Update on the sterile neutrino analysis

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Outline of the talk

- Reminder of the analysis method
- status of the nue-only analysis
- status of the combined ν_e - ν_μ analysis
- Conclusions and outlook

nue-only analysis

Details of the analysis

- **ν_e selection**:
  - standard selection applied : `dWall>200cm && Evis>200MeV && toWall>320cm`

  → estimation of the expected background (intrinsic (anti-)ν_e bkg + (anti-)ν_μ bkg)

- **Expected ν_e signal** ($\nu_\mu \rightarrow \nu_e$):
  - selection of the ν_e candidates (background)
  - multiply it for the ν_μ/ν_e flux ratio :

$$Nb\nu_{\mu\ befOsc} = Nb\nu_e \times \phi_{\nu\mu}/\phi_{\nu e}$$
$$= \phi_{\nu e} \times \varepsilon_e \times \sigma_e \times \phi_{\nu\mu}/\phi_{\nu e}$$
$$= \phi_{\nu\mu} \times \varepsilon_e \times \sigma_e$$

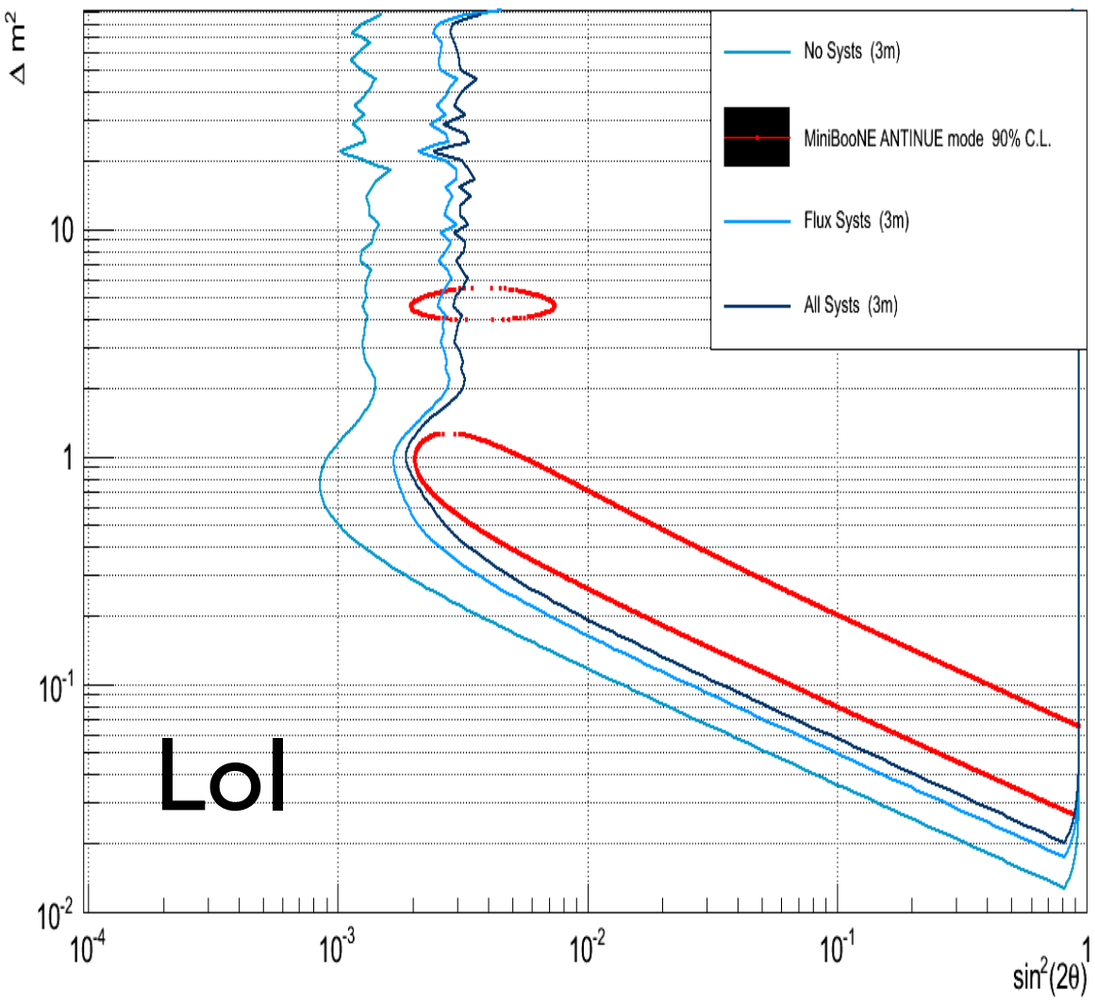
  - apply the oscillation probability :

$$\nu_e \text{ signal} = \nu_{\mu\ befOsc} \times P(\nu_\mu \rightarrow \nu_e)$$

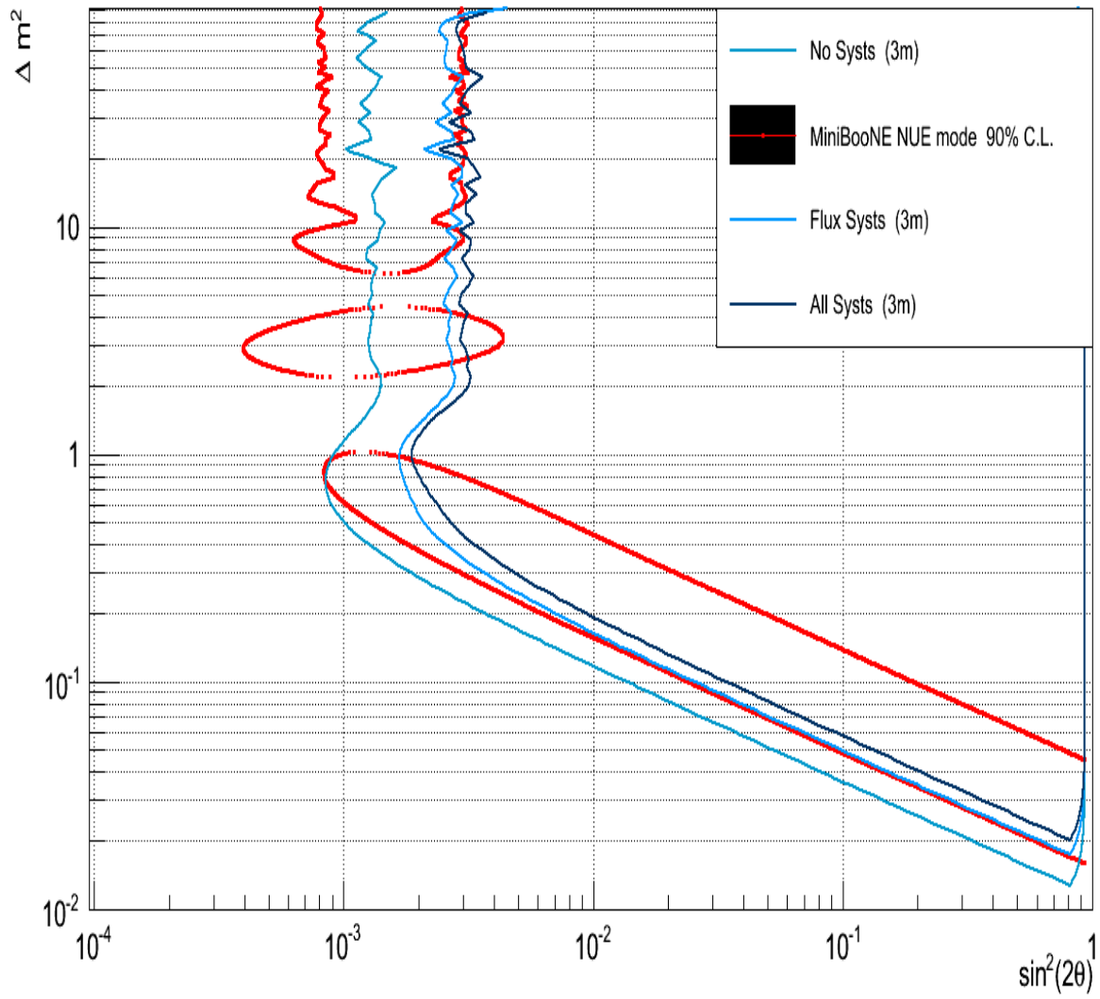
- The analysis is performed considering 10 bins in RecoEnergy and 10 in off-axis angle

