MIND and TASD

Neutrino Factory Detectors Great and Small

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on behalf of the IDS-NF collaboration

European Strategy for
Neutrino Oscillation Physics
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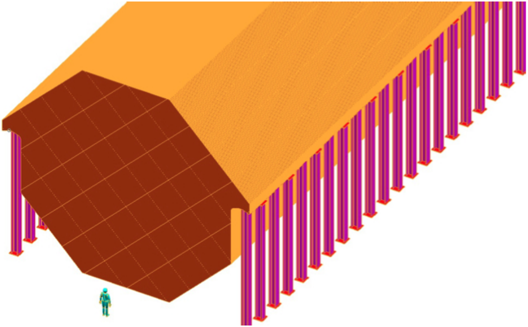
Detector Requirements for a Neutrino Factory

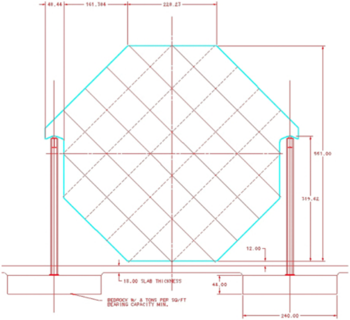
- A neutrino factory stores μ^+ and μ^-.
- Extract decay products: ν_μ, $\bar{\nu}_\mu$, ν_e, and $\bar{\nu}_e$.
- Long baseline oscillations used to probe CP violation.

Oscillation Appearance Channel: $\nu_e(\bar{\nu}_e) \rightarrow \nu_\mu(\bar{\nu}_\mu)$

- Easily identified signal: wrong sign muon.
- Background species are
  - $\nu_e(\bar{\nu}_e)$,
  - $\bar{\nu}_\mu(\nu_\mu)$,
  - and neutral current events.
- Need to differentiate μ^+ from μ^-.

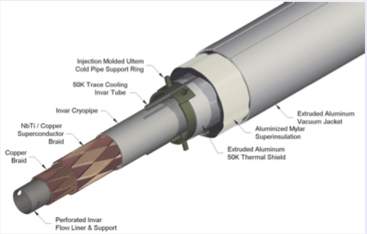
MIND Design for Neutrino Factory





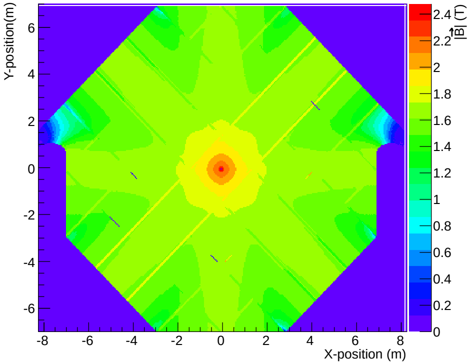
- 100 kTon detector
- 14 m$\times$14 m$\times$140 m.
- X and Y views from 2 cm thick lattice of 1 cm$\times$3.5 cm scintillator bars.
- $\vec{B}$ field from 3 cm Fe plates, induced by 120 kA current carried by 7 cm diameter SCTL

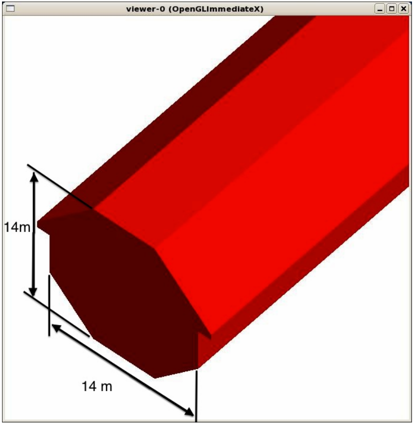
Superconducting Transmission Line



MIND Simulation

- Events simulated with GENIE.
- Full geometry & $\vec{B}$ field in GEANT 4
- Realistic field map generated by Bob Wands at FNAL
  - default positive focussing.



