

# Shining light on the Scotogenic model

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Motivated by [arXiv:1806.06864](https://arxiv.org/abs/1806.06864)

With Vedran Brdar, Pedro Schwaller and Alexander Segner

Invisibles '19  
Workshop



# The Scotogenic Model

## Spectrum

SM

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$$\text{SM} + 3N_i + \Sigma = \begin{pmatrix} \sigma^\pm \\ S + iA \end{pmatrix}$$

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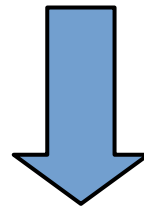
**Why do we care?**

# The Scotogenic Model

## Spectrum

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Testing?



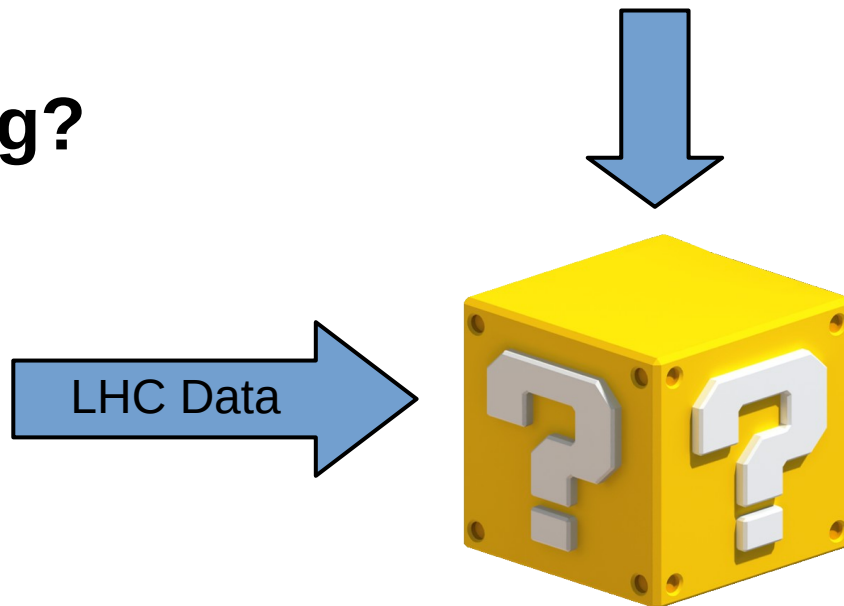
Source: [gammingsymmetry.com](http://gammingsymmetry.com)

# The Scotogenic Model

## Spectrum

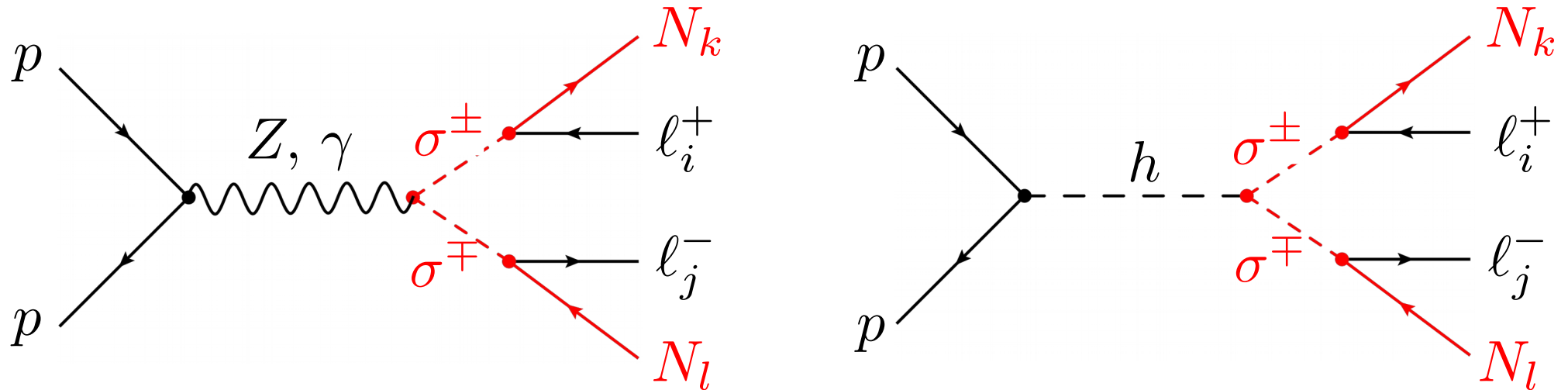
$$\text{SM} + \overbrace{3N_i}^{\mathbb{Z}_2} + \Sigma = \begin{pmatrix} \sigma^\pm \\ S + iA \end{pmatrix}$$

Testing?



