# European Strategy for Future Neutrino Physics
# POSTER ABSTRACTS

## 1. Borexino - Low Energy neutrinos from the Sun and the Earth

*A. Ianni*

Borexino, a 300 tons liquid scintillator detector at the Gran Sasso Underground Laboratory, has been taking data since May 2007. At present Borexino has measured for the first time both 7Be and 8B solar neutrinos providing an important test of the MSW-LMA predicted transition (vacuum-matter regimes) of the neutrino survival probability at Earth.

Main scientific goals of Borexino are: the search for solar neutrinos, including 7Be, 8B and CNO neutrinos, these latter after 11C subtraction; the search for geoneutrinos; the search for rare processes; application of the developed technology for further developments in the field of astroparticle physics; in case of a galactic core collapse supernova an important measurement based on the NC neutrino-proton elastic scattering due to the low detection threshold (200 keV).

Measurements of solar neutrinos allow to test the Solar Standard Model and in particular the recent so-called solar abundance problem. Solar neutrino measurements in Borexino could improve the understanding of such an anomaly.

Measurements of geoneutrino in Borexino will allow for the first time to determine in a model independent way the chondritic ratio Th/U due to the low background in the antineutrino signal.

For a core collapse supernova the possibility to probe the neutrino-proton elastic scattering allows to measure both the temperature and the fluence of $\nu\mu$ and $\nu\tau$ at Earth after oscillations: a unique information channel which can be probed only by Borexino at present.

The technology developed in Borexino to reach very high level of radiopurity opens new opportunities for scientific goals in physics and astrophysics.

The low background allows to search for rare processes such as nucleon decays into invisible channels, electron decay in a charge non conserving process, a non zero effective neutrino magnetic moment.

The physics potentiality of Borexino will be discussed and the technology developed presented in order to be taken into consideration for future projects.

## 2. Charm searches and kinematical analysis with the OPERA experiment

*F. di Capua*

The OPERA experiment has the unique opportunity to measure the decay detection efficiencies and the main backgrounds to the tau sample by searching for neutrino-induced- cahrm-production and hadronic interactions.

The identification of a particle decay consists of two steps: 1) a topological decay search (the methods exploited by the Collaboration are described in another poster); 2) a detailed kinematical analysis of the event.

In this poster we summarize the methods developed for the kinematical reconstruction of the events (momentum measurements by Multiple Coulomb Scattering; electron/pion separation; electromagnetic energy measurement; charm-production and hadronic interaction searches.

## 3. Recent Results from the MINOS Experiment

*J. Evans*

The MINOS experiment utilizes the NuMI beam of muon neutrinos to study the phenomenon of neutrino oscillations. Neutrinos are sent over a baseline of 735 km, with a detector near the production point at Fermilab and one at the Soudan Underground Laboratory in northern Minnesota. By measuring the disappearance characteristic of oscillations, MINOS has made the best measurement of the atmospheric neutrino mass splitting to date: $\Delta m^2_{\ atm} = 2{:}43 \pm 0{:}13 \times 10^{-3}$ eV$^2$ and $\sin^2(2\theta_{23}) > 0{:}9$ (90% c.l.). A study of neutral current interactions has allowed limits to be placed on the existence of additional, sterile neutrino avours beyond the three of the standard oscillation model. Using the 7% muon antineutrino component of the beam, the first direct observation of muon antineutrinos in a long baseline experiment has been made, along with direct limits on the antineutrino oscillation parameters. In September 2009, the current in the NuMI focusing horns will be reversed to begin running with a dedicated antineutrino beam. This will allow the first precision measurements of the atmospheric-regime antineutrino oscillation parameters, an important test of CPT-invariance in the neutrino sector.

## 4. T2K neutrino oscillation experiment.

*B. Still*

The Tokai to Kamioka (T2K) experiment will begin taking data in late 2009; using the most intense source of man made neutrinos to probe the extremely rare oscillation of $\nu\mu \rightarrow$ ve and therefore the third and final unmeasured θ13 lepton mixing angle. T2K will a chieve this with near (ND280) and far detector (Super Kamiokande) combination characterising the beam content before and after oscillation at distance of 295 km.

The confident measurement of small numbers of ve interactions at Super Kamiokande require accurate understanding of all signal and background processes, and this is the second aim of the ND280 near detector

## 5. A Search for $\nu_\mu \rightarrow \nu_e$ Oscillations in the MINOS Experiment

*J. Evans*

The MINOS experiment uses the NuMI neutrino beam to make precision measurements of the neutrino mixing parameters. A beam of muon neutrinos is produced at Fermilab. Its energy spectrum is measured near the production point, and again after 735 km at the Soudan Underground Laboratory in northern Minnesota. By looking for electron neutrino appearance in the muon neutrino beam, limits can be placed on the as yet unmeasured mixing angle $\theta_{13}$. At the far detector (in the Soudan laboratory), 35 electron neutrino candidate events are observed with a predicted background of 27 ± 5(stat.) ± 2(syst.) events: a 1.5σ excess. At 90% C.L. this gives an upper limit range of $\sin^2(2\theta_{13}) < 0.28$-0.34 for the normal neutrino mass hierarchy and $\sin^2(2\theta_{13}) < 0.36$-0.42 for the inverted hierarchy, depending upon the CP-violating phase $\delta_{CP}$.

