Flux determination with lepton scattering using a scintillating fibre near detector

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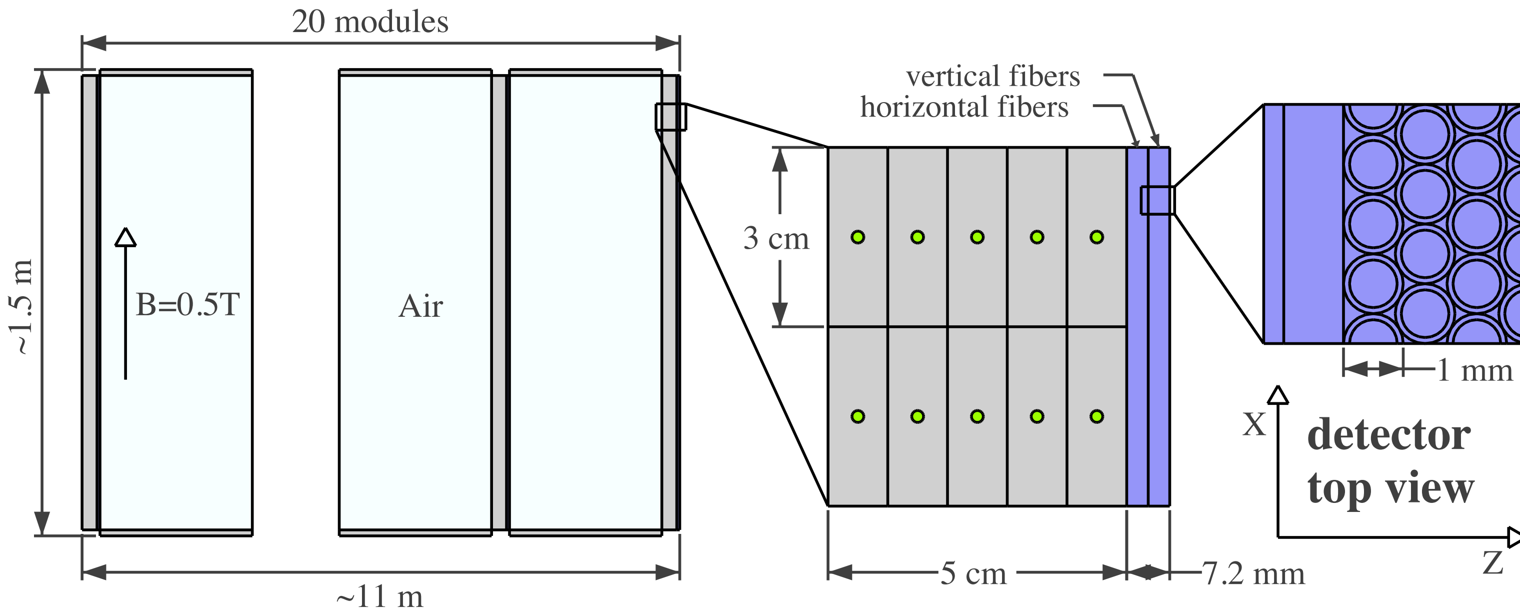
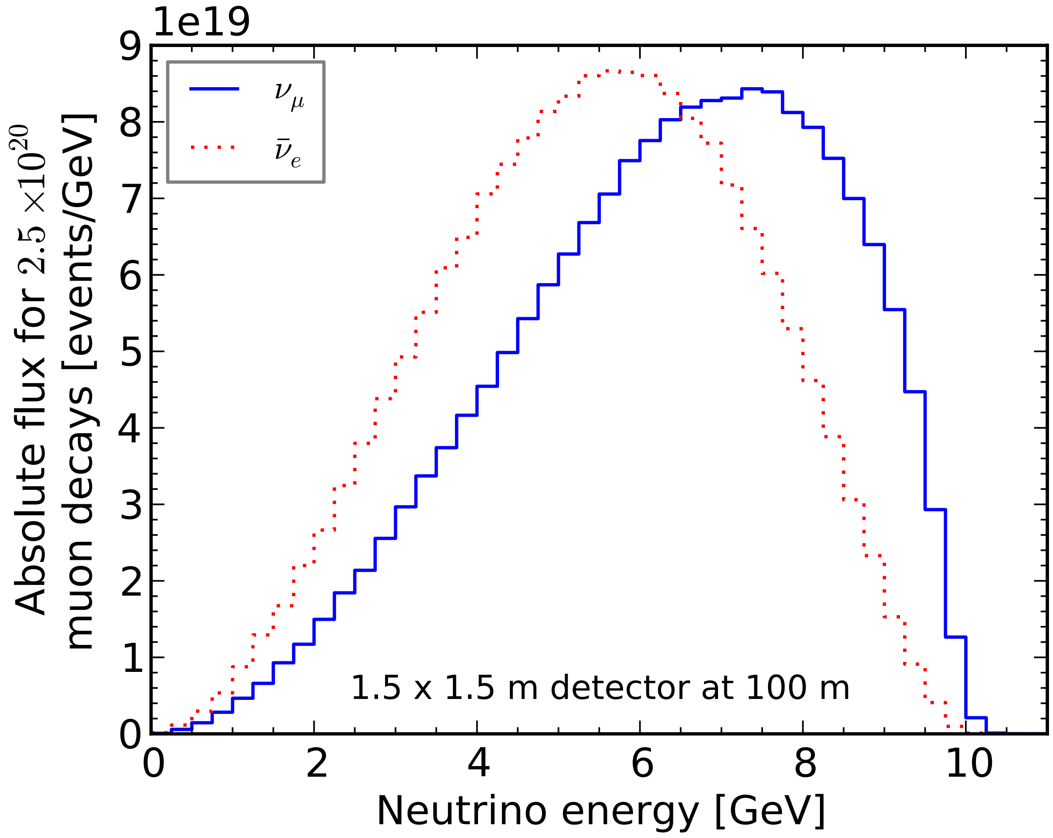
Scinitllating Fibre tracker baseline



