Measurement of the tau energy scale uncertainty for Higgs physics in Run II at ATLAS

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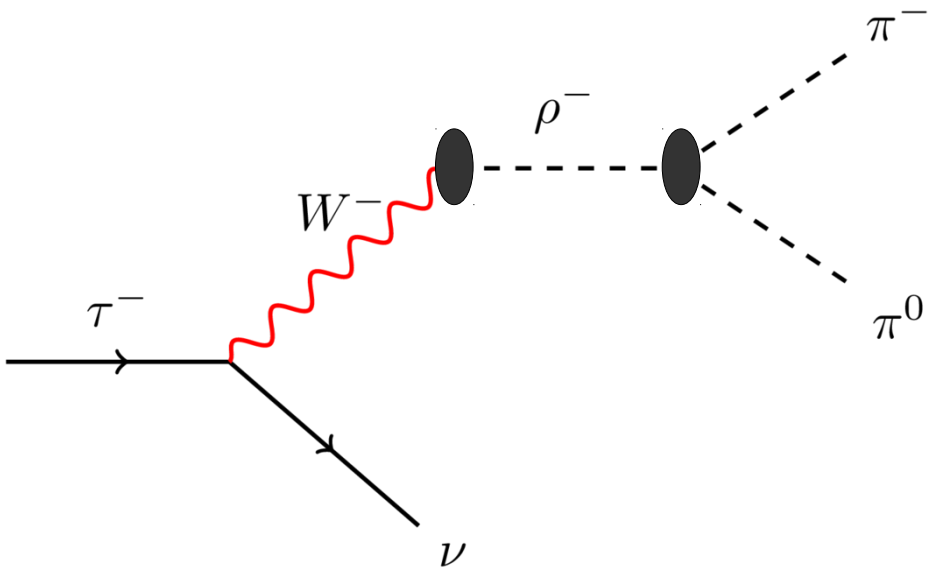
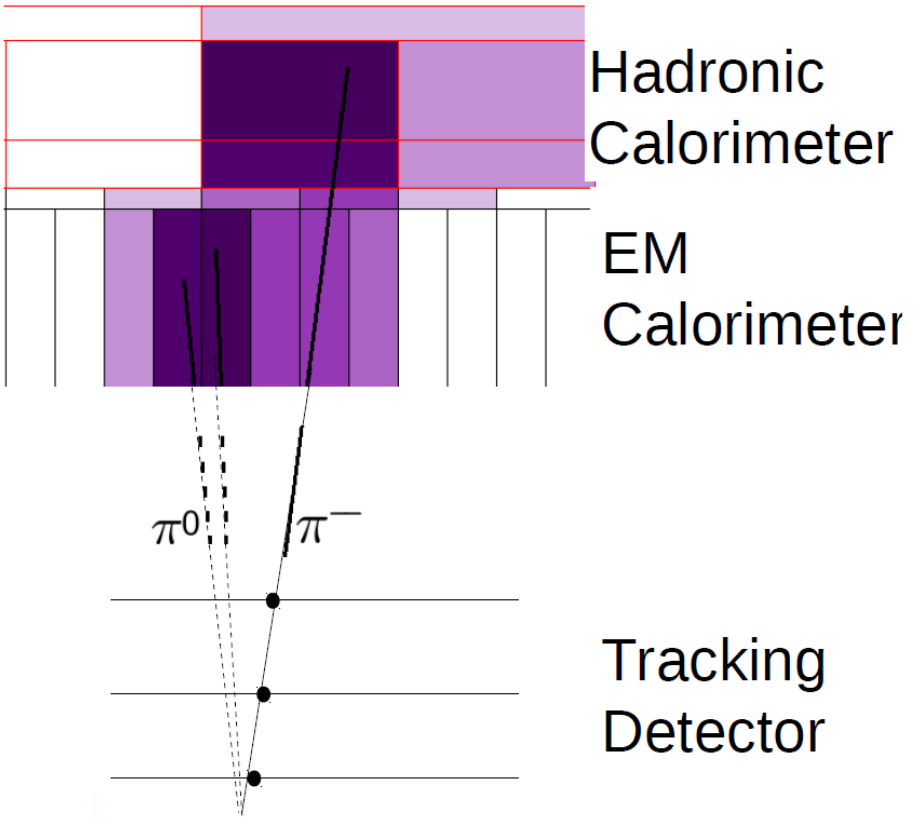
The Tau Lepton

- Short lifetime: ~290 fs
- Decays inside the beam pipe
  - Neutrino not visible in the detector
  - Classification into leptonic and hadronic decays
- Interesting for measurements of the Yukawa coupling or possible CP violation in Higgs decays



Hadronic Tau Decays

- Hadronic tau decays are mostly made up by a varying number of
  - Neutral pions: EMcal
  - Charged pions: Tracker
- New tau reconstruction takes advantage of this
- For more details of the reconstruction, please refer to arXiv:1512.05955 [hep-ex]



P. Wagner, Seminar über Teilchenphysik, 01.06.2017

Motivation TES/TER

- Reconstruction algorithms are calibrated
- Remaining differences between data and MC are determined by measurements
  - Tau Energy Scale (TES) accounts for an offset
  - Tau Energy Resolution (TER) accounts for resolution effects
- Measured in well-understood processes of the Standard Model, here: $Z \to \tau\tau$
- One of the dominant uncertainties in $H \to \tau\tau$ analyses