## 6. The Low Energy Neutrino Factory

*T. Li*

We show that a low energy neutrino factory is a potential candidate for a next-generation neutrino oscillation experiment in the event that theta 13 is large. The results of our optimization sutides show

that a setup with a baseline of 1300 km. muon energy of 4.5 GeV, and either a 20 kton totally active scintillating detector or 100 kton liquid argon detector can have remarkable sensitivity to $\theta_{13}$ and delta for $\sin^2(2\theta_{13})>10^{-3}$.
We also consider the experimental sensitivity to non-standard interactions. Here we find that the LENF unique combination of golden and platinum channels is particularly powerful in reducing the standard oscillation-NSI degeneracy, enabling competitive bounds to be placed on $\varepsilon_{e\tau}$

# 7. Study of the SPL-Frejus neutrino Super Beam performanceusing a solid target

*A. Longhin*

An optimization of the CERN SPL neutrino beam line has been performed guided by the idea of employing a graphite target. The interactions of protons of kinetic energies of 2.2- 3.5-4.5 and 8 GeV/$c^2$ on a cylindrical 1.5 cm diameter carbon target have been simulated with FLUKA2008. Energy deposition and particle yields with mercury and carbon have been compared.

Power deposition and neutron fluxes are suppressed to a large extent with carbon. The transportation and decay of secondary mesons was done with GEANT3 in order to calculate the neutrino fluxes. Sensitivities were calculated with GLoBES assuming a beam power of 4 MW (HP-SPL) and a 440 ktons water Cherenkov detector (MEMPHYS) located at 130 km from the target in a new foreseen Fr´ejus laboratory. The obtained sensitivities with the carbon target are comparable to the ones achieved with the mercury target. The full simulation has been recently rewritten using GEANT4 which allows a higher degree of flexibility for arranging the horn geometries. A detailed comparison of the algorithms has been done and a good agreement is found for the final neutrino fluxes. A preliminary comparison of the sensitivities to $\sin^2(2\theta_{13})$ as a function of $\delta$ with a optimized horn shape will also be presented.

# 8. R&D towards the MEMPHYS detector

*M. Marafini*

MEMPHYS is a 0:5 Mton scale Water Cerenkov detector proposed for deep underground installation*. Its performance with neutrino beams includes the possibility of measuring the mixing angle $\theta_{13}$, the CP violating phase and mass hierarchy. In addition, it would have an unprecedented reach for nucleon decay searches and for supernova neutrino detection. One R&D item currently being carried out is Memphyno, a small-scale prototype.

Its main purpose is to serve as a test bench for new photodetection and data acquisition solutions, such the grouped readout and HV feeding system (developed in the PMm2 project). We will present the aims and status of Memphyno.

*Possible sites are under study in the European program Laguna.

# 9. Large Underground Observatory for Proton Decay, Neutrino Astrophysics and CP-violation in the Lepton Sector (GLACIER)

*S. Horikawa, A. Curioni*

A new very massive underground neutrino observatory GLACIER (Giant Liquid Argon Charge Imaging ExpeRiment) is proposed to address the unification of elementary forces by discovering the spontaneous radioactive decay of protons, and to advance in the multimessenger neutrino astronomy with the detection of astrophysical and terrestrial neutrinos (solar, atmospheric neutrinos, or from Dark Matter annihilation). For example, neutrino bursts from galactic and extragalactic supernovae will unveil the mechanisms of the stellar collapse. In addition, the observed neutrino oscillations point to the need to couple the observatory to intense neutrino beams, for instance from CERN, to address the puzzle of the origin of matter excess over antimatter in the Universe (discovery of CP-violation in the Lepton Sector).

The underground localization of the experiment is being investigated along the JPARC neutrino beam in Collaboration with KEK (Japan) and in Europe within the LAGUNA design study.

The detector relies on a new liquid argon detector concept, scalable to a single unit of mass 100 kton: it relies on a cryogenic storage tank developed by the petrochemical industry (LNG technology) and on a novel method of operation called the LAr LEM-TPC. LAr LEM-TPCs operate in double phase with charge extraction and amplification in the vapor phase. The concept has been very successfully demonstrated on small prototypes: ionization electrons, after drifting in the LAr volume, are extracted by a set of grids into the gas phase and driven into the holes of a double stage Large Electron Multiplier (LEM), where charge amplification occurs. Each LEM is a thick macroscopic hole multiplier, which can be manufactured with standard PCB techniques. The electrons signal is readout via two orthogonal coordinates, one using the induced signal on the segmented upper electrode of the LEM itself and the other by collecting the electrons on a segmented anode. The images obtained with the LAr LEM-TPC are of very high -- « bubble-chamberlike » -- quality, owing to the charge amplification in the LEM and have good measured dE/ dx resolution. Compared to LAr TPCs with immersed wires, whose scaling is at least limited by mechanical and capacitance issues of the long thin wires and by signal attenuation along the drift direction, the LAr LEM-TPC is an elegant solution for very large liquid Argon TPCs with long drift paths and mm-sized readout pitch segmentation.

Effective extrapolation to the required scale requires concrete R&D. A ton-scale LAr LEMTPC detector is being operated at CERN in Blg 182 within the CERN RE18 experiment (ArDM). In order to prove the performance for neutrino physics, additional dedicated test beam campaigns are being considered, to test and optimize the readout methods and to assess the calorimetric performance of such detectors.

