

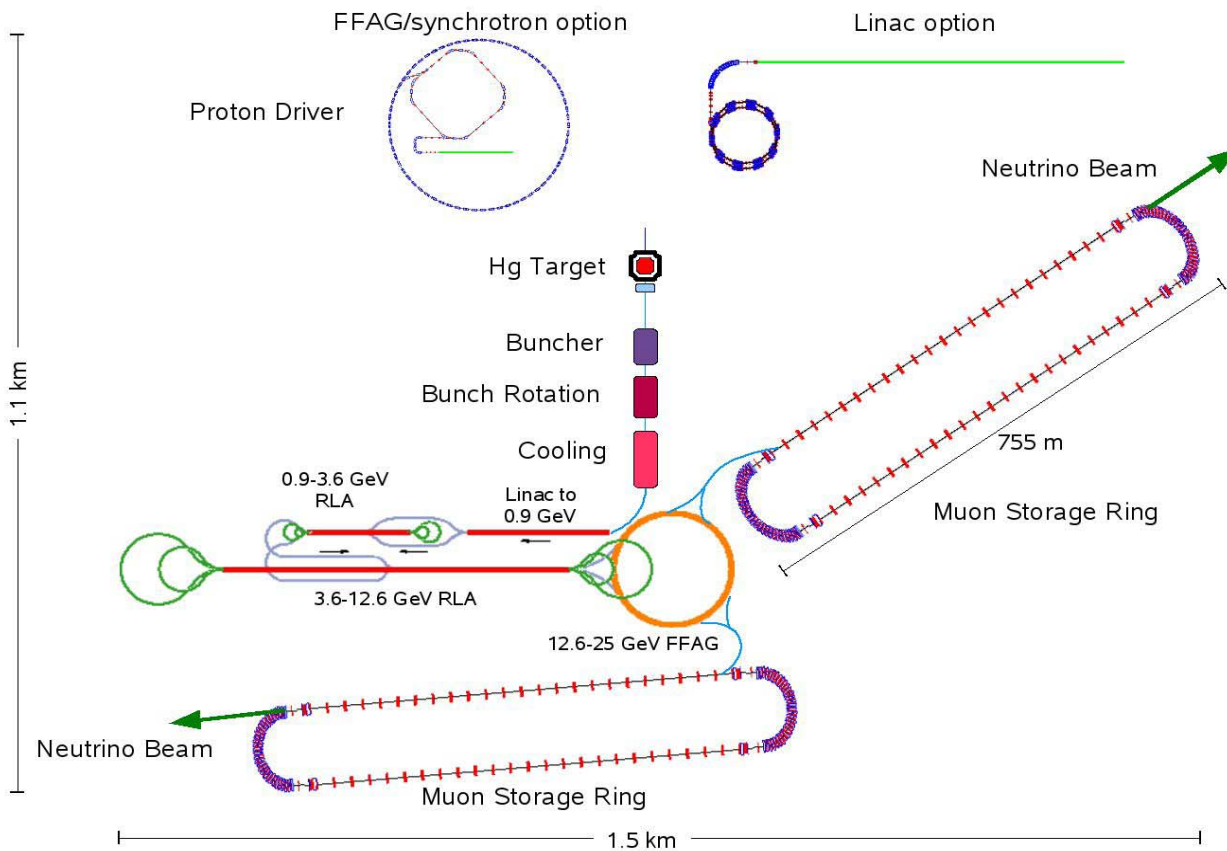


Status of the Near detector simulation

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NF baseline



$$E_{\mu} = 25 \text{ GeV}$$

Straight section
length = 600 m

5×10^{20} muon
decays/year

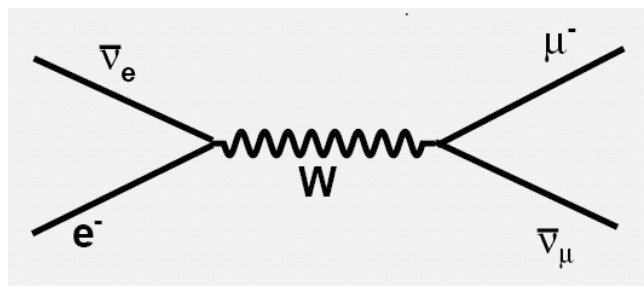
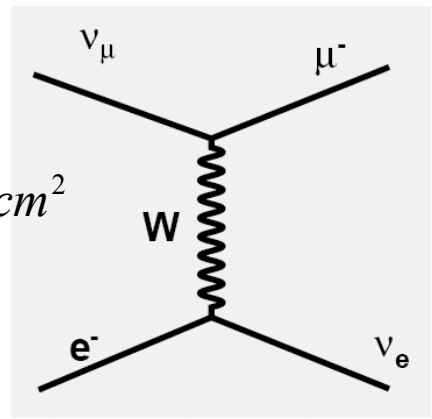


Measurement of the neutrino flux with a Near detector

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:



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

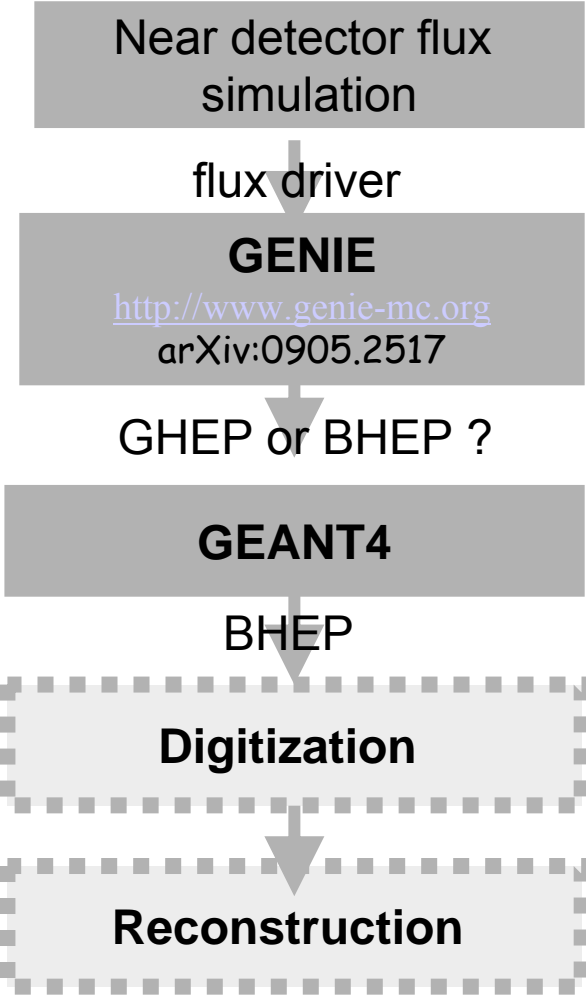


at 20 GeV ν_μ :
~ 10^3 times less than inclusive one

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



Simulation



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

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

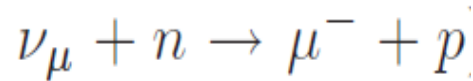
$\bar{\nu}_e + e^{-} \rightarrow \bar{\nu}_{\mu} + \mu^{-}$ is not.



