Status of the Near detector simulation

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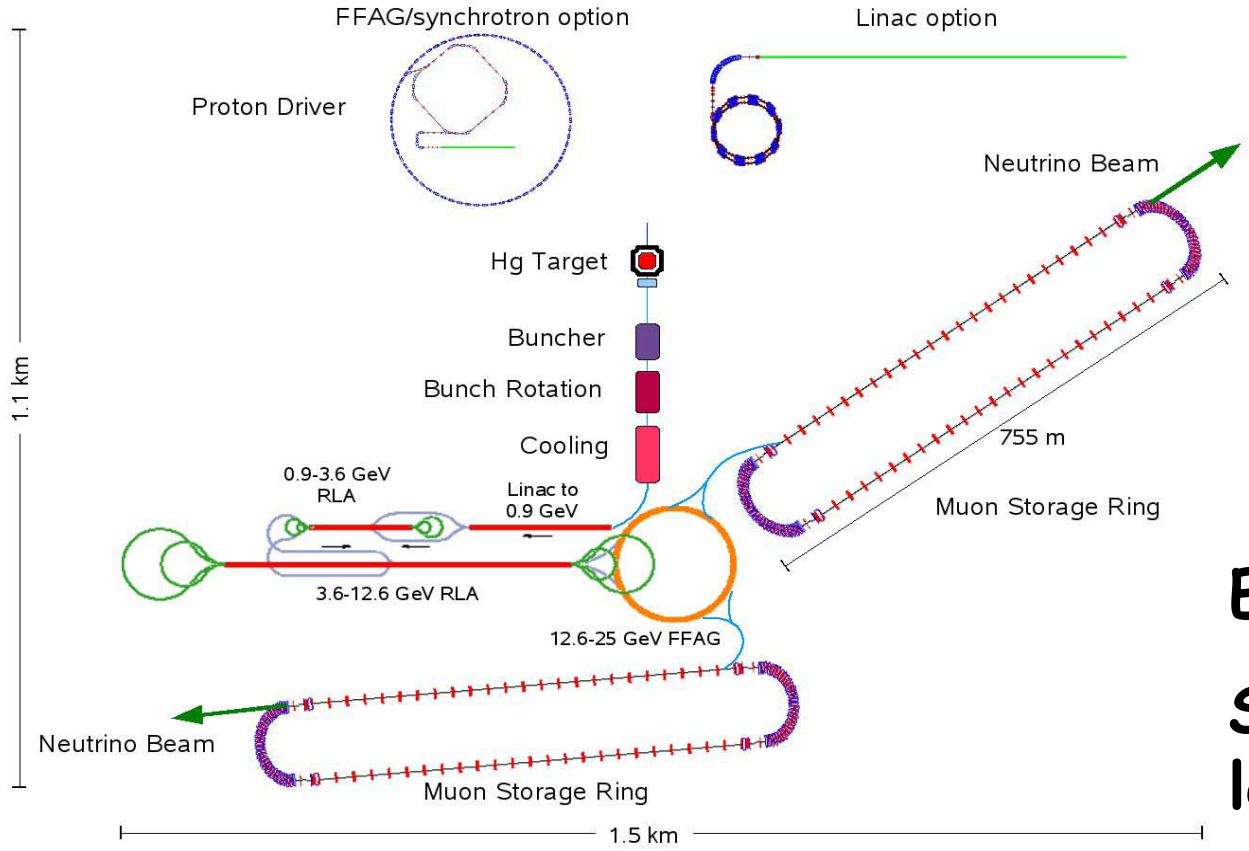
NF baseline



E_μ = 25 GeV

Straight section length = 600 m

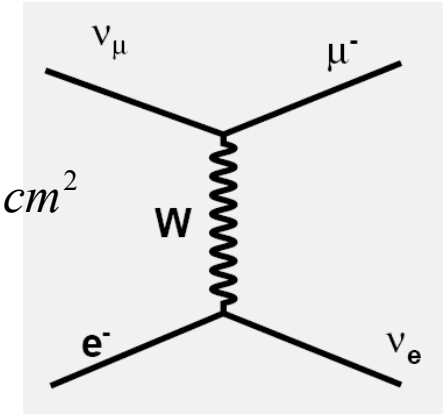
5×10^{20} muon decays/year

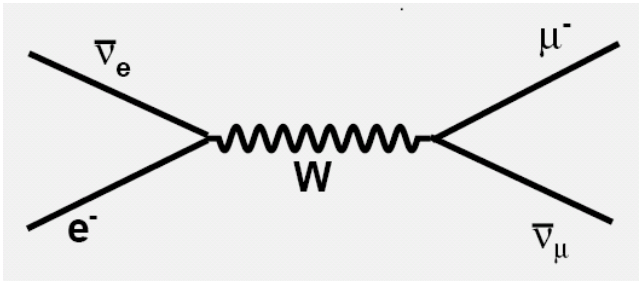
Measurement of the neutrino flux with a Near detector

Quasi elastic scattering off electrons can be used to measure the flux, because its absolute cross-section can be calculated theoretically with enough confidence. The two processes of interest for neutrinos from μ^- decays are:

$$\nu_\mu + e^- \rightarrow \nu_e + \mu^- \qquad \overline{\nu_e} + e^- \rightarrow \overline{\nu_\mu} + \mu^-$$

$$\sigma = \frac{G_F^2}{\pi}\frac{\left(s - m_\mu^2\right)^2}{s} = 8\times 10^{-41} cm^2$$



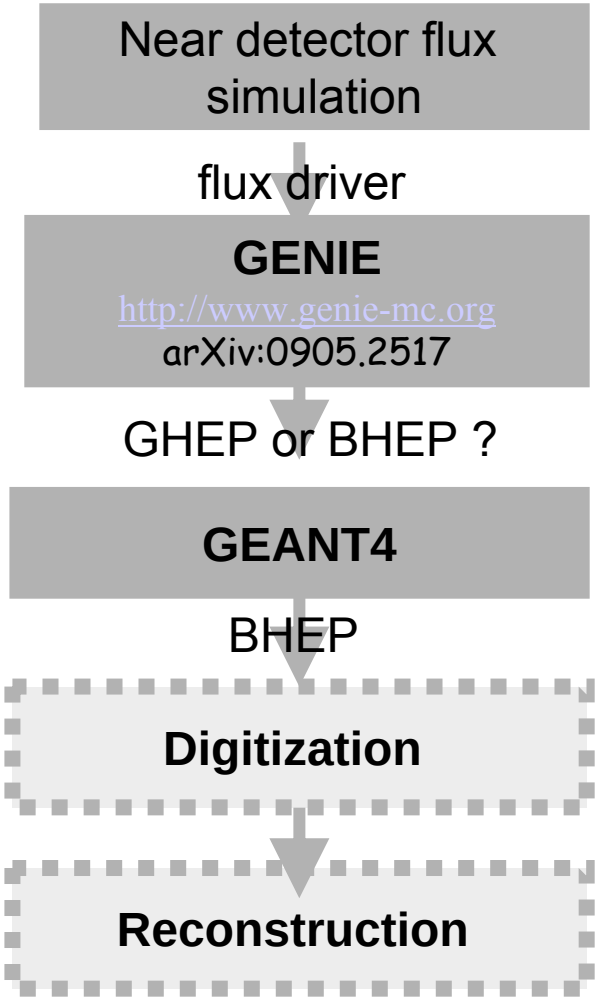


at 20 GeV ν_μ:

~10^3 times less than inclusive one

$$\sigma = \frac{2G_F^2}{\pi}\frac{\left(s - m_\mu^2\right)^2 (E_e E_\mu + \frac{1}{3} E_{\nu 1} E_{\nu 2})}{s^2}$$

Simulation



We aim at measurement of pure leptonic interactions, not inclusive neutrino interactions!

