

HOW TO IMPROVE LHC SEARCHES FOR NEUTRINO RELATED PHYSICS

Channels and observables for
neutrino mass models at colliders

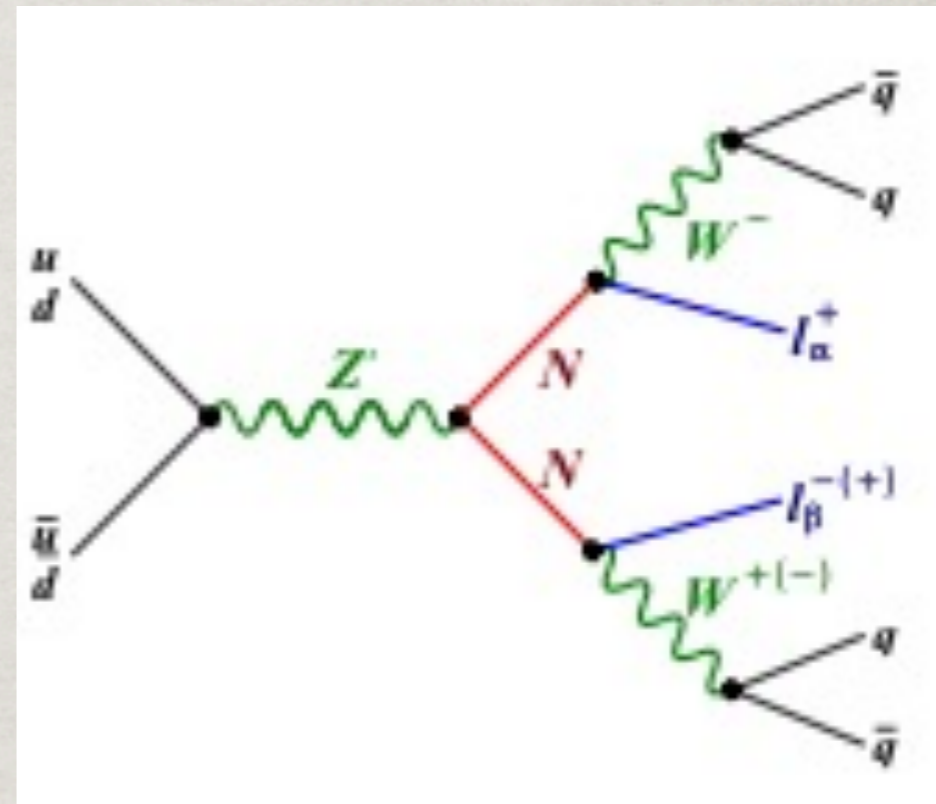
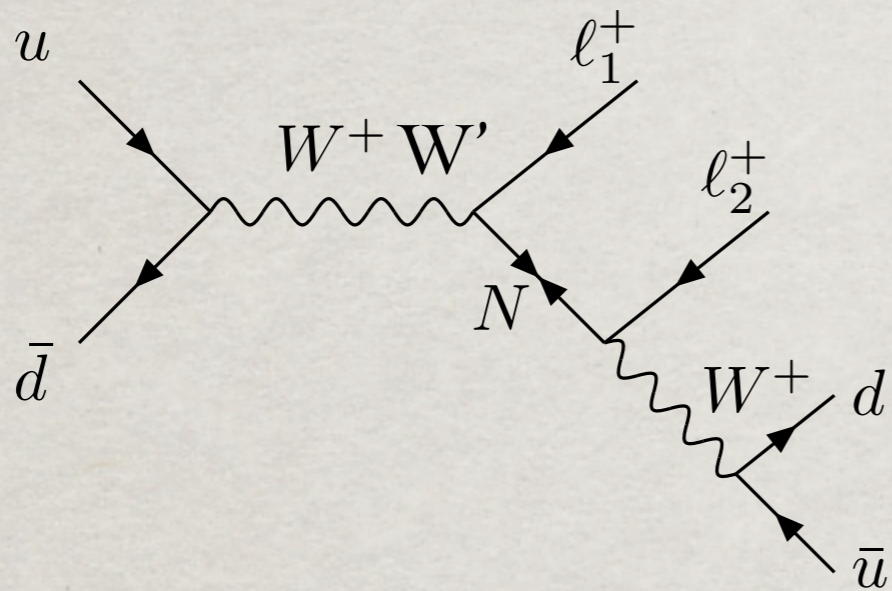
Tao Han & Albert De Roeck
March 29, 2017

Good & Bad for neutrino-related signatures

- 😊 It is in the “leptonic sector”:
- Nice collider signals;
 - Clean, low SM backgrounds.

