Compressed Higgsino Searches at ATLAS

Les Rencontres de Physique de la Vallée d'Aoste

Maximilian Swiatlowski

University of Chicago

on behalf of the ATLAS collaboration

The SUSY Electroweak Sector

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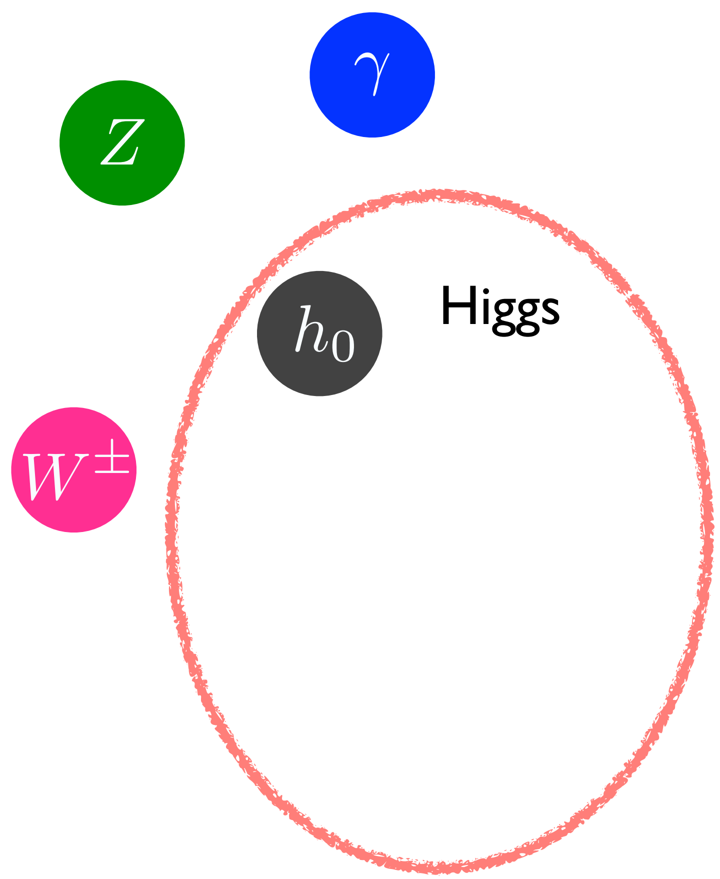
SM particles



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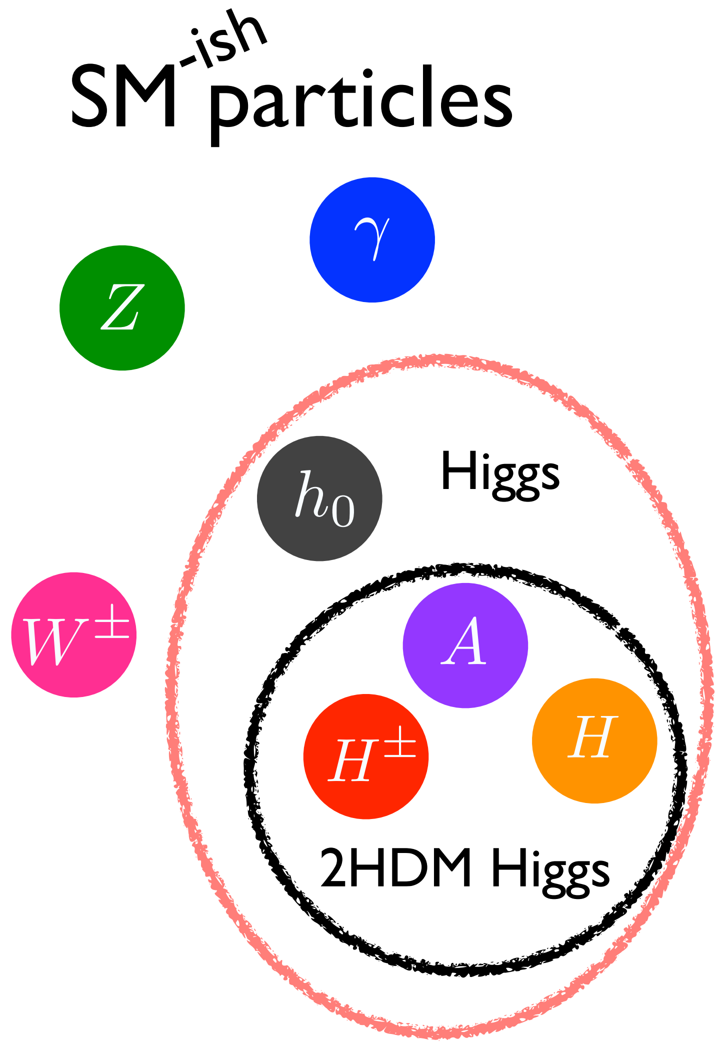

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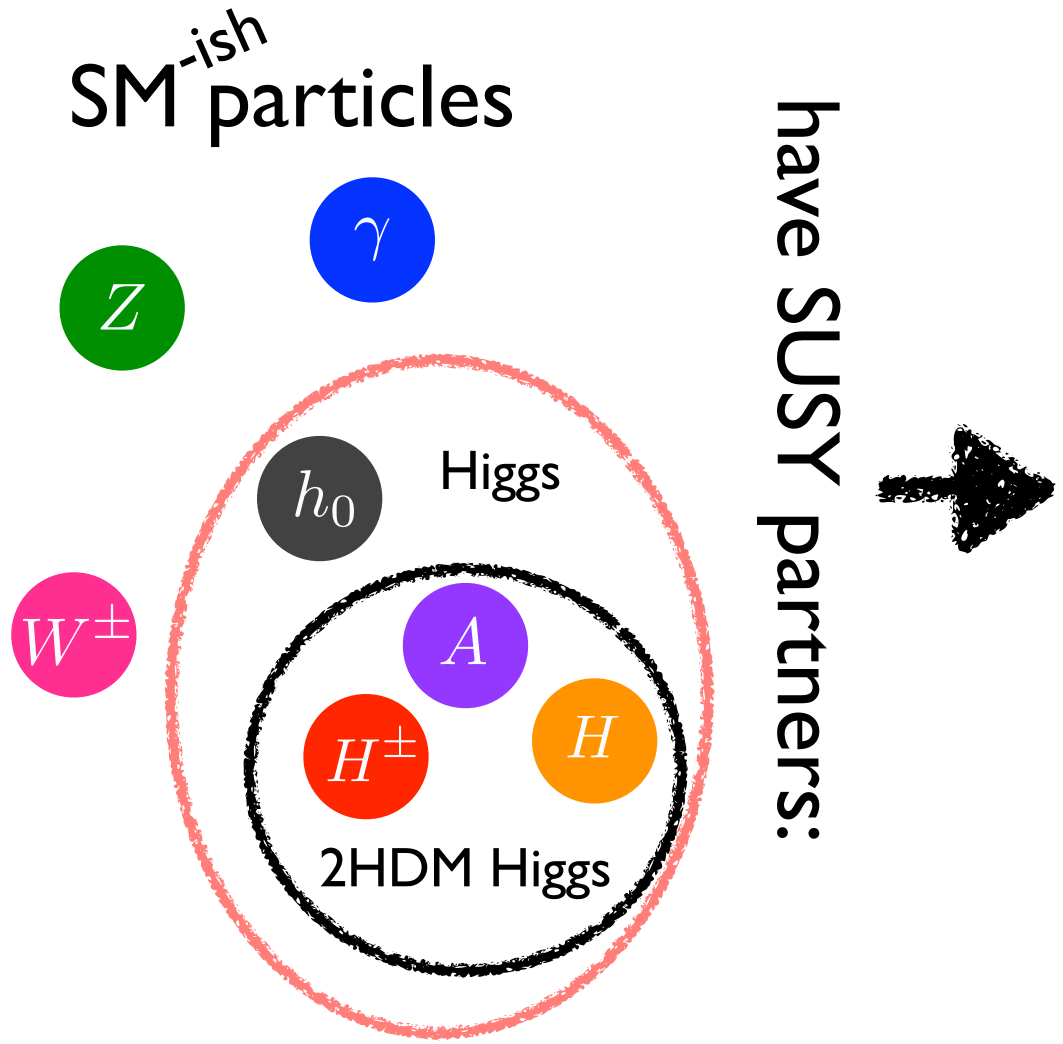

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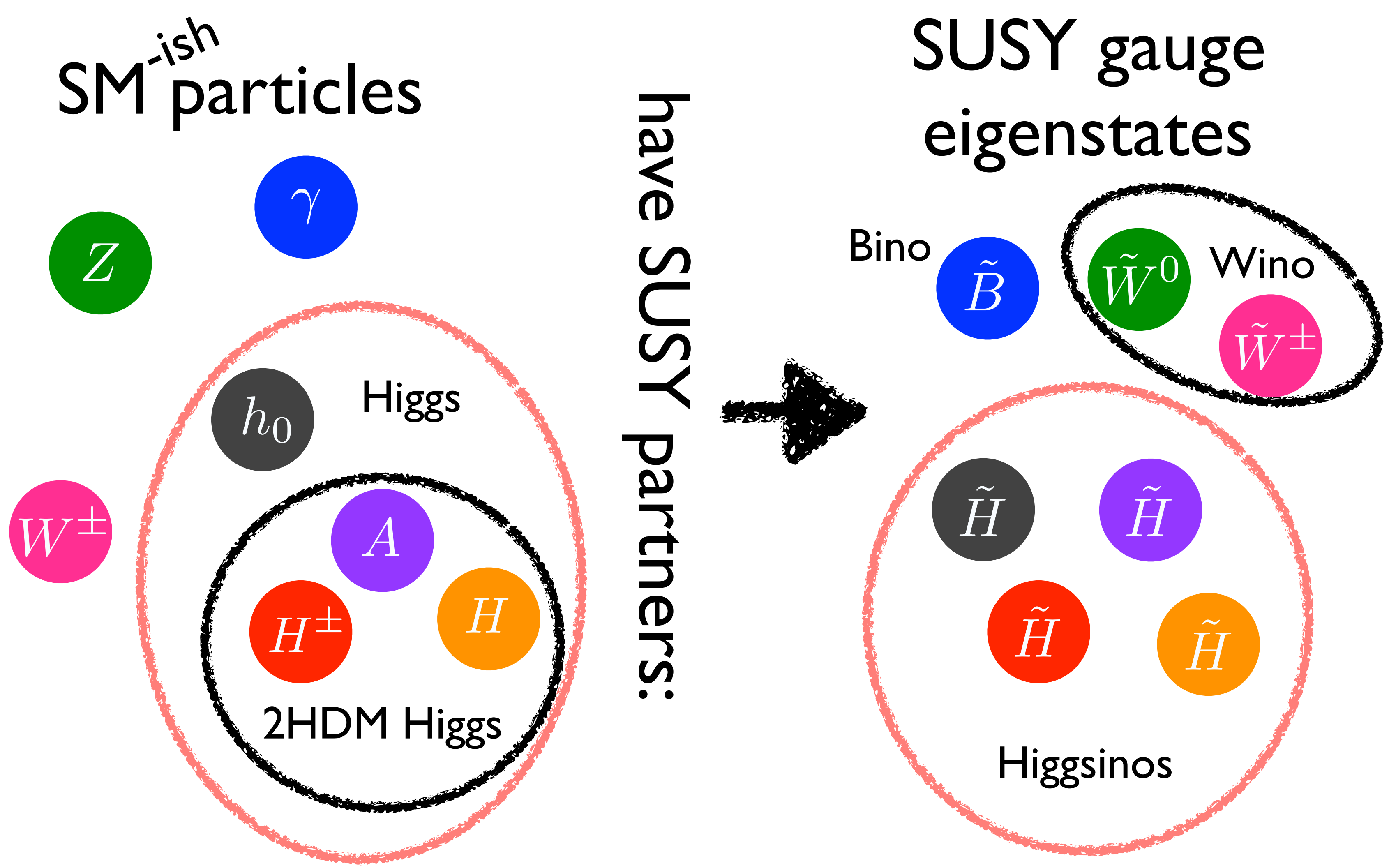

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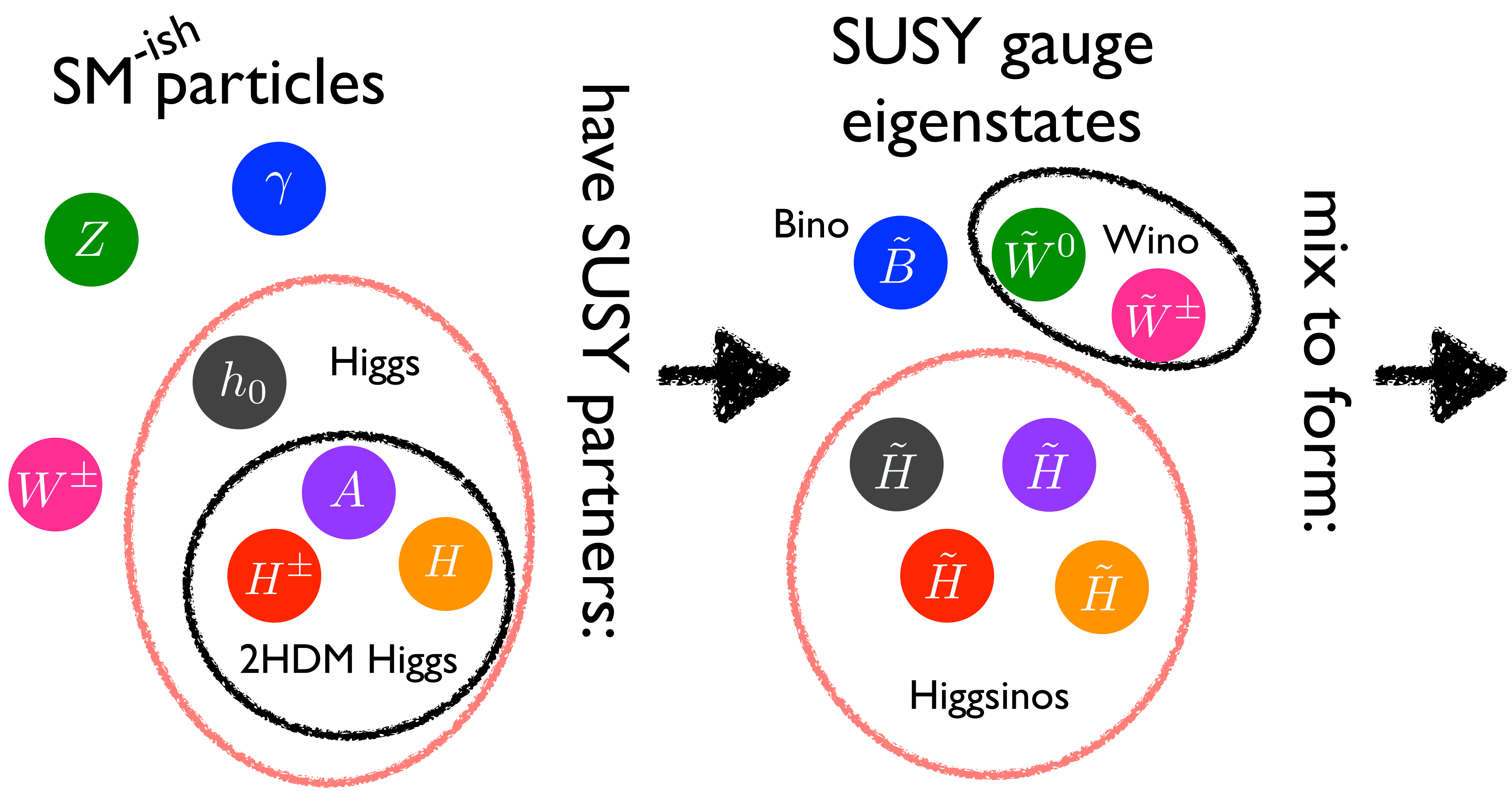

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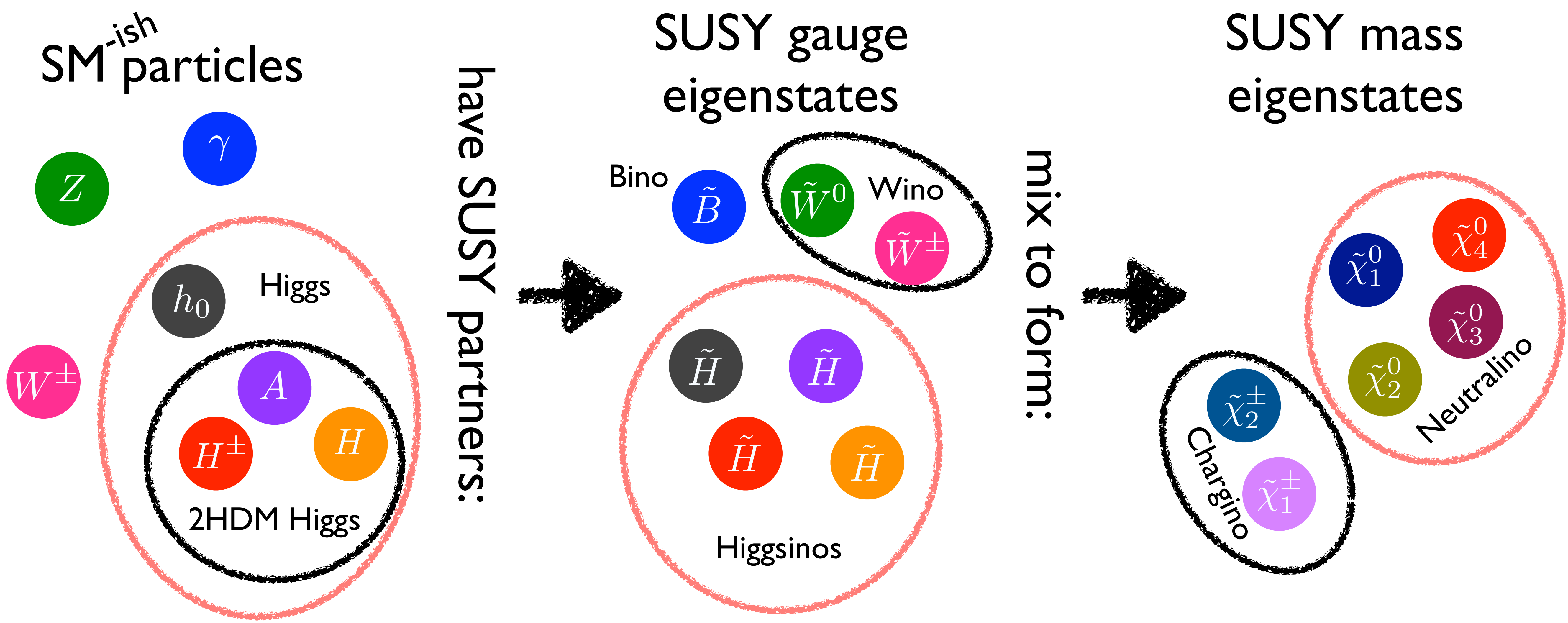

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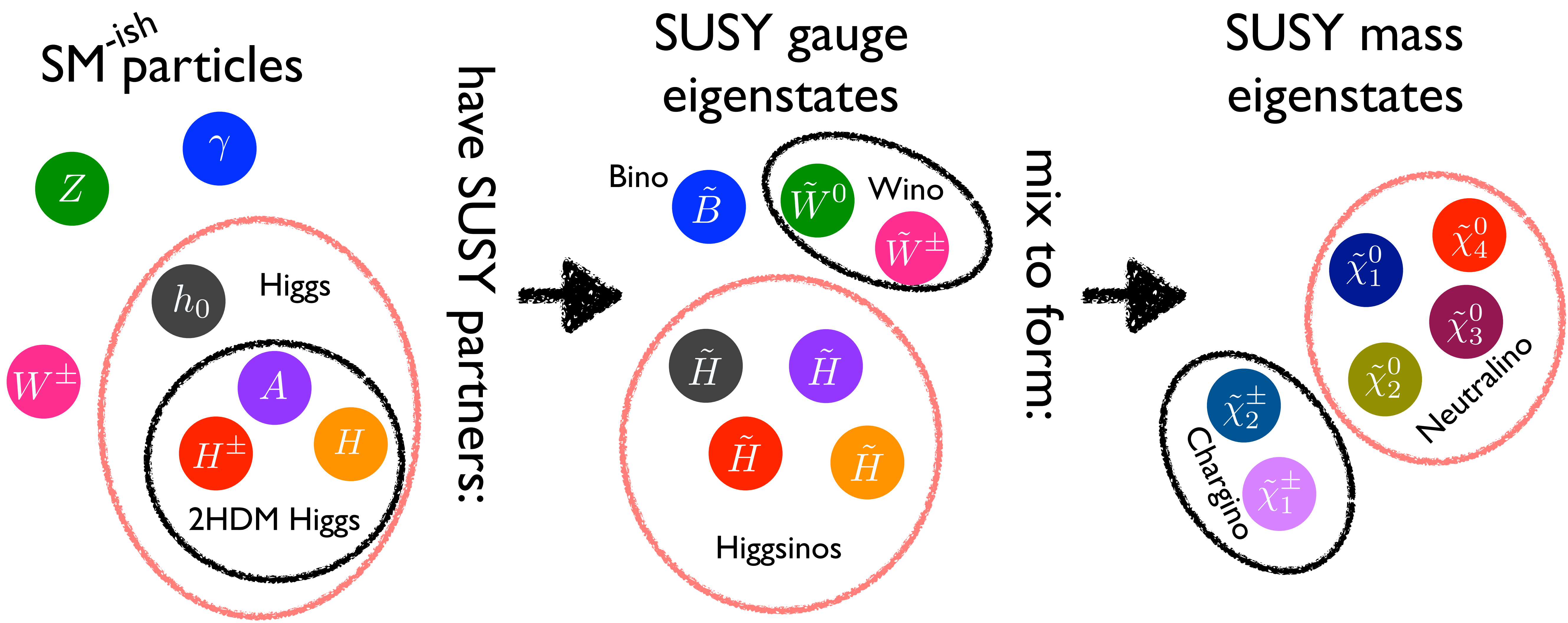

