"SENSITIVITY TO HEAVY NEUTRAL LEPTONS WITH THE SAND DETECTOR AT THE DUNE ND COMPLEX"

Zahra Ghorbani Moghaddam

INFN Genova and University of Perugia

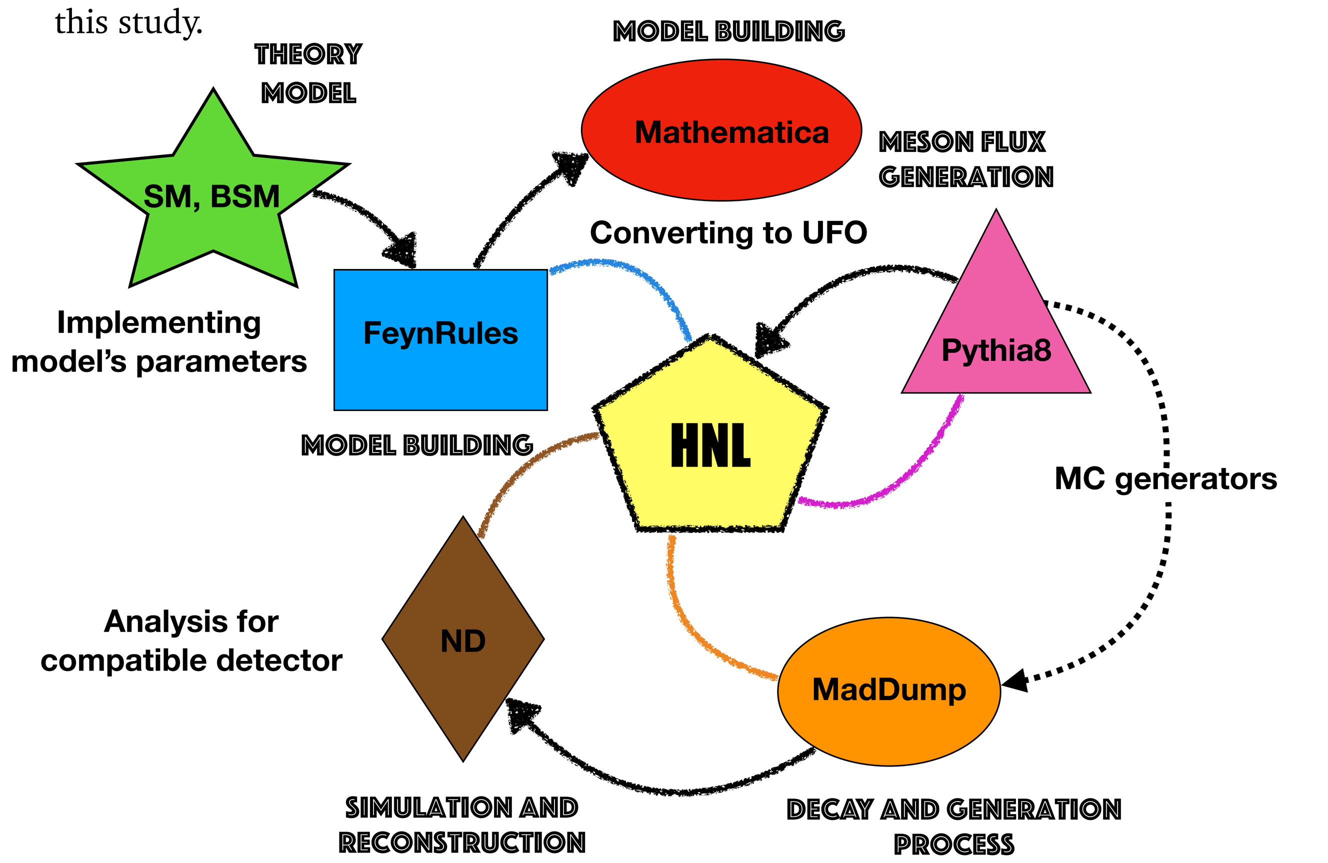
On behalf of DUNE collaboration

ICHEP 2022 BOLOGNA

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Introduction

Heavy Neutral Leptons (HNLs) have been an interesting topic for experimental particle physics in the past few years.
A study has been performed within the framework of the multi-instrument DUNE Near Detector complex, SAND. The following diagram shows the work flow of this study.



