Activities towards future accelerator-based neutrino facilities in Europe

1. little historical perspective

2. general situation with neutrinos in Europe and a possible road-map

3. EMCOG

4. Main objectives and realizations
   - SPL
   - target Collection
   - MICE
   - Beta-beam
   - design study strategy

5 upcoming events (besides MICE)
   - Megawatt workshop
   - Preparation of EU FP6 design study proposal
   - Preparation of world design study

A few dates (EU-view)

1997: Bruno Autin begins discussion groups about muon collider @ CERN
1997: Workshop on physics at the front-end of a muon collider @ Fermilab
concept of neutrino facility based on muon storage ring (Geer)
1998: SuperKamiokande declares 'neutrino oscillations are established'
1998: ECFA sponsored 'prospective study of muon storage rings in Europe'
==> the high intensity + muon 'line' offers
'many fundamental experiments for many years'
Realization that observation of CP violation by neutrinos is possible!

1999: CERN mandates Helmut Haseroth to assemble Neutrino Factory Working Group
with budget expected up to 1/3 of CERN R&D budget (7MCHF/Yr)
First NUFACT Workshop (Autin/AB + Wojcicki/Wurtele) in Lyon
Peter Gruber creates NUFACT logo
2000: Fermilab-sponsored Study I
2001: BNL-sponsored Study II ---> comes out with first serious cost estimate
for a Neutrino Factory producing 10^{21} muons of 20 GeV per year (~2 B$)
2001: Snowmass 'consensus' for linear collider -- ECFA WG gives LC first priority
2001: CERN budget crisis, accelerator R&D is cut by 1/3 and concentrated on CLIC

2002: EMCOG is created to promote European collaboration for Neutrino R&D
2003: CARE (Coordinated Accelerator R&D in Europe) is proposed and approved
(includes High intensity proton injector and BENE network)
Steering group for World Design Study III is created
MICE experiment is approved … subject to gateway process (i.e. funding)

ECFA recommendations (September 2001:)

4) an improved educational programme in the field of accelerator physics and increased support for accelerator R&D activity in European universities, national facilities and CERN.

For the long-term:

5) a co-ordinated collaborative R&D effort to determine the feasibility and practical design of a neutrino factory based on a high-intensity muon storage ring;

European Muon Concertation and Oversight Group (EMCOG)

CERN:	Carlo Wyss (Chair), Helmut Haseroth, John Ellis
CEA-DAPNIA	Pascal Debu, François Pierre
IN2P3	Stavros Katsanevas, Jacques Dumarchez
INFN	Marco Napolitano, Andrea Pisent
GSI	Oliver Boine Frankenhein, Ingo Hofman
PSI	Albin Wrülich
Geneva	Alain Blondel
RAL	Ken Peach, Rob Edgecock
PPARC	Ian Haliday, Ken Long

EMCOG (European Muon Concertation and Oversight Group) FIRST SET OF BASIC GOALS

The long-term goal is to have a Conceptual Design Report for a European Neutrino Factory Complex by the time of JHF & LHC start-up, so that, by that date, this would be a valid option for the future of CERN.

An earlier construction for the proton driver (SPL + accumulator & compressor rings) is conceivable and, of course, highly desirable.
The SPL and targetry and horn R&D have therefore to be given the highest priority.

Cooling is on the critical path for the neutrino factory itself; there is a consensus that a cooling experiment is a necessity.

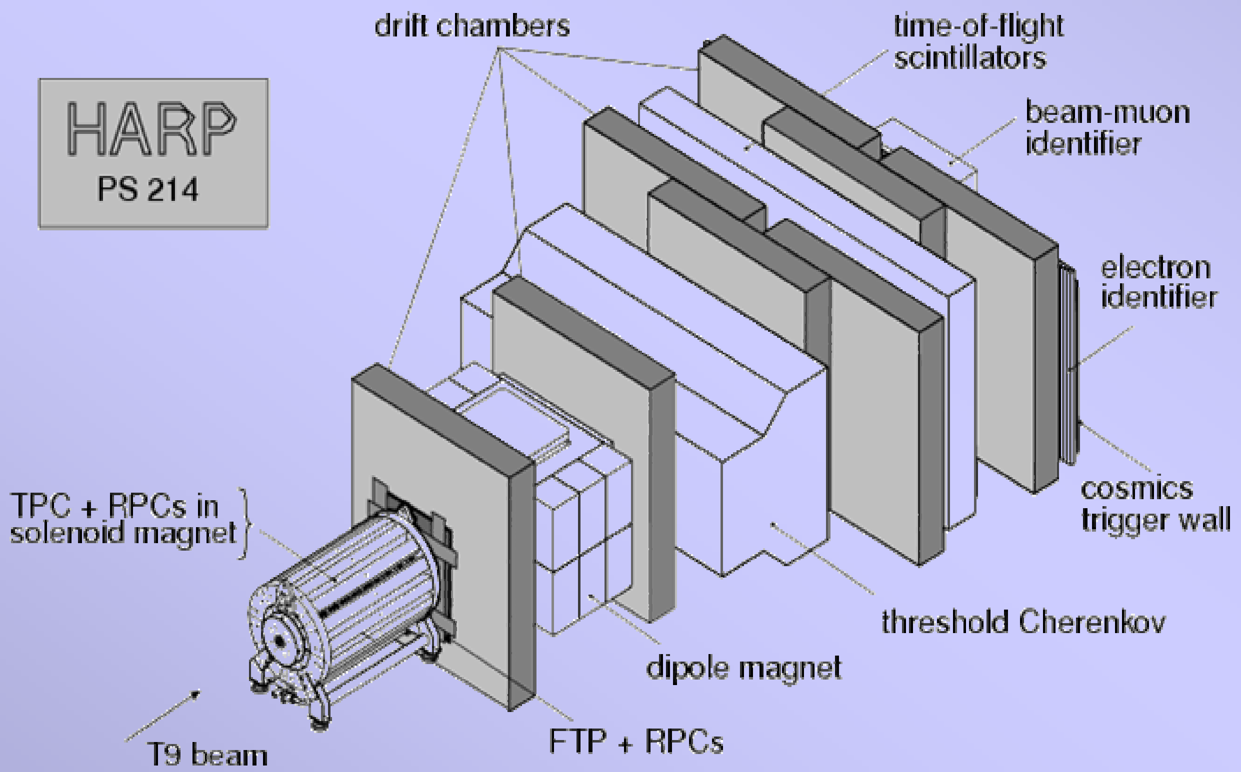
The emphasis should be the definition of
practical experimental projects with a duration of 2-5 years.
Such projects can be seen in the following areas:

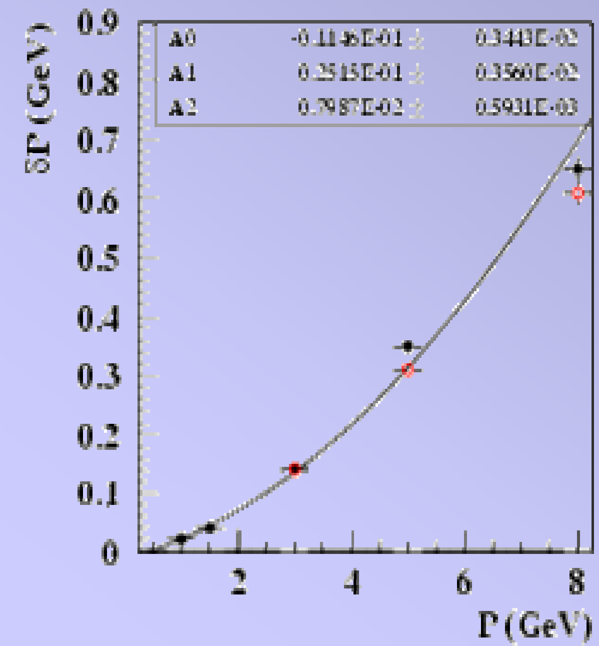
1. **High intensity proton driver.**
2. **Target studies**
3. **Horn studies**
4. **Muon Ionization Cooling**
5. **Beta-beam study**

HARP, which was the first such project started in 1999 produced first physics results in Moriond (MARCH 04)

The HARP experiment

HARP
PS 214





Spectrometer resolution

124 people

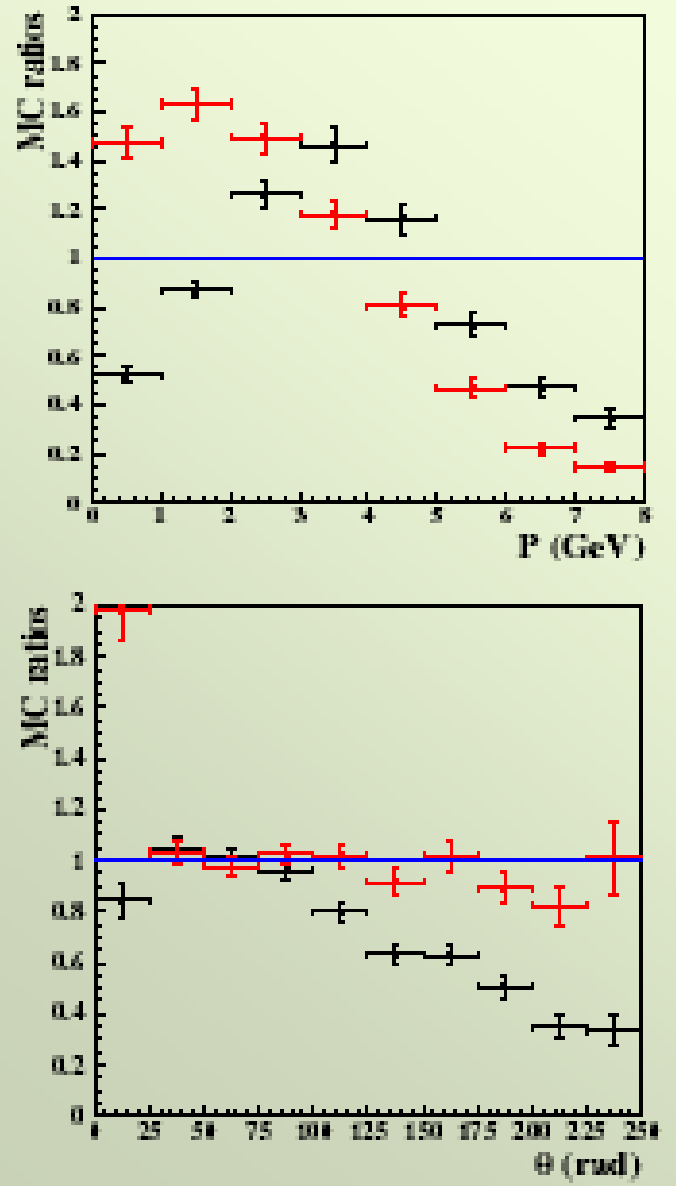
24 institutes

HARP Physics goals

- Systematic study of
  HAdRon Production:
  - Beam momentum: *1.5-15 GeV/c*
  - *mostly protons*
  - Target: *from hydrogen to lead*

