Optimizing SHiP Sensitivity with Particle Identifiction (Pid)

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Overview

- Pid on HNL data
- Neutrino background
- Toy MC and SHiP sensitivity
- Visible decay efficiencies
- SHiP sensitivity with cuts on impact parameter

Pid

- Pid is a tool for particle identification in the reconstruction in FairShip
- Pid divides the particles in to three categories: Electrons, muons and hadrons

HNL Data

- The HNL data used has all visible decay channels open and a mass of 1 GeV
- The couplings are from model 2 in the TP

Applied cuts

	HNL 1 GeV
Simulated Events	30000
Reconstructed HNL candidates	4188
1 HNL candidate in event	3945
Vertex in fiducial volume	3333
Tracks in fiducial volume	3072
N.d.f > 25	2874
Doca < 1 cm	2614
Chi^2/N.d.f < 5	2613
P > 1.5 GeV	2563
Ip < 10 cm	929
No Veto	897

Pid Efficiency from HNL 1 GeV after N.d.f cut

	2 e	2 mu	2 h	E + mu	H + e	H +μ	Total
Identified with MC	102	289	438	502	93	1450	2874
Identified with MC as well as Pid	96	234	419	441	86	1267	2543
Efficiency	0.941	0.809	0.957	0.878	0.914	0.874	0.884

Improvements have been made on Pid[1] since the version used in this study (from FairShip version 1.7.1)

[1] see Behzad's talk from Tuesday

HNL 1 GeV Final states according to Pid

Cuts\Pid final states		2e	2μ	2h	E + μ	E + h	H + μ	Total
N.d.f > 25		103	256	544	480	156	1333	2872
lp<10 cm	lp cut	2	23	74	31	45	754	929
	Veto	2	23	71	31	41	729	897
lp < 250 cm	lp cut	76	214	451	410	107	1177	2435
	Veto	75	213	420	408	97	1085	2298

The figures in this table show the gain in signal when increasing the lp tolerance of specific final states with Pid

Comparison to MC Identification

	Ip < 10 cm for H+L Ip < 250 cm for L+L and H+H		Ip < 250 cm for L+L, Ip < 10 cm for H+L and H+H		Ip < 250 cm
Simulated events	30000		30000		30000
Cuts up to Doca	2874		2874		2874
	Using MC Pdg	Using Pid	Using MC Pdg	Using Pid	
Ip cut	1941	1950	1583	1573	2435
Not Vetoed	1887	1886	1549	1537	2298
Increase compared to cutting on Ip = 10 cm on everything	1887/897 =2.10	1886/897 =2.10	1549/897 =1.73	1537/897 =1.71	2298/897 =2.56

This shows the gain in signal acceptance in the 1 GeV case with the different selections with – or without Pid

Neutrino Background

- $1.4*10^7$ Neutrino interactions in vacuum have been used

Neutrino background after all cuts (Ip<250 cm) except veto			
Identified with MC\Pid	L+L	H+H	H+L
L+L	19	3	0
H+H	0	13	1
H+L	3	5	26