Beyond these efforts, a 1 kton-scale device is the appropriate choice for a full engineering prototype of a 100 kton detector. The chosen size for the prototype is the result of two a priori contradictory constraints: (1) the largest possible detector as to minimize the extrapolation to 100 kton (2) the smallest detector to minimize timescale of realisation and costs. A 1 kton detector can be built assuming the GLACIER design with a 12 m diameter and 10 m vertical drift. From the point of view of the drift path, a mere factor 2 will be needed to extrapolate from the prototype to the 100 kton device. Hence, the prototype will be the real demonstrator for the long drifts. At the same time, the rest of the volume scaling from the 1 kon to the 100 kton achieved by increasing the diameter to about 70 m, can be realized noting that (a) large LNG tanks with similar diameters and aspect ratios already exist (b) the LAr LEM-TPC readout above the liquid will be scaled from an area of 80 m2 (1 kton) to 3800 m2 (100 kton). This will not require a fundamental extrapolation of the principle, but rather only pose technical challenges of production, which can be solved in collaboration with industry.

## 10. Neutrino Detector in Armenia

*A. Ioannisyan*

We suggest to construct ultra high energy Neutrino Detector in salt mine near Yerevan. Rock salt is considered as a radio wave transmission medium. The radio waves are generated by Askaryan effect (coherent impulsive radio Cherenkov radiation from the charge asymmetry in an electromagneticshower) in the neutrino interaction in the rock salt.

## 11. Large Apparatus for Grand Unification and Neutrino Astrophysics (LAGUNA)*

*S. Horikawa, A. Curioni*

A new research infrastructure supporting deep underground cavities able to host a very large multipurpose next-generation neutrino observatory of a total volume in the range of 100.000 to 1.000.000 m3 will provide new and unique scientific opportunities in the field of particle and astroparticle physics, attracting interest from scientists worldwide to study proton decay and neutrinos from many different natural sources, very likely leading to fundamental discoveries.

One of the main reasons for a new observatory beyond the presently running Superkamiokande (Japan) is to find direct evidence for the Unification of all elementary forces, by searching for a rare process called proton decay. The new underground detector will pursue the only possible path to directly test physics at the GUT scale, significantly extending the proton lifetime search sensitivities up to 1035 years, a range compatible with several theoretical models.

While searching for proton decays, the continuously sensitive underground observatory will offer the opportunity to concurrently detect several other rare phenomena. In particular, it will sense a large number of neutrinos emitted by exploding galactic and extragalactic type-II supernovae, allowing an accurate study of the mechanisms driving the explosion. The neutrino observatory will also allow precision studies of other astrophysical or terrestrial sources like solar and atmospheric ones, and search for new sources of astrophysical neutrinos, like for example the diffuse neutrino background from relic supernovae or those produced in Dark Matter (WIMP) annihilation in the centre of the Sun or the Earth.

In addition, the recent measurements of neutrino oscillations point forward to the need to couple the new neutrino observatory to advanced neutrino beams for instance from CERN, to study matter-antimatter asymmetry in neutrino oscillations, thereby addressing the outstanding puzzle of the origin of the excess of matter over antimatter created in the very early stages of evolution of the Universe.

Europe currently has four world-class national deep underground laboratories with highlevel technical expertise, located in Boulby (UK), Canfranc (Spain), Gran Sasso (Italy), and Modane (France), hosting detectors looking for Dark Matter or for neutrino-less double beta decays, or performing long-baseline experiments. However, none of the existing laboratory is large enough for the next-generation experiment contemplated here.

The FP7 Design Study LAGUNA (Large Apparatus studying Grand Unification and Neutrino Astrophysics), involving 21 beneficiaries, composed of academic institutions from Denmark, Finland, France, Germany, Poland, Spain, Switzerland, United Kingdom, as well as industrial partners specialized in civil and mechanical engineering and rock mechanics, is assessing the feasibility of this Research Infrastructure in Europe. The LAGUNA consortium is evaluating possible extensions of the existing deep underground laboratories in Europe, and on top considers the creation of new laboratories in the following regions: Umbria Region (Italy), Pyhäsalmi (Finland), Sierozsowice (Poland) and Slanic (Romania).

Similar plans are emerging worldwide, for instance in North America with the Deep Underground Science and Engineering Laboratory (DUSEL) at Homestake (South Dakota), envisioning a deep underground facility coupled to US accelerator laboratories located at appropriate distances, for long baseline neutrino oscillation experiments. In Asia, the Japanese High Energy Research Accelerator Research Organization (KEK) roadmap foresees extensions of the JPARC neutrino programme beyond the current T2K experiment by increasing the neutrino beam intensity and by constructing a new far detector in addition to SuperKamiokande.

This international landscape underlines the “global” nature of the project, with potential options being considered in several continents, jointly debated by the international scientific community. It is therefore likely that only one such facility will be built worldwide.

## 12. Search for Flavor Changing Neutral Currents (FCNC) at LHC with tagged neutrino beam directed into Lake Geneva

*G. Vesztergombi*

The possibility is studied that high energy neutrinos originating from Klong decays produced in 7 TeV proton-nucleus interactions could be tagged by Silicon detector equipped with extremely fast electronics. The neutrino beam would be directed along the Lake Geneva which could serve as a multi-kilotonn Cherenkov detektor. The aim would be the study neutrino-electron scattering with identified electronic and muonic neutrinos with known energy. One could distinguish with high precision the single particle final states containing electron or muon. Due to the exact timing the cosmic ray background is expected to be negligible. The nonzero muon/electron ratio would indicate directly the existence and the size of FCNC.