- 20 tracker stations, each consists of 4 X and 4 Y layers of 1 mm diameter scintillating fibres shifted with respect to each other; 12 000 fibres per station (240k in total);
- 5 cm thick active absorber (target), divided into 5 slabs to allow for more precise measurement of recoil energy near the event vertex;
- Air gaps are closed by a layer of scintillating bars;
- Overall detector dimensions: 1.5 x 1.5 x 11 m^3 (2.7 tons);

10 GeV Neutrino Factory scenario



- Adapted muon storage ring parameters

(David Kelliher, https://indico.cern.ch/getFile.py/access?contribId=31&sessionId=4&resId=0&materialId=slides&confId=189421)

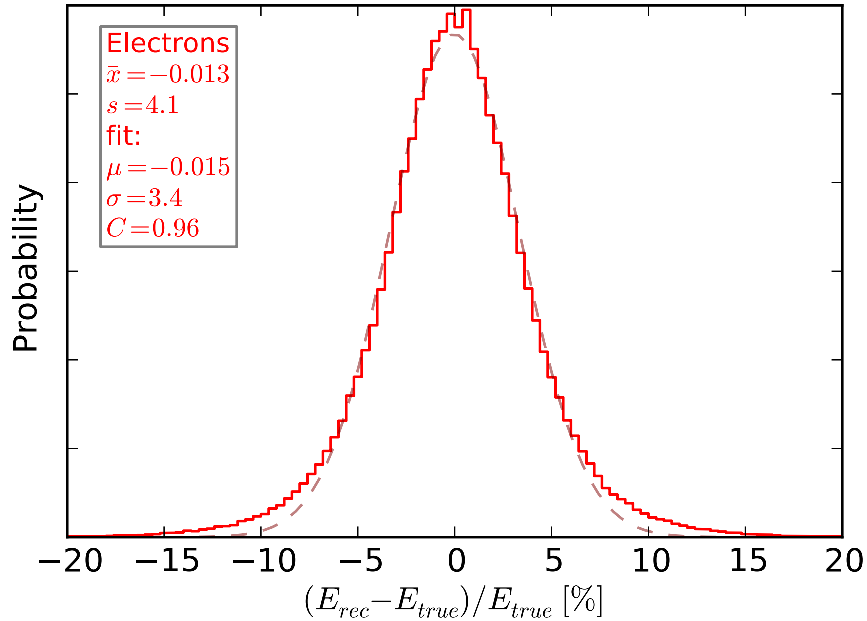
- No inverse muon decay!

