Midterm Reports
of

the EuCARD Networking Activity

NEu2012
(WP3, WP3.2, WP3.3)

DRAFT
report due 26 May 2011
to the EuCARD management

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Introduction I. Efthymiopoulos

approx 1 page promised

1 Motivation for neutrino physics

1.1 Motivation for neutrino accelerator experiments (S. King)

few pages received

4.1 OPERA (A. Ereditato)

approx 1 page based on info from him

Dear Vittorio,
thanks for the kind invitation. Unfortunately, due to the short notice, we could not accommodate a presentation for your event. However, I can give you some information that you might desire forwarding to the attendance:

1) OPERA is in the process of completing the analysis of the full 2008-2009 statistics. Results will be disclosed in June.

2) Today we passed 10^19 pot for the 2011 run (for this year, we expect to exceed the nominal integrated intensity of 4.5x10^19 pot).

3) No plans yet for the future, i.e. beyond the 2012 run.

Kind regards,
Antonio

5.1.2 LAGUNA detectors at Fréjus

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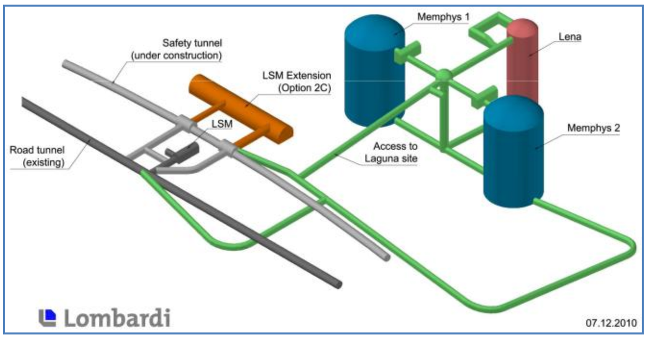
AstroParticule et Cosmologie (APC), CNRS, Univ. Paris 7, CEA, Obs. de Paris

Out of the 7 underground sites under study in the LAGUNA FP7 Design Study, an extension of the LSM (Laboratoire Souterrain de Modane) at Fréjus is one of the best candidates for hosting a very large multipurpose next-generation neutrino observatory.
Three detector options are being considered in LAGUNA[1]: GLACIER (Liquid Argon) [2], LENA (Liquid Scintillator) [3], MEMPHYS (Water Cherenkov) [4]. The potential of the MEMPHYS detector located at LSM for measuring neutrino oscillation parameters with a low-energy super-beam or beta-beam from CERN is also being addressed in the EUROnu FP7 Design Study [5] and will be studied for other beam and detector options in LAGUNA-LBNO [6].
LAGUNA has assessed the feasibility of large underground cavities at Fréjus suitable for the three types of detectors. This section will focus on MEMPHYS and LENA, while GLACIER, whose physics scope render other sites more interesting, is discussed in [7].

Large underground cavities at Fréjus



The Laboratoire Souterrain de Modane (LSM) is located adjacent to the Fréjus road tunnel in the French-Italian Alps. The distance from CERN is 130 km, adapted for the study of the first oscillation peak with neutrino beams of 0.2-0.4 GeV energy.
Originally, the proposal of a new neighbouring laboratory was discussed for the MEMPHYS detector. LAGUNA has shown that Fréjus will suit the requirements of LENA as well, and lately a laboratory hosting both detectors in a common infrastructure has been discussed, as shown in the Figure. The feasibility study was carried out by the Suisse company Lombardi Ltd. A special three years programme between french and german institutes has been financed by CNRS to study the physics potential of this proposal (PICS 5226), as well as to address common R&D and simulation issues between the two detectors.

LSM is the deepest existing site in Europe, with an overburden 4800 m.w.e.. The muon flux is thus very low, $5x10^{-5}$ $m^{-2}s^{-1}$. The radon content in the air was measured to be 15 Bq/m^3. Due to the neighbouring power plants in France, the flux of reactor anti-neutrinos is rather important: about 700 counts per 10^{32} target protons per year.
In spite of its ductile behaviour, the calc-schist formation of the surrounding rock is of good quality for building, relatively dry and at a temperature of 30^{o}C. Seismic activity is present but not dangerous. The excavation of the large detector caverns is foreseen in various stages, using a preliminary support of anchors and shotcrete. Once excavated, the cavern walls will be sealed by a strong layer of concrete to compensate for plasticity of the rock. The caverns considered for the LAGUNA detectors are vertical cylinders, with possible diameter up to 65m and height up to 105 m.
Detailed projects of the engineering each main cavern and of the layout of the whole underground site, with all the additional infrastructure, have been prepared in LAGUNA. The cost of the excavation will be relevant, but it will not be the main cost of the project. The laboratory can profit from the already available underground infrastructure of the road tunnel (ventilation). Currently, a safety tunnel is being excavated close to the already existing road tunnel, which can be used for excavation works and transport of materials to minimize interference with road traffic. Water will be brought to the Memphys cavern by pipeline and purified underground. The liquid scintillator for the LENA detector

filling will be supplied by road trucks.
Steel tanks placed in contact with the rock mass, which allow saving on the amount of steel needed, are feasible at Fréjus for LENA and MEMPHYS, while for the GLACIER option an independent tank is preferable.

