Bundesministerium
für Bildung
und Forschung

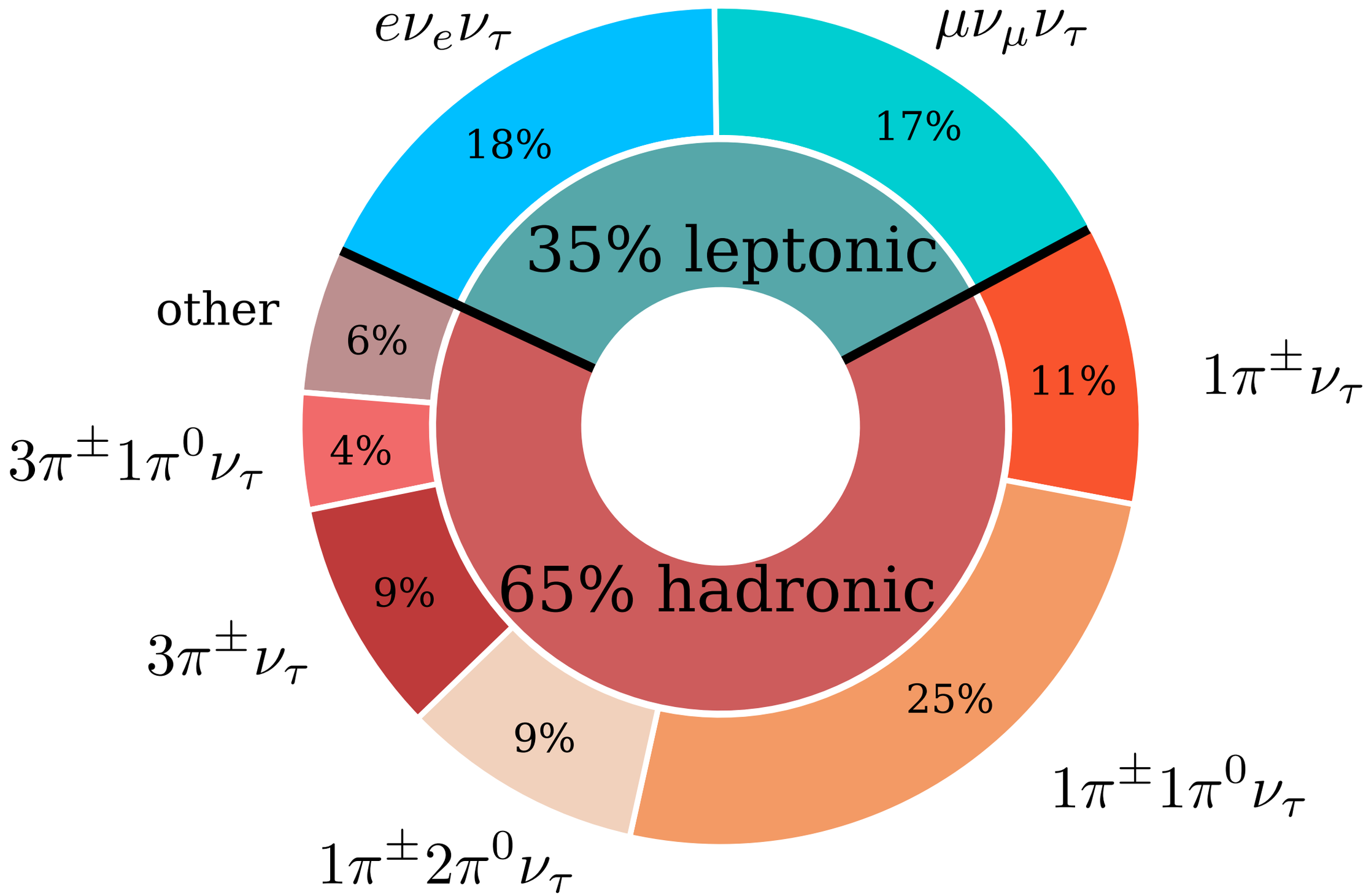
ATLAS EXPERIMENT

TECHNISCHE UNIVERSITÄT DRESDEN

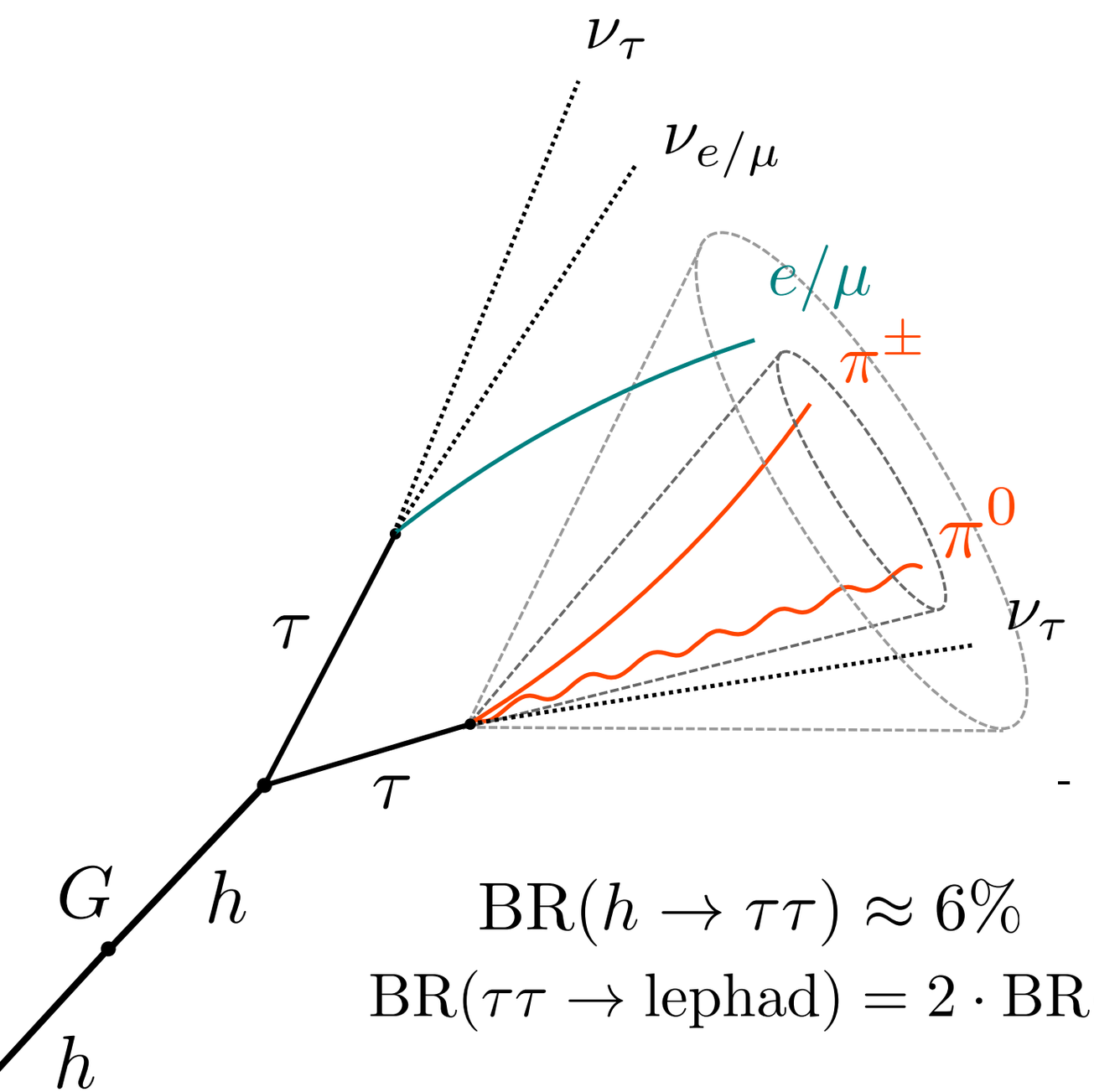
Reconstruction and Identification of Semi-Leptonic Di-Tau Decays in Boosted Topologies at ATLAS

Tau Lepton Properties

mass	(1776.82 ± 0.16) MeV
mean lifetime	$2.906 \cdot 10^{-13}$ s



Motivation

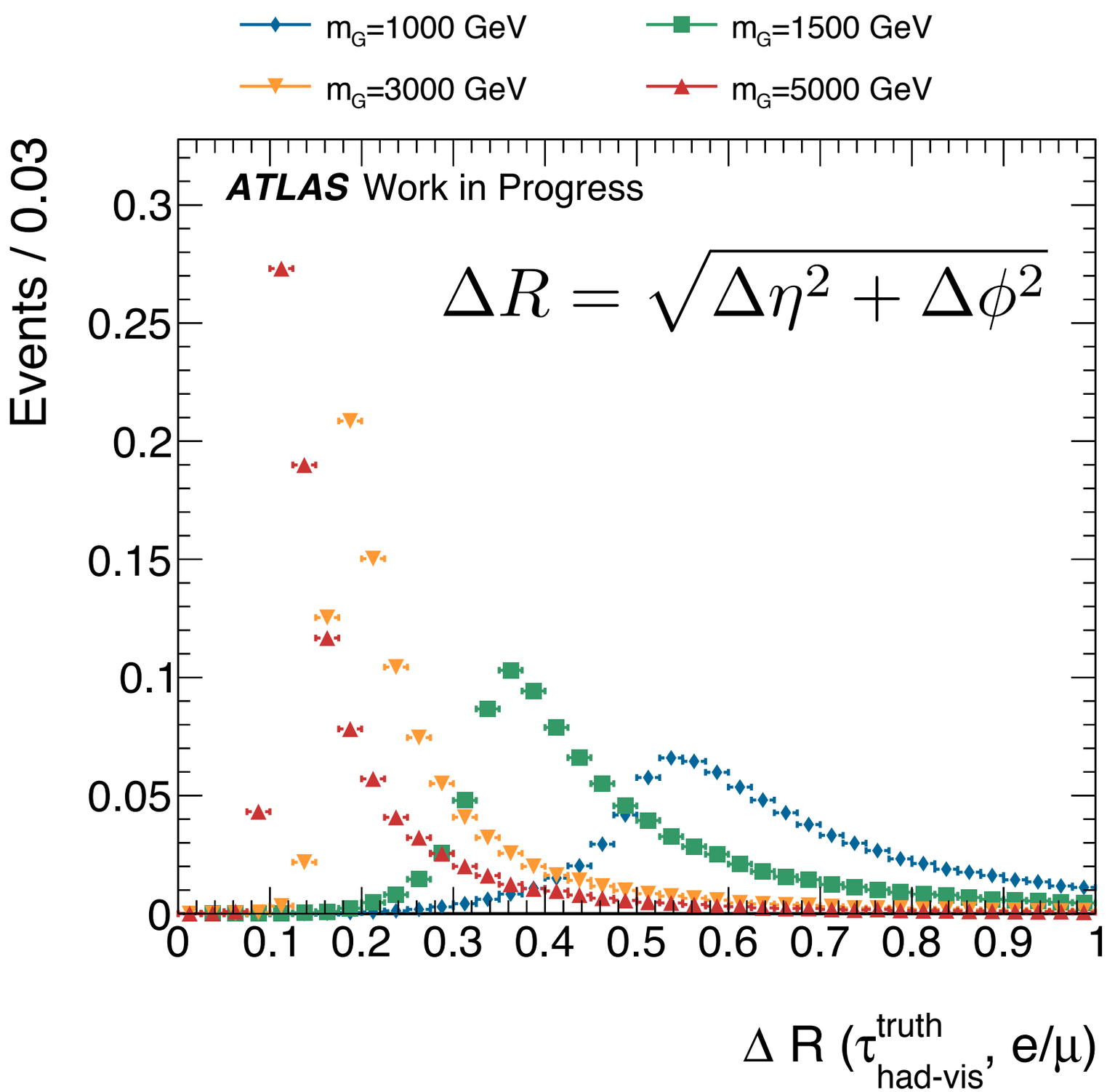


- $G \to hh \to bb\tau\tau$ analysis
- high mass resonance decaying into pair of Higgs bosons
  - ➡ production of Higgs bosons with high momentum
  - ➡ two tau leptons with low spatial separation („Boosted Topology“)
  - ➡ one decays hadronically
  - ➡ other decays leptonically
  - ➡ „Semi-Leptonic“
- algorithms for full hadronic boosted di-taus already exist

$$\mathrm{BR}(h \to \tau\tau) \approx 6\%$$

$$\mathrm{BR}(\tau\tau \to \mathrm{lephad}) = 2 \cdot \mathrm{BR}(\tau \to \mathrm{lep})\mathrm{BR}(\tau \to \mathrm{had}) \approx 46\%$$

