A near detector for νSTORM

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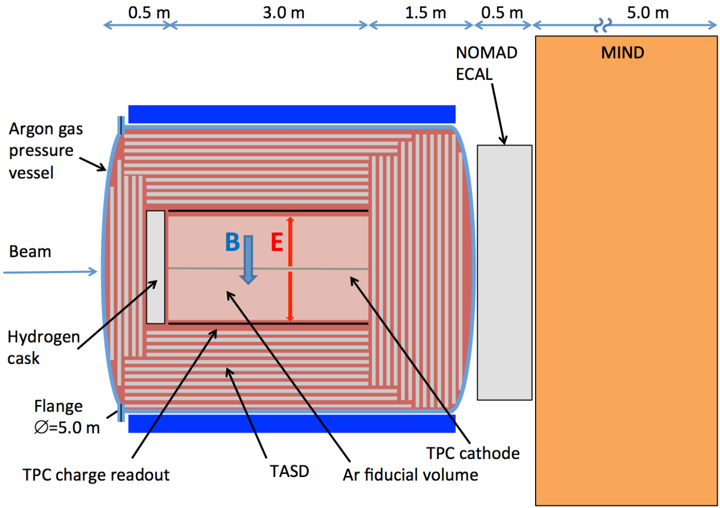
Near detector purpose

- Specific to the νSTORM sterile neutrino searches:
  - Reduction of systematics by characterizing ν beam prior to oscillation (flux normalization as a function of E_ν);
  - Near detector at 20-50 m identical to far detector at 1500 m but 1/10 the fiducial mass (MIND-type).
- Exploit νSTORM's unique 1% precision on neutrino flux to measure more generally:
  - ν_eN ($\overline{\nu}_e$N) cross-sections;
  - ν_μN ($\overline{\nu}_\mu$N) cross-sections;
  - ...If possible over wide range of nuclear targets, especially low Z H2/D2.
- Near detector facility:
  - Likely consist of several detectors (sub-detectors) to cover flux normalization and cross-section measurements;
  - Test bed for neutrino detector prototypes;
- .... one option being studied for Laguna-LBNO is presented here.

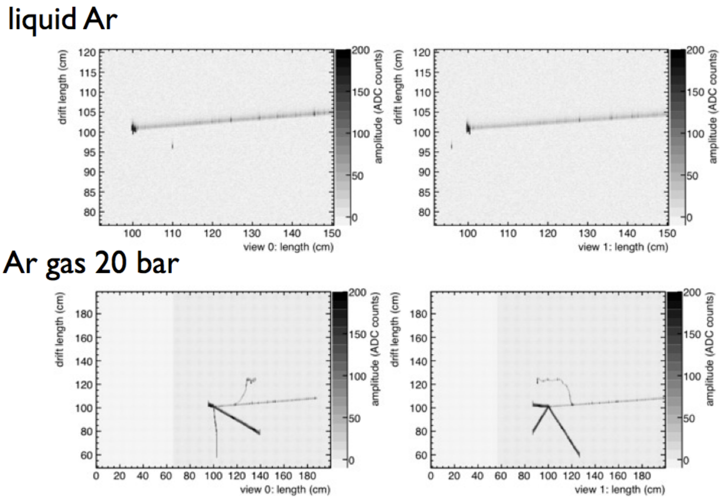
LBNO near detector requirements

- Should be capable of handling high multiplicity events;
- Magnetic detector necessary especially for $\overline{\nu}$ exposure;
- Energy resolution as good as far detector;
- The sub-components:
  - Vertexing- TPC;
  - Particle ID - Totally Active Scintillator Detector (TASD);
  - EM showering/gamma conversion - ECAL;
  - Muon/pion distinction - HCAL.

LBNO near detector sketch

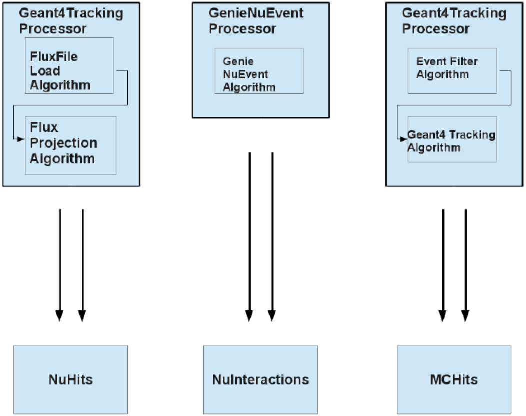


Vertex in argon gas...



