Beams for European Neutrino Experiments

CARE BENE Network: Final Report 2004-8

the BENE Steering Group

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Introduction and Executive Summary

The CARE-**BENE** network[1] has **kept alive** awareness of **the compelling physics case** of a Next accelerator Neutrino Facility (NNF), **the merits of a common European strategy** in this sector of particle physics **the assets rooted in the 50 years of European know how** in neutrino beams and detectors. In more detail, it

-**promoted** a large number of international **R&D** and/or feasibility demonstration projects (MUSCAT, HARP, HIPPI, MICE, MERIT, EMMA, HPSPL and more) for multi megawatt proton drivers & targets and capture, manipulation, acceleration and storage of neutrino parents.
-**prompted** a first decisive **endorsement** of its approach **by the CERN SPSC in** September **2004**, that first envisaged the notion a future "neutrino construction window" for Europe
-**reinforced international** collaborations and synergies with R&D and design work world wide, organized several of the key international yearly **NuFact and NNN workshops**
-**secured recognition,** for a next neutrino facility, **of the status of emerging facility of Eu interest** in the CERN Council Strategy Document of **Summer 2006**
- **promoted** the few preliminary Design Studies (Betabeam WP in Eurisol DS, Scoping Study of Superbeam & Neutrino Factory), European and International collaborations **assessing** available **R&D** results **and** producing **preliminary conceptual design baselines as well as comparative analysis of physics reach** for three most promising options: Superbeam, Betabeam, Neutrino Factory
-**managed the approval of** a complete Design Study **(EUROneutrino**) of the three options and a new network (**EuCARD/NEu2012**). These two **FP7** initiatives will **continue** the path **towards** the final proposal of the optimal neutrino program, recommended by CERN Council for **2012 or so**.

In FP7 we will draw the road map to approval and construction. Our FP6 **road map was to be** instead **one of** steps in **R&D, baseline design work and peer recognition**. **Pan-European collaboration emerged much stronger**, composing sometimes different national interests and preserving a common intent. **Dissemination** effort **was given the necessary attention** throughout the 5-year programme, by means of publications, presentations and web site.

The steps of BENE's impact on the European Research area

BENE and all the activities preceding and following it are driven by the growing interest[2] in the implications of the recently (1998) discovered fundamental phenomenon of spontaneous transitions in flight among different the three neutrino species (flavours).

BENE was the CARE network for Beams for European Neutrino Experiments, comprising 13 participating nodes, summarized in Appendix 1 with their implication in the Work Packages, approaching the totality of the accelerator neutrino physics community.. The network grew out of ECFA Muon Groups (MUG), studying a muon decay ring as a novel and superior **Neutrino Factory** (NF), active since1998. One of its pillar, the CERN NF Working Group (NFWG) was

[1] approved "to integrate and coordinate the activities of the accelerator and particle physics community working together, in a worldwide context, towards achieving superior neutrino beam facilities for Europe, with the objectives to establish a first road map, to assemble a community capable of sustaining it, and to establish and propose the necessary R&D effort".

[2] Study of these phenomena promises insight into primordial physics questions ranging from mixing among lepton generations, to violation of charge-parity symmetry in lepton flavour transitions, to generation of the unexplained observed lepton and baryon asymmetries in the universe, to the extremely high energy phenomena responsible of the minute, but non zero, neutrino masses and more.

however very painfully closed in 2002 by the LHC crisis, imposing years of deceleration of our initiative. Two workshop series had established, in 1999, two large, independent but connected, international coordination Workshop series, NuFact [3] on neutrino sources and NNN [4] on neutrino detectors.

The Muon Groups established soon the necessity of a new very high intensity, Multi Mega Watt (MMW) proton facility. The potential of a conventional pion decay tunnel neutrino **SuperBeam** (SB) at such a MMW proton facility was also explored as most natural reference for the novel muon decay ring option. Somewhat later, 2000 or so, a second very attractive novel concept, that of an ion beta decay ring, named **BetaBeam** (BB), also became object of much interest. After a few very difficult years, the growing recognition of the physics case of frontier accelerator neutrino facilities lead to approval of the BENE NA in 2004. The HIPPI JRA, R&D for high intensity proton drivers, was also approved then.

First initiative of BENE was a workshop at CERN in May 2004 on the general theme of the high intensity frontier of particle and nuclear physics, complementary to the high energy frontier of the large colliders. Very successful, this workshop on **Physics with a MultiMegaWatt Proton Source** was organized together with other particle physics and nuclear physics (Eurisol) communities interested in the opportunities open by a MMW proton driver.
The proceedings were then submitted to the special session of the CERN SPSC (Super Proton Synchrotron Program Committee) in September. Nine invited talks delivered by BENE to the SPSC resulted in renewed attention to a European neutrino accelerator program and to the R&D recognized as mandatory to make that conceivable. The SPSC suggested the possibility of a "construction window" for a neutrino facility between LHC and next CERN big collider.

A second result at the end of the 2004 was the approval of a first BetaBeam (BB) design study as a WP of the Eurisol FP6 DS. First data from the MUSCAT and HARP R&D experiments were made public.

In 2005, BENE consolidated its status on the European and the international scene, organizing both our two international workshops, **NNN05** in Aussois in April **and NuFact05** in June in Frascati, further establishing the compelling physics case of experimentation at high intensity neutrino facilities. NuFact05 **launched an International Scoping Study (ISS)** of Neutrino Factory and Superbeam, that BENE carried then out in collaboration with the US Neutrino Factory Collaboration, the Japanese NUFACTJ group, and teams from India and other countries. We kept thus momentum of R&D and studies, in spite of the postponement to FP7 of the next opportunity to propose a Design Study. The MICE and MERIT R&D experiment were approved this year.