Motivation

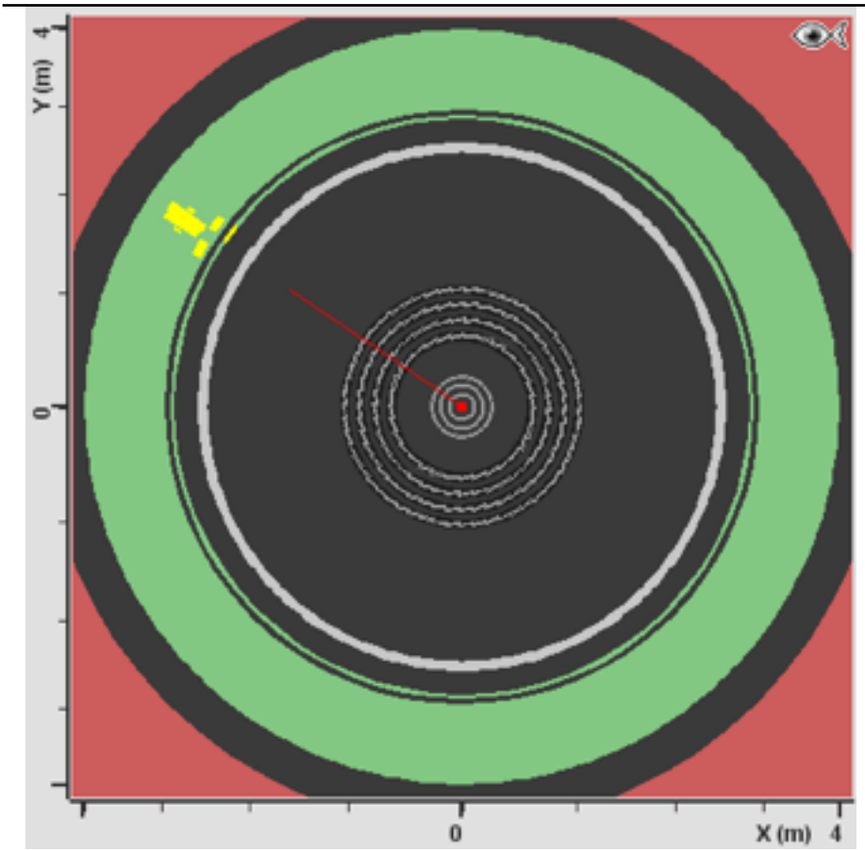


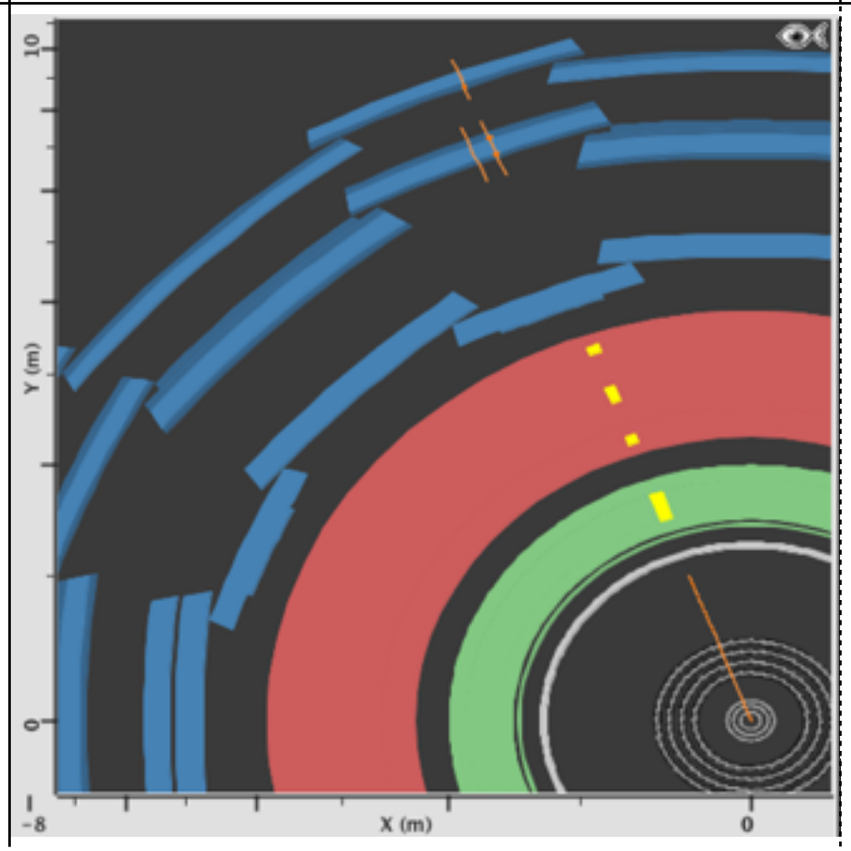
- Monte Carlo samples for G→hh→ττττ process with different graviton masses

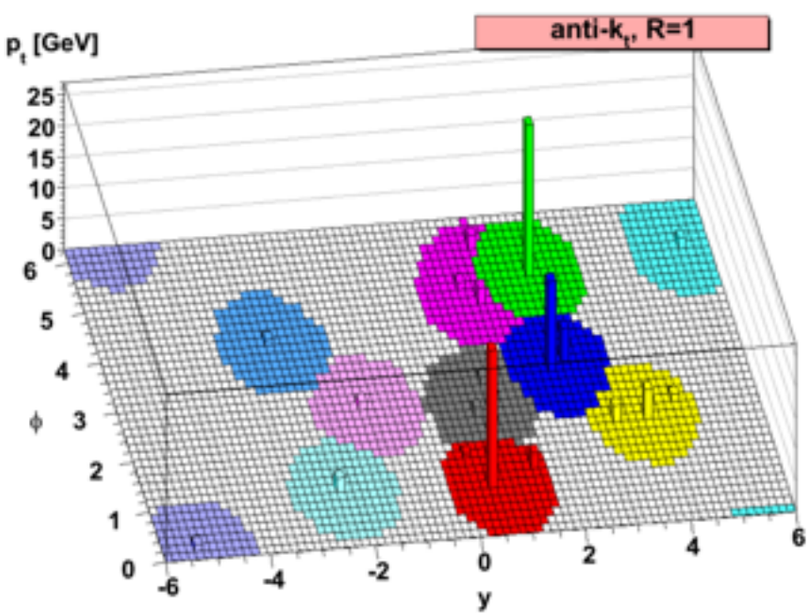
➡ How do existing tau-, electron and muon algorithms perform for low ΔR?

Reconstruction of Hadronic Tau Decays, Electrons and Muons at ATLAS

electron	**muon**	**tau**
- energy in sliding window exceed threshold - inner detector track matches to calorimeter energy deposition	- inner detector track - muon spectrometer track	- anti-k_t(R=0.4) jets build from calorimeter energy deposition - one or three classified tracks in jet region





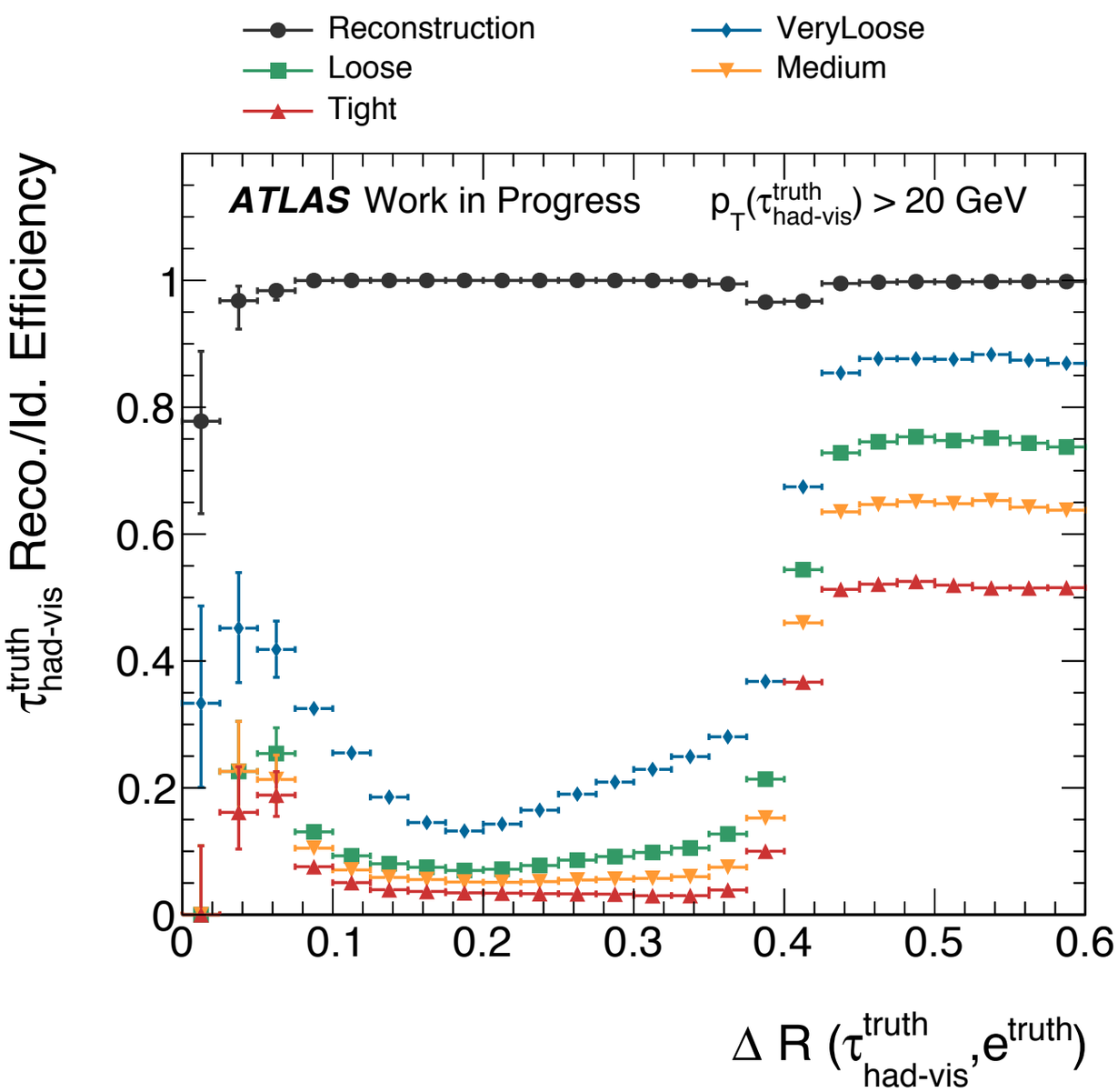


http://atlas.physicsmasterclasses.org/en/wpath_teilchenid3.htm

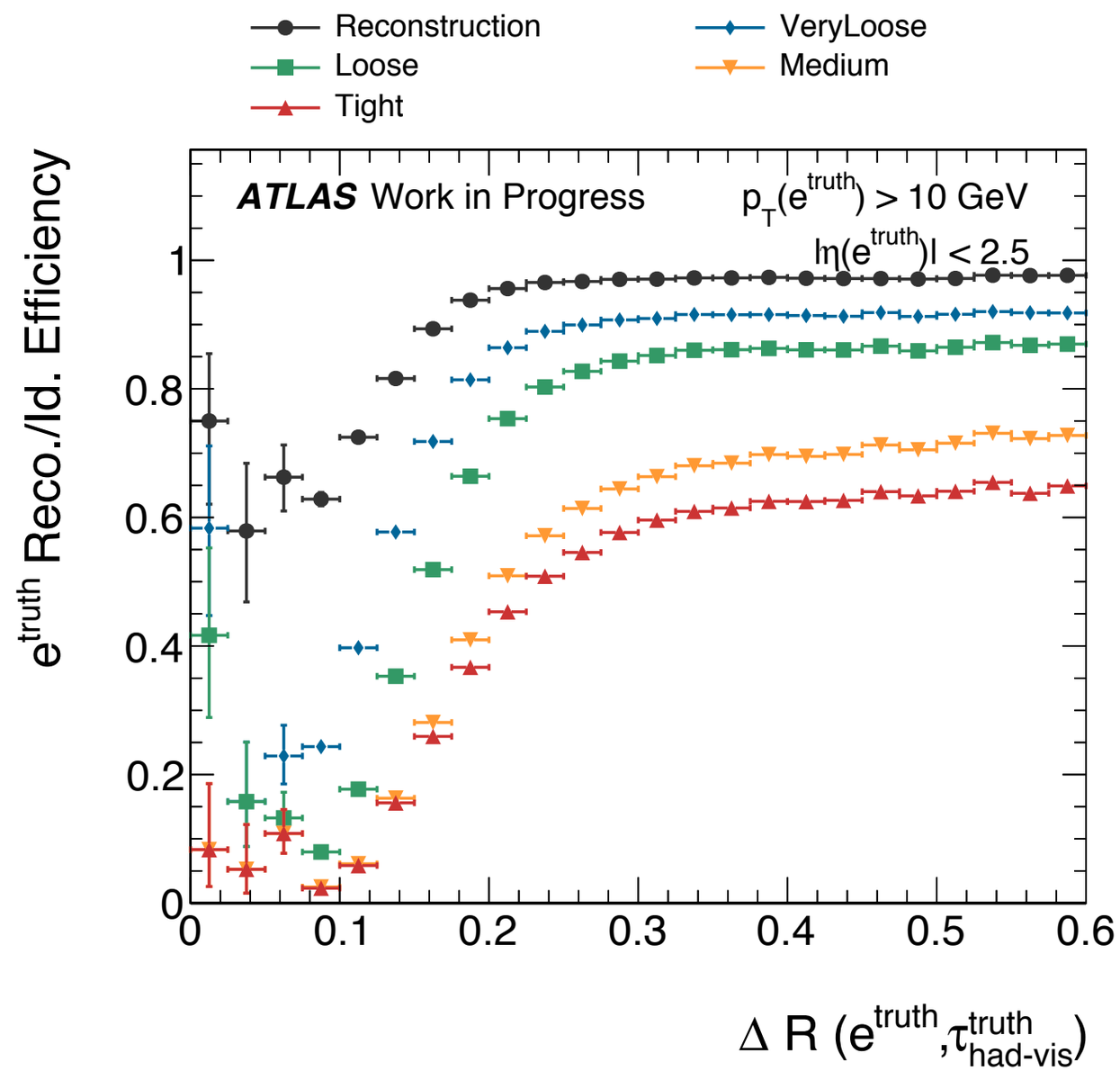
M. Cacciari, G. P. Salam, G. Soyez, *The Anti-k(t) jet clustering algorithm* JHEP 0804 (2008) 063

