Beams for European Neutrino Experiments

CARE BENE Network: Report Jan 1- Aug 31 2006

the BENE Steering Group

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N2 : Beams in Europe for Neutrino Experiments (BENE)

BENE is the CARE network for Beams for European Neutrino Experiments. It comprises 13 countries. The table of the participants and their implication in the BENE Work Packages is given in the table below. The overall management is done by INFN-Na. During the period reported, an alternance of WP coordinators took place for the DRIVER (M. Zito) and COLLECTOR (M. Dracos) WP. A new PHYSICS co-coordinator was drafted (A. Donini). A new Deputy Coordinator is also being searched.

Participant number	Participant	PHYSICS	DRIVER	TARGET	COLLECTOR	NOVEL NEUTRINO BEAMS
1	**CEA**	X	**C**	X	X	**C**
2	**UCLN**	X				X
3	**CNRS**	X			X	X
	CNRS-Orsay	X			X	X
	CNRS-LPNHE	X			X	
	CNRS-CENBG	X				
	CNRS-IPNL	X			X	
	CNRS-LPSC					**C**
	CNRS-IReS	X			**C**	
4	**GSI**					X
7	**FZJ**		X	X		
8	**TUM**	X				X
10	**INFN**	**C**	X	X	X	X
	INFN-LNF	X				X
	INFN-Ba	X				X
	INFN-Ge					X
	INFN-GS	X				
	INFN-LNL	X	X			X
	INFN-Mi	X				X
	INFN-Na	X				X
	INFN-Pa	**C**				X
	INFN-Pi	X				
	INFN-Tr	X				X
	INFN-Ro3	X				X
	INFN-To	X				
16	**CSIC**	X				
	UBa	X				
	IFIC	X				
	UAM	**C**				
17	**CERN**	X	X	X	X	**C**
18	**UNI-GE**	X		X	X	X
19	**PSI**			X		
20	**CCLCR**	X	X	**C**	X	X
	CCLRC-RAL	X	X	**C**	X	X
21	**ICL**	X		X		**C**

During the first 8 months of 2006, the BENE[1] Network has

1) **welcome first operation of the CNGS in August:** while BENE looks forward to more ambitious future facilities, it is well aware that these can only be rooted in the

[1] BENE's mandate is that to promote clear awareness, in our particle physics peer community, a) the physics interest of superior accelerator neutrino beams (Superbeams, Betabeams, Neutrino Factories) b) the promising on-going developments of accelerator technology that will make them possible c) the opportunities that exist to plan, fund and realize, on a realistic time scale, a much enhanced European accelerator neutrino complex .

expertise that has produced the CNGS and its predecessors, the WANF and the PS neutrino beams. Exploration of the upgrade paths to maximal CNGS performance remains BENE immediate priority.

2) **submitted its recommendations to the CERN Council Strategy Group**.
BENE prepared a comprehensive report electronically submitted by Jan 31st,, for the preparatory Open Symposium of the CERN Council Strategy Group in Orsay. It is an outline and a plea for a timely R&D program in the accelerator (and detector) neutrino sector.
Before this, members of BENE were present in the task forces that CERN set up to look into its options for proton accelerator of the future (PAF) and into the physics opportunities of those future proton accelerators (POFPA), with the decisive task of designing the best possible proton complex capable of best serving LHC and its upgrades, an ambitious neutrino program, some frontier aspects of kaon, muon and other fixed target physics, the nuclear physics of radioactive ion beams and possibly more
A. Blondel, senior member of BENE, organized the neutrino session in Orsay. M. Mezzetto, BENE PHYSICS coordinator was secretary. P. Huber and A. Cervera gave the theory and experiment talk, respectively. This was a success, according to neutral observers, it showed that the European accelerator neutrino community has the physics case, the enthusiasm, the organization and, we trust, also the technical competence, necessary to make a new accelerator neutrino complex, built with a decisive EU contribution, conceivable. Many interventions of BENE members underlined different crucial tasks ahead of us. The conclusions of the session were voiced by the BENE coordinator**: a timely R&D program should not be procrastinated**.

3) **produced Networking Activity Midterm Scientific Report (**CERN 2006-05, CARE 2006-009-BENE, ECFA 06/242) evolved from the electronic report for Orsay. **produced** It summarizes the state of advancement of our initiative, reviewing progress and proposing a preliminary road map towards a superior European accelerator neutrino facility to be built in the coming decade.

4) **contributed to the syllabus of the International Scoping Study (ISS), the one year study on Neutrino Factories and Superbeams** to be completed by August 2006, launched at the BENE edition of Nufact05 in Frascati in June 2005 and expected to be completed in Aug 2006 at NuFact06.
The Study has been organized jointly by the Neutrino Factory and Muon collider collaboration in the US, the Japanese NuFACTJ collaboration and our ECFA BENE Network for future neutrino beams in Europe, where it was hosted at CCRLC laboratories by the UK neutrino factory collaboration that has promoted it first. Important contributions have also come from India, Russia, Poland and Bulgaria. The coordinator of BENE, a representative of the US-MC (S. Geer), NuFACTJ (Y. Kuno) and UKNF (K. Peach) were asked to overview the study. Their proposal to have 3 substudies and to nominate coordinators Yori Nagashima (Physics Group), Mike Zisman (Accelerator Group) Alain Blondel (Detector Group) was accepted. Overall leader is Peter Dornan (UK).
The ***Physics*** group studies the reach of future accelerator neutrino beams. Neutrino factories and superbeams are compared to each other and to neutrino betabeams The ISS boosted the work on comparison between facilities constructing more reliable, though not yet final, comparison yardsticks. It reviewed the deep underlying physics motivations for a precision neutrino facility and the value of measurements within and beyond the minimal 3 neutrino scenario. It also explored the synergy between precision physics with slow muons and neutrino factories.
Member of the BENE network played leading roles in the ISS Physics Study. Five