The assembly of the proceedings of NuFact05 and NNN05 proved invaluable in preparing our **BENE Midterm scientific report**, comprehensive 105 pages CERN Yellow Report pre-**submitted**, in electronic form, **to the** open Symposium held in Orsay (Paris) on Jan 30 - Feb 1 2006, by the **CERN Council Strategy Group**. The CERN Council Strategy Document published in July, in Lisbon, raised **Next neutrino facility to the status of emerging facility of Eu interest** in the context of the ESFRI road map[5].

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[3] NuFact Workshop series on Neutrino Factories, Superbeams and Betabeams

[4] NNN Workshop series on Next Neutrino and Nucleon decay detector

[5] It stated that a "*coordinated accelerator R&D program should be intensified to be able … to play a significant role in the study and development of a high intensity neutrino facility*" and that "*studies… and R&D are required … to be in a position to define the optimal neutrino program … in around 2012*".

The last part of 2006 started an intense period of preparation of FP7 proposals. BENE contributed also to the approval of the EMMA electron prototype of non scaling Fixed Field Alternating Gradient (FFAG) accelerator in the Daresbury Laboratory in UK

In 2007, the Scoping Study (ISS) published three final reports (physics, accelerators, detectors) establishing the baseline configurations of Neutrino Factory and Superbeam that will be object of the Design Studies. A similar Betabeam baseline configuration had meanwhile emerged in the context of the Eurisol Design Study WP.

These three baselines defined the proposal of the **EUROnu Design Study** that was prepared and submitted by BENE late in May. EUROnu **was approved** in August to design, cost and compare the three options. It finally started only on Sep 1, 2008, with first funds yet later. Its design of a neutrino factory is being carried out in the larger international context of **the International Design Study** of a Neutrino Factory (IDS) that **was** meanwhile **established** as natural continuation of the ISS. The LAGUNA Design Study of neutrino detector sites was also approved.

In 2008, **several WPs or Tasks directly inspired by BENE, in the R&D program proposed by the EuCARD IA, were approved**: the new NEu2012 continuing BENE, the MICE-TA program, the HPSPL task of the SRF JRA and the EUROFFAG task of the ANAC JRA. So were other WPs of BENE interest for possible synergy with the R&D toewards upgrade of LHC and towards ILC and CLIC. Like in 2005, again NuFact08 (July, Valencia) and NNN08 (October, Paris) returned both in Europe. BENE started following the progress of EUROnu and finally preparing its final meeting and final reports.

2012-3 is indeed the appropriate time to define the optimal next accelerator neutrino program: solid physics results will have come from LHC and from the current neutrino (T2K and Double-CHOOZ) experiments, financial resources liberated by the end of the payments for LHC and its detectors, major decisions mature, for ILC, for accelerator neutrino and for other sectors. The deadline must be met.
In order for that to be even conceivable, there is no doubt that **a CERN neutrino task force must be put again in place**. Discussions have been reopened by BENE with the new CERN Management and are being continued by EUROnu and NEu2012.
BENE established a first detailed roadmap for European high-intensity neutrino-beam facilities, defined baselines options and was constantly pushing and initiating the pertinent technical developments. Long term initiatives beyond BENE were established through new collaborations and projects, sometime with involvement of European industry. Significant ideas and concepts first originated in BENE workshops and its topical meetings that guided and stimulated progress. Networking activities included an intense dissemination effort of publications and presentations.

A significant last result, in the very last months, was the creation of institutional review bodies of the prospects of physics with accelerator neutrinos and of EUROnu and NEu2012 initiative: the CERN SPC neutrino panels in 2009 and, in the longer term, the CERN Council Strategy Secretariat.

Work packages and Networking dynamics

BENE was organized in five work packages: Physics, of general nature, Proton Driver, Target, Collector (focusing on issues common to conventional and novel beams and directly relevant for upgrades of our present conventional facilities to superbeams). and Novel Neutrino Beams (in turn subdivided in three sub-packages, two on neutrino factory, one on betabeam).

The Network relied on three major events per year, NNN, NuFact and the yearly BENE workshops during the days of the yearly CARE meeting

Date	Title/subject	Location	Number of participants
3 November 2004	BENE2004 Workshop	Hamburg (D)	60
23 November 2005	BENE2005 Workshop	CERN (CH)	40
17 November 2006	BENE2006 meeting	Frascati (I)	40
31 October 2007	BENE2007 meeting	CERN (CH)	40
2-3 December 2008	BENE2008 meeting	CERN (CH)	30

More topical workshops was organized in the first two years of BENE, replaced by strong support of ISS meetings later. Dissemination reached the other main yearly international neutrino events, whenever possible.

During the five years, all BENE WPs followed closely
- the progress of the CNGS, the present Eu accelerator neutrino facility, its initial radiation problems, its approach to full intensity, likely in 2009, fostering first estimates of the ultimate long term performance of the complex by the CERN/AB CNGS team and their re-visitation, in view a new round of experimentation with emerging detector options
- emerging plans emerging outside Europe, sometimes contributing to them, thus identifying a scenario that includes upgrade programs of the JPARC neutrino facility in Japan (somewhat limited in ultimate power reach), upgrade programs[6] of the Fermilab NuMi conventional pion decay neutrino facility, longer term studies[7], always at Fermilab, of a neutrino factory

All accelerator WPs contributed very significantly to the definition of the baseline Superbeam, and Neutrino Factory parameters documented in the final ISS accelerator report.

BENE and in particular its PHYSICS WP1 constantly monitored the physics results[8] of the experiments and phenomenological work in progress from the largest neutrino community and their implications for the directions of the field. PHYSICS WP1 contributed its good share of the ISS reports on preliminary comparative analysis of the physics reach of the different options of neutrino beams and detectors. Close contacts were kept with the Eu accelerator neutrino teams busy in experiments in progress or preparation. In addition to the EU teams at the CNGS (OPERA, ICARUS) or in Double CHOOZ, also the large EU component of the T2K experiment in Japan and the smaller EU teams working in the US Fermilab neutrino beams.