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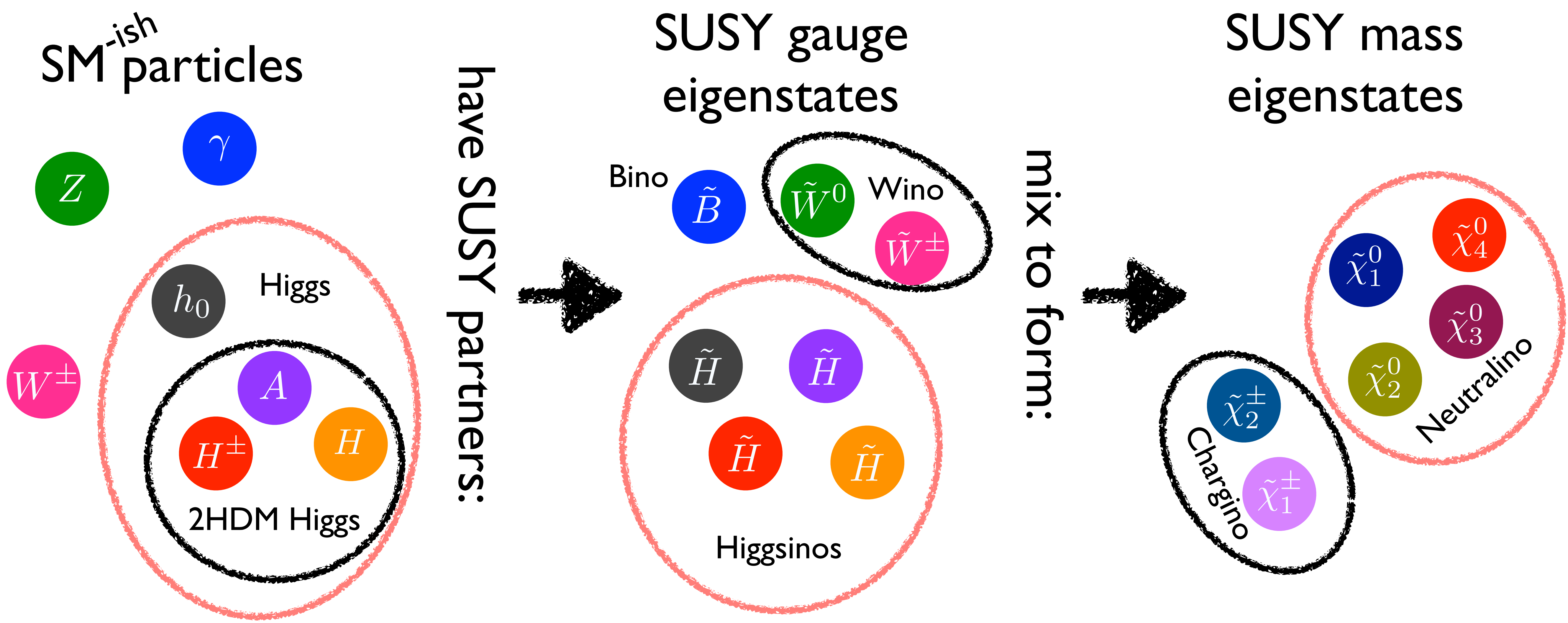

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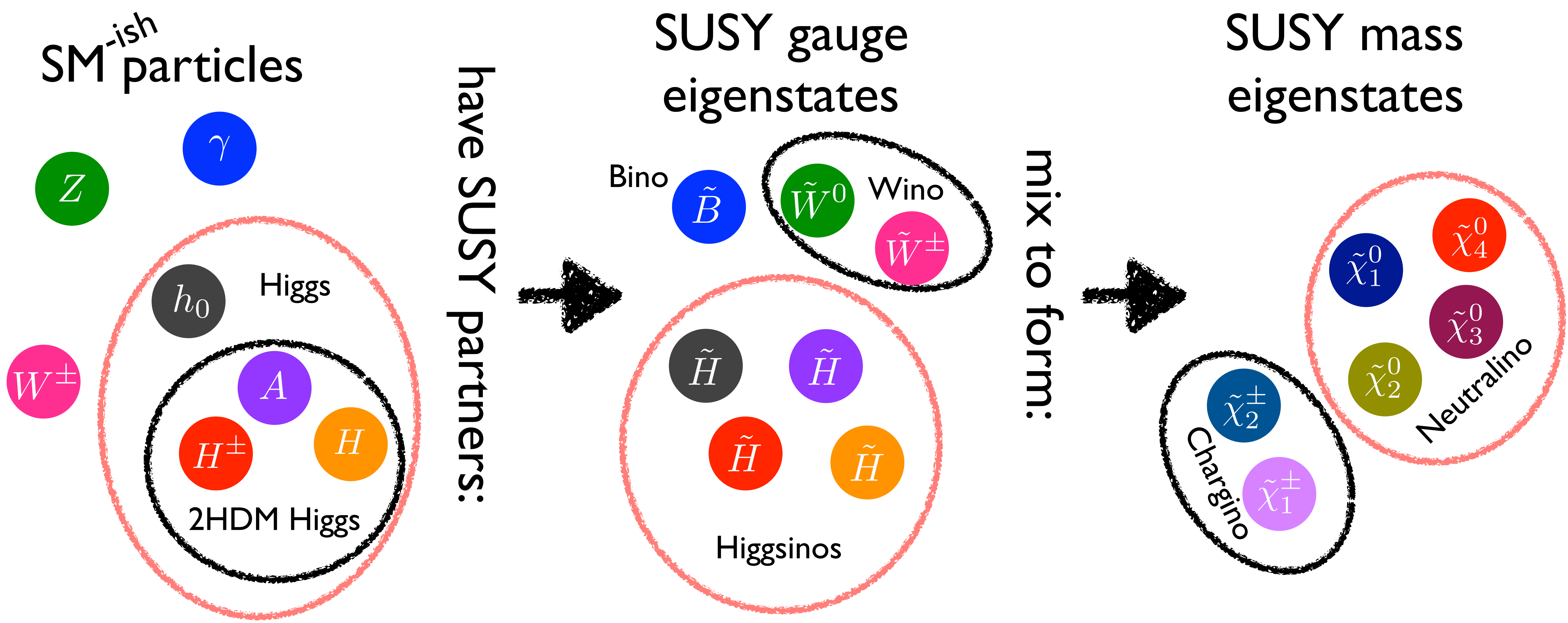

- SUSY has a rich electroweak sector
  - Lots of topologies determined by the composition of the mass eigenstates!
  - $\tilde{\chi}^0_1$ usually assumed to be the Lightest Supersymmetric Particle (LSP)

Why Compressed Higgsinos?

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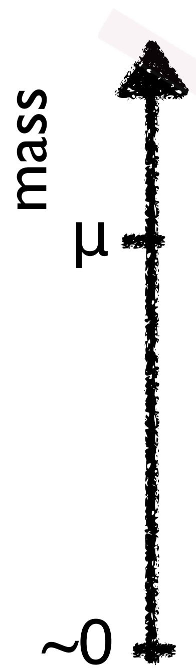
3. Large datasets at the LHC mean we are finally competitive with LEP limits!

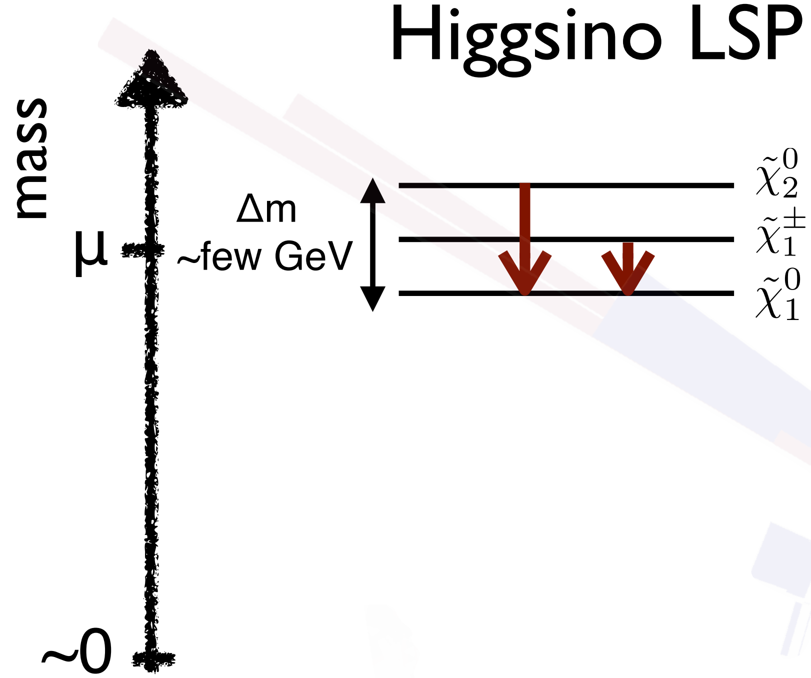
Higgsino Signatures

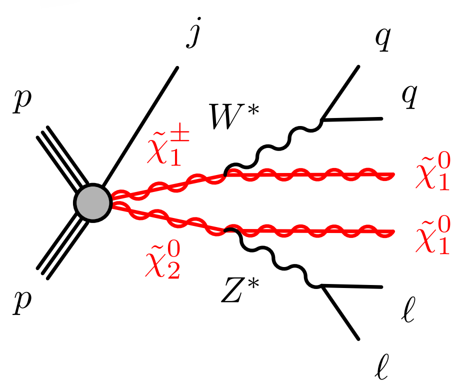


- Depending on model details, wide variety of signatures possible

Higgsino Signatures

Higgsino LSP





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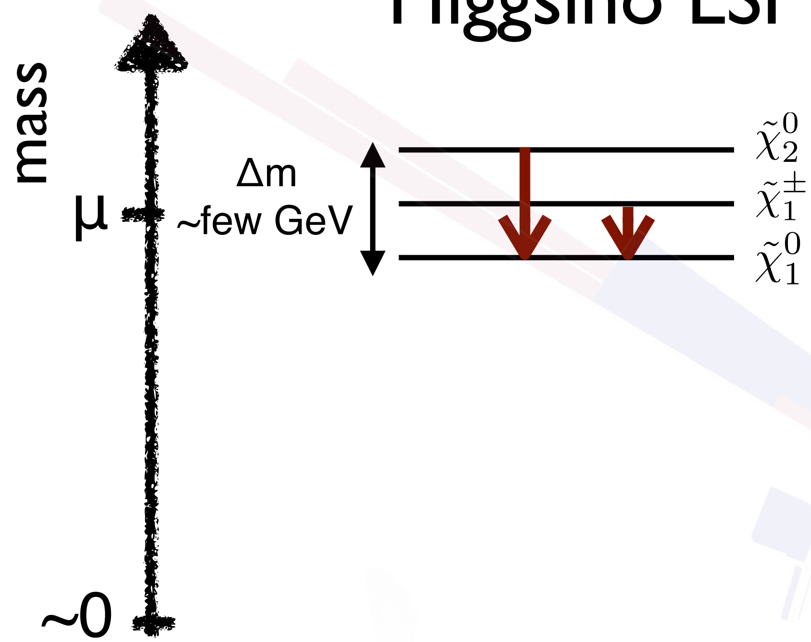
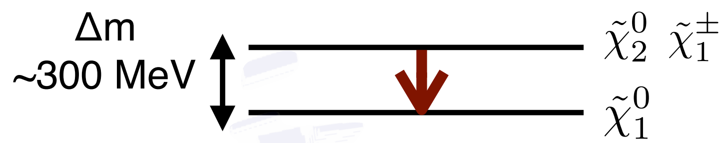
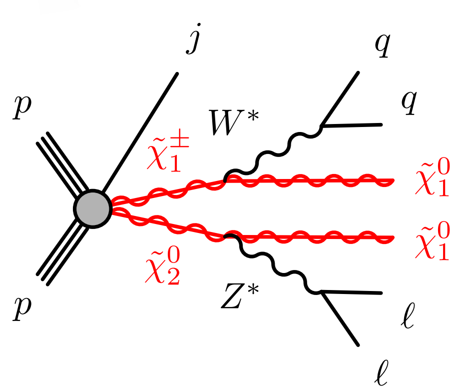


Ultra-compressed Higgsino LSP





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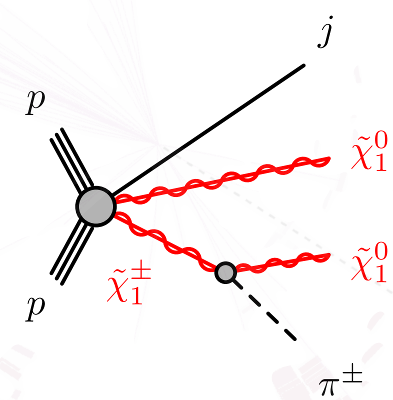

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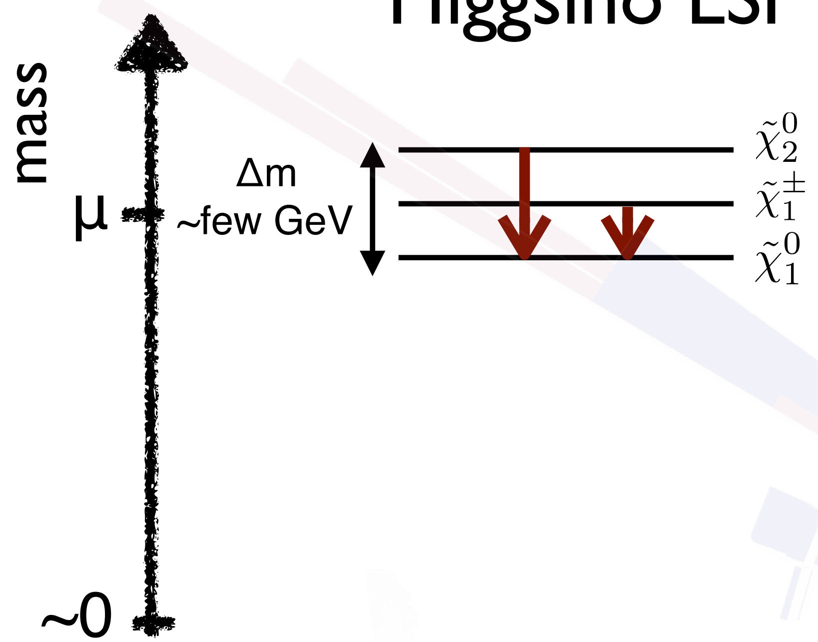

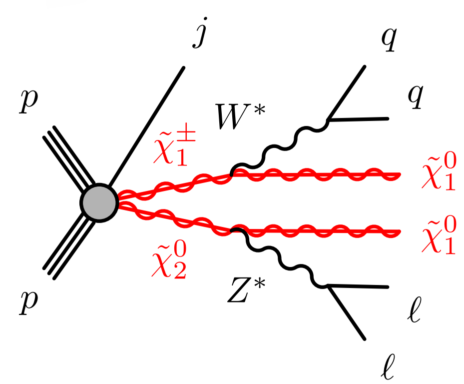

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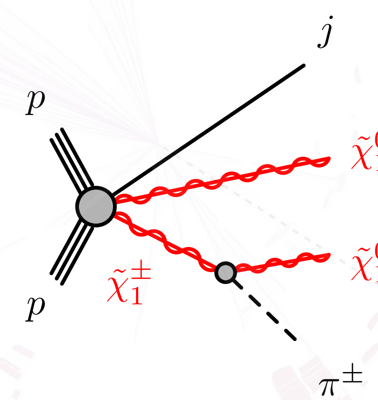
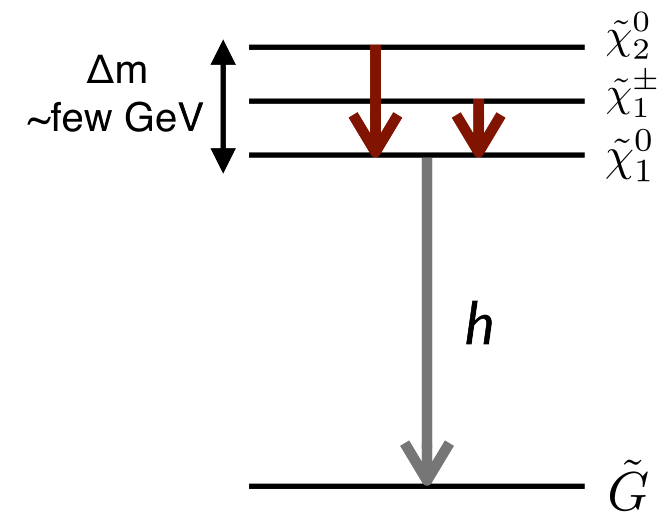
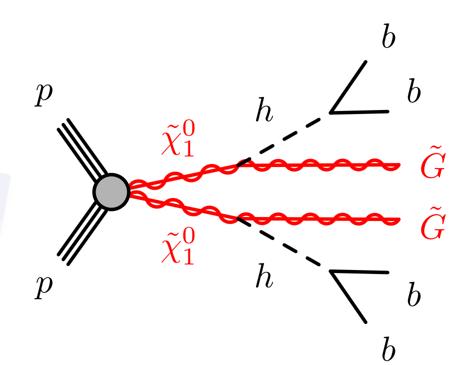


Disappearing tracks

GMSB Higgsino NLSP





hh + E_T^{miss}

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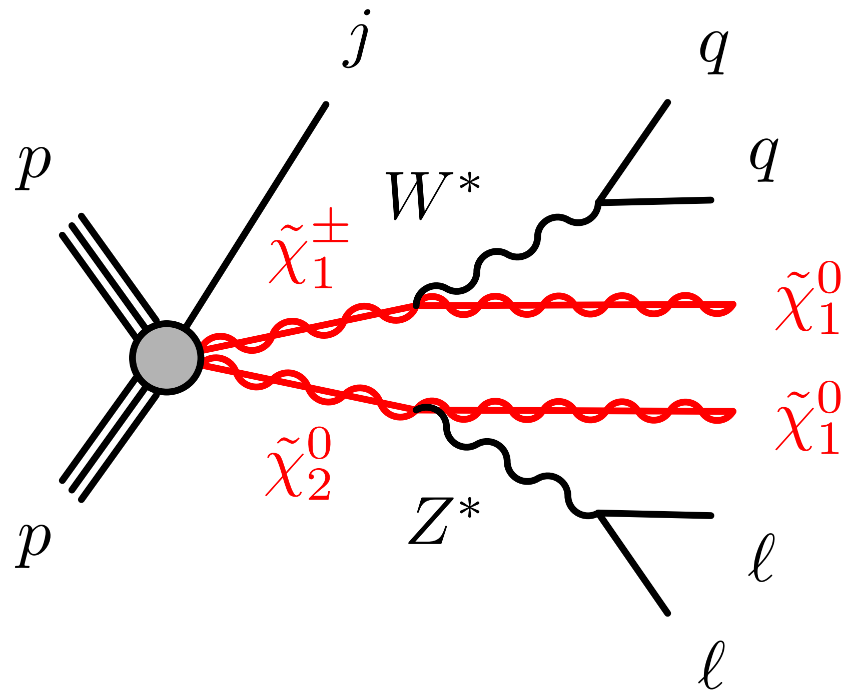
Higgsinos LSPs with Soft Leptons

arXiv:1712.08119



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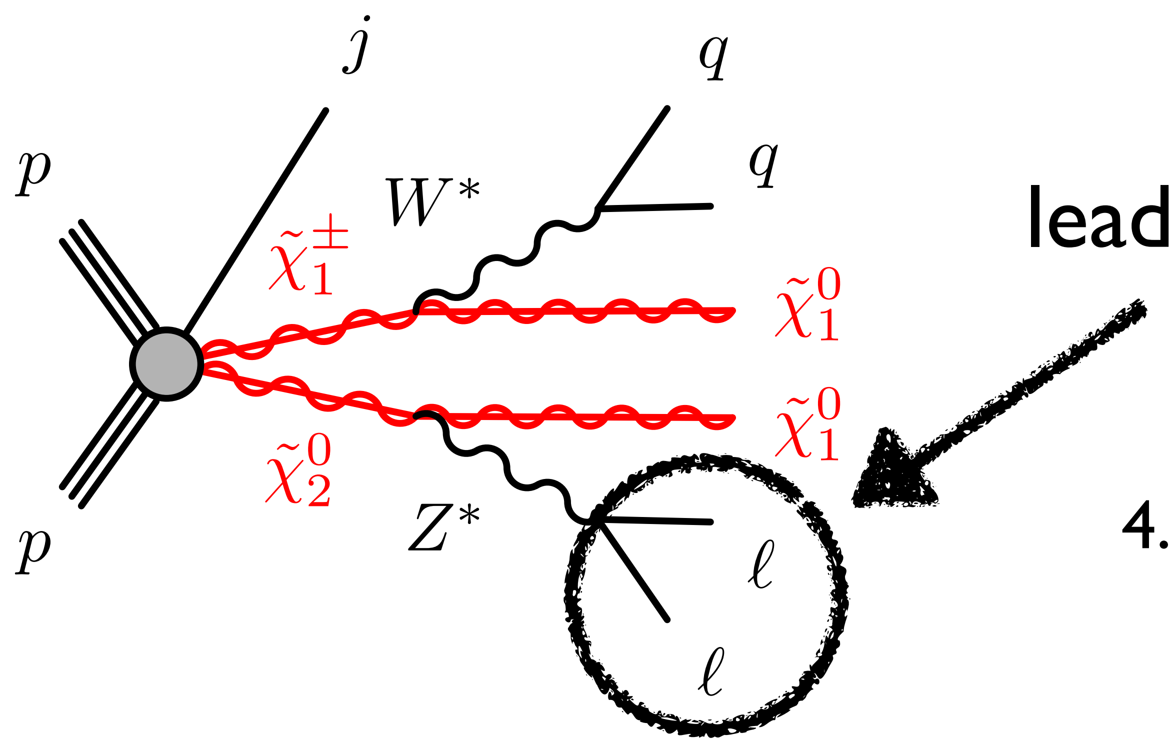

