

Precise SM measurements as BSM probes: a new purpose for the W mass measurement

Lorenzo Ricci

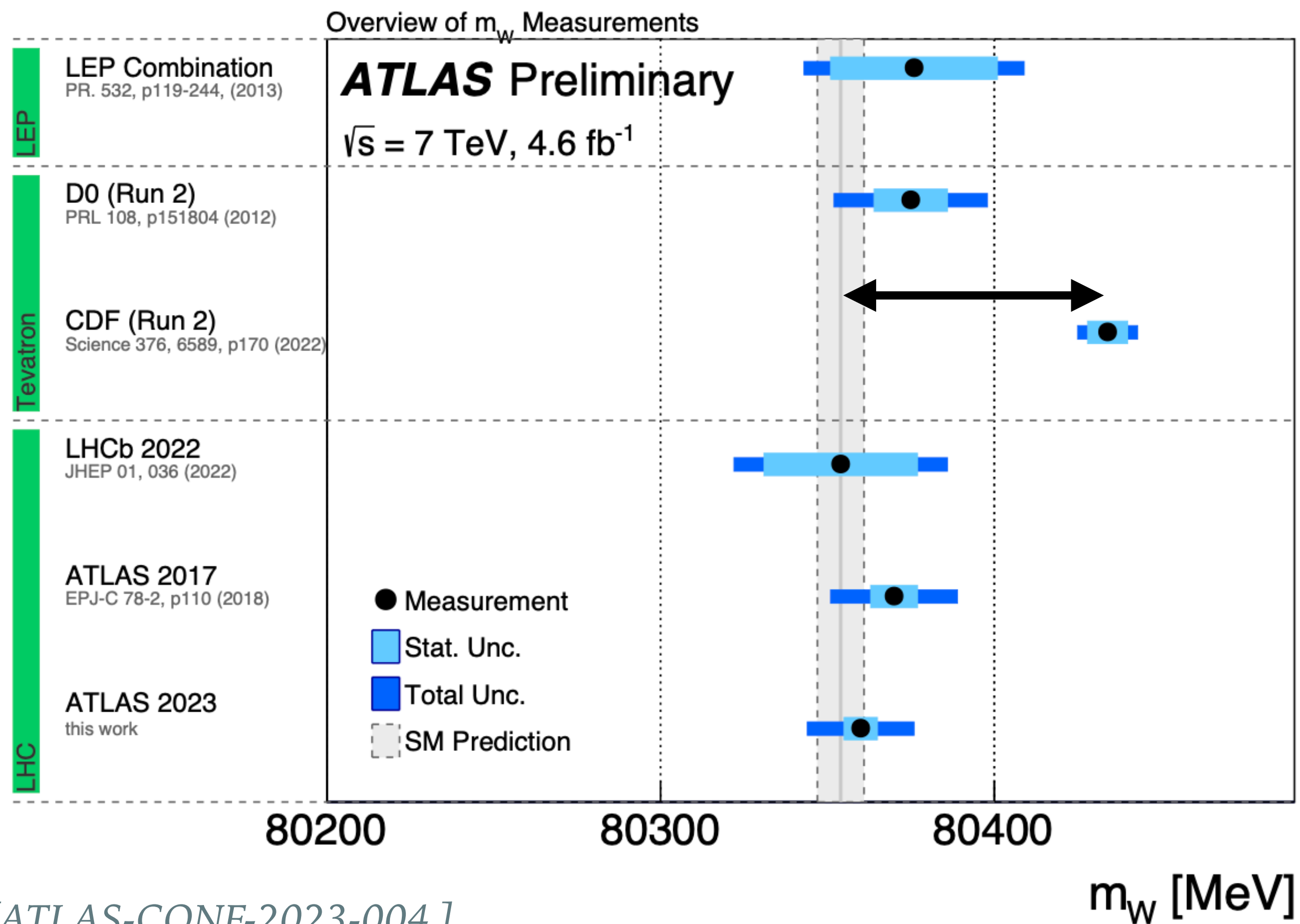


Wednesday 17th May

Mitchell 2023

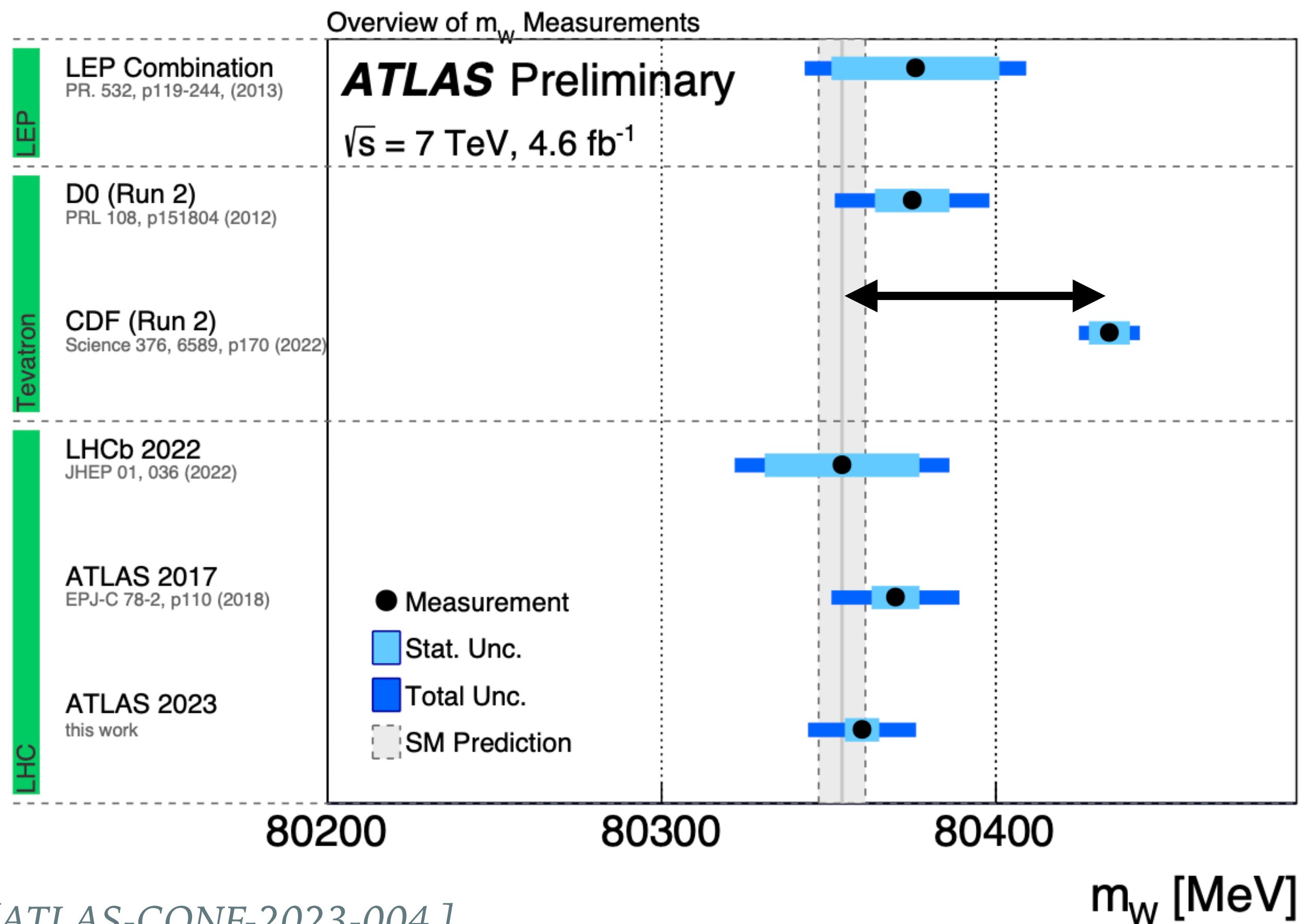
Based on [K. Agashe, S. Airen, R. Franceschini, D. Kim, LR, D. Sathyan (in preparation)]

BSM & W-mass anomaly



$$m_W^{SM}(G_F, m_Z, \alpha_{em}, \dots) \neq m_W^{meas}$$

BSM & W-mass anomaly

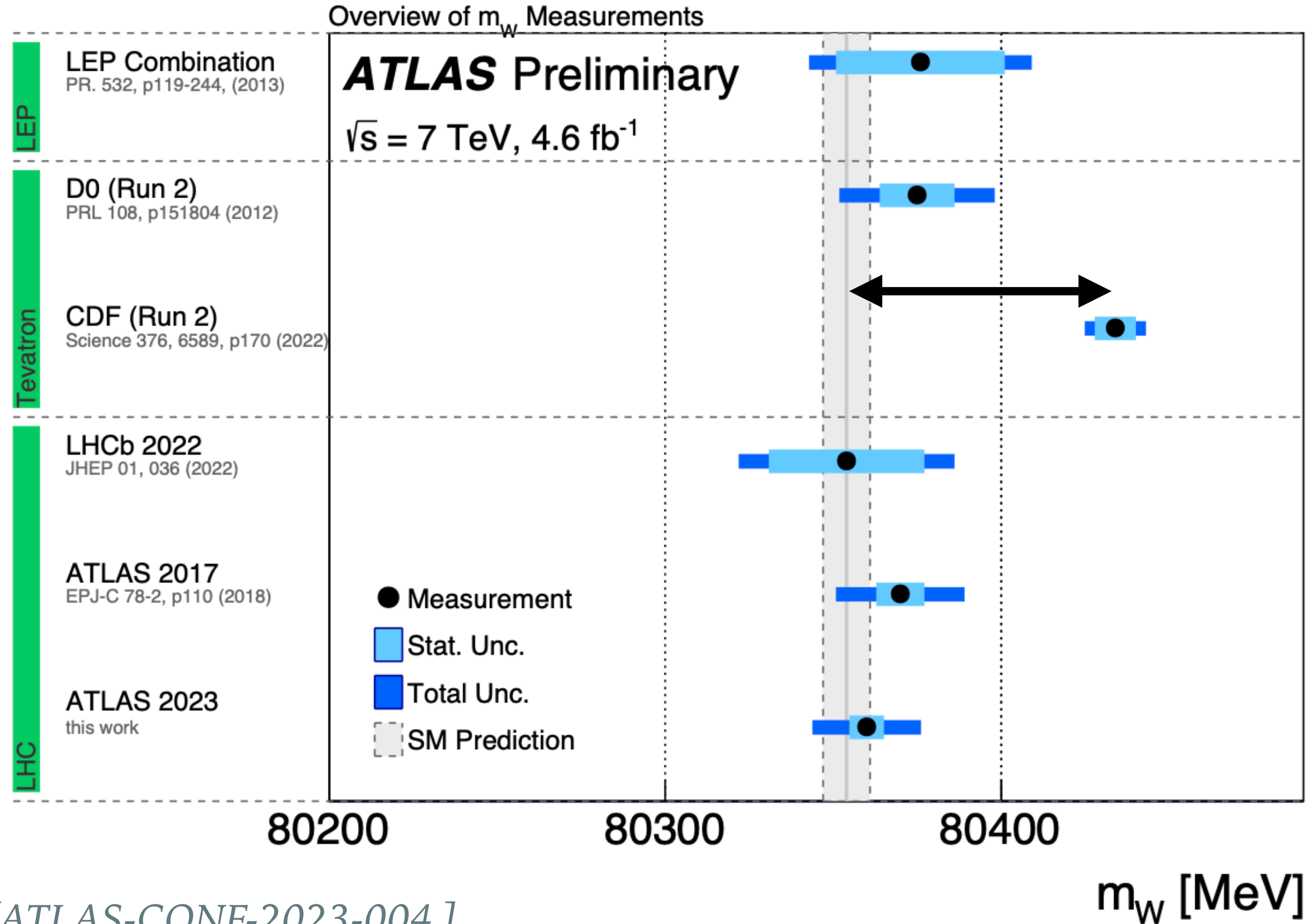


Can BSM explain the W mass anomaly?

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BSM & W-mass anomaly



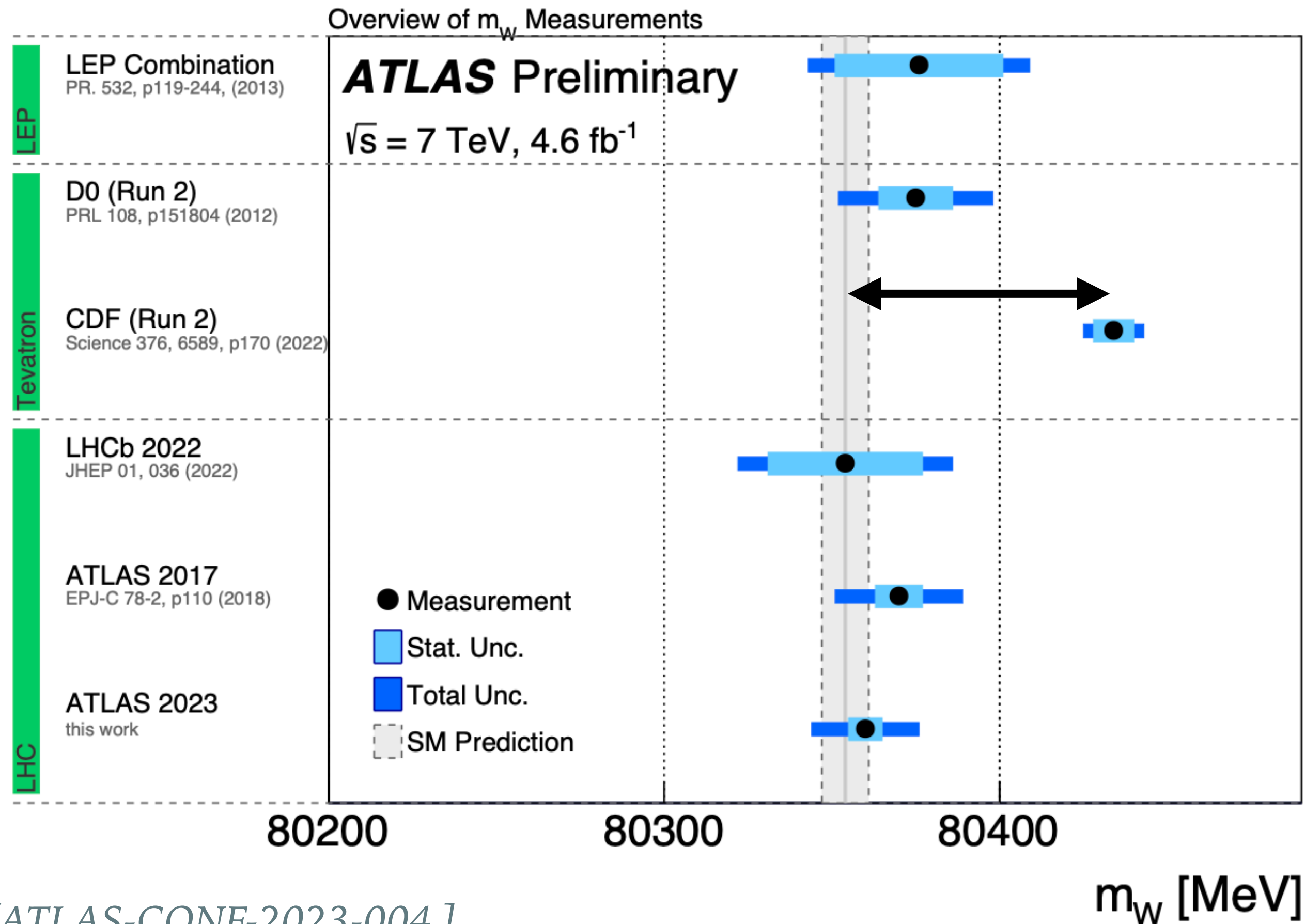
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[2204.04191, 2204.04514, 2204.04834, 2204.05285, 2204.05283, 2204.05085, 2204.05302, 2204.05260, 2204.05284, 2204.05296, 2204.05267, 2204.06327, 2204.05975, 2204.05992, 2204.05942, 2204.05760, 2204.05965, 2204.05728, 2204.06485, ...]

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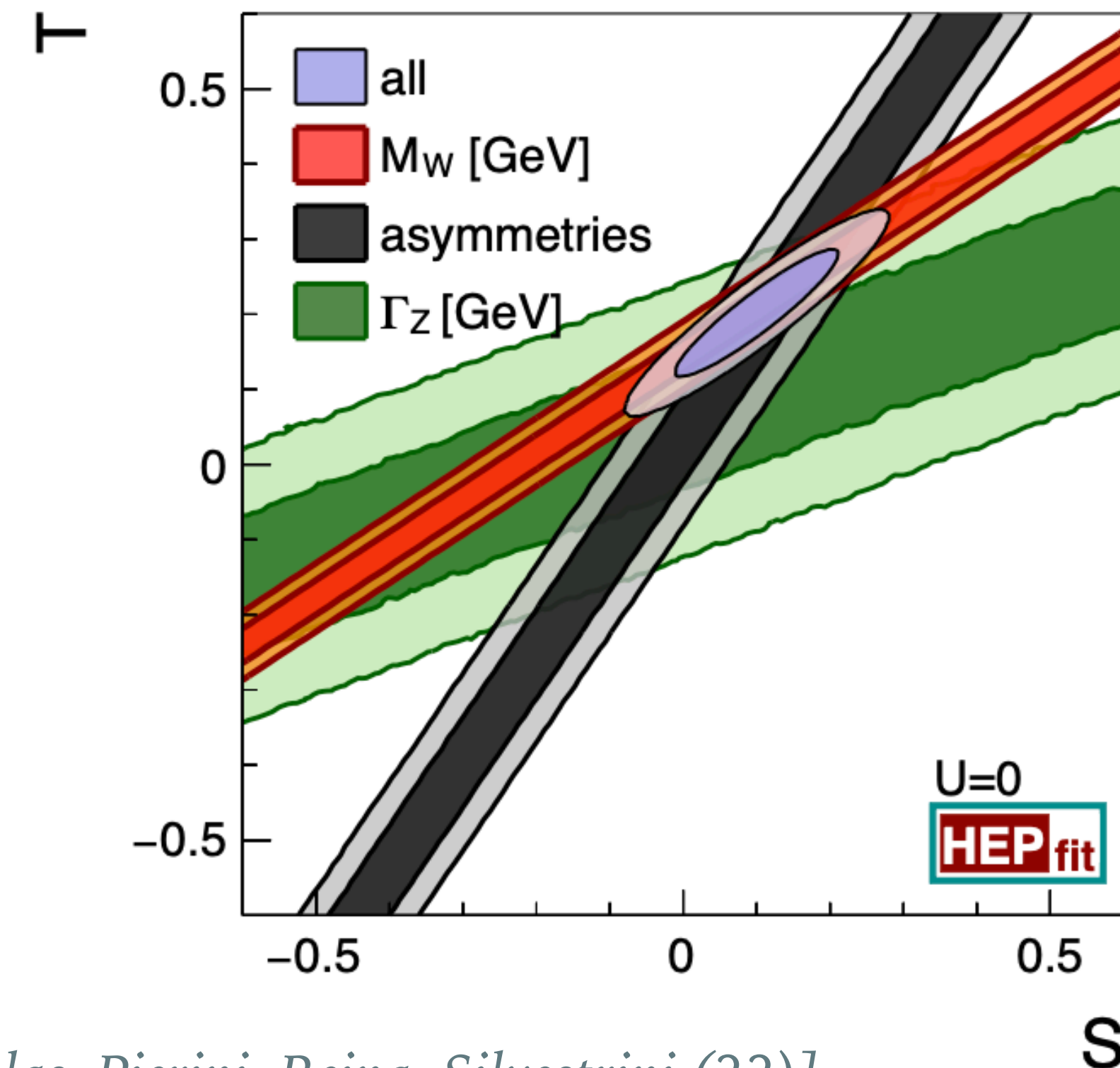
BSM & W-mass anomaly



Can BSM explain the W mass anomaly?

$$m_W^{BSM}(G_F, m_Z, \alpha_{em}, S, T, \dots) = m_W^{meas}$$

“EWFIT”

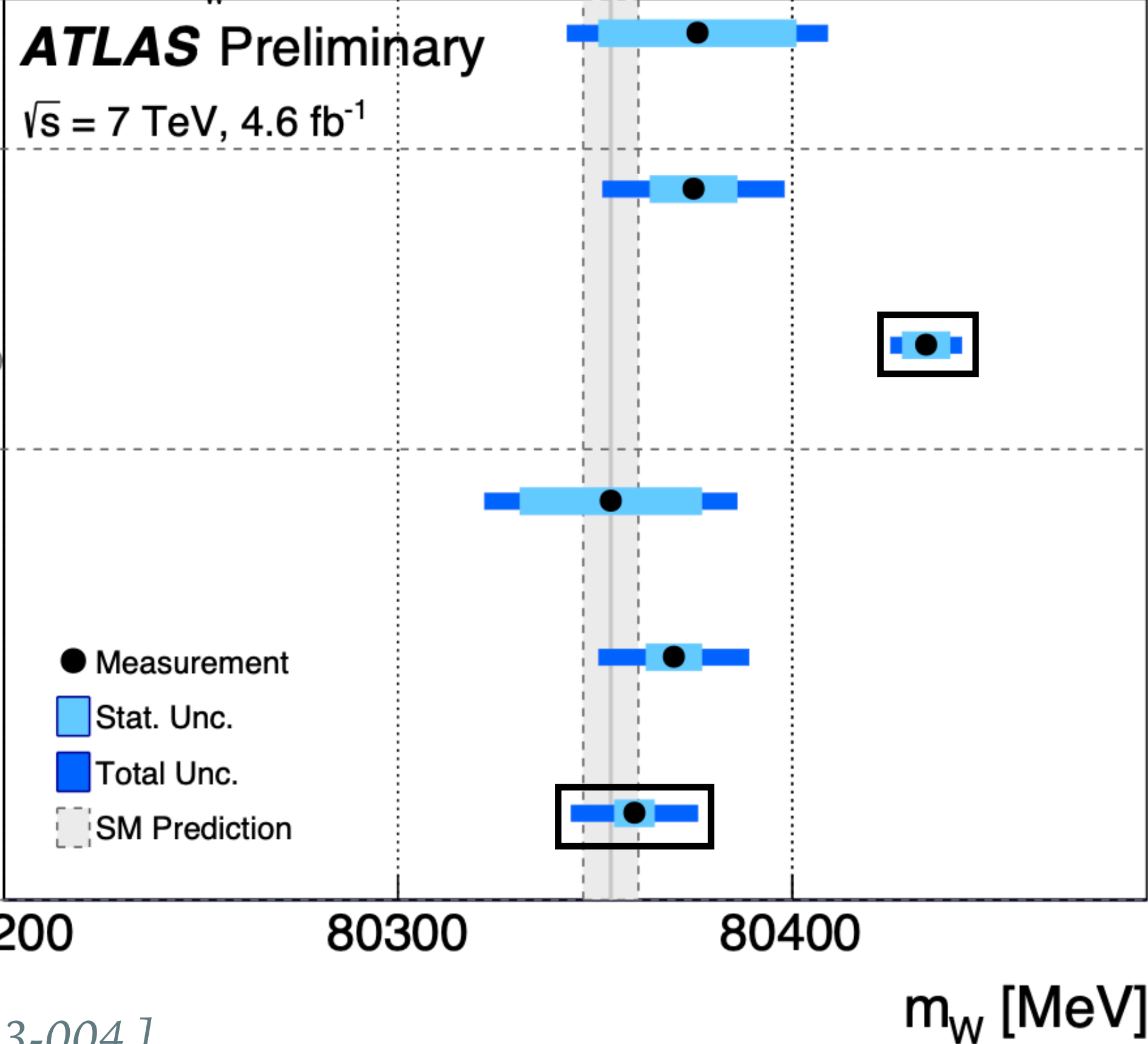


$$m_W^{SM}(G_F, m_Z, \alpha_{em}, \dots) \neq m_W^{meas}$$

[de Blas, Pierini, Reina, Silvestrini (22)]

