Current Status of Search for Majorana Neutrino from Like Sign Muon Final State

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More Signal Generation

- We produced more datasets extending the range up to 210 GeV
  - This is beyond where we are sensitive.
- Also more intermediate masses around the Z peak at 90 GeV
- Cross section below assumes a $|V_{\mu N}|^2$ value of one. We will set a limit on the coupling value (1).

Mass	50	70	75	80	85	90	95	100
$\sigma_0(N_4)$ (pb)	136	70.2	44.2	19.9	2.98	0.488	0.352	0.613

Mass	105	110	130	150	170	190	210
$\sigma_0(N_4)$ (pb)	1.64	1.28	0.574	0.308	0.181	0.115	0.0776

1) arXiv:0901.3589v2

Muon Selection Criteria Efficiencies

DataSet (N_4 Mass)	# Events	Quality	Eta & P_T	Isolation	All Muon
50	10000	71.96%	46.71%	35.40%	24.67%
70	10000	72.57%	32.29%	32.31%	17.15%
75	10000	72.85%	28.95%	29.32%	14.20%
80	9499	72.02%	19.35%	23.18%	8.55%
85	9497	67.99%	17.64%	21.29%	9.29%
90	10000	72.05%	38.23%	32.25%	21.69%
95	9499	72.65%	36.32%	29.09%	19.42%
100	10000	72.60%	30.69%	24.18%	13.28%
105	10000	74.94%	61.86%	45.03%	36.78%
110	10000	76.81%	68.87%	51.04%	44.42%
130	10000	76.84%	76.66%	60.87%	55.11%
150	10000	77.77%	79.47%	63.97%	58.56%
170	10000	78.46%	80.77%	66.56%	60.79%
190	8092	78.81%	82.08%	67.02%	61.49%
210	6361	80.07%	83.19%	68.65%	63.20%
WZ	4265243	7.47×10^{-3}	8.11×10^{-3}	4.31×10^{-3}	2.06×10^{-3}
ZZ	4187885	9.01×10^{-3}	9.12×10^{-3}	5.20×10^{-3}	1.26×10^{-3}

Cut Flow Summary

- Pre-selection
  - 2 “loose” muons $p_T > 10$, eta < 2.4, relIso < 0.4, normalized chi^2 < 50, $D_0 < 0.2$, and passing standard track quality cuts
  - 1 jet $p_T > 20$ (2^{nd} jet $p_T > 10$ for mass plots)
- Tight Muons
  - 2 muons passing full “tight” cuts
- Full Cuts
  - 2^{nd} jet $p_T > 20$
  - Muons must have the same charge

Selection Criteria Efficiencies

DataSet (N_4 Mass)	# Events	Pre Selection	Tight Muons	All Cuts
50	10000	30.89%	17.29%	7.01%
70	10000	36.93%	19.01%	8.66%
75	10000	34.23%	16.98%	8.05%
80	9499	21.43%	10.18%	5.67%
85	9497	16.57%	9.29%	5.48%
90	10000	35.43%	21.61%	13.73%
95	9499	31.96%	19.23%	13.14%
100	10000	25.68%	13.52%	10.37%
105	10000	55.98%	37.24%	28.82%
110	10000	60.06%	42.94%	33.21%
130	10000	66.14%	53.01%	42.67%
150	10000	69.27%	56.61%	46.50%
170	10000	71.08%	59.12%	49.03%
190	8092	72.08%	59.81%	50.90%
210	6361	73.56%	61.85%	53.78%
WZ	4265243	1.59%	1.31%	1.32×10^{-4}
ZZ	4187885	3.43%	2.77%	5.23×10^{-5}

Trigger and MC reweighing

- Follow the same procedure outlined in HIG-11-003 and used in SUS-11-010.
- Data driven method using T&P to determine offline muon reconstruction efficiency of muons passing our quality and isolation cuts.
- Likewise this can be used to determine our trigger efficiencies.
- We don't apply trigger to MC but rather reweight the MC events by these efficiencies.

$$\varepsilon_{\text{total}} = \varepsilon_{\text{offline}} \times \varepsilon_{\text{trigger}}$$

Exclusion

- Use official CMS cls95 roostats package
- Currently including some systematics
  - Fake Rate prediction: 50%
  - Signal “Bare” Cross Section: 20%
  - Luminosity: 10%

Current Status & Going Forward

To Do Last Update

- Extend the mass range of the MC ✔
- Produce and exclusion plot ✔
  - Currently includes fake rate, cross section and luminosity systematics as well as statistical errors.
- Make a decision regarding fake rate variables. ✔?
- ?Remove the fake muon events from the MC prediction. ✔