Parametrisation For TES

- Different resolutions for EM part and hadronic part of the tau decay, i.e. for the neutral and charged pions
- Calculate EM fraction of tau decay based on MC
  ($\pi^0 \rightarrow \gamma\gamma \rightarrow$ showering in EM calorimeter)

$$f_{EM} = \frac{p_{T,neutral}^{truth}}{p_T^{truth}}$$

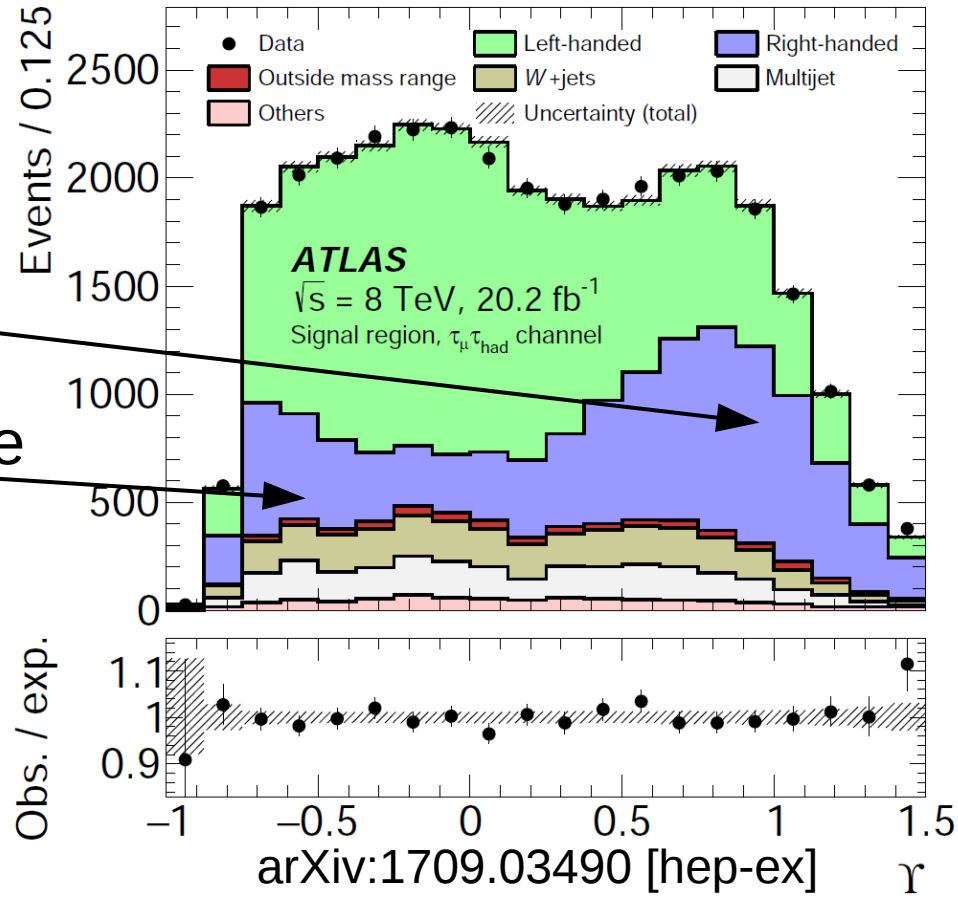
- Define seperate scale factors for EM part and hadronic part of the tau p_T

$$\mathrm{p}_T(\alpha_{EM}, \alpha_{had}) = (\alpha_{EM} f_{EM} + \alpha_{had}(1 - f_{EM}))\, p_T$$

- Tau energy resolution is parametrised in a similar way
- Fit to an observable is performed to extract these scale factors

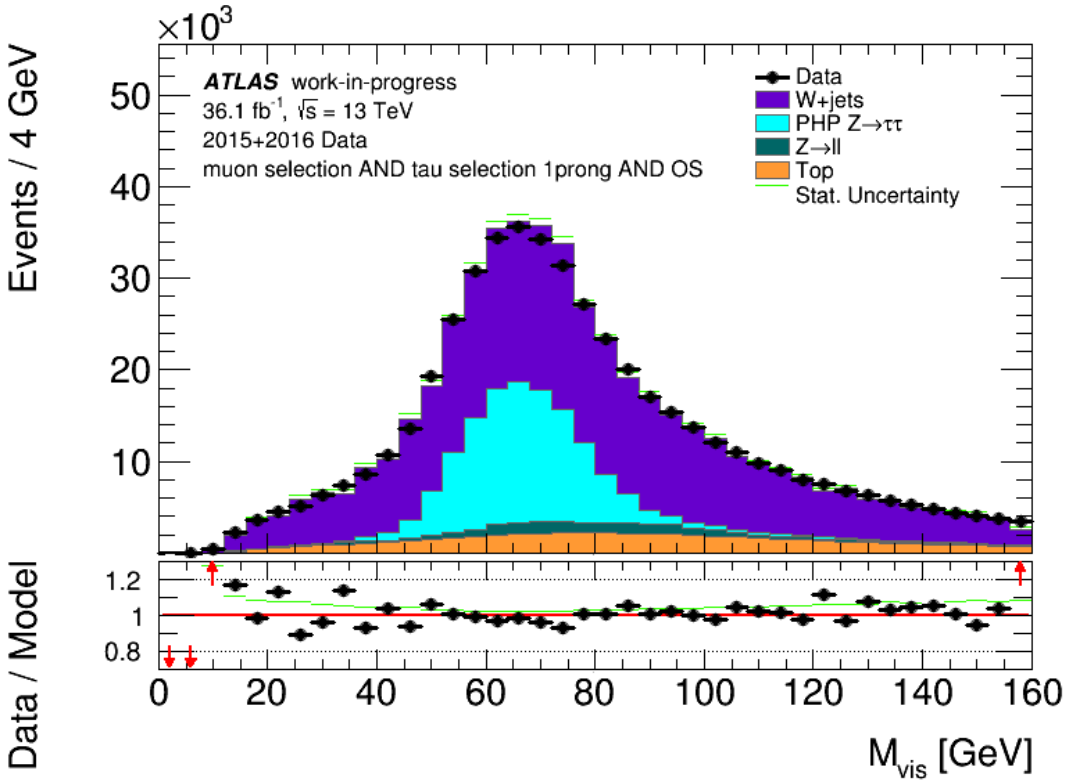
Observable

- Choose observable that is sensitive to the different components of the tau decay
- $\Upsilon = 2 \cdot \frac{p_T^{\tau,\mathtt{allTracks}}}{p_T^{\tau,\mathtt{vis}}} - 1$
- $\pi^{\pm}$ are located at high values
- π^{0} are located at small/negative values
- Was already used in the tau polarisation measurement
- Different parameter of interest!
- Need some adjustments in background and systematic estimation



