Beams for European Neutrino Experiments (BENE)

subtitle:

A Network aiming at a consensual road map for accelerator based neutrino programs in Europe

A complex multi-parameter problem

International Scoping Study

of a future Neutrino Factory and Superbeam facility

(ISS)

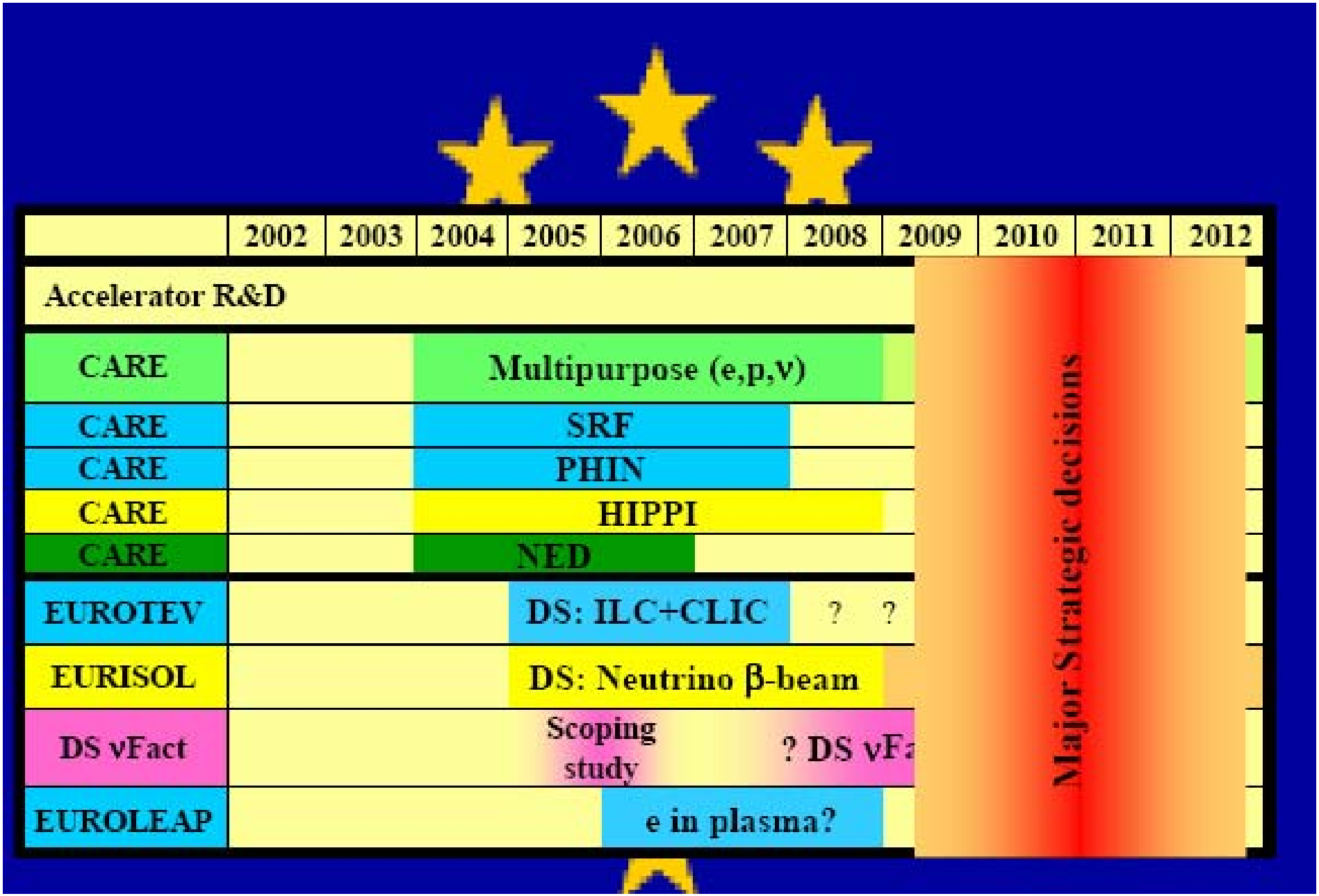
FP7 Design Study

of next European Accelerator Neutrino Facility

"Eurov" DS

in world wide collaboration

WorldDS


2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Accelerator R&D
CARE
Multipurpose (e,p,ν)
CARE
SRF
CARE
PHIN
CARE
HIPPI
CARE
NED
EUROTEV
DS: ILC+CLIC
? ?
EURISOL
DS: Neutrino β-beam
DS νFact
Scoping study
? DS νFa
EUROLEAP
e in plasma?
Major Strategic decisions

The matrix of neutrino transition probability

P_{ee}=1- ….. $P_{e\mu}$= $P_{e\tau}$=

$P_{\mu e}$ = $P_{\mu\mu}$=1- ….. $P_{\mu\tau}$=

$P_{\tau e}$ = ……. $P_{\tau\mu}$= ….. $P_{\tau\tau}$=1- …..

The matrix of neutrino transition probability

Solar (SuperK,SNO)
LBL Reactors (Kamland)

P_{ee}=1- …..

$P_{e\mu}$= $- 4\,Re\,J_{e\mu}{}^{12}\sin^2\Delta_{12}$
$- 4\,Re\,J_{e\mu}{}^{13}\sin^2\Delta_{13}$
$- 4\,Re\,J_{e\mu}{}^{23}\sin^2\Delta_{23}$
$\pm 8J\,\sin\Delta_{12}\sin\Delta_{23}\sin\Delta_{13}$

$P_{e\tau}$= $- 4\,Re\,J_{e\tau}{}^{12}\sin^2\Delta_{12}$
$- 4\,Re\,J_{e\tau}{}^{13}\sin^2\Delta_{13}$
$- 4\,Re\,J_{e\tau}{}^{23}\sin^2\Delta_{23}$
$\pm 8J\,\sin\Delta_{12}\sin\Delta_{23}\sin\Delta_{13}$

atmo
$\nu_e \leftrightarrow \nu_\mu$ crucial

$P_{\mu e}$ = - 4 …
- 4 …
- 4 …
- (± 8J….

$P_{\mu\mu}$=1- …..

$P_{\mu\tau}$= $- 4\,Re\,J_{\mu\tau}{}^{12}\sin^2\Delta_{12}$
$- 4\,Re\,J_{\mu\tau}{}^{13}\sin^2\Delta_{13}$
$- 4\,Re\,J_{\mu\tau}{}^{23}\sin^2\Delta_{23}$
$\pm 8J\,\sin\Delta_{12}\sin\Delta_{23}\sin\Delta_{13}$

Atmo
K2K, NuMI, CNGS

T & CP violating term $e^{-i\delta}$
universal

$P_{\tau e}$ = …….

$P_{\tau\mu}$= …..

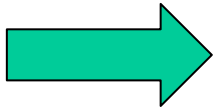
$P_{\tau\tau}$=1- …..

….. experiments ahead of us, for decades ……..

Two years of BENE in a nutshell

CARE-Report-04-034-BENE.doc
CARE-Report-05-021-BENE.doc

- **2004** BENE established on the EU scene
  - MMW workshop May 2004: the MMW frontier



Villars SPSC meeting Sep 04, where we cashed

renewed attention to a Eu ν program (R&D)

emergence of a ν "construction window" !!!!!!!!!!

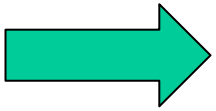
Betabeam DS approved !