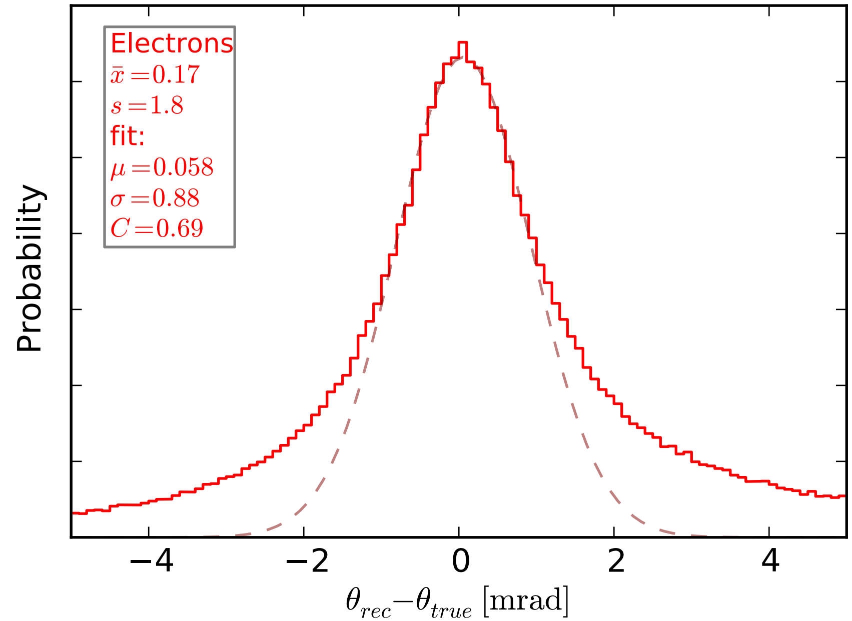
10 GeV Neutrino Factory scenario

- Measuring electron energy in nu-e interactions is crucial
  - need for ECAL surrounding the tracker
  - adopted EM energy resolution from HiResMuNu – $6\%/\sqrt{(E/GeV)}$
- Assumed 100% e/mu separation above 0.5 GeV
- Analysis cuts have been adapted to the new setup

Reconstruction performance

(10 GeV NF)

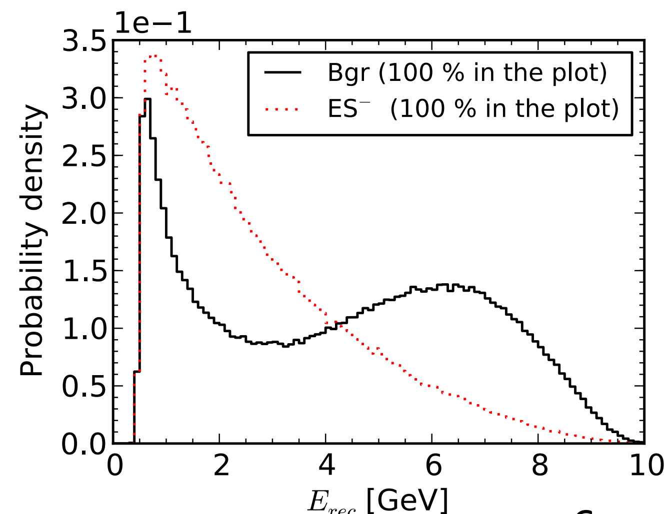




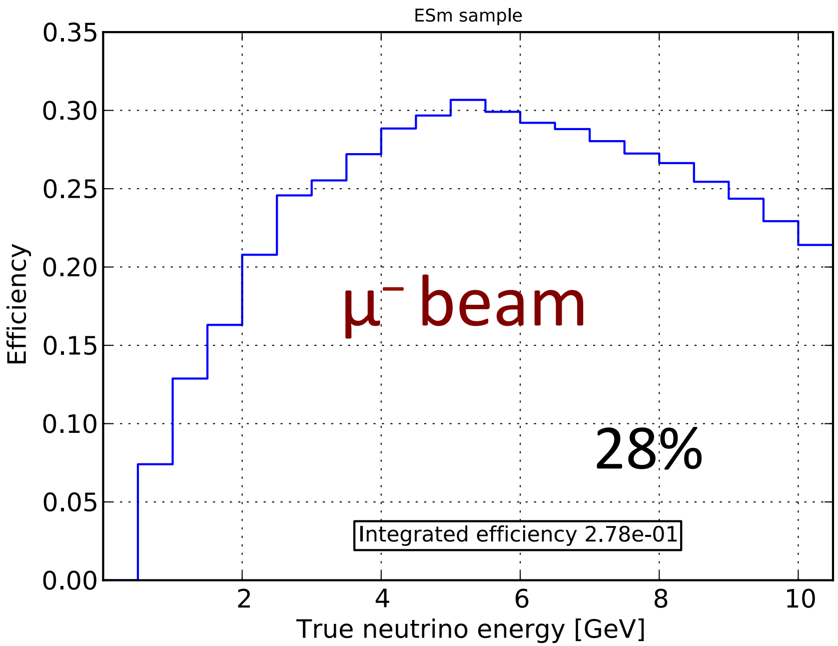
- Electron energy **σ(E)/E = 3.4%** (from ECAL)
- Electron angle **σ(θ) = 0.88 mrad**

