Future Neutrino Beams (US and EU)

Motivation & road-map

(conventional neutrino beams …off-axis)

Low energy Superbeam … and betabeam

Neutrino Factory overview

Neutrino Factory R&D

Recent developments: EMCOG, MICE, ring cooler

Conclusions

Alain Blondel, ICFA @cern - 2002

http://www.hep.ph.ic.rl.uk/Nufact02

163 registered participants

Also: NUFACT02 School
on future neutrino beams and neutrino factory
mixing experimenters and accelerator physicists

General framework :

1. **We know that there are three families of active, light neutrinos** ***(LEP)***
2. **Solar neutrino oscillations are established** ***(Homestake+Gallium+Kam+SK+SNO)***
3. **Atmospheric neutrino (n_m ->) oscillations are established** ***(IMB+Kam+SK+Macro+Sudan)***
4. **At that frequency, electron neutrino oscillations are small** ***(CHOOZ)***

This allows a consistent picture with 3-family oscillations preferred:

LMA: q_{12} ~30^0 D$m_{12}{}^2$~6 10^{-5}eV^2 , q_{23} ~45^0 D$m_{23}{}^2$~ ±2.5 10^{-4}eV^2, q_{13} <~ 10^0
with several unknown parameters

=> an exciting experimental program for at least 25 years *)
including leptonic CP & T violations

5. **There is indication of possible higher frequency oscillation (LSND) to be confirmed (miniBooNe)**
   This is not consistent with three families of neutrinos oscillating, and is not supported (nor is it completely contradicted) by other experiments.
   (Case of an unlikely scenario which hangs on only one not-so-convincing experimental result)

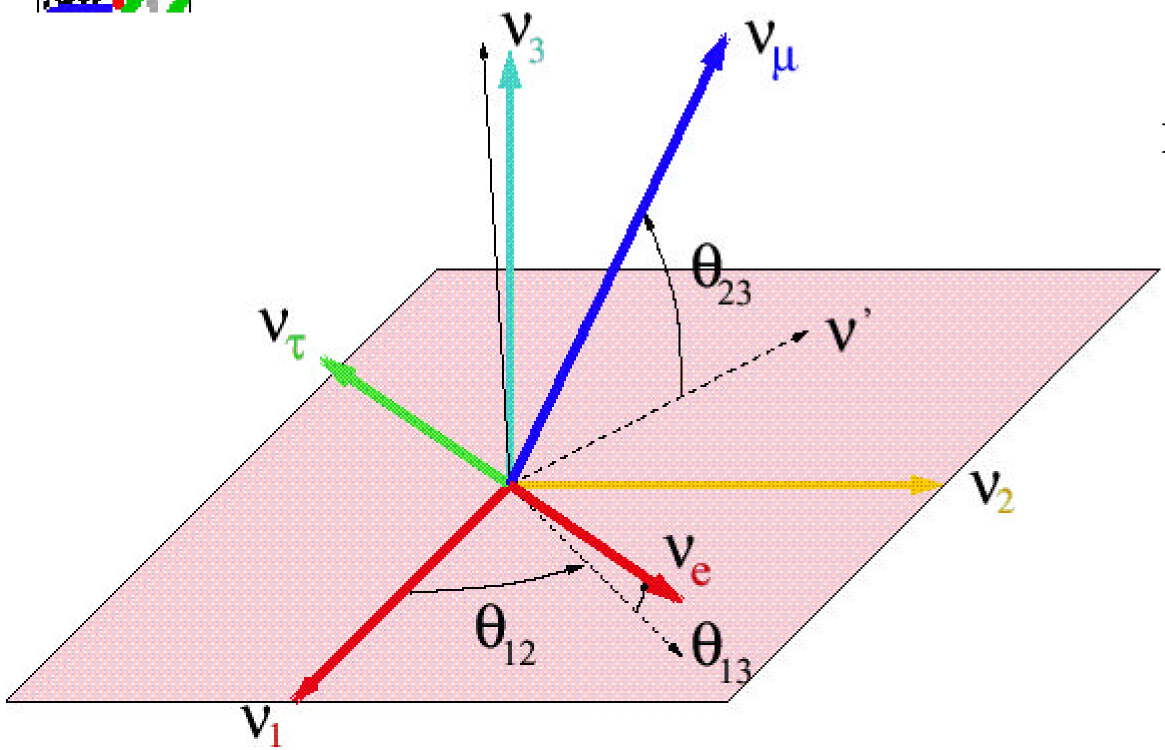
If confirmed, this would be even more exciting

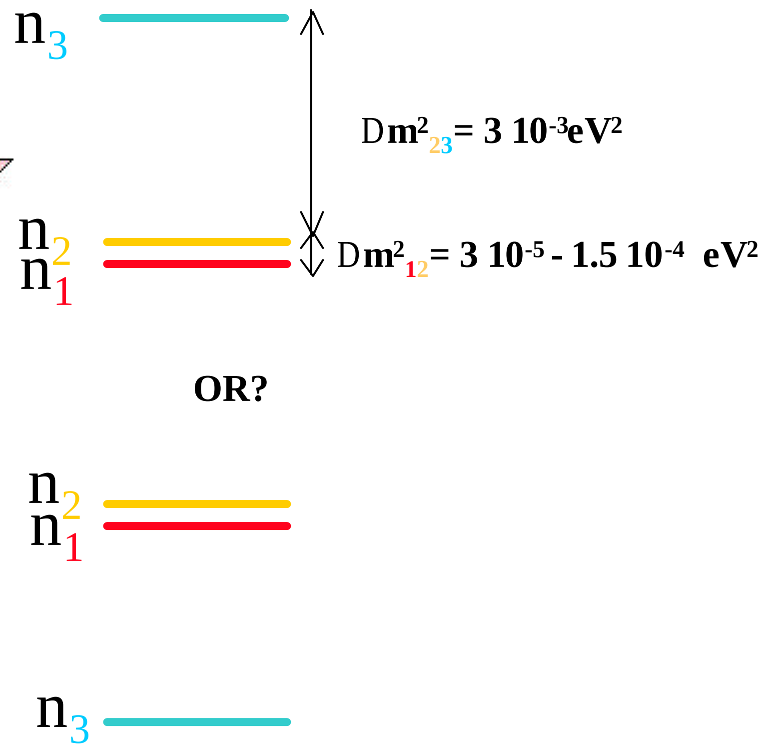
(I will not explore this here, but this has been done. See ***Barger et al PRD 63 033002*** **)**

***)to set the scale: CP violation in quarks was discovered in 1964**
and there is still an important program (K0pi0, B-factories, Neutron EDM, BTeV, LHCb..)
to go on for 10 years…i.e. a total of ~50 yrs.

and we have not discovered leptonic CP yet!

The neutrino mixing matrix (LMA)





q_{23} **(atmospheric) = 45^0**

q_{12} **(solar) = 30^0**

q_{13} **(Chooz) < 13^0**

$$U_{MNS}: \begin{pmatrix} \sim \frac{\sqrt{2}}{2} & \sim -\frac{\sqrt{2}}{2} & \sin\theta_{13}\, e^{i\delta} \\ \sim \frac{1}{2} & \sim \frac{1}{2} & \sim -\frac{\sqrt{2}}{2} \\ \sim \frac{1}{2} & \sim \frac{1}{2} & \sim \frac{\sqrt{2}}{2} \end{pmatrix}$$

Unknown or poorly known even after approved program:
q_{13} , **phase** d , **sign of** D**m$^2_{13}$**

$$P(\nu_e \rightarrow \nu_\mu) = |A|^2 + |S|^2 + 2\,A\,S\,\sin\delta$$

$$P(\bar{\nu}_e \rightarrow \bar{\nu}_\mu) = |A|^2 + |S|^2 - 2\,A\,S\,\sin\delta$$

$$\frac{P(\nu_e \rightarrow \nu_\mu) - P(\bar{\nu}_e \rightarrow \bar{\nu}_\mu)}{P(\nu_e \rightarrow \nu_\mu) + P(\bar{\nu}_e \rightarrow \bar{\nu}_\mu)} = A_{CP} \propto \frac{\sin\delta \quad \sin(\Delta m^2_{12} L/4E) \quad \sin\theta_{12}}{\sin\theta_{13} + \text{solar term...}}$$

… need large values of sin θ_{12}, Δm^2_{12} (LMA) but *not* large $\sin^2\theta_{13}$