[6] NuMi is Neutrino from the MI (the Main Injector). It is planned to add a new NuMI West line, towards the new big DUSEL deep underground national lab in S Dakota, to the present NuMI North line and to enhnce both by means of Project-X, a new 1 MW proton driver, a 8 GeV ILC like linac, that could bring about 2.3 MW in the MI

[7] coupled to even longer term plans for a high energy frontier Muon Collider, a muon based vision for the future of the Laboratory. The push for Project-X and its upgrade path to 4 MW is a decisive part of this too.

[8] Most important results were the unequivocal final evidence for solar neutrino transitions from the SNO experiments in 2004, the measurement of the mixing quantities governing them provided by the KAMLAND experiments, the null result of the MiniBoone experiment in 2007 strongly disfavouring a the fourth light neutrino claimed by LSND and finally the recent much improved MINOS measurements of atmospheric transitions. The scenario provided by a 3*3 complex lepton flavour mixing matrix, with one sole and measurable CPV phase, is today much stronger as the leading candidate mechanism ruling neutrino transition and as a compelling motivation for the strategy proposed by BENE and its international collaborators. Last support came late in 2008, not from an experimental result, but from phenomenological hints of a non zero, order 1%, value of the so far undetected $\sin^2$ of the third mixing angle θ_{13}, essential for the 3*3 mixing matrix scenario.

WP2 was faced with the definition of the optimal proton driver[9].A high rep rate low energy (5-8 Gev) proton linac is maybe slowly proving most convenient both for most intense, MMW, proton beam technology and for optimal neutrino rates. Only final bunch accumulation and compression would use circular machines. The debate is still open among international experts, however. The choices being made for the LHC injectors will be decisive. The time scale of these decisions is likely to be 2010-1, mid-way in the life of our new FP7 initiatives.

The area of WP3 interest was high power targets capable to sustain MMW proton beams, surviving mechanical, thermal and radiation shocks and fatigue.[10] Liquid metal jet target are today baseline design for neutrino factories, solid (carbon) target technologies for conventional beams.

The task of WP4 was evaluation of high power collection devices of neutrino parents (pions and muons) downstream of MMW targets[11]. Today's baselines are a long high field tapered solenoidal collector for neutrino factories. and toroidal devices like horns and reflectors. for Superbeam applications,

WP5 focused on novel neutrino beam options:
WP5a (MUFRONT) focused on the front end of a neutrino factory, downstream of the solenoidal collection device[12].

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[9] by assessment of wide ranging items as design performance of the HP SPL and of realistic alternative designs in Europe and elsewhere, results from the HIPPI JRA and all R&D in progress in the sectors, the first steps in the construction of LINAC4, new data on energy dependence of pion production from HARP and, more in general, the wide context of the definition in progress of the new chain of LHC injectors.

[10] A major demonstration experiment (MERIT) was proposed, fostered and carried out, with the decisive push of US collaborators, at the CERN PS. Analysis of these data seems to be validating the concept of a liquid metal jet target as baseline design for neutrino factories (as well as Eurisol, remarkably enough). Solid (carbon) target technologies remain instead favoured for conventional neutrino beams. They have been adopted for the JPARK T2K beam in Japan, with decisive contributions from the RAL team of our WP3 coordinator. They remain also those most considered for future higher power superbeams. Hybrid technologies, flowing powder targets among others, are also strongly pushed. The BENE WP3 team moved on very successfully to take large responsibilities in the relevant EUROnu WPs.
International co-ordination in this sector has developed into a new phase, with various strands of endeavour in high power targets for neutrino facilities being aligned with overlapping programmes, in view of maximal synergy, by means of regular yearly international meetings.

[11] MERIT is likely to validate also the concept of a long high field tapered solenoidal collector, surrounding the liquid metal jet, for neutrino factories. Superbeam applications, that have even more severe target-collector integration problems, keep a strong preference for toroidal devices like horns and reflectors. These studies will now continue in the framework of the EUROnu FP7 DS project; where the BENE WP4 team too has taken large responsibilities. The concept of multiple pairs of horn and (solid) target is emerging, so to divide up the power on each pair, mitigate the damage and increase lifetime of components and ancillary equipment. R&D is in fact being fostered also for the ancillary bulky electro-mechanic components that must pulse horns at high current and high repetition rate. Most of the expertise resides in the CERN CNGS team, that may hopefully soon be more available to contribute to more rapid progress

[12] WP5a contributed to the assessment of the various options that were considered to define the baseline muon front end in the ISS final accelerator report. This consists of an unprecedented arrangement of normal RF for bunching, phase rotation, ionization cooling and pre-acceleration, in large solenoidal magnetic fields. WP5a has been leading the effort to propose and have approved and funded the MICE muon ionization cooling demonstration experiment the Rutherford Appleton Laboratory (RAL and is currently leading the commissioning of its beam and the instrumentation. Resulrs must be there before the conclusion of the EUROnu Design study and the 2012 decision point.
Field emission from RF cavity surfaces, . in large magnetic fields, threatens fundamental limitations to achievable accelerating gradients. This is taking years of careful studies, mostly at the Fermilab Muon Test Area, from the MUCOOL project that WP5a has been closely following and contributing to. Key members of WP5a have meanwhile become leaders in the NF WP of EUROnu and in the larger context of the NF International Design Study. The development of the conceptual design for the muon

WP5b (MUEND) focused on the back end of a neutrino factory, acceleration and storage ring.[13] WP5c (BETABEAM) was BENE link to the Betabeam R&D and Design work[14]

Dissemination and Outreach

BENE generated a significant number of documents reflecting presentations or publications delivered within and outside the previously mentioned workshops, plus proceedings of the main workshops organized and the comprehensive BENE Interim Scientific Report. A complete list of documents, summarized in the table below, is appended to this report.