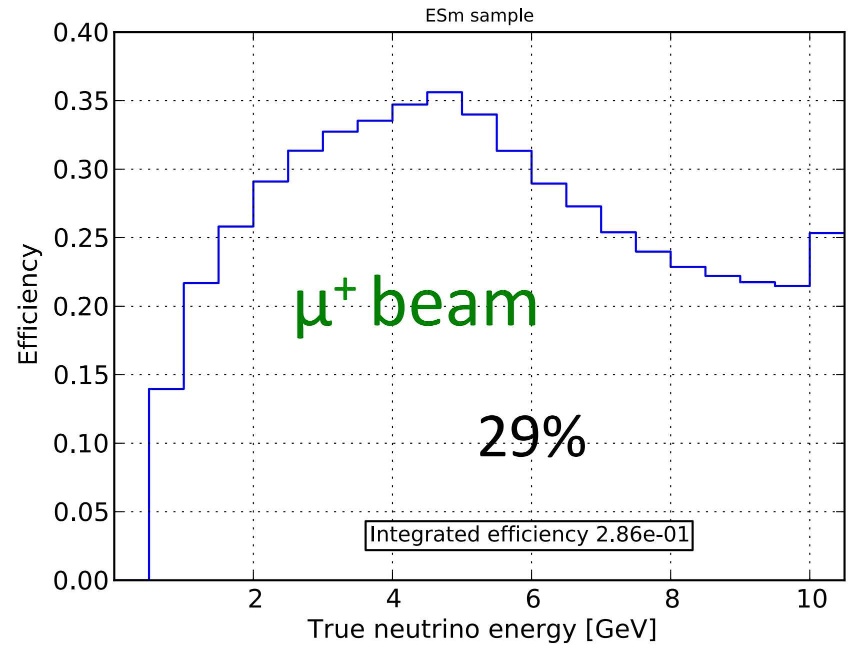
Selection of leptonic events

- Veto events with muon identified in the muon catcher
- Reject events without reconstructed vertex
- Pass events with only one properly reconstructed track going out from the vertex
- Require energy deposit in vertex bar < 3 MeV
- Cut events with asymmetric energy deposition relative to the lepton track
- $q/p < 0$
- Total EM energy of event < 5 GeV
- $\theta_e^2 E_e < 2\ \mathrm{rad}^2\mathrm{MeV}$