- 😞 It is in the “leptonic sector”:
- Signals typically weak;
 - Unknown couplings/BRs;
 - Unknown mass scale.

Search for N , T^\pm & T^0



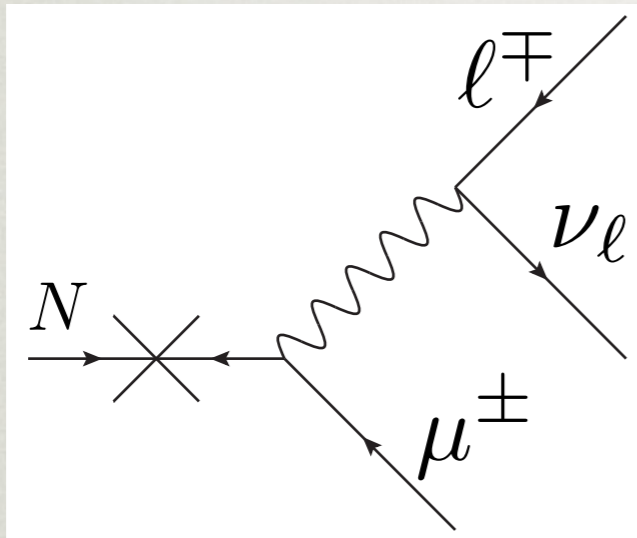
Prompt decays: $N, T \rightarrow l^\pm W^\mp, \nu Z, \nu h$

A very clean channel:

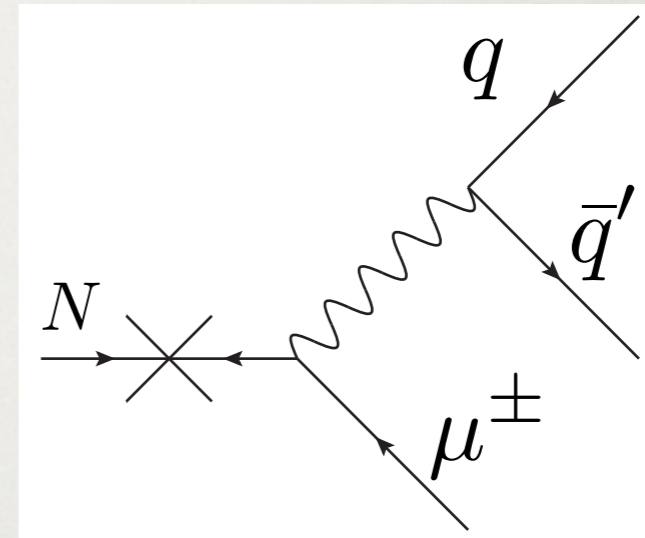
- like-sign di-muons plus two jets;
- no missing energies;
- $m(jj) = M_W, m(jj\mu) = m_N$.

Long-Lived Searches

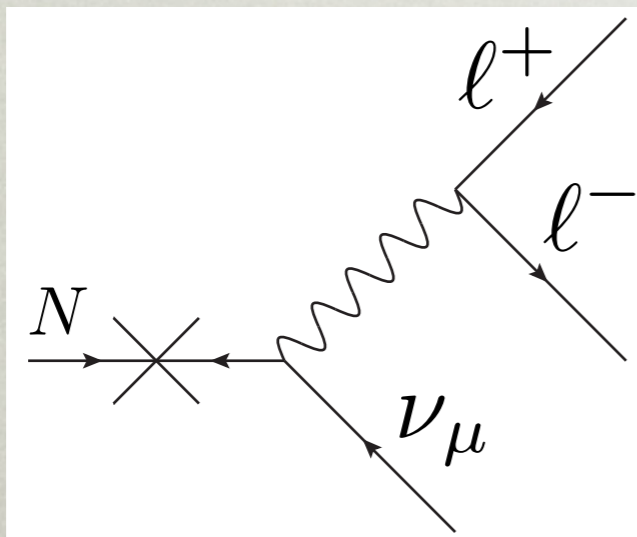
- What do the X decay to NN look like? (resolved only for now)