	2004	2005	2006	2007	2008	Sum
Notes	5	0	0			**5**
Publications	0	0	0	3	5	**8**
reports	0	4	5	2	3	**14**
Conf. contributions	1	0	0	3		**4**
total	**6**	**4**	**5**	**8**	**8**	**31**

BENE supported largely scientist and student travel to the main events organized by BENE or of direct BENE interest. The BENE Web Site was given much CARE and will live beyond BENE as a summary of its five years initiative and a repository of references relevant for our future activities.

Deliverables

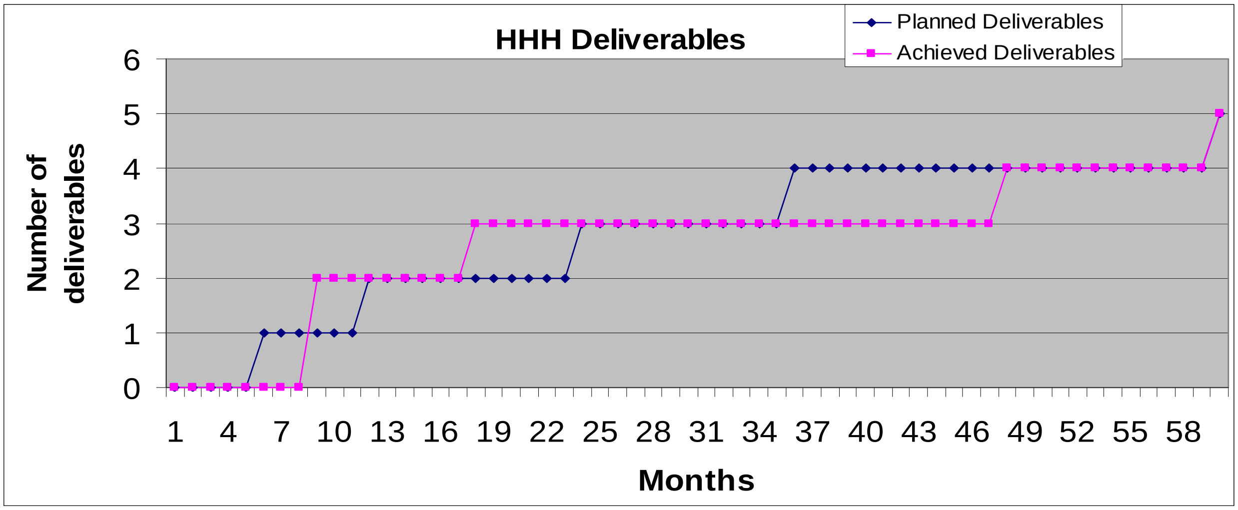
front end is considering novel designs, with smaller magnetic fields to allow the desired accelerating gradient to be achieved. Cooling absorbing materials of easier use than the Li-H absorbers adopted in MICE are also very actively investigated

[13] It contributed to the definition of the ISS acceleration baseline based on a muon linac, recirculating linear accelerators (RLAs) and a final muon FFAG. In the same years, it motivated, proposed and brought home approval of the EMMA electron prototype of non scaling Fixed Field Alternating Gradient (FFAG) accelerator in the UK laboratory in Daresbury and of the RACCAM FFAG Design Study in France and Belgium that has built and measured a S-FFAG magnet prototype in 2008, with significant industrial involvement. This generated recently also a new spiral scaling FFAG RACCAM++ activity.
Its key members have now taken responsibilities in the EURONu DS and the IDS, in collaboration with the US groups around Brookhaven, KEK and the KURR-Institute in Japan. Last, they also proposed successfully the EUROFFAG Task in the ANAC WP of the EuCARD FP7 IA. Funds will be dedicated to the EMMA upgrade (diagnostic systems). BENE WP5b has also been active in dissemination, bringing three times to Europe the FFAG workshop series initiated in Japan and running the European Accelerator School JUAS

[14] The team secured approval of the betabeam WP within the FP6 design EURISOL DS late in 2004 and kept BENE and the neutrino community constantly aware of its developments. BENE provided in turn the proper forum to discuss performance of different pure electron (anti-)neutrino betabeam variants for neutrino oscillation physics and stimulate input from neutrino physicists to their design.
The FP6 DS WP concerns only the original first variant of betabeam, based on a new ion storage ring filled by the present PS and SPS with low Q value He (anti-□) and Ne (□) ions produced with the ISOL ion production technique. WP5c prepared the proposal of a betabeam WP in the FP7 EuroNu design study that will continue the Eurisol design study. and will also explore more recently proposed betabeam and detector arrangements and new, non ISOL, ion production techniques. Some of these variants are already compared to those achievable with superbeams and neutrino factories in the ISS physics report.
The final report of the Eurisol based DS is presently eagerly awaited. It will report on the entire set of studies, the comforting results of studies on radiation and heat deposition, the less comforting results on ion production, the demonstration at the PS of decay ring stacking, the benefits of an extra accumulator ring and more.
A monograph on beta-beams – theory, phenomenology and accelerator aspects − has been produced in 2008 and will be published as a single volume in spring 2009. Discussions on a beta-beam facility at DESY continues. The beta-beam concept was also presented to ICFA.

