Neutrino Beams and Physics at CERN

subtitle:

Towards a consensual road map for accelerator based neutrino programs in Europe

Beams for European Neutrino Experiments (BENE)

V. Palladino
Univ & INFN Napoli, Italy
Neutrino Super Beams, Detectors & Proton Decay
Joint BNL/UCLA –APS Workshop
March 3-5, 2004, BNL
EU accelerator $\nu$ may be emerging from their long crisis

enthusiastic initiative .......... beyond the CNGS
1998 onwards ..... met dramatic setback ..... 2001-02 ..... LHC crisis ..... except NuFact in UK & Frejus plans

Very positive signal from Bruxelles (EC) in 2003
15 M ..... CARE ... HIPPI ...BENE
and from national agencies ... CEA, IN2P3, INFN ...

Open attitude of the new CERN management ... 2004

R. Aymar & J. Engelen

thou LHCdoes maintain absolute priority!

May well be heading towards a new wave of initiative

particularly in the area addressed by this Workshop

Neutrino Super & Beta Beams, Detectors & Proton Decay
A. Blondel

H. Haseroth

M. Lindroos

ECFA Muon Study Groups (physics)

European Neutrino Group (ENG, accelerator)

Betabeam WorkGroup

since 1998

formerly CERN NFWG
Nu Factory WG

redefined to
do justice to Nu Superbeam
emphasize national contributions

formerly CERN
now also EU

a rich prospective emerged
before and during the crisis

see Gilardoni on Wednesday
The options we have explored
NB: beam + detector configurations

Conventional beam $\pi$ decay channel $\ldots \nu_\mu (0.1-1\% \nu_e)$

SuperBeam, if MW power $\ldots$
need Very Large Detector (water C, Li-Ar)
the same as p-decay

50-500 Ktons
ie new lab

Neutrino Factory $\mu$ storage ring $\ldots \nu_\mu \& \nu_e$
(& $\mu$ accelerator complex! )
needs Large Magnetic Detector
(SuperMINOS, Li-Ar in $\beta$)

30-100 Ktons
LNGS!
new lab?

BetaBeam $\beta$ storage ring $\ldots$ pure $\nu_e$
(& EU accelerator complex)
d Detectors same as SuperBeams

NB: $\pi\nu\beta$ possible, in all cases, for CP, T & CPT studies
Any option relies on a new powerful EU p-driver !!!!!!!!!!!!!!!!!!!!!

SPL basics

Study group since 1999
design of a Superconducting Proton Linac (H-, 2.2 GeV).
- higher brightness beams into the PS for LHC
- intense beams (4 MW) for neutrino and radioactive ion physics

E\text{KIN} = 2.2 \text{ GeV}
Power = 4 \text{ MW}
Protons/s = 10^{16}

H\textsuperscript{-} RFQ chopping DTL CCDTL \beta 0.52 \beta 0.7 \beta 0.8

Source Low Energy section DTL Superconducting section

95 keV 3 MeV 7 MeV 120 MeV 2.2 GeV
6 m 4 m 64 m 40 MeV 237 MeV 383 MeV 584 m

660 m

NB Rapid Cycling Synchrotrons (RCS) also an option: HARP !

PS / Isolde Accumulator Ring

Stretching and collimation line

CERN 2000-012
Conventional SuperBeam: the CERN scheme

Flux intensities at 50 km from the target

<table>
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<tr>
<th>Flavour</th>
<th>Absolute Flux ($\nu/10^{23}$pot/m²)</th>
<th>Rel. Flux (%)</th>
<th>$\langle E_{\nu}\rangle$ (GeV)</th>
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</thead>
<tbody>
<tr>
<td>$\nu_\mu$</td>
<td>$3.2 \cdot 10^{12}$</td>
<td>100</td>
<td>0.27</td>
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<tr>
<td>$\bar{\nu}_\mu$</td>
<td>$2.2 \cdot 10^{10}$</td>
<td>1.6</td>
<td>0.28</td>
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<tr>
<td>$\nu_e$</td>
<td>$5.2 \cdot 10^{9}$</td>
<td>0.67</td>
<td>0.32</td>
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<tr>
<td>$\bar{\nu}_e$</td>
<td>$1.2 \cdot 10^{8}$</td>
<td>0.004</td>
<td>0.29</td>
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</tbody>
</table>

$\nu_\mu \rightarrow \nu_e$ appearance
A Megaton Physics project in the Fréjus underground site, focused on Proton Decay, Neutrinos from Supernovae, Atmospheric Neutrinos and Neutrinos from a long-baseline, is presented and compared with competitor projects in Japan and USA sites. The advantages of the European project are discussed, including the possibility of a neutrino long-baseline from CERN, at a magic distance.

