

SEARCH FOR SUPERSYMMETRY AND DARK MATTER

Netzwerk Teilchenwelt Projektwochen 2017

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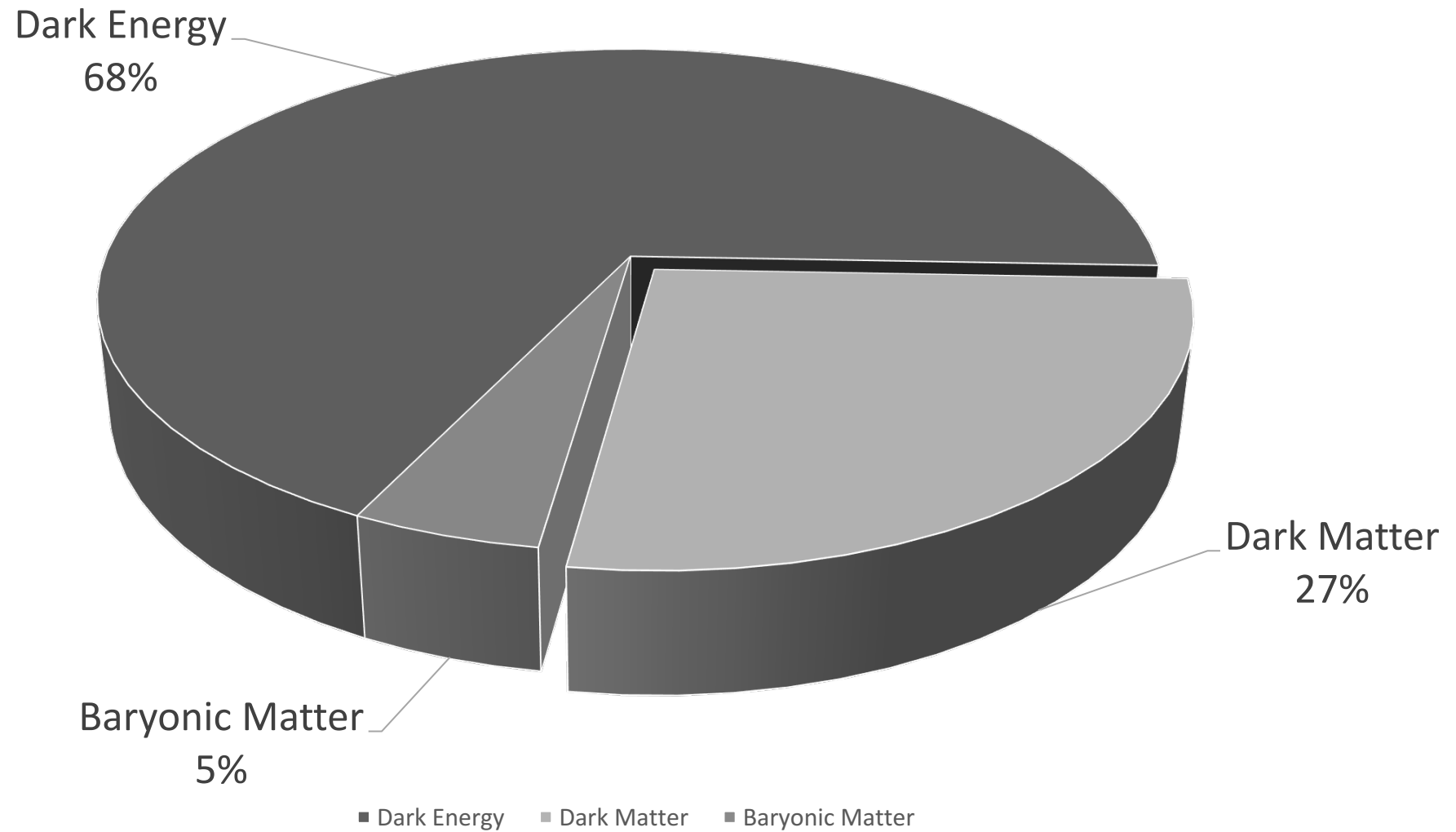


27.10.17, CERN

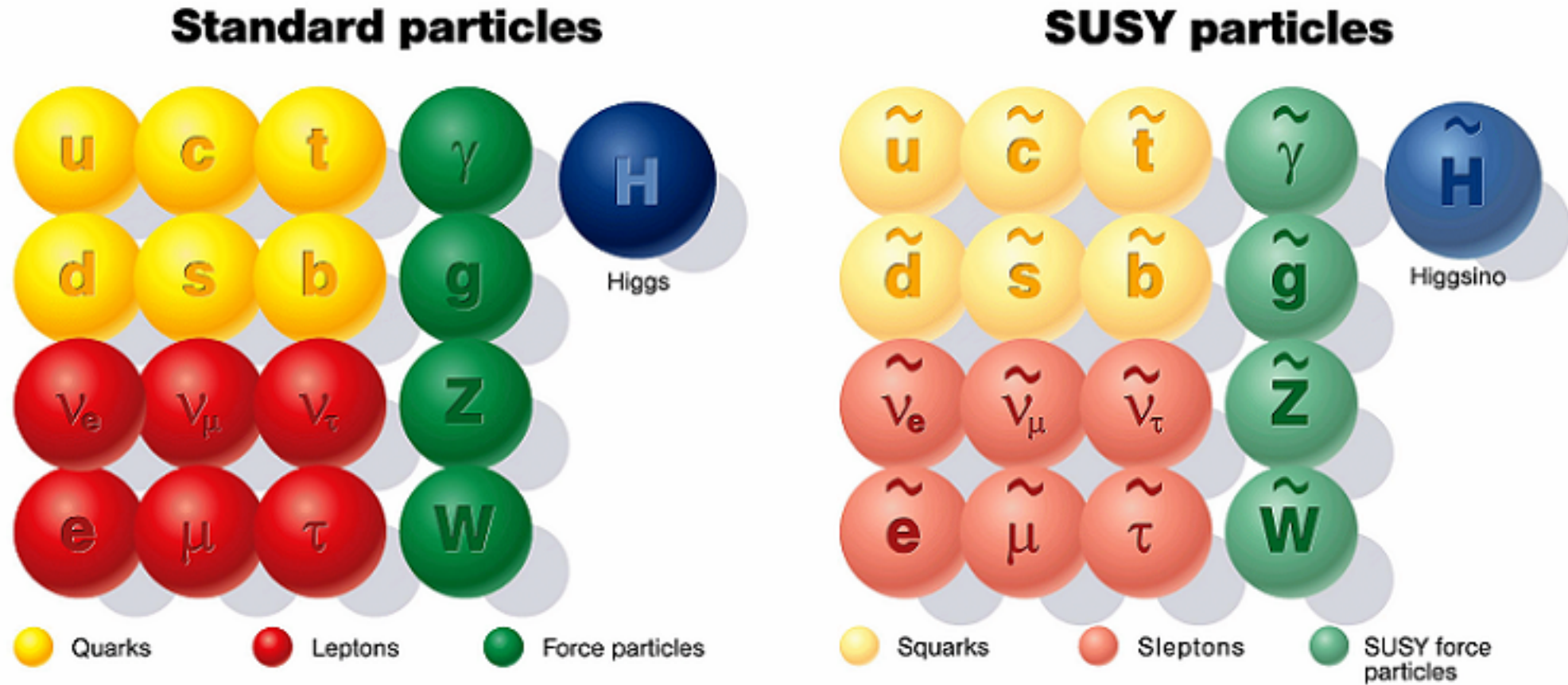
Supersymmetry and Dark Matter



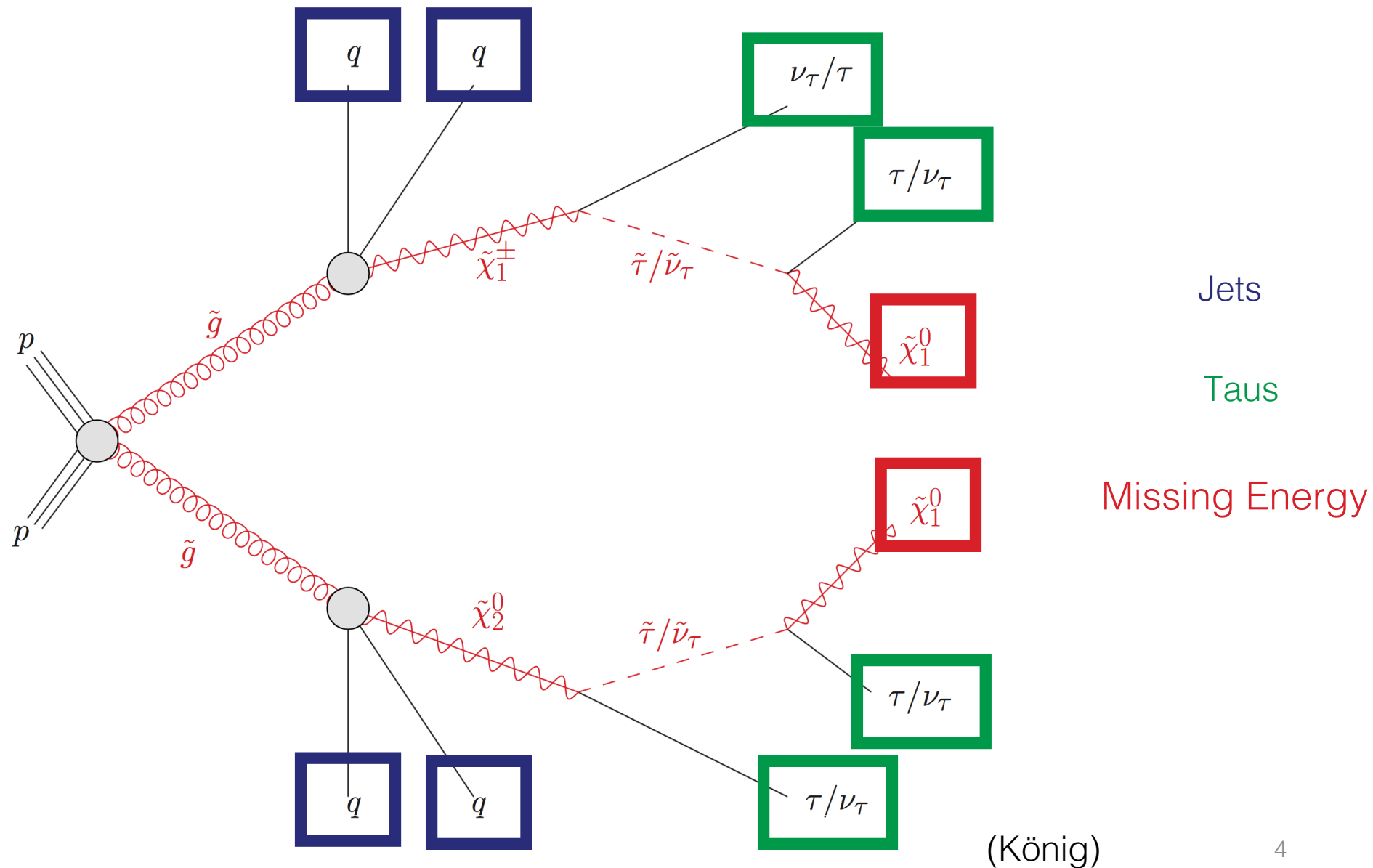
Matter and Energy Distribution in the Universe