The water-Cherenkov option: MEMPHYS (MEgaton Mass PHYSics)

MEMPHYS relies on one of the most reliable and well-known techniques for neutrino detection, based on Cherenkov light emission in water by the final state particles resulting from neutrino interactions. The aim is a fiducial mass around half a megaton, originally planned with 3 cylindrical detector modules of 65 meters in diameter and 60 meters in height. As mentioned above, at the Fréjus site the characteristics of the rock excavations allow for a higher detector in the vertical direction. With the new design of 80m height, the fiducial volume increases up to 572 kilotons (30% bigger). It has been verified with a full Geant-4 simulation that the performance of the detector is not affected. Heights up to 105m are possible, which would allow for the same total fiducial mass with only two modules.

The design of each MEMPHYS module takes into account a veto volume, 1,5 m thick, plus a minimal distance of about 2 meters between photodetectors and interaction vertices. The light sensors choice is to instrument the detector with photomultipliers tubes (PMTs) with a geometrical coverage of 30%: a total of about 220000 8” PMTs will be needed.

The detector has excellent performances in terms of energy and direction reconstruction and particle identification, while a detection threshold for neutrinos as low as 3 MeV can be envisaged.
The discovery potential for $\sin^2 2\theta_{13}$ is $5\text{x}10^{-3}$-$3\text{x}10^{-4}$ (upper-lower limits) at 3σ whatever the actual value of the δ_{CP} phase, and the sensitivity is significantly improved for some values of δ_{CP}. Discovery limits around $3\text{x}10^{-4}$ are obtained for a large fraction of δ_{CP} values with a beta-beam or super-beam alone. See [8] for latest studies. Mass hierarchy can be determined at 2σ CL in 5 years if $\sin^2 2\theta_{13}>0.025$, by combining beam and atmospheric neutrino data. For the physics reach on supernova core-collapse, diffuse supernova neutrinos, proton decay, solar and atmospheric neutrinos, see [4].

The Liquid Scintillator option: LENA (Low Energy Neutrino Astronomy)

LENA is proposed as a next-generation neutrino observatory with a fiducial mass of 50kt. The success of experiments such as Borexino and KamLAND demonstrate the potential of the liquid scintillator technique for low-energy neutrino detection.

The current design is based on a cylindrical shape with 13m diameter and 100m height, the size being limited by the light attenuation length in the scintillator. The target scintillator is contained in a nylon vessel and surrounded by a 2m-thick veto filled with an inert liquid of similar density. The inner wall of the main steel vessel will be PMTs providing an optical coverage of 30%. About 45000 8” PMTs would be needed, the number depending of course on the photocatode size. A muon veto, consisting of a plane of plastic scintillator or RPCs, will be placed on the top of the cylinder.

LENA can detect neutrinos with a very low threshold (1.8 MeV) and measure their energy with good resolution up to 10 MeV with excellent background discrimination. The main focus of its physics program is on super-nova and solar neutrinos and geo-neutrinos, however recent studies have shown the capability to track high-energy particles based on Cherenkov-like scintillation light fronts, which make this detector option interesting for beam physics as well. With a beta-beam from CERN to Fréjus, a rejection of ν_e quasi-elastic interactions of 99.96% (95%CL) can be achieved for 85% ν_μ acceptance. The reach in terms of θ_{13} and δ_{CP} is currently under study.

Development of readout electronics for MEMPHYS and LENA

One important R&D item towards the construction of MEMPHYS and LENA is focused on the reduction of the number of electronics channels for power supply and signal readout of the PMTs, which is expected to be one of the major costs of the experiment.

The PMm2 project [9] has developed a readout integrated electronics circuit (called ASIC) for groups of PMTs (matrix of 4x4). This electronics and acquisition is going to be fully tested with the MEMPHYNO prototype [10], a test bench for any kind of light sensor or electronics solution for next generation large size experiments. MEMPHYNO is also going to measure the trigger threshold, the track reconstruction performance and the properties of the PMTs.

