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“ Implementation of SPL and Beta Beams”

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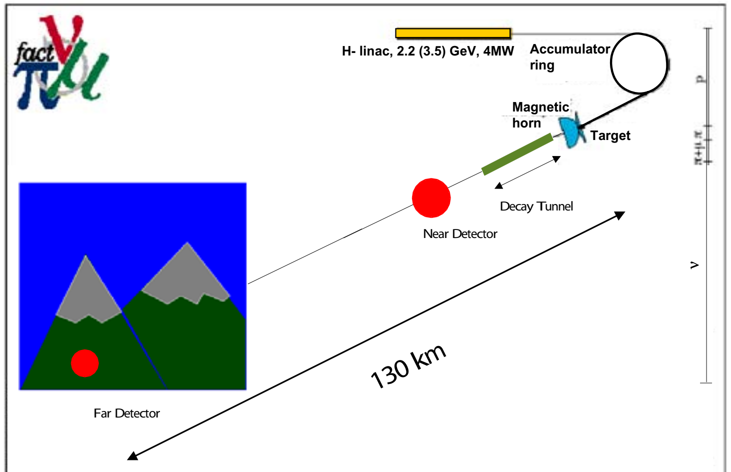
SPL implementation



Possible Low Energy Super Beam Layout

The SPL SuperBeam experiment is conceptually identical to T2HK: generate a conventional neutrino beam and fire it to a megaton water Cerenkov detector. So why don't simply take the default description of T2HK in Globes and adapt it to the different beam?:

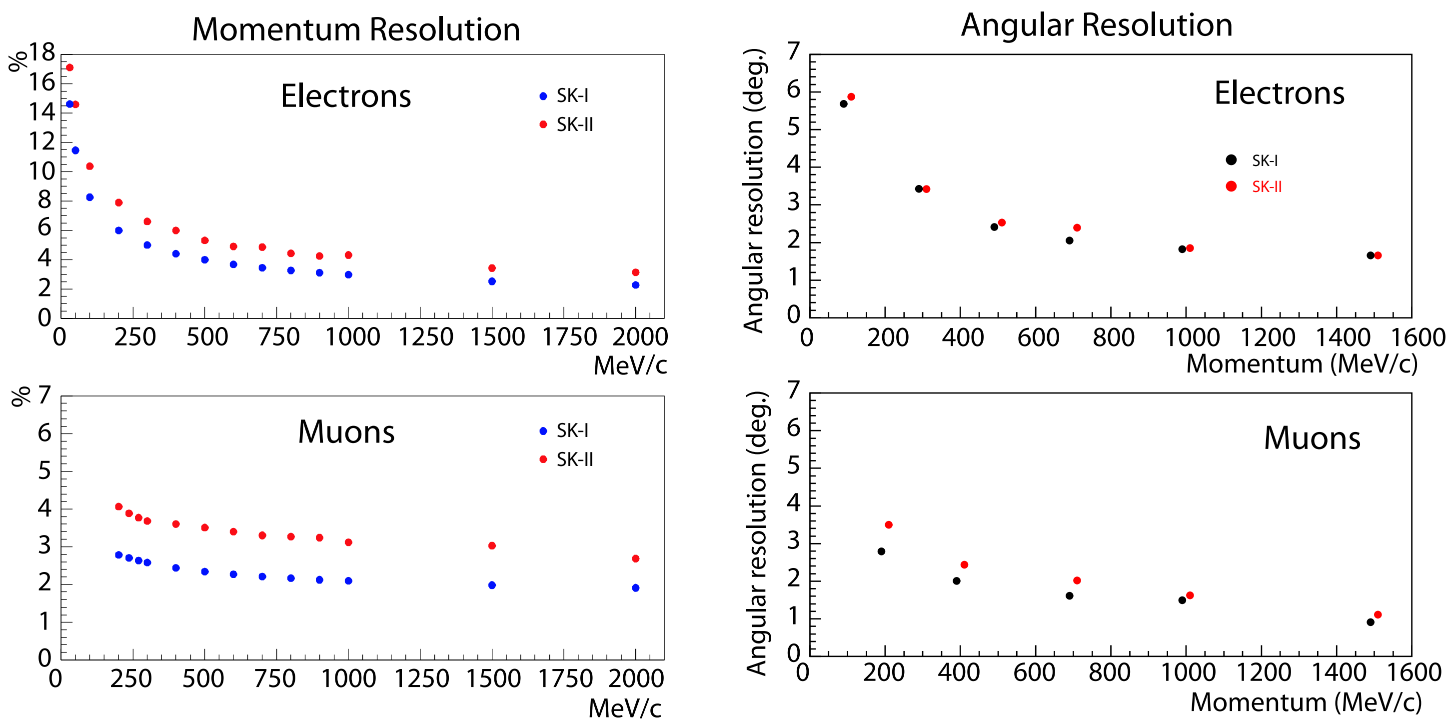
- The default T2HK (and T2K) AEDL file is too tricky for me.
- The SPL environment is simpler
- The new file is derived from the Beta Beam development.