Final states that pass veto in neutrino background		
L+L	H+H	H+L
10 %	30 %	60 %

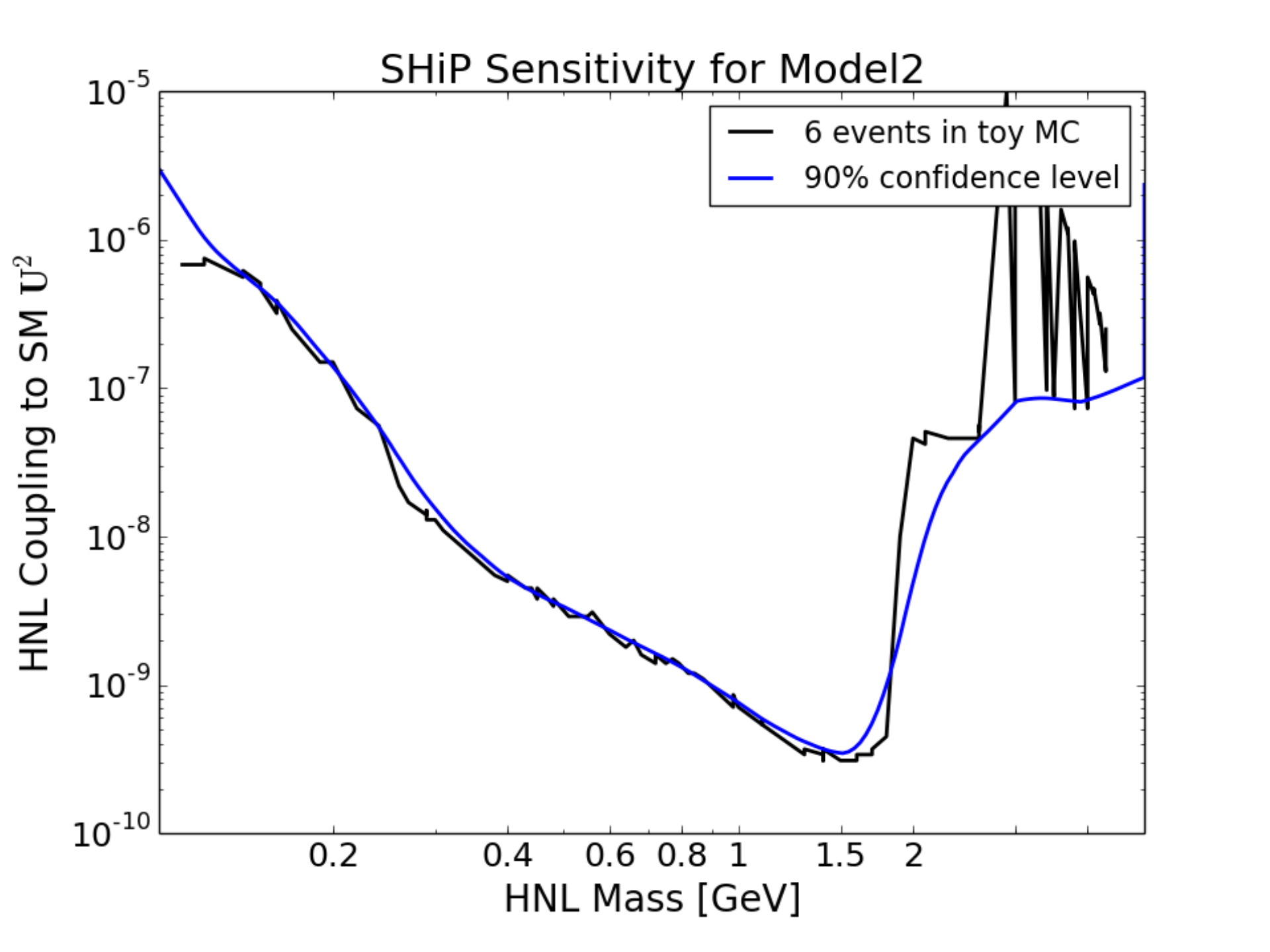
- The neutrino background is estimated to be 0.5 during the 5 years of data taking, when cutting at Ip=250 cm and veto

Ip < 250	Pid: H+L -> Ip < 10 cm	Pid: L+L -> Ip<250 cm	Ip < 10 cm
0.5	0.23	0.07	<0.029

