NON−NEUTRINO FLUXES IN NUMI NEAR HALL

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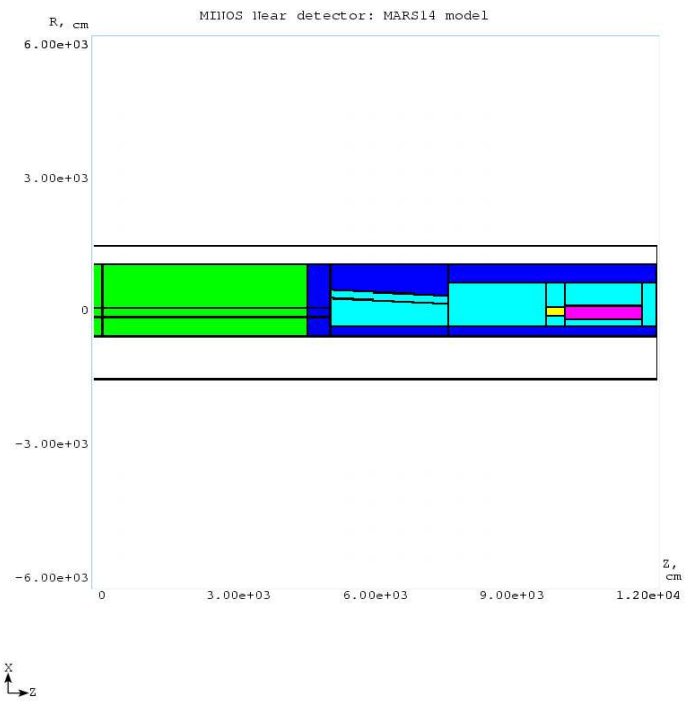
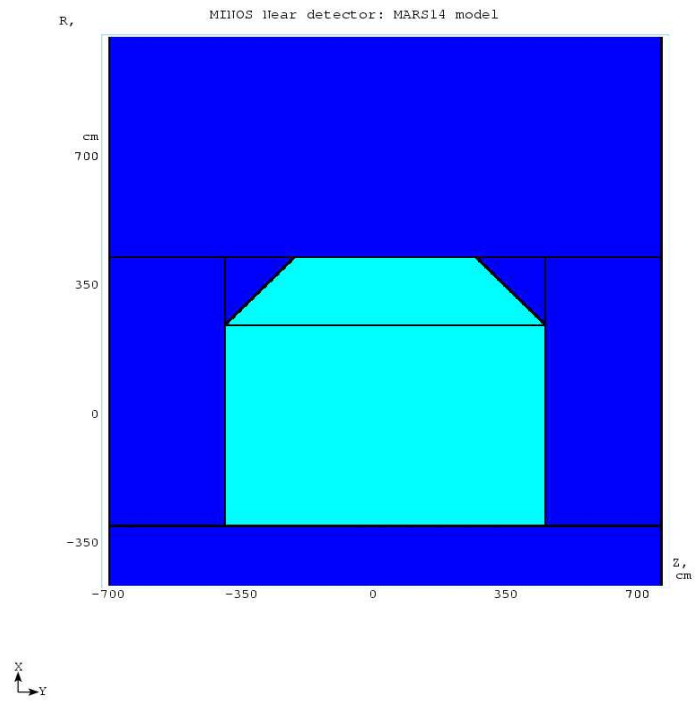
OUTLINE

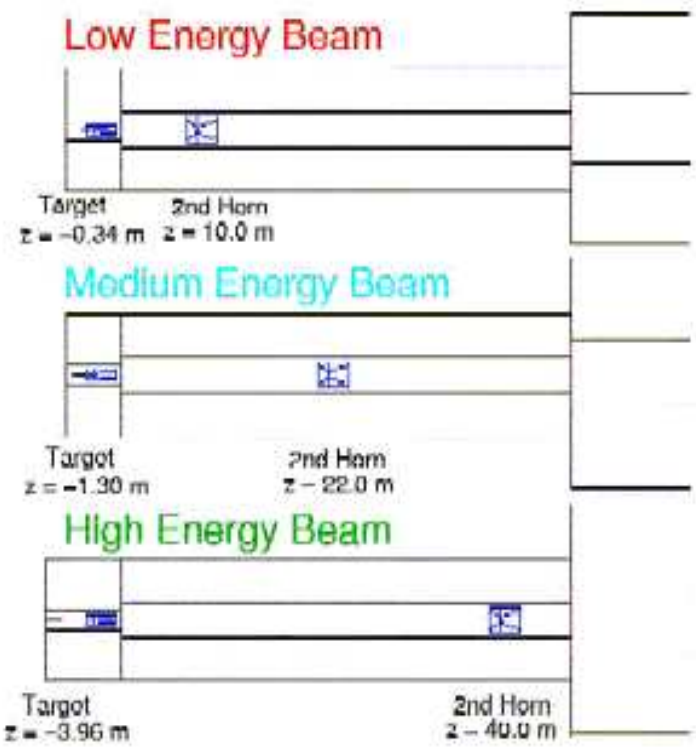
- Neutrino fluxes in the NuMI near hall
- Neutrino interaction model in MARS14 code
- Geometry model
- Particle fluxes
- Plans