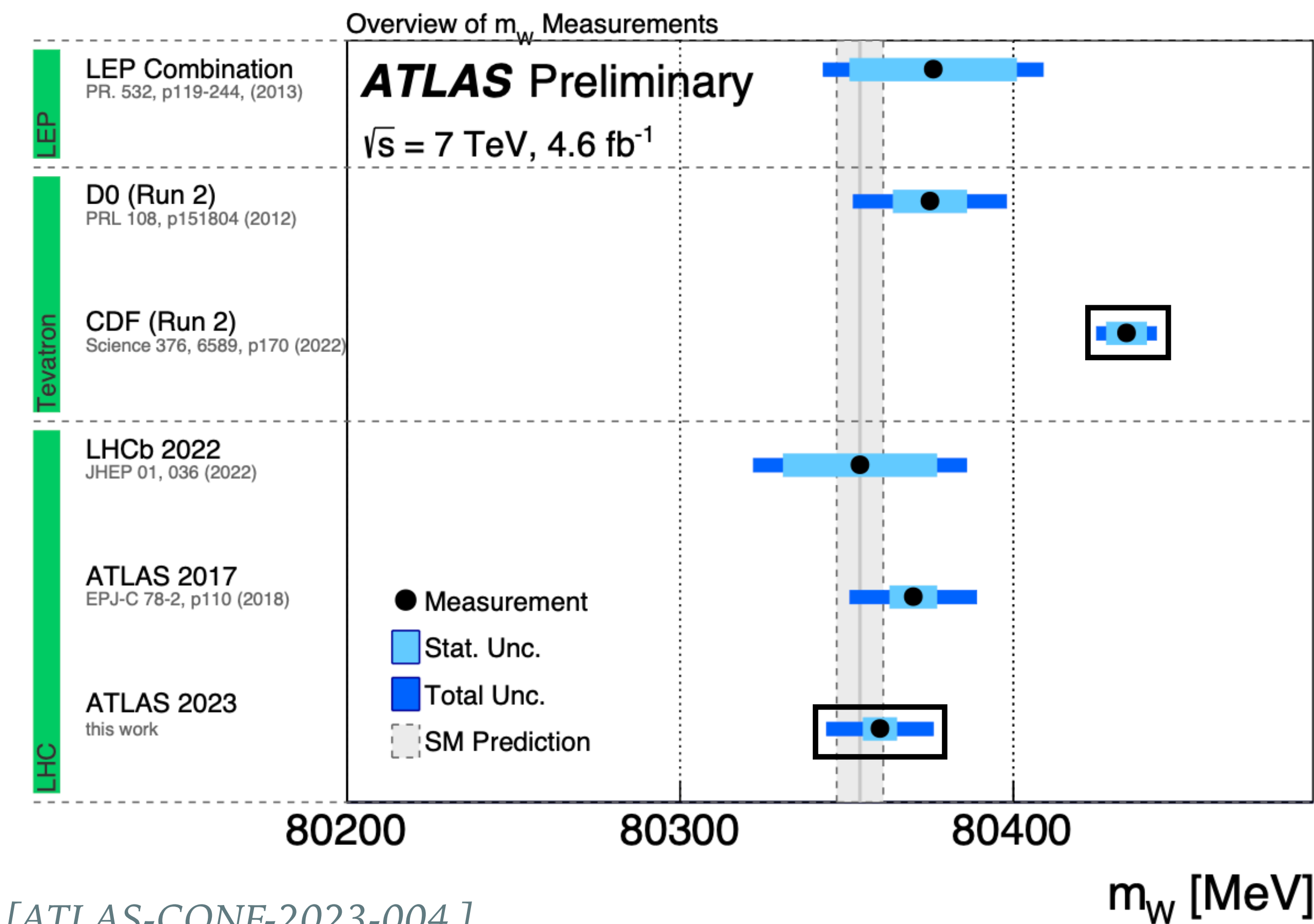
BSM & W-mass measurements

Overview of m_W Measurements

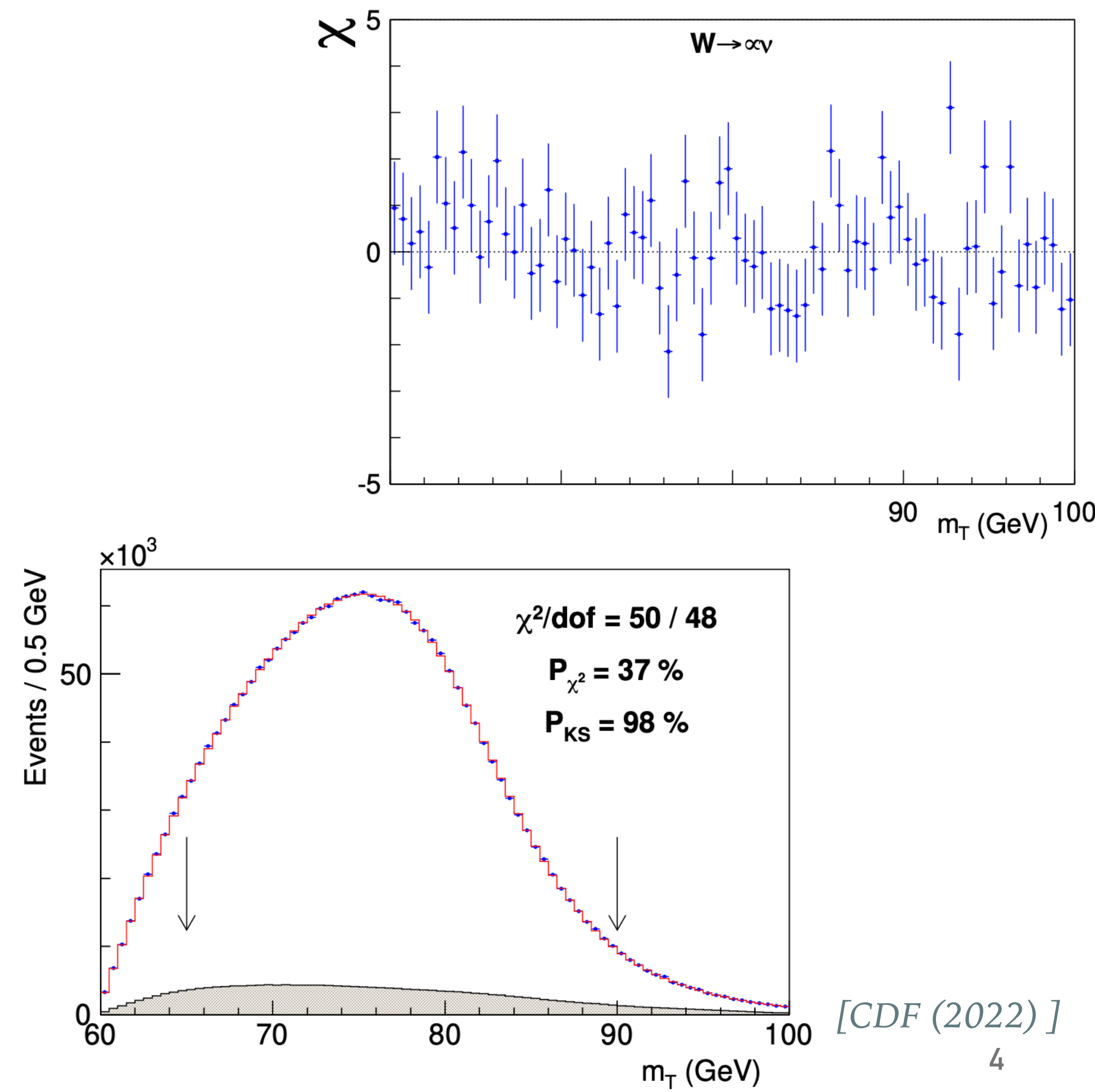


[ATLAS-CONF-2023-004]

BSM & W-mass measurements

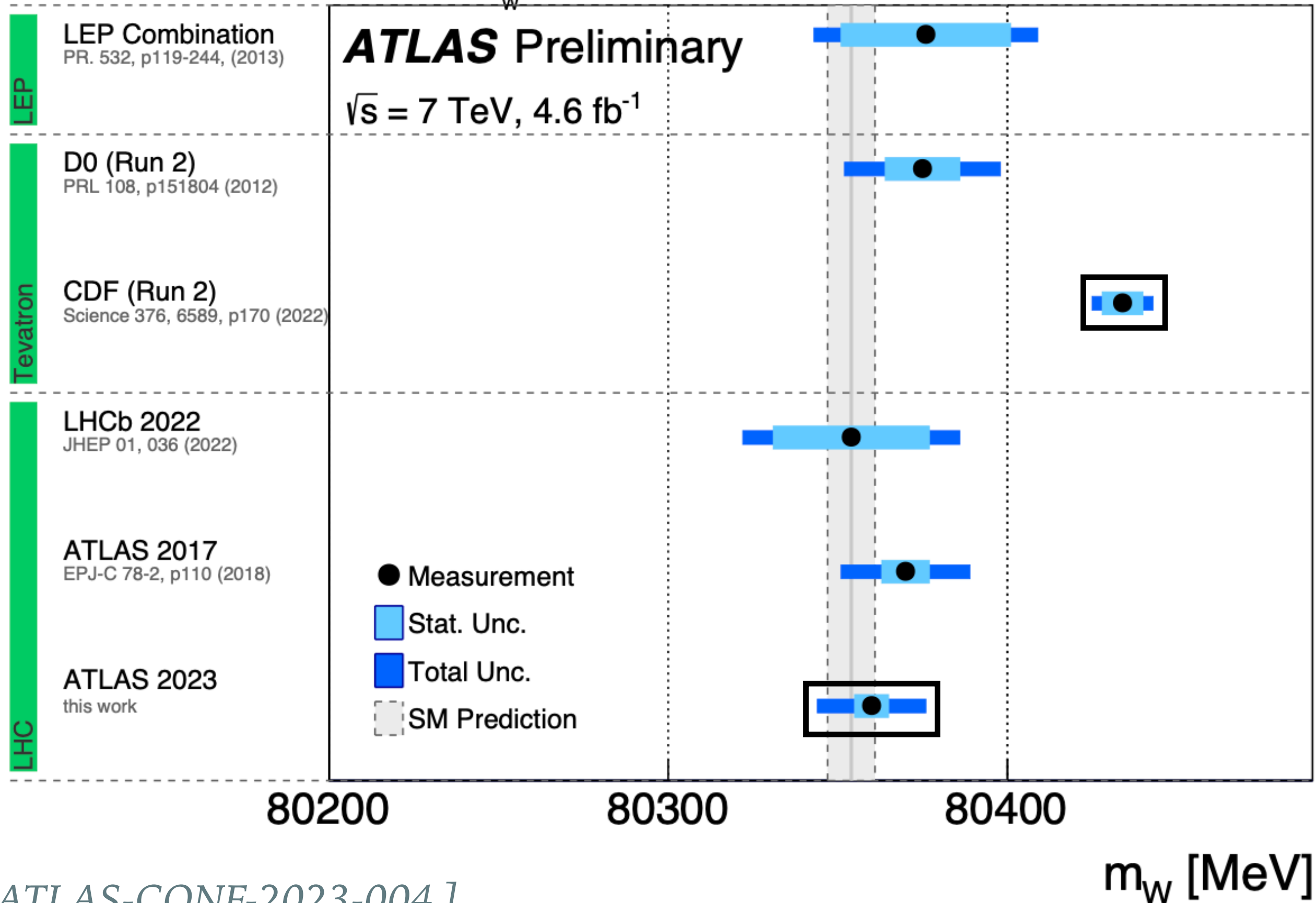


$$\chi^2_{SM}/dof \simeq 1$$



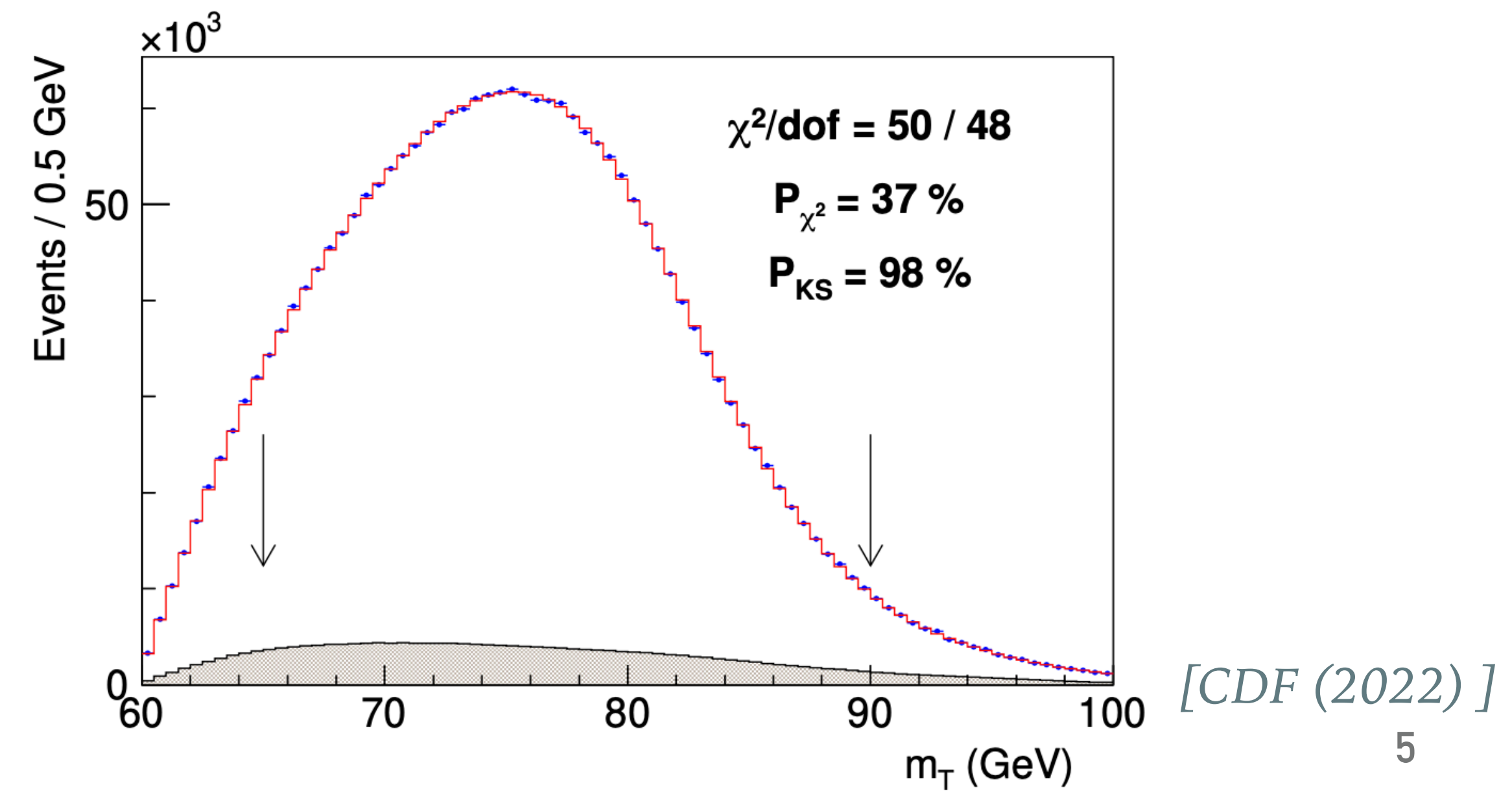
BSM & W-mass measurements

Overview of m_W Measurements



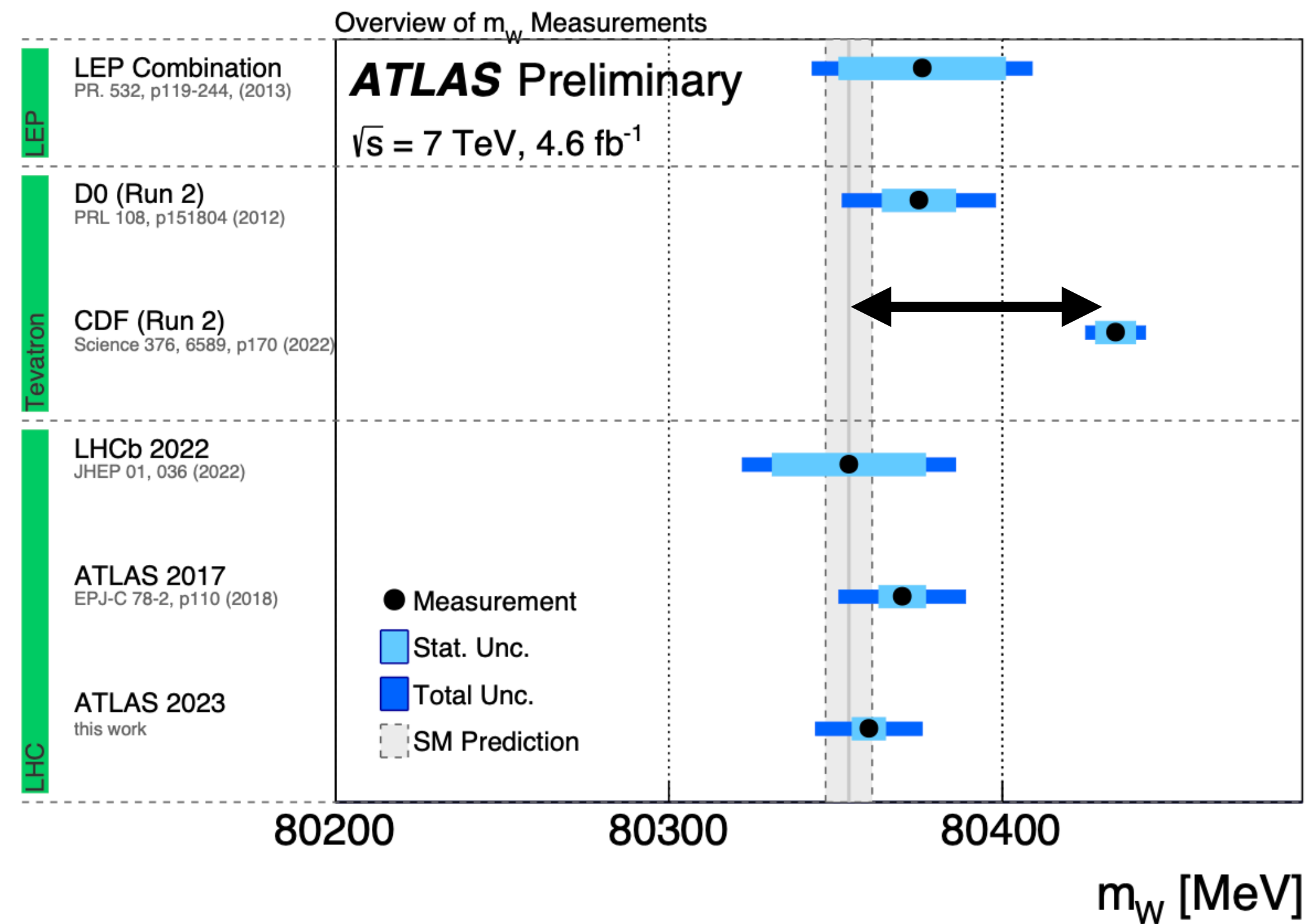
Can the W mass measurement *alone* constrain BSM?

Independently from the EW fit and from any anomaly



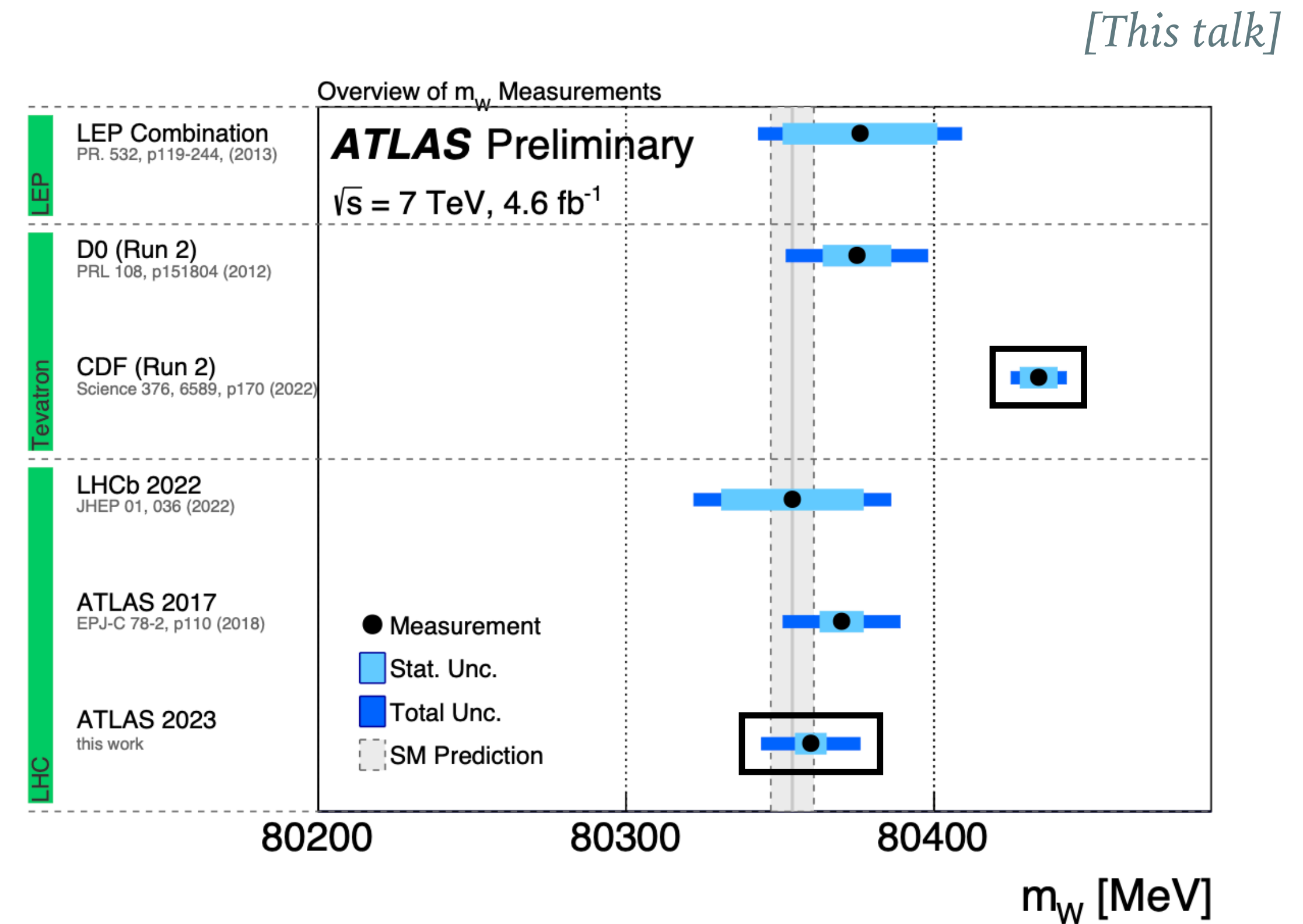
$$\chi^2_{SM}/dof \simeq 1$$

BSM & W-mass measurements



Can BSM explain the W mass anomaly?

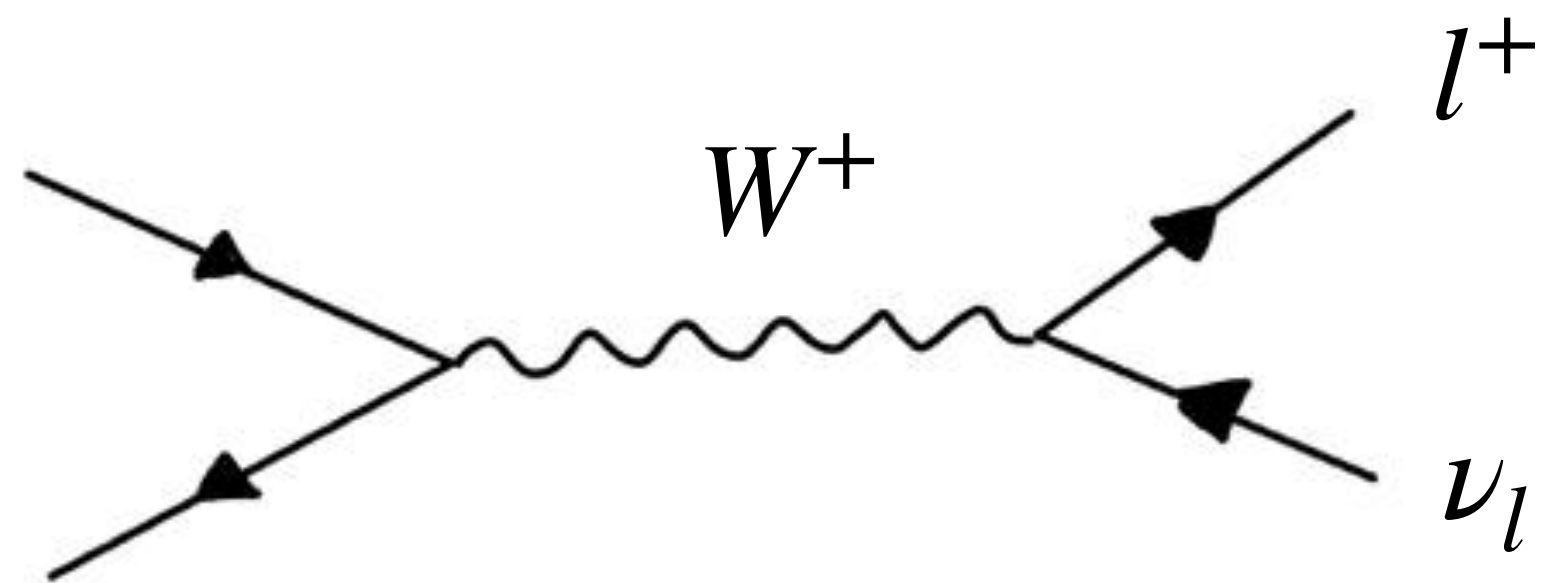
Relies on m_W prediction and measured value