… need APPEARANCE … $P(\nu_e \rightarrow \nu_e)$ is time reversal symmetric (reactors or sun are out)

… can be large (30%) for suppressed channel (one small angle vs two large)

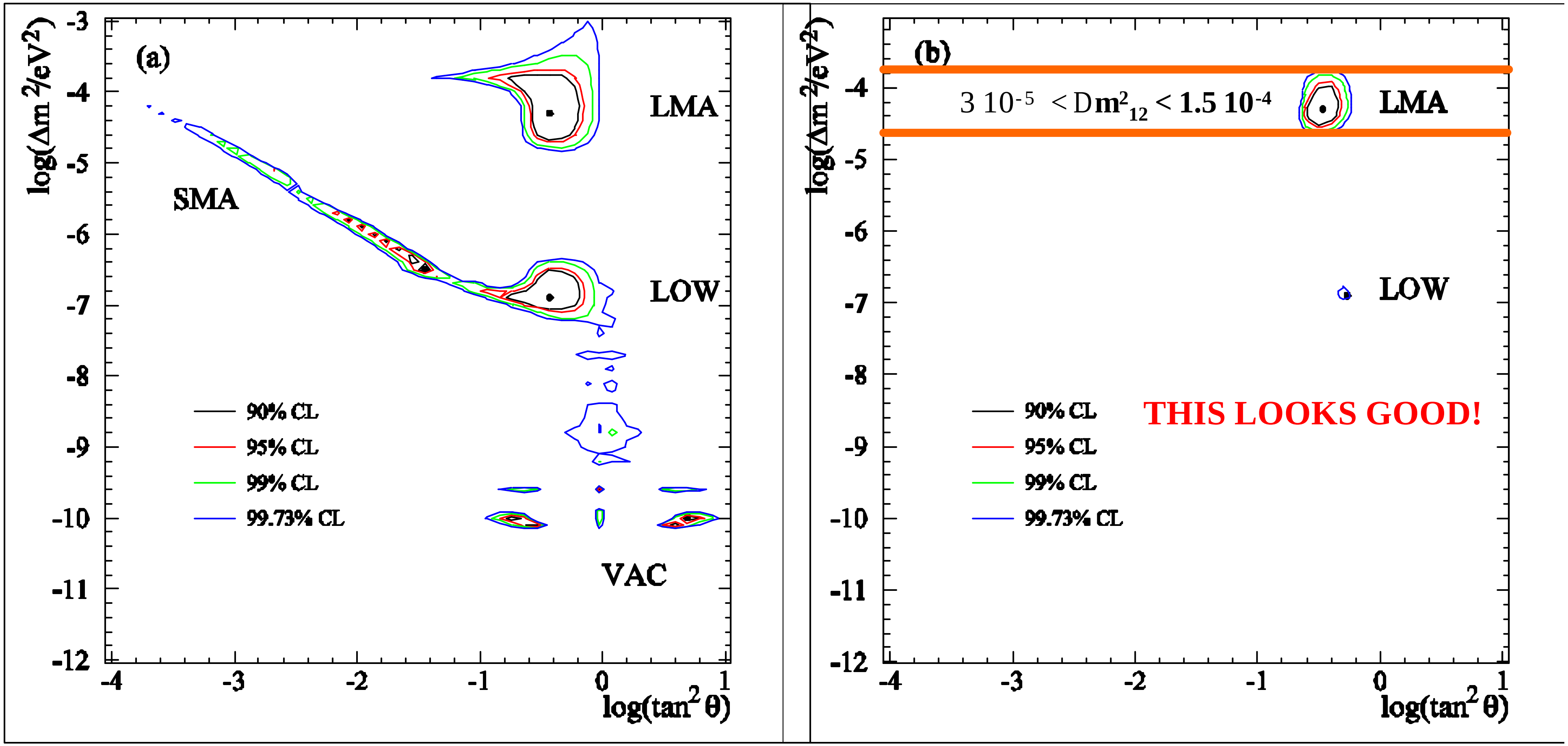
at wavelength at which ‘solar’ = ‘atmospheric’ and for $\nu_e \rightarrow \nu_\mu$, ν_τ

… asymmetry is opposite for $\nu_e \rightarrow \nu_\mu$ and $\nu_e \rightarrow \nu_\tau$

Prerequisite for CP violation in neutrinos: Solar LMA solution

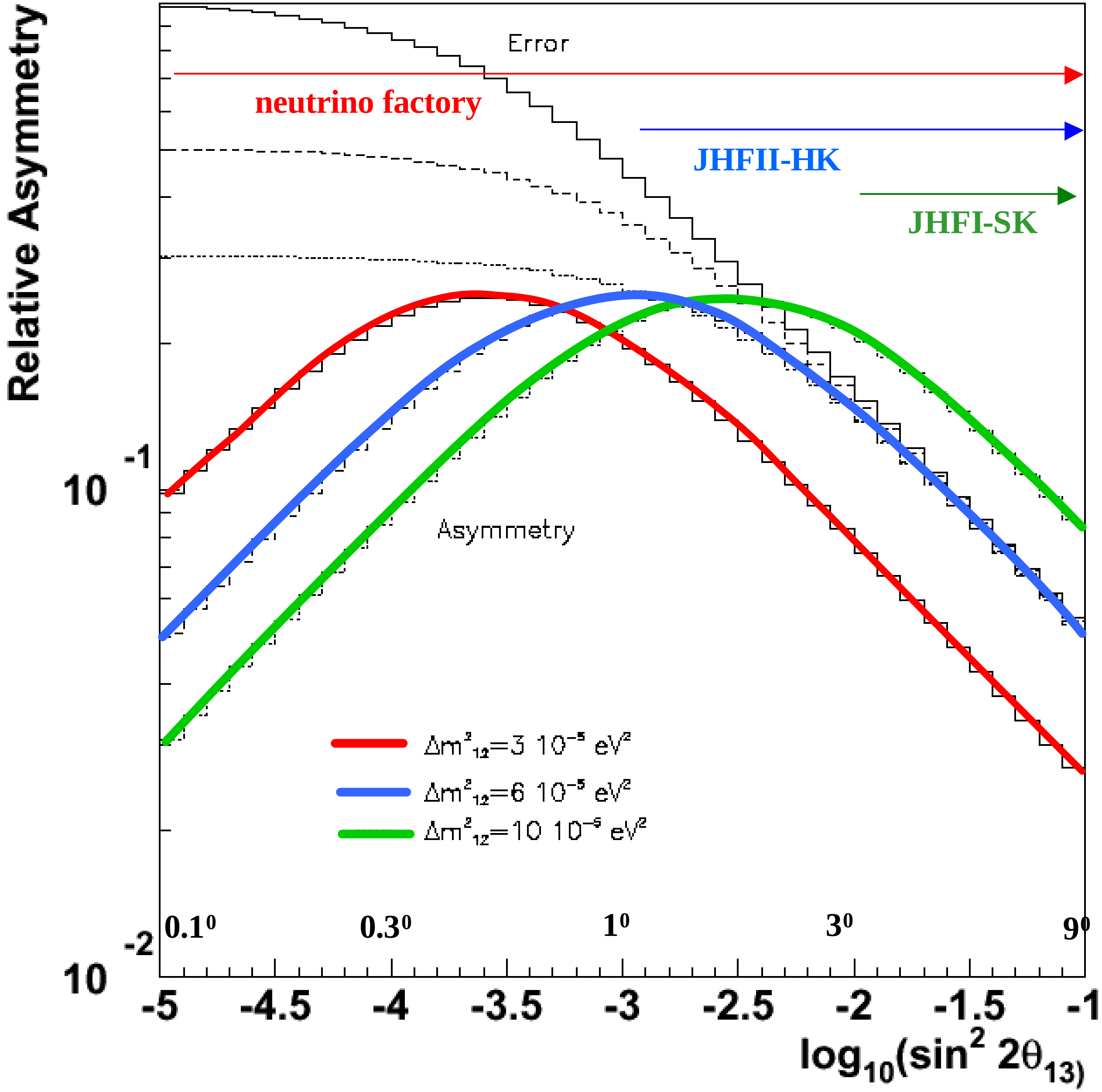
SNO Day and Night Energy Spectra Alone

Combining All Experimental and Solar Model information



This will be confirmed and Dm^2_{12} measured precisely by e.g. KAMLAND in next 2-4 yrs

T asymmetry for sin d = 1



!

asymmetry is up to 30% but requires excellent flux normalization (neutrino fact. or off axis beam with not-too-near near detector)

!