$\nu_\mu + e^- \rightarrow \nu_e + \mu^-$ is in GENIE

$\overline{\nu_e} + e^- \rightarrow \overline{\nu_\mu} + \mu^-$ is not.

Processes included in GENIE

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Quasi-elastic scattering $\nu_\mu + n \rightarrow \mu^- + p$

Elastic NC scattering

Baryon resonance production in CC and NC

Coherent neutrino-nucleus scattering $\nu_\mu + A \rightarrow \mu^- + \pi^+ + A$, $\nu_\mu + A \rightarrow \nu_\mu + \pi^0 + A$

Non-resonant inelastic scattering (DIS)

Quasi-elastic charm production

Deep-inelastic charm production

Neutrino-electron elastic scattering and inverse muon decay $\nu_\mu + e^- \rightarrow \nu_e + \mu^-$

C. Andreopoulos et al., The GENIE Neutrino Monte Carlo Generator, arXiv:0905.2517

Simulation

Muon beam energy smearing : Gaussian

(σ = 80 MeV).

Muon angular spread : Gaussian (σ = 0.5 mrad).

Polarisation: 0 → only $\nu_\mu + e^- \rightarrow \nu_e + \mu^-$ retained.

Number of simulated muon decays: 6.24×10^{16}.

(Event rates on most plots are scaled to 5×10^{20} decays.)

Near detector parameters

Position: 100 m after the straight section end

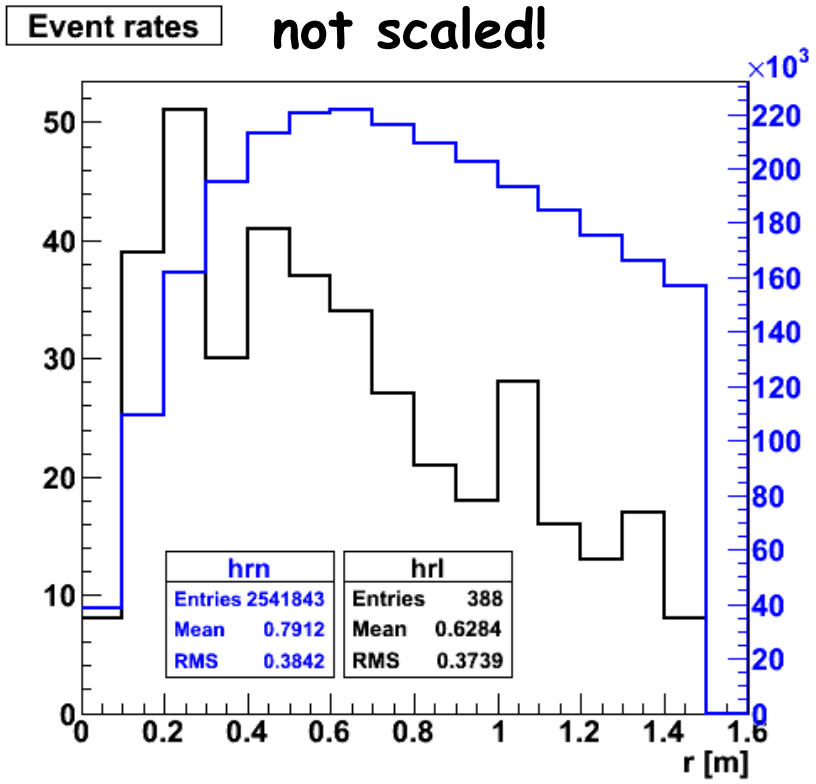
Material: polystyrene (ρ = 1.032 g/cm^3)

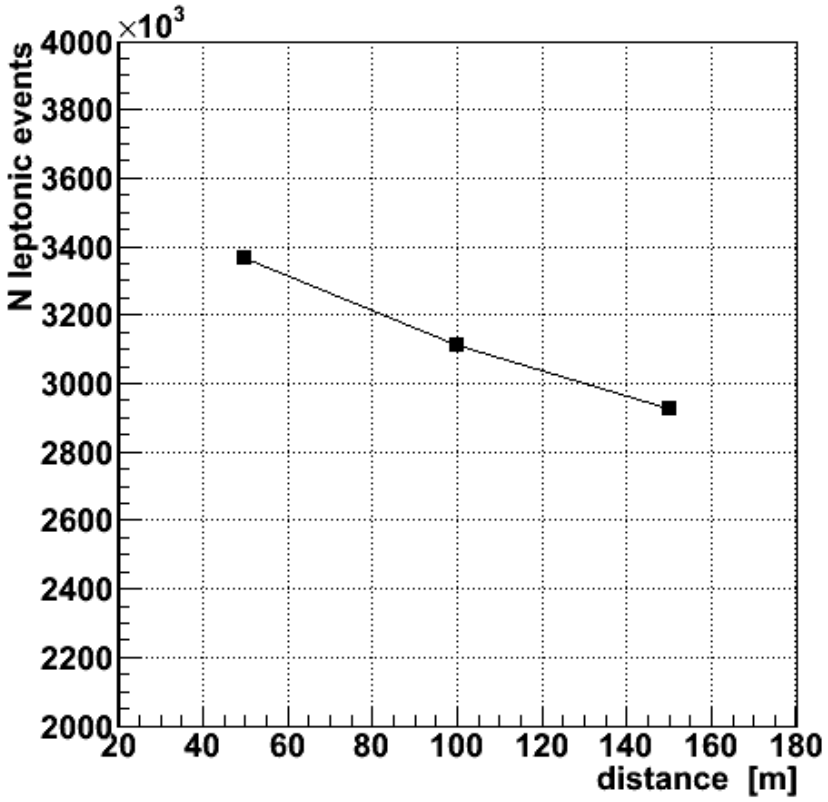
Size: radius 1.5 m, length = 10 m.

Detector resolutions:

	$\delta\theta$ (mrad)	$\delta p/p$ (%)	$\delta E/E$ (%) [recoil (hadron) energy]	
Poor :	1.0	10	10	version 1
Medium:	0.5	5	5	version 2
Best :	0.1	1	1	version 3

Event rates


Event rates
not scaled!
×10³
hrn
Entries 2541843
Mean 0.7912
RMS 0.3842
hrl
Entries 388
Mean 0.6284
RMS 0.3739
r [m]


×10³
N leptonic events
distance [m]

