

Abstract

We are exploring the phenomenology of multi-charged scalars in the framework of a radiative neutrino mass generation model. In particular, we are interested in the collider signatures of this model at the LHC with $\sqrt{s} = 13$ TeV. We have studied the production, decays and possible signatures of these multi-charged scalars at the LHC experiment and suggested required luminosities to discover them. Apart from the Drell-Yan pair production, we have also studied photo-production of these particles.

Model

Symmetry Group: $SU(3)_C \times SU(2)_L \times U(1)_Y$

Particle \Rightarrow	E^{++}	k^{++}	$\Phi_{\frac{3}{2}}$	$\Phi_{\frac{5}{2}}$
$SU(3)_C$	1	1	1	1
$SU(2)_L$	1	1	2	2
$U(1)_Y$	2	2	3/2	5/2

Yukawa Lagrangian:

$$\mathcal{L}_Y = m_E^{\alpha\beta} \overline{E_\alpha^{++}} E_\beta^{++} + y_{\frac{5}{2}}^{\alpha\beta} \overline{L_{\alpha L}} \cdot \Phi_{\frac{5}{2}}^* E_{\beta R}^{++} + y_{\frac{3}{2}}^{\alpha\beta} \overline{L_{\alpha L}} \cdot \Phi_{\frac{3}{2}} (E_{\beta L}^{++})^c + f_\kappa^{\alpha\beta} \overline{e_{\alpha R}} k^{--} (e_{\beta R})^c + h.c.$$

$\alpha, \beta \in 1, 2, 3$ are generation indices.

Scalar Potential:

$$\mathcal{V} = \mu (H^T \cdot \Phi_{\frac{3}{2}}) k^{--} + \mu' (H^\dagger \Phi_{\frac{5}{2}}) k^{--} + \lambda (H^T \cdot \Phi_{\frac{3}{2}}) (H^T \Phi_{\frac{5}{2}}^*) + c.c$$

Physical states after mixing of doubly charged Higgs bosons (after EWSB):