Unique opportunity, 2008 or so

Figure 2: Proposal for a new excavation in the Fréjus tunnel.
Neutrino Factory: CERN Scheme

Disappearance
\(\bar{\nu}_e \rightarrow e \) deficit
\(\nu_\mu \rightarrow \mu \) deficit

Appearance
\(\nu_\mu \rightarrow \nu_e \rightarrow e \) excess
\(\nu_\tau \rightarrow \tau \) excess

Appearance ... Wrong Charge Signature
\(\bar{\nu}_e \rightarrow \bar{\nu}_\mu \rightarrow \mu \) excess  Golden
\(\bar{\nu}_\tau \rightarrow \tau \) excess  Silver

Magnetic detector
Neutrino Factory: CERN Scheme

Disappearance
\[ \bar{\nu}_e \rightarrow e \text{ deficit} \]
\[ \nu_\mu \rightarrow \mu \text{ deficit} \]

Appearance
\[ \nu_e \rightarrow \nu_e \text{ excess} \]
\[ \nu_\tau \rightarrow \tau \text{ excess} \]
\[ \mu \rightarrow e \nu_\mu \bar{\nu}_e \]

Appearance ... Wrong Charge Signature
\[ \bar{\nu}_e \rightarrow \nu_\mu \rightarrow \mu \text{ excess } \]
\[ \nu_\tau \rightarrow \tau \text{ excess } \]

Golden
Silver
Magnetic detector
Iron calorimeter
Magnetized
Charge discrimination
\( B = 1 \text{ T} \)
\( R = 10 \text{ m}, L = 20 \text{ m} \)
Fiducial mass = 40 kT

Also: L Arg detector: magnetized ICARUS
Wrong sign muons, electrons, taus and NC evts

Events for 1 year

<table>
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<tr>
<th>Baseline</th>
<th>( \overline{\nu}_\mu \text{ CC} )</th>
<th>( \nu_e \text{ CC} )</th>
<th>signal ( (\sin^2\theta_{13} = 0.01) )</th>
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<tbody>
<tr>
<td>732 Km</td>
<td>3.5 \times 10^7</td>
<td>5.9 \times 10^7</td>
<td>1.1 \times 10^5</td>
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<tr>
<td>3500 Km</td>
<td>1.2 \times 10^6</td>
<td>2.4 \times 10^6</td>
<td>1.0 \times 10^5</td>
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</tbody>
</table>

(cf 40 in JHF-SK)

Alain Blondel, Venice, March 2003
Betabeam & Eurisol

M. Lindroos and collaborators, see http://beta-beam.web.ch/beta-beam

Betabeam & Eurisol

Moriond Mar 03

Factor 2*3!

1 ISOL target to produce $^{6}\text{He}$, 100 $\mu A$, $\Rightarrow 2.9 \times 10^{18}$ ion decays/straight session/year. $\Rightarrow \overline{\nu}_{e}$.

3 ISOL targets to produce $^{18}\text{Ne}$, 100 $\mu A$, $\Rightarrow 1.2 \times 10^{18}$ ion decays/straight session/year. $\Rightarrow \nu_{e}$.

The 4 targets could run in parallel, but the decay ring optics requires:

Same detector as Superbeam. At the same time! $\gamma(Ne^{18}) = 1.67 \cdot \gamma(He^{6})$. 
The matrix of neutrino transition probability

\[
\begin{align*}
P_{ee} &= 1 - \ldots \quad & P_{\mu\mu} &= 1 - \ldots \\
P_{\mu e} &= \quad & P_{\mu\tau} &= \ldots \\
P_{\tau e} &= \ldots \quad & P_{\tau\mu} &= \ldots \\
P_{\tau\tau} &= 1 - \ldots
\end{align*}
\]
The matrix of neutrino transition probability

$$P_{ee} = 1 - \ldots$$

$$P_{e\mu} = -4 \text{ Re } J_{e\mu} 13 \sin^2 \Delta_{13}$$

$$P_{e\tau} = -4 \text{ Re } J_{e\tau} 13 \sin^2 \Delta_{13}$$

$$P_{\mu e} = -4 \ldots$$

$$P_{\mu \mu} = 1 - \ldots$$

$$P_{\mu \tau} = -4 \text{ Re } J_{\mu \tau} 13 \sin^2 \Delta_{13}$$

$$P_{\tau e} = \ldots$$

$$P_{\tau \mu} = \ldots$$

$$P_{\tau \tau} = 1 - \ldots$$

BetaBeam, NuFact

**golden**

SuperBeam, NuFact

NuFact

silver

can we exploit them all? what strategy?
Sensitivity to $\theta_{13}$ $\nu_\mu \leftrightarrow \nu_e$ transitions

