Heavy Neutrino Search with Left-right symmetric extension of the Standard Model

BRL Workshop 2017
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Left-right Symmetric (LRS)?

- The Standard Model (SM) is left handed
  - W boson interacts only with left-handed fermions
    - no right-handed neutrinos
    - no Higgs interactions for neutrinos
- It’s not natural

Left-right Symmetric?

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- It's

Left-right Symmetric (LRS)?

- The Standard Model (SM) is left handed
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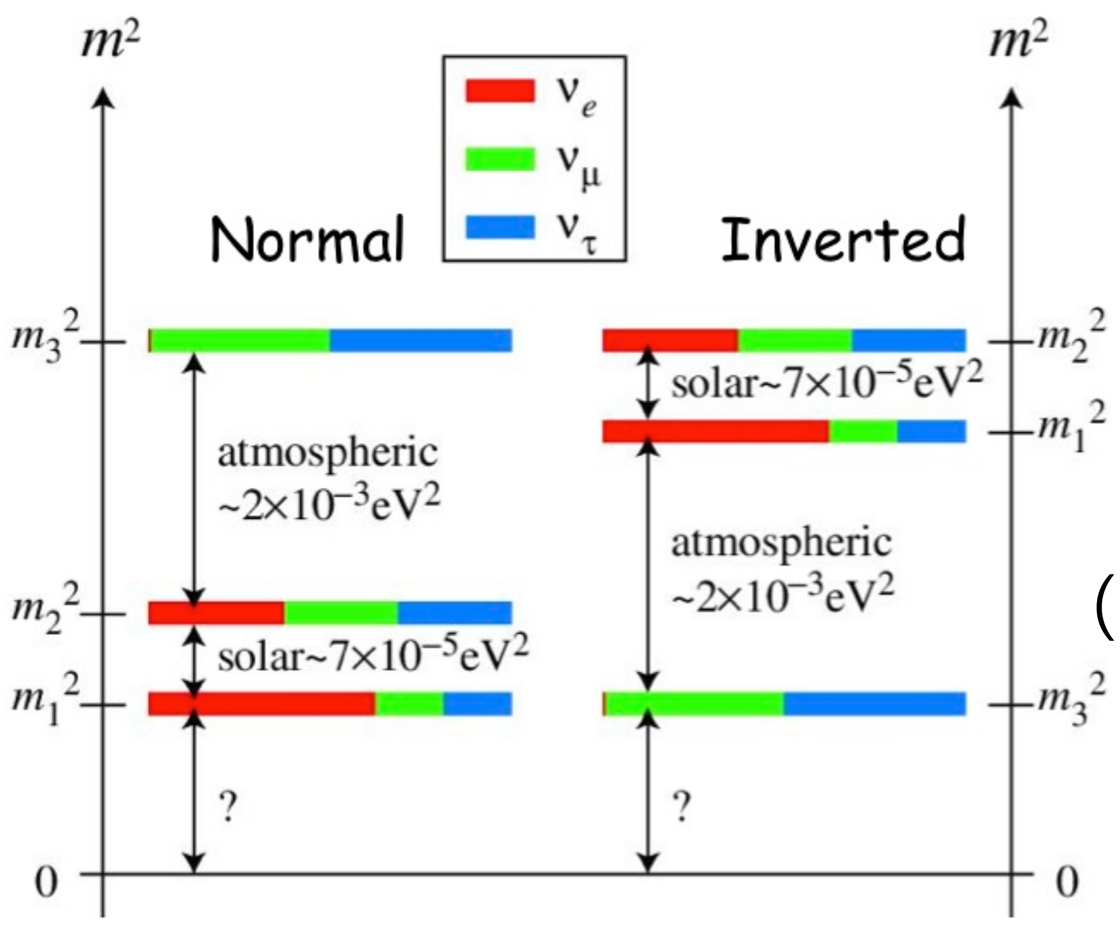
    - no right-handed neutrinos
    - no Higgs interactions for neutrinos
- It's not natural
  - Let's assume that the universe was left-right symmetric at once
  - This is spontaneously broken at certain energy scale
    - Higher than our searching available region until today
- Heavy particles can be detected with extremely energetic interactions, possibly at LHC

Left-right Symmetric (LRS)?

- SM neutrino is massless
  - The discovery of neutrino oscillations represents the existence of neutrino masses
  - and it's mass is really smaller than other fermions



$\Sigma m < 0.0926$ eV
from Cosmology
(Phys.Rev. D93 (2016) no.8, 083527)

Left-right Symmetric (LRS)?

- SM neutrino is massless
  - Applying the see-saw mechanism to LRS between v_L and v_R

$$\lambda = \frac{1}{2}(m_{\upsilon L}+m_{\upsilon R}) \pm \frac{1}{2}\sqrt{(m_{\upsilon L}+m_{\upsilon R})^2 - 4(m_{\upsilon L}m_{\upsilon R} - m_D^2)}$$

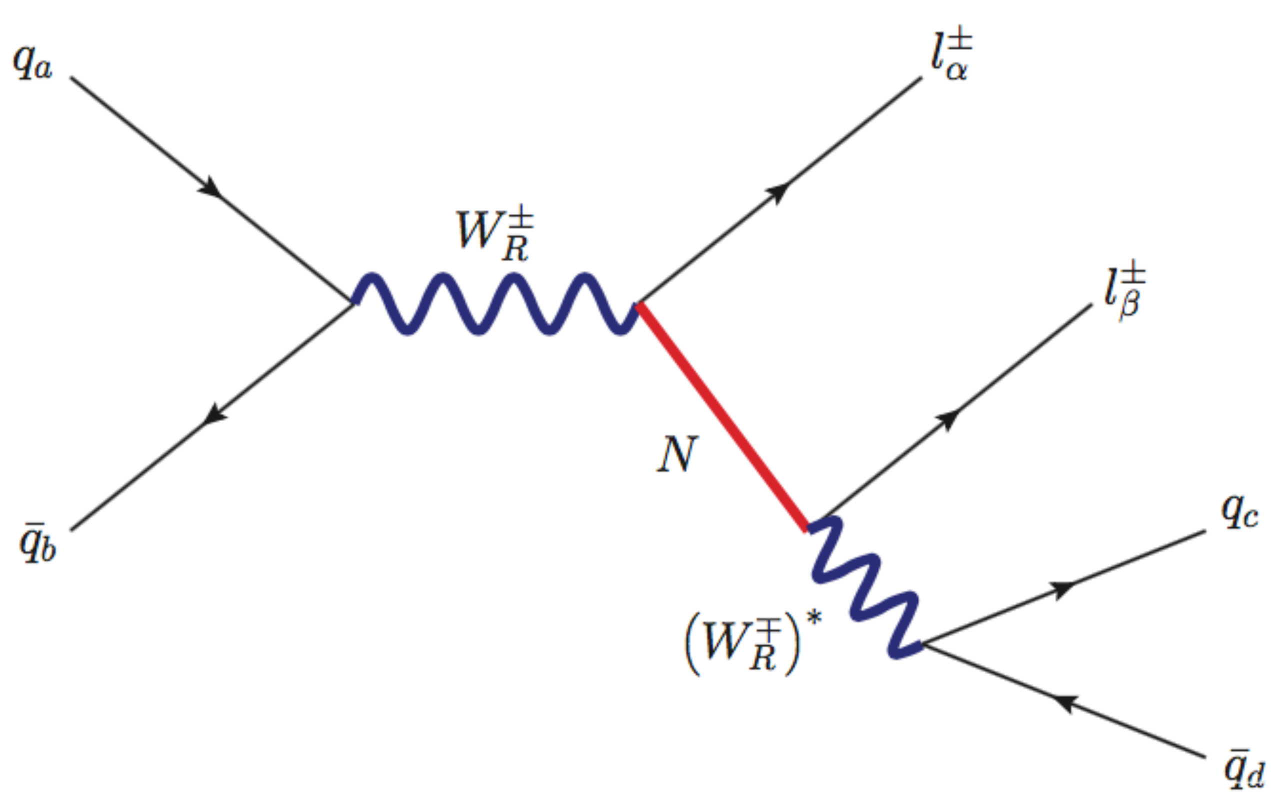
$$\begin{pmatrix} m_{\nu L} & m_D \\ m_D & m_{\nu R} \end{pmatrix}$$

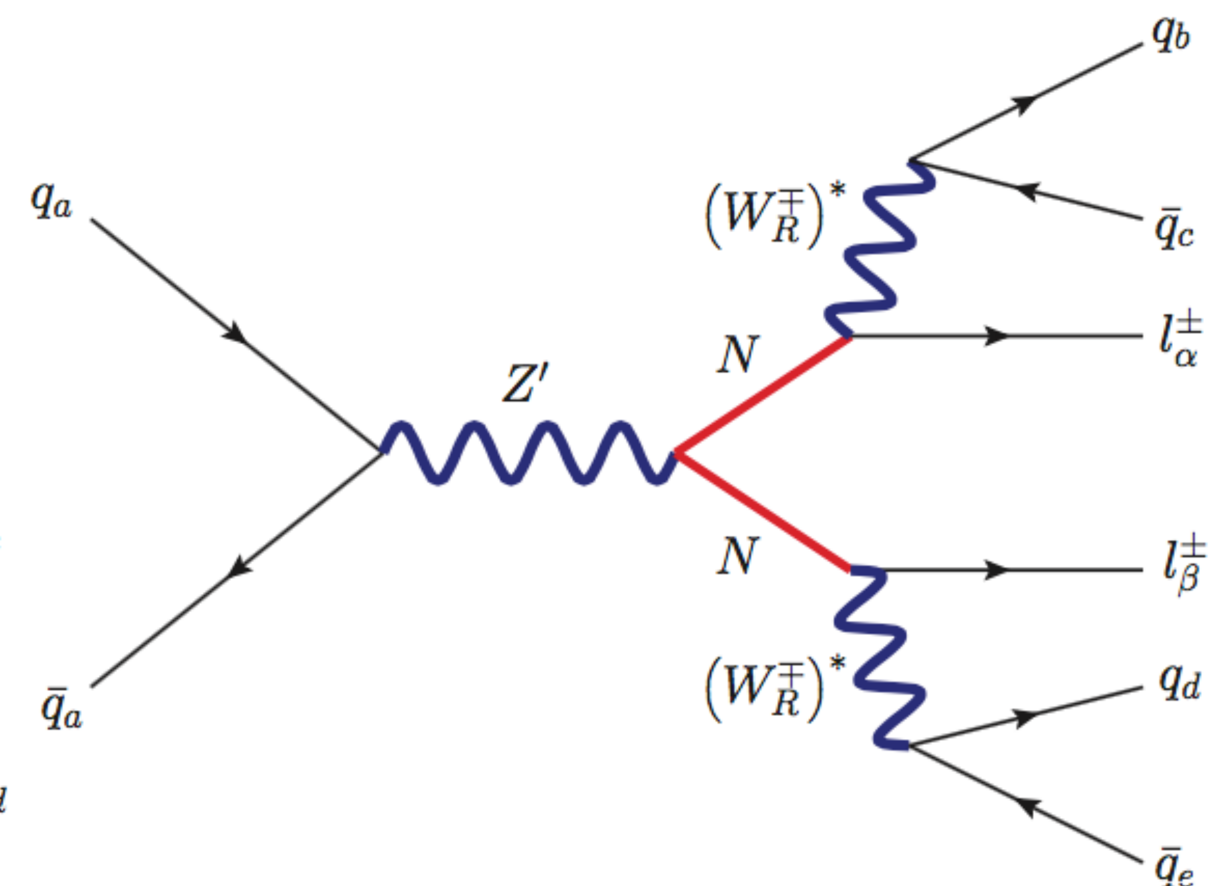
$$m_{\upsilon L} << m_D << m_{\upsilon R}$$