Processes included in GENIE



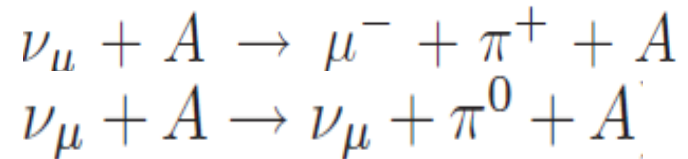
Quasi-elastic scattering



Elastic NC scattering

Baryon resonance production in CC and NC

Coherent neutrino-nucleus scattering



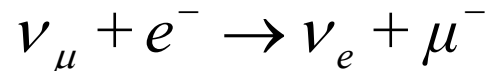
Non-resonant inelastic scattering (DIS)

Quasi-elastic charm production

Deep-inelastic charm production

Neutrino-electron elastic scattering and

inverse muon decay



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



Simulation

Muon beam energy smearing : Gaussian
($\sigma = 80 \text{ MeV}$).

Muon angular spread : Gaussian ($\sigma = 0.5 \text{ mrad}$).

Polarisation: 0 \rightarrow 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 ($\rho = 1.032 \text{ g/cm}^3$)

Size: radius 1.5 m, length = 10 m.

Detector resolutions:

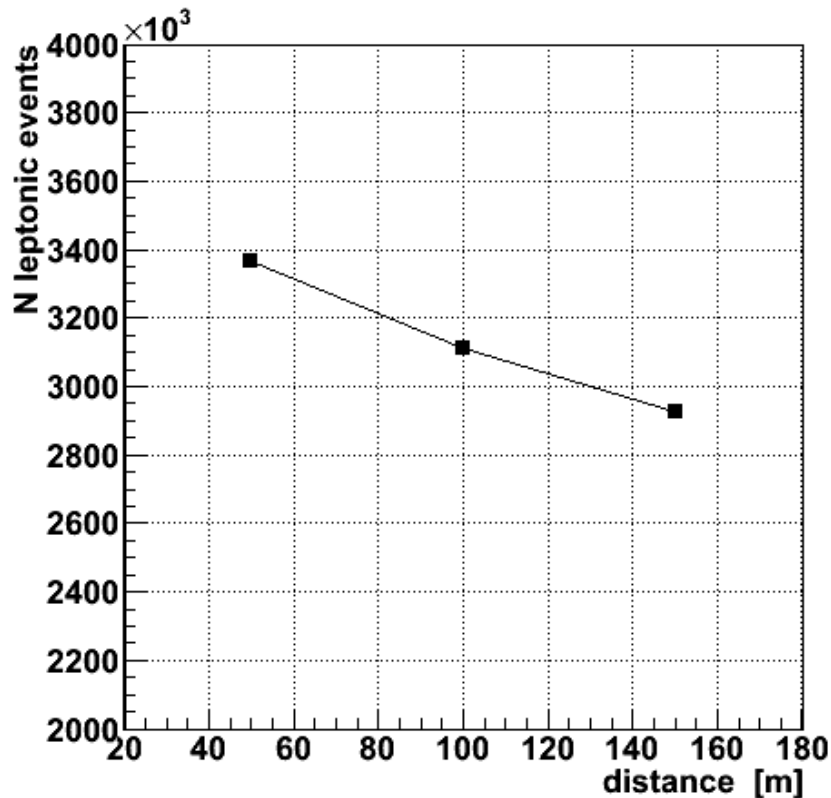
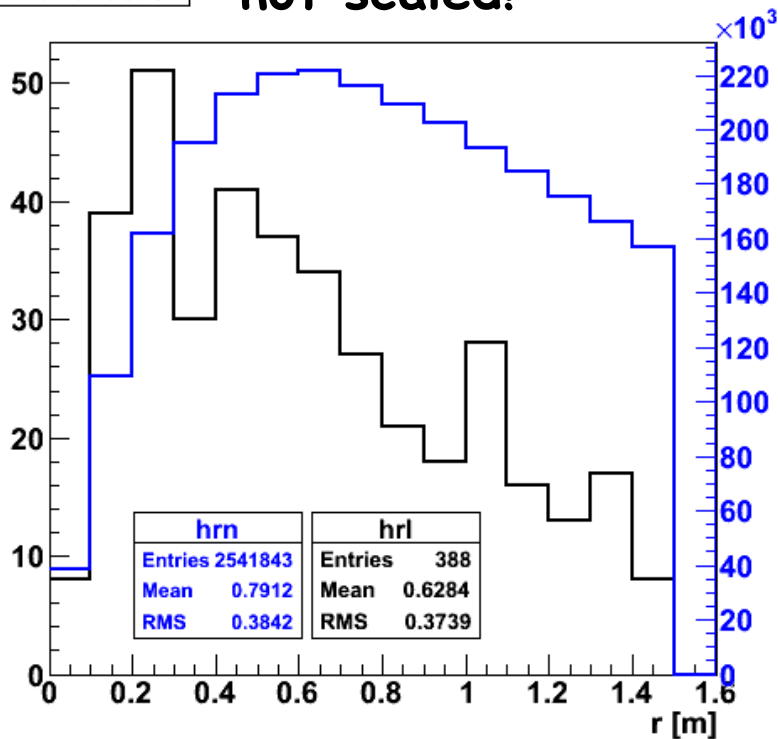
	$\delta\theta$ (mrad)	$\delta p/p$ (%)	$\delta E/E$ (%) [recoil (hadron) energy]	
Poor :	1.0	10	10	version 1
Medium:	0.5	5	5	version 2
Best :	0.1	1	1	version 3



Event rates

Event rates

not scaled!



