V. Palladino
Gruppo II INFN
Napoli 20/5/2004

Iniziative future sui neutrini da acceleratore

dopo OPERA & ICARUS

UN ESPERIMENTO **: T2K … approvato**
sigla INFN 05?

UN NETWORK EUROPEO: **BENE**
approvato 2004-2008 cofin EC-INFN

Un WW R&D PROJECT: **MICE at RAL**
in fase di disegno & fund raising

The matrix of neutrino transition probability

Solar (SuperK,SNO)
LBL Reactors (Kamland)

$P_{ee}=1-$ …..

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

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

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

$P_{\mu\mu}=1-$ …..

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

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 ……..

The matrix of neutrino transition probability

P_{ee}=1- …..

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

golden

BetaBeam, NuFact

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

silver

NuFact

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

$P_{\mu\mu}$=1- …..

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

SuperBeam, NuFact

$P_{\tau e}$ = ……

$P_{\tau\mu}$= …..

$P_{\tau\tau}$=1- …..

The Neutrino Factory does them all !

A possible coherent plan of EU initiative in neutrino Physics ?

2006 2009 2014 >2014

CNGS Opera & ICARUS

EU T2K .... T2H?

R&D targets, horns
beta ions

Superbeam
Betabeam
CERN ν to Frejus

R&D μ cooling, reacceleration, storage

NuFact
CERN ν to LNGS & al

Neutrino mixing

If neutrino have finite mass, weak and mass eigenstates can differ

$$|\nu_l\rangle = \Sigma U_{li} |\nu_i\rangle$$

Weak — Mass eigenstates

Pontecorvo-**M**aki-**N**akagawa-**S**akata **Matrix**

$s_{ij}=\sin\theta_{ij}$, $c_{ij}=\cos\theta_{ij}$

$$U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix}$$

3 mixing angles and 1 CPV phase

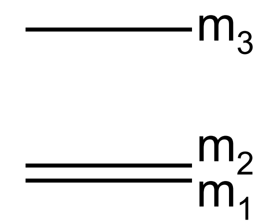
$$= \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & e^{-i\delta} \end{pmatrix} \cdot \begin{pmatrix} c_{13} & 0 & s_{13} \\ 0 & 1 & 0 \\ -s_{13} & 0 & c_{13} \end{pmatrix}$$

Solar — Atm ν — Reactor, Acc

Neutrino Oscillation

as an unique way to access neutrino (very small) mass and mixing

Oscillation Probabilities when $\Delta m_{12}^2 << \Delta m_{23}^2 \approx \Delta m_{13}^2$



ν_e appearance

$$P_{\mu \to e} \approx \sin^2 \theta_{23} \cdot \sin^2 2\theta_{13} \cdot \sin^2 (1.27 \Delta m_{23}^2 L / E_\nu)$$

ν_μ disappearance

$$P_{\mu \to x} = 1 - (P_{\mu \to e} + P_{\mu \to \tau}) \approx 1 - P_{\mu \to \tau}$$

ν_τ appearance

$$P_{\mu \to \tau} \approx \cos^4 \theta_{13} \cdot \sin^2 2\theta_{23} \sin^2 (1.27 \Delta m_{23}^2 L / E_\nu)$$

Same

CPV

$$A = \frac{P_{\mu \to e} - P_{\bar{\mu} \to \bar{e}}}{P_{\mu \to e} + P_{\bar{\mu} \to \bar{e}}}$$

All 3angles, 3Δm^2 need to be non-zero

$$\propto \sin\delta \cdot s_{12} \cdot s_{23} \cdot s_{13} \cdot \sin^2\left(\frac{1.27 \Delta m_{12}^2 L}{E}\right) \cdot \sin^2\left(\frac{1.27 \Delta m_{23}^2 L}{E}\right) \cdot \sin^2\left(\frac{1.27 \Delta m_{13}^2 L}{E}\right)$$

L : flight length(km), E_ν : neutrino energy(GeV), $\Delta m_{ij}^2 \equiv m_i^2 - m_j^2$, m_i : mass eigenvalues(eV)

Present knowledge on neutrino

Masses

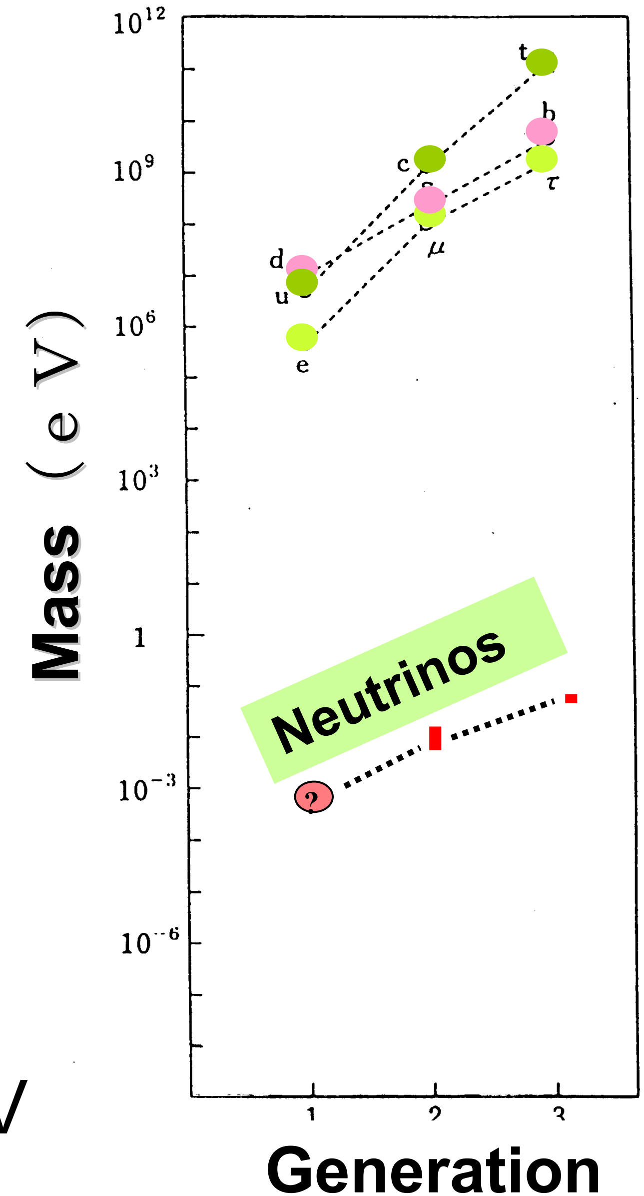
- □ $\Delta m_{23}^2 \sim 1.6 - 3.6 \times 10^{-3}$ eV^2 (atm ν)
- □ $\Delta m_{12}^2 \sim 3 - 20 \times 10^{-5}$ eV^2 (sol ν)
- Hierarchical masses:
  - $m_3 \sim 0.04 - 0.06$ eV
  - $m_2 \sim 0.005 - 0.014$ eV

Mixing angles

$\sin^2 2\theta_{23} \sim 1$ ($\theta_{23} \sim 45°$)

$\sin^2 2\theta_{12} \sim 0.8$ ($\theta_{12} \sim 30°$)

$\sin^2 2\theta_{13} < 0.12$ ($\theta_{13} < 10°$) @$\Delta m_{13}^2 \sim 3 \times 10^{-3}$eV^2



- Extremely small masses
- Large mixing
- $\theta_{13} > 0$? → important for CPV

Purposes of T2K experiment

1. **Test 3 flavor neutrino mixing framework**
   - **Discovery of ν_e appearance ($\theta_{13}>0$?)**
     - At the same Δm^2 as ν_μ disapp. →Firm evidence of 3gen. mix.
     - Most impotant and urgent in 1st phase
     - Open possibility to search for CPV
   - **Precision measurements of osc. params.**

     $\Delta m_{23},\theta_{23}/\Delta m_{13},\theta_{13}$

     Comparison w/ quark sector

     Test exotic models (decay, extra dimensions,….)
   - **NC measurement**

     No additional light “neutrino”?
2. **Search for CPV in lepton sector (2nd phase)**

   Give hint on Matter/Anti-matter asymmetry in the universe
3. **Proton decay search (2nd phase)**

   Direct evidence of Baryon number violation

Overview of T2K experiment

ν_μ beam of ~1GeV

Kamioka

Super-K: 50 kton
Water Cherenkov

~Mt "Hyper Kamiokande"

JAERI
(Tokai-mura)

0.75 MW 50 GeV PS

4MW 50GeV PS

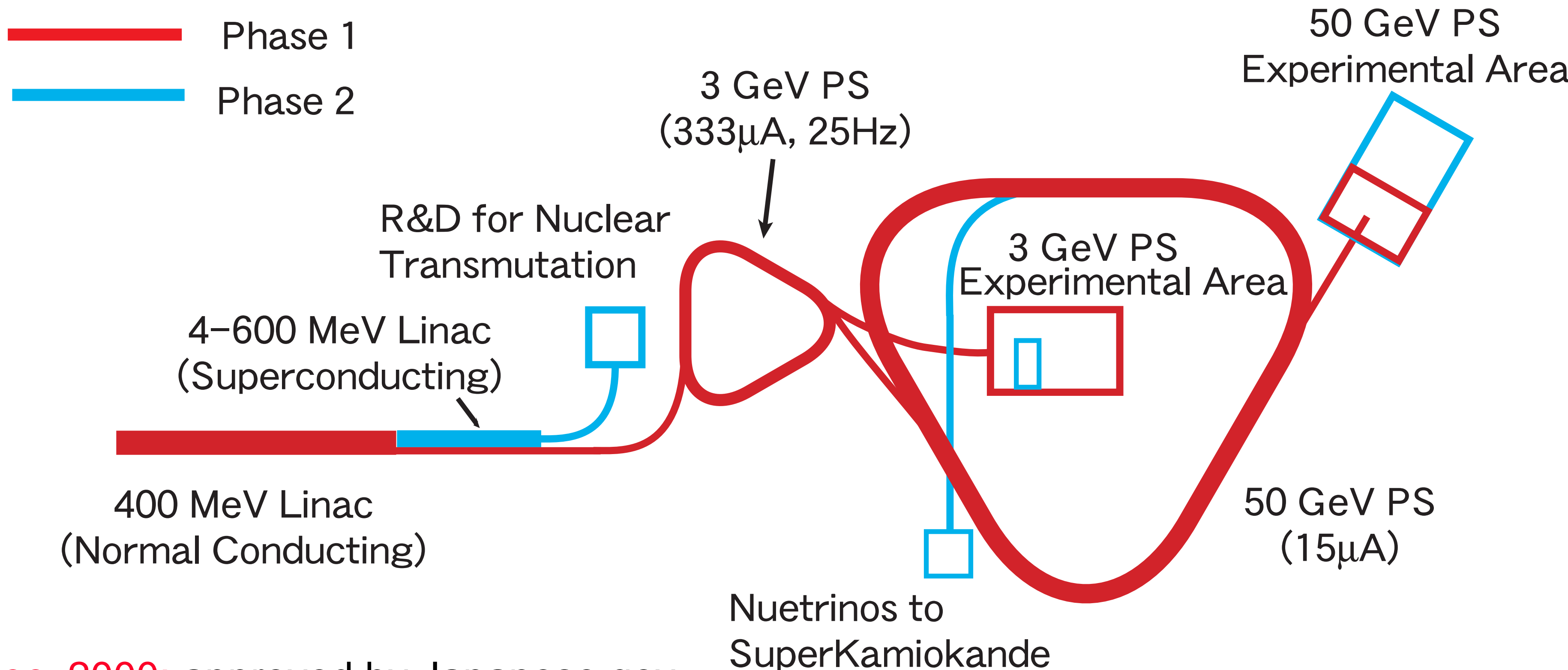
1st Phase

- $\nu_\mu \rightarrow \nu_x$ disappearance
- **$\nu_\mu \rightarrow \nu_e$ appearance**
- NC measurement

2nd Phase

- **CPV**
- **proton decay**

JHF project



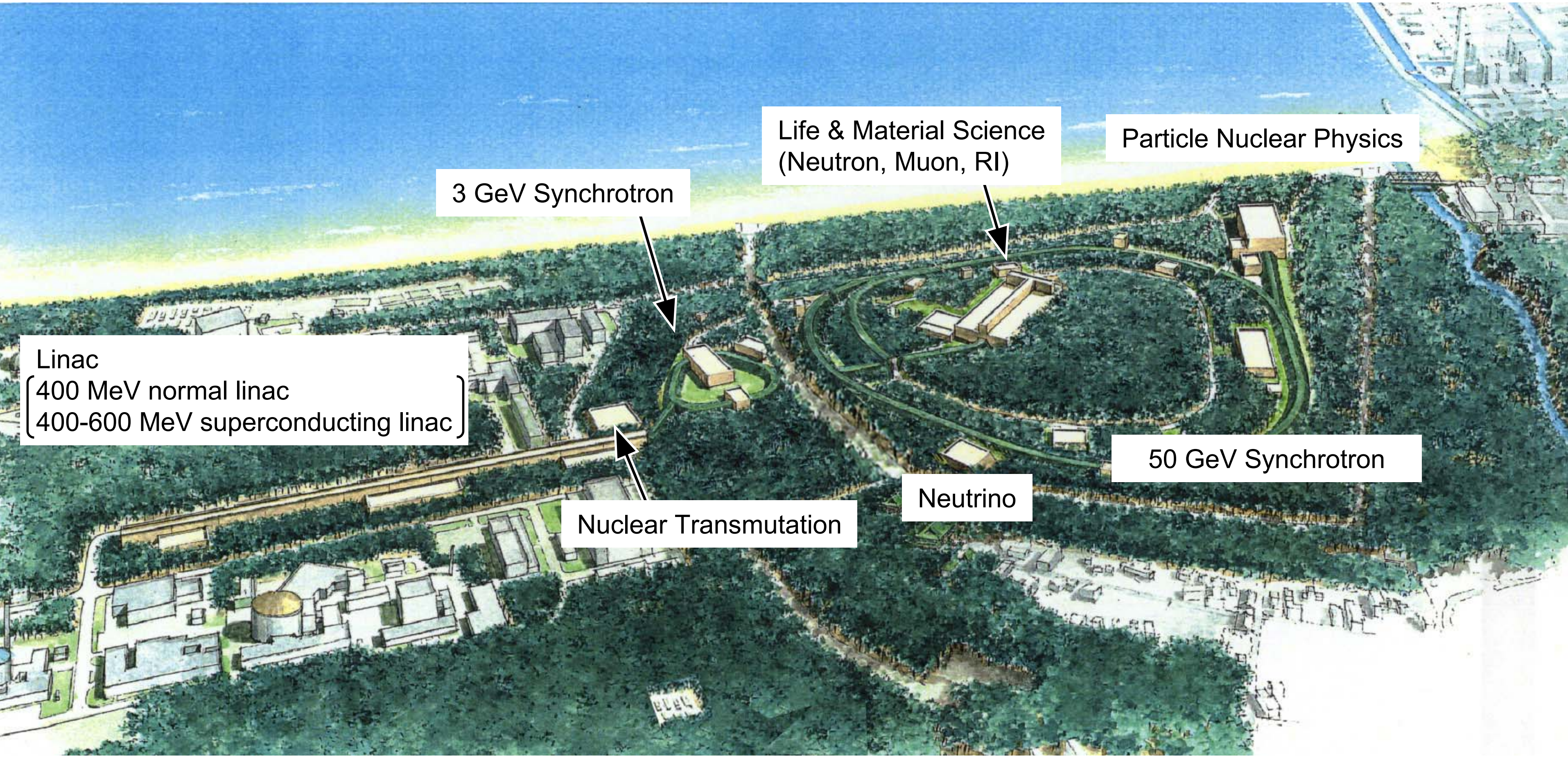
Dec. 2000: approved by Japanese gov.
April, 2001: Phase 1 construction started.

Phase 1 + Phase 2 = 1,890 Oku Yen.
Phase 1 = 1,335 Oku Yen for 6 years.
Cash in fund = 30 (JFY00) + 47 (JFY01) Oku Yen.
Construction budget does not include salaries.

March,2007: Phase 1 compelete

1 oku Yen= 1M$
when 1$=100yen

Site View of the Project



T2K

Giappone, USA, EU, Russia, Canada, Korea, Poland, ….