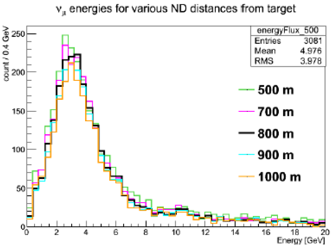
Software framework: T. Stainer & Y. Karadzhov

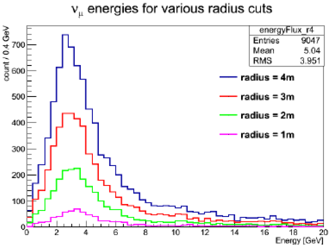
- Code available at https://launchpad.net/lbno-nd



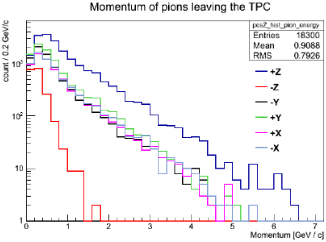
Simulation parameters

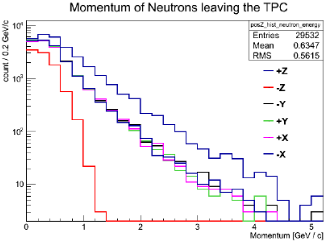
- Flux file (Fluka) from P. Velten for 10^6 p.o.t;
- ND is 800 m from target;
- 10^5 ν_μ only simulated, $E_\nu <$ 10 GeV;
- Interactions only in TPC: 2.4 x 2.4 x 3.0 m, 605 kg;
- Uniform 0.5 T dipole field across TPC.
- Calculated event rate: for 7e13 p.p.p:
  - 0.10 ν_μ for $E_\mu < 10 GeV$
  - 0.17 ν_μ for $E_\mu < 30 GeV$