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[7] contribution by A.Rubbia and A.Marchionni in this report
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[9] B.Genolini et al., NIM A610 (2009) 249
[10] M.Marafini, PhD thesis, Université Paris-Diderot – Laboratoire APC, 2011

Development of long scintillator detectors with WLS fibers for large volume neutrino detectors

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Goals of this R&D is to develop scintillator detectors for magnetized or non-magnetized TASD (totally active scintillator detector) and Magnetized Iron Neutrino Detector (MIND)
for future neutrino detectors. The approximate size of tracking calorimeters (Nova) and future detectors will be about 15x15x100m^3. To meet the various physics requirements, a fine granularity of the scintillator bars, the main active elements of the detector, is needed. Such detectors have a large number of readout channels that requires the usage of very compact photo-sensors insensitive to magnetic field with a high quantum efficiency.

The extruded 1 m long and 0.7 cm thick bars with several width of 1, 2, 3, 4 cm, produced in Uiniplast, Vladimir, Russia, were used for tests. These bars were covered by a chemical reflector by etching the scintillator surface in a chemical agent. A 2 mm deep and 1.1 mm wide groove was machined along the bar central line to accommodate a 16 m long Y11 fiber. The optical contact between the scintillator and the wave lengthshifting (WLS) fiber is provided by an optical grease. The readout at both ends of the fiber is performed with Multipixel Avalanche Photodiodes operation in a limited Geiger mode (SiPM). The SiPMs from T2K ND280 (MPPC produced by Hamamatsu) and MRS APDs manufactured by CPTA/ Moscow are used for the tests. The MPPC has a sensitive area of 1.3×1.3 mm^2 with 667 pixel each of 50×50 μm^2 . It has a typical overvoltage of 1.4 V, a dark rate of 700 kHz, and a gain of 7×10^5. The MRS APD sensitive area is approximated to a circle with a diameter of 1.28 mm with 796 pixels. The pixel size is 43×43 μm^2, the dark rate is about 1.2 MHz, and a typical gain is close to 10^6.

The photon detection efficiency (PDE) of these devices, which is a product of the quantum efficiency, geometrical factor and the probability of forming Geiger avalanche , was measured using a spectrophotometers calibrated with a PIN diode. The PDE values of about 30% (MPPC) and 40% (MRS APD) were obtained. It should be noted that in case of MRS APD the maximum of PDE is shifted to the red light with the lengths of about 650 nm, while the maximum sensitivity of MPPC is at 450 nm. This feature (MRS APD) can be realized in the light detection with long WLS fibers.

The tests of the detectors were provided using cosmic muons. Both fiber ends were connected to photodiodes using optical connectors. All measurements were done at ambient temperatures in the range 19-23^{0}C. For MRS APDs, the light yield per minimum ionizing particle (MIP) was obtained to be about 40 photoelectrons (p.e.) at a distance of 1 m from the photodiode and reduced to 2 p.e. at the distance of 15 from photodiode. For sum of both end the minimum l.y. of about 10 p.e./MIP was measured for 4 cm wide scintillator at the distance of about 8 meters from both diodes, i.e. in the mid point. The minimum l.y. of 15 p.e./MIP was obtained for 1 cm wide scintillator. The tests with

MPPC showed similar results. The time resolution of about 2 ns (in central part) and about 1 ns (close to the fiber ends) were obtained for such detectors.

To conclude, these tests show that the readout of 15 m long scintillator bars with a single WLS fiber and SiPMs give a high light yield along all bar with signal-to-noise ratio of about about 10 providing a high detection efficiency of MIPs.

References

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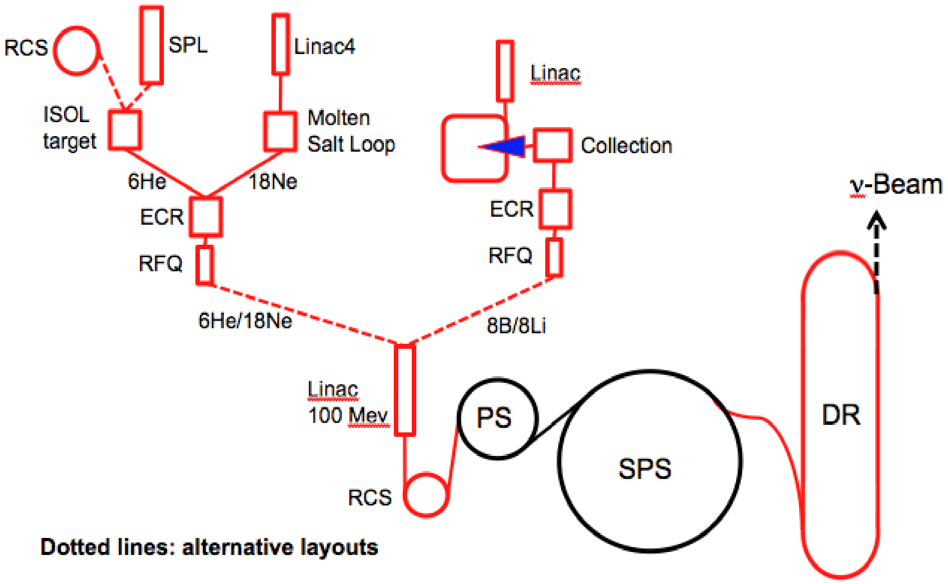
EUROnu Beta Beams

