Beams for European Neutrino Experiments

CARE BENE Network: Yearly Report 2006

the BENE Steering Group

M. Mezzetto, A. Donini (PHYSICS WP)
M.Zito (DRIVER WP)
R. Bennett, C. Densham (TARGET WP)
M. Dracos (COLLECTOR WP)
K. Long (Novel Beams WP/MuFRONT)
F. Meot (Novel Beams WP/MuEND)
M. Lindroos (Novel Beams WP/BETABEAM)
V. Palladino (NA Coordinator)

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395

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, we finally welcome a new Deputy Coordinator (S. Pascoli, from Univ. of Durham) who accepted the job in December. New WP coordinators have taken up the DRIVER (M. Zito), TARGET (C. Densham) and COLLECTOR (M. Dracos) WP. A new PHYSICS co-coordinator was drafted (A. Donini).

Participant number	Participant	PHYSICS	DRIVER	TARGET	COLLECTOR	NOVEL NEUTRINO BEAMS
1	**CEA**	X	**C**	X	X	
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					**Cb**
	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	**Cc**
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		**Ca**

During 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, a senior member of BENE, organized the neutrino session in Orsay. M. Mezzetto, BENE PHYSICS coordinator, was secretary. P. Huber and A. Cervera gave the theoretical and experimental talk, respectively. This was a success, according to neutral observers, it showed that the European accelerator neutrino community has the physics case, the enthusiasm, and 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. It summarizes the state of advancement of our initiative, reviewing progress and proposing a preliminary road map towards a new 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** launched at the BENE edition of Nufact05 in Frascati in June 2005 and completed in Aug 2006 at NuFact06.
The **concluding recommendation** of the ISS was to proceed now to a few few-years **International Design Studies**: presumably an IDS on neutrino factories, one on betabeams, and one for each superbeam option presently envisaged. The final report of the ISS is expected in Jan 2007 and IDSs should now be promoted.
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 (INO), Russia, Poland and Bulgaria. The coordinator of BENE, one 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 sub-studies coordinated by Yori Nagashima (Physics Group), Mike Zisman (Accelerator Group), Alain Blondel (Detector Group) was accepted. Overall leader of the ISS is Peter Dornan (UK).
The ***Physics*** group has been revisiting 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, IC London). 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 has been revisiting 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 are contributed to this work and are now writing portions of the Report. EU contributions are however still far from having the necessary impact. We hope that can come in the context of the IDS and the FP7 initiatives (see below), with a more resolute involvement of CERN experts.

The *Detector* Group revisited 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. It also emphasized areas where we need however to score better results:

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**.** The NuFact Workshop is the yearly international forum of a world-wide collaboration of several regional communities and has gained importance over the years, as can also be judged from the number of accompanying satellite events.. A large BENE delegation was present to both meetings, presenting the work of one year in about 1/3 of the talks given 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) **brought about,** as in each previous year, **the approval of R&D programs,** notably this year in the sector of particle acceleration by FFAG, securing **the funding of the EMMA** project in the UK **and of the RACCAM project** in France. This is taking off fairly well in Jan 2006 on scaling FFAG and magnet prototyping, that will also concern the type of FFAG needed in Japan for their NuFact acceleration scheme and for the KURRI high power p beams**.**

7) **has been and is now even more preparing very actively the proposals for the IDSs and for several possible FP7 programs .** We are following closely the guidance of the ESGARD in this domain and reporting regularly to ECFA, last on Nov 30. Open meetings of the BENE Steering Group (SG) were held at CERN on this subject on July 4, on October 25, at BENE06 on Nov 14 and during CARE06 on Nov.15-17. We are preparing a coherent set of multiple FP7 initiatives: to apply for Design Study funds in the first FP7 call and for a number of indispensable JRA's within either a Neutrino I3 or larger scope I3s for the second FP7 call, to explore one or more "ERC" projects at the frontiers of science and to address other EC programs that are also being investigated. This is the most recent and advanced document produced on this subject.