$$\lambda^+ \sim m_{\upsilon R}$$

$$\lambda^- \sim m_{\upsilon L} - \frac{m_{\upsilon L}^2+4m_D^2}{4m_{\upsilon R}}$$

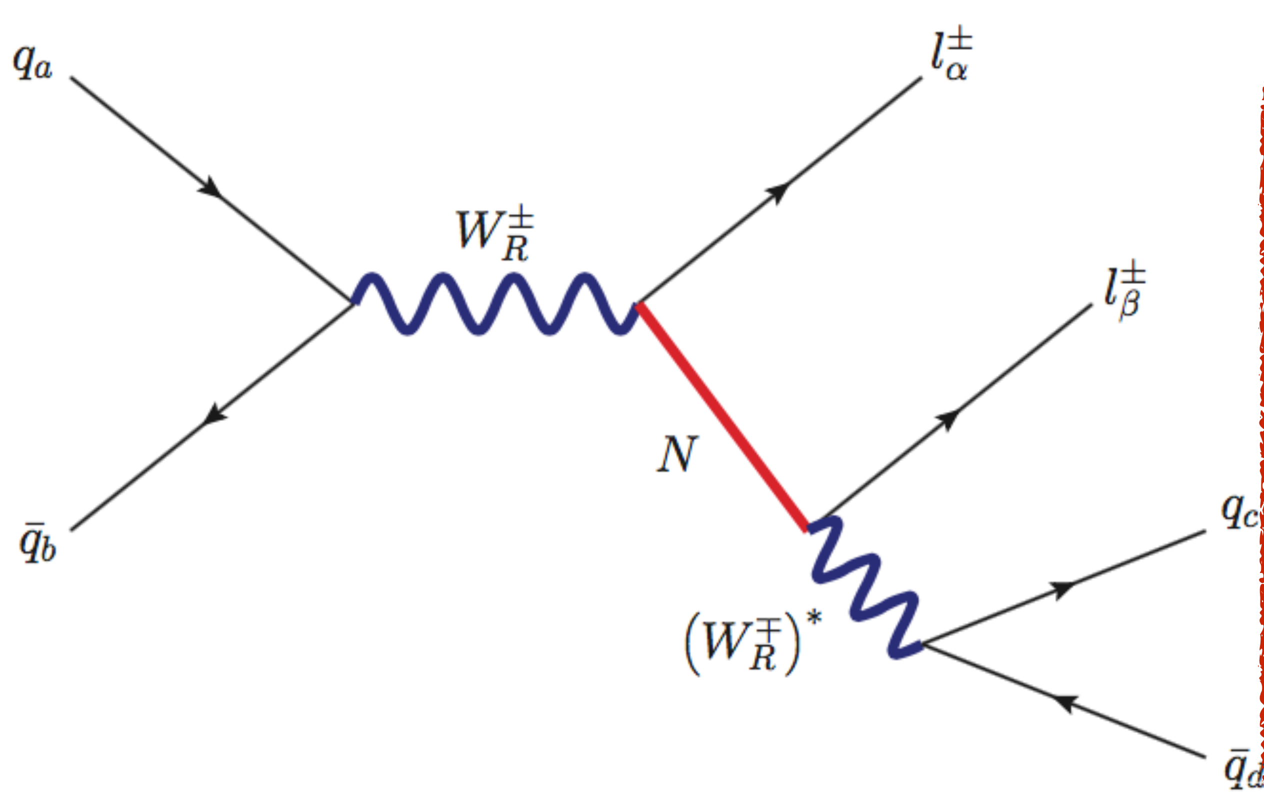
Processes we can challenge in Heavy Neutrino Sector

