Searches for Dark Matter and Extra Dimensions with the ATLAS Experiment at the LHC

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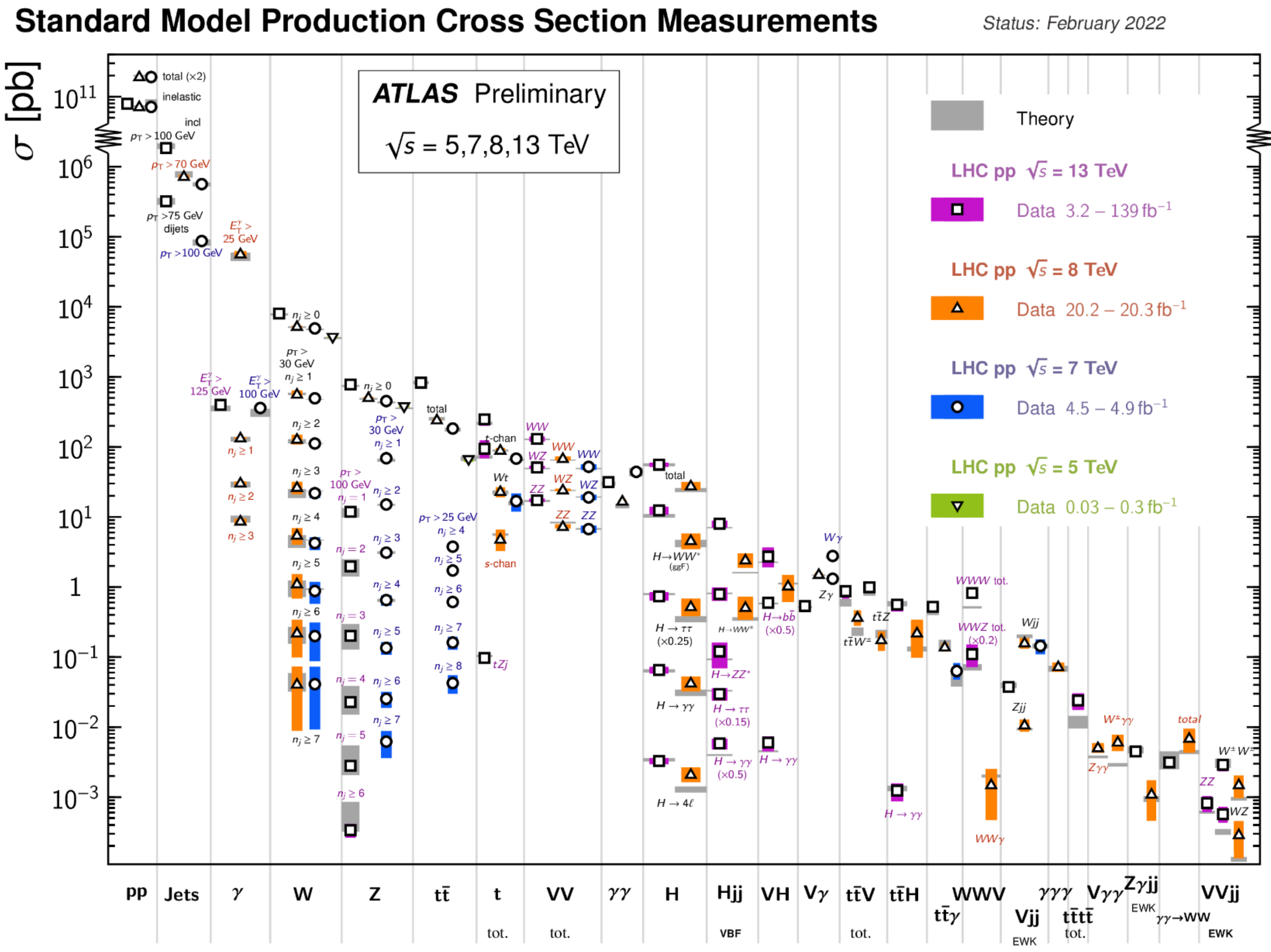
Motivation for Dark Matter Searches @ ATLAS

- The SM theory has successfully explained almost all experimental results and precisely predicted a wide variety of phenomena!

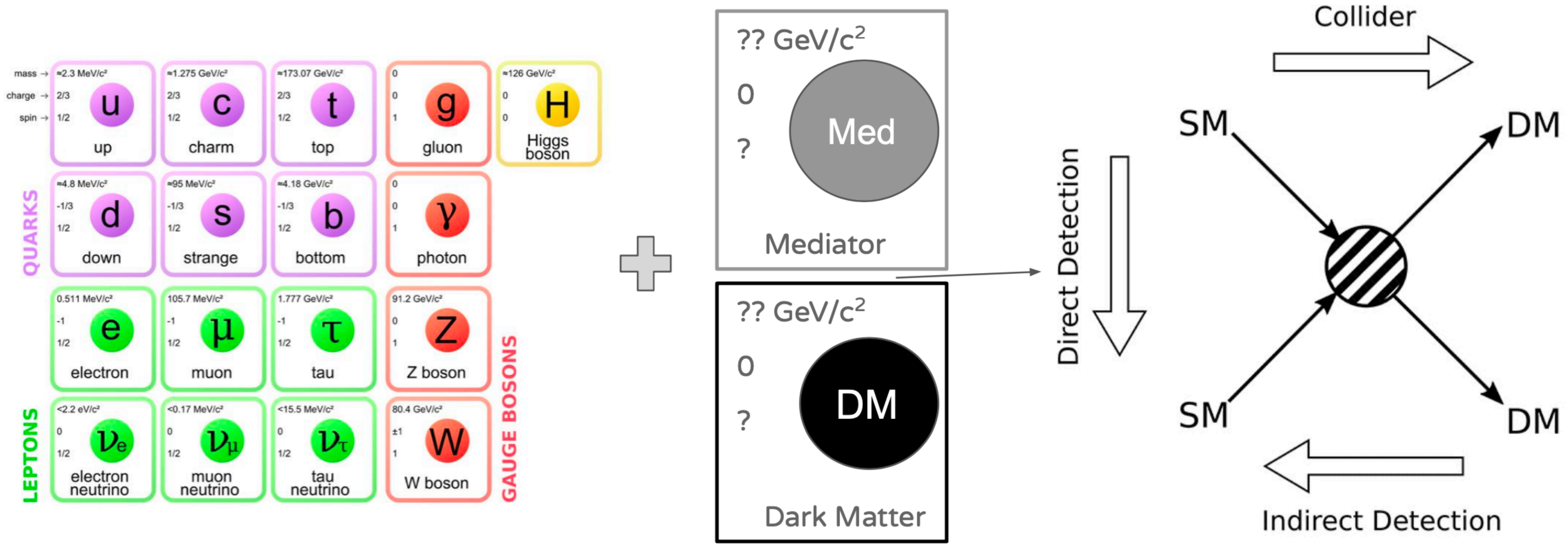
    - **The SM is currently the best description** there is of the subatomic world, **but it does not explain the complete picture.** Still some open questions as hierarchy problem, the origin of neutrino masses, the dark matter…



Exploring SUSY/Exotics signatures

DM couples to SM: This can be studied at colliders ! For example at LHC in pp → SM + DM

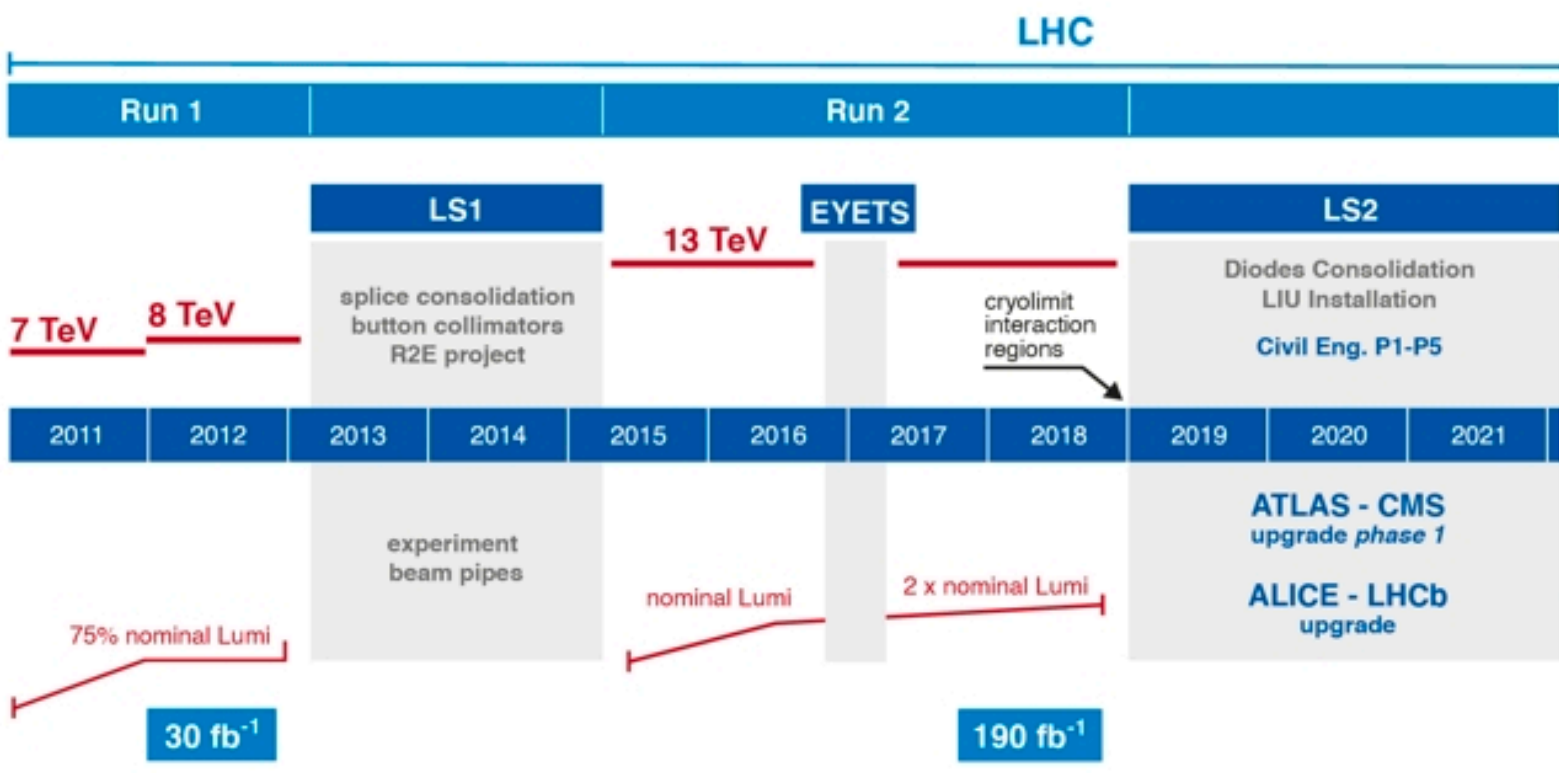
- Many theories predicting DM + SM interactions (DM searches widely use simplified models).
- Assuming an interaction between dark matter and SM particles through mediators (either SM or new as Higgs, Higgs-like, Z′, neutrino…).

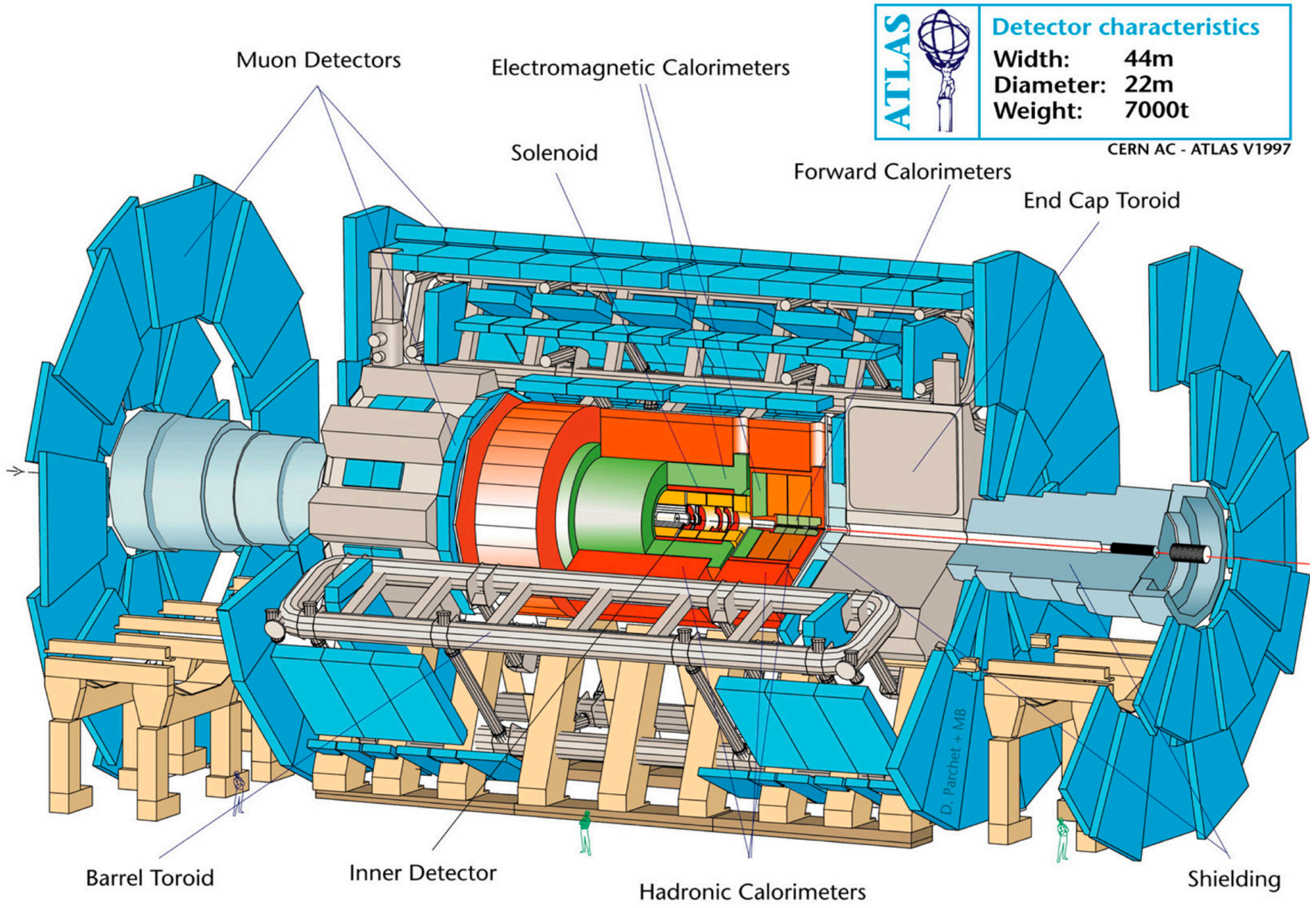


Dark matter searches include (1) direct searches for weakly interacting particles WIMPs in final states with large missing transverse energy and (2) searches for mediators as resonances or exotic signatures. **Many BSM models predict WIMPs as Dark Matter Candidate. In R-parity conserving SUSY models, the lightest SUSY particle LSP is a candidate for dark matter.**

New Physics in ATLAS

ATLAS @ Full Run2 recorded 139 fb^{-1} (year 2015-2018)
ATLAS @ 2015-2016 about 36 fb^{-1}





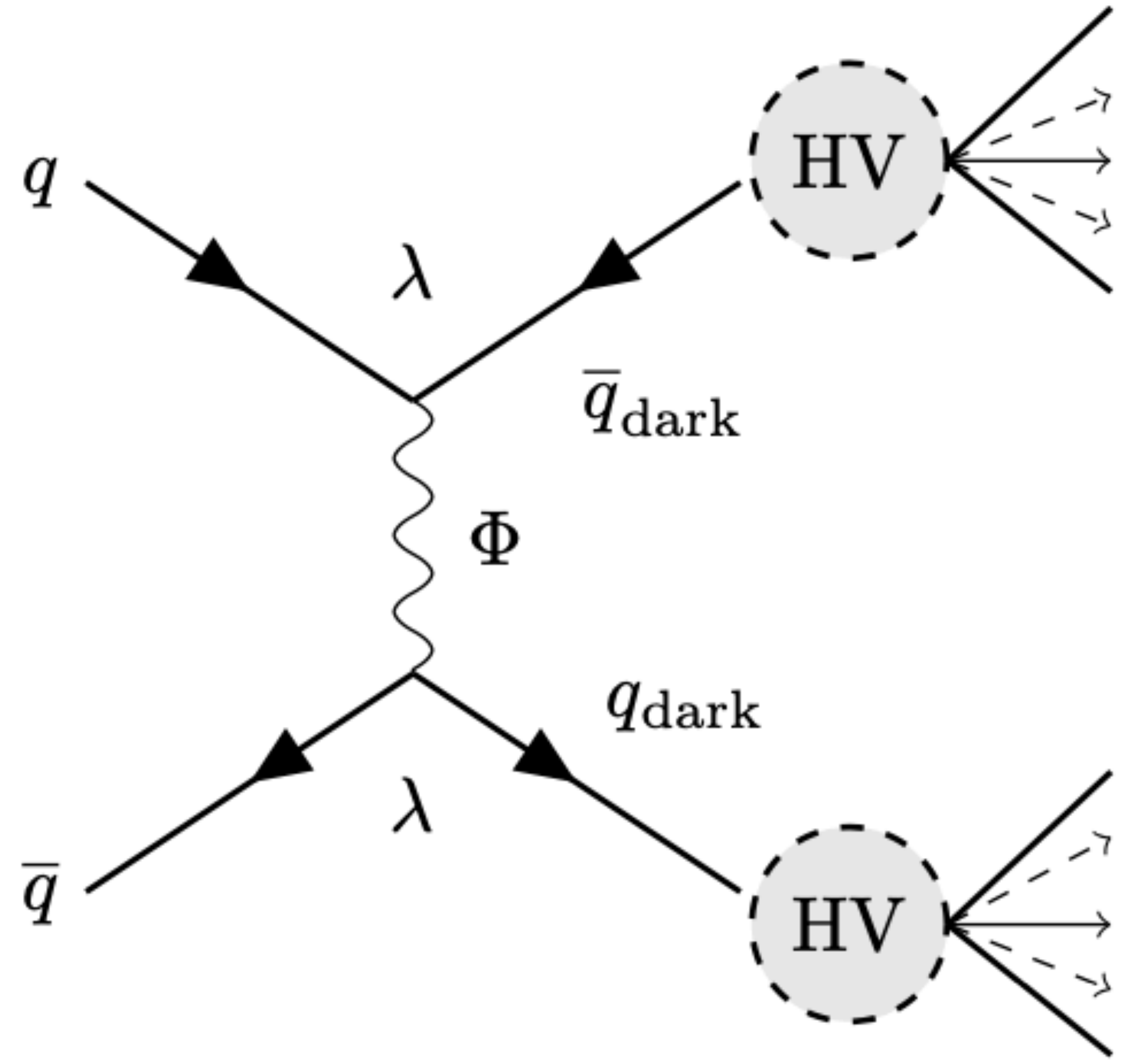
- **In this talk we will explore some dark matter searches in ATLAS with the full Run-2 data of 139 fb^{-1}**
  - Dark quark, Invisible Higgs decays, Higgs decays in dark photons, top + dark matter candidate
  - Production of Winos and Higgsino, direct production of electroweakinos , production of charginos and neutralinos decaying in taus
  - Extra dimension limits on KK-states

Search for non-resonant production of semi-visible jets

ATLAS-CONF-2022-038

This is a search for semi-visible jets (SVJ) in the *t*-channel production mode (non-resonant search). A scalar bi-fundamental mediator (Φ) acts as a portal between the SM and dark sectors. It couples to a SM quark and a dark quark and mediates the production of dark quarks.

- **The ratio of the rate of stable dark hadrons over the total number of hadrons in the event is correlated to Rinv, which is a free parameter of the model.**



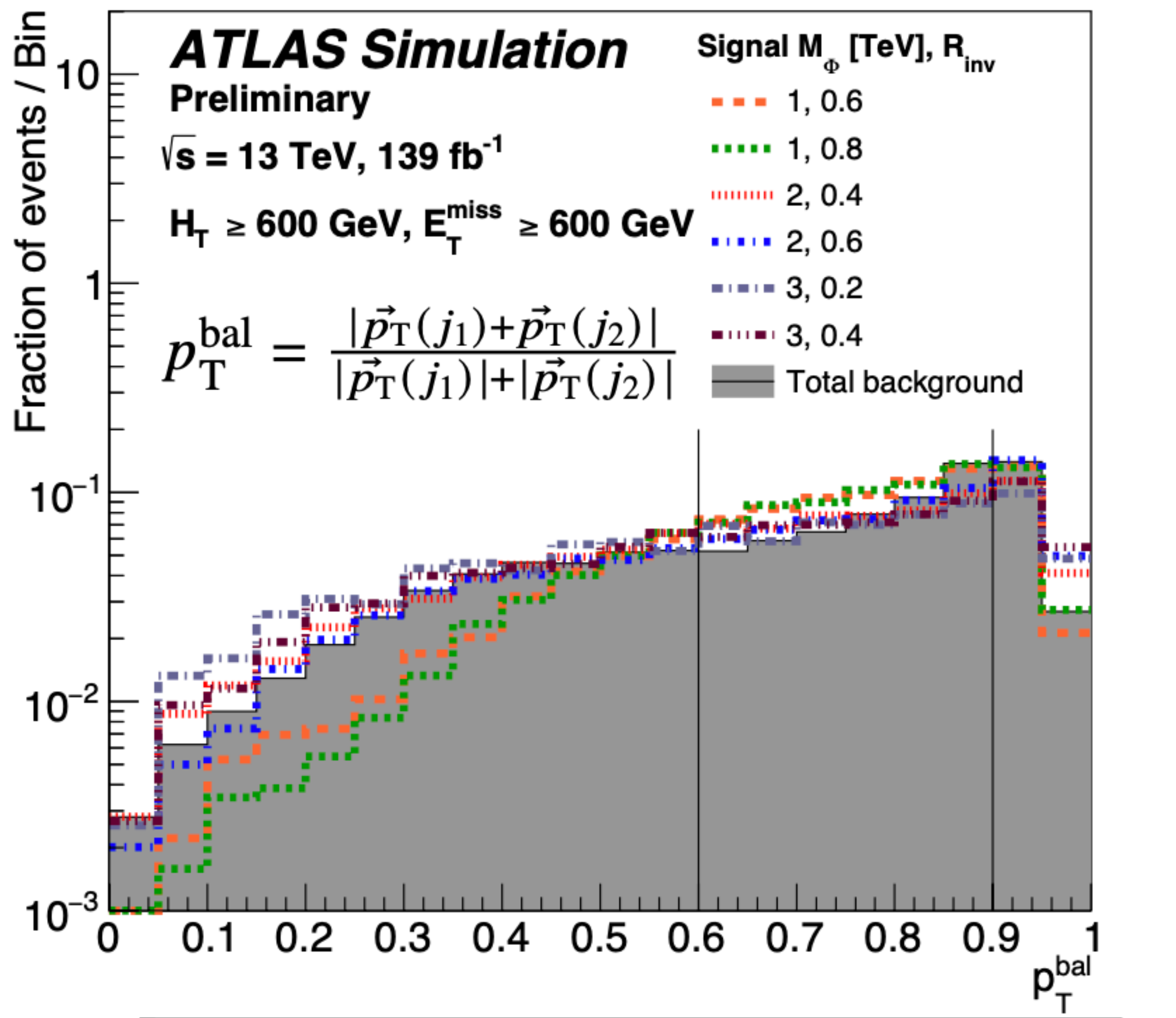
- At leading order the two SVJs are back-to-back and the direction of the missing transverse momentum (E_T^{Miss}) direction is aligned with one of the two reconstructed jets.
  - This signature is dominated by background events from multi-jets processes.

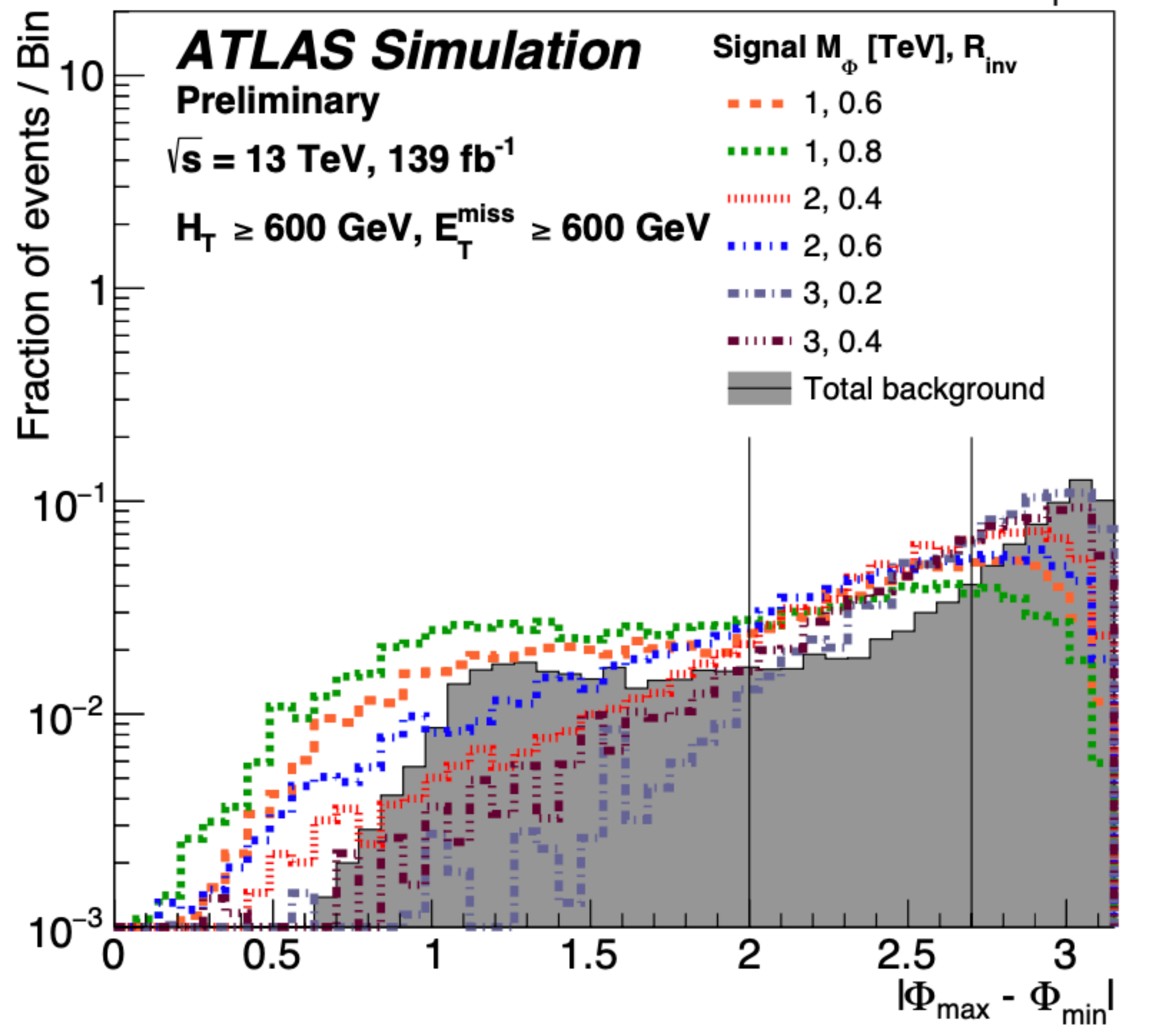
Main Backgrounds:
W/Z+jets , $t\bar{t}$ and single top,
MultiJets, Diboson

Analysis Strategy

ATLAS-CONF-2022-038

- **Events Selection**
  - Unprescaled E_T^{Miss} trigger: 70 GeV up to 110 GeV depending on data taking year.
  - Events with offline $E_T^{Miss} > 250$ GeV are selected in order to have a close to fully efficient trigger.
  - at least two jets within $|\eta| < 2.8$, the leading jet with $p_T > 250$ GeV, other jets with $p_T > 30$ GeV. Events with any electrons or muons are discarded.
  - at least one jet within $\Delta\phi < 2.0$ of the E_T^{Miss} direction. The distance of the closest jet to E_T^{Miss} direction decreases with higher R_{inv} fraction
- **Two key uncorrelated observables:**
  - the difference in the azimuthal angle between j_1 and j_2 as defined above, termed $|\phi_{max}-\phi_{min}|$
  - the p_T balance between the closest jet (j_1) and farthest jet (j_2) from E_T^{Miss} direction