Sensitivity with 4.6×10^{20} POT

- Sensitivity plot considering a **3m Inner detector radius**
- MiniBooNE contours in neutrino and anti neutrino mode are shown (PhysRevLett.110.161801)



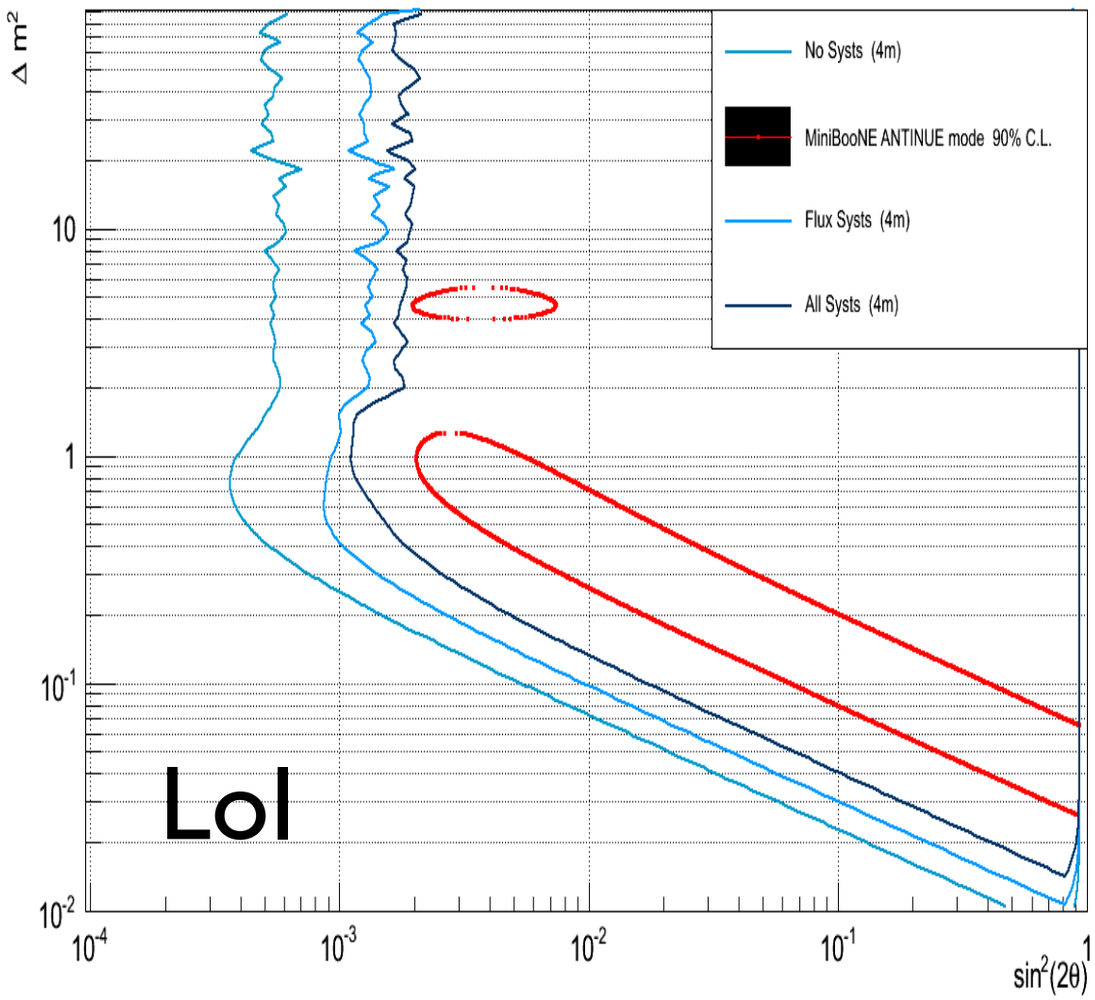
— MiniBooNE 90% CL in anti-nu mode



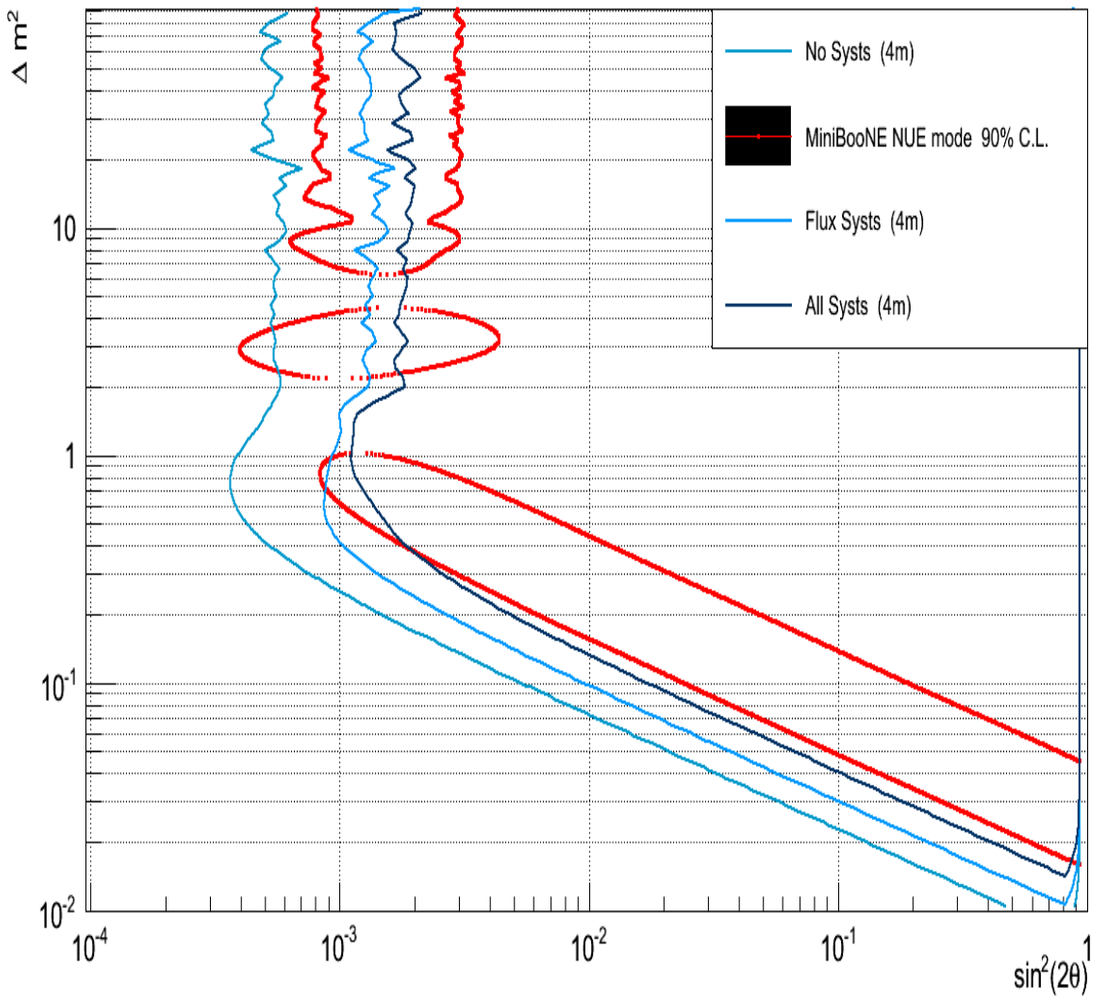
— MiniBooNE 90% CL in nu mode

Sensitivity with 4.6 x 10^{20} POT

- Sensitivity plot considering a **4m Inner detector radius**
- MiniBooNE contours in neutrino and anti neutrino mode are shown (PhysRevLett.110.161801)