- **2005 BENE** consolidated on the EU & international scene
  - **NNN05** in April and **NuFact05** in June

physics case further established in the two workshops

R&D advancing :**HARP+MUSCAT** data out, **MERIT+MICE** approved,

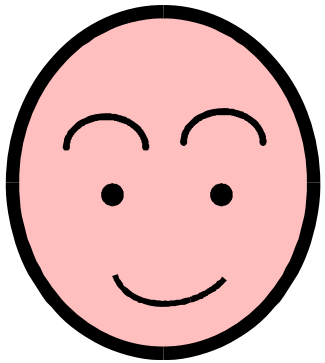
ISS launched, aiming resolutely to DS Proposal



making the ν case
in the strategic discussion ahead

proud to have gotten this far

Matching our two crucial 2005 milestones



- **Physics case developped** as far as possible today
  in the most international context possible
  becoming **a** polished **BENE Interim Report**
- **Design Study road traced** by ISS

in spite of outstanding difficulties

smaller size of our community & its core of active people

CERN contribution being resurrected only now (very slowly)

richness of options that makes consensus more laborious

NB legitimate different scientific interests do exist

collapse of FP6 calls **and more**

John Dainton
Villars 2004
October 7th 2004
CERN seminar

Villars 2004

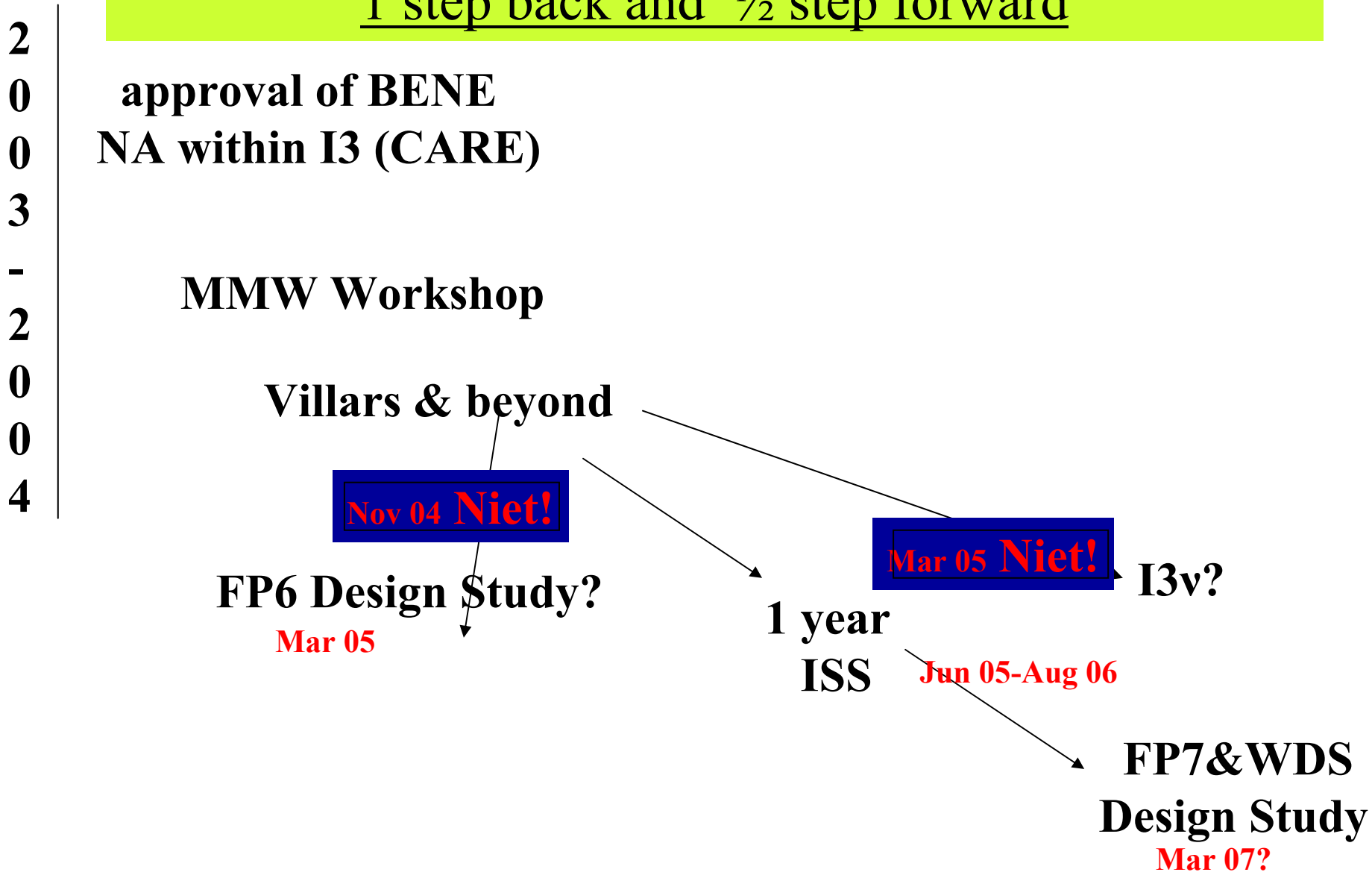
John Dainton
Villars 2004
October 7th 2004
CERN seminar

SPSC

- Future neutrino facilities offer great promise for fundamental discoveries (such as CP violation) in neutrino physics, and a post-LHC construction window may exist for a facility to be sited at CERN.
- CERN should arrange a budget and personnel to enhance its participation in further developing the physics case and the technologies necessary for the realization of such facilities. This would allow CERN to play a significant role in such projects wherever they are sited.
- A high-power proton driver is a main building block of future projects, and is therefore required.
- A direct superbeam from a 2.2 GeV SPL does not appear to be the most attractive option for a future CERN neutrino experiment as it does not produce a significant advance on T2K.
- We welcome the effort, partly funded by the EU, concerned with the conceptual design of a β-beam. At the same time CERN should support the European neutrino factory initiative in its conceptual design.

After a few nice forward jumps

1 step back and ½ step forward



Two main physics strategies

use of the high neutrino rate (>10^{20}/year) and energy (10-50 GeV) of

Neutrino Factory + LMD ("Hyper-MINOS")

$\mu \Rightarrow \bar{\nu}_e + \nu_\mu$ detector of large but not huge mass (**50-100 Kt**), necessarily magnetic

(a dense magnetized **Iron** detector, or, possibly, Li-Argon),

a **few 1000 Km** away.

use of the lower neutrino rate ($10^{18\text{-}19}$/year) and energy (sub-GeV) of

Betabeam + Megaton ("Hyper-Kamioka")