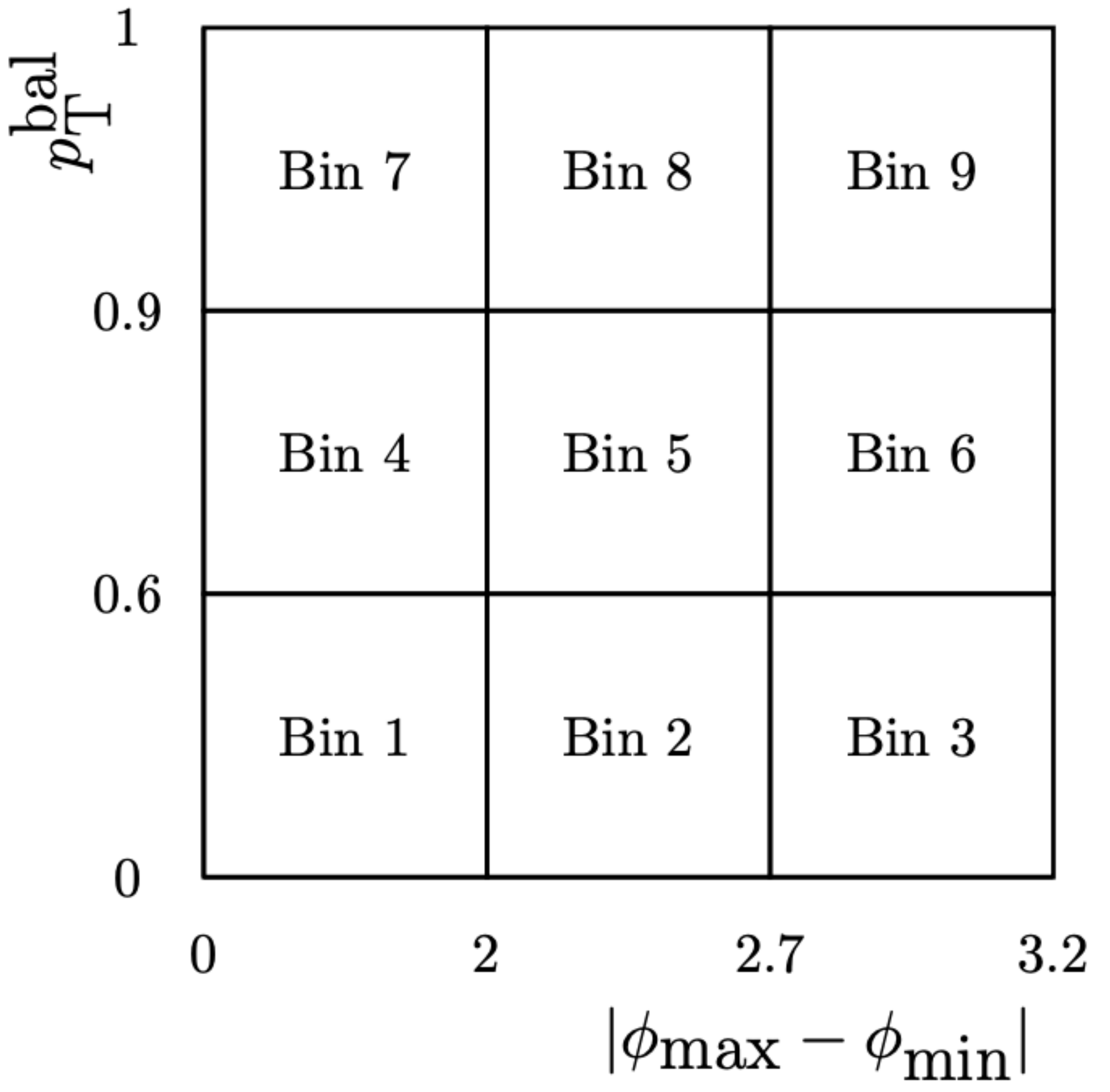


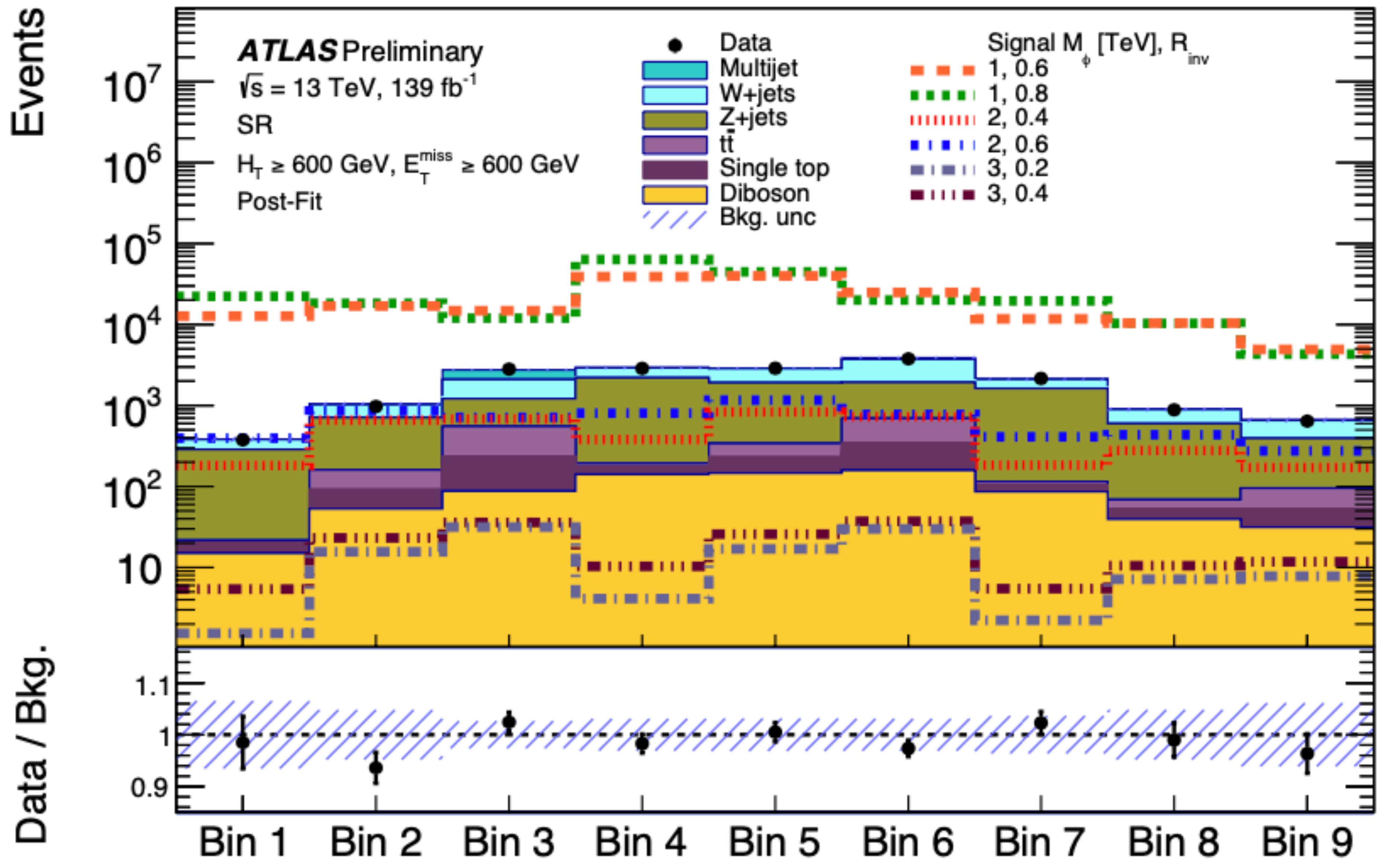


Analysis Regions

[ATLAS-CONF-2022-038]

- **Signal Region (SR):** E_T^{Miss} > 600 GeV and H_T > 600 GeV
  (H_T is the scalar sum of p_T of jets in the event)
- **Control Regions (CR):** the control regions are defined using the muon and b-tagged jet requirements with the same E_T^{Miss} and H_T requirements as in the SR:
  - **1L: exactly one muon and no b-tagged jet.** Dominated by W+jets events
  - **1L1B: exactly one muon and exactly one b-tagged jet.** Dominated by semi-leptonic $t\bar{t}$ and single top quark processes.
  - **2L: two opposite charged muons with di-muons mass 66 GeV < $M_{\mu\mu}$< 116 GeV, and no b-tagged jets.** Only Z+jet events
- **Validation Regions (VR):** 250 GeV <E_T^{Miss} < 300 GeV and 300 GeV <E_T^{Miss} < 600 GeV with the same H_T> 600 GeV of the SR.

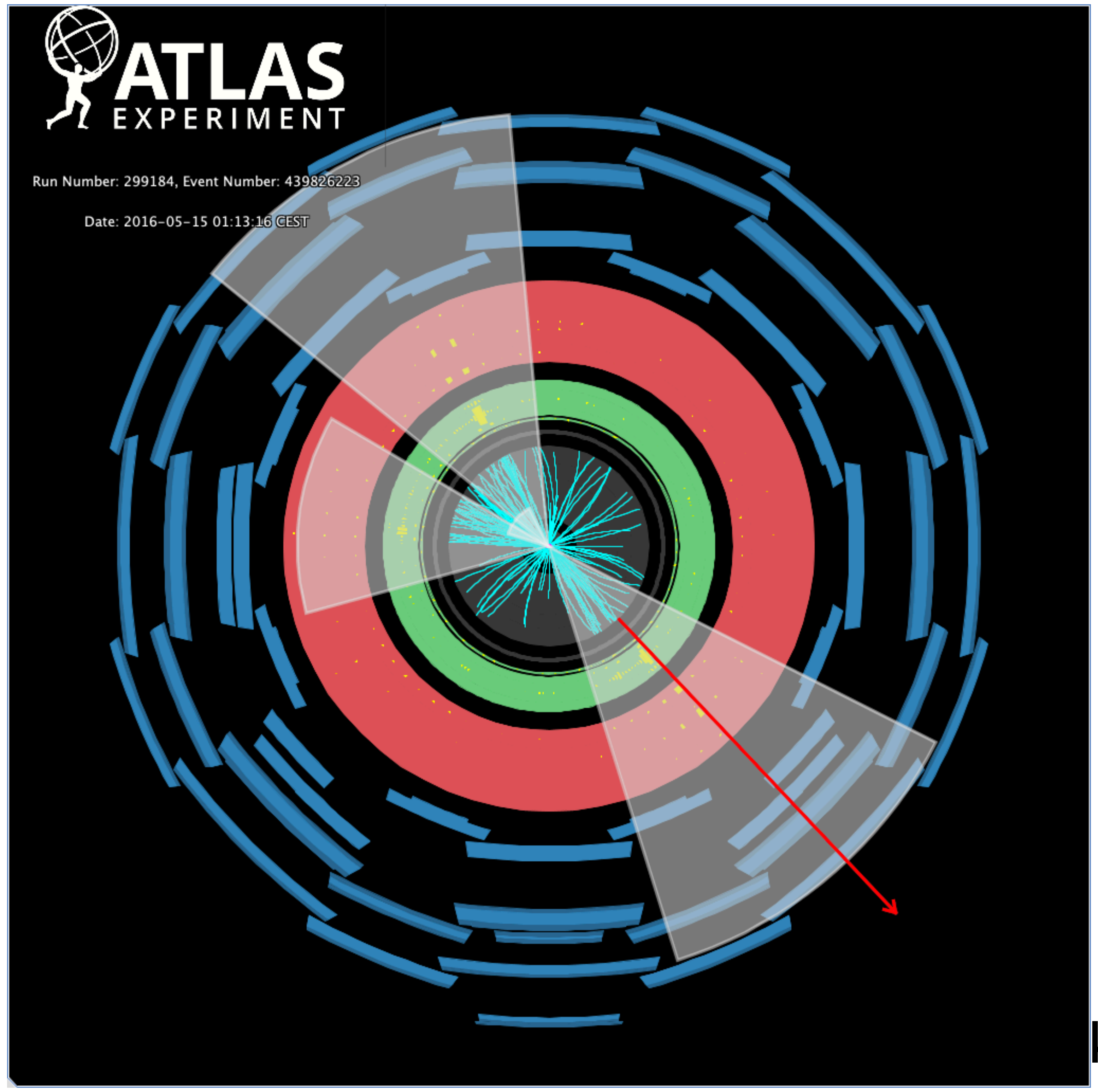


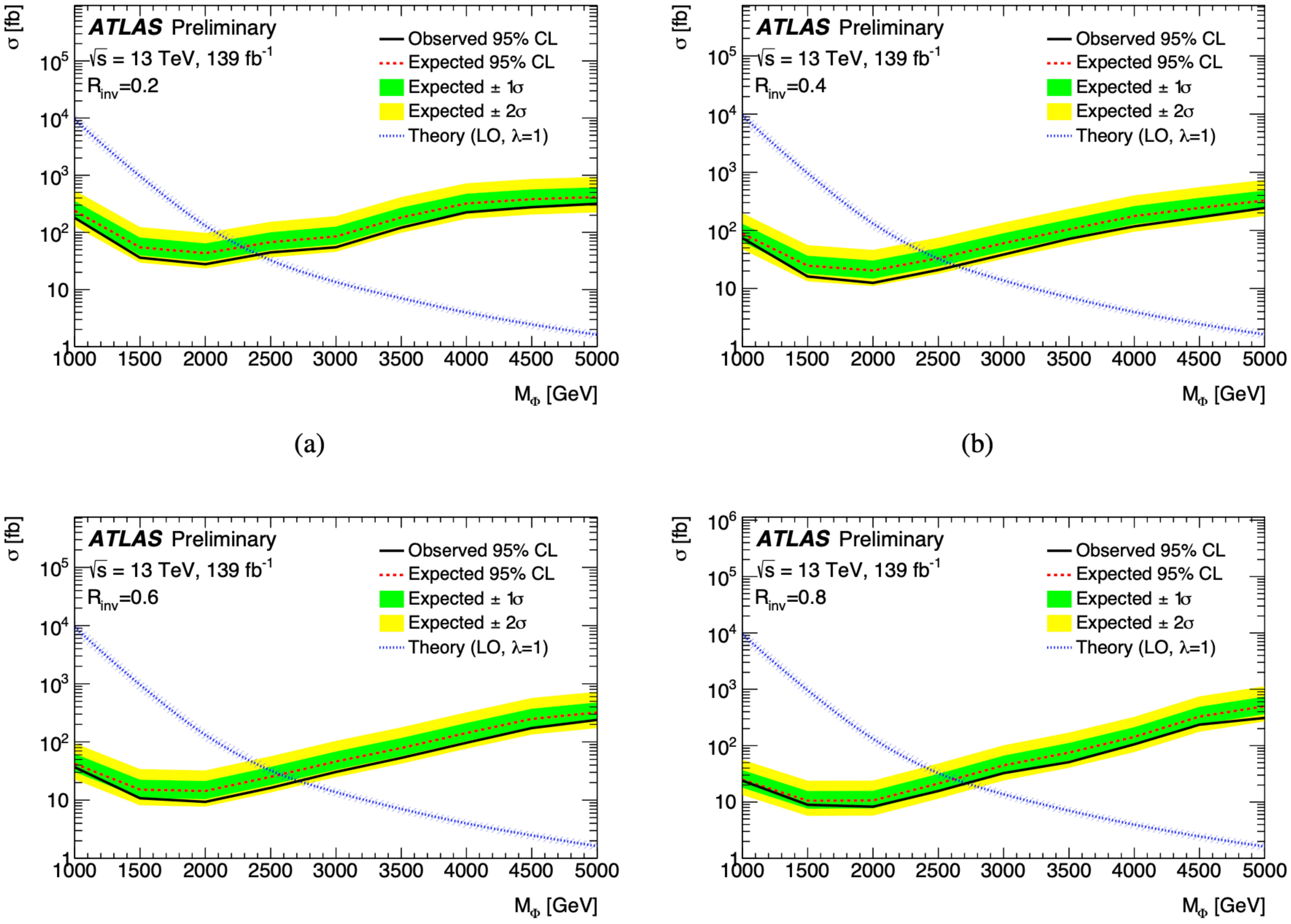


Results

ATLAS-CONF-2022-038

The 95% CL upper limit on the semi-visible jet production cross-section as a function of mediator mass are shown for invisible fraction of 0.2 (a), 0.4 (b), 0.6 (c), and 0.8 (d).





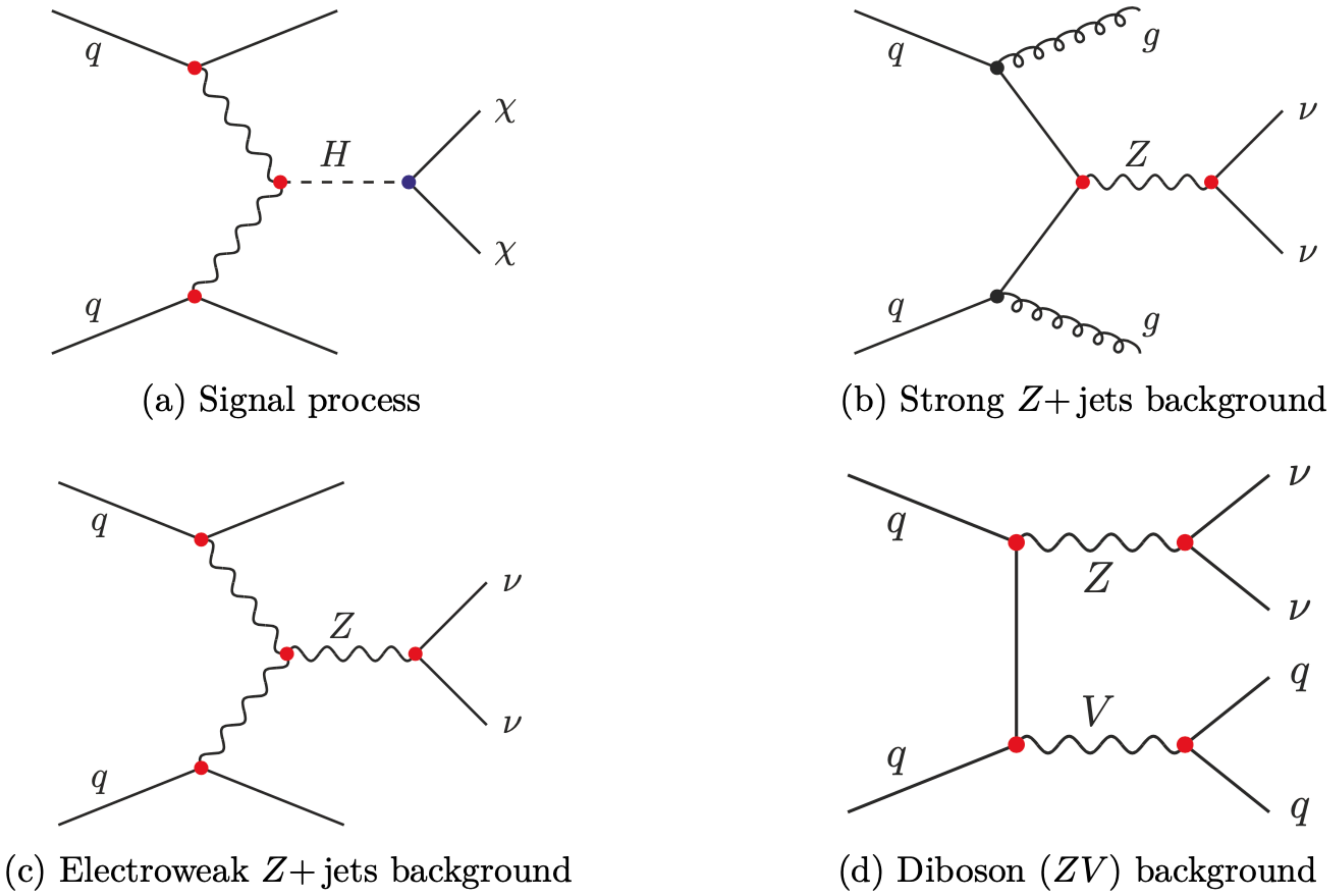
(a) (b) (c) (d)

Invisible Higgs-boson decays in vector-boson fusion

JHEP 08 (2022) 104

Direct search for Higgs bosons produced via vector-boson fusion and subsequently decaying into invisible particles

- This search targets the VBF production process: distinct signature of a pair of energetic quark-induced jets with a wide gap in pseudorapidity ($\Delta\eta_{jj}$) resulting in a large invariant mass (m_{jj}).
  - Higgs boson production via the gluon-gluon fusion (ggF) and in association with a vector boson (V H) are also considered as signal, but their contributions are small compared to the VBF process after the selection.

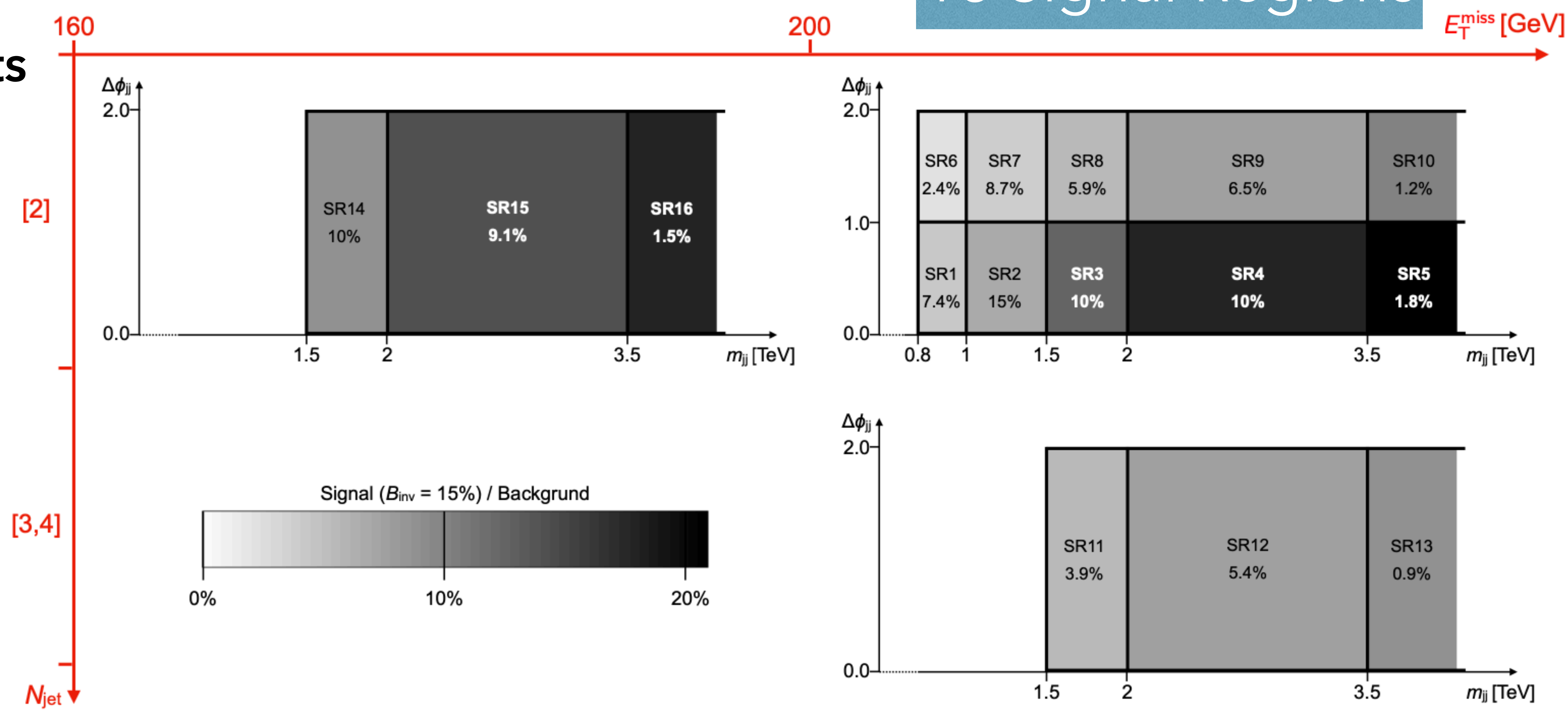


Event Selection

JHEP 08 (2022) 104

- **Events Selection**
  - **Unprescaled E_T^{Miss} trigger**: 70 Gev up to 110 GeV depending on data taking year
  - **no lepton candidate, nor a photon but 2,3,4 jets**
    - **3,4 from Final State Radiation FSR: cuts on centrality less than 1 and small invariant mass (with one of leading two jets)**
  - **E_T^{Miss} >160 GeV**, which strongly suppresses the multijet background
  - **$p_T^{all-jets}$ > 140 GeV and two leading jets $\Delta\varphi jj$ < 2** : suppress the multijet background
  - **The two leading jets must fulfil the VBF topology** requirements of opposite longitudinal hemispheres ($\eta^{j1}\eta^{j2}$ < 0), large pseudorapdidity separation ($\Delta\eta jj$> 3.8), and large invariant mass (mjj> 0.8 TeV).