# The “golden” channel

$$pp \rightarrow \sigma^\pm \sigma^\mp \rightarrow l^+ l^- + \cancel{E}_T$$



Pair production of new scalars and decay into leptons + missing energy  $1708.07875 + 1803.02762$

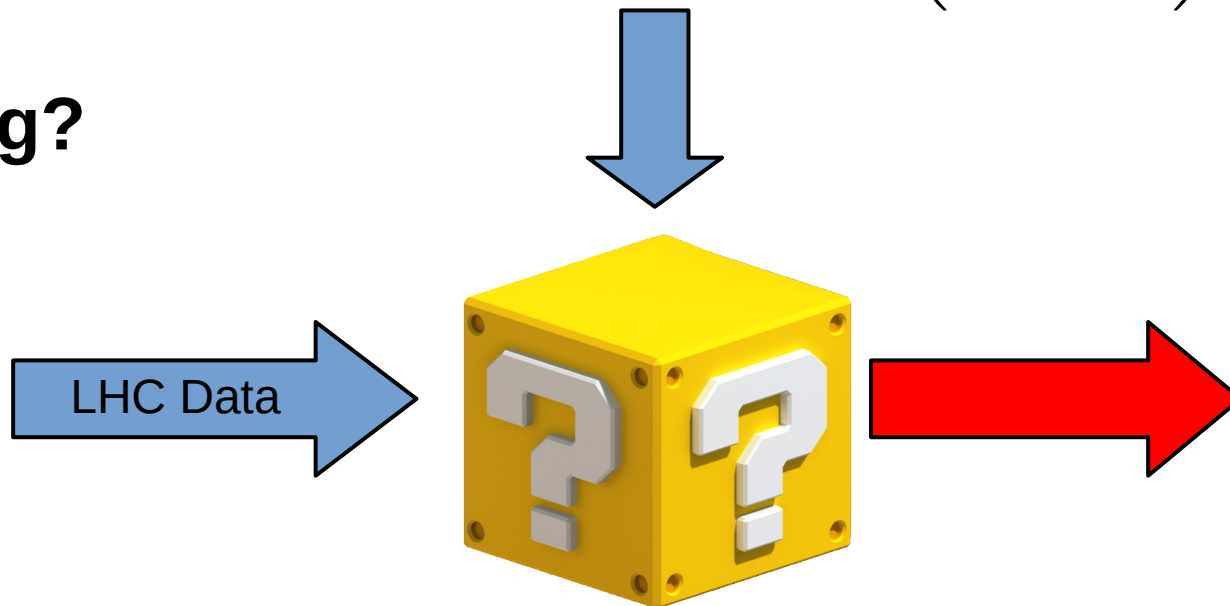