Value of sin^{2}q$_{13}$ is critical for design of CP experiments

Alain Blondel, ICFA @cern - 2002

$\sin^2 q_{13} = 1/4 \sin^2 2q_{13} = 1/2 \sin^2 q_{m\,e}$

Road Map

Experiments to find q_{13} :

1. search for n_m ® n_e in conventional n_m beam (ICARUS, MINOS)
limitations: NC p^0 background, intrinsic n_e component in beam
2. Off-axis beam (JHF-SK, off axis NUMI, off axis CNGS) or
3. Low Energy Superbeam

Experiments to find CP/T violation or search further if q_{13} is too small

1. beta-beam $^6He^{++}$ ® $^6Li^{+++}$ $\bar{n}_e$ e^- $\quad {}^{18}_{10}Ne$ ® ${}^{18}_{9}F$ n_e e^+

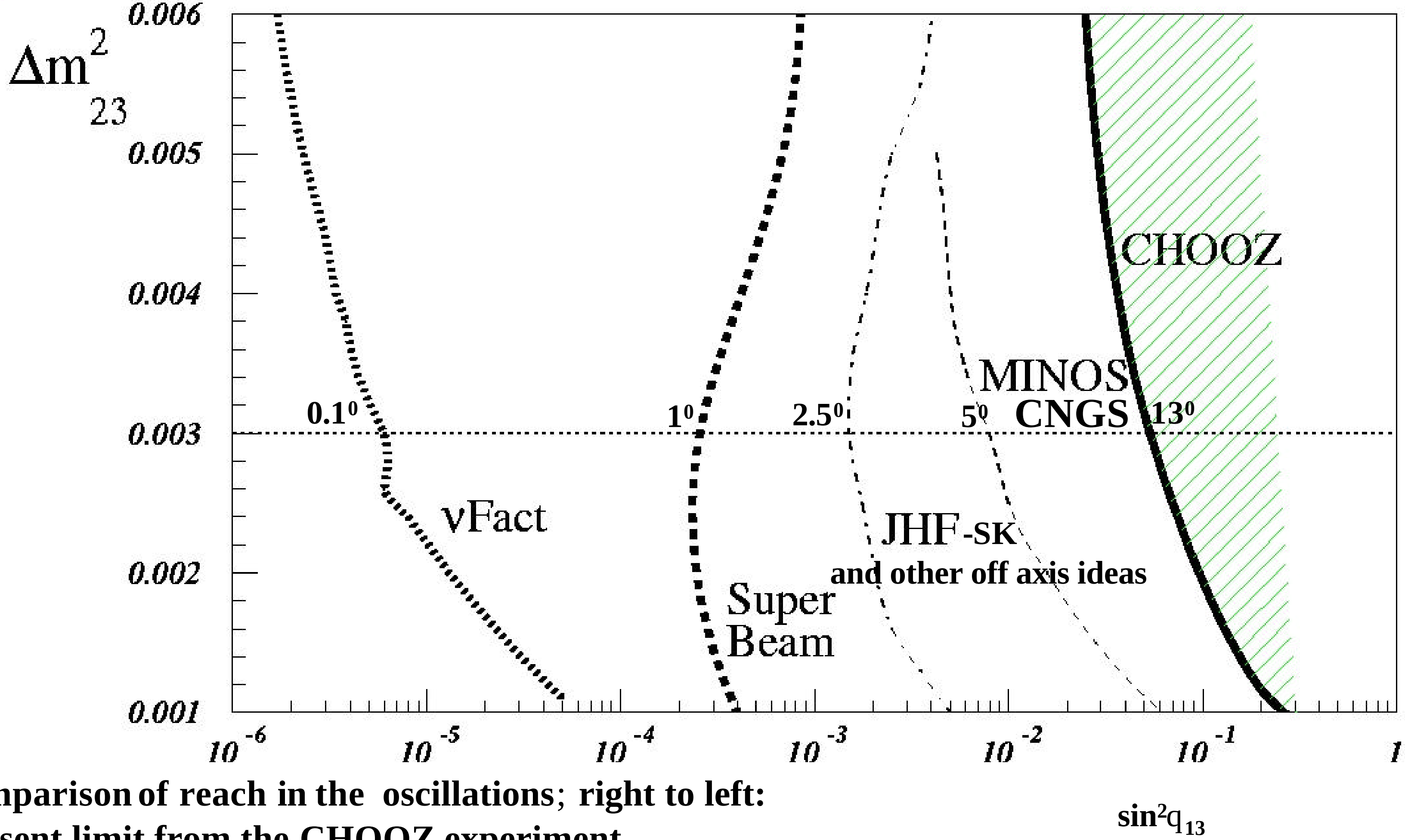
2. Neutrino factory with muon storage ring (will also establish the sign of

m^+ ® $e^+ n_e \bar{n}_m$ **and** m^- ® $e^- \bar{n}_e n_m$

fraction thereof will exist.

R&D on accelerators takes a long time, it should start now.

Where will this get us…



comparison of reach in the oscillations; right to left:
present limit from the CHOOZ experiment,
expected sensitivity from the MINOS experiment,
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
from a Neutrino Factory with 40 kton large magnetic detector. INCLUDING SYSTEMATICS

Sensitivity to $\sin^2 2\theta_{13}$ as a function of the year

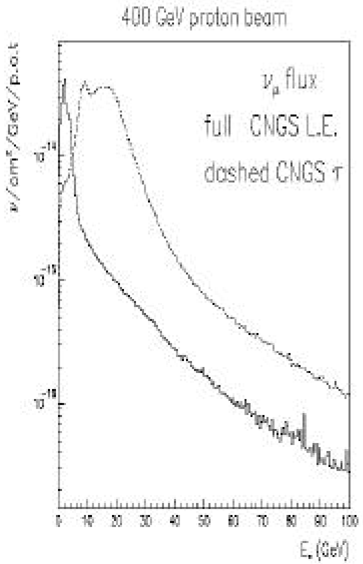
	2004	2005	2006	2007	2008	2009
CHOOZ	**<0.14**	**<0.14**	**<0.14**	**<0.14**	**<0.14**	**<0.14**
MINOS		→	<0.085	<0.06	<0.049	<0.042
CNGS*			→	<0.067	<0.047	<0.039
CNGSx1.5*			→	<0.056	<0.039	<0.033
Low energy CNGS				? →	<0.040	<0.028
JHF-SK					→	<0.013

* Designed for ν_τ appearance

Pasquale Migliozzi ECFA-NOWG, sept 2002

Optimization of CNGS for n_m ® n_e appearance

A.Rubbia/P.Sala
hep-ph-020-7084



	CNGS τ	CNGS L.E.
Target		
Material	Carbon	Carbon
Total target length	2 m	1 m
Number of rods	13	**1**
Rod spacing	first 8 with 9 cm dist.	none
Diameter of rods	first 2 5 mm, then 4 mm	**4mm**
Horn		
Distance beginning of target-horn entrance	320 cm	**25 cm**
Length	6.65 m	**4 m**
Outer conductor radius	35.8 cm	80 cm †
Inner conductor max. radius	6.71 cm	11.06 cm
Inner conductor min. radius	1.2 cm	0.2 cm
Current	150kA	300kA
Reflector		
Distance beginning of target-reflector entrance	43.4 m	**6.25 m**
Length	6.65 m	**4 m**
Outer conductor radius	55.8 cm	90 cm †
Inner conductor max. radius	28 cm	23.6 cm
Inner conductor min. radius	7cm	5 cm
Current	180kA	150kA
Decay tunnel		
Distance beginning of target-tunnel entrance	100 m	50 m
Length	992 m	350 m
Radius	122 cm	350 cm †

more compact target, shorter decay tunel, bring horns closer to target.
How consistent is this with CNGS programme?

OFF-AXIS BEAMS:
NUMI and CNGS

Design principles:

depending on detector, chose the neutrino energy.