All deliverables (organization and proceedings of workshops, reports of different size and scopes and last but most relevant, proposals to carry out R&D projects and design studies, both towards and independently of EC FP7 calls) have been delivered. Primary deliverables were, in addition to the BENE Web Site,

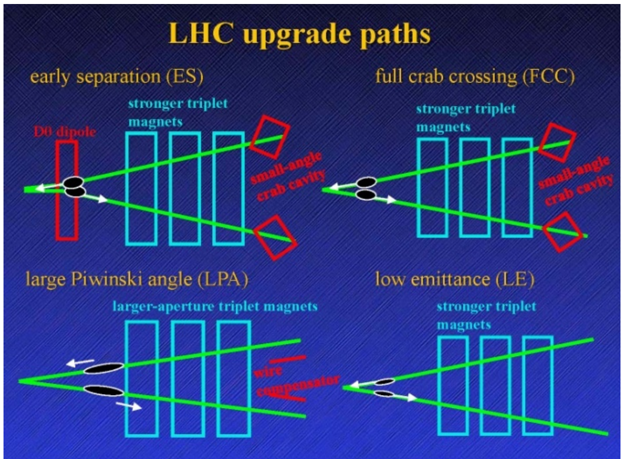
-*the Workshop PHYSICS WITH A MULTI-MW PROTON SOURCE,* CERN, Geneva, May 25-27 2004 and its Proceedings, that prompted a first positive response of the SPSC in Villars
-*the comprehensive BENE Midterm scientific report* , 105 pages CERN Yellow Report number that was our successful input to the CERN Council Strategy process early in 2006
-*the two NuFact International Workshops* on Neutrino Factories, Super beams and Beta beams, NuFact05 in Frascati and NuFact08 in Valencia)
-*the two successful FP7 proposals for EUROnu and* the neutrino related aspects of *EuCARD*
-*this last BENE Final Report*

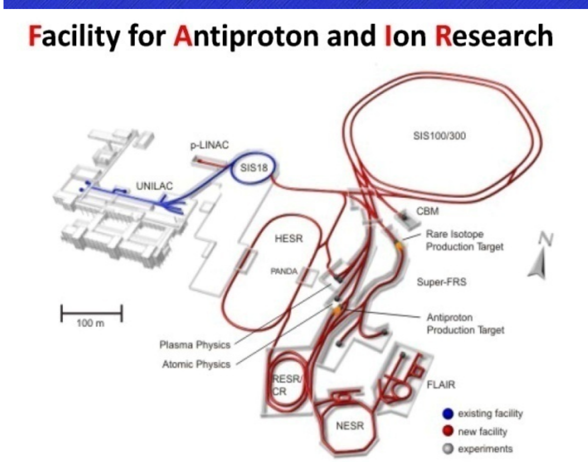


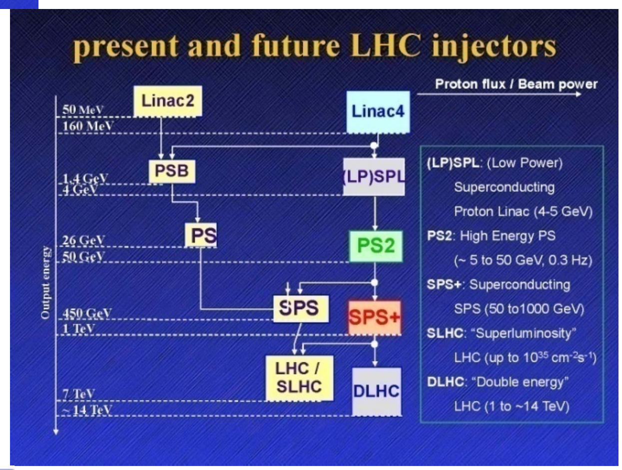
Conclusions

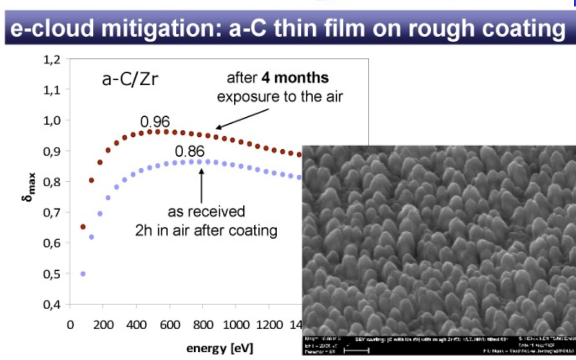
After 5 years of intense BENE Networking Activity, R&D and design study, a common strategic European involvement in a global accelerator neutrino program appears solidly on the agenda of CERN Council, for the year 2012 or so. Most of the tools necessary to match this challenge have been put in place during BENE's term. A solid R&D program is in progress. A complete EURONeutrino Design Study has started, a new EUCARD Neu2012 NA is in place. Highlight scientific and technical achievements from this international community during the lifetime of BENE are summarized below

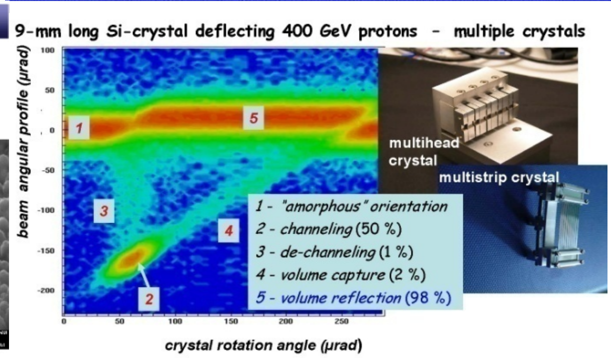
Selected Achievements	Impacted infrastructure	Main improvement	Future impacted infrastructure	Expected future impacts
confirmation of the 3*3 complex lepton flavour mixing matrix scenario	CNGS	one sole **and** measurable CPV phase exists	Any next ν facilities	Conclusive CPV statement possible
nearly complete design of a 4 and more MW proton driver (HPSPL)	CNGS	Higher beam power	Superbeam and Neutrino factory	Higly improved Eu proton complex
MERIT demonstration of feasibility of MMW target and collection	CNGS	Higher power production and collection of neutrino parents	Superbeam and Neutrino factory	Higher neutrino fluxes
MICE demonstration experiment	RAL/ISIS muon beam	demonstration of muon ionization cooling	Neutrino factory	Higher neutrino fluxes
EMMA non scaling (NS) FFAG electron prototype	Daresbury Laboratory	proof of principle of novel NS FFAG	Neutrino factory	Higher neutrino energies