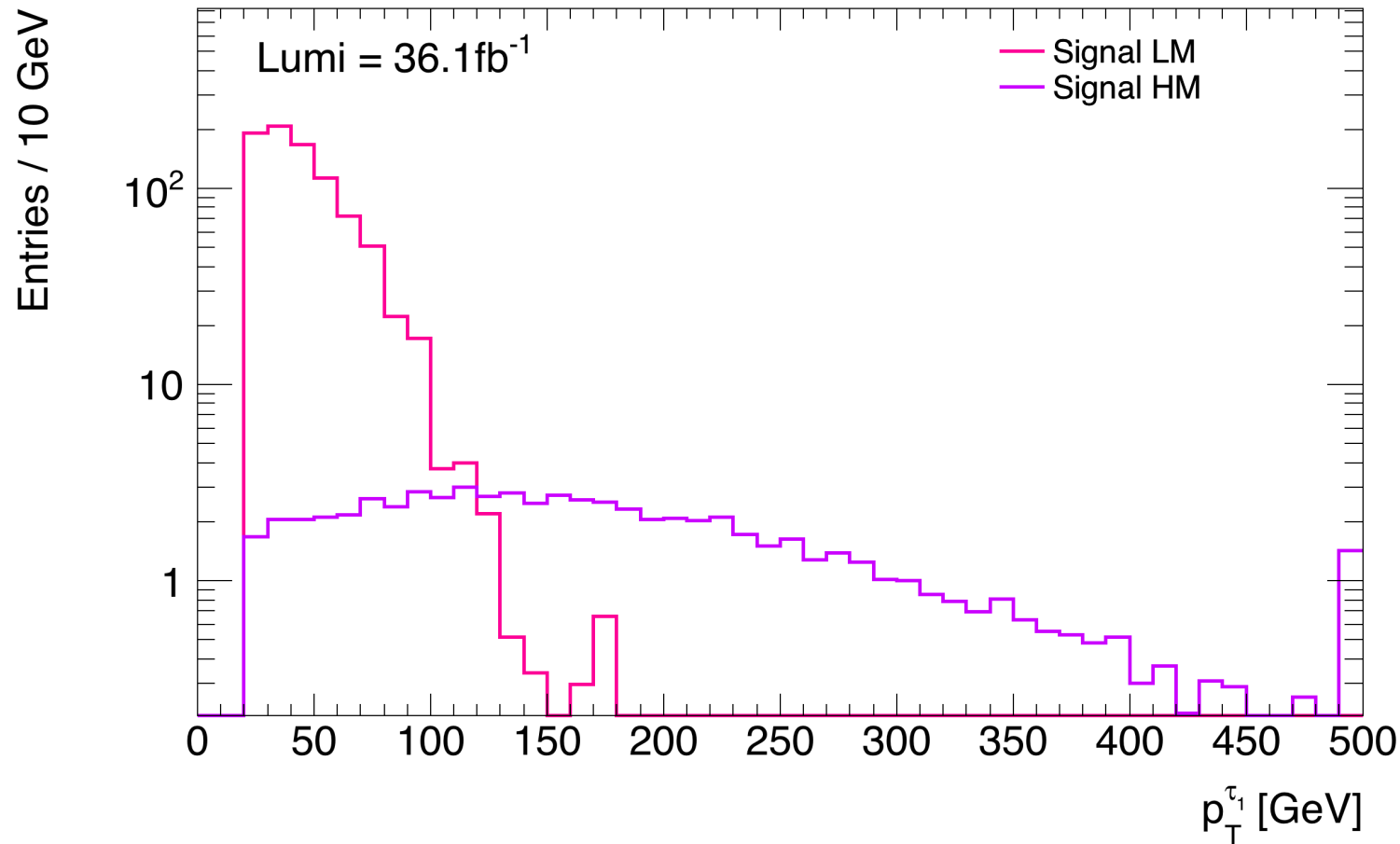
Supersymmetry



Simplified Model



Signals



Compressed Δm
Signal Region

\tilde{g} : 1065 GeV



$\tilde{\chi}_1^0$: 825 GeV

High Δm Signal
Region

\tilde{g} : 1705 GeV



$\tilde{\chi}_1^0$: 345 GeV

Backgrounds

QCD

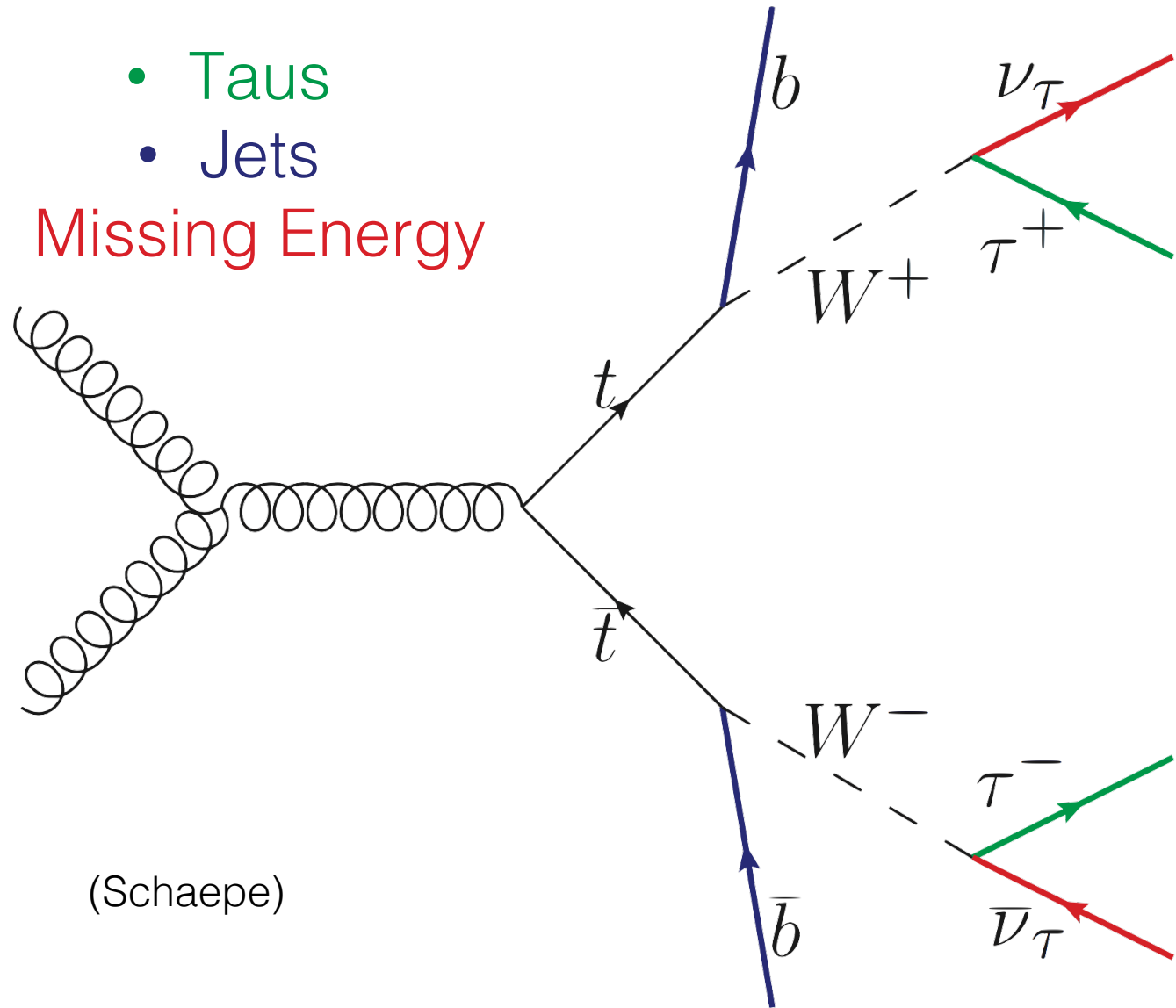
W Bosons

Z Bosons

Top/Anti-top

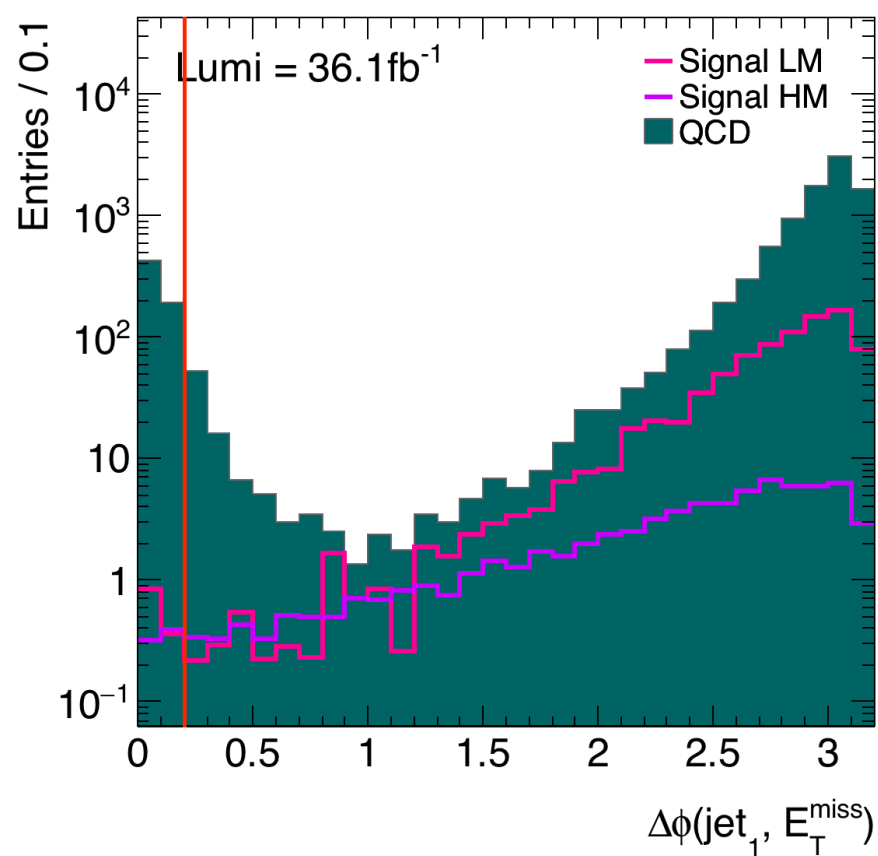
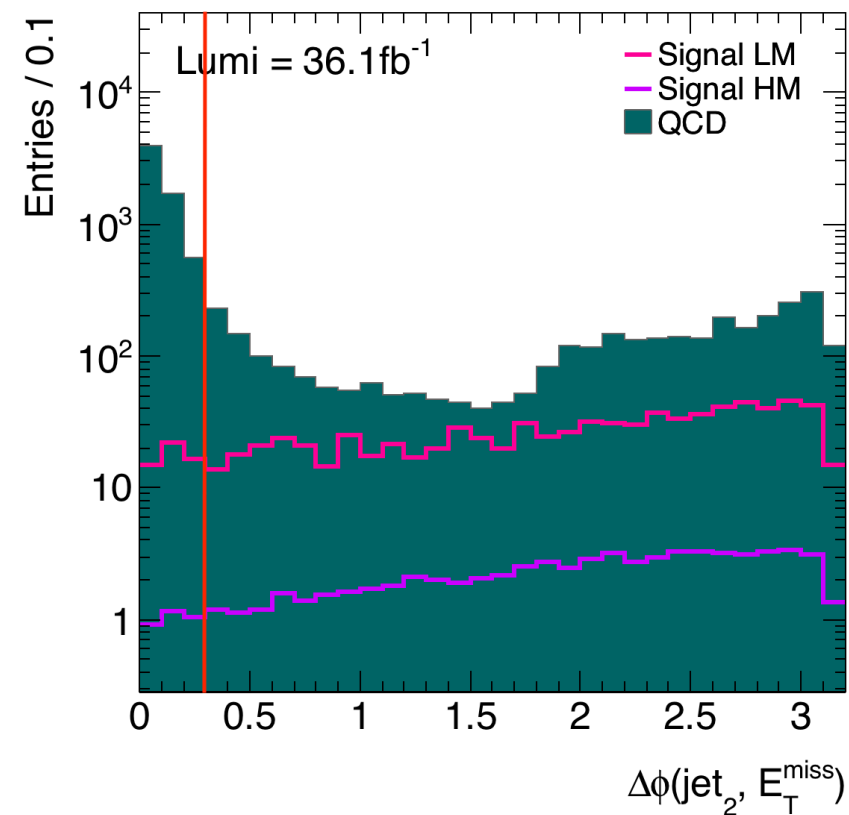
Other Processes

- Taus
- Jets
- Missing Energy



(Schaepe)

QCD Background



$$\Delta\phi(\text{jet}_1, E_T^{\text{miss}}) > 0.2 \text{ GeV}$$

$$\Delta\phi(\text{jet}_2, E_T^{\text{miss}}) > 0.3 \text{ GeV}$$

- QCD Fake E_T^{miss} from jet mismeasurement
- Signal E_T^{miss} from $\tilde{\chi}_1^0$

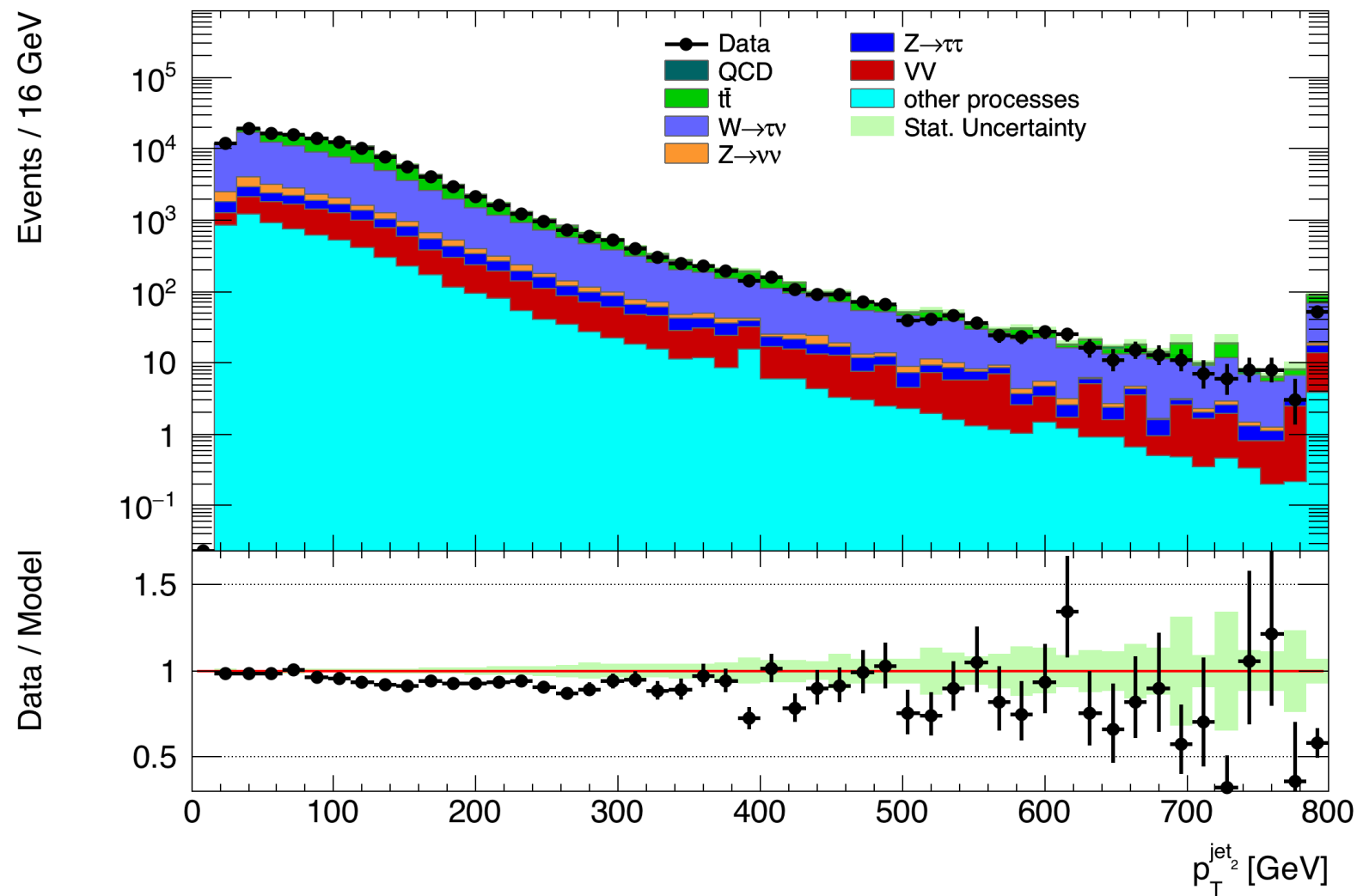
Preliminary Cuts

- Event Cleaning
- Trigger Plateau
 - $E_T^{miss} > 180 \text{ GeV}$
 - $p_T^{jet_1} > 120 \text{ GeV}$
 - $p_T^{jet_2} > 25 \text{ GeV}$
- ≥ 2 Taus

Tau Reconstruction

- Distinguish between taus and jets
- Boosted Decision Tree

Data Monte Carlo Comparison

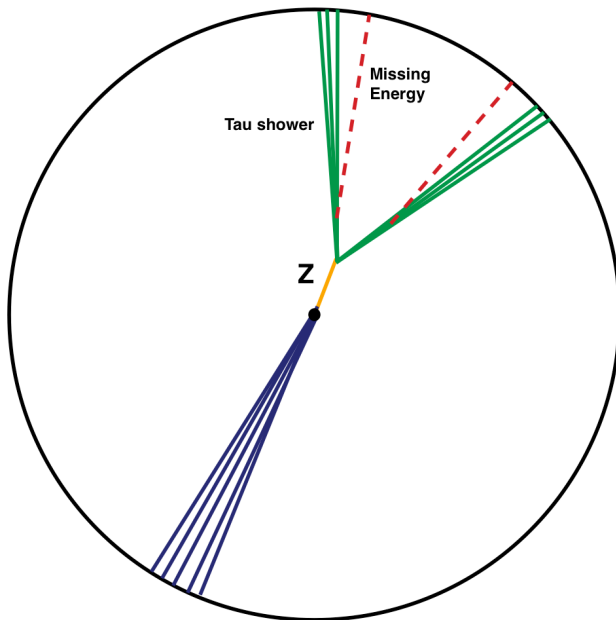


- 2015 + 16 Dataset
- 36.1 fb^{-1}
- $\sqrt{s} = 13 \text{ TeV}$

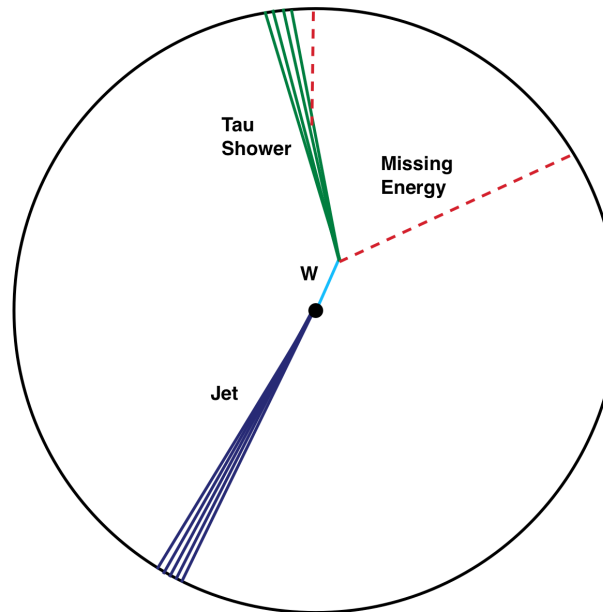
HM Cut 1: Tau transverse mass

$$\text{Transverse mass } m_T^\tau = \sqrt{2p_T^\tau E_T^{\text{miss}} (1 - \cos(\Delta\phi(\tau, p_T^{\text{miss}})))}$$