— MiniBooNE 90% CL in anti-nu mode



— MiniBooNE 90% CL in nu mode

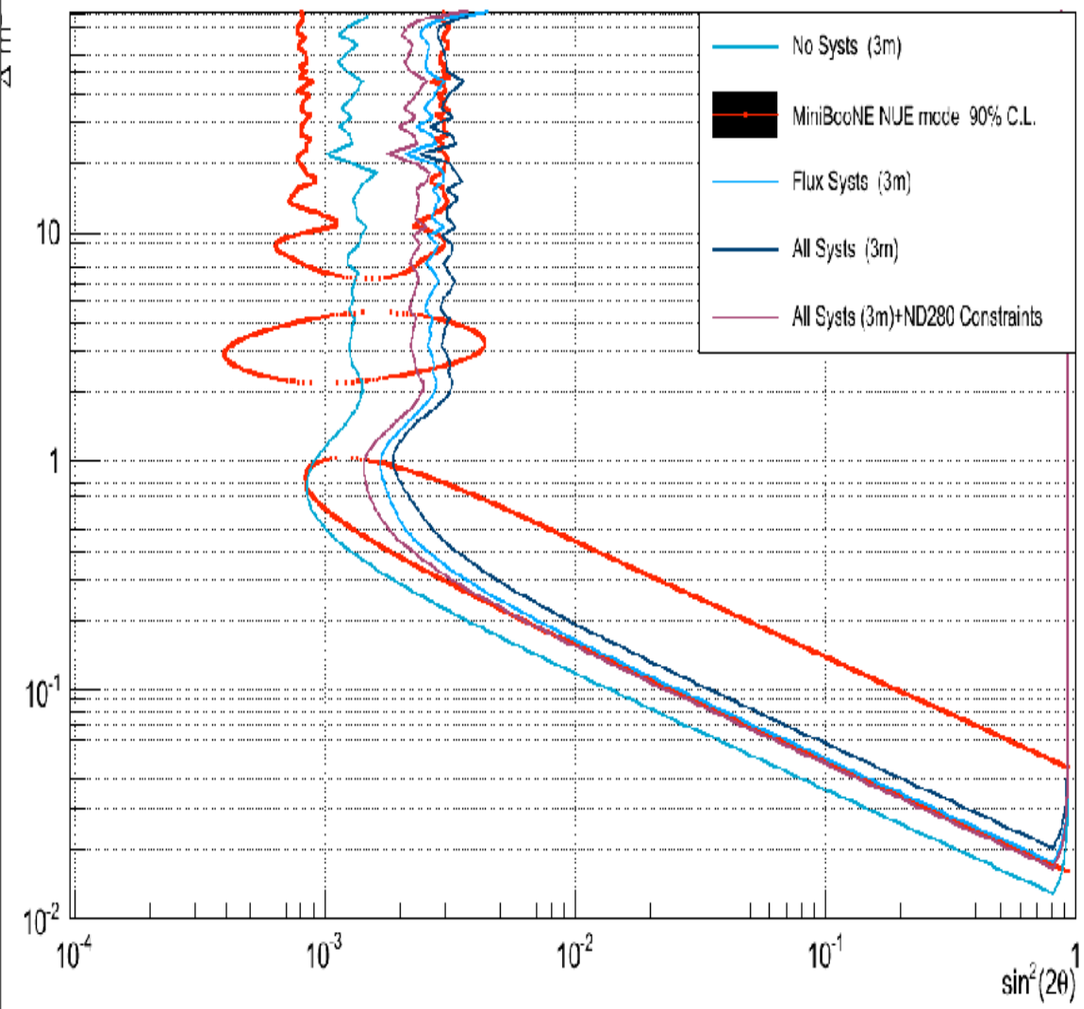
Improving the sensitivity

- To improve the foreseen sensitivity of nuPRISM detector an estimation of the systematics reduction thanks to ND280 constraints is presented
- Method:
  - estimation of a reduction factor from the T2K oscillation analysis (~ 28% w/o ND280 and ~8% w/ ND280)
  - reduction factor applied to all terms in the covariance matrix

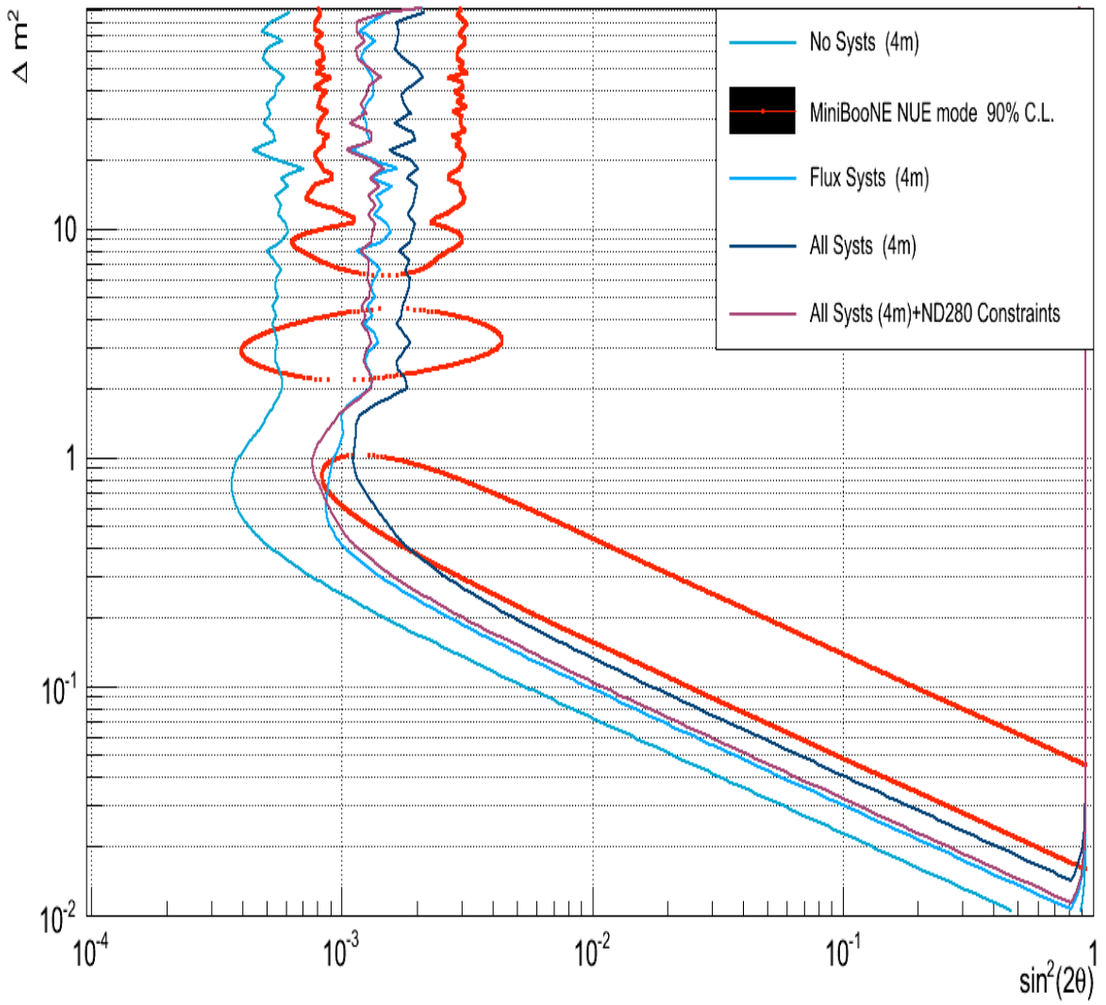
Sensitivity w/ ND280 constraints

4.6x10^{20} POT

3m ID radius



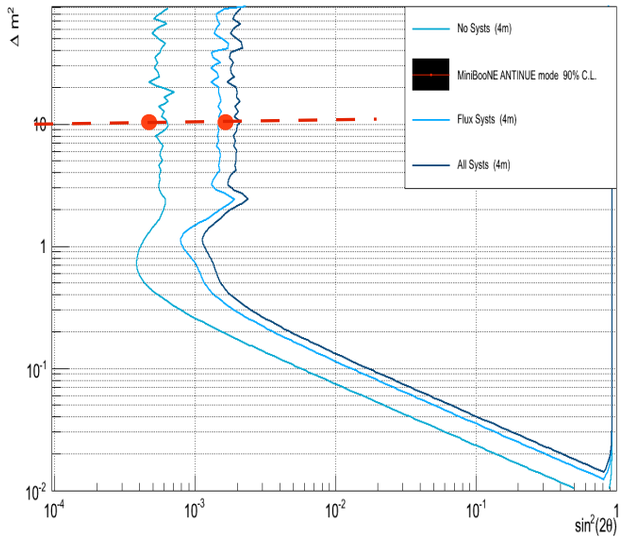
4m ID radius



— MiniBooNE 90% CL in nu mode

Validation

- An analytical study has been developed to cross-check our results
- Method :
  - We consider the fast oscillation region (high $\Delta m2$) where the limit is determined by the fluctuations of the number of background events
    - $N(\nu_e) \approx A \times \sin^2(2\vartheta)$
    - $B\ \Delta N(\nu_e^{bkg}) = A \times \sin^2(2\vartheta) \rightarrow \sin^2(2\vartheta) = B/A\ \Delta N(\nu_e^{bkg})$
  - Errors should scale similarly to the oscillation parameter
    - $\Delta N(\nu_e^{bkg})|_{stat} = A/B \times \sin^2(2\vartheta)|_{stat}$
    - $\Delta N(\nu_e^{bkg})|_{stat+sys} = A/B \times \sin^2(2\vartheta)|_{stat+sys}$
  - The ratio between the errors and the limits should then scale by the same factor



