A search for high-mass resonances decaying to τν in pp-collisions at center-of-mass energy of 13 TeV with the Run-2 data of the ATLAS detector

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IOP HEPP APP NPP 2024

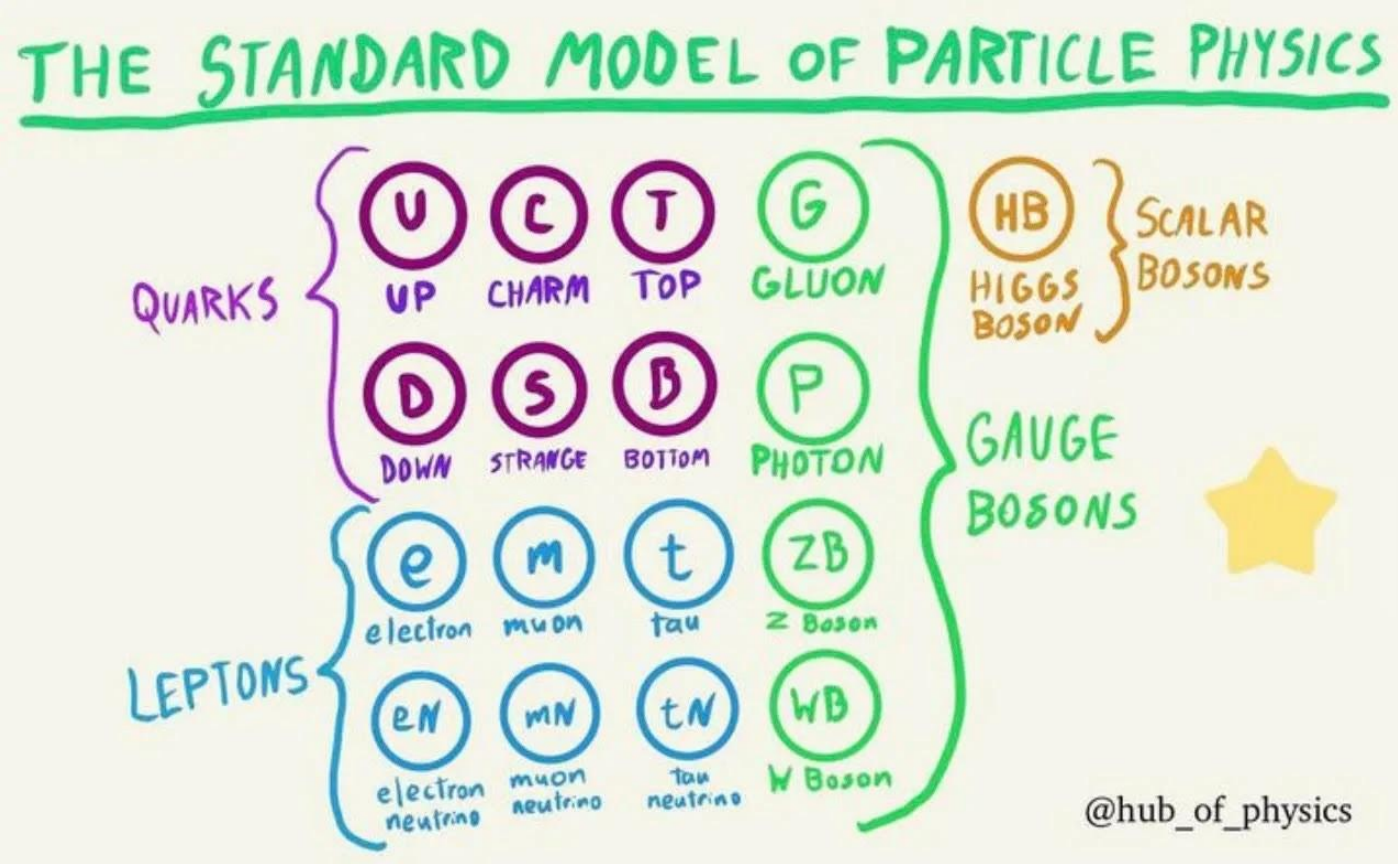
Queen Mary University of London

Science and Technology Facilities Council

ATLAS EXPERIMENT

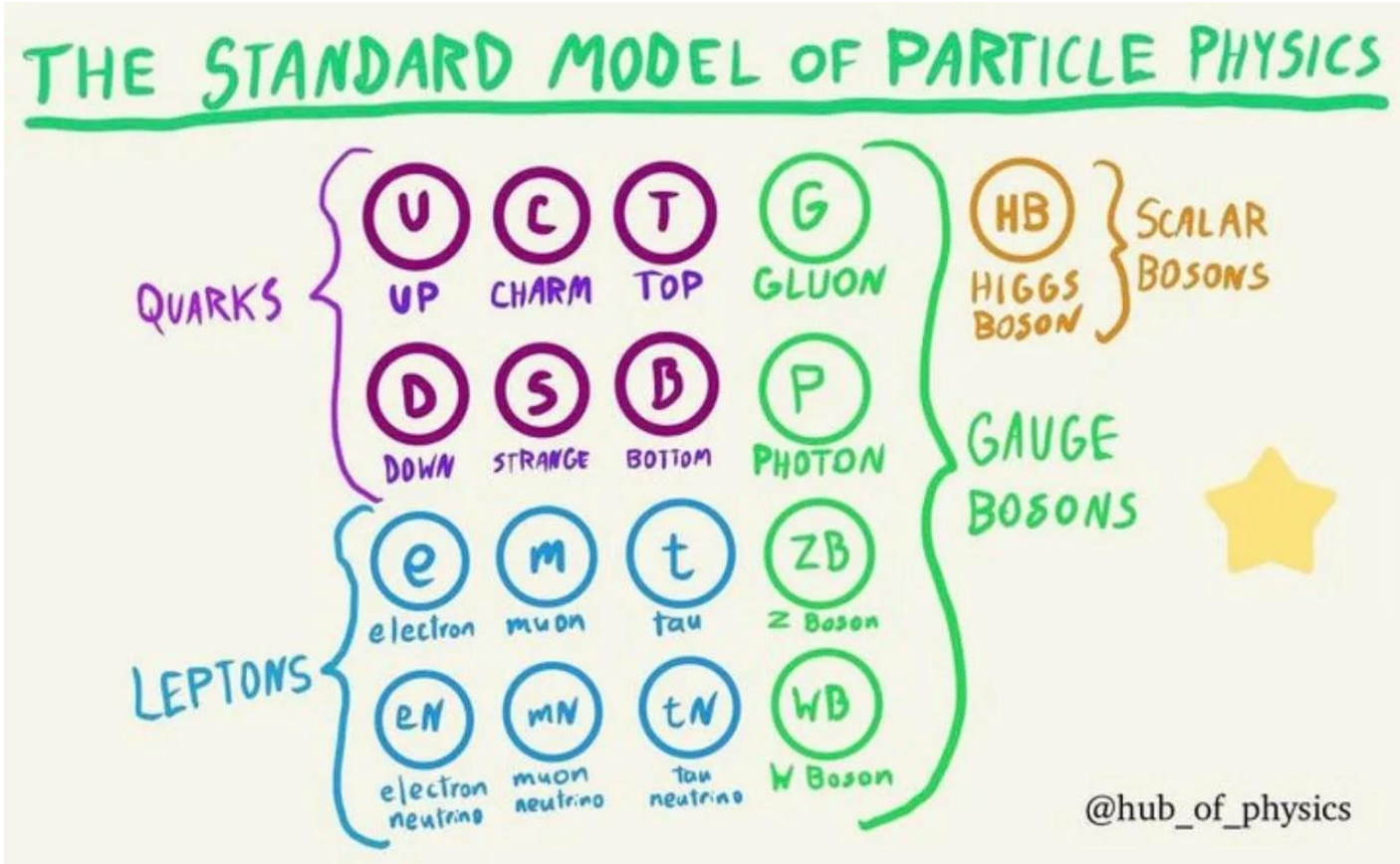
Motivation

- Standard Model incomplete



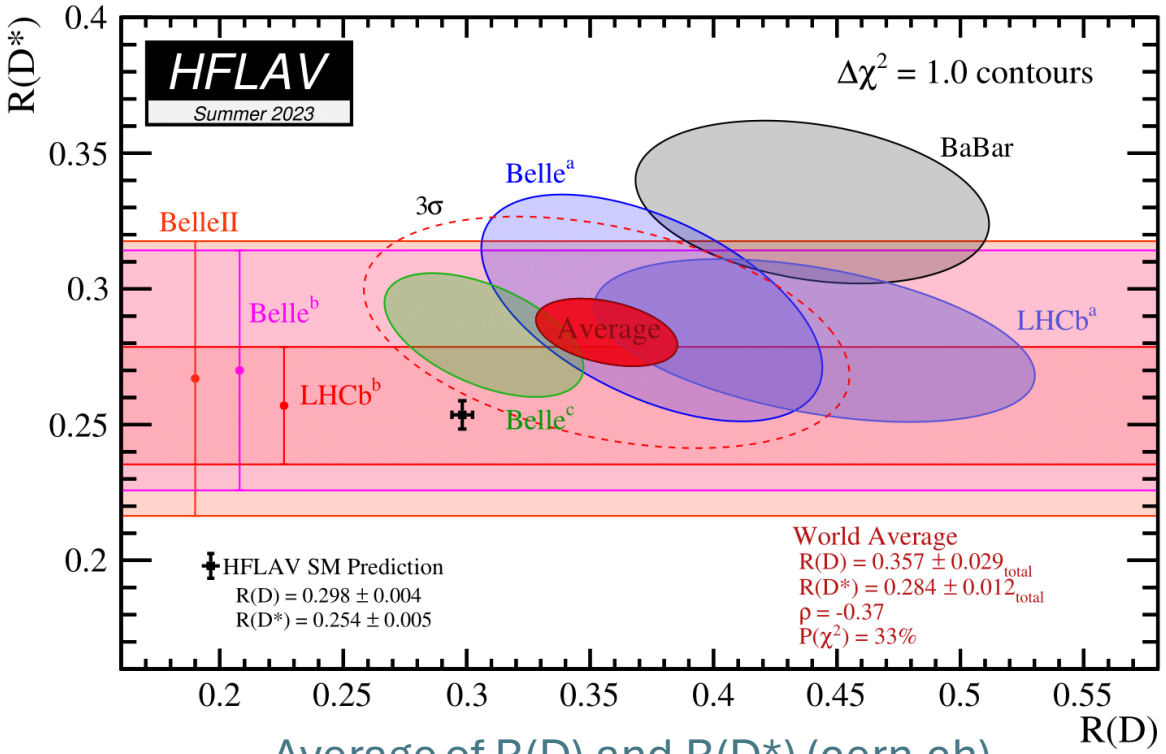
Motivation

- Standard Model incomplete
- Physics Beyond the SM :
  New heavy gauge bosons (W'/Z')



Motivation

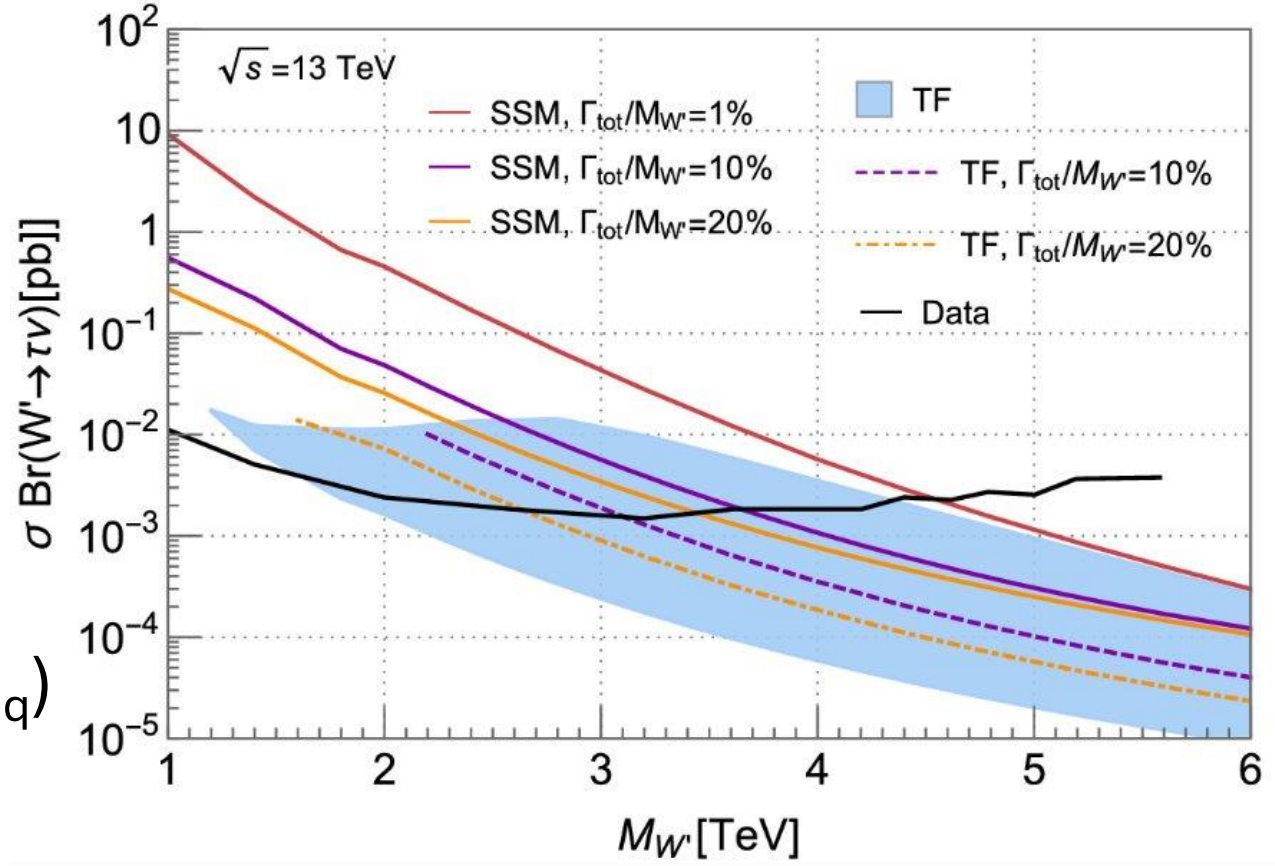
- Standard Model incomplete
- Physics Beyond the SM :
  New heavy gauge bosons (W'/Z')
- Enhanced coupling to 3rd generation
  i) Discrepancy in R(D*)-R(D)



Average of R(D) and R(D*) (cern.ch)