members of the eleven in the ISS Physics Council were drawn from BENE with M. Mezzetto (Padua) on both the Physics and Detector councils to form a link between the two working groups. Two of the four Physics subgroup conveners were members of the BENE network (Theory Subgroup convener, S. King, Southampton, and Experimental Subgroup convener K. Long, Imperial). Significant portions of the theoretical and phenomenological sections of the ISS report are being provided by BENE members. The comparison of the performance of the various proposed facilities received substantial input from the Munich, Madrid and Valencia groups. The outcome of the study is that the Neutrino Factory offers the best sensitivity over a large region of the parameter space, the beta-beam being a competitive option for intermediate values of the small mixing angle θ_{13}. At large values of θ_{13} super-beams, beta-beams and the Neutrino Factory give comparable performance.

The ***Accelerator*** Group studies the components of the accelerator chain, proton drivers, target and collection systems (common to Factories and Superbeams) and ionization cooling, acceleration and storage of muons (specific of Factories). It established a coherent set of baseline parameters and options for the various components of a neutrino factory capable of 10^{21} muon per year per decay straight section with the desired angular divergence. Some preliminary studies of a MMW superbeam were also started. A first list of important R&D items, being prepared, will be included in the Accelerator section of the ISS Report. All the convenors of the BENE WP's contributed to this work and are now writing portions of the Report. EU contributions are however still far from having the necessary impact. It will be hard to progress fast without a more resolute involvement of CERN experts.

The *Detector* Group studies the outstanding issues involved in the realization of neutrino detectors of adequate mass and performance for each of the three beam options. It rejuvenated simulation and study of neutrino factory detectors and established "baselines" (detectors that can be built, with reasonable first estimates of performance and cost) and "optimistic baselines" (detectors with potentially better performance, but feasibility and affordability still to be ascertained): A first list of important R&D items, being prepared, will be included in the Detector section of the ISS Report. Main editors (and Group convenors) are A. Blondel and P. Soler, that have raised help from a large number of BENE colleagues.

Finally, a collaboration of the physics and detector groups addressed the systematic issues of experimental nature (matter effects, uncertainties of neutrino cross sections, flux control etc..)

The ISS has thus proven a valuable tool and reached quite a few goals. Its final report should now be available within 2006. We need however to score better results in

1) raising funds for the studies and

2) rallying more coherently the entire community of experimental physicists presently operating or preparing experiments on accelerator neutrino beams

5) **contributed to the NuFact06 Workshop and to the formulation of the proposal for the evolution of the ISS** that emerged there**.** This is the yearly international forum of a world-wide collaboration of regional communities and has gained importance over the years, as can also be judged from the number of accompanying satellite events. The main conclusions reached there are discussed later. A large BENE delegation was present to both meetings, presenting the work of one year in about 1/3 of the talks in all parallel and plenary sessions of the workshop. More than ever, for the scope of presenting and evaluating the ISS, NuFact06 provided the most advanced possible review today of the potential of both conventional and novel neutrino facilities. The most promising physics result emerged was probably a scheme proposed by C. Rubbia for enhanced production of parent ions for betabeams. .

6) **kept preparing its proposals to different possible FP7 programs .** The picture being still unclear, we are following closely the evolution of the ESGARD policy in this domain. One open meeting of the BENE Steering Group (SG) was held on this subject on July 4 at CERN , one will be on October 25 in preparation of BENE06 on Nov 13-14 and CARE06 on Nov.15-17 and the ECFA meeting of Dec 1. We are presently exploring many options: among them, to apply for Design Study funds, to obtain a number of indispensable JRA's by means of either a Neutrino I3 or by joining in a larger I3, to assemble one or more "ERC" projects at the frontiers of science or address other EC programs that are also being investigated.

There were two key events this year so far for BENE. **One** has no doubt been the special session of **CERN Council on July 14 in Lisbon**. This approved a document outlining a **Strategy for European particle physics**. Council emphasized early in the document "the *vital need to strengthen the advanced accelerator R&D programme*", stating that "*a coordinated programme should be intensified, to develop the CLIC technology and high performance magnets for future accelerators, and to play a significant role in the study and development of a high-intensity neutrino facility*", adding finally that "*studies of the scientific case for future neutrino facilities and the R&D into associated technologies are required to be in a position to define the optimal neutrino programme based on the information available in around 2012; Council will play an active role in promoting a coordinated European participation in a global neutrino programme*".

It seems therefore that the BENE strategy, including its attention to international collaborations in a truly global context , **was recognized by Council**. We look now forward to deploy the strongest possible effort to contribute to establishment of such a coordinated European participation to a structured international R&D program. The task is that of assembling a large and solid collaboration of laboratory and university teams supported by all the European agencies willing to contribute funds and human resources to our sector. This EU collaboration would participate to a global effort, clustering around a small but freshly re-motivated CERN task force and heading resolutely towards securing crucial FP7 EC funds.

More generally, the process started by BENE with the "Physics with a multi MegaWatt proton source" Workshop at CERN, in May 2004, described in the 1st CARE/BENE annual report, has continued. It was much reinforced by the SPSC recommendations, following our participation to its strategic meeting in Villars in September 2004, by the start of a BetaBeam Design Study in January 2005 and by the launch of the ISS in 2005. ECFA support has also been warm and constant. This continuity of strategy and initiative has taken us to the present time that seems be preparing important decisions on R&D support. Council has now all the elements to take them, possibly before the end of 2006.