16 Signal Regions



Results

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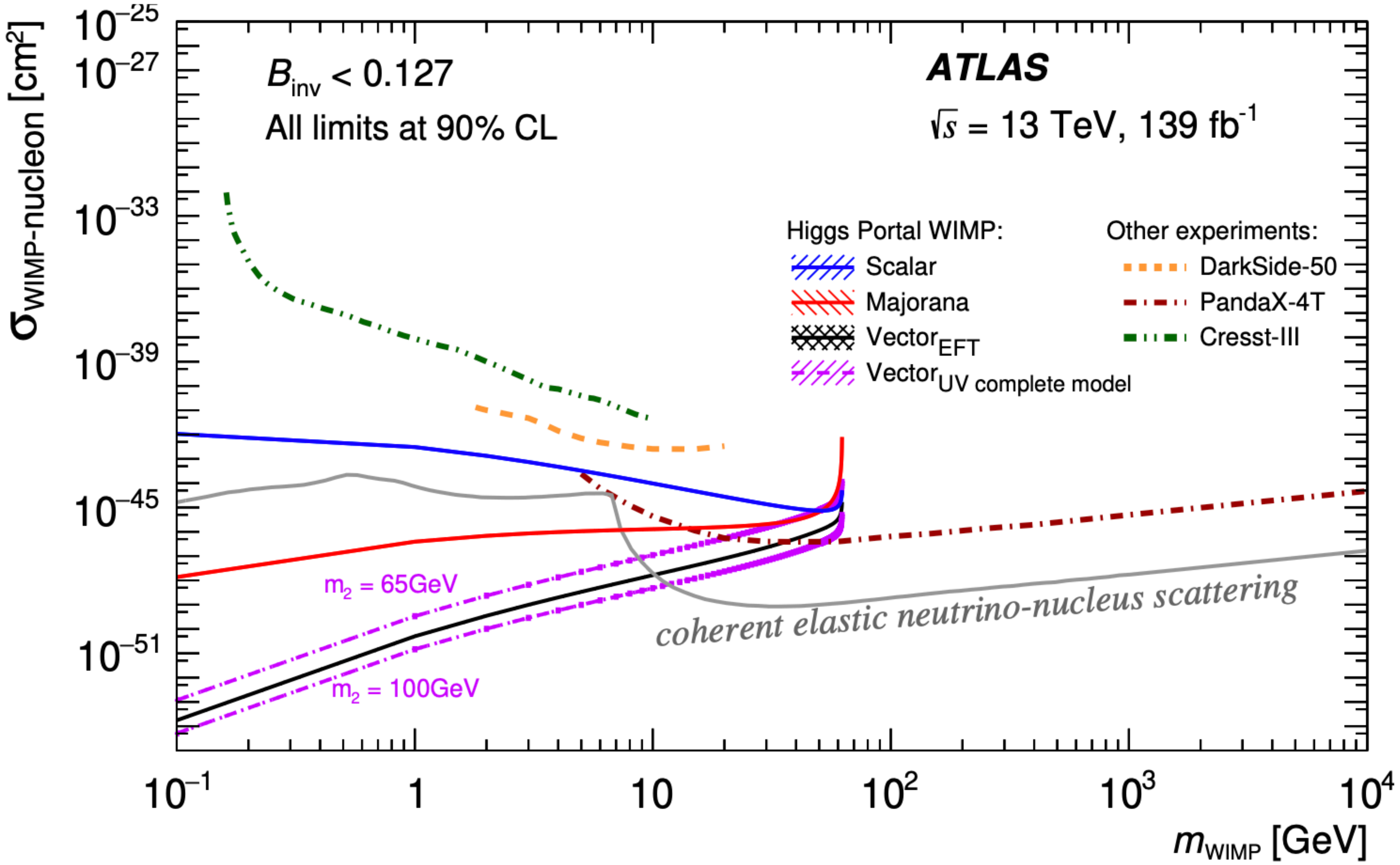
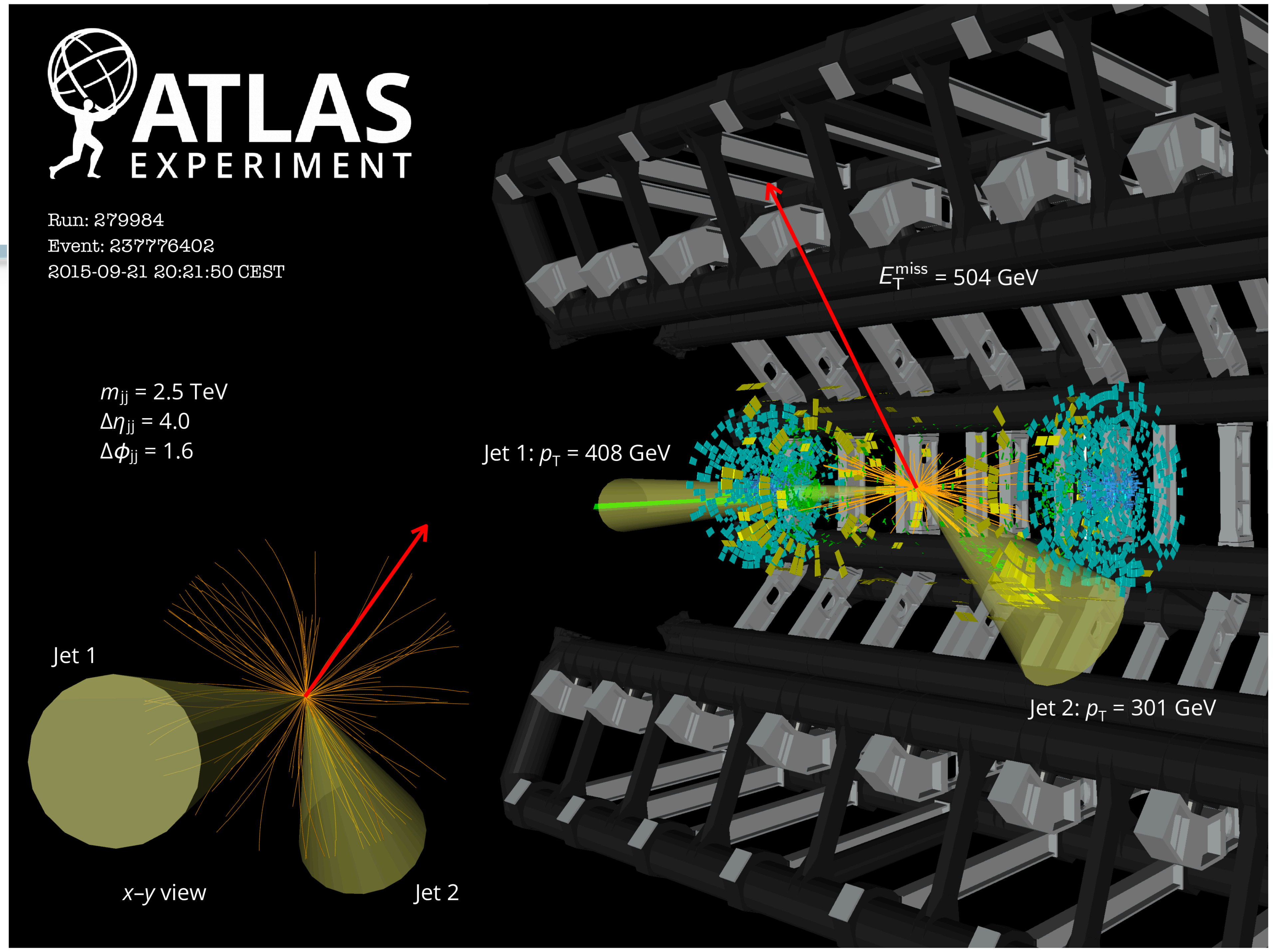
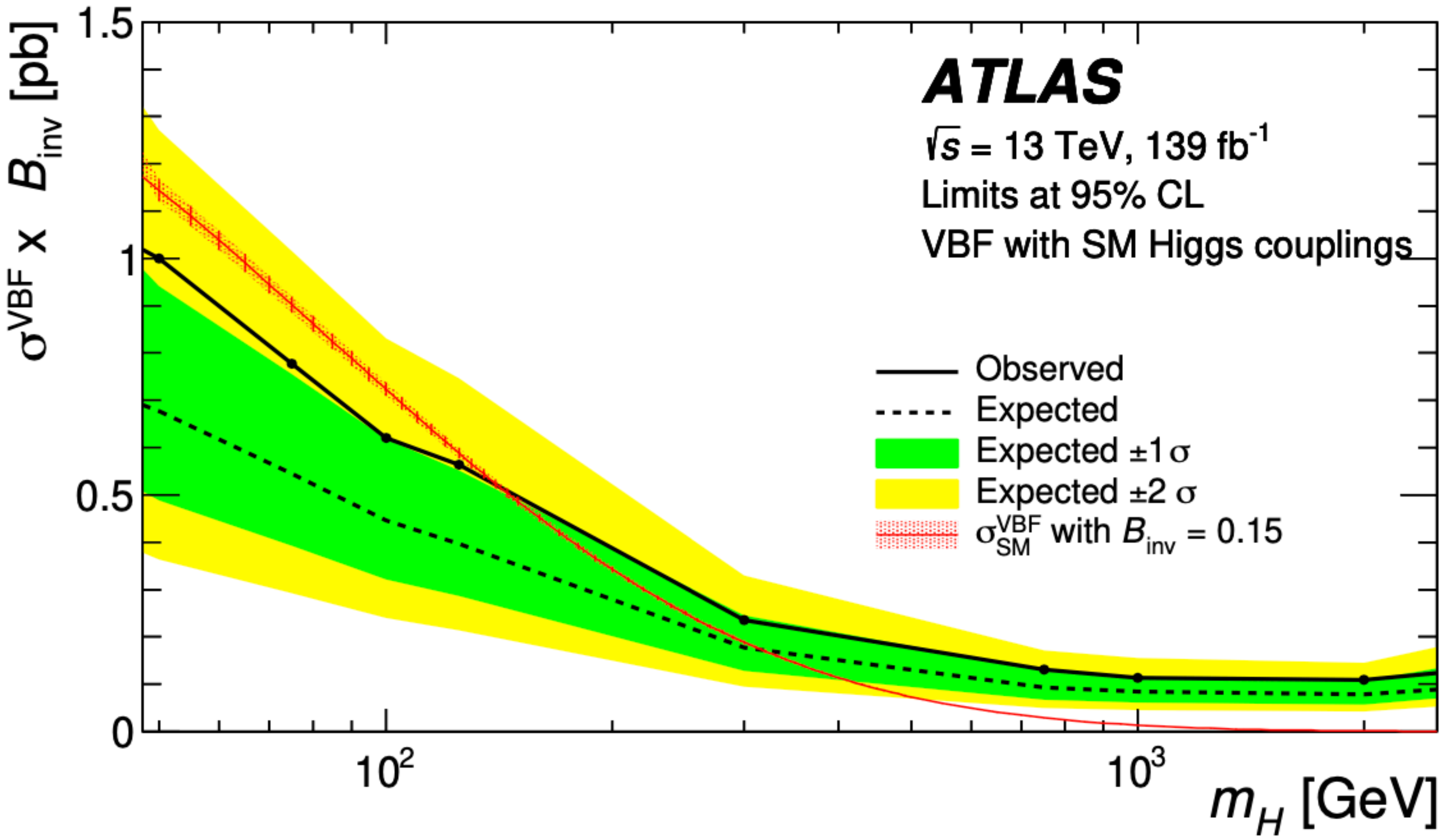
These results are interpreted in the context of models where the Higgs boson acts as a portal to dark matter, and limits are set on the scattering cross section of weakly interacting massive particles and nucleons. More on Higgs2022 presentation.



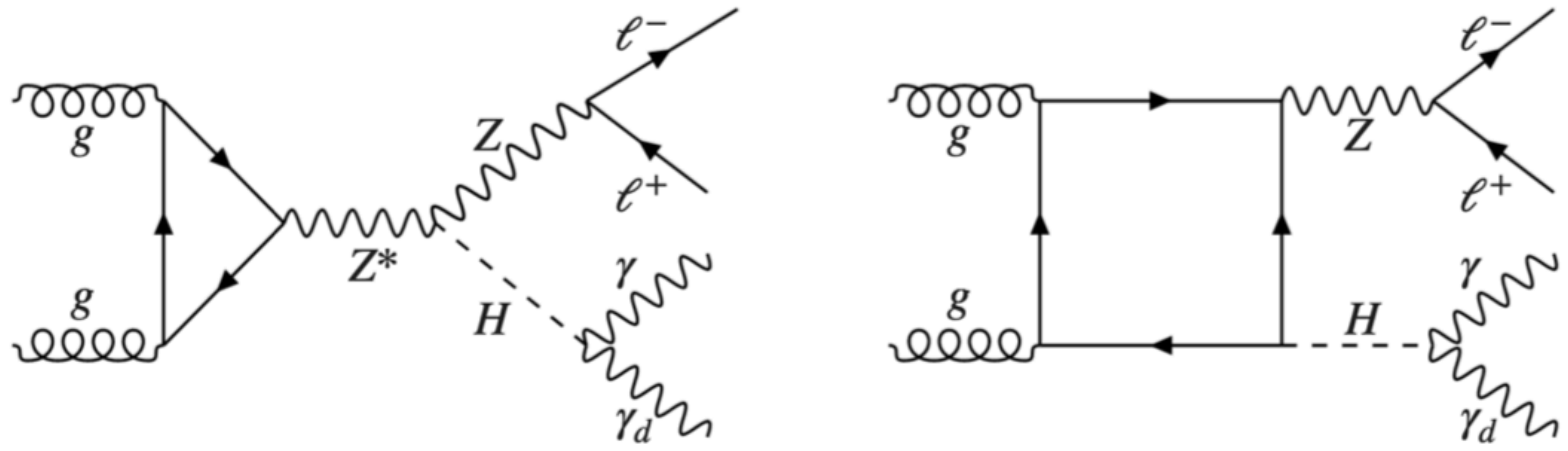




H boson decays in dark photon in HZ production

ATLAS-CONF-2022-064

This is a search for dark photons (γ_d) in Higgs boson decay ($H \rightarrow \gamma\gamma_d$) produced in proton-proton collisions through the Z H production mode where $Z \rightarrow ll$ ($l = e, \mu$)



- Final state consists of two same-flavour, opposite-charge electrons or muons, an isolated photon and missing transverse momentum

- Analysis constraints on:
  - **Z boson mass for the two leptons**
  - **Photon and E_T^{Miss} originating from a SM Higgs boson decay**

Main Backgrounds:
W/Z+jets , $t\bar{t}$ and single top,
MultiJets, Diboson

Analysis Strategy and Results

ATLAS-CONF-2022-064

Two same flavour, opposite sign, medium ID and loose isolated leptons, with leading $p_T > 27$ GeV, sub-leading $p_T > 20$ GeV
Veto events with additional lepton(s) with loose ID and $p_T > 10$ GeV
76 GeV $< m_{\ell\ell} <$ 116 GeV
Only one tight ID, tight isolated photon with $E_T^{\gamma} > 25$ GeV
$E_T^{miss} > 60$ GeV with $\Delta\phi(\vec{E}_T^{miss}, \vec{p}_T^{\ell\ell\gamma}) > 2.4$ rad
$m_{\ell\ell\gamma} > 100$ GeV
$N_{jet} \leq 2$, with $p_T^{jet} > 30$ GeV, $\|\eta\| < 4.5$
Veto events with b-jet(s)

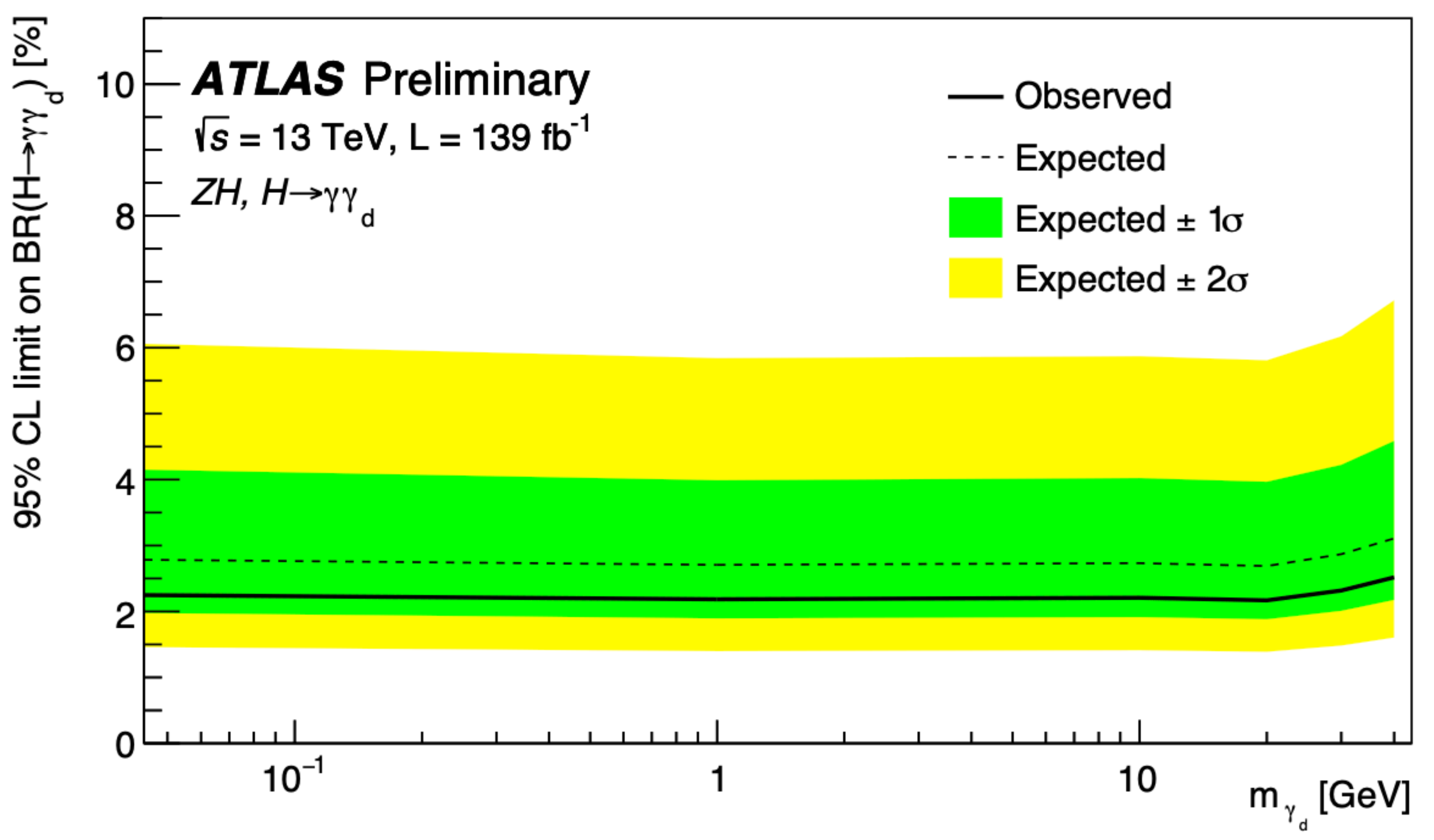
Event Selection:

- Single lepton trigger.
- A set of cuts on offline level to identify Z and H decays
- Finally a boosted decision tree (**BDT**) algorithm was implemented including **6 observables** (according to their ranking):
  - S (E_T^{Miss} significance), m_T, m_{ll}, $p_{T(\gamma)}$, $m_{ll\gamma}$, and $|p_T|$
- Several Control/Validation regions. For estimating the background from fake E_T^{Miss} a data driven ABCD method was used.

The observed (expected) upper limits on BR(H→ γγd) are at the level of 2.3% (2.8%) for massless γd, moving to 2.5% (3.1%) for mass (γd) of 40 GeV.

$$m_T = \sqrt{2E_T^{miss} p_T^{\gamma}[1 - \cos[\Delta\phi(\vec{E}_T^{miss}, \vec{p}_T^{\gamma})]]}$$

$$|p_T| = \frac{|\vec{E}_T^{miss} + \vec{p}_T^{\gamma}| - p_T^{\ell\ell}}{p_T^{\ell\ell}}$$

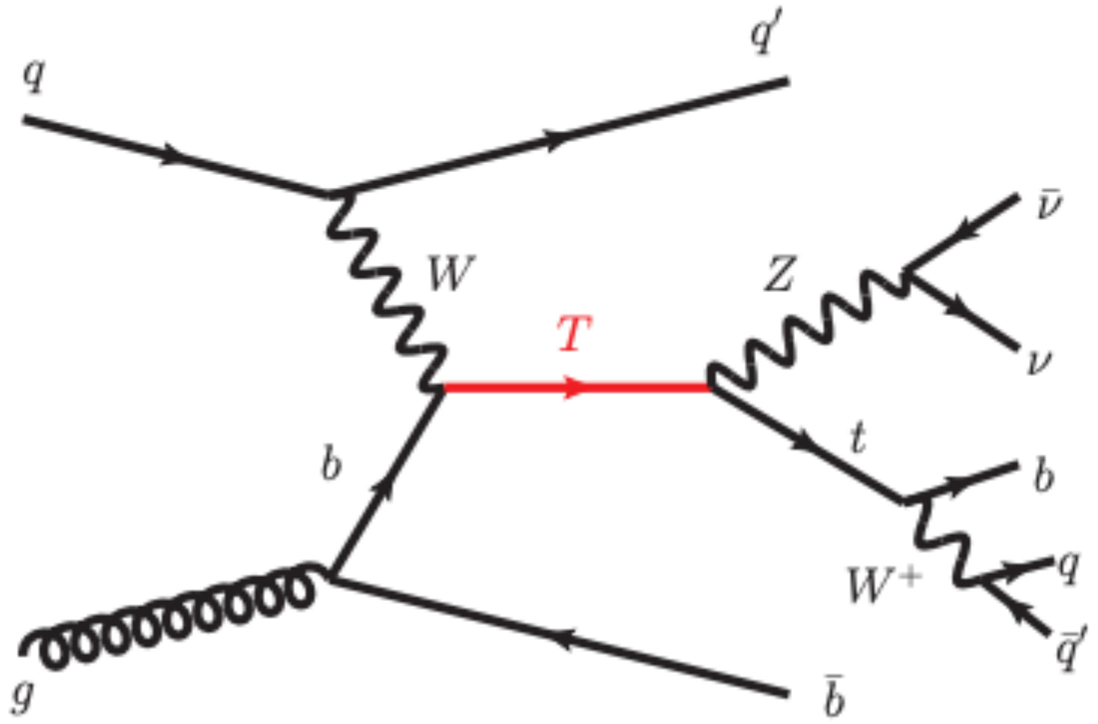


Invisible particles produced in association with single top quarks

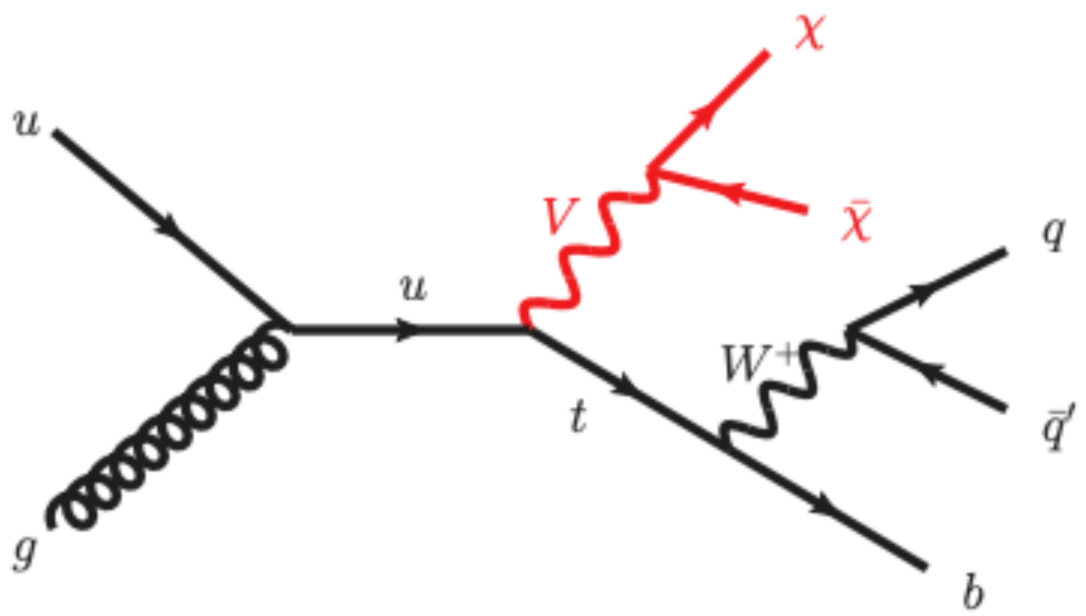
The search look for events with one top quark and missing transverse momentum in the final state. The results are interred in terms of simplified models.

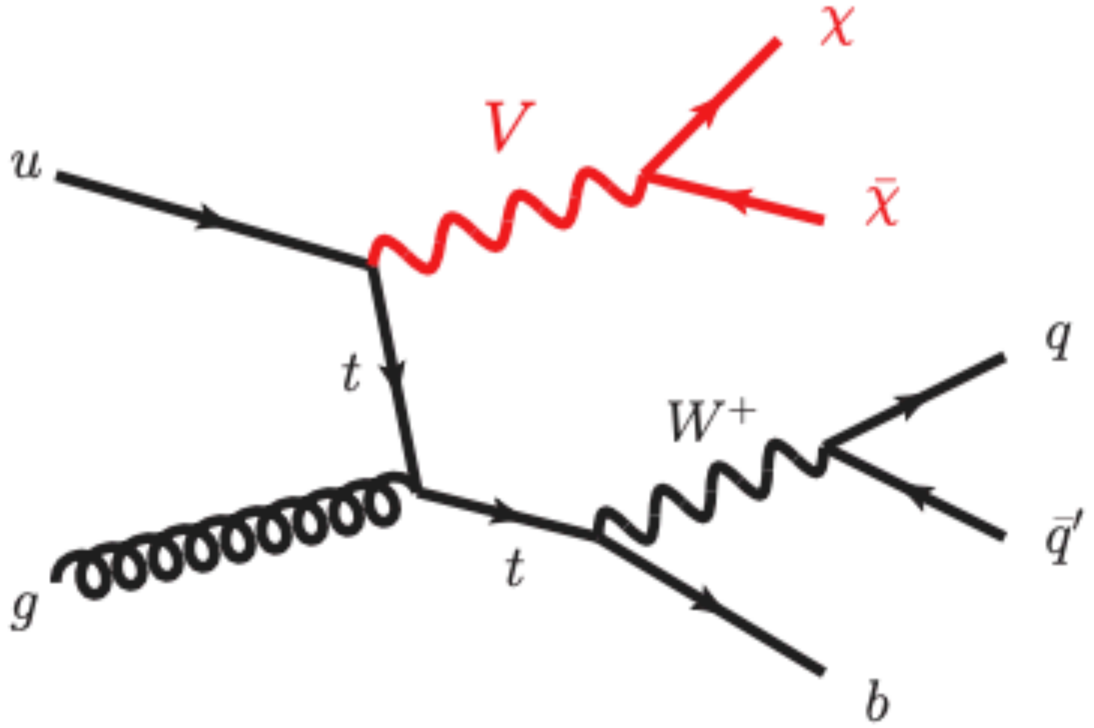
Experimentally: presence of a top quark and significant missing transverse momentum.

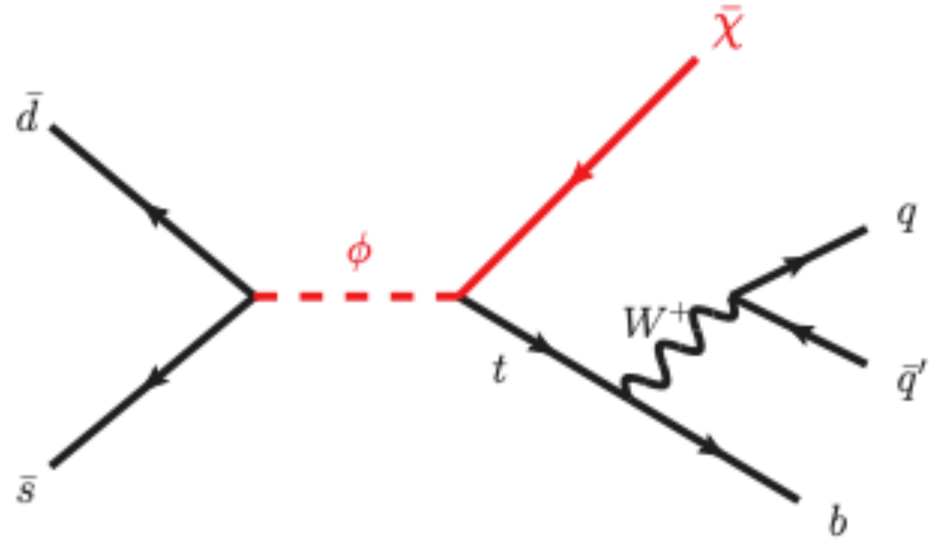
Single production of a vector-like Tquark via WTb and ZTt vertices. The contribution via ZTt vertex is highly suppressed by the requirement of a top quark in the initial state.



Dark Matter particle production in association with a single top quark: resonant and non-resonant cases







Event Selection

ATLAS-CONF-2022-036

- **Events Selection**
  - **Unprescaled E_T^{Miss} trigger**: 70 GeV up to 110 GeV depending on data taking year
    - Offline E_T^{Miss} **>250 GeV** to reduce the number of multijet background
  - **zero leptons and at least one large-R jet (large radius defined as $\sqrt{\Delta\phi^2 + \Delta\eta^2}$ =1.0)**
    - The leading large-R jet is then required to be top-tagged and have a p_T within 350 and 2500 GeV, and a mass between 40 and 600 GeV
    - $\Delta\phi_{min}$ (jet, E_T^{Miss}), is required to be larger than 0.2 to remove the contribution from mis-reconstructed E_T^{Miss}
  - **extreme gradient BDT by using several input observables (XGBoost)**

Variable	Description	Resonant DM model	Non-resonant DM model	VLQ
E_T^{miss}	Missing transverse momentum	✓	✓	✓
Ω	E_T^{miss} and large-R jet p_T balance: $\frac{E_T^{miss}-p_T(J)}{E_T^{miss}+p_T(J)}$	✓	✓	✓
N_{jets}	Small-R jet multiplicity	✓	✓	✓
ΔR_{max}	Maximum ΔR between two small-R jets	✓	✓	✓
$m_{T,min}(E_T^{miss}, b\text{-jet})$	Transverse mass of E_T^{miss} and the closest b-tagged jet.	✓	✓	✓
$m_{top\text{-}tagged\ jet}$	Mass of the large-R top-tagged jet	✓		✓
$\Delta p_T(J, \text{jets})$	Scalar difference of large-R jet p_T and the sum of p_T of all small-R jets.	✓	✓	
H_T	Sum of all small-R jet p_T		✓	✓
H_T/E_T^{miss}	Ratio of H_T and E_T^{miss}		✓	✓
$\Delta E(E_T^{miss}, J)$	Energy difference between E_T^{miss} and the large-R jet		✓	✓
$\Delta\phi(E_T^{miss}, J)$	Angular distance in the transverse plane between E_T^{miss} and large-R jet		✓	✓
$p_T(J)$	Large-R jet p_T			✓
$m_T(E_T^{miss}, J)$	Transverse mass of the E_T^{miss} and large-R jet			✓
$\Delta\phi(b\text{-tagged jet}, J)$	Angular distance in the transverse plane between the large-R jet and the leading b-jet			✓

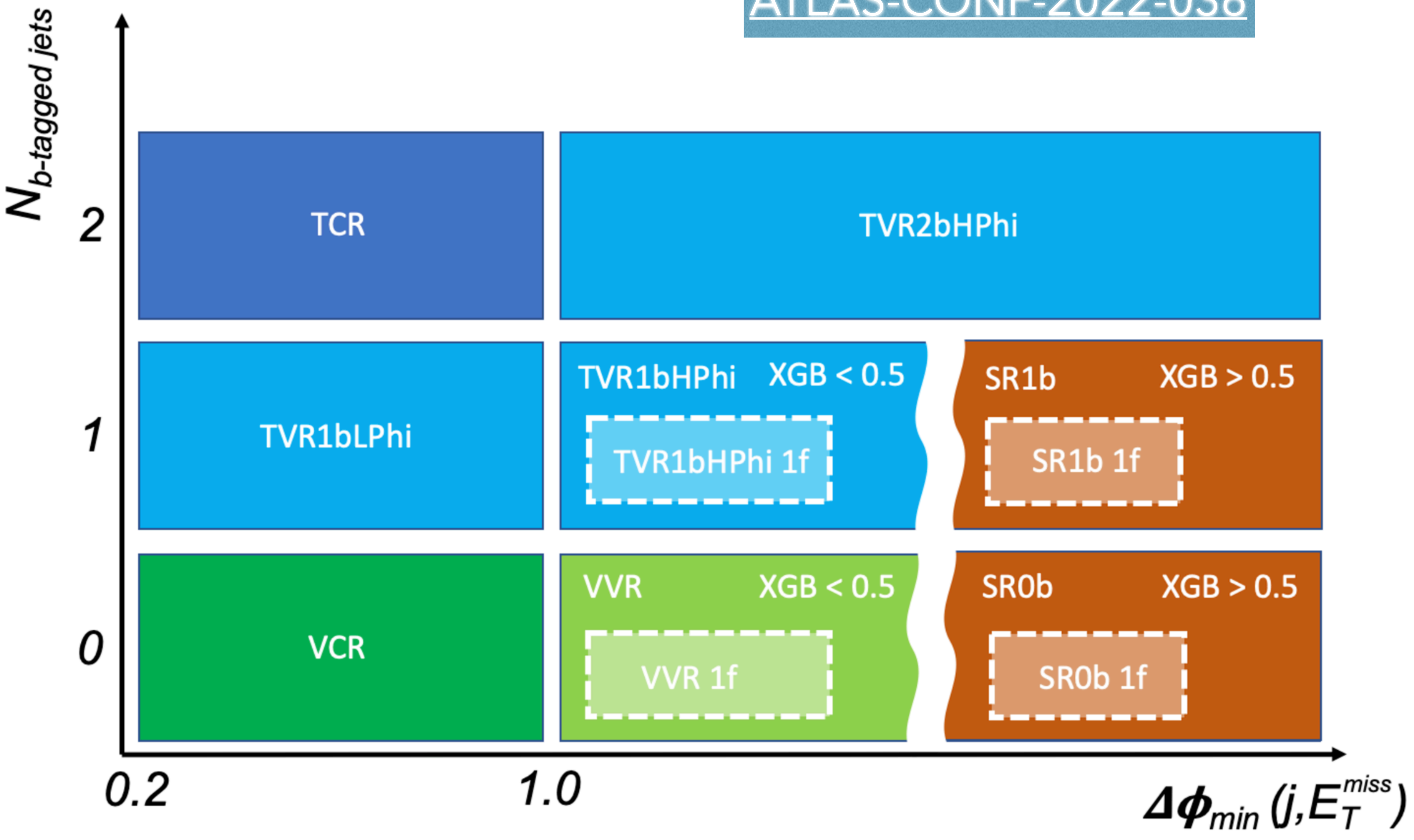
Analysis Regions

ATLAS-CONF-2022-036

All regions are required to contain:

- zero leptons in the final state
- $E_T^{Miss} \geq 250$ GeV
- and at least one top-tagged large-R jets.

