Optimization of jet reconstruction in Matrix Element Method calculations for semi-leptonic ttH at ATLAS

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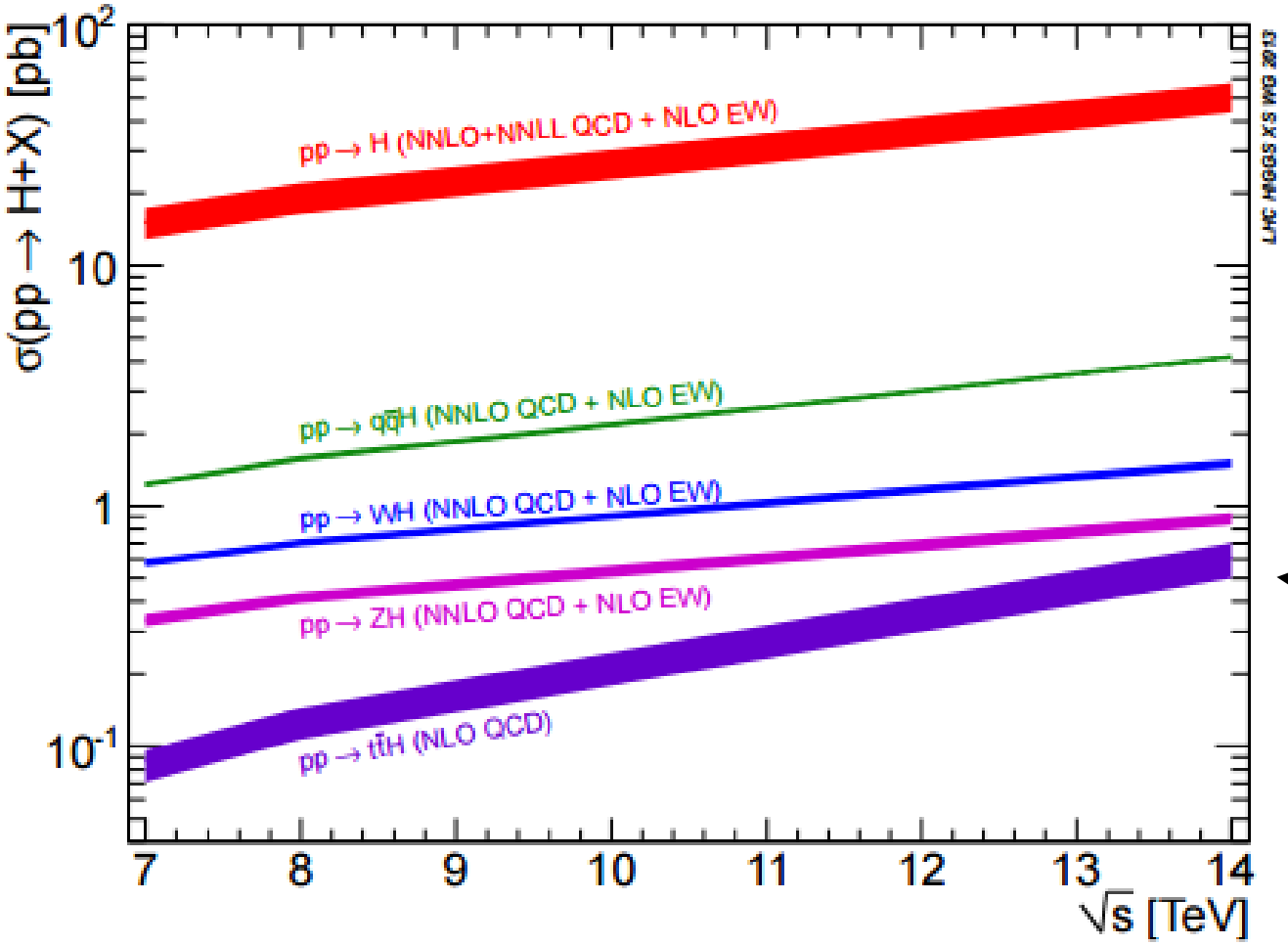
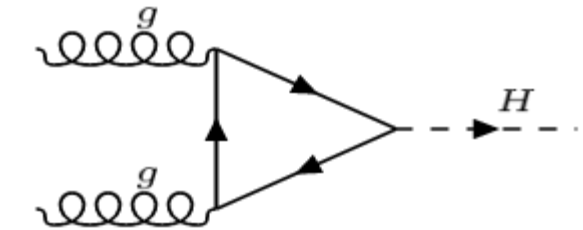
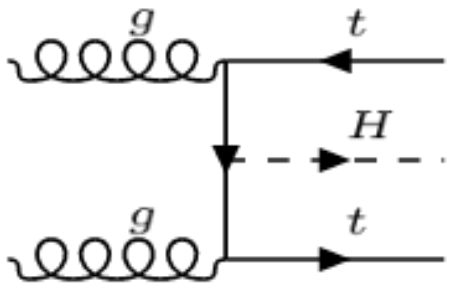
Summer Student Session
2016

Higgs





ggF



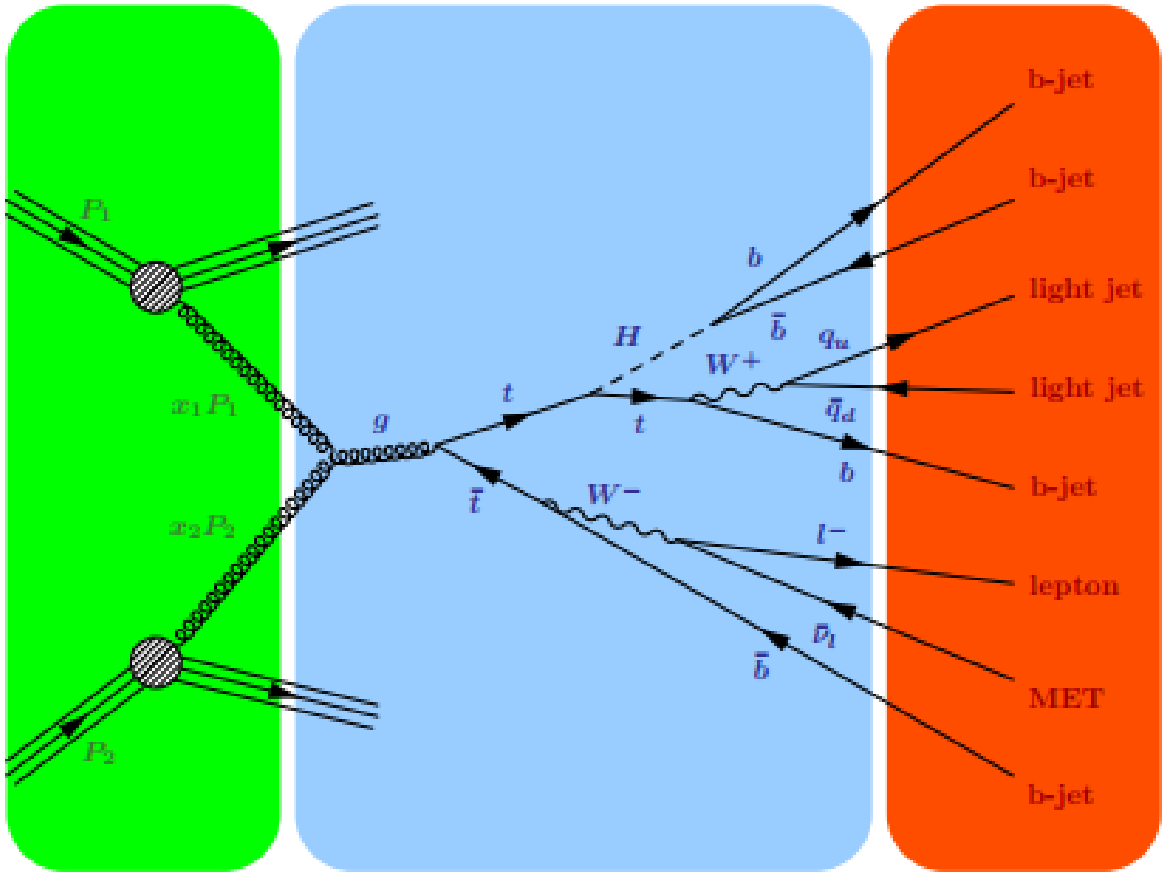
ttH – signal

Access to top-Higgs Yukawa coupling

Status of Higgs boson Physics, M. Carena et al. (FNAL), ATLAS/CMS (2014)