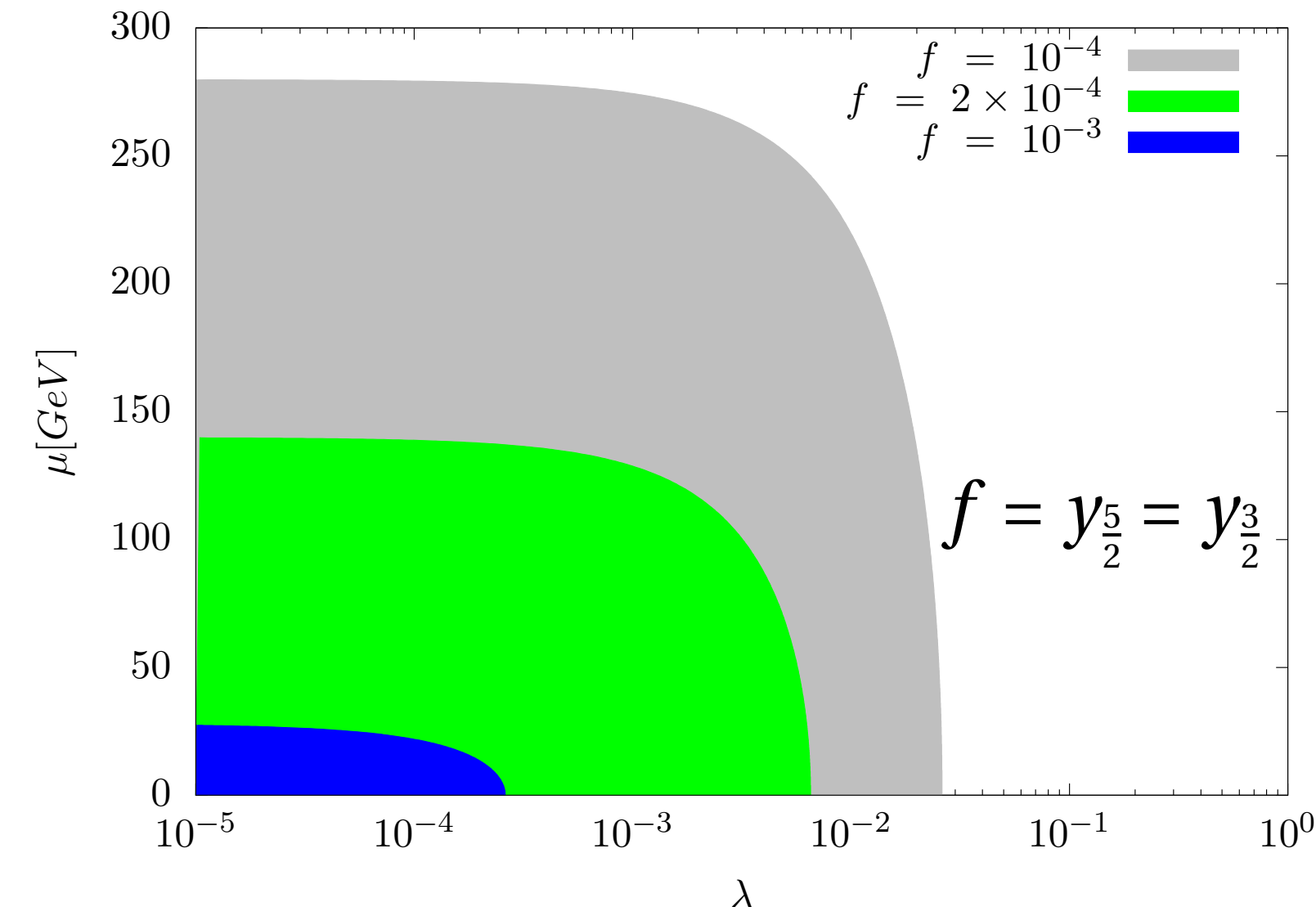
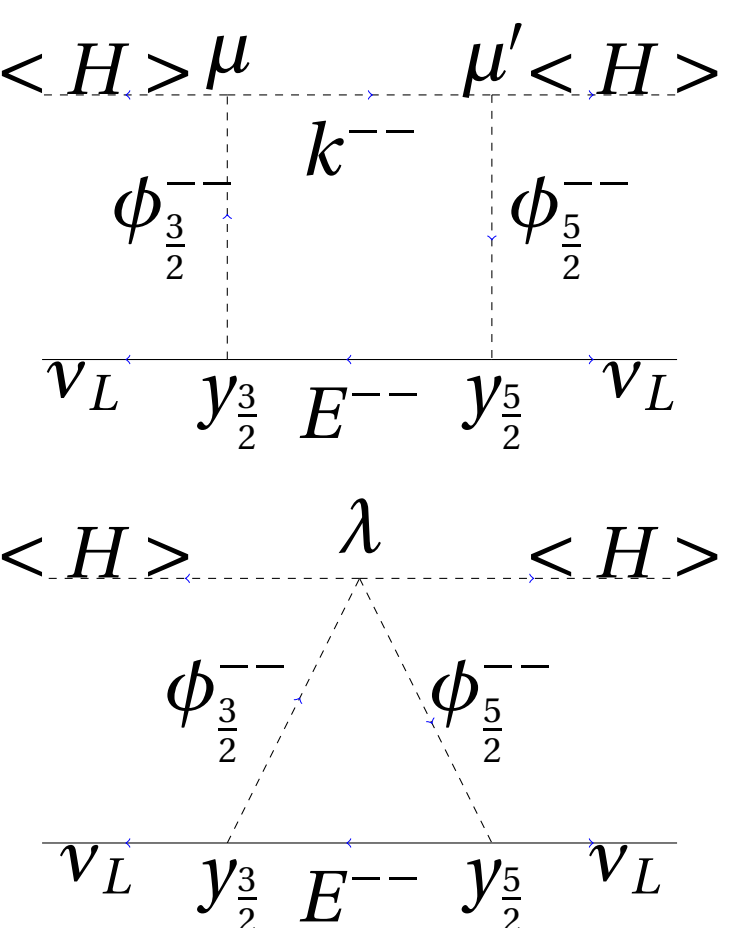
$$H_a^{++} = O_{a1} \Phi_{\frac{5}{2}}^{++} + O_{a2} \Phi_{\frac{3}{2}}^{++} + O_{a3} k^{++}$$