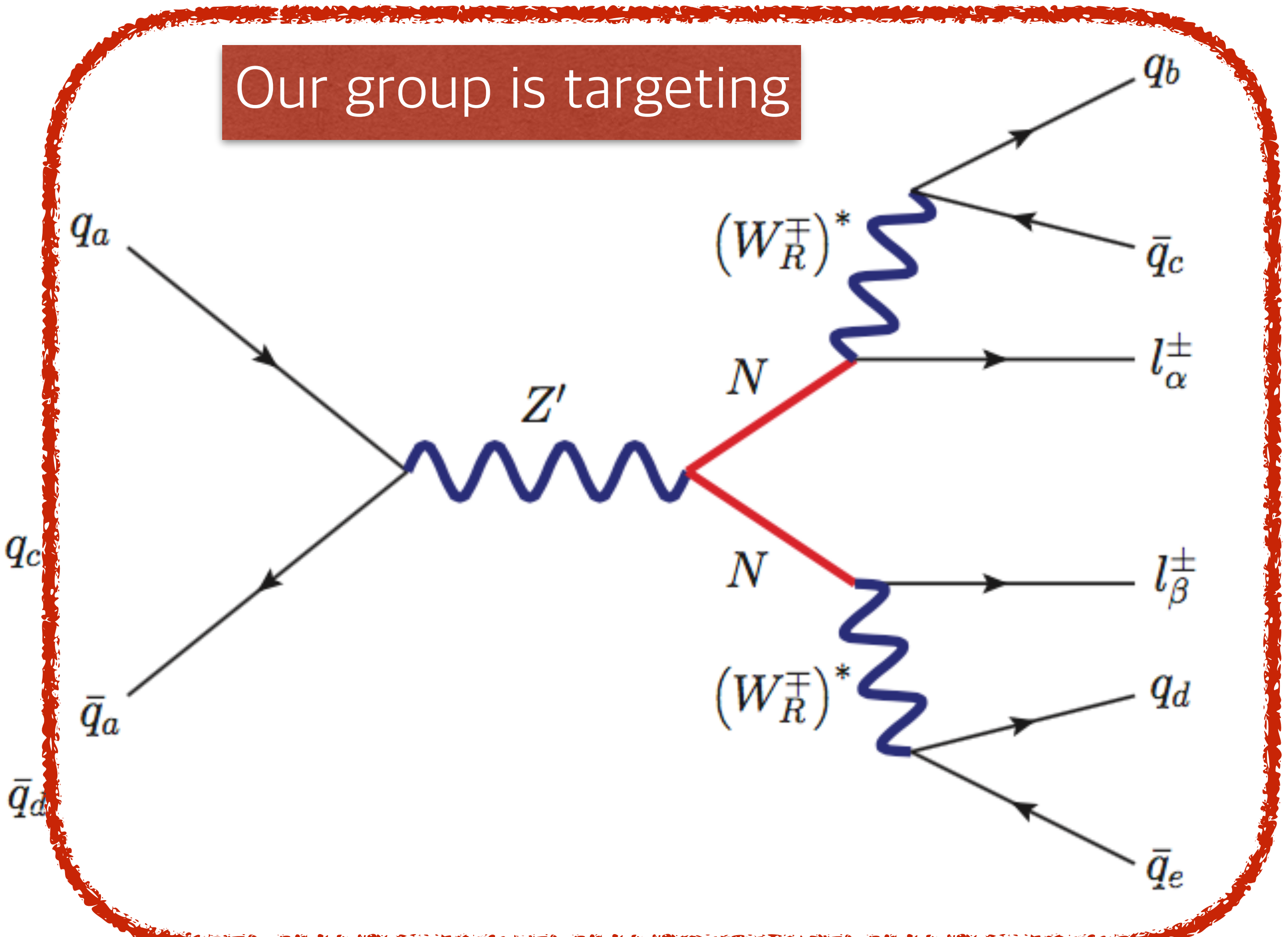




$\sigma(qq > W_R > llqq) > \sigma(qq > Z' > NN > llqqq)$

Processes we can challenge in Heavy Neutrino Sector

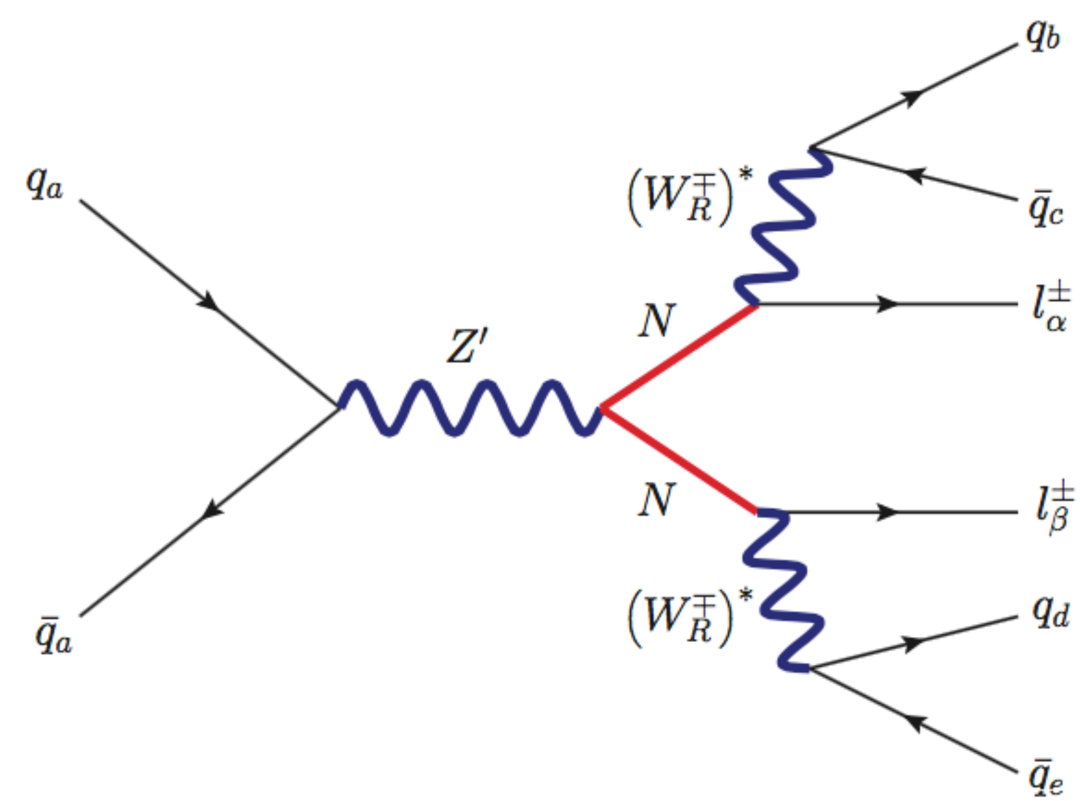




$\sigma(qq > W_R > llqq) > \sigma(\ qq > Z' > NN > llqqqq)$

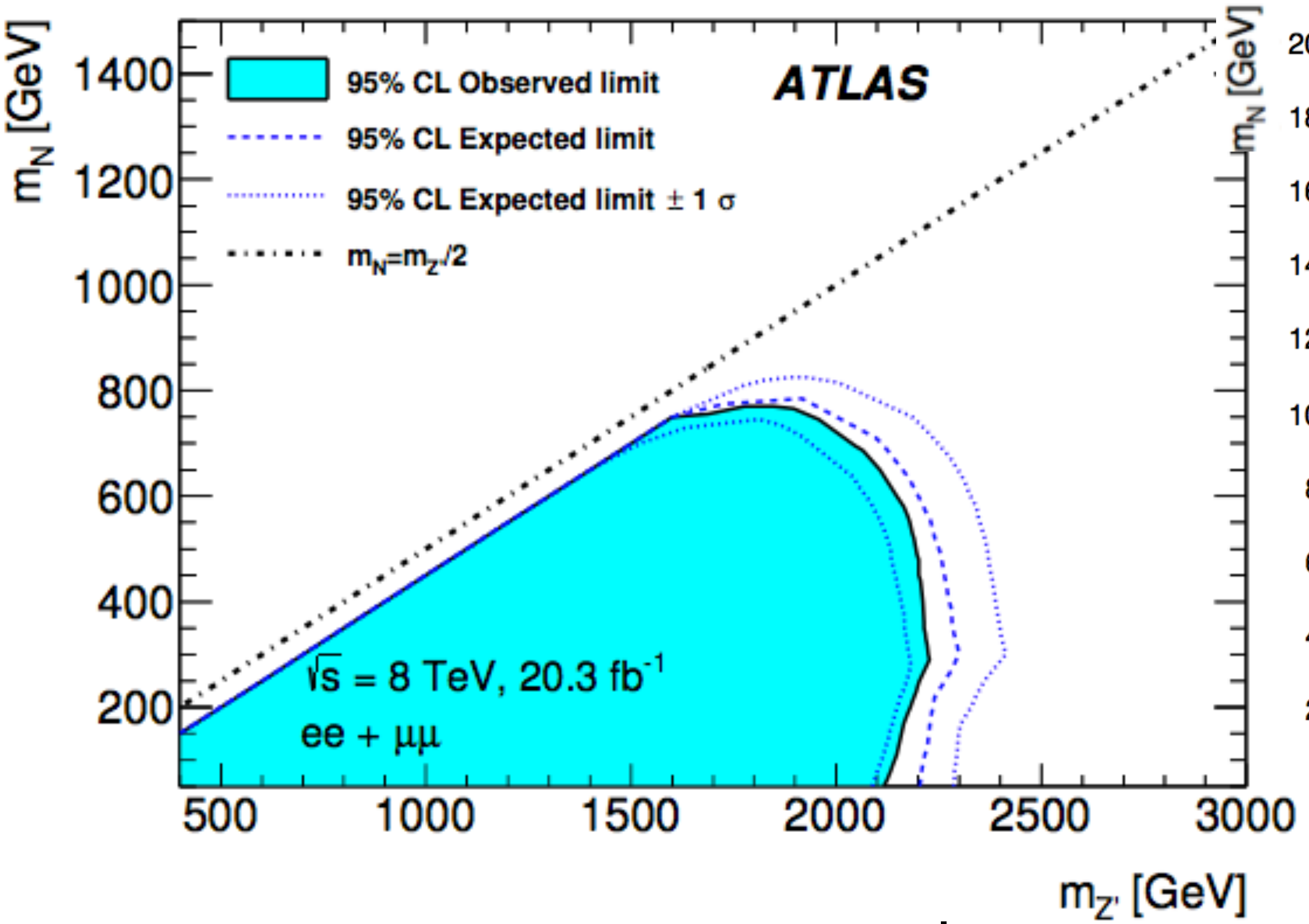
Heavy Neutrino Pair Production

- Event Selection
  - Two leptons
    - ee
    - μμ
  - Njets ≧ 4
  - No b-jet
  - No MET (small missing transverse energy)