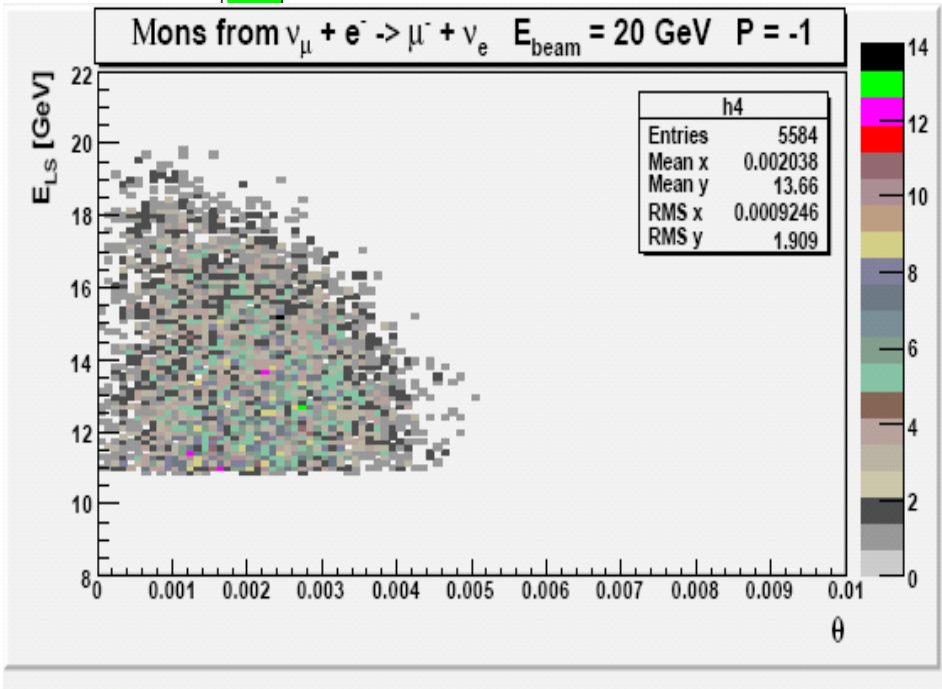
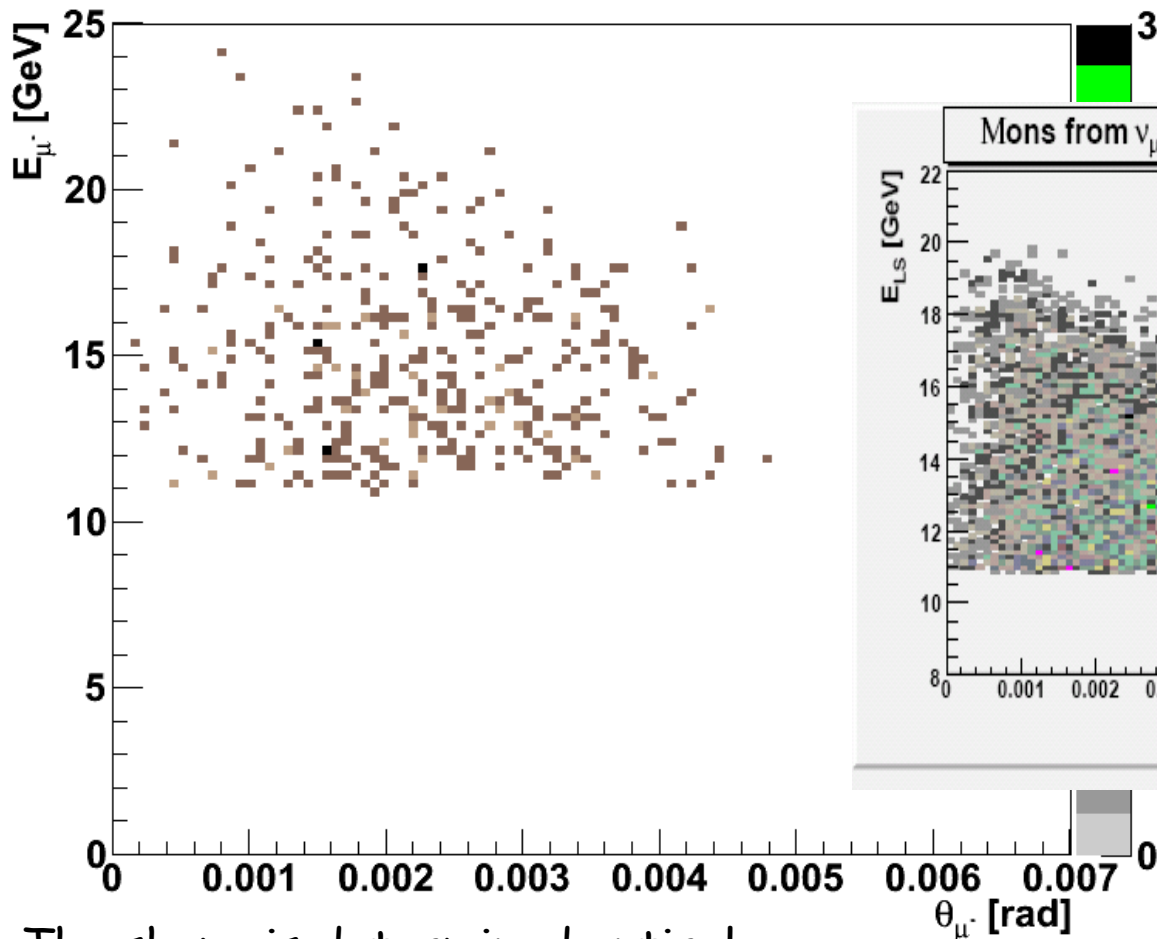


Leptonic scattering



E_{μ^-} vs θ_{μ^-} Leptonic

event rates not scaled



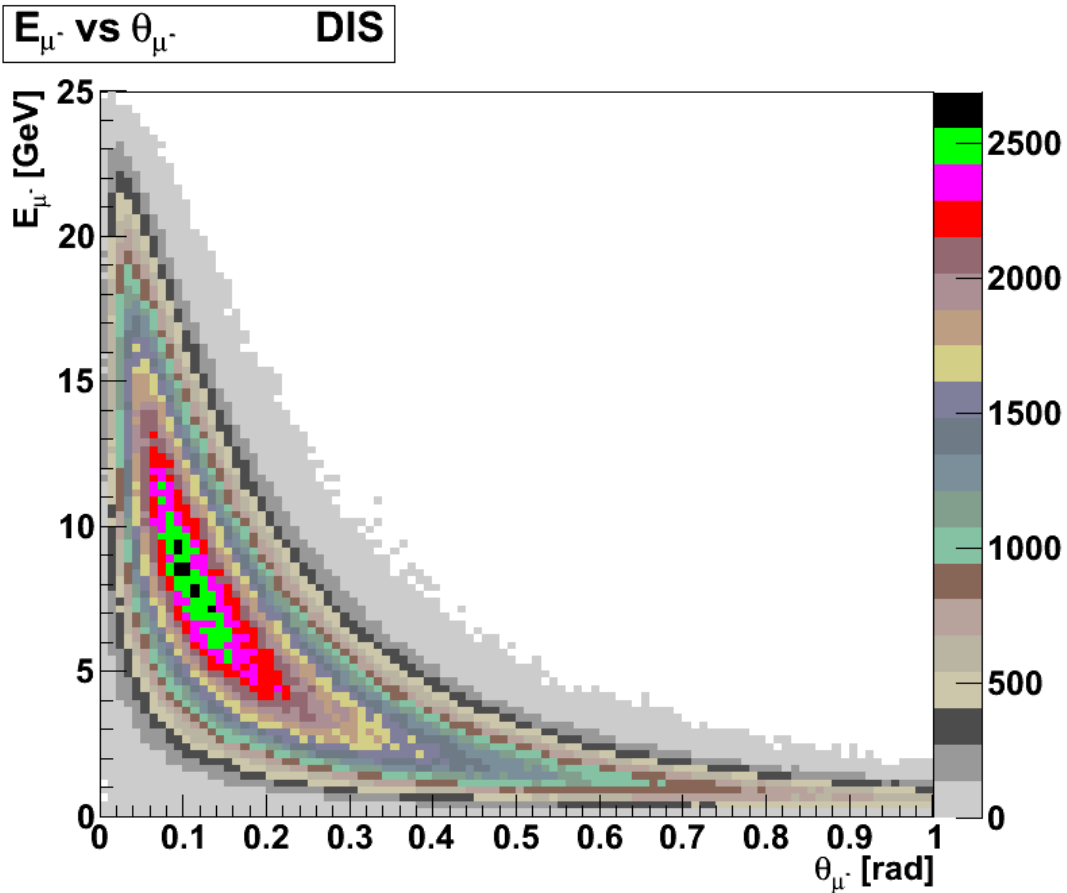
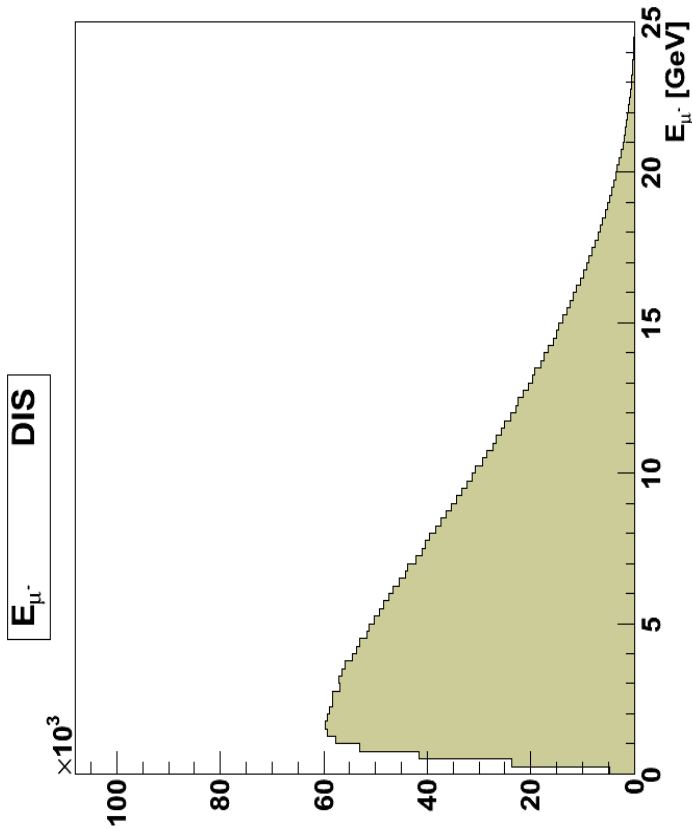
The shape is determined entirely

by the muon decay kinematics and beam divergence.