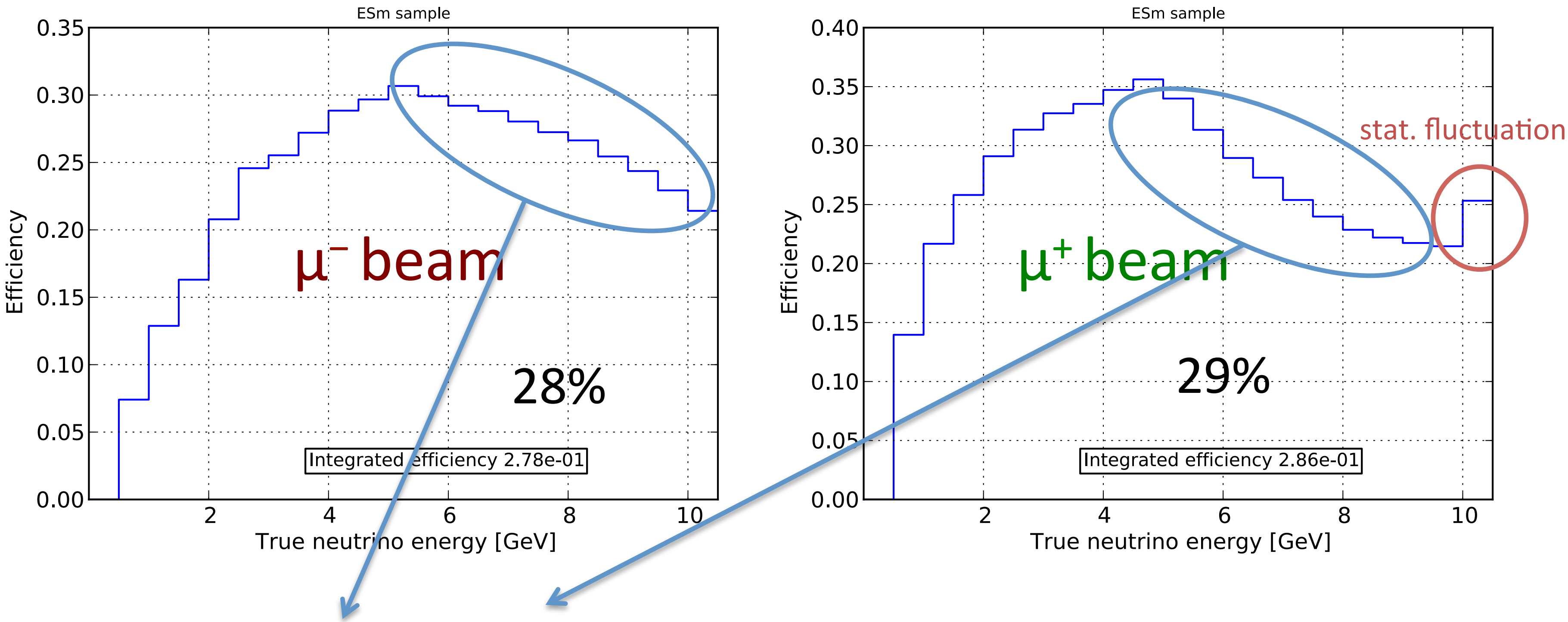
Signal selection efficiency





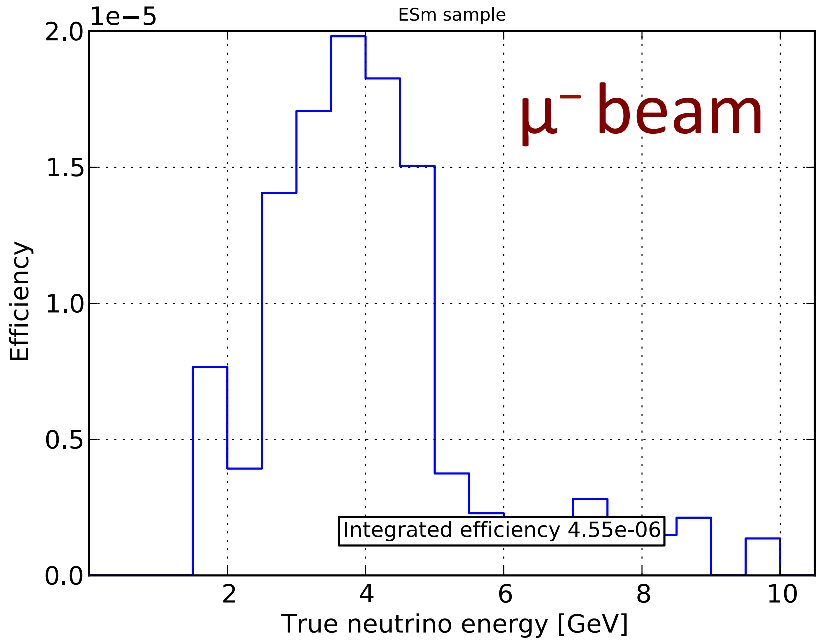
- Reconstruction efficiency ~43%
- Selection cuts ~66%

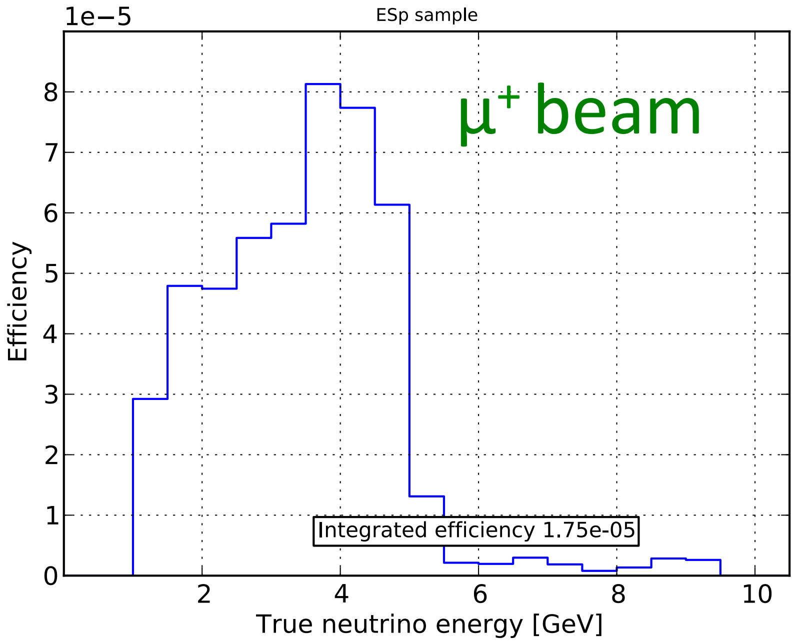
Signal selection efficiency



- Negative slope due to requirement $E_{ECAL} < 5$ GeV
- Probably can be flattened with composite (θ, E) cut

