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Quark/Gluon Jet Response from different Event Topologies at ATLAS

Winter Nuclear and Particle Physics Conference

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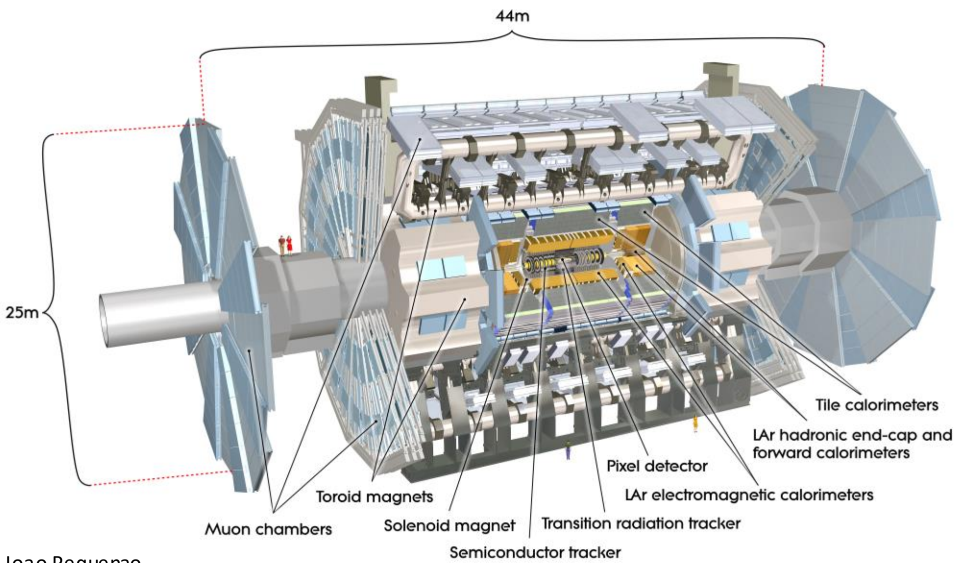
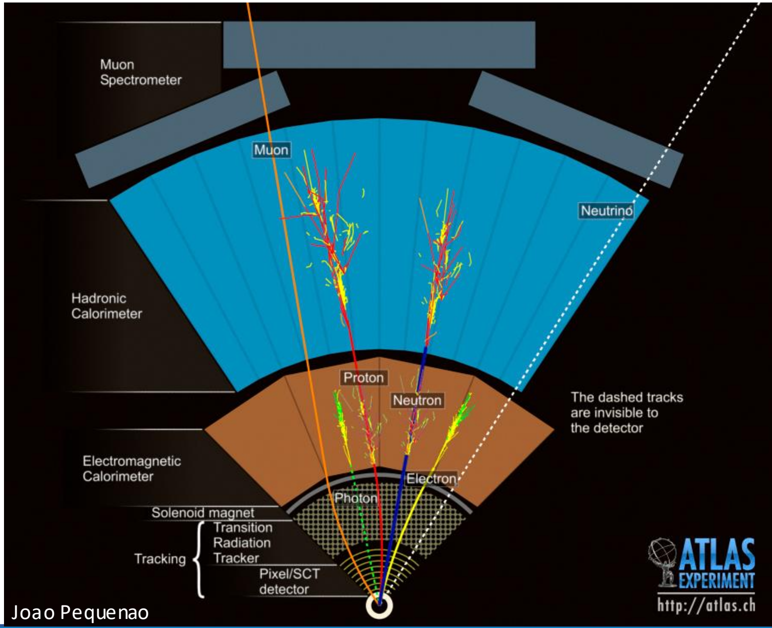
ATLAS

- The largest general purpose particle detector at the LHC.
- Inner detector for tracking, **Calorimeters** for energy measurement, outer muon spectrometer.
- Jets can be defined from the calorimeter, or from a combination of the calorimeter and the tracker