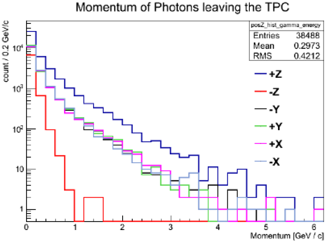


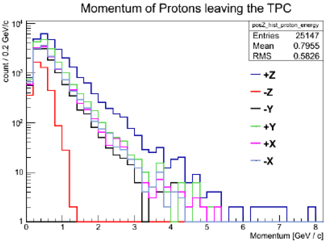


Particles leaving the 6 TPC faces

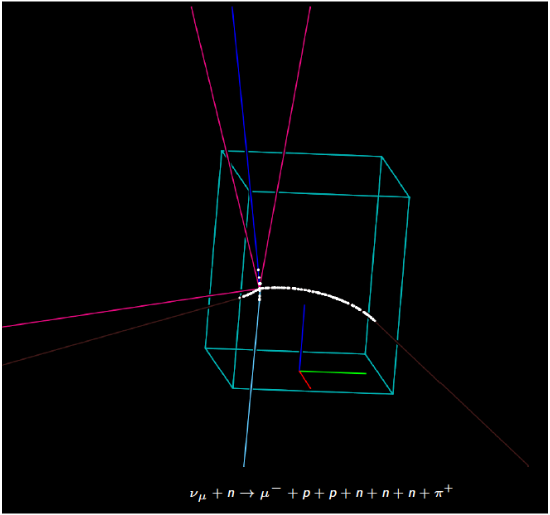






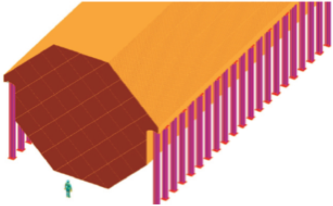


Event display

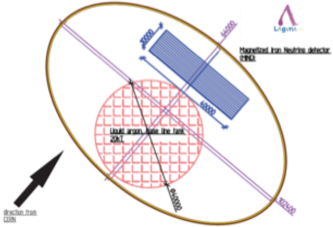


Detectors for future facilities

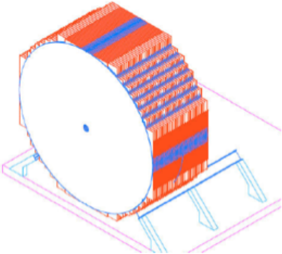
MIND at a Neutrino Factory



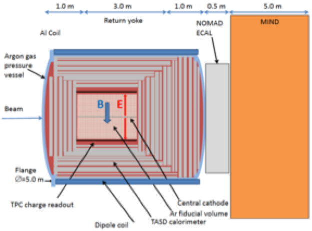
LBNO Far Detector



SuperBIND: MIND for νSTORM



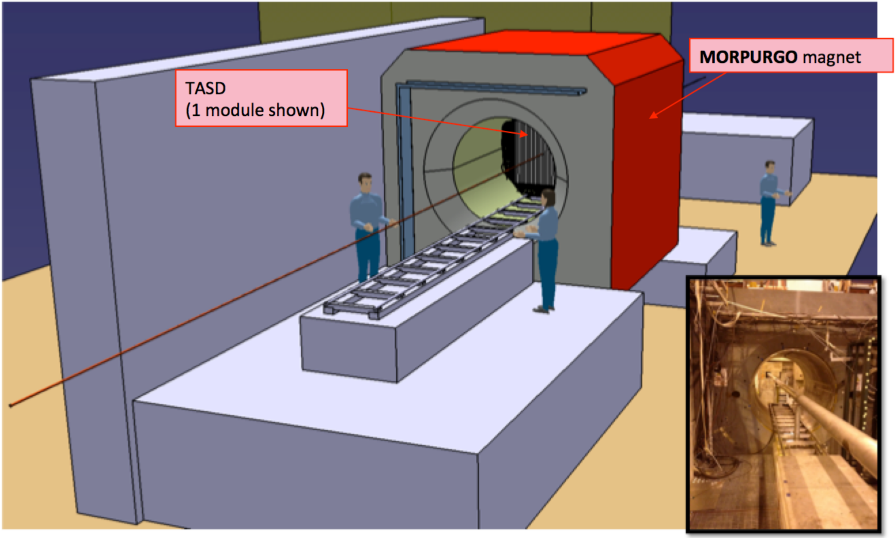
LBNO Near Detector



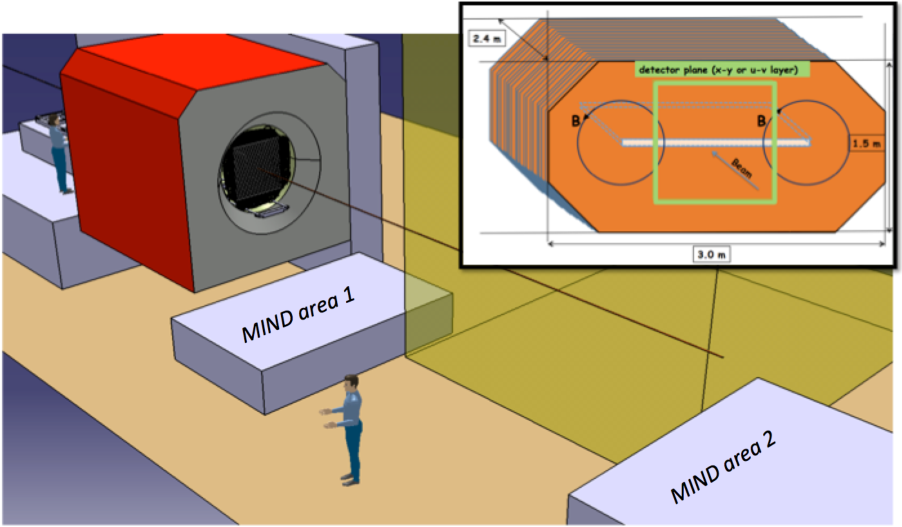
AIDA WP8.5.2: MIND and TASD test beam prototypes

- Magnetised Iron Neutrino Detector (MIND):
  - Muon charge identification, for wrong sign muon signature of a neutrino oscillation event: golden channel at a NF: requires correct sign background rejection of 1 in 10^4: test beam 0.8 to 5 GeV/c;
  - Hadronic shower reconstruction for identification of charged current neutrino interactions and rejection of neutral current n.i.: test beam protons/pions 0.5 to 9 GeV/c.
- Totally Active Scintillating Detector (TASD):
  - Stopping properties of pions and muons up to 200 MeV/c (MICE EMR);
  - Electron and muon charge separation inside a magnetic field, in particular electron charge ID in electron neutrino interaction for the platinum channel at a neutrino factory: 0.5 to 5 GeV/c.
- Test beam: electrons, muons and hadrons (pions, protons), 0.5 to 5.0 GeV/c, possibly at H8 beam line in North Area.