Background rejection

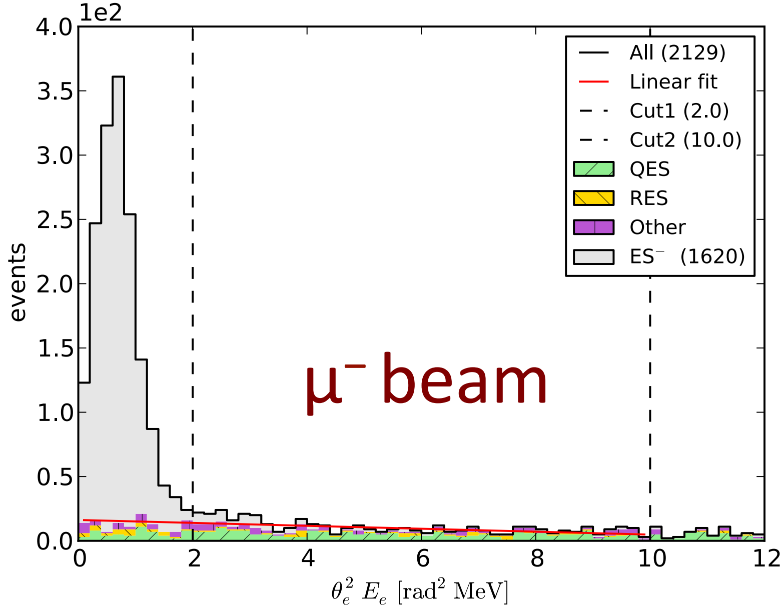


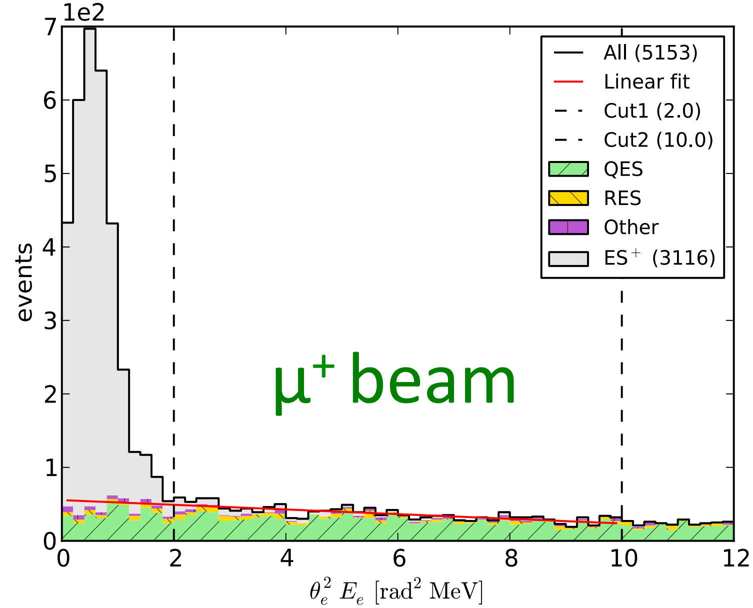


(fluctuations due to low statistics)

- Substantial background rejection
- μ^- beam – 5×10^{-6}
- μ^+ beam – 2×10^{-5}

nu-e event counting





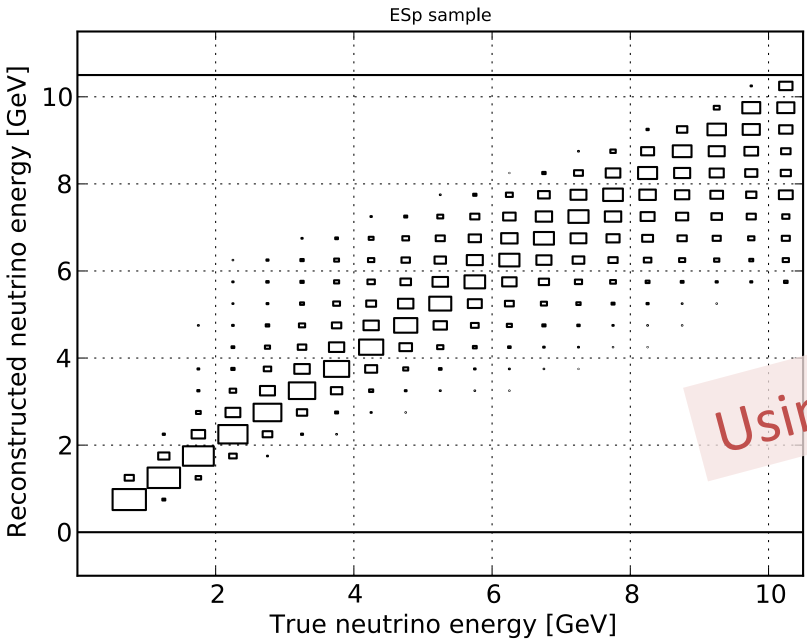
Statistics correspond to 2/10 of a nominal year (5×10^{19} μ^- decays and as many μ^+ decays)