LHC upgrade paths
early separation (ES)
full crab crossing (FCC)
stronger triplet magnets
D0 dipole
small-angle crab cavity
large Piwinski angle (LPA)
low emittance (LE)
larger-aperture triplet magnets
wire compensator


Facility for Antiproton and Ion Research
p-LINAC
SIS18
UNILAC
SIS100/300
HESR
PANDA
CBM
Rare Isotope Production Target
Super-FRS
Antiproton Production Target
100 m
Plasma Physics
Atomic Physics
RESR/CR
NESR
FLAIR
existing facility
new facility
experiments


present and future LHC injectors
Proton flux / Beam power
Linac2
Linac4
50 MeV
160 MeV
1.4 GeV
4 GeV
PSB
(LP)SPL
26 GeV
50 GeV
PS
PS2
450 GeV
1 TeV
SPS
SPS+
LHC / SLHC
DLHC
7 TeV
~ 14 TeV
Output energy
(LP)SPL: (Low Power) Superconducting Proton Linac (4-5 GeV)
PS2: High Energy PS (~ 5 to 50 GeV, 0.3 Hz)
SPS+: Superconducting SPS (50 to1000 GeV)
SLHC: "Superluminosity" LHC (up to 10^{35} cm^{-2}s^{-1})
DLHC: "Double energy" LHC (1 to ~14 TeV)


e-cloud mitigation: a-C thin film on rough coating
a-C/Zr
after 4 months exposure to the air
0.96
0.86
as received
2h in air after coating
δ_{max}
energy [eV]


9-mm long Si-crystal deflecting 400 GeV protons – multiple crystals
beam angular profile (μrad)
crystal rotation angle (μrad)
multihead crystal
multistrip crystal
1 - "amorphous" orientation
2 - channeling (50 %)
3 - de-channeling (1 %)
4 - volume capture (2 %)
5 - volume reflection (98 %)

Appendix 1: NA participants and their implication in the Work Packages

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					**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**

Appendix 2: Main comprehensive documents produced by BENE

The list

begins with the two main, comprehensive reports, produced by BENE,

Proceedings of the Workshop on **Physics with a MultiMegaWatt Proton Source, CERN**, Geneva, May 25-27 2004, CERN SPSC-2004-024. CARE-Conf-2004-036-BENE, BENE's statement in the first year of its activity, just before the special SPSC strategy session in Villars, CH, September 2004,

CERN Yellow Report number CERN-2006-005 ; CARE-2006-009-BENE ; ECFA-2006-242 **Beams for European Neutrino Experiments (BENE) : Midterm scientific report** ,BENE Steering Group, Geneva : CERN, 2006. - 105 p., at the start of the CERN Council Strategy process in January 2006

that do provide a full snapshot of the network activities and are singled out here for more visibility from those in the longer list of similar publications further below

and must include also the three reports concluding the International Scoping Study (ISS) of Neutrino Factory and Superbeam

RAL-TR-2007-019 **Physics at a future Neutrino Factory and super-beam facility** (http://www.hep.ph.ic.ac.uk/iss/reports/0710.4947v2.pdf)
RAL-TR-2007-023 **Accelerator design concept for future neutrino facilities** (http://www.hep.ph.ic.ac.uk/iss/reports/ISS-AcceleratorWG-final.pdf)
RAL-TR-2007-024 **Detectors and flux instrumentation for future neutrino facilities** (http://www.hep.ph.ic.ac.uk/iss/reports/0712.4129v1.pdf)

The ISS was launched, carried out and strongly supported by BENE (most enthusiastic being its UK component organized in a national neutrino factory group UKNF), in international collaboration with the US Neutrino Factory Collaboration, the Japanese NUFACTJ group, a team from India and additional contributors from other countries. BENE support is gratefully acknowledged in the executive summary accompanying the three reports.

Appendix 3: complete list of BENE and BENE related publications

In the period 2004-2008, more than 35 articles, reports and notes have been partially financially supported by BENE. Most of these have been published in leading scientific journals as Physical Review C and D, Physics Letters B and JHEP or in the proceedings of major international conferences as NuFact. They also include one review article published in Physics Report B and the ISS Physics Working Group Report. BENE contributed substantially to supporting the neutrino physics community and it favoured a thriving scientific climate in which a detailed and deep understanding of the technical and phenomenological aspects of present and future long baseline facilities was achieved. More than 150 papers published in leading journals and conference proceedings were indirectly fostered by BENE. A detailed list follows of articles directly supported by BENE and properly acknowledging the CARE contract.

Publications in refereed journals and proceedings

1) J.-E. Campagne and A. Cazes,
The theta(13) and delta(CP) sensitivities of the SPL-Frejus project revisited,
published in Eur. Phys. J. C 45 (2006) 643 [arXiv:hep-ex/0411062], BENE-WP4-Article-04-1.

2) V. Bollini et al., presented by F.Goldenbaum for the PISA collaboration,
Light charged particle and intermediate mass fragment cross sections in GeV proton induced reactions---the PISA experiment,
published in AccApp05, Proceedings of the 7th Int. Conference on Accelerator Applications, NIM A, Volume 562, Issue 2, Page 733-736, ISSN 0168-9002, 29.8-1.9.2005, Venice, Italy, (2005).

3) M. Bonesini, A. Guglielmi,
Hadroproduction experiments for precise neutrino beam calculations,
published in Phys. Rept. 433 (2006) 65.

4) O. Mena, S. Palomares-Ruiz and S. Pascoli,
Reconstructing WIMP properties with neutrino detectors,
published in Phys. Lett. B 664: (2008) 92 [arXiv:0706.3909 [hep-ph]].