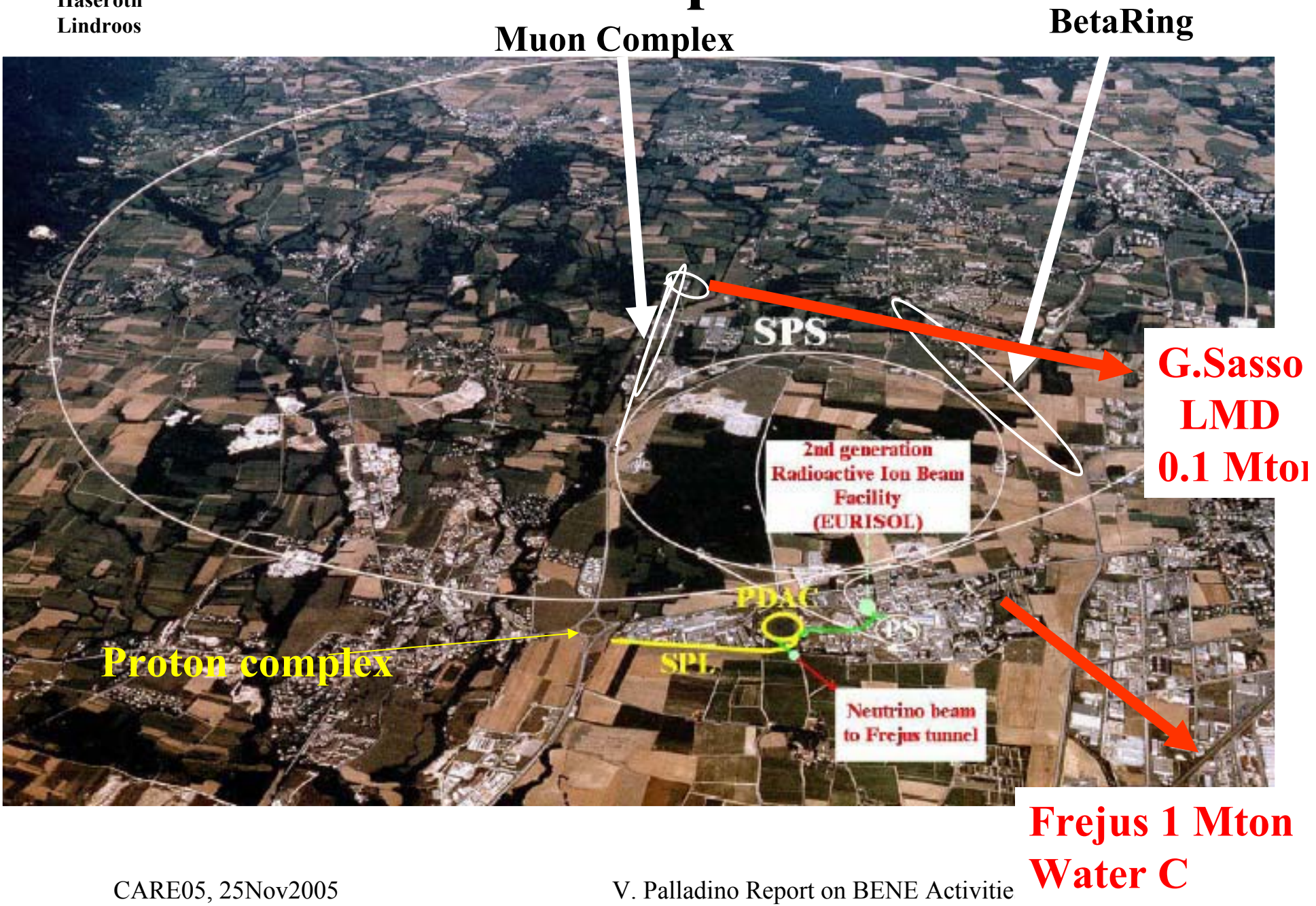
$\beta \Rightarrow \nu_e$ low density detector of very large mass (0.5-1 Mt) and volume (0.5-1 Mm^3) non magnetic

(a **Water** Cerenkov detector, or possibly, again Li-Argon),

a few **100 Km** away

Garoby
Haseroth
Lindroos

EU Neutrino Complex



Superbeam (high power conventional beams)

$\pi \Rightarrow \nu_\mu$ **is less performing, per se**

but does have **technical synergy with the NuFact**

largely coincides with **the front end of a Factory**

solving the technical challenges of a several MegaWatt proton driver and target & collection system, on the way to build a factory, yields a superbeam facility essentially for free (not its detector, however!)

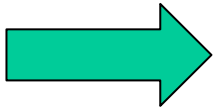
and does have **scientific synergy with the Betabeam**

can use the same detector

combination has some truely unique features:

1) oscillation signal is $\nu_e \rightarrow \nu_\mu$ in the first, $\nu_\mu \rightarrow \nu_e$. in the second, one calibrates the signal (and background) of the other !

2) T-reversal and CPT asymmetries can be measured



likely to be integrated in both strategies

Esample of comparison of physics reach: θ_{13} and CP violating phase

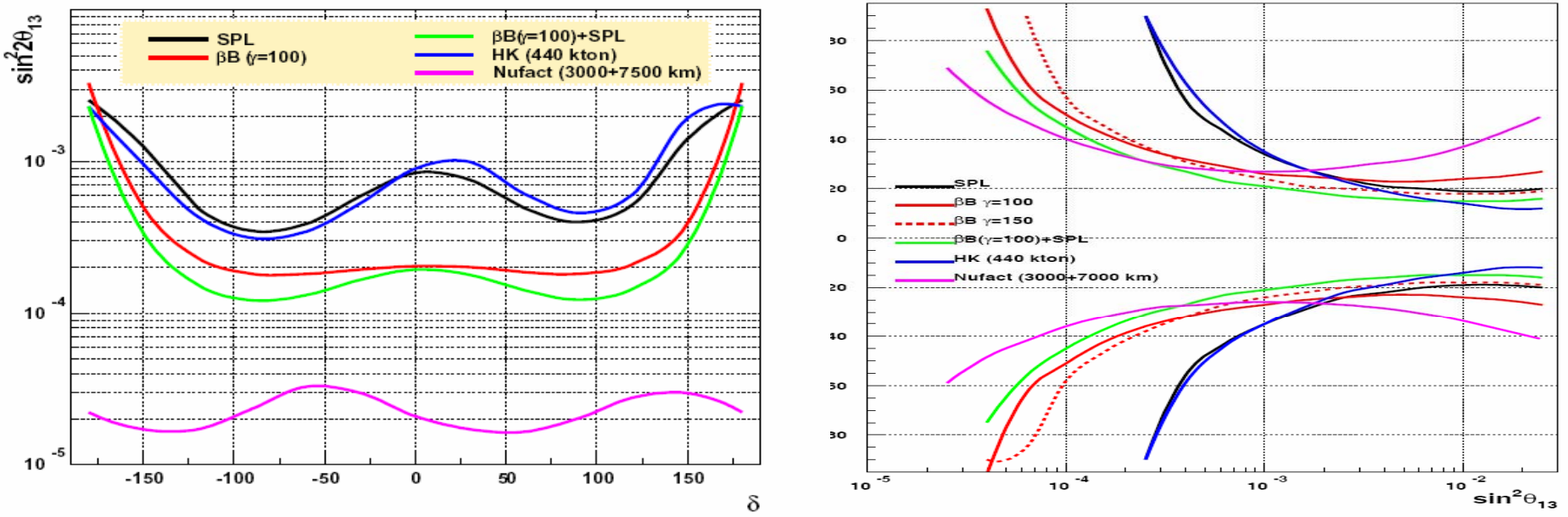


Figure 18: Temporary plot, waiting for Patrick. LEFT: θ_{13} 90% C.L. sensitivity as function of δ_{CP} for $\Delta m^2_{23} = 2.5{\cdot}10^{-3} eV^2$, $\mathrm{sign}(\Delta m^2_{23}) = 1$, 2% systematic errors. RIGHT: δ_{CP} discovery potential at 3σ (see text) computed for 10 years running time (5 years ν + 5 years $\overline{\nu}$ for both the facilities). The SPL-SB 3.5 GeV, BetaBeam with $\gamma = 100, 100$ and their combination are shown.

Comparable merits :

NuFact somewhat better and more versatile for ν oscillations

Megaton offers sinergy with N decay and more !!!

NB conclusions highly preliminary

based on still not well agreed yardsticks

must now be re-scrutinized much more in depth (ISS)

A general remark

Betabeam + Megaton and **NuFact + LMD**

are complementary !!!!!!!!!!
each has merits unaccesible to the other

(matter effects, CP, T , CPT violation, p decay, astroph. & cosmology ..)

! by means of truely international collaboration we could and should aim at having both facilities !

we must push both very actively
catch opportunities wherever they emerge
seriously aim at building one in Europe in the "construction window"

Further caveat

Intermediate solutions also emerging !

Higher energy and higher rate betabeams heading to detectors at intermediate distances

thou technically more difficult
(beta acceleration in new higher energy SPS or LHC !)

do deserve very careful attention

NNN05

Next Generation of Nucleon Decay and Neutrino Detectors
7-9 April 2005
Aussois, Savoie, France

HyperK
UNO
Memphys

100 participants

Bulletin	Registration	program and transparencies	participants	Practical information	Photos

After "Neutrino 2004" the convergence of results from atmospheric, solar, reactor and accelerator experiments confirms the massive neutrino and gives the first opportunity to test physics beyond the Standard Model. The neutrino oscillations picture is still missing 3 fundamental ingredients: the mixing angle θ_{13}, the mass pattern and the CP phase δ.

Future neutrino beams of conventional and novel design aimed at a megaton type detector could give access to these parameters. Such a detector would also be the next generation facility for proton decay searches and an invaluable supernovae neutrino observatory.

