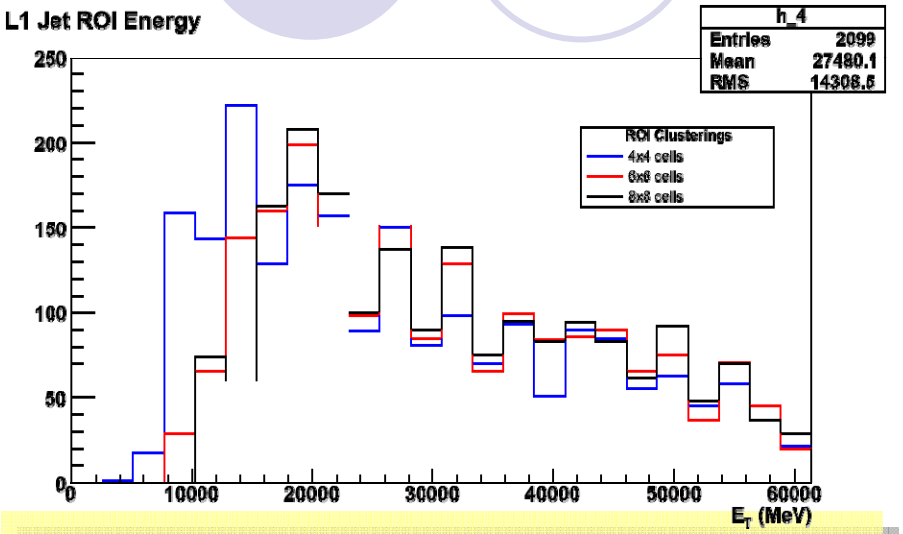
- Position resolution of the truth b-quark and the truth jet

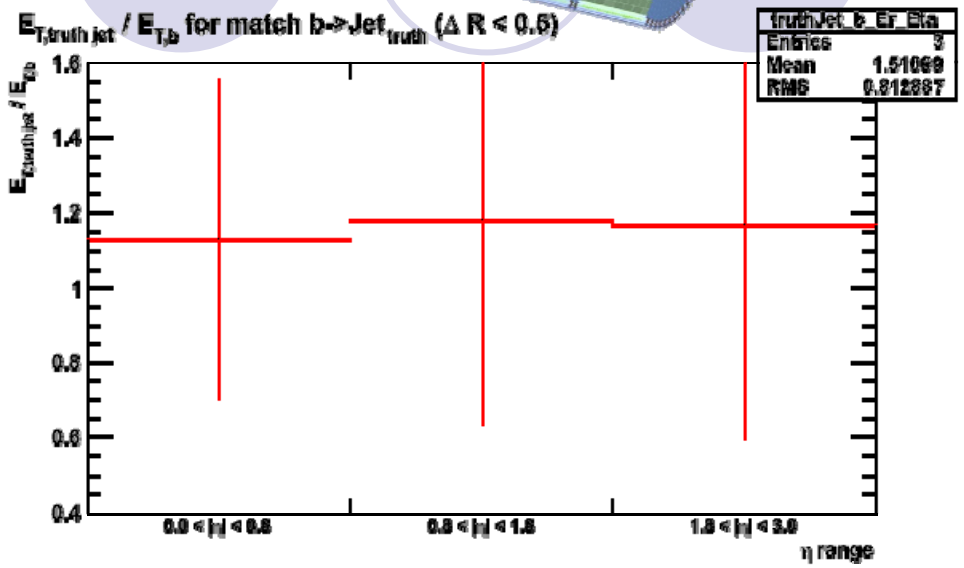
- Position resolution of ROI and truth jet