There were a few key events this year 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 the establishment of such a coordinated European participation to a structured European and 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 completion of the ISS in 2006. 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 soon in 2007.

A **second key event** of the year 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 preceded 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 continues the work of evaluation of performance 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 19-21. It will start defining 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 particle physics funding agencies and from Framework Programme 7.

A third event was the **NNN06 Workshop on Next Nucleon decay & Neutrino** detector in Seattle, USA, Sep 21-23, that reviewed the physics case and the technical challenges of these very large mass detectors and further structured 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^{18-19}/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.

The statements of our last yearly report and, more extensively, of our Midterm Report, have been confirmed by the ISS: 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 conclusions, particularly after the work of the ISS Physics group, are now based on much better agreed yardsticks. They must still however undergo sharper and sharper scrutiny.

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 truly 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, and the beta-beam Design Study. Much scientific, technical and organizational work in these Collaborations has been done by BENE members.

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 drew 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.

7) 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 was further strengthened in Seattle.

8) a second Open BENE SG Oct 25; we progressed 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.

9) A regular week of meetings of BENE related work packages, study groups and R&D projects (BENE06) took place during and immediately before CARE06 in Frascati. We had 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 followed. Finally, discussion took place on the evolution from the ISS to the IDSs and on the IDSs relation with the FP7 commitments that we hope to take. Last, the agenda of BENE in 2007 was finalized.

At the WP level, only rarely dedicated meeting were held, in addition to the CARE06 meetings and 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 and during CARE06 in Frascati.

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, at a dedicated Accelerator Group meeting July 26–28, 2006 at Princeton University and finally at CARE06.

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. EMMA proto-collaboration phone meetings also take place with periodicity of 2-3 week since more than a year, involving BENE people, US, TRIUMF and Japan

The members of 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 deputy coordinator. It should now soon finally 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 preparation of FP7 proposals is now becoming one of the highest priorities of the SG and each WP.

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 unknowns 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 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 and since then a big effort has been developed to collect and rationalize the terms of comparison of different facilities. A long report is almost ready.

In the latest BENE meeting of November 14-17, the Physics groups discussed the issue of neutrino cross sections at low energies, a critical aspect of neutrino super beams and beta beam, the comparison of superbeam experiments like Nova and the Brookhaven wide band beam, and the importance of large statistics atmospheric neutrino samples in future analysis of neutrino oscillations. A long discussion was held on the topic of possible upgrades of the CNGS neutrino beam, specially focused on the intensity upgrades of the SPS.
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. An innovative pumplet lattice is now part of the UK FFAG design.
It is also clear that the CERN PAF and POFPA task forces have enlarged this debate out to a much larger forum and consequently re-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.

The last part of the year has been devoted to the early stage of the preparation of the FP7 proposal for the design study. In this context, new energies from RAL and Saclay have been attracted to the BENE framework. Clearly the design study will provide an excellent focussing point for the studies related to the proton driver, especially if the common aspects between different facilities are recognized and the WP structure is carefully devised to fully integrate these synergies. Concerning the FP7 plans, special attention needs to be paid to the coordination of the design study activity and the R/D effort in the IA.s.

WP3 (TARGET). The status of the target WP studies is summarized below:

a) Liquid Metal Jet (Free Mercury) Targets

A free mercury jet is the current solution favoured by the ISS for a neutrino factory target, as it is hoped to minimise problems of shock, radiation damage and cooling. Problems with the generation of radioactive mercury have lead to discussions at NuFact06 on the use of a liquid lead-bismuth eutectic as an alternative. There are also expected to be severe problems associated with the target station window. High velocity micro-jets of liquid metal induced by the proton beam are believed to be suppressed by the capture solenoid. Many of the technical questions regarding the liquid metal jet will be addressed by the MERIT experiment at CERN. The construction of this experiment is nearing completion and will be run early in 2007. The 15 Tesla pulsed capture solenoid has been successfully tested and the MERIT experiment consequently promises significant additional progress for WP4 (COLLECTOR).