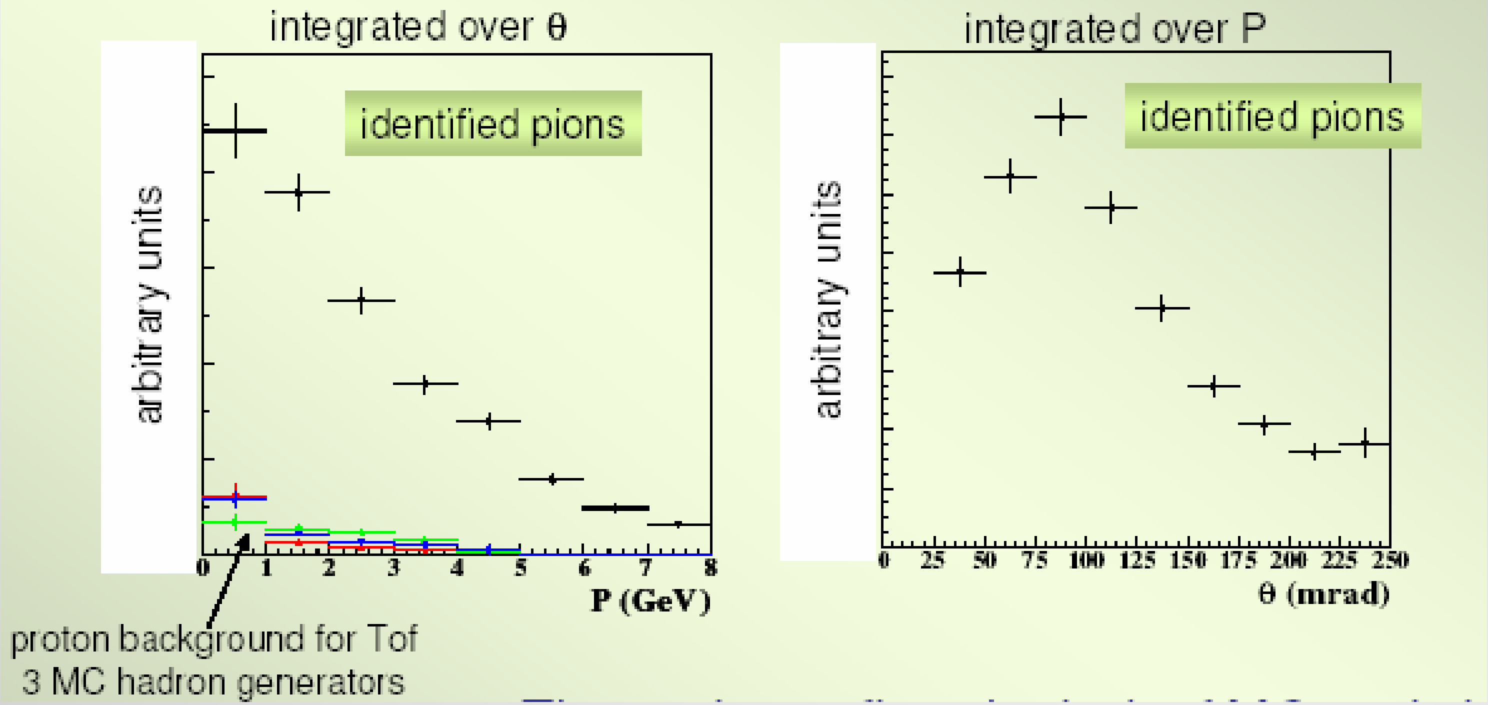
- Motivation:
  - Pion/kaon yield for the design of the proton driver of *neutrino factories* and SPL-based *superbeams*
  - Calculation of *atmospheric neutrino flux*
  - Prediction of neutrino fluxes for the *MiniBooNE* and *K2K* experiments
  - Input for *Monte Carlo* generators (GEANT4,for LHC, space applications)

Physical differences between had generators:



First HARP Physics results

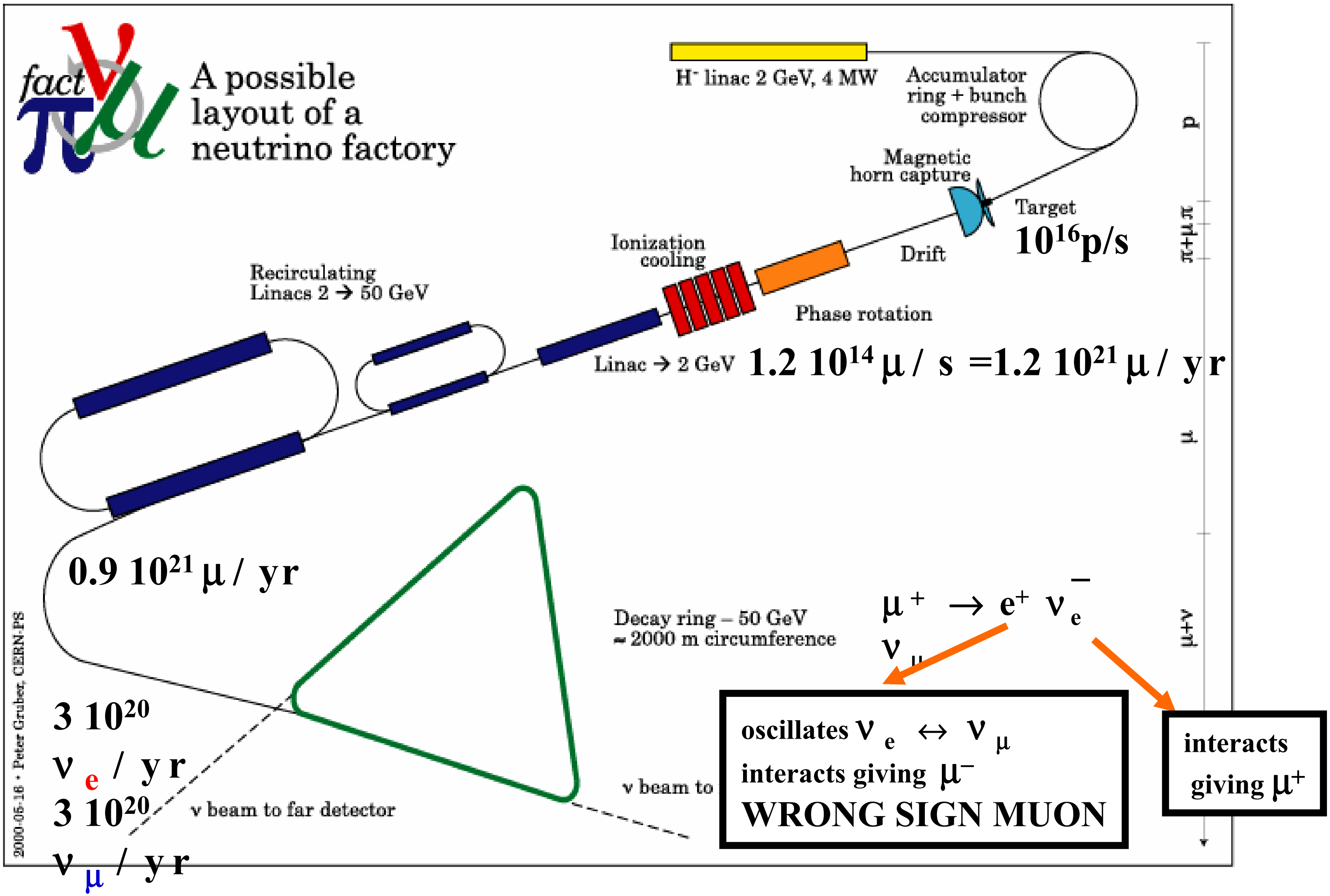
FIRST RESULTS = unnormalized momentum distributions for K2K target