Theory Model https://arxiv.org/abs/0705.1729

The nuMSM scenario is one of the most promising beyond the standard model pictures through which neutrino masses and hierarchy, baryon asymmetry and dark matter can be explained.
The Lagrangian of the nuMSM contains three right handed neutrinos (HNL), two of which are almost degenerate, and the third, the lightest, is a dark matter candidate.

$$\mathscr{L}_{\nu MSM} = \mathscr{L}_{MSM} + \bar{N}_I i\partial_\mu \gamma^\mu N_I - F_{\alpha I}\bar{L}_\alpha N_I \Phi - \frac{M_{IJ}}{2}\bar{N}_I^c N_J + h.c.$$

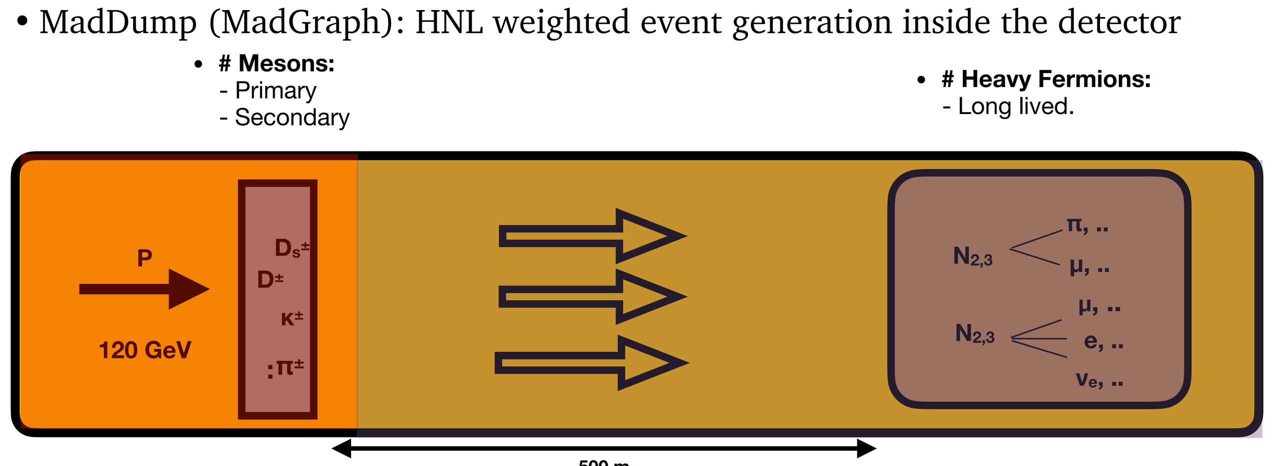
The sensitivity related the three benchmark models, regarding the Yukawa sector, is shown.

$$\begin{cases} f_e^2 : f_\mu^2 : f_\tau^2 \approx 52 : 1 : 1 \\ f_e^2 : f_\mu^2 : f_\tau^2 \approx 1 : 16 : 3.8 \\ f_e^2 : f_\mu^2 : f_\tau^2 \approx 0.061 : 1 : 4.3 \end{cases}$$

Phenomenological Sensitivity

The experimental set-up is like beam-dump experiments.
Model building is done by FeynRules and the two Monte Carlo generators are:

- Pythia: meson flux generator, used as input to MadDump
- MadDump (MadGraph): HNL weighted event generation inside the detector