- **Two Signal Regions (SRs)** with one or zero b-tagged jet (SR0b, SR1b)
- **Two Control Regions (CRs)**: TCR dominated by $t\bar{t}$ events and VCR dominated by V+jets events
- **Few Validation Regions (VR)**



	$N_{b\text{-tagged jets}}$	$\Delta\phi_{\min}(j, E_T^{\text{miss}})$	BDT score	$N_{\text{forward-jets}}$
TCR	2	$\in [0.2, 1]$	-	-
TVR1bLPhi	1	$\in [0.2, 1]$	-	-
TVR1bHPhi (1f)	1	≥ 1	< 0.5	- (≥ 1)
TVR2bHPhi	2	≥ 1	-	-
VCR	0	$\in [0.2, 1]$	-	-
VVR (1f)	0	≥ 1	< 0.5	- (≥ 1)
SR0b (1f)	0	≥ 1	≥ 0.5	- (≥ 1)
SR1b (1f)	1	≥ 1	≥ 0.5	- (≥ 1)

Results

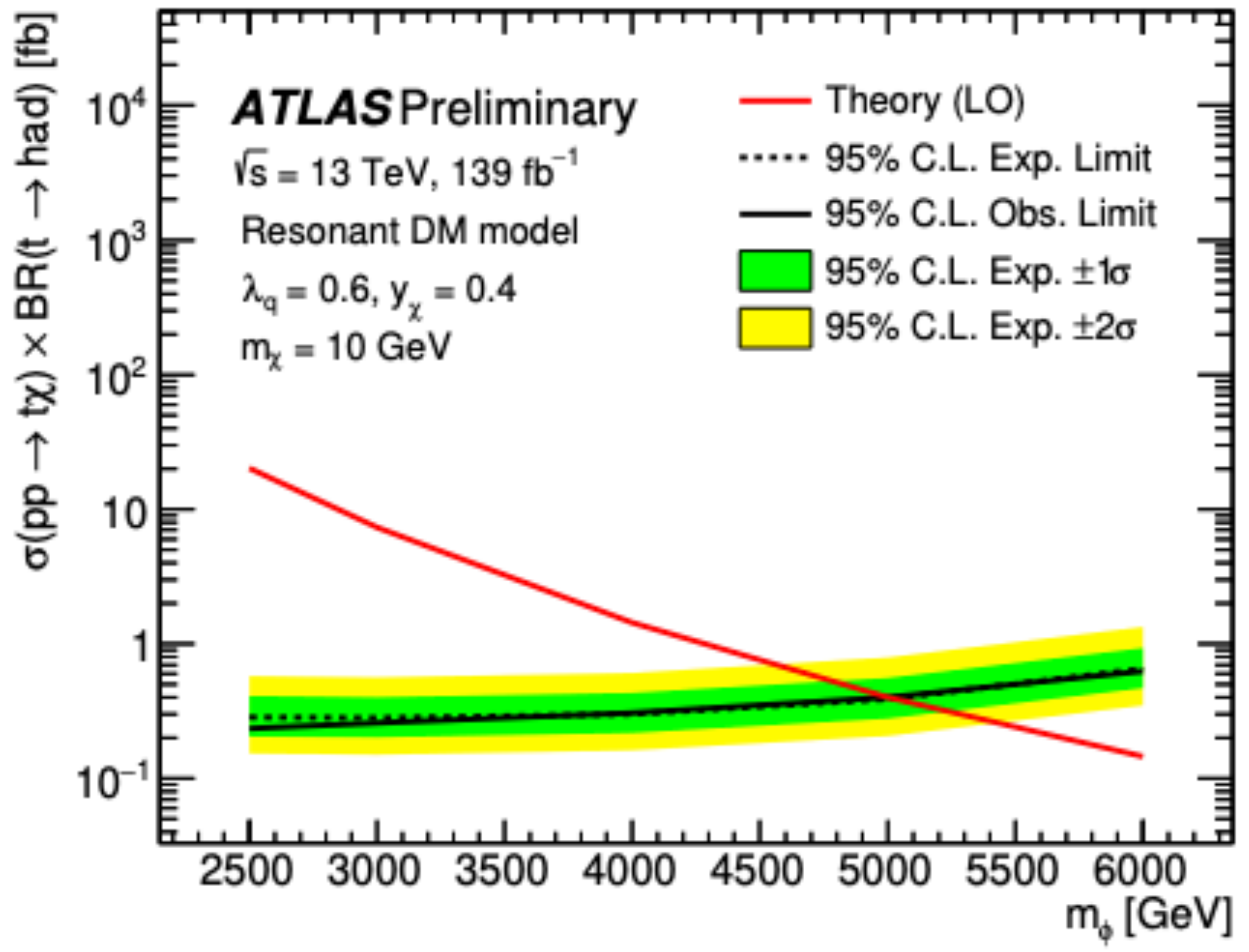
ATLAS-CONF-2022-036

The 95% CL upper limit on the production cross-section of the considered signal models as a function of:

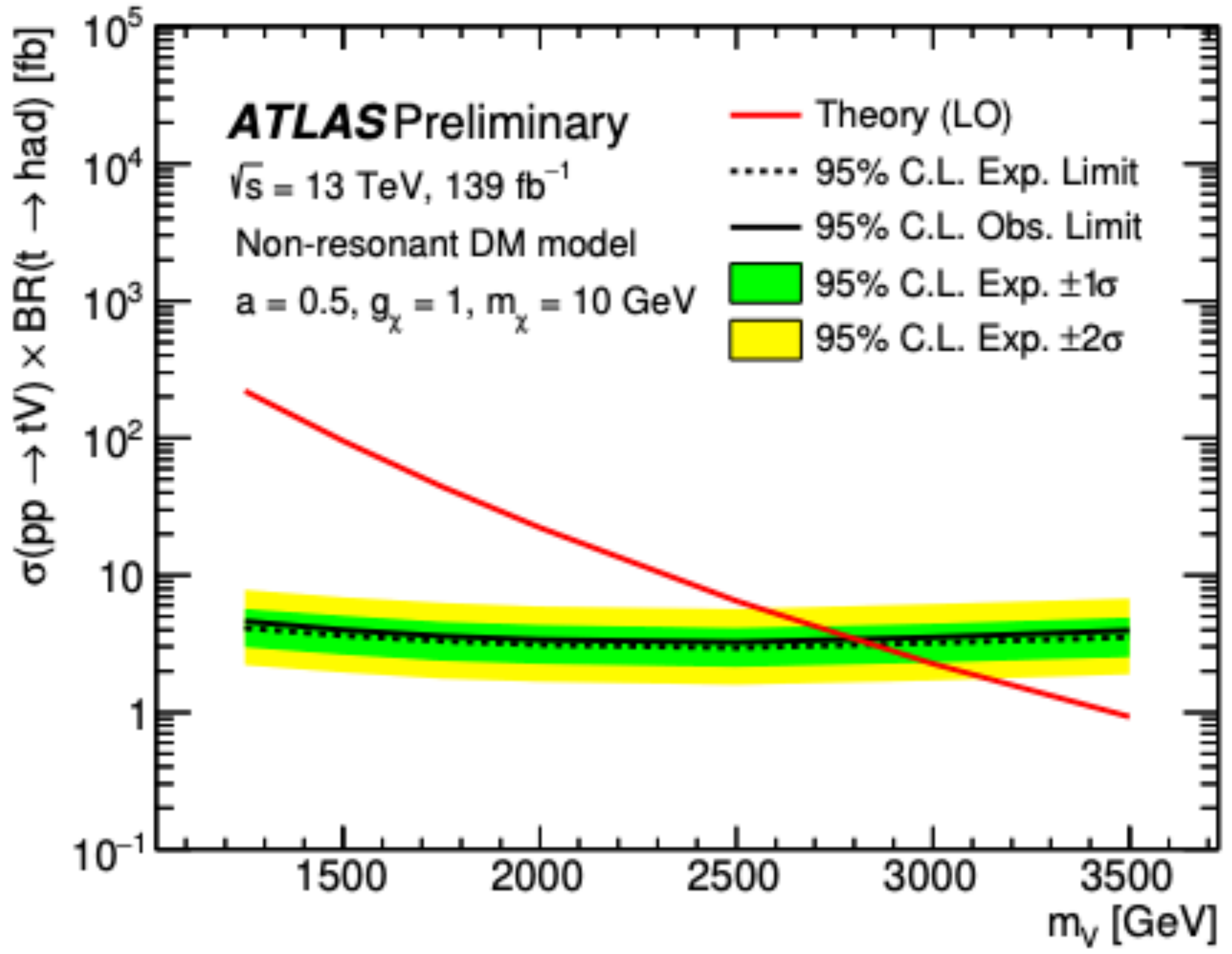
(a) the mass of the scalar particle ϕ in the resonant DM production,

(b) the V mass in the non-resonant DM production and

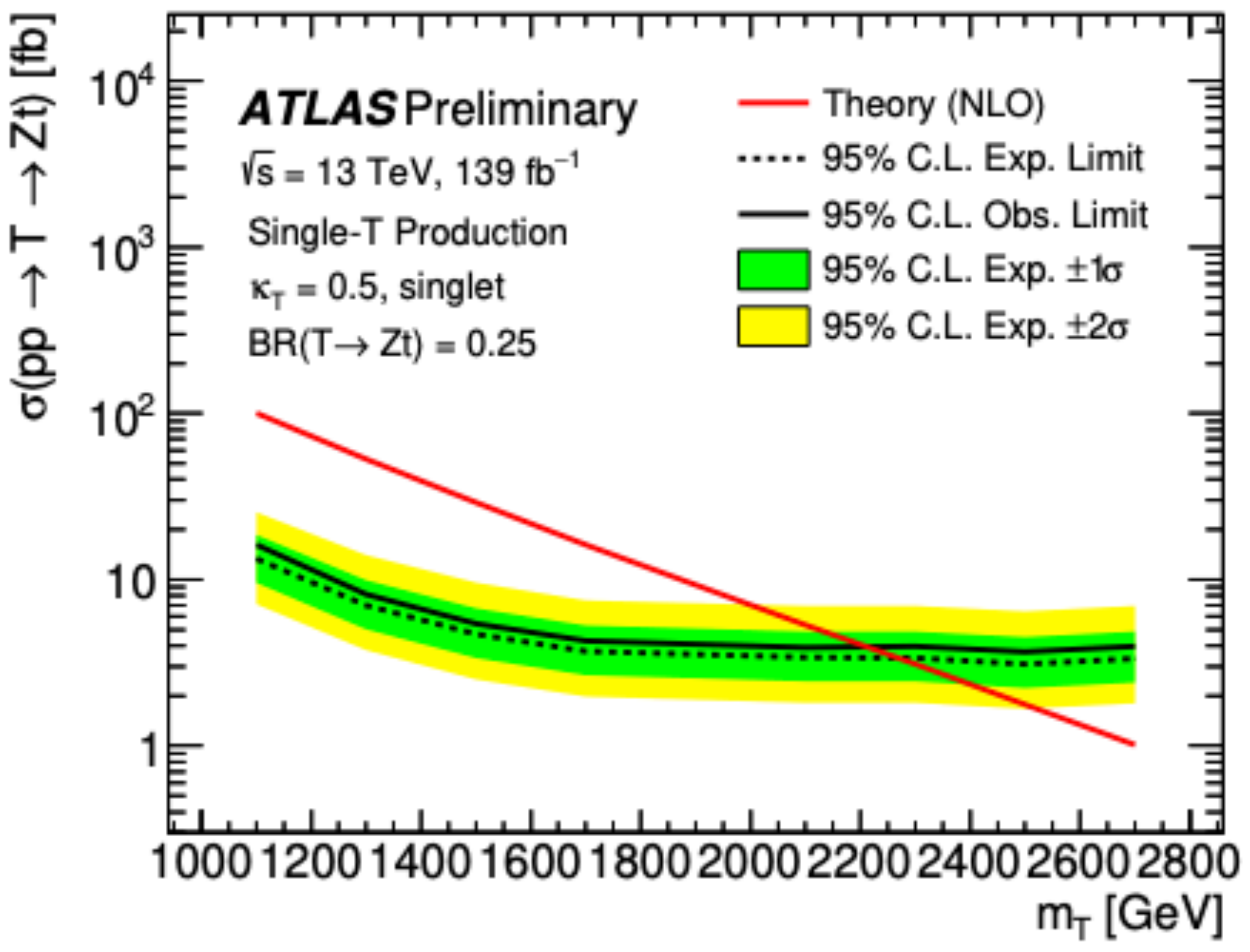
(c) the vector-like T quark mass.



(a)



(b)



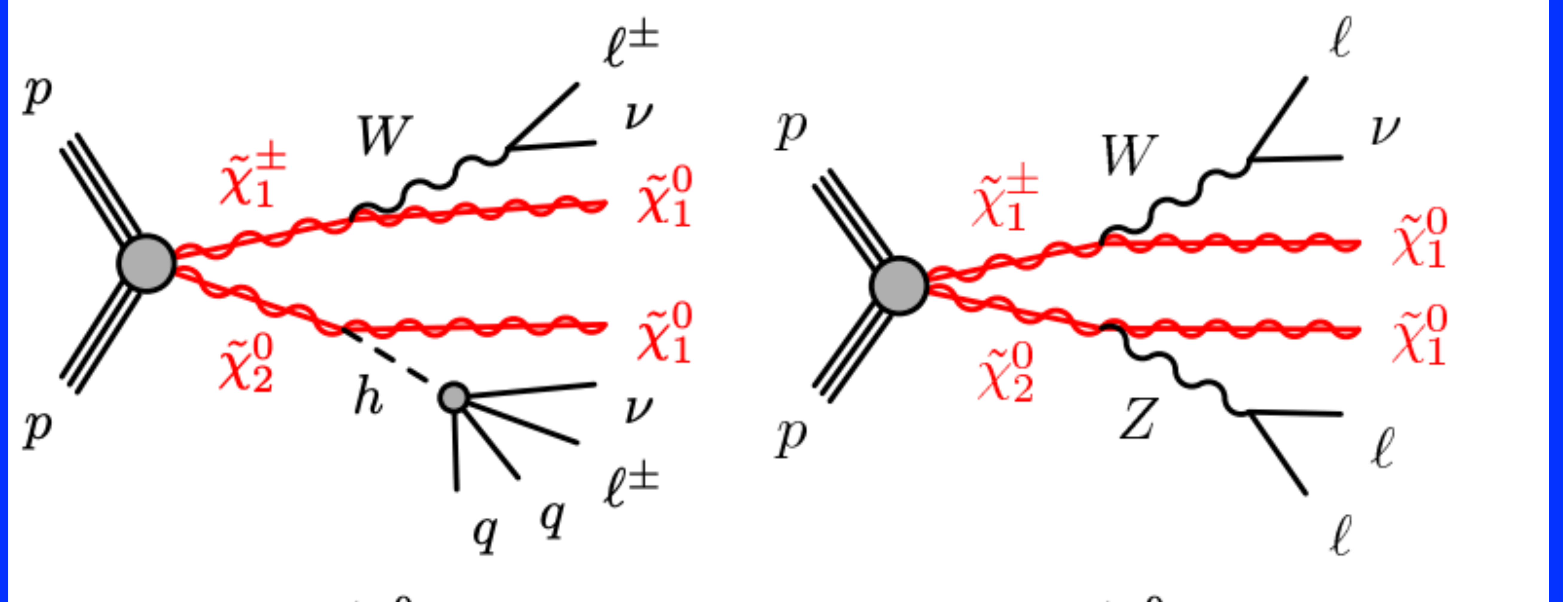
(c)

Direct production of winos and higgsinos

SS-leptons and 3-leptons

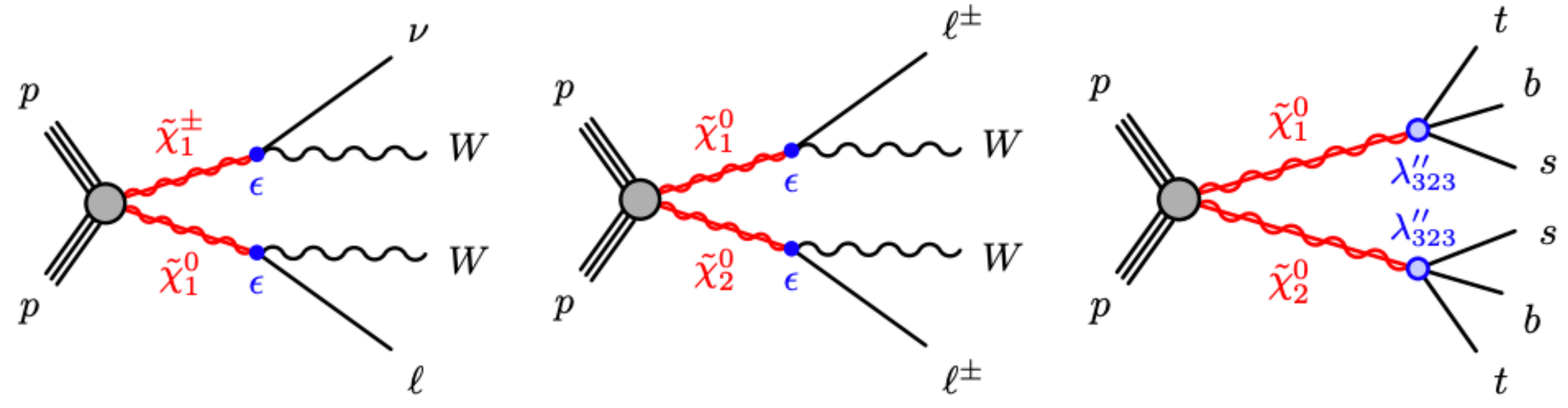
A search for supersymmetry targeting the direct production of winos and higgsinos.

- Simplified and complete models with and without R-parity conservation are considered:
  - **directly produced wino-like electroweakinos with bino-like LSP in RPC SUSY,**
  - higgsino-like electroweakinos with RPV terms.
- Final states defined by either two leptons (e or μ) with the same electric charge, or at least three leptons.



(a) Wino $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ with Wh (b) Wino $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ with WZ

Dark matter candidate



(a) Higgsino $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^0$ bRPV (b) Higgsino $\tilde{\chi}_1^0\tilde{\chi}_2^0$ bRPV (c) Higgsino $\tilde{\chi}_1^0\tilde{\chi}_2^0$ *UDD* RPV

Event Selection

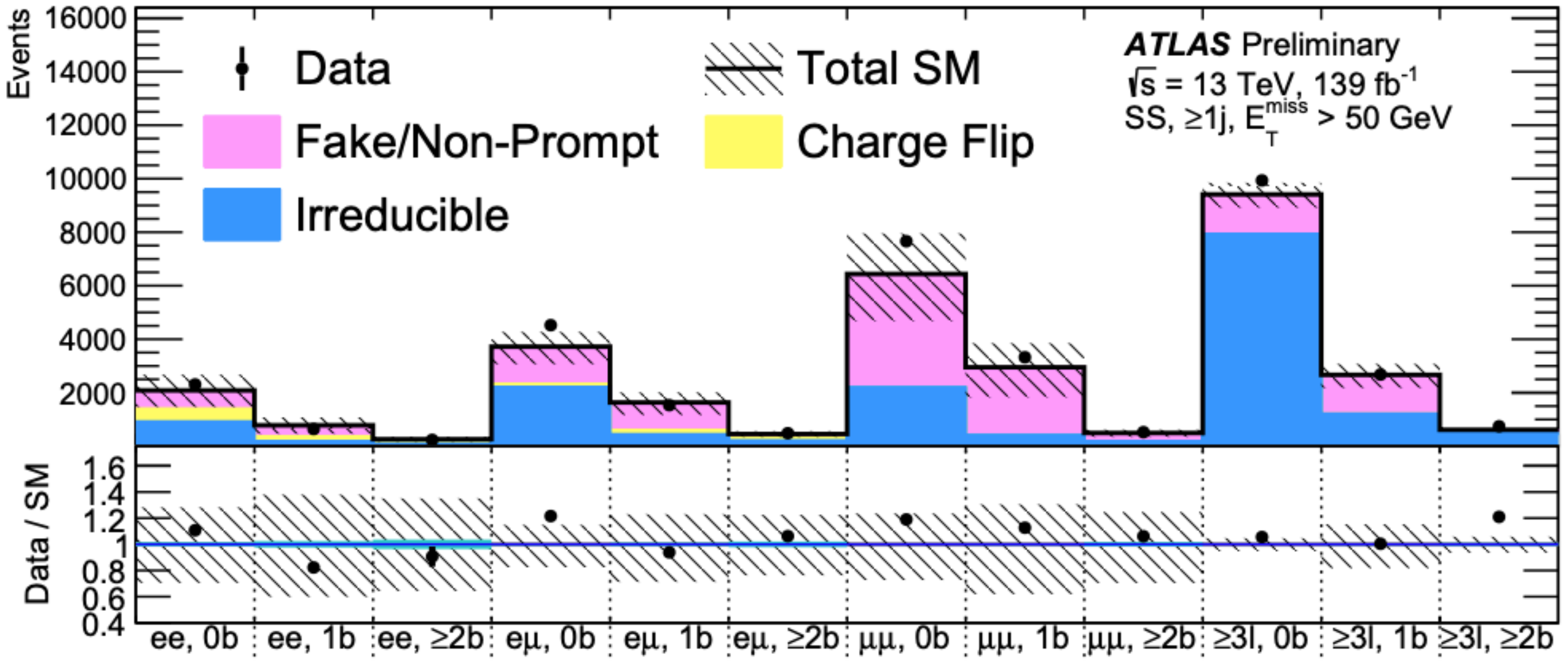
ATLAS-CONF-2022-057

- **Events Selection**
  - lowest unprescaled dilepton and E_T^{Miss} triggers were used with a logical OR combination.
    - lepton offline p_T threshold are set to be in the plateau region of the corresponding trigger: 25 (21) GeV to 27 (27.3) GeV for electron (muon)
  - Exactly one signal electron or muon, one to three signal jets and large E_T^{Miss}
  - All events are additionally required to contain at least one large-radius (large-R) jet to probe boosted SM boson decays.
  - Events are categorised according to several observables as the number of jets and b-jets, E_T^{Miss}, the effective mass or the transverse mass m_T.

Main Backgrounds:

Irreducible: WZ, $W^\pm W^\pm$ for b-jet-vetoing and $t\bar{t}+V$ for the b-jet-agnostic selection

Reducible: mis-identification of the lepton ('fake/non-prompt') or the lepton charge ('charge-flip').



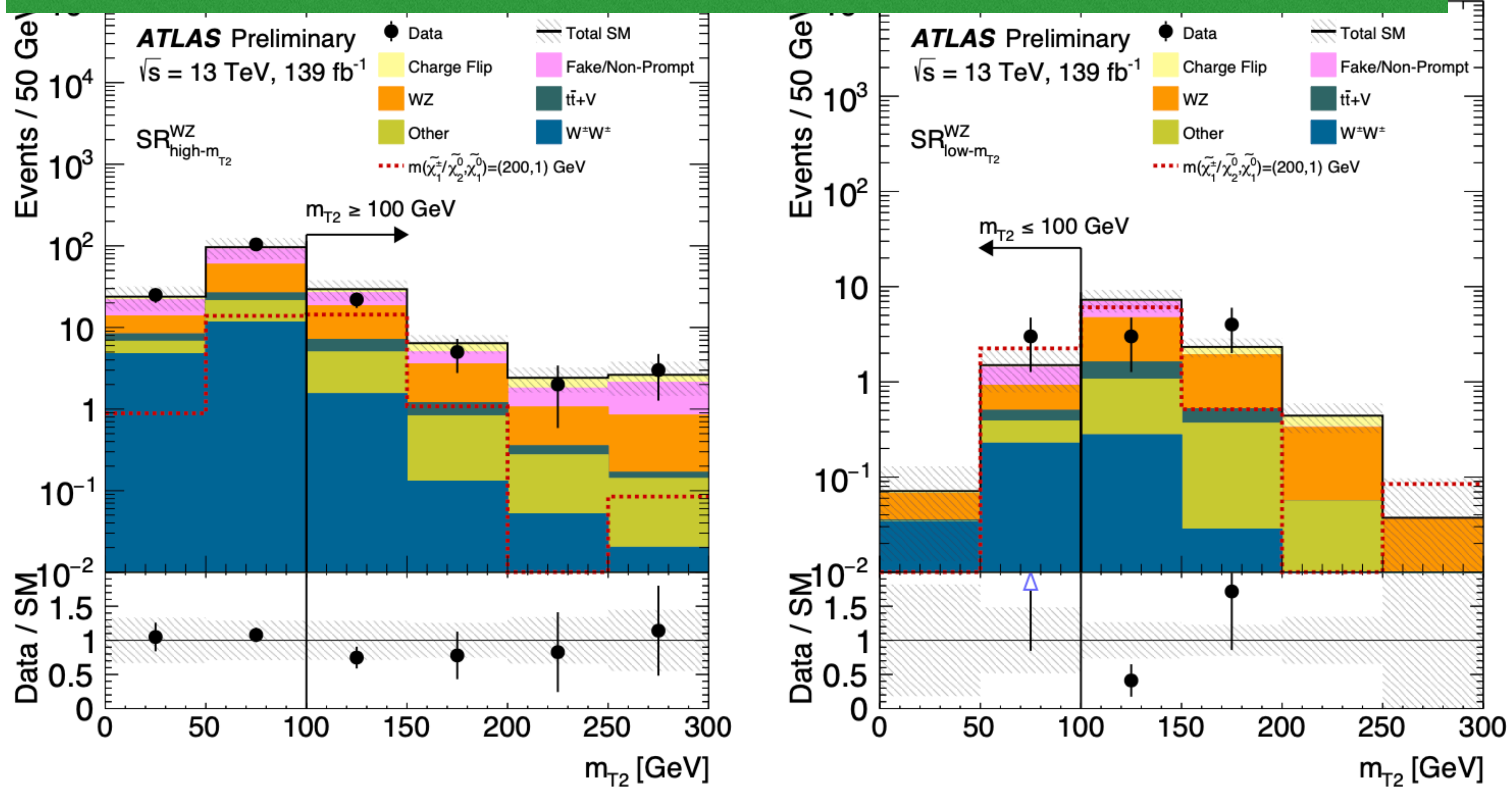
Data event yields compared with the expected contributions from the irreducible and the reducible backgrounds after a loose preselection

Analysis Regions

ATLAS-CONF-2022-057

- **Signal Region (SR): Wh scenario (2SRs) WZ (2SRs)**
- **Different Control Region (CR) and Validation Region (VR) for reducible and irreducible backgrounds**

All SR selection criteria are satisfied except for that on m_{T2}.