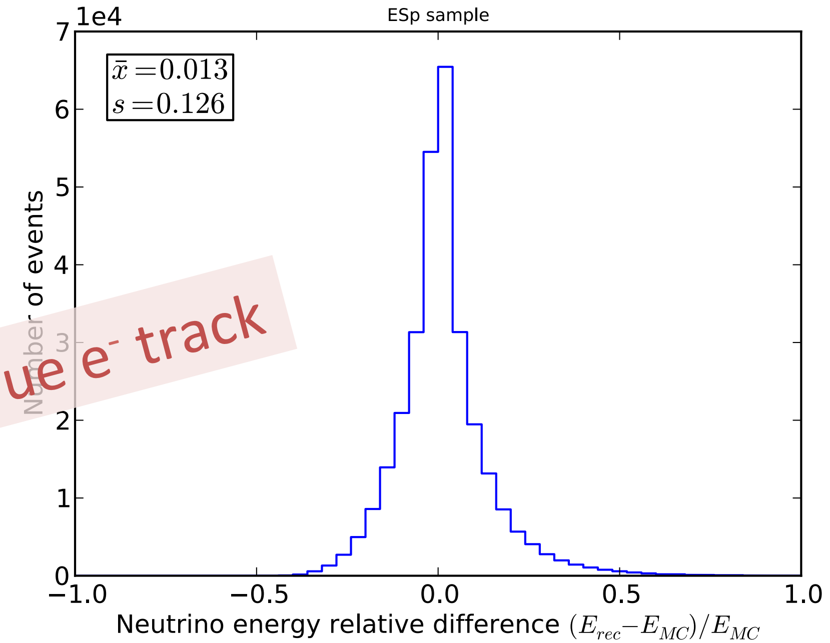
Sample	Efficiency	Purity	Signal + Bgr	# signal	# signal linear fit
ES$^-$	29%	92%	1637	1511	1486 ± 40
ES$^+$	28%	86%	3414	2951	2892 ± 58

Need to estimate number of background events with 10% precision to have 1% uncertainty on number of signal events

Neutrino energy reconstruction

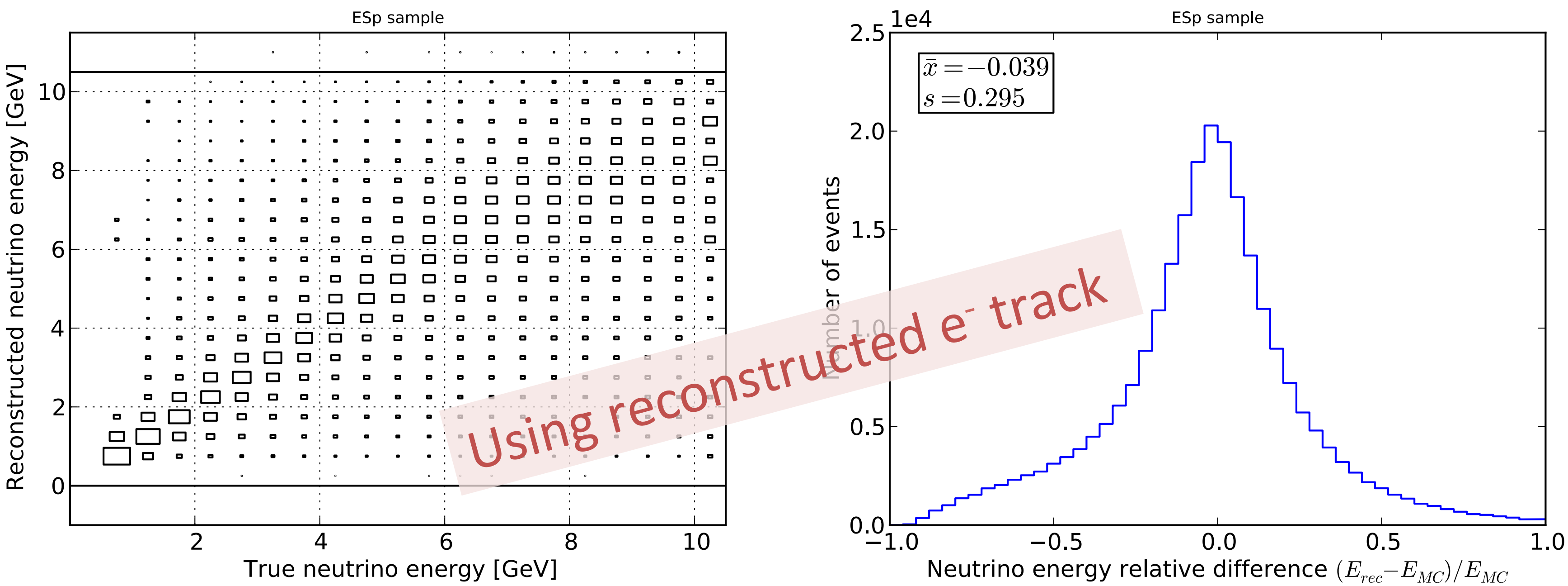
(from leptonic events)