Off-shell Z
leads to soft-leptons
and m_{ll} peak

4 GeV muons
4.5 GeV electrons

Analysis Strategy

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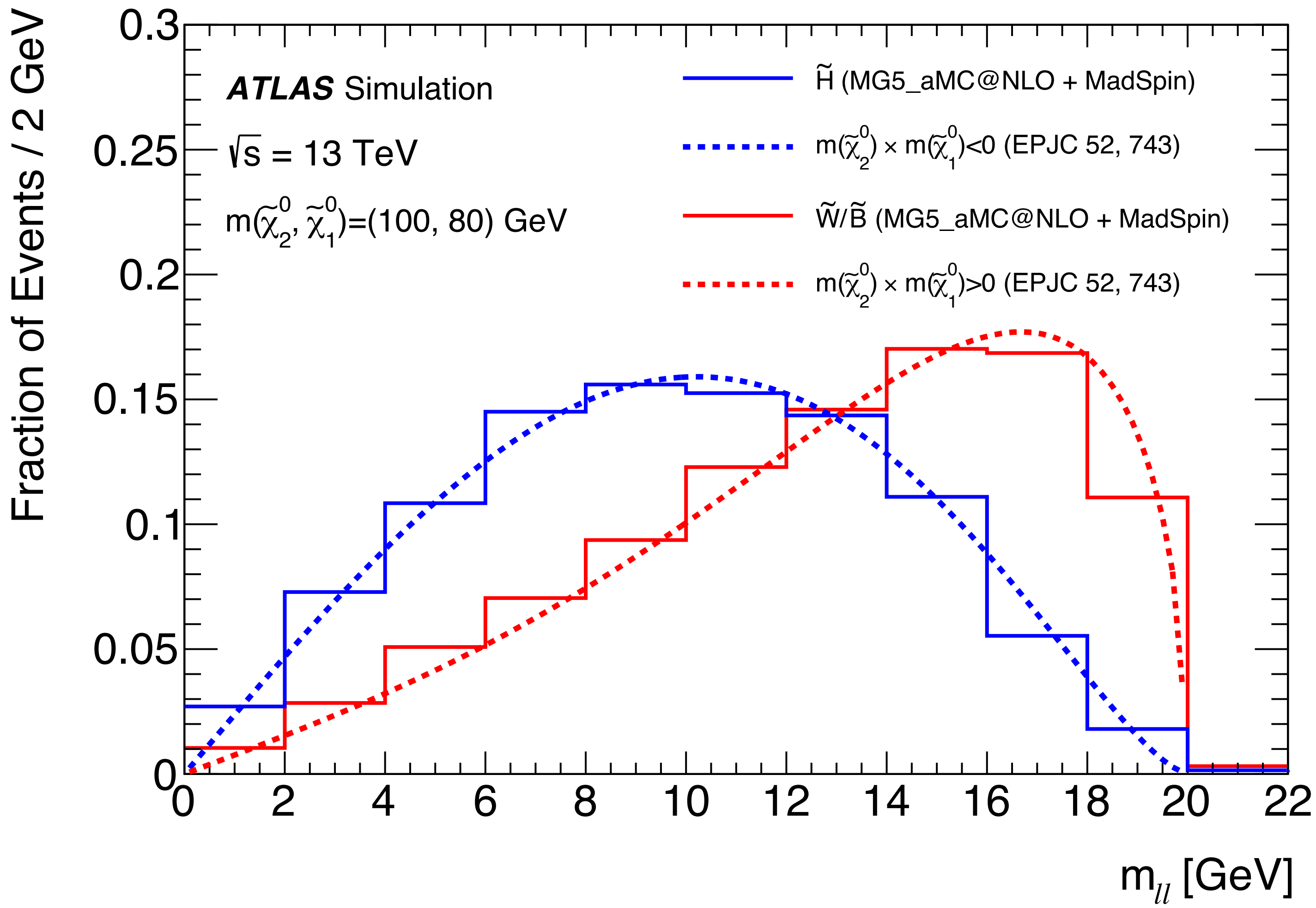

- m_{ll} has a kinematic endpoint at $\Delta m(\chi_2^0, \chi_1^0)$ (different for wino than higgsino)
  - Critical to identify soft leptons from off-shell Z decays

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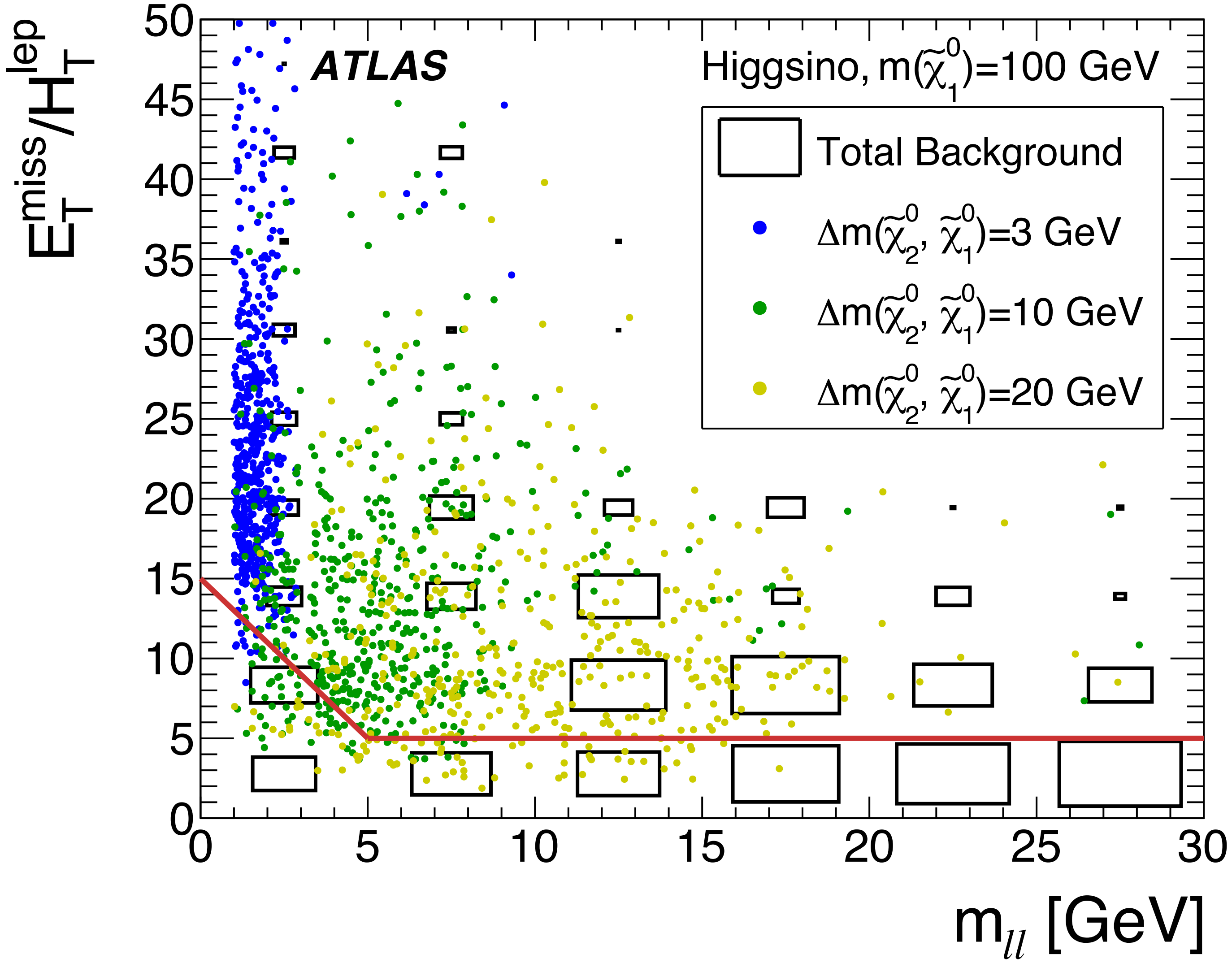

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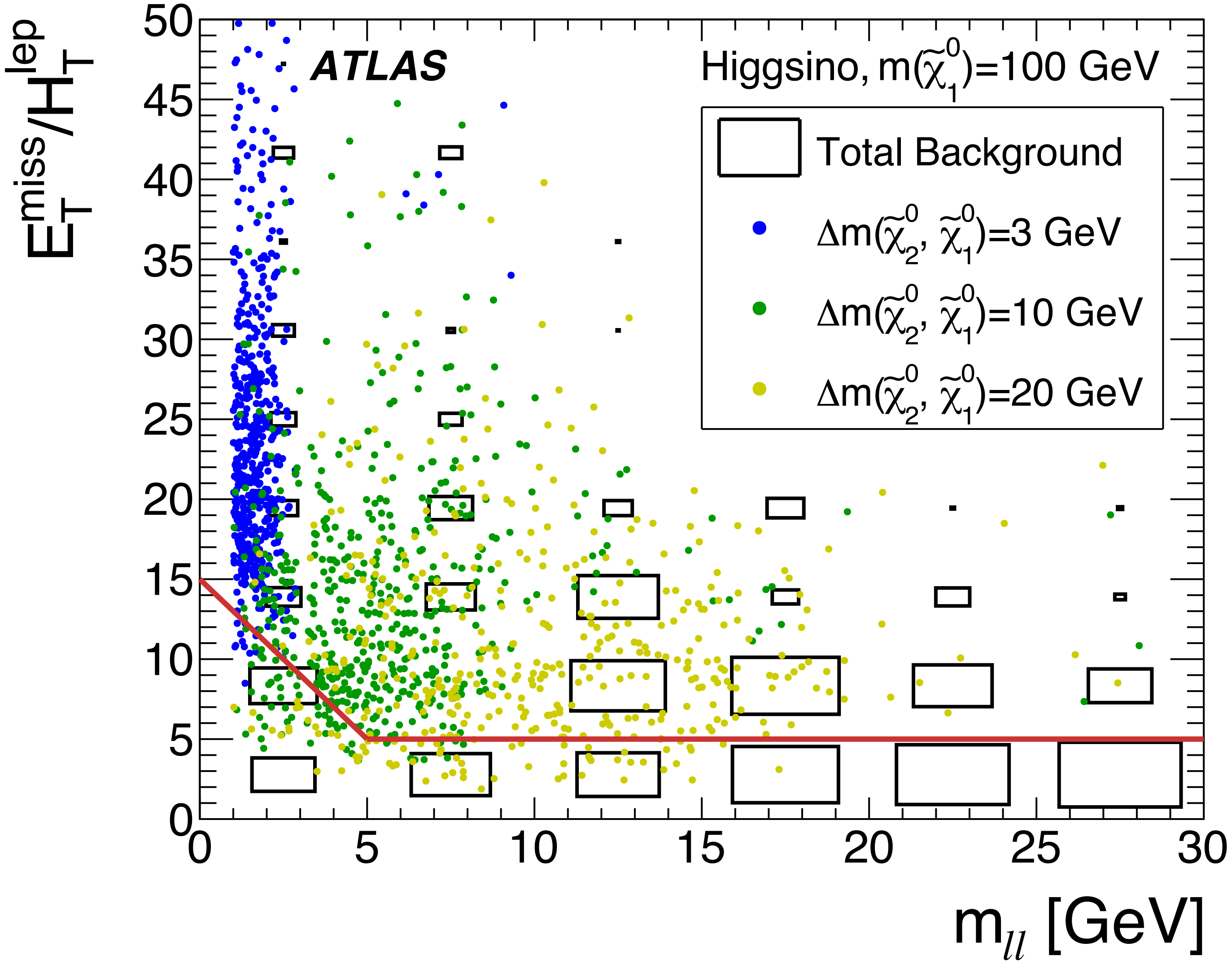

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  - Critical to identify soft leptons from off-shell Z decays
- E_T^{miss}/H_T^{lep} higher in signal than background
- Cut on E_T^{miss}/H_T^{lep} and fit the m_{ll} spectrum

Backgrounds

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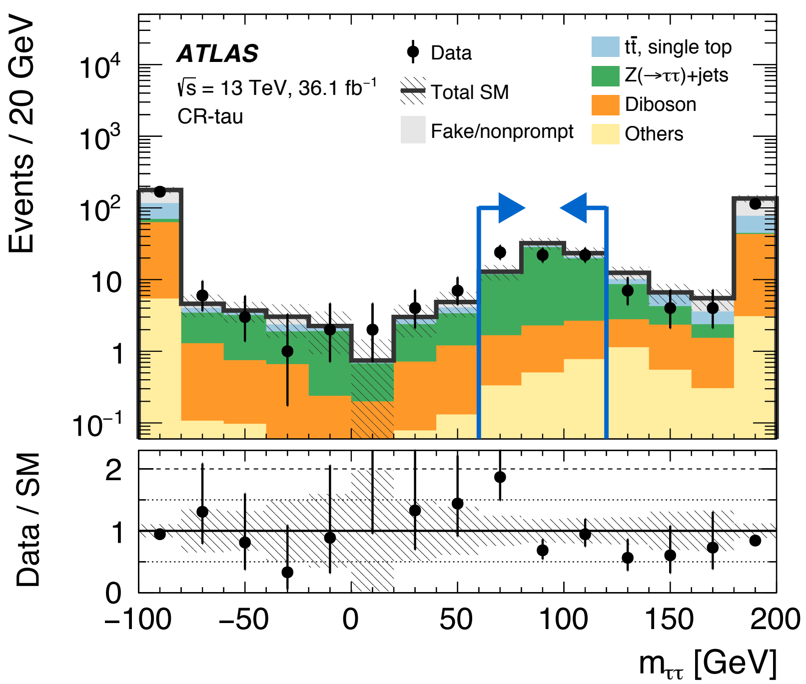
Taus



leptonic tau decays
lead to off-Z m_{ll}

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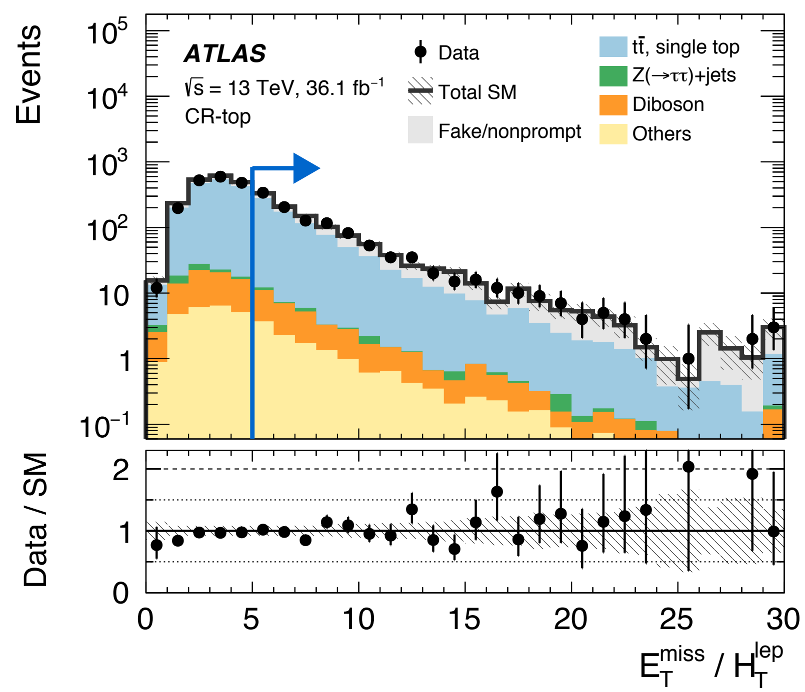

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- Estimated via control regions
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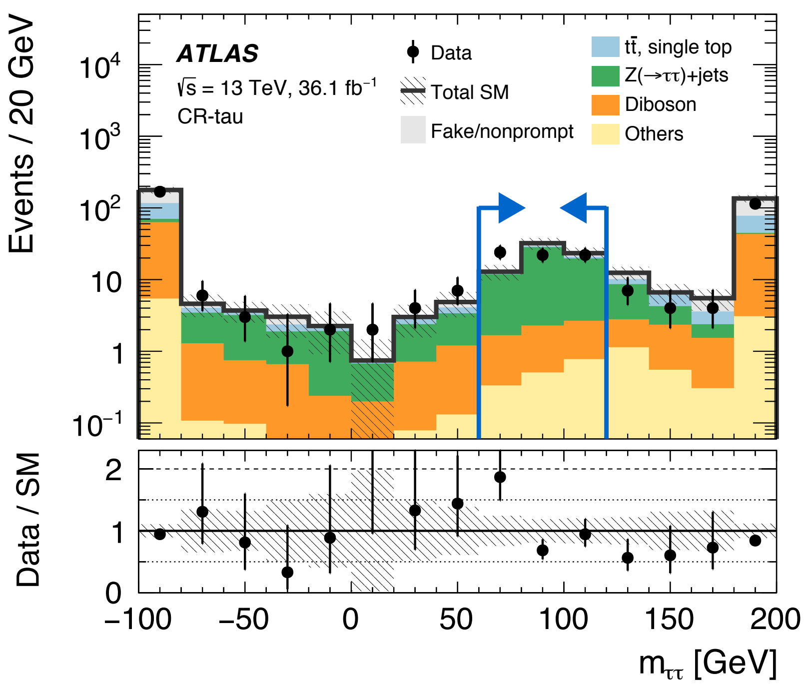

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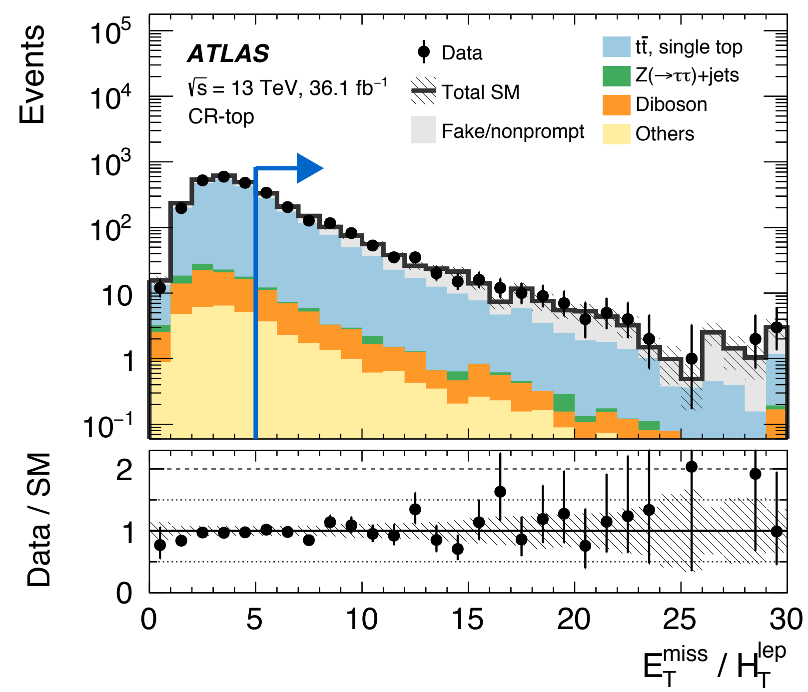