Motivation

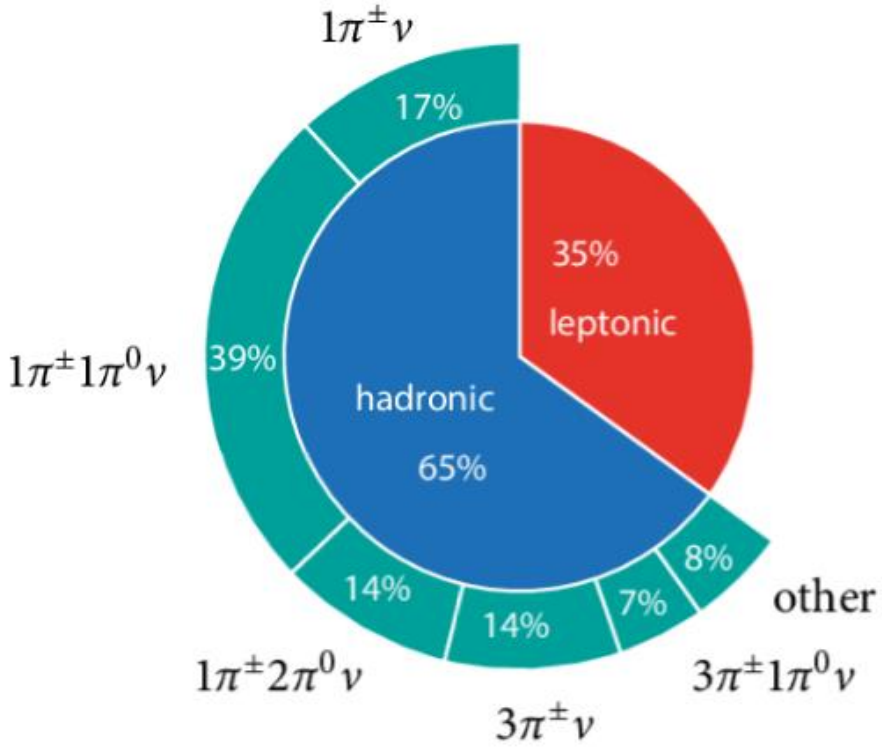
- Standard Model incomplete
- Physics Beyond the SM :
  New heavy gauge bosons (W'/Z')
- Enhanced coupling to 3rd generation
  - i) Discrepancy in R(D*)-R(D)
  - ii) Hierarchy of masses ($m_t \gg m_q$)



https://doi.org/10.1103/PhysRevD.104.055006

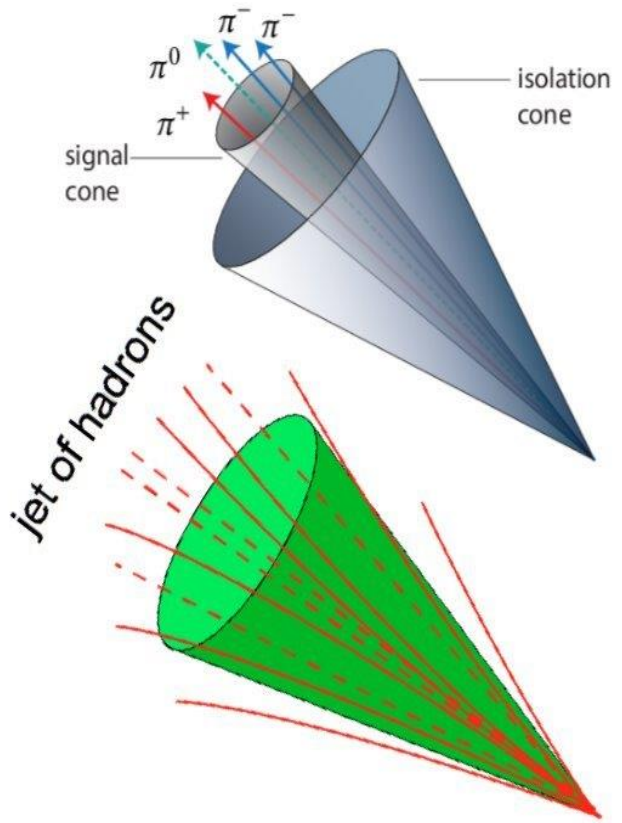
Tau leptons

- Tau leptons: 3rd generation
- Decay hadronically (65%)



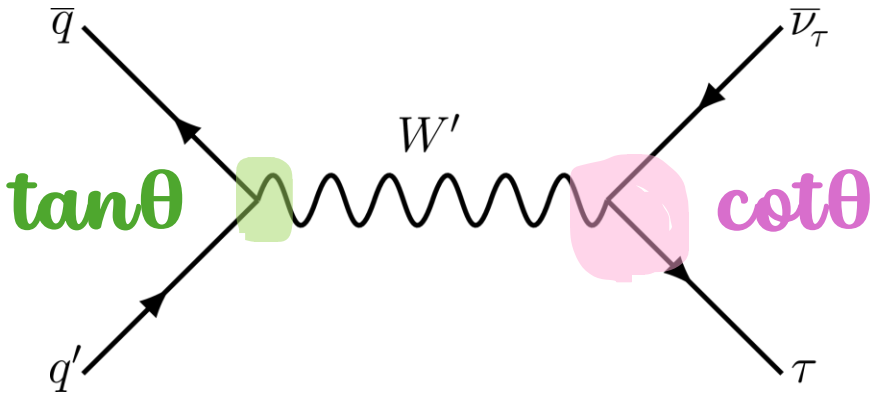
Tau leptons

- Tau leptons: 3rd generation
- Decay hadronically (65%)
- Challenge : Identification from jets
- Used dedicated RNN algorithms

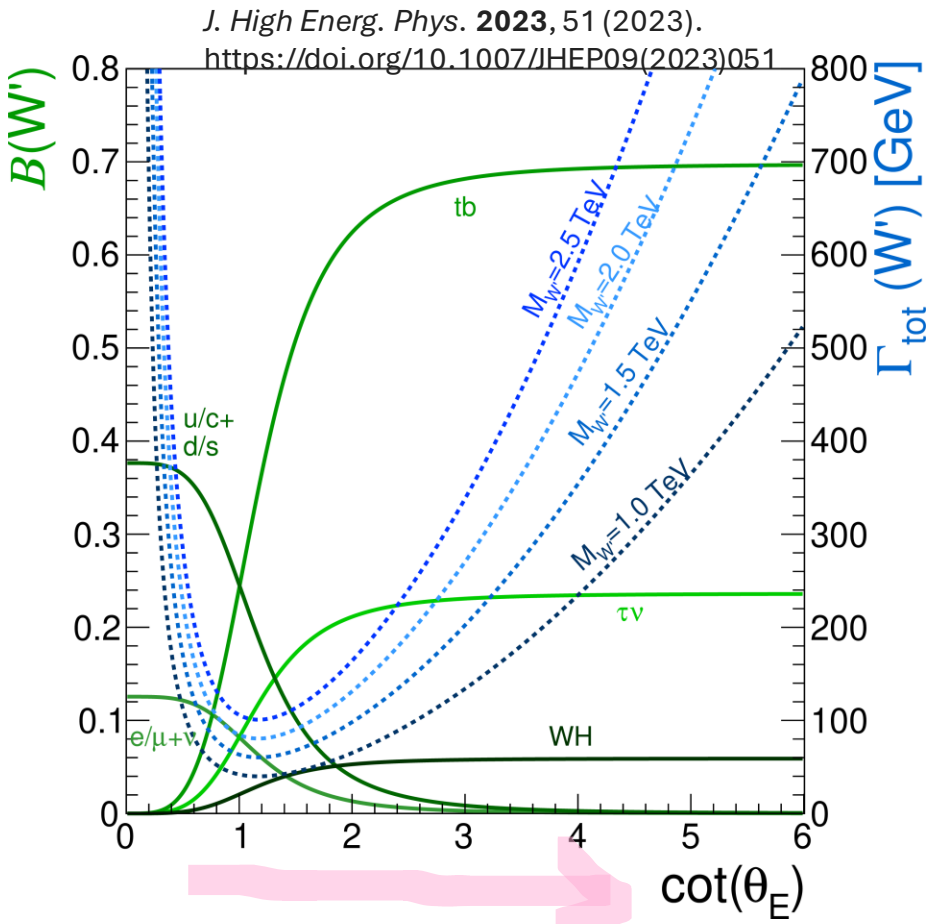


Signal Production

- Flat signal sample reweighted to **M** and **Γ**

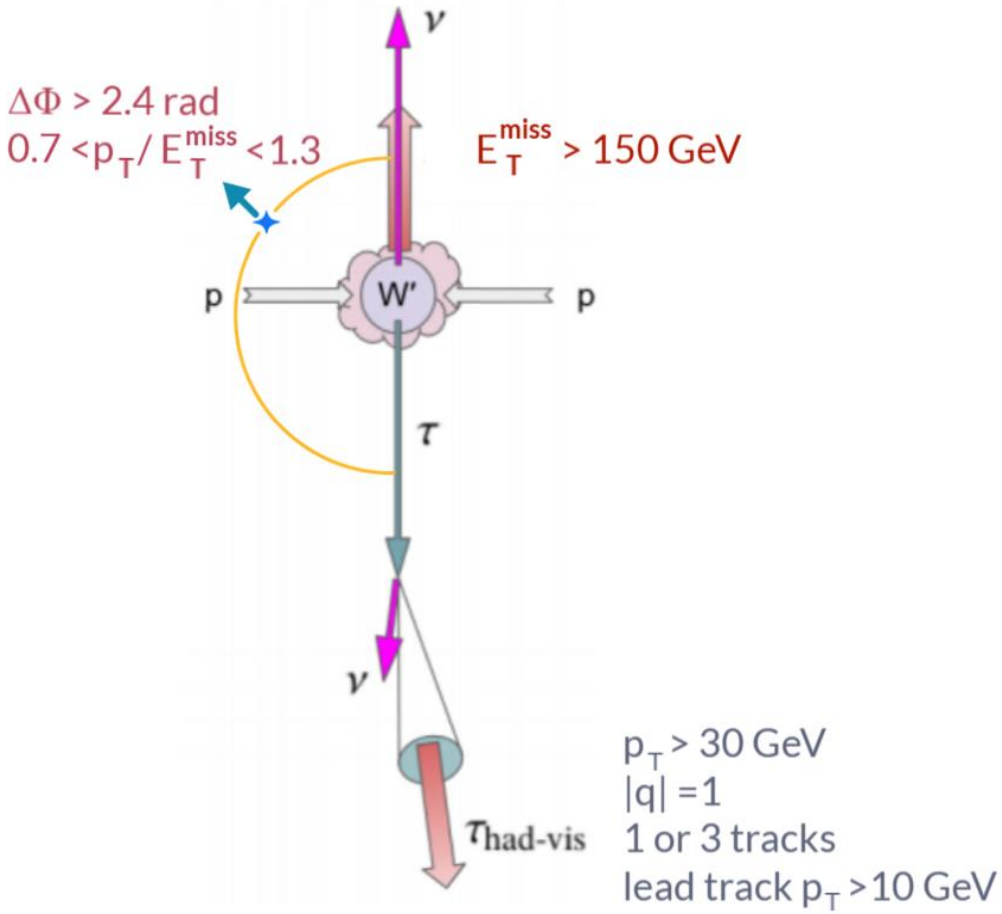


$$B(m_{\tau\nu}; M) = \frac{1}{\left(m_{\tau\nu}^2 - M^2\right)^2 + \left(m_{\tau\nu}^2 \frac{\Gamma(M)}{M}\right)^2}$$



Event Selection / Strategy

- Event Cleaning
- Tagging $E_{\mathrm{T}}^{\mathrm{miss}}$ (Trigger)
- Require back-to-back and balanced momenta
- No additional leptons



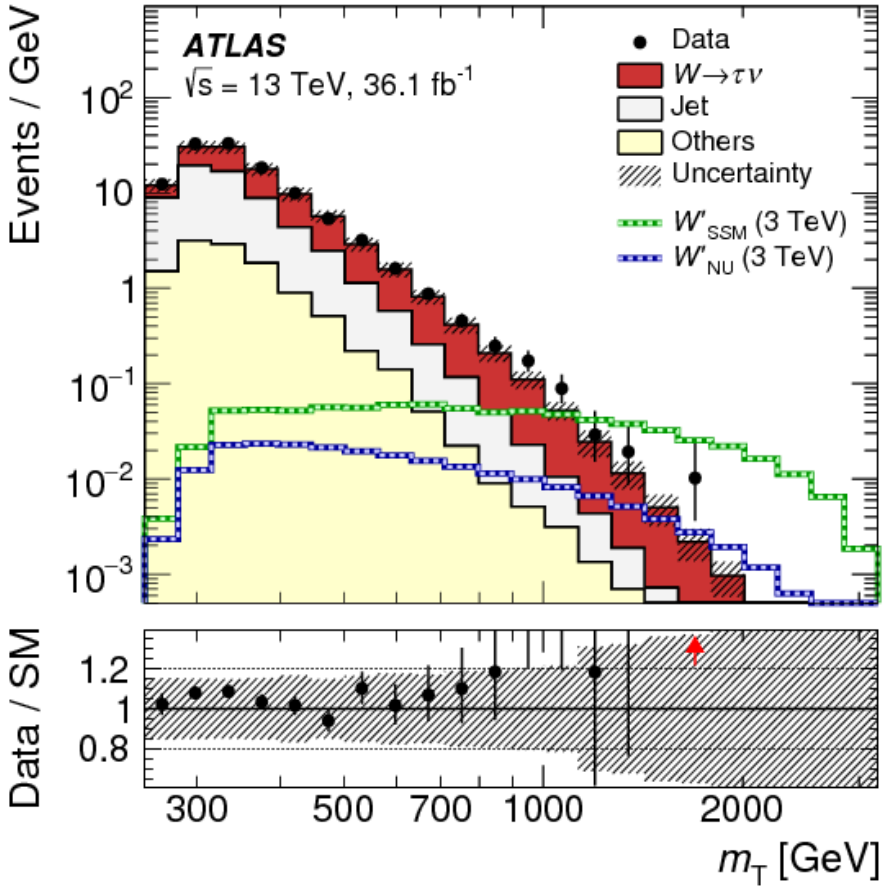
Event Selection / Strategy

- Event Cleaning
- Tagging $E_{\mathrm{T}}^{\mathrm{miss}}$ (Trigger)
- Require back-to-back and balanced momenta
- No additional leptons