The **second** of the two **key event**s of the year so far for BENE has been then at Univ. of California, Irvine 21-23 and 24-30 August, with **the fourth meeting of the ISS and NuFact06**, the 8th International Workshop on Neutrino Factory, Superbeam & Betabeam. The main conclusions reached at NuFact06 (and the ISS meeting that preceeded it) were summarized in a document
http://www.hep.ph.ic.ac.uk/~longkr/tmp/ISS_Doc4-v06_28-8_2006.pdf
proposed by the Programme Committee of the ISS that NuFact06 discussed and endorsed in a dedicated session. In view of the fact that "*Conceptual Design Report (CDR) for the considered facilities should* be available *around 2012*" with Interim *Design Reports available around 2010"* it states *"that full international design studies (IDS's) of the super-beam, betabeam and neutrino factories are needed*" and that these "*design studies would each be*

initiated by those seeking to propose a particular option and would be carried in parallel. The teams carrying out the studies would be encouraged to work together on areas of common interest. The detector requirements for the betabeam and superbeam are very similar as are the multi megawatt proton driver and target for the neutrino factory and Superbeam". It recommends too that a "*physics working group continue the work of performance and evaluation and comparison that was initiated by the ISS"* and suggests that the **"***regional oversight bodies could provide a degree of coordination***".**
The next ISS/IDS meeting will be at CERN in February. Most likely Feb 21-22. It will set the ways of the transition from ISS to IDS's.
The results of the ISS clearly emphasise the need for a coordinated programme of R&D and design work. Resources to support this programme will be sought from all EU agencies and from Framework Programme 7

A third event, in preparation, will be the **NNN06 Workshop on Next Nucleon decay & Neutrino** detector in Seattle, USA, Sep 21-23, that will review the physics case and the technical challenges of these very large mass detectors and will further structure the international collaboration towards their realization

The two NuFact and NNN workshop series remain the yearly international forums of the two physics options that BENE tries to promote. These two main physics strategies that have been consolidating over the last few years are:

1) use of the **high** neutrino rate (>10^{20}/year) and **energy** (10-50 GeV) promised by the **Neutrino Factory**, in conjunction with a detector of large but not huge mass (50-100 Kt), necessarily magnetic (a dense magnetized iron detector, or, possibly, Li-Argon in mag field), a few 1000 Km away.
2) use of the **low**er neutrino rate ($10^{18\text{-}19}$/year) and **energy** (sub-GeV) offered by a **Betabeam**, in conjunction with a low density detector of very large mass () and volume, non magnetic (a 0.5-1 Mt Water Cerenkov detector, or possibly, again 100 Kt Li-Argon), a few 100 Km away. This is the same detector needed to extend the search for nucleon instability, supernovae and other astrophysical phenomena.

As stated in our last yearly report and, more extensively, in our Midterm Report, a first level of comparison has concluded that the two options have comparable merits. The second option appears to have somewhat lower performance, for neutrino oscillation physics, but offers also a synergy with other fundamental sectors of physics, as detection of super-nova, atmospheric or solar neutrinos and proton lifetime.

These preliminary conclusion are based on still not well agreed yardsticks and must now be re-scrutinized much more in depth.

The two strategies are also, to large extent, complementary. Both are and must be pushed very actively. We are confident that international collaboration can bring about, in due time, both type of facilities and we should seriously aim at hosting one of them in Europe.

NB It should be**, however**, kept in mind that more recently proposed, **intermediate solutions with higher energy** and higher rate **betabeams**, very attractive though possibly more difficult, **deserve** indeed continued **attention**.

Superbeams are less performing, per se. But they do offer a technical synergy with Neutrino Factories and a scientific synergy with Betabeams. Their realization should be possible early on the path leading to either of the two others. So they **are likely to be integrated in both strategies** and be available for physics at a rather early stage.

A superbeam facility technically largely coincides with the front end of a Factory. High power is the crucial keyword. If one solves the technical challenges presented by a several MegaWatt class proton driver and target and collection system, on the way to build a factory, a superbeam facility will be available essentially for free and usable in conjunction with a large volume detector built for astroparticle physics.

A betabeam and superbeam can instead use together this same detector and their combination has some truely unique features. The oscillation signal is $\nu_e \rightarrow \nu_\mu$ in the first, $\nu_\mu \rightarrow \nu_e$ in the second, so that one calibrates the signal (and the background) of the other. T-reversal and CPT asymmetries, probably not accessible to a factory, can be measured.

Neutrino Betabeams are the subject of a complete 4 years Design Study that was approved in 2004, will last from 2005 to 2008 and produce a Conceptual Design Report (CDR) by early or mid 2009.

Neutrino Factory and Superbeam need to advance to a similar status with FP7. One can thus understand the push to propose a longer and more in depth, effort, possibly under more than one FP7 program, so to have a CDR ready by 2012 or so in this sector too.

A proposal for a new superior neutrino facility will become thus possible, based on the final CDRs, at about the right time for new major investments in particle physics. When presumably LHC expenditures will be completed, its first results available and a decision on the ILC taken.

In this general process, of course, our NA has been consistently supporting and reviewing the on going R&D projects HARP, MUSCAT, MUCOOL, HIPPI, MICE, MERIT, the beta-beam Design Study. Much scientific, technical and organizational work in these Collaborations has been done by BENE members.

In the immediate future, besides NNN06, we are now preparing a second BENE Open SG in Oct 25, the plenary CARE06 and BENE06 meetings in November in Frascati and a contribution to the ECFA meeting of Dec 1st.