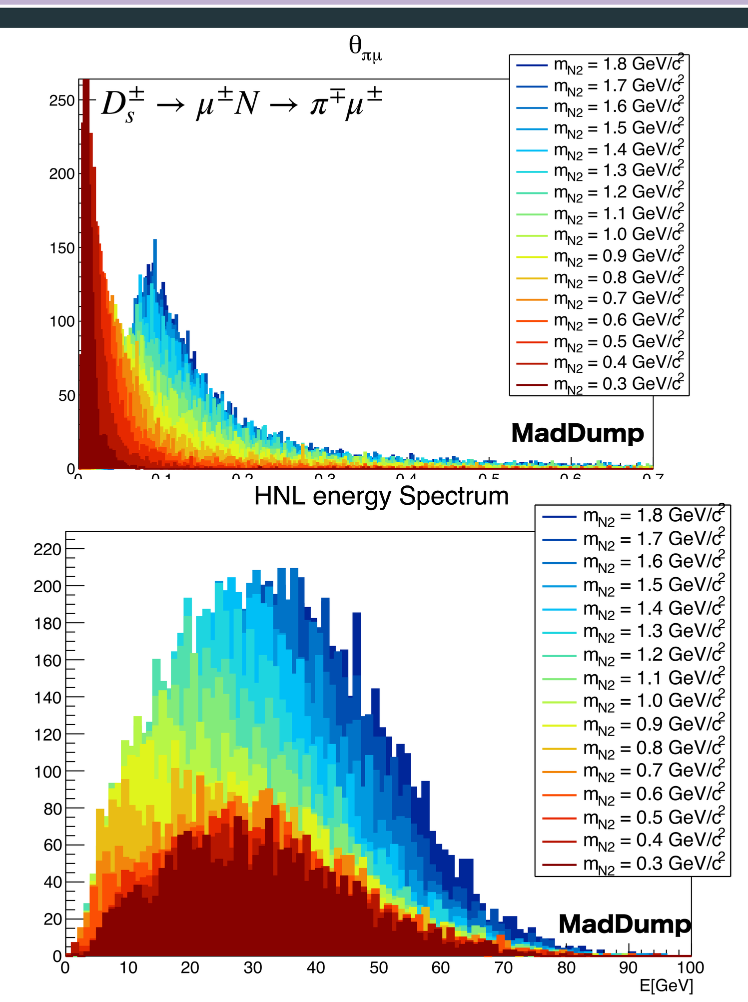
Particle	Channel
D_s	$\to eN_{2,3}$
	$\to \mu N_{2,3}$
	$\to \tau\nu_\tau$
τ	$\to \nu_\tau \mu N_{2,3}$
	$\to \nu_\mu \mu N_{2,3}$
	$\to \rho N_{2,3}$

Particle	Channel
$N_{2,3}$	$\to \pi^+\mu^-$
	$\to \pi^-\mu^+$

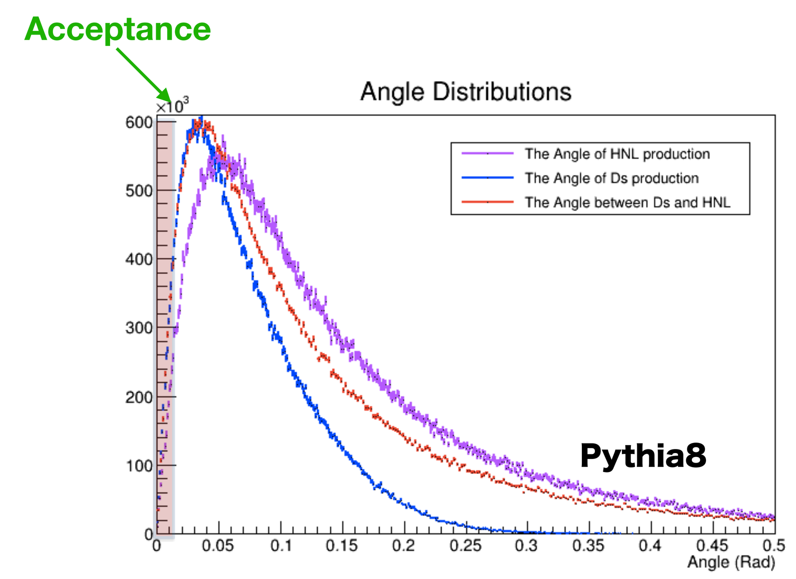
The chosen channels, both for generation and decay, are motivated by the dominant nature of the channel (in M =[0.3, 1.8] GeV/c²), available computational power and, with an eye on the detector studies, how well the event is reconstructible:

- HNL Generation - meson channel: all Ds relevant channels
- HNL Decay - Charged current channel: μ π

