BSM theory perspectives for Run 3 and beyond

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Topics in BSM

- BSM is in part "opinion based", in part "evidence based"
- Driven by the shortcomings of the SM that we deem as important and timely to work on
- We are sure of nothing, but we try to imagine everything about how things could be and make sense of it.

- Lots of "ideas" build on past experience:
  - in the 60s & 70s: "*Gauge symmetry worked for QED let us do it for the other forces*"
  - today: "*The Higgs boson might be a composite like the pion, that is the lightest of the mesons*" or "*Symmetry protects the masses of fermions, let us do the same for Higgs boson(s)*" or "*There are flavors of fermions, let us do the same for Higgs boson(s)*"

Well recognized topics (including at this conference)

- "Straight Face" Supersymmetry
- EFT for decoupled New Physics
- BSM in Higgs (single couplings, self-coupling)
- New Vector-Like Fermions, Vector Resonances, Scalars
- Used to be "*off the beaten path*": See Andrea Thamm, Dipan Sengupta earlier in this conference
  - Dark Sectors (with and without resonances)
  - (Very) Light Particles (may overlap with Dark sector)
  - Long Lived Particles

Outline

- Run3 and HL-LHC highlights and strategic goals:
    - Precision era in SM measurements and BSM (look under every rock, even those you are “sure” they will bring no results)
    - Re-interpretation and re-use of results (SModelS, CheckMATE, Contour, …)
    - Impact on indirect limits for Future Colliders ($rate \sim M_{NP}^{-4}$)
    - High-p_T precision era

LHC has excluded light new physics, period.

Has it?

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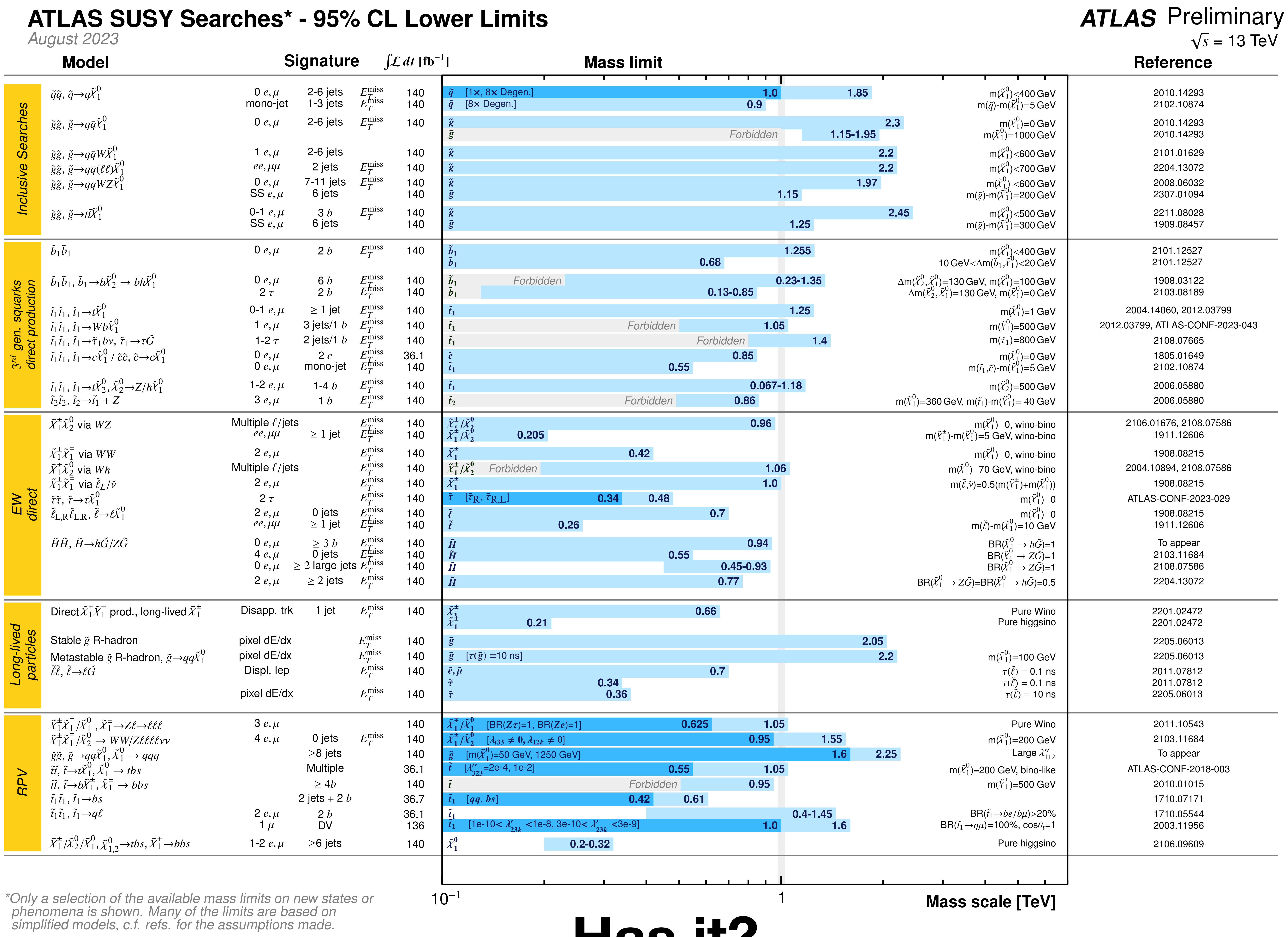

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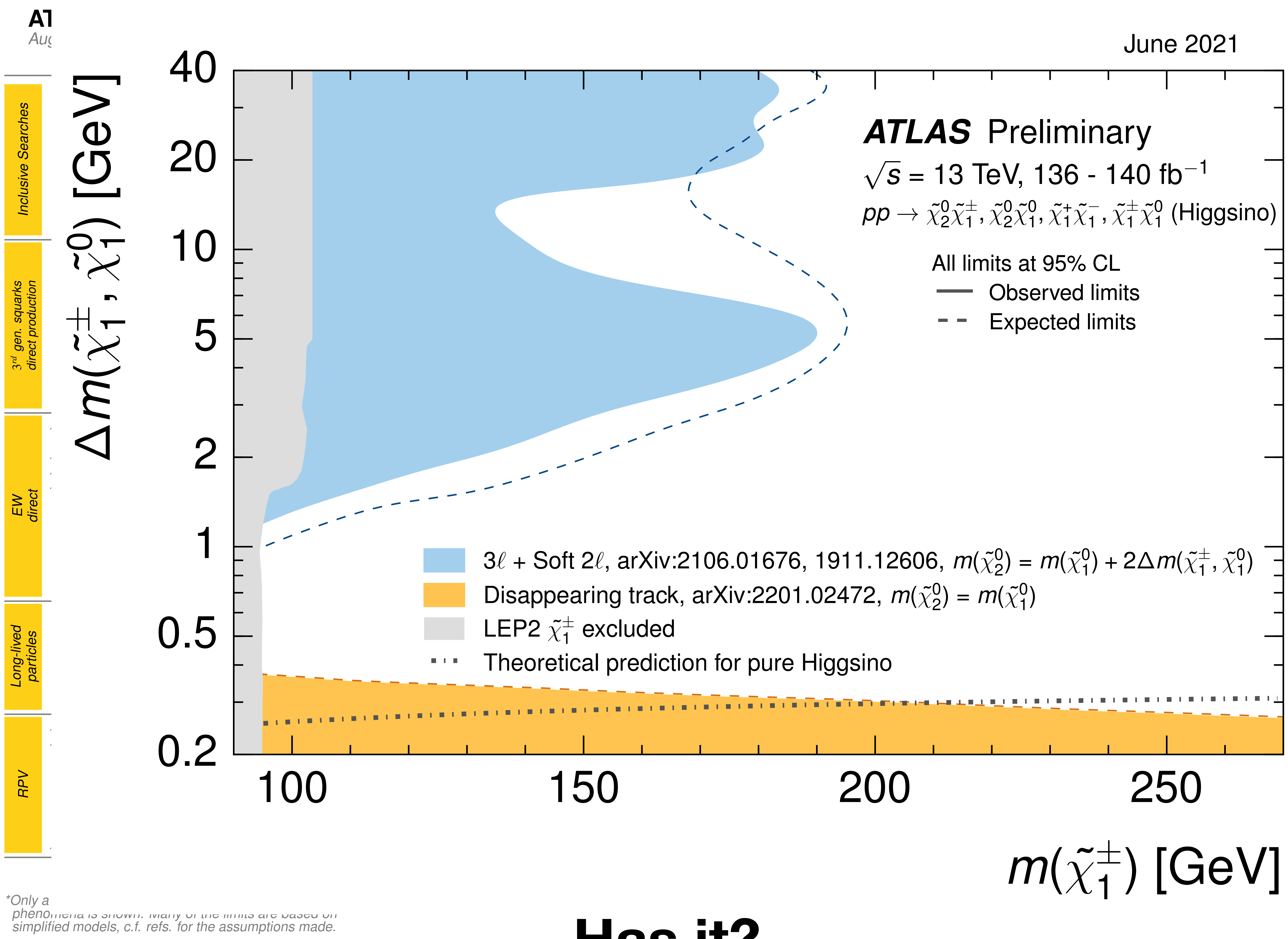

Has it?

Eur. Phys. J. C (2023) 83:718
https://doi.org/10.1140/epjc/s10052-023-11508-9

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

Measurements of W^+W^- production in decay topologies inspired by searches for electroweak supersymmetry

ATLAS Collaboration[⋆]

CERN, 1211 Geneva 23, Switzerland

Received: 1 July 2022 / Accepted: 9 October 2022

Abstract This paper presents a measurement of fiducial and differential cross-sections for W^+W^- production in proton–proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS experiment at the Large Hadron Collider using a dataset corresponding to an integrated luminosity of 139 fb^{-1}. Events with exactly one electron, one muon and no hadronic jets are studied. The fiducial region in which the measurements are performed is inspired by searches for the electroweak production of supersymmetric charginos decaying to two-lepton final states. The selected events have moderate values of missing transverse momentum and the 'stransverse mass' variable m_{T2}, which is widely used in searches for supersymmetry at the LHC. The ranges of these variables are chosen so that the acceptance is enhanced for direct W^+W^- production and suppressed for production via top quarks, which is treated as a background. The fiducial cross-section and particle-level differential cross-sections for six variables are measured and compared with two theoretical SM predictions from perturbative QCD calculations.

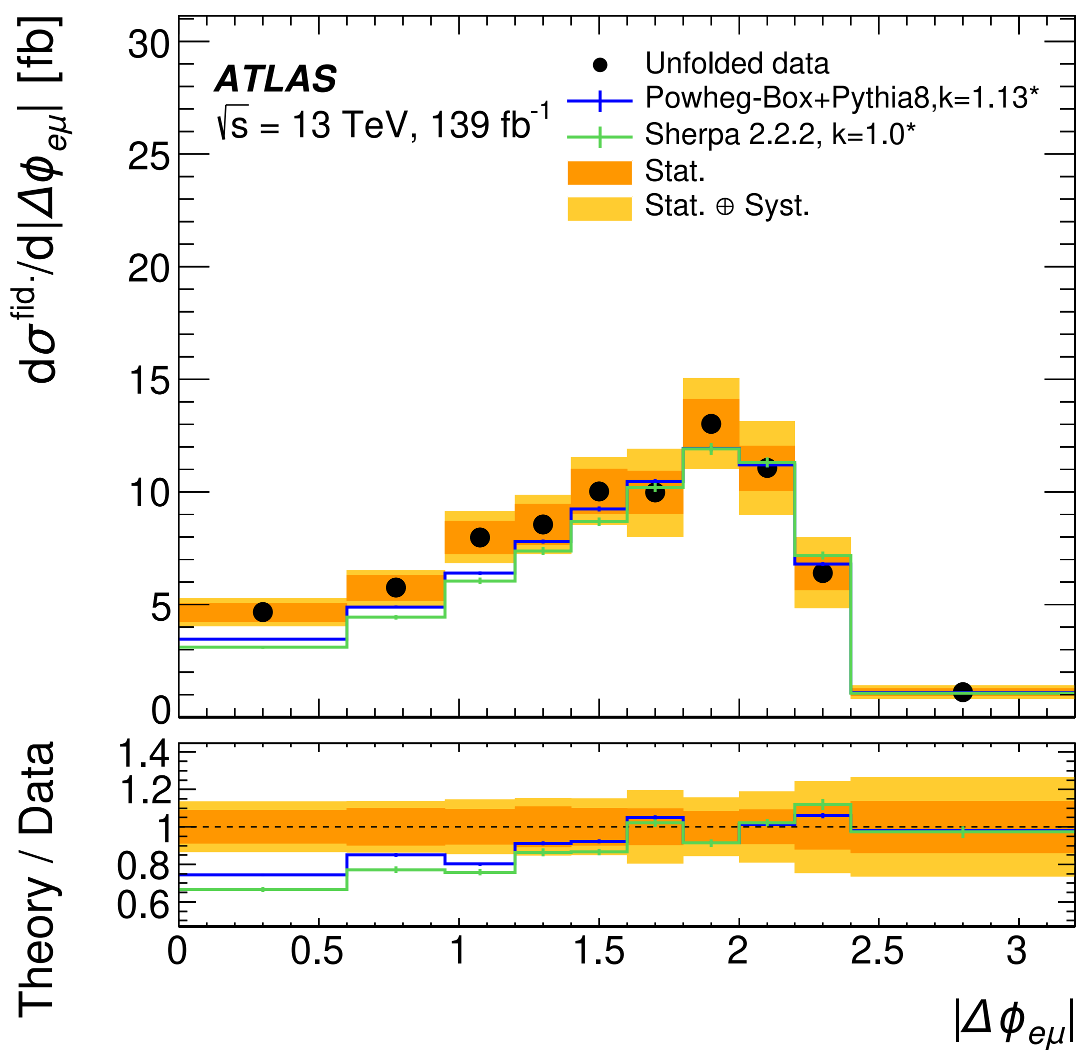

Table 4 Chi-squared per number of degrees of freedom χ^2/NDF for a comparison of unfolded distributions with different theory predictions. The calculation takes into account bin-by-bin correlations of systematic and statistical uncertainties. Uncertainties in the theory predictions are not considered

	$\|y_{e\mu}\|$	$\|\Delta\phi_{e\mu}\|$	$\cos\theta^*$	$p_T^{\text{lead}\,\ell}$	$m_{e\mu}$	$p_T^{e\mu}$
POWHEG BOX v2+PYTHIA 8 ($q\bar{q}$) and SHERPA 2.2.2+OPEN LOOPS (gg)	14.4/8	10.1/10	13.3/7	15.4/6	2.8/6	3.9/5
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Regular Article - Experimental Physics

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ATLAS Collaboration*
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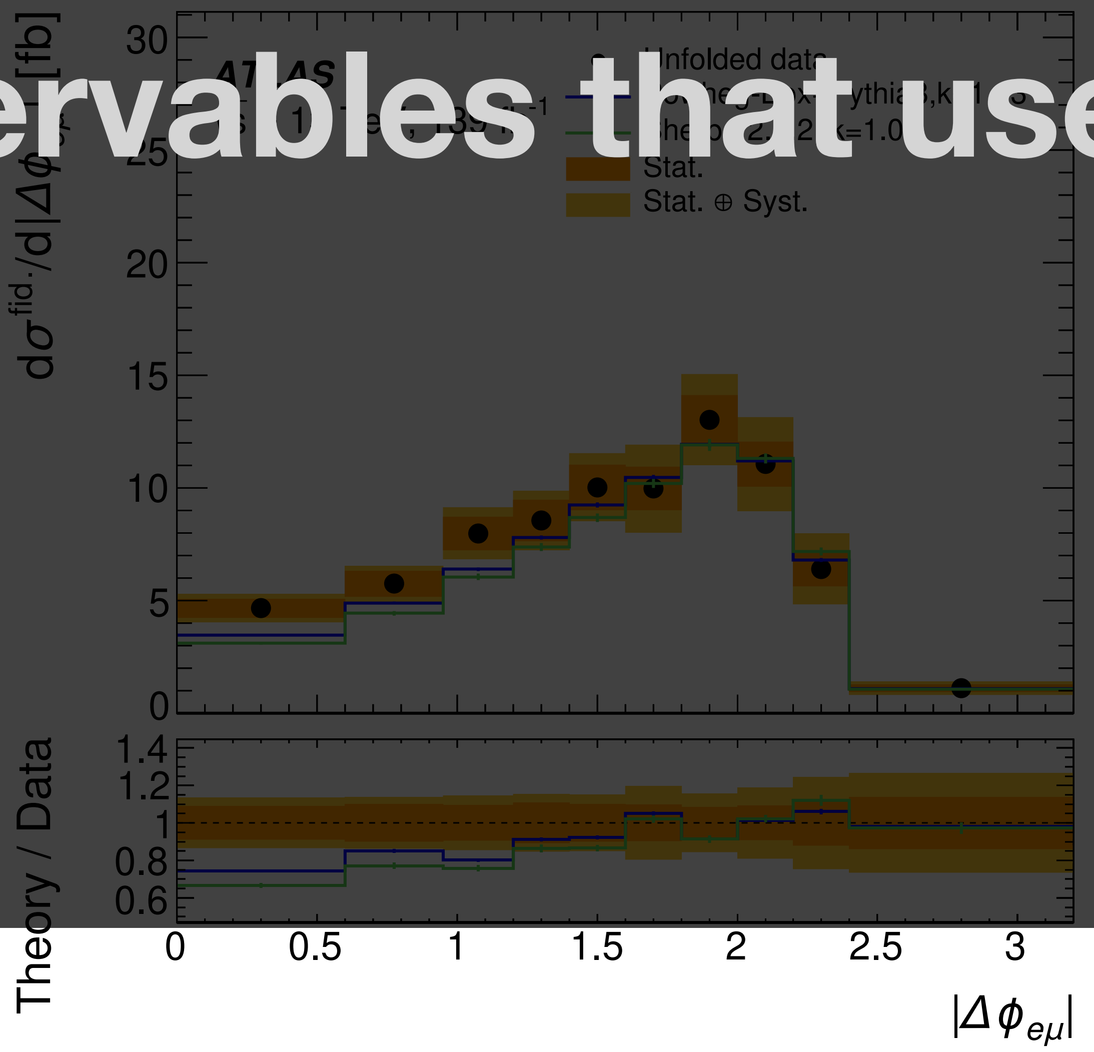
This is one example of reaching the finest control and the highest scrutiny for a measurement of SM final states (in observables that useful for BSM searches)

Abstract This paper presents a measurement of fiducial and differential cross-sections for W^+W^- production in proton–proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS experiment at the Large Hadron Collider using a dataset corresponding to an integrated luminosity of 139 fb^{-1}. Events with exactly one electron, one muon and no hadronic jets are studied. The fiducial region in which the measurements are performed is inspired by searches for the electroweak production of supersymmetric charginos decaying to two-lepton final states. The selected events have moderate values of missing transverse momentum and the 'stransverse mass' variable m_{T2}, which is widely used in searches for supersymmetry at the LHC. The ranges of these variables are chosen so that the acceptance is enhanced for direct W^+W^- production and suppressed for production via top quarks, which is treated as a background. The fiducial cross-section and particle-level differential cross-sections for six variables are measured and compared with two theoretical SM predictions from perturbative QCD calculations.



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STANDARD & MODEL

SEARCH & MEASURE

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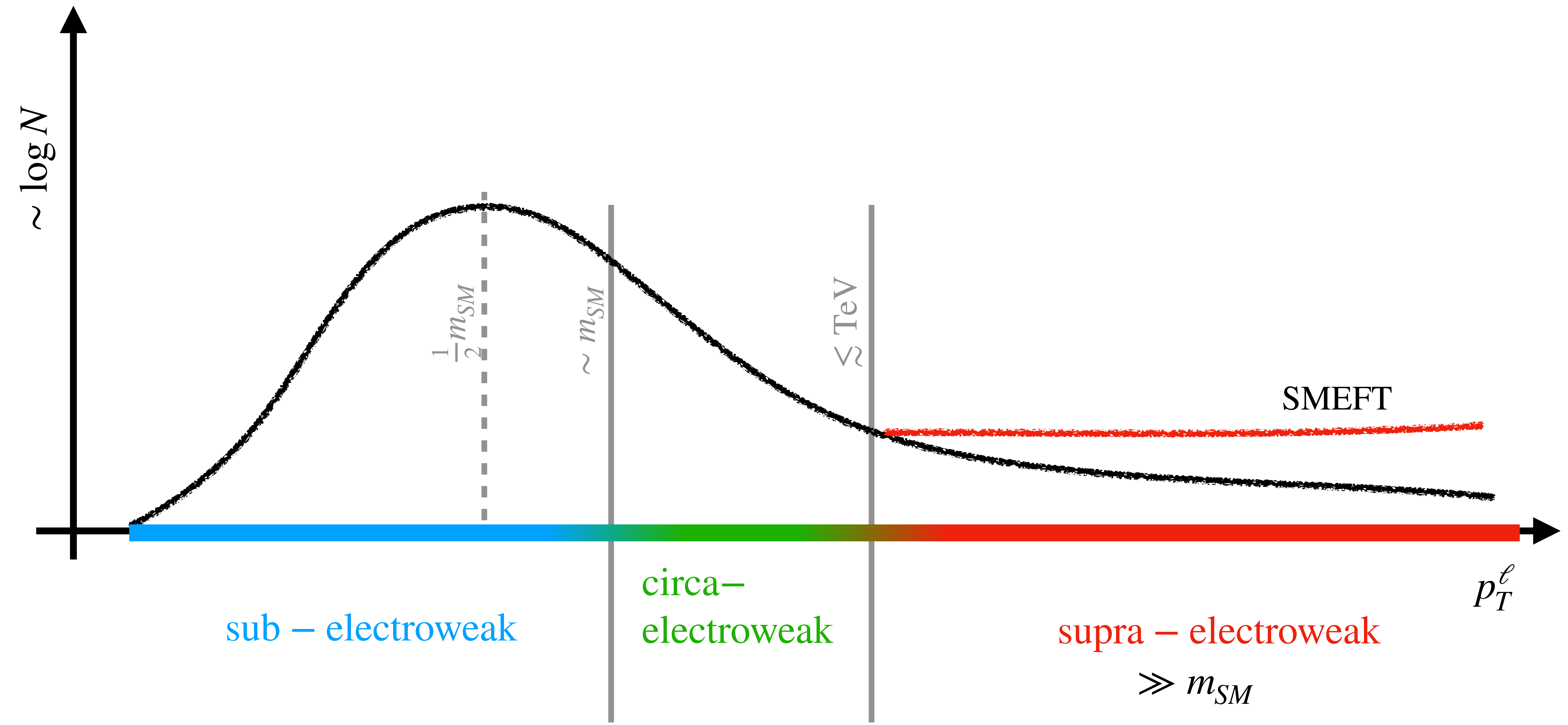
2301.04407, 2312.09794 Bagnaschi, Corcella, RF, Sengupta



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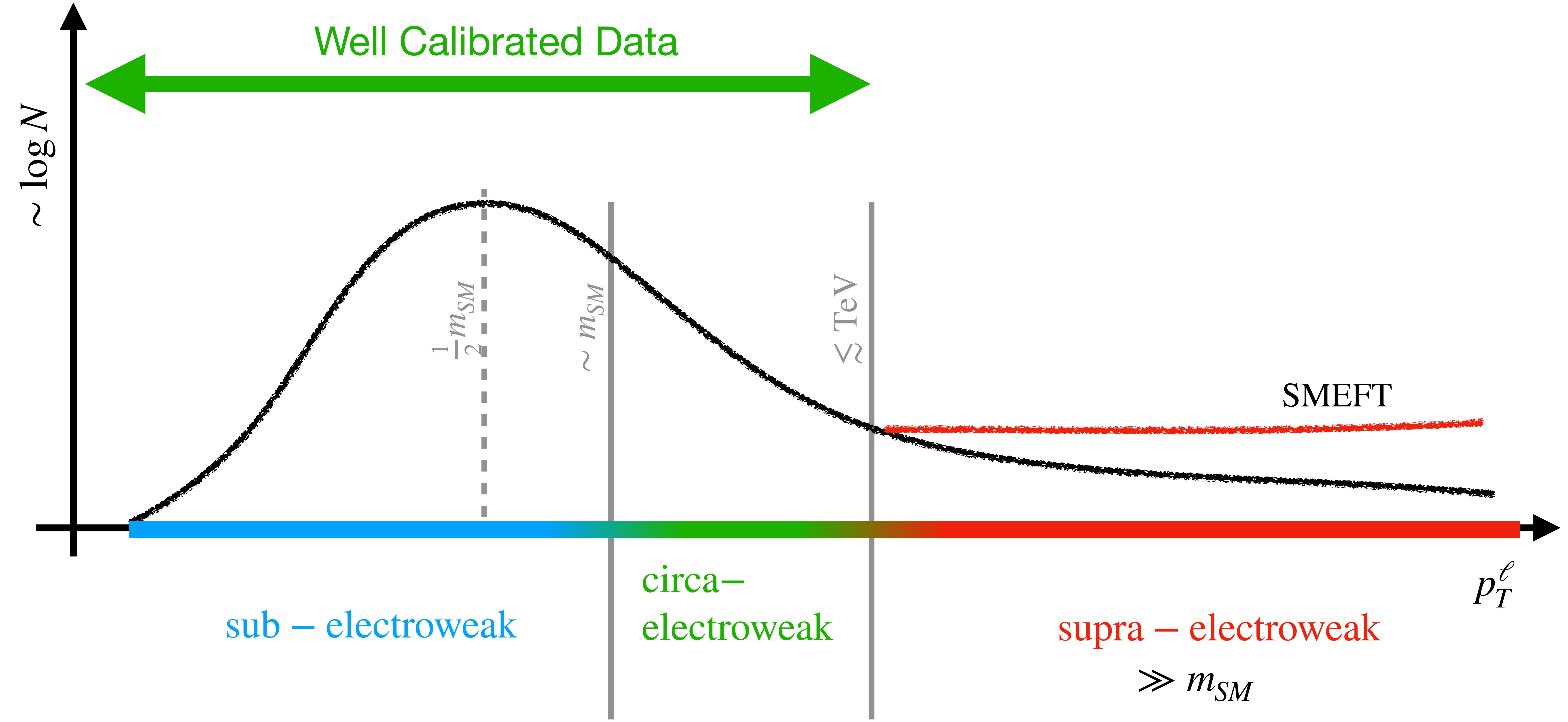

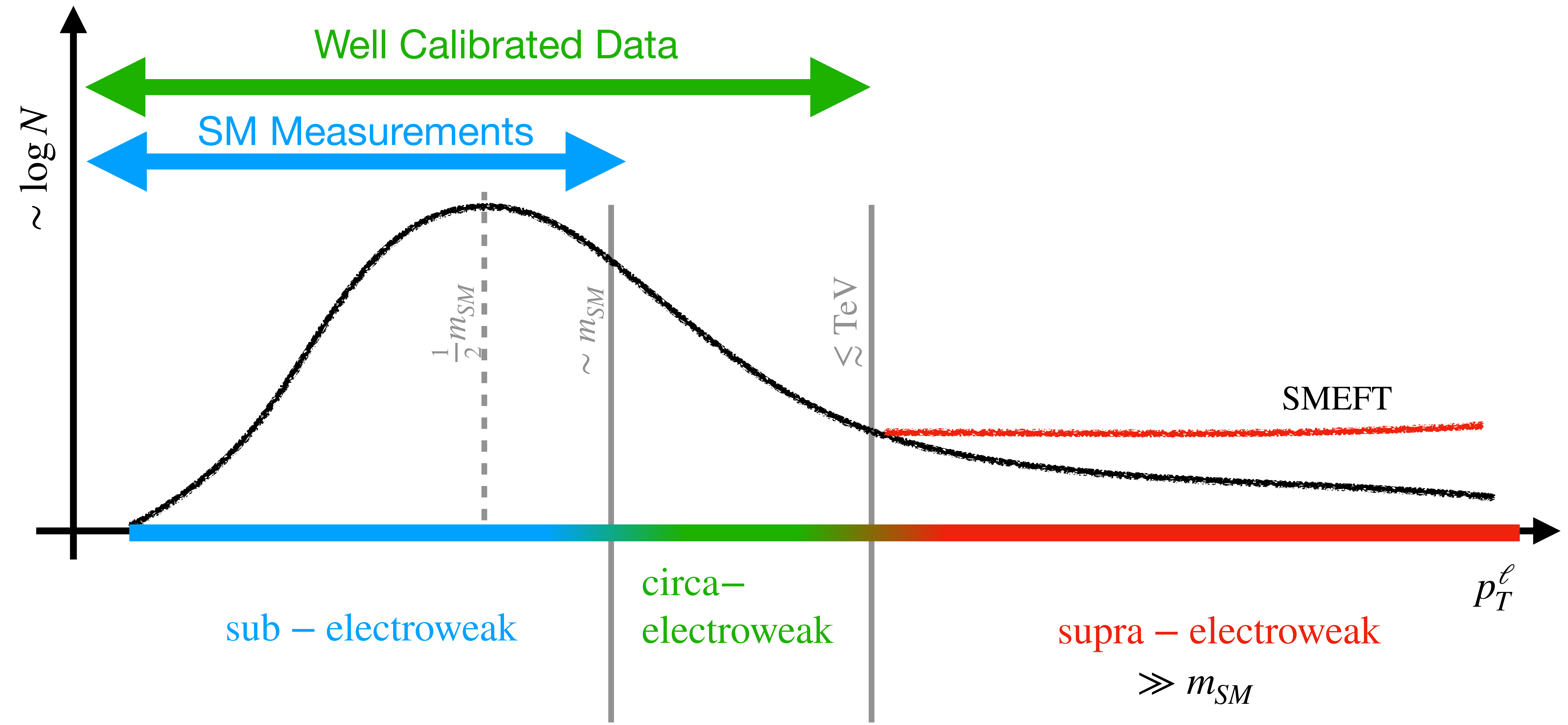
Well Calibrated Data
SM Measurements
~ log N
$\frac{1}{2} m_{SM}$
$\sim m_{SM}$
$\lesssim$ TeV
SMEFT
p_T^ℓ
sub – electroweak
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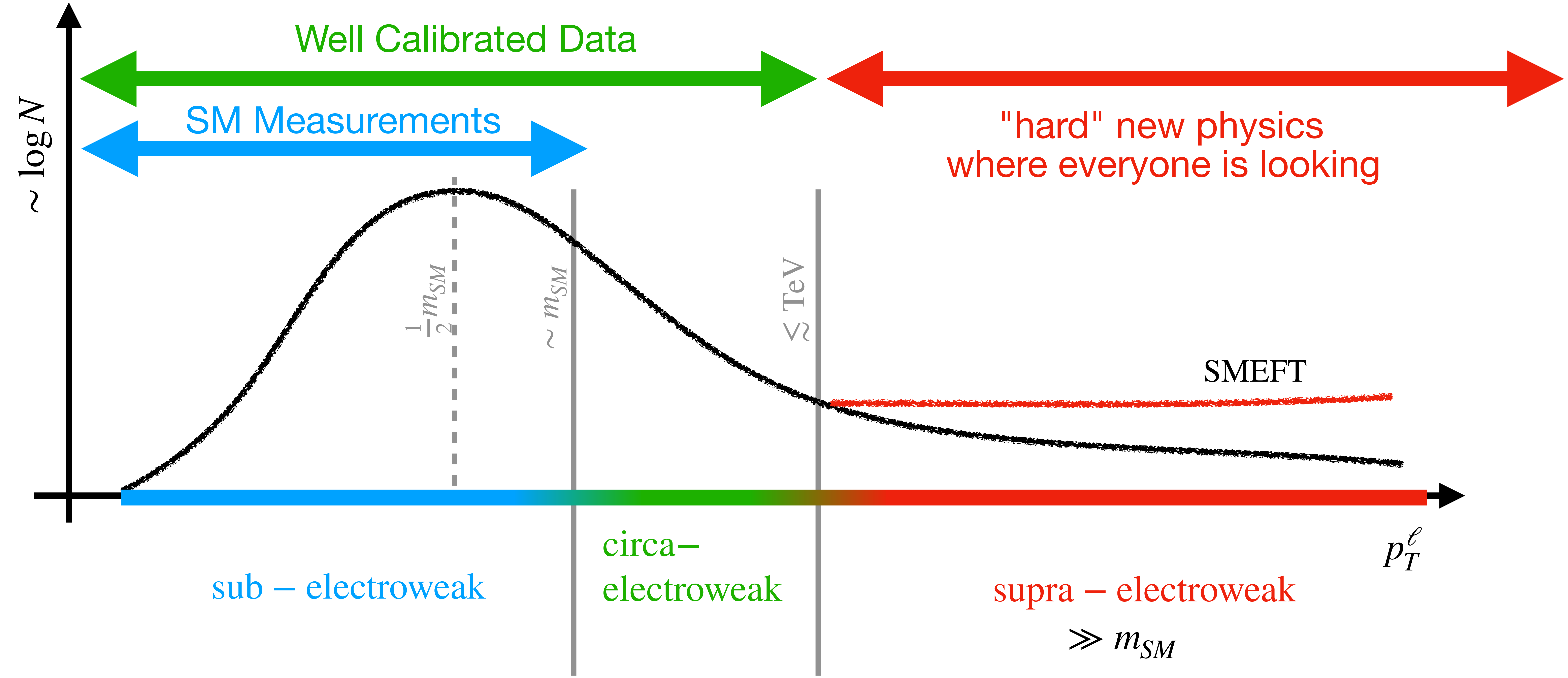
$\gg m_{SM}$


Well Calibrated Data
SM Measurements
"hard" new physics
where everyone is looking
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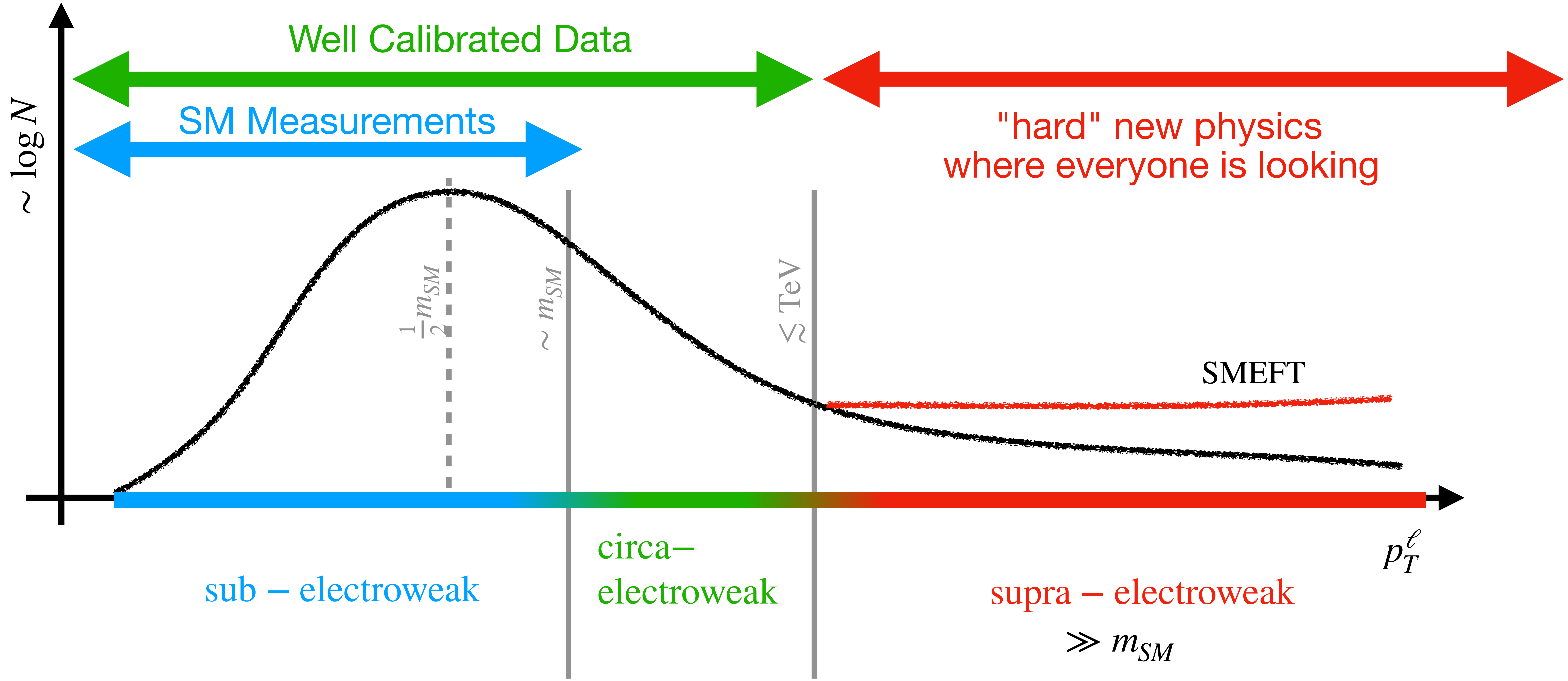

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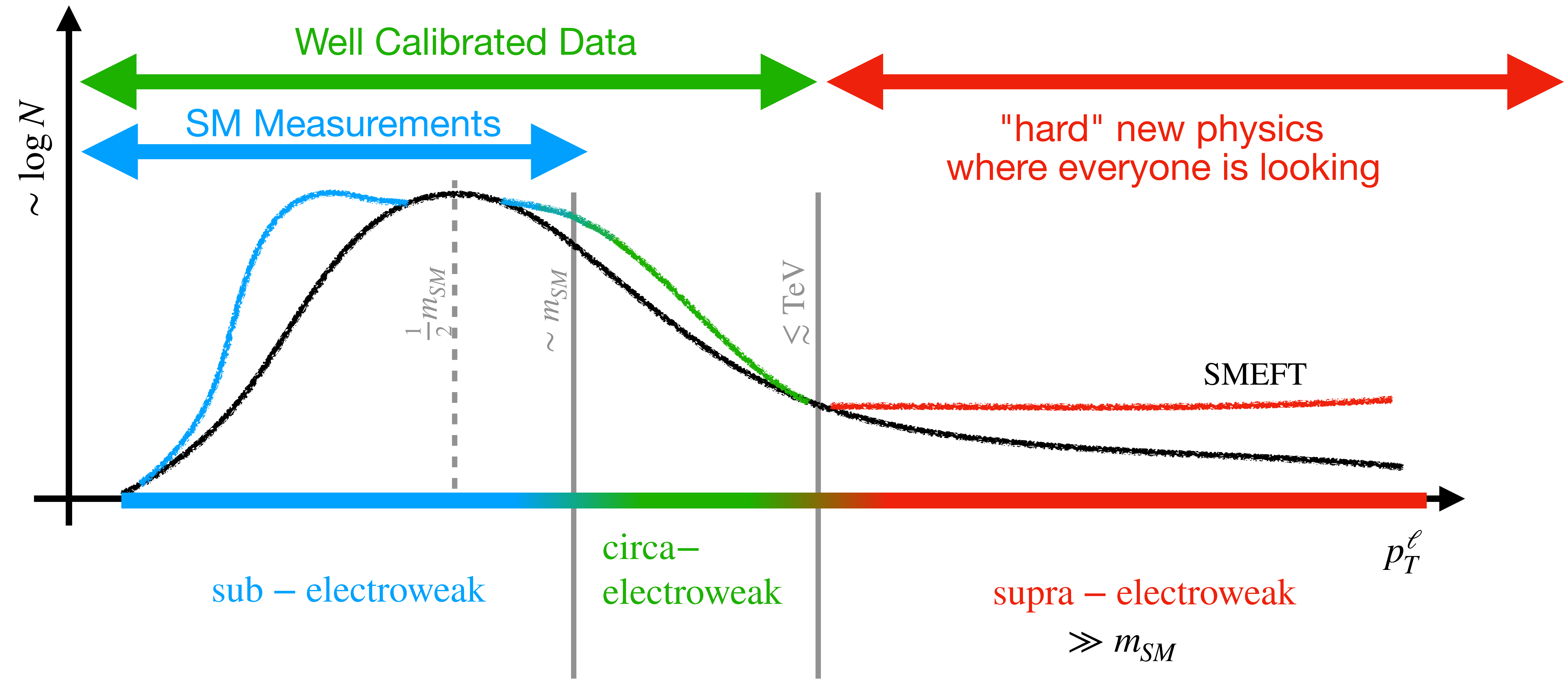
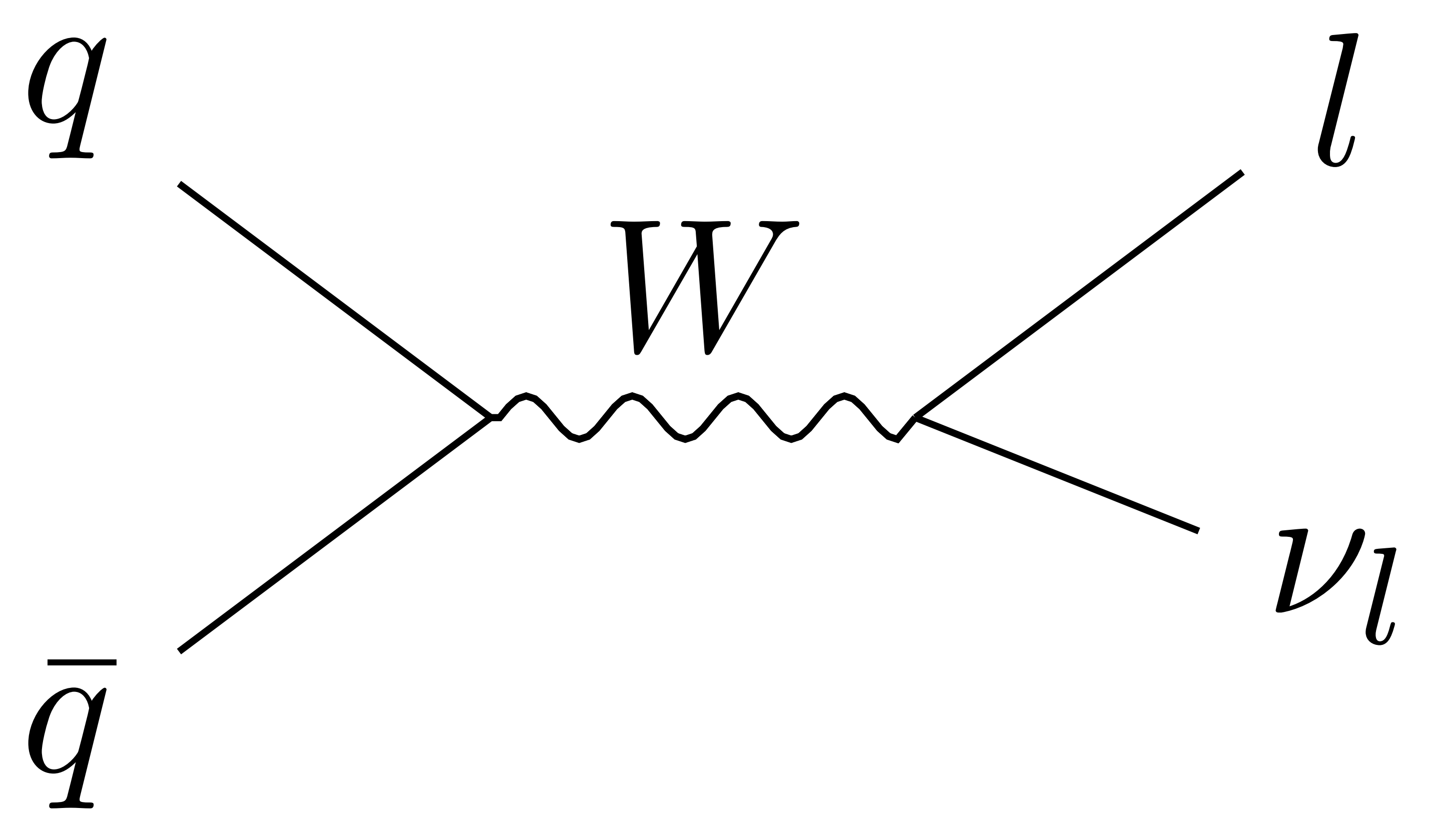
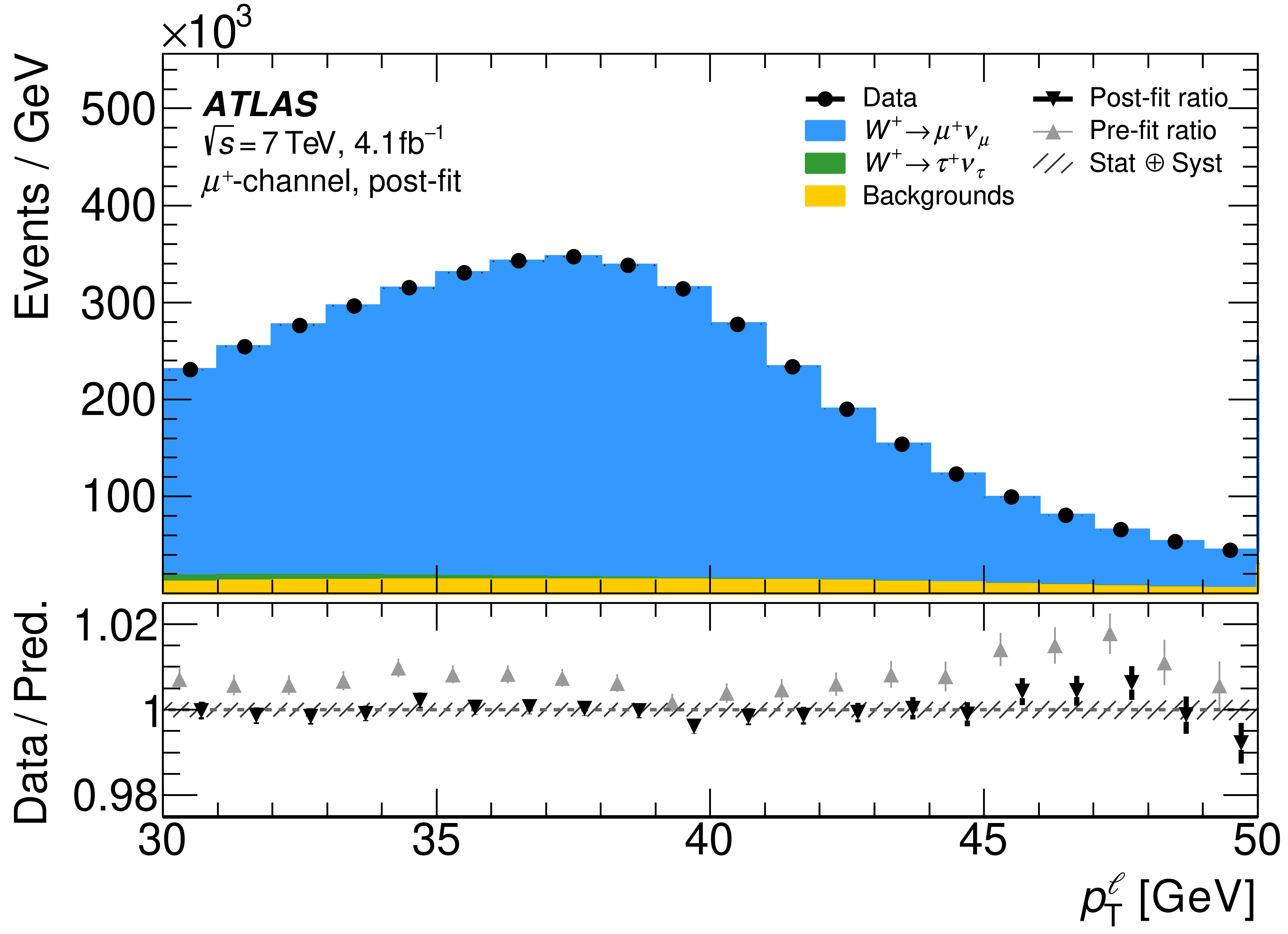
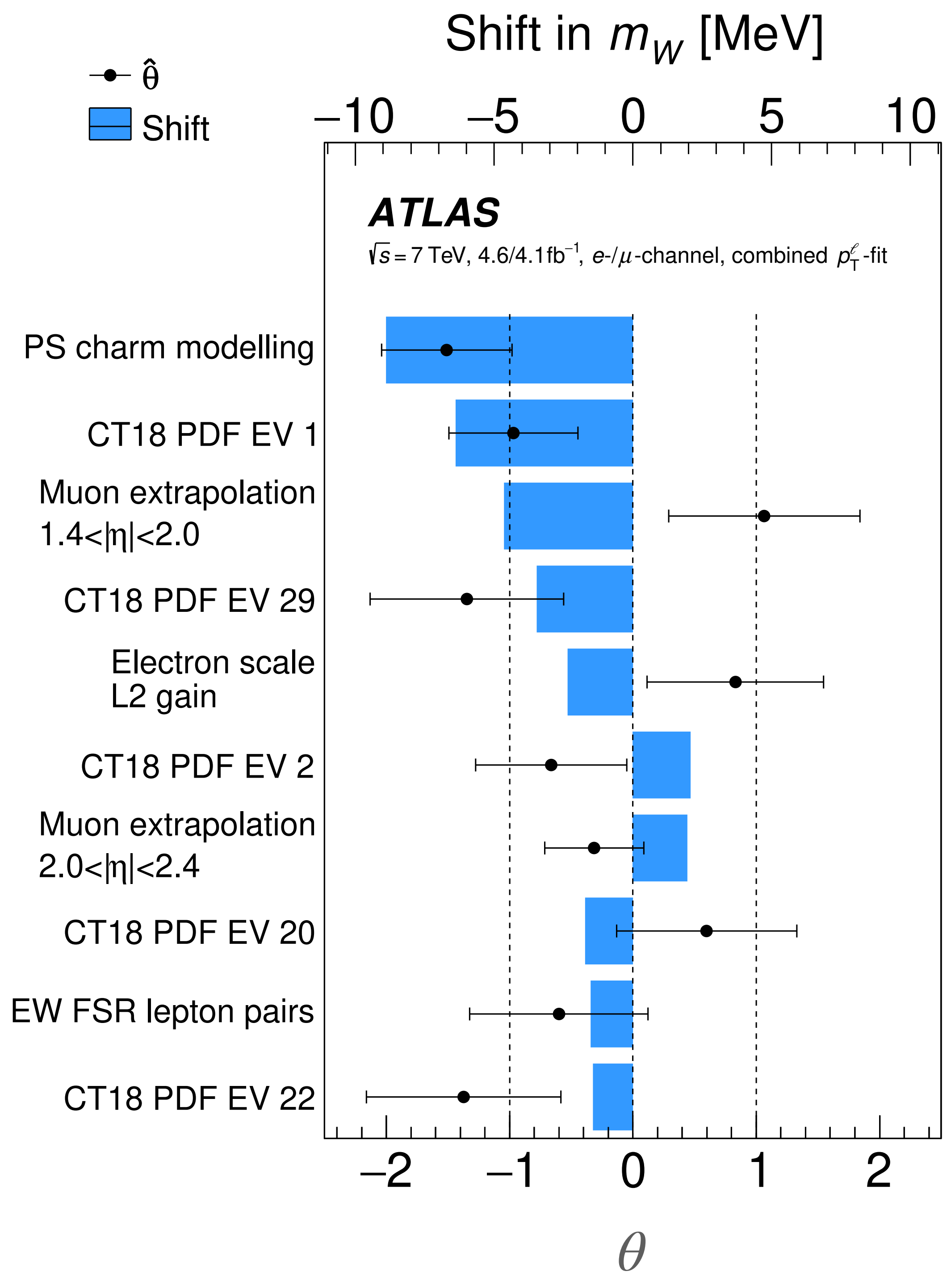


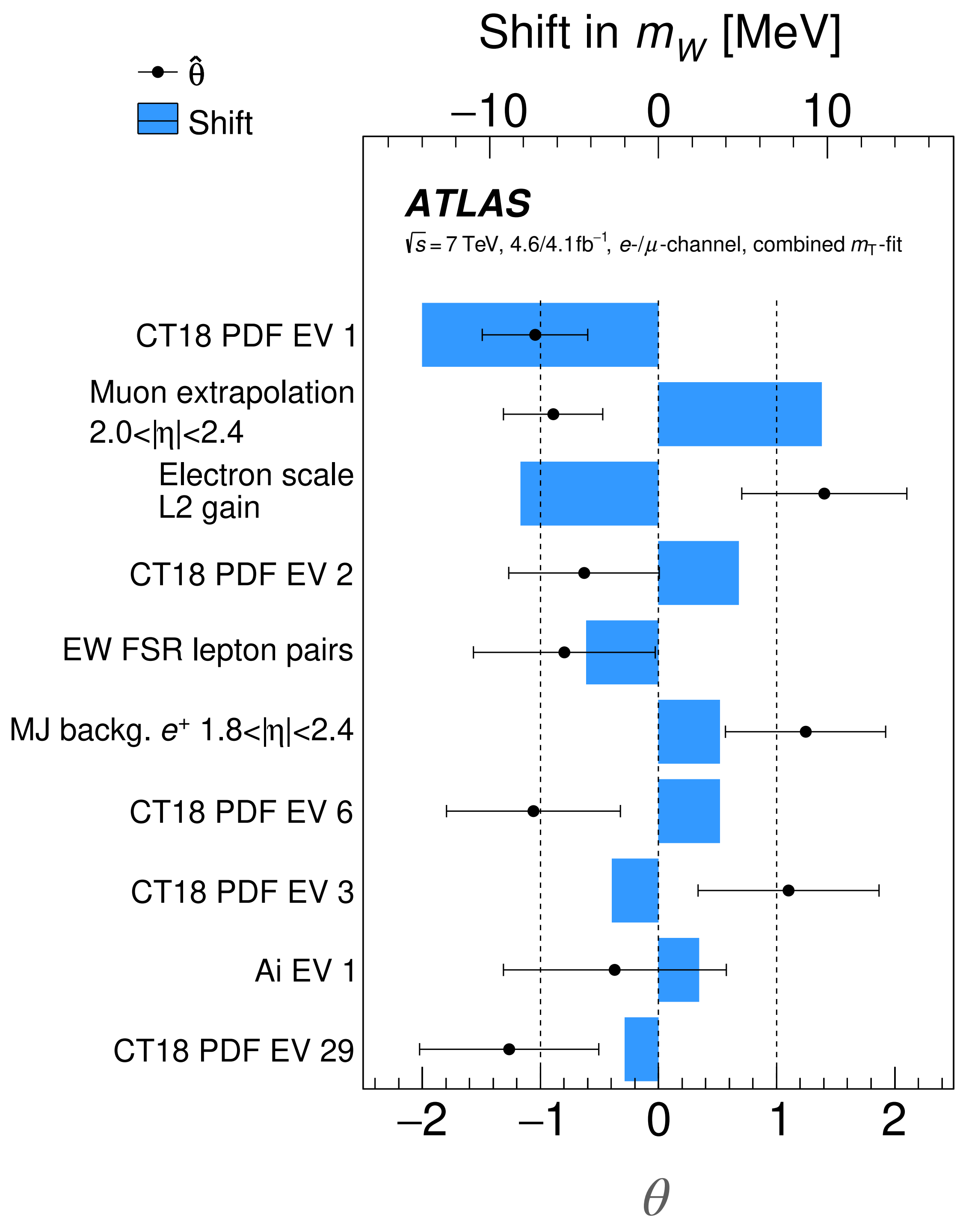
STANDARD MODEL





See Yongbin Feng, Giuseppe Bozzi earlier in this conference





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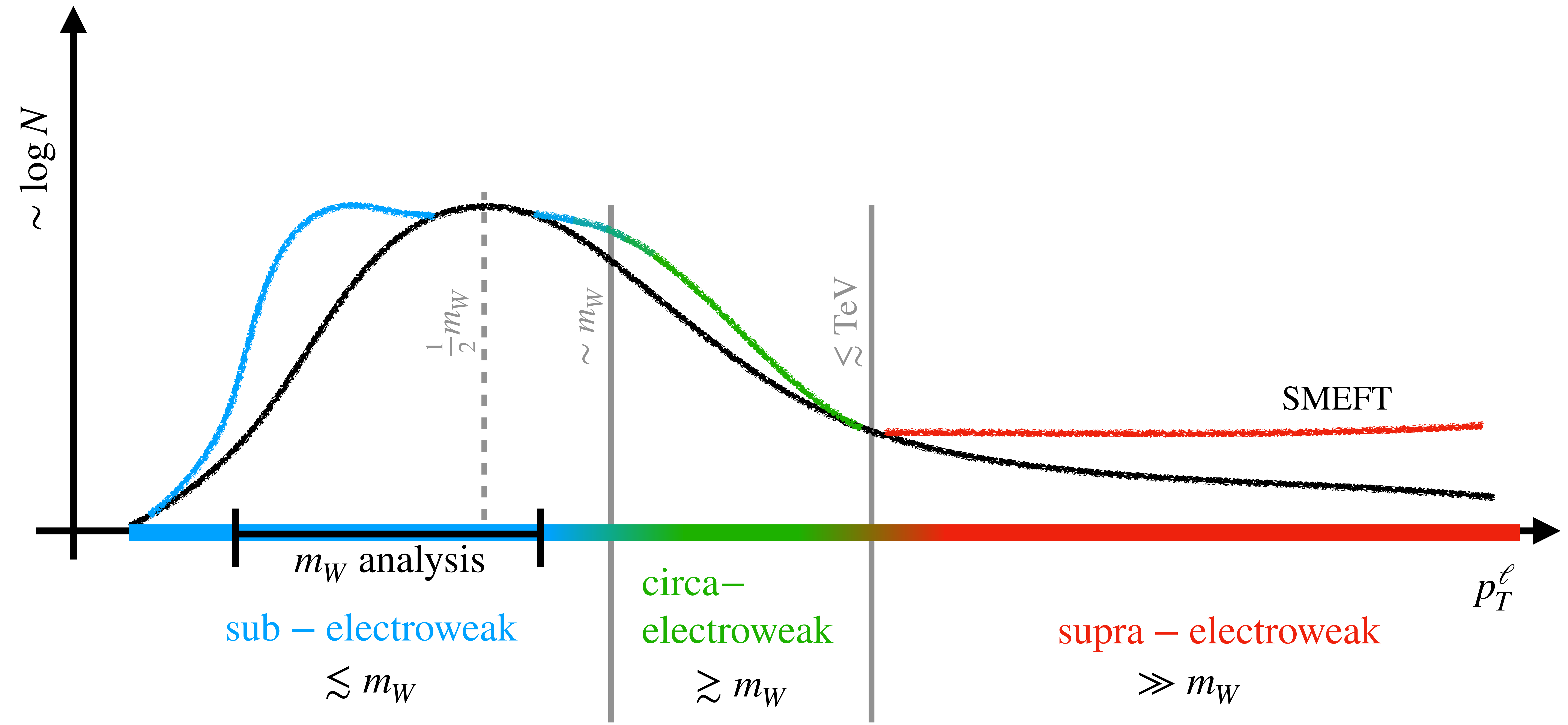

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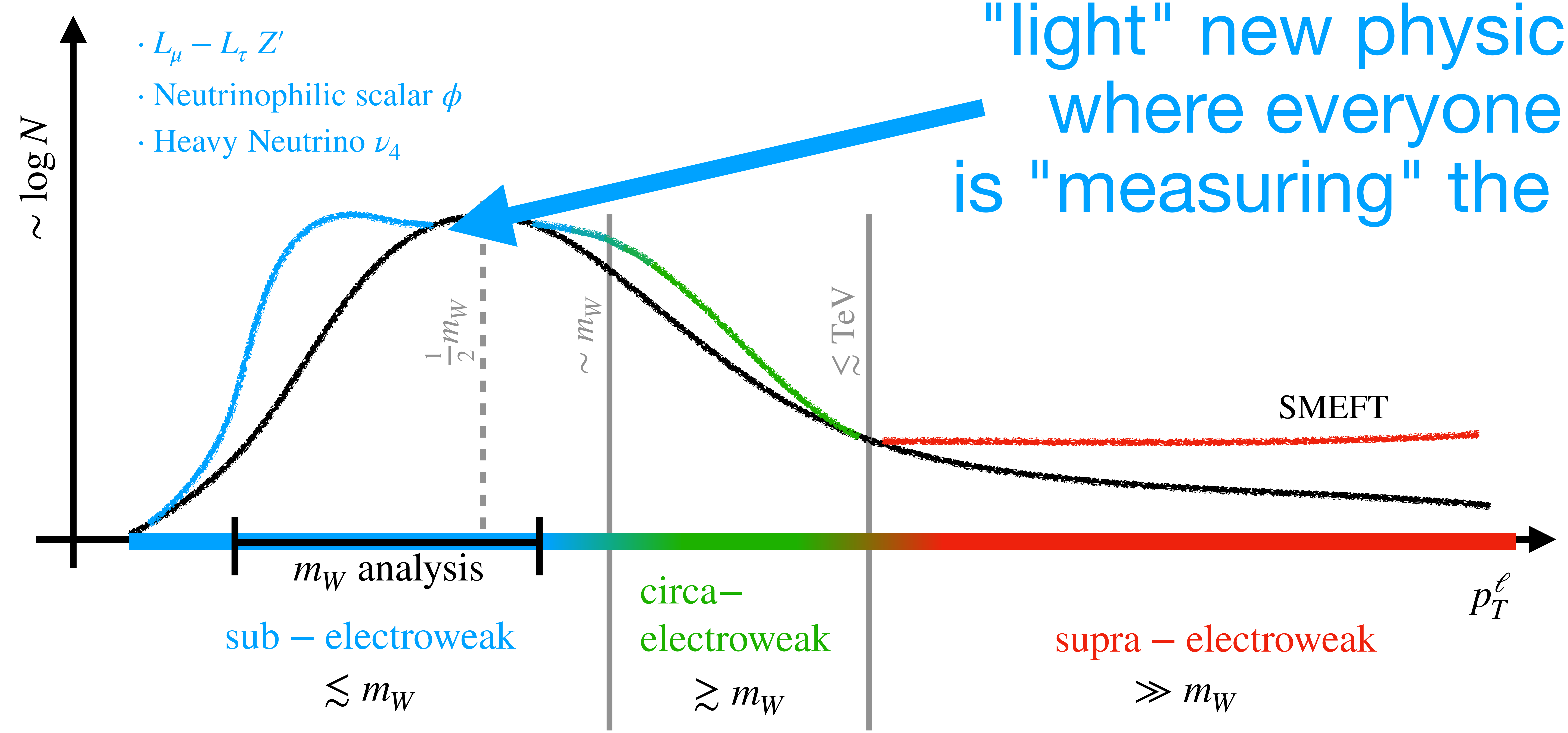
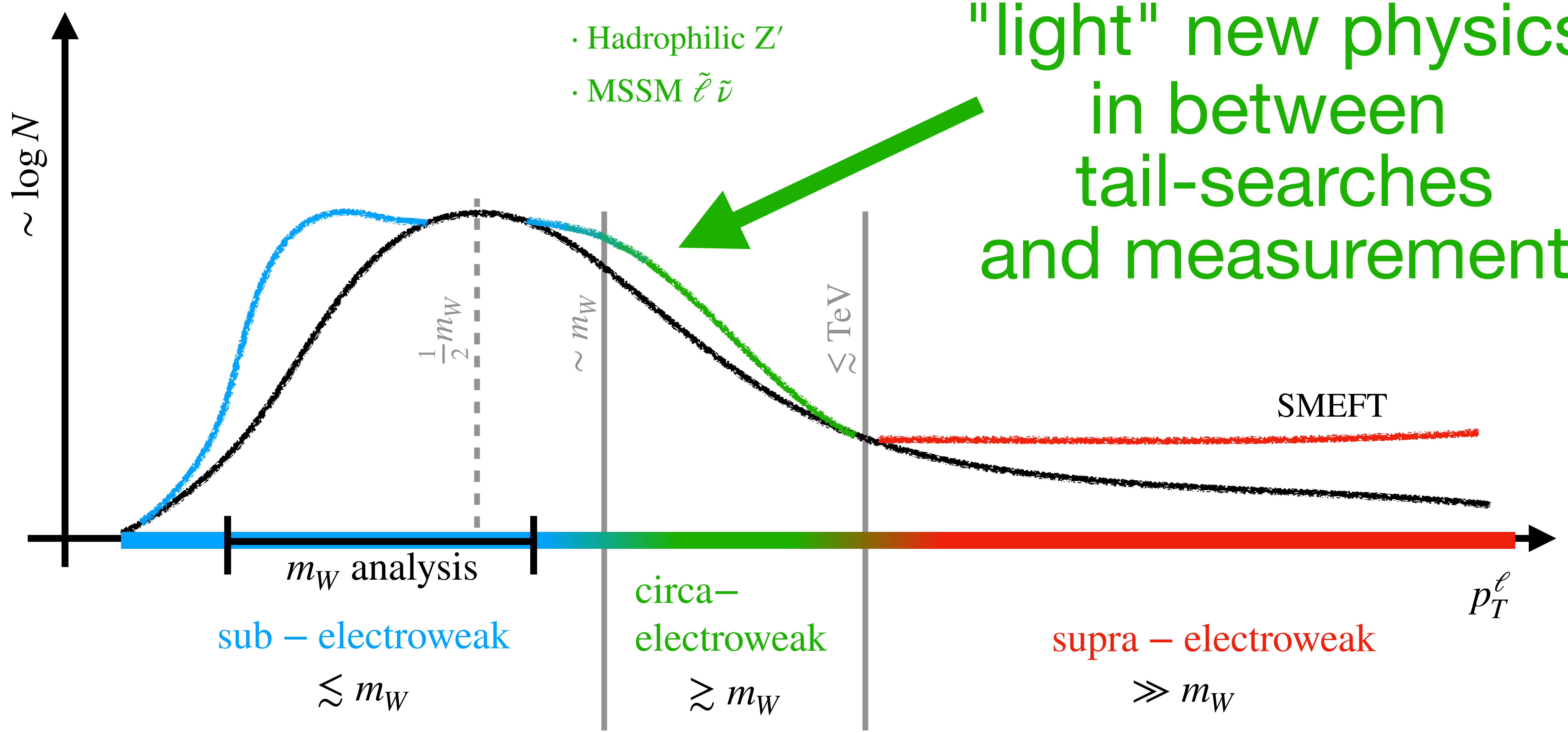