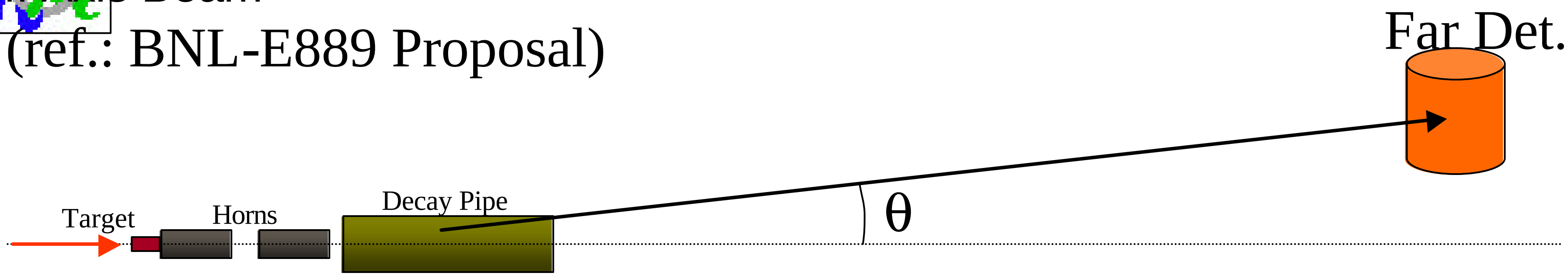
For Water Cernekov, optimum is around 0.5 GeV

the most efficient pion energy is a few GeV ($g \sim \mu\ 2E_n$ /P*)

=> need low energy version of the NUMI or CNGS beam

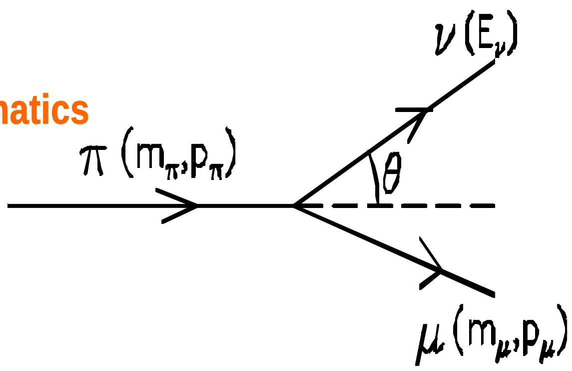
Off Axis Beam

(ref.: BNL-E889 Proposal)

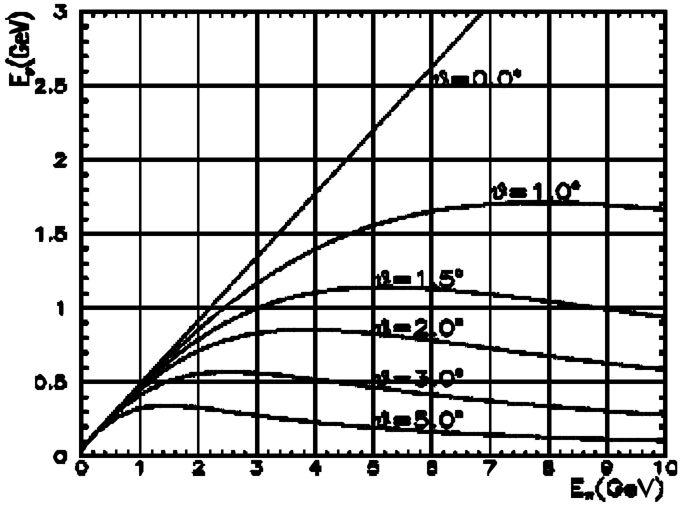


WBB w/ intentionally misaligned beam line from det. axis

Decay Kinematics



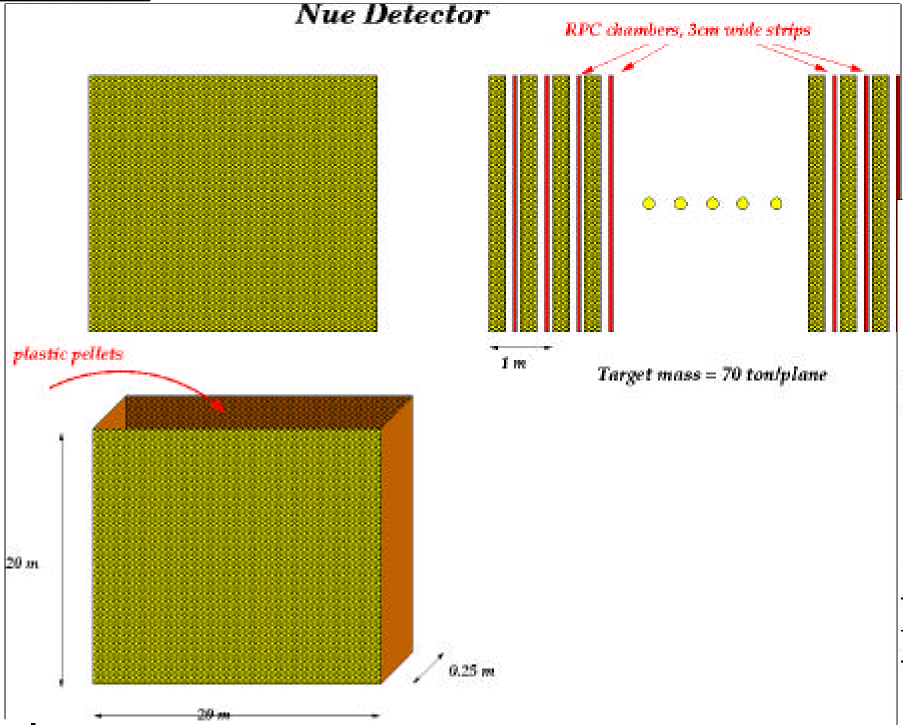
$$E_\nu = \frac{m_\pi^2 - m_\mu^2}{2(E_\pi - p_\pi \cos\theta)}$$



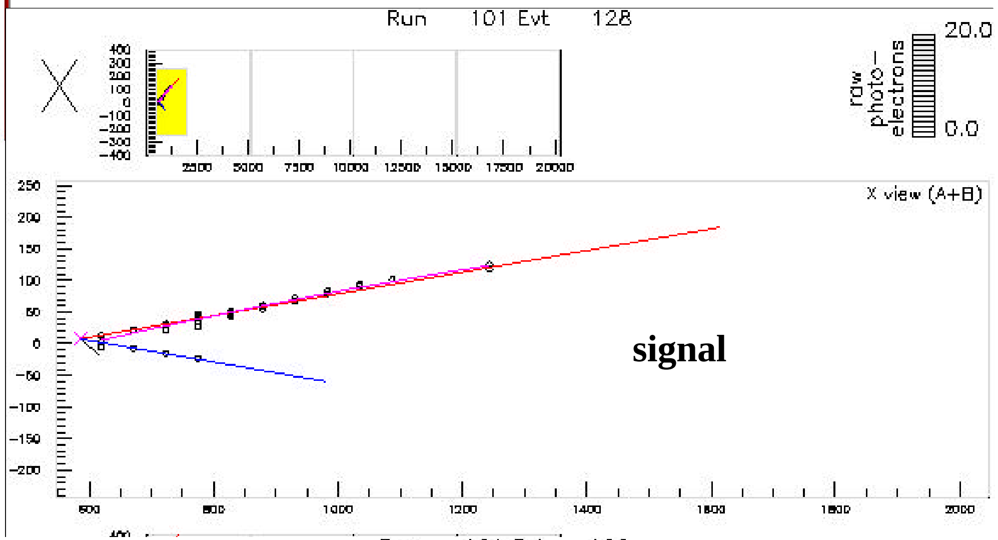
- **Quasi Monochromatic Beam**
- **x2~3 intense than NBB**