N2.1 MEETINGS

The major events organized or co-organized by BENE in 2006 were:

1) after the first meeting at CERN Sep 22-24, 2005, **the second meeting of the ISS in KEK, Tsukuba, Jan 23-25.** It was a good success with over 60 people with parallel group meetings of the three working groups, accelerator, detector and physics, and joint plenary meetings Details can be found on the transparencies, available from the ISS website,

2) **the third meeting of the ISS at RAL 25-27 Apr., again a** good success with over 70 people Again meetings of the three working groups and joint plenary meetings Transparencies, available from the ISS website,

3) **the 1st BENE plenary meeting Apr 28 at RAL**. This was a special shorter meeting of one day dedicated to the exam of FP7 options. The chair of ESFRI, J. Wood, addressed BENE there. A complete review of BENE FP7 options was the main theme.

4) One Open meeting of the BENE Steering Group (SG) was held on the preparation of FP7 proposals on July 4 at CERN. It proved to be a useful tool.

5) the fourth meeting of the ISS at UC Irvine, Aug 21-23, that draw the conclusions of this first phase, largely described above

6) **the NuFact06 International Workshop, the 8th International Workshop on Neutrino Factories, Suprbeams & Betabeams**, still in Irvine Aug 24-30, 2006.
Also this year, **the 5th NuFact06 International Summer School** on Neutrino Factories & Superbeams & Betabeams took place in Irvine next to the workshop. First introduced in 2002 by the EU component (not yet known as BENE) the School is now well established. The aim of the school is to provide young particle physicists with an introduction to both particle and accelerator physics aspects of conventional and novel neutrino beams. The long-term goal of this series is to lay the foundation for a large international group of scientists with the diverse skills essential to secure the future of accelerator neutrino experiments. An essential task indeed, for BENE. We had many EU lecturers as usual, a few EU students attended, most being of course Americans, this year.
Plans are already being made to host again the NuFact08 workshop and school in Europe, after NuFact07 in japan.

We are now preparing

1) the **NNN06 Workshop on Next Nucleon decay & Neutrino** detector in Seattle, Sep 21-23. This is the 5th edition of this international Workshop, organized with decisive contributions of groups working in BENE. The concept of a large Megaton water detector has emerged independently in the 3 regions, under the name of Hyper-Kamiokande in Japan, of UNO in the USA, MEMPHYS in the Western Alps in Europe, where the Li-Argon option is also well alive. The three designs have much in common, the collaborations have significant overlap and work in very close cooperation, with the aim of realizing commonly one such detector in the region that will offer the best and earliest opportunity. Cooperation ties will further be strengthened in Seattle.

2) a Second Open SG Oct 25.: we expect to progress on the formulation of our FP7 proposals, in view of the the outcome of the ESGARD and CARE meetings in September and once again of CERN Council in October.

3) A regular week of meetings of BENE related work packages, study groups and R&D projects will take place during and immediately before CARE06 in Frascati. We will first have parallel meetings of several WPs. Then a plenary session of all accelerator WP together, where the themes of each of them (DRIVER, TARGET, COLLECTOR, MUFRONT, MUEND and BETABEAM) and those specific of the HARP, MICE, MERIT and other R&D experiments will each covered by a few hours of presentations and discussion. A plenary session of the PHYSICS WP will follow. Finally Discussion on the evolution from the ISS will be resumed and the agenda of BENE in 2007 finalized.

At the WP level, only rarely dedicated meeting were held, in addition to the many meetings of the ISS. Phone-meeting are instead common practice by now to prepare the major events.

The PHYSICS WP met in both Physics and Detector groups of the ISS at the KEK meeting of the ISS in January, at the Joint BENE/ISS meeting at RAL 24-29 April, at the Irvine meeting of the ISS in August, in the ISS Physics Group meetings in Boston (6-10 Mar) and Valencia 3-6 July, 2006, in the ISS Detector meeting at CERN July 3-5, 2006.

The accelerator WP's (DRIVER, TARGET, COLLECTOR., MuFRONT, MuEND) met in in the specific sessions of the Accelerator group of the ISS at the KEK meeting of the ISS in January, at the Joint BENE/ISS meeting at RAL 24-29 April, at the Irvine meeting of the ISS

in August, and at a dedicated Accelerator Group meeting July 26–28, 2006 at Princeton University.

In the COLLECTOR WP additional travel was necessary for some meetings with institutes (outside of our field) and private companies to define the horn pulse generator.

MuEND participated to FFAG06, BNL, April, where F. Méot was rapporteur of "Muon acceleration" session and to the EMMA team meeting, RAL, 22 April. EMMA aims at a first European electron model of a linear non-scaling FFAG. Proto-collaboration phone meetings also take place with periodicity 2 to 4 weeks

The members of the the BETABEAM WP reported, to all meetings of BENE interest listed above, the progress of their work package in the Eurisol Design Study that has its own regular schedule of meetings.

In addition, BENE has been present to all major neutrino events in the year. In 2006 we will mention only two most important and representative events, the International Neutrino Conference NU2006 in Santa Fe in June and the ICHEP Conference in Moscow, all attended by a significant BENE delegation with speakers in several sessions and/or panel discussions.

BENE has also made reports at regular ECFA meetings in the year. It also keeps regular contact with the Chairs of the CERN scientific committees (SPSC, SPC) and the CERN Directorate.

N2.2 Publications

The main publication of the year is of course the Scientific Midterm Report mentioned above.

An overview of BENE documents and publications can be found in:
http://bene.web.cern.ch/bene/publications/
From there one can link to the documents created by each work package. They are structured in the same way as it is proposed for the general CARE publication policy, i.e. CARE-Note/Report/Conf/Pub/Document.
Regular update of the database of publications by the work package convenors and the BENE deputy coordinator has been hindered by the lack of a deutu coordinator. It will soon be resuming in earnest.

N2.3 Web Sites

The BENE Main Web Page has been improved and refurbished at http://bene.web.cern.ch/bene/.