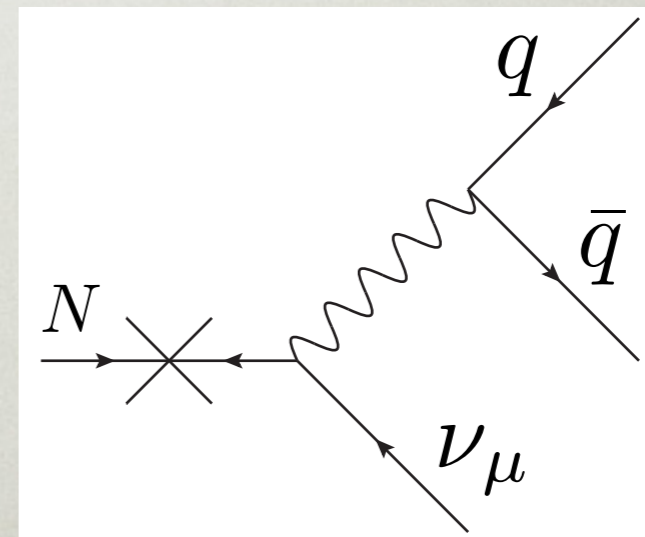
ATLAS displaced dilepton (1504.05162)
 CMS displaced dilepton (1411.6977)
 CMS "displaced SUSY" (1409.4789)



ATLAS displaced lepton + tracks (1504.05162)
 ATLAS displaced jets (1504.03634)
 CMS displaced jets (1411.6530)
 CMS "displaced SUSY"

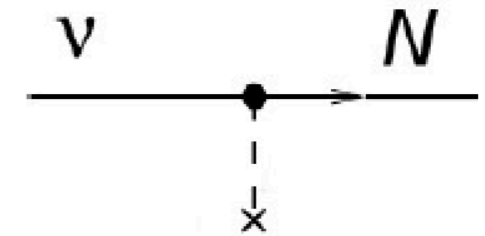


ATLAS displaced dilepton
 CMS displaced dilepton
 CMS "displaced SUSY"