Old simulation, but with more events

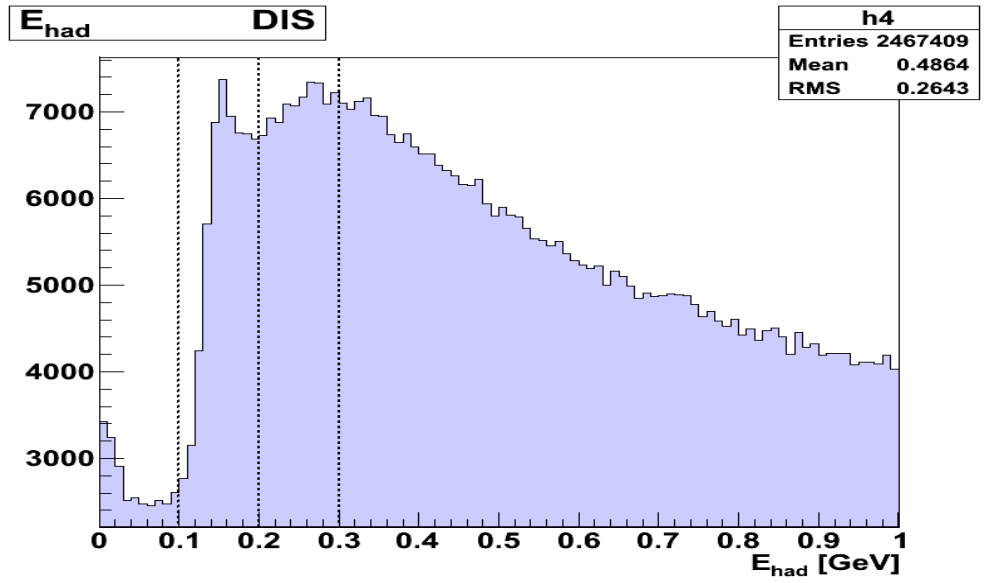
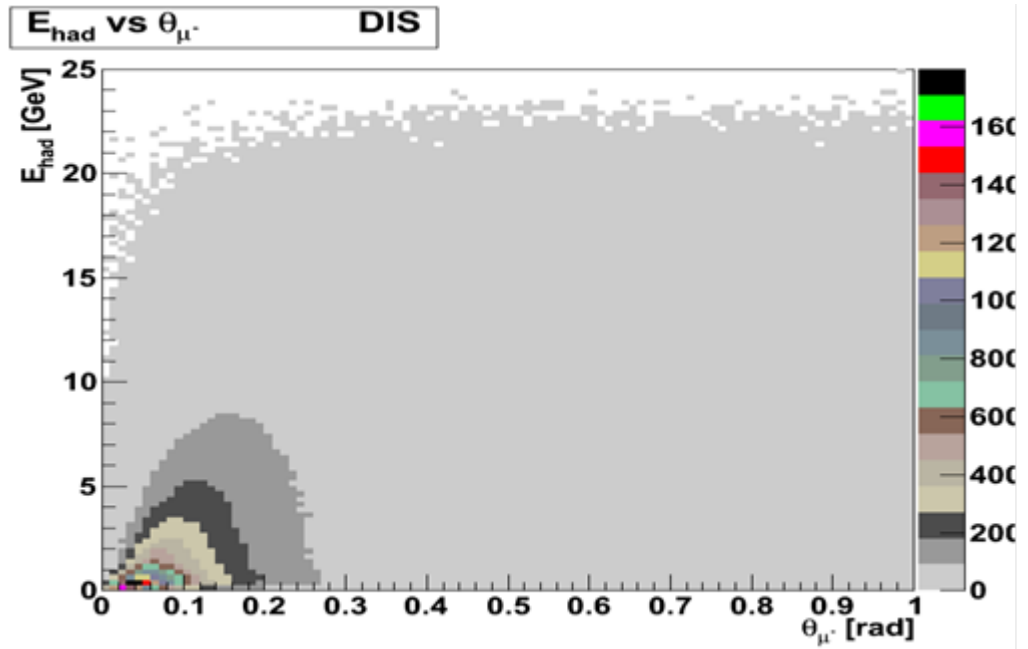
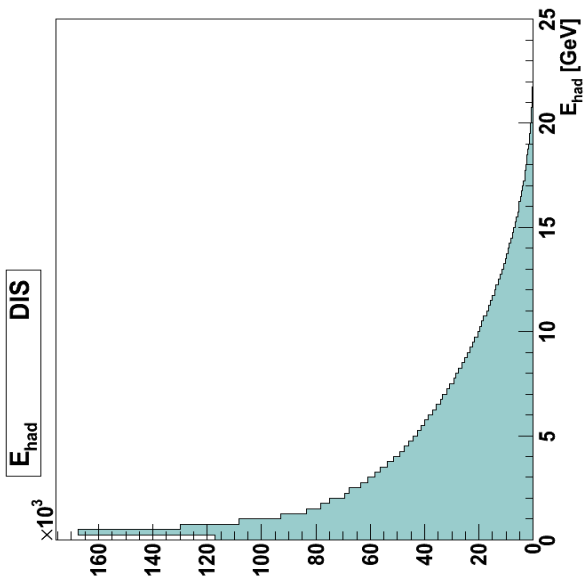


Inclusive scattering





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);
- $E_{\mu} * \theta_{\mu}^2 \rightarrow E_{\mu} \theta_{\mu}^2 \approx (1 - y)$, y – inelasticity;
- recoil (hadronic) energy $E_{had.}$

