Search for chargino and neutralino production in events with an isolated lepton, jets and missing transverse momentum at $\sqrt{s} = 13$ TeV with ATLAS detector

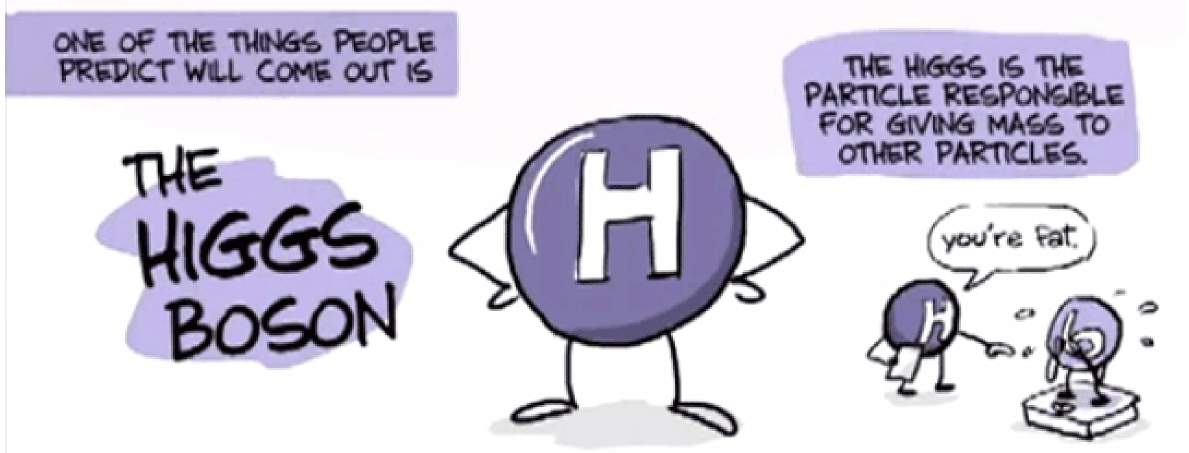
VU Ngoc Khanh, Steve MUANZA

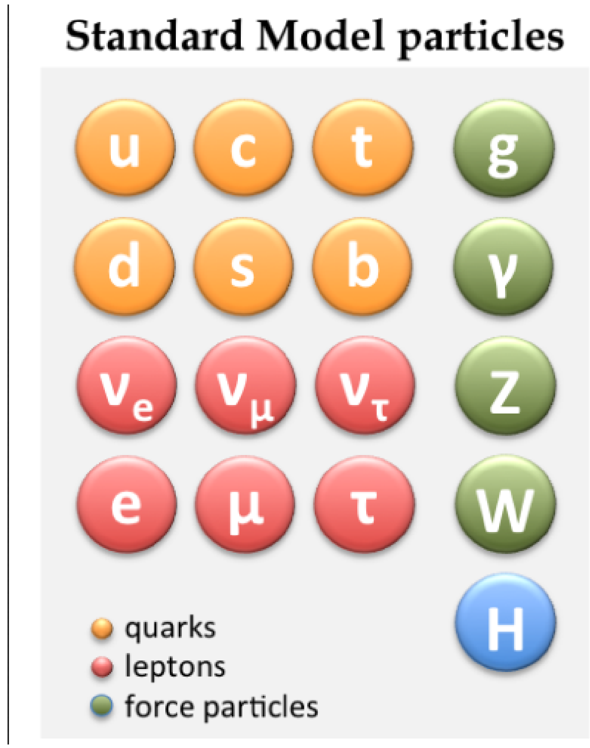
Journées de Rencontres Jeunes Chercheurs 2019
Centre de Physique des Particules de Marseille – CPPM
Aix-Marseille University – AMU

November 28, 2019

Outline

- **Standard Model** (SM): **very successful**. However, leaves **many open questions**.





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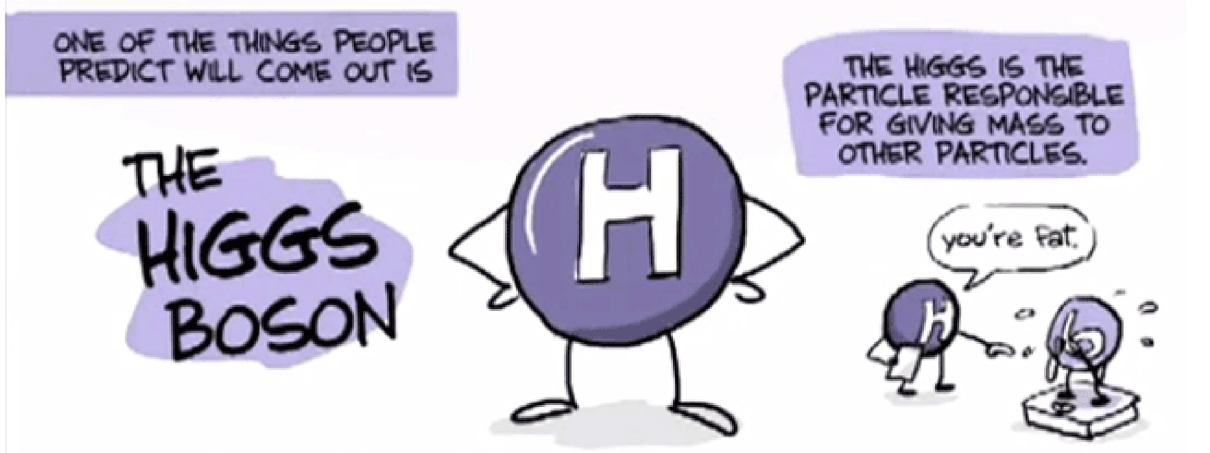

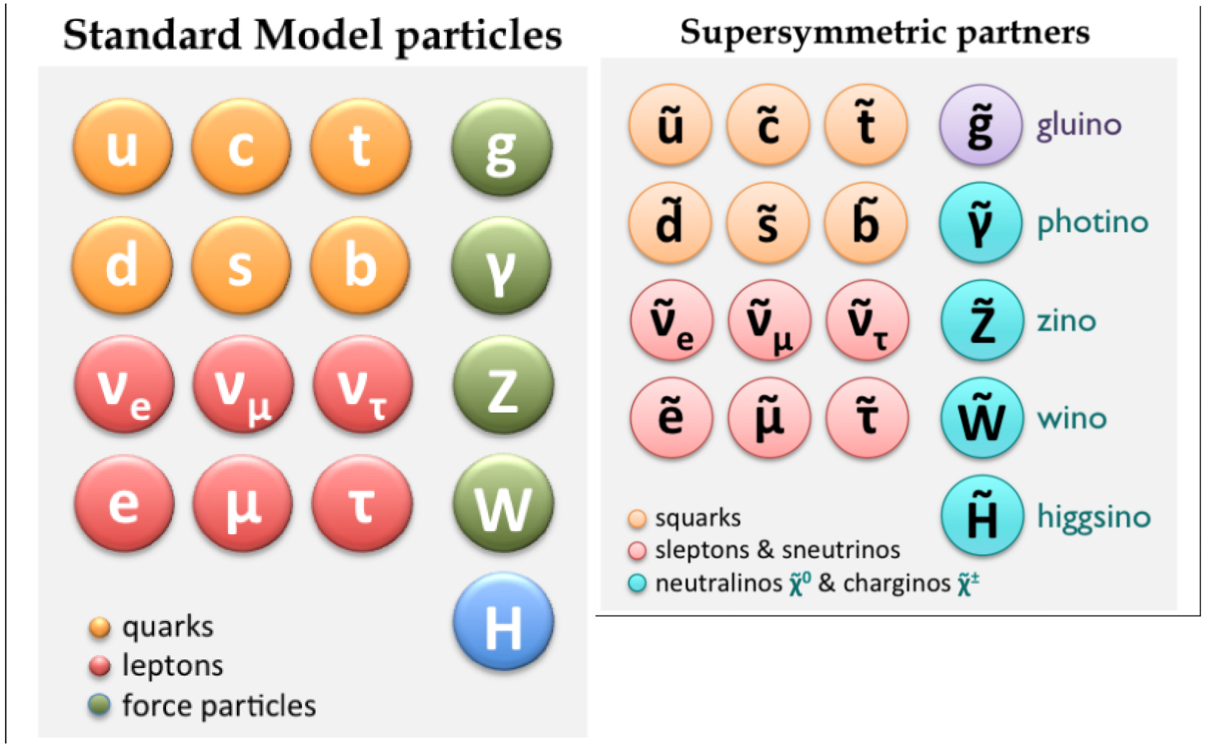

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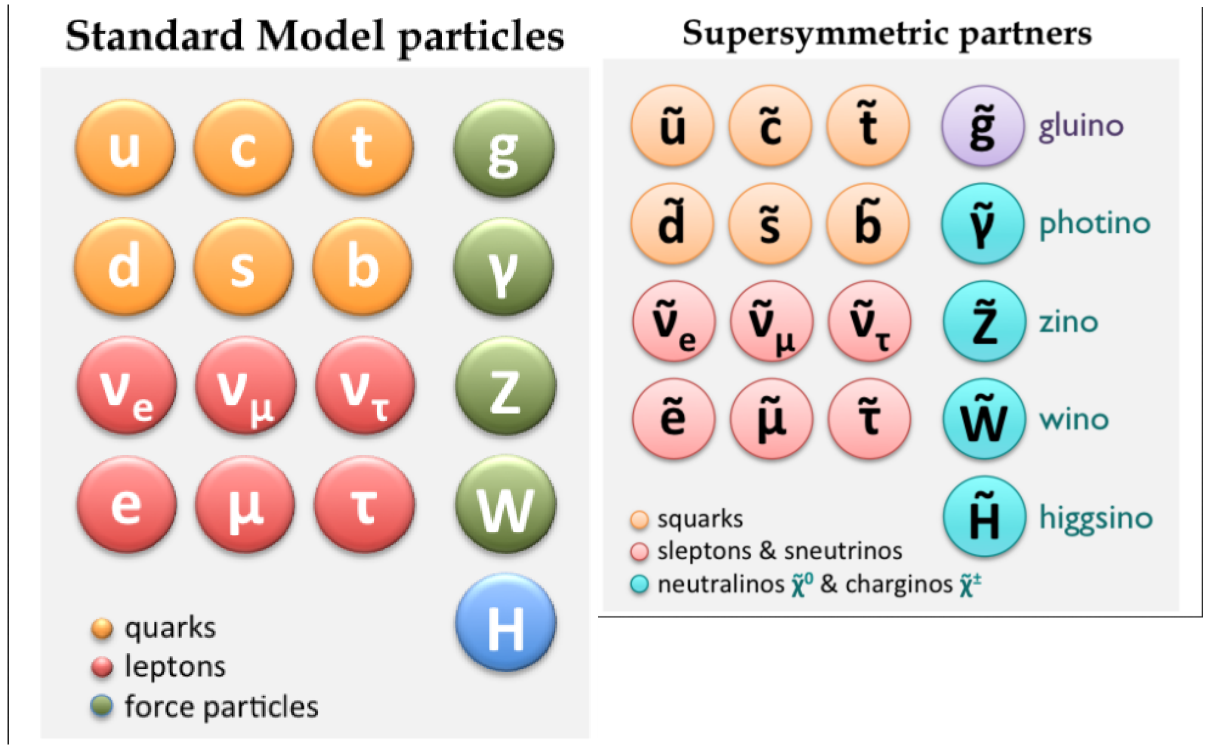

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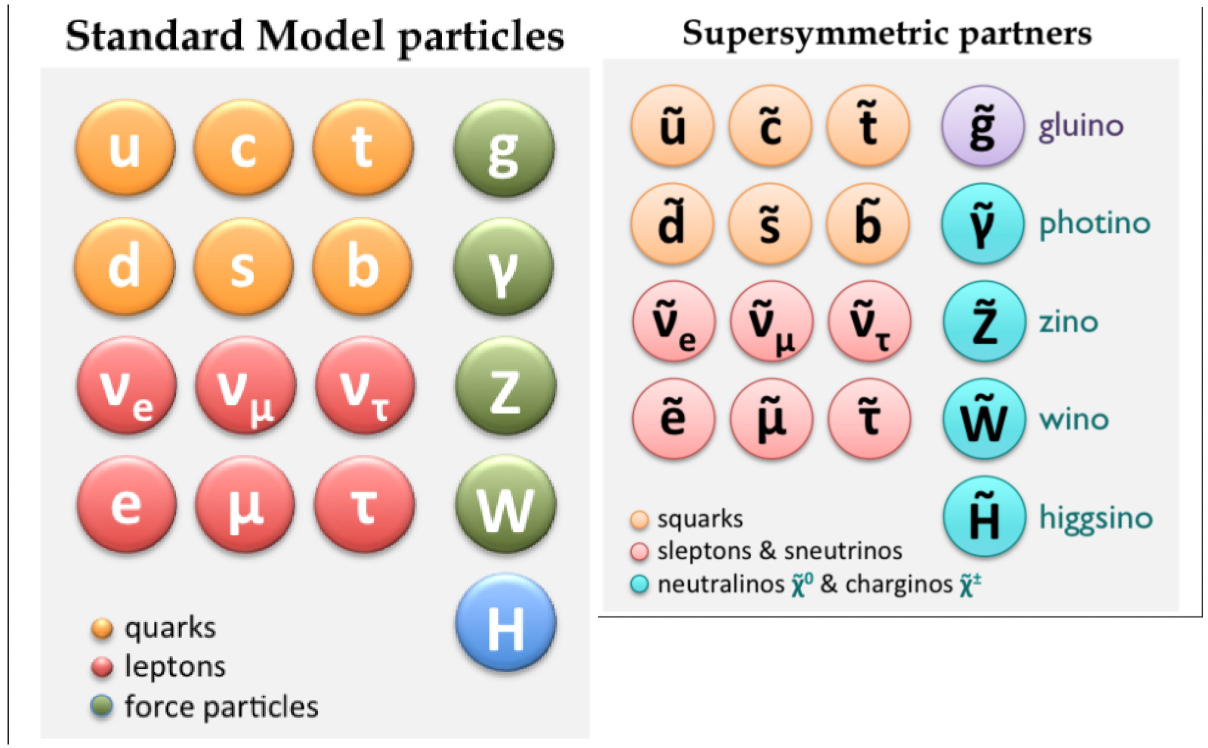

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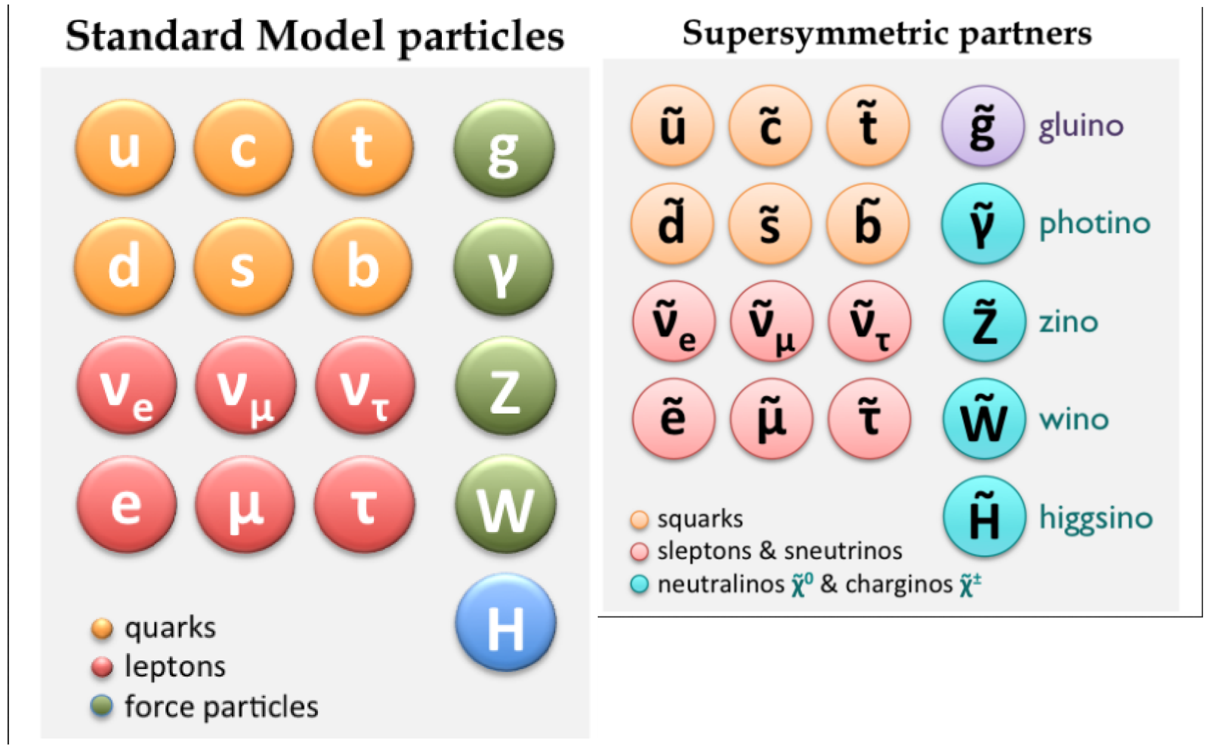

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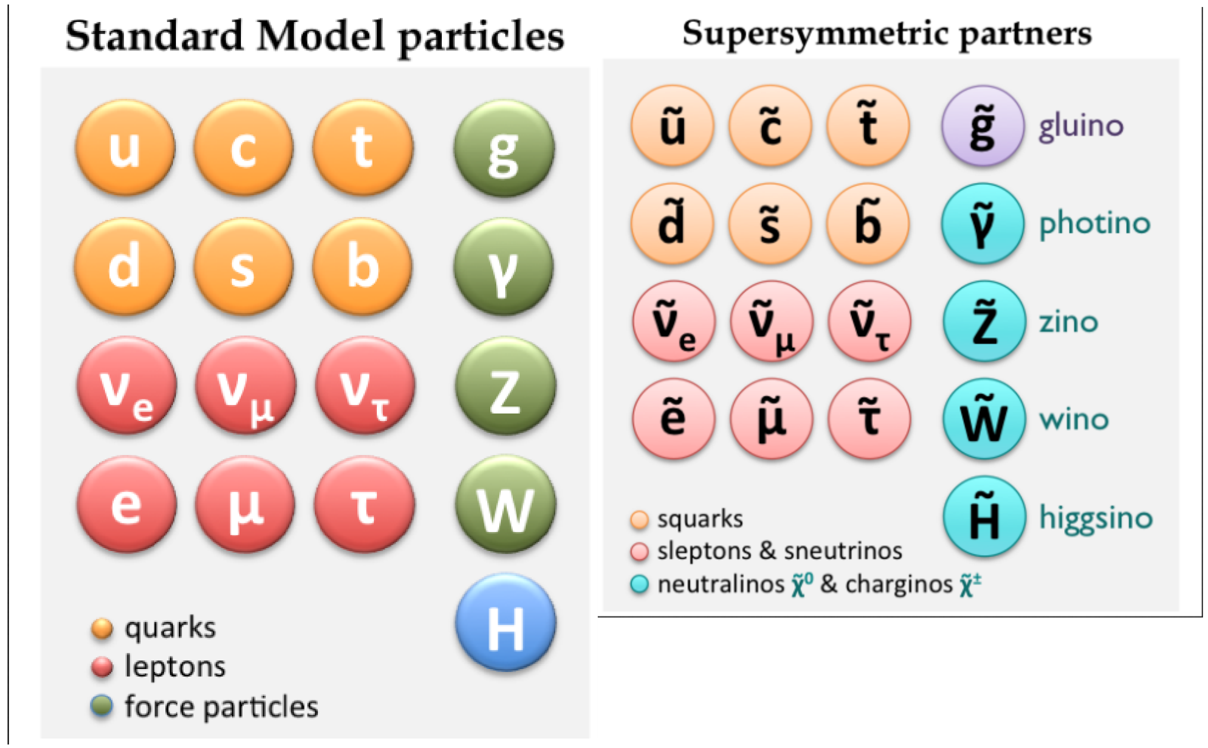
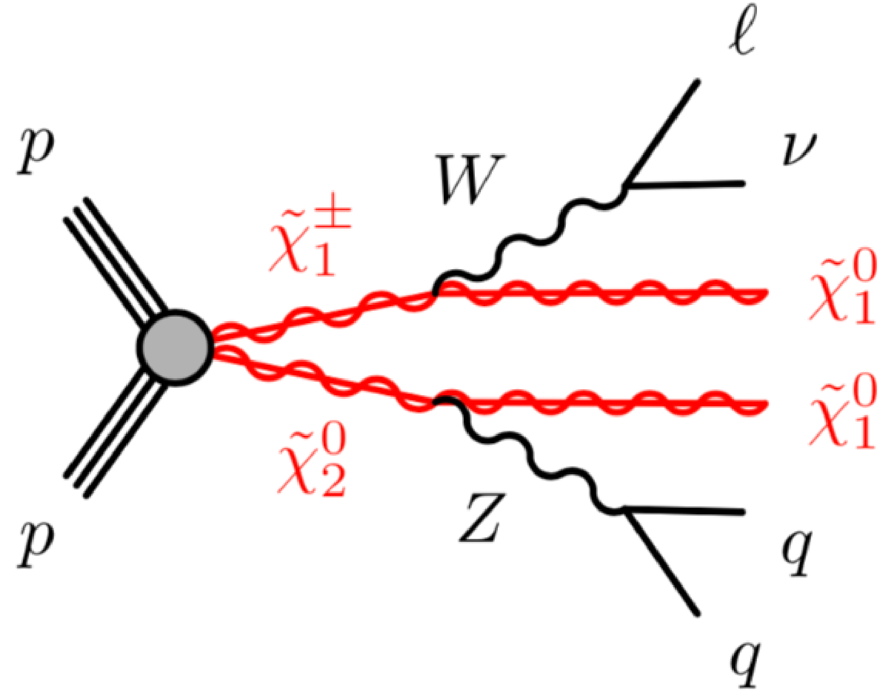
- ***R*-parity**: $\mathcal{P}_R = (-1)^{3B+L+2s}$. ***R*-parity conserved** (RPC):
  - SUSY particles produced **in pairs**.
  - **Lightest supersymmetric particle** (LSP) **stable**, **weakly interacting $\rightarrow$ invisible** to detector, **Dark Matter candidate**.