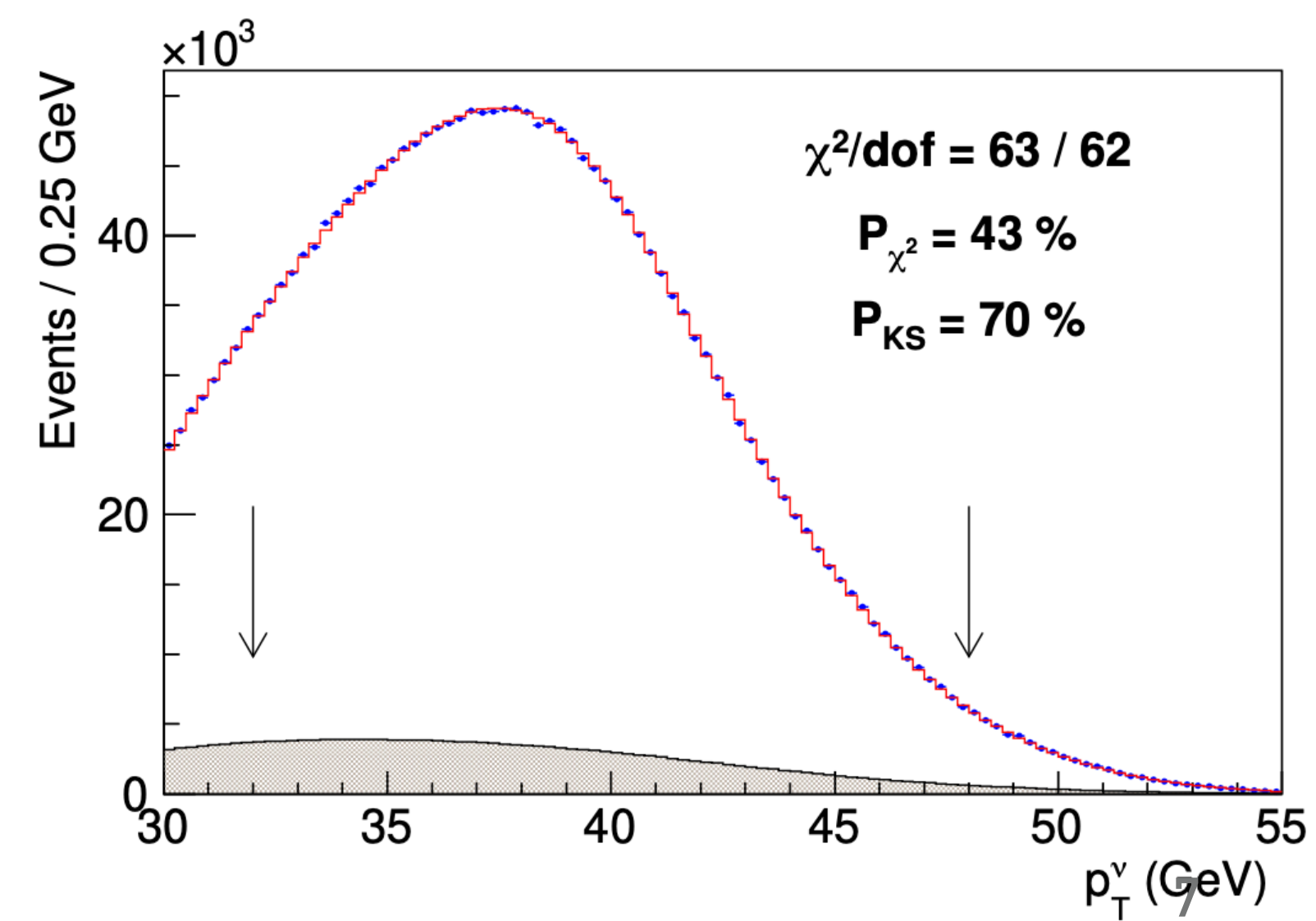
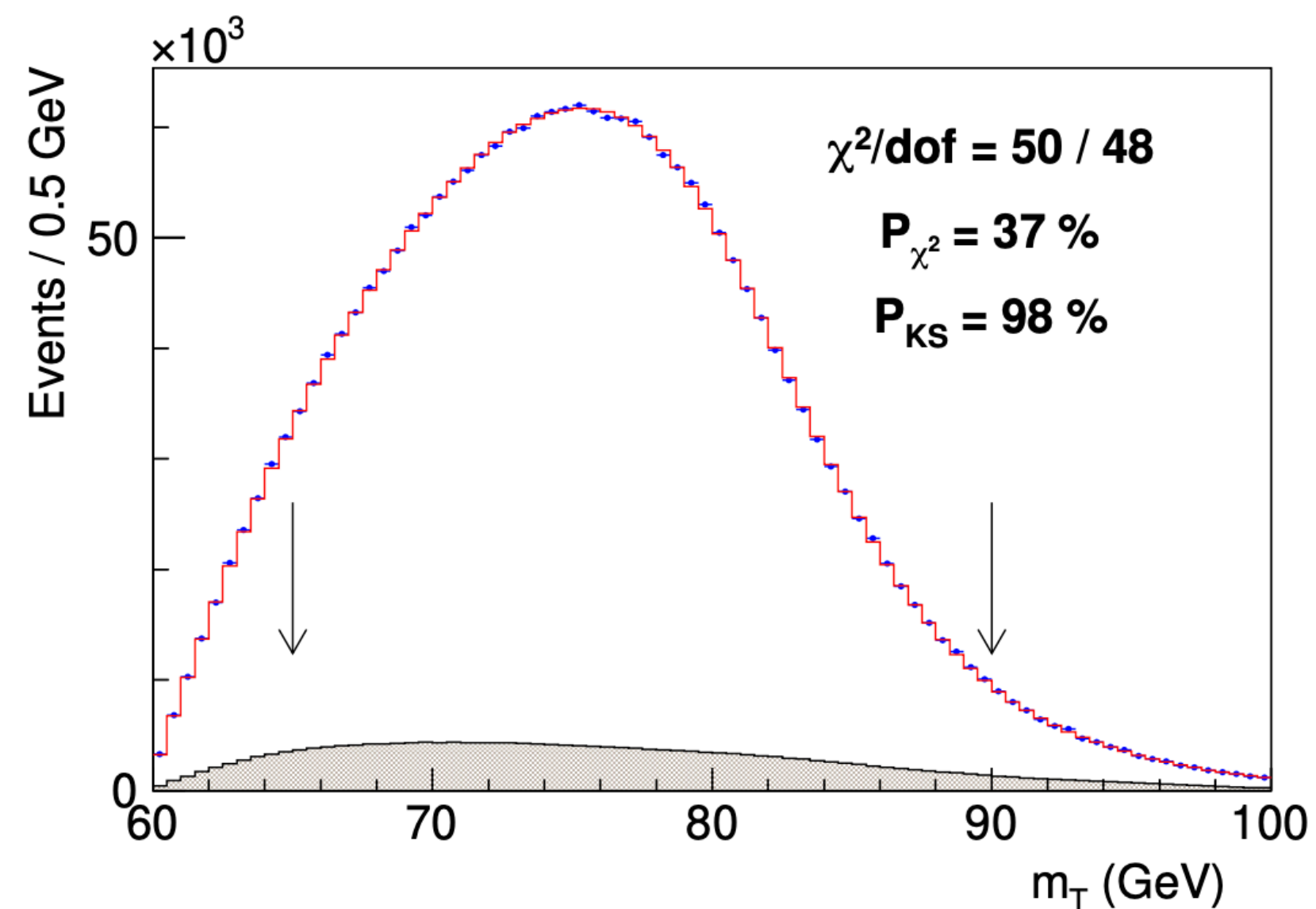
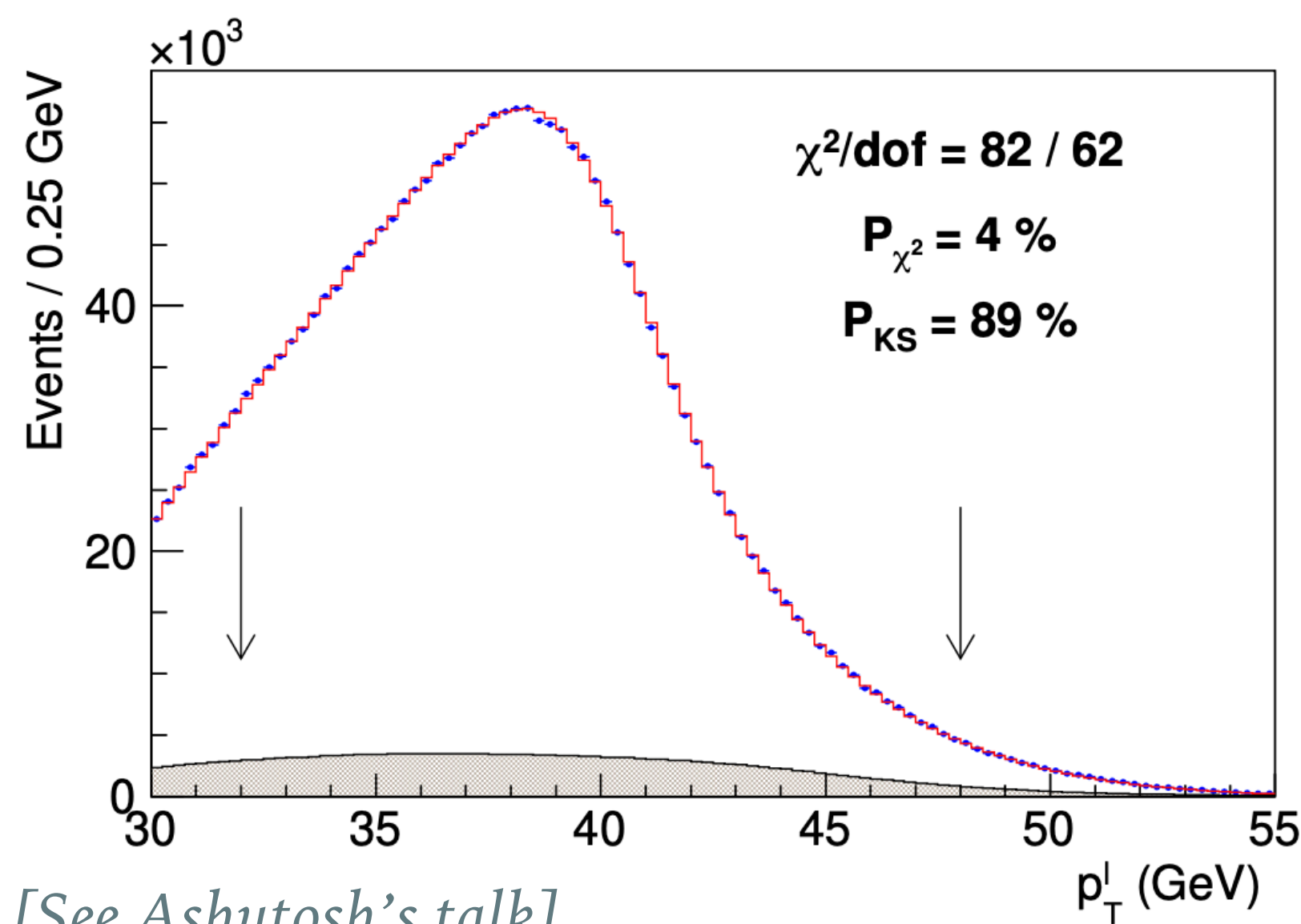
Can a W mass measurement *alone* constrain BSM?

Relies only on the m_W measurement₆

New physics in the W measurement

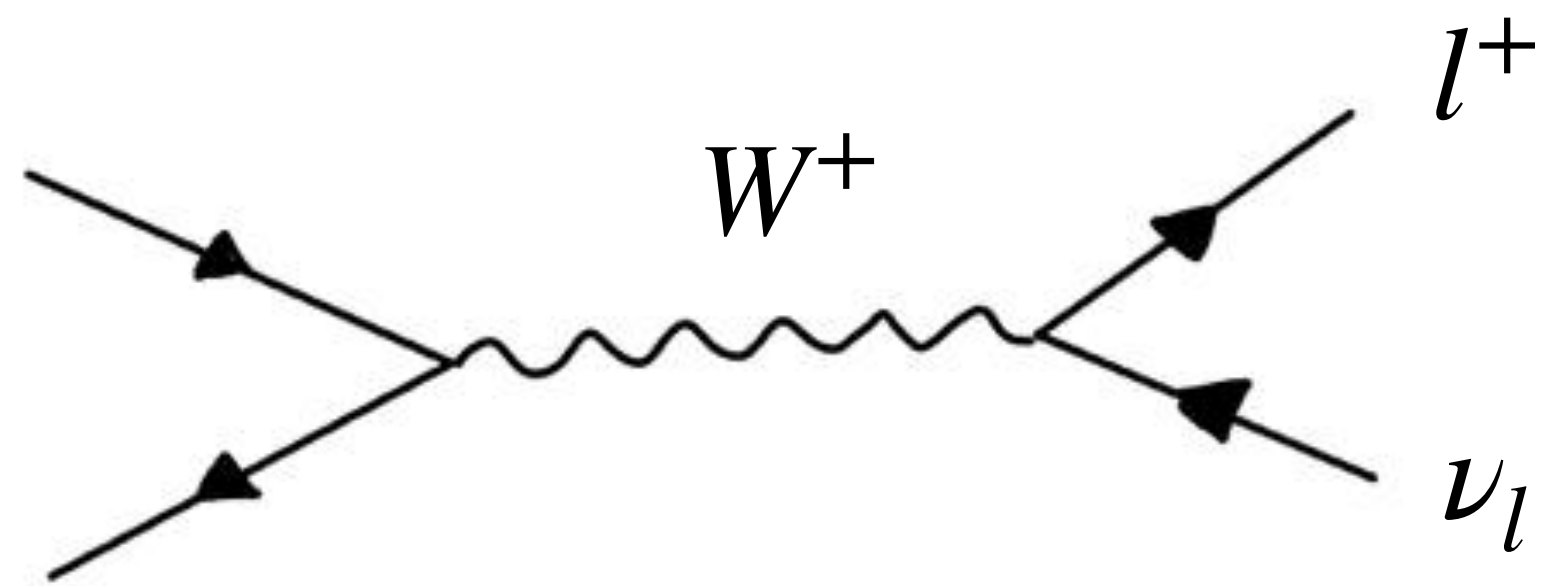


m_W is extracted from the three kinematic distributions

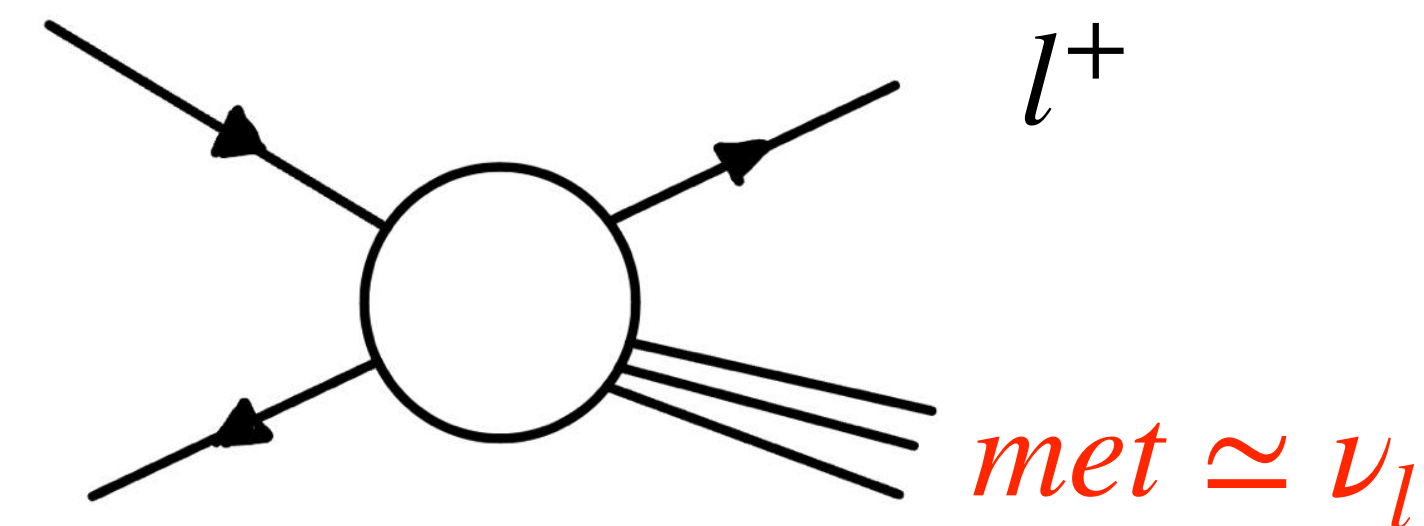


[See Ashutosh's talk]

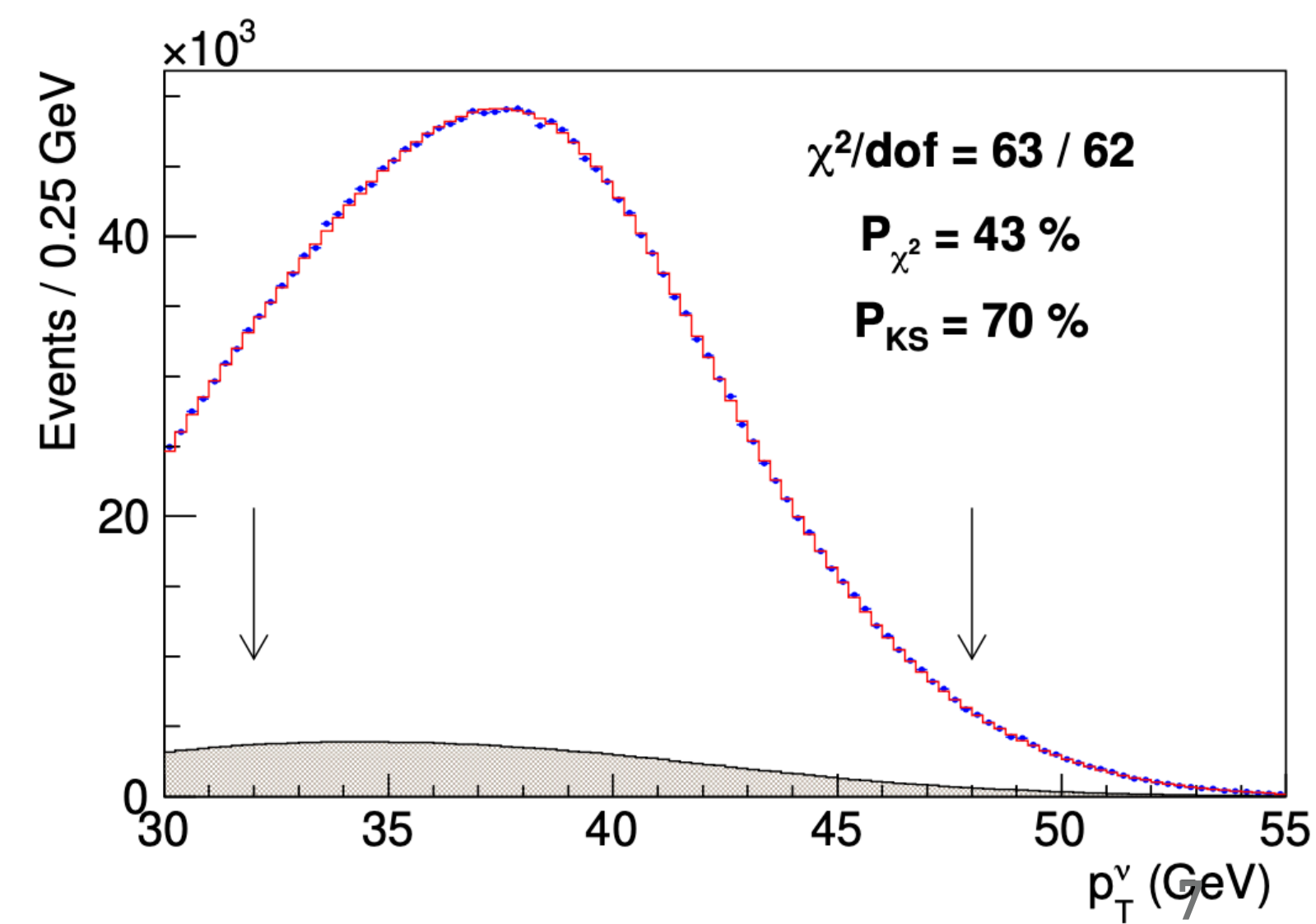
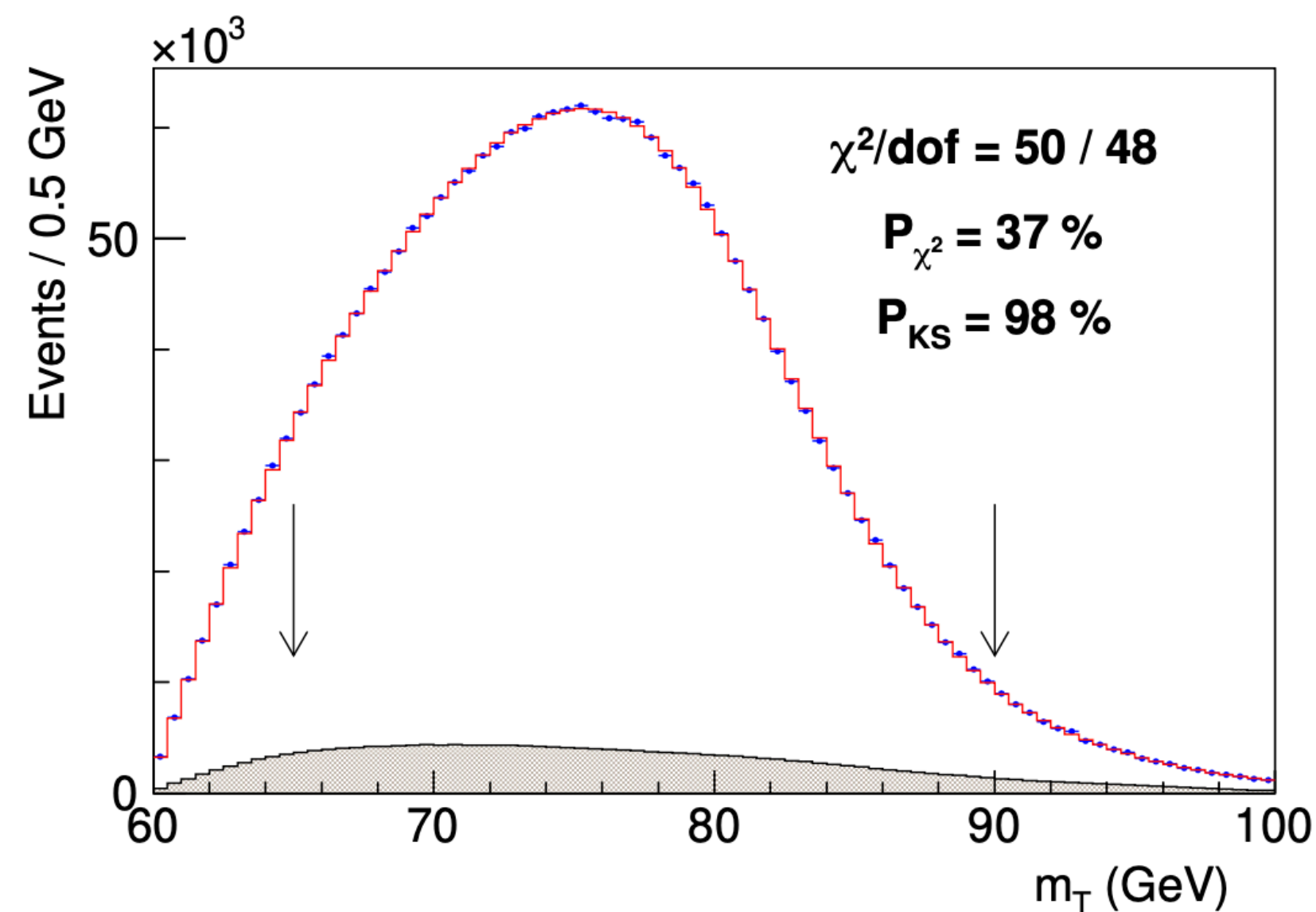
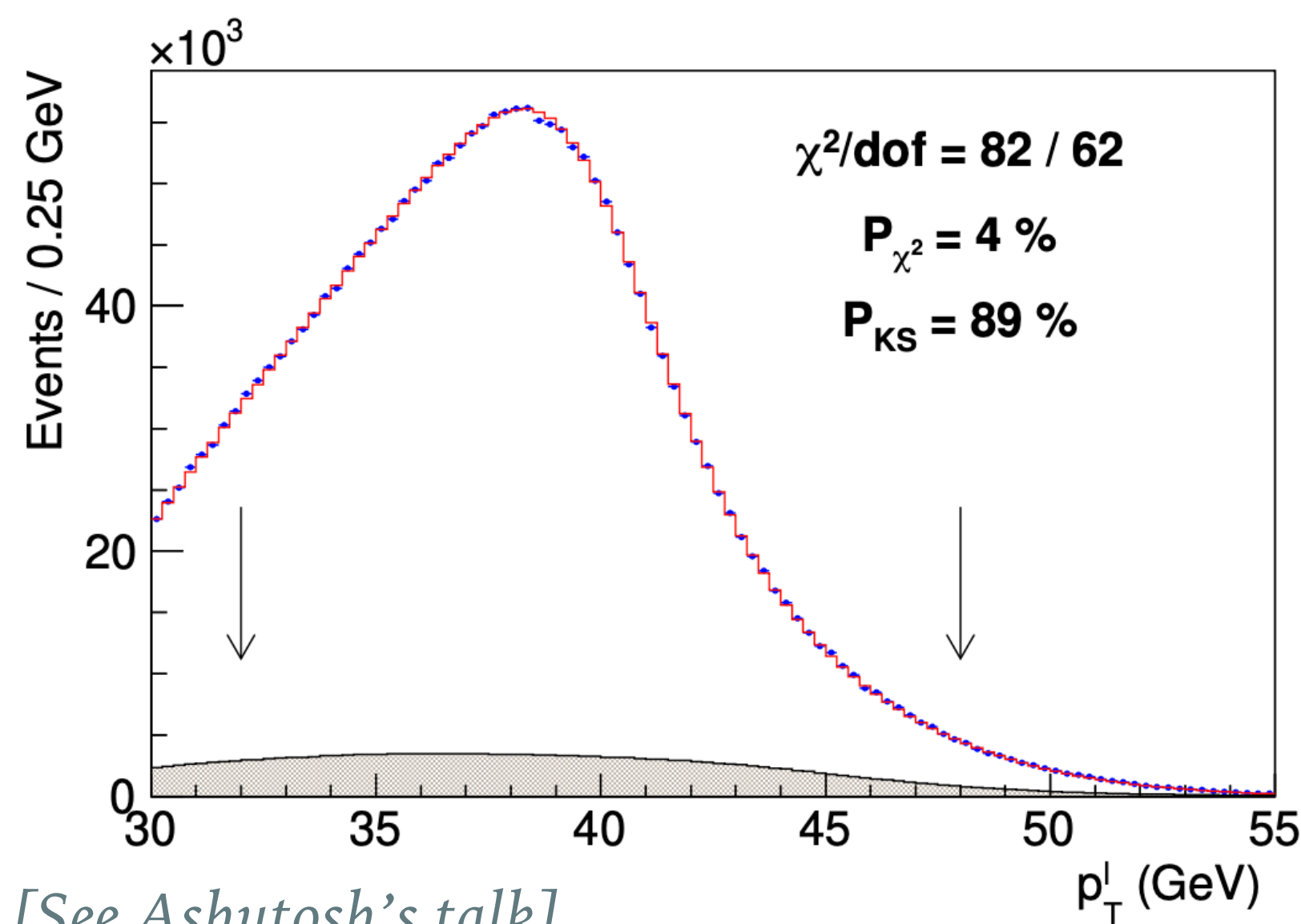
New physics in the W measurement