Leptonic scattering

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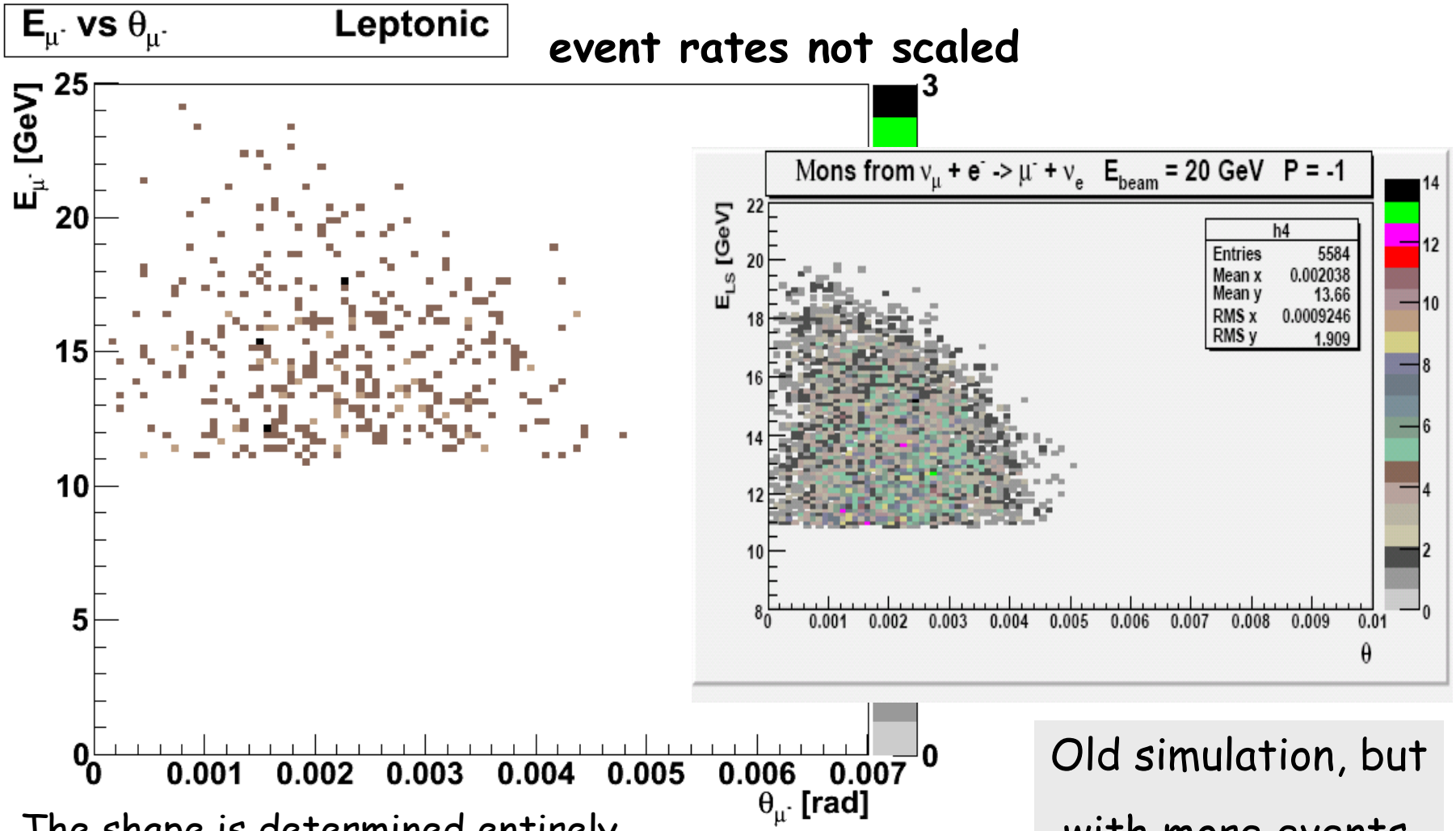
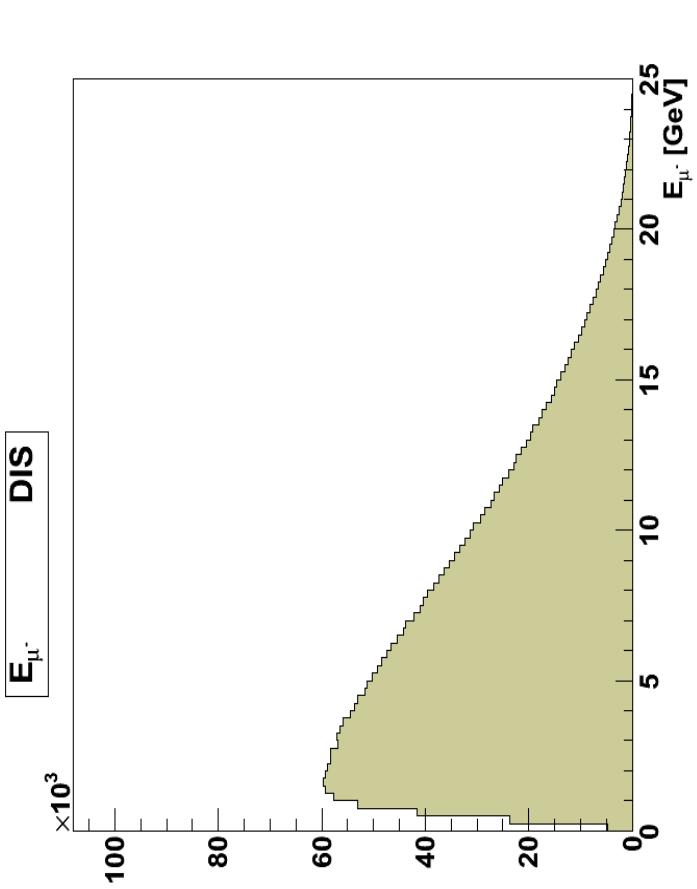


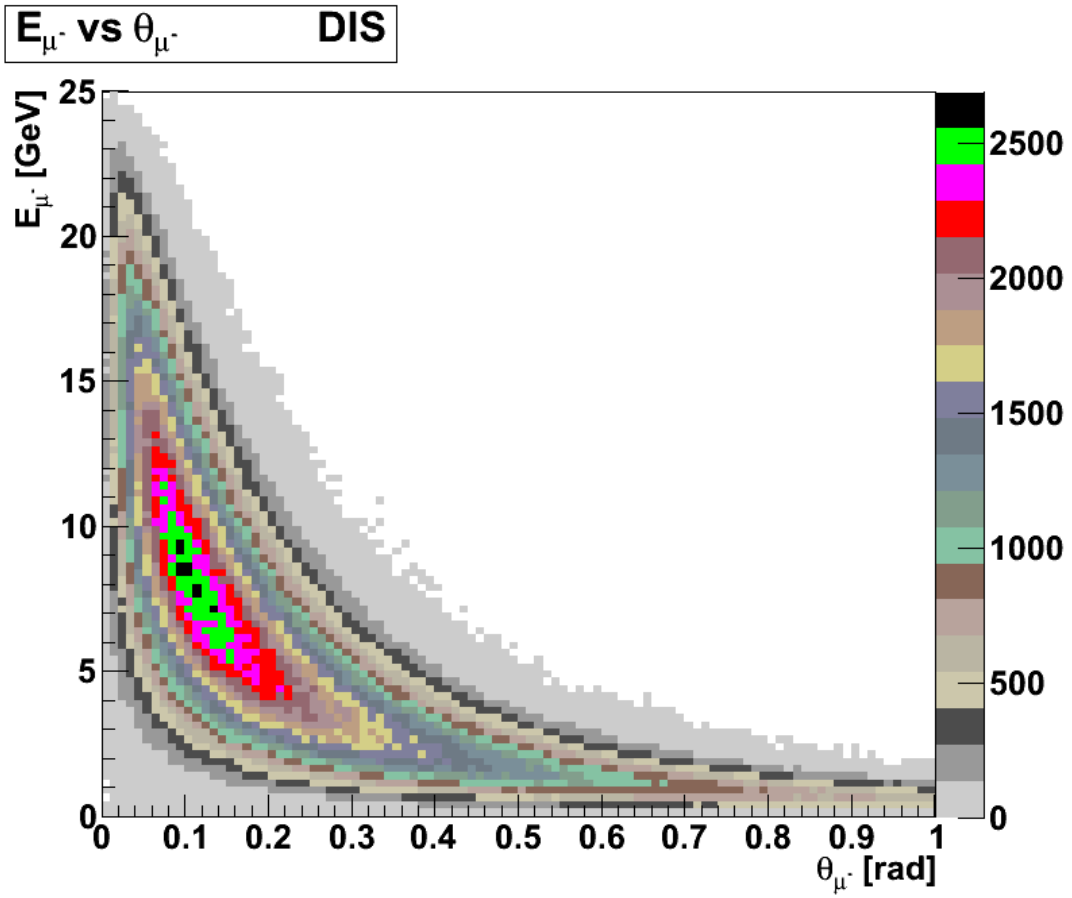
The shape is determined entirely

by the muon decay kinematics and beam divergence.