Simplified signal model



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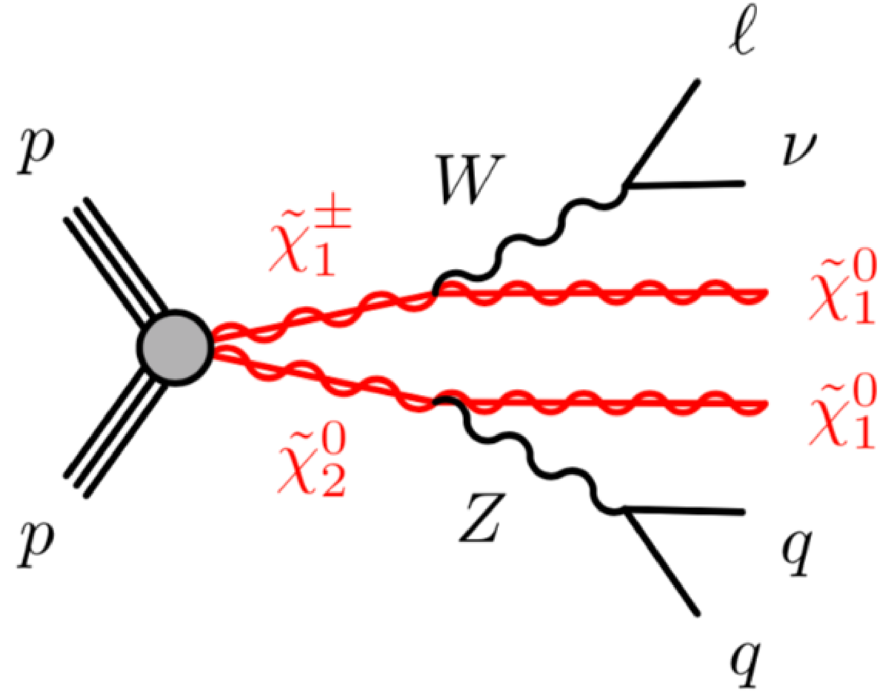

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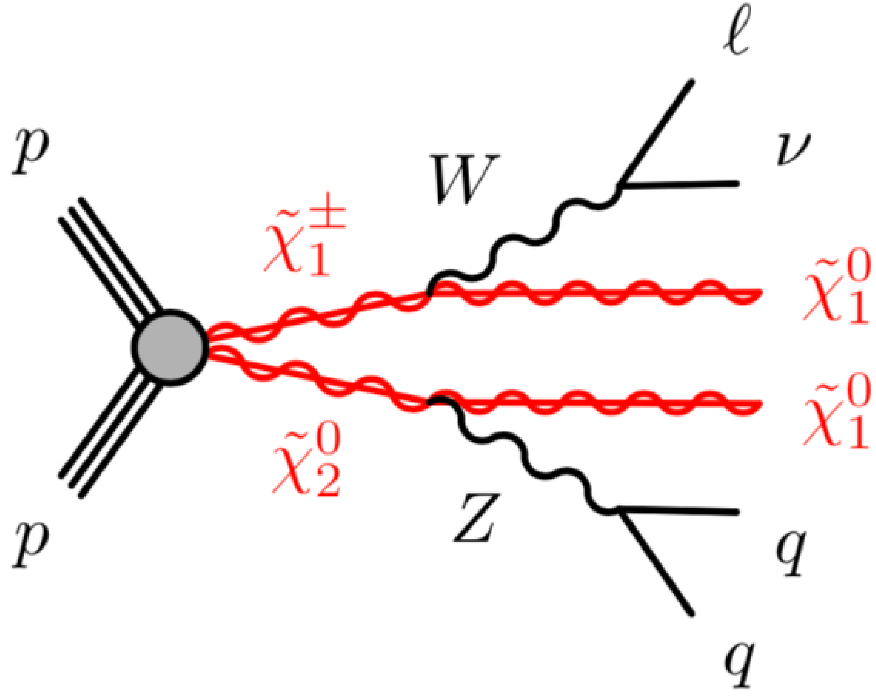

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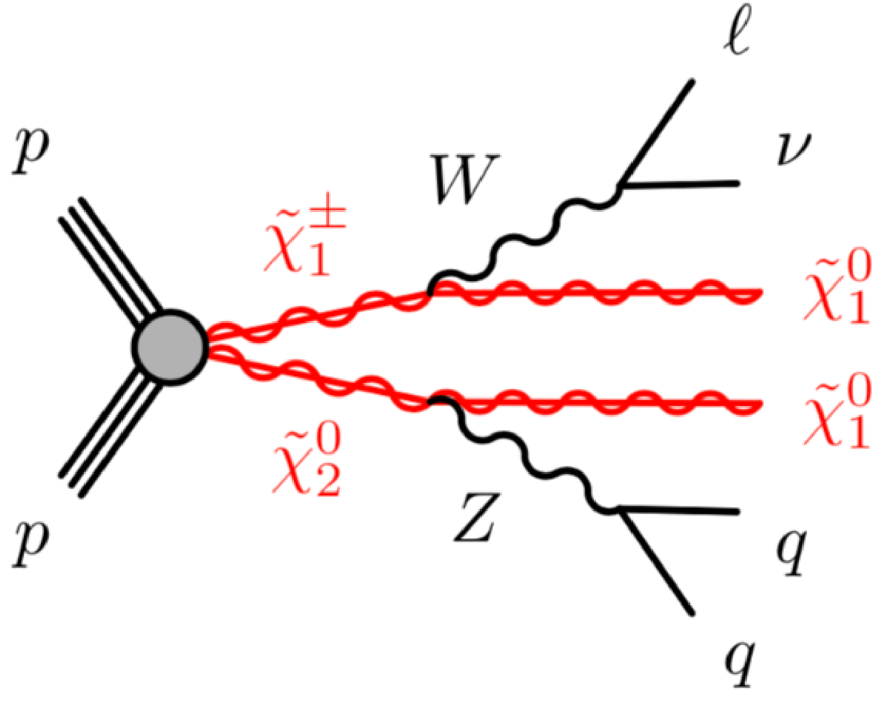

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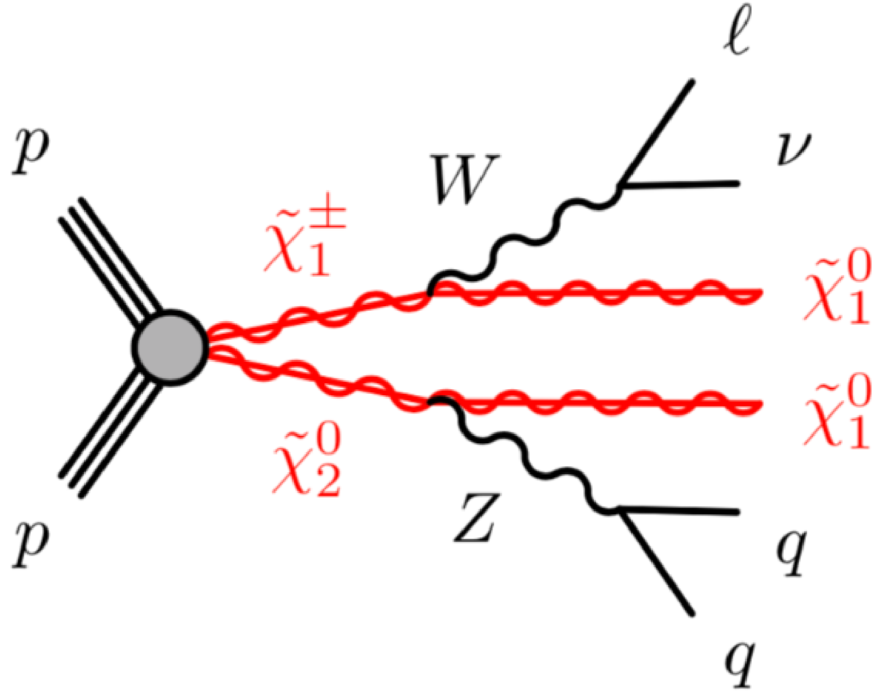

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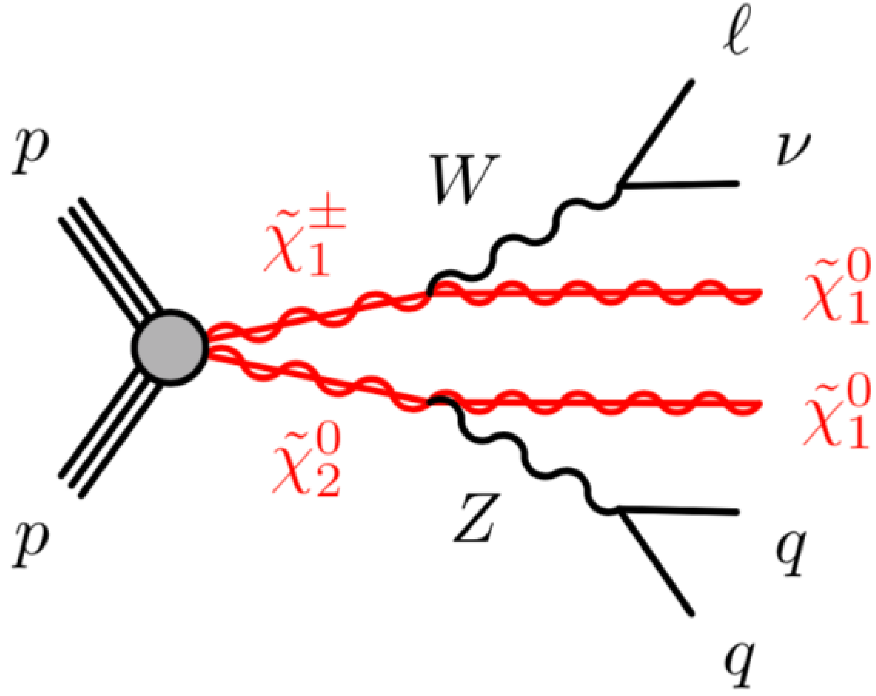

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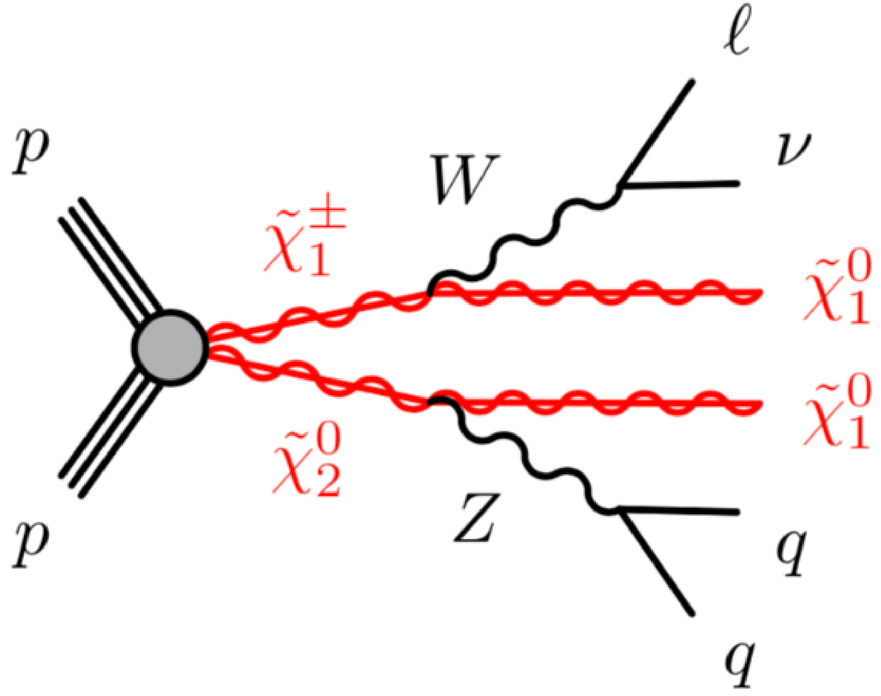

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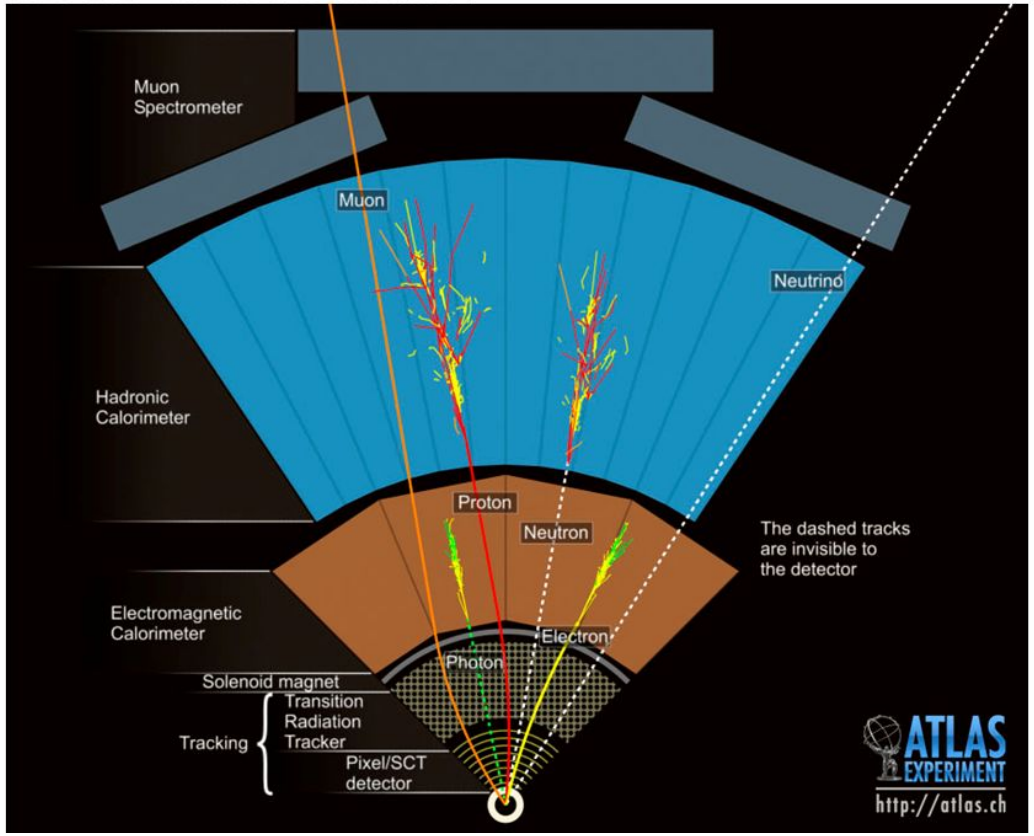
Simulated samples

- generated **signal samples** for different $(m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0})$.
- generated samples for **background processes** e.g $t\bar{t}$, W + jets, *diboson*, *singletop*, *etc*. which share **same final state topology** with signal.

Reconstructed Objects

Detector Cross Section



http://atlas.ch/photos/events-general-detection.html

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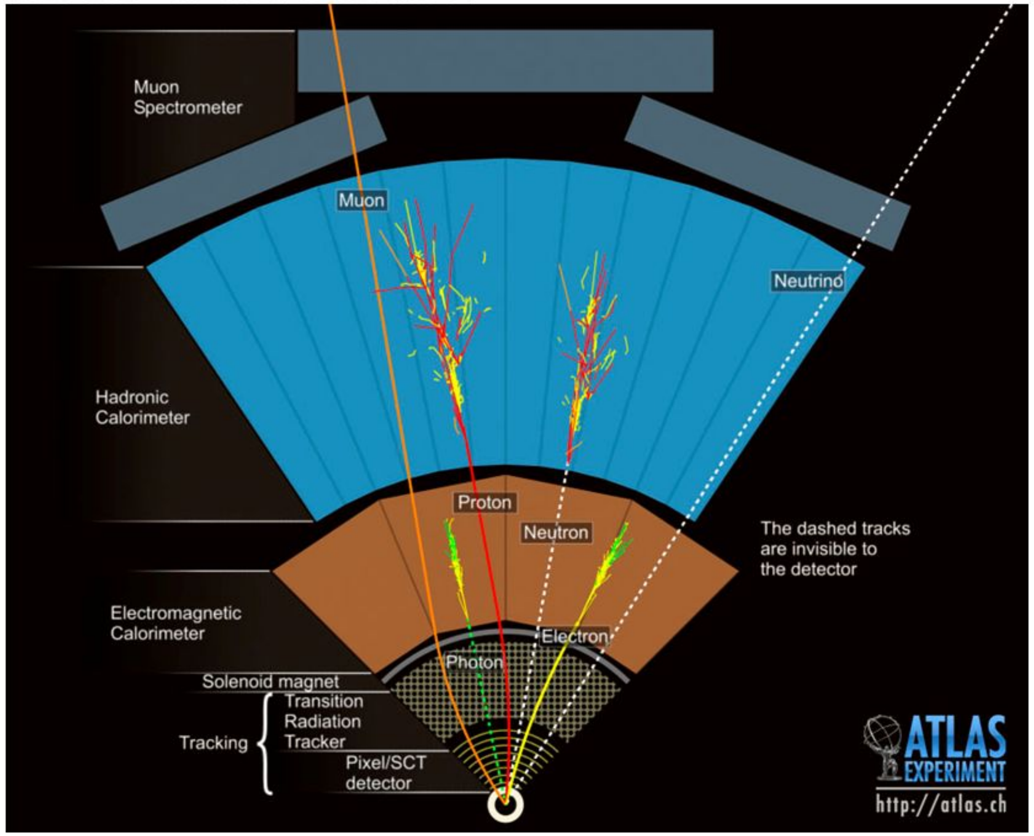

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- **Electrons**: $p_T > \mathbf{7}$ GeV, $|\eta| < \mathbf{2.47}$.
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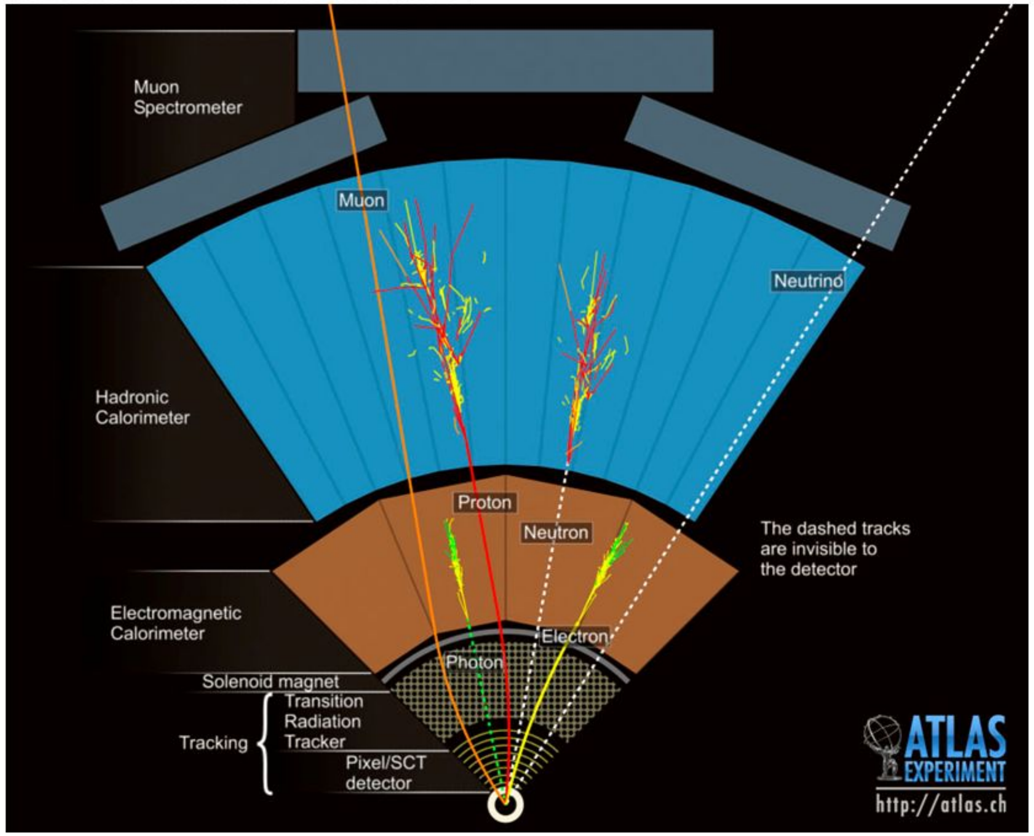

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- Required $p_T >$ **20 GeV** and $|\eta| < \mathbf{4.5}$.
- Observables built from **central jets** ($p_T >$ **20 GeV**, $|\eta| < \mathbf{2.8}$).
- ***b*-jets**: **MV2c10** with ***b*-tagging efficiency of 77%**. Required $p_T >$ **20 GeV**, $|\eta| < \mathbf{2.5}$.