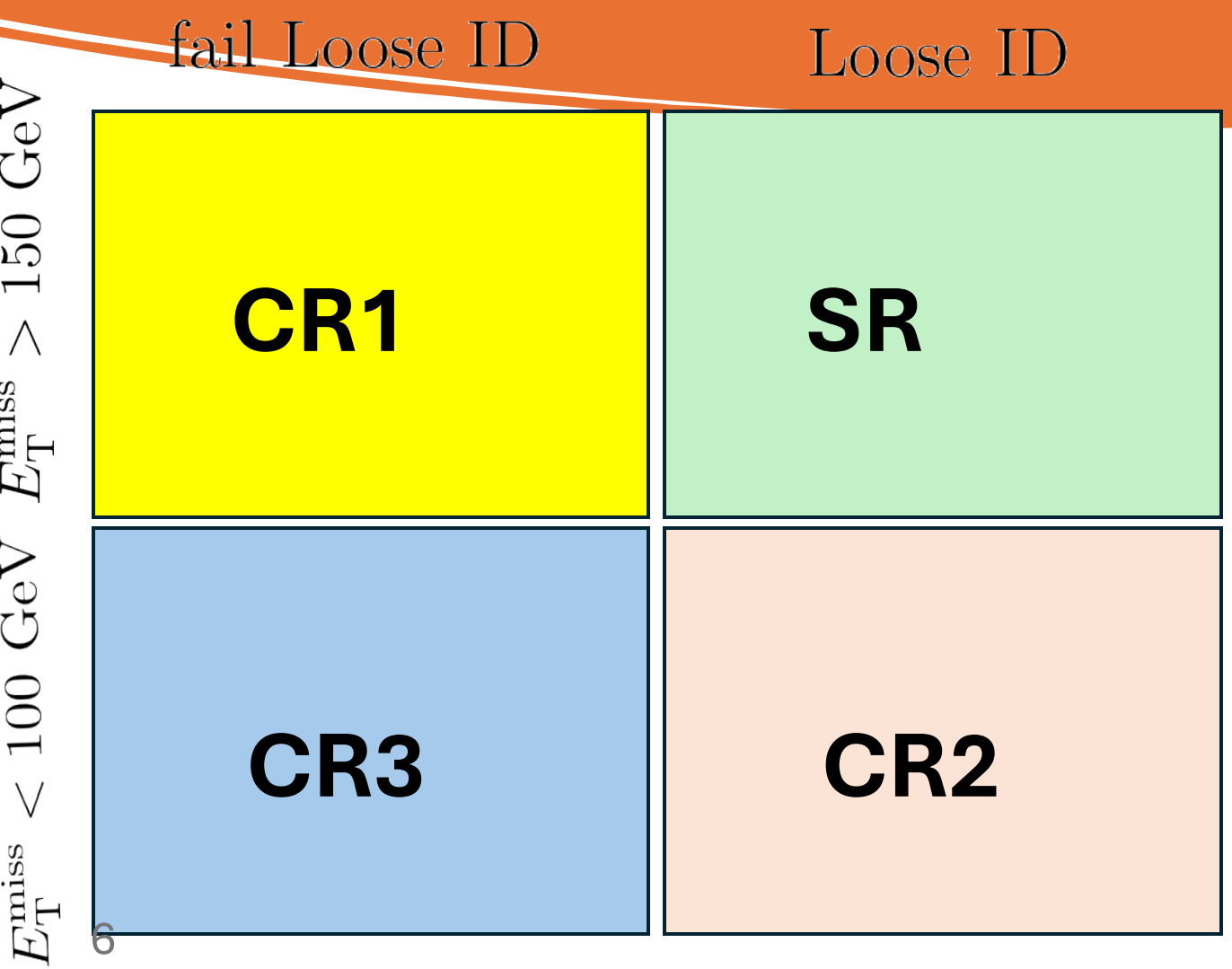
- Mainly interested in Transverse Mass

$$m_{\mathrm{T}} = \sqrt{2 \cdot p_{\mathrm{T}}^{\tau_{\text{had-vis}}} \cdot E_{\mathrm{T}}^{\mathrm{miss}} \cdot cos\Delta\phi}$$

PhysRevLett.120.161802



Jet Background Estimation



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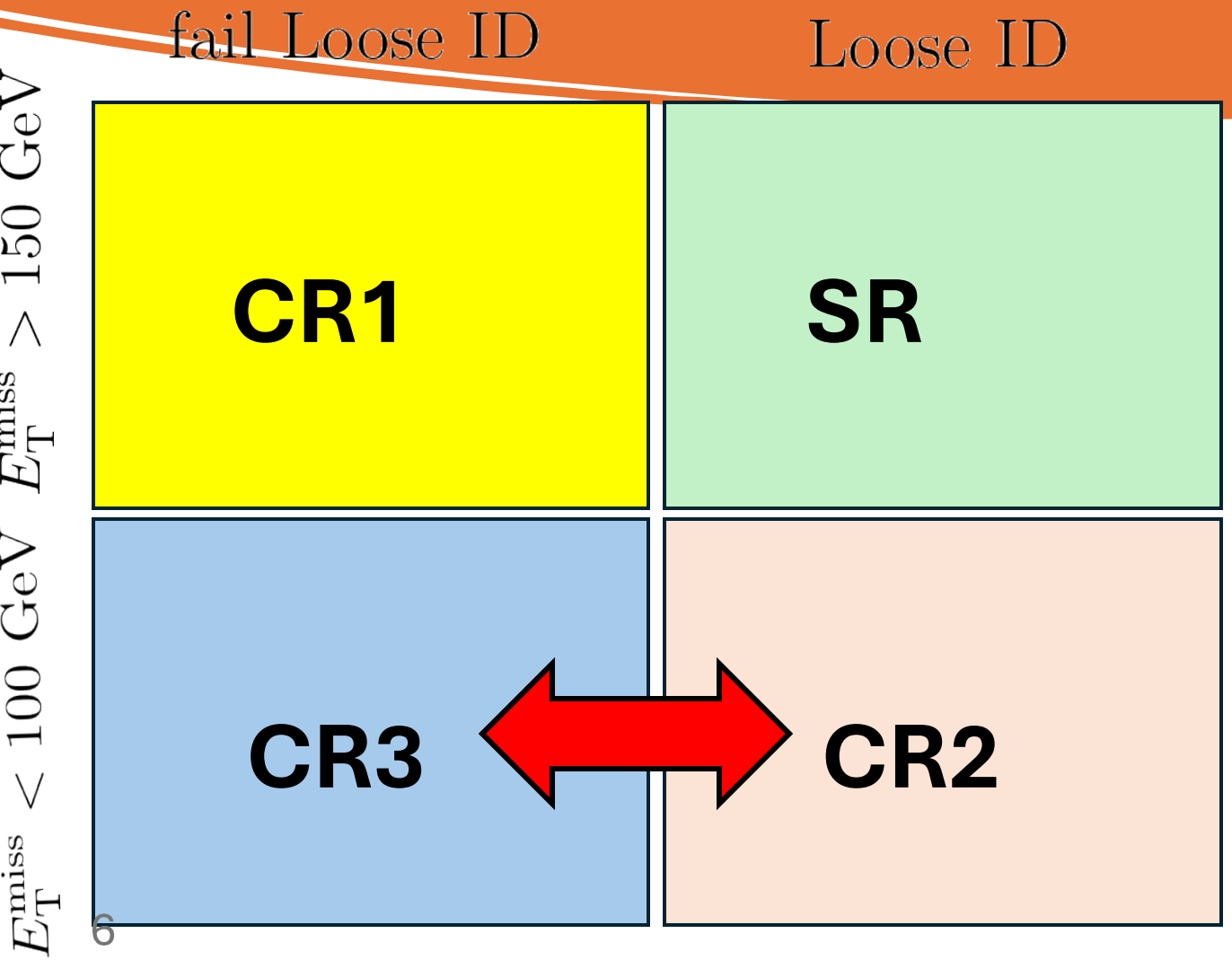

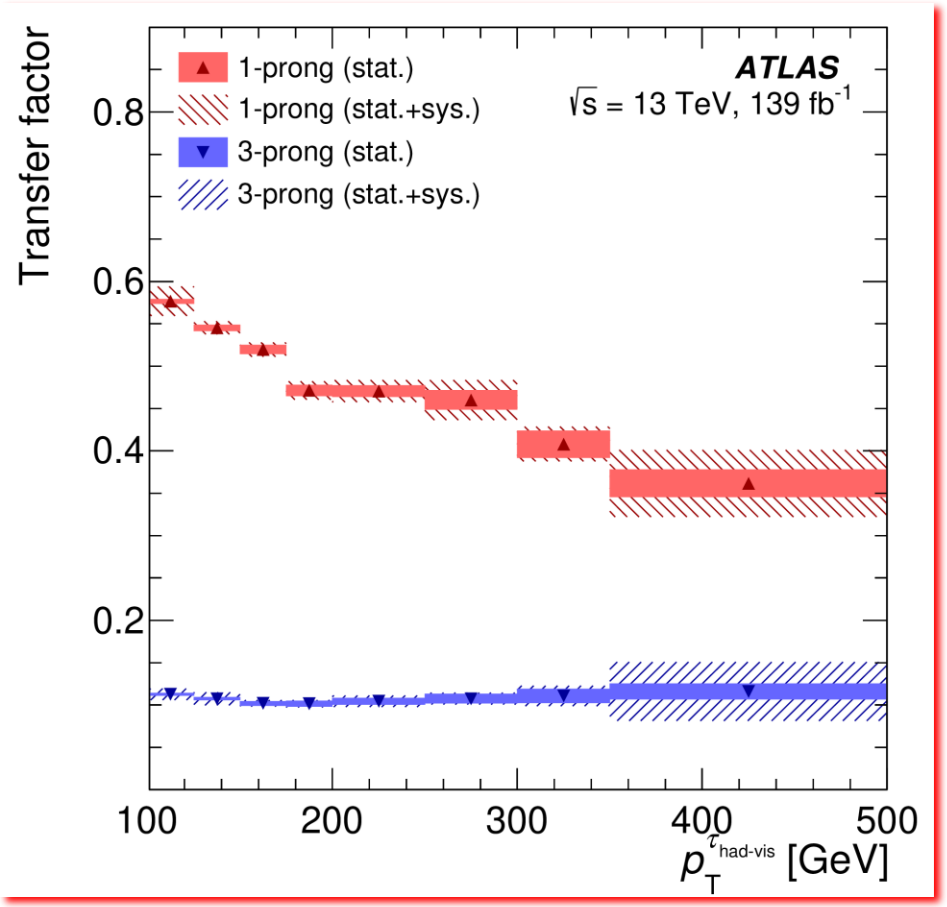

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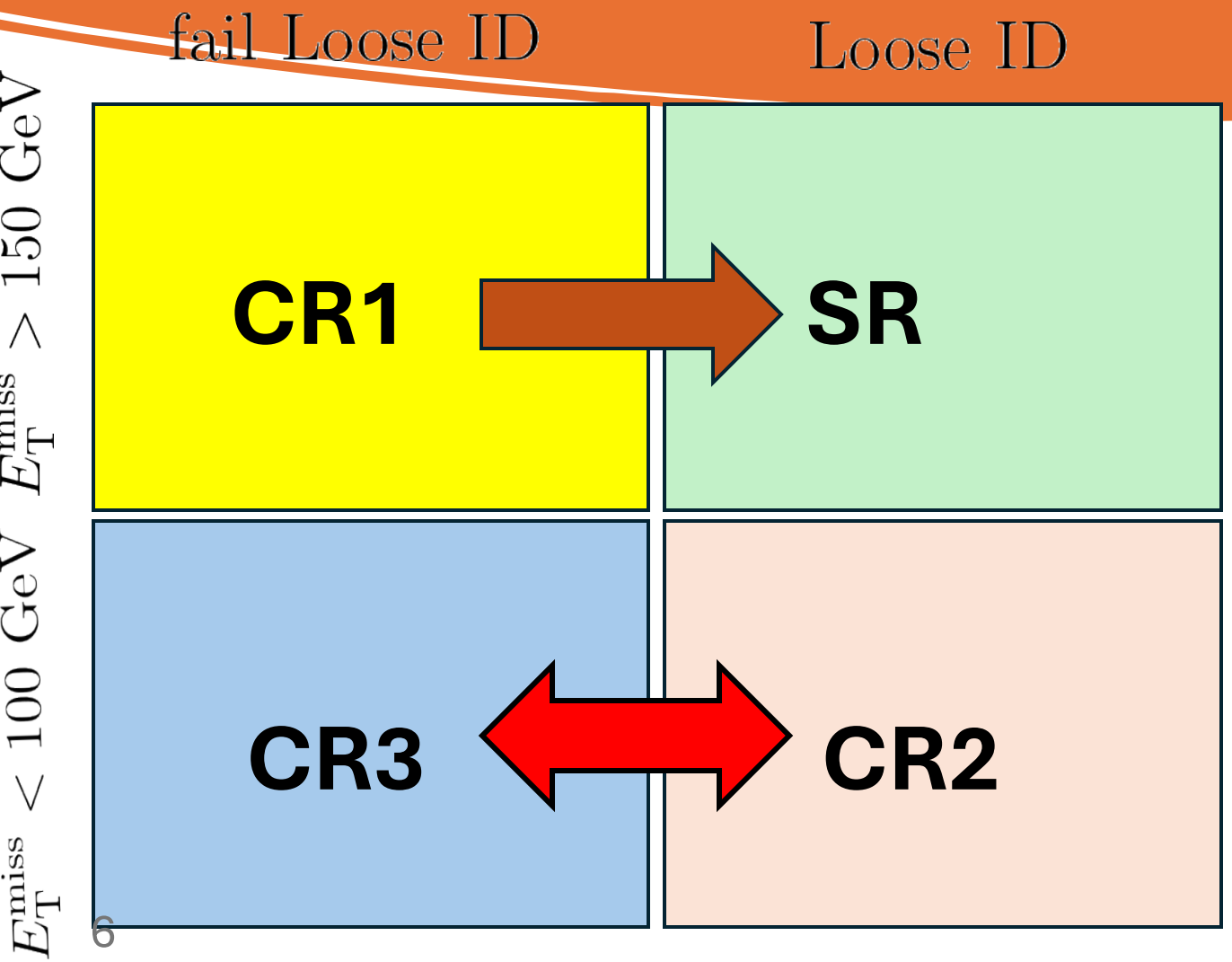
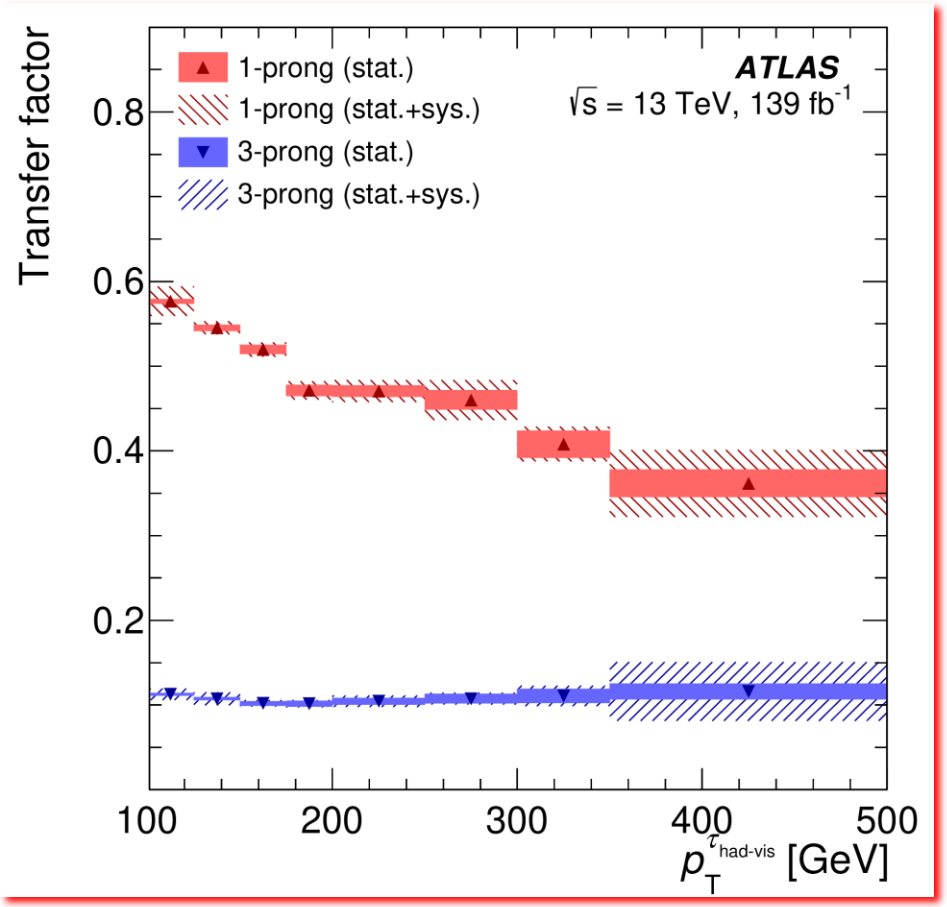
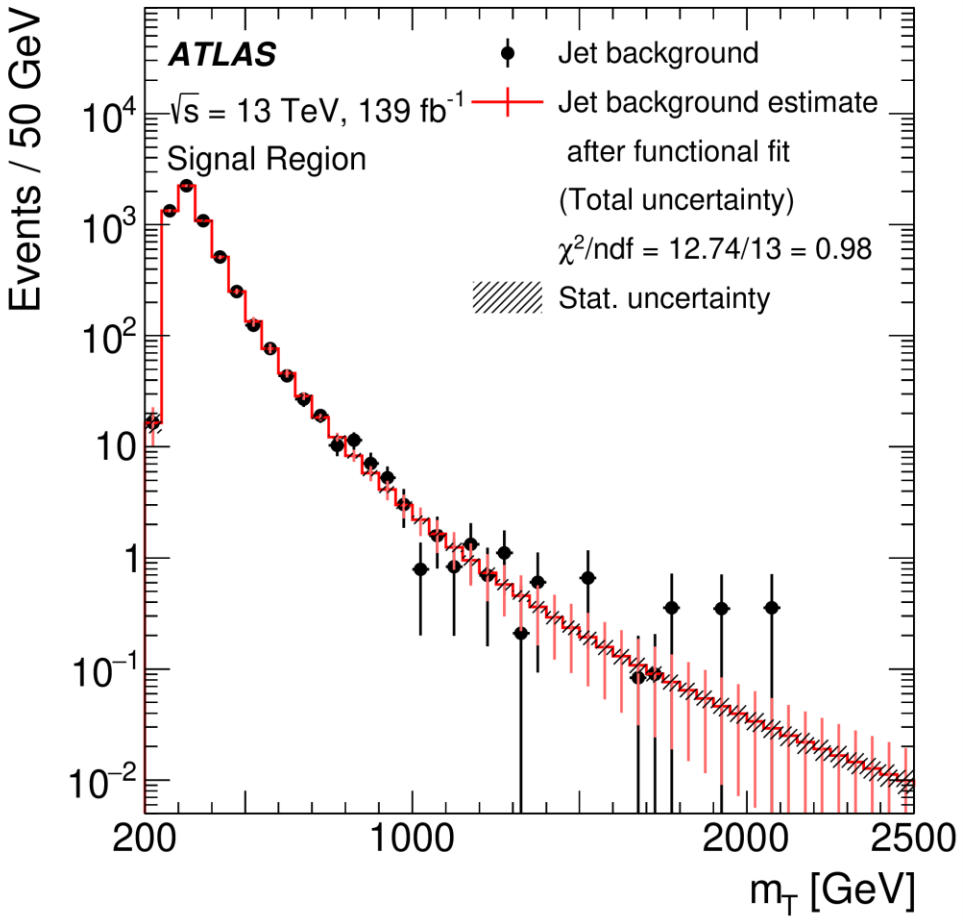