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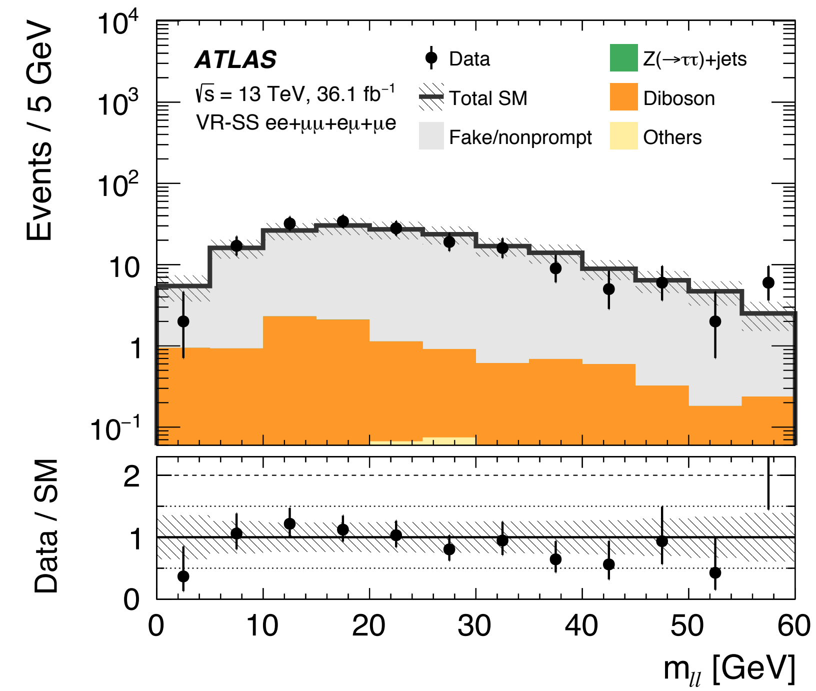
Fake Leptons

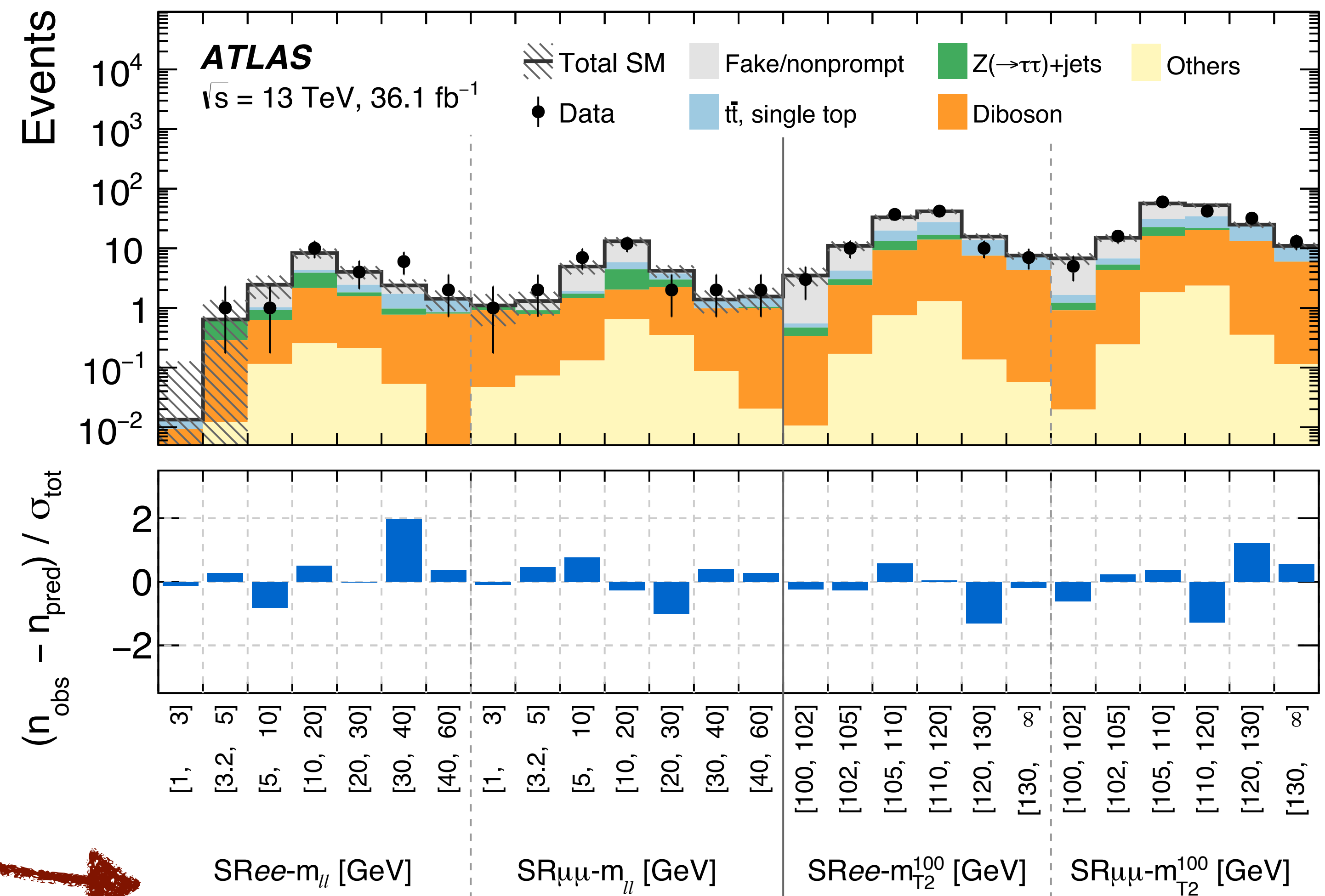


- Estimated via control regions
  - Scale MC prediction by data yield in background enriched regions

- Estimated via "fake factor" method
  - Validated in regions with same-sign leptons

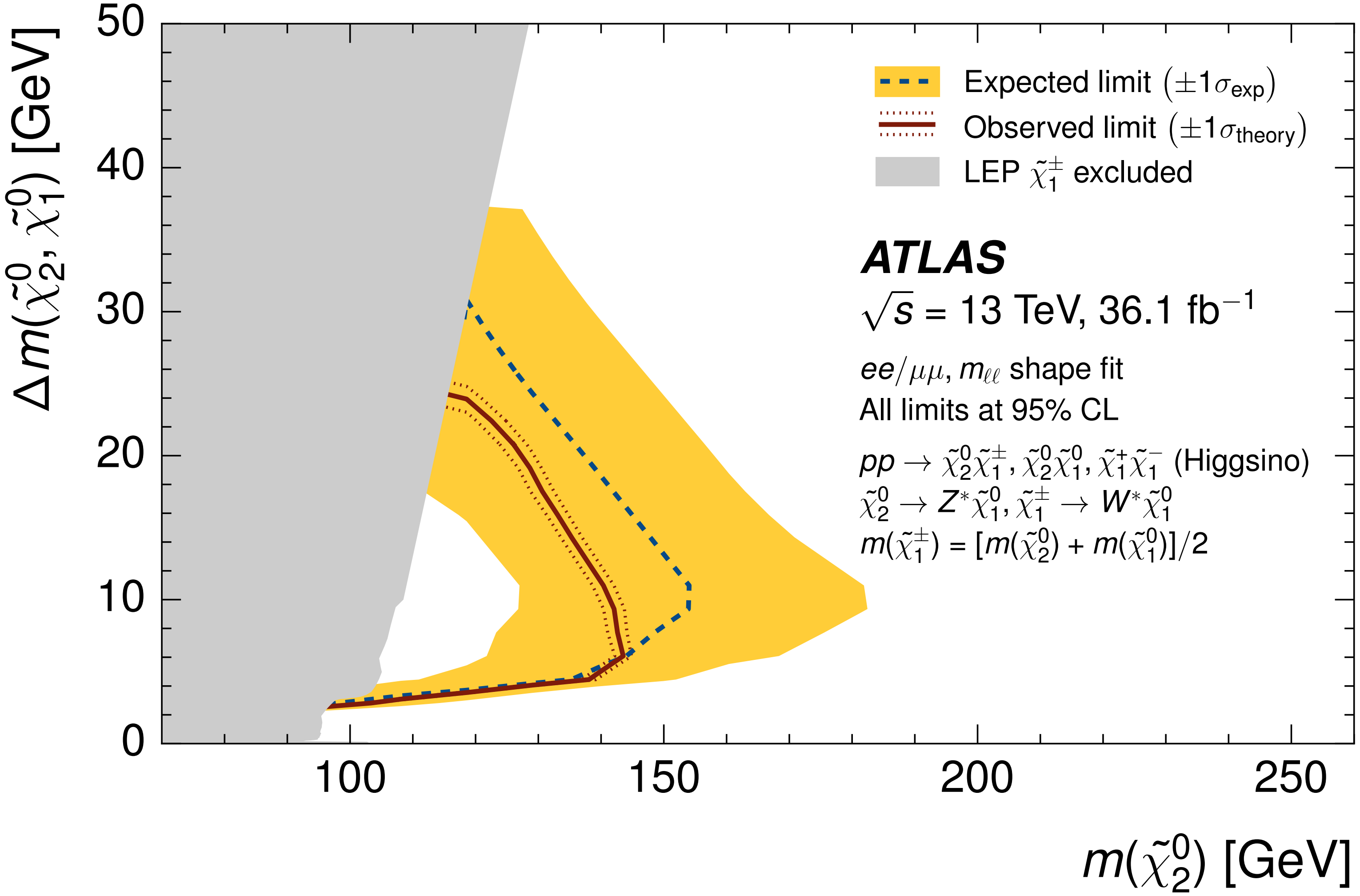
Results

Higgsino regions



- No significant excess observed: set limits on simplified models

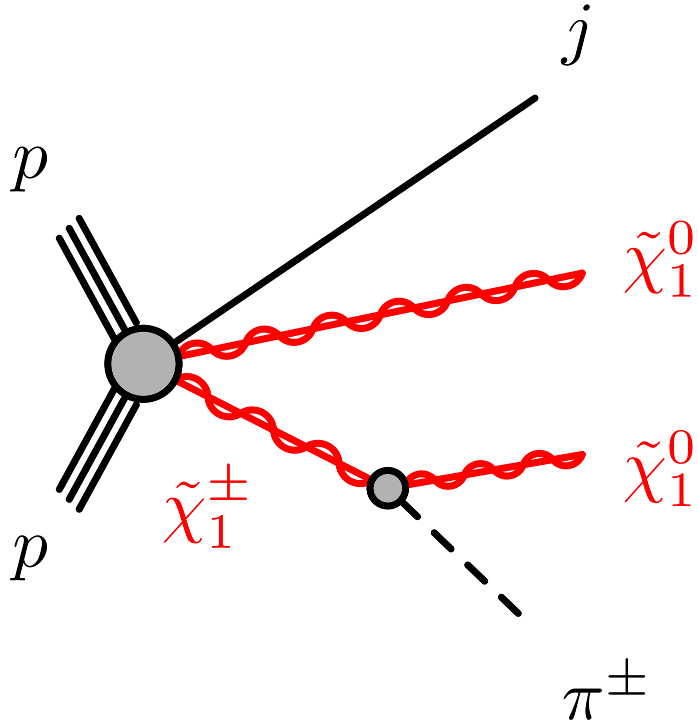
Interpretation



- First ATLAS results on direct higgsino production!
  - Mass splittings as low as 3 GeV have limits beyond LEP

Higgsinos LSPs with Disappearing Tracks

arXiv:1712.02118
ATL-PHYS-PUB-2017-019



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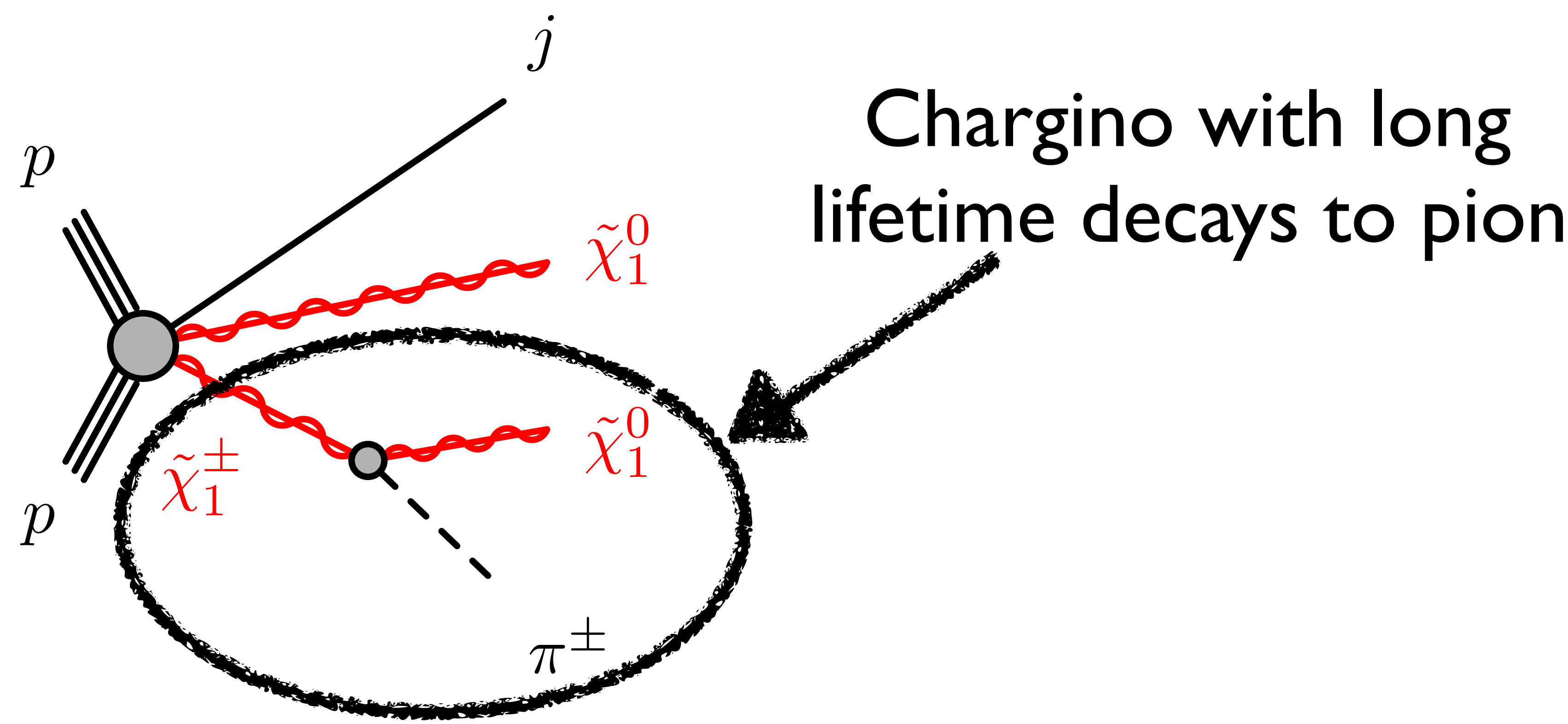
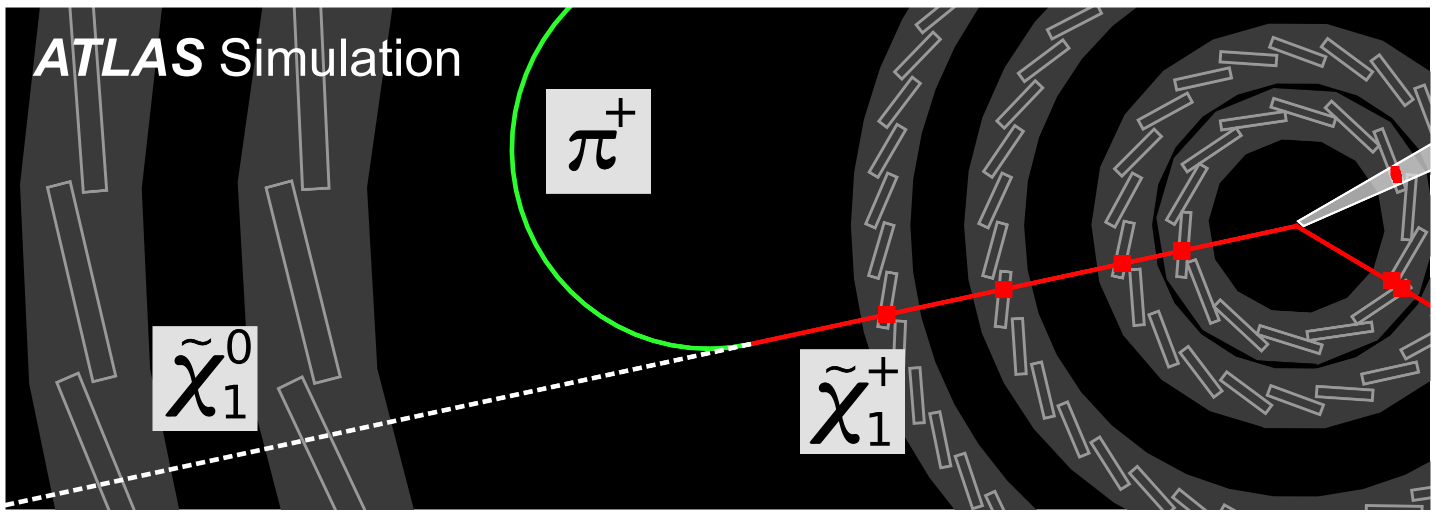
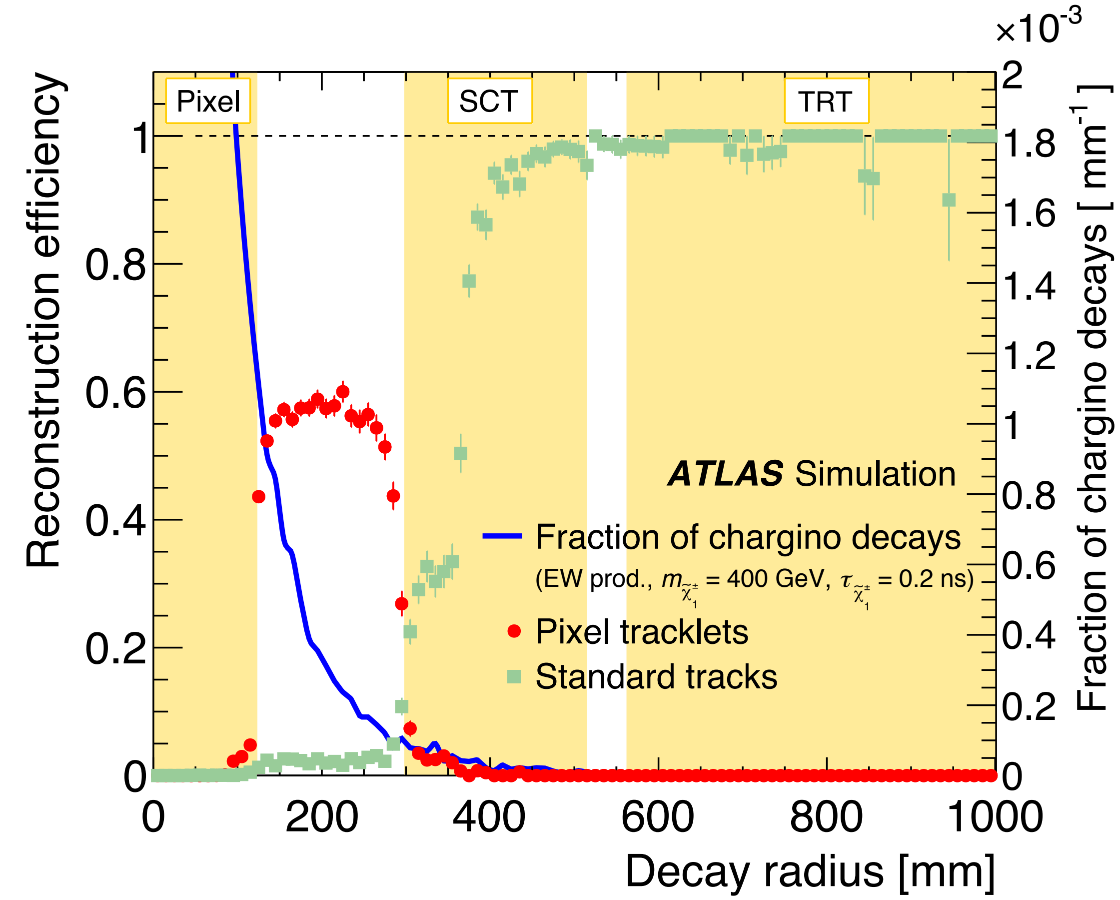