Had-Electron Channel

Standard Tau Reconstruction/Identification



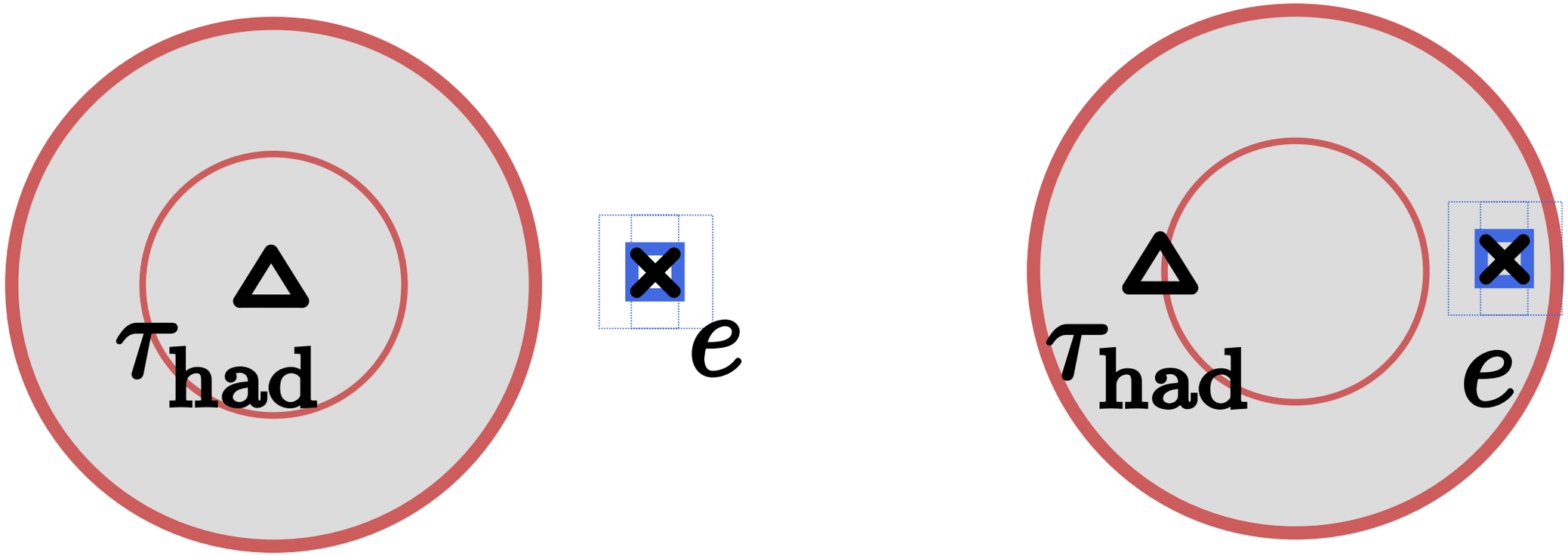
Standard Electron Reconstruction/Identification



Main Problem for Existing Algorithm

$$\Delta R(\tau_{\mathrm{had}}, e) > 0.4 \qquad \Delta R(\tau_{\mathrm{had}}, e) < 0.4$$

anti-k_t(R=0.4)-jet

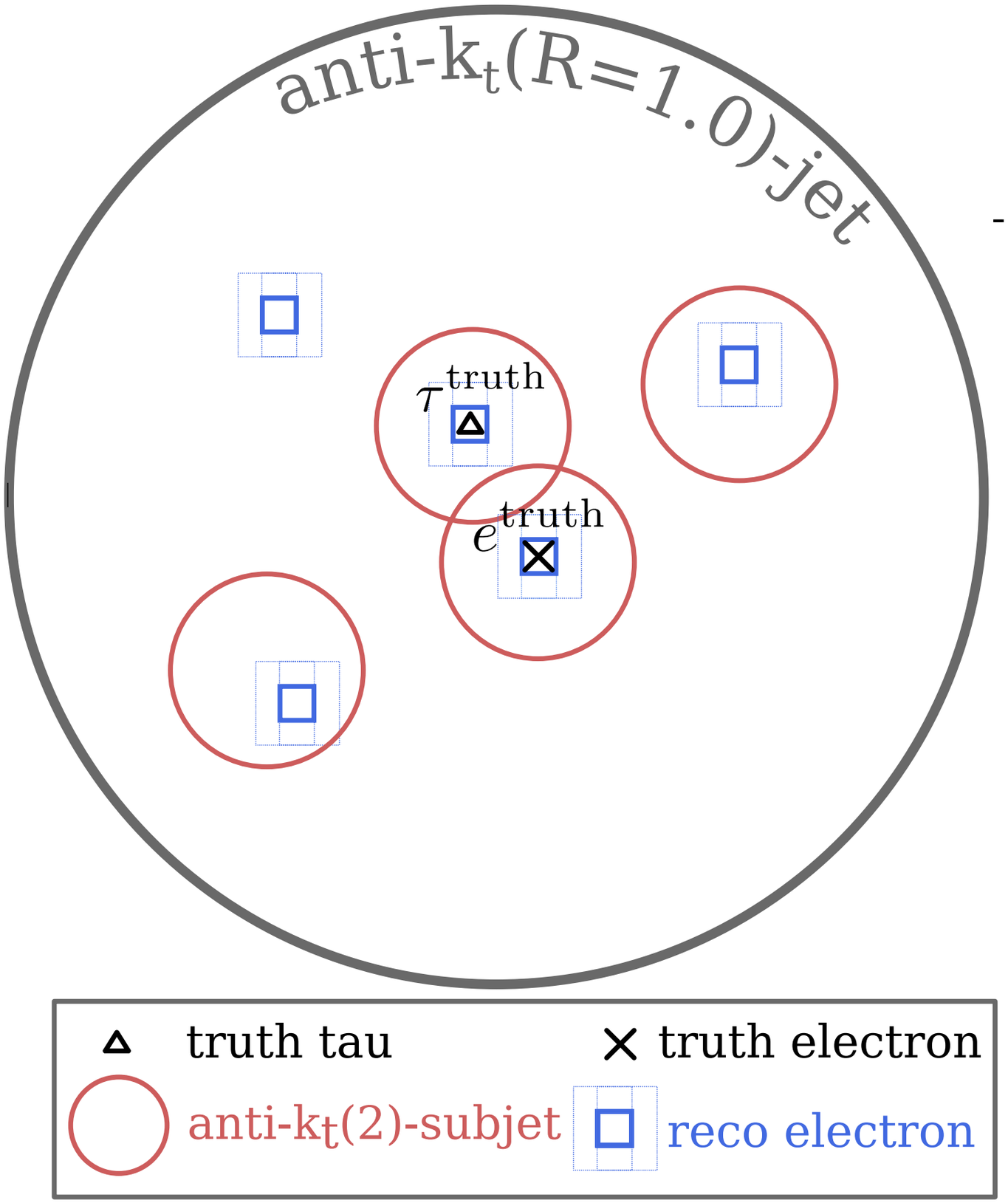


- tau reconstruction uses anti-k_t(R=0.4) seed jet

➡ energy depositions merge into one seed jet for ΔR smaller than 0.4

➡ axis of reconstructed hadronic tau shifted

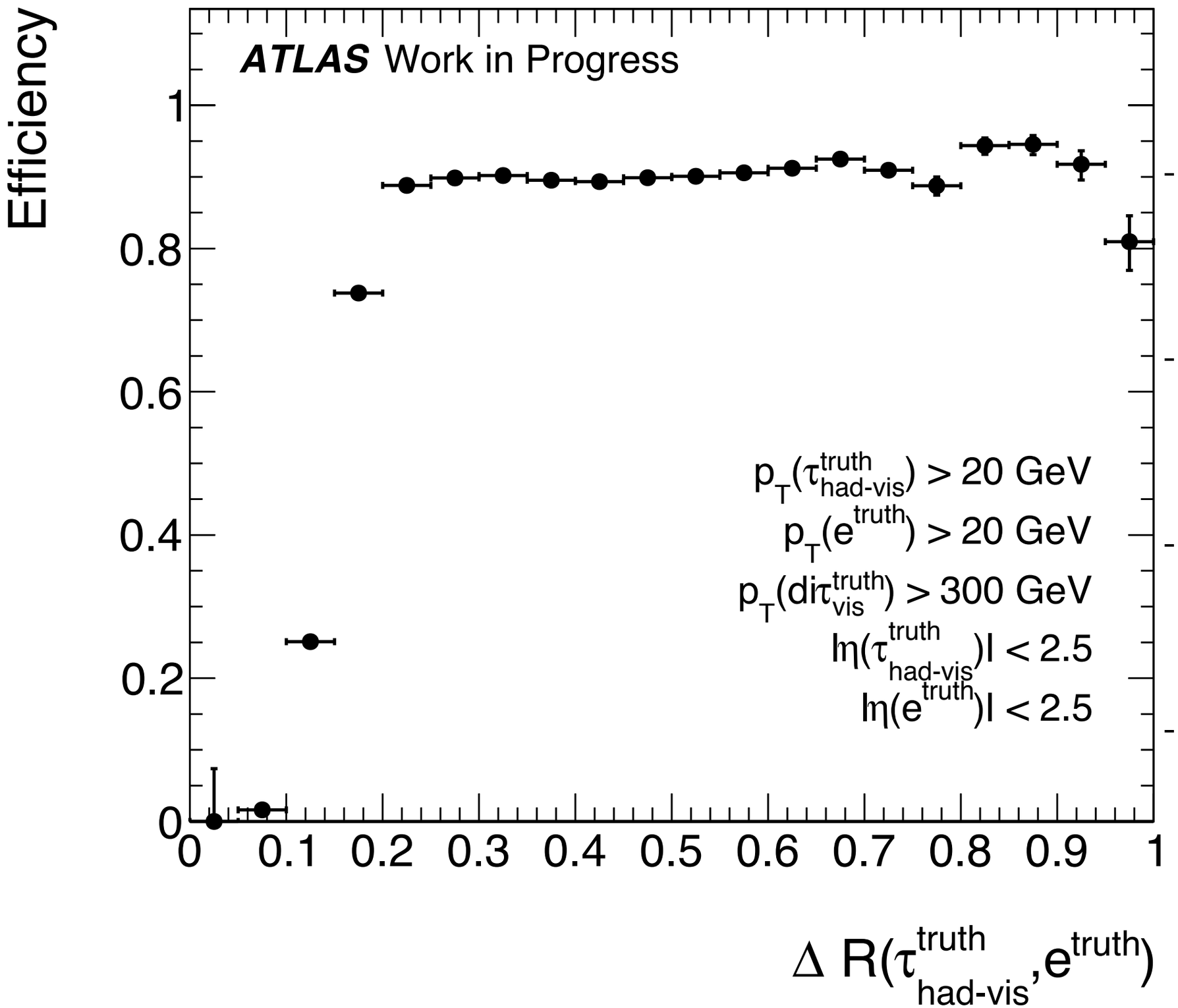
New Reconstruction for the HadEl Channel