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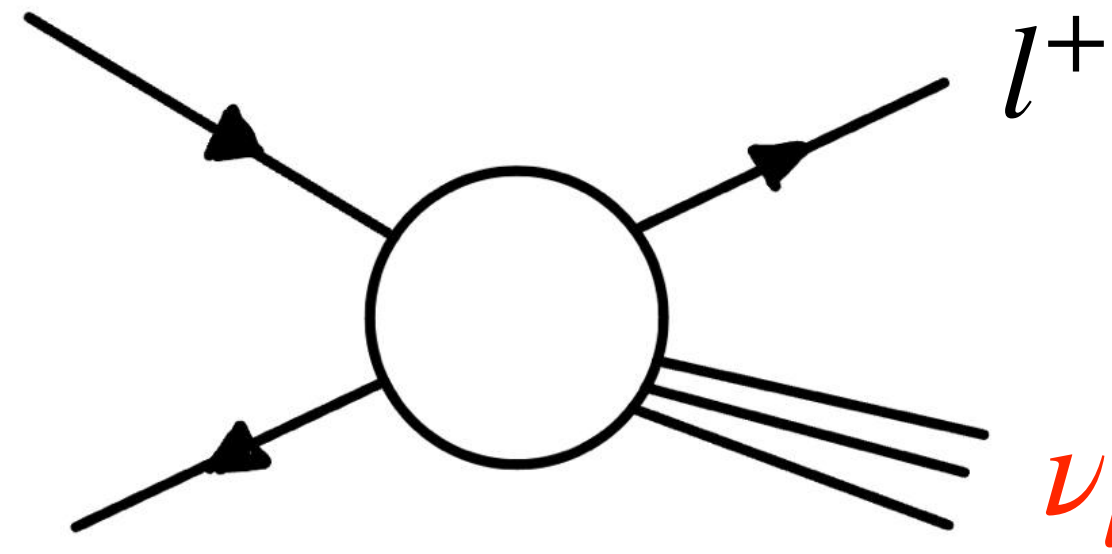


Any $l + met$ process can contaminate the W sample and distort the distributions

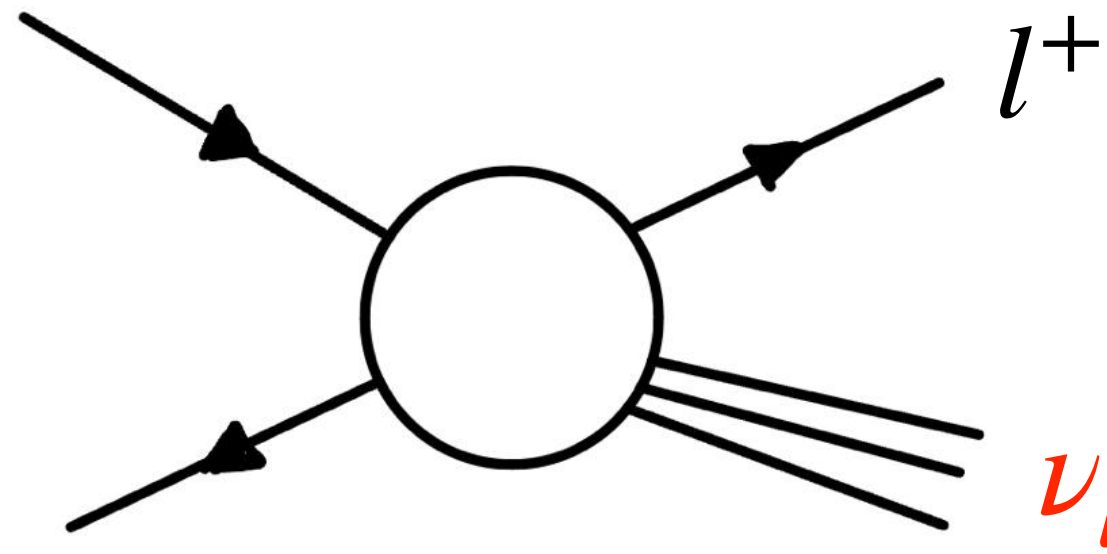


[See Ashutosh's talk]

New physics in W mass measurement

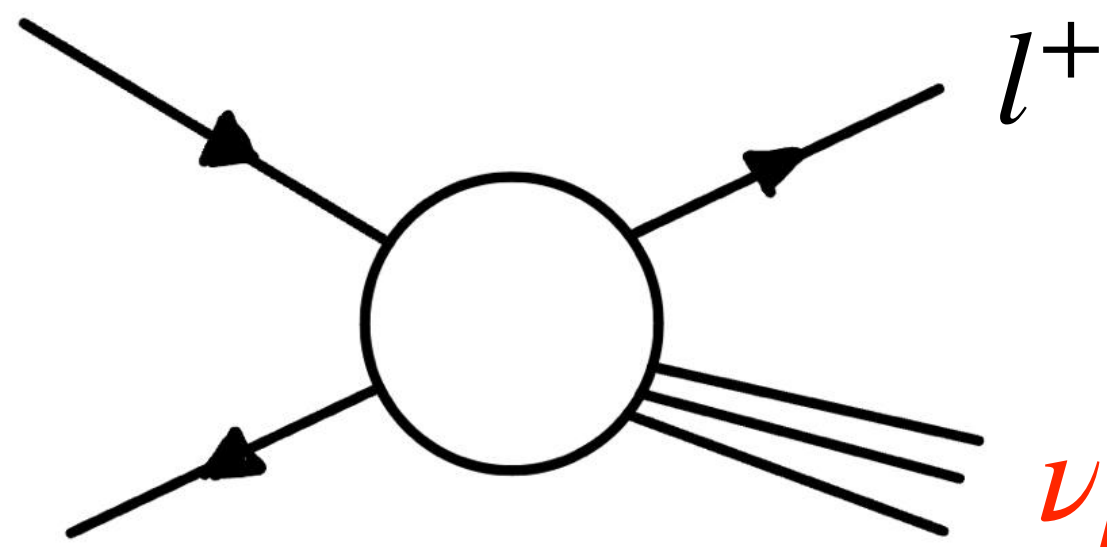


New physics in W mass measurement



Three different options

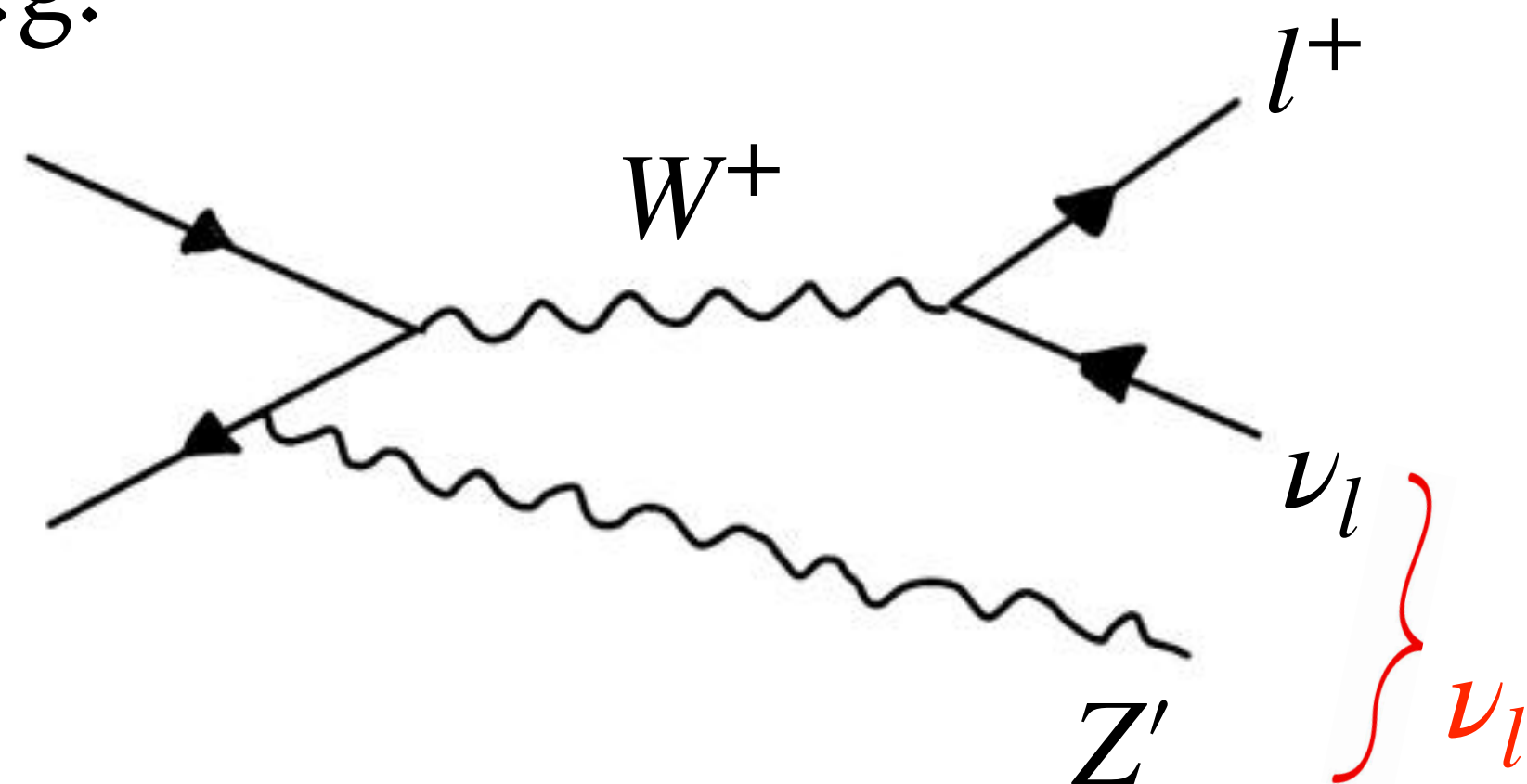
New physics in W mass measurement



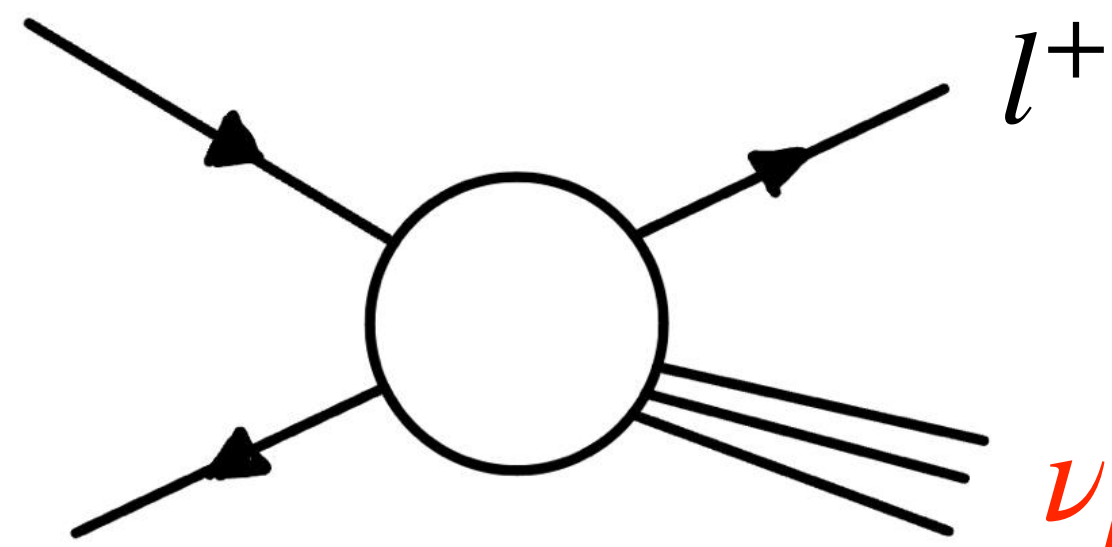
Three different options

Production

e.g.



New physics in W mass measurement

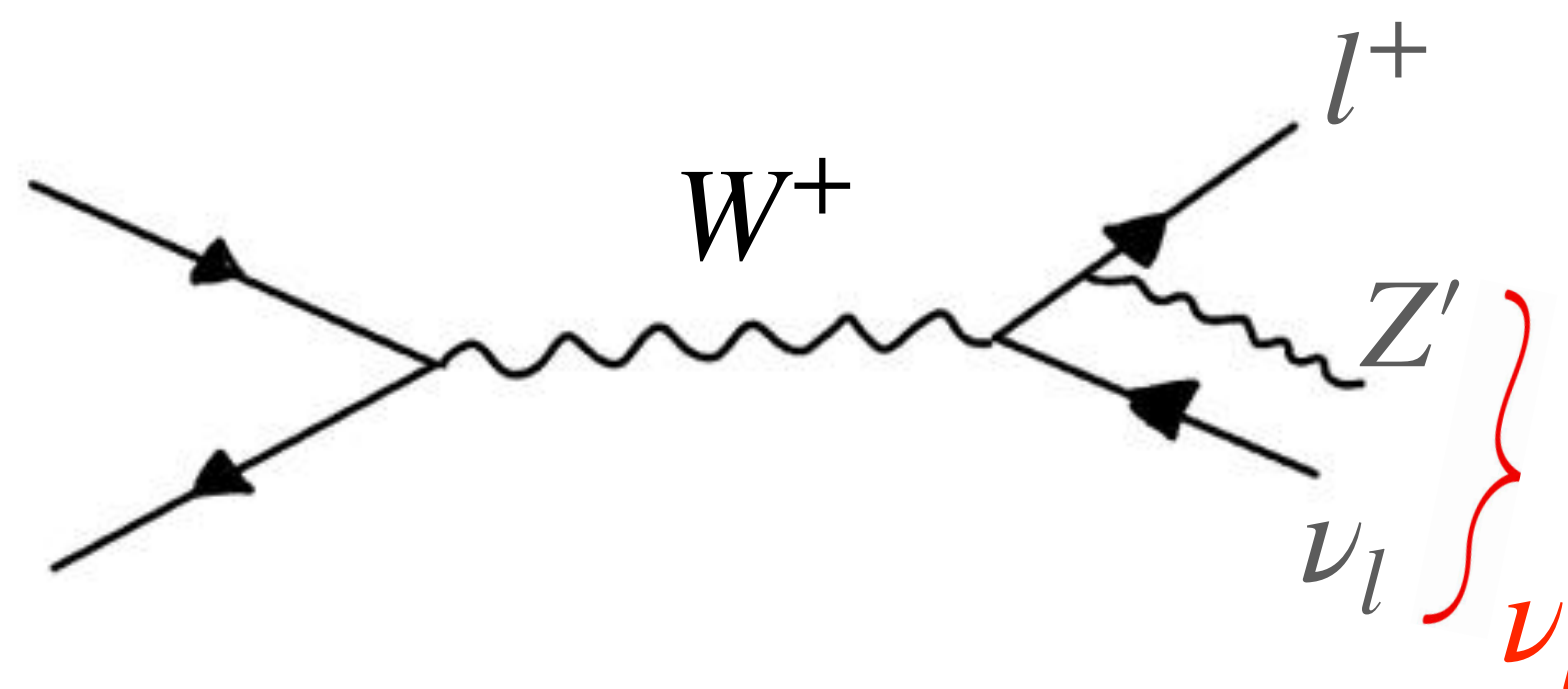
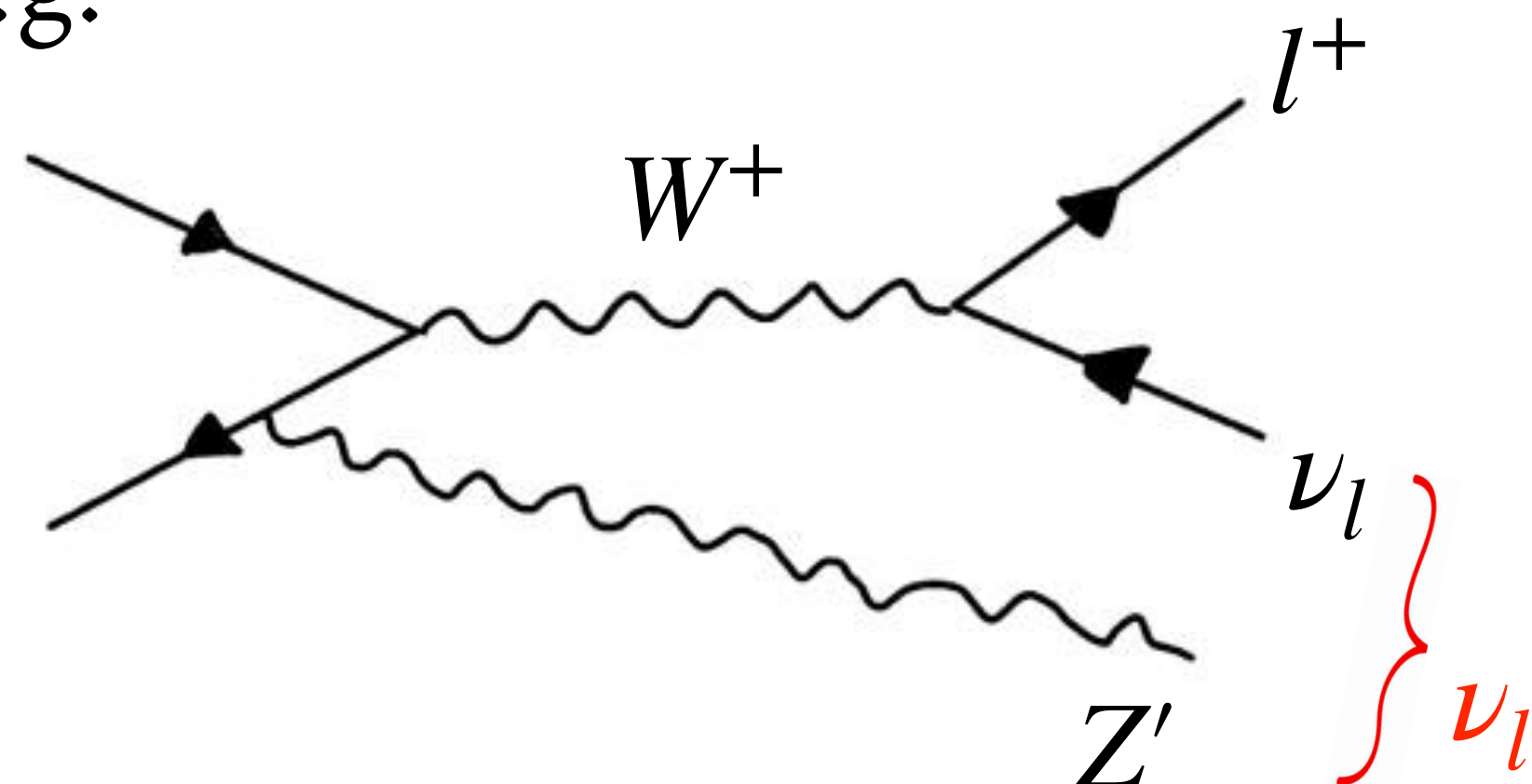


Three different options

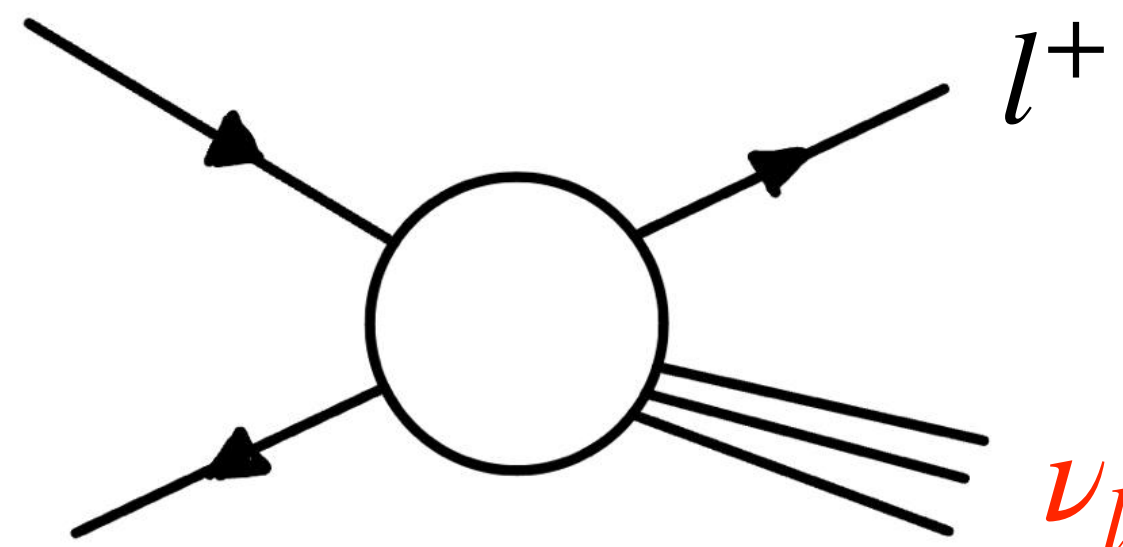
Production

Decay

e.g.