Jet Background Smoothening

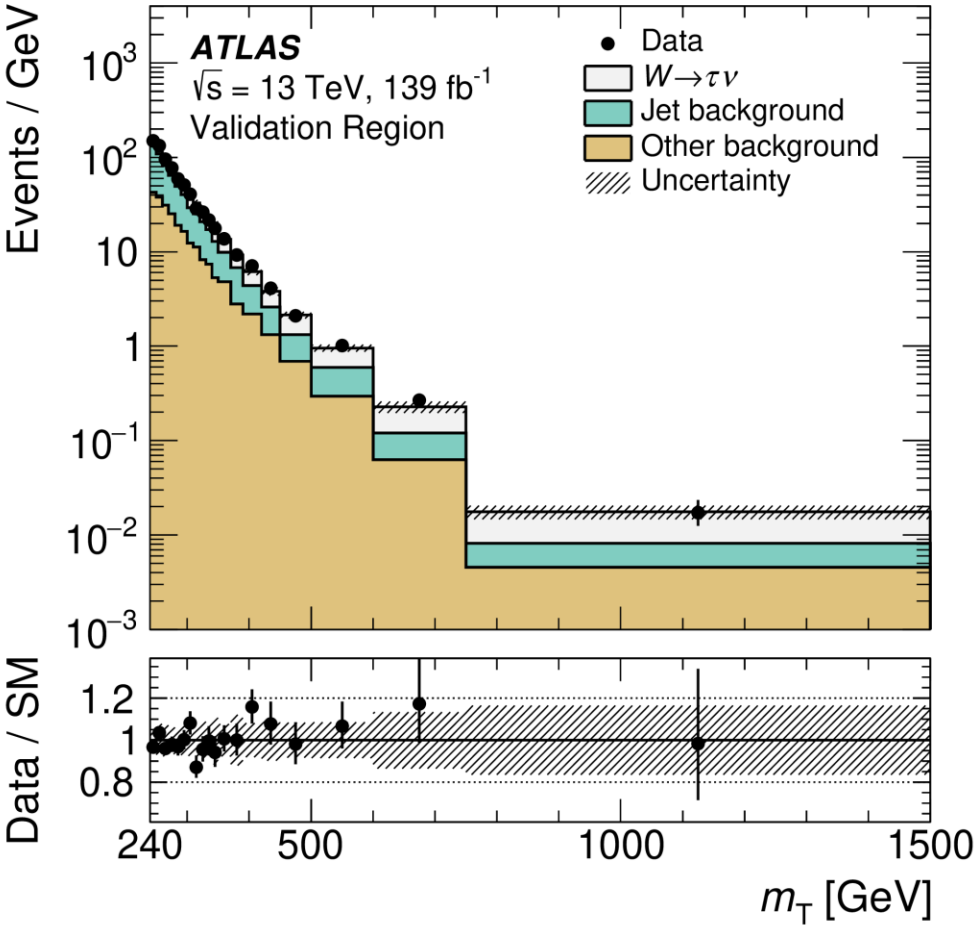
- Applying transfer factors
- At high-m_T (>500 GeV) use **functional fit**
- Extrapolation from smoothening :
  not affect final results



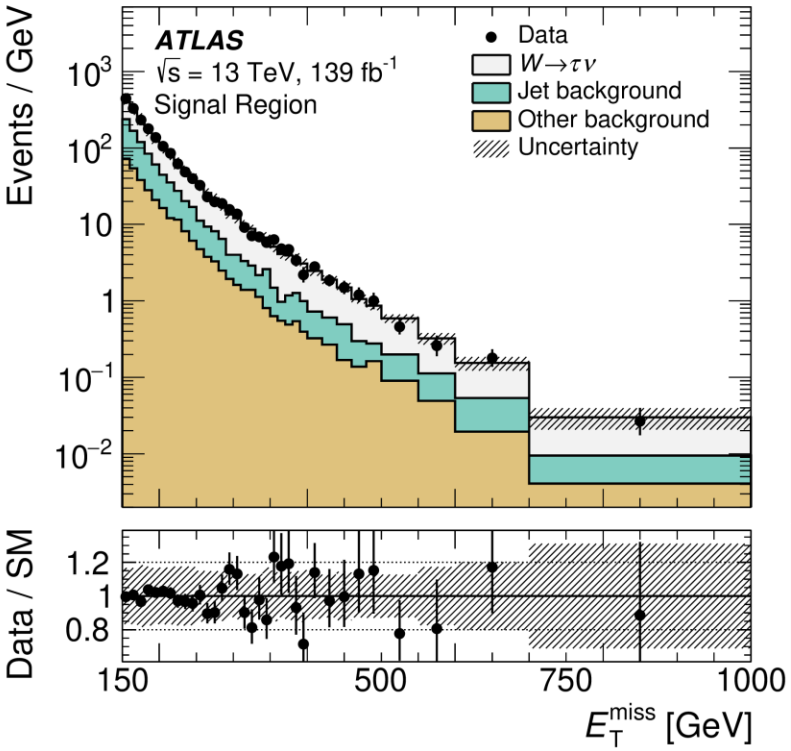
Background validation

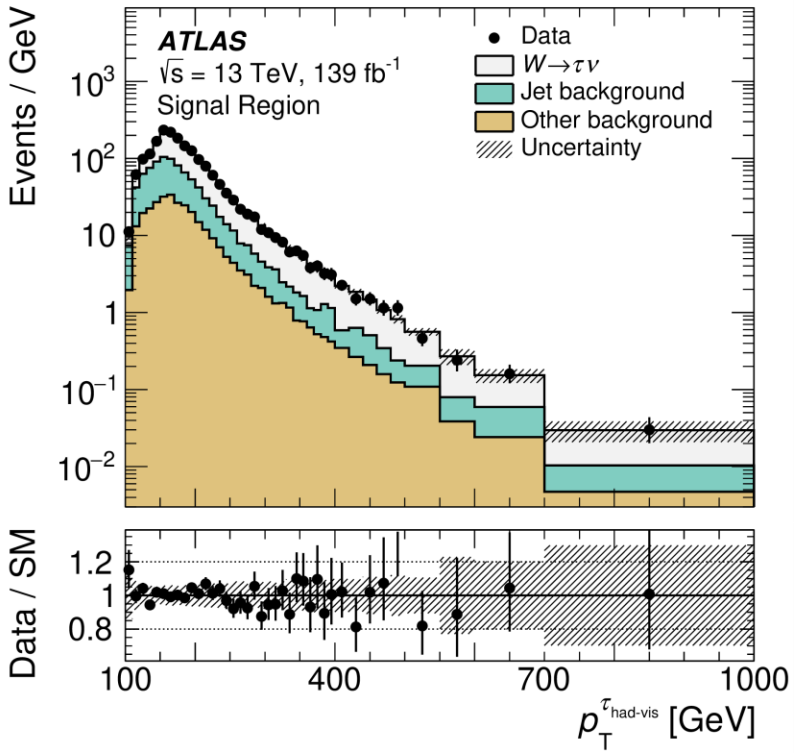
Rest backgrounds from simulation

Data driven background validation:
Good SM background agreement at high-m_T



Signal Region

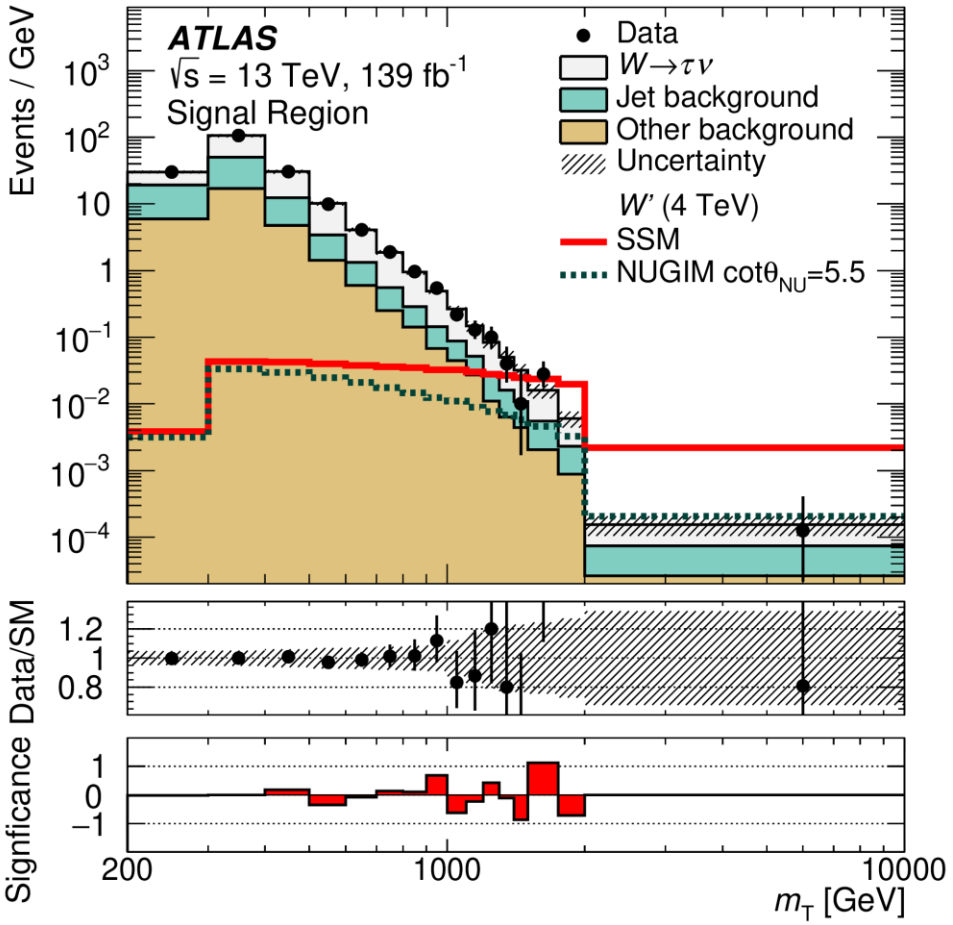




Good agreement between data/background in SR

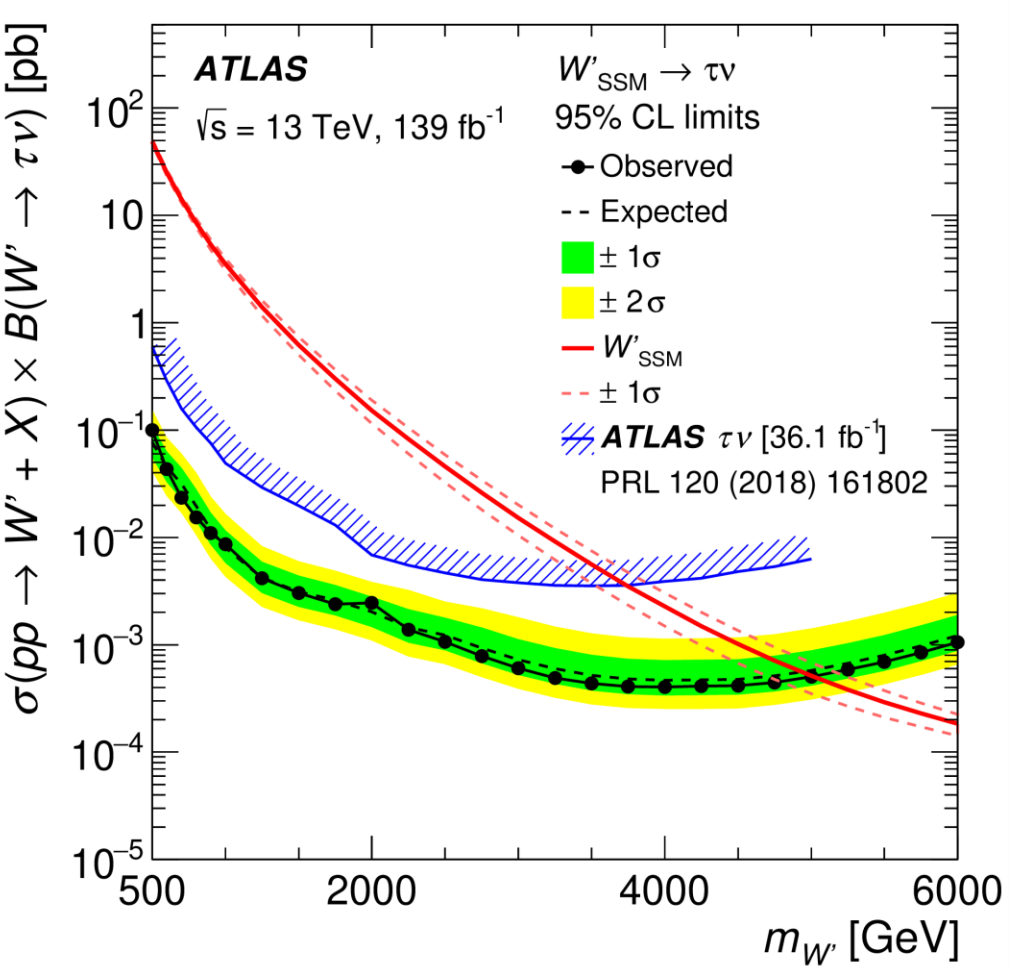
Profile Likelihood Fit

- No significant deviation to SM observed
- Performed PL Fit in transverse mass
- Derive upper limits on signal strength μ