- approach based on Di-Tau reconstruction for HadHad channel

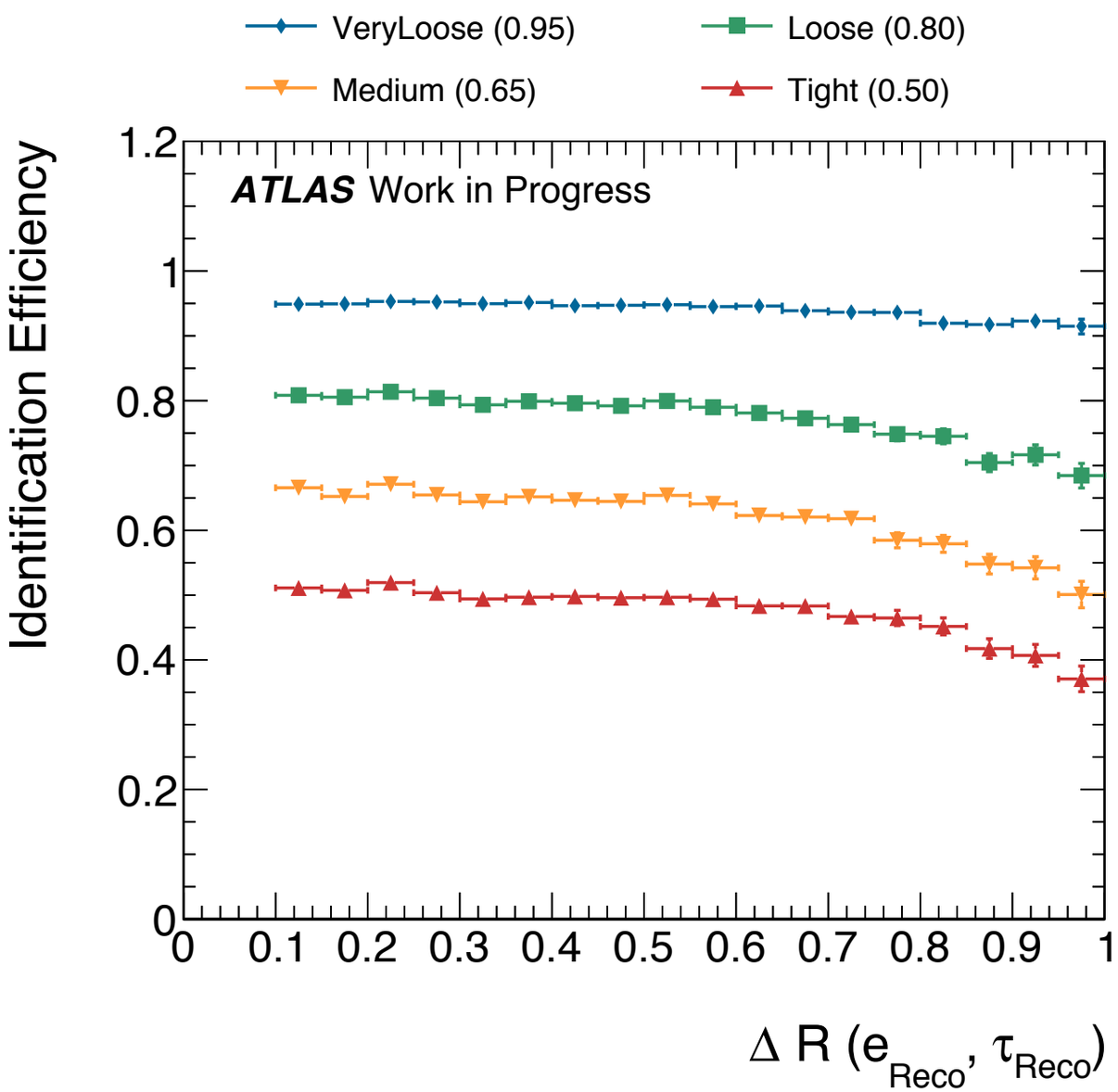
1. find seed: large anti-k_t(R=1.0)-jet with > 300 GeV
2. groom small anti-k_t(R=0.2) subjets from clusters in seed jet
3. search for reconstructed electrons in region
4. create HadEl candidate for each reconstructed electron-subjet combination with $\Delta R > 0.1$

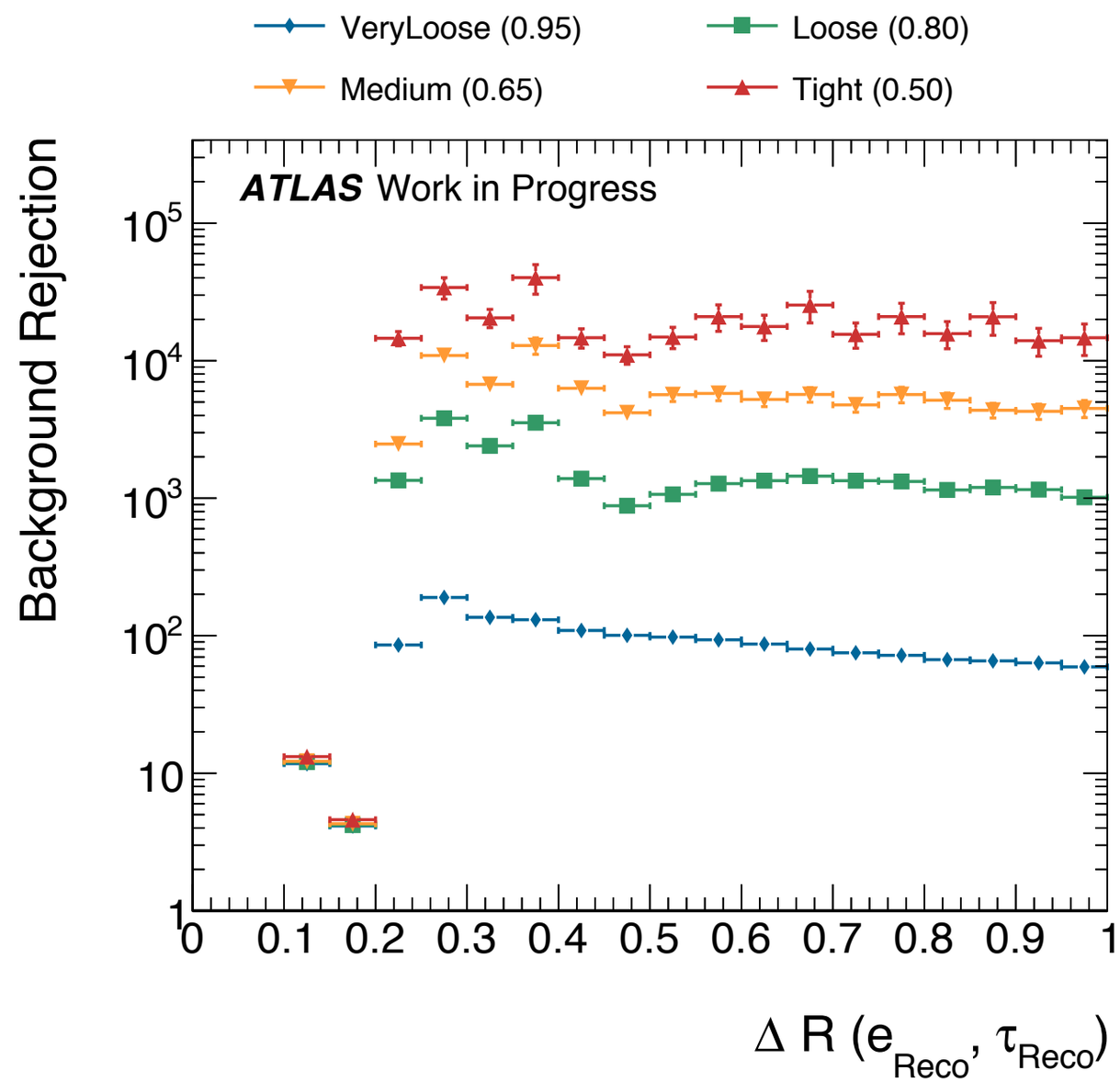
Performance of New HadEl-Reconstruction



- reconstruction efficiency for true HadEl di-taus
- some cuts applied on all HadEl di-taus beforehand
- good efficiency ~90% for $0.2<\Delta R<0.4$
- drops at 0.2 because of size of anti-k_t(R=0.2)-jets