An example of a possible detector

Low Z tracking calorimeter

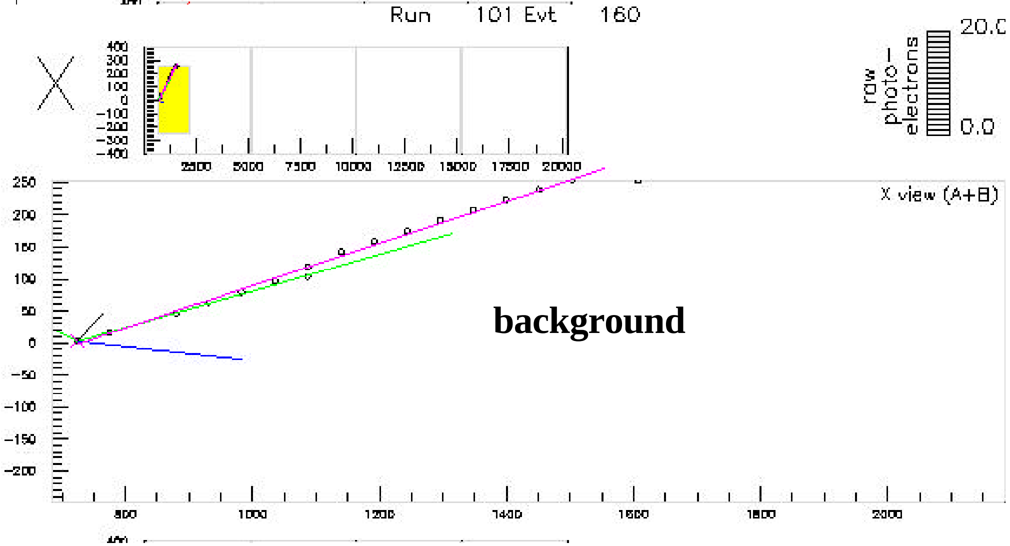


NuMI off-axis detector workshop: January 2003

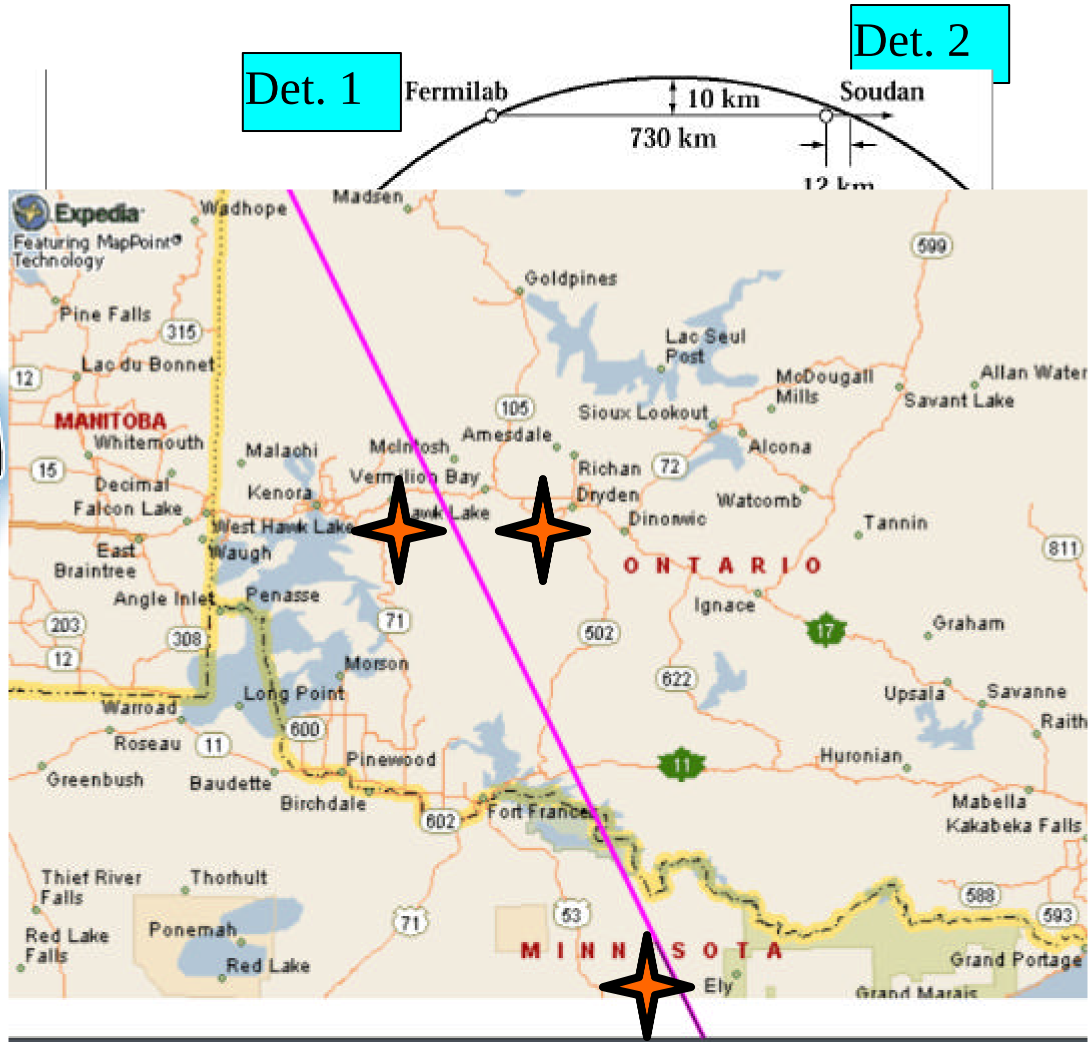


Issues:

- ⌘ absorber material
- ⌘ (plastic? Water? Particle board?)
- ⌘ longitudinal sampling (ΔX_0)?
- ⌘ What is the detector technology (RPC? Scintillator? Drift tubes?)
- ⌘ Transverse segmentation (e/π^0)
- ⌘ Surface detector: cosmic ray background? time resolution? . .



NuMI Beam: on and off-axis



similar ideas for Europe:

CNGT– Golf of Taranto below the CNGS beam
(off axis at second minimum 1400 km from CERN, 1 Mton of sea water 1km deep.
F.Dydak, neutrino 2002

NB second minimum has less flux and signal (1/9 both) .
higher sensitivity to solar neutrino oscillation which acts as a background
this may or may not prove better for CP violation if $\sin^2\theta_{13}$ is large.

Ideas with air cerenkov beyond the beam exit point *(Vannucci)*

Studies will continue, for sure…. reach in $\sin^2\theta_{13}$ typically around 10^{-3}
Points to remember:

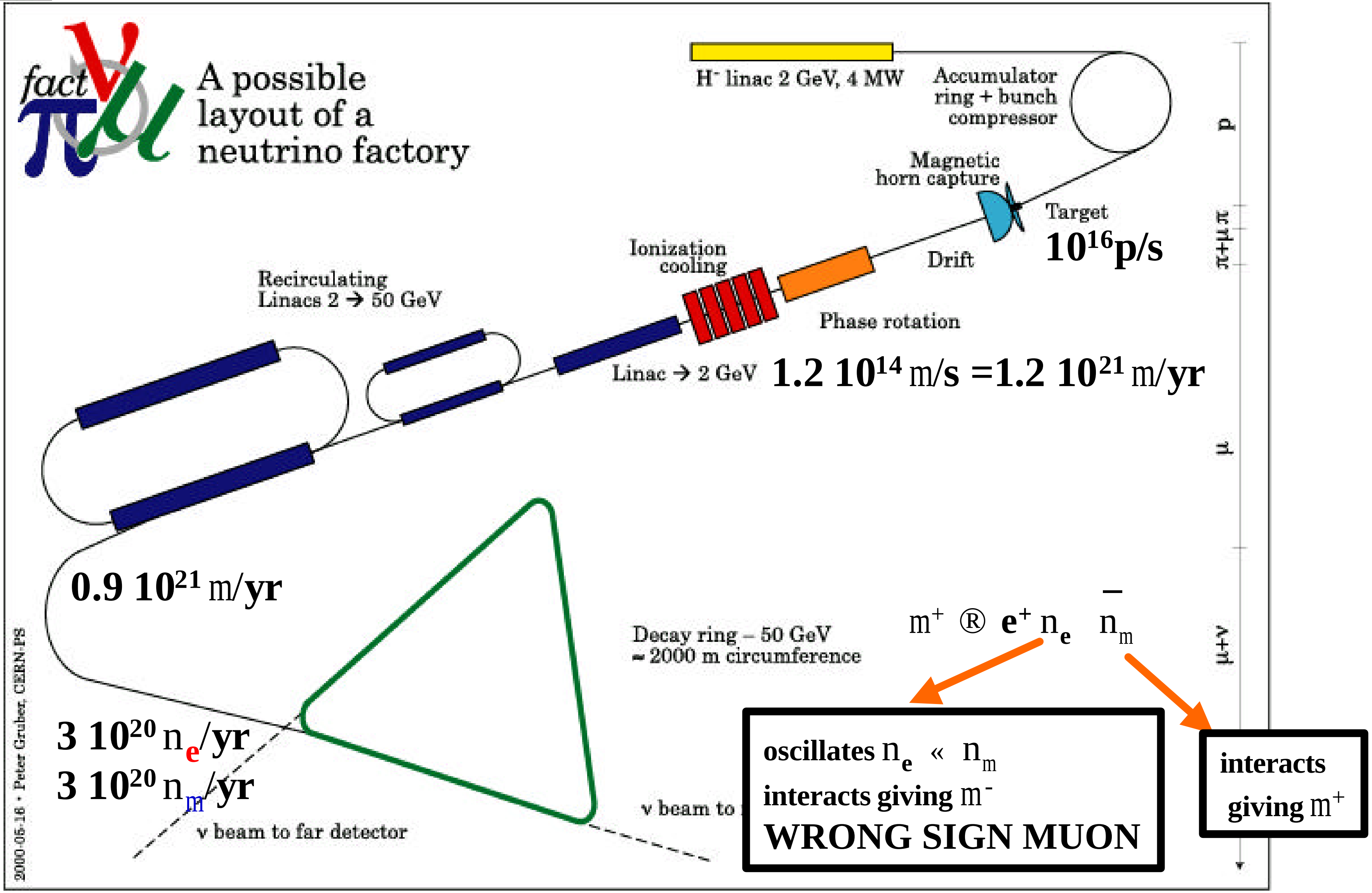
1. **energy of CNGS pions must be reduced to a few GeV -> what flux?**
2. **first maximum is better place for $\sin^2\theta_{13}$ search.**
3. **near detector (at a few km from the end of decay tunel) seems mandatory for CP violation search**
4. **claimed precision on fluxes of a few %**