b) Solid Targets

A solid refractory metal target is the back-up solution to liquid metals, with radiatively cooled tungsten as the leading contender. A number of experiments on thermal shock in tantalum and tungsten have started at RAL. These tests use a pulsed power supply to generate thermal and Lorentz force induced shock waves in thin wires that replicate those generated in a neutrino factory target material by the pulsed proton beam. Life tests indicate that tantalum is too weak at temperatures of 1800 - 2000 K to withstand more than a few hundred thousand beam

pulses. However tungsten shows considerable promise and a number of specimens have withstood >10 million pulses at 2000 K. These results indicate that if an engineering solution can be developed to circulate 500 bars through the beam and solenoid, then a 4 MW tungsten target material could run for 10 years.
In the UK, the Universities and CCLRC (RAL) are applying for further funding (led by Ken Long). This includes a critical application for continued funding of the solid target work, which has already shown that thermal shock should not be 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 and is a key part of the next work programme.

c) Fluidised bed target

A new idea was presented at BENE06 to use a fluidised bed target. The rationale behind this is that a fluidised bed of tungsten granules can in principle combine many of the advantages of a solid target with those of a liquid target, without many of their respective difficulties. However it does present new technical difficulties and these would need to be examined and addressed before it can become a serious contender.
The WP has been, in the last part of the year, focussing more and more on the preparation of the FP7 design study proposal.

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 area target integration and simulation of relevant effects and comparison with existing devices.
Like BENE in general, this WP has been, in the last part of the year, focussing more and more on the preparation of the FP7 design study proposal.

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

a) WP5a (MUFRONT) Progress in the design and specification of the Neutrino Factory muon front-end was made during the ISS. The ISS baseline calls for an ionisation cooling channel in which lithium-hydride absorbers are interspersed with RF cavities in a solenoidal transport lattice.
The proof-of-principle of the ionisation cooling technique will be provided by the international Muon Ionisation Cooling Experiment (MICE) which is being prepared at the Rutherford Appleton Laboratory. Over the reporting period, significant progress has been made in the preparation of infrastructure required in the MICE Hall. In addition, the pion-production target has been successfully tested in the ISIS proton beam. Construction of beam-line components and refurbishment of the magnets required for the beam line (from RAL and PSI) is ongoing. The design of the particle identification system (time-of-flight counters, a Cherenkov detector, and a calorimeter) has been finalised. The spectrometer solenoids as well as the scintillating-fibre trackers for the experiment are in construction. It is anticipated that the experiment will enter its first data taking phase in the autumn of 2007.
Work has continued on the study of novel cooling- and phase-rotation schemes based on non-scaling FFAGs. European physicists have given presentations on the

experiment at a number of international meetings and workshops including the International Neutrino Factory, beta-beam, and super-beam Workshop (NuFact06), which took place in Irvine, Caifornia, in August.
WP5a has been, in the last part of the year, focussing more and more on the preparation of the FP7 design study proposal.

b) WP5b (MUEND): Design study actvities for 2006 have concerned the muon FFAG accelerators and its electron model EMMA, and the two possible geometries for the muon storage ring, triangle and bow-tie. In this frame, new types of proton driver lattice designs, of the FFAG type, have been devised (see WP2 above). Investigations on scaling FFAG methods in muon beam cooling have been launched at the Imperial College, London, in collaboration with BNL and the muon beam capture and damping PRISM project (Osaka University). The "harmonic number jump" method is resurrected in the frame of fast FFAG acceleration, as a possible way of combining scaling FFAGs and high frequency RF. These studies have been performed in collaboration with the ISS accelerator working group. They have been subject to contributions to FFAG-2006 (BNL), EPAC06, NuFact06, FFAG06 (Kyoto), the EU Cyclotron Conference (Nice).
The construction of EMMA by CCLRC at Daresbury, next to the 4th generation energy-recovery light source, has been launched, following the announcement, in December, of its funding by UK BASTOC, with money to arrive in March. The EMMA collaboration will involve scientists from CARE/BENE, BNL, FERMILAB, KEK, KURRI, LPSC-Grenoble. Given the construction, WP5b's involvement in EMMA should increase.