Neutrino Factory cf. conventional sources:
\[ A_{\text{CP}} = \frac{P_{\nu} - P_{\bar{\nu}}}{P_{\nu} + P_{\bar{\nu}}} \] v/\bar{v} asymmetry

\[ A_T = \rightarrow \leftarrow \text{ asymmetry} \ldots \]

\[ A_{\text{CPT}} \] both asymmetries

\[ \nu_e \leftrightarrow \nu_\mu \] at NuFact + Betabeam

\[ \nu_\mu \leftrightarrow \nu_e \] Superbeam

\[ \nu_e \leftrightarrow \nu_\mu \] at NuFact?

\[ \nu_e \leftrightarrow \nu_\mu \] Betabeam + Superbeam

\[ \nu_e \leftrightarrow \nu_\mu \] Betabeam + Superbeam

All of great interest!
The betabeam/superbeam synergy

**CP Searches**
- SuperBeam running with $\nu_\mu$ and $\bar{\nu}_\mu$.
- Beta Beam running with $^6$He ($\bar{\nu}_e$) and $^{18}$Ne ($\nu_e$).

**T searches**
- Compare Super Beam $p(\nu_\mu \rightarrow \nu_e)$ with Beta Beam $^{18}$Ne $p(\nu_e \rightarrow \nu_\mu)$.
- Compare Super Beam $p(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$ with Beta Beam $^6$He $p(\bar{\nu}_e \rightarrow \bar{\nu}_\mu)$.

**CPT searches**
- Compare Super Beam $p(\nu_\mu \rightarrow \nu_e)$ with Beta Beam $^6$He $p(\bar{\nu}_e \rightarrow \bar{\nu}_\mu)$.
- Compare Super Beam $p(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$ with Beta Beam $^{18}$Ne $p(\nu_e \rightarrow \nu_\mu)$. 
Comparative Physics Reach .... 90% discovery contour for $\delta_{\text{CPV}} = 90^\circ$

Mezzetto NuFact03

$\Delta m_{12}^2 (x10^{-4}) \text{eV}^2$

- Nufact
- SPL SuperBeam
- Beta Beam
- SB+BB, 440 kton
- SB+BB, 1 Mton

Best LMA, hep-ph/0212127

JHF $\theta_{13}$
Meanwhile, R&D work proceeded as vigorous as permitted

**HARP** hadrproduction from high power targets

**P driver R&D**

**Target R&D**

**BNL**

**Horns R&D**

**See Gilardoni**

**BetaBeam R&D**

**new LOI**

to CERN INTC

H.Kirk & al.

**MUSCAT at TRIUMPH**

**MICE at Rutherford Lab**

US, Japan .... EU ...

approved ... now raising funds
10% cooling of 200 MeV/c muons requires ~ 20 MV of RF

**single particle measurements** =>

measurement precision can be as good as $\Delta \left( \frac{\epsilon_{out}}{\epsilon_{in}} \right) = 10^{-3}$

never done before either….
Coordinated Accelerator R&D in Europe

**Networking Activities** (3 subprojects)

- **N2: ELAN**
  - (Electron linear accelerators & colliders)
  - (F. Richard/Orsay)

- **N3: BENE**
  - (Beams for European Neutrino Experiments)
  - (V. Palladino/INFN)

- **N4: HEHIHIB**
  - High Energy and High Intensity Hadron Beams
  - (H. Haseroth/CERN)

**Joint Research Activities** (5 subprojects)

- **JRA1: SRFCAV**
  - (SRF Cavity)
  - (D. Proch/DESY)

- **JRA2: SRFTECH**
  - (SRF Technology)
  - (T. Garvey/ORSAY)

- **JRA3: PHIN**
  - (Photo-Injector)
  - (A. Ghigo/INFN)

- **JRA4: HIPPI**
  - (High Intensity Proton Pulsed Injector)
  - (R. Garoby/CERN)

- **JRA5: NED**
  - (Next European Dipole)
  - (A. Devred/Saclay)

**NB: this is the R&D towards a MW Injector for the p driver !!!**
(first 200 MeV)

CNGS !!!!, LHC

NB EC co-funding scheme !
Evolution of the SPL Design

• **Linac 4**

  - Energy is increased to 160 MeV
  - High energy section (> 90 MeV) operates at **704 MHz** to fit inside the available space (higher gradients & higher power pulsed klystrons) and to prepare for a superconducting linac section at that frequency.

• **SPL**

  - Considering that the LEP cavities and their technology are aging, that CERN management does not support it anymore and that the corresponding know-how is disappearing, while bulk Nb is supported by other laboratories and provides higher gradients, the choice has been made to base the future design of the SPL on **704 MHz bulk Nb resonators. No superconducting LEP cavities will be used anymore.**
  - A new conceptual design will be prepared in 2004. The energy will be optimized as a function of the physics goals.