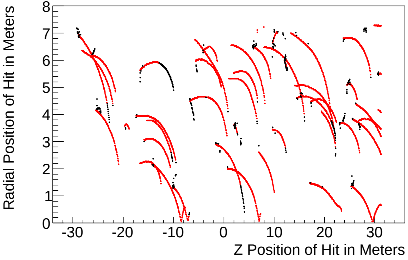


- Dimensions of detector easily altered for
  - optimization.
  - testing variations.

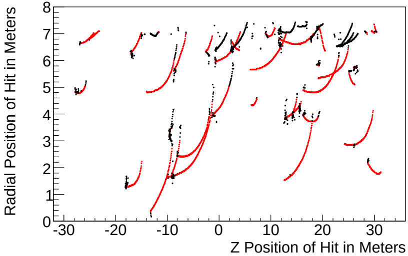
MIND Event Reconstruction

- Simulated events digitized.
  - Hits positions smeared and energy deposition attenuated.
  - Edep clustered into 3.5 cm$\times$3.5 cm units.
- Tracks identified by Kalman Filter or Cellular automata.
- Kalman fitting used to determine momentum and charge.
- Algorithms from RecPack.
  - supported by Cervera-Villanueva *et al.*

- 50 $\bar{\nu}_\mu$ CC events.



- 50 ν_μ CC events.



- Fitted hits in red others in black.

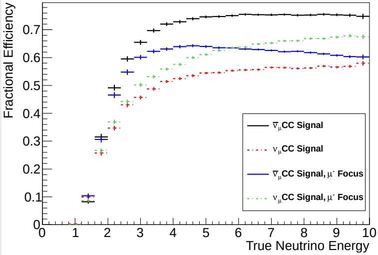
Golden Channel Analysis for 10 GeV Stored μ

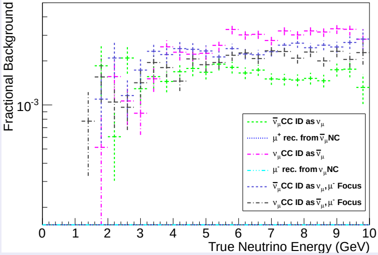
- Cuts designed to select muon in CC event
  - Select good quality tracks.
  - Optimized to reject NC-like events.

Still under development.

- Trying to recover low neutrino energy events.
- Re-evaluating pattern recognition and event classification.
- Investigating multi-variate analysis for event selection.

Preliminary: Detector behaviour and CP Precison





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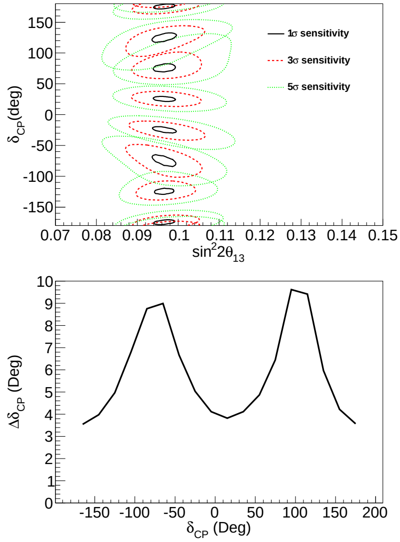
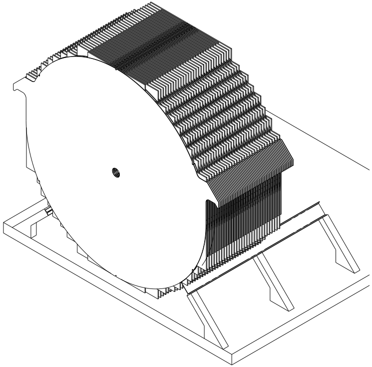
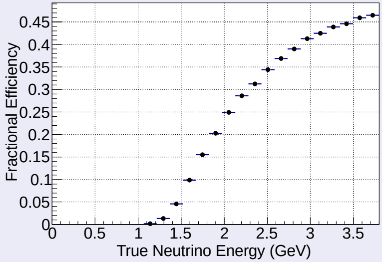