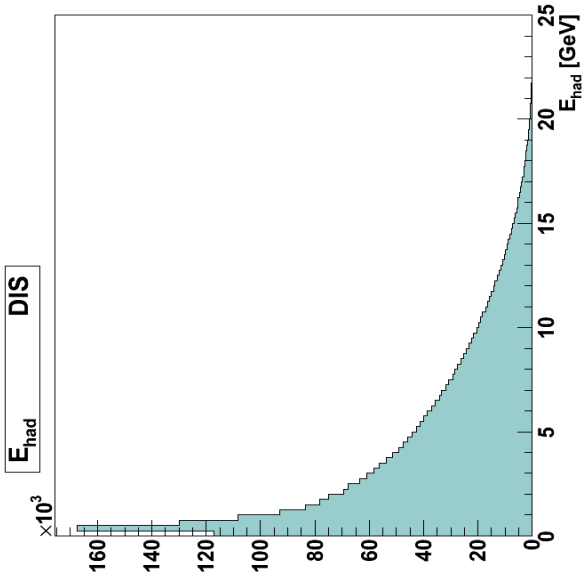
Old simulation, but with more events

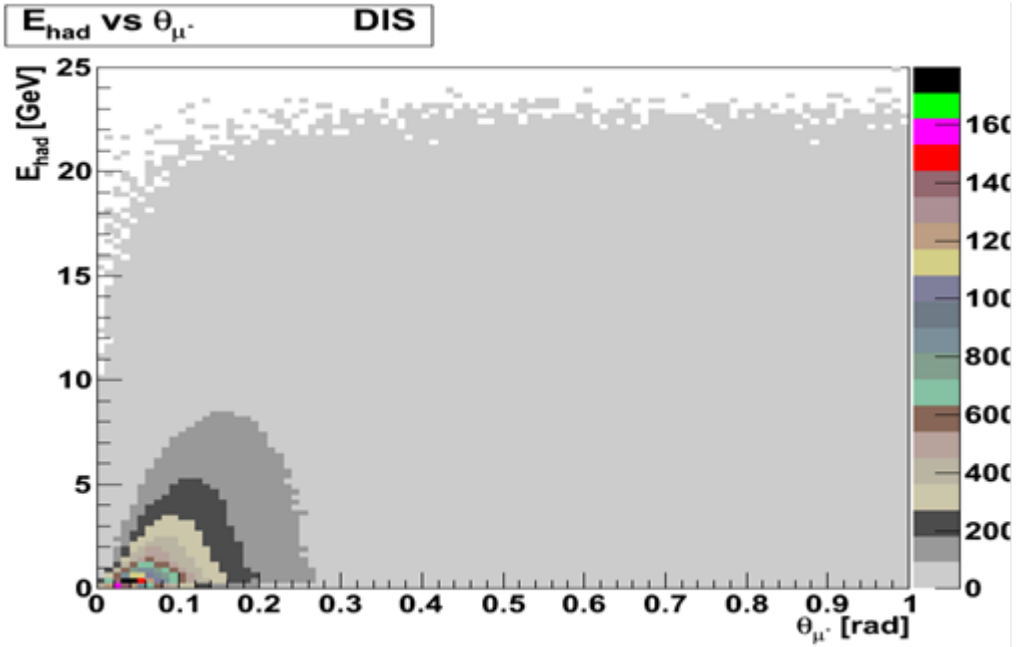
Inclusive scattering

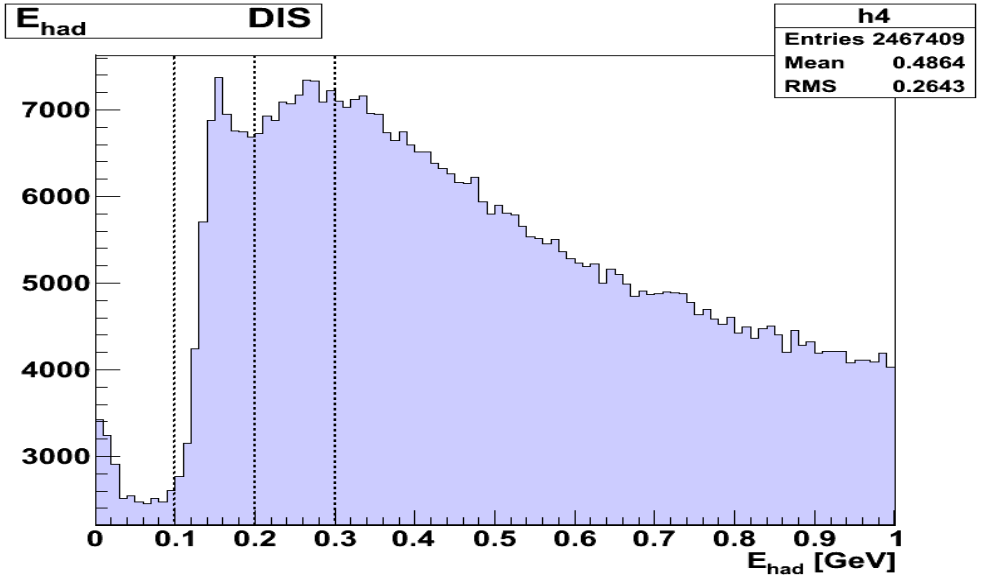




Recoil (hadronic) energy)







Discriminating variables

- muon scattering angle θ_μ;
- transverse momentum p_T (less powerful than θ_μ, see Y. Karadzhov's poster at NUFACT09, will not be examined here);
- $E_\mu * \theta^2{}_\mu \rightarrow E_\mu \theta_\mu^2 = \sim (1-y)$, y – inelasticity;
- recoil (hadronic) energy $E_{had.}$

Table with numbers

θ	cut value [rad]	Purity [%]	Signal evts	All evts below the cut	Bkgr evts	Bkgr evts deduced from the fit
v1 E_{had} <100MeV	0.0055	66	388	582	205	262 +- 37
v2 E_{had} <100MeV	0.0055	72	388	536	152	210 +- 34
v3 E_{had} <100MeV	0.0055	73	388	528	140	175 +- 30
v1 E_{had} <200MeV	0.0060	31	388	1216	836	830 +- 100
v2 E_{had} <200MeV	0.0050	42	388	913	533	641 +- 72
v3 E_{had} <200MeV	0.0050	42	388	922	538	544 +- 63
v1 E_{had} <300MeV	0.0050	30	388	1261	898	990 +- 90
v2 E_{had} <300MeV	0.0045	36	388	1058	693	656 +- 62
v3 E_{had} <300MeV	0.0045	37	388	1031	658	639 +- 62
$\theta^2 * E_\mu$	[rad^2*GeV]					
v1 E_{had} <100MeV	0.42	63	388	608	237	273 +- 13
v2 E_{had} <100MeV	0.42	68	388	565	179	229 +- 12
v3 E_{had} <100MeV	0.42	70	388	551	163	216 +- 11
v1 E_{had} <200MeV	0.36	37	388	1034	669	793 +- 19
v2 E_{had} <200MeV	0.36	37	388	1030	652	800 +- 19
v3 E_{had} <200MeV	0.30	44	388	870	493	677 +- 15
v1 E_{had} <300MeV	0.36	27	388	1436	1071	1286 +- 24
v2 E_{had} <300MeV	0.36	27	388	1436	1058	1267 +- 24
v3 E_{had} <300MeV	0.36	27	388	1394	1011	1266 +- 23