The main problem:

- Energy reconstruction in WC detectors works well only for quasi elastic events, while for non QE events it is biased.
- A gaussian approximation for the energy reconstruction is by no mean wrong.
- At the SPL energies (200-500 MeV) QE elastic events dominate and the problem is attenuated.

The solution:

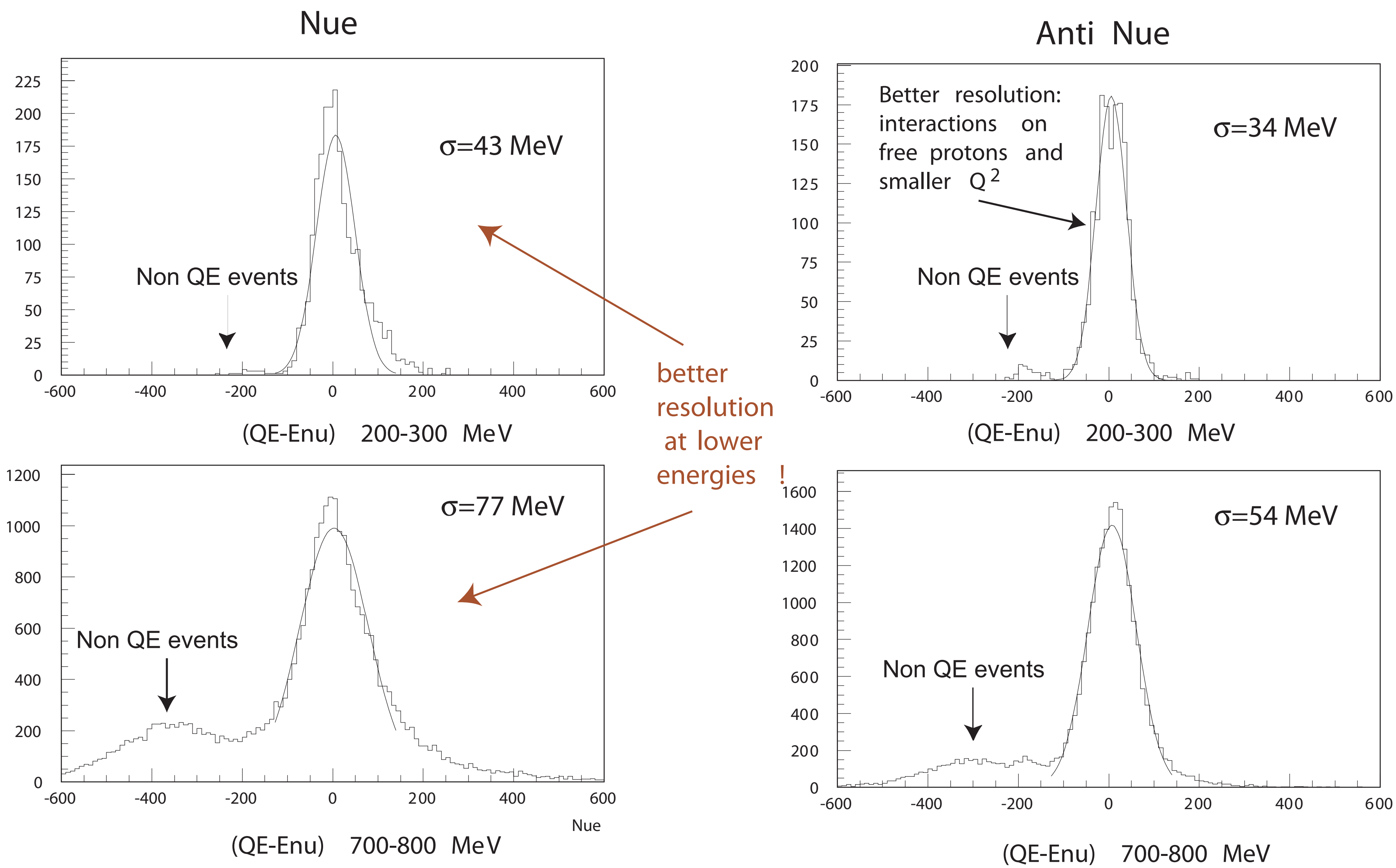
- Generate inclusive neutrino events with Nuance (v3.0)
- Smear momentum and angular reconstruction with the known SuperKamiokande functions.