Italia
Francia
Spagna
Svizzera
UK

Bari
Napoli
Padova (Mezzetto)
Roma I

Milano
Roma III
Bologna
Cagliari

Principle

- Neutrino energy reconstruction by using **Quasi-elastic** (QE) interaction.
  - Oscillation pattern measurement
  - BG due to miss-reconstruction of inelastic interaction
    - Greatly improved by using narrow spectrum
- **Narrow spectrum tuned at the oscillation maximum.**
  - High sensitivity
  - Less background

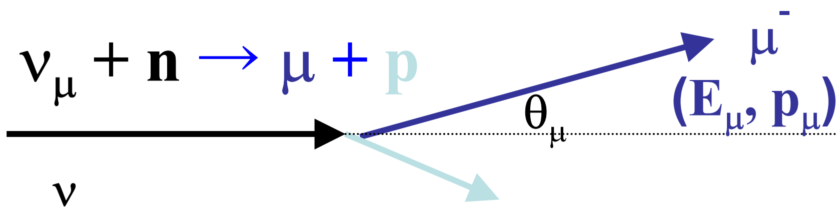
$\Delta m^2 = 1.6 \sim 4 \times 10^{-3}\,\mathrm{eV}^2$

$E_\nu = 0.4 \sim 1\,\mathrm{GeV}$

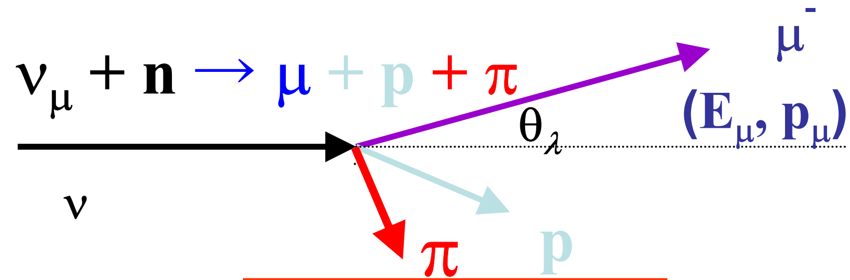
- **Gigantic water Cherenkov detector**
  - High statistics
  - High efficiency for low energy
  - Good PID (e/μ) capability

Neutrino Energy E_ν reconstruction

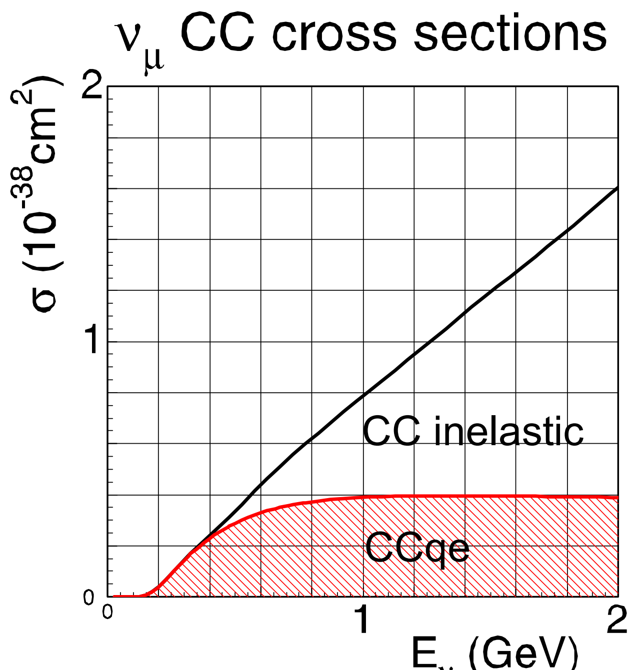
CC quasi elastic reaction $\Leftrightarrow$ $$E_\nu = \frac{m_N E_\mu - m_\mu^2/2}{m_N - E_\mu + p_\mu \cos\theta_\mu}$$

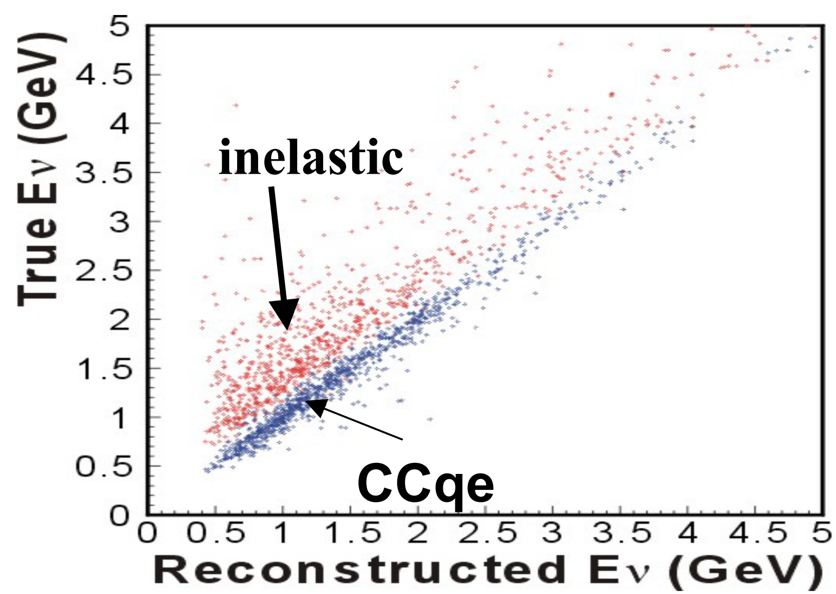


CCqe



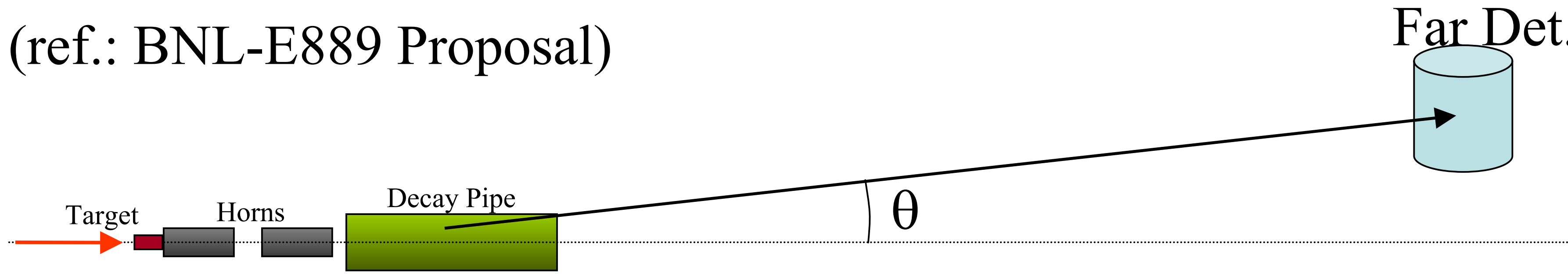
Inelastic (BG)





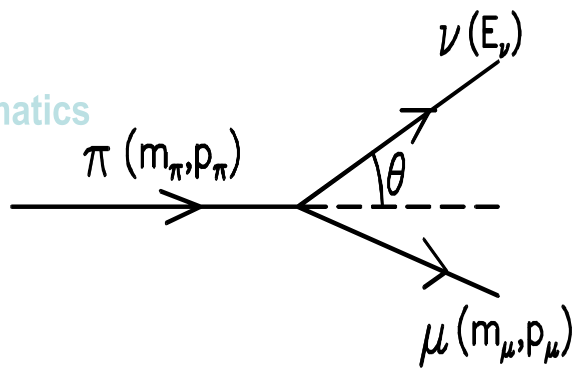
Off Axis Beam (another NBB option)

(ref.: BNL-E889 Proposal)



WBB w/ intentionally misaligned beam line from det. axis

Decay Kinematics

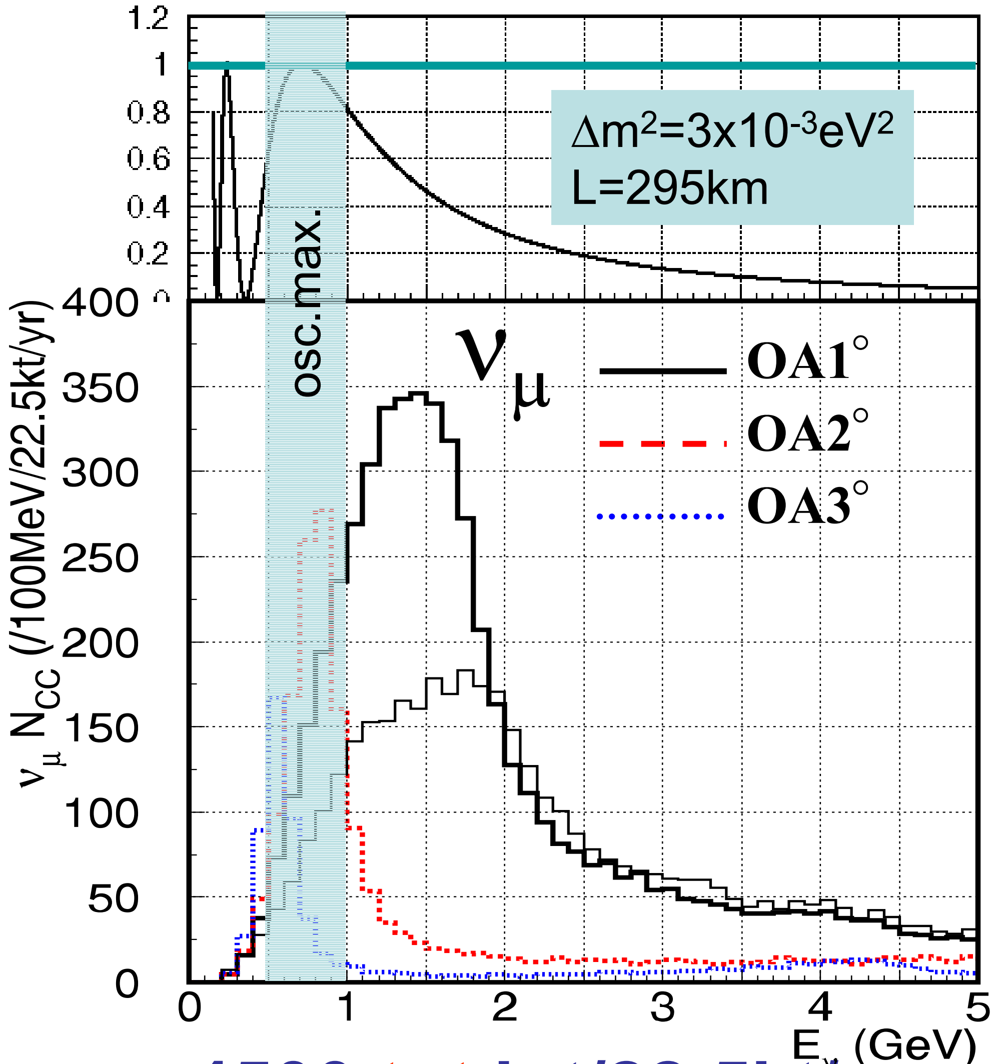


$$E_\nu = \frac{m_\pi^2 - m_\mu^2}{2(E_\pi - p_\pi \cos\theta)}$$

- Quasi Monochromatic Beam
- x2~3 intense than NBB

Expected spectrum

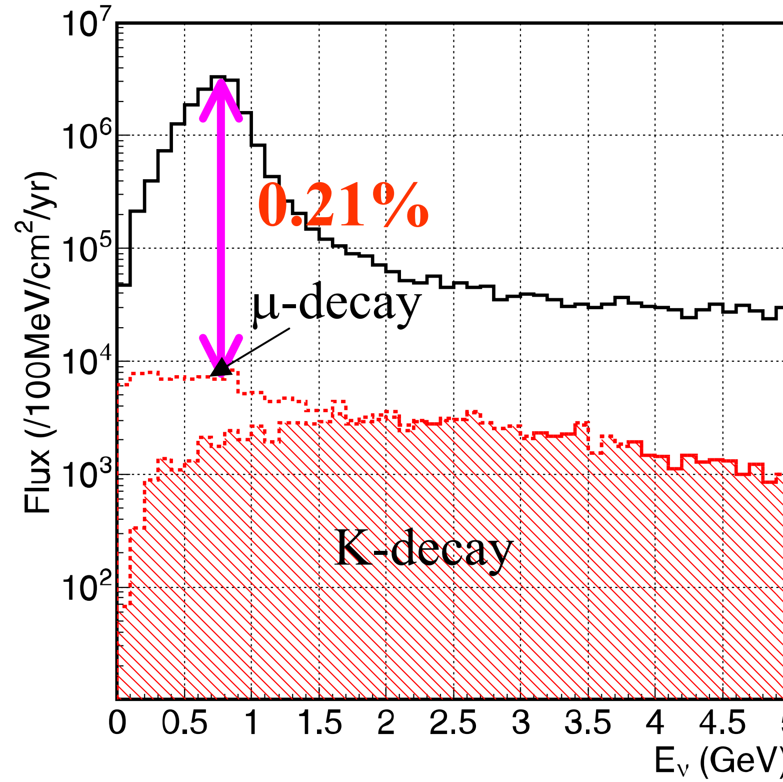
Osc. Prob.=$\sin^2(1.27\Delta m^2 L/E_\nu)$



~4500 tot int/22.5kt/yr

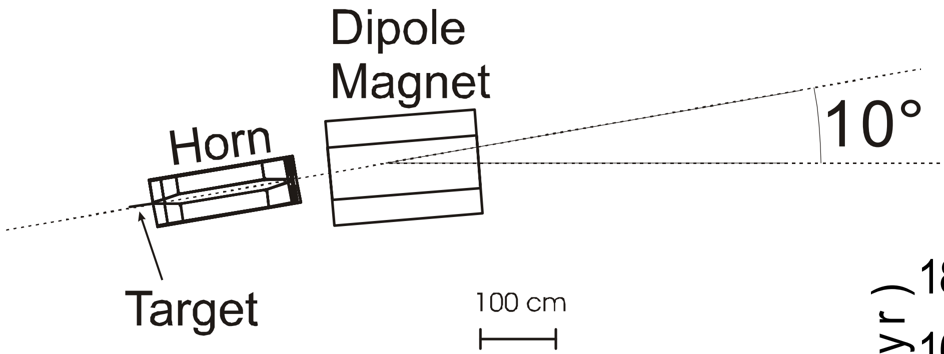
~3000 CC int/22.5kt/yr

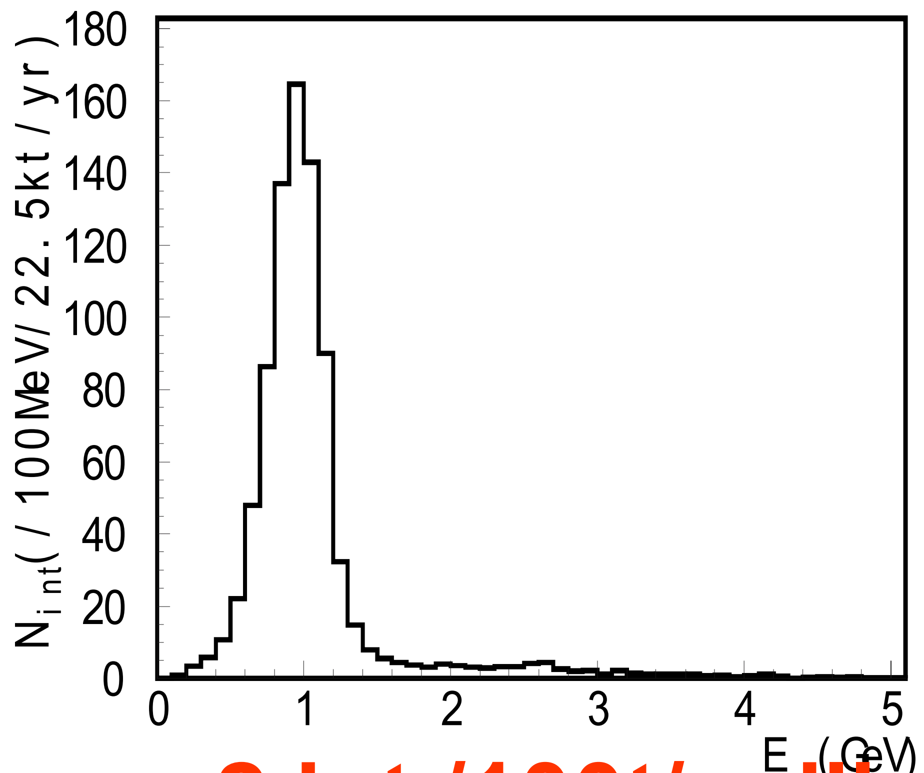
ν_e contamination



Very small ν_e/ν_μ @ ν_μ peak

Narrow Band Beam for ν int study @ near





- **Easy to tune E_ν**
- Less HE tail (than OAB)