Inclusive background subtraction

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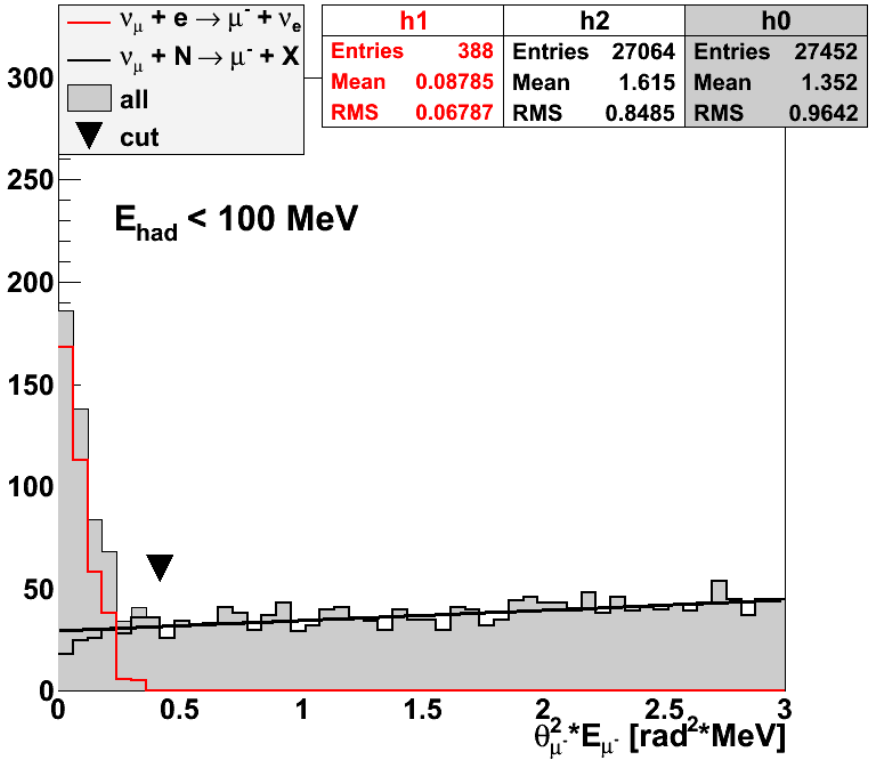
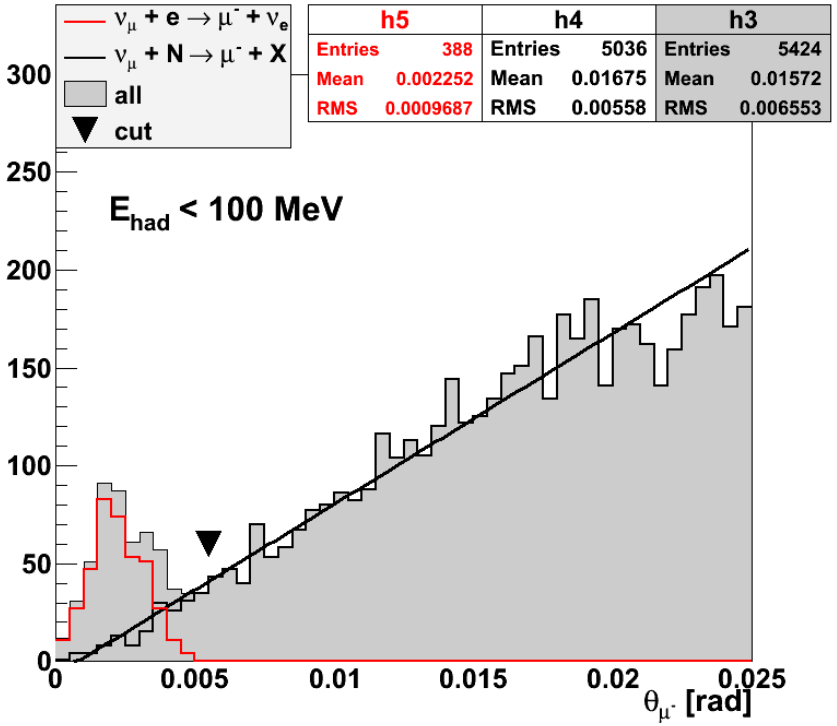


"Best" resolutions,

tight cut on E_{had}



Inclusive background subtraction

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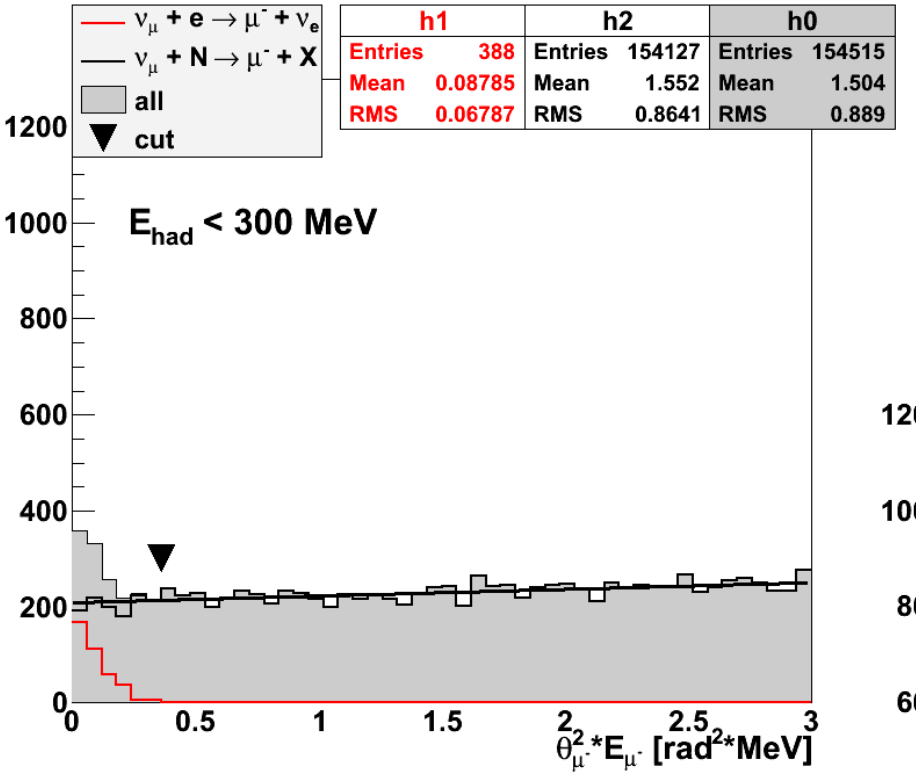
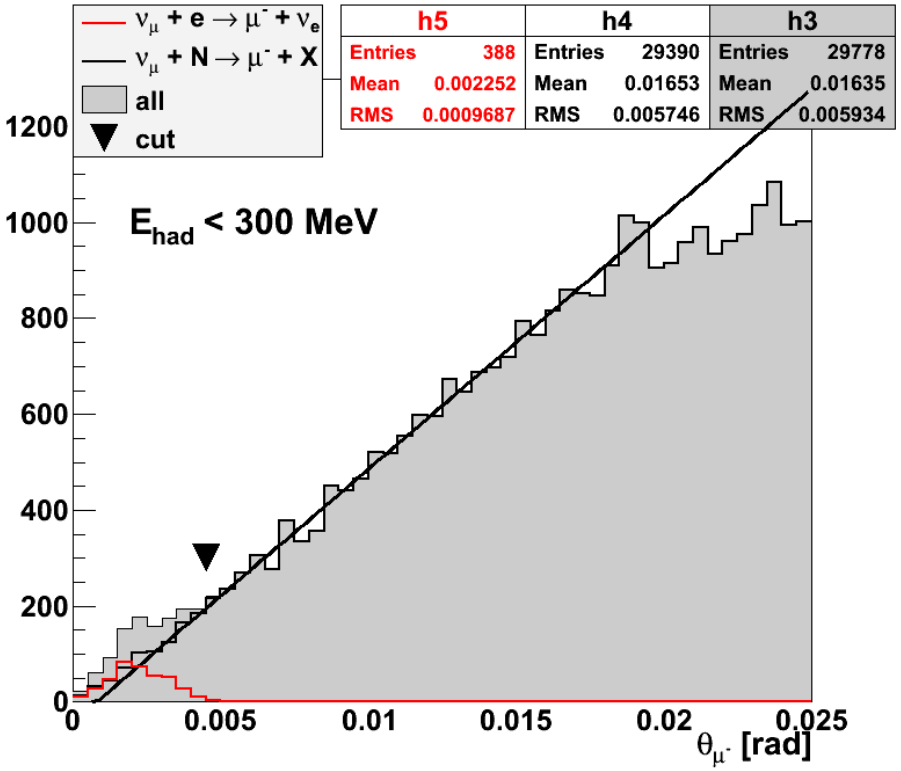