O_{ab} is the mixing matrix.

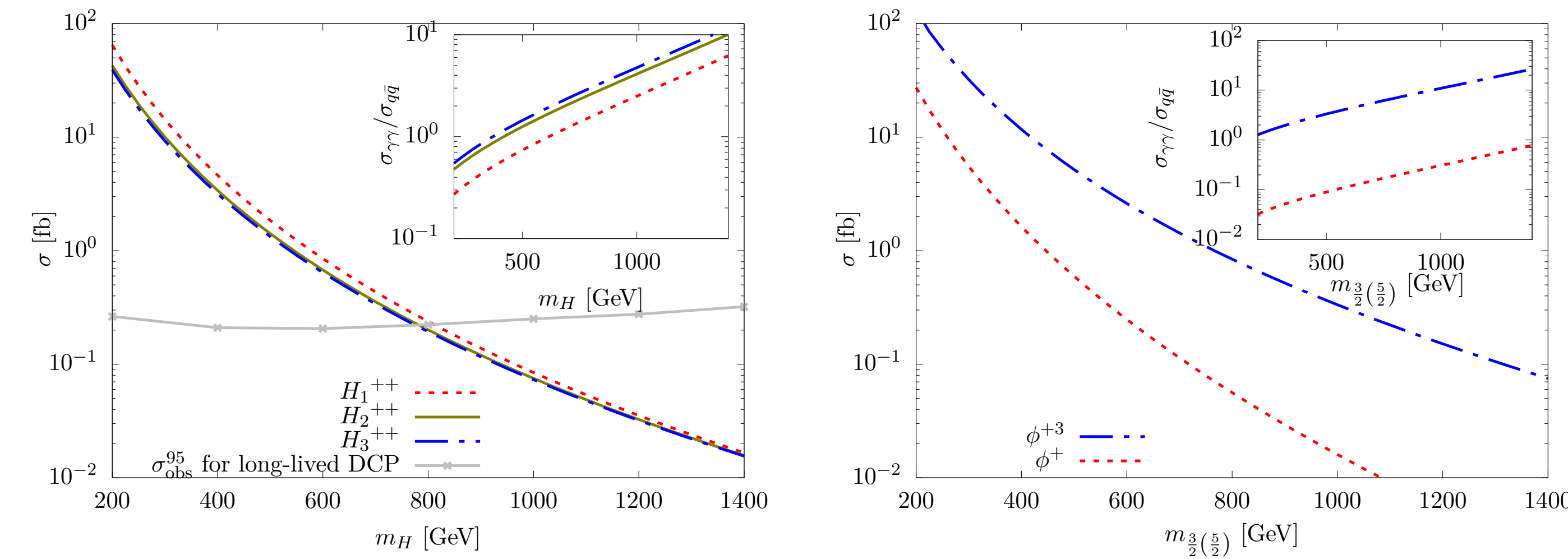
Neutrino Mass