## 13. The Emulsion Scanning System in the OPERA experiment

*F. Juget*

The OPERA experiment has for goal the direct detection of º¹ $ º¿ oscillation, using an hybrid apparatus composed of electronic detectors and nuclear photographic emulsions. A charged particle crossing an emulsion layer ionizes the medium along its path leaving a latent image which leads, after development, to a sequence of aligned grains. Nuclear emulsions are analyzed by means of optical microscopes to reconstruct the 3D particle tracks. The OPERA collaboration has developed a dedicated system to scan a large number of emulsions (surface ~ 1000 $m^2$). The achieved resolution is ~1 μm and ~1 mrad allowing to observe directly the short-lived ¿ particles produced in $\nu_\tau$ CC interactions.

## 14. OPERA: Electronic Detectors

*A.Meregaglia*

OPERA is an hybrid detector for the $\nu_\tau$ appearance search in a direct way, and the Electronic Detectors (ED) have the crucial role of triggerring for the neutrino events and of localizing such an interaction inside the target. Another very important task of the ED is to identify the muon since only a correct matching of such a track with a track in the emulsion connected to the vertex of the event allows to reduce the charm background to the desired level. The ED, fully working since 2006, consist of a target tracker (scintillator bars) and a spectrometer (RPC and drift tubes). The different sub-detectors are described in the poster, as well as their performance both on Monte Carlo and real data.

## 15. Cold front-end electronics and Ethernet-based DAQ systems for large LAr TPC readout

*C. Girerd*

Large LAr TPCs are among the most powerful detectors to address open problems in particle and astro-particle physics, such as CP violation in leptonic sector, neutrino properties and their astrophysical implications, proton decay search etc. The scale of such detectors imply severe constraints on their readout and DAQ system.

We are carrying on a R&D in electronics on a complete readout chain including an ASIC located close to the collecting planes in the argon gas phase and a DAQ system based on smart Ethernet sensors implemented in a microTCA standard. The choice of the latter standard is motivated by the similarity in the constraints with those existing in Network Telecommunication Industry.

The front-end readout architecture proposed allows to benefit from the intrinsic noise reduction due to the low temperature (around 120K in the argon gas phase) and the limited cable capacitance before the preamplifiers. The typical signals are around 3 fC per particle per wire with a dynamic range of 40. The aim is to reach a low noise level, better than 1000e- ENC with a detector capacitance of 250pF. Three chips have been submitted in the standard 0.35µ CMOS technology (AMSC35B4) and the results obtained so far are presented here.

To readout this front-end stage we developed an Advanced Mezzanine Board (AMC) including 32 ADC channels ADC in the microTCA standard. This board receives 32 analogical channels at the front panel and sends the formatted data through the backplane using a Gigabit Ethernet link.

The core of this card is a FPGA (ARIA-GX from ALTERA) including the whole system except the memories.

Obviously, in order to be able to reconstruct the traces from the events a time synchronisation system is mandatory. We decided to implement the IEEE1588 standard also called Precision Timing Protocol, another emerging and promising technology in Telecommunication Industry. We present an original method implementing the PTP and using the recovered clock of the Gigabit link.

## 16. Neutrino-nucleus cross-sections: a unified theoretical approach for nucleon knock-out, coherent and incoherent pion production

*M. Martini*

Neutrino-nucleus cross-sections for several partial channels are needed to interpret neutrino oscillation data, as neutrino detectors involve complex nuclei. Present and future accelerator experiments involve energies where nuclear effects are important. We present a theory of neutrino interactions with nuclei aimed at a unified description of the partial cross-sections, namely quasi-elastic and multi-nucleon emission, coherent and incoherent single pion production. The theory is based on nuclear responses treated in the random phase approximation. We compare our approach with the available neutrino experimental data on carbon (K2K, MiniBoNE, SciBooNe). We also discuss the evolution of the neutrino cross-sections with the mass number in view of future precision experiments such as T2K.

## 17. Neutral current π0 production

*P. Przewlocki*

We evaluate uncertainty of the neutral current π0 production coming from limited knowledge of axial form-factor. The uncertainties of the form-factor parameters are obtained from a self-consistent fit to the results of ANL and BNL experiments measuring pion production free of significant nuclear effects. The evaluated uncertainties are important for T2K background estimates.

## 18. Alternative approach to extraction of oscillation parameters

*J. Sobzcyk*

We discuss a method to extract neutrino oscillation parameters based on the directly observable quantities, without reconstruction of neutrino energy.