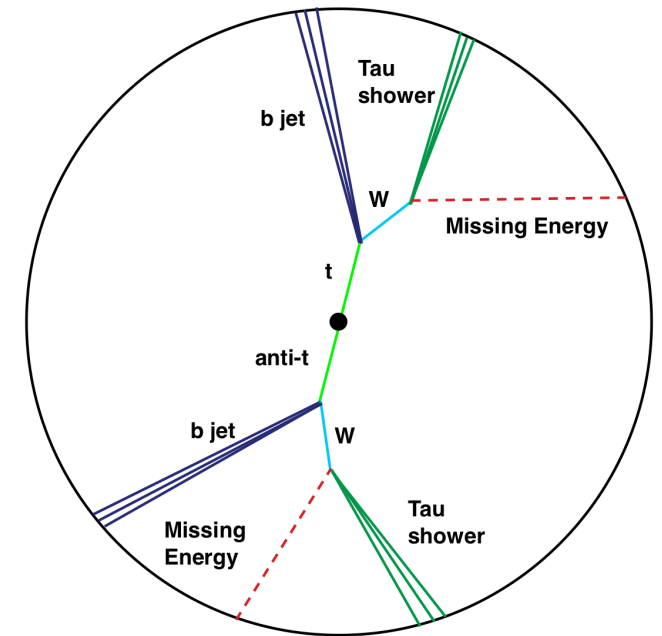
$$Z \rightarrow \tau^+ + \tau^-$$



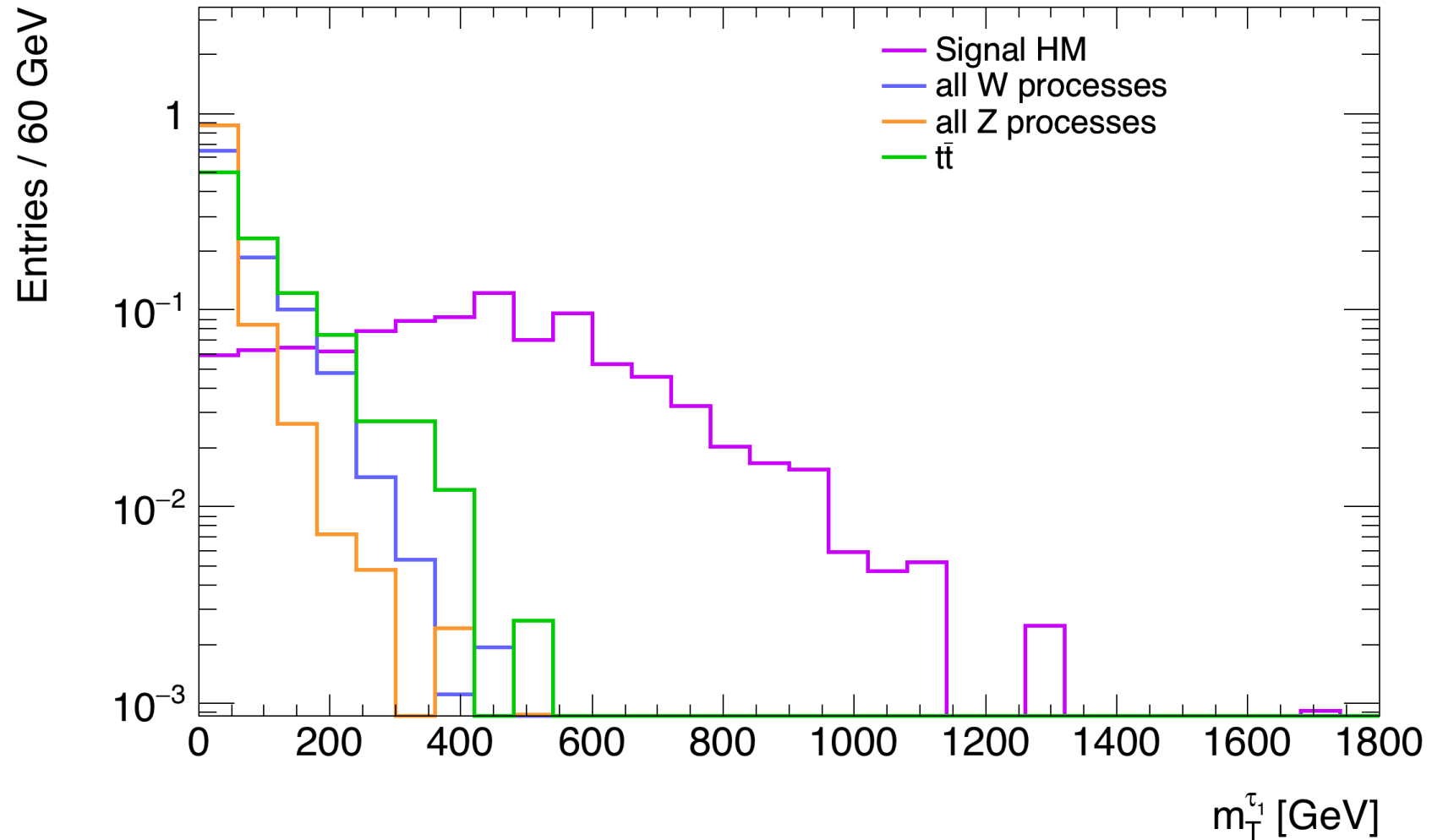
$$W \rightarrow \tau + \bar{\nu}$$



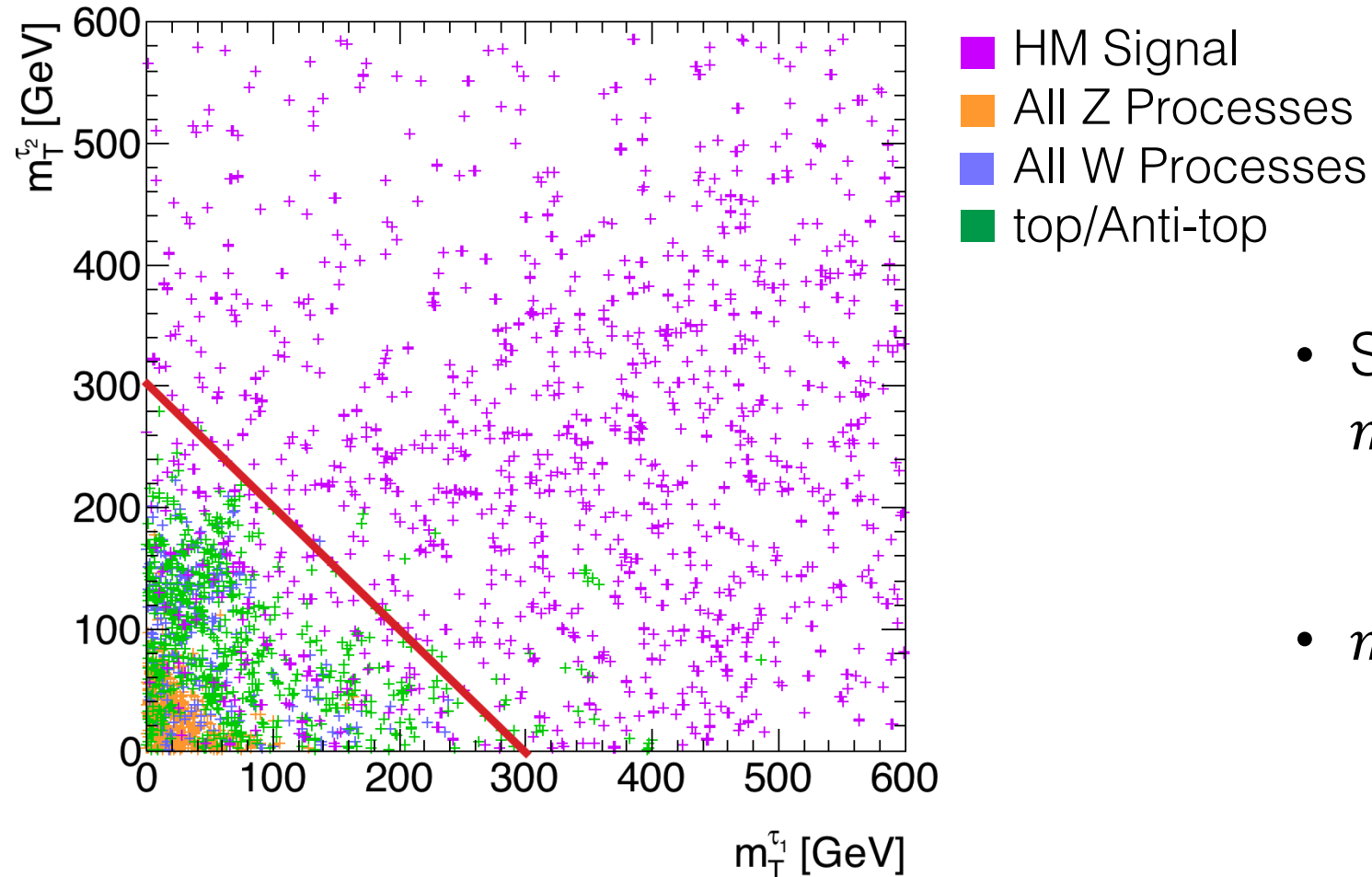
$$t \rightarrow b + W^+$$



HM Cut 1: Transverse mass



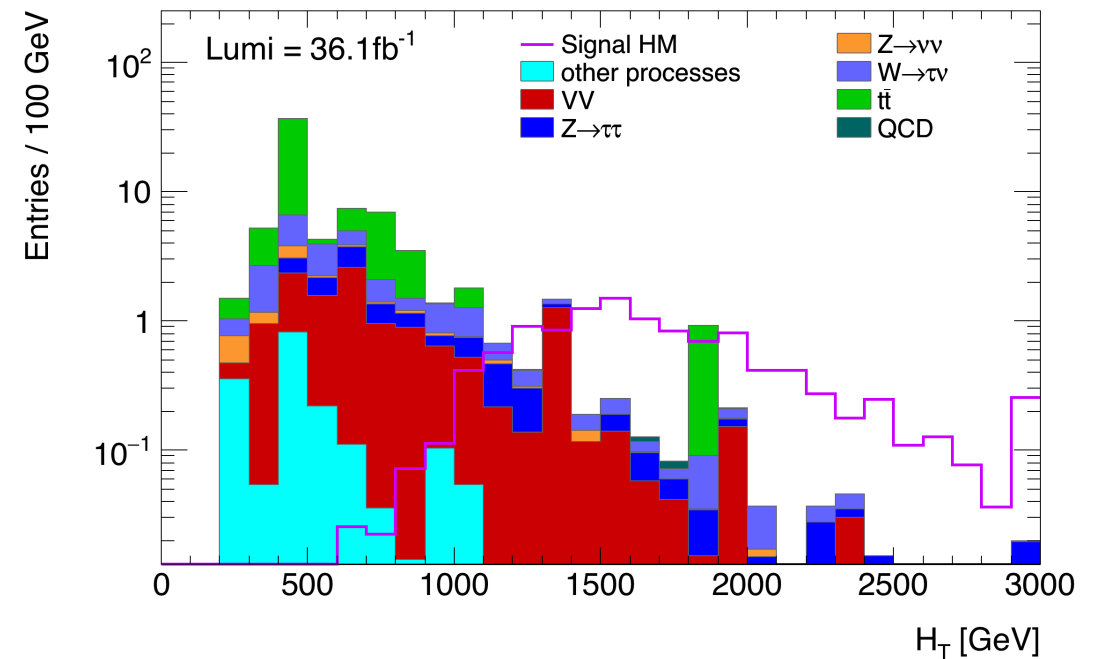
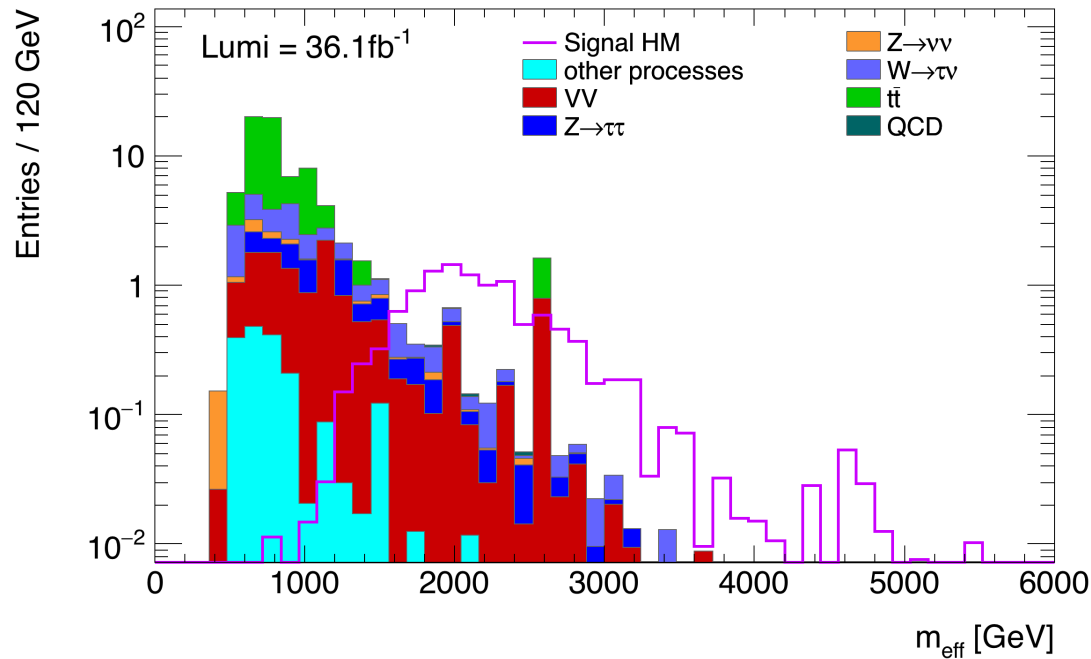
HM Cut 1: Transverse mass



- Sum of transverse masses
 $m_T^{sum} = m_T^{\tau_1} + m_T^{\tau_2}$
- $m_T^{sum} > 300$ GeV