Semi-leptonic ttH event

- Need to reconstruct: 4 b quarks, **2 light quarks** + lepton + neutrino (W decay)
- Main background: **tt**
  - **Similar products and kinematics** as signal
  - Comparatively large cross section



A representative Feynman diagram of ttH (10 such diagrams)

Olaf Nackenhorst, CERN-THESIS-2015-186

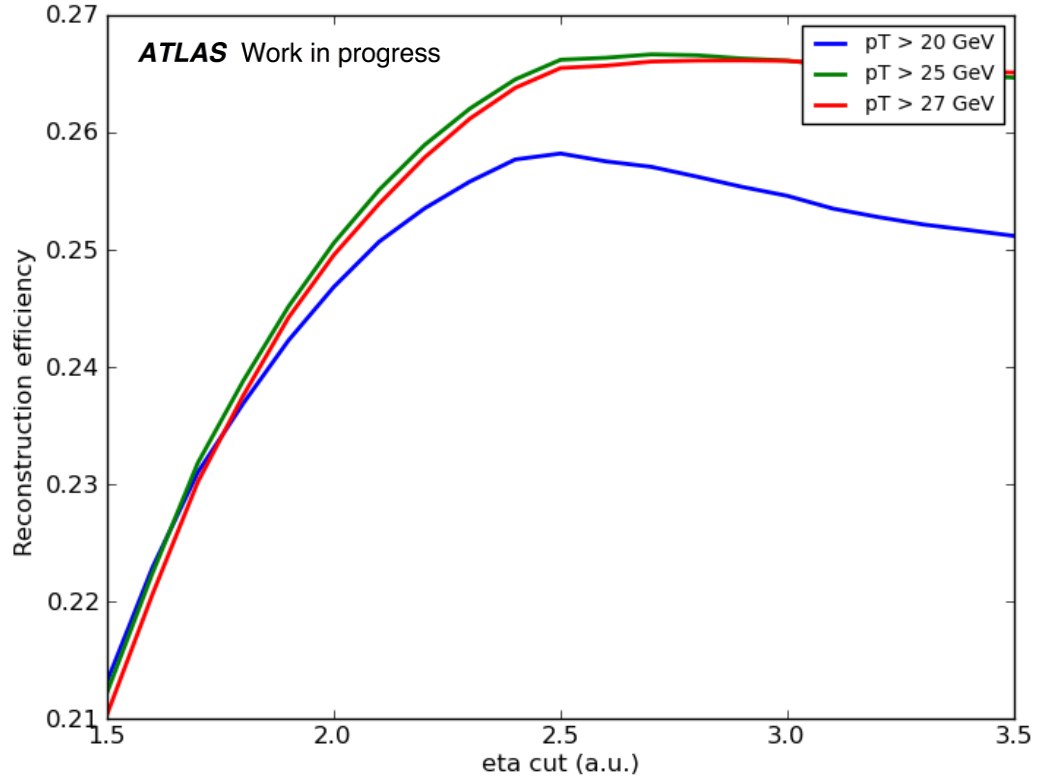
MEM

Reconstruction efficiency ≡
$$\frac{\text{events with W selected + truth-matched}}{\text{events in signal region}}$$

Separation variable, D1 ≡ $\frac{L_{sig}}{L_{bg}}$

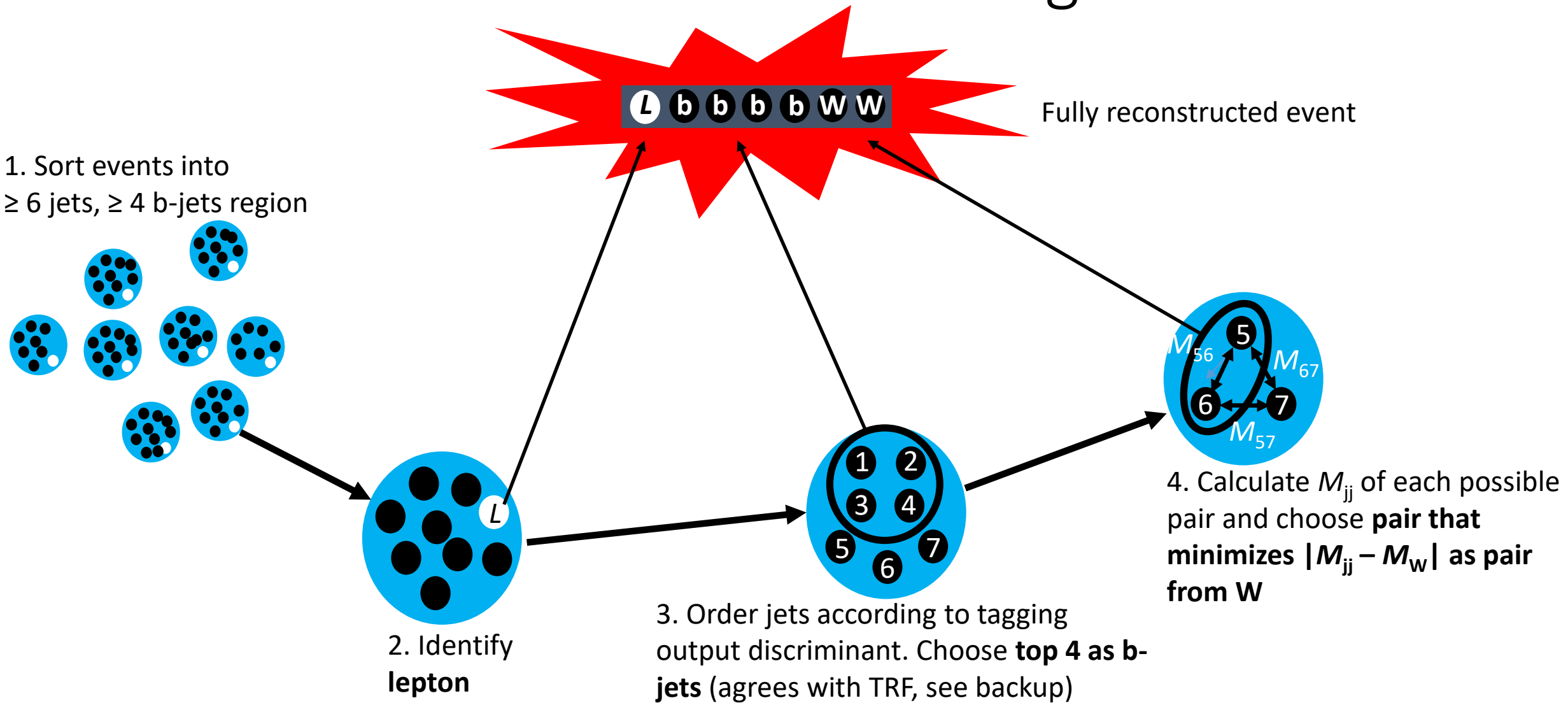
Separation power, S ≡ $\frac{1}{2}\sum \frac{(N_{sig}-N_{bg})^2}{N_{sig}+N_{bg}}$