It displays the general plan of BENE activities for about 1 year ahead. Basic informations are kept up to date. BENE federates several pre-existing working groups and relies on their several pre-existing Web sites
http://muonstoragerings.web.cern.ch/muonstoragerings/Welcome.html
http://nfwg.home.cern.ch/nfwg/nufactwg/nufactwg.html
http://beta-beam.web.cern.ch/beta-beam/

The process of re-organization into a unitary site, in tune with the BENE federative process, continues. In each BENE WP Web page, the fraction of the material relevant to the scope of WP is being reorganized in a coherent set of links.

The Mailing List of members, bene@cern.ch, has been further extended. In addition there exist mailing lists of each work packages. (hep-mgt-betabeam@cern.ch, hep-mgt-bene-collector@cern.ch, hep-mgt-bene-drivers@cern.ch, hep-mgt-bene-muend@cern.ch, hep-mgt-

bene-mufront@cern.ch, hep-mgt-bene-physics@cern.ch, hep-mgt-bene-target@cern.ch).
Other lists of more loosely connected colleagues are also maintained.

N2.4 Activities of BENE in 2006

BENE's further acceleration of initiative in 2006 is driven by the work of its Steering Committee that has created the necessary networking tools for this and organized the main meetings and the other events. Regular phone-conferences are the main tool of coordination in the interval between meetings. Closed or Open meeting of the SG in person occur then at each of the major events that BENE supports.

The BENE SG was the core of the editorial board of the Midterm Report. Its main long term task is presently to identify and formulate content and ways of proposals for a larger, stronger, well coordinated R&D program. Including proposals for FP7 funds.

The following text and five tables highlight the progress of work done by each work package by listing the lowest level subtasks of the BENE detailed implementation plan. No major deviations are reported, with one notable exception in the driver sector (see below).

All WPs have had regular phone-meetings over the year.

WP1 (PHYSICS) The comparison of different facilities is now close to its final version, from the Physics point of view. Several presentations have been made at the Nufact 06 workshop about this topic. The main unknown now are the input fluxes and the cost and timescales of the different facilities. Beta Beam studies focused on a new, improved description of Beta Beam experiments and investigates the physics reach with different ions than the baseline He6 and Ne18. Nufact studies focused on a better description of the Magnetic Detector, optimized to the Neutrino Factory needs, and on a discussion of the optimization of the possible different options about baselines, muon stored energies and experimental measures. Also the SPL SuperBeam description has been updated and a comprehensive study of combined capabilities of long baseline neutrinos with atmospheric neutrinos published. A study of the design and physics performances of a megaton class water Cherenkov detector, Memphys, under the Frejus, has been published.
The comparison of options will remain the core activity of the WP.

WP2 (DRIVER) has continued its comparative study of M-Watt proton driver designs. An important element in this comparison is the recently published (CERN 2006-006) CDR of a SC proton linac (SPL) of higher energy (3.5 GeV), stimulated by this WP. This design study complies with the parameters optimization for physics needs for a Megaton-class detector at Fréjus but could also support an upgrade in order to be the proton driver of a neutrino factory.

The WP is also looking carefully at the Fermilab option of a still higher energy linac (8 GeV). It was less effective, so far, in stimulating more systematic studies of the Rapid Cycling Synchrotron option, where only slower efforts are being deployed by European (and non-European) labs and funding agencies. Finally, it is starting looking into the exciting recent idea of using Fixed Field Alternating Gradient (FFAG) machines also as MWatt p-drivers. It is also clear that the CERN PAF and POFPA task forces have enlarged this debate out to a much larger forum and consequently scheduled decisions on a longer time scale.
The discussion and comparison of these options is thus being enlarged in consultations with other communities of potential users of the proton driver. The WP will closely follow the works of CERN PAF task force as the choice of the appropriate proton driver is a corner stone of the future of particle physics in Europe.
Two topics of interest of this WP, namely,

. the prospects for intense H- sources and high power injectors
. the HIPPI results on fast choppers and accelerating structure

are and will continue to be closely followed by the WP. An example of the progress in this field is provided by the efforts deployed in UK towards a Front End Test Stand (FETS). In this framework relevant R/D is ongoing in the domain of the ion source and the chopper, a crucial element in the proton driver. For this last point it is worthwhile underlining the synergies with the CERN studies which are being properly exploited in the frame of the HIPPI JRA.

WP3 (TARGET). The status of the WP studies can be thus summarized

a) Liquid (Free Mercury) Jet Targets

The free mercury jet is the current choice by the ISS for the target for a neutrino factory. Consideration of lead-bismuth in place of mercury was openly considered at NuFact06 for the first time.

The construction of the crucial proof of principle experiment, MERIT, at CERN is continuing and will be run early in 2007. The 15 Tesla pulsed magnet has been successfully tested and promises, as efficient collection device a major progress also for WP4 (COLLECTOR).

b) Solid Targets

Experiments on thermal shock in tantalum and tungsten have started at RAL. Life tests indicate that tantalum is too weak at temperatures of 1800 - 2000 K to withstand more than a few hundred thousand beam pulses.

Tungsten shows considerable promise and specimens have withstood >8.5 million pulses at 2000 K. If these results are confirmed in further tests it indicates that a tungsten target system will run for at least 10 years. About 500 bars will be rotated through the beam.

In the UK, the Universities and CCLRC are applying for further funding (led by Ken Long). This includes a critical application for continued funding of solid target work, which has already shown that thermal shock is not a problem in tungsten. Work on an engineered design for the targets and target station is an important part of this proposal towards a practical solid target system.