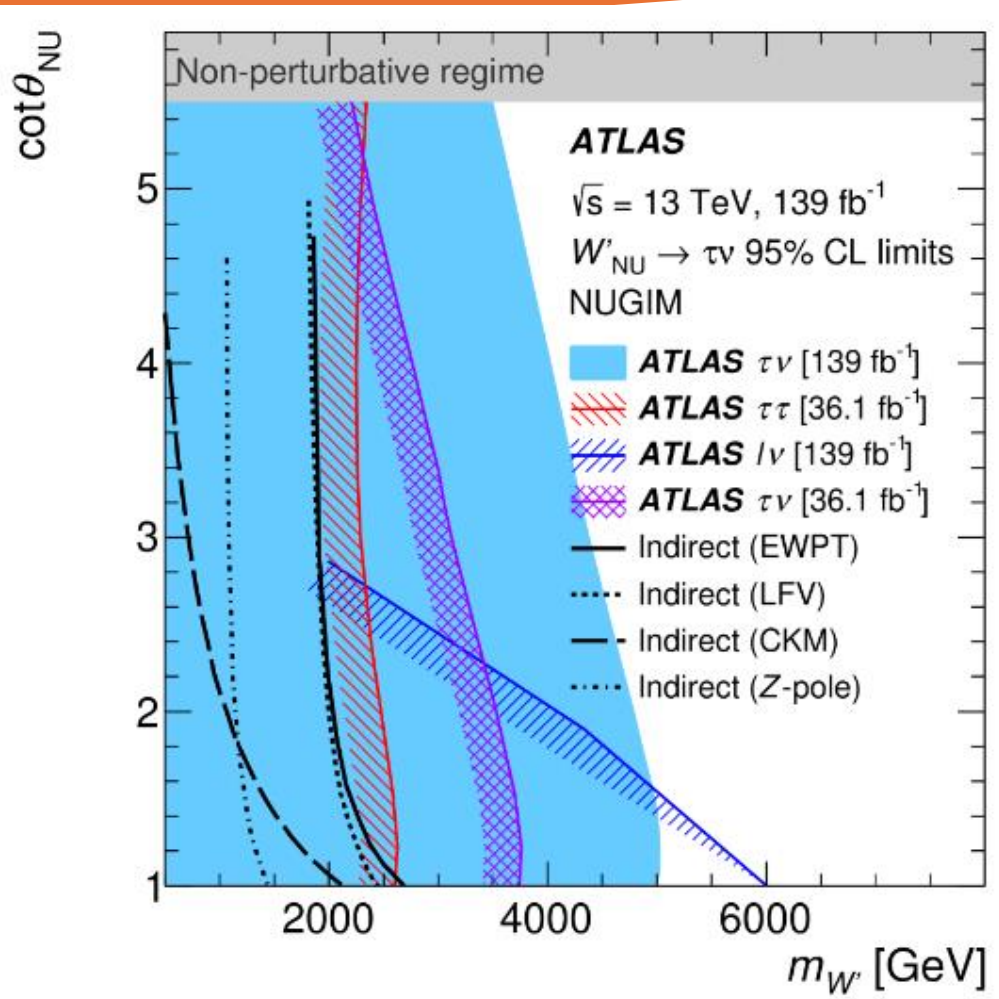
Model Exclusions

- SSM excluded below 5 TeV (@ 95% CL)



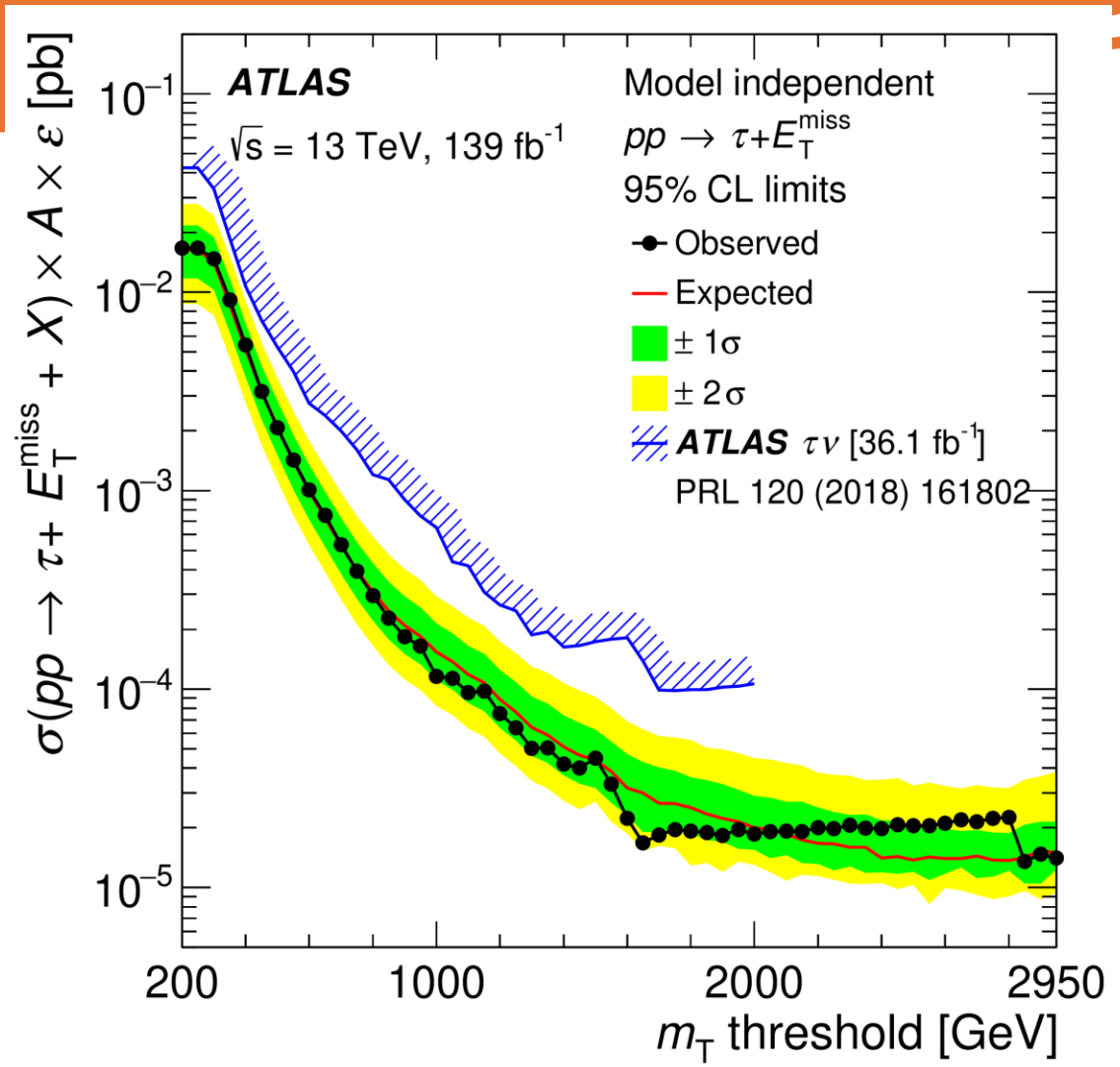
Model Exclusions

- SSM excluded below 5 TeV (@ 95% CL)
- Non-Universal gauge interaction models excluded below 5 TeV to 3.5 TeV (@ 95% CL)



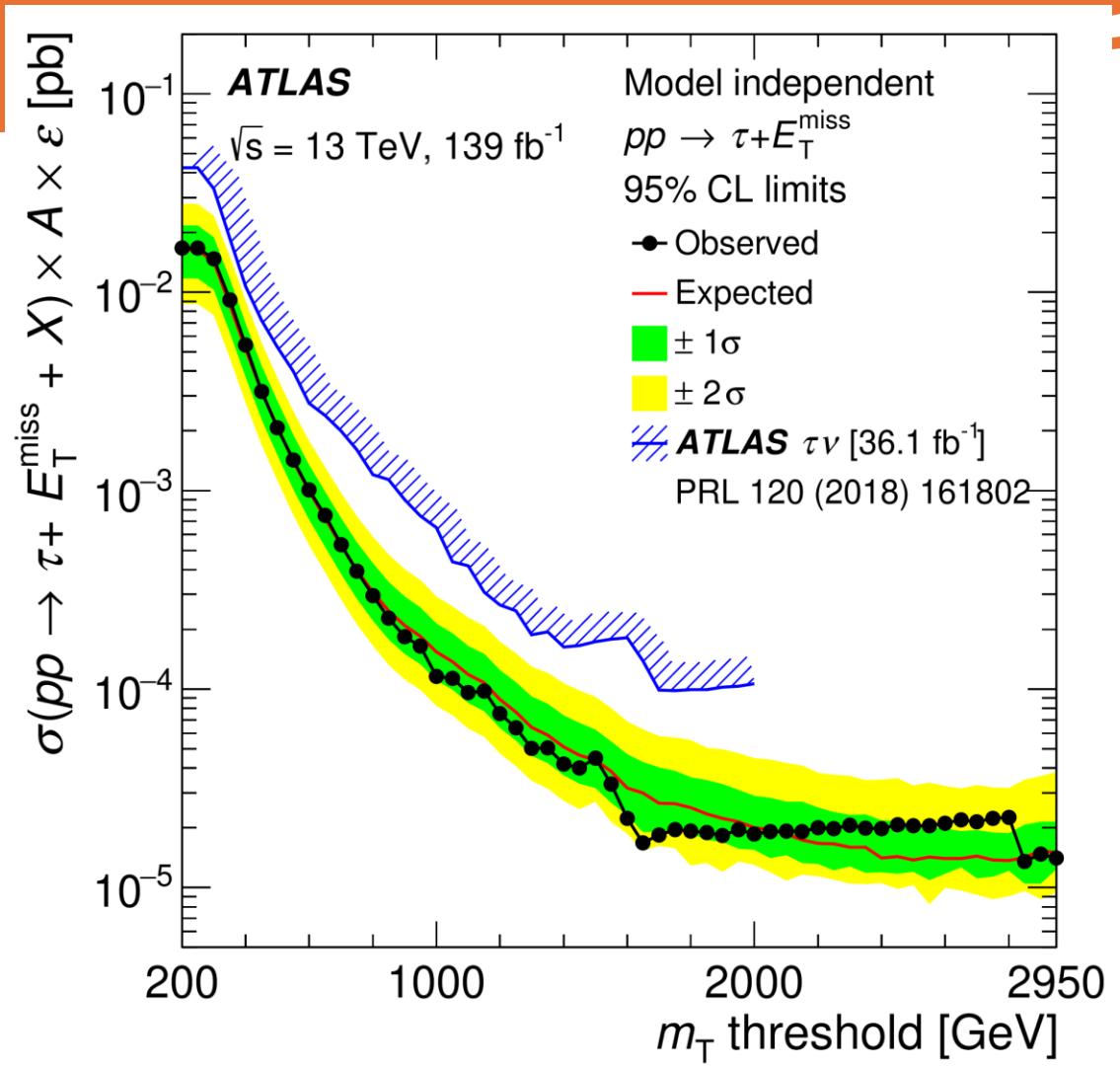
Model-independent limits

- Model independent limits derived on visible cross-section above m_T threshold (signal shape independence)



Model-independent limits

- Model independent limits derived on visible cross-section above m_T threshold (signal shape independence)
- Acceptances to be determined by theorist
- Provide reconstruction efficiency as function of m_T



Conclusions

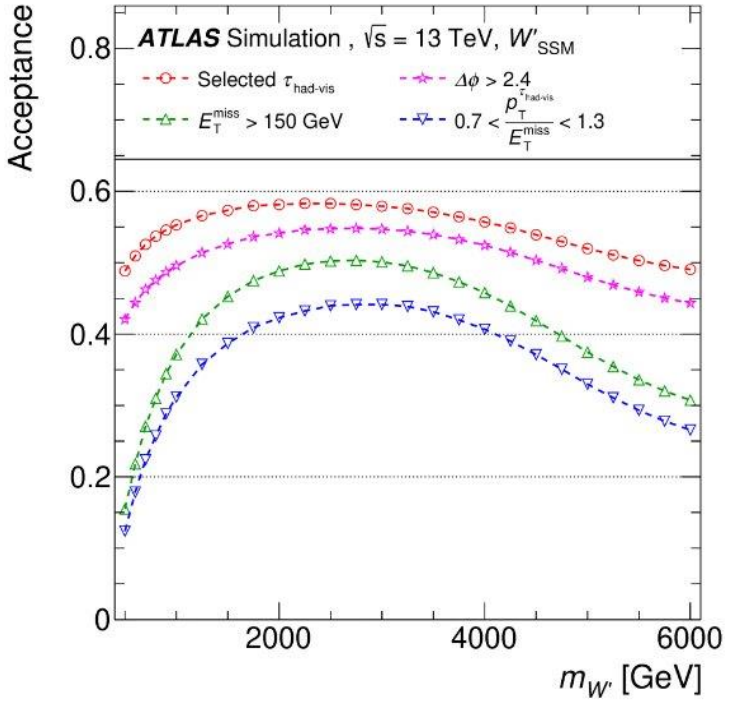
- Presented ATLAS Run-2 search for W' in τν channel
- Result recently published:
  arxiv 2402.16576 (arxiv.org) (Subm: Physical Review D)
- Highest exclusion limits to-date