To Do

- Understand systematic errors and include into exclusion – ongoing. (Warren)
  - Muon reconstruction, and trigger as HIG-11-003 and SUS-11-010
  - JES from official jet energy correction uncertainties.
- Continue to refine cuts. (e.g. move to 5 eta bins in PU subtraction)
- Jet studies of fake rate. (Ferdinando)

Backup

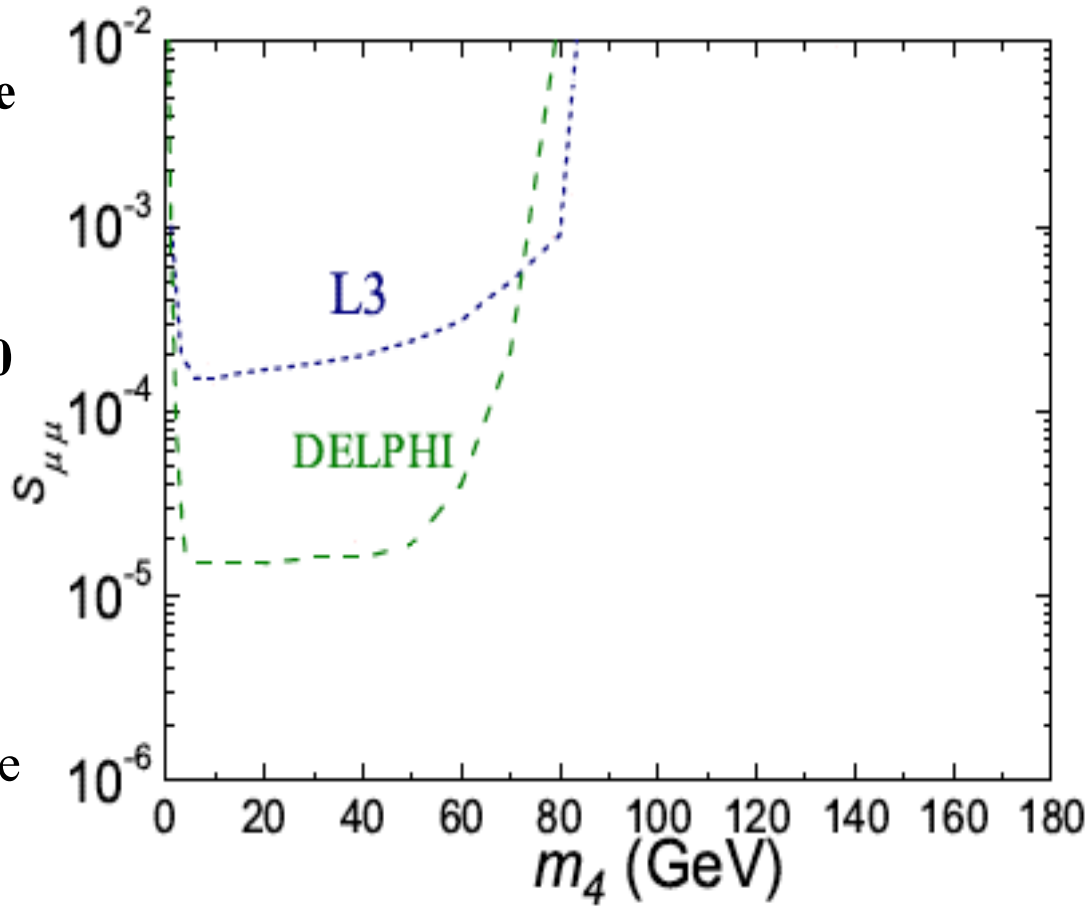
Other MC used:

- /ZZ_TuneZ2_7TeV_pythia6_tauola
- /WZ_TuneZ2_7TeV_pythia6_tauola
- /WW_TuneZ2_7TeV_pythia6_tauola
- /DYToMuMu_M-10To20_TuneZ2_7TeV-pythia6
- /DYToMuMu_M-20_TuneZ2_7TeV-pythia6

All the MC are Summer11 with pileup.