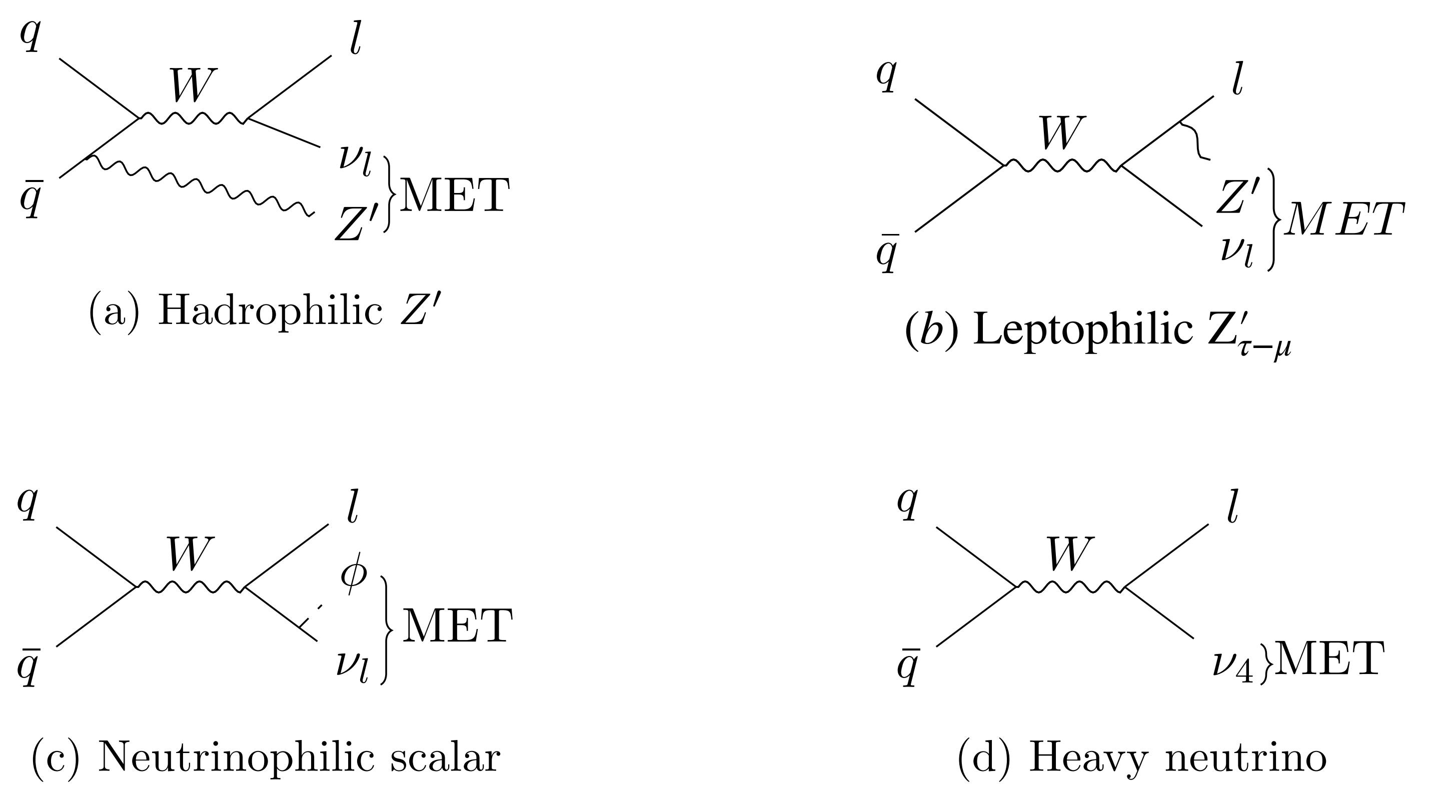
"light" new physics
where everyone
is "measuring" the SM

SEARCH & MEASURE

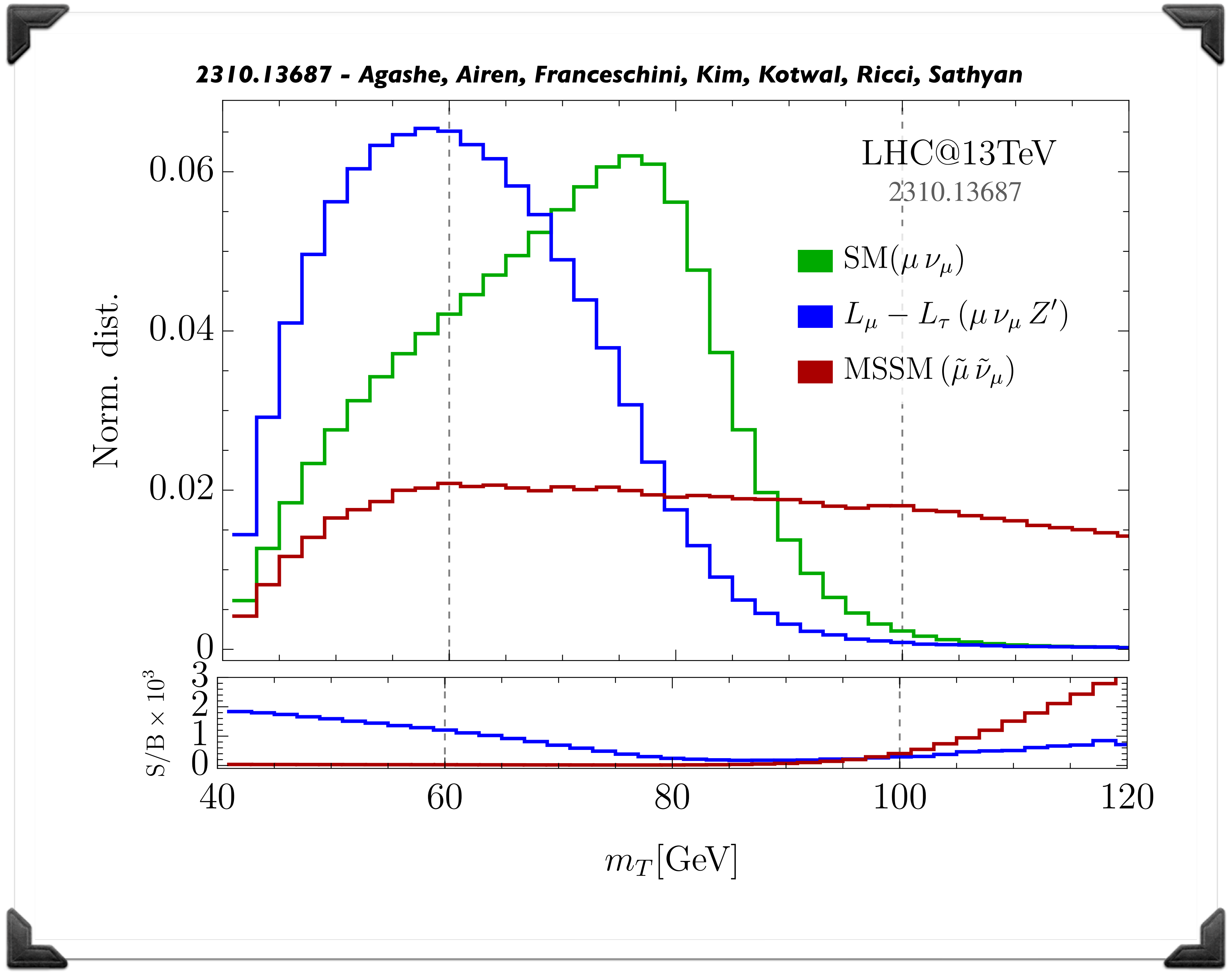


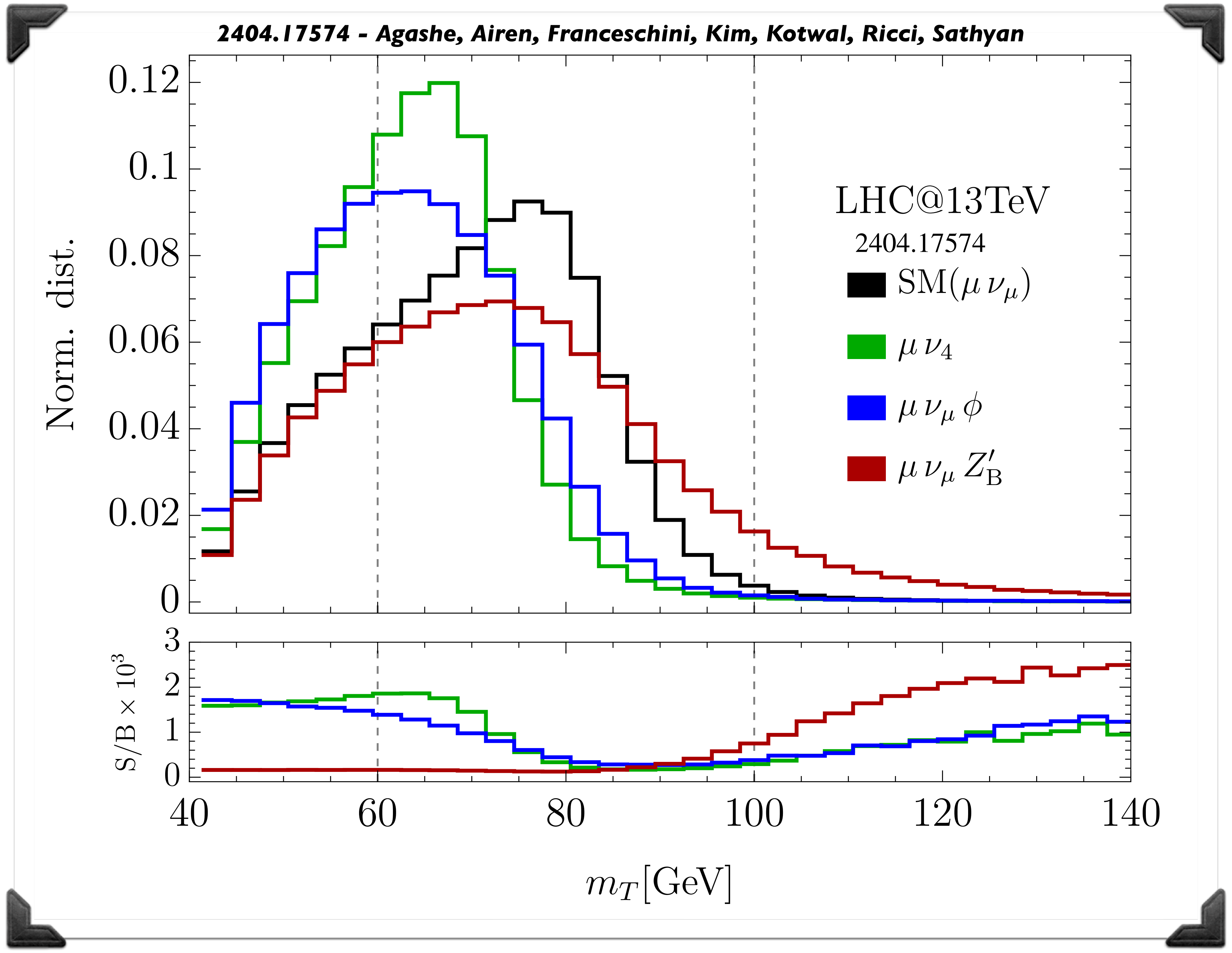
"light" new physics
in between
tail-searches
and measurements

SEARCH & MEASURE in ℓ + mET



(a) Hadrophilic Z'
(b) Leptophilic $Z'_{\tau-\mu}$
(c) Neutrinophilic scalar
(d) Heavy neutrino





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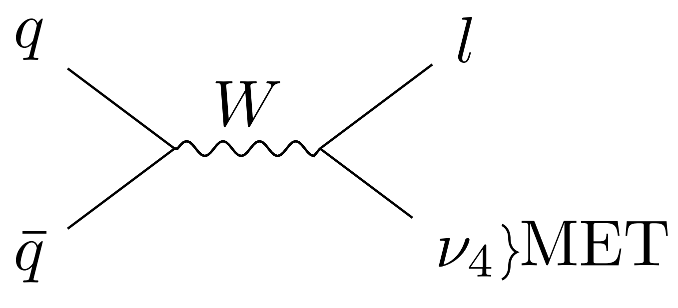

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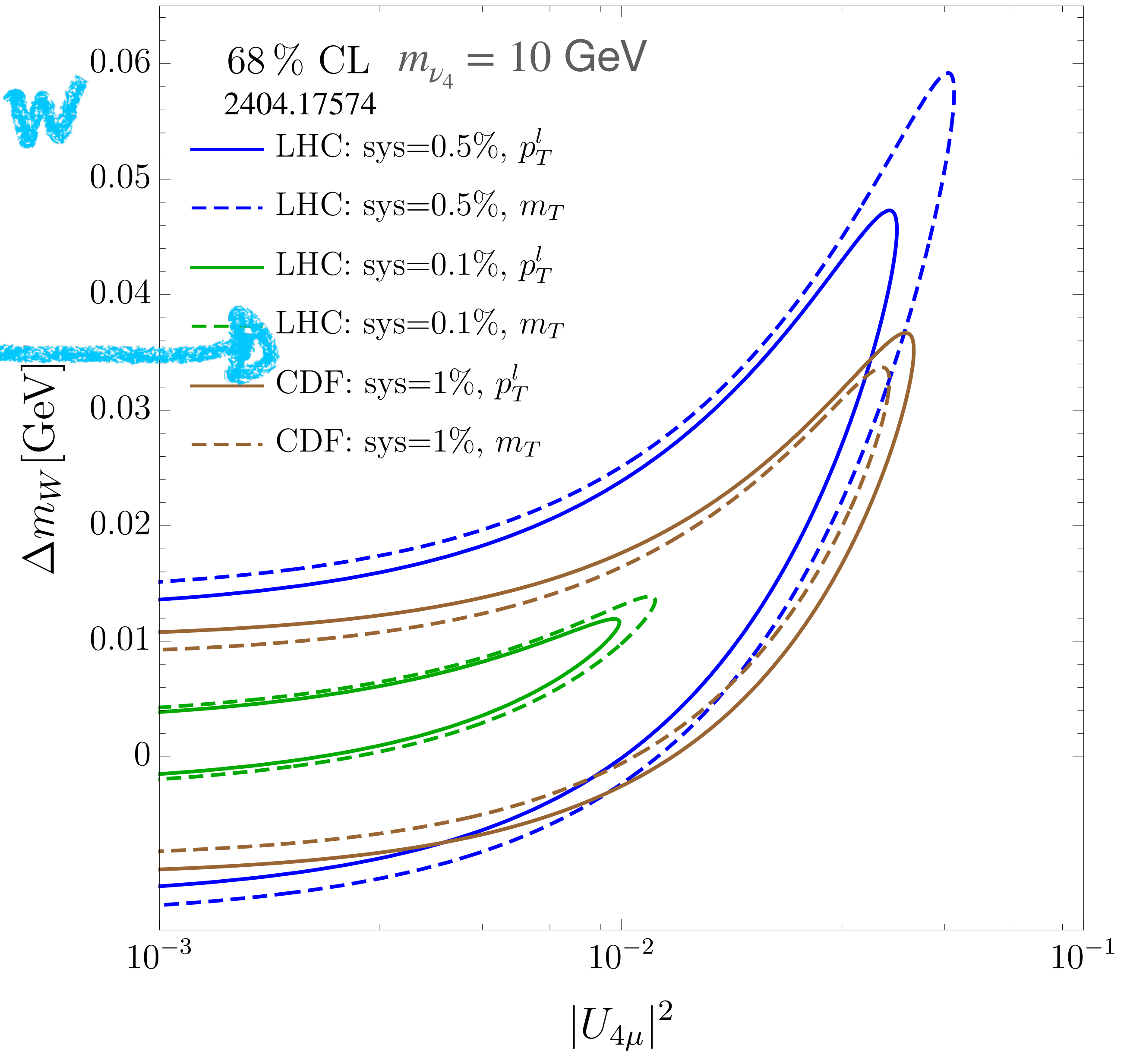
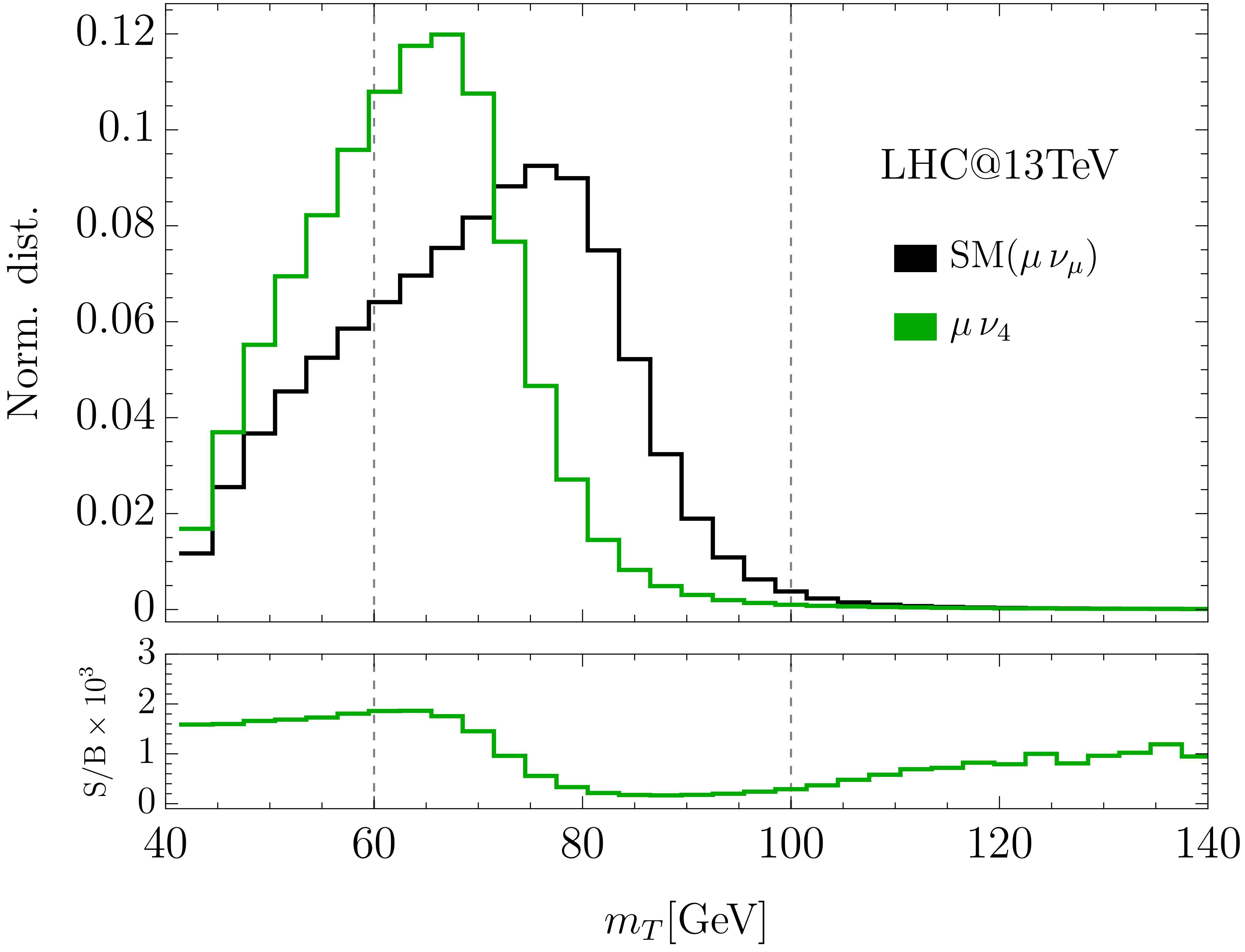
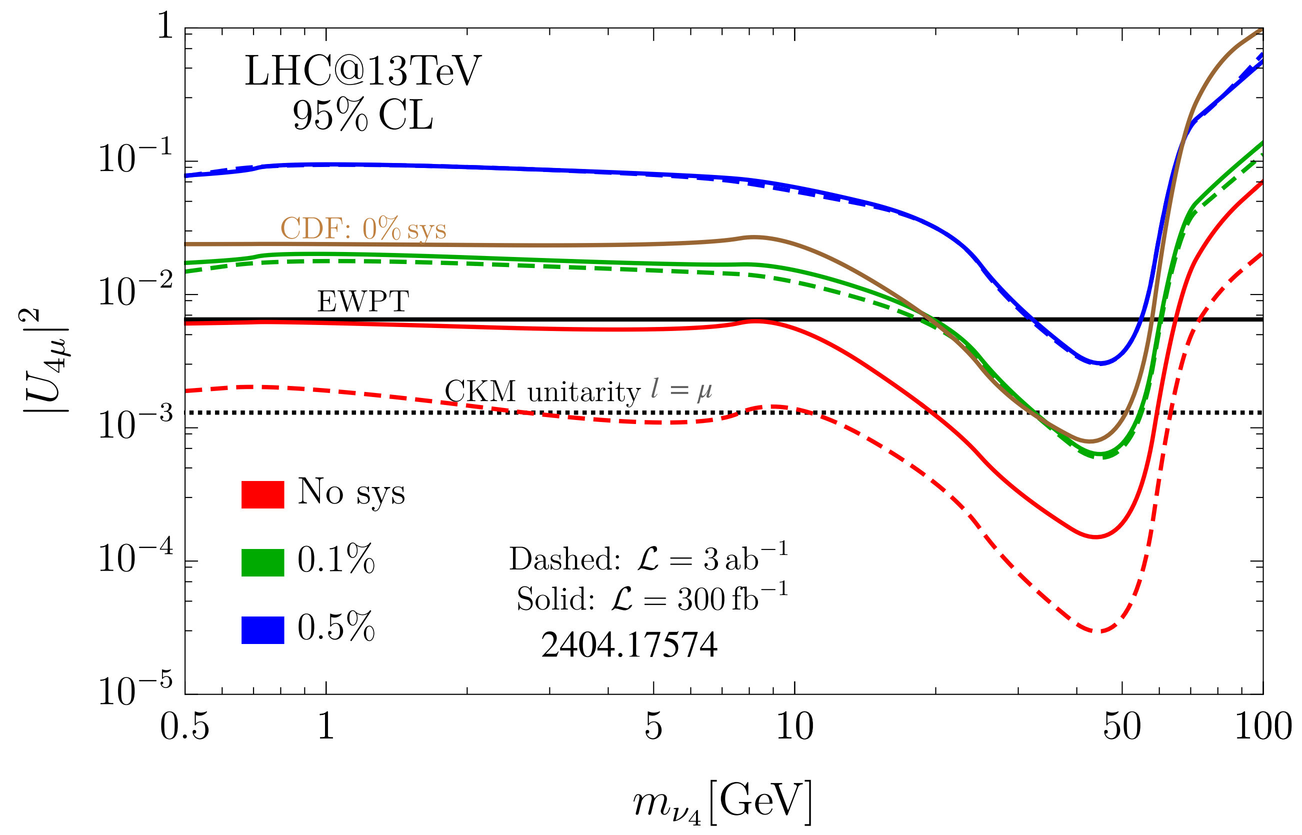
FLOAT NEW PHYSICS AS WELL AS M_W







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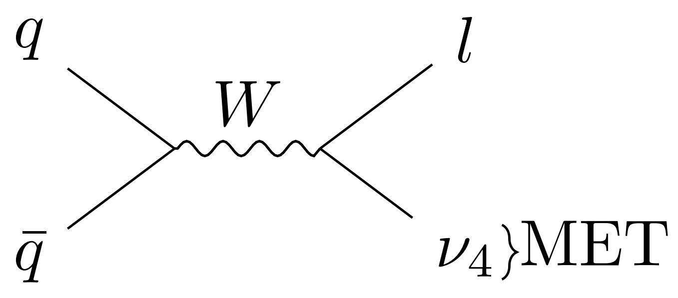

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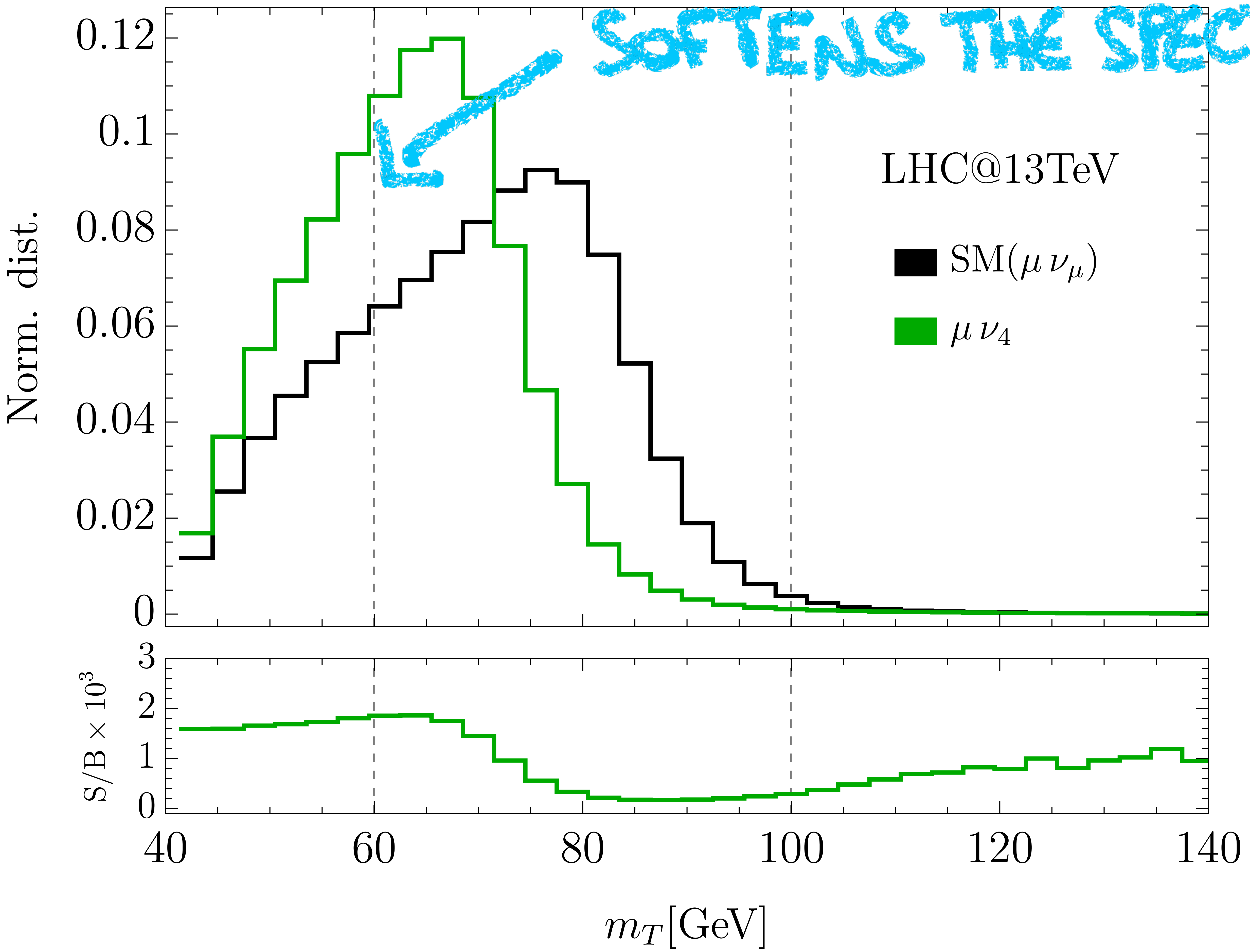
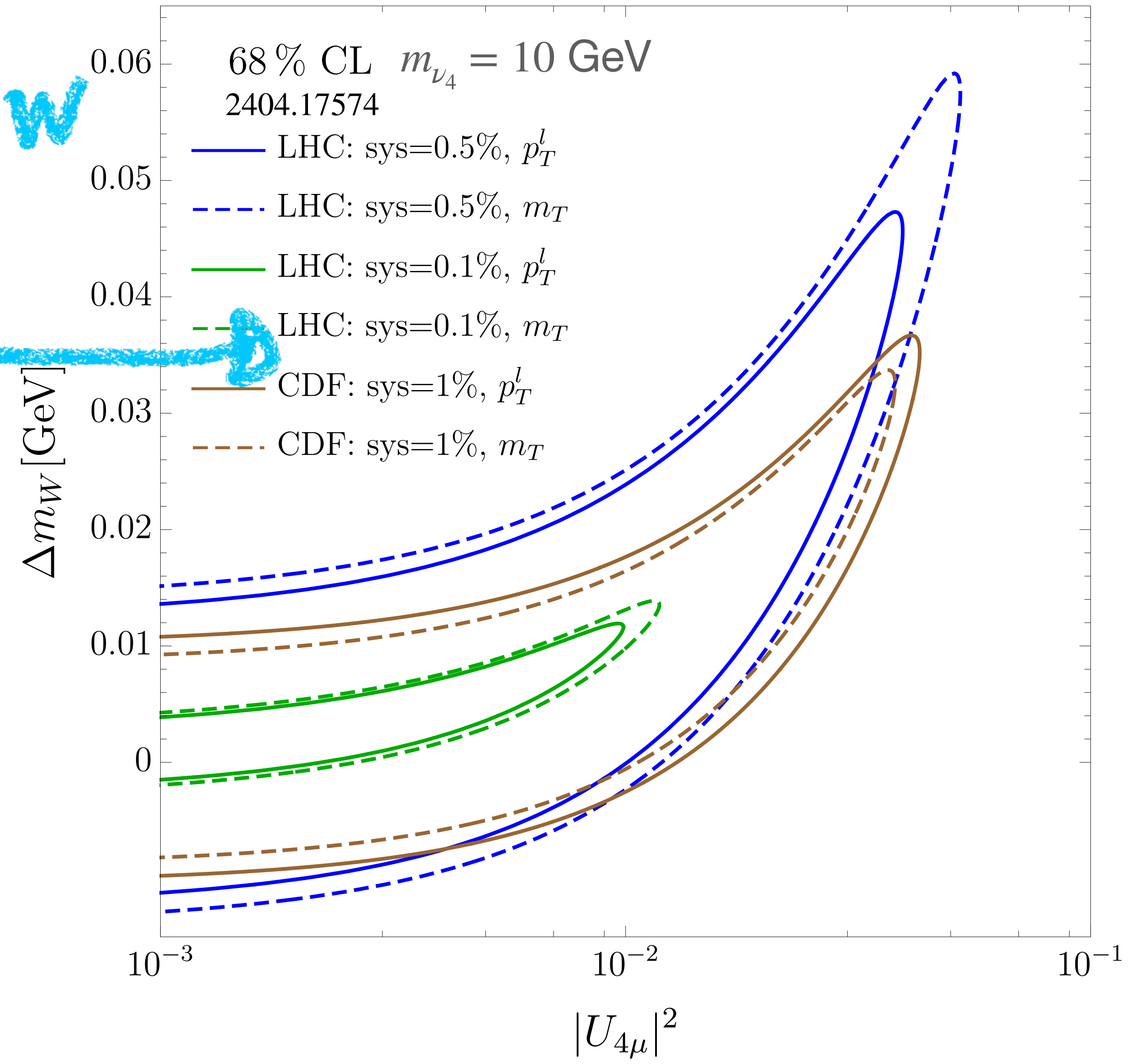
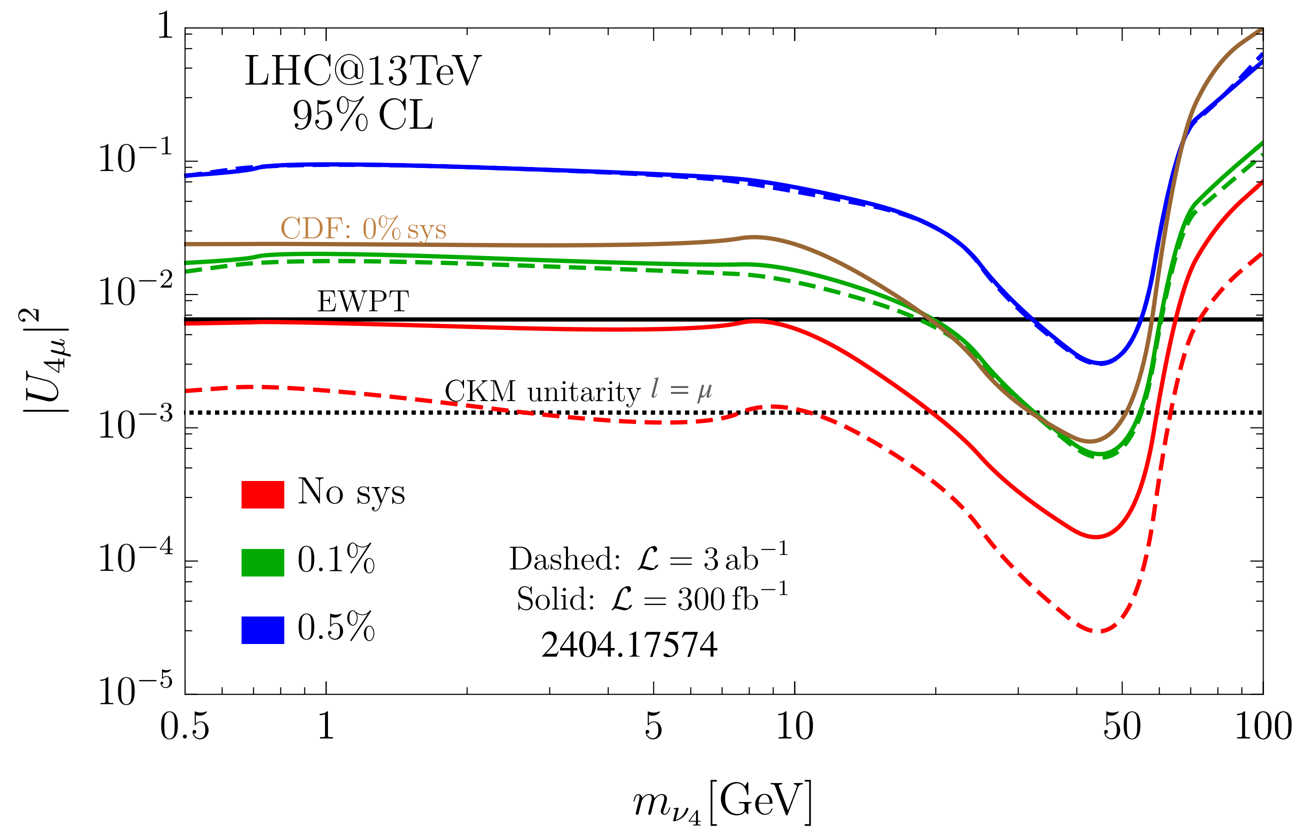
FLOAT NEW PHYSICS AS WELL AS M_W

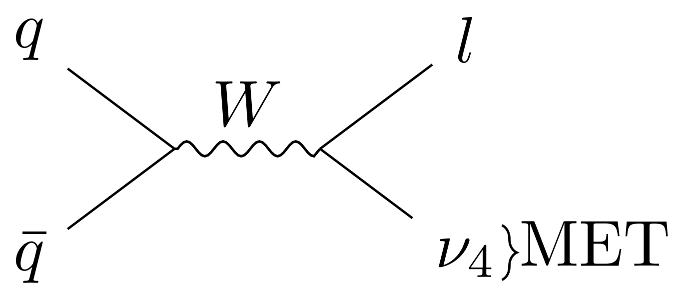
NEW PHYSICS SOFTENS THE SPECTRUM







SEARCH & MEASURE in ℓ + mET



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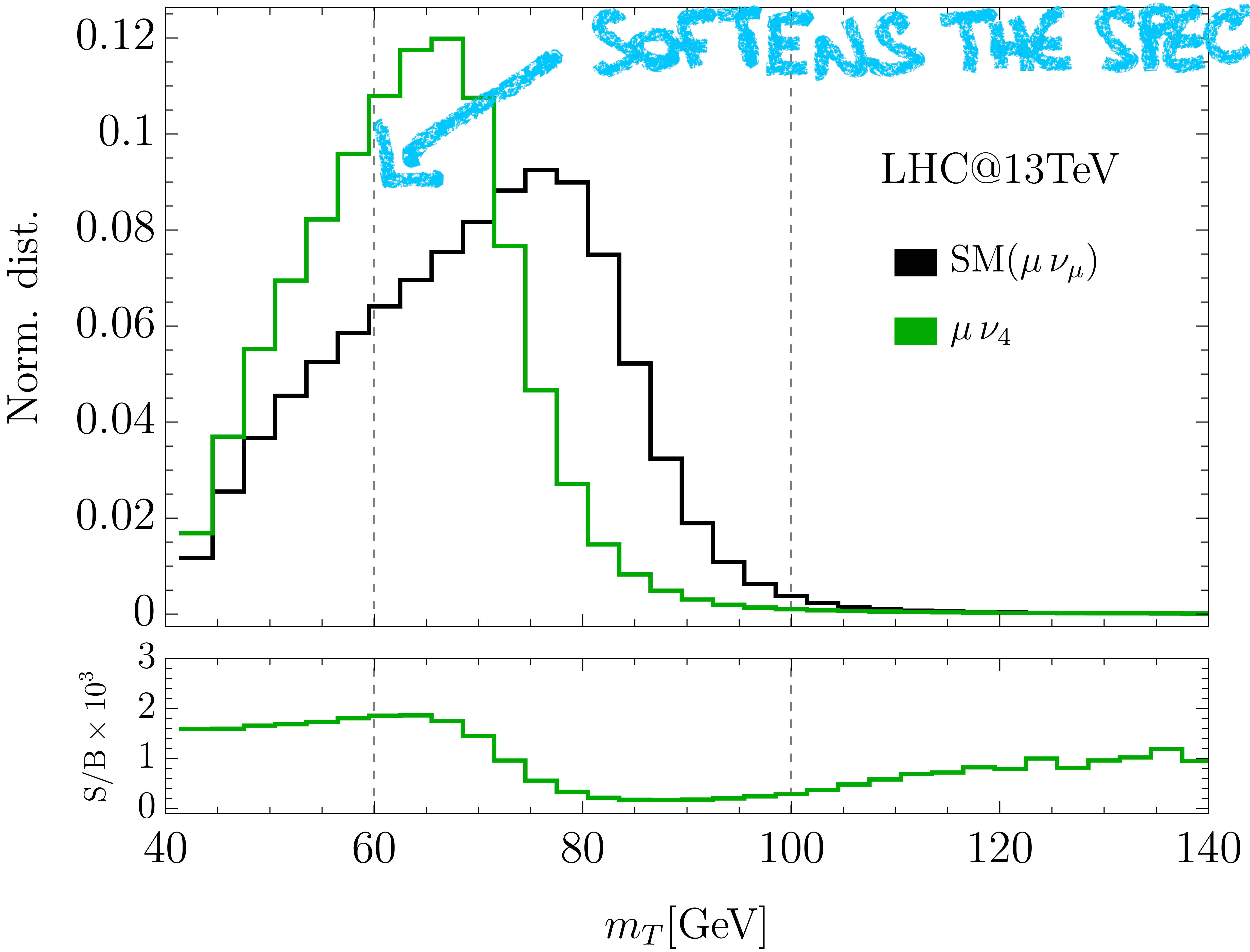
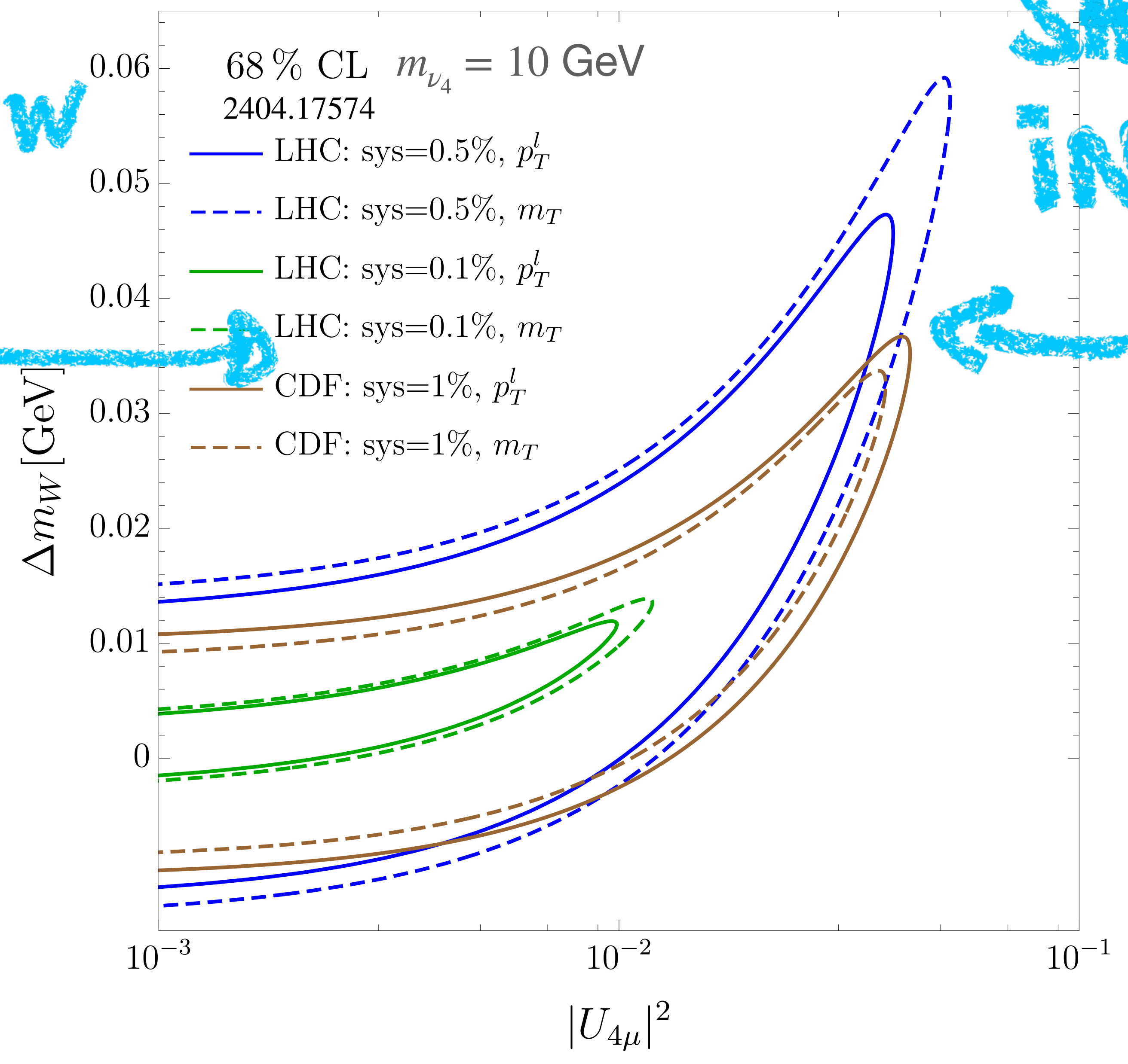
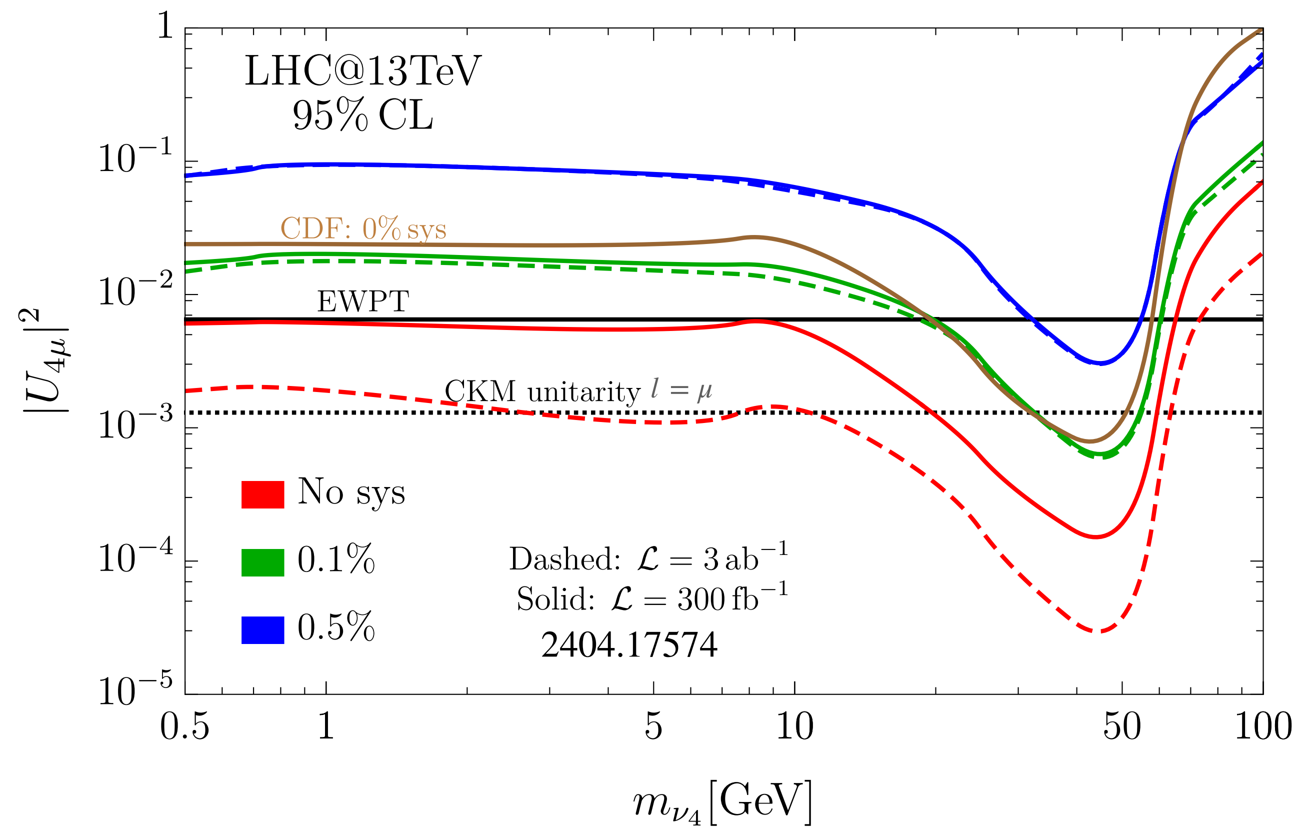
FLOAT NEW PHYSICS AS WELL AS M_W

SHIFT IN M_W

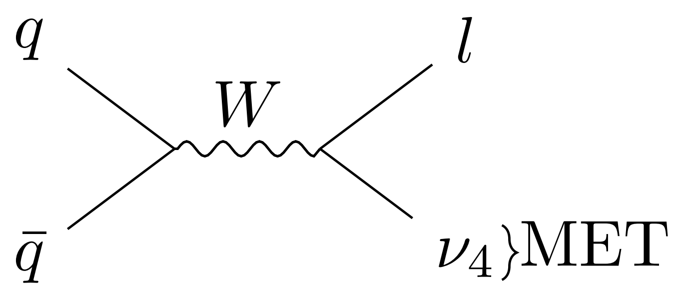
NEW PHYSICS SOFTENS THE SPECTRUM







Search & Measure in ℓ + mET



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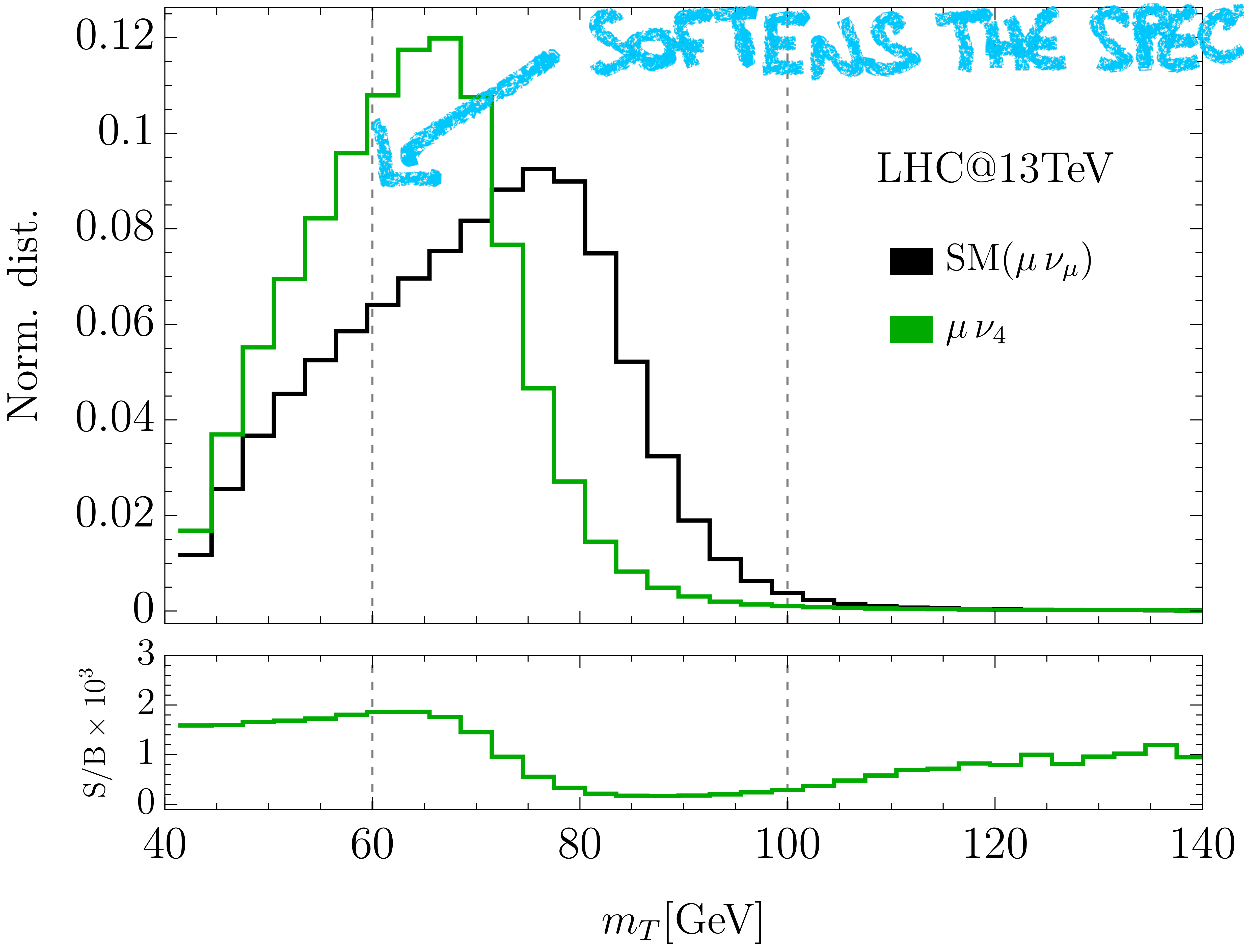
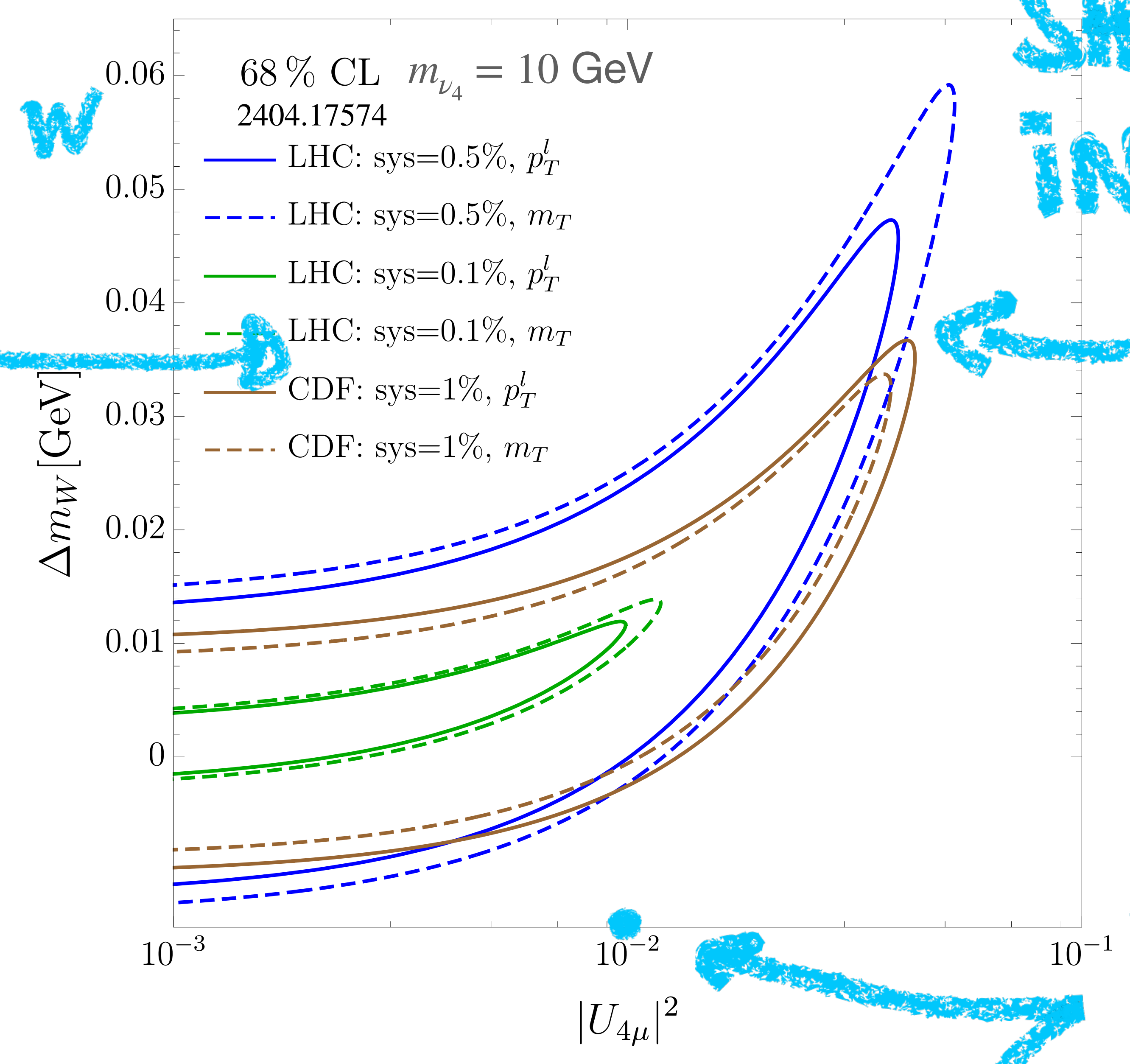
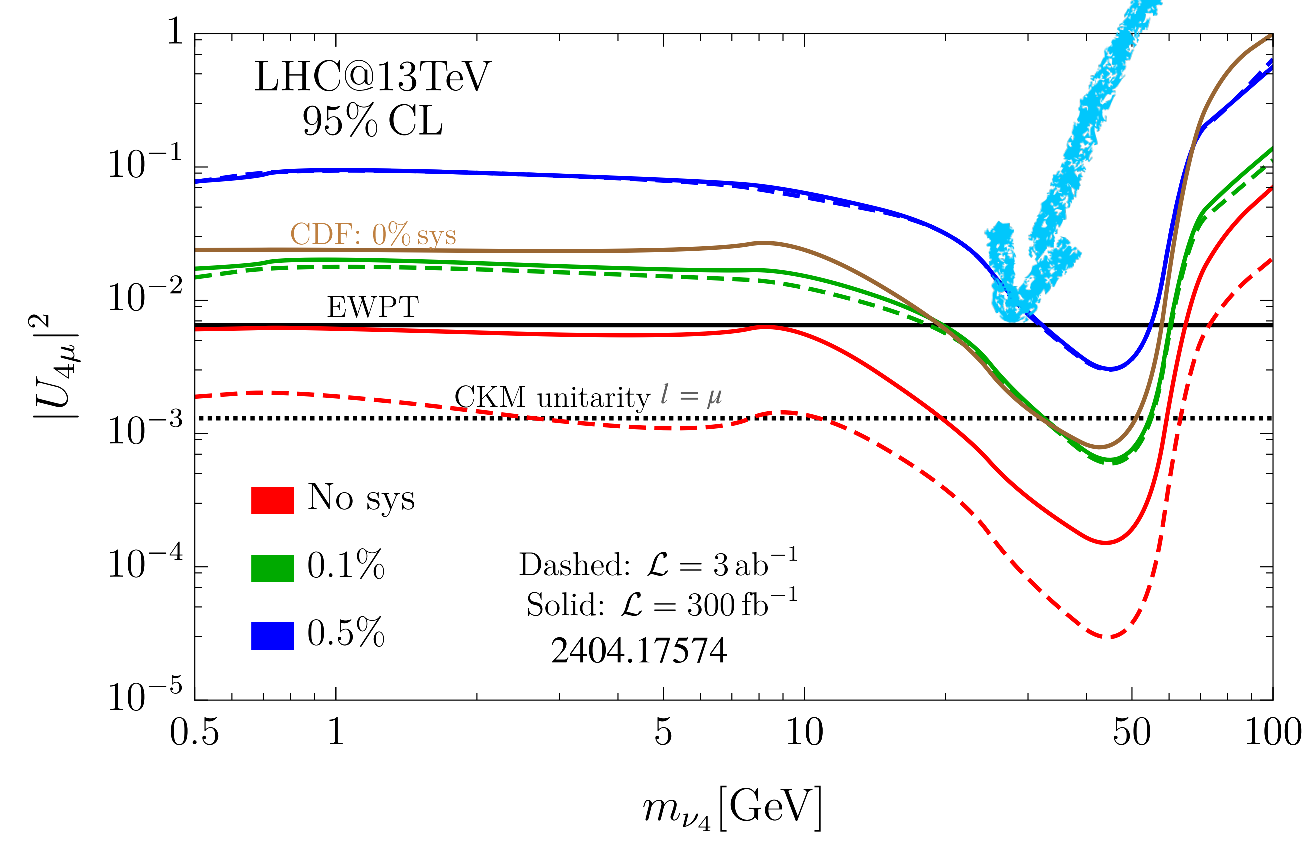
NEW PHYSICS SOFTENS THE SPECTRUM





COUPLINGS AROUND EWPT BOUNDS



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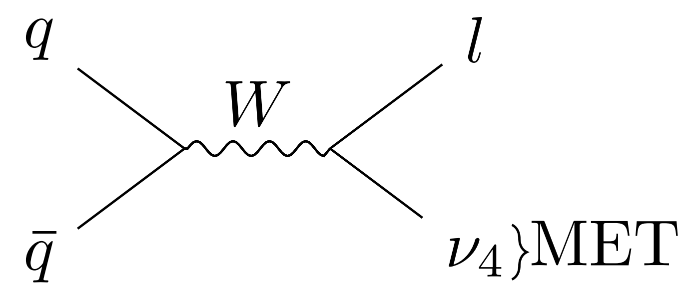

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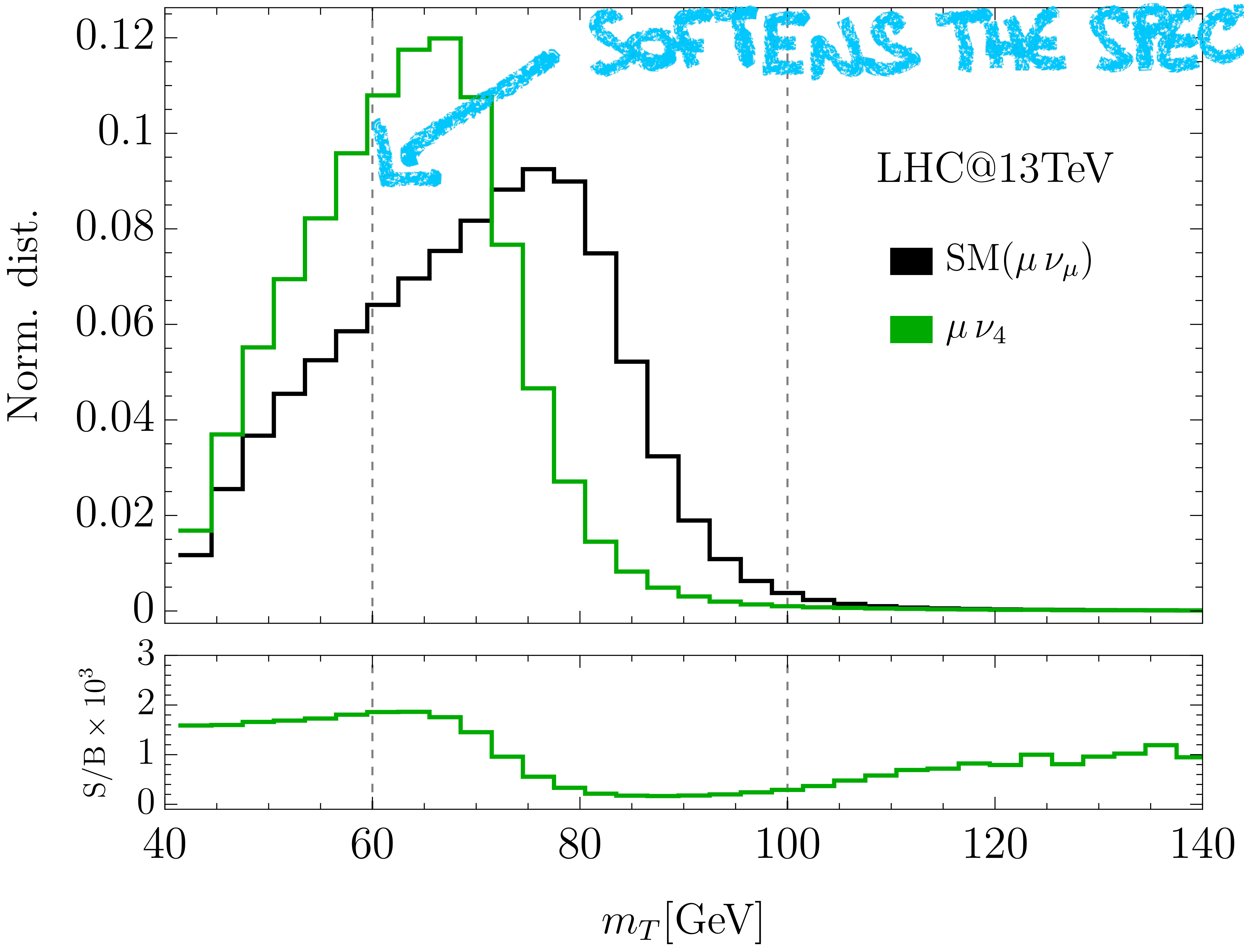