WP4 (COLLECTOR) The process of reorganization of the WP under the new IN2P3 leadership (of Strasbourg that has replaced LAL) is now completed. WP4 aims at connecting more solidly with the CERN group that has once more with the CNGS been reviving the brilliant European tradition and know-how (Van der Meer) in the sector of magnetic horns. This appears essential in order to establish a steady rate of progress and a larger European effort. As stated in previous reports, pre-BENE work had produced an initial design of a collection system based on a magnetic horn, a horn prototype optimized for a Neutrino Factory, and a series of feasibility tests. LAL, did a redesign to fulfil the superbeam requirements..During this last period,more weight has been put on the design of the superbeam horn power supply able to send 350 kA pulses at 50 Hz. This design is under study with the help of institutes and private companies specialized in pulsed high magnetic fields and high current pulsers. Progress is under way also in the areaof target integration and of simulation of relevant effects and comparison with existing devices.

The main achievements of the 3 components of **WP5** (NOVEL NEUTRINO BEAMS)

a) **WP5a** (MUFRONT) marked significant progress on the design of the Front End of a neutrino factory. Confirmation of the range 5-15 GeV as the ideal proton driver energy for a neutrino factory, once all successive muon manipulations are also taken into account. Following approval of the MICE experiment, the detailed design work has been stepped up. Preparations for the experiment at the Rutherford Appleton Laboratory are now becoming advanced. Successful test-beam activities have been mounted to validate the tracker (UK groups contributing to a test beam exposure of the

final prototype at KEK) and the time-of-flight and calorimeter systems which were tested in the Test Beam Facility at Frascati.
The activity withing the MuFront package has focussed on the preparation of the MICE experiment at the Rutherford Appleton Laboratory and on the study of novel cooling and phase rotation schemes based on non-scaling FFAGs. The MICE experiment, which will start to take data in the autumn of next year, has been the subject of a number of meetings over the course of the year. European physicists have given presentations on the experiment at the European Particle Accelerator Conference, the Neutrino Factory, super-beam, and beta-beam workshop, and at other meetings. Work on the FFAG schemes has been presented at a number of BENE meetings and the work has appeared in presentations at EPAC and elsewhere.

b) WP5b (MUEND): Design study work for the Jan.-Aug. 2006 period have concerned the muon FFAG accelerators, the muon storage ring, and the electron model EMMA (Electron Model of a Muon Accelerator). They have been performed in collaboration with the ISS NuFact structure. They have been subject to contributions to FFAG-2006 and to EPAC06.
WP5b is active in the two projects EMMA and PAMELA (low energy model of a proton accelerator for medical application, other proton uses), that CCLRC wants to construct, respectively at Daresbury and Oxford. These have passed (and been highly ranked in) the 1st round of the Basic Technology programme in the UK. Deadline for the 2nd round proposals is 27th July. Answer expected fall 2006.

WP5b has fostered the emergence of the French RACCAM FFAG project, funded by l'"Agence Nationale de la Recherche", coordinator Laboratory IN2P3/LPSC, Grenoble. RACCAM has the goal of participating to international collaborationon FFAG R&D (Neutrino Factory and EMMA), to build a prototype of an FFAG accelerator magnet, and to show the interest of the fast cycling FFAG accelerators for medical and biological applications. LPSC is reinforcing his FFAG team, which means a reinforcement of its contributions the NuFact activity, within BENE.

The yearly FFAG Workshop, held this year (FFAG06) at BNL, April 2006, has decided that the next release will take place in France , LPSC, Grenoble.

An LOI has is been proposed to ESGARD in view FP8 bids, entitled "Developement of FFAG Accelerators in Europe for a variety of applications" (F. Méot and R. Edgecock in charge). Copy in Appendix. Will be presented to the ESGARD SG on Sept. 12th.

c) WP5c (BETABEAM): The beta-beam BENE WP serves as a link between the on-going design study of a beta-beam facility within EURISOL DS and the neutrino physics community. The design study is making good progress and the BENE community has been updated on a regular basis through the BENE meeting on this progress. The main areas of progress this year, in addition to the one on general design, have been: 1) collimation studies for absorption of ion losses and recognition of the interest of a new PS 2) decay ring optics design and optimization 3) design of large aperture dipoles for the decay ring 4) introduction of a low energy ion accumulator and cooling ring promising recovery of part of the presently missing production rate for neon parents .
The possible continuation of the design study has been discussed at the BENE meetings. Main issues which are not within the scope of the design study but which should be addressed within any future work is a high gamma beta-beam, a high Q-value beta-beam and new scenarios for production and bunching of isotopes. The new ideas presented by Prof. Carlo Rubbia on a high Q value beta-beam with production of the ions in a small stoarge ring with ionzation cooling is very interesting option and

should be considered for any future beta-beam studies. The web site for the beta-beam at http://cern.ch/beta-beam is documenting the progress within the design study and gives reference to new published work.

Work Package 1: PHYSICS.

	Title	Original begin date (Annex 1)	Original end date (Annex1)	Estimated Status	Revised end date
WP1	**PHYSICS**				
1.1	Improvement of the WP Web Site	Jan. 2006	Mar 2005	95%	Continuously improving
1.2	WP Spring Meeting	Mar 2006	Mar 2006	100 %	held jointly with ISS
1.3	Close in on physics analysis, motivate IDS	Jan 2006	Jun 2006	100%	presented at Nufact06 IDS promoted
1.4	WP Summer Meeting	Aug 2006	Aug 2006	100 %	joint with ISS & NuFacto6
1.5	WP Fall Meeting	Nov 2006	Nov 2006	10 %	being prepared
1.6	Physics section of ISS Report	Sep2006	Dec 2006	10 %	being prepared