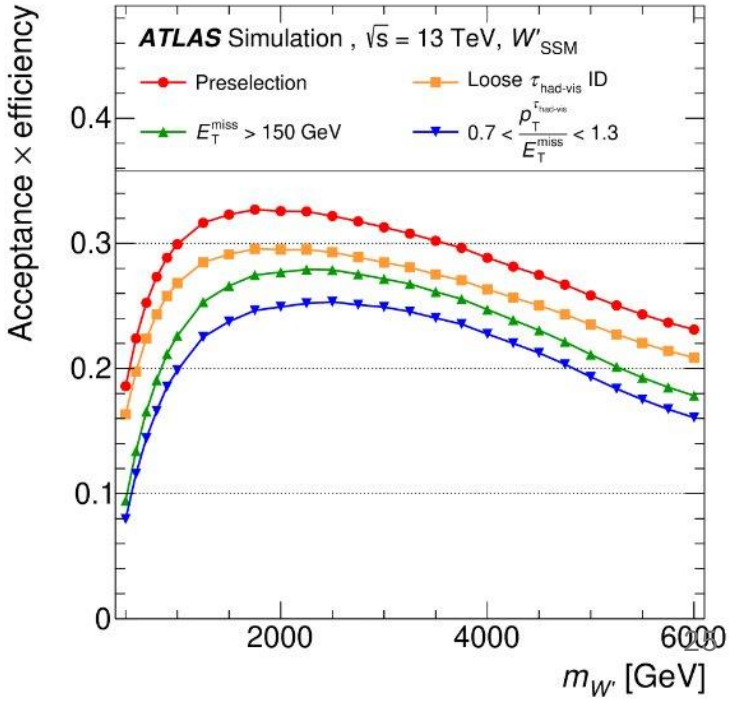
Thank you


3-prong $\tau_{\text{had-vis}}$
$p_T = 1.4$ TeV
$E_{\text{T}}^{\text{miss}} = 1.4$ TeV
ATLAS
EXPERIMENT
Run Number: 350184, Event Number: 1106430887
Date: 2018-05-14 08:58:04 CEST

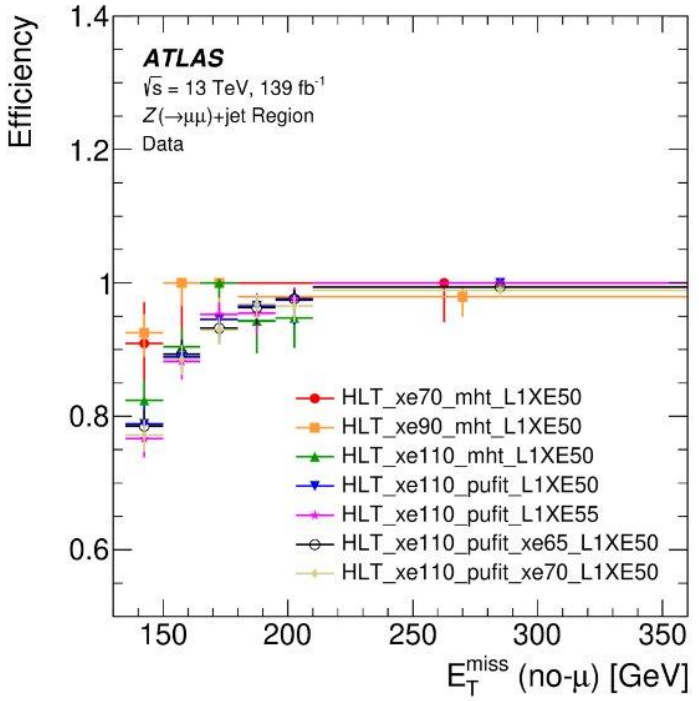
Backup

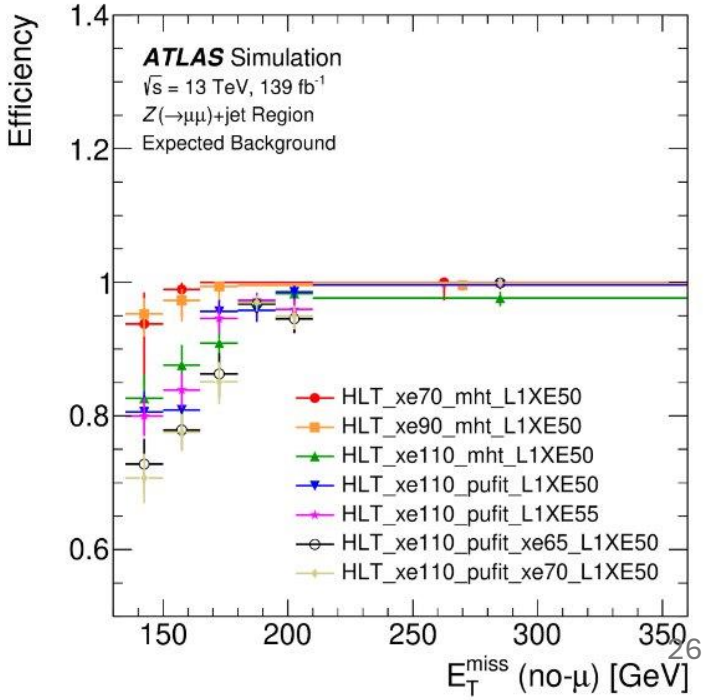
Acceptancies



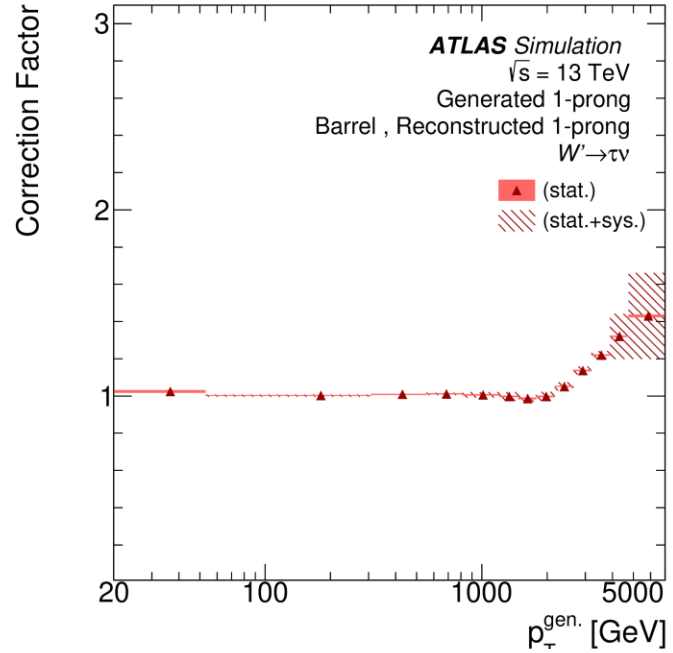


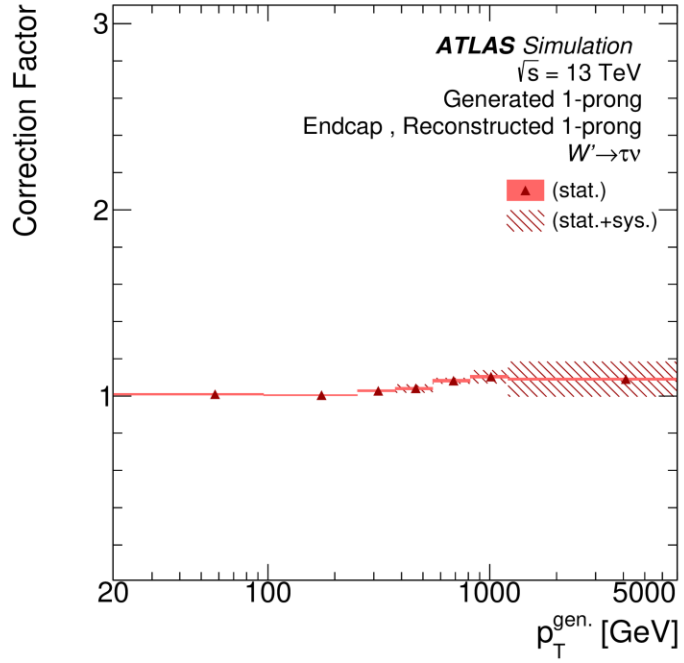
Trigger Efficiency

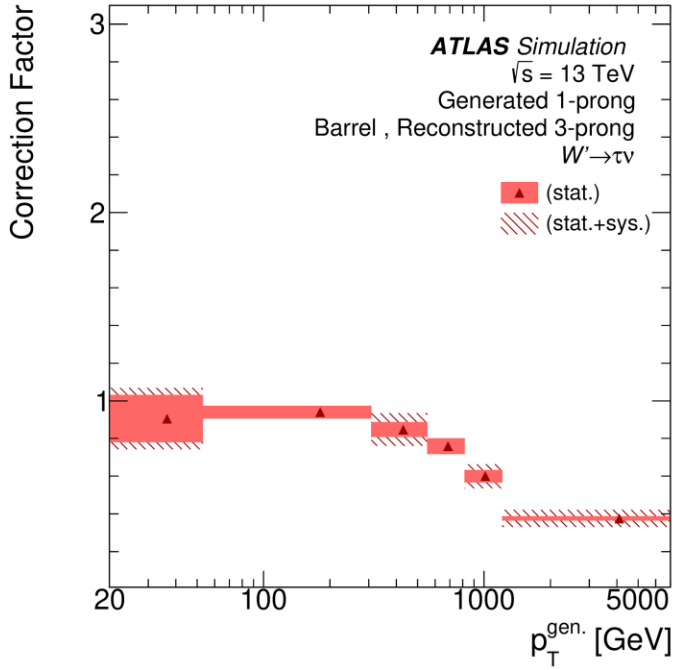


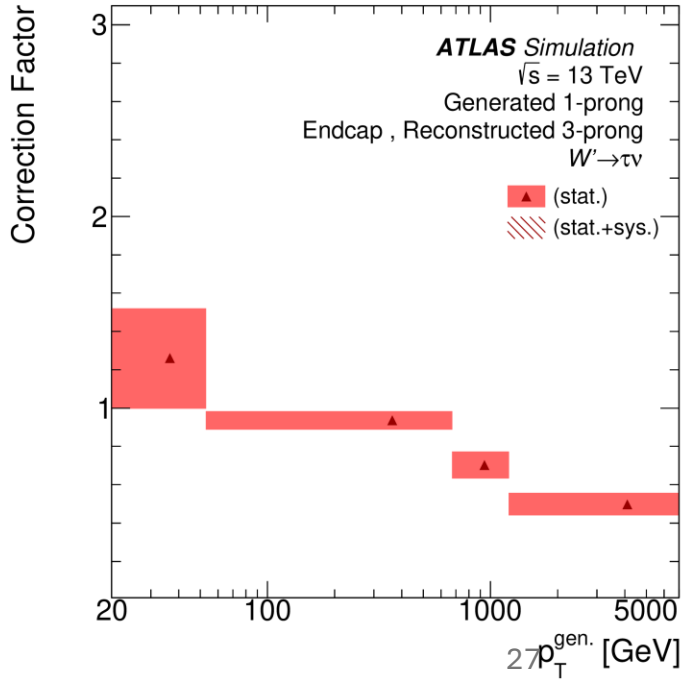


Tau detector interactions Corrections (1-prong)