Review 2009 10 TeV Study

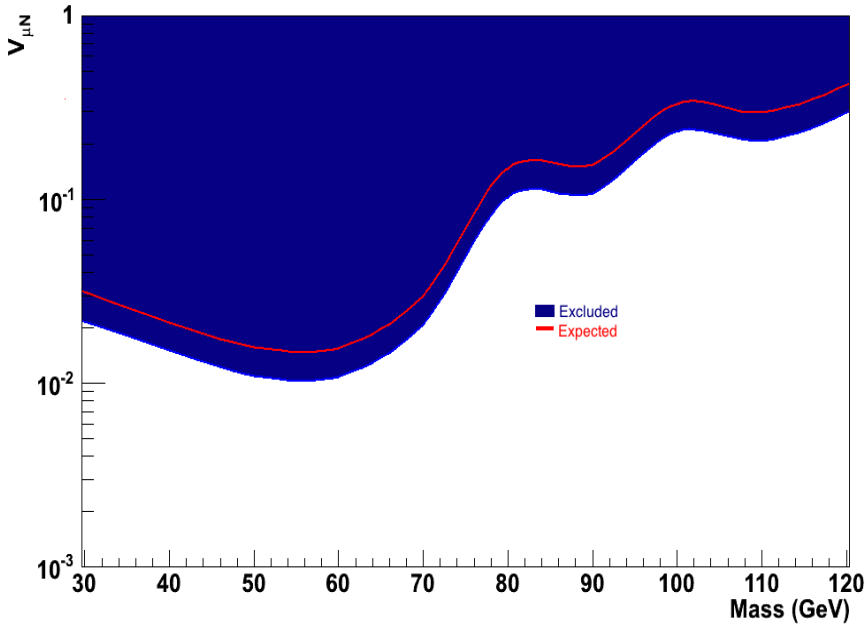
- **Studied the mass range of 100 GeV – 200 GeV, this mass range has no limits set from direct searches.**
- **We expected that the full mass range may be excluded with 100 pb^{-1} at 10 TeV. ($S_{\mu\mu}$=1 & $S_{\mu\mu} \cong V_{N\mu}$).**
- I've shown the equation relating the S value and the cross section for quick reference[1].
- The other parameter, $\sigma_0(N_4)$, is the "bare" cross section depending only upon the neutrino mass and the collision energy.

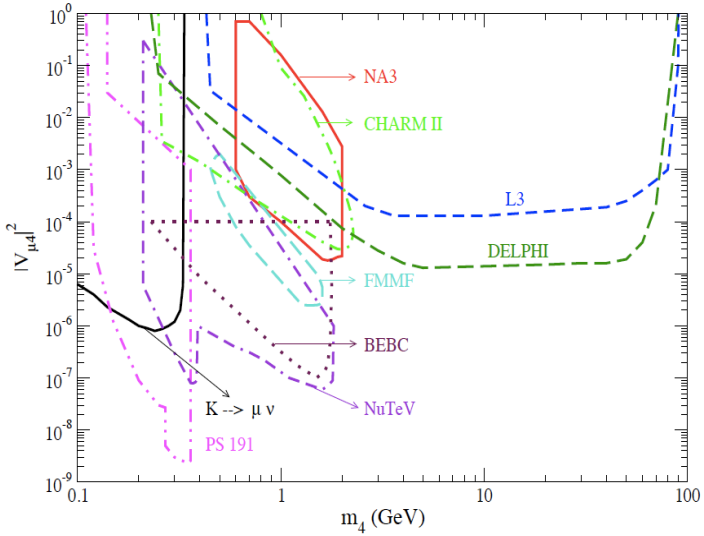


$$\sigma(pp \to \ell_1^{\pm}\ \ell_2^{\pm}\ W^{\mp} \to \ell_1^{\pm}\ \ell_2^{\pm}\ j\ j') = (2 - \delta_{\ell_1\ell_2})\ S_{\ell_1\ell_2}\ \sigma_0(N_4)$$

1) arXiv:0901.3589v2

2010 Work





- We did a very preliminary counting experiment with the 2010 data.
- No SS lepton candidate events were found in the 2010 data.
- The limited amount of data from 2010 precluded any competitive limits being set.
- Our investigated mass range started at 30 GeV, but the LHC's trigger requirements mean that we are not very sensitive below 100 GeV.
  - It is doubtful that we can compare with the LEP limits set below 90 GeV

Selection Cuts

- Muons
  - Mu pt > 20, 10 (1st muon, 2nd muon)
  - Eta < 2.4
  - Ecal Isolation < 4 GeV
  - Hcal Isolation < 6 GeV
  - Relative Isolation < 0.15
  - Normalized Chi^2 < 10
  - D_0 < 0.2 mm
  - 11 hits in tracker, at least one muon system hit
  - Global and tracker Muon
  - Dimuon mass > 5 GeV
  - No event with 3rd muon in Z mass window
- Jets
  - 2 Jets with pt > 20 GeV, eta < 3.0

Pt Cuts

Isolation Cuts

Quality Cuts

Z veto