## 19. Preliminary results of NA61/SHINE at the CERN SPS on pion productionin p+C interactions at 31 GeV/c for T2K

*T.J. Palczewski*

This poster will present preliminary results from a fixed target experiment NA61/SHINE at the CERN SPS. One of the main physics goals of the NA61 experiment is to provide new experimental information on hadron production in p+C interactions in the region of several tens of GeV. These data are necessary for the T2K neutrino experiment at J-PARC to improve the accuracy of neutrino flux simulations and consequently calculate the initially produced neutrino flux. For precise predictions of the T2K neutrino beam parameters the measurements were perform on two different types of targets:

thin carbon target  and replica of the target installed at Tokai. The NA61 data are also important for the cosmic ray experiments for a better energy estimate of incident cosmic particles. The NA61 detector has a large angular acceptance, full coverage of T2K phase space region, and good particle identification. In this poster, preliminary dn/dp distributions of negatively charged pion in p+C interactions at 31 GeV /c from the 2007 pilot run data will be presented. Three different types of analyses of the negatively charged pion production will be compared. New high statistics data have been already registered in the 2009 run of NA61. We collected 6M triggers with a thin target and 3M with the T2K replica target configurations. Analysis of these data starts now.

## 20. Pion cross-sections from HARP-CDP or from the HARP Collaboration?

*F. Dydak*

There is overwhelming evidence, brought to light by the HARP-CDP group and confirmed by two Review Committees, that cross-sections published by the HARP Collaboration are wrong. This is of particular relevance for the optimization of the proton driver of a neutrino factory.

## 21. Measurement of the atmospheric muon charge ratio with the magnetic spectrometers of the OPERA detector at Gran Sasso

*M. Sioli*

OPERA is a long-baseline neutrino experiment located in the Hall C of the Gran Sasso underground Laboratories at an average depth of 3800 hg/cm$^2$, corresponding to an average muon energy at surface of 1.4 TeV.

We present the measurement of the atmospheric muon charge ratio with the magneticspectrometers of the detector, using the data collected in parasitic way during the 2008 neutrino run. We report the unfolded underground value and the charge ratio as a function of the vertical surface muon energy. We also provide an interpretation of the results in terms of the main contributions to the atmospheric muon flux.

## 22. CMS: Cosmic muons in simulation and measured data

*L. Sonnenschein*

A dedicated cosmic muon Monte-Carlo event generator CMSCGEN has been developed for the CMS experiment. The simulation makes use of parameterisations of the muon energy and the incidence angle, based on measured and simulated data of the cosmic muon flux, taking the energy dependence of the incidence angle into account. The geometry and material density of the CMS cavern and access shafts are taken into account, too. The event generator is integrated n the complete CMS detector simulation chain. Cosmic muons can be generated on earth’s surface as well as for the detector located underground. Many million cosmic muon events have been generated and compared to measured data, taken with the CMS detector at its nominal magnetic field of 3.8 T during commissioning.

## 23. Lepton-Flavor violation in a neutrino mass model with discrete S3 symmetry

*P. Leser*

A discrete family symmetry using the group S3 is able to explain the observed maximal atmospheric angle in the neutrino sector while maintaining the ability to generate the observed CKM angles (Chen, Frigerio, Ma; Phys. Rev. D70:073008, 2004). The model requires an enlarged scalar sector which includes features that might be used to test the model experimentally, such as scalar particles with masses below 1 TeV and manifestly non-zero matrix elements for lepton flavor violating decays. We investigate distinct channels, in particular the decays of the scalars and leptonic processes, in order to compare model predictions with experimental bounds.

## 24. Baseline-dependent neutrino oscillations in asymmetrically-warped spacetimes

*S. Hollenberg*

In theories with large extra dimensions, the Standard Model particles are typically confined to the 3+1-dimensional Minkowskian brane, which is embedded in an extra-dimensional bulk. Singlets under the gauge group, like sterile neutrinos, however are allowed to travel freely in the bulk as well as on the brane.

In such theories oscillations between active and sterile neutrinos can be governed by a new resonance in the oscillation amplitude which might explain the LSND neutrino oscillation anomaly as well as the MiniBooNE null result.

The resonance arises due to an additional phase difference induced when sterile neutrinos take temporal shortcuts through an extra dimension. Thus in these models there are two sources of phase difference, the standard one related to the neutrino mass-squared difference and a new geometric one arising from temporal shortcuts through the bulk available to gauge singlet quanta. The two phase differences may beat against one another to produce resonant phenomena.

We introduce a specific metric for the brane-bulk system, from which we explicitly derive extra-dimensional geodesics for the sterile neutrino, and ultimately the oscillation probability of the active-sterile two-state system. We find that for an asymmetrically-warped spacetime, the resonance condition involves both the neutrino energy E and the travel distance L on the brane. In other words, the resonant energy may be viewed as baseline-dependent. The resonance condition is not on E or on L, but to a good approximation on the product LE.

The model is rich in implications, including the possibility of multiple solutions to the resonance condition, with ramifications for the existing data sets, e.g. LSND and MiniBooNE.

Some phenomenology with these brane-bulk resonances will be presented such as the compatibility of our brane-bulk model with atmospheric and short baseline neutrino oscillation data.

## 25. Multiparameter approach to R-parity violating supersymmetric couplings

*F. Tahir*

We introduce and implement a new, extended approach to placing bounds on trilinear R-parity violating couplings. We focus on a limited set of leptonic and semileptonic processes involving neutrinos, combining multidimensional plotting, and cross-checking constraints from different experiments. This allows us to explore new regions of parameter space and to relax a number of bounds given in the literature. We look for qualitatively different results compared to those obtained previously using the assumption that a single coupling dominates the R-parity violating contributions to a process (SCD). By combining results from several experiments, we identify regions in parameter space where two or more parameters approach their maximally allowed values. In the same vein, we show a circumstance where consistency between independent bounds on the same combinations of trilinear coupling parameters implies mass constraints among slepton or squark masses. Though our new bounds are in most cases weaker than the SCD bounds, the largest deviations we find on individual parameters are factors of two, thus indicating that a conservative, order of magnitude bound on an individual coupling is reliably estimated by making the SCD assumption.