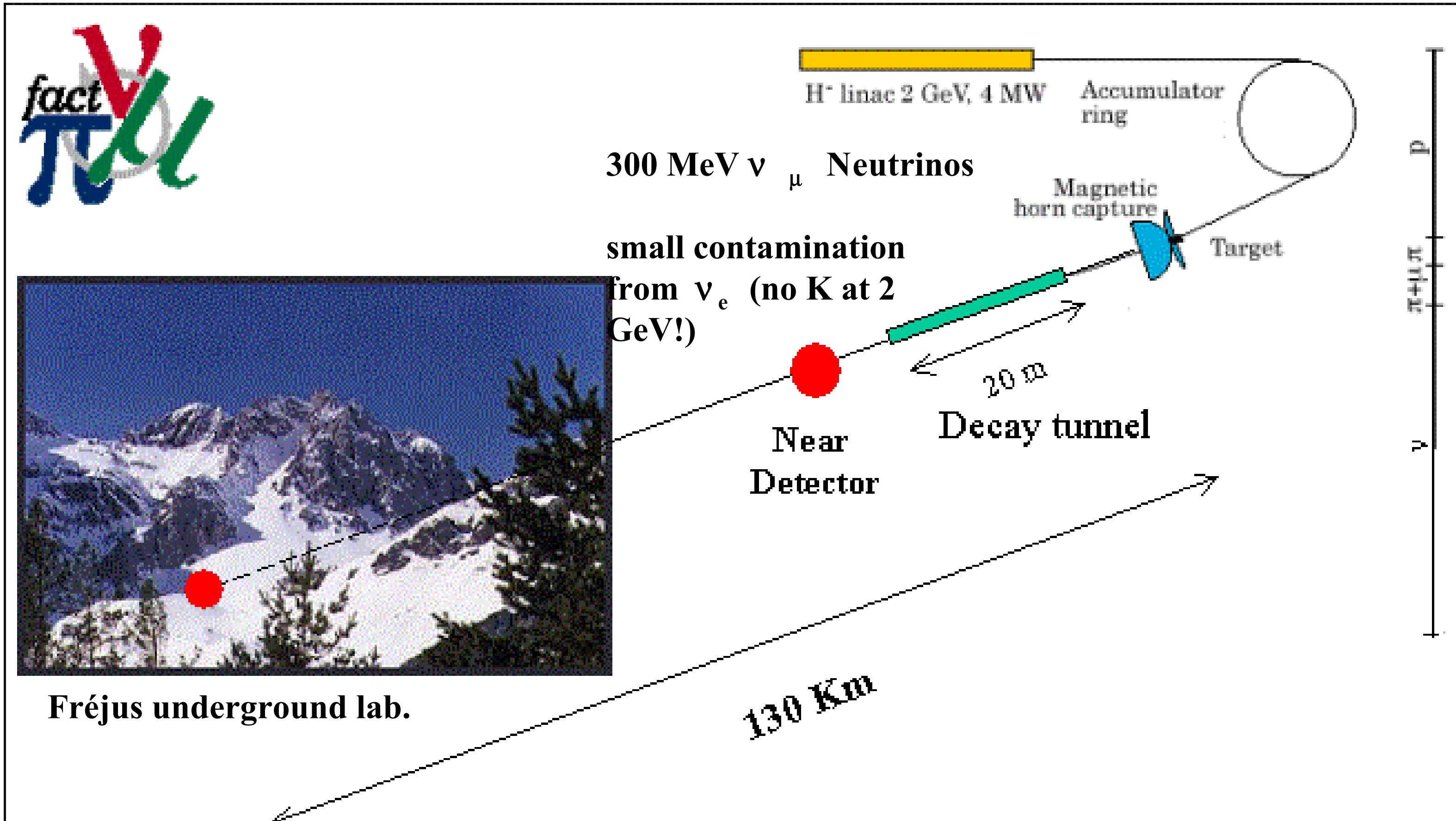
12.9 GeV/c beam Aluminum rod

Large errors reflect lack of Monte-Carlo statistics

-- Neutrino Factory --
CERN layout



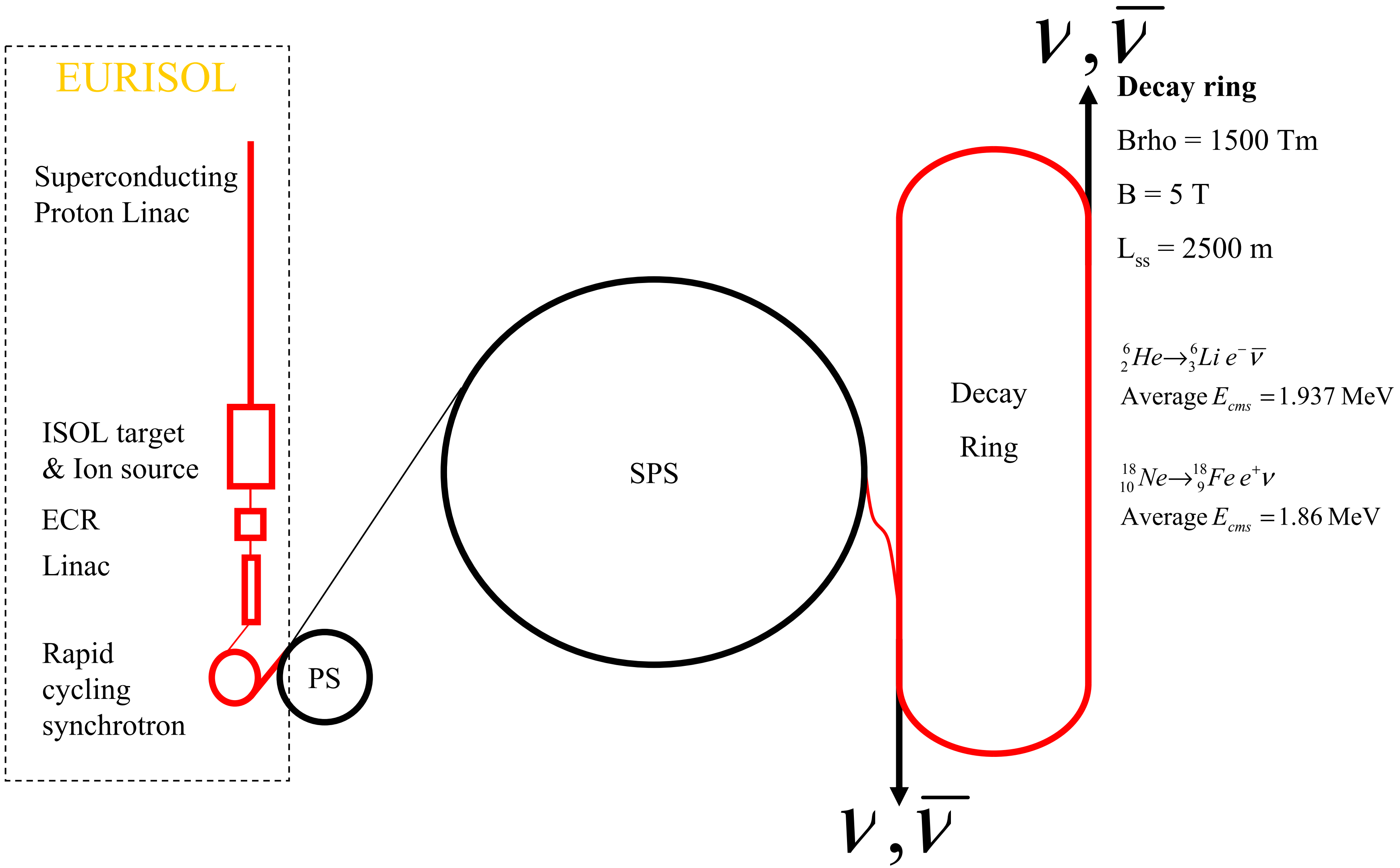
Possible step 0: Neutrino SUPERBEAM



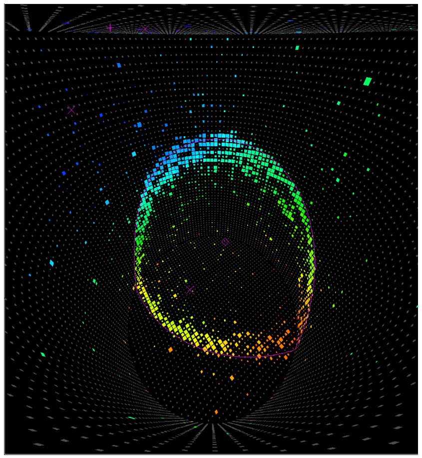
Fréjus underground lab.

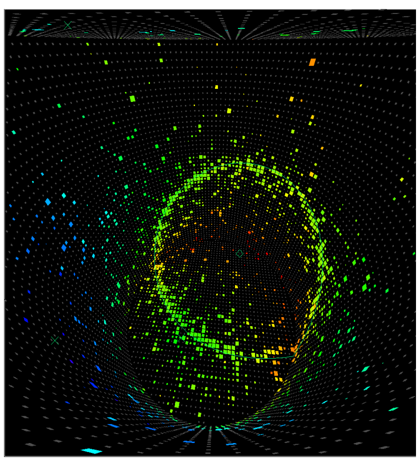
A large underground water Cerenkov (400 kton) UNO/HyperK or/and a large L.Arg detector.
also : proton decay search, supernovae events solar and atmospheric neutrinos. Performance similar to J-PARC II
There is a window of opportunity for digging the cavern stating in 2008-9 (safety tunnel in Frejus)

CERN: β -beam baseline scenario



Combination of beta beam with low energy super beam





Unique to CERN:

combines CP and T violation tests

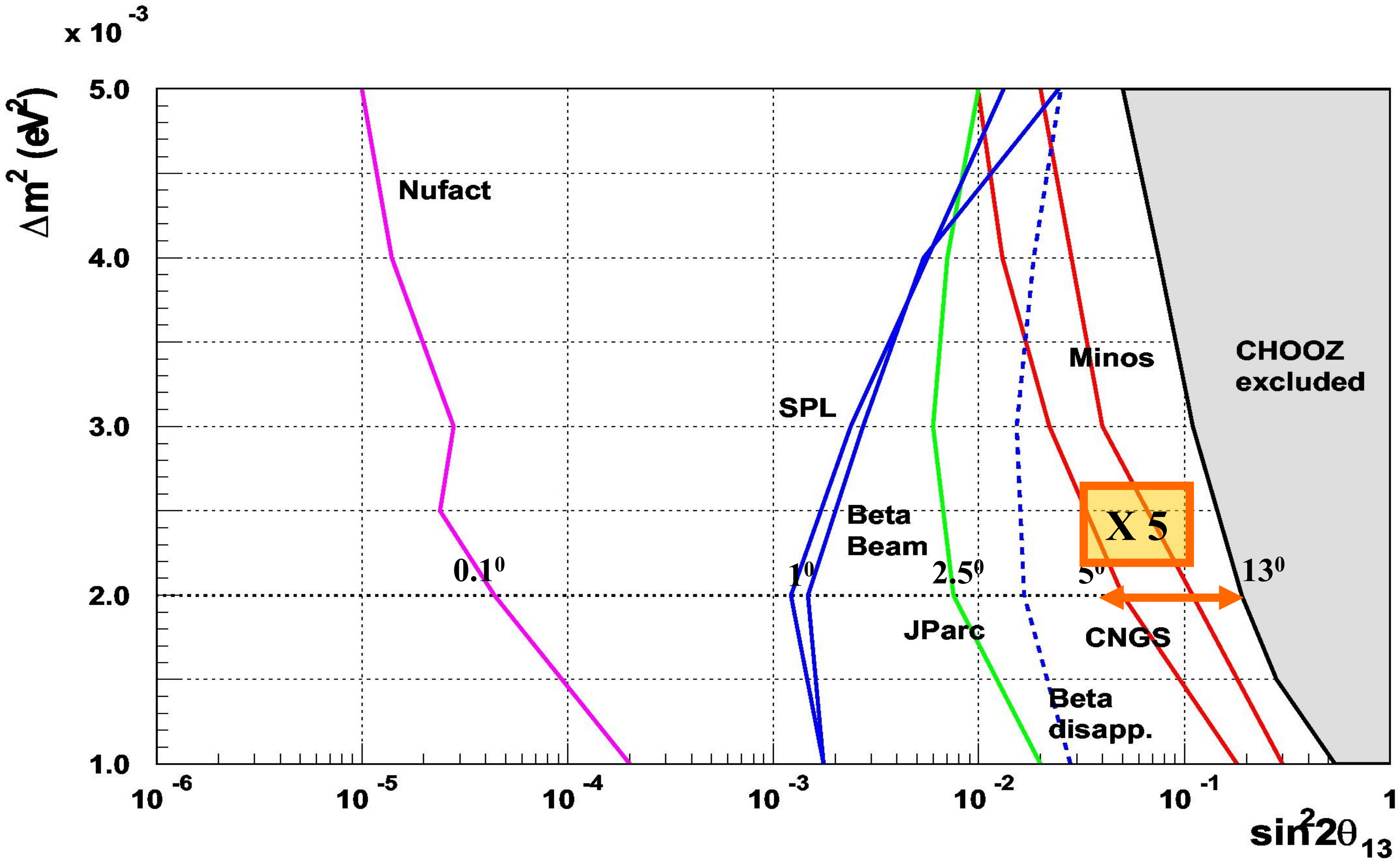
$\nu_e \rightarrow \nu_\mu$ $(\beta+)$ ⟷ T ⟷ $\nu_\mu \rightarrow \nu_e$ (π^+)

CP ⇕ CP

$\overline{\nu}_e \rightarrow \overline{\nu}_\mu$ $(\beta-)$ ⟷ T ⟷ $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ (π^-)

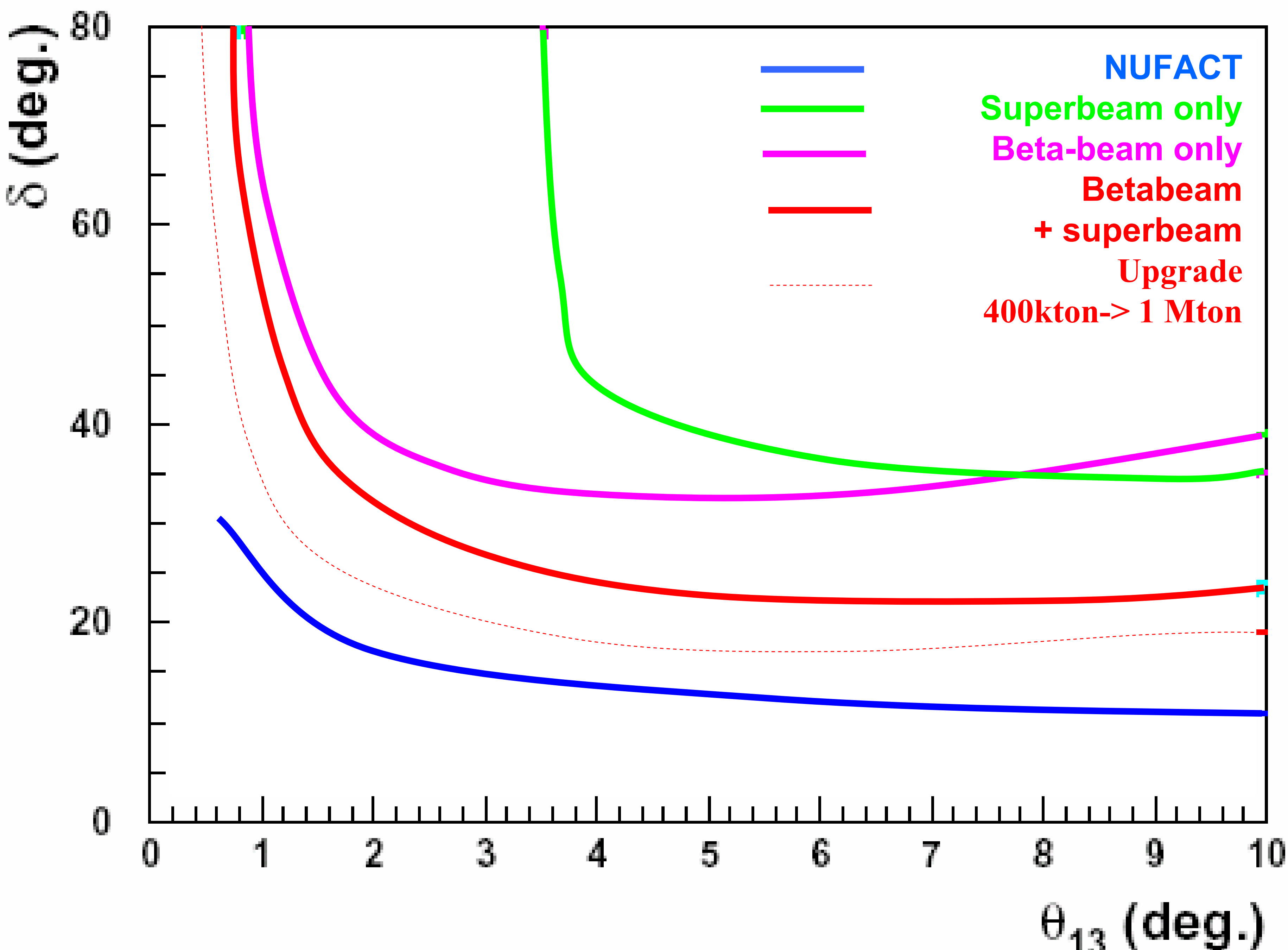
A. Blondel

Where will this get us…



Mezzetto

comparison of reach in the oscillations ; right to left:
present limit from the CHOOZ experiment,
expected sensitivity from the MINOS experiment, CNGS (OPERA+ICARUS)
0.75 MW JHF to super Kamiokande with an off-axis narrow-band beam,
Superbeam: 4 MW CERN-SPL to a 400 kton water Cerenkov in Fréjus (J-PARC phase II similar)
from a Neutrino Factory with 40 kton large magnetic detector.