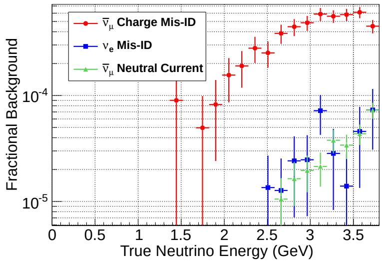
MIND Variant: νSTORM Far Detector

- 1cm thick iron plates.
- 5 m dia. circular cross-section.
- 1 kTon mass $\rightarrow$ 20 m length.
- Stored μ energy: 3.8 GeV.

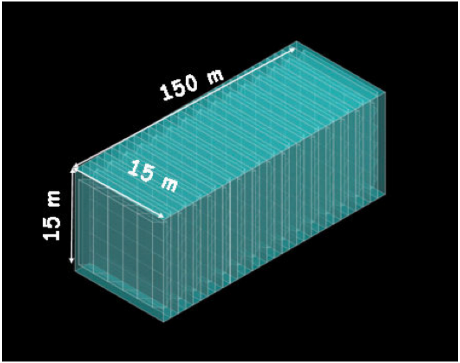


Efficiency and Backgrounds



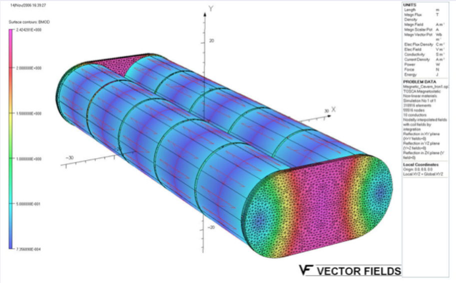


TASD Concept



- Detector composed entirely of scintillator bars.
- High granularity detector
- Can identify electron and muon tracks.

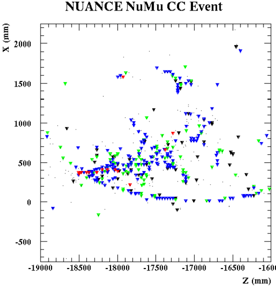
External Field: Magnetic cavern



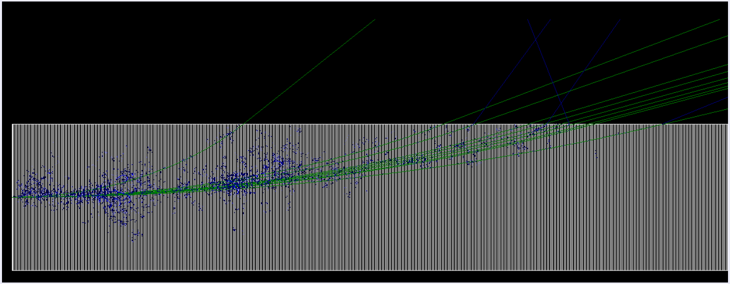
- Field induced by many turns of SCTL around cavern walls.
- Engineering is incomplete.

TASD Simulation and Reconstruction

- Produced using MIND framework.
  - Upgraded with discrete scintillator bars
  - Parametrized model of detector response
- Benchmarking done with single particles.