TASD at the H8 beam line in the North Area



MIND at the H8 beam line in the North Area

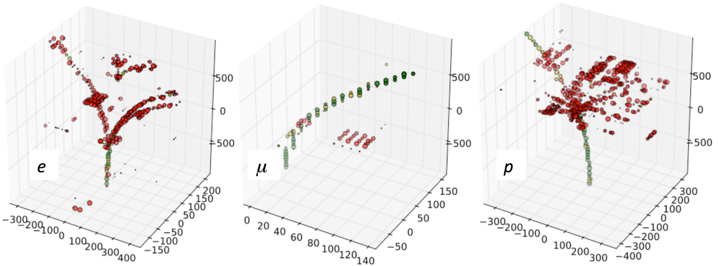


TMVA for the AIDA baby-MIND: R. Bayes

- Muon ID by range done by MIND/SuperBIND absent in baby-MIND:
  - Muons rarely range out;
  - Need to rely on other PID metrics;
- Existing PID methods could be adapted for PID in AIDA;
  - TMVA-based PID for MICE EMR;
  - Clear differentiation between e, π, μ;
  - Training baby-MIND on μ, π, p, e.

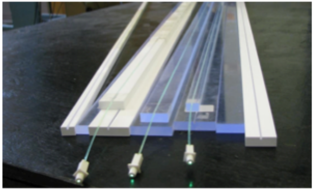
TASD prototype simulations: R. Matev

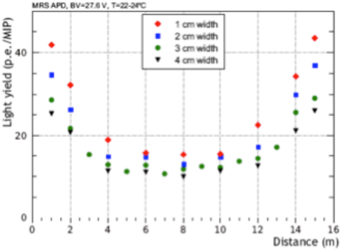
- 50 plastic scintillator detector modules;
- One X & one Y plane per module, 90 scintillator bars/plane;
- Variable distance between modules: 0 to 2.5 cm;
- Targets can be inserted in gap between modules;
- Basic digitization in Geant4, summing *Edep* in each bar, Poisson dist. with 15 p.e./(1.8 MeV) mean.



MIND readout with scintillator bars: Y. Kudenko

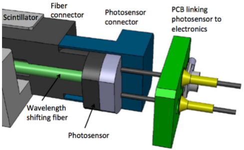
- Extruded scintillator slabs produced by Uniplast;
- Polysterene, 1.5% paraterphenyl (PTP), 0.01% POPOP;
- Used in T2K SMRD detector;
- Surface etched with chemical agent to create 30-100 μm layer that works as diffusive reflector;
- Grooves milled for wavelength shifting fibres;
- Photosensor is silicon photomultiplier.

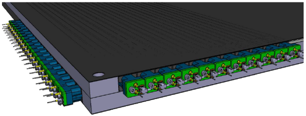


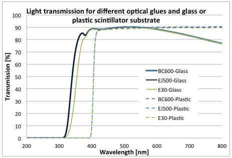


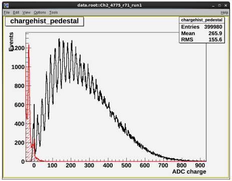
Components for detector modules

- Light transmission tests in range 200 − 800 nm to select optical cement;
- Selection of wavelength shifting fiber;
- Photosensor comparison;
- Photosensor connector design;









Summary

- Gas TPC-based near detector for νSTORM:
  - Good visualization of the interaction vertex;
  - Integration of scintillation counters within pressure vessel for improved energy resolution;
  - "Safe" insertion of nuclear targets within pressure vessel (1st safety barrier);
  - MIND downstream of TPC.
- Design and simulation work underway for LBNO ND:
  - Determine neutrino event energy resolution;
  - Compare with other detector options, e.g. L.Ar;
  - Study engineering aspects: pressure vessel, coil, integration etc.
- Plastic scintillator-based detector R&D:
  - Activities carried out under AIDA WP8.5.2;
  - Beam tests planned end 201;
  - Train simulations tools.