Near detector simulation

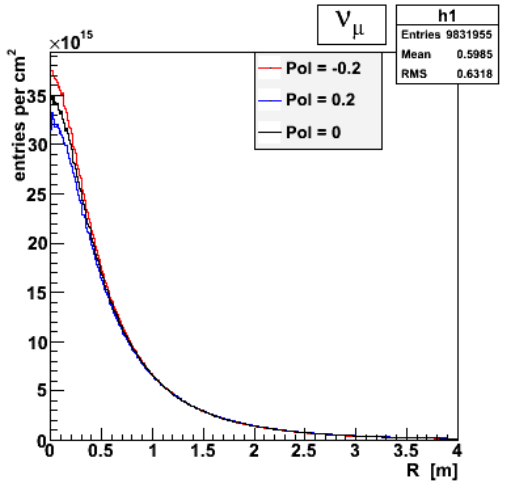
Muon decay matrix element

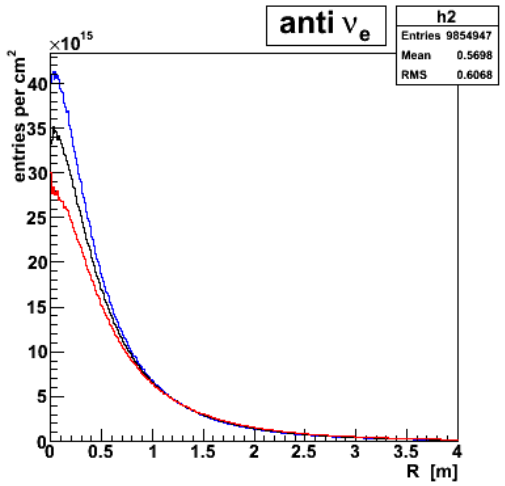
For ν_μ $$\frac{d^2N_v}{dxd\Omega} \sim \left((3-2x)+\cos\theta P_\mu(1-2x)\right)x^2$$

For antiν_e $$\frac{d^2N_v}{dxd\Omega} \sim \left((1-x)+\cos\theta P_\mu(1-x)\right)x^2$$

where $x = 2E_v/m_\mu$, P_μ is the polarization of the muon and θ is the angle between polarization vector and neutrino direction.

Simulation of the neutrino flux in the Near detector





The neutrino flux depends on the polarization of the beam. The figure shows the neutrino flux at 100 m after the end of the straight section of the muon storage ring for 1021 muon decays (1 year) for three different polarizations of the muon beam. The input parameters of the simulation are:

- Length of the straight section of the muon storage ring : 400 m.
- beam energy : 25 GeV.
- muon energy distribution : Gaussian (σ = 80 MeV)
- muon angular distribution : Gaussian (σ = 0.5 mrad)

Measurement of the neutrino flux in the Near detector

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

$$\nu_\mu + e^- \rightarrow \nu_e + \mu^-$$

and

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

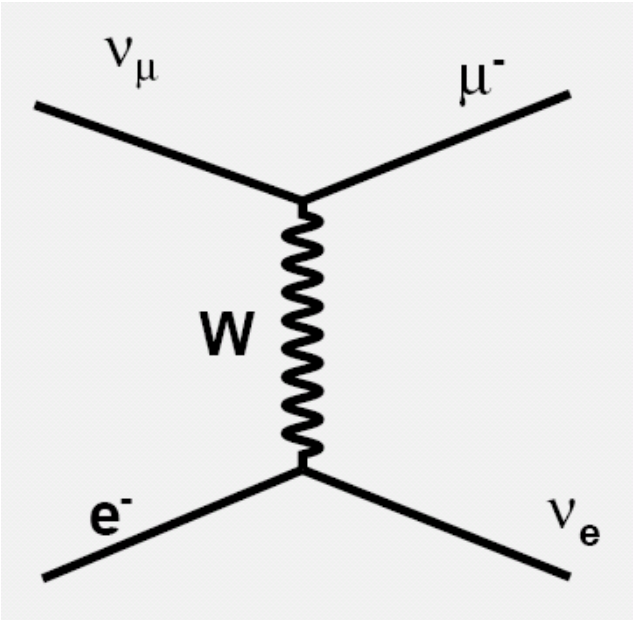
In addition, it is possible to measure the polarization of the beam.