- Idea: calculate **likelihood** that an event is signal or background in origin
  - Calculates Feynman diagrams
  - Can provide a **powerful discriminating variable** to extract signal from background
- Challenge: **reconstruction of jets from W**
  - Reconstruction efficiency = 30%
  - W is a difficult object to reconstruct
    - W has mass of 80 GeV → decay products have $\langle E \rangle \approx \langle p \rangle \approx 40$ GeV, transverse component **close to cut**
    - W jets lost by pT ≥ 25 GeV and eta ≤ 2.5



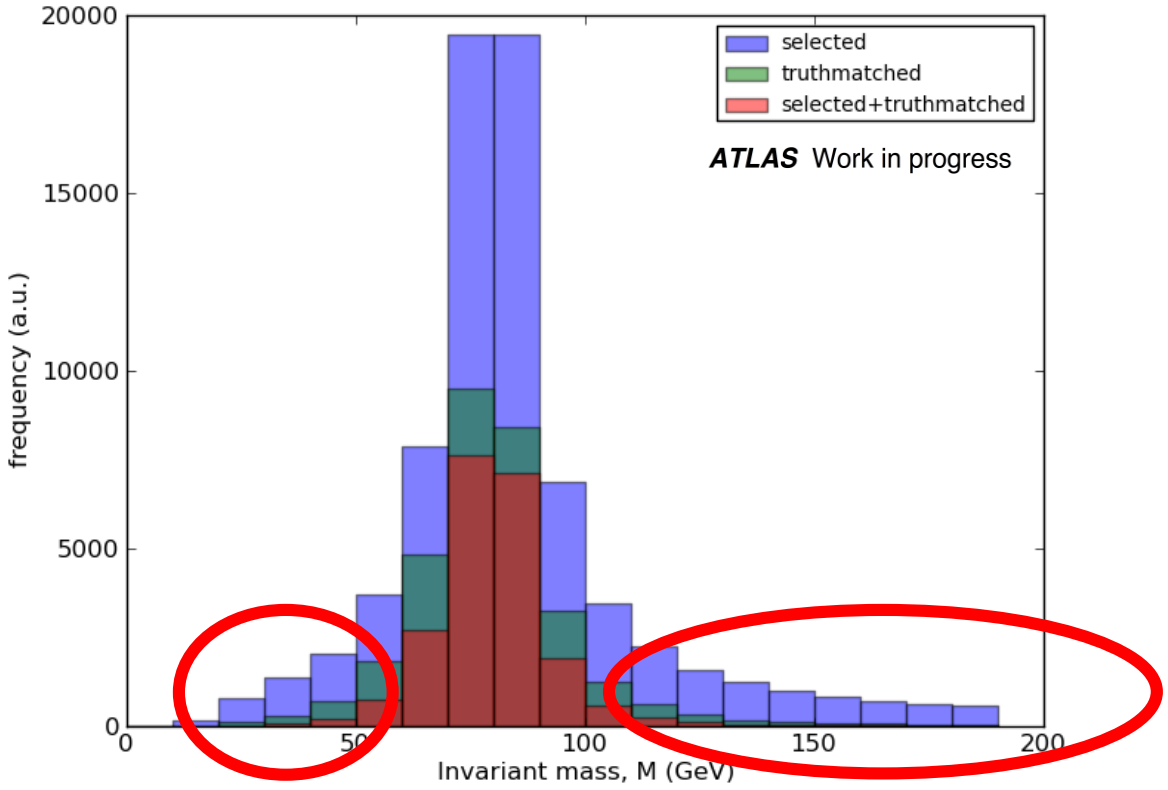
Combinatorics, pileup, mis-tagged b-jets → Recovering jets is non-trivial

Nominal event reconstruction algorithm

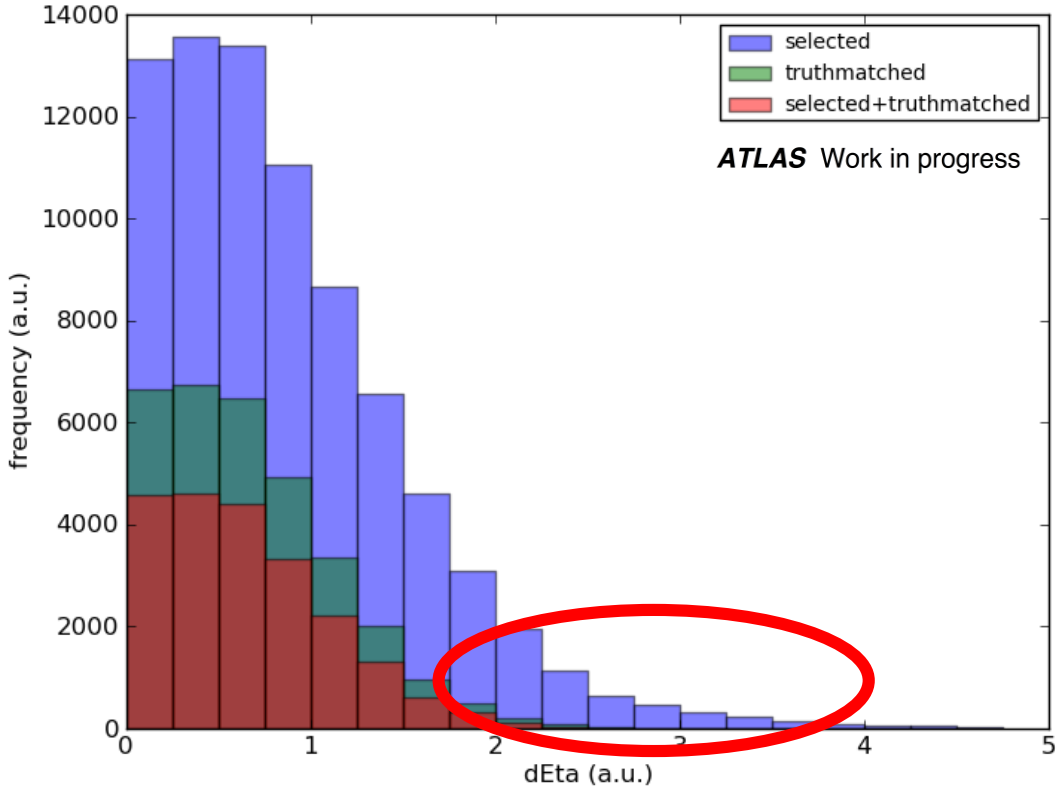


Reconstruction- and truth-level information

- How do the properties of the truth-matched jets compare to the jets selected by our algorithm?