Tracklets



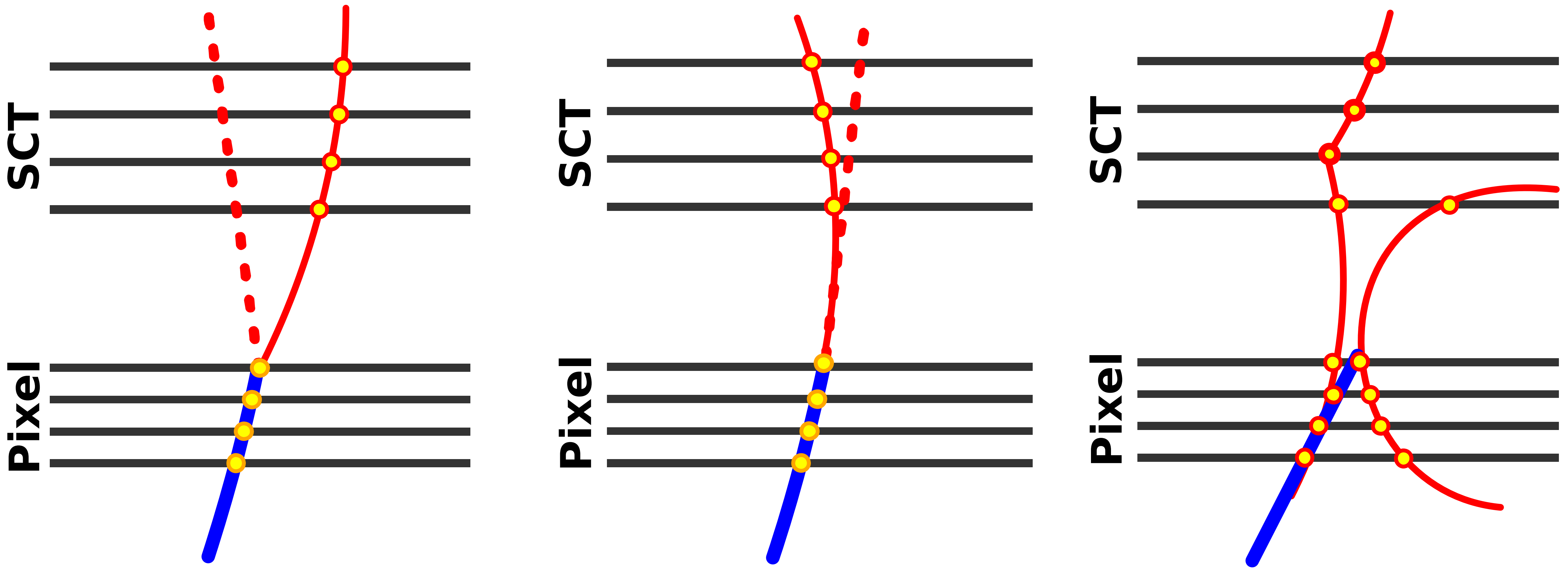


- Very small mass-splitting leads to macroscopic lifetime
  - Chargino can leave hits in the tracker before decay!
  - Look for "tracklets" with hits in pixel, but not in strips

Backgrounds

Hadron/lepton with hard scatter or photon

Random combinations



- Backgrounds suppressed with isolation, impact parameter cuts, and quality requirements for tracklets

- Estimated by building templates of tracklet p_T by smearing/fitting control samples

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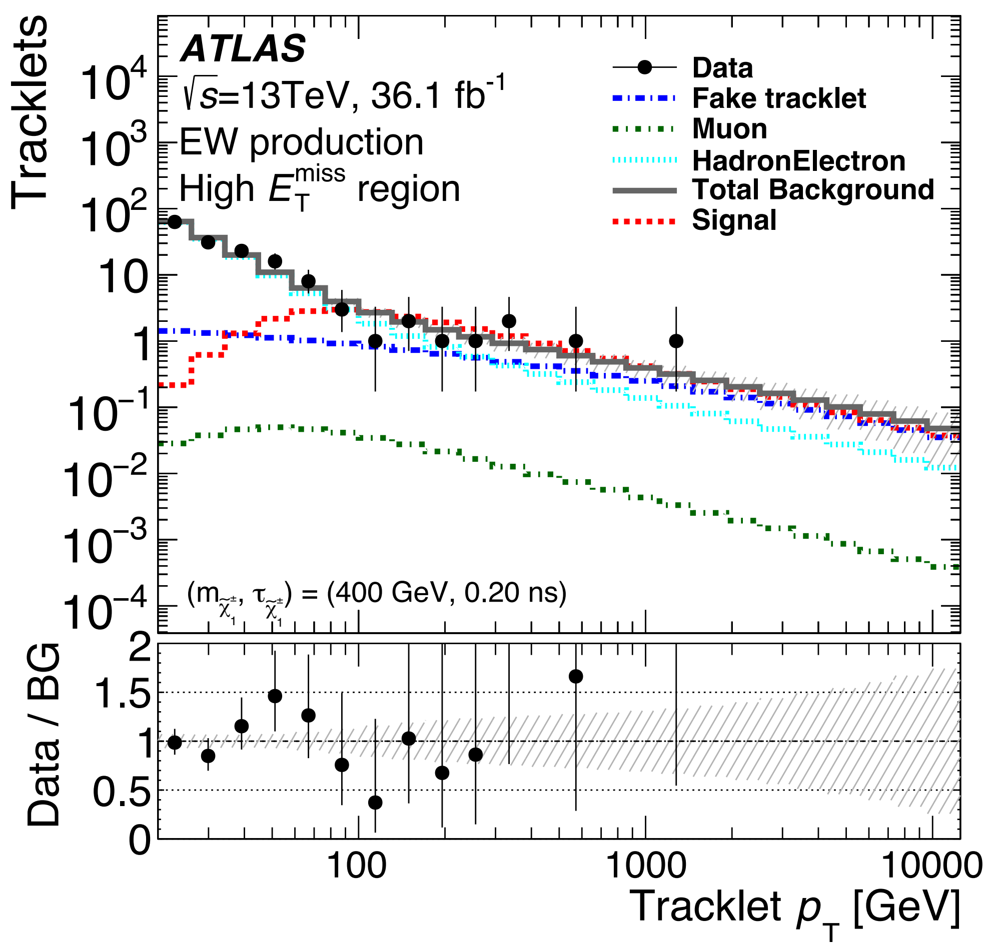

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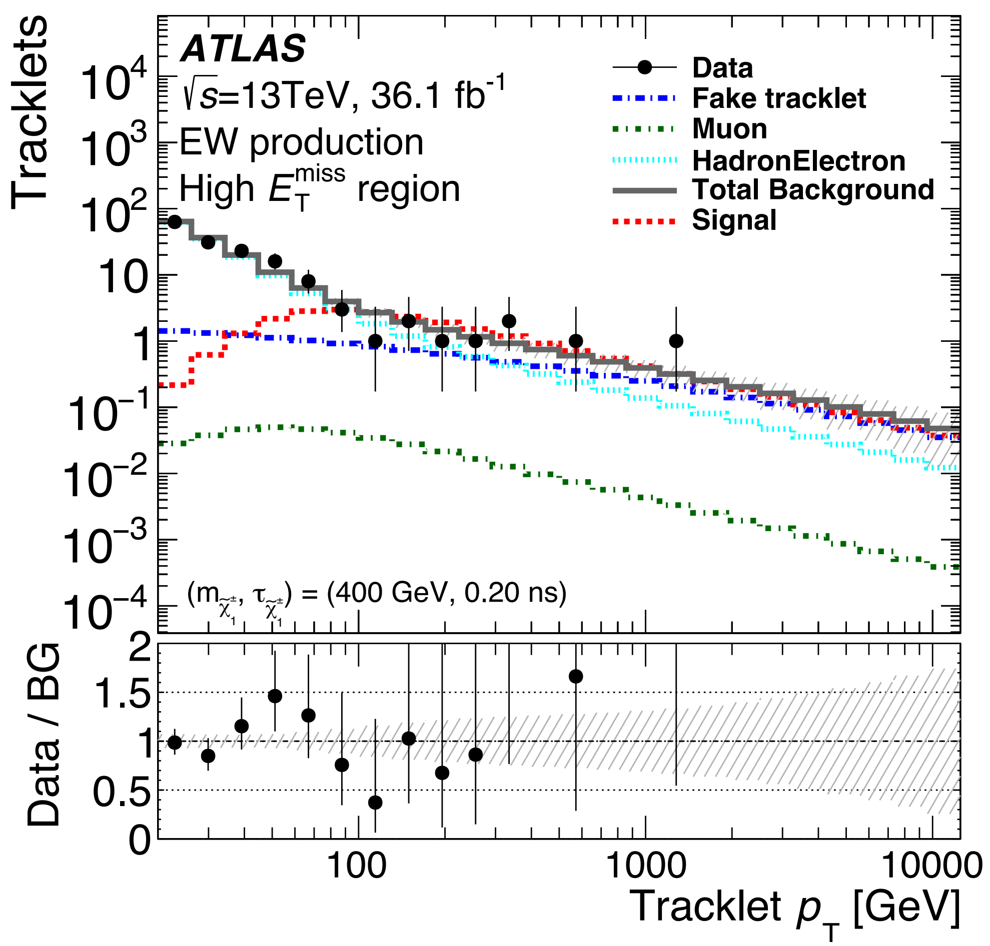
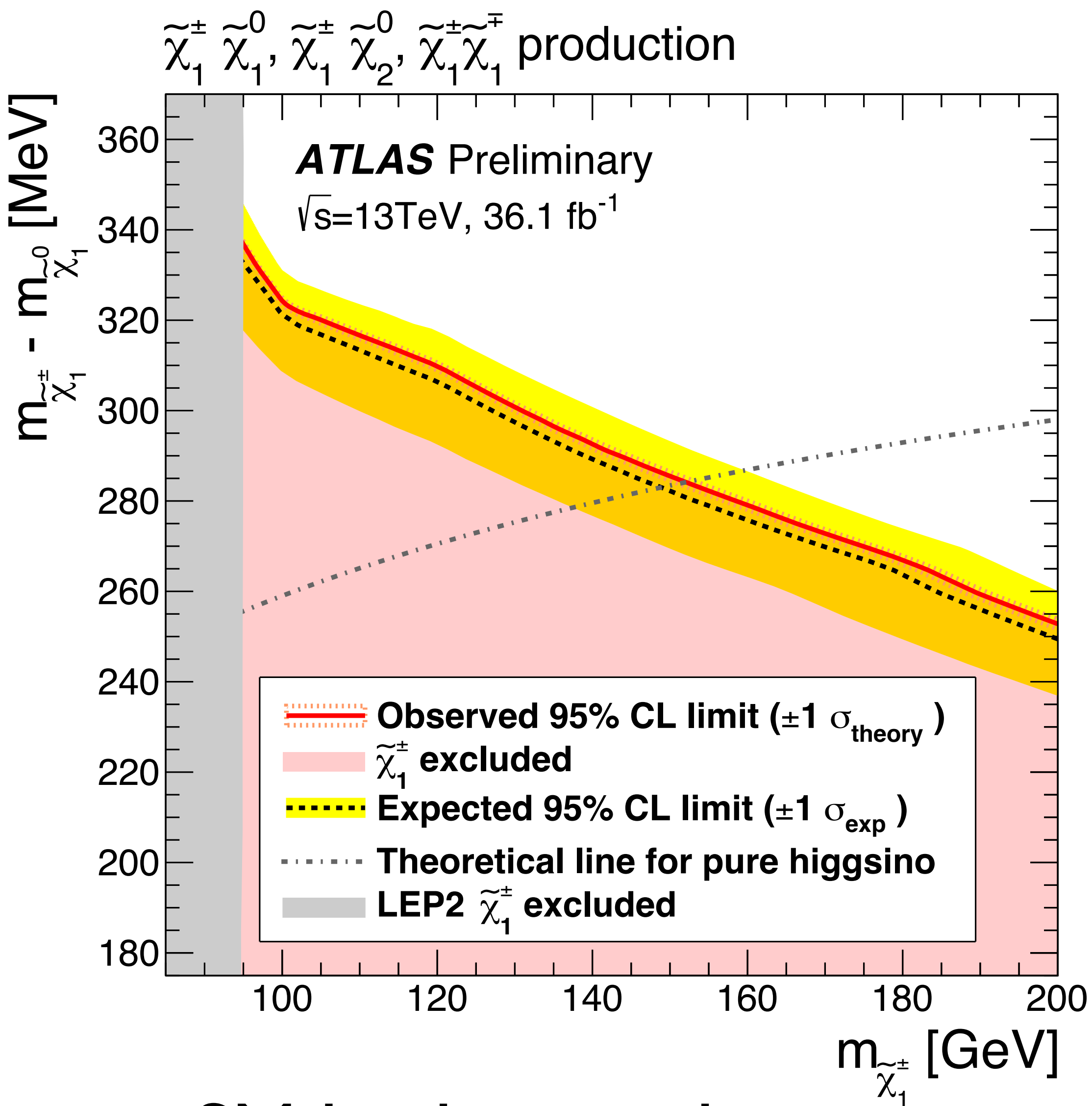
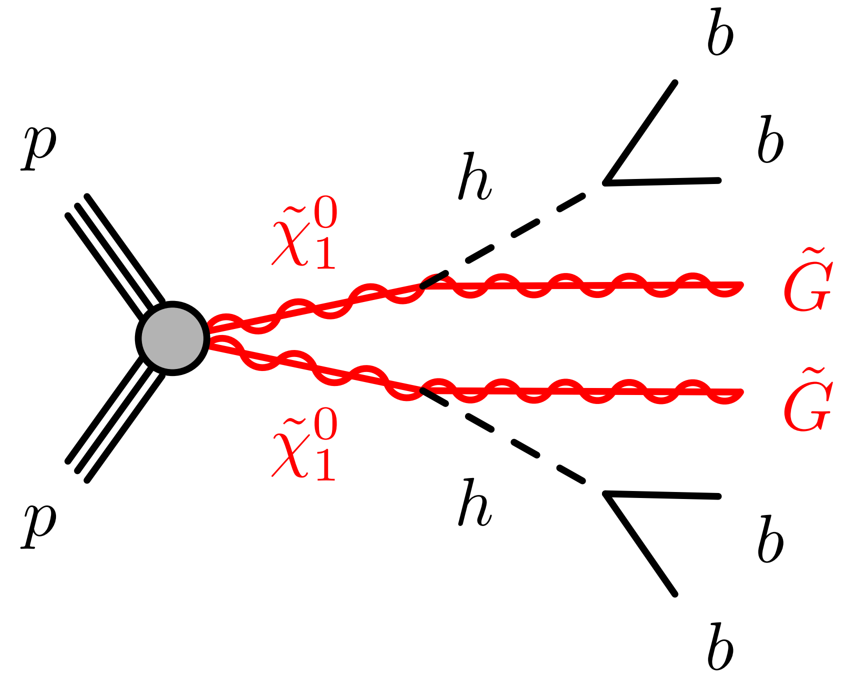




- No significant excess observed over SM backgrounds
- Set limits on higgsino masses below 150 GeV

Higgsinos NLSPs with Higgs Decays

ATLAS-CONF-2017-081



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- Key component: 3 or 4 b-tagged jets used to form Higgs bosons

High-Mass Analysis

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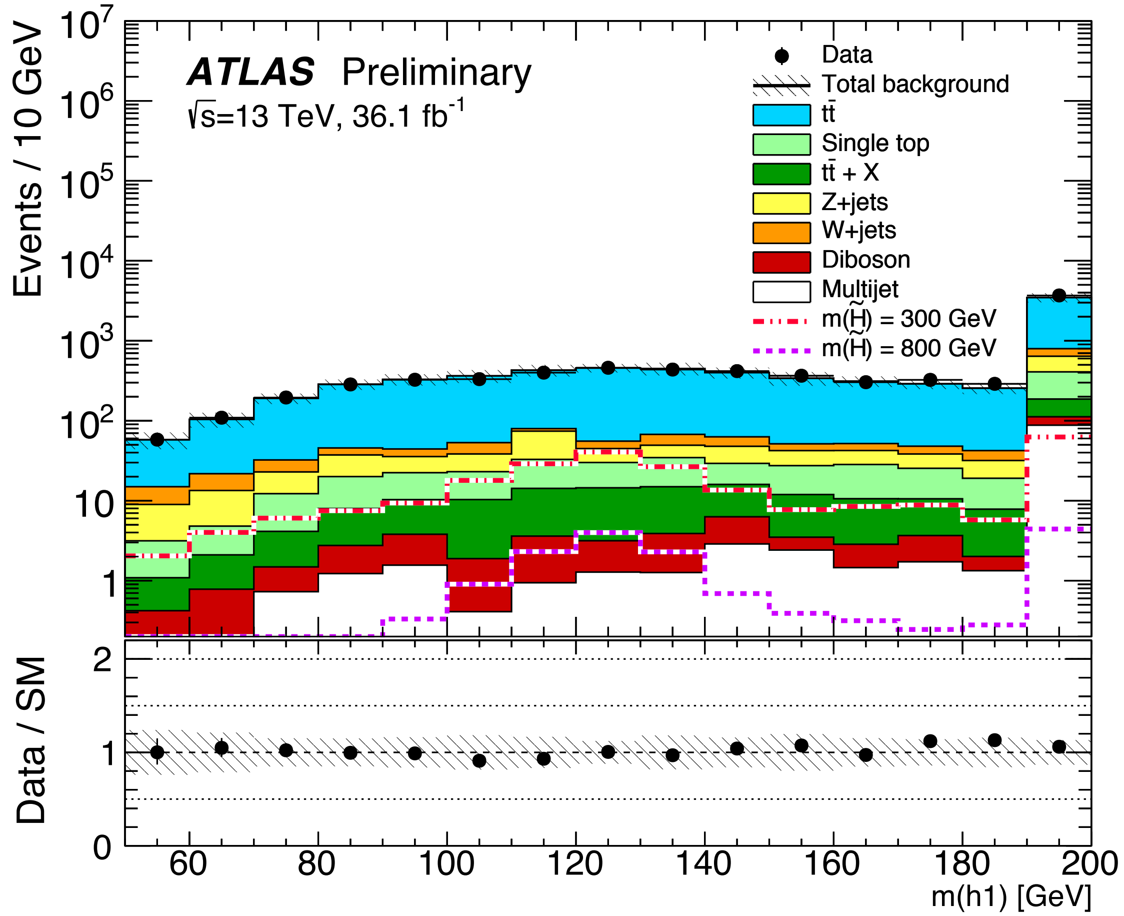

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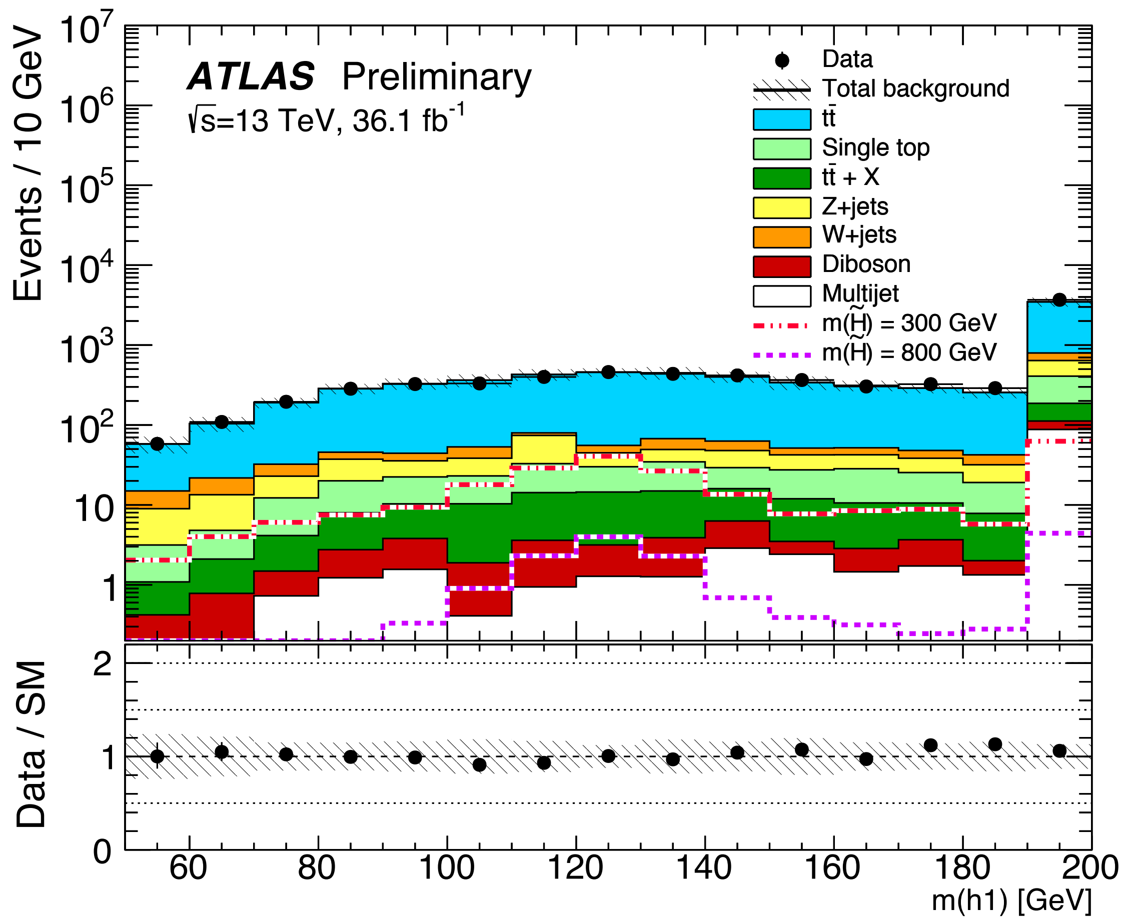