There are currently studies for building such a detector in at least three regions in the world (Japan, US and Europe). This workshop, faithfull to the tradition of previous NNN conferences, aims at a wide discussion on the roadmap and the overall coordination of the megaton scale detector community.

The meeting will be organized in Aussois, a little village in the french Alps, 10 km away from the Frejus tunnel, which hosts the Modane Underground Laboratory.

Thursday April 7th

All aspects of Megaton physics revised and updated

Morning Session: Physics Motivations
Chairperson M. Baldo Ceolin (Padova)

30' - **Introduction**
J. Ellis (CERN) - Transparencies

30' - **Neutrino parameters**
G.L. Fogli (Bari) - Transparencies

25' - **Proton decay and flavour structure**
L. Covi (CERN) - Transparencies

15' - **Proton Decay Searches**
M. Shiozawa (Tokyo) - Transparencies

25' - **Galactic supernova for neutrino physics and astrophysics**
A.Dighe (Mumbai) - Transparencies

20' - **Relic supernova neutrino background: Current status and prospects of future detectors**
S.I. Ando (Tokyo) - Transparencies

20' - **Resolving parameter degeneracies in long-baseline experiments by atmospheric neutrino data**
Th. Schwetz (Trieste) - Transparencies

Afternoon Session: Underground Projects
Chairman L. Sulak (Boston and Marseille)

15' - **Overview of Hyper-Kamiokande R & D**
K. Nakamura (KEK) - Transparencies

15' - **Low energy astrophysical neutrino observations with megaton class detectors**
T. Nakahata (Tokyo) - Transparencies

15' - **Neutrino oscillation studies with atmospheric neutrinos in HyperK**
T. Kajita (Tokyo) - Transparencies

15' - **The DUSEL Site Undependant Study**
B. Sadoulet (Berkeley) - Transparencies

25' - **Status of UNO and Future Outlook**
C. K. Jung (Stony Brook) - Transparencies

15' - **Project of a Megaton-scale experiment at Fréjus (MEMPHYS = MEgaton Mass PHYSics)**
J. Bouchez (Saclay) - Transparencies

25' - **Very large LAr TPCs**
A. Rubbia (Zürich) - Transparencies

15' - **GADZOOKS!: Megaton Scale Neutron Detection**
M. Vagins (Irvine) - Transparencies

15' - **LENA: XSLow Energy Neutrino Astrophysics**
L. Oberauer (Munich) - Transparencies

15' - **INO: India-based Neutrino Observatory**
N. Mondal (Mumbai) - Transparencies

15' - **Large TPCs for low energy rare event detection**
I. Giomataris (Saclay) - Transparencies

state of the art material for full elaboration of BENE physics case

Friday April 8th

Morning Session : Present and Future Neutrino Beams
Chairman T. Kajita (Tokyo)

15' - **Status and future prospects of Gran Sasso**
A. Ianni (Gran Sasso) - Transparencies

25' - **CNGS experimental program: OPERA and ICARUS**
D. Duchesneau (Annecy) - Transparencies

25' - **Status of J-PARC neutrino project**
T. Kobayashi (KEK) - Transparencies

15' - **Status of the MINOS experiment**
M. Bishai (Brookhaven) - Transparencies

15' - **BNL Very Long Baseline Neutrino Oscillation Experiment**
M. Bishai (Brookhaven) - Transparencies

25' - **A program of Long Baseline Neutrino Exploration at Fermilab**
R. Ray (Fermilab) - Transparencies

04

. . . . . .

Evening Session: Round Table
Moderator M. Spiro (Paris)

60' - **Inter-Regional coordination around a Megaton Detector**
A. Blondel, J. Bouchez, G.L. Fogli, C.K. Jung, K. Nakamura, A. Rubbia, B. Sadoulet

Strong reinforcement of international cooperation achieved

200 participants All aspects of future ν physics revised and updated

state of the art material for full elaboration of BENE physics case

Preliminary Programme

All time allocations include 5' discussion

Tuesday 21, Aula B. Touschek		
08.00-09.00	*Registration*	
09:00-09:05	Welcome address	M. Calvetti (INFN LNF)
Introductory Session, Chairman: F. Ronga		
09:05-09:35	Neutrino masses and neutrino mixing	E. Lisi (Bari Univ.)
09:35-10:05	Massive neutrinos in cosmology and astrophysics	M. Fukugita (Tokyo Univ.)
10:05-10.35	The Fermilab neutrino program	R. Plunkett (FNAL USA)
10:35-11:00	*Coffee Break*	
Introductory Session, Chairman: K. Nakamura		
11.00-11:25	The CNGS program	P. Migliozzi (INFN Napoli)
11.25-11:50	The T2K program	Y. Yamada (KEK)
Introducing the Working Groups, Chairman: J. Bouchez		
11.50-12:20	WG1: Physics reach of future superbeam facilities	M. Messier (Indiana Univ.)
12:20-13:00	WG1: Physics reach of neutrino factories and betabeams	S. Rigolin (Madrid Univ.)
13:00-13:30	WG2: Neutrino scattering physics and experiments at future Facilities	J.G. Morfin (FNAL)
13:30-15:00	*Lunch Enea Canteen*	
Introducing the Working Groups, Chairman: M. Zisman		
15:00-15:30	WG3: The Technical challenges of Super-Beams and Neutrino Factories	H. Haseroth (CERN)
15:30-16:00	WG3: The Technical challenges of Beta-Beams	M. Lindroos (CERN)
16.00-16:30	*Coffee Break*	
16.30-19:00	Joint sessions: WG1, WG2	B. Touschek
	WG3	A-34
19:30-21:00	*Welcome Party (Hotel Villa Mercede)*	
Wednesday 22 , Aula B. Touschek		
Introducing the Working Groups, Chairman: N. Skrinsky		
09:00-09:30	WG4: Slow muon physics	Y. Kuno (Osaka)
Proton Driver Session, Chairman: N. Skrinsky		
09:30-10:00	Proton driver: the evolution of J-Parc	S. Machida (KEK)
10:00-10:30	Proton driver: prospects in US	G. Apollinari (FNAL)
10:30-11:00	Proton driver: prospects in Europe	R. Garoby (CERN)
11:00-11:30	*Coffee Break*	
Accelerator R&D Session, Chairman: R. Palmer		
11:30-12:00	High power targets and particle collection	K. McDonald (Princeton Univ.)
12:00-12:30	Muon front-end	R. Fernow (BNL)
12:30-13:00	Muon cooling: MUCOOL & MICE	Y. Torun (IIT)
13:00-13:30	Acceleration and storage	F. Meot (Saclay)
13:30-15:00	*Lunch Enea Canteen*	
15:00-15:30	The technical challenges of muon colliders	R. Johnson (Mulnc)
15:30-19:00	WG1	B. Touschek
	WG2	A-1
	WG3	A-34
	WG4	B-1

Thursday 23, Aula B. Touschek		
Planning the experiments, Chairman: P. Strolin		
09:00-09:30	Detectors for the future neutrino beams	S. Ragazzi (Milano)
09:30-10:00	A Megaton water detector for particle and astroparticle physics	T. Kajita (Tokyo Univ.)
10:00-10.25	Hadron production cross-sections	E. Radicioni (Bari)
10:25-10:45	Physics with a first very low energy Beta-Beam	C. Volpe (Orsay)
10.45-11:15	*Coffee Break*	
11:15-12:30	Joint sessions: WG1, WG2, WG3, WG4	B. Touschek
12:30-13:30	Joint sessions: WG1, WG2, WG4	B. Touschek
	WG3	A-34

Sunday June 26
9:00-13:00

WW R&D Session

1) Physics Studies : Status & priorities

1) Accelerator R&D : Status & priorities

2) Neutrino Detectors: Status & priorities

PANEL & OPEN DISCUSSION
Launch International Scoping Study … to report at NuFact06