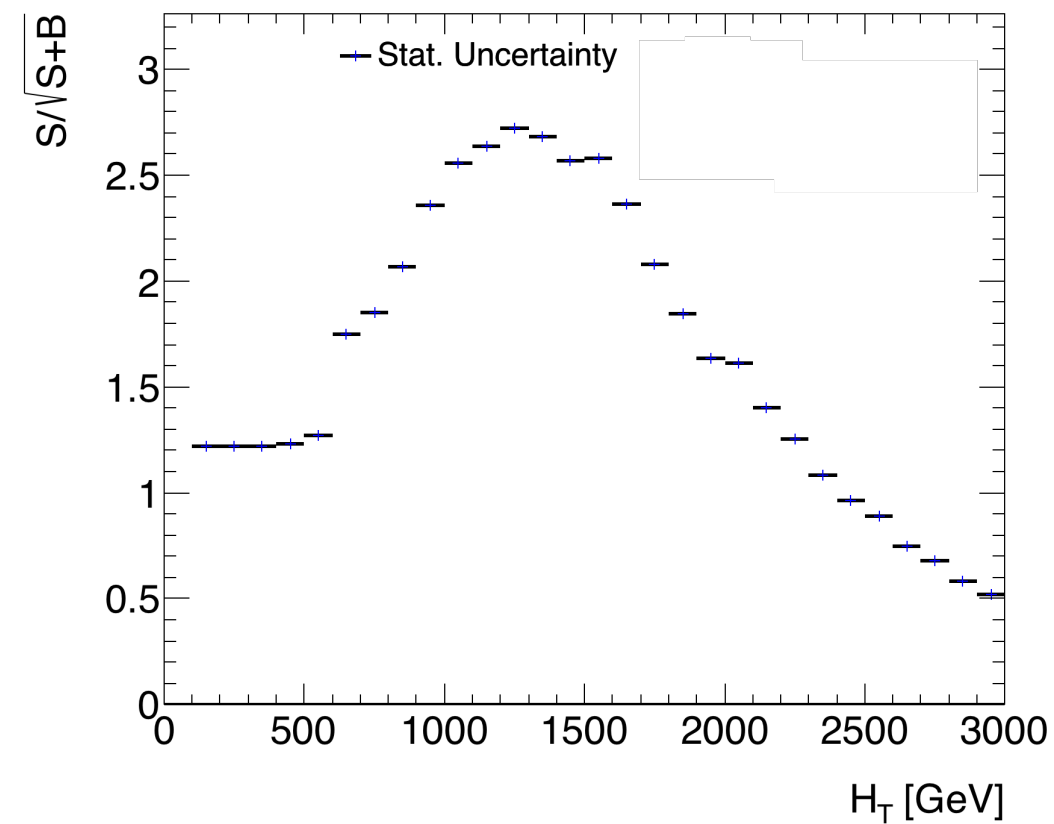
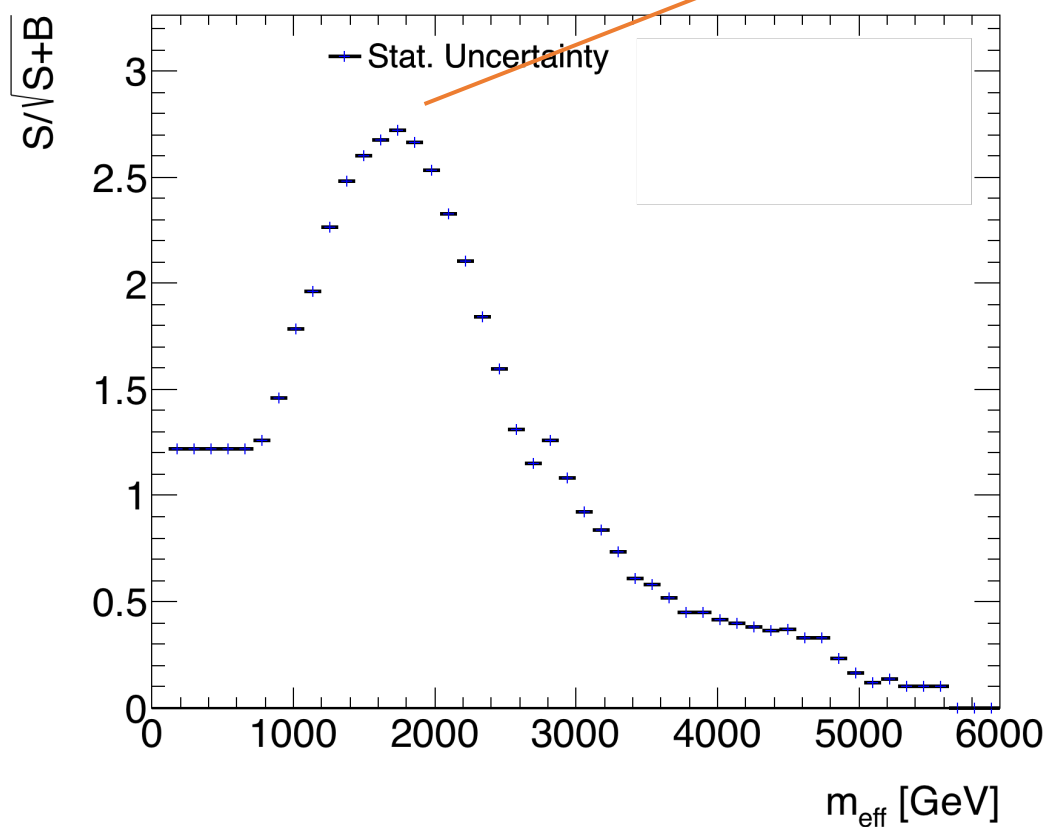
HM Cut 2: m_{eff}/H_T

- Scaler sum of transverse momenta $H_T = \sum_{all \tau} p_T^\tau + \sum_{i=1,2} p_T^{jet}$
- Effective mass $m_{eff} = H_T + E_T^{miss}$



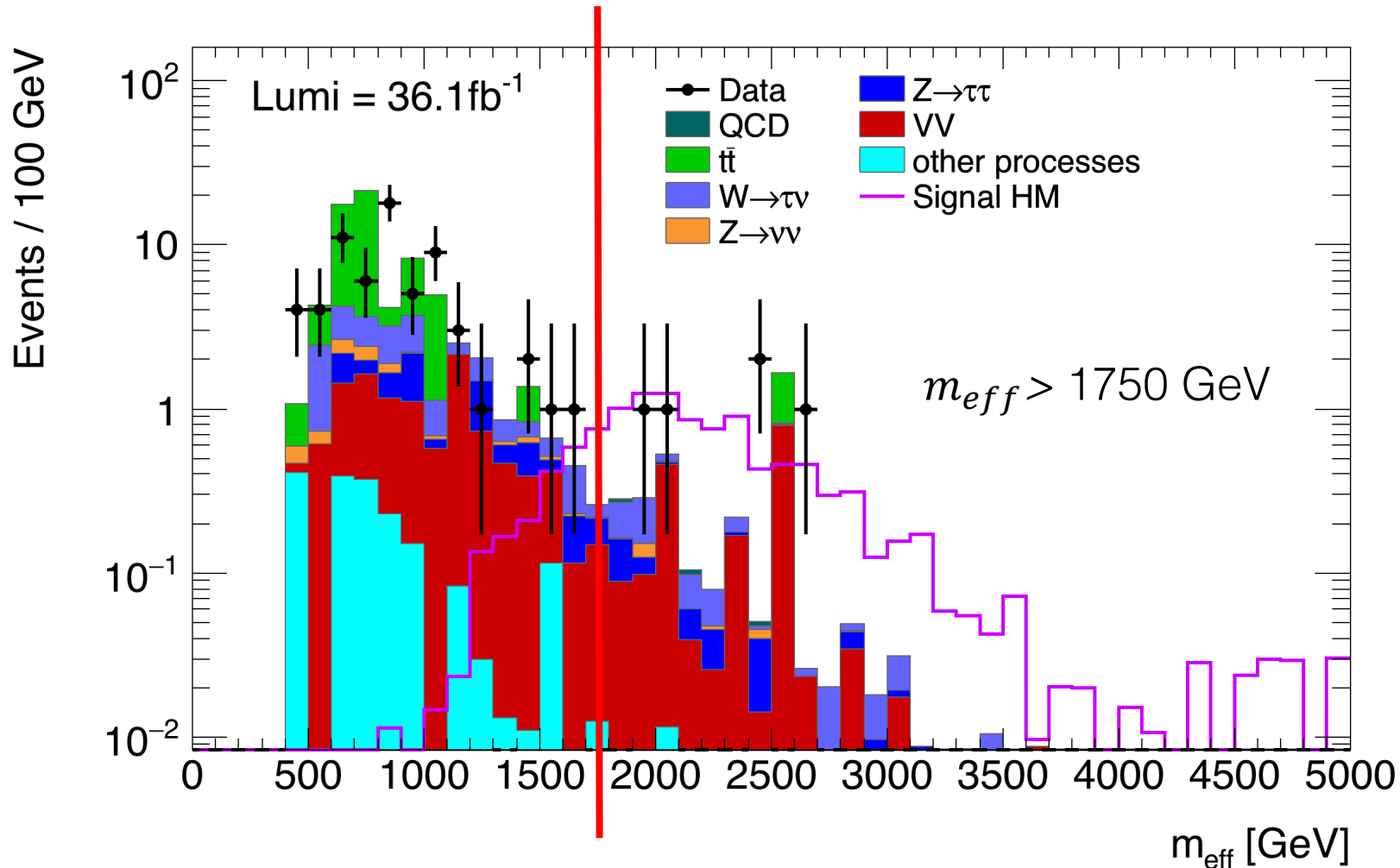
HM Cut 2: m_{eff}/H_T

- Greater significance



Data Comparison

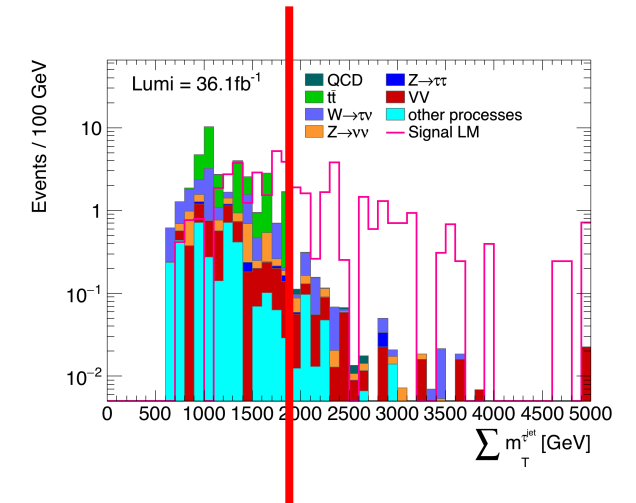
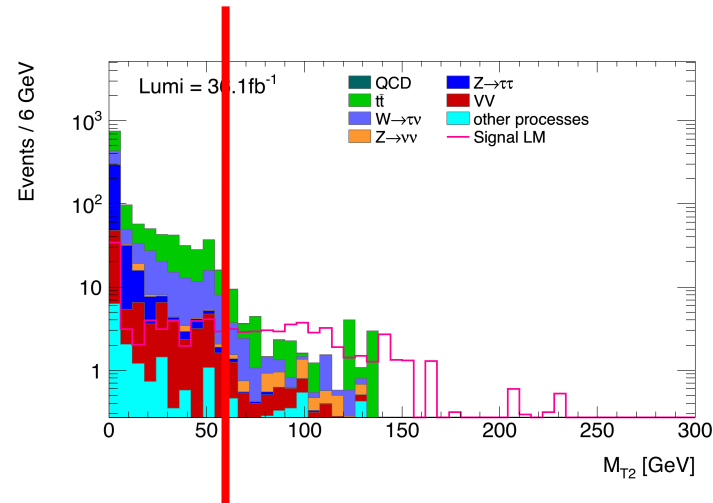
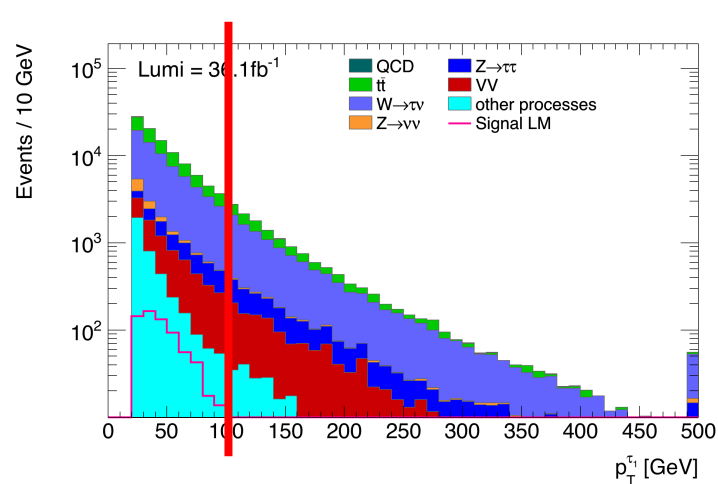
Effective mass $m_{eff} = H_T + E_T^{miss}$



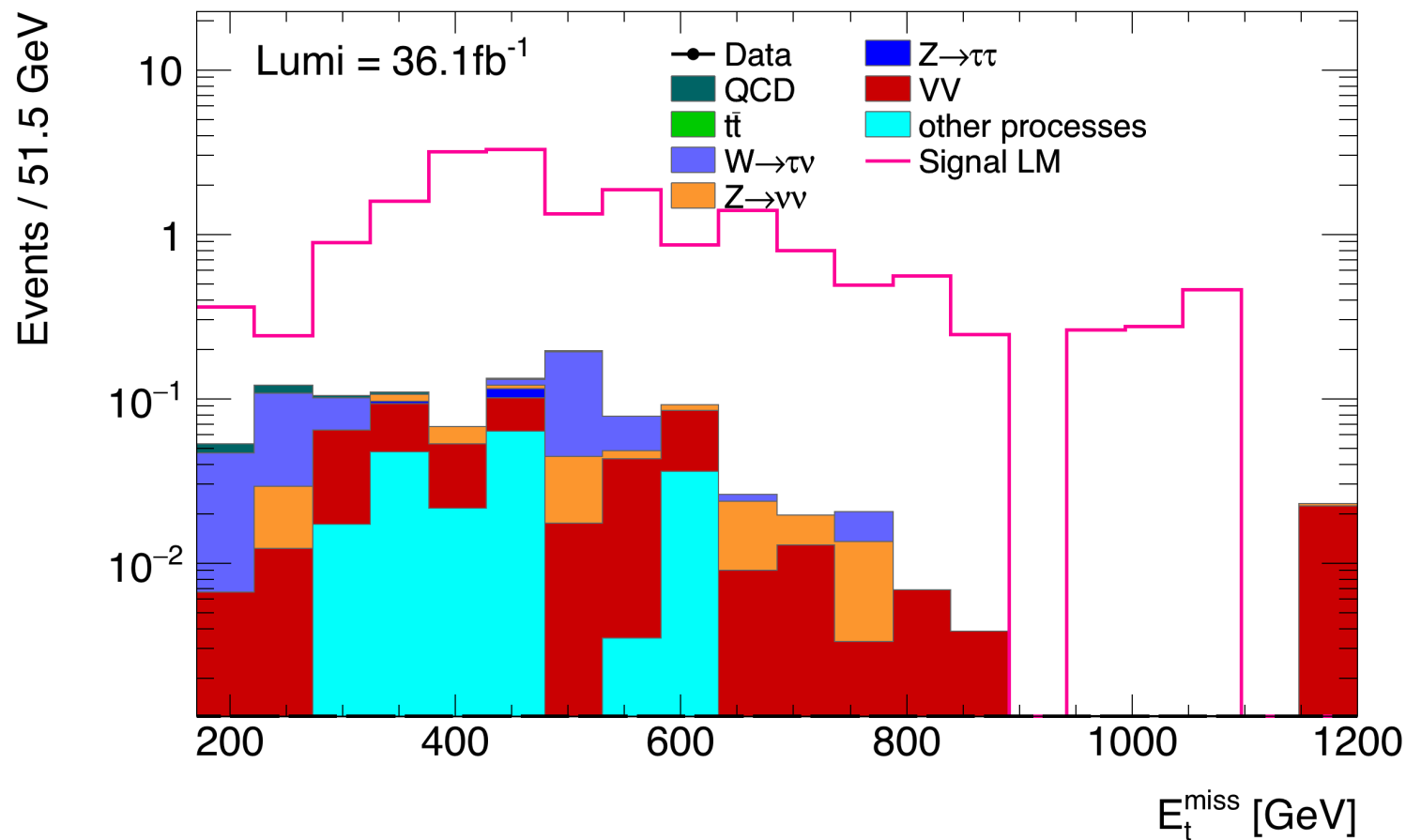
	Count Number
Signal	9.29
Background	3.53 ± 1.88
Data	5