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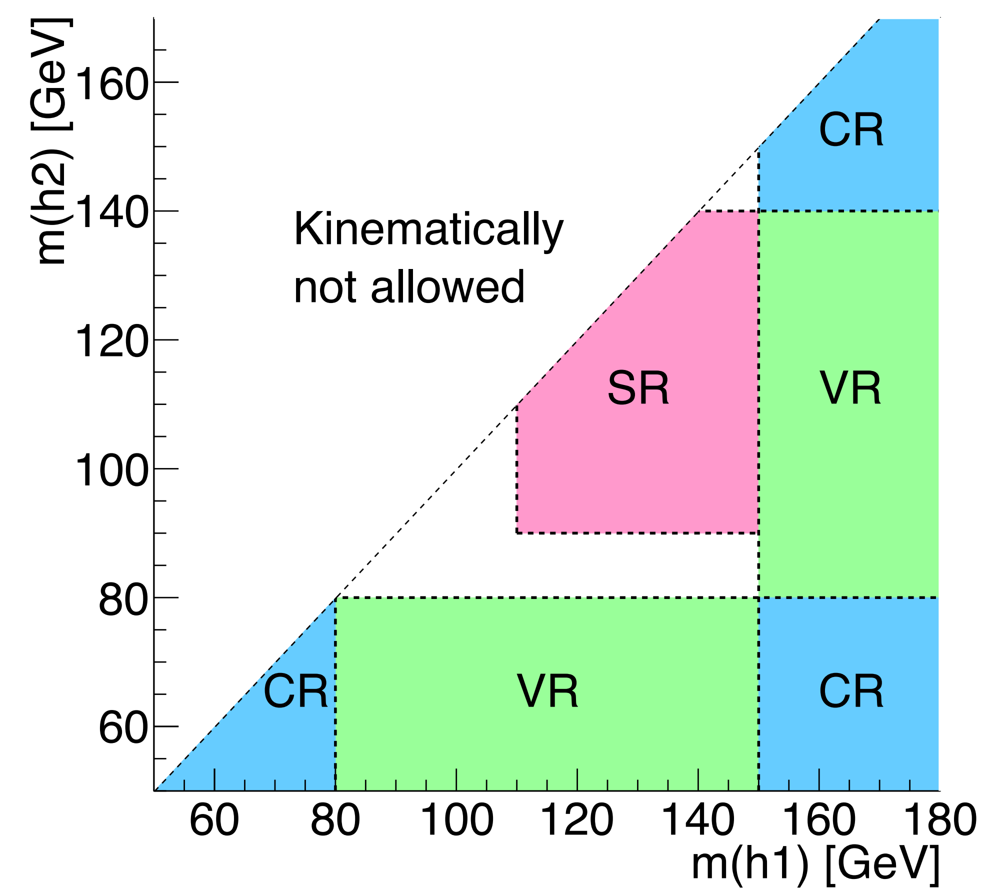
Background Estimate



- Higgs masses used to construct control, validation, and search regions
- Normalize main top background in control regions

Low-Mass Analysis

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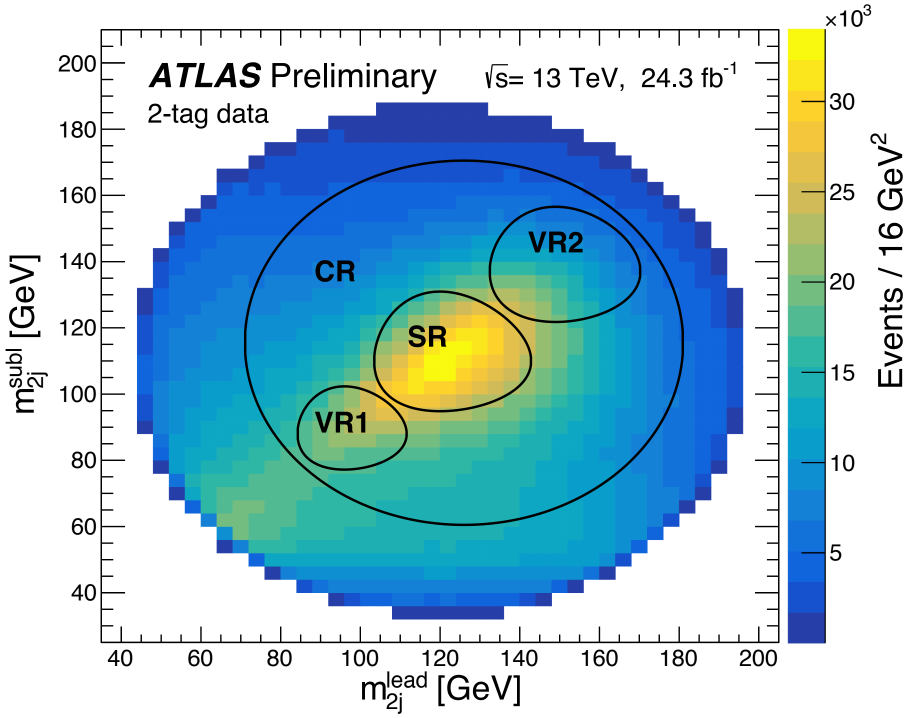

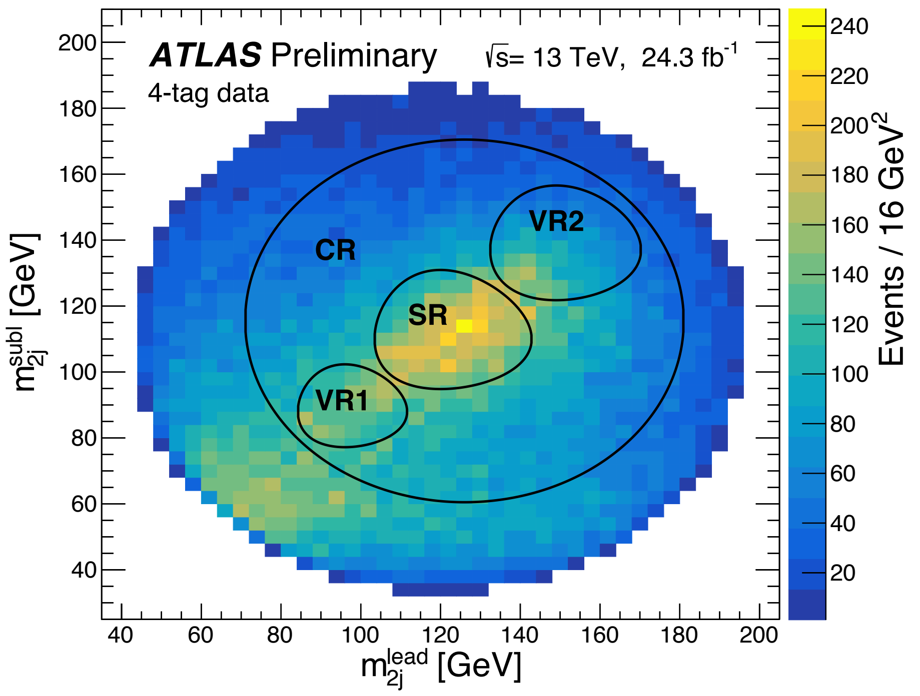

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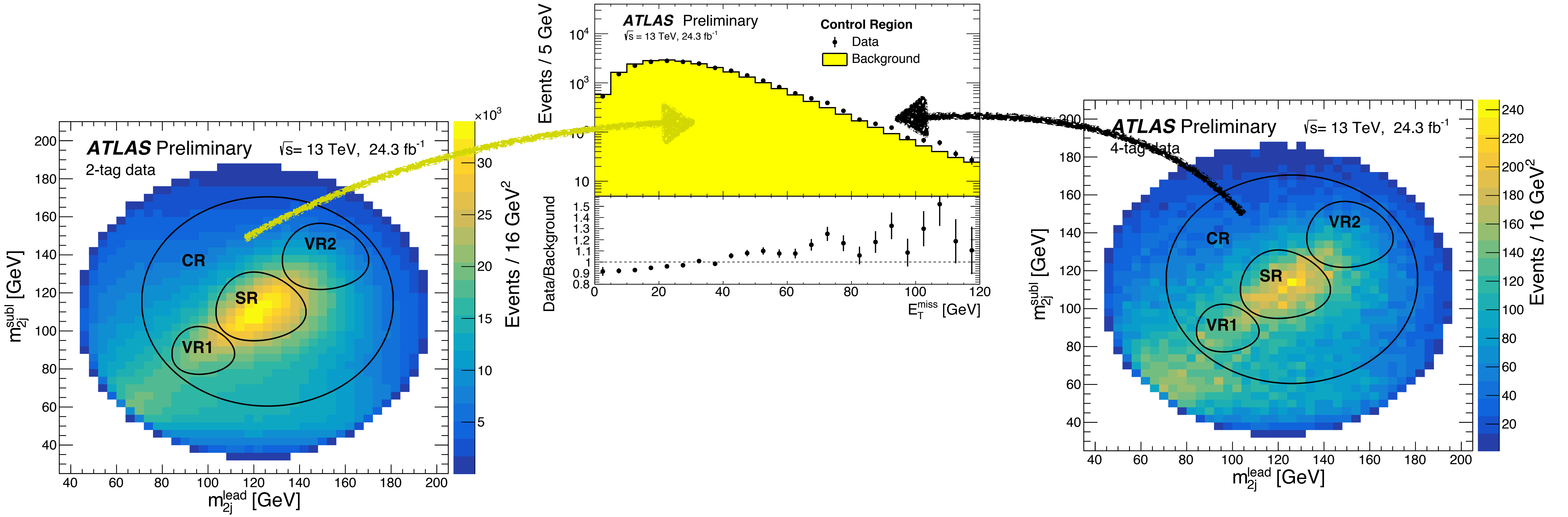

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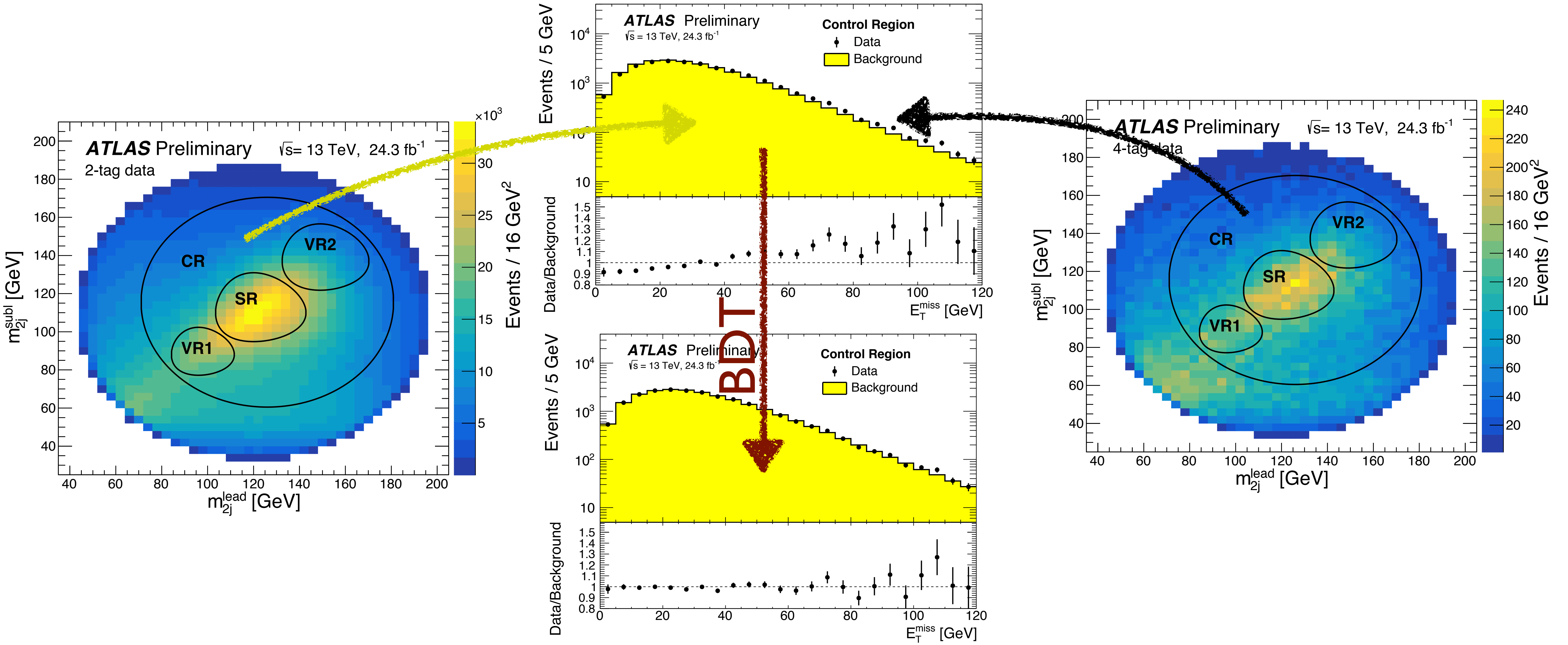

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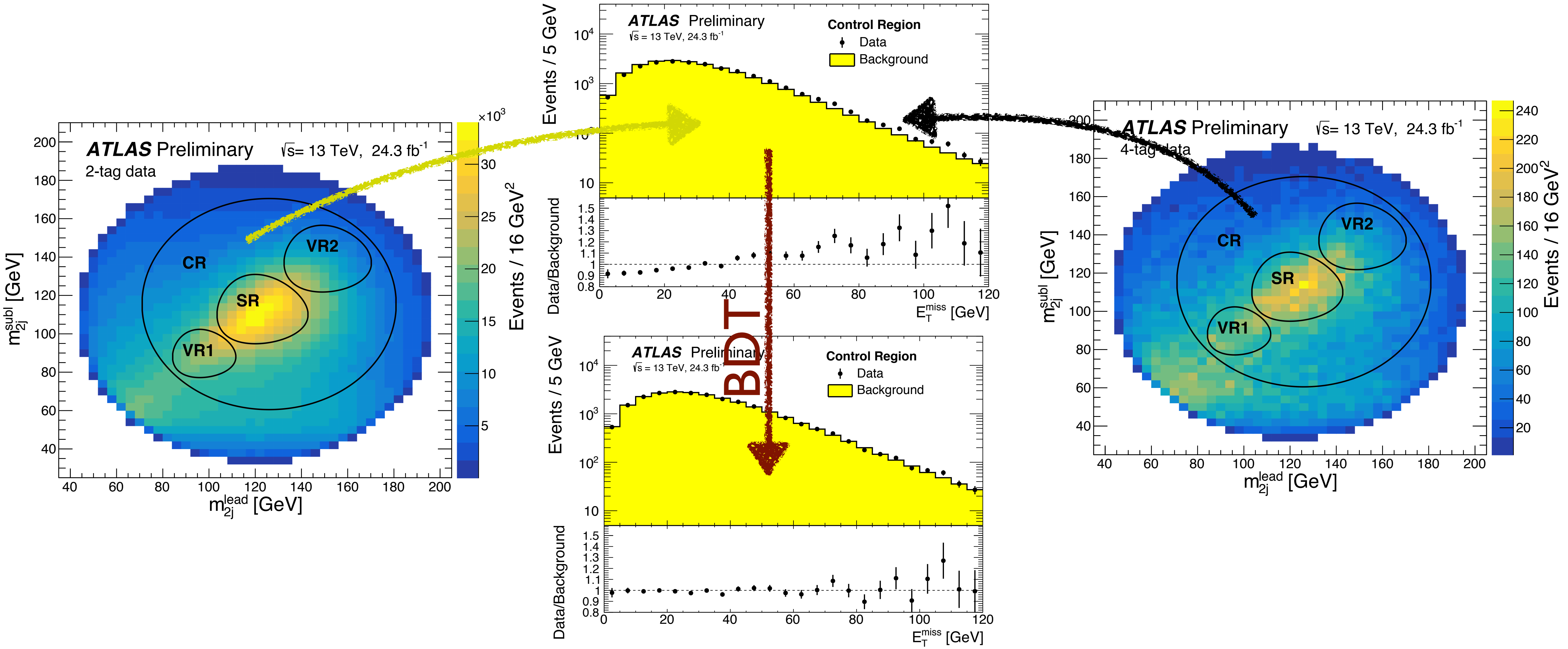

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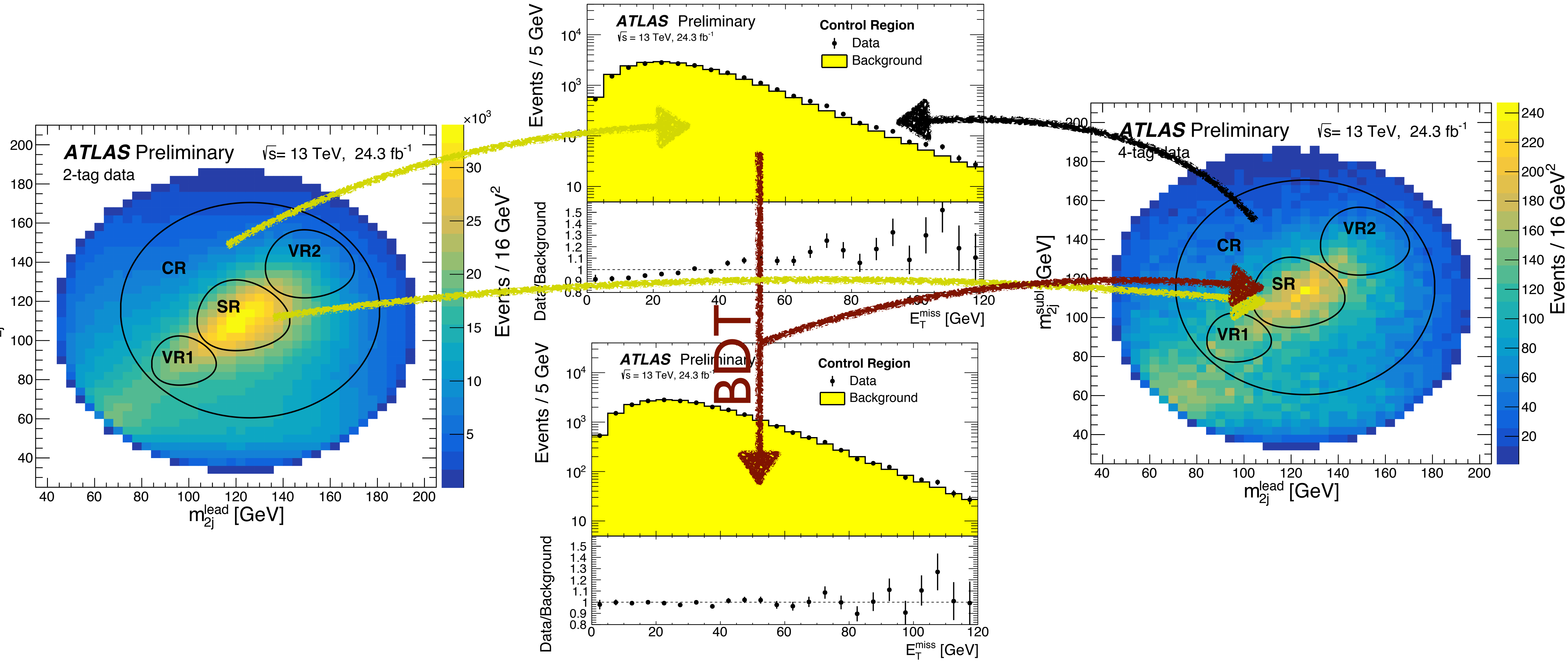