"Best" resolutions,

loose cut on E_{had}



Inclusive background subtraction

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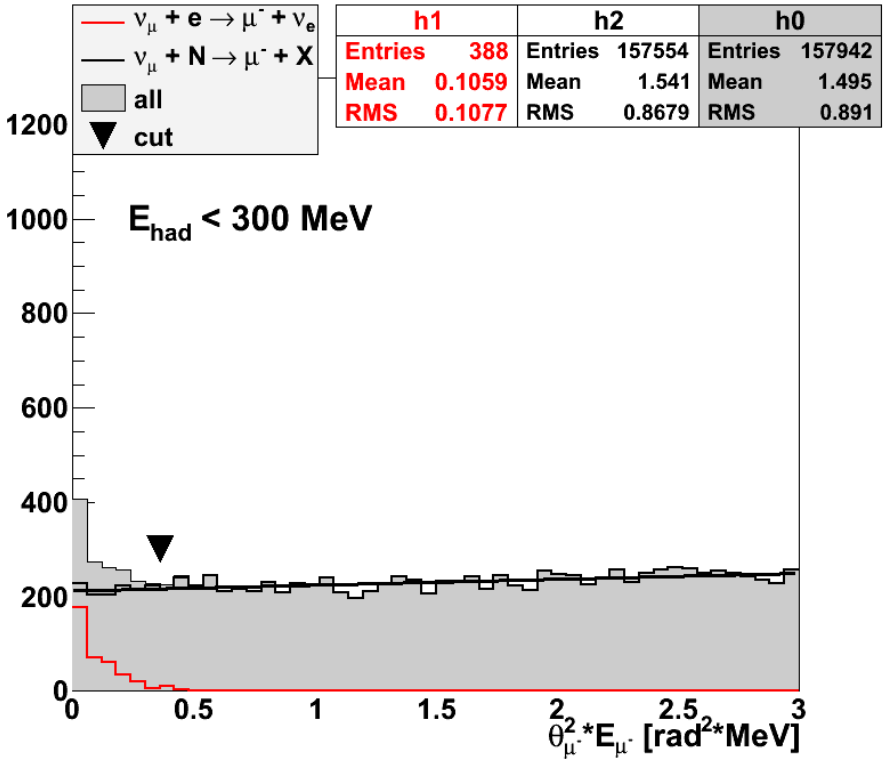
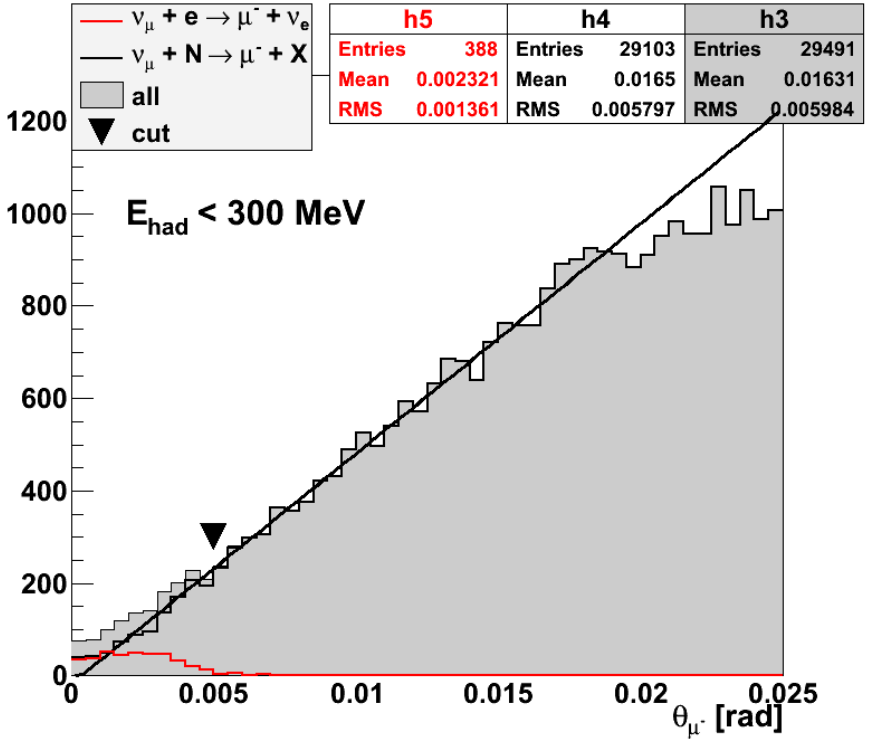
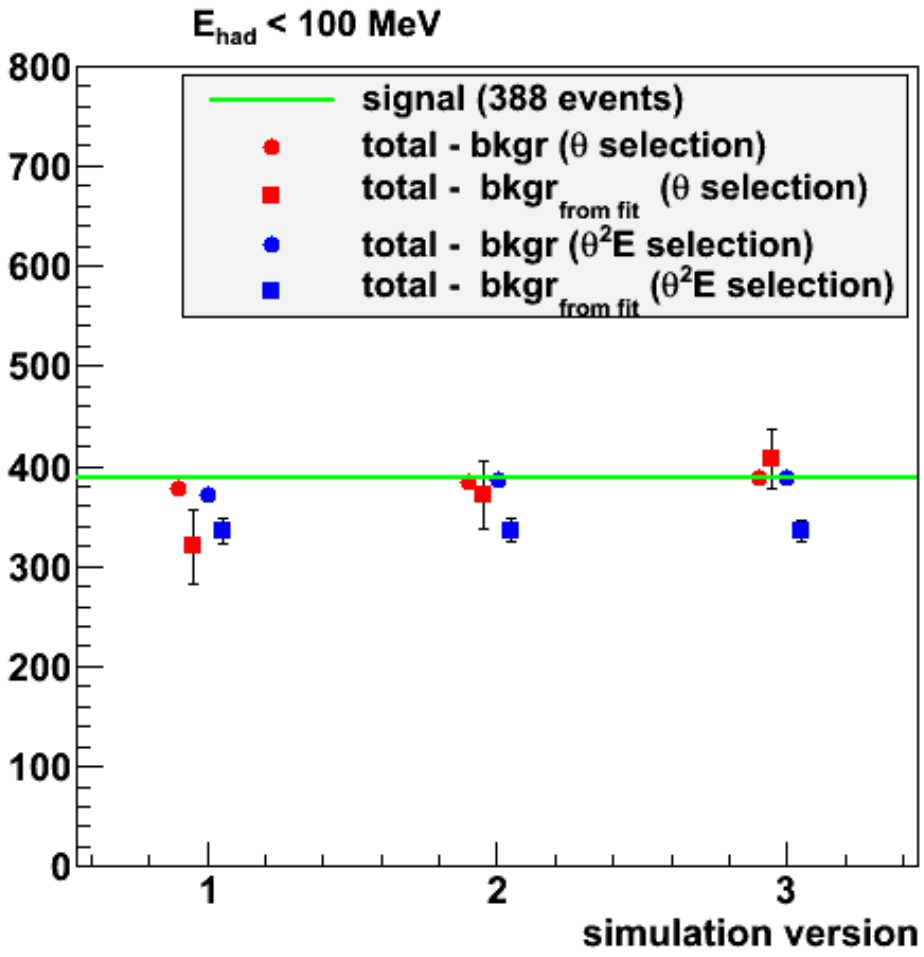