WP5b is active in the French RACCAM FFAG project, now planning a collaboration to the 180 MeV upgrade of the 65 MeV medical beam at the MEDICYC cancer treatment clinic, in Nice, France. This should result in an enhancement of WP5b's implications in that proton scaling FFAG prototyping.

The LPSC, Grenoble, team in WP5b is now preparing the FFAG-2007 workshop, to be held 12-17 April 2007.

WP5b is defining now the Accelerator and Storage Ring WPs of the FP7 NuFact-BetaBeam-SuperBeam Design Study proposal (coordinator R. Edgecock, RAL) planned for submission in May 2007 (see Appendix). WP5b is also fostering a EUROFFAG JRA proposal (coordinator F. Méot, LPSC), discussions are going on concerning its integration within the "New acceleration methods" IA proposal (in preparation with coordinator E. Jensen, CERN) in view of 2008's bids (see proposal in Appendix).

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.
In return, the BENE Betabeam team has assured talks on neutrino physics and informative talks on other alternatives for generating neutrino beams at the regular EURISOL meetings. In the EURISOL town meeting in November 2006 the task contributed with two talks, one on neutrino physics in general and one on the

conclusions of the ISS studies. The EURISOL International Advisory Panel stressed that both talks were very important as they assure that the design studies beta-beam task is well integrated in the field of neutrino beams. The lectures on general accelerator physics and beta-beams at the Nufact summer school at UCLA/UCI in California were also delivered by the BENE beta-beam task.
The possible continuation of the design study has been discussed at the BENE meetings. Main issues which are not within the scope of the current 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 storage ring with ionization cooling is a 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	100 %	
1.6	Physics section of ISS Report	Sep2006	Dec 2006	90%	March 2007

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	100 %	
2.7	Driver section of ISS Report	Sep2006	Dec 2006	90%	March 2007

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	100 %	
3.6	Target section of ISS Report	Sep2006	Dec 2006	90%	March 2007

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	100 %	
4.6	Collector section of ISS Report	Sep2006	Dec 2006	90%	March 2007

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	100 %	
5.6	WP sections of ISS Report	Sep2006	Dec 2006	90%	March 2007

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).
- Timely progress on the preparation of FP7 Design Study proposal, whose content will also determine our contributions to the 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
D	Draft of FP/ Design Proposal, to be delivered by month 41	All WPs	CCLRC, IN2P3 CERN	30	36

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	2nd meeting of the ISS	KEK	65	http://www-kuno.phys.sci.osakau.ac.jp/%7Eyoshida/ISS/index.html
Apr 24-27	3rd meeting of the ISS	RAL	70	http://www.hep.ph.ic.ac.uk/iss/iss-plenary-meetings/iss-benemain.html
Apr 28	BENE day	RAL	60	http://bene.web.cern.ch/bene/060428Agenda.htm
4-Jul	Open meeting of the BENE Steering Group	CERN	30	http://bene.web.cern.ch/bene/060704Agenda.htm
21-23 Aug	4th meeting of the ISS	Irvine	60	http://nufact06.physics.uci.edu/ISS/Program/Default.aspx
24-30 Aug	8th NuFact06 Workshop	Irvine	120	http://nufact06.physics.uci.edu/
21-23 Sep	NNNO6	Seattle	74	http://neutrino.phys.washington.edu/nnn06/
Oct 25	Open meeting of the BENE Steering Group	CERN	30	http://bene.web.cern.ch/bene/061025OpenBENESG.htm
Nov 14-17	BENE06/CAREO6	Frascati	40 150	http://bene.web.cern.ch/bene/BENE meeting at CARE06.htm

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 accelerators: 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	10	1000	
Magnets			1000
RF			1200
Injector			600
Other (kickers, diag, vac, etc			1500
Sub-totals	51	5100	10800

Activity	**Man-years**	**Cost (k€) man.years**	**Cost (k€)hardware**
Grand-total		15900	