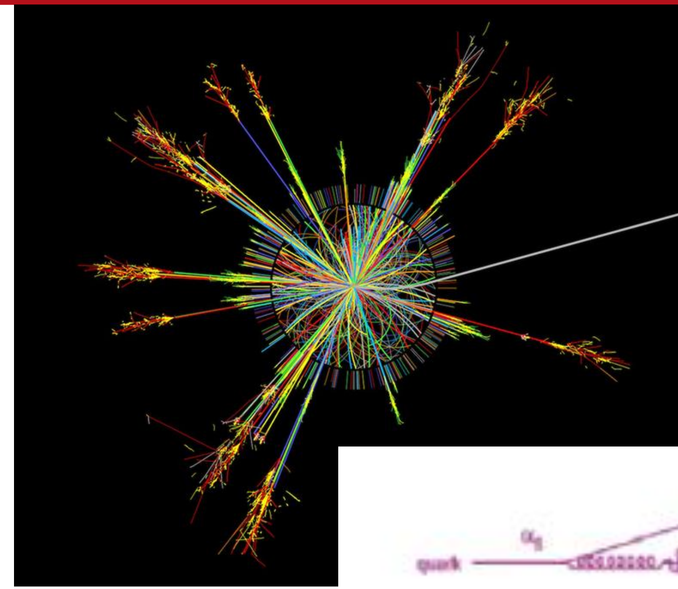


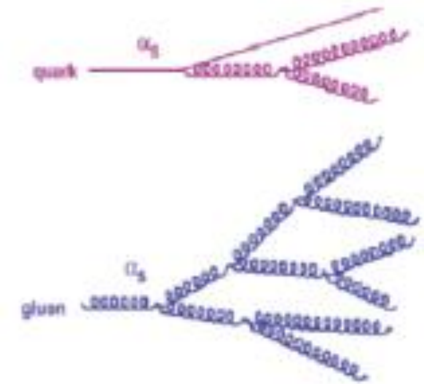
Joao Pequenao



Jets

- QCD confinement: partons produced in collisions have color charge, which cannot exist freely.
- Iterative quark/gluon production, combine to form color neutral streams of hadrons, called jets.
- Jets can originate from quarks or gluons; Different width, depth, particle count and particle energy





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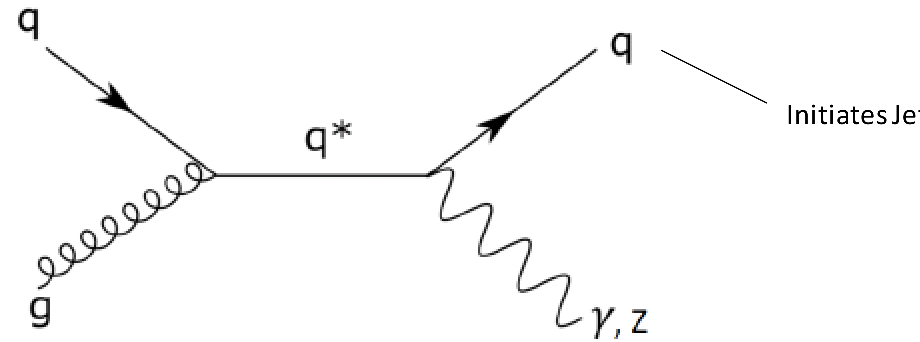
Calibration

- The Calorimeters do not see all the energy from jets:
  - The energy used to break nuclear bonds is *fundamentally invisible* to the detector (hadronic/strong interactions).
  - EM particles are well measured.
- $Response = Measured/Truth$: <1 for jets, ~1 for EM particles.
- Transverse momentum must balance! Calibrate a jet against a well-defined reference.

- Initial quark/gluon have no transverse momentum.
- Quark jet and reference object are "back-to-back in phi", momentum must balance to 0



[3] Singh, Sundeep

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Quarks & Gluons

- How does the response of quark jets differ from that of gluon jets?
- Compare different event topologies: determine event responses and particle fractions.