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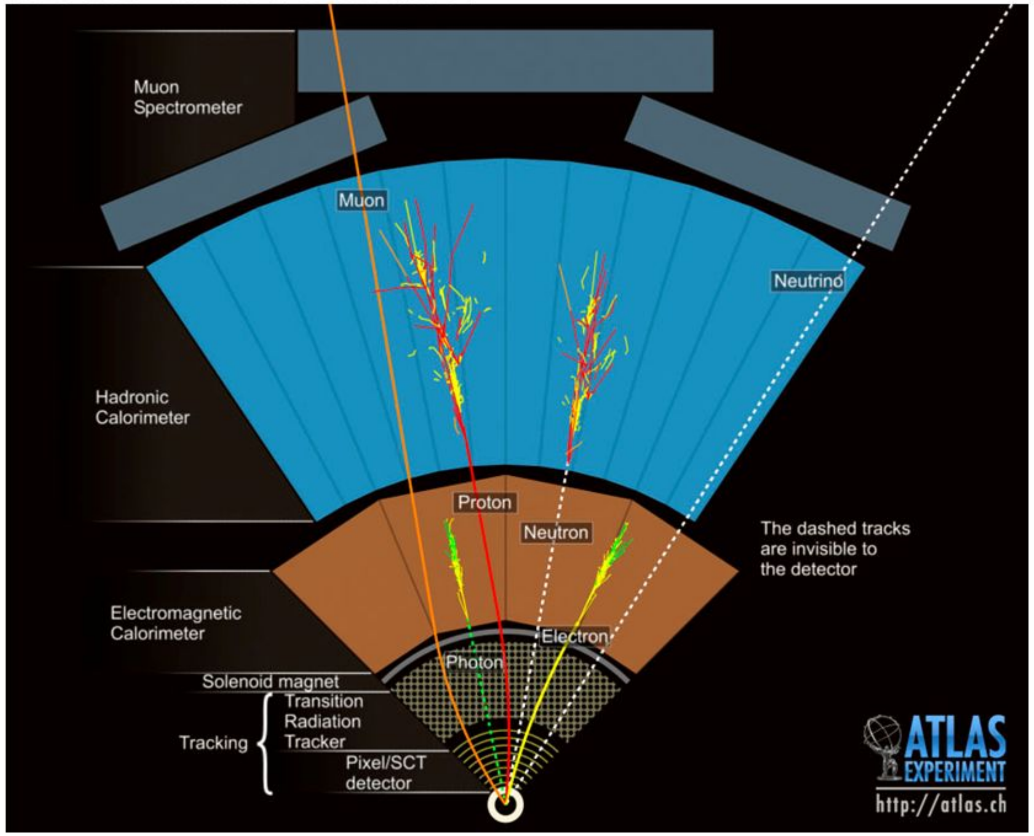

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Missing transverse momentum

- reconstructed using **fully calibrated baseline objects**.

Event pre-selection

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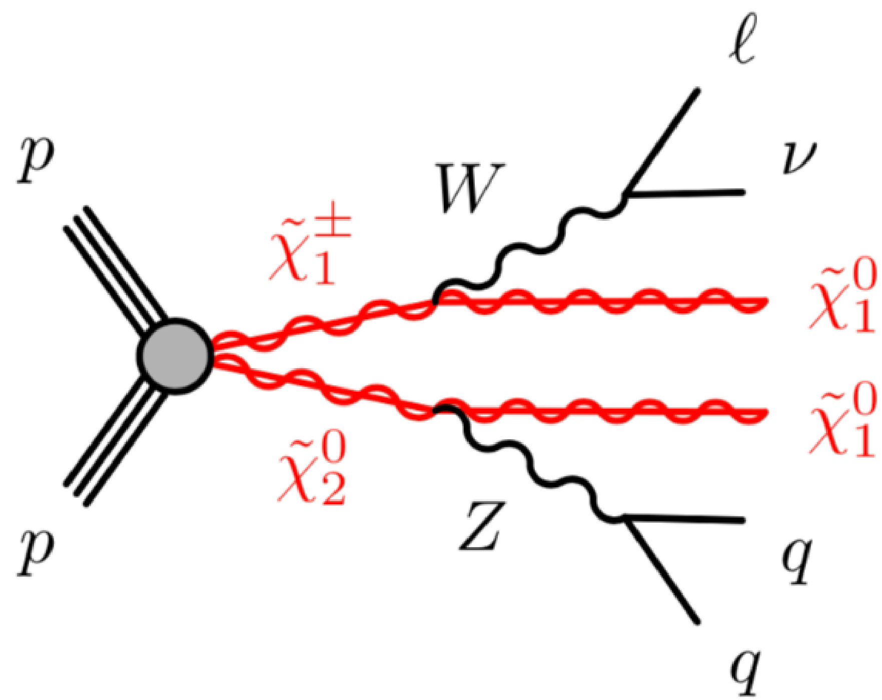

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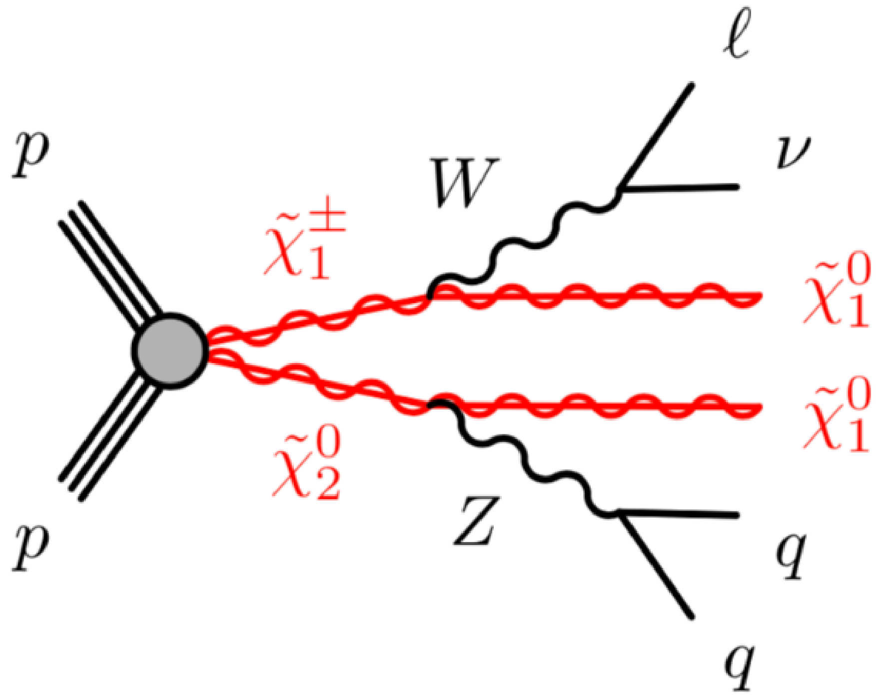

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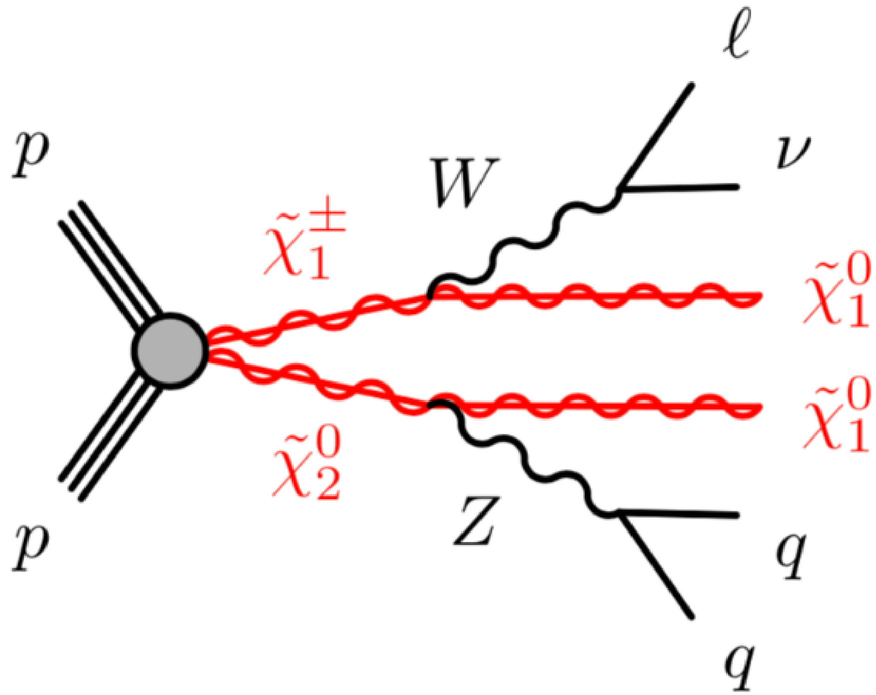

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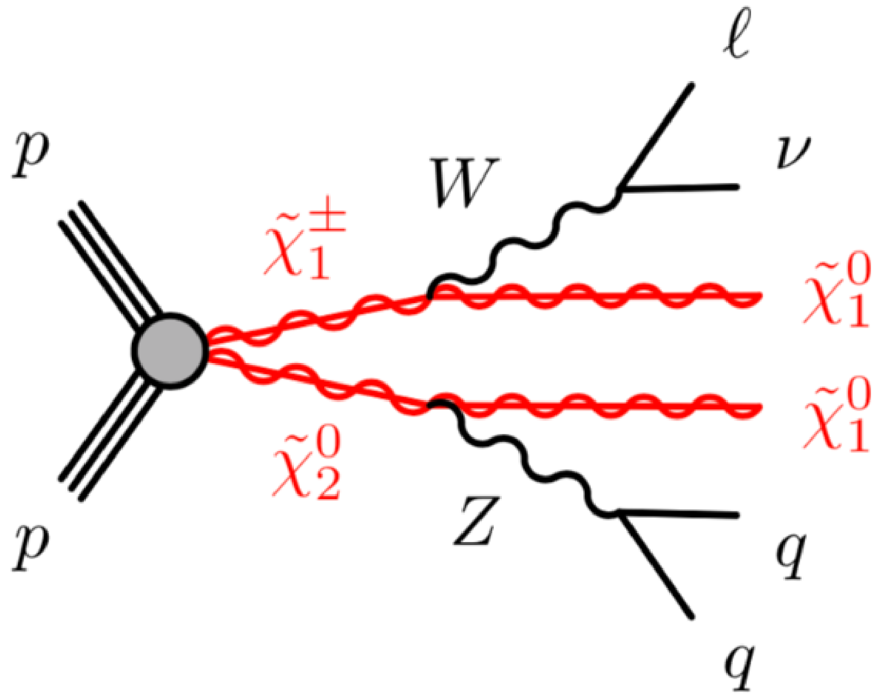

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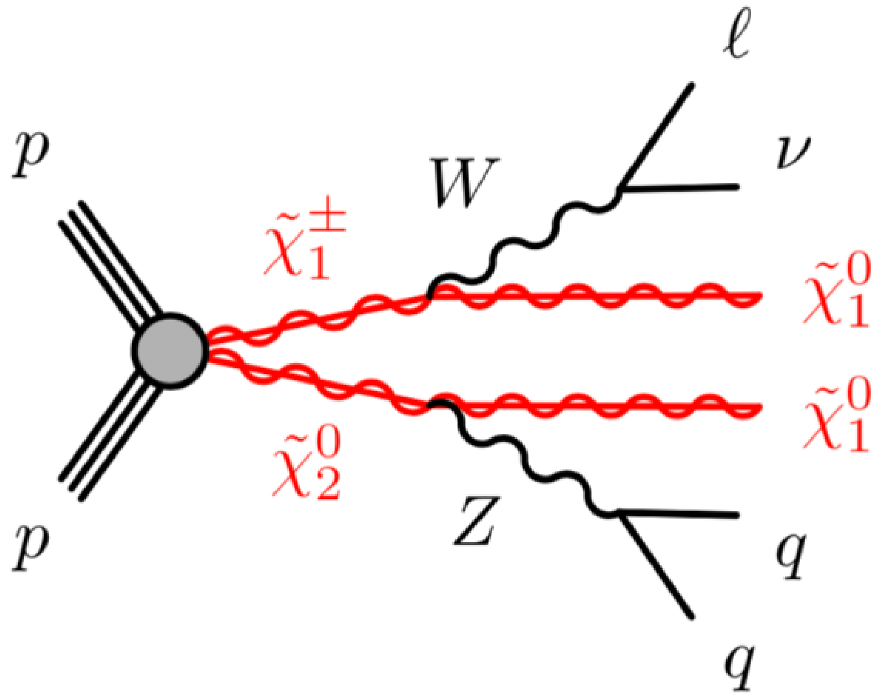

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***Zqq* analysis**

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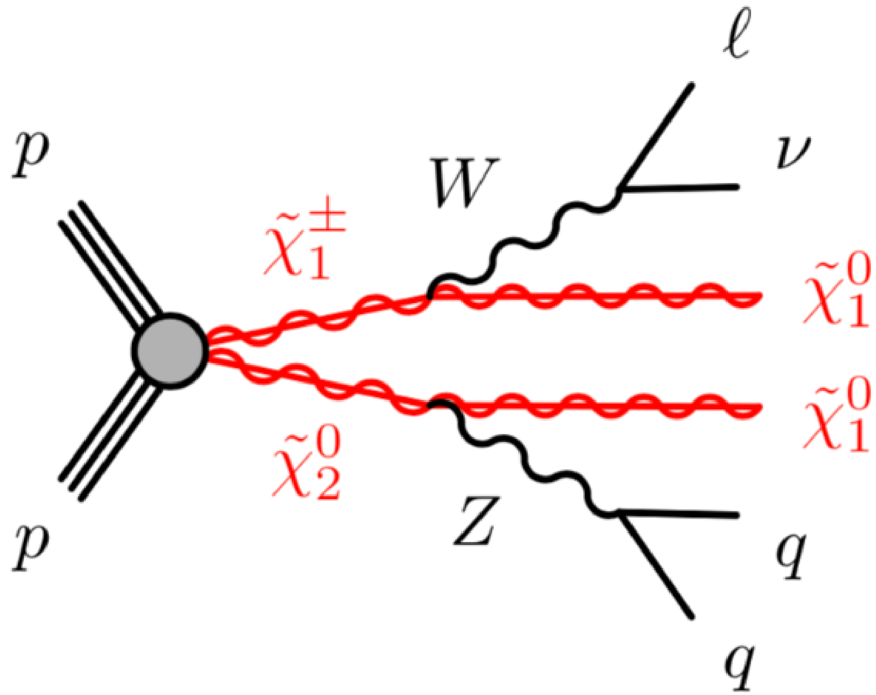

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$$Z \to u\bar{u}/d\bar{d}/s\bar{s}/c\bar{c}$$

- $BR(Z \to$ **light jets**$) \approx$ **55**%.
- **0 *b*-tagged jet** in events.

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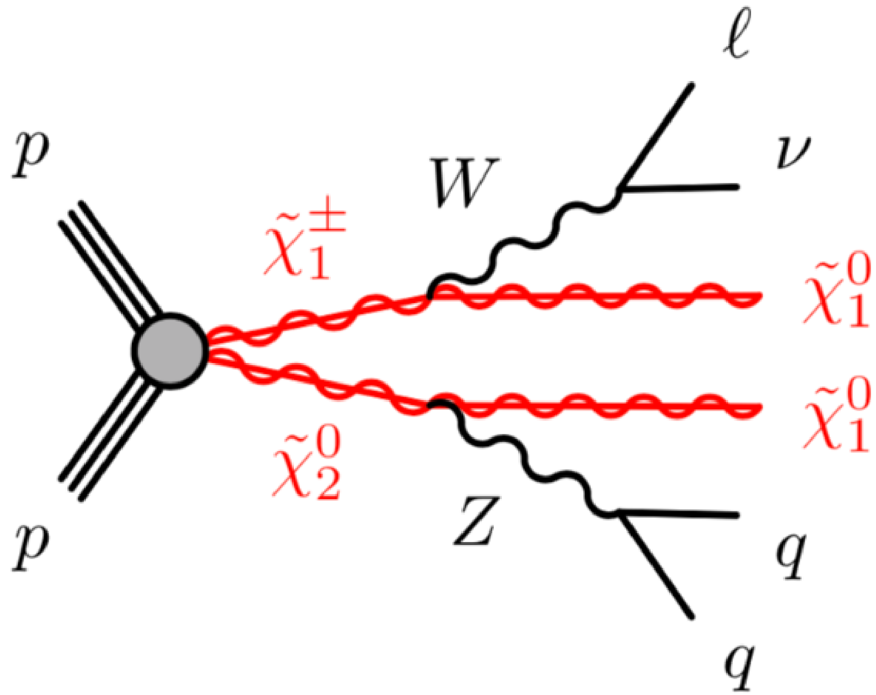

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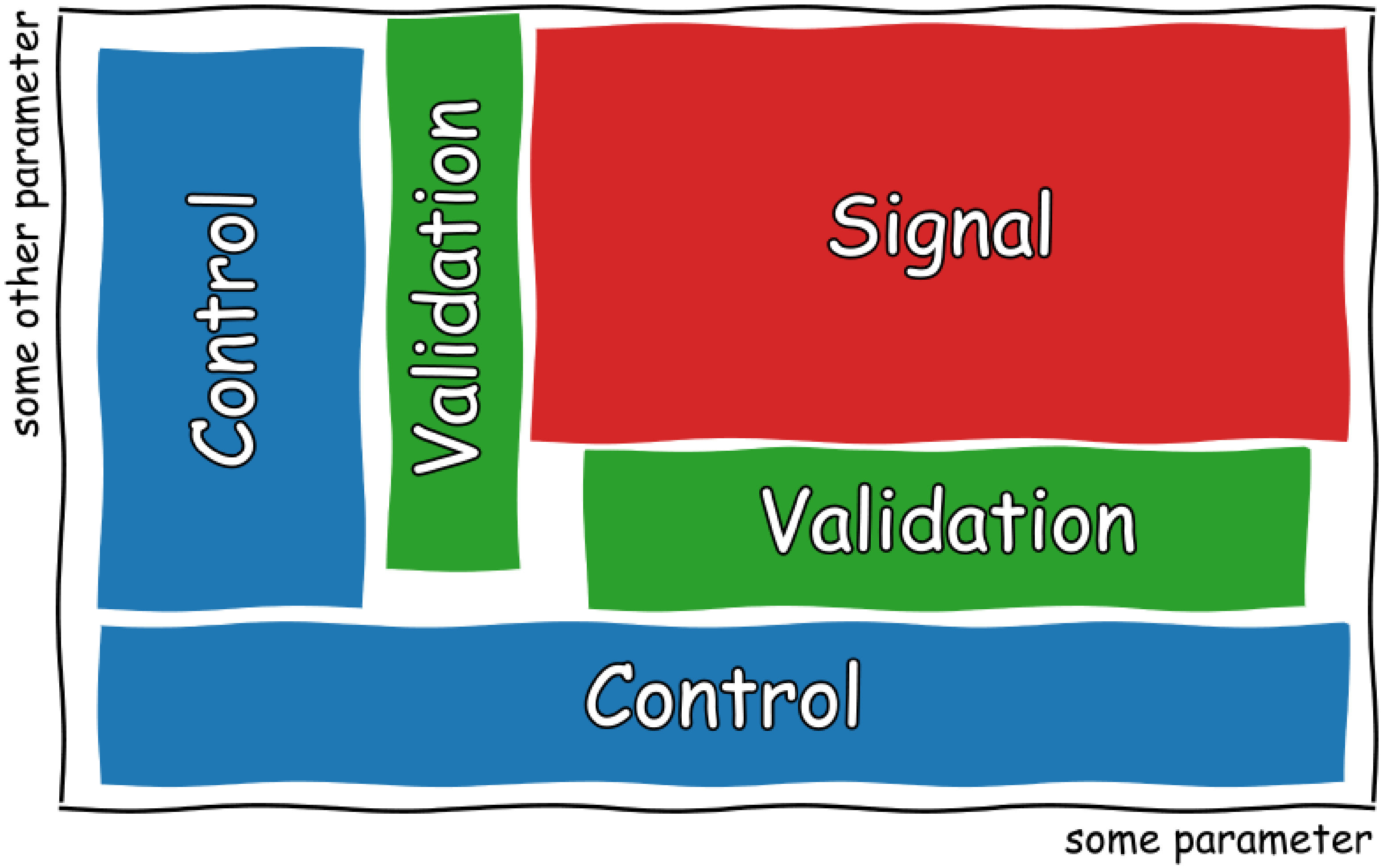
Zbb analysis

$Z \to b\bar{b}$

- $BR(Z \to b\bar{b}) \approx$ **15**%.
- **2 b-tagged jet** in events.