δ (deg.)
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
θ13 (deg.)
NUFACT
Superbeam only
Beta-beam only
Betabeam
+ superbeam
Upgrade
400kton-> 1 Mton

possible road map:

1. establish case for a high intensity proton driver

2. make sure target and collection systems are studied

(These are the first steps towards a neutrino factory!)

3. take advantage of large underground lab. opportunity to do competitive neutrino oscillation physics (and more)

4. make sure that the crucial feasibility experiments for the more powerful beta-beam and neutrino factory are done (i.e. MICE).

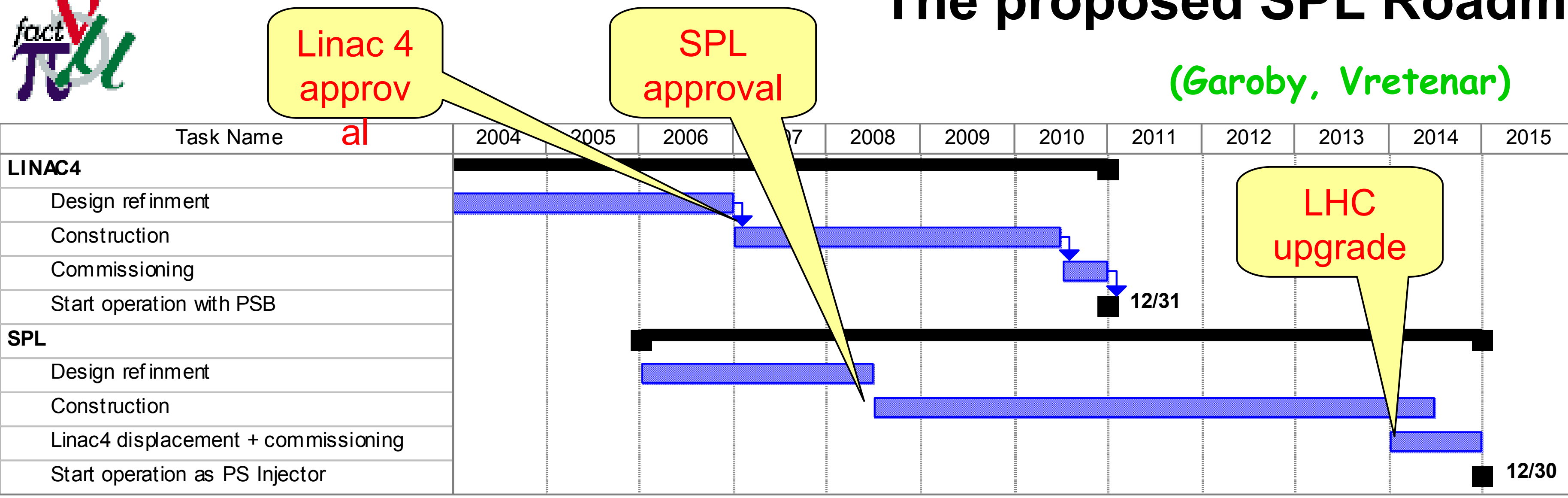
Nufact is always more precise

and offers $\nu_e \leftrightarrow \nu_\tau$ silver channel

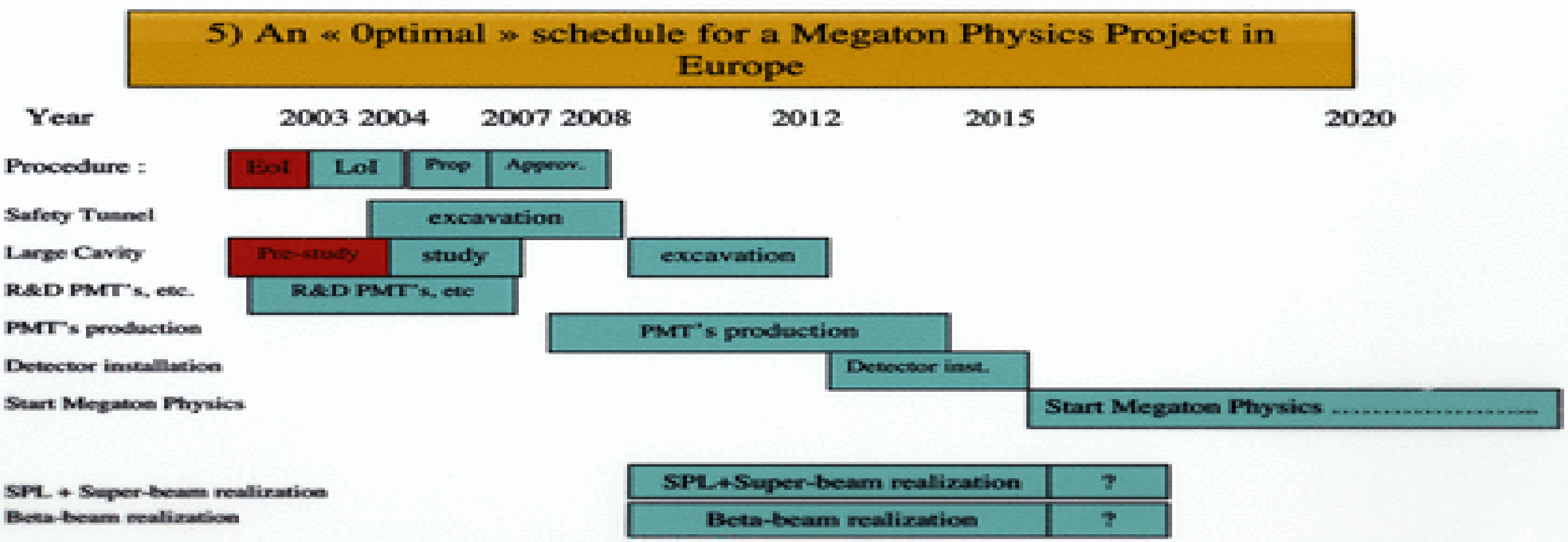
(intensity and energy ARE needed!)

The proposed SPL Roadmap

(Garoby, Vretenar)



18



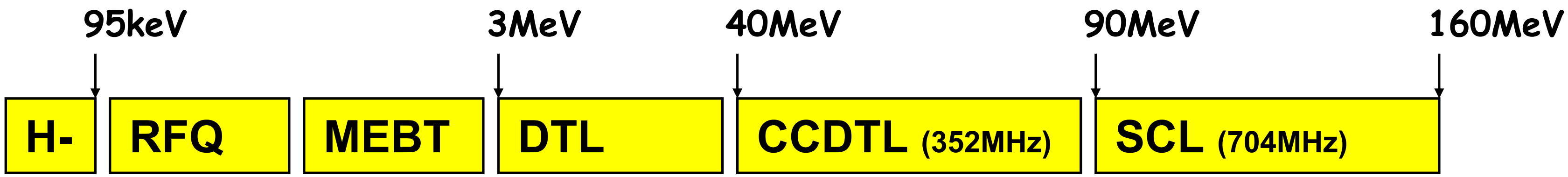
SPL Status and Plans

OUTLINE :

1. A strategy towards high intensity accelerators at CERN
   New SPL Layout and LINAC IV
2. Strengthening the international collaborations
   The CERN-IPHI Collaboration
   The HIPPI Joint Research Activity in CARE
   The ISTC-funded Russian collaborations
3. Boosting the R&D effort
   The 3 MeV test stand
   The chopper line
   The structure development

(Garoby, Vretenar)

Evolution of the SPL design



- The Linac4 design now includes a section at 704 MHz (90-160 MeV) to reach efficiently the 160 MeV energy.
- The technology of the LEP cavities is aging, the know-how for sputtering is disappearing. Conversely, the technology for high-gradient bulk Nb cavities is progressing fast and is supported by many labs.
- Many requests for the LEP klystrons from other labs.

In conclusion, the future design of the SPL will be based on 704 MHz bulk-Nb cavities. No SC LEP cavities will be used anymore.
A new conceptual design (shorter linac!) will be prepared in 2004.
The LEP RF will be still used efficiently for the low-energy part of the SPL.

(Garoby, Vretenar)

Preliminary HIP Conclusions 3

Intermediate report:

• **Case 3 (optimum improvements – different options, Linac4 has the highest potential)**

- 0.9 s basic period
- Double PSB batch for CNGS (**8.6×10^{13} ppp (!) in SPS**)
- Linac 4 (**6.4×10^{13} ppp for ISOLDE + single PSB batch for LHC & CNGS**)

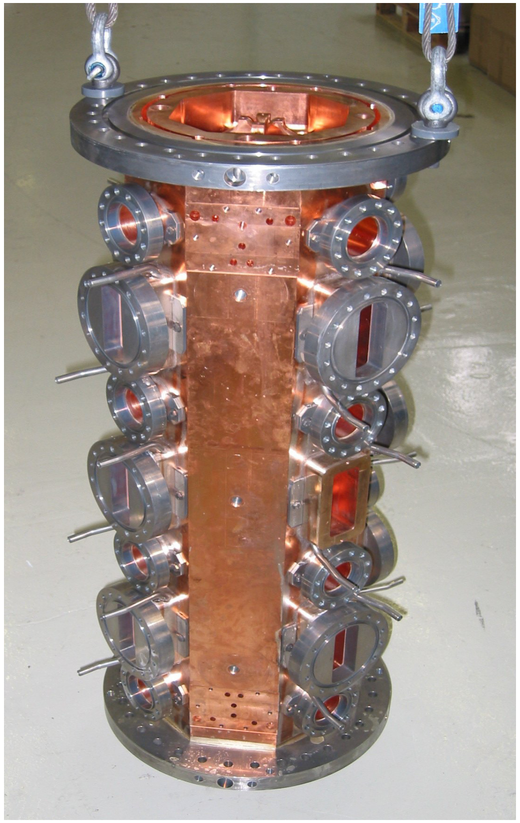
	0.9 s basic period	0.9 s basic period + Double PSB batch for CNGS	0.9 s basic period + Linac 4
LHC	OK (23.4 s supercycle)	OK (25.2 s supercycle)	OK (17.1 s supercycle)
CNGS	Flux × 0.95	Flux × 1.8	Flux × 1.8
ISOLDE	Flux × 1.6	Flux × 1.65	Flux × 3.9 (1.95×2)
Comments	- Shorter SPS porch	- Shorter SPS porch	- Shortest SPS & LHC porches, - Simple operation, margin - Potential for LHC upgrade

(Garoby, Vretenar)

The CERN - IPHI Collaboration

IPHI = Injecteur de Protons Haute Intensité

- The IPHI RFQ (originally 5MeV, 100 mA CW) modified to be used as injector for Linac4 – SPL (3 MeV, lower duty) after a CW test at Saclay. CERN will do all the brazings.
- First section (prototype) finished, contract is ready for the machining of the remaining 5 sections.
- Uncertainties due to the unclear financial situation in France, but both CEA and IN2P3 expressed their continuing support for the project (IN2P3 ready to contribute for the missing CEA contribution in 2004).
- An addendum to the MoU is ready and will be signed when the financial situation will be clear: CEA and IN2P3 will finally offer to CERN the RFQ with related equipments and electronics, and will lend a large fraction of the measurement line to be used on the test stand.