Event Selection

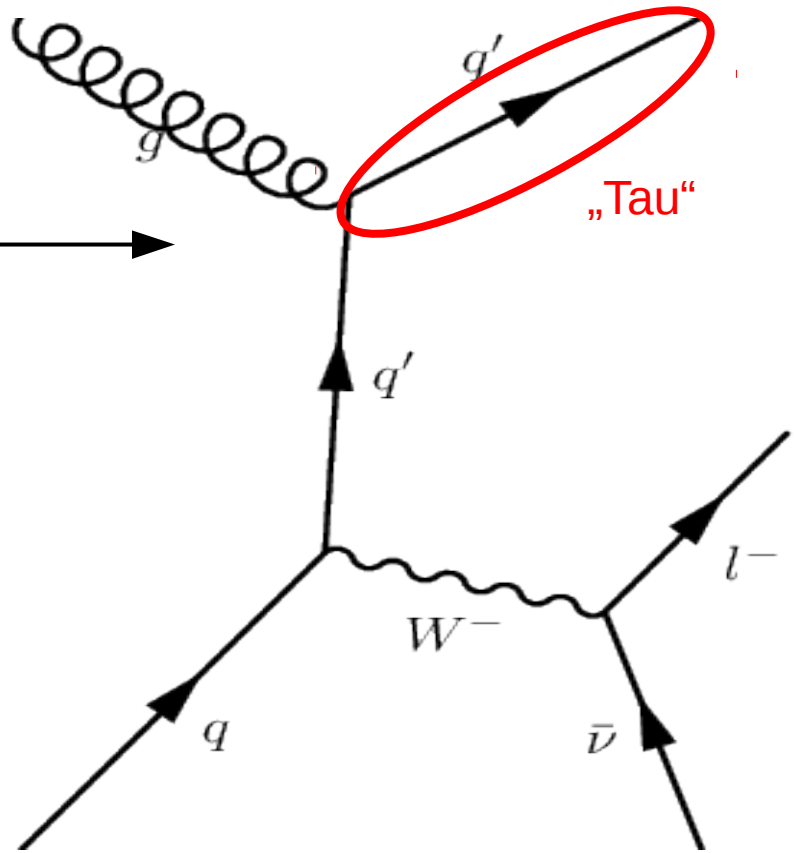
- Select $Z \to \tau(\to \mu\nu\nu)\tau(\to \mathtt{had})$ events
- Tag muon and probe hadronically decaying tau:
  - 1 identified and isolated muon
  - 1 identified and hadronically decaying tau with 1 or 3 tracks oppositely charged to the muon
  - Additional topological cuts to suppress background



- Additional regions are defined to estimate backgrounds and systematic errors (W Control Region, QCD Control Region, Validation Regions)

Backgrounds

- Standard model backgrounds
  - W+jets: jet misidentified as tau
  - Multijet/QCD: jet misidentified as tau + single lepton
  - $Z \rightarrow ll$: lepton misidentified as tau
  - Top+Antitop: e.g. W decaying leptonically and quark misidentified as tau



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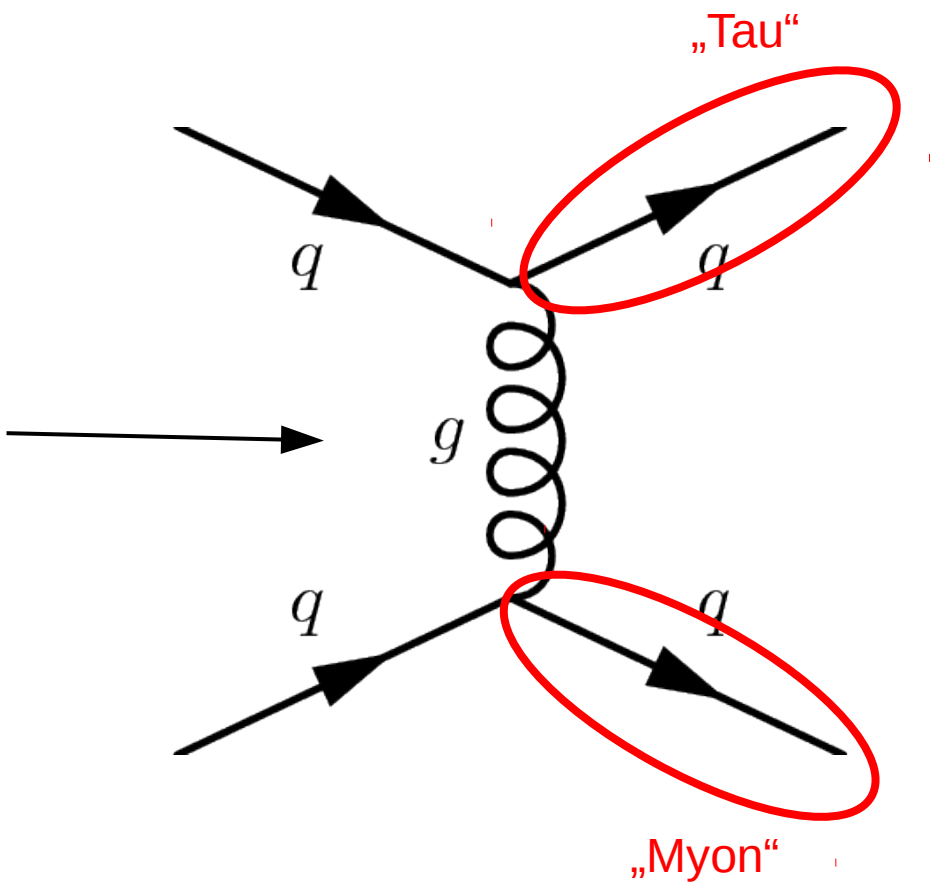