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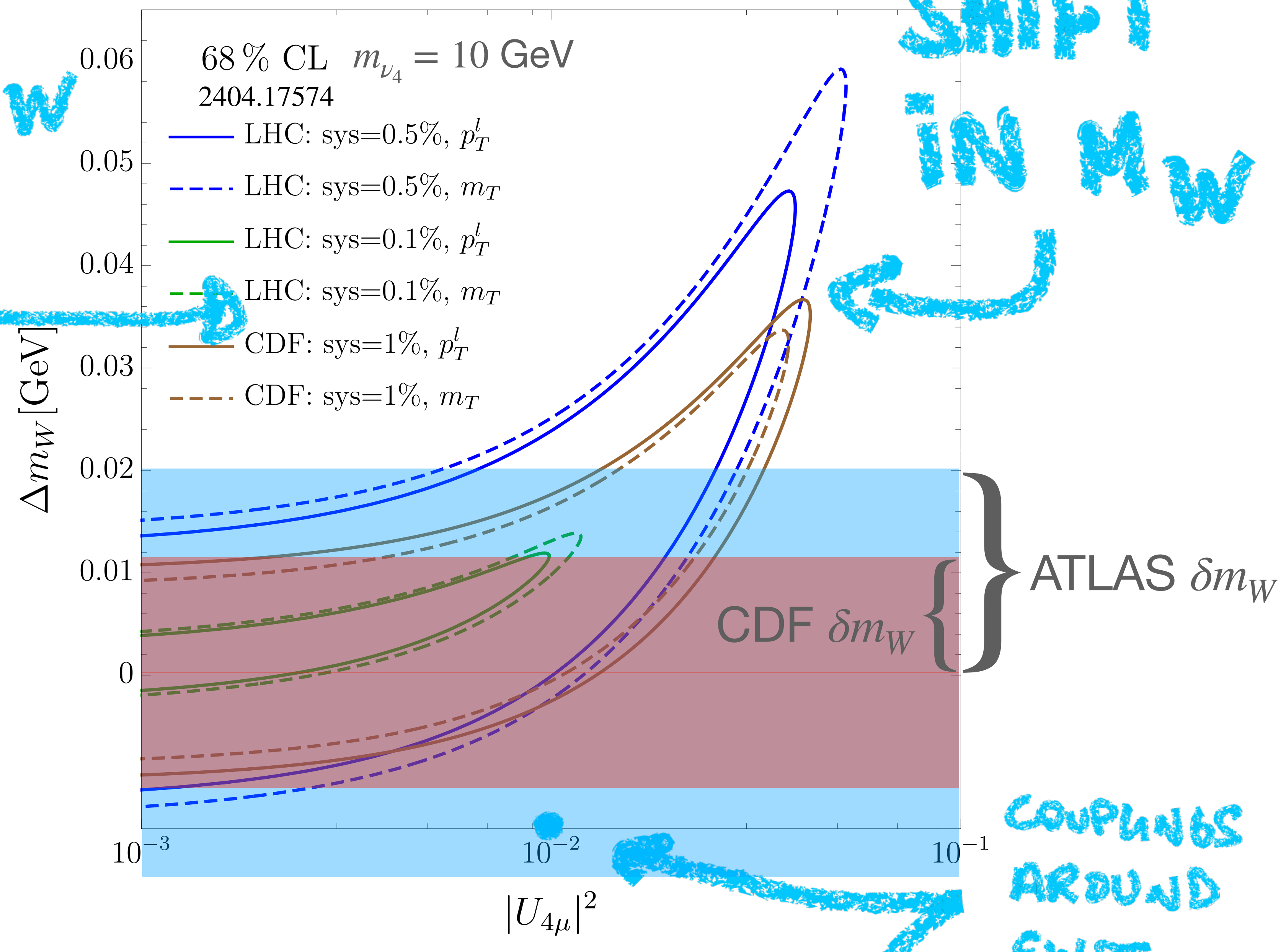

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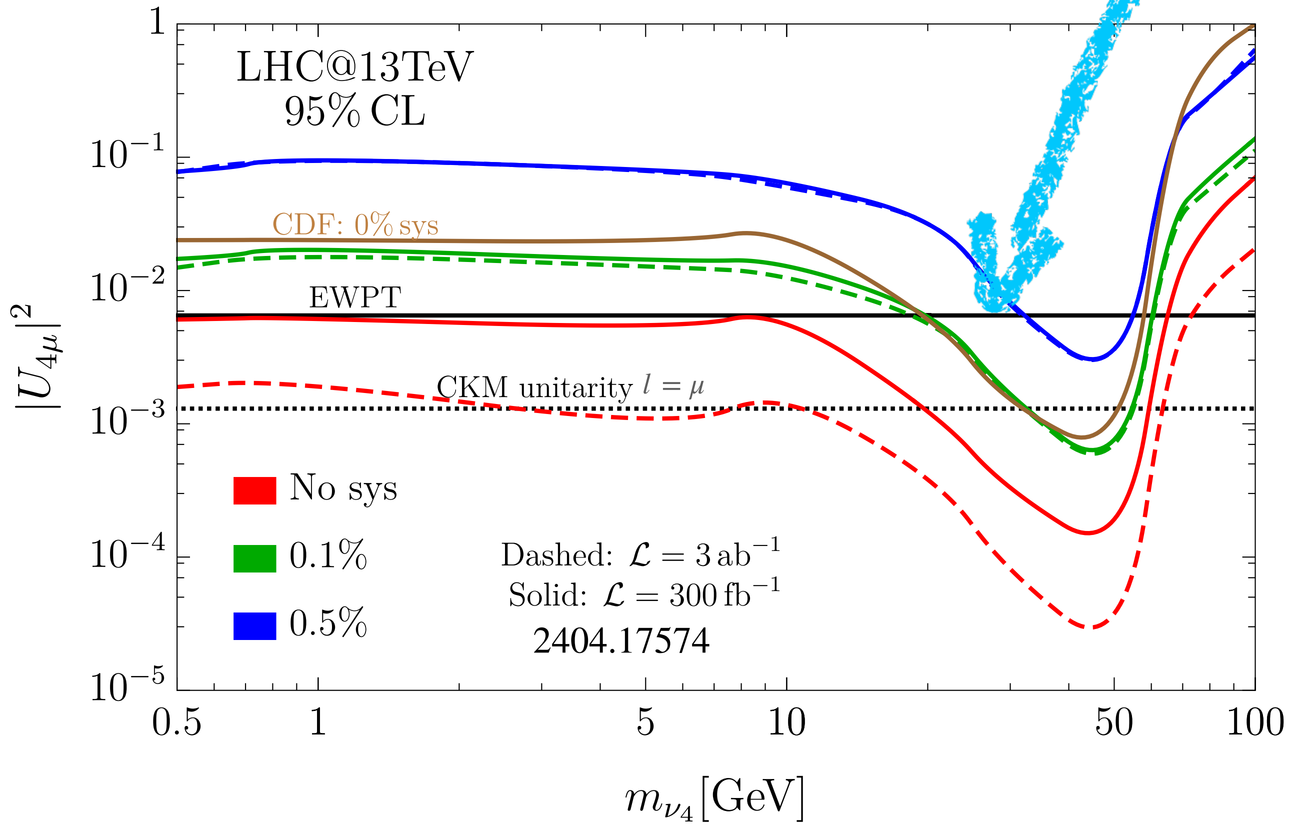
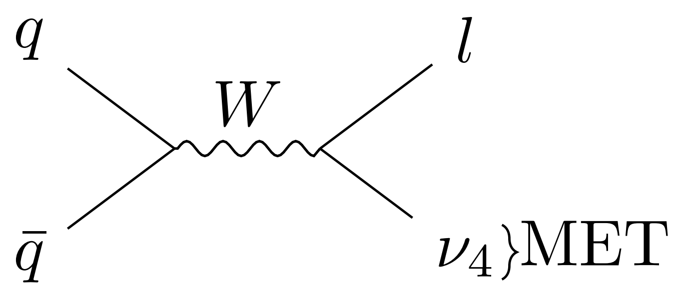


SEARCH & MEASURE in ℓ + mET



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NEW PHYSICS

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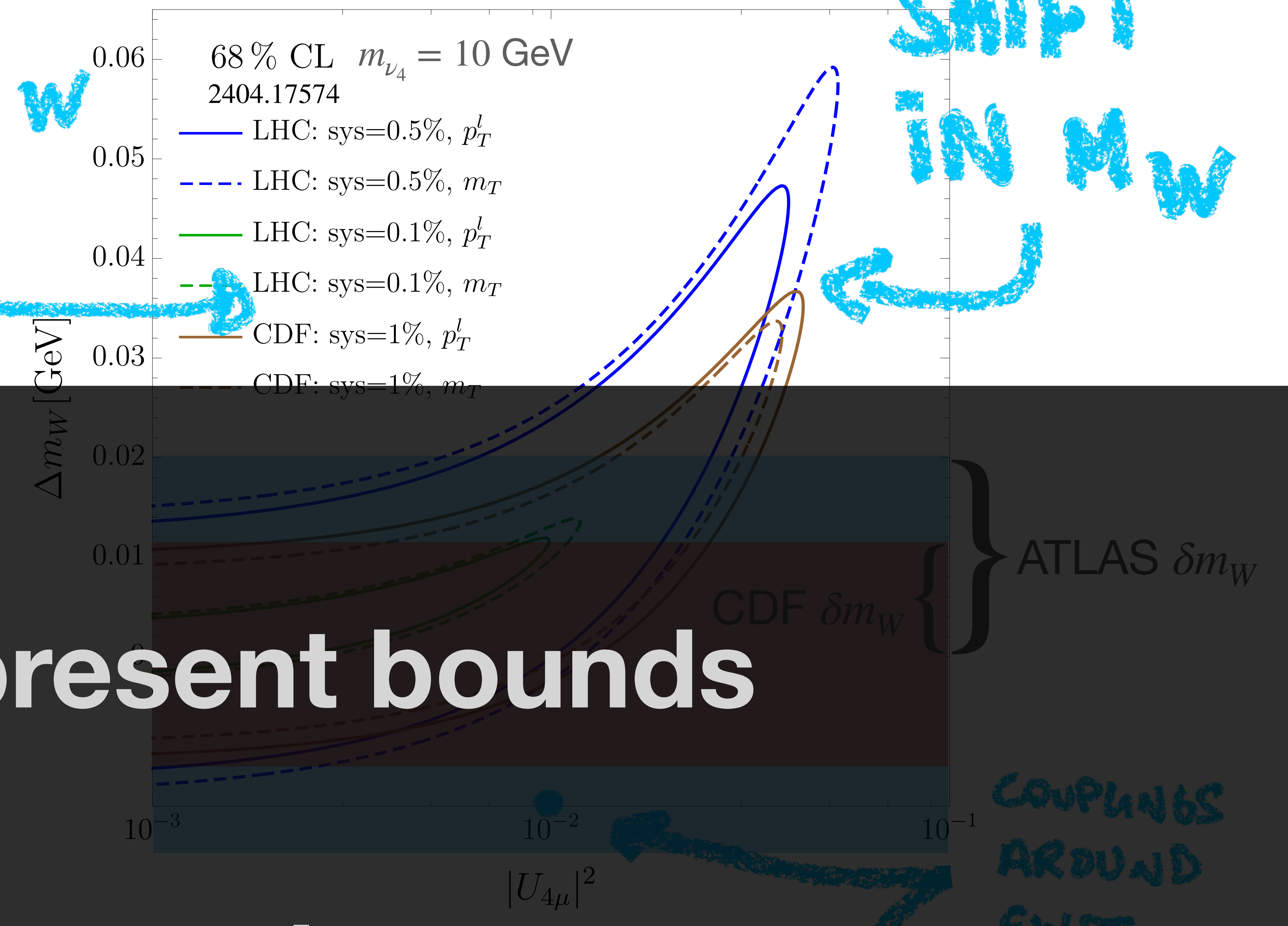
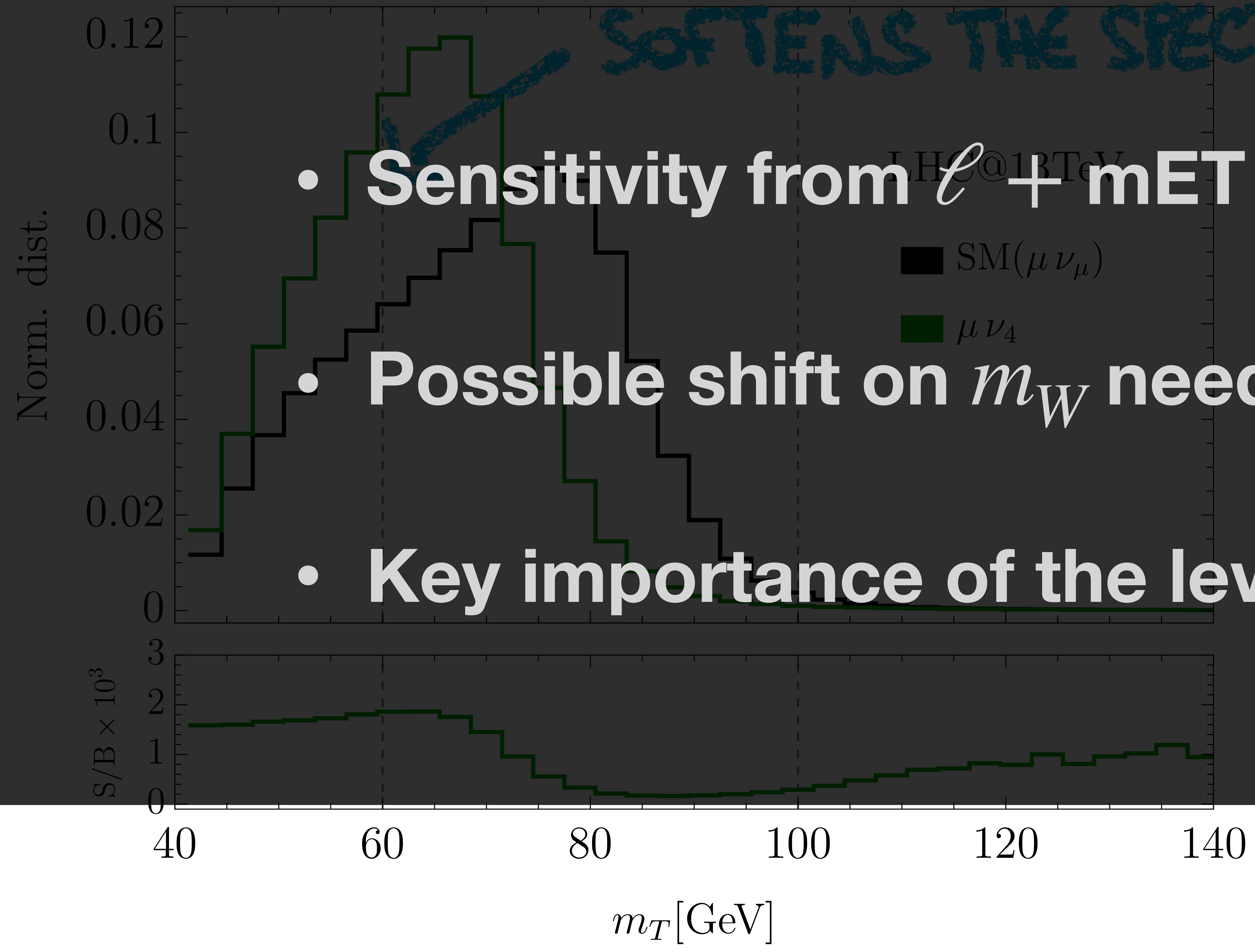
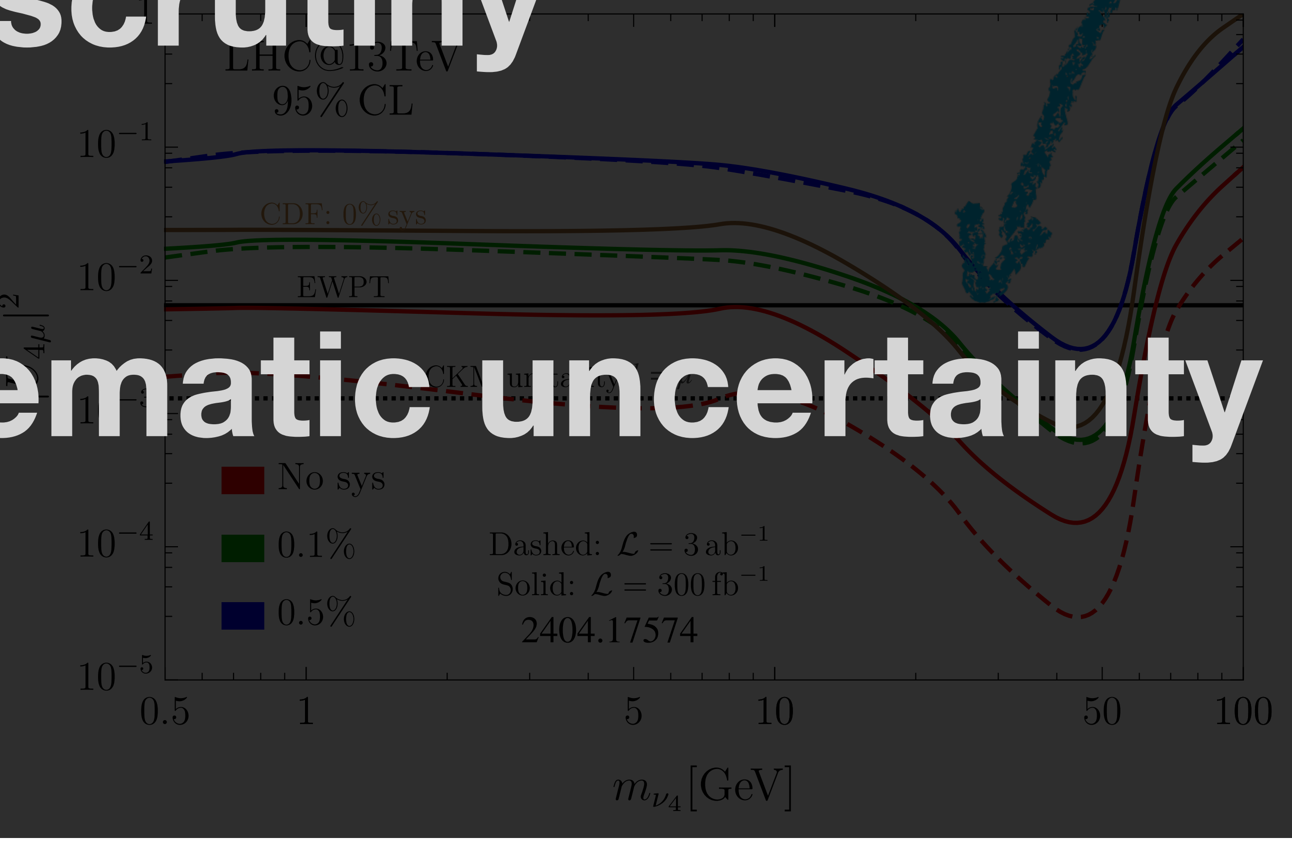
SHIFT IN M_W

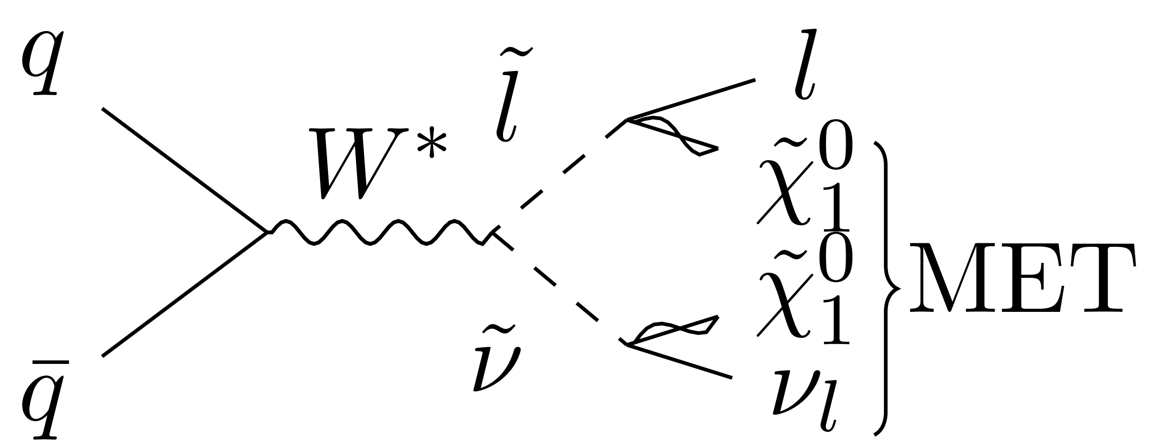


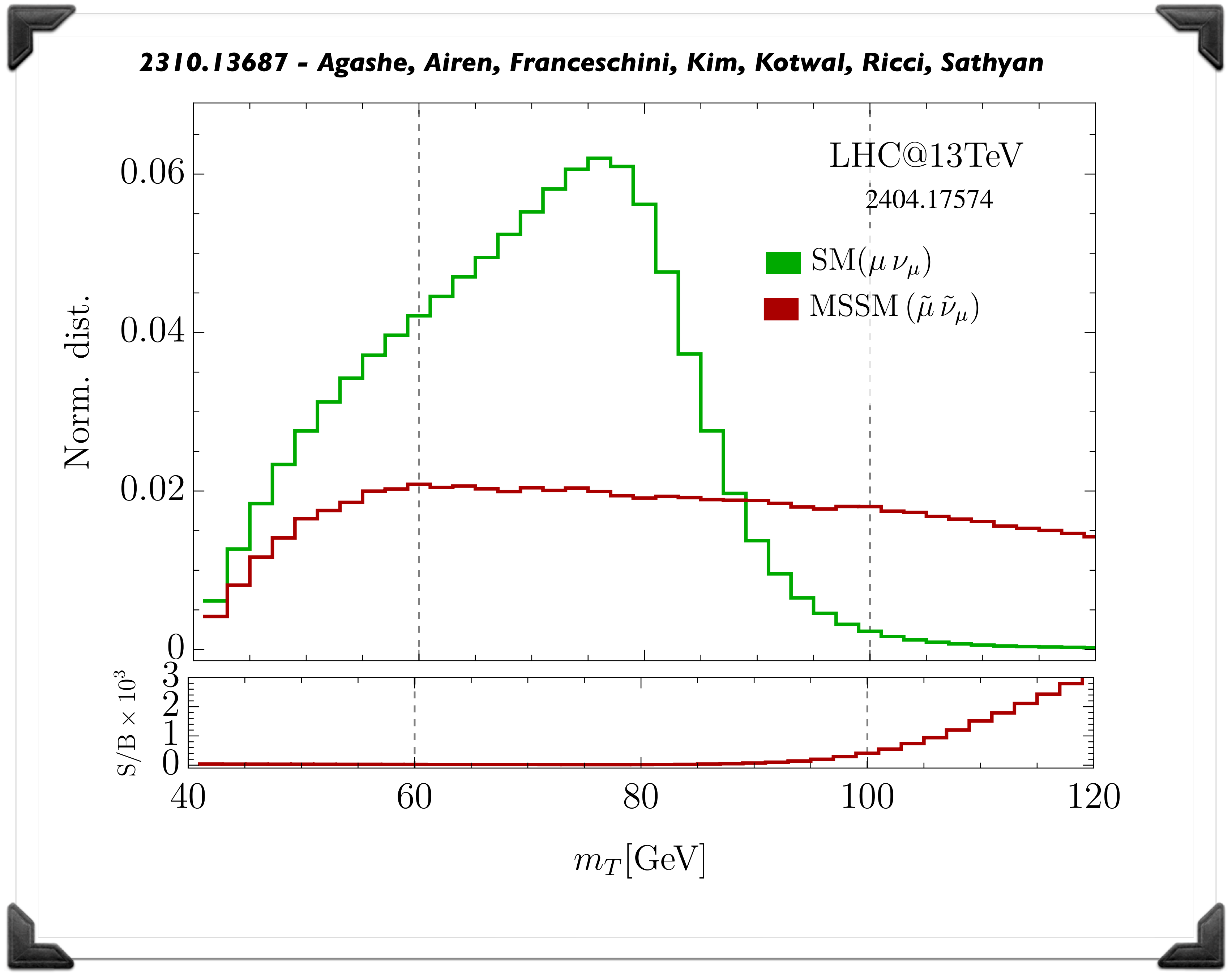


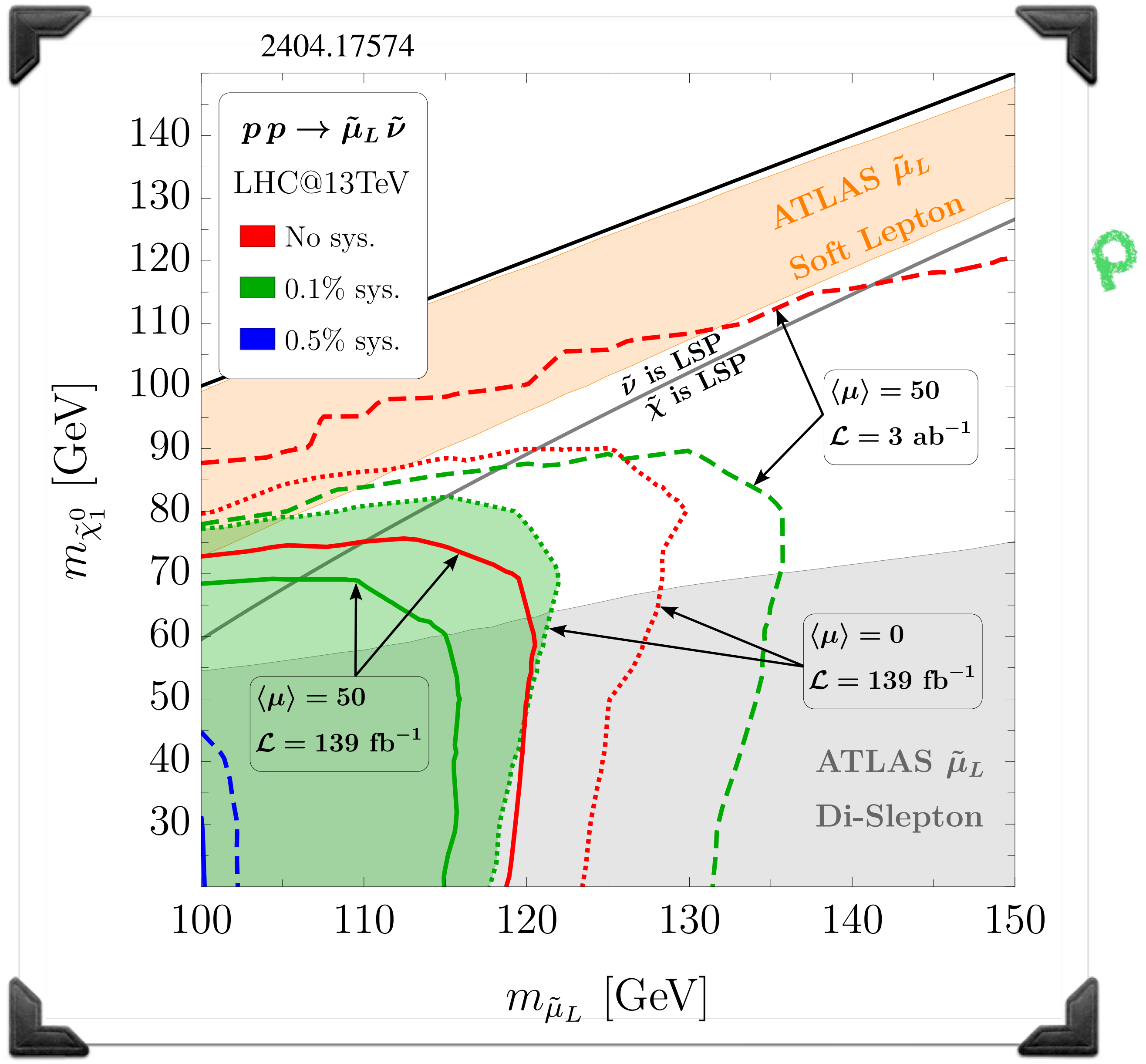


- **Sensitivity from ℓ + mET beyond present bounds**
- **Possible shift on m_W needs further scrutiny**
- **Key importance of the level of systematic uncertainty**

SEARCH & MEASURE in ℓ + mET







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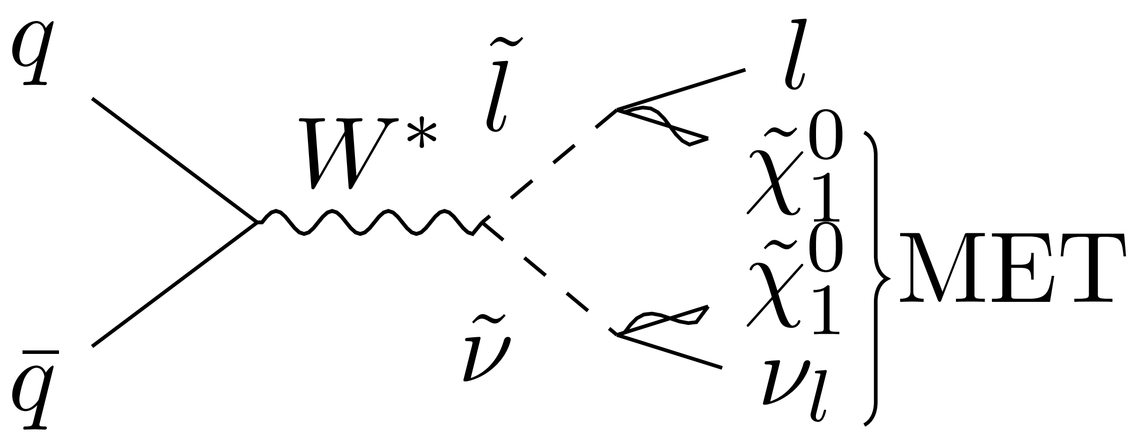

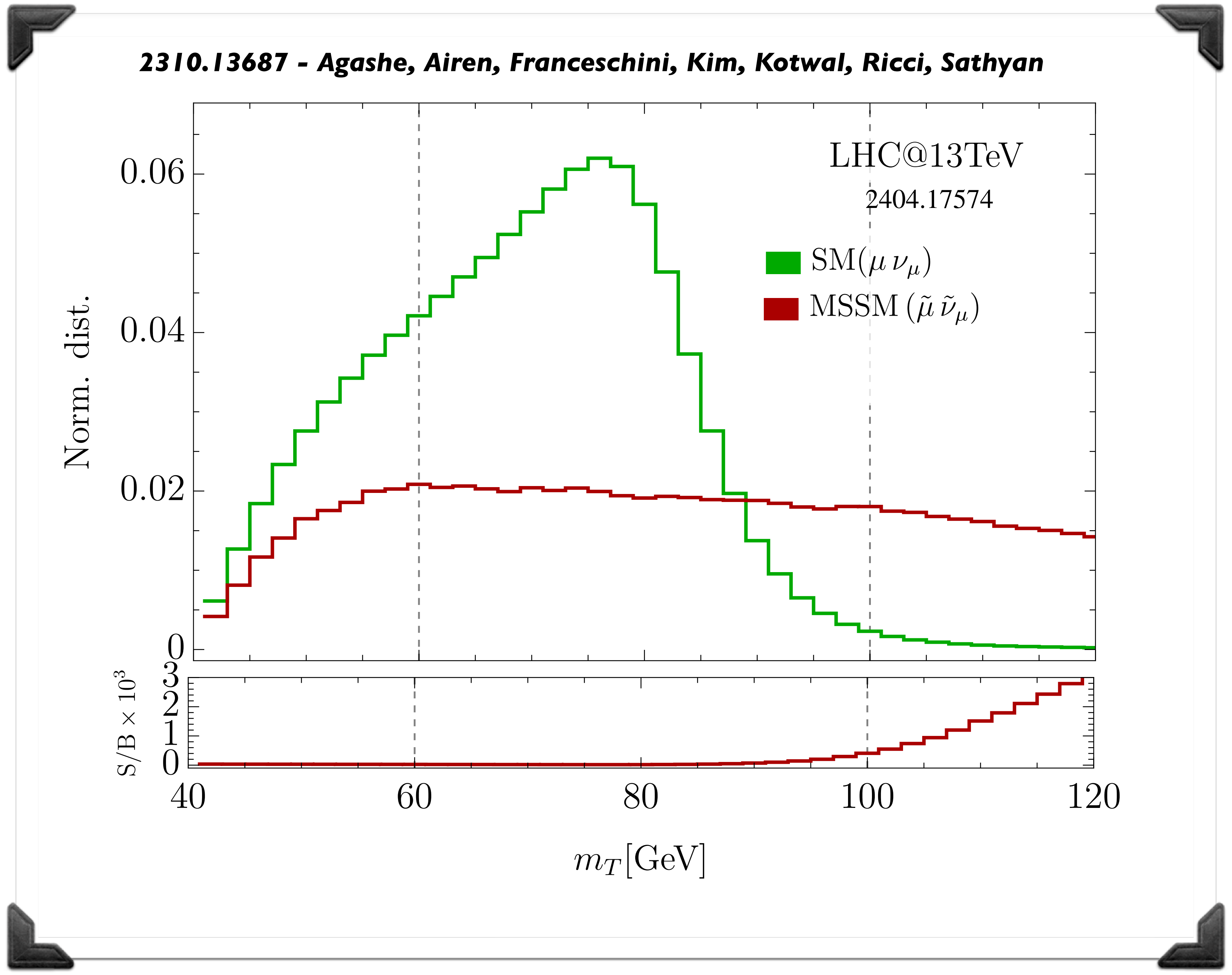

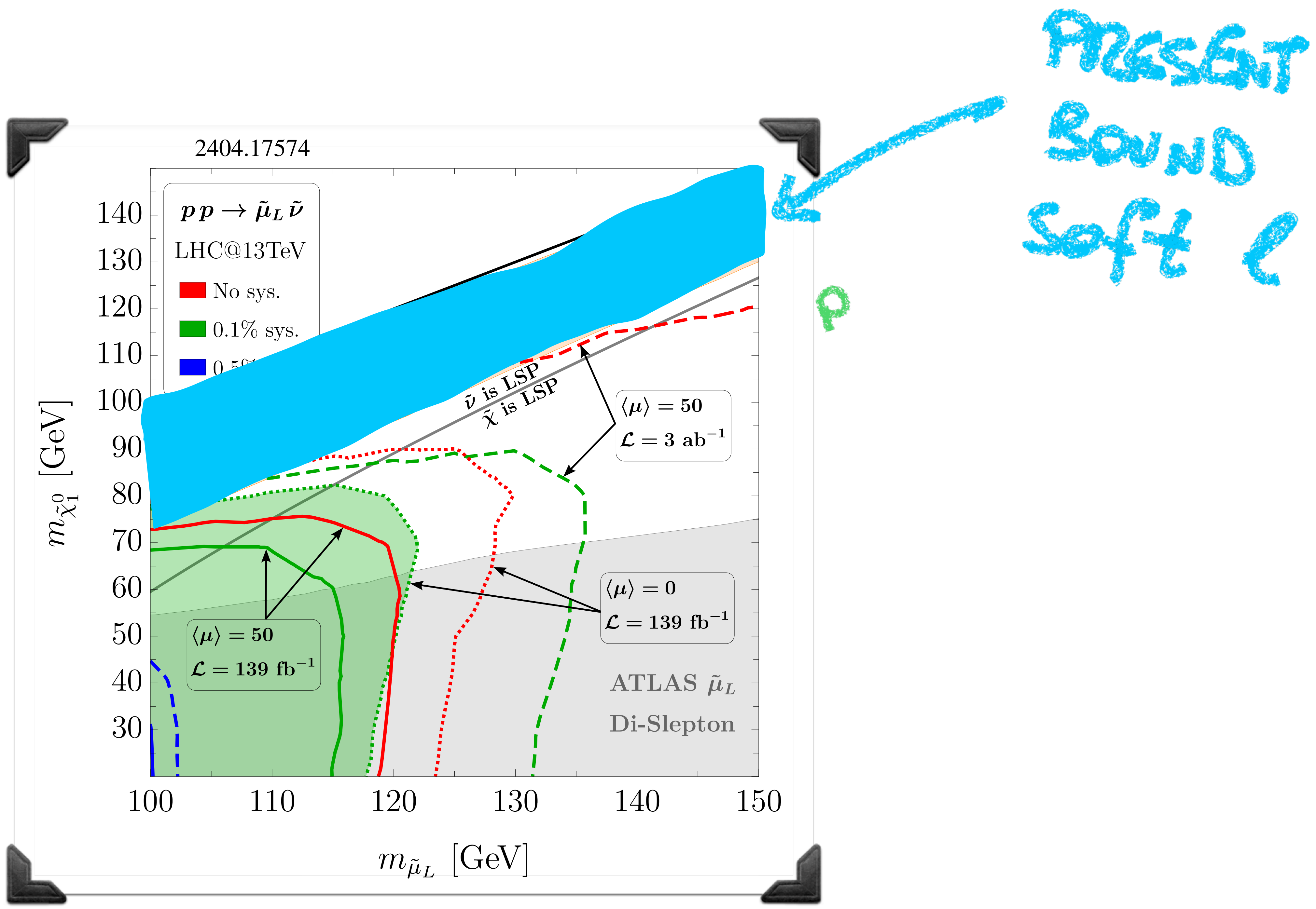

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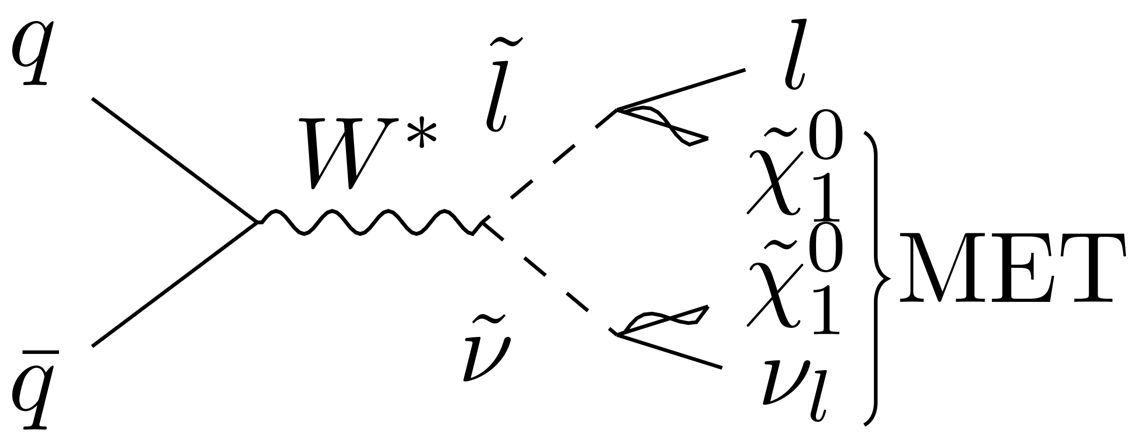
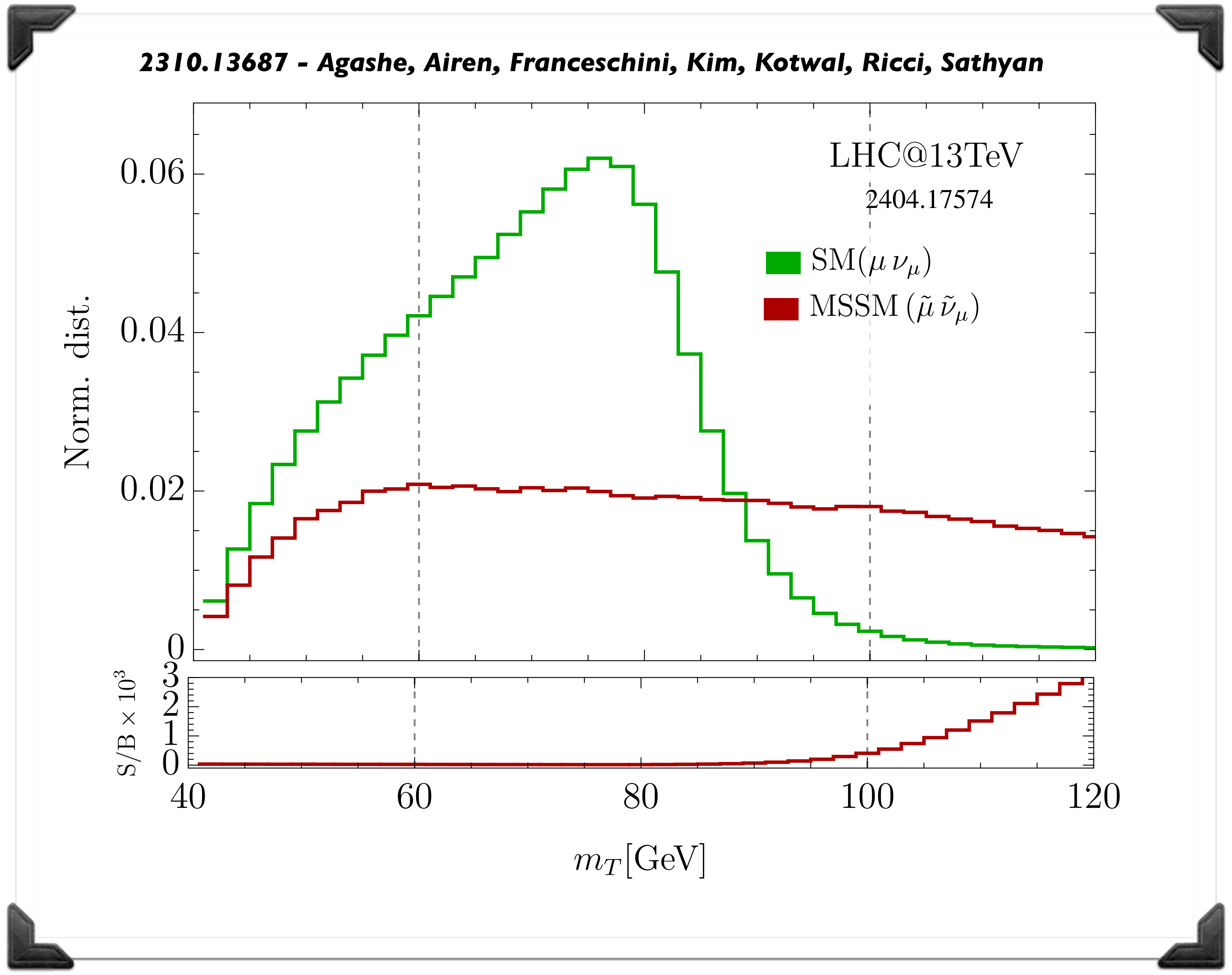
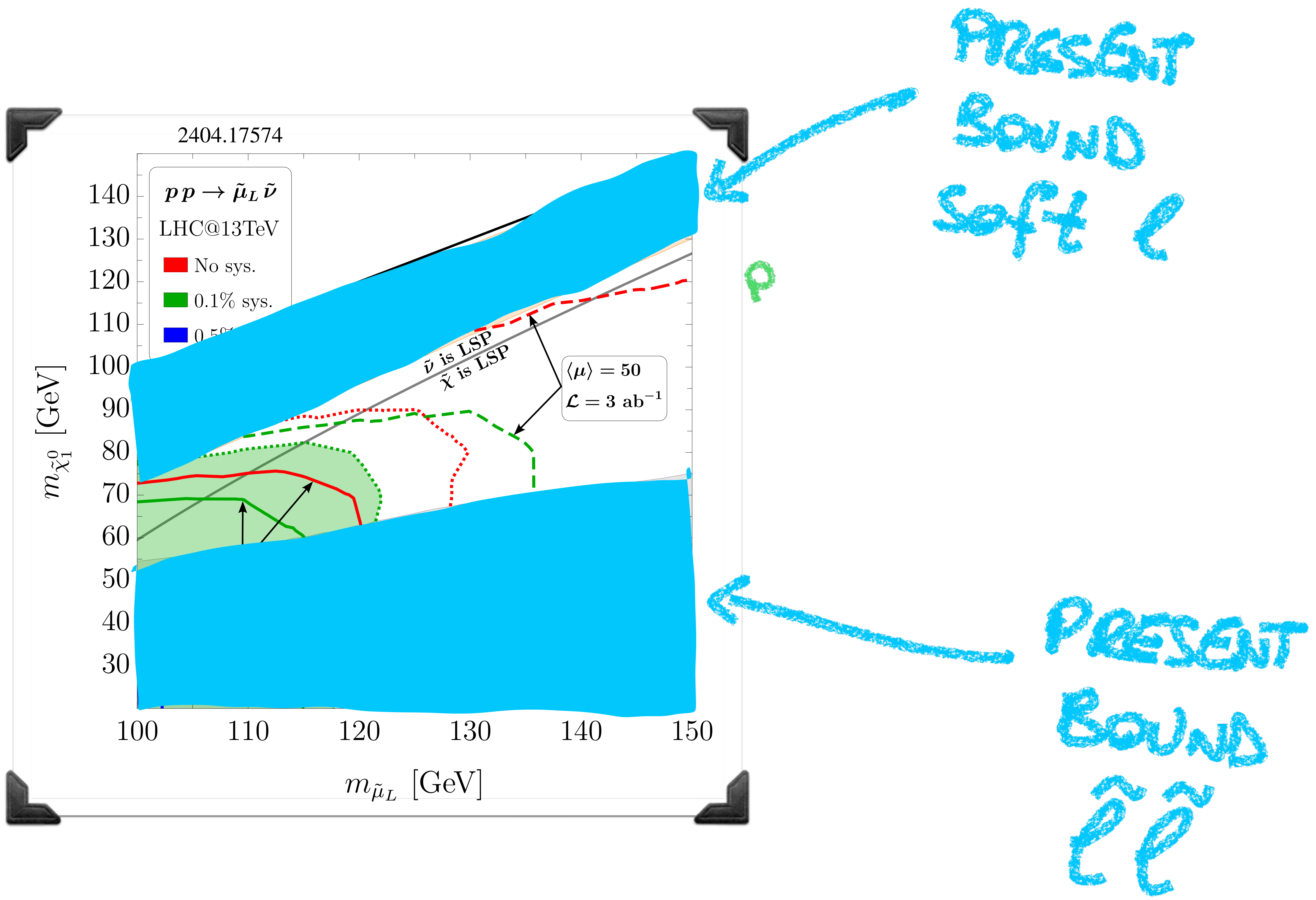
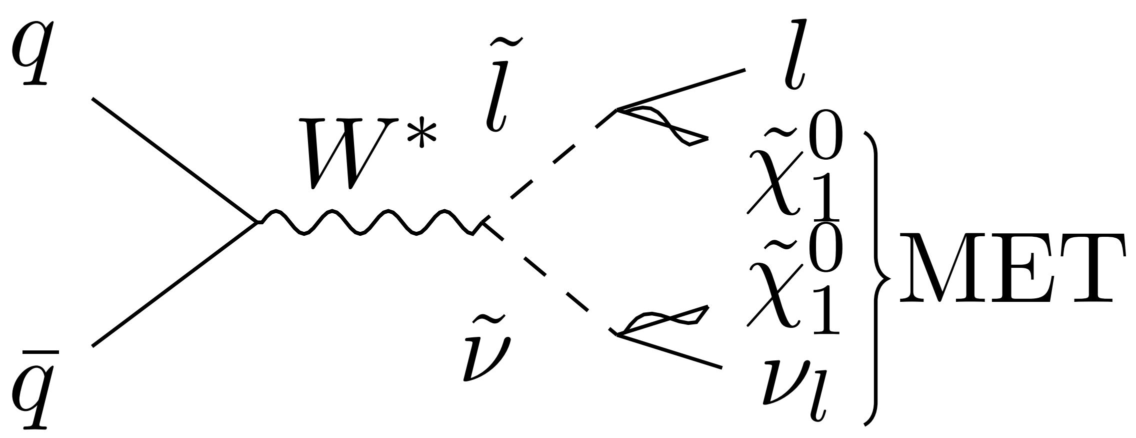
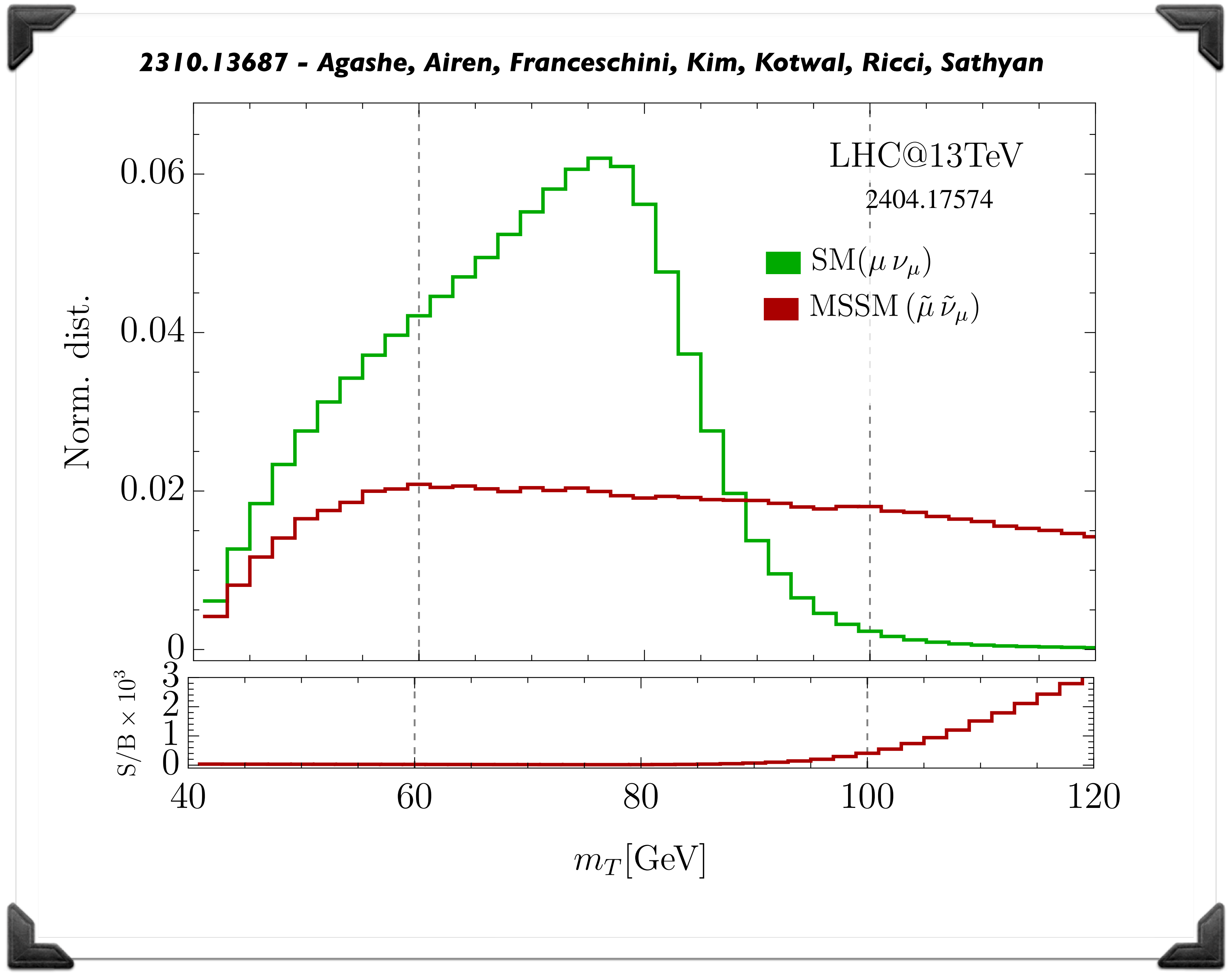


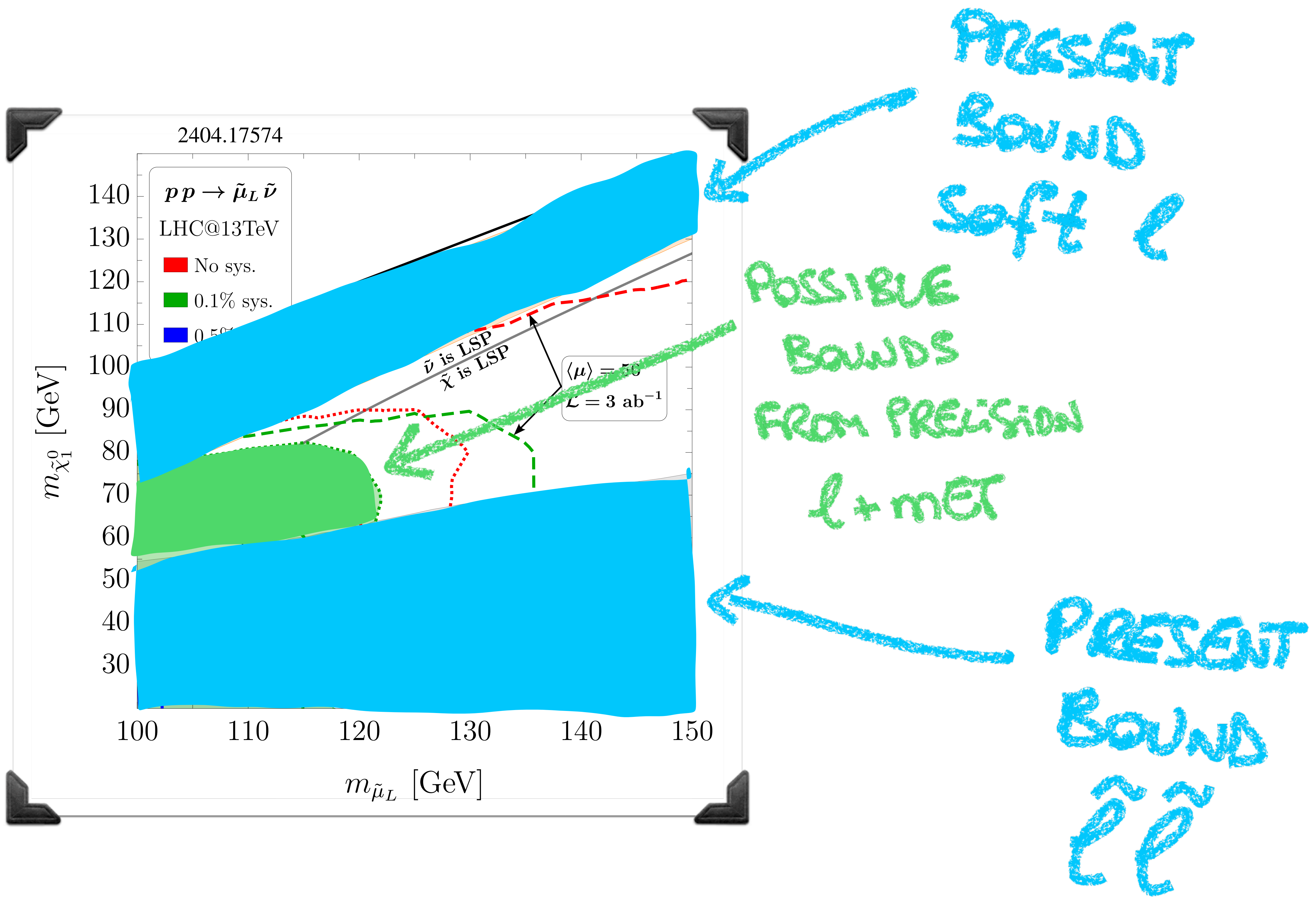




SEARCH & MEASURE in ℓ + mET







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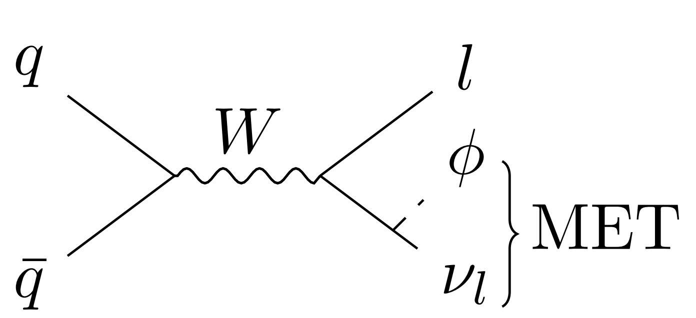
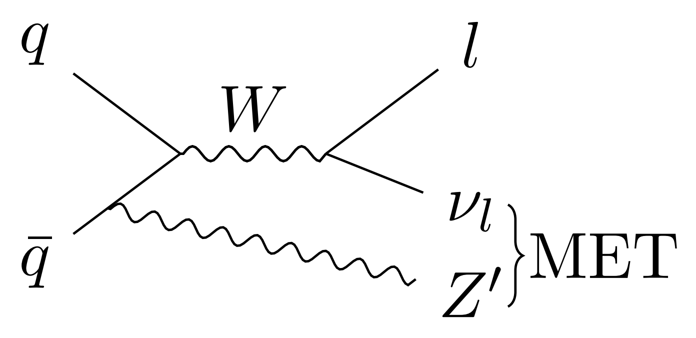
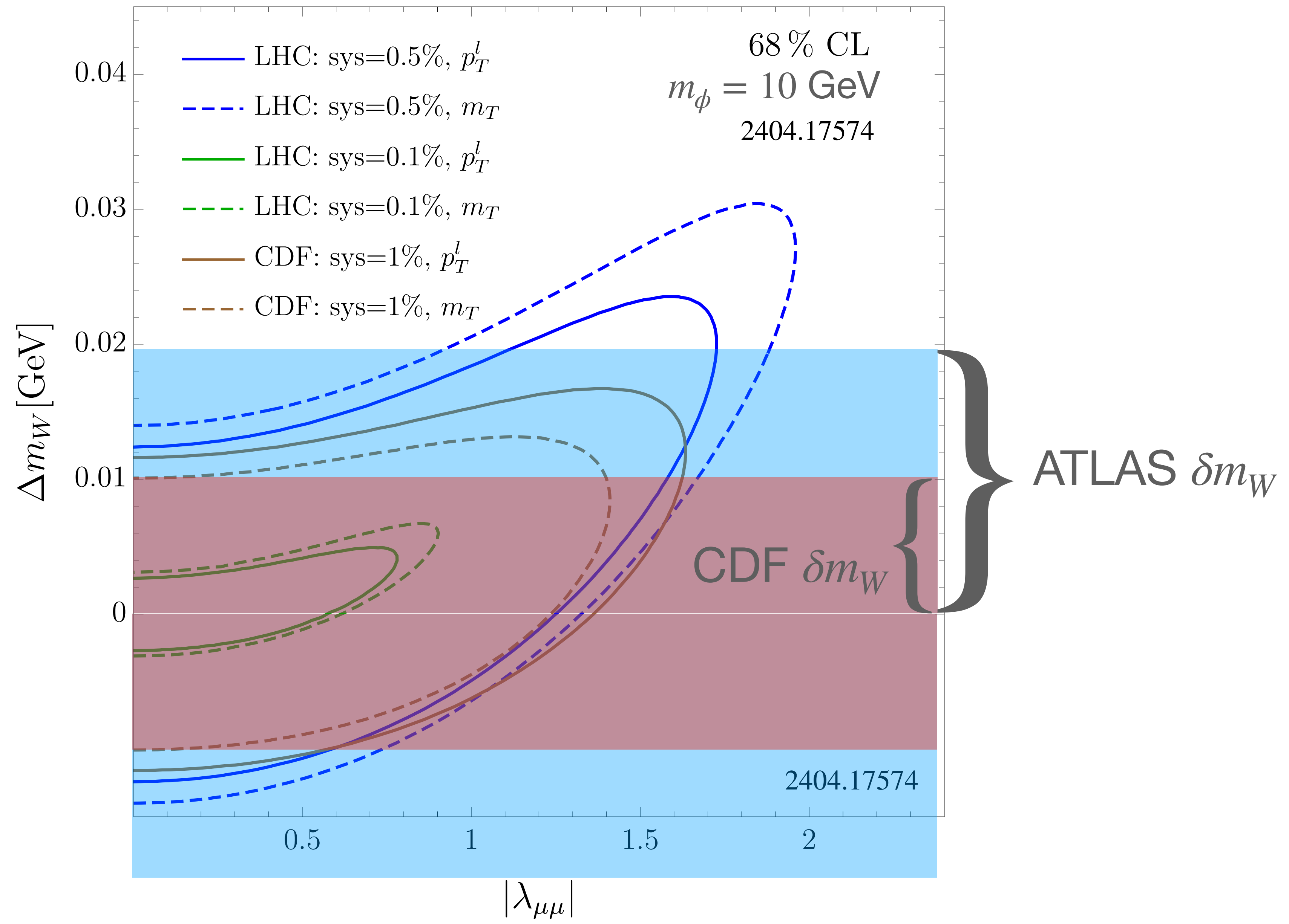
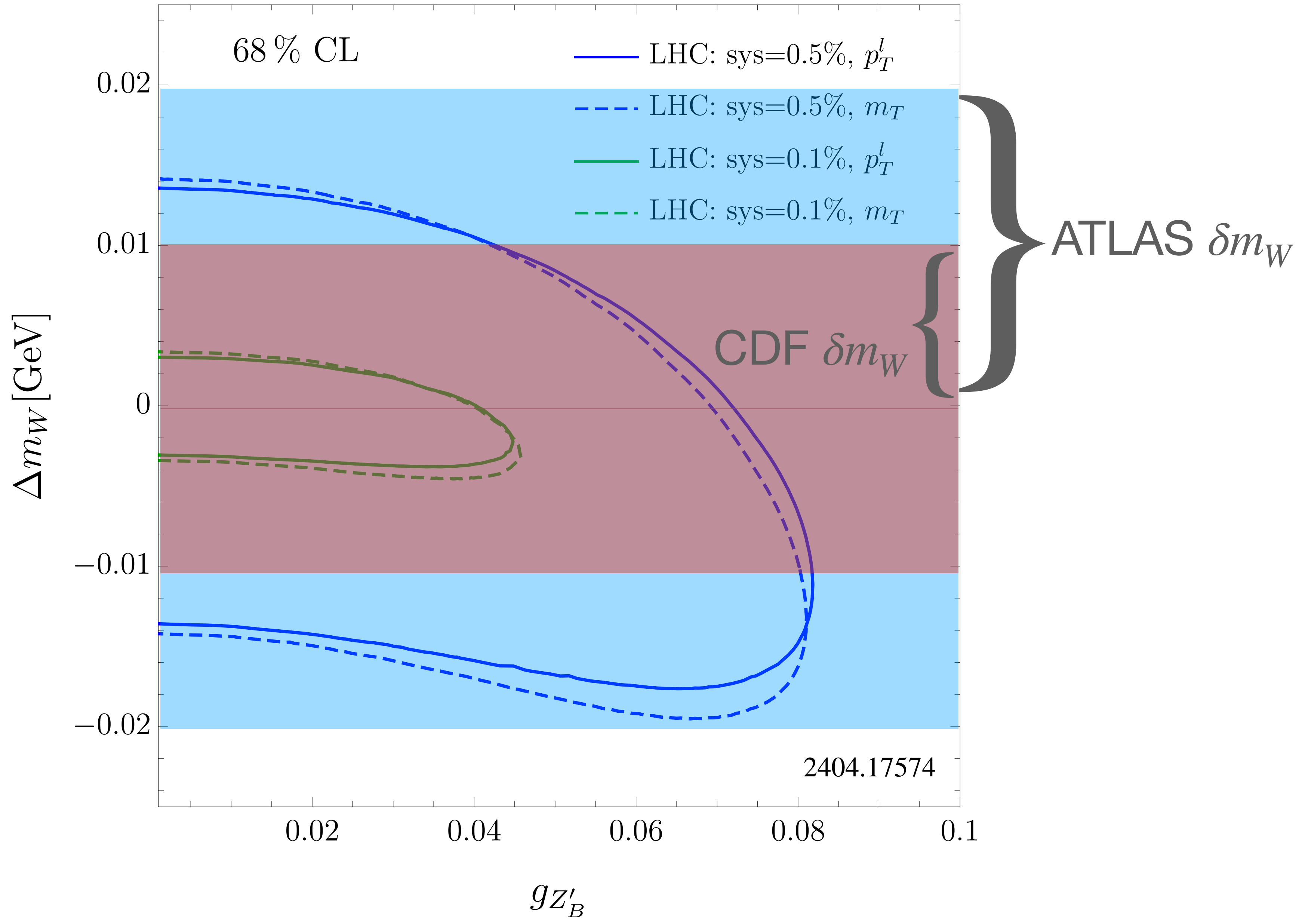