Work Package 2: DRIVER

	Title	Original begin date (Annex 1)	Original end date (Annex1)	Estimated Status	Revised end date
WP2	**DRIVER**				
2.1	Improvement of the WP Web Site	Jan 2006	Mar. 2006	95%	Continuously improving
2.2	Finalize criteria of SPL vs RCS comparison	Jan 2006	Mar. 2006	20% It is going to take longer!!	Larger picture emerging, CERN debate wide open
2.3	Identify R&D beyond HIPPI, motivate IDS	Jan 2006	Mar. 2006	100 %	presented at Nufact06 IDS promoted
2.4	WP Spring Meeting	Mar 2006	Mar 2006	100 %	held jointly with ISS
2.5	WP Summer Meeting	Aug 2006	Aug 2006	100 %	joint with ISS & NuFacto6
2.6	WP Fall Meeting	Nov 2006	Nov 2006	10 %	being prepared
2.7	Driver section of ISS Report	Sep2006	Dec 2006	10 %	being prepared

Work Package 3: TARGET

	Title	Original begin date (Annex 1)	Original end date (Annex1)	Estimated Status	Revised end date
WP3	**TARGET**				
3.1	Improvement of the WP Web Site	Jan 2006	Mar. 2006	95%	Continuously improving
3.2	Close in on hi power target choice, motivate IDS (R&D beyond MERIT)	Jan 2006	Mar. 2006	100 %	presented at Nufact06 IDS promoted
3.3	WP Spring Meeting	Mar 2006	Mar 2006	100 %	held jointly with ISS
3.4	WP Summer Meeting	Aug 2006	Aug 2006	100 %	joint with ISS & NuFact06
3.5	WP Fall Meeting	Nov 2006	Nov 2006	10 %	being prepared
3.6	Target section of ISS Report	Sep2006	Dec 2006	10 %	being prepared

Work Package 4: COLLECTOR

	Title	Original begin date (Annex 1)	Original end date (Annex1)	Estimated Status	Revised end date
WP4	**COLLECTOR**				

4.1	Improvement of the WP Web Site	Jan 2006	Mar. 2006	95%	Continuously improving
4.2	Close in on collector choices, motivate IDS and other R&D	Jan 2006	Mar. 2006	100 %	presented at Nufact06 IDS promoted
4.3	WP Spring Meeting	Mar 2006	Mar 2006	100 %	held jointly with ISS
4.4	WP Summer Meeting	Aug 2006	Aug 2006	100 %	joint with ISS & NuFact06
4.5	WP Fall Meeting	Nov 2006	Nov 2006	10 %	being prepared
4.6	Collector section of ISS Report	Sep2006	Dec 2006	10 %	being prepared

Work Package 5: NOVEL NEUTRINO BEAMS

	Title	Original begin date (Annex 1)	Original end date (Annex1)	Estimated Status	Revised end date
WP5	**NOVEL NEUTRINO BEAMS**				
5.1	Improvement of the WP Web Site for the three areas of interest of the WP	Jan 2006	Mar. 2006	95%	Continuously improving
5.2	Review of existing designs for NuFact and Betabeams, motivate ISS	Jan 2006	Mar. 2006	100 %	presented at Nufact06 IDS promoted
5.3	WP Spring Meeting	Mar 2006	Mar 2006	100 %	held jointly with ISS
5.4	WP Summer Meeting	Aug 2006	Aug 2006	100 %	joint with ISS & NuFact06
5.5	WP Fall Meeting	Nov 2006	Nov 2006	10 %	being prepared
5.6	Physics section of ISS Report	Sep2006	Dec 2006	10 %	being prepared

N2.5 SIGNIFICANT ACHIEVEMENTS

- Recognition from CERN Council of the importance of promoting a coordinate European participation in a global neutrino programme".
- The BENE Midterm Interim Scientific Report was published in final form: a detailed outline, and a plea, for a timely R&D program
- Completion of the International Scoping Study and clear indication towards next step, the one of complete, in depth International Design Studi(es).

N2.6 List of all milestones and deliverables (D) during the reporting period

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Task No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
D	**Final Publication of Interim (Midterm) Scientific Report**	All WPs	INFN-Na,	23	29
D	**Promotion of International Design Studies on Neutrino Factories, Superbeams, Betabeams**	All WPs	CCLRC, ICL, INFN-Na, Uni-Ge	30	32

N2.7 List of major meetings organized under BENE during the reporting period

Date	Title/subject	Location	Number of participants	Web Site Address
Jan 23-25 2006	2nd meeting of the ISS	KEK	65	http://www-kuno.phys.sci.osakau.ac.jp/%7Eyoshida/ISS/index.html
Apr 24-27 2006	3rd meeting of the ISS	RAL	70	http://www.hep.ph.ic.ac.uk/iss/iss-plenary-meetings/iss-benemain.html
Apr 28 2006	BENE day	RAL	60	http://bene.web.cern.ch/bene/060428Agenda.htm
4-Jul 2006	Open meeting of the BENE Steering Group	CERN	30	http://bene.web.cern.ch/bene/060704Agenda.htm

21-23 Aug 2006	4th meeting of the ISS	Irvine	60	http://nufact06.physics.uci.edu/ISS/Program/Default.aspx
24-30 Aug 2006	8th NuFact06 Workshop	Irvine	120	http://nufact06.physics.uci.edu/

N2.8Appendices

The following additional information was provided by WG5b

Development of FFAG Accelerators in Europe for a Variety of Applications - EUROFFAG

Contact people: **Francois Meot, CEA, meot@lpsc.in2p3.fr;**
Rob Edgecock, RAL, rob.edgecock@rl.ac.uk

Type of the anticipated proposal: "**JRA, DS or CNI**"

List of interested institutes: IN2P3/LPSC, CEA/DAPNIA, Grenoble Univ. Hospital, SIGMAPHI (Magnet Industrial), CCLRC, Cockcroft Institute, John Adams Institute
Collaborators : CARE/BENE, KURRI Institute (Japan), BNL, Fermilab

Estimated duration: 5 years Estimated Cost (including manpower): 16M€

Introduction

The acceleration of particle beams is nowadays facing the difficult issues of providing high power beams (e.g. proton drivers for the SLHC, neutron spallation sources, the Neutrino Factory, ADS, etc), high average intensities (e.g. for medical applications), fast acceleration and/or manipulation of short lived beams (e.g. for muon and radioactive beams) and large acceptance for reducing losses. Current designs generally plan on delivering only a subset of these requirements by using fast-cycling synchrotrons, linacs or cyclotrons and often have to rely on technological break-throughs in domains such as SCRF, fast pulsed SC magnets, and high power collimation systems to achieve this.