Compressed Signal Region Cuts

Variable Name		Cut
Transverse Momentum of leading tau	p_T^τ	$> 60 \text{ GeV}$
Stransverse Mass	M_{T2}	$> 60 \text{ GeV}$
Sum of the transverse masses of taus and jets	$\sum m_T^{\tau+jets}$	$> 1900 \text{ GeV}$



Data Comparison: Low Δm Signal Region



	Count Number
Signal	18.56
Background	1.05 ± 1.02
Data	0

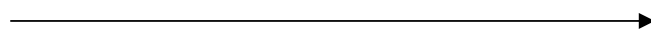
Summary, Conclusion and Outlook

- Search for Dark Matter
- Supersymmetry → Possible Model
- Signal Regions for 2 different mass scenarios
- No results beyond expected SM Background



No Dark Matter found

...Yet



- Exactly 1 Tau
- Other possible decay chains
- Electroweak SUSY production
- More Lumi → Higher mass scenarios

Thank you!

*Special thanks to the organizers of Netzwerk Teilchenwelt,
Philipp König
and all others at Bonn University*

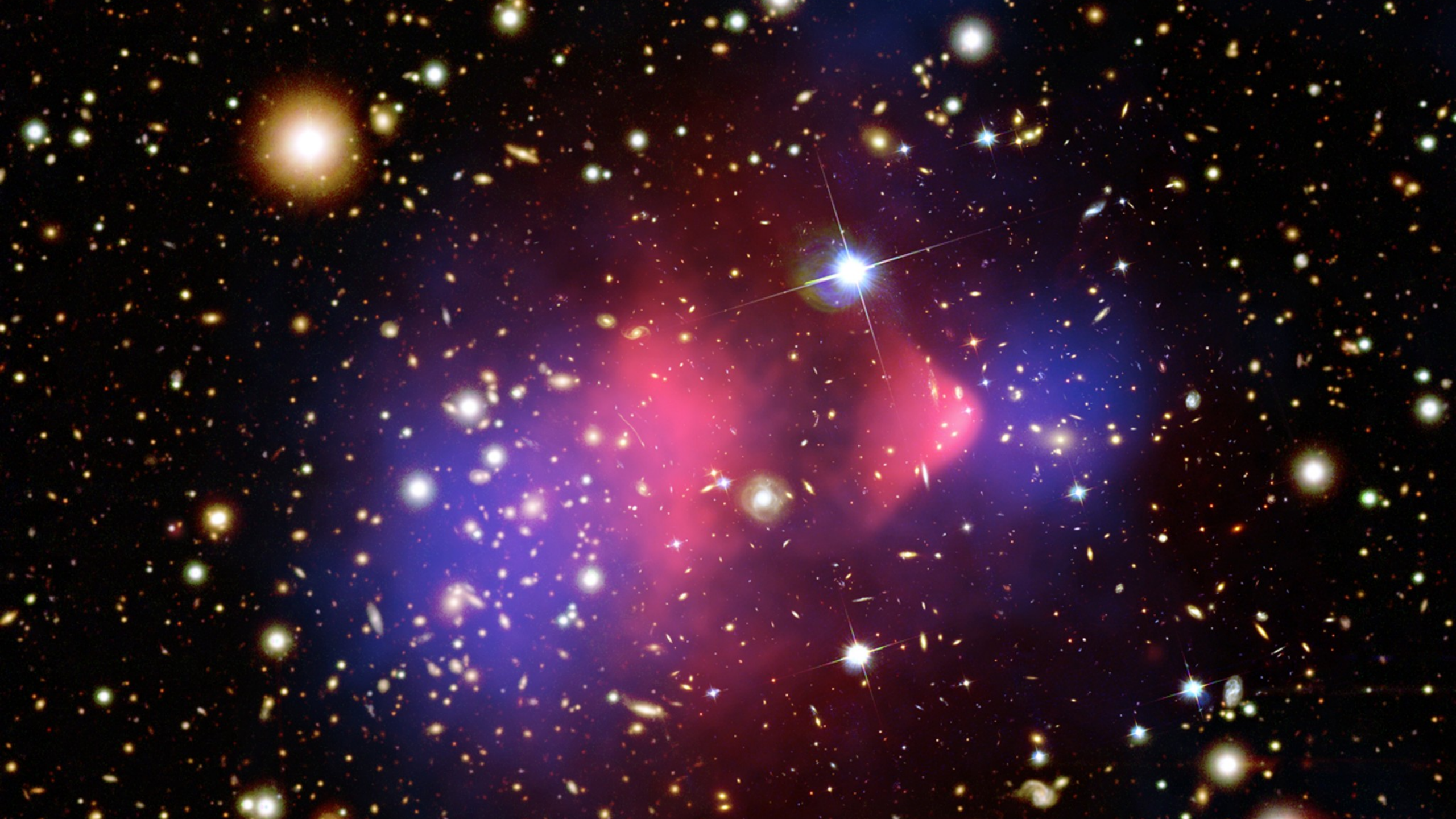
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König, Philipp. “Simplified Models with High Dimensionality in the Search for Supersymmetry at the ATLAS Experiment.” Experimentelle Teilchen Physik , Rheinische Friedrich-Wilhelms-Universität Bonn, Rheinische Friedrich-Wilhelms-Universität Bonn, Sept. 2016, www.lhc-ilc.physik.uni-bonn.de/ergebnisse/dateien/t00000079.pdf?c=t&id=79.

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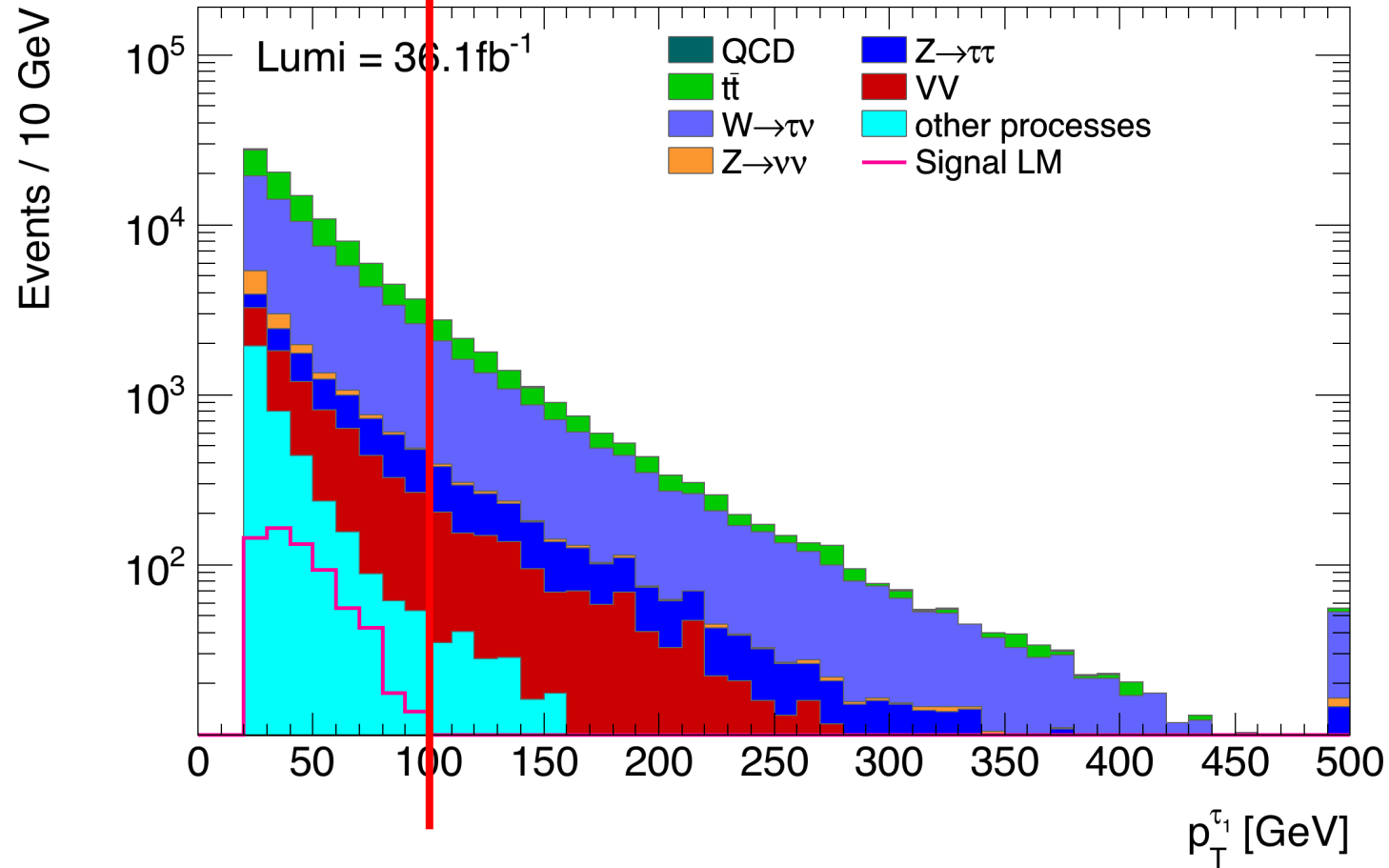
Schaepe, Steffen. “Search for Supersymmetry in Tau Lepton Final States with the ATLAS Detector.” Uni Bibliotek Bonn, Rheinische Friedrich-Wilhelms-Universität Bonn, Rheinische Friedrich-Wilhelms-Universität Bonn, June 2015, hss.ulb.uni-bonn.de/2016/4238/4238.pdf.



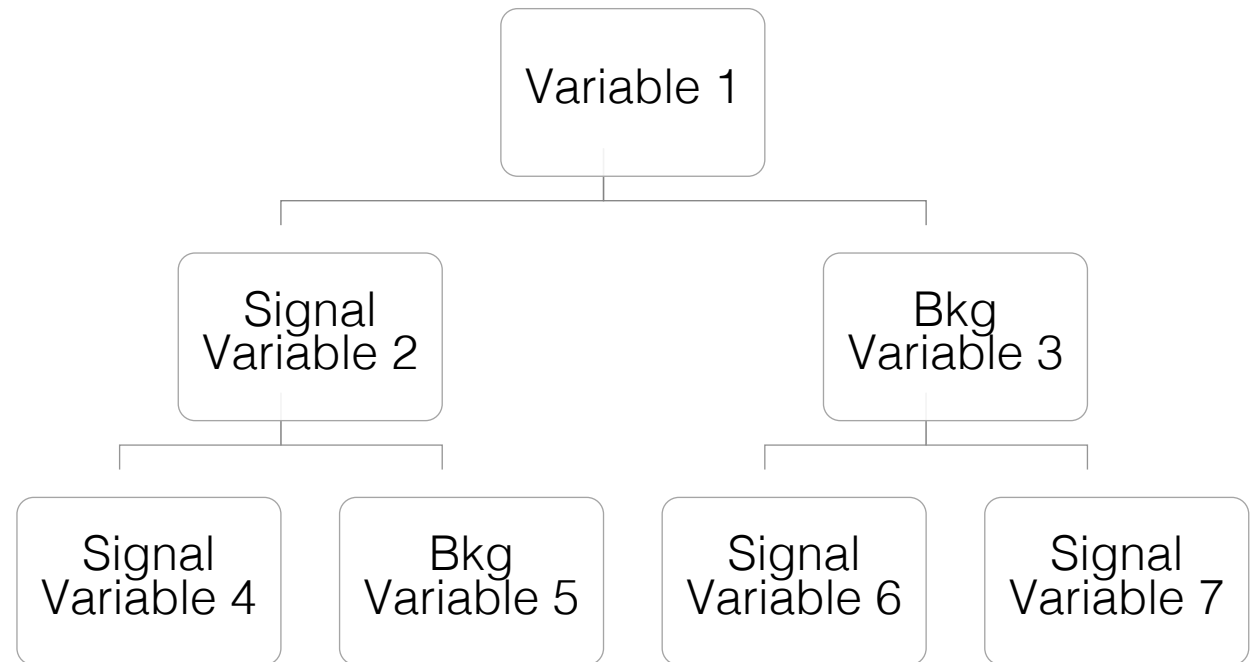
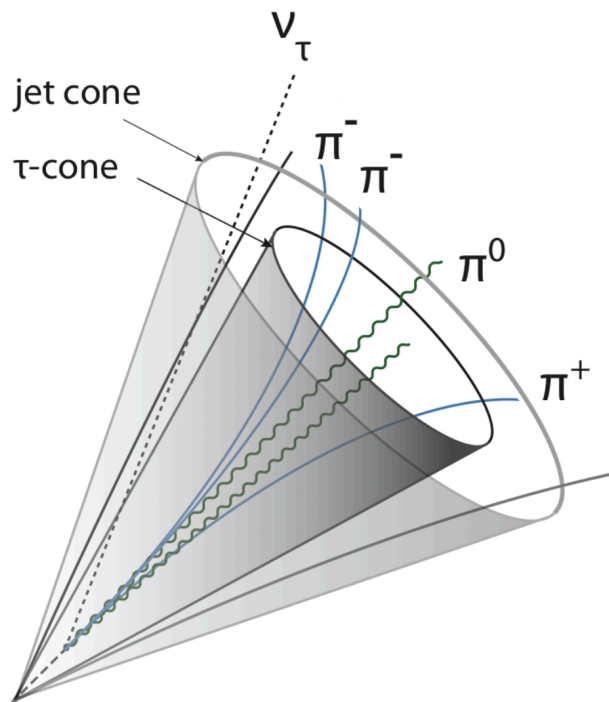
Important Kinematic Variables