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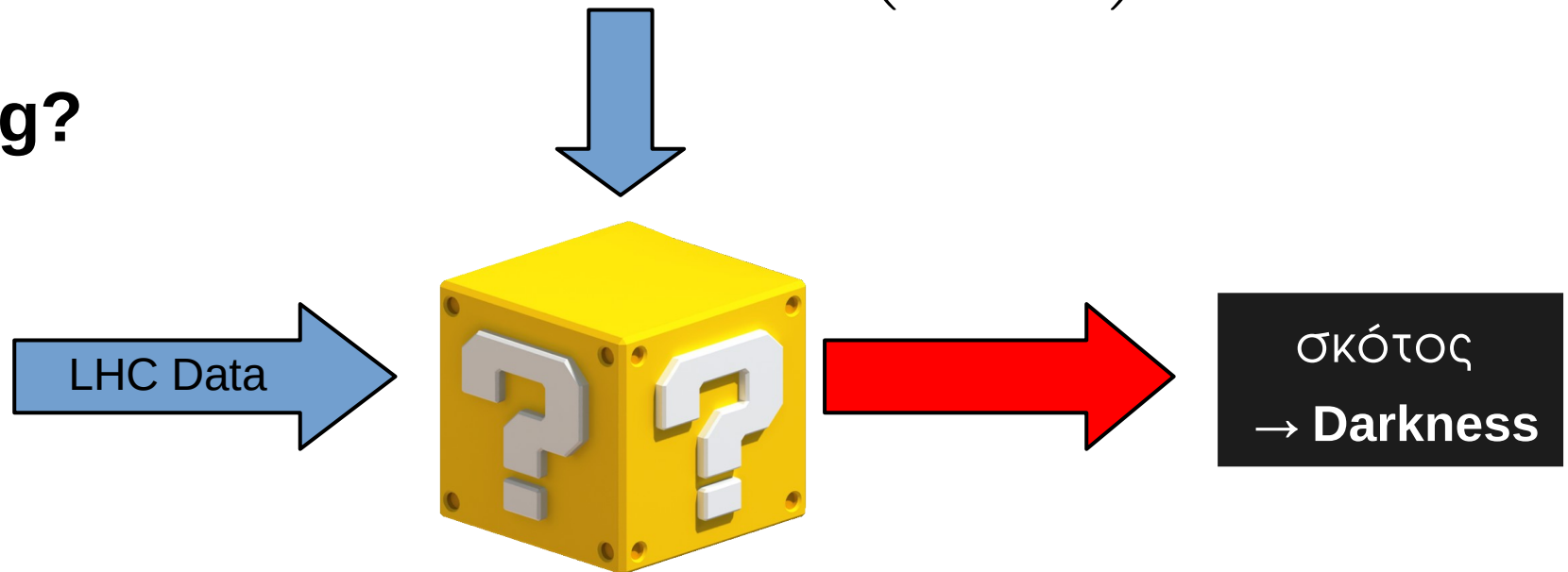


# The Scotogenic Model

## Spectrum

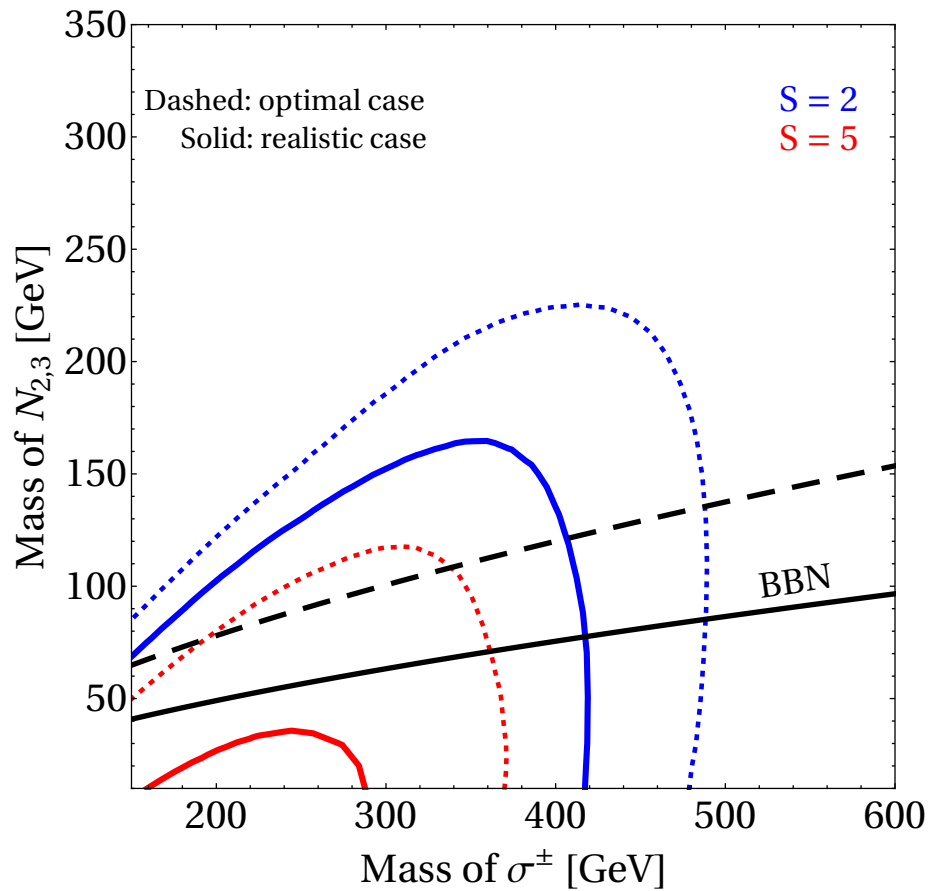
$$\text{SM} + \overbrace{3N_i}^{\mathbb{Z}_2} + \Sigma = \begin{pmatrix} \sigma^\pm \\ S + iA \end{pmatrix}$$