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**HIPPI**

**transfer line to PSB**
Benefit to approved physics programme

• Need for higher beam performance (brightness*, intensity) to:

  – Reduce the LHC filling time,
  – Improve the reliability in the generation of the ultimate beam actually foreseen for LHC,

  – Increase the proton flux onto the CNGS target,

  – Increase the proton flux to ISOLDE,

  – Prepare for further upgrades of the LHC performance beyond the present ultimate.

* For protons, brightness can only degrade along a cascade of accelerators
  ⇒ Any improvement has to begin at the low energy (linac) end

 courtesy of R. Garoby
Idea: Take only the room temperature part of the SPL (120 MeV) and install it in the PS South Hall, to inject H- into the PS Booster > twice the number of protons/pulse in the PSB (5 \times 10^{13})
Proposed Roadmap

Consistent with the content of a talk by L. Maiani at the “Celebration of the Discovery of the W and Z bosons”. Contribution to a document to be submitted to the December Council (“CERN Future Projects and Associated R&D”).

Assumptions:
• construction of Linac4 in 2007/10 (with complementary resources, before end of LHC payment)
• construction of SPL in 2008/15 (after end of LHC payments)

“Physics at SPL” Workshop, late May 04 in view of Cogne IX Sep 04
SPL Multi-year planning: 3 stages

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- **3 MeV**
  - RF test place ready
  - 3 MeV test place ready

- **160 MeV**
  - Linac4 approval
  - 31/12

- **few GeV**
  - SPL approval
  - 26/12

- **LHC upgrade**
BENE as an integrating activity

ECFA
Muon Study Groups
(physics)

European Neutrino
Group
(accelerator)

Betabeam
WorkGroup

PHYSICS
WP

DRIVER
WP

TARGET
WP

COLLECTOR
WP

NOVEL ν BEAMS
WP

mufront
muend

betabeam

N3: BENE (Beams for European Neutrino Experiments) Work Packages
... from BENE proposal:
coordinate and integrate the activities of
the accelerator and particle physics communities working together,
in a worldwide context,
towards achieving superior
neutrino (ν) beam facilities for Europe.

1) to establish a road map for upgrade of our present facility and
the design and construction of new ones

2) to assemble a community capable of sustaining
the technical realisation and scientific exploitation
of these facilities

220 signatures

3) to foster a sequence of carefully prioritized & coordinated
initiatives

capable to establish, propose and execute
the R&D efforts necessary to achieve these goals.
Betabeam & Eurisol

M. Lindroos and collaborators, see http://beta-beam.web.ch/beta-beam

Moriond Mar 03

Factor 2*3!

Eurisol

Radio

Isotopes

On

Line

!!!

SPL

Isol target & Ion source

LINAC 3

FSB

PS

SPS

Existing at CERN

Decay ring

$B \rho = 1500 \text{Tm}$

$B = 5 \text{T}$

$L_s = 2500 \text{ m}$

Radio Isotopes

$\beta$ emitters

Few 100 MeV!

- 1 ISOL target to produce $^{6}\text{He}$, 100 $\mu$A, $\Rightarrow 2.9 \cdot 10^{18}$ ion decays/straight session/year. $\Rightarrow \bar{\nu}_e$.
- 3 ISOL targets to produce $^{18}\text{Ne}$, 100 $\mu$A, $\Rightarrow 1.2 \cdot 10^{18}$ ion decays/straight session/year. $\Rightarrow \nu_e$.
- The 4 targets could run in parallel, but the decay ring optics requires:

Same detector as Superbeam. At the same time!

$\gamma(\text{Ne}^{18}) = 1.67 \cdot \gamma(\text{He}^6)$.  

Eurisotopes
ν’s & EURISOL

EURISOL and future ν programs may share a new powerful European p driver

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20ms rep rate

Moriond 2003 !!!

…. unique opportunity …
Super-ISOLDE at CERN employing SPL beams

H⁻ \rightarrow RFQ \rightarrow chopping \rightarrow DTL, CCDTL \rightarrow superconducting section \rightarrow debunching \rightarrow dump