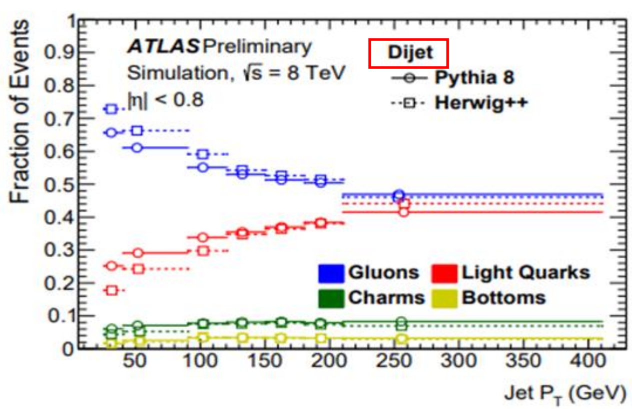
$$R_{ZJ} = R^q \times f^q_{ZJ} + R^g \times f^g_{ZJ}$$

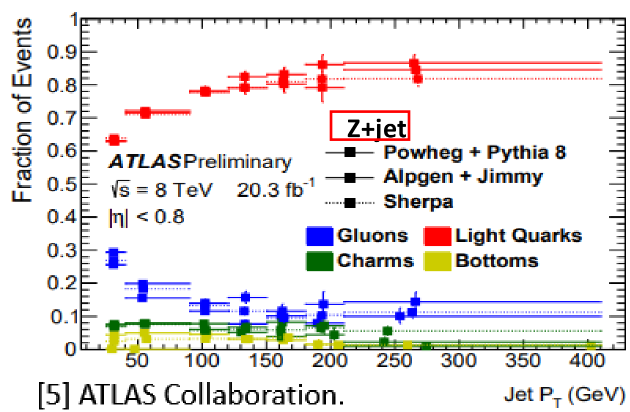
$$R_{DJ} = R^q \times f^q_{DJ} + R^g \times f^g_{DJ}$$

$$R^g = \frac{R_{ZJ} f^q_{DJ} - R_{DJ} f^q_{ZJ}}{f^g_{ZJ} f^q_{DJ} - f^g_{DJ} f^q_{ZJ}}$$

$$R^q = \frac{R_{DJ} f^g_{ZJ} - R_{ZJ} f^g_{DJ}}{f^q_{DJ} f^g_{ZJ} - f^g_{DJ} f^q_{ZJ}}$$

Particle fractions from MC:

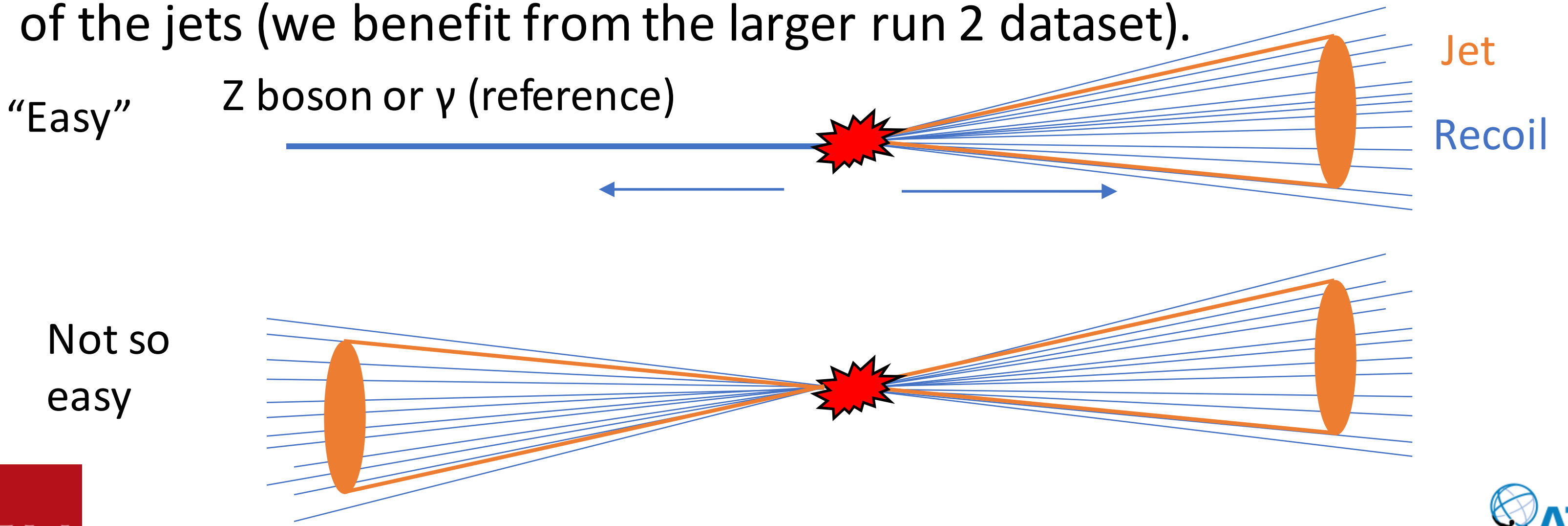




[5] ATLAS Collaboration.

Response

- We saw how to get the response for Z/gamma + jets, but we also need it for Dijets.
- No well-defined reference!
- 2016 study [4] used run 1 data to outline a method for correcting one of the jets (we benefit from the larger run 2 dataset).



Adapting Dijets

- Can use the characteristics of jets to determine the response, allowing a jet to be used as a reference object in calibration.
  1. Sort jets into high and low response groups (such as R>0.9, R<0.7), save jet variables in these groups
  2. Determine which variables are most sensitive to differences in response, sort for correlation
  3. Combine the best variables into a Likelihood function
- Doing this in MC, where response is known, allows us to create a "look-up table" to use in determining the response in data.
  - Want to see a correlation between likelihood and response.
- Once the response of one jet is known, it can be used as a reference for the other!

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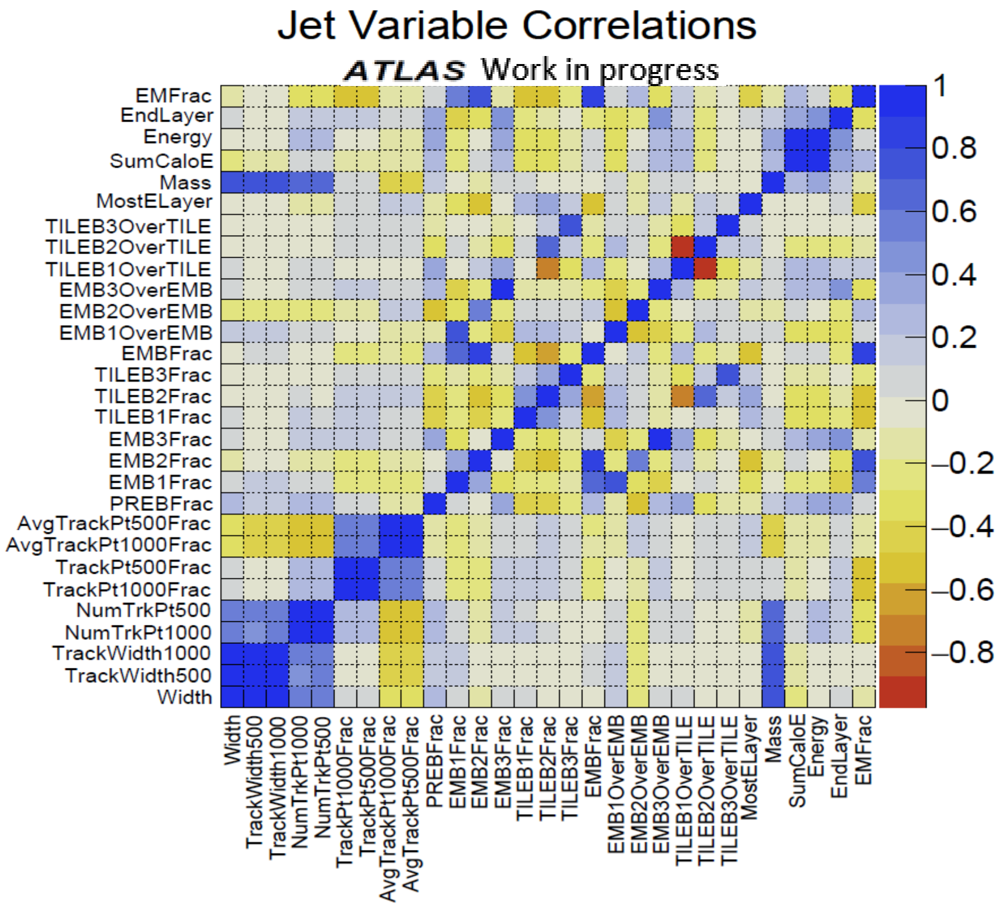
Ranking Variables