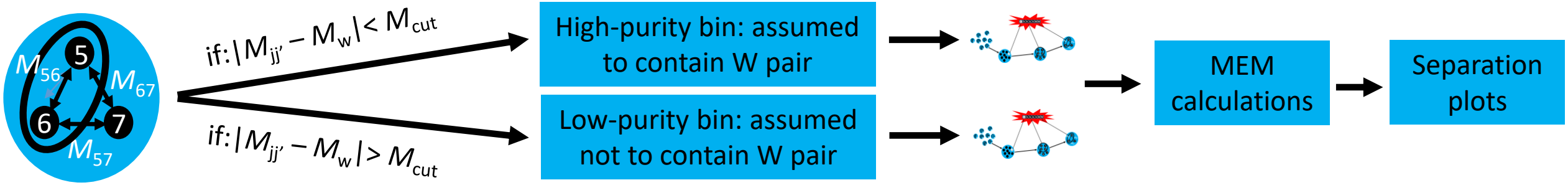
→ selected W pairs outside of a certain M window are **chosen incorrectly**



→ selected W pairs outside of a certain dEta window are **chosen incorrectly**

An approach to improving W reconstruction

- W is reconstructed rarely → account for this in the analysis
- Modify algorithm to **separate events** (data and MC) into **two bins** prior to MEM calculations: i) high-W purity ii) low-W purity

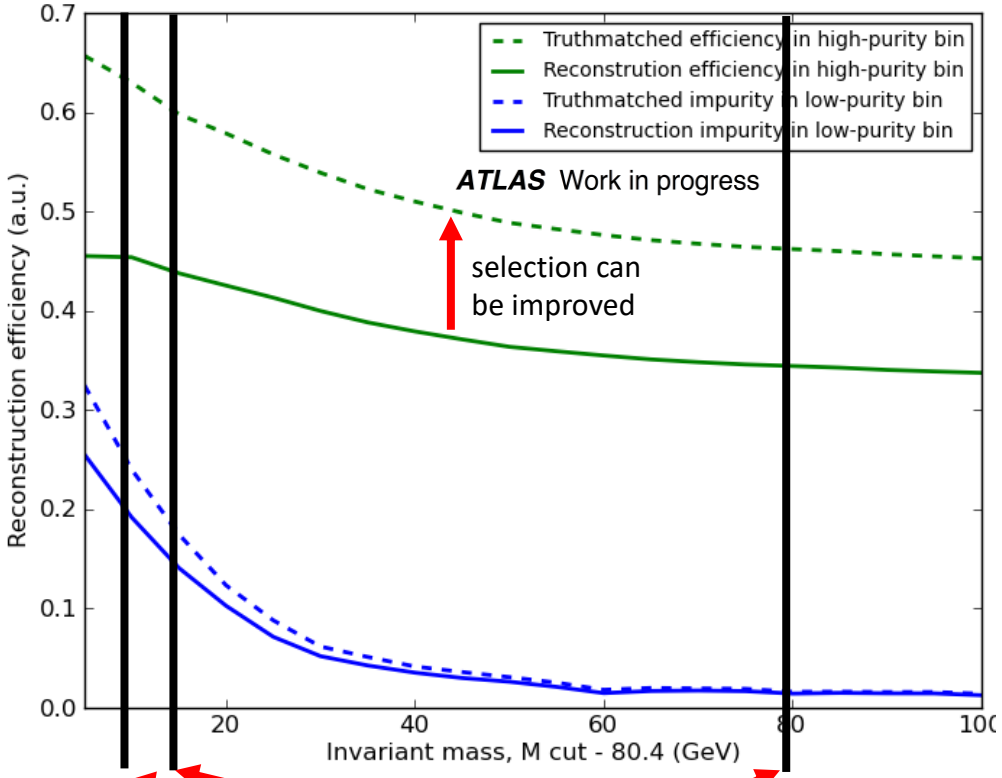


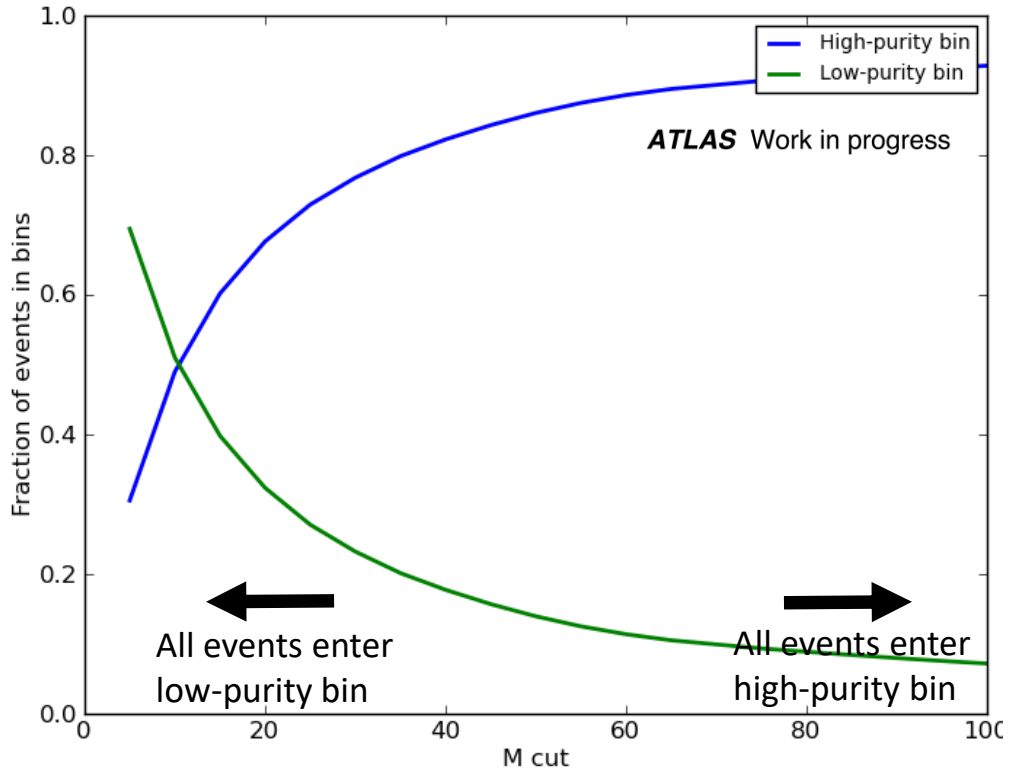
$$|M_{jj'} - M_w| = \min\{|M_{\text{all jet pairs}} - M_w|\}$$

M_{cut} not be symmetric!

Challenges to address

1. Need appropriately large bin sizes (prefer ½ of events in both high- and low-purity bins)
2. Prefer bins with higher purity (low impurity)