1-loop Feynman Diagrams

ν -mass bound



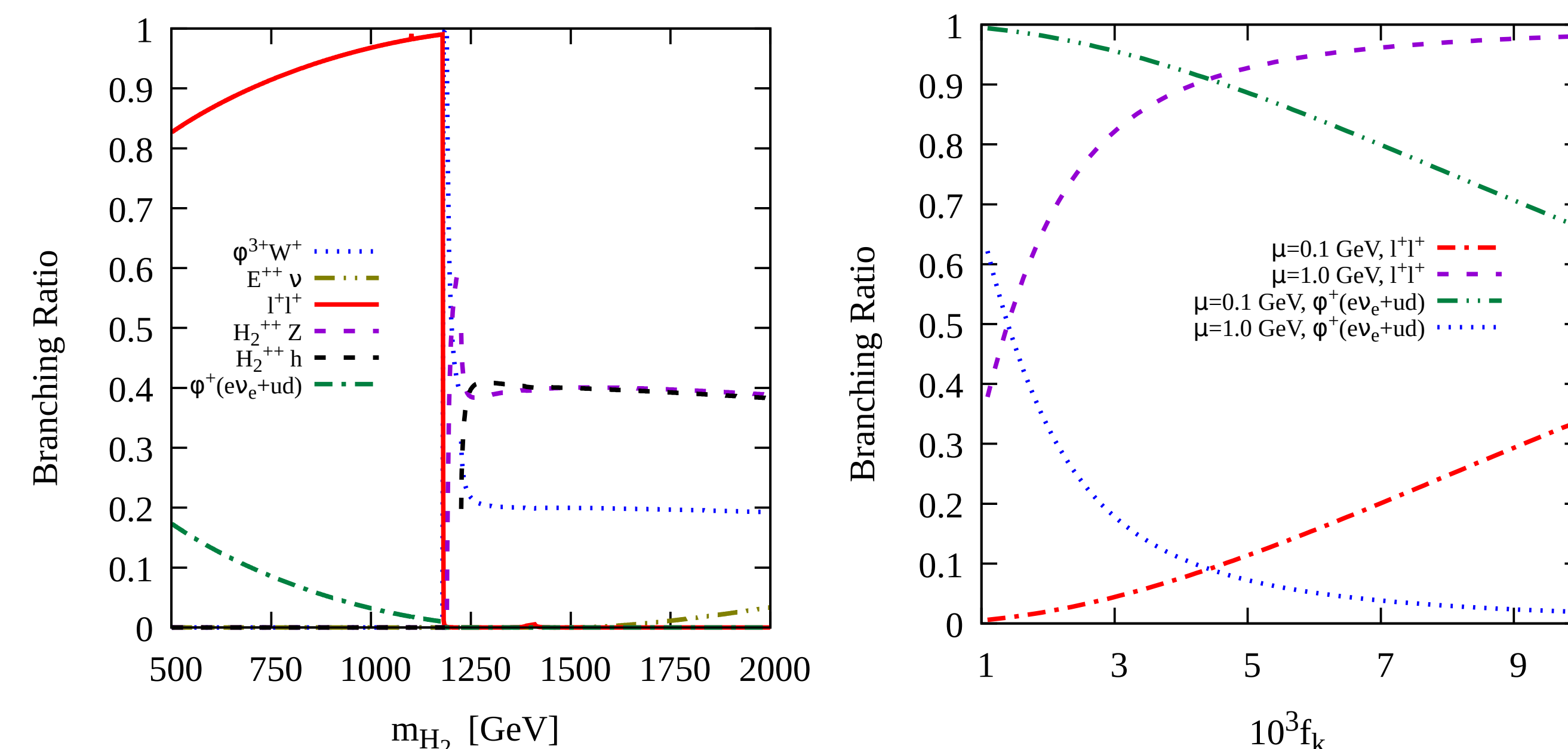