(a) $\mathrm{SR}^{WZ}_{\mathrm{high}-m_{T2}}$ (b) $\mathrm{SR}^{WZ}_{\mathrm{low}-m_{T2}}$

Wh	$\mathrm{SR}^{Wh}_{\mathrm{high}-m_{T2}}$			$\mathrm{SR}^{Wh}_{\mathrm{low}-m_{T2}}$		
	$e^\pm e^\pm$	$e^\pm\mu^\pm$	$\mu^\pm\mu^\pm$	$e^\pm e^\pm$	$e^\pm\mu^\pm$	$\mu^\pm\mu^\pm$
$N_{\mathrm{BL}}(\ell)$	$= 2$					
$N_{\mathrm{Sig}}(\ell)$	$= 2$					
Charge(ℓ)	same-sign					
$p_T(\ell)$	≥ 25 GeV					
n_{jets} ($p_T > 25$ GeV)	≥ 1					
$n_{b\text{-jets}}$	$= 0$					
m_{jj}	< 350 GeV					
m_{T2}	≥ 80 GeV			< 80 GeV		
m_T^{min}	–			≥ 100 GeV		
$\mathcal{S}(E_T^{\mathrm{miss}})$	≥ 7			≥ 6		
E_T^{miss}	≥ 75 GeV			≥ 50 GeV		
E_T^{miss} binning (GeV)[a]	$\mathrm{SR}^{Wh}_{\mathrm{high}-m_{T2}}$-1: $\in [75, 125)$ $\mathrm{SR}^{Wh}_{\mathrm{high}-m_{T2}}$-2: $\in [125, 175)$ $\mathrm{SR}^{Wh}_{\mathrm{high}-m_{T2}}$-3: $\in [175, +\infty)$			–		

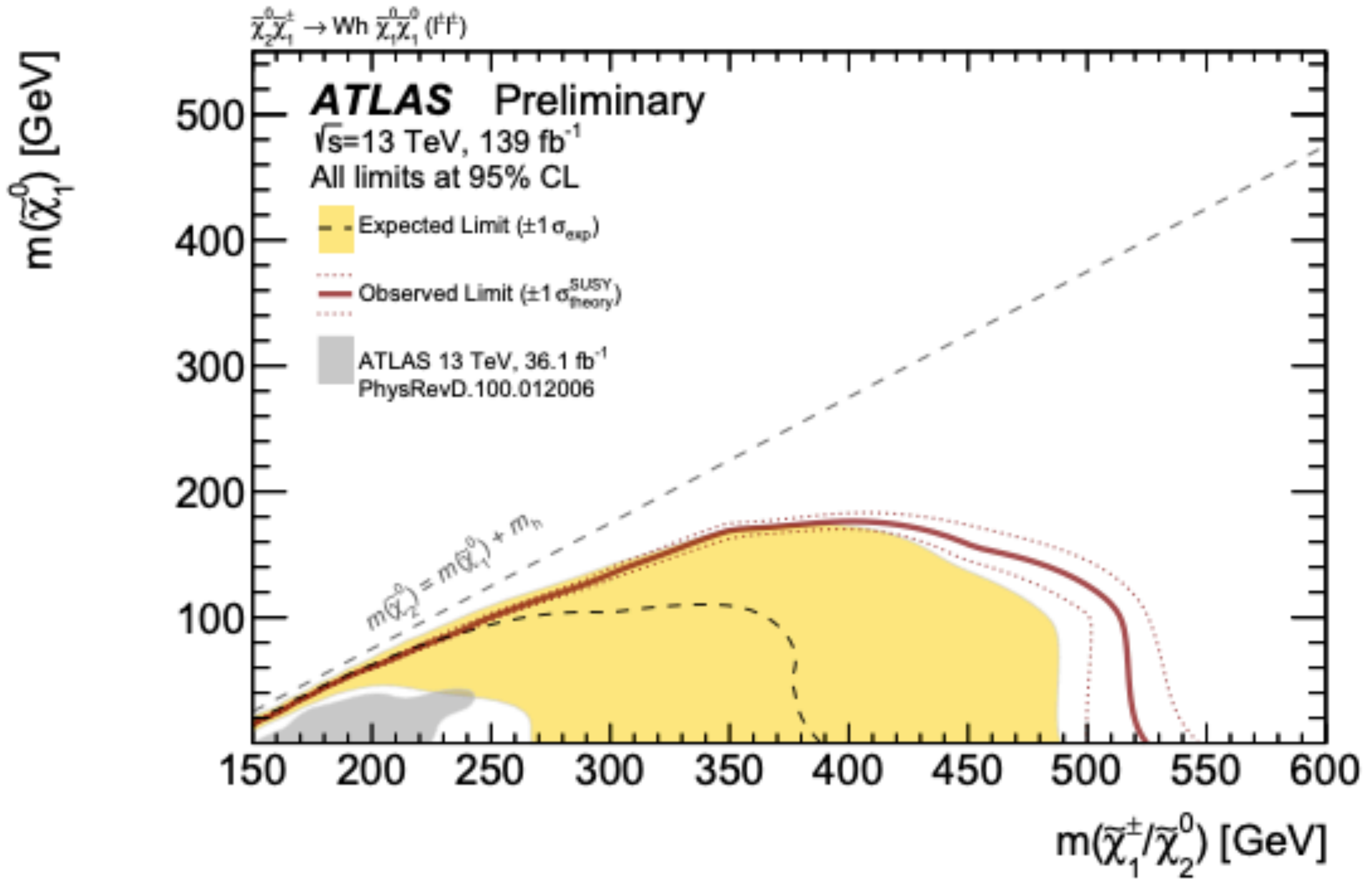
WZ	$\mathrm{SR}^{WZ}_{\mathrm{high}-m_{T2}}$	$\mathrm{SR}^{WZ}_{\mathrm{low}-m_{T2}}$
$N_{\mathrm{BL}}(\ell)$	$= 2$	
$N_{\mathrm{Sig}}(\ell)$	$= 2$	
Charge(ℓ)	same-sign	
$p_T(\ell)$	≥ 25 GeV	
n_{jets} ($p_T > 25$ GeV)	≥ 1	
$n_{b\text{-jets}}$	$= 0$	
m_{jj}	≤ 350 GeV	
m_{T2}	≥ 100 GeV	≤ 100 GeV
m_T^{min}	≥ 100 GeV	≥ 130 GeV
E_T^{miss}	≥ 100 GeV	≥ 140 GeV
m_{eff}	–	≤ 600 GeV
$\Delta R(\ell^\pm, \ell^\pm)$	–	≤ 3
Bins	$\mathcal{S}(E_T^{\mathrm{miss}})$: $\in [0, 10)$ Spread$(\Phi) \geq 2.2$ $\mathcal{S}(E_T^{\mathrm{miss}})$: $\in [10, 13)$ $\mathcal{S}(E_T^{\mathrm{miss}})$: $\in [13, +\infty]$ $\Delta R(\ell^\pm, \ell^\pm) \geq 1$	–

$$m_{T2} = \min_{\mathbf{q}_T} \left[\max \left(m_{T,\ell_1}(\mathbf{p}_{T,\ell_1}, \mathbf{q}_T), m_{T,\ell_2}(\mathbf{p}_{T,\ell_2}, \mathbf{p}_T^{\mathrm{miss}} - \mathbf{q}_T) \right) \right]$$

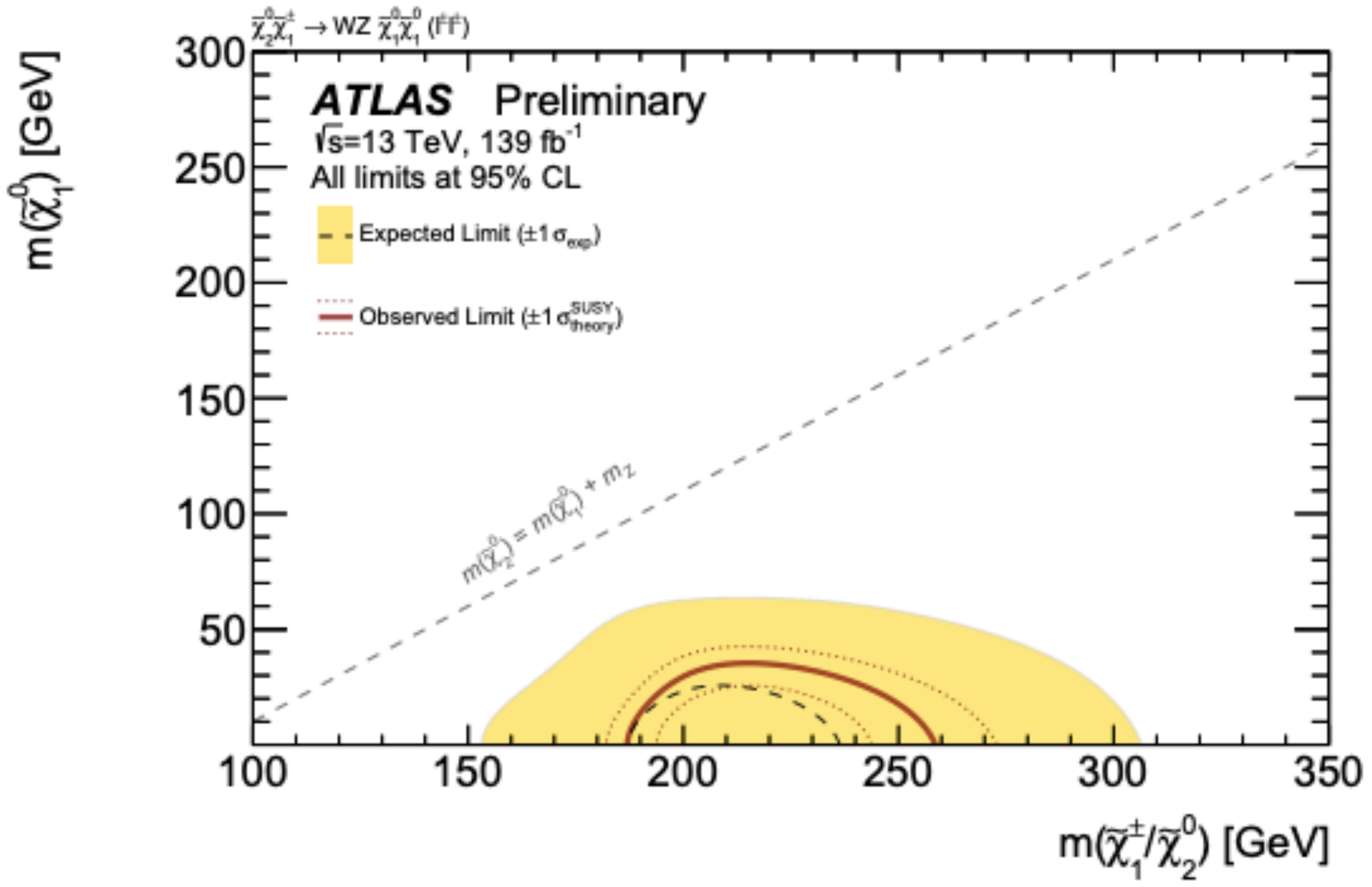
Results

ATLAS-CONF-2022-057

- In a **wino-bino** Wh**-mediated model**, NLSP masses of up to 525 GeV have been excluded for a massless lightest neutralino, while WZ **topology is between** 190 GeV and 260 GeV (first time in ATLAS in SS final states!)



(a) Wino $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ with Wh



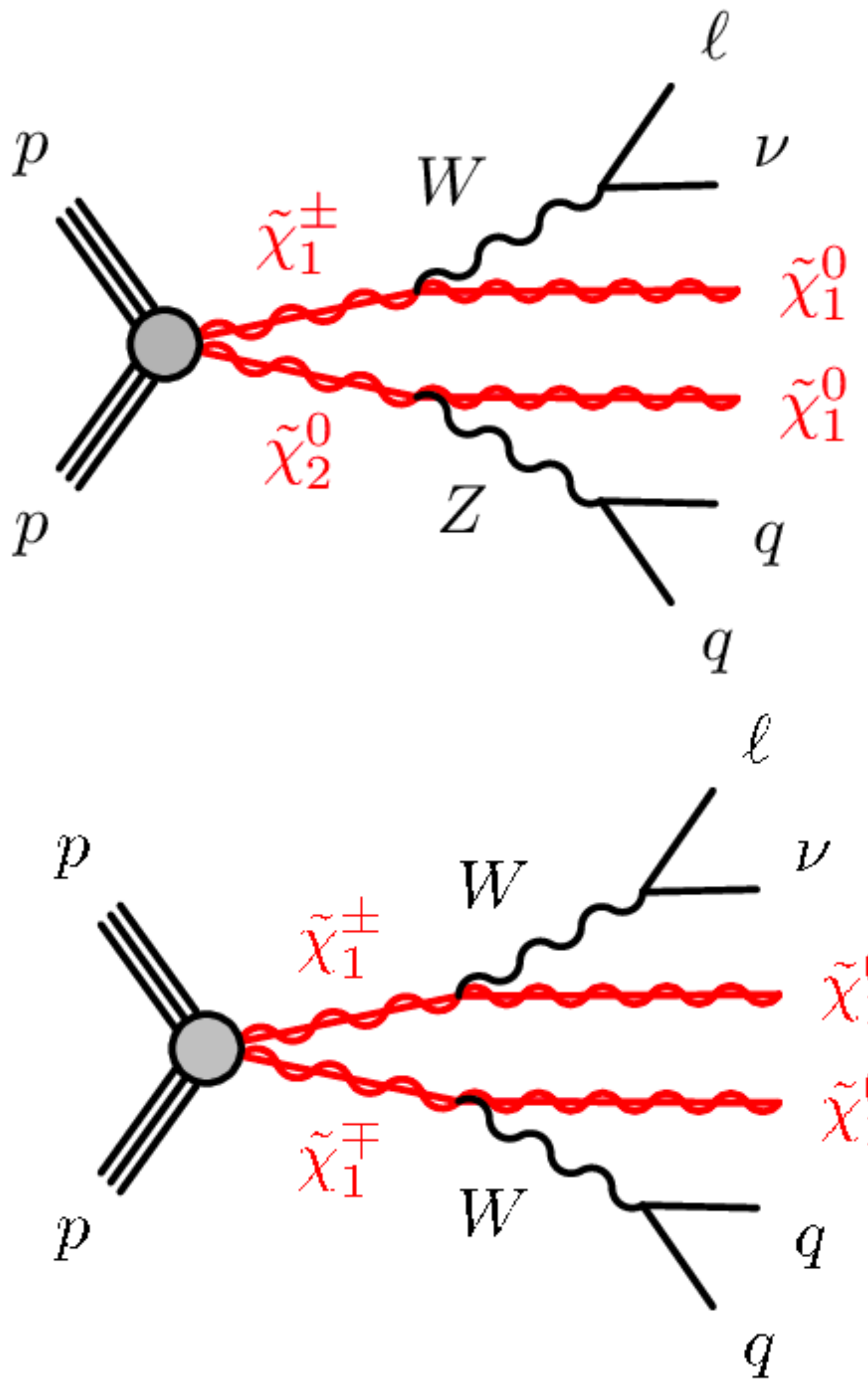
(b) Wino $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ with WZ

Search for direct production of electroweakinos

1-lepton Search

Electroweak production of chargino-neutralino and chargino-chargino pairs.

- In both scenarios the chargino decays into a W boson and the lightest neutralino, and second-to-lightest decays into a Z boson and the lightest neutralino.
- The signal signature for both processes is characterised by a single isolated lepton, at least two jet, and missing transverse energy.



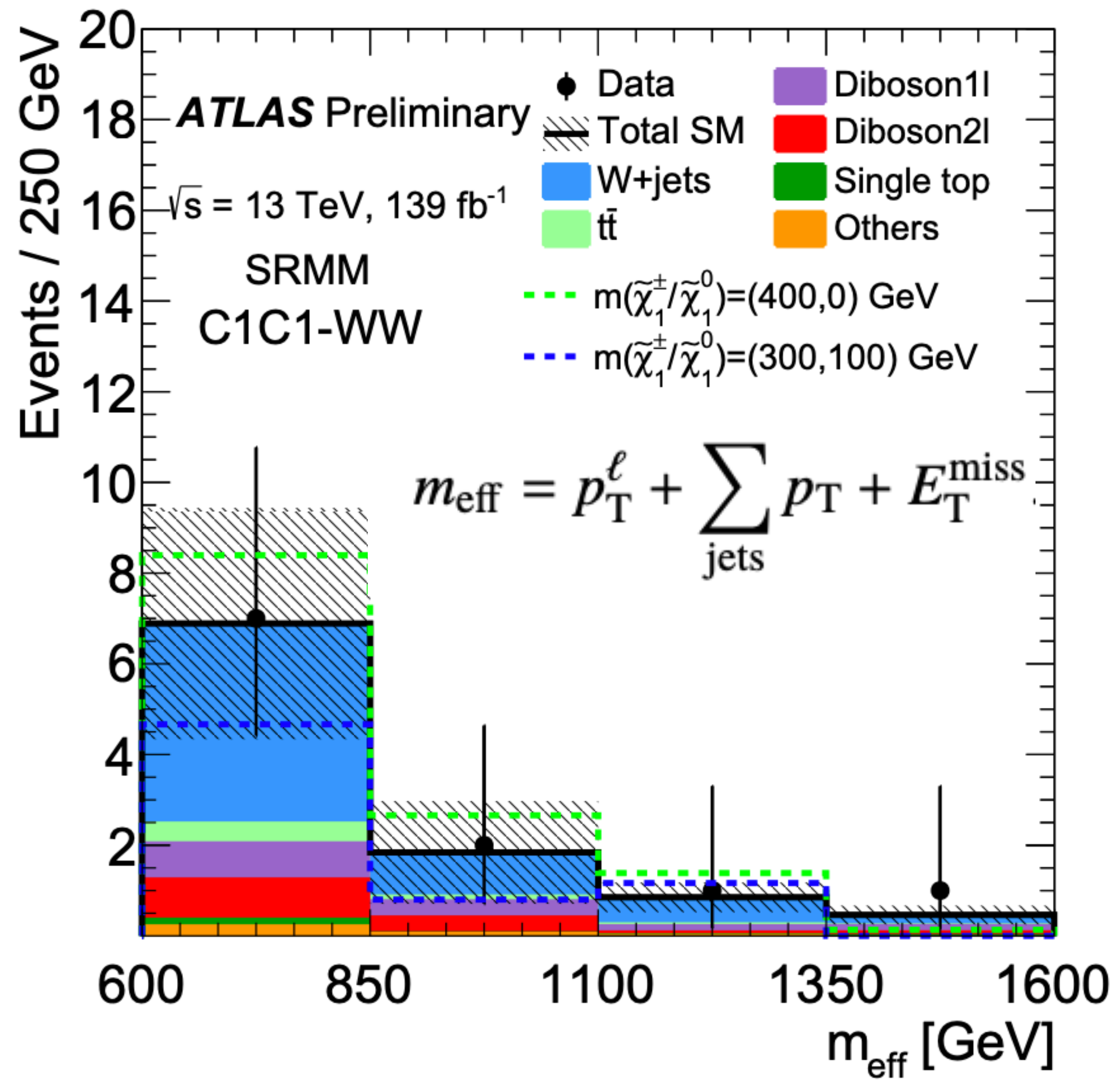
Main Backgrounds:
$t\bar{t}$ pair; single-top; W/Z+jets; $t\bar{t}$ associated with an electroweak boson ($t\bar{t}$ + V); Higgs boson production ($t\bar{t}$ +h , V h); diboson (WW, W Z, Z Z) and multiboson (VVV, with V = W, Z).

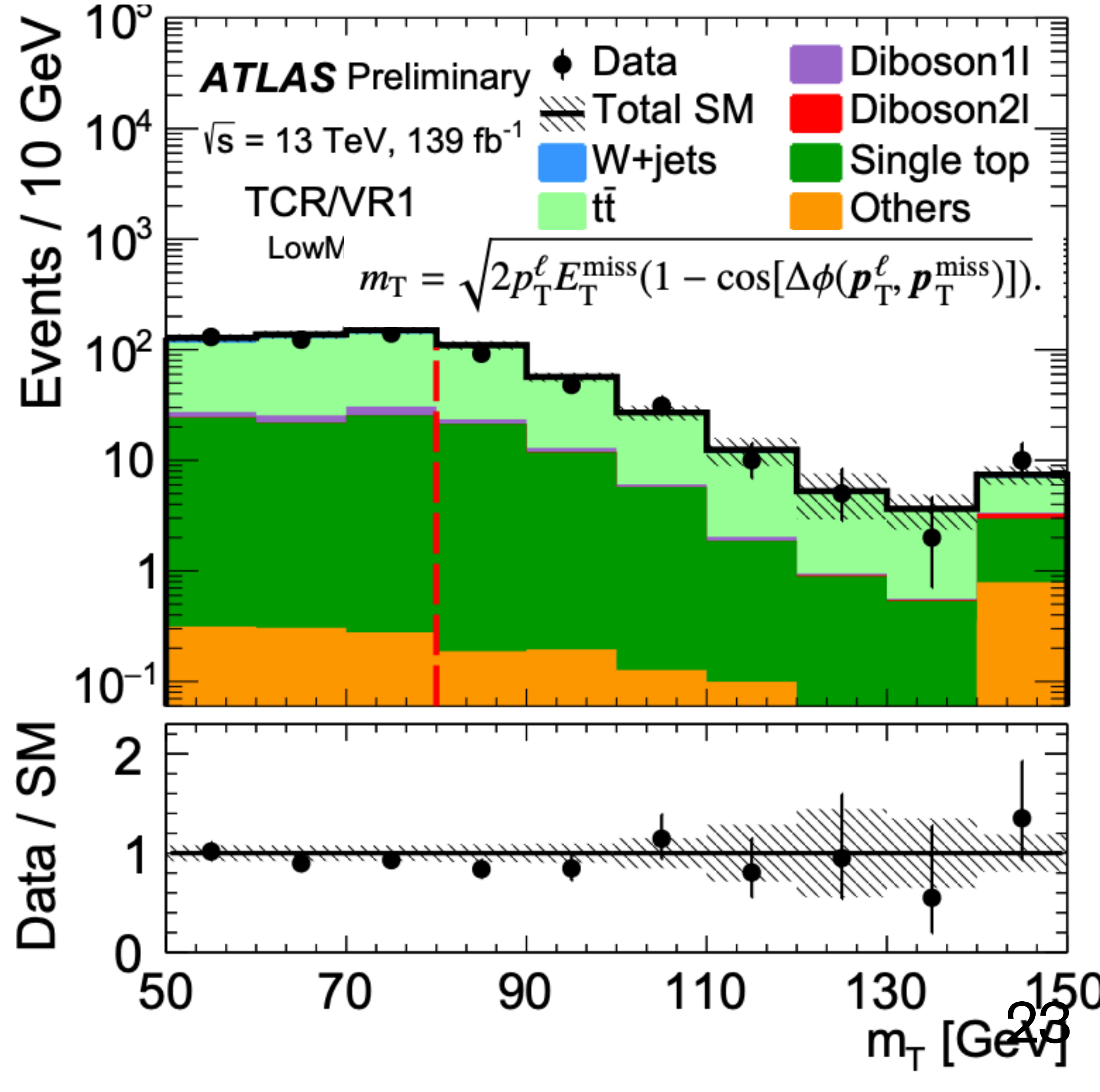
Event Selection

ATLAS-CONF-2022-059

- Events Selection
  - Events are recorded with single lepton (electron and muon) triggers
    - lepton offline p_T threshold are set to be in the plateau region of the corresponding trigger: 25 (21) GeV to 27 (27.3) GeV for electron (muon)
  - Exactly one signal electron or muon, one to three signal jets and large E_T^{Miss}
  - All events are additionally required to contain at least one large-radius (large-R) jet to probe boosted SM boson decays.
  - Analysis regions defined by: transverse mass (m_T), effective mass, (m_{eff}), missing transverse energy significance ($\sigma(E_T^{Miss})$)* and the invariant mass of the two leading jets, mjj
- **Signal Region (SR): chargino-chargino scenario (C1C1-WW) and chargino-neutralino scenario (C1N2-WZ). Several Validation and Control Regions**

$$\sigma_{E_T^{miss}} = \sqrt{2\ln\left[\frac{\max_{p_T^{inv}\neq 0}\mathcal{L}\left(E_T^{miss}|p_T^{inv}\right)}{\max_{p_T^{inv}=0}\mathcal{L}\left(E_T^{miss}|p_T^{inv}\right)}\right]}.$$



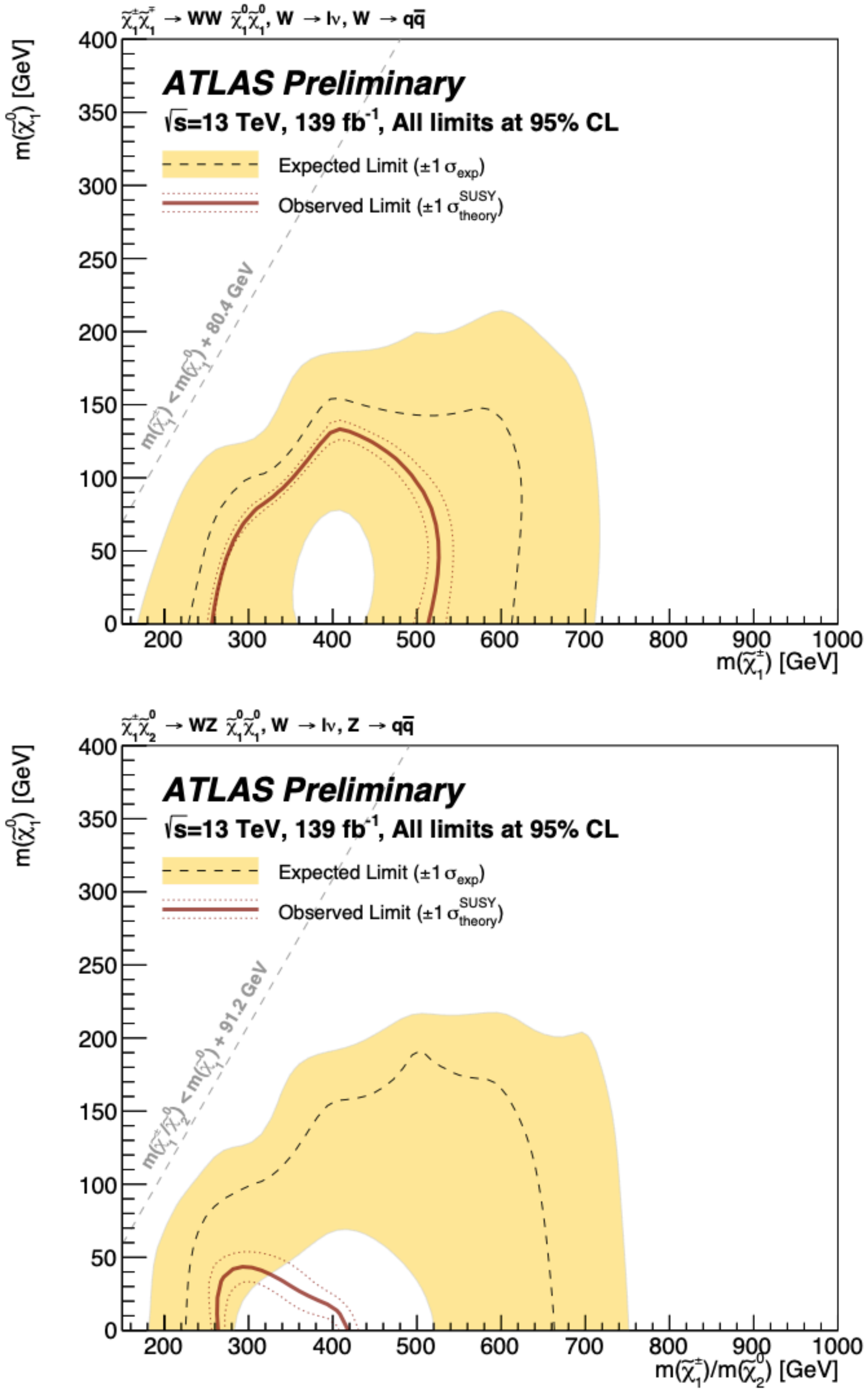


Results

ATLAS-CONF-2022-059

Limits are set on the direct production of the electroweakinos in simplified models.