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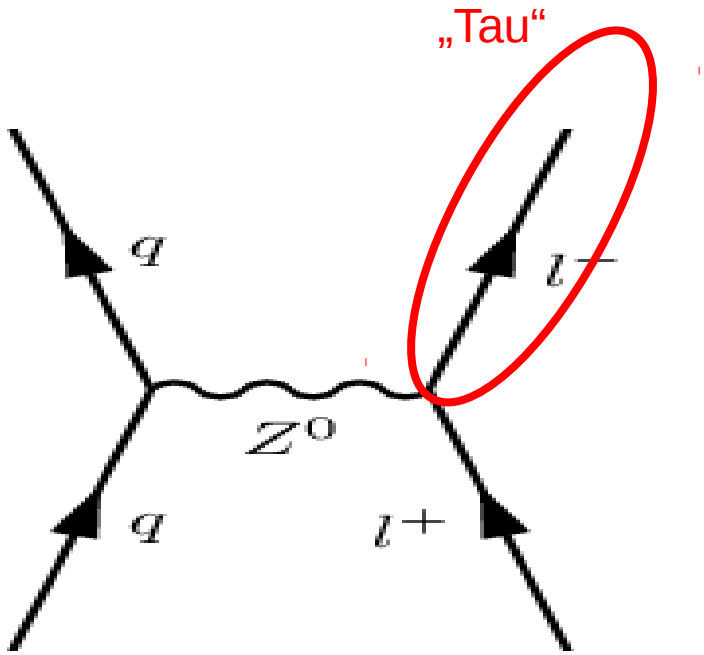

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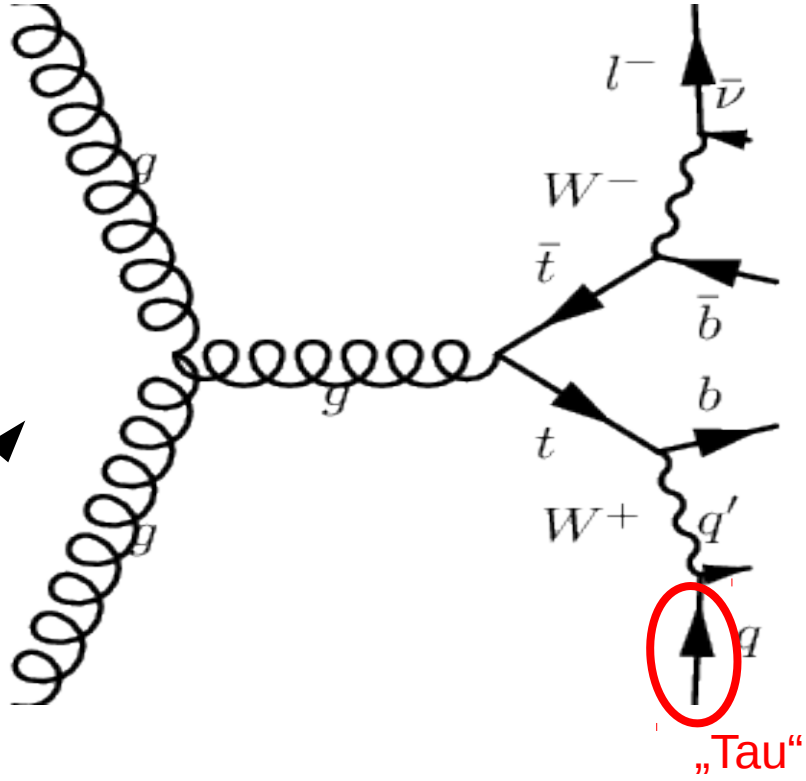
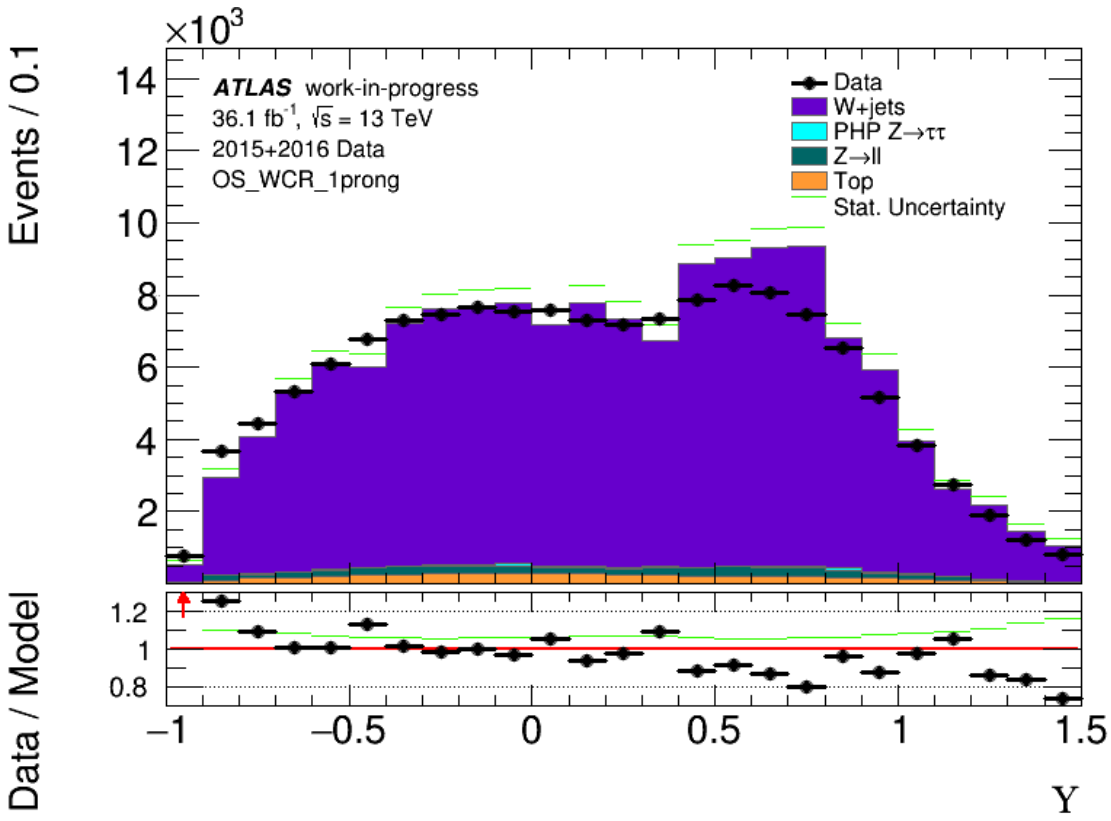