## Testing?



$$\mathcal{L}_{13 \text{ TeV}} = 36.1 \text{ fb}^{-1} \Rightarrow \mathcal{L}_{14 \text{ TeV}} = 4000 \text{ fb}^{-1}$$

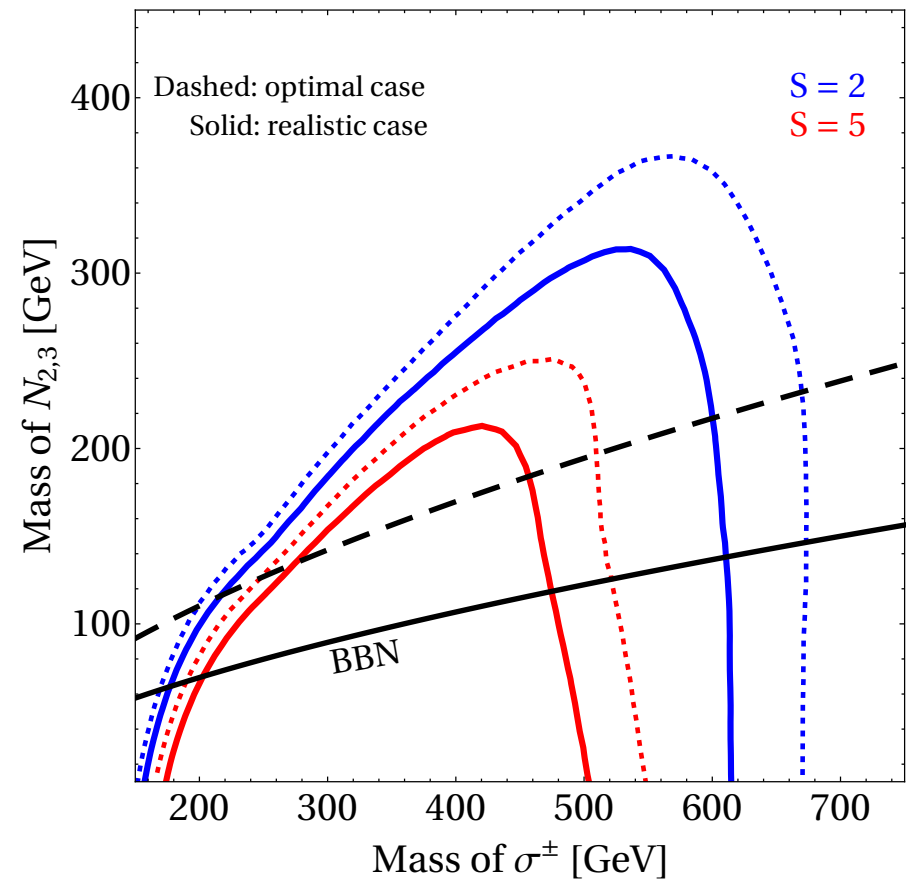
## Di-Tau + MET



**Preliminary**

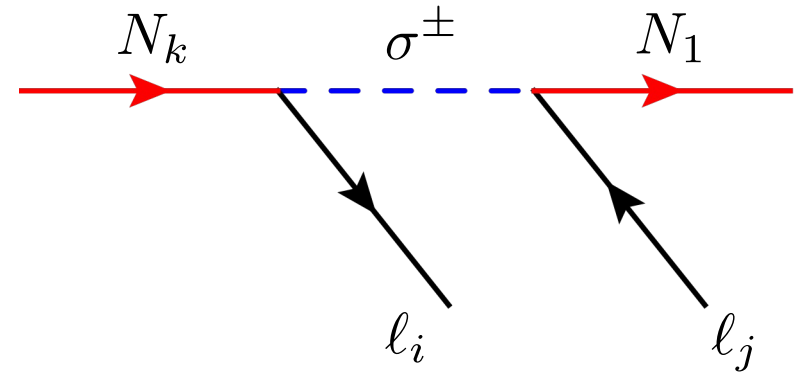
