



University of  
Zurich<sup>UZH</sup>



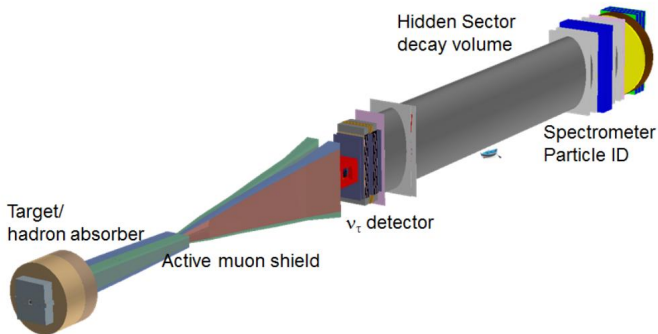
## SHiP

ν Background in Air

N. Chételat   N. Serra   B. Storaci  
6th SHiP Collaboration Meeting 7-9.10.15

9.10.2015

# Set up



Is vacuum really needed in the decay volume?

Or can we work with air at atmospheric pressure and a low density gas?

## How to produce an neutrino sample sample?

- ▶ Produce events in Genie (with `run_simScript.py`)
- ▶ Run the reconstruction (with `ShipReco.py`)
- ▶ Run our own analysis file which is based on `ShipAna.py`
- ▶ study the ntuple

## How to produce this sample?

- ▶ replace the vacuum in the decay volume by air at atmospheric pressure (in `cave.geo`)
- ▶ reconfigure Genie to only produce events in the z-range of the decay volume (change in `run_SimScript.py`)
- ▶ reconfigure the interaction points such that it only interacts inside the decay volume (change in `GenieGenerator.cxx`)

## Characteristics of the ntuple

With only the first 2 steps from last slide and then removing all events not inside the decay volume

	# Generated events	reconstructed (entries)	not vetoed (entries)
$\nu$	48553	5676	213
$\bar{\nu}$	47777	3344	186

- ▶ air density in the cave:  $1.205\text{e-}3 \text{ g} \cdot \text{cm}^{-3}$  ( $10^5 \cdot$  vacuum)
- ▶ produced between the straw veto (center + 1m) and the first tracking station (center - 1m)
- ▶ produced inside the ellipse:  $(x^2/249^2 + y^2/499^2) < 1$

## $\nu$ Interaction in the Air sample

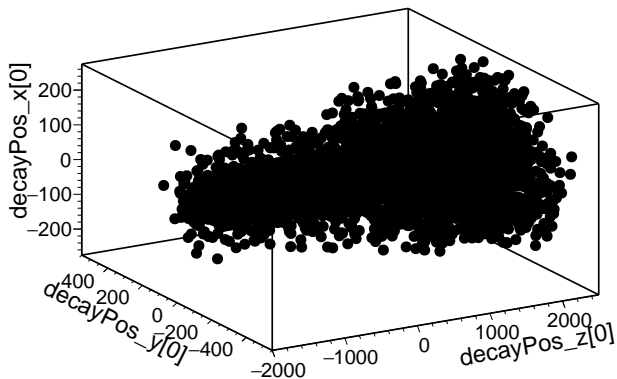


Figure : Position of nuAir interactionPoint (reconstructed)

## Where the neutrinos interact, comparison Addendum ntuple - Air ntuple

<b>neutrino in surroundings</b>			
detector	total reconstructed (%)	not vetoed (%)	selected (%)
$\nu$ detector	17957.4 (57.6)	4.3 (4.9)	0.2 (100.0)
vessel lids	281.6 (0.9)	0 (0.0)	0 (0.0)
vessel walls	12556.9 (40.3)	37.5 (43.0)	0 (0.0)
straw veto	0 (0.0)	0 (0.0)	0 (0.0)
tracking system	362.2 (1.2)	45.5 (52.1)	0 (0.0)
cave	0 (0.0)	0 (0.0)	0 (0.0)
others	4.1 (0.0)	0 (0.0)	0 (0.0)
<b>total</b>	<b>31162.1</b>	<b>87.3</b>	<b>0.21</b>
<b>neutrino in air</b>			
detector	total reconstructed (%)	not vetoed (%)	selected (%)
$\nu$ detector	0 (0.0)	0 (0.0)	0 (0.0)
vessel lids	0 (0.0)	0 (0.0)	0 (0.0)
vessel walls	0 (0.0)	0 (0.0)	0 (0.0)
straw veto	0 (0.0)	0 (0.0)	0 (0.0)
tracking system	0 (0.0)	0 (0.0)	0 (0.0)
cave	5774.2 (100.0)	216.7 (100.0)	2.03 (100.0)
others	0 (0.0)	0 (0.0)	0 (0.0)
<b>total</b>	<b>5774.2</b>	<b>216.7</b>	<b>2.03</b>

## How the interactions are distributed inside the decay volume

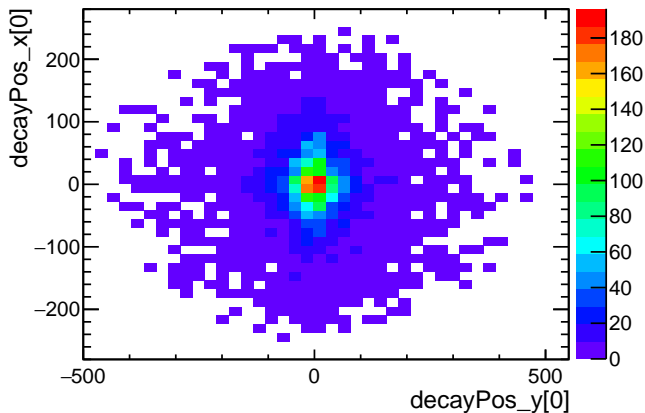


Figure : interaction coordinates of interaction in cave, nu-Air-sample



## Selection cuts

- ▶ 1 HNL candidate
- ▶ Vertex position in the vacuum vessel
- ▶ Tracks are in the fiducial volume
- ▶ Ndf of the tracks  $> 25$
- ▶ Distance of closest approach  $< 1$  cm
- ▶  $\chi^2/\text{N.d.F}$  of the reconstructed tracks  $< 5$
- ▶ The minimum track momentum  $> 1.5$  GeV
- ▶ Impact parameter  $< 10$  cm OR IP  $< 2.5$ m
- ▶ Event not vetoed