- Reconstruct neutrino energy following the two body Quasi Elastic kinematics

$$E_\nu = \frac{ME_\mu - m_\mu^2/2}{M - E_\mu + p_\mu \cos\theta_\mu}$$

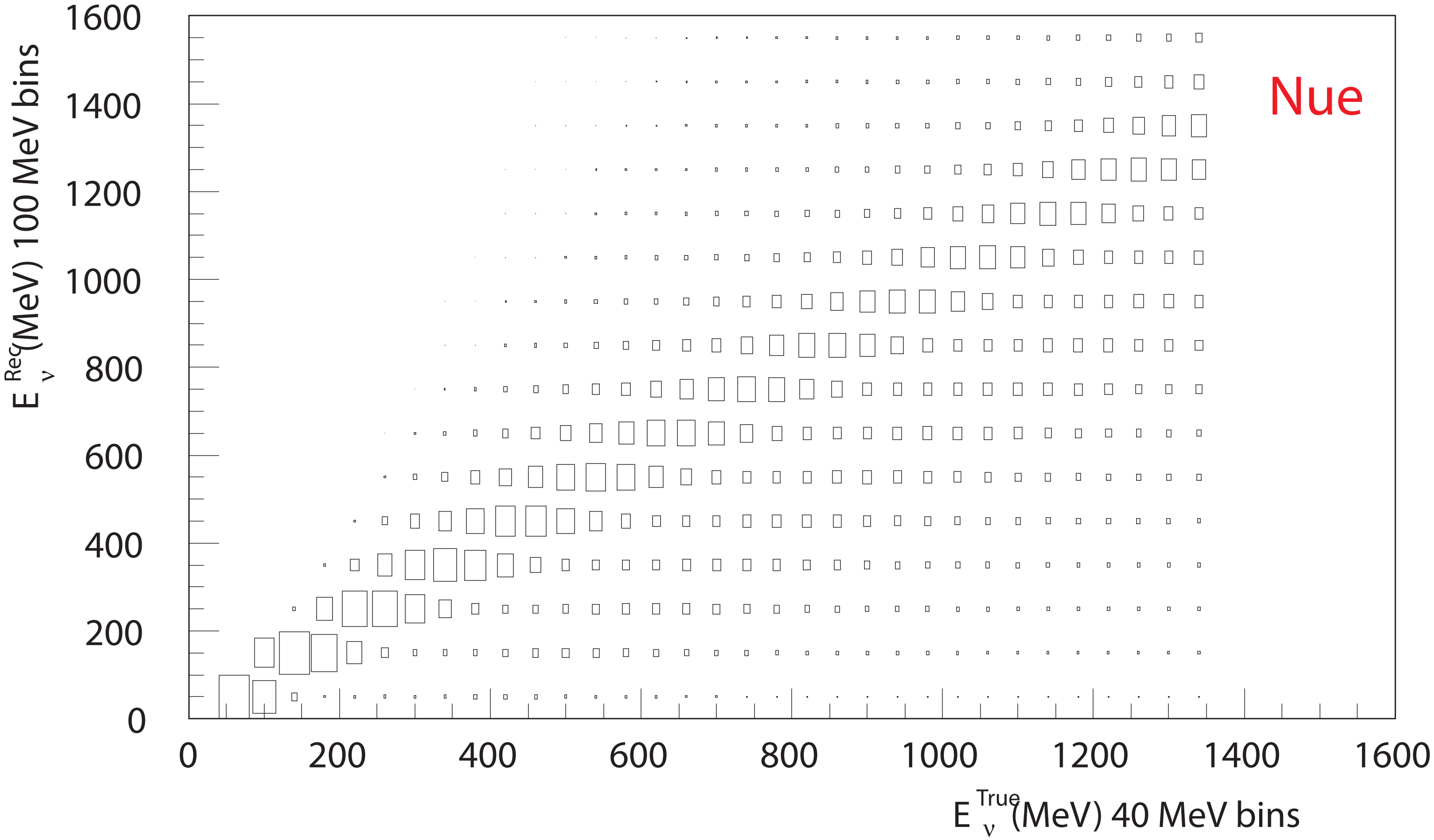
Neutrino energy reconstruction (QE kinematics)