Signal Region Optimization



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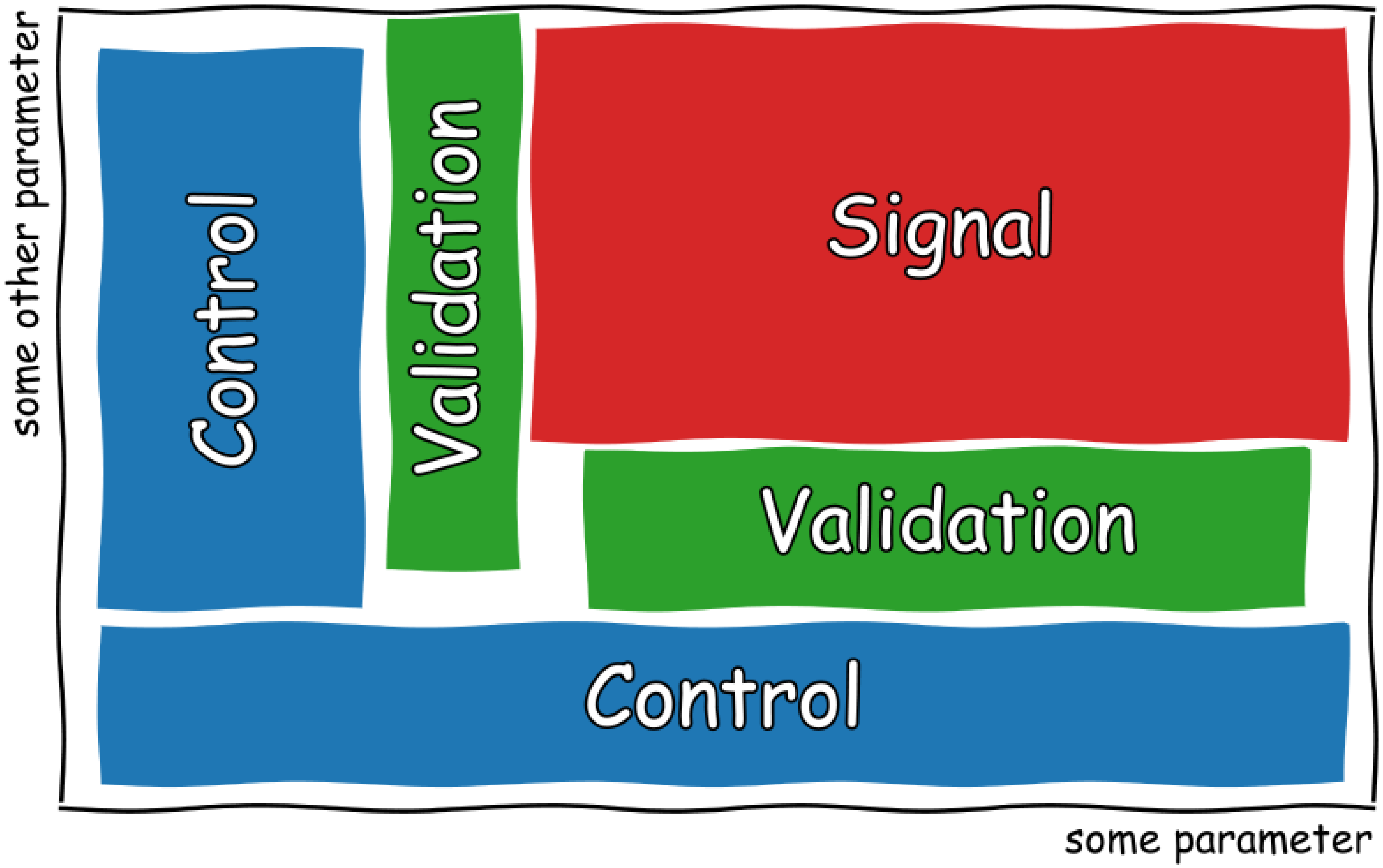

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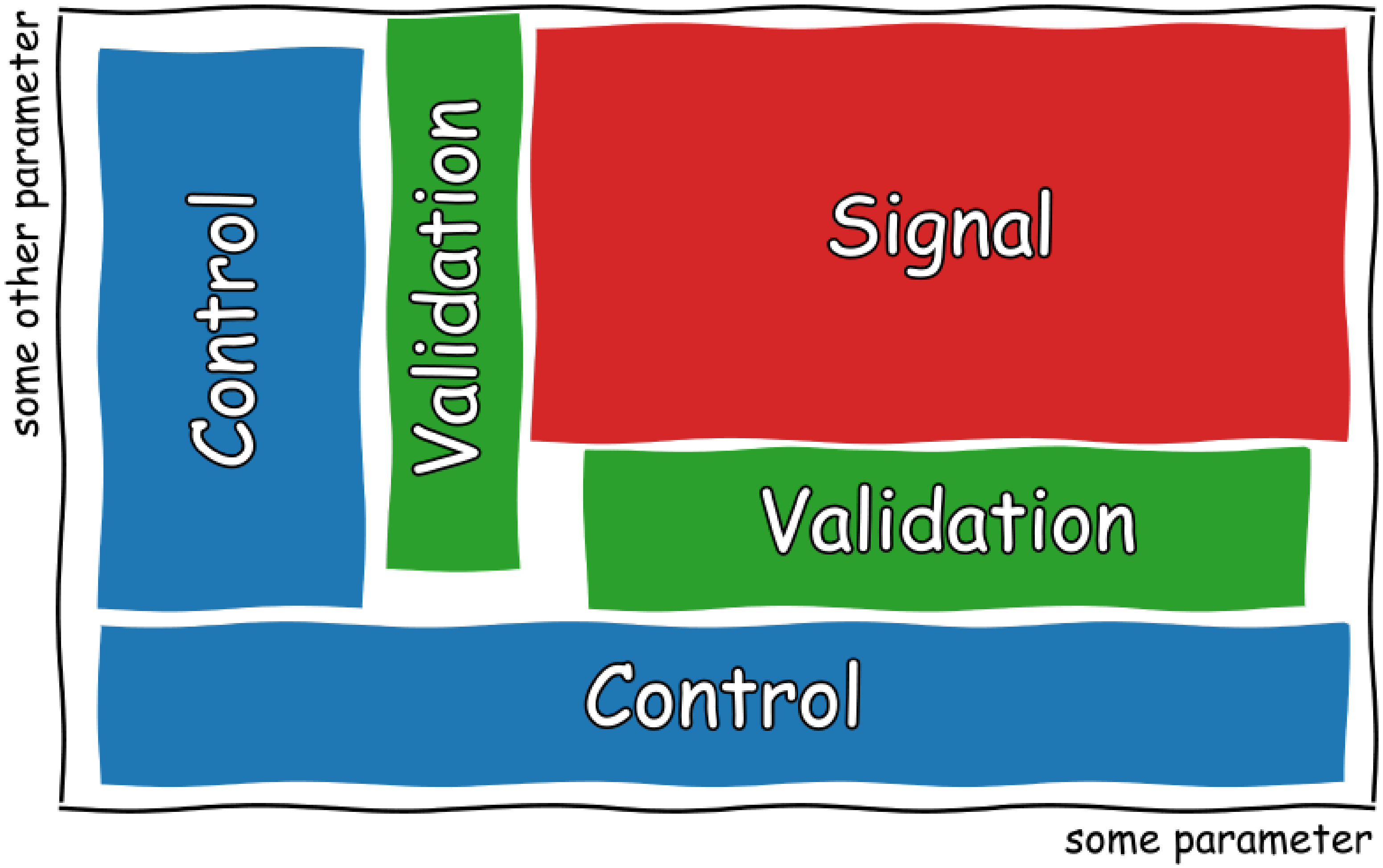

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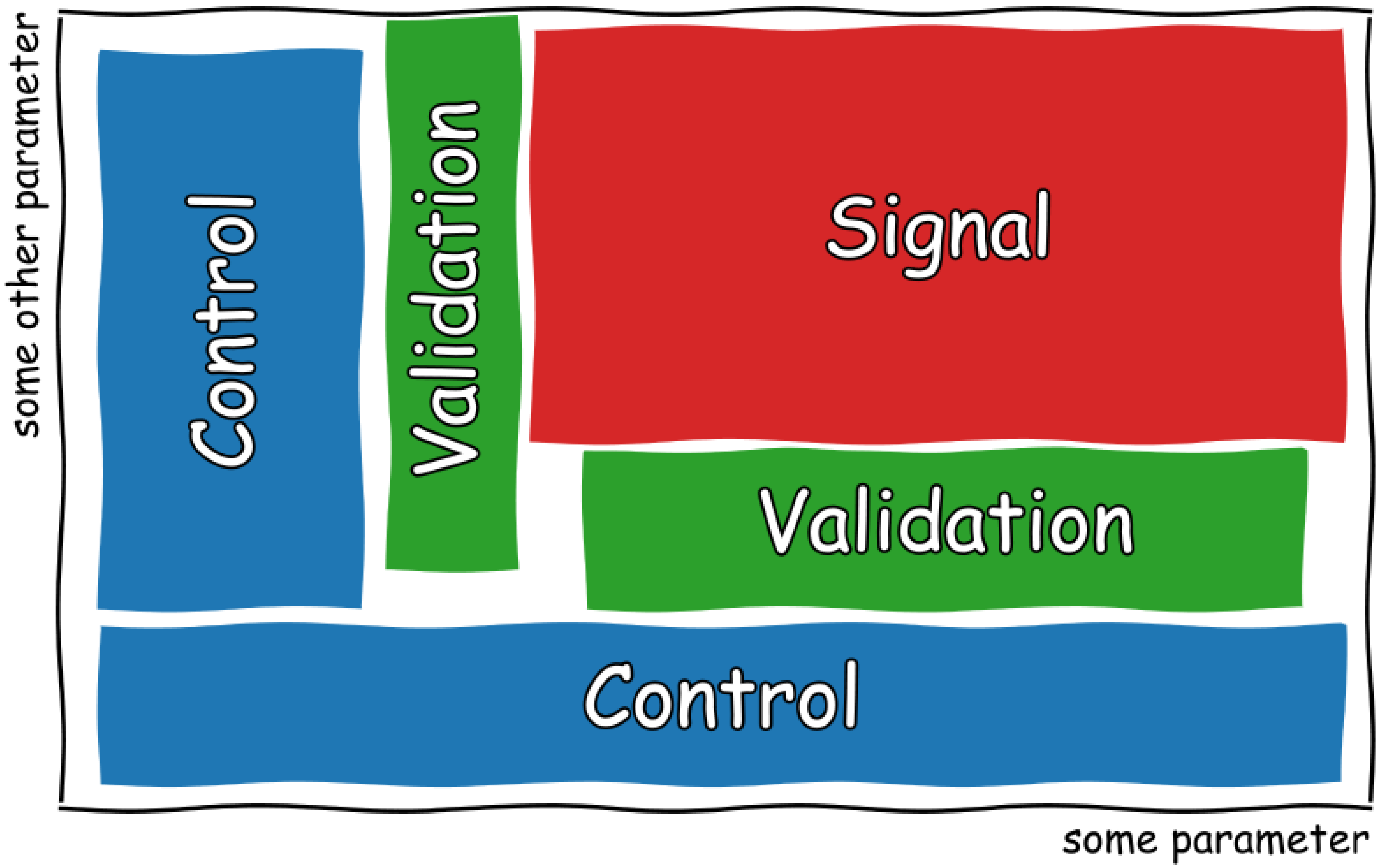

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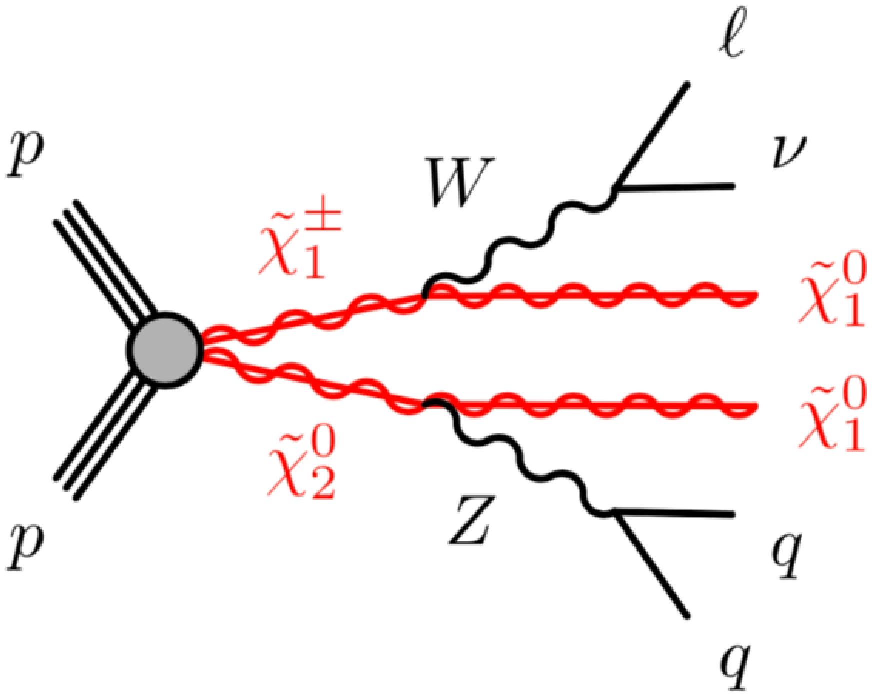

Reconstruction of Z boson

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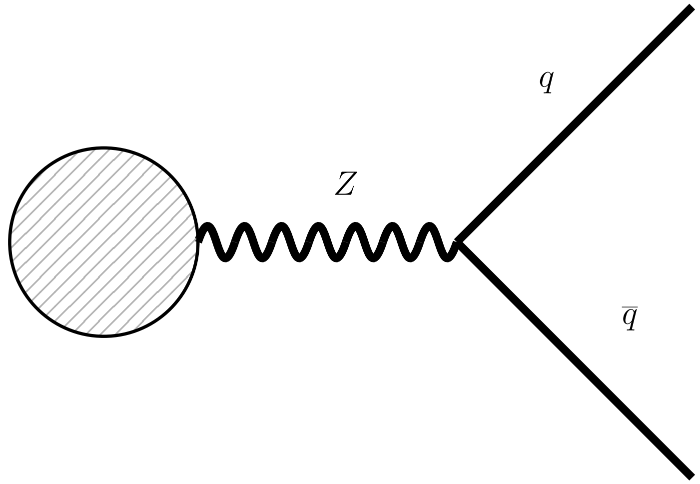
- **2-jets** events, all jets from Z decay.



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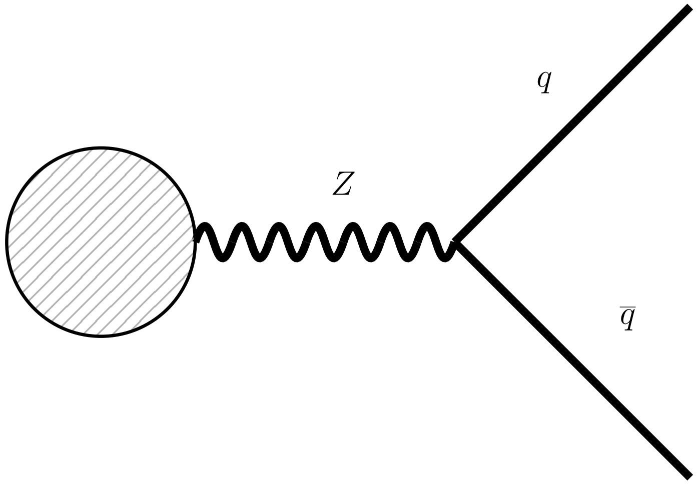

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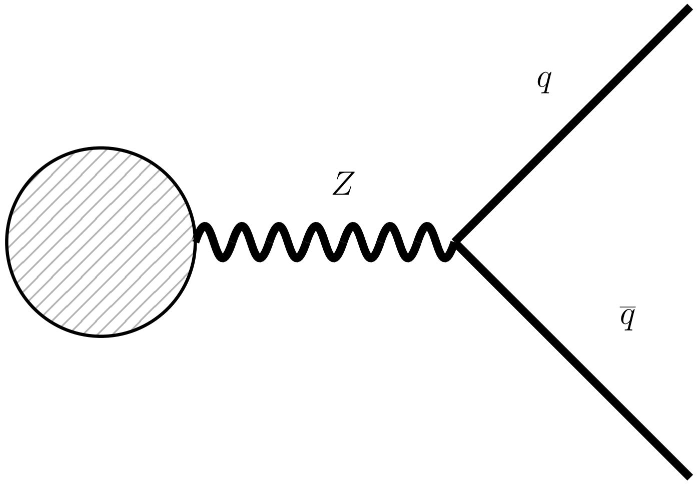

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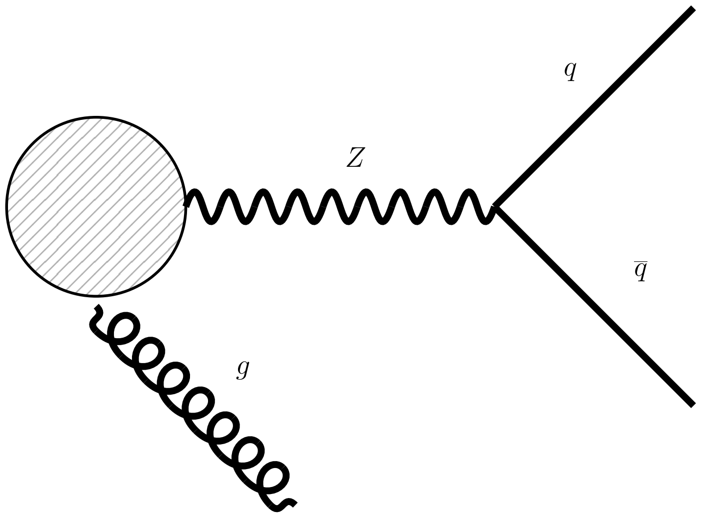

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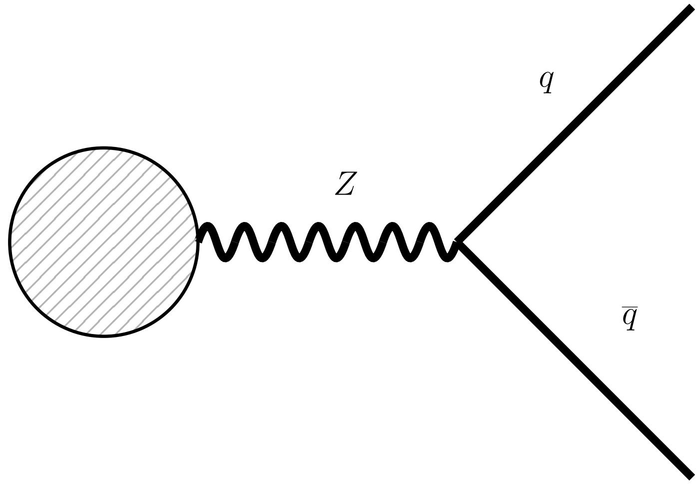
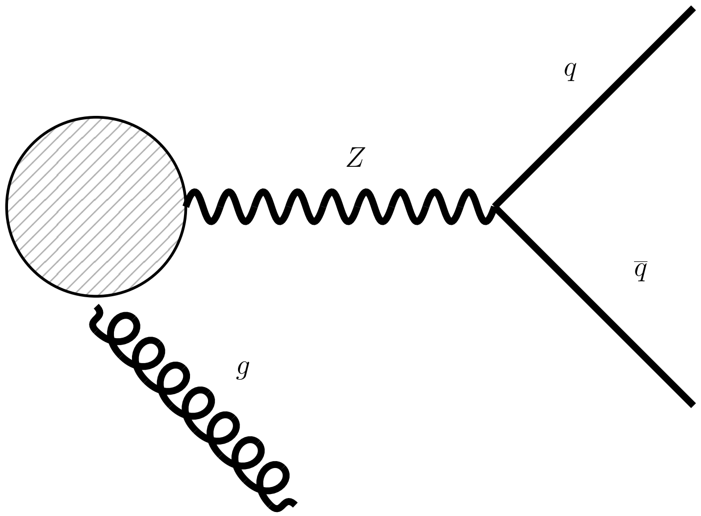
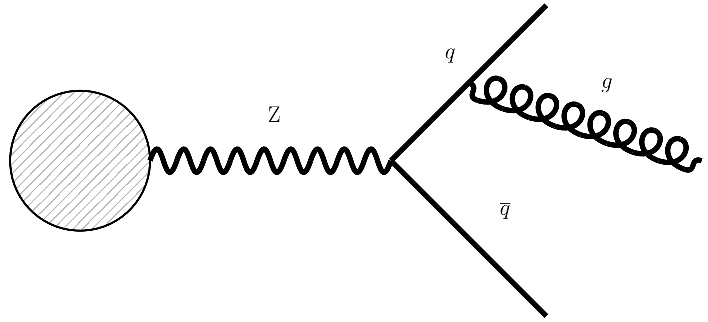


- in **3-jets** events, 2 jets from Z boson decay, **the other** from **initial state radiation** (ISR) or **final state radiation** (FSR).