Backgrounds - W+jets

- Use data from the W CR
- Subtract all MC backgrounds from data
- Scale template with

$$\mathrm{r}_W^r = \frac{N_{W,MC}^r}{N_{W,MC}^{WCR}}$$

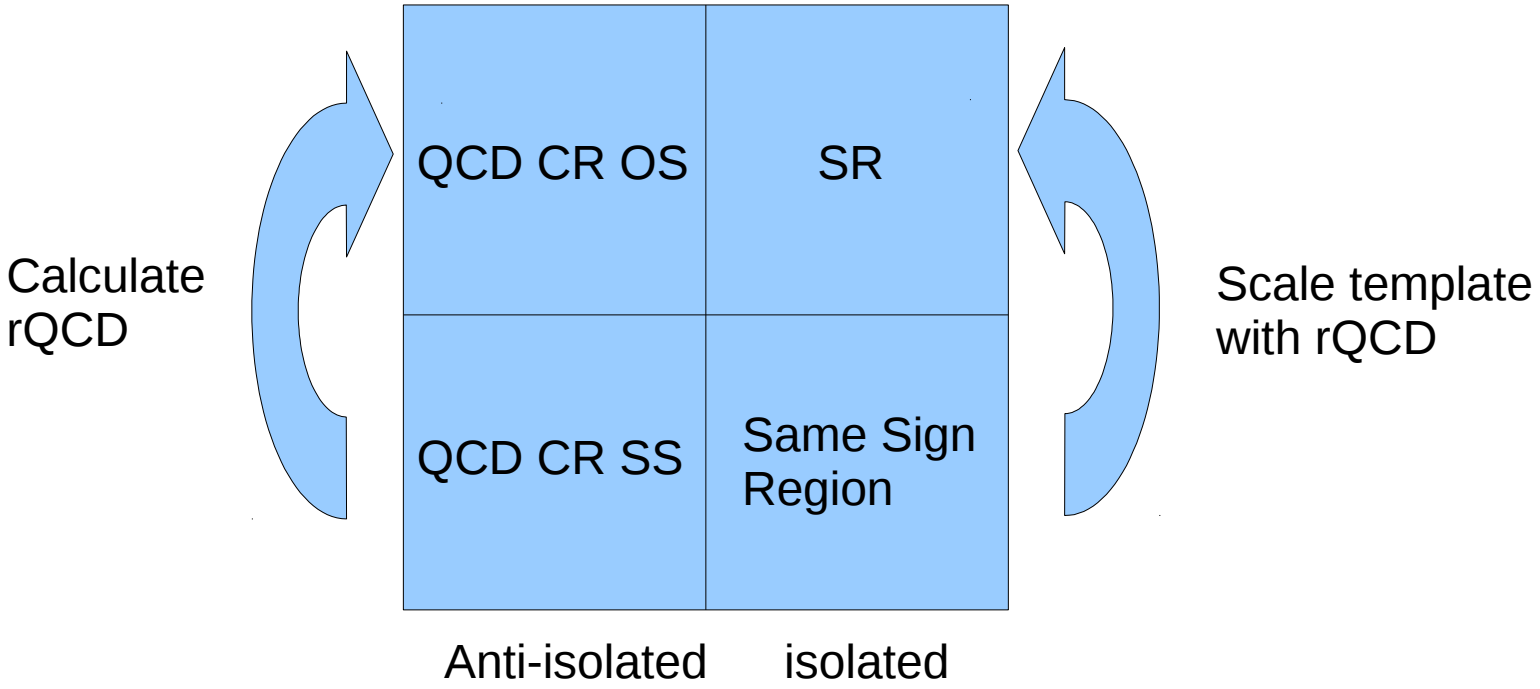
- Need estimate of systematic error on the Υ shape
- W CR definition:
  - $m_\mathrm{T} > 70$ GeV
  - $\Sigma \cos(\Delta\phi(\mu, MET)) < -0.15$