Identification of HadEl Di-Taus

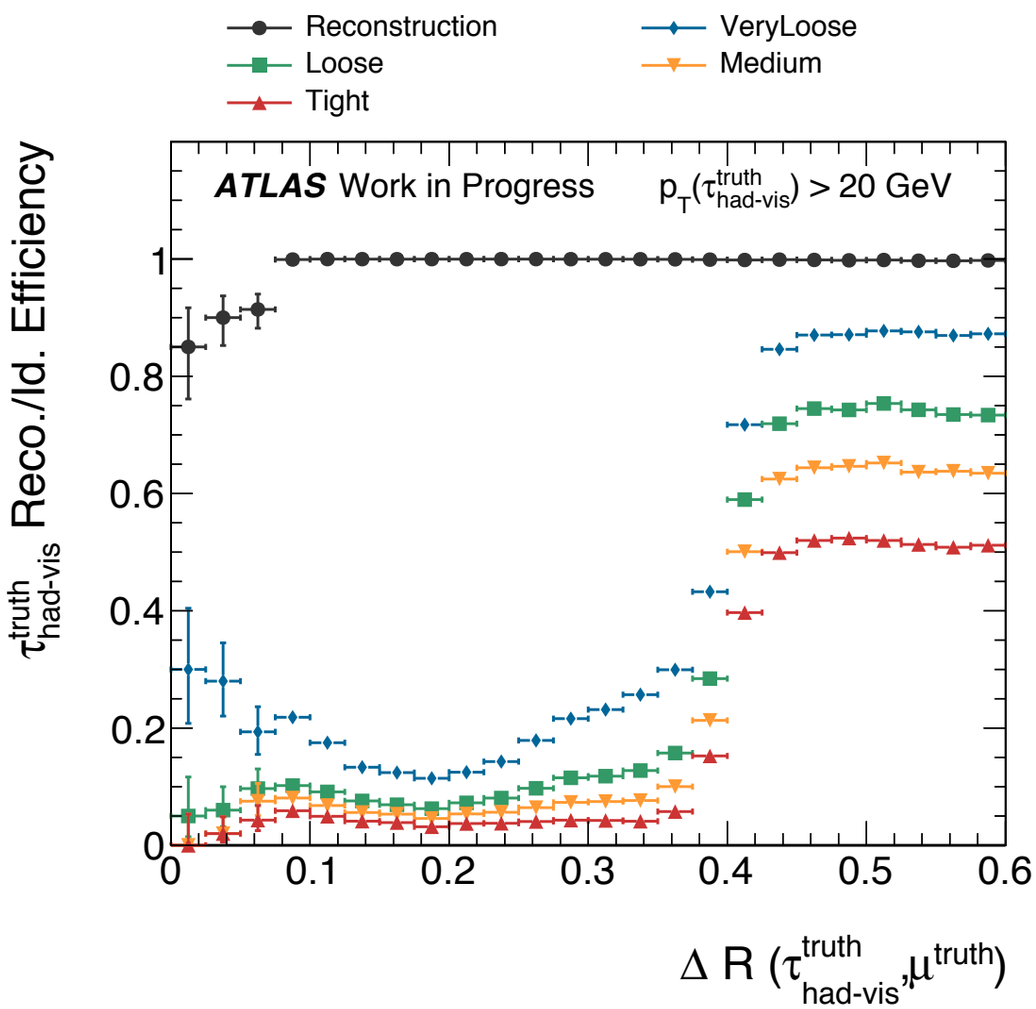




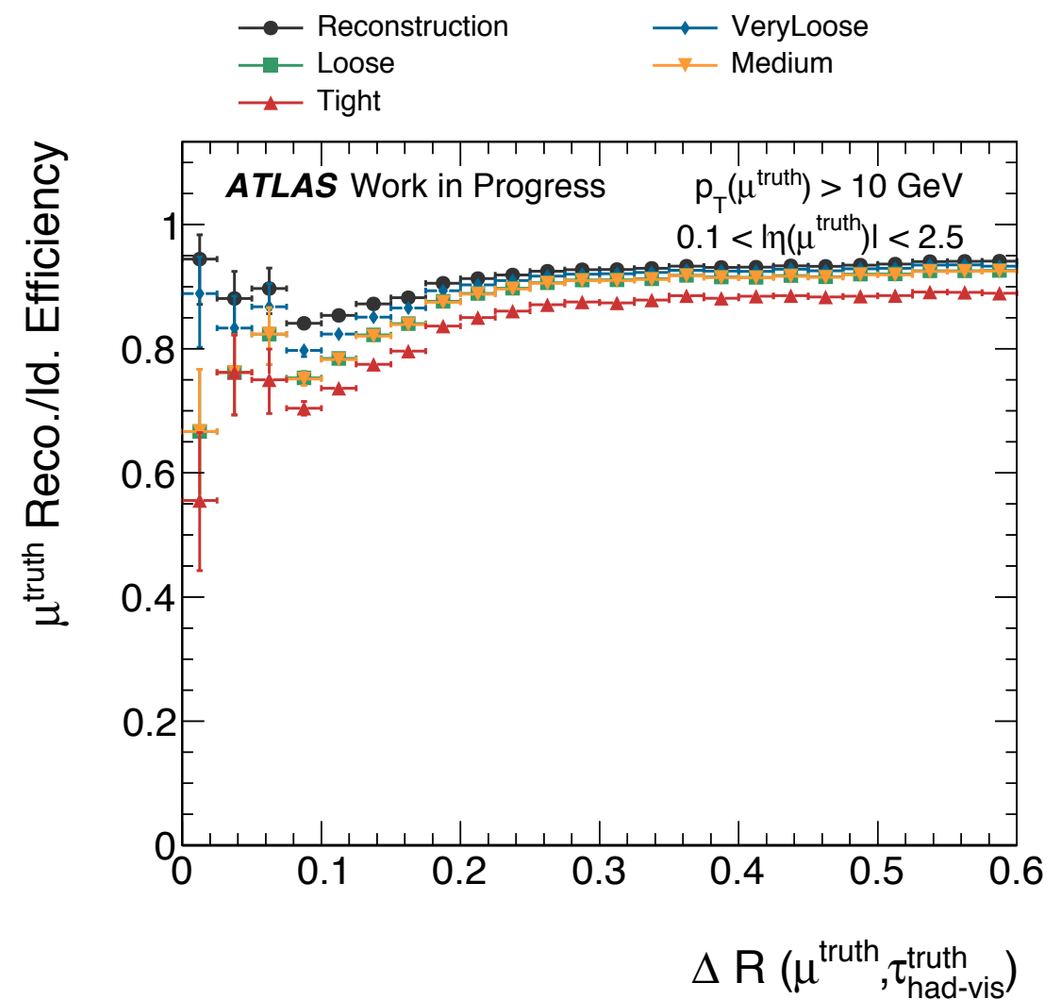
- tight/medium/loose/veryloose working points tuned to 50%/65%/80%/95% efficiency
- high background rejection for $\Delta R > 0.2$

Had-Muon Channel

Standard Tau Reconstruction/Identification

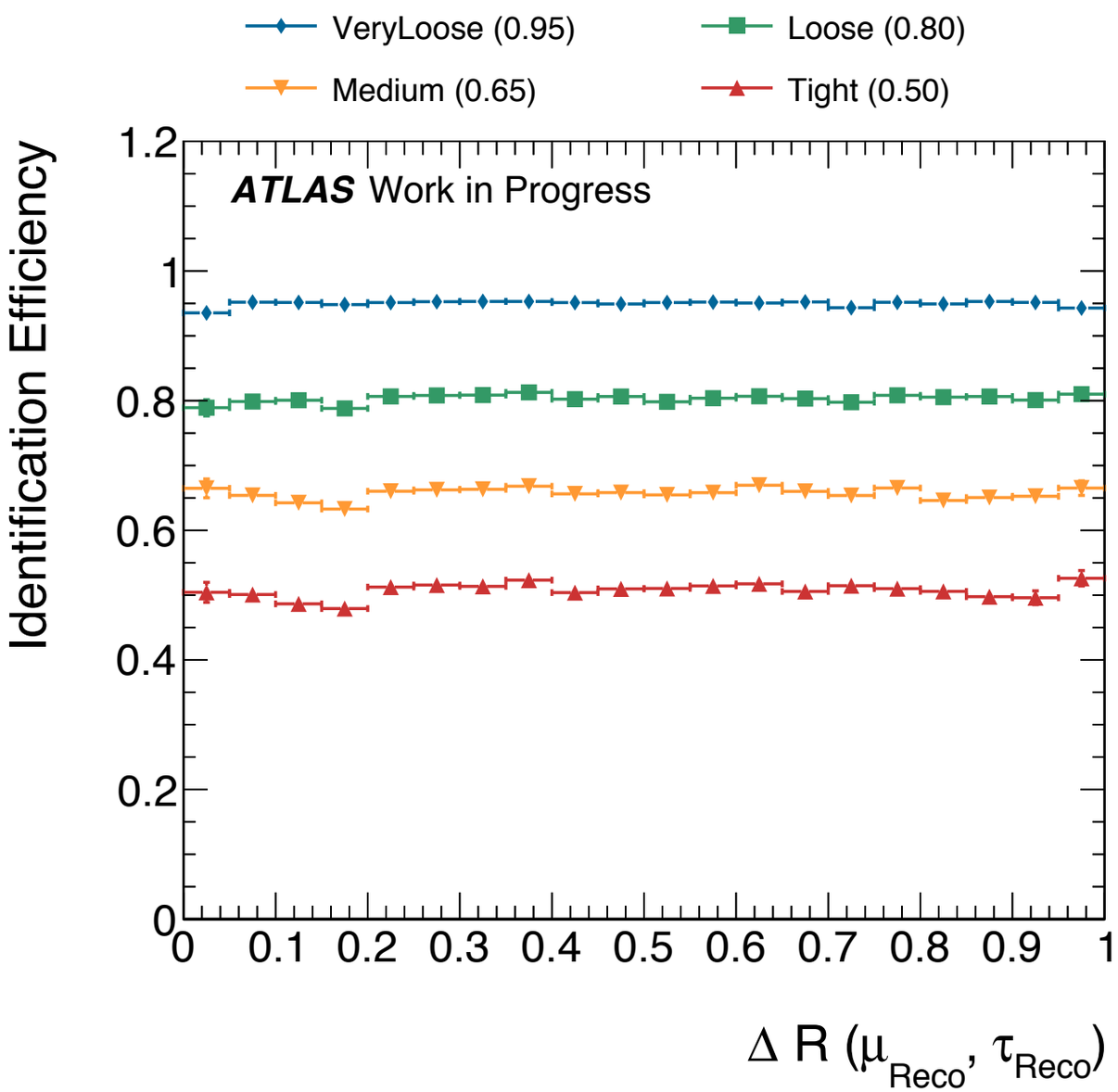


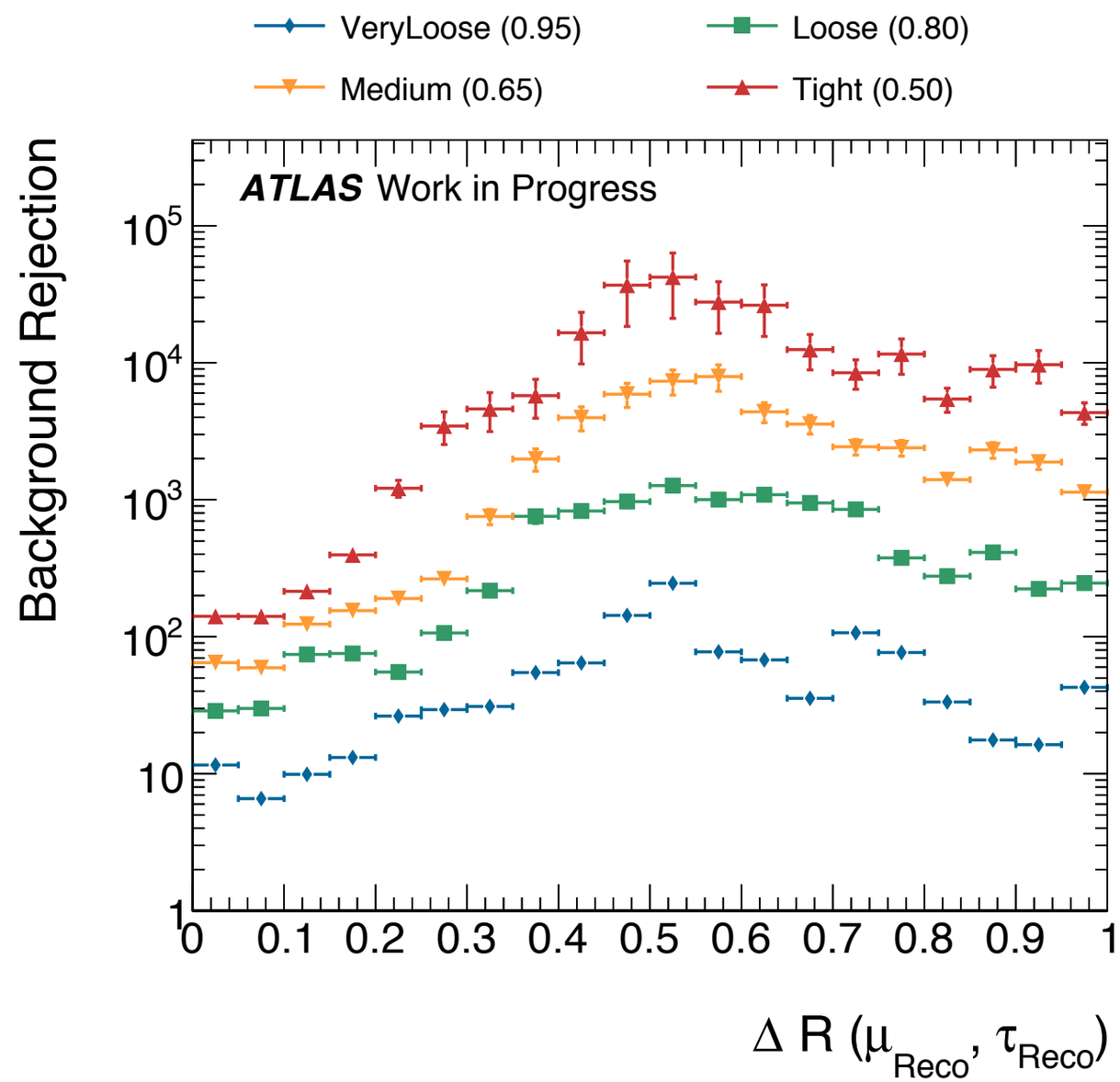
Standard Muon Reconstruction/Identification



- hadronic tau and muon reconstruction independent
- build candidates by matching taus and muons with $\Delta R<1.0$
- new boosted decision tree uses:
  - muon identification
  - tau identification variables corrected for muon tracks

Identification of HadMu Di-Taus





- tight/medium/loose/veryloose working points tuned to 50%/65%/80%/95% efficiency
- high background rejection for $\Delta R > 0.2$

Summary and Outlook

- new reconstruction and identification algorithms for boosted di-taus in the HadEl and HadMu decay channel
- good performance where existing algorithms cease to work
- tools already implemented in official ATLAS Athena software framework
- ready for evaluation in analysis:
  - $G \rightarrow HH \rightarrow bb\tau\tau$
  - $H \rightarrow aa \rightarrow \tau\tau\tau\tau$ ($m_a \sim 10$ GeV)
- ongoing studies on systematic uncertainties (talk by Fabian Petsch)

Backup

Identification of HadEl Di-Taus

Signal: truth matched HadEl di-taus from $G \to hh \to \tau\tau\tau\tau$ MC sample with graviton masses between 1 TeV and 5 TeV