～2 int./100t/spill

Detectors

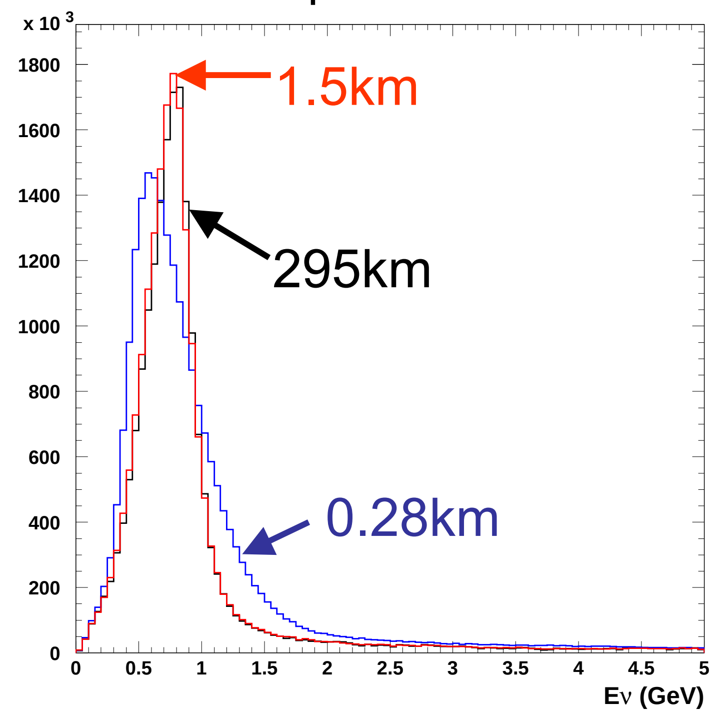
- **Muon monitors @ ~140m**
  - Behind the beam dump
  - Fast (spill-by-spill) monitoring of beam direction/intensity

- **First Front detector** "Neutrino monitor" @280m
  - Neutrino intensity/direction
  - Study of neutrino interactions

- **Second Front Detector @ ~2km**
  - Almost same E_ν spectrum as for SK
  - Absolute neutrino spectrum
  - Precise estimation of background

- **Far detector @ 295km**
  - **Super-Kamiokande (50kt)**
  - **Hyper-Kamiokande (~1Mt)**

Neutrino spectra at diff. dist

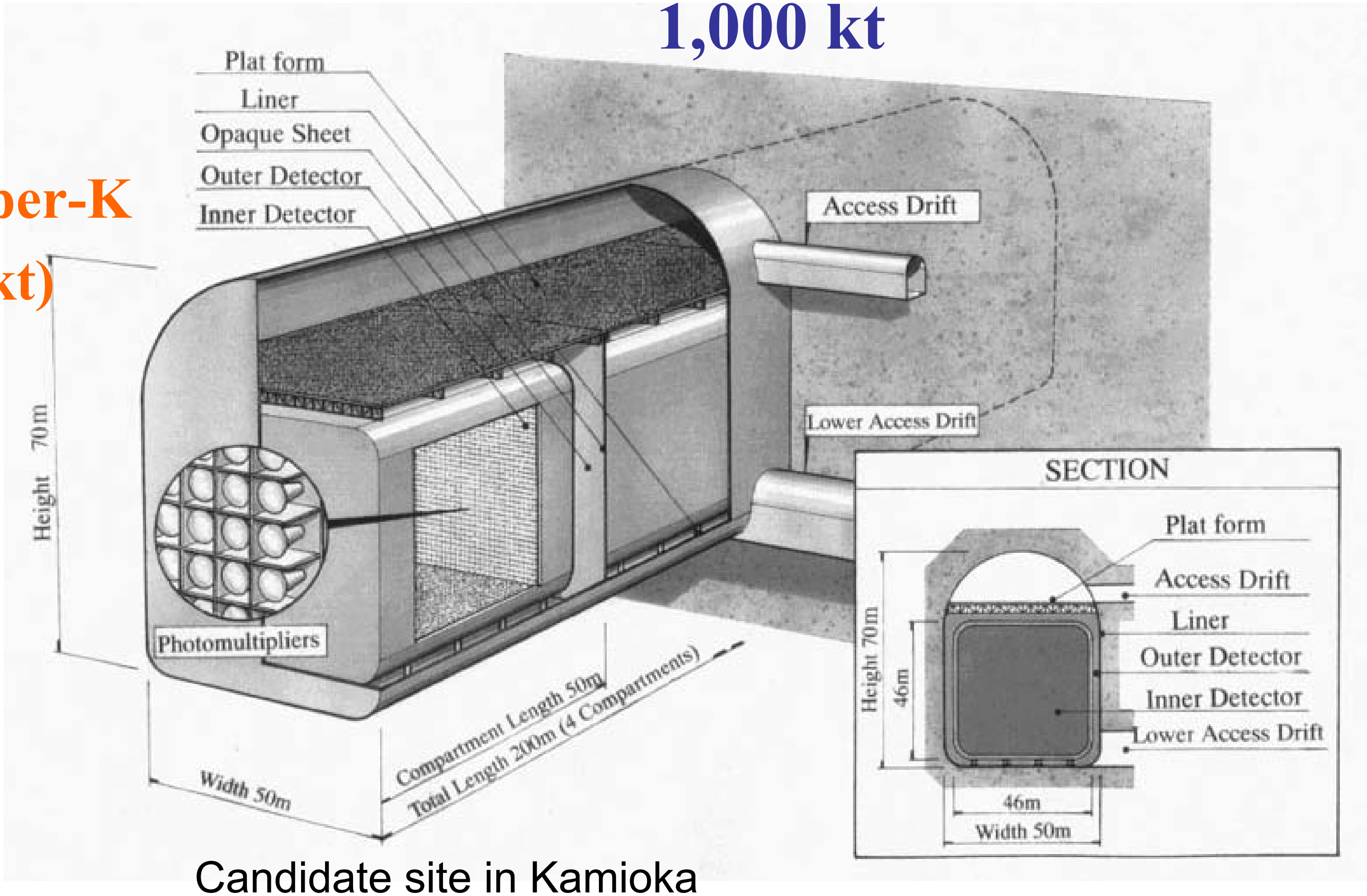


dominant syst. in K2K

Far detector in second phase

Phase-II: Hyper-K
1,000 kt

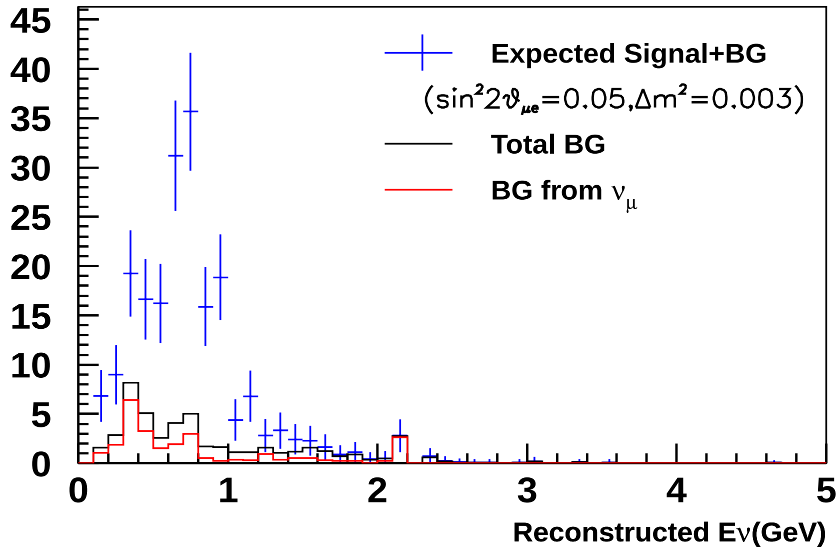
Phase-I: Super-K
22.5kt (50kt)



Candidate site in Kamioka

ν_e appearance

Off Axis (2°) 5year



5yr, 22.5kt

Chooz limit

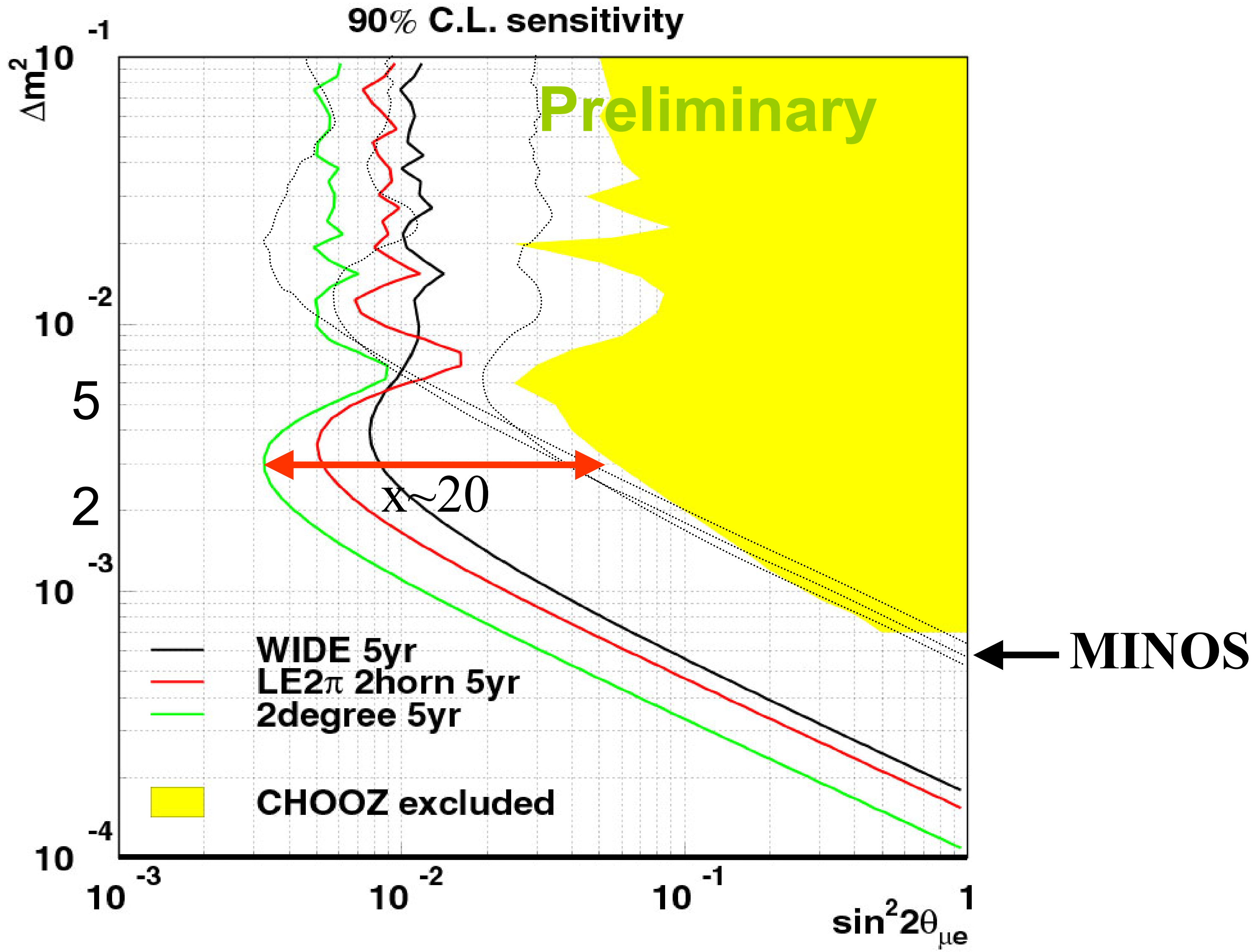
$\Delta m^2 = 3\times10^{-3}eV^2$, $\sin^2 2\theta_{13} = 0.1$

	ν_μC.C.	ν_μN.C.	Beam νe	Osc'd νe
Generated	10713.6	4080.3	292.1	301.6
Selected $.4<E_\nu^{rec}<1.2$	1.8	9.3	11.1	123.2
red.eff.	0.02%	0.2%	3.8%	40.8%

~90% of ν_μ BG from π^0 production

~60% of ν_μ BG comes from HE tail (E_ν^{true}>1.2GeV)

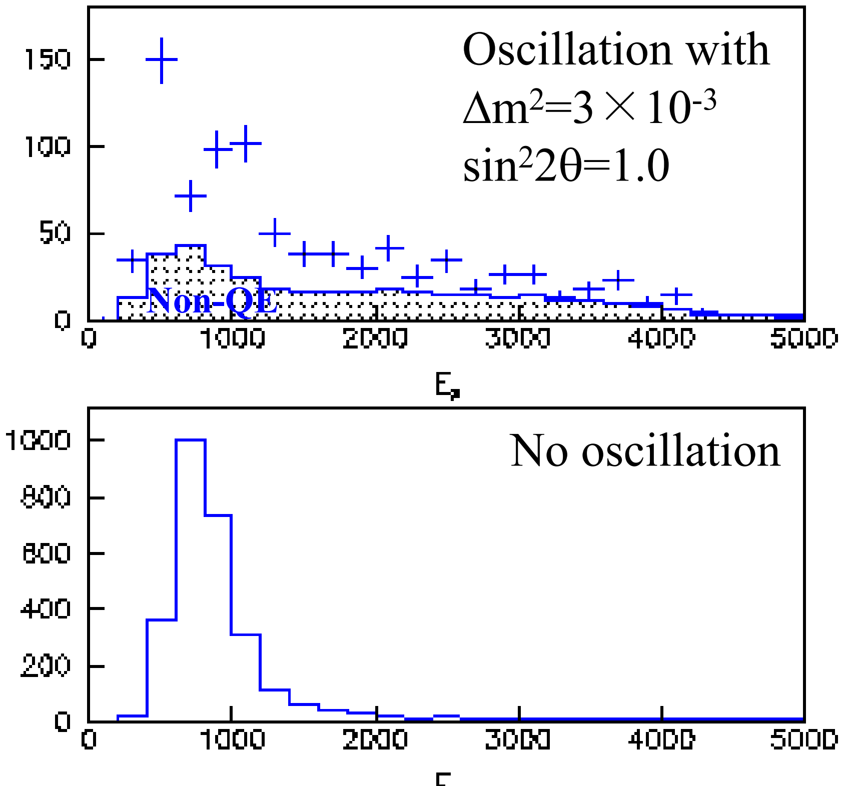
Sensitivity on $\nu_\mu \rightarrow \nu_e$ appearance



Dashed lines: MINOS Ph2le, Ph2me, Ph2he from right
(A.Para, hep-ph/0005012)

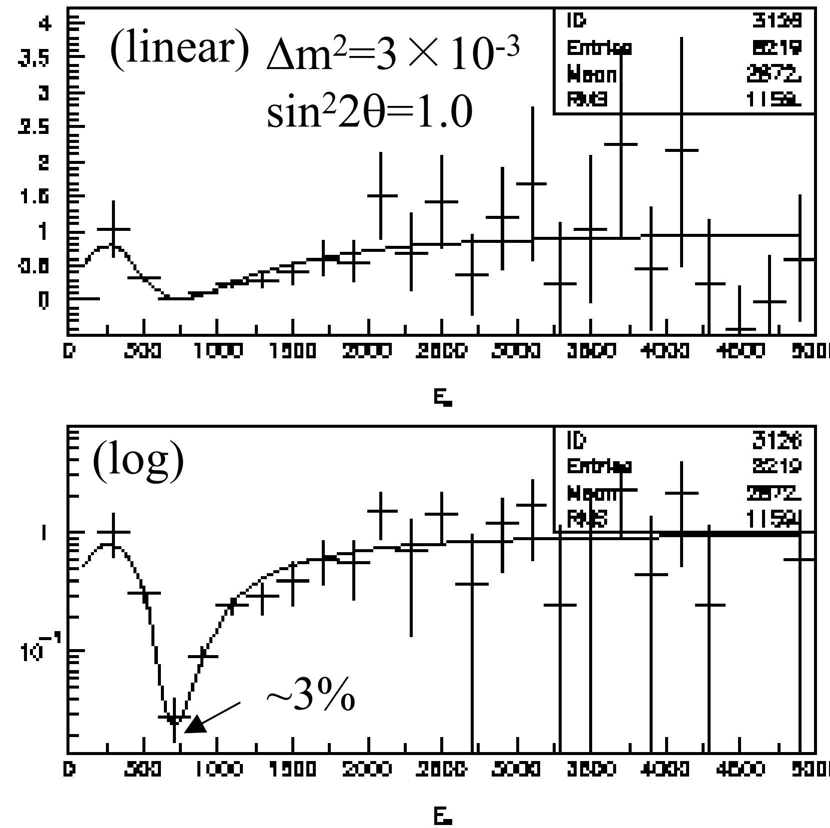
ν_μ disappearance

1ring FC μ-like



Reconstructed Eν (MeV)