Elena Wildner, CERN

“Beta Beams" produce collimated pure electron neutrino and antineutrino beams by accelerating beta active ions to high energies and letting them decay in a race-track shaped storage ring. The work on the implementation of a Beta Beam facility is essentially based on CERN’s infrastructure using the fact that some of the already existing accelerators can be used. To use existing machines is a strong advantage for the cost evaluation, however this choice is also constraining the Beta Beams.

The two options to produce (anti-)neutrinos, which are presently subject to studies within the EUROν collaboration (FP7), are schematically shown in Fig. 1.



Dotted lines: alternative layouts

Fig. 1: Synoptic showing two alternative beta beams at CERN, having a relativistic γ of 100, the “high-Q” option (8B and 8Li) and the “low-Q option (6He and 18Ne). DR stands for Decay Ring.

Radioactive isotopes, with properties suitable to be accelerated in the CERN accelerator chain, are produced in different ways depending on the species. The characteristics (in parentheses) of the neutrino beams produced are given by:

- the Q-value of the isotope (the neutrino beam energy)
- the decay time of the isotope (the neutrino beam intensity)
- the intensity of the isotopes in the DR (neutrino beam intensity)
- the energy of the isotopes in the DR (the neutrino energy and divergence)
- length of the decay ring straight section (neutrino beam intensity)

Preferably there also has to be a neutrino and an antineutrino emitter pair of similar characteristics for one beta beam facility.

The main technological constraints are the following:

- some of the Beta Beam isotopes are very difficult to produce and need R&D
- to suppress atmospheric background small and intense bunches in the DR
- the gamma boost is presently limited by the SPS max energy
- the PS and the SPS are not optimized for Beta Beams (RF constraints, instabilities, radiation…)

The optimization of the Beta Beam has to take all these points into account and weigh the physics reach, the cost and the needed R&D to make a balanced proposal to the neutrino physics community.

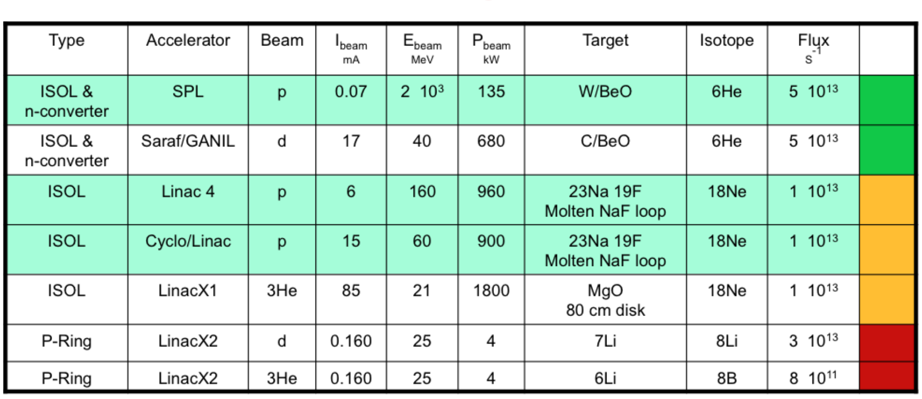
To our knowledge, work on beta beam is presently going on essentially within EUROν. The work units on Beta Beams in EUROν are dedicated to ion production, primarily to “high-Q” ion production, and acceleration and they are (the main contributors to the work units within parentheses)

- 8B and 8Li production ring, internal target, optics of ring, beam cooling (CERN)
- collection of produced isotopes (LLN, Louvain la Neuve)
- measurement of cross section for production of 8Li and 8B (INFN, Legnaro)
- ECR source, charge breeder (LPSC, LNMC, Grenoble)
- The Decay Ring (CEA, Saclay)
- The CERN accelerators (CERN)

Due to the difficulties with the production methods in the EUROν proposal, the Beta Beam work-package management proposed to continue the development of the beta beam option already started within FP6, EUROSOL. The reason for the new FP7 proposal was to overcome difficulties with ^{18}Ne production by using isotopes, ^{8}Li and ^{8}B, that could, theoretically, be produced in huge amounts in a production ring. One additional advantage is the higher Q-value that gives higher neutrino energy. But the proposal did not consider explicitly the fact that, due to the more distant detector needed for the higher energy neutrino beams, we need some factor 5 more ions in our machines which is a major difficulty. However, the production mechanisms for this option are by far not yet realistic. Collaboration with ISOLDE specialists on ^{18}Ne production has given the opportunity to experimentally test new ideas on ^{18}Ne production using molten salt loops (ISOLDE). The ^{6}He/^{18}Ne option is now the base line option. However the research on the ^{8}B and ^{8}Li option continues according to the EUROν plans. The parameters of the machines can be accessed from our parameter database via the web: http://j2eeps.cern.ch/beta-beam-fp7-parameters/