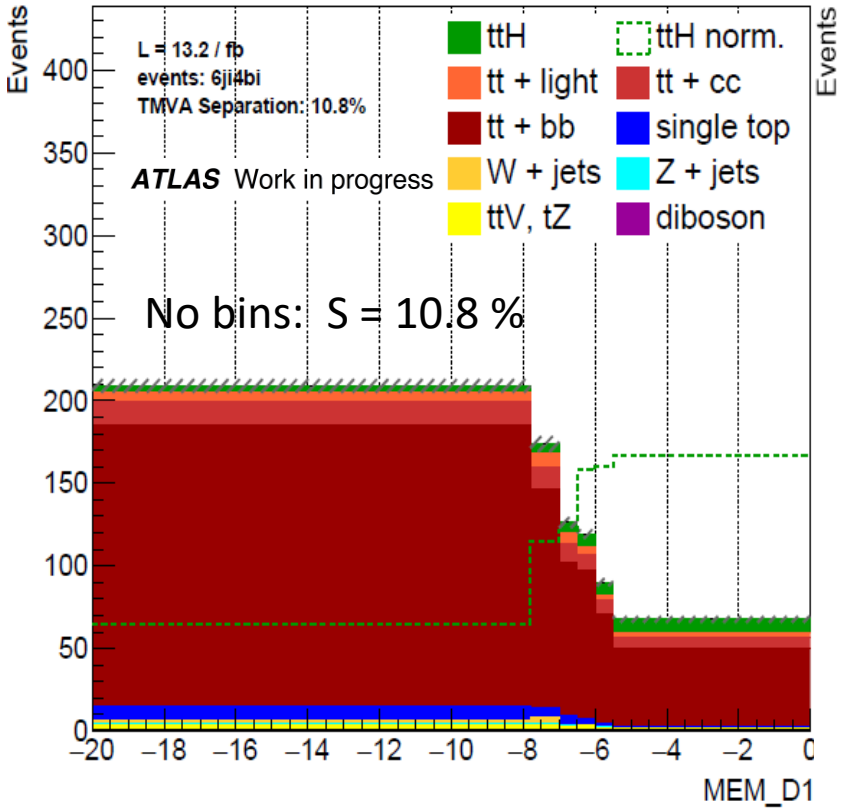
Results overview: split binning

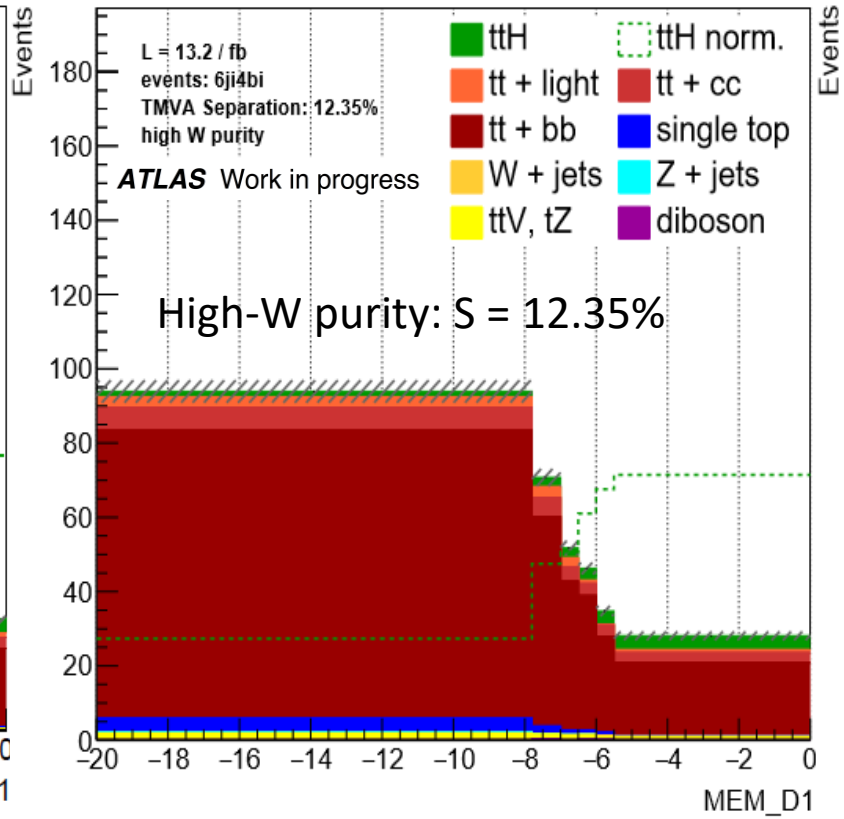
	No bins	High W-purity	Separation Improvement	Low W-purity
M cut = 80.4 +/- **5 GeV**	9.67%	13.77%	42%	9.36%
M cut = 80.4 +/- **11 GeV**	10.44%	13.21%	26%	9.75%
M cut = 80.4 +/- **80 GeV**	10.17%	10.89%	7%	9.28%

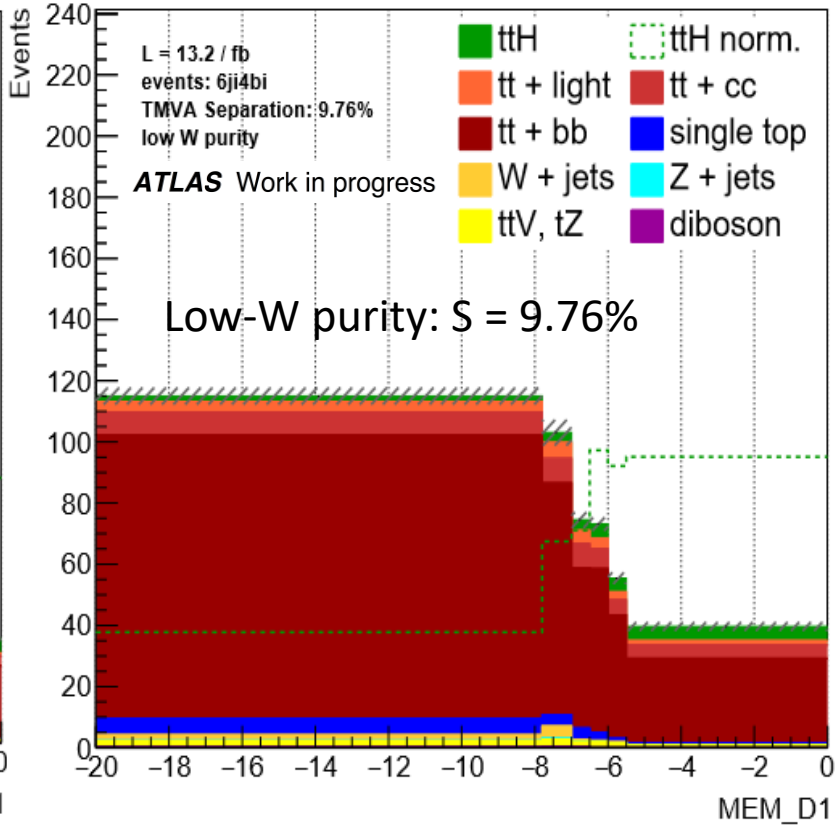
Improvement increases as M cut becomes restricted, but improvement is stat-limited → need to do full fit to see effect

Results 20.7: split binning

For M cut = 80.4 +/- 11 GeV
and secondary dEta cut
(more settings in backup)



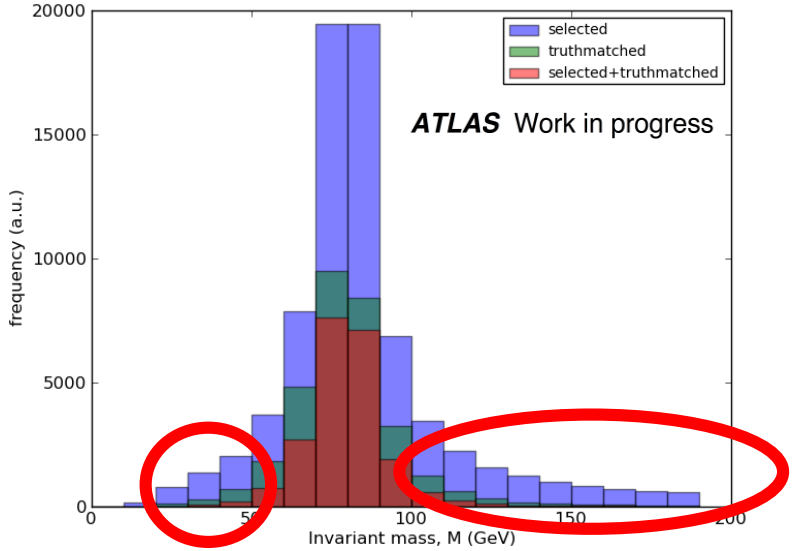




14% relative separation gain → **still seems effective, need more results**

Conclusion

- Observed **increase in relative separation**
  - In principle, correct reconstruction is done more often
- Very little cost
  - Additional **computation time is negligible** → any improvements are for free
- Further studies required to fully understand invariant mass separation and secondary selections in 20.7
  - Asymmetric invariant mass cut
  - Different variable to cut on
- Need to do full fit