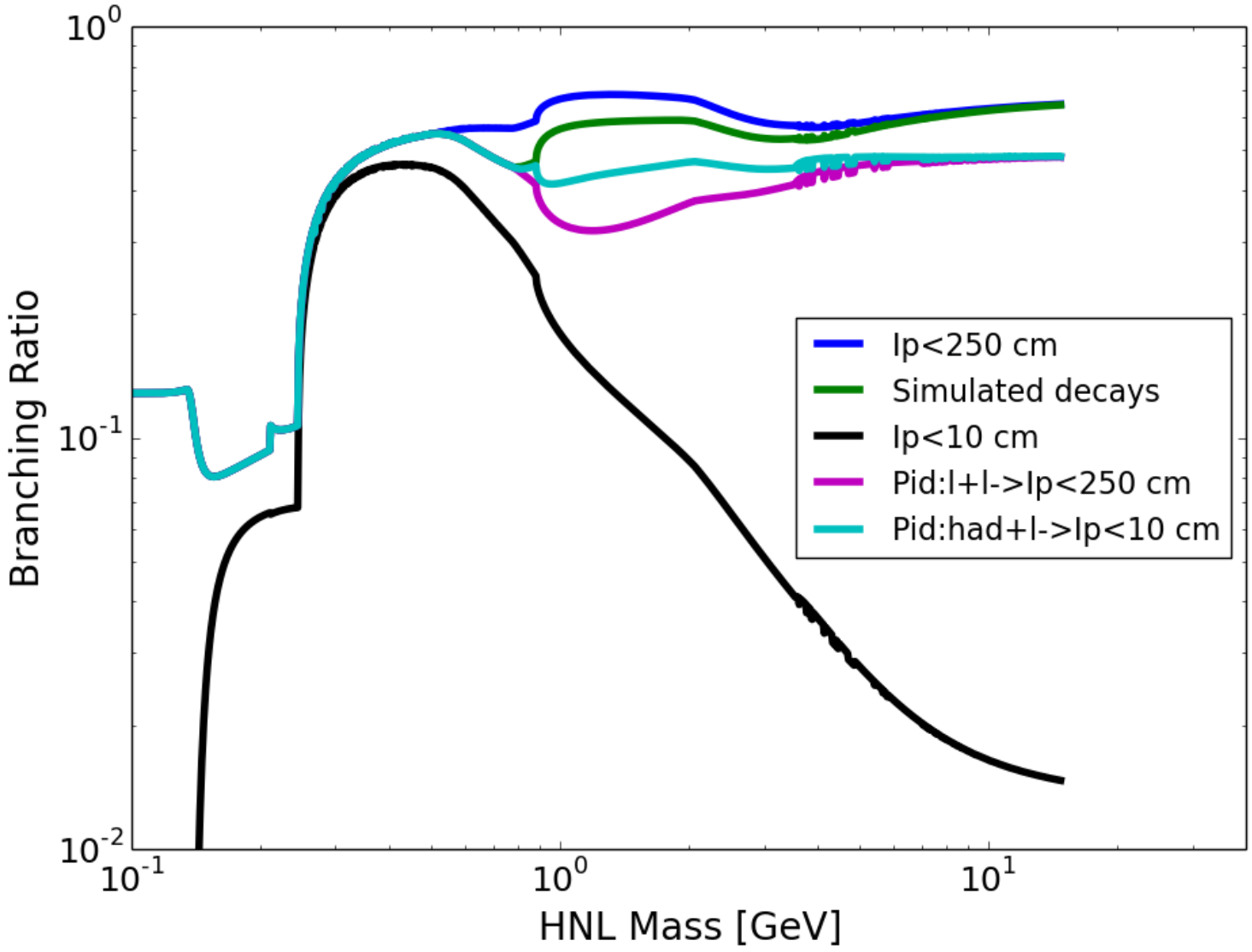
- Using Pid at this stage, one can reduce the neutrino background by up to a factor 7 compared to cutting on Ip = 250 cm on everything

Toy MC and Ship sensitivity

- The toy MC applies the following cuts before printing out the HNL yield:
  - Decay within decay volume
  - Vertex and tracks within fiducial volume
  - Tracks hitting straw trackers and muon stations
  - Multiplied by 0.6 as a correction factor due to fluctuations in toy MC compared to FairShip
- The 90% confidence limit for at least 2 HNL events is set at 6 events in the toy MC


SHiP Sensitivity for Model2
6 events in toy MC
90% confidence level
HNL Coupling to SM U²
HNL Mass [GeV]
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
0.2
0.4
0.6
0.8
1
1.5
2