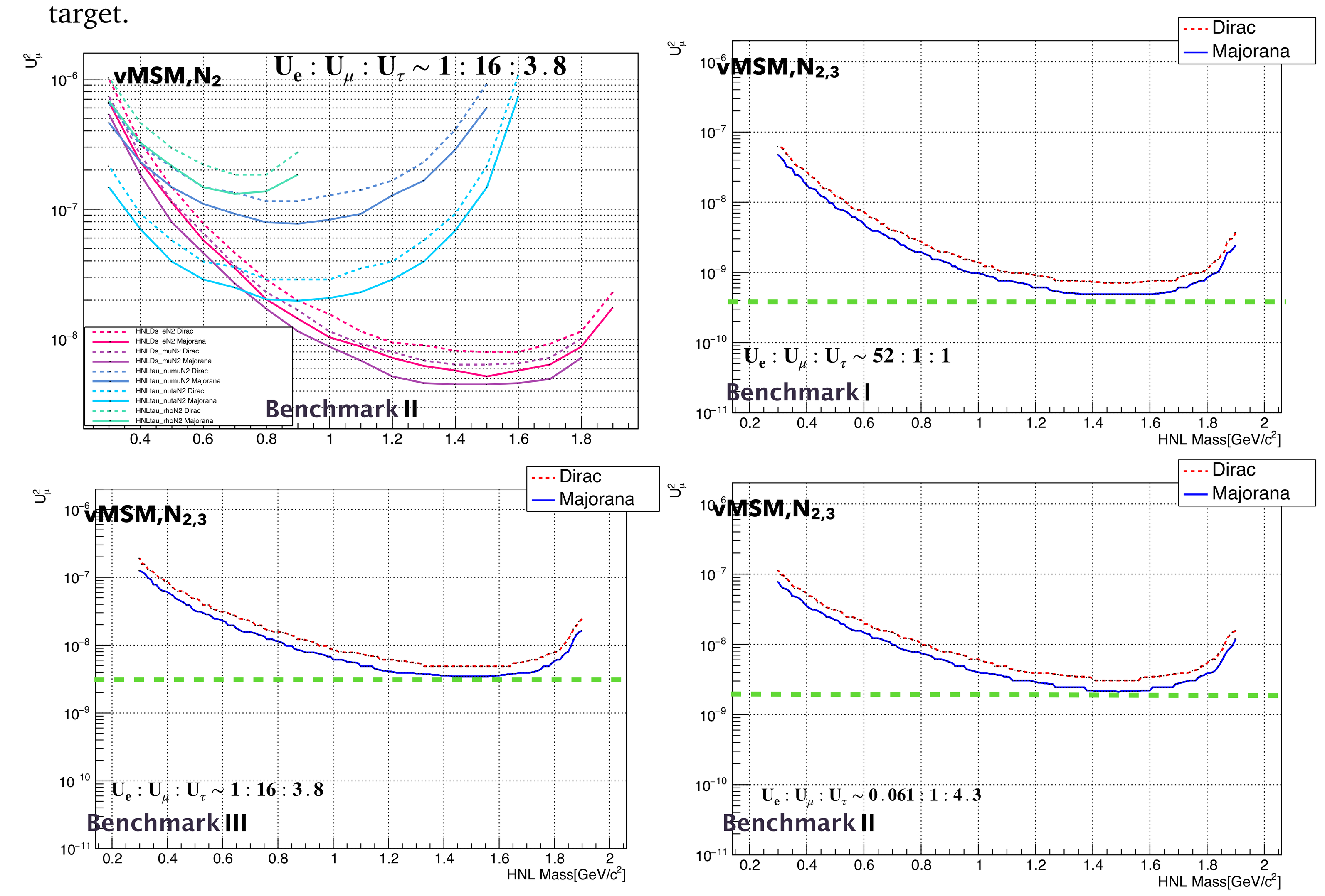
The covered HNL mass range is [0.3, 1.8] GeV/c²