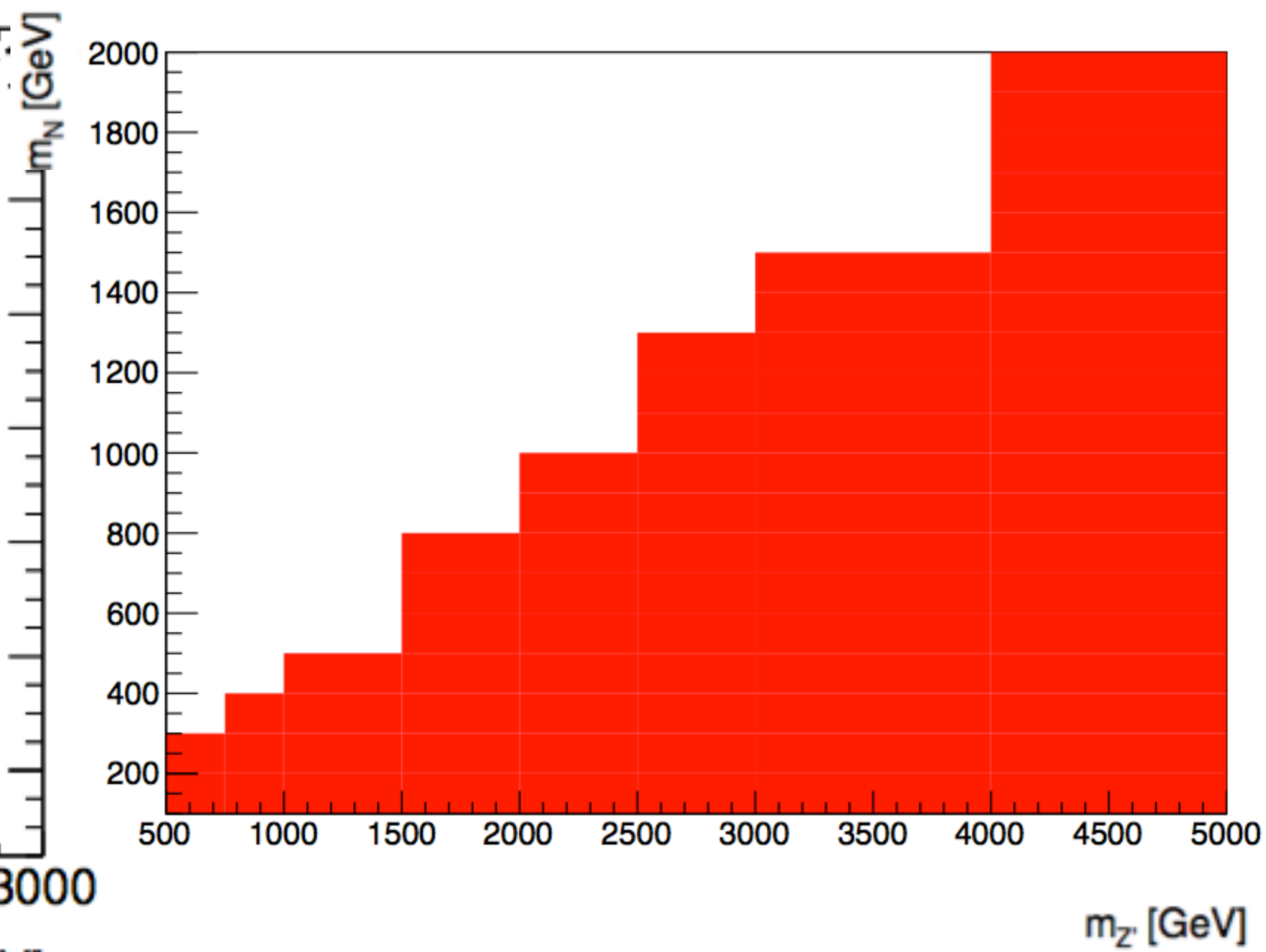


Heavy Neutrino Pair Production

- Search mass region



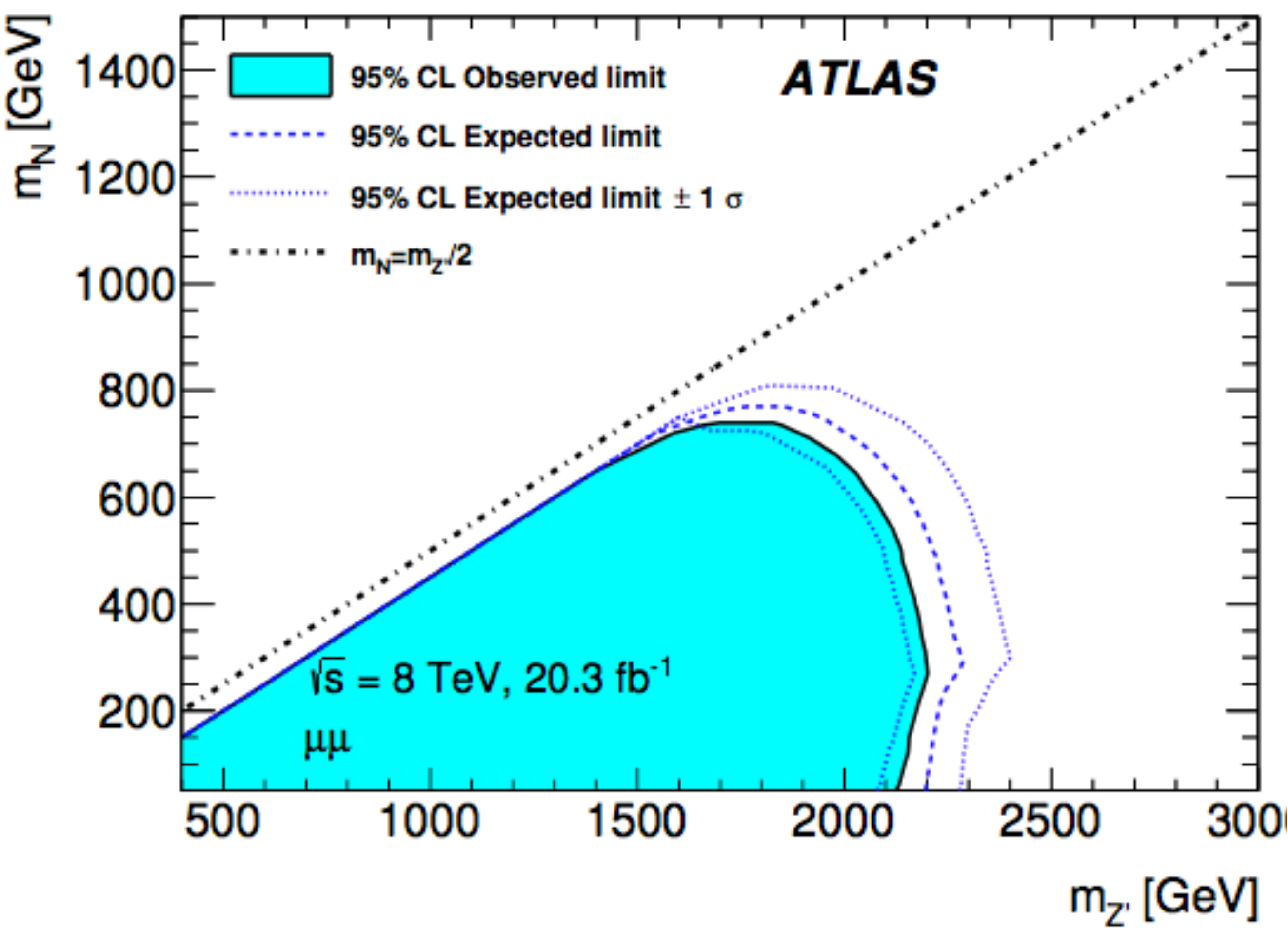
Previous result

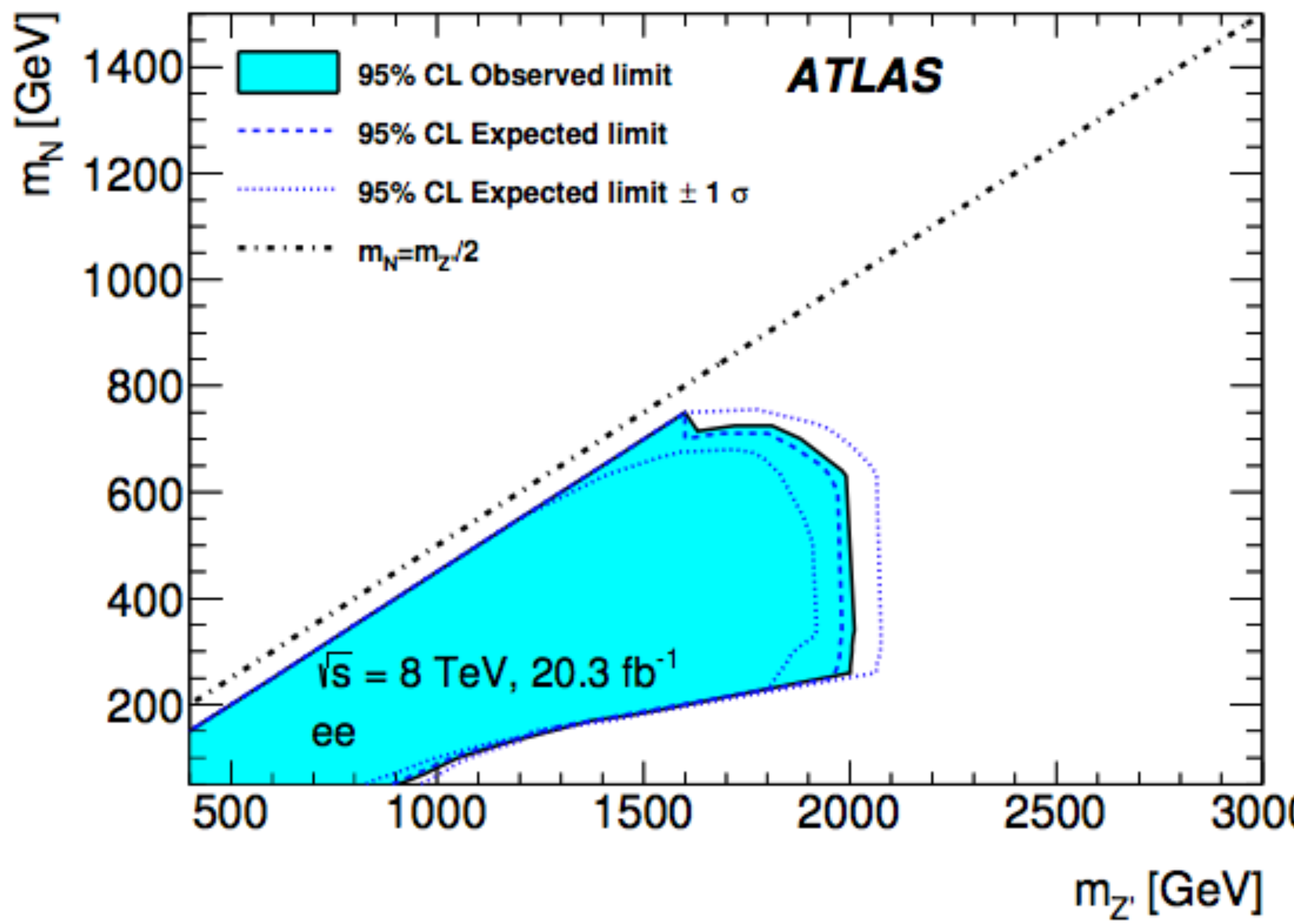


Our Searching region

Today's Issue

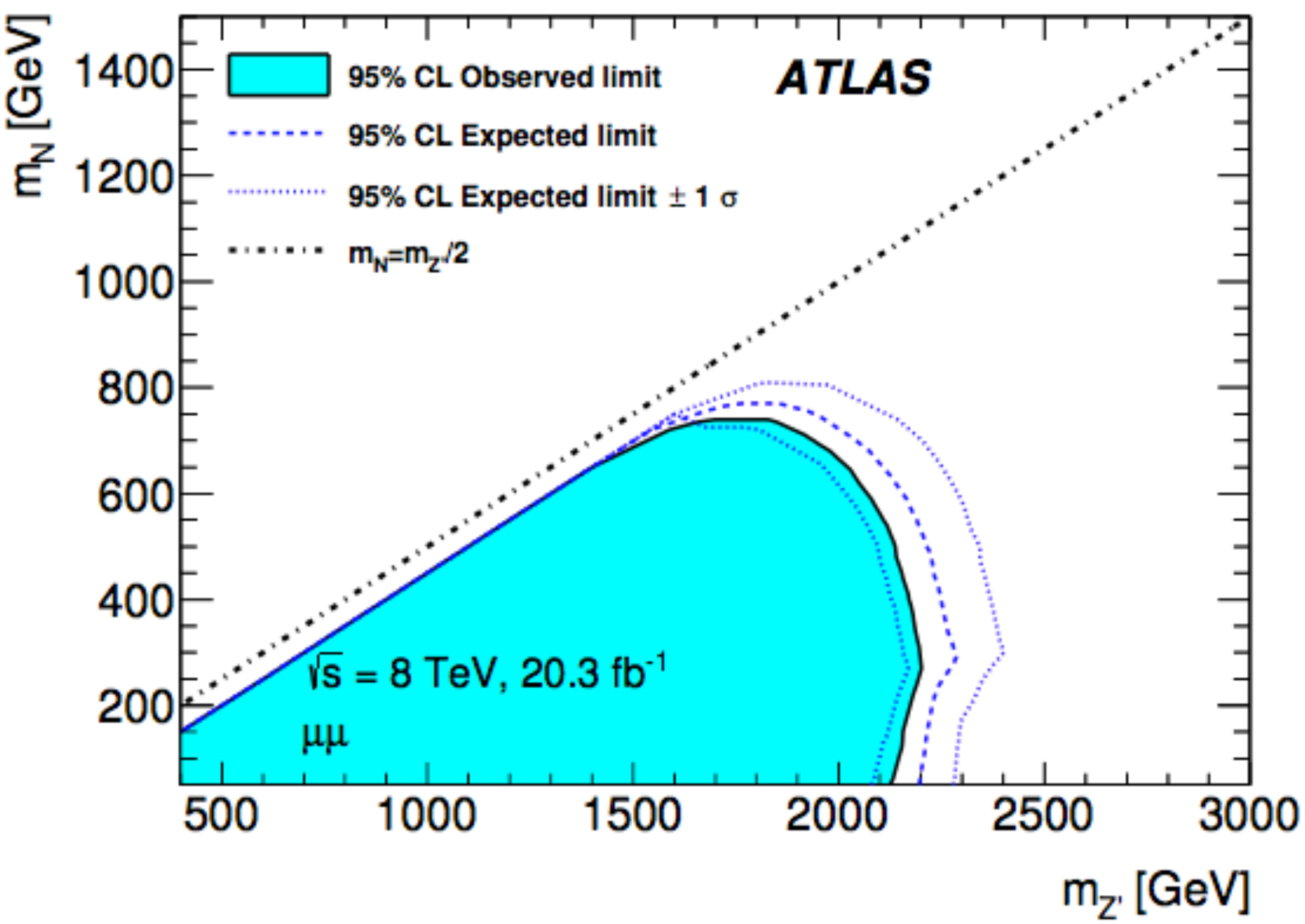
- Low signal efficiency for boosted cases