A Summer School accompanied the workshop: 22 students, 12 lecturers

The International Scoping Study (ISS)

on Neutrino Factories and Superbeams

that must advance to same level of progress as Betabeams

A joint venture, jointly set up by the coordinators of

S. Geer the US Neutrino Factory Collaboration

Y. Kuno the Japanese NuFact-J Work Group

V. Palladino the Eu BENE Network

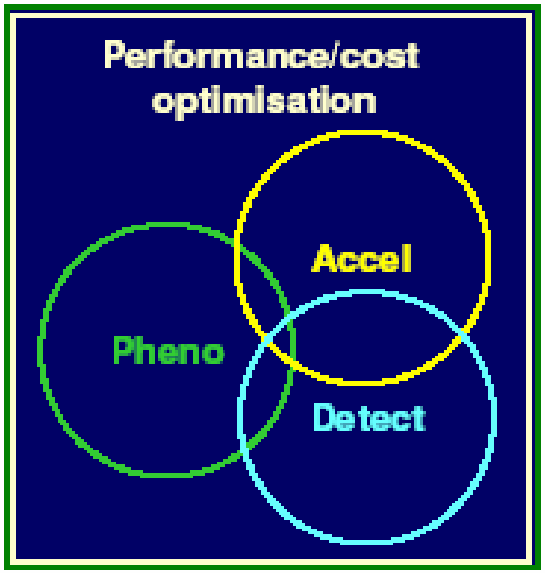
K. Peach and the host (RAL) UKNF Collaboration

to lay the foundation of a full blown International Design Study

All aspects included, except accelerator Betabeam studies

Scoping study: started in March-April by RAL

- Top-level divisions – to provoke discussion:
  - Phenomenolgy/theory:
    - Precision/high-sensitivity oscillation measurements
    - Comparison of NF sensitivity with β-/super-beam
  - Accelerator-facility concept/R&D:
    - Proton driver; front-end and acceleration
    - Target and collection
    - Muon front end
    - Rapid acceleration
    - Storage
  - Neutrino detector:
    - Iron calorimeter
    - LAr
    - H_2O Cherenkov
    - Other options …



International Scoping Study :

agenda for one year

Matching funds

22-24 Sep	CERN a success !!!
Late January	KEK
Mid April	RAL
Late August	NuFact06 in Irvine

+ topical intermediate workshops
Physics, London, 14-21 Nov.

hopefully, NuFact06 will launch International Design Study **and FP7 Eu Design Study**

The three sectors of SS (andDS)

NB BetaBeam included

Physics (Y. Nagashima)

compare performance of various options
on equal footing of
parameters and conventions
and agreed standards of
resolutions, simulation etc.

identify tools needed to do so
(e.g. Globes upgraded?)

propose « best values » of
baselines, beam energies etc..

Detectors (NEW!) (A.Blondel)

Water Cherenkov (1000kton)
Magnetized Iron Calorimeter (50kton)
Low Z scintillator (100 kton)
Liquid Argon TPC (100 kton)
Hybrid Emulsion (4 kton)

Near detectors (and instrumentation)

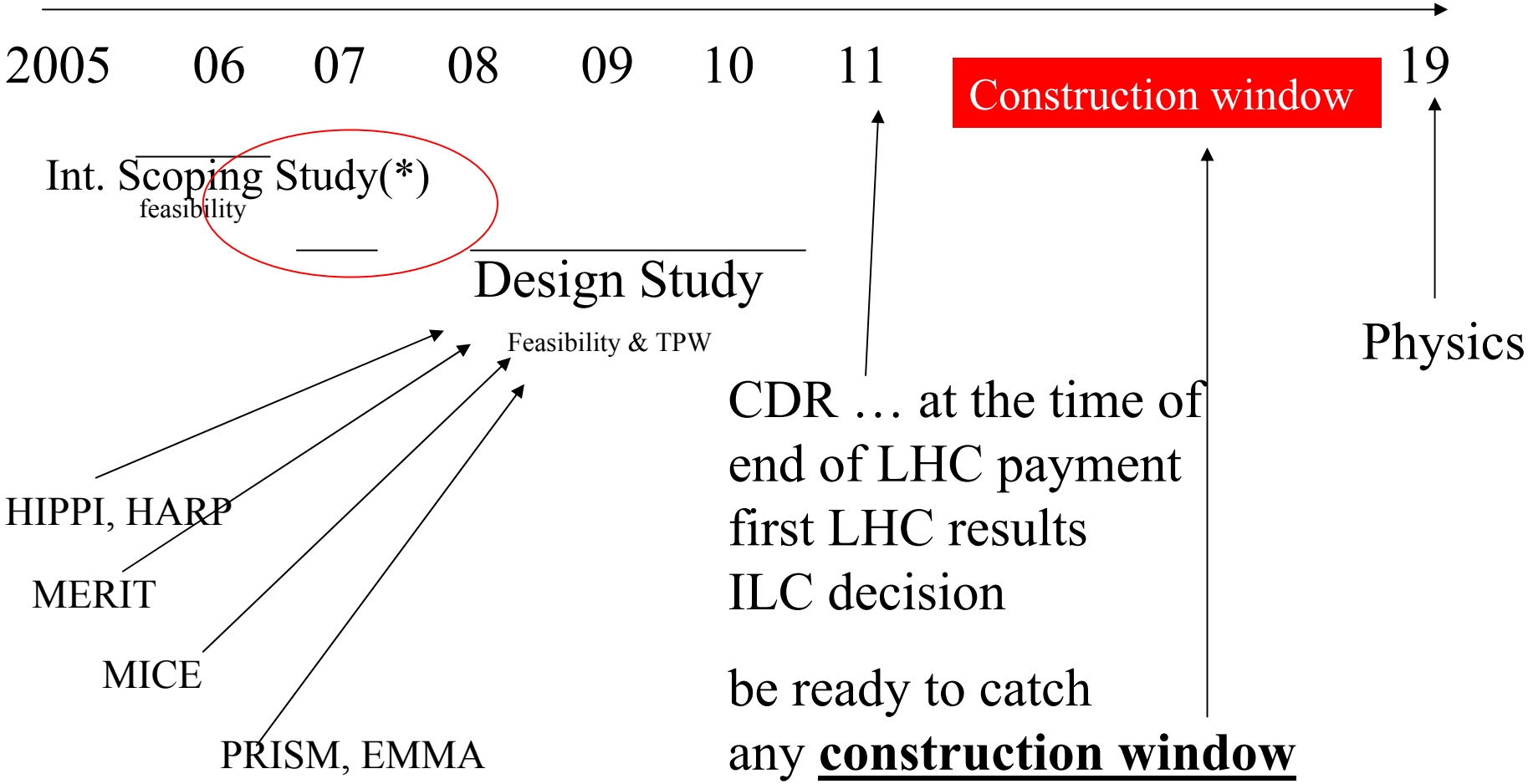
P. Dornan

Accelerator: (M. Zisman)

-- proton driver (energy, time structure and consequences)
-- target and capture (chose target and capture system)
-- phase rotation and cooling
-- acceleration and storage

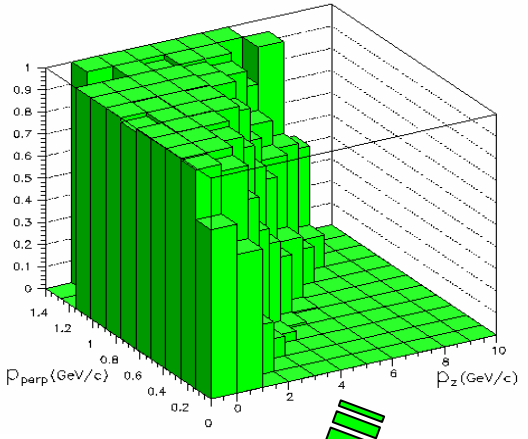
evaluate economic interplays and risks
include a measure of costing and safety assessment