ATLAS displaced jets
 CMS displaced jets

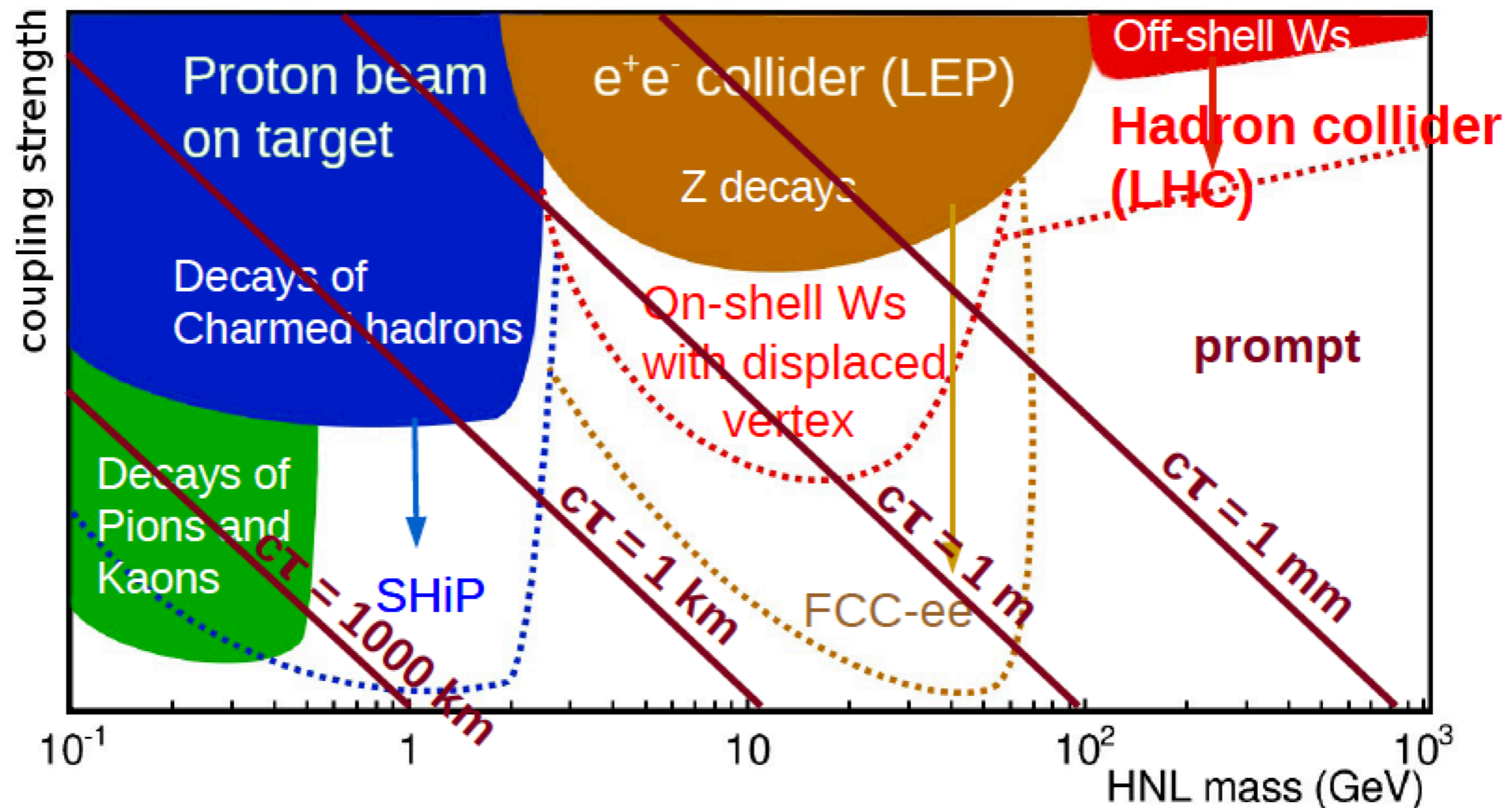
N production and detection in the lab



Very small mixing for BAU
and to evade existing
experimental constraints