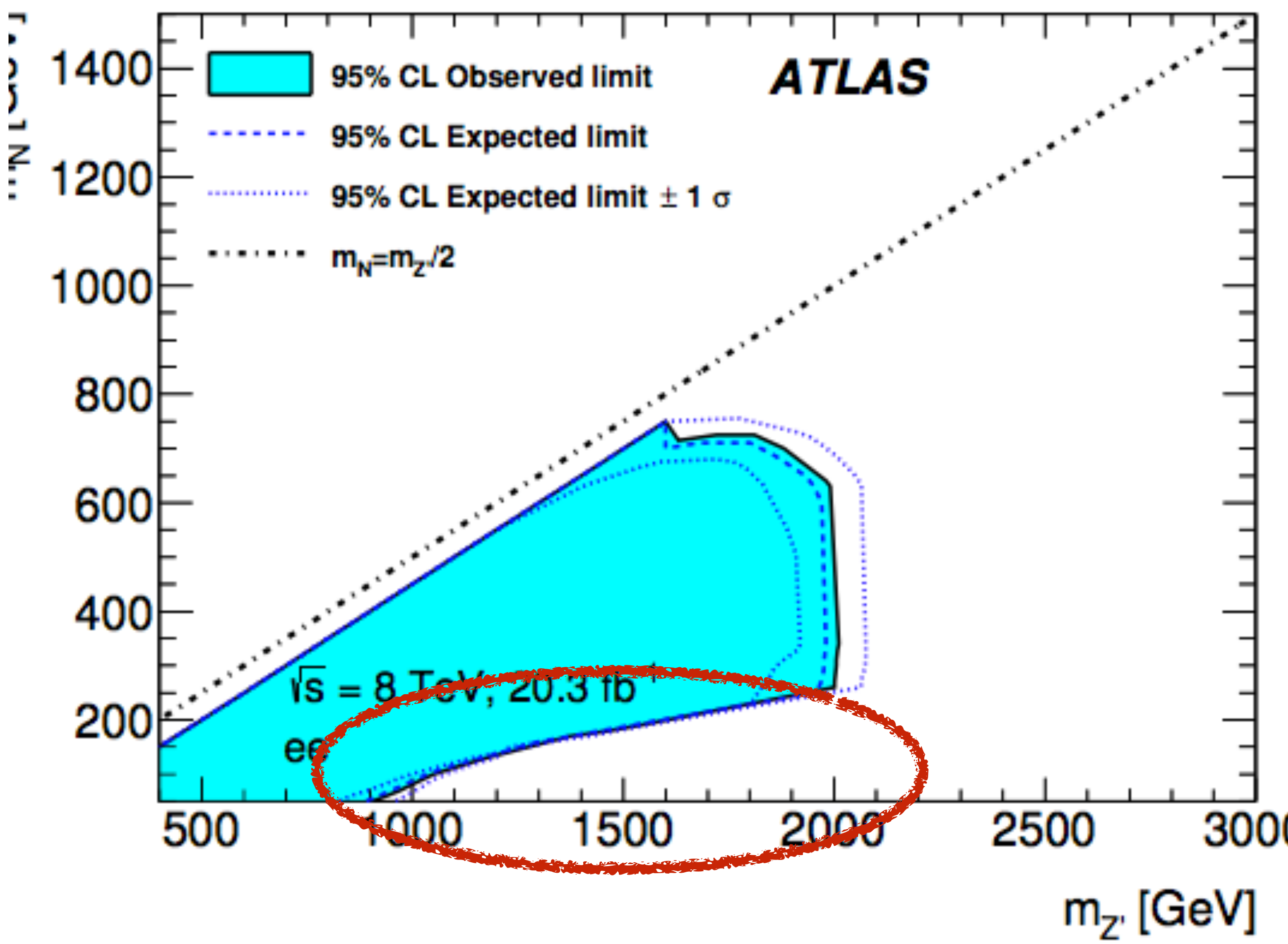




Today's Issue

- Low signal efficiency for boosted cases
  - Probability of signal events passing the event selection





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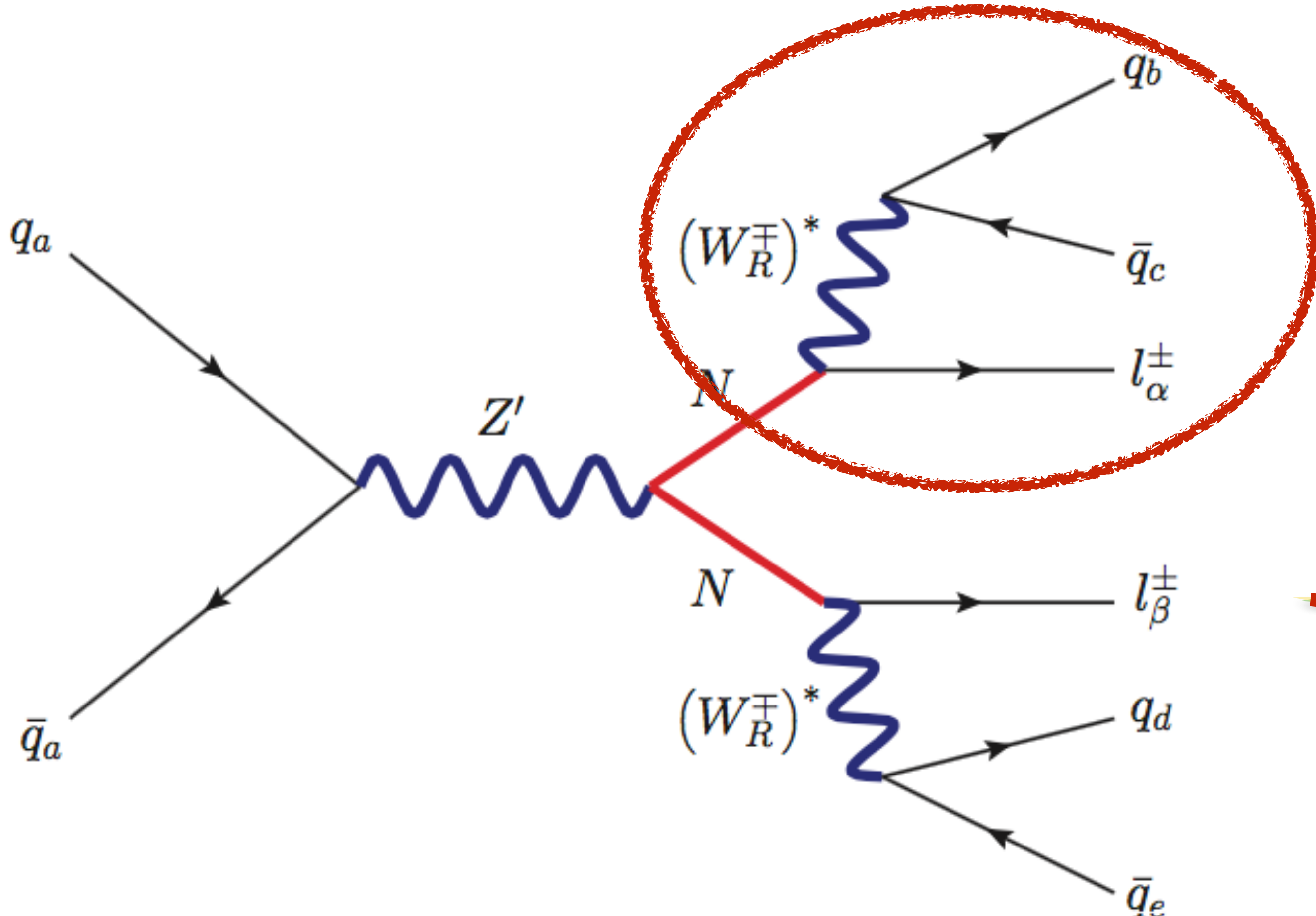
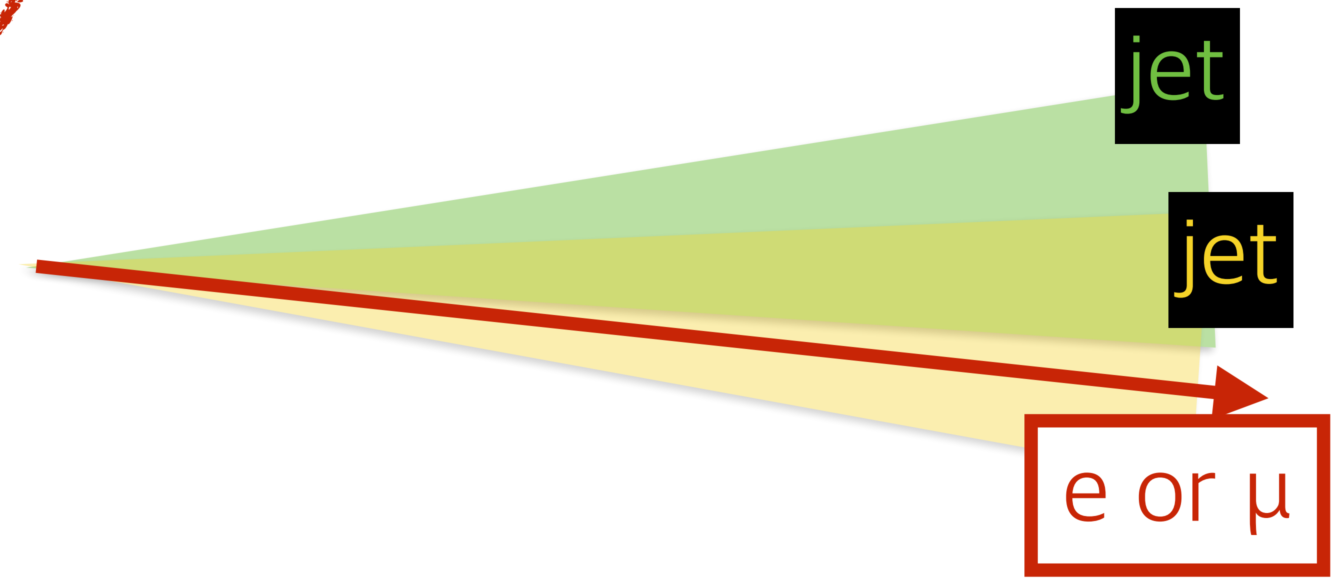