3m ID radius

Binning	ratio errors		ratio Osc Param	Difference
10x10	6.3	≠	2.2	4.1

4m ID radius

Binning	ratio errors		ratio Osc Param	Difference
10x10	17.6	≠	3.2	14.4

Validation

- The ratio between the limit and the errors has been found different
  - More precisely the ratio of the limit is giving a smaller scaling factor than the ratio of the errors
- Correlations between bins may explain this behavior
- Do the same exercise for different binning to try to disentangle a possible effect coming from correlations

3m ID radius

Binning	ratio errors	ratio Osc Param	Difference
1x1	6.29	6.26	0.03
2x2	6.3	5.8	0.5
5x5	6.3	3.0	3.3
7x7	6.3	2.8	3.5
10x10	6.3	2.2	4.1

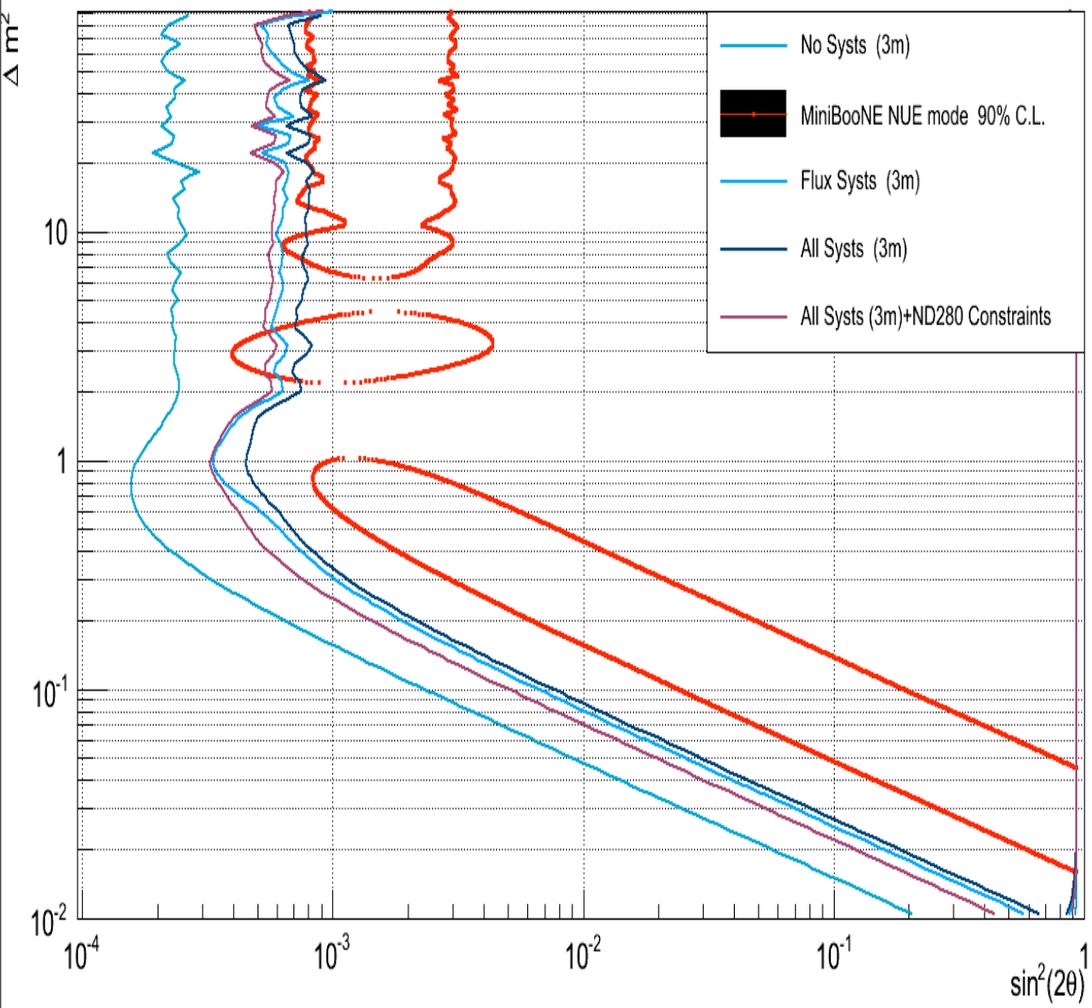
4m ID radius

Binning	ratio errors	ratio Osc Param	Difference
1x1	14.8	14.6	0.2
2x2	14.9	12.6	2.3
5x5	14.9	4.3	10.6
7x7	14.9	3.4	11.5
10x10	17.6	3.2	14.4