- $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ model, masses of $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ ranging from 260 to 420 GeV are excluded at 95% CL for a massless $\tilde{\chi}_1^0$.
- In the $\tilde{\chi}_1^{+}\tilde{\chi}_1^{-}$ model, masses of $\tilde{\chi}_1^{\pm}$ ranging from 260 to 520 GeV are excluded at 95% CL for a massless $\tilde{\chi}_1^0$.
- The current search improves on the previous ATLAS limit by around 100 GeV in $m(\tilde{\chi}_1^{\pm})$ for a massless $\tilde{\chi}_1^0$



Direct production of charginos and neutralinos decaying in tau leptons

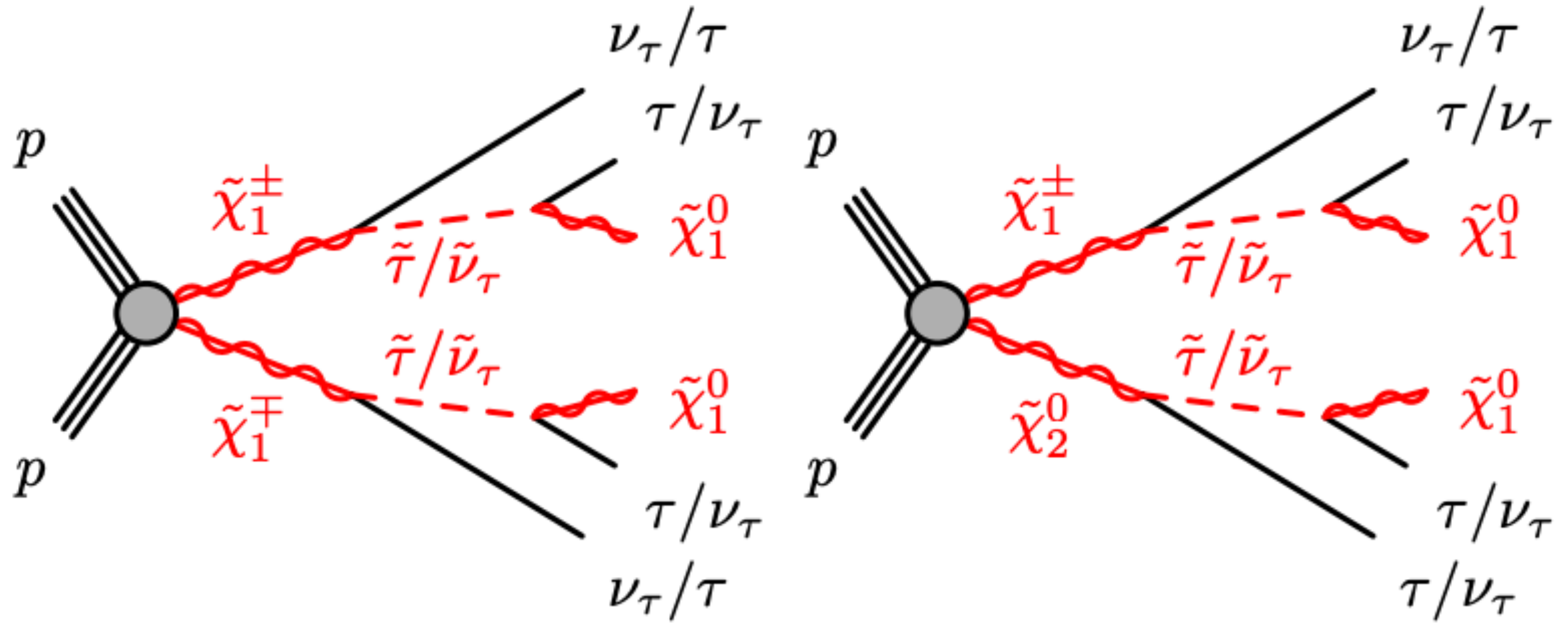
ATLAS-CONF-2022-042

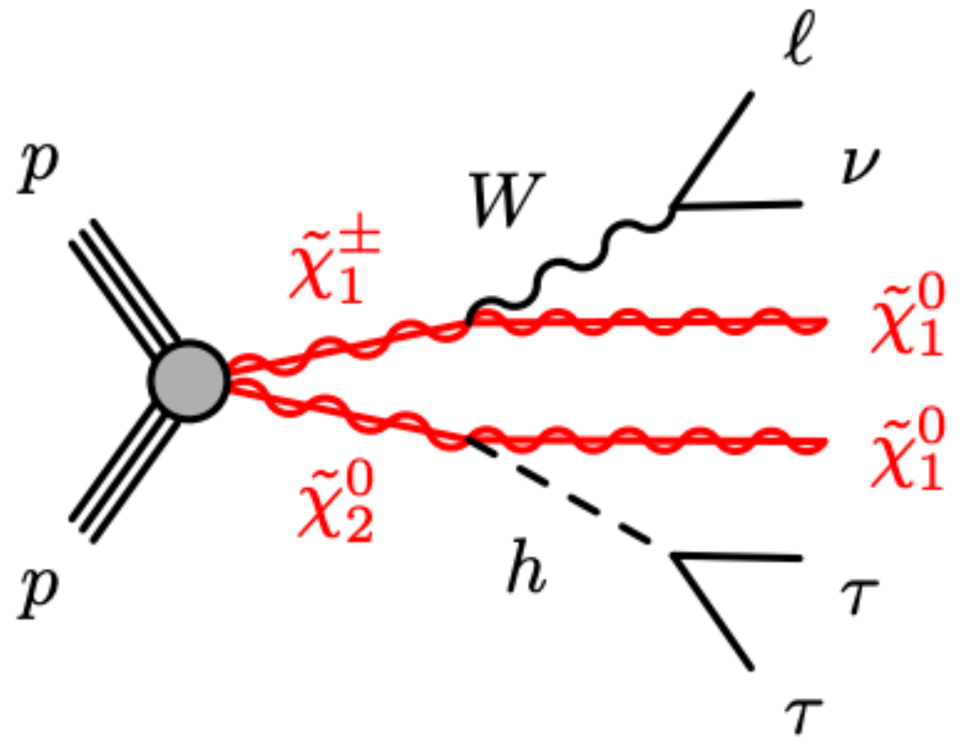
Two searches for direct production of charginos $\tilde{\chi}_1^{\pm}$ (C_1) and neutralinos $\tilde{\chi}_2^0$ (N_2) with intermediate tau sleptons or Wh.

- **Intermediate stau**: decay to the lightest neutralino only through intermediate tau sleptons (stau) / tau sneutrinos.
  - Final states with two same-sign (SS) or opposite-sign (OS) tau-lepton pairs.
- **Intermediate Wh:** decay via the lightest neutral Higgs boson (h), consistent with the SM Higgs boson, a W boson and two neutralino.
  - Final state contains two hadronic tau-leptons from the Higgs boson decay and one charged light lepton from the W boson decay.

SM backgrounds containing both real and misidentified tau-lepton as: $t\bar{t}$ pair; single-top with W; W/Z;W/Z+jets; Higgs boson production; diboson (WW, W Z, Z Z); multijets.

Intermediate stau





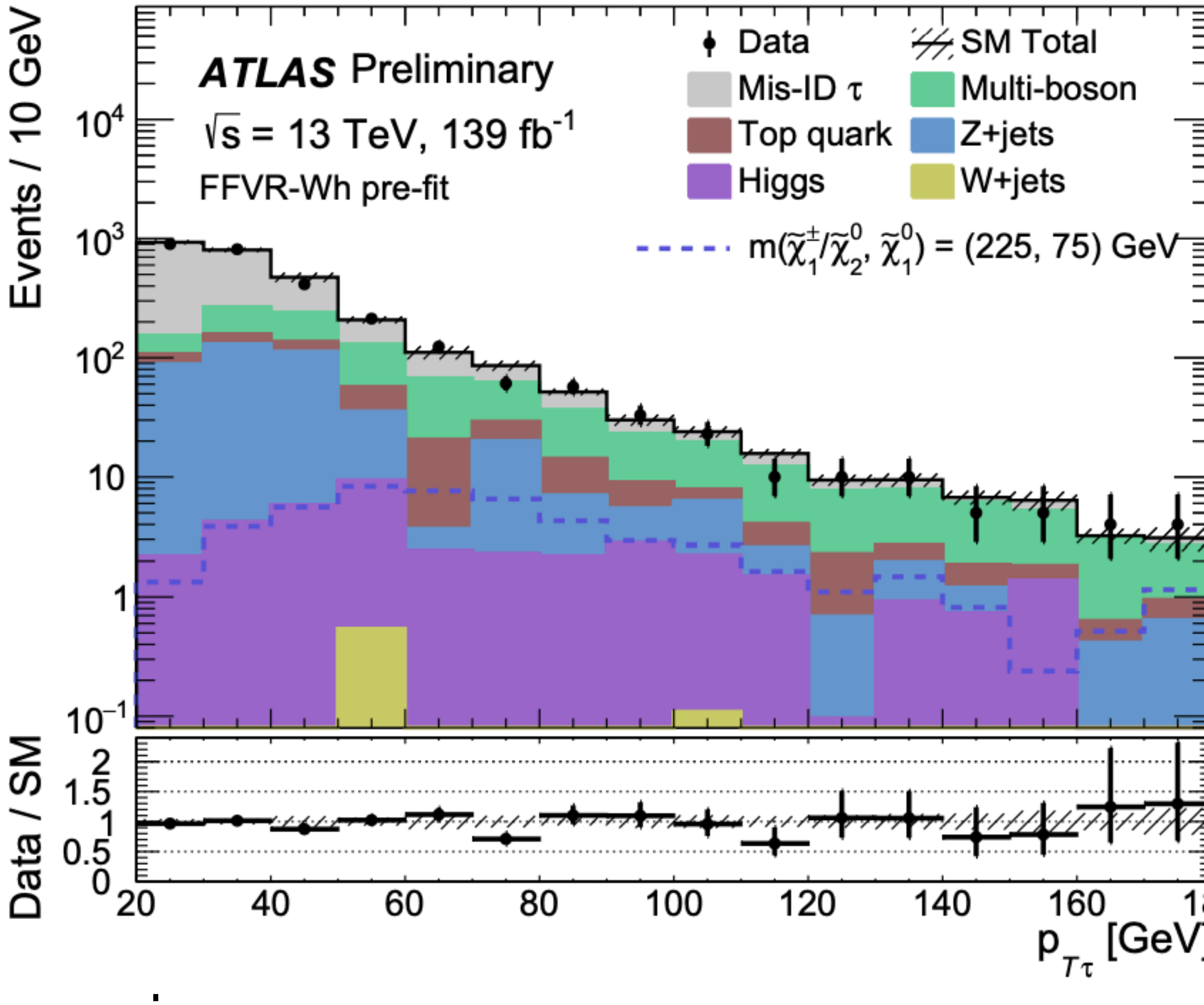
Intermediate Wh

Analysis Strategy

ATLAS-CONF-2022-042

Several Signal Regions , Validation and Control driven by di-tau leading kinematics and transverse mass combination

- The main signatures studied include those with two hadronically decaying tau-leptons $tau_{had}tau_{had}$:
  - low jet activity and large missing transverse momentum p_T^{miss} from the neutralinos and neutrinos.
  - Lowest unprescaled light lepton trigger (Wh) and di-tau trigger (stau)
- Tau-leptons identification is based on:
  - Tau identification weights obtained from tracks in the ID and three-dimensional clusters in the calorimeters
  - Tau candidates are required to have one or three associated charged-particle tracks (prongs) and the total electric charge equal to +/-e
  - Recursive neural network discriminant is used to reject jets that do not originate from a hadronically decaying tau-lepton

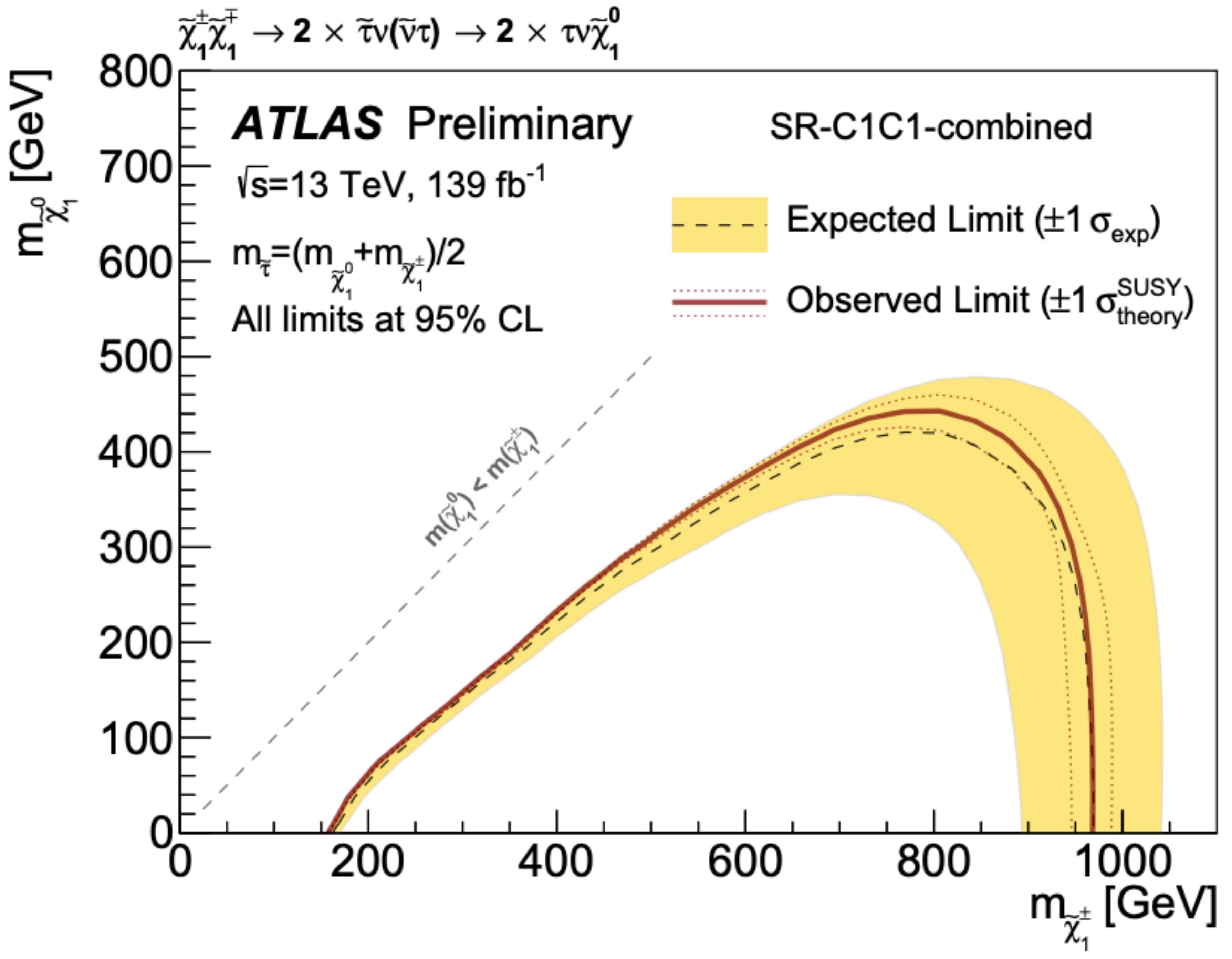


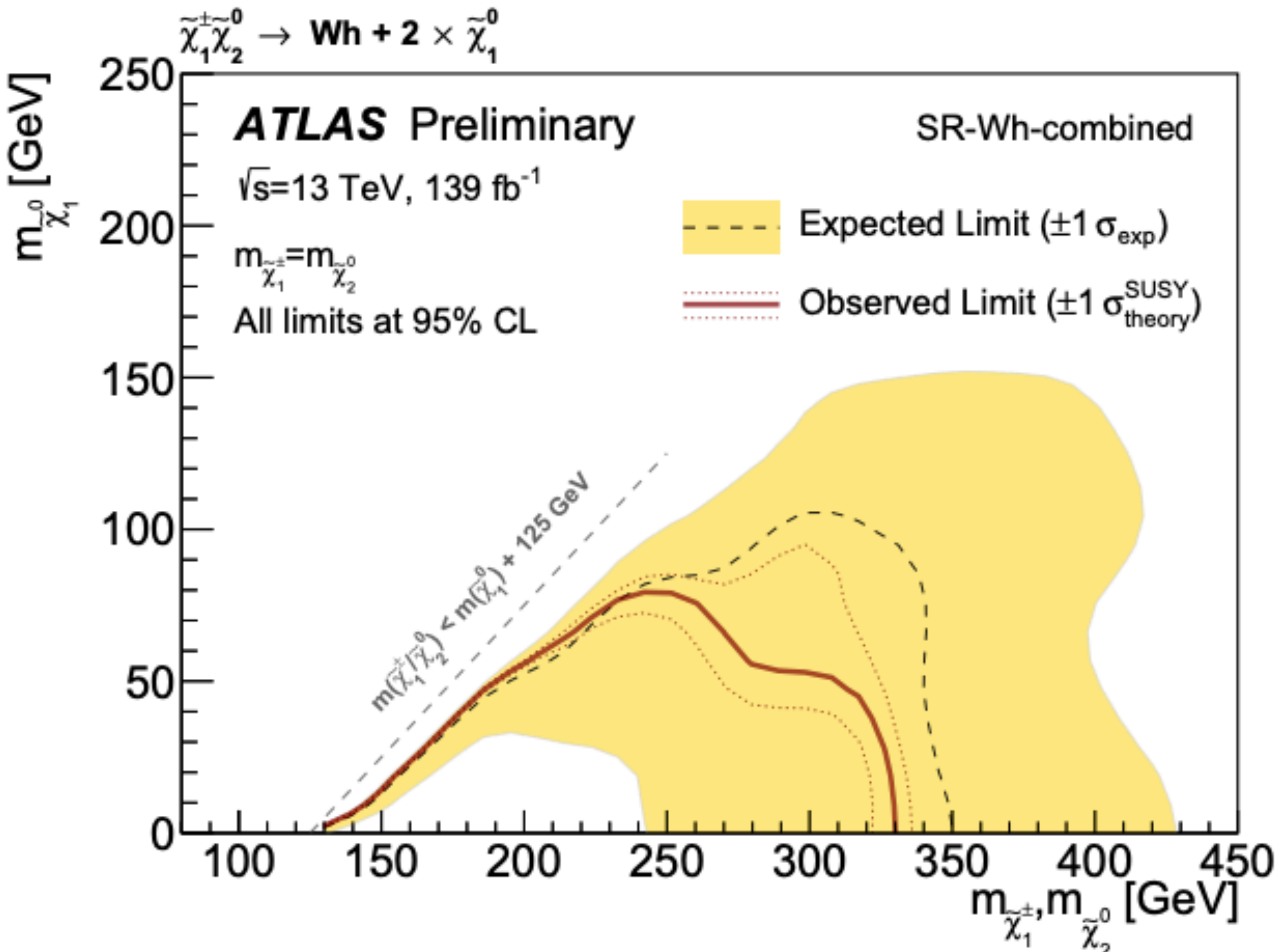
Results

ATLAS-CONF-2022-042

Intermediate stau

Chargino masses up to 970 GeV are excluded for decays to a massless neutralino in the direct production of chargino pairs. For production of chargino pairs of mass-degenerate charginos and next-to-lightest neutralinos, chargino masses up to 1160 GeV are excluded for a massless neutralino.





Intermediate Wh

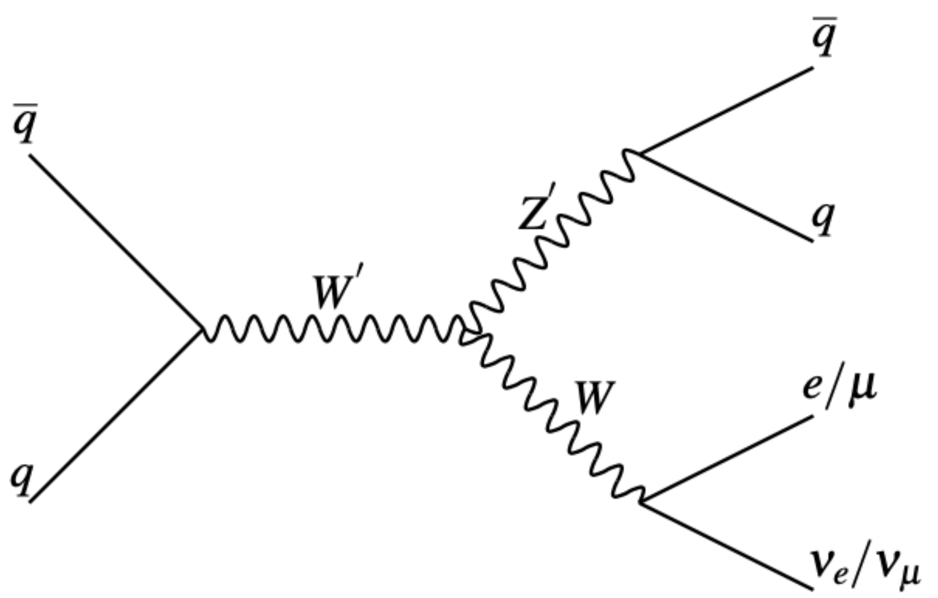
Gaugino masses up to 330 GeV are excluded for a massless lightest neutralino

New phenomena in multi-body invariant mass

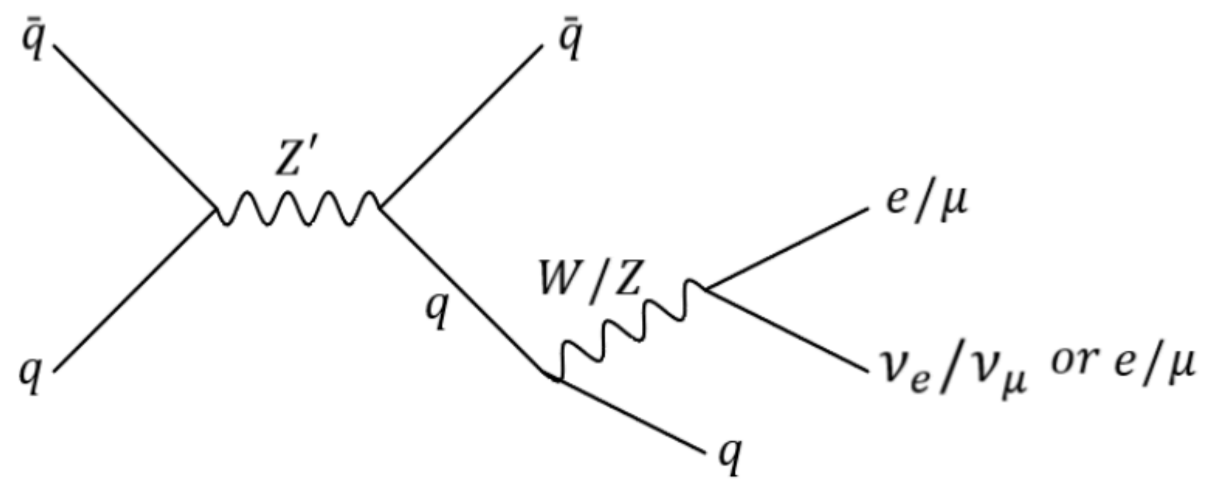
ATLAS-CONF-2022-050

Search for resonances in events with at least one isolated lepton (e or μ) and two jets (including b-jets)

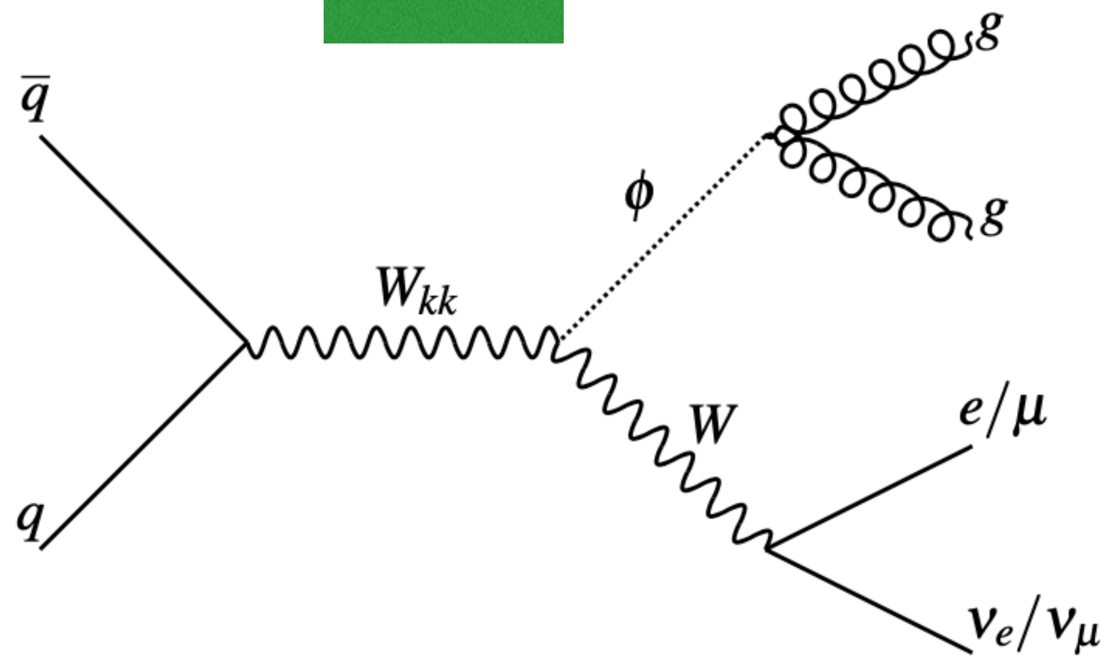
- Deviations from a smoothly falling background hypothesis are tested in three- and four-body invariant mass distributions, setting a model-independent limits on generic resonances. In addition, the invariant mass was used to study:
  - dark-matter models with an axial-vector mediator, the Sequential Standard Model with W' and Z' bosons, models with left-right symmetry, composite resonances breaking lepton-flavour universality and radion models



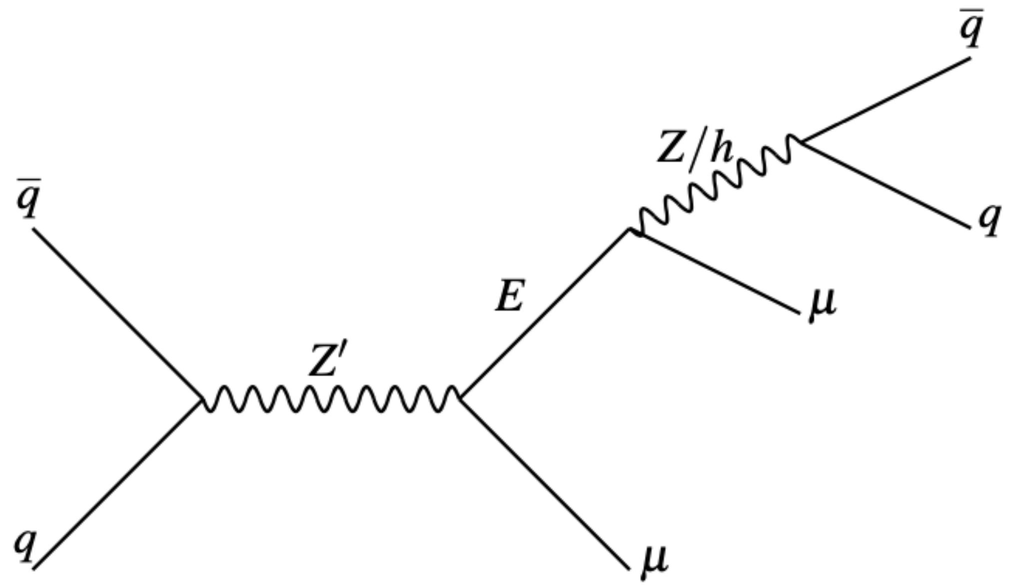
SSM



Simplified DM



KK with Radion



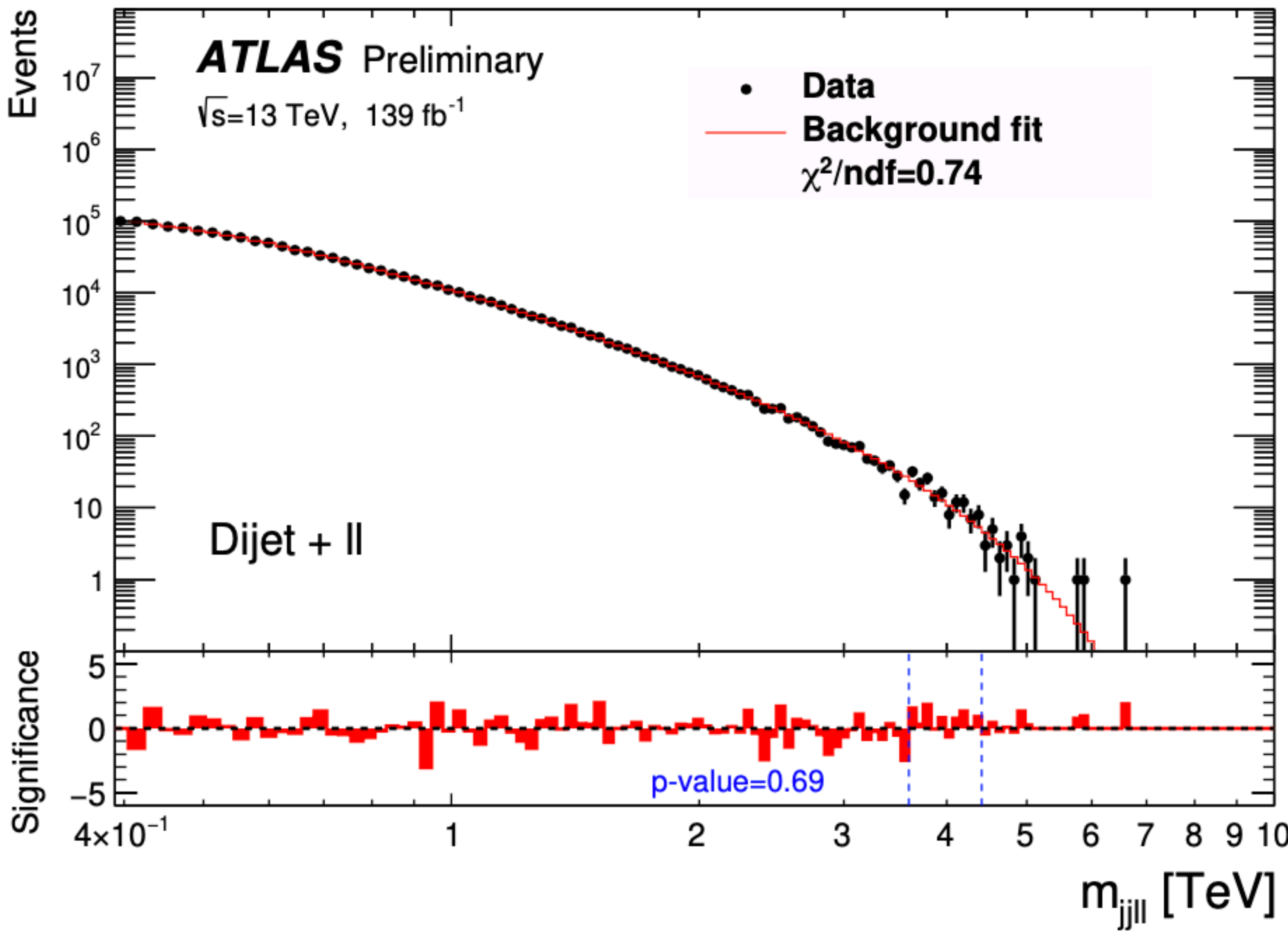
Composite Lepton

Main background: multijets.