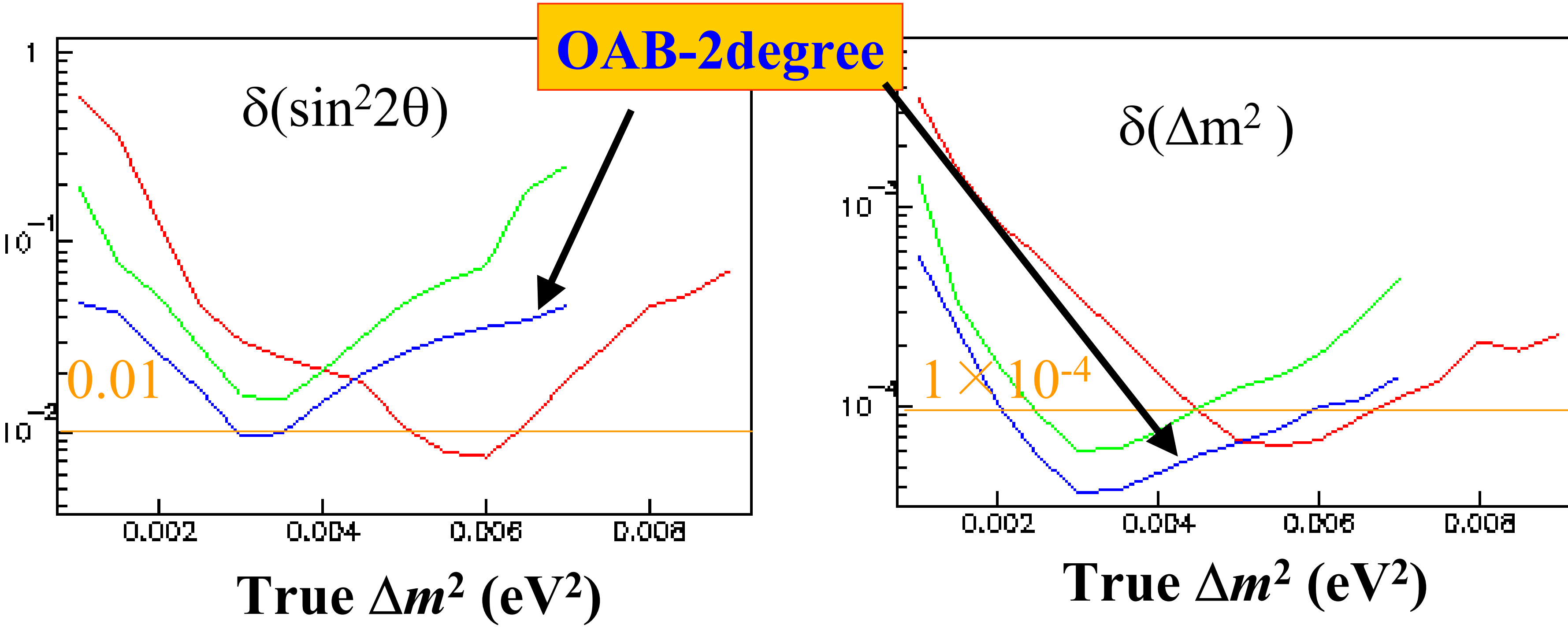
Ratio after BG subtraction



Fit with $1-\sin^2 2\theta \cdot \sin^2(1.27\Delta m^2 L/E)$

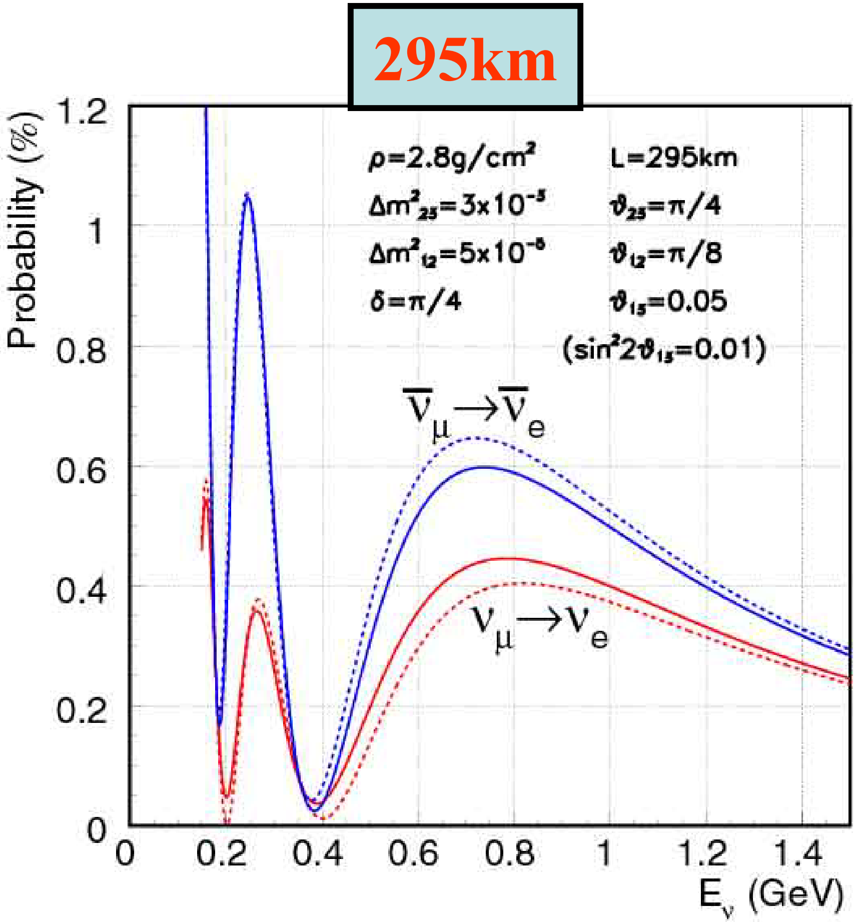
$\nu_\mu \rightarrow \nu_x$ disappearance

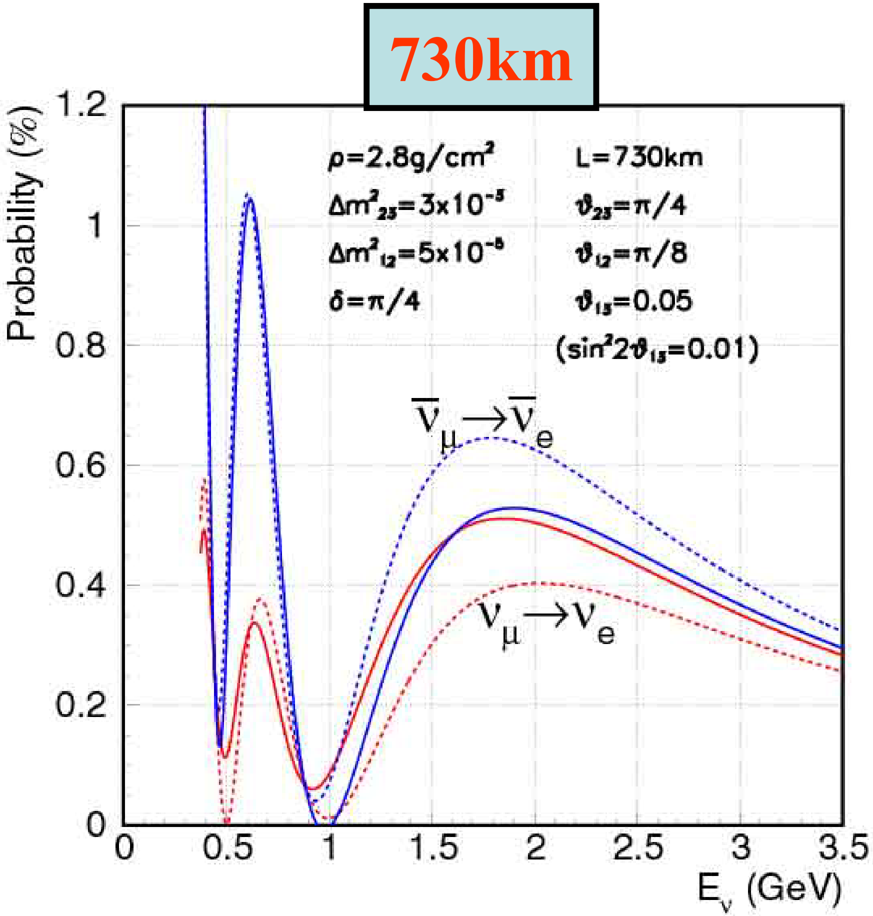
5 years precision



$\delta(\sin^2 2\theta) \sim 0.01$ in 5 years
$\delta(\Delta m^2) \quad \sim< 1 \times 10^{-4}$ in 5 years

$\nu_\mu \rightarrow \nu_e$ oscillation probability(2)

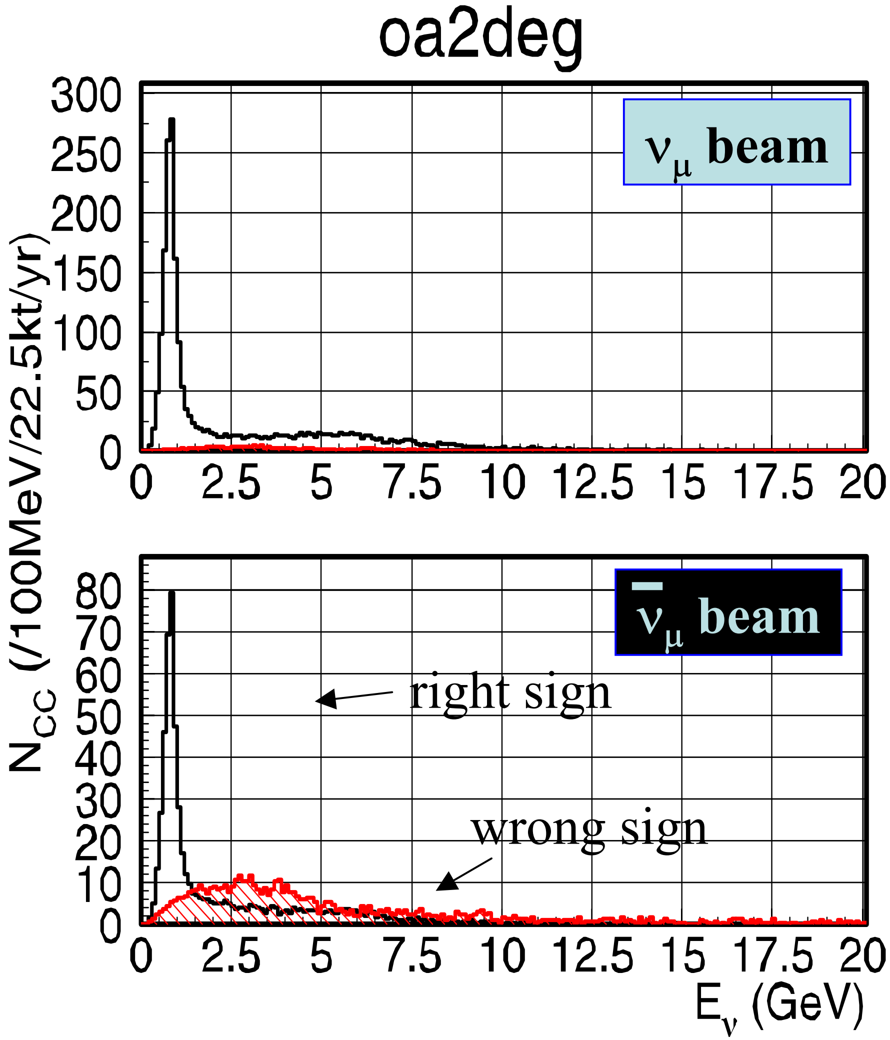




Solid line: w/ matter
Dashed line: w/o matter

Small Matter Effect at 295km.

$\nu_\mu / \bar{\nu}_\mu$ # of CC int.

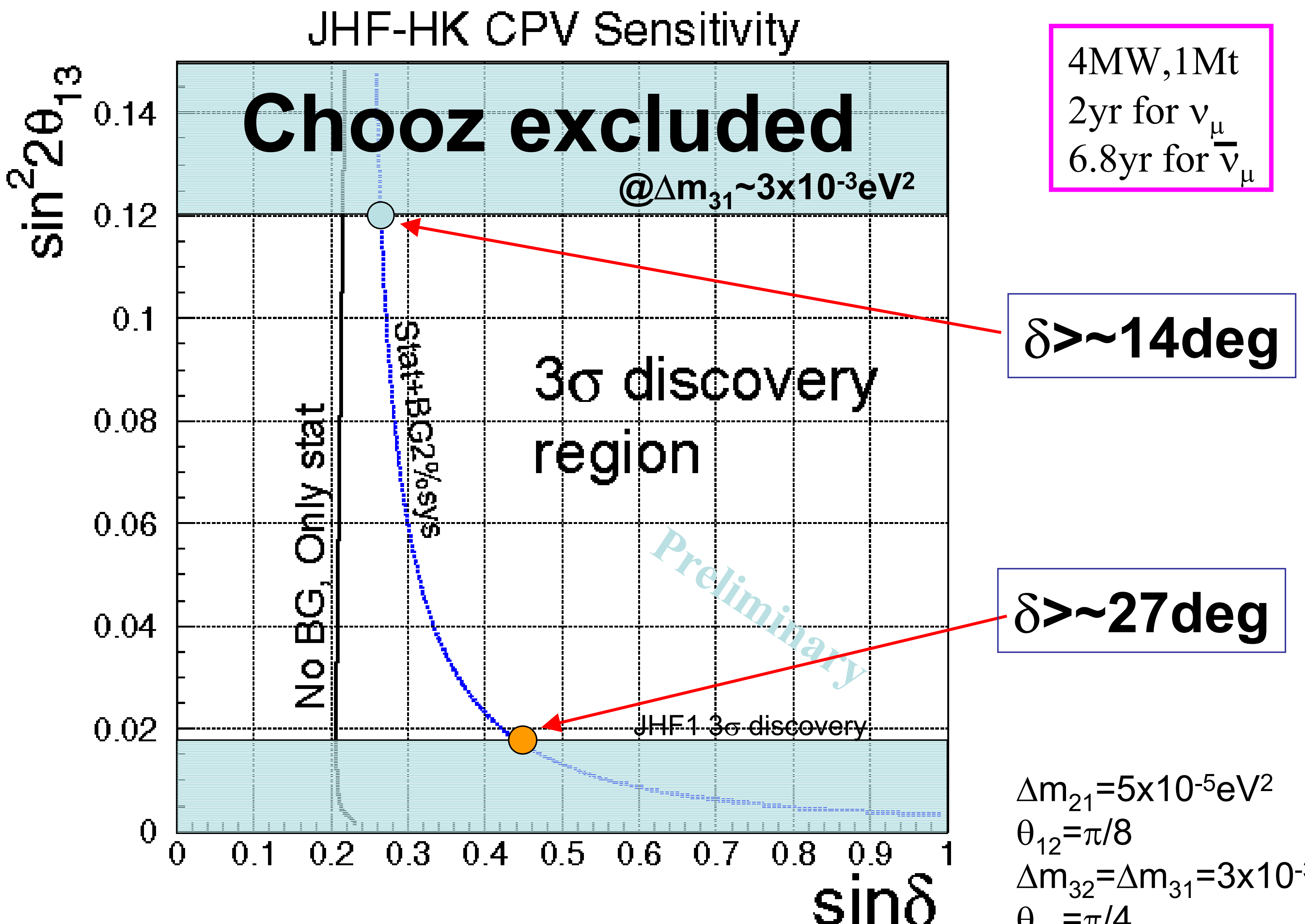


10^{21}pot/yr (1st phase)

80m pipe

- # of int. for $\bar{\nu}_\mu$ is factor ~3 smaller than ν_μ due to cross section.
- Wrong sign contamination is much higher for anti-ν.