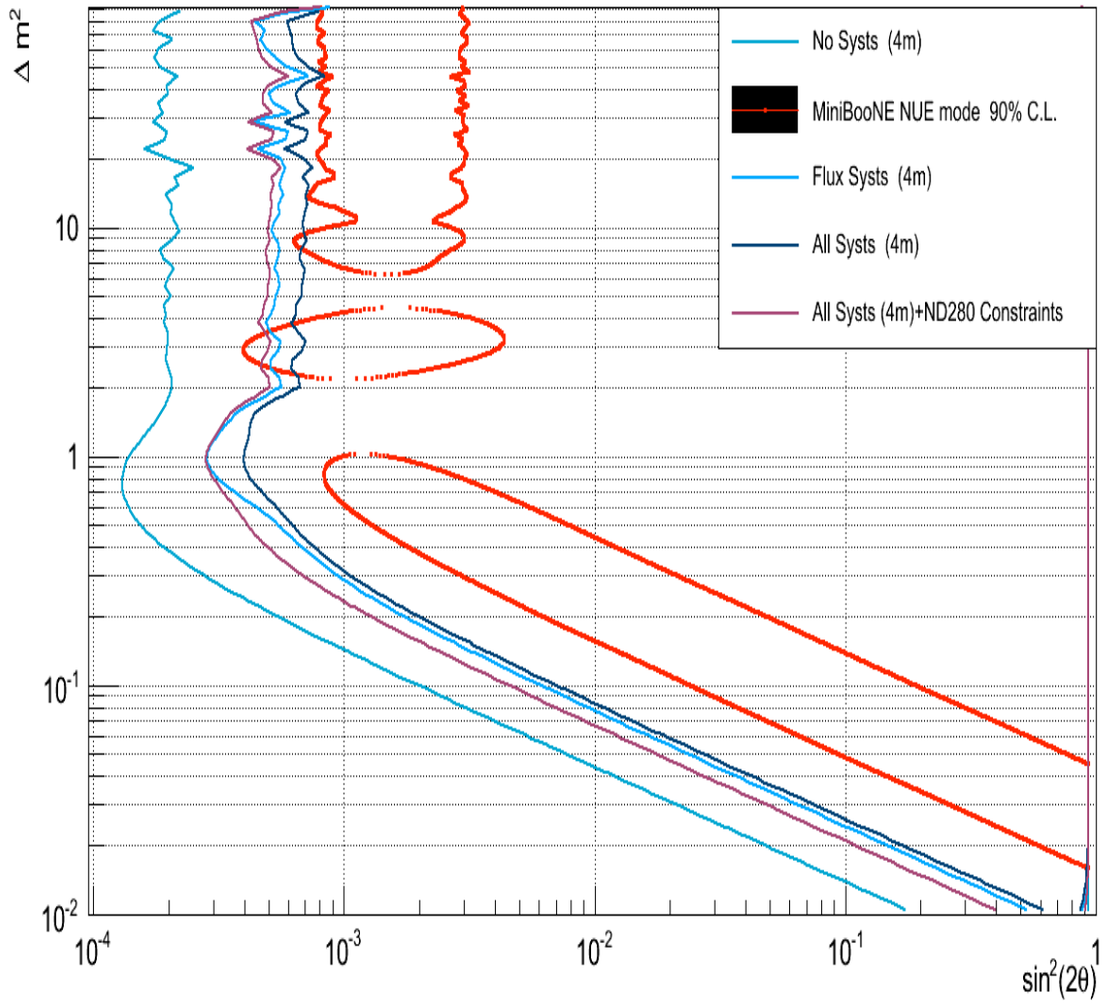
Sensitivity w/ ND280 constraints

1.5 x 10^{22} POT

3m ID radius



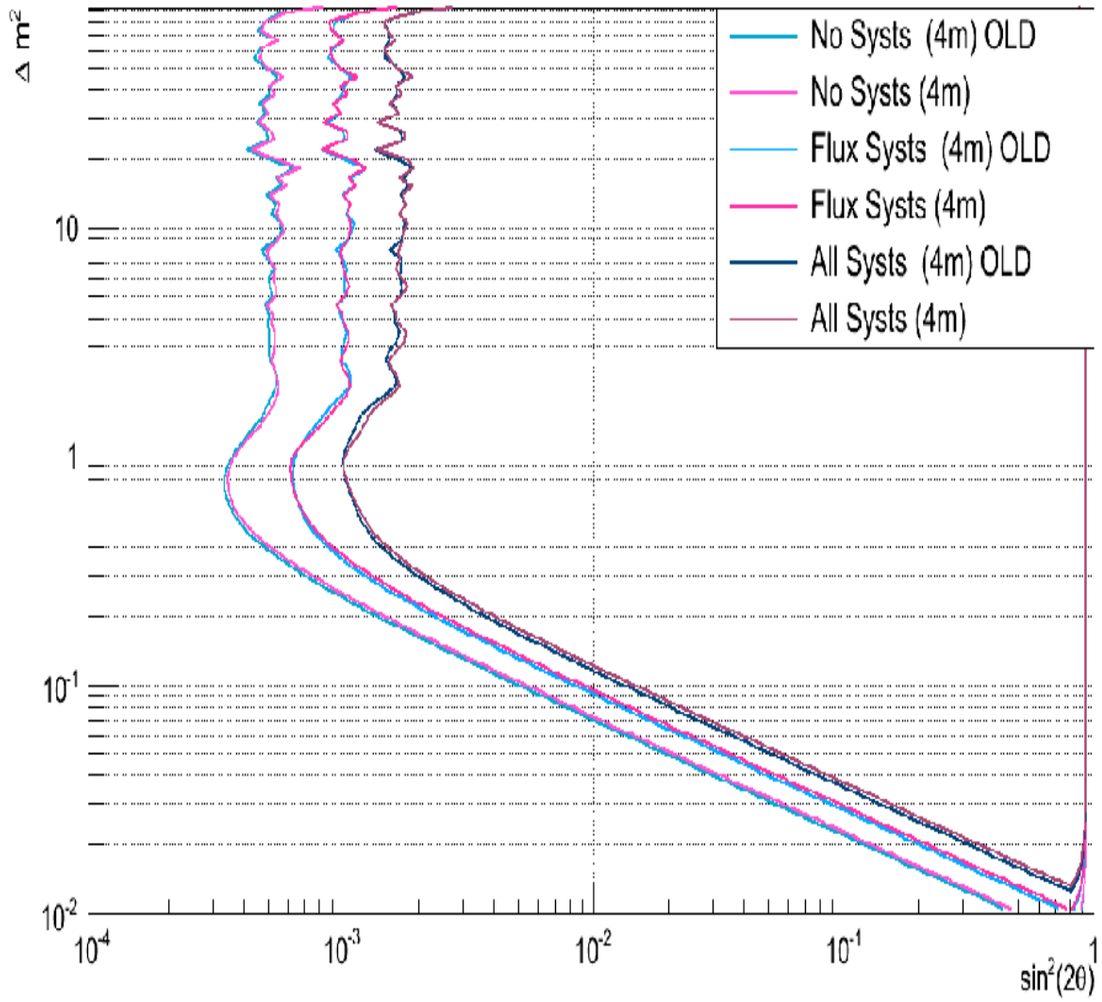
4m ID radius



combined ν_e-ν_μ analysis

Ratio ν_e/ν_μ analysis

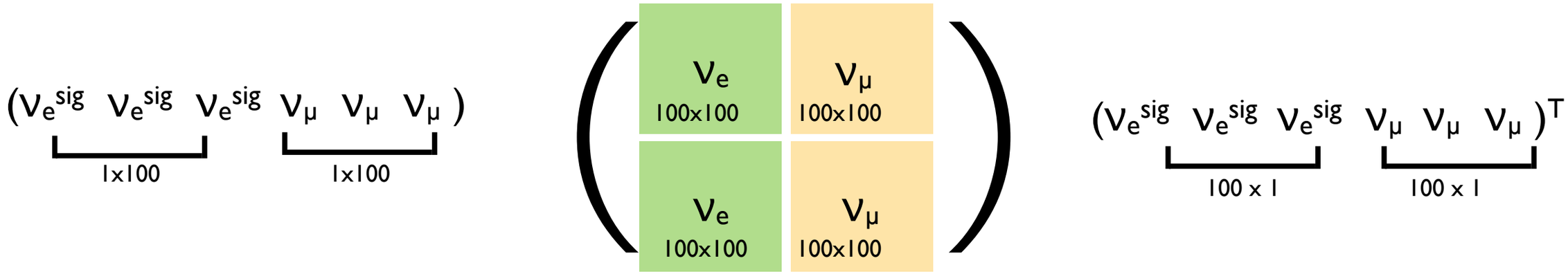
- The bug on the event selection related to events satisfying both the ν_e and ν_μ selection criteria has been solved
- The background composition is now in agreement with what observed for the ν_e-only analysis
- Nevertheless, almost no impact on the sensitivity curve



Alternative method

- An alternative and promising method is to fully exploit the possible correlations between ν_e and ν_μ events, regardless the energy and the off-axis angle

- To do so a big 200x200 covariance matrix can be build



- The matrix is ready, some work in on-going to built χ^2 map and draw the sensitivity contours

Conclusions

- We presented the nuPRISM sensitivity curves compared to the MiniBooNE 90%CL in both neutrino and anti-neutrino mode
  - with 4.6×10^{20} POT the MiniBooNE contour in anti-neutrino mode is almost fully covered, while this is only partially true for the contour in neutrino mode
  - This conclusion is true for both the considered case of the detector ID radius
  - For an higher statistics (1.5×10^{22} POT) the MiniBooNE contours are almost fully covered.
- A first estimation of the possible systematics errors reduction we can achieve thanks to the ND280 constraints has been presented
  - The estimation has been cross-checked with a simple analytical calculation and further reduction of the systematics has been observed thanks to the existing correlations between the bins
- Further studies on the reduction of the systematics are on-going (ratio and 200x200 cov. matrix). These two approaches look promising to reach a fully coverage of the MiniBooNE accepted regions

Outlook and future plans

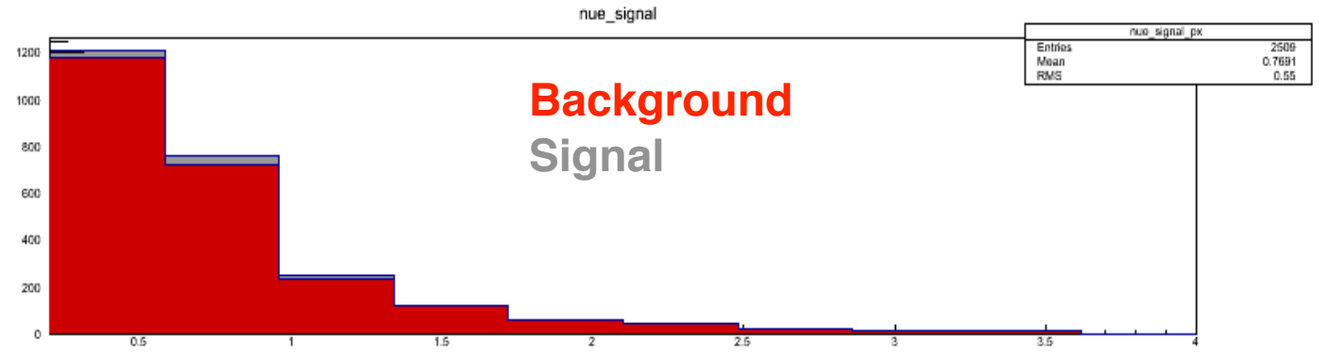
- Several key studies has to be done to have a full overview of the potential of nuPRISM in contributing to the short baseline nu-oscillation searches (see also Mike's talk this morning)
  - ~~add ND280 constraints~~
  - estimated constraints on background process
  - Full ν_e+ ν_μ fit
  - use of efficiencies and resolutions from the new simulation