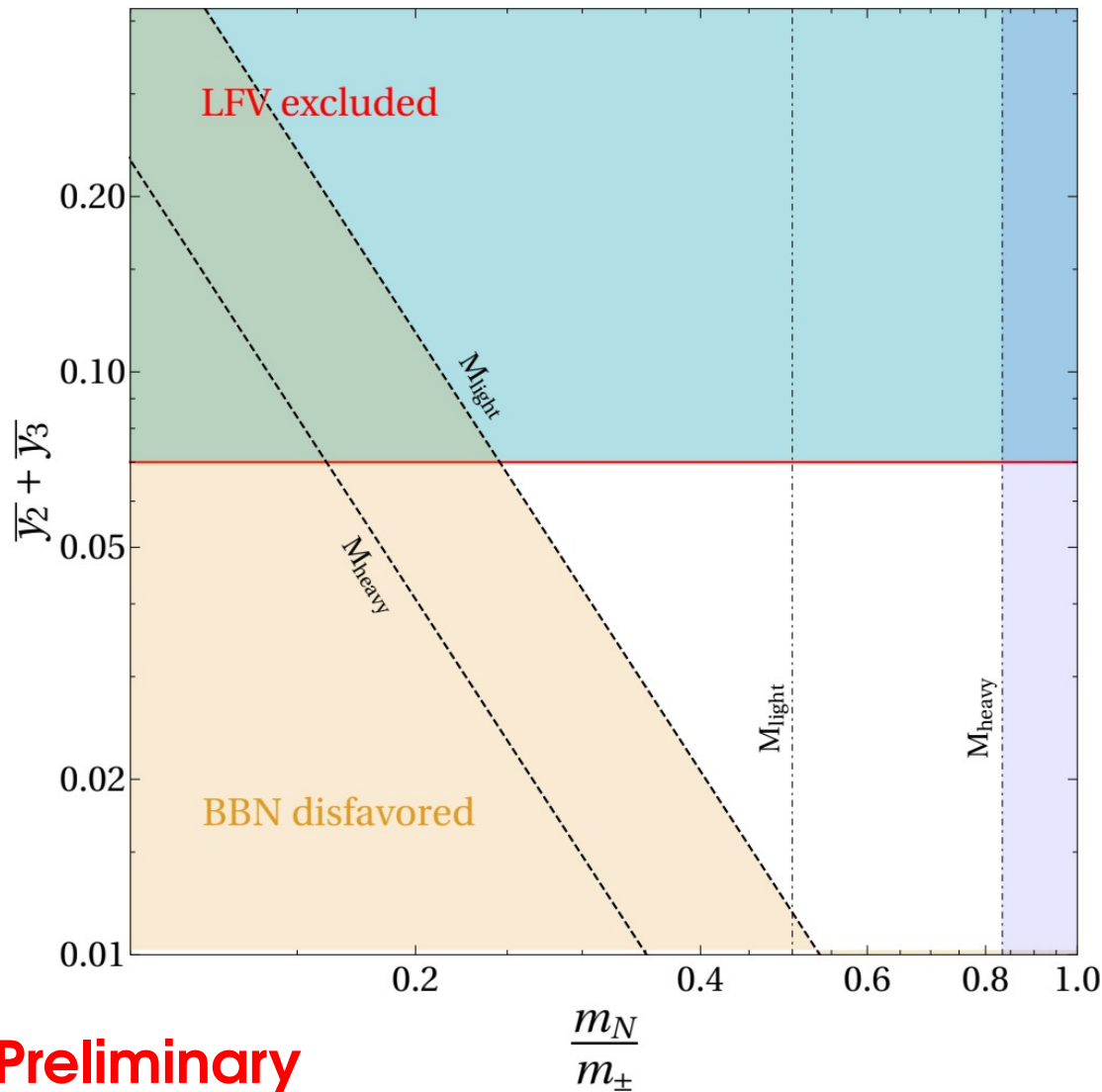
1708.07875

## Di-Lepton + MET



1803.02762

# A shadow arises...



- Upper bound on strength set by **lepton flavour violation**
- Lower bound from **BBN**
- Mass ratio restricted to “**LHC friendly**” region

Lower mass bound for neutrinos!