Sensitivity(3σ) to CPV(2nd phase)



4MW,1Mt
2yr for ν_μ
6.8yr for $\bar{\nu}_\mu$

$\Delta m_{21}=5\mathrm{x}10^{-5}\mathrm{eV}^2$
$\theta_{12}=\pi/8$
$\Delta m_{32}=\Delta m_{31}=3\mathrm{x}10^{-3}\mathrm{eV}^2$
$\theta_{23}=\pi/4$

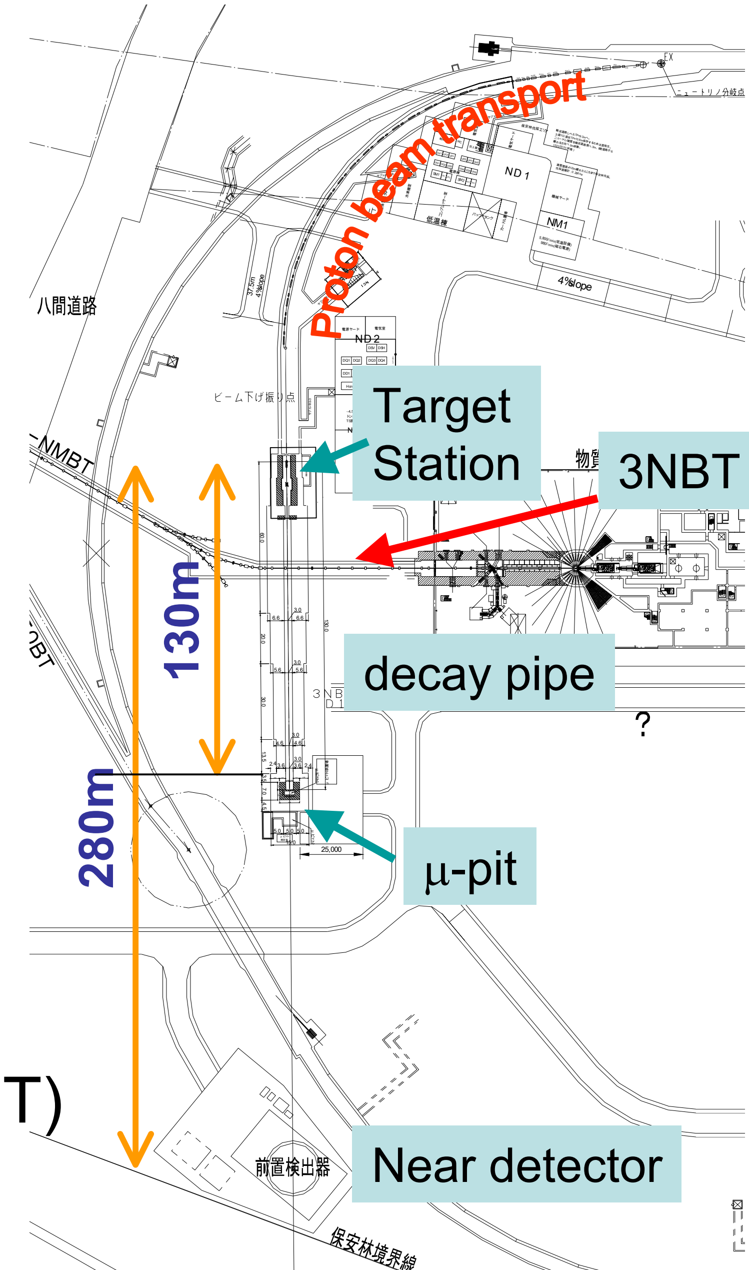
Neutrino Facility

Neutrino beam line

p+(target)→ π → ν_μ + μ

Components

- Proton beam transport
  - Preparation section
  - **Arc section (Supercond.)**
  - Final focusing
- Target/Horn system
- Decay pipe (130m)
- Beam dump



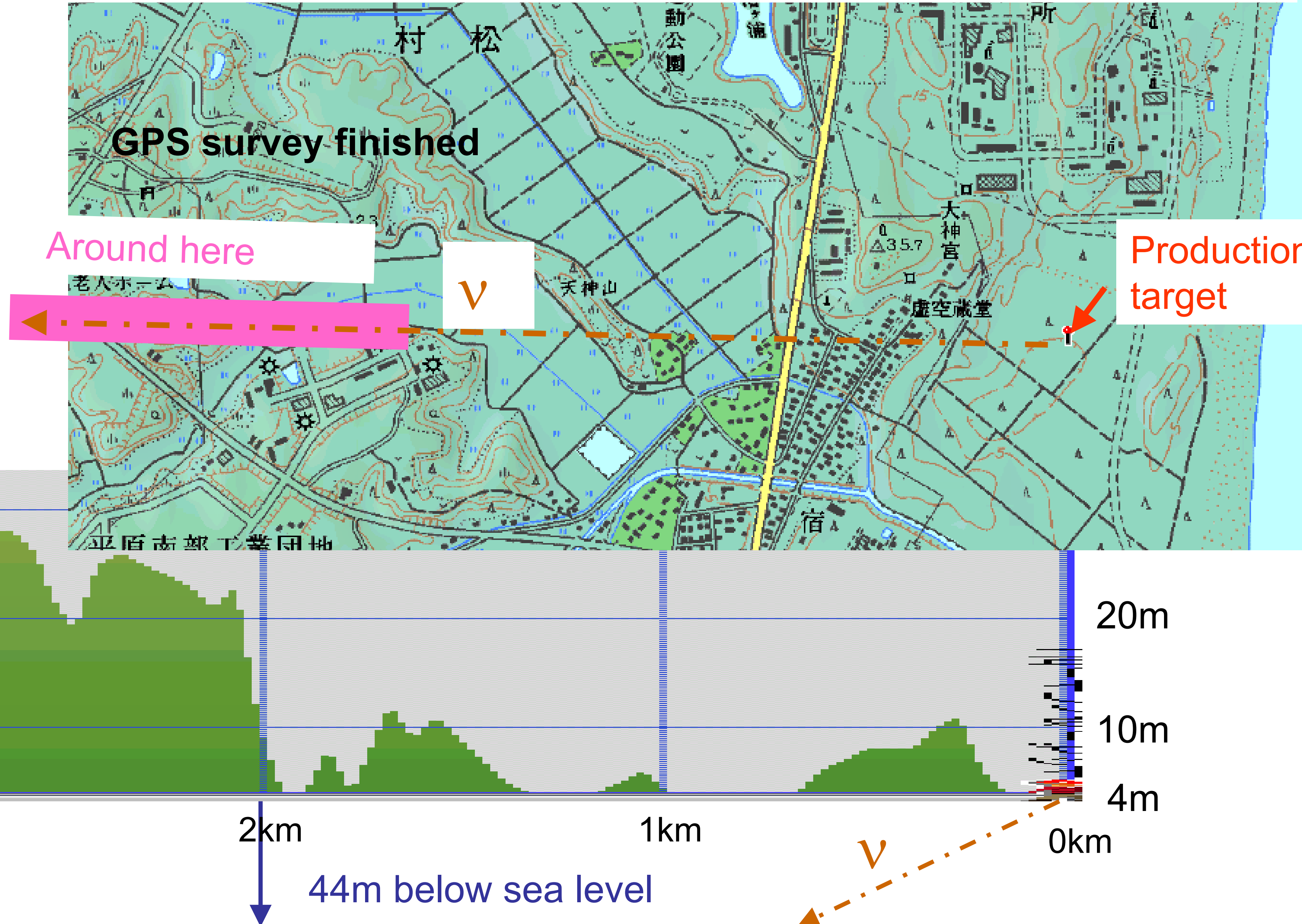
- Single turn fast extraction
- 8 bunches/~5μs
- 3.3×10^{14}proton/pulse
- 3.94 (3.64) sec cycle
- 1 yr ≡ 10^{21}proton on target(POT)

(3300hr~140days)

Specification

Beam kinetic energy	50GeV
Protons/pulse	3.3×10^{14}
Beam current	15μA
Beam power	750kW
Extraction	Single turn fast extraction
Micro structure	8bunches/9 RF buckets
Bunch spacing	598ns
Spill width	~5μs
Cycle	3.64~3.94sec
Rep rate	0.254~0.275Hz
Proton beam emittance	6.1πmm.mrad
Physical acceptance	60πmm.mrad
Beam loss(proton transport)	1W/m
Curvature of arc	106m
Decay pipe length (target-dump)	130m (from target)
Distance to near detectors	280m/~2km
Distance to SK	~295km
Target-SK beam decline	-1.25deg

Candidate sites for 2km front detector

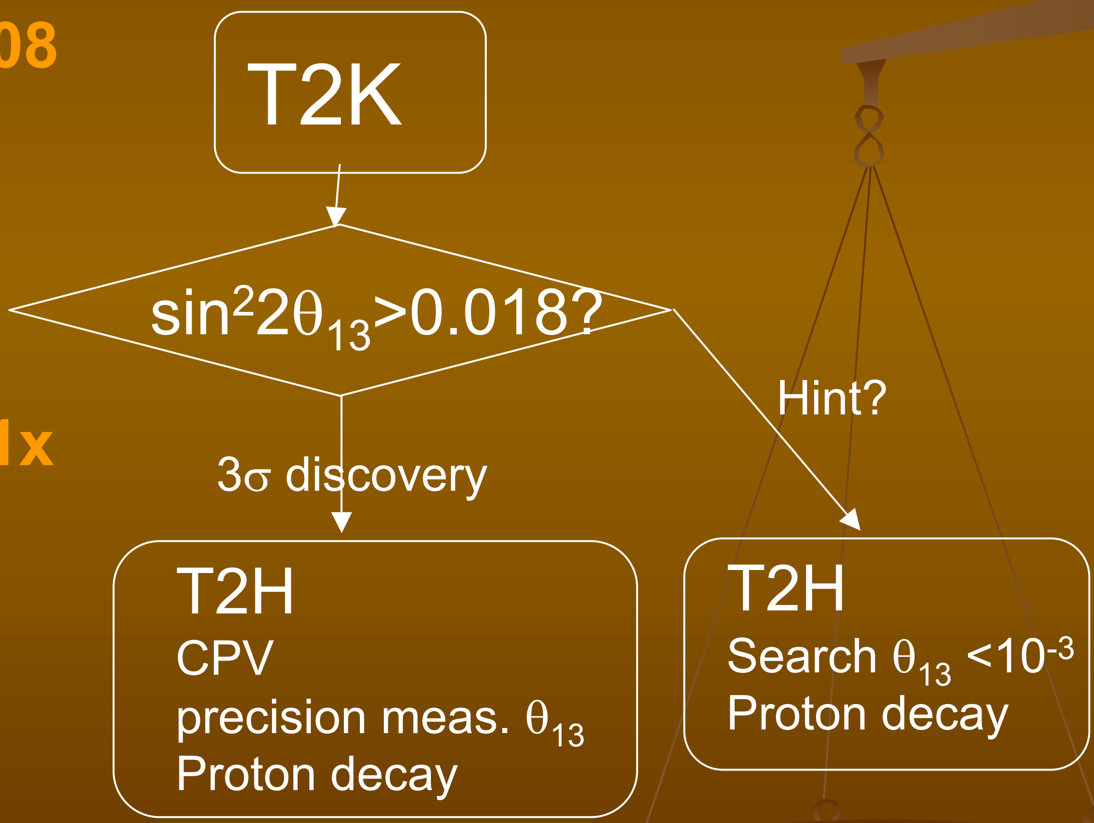


Future Prospect

2003 : JHFn budget request&approval
2004 : start construction
2005 : K2K final results

2008

201x

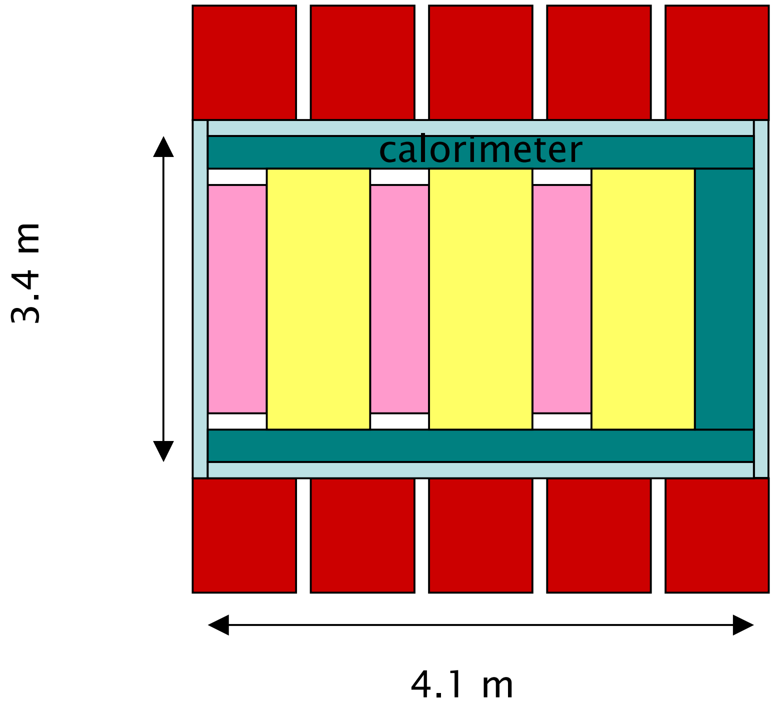


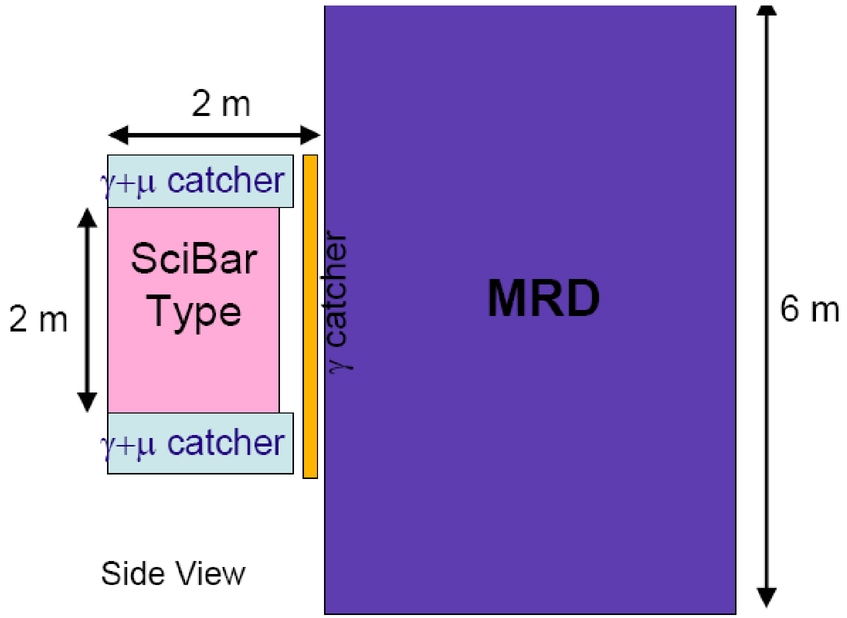
20xx Future SuperBeam, VLBL, ν-fact for very small θ_{13}, CPV, sign of Δm^2

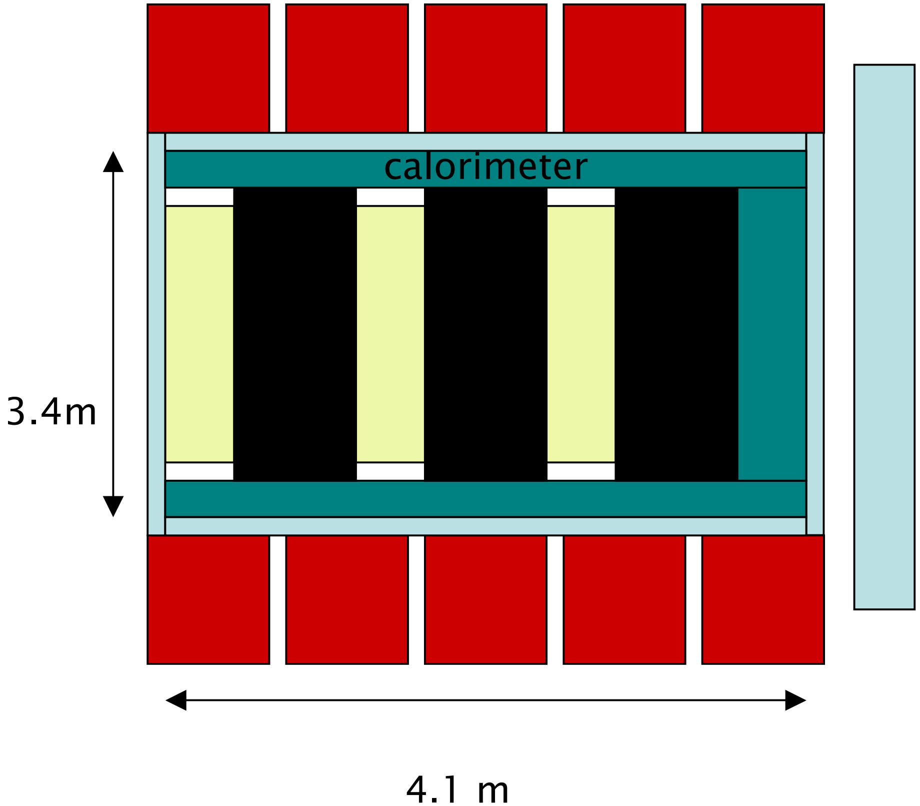
280 m The two conceptual designs

EU initiative

US initiative







magnet (engineering, coils, power supply)

optimal segmentation (Federigo, Lucio)

tracking device (Emilio)

scintillators in iron

e.m. calorimeter

external hadron absorber

Magnet – coils, power supply, transport ~ 1 MEuro

Tracking
Electronics 1–2 MEuro

SCIBAR – Japan+US ?