- Transverse momentum p_T
- Magnitude of missing transverse momentum E_T^{miss}
- Transverse mass $m_T^\tau = \sqrt{2p_T^\tau E_T^{miss} (1 - \cos(\Delta\phi(\tau, p_T^{miss})))}$
- Sum of transverse masses $m_T^{sum} = m_T^{\tau 1} + m_T^{\tau 2}$
- Scalar sum of transverse momenta $H_T = \sum_{all \tau} p_T^\tau + \sum_{i=1,2} p_T^{jet}$
- Effective mass $M_{eff} = H_T + E_T^{miss}$

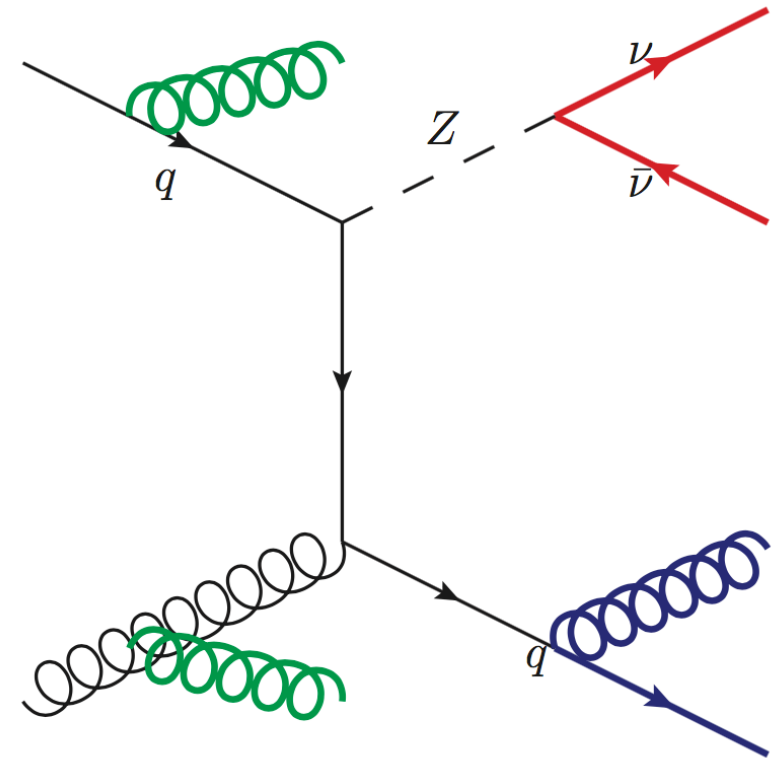
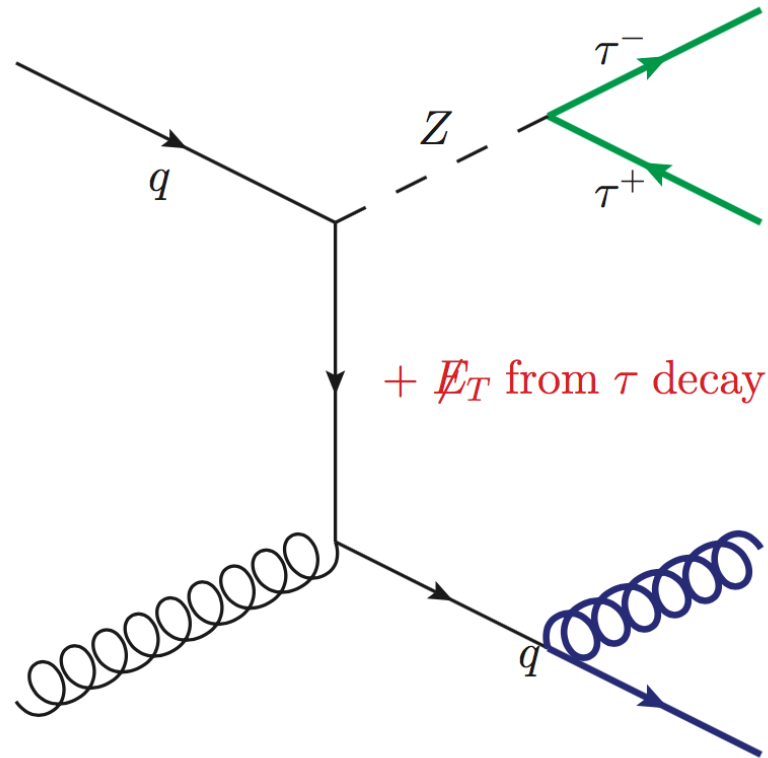
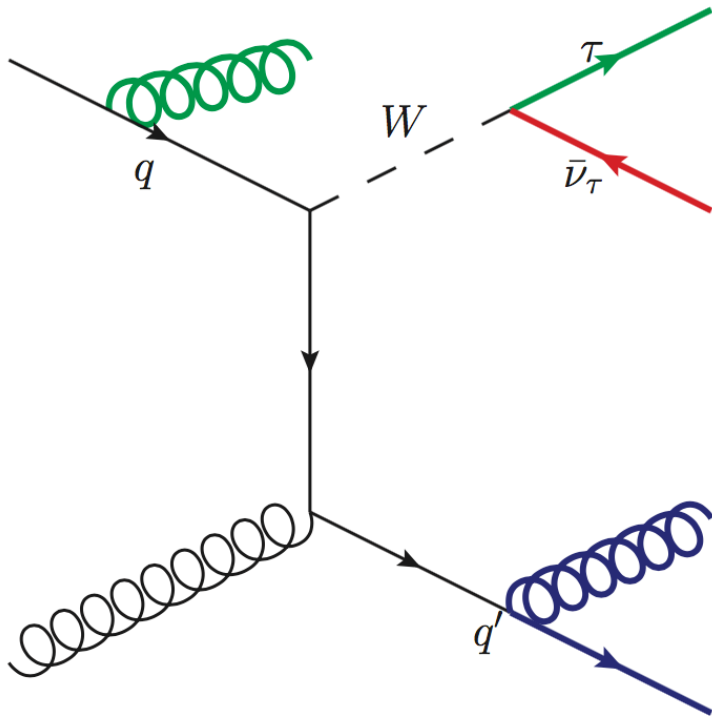
LM Cut 1: $p_T^{\tau_1}$



- $p_T^{\tau_1} < 100$

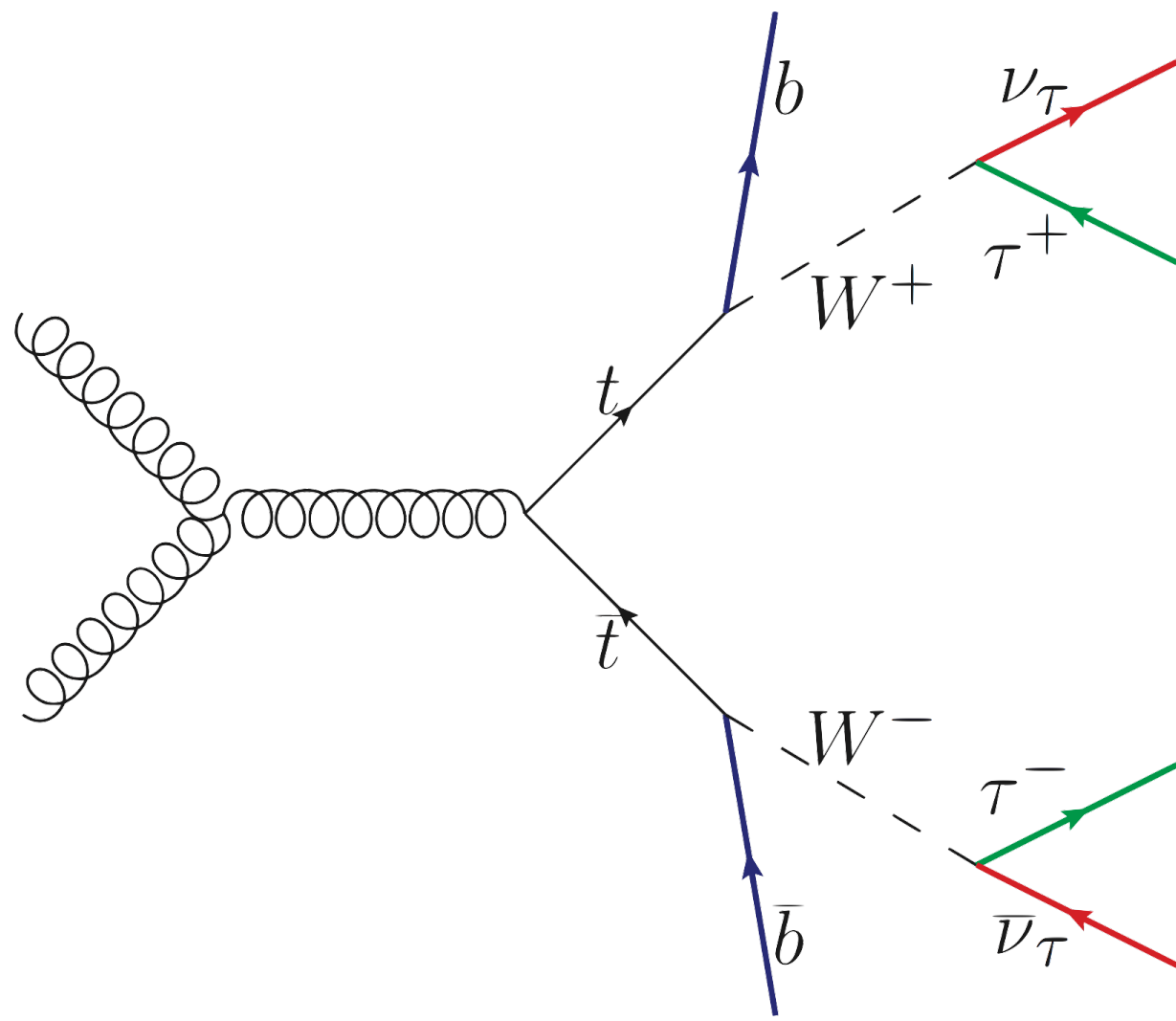


W Boson and Z Boson



Taus, Jets, Missing Energy

$t\bar{t}$

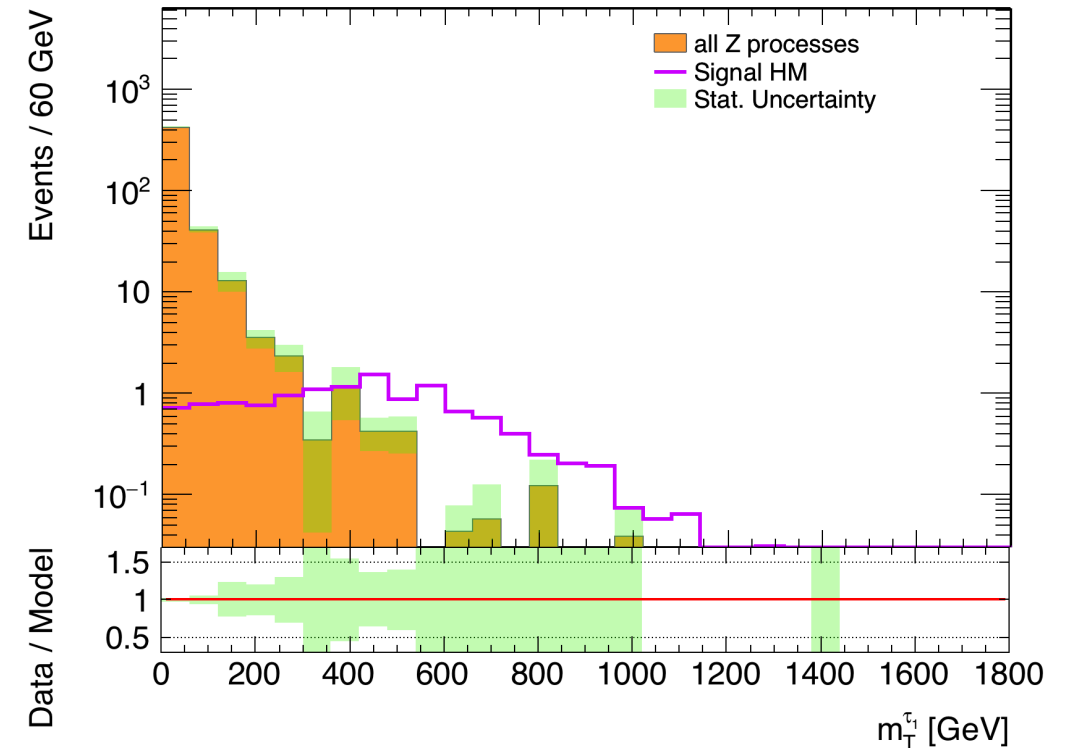
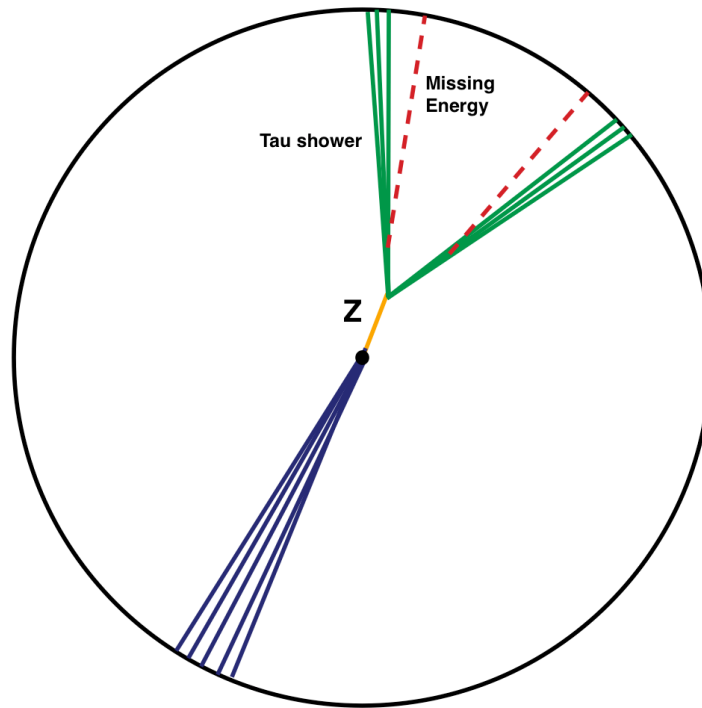


Taus
Jets
Missing
Energy

HM Cut 1: Transverse mass

$$\text{Transverse mass } m_T^\tau = \sqrt{2p_T^\tau E_T^{\text{miss}} (1 - \cos(\Delta\phi(\tau, p_T^{\text{miss}})))}$$