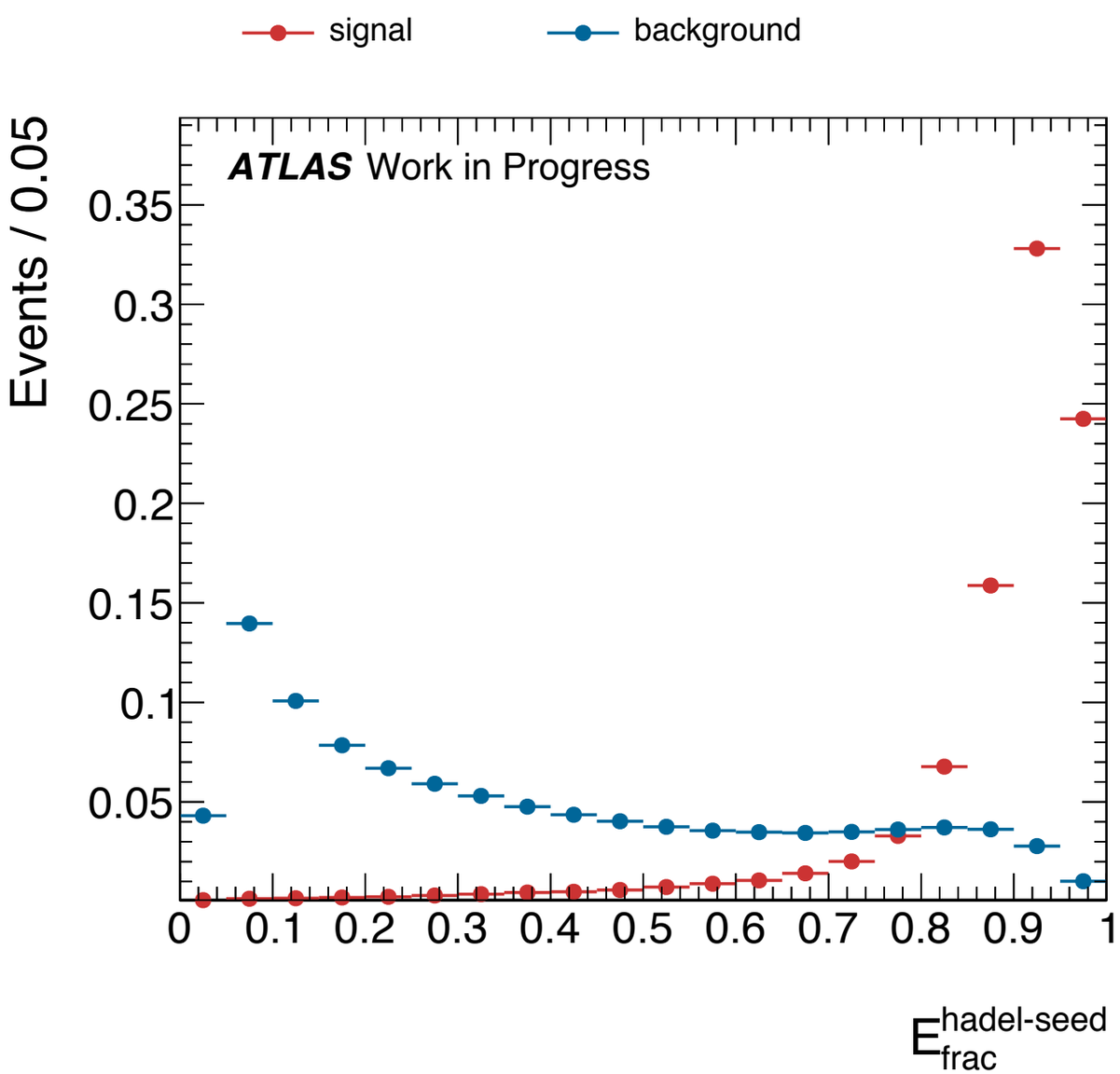
Background: HadEl di-tau candidates from data15 with fat jet triggers

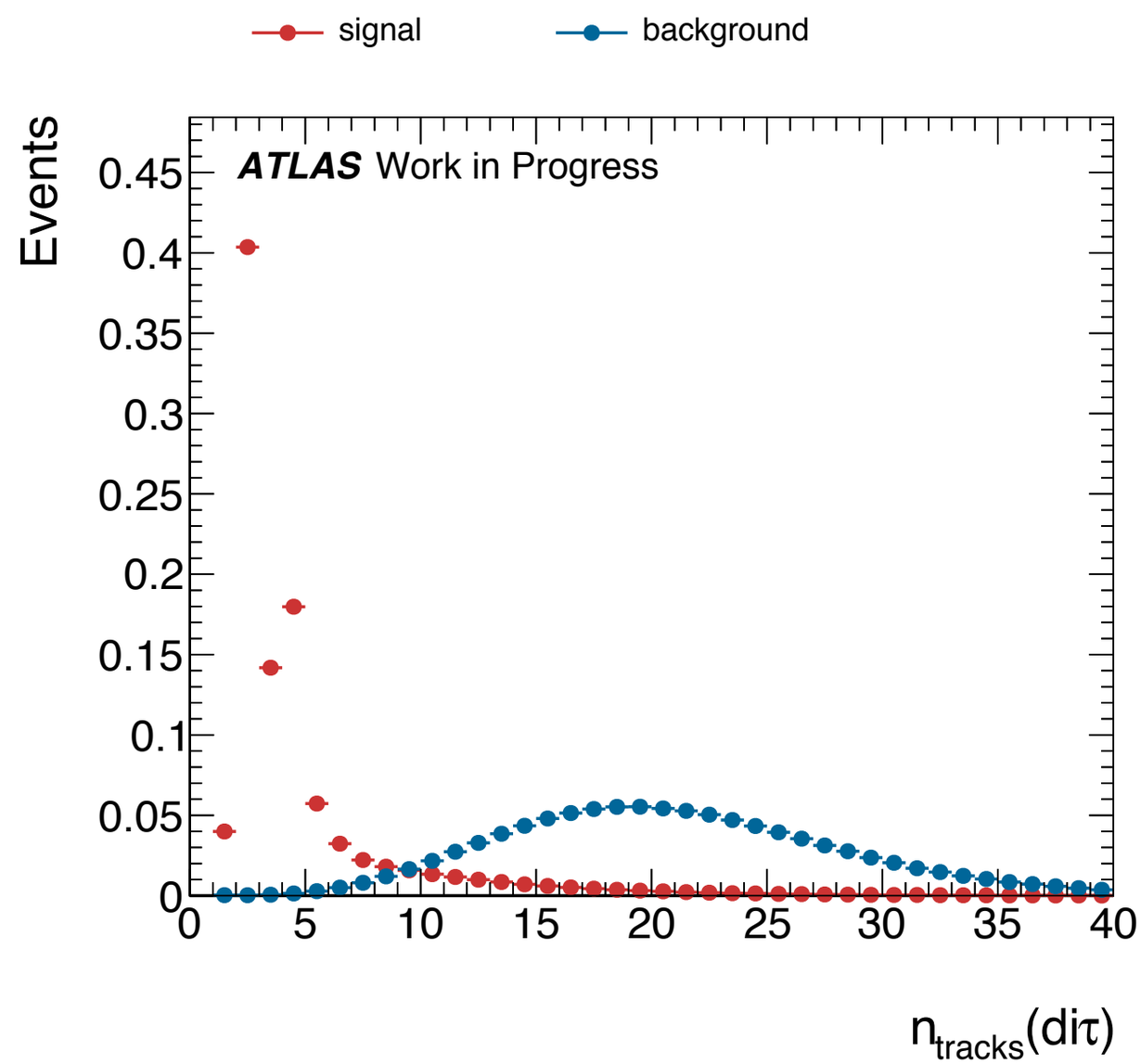
1. **Reweight** background to achieve same 2D tau pt vs electron pt distribution as in signal sample
2. **Train** boosted decision tree (BDT)
3. **Tune** WP to reach flat signal efficiency in ΔR vs ditau pt (different BDTScore cut for each 2D (ΔR,ditau pt) bin)

three sets of ID variables:

- variables using information from electron
- variables using information from tau subjet
- variables using information of whole anti-kt(10) area

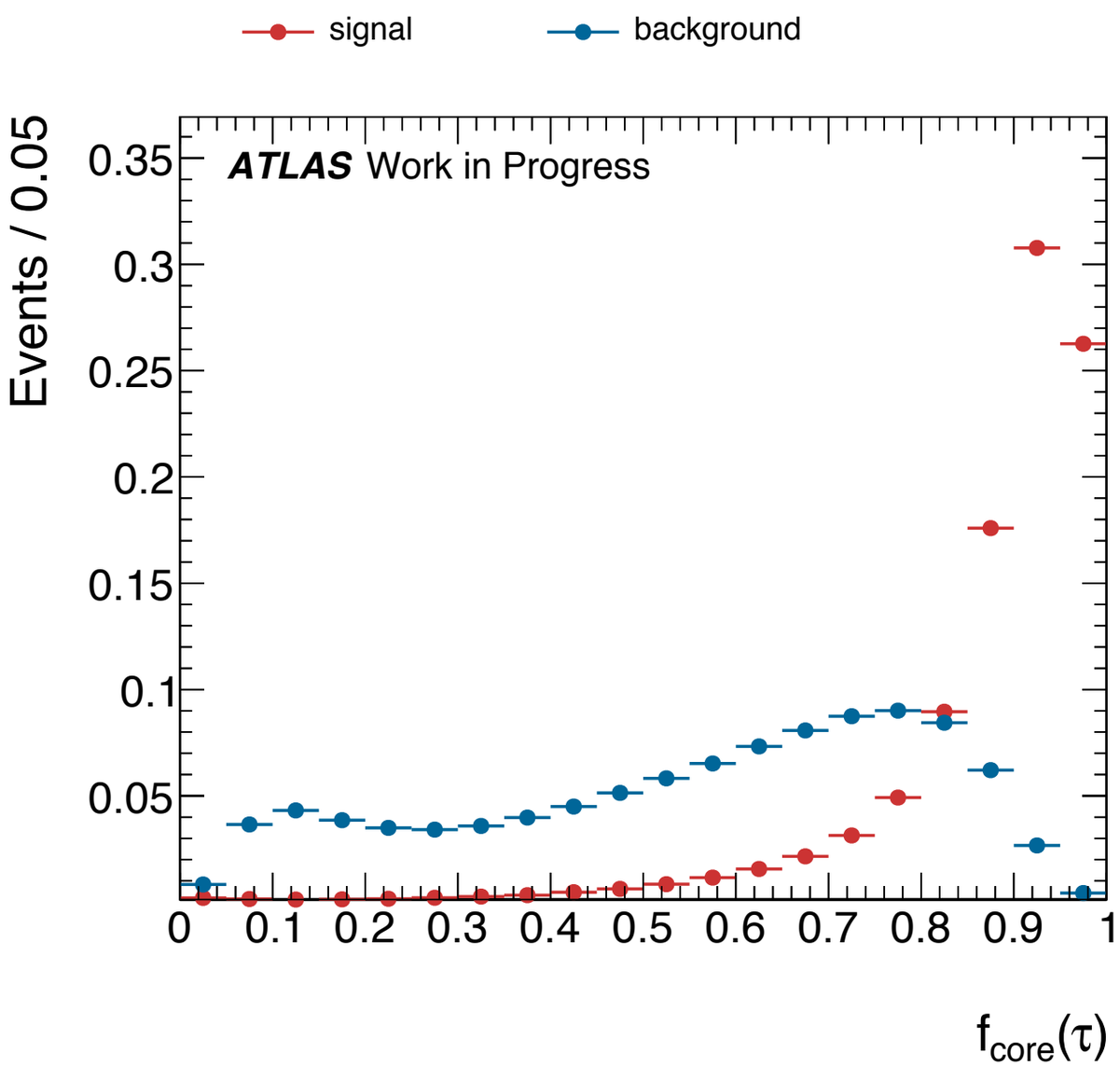
Example of HadEl Di-Tau Identification Variables

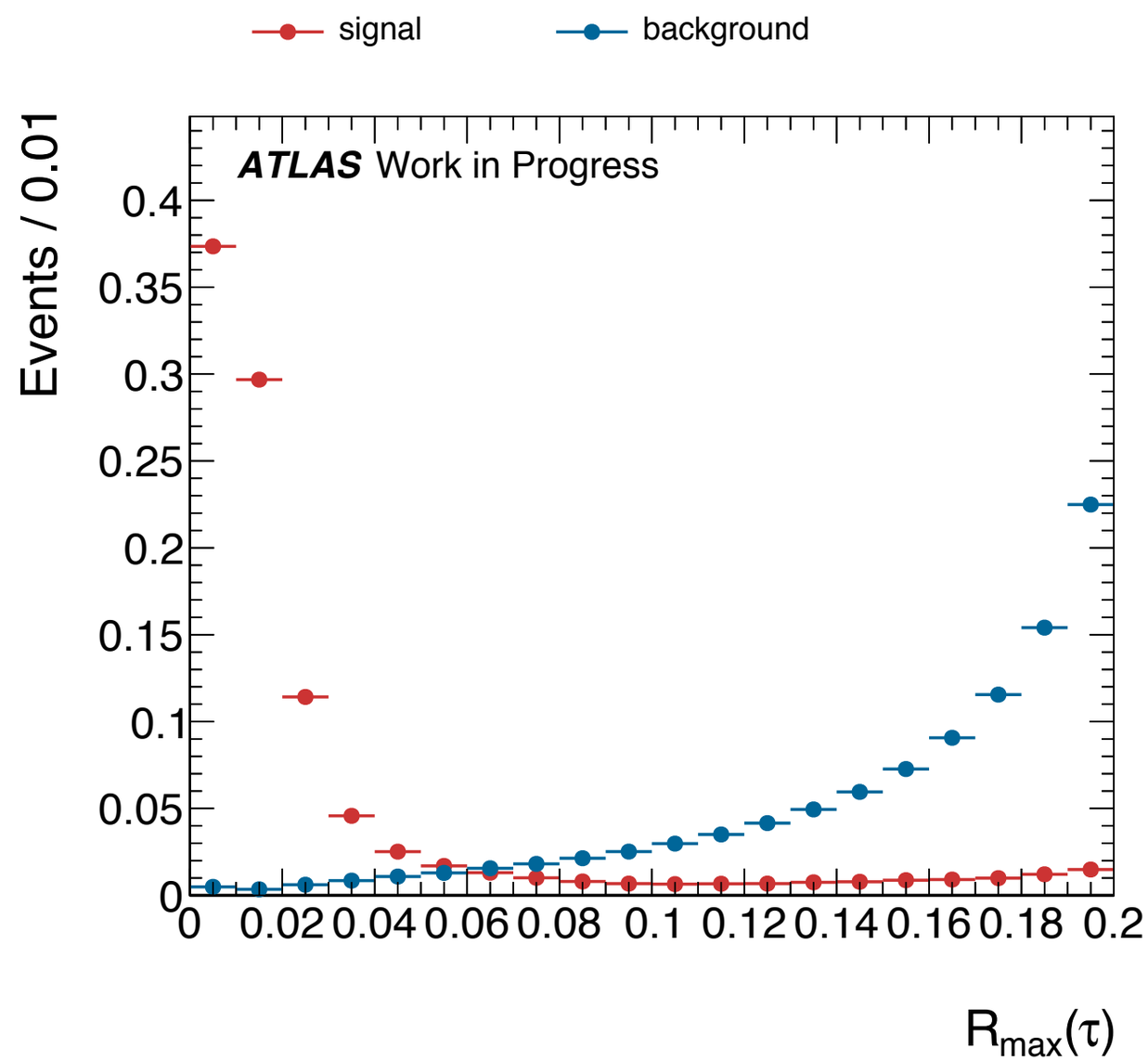




$$E_{\text{frac}}^{\text{hadel}-\text{seed}} = \frac{p_{\text{T}}(\tau_{\text{subjet}}) + p_{\text{T}}(e)}{p_T(\text{anti}-k_t(10) - \text{seed})}$$