If M(Z') >> M(N)
N is boosted



Decay products are merged

Today's Issue

- Problems
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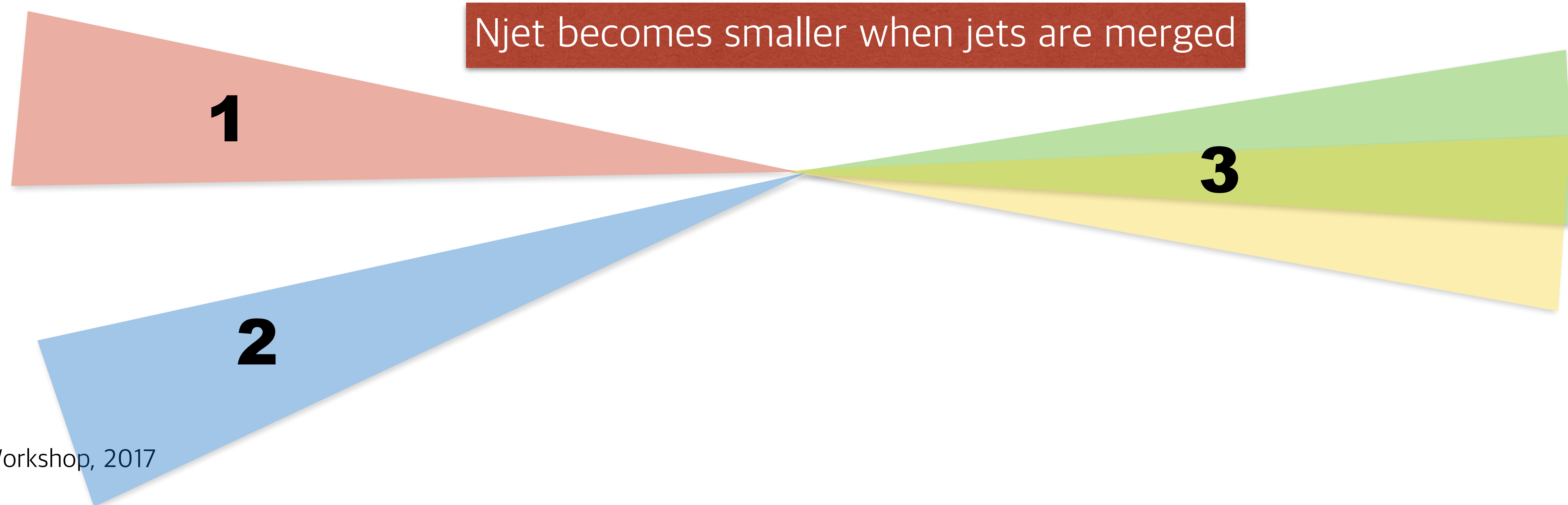
Difficult to pass Relative Isolation ID cut

Main Reason of low signal efficiency

Njet becomes smaller when jets are merged



Relative Isolation

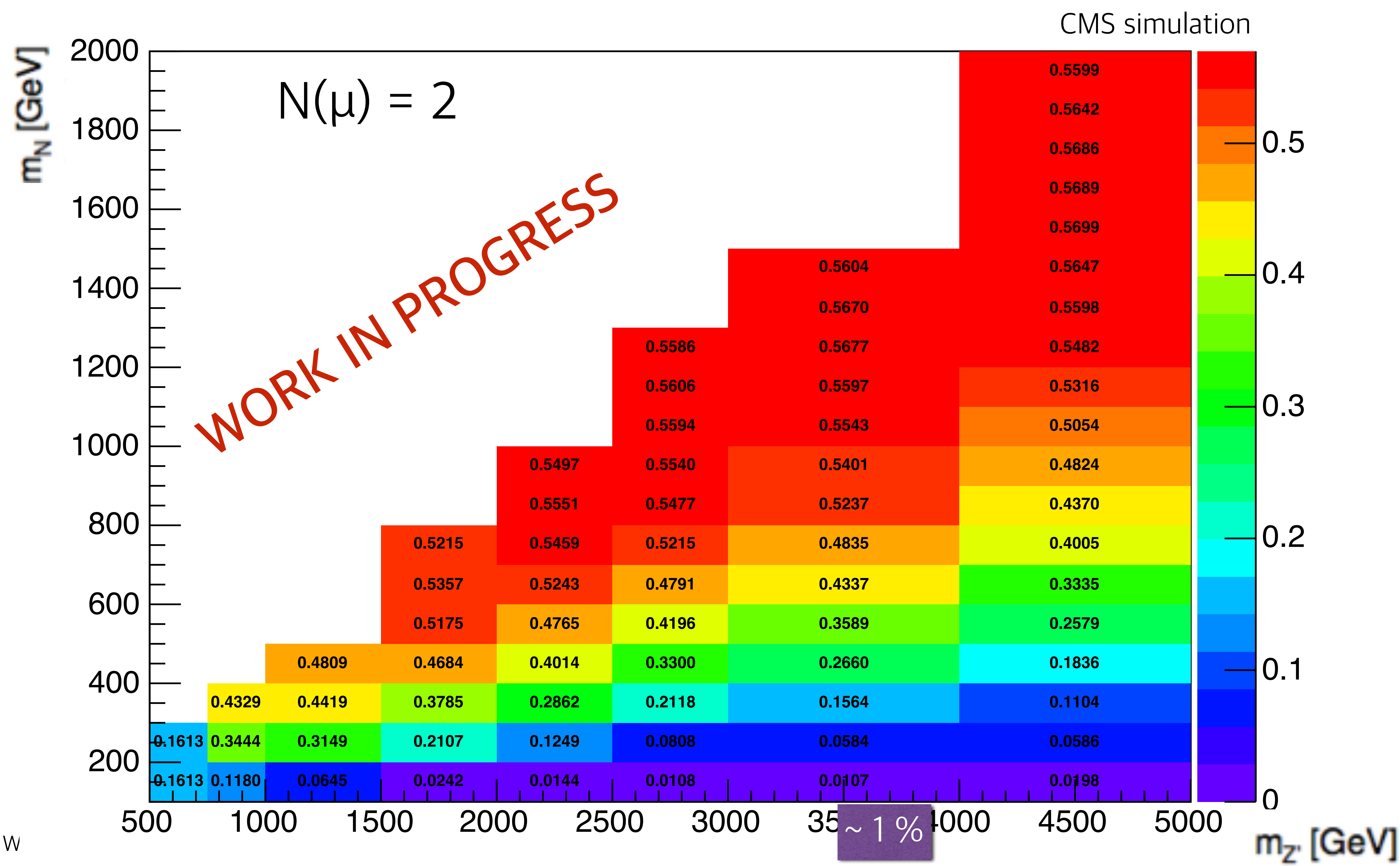
- Main source of electron and muon in LHC
  - Fake lepton from jets – Dominant Bkg in our analysis
    - Electron : $\pi^0 + \pi^{\pm}(\rightarrow \boldsymbol{\gamma\gamma})$ at similar direction
      - Track + ECAL shower
    - Muon : $K^{\pm}$ decay, punch through of hadrons
      - Track + hits at muon chamber
  - We use RelIso cut to reduce fake lepton background
    - RelIso < 0.1 for lepton ID with 0.4 cone $\boxed{\Delta R = \sqrt{\Delta\varphi^2 + \Delta\eta^2}}$