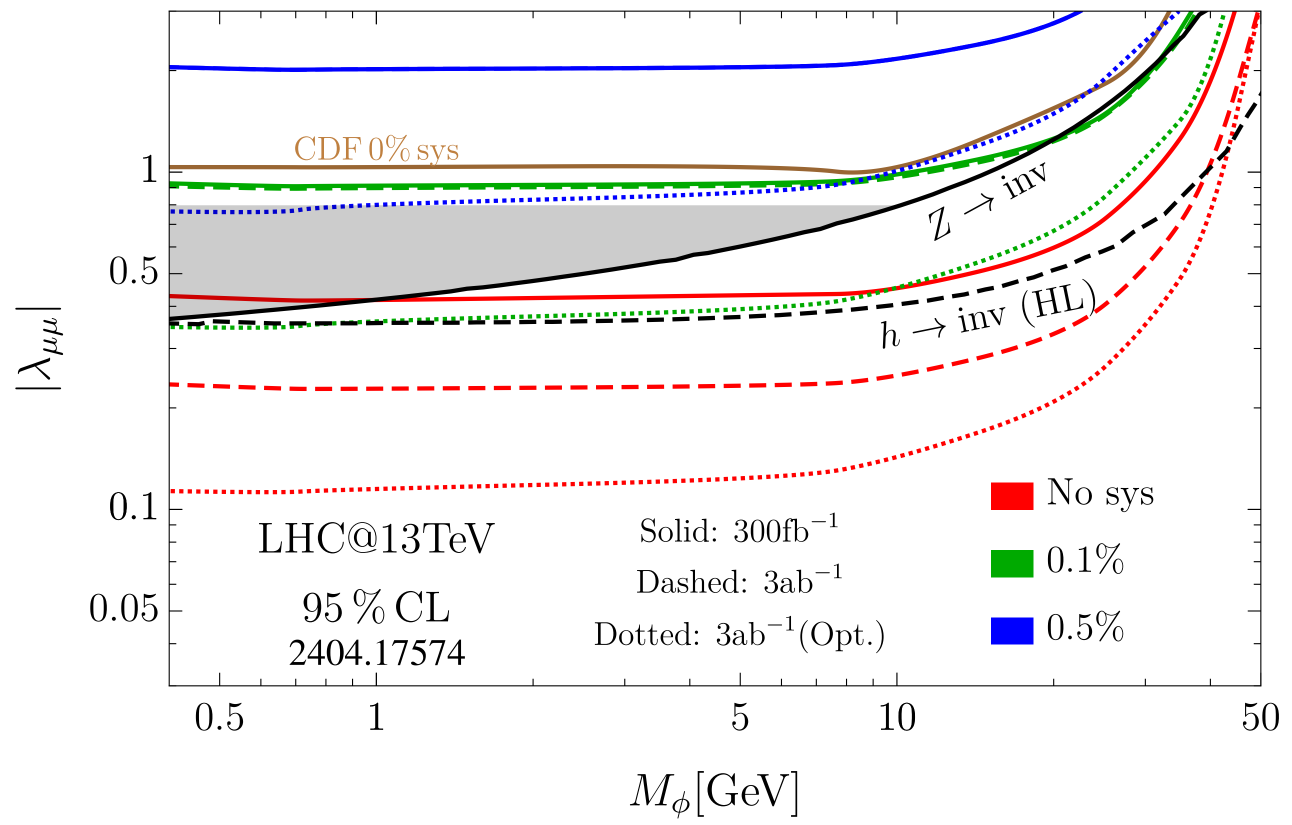
(c) Neutrinophilic scalar

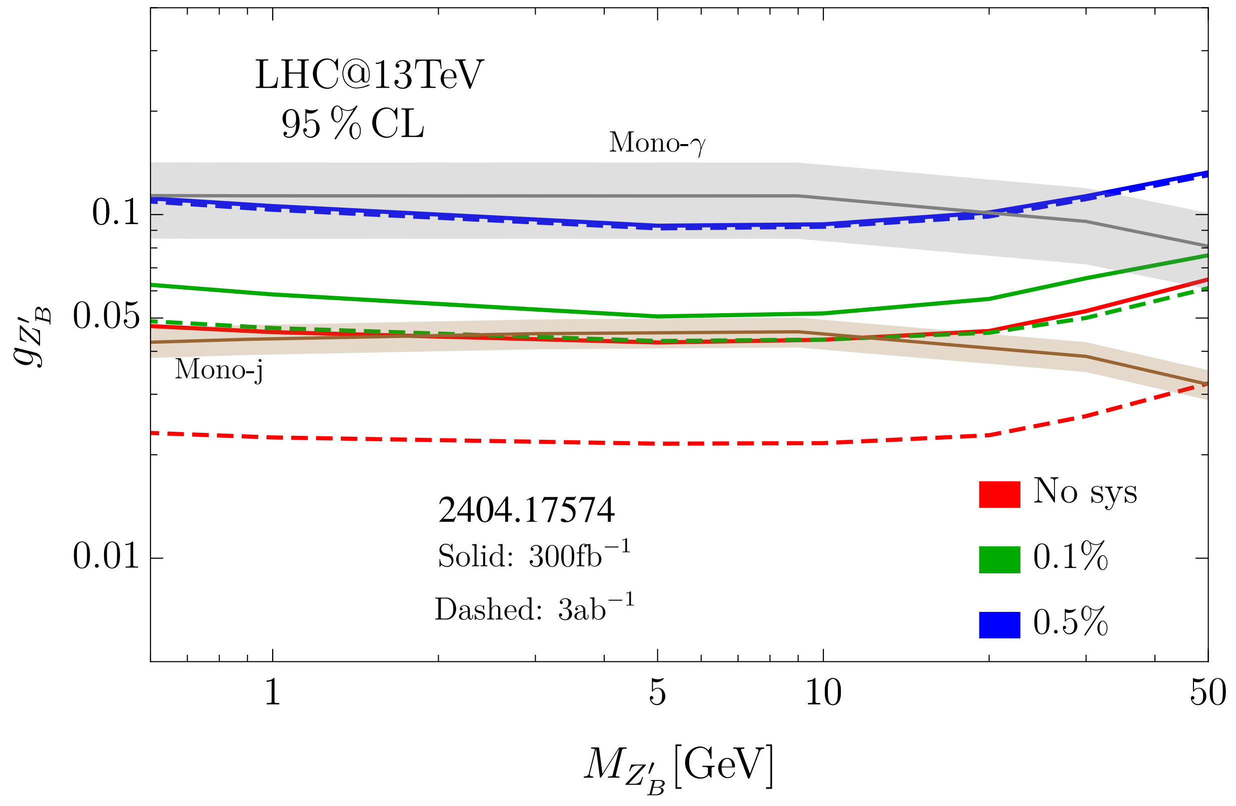


(a) Hadrophilic Z'

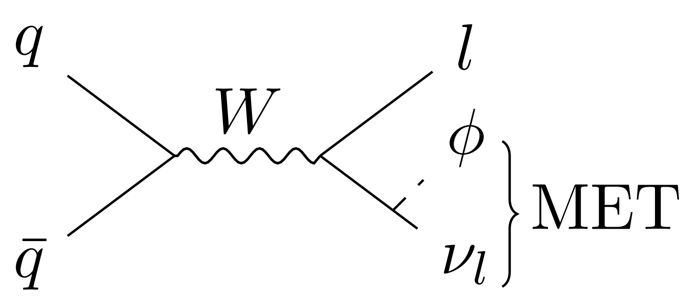








SEARCH & MEASURE in ℓ + mET



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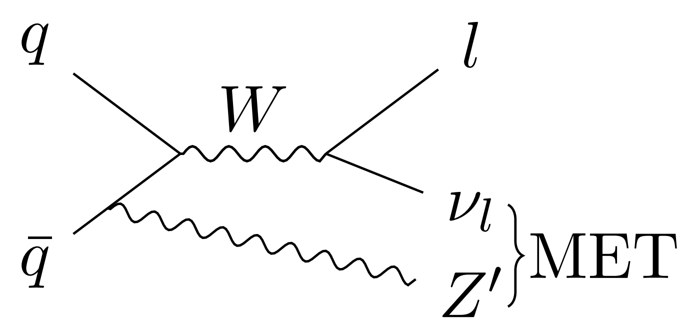

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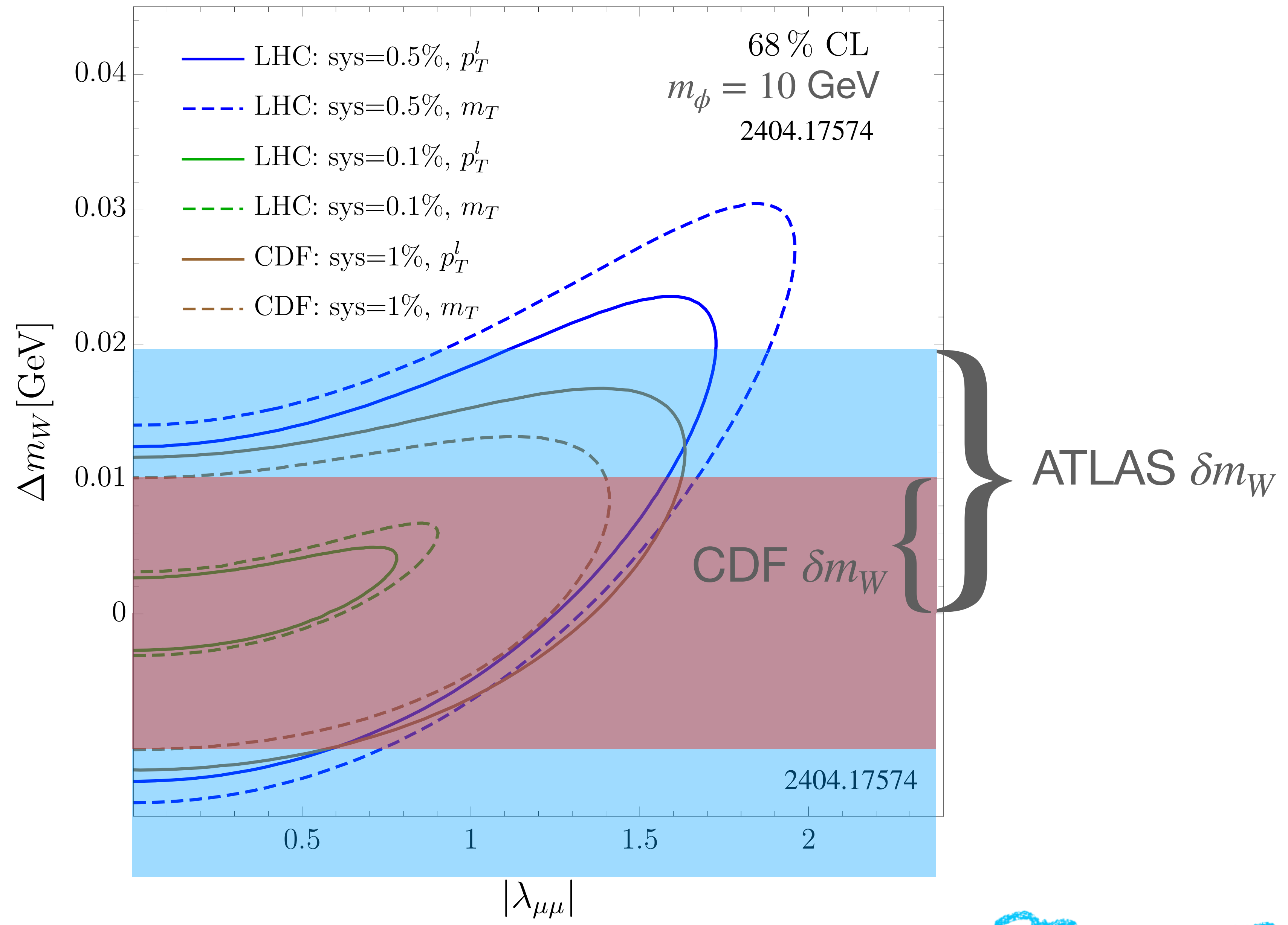
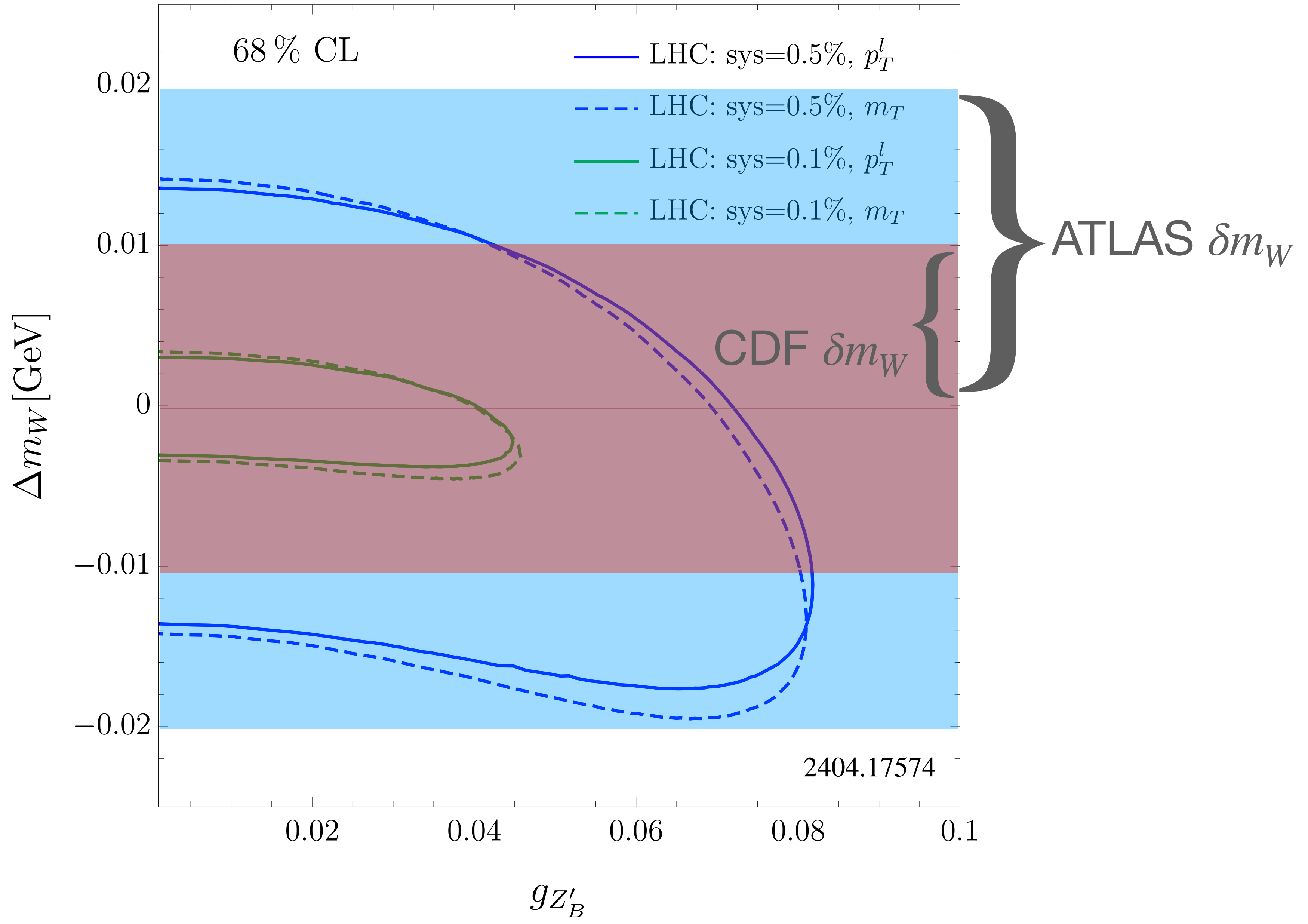
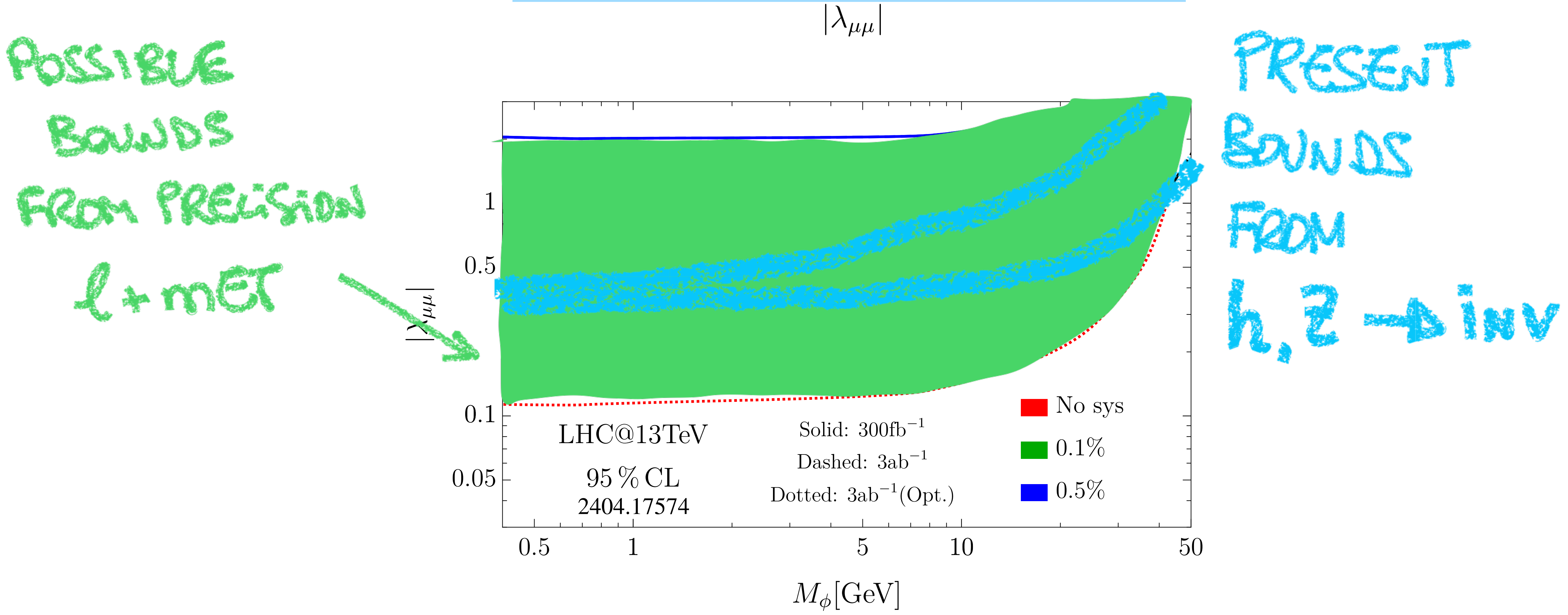
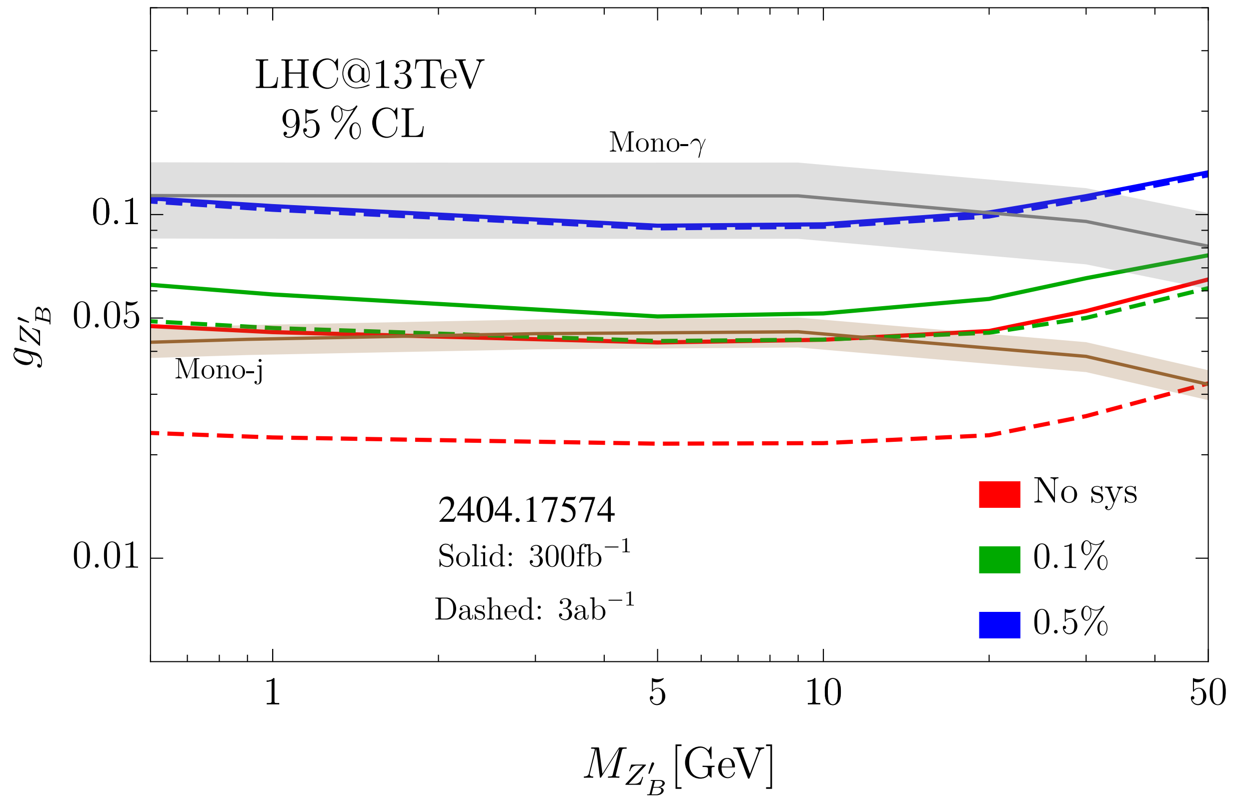
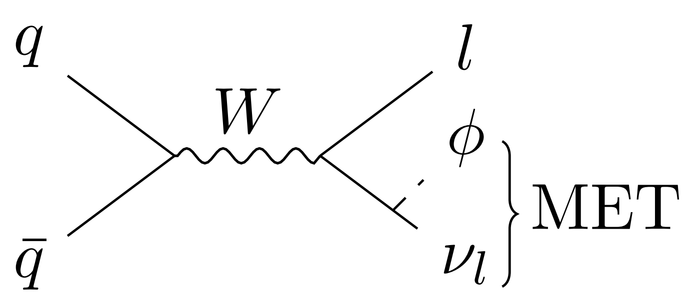








SEARCH & MEASURE in ℓ + mET



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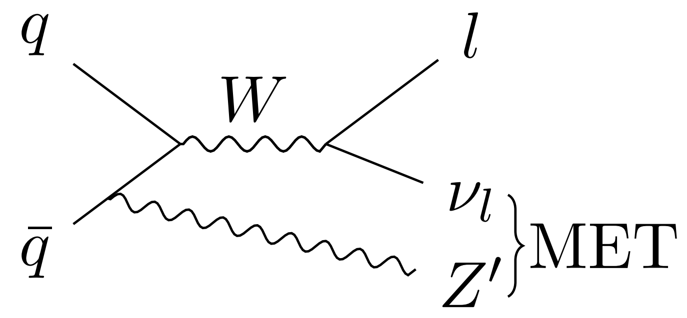

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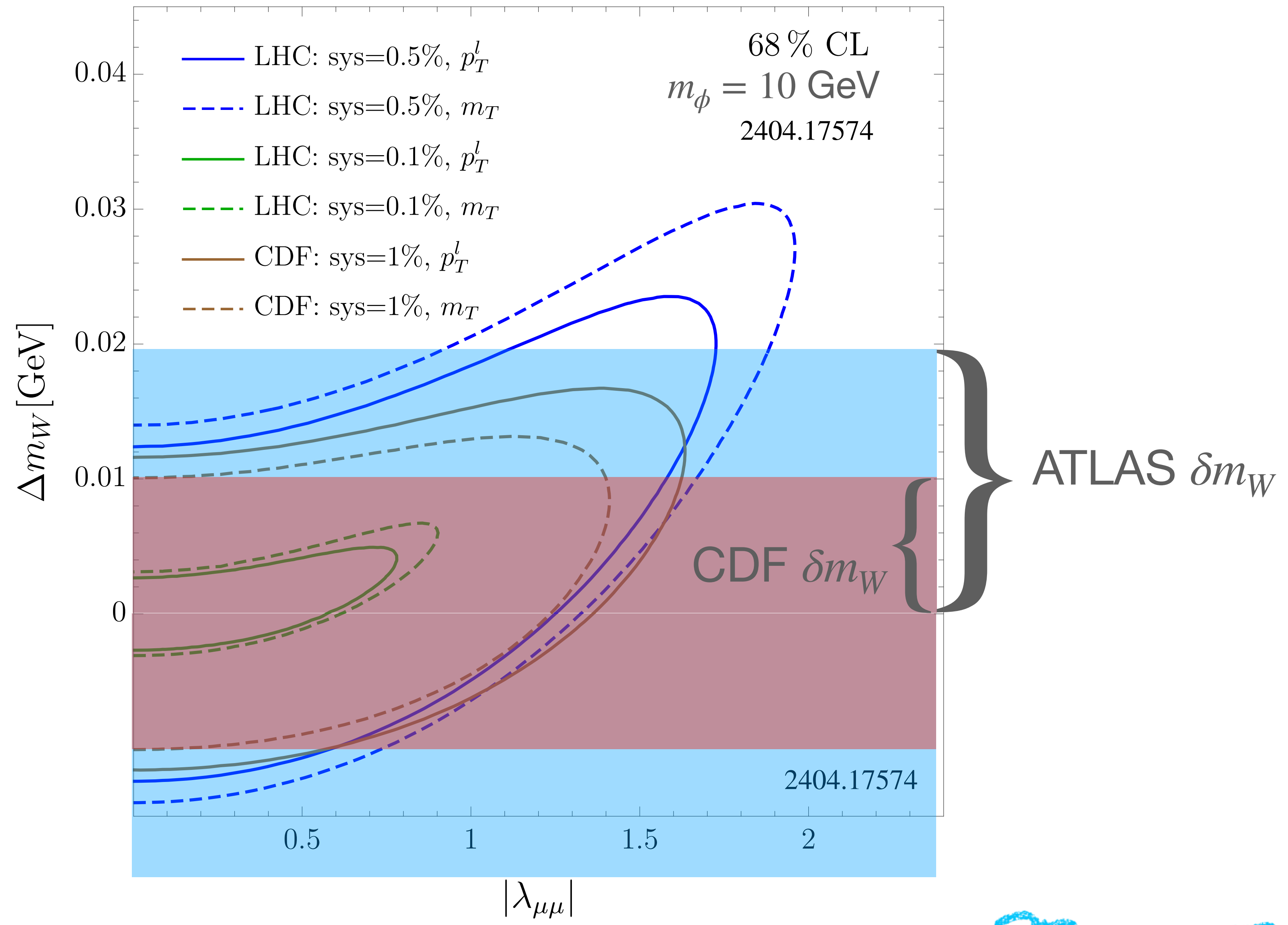
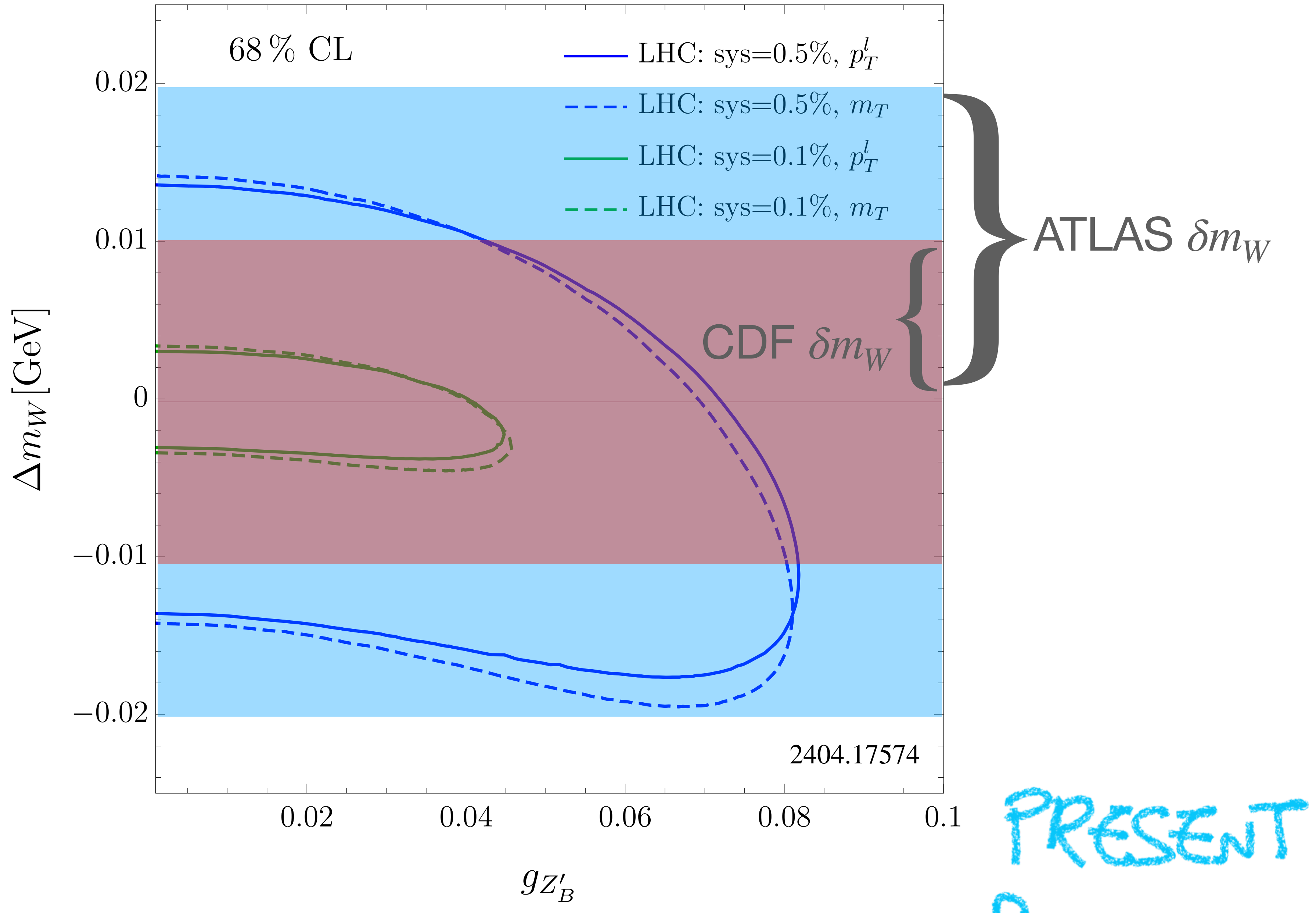
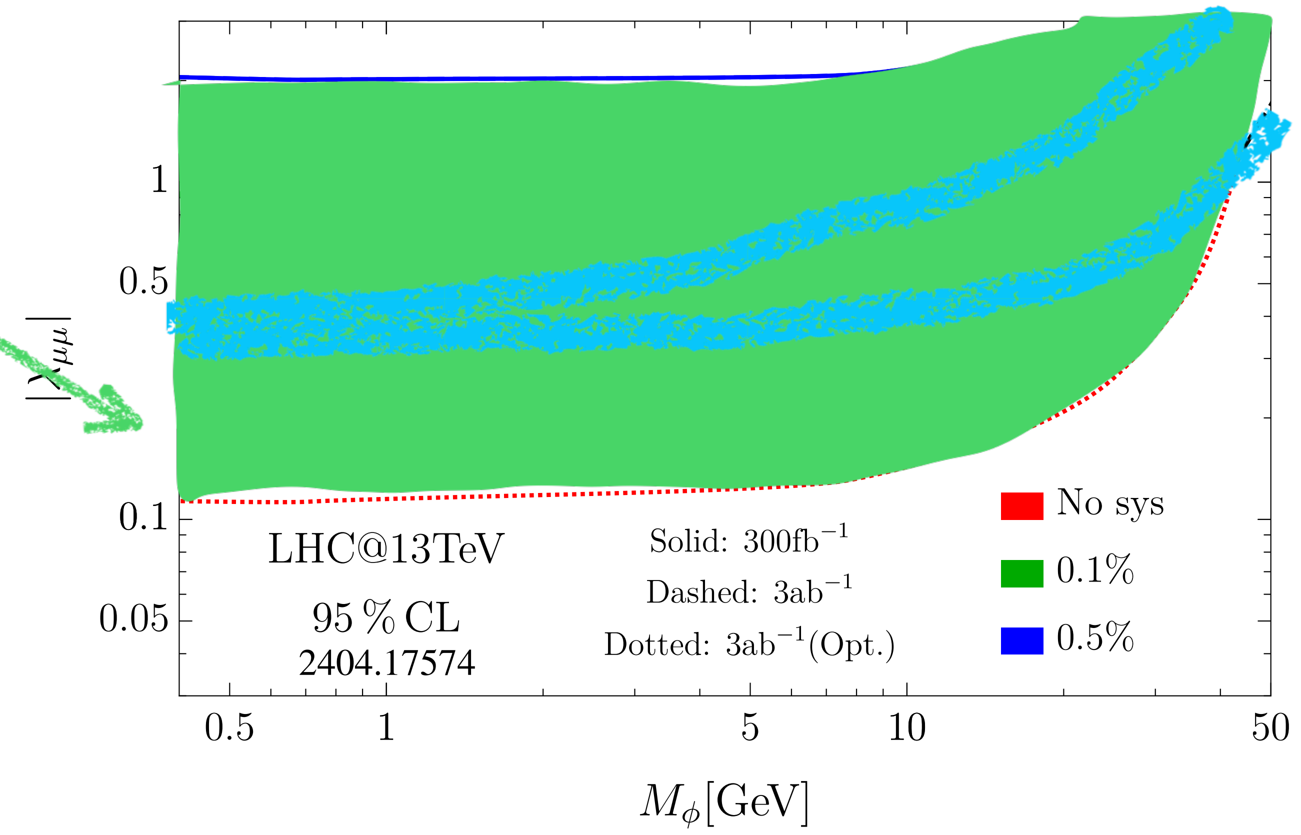


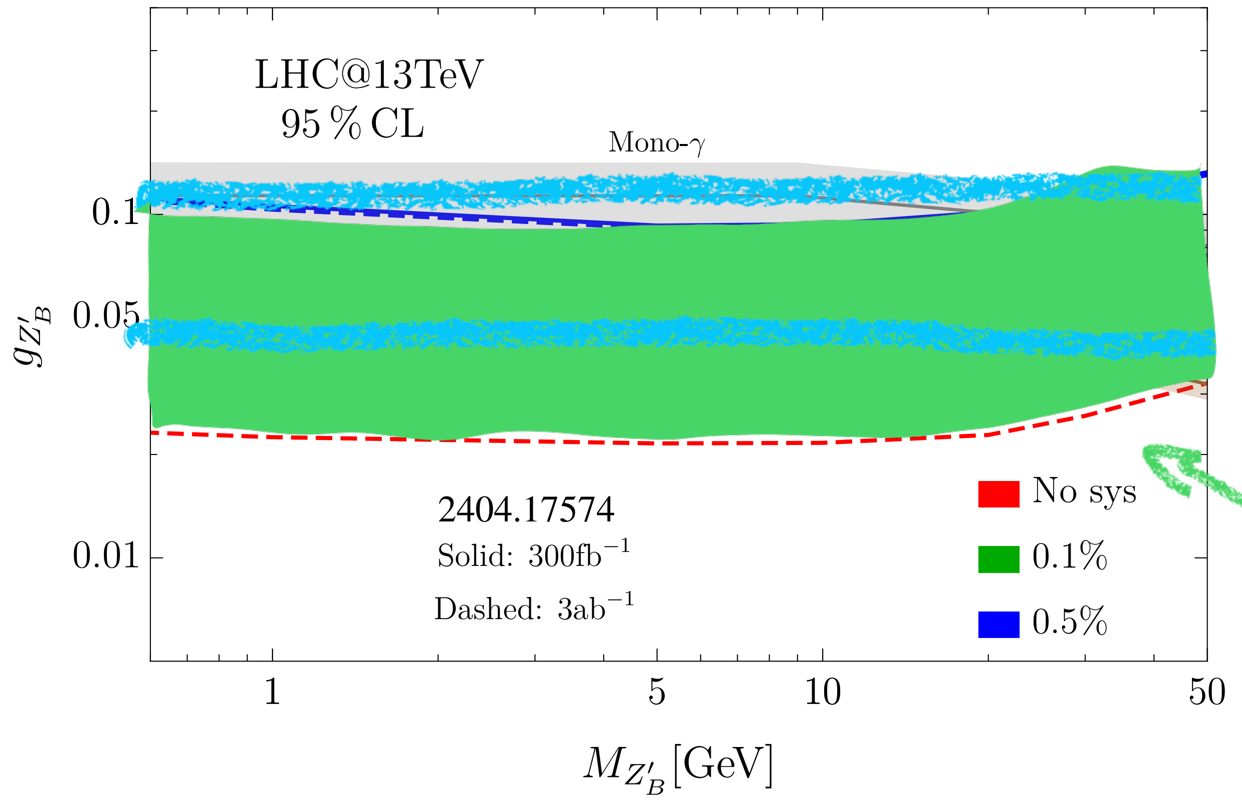


POSSIBLE BOUNDS FROM PRECISION ℓ + mET



PRESENT BOUNDS FROM h, Z → inv

PRESENT BOUNDS FROM MONO-X



POSSIBLE BOUNDS FROM PRECISION ℓ + mET

S&M

- Every SM measurement is a new physics search.
- Every BSM search is a SM measurement (of some quantity)

This is a widely applicable lesson
Run3 and HL-LHC the ideal time to apply it!

SEARCH & MEASURE

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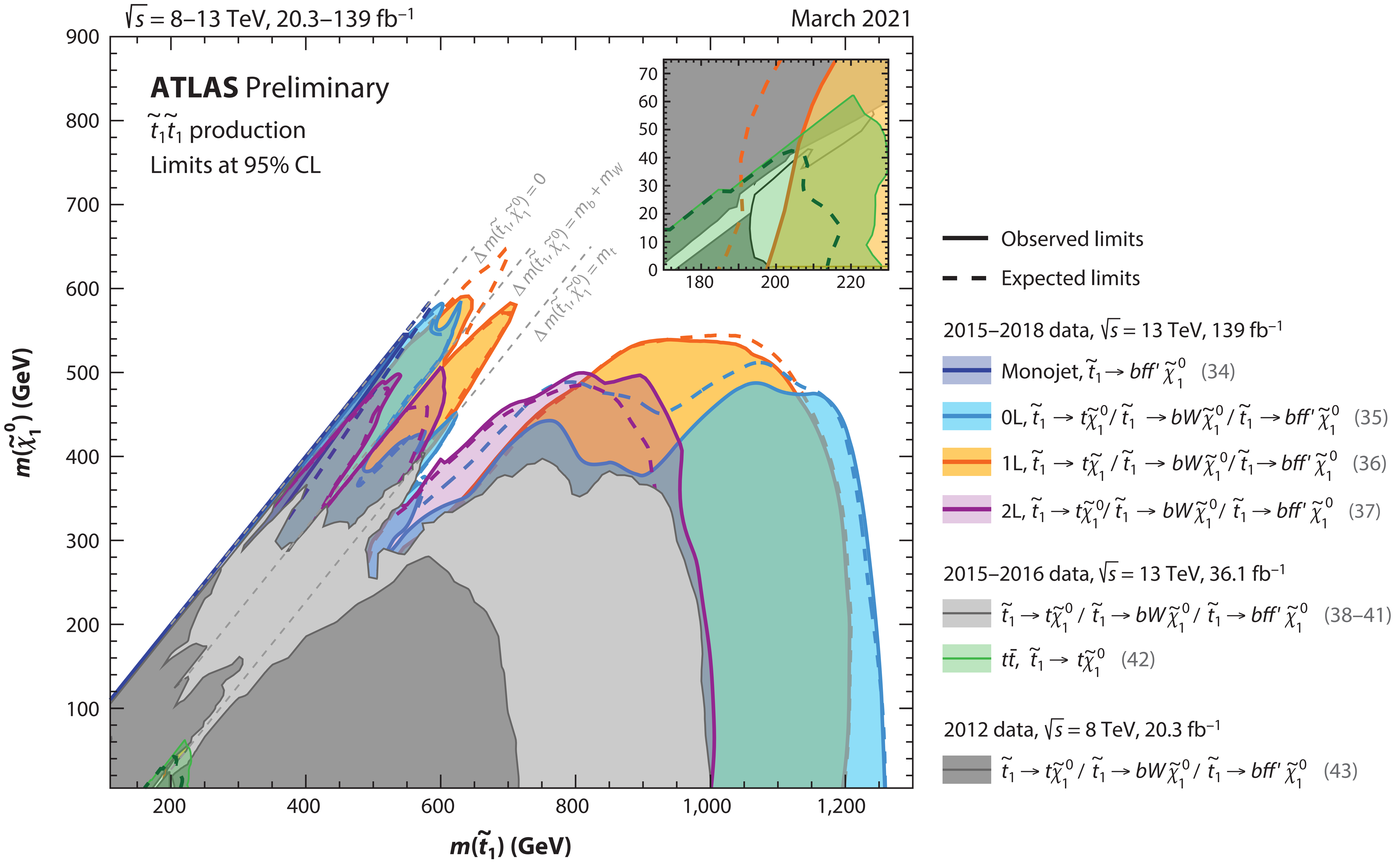
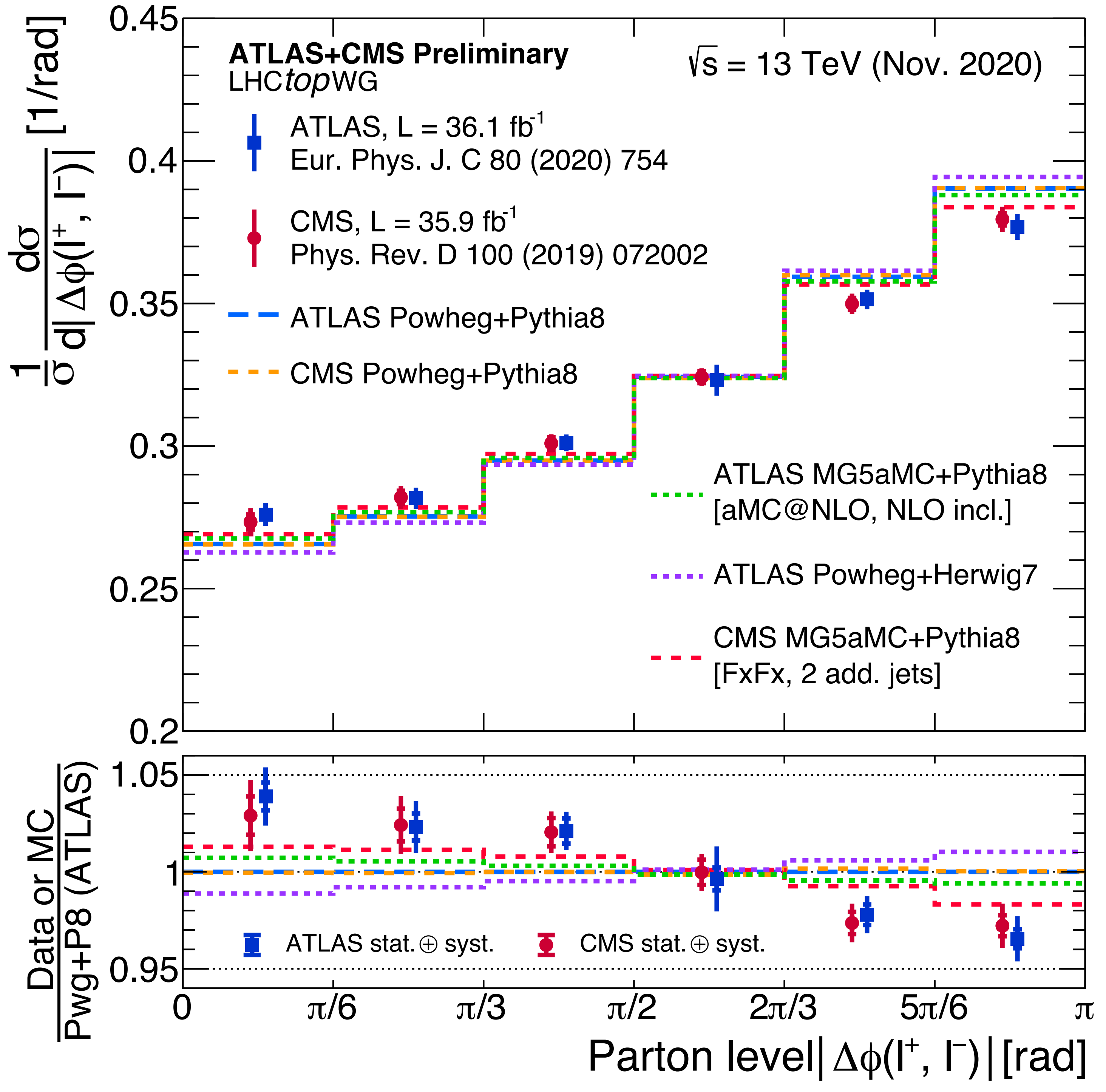
Situation in top quark physics





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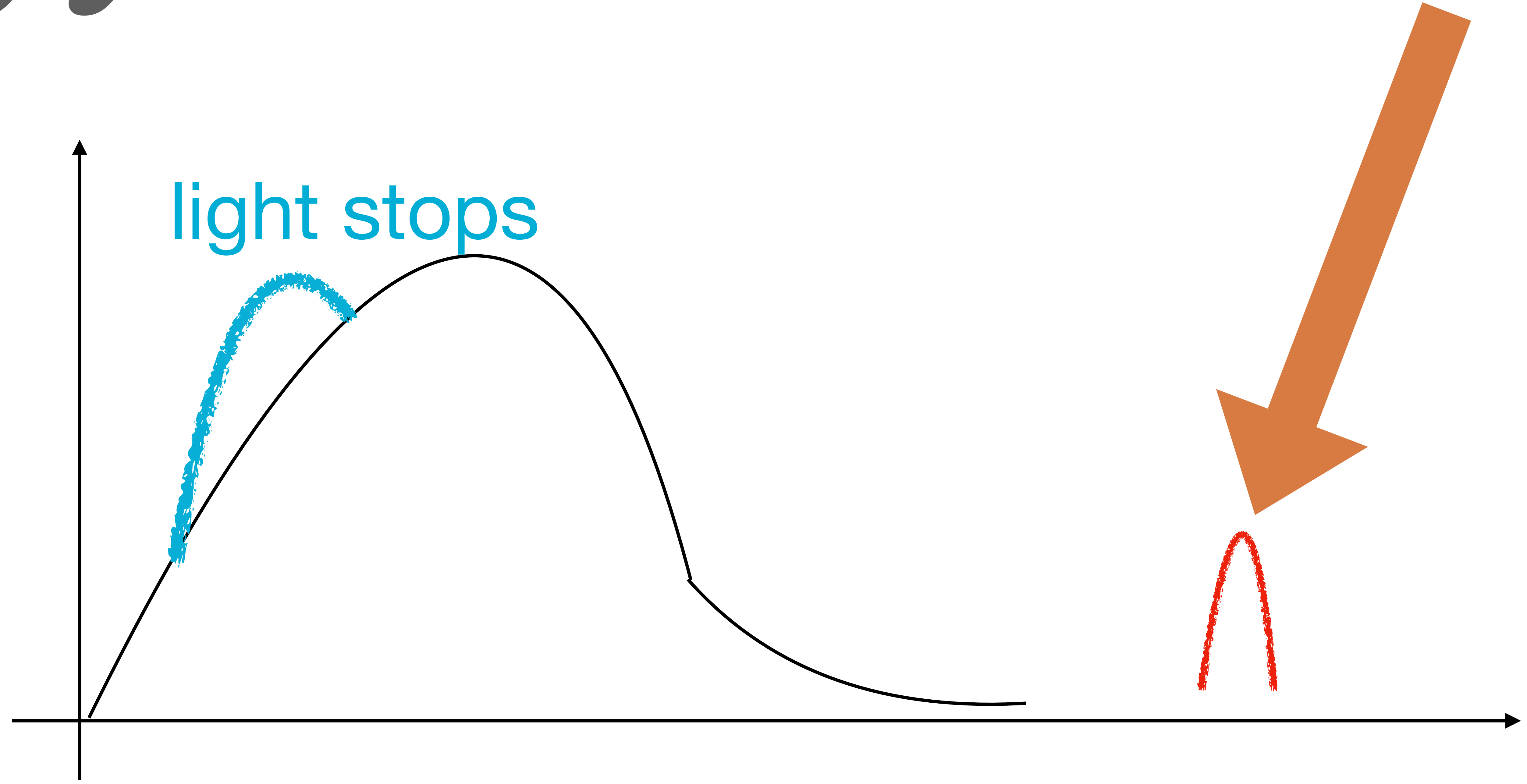
SEARCH & MEASURE

in $t\bar{t}$

"hard" new physics
where everyone is looking



Targeted new physics scenario

$\tilde{t} \to b\,\chi^{+} \to b\ell\nu\chi^{0}$

$t \to bW \to b\ell\nu$

Due to small mass differences between the NP states each energy release gives "soft" leptons and/or (b-)jets.

New physics that gives only "soft" leptons and (b-)jets is not the target of "*Search for …*"

Targeted new physics scenario

SEARCH & MEASURE in $t\bar{t}$

$\tilde{t} \to b\,\chi^{+} \to b\ell\nu\chi^{0}$

$t \to bW \to b\ell\nu$

Ideally one would have to devise a search analysis that can deal with O(10) GeV p_T leptons and (bottom) jets

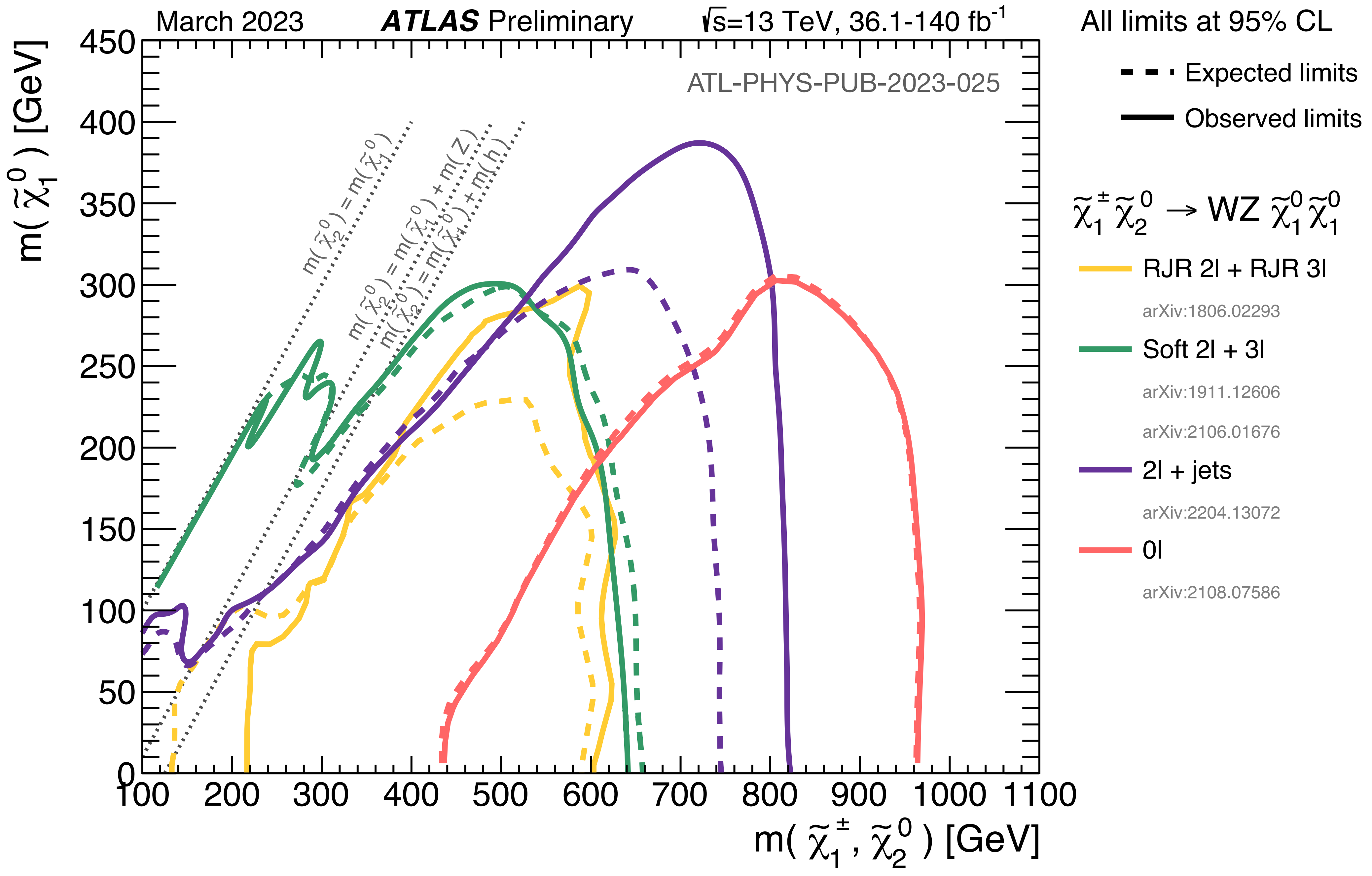
All the accurate work on these leptons and jets is already in place for the measurements of top quark properties!

Is this New Physics scenario excluded?

$m_{\tilde{t}} \simeq 200$ GeV —— $\tilde{t}$ SU(2) singlet

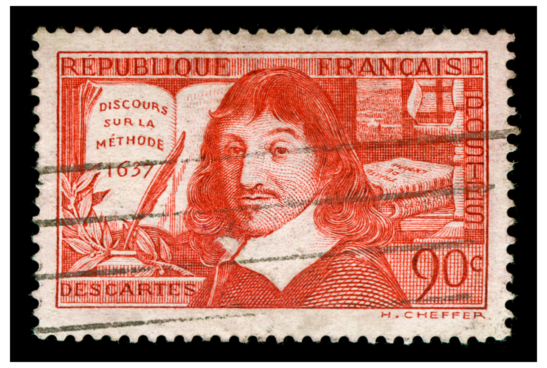
$m_{\chi^\pm} \simeq 170$ GeV —— $\chi^\pm$ Higgsino-like

$m_{\chi^0} \simeq 130$ GeV —— χ^0 Bino-Higgsino



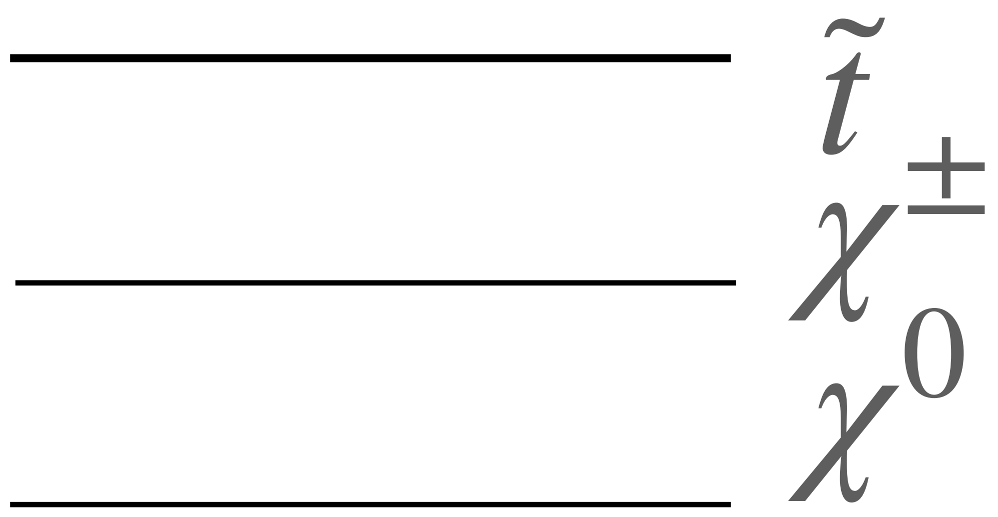
It is objectively difficult, if not impossible, to cover all the possible scenario that new physics can populate.

Especially hard with a bunch of 2D plots …



FROM THE CAPTION: The production cross-section is for pure Wino $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$.

Recast bounds on the NP scenario



SModelS

2013 → 2023

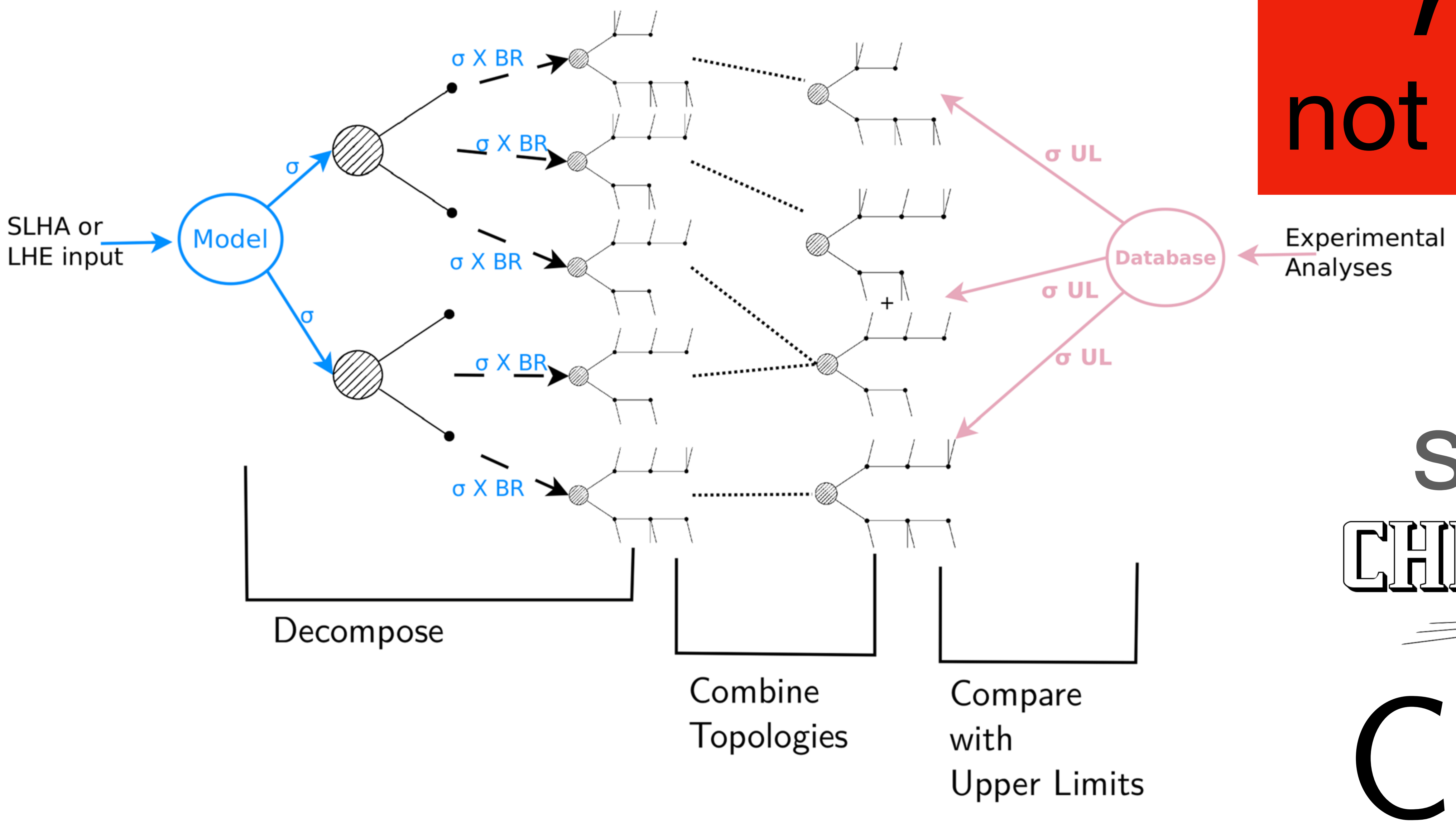
1312.4175 → 2306.17676

v1.0 → v2.3

$r > 1$ excluded

$r < 1$ not excluded

A point that made the development of this idea in practice very difficult for years is the objective difficulty to test if a new physics scenario is excluded by present searches that were not tailored for that scenario.



see also

CHECKMATE

1312.2591

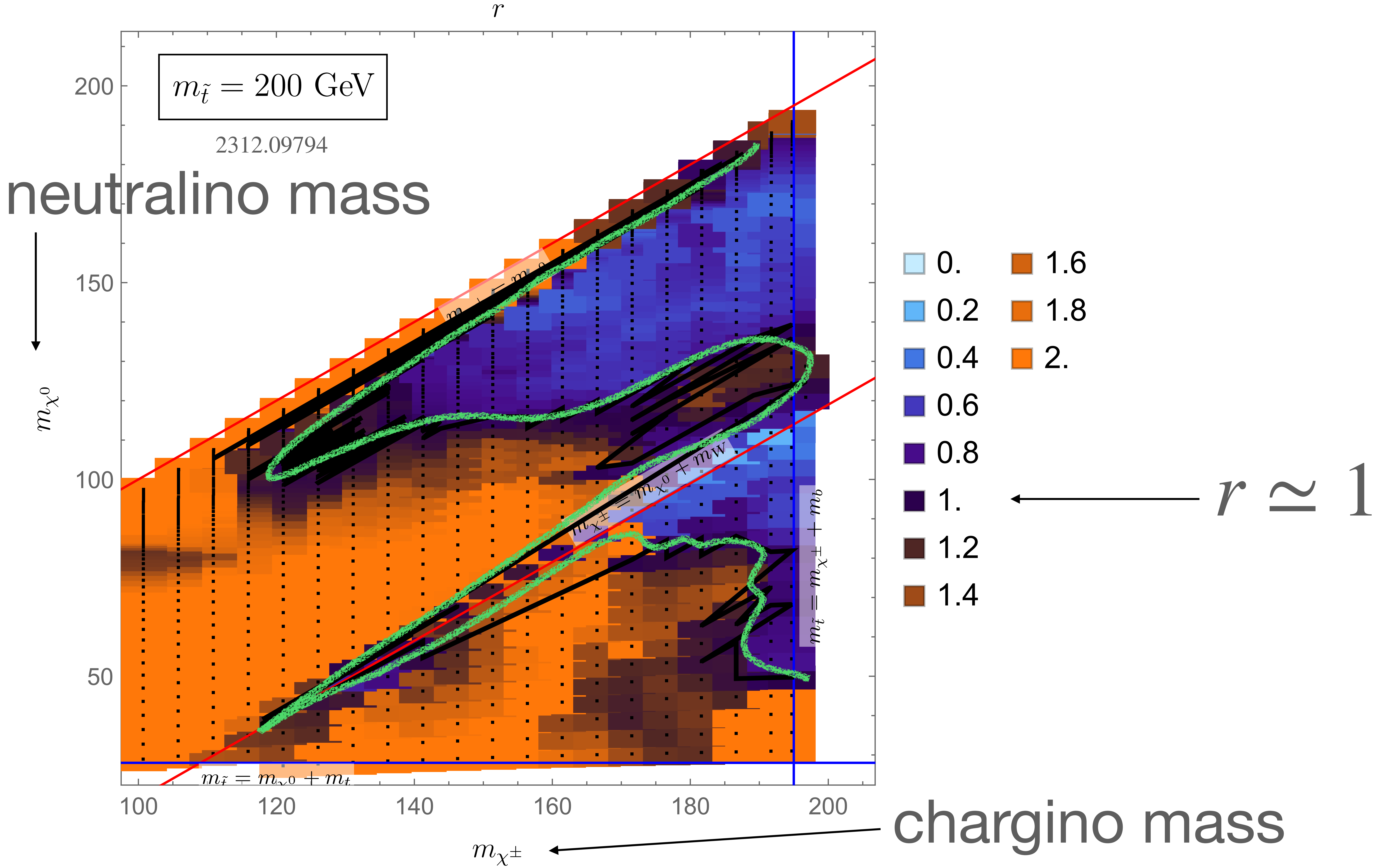
Contur

1606.05296,2102.04377

Recast bounds on the NP scenario

using all analyses included in SModelS

comprising 5744 individual maps from 1152 distinct signal regions, 100 different SMS topologies, from a total of 111 analyses



There are scenarios in the MSSM that cannot be excluded by the searches presently included in SModelS

(they even give the right Higgs boson mass at 1-loop, and the correct Higgs boson couplings, but never mind, just a lucky strike)

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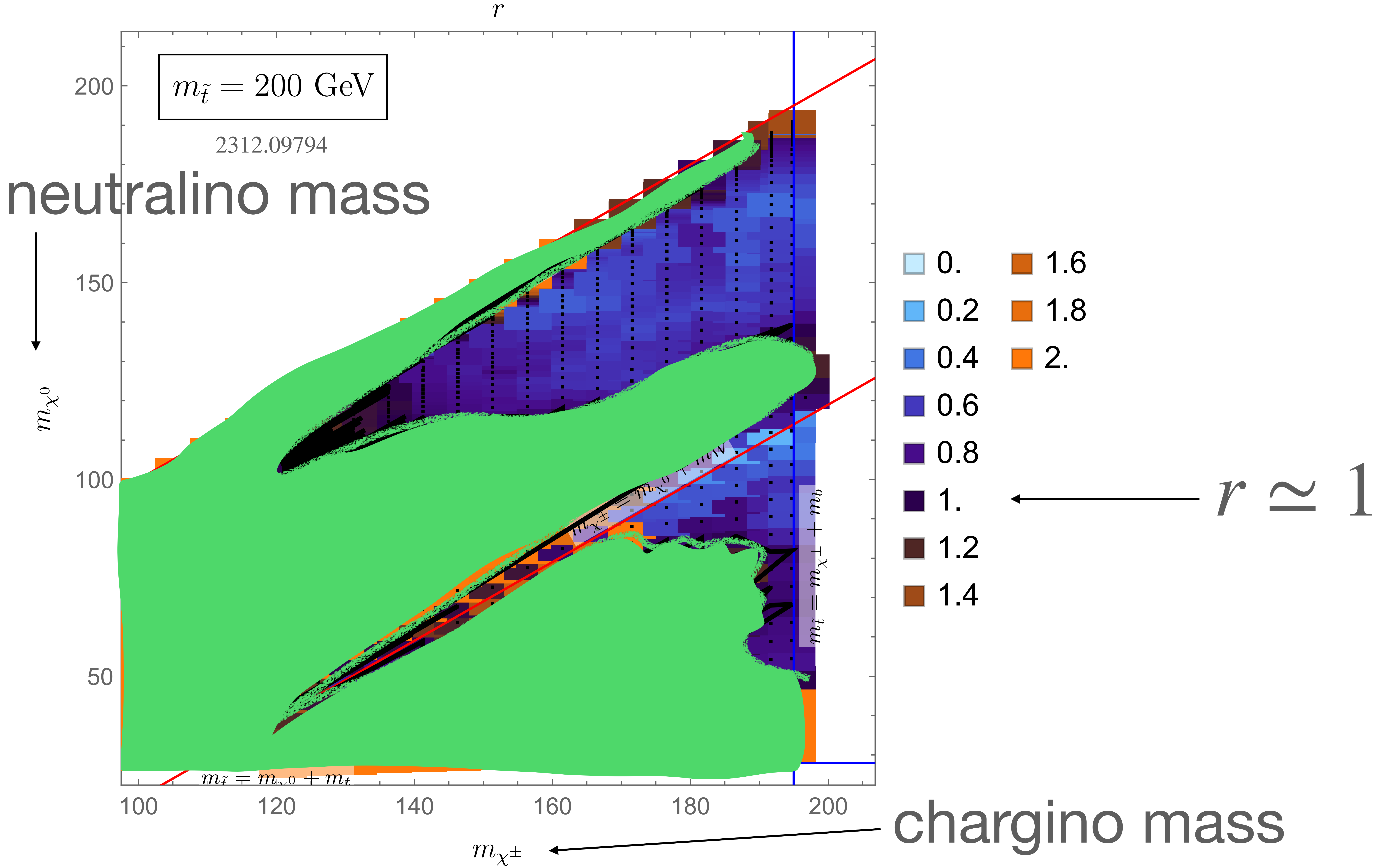