$\mathrm{r} \in \{\mathrm{SR}, \mathrm{QCD\ CR}, \mathrm{VR}\}$

Backgrounds – Multijets

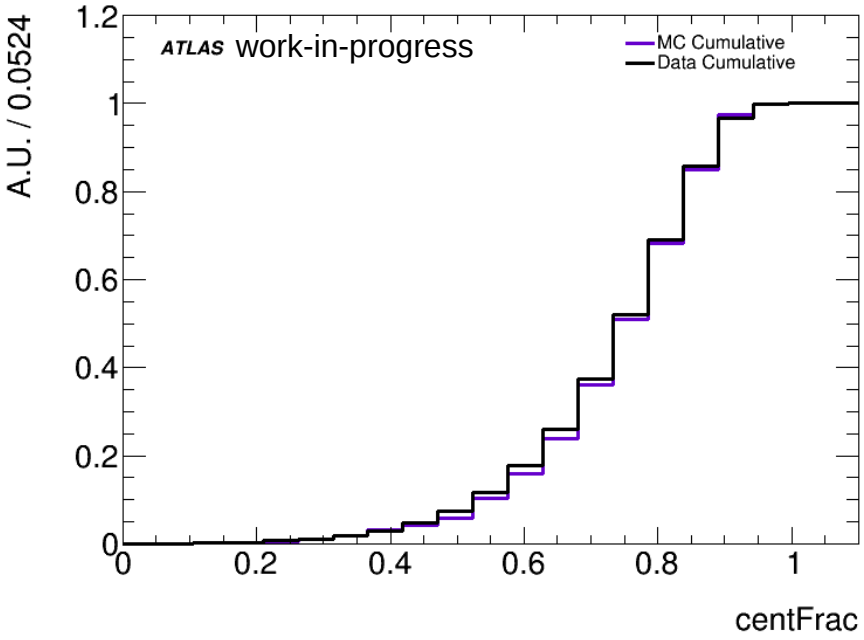
- No MC dataset available with enough statistics
- Estimated using data from the Same Sign Region (same selection as Signal Region with inverted charge requirement)

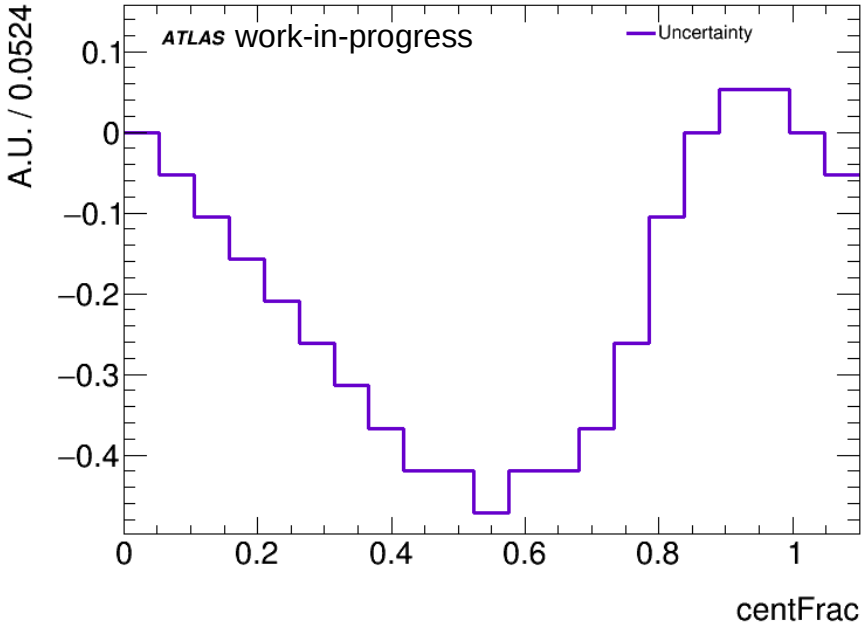


Tau ID Shape Systematics

- Check each individual input variable of tau ID BDT
- Compare input variable distributions in W CR for data and MC
- Derive absolute error on input variables from those distributions
- Vary input variables by obtained error
- Recalculate BDT score
- Cut on new BDT score gives systematic templates for Υ