Below 0.5 GeV the energy resolution is optimal and the non QE contamination negligible.

Migration matrices

Migration Matrix (4 matrixes for nue, numu and anti's)



The matrixes are built for neutrino energies $0 < E_\nu < 1.6$ GeV and can be used by any experiment where E_ν is reconstructed from the QE kinematics in a WC detector

SPL implementation: backgrounds

ν_e ($\overline{\nu}_e$) contamination is simply simulated with the appropriate MM and an efficiency of 70.7 % (ν_e) and 67.7% ($\overline{\nu}_e$), flat in E_ν.

NC backgrounds (π°): so far they are treated as in the T2HK Globes file: normalized to the known background rate and with an energy equal to the true neutrino energy from NC interactions.

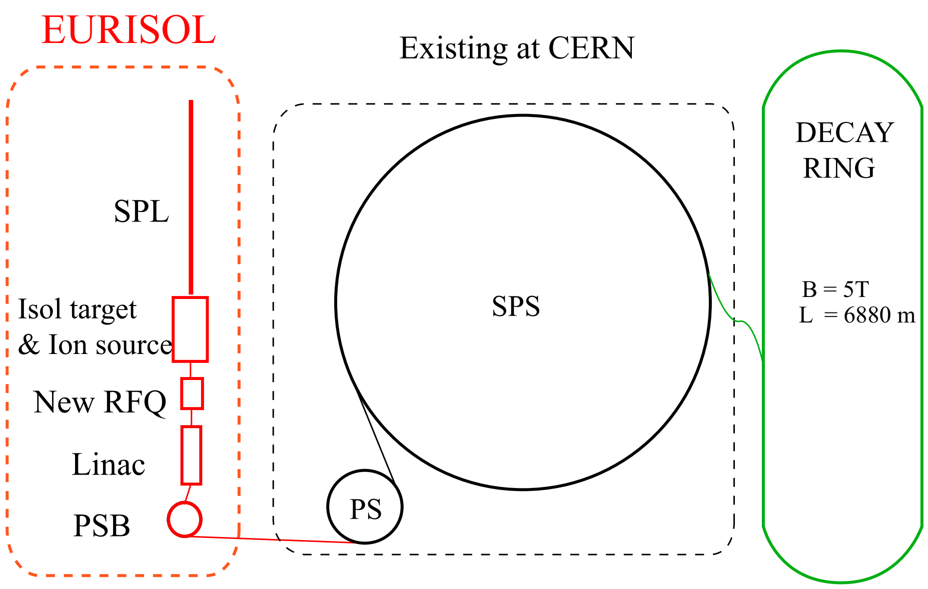
This approximation is rather crude: π° events have a reconstructed energy very different from ν_μ NC events, it is anyway acceptable because NC backgrounds are less than the intrinsic ν_e contamination and a wrong treatement of their energy doesn't affect very much final sensitivities.