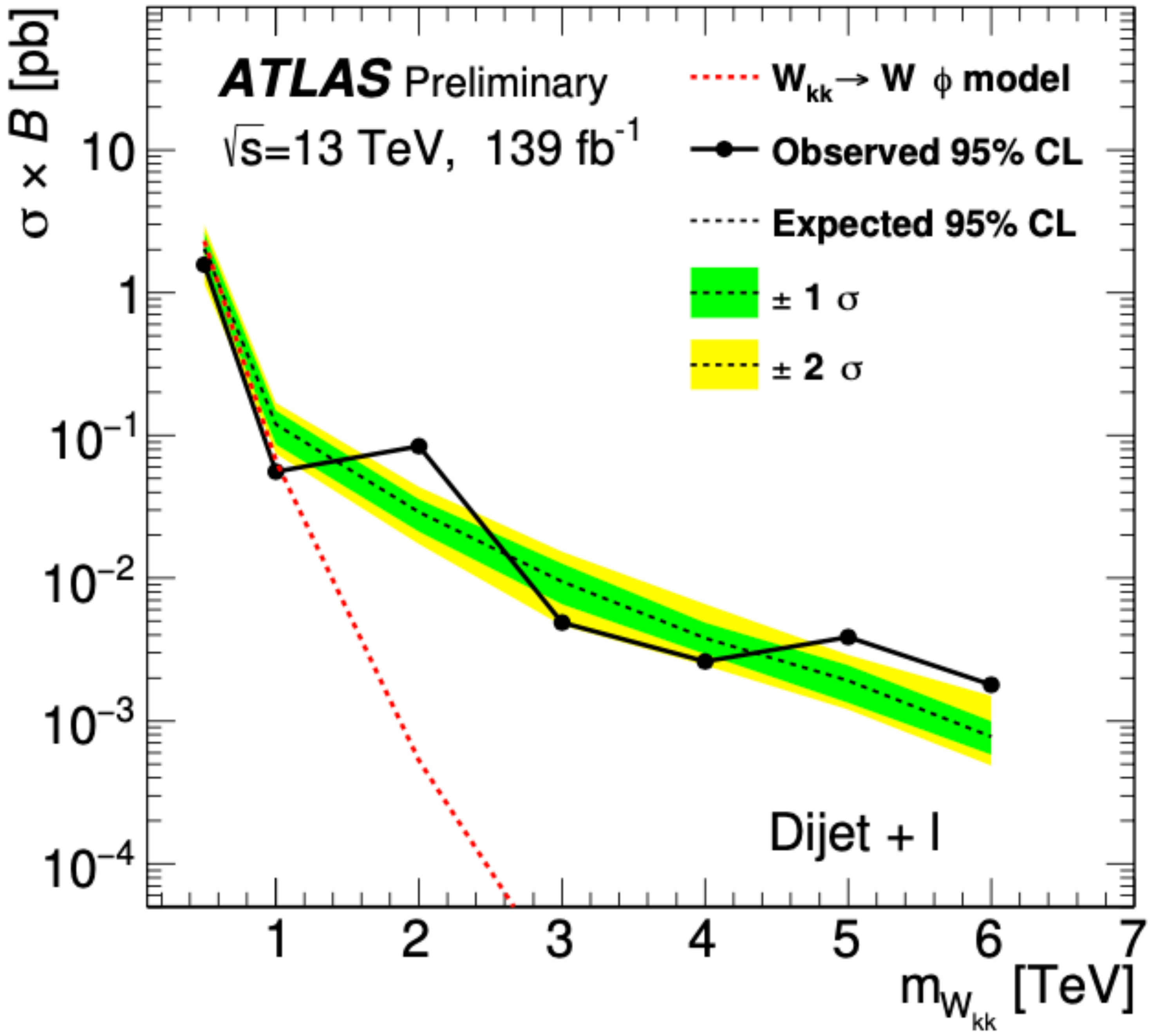
Analysis Strategy and Results

ATLAS-CONF-2022-050

- Events Selection
  - Events are recorded with single lepton (electron and muon) triggers
  - **SR**: least one isolated lepton (e or μ) with $p_T \geq$ 60 GeV and at least two jets (overlap removal applied)
    - The invariant masses are constructed by combining the two jets having the highest p_T with one or two leptons: m_{jjl}, m_{jjll}, m_{jbl}, m_{bbl}



- Results
  - SSM models: W'< 2.5 TeV is excluded with m(W'-Z')< 250 GeV.
  - Radion model, with mass splitting between a radion ϕ and W' small (250 GeV), ϕ mass below 1 TeV is excluded.
  - Composite lepton model with a Z' boson: m(Z') < 1.3 TeV and masses of the composite leptons < 500 GeV are excluded



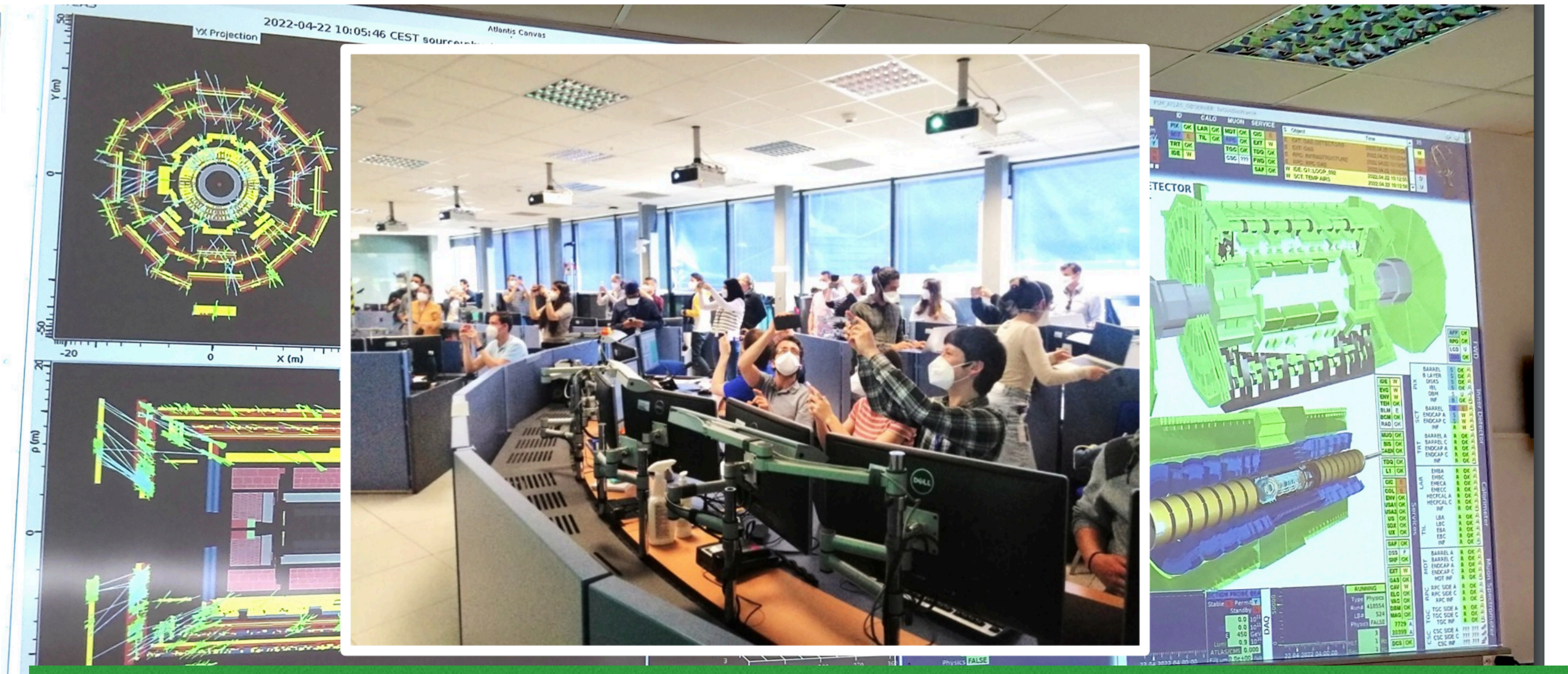
Conclusions

The large data statistics of the full Run-2 dataset allows **to address difficult BSM and SUSY scenarios**, using advances in analysis techniques.

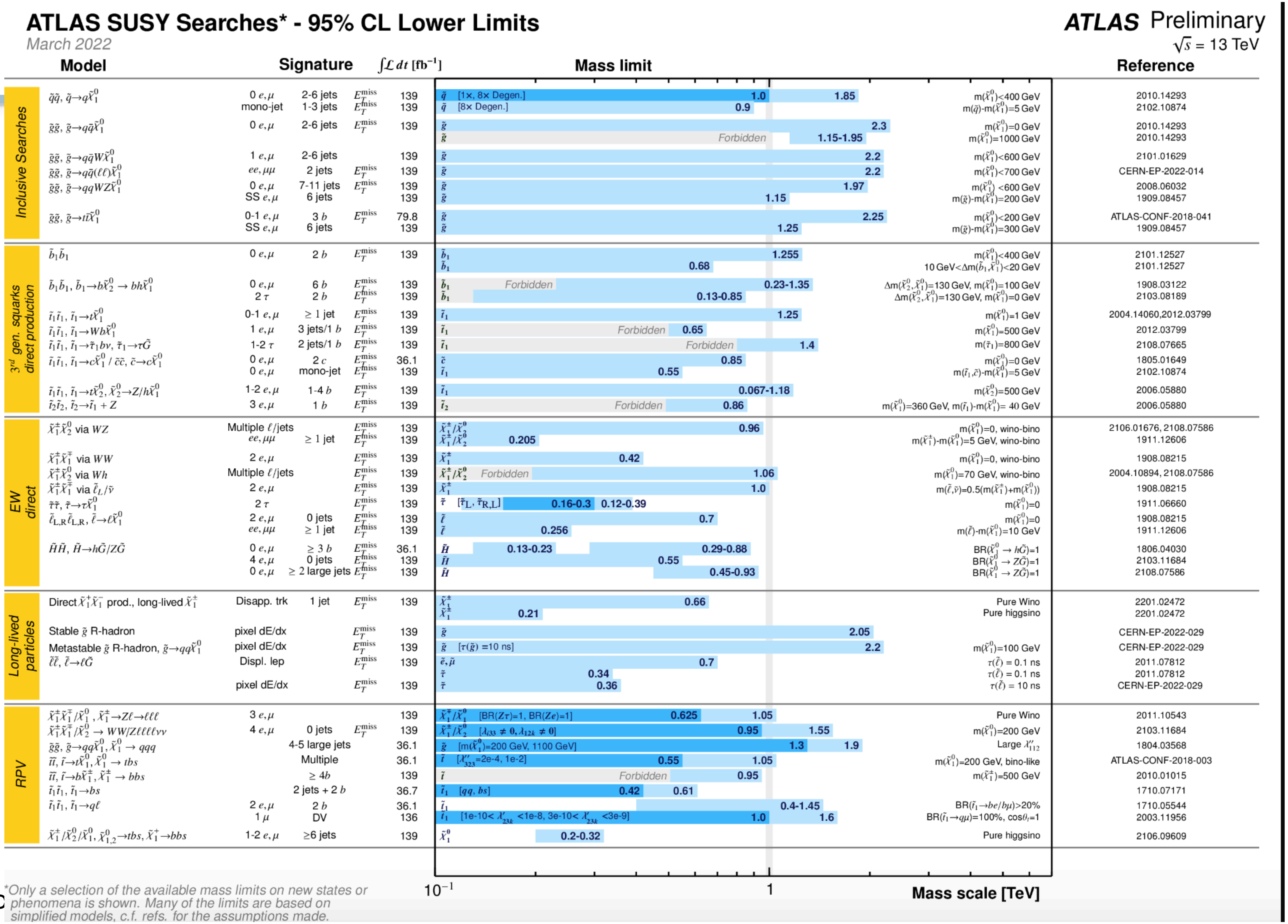
Presented **few new analyses**. **No significant excess seen → stronger exclusion limits.**

Run3 started this year! Possibility to identify not yet covered phase-space and prepare new search strategies for Run-3!

- For any comments or questions you can send me an email to **monica.verducci@cern.ch**



First 13.6 TeV stable-beams collisions for Run3 data taking started on 5 July 2022!

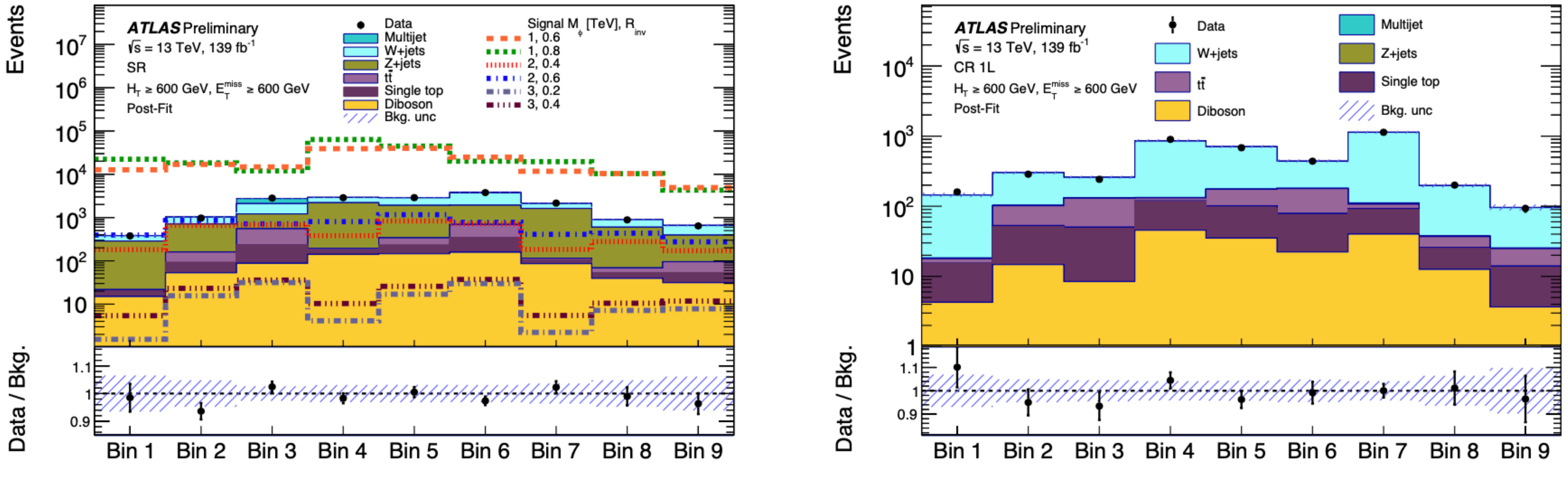


This was a short summary here the complete ATLAS SUSY Searches

Backup

Post-Fit Distributions

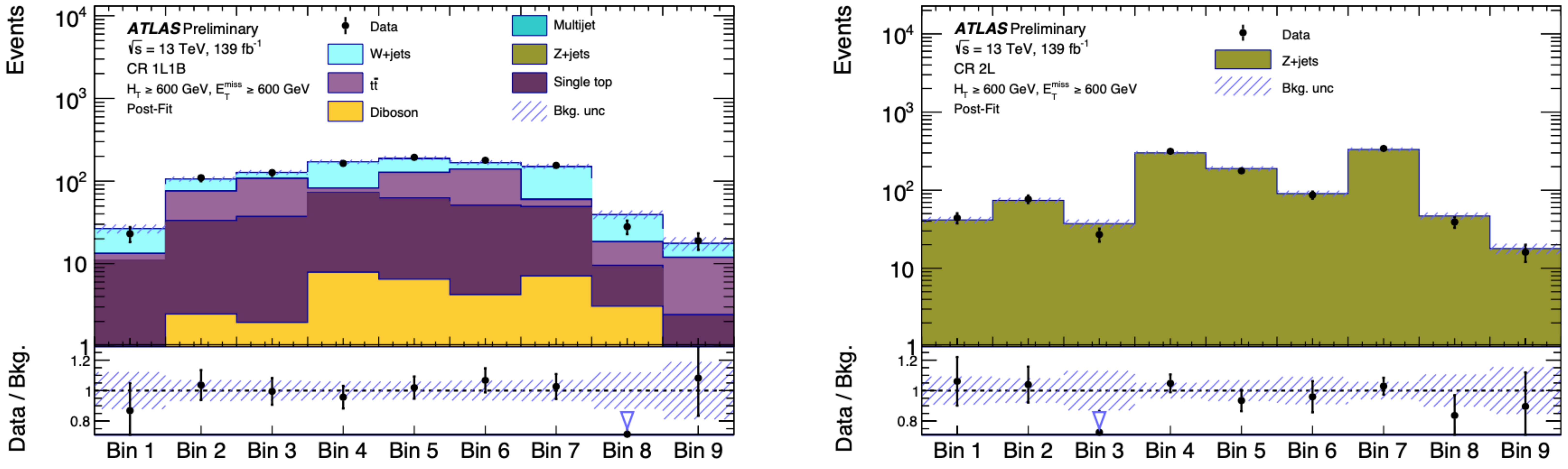
9 bins after the E_T^{Miss} > 600 GeV and H_T > 600 GeV cuts



(a) SR (a), 1L CR (b) (b)

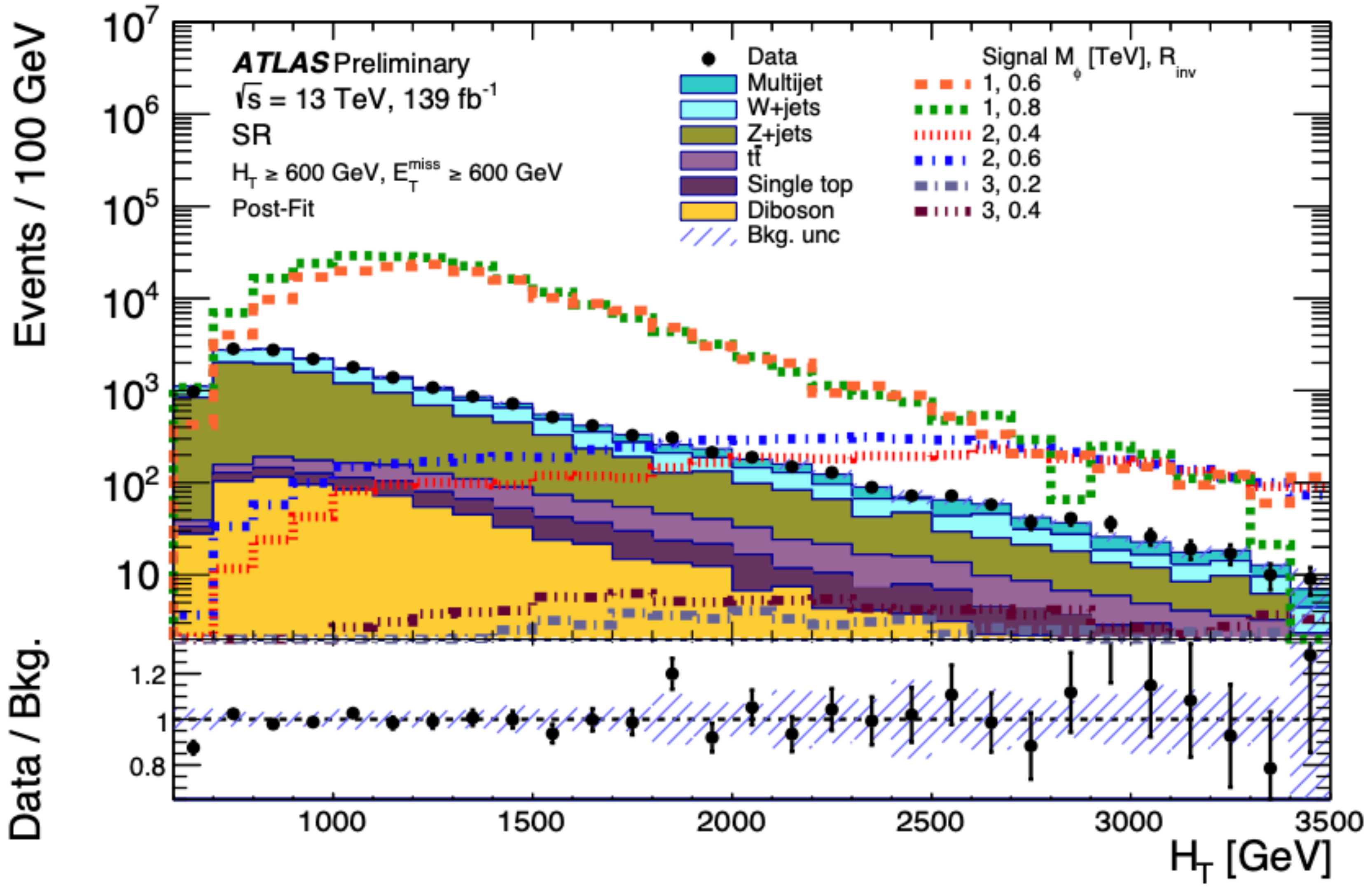
Scale Factor after the Fits

Process	k_i^{SF}
Z+jets	1.18 ± 0.05
W+jets	1.09 ± 0.04
Top processes	0.64 ± 0.04
Multijet	1.10 ± 0.04

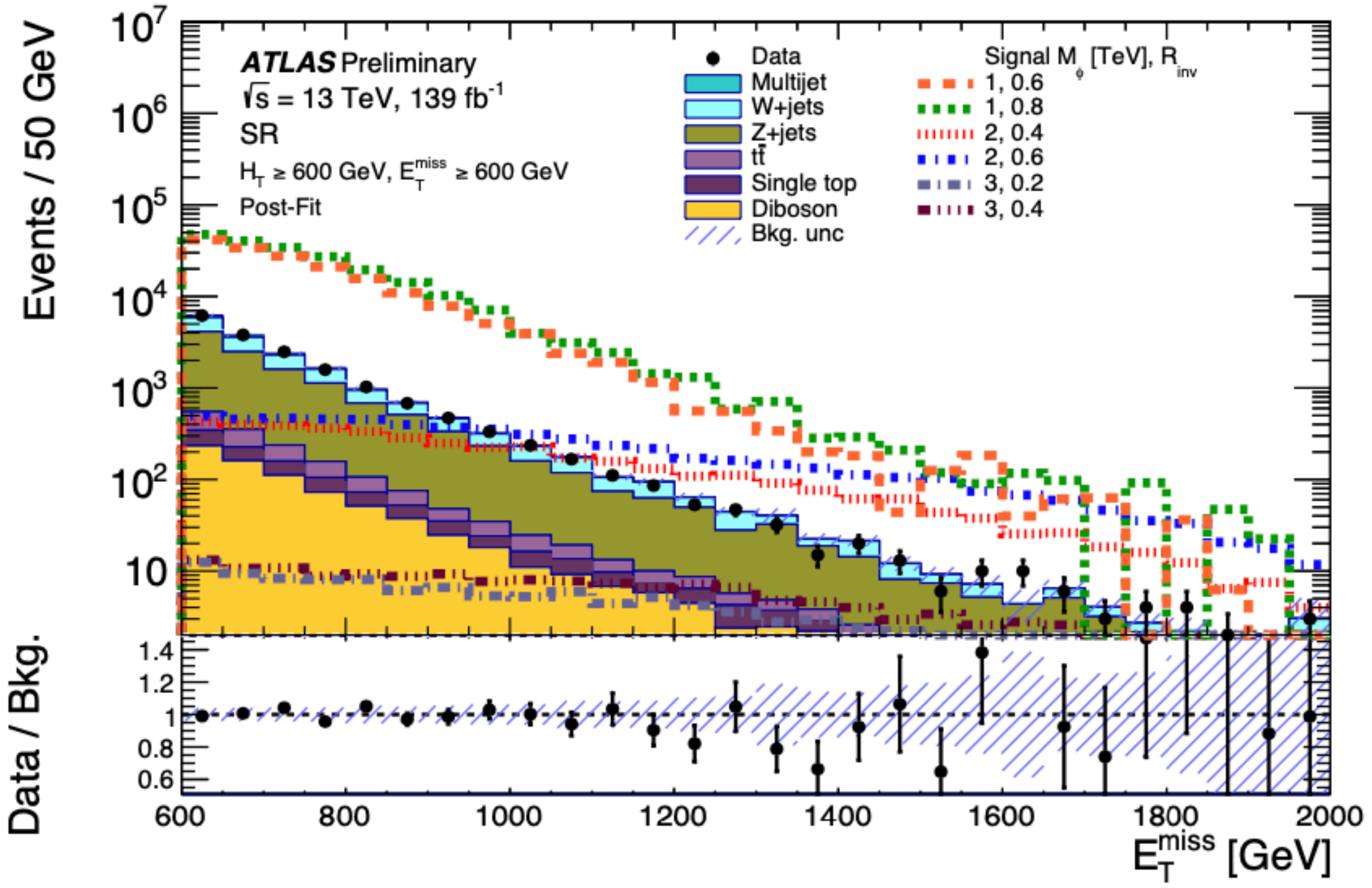


(c) 1L1B CR (c), 2L CR (d) (d)

Post-Fit Distributions

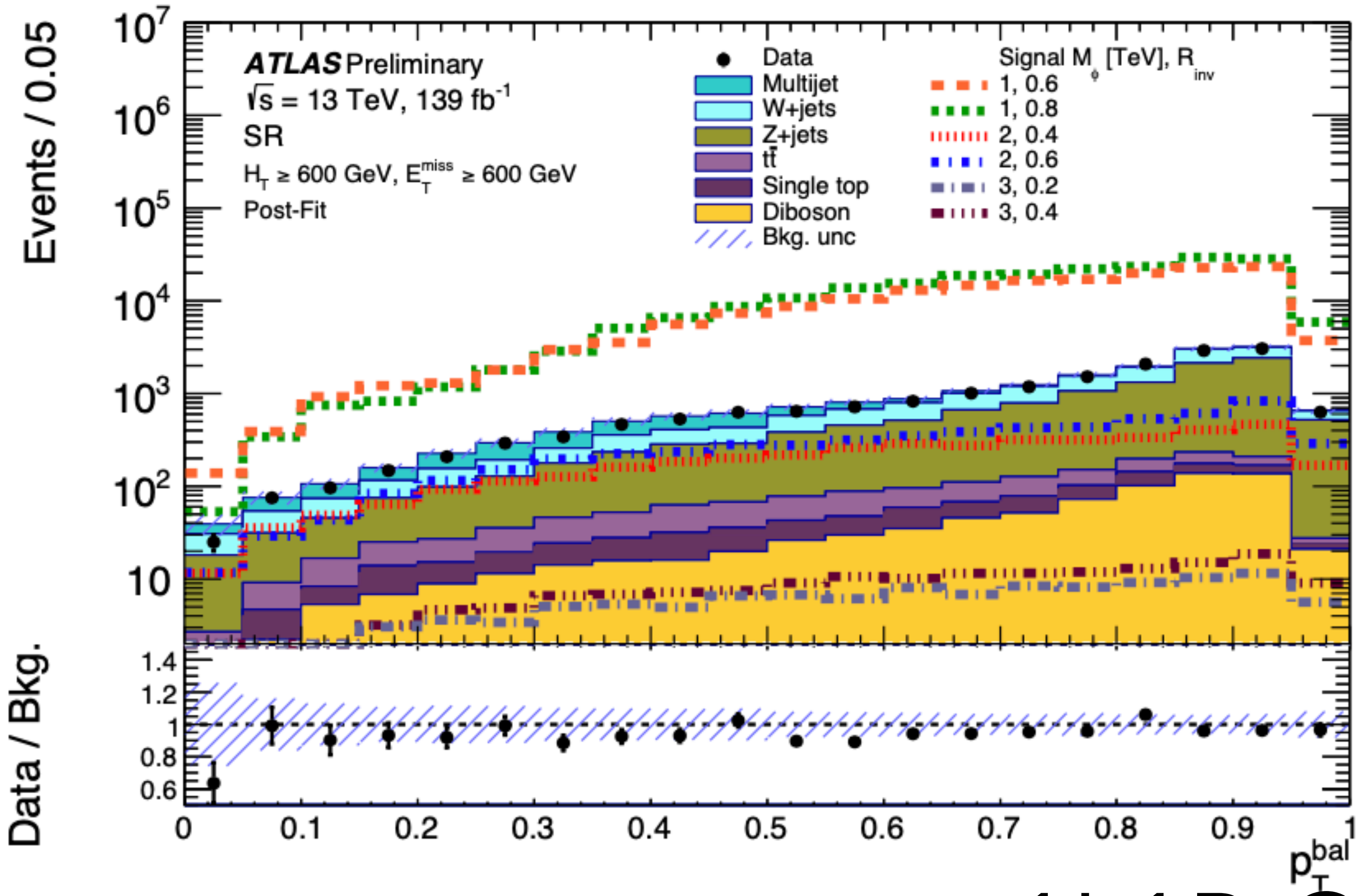


(a)