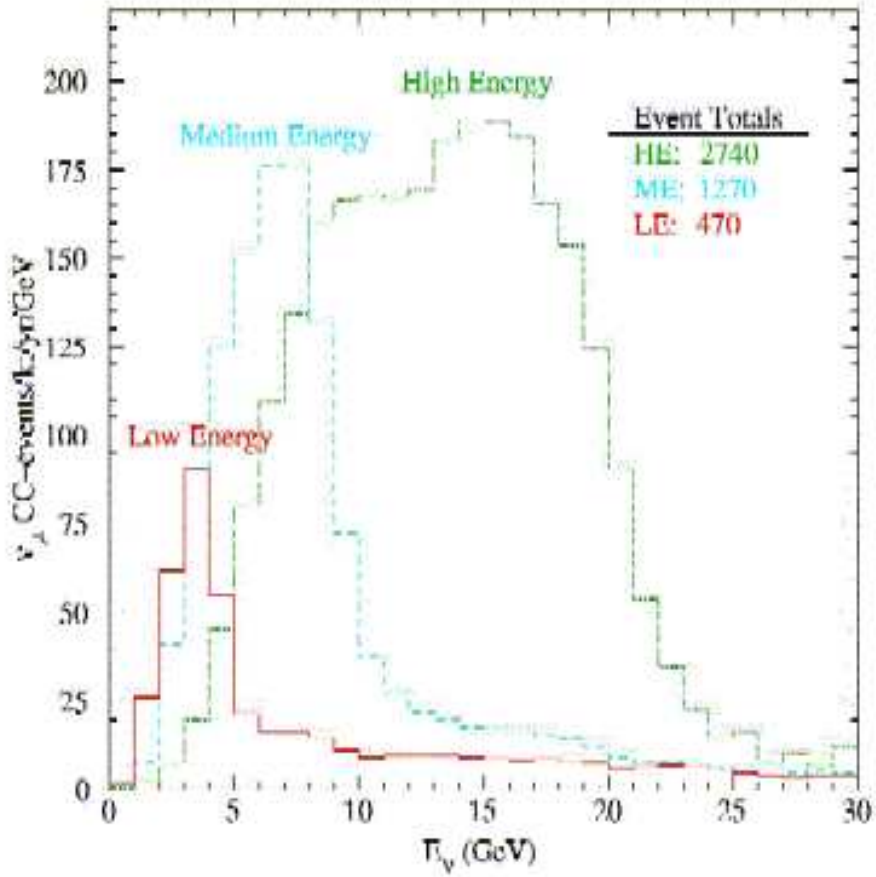
NEAR HALL MARS14 MODEL



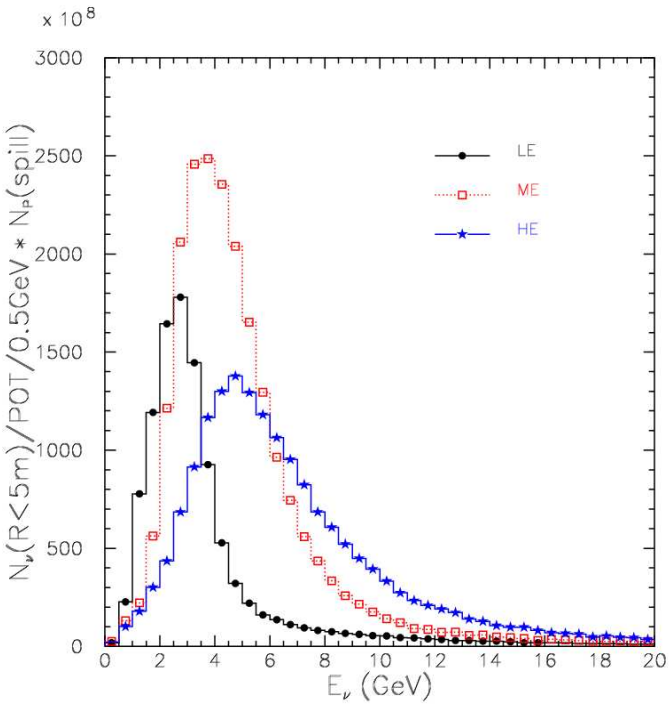


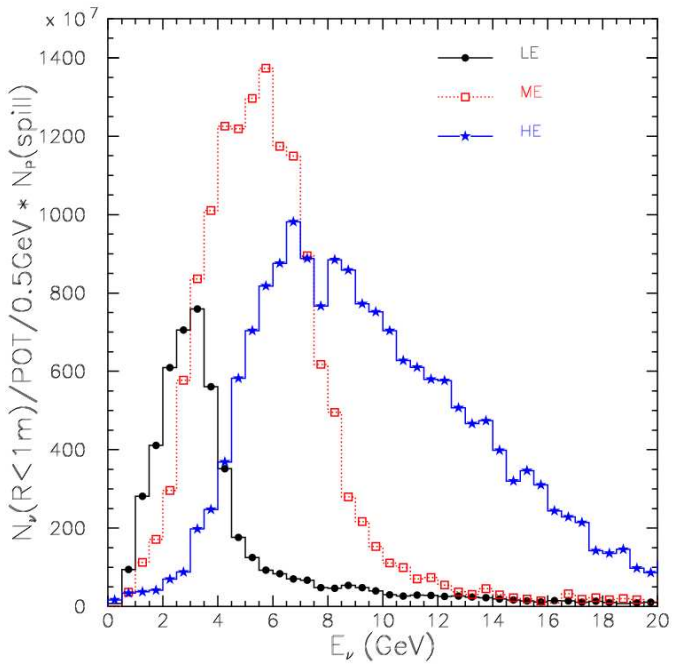
NuMI Beam Lines



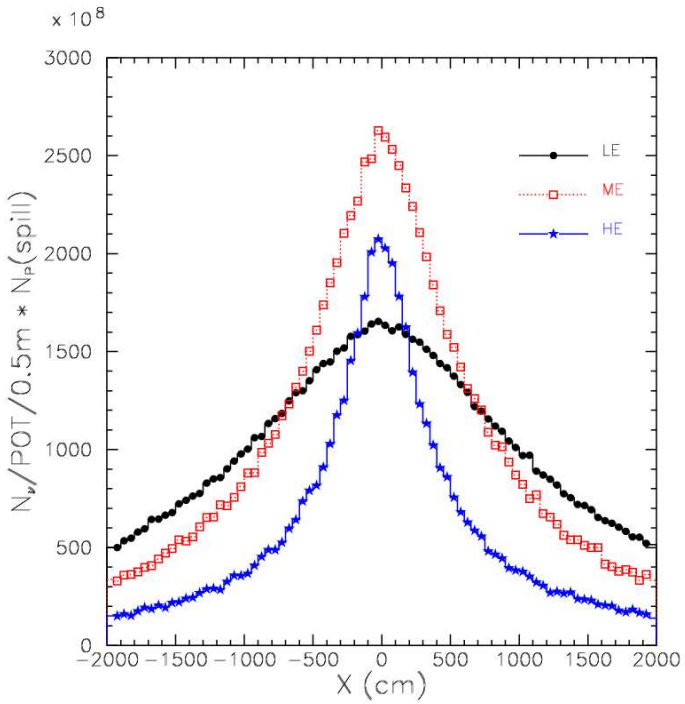


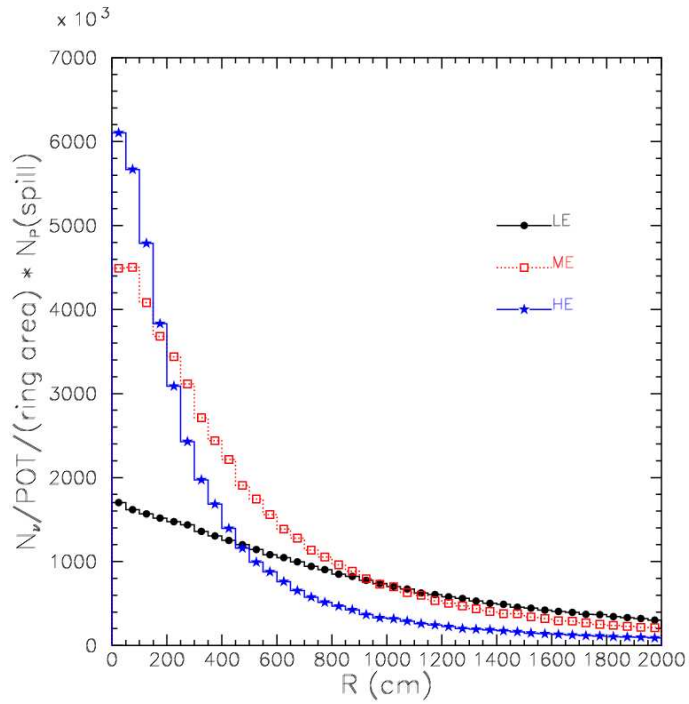