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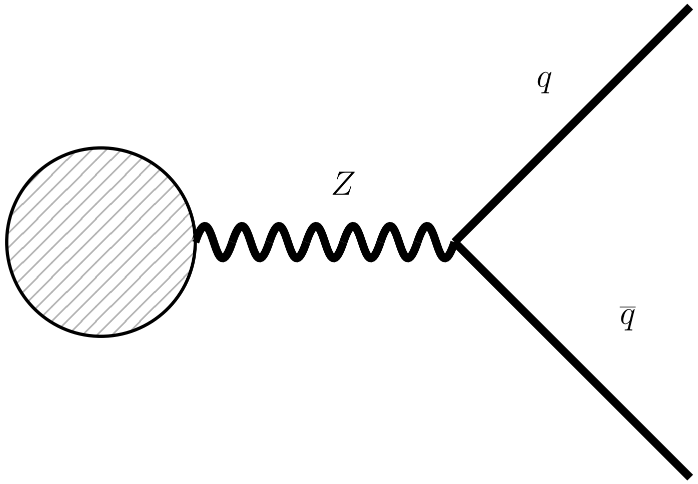

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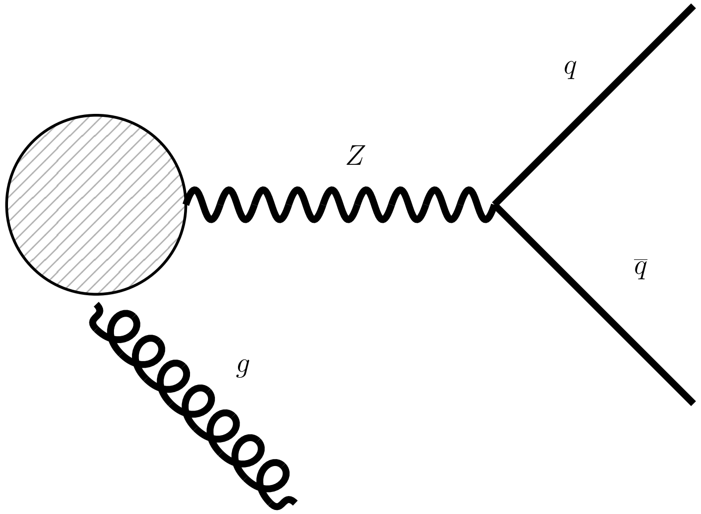

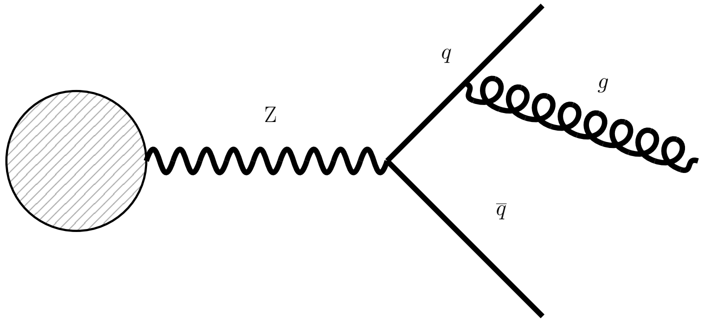

- apply **kinematic fit** to introduce **tagger differentiating ISR and FSR case**.

Signal Region Optimization

- **FSR kinematic fit**:

$$\chi^2_{FSR} = \sum_{i=1}^{3} \frac{\left[p_T^{Meas}(j_i) - p_T^{Fit}(j_i)\right]^2}{\sigma^2_{p_T(j_i)}} + \frac{\left[p_T^{Meas}(l^\pm) - p_T^{Fit}(l^\pm)\right]^2}{\sigma^2_{p_T(l^\pm)}} + \frac{\left[\not{p}_x^{Meas} - \not{p}_x^{Fit}\right]^2}{\sigma^2_{\not{E}_T}} + \frac{\left[\not{p}_y^{Meas} - \not{p}_y^{Fit}\right]^2}{\sigma^2_{\not{E}_T}} + \frac{\left[M^{Fit}(j_1, j_2, j_3) - M_Z^{PDG}\right]^2}{\Gamma_Z^2}$$

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- **ISR kinematic fit**:

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Signal Region Optimization

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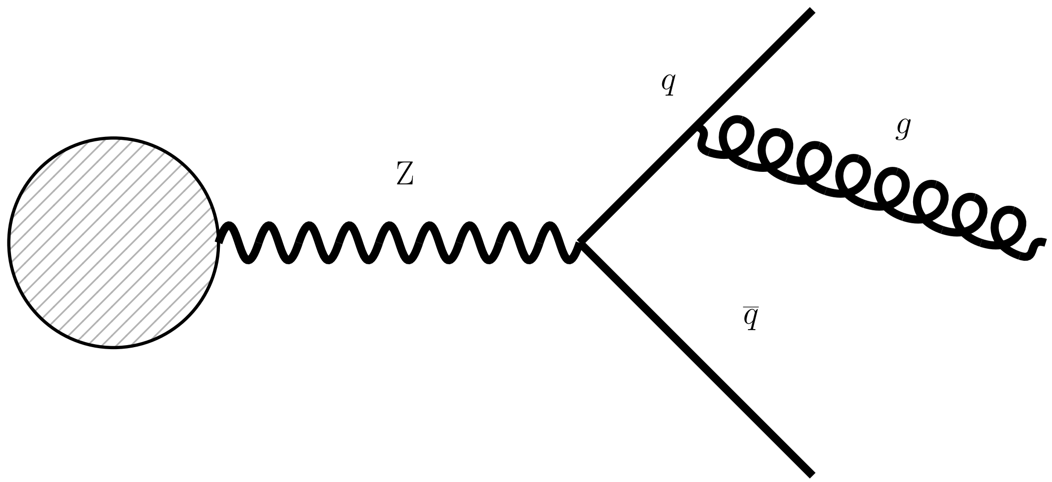

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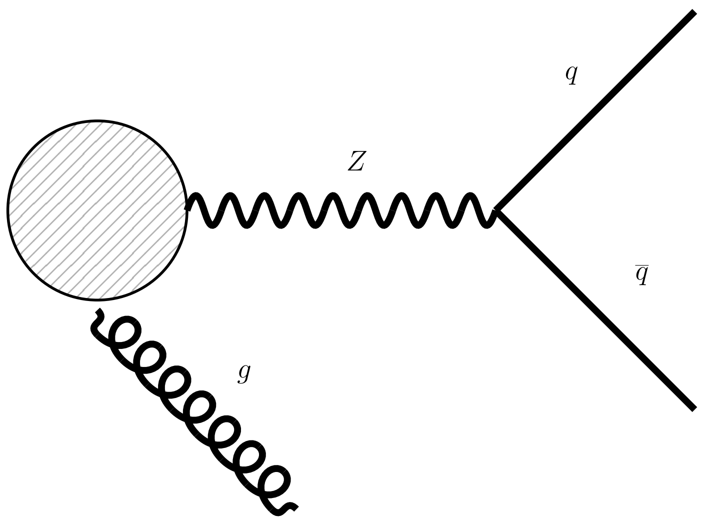

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  - For each event, consider 3 jet indices $\boldsymbol{k, l, m}$, each of which $\in [1, 3]$.
  - $M^{Fit}(j_k, j_l)$ built from **combination of dijet mass closest to M_Z^{PDG}**.
  - Index m corresponds to **ISR jet**.

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Zqq **analysis**:

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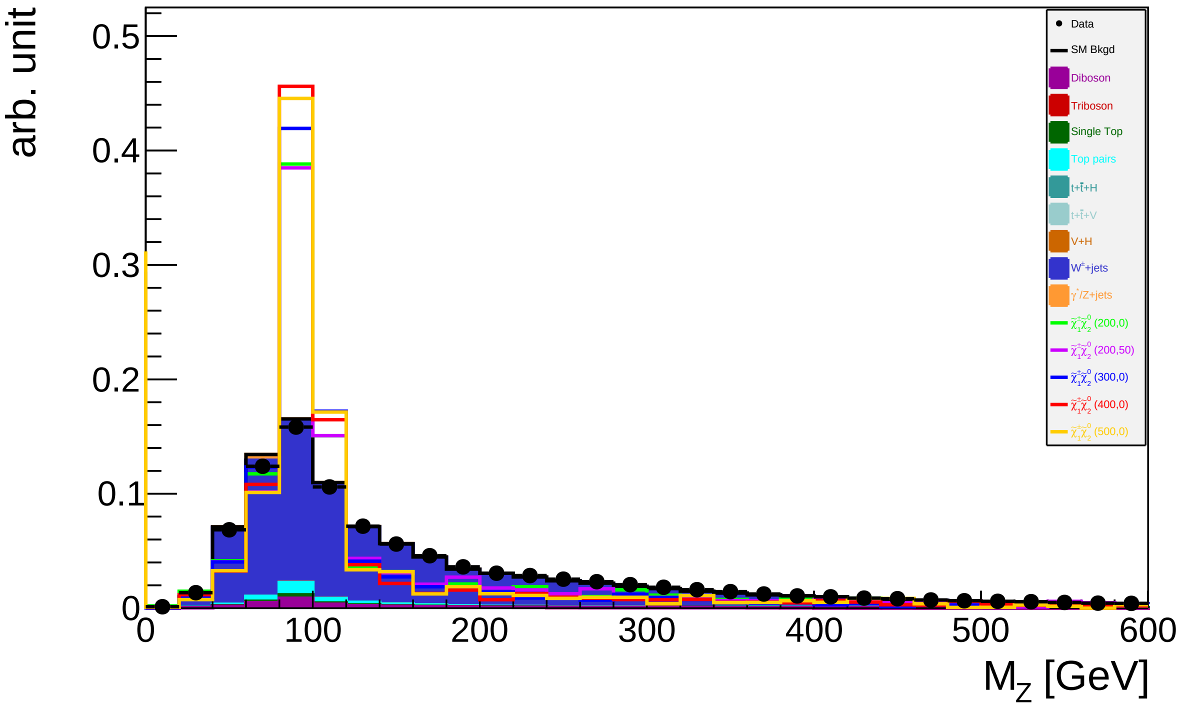

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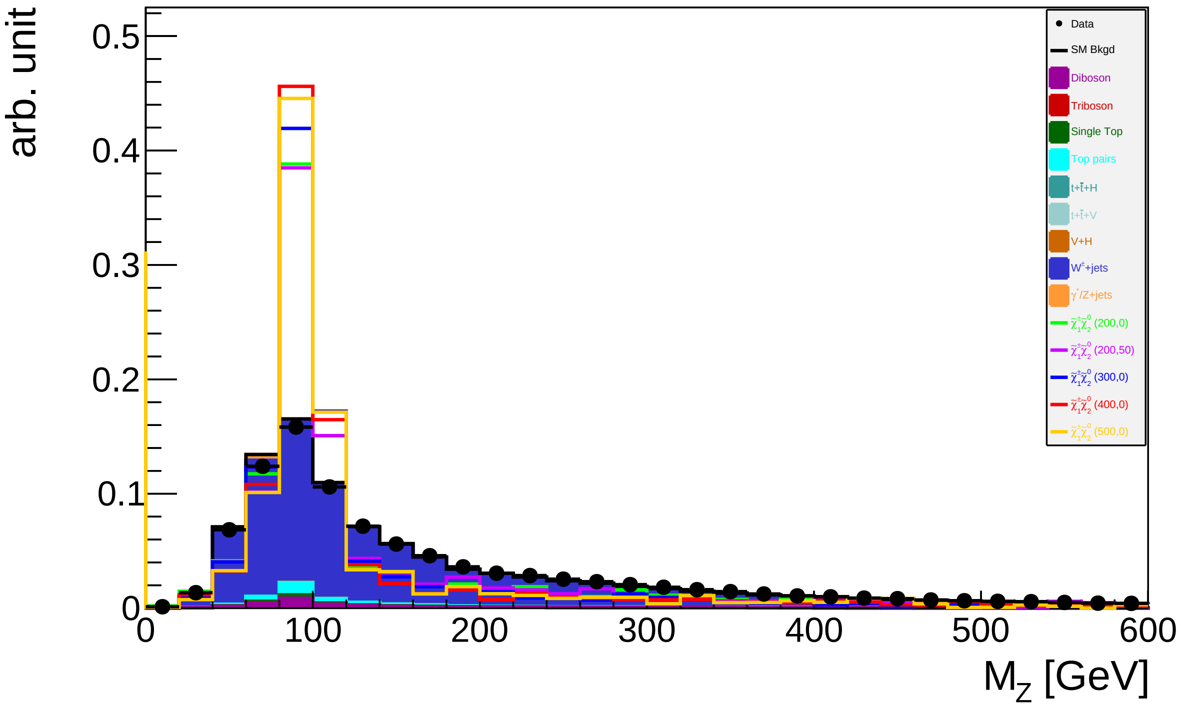

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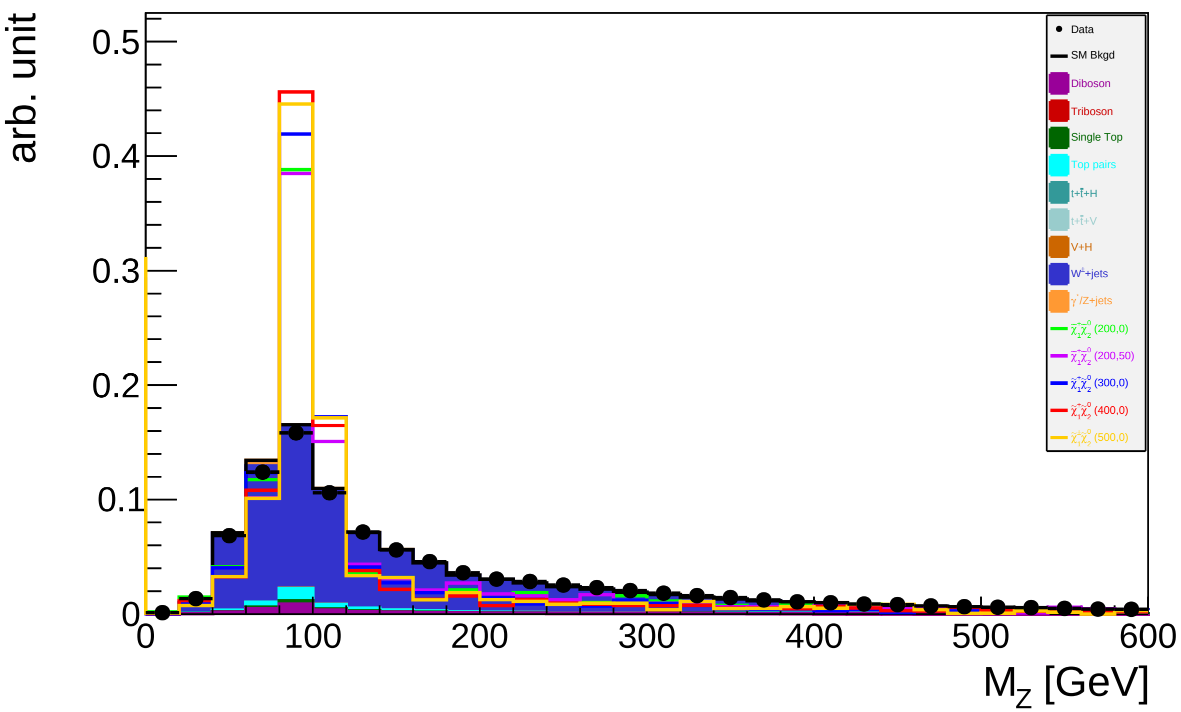

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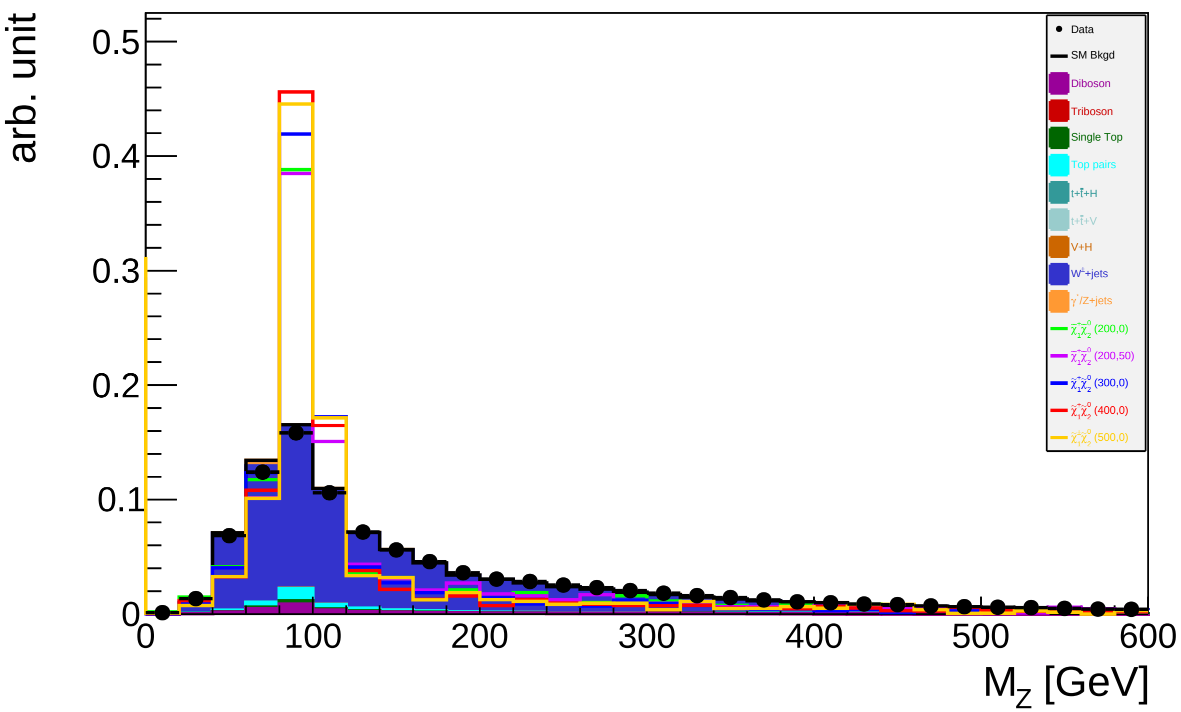