$$RelIso = \frac{\sum_{\Delta R < 0.4}^{all} Pt(particles)}{Pt(lepton)}$$

Should be high for fake leptons
& small for prompt leptons

very high for boosted cases

Sad Signal Efficiency



Alternatives

- Mini-Isolation
  - RelIso cone size as function of lepton Pt

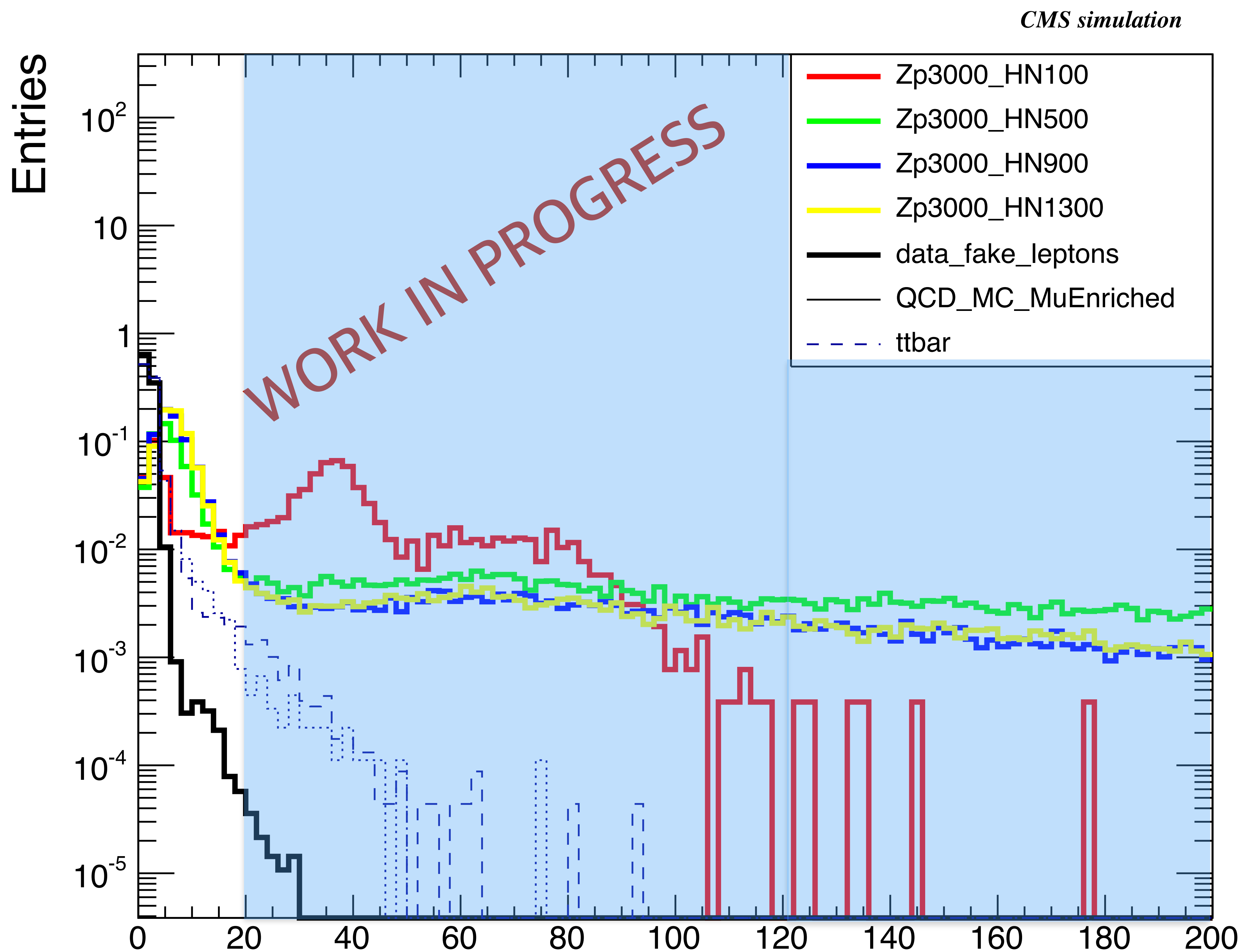
$$(Cone\ \ size) = \begin{cases} 0.2, & if\ \ Pt(l) < 50\ \ GeV \\ -0.15\dfrac{Pt(l)}{50} + 0.35, & if\ \ 50\ \ GeV < Pt(l) < 100\ \ GeV \\ 0.05, & if\ \ Pt(l) > 100\ \ GeV \end{cases}$$

  - Smaller cone size = looser cut
- Leptons from jets usually have small Pt
  - We can expect higher signal efficiency with relatively small increase in fake lepton background

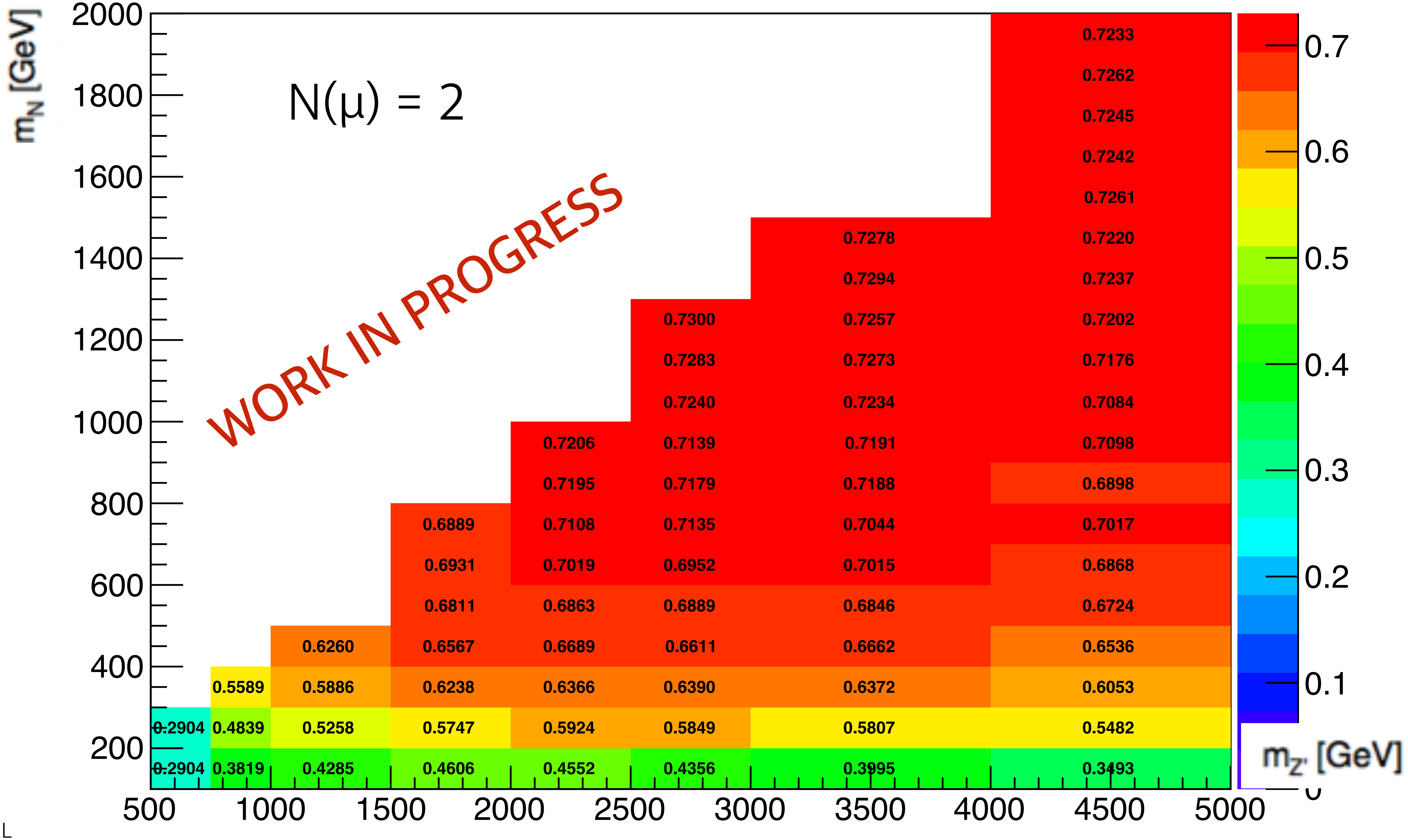
Alternatives

- M(closest jet + lepton) – M(closest jet)
  - Among jets with ΔR(lepton, jet) < 0.7
- For boosted leptons
  - M(jet + lepton) ~ order of HN mass : high
  - M(jet) ~ M(truth level quark)
  - M(jet + lepton) – M(jet) ~ order of HN mass
- Should have very small value for fake leptons
  - M(jet + lepton) ~ truth level quark of the jet ~ M(jet)
- We apply
  - RelIso < 0.4 OR Mass_Drop > 20 GeV for now