Production overview

An overview of the present isotope production rates is shown in Fig. 2 below. The colour legend shows green for production experiments done, yellow for options possible on paper where experiments will be started 2011 and red means that rates are theoretically still too low. “Aimed production” will give the physics reach obtained from estimations within EUROν, using our present estimations for throughput of ions.



Aim: 2.0 10^{13} for low-Q

Targets below MWatt are aimed !!!

Type	Accelerator	Beam	I_{beam} mA	E_{beam} MeV	P_{beam} kW	Target	Isotope	Flux s^{-1}	
ISOL & n-converter	SPL	p	0.07	2 10^{3}	135	W/BeO	6He	5 10^{13}	🟩
ISOL & n-converter	Saraf/GANIL	d	17	40	680	C/BeO	6He	5 10^{13}	🟩
ISOL	Linac 4	p	6	160	960	23Na 19F Molten NaF loop	18Ne	1 10^{13}	🟨
ISOL	Cyclo/Linac	p	15	60	900	23Na 19F Molten NaF loop	18Ne	1 10^{13}	🟨
ISOL	LinacX1	3He	85	21	1800	MgO 80 cm disk	18Ne	1 10^{13}	🟨
P-Ring	LinacX2	d	0.160	25	4	7Li	8Li	3 10^{13}	🟥
P-Ring	LinacX2	3He	0.160	25	4	6Li	8B	8 10^{11}	🟥

Fig.2: Status of isotope production for Beta Beams

Production Ring, high-Q

The layout of the ring producing 8Li and 8B is shown in Fig. 3.

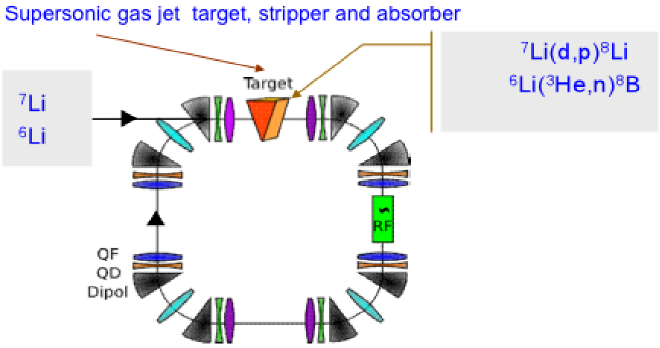


Fig. 3: Production ring layout.

8B and 8Li are not possible to produce in the Production ring due to the need of too high densities of the gas jet target. Inverse kinematic reactions are now simulated and we hope to have indications soon about the feasibility to use liquid film targets for the production. Experiments could be possible at the TSR Ring in Heidelberg or, if ISOLDE can have the ring installed at CERN, test can be made at that point in time. Tests to be done is the beam cooling and production rates.

Production Ring, status sheet		
Lattice	**Ok**	**Only basic lattice**
Reverse kinematics gas jet target	**Low priority**	**Technologically not feasable**
Cooling simulations	**Under development**	**Lattice tuning, large apertures**
Direct kinematics liquid targets	**Under development**	**New collaboration (ANL)**
Direct kinematics simulations	**To be started**	**Collaboration (INFN Padova)**
Direct kinematics collection	**To be started**	**Discussions necessary (LNL)**

Collection

Production low Q

The Ion production of 6He can give us the rates we need, confirmed by experiments already. On paper we can now produce sufficient amounts of 18Ne. Production of 18Ne has recently been proposed as an experiment at CERN using molten salt loops. A research program for 2 years at ISOLDE will permit to get results on this production method. A collaboration with LPSC in Grenoble has been set up for developing and testing molten salt loop performance. LPSC has valuable experience in this field.

Source

Source: Plasma tests, extraction of beam extracted form cusp and measurements of charge state distribution is planned for 2011. The time-structure of the extracted beam is modeled and will be tested when the 60GHz gyrotron will arrive at LPSC (end 2011). Power supply availability and experiment time is being set up.

RFQ/Linac

RFQs and Linac have not yet been fully designed; we wait for more information from the Ion source performance.

RCS

RCS: Machine designed.

PS/SPS

PS: tests on space charge is ongoing, tune scans are made to cover the injection area for placing the injected beam in a resonance free area of the tune diagram. Fluka models for the PS are developed for the LHC beams and they will be used for beta beams for radiation calculations. Collaboration with the LIUWG. Stability calculations have still to be done.