BENE : the longer term plan

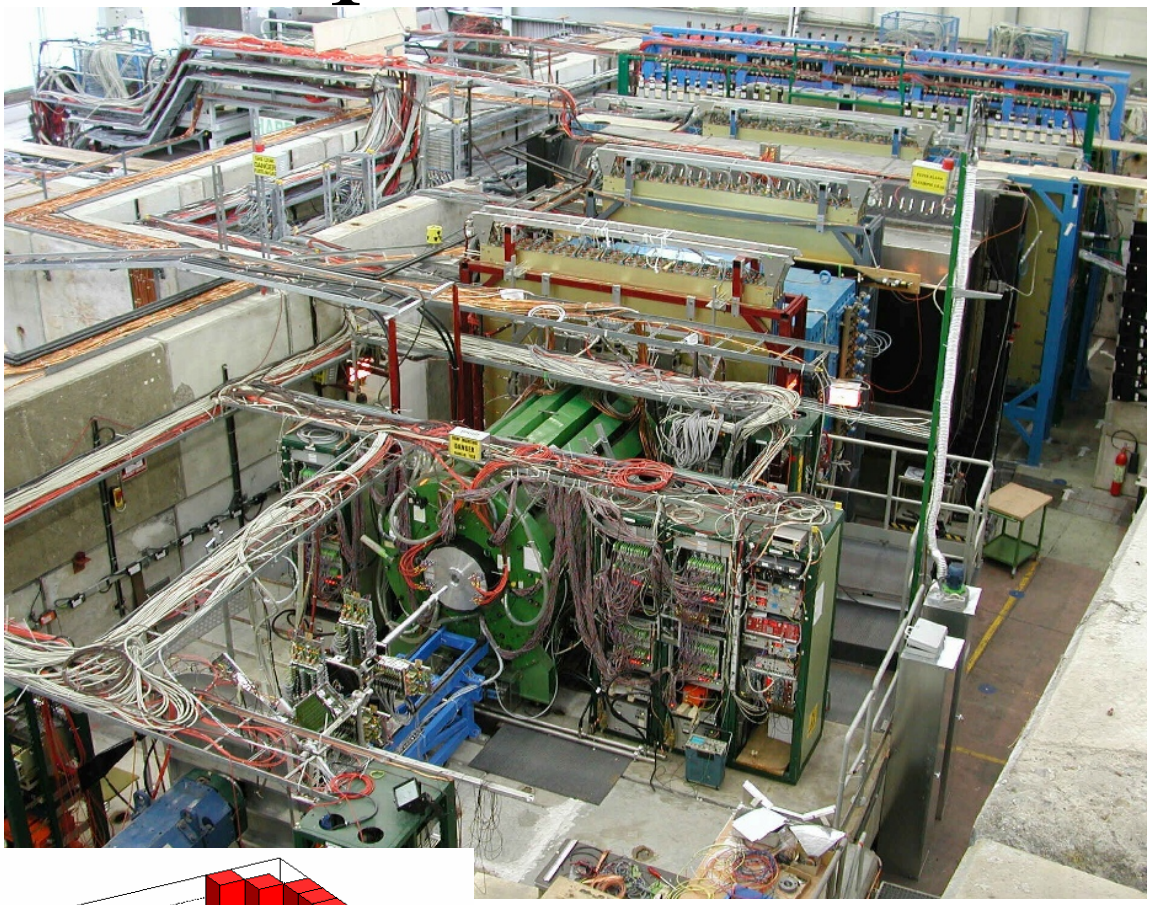


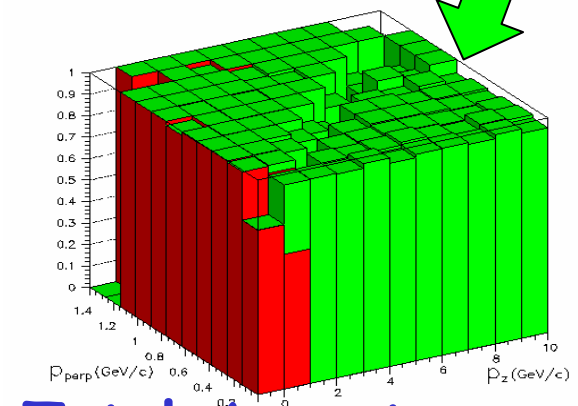
NB Betabeam CDR End 2009 !

The HARP experiment

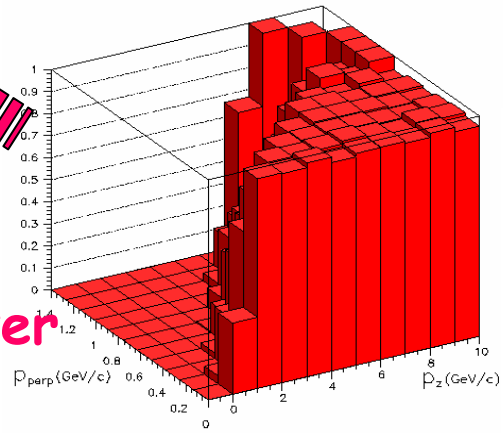


TPC





Total Acceptance



Forward Spectrometer

Scan
CERN PS
energy range
… RCS is an option

The MERIT (nTof 11) experiment

(US, Japan, CERN&RAL)

holds the key to any superbeam !!!

tests the single shot behavior at MMW driver of target and collection (solenoid, horn?)

can we master the MMW?

should make that more known

better supported and manned

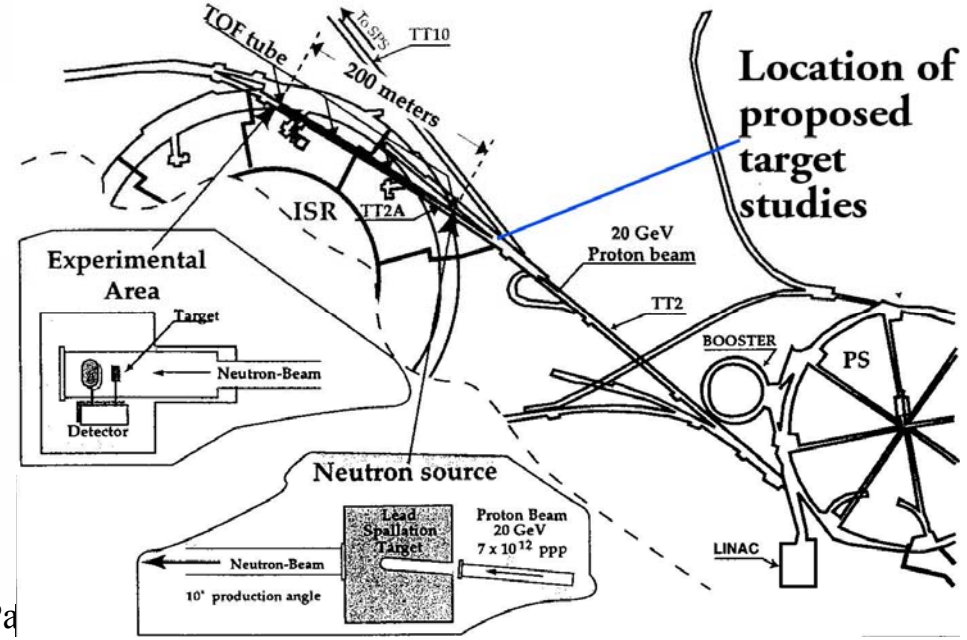
should evolve that into a MMW target and collector Test Area?