New physics in W mass measurement



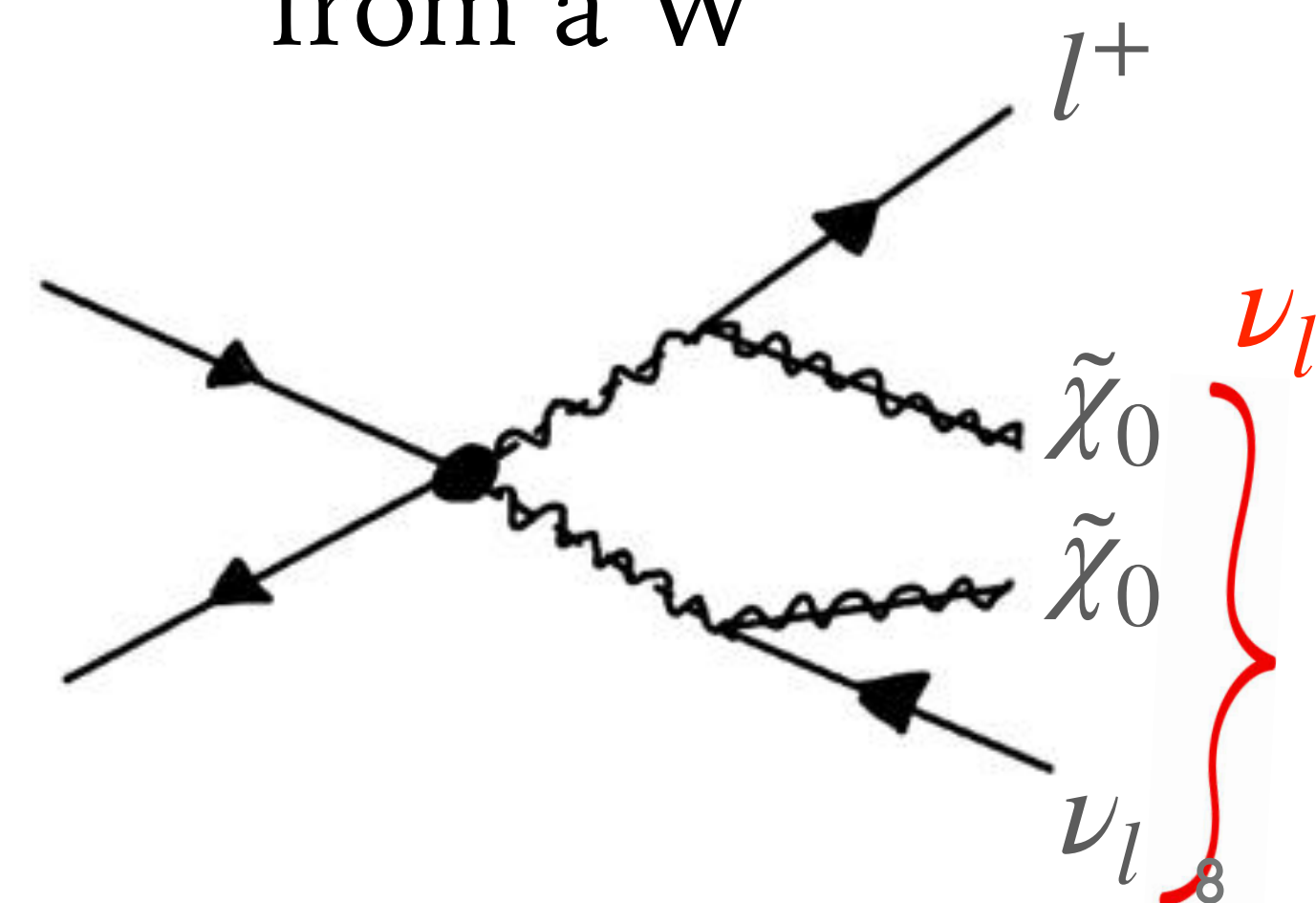
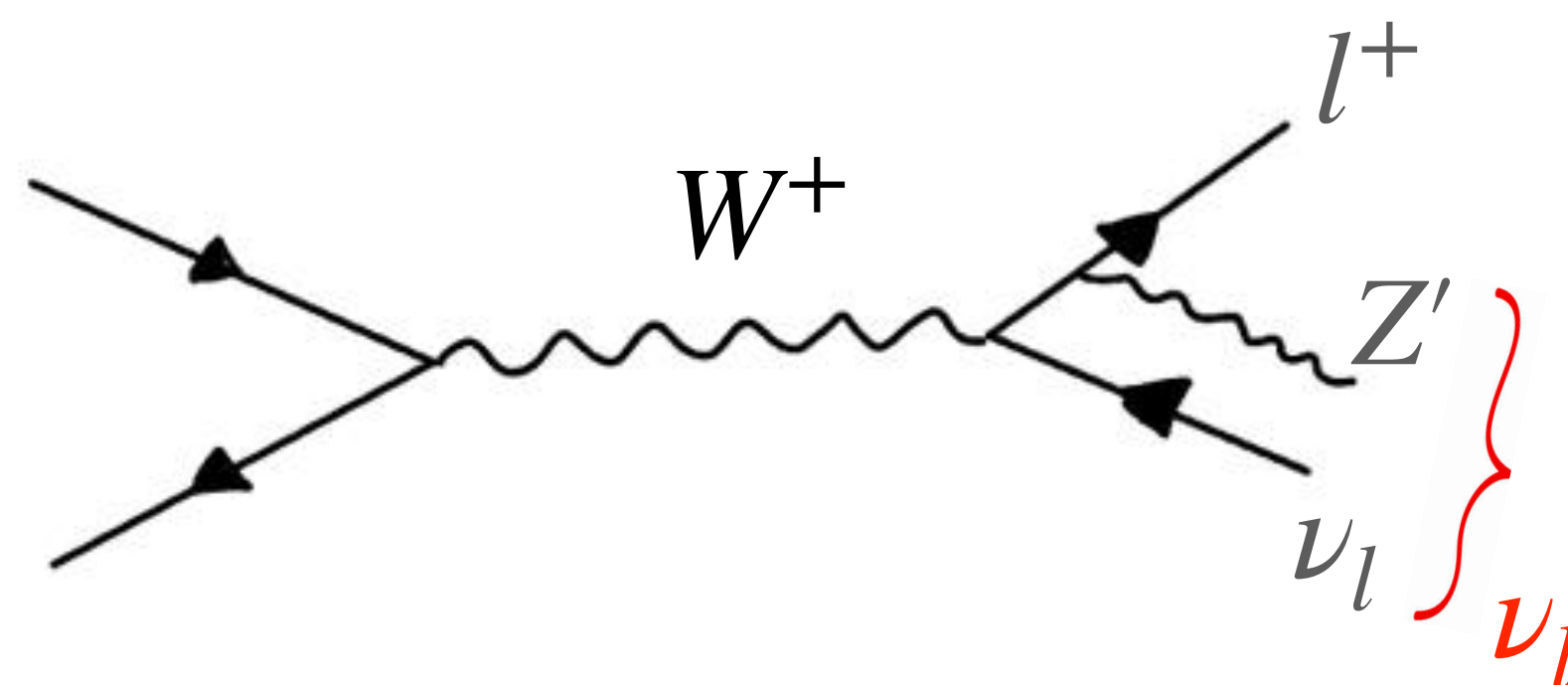
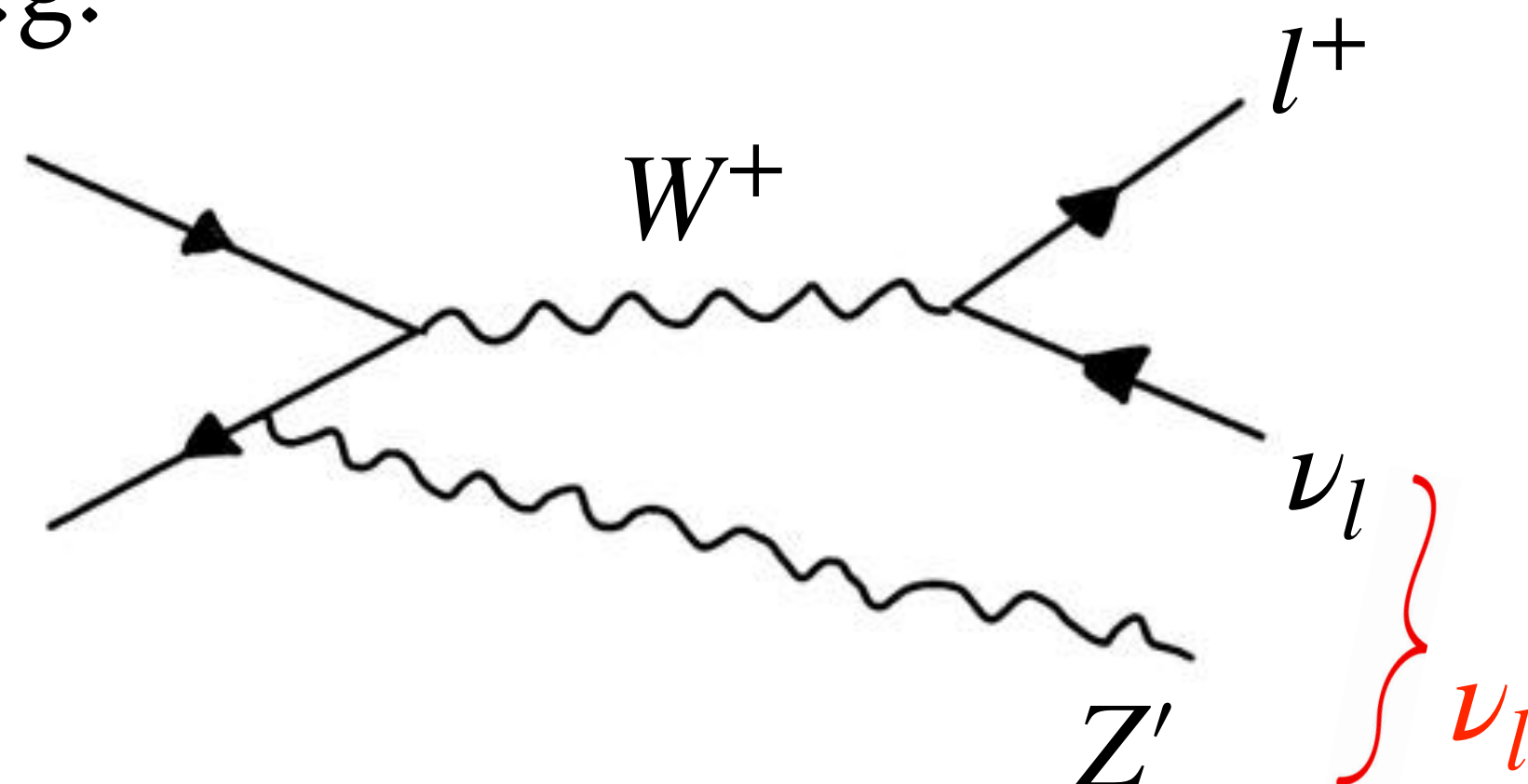
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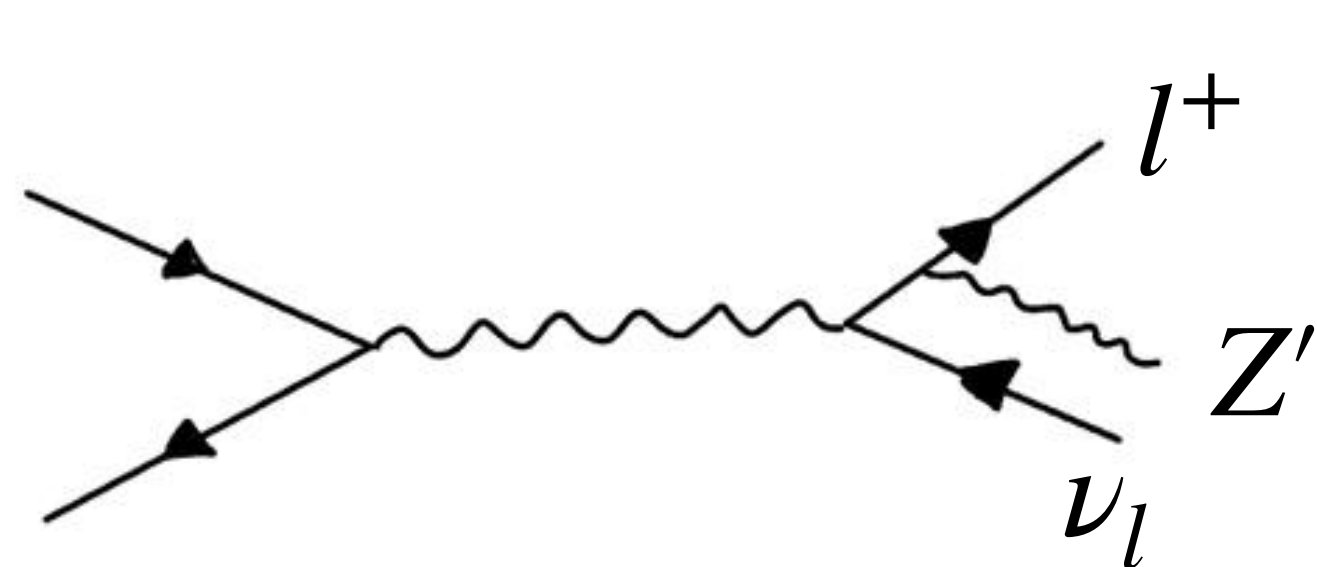
Decay

$l + \nu_l$ not
from a W

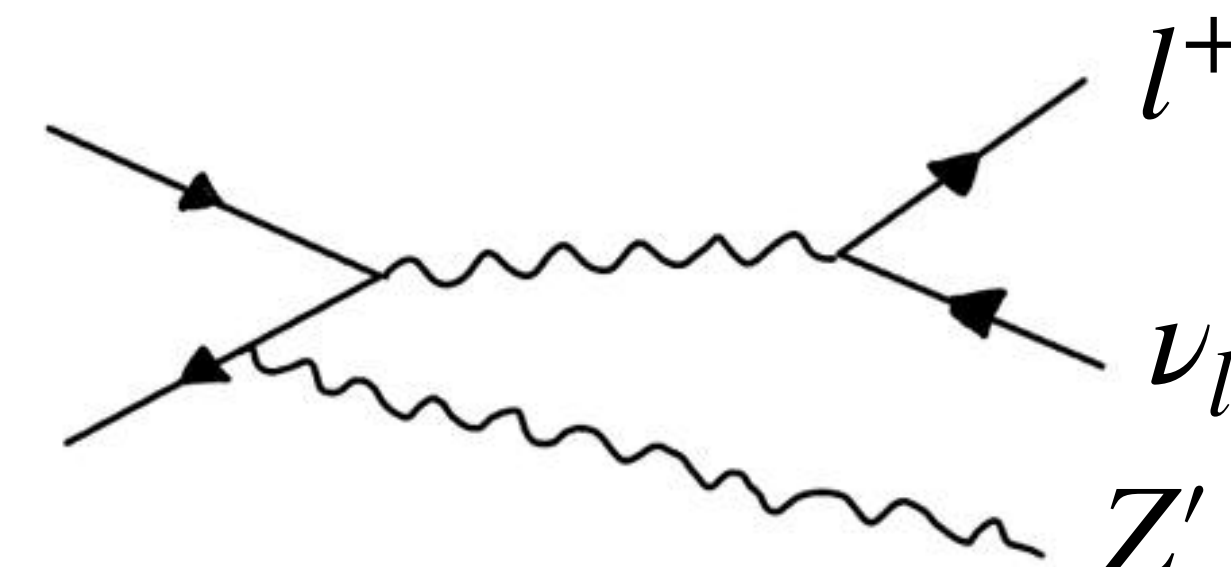
e.g.



New physics in W mass measurement



$$\mathcal{L}_{int} = g_{Z'} Z'_\mu J^\mu_{U(1)_X}$$

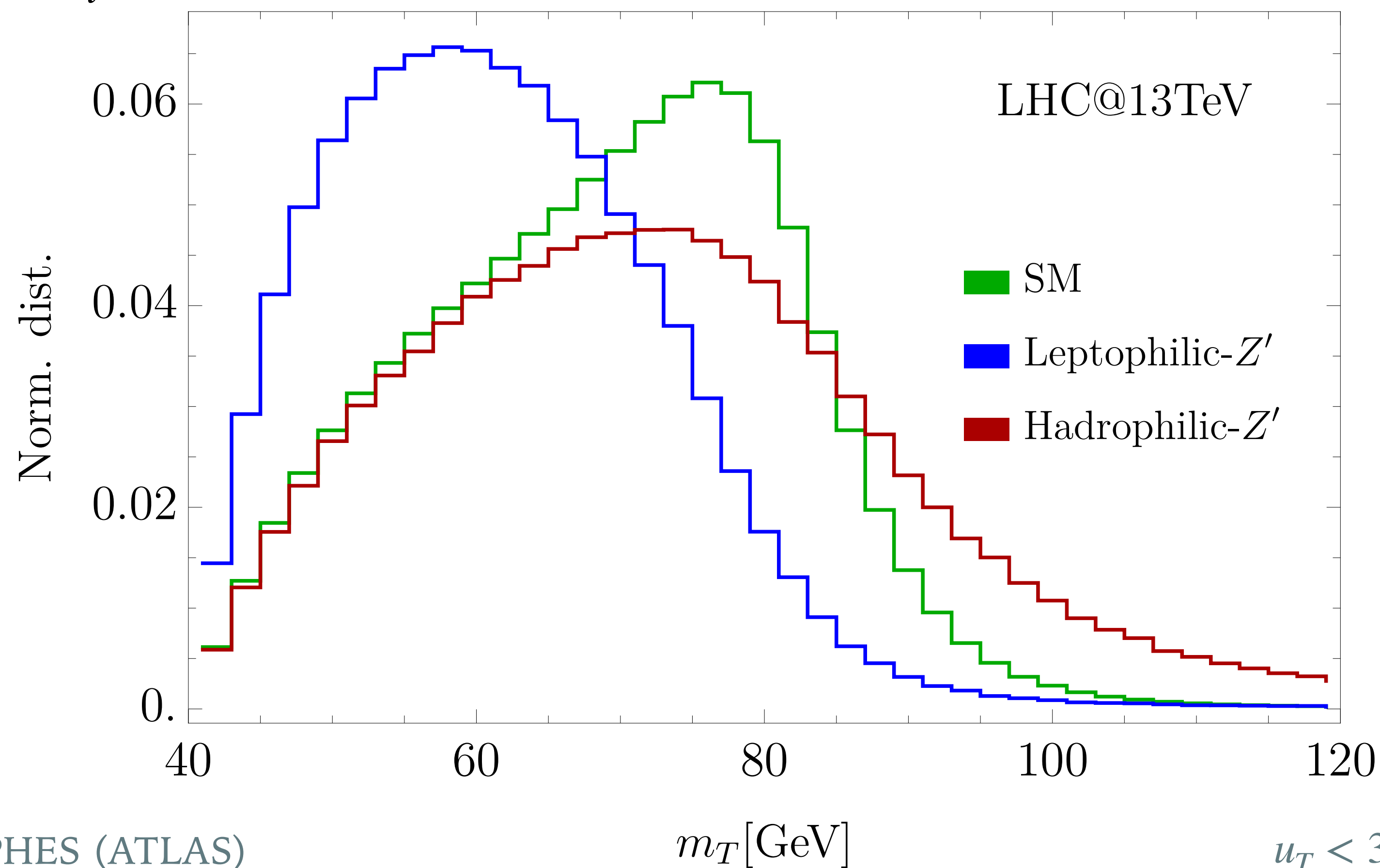


Decay

$U(1)_{L_\mu - L_\tau}$

Production

$U(1)_B$

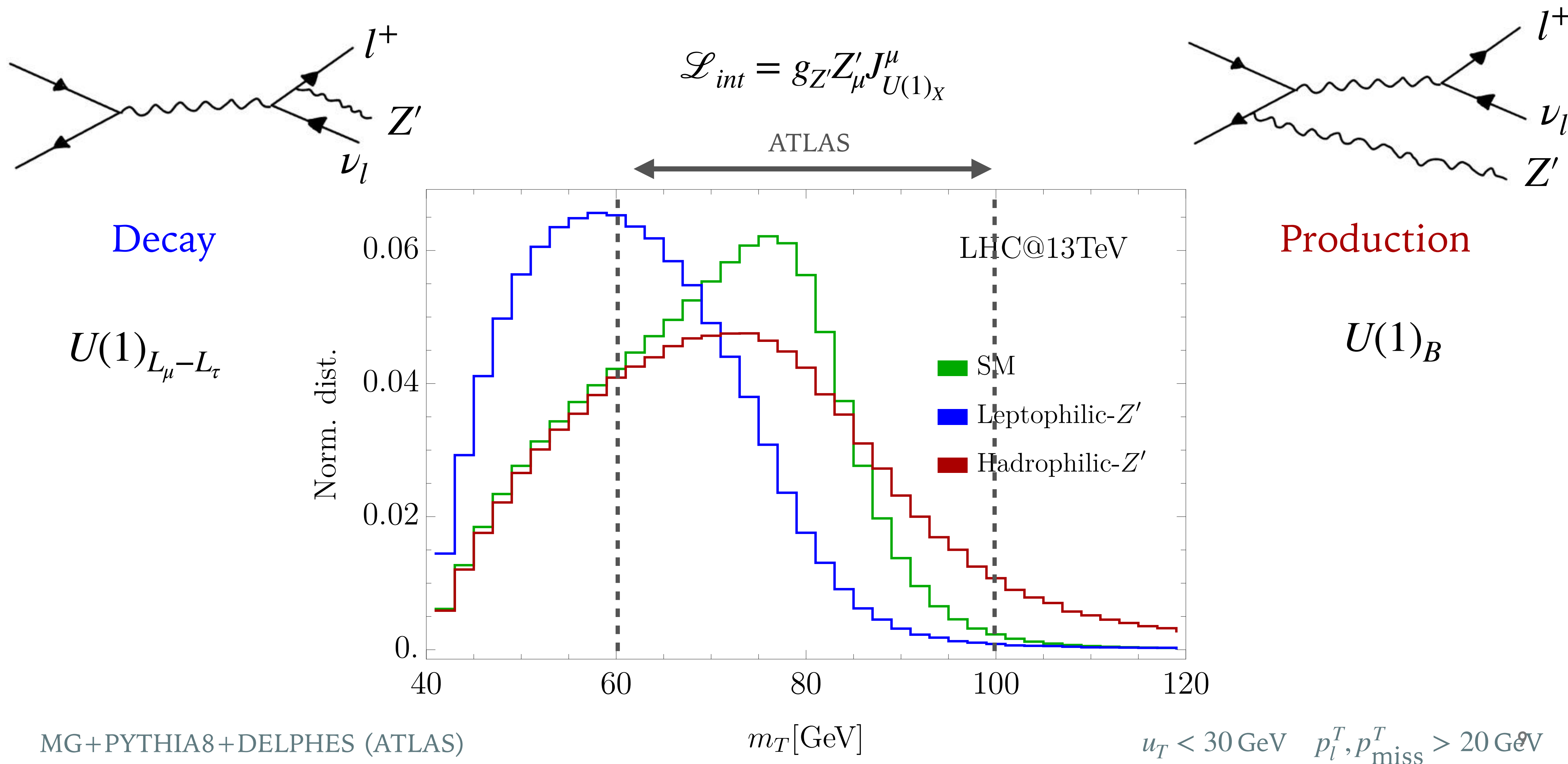


MG+PYTHIA8+DELPHES (ATLAS)

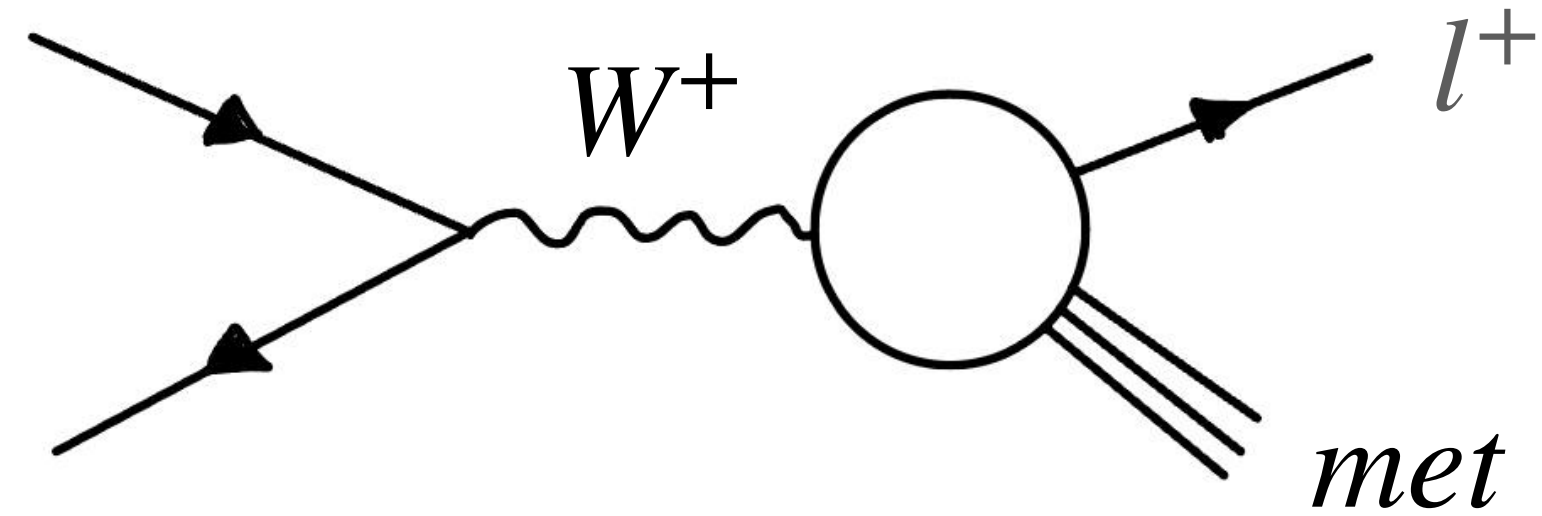
m_T [GeV]

$u_T < 30 \text{ GeV}$ $p_l^T, p_{\text{miss}}^T > 20 \text{ GeV}$

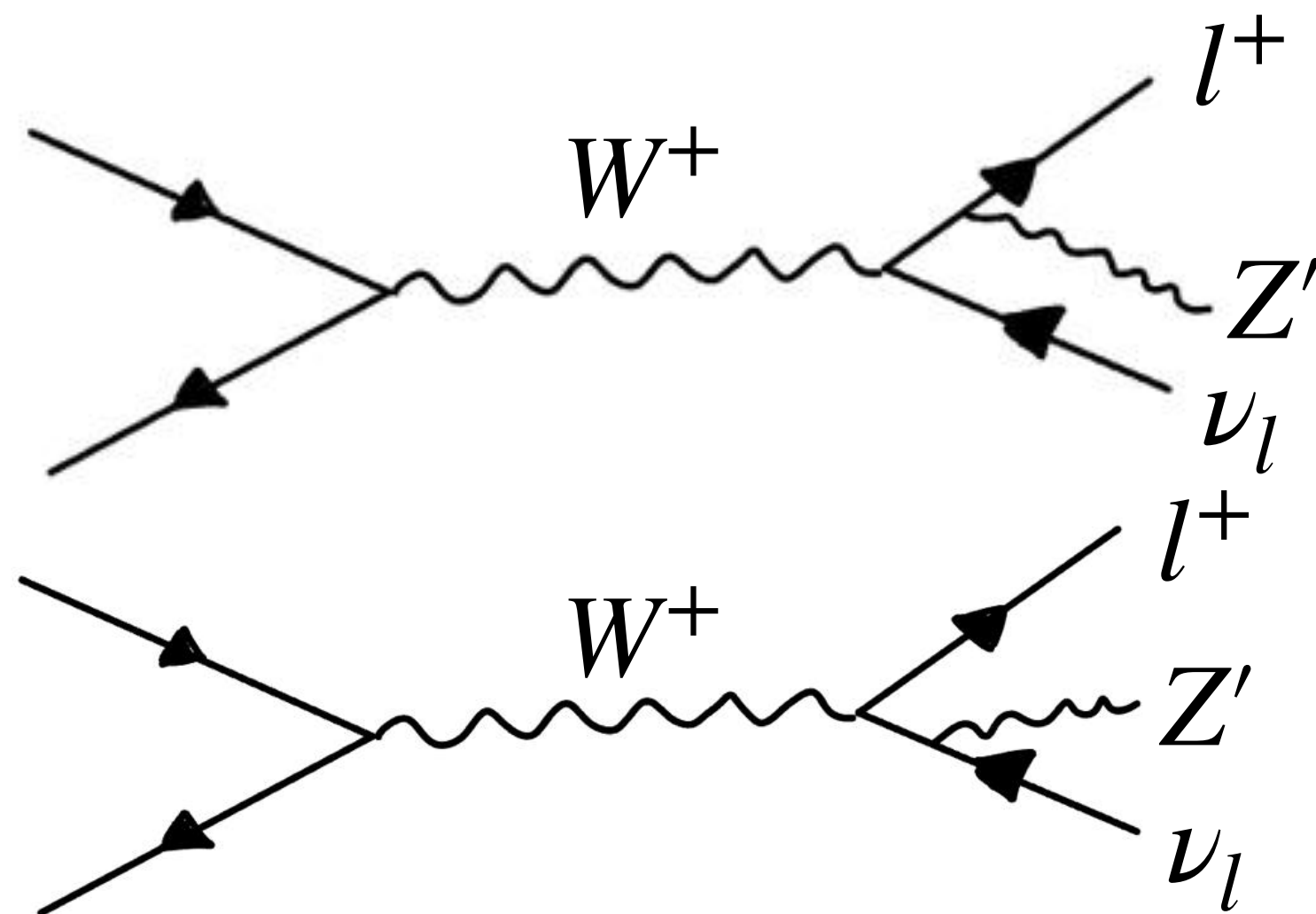
New physics in W mass measurement



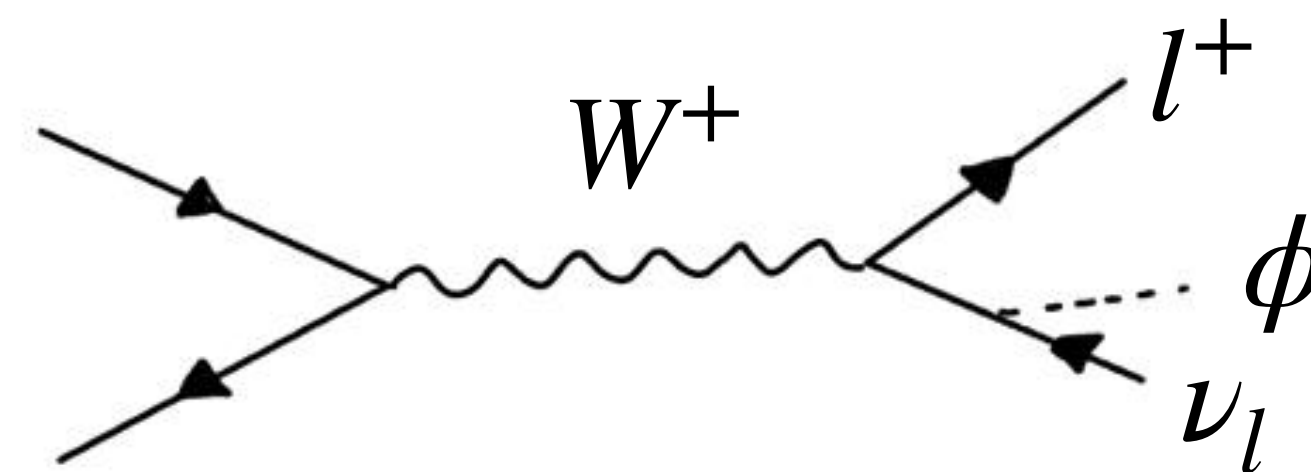
New physics in the W decay



$$L_\mu - L_\tau$$

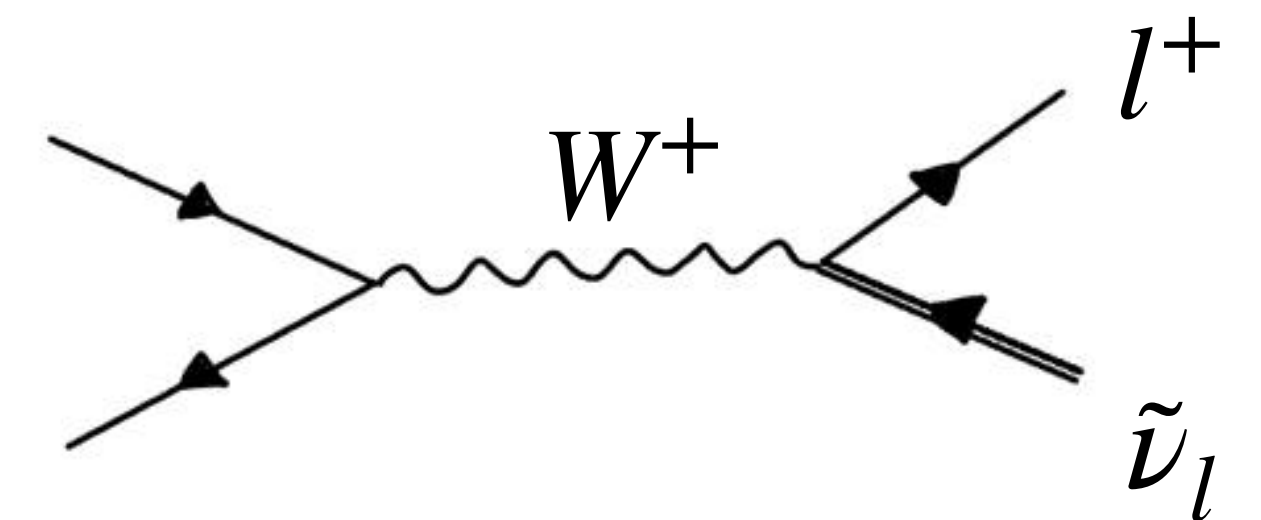


“Neutrinophilic” scalar



[1802.00009, 1910.0113]