NEUTRINO SPECTRA AT R<5m AND R<1m





NEUTRINO RADIAL DISTRIBUTIONS





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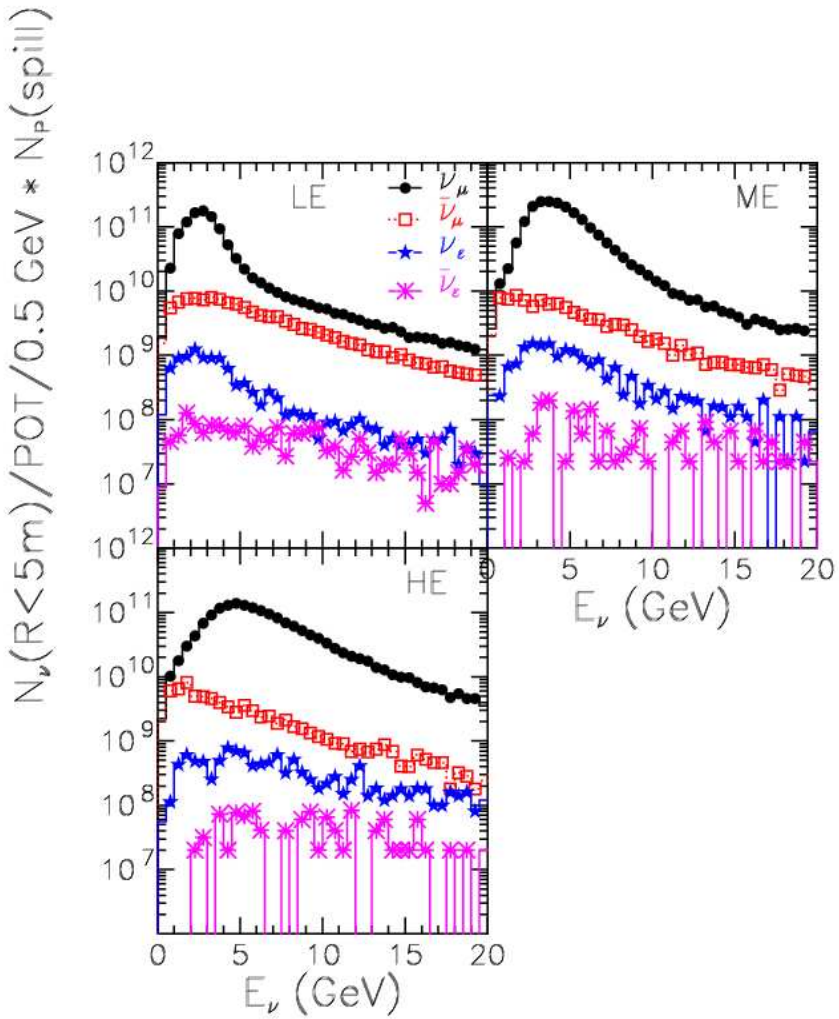
NEUTRINO SPECTRA AT NEAR HALL



NEUTRINOS IN MARS14

The neutrino interaction model represents energy and angle of the emanating particles, i.e. ν, $e^{\pm}$, $\mu^{\pm}$ and hadrons.

The model distinguishes ν_μ, $\overline{\nu}_\mu$, ν_e and $\overline{\nu}_e$.

The model identifies *eight* types of interactions for ν_μ, $\overline{\nu}_\mu$. And similarly for ν_e, $\overline{\nu}_e$.