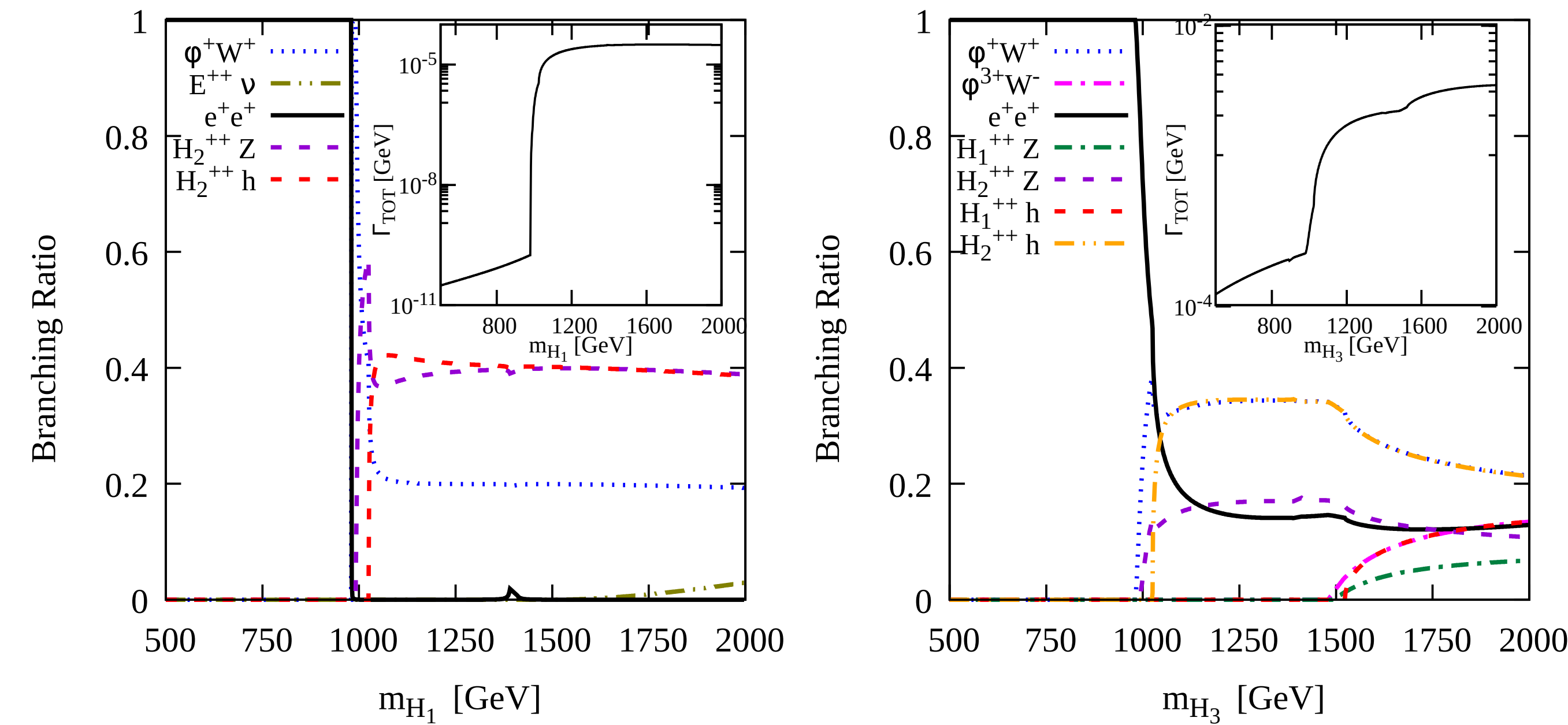
Total pair production at the LHC-13 TeV