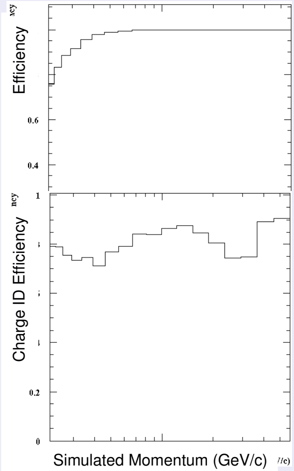


Example: 10 muons in a TASD-like detector

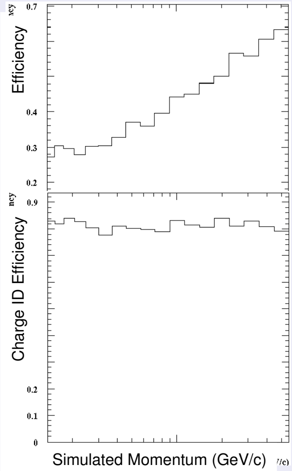


TASD Performance

Muon Reconstruction



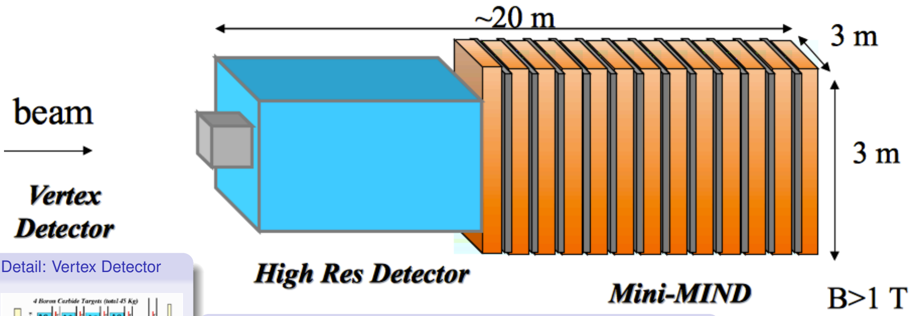
Electron Reconstruction



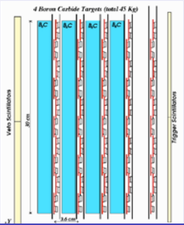
- Efficiency is fraction of events which are reconstructed.
- Charge ID Efficiency is fraction of reconstructed events with the correct charge.

Near Detectors for a Neutrino Factory

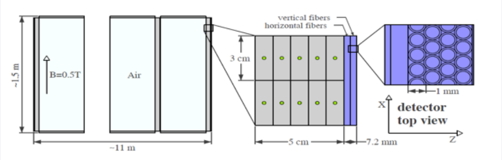
- 1% precision ν flux extrapolation
- Charm production for non-standard interaction searches
- Cross-sections and other measurements.



Detail: Vertex Detector



Detail: Scintillating Fibre High Resolution Detector

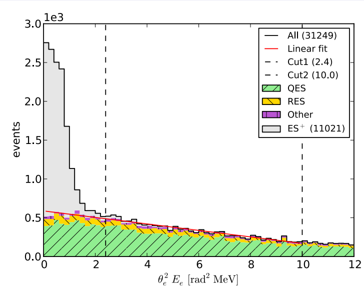


2 near detectors at neutrino factory (one per straight).

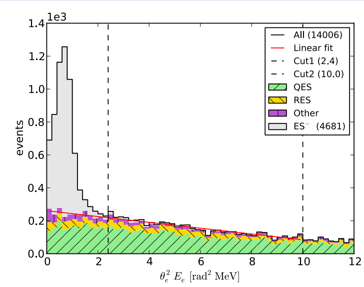
Near Detector Flux Measurements

- Simulation of SciFi detector done by Sofia group.
- Flux determined from Neutrino-Electron scattering.

ES^+ signal extraction



ES^- signal extraction



Event sample	Selection eff.	Overall eff.	Purity	All events	Signal events	Signal events from fit
ES^-	70%	32%	61%	7355	4491	4479±86
ES^+	83%	37%	63%	16964	10607	10512±131

Summary

- Magnetized detectors are essential for the measurement of CP violation at a neutrino factory.
- MIND type NF far detector well developed.
  - Engineering of the detector is advanced
  - Simulation and reconstruction software well developed.
  - Progress still to be made in reconstruction&analysis
- Low mass — low energy TASD also considered.
  - Magnetization extremely difficult.
  - Reconstruction&analysis not so advanced as MIND.
- Near detectors are essential for control of flux systematics
  - Design and simulation of high resolution detectors (i.e. SciFi) are advanced.
  - Demonstrated to have 1% precision from electron scattering measurements.