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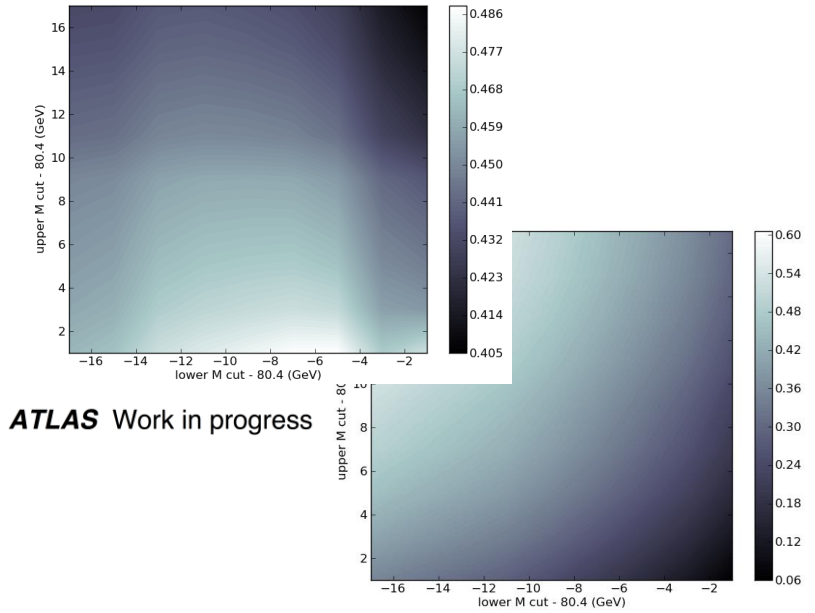

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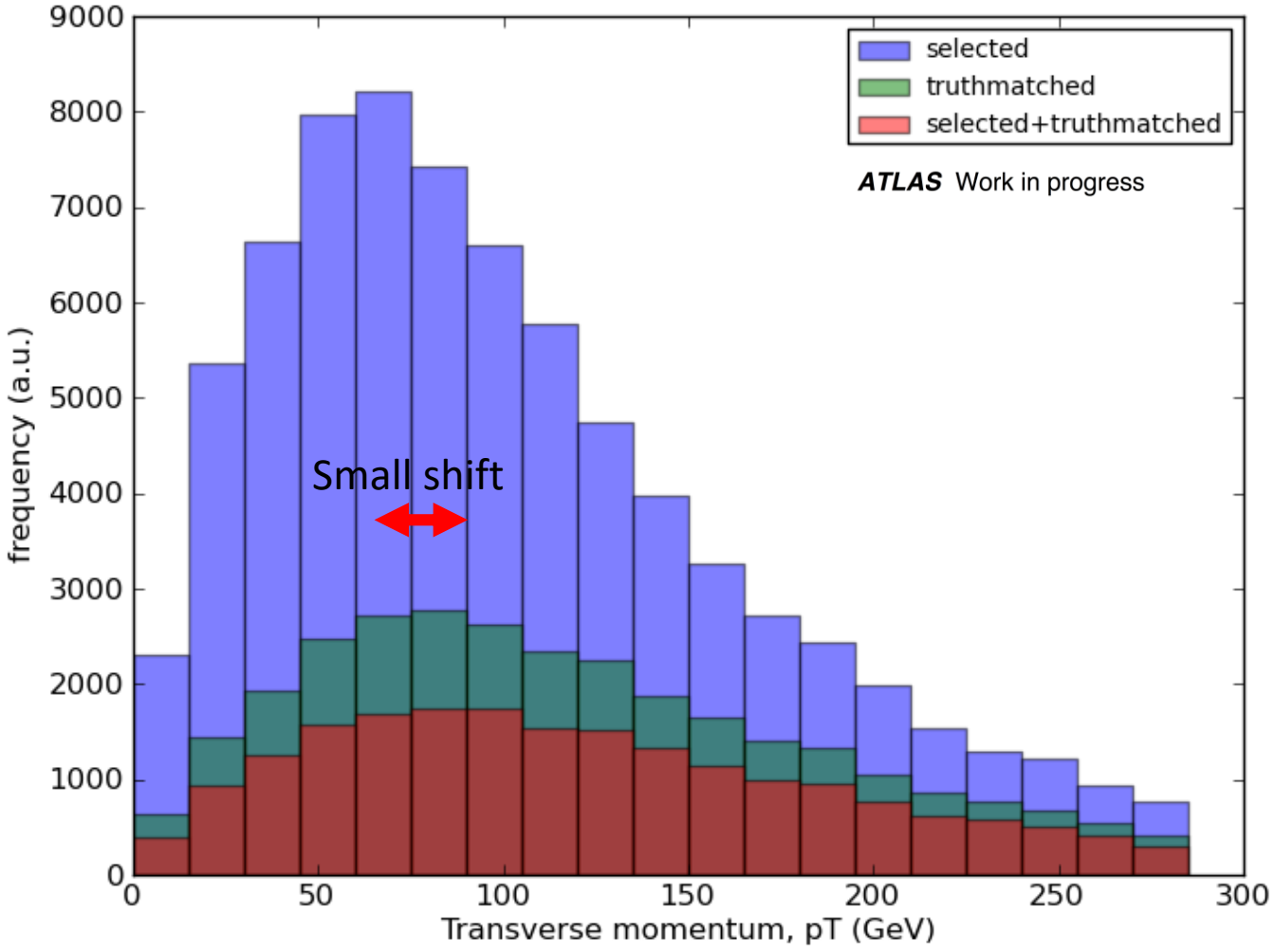
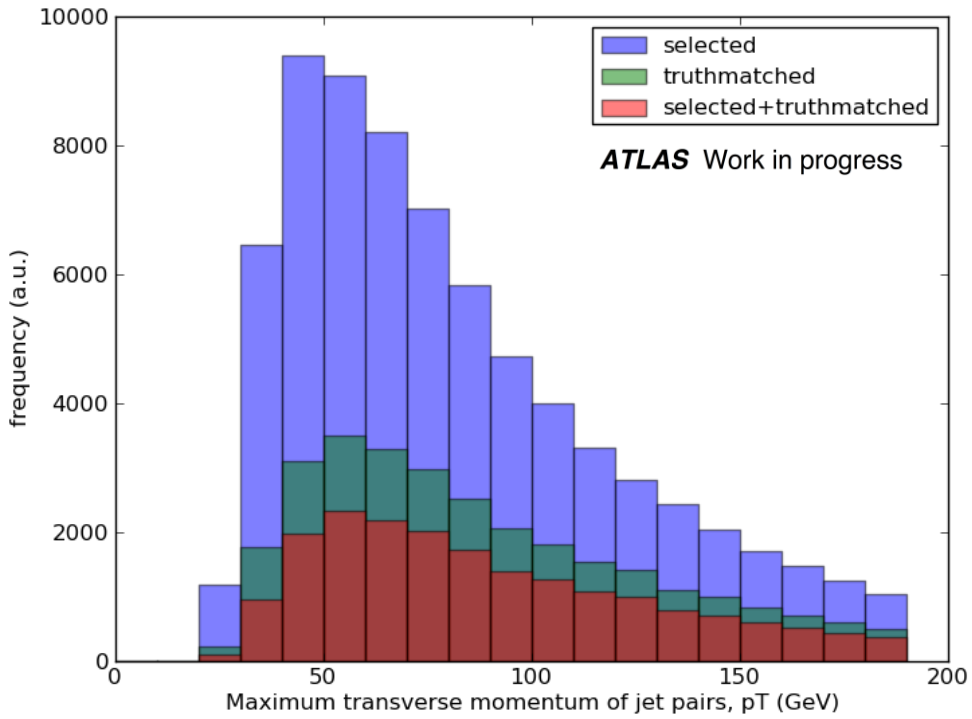
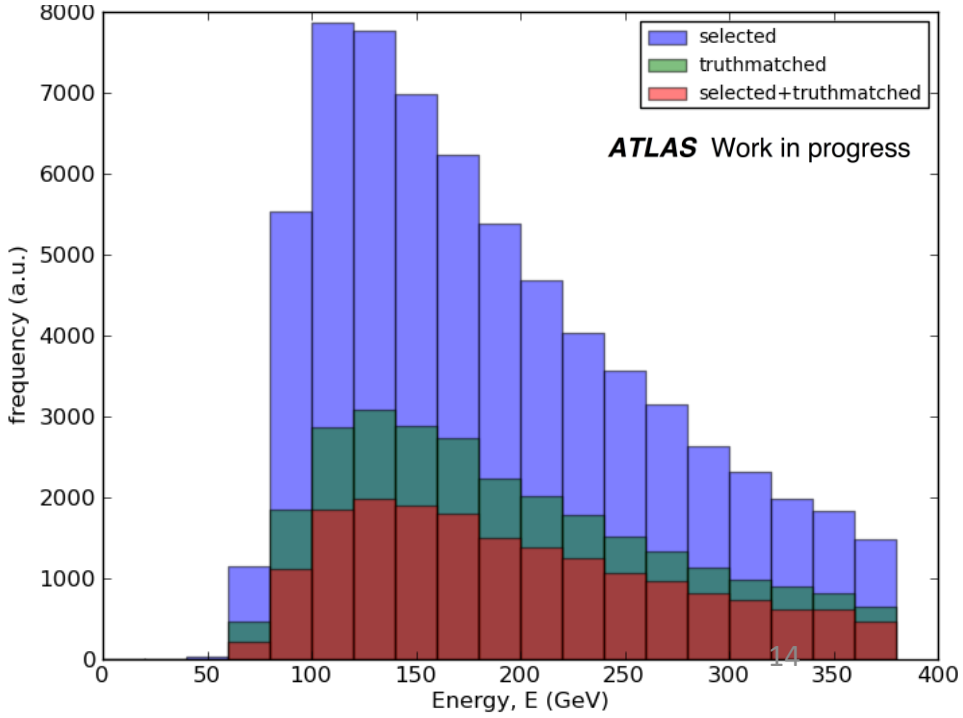
- Institute of Particle Physics
- TRIUMF