Quasielastic scattering off electrons in the near detector (from "Leptons and quarks" L.B.Okun)

$$\nu_\mu + e^- \rightarrow \nu_e + \mu^-$$

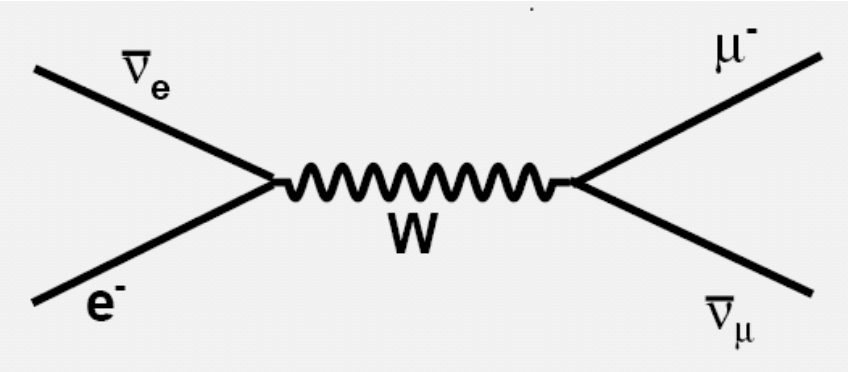
Cross section is isotropic in c.m. system

$$\sigma = \frac{G_F^2}{\pi} \frac{\left(s - m_\mu^2\right)^2}{s}$$



Quasielastic scattering off electrons in the near detector (from "Leptons and quarks" L.B.Okun)

$$\overline{\nu}_e + e^- \rightarrow \overline{\nu}_\mu + \mu^-$$



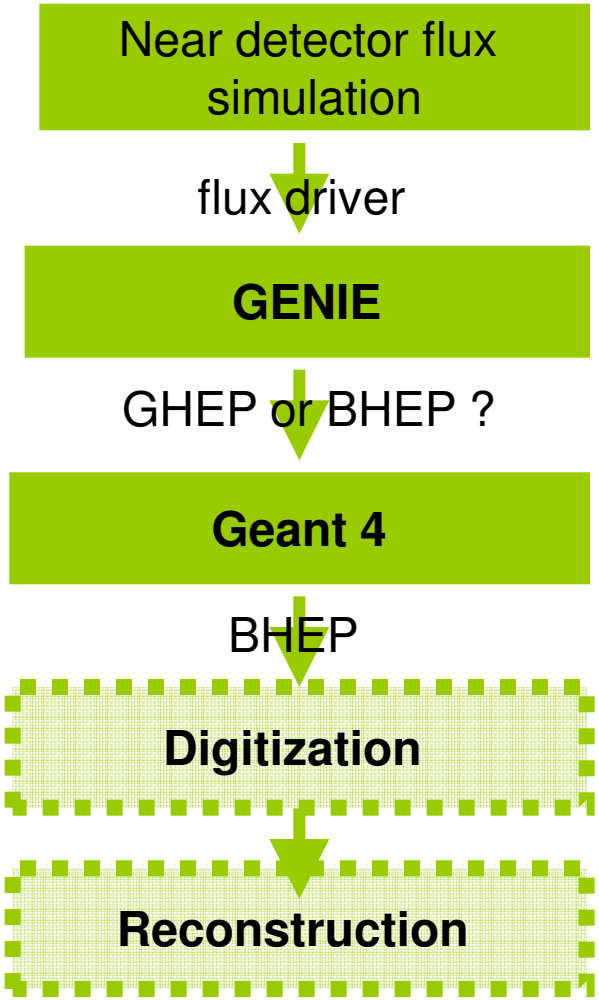
Differential cross section in c.m. system is:

$$\frac{d\sigma}{dcos\theta} = \frac{2G_F^2}{\pi}\frac{\left(s-m_\mu^2\right)^2 E_e E_\mu}{s^2}\left(1+\frac{s-m_e^2}{s+m_e^2}cos\theta\right)\left(1+\frac{s-m_\mu^2}{s+m_\mu^2}cos\theta\right)$$

And total cross section is:

$$\sigma = \frac{2G_F^2}{\pi}\frac{\left(s-m_\mu^2\right)^2 (E_e E_\mu + 1/3 E_{v1} E_{v2})}{s^2}$$

Summary of software status



Possible to generate neutrino flux for different polarizations and distances.