- Multiple statistical tests used to rank variables.
- Highly (anti)correlated (such as $\pm$ 0.4) variables removed.
  - EX: TILEB2OverTILE Vs. TILEB1OverTILE (red square)
- Combine the best variables into the likelihood function
- Multiple likelihood functions created by varying high and low response cut, correlation cut



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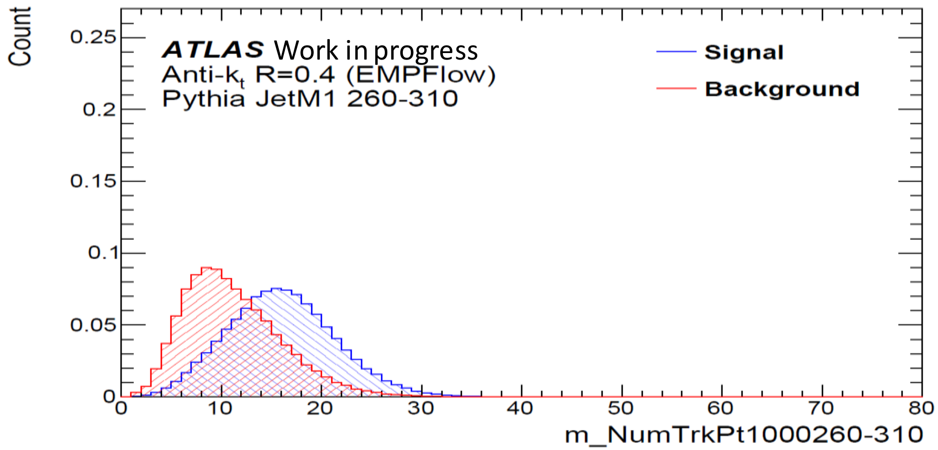
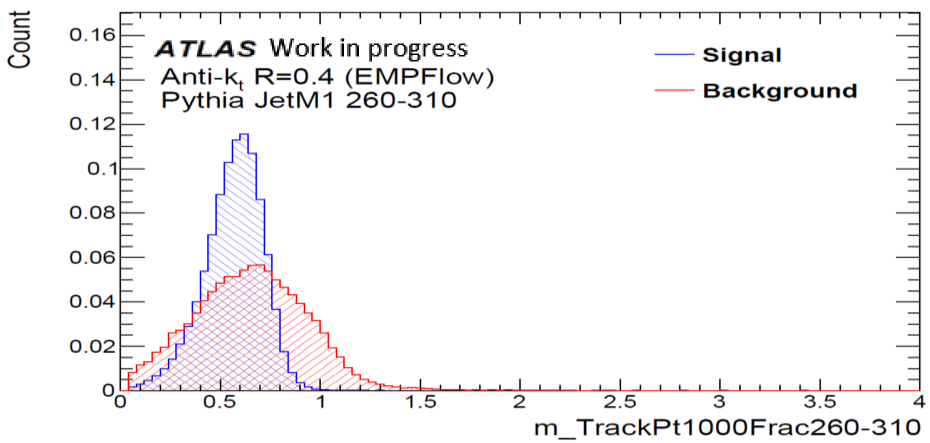
A "Final List" Example