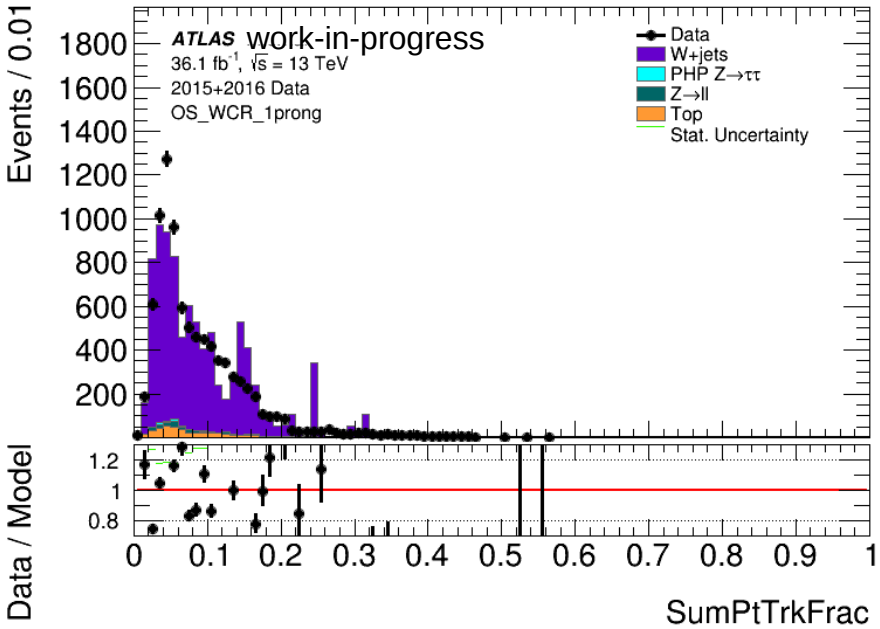
Tau ID Shape Systematics





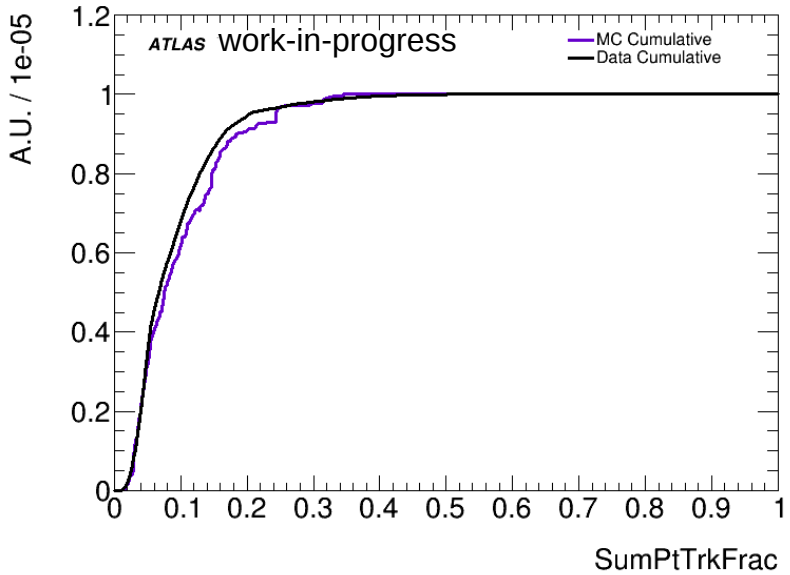
$$CDF_{data}(x') = CDF_{MC}(x) \Rightarrow uncertainty(x) = x' - x$$

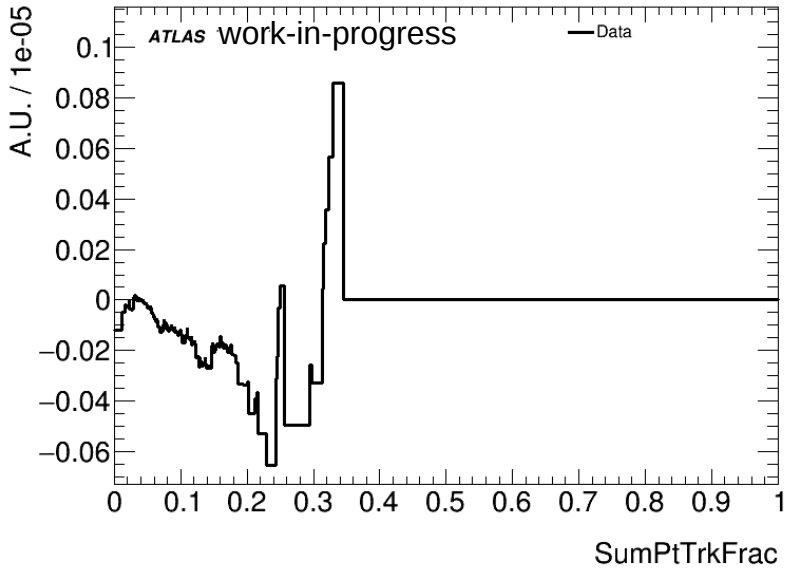
Tau ID Shape Systematics



- Need special treatment for SumPtTrkFrac (fraction of tracks in isolation region)
- combination of integer (at 0) and float variable (>0)