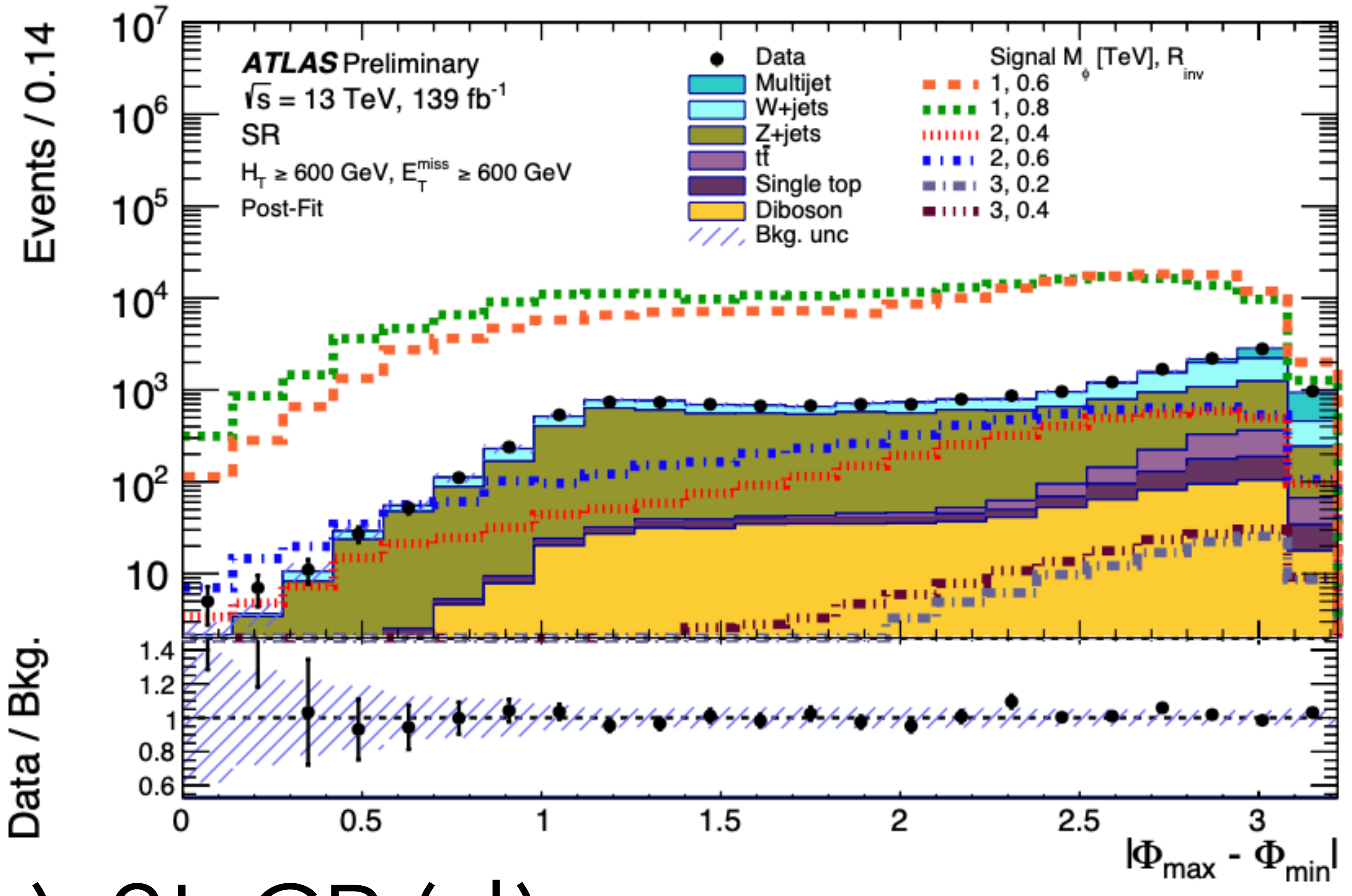


(b)

SR (a), 1L CR (b)



(c)



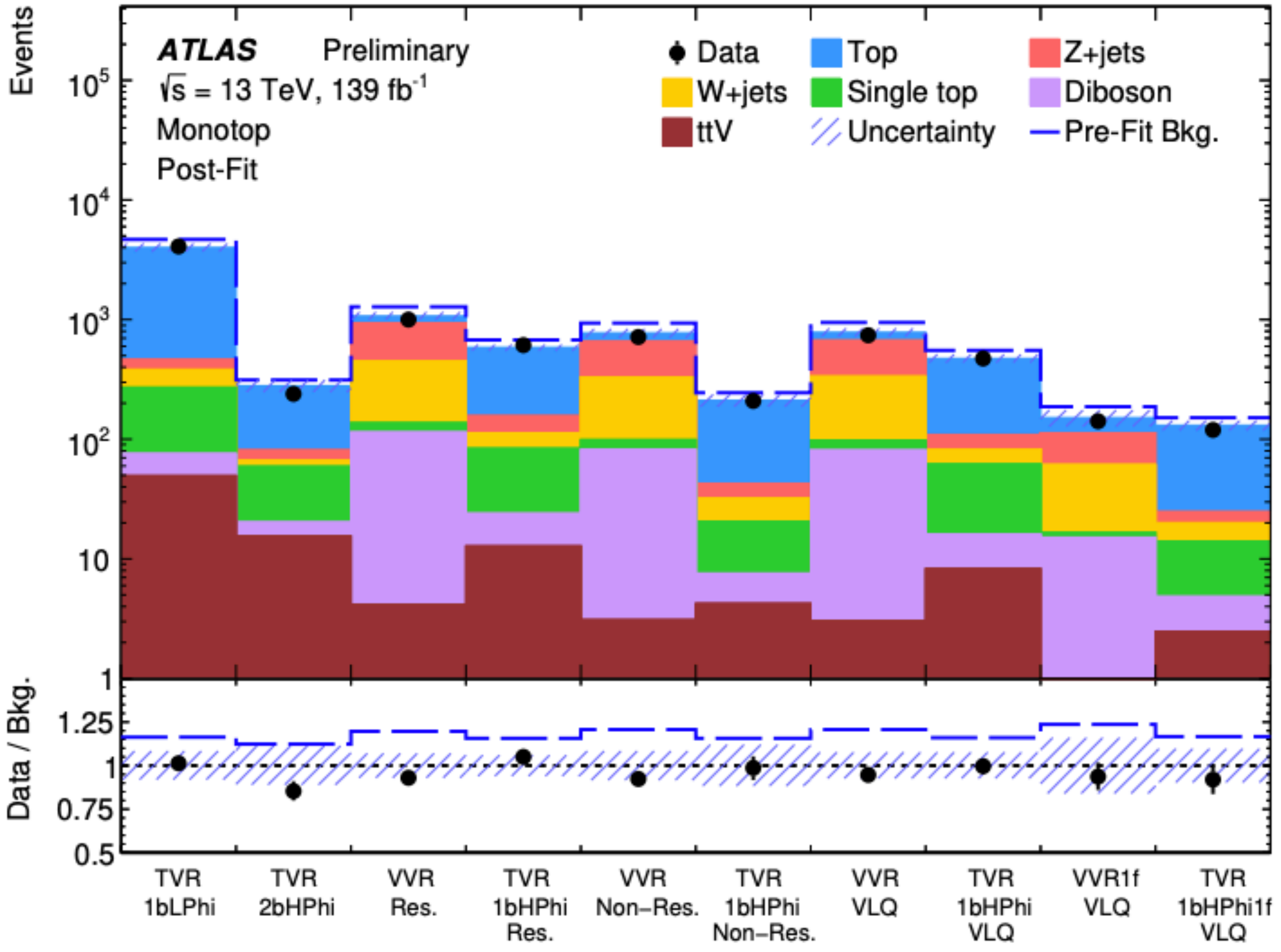
(d)

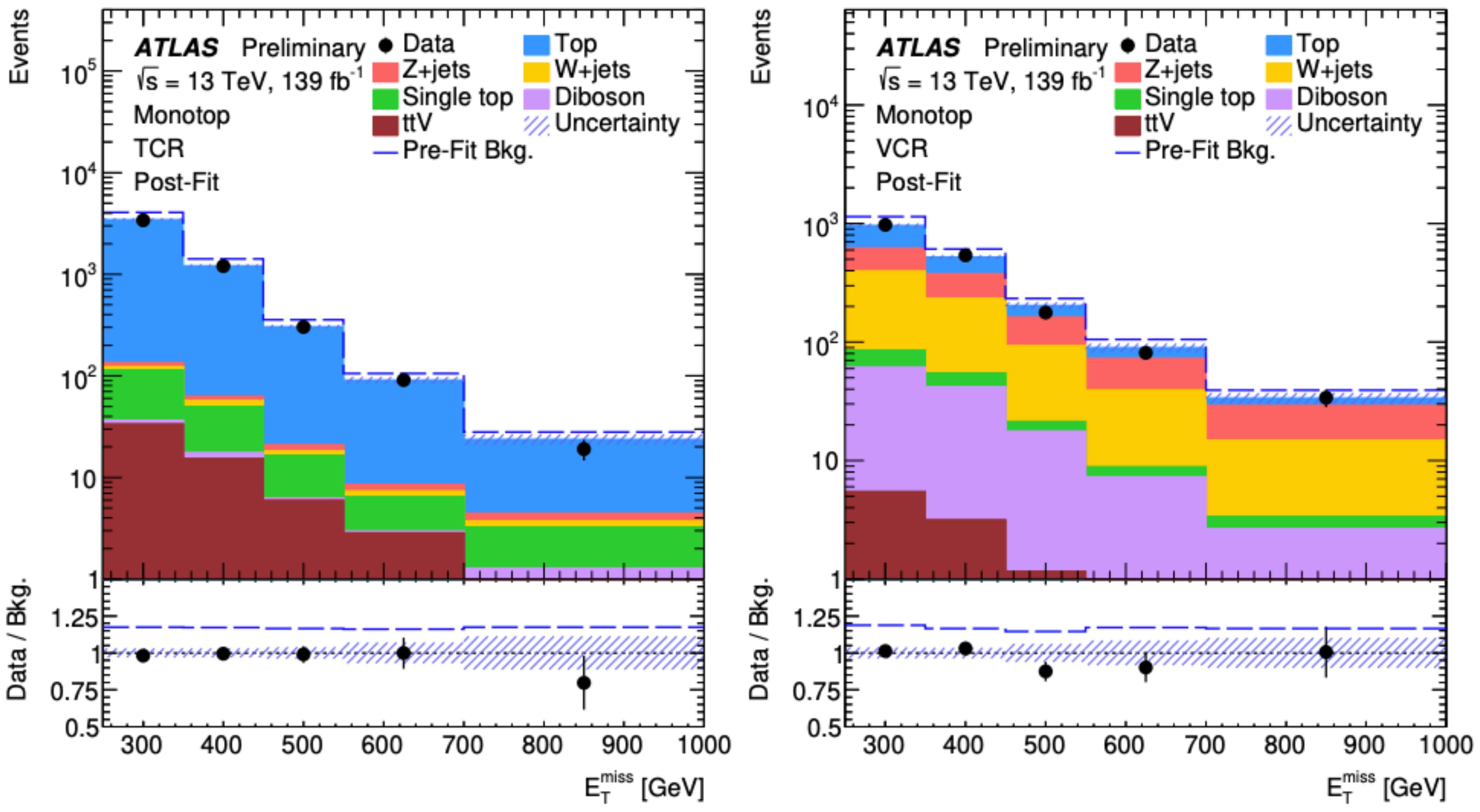
1L1B CR (c), 2L CR (d)

Post-Fit Distributions

ATLAS-CONF-2022-036

Comparison of data and SM predictions for the event yields in each validation region. SR targeted for the DM non-resonant production.





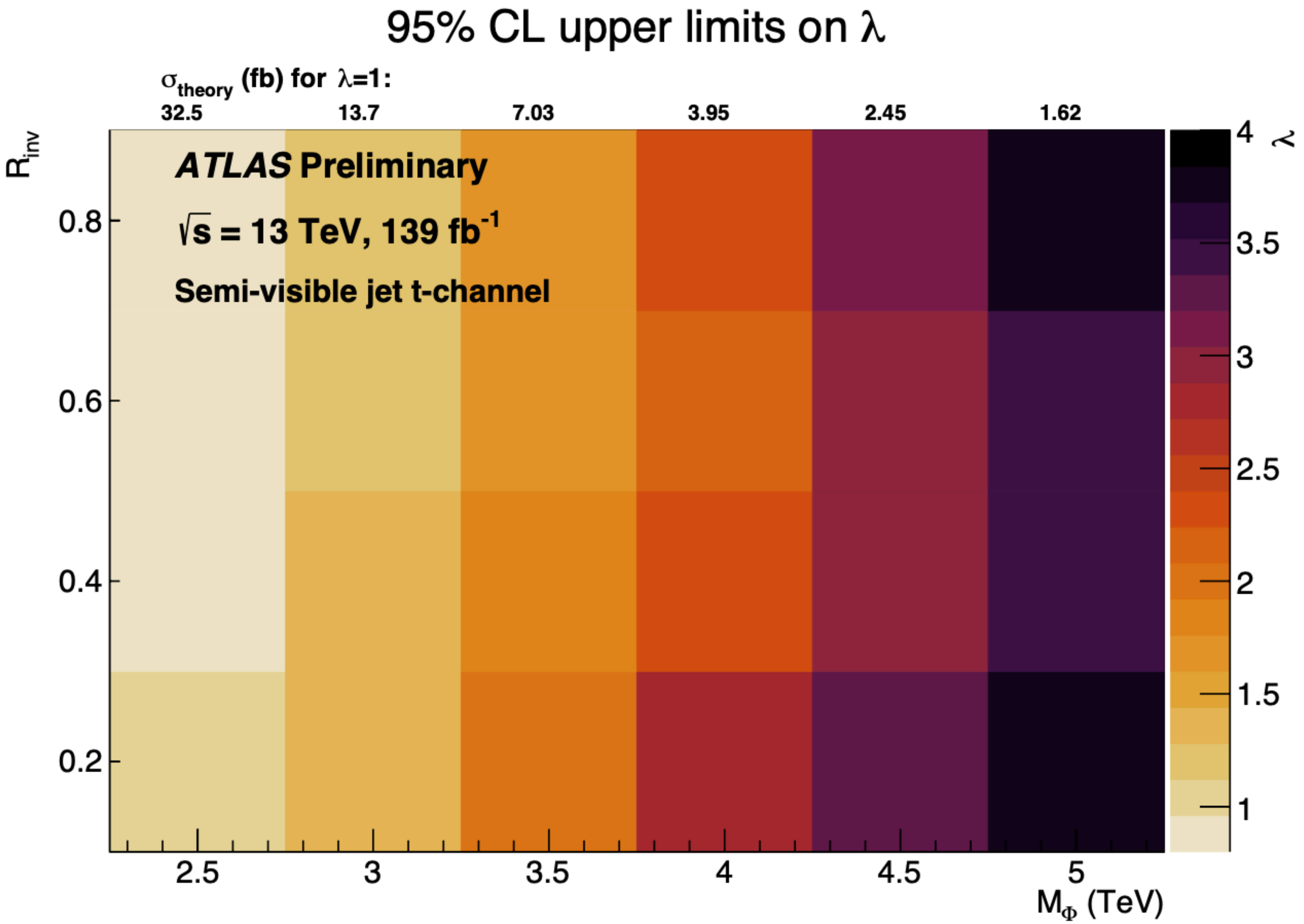
(a) (b)

Comparison of data and SM prediction for the E_T^{Miss} distribution in control regions targeting (a) $t\bar{t}$ and (b) V+jets processes. SR targeted for DM resonant production.

Event Yield

	SR	CR 1L	CR 1L1B	CR2L
Z+jets	8490 ± 260	11.6 ± 1.4	2.2 ± 0.6	1120 ± 40
W+jets	5820 ± 300	3190 ± 170	351 ± 41	-
$t\bar{t}$	920 ± 70	350 ± 29	304 ± 24	-
Single top	533 ± 47	358 ± 29	290 ± 25	-
Multijet	850 ± 100	28 ± 11	7.7 ± 3.1	-
Diboson	757 ± 10	187 ± 9	34.5 ± 2.8	-
Total background	17 370 ± 280	4120 ± 100	990 ± 35	1120 ± 40
Data	17 388	4136	999	1124
Signal:				
M_{ϕ}=1 TeV, R_{inv}=0.6	180 000 ± 40 000	-	-	-
M_{ϕ}=1 TeV, R_{inv}=0.8	220 000 ± 50 000	-	-	-
M_{ϕ}=2 TeV, R_{inv}=0.4	4100 ± 900	-	-	-
M_{ϕ}=2 TeV, R_{inv}=0.6	5800 ± 1300	-	-	-
M_{ϕ}=3 TeV, R_{inv}=0.2	117 ± 26	-	-	-
M_{ϕ}=3 TeV, R_{inv}=0.4	170 ± 40	-	-	-

Limits



95% CL upper limits on λ
σ_theory (fb) for λ=1:
32.5
13.7
7.03
3.95
2.45
1.62
ATLAS Preliminary
√s = 13 TeV, 139 fb⁻¹
Semi-visible jet t-channel
R_inv
0.8
0.6
0.4
0.2
2.5
3
3.5
4
4.5
5
M_Φ (TeV)
4
3.5
3
2.5
2
1.5
1
λ

Signal Region (SR): Wh scenario (2SRs) Zh (2SRs) and RPV2 (2SRs)

ATLAS-CONF-2022-057

	$\mathrm{SR}^{WZ}_{\mathrm{high}-m_{\mathrm{T2}}}$	$\mathrm{SR}^{WZ}_{\mathrm{low}-m_{\mathrm{T2}}}$
$N_{\mathrm{BL}}(\ell)$	$= 2$	
$N_{\mathrm{Sig}}(\ell)$	$= 2$	
$\mathrm{Charge}(\ell)$	same-sign	
$p_{\mathrm{T}}(\ell)$	≥ 25 GeV	
n_{jets} ($p_{\mathrm{T}} > 25$ GeV)	≥ 1	
$n_{b\text{-jets}}$	$= 0$	
m_{jj}	≤ 350 GeV	
m_{T2}	≥ 100 GeV	≤ 100 GeV
$m_{\mathrm{T}}^{\mathrm{min}}$	≥ 100 GeV	≥ 130 GeV
$E_{\mathrm{T}}^{\mathrm{miss}}$	≥ 100 GeV	≥ 140 GeV
m_{eff}	–	≤ 600 GeV
$\Delta R(\ell^{\pm}, \ell^{\pm})$	–	≤ 3
Bins	$\mathcal{S}(E_{\mathrm{T}}^{\mathrm{miss}})$: $\in [0, 10)$ Spread$(\Phi) \geq 2.2$	–
	$\mathcal{S}(E_{\mathrm{T}}^{\mathrm{miss}})$: $\in [10, 13)$	
	$\mathcal{S}(E_{\mathrm{T}}^{\mathrm{miss}})$: $\in [13, +\infty]$ $\Delta R(\ell^{\pm}, \ell^{\pm}) \geq 1$	

	$\mathrm{SR}^{Wh}_{\mathrm{high}-m_{\mathrm{T2}}}$			$\mathrm{SR}^{Wh}_{\mathrm{low}-m_{\mathrm{T2}}}$		
	$e^{\pm}e^{\pm}$	$e^{\pm}\mu^{\pm}$	$\mu^{\pm}\mu^{\pm}$	$e^{\pm}e^{\pm}$	$e^{\pm}\mu^{\pm}$	$\mu^{\pm}\mu^{\pm}$
$N_{\mathrm{BL}}(\ell)$	$= 2$					
$N_{\mathrm{Sig}}(\ell)$	$= 2$					
$\mathrm{Charge}(\ell)$	same-sign					
$p_{\mathrm{T}}(\ell)$	≥ 25 GeV					
n_{jets} ($p_{\mathrm{T}} > 25$ GeV)	≥ 1					
$n_{b\text{-jets}}$	$= 0$					
m_{jj}	< 350 GeV					
m_{T2}	≥ 80 GeV			< 80 GeV		
$m_{\mathrm{T}}^{\mathrm{min}}$	–			≥ 100 GeV		
$\mathcal{S}(E_{\mathrm{T}}^{\mathrm{miss}})$	≥ 7			≥ 6		
$E_{\mathrm{T}}^{\mathrm{miss}}$	≥ 75 GeV			≥ 50 GeV		
$E_{\mathrm{T}}^{\mathrm{miss}}$ binning (GeV)[a]	$\mathrm{SR}^{Wh}_{\mathrm{high}-m_{\mathrm{T2}}}$-1: $\in [75, 125)$ $\mathrm{SR}^{Wh}_{\mathrm{high}-m_{\mathrm{T2}}}$-2: $\in [125, 175)$ $\mathrm{SR}^{Wh}_{\mathrm{high}-m_{\mathrm{T2}}}$-3: $\in [175, +\infty)$			–		

[a] The $E_{\mathrm{T}}^{\mathrm{miss}}$ binning applies separately to each flavour channel of $\mathrm{SR}^{Wh}_{\mathrm{high}-m_{\mathrm{T2}}}$.

	$\mathrm{SR}^{\mathrm{bRPV}}_{2\ell-\mathrm{SS}}$	$\mathrm{SR}^{\mathrm{bRPV}}_{3\ell}$
$N_{\mathrm{BL}}(\ell)$	–	
p_{T} (ℓ)	≥ 20 GeV for (sub)leading leptons	
n_{jets} ($p_{\mathrm{T}} > 25$ GeV)	≥ 1	
$N_{\mathrm{Sig}}(\ell)$	$= 2$	$= 3$
$\mathrm{Charge}(\ell)$	same-sign	–
m_{T2}	≥ 60 GeV	≥ 80 GeV
$E_{\mathrm{T}}^{\mathrm{miss}}$	≥ 100 GeV	≥ 120 GeV
m_{eff}	–	≥ 350 GeV
$n_{b\text{-jets}}$	$= 0$	–
n_{jets} ($p_{\mathrm{T}} > 40$ GeV)	≥ 4	–
$m_{e^{\pm}e^{\mp}}$, $m_{\mu^{\pm}\mu^{\mp}}$	–	$\notin [81, 101]$ GeV

Analysis Regions

ATLAS-CONF-2022-036

- **Signal Region (SR): chargino-chargino scenario (C1C1-WW) and chargino-neutralino scenario (C1N2-WZ).**
  - SRLM, SRMM and SRHM indicate low (LM), medium (MM) and high (HM) mass differences, respectively. The requirements on m_T additionally make the three regions mutually exclusive.

Variable	C1C1-WW model SRLM	C1C1-WW model SRMM	C1C1-WW model SRHM	C1N2-WZ model SRLM	C1N2-WZ model SRMM	C1N2-WZ model SRHM
N_{lep} ($p_T > 25$ GeV)	1					
N_{jet} ($p_T > 30$ GeV)	1 – 3					
$N_{large-Rjet}$ ($p_T > 250$ GeV)	≥ 1					
E_T^{miss} [GeV]	> 200					
$\Delta\phi(\ell, E_T^{miss})$	< 2.6					
large-R jet type	W-tagged			Z-tagged		
m_T [GeV]	120–200	200–300	> 300	120–200	200–300	> 300
Exclusion SR						
m_{eff} [GeV] (excl.)	[600–850, > 850]			[600–850, > 850]		
m_{jj}[GeV] (excl.)	[70–90, -]			[80–100, -]		
$\sigma_{E_T^{miss}}$ (excl.)	[> 12, > 15]			[> 12, > 12]		
Discovery SR						
m_{eff} [GeV] (disc.)	> 600	> 600	> 850	> 600	> 850	> 850
m_{jj}[GeV] (disc.)	-	-	-	80–100	-	-
$\sigma_{E_T^{miss}}$ (disc.)	> 15	> 15	> 15	> 12	> 12	> 12

Variable	WDB1L and T CR	VR1	VR2
N_{lep} ($p_T > 25$ GeV)	1		
N_{jet} ($p_T > 30$ GeV)	1 - 3		
N_{b-jet} ($p_T > 30$ GeV)	0 for WDB1L; > 0 for Top		
$N_{large-Rjet}$ ($p_T > 250$ GeV)	≥ 1		
E_T^{miss} [GeV]	> 200		
$\Delta\phi(\ell, E_T^{miss})$	< 2.9		
large-R jet type	W-tagged		
m_{eff} [GeV]	[600-850,> 850]		
$\sigma_{E_T^{miss}}$	< 12	< 12	> 12
m_T [GeV]	50 – 80	> 80	50 – 120

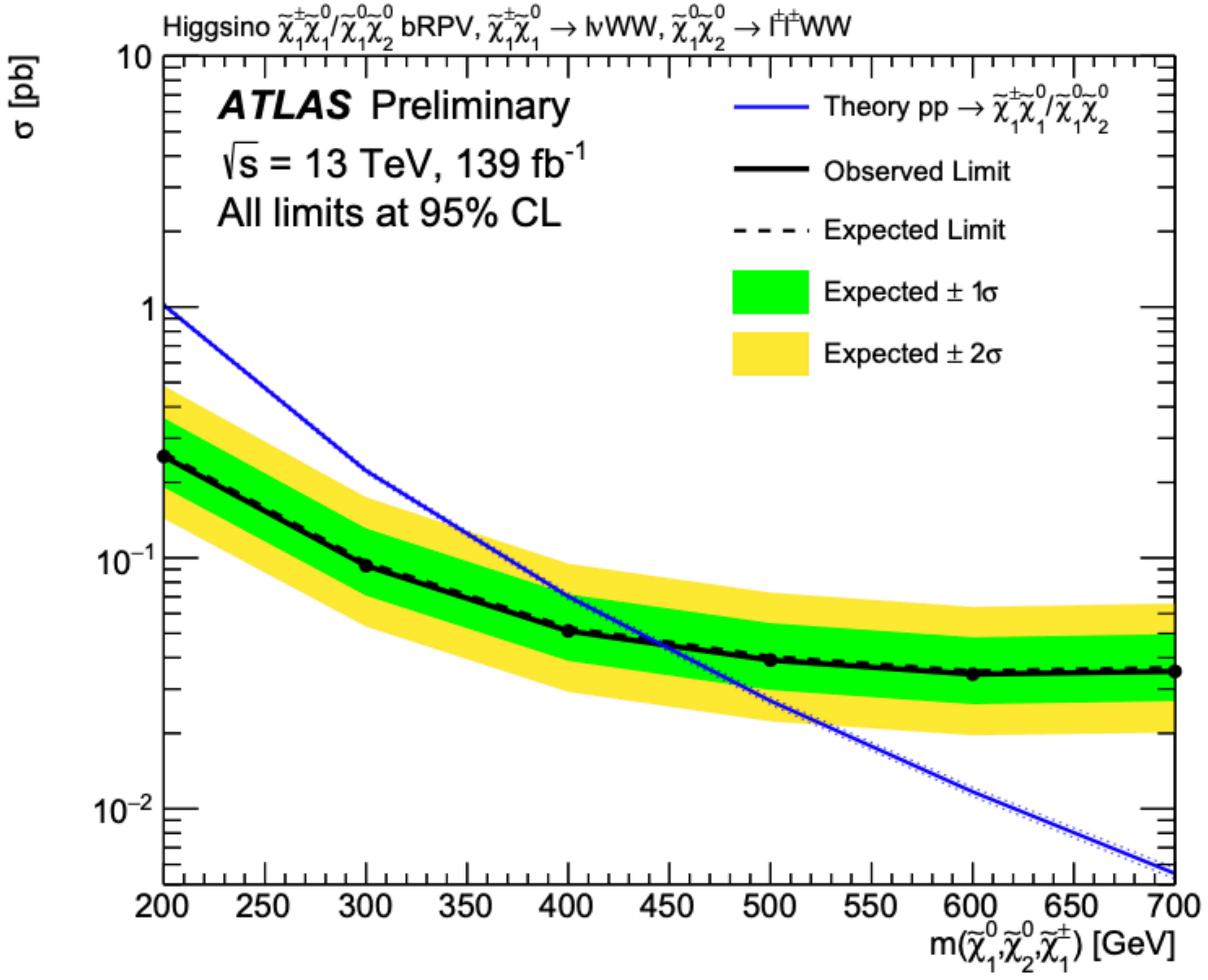
Variable	DB2L CR	VR
N_{lep} ($p_T > 25$ GeV)	2	
N_{jet} ($p_T > 30$ GeV)	1 - 3	
N_{b-jet} ($p_T > 30$ GeV)	0	
E_T^{miss} [GeV]	> 200	
$\Delta\phi(\ell, E_T^{miss})$	< 2.9	
$m_{\ell\ell}$ [GeV]	70 – 100	
m_{jj} veto [GeV]	75 – 95	
$\sigma_{E_T^{miss}}$	> 12	> 10
m_T [GeV]	50 – 200	200 – 350

- **Control Region (CR) and Validation Region (VR):**
  - WDB1LC/VR (single-lepton diboson $l\nu\nu\nu$ and W+jets), TC/VR ($t\bar{t}$),DB2LC/VR (chargino and neutralino search with two leptons and two jets)

Results

ATLAS-CONF-2022-057

- In a **natural RPV model** with bilinear terms mass-degenerate higgsinos **lighter than 4**
been excluded.



Analysis Regions

Additional requirements are used to define several orthogonal regions:

- signal regions (SRs) optimised to maximise the sensitivity to the target signal models;
- control regions (CRs) designed to measure the normalisation of the main contributing background processes;
- and validation regions (VRs) to check the background modelling in regions kinematically closer to the signal regions.
- The control and validation regions are defined to have a negligible signal contribution.