- John will be in Japan for three months to work with Mark

- on a long(er) term, we aim to have paper fully focusing on the sterile searches. This now a low priority and it will be discussed again after the PAC meeting

Backup

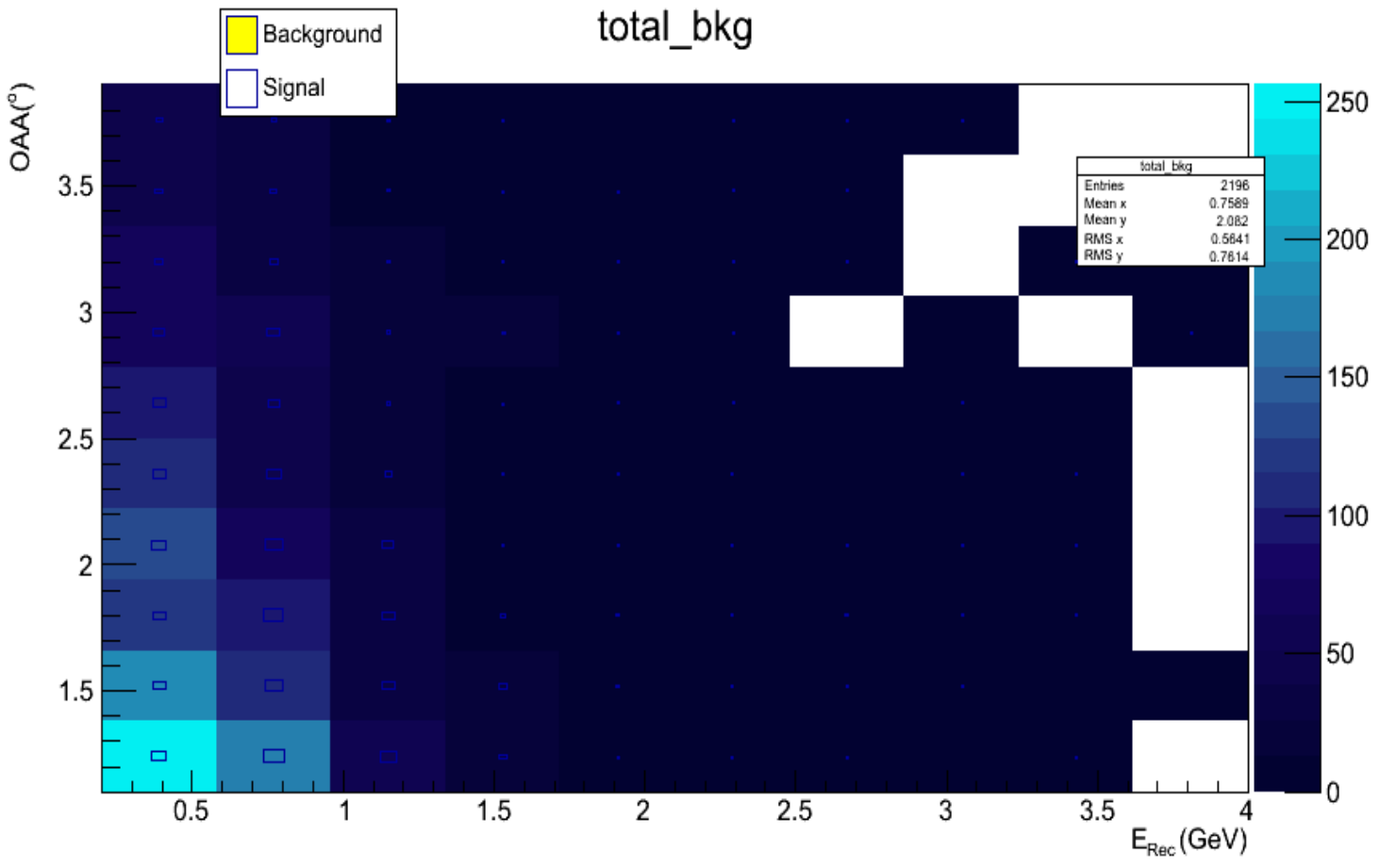
Signal and background (3m)

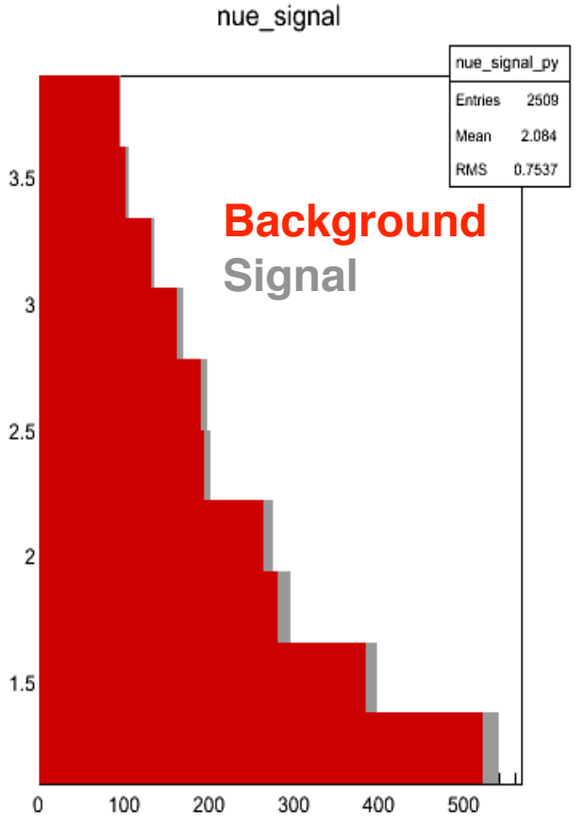


BCKG = 2326
Signal = 86

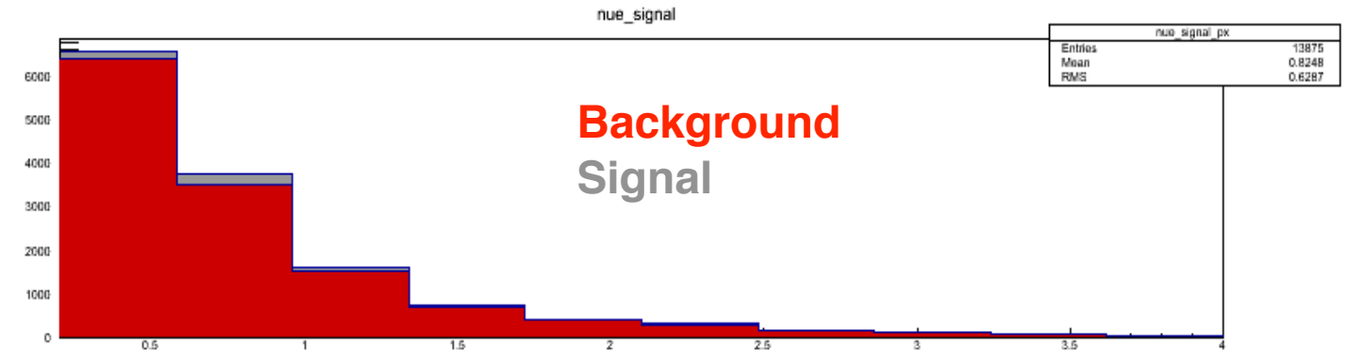
Background Composition:

$\#(CC\nu_e) = 1018$ (~48%)
$\#(CC\nu_\mu) = 1308$ (~52%)