Tele Meeting T2K-I
oggi 14:30 !!!
Lab PAMELA

Beams for European Neutrino Experiments (BENE)

5 years Networking Activity within CARE:
N3

subtitle:

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

V. Palladino
Univ & INFN Napoli
INFN/CSN2, LNGS, 22/3/04

an UPDATE SINCE CARE kick-off meeting
21 October 2003
CERN

CARE
Coordinated Accelerator R&D in Europe

15 M€

R. Aleksan, S. Guiducci at al

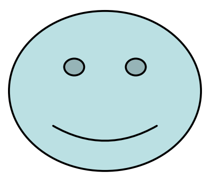
Networking Activities
(3 subprojects)

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

600KE

N3: BENE
(Beams for European NeutrinoExperiments)
(V. Palladino/INFN)

500KE / 220 scientists



N4: HEHIHB
High Energy and High Intensity Hadron Beams
(H. Haseroth/CERN)

400KE

Joint Research Activities
(5 subprojects)

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

2600KE

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

2600KE

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

3600KE

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

3600KE

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

!

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

1000KE

NB EC co-funding scheme !

...

...

all the major players

Table 8.N2.2a: List of contracting participants

Participant number	Participant	PHYSICS	DRIVER	TARGET	COLLECTOR	NOVEL NEUTRINO BEAMS
1	CEA	X	X	X	X	X
2	UCLN	X				X
3	CNRS	X			X	X
	CNRS Orsay	*X*			*X*	*X*
	CNRS LPHNE	*X*			*X*	
	CNRS CENBG	*X*				
	CNRS Lyon	*X*			*X*	
	CNRS LCSC					*X*
4	GSI					X
7	FZJ		X	X		
8	TUM	X				X
10	INFN	X	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	*X*				*X*
	INFN-Pi	*X*				
	INFN-Tr	*X*				*X*
	INFN-Ro3	*X*				*X*
	INFN-To	*X*				
16	CSIC	X				
	UBa	*X*				
	IFIC	*X*				
	UAM	*X*				
17	CERN	X	X	X	X	X
18	UNI-GE	X		X	X	X
19	PSI			X		
20	CCLCR	X	X	X	X	X
21	ICL	X		X		X

DESY& Univ ? ← (8 TUM)

world wide context … road maps

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

Participant number	Participant	PHYSICS	DRIVER	TARGET	COLLECTOR	NOVEL NEUTRINO BEAMS	Associated to
13	UnO	X	X	X	X	X	CERN
15	IPUL			X			FZJ
16	NRG			X			FZJ
22	UNI-Bern	X					UNI-GE
23	UNI-Neuchatel	X					UNI-GE
26	PIUZ	X				X	UNI-GE
27	BAT	X		X			ICL
28	BRU	X				X	ICL
29	CAM	X					ICL
31	DUR	X					ICL
32	EDIN	X					ICL
33	GLA	X				X	ICL
35	QMUL	X					ICL
38	ULI	X				X	ICL
39	UOX	X		X		X	ICL
40	SHEF	X		X		X	ICL
41	SOTON	X					ICL
43	SUSS	X					ICL
44	FNAL	X	X	X	X	X	CERN
45	LBL	X				X	CERN
46	BNL	X	X	X	X	X	CERN

accelerator and particle physics …

from theory to detectors

35 scientists in Infn team in BENE

INFN	
Bari	*G. Catanesi*
	E. Radicioni
Genova	*P. Fabbricatore*
	R. Musenich
	S. Farinon
Gran Sasso	*O. Palamara*
Legnaro	*U. Gastaldi*
	A. Pisent
	A. Facco
Milano	*M. Bonesini*
	S. Ragazzi
	M. Paganoni
	A. Demin
	T.Tabarelli
Napoli	**V. Palladino**
	G. De Lellis
	P. Migliozzi
Padova	*M. Mezzetto*
	M. Laveder
	F. Bobisut
	A. Guglielmi
	S. Dusini
Pisa	A. Strumia
Roma 3	L. Tortora
	A. Tonazzo
	F. Pastore
	D. Orestano
Torino	*C. Giunti*
Trieste	G.R. Giannini
	P. Chimenti
	M. Apollonio
LNF	M. Castellano
	M. Migliorati
	C. Vaccarezza
	F. Terranova

Particle & Accelerator Physicists

Membership completely OPEN !!!!

tutti possiamo/dobbiamo contribuire

INFN/Milano in HIPPI … more in DS

The options we have explored

NB: beam + detector configurations

novel beams

Conventional beam π **decay channel** ... ν_μ (0.1-1% ν_e)

SuperBeam, if MW power ....

need Very Large Detector (water C, Li-Ar)

the same as p-decay

50-500 Ktons ie new lab

Neutrino Factory μ **storage ring** ..... ν_μ & $\bar{\nu}_e$

manipulate & accelerate ν parents !

(& μ accelerator complex!)

needs Large Magnetic Detector

(SuperMINOS, Li-Ar in $\vec{B}$)

30-100 Ktons LNGS ! new lab ?

BetaBeam β **storage ring** ... pure ν_e

(& EU accelerator complex)

detectors same as SuperBeams

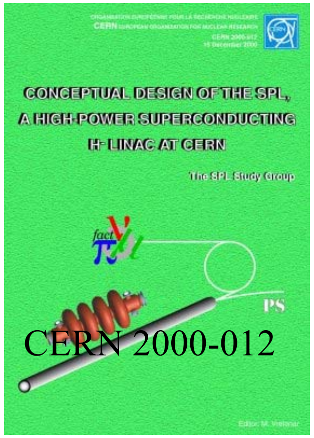
NB : $\bar{\pi}$ $\bar{\mu}$ $\bar{\beta}$ possible, in all cases, for CP, T & CPT studies

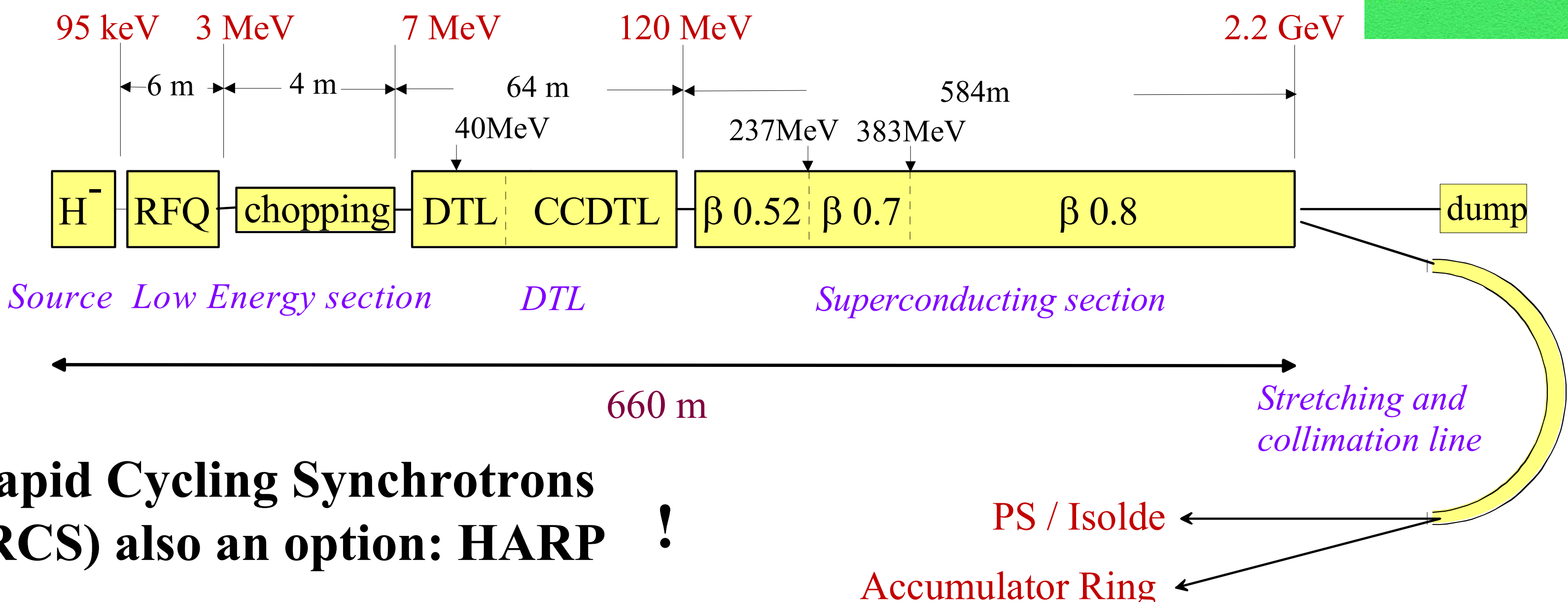
Any option relies on a new powerful EU p-driver !!!!!!!!!!!!!!!!!!

EKIN = 2.2 GeV
Power = 4 MW
Protons/s = 10^{16} → 10^{23} protons/year

SPL basics

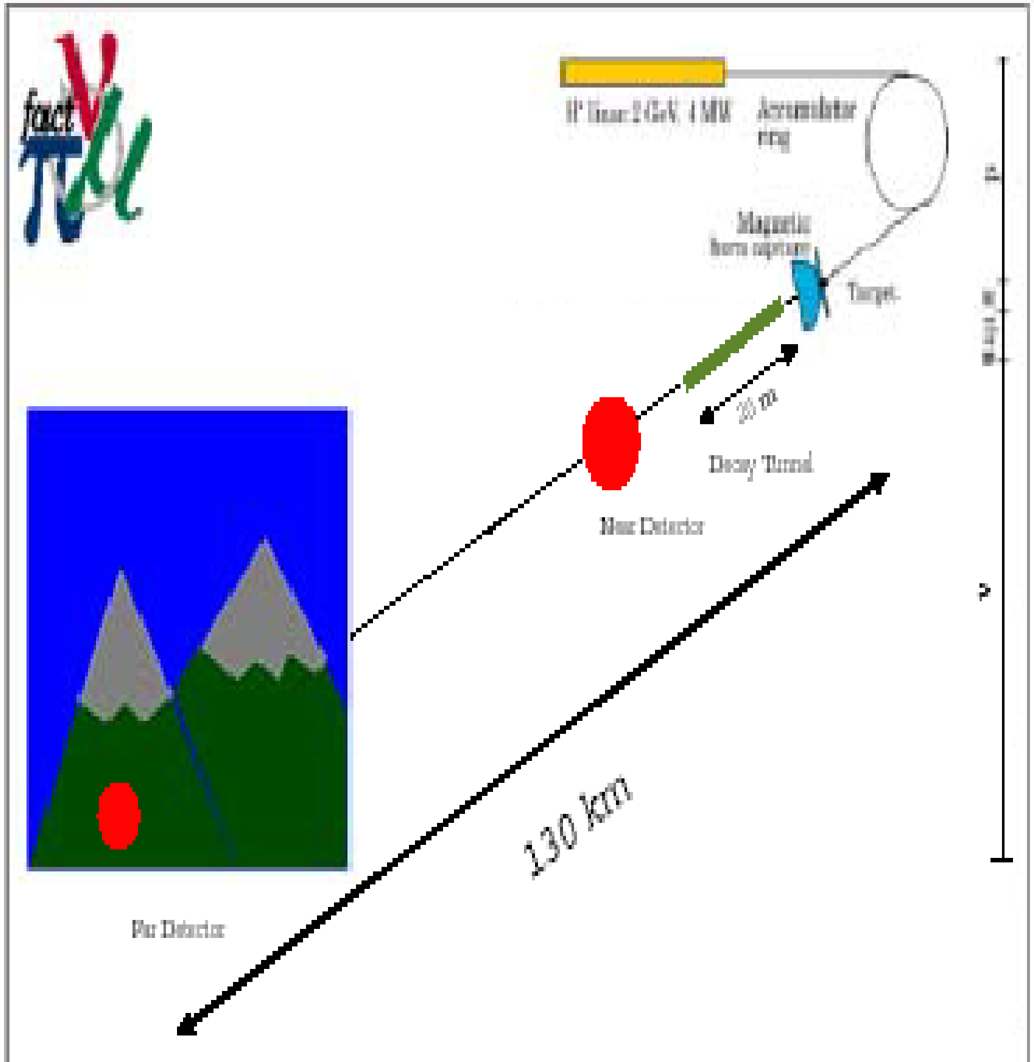
Study group since 1999
design of a Superconducting Proton Linac (H-, 2.2 GeV).
- ☞ higher brightness beams into the PS for LHC
- ☞ intense beams (4 MW) for neutrino and radioactive ion physics



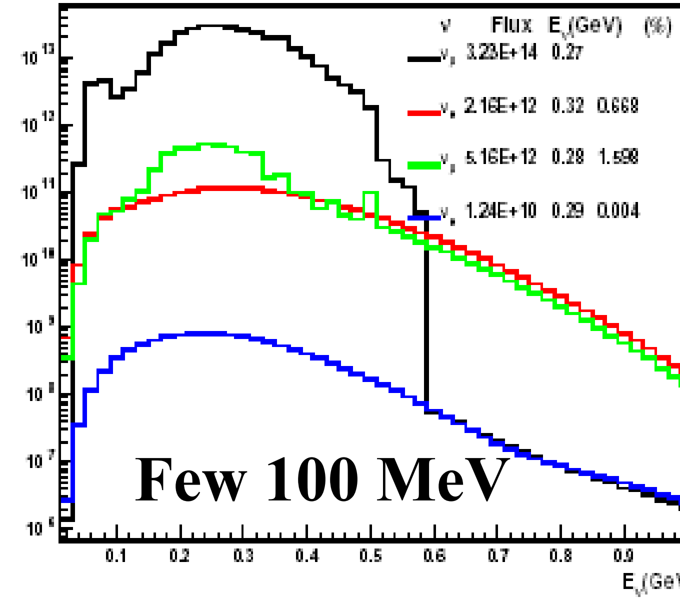


NB Rapid Cycling Synchrotrons (RCS) also an option: HARP !