Wait eagerly for performance estimates with a realistic scenario

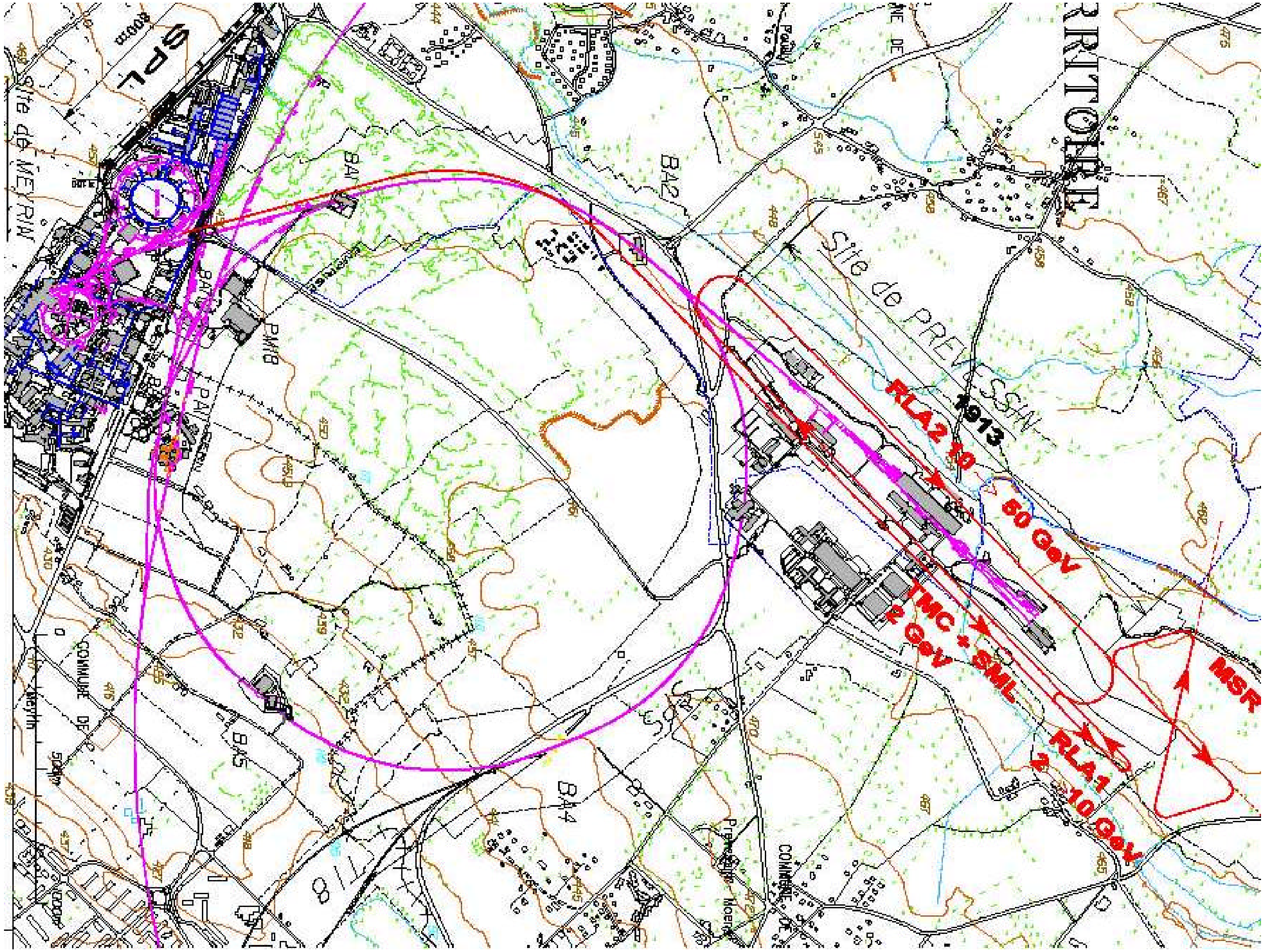
To go beyond;
super-beam,
beta-beam,
NEUTRINO FACTORY

Nufact CERN layout

(Geer 1998)

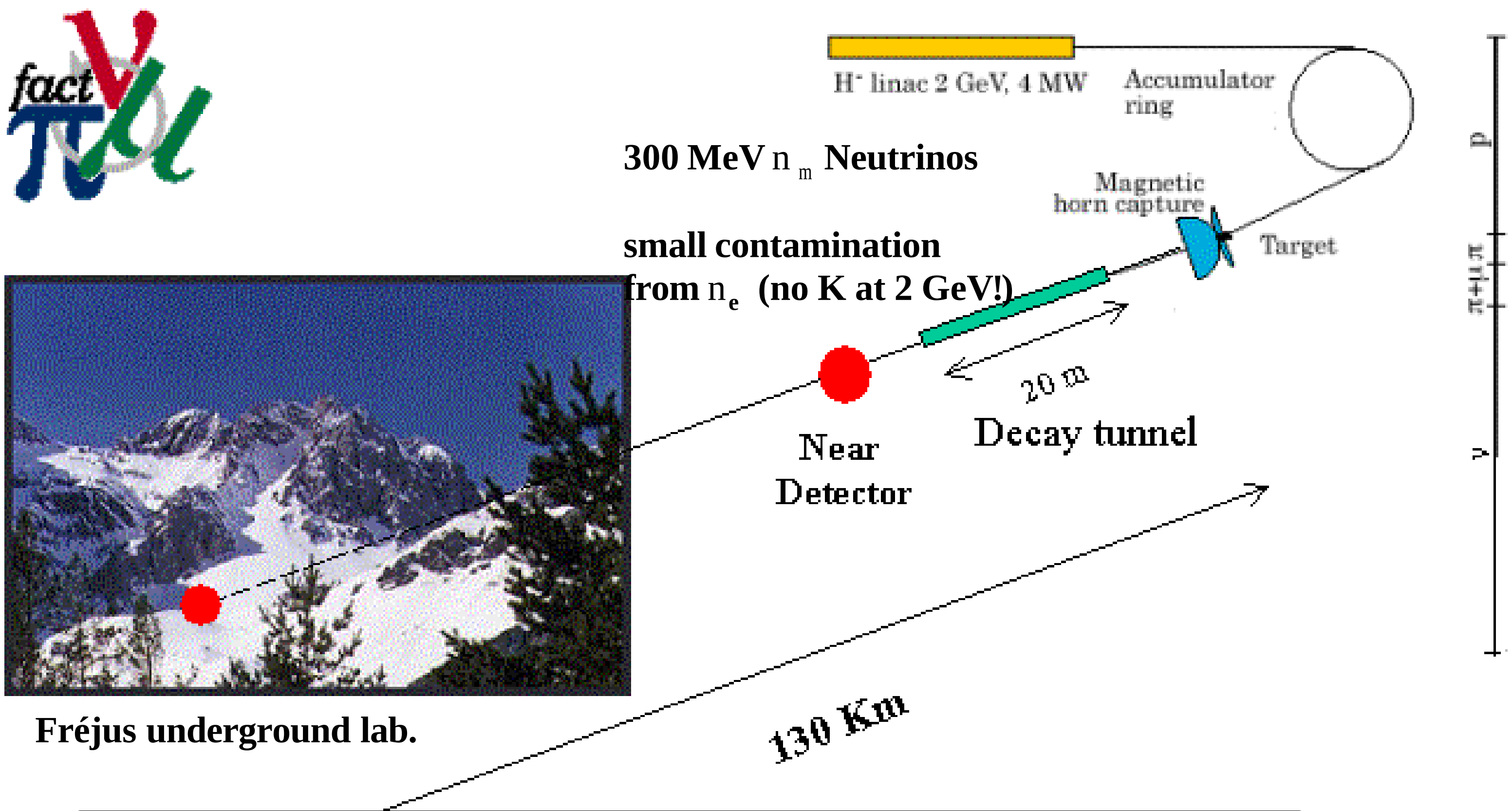


Preliminary Layout of Neutrino Factory



Possible step 0: Neutrino SUPERBEAM

no K at 2 GeV!