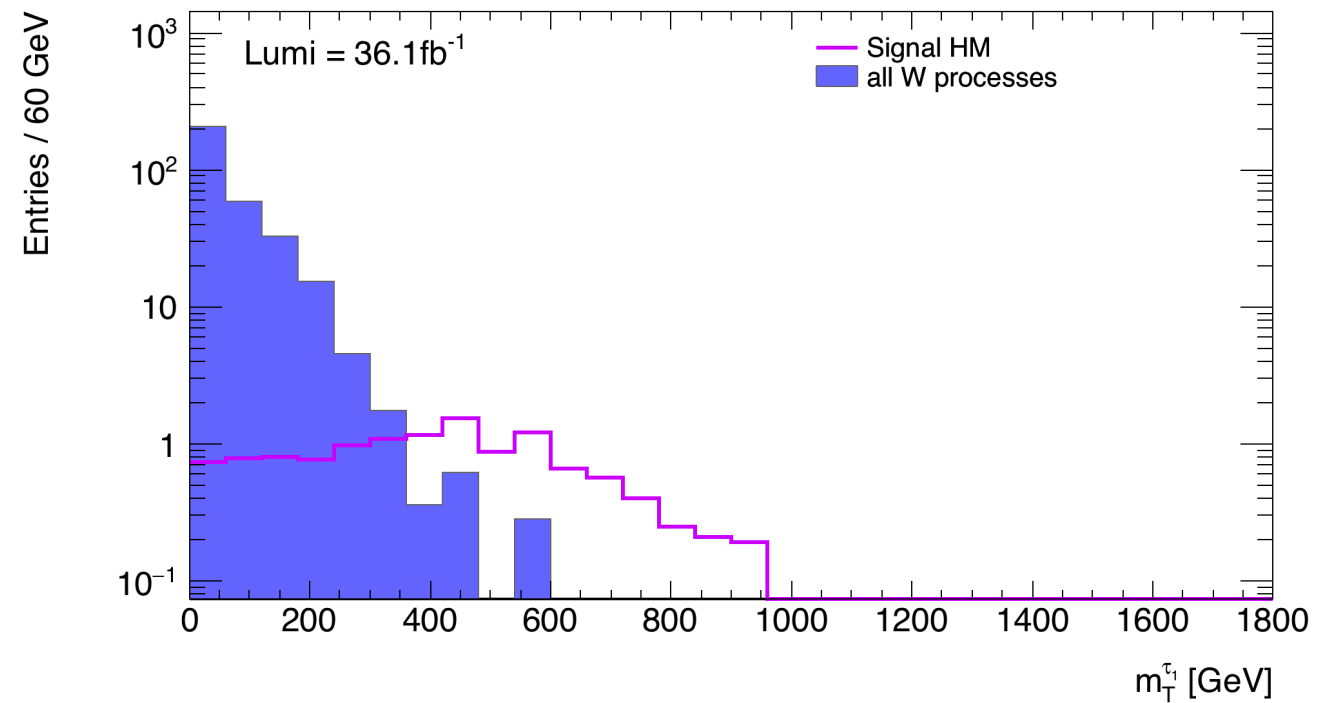
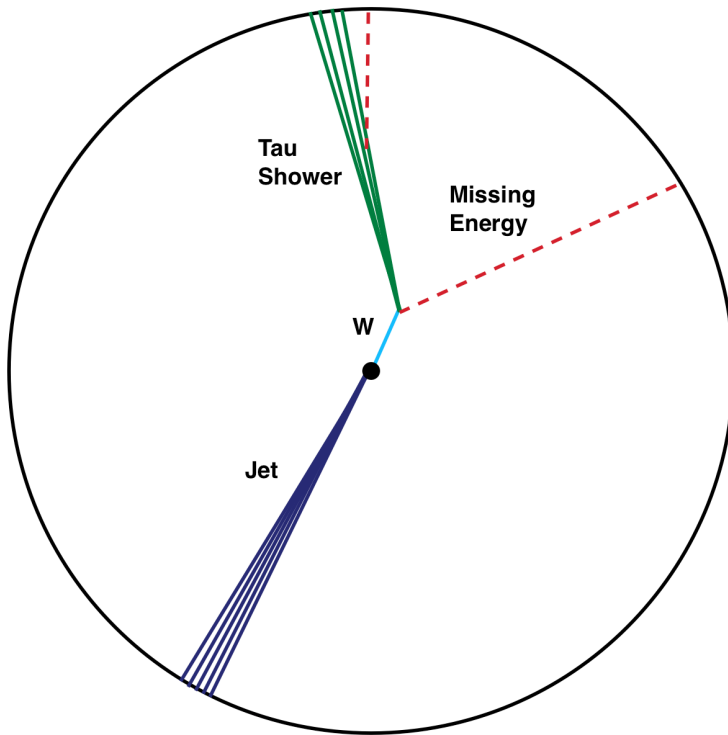
$$Z \rightarrow \tau^+ + \tau^-$$



HM Cut 1: Transverse mass

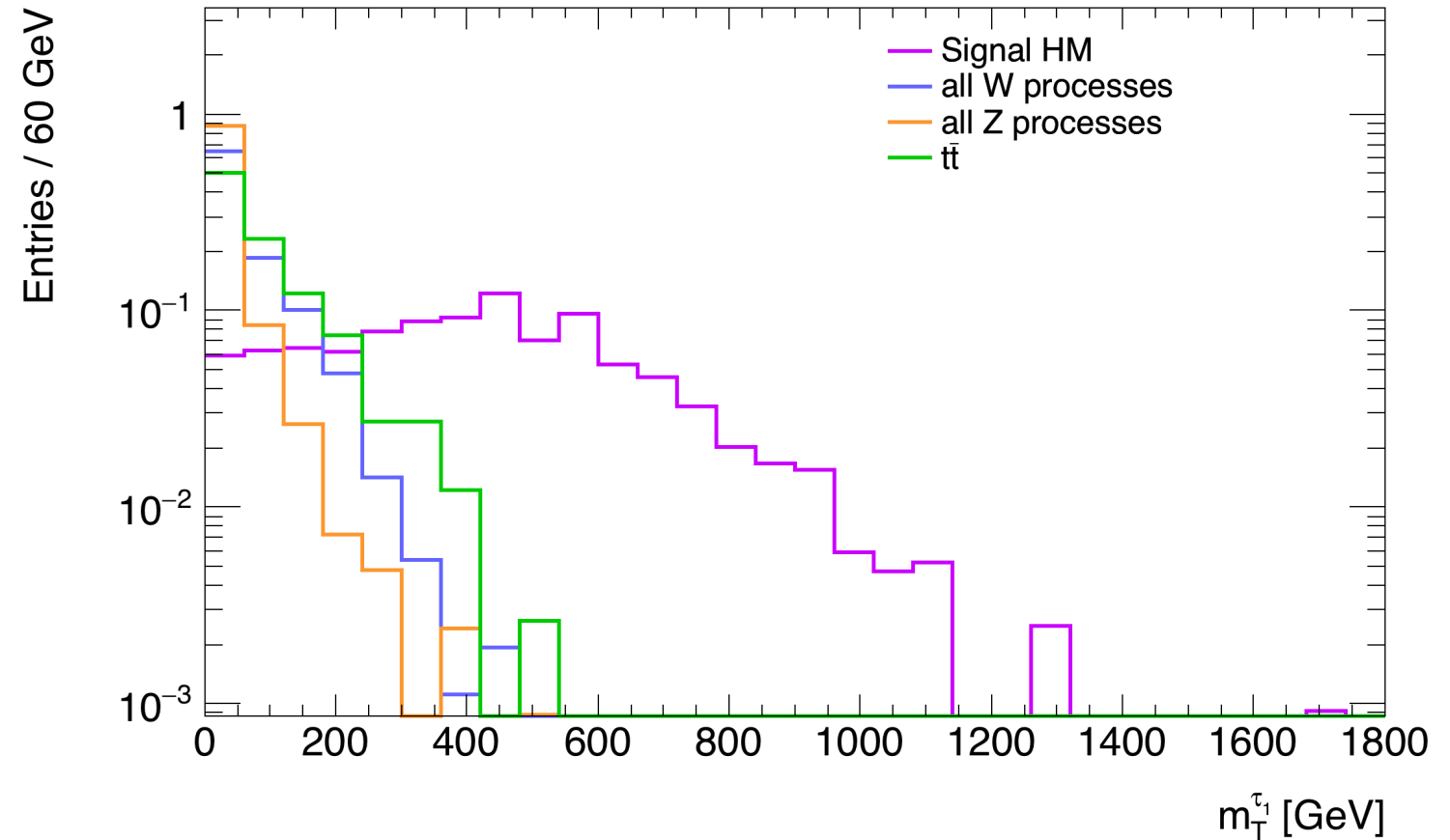
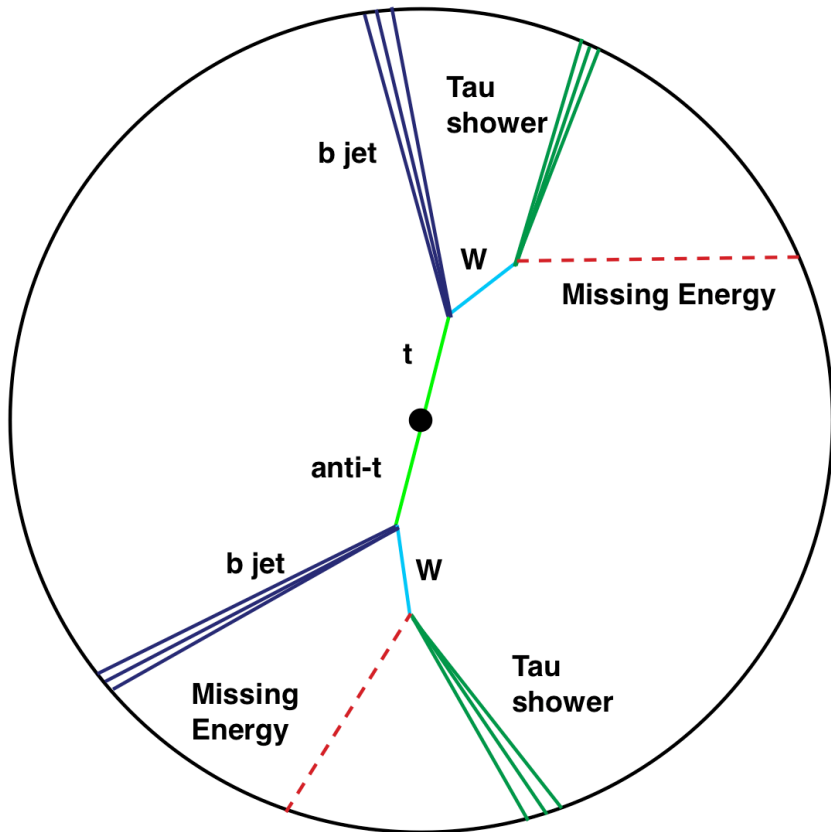
Transverse mass $m_T^\tau = \sqrt{2p_T^\tau E_T^{miss} (1 - \cos(\Delta\phi(\tau, p_T^{miss})))}$