SPS: Collaboration for the upgrades is being set up. Instability calculations (TMCI)are ongoing to cover the whole cycle. The injection part is almost finished.

Decay Ring

Lattice options for all ion species exist with DA calculations. Optimization for increased neutrino fluxes is being done (new lattice with higher field magnets of ~8T) gives 10% more neutrinos. Stability calculations (TMCI) have necessitated a new lattice design with lower gamma transition. With this design we can manage the intensities either with a double bore magnet and/or octupoles. The design gives a lattice with which give some good and useful simplifications of the lattice arcs.

Costing

The costing needs information for implementation on the CERN site. This would need a civil engineer for some 6 months.

Costing and safety excersises have started, a WBS structure exists that has to be refined. After the costing workshop a list of elements to be costed will be injected into the costing costing team for treatment.

Acknowledgements

The work described is the result of efforts done within EURISOL and EUROn collaborations.

Detectors for a Neutrino Factory

Magnetised Iron Neutrino Detector (MIND)

At a Neutrino Factory, muons accelerated to 25GeV decay in the straight sections of two storage rings, one pointing to a detector 2500-5000 km away (intermediate baseline) and the other pointing to a detector 7000-8000 km away (magic baseline). The detectors at a Neutrino Factory consist of a 100 kton Magnetised Iron Neutrino Detector (MIND) at the intermediate baseline and a 50 kton detector at the magic baseline (in which the oscillation formula is insensitive to CP violation, allowing degeneracies to be resolved). The main signature in MIND at a Neutrino Factory consists of measuring neutrino oscillations by detecting the wrong-sign muon from the sub-dominant $\nu_e \rightarrow \nu_\mu$ Golden Channel signal.

Recent advances in the development of the simulations of MIND at a Neutrino Factory include development of a reconstruction and pattern recognition framework [1], new simulations using Nuance [2] and Geant4 [3], which include Quasi-elastic, Deep-inelastic and Resonance production from neutrino interactions, digitisation of the detector signals and a new likelihood based analysis that exploits the separation of the wrong-sign muon signal with respect to the dominant backgrounds from Charged Current (CC) and Neutral Current (NC) backgrounds. This analysis has been described in the Interim Design Report (IDR) of the International Design Study for a Neutrino Factory (IDS-NF) [4]. The resultant efficiencies for both polarities are shown in Figure 1. Numeric response matrices for each of the channels may be found in references [4,5]. The background from misidentification of the beam inherent muon type neutrino is the largest of the main backgrounds and is significantly below 10^{-3} at all energies. The background from neutral current interactions also lies at or below the 10^{-4} level. The background from ν_e ($\bar{\nu}_e$) CC interactions constitute a very low level addition to the observed signal (10^{-6} level). The efficiency of detection of the two ν_μ polarities was expected to have a threshold lower than that seen in previous studies due to the presence of non-DIS interactions in the data sample. The efficiencies expected for the current analysis are shown in Fig. 1. The resultant ν_μ efficiency has a plateau around 63% and for $\bar{\nu}_\mu$ it is above 70%. The difference between the two is attributed to the inelasticity of anti-neutrino events, with higher average muon momentum than neutrino events. The threshold is now lower to that extracted in previous studies (around 2 GeV) due to the addition of quasi-elastic and resonance events.

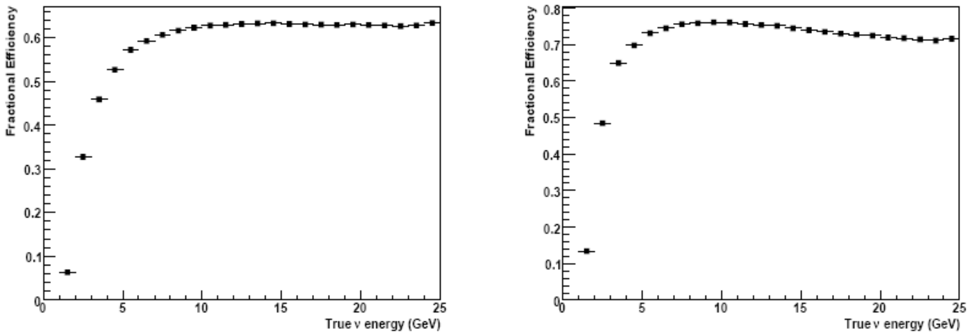


Figure 1 *Efficiency of reconstruction of* ν_μ ($\bar{\nu}_\mu$) *CC interactions. (left)* ν_μ *CC efficiency, (right)* $\bar{\nu}_\mu$ *CC efficiency.*

The sensitivity of MIND to θ_{13}, to the discovery of CP violation (δ_{CP}) and to the determination of the neutrino mass hierarchy as a consequence of these studies has improved. The sensitivities achieved can be seen in Figure 2. As a consequence of the lower energy threshold, MIND now becomes a suitable detector at a low energy neutrino factory (10 GeV), which is optimal for higher values of θ_{13} (when $\sin^2\theta_{13}>10^{-2}$).