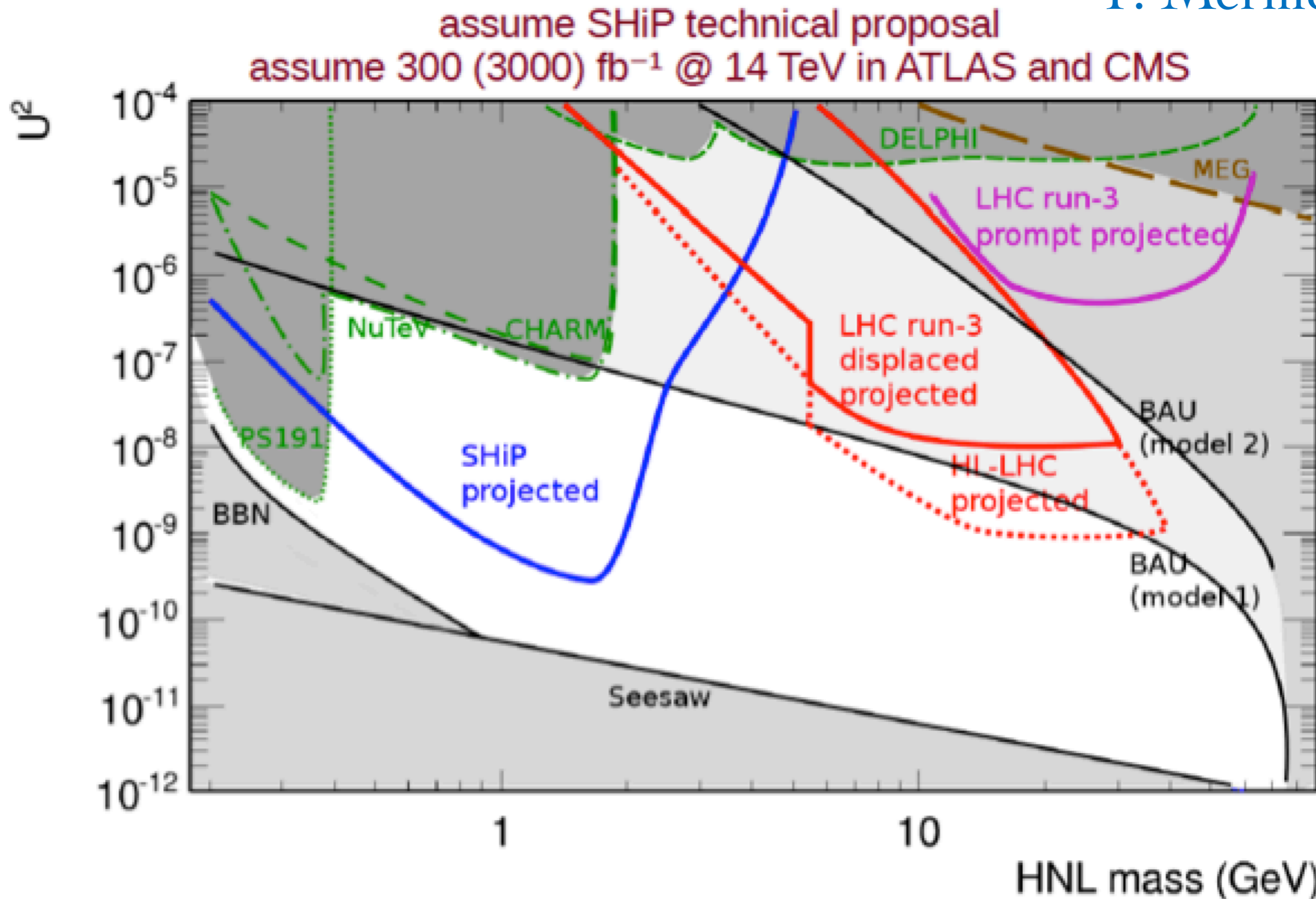


- High-intensity beams
- Displaced decays



OVERALL PROSPECTS PICTURE

P. Mermod

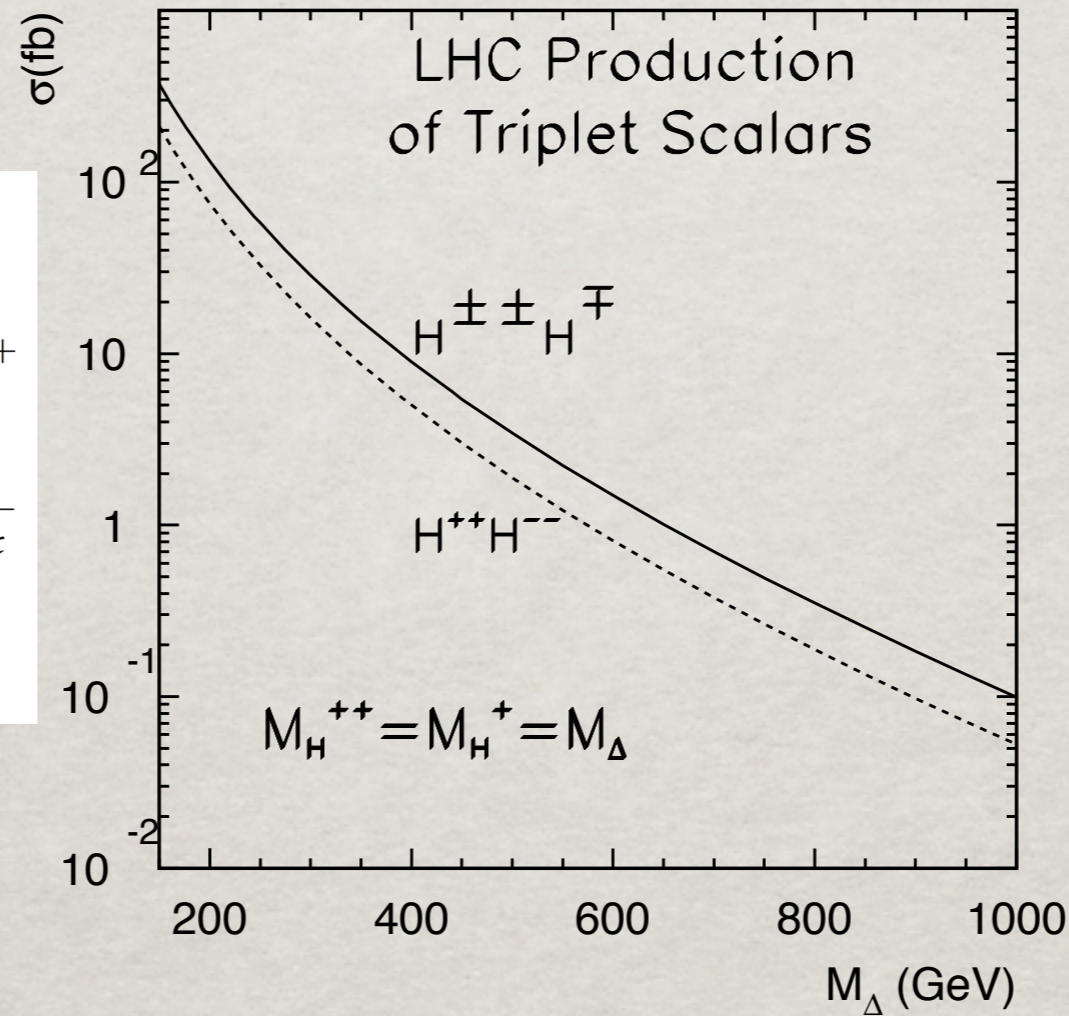
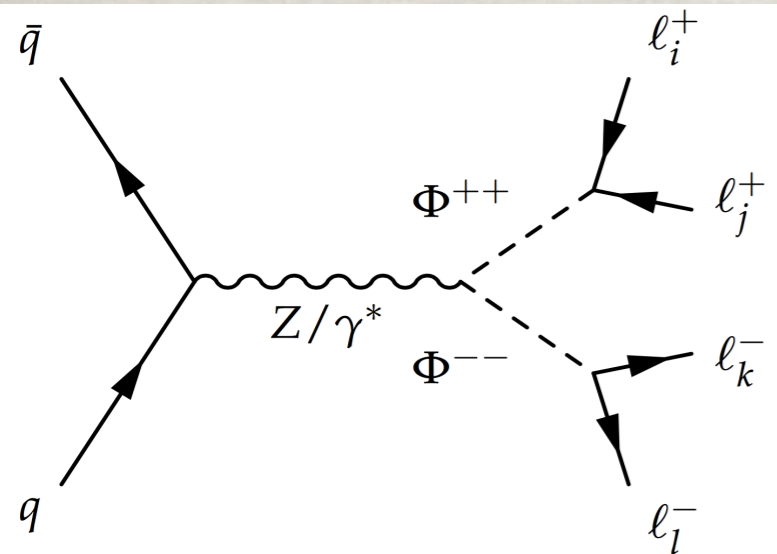


model 1: [PRD 87, 093006 \(2013\)](#) (N_1 does not participate in BAU \rightarrow dark matter)

model 2: [PRD 90, 125005 \(2014\)](#) (allow all three HNLs to participate in BAU)