Alternatives



Improvements – MiniIso



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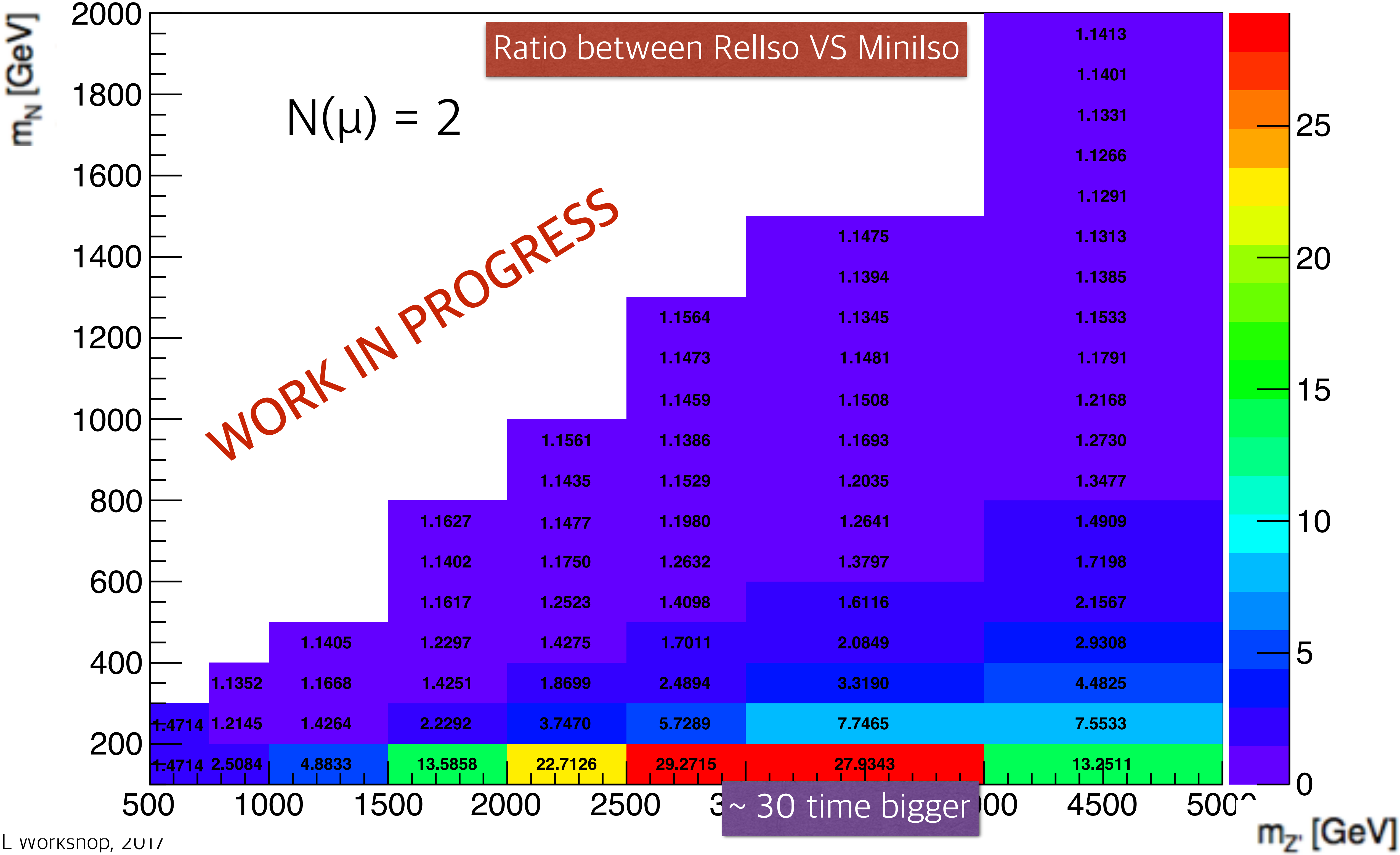

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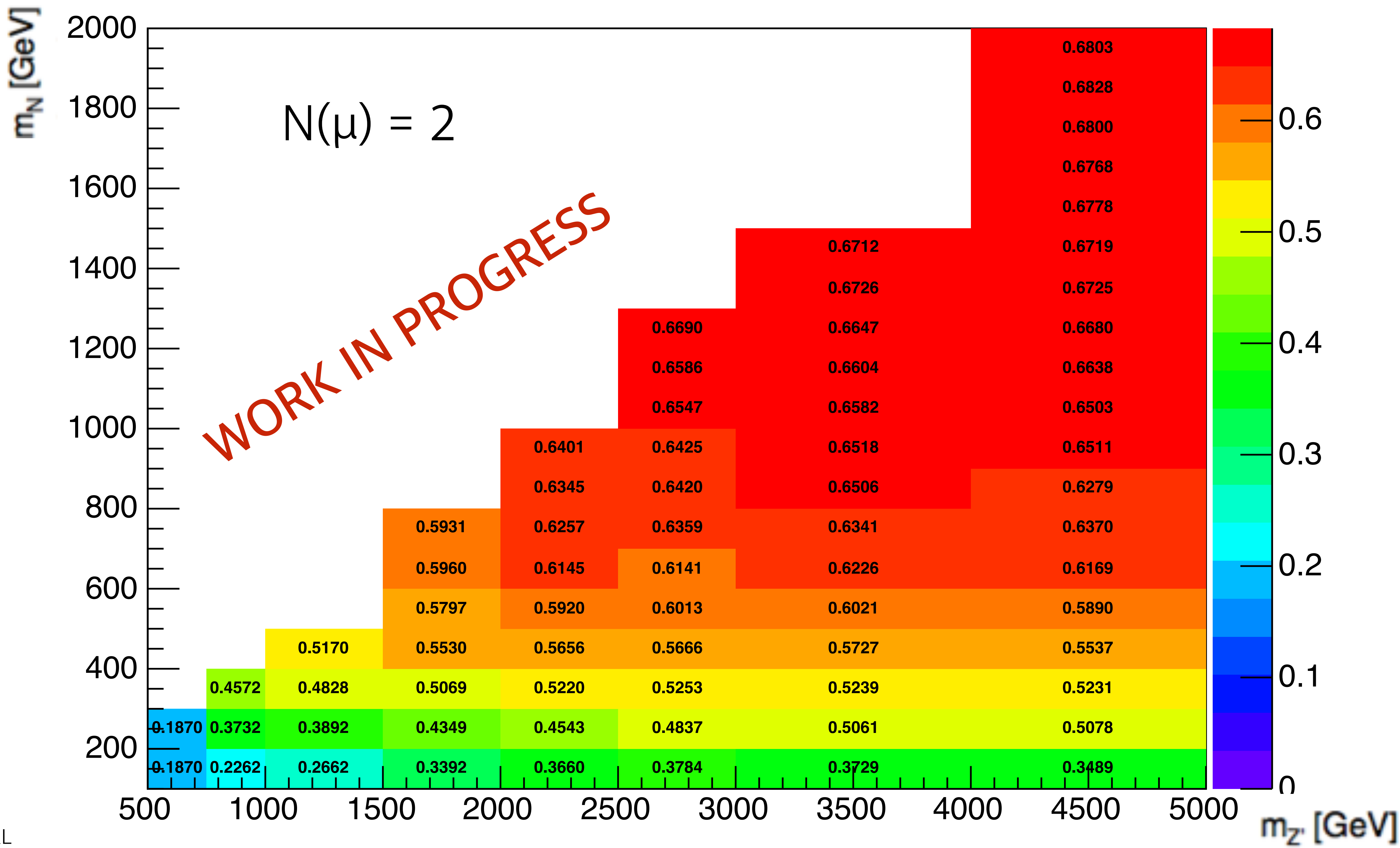

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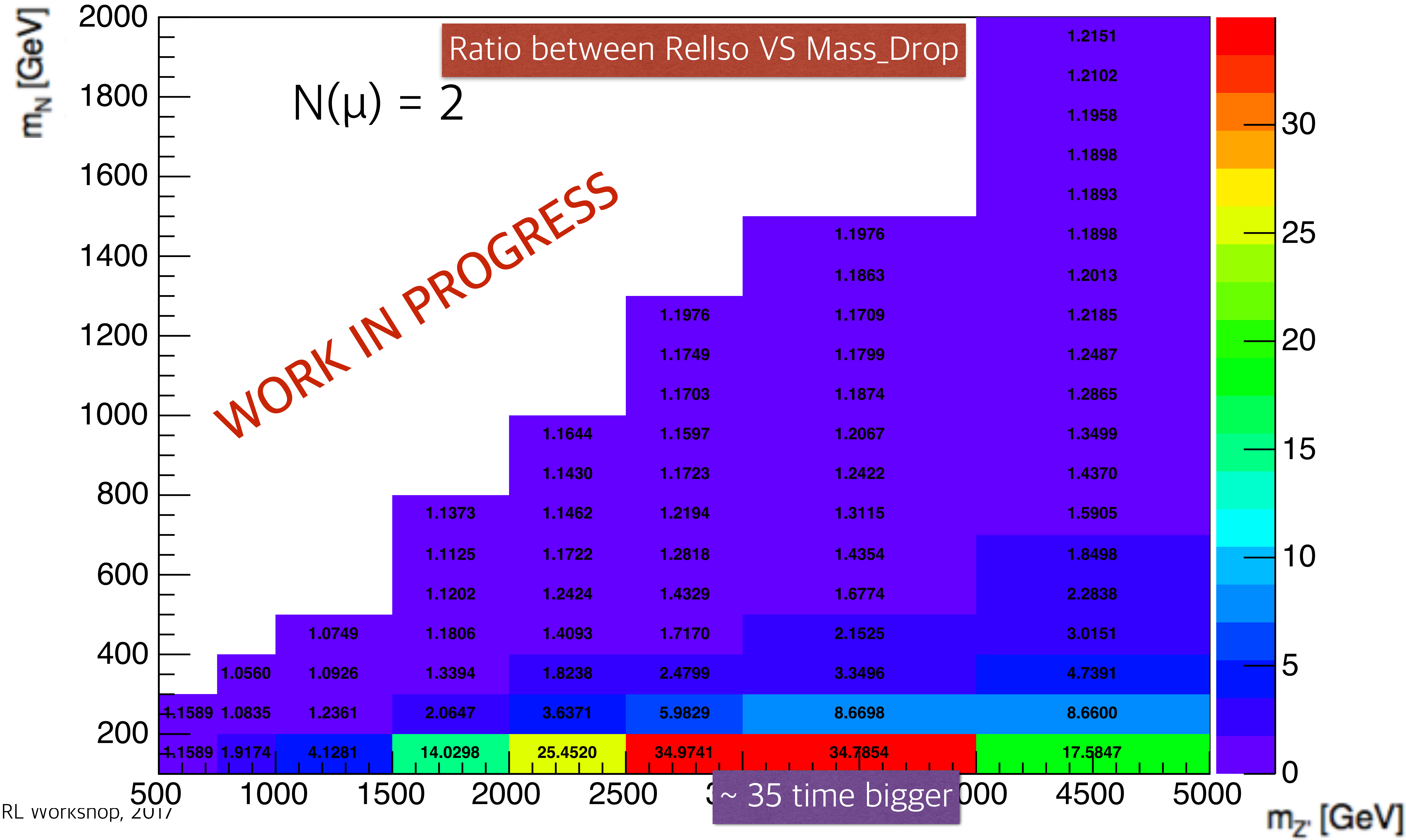

Conclusion

- We wants to do search for Z' to heavy neutrino pair production at di-lepton + 4 jets channel

- Small signal efficiency with boosted signature is serious problem to do search
  - Relative isolation cut for lepton ID is main reason of it

- MiniIso and Mass_Drop was tested as alternative way for lepton ID
  - We got about 30~ 40 time bigger signal efficiency maximum at boosted cases

- Remaining
  - Background level's behavior with alternative isolation cuts should be investigated