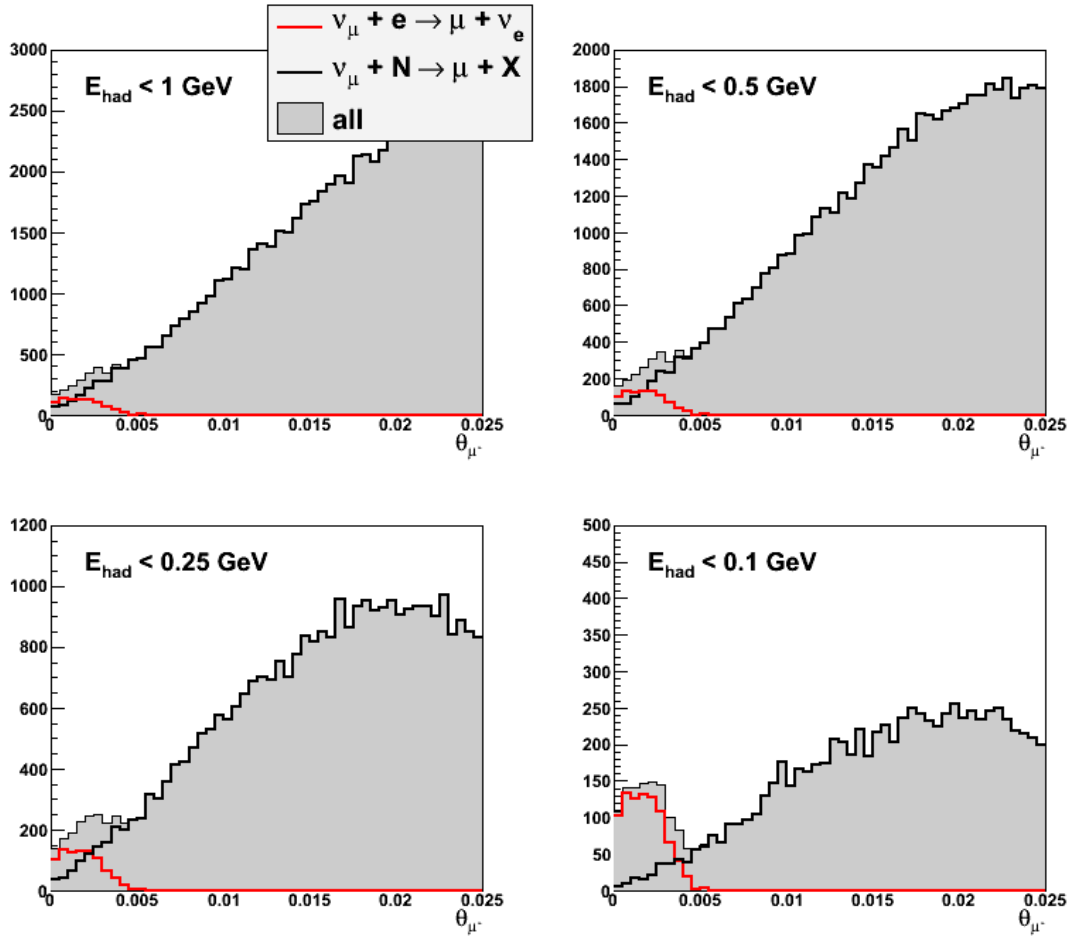
$\nu_\mu + e^- \rightarrow \nu_e + \mu^-$ is included in GENIE but

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

Interface between **GENIE** and **Geant4** under development.

Very simple simulation. To be improved.