Type II Seesaw: $H^{\pm\pm}$ & H^\pm

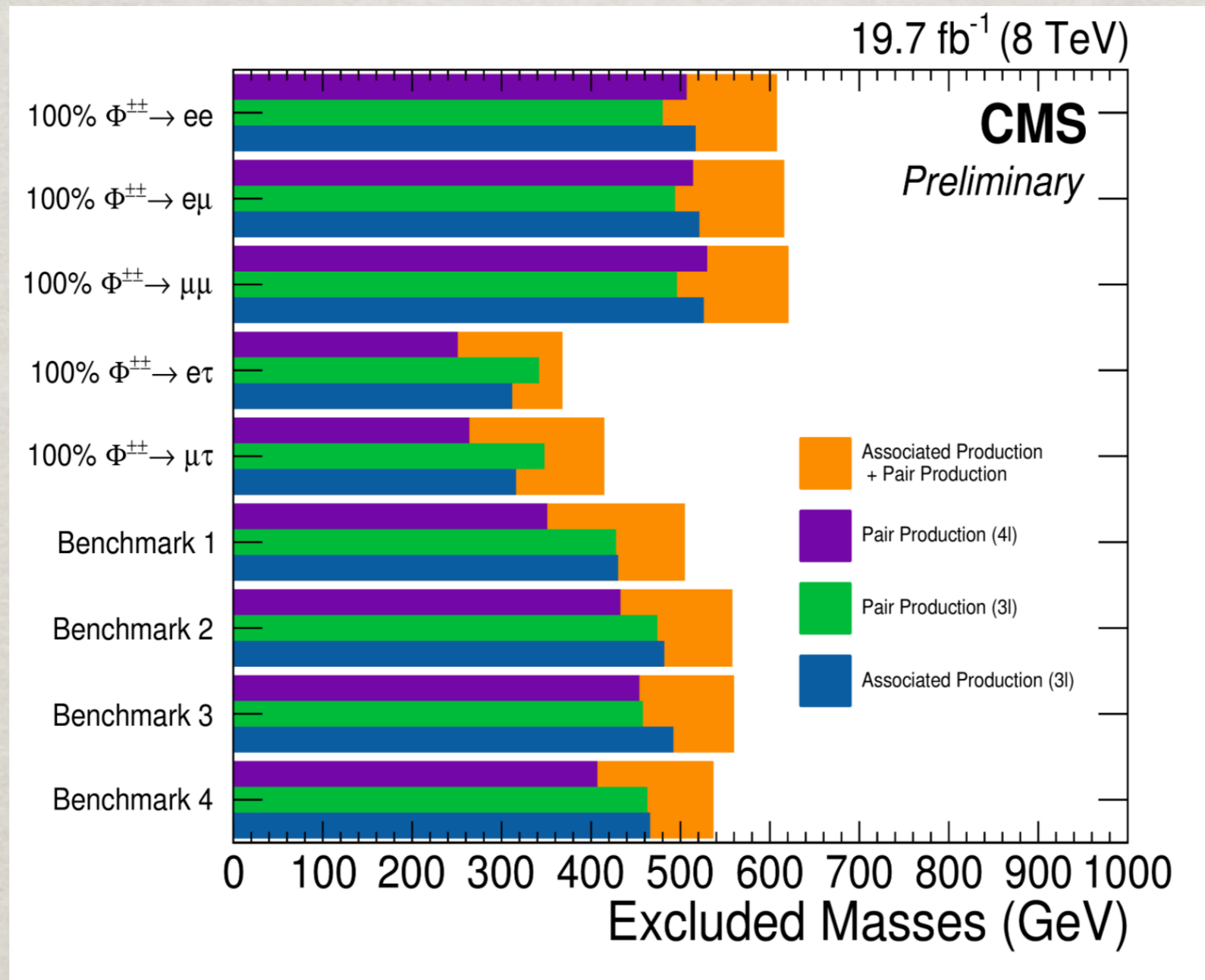
$H^{++}H^{--}$ production at hadron colliders: †
 Pure electroweak gauge interactions



$\gamma\gamma \rightarrow H^{++}H^{--}$ 10% of the DY.

†Revisit, T.Han, B.Mukhopadhyaya, Z.Si, K.Wang, arXiv:0706.0441.