Different the case for the Beta Beam, see the following slides.

SPL implementation: other inputs

- Neutrino fluxes are taken from J. E. Campagne and A. Cazes, Eur. Phys. J. C **45** (2006) 643 [arXiv:hep-ex/0411062].
- Neutrino cross sections are taken from Nuance, using specifically water
- The latest AEDL files has been firstly used in J. E. Campagne, M. Maltoni, M. Mezzetto and T. Schwetz, arXiv:hep-ph/0603172.

Beta Beam implementation



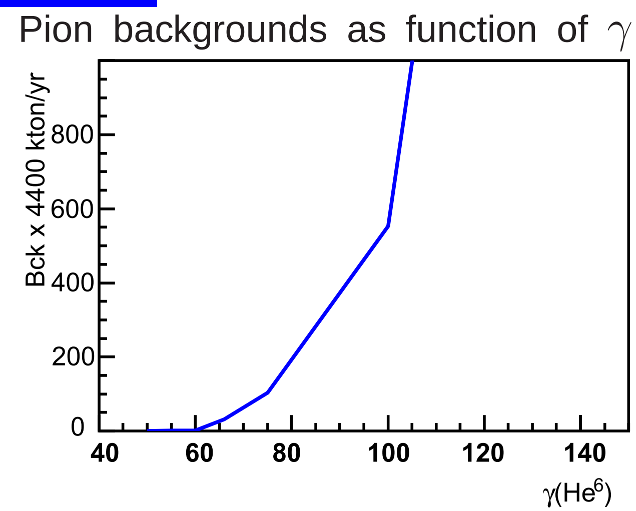
Energy reconstruction: Conceptually identical to the SPL description (same migration matrixes).

Backgrounds Main background come from charged pions from NC events, their energy distribution heavily effects final sensitivities and an accurate description is needed.

Additional backgrounds come from atmospheric neutrinos (negligible for the SPL and any other SuperBeam experiment).

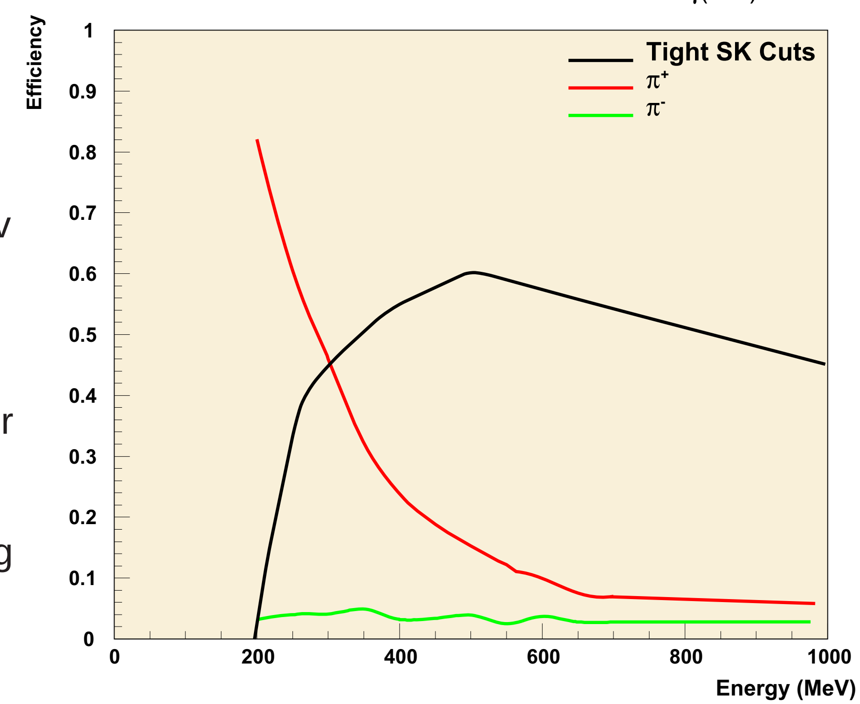
Beta Beam Backgrounds: Pions

The pions generated in NC events can fake the muon signal.
They are the main concern.