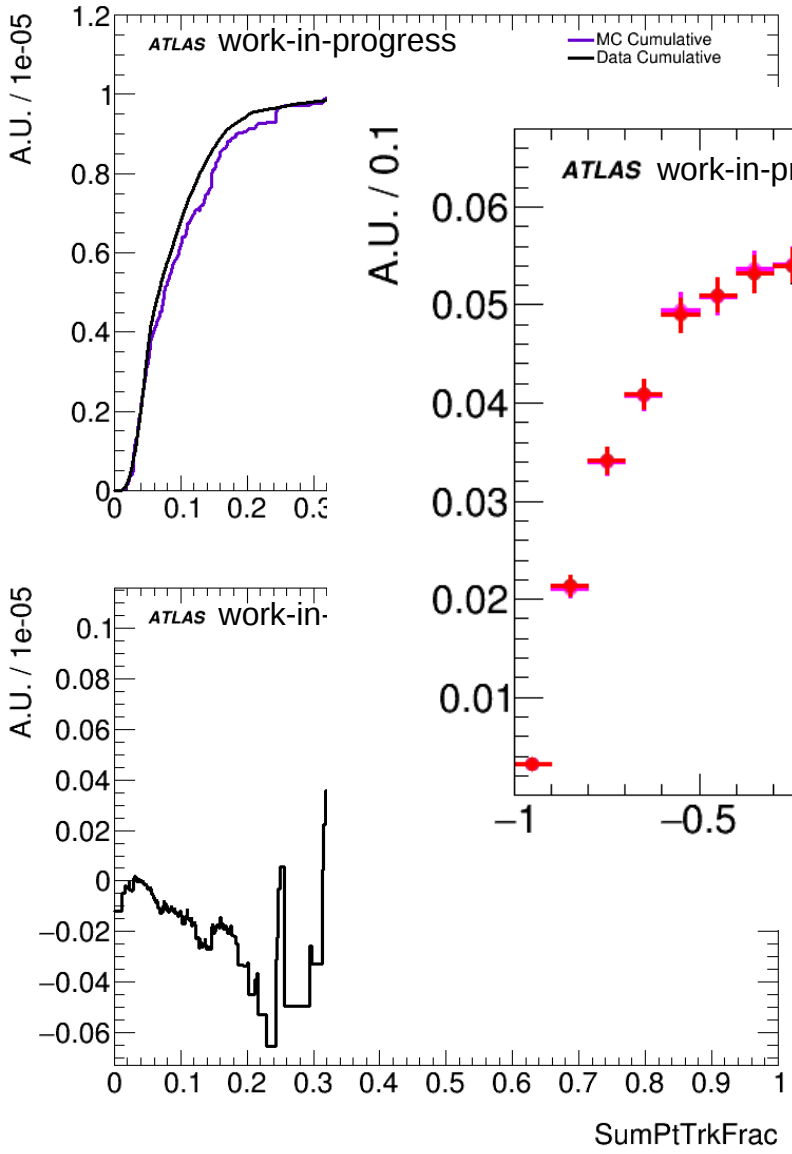
Tau ID Shape Systematics

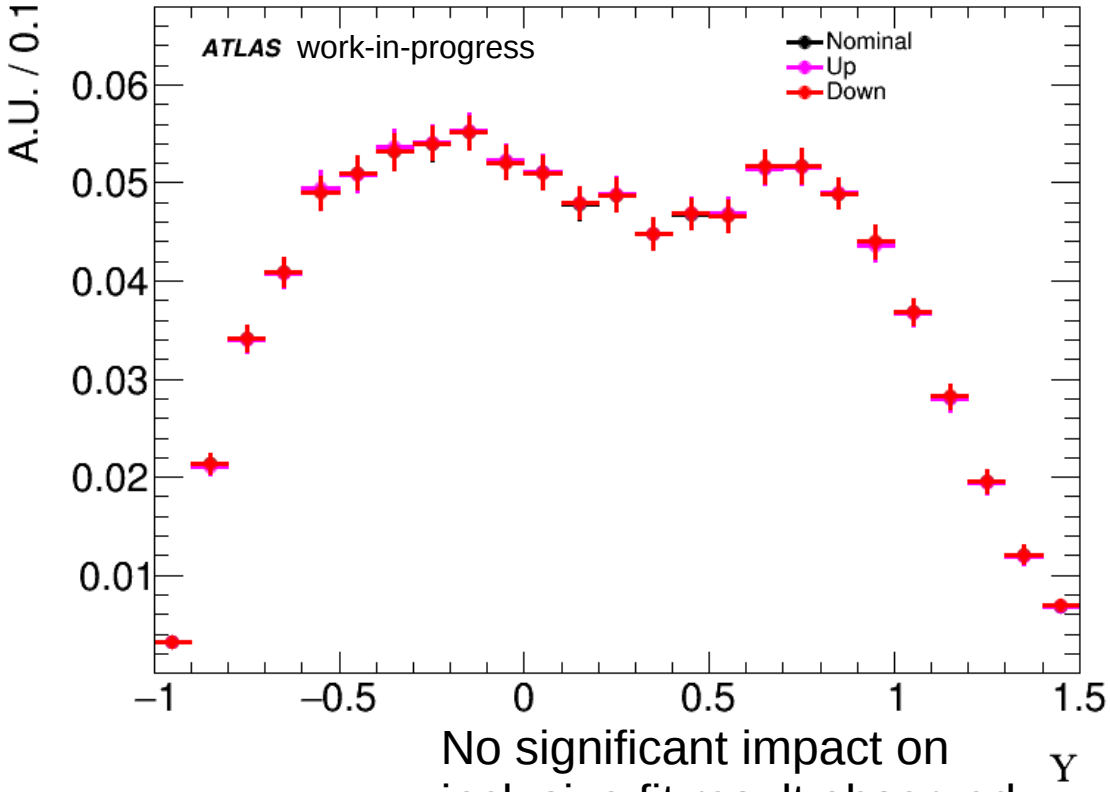




- Exclude SumPtTrkFrac=0 for CDF and error calculation
- Reweight events with SumPtTrkFrac>0 with $\frac{N_{data}}{N_{MC}}(@\texttt{sumpttrkfrac} = 0)$ and vice versa

Tau ID Shape Systematics





- Exclude

ac=0 for
or

vents with
ac>0 with

$\texttt{trkfrac} = 0)$

sa

No significant impact on inclusive fit result observed

Summary & Outlook

Summary

- Presented ATLAS TES & TER measurement
- Overall analysis strategy
- Shape systematics caused by variation of tau ID

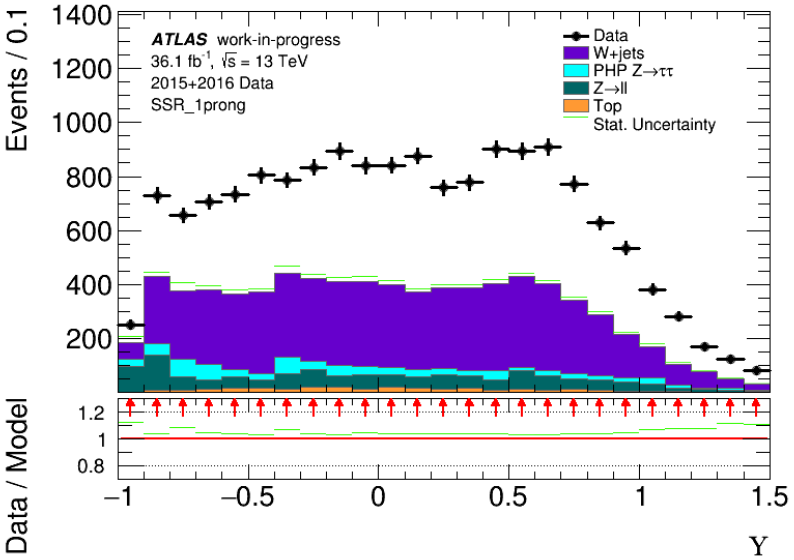
Outlook

- Finalize background shape systematics
- Perform fit for 1 and 3 prong taus
- Binned in eta and track pT

Backup

Backgrounds – Multijets II

- Template from Same Sign Region
  - Subtract all MCs and data driven W+jets from data
- Calculate rQCD
  - Subtract all MCs and data driven W+jets from data in both QCD CRs



$$r_{QCD} = \frac{N^{OSQCD}_{\texttt{multijet}}}{N^{SSQCD}_{\texttt{multijet}}}$$