1)	$\nu_\mu N \to \mu^+ X$	$\overline{\nu}_\mu N \to \mu^- X$
2)	$\nu_\mu N \to \nu_\mu X$	$\overline{\nu}_\mu N \to \overline{\nu}_\mu X$
3)	$\nu_\mu p \to \mu^+ n$	$\overline{\nu}_\mu n \to \mu^- p$
4)	$\nu_\mu p \to \nu_\mu p$	$\overline{\nu}_\mu p \to \overline{\nu}_\mu p$
5)	$\nu_\mu n \to \nu_\mu n$	$\overline{\nu}_\mu n \to \overline{\nu}_\mu n$
6)	$\nu_\mu e^- \to \nu_\mu e^-$	$\overline{\nu}_\mu e^- \to \overline{\nu}_\mu e^-$
7)	$\nu_\mu e^- \to \nu_e \mu^-$	
8)	$\nu_\mu A \to \nu_\mu A$	$\overline{\nu}_\mu A \to \overline{\nu}_\mu A$

1) CC DIS
X – π, K and nucleons
$\sigma_\nu = 6.7 \times 10^{-39} E_\nu$ per nucleon
$\sigma_{\overline{\nu}} = 3.4 \times 10^{-39} E_{\overline{\nu}}$ per nucleon
(E in GeV, σ in cm^2)

The differential cross section:
$\frac{d\sigma}{dx\,dy} = \frac{G^2 xs}{2\pi}(Q(x) + (1-y)^2 \overline{Q}(x))$
$x = -q^2/2M\nu$, q - momentum transfer, M - nucleon mass, ν - energy loss of neutrino in the lab, y = ν/E_ν, G - Fermi coupling constant, $Q(x)$ - quark momentum distribution.
For antineutrinos $Q(x)$ and $\overline{Q}(x)$ are interchanged.
$Q(x)$ and $\overline{Q}(x)$ are taken from experiment in numerical form.

Once $\vec{p}$ of lepton is decided, total vectorial momentum is balanced by a single π which is forced to undergo a deep inelastic interaction in the same nucleus. This coarse 'hadronization' is justifiable since we are interested in certain gross averages over the showers.

NEUTRINOS IN MARS14

2) NC DIS

$\sigma_\nu = 2.2 \times 10^{-39} E_\nu$

$\sigma_{\overline{\nu}} = 1.35 \times 10^{-39} E_{\overline{\nu}}$

$\frac{d\sigma}{dx\,dy} = \frac{G^2 xs}{2\pi} g_L^2 (Q(x) + (1-y)^2 \overline{Q}(x))$

$+ \frac{G^2 xs}{2\pi} g_R^2 (\overline{Q}(x) + (1-y)^2 Q(x))$

with $g_L^2 = 0.30$ and $g_R^2 = 0.024$.

$Q(x)$ and $\overline{Q}(x)$ are interchangeable for antineutrinos.

Same 'hadronization' as for CC DIS.

CC DIS and NC DIS form the main contribution to dose from neutrino interactions.

3) – 5) – neutrino nucleon elastic and quasi-elastic scattering.

$\frac{d\sigma}{d|q^2|} = \frac{G^2 x M^2}{8\pi E_\nu^2} (A \pm B \frac{s-u}{M^2} + C \frac{(c-u)^2}{M^4})$

'+' for ν, '-' for $\overline{\nu}$

A,B,C – functions of q^2-dependent form factors (taken from some paper).

Total cross section is obtained by integrating the above equation. The equation is difficult to sample directly so that results from it are fitted to simple analytical forms. For nuclear targets a 'Pauli factor' is included (as a weight) to discourage small $|q^2|$ which are insufficient to liberate a nucleon or promote the nucleus to an excited state.

NEUTRINOS IN MARS14

6) – 7) – neutrino interactions with atomic electrons.
Included for completeness (contribution to dose is small)

For NC:
$\frac{d\sigma}{dy} = \frac{G^2 m_e E_\nu}{8\pi}(a + b(1-y)^2)$
where a,b are simple combinations of coupling constants. For ν_μ and $\overline{\nu}_\mu$ $a \approx b \approx 1$, for ν_e and $\overline{\nu}_e$ $a \approx 9, b \approx 1$, a and b are reversed for $\overline{\nu}_e$

For CC, only $\nu_\mu e^- \rightarrow \nu_e \mu^-$ and $\overline{\nu}_e e^- \rightarrow \overline{\nu}_\mu \mu^-$