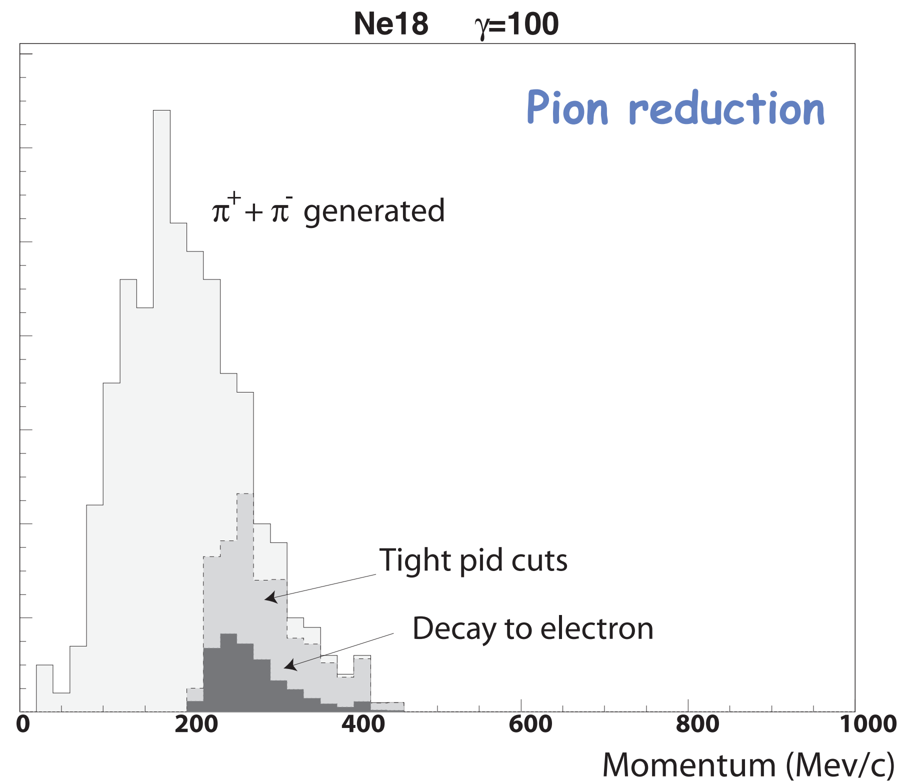


To estimate these backgrounds

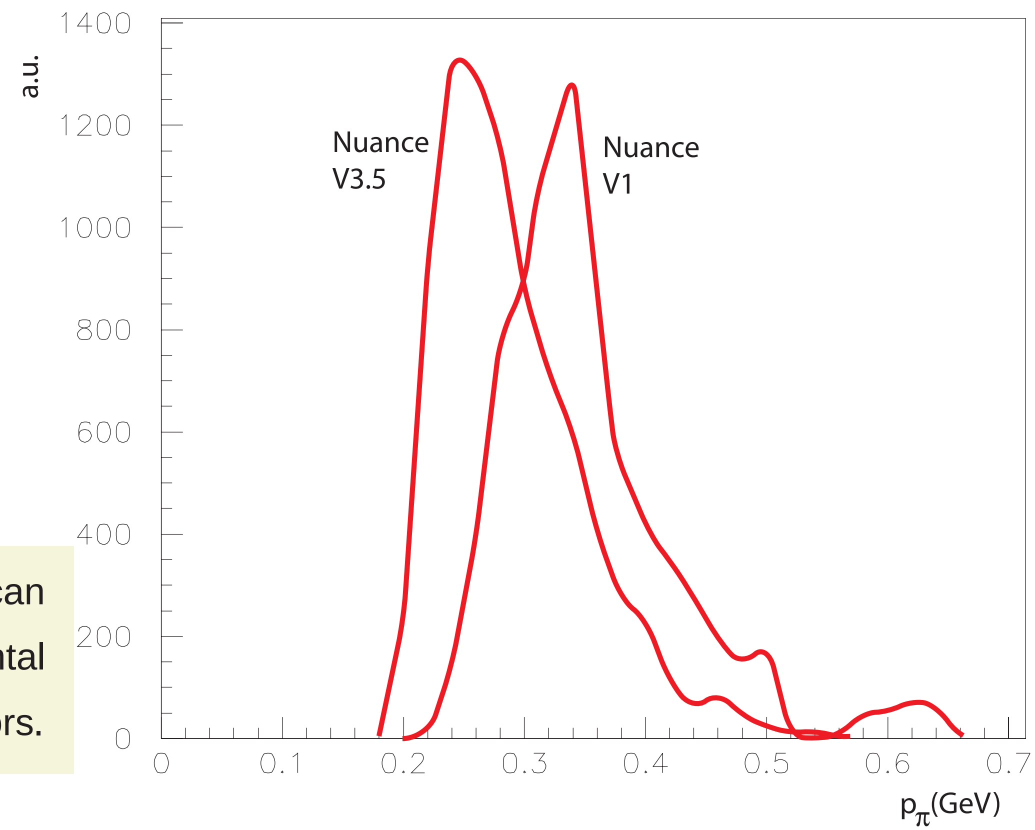
- Generate CC and NC events with Nuance
- Count events with a pion and no other track above the Čerenkov threshold (single ring events)
- Apply the particle identification cuts of SuperKamiokande
- Follow pions in water (Geant 3.21) to compute the probability for $\pi \longrightarrow \mu \longrightarrow e$.
- Reconstruct the neutrino energy from the survived pions treating them as the signal muons



The pion background (cont.)



	Ne18			He6		
	ν_μ	π^+	π^-	$\overline{\nu}_\mu$	π^+	π^-
generated	133078	560	334	113631	673	400
pid	105923	202	102	83419	241	119
decay	67888	106	8	67727	121	7



Pion production cross sections and nuclear effects can heavily change these numbers and the overall experimental sensitivity. Potentially the worst source of systematic errors.

Pion background in the AEDL file

Three possibilities:

- Describe backgrounds as pre or post-smearing backgrounds: not followed because it constrains the backgrounds to a given binning and for I while I studied βB sensitivities as function of the different binning.
- In Globes, at least until version 2, only fluxes can be described bin free, not CC rates. To overcome this I built an had hoc cross-section file corresponding to unity, so background rates are the product of a fake flux file times a fake cross section file (poor man solution, but satisfactory to my needs).