(Garoby, Vretenar)

HIPPI and CARE

HIPPI = High Intensity Pulsed Proton Injector, concentrates on the R&D for pulsed linacs in the energy range 3 to 200 MeV (i.e. after RFQ).
Pools together the efforts of RAL, GSI, IAP-FU, FZJ, INFN-MI, CEA, IN2P3 (Grenoble and Saclay) and CERN.
Aims at deloping common solutions for the upgrade of the CERN, RAL and GSI injectors.

From the Evaluation summary report:

"This JRA addresses issues that are basic and necessary to solve. Several fields do benefit from this research and existing accelerators (e.g. CERN, RAL) would be able to increase their intensity if appropriate injectors were made available. The issues are appropriately addressed in the proposal. The deliverables are clear and should be guaranteed by the end of the funding cycle. Since superconducting structures are addressed integration with JRA1 and JRA2 is encouraged. … we think that the resources for this activity are adequate."

90% of the requested funds have been allocated (3.6 MEUR over 5 years)

(Garoby, Vretenar)

ISTC Collaborations

INTERNATIONAL SCIENCE & TECHNOLOGY CENTER

I S T C

М Н Т Ц

STATUS OF PROJECTS (2 years)

1. BINP + VNIITF
   - *Subject: "Development of the technological basis for serial production of CCDTL structures in the energy range of 40-100 MeV for the SPL project. Feasibility study of effective application of normal conducting CCL structures up to the energy of 150-180 MeV. "*
   - **Cost: k$ 550**
   - **Status: approved (10/2003) & starting**
2. ITEP + VNIIEF
   - *Subject: "Development of Alvarez-type accelerating structures for the room-temperature part of the CERN SPL project."*
   - **Cost: k$ 498**
   - **Status: approved (03/2004)**
3. IHEP + VNIIEF
   - *Subject: "Design and manufacture of DTL-RFQ focusing and accelerating structure prototype for a 3-40 MeV H- linac of the SPL project."*
   - **Cost: k$ 500**
   - **Status: approved(03/2004)**

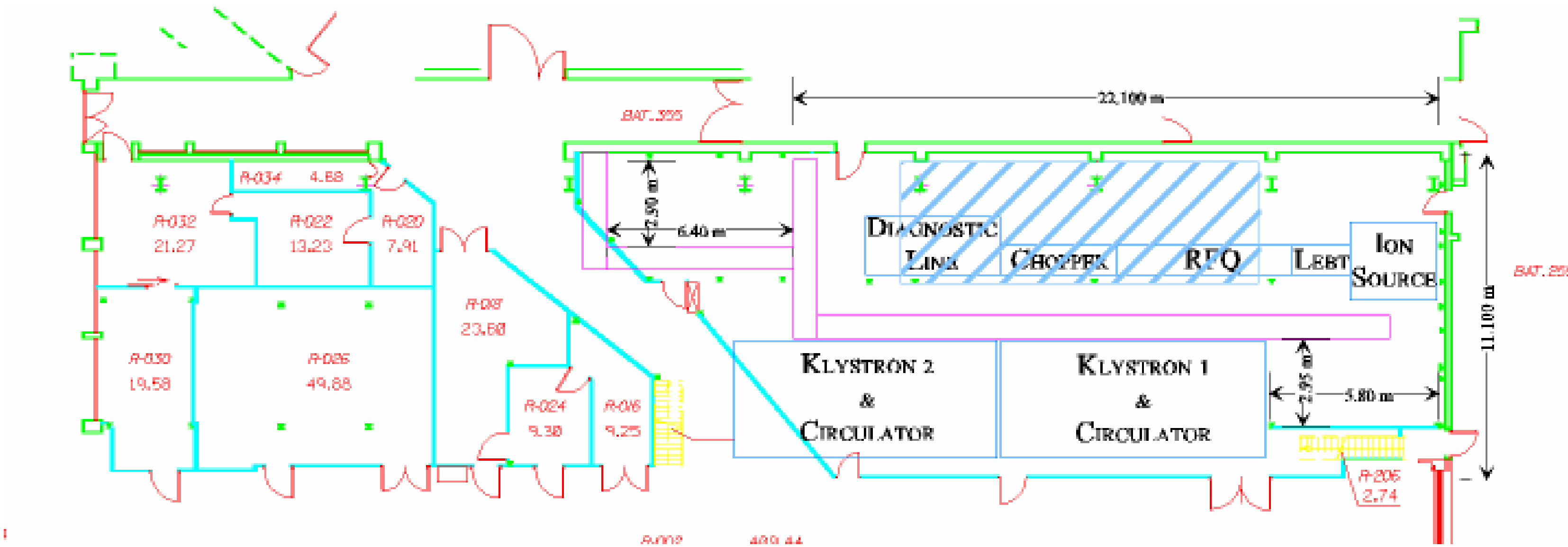
(Garoby, Vretenar)

Other collaborations

- Collaboration with India (will send people interested to learn technology for high-intensity linac).
- Possible collaborations to profit from LEP material being given to other laboratories: GSI is going to develop low duty cycle modulators to be used with the LEP klystrons and is considering to compensate with some modulators for Linac4 the acquisition of the LEP klystrons.

(Garoby, Vretenar)

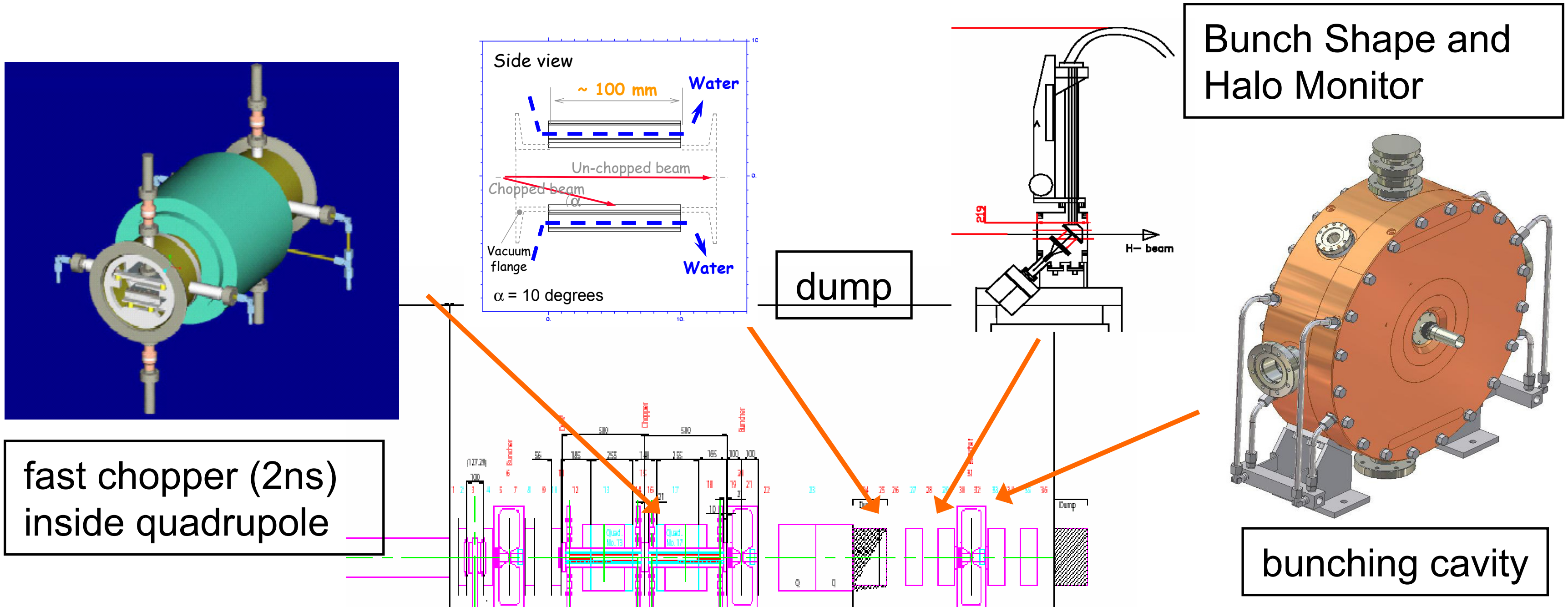
The 3 MeV test stand



- A 3 MeV Test Stand will be installed in the PS South Hall
- Goal: test essential front-end issues (hardware and beam dynamics)
- Made of IPHI RFQ + CERN chopper line + IN2P3 diagnostics line + 2 LEP klystrons (1 for RFQ, 1 for RF structure testing) + infrastructure.
- Initially use a standard CERN proton source, then a new H- source.
- The elements will be placed in the exact position foreseen for Linac4.
- *Operation with beam in 2007 !*

(Garoby, Vretenar)

The CERN chopper line



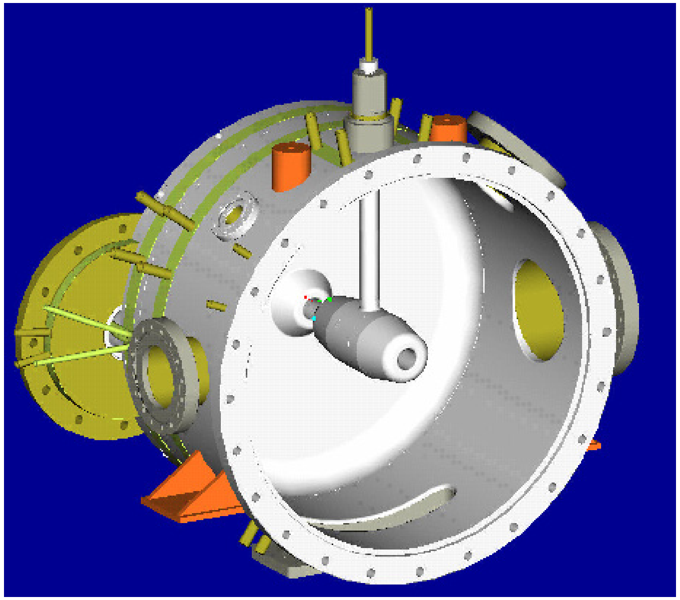
- 3.6 m long line: chopping of the beam (minimization of longitudinal capture loss in the synchrotron) plus matching from RFQ and to DTL.
- Beam dynamics studied; Final prototypes of key equipments in construction: Chopper deflector + power supply, Bunchers, Bunch Shape and Halo Monitor (high dynamic range), Dump.
- Quadrupoles and power supplies are recuperated from the CERN linacs

(Garoby, Vretenar)

RF Structure Studies

RF structures 3-160 MeV:

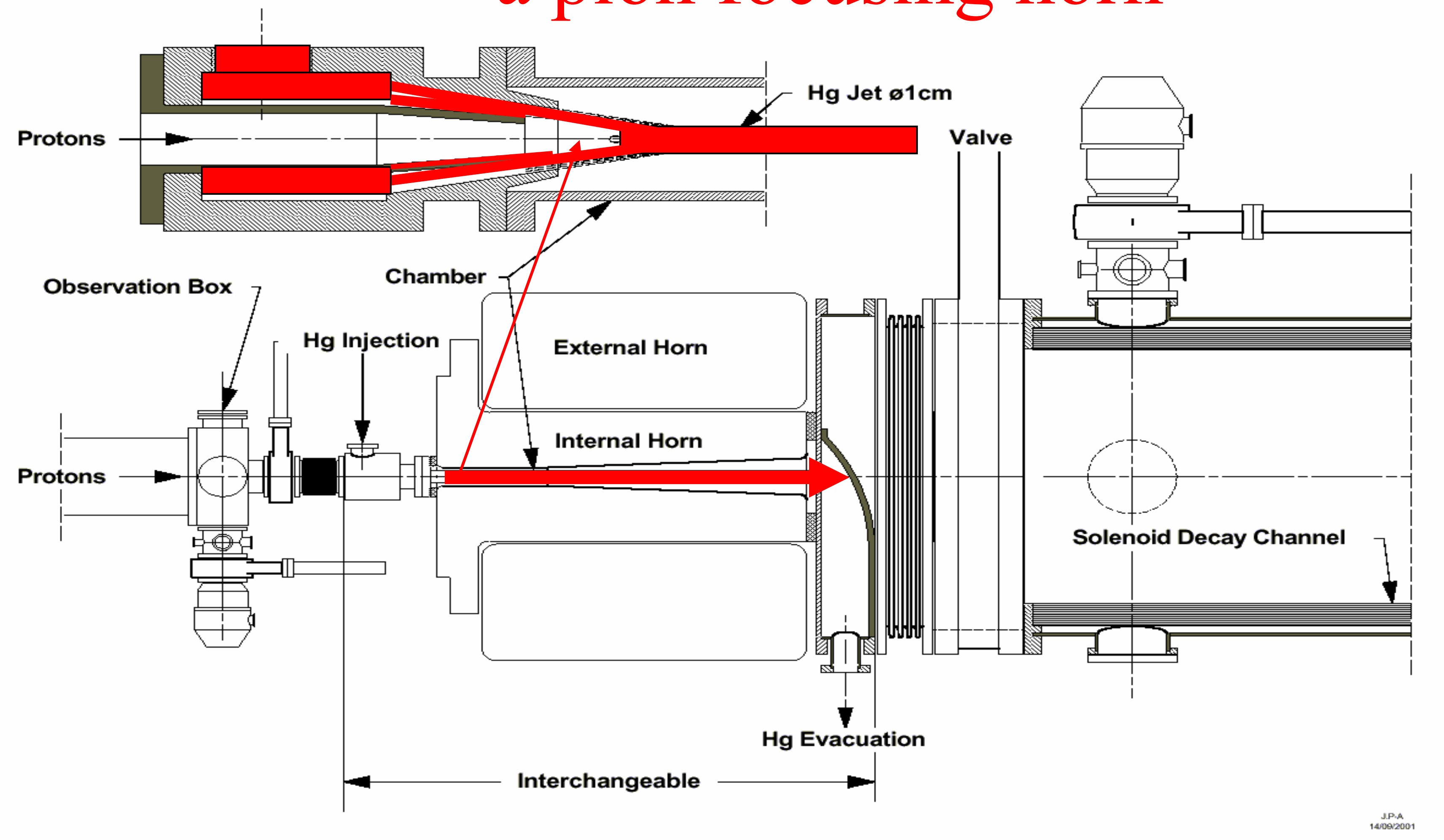
1. **DTL** (with CEA/IN2P3 and ITEP/VNIIEF): construction of a prototype Tank1 with dummy drift tubes + complete drift tube prototype (2006)
2. **DTL-RFQ**: high power prototype to be designed and built by IHEP/VNIIEF (2006)
3. **CCDTL** (40-90 MeV): full power one-cell prototype built at CERN (end 2003). Multi-cell prototype to be built at BINP/VNIITF (2006).
4. **SCL**: low power prototypes to be made at Grenoble and BINP/VNIITF.



internal view of the CCDTL prototype

(Garoby, Vretenar)

Hg-jet p-converter target with a pion focusing horn



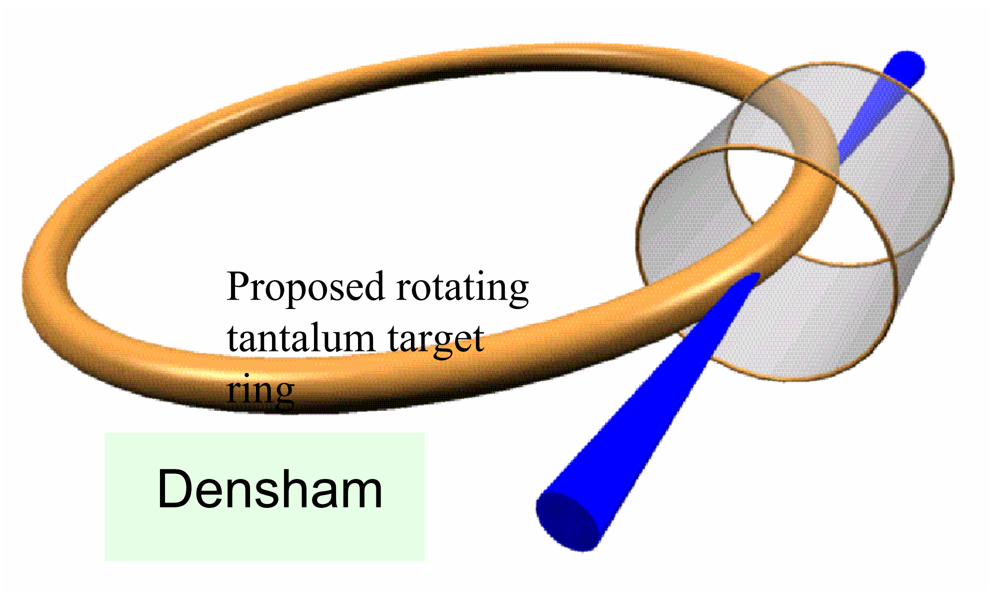
Many difficulties: enormous power density

⇒ lifetime problems

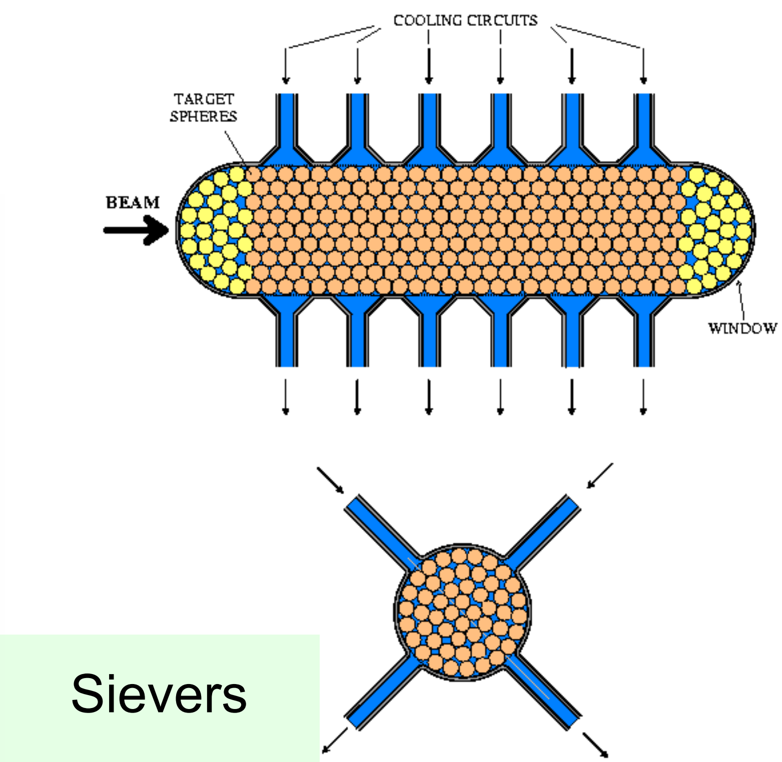
pion capture

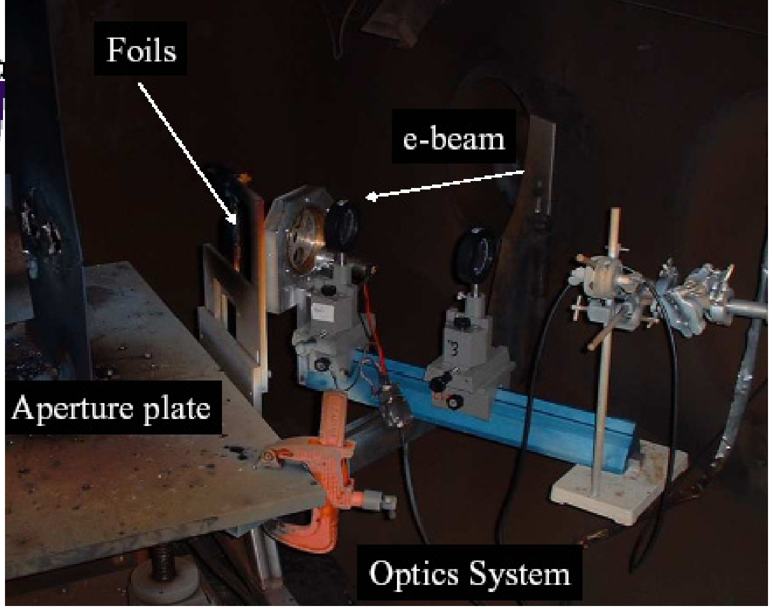
Replace target between bunches:

Liquid mercury jet or rotating solid target

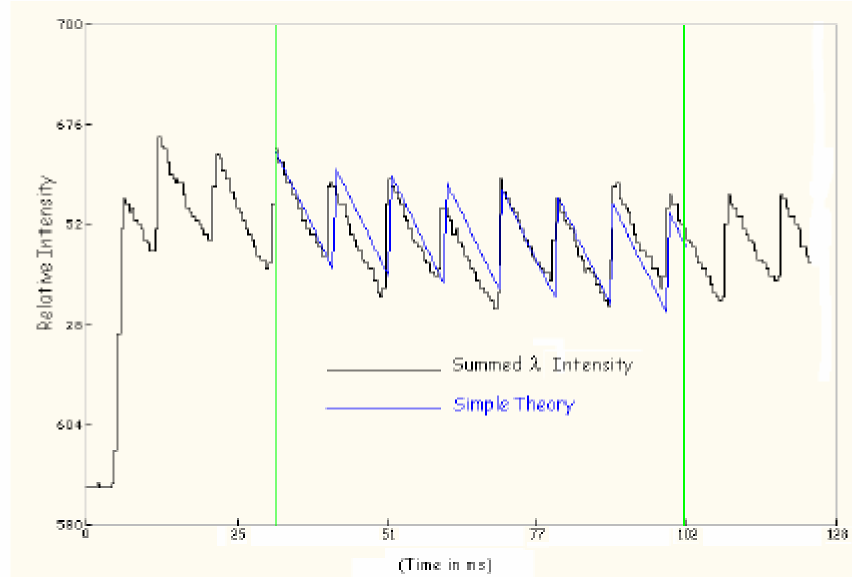


Stationary target:

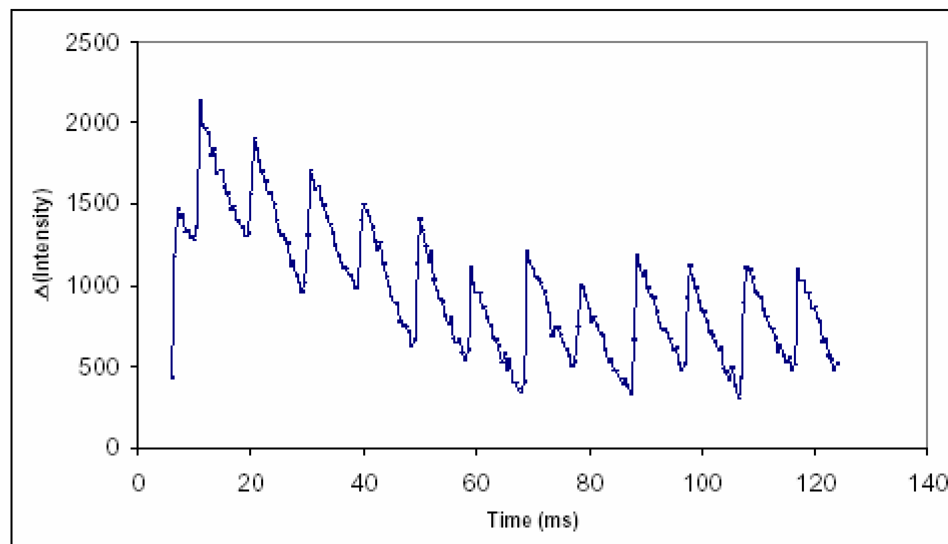




Real Time measurement of visible light from foils:

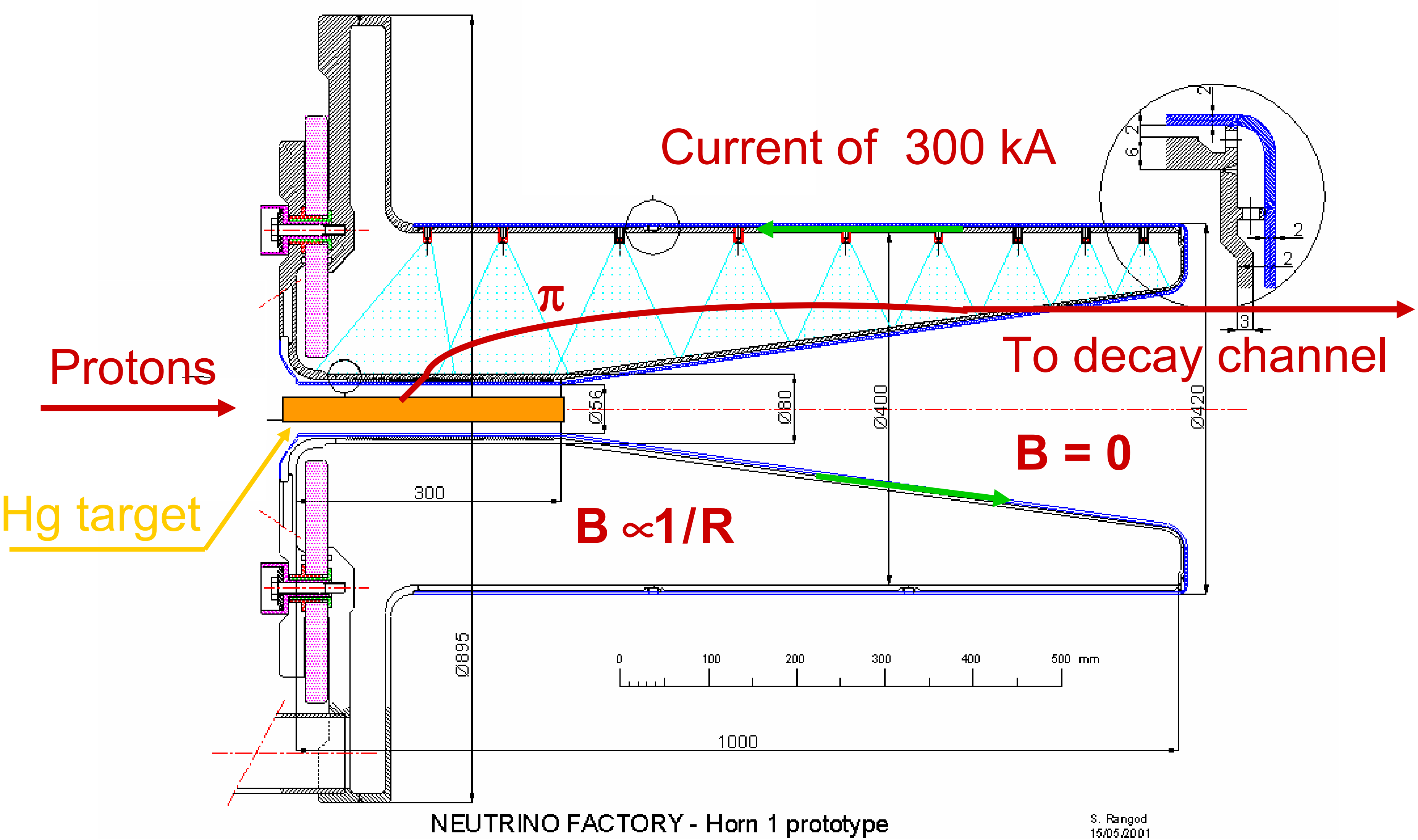


Real Time measurement of visible light from foils:



electron beam material tests
(Drumm, Densham RAL and Cambridge)

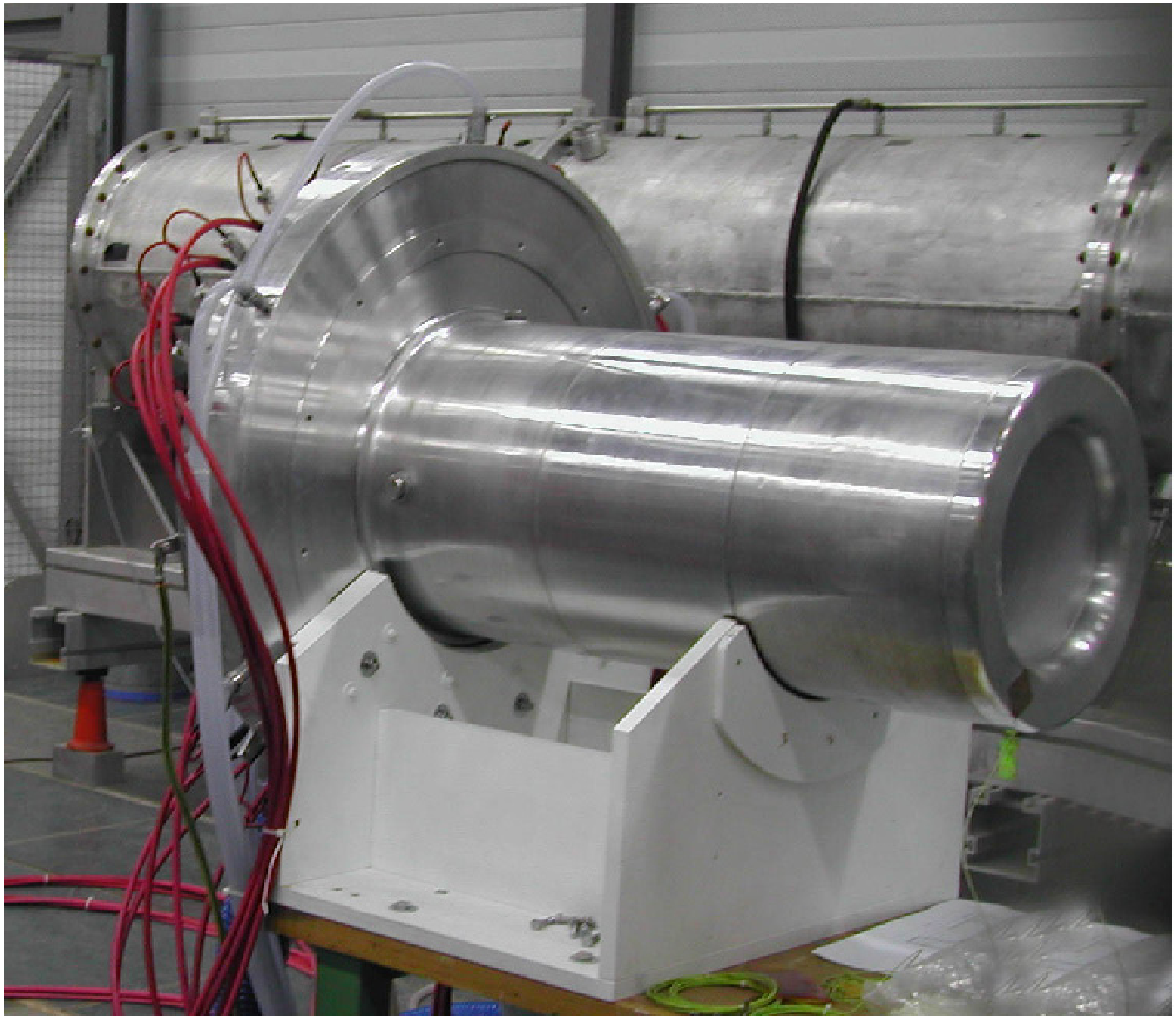
Horn focusing system



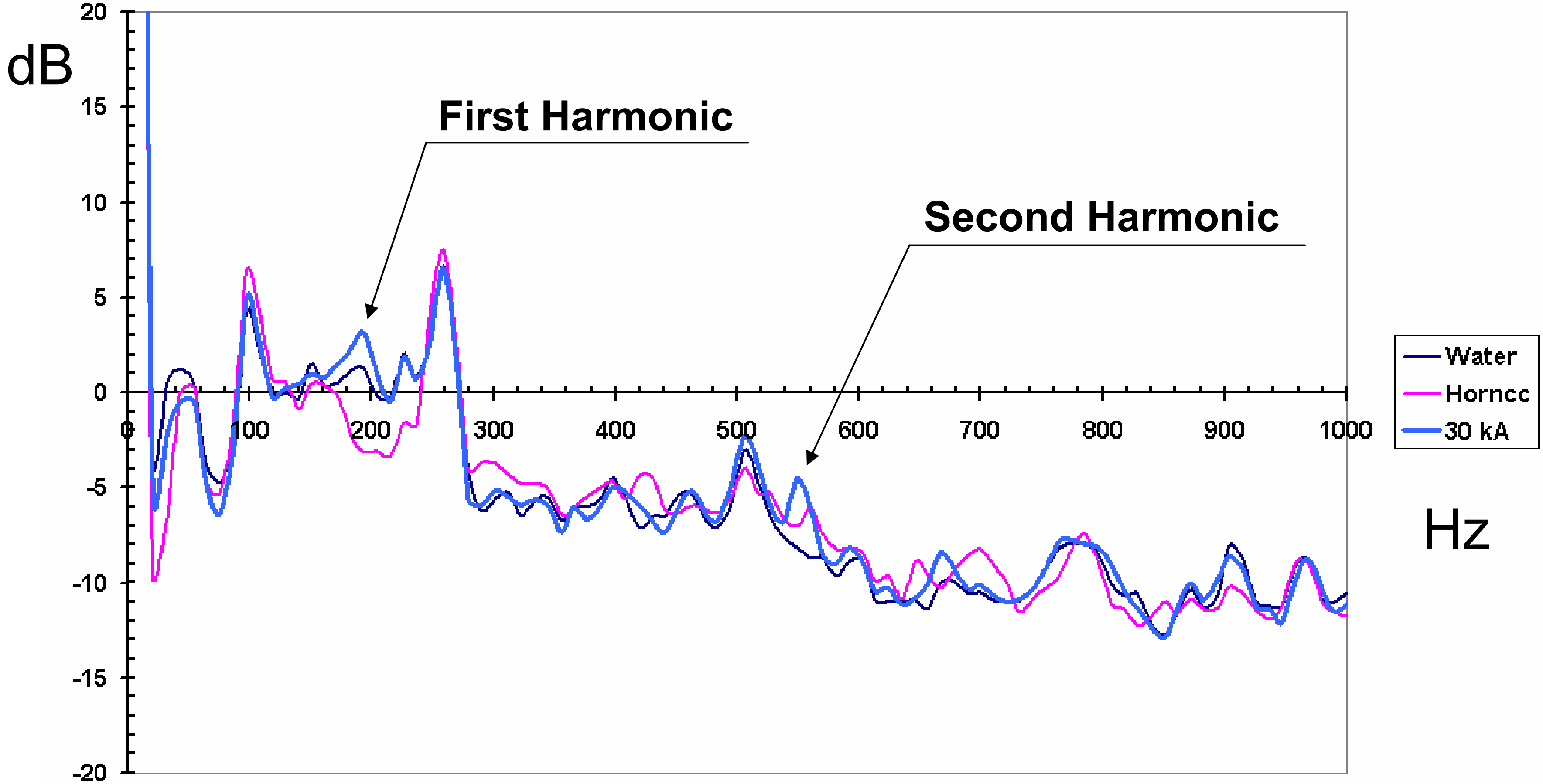
HORN STUDIES First prototype ready

S. Gilardoni

Horn prototype ready for tests

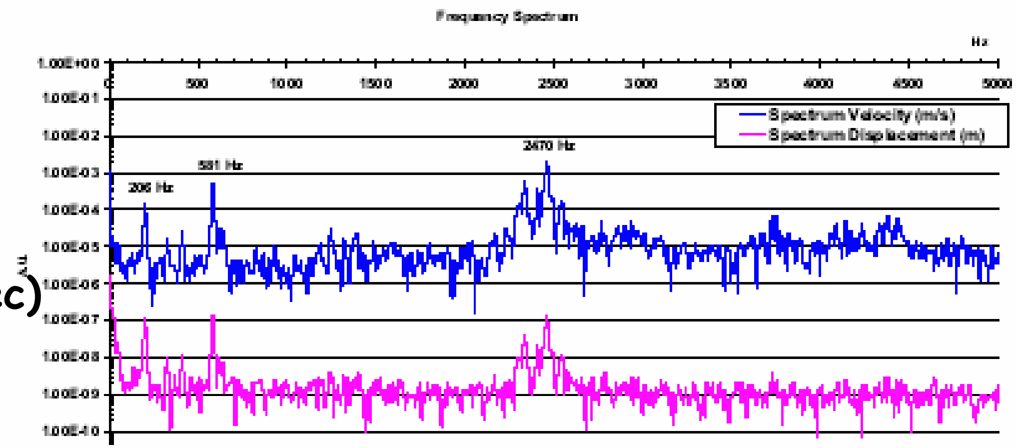


Horn eigenfrequencies from horn “sound”