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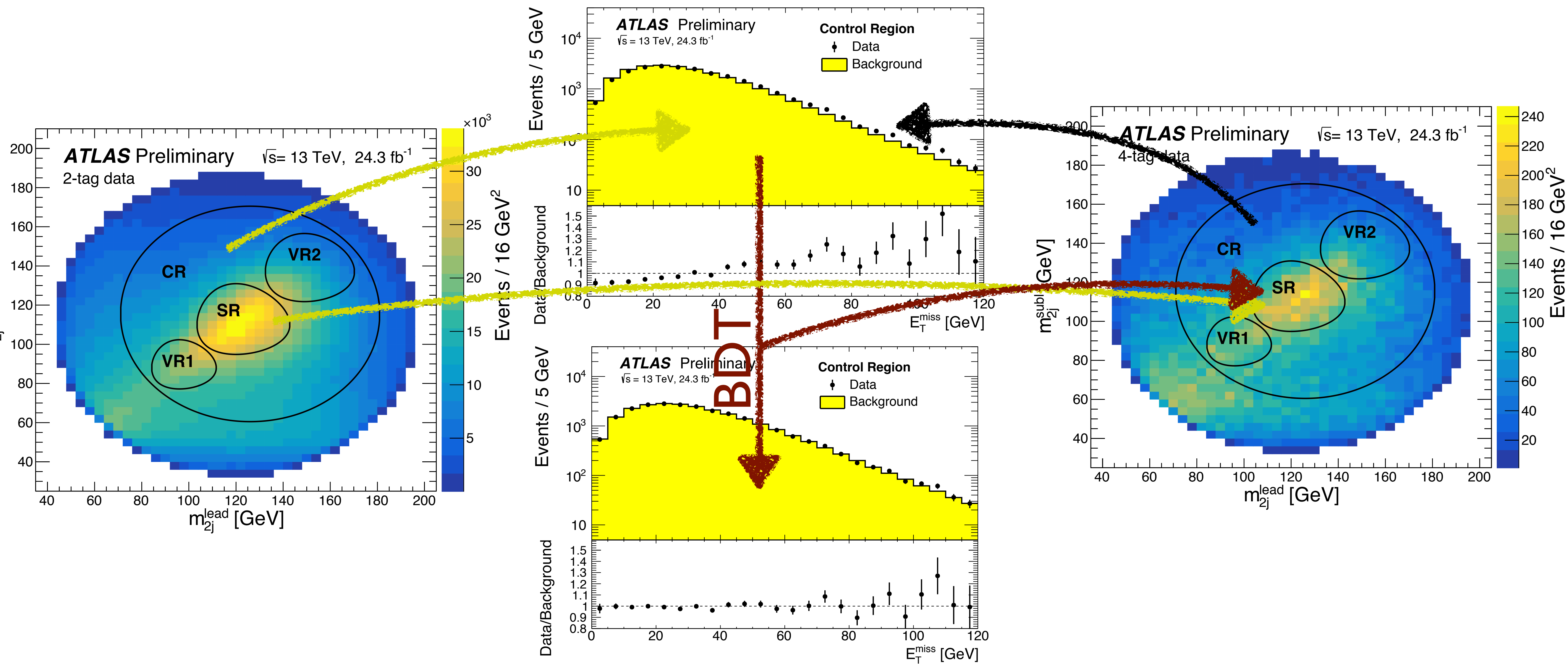

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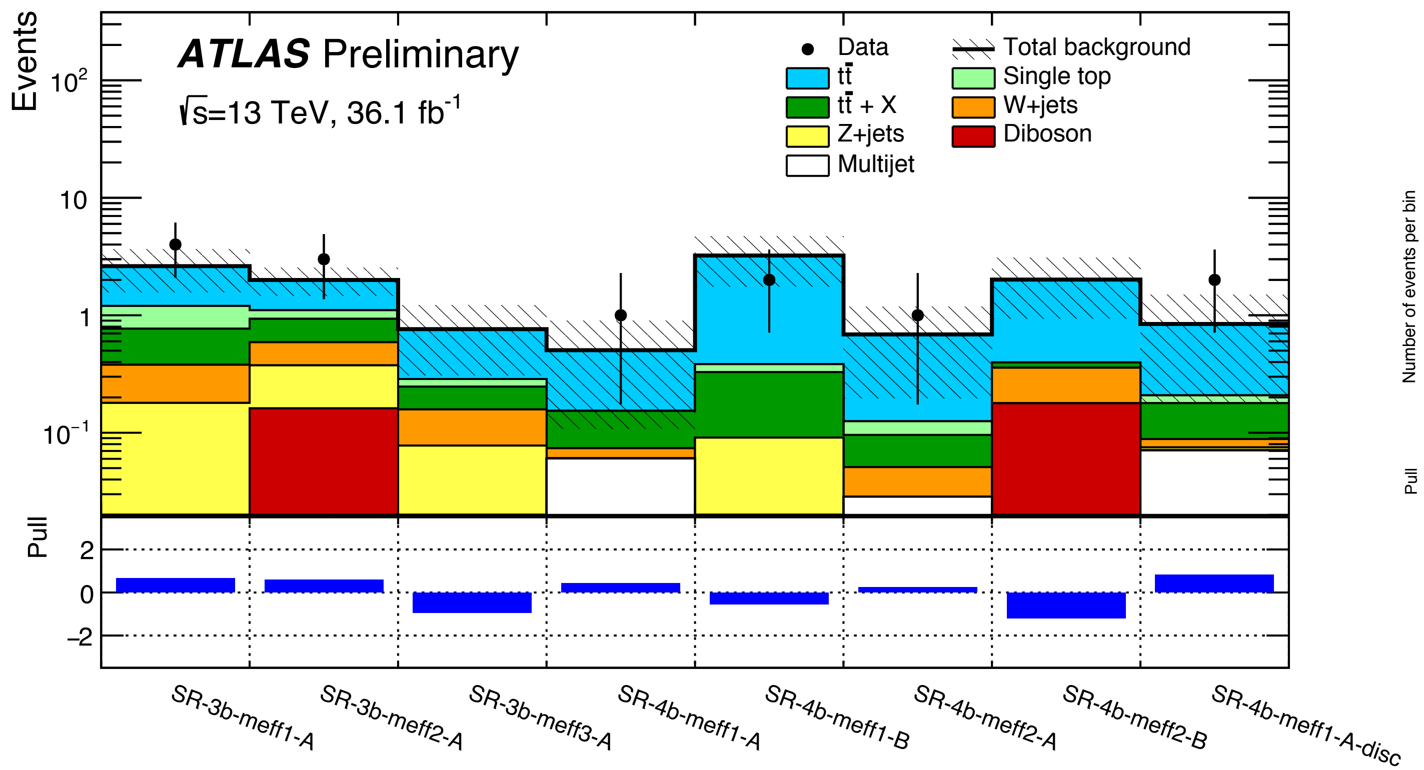
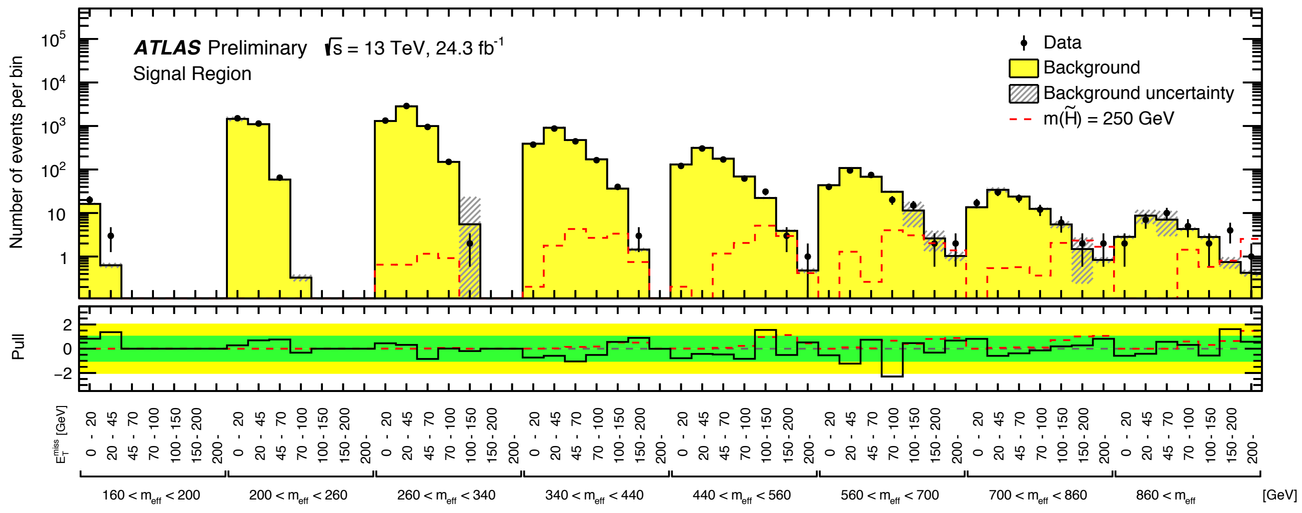
    - BDT is trained in CRs and validated in VRs
    - Data in 2-tag "SR" uses reweighting BDT for background in real 4-tag SR
- Use 56 E_T^{miss}, m_{eff} bins to search

Results





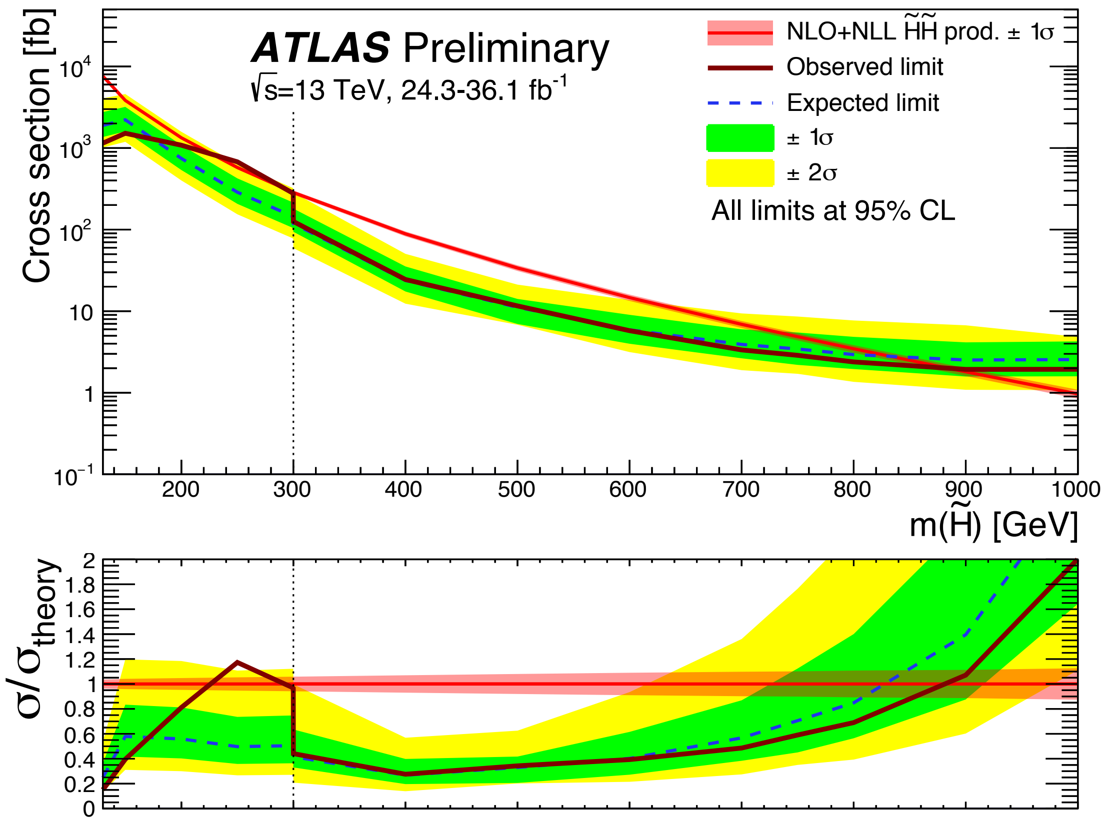
High-mass

Low-mass

- No significant excess from either high-mass or low-mass analysis

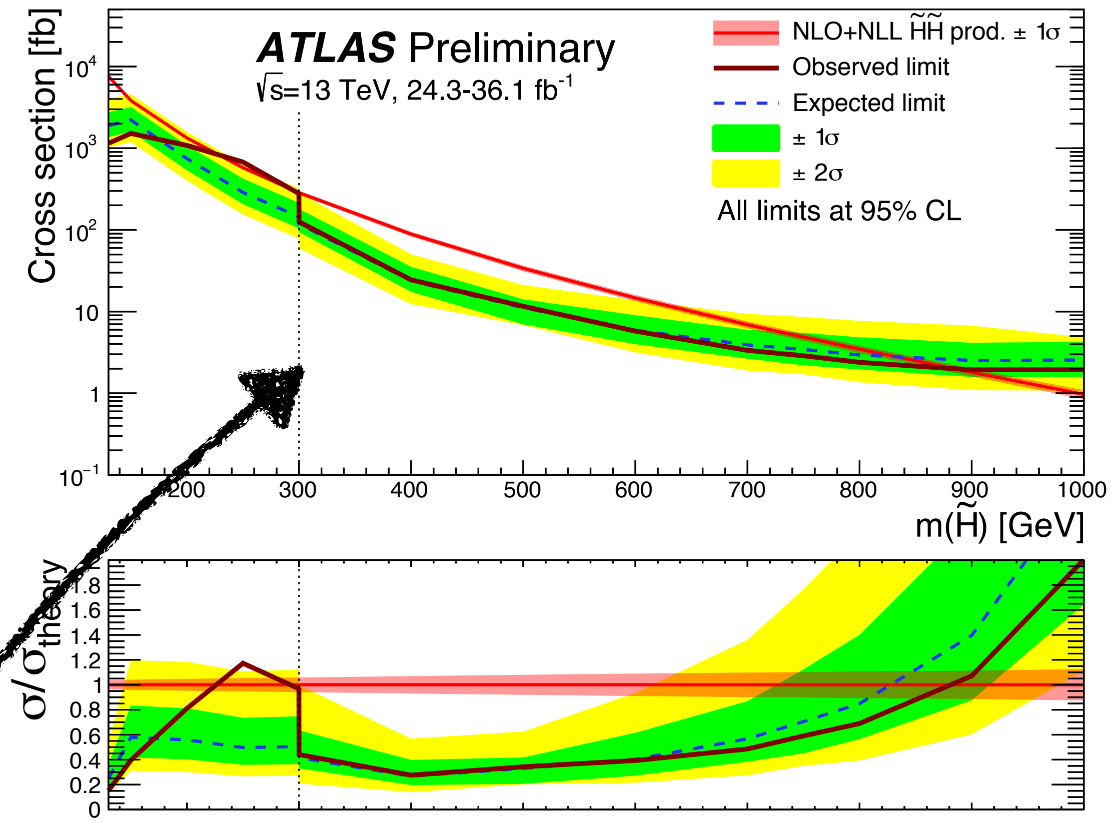
Interpretations

Interpretations



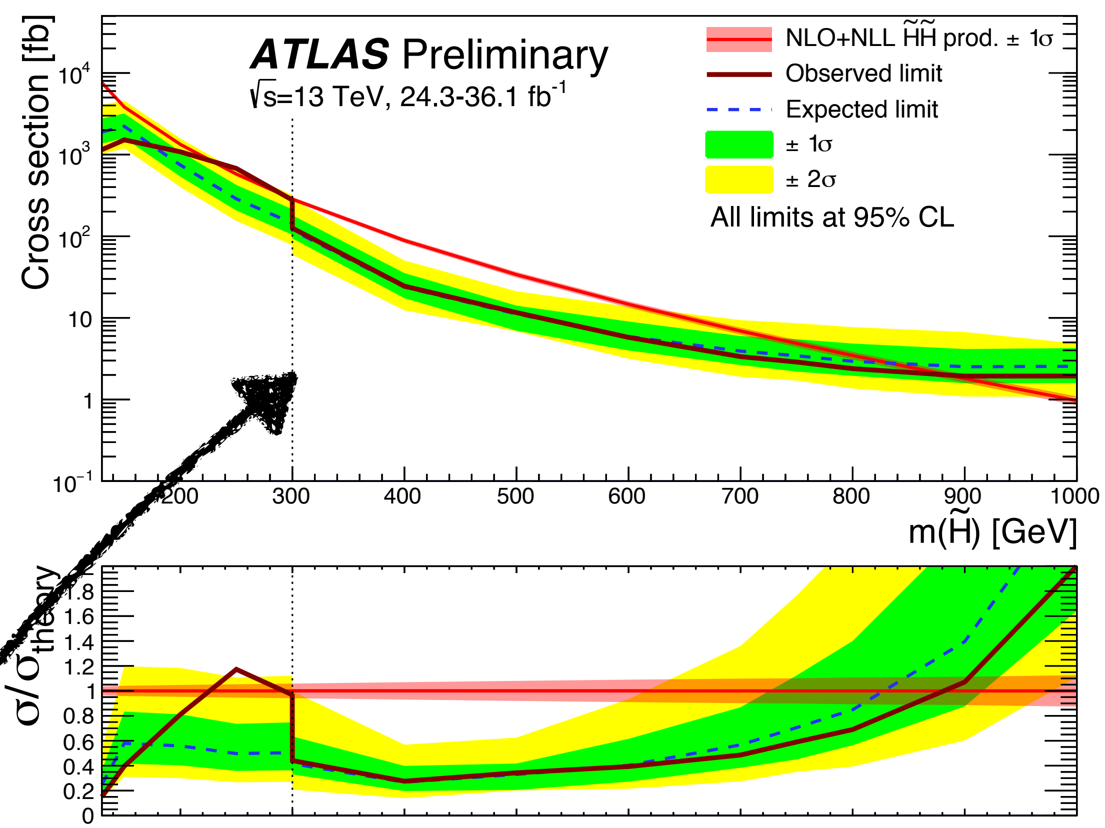
- Set limits in models assuming 100% higgsino to Higgs
  - Limits as low as 130 GeV, and as high as 880 GeV

Interpretations

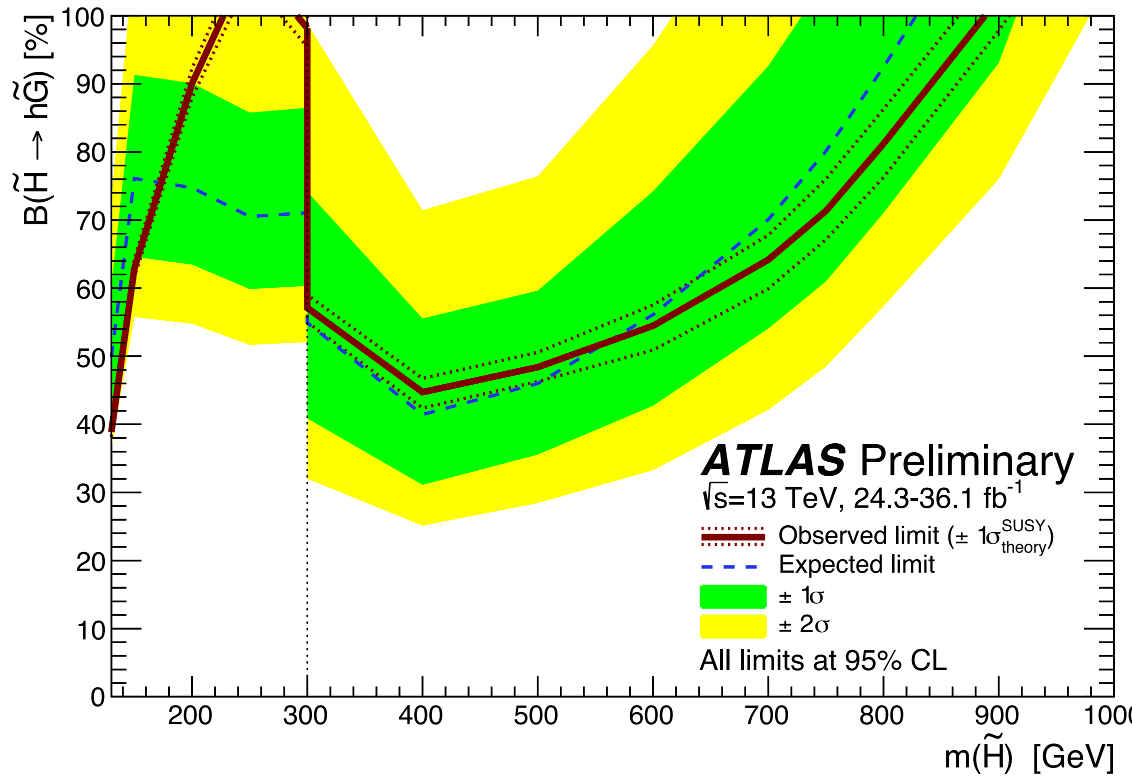


- Set limits in models assuming 100% higgsino to Higgs
  - Limits as low as 130 GeV, and as high as 880 GeV
  - Low-mass and high-mass analyses both contribute!