## 26. SPL-based Proton Driver for a neutrino Factory at CERN

*E.Benedetto*

The conceptual design and feasibility studies for a neutrino Factory Proton Driver based on the CERN Superconducting Proton Linac (SPL) have been completed. In the proposed scenario, the 4 MW proton beam (H- beam) is accelerated with the upgraded High Power (HP)-SPL to 5 GeV. The beam is then stored in an accumulator ring and finally transported to a compressor ring, where the longitudinal phase rotation takes place, in order to achieve the specific time structure at the target, as required by the 3rd International Scoping Study (ISS).

We here summarize the choices in terms of lattice, magnet technology and RF manipulations in the two rings. The possible critical issues, such as heating of the foil for the charge-exchange injection, space-charge problems in the compressor and beam stability in the accumulator ring, have been addressed and are shown not to be show-stoppers. The analysis focuses on the baseline scenario, considering 6 bunches in the accumulator, and preliminary studies are discussed for the option of 3 or a single bunch per burst.

## 27. The Proton Driver Front End prototype

*L. Jenner*

This poster outlines the current effort from the UK towards a future neutrino factory and its contribution to the European Neutrino Strategy.

The main topics of discussion are as follows: The Proton Driver Front End prototype known as FETS, FFAG designs, Mercury Jet and Metal Powder Target studies, the MICE experiment and Novel RF surface treatment techniques

## 28. The MERIT High-Power target experiment at the CERN PS

*I. Efthymiopoulos*

The MERIT experiment is a proof-of-principle test of a free mercury jet inside a high-field solenoid magnet foreseen as a front-end target system for a pulsed high-power 4MW proton beam. The target is foreseen for a Neutrino factory complex or a Muon Collider. The experiment took data in autumn 2007 with the fast extracted beam from the CERN Proton Synchrotron (PS) to a maximum intensity of about $30^{12}$ protons per pulse. We report results from the experiment which validates the target concept.

## 29. Solid target for a neutrino factory

*G. P. Skoro*

The UK programme of high power target developments for a Neutrino Factory is centered on the study of high-Z materials (tungsten, tantalum). A description of lifetime shock tests on candidate materials is given as part of the research into a solid target solution. A fast high current pulse is applied to a thin wire of the sample material and the lifetime measured from the number of pulses before failure. These measurements are made at temperatures up to ~2000 K. The stress on the wire is calculated using the LS-DYNA code and compared to the stress expected in the real Neutrino Factory target. It has been found that tantalum is too weak at these temperatures but a tungsten wire has reached over 26 million pulses (equivalent to more than ten years of operation at the Neutrino Factory). Measurements of the surface velocity of the wire using a laser interferometry system (Laser Doppler Vibrometer) are in progress, which, combined with LS-DYNA modelling, will allow the evaluation of the constitutive equations of the material. An account is given of the optimisation of secondary pion production and capture in a Neutrino Factory and of the latest solid target engineering ideas.

## 30. Neutrino Factory Front-End: muon capture and cooling optimization

*G. Prior*

The neutrino factory is one of the proposed designs for a future intense neutrino beam facility. The layout discussed here focuses on the current baseline front end of the neutrino factory (part of the facility between the target and the beginning of the acceleration system). A high-power proton beam impinges on a mercury jet target producing pions that will decay into muons. Subsequent cooling of the muons in a solenoidal ionization cooling channel is needed to reduce the article beam emittance It involves the use of absorber material (reducing the muon momenta )alternated with RF cavities (restoring the muon longitudinal momenta) in intense magnetic field. The challenges inherent to the cooling of muons are shown together with possible optimization of the current baseline.

## 31. The Normal Conducting RF Cavity for the MICE Experiment

*M. S. Zisman*

The international Muon Ionization Cooling Experiment (MICE) requires low frequency, normal conducting RF cavities to compensate for the muon beam's longitudinal energy loss in the MICE cooling channel. Eight 201-MHz normal conducting RF cavities with conventional beam irises terminated by large, thin beryllium windows are needed. The cavity design is based on a successful prototype cavity for the U.S. MuCool program. The MICE RF cavity will be operated at 8 MV/m in a few tesla magnetic field with 1 ms pulse length and 1 Hz repetition rate. The cavity design, fabrication, and post processing plans, as well as integration into the MICE cooling channel, will be discussed and presented

## 32. MICE Particle Identification System

*M. Bogomilov*

The Muon Ionization Cooling Experiment mICE, at the ISIS accelerator located at the Rutherford Appleton Laboratory, UK, will be the first experiment to study muon cooling at high precision. Demonstratioon of muon ionization cooling is an essential step towards construction of a neutrino factory or a muon collider.

Muons are produced by pion decay in a superconducting solenoid and reach MICE with a range of emittances and momenta. The purity of the muon beam is ensured by a system of particle detectors: a Time-of-Flight system, two threshold Cherenkov counters and a low energy muon/electron ranger. We will briefly describe the MICE particle identification system and show measurements of current performance of these detectors.