FFAG rings offer a radical alternative as they can deliver all of these requirements simultaneously. With their fixed magnetic fields, as in cyclotrons, modulated RF and pulsed acceleration, as in synchrotrons, FFAGs feature a potentially ultra-high repetition rate (in the kHz range), synonymous with fast acceleration and high average intensity hadron beams in space-charge free accelerating regimes, and very large geometrical (in the centimetre range) and momentum (in the +/-50 % range) acceptance (giving high transmission efficiency and low environment activation).

The FFAG method was invented in the 1950's, with the development of successful electron models at MURA. It was supplanted in the early 60's, in the race to high energies, by the pulsed synchrotrons with their simpler magnets and more flexible lattice geometry. Yet, the FFAG method has become the focus of renewed attention in recent years. A strong push has

been given in Japan where two proton prototypes have been built, a 3-stage prototype of an ADS is being commissioned, a muon beam manipulation ring is under construction and electron drivers are being developed. In addition, a project to study medical FFAGs and undertake related prototyping has been launched in France, there is strong interest in building an FFAG electron model and a proton prototype for hadron therapy in the UK, and a variety of designs are being studied for the acceleration of protons and muons, in particular in the frame of the international US/Japan/EU(CERA/BENE) collaboration on the Neutrino Factory, and of heavy ions and electrons, with applications as diverse as proton drivers, acceleration of muons, cancer therapy, industrial irradiation, ADS for reactors and neutron production.

Description of the proposal

The FFAG method can be divided into the following three classes:

- scaling optics : these are based on challenging non-linear magnets, larger than regular synchrotron magnets. Their advantage is in the optical property of constant focusing which gives flexibility with beam manipulation, including promising features such as arbitrary RF programs.
- non-scaling optics : these are based on simpler, smaller, linear magnets, not much larger than for a regular synchrotron. They have the drawback of non-constant focusing and the resulting beam dynamics effects such as large numbers of resonance crossings.
- semi-scaling optics : these also have non-constant focussing, but use non-linear magnets to compensate for this and reduce the beam dynamics problems.

All three methods require validation based on: (i) beam dynamics and machine design studies, (ii) R&D, particularly on magnets and accelerating systems, (iii) prototyping of these systems, and (iv) the construction of proof-of-principle accelerator prototypes. **This study will undertake several complete design studies and the associated prototyping work, including the construction of accelerator models. It will examine the challenges and potentials of the FFAG method and identify the design concepts and methods providing the best answers for several applications. In particular, it is planned to undertake:**

Lattice design and beam dynamics studies – proton acceleration, in the 10s of MeV range, using the scaling and semi-scaling FFAG methods; linear electron model, in the 10-20 MeV range; fast acceleration, beam stability upon resonance crossing, alignment and field tolerances; geometrical and momentum acceptance, and magnet apertures ; momentum range ; injection and extraction

Component design studies – non-linear and linear magnets: field requirements, precision, technological implications, optimizations; broad band modulated RF systems; high gradient fixed frequency RF systems; injection and extraction kicker systems; beam diagnostics ; vacuum

Prototyping and experimental tests - linear and non-linear magnets; broad band modulated RF systems; injection and extraction kicker systems

Proof-of-principle accelerator prototypes – we propose to launch the construction of two prototypes: the linear electron model (EMMA) and a spiral non-linear proton accelerator of 70 MeV

Comparison of the FFAG methods – scaling, semi-scaling and non-scaling: undertake costing studies and assess advantages and drawbacks; determine best for a number of applications, in particular for proton drivers and for hadron therapy and biological research

Deliverables
Documents: (i) full machine descriptions for three machines: EMMA, a spiral 70 MeV proton model and a full energy hadron therapy FFAG, (ii) component specifications for magnets, RF, kickers, vacuum, beam diagnostics, (iii) design requirements identified for the CARE/BENE and ISS-NuFact proton driver and muon uses, (iv) design requirements identified in the RACCAM medical application, (v) specifications for medical use of FFAG beams
Software: Computing tools for component and machine design
Hardware: Magnet and RF system prototypes, from design to fabrication and measurements.
*Proof-of-principle accelerator*s: Completion of the proton model and EMMA

Budget

Activity	**Man-years**	**Cost (k€) man.years**	**Cost (k€)hardware**
Lattice design and beam dynamics studies	12	1200	
Components studies and specs			
Magnet	3	300	
RF	3	300	
Other (kickers, diag., vac., etc.)	2	200	
Prototyping and experimental tests			
Magnets	6	600	600
RF	3	300	600
Other (kickers, diag., vac., etc.)	2	200	600
Accelerator prototyping: EMMA	10	1000	
Magnets			700
RF			2500
Diagnostics			300
Other (vac.,supports, etc.)			1200
p-model			
Magnets	10	1000	
RF			1000
Injector			1200
Other (kickers, diag, vac, etc			600
			1500
Sub-totals	51	5100	10800
Grand-total		15900	