- **Photo-production** contributes significantly in total production cross-section.
- Ordering in values of σ_{prod} for H_a^{++} depends upon **hyper-charges**.
- For low mixing, $H_1^{++} \approx \phi_{\frac{3}{2}}^{++}$, $H_2^{++} \approx \phi_{\frac{3}{2}}^{++}$ and $H_3^{++} \approx k^{++}$.

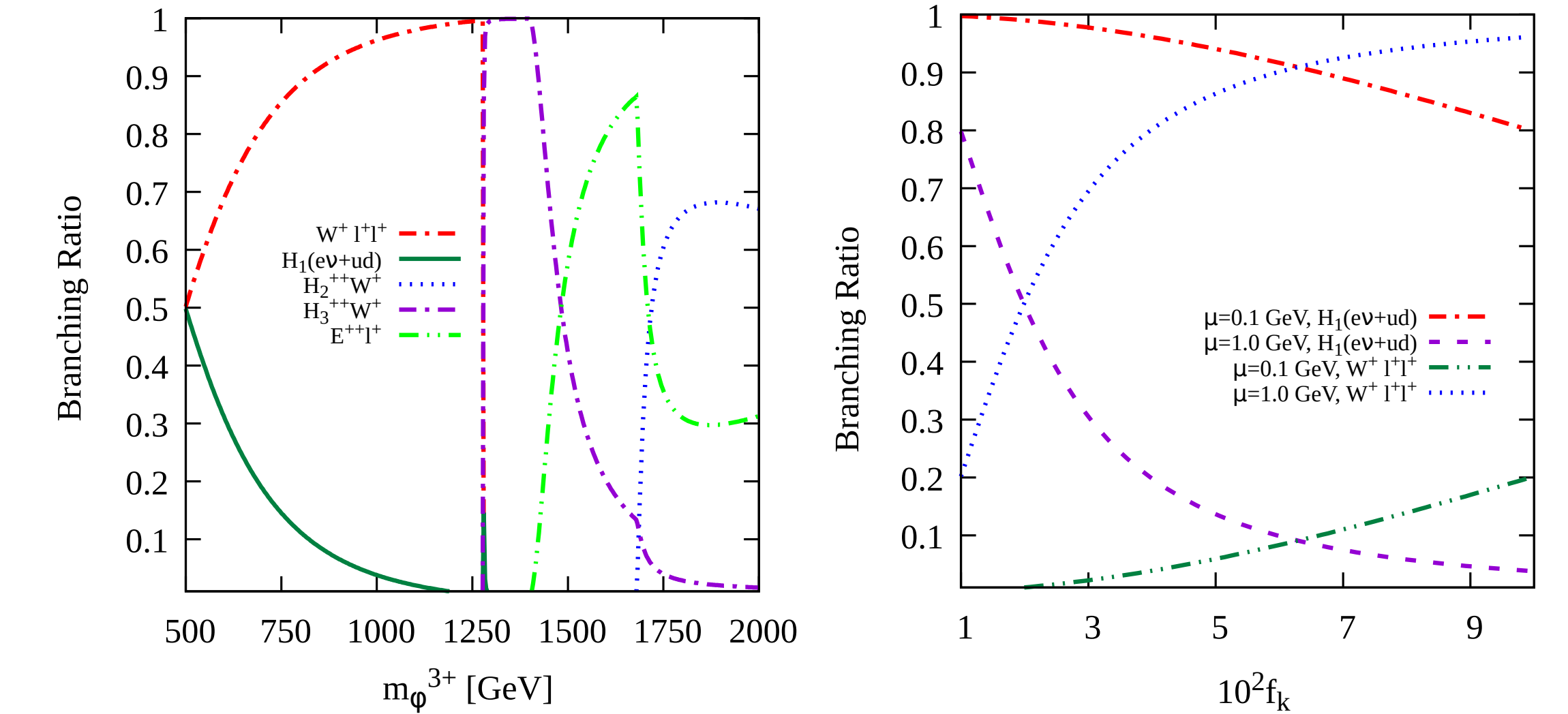
Decay of doubly charged scalars

- Parameters μ, μ' and λ play vital role in decays of H_a^{++} 's **through mixing**.
- Decay to **same sign dileptons** is among important decay channels of H_a^{++} 's.