5) A. Bubak, A. Budzanowski, D. Filges, F. Goldenbaum, A. Heczko, H. Hodde, L. Jarczyk, B. Kamys, M. Kistryn, St. Kistryn, St. Kliczewski, A. Kowalczyk, E. Kozik, P. Kulessa, H. Machner, A. Magiera, W. Migdal, N. Paul, B. Piskor-Ignatowicz, M. Puchala, K. Pysz, Z. Rudy, R. Siudak, M. Wojciechowski, and P. Wüstner,
Non-equilibrium emission of complex fragments from p+Au collisions at 2.5 GeV proton beam energy,
published in Phys. Rev. C 76 (2007) 014618 [arXiv:0709.2816].

6) F. Goldenbaum,
Progress in nuclear data for accelerator applications in Europe,
published in the Proceedings of ND2007, International Conference on Nuclear Data for Science and Technology, Nice, France, April 22-27 (2007), arXiv:0709.3083v1 [nucl-ex].

7) A. Bross, M. Ellis, S. Geer, O. Mena and S. Pascoli,

A Neutrino Factory for both Large and Small theta_13,
published in Phys. Rev. D 77 (2008) 093012 [arXiv:0709.3889 [hep-ph]].

8) T. Schwetz,
Neutrino oscillations: present status and outlook,
published in AIP Conf. Proc. 981 (2008) 8 [arXiv:0710.5027 [hep-ph]].

9) P. Huber, M. Mezzetto and T. Schwetz,
On the impact of systematical uncertainties for the CP violation measurement in superbeam experiments,
published in JHEP 0803 (2008) 021 [arXiv:0711.2950 [hep-ph]].

10) A. Donini, P. Huber, S. Pascoli, W. Winter and O. Yasuda,
Physics and Performance Evaluation Group,
published in AIP Conf. Proc. 981 (2008) 43 [arXiv:0712.0909 [hep-ph]].

11) A. Budzanowski, M. Fidelus, D. Filges, F. Goldenbaum, H. Hodde, L. Jarczyk, B. Kamys, M. Kistryn, St. Kistryn, St. Kliczewski, A. Kowalczyk, E. Kozik, P. Kulessa, H. Machner, A. Magiera, B. Piskor-Ignatowicz, K. Pysz, Z. Rudy, R. Siudak, and M. Wojciechowski,
Competition of coalescence and "fireball" processes in nonequilibrium emission of light charged particles from p+Au collisions,
published in Phys. Rev. C 78 (2008) 024603 [arXiv:0801.4512].

12) A. Bross, M. Ellis, S. Geer, O. Mena and S. Pascoli,
The Low-Energy Neutrino Factory,
published in AIP Conf. Proc. 981 (2008) 187.

13) D. Meloni, O. Mena, C. Orme, S. Palomares-Ruiz and S. Pascoli,
An intermediate gamma beta-beam neutrino experiment with long baseline,
published in JHEP 0807 (2008) 115 [arXiv:0802.0255].

14) P. Loveridge, D. E. Baynham, A. Devred, D. Leroy,
Mechanical Design of the Next European Dipole,
published in Applied Superconductivity, IEEE Transactions on, 18 (2008) 1487.

15) P. Huber and T. Schwetz,
A low energy neutrino factory with non-magnetic detectors,
published in Phys. Lett. B 669 (2008) 294 [arXiv:0805.2019 [hep-ph]].

16) T. Schwetz,
Neutrino oscillations: present status and outlook,
contribution to the proceedings of WHEPP X, Jan 2008, Chennai, India to appear in Pramana J. Phys..

17) F. Goldenbaum,
Experimental data on evaporation and pre-equilibrium emission in GeV p-induced spallation reactions,
published in IAEA TEC-DOC, Joint ICTP-IAEA, NDC(NDS)-0530, Distr. SC, page 91-109, Advanced Workshop on Model Codes for Spallation Reactions, 4-8 February 2008, Miramare, Trieste, Italy (2008).

18) P. Loveridge, D. E. Baynham, A. Devred, D. Leroy,

Mechanical Design of the Next European Dipole,
it has been accepted for publication in the June 2008 issue of the IEEE Transactions on Applied Superconductivity.

19) M. Lindroos,
Future options for the beta-beam with a focus on production issues,
published in AIP Conf. Proc. 981 (2008) 93

20) M. Lindroos, A. Donini,
Beta-beam optimization, questions and answers,
Proceedings of NuFact08, Valencia (Spain) 30 Jun – 4 Jul 2008.

Articles submitted for publication

1) S. F. King, K. Long, Y. Nagashima, B. L. Roberts and O. Yasuda (Editors),
The ISS Physics Working Group,
Physics at a future Neutrino Factory and super-beam facility,
arXiv:0710.4947.

2) T. Schwetz,
Physics Potential of Future Atmospheric Neutrino Searches,
arXiv:0812.2392 [hep-ph].

3) M. Maltoni and T. Schwetz,
Three-flavour neutrino oscillation update and comments on possible hints for a non-zero theta_{13},
arXiv:0812.3161 [hep-ph].

4) J. Bernabeu, C. Espinoza, C. Orme, S. Palomares-Ruiz and S. Pascoli,
A combined beta-beam and electron capture neutrino experiment,
arXiv:0902.4903 [hep-ph].

5) T. Schwetz,, Neutrino oscillations: present status and outlook, contribution to the proceedings of WHEPP X, Jan 2008, Chennai, India, to appear in Pramana J. Phys

Conference posters and paper contributions

1) A. Cazes,
CNGS/OPERA and SPL/Frejus,
BENE-WP4-Conf-04-1, poster presented at Neutrino 2004, Paris 14-19 Jun 2004.