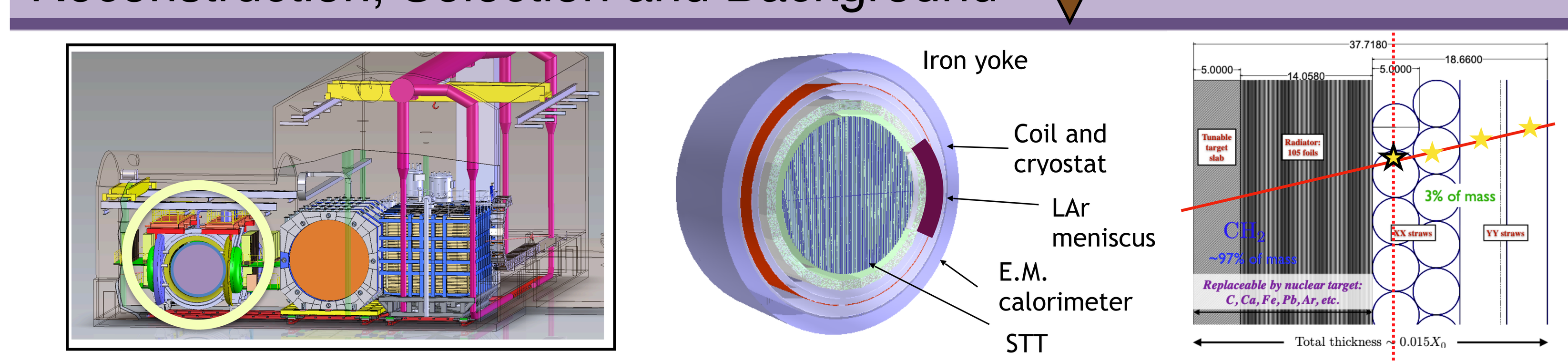
The angle of the Ds emission plays a major role in the HNL geometrical acceptance.
The HNL flux and the final decay product angle is shown for one Ds channel.



Different sensitivity regarding the covered channels for 6 years of exposure are shown for N2 in benchmark II.
The total phenomenological sensitivity is shown for three benchmark models, with finer mass bins. The sensitivity estimate can be considered conservative, not including the proton multiplicity factor of the target.



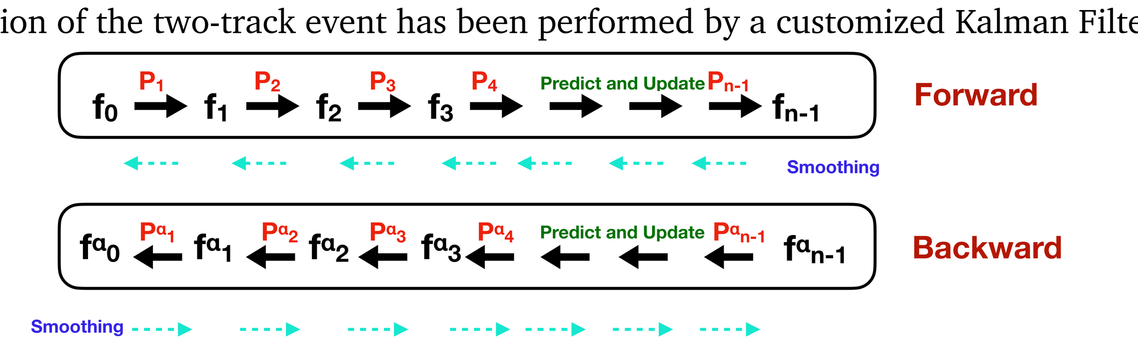
Reconstruction, Selection and Background