Interpretations



Pure Higgs decay



Variable Higgs/Z decay

- Set limits in models assuming 100% higgsino to Higgs
  - Limits as low as 130 GeV, and as high as 880 GeV
  - Low-mass and high-mass analyses both contribute!

- Also set limits on variable BR of higgsino to Z or Higgs
  - Can exclude as low as 45% BR to Higgs decays
  - Many regions with weaker constratints

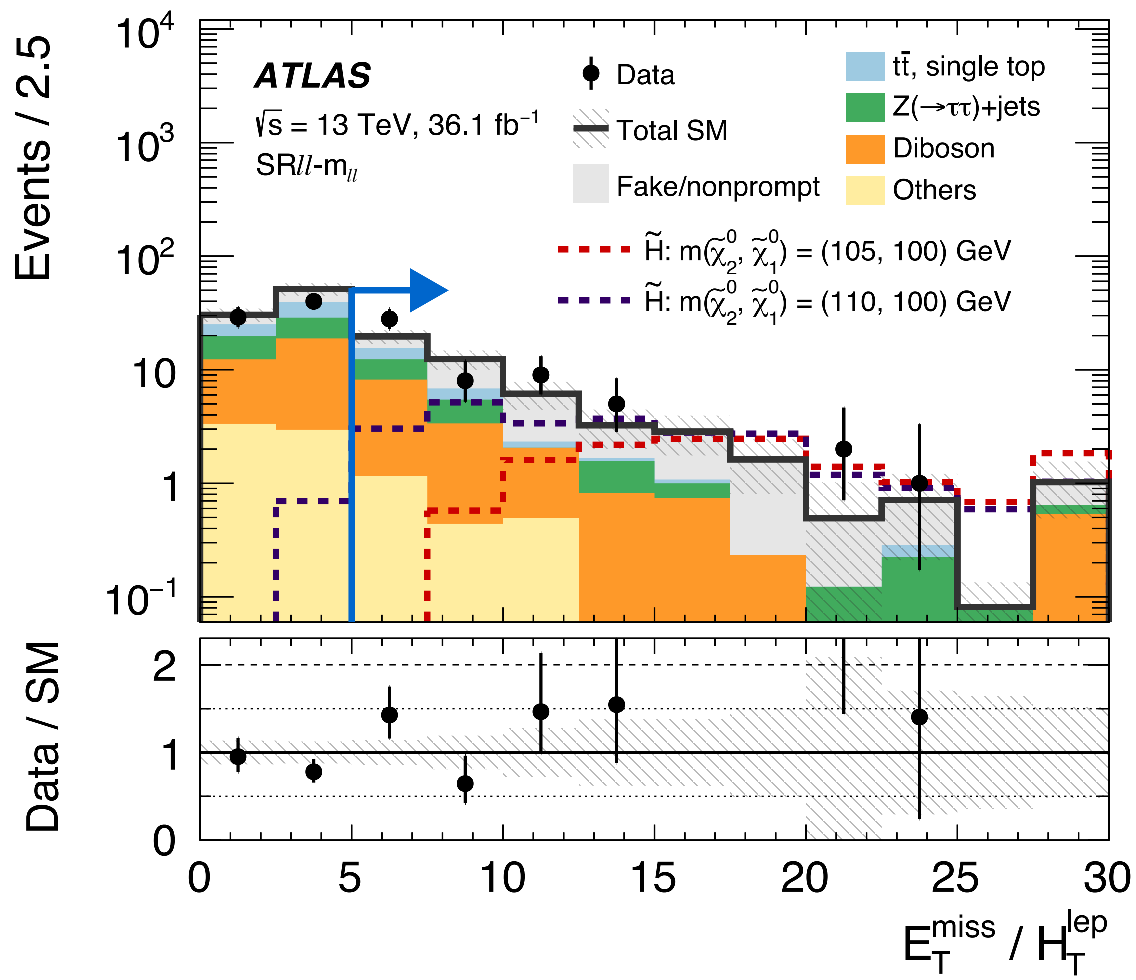
Conclusions

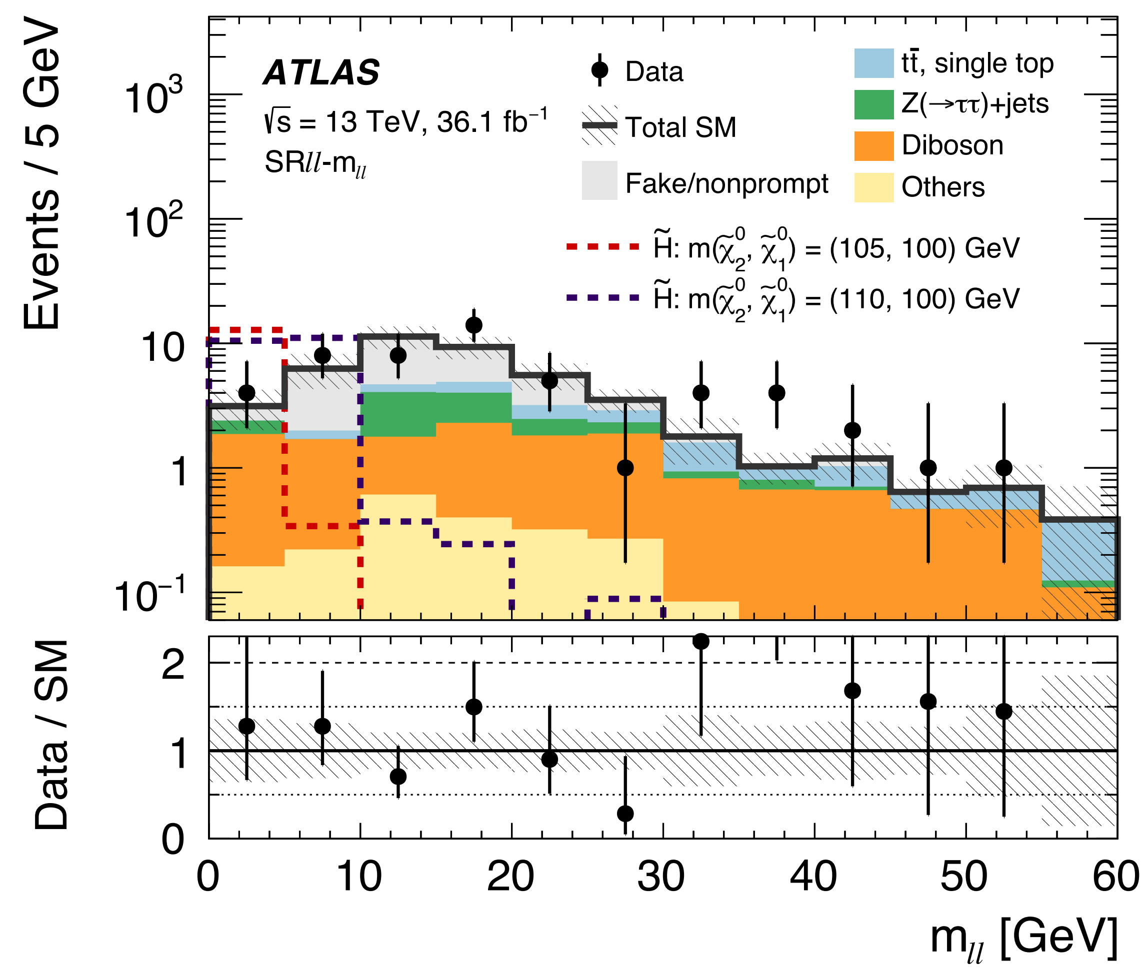
The Hunt Continues

- No smoking guns for higgsinos at the LHC (so far)
- Compelling naturalness arguments require light higgsinos: **need to keep looking!**
  - Lots of room to still cover: challenging signatures with soft leptons and disappearing tracks still have lots of open viable phase space
  - GMSB models still have lots of ground to cover by relaxing branching ratios to Higgs
- Stay tuned for full run 2 results: 4x the data (!?)

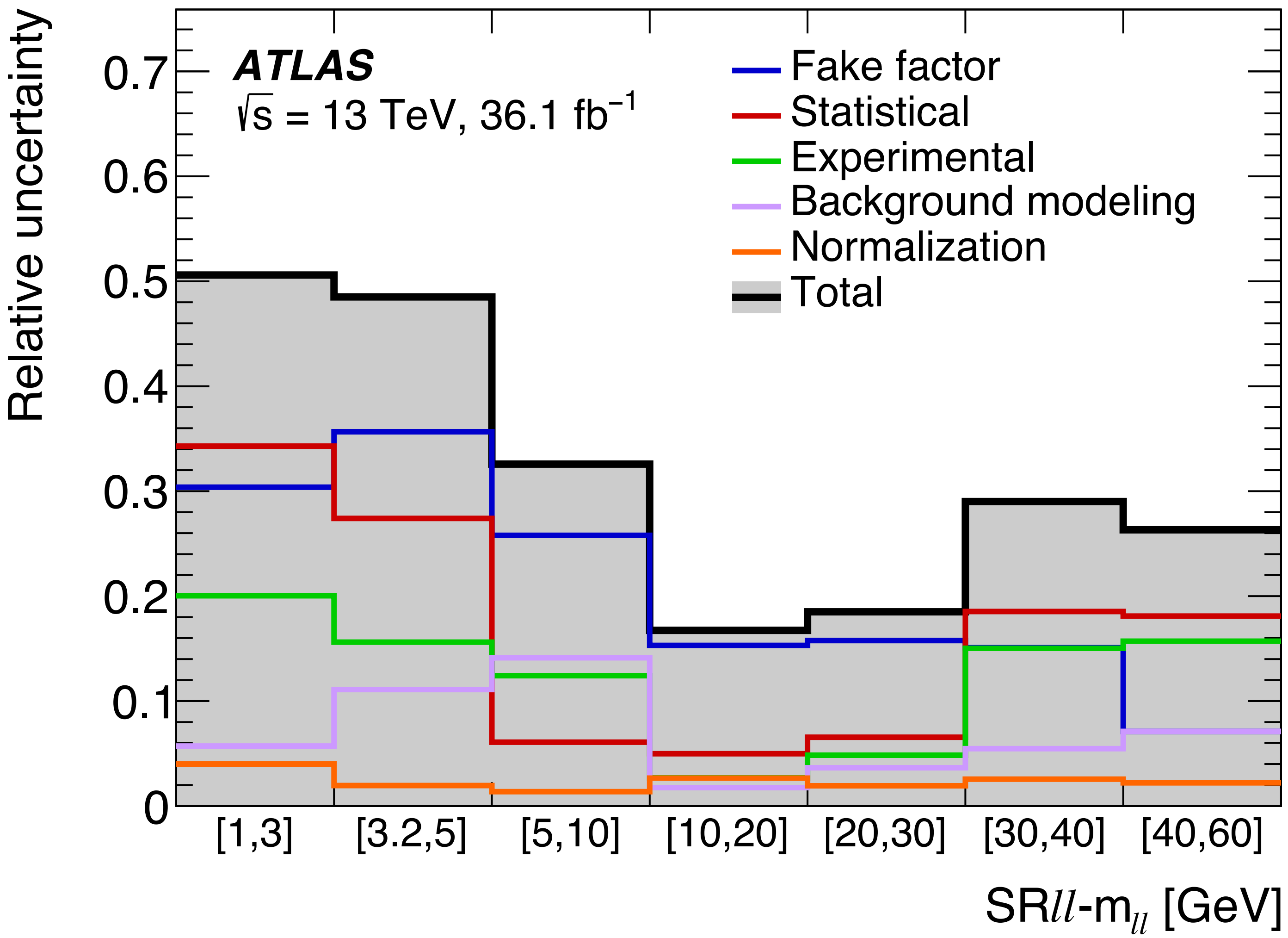
Backup

Soft Lepton Distributions



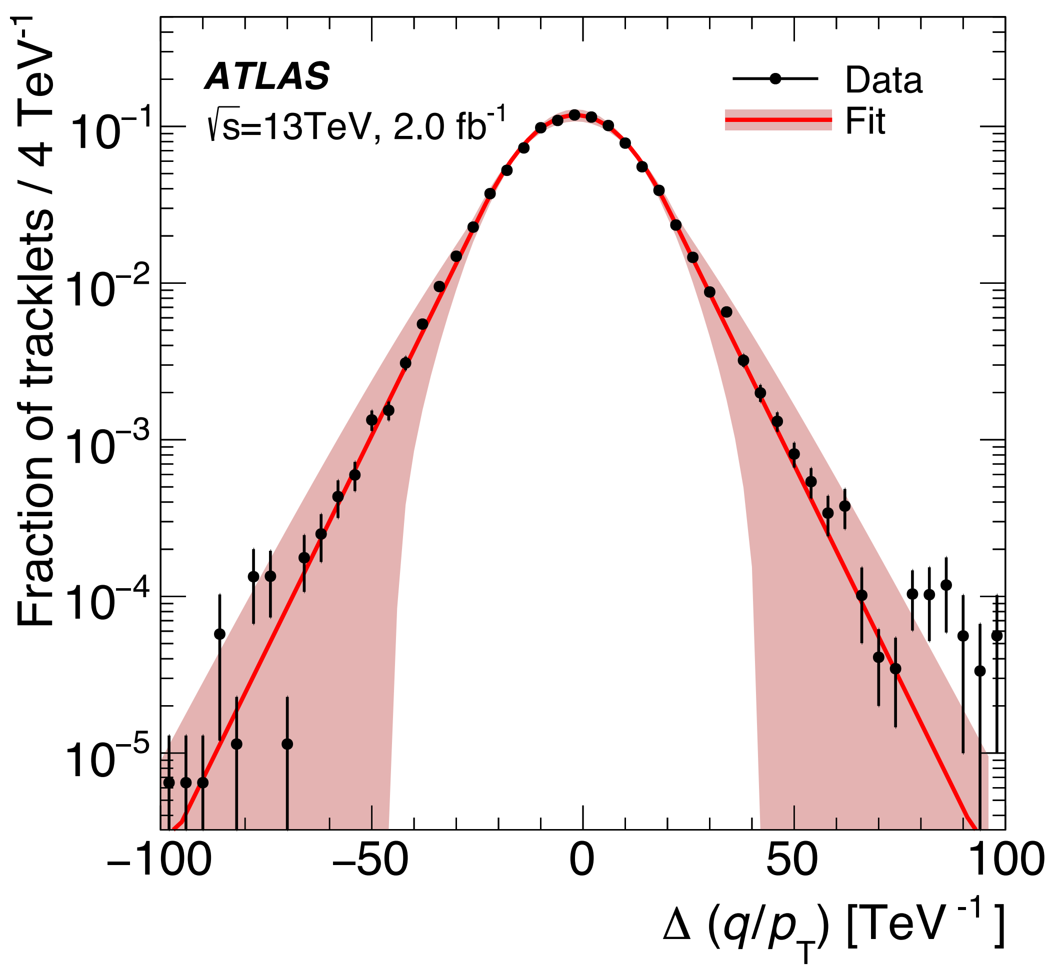


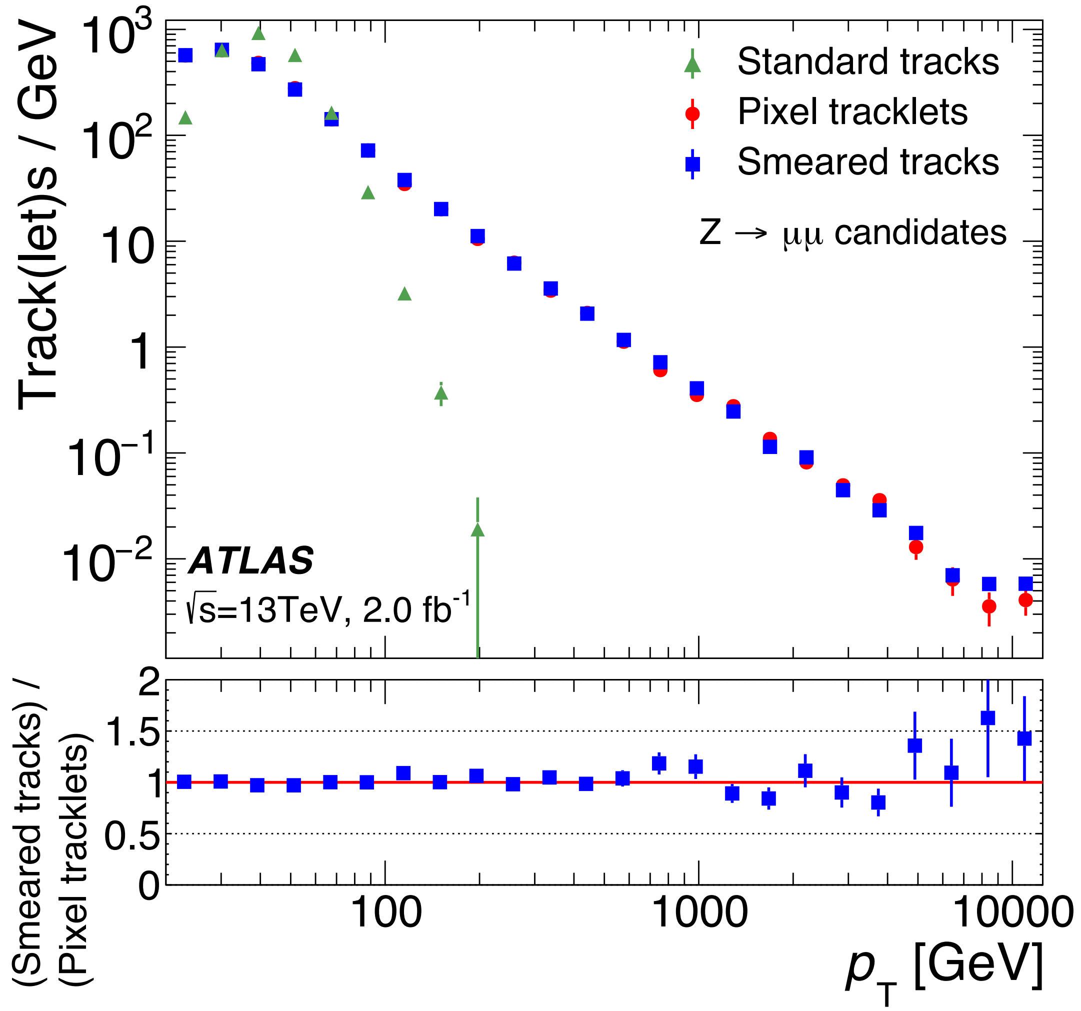
Soft Lepton Uncertainties



Tracklet Backgrounds

pT Smearing Estimation





Tracklet Uncertainties

<table>
<tr><th>Relative uncertainties [%]</th><th>Electroweak channel</th><th>Strong channel</th></tr>
<tr><td>MC statistical uncertainty</td><td>6.6</td><td>6.5</td></tr>
<tr><td>ISR/FSR</td><td>7.6</td><td>0.2</td></tr>
<tr><td>Jet energy scale and resolution</td><td>2.0</td><td>0.7</td></tr>
<tr><td>Trigger efficiency</td><td>0.2</td><td><0.1</td></tr>
<tr><td>Pile-up modelling</td><td colspan="2">11</td></tr>
<tr><td>Tracklet efficiency</td><td colspan="2">6.9</td></tr>
<tr><td>Luminosity</td><td colspan="2">3.2</td></tr>
<tr><td>Sub-total</td><td>17</td><td>15</td></tr>
<tr><td>Cross-section</td><td>6.4</td><td>28</td></tr>
<tr><td>Total</td><td>18</td><td>32</td></tr>
</table>

High-Mass Regions

	SR-3b-meff1-A	SR-3b-meff2-A	SR-3b-meff3-A	SR-4b-meff1-A	SR-4b-meff1-B	SR-4b-meff2-A	SR-4b-meff2-B	SR-4b-meff1-A-disc
$N_{\text{b-jet}}$	=3	=3	≥3	≥4	≥4	≥4	≥4	≥ 4
E_T^{miss}	> 200							
$\Delta\phi_{\text{min}}^{4j}$	>0.4							
N_{jet}	4-5	4-5	4-5	4-5	4-5	4-6	4-6	4-5
$m_{T,\text{min}}^{b-\text{jets}}$	>150	>150	>130	-	-	-	-	-
m(h1)	110-150							
m(h2)	90-140							
$\Delta R_{\text{max}}^{bb}$	0.4-1.4	0.4-1.4	0.4-1.4	0.4-1.4	1.4-2.4	0.4-1.4	1.4-2.4	0.4-1.4
m_{eff}	600-850	850-1100	>1100	600-850	600-850	850-1100	850-1100	> 600

4b Uncertainties