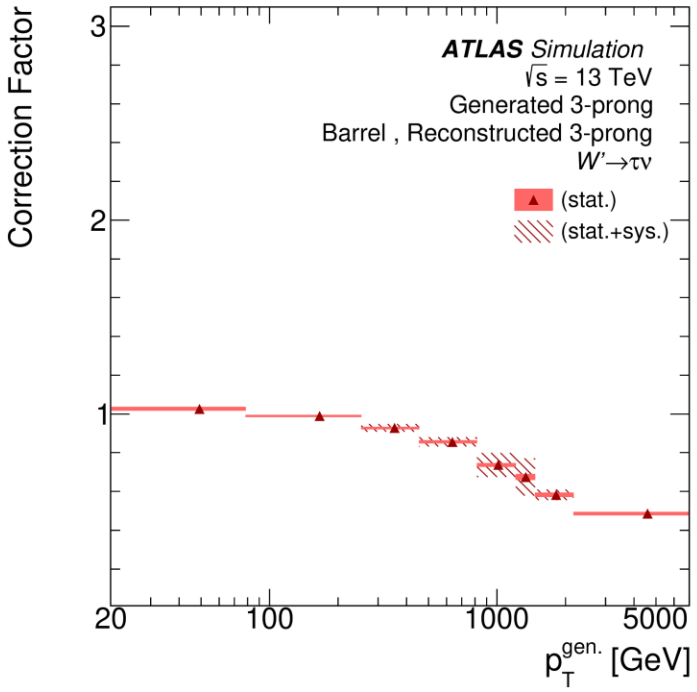


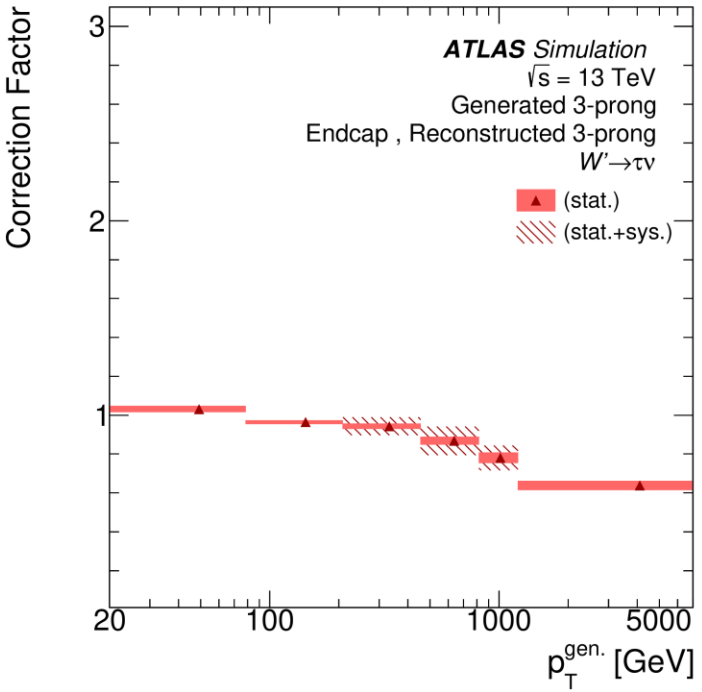


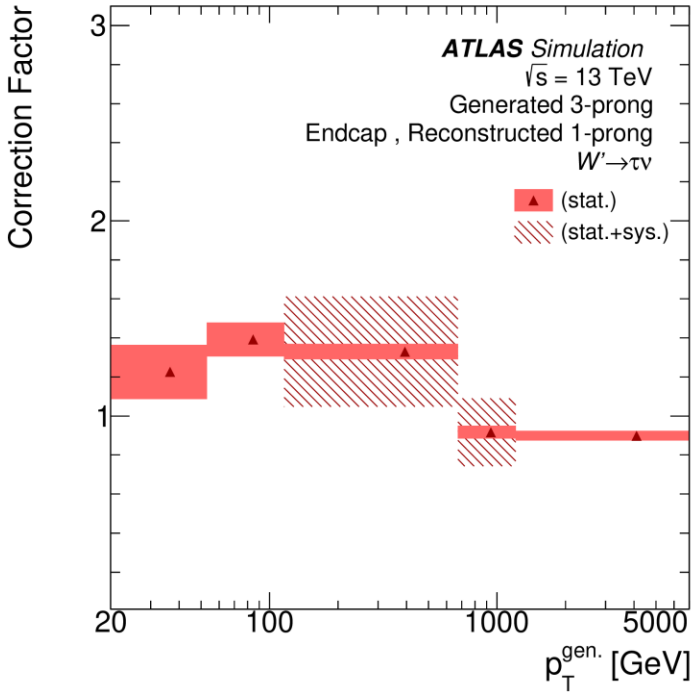


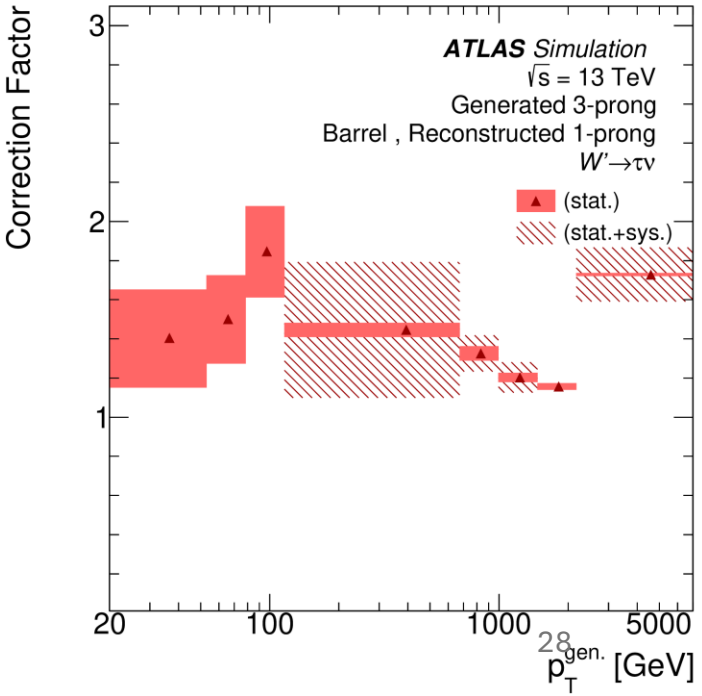


Tau detector interactions Corrections (3-prong)

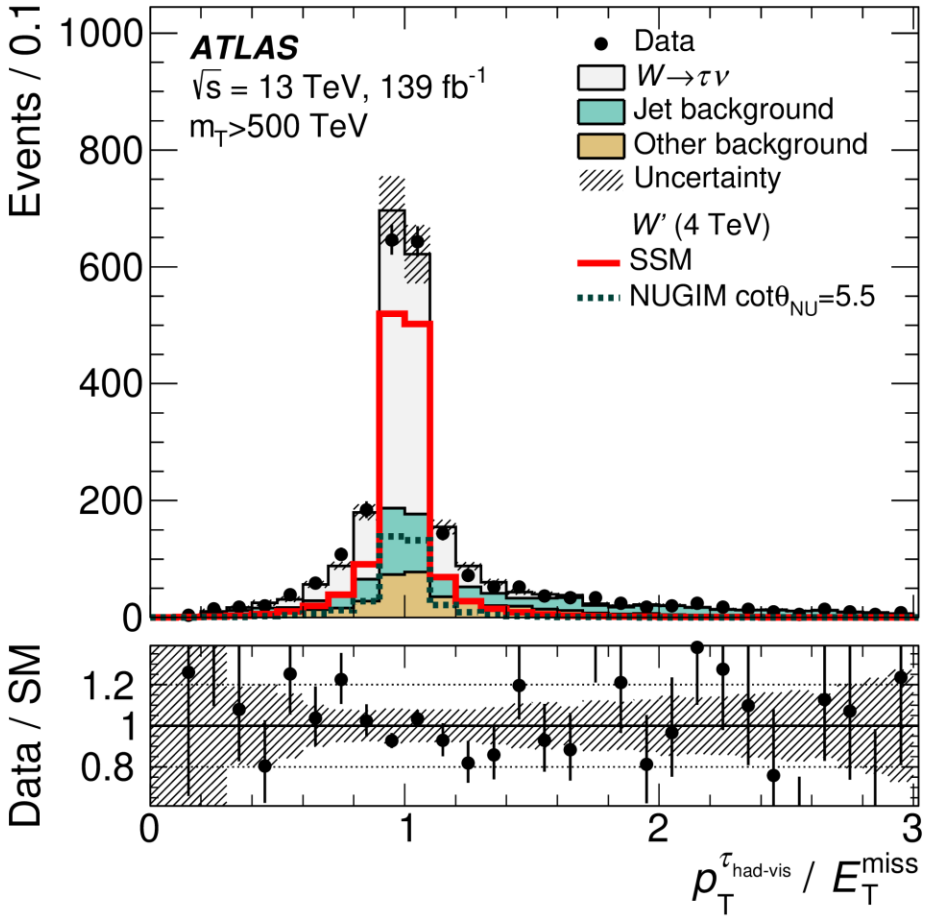






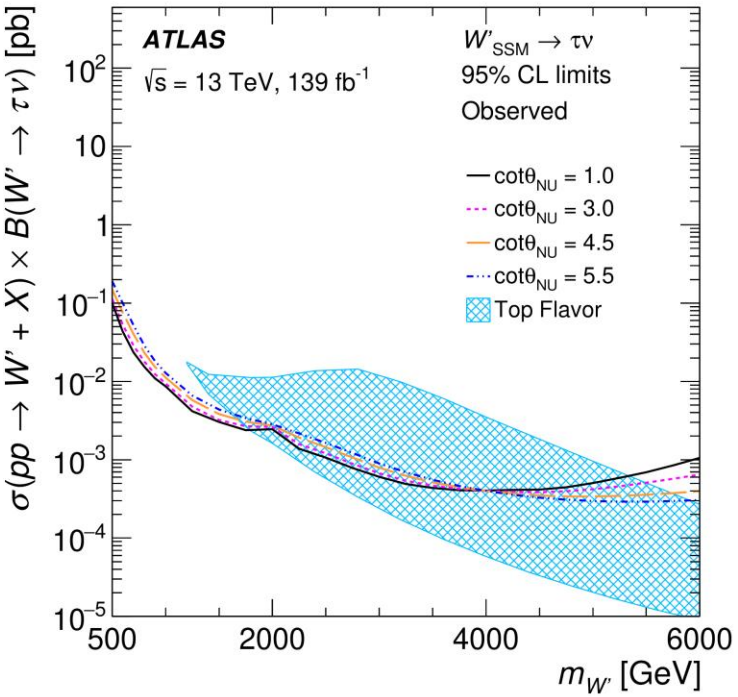


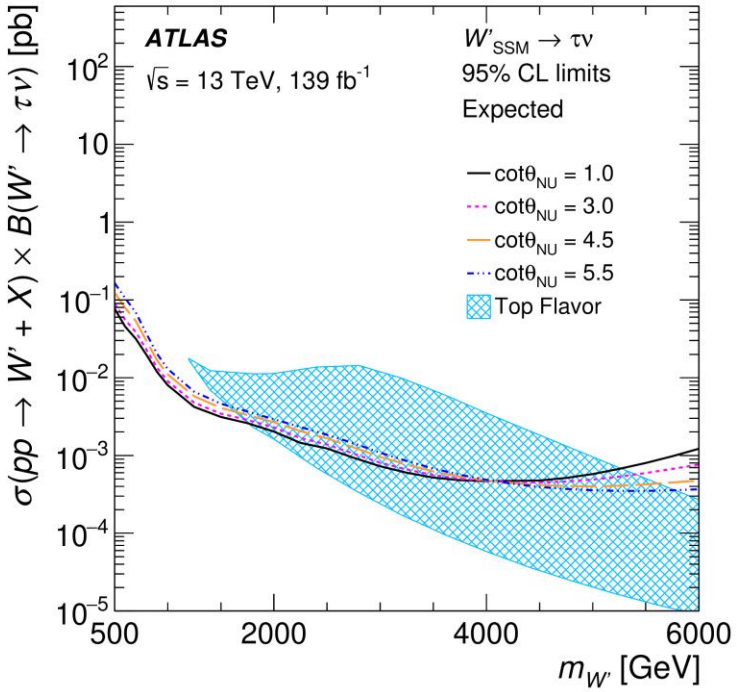
Selection



Selection	Data	$W \to \tau\nu$	Jet background	Other background	W'_{SSM} (5 TeV)
Preselection	3 640 749	102 000 ± 6 000	–	73 000 ± 6 000	18 ± 5
τ-lepton identification	1 189 863	84 000 ± 5 000	–	52 000 ± 4 000	17 ± 4
$E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV	58 528	13 400 ± 1 600	31 000 ± 9 000	12 000 ± 1 500	15 ± 4
$0.7 < \frac{p_{\mathrm{T}}^{\tau\text{had-vis}}}{E_{\mathrm{T}}^{\mathrm{miss}}} < 1.3$	18 528	9 700 ± 1 400	5 800 ± 400	2 900 ± 500	14 ± 4
$m_{\mathrm{T}} > 1$ TeV	58	51 ± 12	10 ± 4	12.0 ± 2.7	7.2 ± 3.3

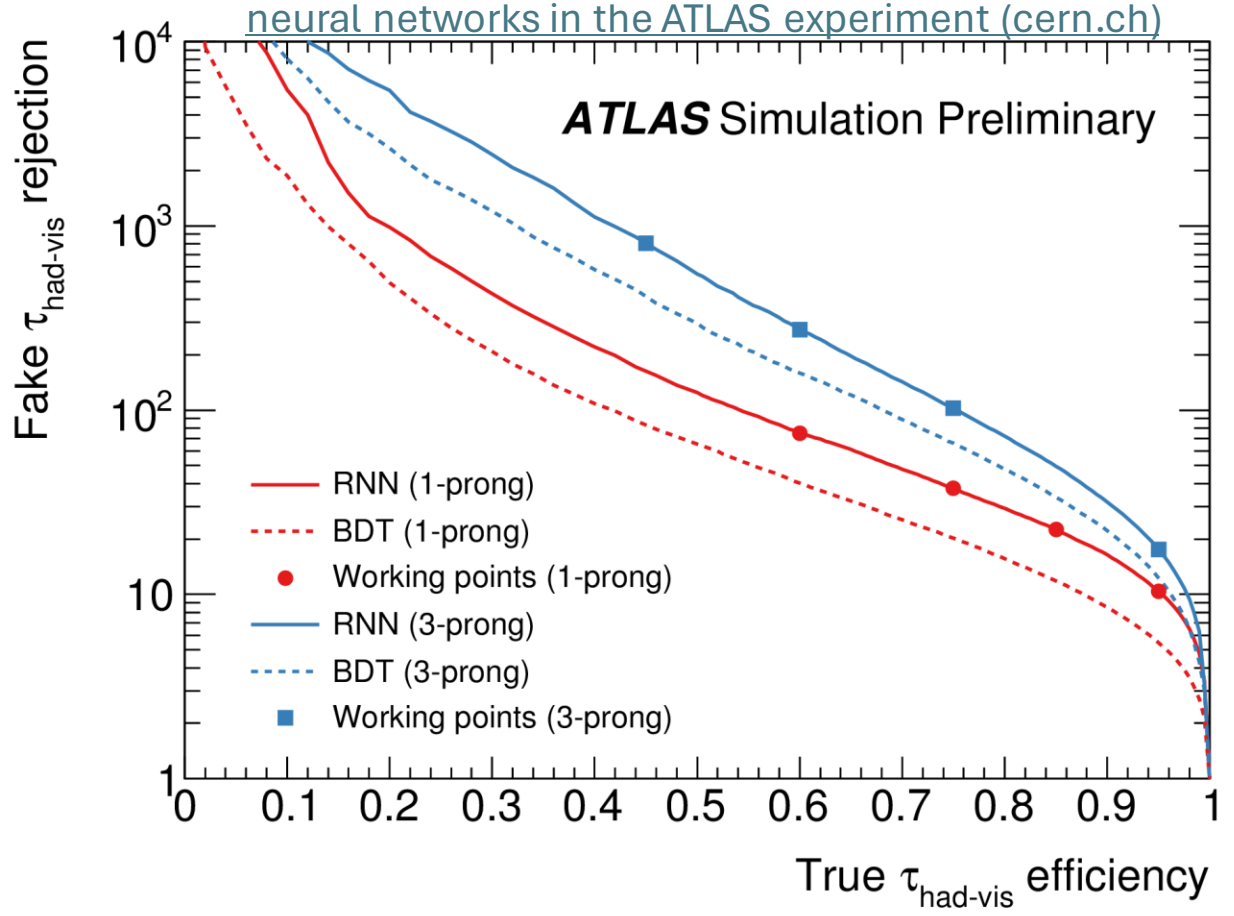
TopFlavor Limits





Tau Identification

Identification of hadronic tau lepton decays using neural networks in the ATLAS experiment (cern.ch)



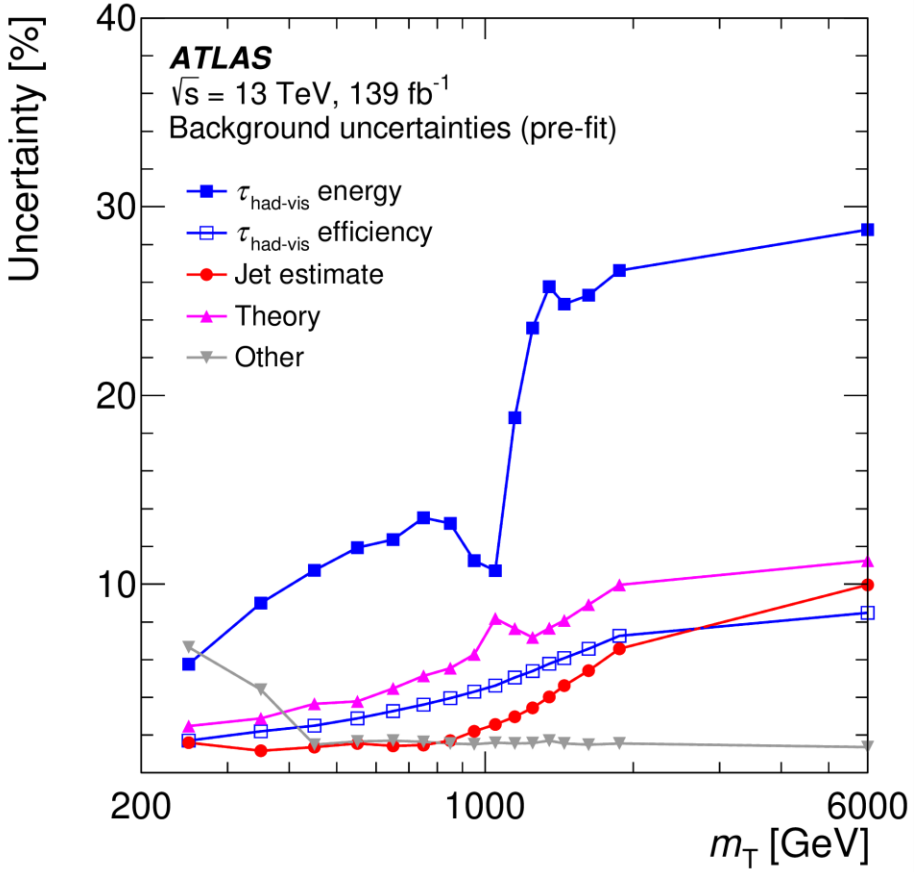
Working point	Signal efficiency 1-prong	Signal efficiency 3-prong	Background rejection BDT 1-prong	Background rejection BDT 3-prong	Background rejection RNN 1-prong	Background rejection RNN 3-prong
Tight	60%	45%	40	400	70	700
Medium	75%	60%	20	150	35	240
Loose	85%	75%	12	61	21	90
Very loose	95%	95%	5.3	11.2	9.9	16[31]