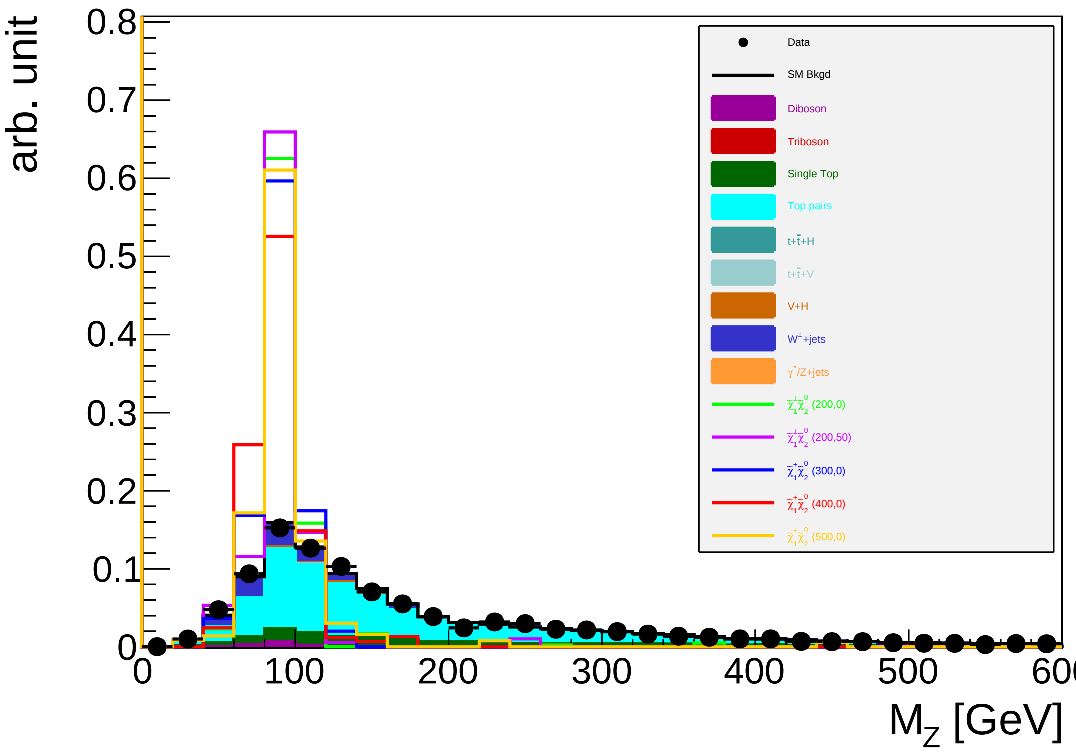

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$$m_{CT} = \sqrt{2p_T(j_k)p_T(j_l)(1+\cos\Delta\phi_{j_k j_l})}$$

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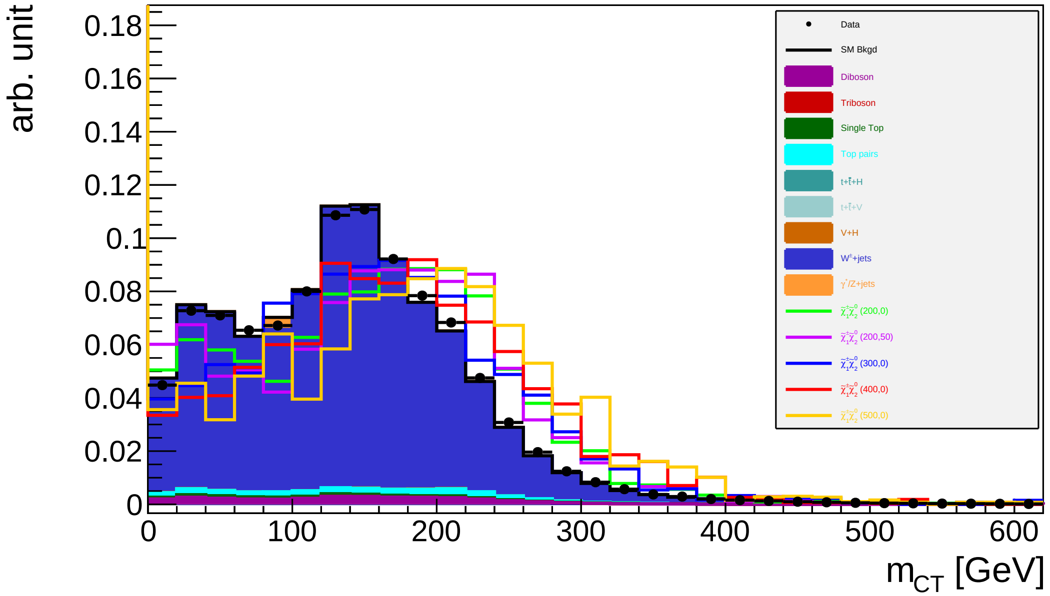

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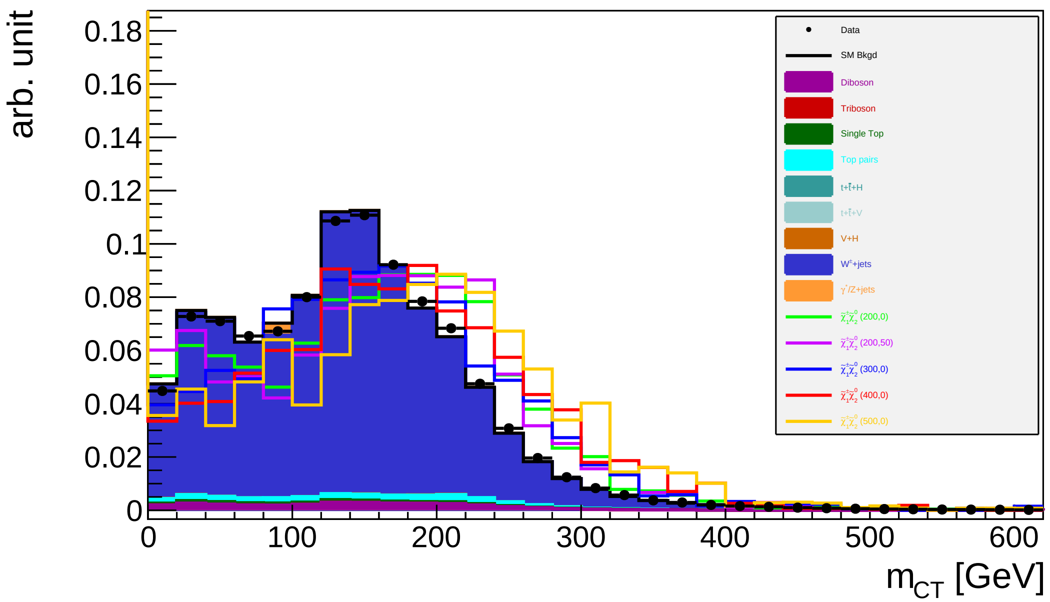

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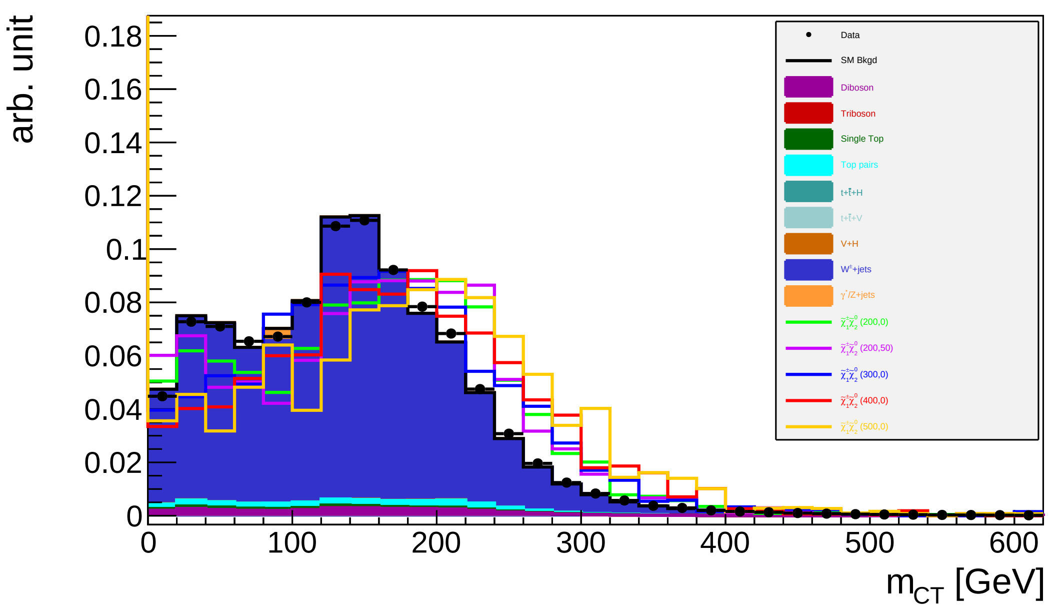

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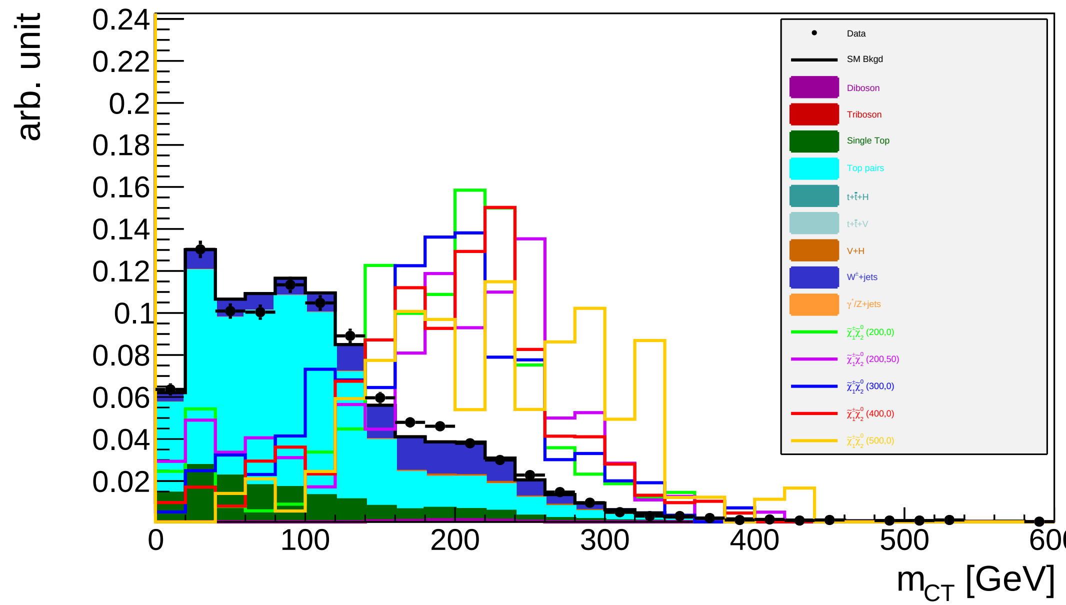

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Signal Region Optimization

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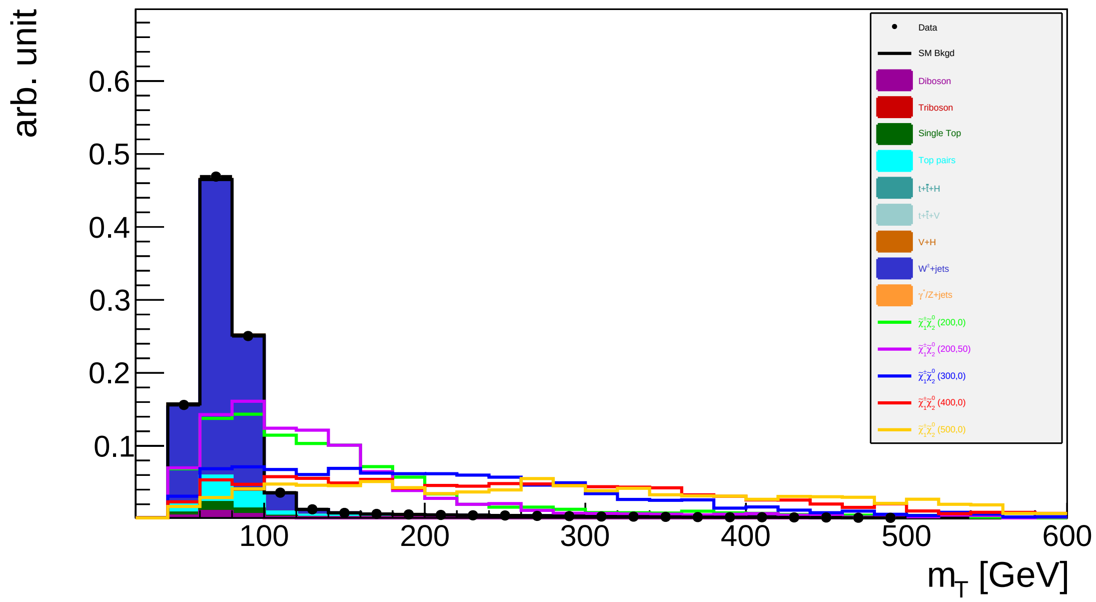

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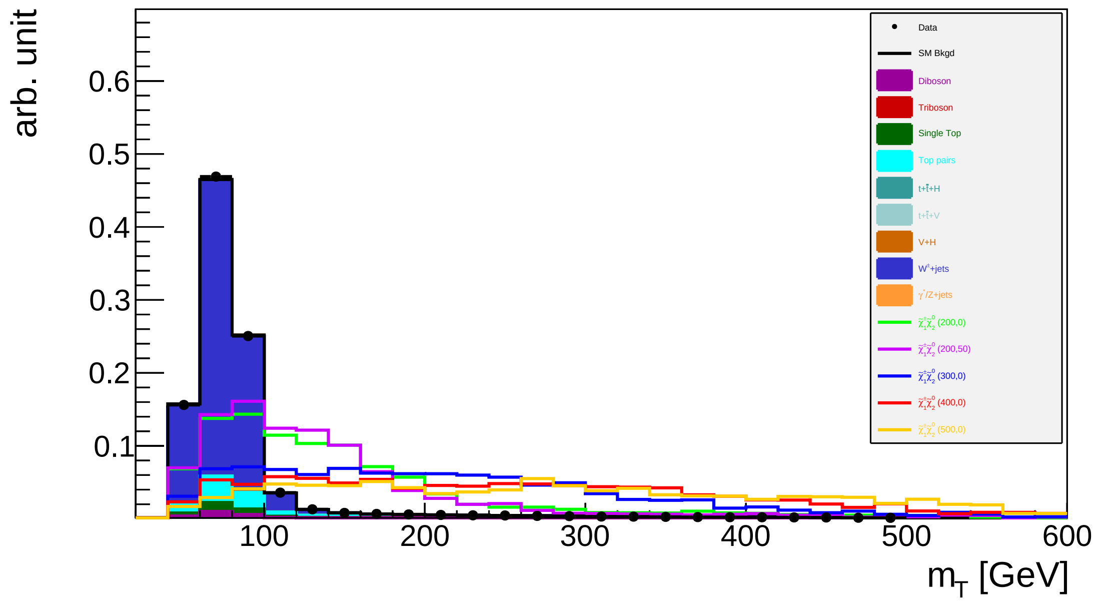

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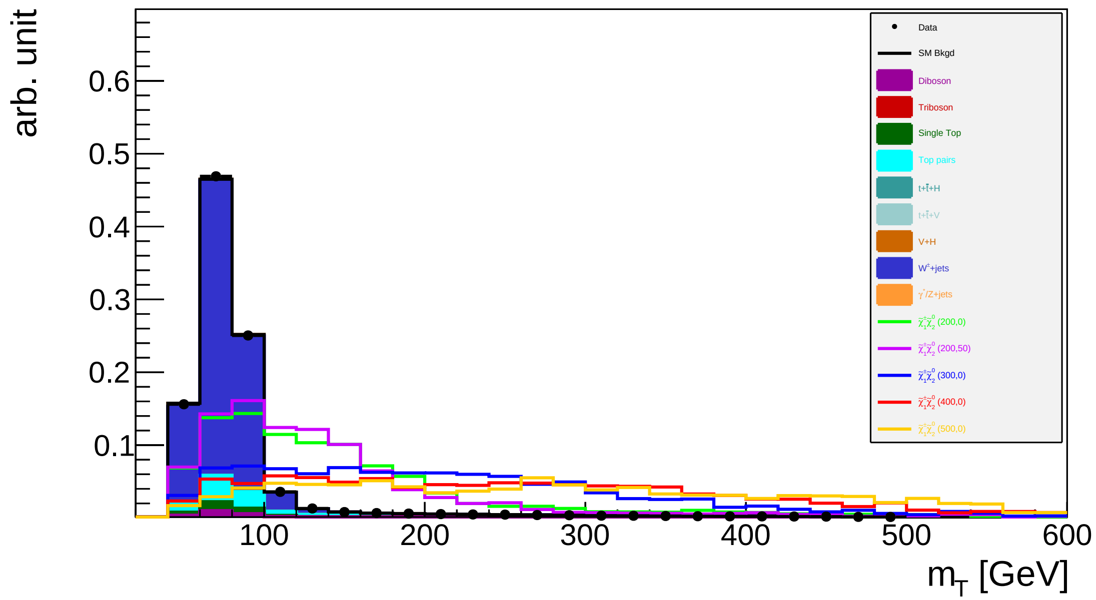

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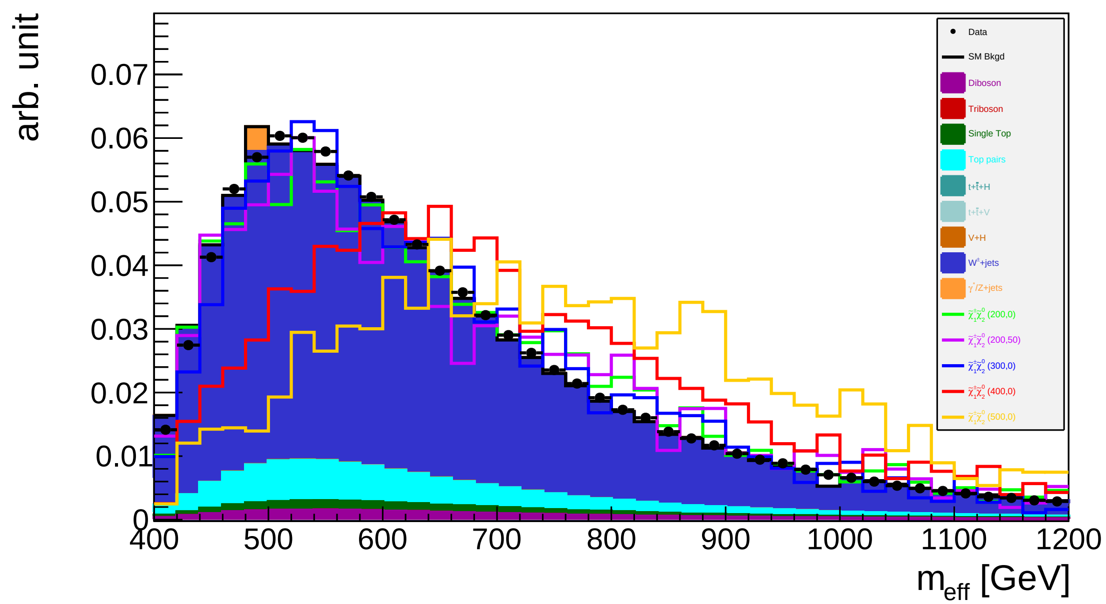
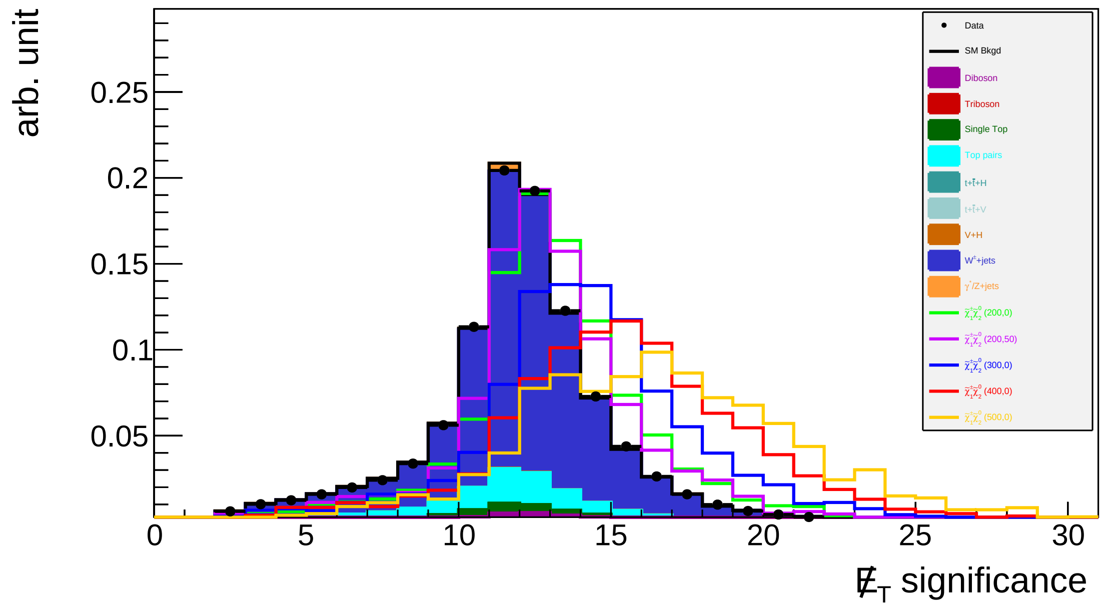