$\frac{d\sigma}{dy} = 2\frac{G^2 m_e E_\nu}{\pi}$ for ν_μ and

$\frac{d\sigma}{dy} = 2\frac{G^2 m_e E_\nu}{\pi}(1-y)^2$ for $\overline{\nu}_e$

8) – coherent elastic scattering

$\frac{d\sigma}{d\Delta^2} = \frac{G^2 N^2}{8\pi}(1 - \frac{\Delta^2}{\Delta^2_{max}})$

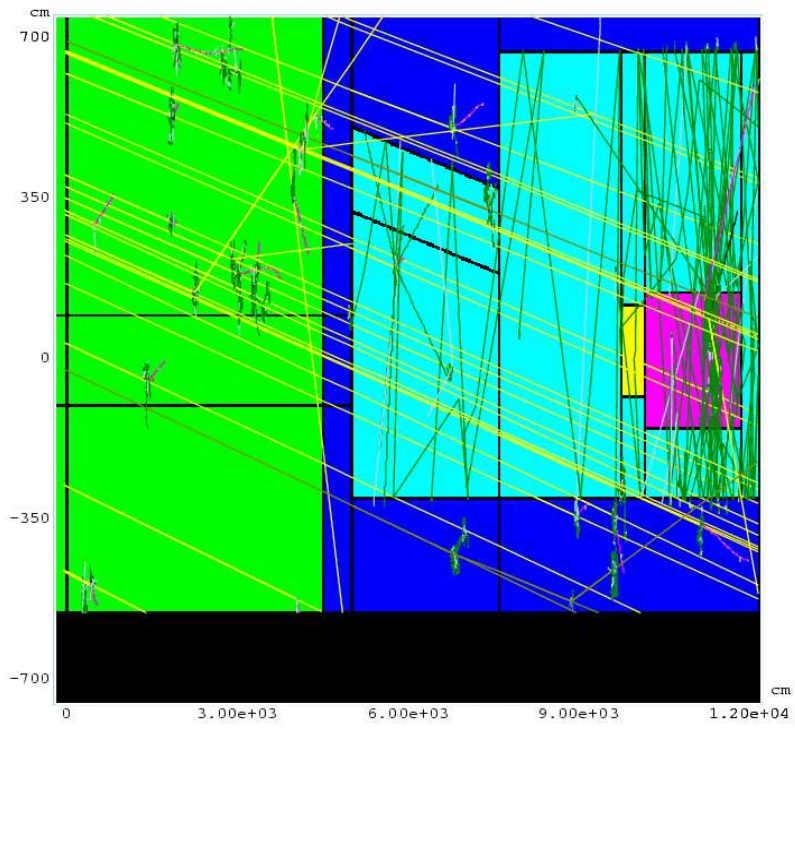
N – number of neutrons in the nucleus

Δ – momentum transfer to the nucleus with $\Delta_{max} = R_A^{-1}$, the inverse nuclear radius.

For all 'elastic' interactions only the recoil is of interest and simulated.

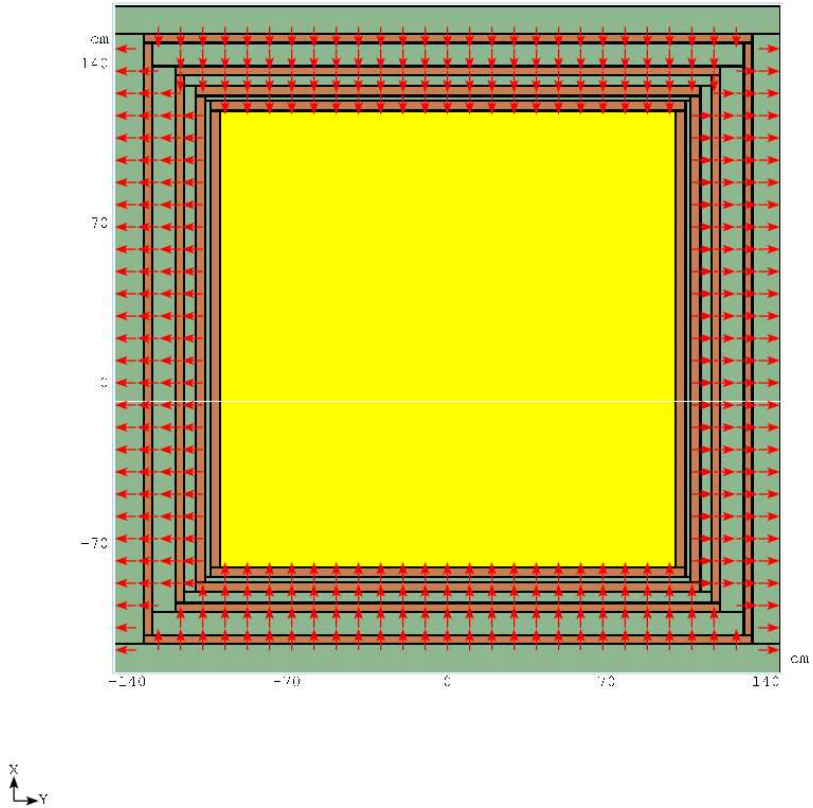
No π production via resonances. Cross section and energy deposition are small compared to deep inelastic processes and coherent elastic scattering.