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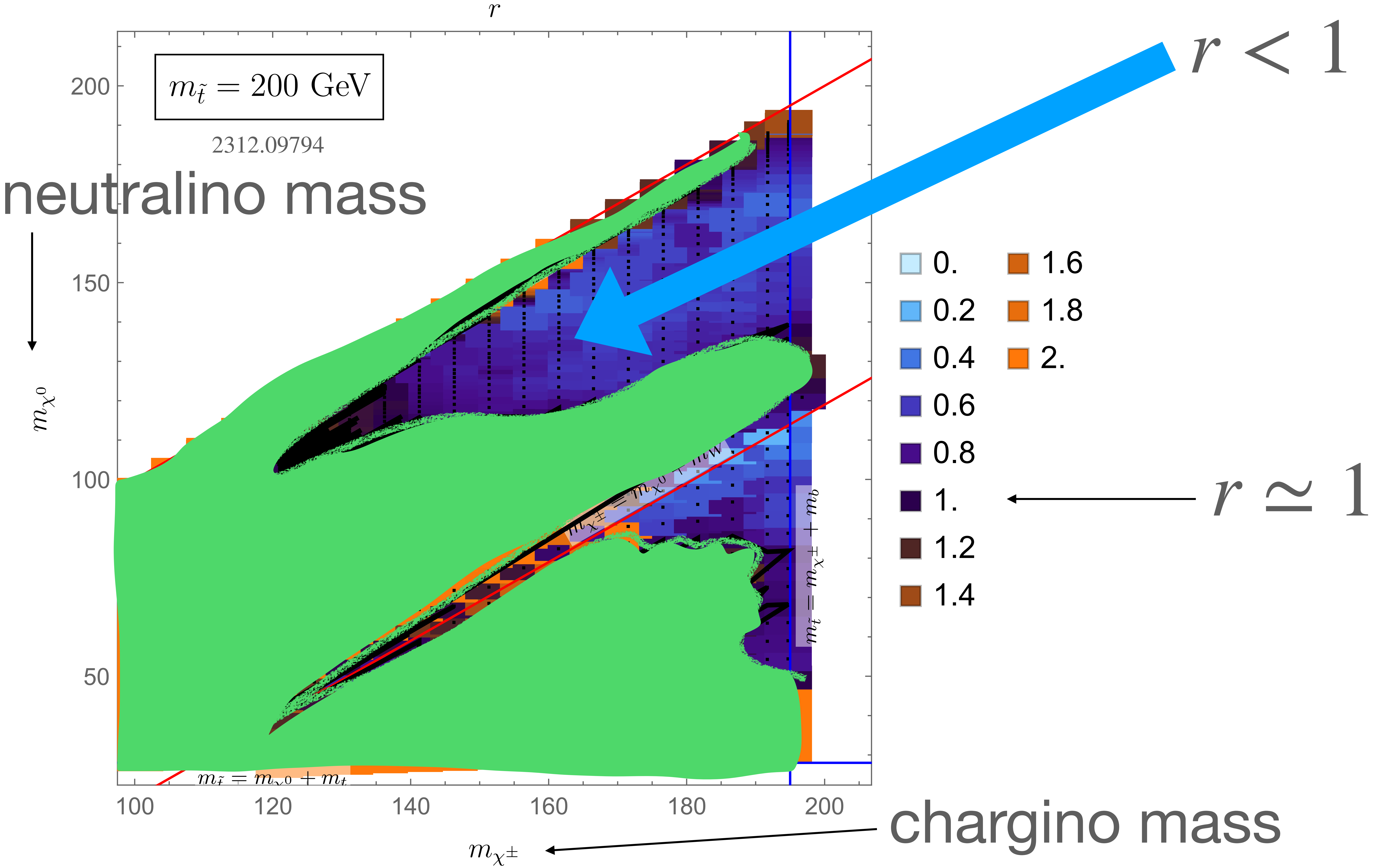

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There are scenarios in the MSSM that cannot be excluded by the searches presently included in SModelS

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Top precision measurements in "search mode"

SEARCH & MEASURE in $t\bar{t}$

$t \rightarrow bW \rightarrow b\ell\nu$

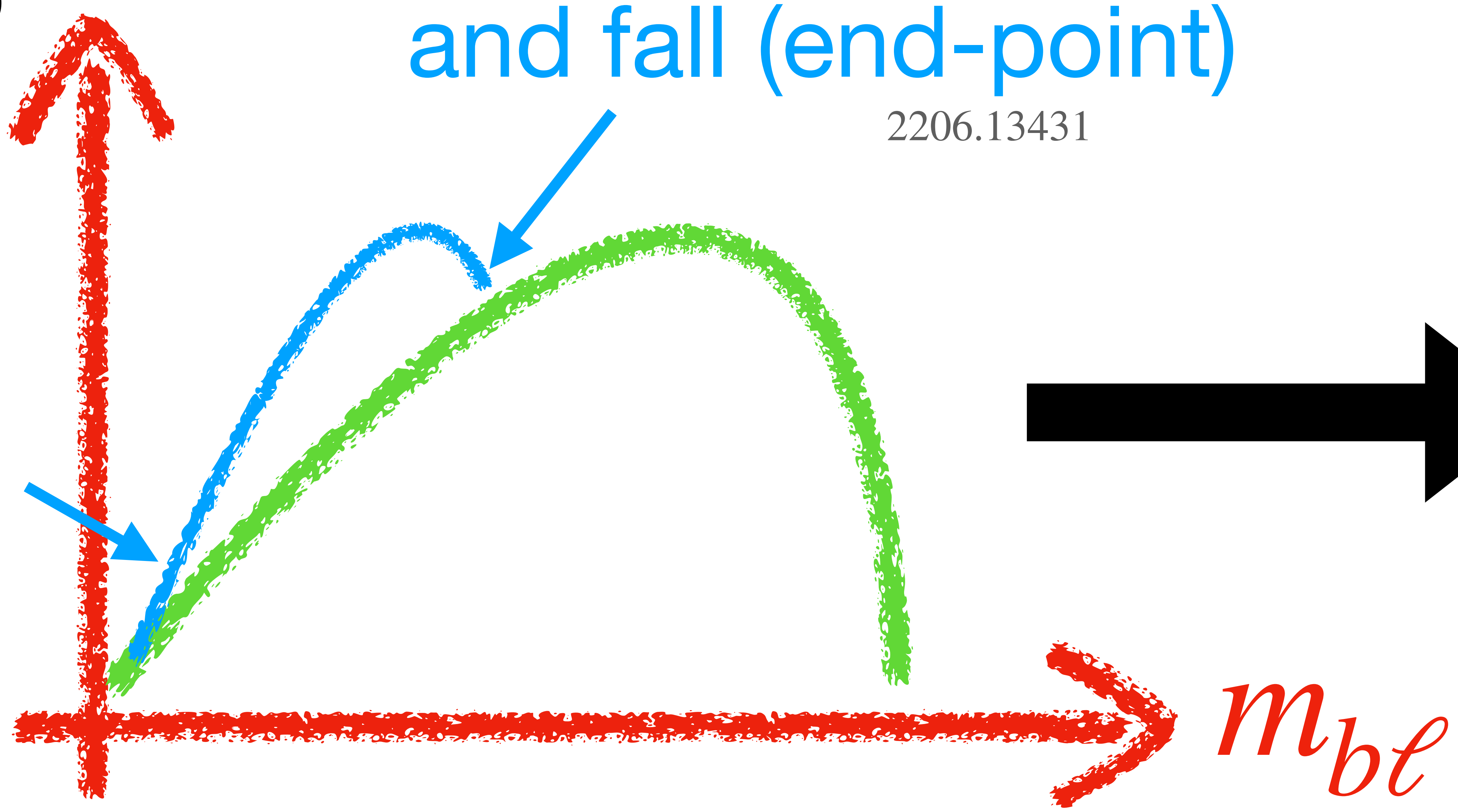
$\tilde{t} \rightarrow b\,\chi^{+} \rightarrow b\ell\nu\chi^{0}$

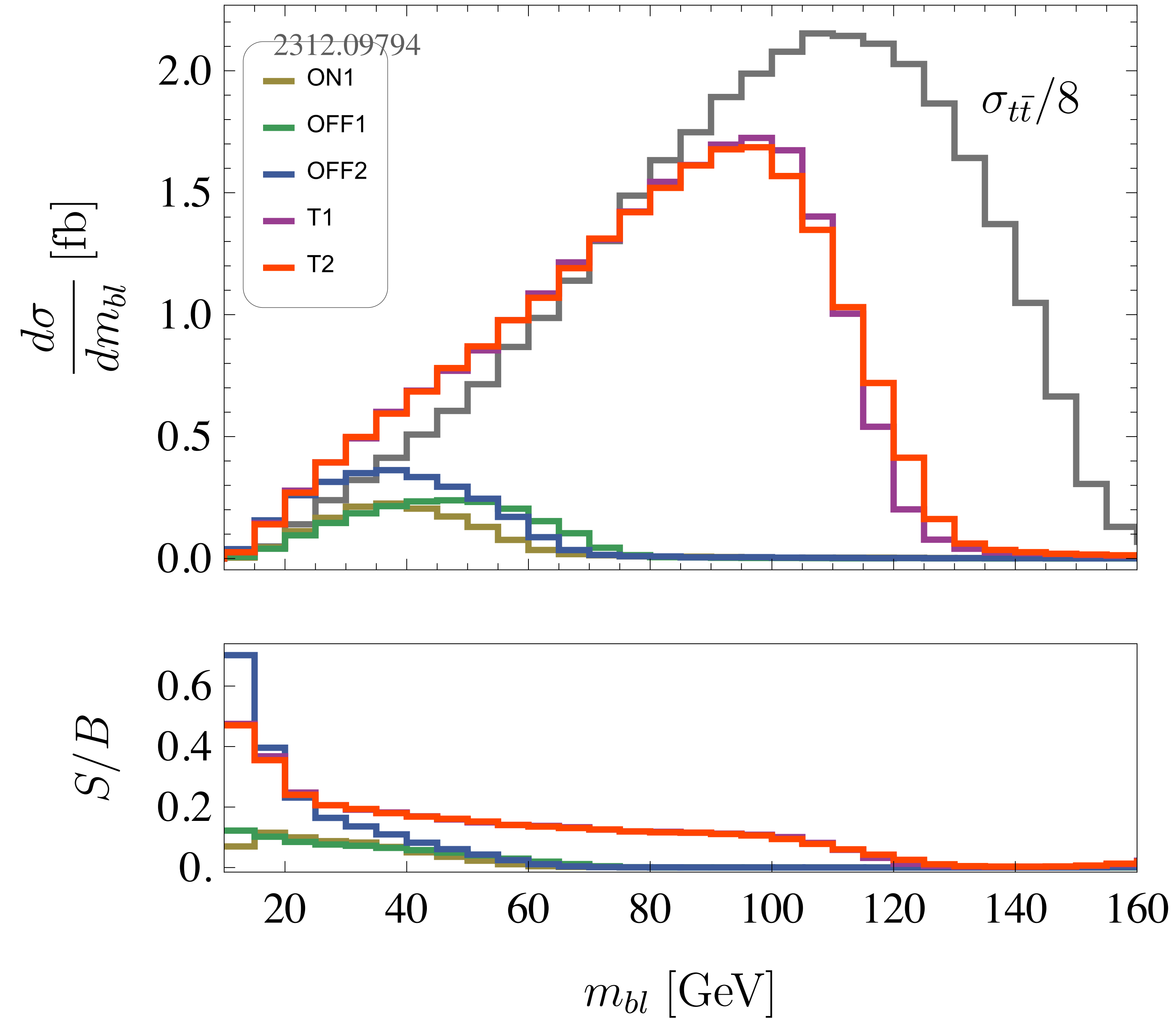
$$m_{b\ell}^{max}\Big|_{m_b=0} = \sqrt{\frac{(m_{\tilde{t}}^2 - m_{\chi^+}^2)(m_{\chi^+}^2 - m_{\chi^0}^2)}{m_{\chi}}}$$

and fall (end-point)

2206.13431

the rise ($m_{b\ell} > 0$)

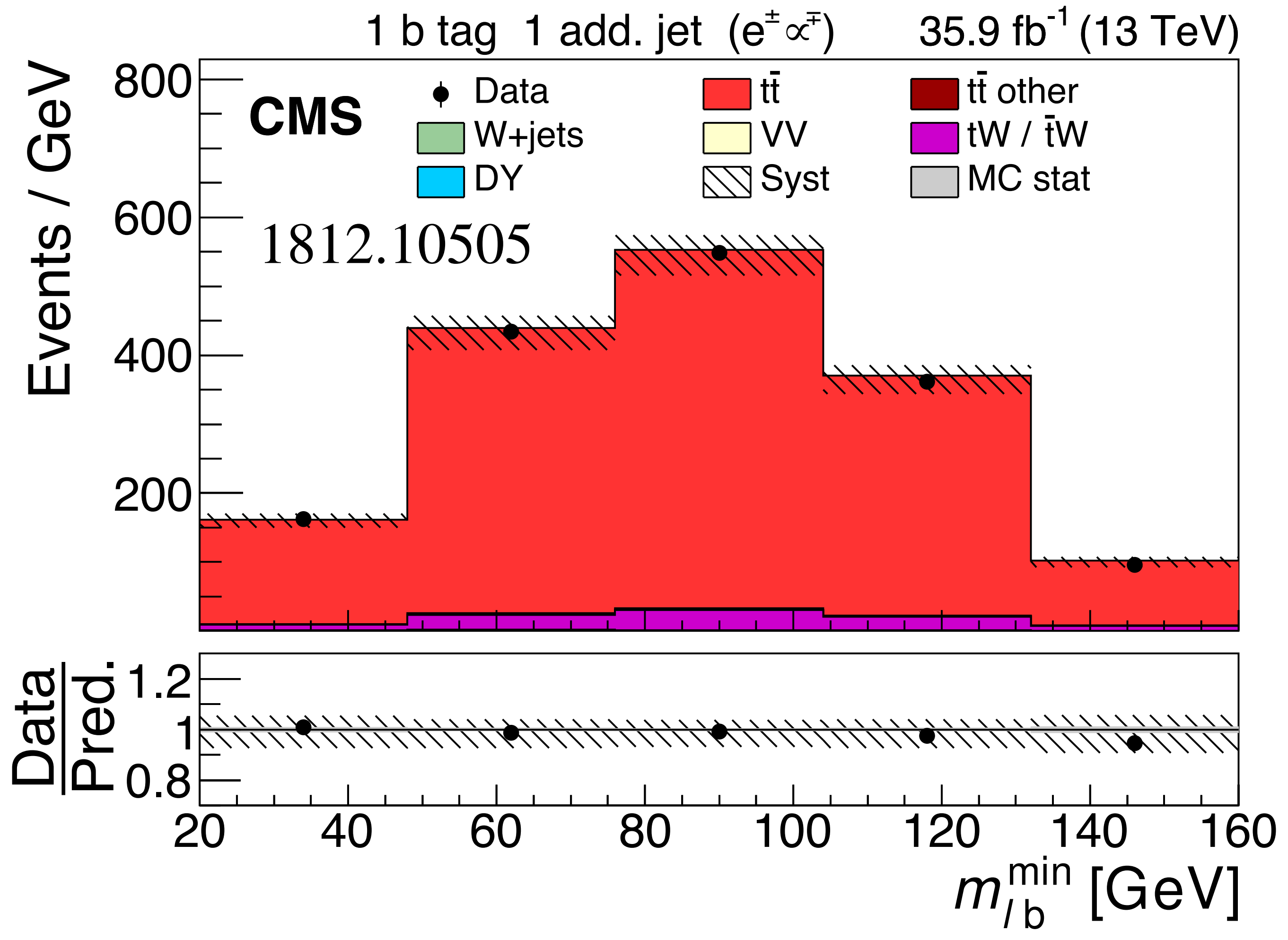


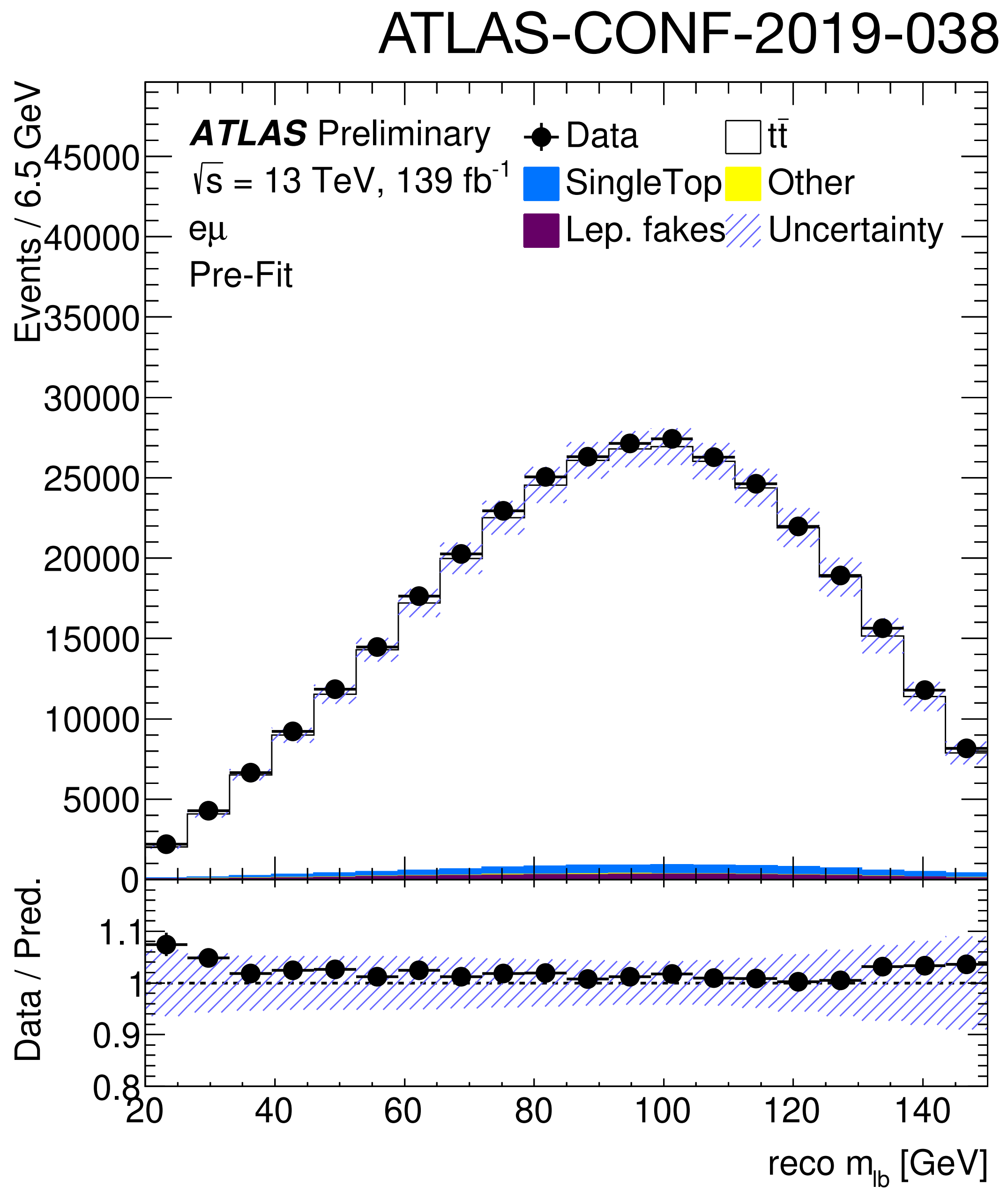


Other observables can be used as well ($p_{T,\ell}, m_{T2}, E_b, \ldots$), a full likelihood study in principle

Sensitivity to the NP scenario

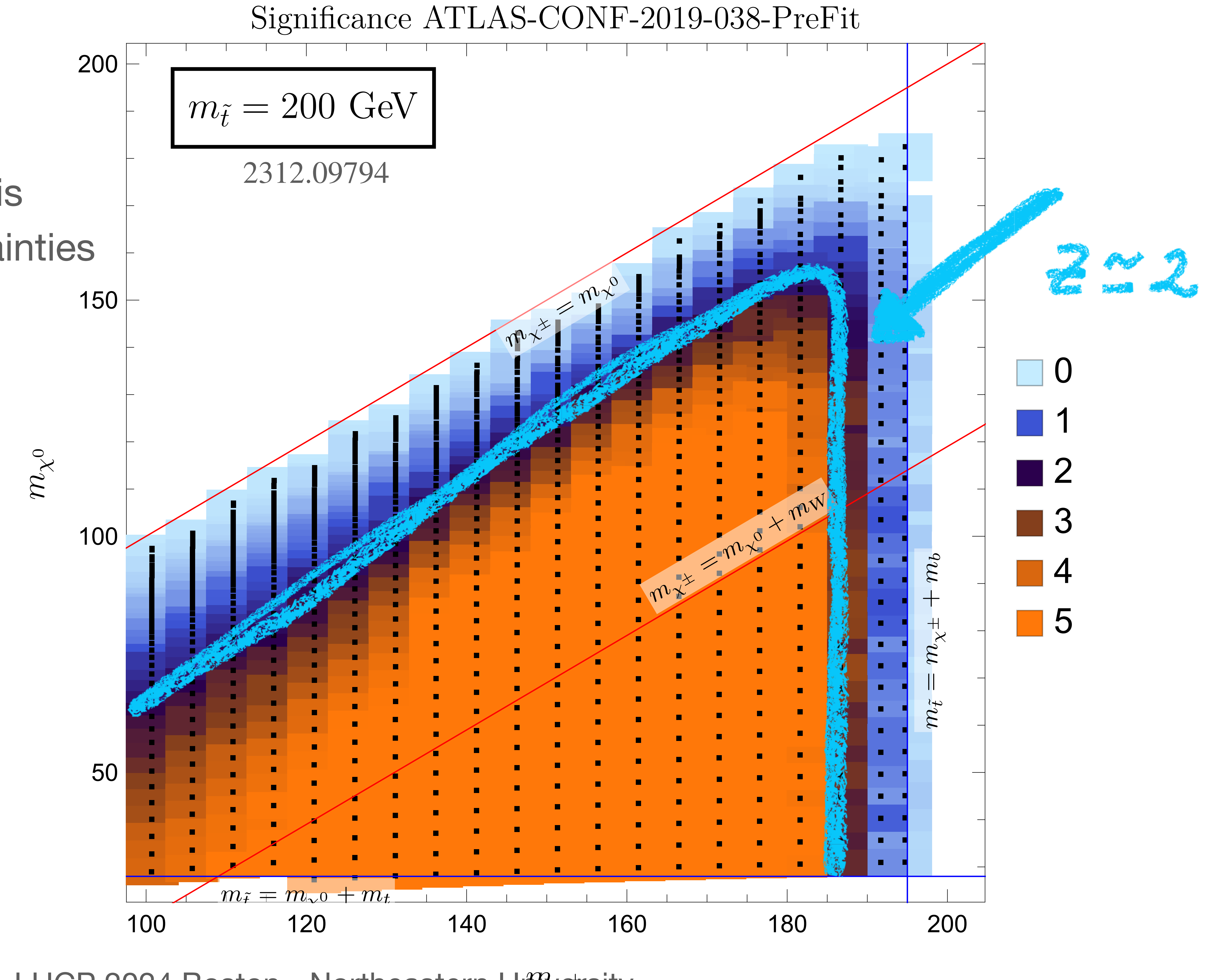
SEARCH & MEASURE in $t\bar{t}$





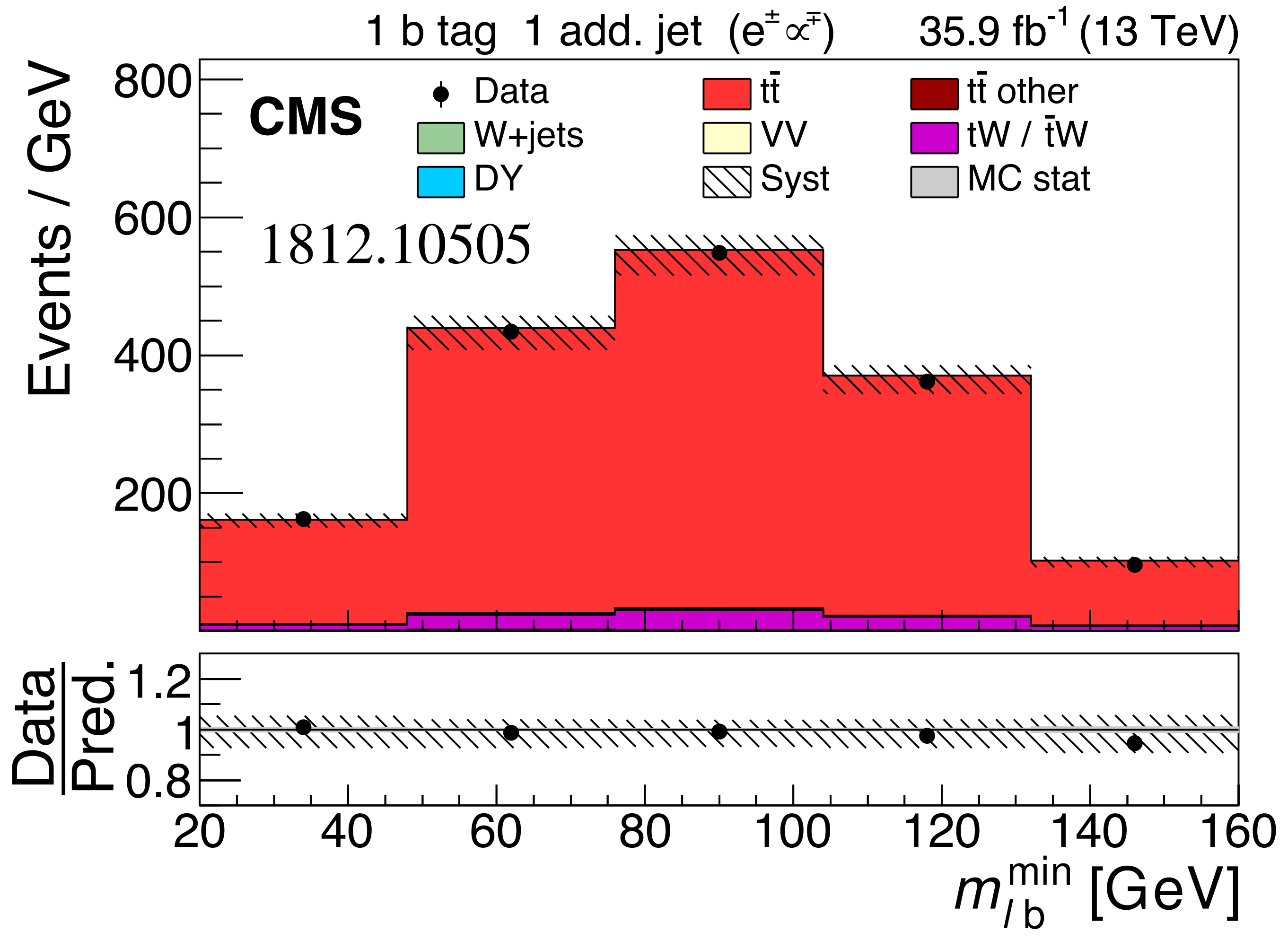
template χ^2 analysis
using published uncertainties

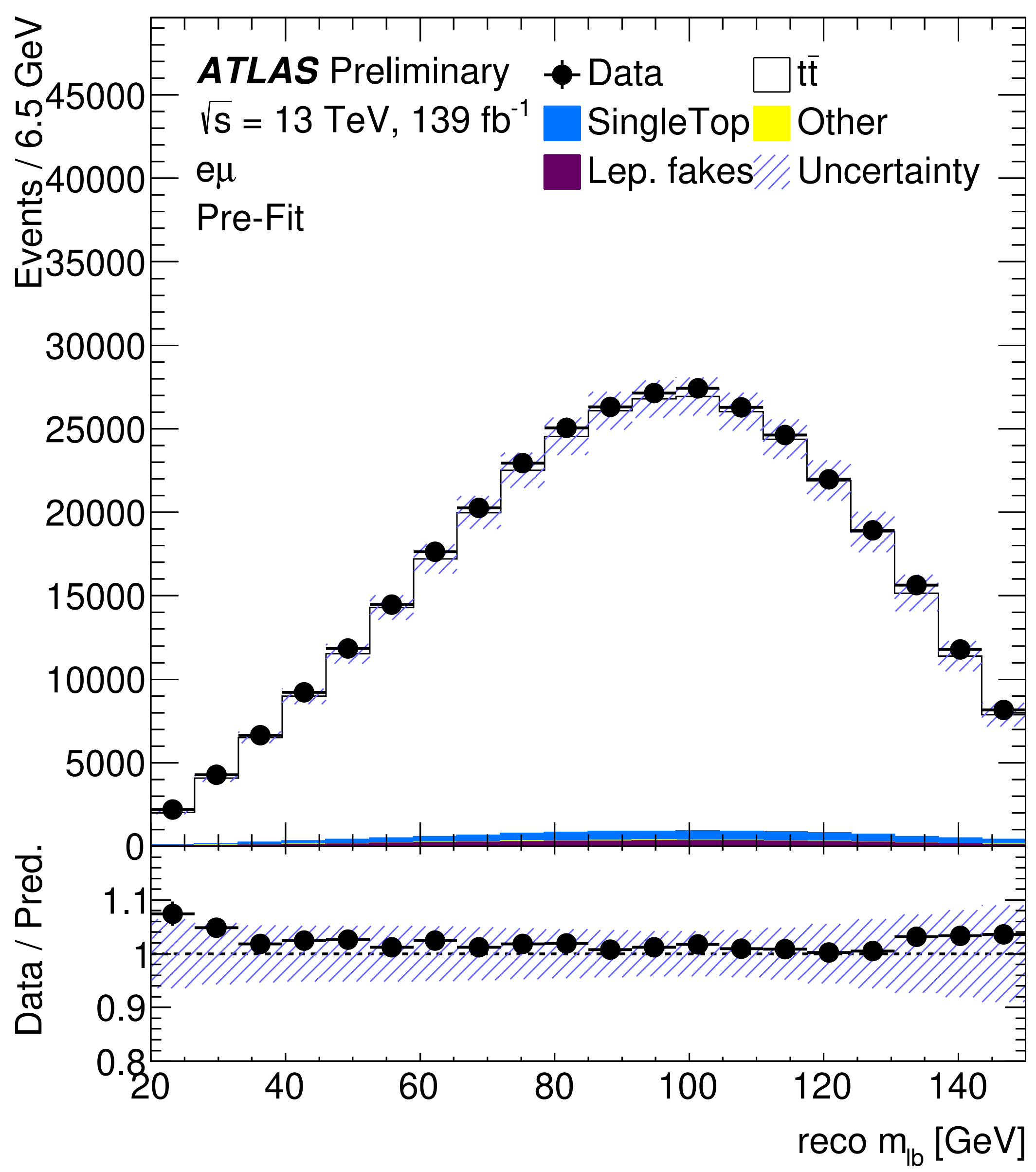
$$m_{b\ell}^{max}\Big|_{m_b=0} = \sqrt{\frac{(m_{\tilde{t}}^2 - m_{\chi^+}^2)(m_{\chi^+}^2 - m_{\chi^0}^2)}{m_\chi}}$$



Sensitivity to the NP scenario

SEARCH & MEASURE in $t\bar{t}$





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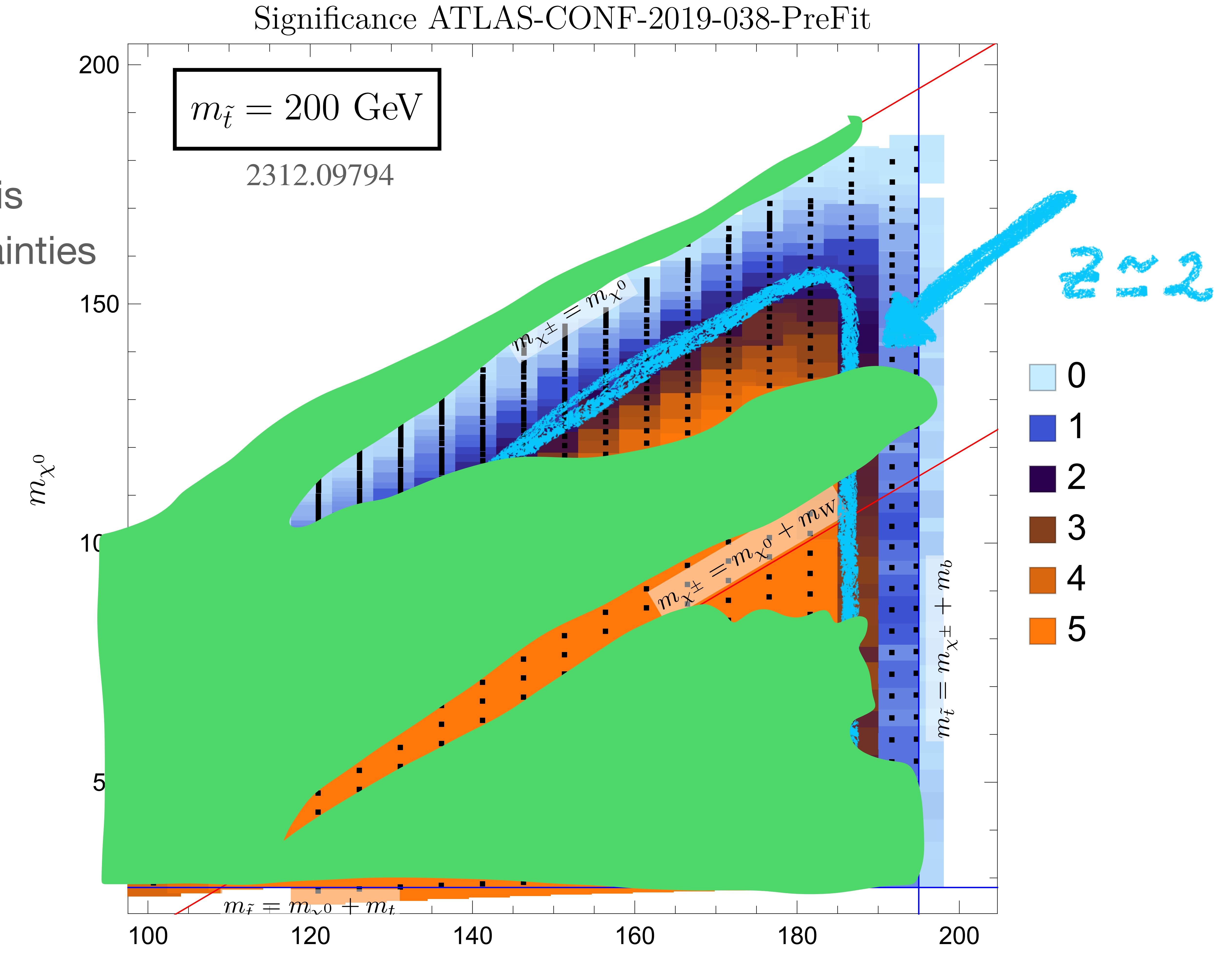

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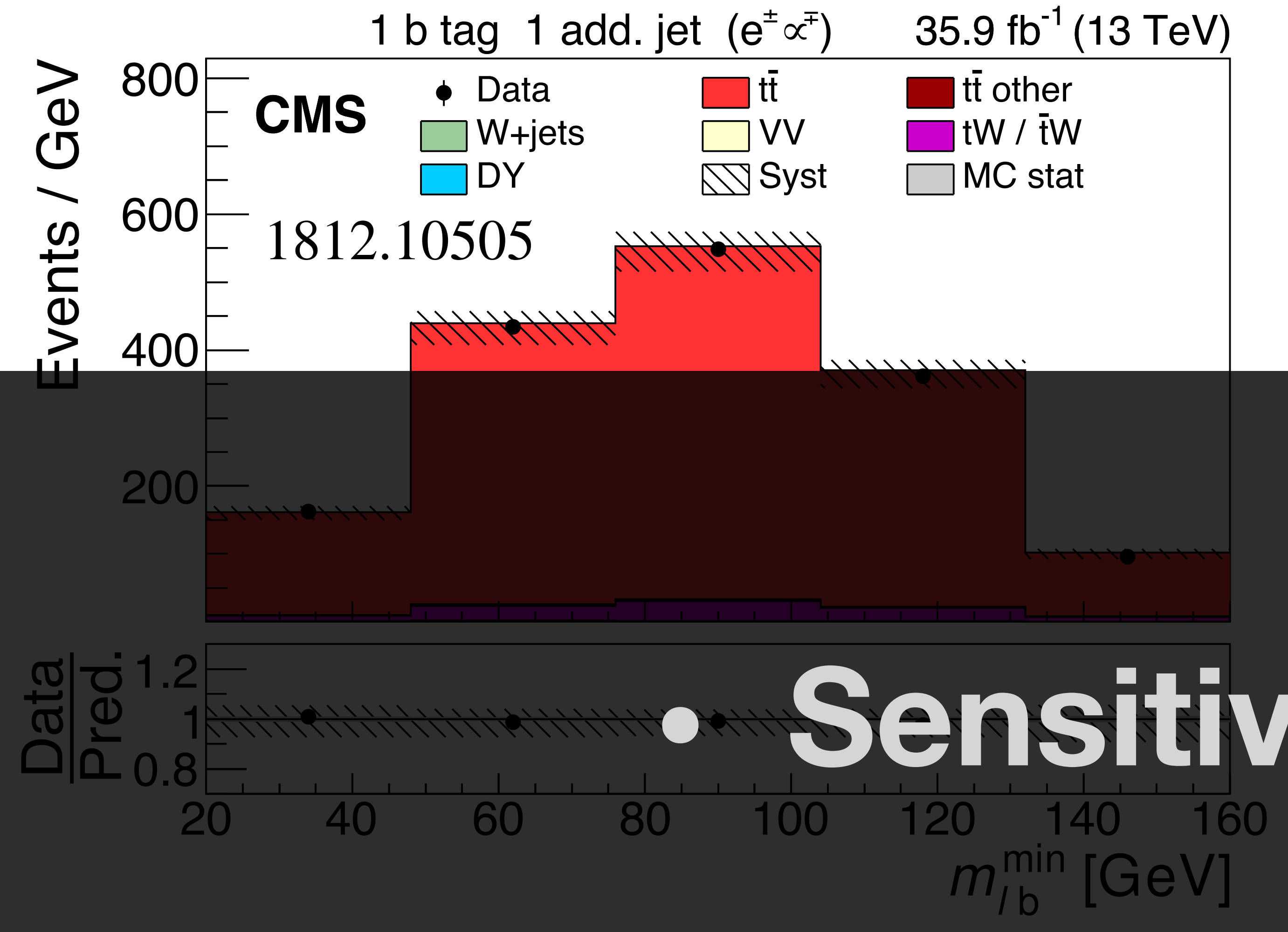
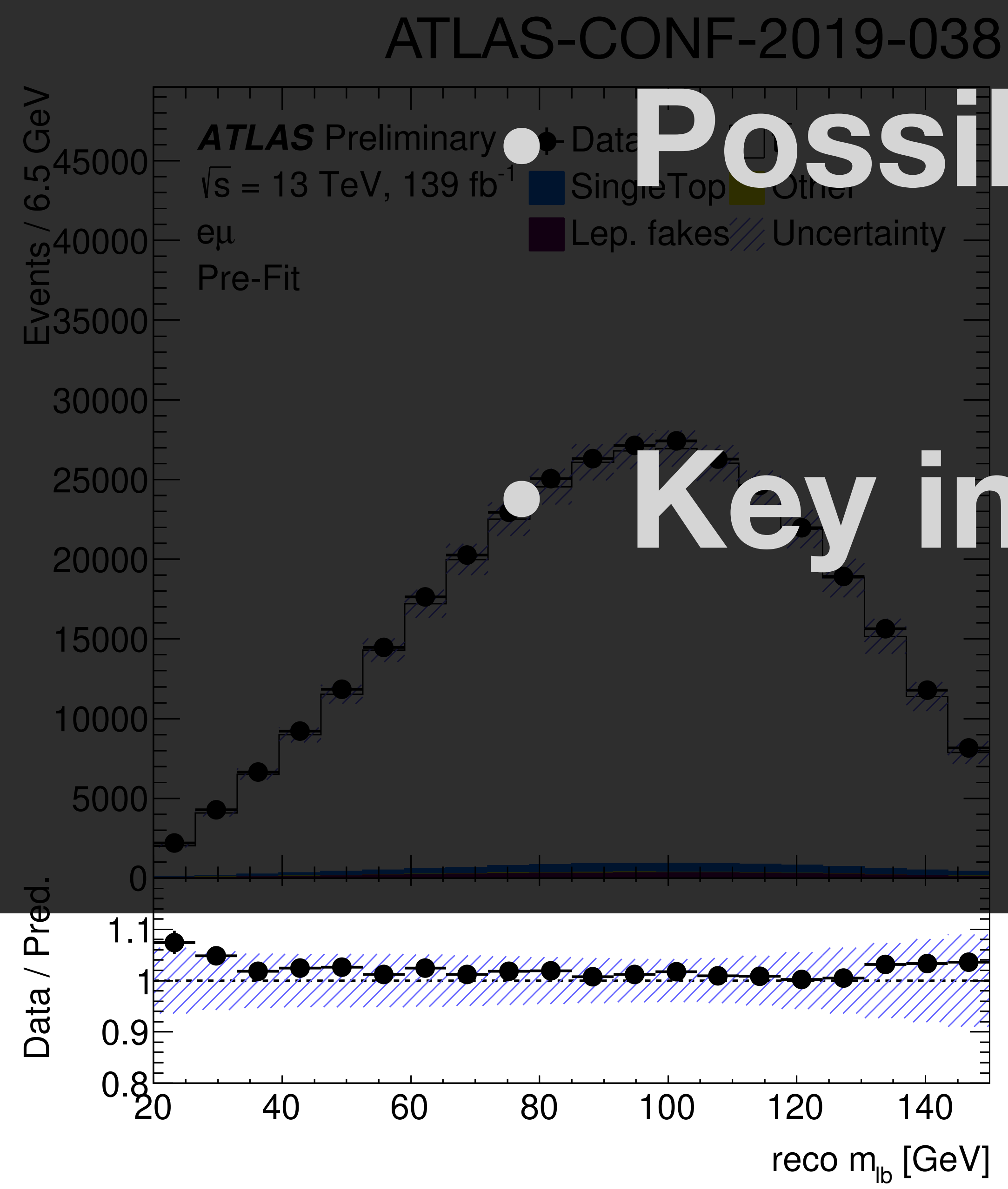
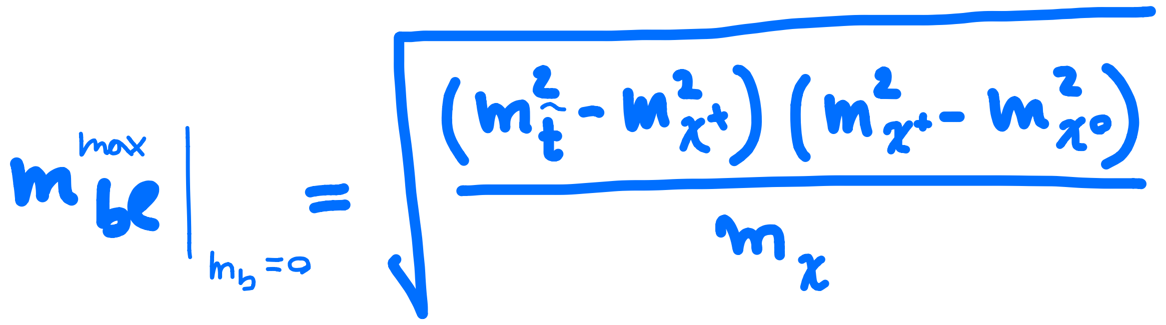
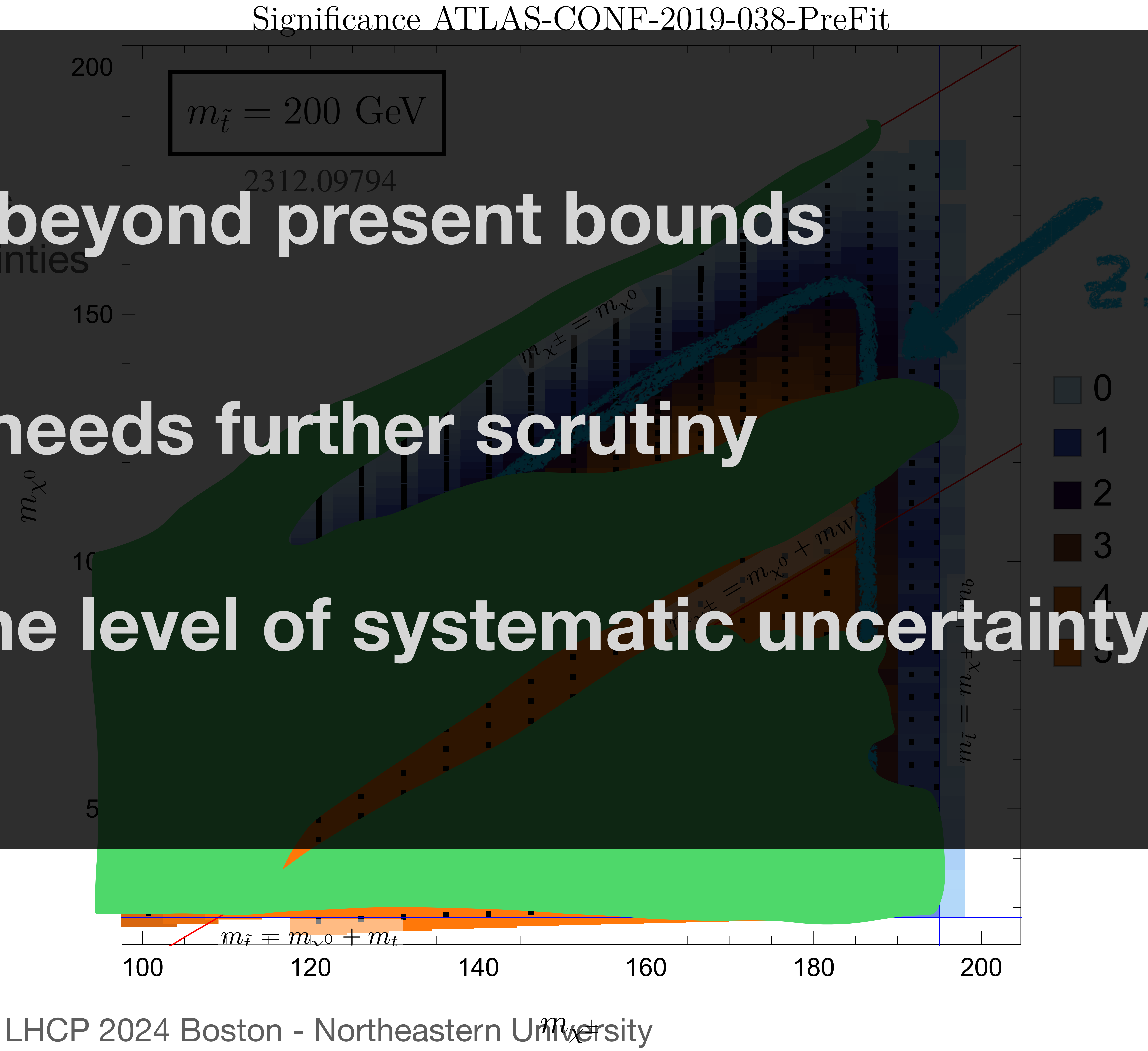








- Sensitivity from $m_{b\ell}$ beyond present bounds
- Possible shift on m_t needs further scrutiny
- Key importance of the level of systematic uncertainty

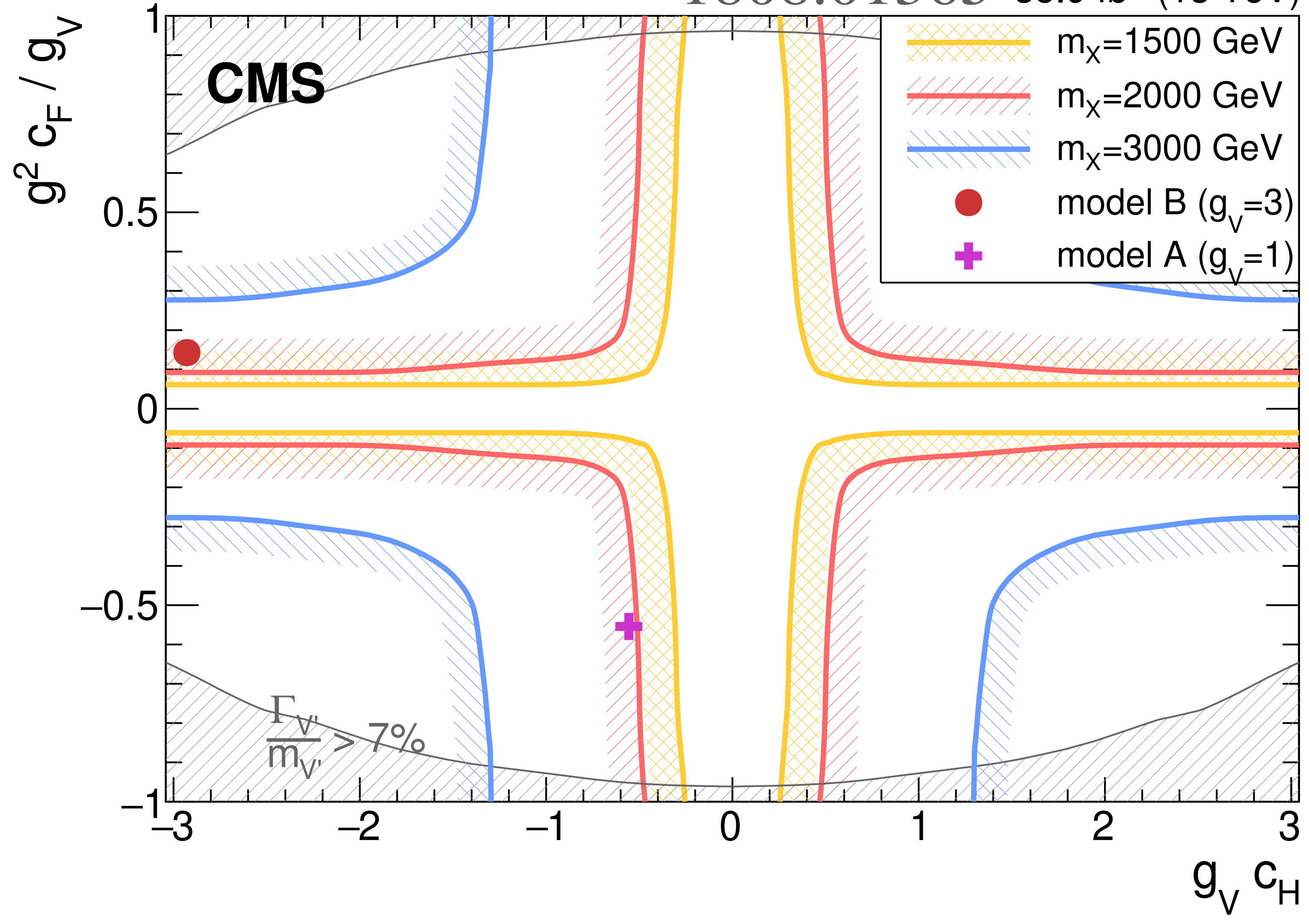
High mass frontier: *Every GeV counts*

As the integrated luminosity grows we can see more and more of the **high-x tails of the parton distribution functions** that result in high-mass or high-p_T events

This progress may seem obvious, and sometimes is dismissed as “incremental”.

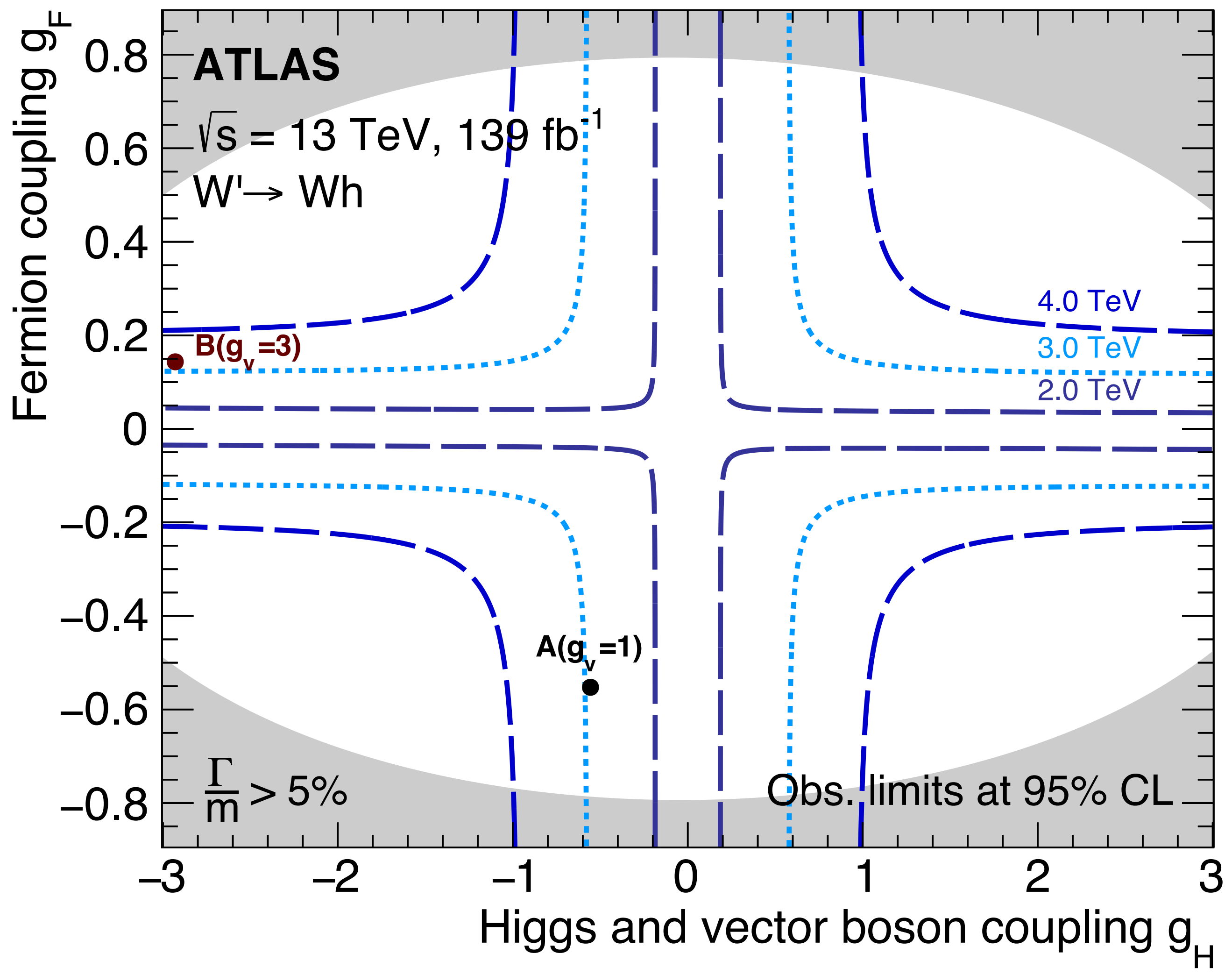
On the contrary, in Run3 and HL-LHC we will explore truly new territory at the high-mass frontier with significant impact on the status of BSM.