Backup

Energy and momentum

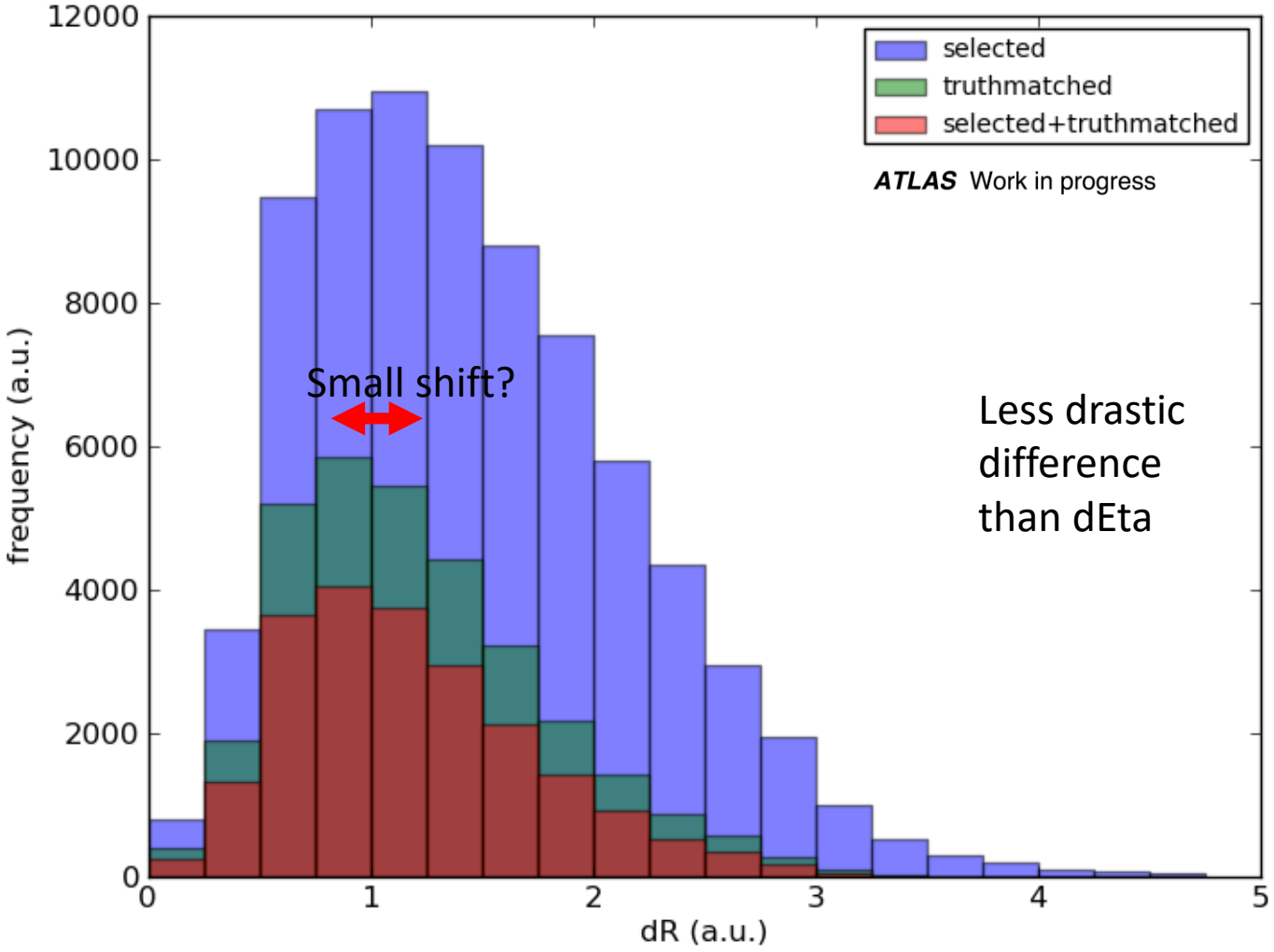




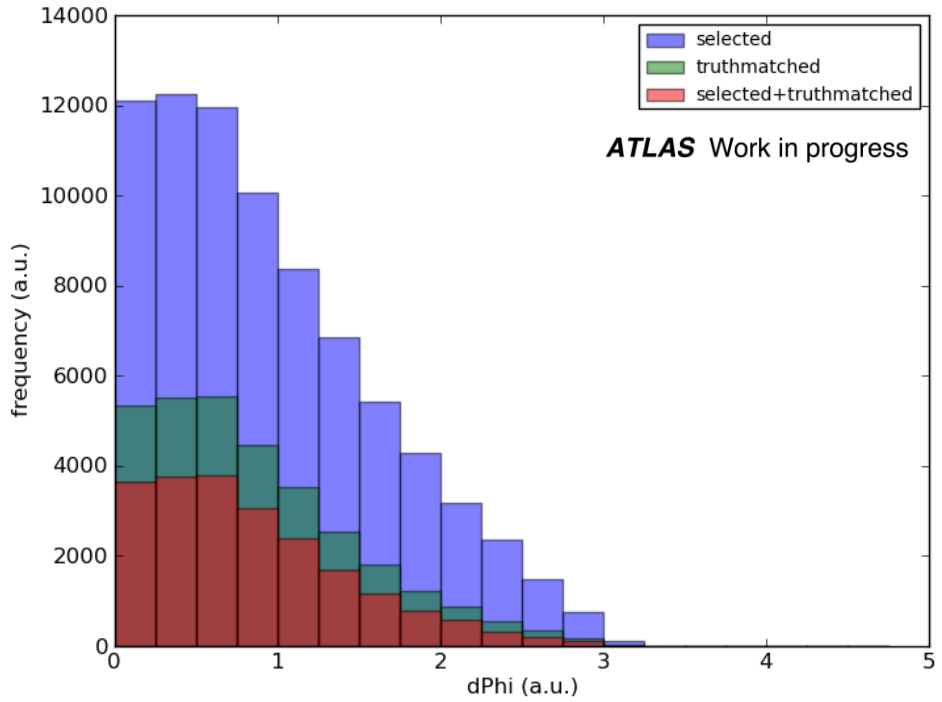


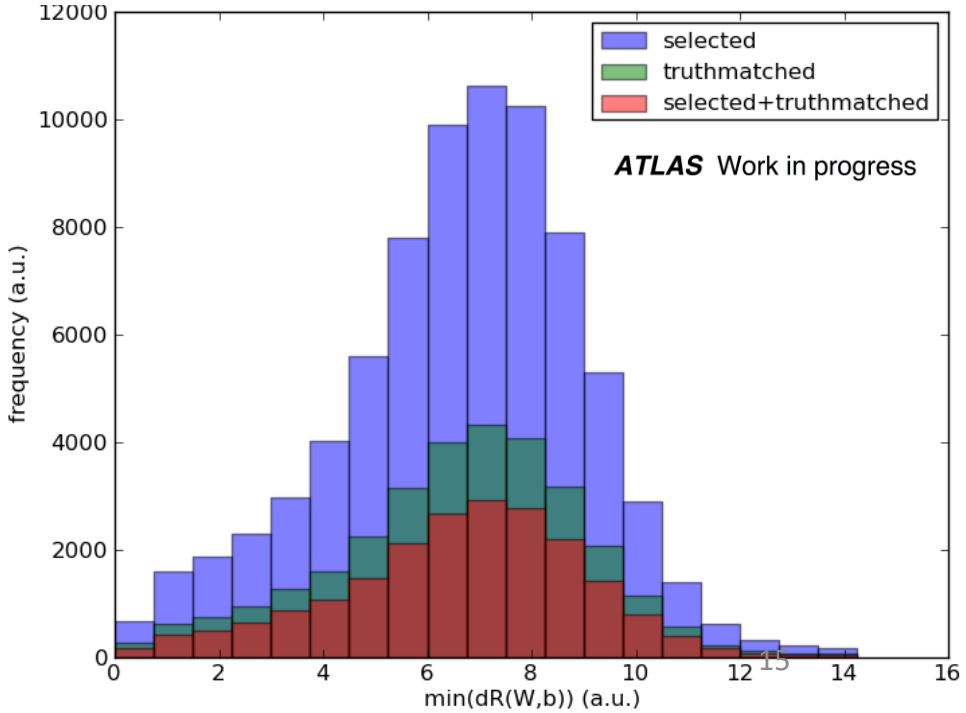
→ Little information to be gained

Angle