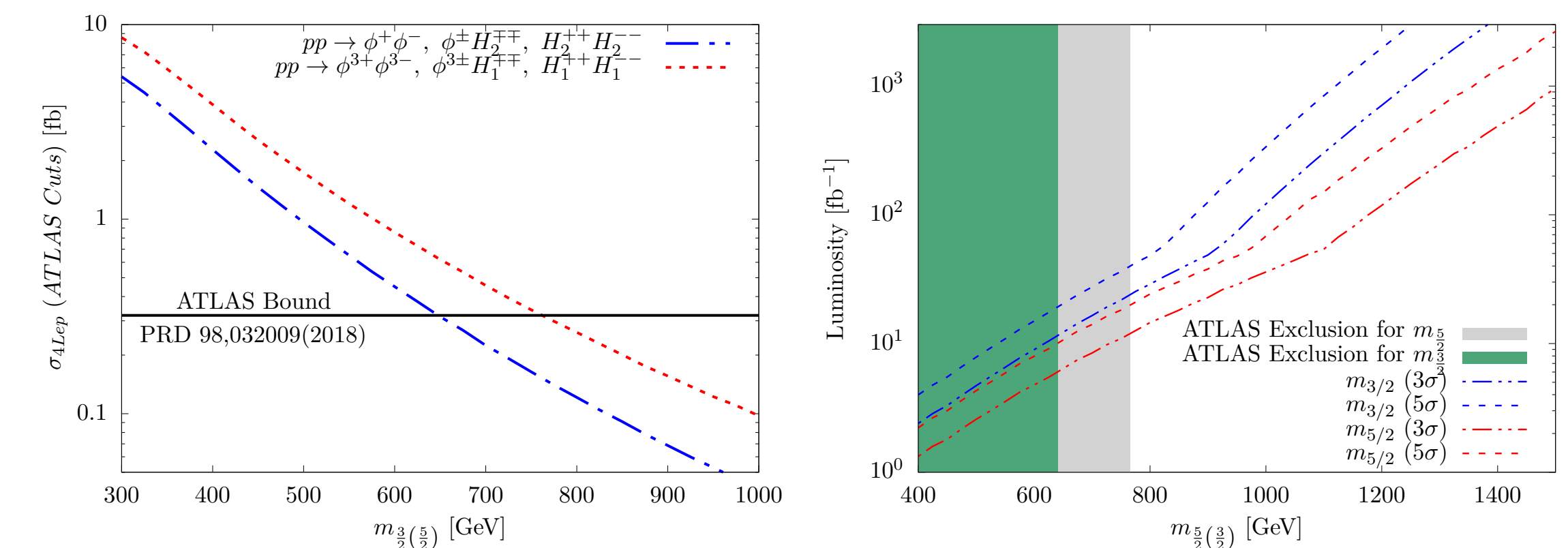
Decay of triply charged scalars

- Decay to **same sign dileptons with a same charged W boson** is among important decay channels of ϕ^{3+} .
- **Yukawa coupling** f_κ also plays a vital role.



Multi-lepton signal search

- $pp \rightarrow \phi_s \phi_s^\dagger \rightarrow 4\text{lepton} + E_T$
- where ϕ_s is **the lightest** among all scalars and fermion.
- ϕ_s and $\phi_s^\dagger \in \phi^{3\pm}, \phi^\pm, H_1^{\pm\pm}, H_2^{\pm\pm}$.
- These are the results for **4-lepton + missing transverse energy** signal search.



References

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- (3) ATLAS collaboration, Search for heavy long-lived multicharged particles in proton-proton collisions at $\sqrt{s} = 13$ TeV using the ATLAS detector, Phys. Rev. D 99 (2019) 052003 [1812.03673].
- (4) ATLAS collaboration, Search for supersymmetry in events with four or more leptons in $\sqrt{s} = 13$ TeV pp collisions with ATLAS, Phys. Rev. D 98 (2018) 032009 [1804.03602].
- (5) Avnish, Kirtiman Ghosh, arXiv: 2007.01766 [ph].