## Selection efficiency of the offline selection - $\nu$

Selection efficiency = how many BG events survive the selection

Selection	Entries	Events / 5 years	Selection efficiency
Event reconstructed	5676	5774	-
1 HNL Candidate	3258	3314	57.4 %
Vtx in fiducial vol.	3062	3115	94.0 %
tracks in fiducial vol.	2470	2513	80.7 %
N.d.f > 25	1841	1873	74.5 %
DOCA < 1cm	985	1002	53.5 %
$\chi^2 / \text{N.d.f} < 5$	985	1002	100.0 %
Daughters $P > 1 \text{ GeV}$	905.0	921	91.9 %
IP < 0.1cm	2	2.0	0.2 %
Event not vetoed	2	2.0	100.0 %
IP < 2.5m	235	239.1	26.0 %
Event not vetoed	20	20.3	8.5 %

## Selection efficiency of the offline selection - $\bar{\nu}$

Selection efficiency = how many BG events survive the selection

Selection	Entries	Events / 5 years	Selection efficiency
Event reconstructed	3344	1790	-
1 HNL Candidate	1928	1032	57.7 %
Vtx in fiducial vol.	1841	986	95.5 %
tracks in fiducial vol.	1506	806	81.8 %
N.d.f > 25	1151	616	76.4 %
DOCA < 1cm	621	332	54.0 %
$\chi^2 / \text{N.d.f} < 5$	621	332	100.0 %
Daughters $P > 1 \text{ GeV}$	584.0	313	94.0 %
IP < 0.1cm	6	3.2	1.0 %
Event not vetoed	5	2.7	83.3 %
IP < 2.5m	206	110.3	35.3 %
Event not vetoed	38	20.3	18.4 %

## neutrino veto systems - $\nu$ and $\bar{\nu}$

Veto efficiency = How many events can be removed by this veto

IP is an pre-selection cut

Selection $\nu$	Entries	Events / 5 years	Veto efficiency
Event reconstructed	3258	3314	-
Straw veto	3184	3239	2.3 %
Upstream veto	3177	3232	0.2 %
Liquid Scintillator	172	175	94.6 %
IP < 10m	125	127	27.3 %

Selection $\bar{\nu}$	Entries	Events / 5 years	Veto efficiency
Event reconstructed	1928	1032	-
Straw veto	1885	1009	2.2 %
Upstream veto	1884	1009	0.1 %
Liquid Scintillator	142	76	92.5 %
IP < 10m	115	62	19.0 %

## Tables for Air sample

The Statistical Factor is  $(\# \text{ MC events})/(\# \text{ weighted events})$

Background source	Statistical Factor	Expected Background
$\nu$ ( $p > 10.0 \text{ GeV}$ )	0.98	5.42
$\nu$ ( $4.0 \text{ GeV} < p < 10.0 \text{ GeV}$ )	0.98	5.42
$\nu$ ( $2.0 \text{ GeV} < p < 4.0 \text{ GeV}$ )	0.98	5.42

Background source	Statistical Factor	Expected Background
$\bar{\nu}$ ( $p > 10.0 \text{ GeV}$ )	1.87	2.85
$\bar{\nu}$ ( $4.0 \text{ GeV} < p < 10.0 \text{ GeV}$ )	1.87	2.85
$\bar{\nu}$ ( $2.0 \text{ GeV} < p < 4.0 \text{ GeV}$ )	1.87	2.85

Density air:  $1.205\text{e-}3 \text{ g} \cdot \text{cm}^{-3}$

Density  $^4\text{He}$ :  $1.785\text{e-}4 \text{ g} \cdot \text{cm}^{-3}$

$$\Rightarrow \text{Reduction factor} = \frac{\rho_{\text{air}}}{\rho_{\text{helium}}} = 6.67$$

Thank you

# neutrino veto systems

## neutrino

Veto Systems - $\nu$	reconstructed entries (weighted)	selected entries (weighted)
No veto applied	5676 (5774.3)	2 (2.0)
Muon Magnetic Spectrometer	5512 (5607.5)	2 (2.0)
Upstream Veto Tagger	5640 (5737.7)	2 (2.0)
Straw Veto Tagger	5553 (5649.2)	2 (2.0)
Surrounding Background Tagger	283 (287.9)	2 (2.0)
All veto systems applied	213 (216.7)	2 (2.0)

## antineutrino

Veto Systems - $\bar{\nu}$	reconstructed entries (weighted)	selected entries (weighted)
No veto applied	3344 (1790.4)	6 (3.2)
Muon Magnetic Spectrometer	3228 (1728.3)	6 (3.2)
Upstream Veto Tagger	3328 (1781.8)	6 (3.2)
Straw Veto Tagger	3269 (1750.2)	6 (3.2)
Surrounding Background Tagger	219 (117.3)	5 (2.7)
All veto systems applied	186 (99.6)	5 (2.7)