Visible decay Efficiencies

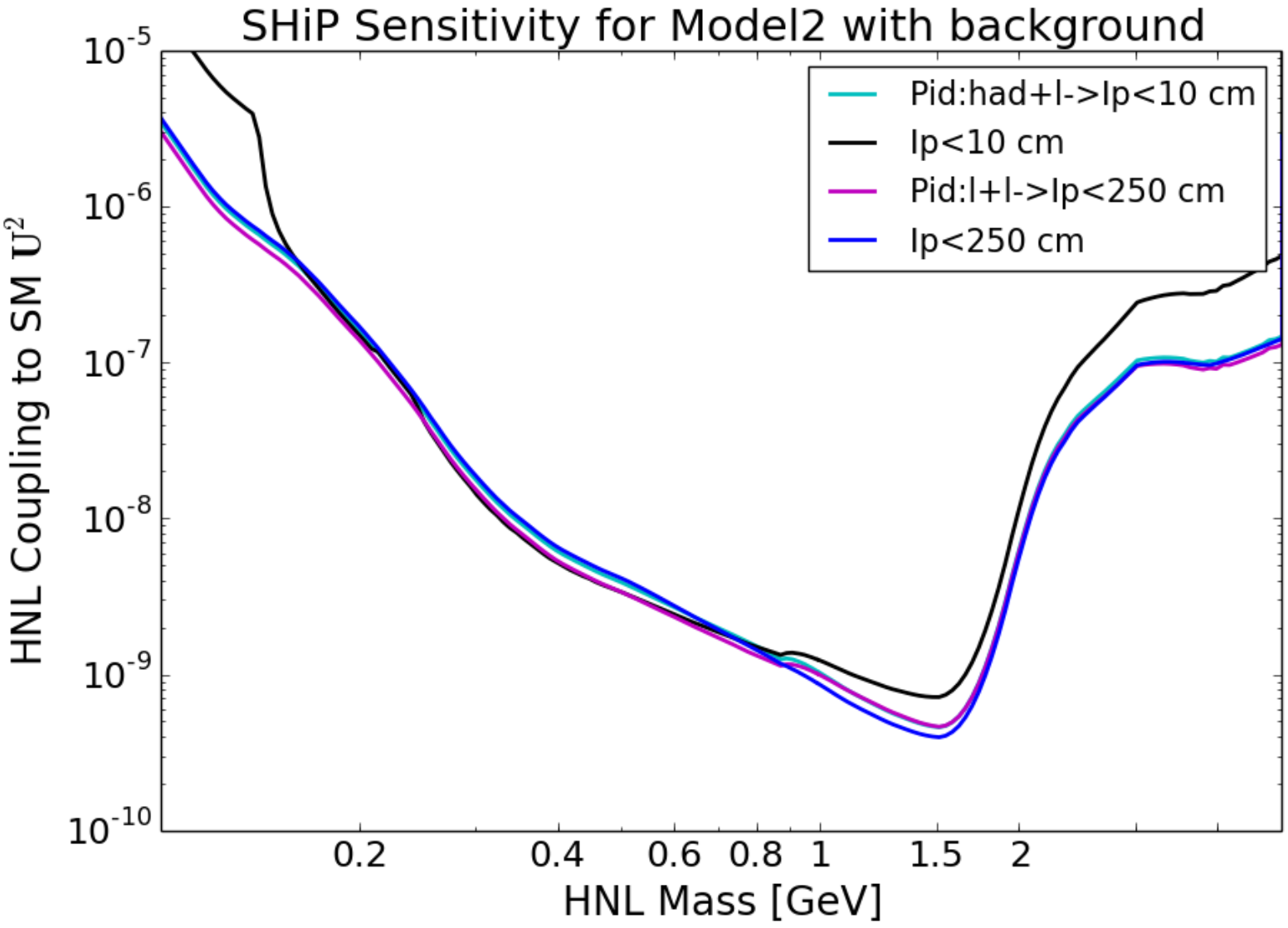


Cut Efficiencies on Background in Vacuum

- The muon backgrounds are assumed to be 0.05 in total
- The neutrino background is estimated to be 0.5, when cutting at lp=250 cm and veto

	neutrino	muon	total	<nHNL>
lp < 250	0.5	0.05	0.55	9
Pid: h+l -> lp < 10 cm	0.23	0.05	0.29	8
Pid: l+l -> lp<250 cm	0.07	0.05	0.12	6
lp < 10 cm	<0.029	<0.003	<0.031	5

SHiP Sensitivity with lp cuts



Conclusion

- The gain in signal/background ratio is cancelled out with the reduction in signal yield when using Pid to adjust the Ip cuts, when vacuum is used in the decay volume
- In the high and low mass regions, there is a large gain in using Pid rather than cutting at Ip = 10 cm on everything
- One can further improve the signal by also making considerations on reconstructed mass
- Identification of the final state will prove useful for analyzing the signal to study the HNL properties

Neutrino background files

- Data for neutrino background on lxplus: /eos/ship/data/neutrinoBacground/Yandex-Prod-Dec-2015/output_antinu/566ebec69e747777cdb531XX
- XX range from 2f to 3f in hexadecimal numbers (excluding 33, 35 and 36)

Neutrino Backround estimate

- From analyzing $4.4*10^7$ events, there were 3 events that passed veto – and the fiducial cuts, all with Ip>250 cm
- When using a fiducial cut that goes all the way to the first straw tracker, there were more events passing veto as well, where 3/13 events have Ip < 250 cm
- The expected number of neutrino interactions during the 5 years of data taking is 10^7 while interactions from anti neutrinos are $3*10^6$
- The estimate is then: 1.3*3*3/13/4.4=0.2 to which is added 1.6 σ (σ=0.18) to get the 90 % confidence level