Conventional SuperBeam: the CERN scheme



Possible Low Energy Super Beam Layout



Flux intensities at 50 km from the target

Flavour	Absolute Flux ($\nu/10^{23}$pot/m^2)	Rel. Flux (%)	$\langle E_\nu \rangle$ (GeV)
ν_μ	$3.2 \cdot 10^{12}$	100	0.27
$\overline{\nu}_\mu$	$2.2 \cdot 10^{10}$	1.6	0.28
ν_e	$5.2 \cdot 10^{9}$	0.67	0.32
$\overline{\nu}_e$	$1.2 \cdot 10^{8}$	0.004	0.29

$\nu_\mu \rightarrow \nu_e$ **appearance**

France+Italy

… Europe

FREJUS EOI SUMMARY

A. De Bellefon, J. Bouchez, L.Mosca et al.

June 3, 2003

Astroparticle Observatory

N decay

S-Novae

atmo ν

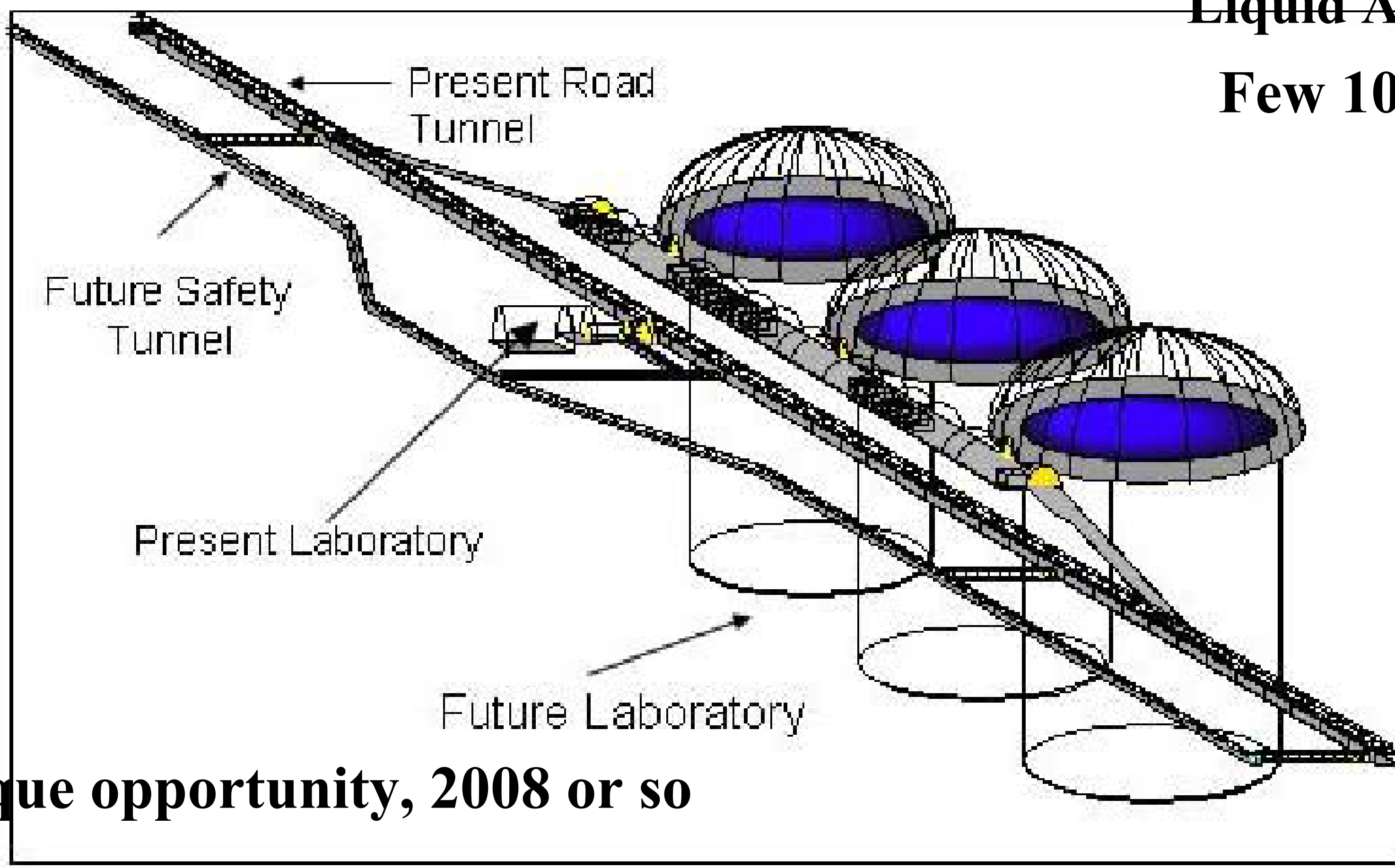
Abstract

A Megaton Physics project in the Fréjus underground site, focalised 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.

UNO, Hyper-K

Liquid Argon

Few 100 MeV



Unique opportunity, 2008 or so

Figure 2: *Proposal for a new excavation in the Fréjus tunnel* .

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	IN2P3/CNRS	INFN
Prof. F. Gounand	Prof. M. Spiro	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 od 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.

May

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.

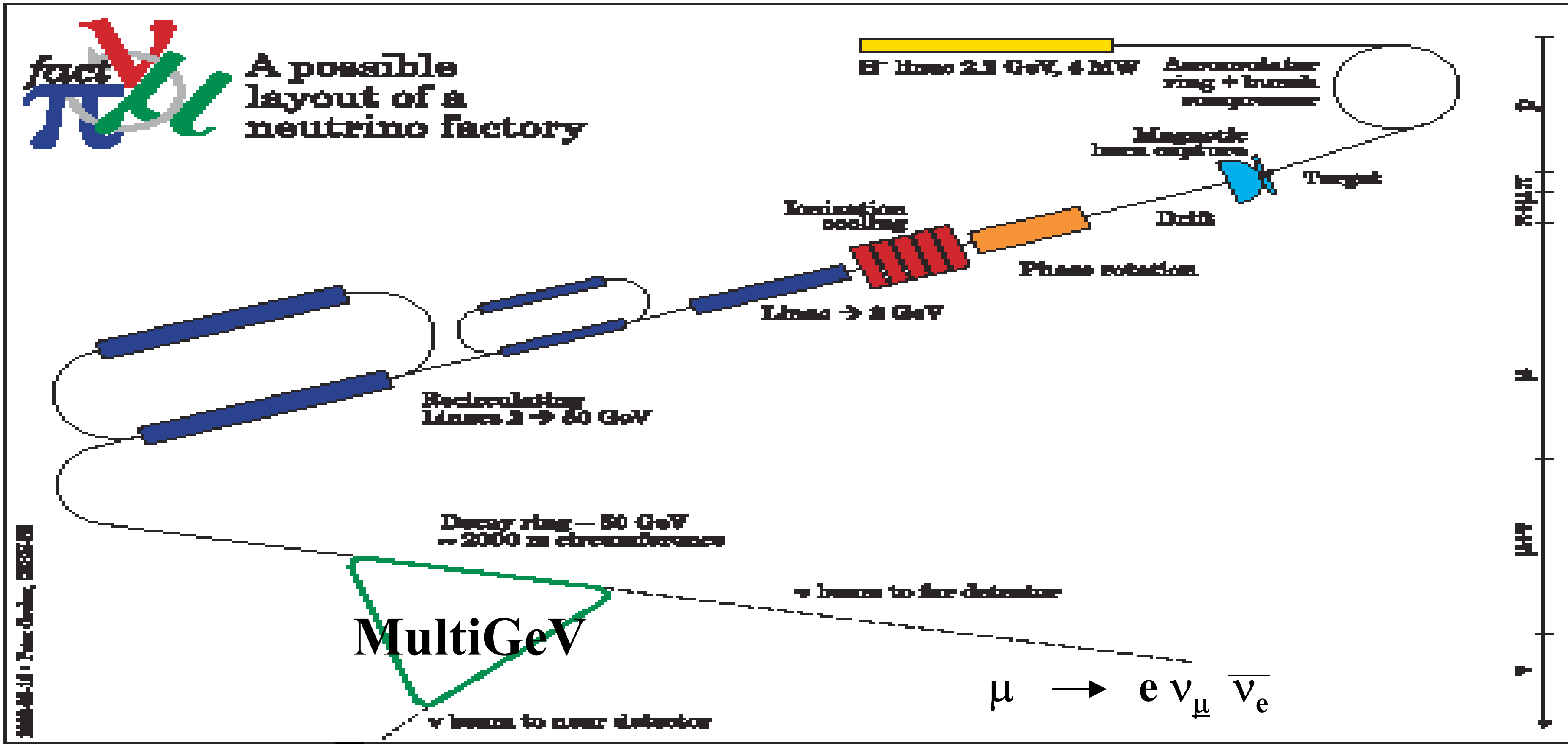
5) An International Workshop is planned at Aussois (near to thr Fréjus site), possibly in May this year, to review this type of projects at the world scale.

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)

June 11 &12, Paris

Neutrino Factory: CERN Scheme



$\mu \rightarrow e\, \nu_\mu\, \nu_e$

Disappearance

$\bar{\nu}_e \rightarrow \bar{e}$ **deficit**

$\nu_\mu \rightarrow \mu$ **deficit**

Appearance

$\nu_\mu \rightarrow \nu_e \rightarrow e$ **excess**

$\nu_\tau \rightarrow \tau$ **excess**

Appearance … Wrong Charge Signature

$\bar{\nu}_e \rightarrow \bar{\nu}_\mu \rightarrow \bar{\mu}$ **excess** **Golden** **!**

$\bar{\nu}_\tau \rightarrow \bar{\tau}$ **excess** **Silver**

LargeMagnetic Detector + **SuperOpera?**

Detector

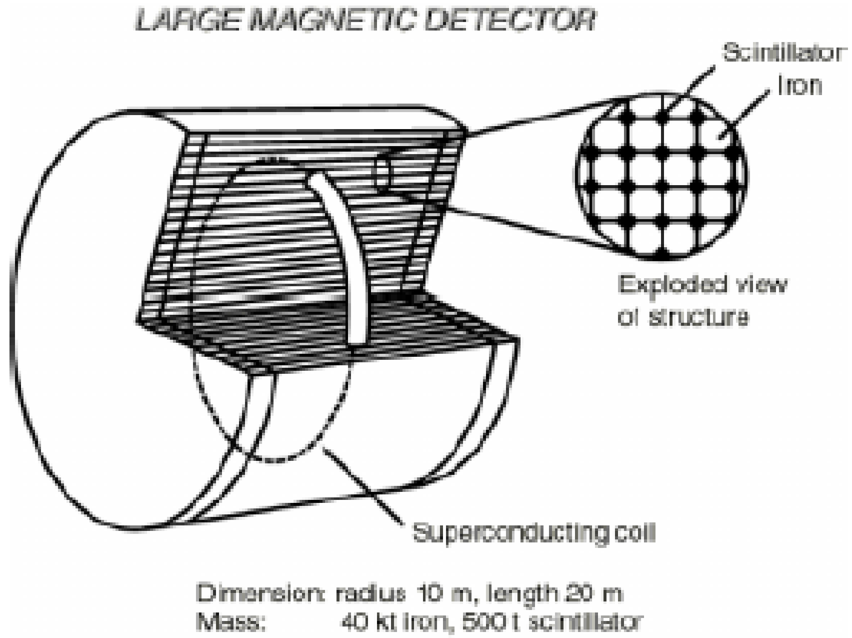
Iron calorimeter

Magnetized

- Charge discrimination
- B = 1 T

R = 10 m, L = 20 m

Fiducial mass = 40 kT



Also: L Arg detector: magnetized ICARUS

Wrong sign muons, electrons, taus and NC evts

Events for 1 year

Baseline	$\bar{\nu}_\mu$ CC	ν_e CC	signal ($\sin^2\theta_{13}=0.01$)
732 Km	3.5×10^7	5.9×10^7	1.1×10^5
3500 Km	1.2×10^6	2.4×10^6	1.0×10^5 (cf 40 in JHF-SK)

Betabeam & Eurisol

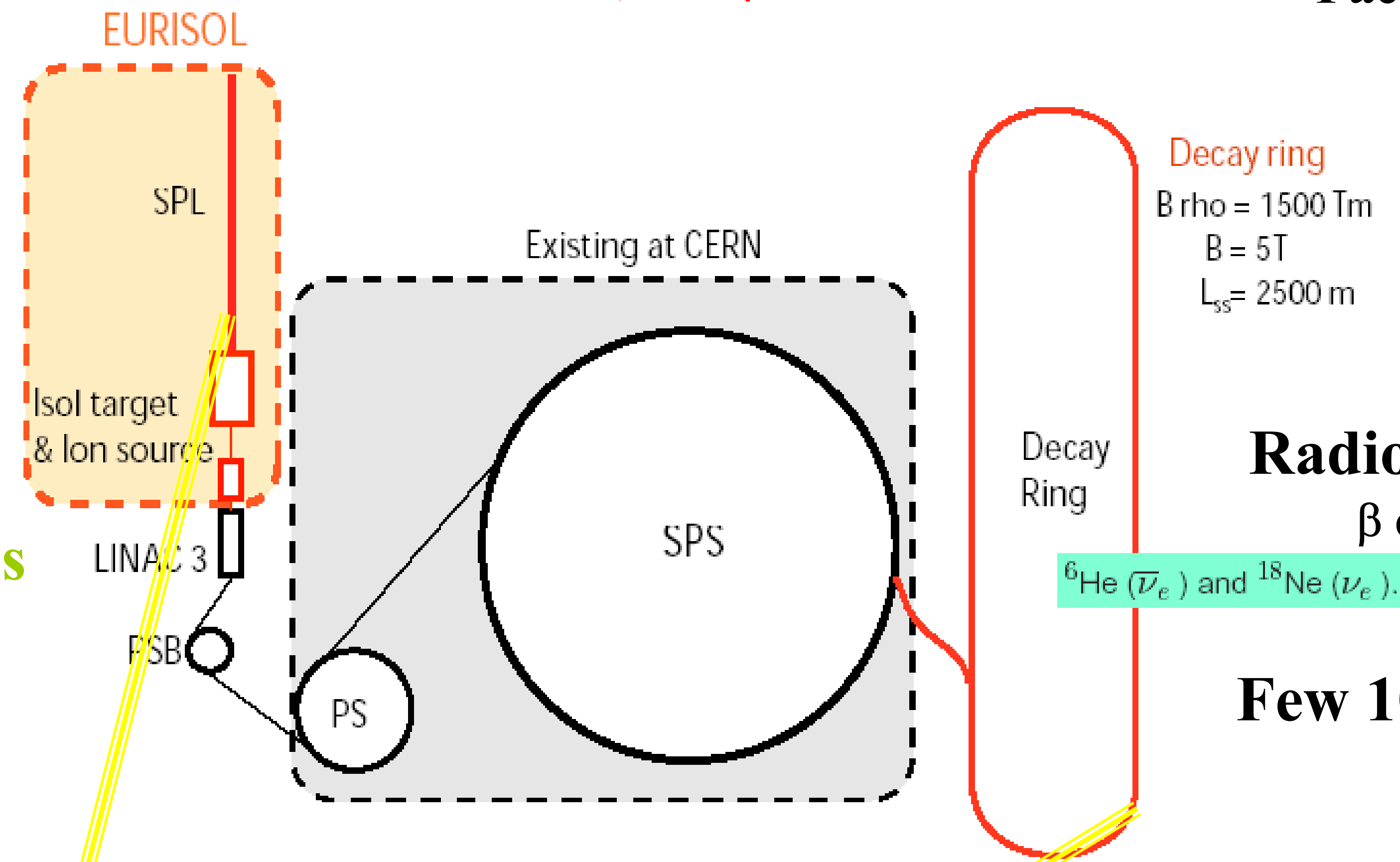
Beta Beam

Moriond Mar 03

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

Factor 2*3 !

E
U
Radio
I
Sotopes
On
Line
!!!



Radio Isotopes

β emitters

Few 100 MeV!

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

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

Same detector as Superbeam. At the same time!