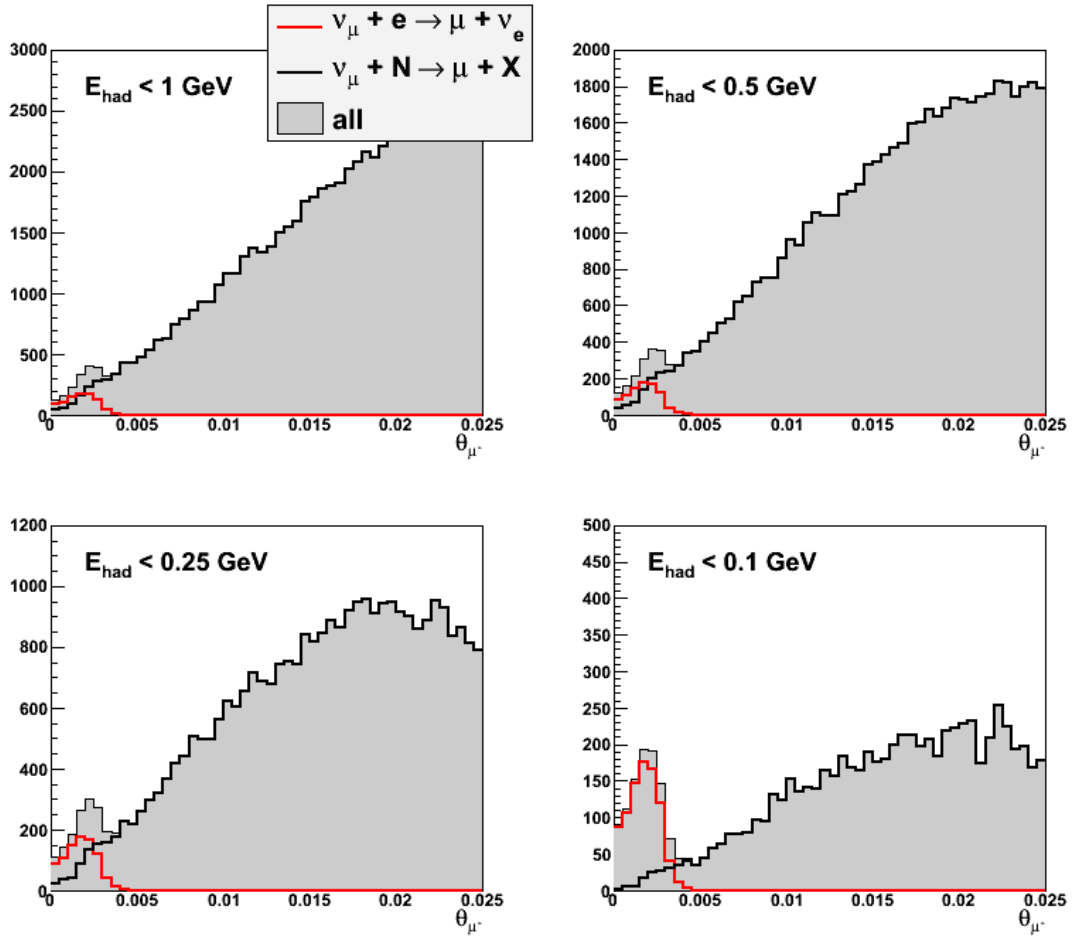
Event selection



$$\sigma(\theta) = 1 mrad$$

$$\frac{E(\theta)}{E} = 0.1E[GeV]$$

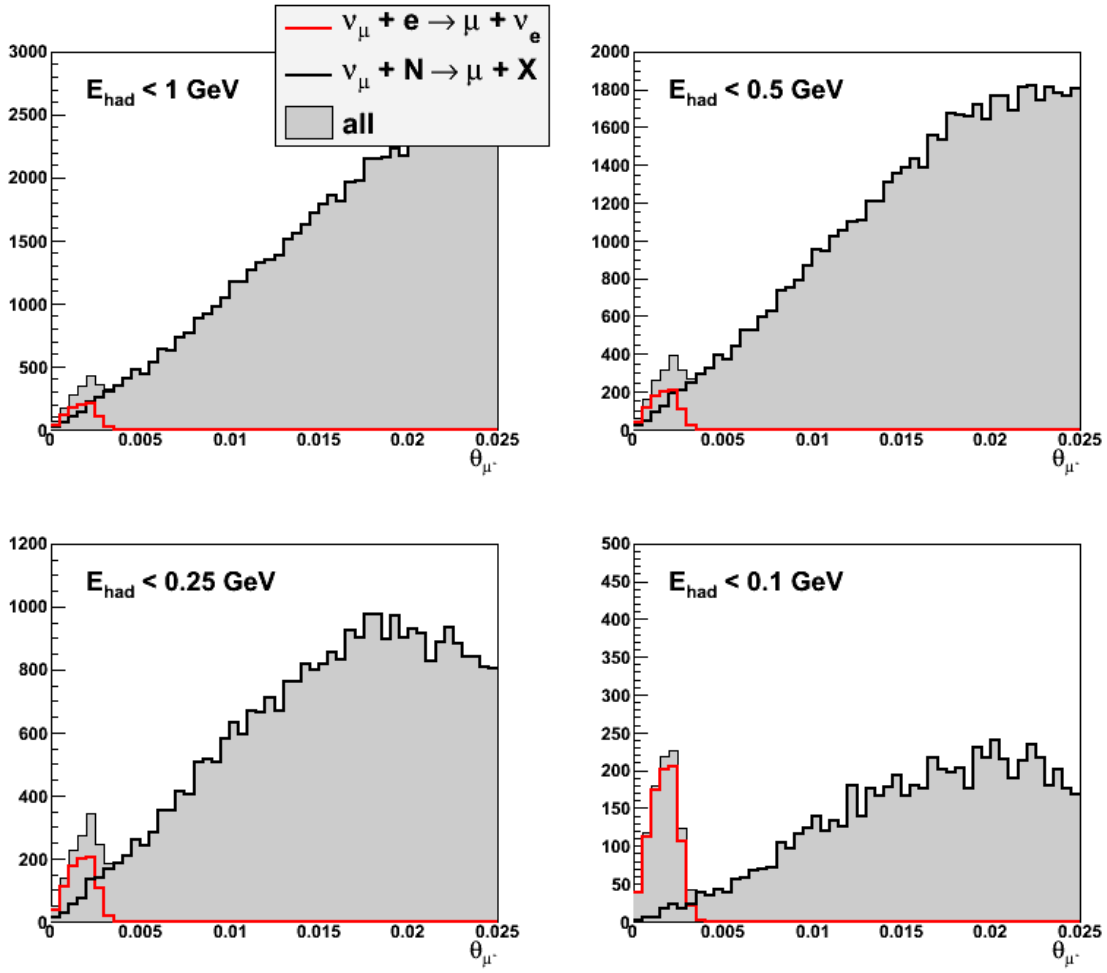
Event selection



$$\sigma(\theta) = 0.5 mrad$$

$$\frac{E(\theta)}{E} = 0.05 E[GeV]$$

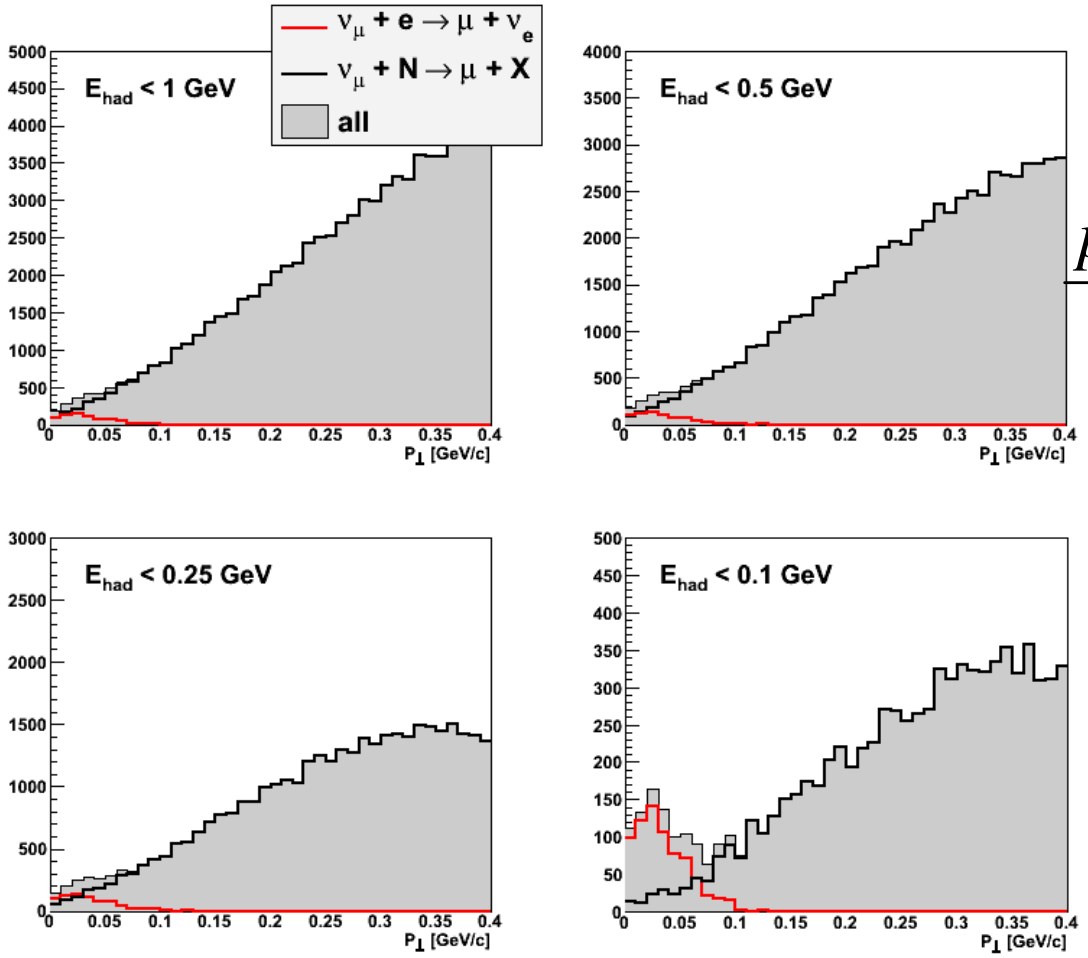
Event selection



$$\sigma(\theta) = 0.1 mrad$$