Dirac neutrino portal



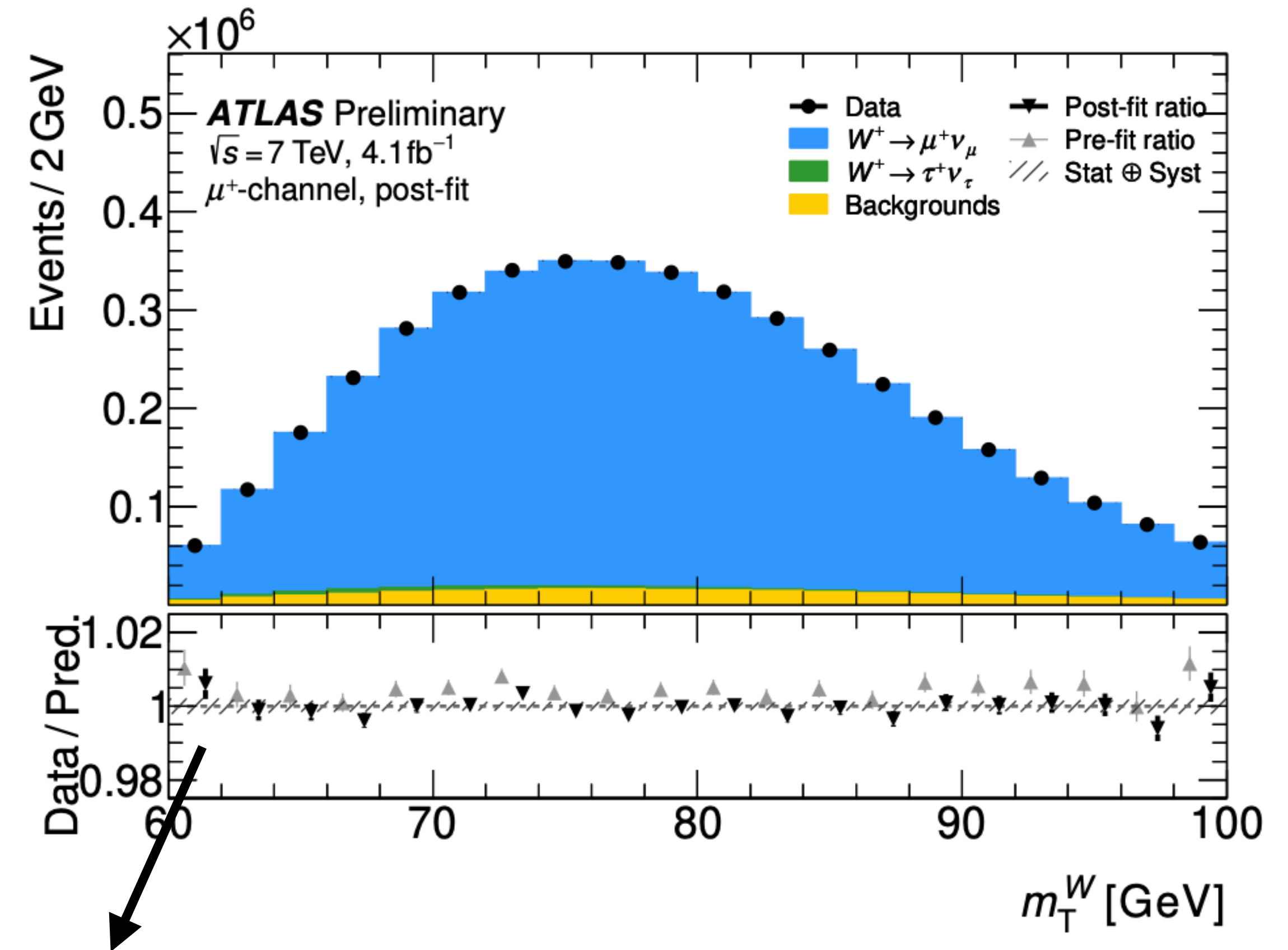
[1412.3113, 1709.07001]

New physics in the W decay: $U(1)_{L_\mu-L_\tau} Z'$

$$\mathcal{L} = -\frac{1}{4}F'^2 + \frac{1}{2}m_Z'^2 Z'^2 + g_{Z'} Z'_\mu J_{L_\mu-L_\tau}^\mu$$

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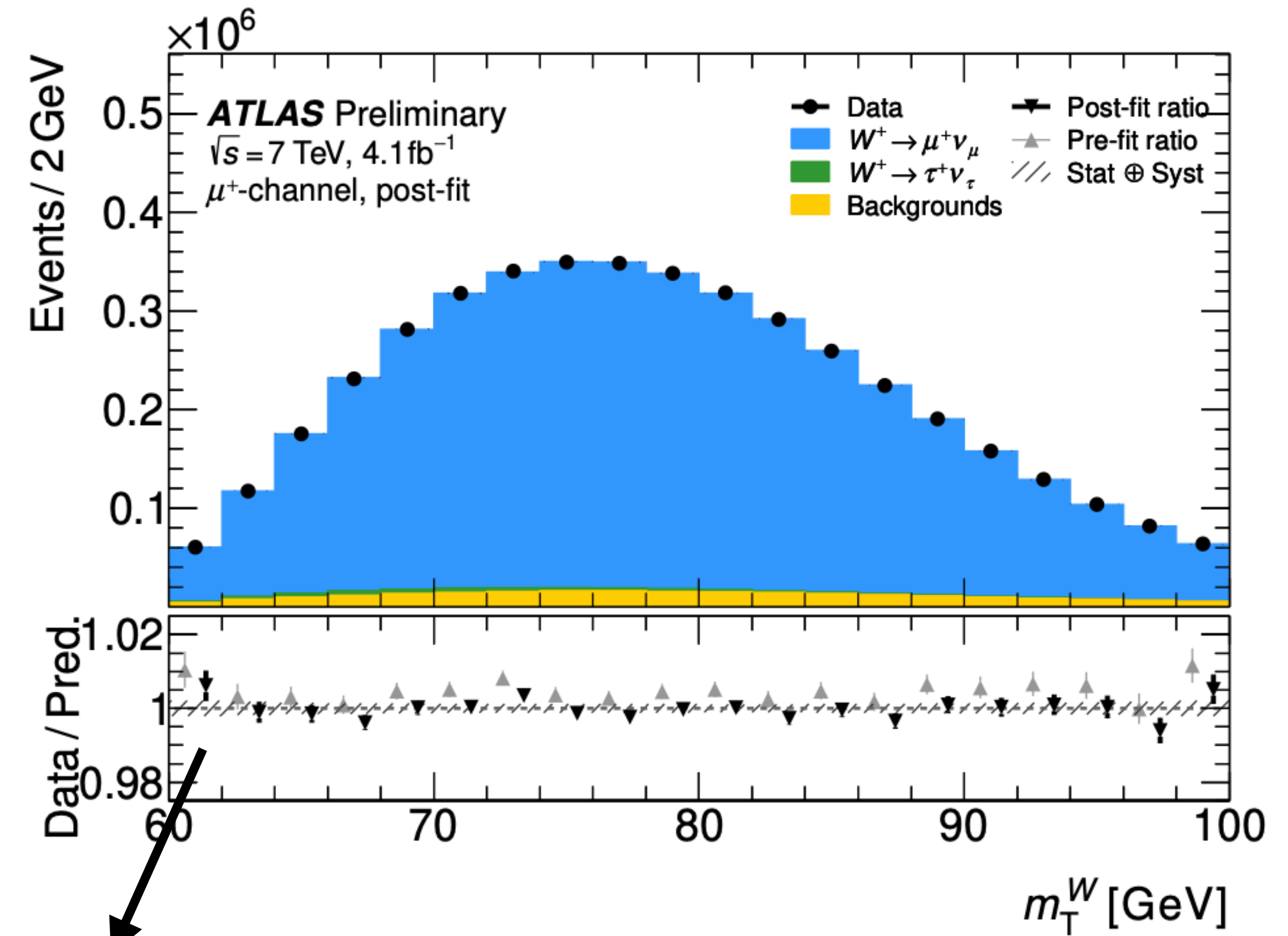
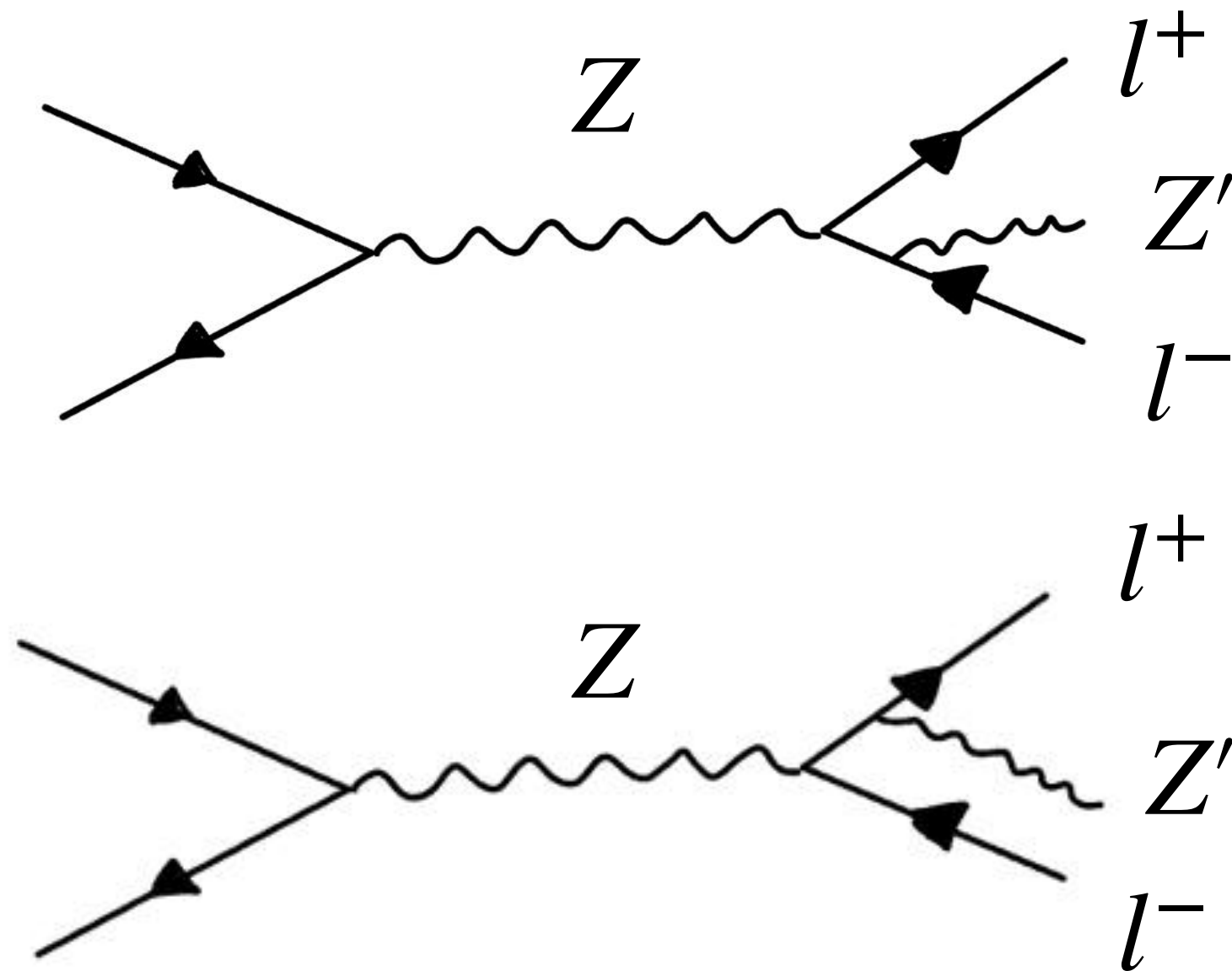


This precision is guaranteed by the data driven approach (Z calibration)

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It also modifies the Z decay!

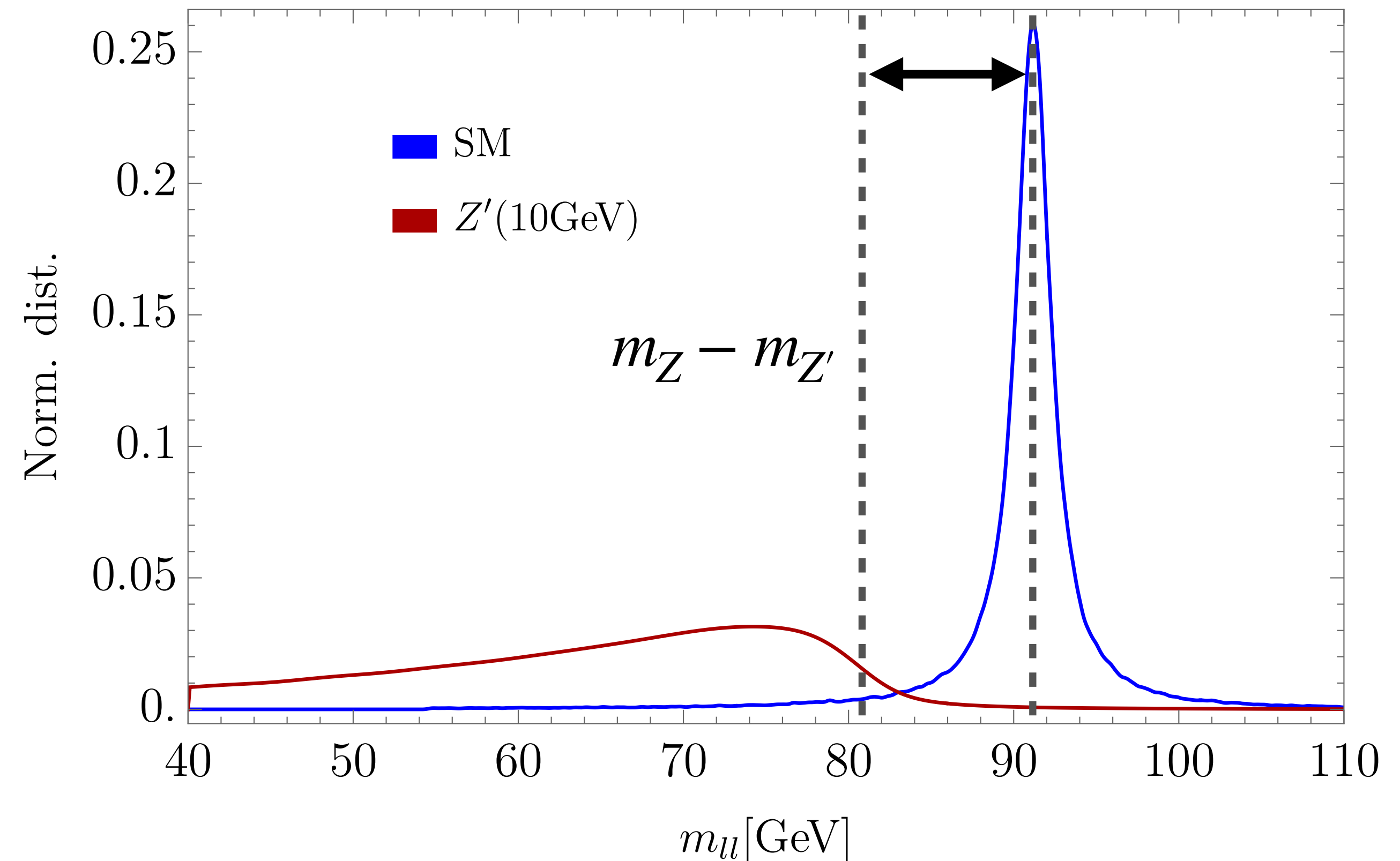
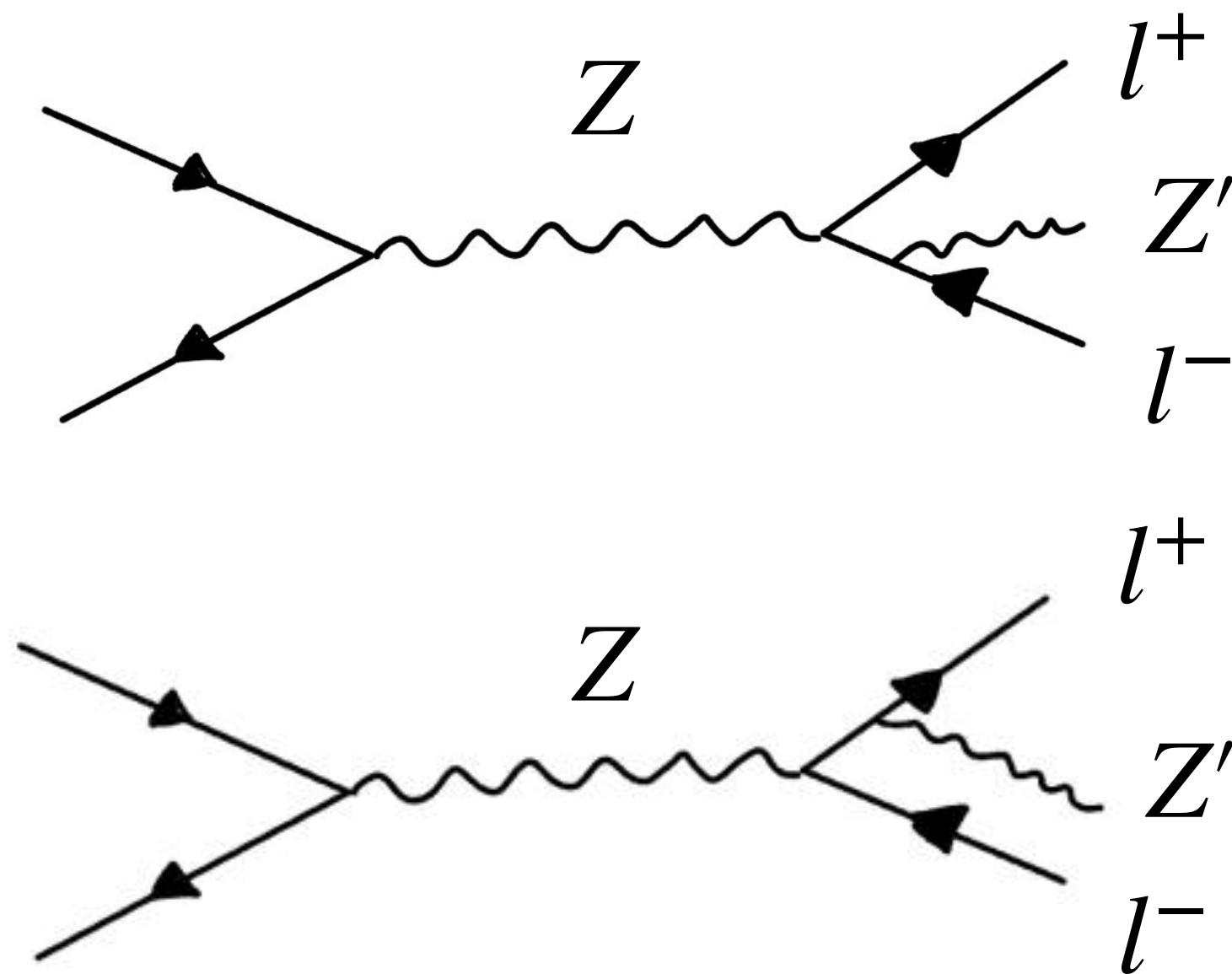


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It also modifies the Z decay!