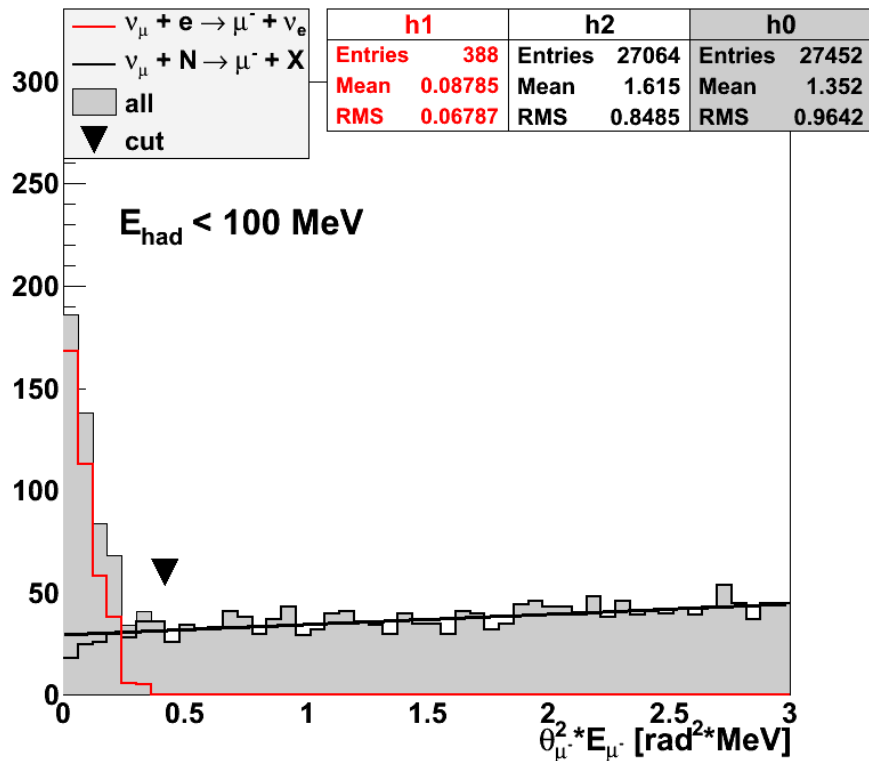


Table with numbers

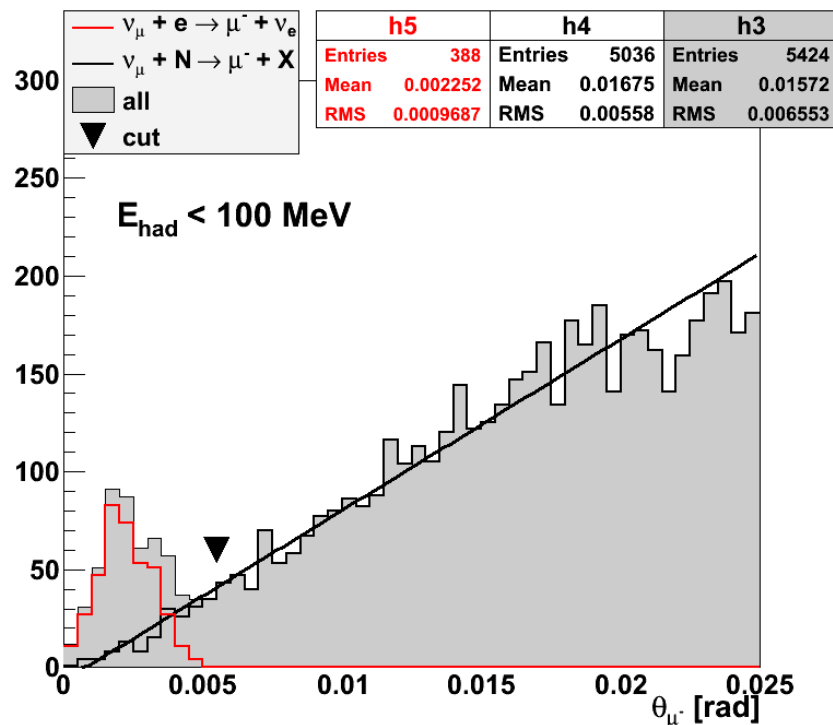
θ	cut value	Purity [%]	Signal	All evts	Bkgr	Bkgr evts
	[rad]		evts	below	evts	deduced
				the cut		from the fit
v1 $E_{had} < 100\text{MeV}$	0.0055	66	388	582	205	262 +- 37
v2 $E_{had} < 100\text{MeV}$	0.0055	72	388	536	152	210 +- 34
v3 $E_{had} < 100\text{MeV}$	0.0055	73	388	528	140	175 +- 30
v1 $E_{had}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