- For details see talk at IDS-NF 8
  (https://www.ids-nf.org/wiki/GLA-2012-04-18/Agenda/Physics/Files?action=AttachFile&do=get&target=Matev-v1.pdf)
- There is muon decay position ambiguity.
- Thus, cannot reconstruct neutrino energy precisely even having the true 4-momentum of the scattered electron.

Neutrino energy reconstruction



- Theoretical performance of method – 12%

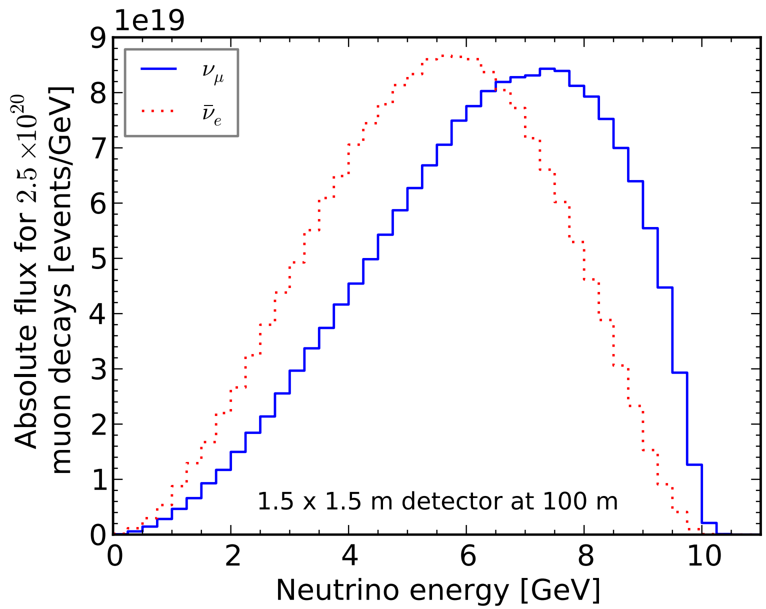
  (with current NF neutrino flux Monte Carlo)

- Best achieved performance – 30%
- Improvement on ingredients (θ_e and E_e) is hard!

Neutrino flux normalization

- Neutrino-electron scattering cross section is well known
- With the achieved s/b ratio, background needs to be known to 10%
- Integrated efficiency needs to be known to a precision of less than 1%
  - Knowing reconstruction and selection efficiencies is a matter of understanding the performance of the detector
  - Geant4 is not enough. A test beam experiment is a MUST

Neutrino flux shape



- We have two neutrino flavours
- Strong correlation between the two spectral shapes (same muon beam)
- Thus, resolving is possible (but needs to be verified by MC)

Conclusion

- Analysis adapted to 10 GeV NF scenario
- Reconstruction performs well
- Neutrino flux can be normalized to 1% if
  - efficiency is known better than 1%
  - remaining background is known better than 10% (linear extrapolation achieves that)
- Neutrino energy in leptonic events is reconstructed with 30% uncertainty
- Having the response matrix one can fit the selected leptonic events to extract the energy spectrum

To do

What is the overall systematic uncertainty on flux normalization and shape (using nu-e events) ?

Need to estimate uncertainties of:

- reconstruction and selection efficiency (integrated and differential)
- response matrices
- fiducial volume