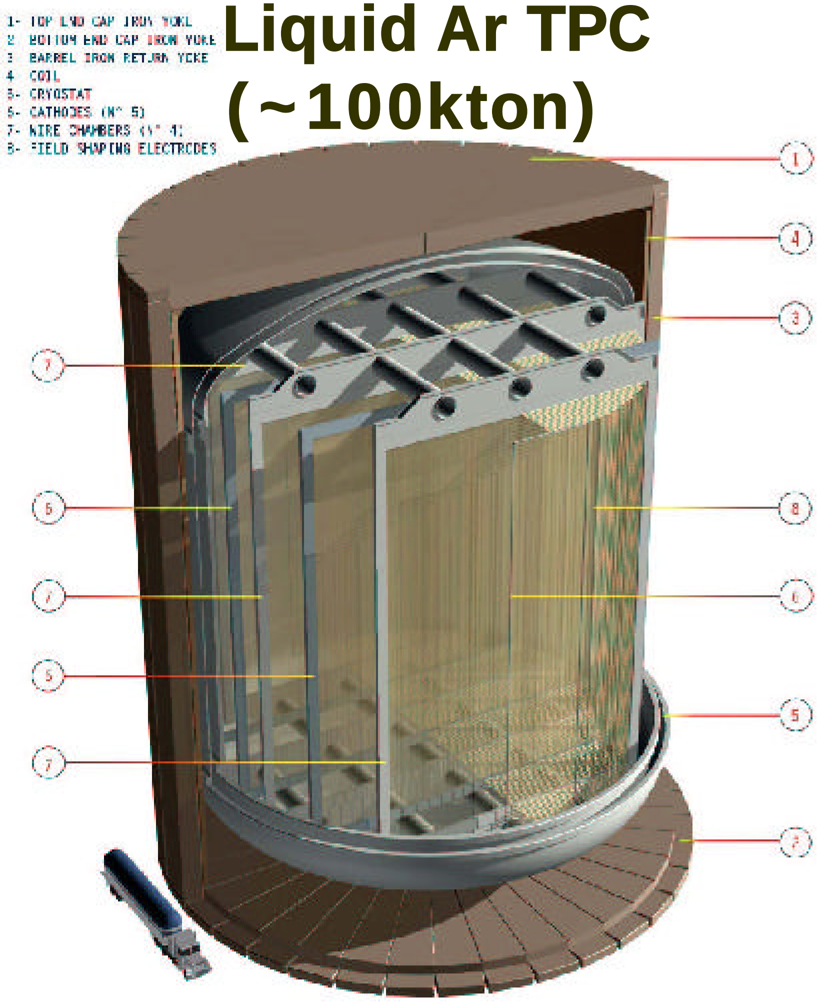
Fréjus underground lab.

A large underground water Cerenkov (400 kton)
UNO/HyperK is best choice, or Larger version of Icarus
also : proton decay search, supernovae events,
solar and atmospheric neutrinos.

Franco-Italian Frejus tunel will be augmented of a safety gallery to be finished in 2008.
This will be a good time to start a large European underground laboratory.

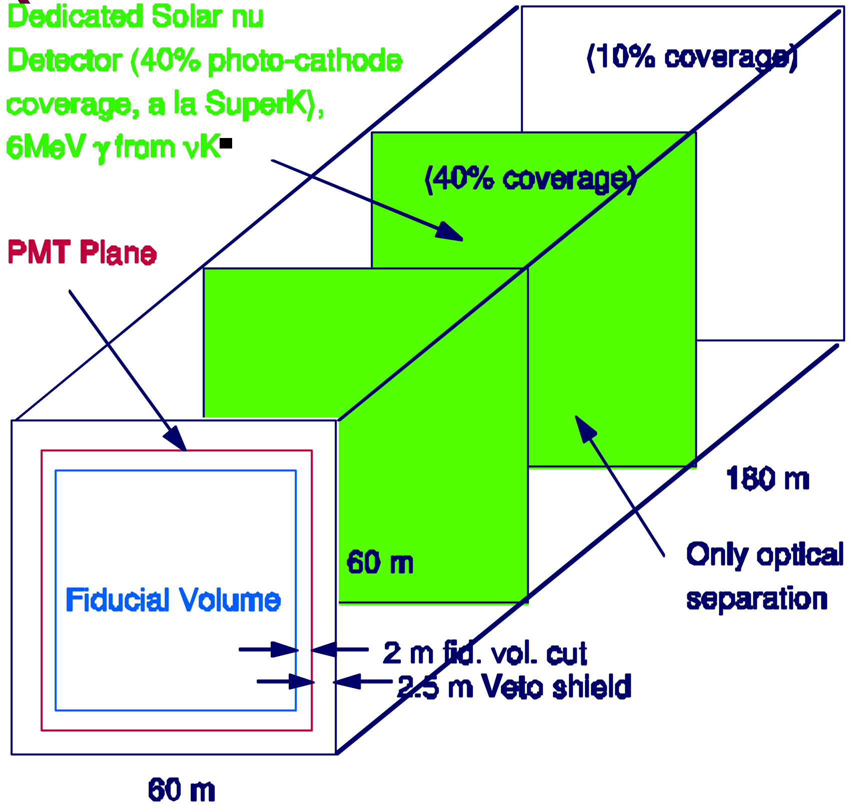
Detectors

Liquid Ar TPC (~100kton)