Inclusive background subtraction



“Best” resolutions,
tight cut on E_{had}

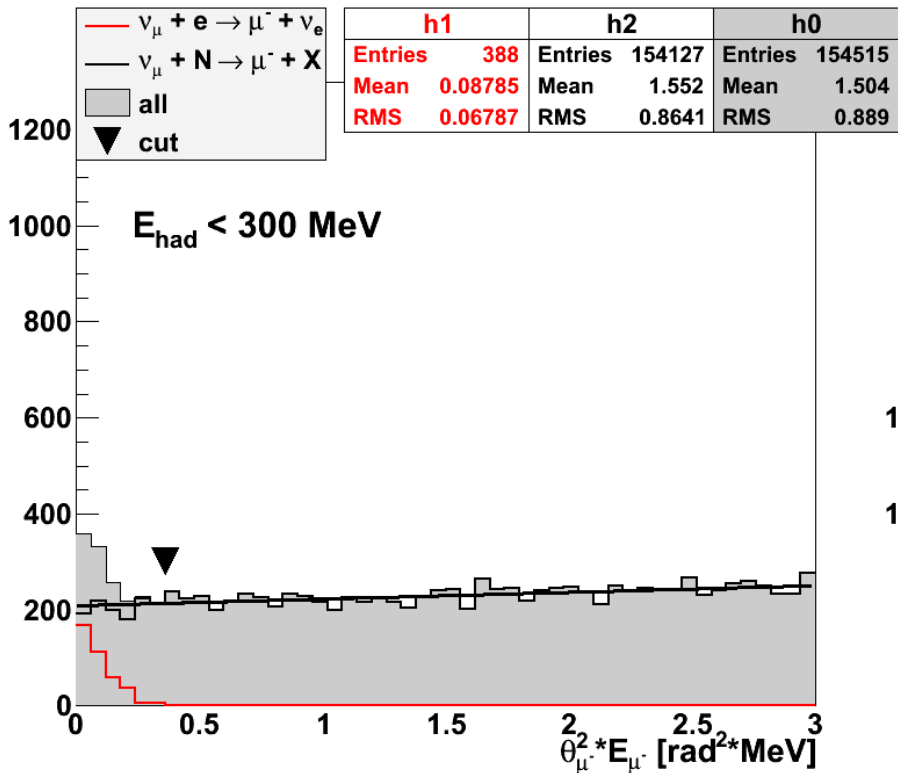




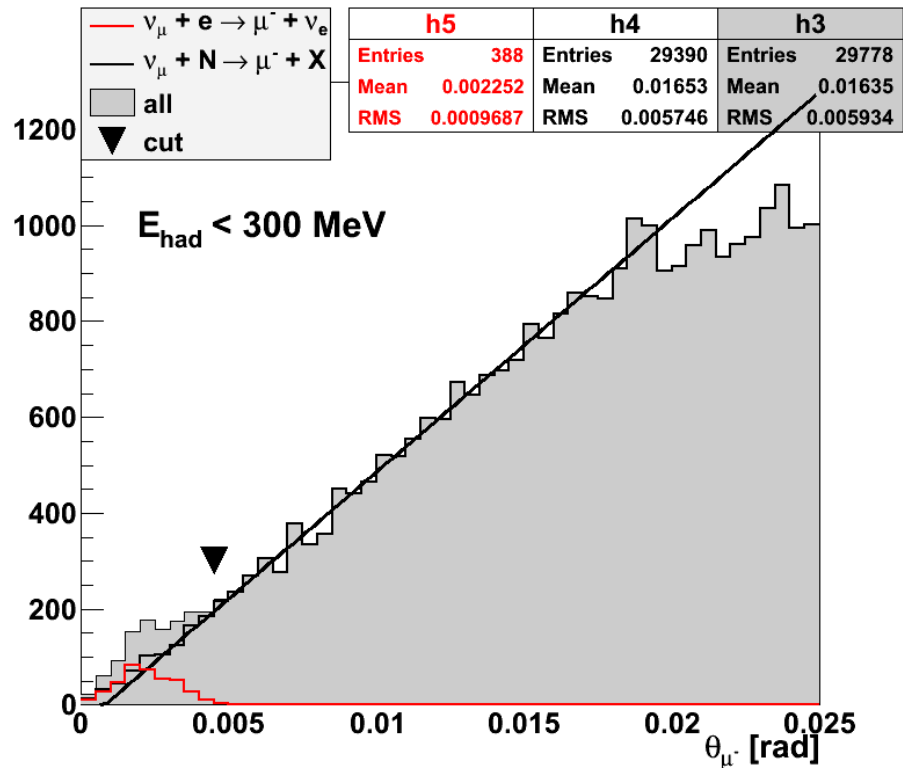
Inclusive background subtraction



University of Sofia

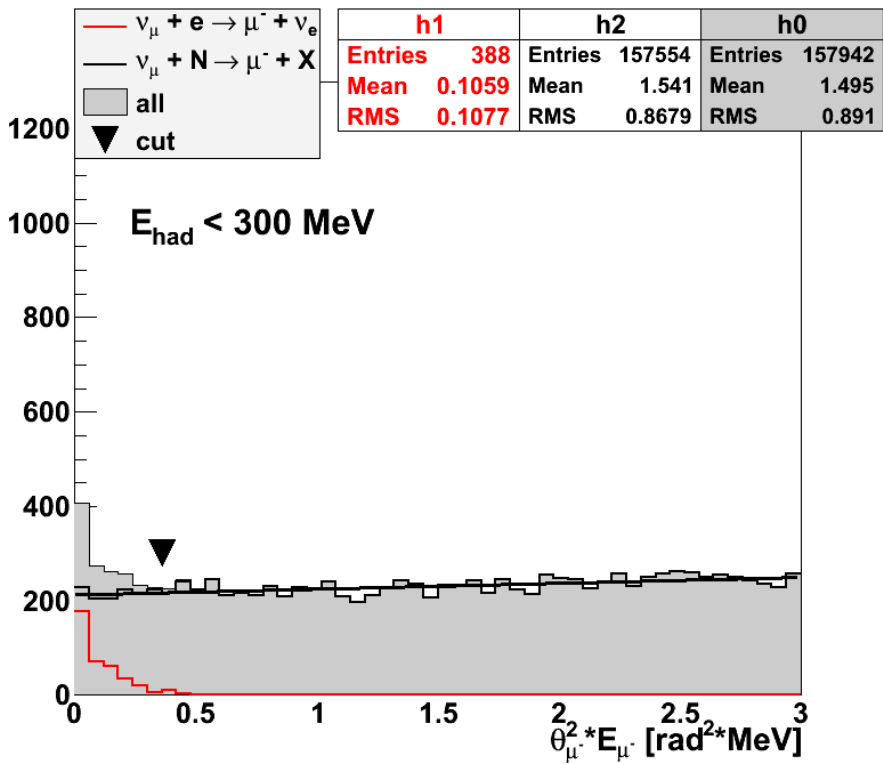


“Best” resolutions,
loose cut on E_{had}

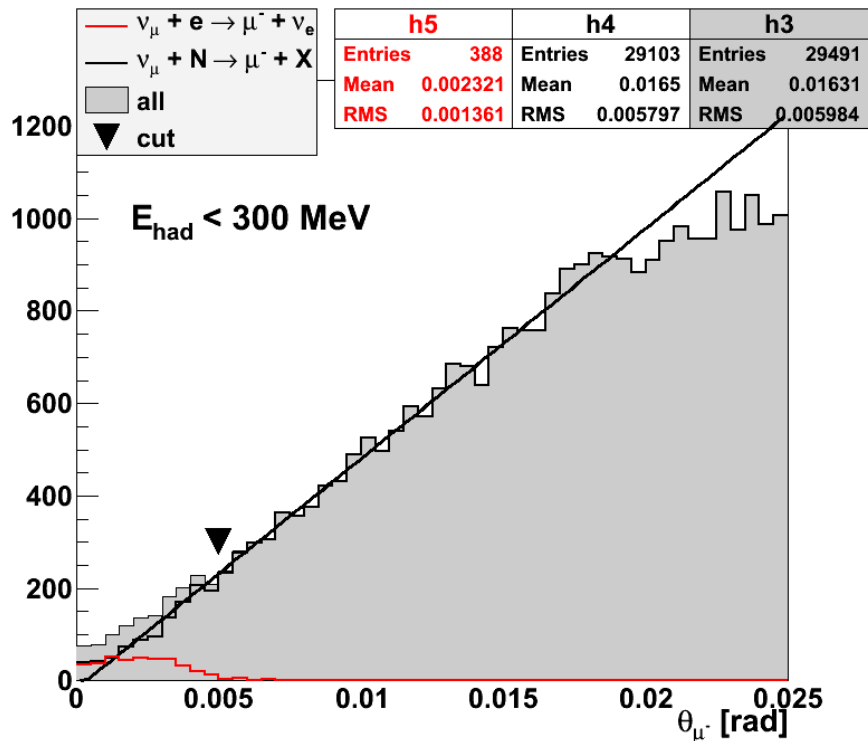




Inclusive background subtraction



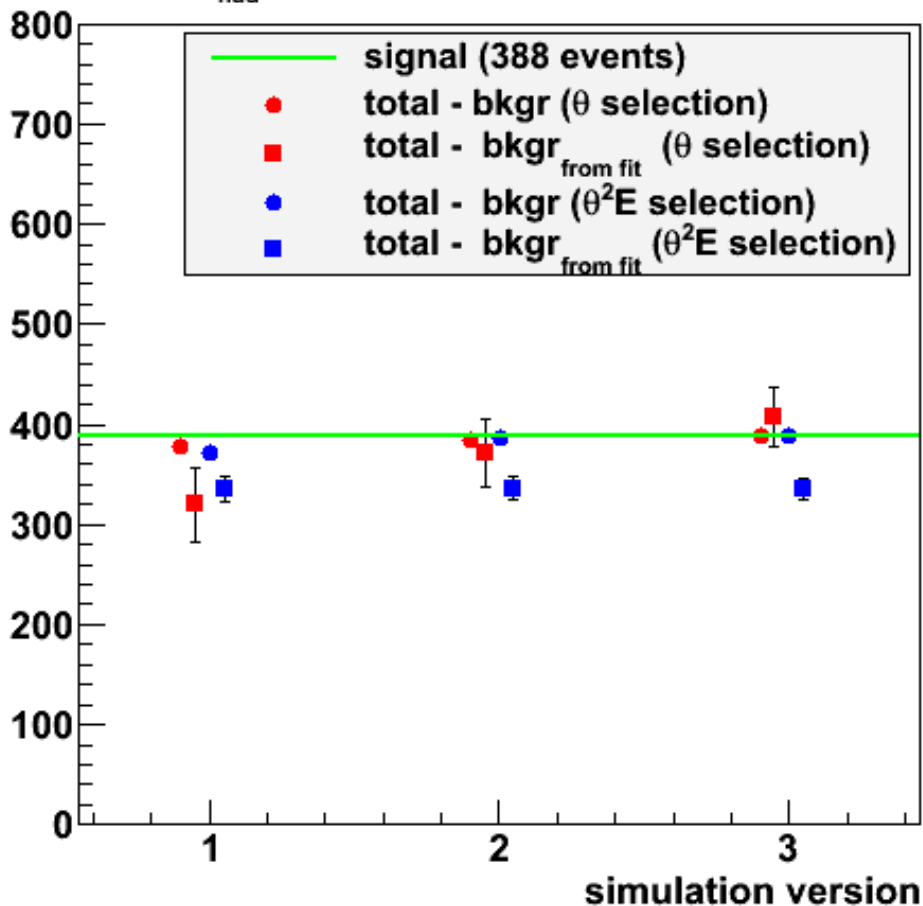
“Poor” resolutions,
loose cut on E_{had}