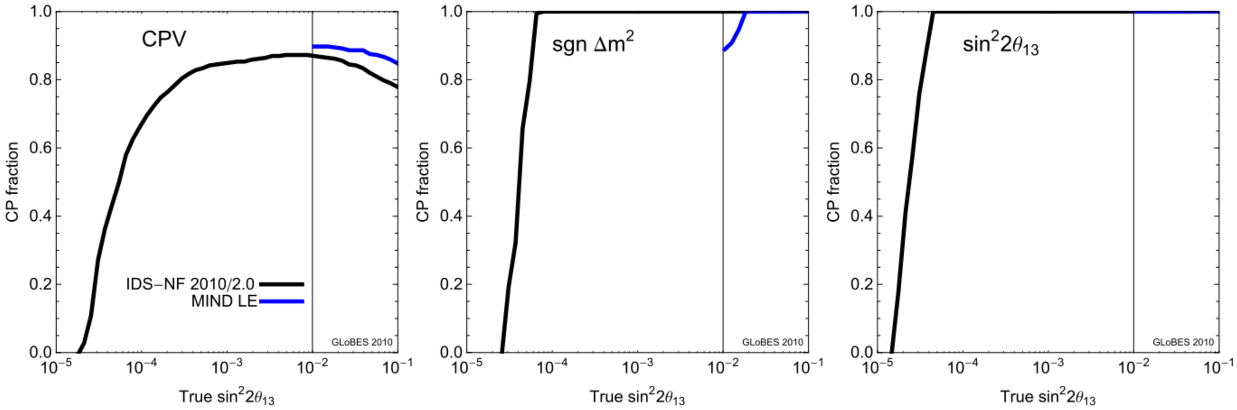


Figure 2 *Sensitivity of a Neutrino Factory to the CP phase δ (left), to the neutrino mass hierarch (middle) and to θ_{13} (right).*

More recently, engineering studies have been carried out and the geometry of MIND has been modified to include octagonally shaped iron plates 14 m × 14 m in transverse size and 3 cm thick (see Fig. 3 for a plot of the new MIND design). Engineering solutions for these plates have been found, including manufacturing of the plates out of two welded layers (1.5 cm thick each) and made out of 2 m wide sections also welded together. Magnetisation occurs via a 100 kA turn current delivered by a Superconducting Transmission Line (STL), a superconducting cable immersed in its own Helium dewar, and which was developed and prototyped as part of the VLHC magnet R&D effort [6]. The STL is threaded through the centre of the iron plates in a 10 cm diameter hole in its centre. Magnetic models show that with a 100 kA turn current, a toroidal magnetic field between 1.2-2.2 T can be achieved (see Fig. 3, right, for the axial field modelled in MIND). After each iron plate, two planes of extruded scintillator, 1 cm thick, and orientated along the *x* and *y* axes, with wavelength shifting fibre readout coupled to a Silicon Photomultiplier (SiPM) are assumed.

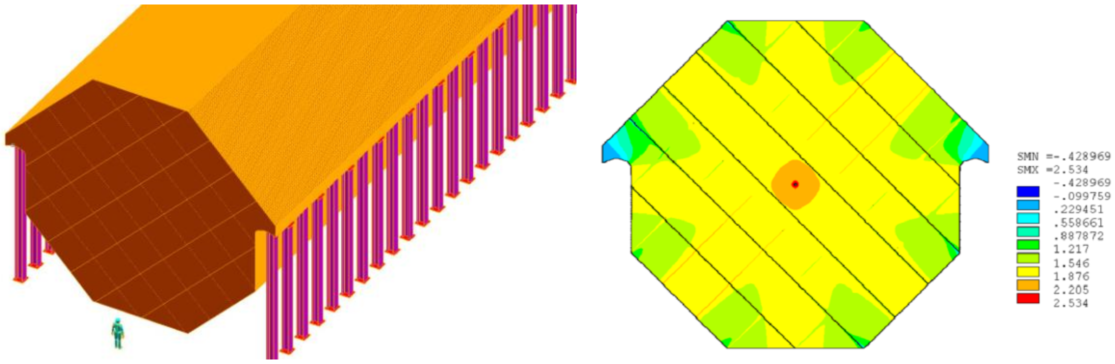


Figure 3 *Left: Engineering drawing of MIND. Right: Toroidal field expected for MIND with a 100 kA turn current. Slots in the manufacture of the large plates produce changes in the field..*

Near Detector

In order to perform measurements of neutrino oscillations at a neutrino facility, it is necessary to establish the ratio of neutrino interactions between a near and far detector. The aim of the near detector of the Neutrino Factory is to measure precisely the absolute neutrino flux, the neutrino cross sections and to estimate the background to the far detector. Hence, the careful design of a near detector is crucial for reduction of long baseline neutrino oscillation experiment systematic errors.