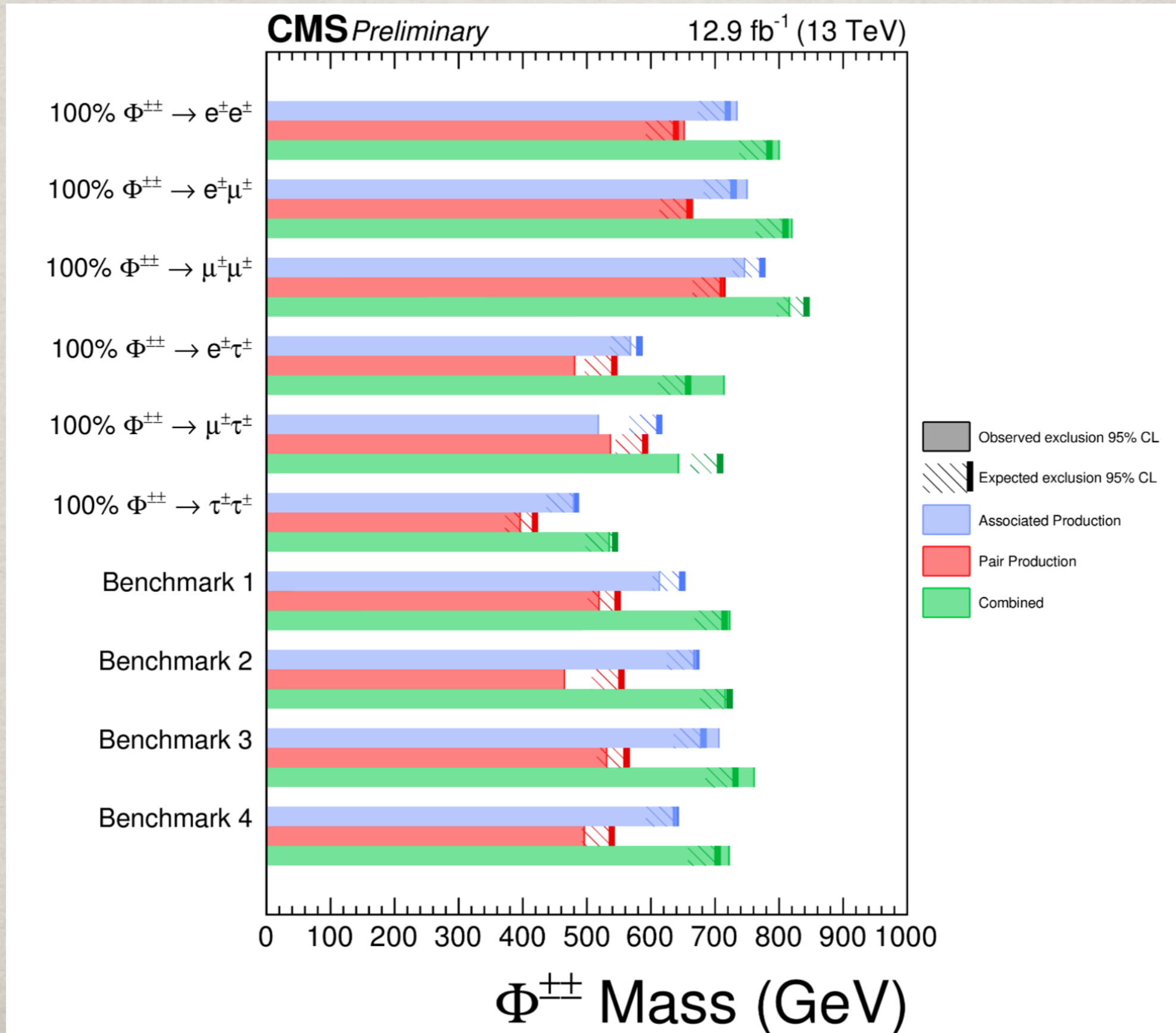
CHARGED AND DOUBLE CHARGED HIGGS



Testing type-II seesaw, with (double)
charged Higgs signatures

See T. Han et al., arXiv:0805.3536

CHARGED AND DOUBLE CHARGED HIGGS



SUMMARY

- Direct searches for new neutrinos at the LHC ongoing
- Searches for heavy neutrinos / charged Higgs bosons by ATLAS and CMS lead to TeV level of mass limits
- Searches for neutrinos at masses of O(10's GeV) starting. Potential to reach an interesting region in parameter space
- No signal for new neutrinos observed yet...
- New ideas for searches/measurements welcome