The most crucial experiment for the future of the ν

- nTOF11 target experiment
  - studied Hg jet with beam and no magnet (E951 at BNL)
  - studied Hg jet with magnetic field and no beam (CERN/Grenoble)
  - need to put entire system together
    - identified CERN as optimal location for test (BNL facility no longer available)
- experiment proposed by international collaboration (April, 2004)
  - BNL, CERN, KEK, ORNL, Princeton, RAL
  - spokespersons: H. Kirk (BNL), K. McDonald (Princeton)
- approval granted April, 2005
  - first beam April 2007

Liquid jet target in 15T mag. field

Beam energy (GeV)	24
Max. protons per 2 μs spill (Tp)	28
Hg jet diameter (mm)	10
Peak energy deposition (J/g)	180
Jet angle from solenoid axis (mrad)	100
Beam angle from solenoid axis (mrad)	67
Hg jet velocity (m/s)	20

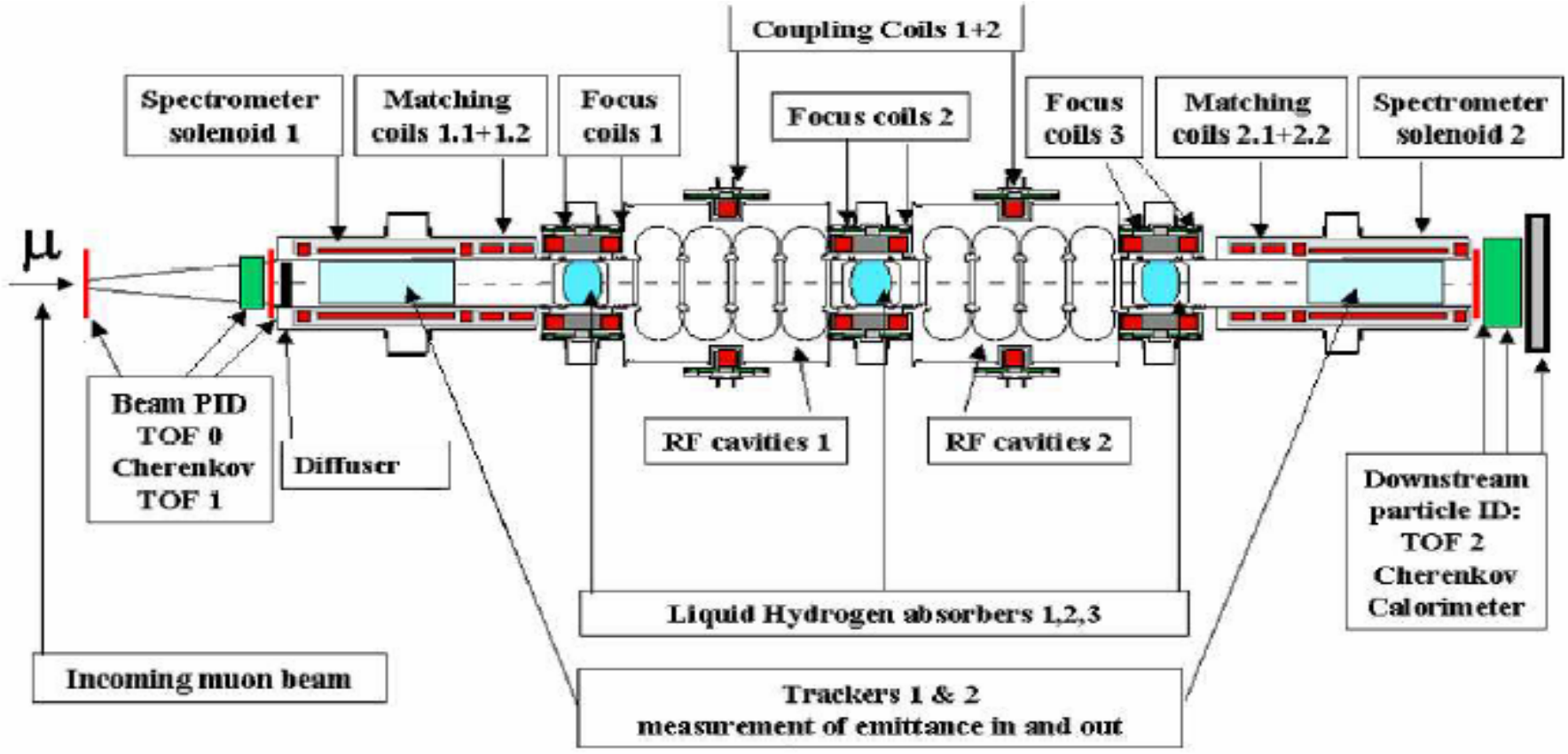


MICE …. crucial demonstration esperiment

for the feasibility of a Neutrino Factory

muon ionisation cooling

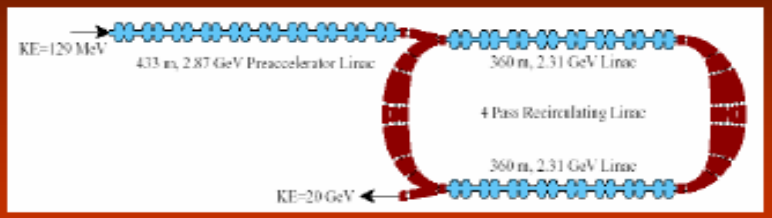
Phase I completely funded by now- Datataking starts April 1 2007



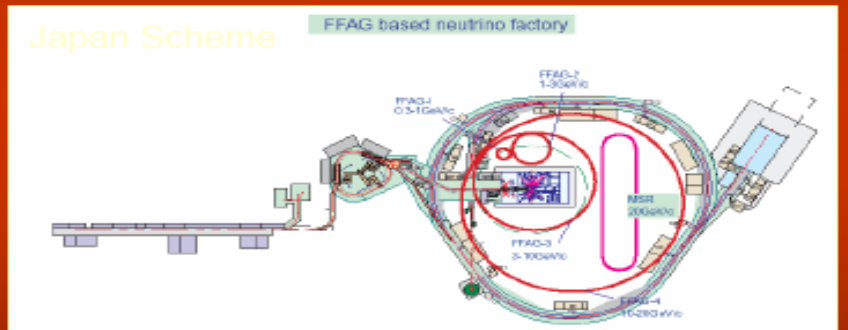
Acceleration: the rise of FFAG!

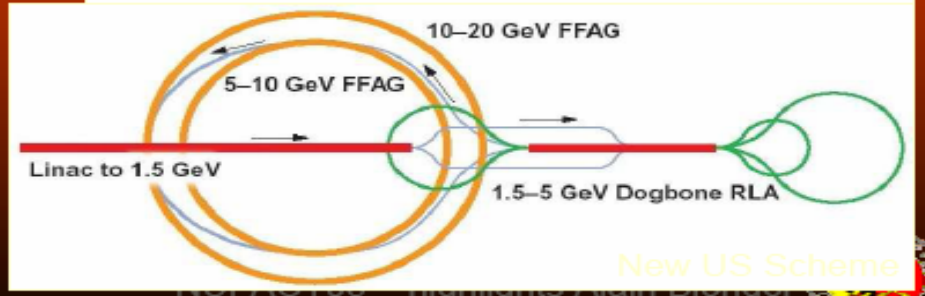
Muon acceleration

Previous accelerator scheme:
LINAC + Recirculating Linear Accelerator (RLA)
Very costly and rigid use.