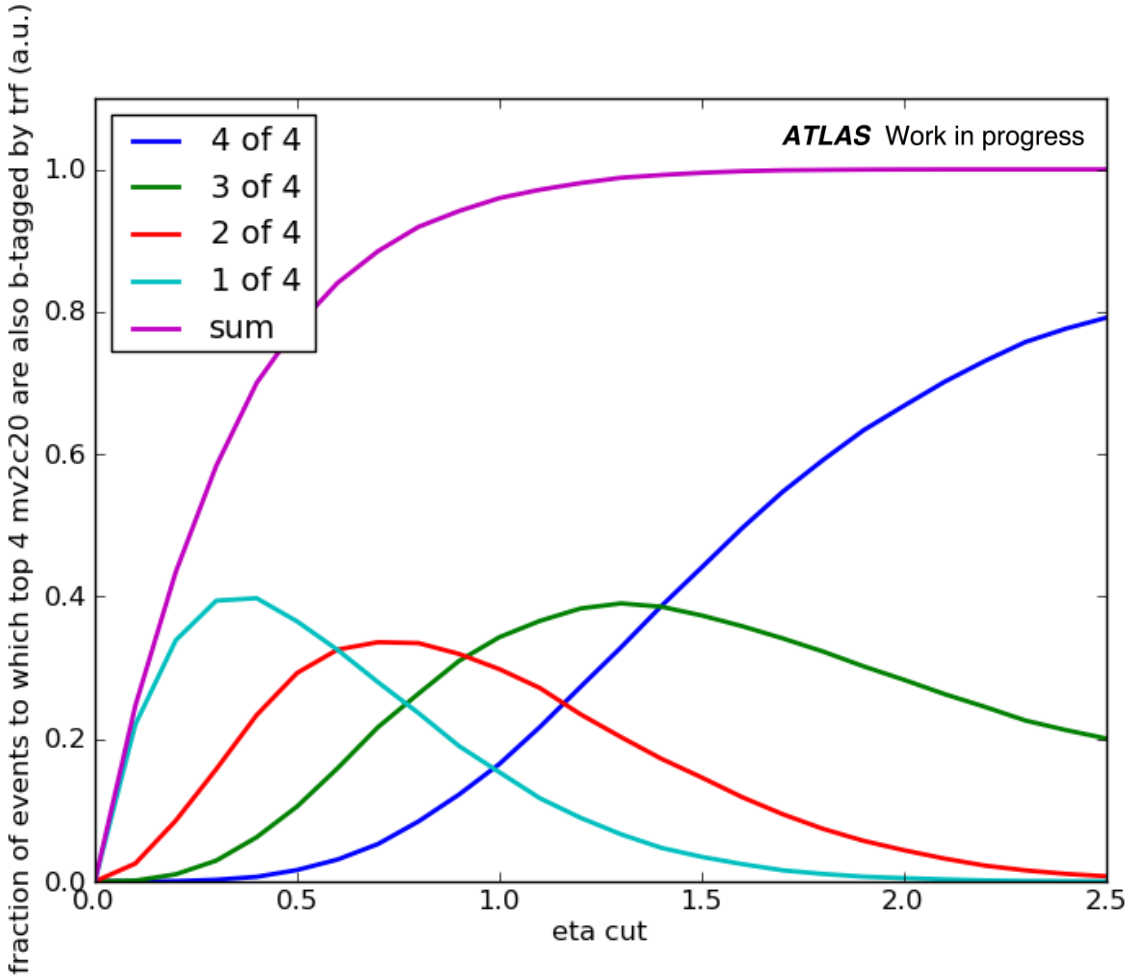
Less drastic difference than dEta





→ Little information to be gained

mv2 / TRF comparison



→ at nominal cut of |eta| < 2.5, TRF and mv2c20 agree on b-tagged jets 80% of the time