2) H. G. Kirk et al.,
A 15-T pulsed solenoid for a high-power target experiment,
paper contribution, EPAC08 conference, Genova (Italy) 23-27 Jun 2008

3) I. Efthymiopoulos et al.,
The MERIT high-power target experiment,
paper contribution, EPAC08 conference, Genova (Italy) 23-27 Jun 2008

Notes and technical reports

1) J.-E. Campagne,
Horn profile determination: the SPL use case,
BENE-WP4-Note-04-01.

2) J.-E. Campagne and A. Cazes,
The CERN horn prototype revisited,
BENE-WP4-Note-03-02.

3) J.-E. Campagne,
Influence des neutrons thermique et rapides sur les alliages d'aluminium de la serie 6000,
BENE-WP4-Note-03-01.

4) M. Omeich,
Cahier des clauses techniques particulieres de l'alimentation pulsee de la CORNE de Neutrinos,
BENE-WP4-TR-03-1.

5) E. Keil,
Alternative electron models of an FFAG Muon Accelerator,
CARE-Note-2004-027-BENE.

6) J. E. Campagne,
Horn profile determination: the SPL use case,
CARE-Note-2004-028-BENE.
7) E. Keil, A. M. Sessler,
Muon Accelerator in FFAG Rings,
CARE-Note-2004-029-BENE.

8) M. Aiba, F. Meot,
Determination of KEK 150 MeV FFAG parameters from ray-tracing in TOSCA field maps
CARE-Note-2004-030-BENE.

9) J. E. Campagne, A. Cazes,
The theta13 and delta sensitivities of the SPL-Frejus project revisited,
CARE-Note-2004-031-BENE.

In addition, please find the above mentioned partial list of publications which are related to and benefited from BENE, although they do not contain an explicit acknowledgement to the CARE contract.

Proceedings of the Workshop on PHYSICS WITH A MULTI-MW PROTON SOURCE, CERN, Geneva, May 25-27 2004, CERNSPSC-2004-024.
Contributions by:

1) R. Aymar, V. Palladino,
Foreword: High Energy and High Intensity Frontiers.

2) A. Blondel and J. Ellis,

The High Intensity Frontier.

3) S. Nagamiya and V. Palladino,
Planned High Intensity facilities in the world.

4) R. Garoby and W. Scandale,
High Intensity Proton Source.

5) R. Garoby,
The Superconducting Proton Linac (SPL) and its potential.

6) C. Prior,
The Rapid Cycling Synchrotron options.

7) A. Blondel, S. Geer, H. Haseroth and A. Rubbia,
Additional installations for a neutrino physics facility.

8) M. Apollonio and A. Blondel,
Hadro-production experiments.

9) M. Lindroos,
A neutrino beta-beam facility at CERN.

10) A. Blondel, S. Geer, P. Hernandez and A. Rubbia,
Overview of neutrino oscillation physics.

11) C. K. Jung, K. Nakamura and V. Palladino,
A megaton water Cherenkov detector.

12) A. Ereditato and A. Rubbia,
Ideas for a next generation liquid Argon TPC detector for neutrino physics and nucleon decay searches.

13) P. Migliozzi,
Short baseline neutrino physics.

14) A. Baldini and A. Van der Schaaf,
High intensity muon physics.

15) A. Blondel and M. Spiro,
Conclusions and outlook: Particle physics.

16) J. Engelen and V. Palladino,
Conclusions and outlook: General outlook.

17) R. Garoby, M. Lindroos, A. Blondel and H. Haseroth,
Recommendations: Recommended accelerator R&D.

18) A. Blondel, V. Palladino and A. Rubbia,
Recommendations: Recommended detector R&D.

AIP Conference Proceedings Volume 981, Proceedings of NEUTRINO FACTORIES, SUPERBEAMS AND BETABEAMS: 9th International Workshop on Neutrino Factories, Superbeams, and Betabeams - NuFact 07, Okayama University, Okayama (Japan), 6–11 August 2007, ISBN: 978-0-7354-0500-4

Editor(s): O. Yasuda, N. Mondal, C. Ohmori

Contributions by:

1) E. Gschwendtner, A. Pardons, L. Bruno, M. Clement, I. Efthymiopoulos, K. Elsener, M. Meddahi, S. Rangod, and H. Vincke,
First Operational Experience Of The CNGS Facility.

2) K. Long,
The International Design Study for the Neutrino Factory.

3) Andrea Donini, Patrick Huber, Silvia Pascoli, Walter Winter, and Osamu Yasuda,
Physics and Performance Evaluation Group.

4) A. Cervera-Villanueva (ISS detector group),
ISS/IDS Detector Study.

5) S. Davidson,
Neutrinos in Cosmology.

6) S. Hancock,
Technical Challenges of the EURISOL Beta-beam.

7) M. Lindroos,
Future options for the beta-beam with a focus on production issues.

8) A. Fabich,
Target R&D for high power proton beam applications.

9) P. Hernández, C. W. Walter, and O. Yasuda,
Summary of Working Group One.

10) A. Cervera-Villanueva,
MIND performance and prototyping.

11) A. Donini, E. Fernandez-Martinez, P. Migliozzi, S. Rigolin, L. Scotto Lavina, M. Selvi, T. Tabarelli de Fatis, and F. Terranova,
Determining the hierarchy of neutrino masses with high density magnetized detectors at the Beta Beams.

12) A. Bross, M. Ellis, S. Geer, O. Mena, and S. Pascoli,
The Low-Energy Neutrino Factory.

13) W. Winter,
Systematic Model Building Based on Quark-Lepton Complementarity Assumptions.

14) F. J. P. Soler, K. Walaron, C. Booth, M. Carson, P. Hodgson, L. Howlett, P. Smith, D. Adams, R. Edgecock, W. Murray, K. Tilley, J. Cobb, M. Rayner, and T. Roberts, Measurement of Particle Production from the MICE Target.