- Example: High response >= 0.95, Low <= 0.75, Correlation cut ± 0.4
  - reco pT 260-310 GeV.
- 6 variables in list, two of the best:
  - NumTrkPt1000: how many tracks have momentum of 1GeV+?
  - TrackPt1000Frac: Fraction of jet momentum carried by tracks with 1GeV+.





Summary/Next steps

- Response of quark- and gluon-initiated jets can be determined from the responses of different event types.
  - Jet variables used to create a reference in dijet events
  - All event types calibrated to get response
- From event responses and particle fractions, determine quark and gluon jet responses.
- In the process of plotting likelihood against response to determine correction factors.
- Variation of correlation and response gave large uncertainty to previous work, can it be improved?
- Good results could improve ATLAS analyses and help with understanding of QCD.

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References

- [1] ATLAS Collaboration. "Jet Energy Scale and Resolution Measured in Proton-Proton Collisions at $\sqrt{s}=13$ TeV with the ATLAS Detector." *ArXiv:2007.02645 [Hep-Ex]*, July 6, 2020. http://arxiv.org/abs/2007.02645.
- [2] Cacciari, Matteo, Gavin P Salam, and Gregory Soyez. "The Anti- k_t Jet Clustering Algorithm." *Journal of High Energy Physics* 2008, no. 04 (April 16, 2008): 063–063. https://doi.org/10.1088/1126-6708/2008/04/063.
- [3] Singh, Sundeep. "Determining the Jet Energy Scale for ATLAS in the Z+Jet Channel." MSc Thesis, Simon Fraser University, 2020.
- [4] Beare, James W. "Reconstructing a Quark and Gluon Jet Response at ATLAS." MSc Thesis, Simon Fraser University, 2016.
- [5] ATLAS Collaboration. "Discrimination of Light Quark and Gluon Jets in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS Detector." July 2016. http://cds.cern.ch/record/2200202

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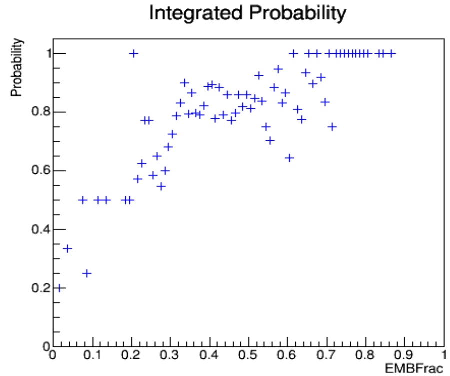
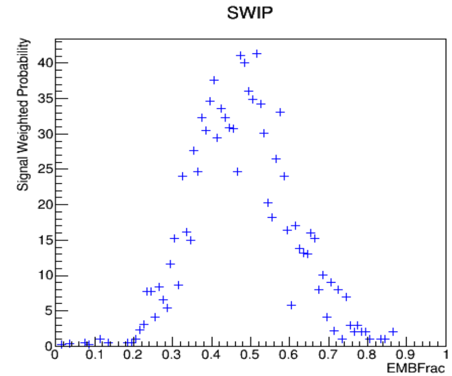
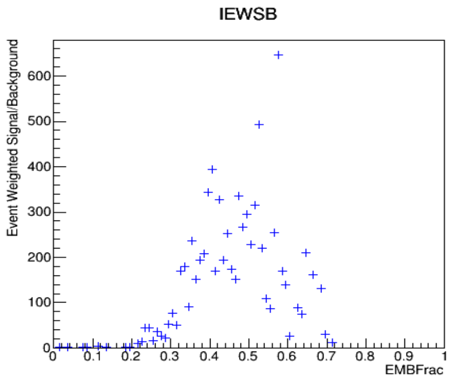
Backup Slides

Statistical tests

- High/Low response cut is somewhat arbitrary, vary and repeat.
- Five statistical test to determine most separated variables
  1. IP
  2. SWIP
  3. IEWSB
  4. Mean Asymm
  5. Chi2
- Ex: EMBFrac is the portion of jet energy deposited in the EM barrel. The high scoring region of the variable changes with different tests.