Source Low Energy section DTL Superconducting section Debunching

45 keV 3 MeV 120 MeV 2.2 GeV

6 m 64 m 584 m

668 m

H⁻ RFQ chopping DTL CCDTL β 0.52 β 0.7 β 0.8 dump

from SPL: 100 μA

155 μs 20 ms

x 1/100 power

PSB: 2 μA

250 ns 320 ns 1.2 s

PS / Isolde Accumulator Ring

Hall 1 Hall 2 Hall 3
EURISOL

SPL

Driver

100 kW direct target

postaccelerator 10 MeV/u

p-rich

4 MW n source

n-rich

postaccelerator 100 Mev/u + higher

β-beam

$^6$He

$^{18}$Ne

storage ring
Eurisol Design Study Tasks

1. Proton Accelerator (Alberto Facco, INFN-LNL)
2. Heavy-Ion Accelerator (MH. Moscatello, GANIL)
3. Cryomodule Development (S. Bousson, IPNO)
4. Direct Target/Ion Source (J. Lettry, CERN)
5. Solid Converter-Target/Ion Source (L. Tecchio, INFN-LNL)
6. Liquid-Metal Target/Ion Source (F. Groeschel, PSI)
7. Safety and Radioprotection (D. Ridikas, CEA-Saclay)
8. Beam Preparation (A. Jokinen, JYFL)
10. Beam Intensity Calculations (K.H. Schmidt, GSI)
11. Beta-Beam Aspects (M. Benedikt, CERN)
12. Co-ordination and Layout (Not yet allocated)

• Preparatory meeting for EURISOL design study proposal
• First drafts presented by task coordinators.
Task: Beta Beam Aspects

Starts at exit of heavy ion LINAC (~100 MeV/u) to Decay Ring (~100 GeV/u).

- **Proton Driver**
  - SPL

- **Ion production**
  - ISOL target & Ion source

- **Beam preparation**
  - ECR pulsed

- **Ion acceleration**
  - Linac

- **Acceleration to medium energy**
  - Bunching ring and RCS

- **Acceleration to final energy**
  - PS & SPS

- **Neutrino Source**

- **Decay Ring**
  - $Br = 1500 \text{Tm}$
  - $B = 5 \text{T}$
  - $C = 7000 \text{m}$
  - $L_{ss} = 2500 \text{m}$

  - $^{6}\text{He}$: $\gamma = 150$
  - $^{18}\text{Ne}$: $\gamma = 60$

- **Experiment**

---

Linac

Beam preparation

ECR pulsed

Ion acceleration

Linac

Acceleration to medium energy

Bunching ring and RCS

Acceleration to final energy

PS & SPS

SPS

Decay ring

Neutrino Source

Experiment
Workshop on
PHYSICS
WITH A
MULTI-MW PROTON SOURCE
CERN, Geneva, May 25-27, 2004

The workshop explores both the short- and long-term opportunities for particle and nuclear physics offered by a multi-MW proton source such as a proton linear accelerator or a rapid-cycling synchrotron. This source would provide Muon and Electron Neutrino beams of unprecedented intensity, superior slow Muon and possibly Kaon facilities, as well as a world-leading Radioactive Ion Beam facility for Nuclear, Astro- and fundamental physics.

Scientific Advisory Committee:
J. Äystö (Jyväskylä), R. Alkasaan (Saclay)
M. Baldo Ceolin (Padova), J. Bouchet (Saclay)
E. Caccia (G. Sasso), J. Delaman (Liverpool)
J.-P. Delahaye (CERN), G. Detraz (CERN)
R. Eichler (PSI), J. Engelen (CERN)
J. Fellous (Saclay), E. Fernandez (Barcelona)
G. Fortuna (Legnano), B. Foster (Oxford)
W. Galleth (Surrey), D. Goutte (GANIL)
D. Guerrouj (IN2P3), M. Harask (KVI Groningen)
N. Haseroth (CERN), W. Hemmig (GSI)
E. Isacchi (INFN), B. Jonson (Göteborg)
K. Jungman (KVI Groningen), S. Kayser (Fermilab)
M. Lindner (TU Munich), A. Müller (IPN Orsay)
S. Nagamya (JPARC), H. Napolitano (Napoli)
W. Niewczas (Oscar Ridge), K. Peach (RAL)
R. Pratese (Roma III), F. Ronga (Frascati)
D. Schmitter (CERN), M. Spiro (IN2P3)
I. Tanaka (RIKEN), G. Wyss (CERN)
J. Zan-Justin (DAPNIA)

Programme Committee:
A. Blondel (Geneva), A. Baldini (Pisa),
Y. Blumenfeld (IPN Orsay), P. Butler (CERN),
P. Debou (Saclay), R. Edgecock (RAL), J. Ellis (CERN),
R. Garoby (CERN), U. Gastaldi (Legnano),
H. Lindroos (CERN), V. Palladino (Napoli),
J. Pavan (CERN), G. Prior (RAL),
A. Rubbia (ETN Zurich), P. Schmelzbach (PSI)

Local Organizing Committee:
H. Bonabht (CERN), A. Blondel, P. Butler (co-chair),
L. Ghirardi (CERN), G. Giudice (CERN),
E. Gschwendner (Geneva), H. Lindroos,
V. Palladino (co-chair), M. Vretenar (CERN)

http://physicsatmwwatt.web.cern.ch/physicsatmwwatt/
Muon Complex

BetaRing

Garoby
Haseroth
Lindroos

G. Sasso
0.1 Mton

Proton complex

SPS

2nd generation Radioactive Ion Beam Facility (EURISOL)

PDAC

Neutrino beam to Frejus tunnel

Frejus 1 Mton

EU Neutrino Accelerator Research Complex… E-vARC?
Four coherent phases of EU initiative in neutrino Physics?