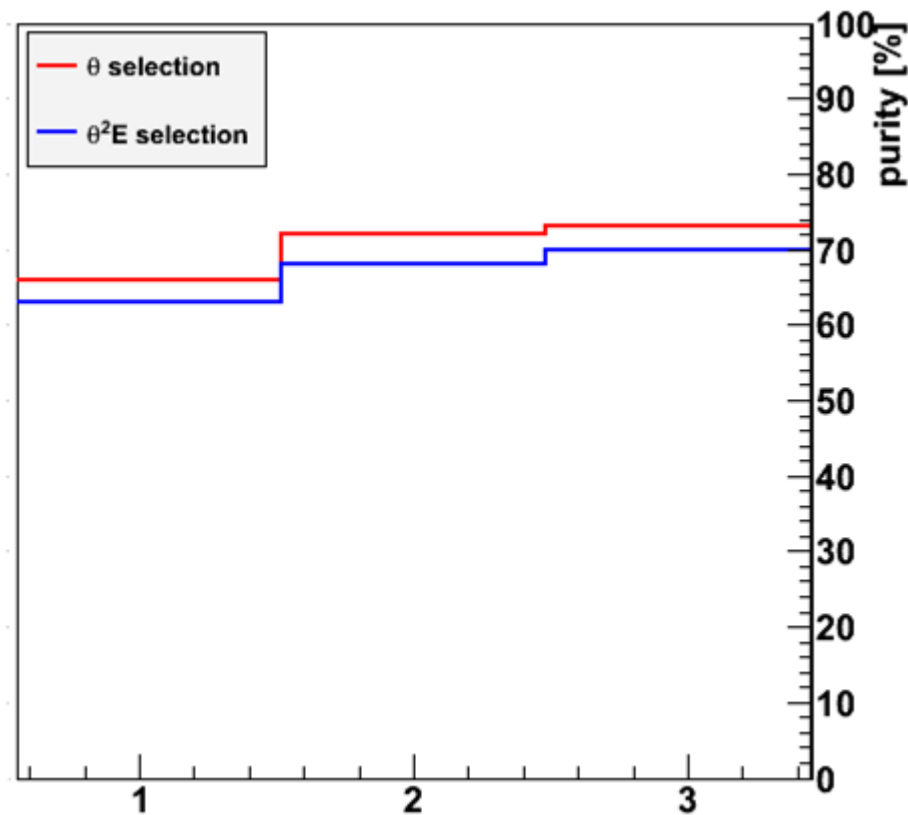


Signal extraction, $E_{had} < 100 \text{ MeV}$

$E_{had} < 100 \text{ MeV}$



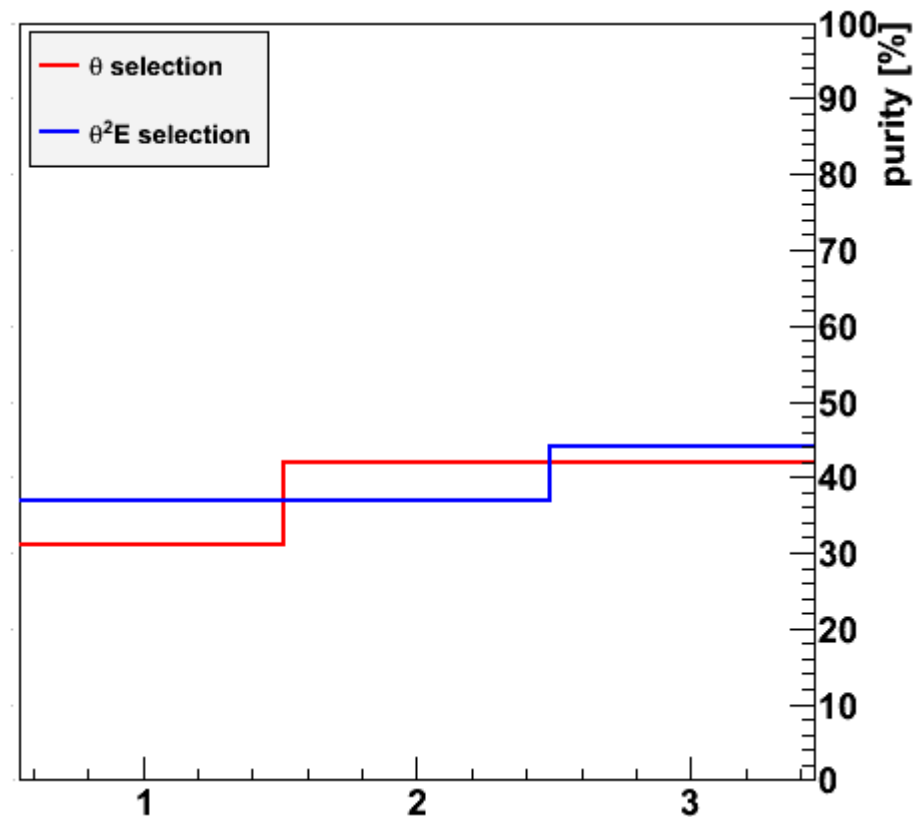
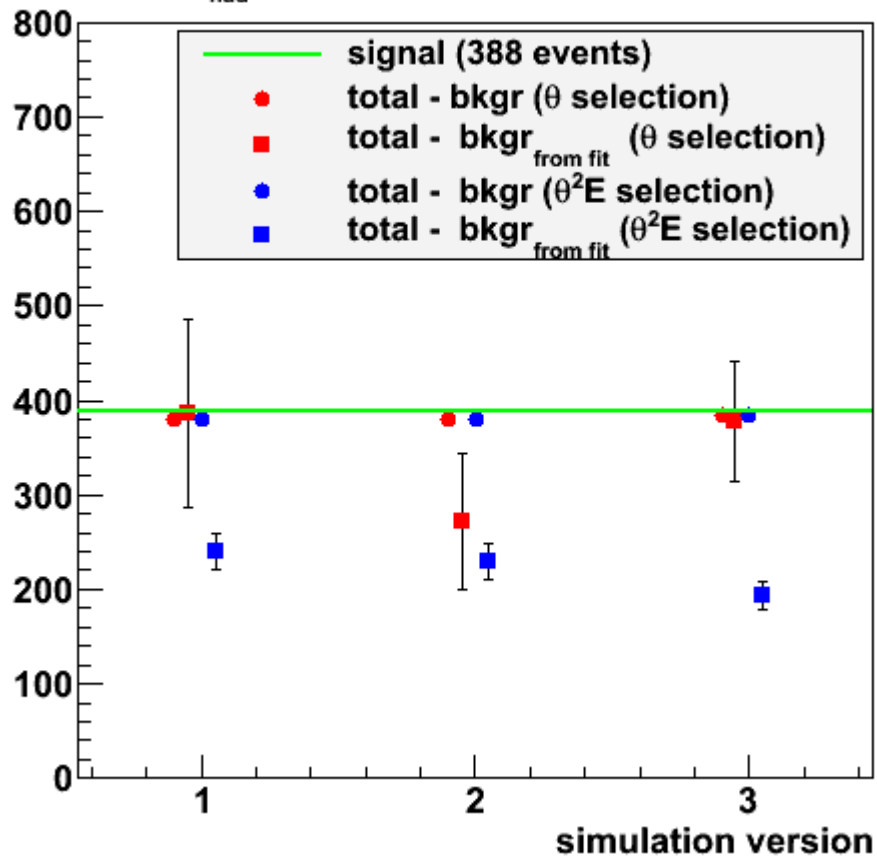
Purity = signal/(evts below the cut)