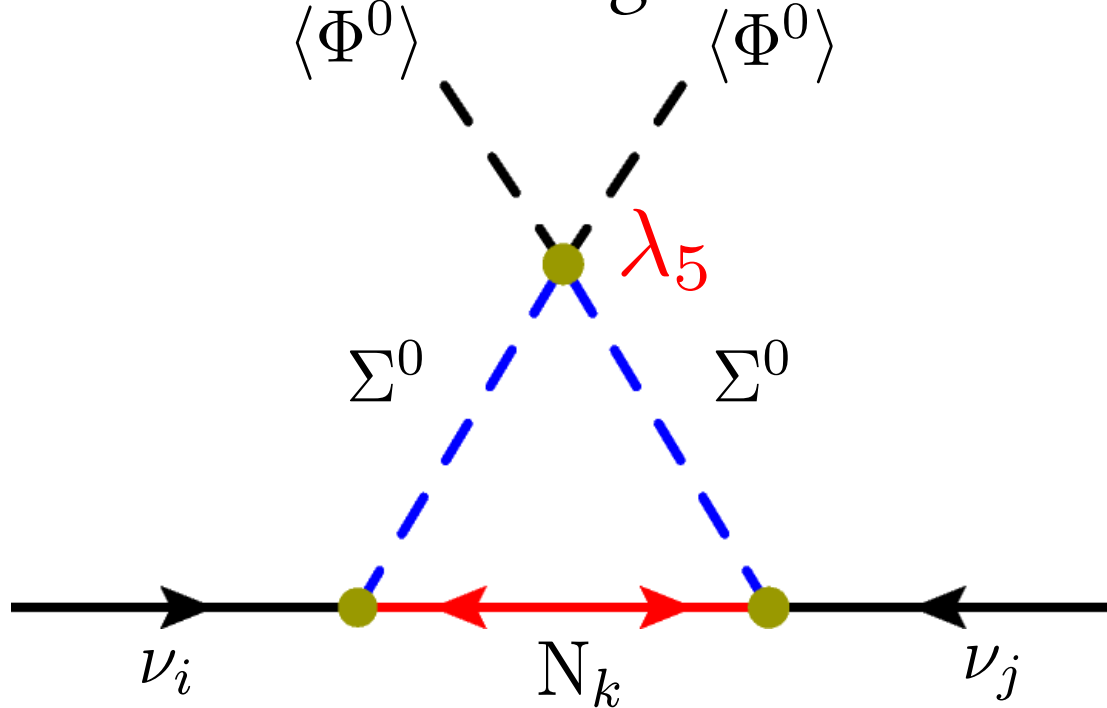
**Preliminary**

Thanks for your attention!

See you at the poster session

# Backup slides

- Neutrino mass generation



$$m_0^2 \equiv \frac{m_S^2 + m_A^2}{2} \gg M_k^2$$

$$(m_\nu)_{ij} \approx \frac{\lambda_5 v^2}{8\pi^2} \frac{y_{ki} y_{kj}}{m_0^2} M_k$$

- Casas-Ibarra Parametrization: [J.A. Casas, A. Ibarra](#)

[\[hep-ph/0103065\]](#)