"Poor" resolutions,

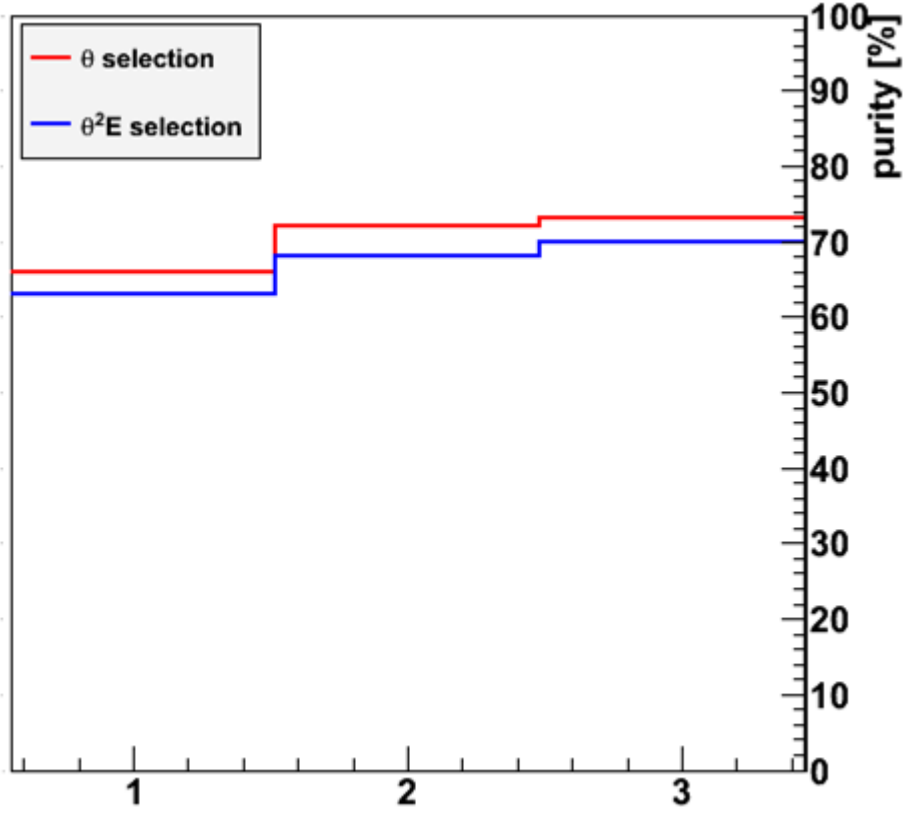
loose cut on E_{had}



Signal extraction, E_{had} < 100 MeV



Purity = signal/(evts below the cut)