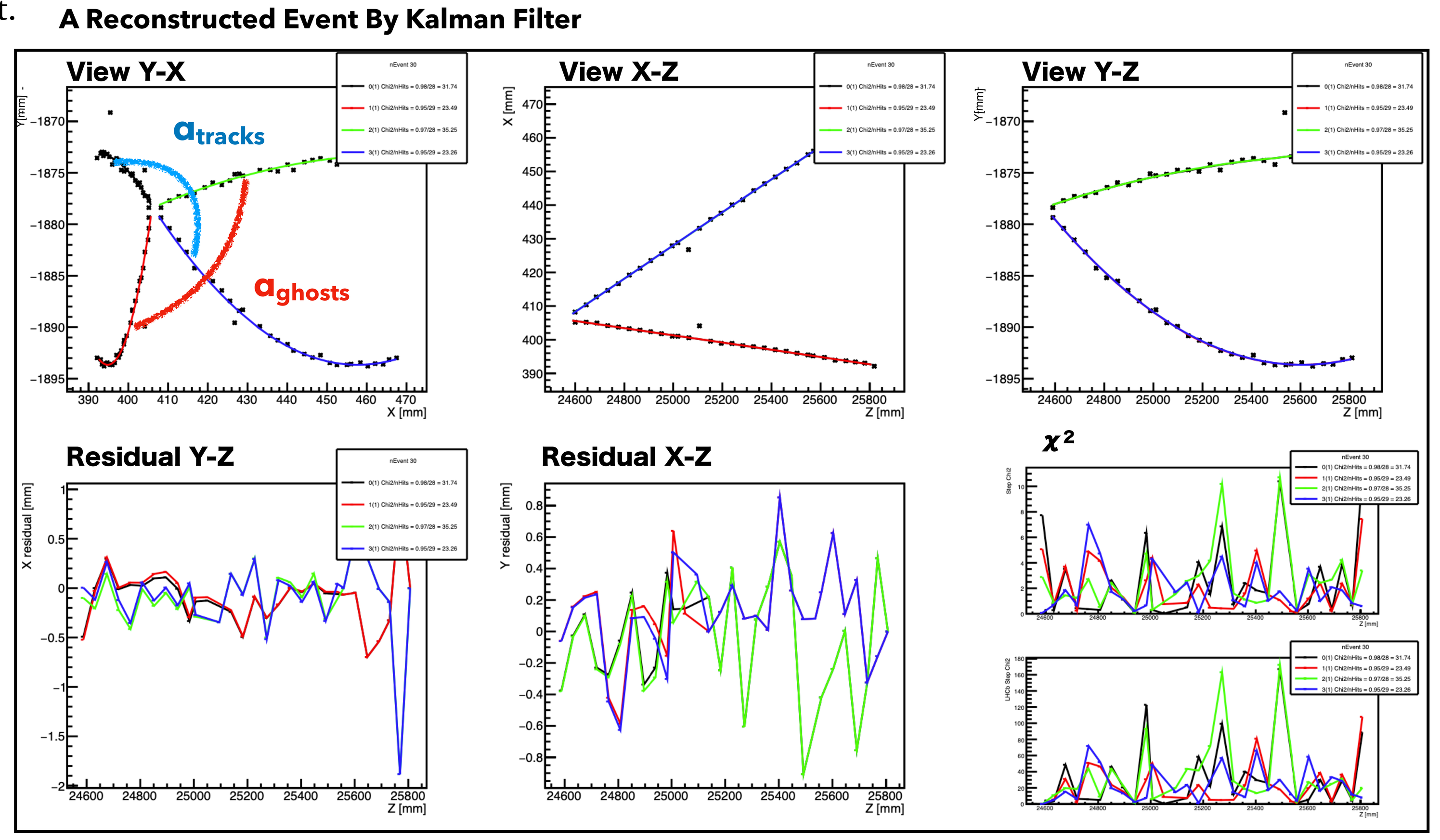
The targeted detector for this study is one of the three detectors of the DUNE Near Detector facility: System for on-Axis Neutrino Detection (SAND):

- Magnetized inner tracker (0.6 T) :
  - Straw tube (STT inner tracker) + liquid argon meniscus (only STT geometry for this study)

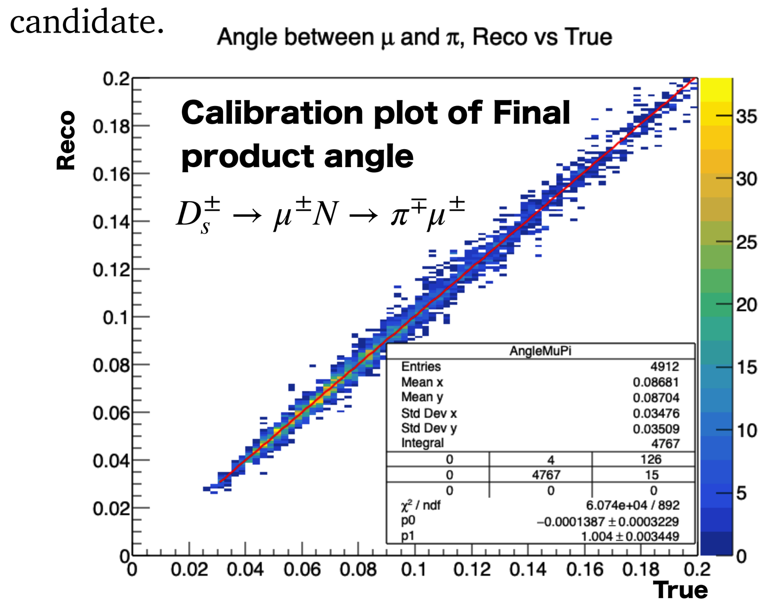
The reconstruction of the two-track event has been performed by a customized Kalman Filter.