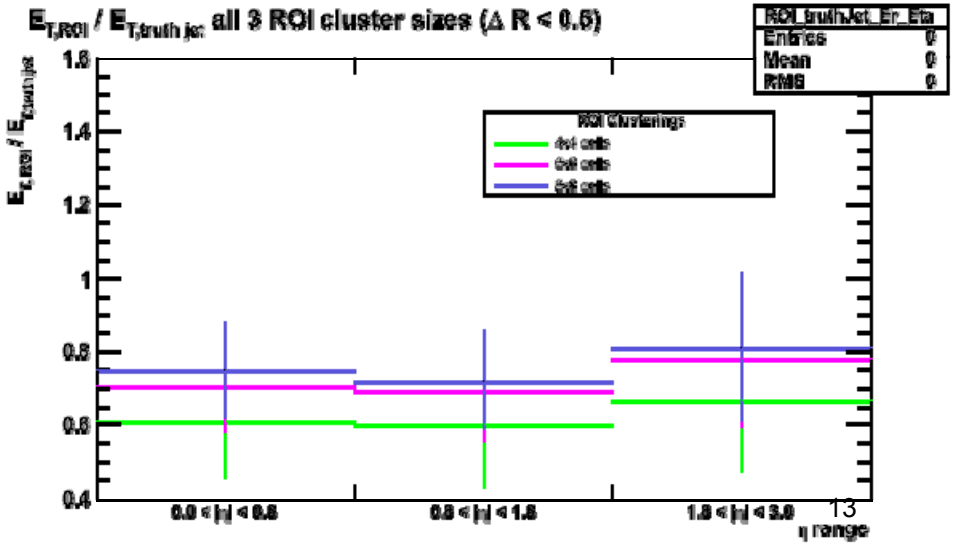


LVL1 Jet E_T versus η_{truth}



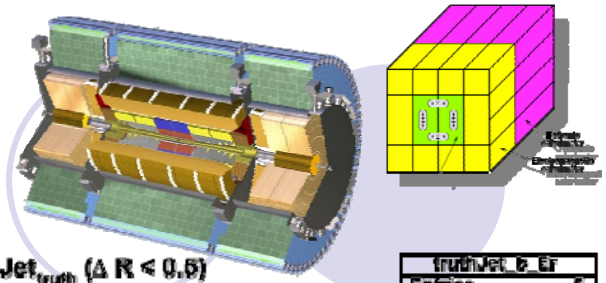


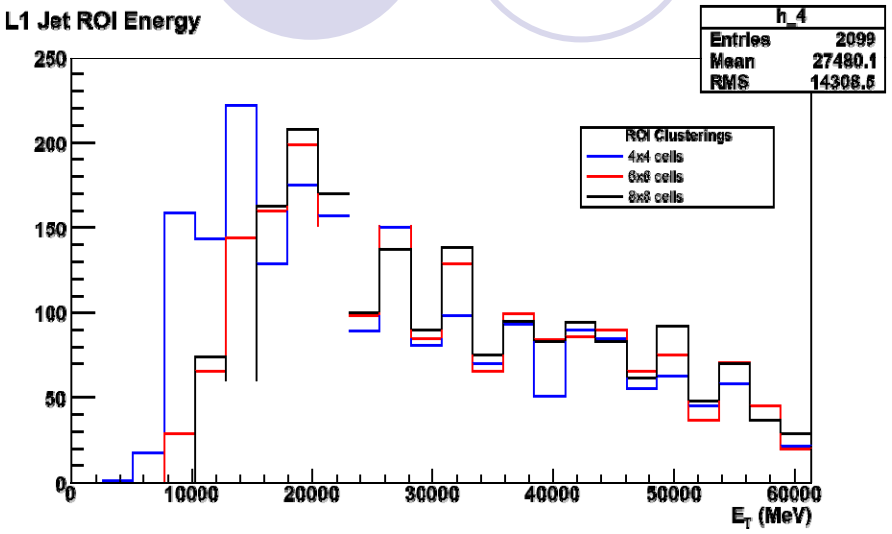


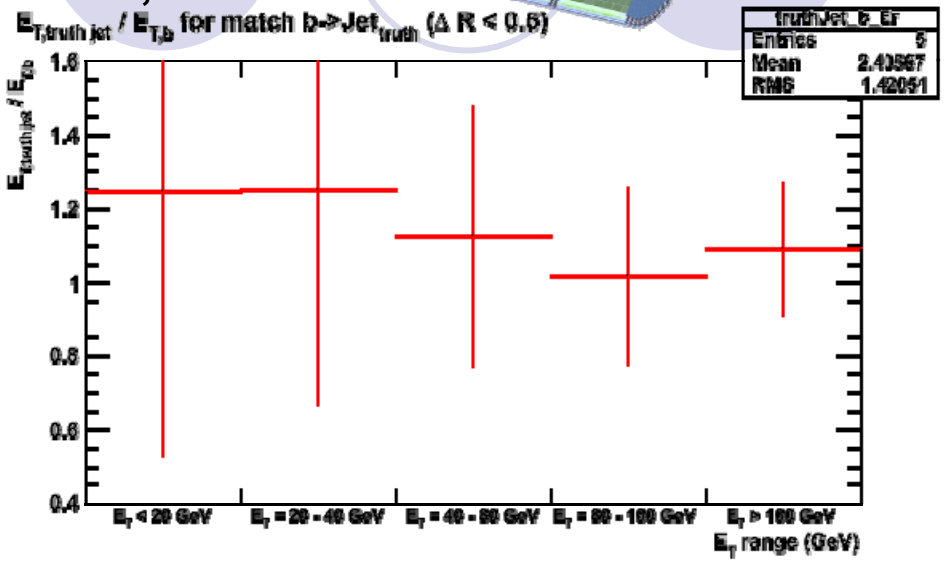


- Larger clusters → higher energy estimates *(for this sample)*
- Truth jet E_T slightly higher than b
- η response quite uniform
  - Presumably due to good calibration
- All 3 cluster sizes underestimate jet energy by ~20-40%
  - **Need this ratio to normalize jet trigger thresholds**