… from BENE proposal :

coordinate and integrate the activities of the accelerator and particle physics communities working together, in a worldwide context,

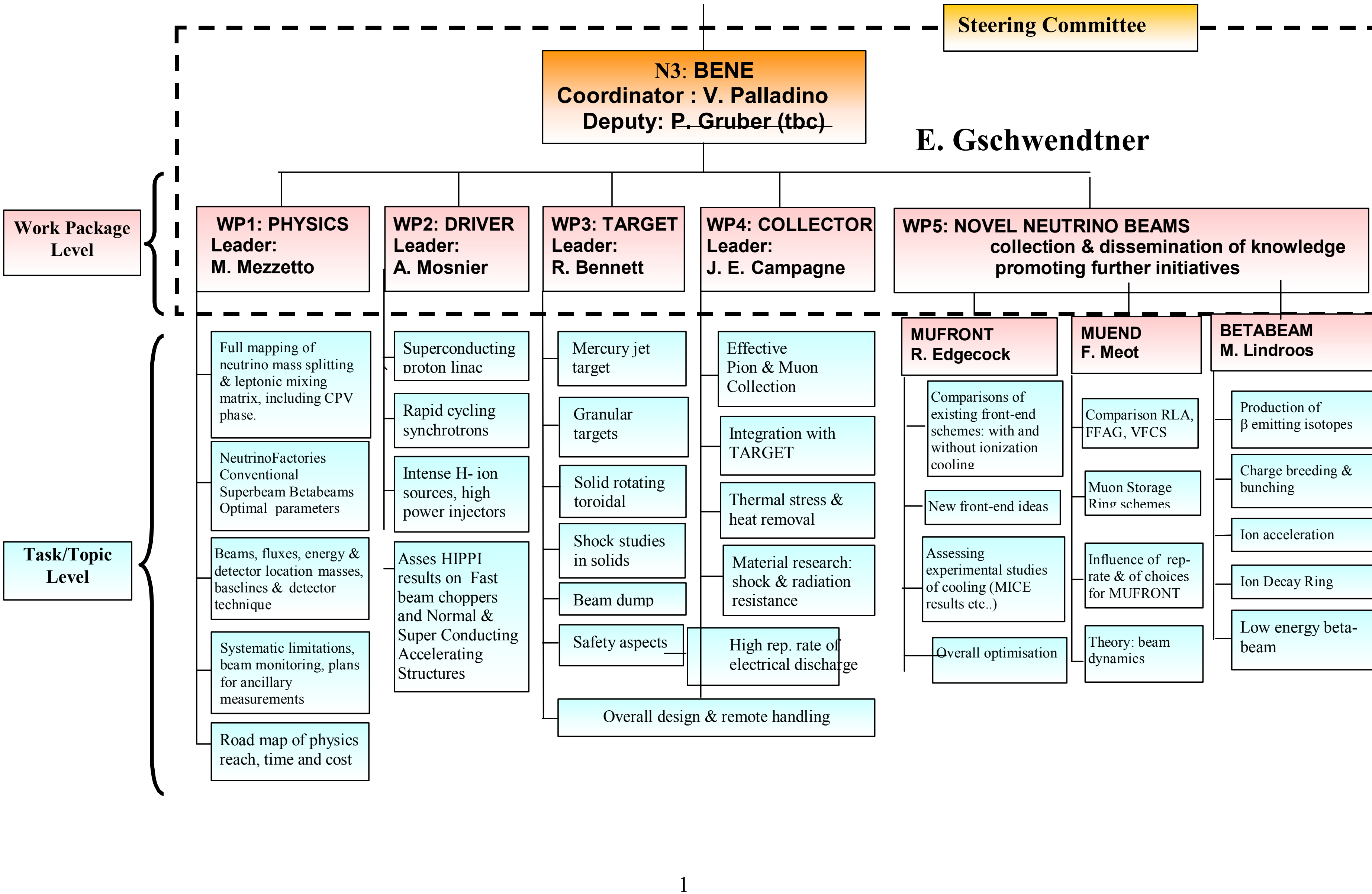
towards **achieving superior neutrino (ν) beam facilities for Europe.**

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.


Steering Committee
N3: BENE
Coordinator : V. Palladino
Deputy: P. Gruber (tbc)
E. Gschwendtner
Work Package Level
Task/Topic Level
WP1: PHYSICS Leader: M. Mezzetto
WP2: DRIVER Leader: A. Mosnier
WP3: TARGET Leader: R. Bennett
WP4: COLLECTOR Leader: J. E. Campagne
WP5: NOVEL NEUTRINO BEAMS collection & dissemination of knowledge promoting further initiatives
MUFRONT R. Edgecock
MUEND F. Meot
BETABEAM M. Lindroos
Full mapping of neutrino mass splitting & leptonic mixing matrix, including CPV phase.
NeutrinoFactories Conventional Superbeam Betabeams Optimal parameters
Beams, fluxes, energy & detector location masses, baselines & detector technique
Systematic limitations, beam monitoring, plans for ancillary measurements
Road map of physics reach, time and cost
Superconducting proton linac
Rapid cycling synchrotrons
Intense H- ion sources, high power injectors
Asses HIPPI results on Fast beam choppers and Normal & Super Conducting Accelerating Structures
Mercury jet target
Granular targets
Solid rotating toroidal
Shock studies in solids
Beam dump
Safety aspects
Overall design & remote handling
Effective Pion & Muon Collection
Integration with TARGET
Thermal stress & heat removal
Material research: shock & radiation resistance
High rep. rate of electrical discharge
Comparisons of existing front-end schemes: with and without ionization cooling
New front-end ideas
Assessing experimental studies of cooling (MICE results etc..)
Overall optimisation
Comparison RLA, FFAG, VFCS
Muon Storage Ring schemes
Influence of rep-rate & of choices for MUFRONT
Theory: beam dynamics
Production of β emitting isotopes
Charge breeding & bunching
Ion acceleration
Ion Decay Ring
Low energy beta-beam
1

A possible coherent plan of EU initiative in neutrino Physics ?

2006 2009 2014 >2014

CNGS

EU T2K ………….. T2H?

R&D targets, horns

beta ions

Superbeam

Betabeam

CERN ν to Frejus

R&D μ cooling, reacceleration, storage

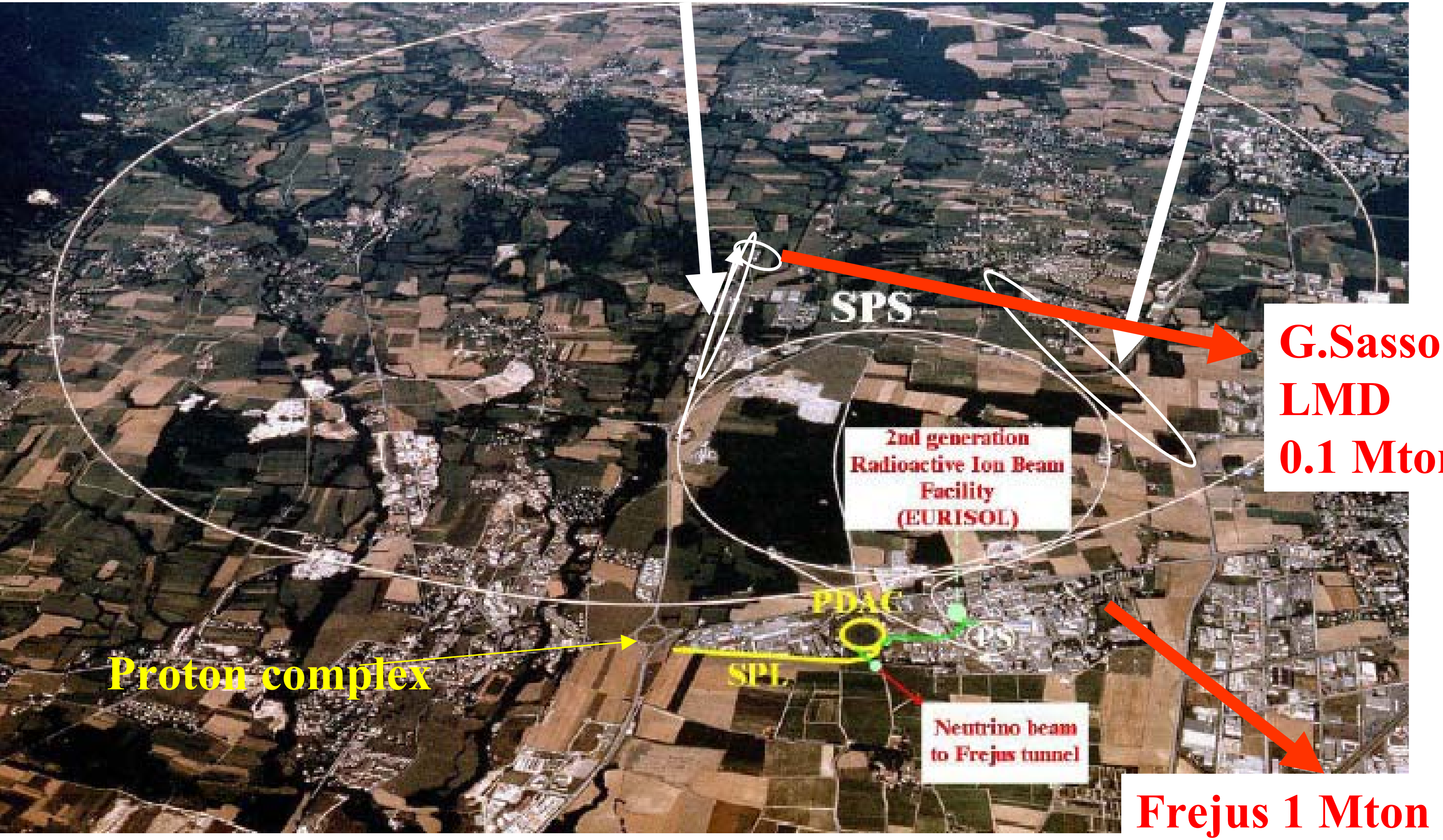
NuFact

CERN ν to LNGS & al

Garoby
Haseroth
Lindroos

Muon Complex

BetaRing



EU Neutrino Accelerator Research Complex… E-νARC?

Long Term Goal of BENE

late 2008 or early 2009

Conceptual Design Report

for a new

EU Neutrino Complex

tools: Network

Design Study Teams (Feasibility &Technical R&D)

Driver(later)

Carefully plan priority & milestones for technical R&D

in tune with US & Japan

Target

BetaBeam

Horns…

Superbeam

Slow Muons

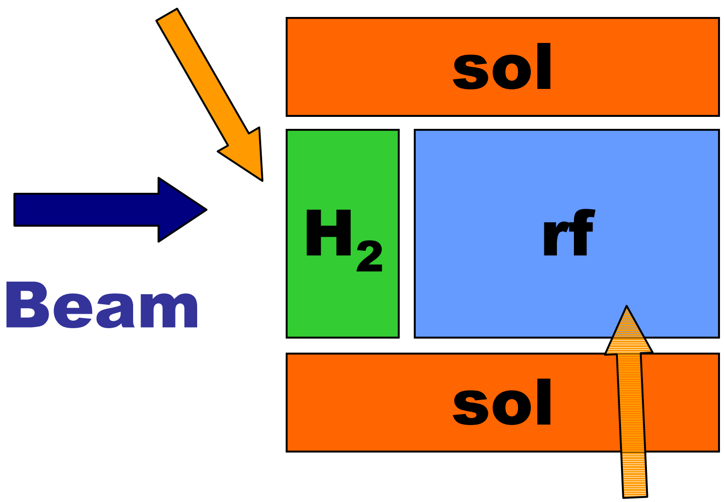
NuFact Front end

NuFact Back end

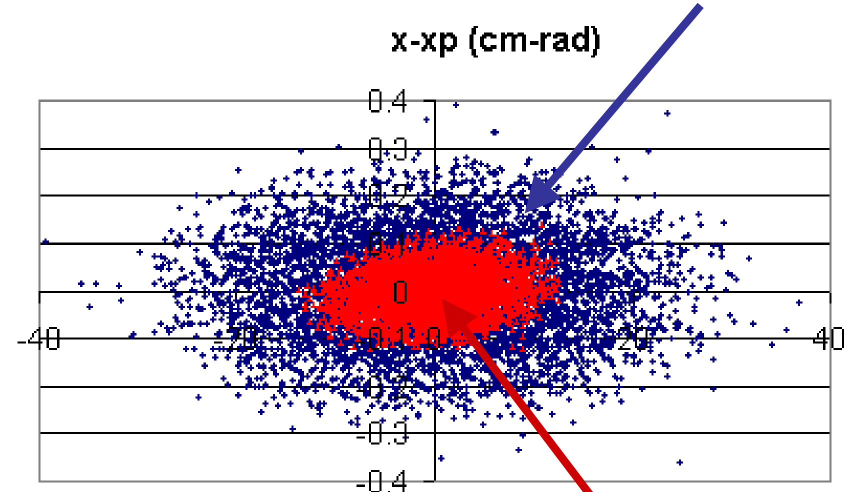
The ideal muon accelerator is a LinAc filled with matter ………

Ionization Cooling : the principle

Liquid H_2: dE/dx



IN



OUT

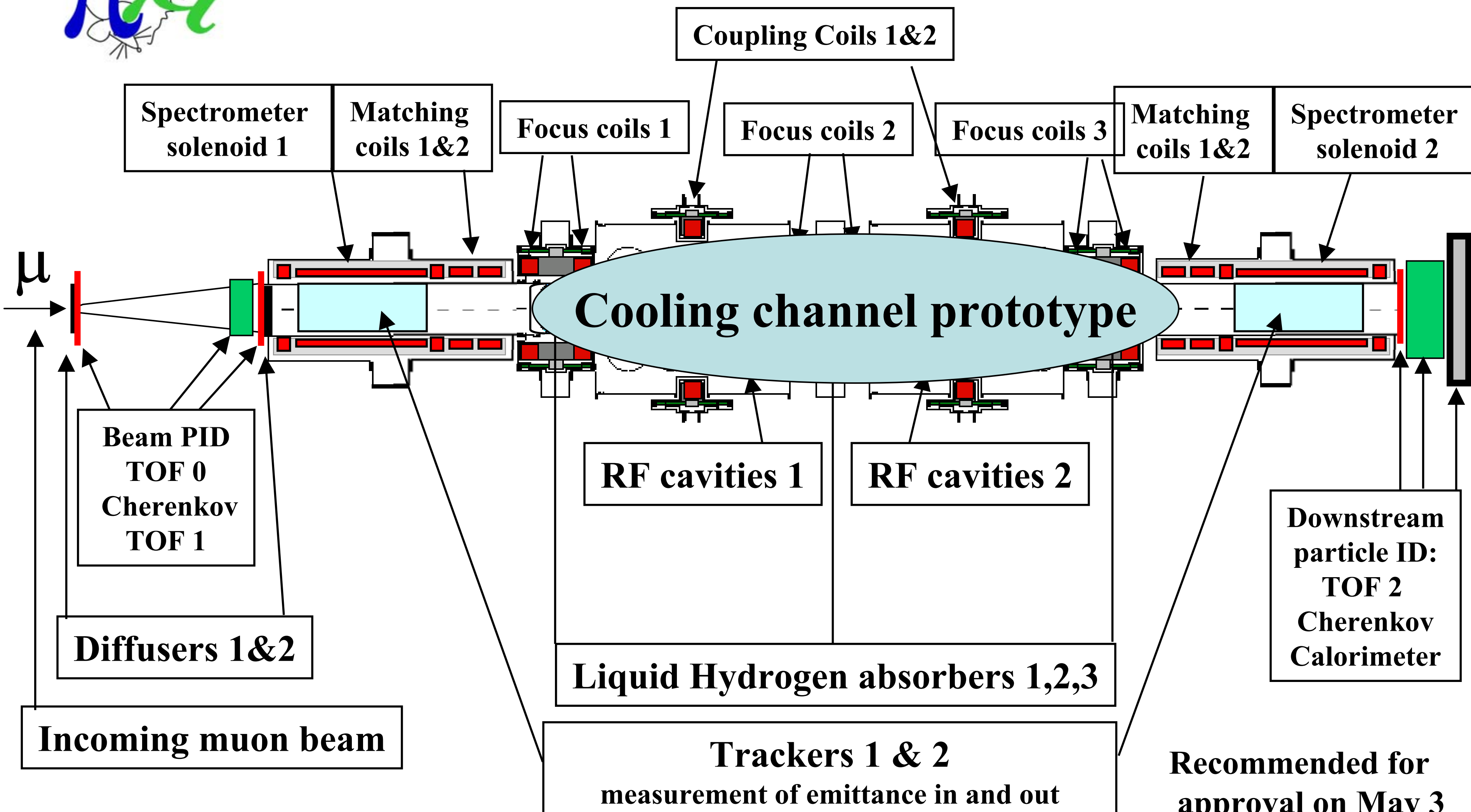
RF restores only $P_{//}$: E constant

10% cooling of 200 MeV/c muons requires ~ 20 MV of RF

single particle measurements =>

measurement precision can be as good as $\Delta (\varepsilon_{out}/\varepsilon_{in}) = 10^{-3}$

never done before either….



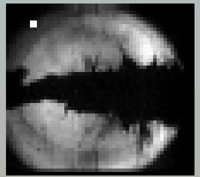
Recommended for approval on May 3

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.



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