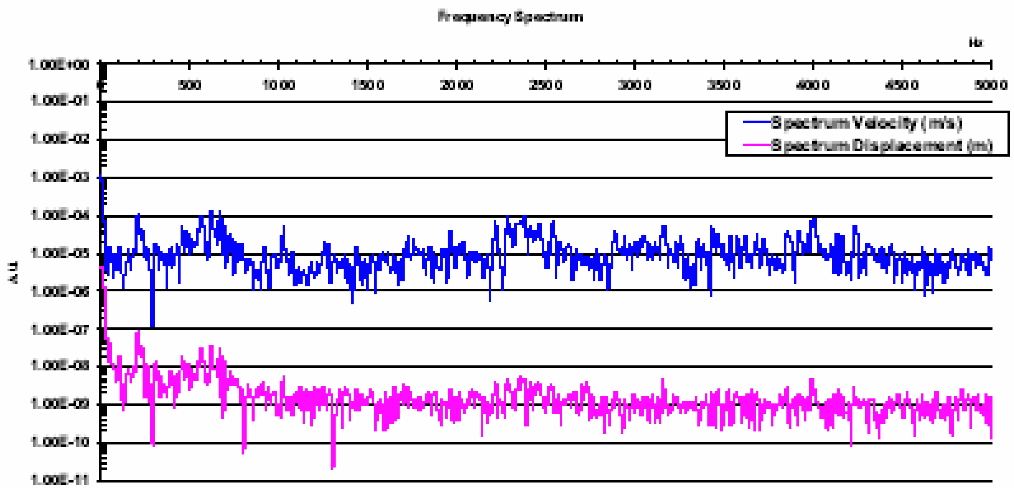
Laser vibrometry allows elimination of surrounding noise.

measurements with no water (pulses of 100 kA, 100 μsec)



vertical scales = 1 order of mag/line

measurements with water cooling (pulses of 100 kA, 100 μsec)



water cooling efficiently damps the vibrations!

1. **High intensity proton driver**. Activities on the front end are ongoing in many laboratories in Europe, in particular at CERN, CEA, IN2P3, INFN and GSI. Progressive installation of a high intensity injector and of a linear accelerator up to 160 MeV at CERN (R. Garoby et al) would have immediate rewards in the increase of intensity for the CERN fixed target program and for LHC operation. **This (HIPPI) has received funding from EU and ISTC!**

2. **Target studies** problem at 4 MW!!

. This experimental program is underway with liquid metal jet studies. Goal: explore synergies among the following parties involved: CERN, Lausanne, Megapie at PSI, EURISOL, etc…Effort lead by the US. **LOI for experiment at CERN under consideration.**

3. **Horn studies. Problem at 50 Hz *and* 4 MW**

A first horn prototype has been built and pulsed at low intensity. Mechanical properties measured (S. Gilardoni's thesis, GVA)

5 year program to reach high intensity, high rep rate pulsing, and study the radiation resistance of horns. Optimisation of horn shape. **IN2P3 Orsay has become leading house** for this.

Collaborations to be sought with Saclay, PSI (for material research and fatigue under high stress in radiation environment)

4. Muon Ionization Cooling **Never done!**

A collaboration towards and International cooling experiment MICE has been established with the muon collaboration in United States and Japanese groups. There is a large interest from European groups in this experiment. Following the submission of a letter of Intent to PSI and RAL, the collaboration has prepared a full proposal at RAL.

Proposal has been strongly encouraged and substantial UK funding envisaged (~10M£).

PSI offers a solenoid for the muon beam line

CERN, which as already made large initial contributions in the concept of the experiment, has earmarked some very precious hardware that could be recuperated for RF power source

FP6 Design Studies

Funding:

- **In first call: 70M€**
- **EC contribution/DS: 1-10M€**
- **Maximum EC contribution: 50%**
- **Total cost has to be justified in proposal**
- **Duration of DS: 24 to 48 months**

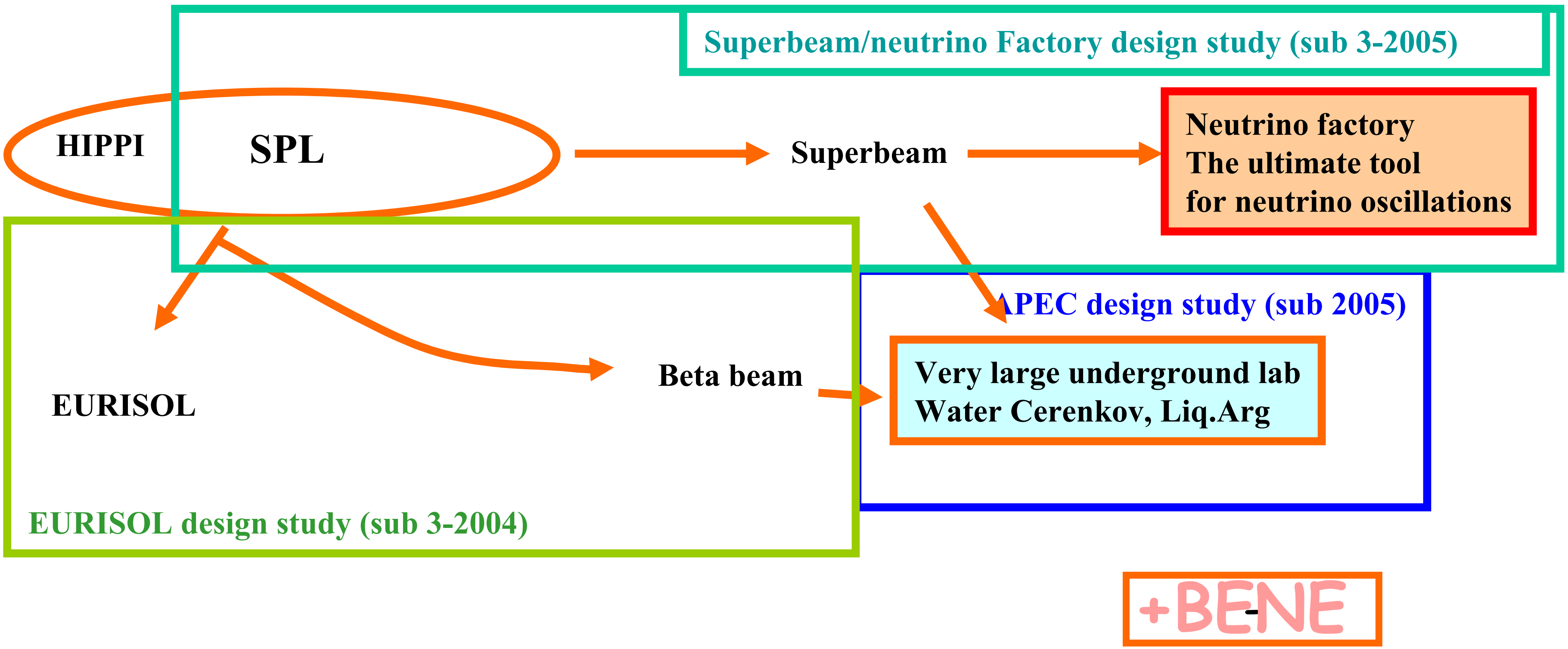
ECFA decided to submit ONE such DS in 2004, the linear collider DS.

The Neutrino factory DS will be submitted in 03/ 2005

Timescale for 2004 proposals:

Call for proposals:	11th November 2003
Submission deadline:	4th March 2004, 5pm
Evaluation/interviews:	June 2004
Results:	July 2004
Contract negotiations end:	September 2004
DS start:	end 2004/start 2005

Proposed structure as worked out in EMCOG + ESGARD + ECFA WGs



SPL physics workshop: 25-27 May 2004 at CERN

→ CERN SPSC Cogne meeting sept. 2004

Workshop on

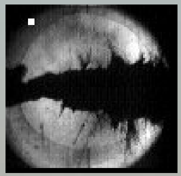
PHYSICS

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. Aleksan (Saclay)
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L. Ghilardi (CERN), G. Giudice (CERN)
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V. Palladino (co-chair), M. Vretenar (CERN)

http://physicsatmwatt.web.cern.ch/physicsatmwatt/

Superbeam/neutrino factory design study

Director:	**Ken Peach**
Coordinator:	**Rob Edgecock**
Japanese representative:	**Yoshi Kuno**
US representative:	**Mike Zisman**
BENE	**Vittorio Palladino**
Proton Driver:	**Roland Garoby**
	Chris Prior
Targetry& horn	**Roger Bennett**
	Jean-Eric Campagne
MICE:	**Alain Blondel**
	John Cobb
FFAGs:	**Francois Meot**
Design & Engineering:	**Helmut Haseroth**
	Rob Edgecock
Detector study	**Paolo Strolin**
Physics	**Mauro Mezzetto**
	Pilar Hernandez

World Design Study

Two feasibility studies so far in US:

- **FS 1: FNAL**
  - → performance not good enough
  - → too expensive
- **FS 2: BNL**
  - → performance good enough
  - → still too expensive
- **FS 3: ?**
  - - Take FS2 and reduce cost
  - - A lot of progress already made

One feasibility study in Japan

- based on FFAG
- produced in 2002

Zero feasibility studies in Europe

- **Before/during NuFact'03:**
  realized it is time for "3rd" Design Study
- **Should be world-wide this time**
- **Steering group created:**

US:	Steve Geer
	Bob Palmer
	Mike Zisman
Japan:	Yoshi Kuno
	Yoshi Mori
	Kenzo Nakamura
Europe:	Alain Blondel
	Rob Edgecock (chair)
	Helmut Haseroth

- **phone meetings regularly**

WDS Status

- Propose to "create" "6" "sub-collaborations"

	Sub-collaboration	Summary of Task
1	Proton Driver	Definition of critical parameters and R&D on components
2	Targetry	R&D on solid and liquid targets to prove viability; R&D on pion collection
3	MICE	Demonstration and study of ionisation cooling
4	FFAGs	Study of FFAG acceleration, proof of principle and R&D on critical components
5	Design and engineering studies	Cost and performance optmised Neutrino Factory Design
6	Physics and detectors	Define parameters for accelerator & detector, inc. detector cost

Time scale : leading to final report at ~ LHC start-up

Conclusions

After an exciting start in 1998/1999 (NUFACT99 and NFWG…)
we had two difficult years in 2001-2003. (re-dispatch CERN studies to outside labs)

We see now positive signals:

-- approval of HIPPI and BENE inside CARE
-- LINAC 4 seems well on the way, SPL with it.
-- strong support of IN2P3 – CEA – INFN for Fréjus Laboratory
-- Support and scientific approval of MICE at RAL

Next big mountains to climb are

SPL workshop

and

Design Study Proposals !