- Having now fixed the binning one could build a migration matrix connecting NC true neutrino energy and the final reconstructed energy. It would have the merit to be general enough to describe βB at different gammas. The problem is statistics: NC backgrounds are order of 100 in a 4400 kton/years exposure, at least 100×100 events would be needed: for the time being it is beyond my computing possibilities.

Final consideration: Energy of these backgrounds affects the final sensitivities and different versions of Nuance have produced different energy distributions of these backgrounds, affecting sigificatively the βB sensitivities. The real experiment will have to measure by itself, with great precision (5% or better) these backgrounds.

Atmospheric neutrino background

- Generate with Nuance atmospheric neutrinos in the Memphys fiducial
- Apply the tight particle identification cuts.
- Reconstruct them with the QE algorithm assuming they are coming from CERN.
- Accept them in the energy and direction window of the βB events:
- Apply the baseline βB duty cycle: $2.2 \cdot 10^{-3}$

The final rate is 5 background events/year (in a solar year, Beta Beam should run about 1/3 of this period)

They are implemented with a separate flux file, in the same way as NC backgrounds.

Beta Beam implementation: some references

- First description of this implementation in M.M.: talk at Nufact 06
- Used in J. E. Campagne, M. Maltoni, M. Mezzetto and T. Schwetz, arXiv:hep-ph/0603172.
- Used in the comparison between different facilities of the ISS scoping study.

Conclusions

- Globes is the right tool at the right moment.
- It makes easy the study of sensitivity of future neutrino facilities and it's extremely useful when a comparison of different facilities is needed.
- I thank the authors very much for their impressive effort.