AntiKt4EMPFlow $\sqrt{s} = 13$TeV

IP: $\int \frac{s}{s+b} = 0.575021$

SWIP: $\int \frac{s^2}{s+b} = 10.6635$

IEWSB: $\int \frac{(s+b)s}{b} = 79.4006$

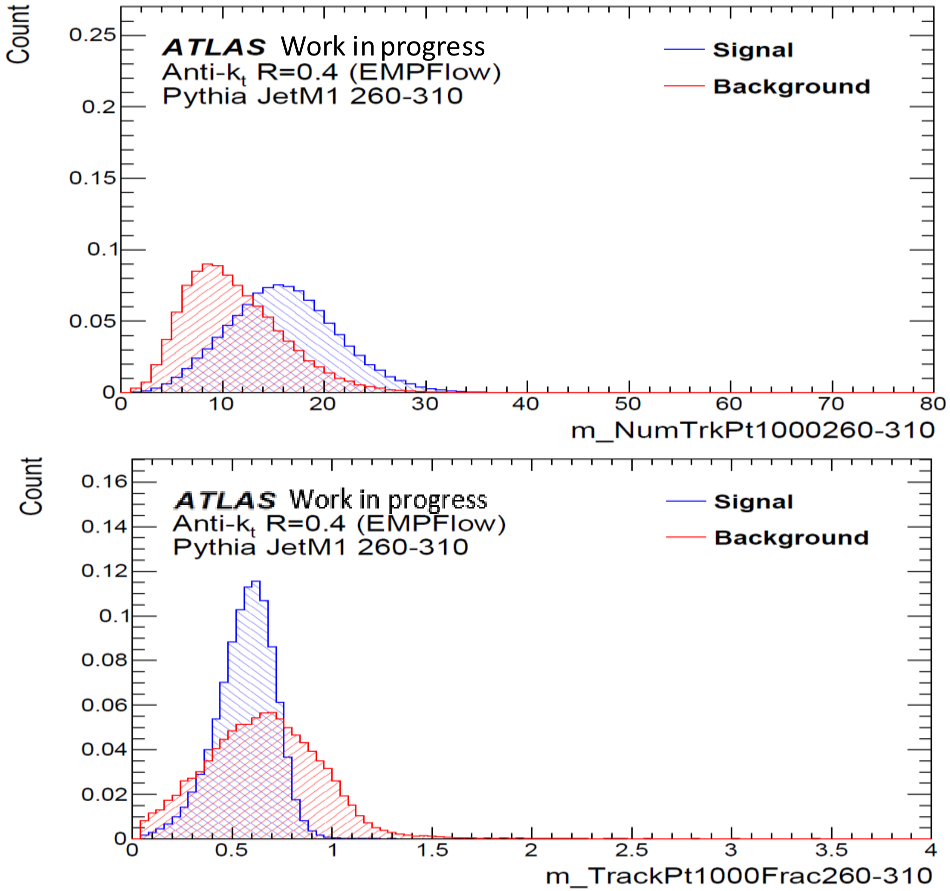
M_a: $\frac{M_s - M_b}{M_s + M_b} = 0.0889974$

$\chi^2 = 164.586$

ATLAS Work in progress

A "Final List" Example

- Example: High response >= 0.95, Low <= 0.75, Correlation cut $\pm$ 0.4
- Top 6 variables, reco p_T 260-310:
  1. NumTrkPt1000
  2. MostELayer
  3. EndLayer
  4. EMB1Frac
  5. TrackPt1000Frac
  6. TILEB2OverTILE



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