We can veto on these events as far as $m_{Z'} > \Gamma_Z$

$$80 < m_{ll} [\text{GeV}] < 100$$

ATLAS

$$66 < m_{ll} [\text{GeV}] < 116$$

CDF

New physics in the W decay: $U(1)_{L_\mu-L_\tau} Z'$

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- The $\chi^2 \equiv \chi^2(m_W^{data}; m_W, g_{Z'}, m_{Z'})$ depends on three parameters ($m_W, g_{Z'}, m_{Z'}$)
- In principle m_W must float
- In practice, it is very hard for BSM to modify the best fit value of m_W

New physics in the W decay: $U(1)_{L_\mu-L_\tau} Z'$

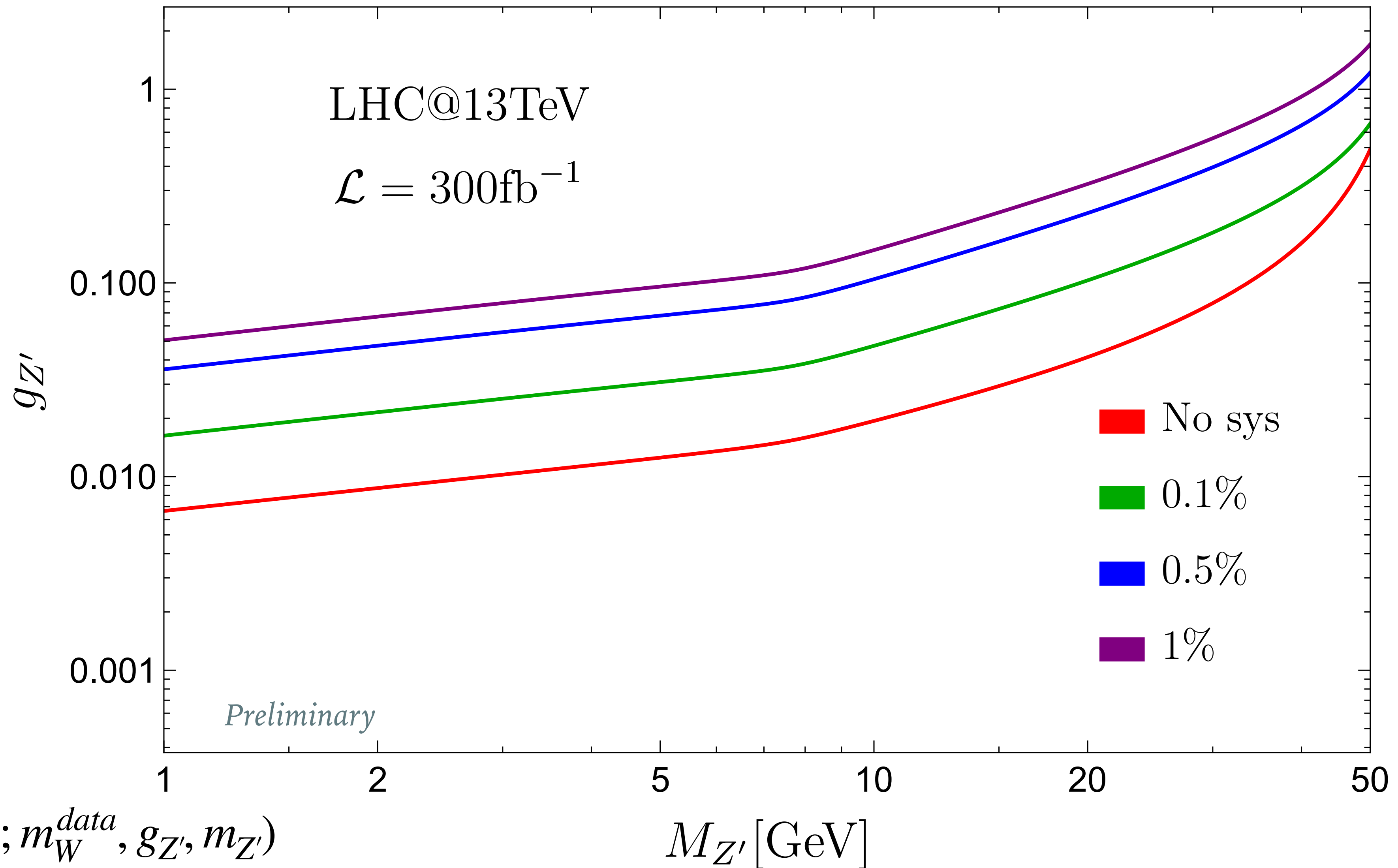
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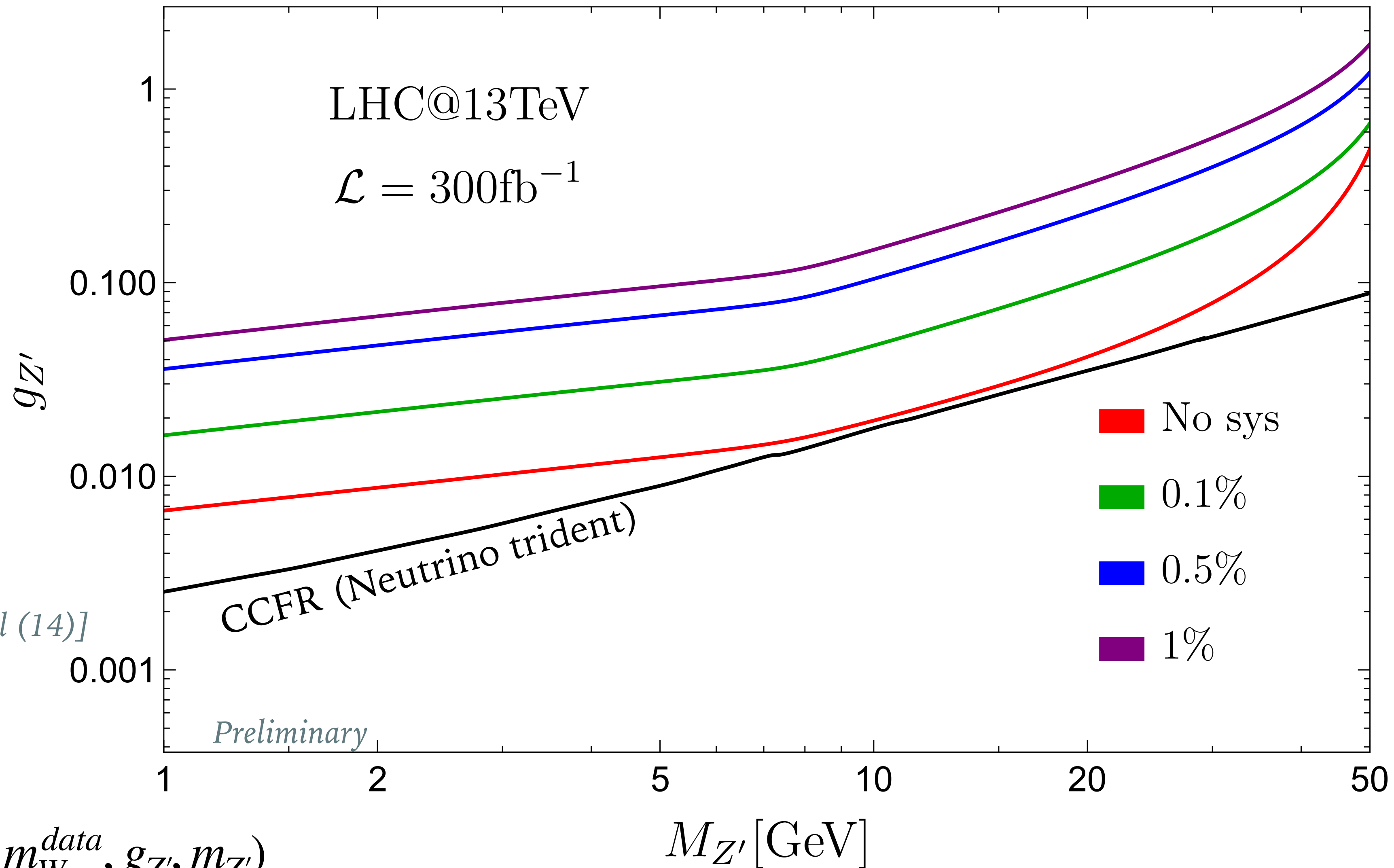
OUR ANALYSIS \longrightarrow

- MG+PYTHIA8+DELPHES(ATLAS)
- $u_T < 30 \text{ GeV}$ $p_l^T, p_{\text{miss}}^T > 20 \text{ GeV}$
- $\chi^2 = \chi_{p_l}^2 + \chi_{m_T}^2$
- Bins size: $p^T \rightarrow 0.5 \text{ GeV}$, $m_T \rightarrow 1 \text{ GeV}$
- Number of events normalised to the data

New physics in the W decay: $U(1)_{L_\mu-L_\tau} Z'$



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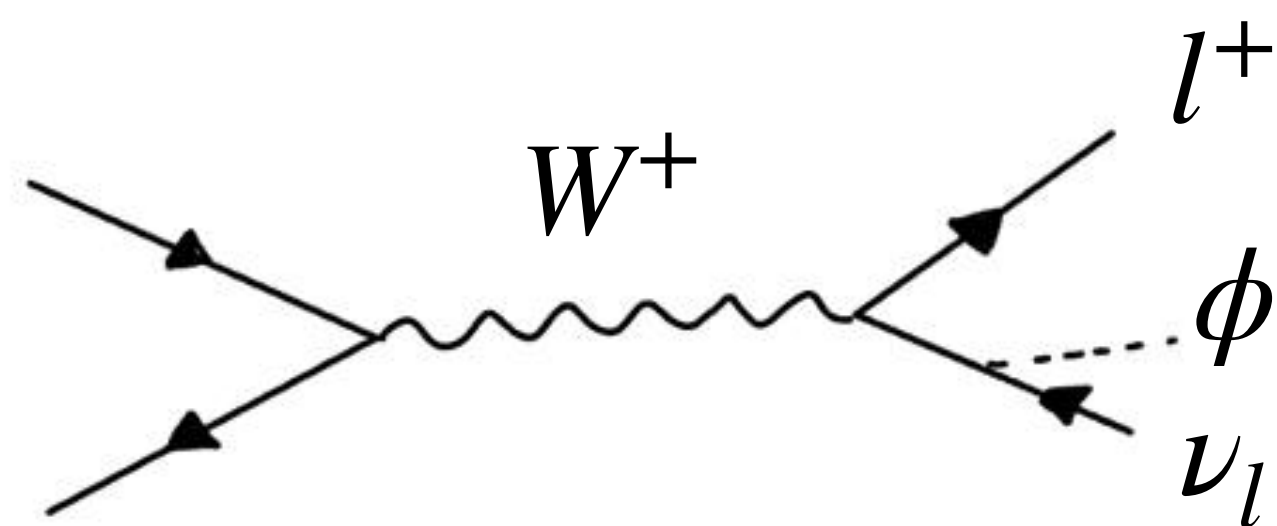


New physics in the W decay: Neutrinophilic scalar

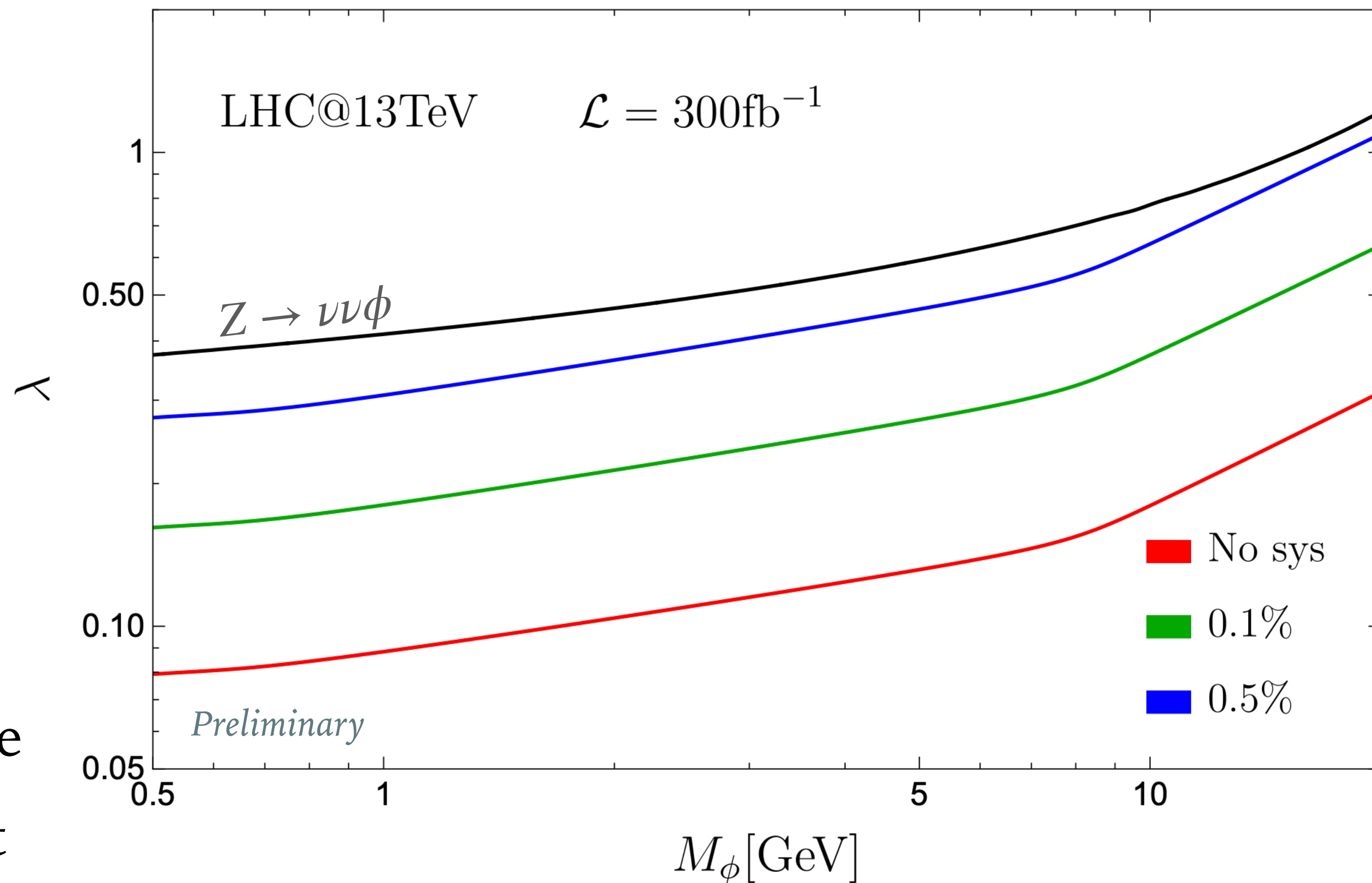
$$\mathcal{L}_{int} = \frac{\tilde{\lambda}}{\Lambda^2} (LH)(LH)\phi$$

$$\downarrow \langle H \rangle$$

$$\mathcal{L}_{int} = \frac{1}{2} \lambda \nu \nu \phi$$



- No new effects in the Z sample
- We don't need to worry about calibration



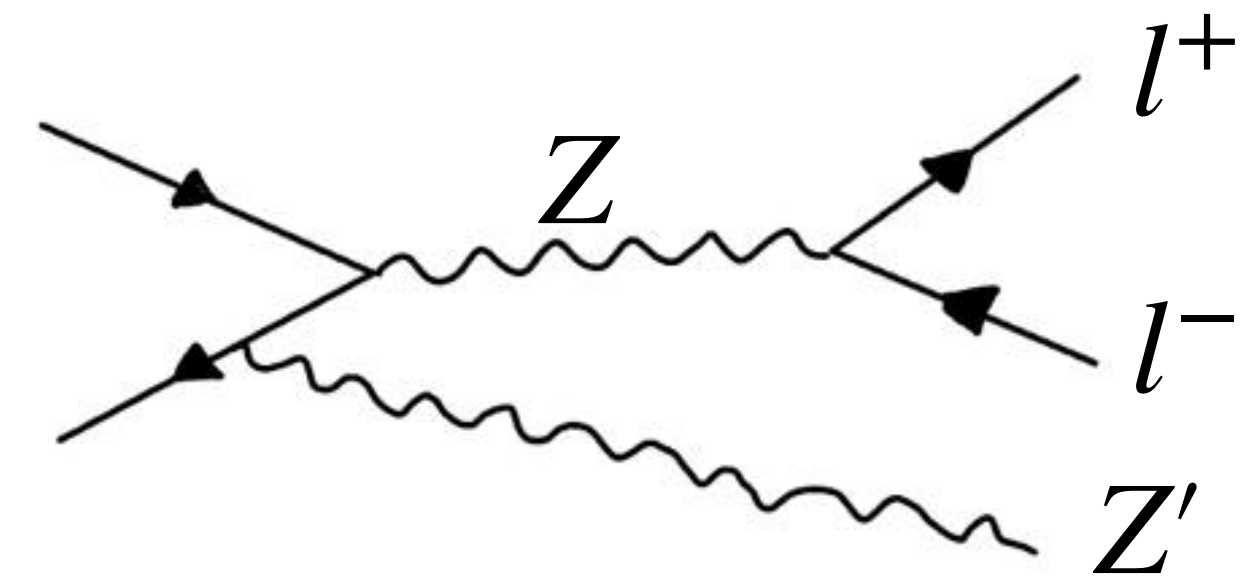
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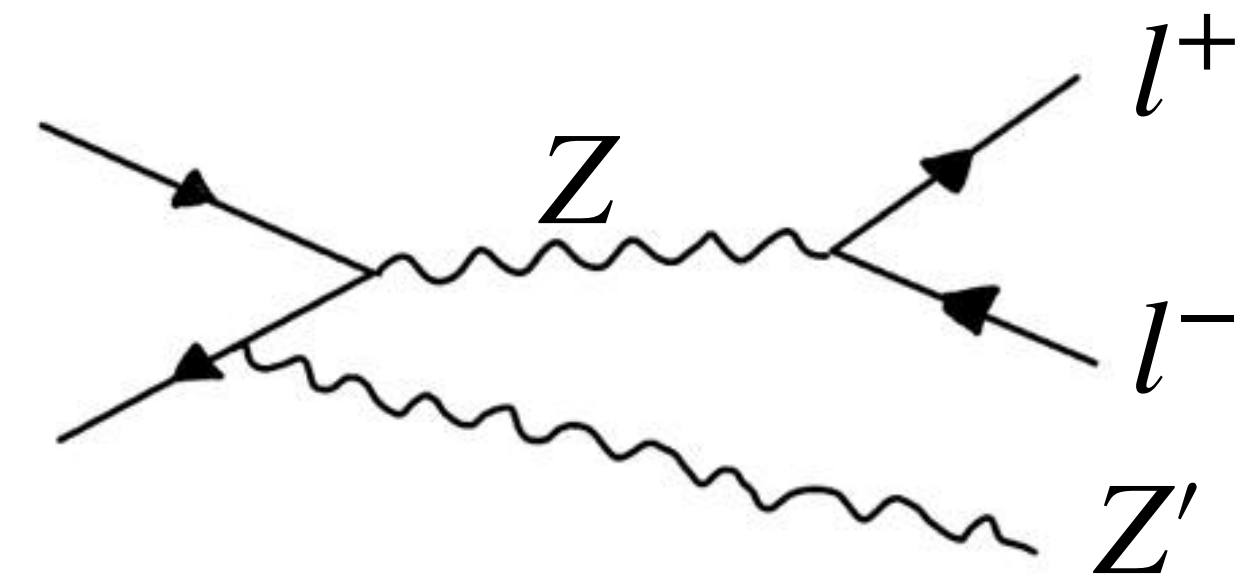
- New physics can modify the Z sample (and so the calibration)



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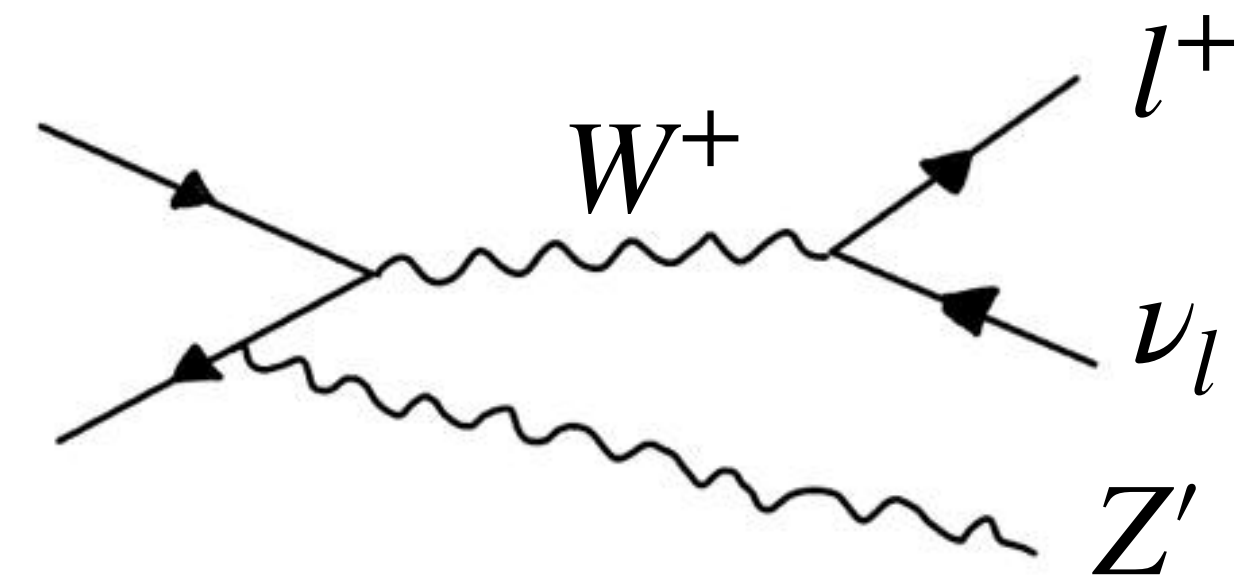
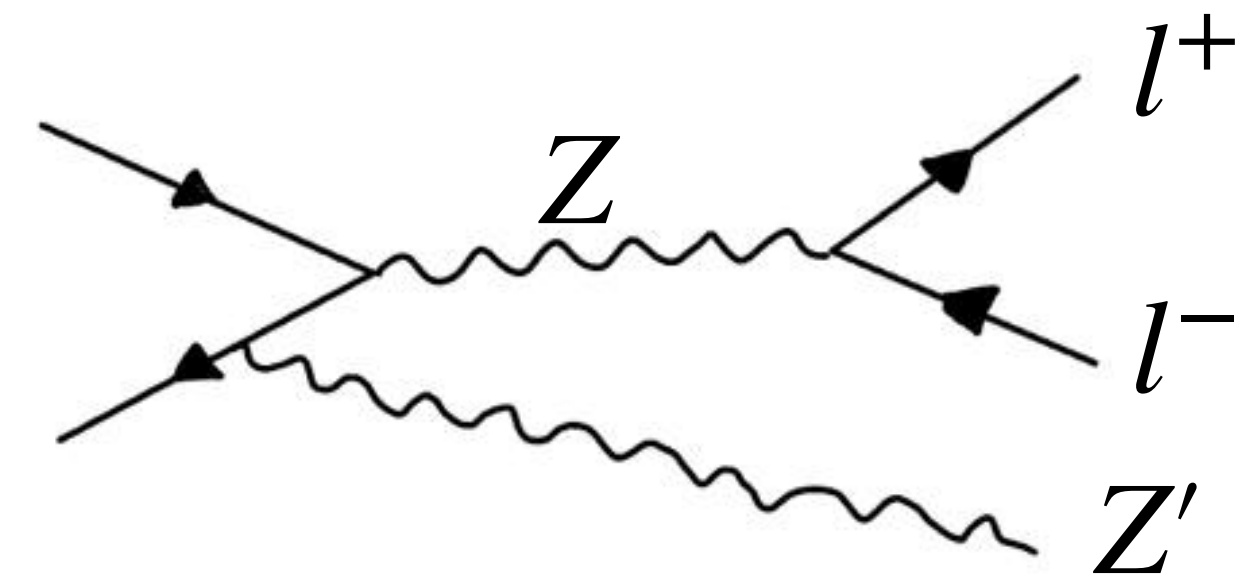
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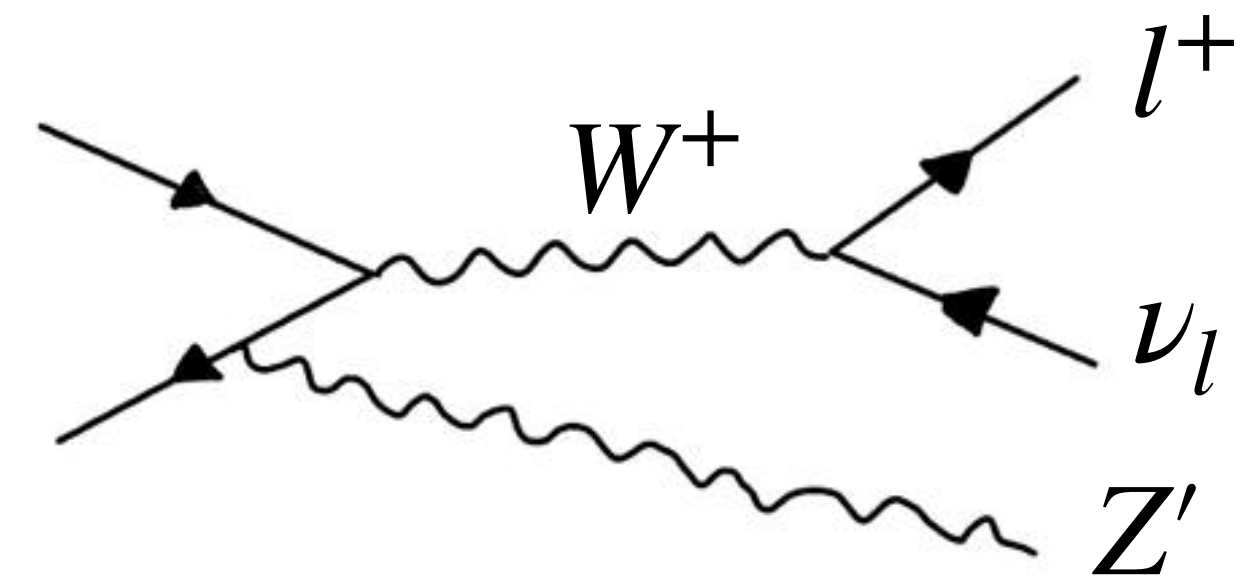
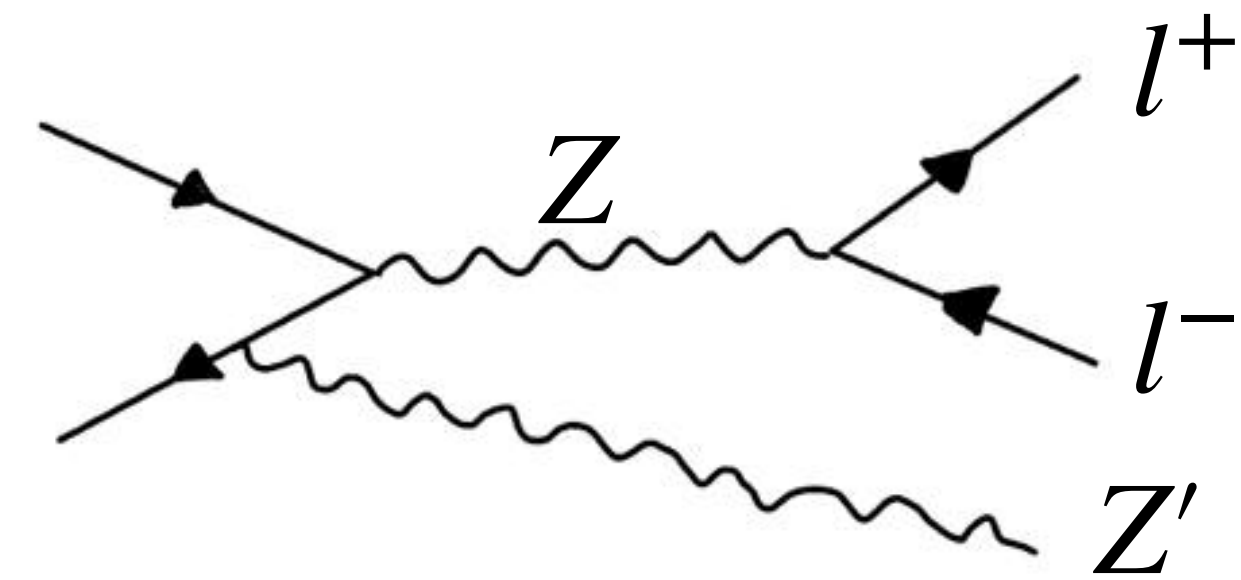


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$$p_{Z,l^+}^T \rightarrow p_{W,l^+}^T(pred) = p_{W,l^+}^T(meas)$$