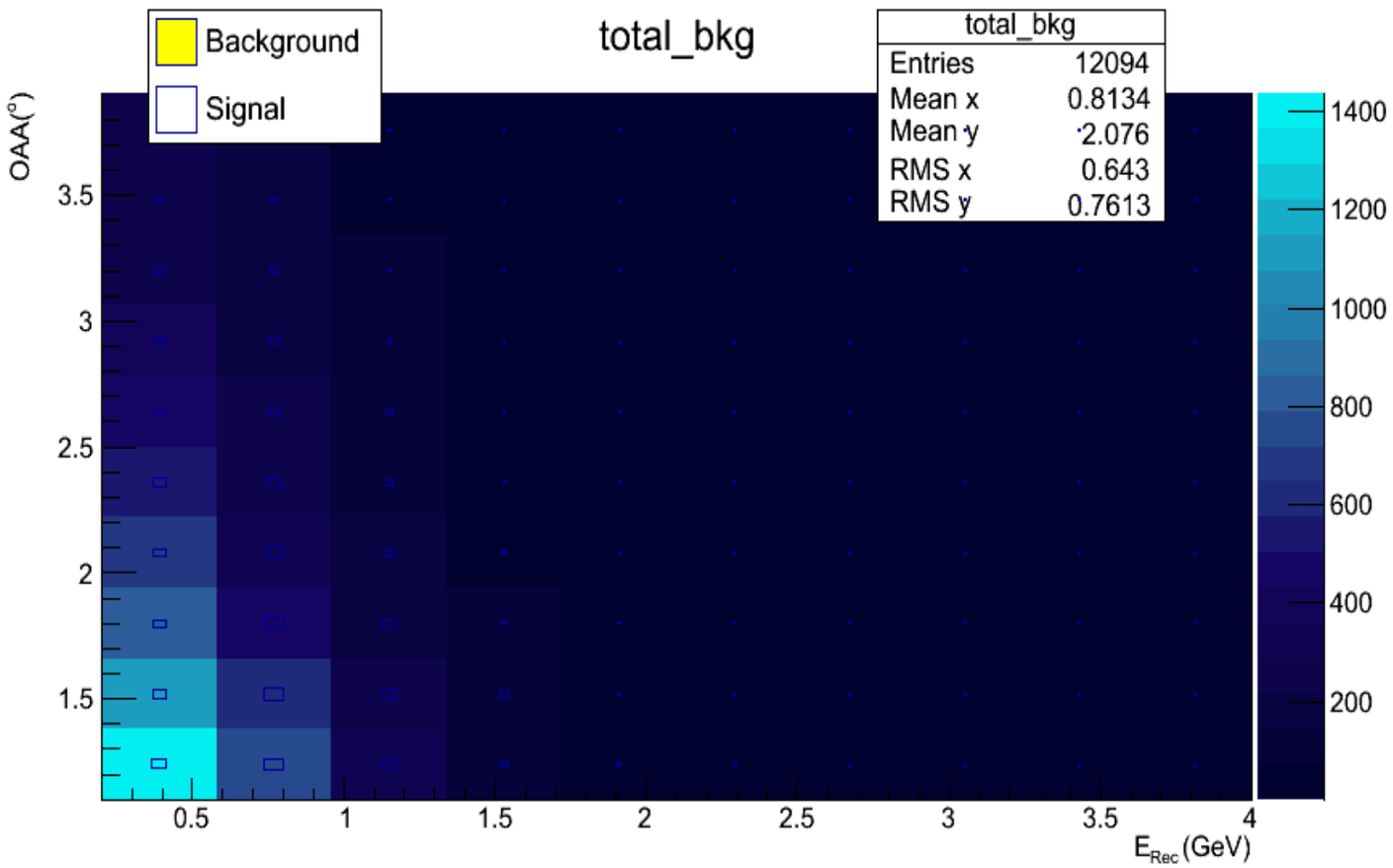
Signal and background (4m)

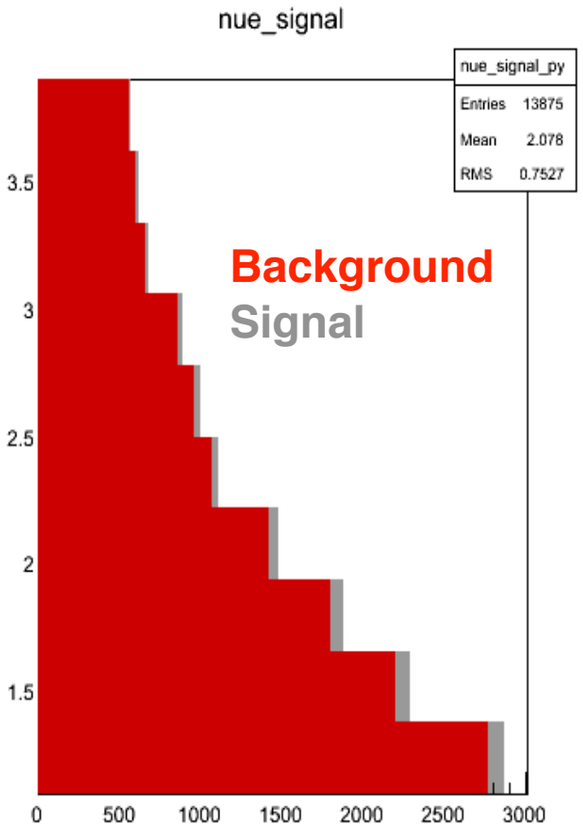


BCKG = 12901
Signal = 466

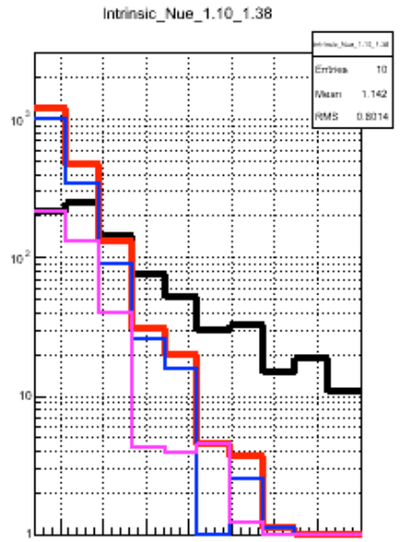
Background Composition:

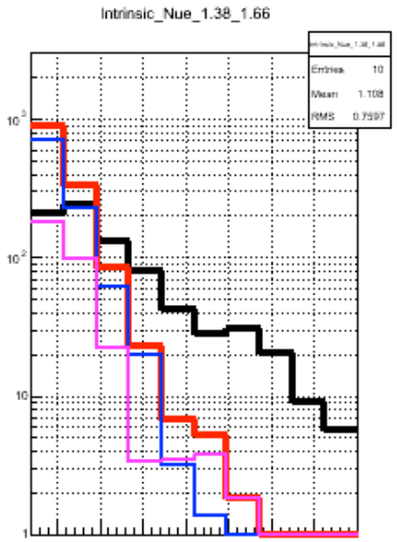
$\#(CC\nu_e) = 6162$ (~48%)
$\#(CC\nu_\mu) = 6739$ (~52%)

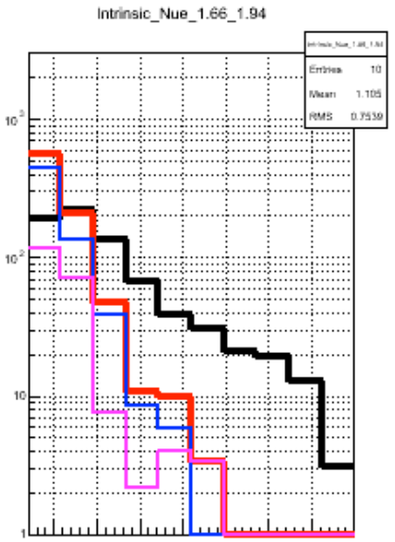


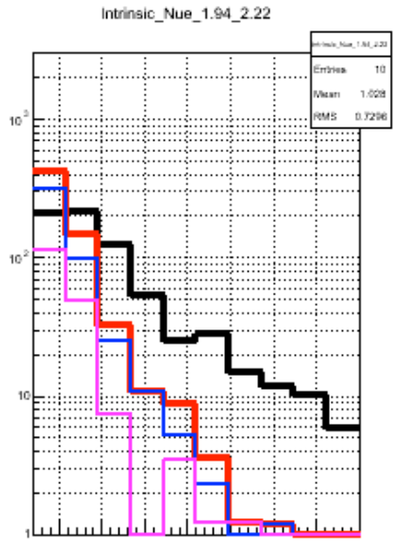


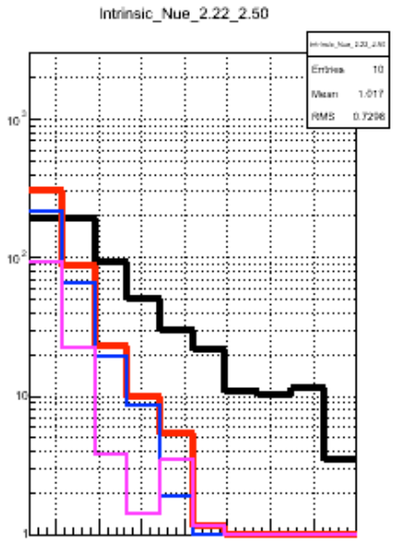
Background composition (4m)