Missing transverse energy significance

$$S^2 = 2\ln\left[\frac{max_{\boldsymbol{p}_T^{inv}\neq 0}\mathcal{L}(\not{E}_T|\boldsymbol{p}_T^{inv})}{max_{\boldsymbol{p}_T^{inv}=0}\mathcal{L}(\not{E}_T|\boldsymbol{p}_T^{inv})}\right]$$



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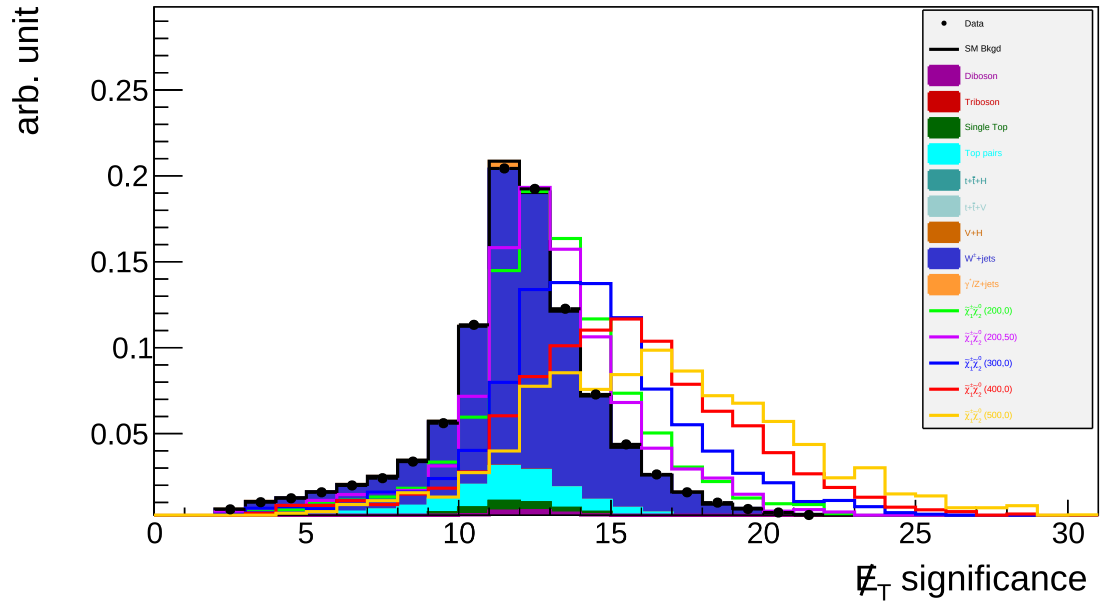
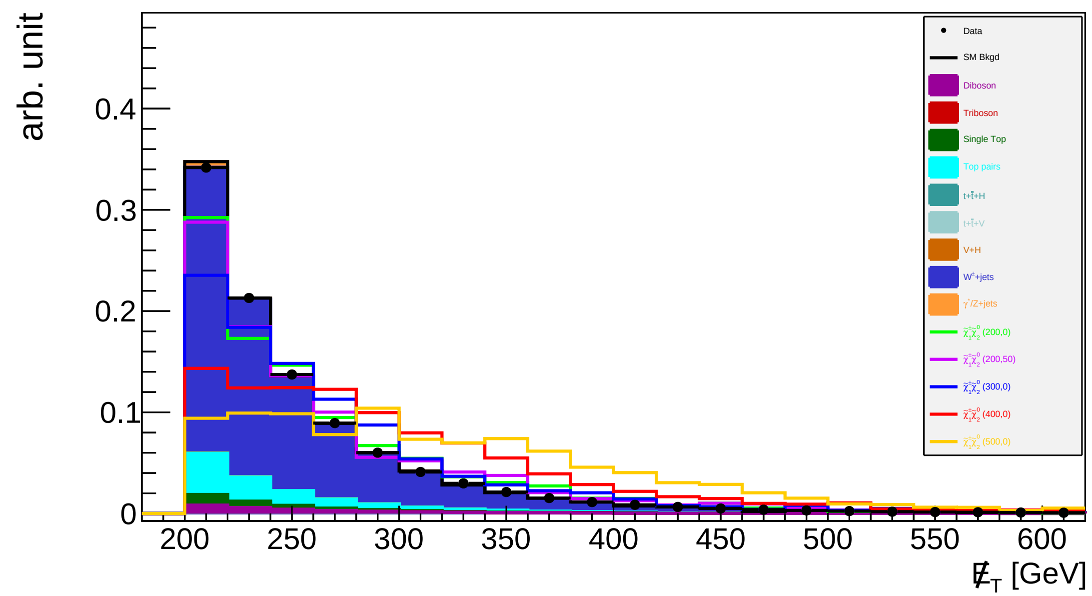


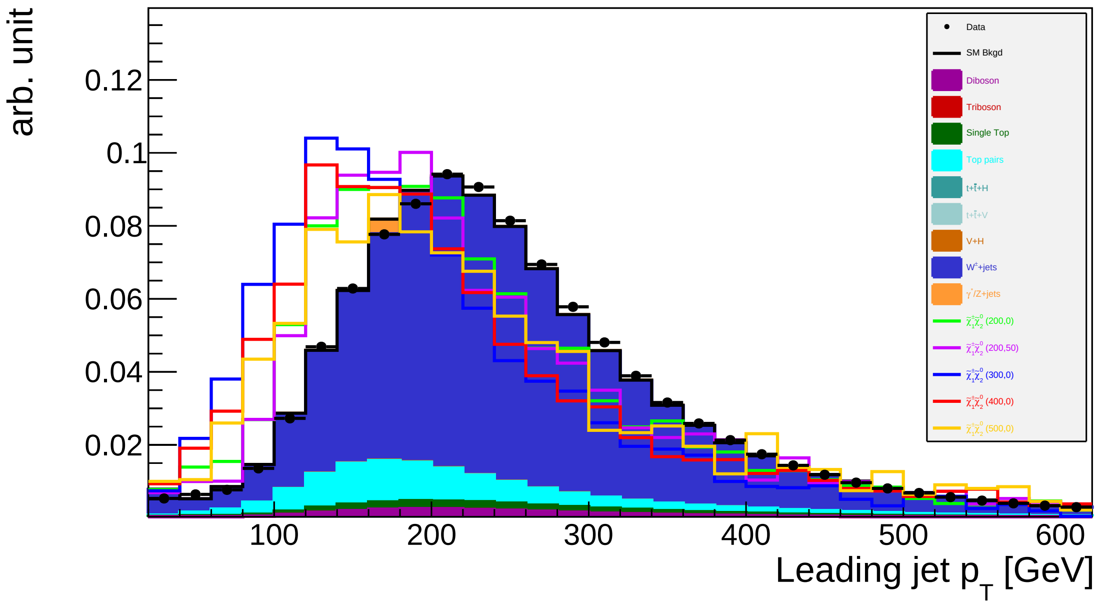
Missing transverse energy

$$\not{E}_T = \sqrt{\left[-\sum_{Reco,TST} p_x\right]^2 + \left[-\sum_{Reco,TST} p_y\right]^2}$$

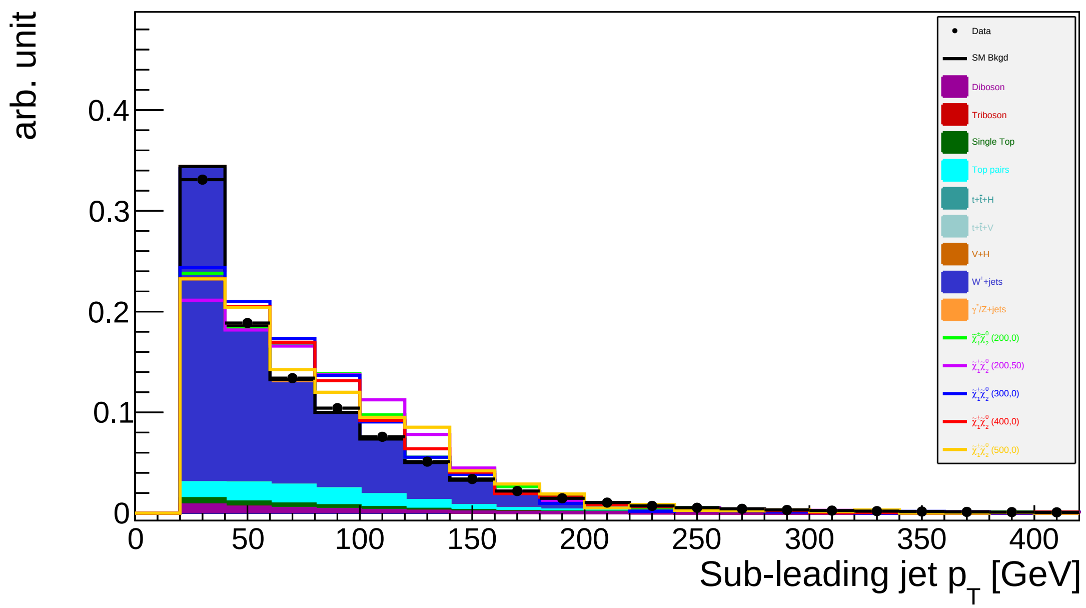


Signal Region Optimization

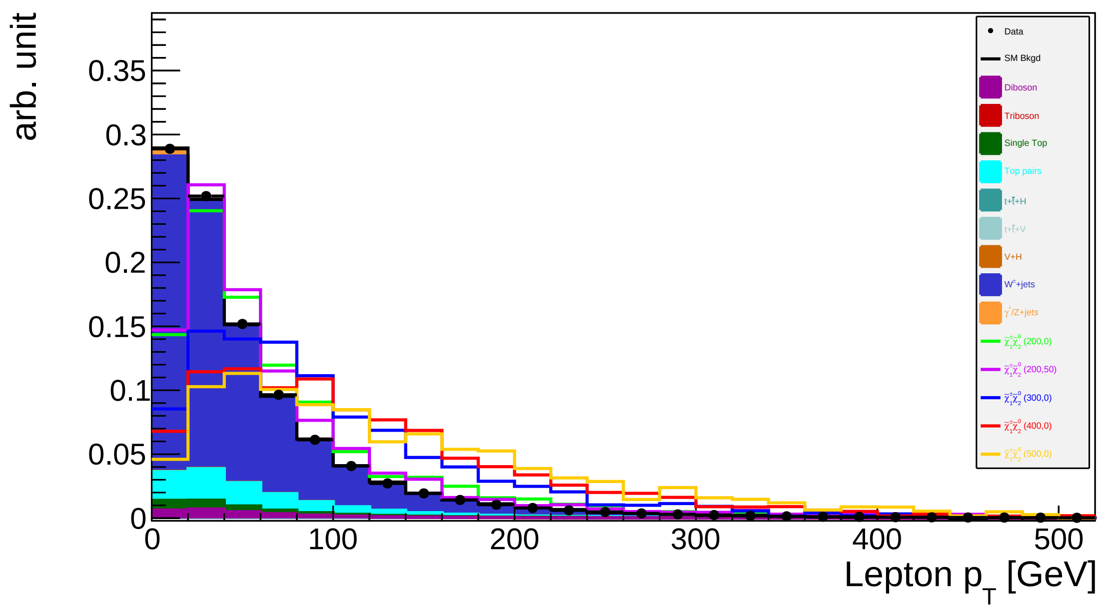
Leading jet p_T



Sub-leading jet p_T



Lepton p_T



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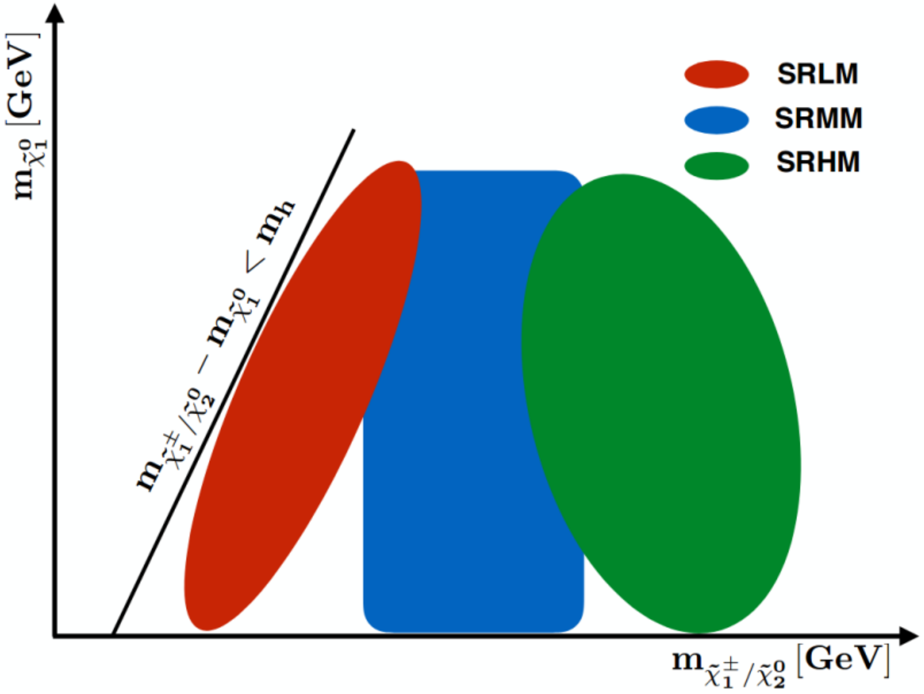

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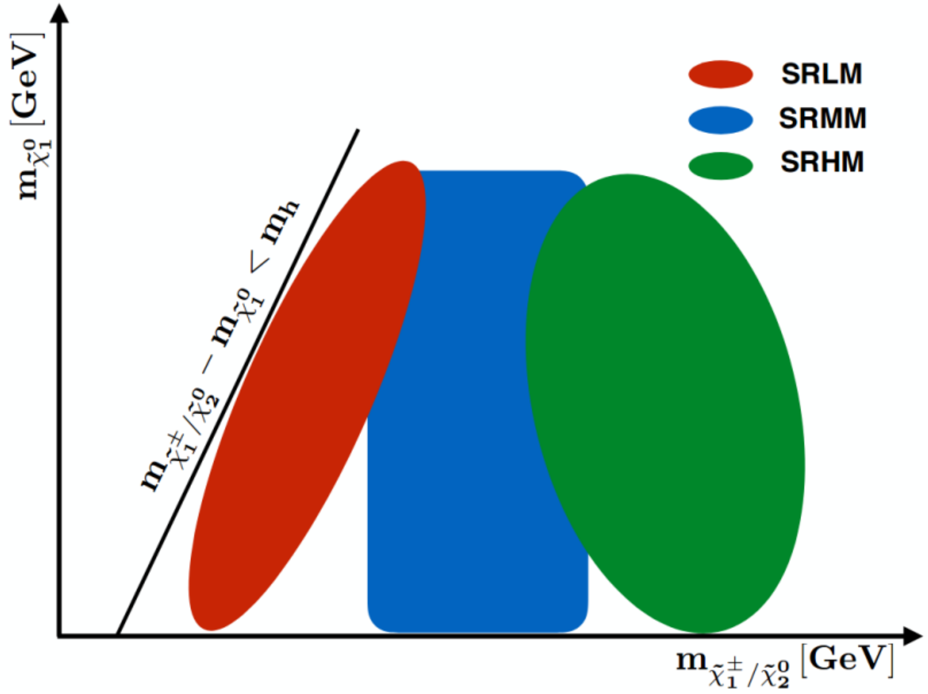

Optimization strategy for each signal point

- scan discriminating variables one-by-one and choose which gives the highest **significance** Z_N.
- Apply this cut for event selection.
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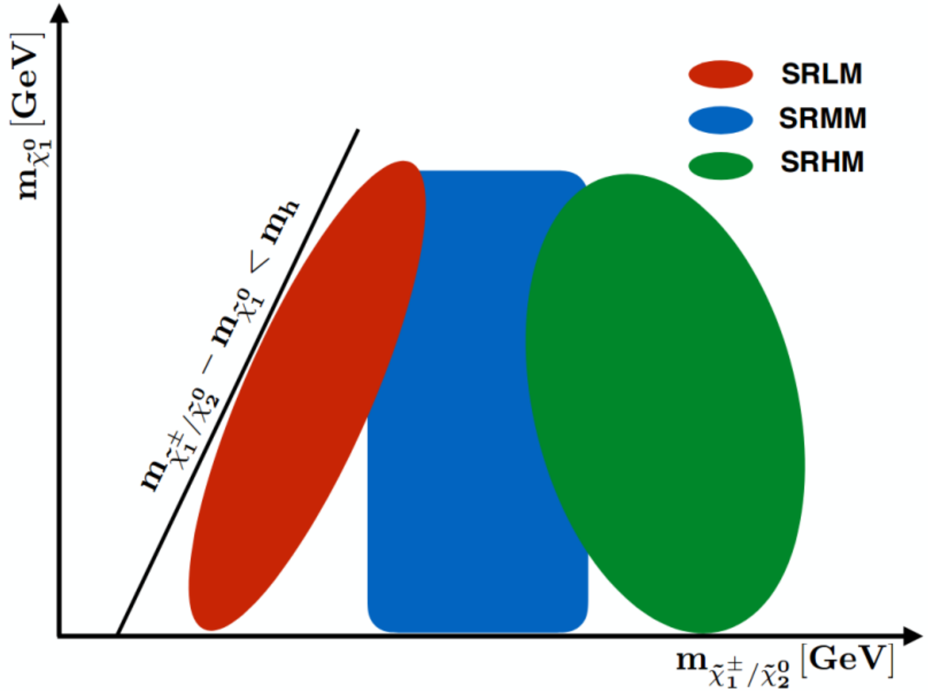

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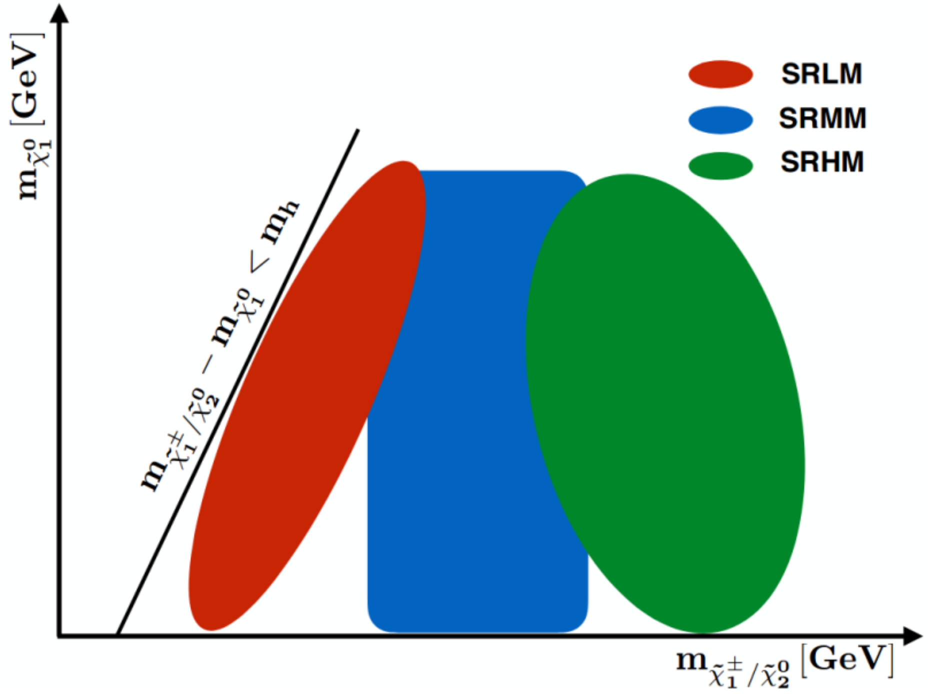

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- Choose the common cut values for all signal points to form the SRs.