2006 2009 2014 >2014

CNGS

EU T2K ... T2H? at J-PARC

R&D targets, horns → CNF at “E-PARC”... CERN ν to Frejus Superbeam Betabeam

R&D cooling, reacceleration → NuFact at “E-PARC”

new CERN ν Complex
Four coherent phases of EU initiative in neutrino Physics?

2006  2009  2014  >2014

CNGS

EU T2K at J-PARC

..... T2H?

R&D targets, horns

CNF at “E-PARC”… CERN ν to Frejus
Superbeam
Betabeam

R&D cooling, reacceleration

NuFact at “E-PARC”

F+I ....

UK
2) Preliminary agenda & general plans

Mon 24 & Tue 25 May … INTC meeting
… ECFA BENE meeting
till lunch

Tue May 25 2 pm General Introductory session Aymar
Accelerator session

Wed May 26 9 am Particle Physics session
2 pm Nuclear Physics session

Thu May 27 morning Outlook session Engelen
… towards Cogne IX …
1) AGREEMENT BETWEEN DSM/CEA, IN2P3/CNRS AND INFN TO PROPOSE A NEW FREJUS LARGE UNDERGROUND LABORATORY IN VIEW OF A JOINT FREJUS-GRAN SASSO EUROPEAN UNDERGROUND FACILITY

Considering

- the successful experience of DSM, IN2P3, and INFN over the last decades in the field of particle, astroparticle and nuclear physics based on the respective laboratories of Fréjus and Gran Sasso

- the long-standing tradition in scientific cooperation between CNRS, DSM and INFN which have led to outstanding achievements such as the European Gravitational Observatory (CNRS/INFN) and the solar neutrino experiment GALLEX (DSM/INFN) in Gran Sasso

- the need to extend the present deep underground multidisciplinary infrastructures

The DSM, IN2P3 and the INFN agree to prepare the design of a very large underground laboratory in the new Fréjus tunnel, with complementary features with respect to the Gran Sasso laboratory, to be submitted as a joint proposal to the French and Italian governments.

The Institutions aim at associating the Fréjus and Gran Sasso laboratories in a single entity, a European Joint Laboratory, open to the world scientific community to carry out advanced experiments in particle, astroparticle and nuclear physics in the coming decades, on topics such as matter stability, neutrino mixing and mass, stellar collapses and nuclear astrophysics.

The unique location and the silent environment in term of particle and seismic noise of the underground infrastructures are suitable to carry out activities of interest in other fields such as nano-science and technology, environment, biology, and geo-physics.

The Institutes have set up a joint study group to start the design activity.

CEA/DSM
Prof. F. Gounand

IN2P3/CNRS
Prof. M. Spiro

INFN
Prof. E. Iarocci
2) This «Joint study group», to start the design activity for the New Laboratory, has been formed at January 14th, with the following members:

Stavros KATSANEVAS, Deputy Scientific Director IN2P3/CNRS
Gabriele PUGLIERIN, Member of the Directory Council of the INFN
Eugenio COCCIA, Director of the Gran Sasso Laboratory
Luigi MOSCA, in charge of the Fréjus Projects
Gilles GERBIER, Director of the present Fréjus (LSM) Laboratory
Christian CAVATA, CEA-Saclay
Mauro MEZZETTO, INFN-Padova

3) A «white paper» on this project is in preparation under the responsibility of this Joint study group.

4) At March 10th an official meeting of this group, in presence of the Heads of the Institutions (CEA/DSM-IN2P3/CNRS and INFN) will take place at the Gran Sasso Laboratory, with a press release, etc.

5) An International Workshop is planned at Aussois (near to the Fréjus site), possibly in May this year, to review this type of projects at the world scale.

6) A preliminary (feasibility) study is already funded (120 k€) by:
   - the 3 Institutions (DSM/IN2P3/INFN)
   - the two Fréjus border Regions (Rhône-Alpes and Piemonte)
   - the two Fréjus Road-Tunnel Companies (SFTRF / SITAF)
White paper

A megaton scale detector in Frejus, a physics and astrophysics observatory with interdisciplinary implications

International workshop:

The physics and logistics of a Megaton detector

Paris 11-12 June (Before Neutrino 2004)

Themes

- Proton decay
- Astrophysics cosmology (supernovae, GRB, galactic center?)
- Understanding the sun and the cosmic rays (solar and atmospheric neutrinos)
- Monitoring of nuclear reactors
- Exploring the matter antimatter asymmetry with accelerator neutrinos from CERN
- Study of the earth interior (geophysics, hydrology, biology, seismology)
- Early warning network
- Technology (cavity, materials, photodetectors, distributed intelligence systems)
- International situation
- Organisation, MC etc....