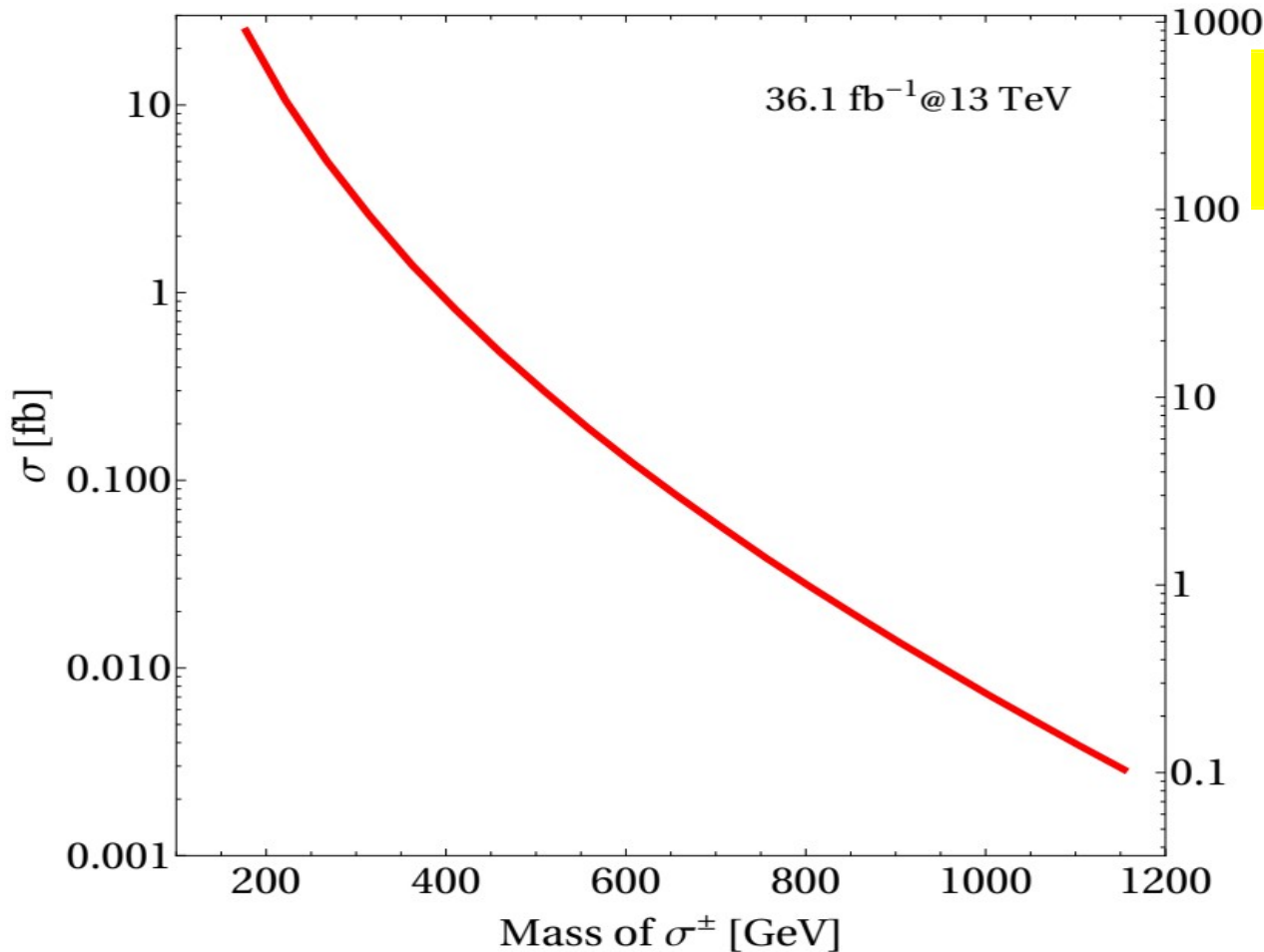
$$y = \sqrt{\Lambda^{-1}} R \sqrt{m_\nu} U_{\text{PMNS}}^\dagger$$

$$m_\nu = \text{Diag}(0, \sqrt{\Delta_{\text{sol}}^2}, \sqrt{\Delta_{\text{sol}}^2 + \Delta_{\text{atm}}^2})$$

$$R = \begin{pmatrix} 0 & \cos(w + i\xi) & \sin(w + i\xi) \\ 0 & -\sin(w + i\xi) & \cos(w + i\xi) \end{pmatrix}$$

# Backup slides

- Cross section

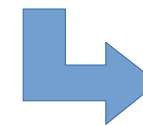


$$\times \text{BR} \left( \sigma^\pm \rightarrow N_k \ell_j^\pm \right)^2$$

(Using the narrow width approximation)

Events

Exact value depends on the **pattern** inside  $y_{ki}$



Optimization possible!