NEUTRINO INTERACTIONS IN NEAR HALL



Source term: Neutrino interactions in dolomite upstream, R<3m, L<50m.
About 0.2 ν per 1 POT carrying energy of about 1 GeV.
Expected non−neutrino particle flux of ~ 10^{-10} x F ν.

NEW DETECTOR CROSS SECTION



Detector : 2m x 2m x 2m scintillator cube surrounded by a 4−layers sandwich.
Each layer of scintillator is 4cm thick.
Thickness of iron is as follows: 2.5, 5, 10, 12.5 cm.
Iron is magnetized to 3.8 kG.

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PARTICLE FLUXES AVERAGED OVER DETECTOR VOLUME

Case 1: detector plus sandwich

Case 2: no sandwich around detector

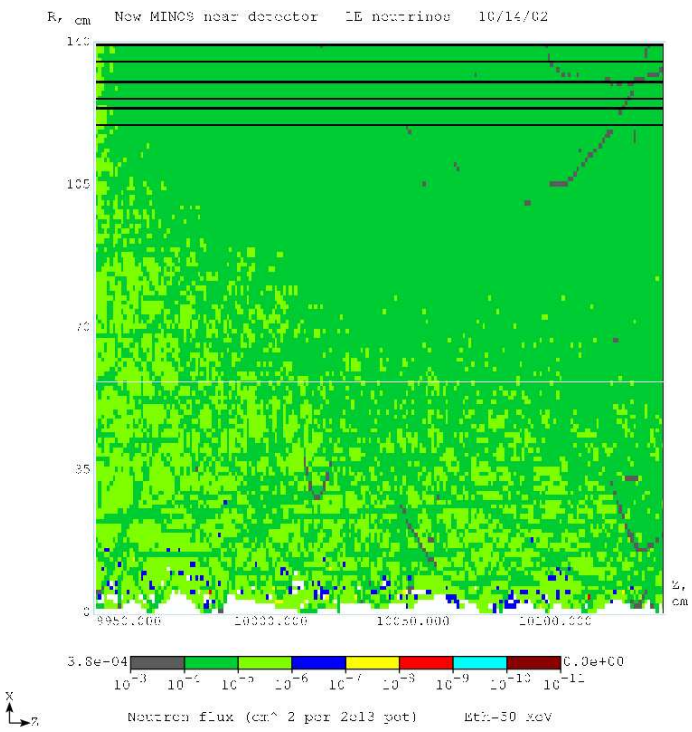
Case 3: detector plus sandwich, particles generated in sandwich ✗do not contribute to the flux in detector.

Eth = 50 MeV; LE neutrino spectra; Ip = 2 x 10e13 POT

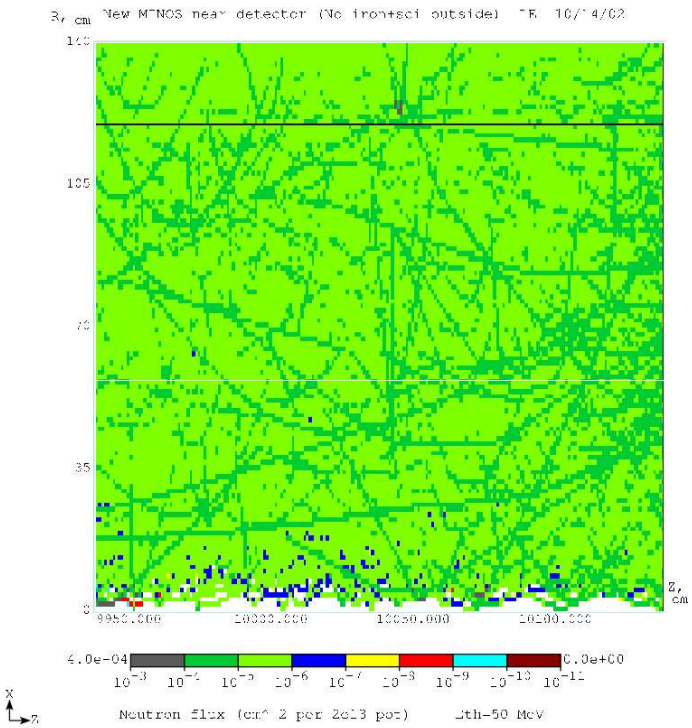
Particle	Flux (10^−5 cm^−2)		
	Case 1	Case 2	Case 3
n	2.235	0.849	0.430
ch. hadrons	0.831	0.458	0.333
photons	1.490	1.058	1.220
e+−	0.758	0.678	0.727
muons	3.644	3.480	3.134