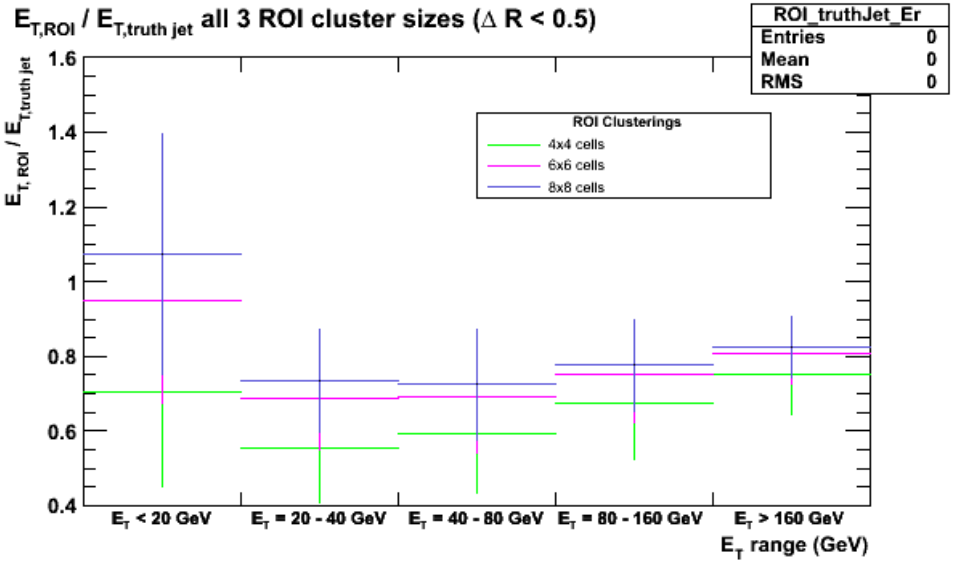
LVL1 Jet E_T versus $E_{T,truth}$





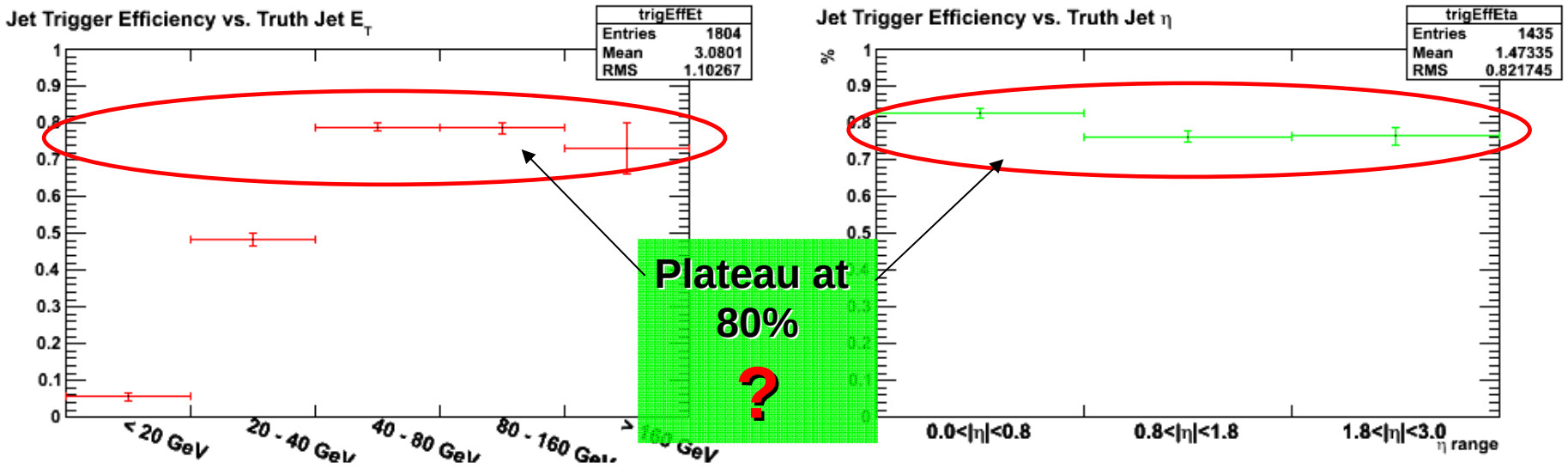


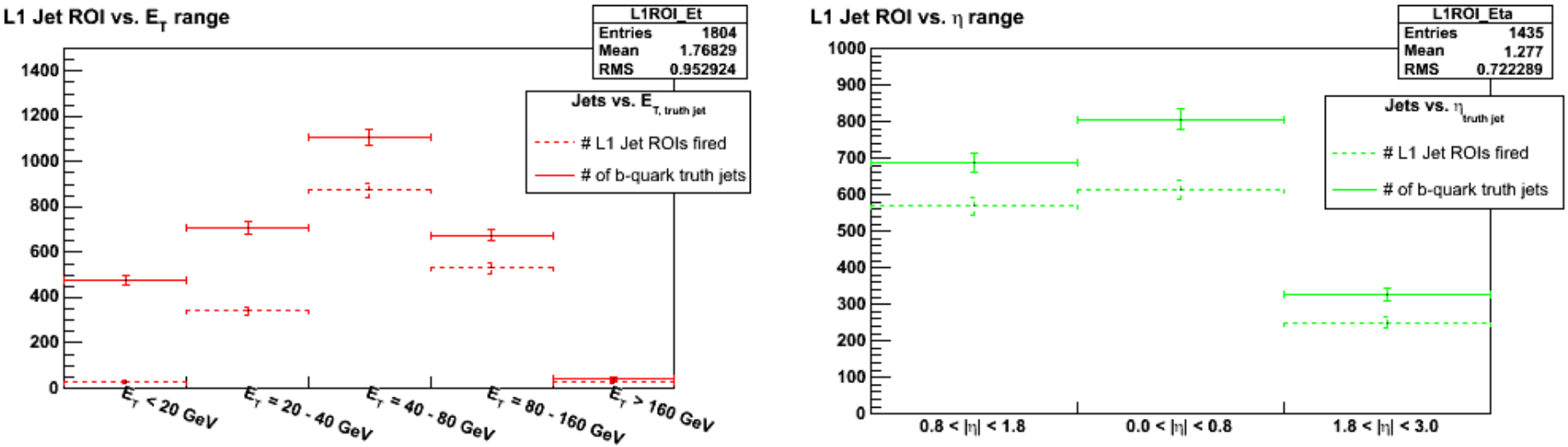
- Jet – b E_T mismatch improves with increasing FS b E_T
- 3 L1 ROI calo cluster sizes converge on their E_T measurements as Jet E_T increases



$$Eff = \frac{\#\,\text{b - Jets with matching LVL1 ROI}}{\#\,\text{Jets matched to b - quarks} (\equiv \text{b - Jets})}$$