Example of HadEl Di-Tau Identification Variables

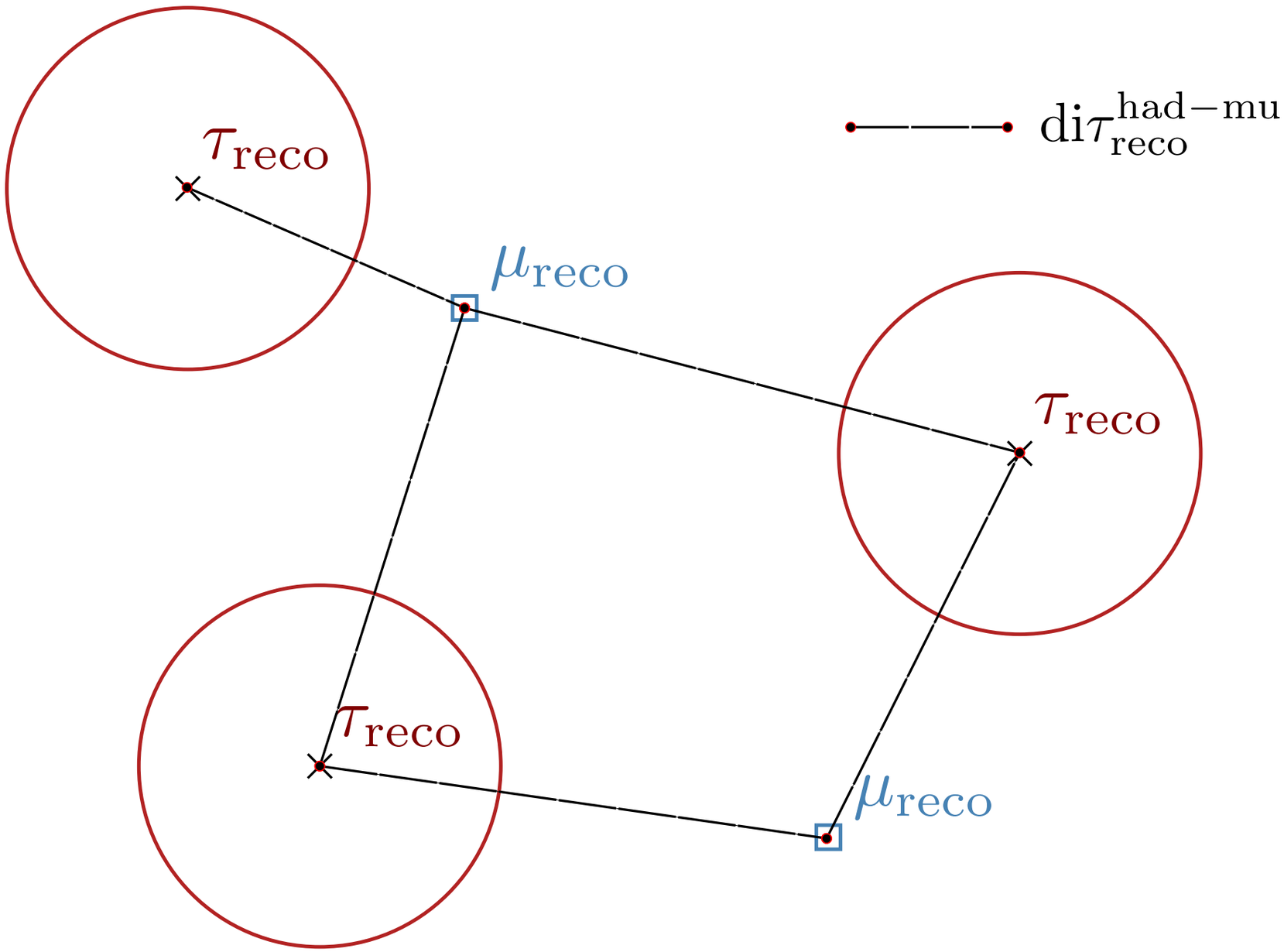




$$f_{\text{core}} = \frac{E_{0.1\times0.1}}{E_{0.2\times0.2}}$$

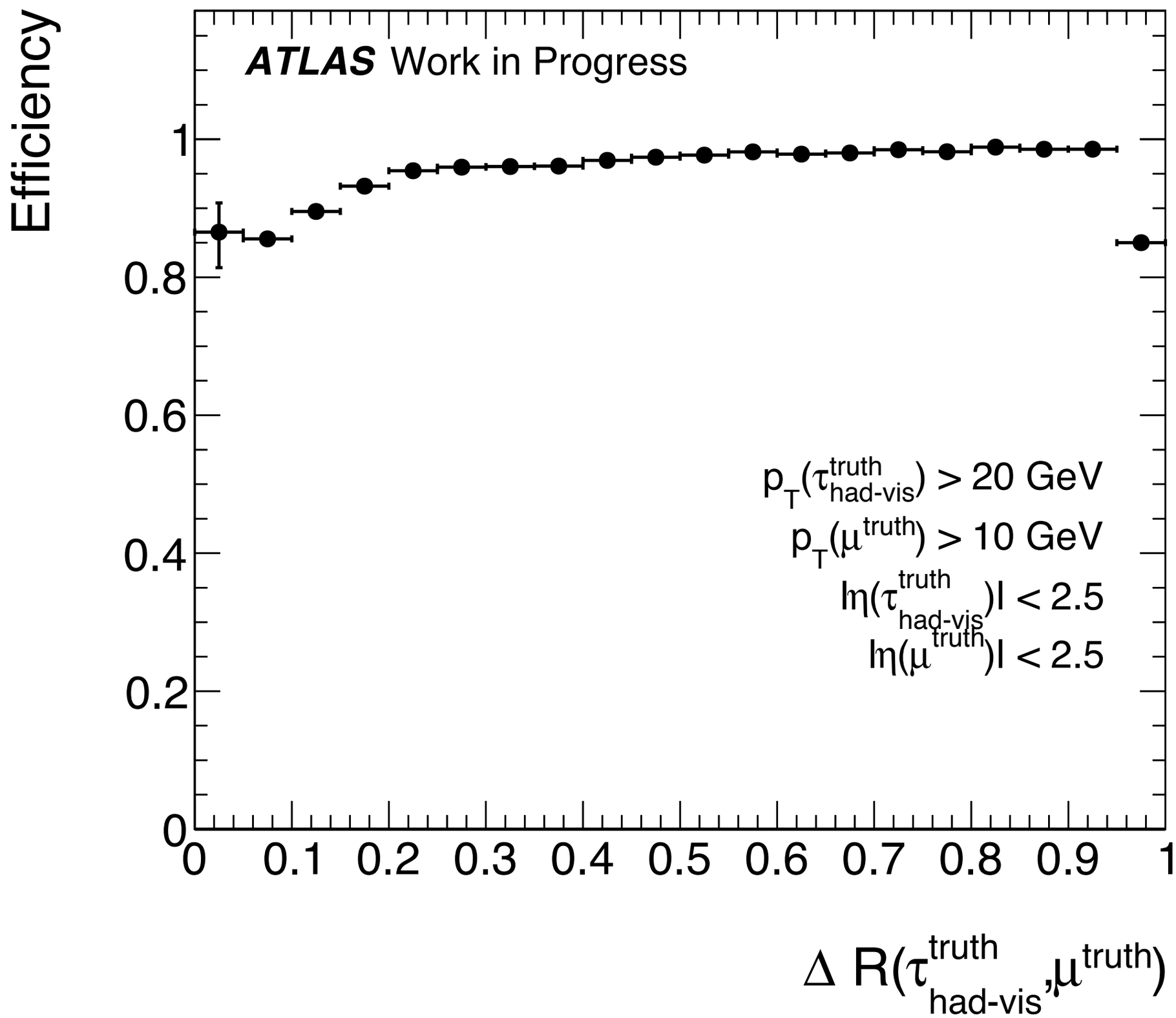
$$R_{\max} = \max_{\Delta R<0.2} \Delta R(\tau_{\text{subjet}}, \text{classified track})$$

New Reconstruction for the HadMu Channel



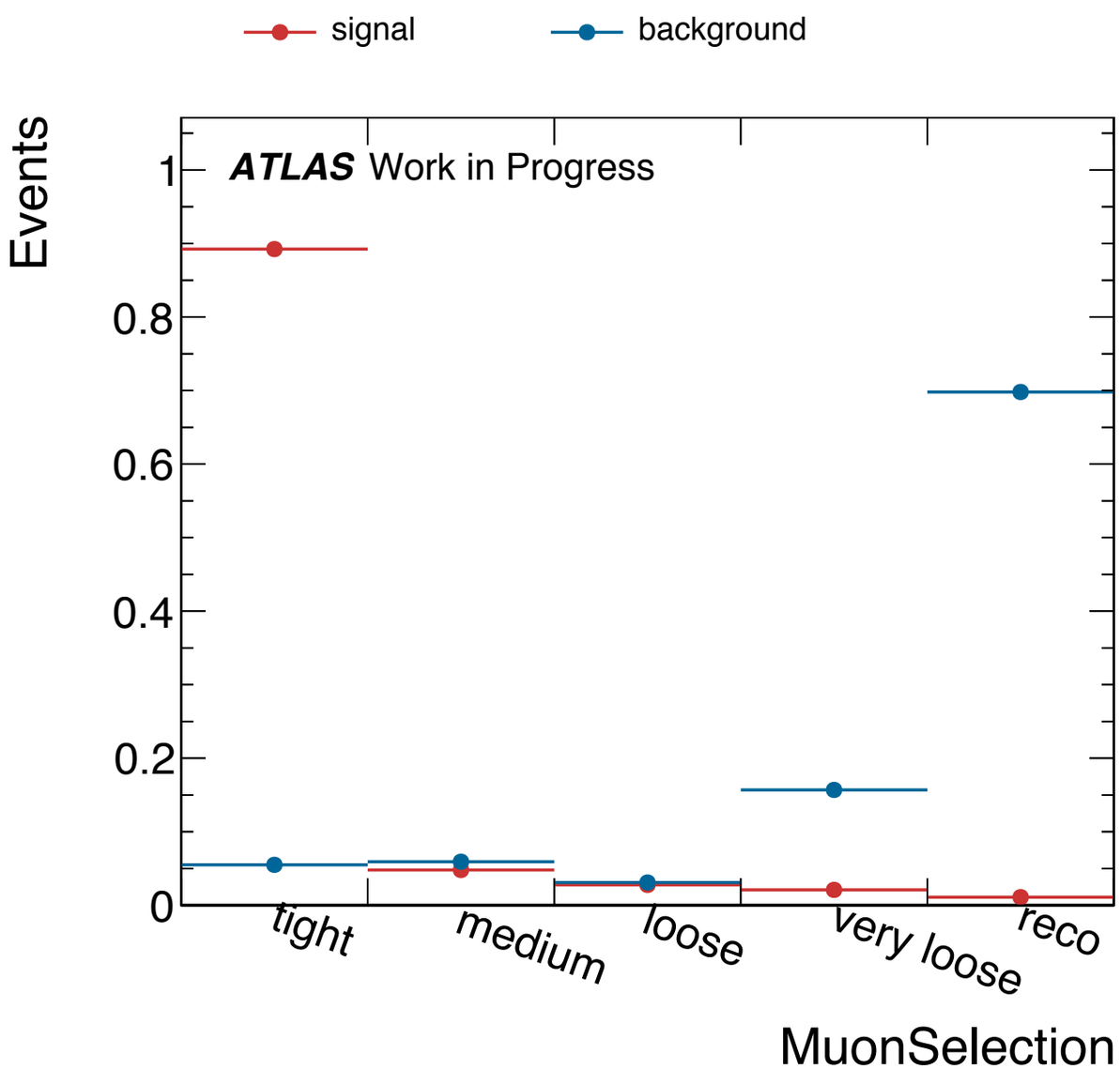
- use standard muon reconstruction and standard tau reconstruction
- use muon as seed
- create new Di-Tau-HadMu for every reconstructed tau in ΔR<1.0 vicinity