## 33. Progress on the MuCool and MICE Coupling Coils

*M. S. Zisman*

The superconducting coupling solenoids for MuCool and MICE will have an inside radius of 750 mm, and a coil length of 285 mm. The coupling magnet will have a self-inductance of 592 H. When operated at its maximum design current of 210 A (the highest momentum operation of MICE), the magnet stored energy will be about 13 MJ. These magnets will be kept cold using two pulse tube coolers that deliver 1.5 W at 4.2 K and 55 W at 60 K. This report describes the progress on the MuCool and MICE coupling magnet design and engineering. Fabrication plans for the coupling coil are discussed

## 34. Progress on the Fabrication and Testing of the MICE Spectrometer Solenoids

*M. S. Zisman*

The Muon Ionization Cooling Experiment (MICE) is an international collaboration that will demonstrate ionization cooling in a section of a realistic cooling channel using a muon beam at Rutherford Appleton Laboratory (RAL) in the UK. At each end of the cooling channel a spectrometer solenoid magnet comprising five superconducting coils will provide a 4 T uniform field region. A scintillating fiber tracker within each magnet's bore tube will measure the emittance of the muon beam as it enters and exits the cooling channel. The 400 mm diameter warm bore, 3 m long magnets incorporate a cold mass consisting of two coil sections wound on a single aluminum mandrel: a three-coil spectrometer magnet and a two-coil section that matches the solenoid uniform field into the MICE cooling channel. Fabrication of the first of two spectrometer solenoids has been completed, and initial testing of the magnet is nearly complete. Key design features of the spectrometer solenoid magnets are presented, along with a summary of the progress on the training and testing of the first magnet.

## 35. The MICE Tracker System

*B. Freemire*

The International Muon Ionization Cooling Experiment aims to measure the reduction in transverse emittance of a beam of muons by 10% to 0.1% precision. The MICE tracker system will utilize planes of scintillating fiber housed within 4T solenoids placed upstream and downstream of the cooling channel to do this. Tests of the tracker have been completed at Rutherford Appleton Laboratory using cosmic rays and the tracker system will soon be ready to be placed in the MICE beamline

## 36. MICE, other application

*M. Rayner*

The Muon Ionization Cooling Experiment is designed to demonstrate the operation of a module of a cooling channel by observing individual particles of a beam with the properties found in a Neutrino Factory. It incorporates timing detectors with a resolution of 50 picoseconds whose primary purpose is particle identification. This poster describes their other uses in beam characterization, specifically the measurement of momentum, transverse and longitudinal beam emittance, and the phase of the muons in the RF cavities.

## 37. Radioactive-Ions Production Ring for Beta-Beams

*E.Benedetto*

Within the FP7 EUROnu program, the issues of production and acceleration of Li-8 and B-8 isotopes through the Beta-Beam complex, for the production of electron-neutrino, are addressed. One of the major critical issues is the production of a high enougth ion flux, to fulfill the requirements for physics.

In alternative to the direct ISOL production method, a new approach is proposed in [Beam cooling with ionization losses, C.Rubbia et al., NIM A 568 (2006) 475-487]. The idea is to use a compact ring for Litium ions at 25 MeV and an internal He or D target, in which the radioactive-isotopes production takes place. The beam is expected to survive for ~10000 turns, therefore cooling in 6D is required and, according this scheme, the ionization cooling provided by the target itself and a suitable RF system would be sufficient.

We present some preliminary work on the Production ring lattice design and cooling issues, for the Li-7 ions, and propose plans for future studies.

## 38. Modify HERA to accelerate beta beams

*A. Stahl*

With the HERA ring at DESY Europe has a proton accelerator that is capable of accelerating protons to almost 1 TeV, but is no longer in use. I show some ideas how HERA can be modified to accelerate a beta beam and direct the neutrinos to a detector at an optimised location.

## 39. $He^{-6}$ for beta beams

*M. Lauscher*

A future beta beam facility will need to produce a large number of He-6 ions. It might be possible to produce these ions from fast neutrons from a deuteron beam in a $Be^{-9}$ (n, $He^{-4}$) $He^{-6}$ reaction. An experiment at the SARAF accelerator at the Soreq Nuclear Research Center in Israel is in preparation. We present perspectives and simulations.

## 40. Limitations in the use of Barrier Buckets in the Beta Beam Decay Ring for the FP7 Scenario

*C. Hansen*

Beta Beam, the concept of letting accelerated radioactive ions generate a pure and intense (anti) neutrino beam by beta decay, is one of the proposed next generation neutrino oscillation facilities, necessary for a complete study of the neutrino oscillation parameter space. The first CERN based scenario, using 18Ne and 6He as nu_e and anti-nu_e emitters respectively, has been thoroughly studied and documented.

We have now entered the era of the studies of the second CERN based baseline. It is being investigated how the ions 8B and 8Li can be produced in a ''Production Ring'', collected in an ECR source, accelerated in two new machines; a linac and an RCS, and in two existing but upgraded machines; PS and SPS and accumulated in a ''Decay Ring''.

In this new Beta Beam scenario preliminary theta_13 and delta_cp sensitivity results show that the required suppression factor (i.e. the ''duty cycle'' of the Decay Ring) is at the same order of magnitude as for the previous scenario, i.e. between 0.1% and 1%.

The idea of an alternative RF scheme for the Decay Ring; to use RF barriers to collect all ions in one ''Barrier Bucket'', has been tested.