$$\frac{E(\theta)}{E} = 0.01 E[GeV]$$

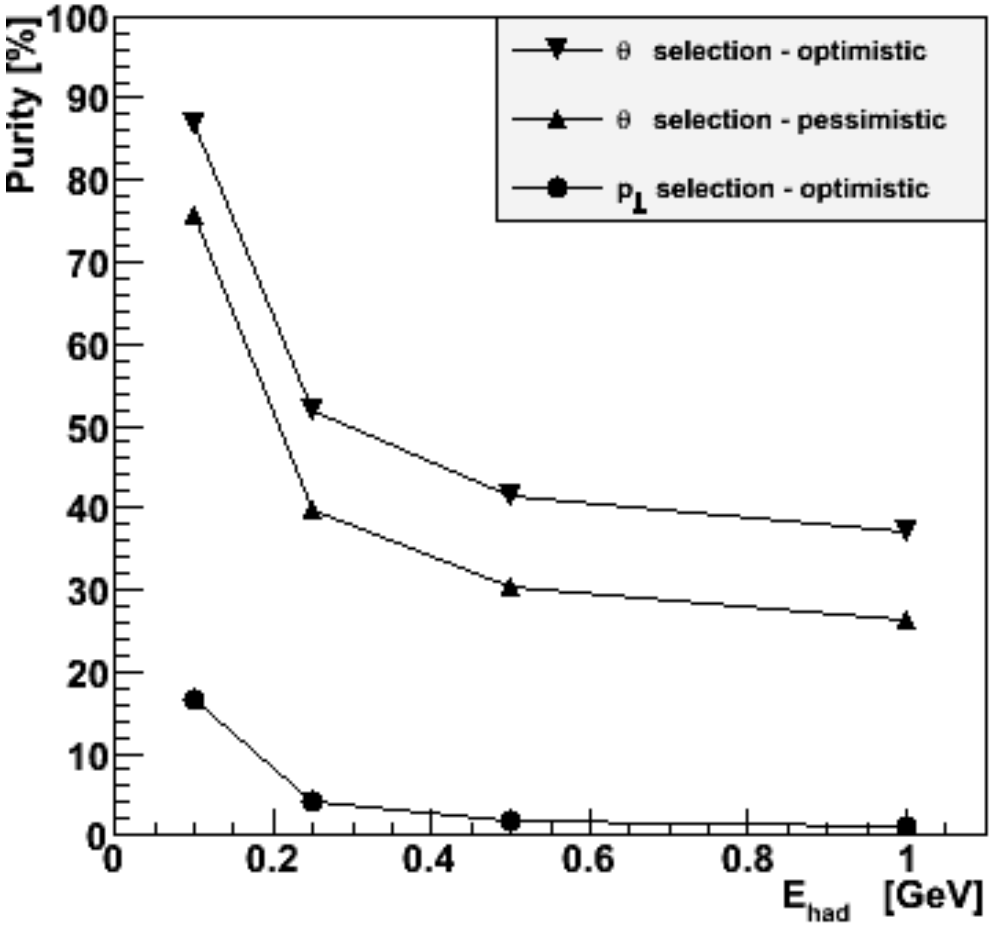
Event selection



$$\sigma(\theta) = 1 mrad$$

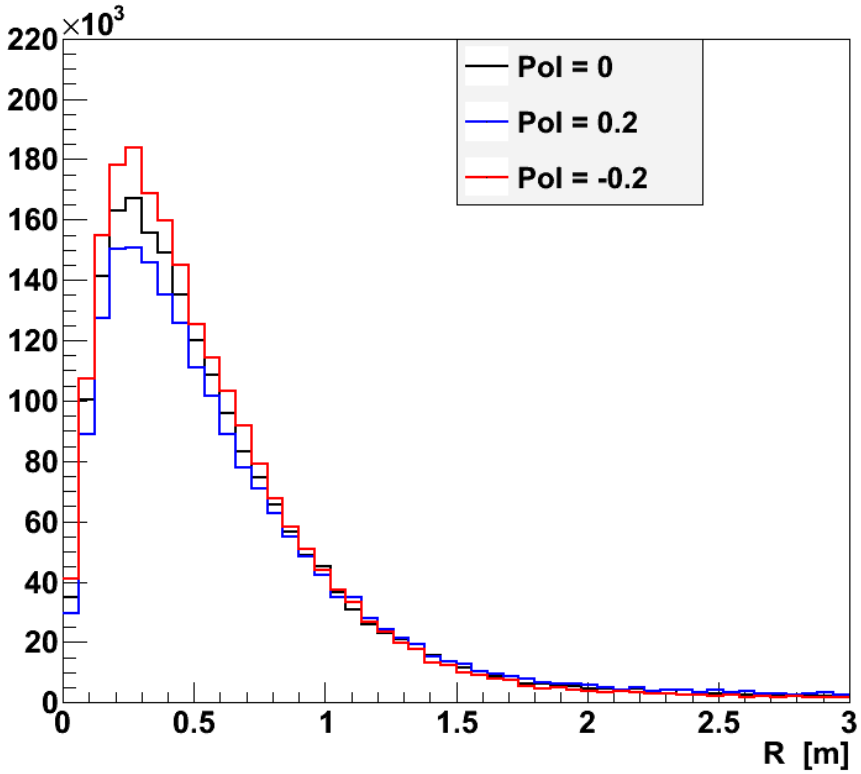
$$\frac{p_T(\theta)}{p_T} = 0.0001 P[GeV/c]$$

Monitoring of the muon beam polarization



For the given resolutions of the measurement of θ, p_T and Ehad the angle θ has better selective power than the transverse momentum pT . The confidence of the measurement of E_{had} in the range between 1 GeV and 100 MeV is critical for the selection.

Monitoring of the muon beam polarization



The leptonoc interactions of the neutrinos can be used to monitor the polarization of the muon beam in the storage ring. The plot shows the number of leptonic events in 5 m long polystyrene detector as a function of the distance from the neutrino beam axis for three different polarizations of the muon beam in the storage ring and for 10^{21} muon decays (1 year). It is clear that the variation of the distribution of the events because of the different polarization of the muon beam is much bigger than the statistical errors.