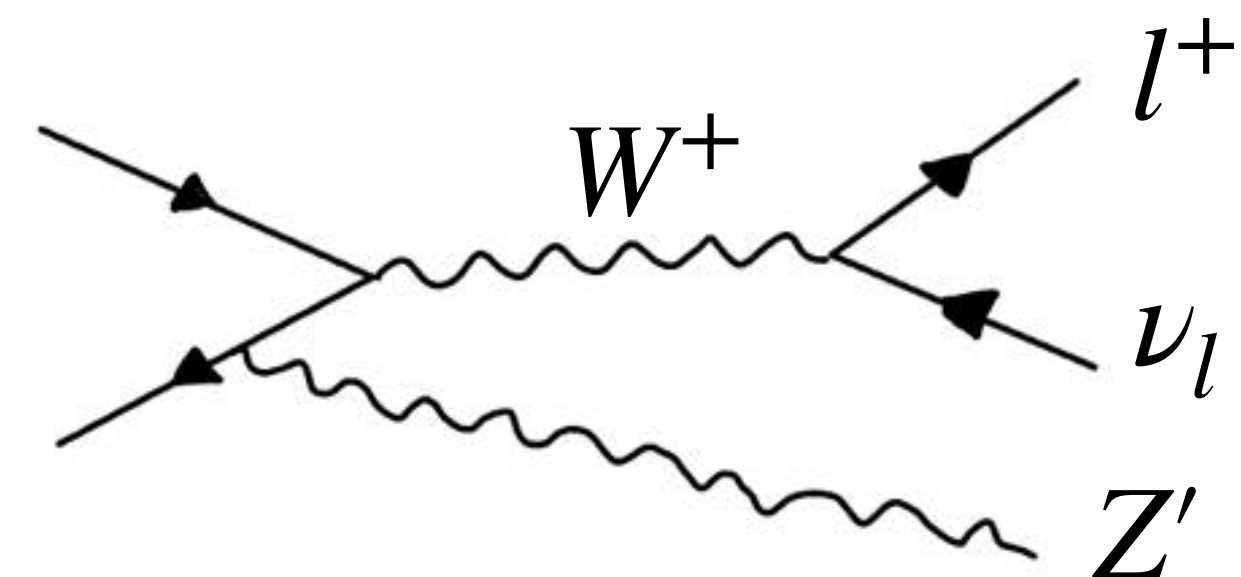
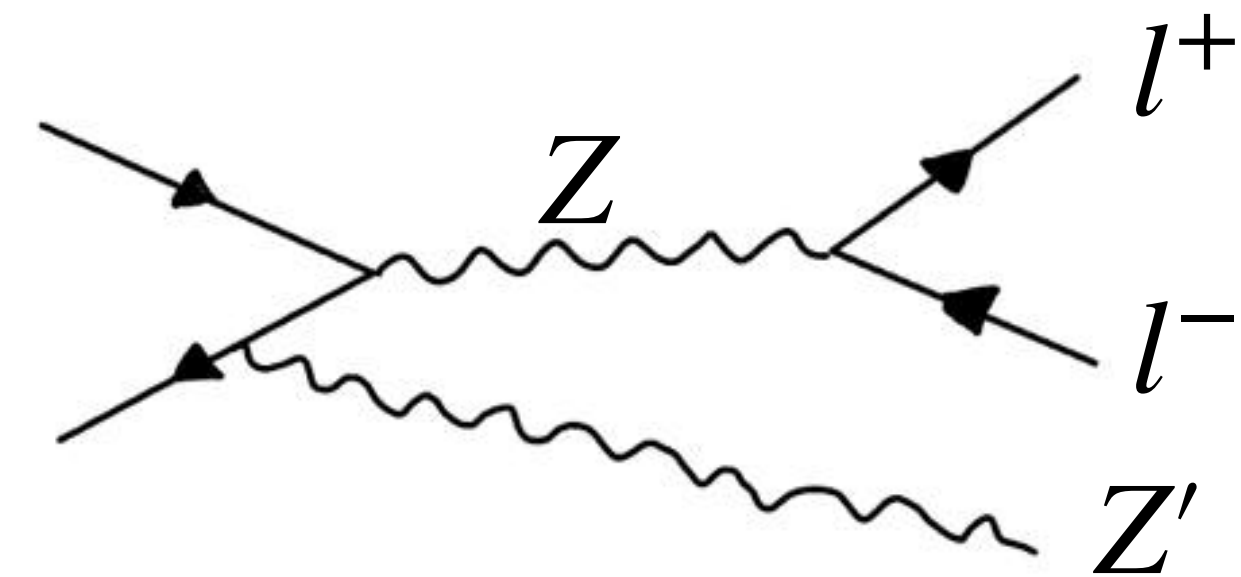
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$$p_{Z,l^-}^T \rightarrow p_{W,\nu_l}^T(pred) = p_{W,\nu_l+Z'}^T(meas) = p_{W,l^+}^T(meas)$$



New physics in the W production: Hadrophilic Z'

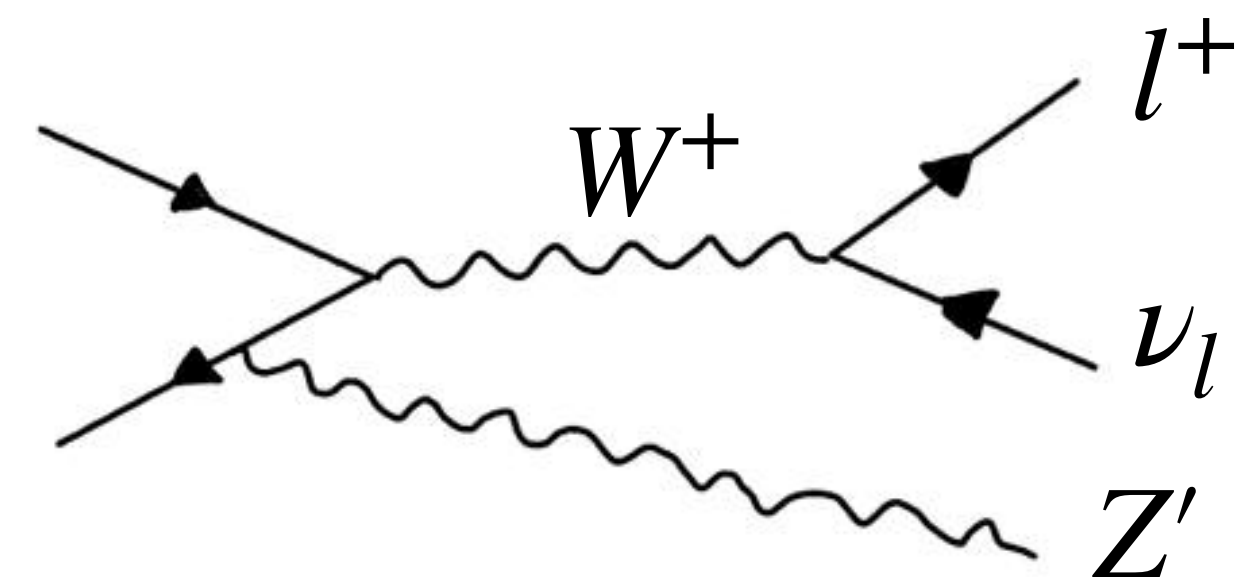
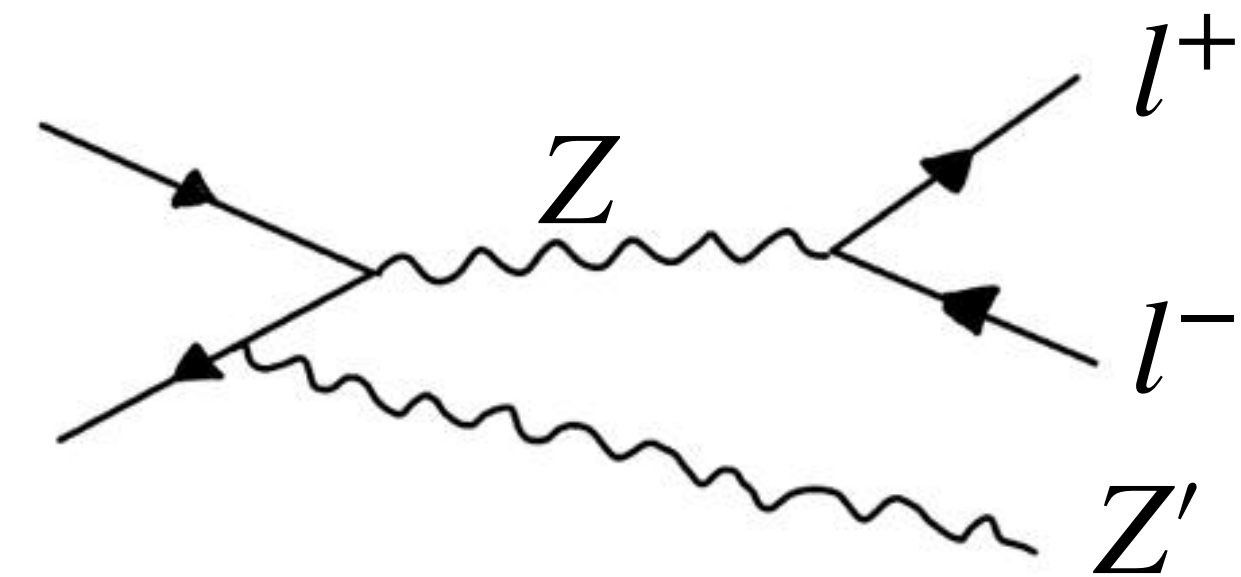
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$$m_T^Z \rightarrow m_T^Z(pred) \neq m_T^Z(meas)$$



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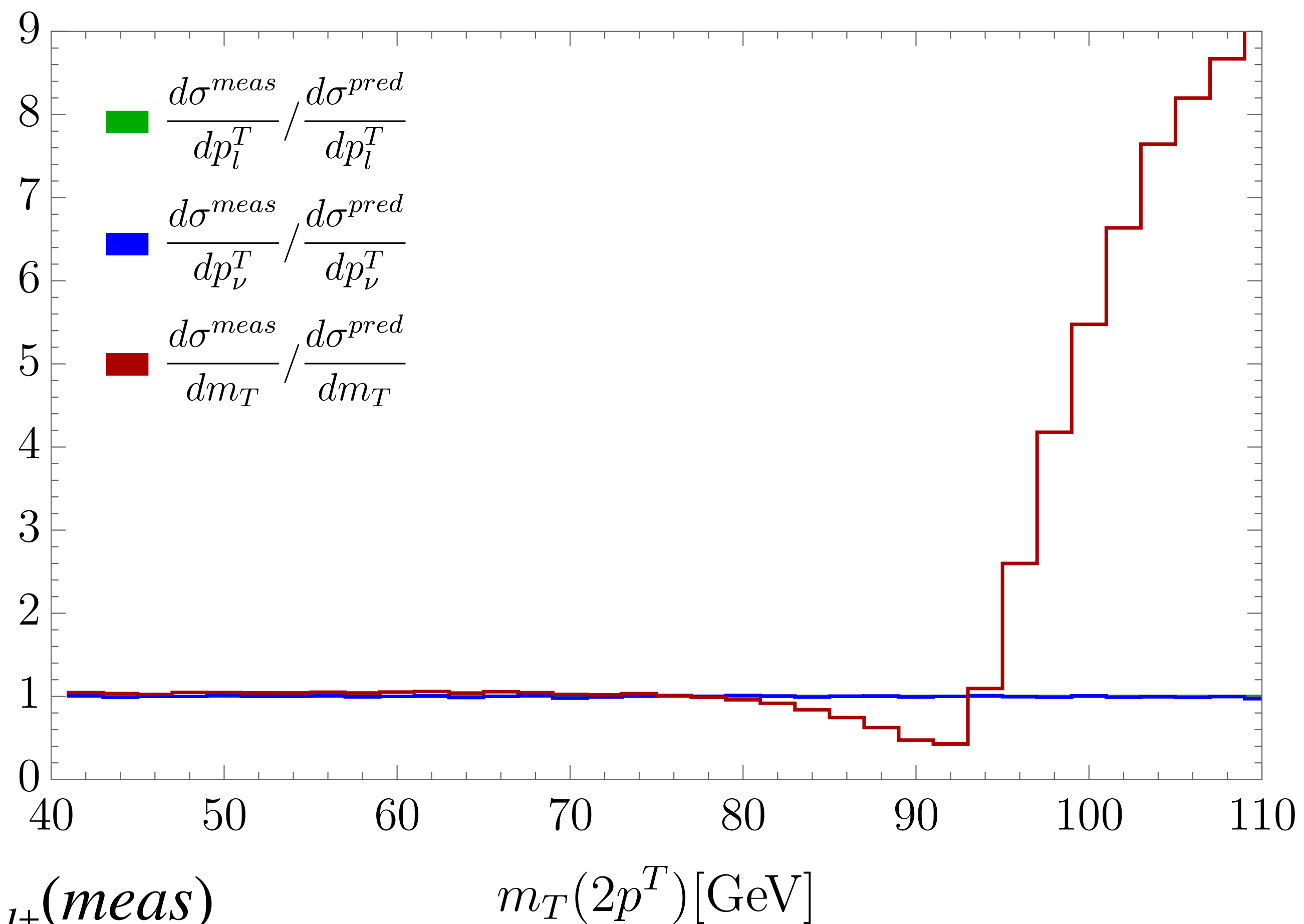
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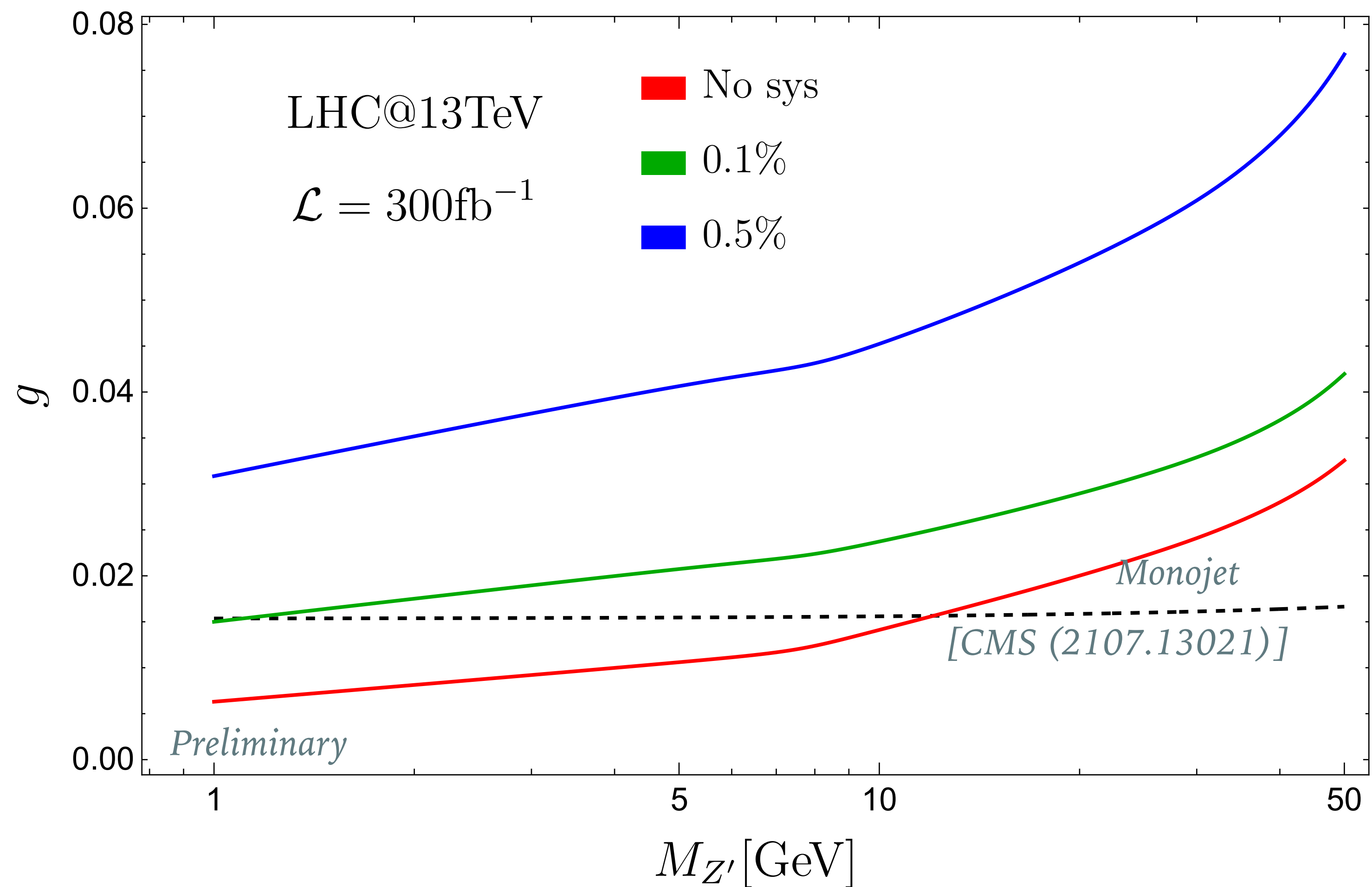


New physics in the W production: Hadrophilic Z'

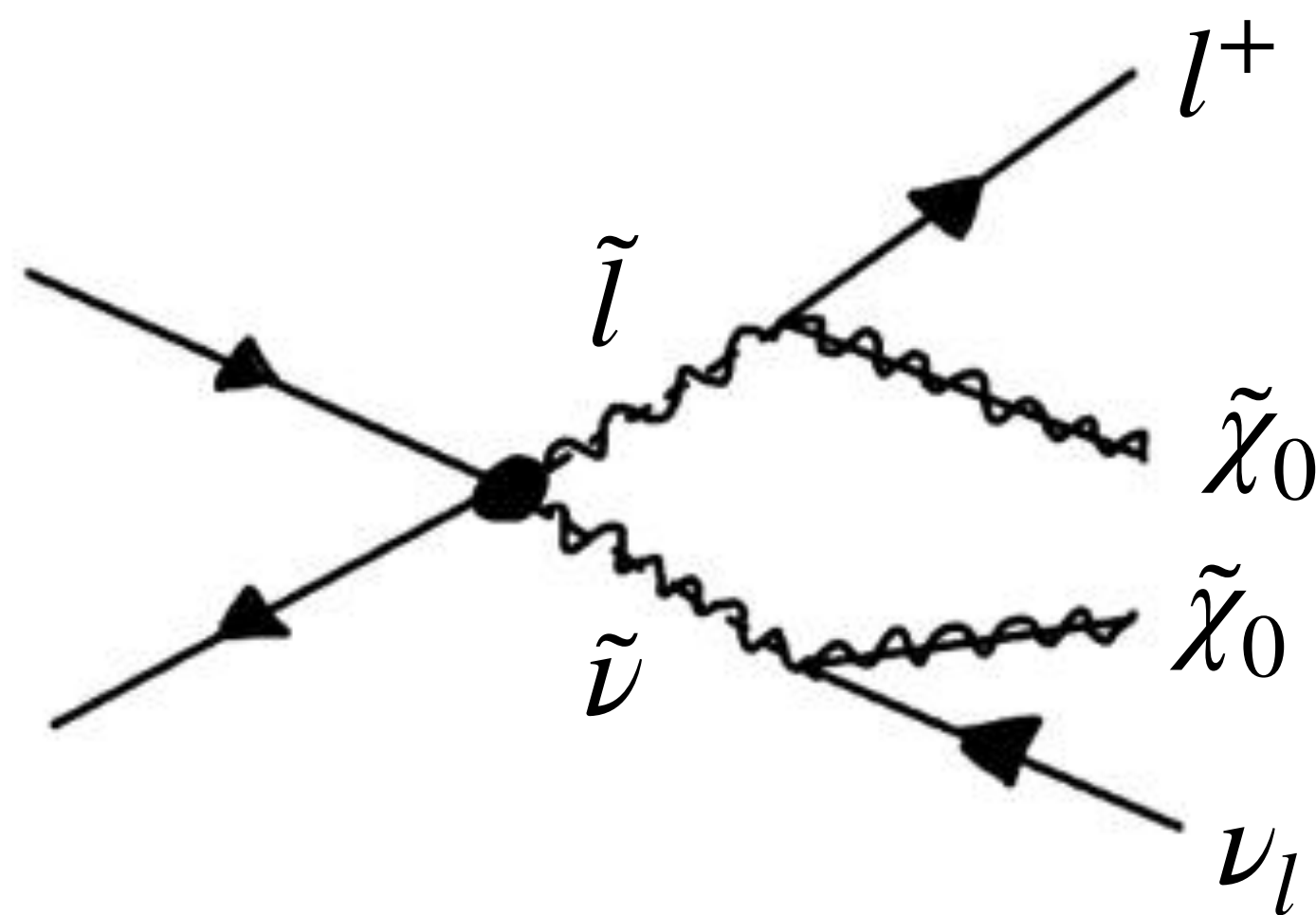
$$\mathcal{L} = -\frac{1}{4}F'^2 + \frac{1}{2}m_Z'^2 Z'^2 + g_{Z'} Z'_\mu J_B^\mu$$

- New physics can modify the Z sample (and so the calibration)
- A possible way out is to veto on Z+met

➤ *To cancel the gauge anomaly we need an anomalon sector and this may lead to additional constraints

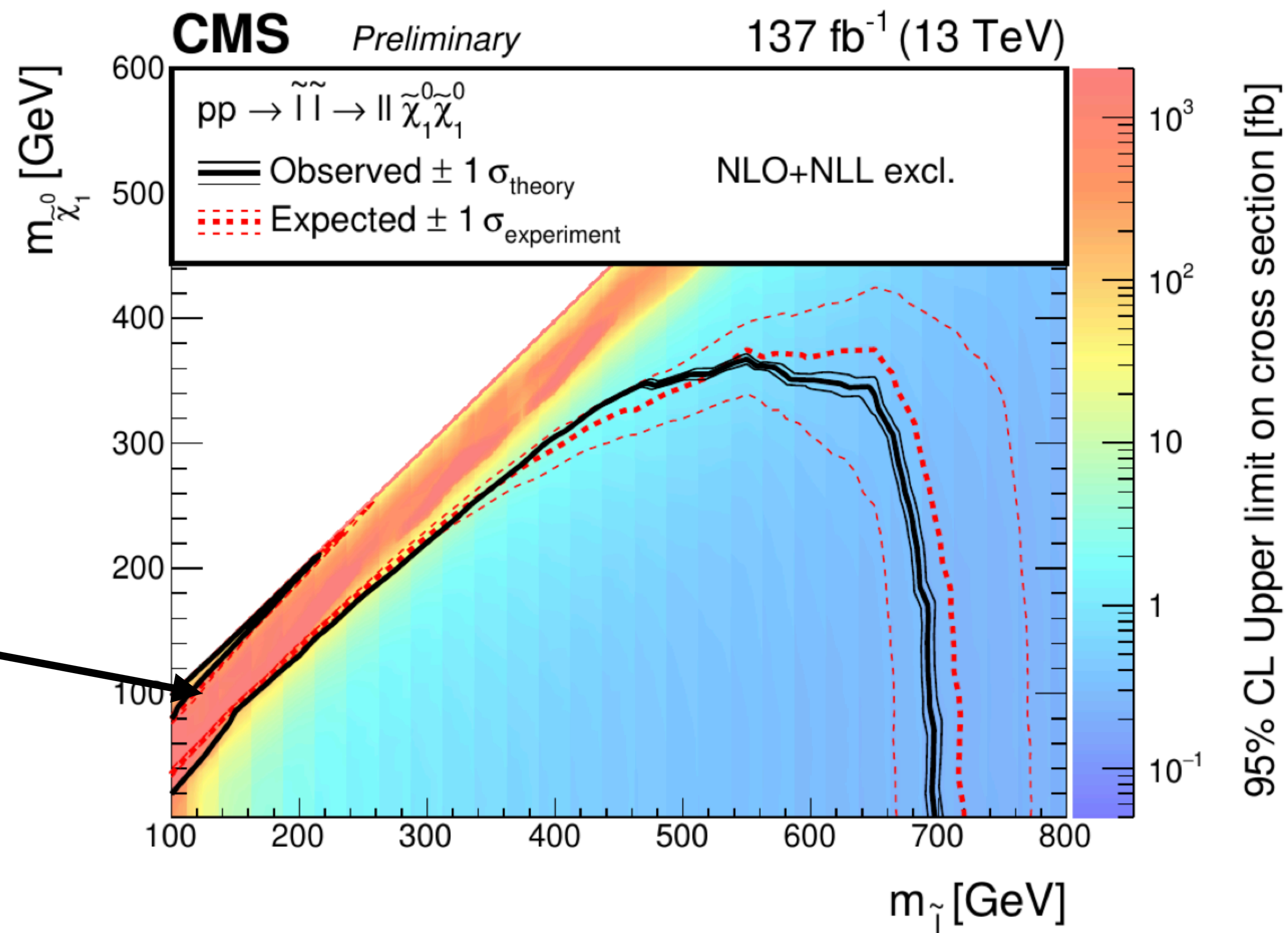


$l + met$ not from a W



This region is not covered
by “standard” searches

We can go in the SM region, where
NP contaminates the W sample



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See also [Curtin, Jaiswal, Maede (12); Curtin, Jaiswal, Maede, Tien (13)]

Conclusion & Outlook

- Invisibly decaying new physics is an irreducible background for the W mass measurement
- Suited kinematic cuts allows to veto BSM from Z decay (crucial for the data driven approach)
- We performed a comprehensive study of the relevant BSM phenomenology and found competitive constraints

Conclusion & Outlook

- Invisibly decaying new physics is an irreducible background for the W mass measurement
- Suited kinematic cuts allows to veto BSM from Z decay (crucial for the data driven approach)
- We performed a comprehensive study of the relevant BSM phenomenology and found competitive constraints
- Precise measurements of the SM parameters are highly non-trivial test of the SM and powerful probes for New Physics:
 - *Indirectly*, through the EW fit
 - *Directly*, through precision tests of the SM distributions



Thank you!