Simulations in the longitudinal phase space show that the short duty cycle, together with the limited filling time of traveling wave cavities, cause restraints in the use of RF barriers.

Therefore the prior RF scheme that used asymmetric merging and rotation in the longitudinal phase space and that proved to accomplish a duty cycle that followed the requirements, will have to be investigated also for the new 8B and 8Li ions

## 41. LENA – Low Energy Astronomy

*L. Oberauer*

We propose LENA (Low Energy Neutrino Astronomy), a large ~50kt liquid scintillator neutrino detector for particle-astrophysics, located in a deep underground laboratory. Main scientific goals of LENA are: the search for proton decay, thus probing grand unified theories; the measurement of the diffuse Supernova neutrino background; the precise determination of thermo-nuclear fusion processes by measuring solar neutrinos with high statistics; a measurement of geo-neutrinos probing Earth's models; in case of an actual galactic Supernova type II an accurate measurement of the time development and flavour content of the emitted neutrino burst.

Furthermore we propose the use of LENA as a detector for a long baseline neutrino oscillation experiment. A high sensitivity on the mixing angle □13 will be achieved. In addition LENA will be used as a detector for low energy atmospheric neutrinos and may perform an indirect search for Dark Matter.

The physics potential of LENA was determined in several Monte-Carlo studies [1,2,3] and several feasibility studies for different liquid scintillator candidates were performed recently [4]. An actual overview of the physics program and technological developments can be found in [4] as well. A possible location for LENA is currently investigated within the European LAGUNA design study.

## 42. Towards the detection of cosmological relic neutrinos with neutrino capture on beta decaying nuclei

*M. Messina*

The poster shows a project based on a novel idea for the detection Cosmological Relic Neutrinos CRN) and more in general, for the detection of neutrinos of vanishing energy. This idea is described in detail in the paper [1]. The method is based on the fact that neutrino interactions on beta-instable nuclei have the key feature of requiring no energy threshold for the neutrino interaction. Furthermore, in reference [1] a very interesting feature of □ v is shown for neutrino interacting with beta-instable nuclei: even if the kinetic neutrino energy vanishes □ v keeps a constant value depending on the considered target nucleus. This allows in principle the detection of neutrinos of vanishing energy. In order to achieve the high detection sensitivity one needs for CRNs discovery new developments are necessary in the field of detectors technology. In the project we propose to investigate the possibility of building a bolometer with an absorber mass as large as ~1 g and, with an energy resolution of a fraction of eV. To accomplish this goal we propose to investigate several read-out set-ups as well as superconducting thermistors (TES) and Ge thermistor. Morover, we also propose to test a magnetic flux based read-out of bolometers arranged in a geometrically metastable geometry. This looks to be a very promising detector scheme in view of realizing bolometers with large mass absorbers (~1 g).

The detector development we propose is a required step in view of the design of future detectors for CRN on a realistically large scale.

## 43. A 10-ton scale Nd-liquid scintillator experiment to search for neutrinoless double beta decay of 150Nd and requirements for Nd isotopic enrichment.

*C. Cattadori*

The experimental search of neutrinoless double beta decay (0νββ) is a powerful tool to probe the Dirac/Majorana neutrino nature and the value of the effective Majorana neutrino mass($m_{ee}$). Nd is a good, almost unexplored, candidate to search for neutrinoless double beta decay thanks to the high Q-value of the transition which is, moreover, above the highest energy γ-ray lines of natural radioactive background.

In this work we present both the first study of the sensitivity on mee reachable by a 12-ton NdLS detector, and the results of a 3 year experimental work on NdLS R&D.

It is shown how merging the achieved technologies on

i) LS radio-purification ($10^{-17}$ g/g of Th&U )and LS radiopurity measurements and

ii) Nd doping of organic LS by means of suitable Nd-organic compounds at concentration 5-10 g/l

a small scale (12-ton) detector could be competitive on $m_{ee}$ sensitivity (100 meV). In such small scale detector the unavoidable solar neutrino background will be negligible. This is feasible provided the Nd enrichment in the 150 isotope (natural abundance 5.6%) up to ~60%.

With the present know-how the Nd enrichment is feasible only by the AVLIS (Atomic Vapour Laser Ionization Spectroscopy) technology, and not by centrifuge due to the non-existence of simple, inorganic, room temperature volatile and stable Nd compound. An European effort on the R&D of the AVLIS technique to enrich rare earth elements with adequate radiopurities to perform a 0νββ experiment will represent an added value for any experimental (LS, ionization chamber, or bolometric) search of $^{150}$Nd 0νββ

## 44. Physics with low energy neutrino beams

*C. Volpe*

We propose to establish a facility for low energy neutrino beams, in the 100 MeV energy range. Such beams can be obtained either with low energy beta beams or with very intense conventional sources. The availability of neutrino beams in the 100 MeV energy range offers a unique opportunity to realize neutrino interaction studies of interest for particle physics, nuclear astrophysics and nuclear physics. For example, performing neutrino-nucleus interaction experiments would furnish essential information for a precise knowledge of neutrino detector's response – based on nuclei – e.g. to detect core-collapse supernova neutrinos and their relics. Another important impact of such measurements is for the search of lepton-number violation. Indeed these experiments would give new constraints to neutrinoless double beta decay half-life calculations.