E_{had} < 200 MeV

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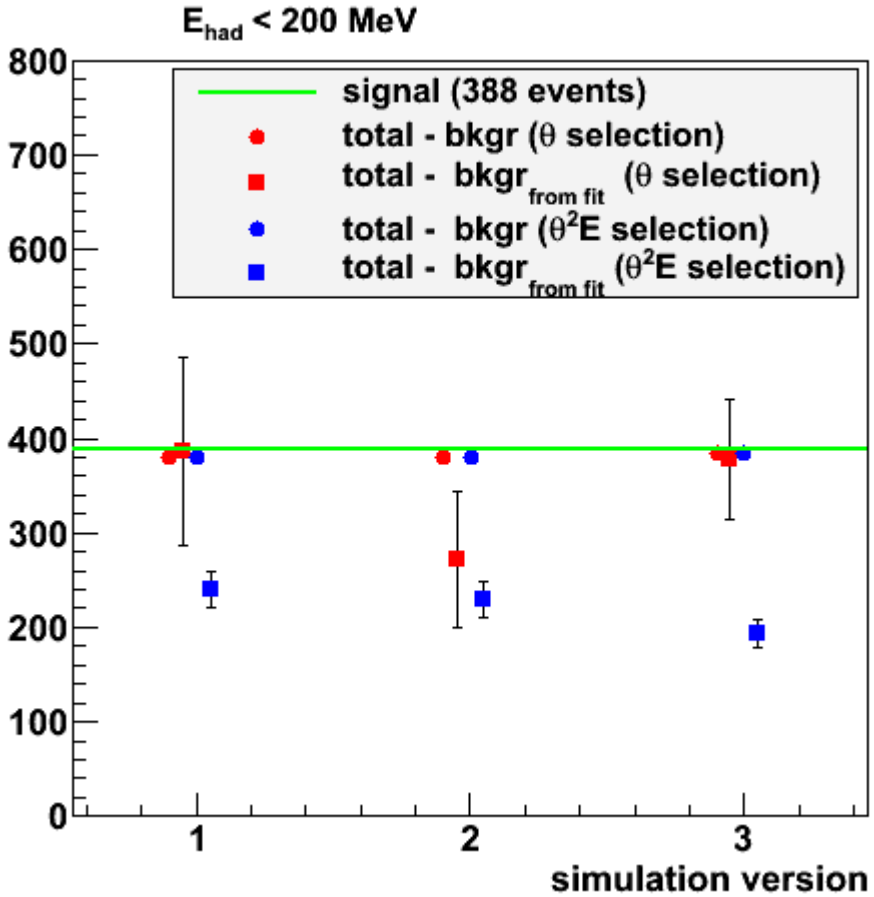
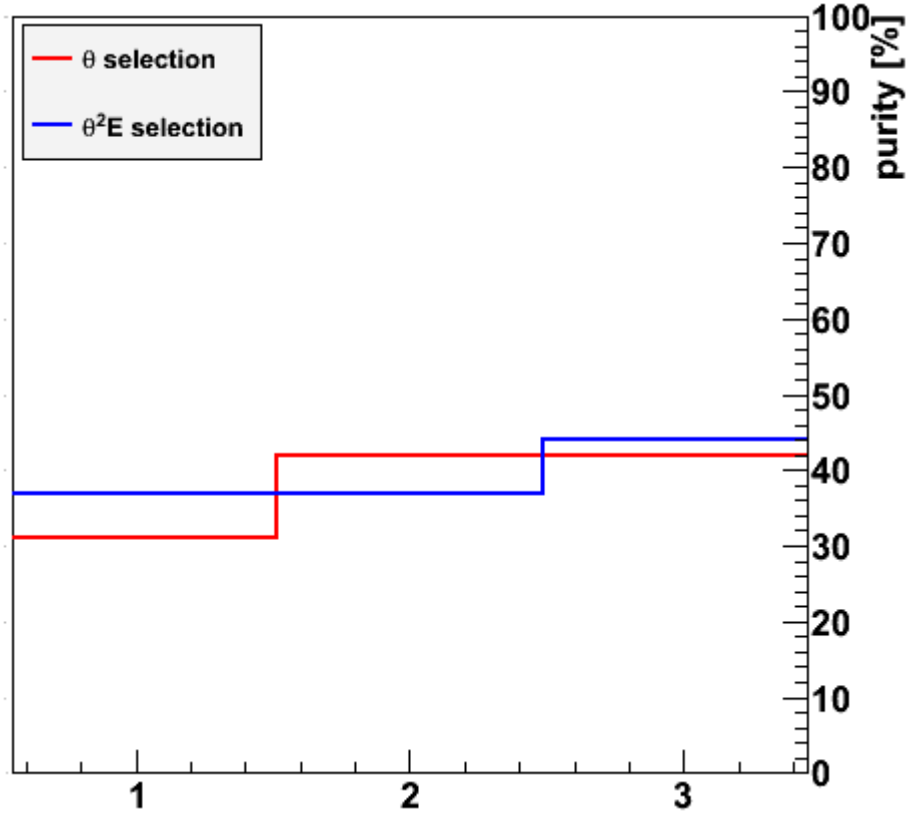
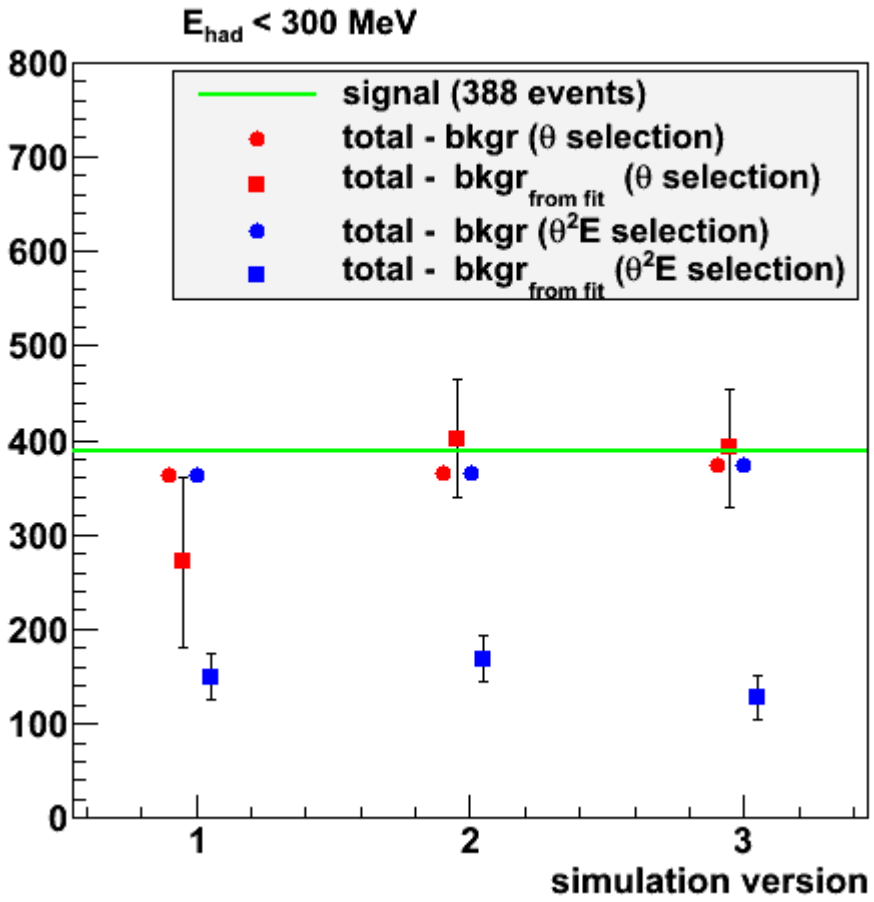
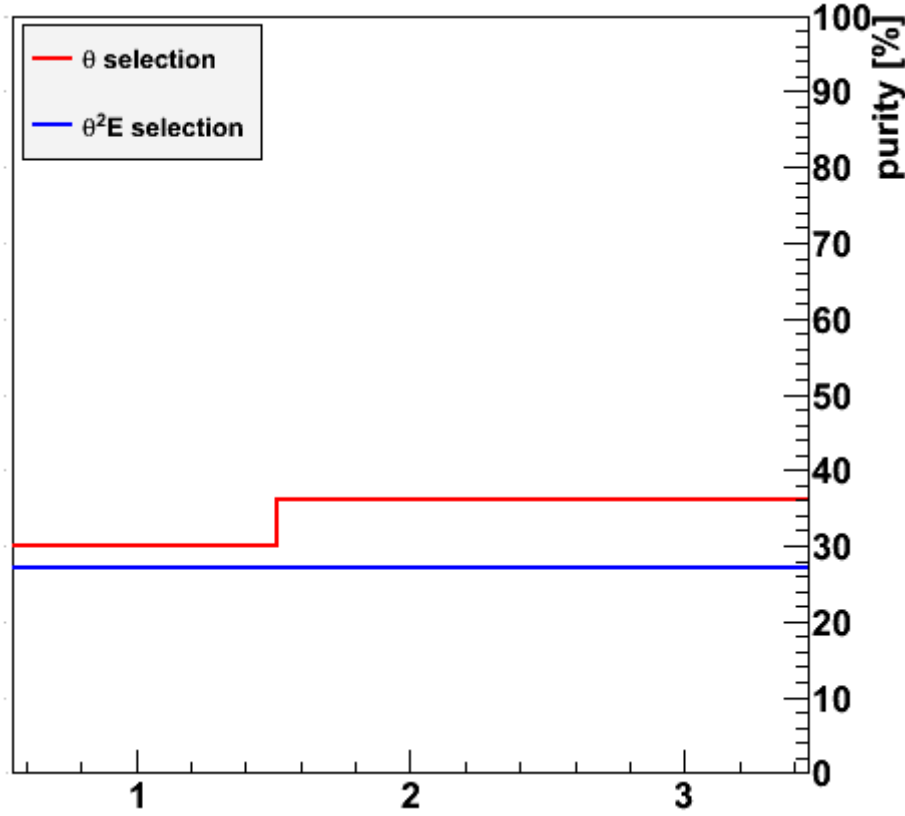




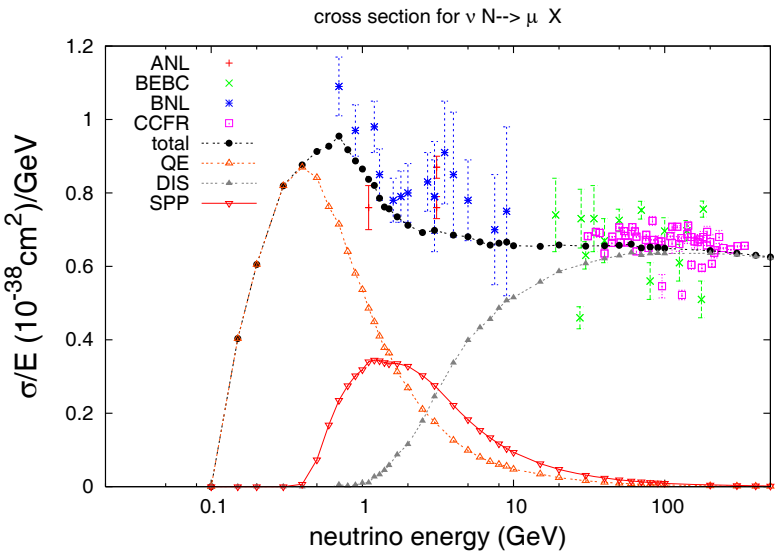
E_{had} < 300 MeV


E_had < 300 MeV
signal (388 events)
total - bkgr (θ selection)
total - bkgr_from fit (θ selection)
total - bkgr (θ²E selection)
total - bkgr_from fit (θ²E selection)
800
700
600
500
400
300
200
100
0
1
2
3
simulation version


θ selection
θ²E selection
100
90
80
70
60
50
40
30
20
10
0
purity [%]
1
2
3

Outcome (preliminary)

- We need good measurement of recoil (hadronic) energy down to few tens of MeV;
- θ_μ *and* $E_\mu * \theta^2_\mu$ have equivalent discriminating power;
- It's not clear yet if the uncertainty of the flux measurement could be made less than a few % → depends on extrapolation of the inclusive cross-section to $\theta \rightarrow 0$.



Next steps

- Specify the detector design and size: plastic fibers with ~0.5 mm diameter (?), magnetic field 0.5-1-2 Tesla;
- Full GEANT4 simulation → true values of measurables;
- Reconstruction→ experimental resolutions;
- Define a procedure for flux determination → estimation of the experimental uncertainties.

Thanks for your attention