Signal Region Optimization

Zqq SR

Observable	SRLM bVeto	SRMM bVeto	SRHM bVeto
N_{lep}	$= 1$		
N_{jets}	$= 2, 3$		
N_{b-jets}	$= 0$		
M_Z [GeV]	$\in [88, 103]$		
$p_T(j_1)$ [GeV]	> 135		
$p_T(j_2)$ [GeV]	> 110		
$p_T(l_1)$ [GeV]	> 40		
m_{CT} [GeV]	> 220		
$\not{E}_T$ [GeV]	> 200		
$\not{E}_T$ *significance*	> 12		
m_T [GeV]	$\in [140, 200]$	$\in [200, 340]$	> 340
m_{eff} [GeV]	$\in [500, 900]$		> 900

Zbb SR

Observable	SRLM bTag	SRMM bTag	SRHM bTag
N_{lep}	$= 1$		
N_{jets}	$= 2, 3$		
N_{b-jets}	$= 2$		
M_Z [GeV]	$\in [75, 105]$		
m_{CT} [GeV]	> 210		
$\not{E}_T$ [GeV]	> 230		
$\not{E}_T$ *significance*	> 12		
m_T [GeV]	$\in [100, 140]$	$\in [140, 250]$	> 250

Yieldstable

Process	SRLM bVeto	SRMM bVeto	SRHM bVeto	SRLM bTag	SRMM bTag	SRHM bTag
Total SM	6.47±1.71	4.54±1.69	6.42±1.20	3.62±0.83	3.57±0.80	1.16±0.45
$t\bar{t}$	0.47±0.14	0.53±0.18	0.15±0.04	1.62±0.39	0.48±0.10	0.28±0.07
W+jets	3.65±1.66	0.97±1.66	4.37±1.13	0.80±0.34	0.97±0.41	0.28±0.34
Single top	0.00±0.00	0.00±0.00	0.29±0.29	0.39±0.60	1.61±0.68	0.28±0.28
Diboson	2.19±0.36	2.83±0.23	1.32±0.15	0.59±0.25	0.18±0.05	0.04±0.08
...	...	...	...	...	...	...
$m_{\chi_2^0} = 200, m_{\chi_1^0} = 0$	9.47±2.03	0.40±0.40	0.00±0.00	5.94±1.54	6.43±1.71	0.00±0.00
$m_{\chi_2^0} = 400, m_{\chi_1^0} = 50$	4.92±0.97	4.94±1.00	1.47±0.57	0.94±0.42	6.55±1.12	4.83±0.95
$m_{\chi_2^0} = 600, m_{\chi_1^0} = 200$	0.30±0.19	2.18±0.47	3.60±0.63	0.62±0.24	0.95±0.31	3.23±0.59

Preliminary Results

- For each signal point, compute Z_N in each SR, then estimate the **total Z_N**:

$$Z_N^{total} = \sqrt{\sum_{i}^{Nbins} [Z_N^2]_i}, \quad [Z_N]_i > 0$$

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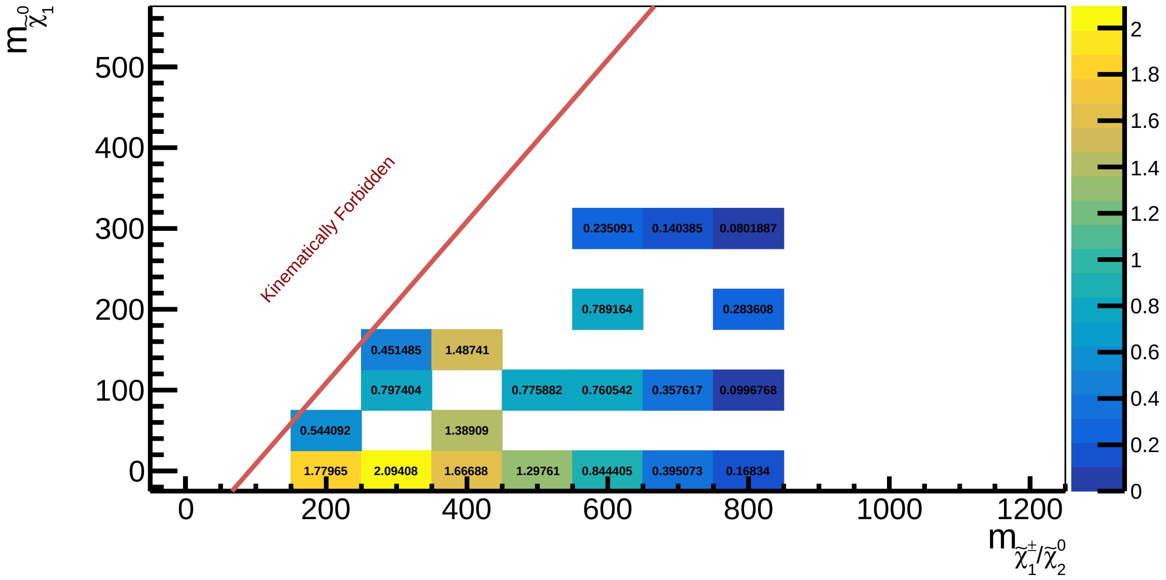
Zqq analysis



- For each signal point, compute Z_N in each SR, then estimate the **total Z_N**:

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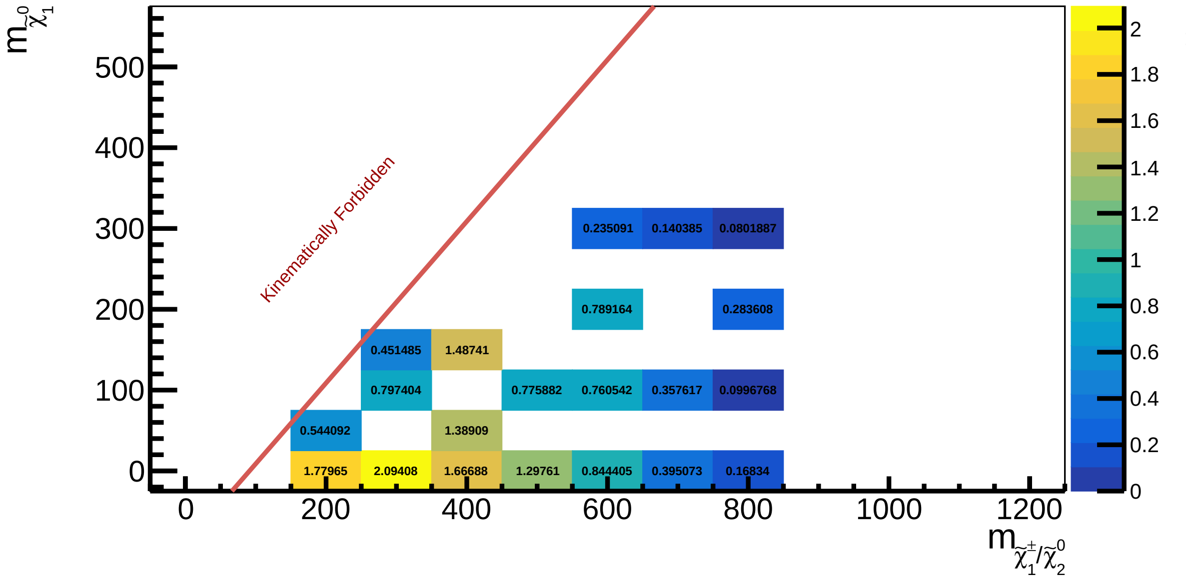
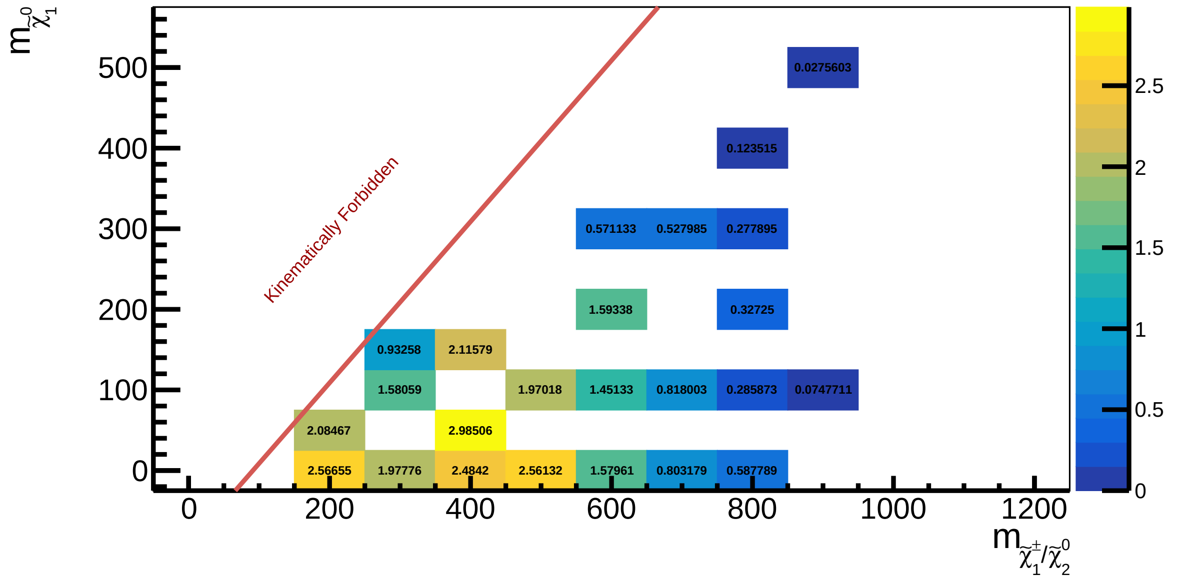
Zqq analysis

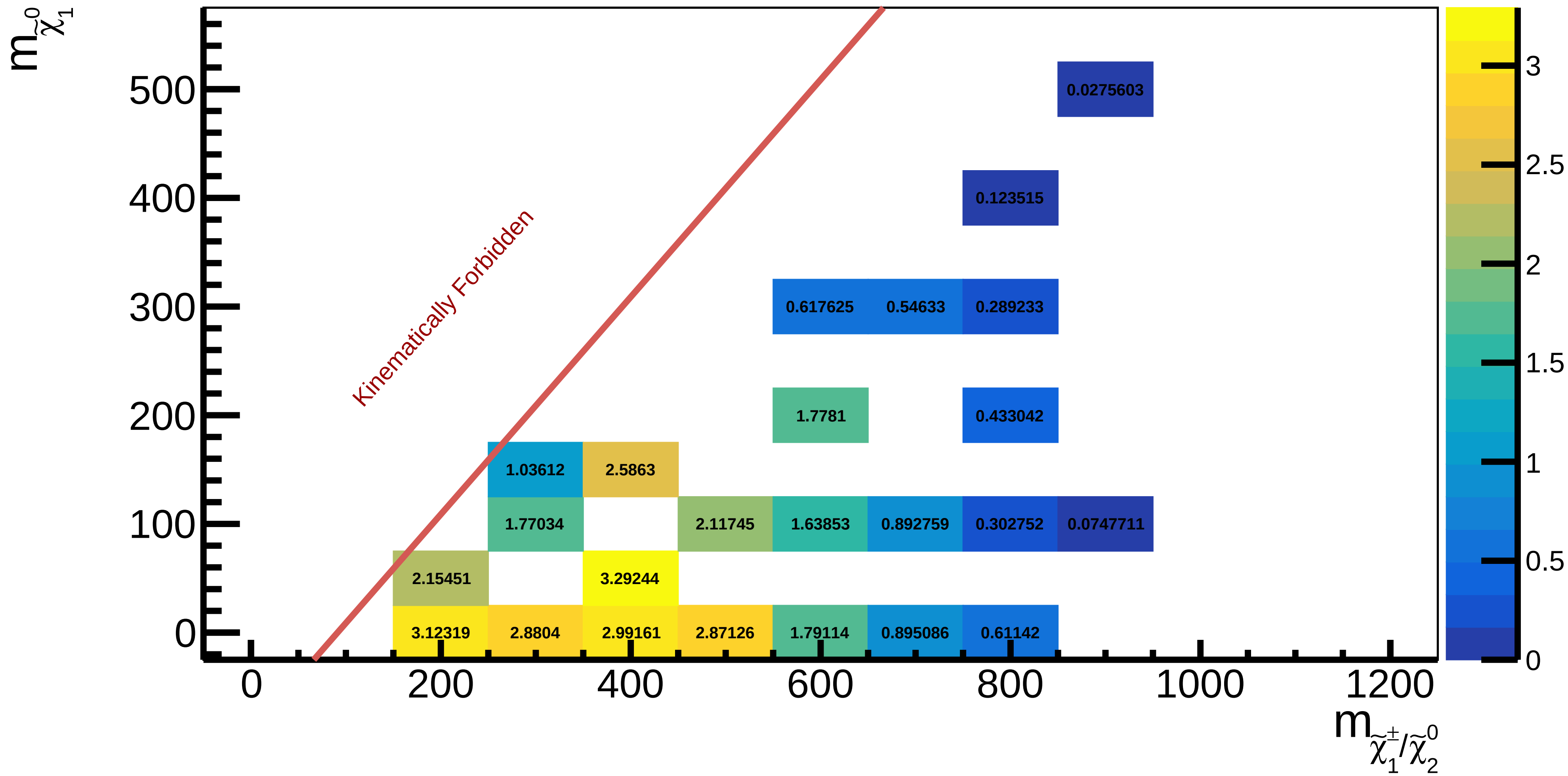


Zbb analysis



Preliminary Results

- Combine the 2 analyses:



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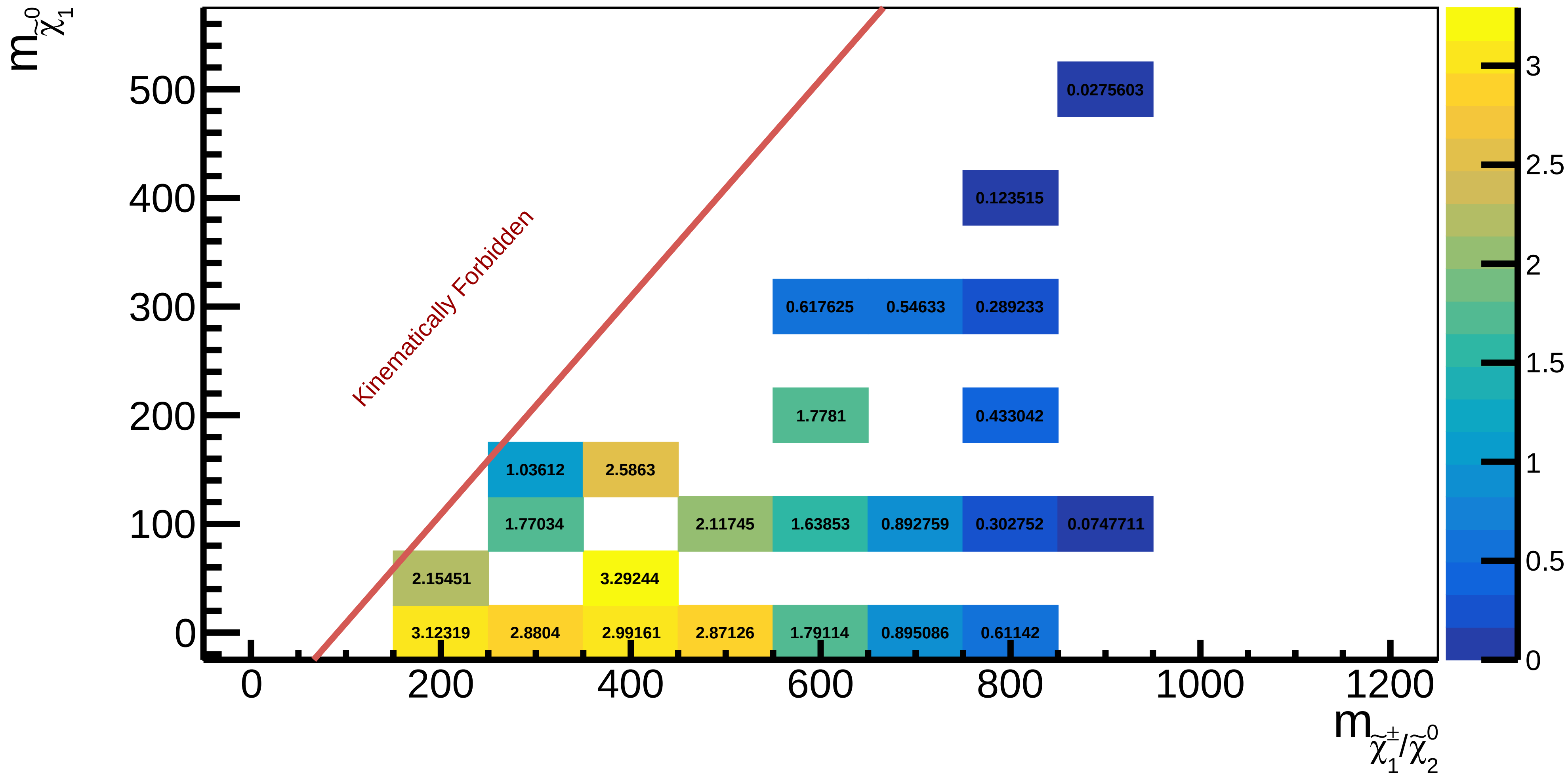

Exclusion limit at 95% ***CL*** seems to reach **600 GeV**.

Summary and Prospect

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- Performed the search for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow W^{\pm}(\rightarrow l^{\pm}\nu) + Z^0(\rightarrow q\bar{q}) + \not{E}_T$ with full LHC Run2 data.
- Introduced **a tagger** using **kinematic fit** to differentiate **ISR** and **FSR** 3-jets events $\rightarrow$ **improve** Z **boson reconstruction**.
- Optimzed the **SRs** and obtained **upper limit of 600 GeV** for **exclusion limit at 95**% CL

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What next?

- Reoptimize the SRs using **more information of kinematic fit** and **applying more complex algorithm** to gain the sensitivity.
- Take into account other regions e.g **Control Regions**, **Validation Regions**, etc. and **systematic uncertainties** for the fit.

THANK YOU

BACK UP

Simulated Samples

- **3 different Monte Carlo production campaigns**

MC campaign	data
MC16a	2015-2016
MC16d	2017
MC16e	2018

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- Each $(m_{\chi_2^0}, m_{\chi_1^0})$ at **leading order** using `Madgraph5_aMC@NLO v2.6.2` and `Pythia 8.230`.
- **Cross sections** at **NLO+NLL**.
- samples with $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) \geq$ **300 GeV** produced with **full ATLAS detector simulation**, otherwise **fast ATLAS simulation**.

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Background samples

- produced with **full ATLAS detector simulation**.

Process	Generator	PS and hadronisation	Tune	PDF	Cross-section
$t\bar{t}$	Powheg-Box v2 [45, 46]	PYTHIA v8.230 [37]	A14 [38]	NNPDF2.3LO [40]	NNLO+NNLL [47]
Single top	Powheg-Box v2	PYTHIA v8.230	A14	NNPDF2.3LO	NLO+NNLL [48]
W/Z+jets	SHERPA v2.2.1[49]	SHERPA v2.2.1	Sherpa standard	NNPDF3.0NNLO	NNLO [50]
Diboson	SHERPA v2.2.1 & v2.2.2	SHERPA v2.2.1 & v2.2.2	Sherpa standard	NNPDF3.0NNLO	NLO
Triboson	SHERPA v2.2.1 & v2.2.2	SHERPA v2.2.1 & v2.2.2	Sherpa standard	NNPDF3.0NNLO	NLO
$t\bar{t}+V$	MadGraph5_aMC@NLO v2.3.3	PYTHIA v8.210	A14	NNPDF2.3LO	NLO [51]
tth	Powheg-Box v2	PYTHIA v8.230	AZNLO [52]	CTEQ6L1 [53]	NLO [54]
Vh	Powheg-Box v2	PYTHIA v8.212	A14	NNPDF2.3LO	NLO [54]

Reconstructed Objects

Electrons and **muons**:

- **baseline**: smaller purity, higher acceptance, useful for e.g. $\not{E}_T$ computation.
- **signal**: **subset of baseline objects**, tighter selection, **used as physical objects**.

Electron	
baseline	$p_T > 4.5$ GeV, $\vert\eta\vert < 2.47$
signal	$p_T > 7.5$ GeV, $\vert\eta\vert < 2.47$

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Jets

- Required $p_T >$ **20 GeV** and $|\eta| <$ **4.5**.
- Observables built from **central jets** ($p_T >$ **20 GeV**, $|\eta| <$ **2.8**).
- ***b*-jets**: **MV2c10** with ***b*-tagging efficiency of 77%**. Required $p_T >$ **20 GeV**, $|\eta| <$ **2.5**.

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Missing transverse momentum

- reconstructed using **fully calibrated baseline objects**.