Event Selection

	Preselection				
$E_{\mathrm{T}}^{\mathrm{miss}}$ trigger	$70, 90, 110$ GeV				
Event cleaning	applied				
$\tau_{\text{had-vis}}$ tracks	1 or 3				
$\tau_{\text{had-vis}}$ charge	± 1				
$p_{\mathrm{T}}^{\tau_{\text{had-vis}}}$	> 30 GeV				
$\tau_{\text{had-vis}}$ $p_{\mathrm{T}}^{\mathrm{leadTrack}}$	> 10 GeV				
Lepton veto	applied				
$\Delta\phi_{\tau_{\text{had-vis}}, E_{\mathrm{T}}^{\mathrm{miss}}}$	> 2.4 rad				
	Region requirements				
	SR	**CR1**	**CR2**	**CR3**	**VR**
τ-lepton identification	L	VL\L	L	VL\L	L
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 150 GeV	> 150 GeV	< 100 GeV	< 100 GeV	> 150 GeV
$p_{\mathrm{T}}^{\tau_{\text{had-vis}}}/E_{\mathrm{T}}^{\mathrm{miss}}$	$\in [0.7, 1.3]$	$\in [0.7, 1.3]$	–	–	< 0.7
m_{T}	–	–	–	–	> 240 GeV

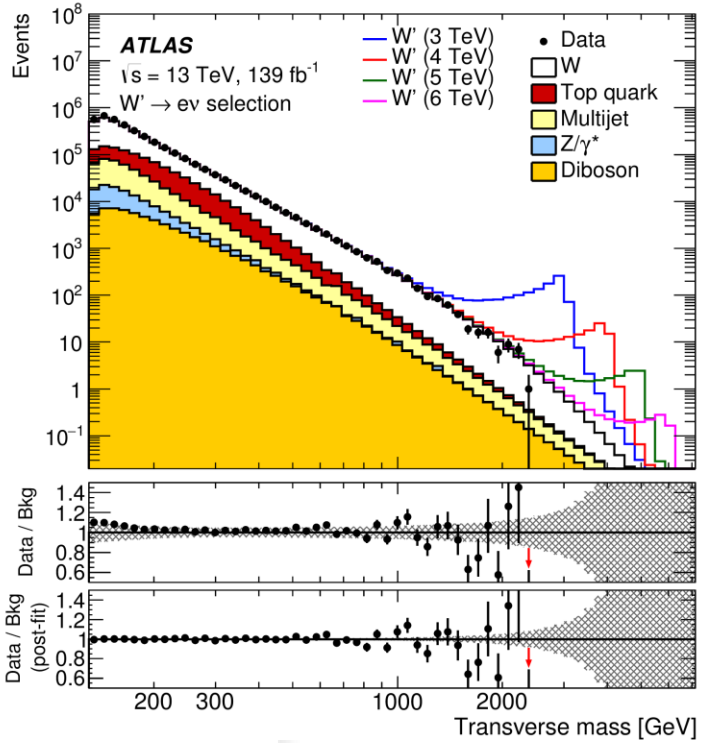
Systematics

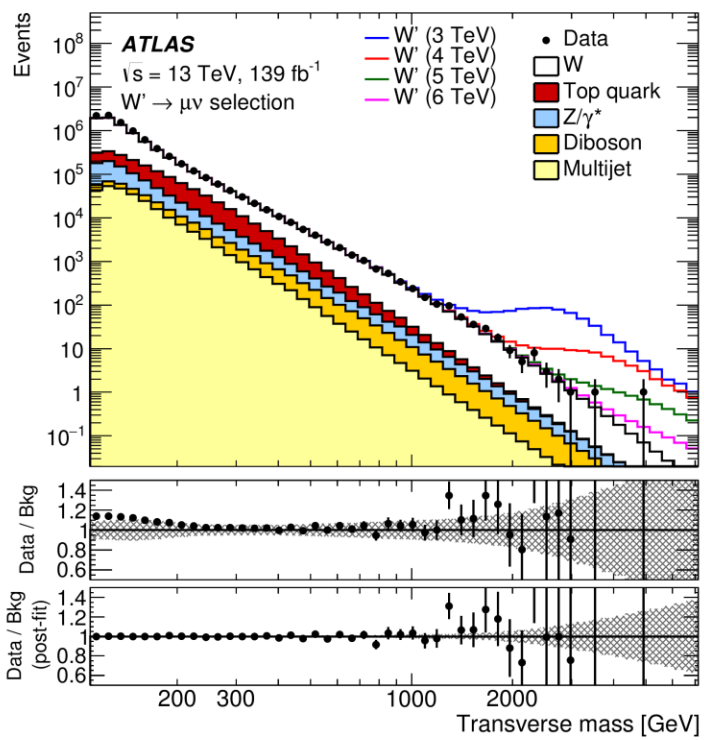
- Systematic uncertainties included as Nuisance Parameters in Profile likelihood fit
- Major background systematics from **Tau Energy Scale**, **theory** and **tau reconstruction/ID efficiency**
- **Jet Estimate** for jet background systematics **Others** trigger, ETmiss, Jet



Light Lepton Searches

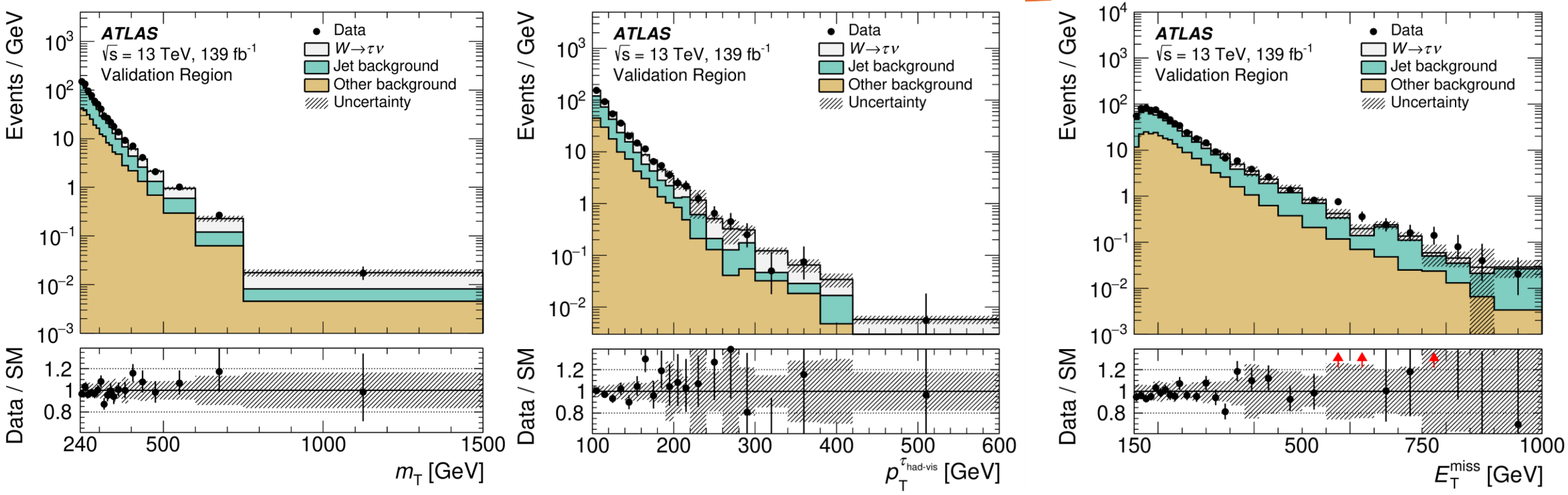
Phys. Rev. D 100 (2019) 052013





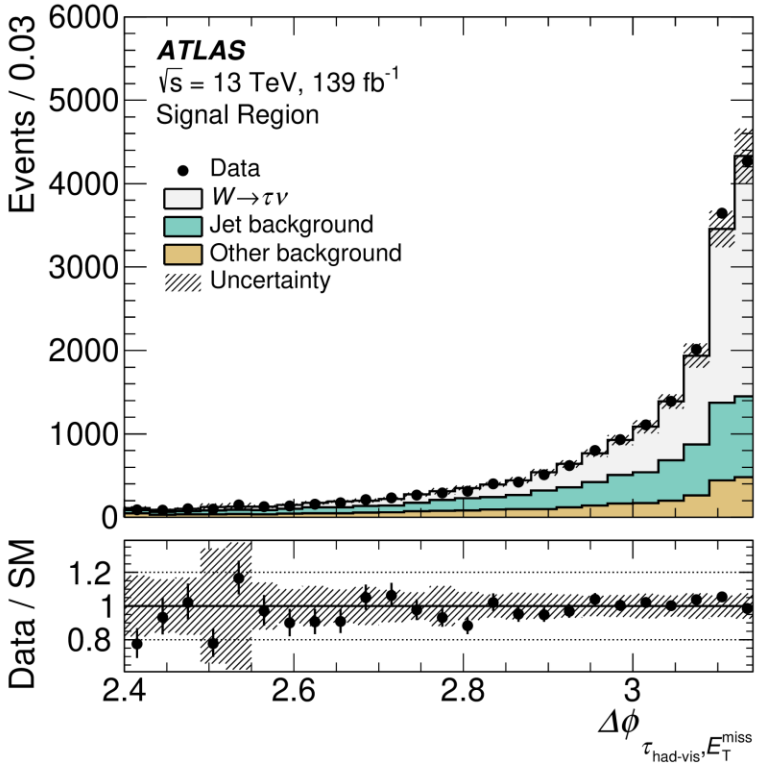
	$m(W')$ lower limit [TeV]	
Decay	Observed	Expected
$W' \to e\nu$	6.0	5.7
$W' \to \mu\nu$	5.1	5.1
$W' \to \ell\nu$	6.0	5.8

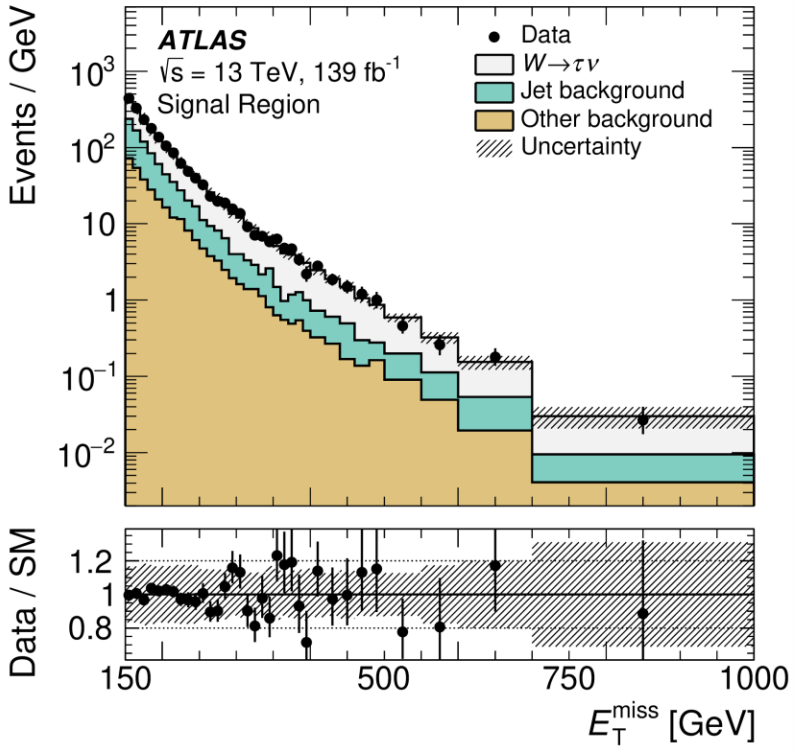
Background validation

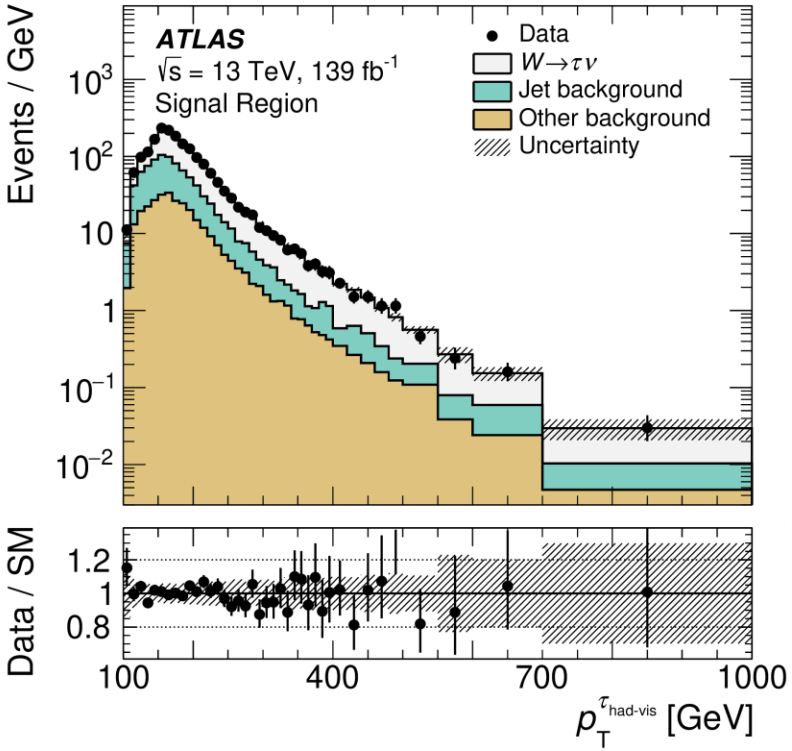


Validate background in dedicated Region

Signal Region







Good agreement between data/background in SR

Model-independent limits

- Model independent limits derived on visible cross-section above m_T threshold (signal shape independence)
- Acceptances to be determined by theorist
- Provide Reconstruction efficiency to correct for reconstruction effects