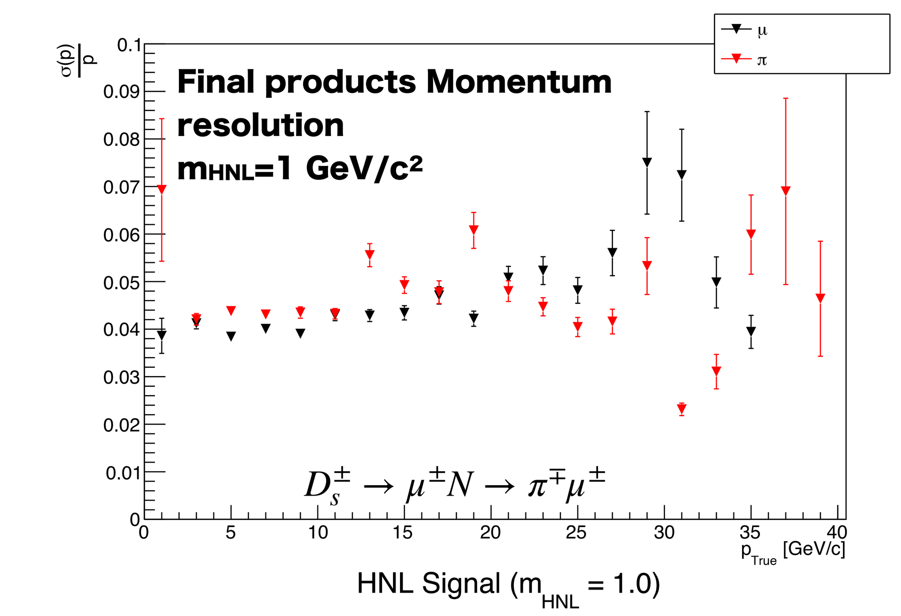


The customized Kalman Filter has been implemented for both forward and backward directions, to optimize the final result.



Due to the nature of the STT detector, a selection scheme has been implemented to select actual tracks from ghosts (based on $\alpha_{track/ghost}$ and opposite charge).
The efficiency of the reconstruction is ~ 80% for both single and paired tracks.
Accepted tracks (passing > 6 STT planes), reconstructed and selected in pairs, constitute the signal candidate.

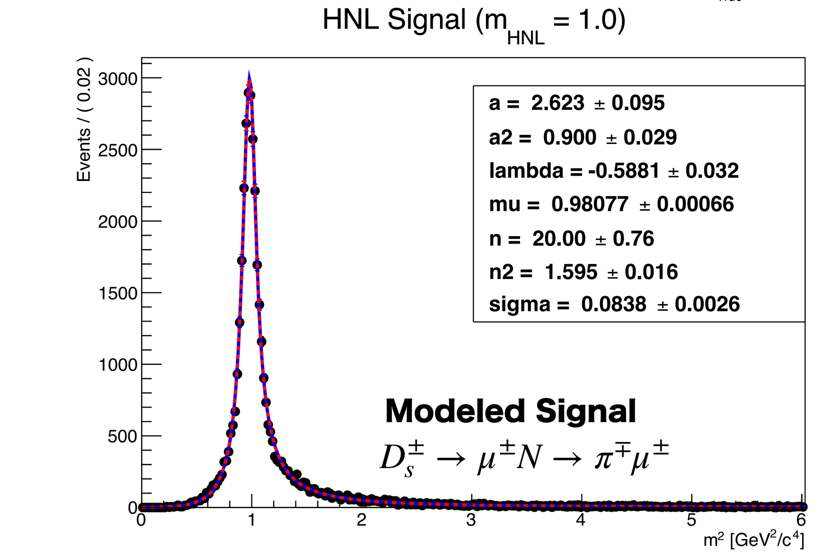




The most dangerous background for this signal is nu CC interactions with single pion in the final state. Due to the high dependence of the background generation on the computational power:

- Generated in STT only
- Cherry picking GENIE technique

From the sample of the reconstructed background events for 6 years of exposure, 11 candidates passed the selection, mimicking the pi mu signal.



Final Sensitivity

The preliminary results final sensitivity has been calculated for benchmark II, and it shows a factor ~ 3 degradation with respect to the phenomenological sensitivity, which is promising, thanks to the performance of the Kalman filter. For all dominant Ds channels the final sensitivity for benchmark II sets an upper limit reaching ~6 10⁻⁹ in the U²-M phase space. Such result can only get better, given the conservative calculation of the phenomenological sensitivity and the missing channels.