UNO +HK +Frejus a world wide group?
EU accelerator ν may be emerging from their long crisis

May well be heading towards a new wave of initiative

particularly in the area addressed by this Workshop

Neutrino Super & Beta Beams, Detectors & Proton Decay

will know much more within 1 year

Workshop May 25-27 CERN .................. Mwatts
Workshop Jun 11-12 Paris ................. Mtons

mid 04 – approval of Eurisol/Betabeam Design Study?
Strategic SPSC Cogne IX (Villars, CH, Sep 22-28)

mid 05 – approval of SuperBeam/NuFact Design Study?
– approval of Megaton u-ground Lab Design Study?

se son rose ........ fioriranno
The end .... Rest is reserve slides
So far emerging from their long crisis

History: Before and during the crisis including HARP, MICE, TOF\n
Still to prepare

What is new? CARE etc
franco-italian agreement
EURISOL+Betabeam DS
Villars and beyond

What next?
Workshop in May
Workshop in June
DS in 2006-2009 for Beams and Caver\n
se son rose ........ fioriranno
The physics of ν transitions is proving extremely rewarding and demands long term experimentation with accelerator ν.

EU accelerator ν are an endangered species.

may extinguish after CNGS & upgrades

a strong initiative is needed

thrive on the richness of options: Superbeams, NuFact, Betabeam + specific detectors

Preliminary conclusion: all options very promising

to first comparative appraisal

NuFact most attractive & challenging

Preliminary road map: head towards it!

pursue NuFact R&D ...

driver, target, collection .... μ complex

have CDR ready by LHC startup

A LARGE & EARLY FRACTION OF THE EFFORT IS COMMON

build a Superbeam along the way? almost free

combine them with a Betabeam?

may exploit sinergies with CERN & EURISOL & GSI
Table 8.2.2a: List of contracting participants

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Table 8.N2.2b: List of associated institutes

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world wide context ... road maps

accelerator and particle physics ...

from theory to detectors
Table 3: Detailed expected and requested budget breakdown.  
(The sums do not include UNI-GE and PSI, participants from Switzerland)

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<td>45,2</td>
</tr>
<tr>
<td>CSIC</td>
<td>AC 37,2</td>
<td>74,8</td>
<td>26,5</td>
<td>0,0</td>
<td>0,0</td>
<td>0,0</td>
<td>0,0</td>
</tr>
<tr>
<td>UCLN</td>
<td>AC 6,2</td>
<td>5,8</td>
<td>2,1</td>
<td>0,0</td>
<td>0,0</td>
<td>0,0</td>
<td>0,0</td>
</tr>
<tr>
<td>SUM per WP(KEuros)</td>
<td>445,9</td>
<td>154</td>
<td>199</td>
<td>71</td>
<td>196</td>
<td>70</td>
<td>120</td>
</tr>
</tbody>
</table>
A possible Road Map

MW P driver

MW Target & Collector R&D

Muon IonizationCooling R&D (MICE)

Muon Acceleration & Storage R&D

NuFact +LMD

C & possibly T

MSW Matter Effects

Superconducting Proton Linac
(few GeV/c)

aim at CDR by LHC startup!
A possible Road Map

Radioactive Ion Beams R&D

Muon Acceleration & Storage R&D

Radioactive Ion Beams R&D

Muon Ionization Cooling R&D (MICE)

Conventional

\[ \nu_\mu \rightarrow \nu_e \] 

\[ \text{BetaBeam} \]

\[ \text{Ne}^{18} \rightarrow \nu_e \]

\[ \text{He}^6 \rightarrow \bar{\nu}_e \]

\[ \theta_{13} \] & maybe CP

\[ \text{N decay!} \]

\[ \text{SuperNovae Obs.!} \]

Conventional

\[ \nu_\mu \rightarrow \nu_\mu \]

\[ \pi^+ \rightarrow \nu_\mu \]

\[ \pi^- \rightarrow \bar{\nu}_\mu \]

Physics at new large u/ground lab
500 Kton Water Cerenkov?
50 kton Li A?

\[ 2 \times \text{CNGS} !!!!!!!!!!!!!!! \]

SuperBeam,

\[ \text{NuFact +LMD} \]

\[ \text{CP} \]

\[ \text{T} \]

\[ \text{CPT} \]

\[ \text{CP} \] & possibly T

\[ \text{MSW Effects} \]

Superconducting Proton Linac
(few GeV/c)
WP3

Targetry
(the most dangerous potential show stopper)