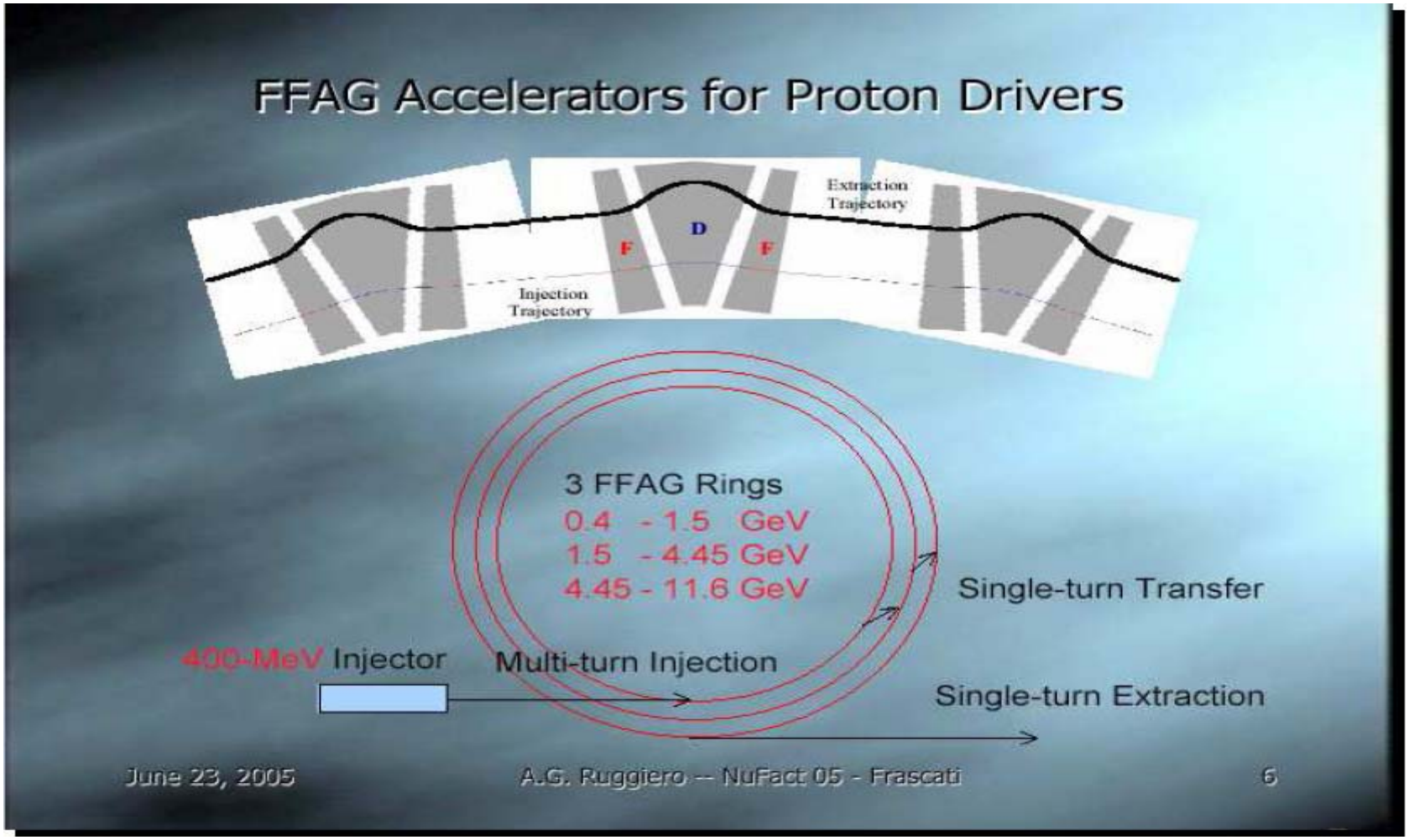


Proposed solution:
Fixed Field Alternating Gradient (FFAG). a new type of accelerator with B-field shaped as r^k
-->particles can be kept and accelerated over a range of energies of ~factor 3 in very short time (no magnet ramping!)





CERN seminar 13/9/2005



Latest ideas in US have lead to the invention of a new type of FFAG ("non-scaling FFAG")

interesting for more than just Neutrino Factories (e.g. from SPL to 20 GeV?)

require a demonstration experiment (PRISM, electron prototype)

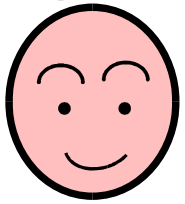
Emma

One crucial task of BENE in the ISS year

assemble a real EDS (Eu DesignStudy) collaboration !!!!!
that will sign
and provide the **manpower &** largest part of the funds,
matching funds, for
a **FP7 bid** able to have
the blessing of ECFA and
good odds of approval in Brussels.

find the synthesis of so far not obviously converging interests
CERN, INFN, CCLRC, IN2P3, CEA, PPARC, CSIC, Germany?,
Belgium, NIKHEF, everybody

CERN positive attitude towards the ISS and BENE's initiative
willingness to assemble a small ISS task force
will no doubt greatly help
a few fractions of FTE can make an impact



Plans for the year ahead

Interim BENE Scientific Report, based on NNN05,NuFact05, ISS

Draft http://people.na.infn.it/~palladin/BENEScientificInterimReport

input to the strategic discussion in progress

FPA, POFPA

Akesson/Peach Strategy group (Orsay Jan 30)

Conclude Scoping Study (NuFact06)

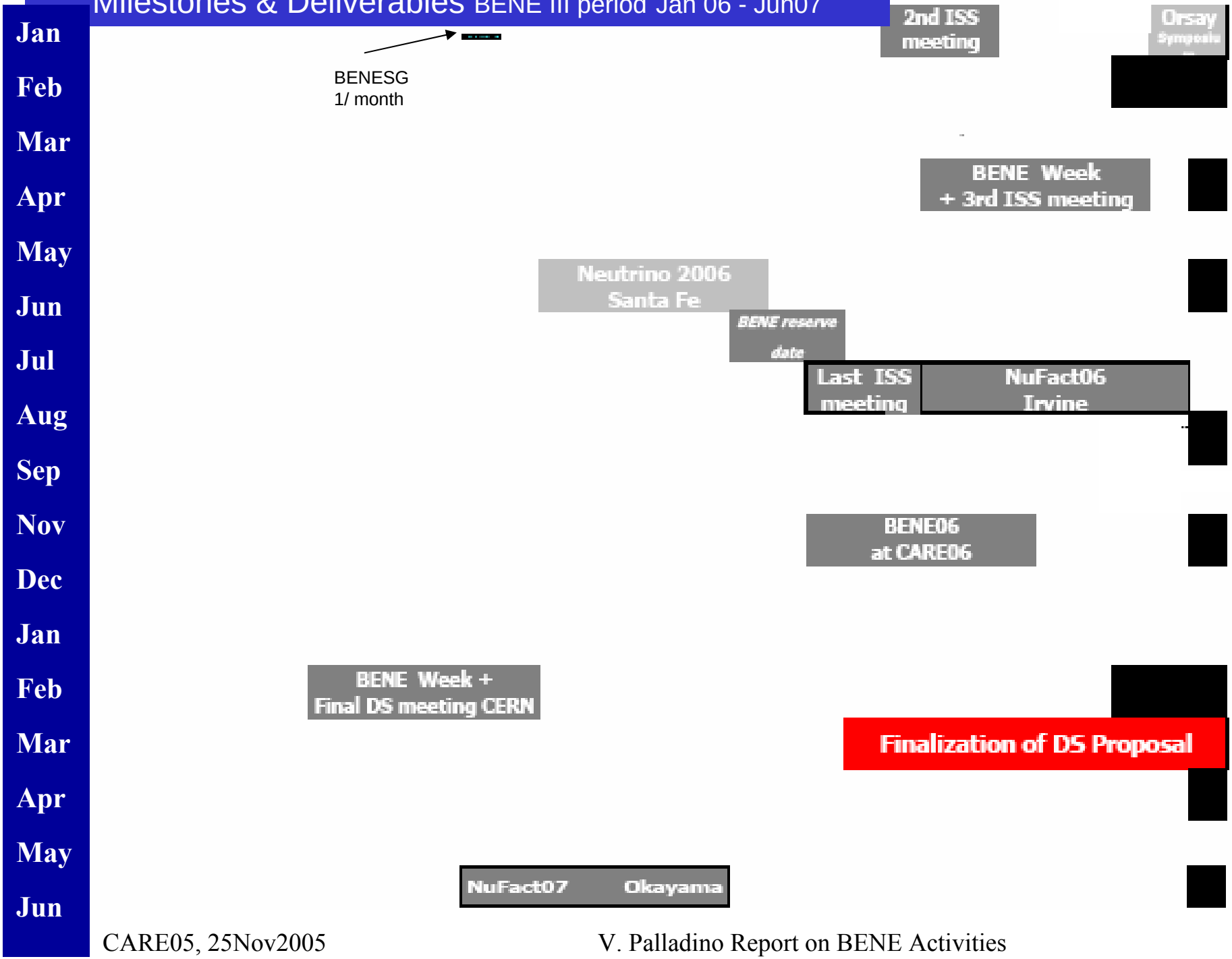
define the content of WDS and FP7 DS

Assemble FP7 Collaboration

prepare FP7 proposal

bridge over Aug 06 to FP7 funding (1Jan2008?)

Milestones & Deliverables BENE III period Jan 06 - Jun07



THE END