NEUTRON FLUXES (R −Z)

Sandwich



No sandwich



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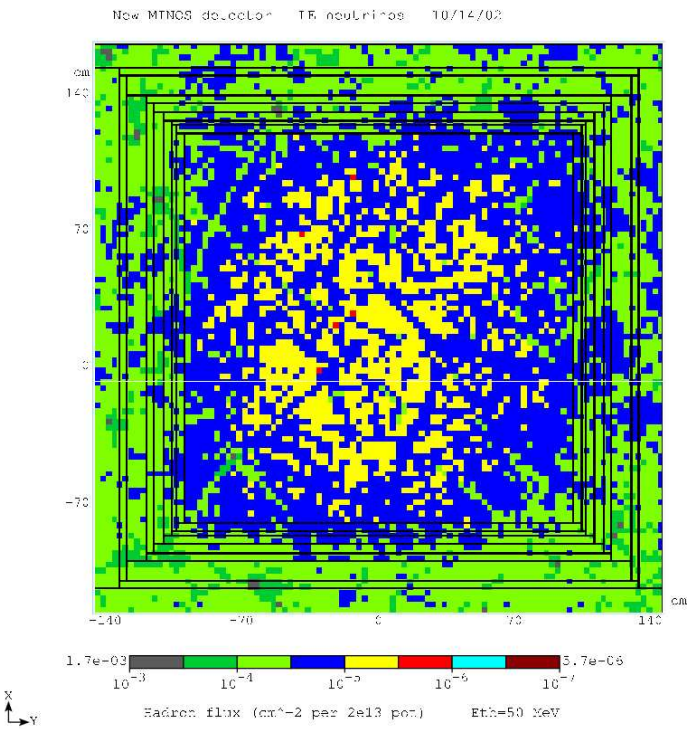
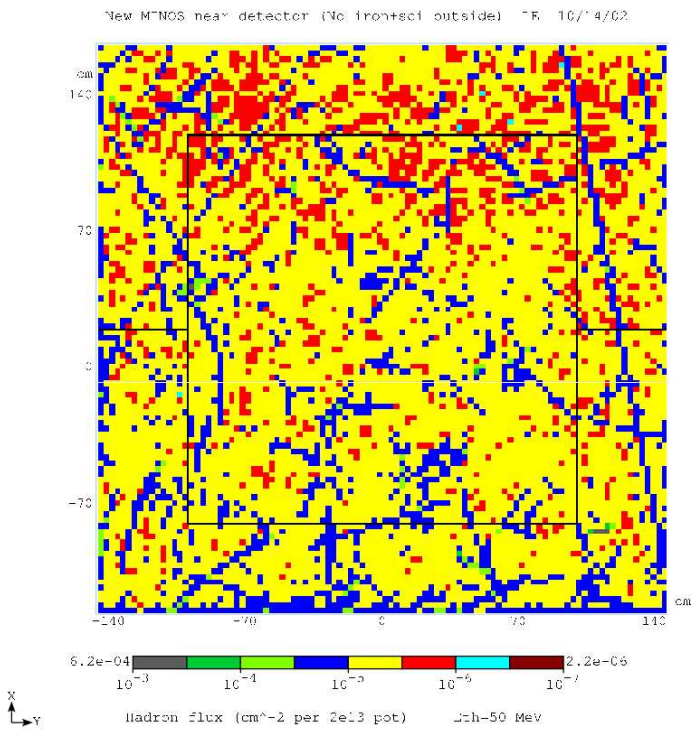
HADRON FLUXES (X −Y)

Sandwich



No sandwich



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FUTURE PLANS

- Revise the model
- Add a proper description of MINOS near detector with B field
- Proper field in new detector
- Try DPMJET III production model
- Write up.