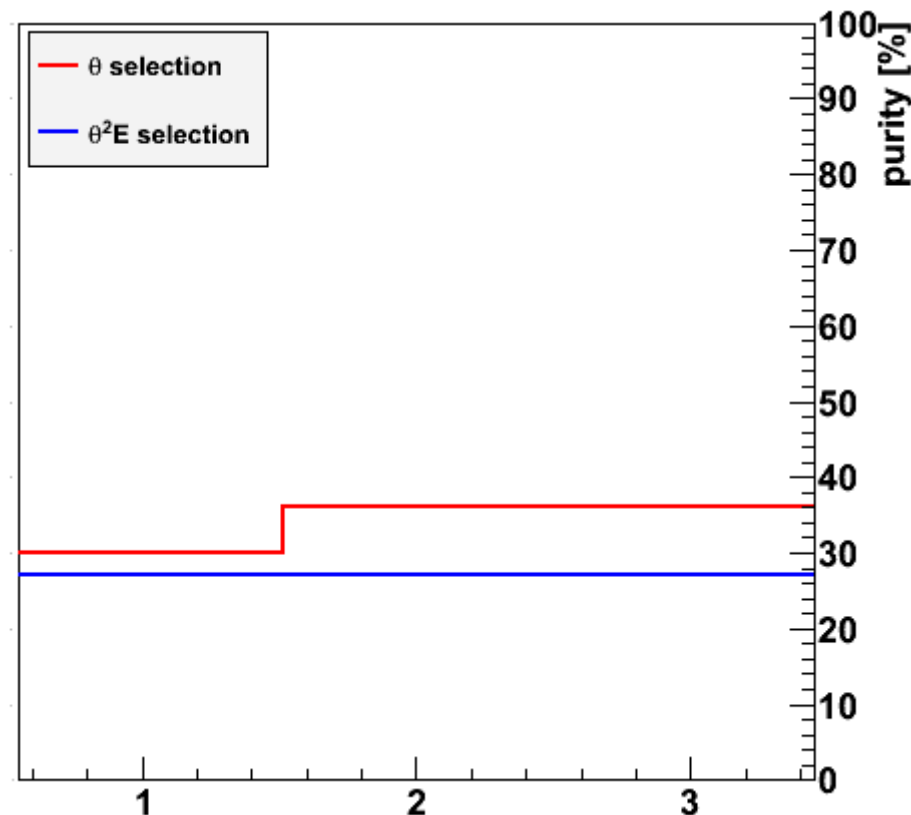
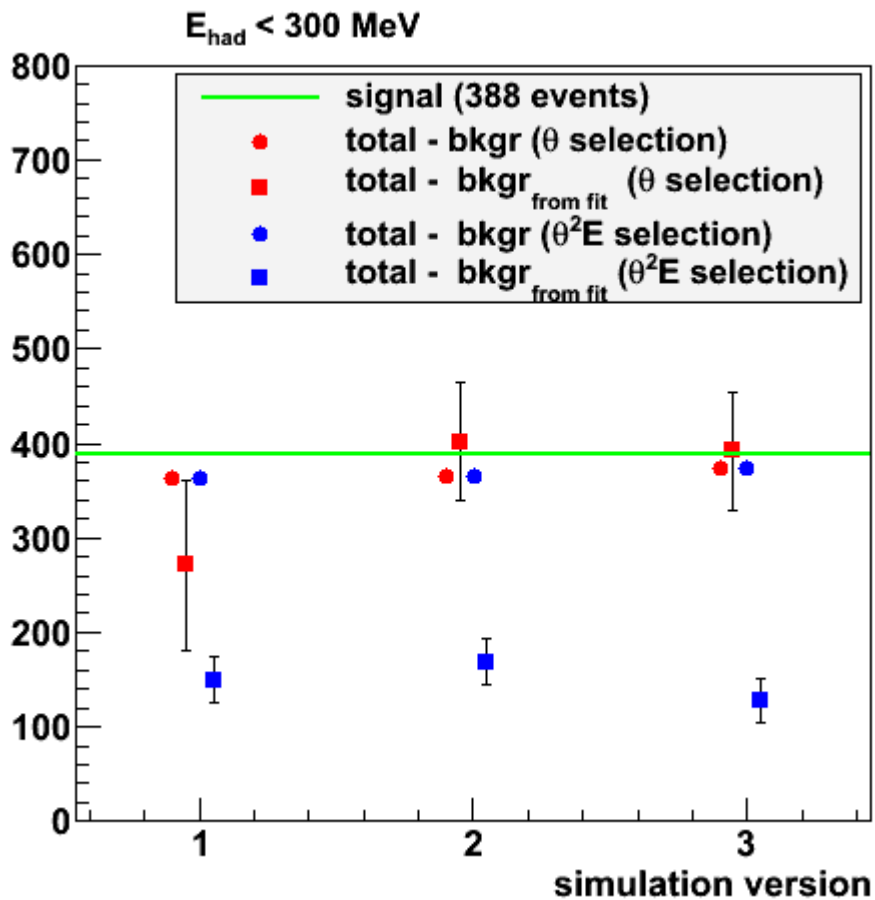
$E_{had} < 200 \text{ MeV}$

$E_{had} < 200 \text{ MeV}$





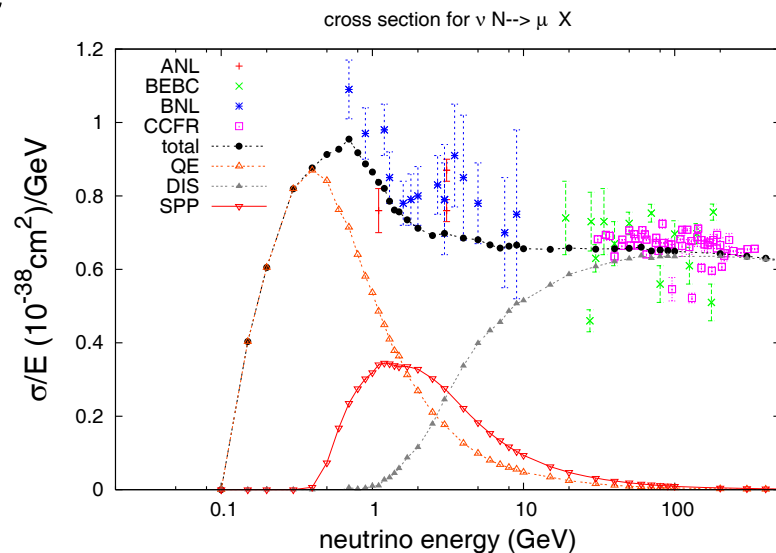
$E_{had} < 300 \text{ MeV}$





Outcome (preliminary)

- We need good measurement of recoil (hadronic) energy down to few tens of MeV;
- θ_μ and $E_\mu * \theta_\mu^2$ have equivalent discriminating power;
- It's not clear yet if the uncertainty of the flux measurement could be made less than a few % \rightarrow 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 \rightarrow true values of measurables;
- Reconstruction \rightarrow experimental resolutions;
- Define a procedure for flux determination \rightarrow estimation of the experimental uncertainties.



Thanks for
your attention