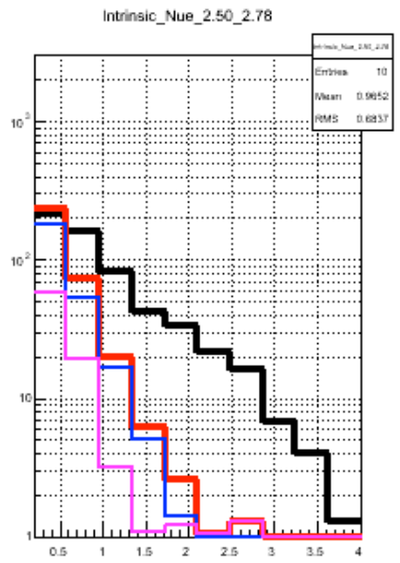


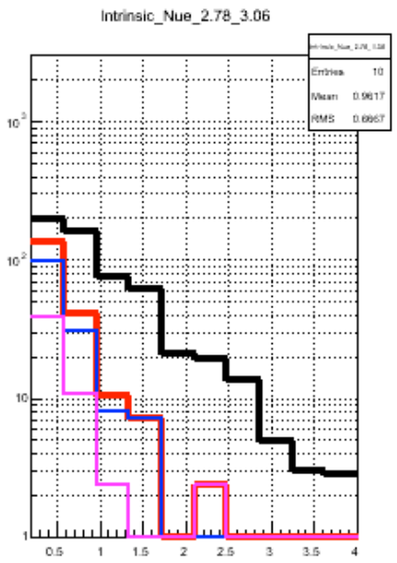


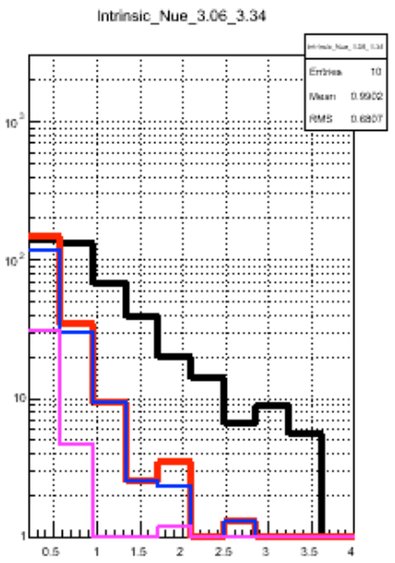


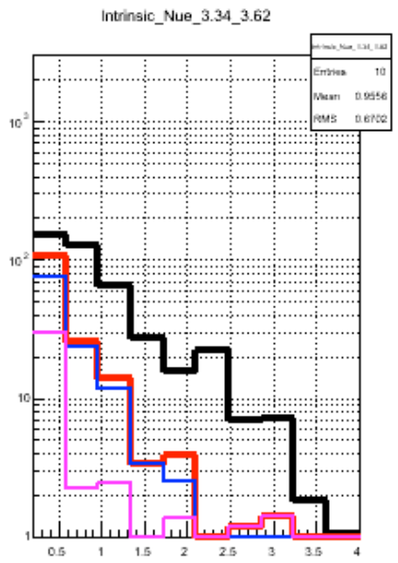


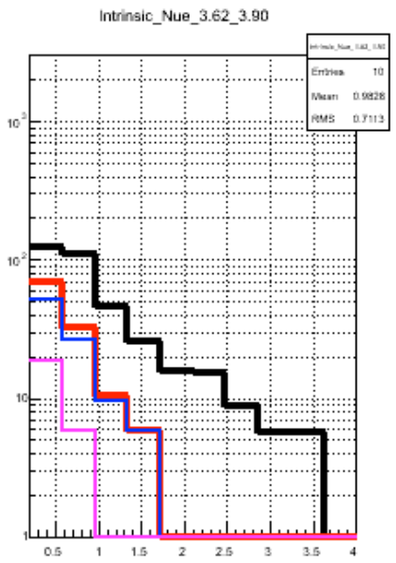




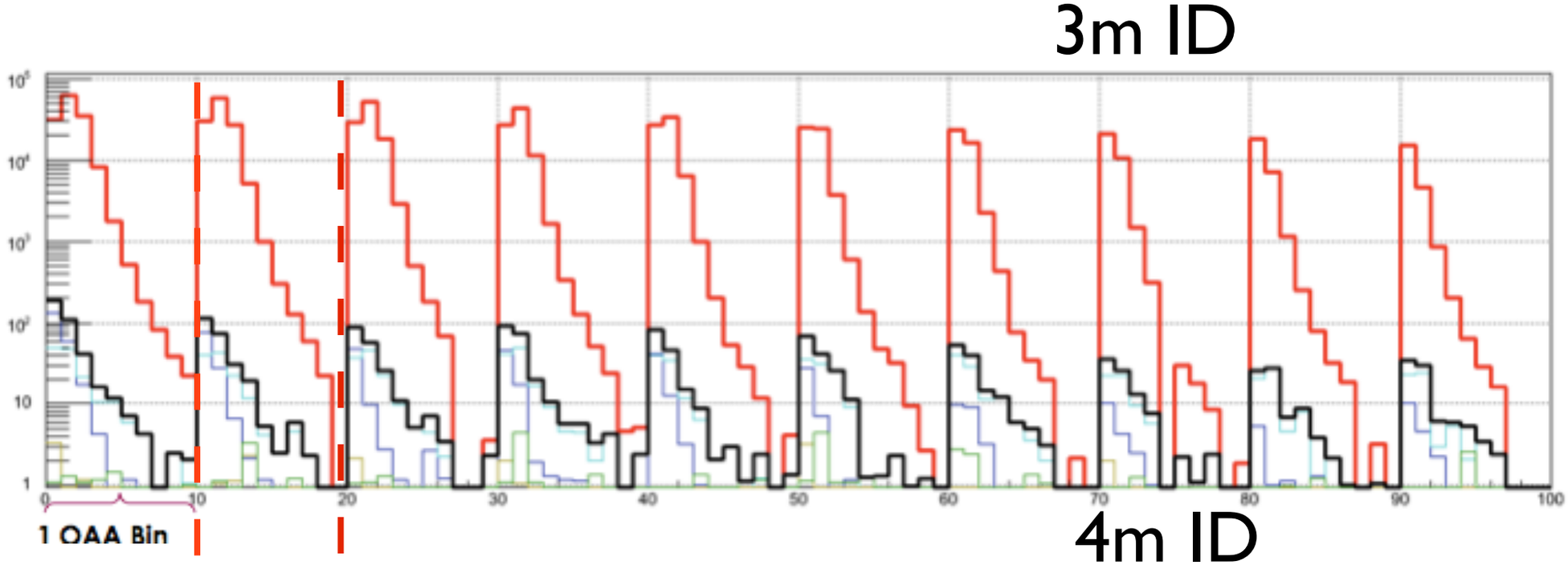


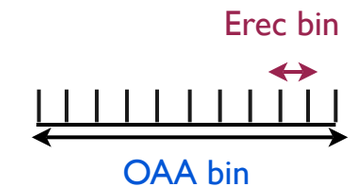






Energy distributions (nue analysis)





Total bkg
nue bkg
numu bkg
anti-nue bkg
anti-numu bkg
numu events

nue/numu ratio