1808.01365



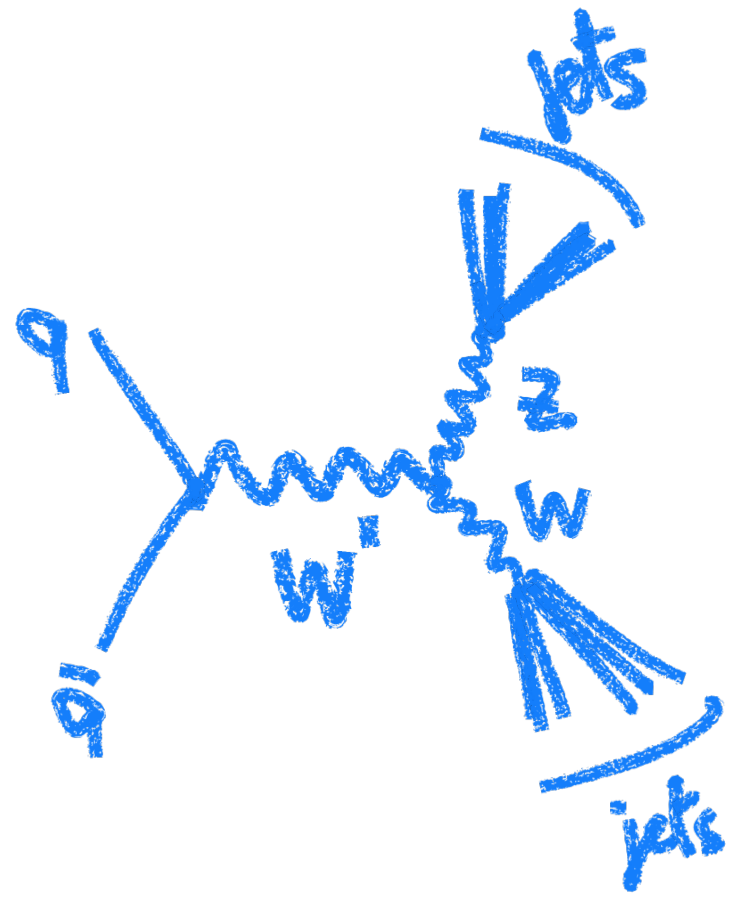
2 TeV → 3 TeV

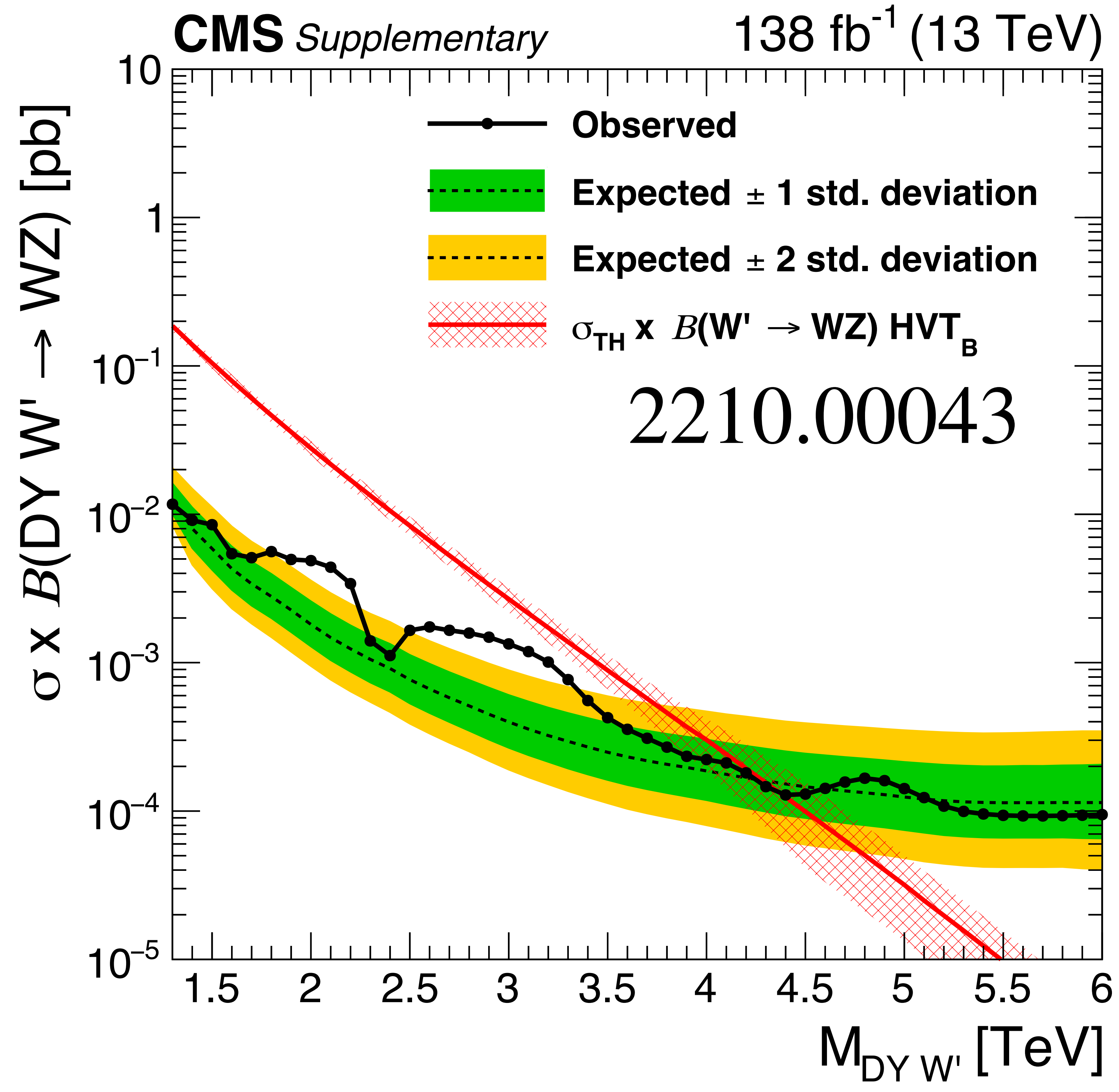
2207.00230

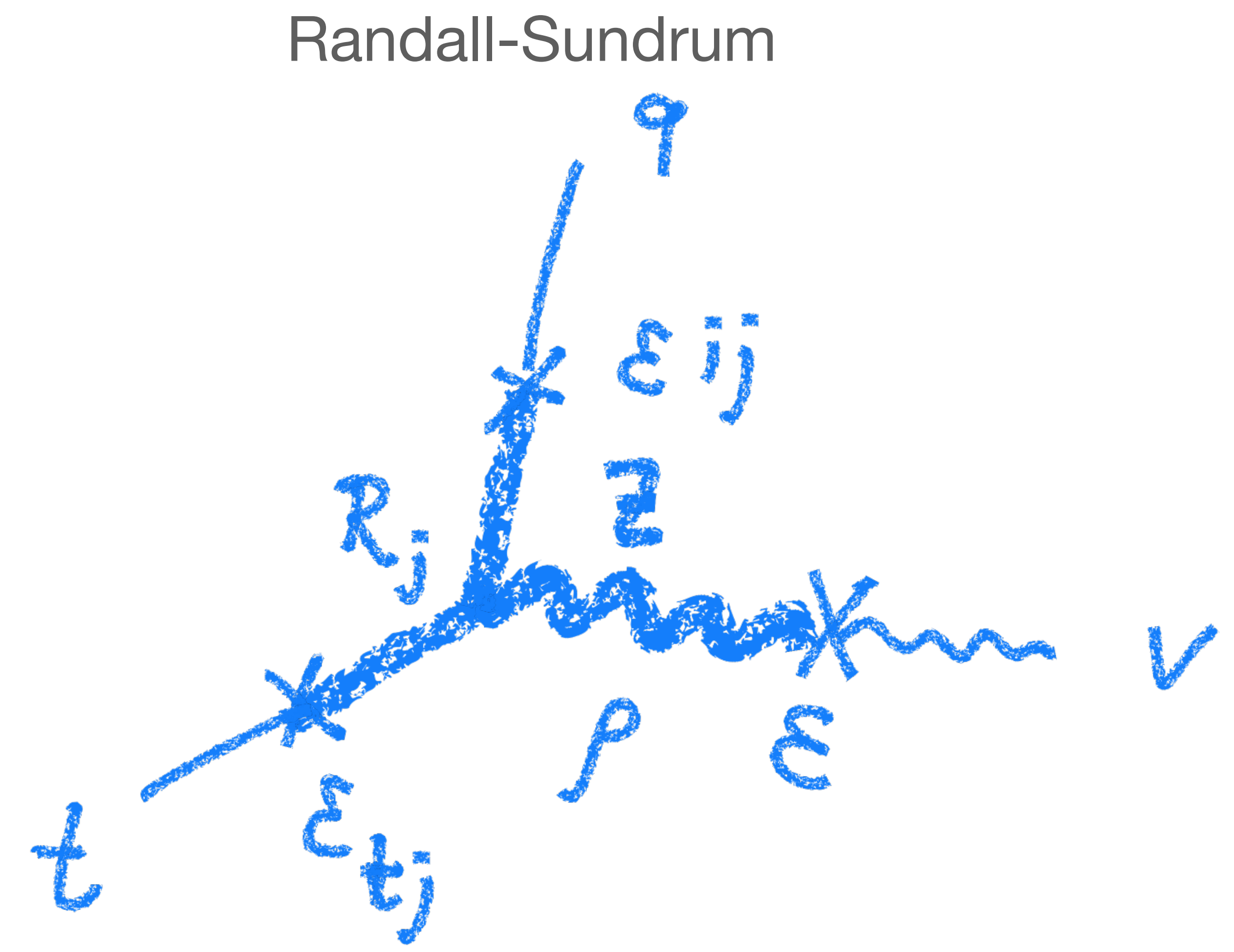


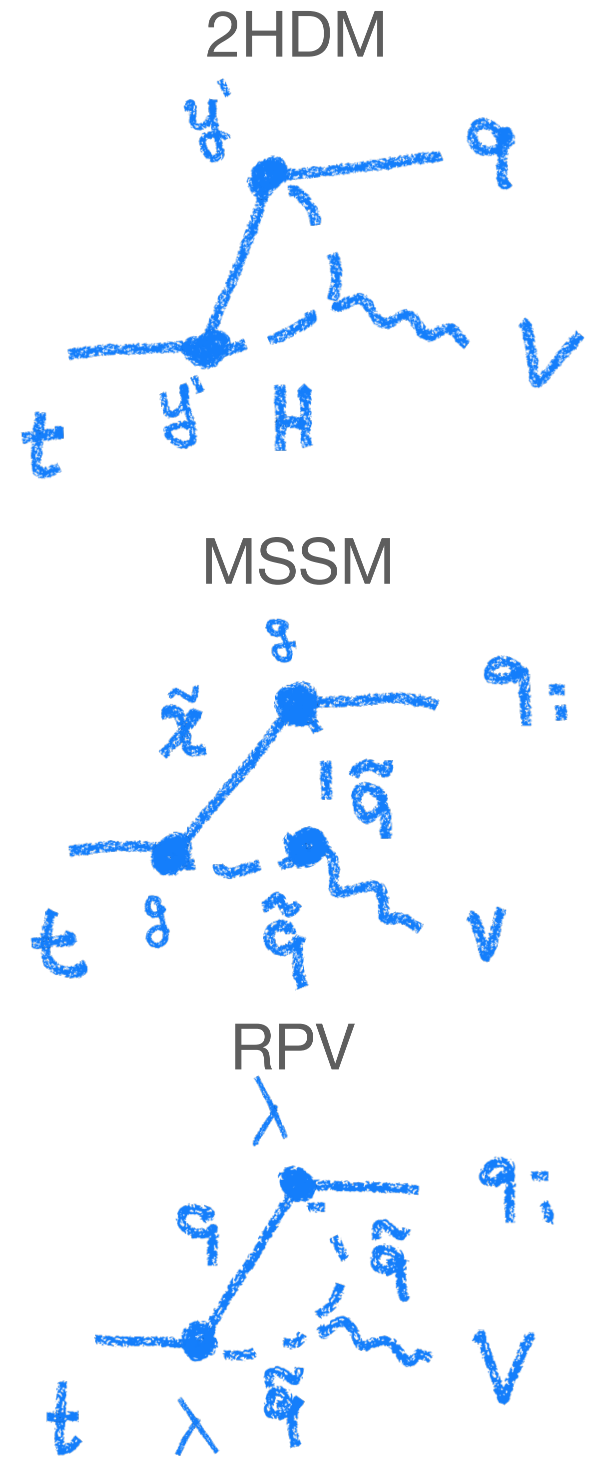
Every GeV counts

Full Run2 analyses reach (and sometimes exceed) 3 TeV









$$\mathrm{BR}\,(t \to cZ) \sim 10^{-5} \left(\frac{3\ \mathrm{TeV}}{m_{KK}}\right)^4$$

hep-ph/0606293

Run3 and HL-LHC will determine indirect reach of future e^+e^-

(e.g. $e^+e^- \to tc$ and $BR(t \to Zc)$ above observable level at future Higgs and top factory)

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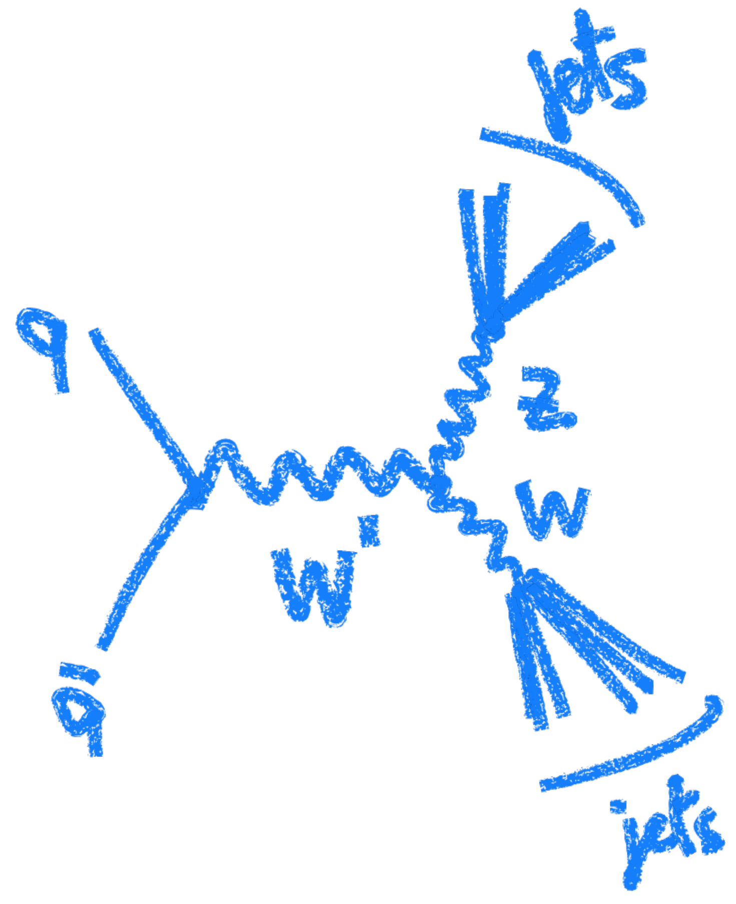
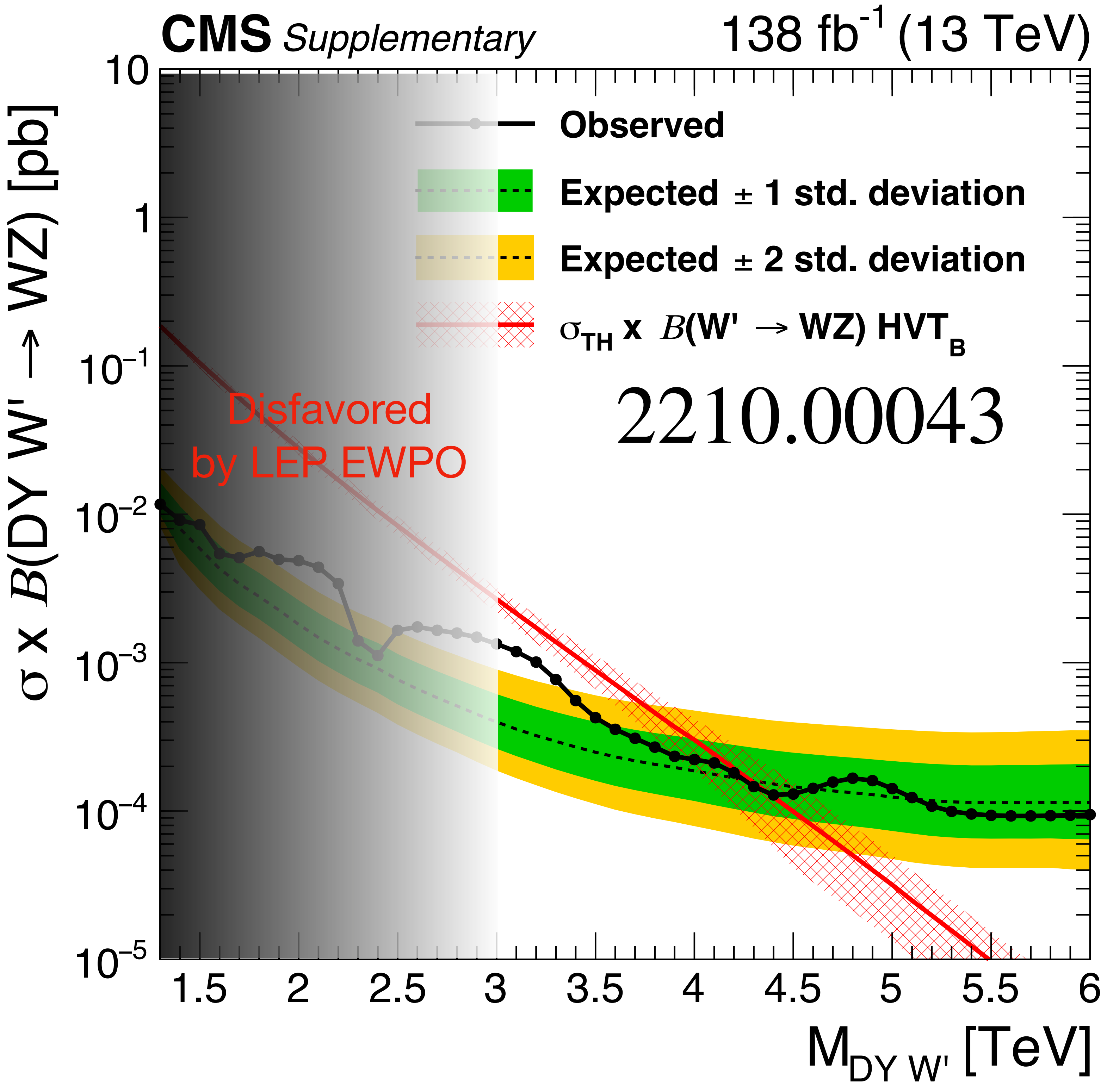
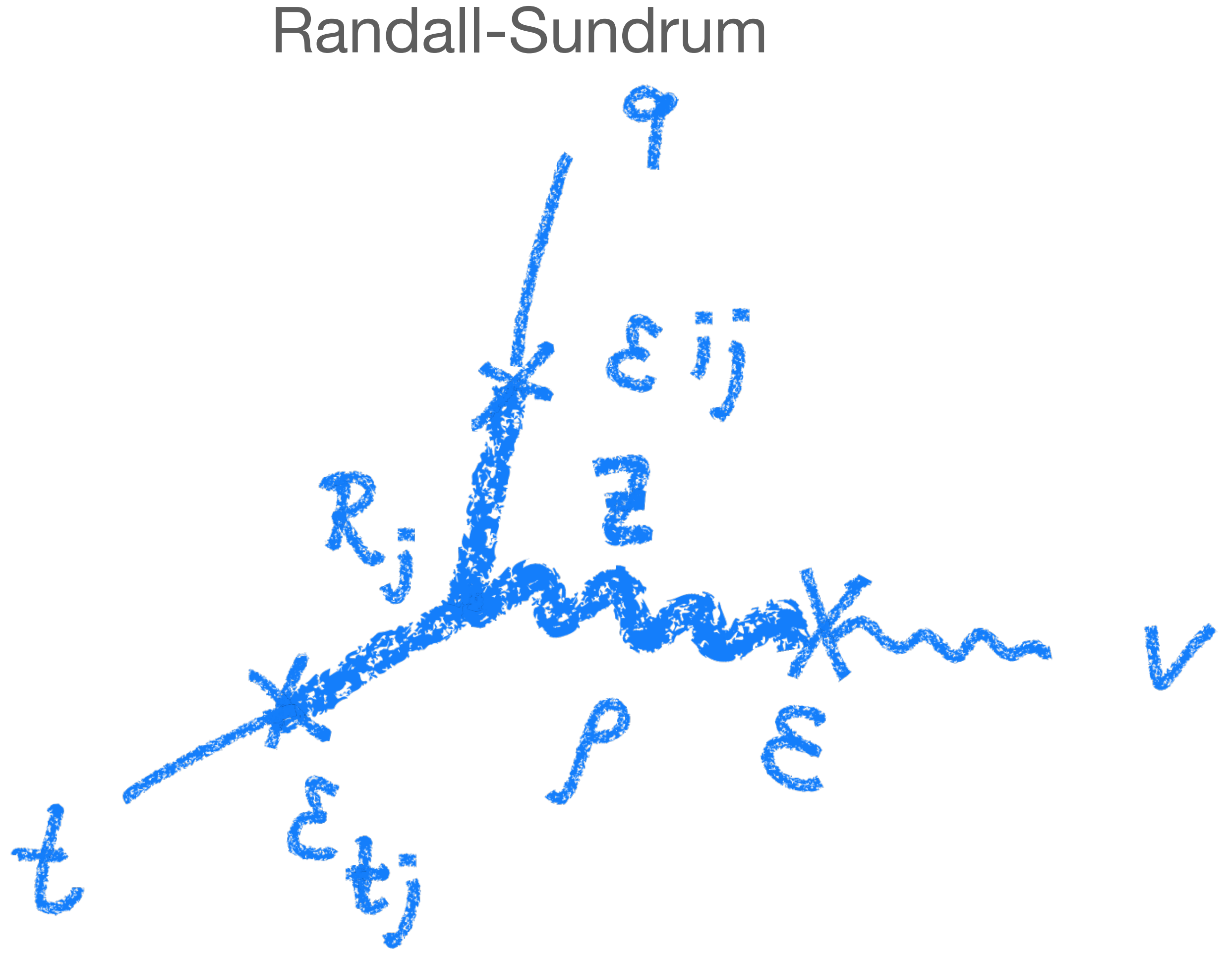
Full Run2 analyses reach (and sometimes exceed) 3 TeV







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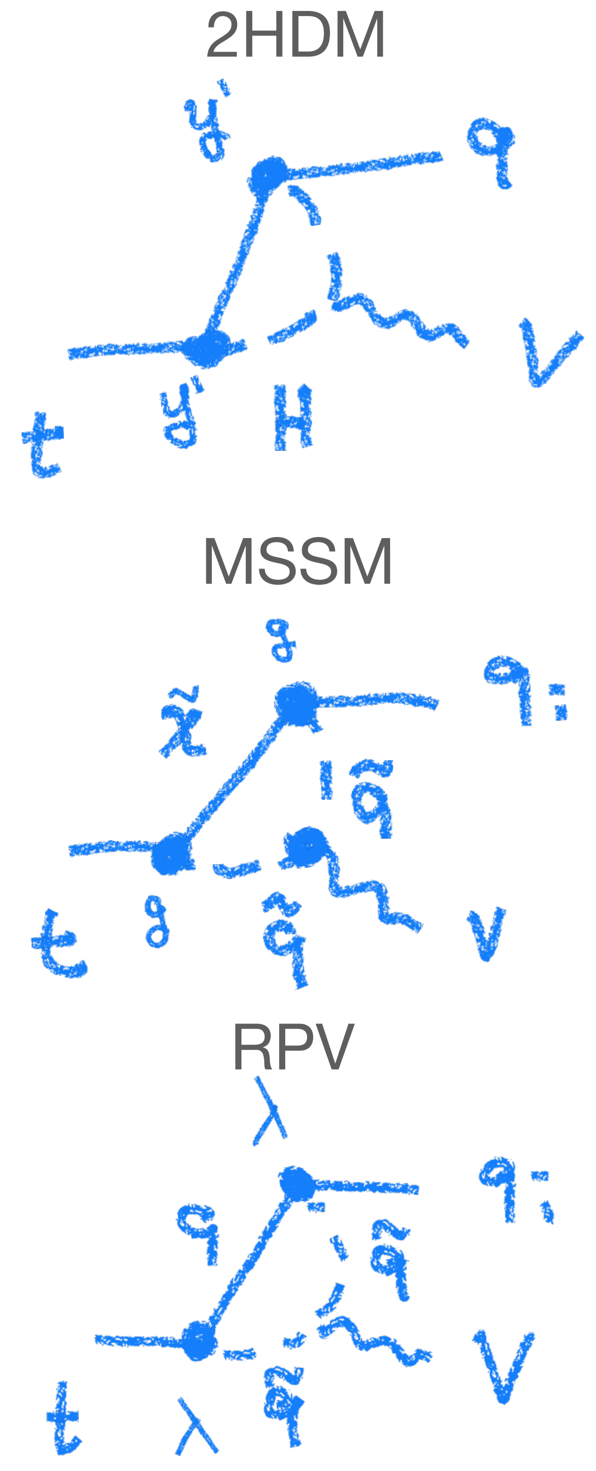

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(e.g. $e^+e^- \to tc$ and $BR(t \to Zc)$ above observable level at future Higgs and top factory)

Every GeV counts

Full Run2 analyses reach (and sometimes exceed) 3 TeV

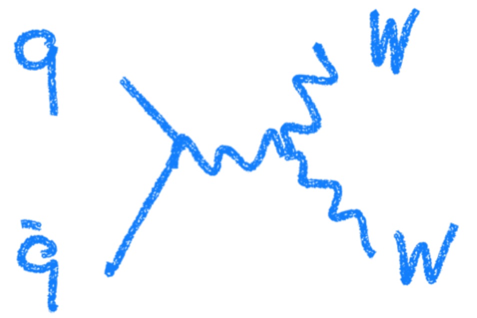
- Future e^+e^- factories expected to probe new physics indirectly
- Indirect effects are highly sensitive to the mass scale of new physics (e.g. non-interfering new physics/EFT $\sim M_{NP}^{-4}$)

Run3 and HL-LHC will determine indirect reach of future e^+e^-

(e.g. $e^+e^- \to tc$ and $BR(t \to Zc)$ above observable level at future Higgs and top factory)

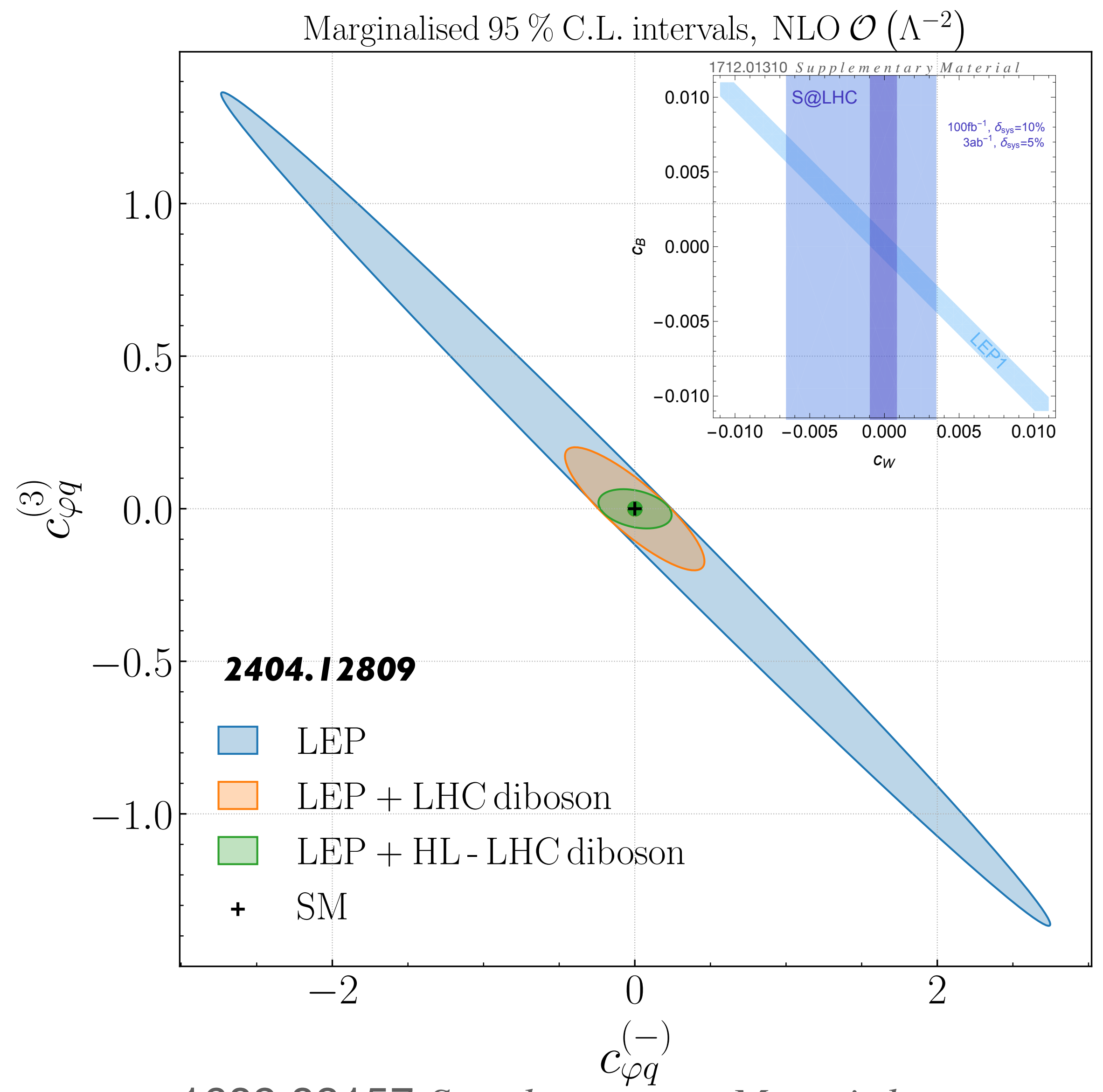
Electroweak just starts to be interesting

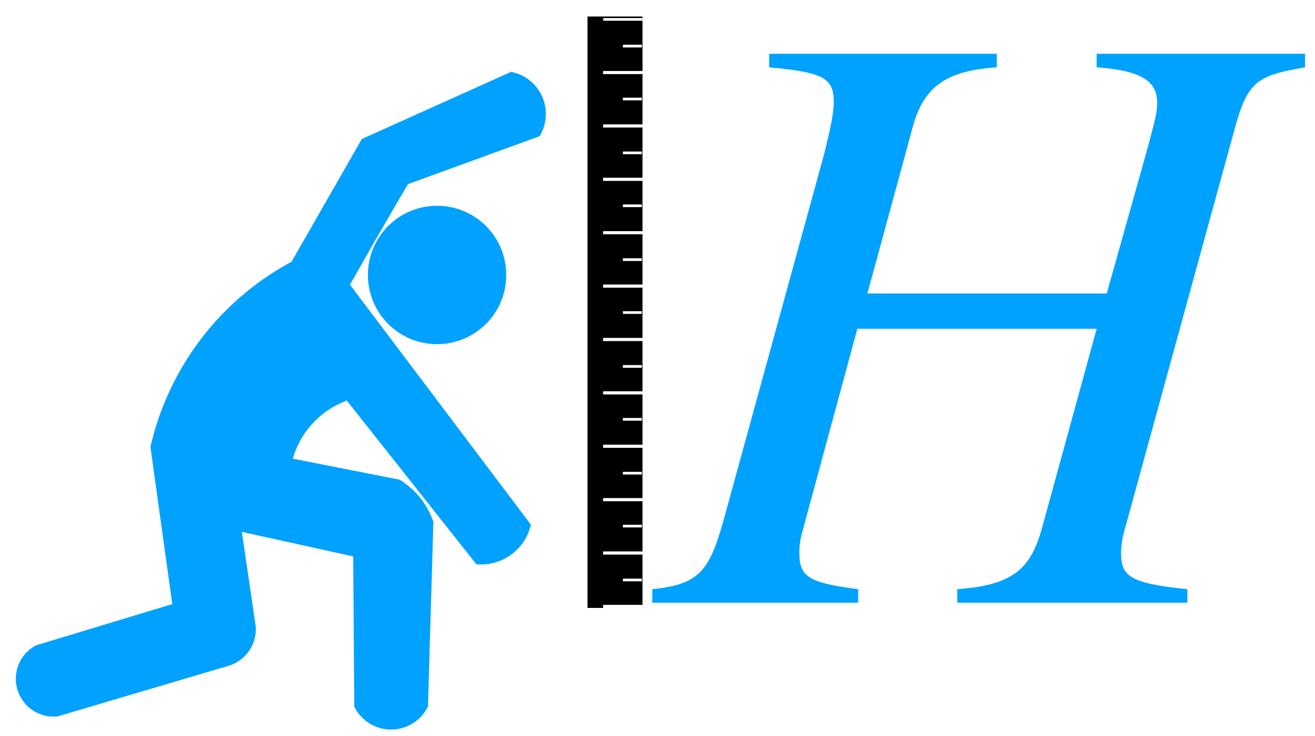
Full Run2 analyses finally comparable to LEP probes of Higgs compositeness and universal NP



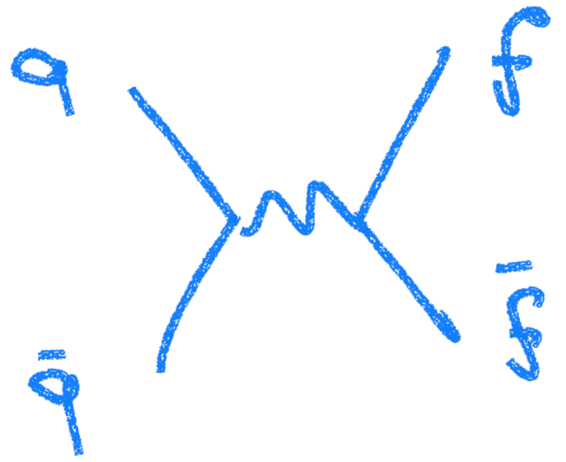
$$O_{\varphi q}^{1(ij)} = (\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar{q}_i \gamma^\mu q_j),$$
$$O_{\varphi q}^{3(ij)} = (\varphi^\dagger i\overleftrightarrow{D}^I_\mu \varphi)(\bar{q}_i \gamma^\mu \tau^I q_j),$$

$$c_{\varphi q}^{-} \equiv C_{\varphi q}^{1(33)} - C_{\varphi q}^{3(33)}$$

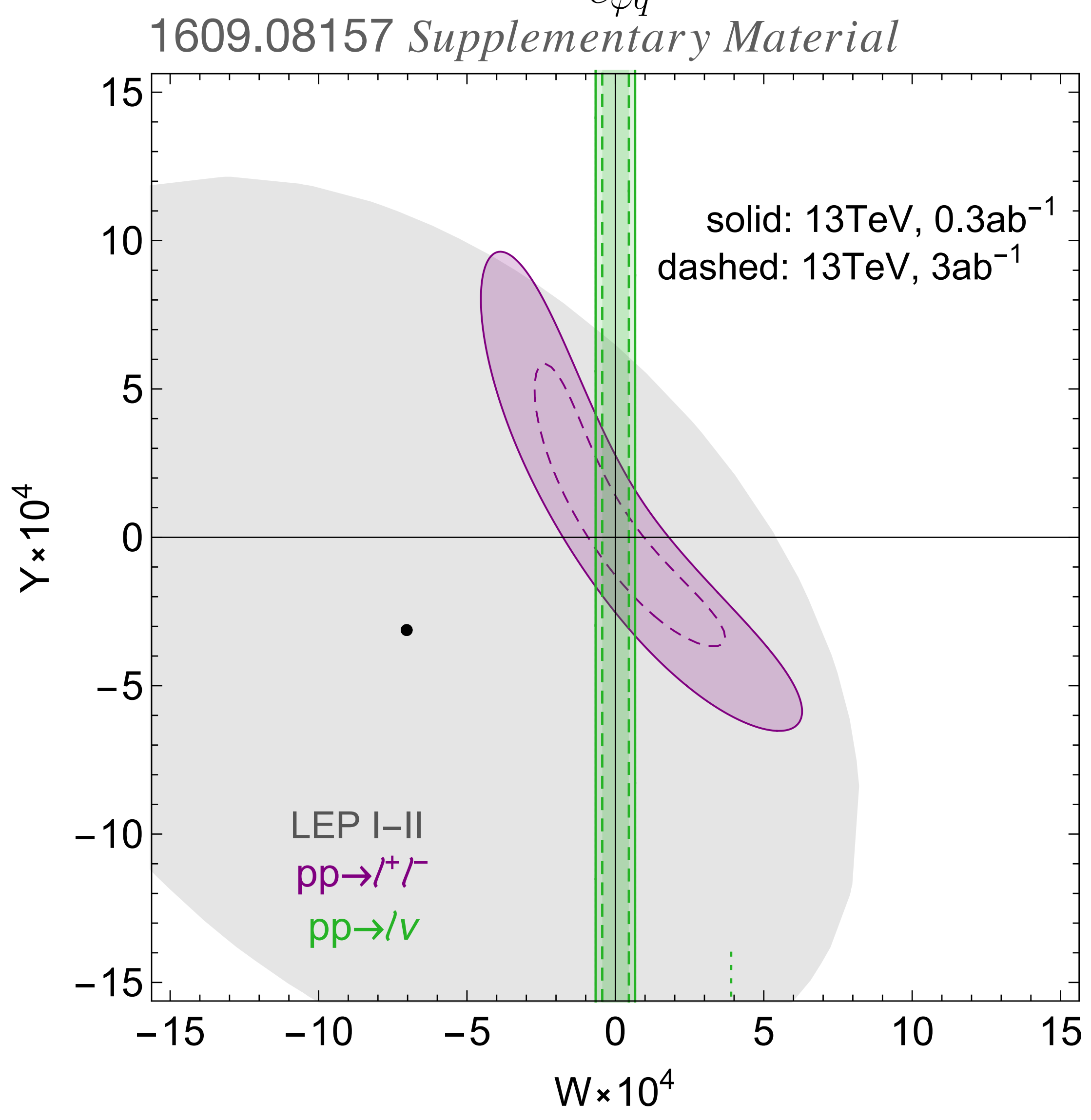


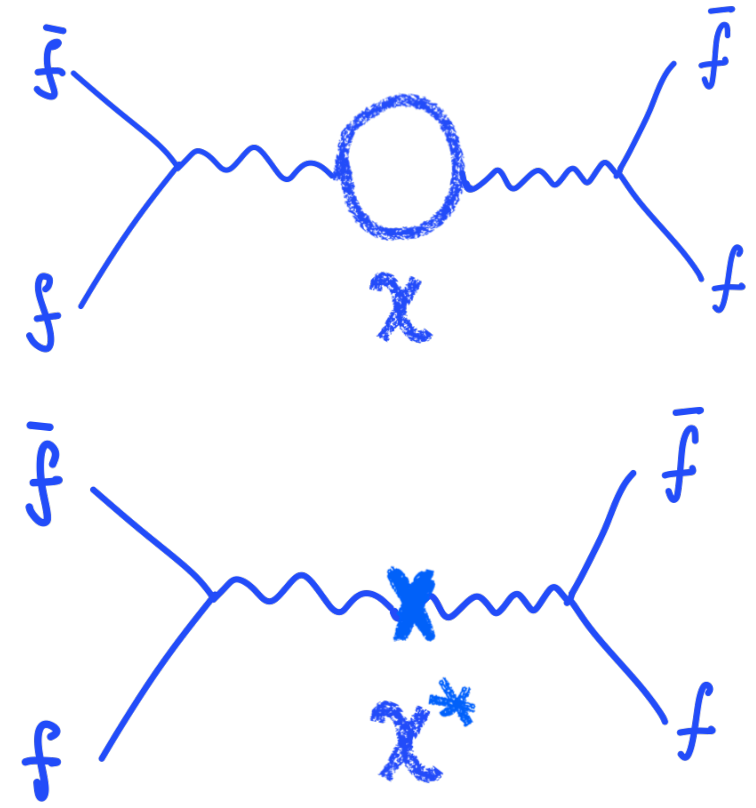


LHC measures the size of the Higgs boson



$$-\frac{W}{4m_W^2}(D_\rho W^a_{\mu\nu})^2$$
$$-\frac{Y}{4m_W^2}(\partial_\rho B_{\mu\nu})^2$$





Electroweak just starts to be interesting

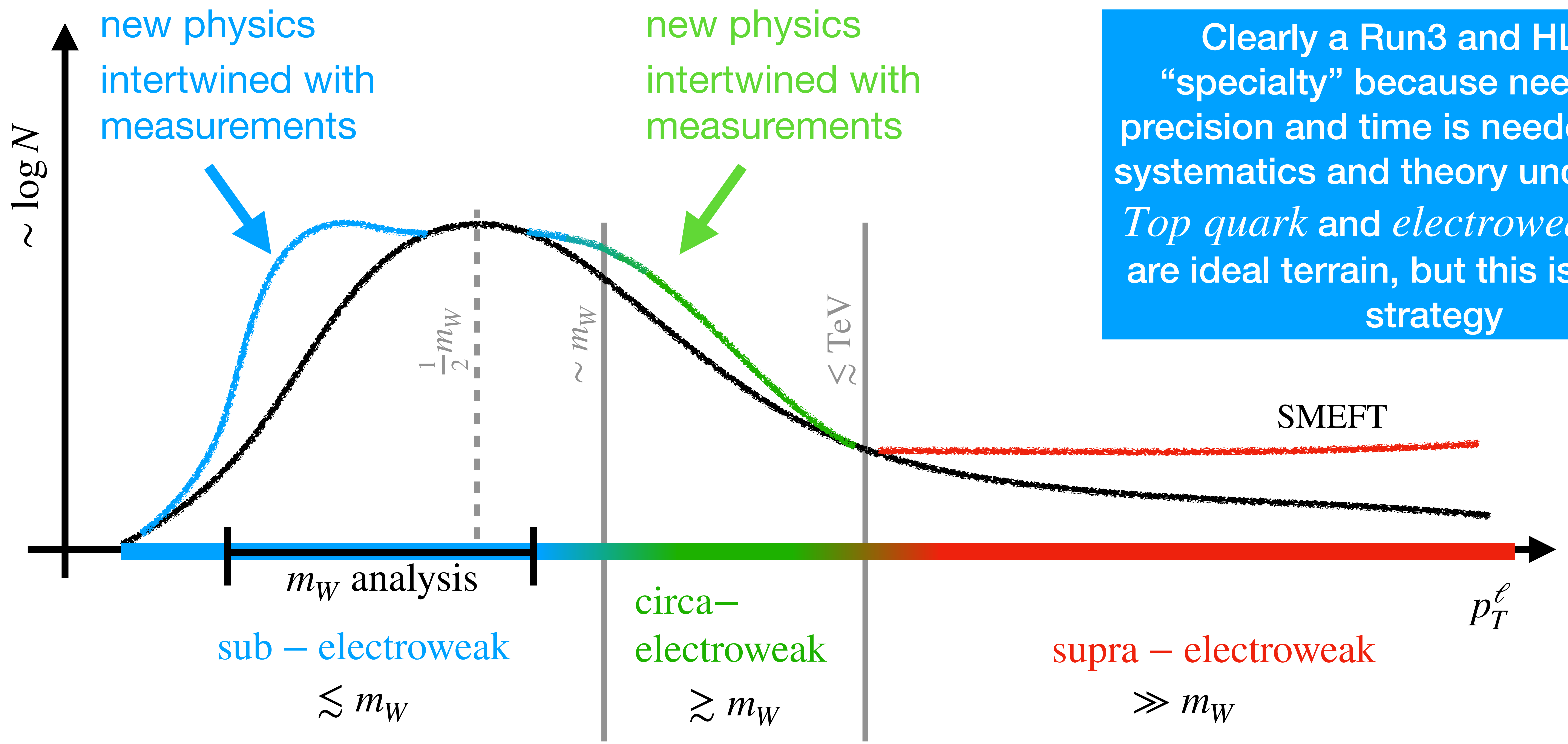
Full Run2 analyses finally comparable to LEP probes of Higgs compositeness and universal NP

- **Run3 and HL-LHC will take the size of the Higgs boson**
- **Probes of new electroweak matter, including (fractions of) Dark Matter enabled by Run3 and HL-LHC**

Conclusions: Plenty of opportunities on all the spectrum

***sub*-electroweak and *circa*-electroweak**

"Every SM measurement is a new physics search. Every BSM search is a SM measurement"



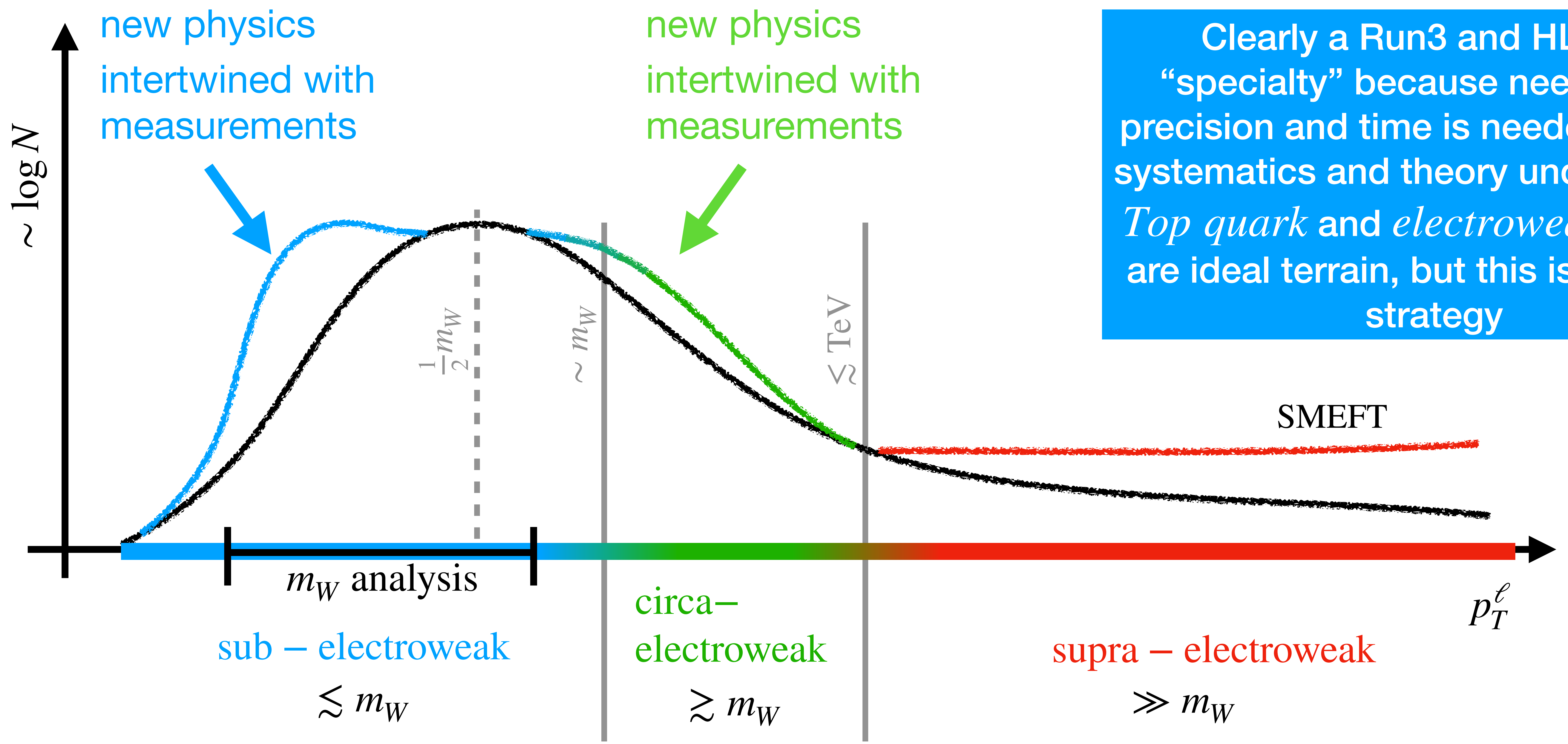
Clearly a Run3 and HL-LHC "specialty" because needs high-precision and time is needed to bring systematics and theory under control. *Top quark* and *electroweak* physics are ideal terrain, but this is a general strategy

Conclusions: Plenty of opportunities on all the spectrum

sub-electroweak and *circa*-electroweak

SEARCH & MEASURE

"Every SM measurement is a new physics search. Every BSM search is a SM measurement"



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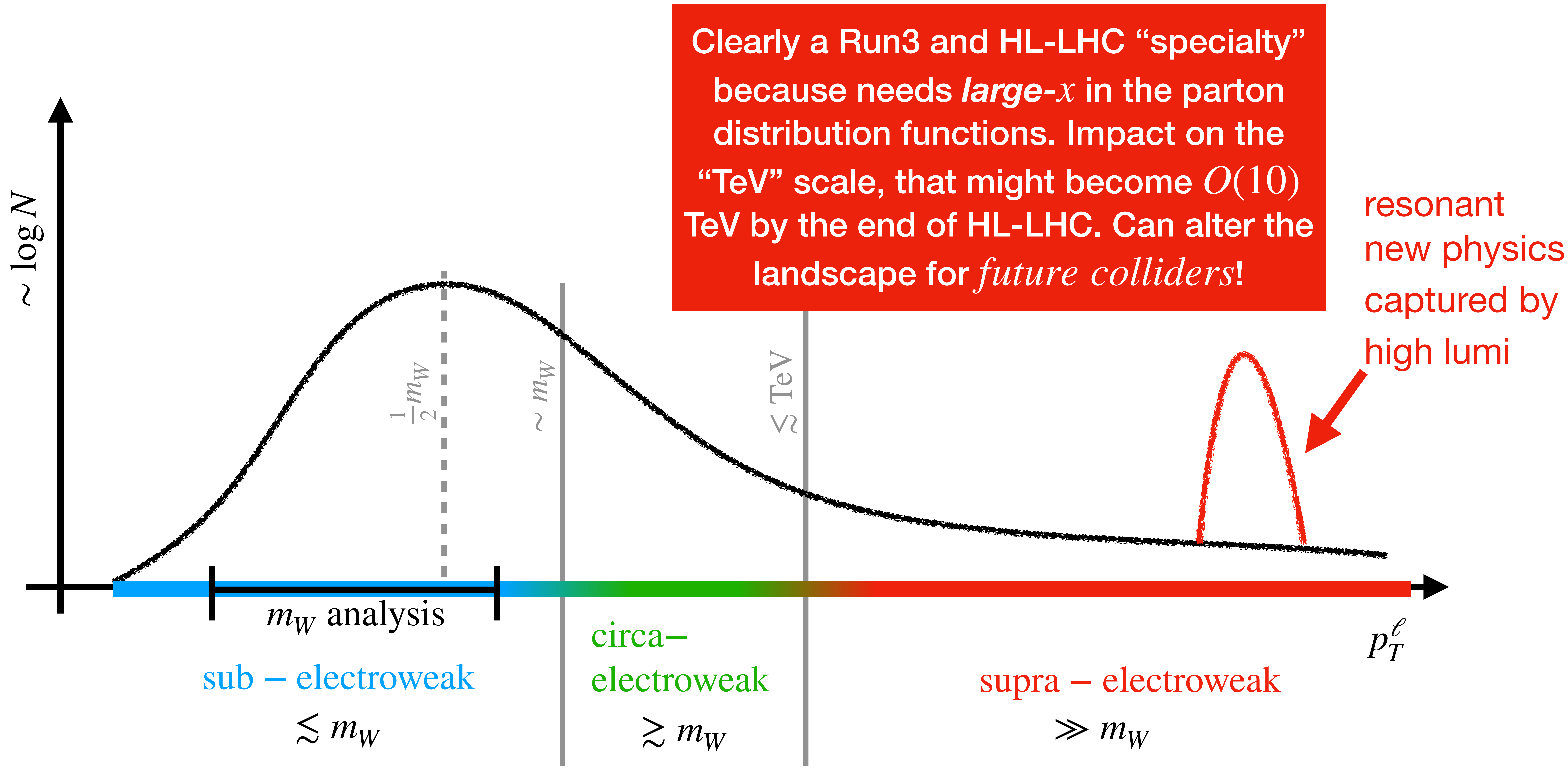
Conclusions: Plenty of opportunities on all the spectrum

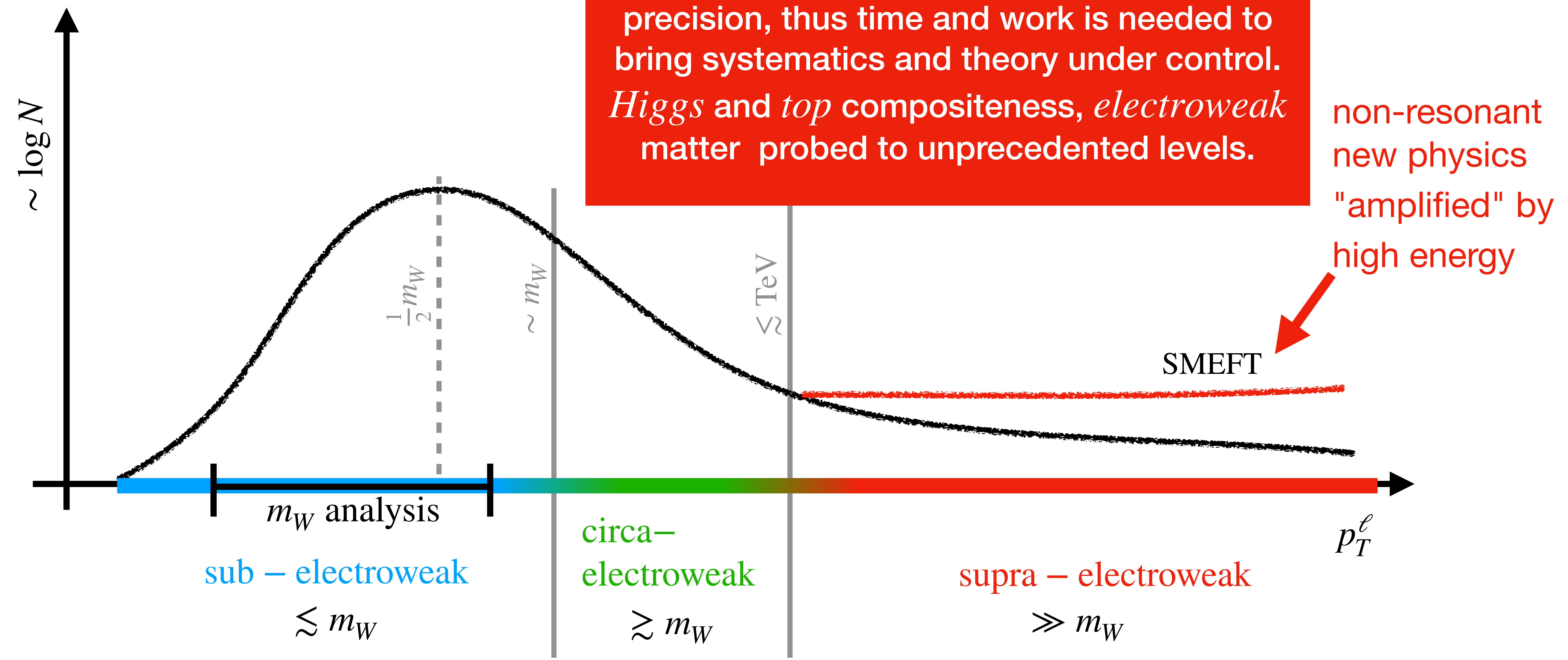
***supra*-electroweak**



Conclusions: Plenty of opportunities on all the spectrum

***supra*-electroweak**

Clearly a Run3 and HL-LHC "specialty" because benefits of large-x and some precision, thus time and work is needed to bring systematics and theory under control. *Higgs* and *top* compositeness, *electroweak* matter probed to unprecedented levels.

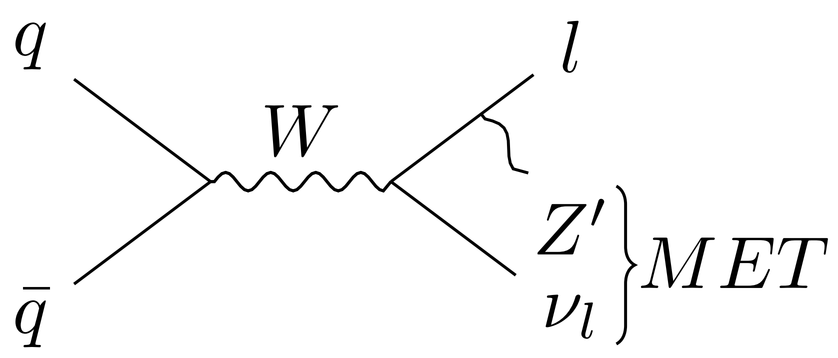


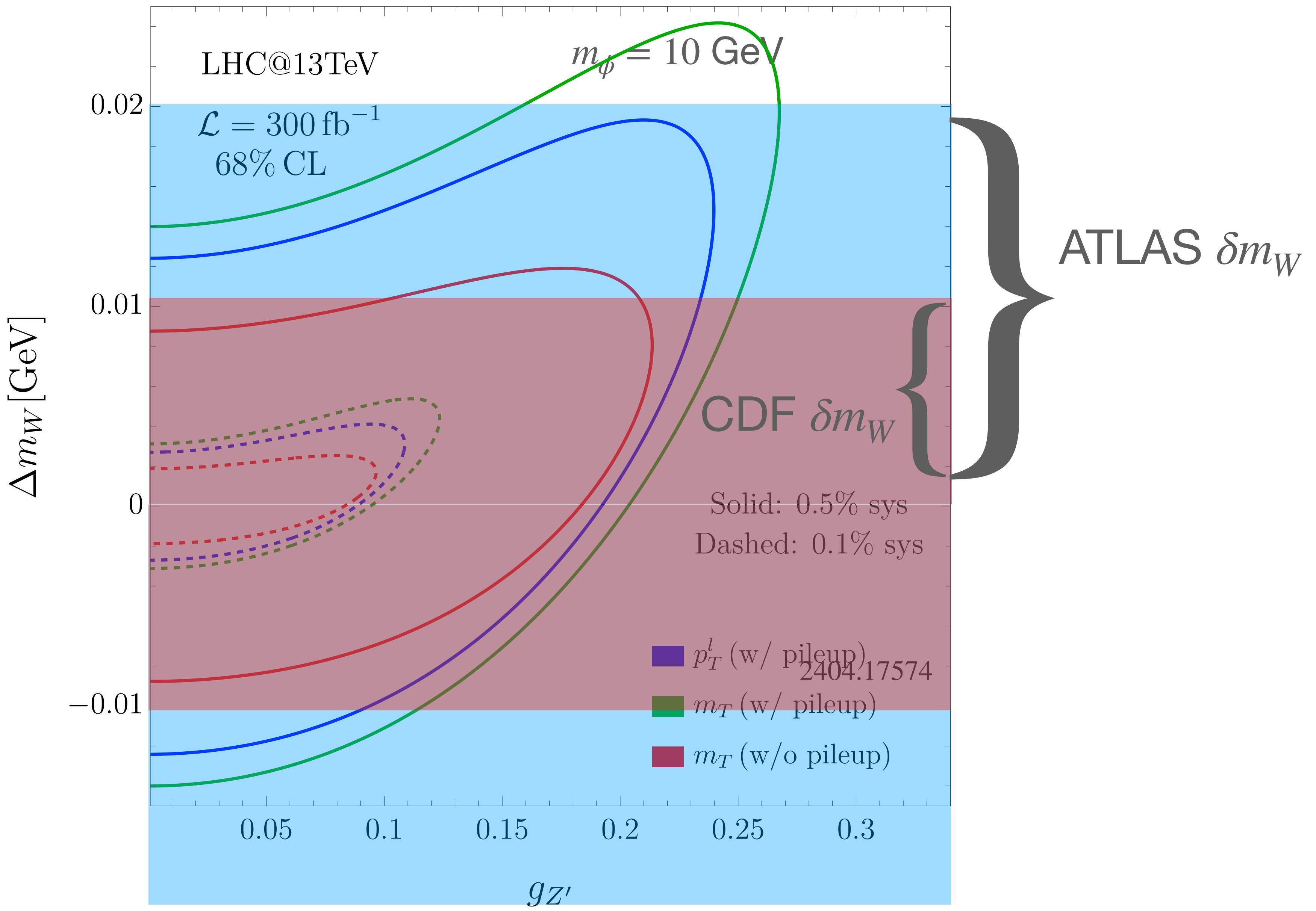
Conclusions

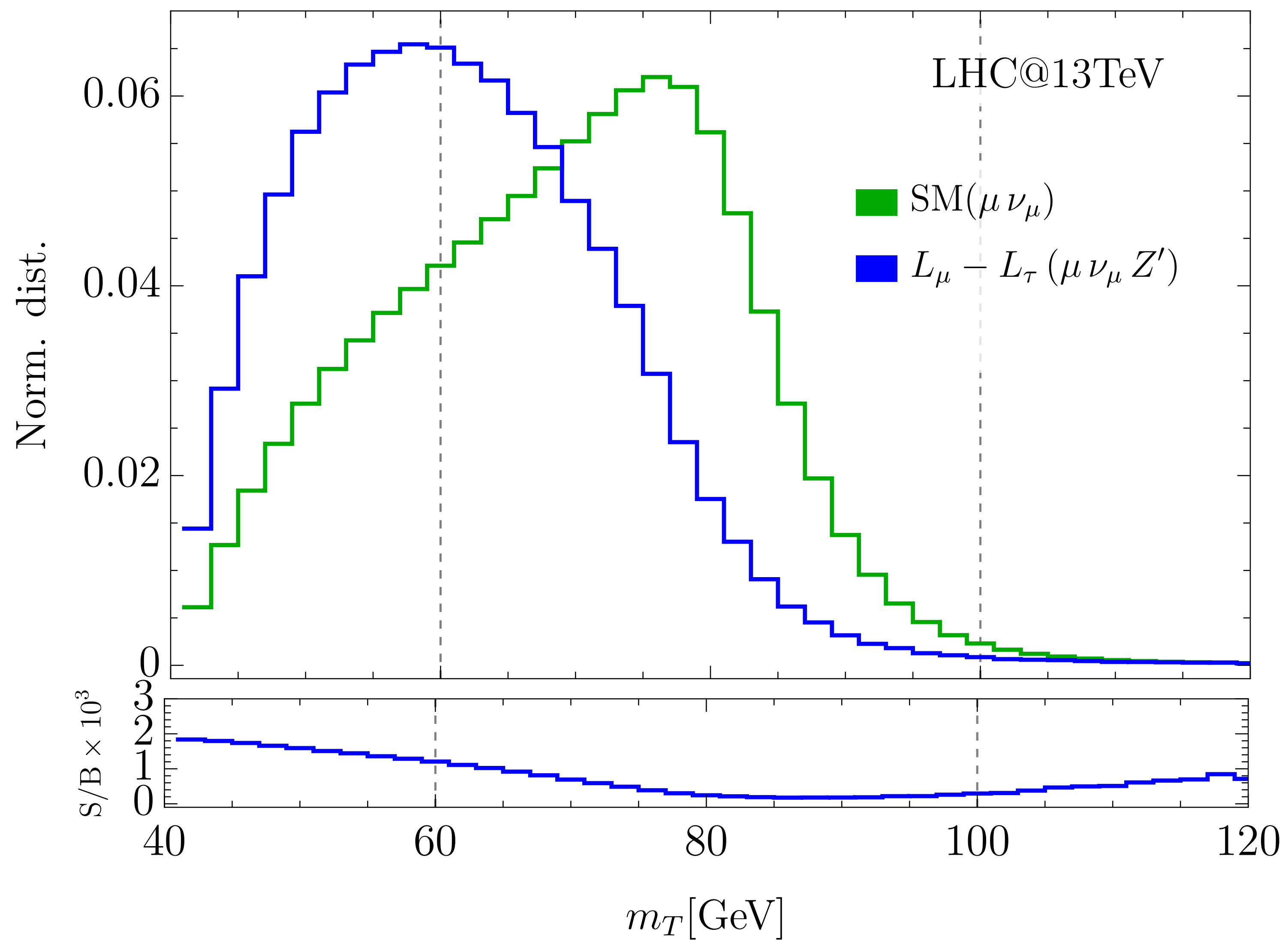
- **Plenty of opportunities on all the spectrum**
    - luminosity of order of **fractions of ab^{-1}** from Run3 and HL-LHC enable unprecedented sensitivity to key aspects of SM and BSM physics
- New physics searches intertwined with measurement of SM quantities in the "sub-electroweak" and "circa-electroweak" phase-space
- High-mass "supra-electroweak" regime will cover new ground in Higgs boson and top quark compositeness, probes of electroweak matter, flavor and electroweak symmetry dynamics ⇒ important and broad impact on the experimental program and future colliders