$W \rightarrow \tau + \bar{\nu}$

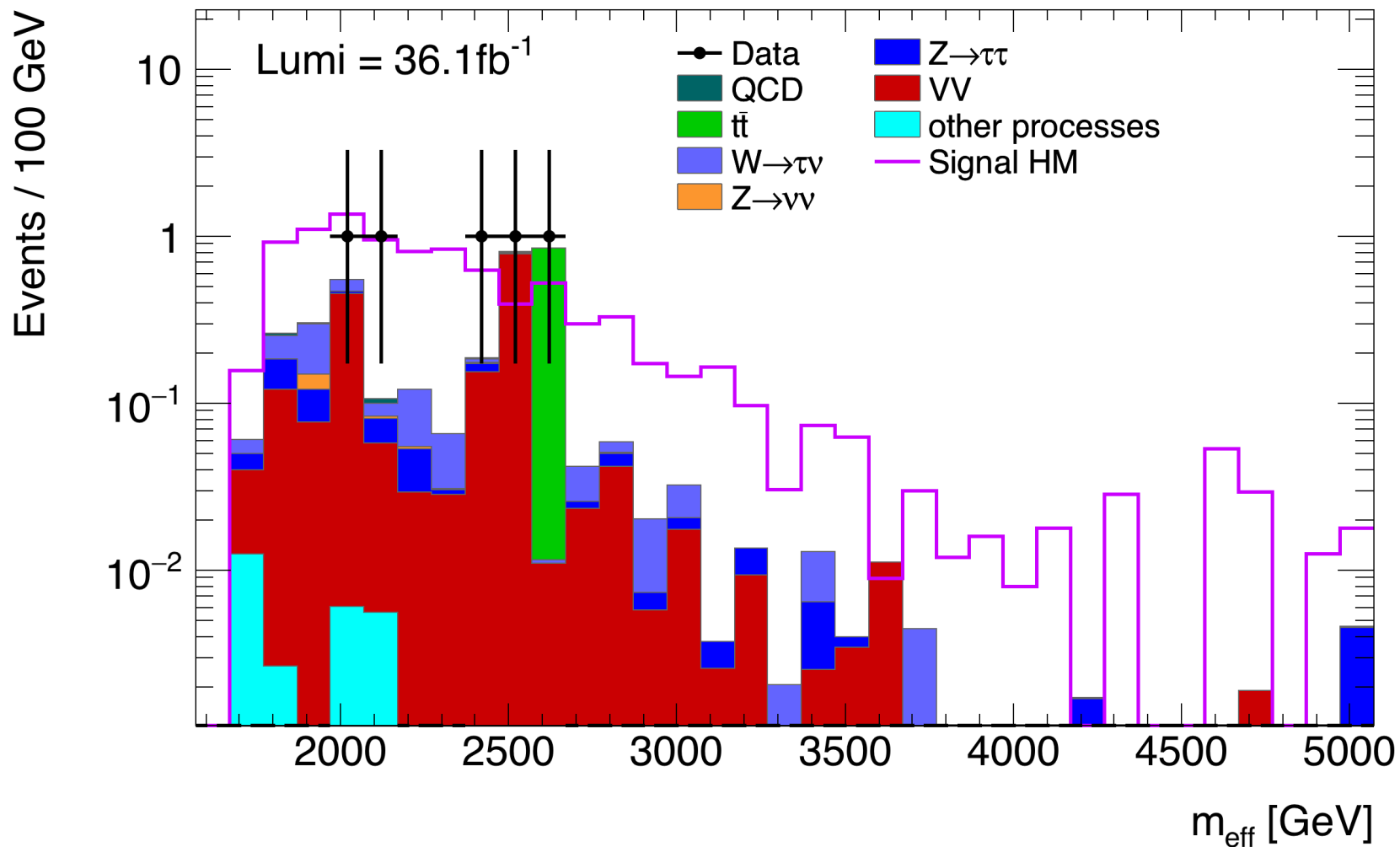


HM Cut 1: Transverse mass

$$t \rightarrow b + W^+$$

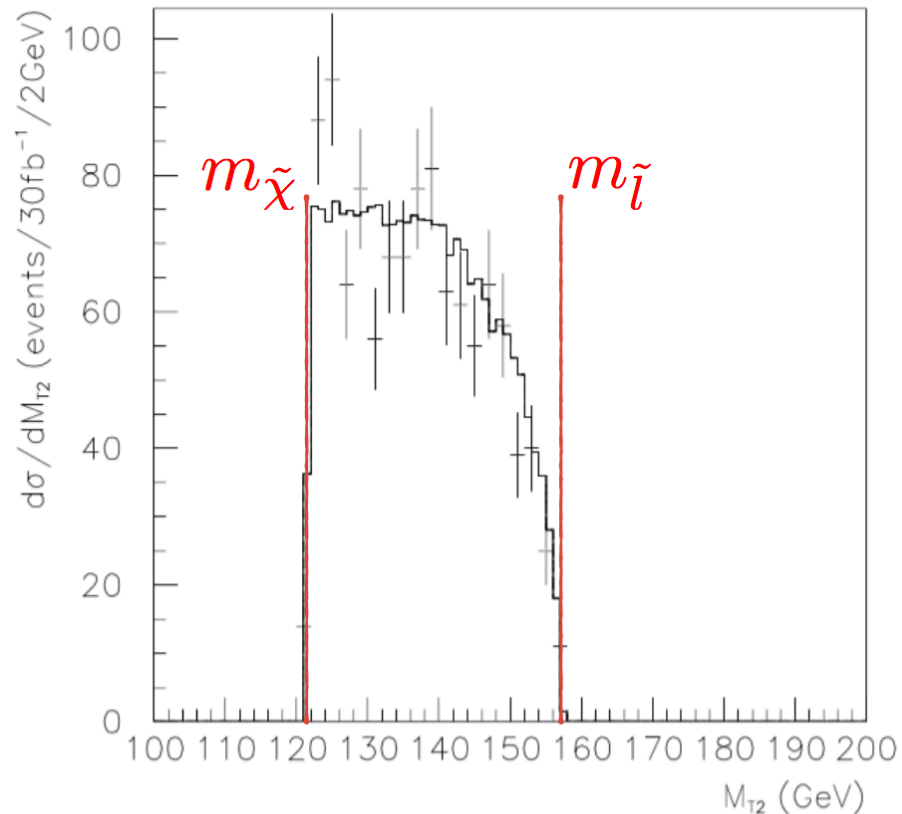


Data Comparison: High Δm Signal Region



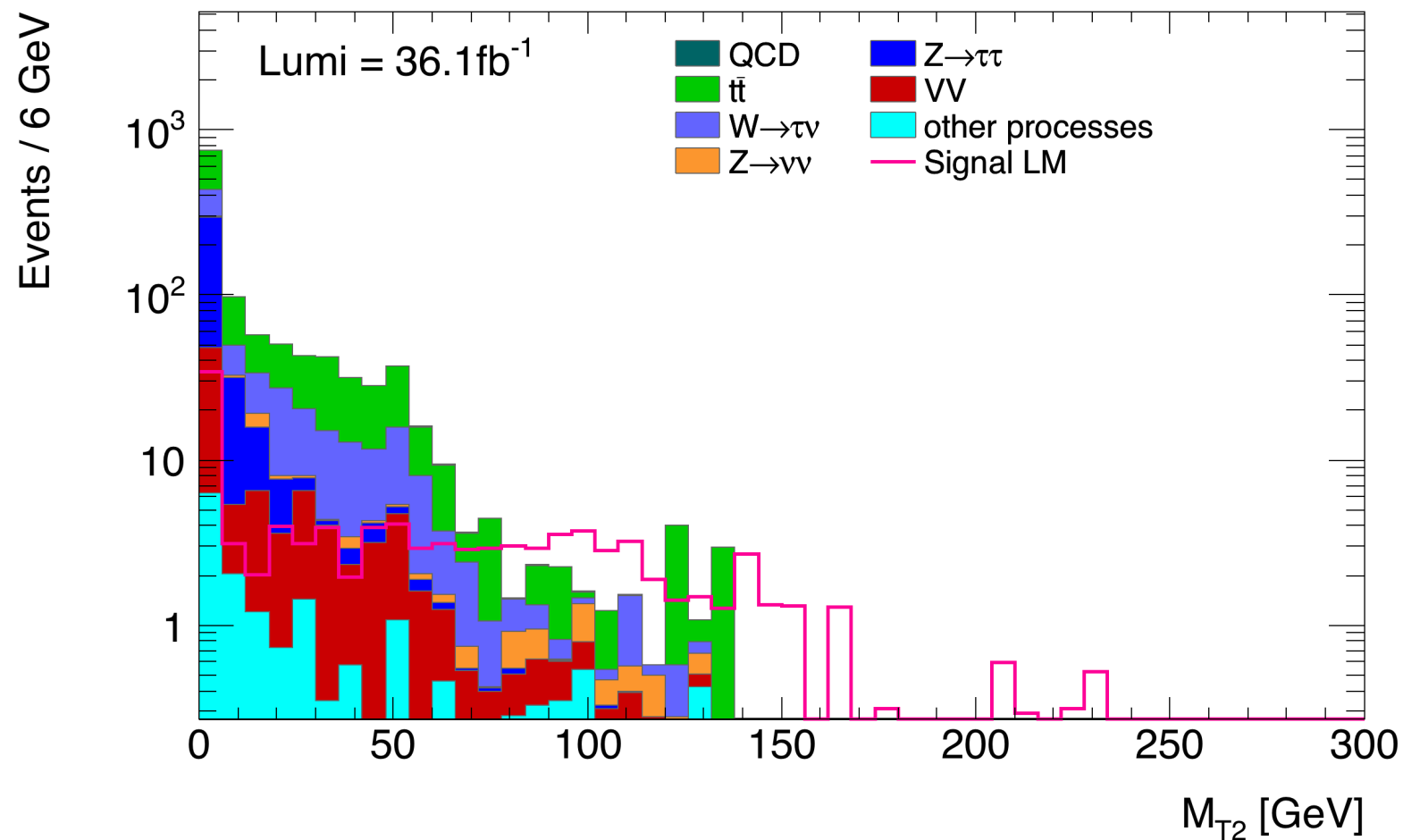
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Stransverse Mass

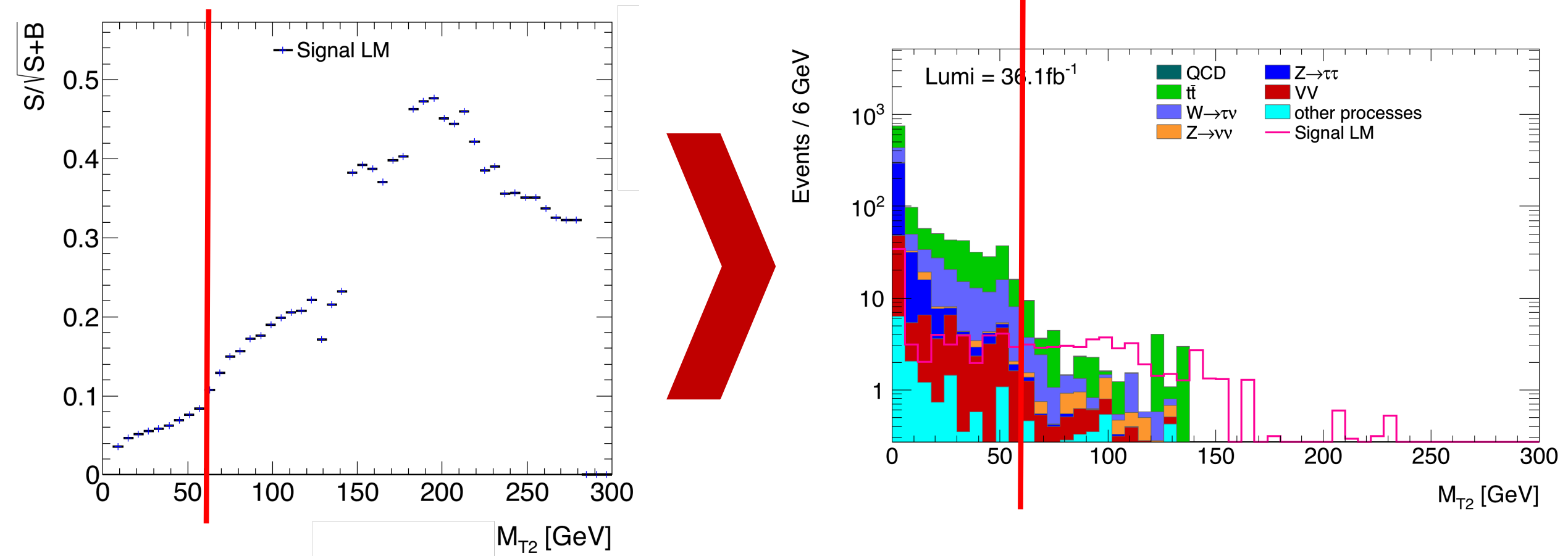


- momenta of two visible particles, missing transverse momentum
- Bound for the masses of an unseen **pair** of particles

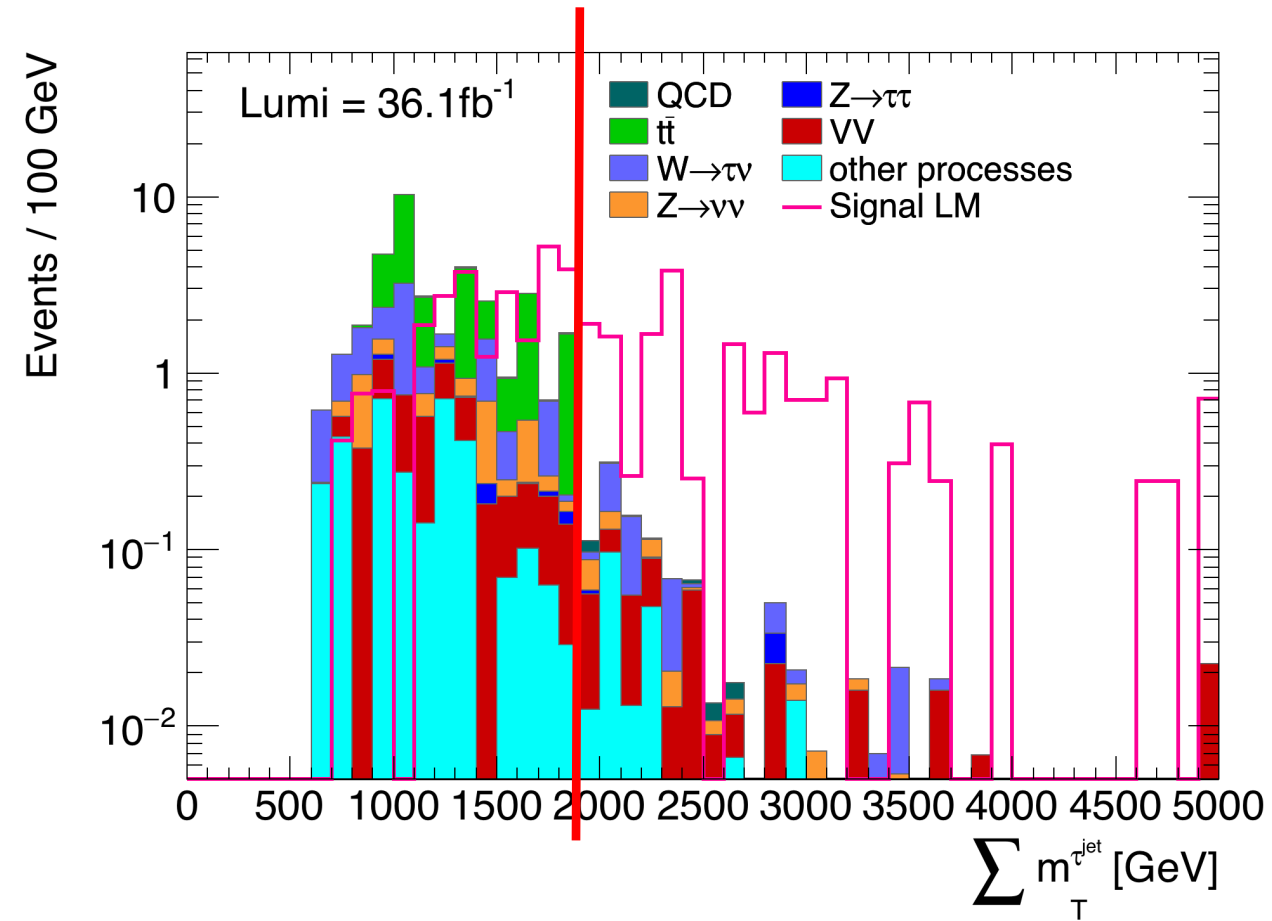
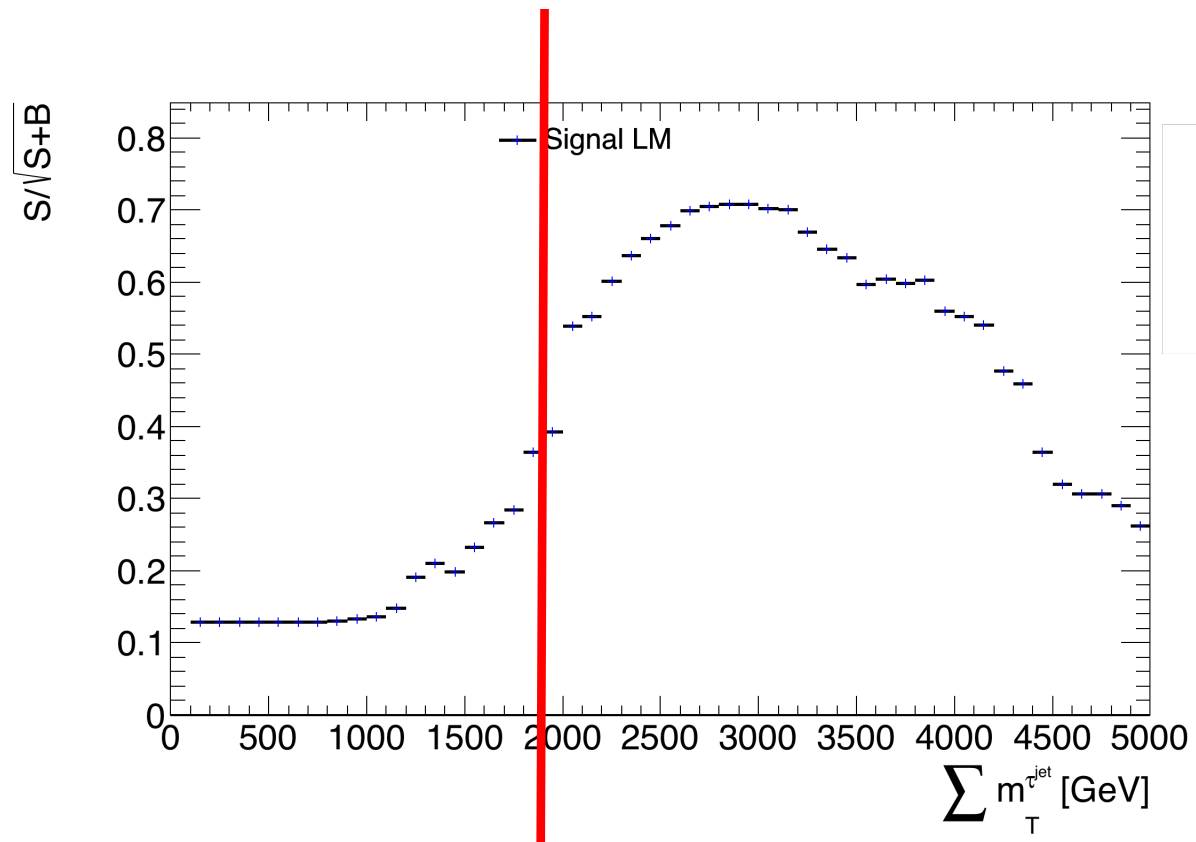
LM Cut 2: Stransverse mass M_{T2}



LM Cut 2: Stransverse mass M_{T2}



LM Cut 3: $\sum m_T^{\tau^{jet}}$



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