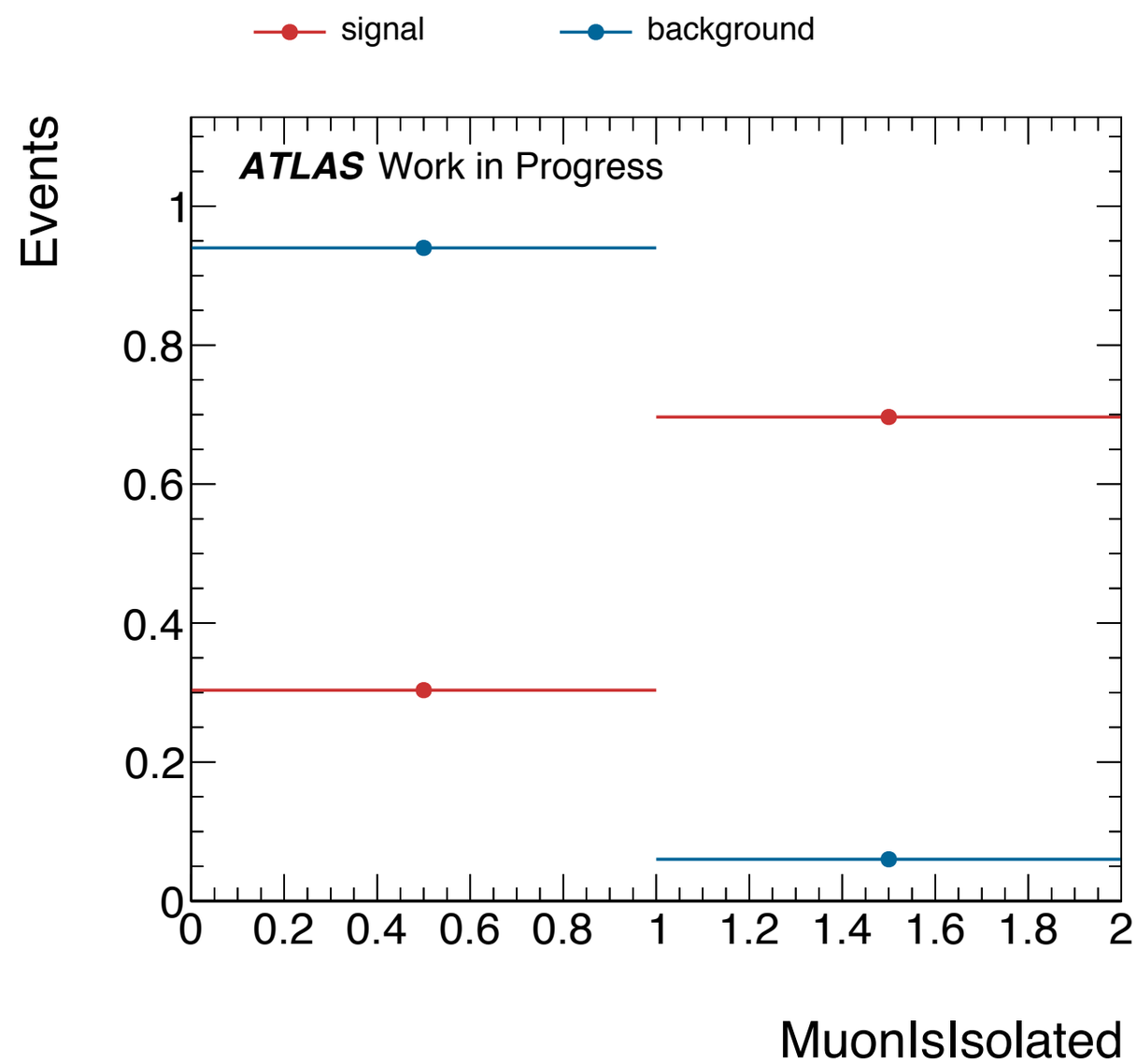
Performance of New HadMu-Reconstruction



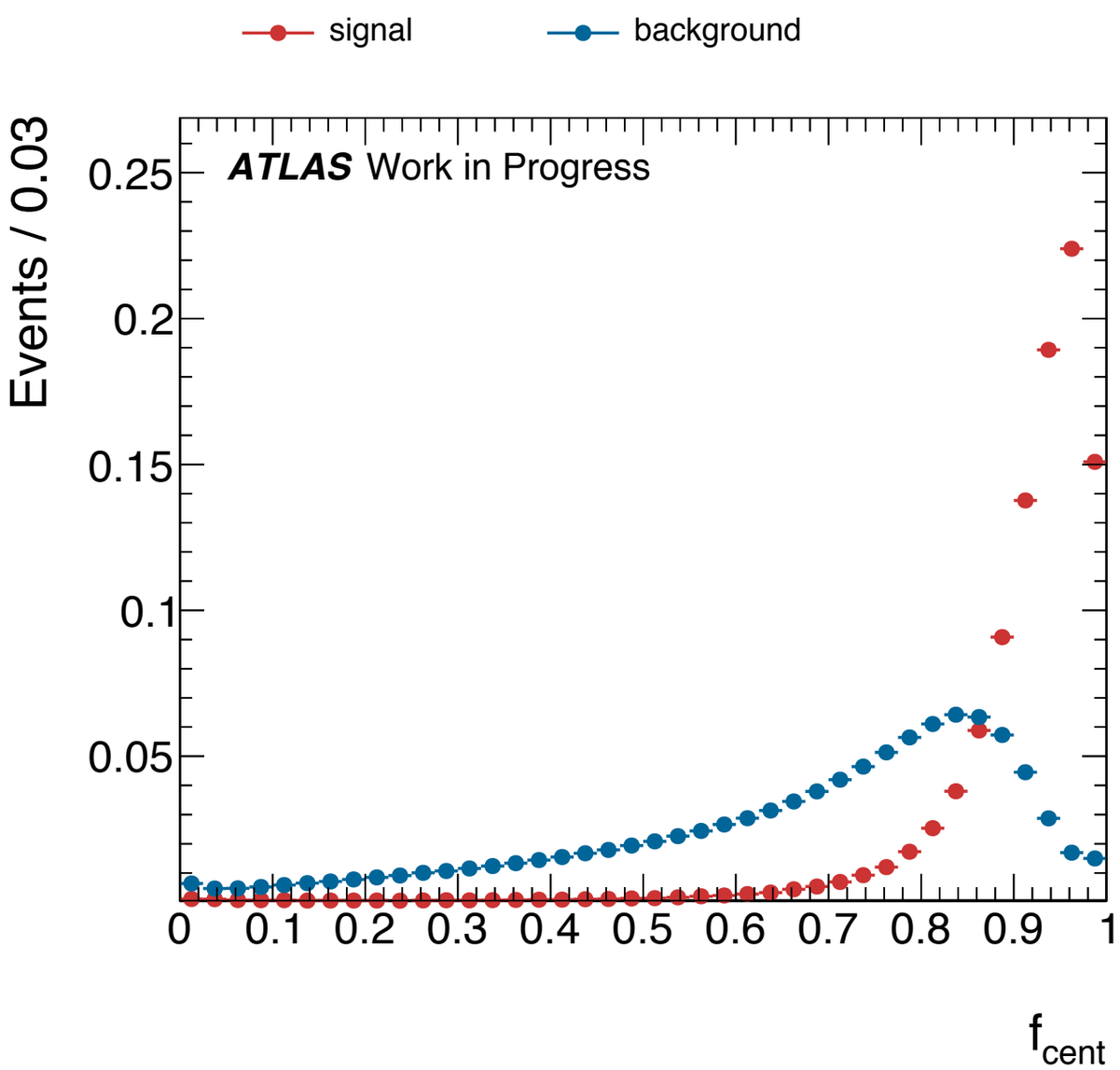
- reconstruction efficiency > ~90%
- slight decrease for very low ΔR due to decreasing muon reconstruction efficiency

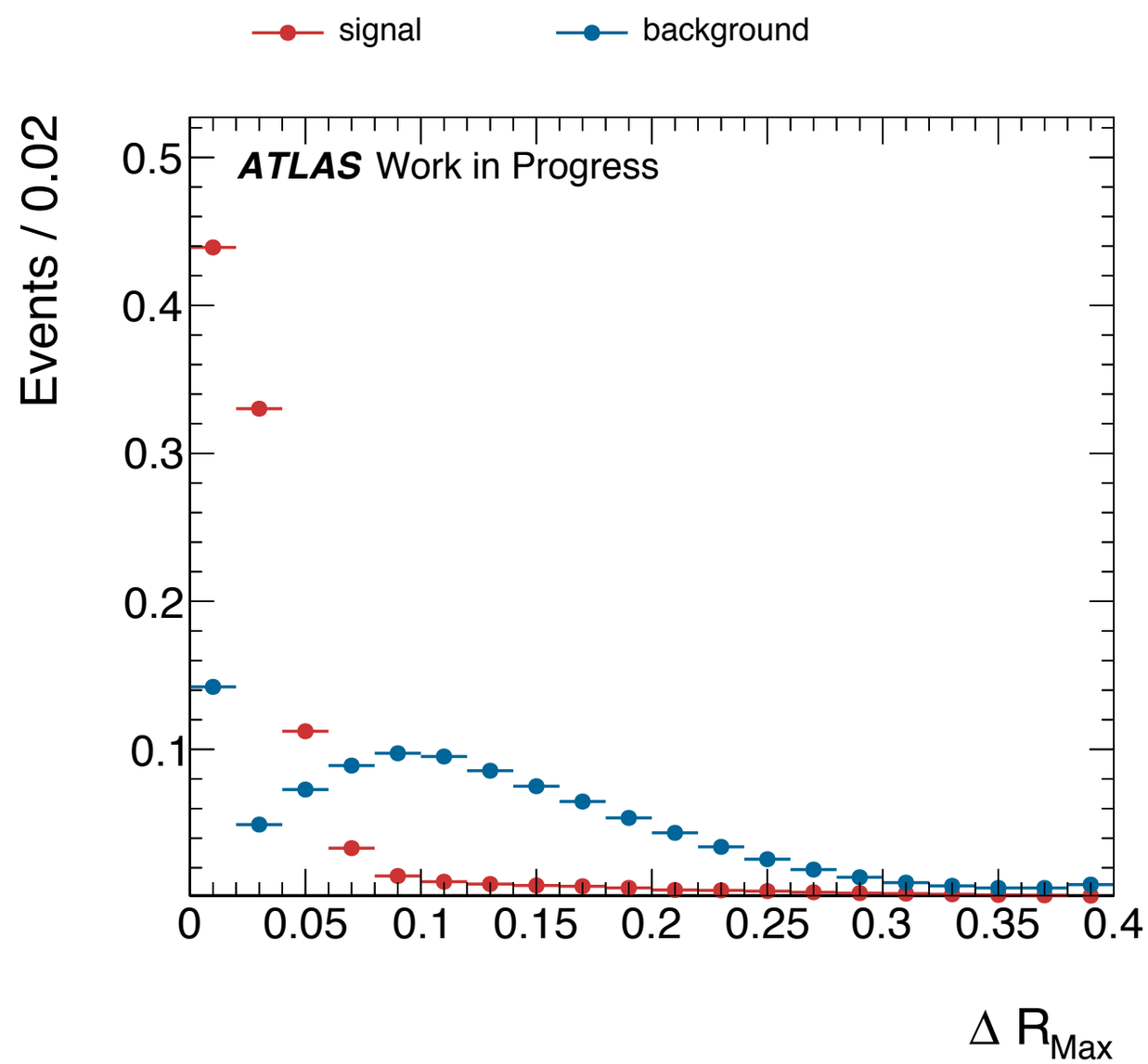
Example of HadMu Di-Tau Identification Variables





Example of HadMu Di-Tau Identification Variables





$$f_{\text{cent}} = \frac{E_{0.1\times0.1}}{E_{0.2\times0.2}}$$

$$R_{\max} = \max_{\Delta R<0.4} \Delta R(\tau_{\text{subjet}}, \text{classified track})$$