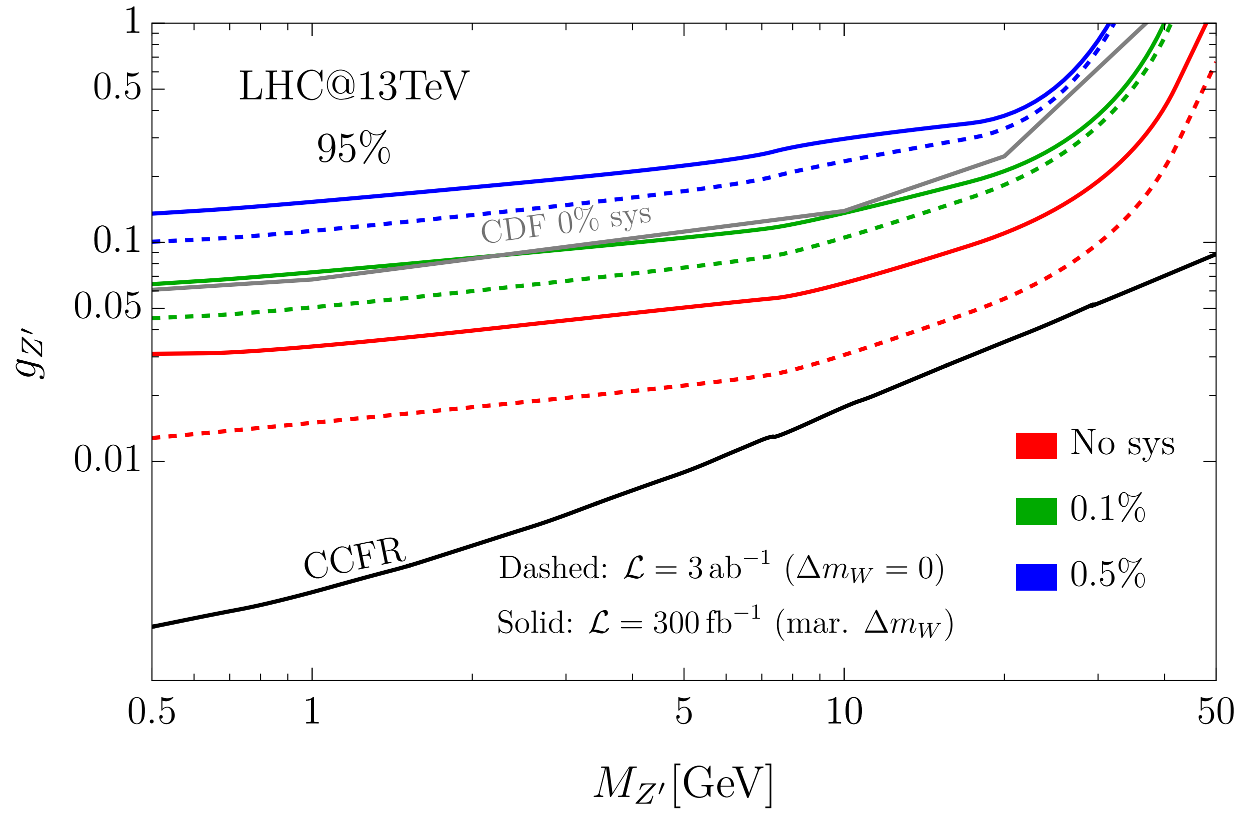
Thank you

Search & Measure
in ℓ + mET

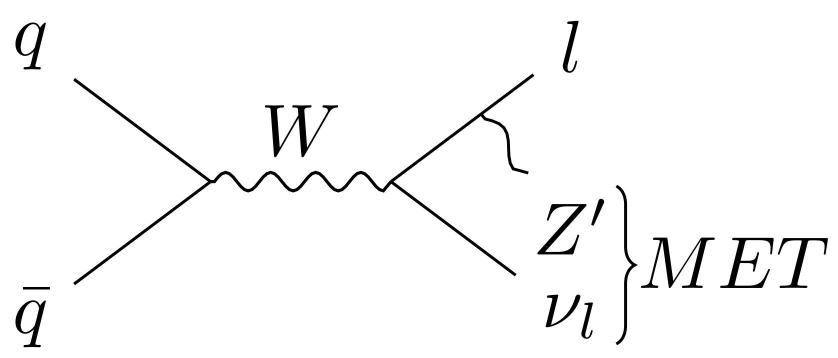


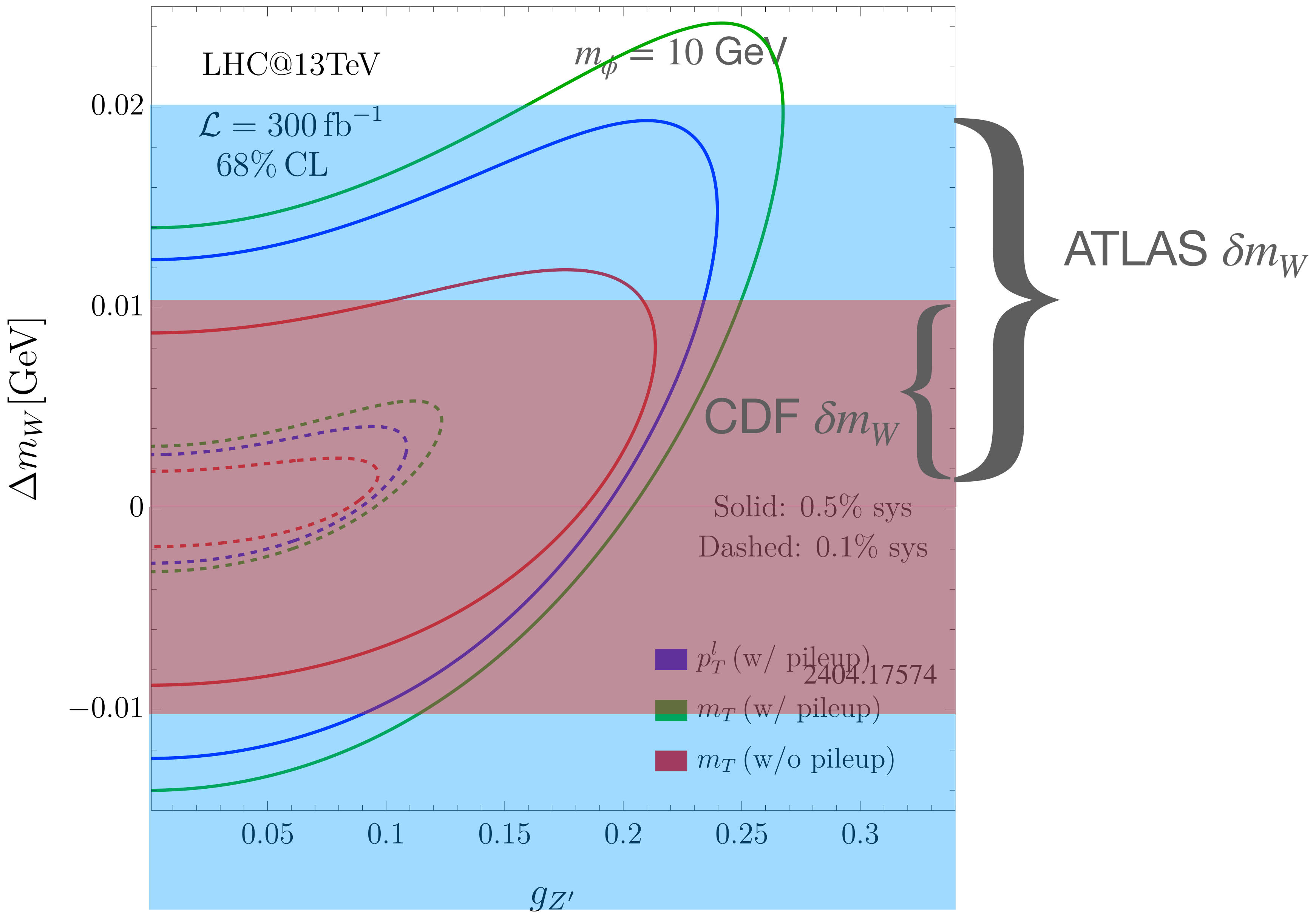




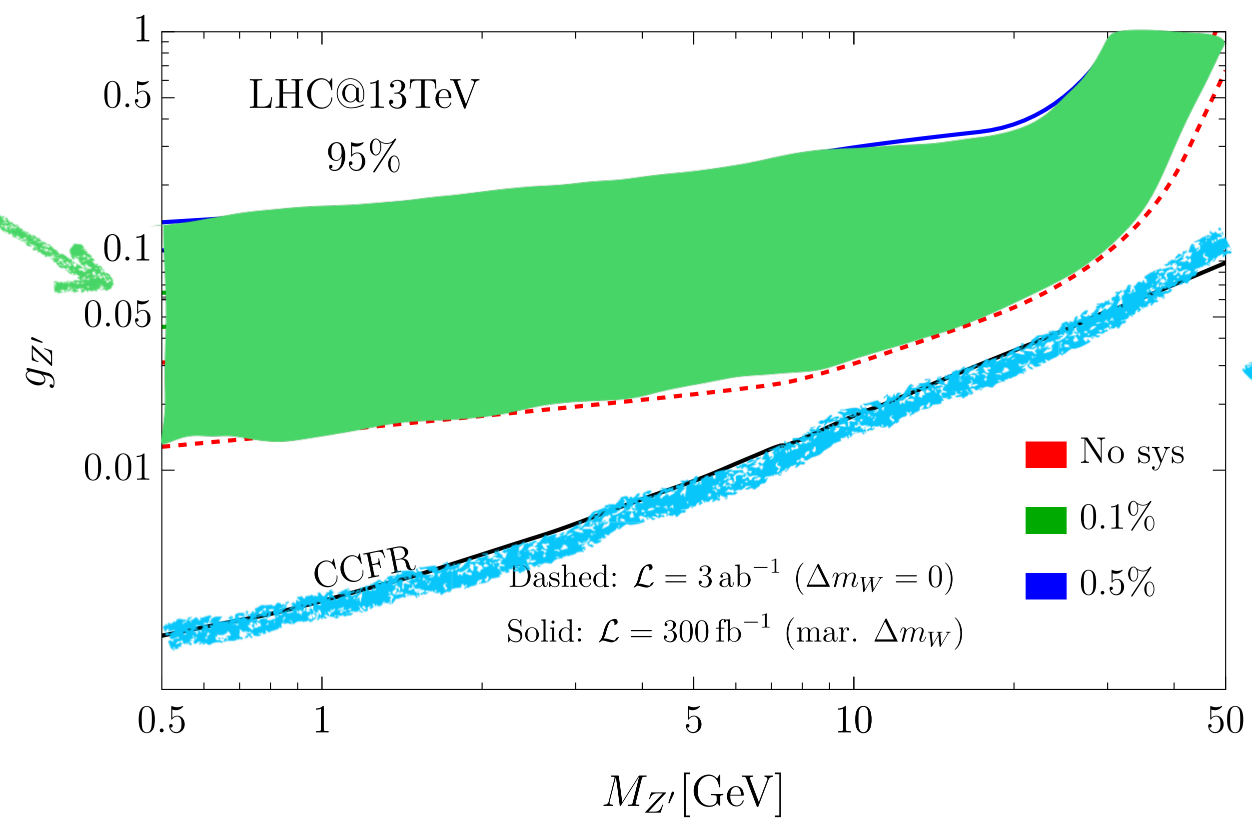


SEARCH & MEASURE in ℓ + mET

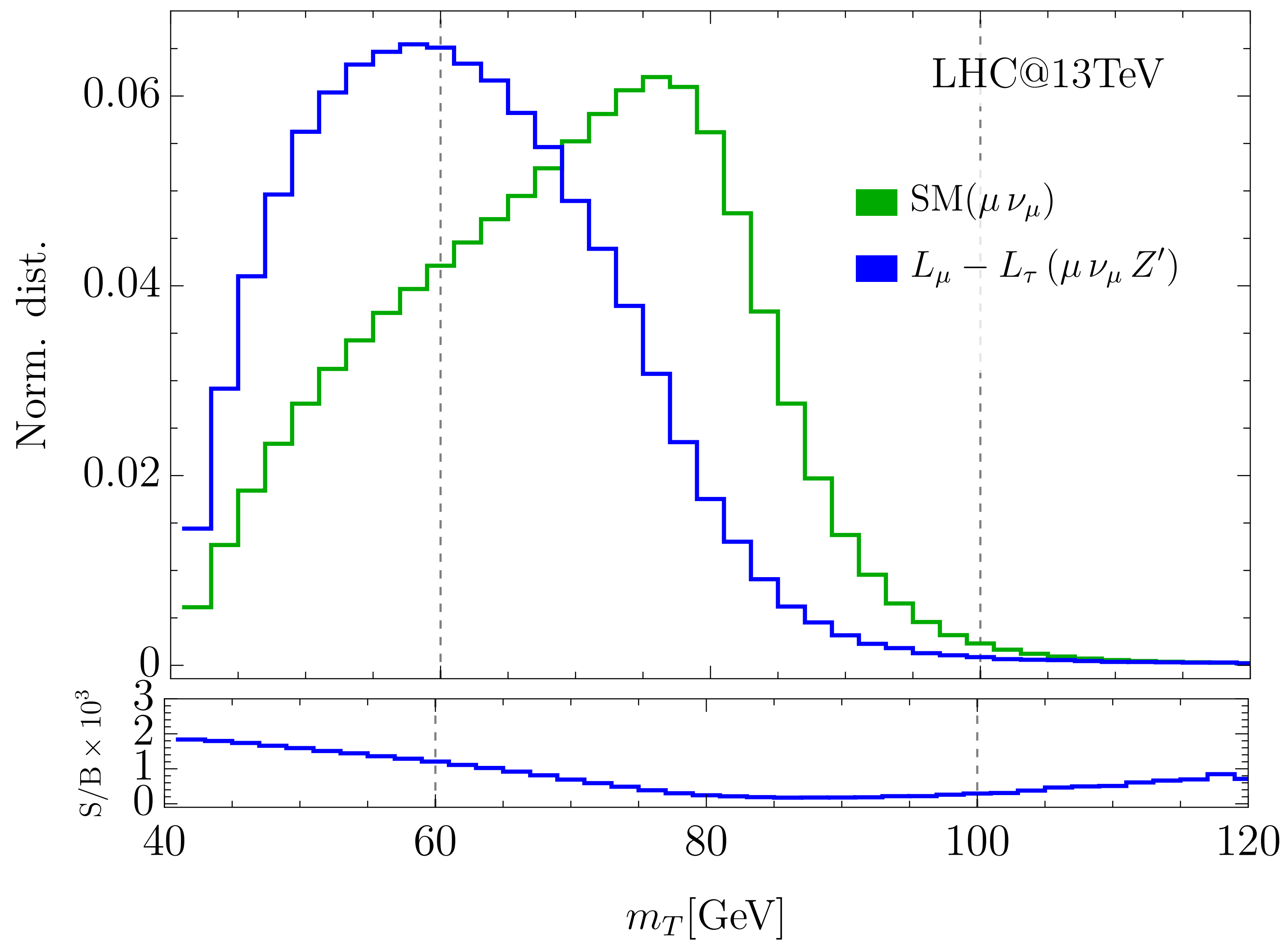




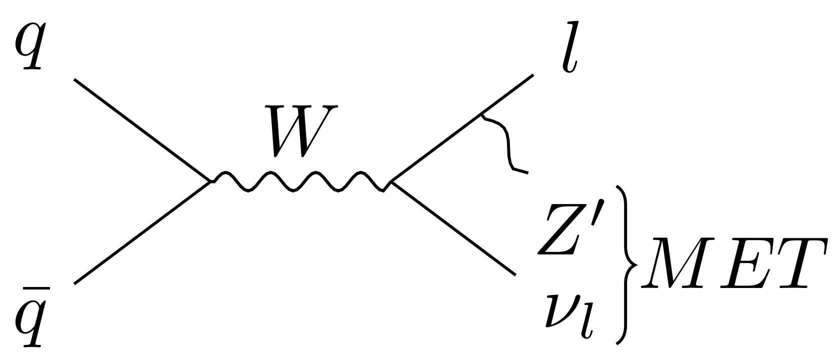
POSSIBLE BOUNDS FROM PRECISION ℓ+mET

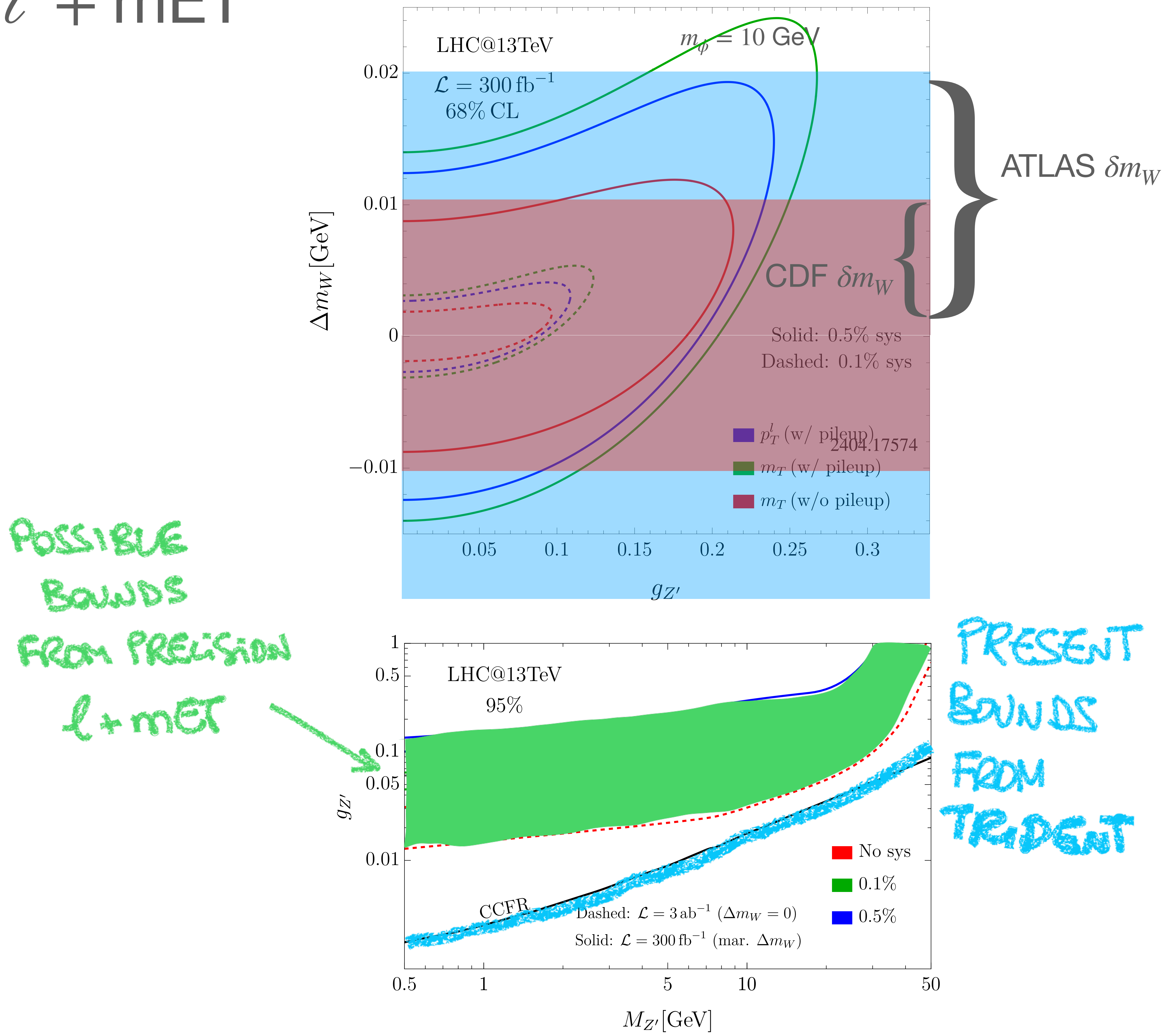


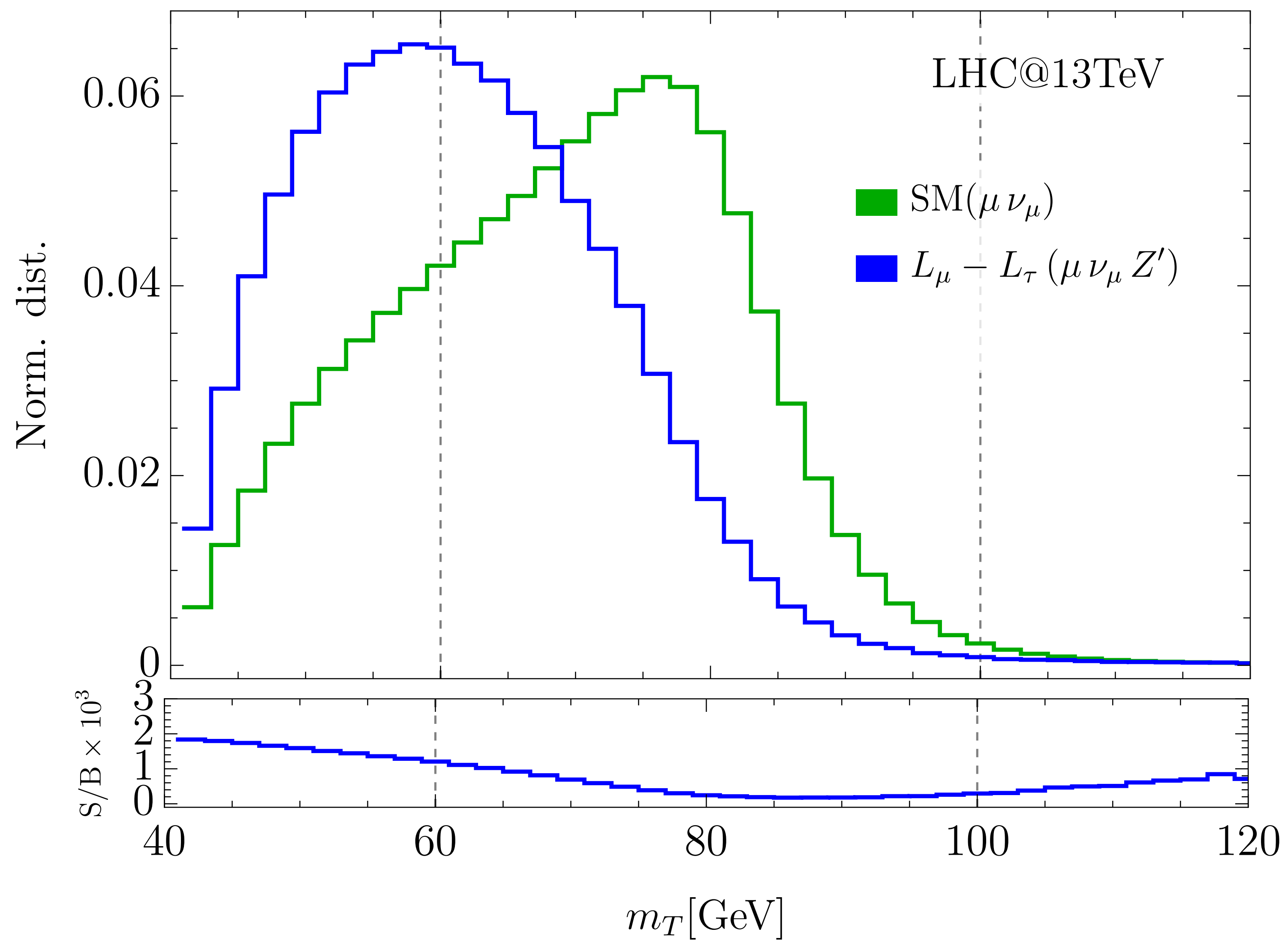
PRESENT BOUNDS FROM TRIDENT



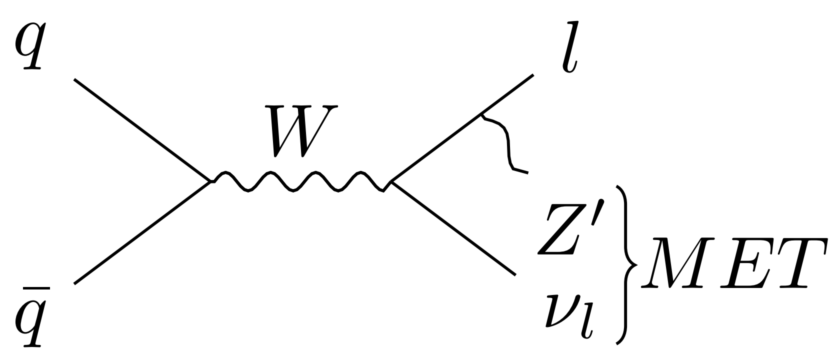
SEARCH & MEASURE in ℓ + mET

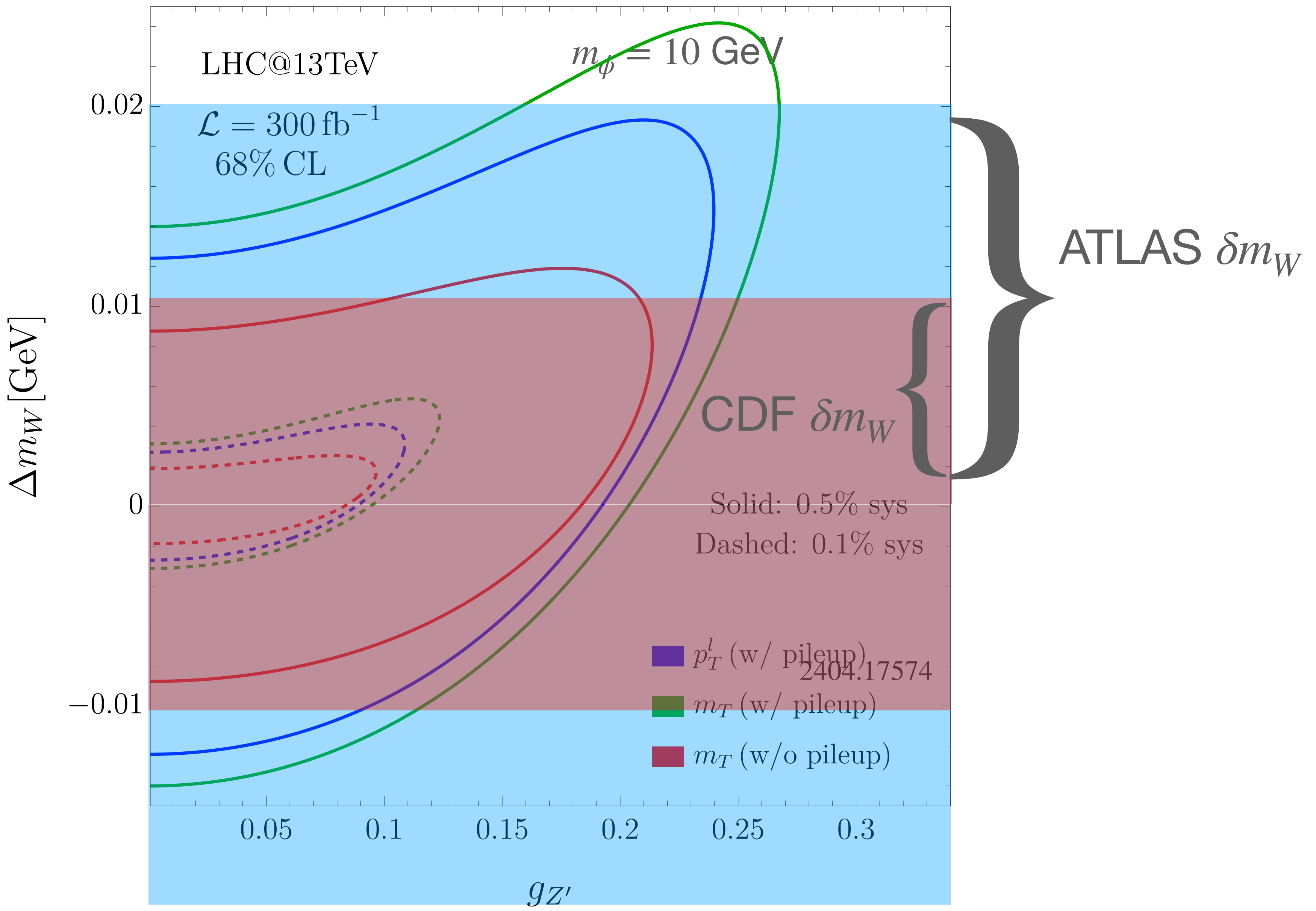


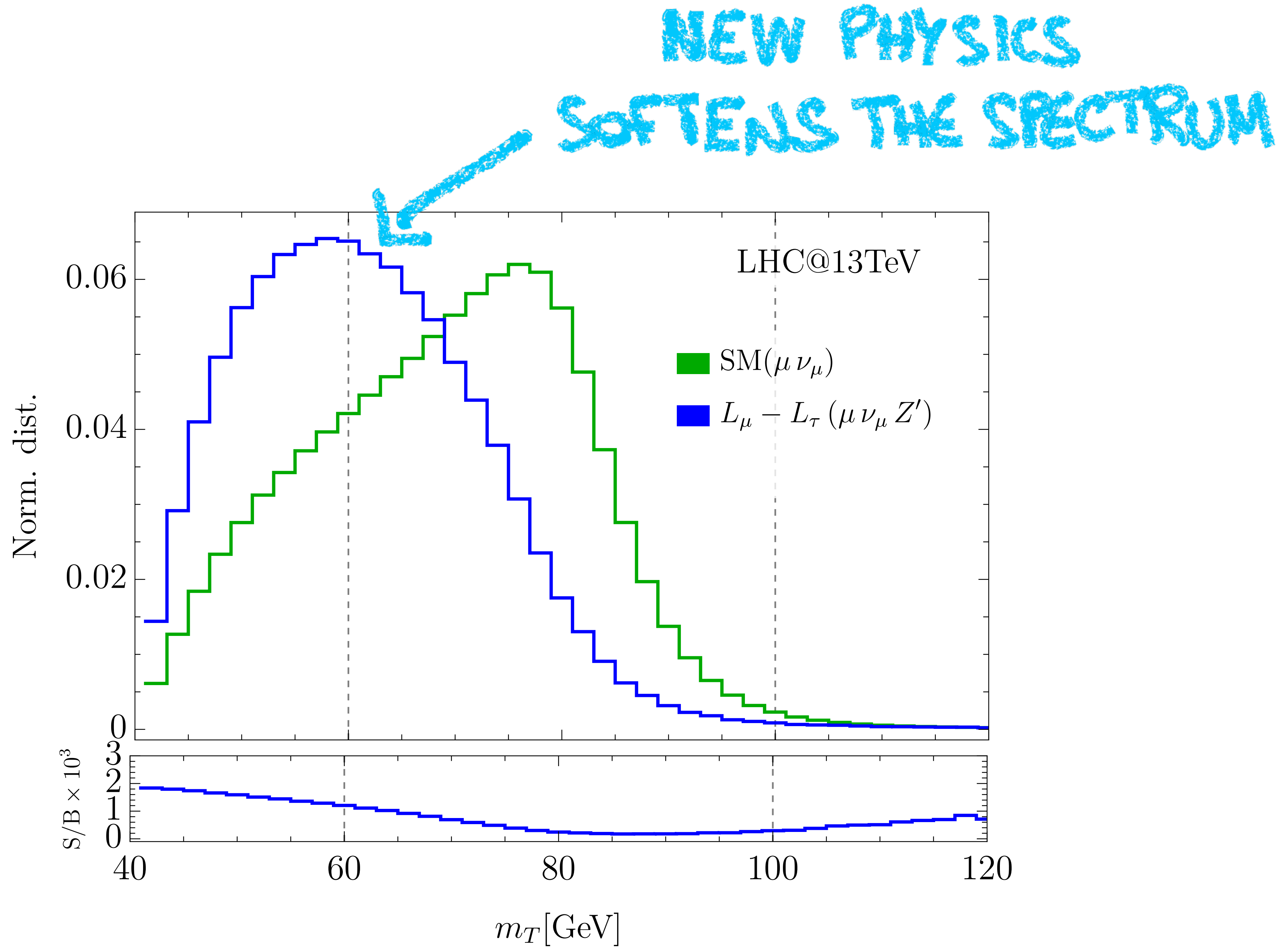


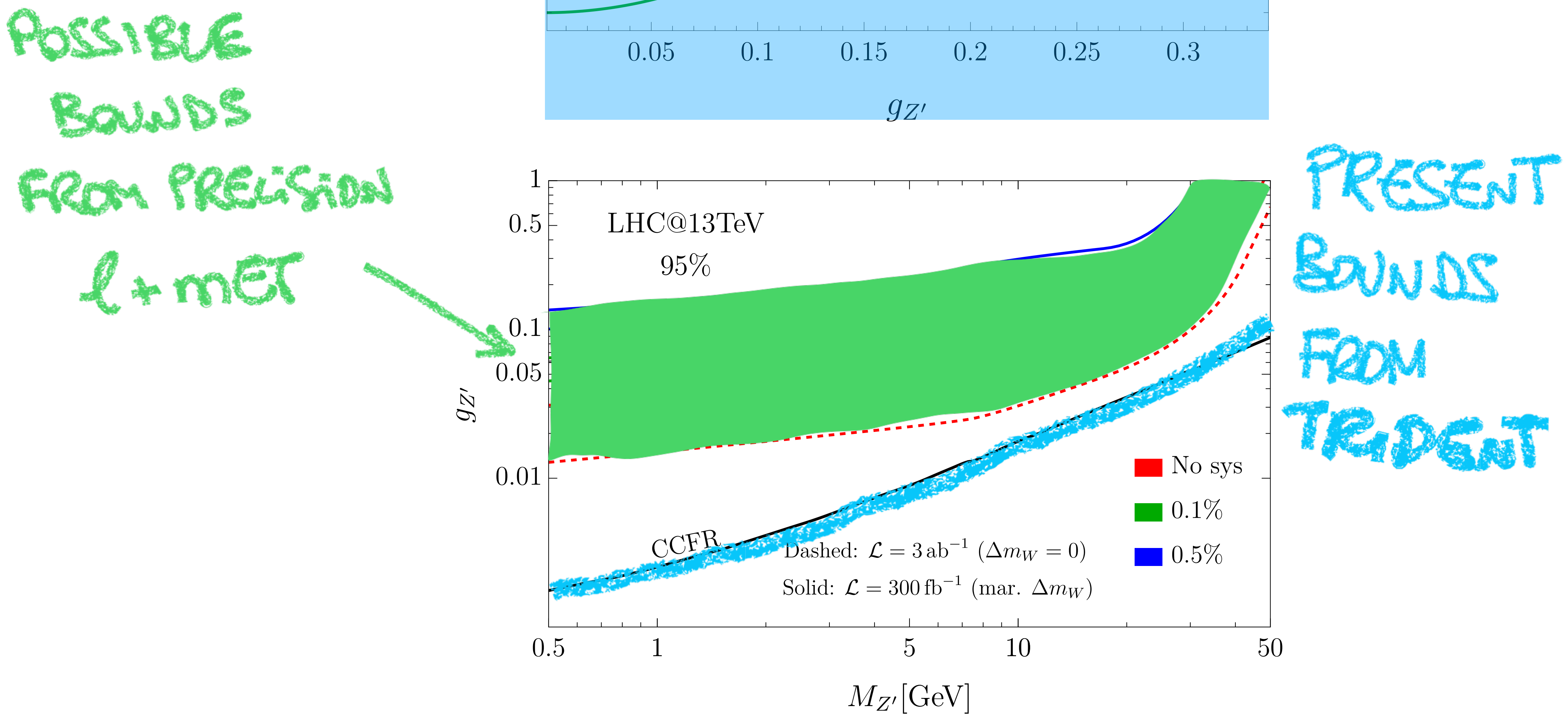


SEARCH & MEASURE in ℓ + mET



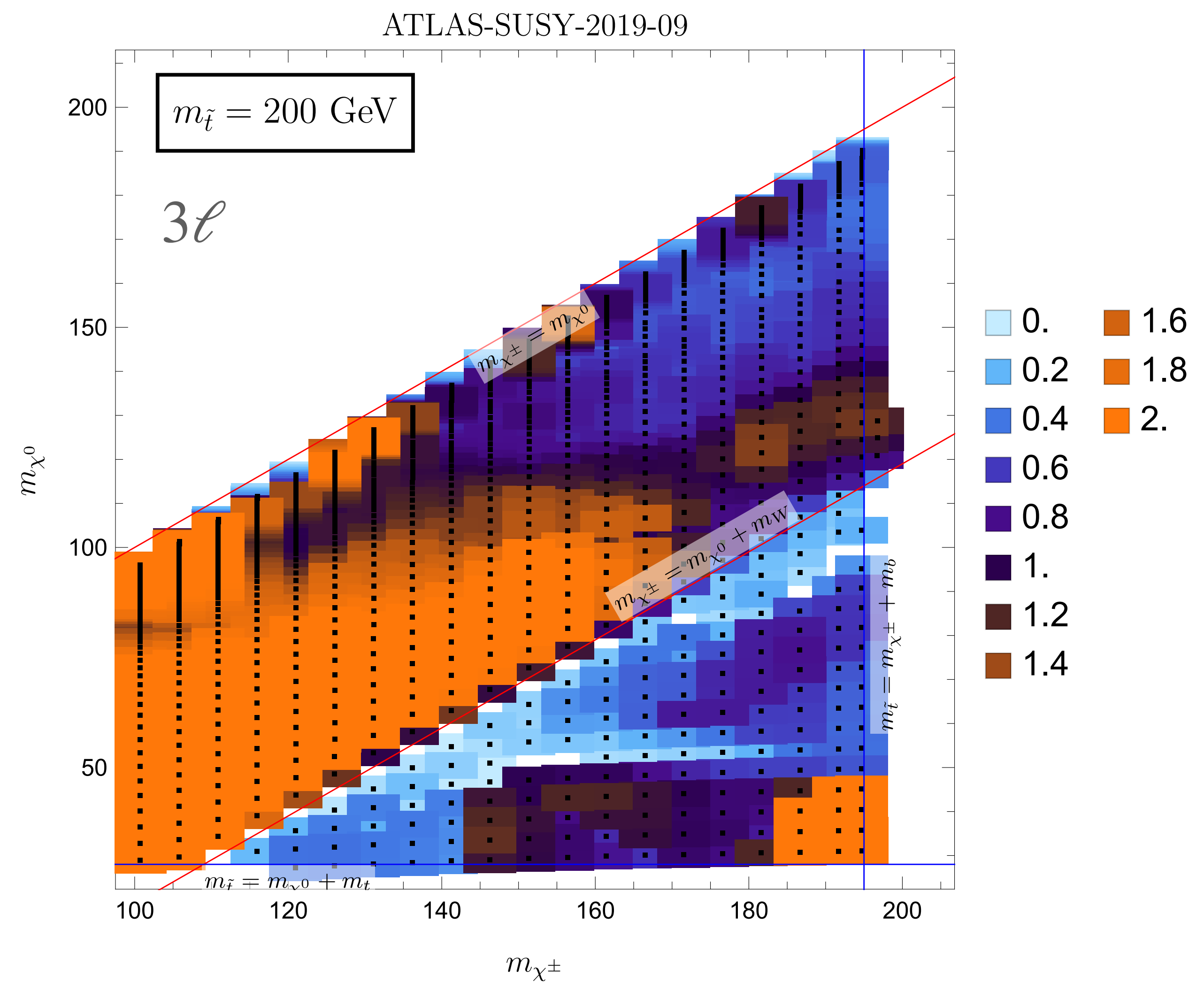


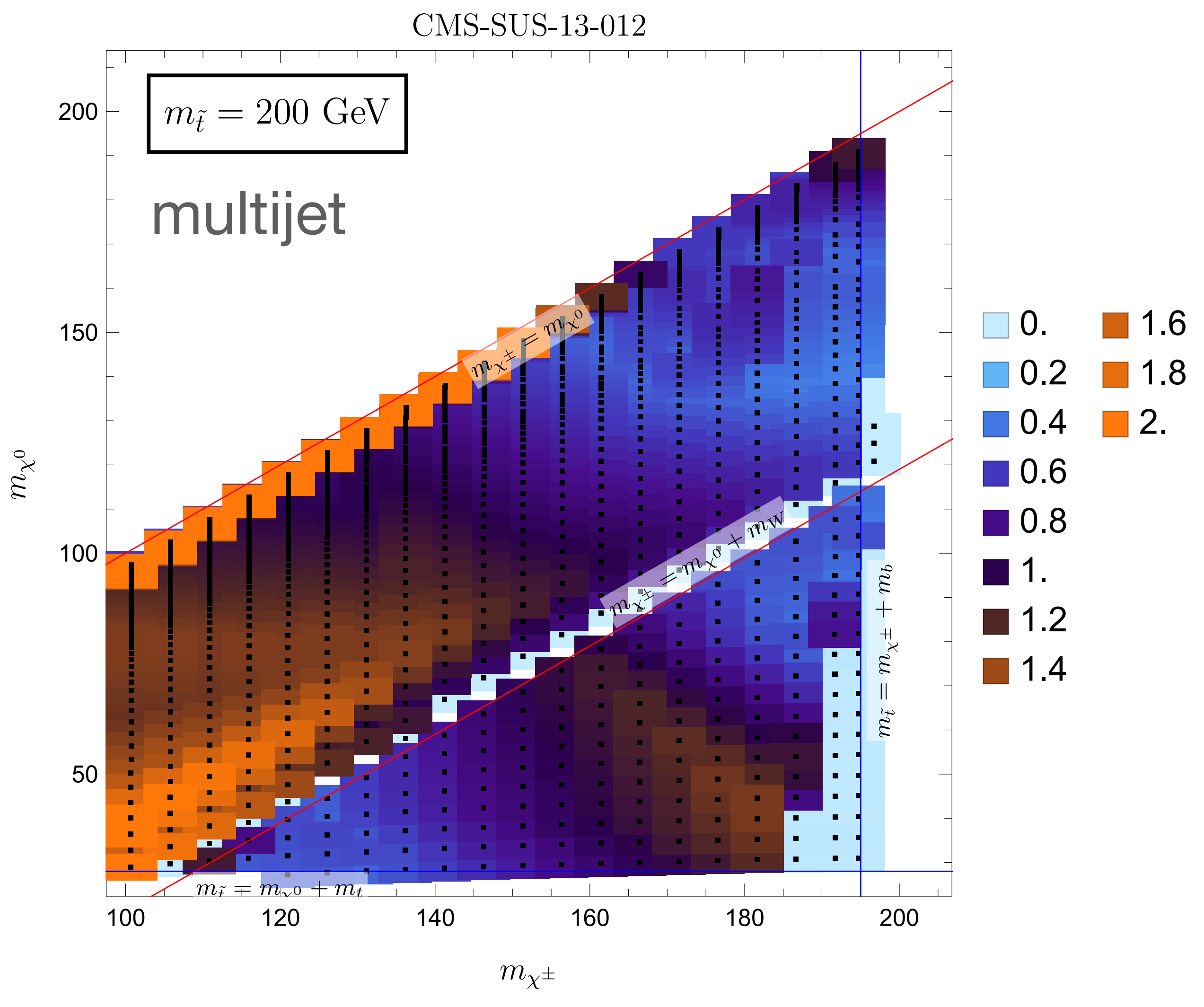


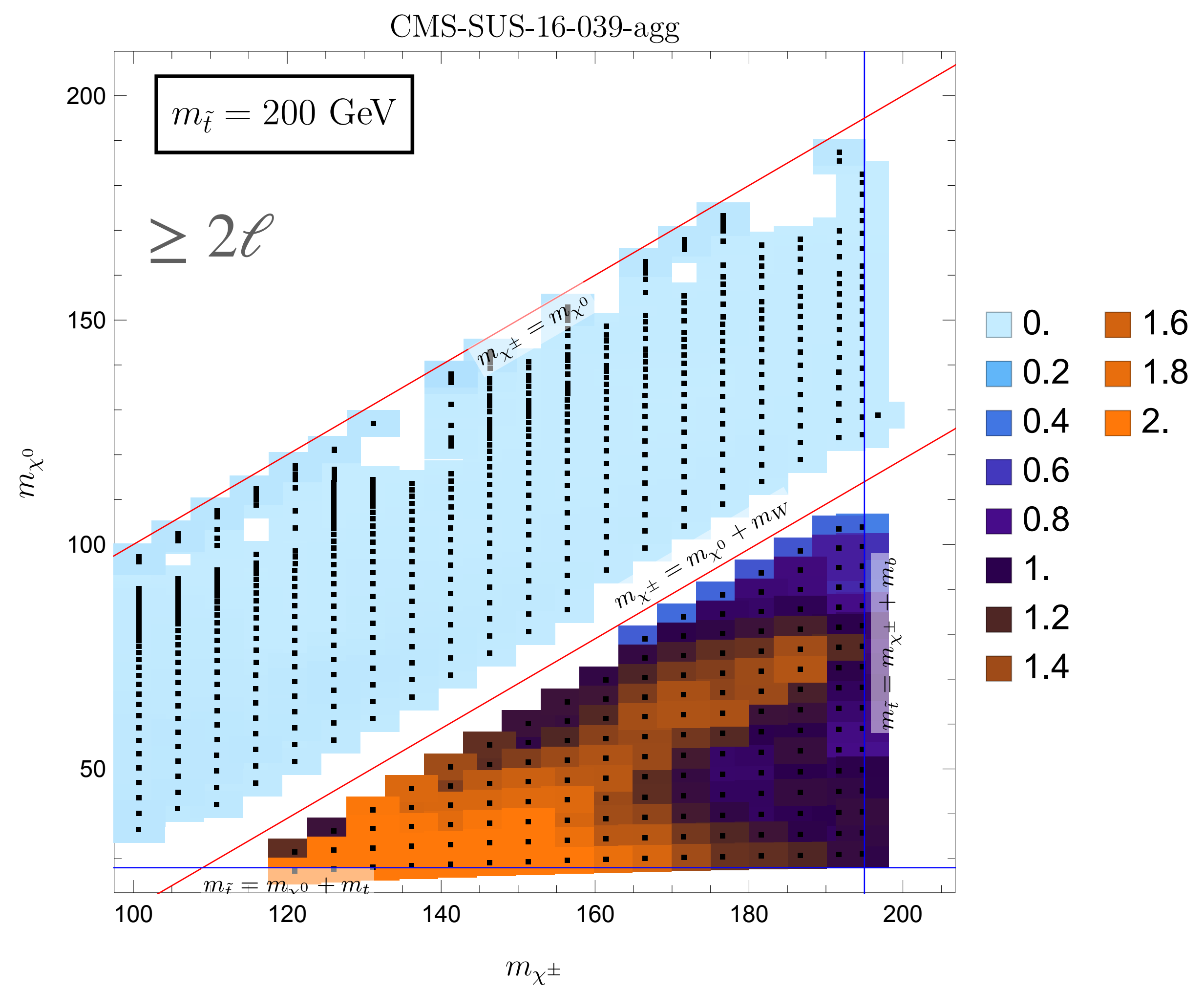


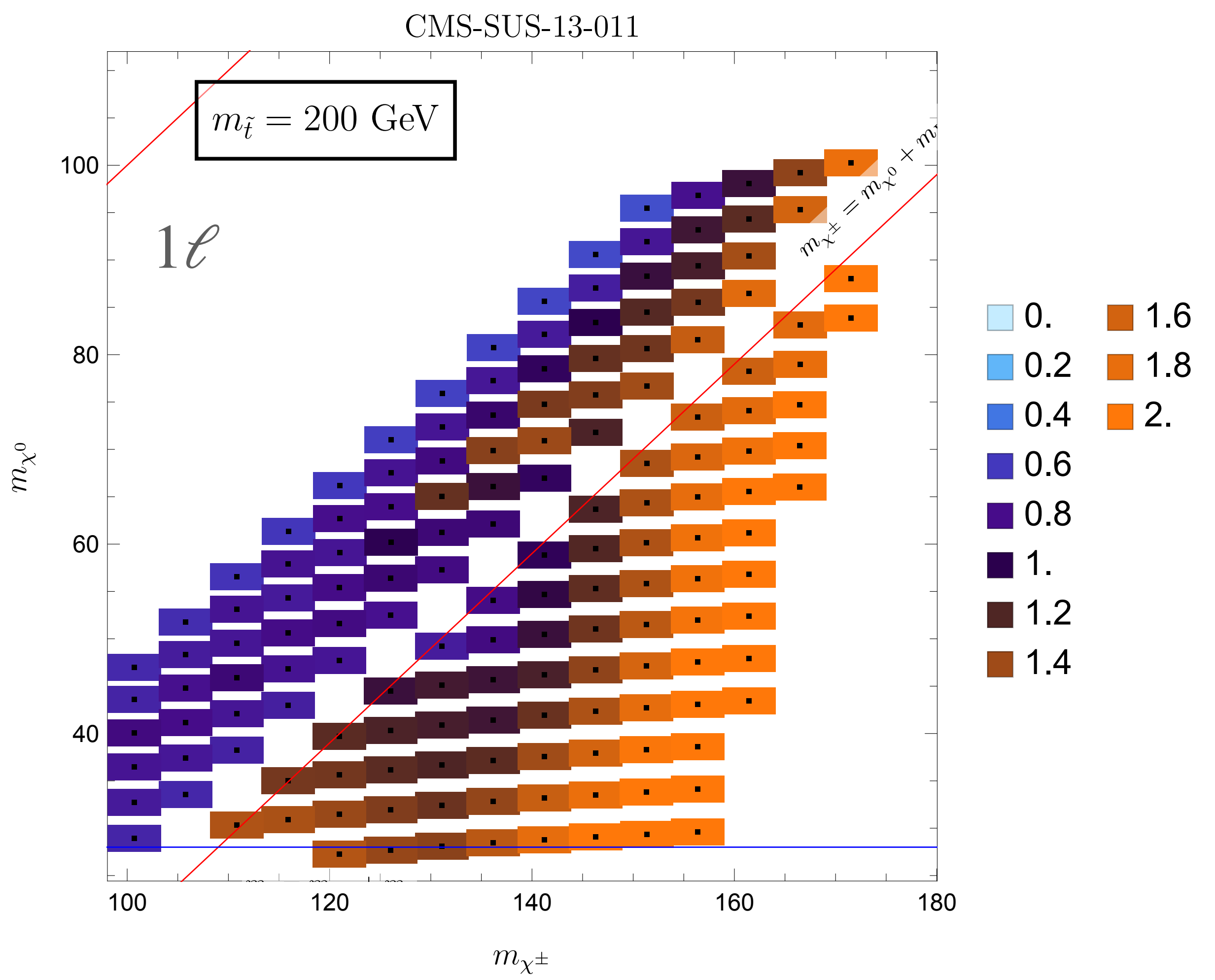
Recast bounds on the NP scenario

analysis by analysis









ATLAS SUSY-2019-09

Table 8: Summary of the preselection criteria applied in the SRs of the off-shell *WZ* selection. In rows where only one value is given it applies to all regions. '-' indicates no requirement is applied for a given variable/region.

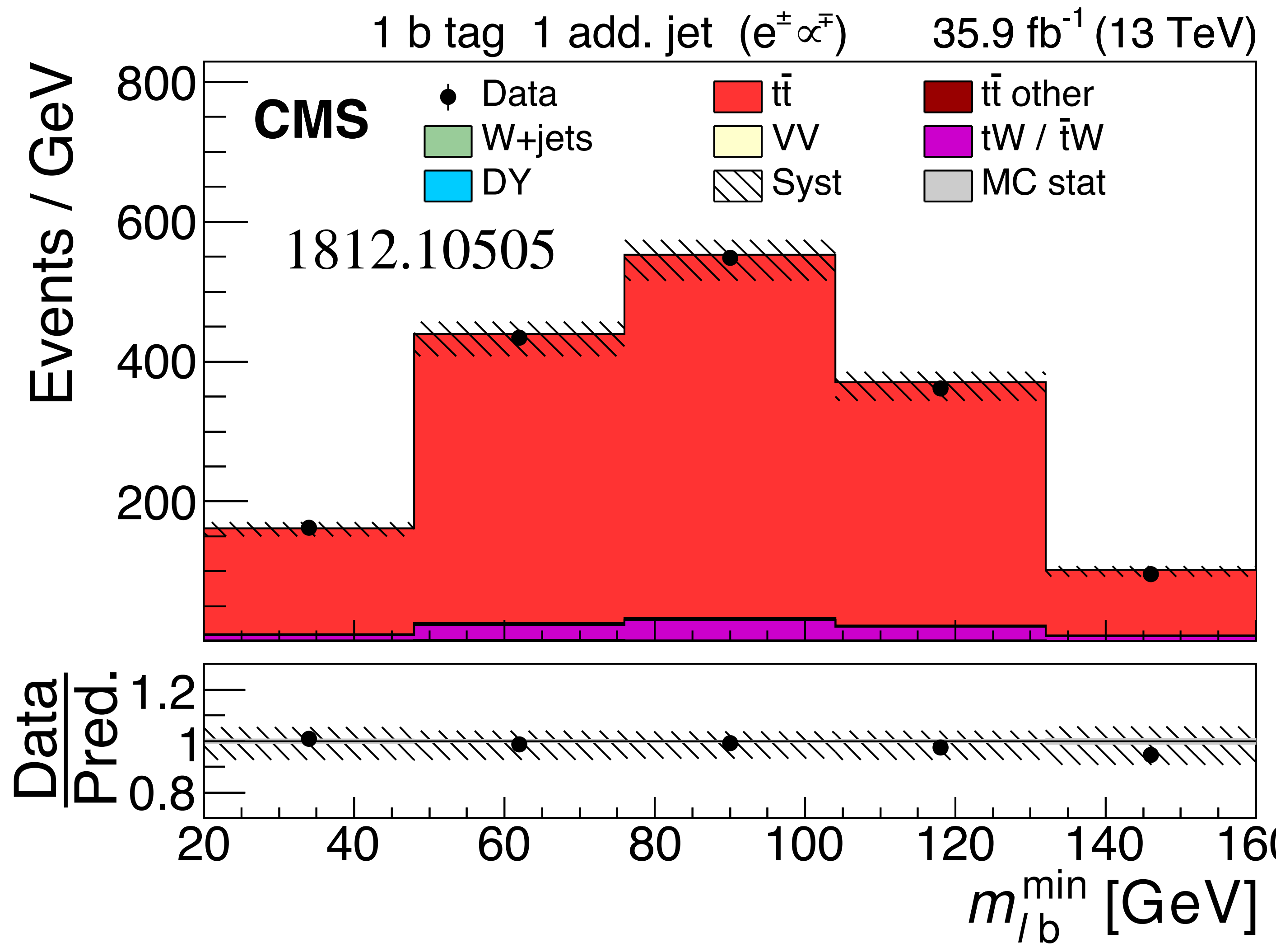
Variable	Preselection requirements: $SR^{offWZ}_{low E_T^{miss}}$-0j	$SR^{offWZ}_{low E_T^{miss}}$-nj	$SR^{offWZ}_{high E_T^{miss}}$-0j	$SR^{offWZ}_{high E_T^{miss}}$-nj
$n_{lep}^{baseline}$, n_{lep}^{signal}	= 3			
n_{SFOS}	≥ 1			
$m_{\ell\ell}^{max}$ [GeV]	< 75			
$m_{\ell\ell}^{min}$ [GeV]	∈ [1, 75]			
$n_{b\text{-jets}}$	= 0			
min $\Delta R_{3\ell}$	> 0.4			
Resonance veto $m_{\ell\ell}^{min}$ [GeV]	∉ [3, 3.2], ∉ [9, 12]		-	
Trigger	(multi-)lepton		((multi-)lepton ‖ E_T^{miss})	
$n_{jets}^{30\ GeV}$	= 0	≥ 1	= 0	≥ 1
E_T^{miss} [GeV]	< 50	< 200	> 50	> 200
E_T^{miss} significance	> 1.5	> 3.0	> 3.0	> 3.0
$p_T^{\ell_1}, p_T^{\ell_2}, p_T^{\ell_3}$ [GeV]	> 10		> 4.5(3.0) for $e(\mu)$	
$\lvert m_{3\ell} - m_Z \rvert$ [GeV]	> 20 ($\ell_W = e$ only)		-	
min ΔR_{SFOS}	[0.6, 2.4] ($\ell_W = e$ only)		-	

Table 2: Summary of the preselection criteria applied in the SRs of the on-shell *WZ* and *Wh* selections. In rows where only one value is given it applies to all regions. '-' indicates no requirement is applied for a given variable/region.

Variable	Preselection requirements: SR^{WZ}	SR^{Wh}_{SFOS}	SR^{Wh}_{DFOS}
$n_{lep}^{baseline}$, n_{lep}^{signal}	= 3		
Trigger	dilepton		
$p_T^{\ell_1}, p_T^{\ell_2}, p_T^{\ell_3}$ [GeV]	> 25, 20, 10		
E_T^{miss} [GeV]	> 50		
$n_{b\text{-jets}}$	= 0		
Resonance veto $m_{\ell\ell}$ [GeV]	> 12	> 12	-
n_{SFOS}	≥ 1	≥ 1	= 0
$m_{\ell\ell}$ [GeV]	∈ [75, 105]	∉ [75, 105]	-
$\lvert m_{3\ell} - m_Z \rvert$ [GeV]	> 15	> 15	-

dedicated analyses for compressed scenarios are included in the recast

In this talk I will elaborate on this theme and provide directions on how to use the measurements of m_{bl} to test new physics scenarios



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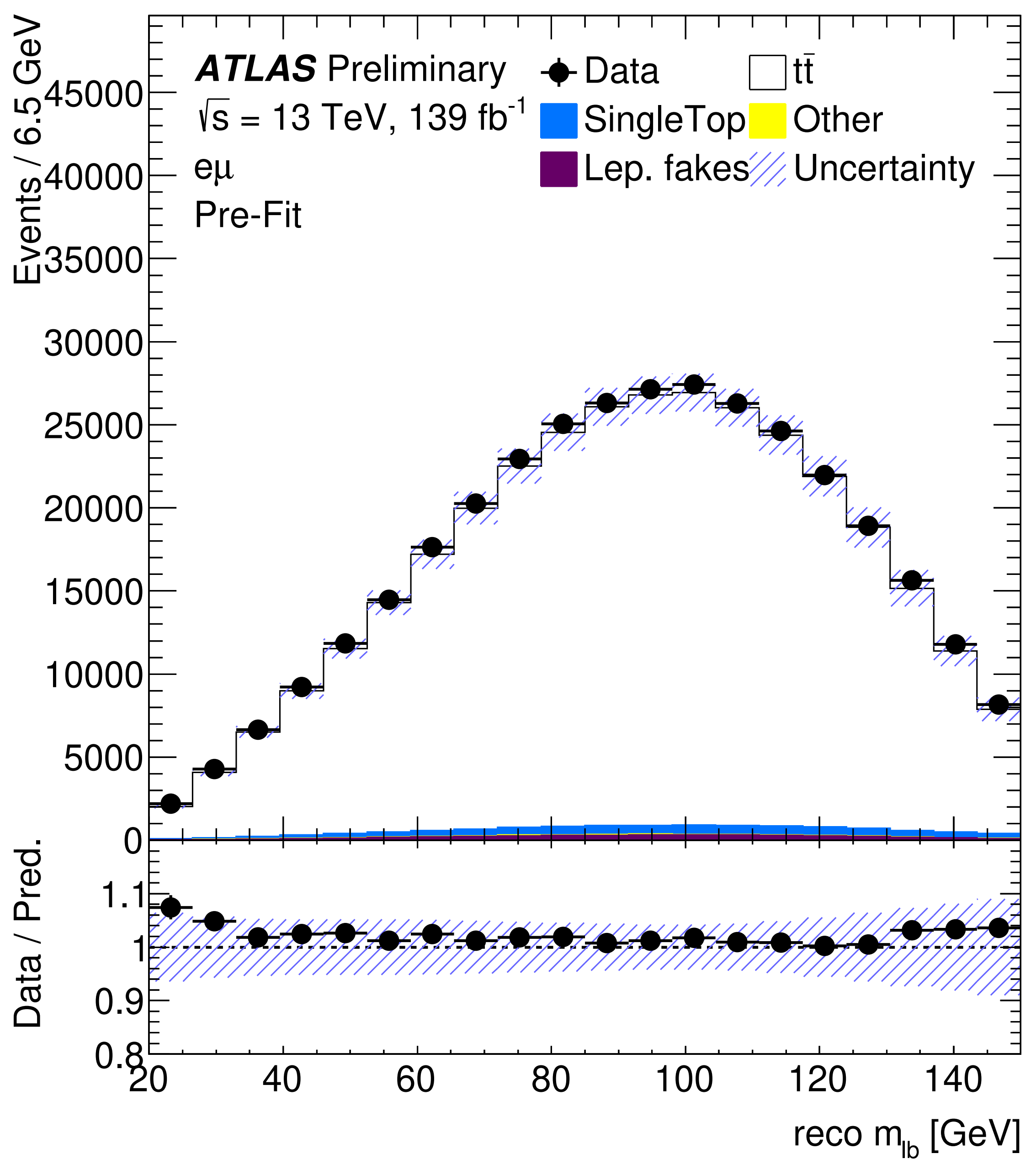
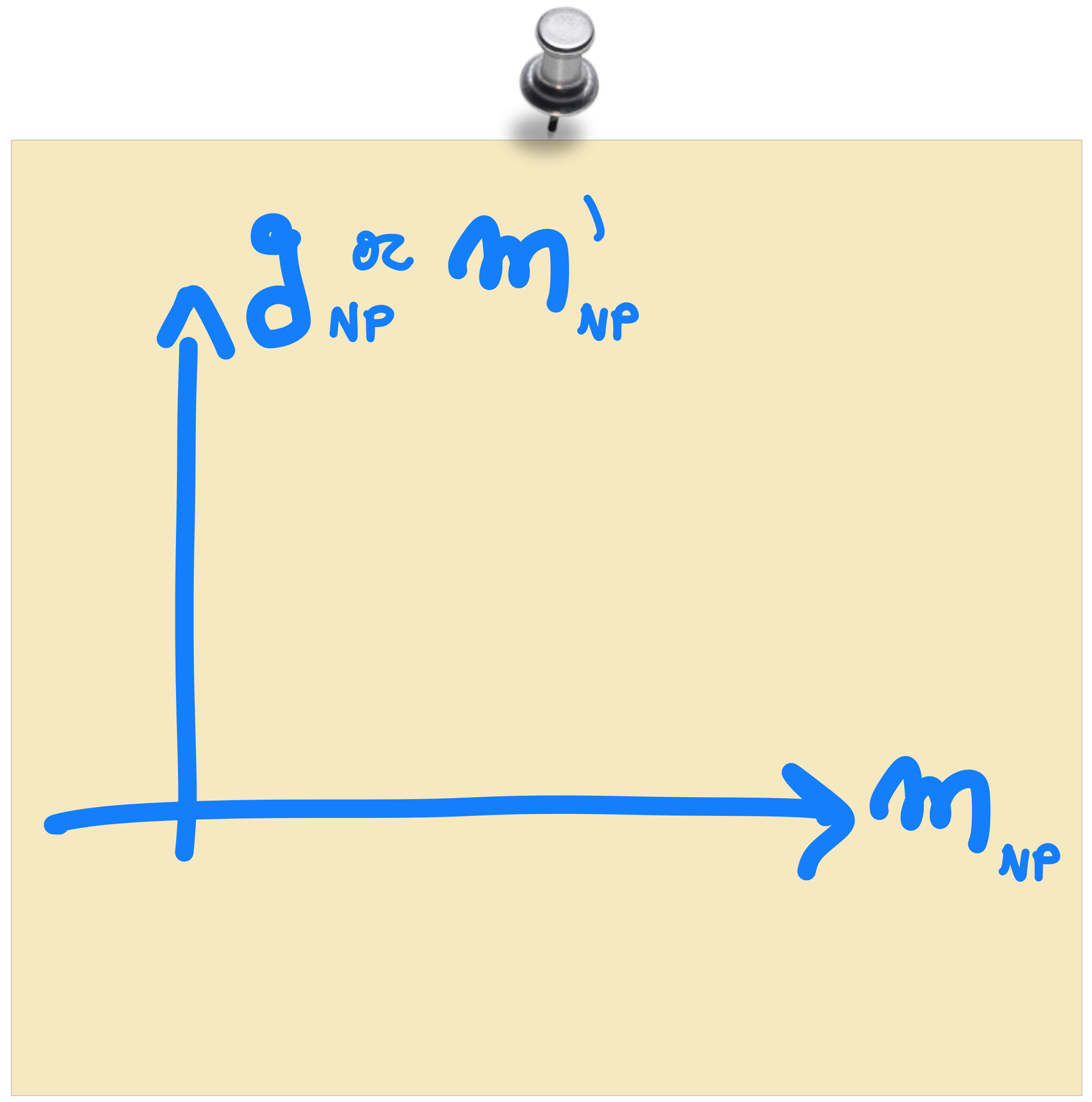
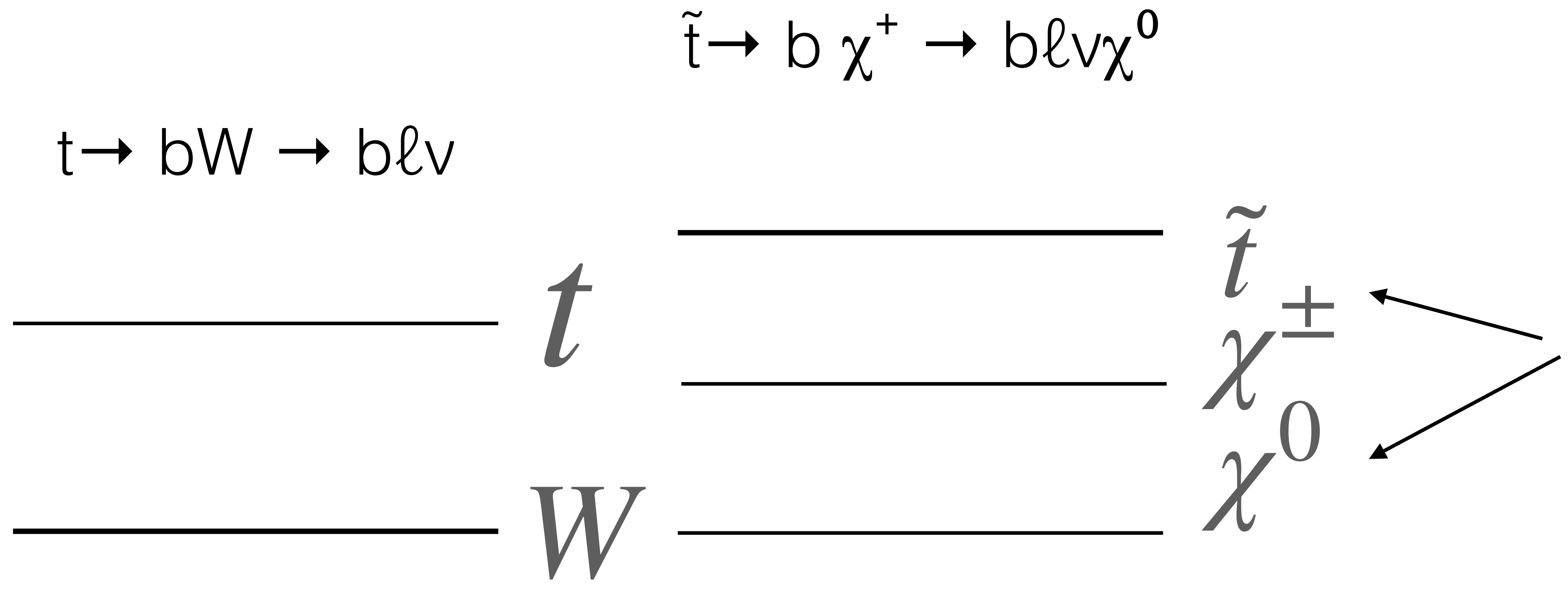




The message can be spread to other observables: 1D distributions of $p_{T,\ell}, m_{T2}, E_b, \ldots$; 2D distributions as well; a full likelihood study in principle

Targeted new physics scenario



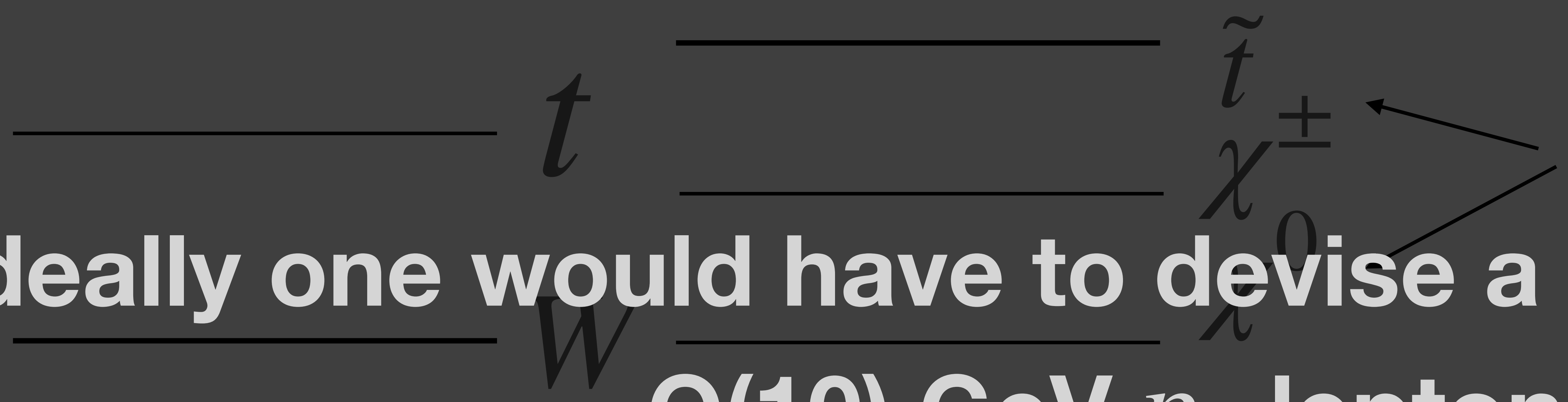
Due to small mass differences between the NP states each energy release gives "soft" leptons and/or (b-)jets.

New physics that gives only "soft" leptons and (b-)jets is not the target of "*Search for …*"

Targeted new physics scenario

$\tilde{t} \to b\,\chi^{+} \to b\ell\nu\chi^{0}$

$t \to bW \to b\ell\nu$



Due to small mass differences between the NP states each energy release gives "soft" leptons and/or (b-)jets.

"New physics that gives only "soft" leptons and (b-)jets is not the target for "Search for ...""

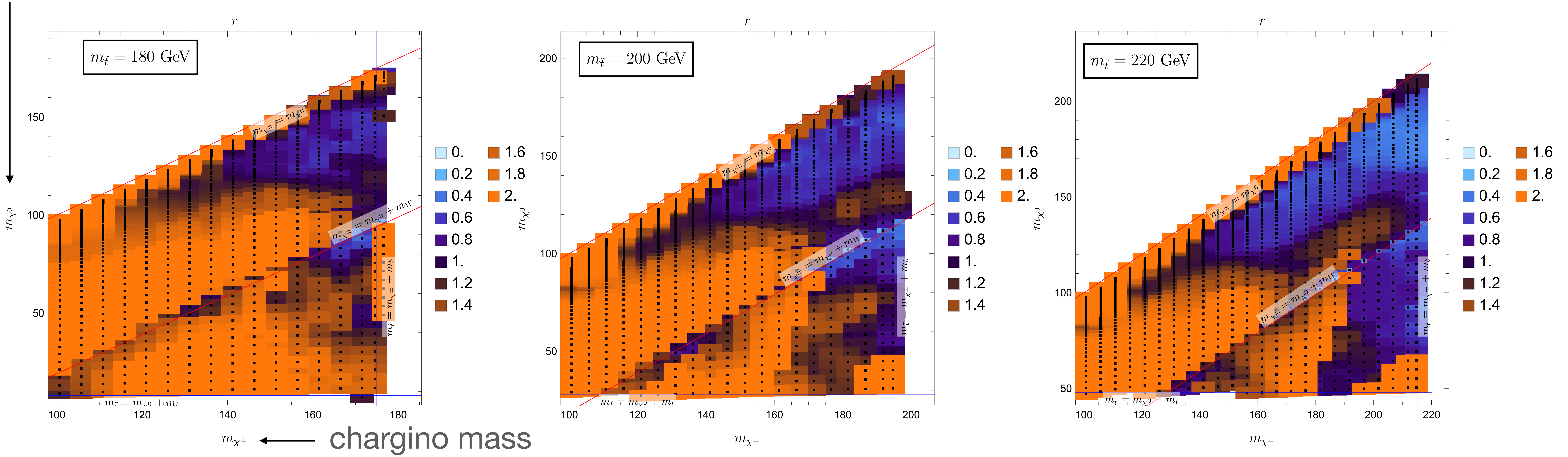
Ideally one would have to devise a search analysis that can deal with O(10) GeV p_T leptons and (bottom) jets

All the accurate work on these leptons and jets is already in place for the measurements of top quark properties!