The quasielastic scattering off electrons is suitable for measurement of the neutrino flux, because its absolute cross-section can be calculated theoretically with enough confidence. The two processes of interest for neutrinos from μ^- decays are $\nu_\mu + e^- \rightarrow \nu_e + \mu^-$ (inverse muon decay) and $\bar{\nu}_e + e^- \rightarrow \bar{\nu}_\mu + \mu^-$ (muon production through annihilation). These cross-sections are very well known (~4 $\times 10^{-41}$cm^2 at 15 GeV) but have a threshold of ~11 GeV and are much smaller than the total CC cross-section (~10^{-37}cm^2).

A Monte Carlo simulation of the muon decay in flight along the 600 m long straight section of the decay ring has been developed, and the GENIE event generator has been used to simulate neutrino interactions in a Geant4 simulation of the near detector. We assume a Near Detector consisting of three parts: a vertex detector to measure charm and taus (for searches of Non Standard Interactions), a high resolution low Z detector (either with a fibre tracker detector or a straw tube tracker) and muon spectrometer, with a similar design to MIND, but smaller in dimensions (Fig. 4).

Studies of the muon flux carried out in the high resolution scintillating fibre tracker have demonstrated that the flux can be measured to a precision of 1% using IMD, and assuming 0.5 mrad angular resolution. Further studies with neutrino electron elastic neutral current scattering are currently underway. A basic matrix method for the projection of the observed near detector spectrum at a neutrino factory to the far detector sites has been developed and has demonstrated improved precision to which the oscillation parameters can be measured for a wide range of values of θ_{13} and δ. Other physics topics that can be addressed with a Near Detector at a Neutrino Factory include extensive neutrino interaction cross-section measurements (quasi-elastic scattering; baryon resonance production, coherent and diffractive neutrino-nucleus scattering; deep inelastic scattering, quasi-elastic and deep inelastic charm production), as well as other physics topics, such as measurements of Parton Distribution Functions and standard model parameters such as $\sin^2\theta_W$.

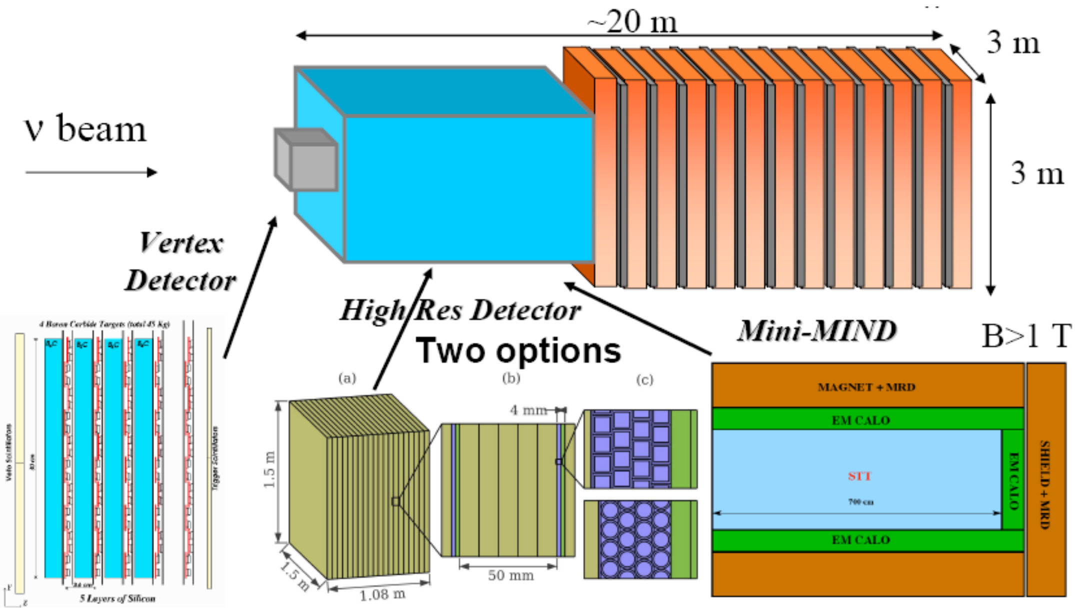


Figure 4: *Concepts for a Near Detector at a Neutrino Factory consisting of a vertex detector, a high resolution tracker to measure flux and cross-sections and MIND spectrometer for muon charge.*

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