Many difficulties: enormous power density
⇒ lifetime problems
pion capture

Replace target between bunches:

Liquid mercury jet or rotating solid target

Proposed rotating tantalum target ring

Stationary target:

Densham

Sievers
Hg-jet system

- Power absorbed in Hg-jet: 1 MW
- Operating pressure: 100 Bar
- Flow rate: 2 t/m
- Jet speed: 30 m/s
- Jet diameter: 10 mm
- Temperature:
  - Inlet to target: 30° C
  - Exit from target: 100° C
- Total Hg inventory: 10 t
- Pump power: 50 kW
Jet test a BNL E-951

Event #11  25th April 2001

K. Mc Donald, H. Kirk, A. Fabich

P-bunch:  $2.7 \times 10^{12}$ ppb
100 ns
$t_o = \sim 0.45$ ms

Hg- jet:  diameter 1.2 cm
jet-velocity  2.5 m/s
perp. velocity  $\sim 5$ m/s

Protons

Picture timing [ms]

0.00
0.75
4.50
13.00
Conclusions

High-power Target for Future Accelerators,
Ronkonkoma, NY, September 8-12, 2003
H. Kirk

- New physics opportunities are demanding more intense proton drivers.
- 1 MW machines are almost here! 4 MW machines are planned.
- Targets for 1 MW machines exist but are unproven.
- But no convincing solution exists yet for the 4 MW class machines.
- Worldwide R&D efforts underway to develop targets for these new machines.
- A key workshop concern was the lack of worldwide support facilities where promising new ideas can be tested.
A Letter of Intent to the ISOLDE and Neutron Time-of-Flight Experiments Committee

Studies of a Target System for a 4-MW, 24-GeV Proton Beam

J. Roger J. Bennett\textsuperscript{1}, Luca Bruno\textsuperscript{2}, Chris J. Densham\textsuperscript{1}, Paul V. Drumm\textsuperscript{1}, T. Robert Edgecock\textsuperscript{1}, Helmut Haseroth\textsuperscript{2}, Yoshinari Hayato\textsuperscript{3}, Steven J. Kahn\textsuperscript{4}, Jacques Lettry\textsuperscript{2}, Changguo Lu\textsuperscript{5}, Hans Ludewig\textsuperscript{4}, Harold G. Kirk\textsuperscript{4}, Kirk T. McDonald\textsuperscript{5}, Robert B. Palmer\textsuperscript{4}, Yarema Prykarpatsky\textsuperscript{4}, Nicholas Simos\textsuperscript{4}, Roman V. Samulyak\textsuperscript{4}, Peter H. Thieberger\textsuperscript{4}, Koji Yoshimura\textsuperscript{3}

Spokespersons: H.G. Kirk, K.T. McDonald
Local Contact: H. Haseroth

Participating Institutions

1) RAL
2) CERN
3) KEK
4) BNL
5) Princeton University

Target Test Area

DS
High Field Pulsed Solenoid

- 70\(^\circ\) K Operation
- 15 T with 4.5 MW Pulsed Power
- 15 cm warm bore
- 1 m long beam pipe

Peter Titus, MIT
Possible Experiment Location at CERN

WP3(TARGET) and WP4 (COLLECTOR)

ie target area & surroundings

 together ........

essentially just as decisive
to make MW power useful

DS ... collector test facility at Orsay
Pion Capture: Solenoid
Pion Capture: Horn

Protons

Current of 300 kA

To decay channel

$\pi$

$B \propto 1/R$

$B = 0$

Gilardoni
Shielding around the T1 Kaon Target

Concrete shield block

Service space: 2m(W) × 1m(H)

Iron shield

Concrete shield

Beam

Water pump

T1 container

~18m

~10m

Beam ~10m

T1 container

an example among many
WP5 Novel neutrino beams

dissemination

R&D proposals

Design studies

NuFact Front end … cooling, phase rotation etc … MICE

NuFact Back end … acceleration (RLA, FFAG), storage

Betabeam …. Design study within Eurisol
The ideal muon accelerator is a LinAc filled with matter ………

**Ionization Cooling : the principle**

**Liquid H₂: dE/dx**

Beam

RF restores only $P_{\parallel}$: E constant
A major relief, recently

**Decay losses**

- Losses during acceleration are being studied:
  - Full FLUKA simulations in progress for all stages (M. Magistris, CERN-TIS)
  - Preliminary results:
    - Can be managed in low energy part
    - PS will be heavily activated
      - New fast cycling PS?
    - SPS OK!
  - Full FLUKA simulations of decay ring losses:
    - Tritium and Sodium production surrounding rock well below national limits
    - Reasonable requirements of concreting of tunnel walls to enable decommissioning of the tunnel and fixation of Tritium and Sodium

A. Jansson