Recast bounds on the NP scenario

at several stop quark mass values

neutralino mass



chargino mass

$m_{\tilde{t}} \simeq 180$ GeV $m_{\tilde{t}} \simeq 200$ GeV $m_{\tilde{t}} \simeq 220$ GeV

Recast bounds on the NP scenario

at several stop quark mass values

$m_{\tilde{t}} \simeq 180$ GeV

$m_{\tilde{t}} \simeq 200$ GeV

$m_{\tilde{t}} \simeq 220$ GeV

Workflow **Easily reproducible with well known codes.**

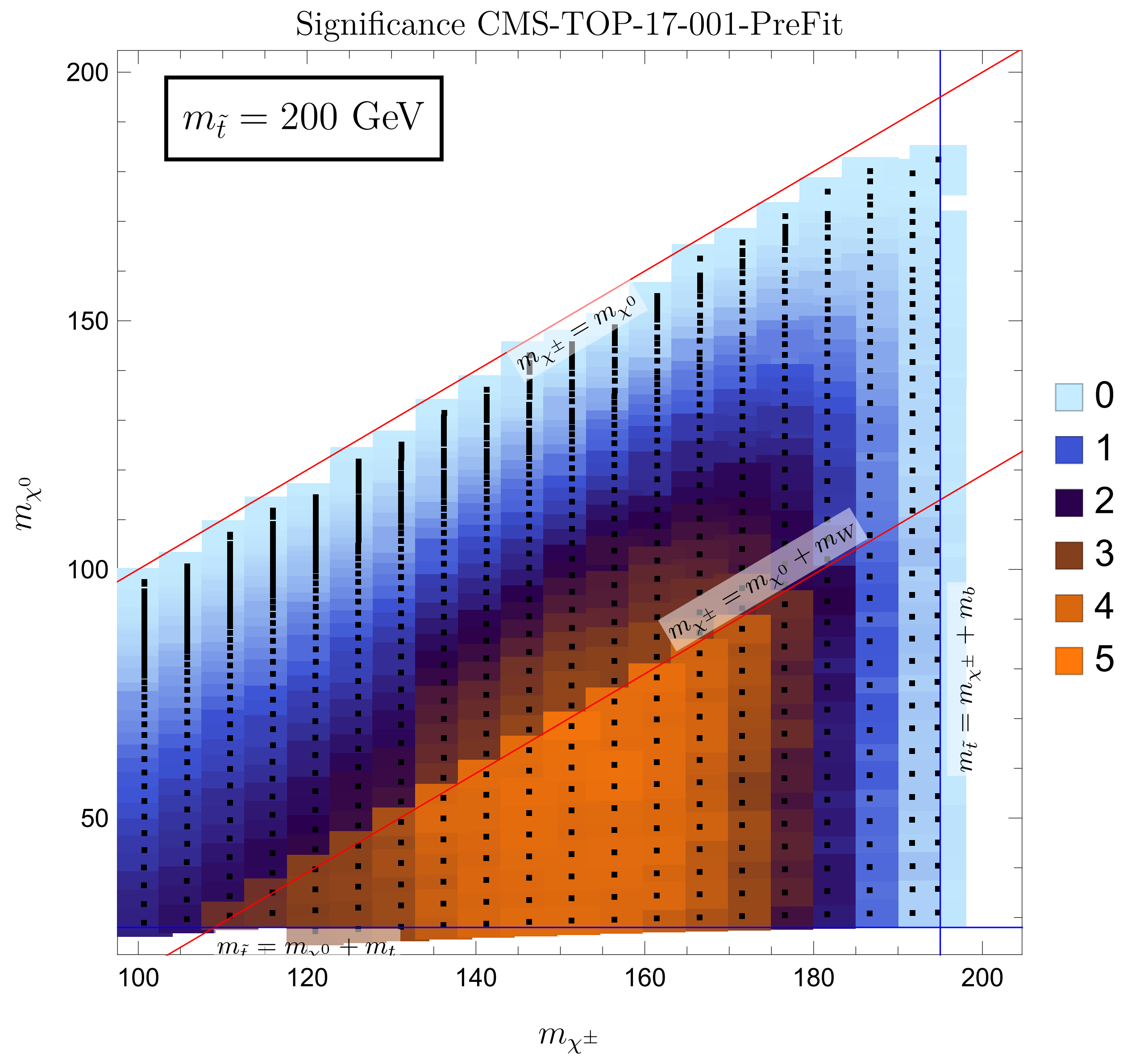
SLHA-based → can be injected in Pythia in your experiment software framework(!)

- Generate MSSM model in SPheno 4.0.1 → SLHA file
- Elaborate the SLHA file with SModelS 2.3.3 (using SR combination)
- Find $r < 1$ or $r > 1$ (soon available on Zenodo for those who want to inject signals in their top quark property measurements)
- Run Pythia 8.3 to generate SM $t\bar{t}$ "background" and $pp \to \tilde{t}\tilde{t}$ signal events (relies on Pythia SLHA interface) → compute any distribution after selection cuts
- For simplicity we compute the correctly paired $m_{b\ell}$, which is different from CMS and ATLAS choices (interesting question to find out what is the best pairing strategy)

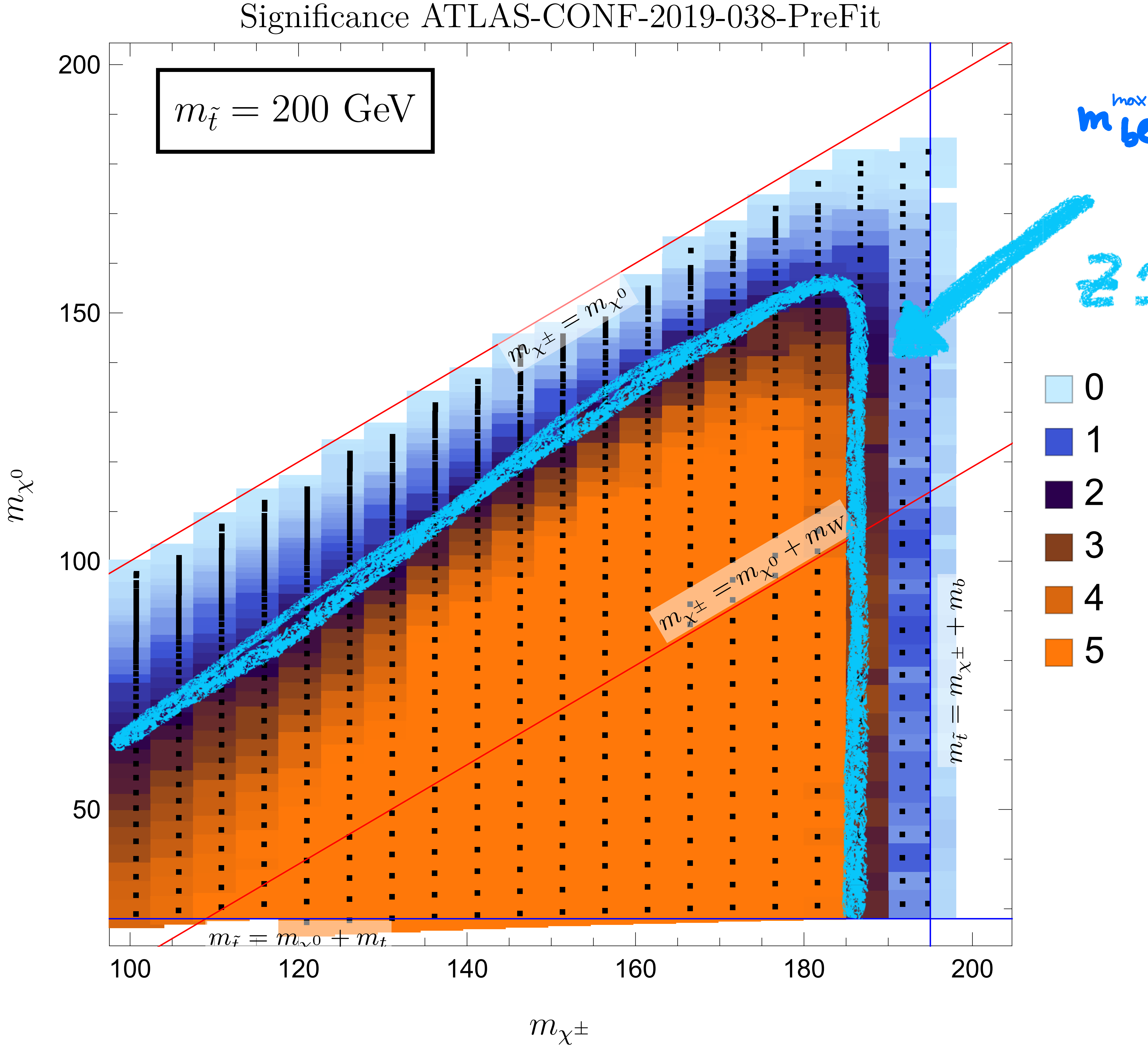
Significance estimator

$$z = \sqrt{\sum_i \left(\frac{S_i}{\delta B_i}\right)^2},$$

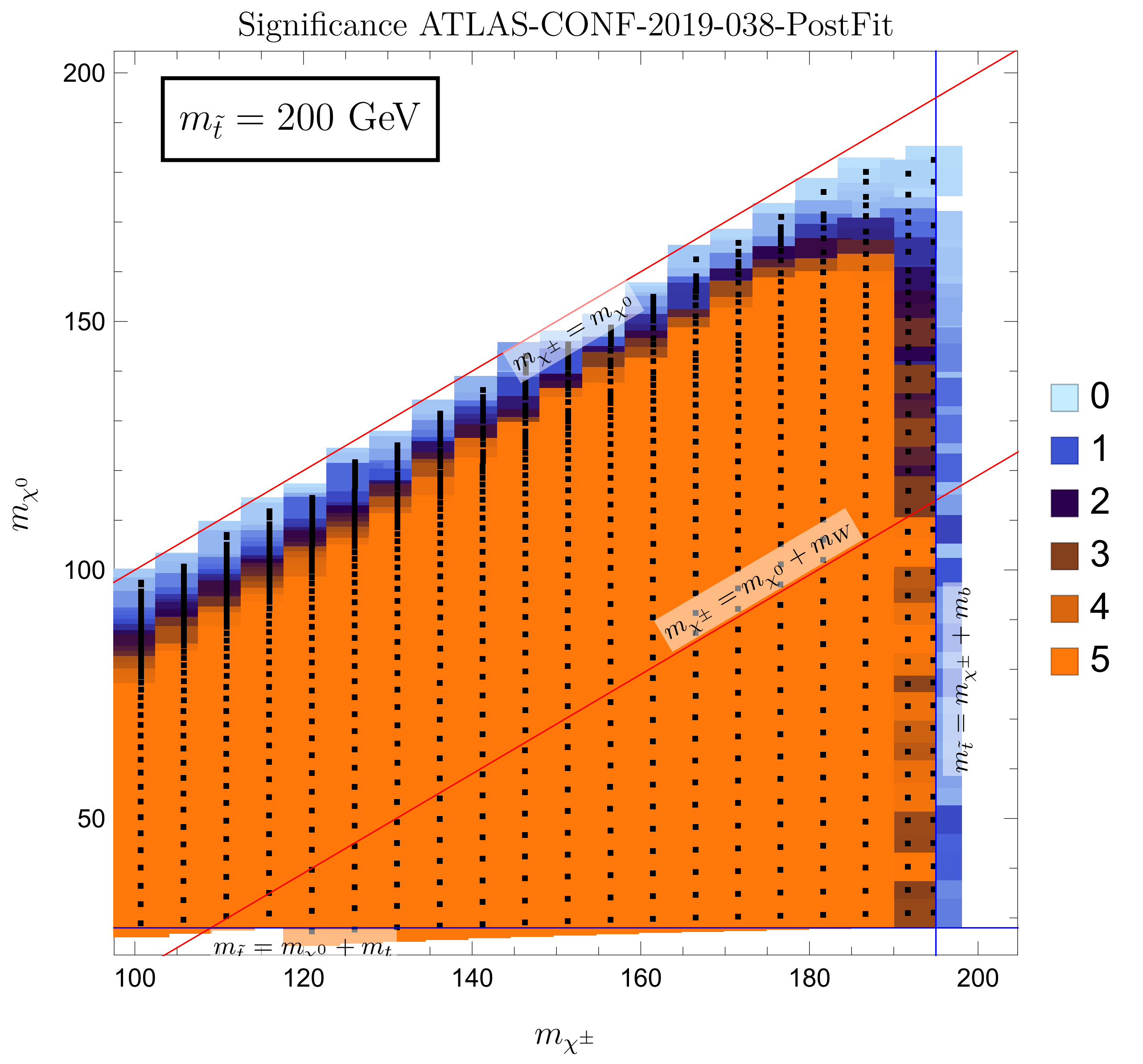
$m_{\tilde{t}} \simeq 200$ GeV



CMS pre-fit



ATLAS pre-fit

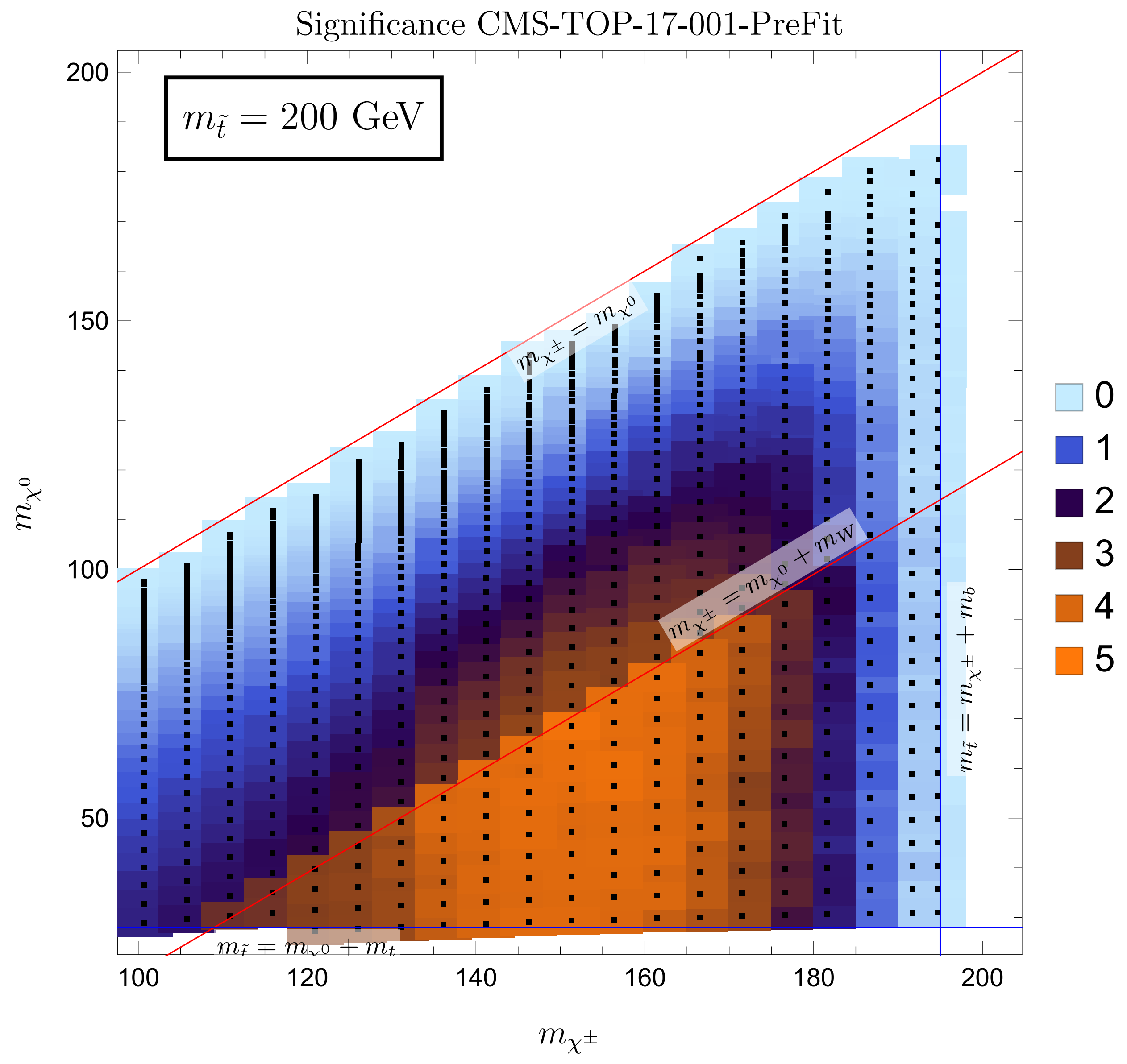


ATLAS post-fit

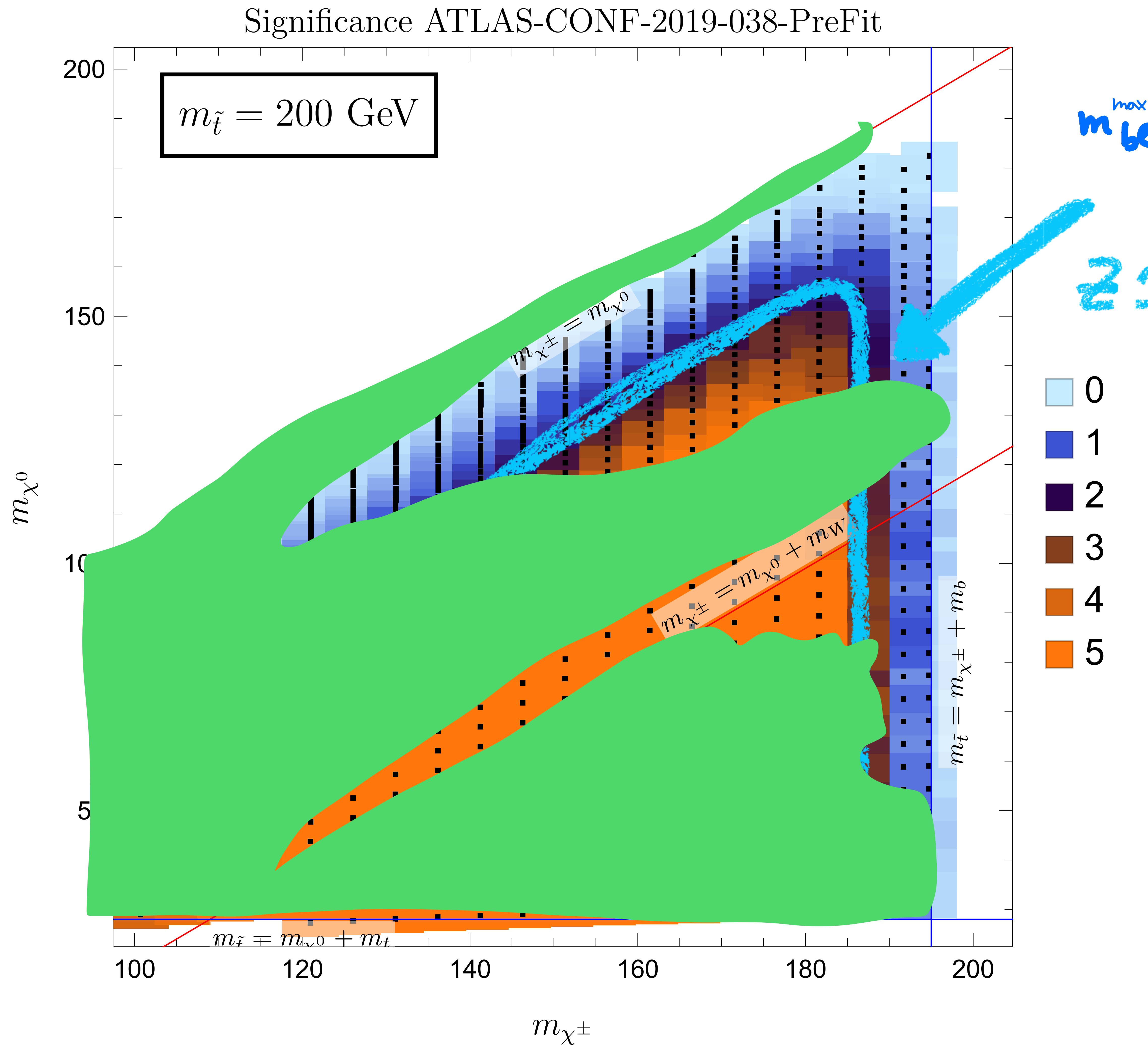
Significance estimator

$m_{\tilde{t}} \simeq 200$ GeV

$$z = \sqrt{\sum_i \left(\frac{S_i}{\delta B_i}\right)^2},$$



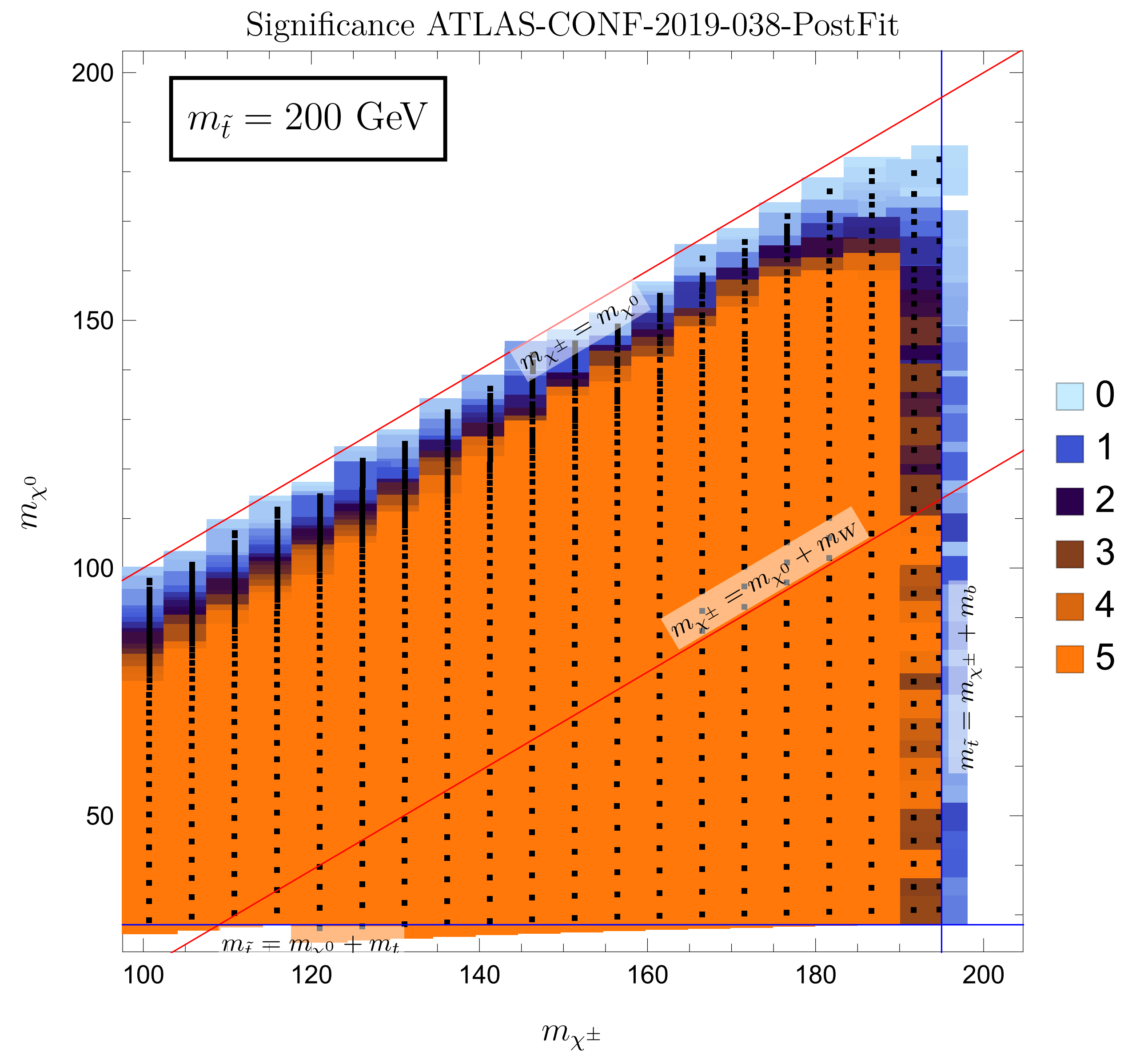
CMS pre-fit



$$m_{b\ell}^{max}\Big|_{m_b=0} = \sqrt{\frac{(m_{\tilde{t}}^2 - m_{\chi^+}^2)(m_{\chi^+}^2 - m_{\chi^0}^2)}{m_\chi}}$$

$z \simeq 2$

ATLAS pre-fit



ATLAS post-fit

Significance estimator

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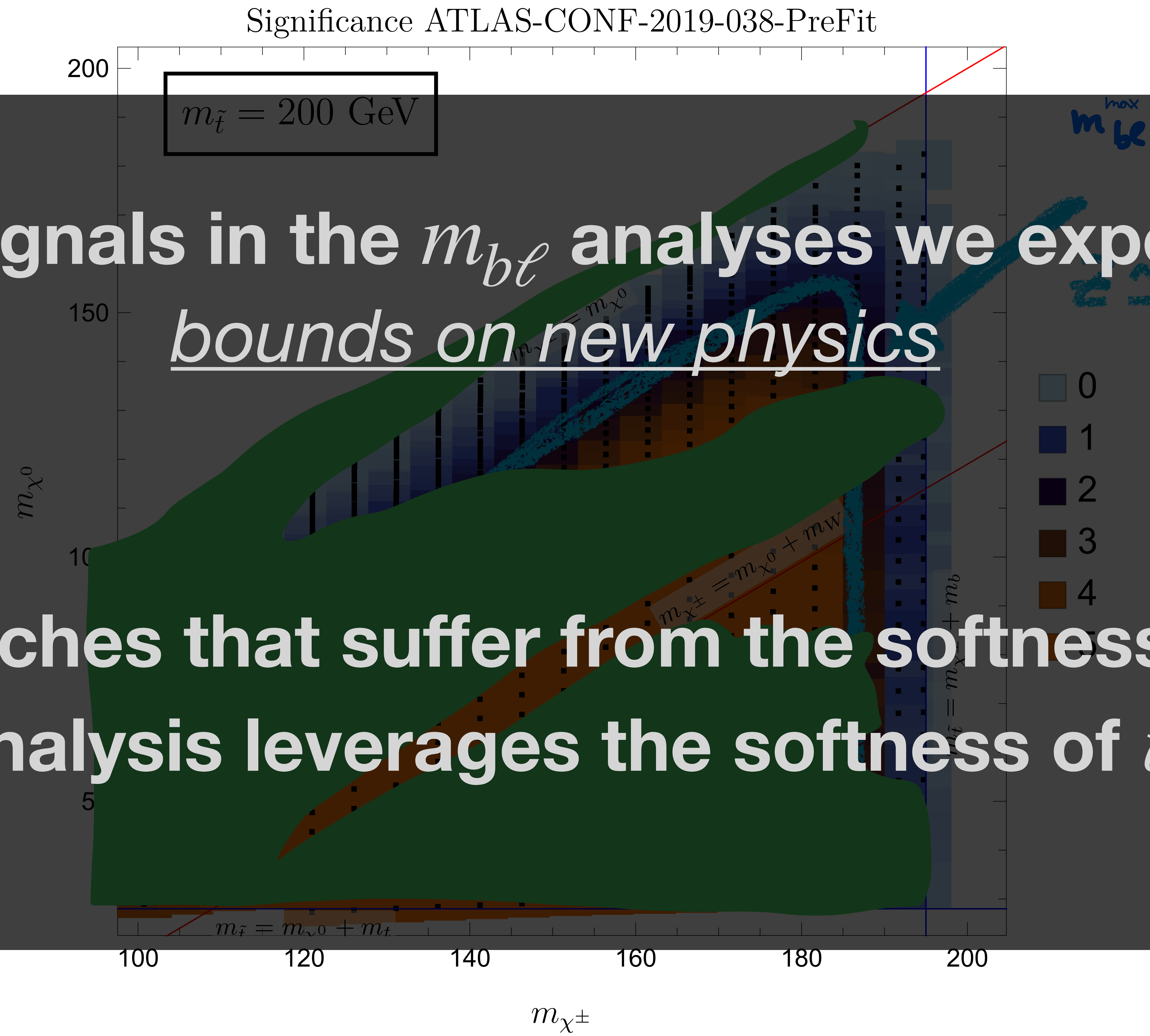
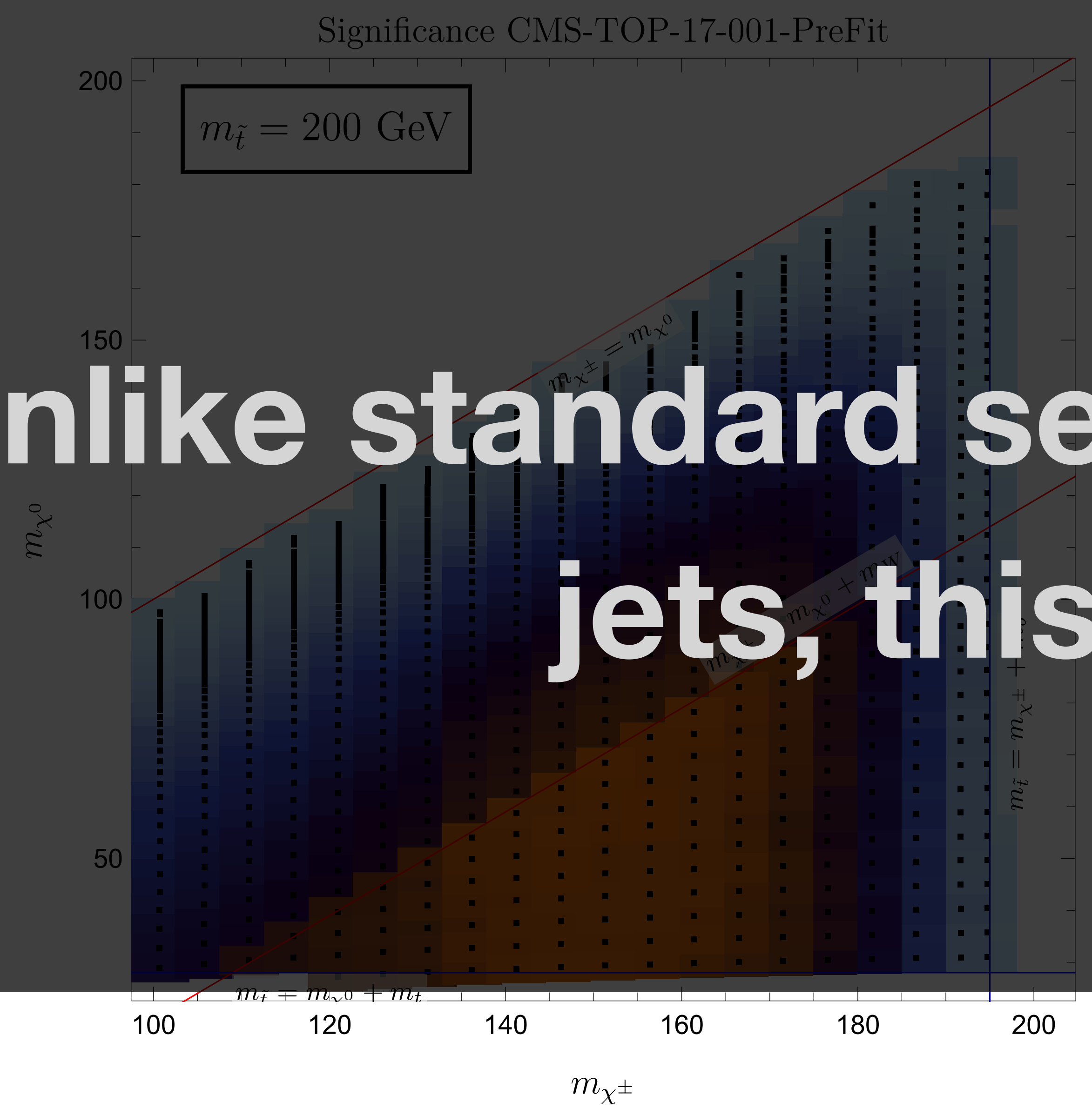
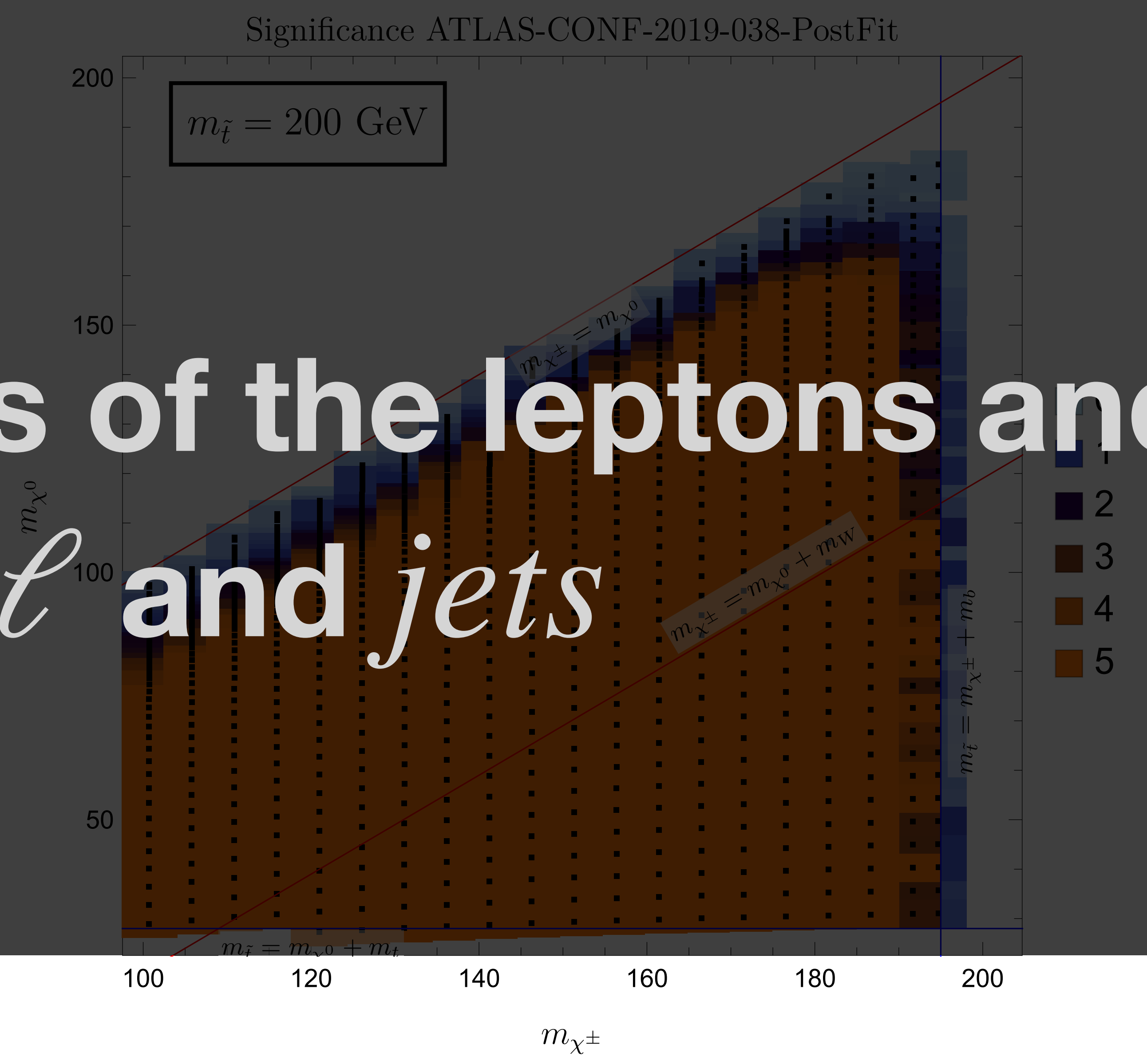


injecting MSSM signals in the $m_{b\ell}$ analyses we expect to obtain *new bounds on new physics*





unlike standard searches that suffer from the softness of the leptons and jets, this analysis leverages the softness of ℓ and *jets*

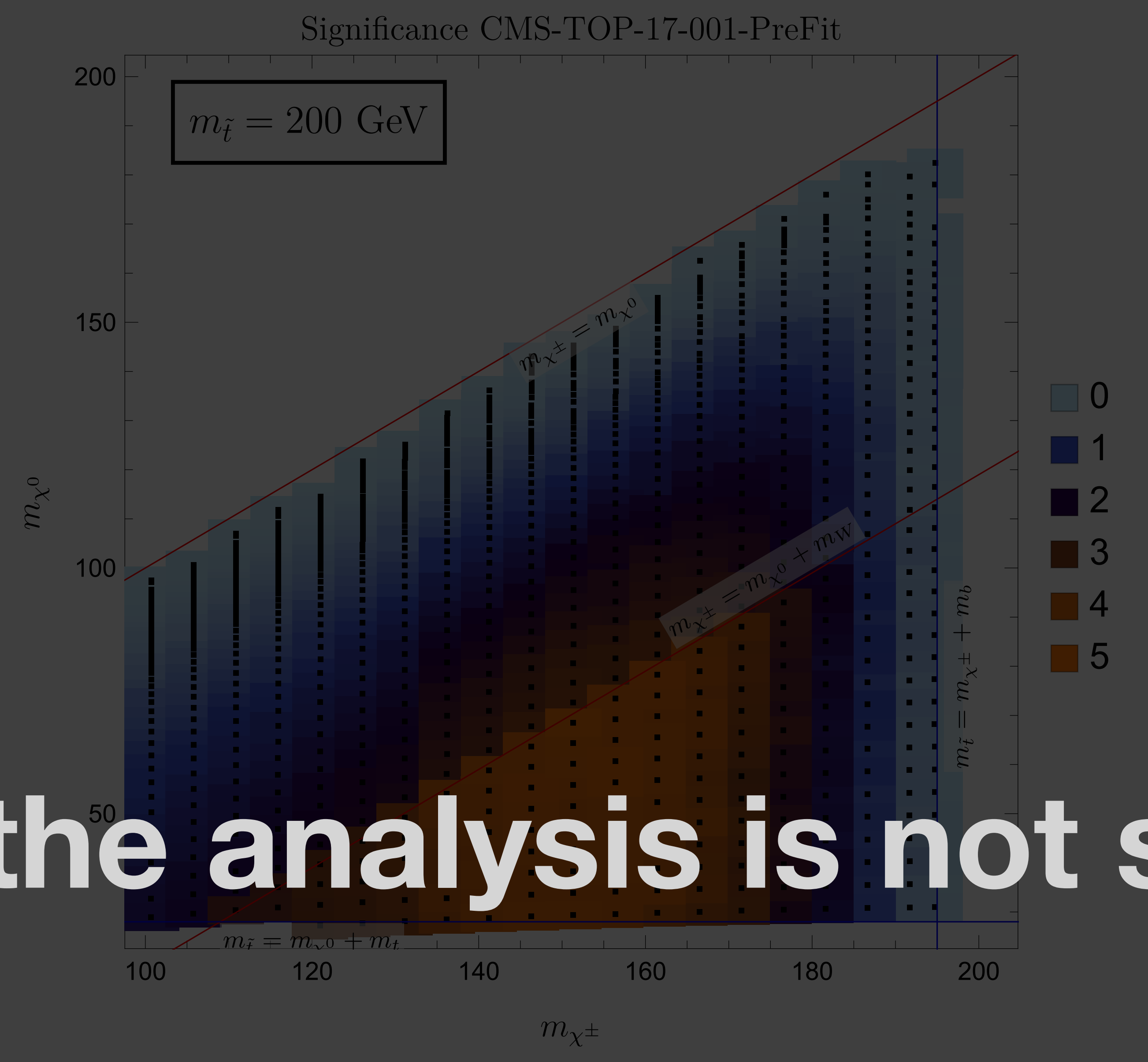
CMS pre-fit ATLAS pre-fit ATLAS post-fit

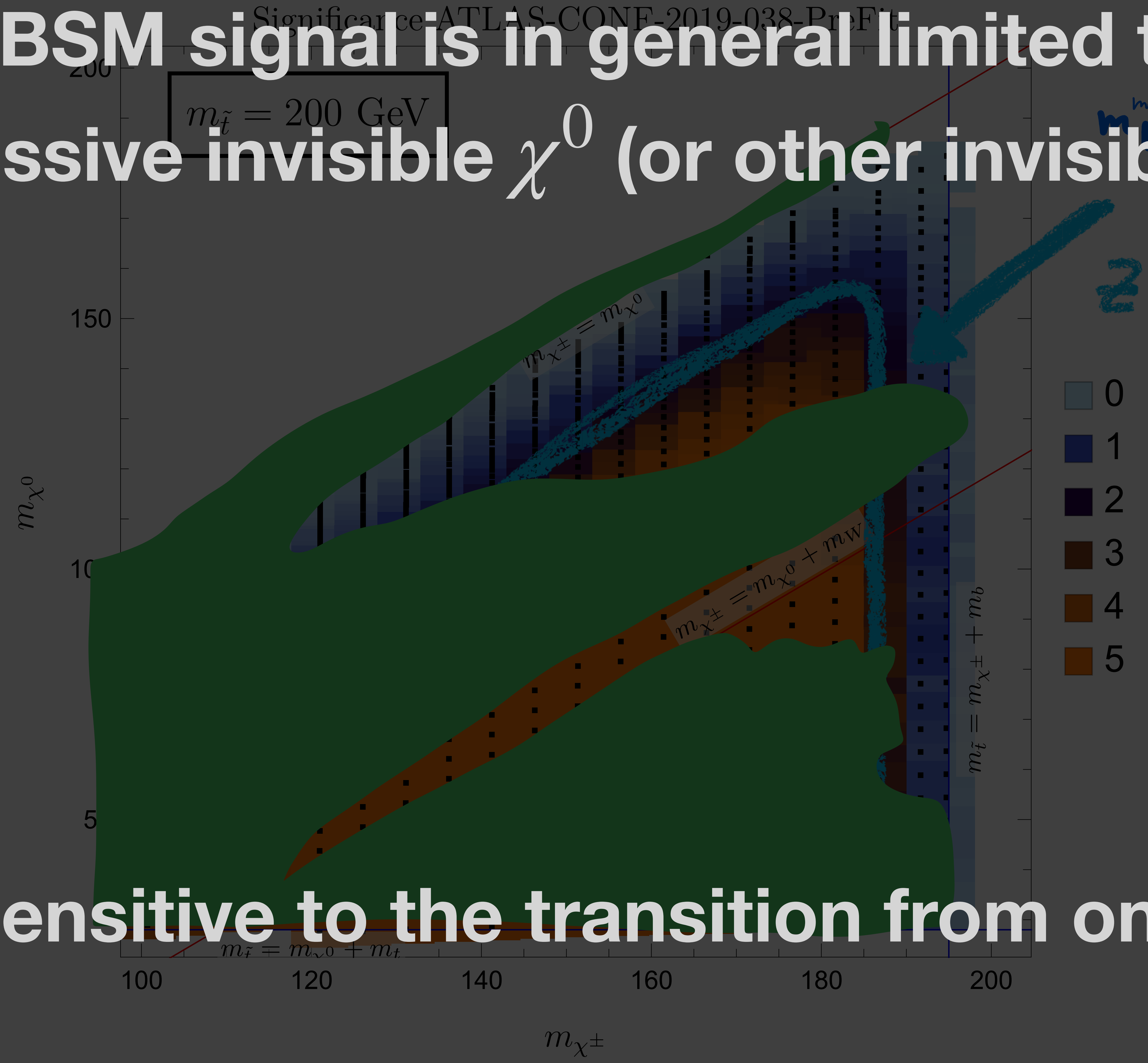
Significance estimator

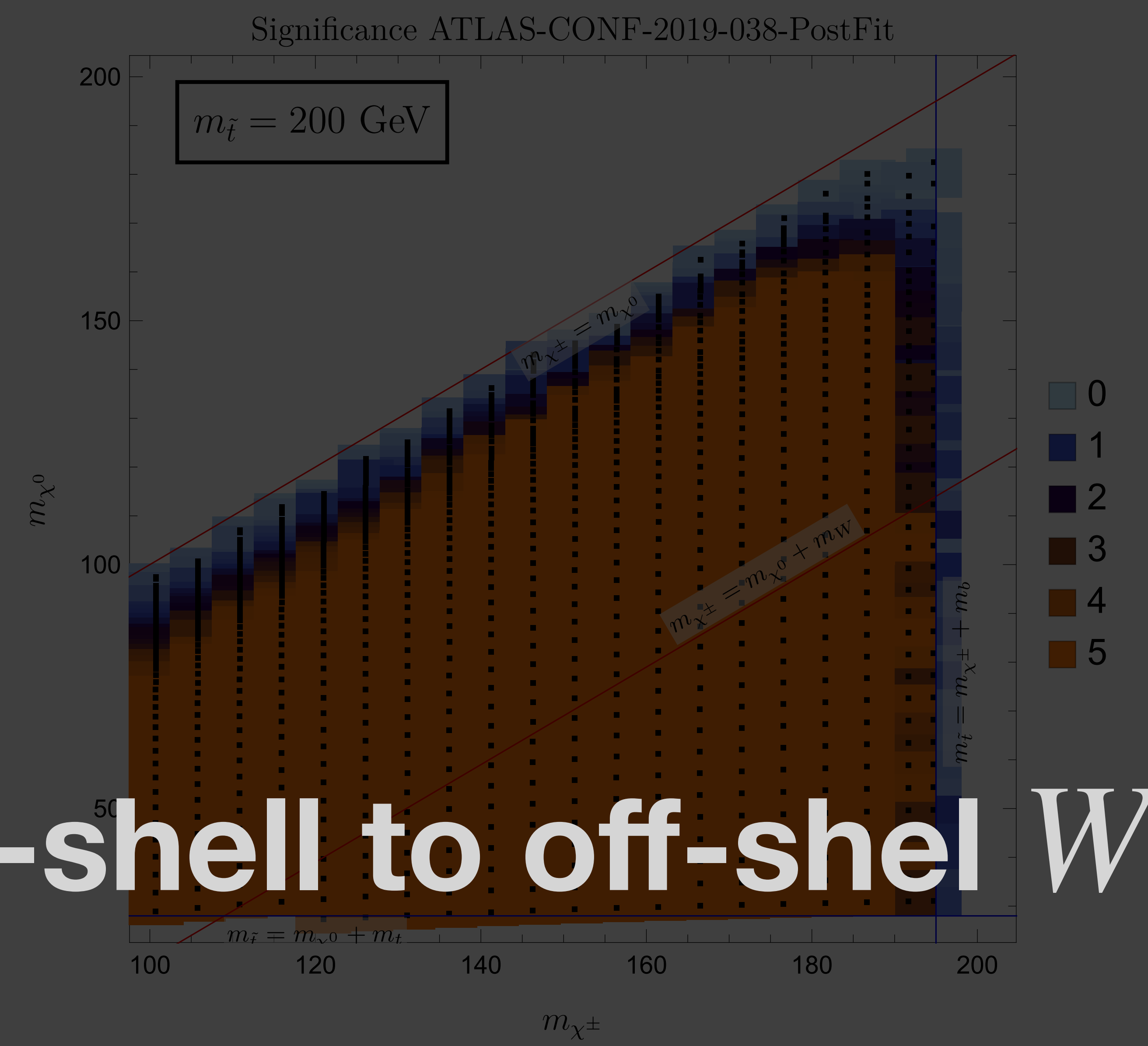
$$z = \sqrt{\sum_i \left(\frac{S_i}{\delta B_i}\right)^2},$$

$m_{\tilde{t}} \simeq 200$ GeV

the presence of the BSM signal is in general limited to low $m_{b\ell}$, because of the massive invisible χ^0 (or other invisibile state)







the analysis is not sensitive to the transition from on-shell to off-shel W

CMS pre-fit ATLAS pre-fit ATLAS post-fit

Significance estimator

$$z=\sqrt{\sum_i \left(\frac{S_i}{\delta B_i}\right)^2},$$

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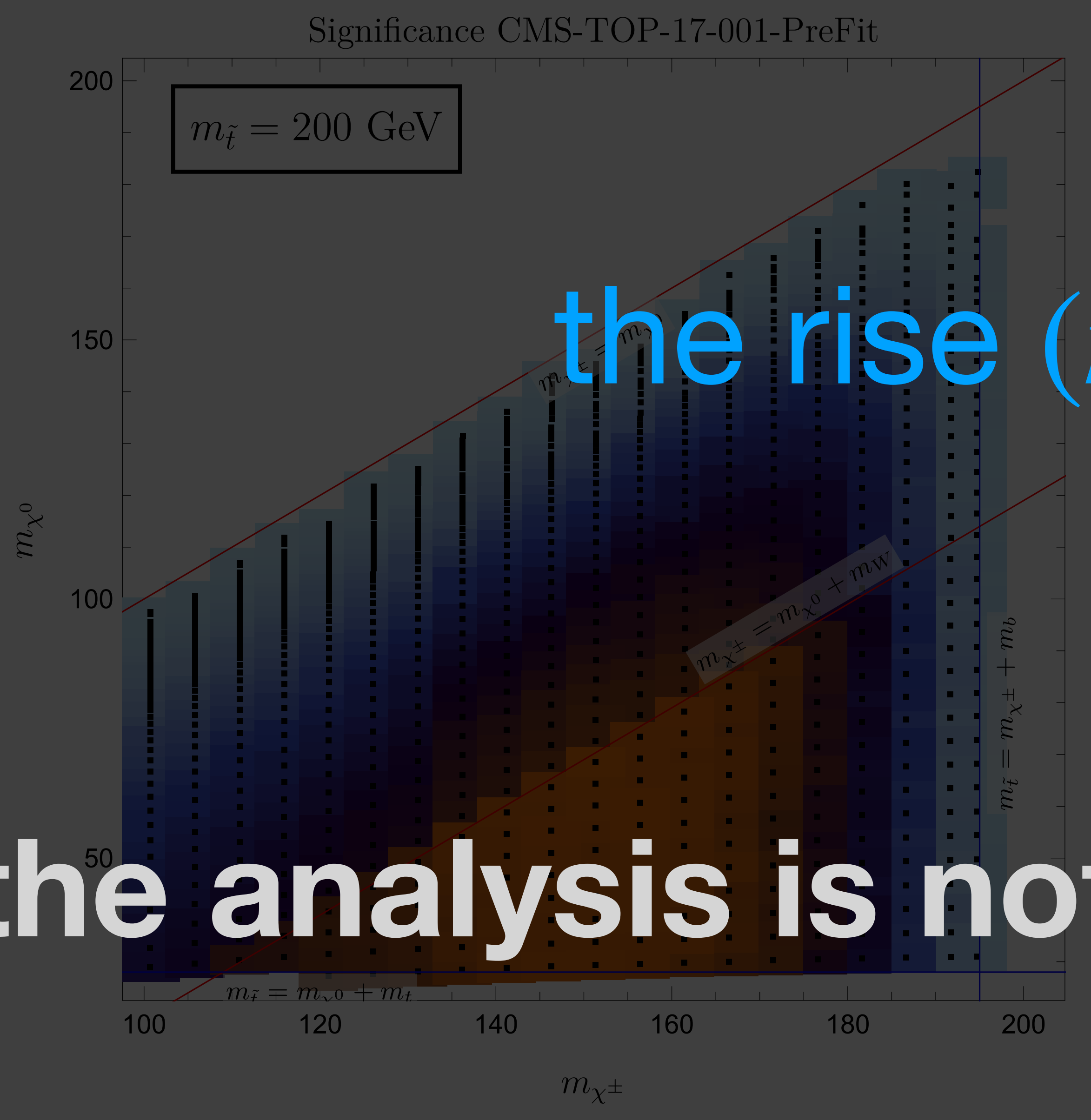

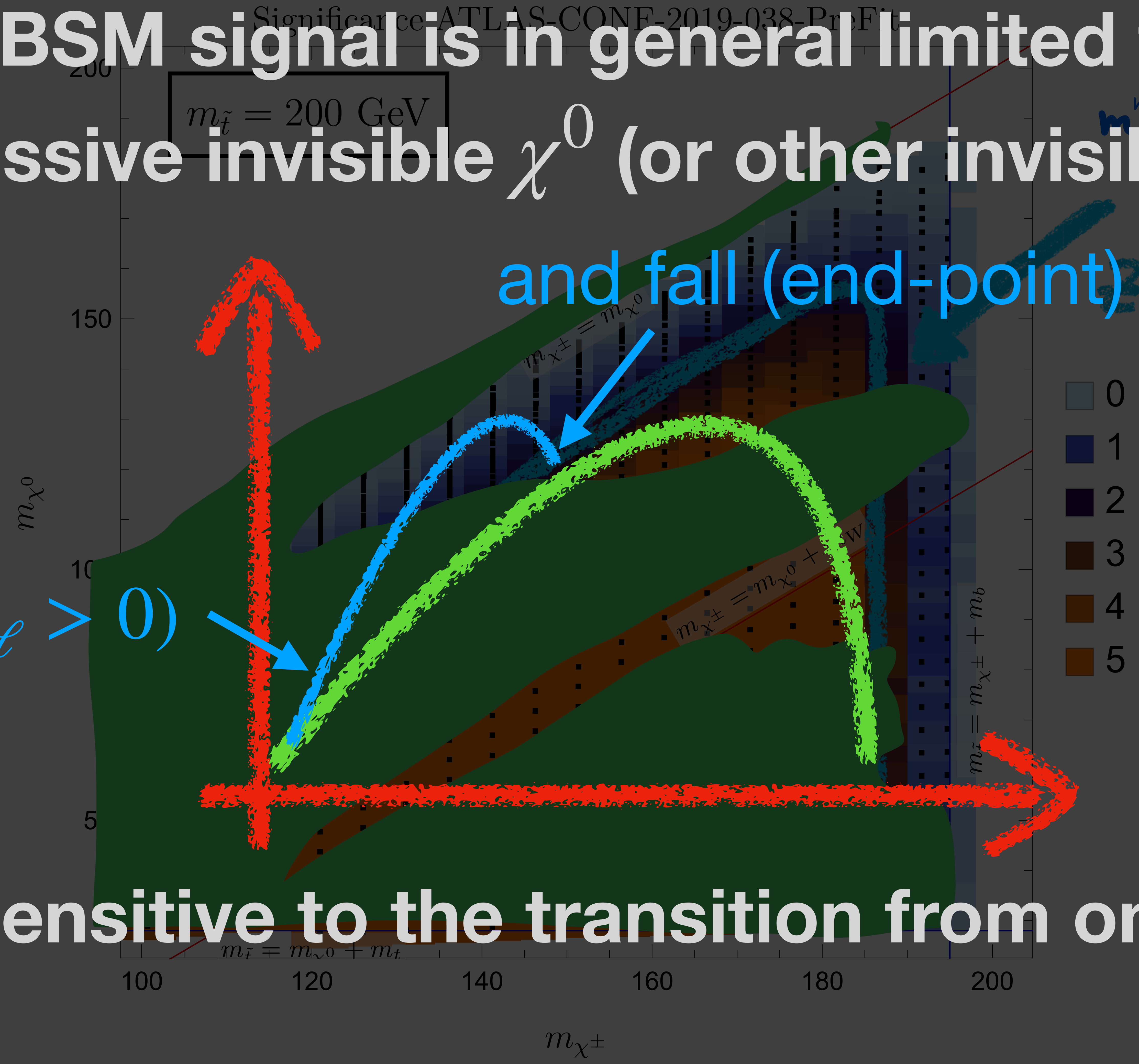

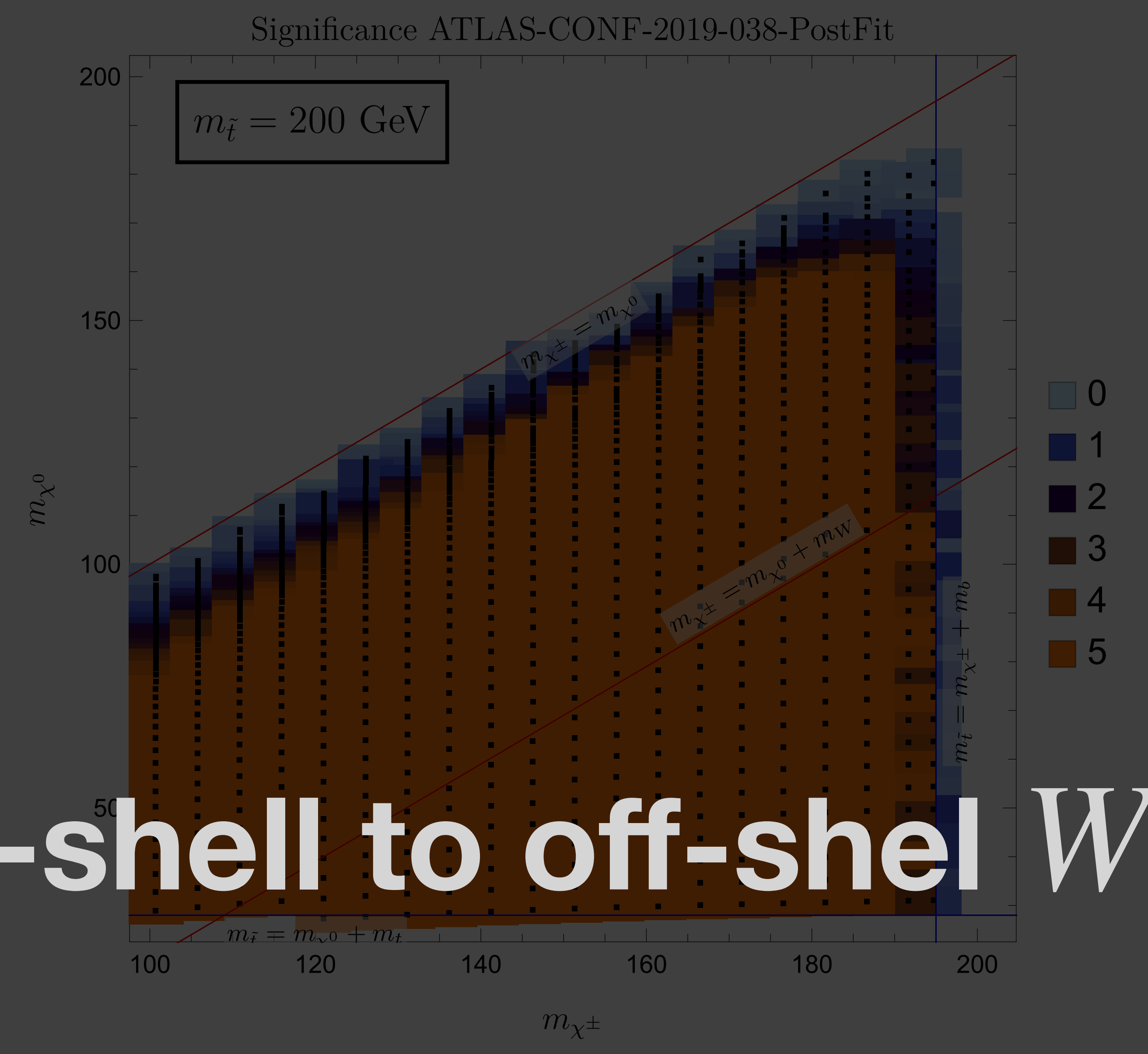

the analysis is not sensitive to the transition from on-shell to off-shel W

CMS pre-fit | ATLAS pre-fit | ATLAS post-fit

Conclusion
and outlook

The (HL)LHC will give us more and more data.
If we want to exploit them at best we need to

- make the result available in a most reusable way
  - Recast Exercises are very useful!
- start leveraging the strategies not pursed much so far
  - measure SM in places we had not traditionally done it
  - search BSM where is not usually sought for

- m_{bl} is a clear example where a *Search&Measure* approach works that brings new BSM models under the scope, plus it strengthens the "precision" of the SM measurement carried out with the same data
- more precision observables can be used

Thank you

Figuring Out New Physics

scientific reports

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Active self-treatment of a facial wound with a biologically active plant by a male Sumatran orangutan

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Abstract

Although self-medication in non-human animals is often difficult to document systematically due to the difficulty of predicting its occurrence, there is widespread evidence of such behaviors as whole leaf swallowing, bitter pith chewing, and fur rubbing in African great apes, orangutans, white handed gibbons, and several other species of monkeys in Africa, Central and South America and Madagascar. To the best of our knowledge, there is only one report of active wound treatment in non-human animals, namely in chimpanzees. We observed a male Sumatran orangutan (*Pongo abelii*) who sustained a facial wound. Three days after the injury he selectively ripped off leaves of a liana with the common name Akar Kuning (*Fibraurea tinctoria*), chewed on them, and then repeatedly applied the resulting juice onto the facial wound. As a last step, he fully covered the wound with the chewed leaves. Found in tropical forests of Southeast Asia, this and related liana species are known for their analgesic, antipyretic, and diuretic effects and are used in traditional medicine to treat various diseases, such as dysentery, diabetes, and malaria. Previous analyses of plant chemical compounds show the presence of furanoditerpenoids and protoberberine alkaloids,

Next we simulate the contribution to $m_{b\ell}$ for each parameter space point using `Pythia` 8.3 [42] in the region of phase space identified by the following selection:

$$p_T(\ell) \geq 25 \text{ GeV}, \ |\eta(\ell)| < 2.5,$$
$$p_T(j) \geq 25 \text{ GeV}, \ |\eta(j)| < 2.5, \qquad (1)$$

for jets made with anti-kT [43] algorithm with $R = 0.4$ and separations between jets and leptons $\Delta R(\ell, j) > 0.2$, $\Delta R(j, j) > 0.4$ and $\Delta R(\ell, \ell) > 0.1$. This is a selection closely following that of the experimental collaborations, e.g. [16, 18, 36], except for minor differences in the selection for $\ell = e$ and $\ell = \mu$ that we do not pursue. We have considered variations of the cuts and found

BM	μ	M_1	A_t	m_{χ^+}	m_{χ^0}	z [31]	z [16]	r
	$m_{\tilde{t}} = 200$ GeV							
ON1	185	95	2820.5	186.6	85.6	[0.8,1.7]	[2.7,14.3]	0.9
OFF1	155	160	2857.5	156.4	123.3	[0.9,1.8]	[2.6,14.8]	0.7
OFF2	175	145	2839.5	176.6	123.5	[1.5,3.]	[5.1,25.5]	0.8
T1	135	65	2895.5	136.2	54.	[4.,7.7]	[10.7,61.3]	0.8
T2	135	60	2895.5	136.2	49.9	[4.1,7.9]	[10.8,60.6]	0.8
	$m_{\tilde{t}} = 220$ GeV							
OFF3	155	150	3140.5	156.4	118.6	[0.7,1.4]	[1.9,10.9]	0.8
OFF4	170	160	3122	171.5	130.8	[0.9,1.8]	[2.5,13.7]	0.6
ON2	190	95	3104	191.7	86.1	[2.1,4.3]	[6.1,32.8]	0.7
OFF5	190	145	3104	191.7	127.7	[1.4,2.8]	[4.2,22.5]	0.6
ON3	190	65	3104	191.7	58.9	[1.9,3.7]	[5.3,28.7]	0.8
	$m_{\tilde{t}} = 180$ GeV							
OFF6	165	115	2570.5	166.5	99.2	[1.2,2.5]	[4.8,22.9]	0.8
OFF7	160	105	2580	161.5	90.4	[2.2,4.5]	[7.2,36.3]	0.8
OFF8	160	170	2570	161.5	130.3	[0.6,1.2]	[2.4,11.2]	0.6
OFF9	155	150	2579.5	156.4	118.5	[1.6,3.2]	[5.3,27.2]	0.8
OFF10	145	175	2598.5	146.3	122.2	[0.8,1.6]	[2.4,12.7]	0.8

TABLE I. Chargino and neutralino masses, input parameters μ, M_1 and A_t, all given in GeV for few benchmarks (BM). Resulting value of r computed from `SModelS` 2.2.1 and the range of the significance eq. (2) expected from the $m_{b\ell}$ spectrum analysis using ATLAS [16] or CMS [31] measurements. The low (high) end the significance range corresponds to uncertainties on the $m_{b\ell}$ spectrum before(after) a fit using SM predictions for the known backgrounds.

$$z = \sqrt{\sum_i \left(\frac{S_i}{\delta B_i} \right)^2},$$