Jet Trigger Efficiency: vs. E_T, η

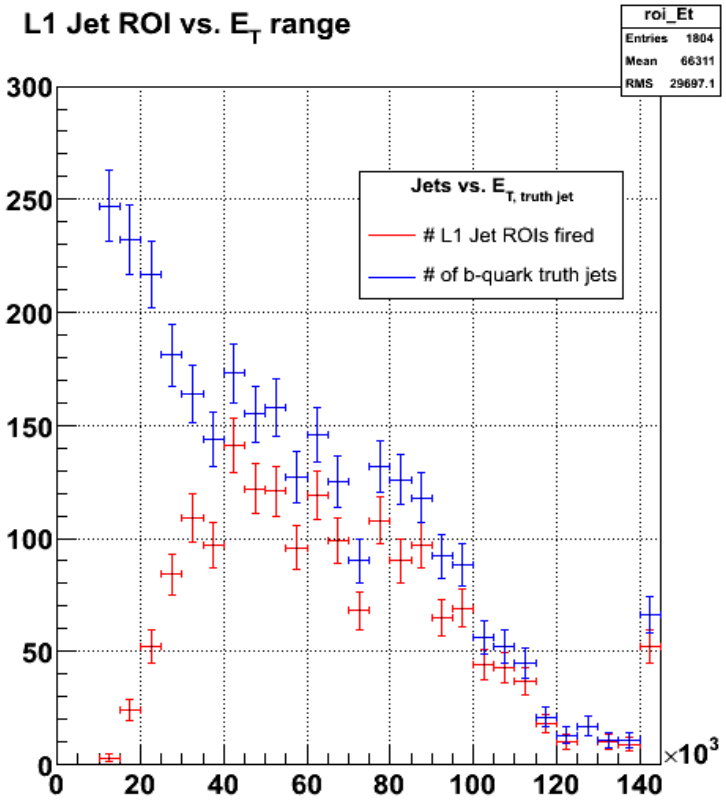


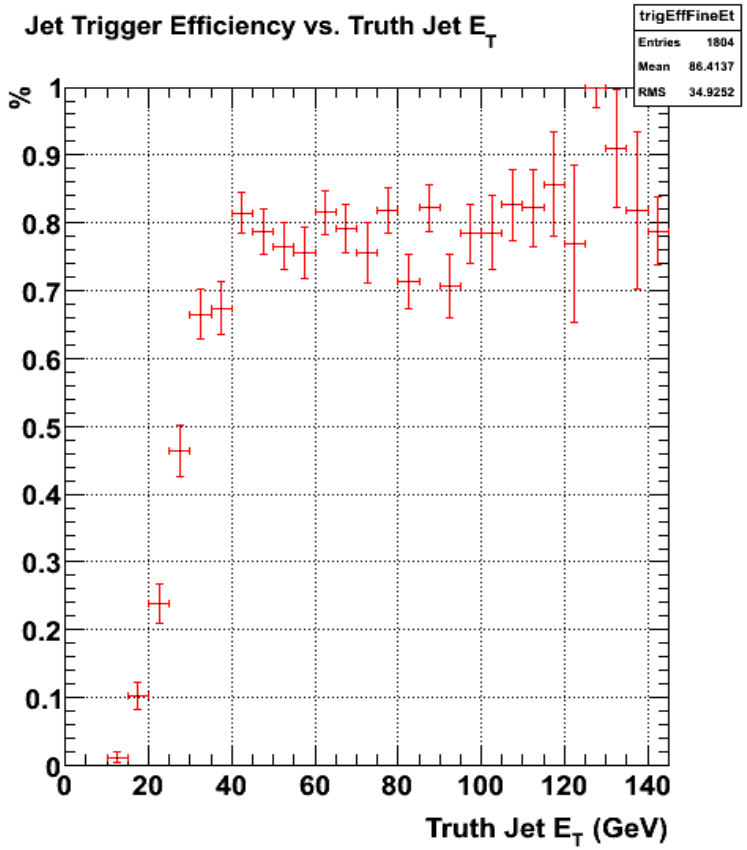


$$Eff = \frac{\#\,\text{b-Jets with matching LVL1 ROI}}{\#\,\text{Jets matched to b-quarks} (\equiv \text{b-Jets})}$$

Trigger Efficiency: "Turn-on" curve

- The more finely binned efficiency curve indeed shows a relatively sharp turn-on, as well as the ~80% efficiency plateau, presumably due to poor ΔR matching.





Further studies (the work is never done...)

- Understand 80% plateau in the trigger efficiency
- Study the turn-on curve for different samples and for various LVL1 ROI energy threshold
- Study in detail the LVL1 efficiency for the bbH/A (H/A→bb) physics
  - Under heavy investigation at Tevatron right now!
- Apply understanding of the LVL1 jet trigger efficiency to develop a parameterization of rough event-generator level trigger trigger efficiency

Conclusions

- Recent ATLAS ATHENA software adequate well equipped for trigger efficiency studies (hasn't always been the case)
- Initial Jet trigger efficiency for one physics sample shows an ~80% efficiency plateau where we expect nearly 100%.
  - Likely due to issues with the ΔR matching between Truth jets and LVL1 ROIs.
- The LVL1 ROI energy reconstruction exhibits expected variations
  - Direct knowledge of this variation is integral to determining rough trigger efficiencies on pure event-generator physics samples