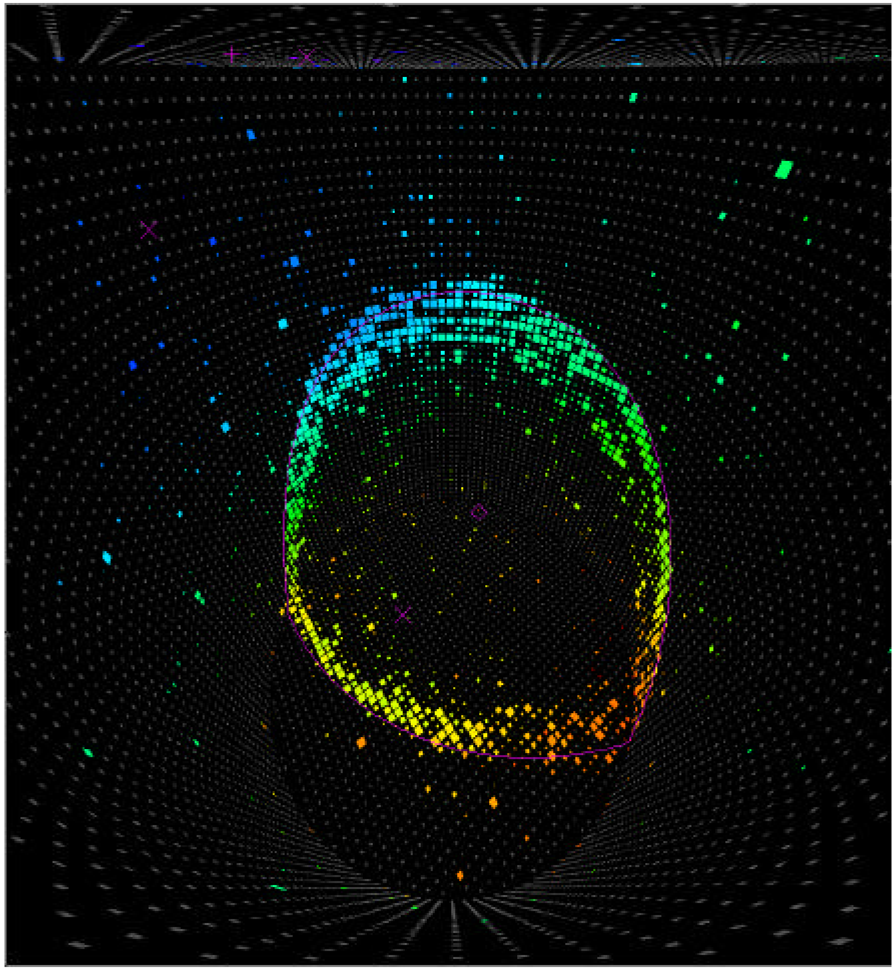


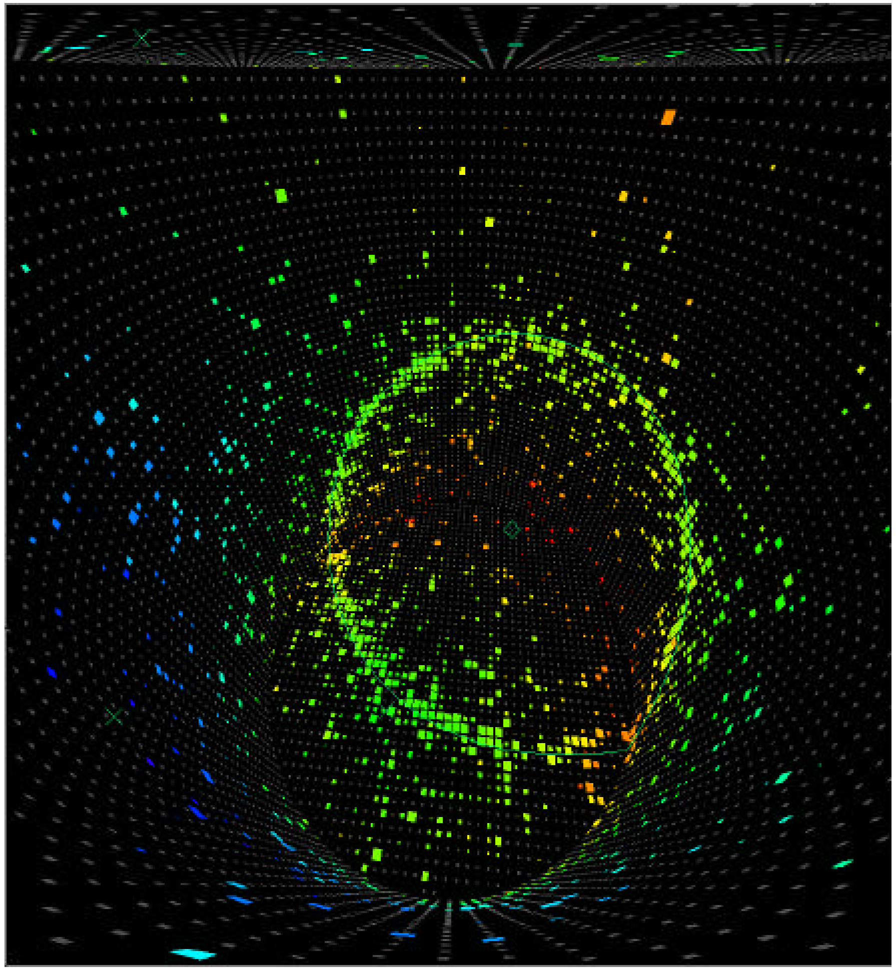
LANNDD
Liquid Argon Neutrino and Nucleon Decay Detector

UNO (400kton Water Cherenkov)



m/e Separation





e/mu separation directly related to granularity of coverage.

Limit is around 10^{-3} (mu decay in flight) SKII coverage OK

BETA Beam

new idea by P. Zucchelli

produce ^{6}He++, store, accelerate (100 GeV/u), store

Consider $^6He^{++} \rightarrow {}^6Li^{+++}\ \bar{\nu}_e\ e^-$

Q=3.5078 MeV T/2 ≈ 0.8067 s

very pure anti-n_e beam at » 600 MeV

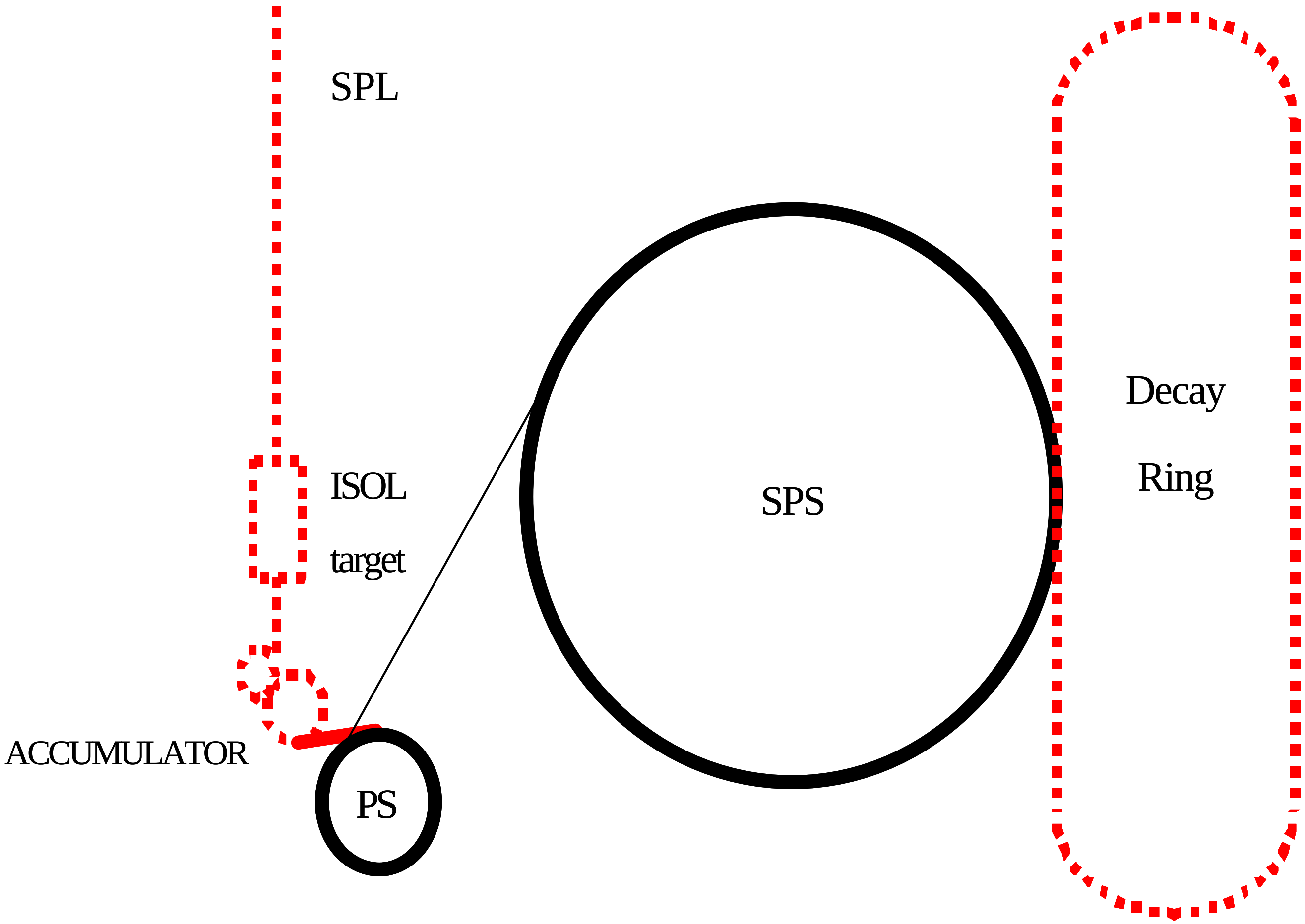
or:

$$^{18}_{10}\mathrm{Ne} \text{ ® } ^{18}_{9}\mathrm{F}\ n_e\ e^{+}$$

very pure n_e beam at » 600 MeV

oscillation signal: appearance of low energy muons
water Cerenkov excellent for this too! Same as for Superbeam
seems feasible; but cost unknown so far.
Critical: duty cycle. A nice * idea to be followed up!**

Beta Beam @cern



M. Lindroos et al.

synergy with Eurisol!

Combination of beta beam with low energy super beam

Unique to CERN:

need few 100 GeV accelerator
experience in radioactive beams at ISOLDE

many unknowns: what is the duty factor that can be achieved? (needs < 10^{-3})

combines CP and T violation tests

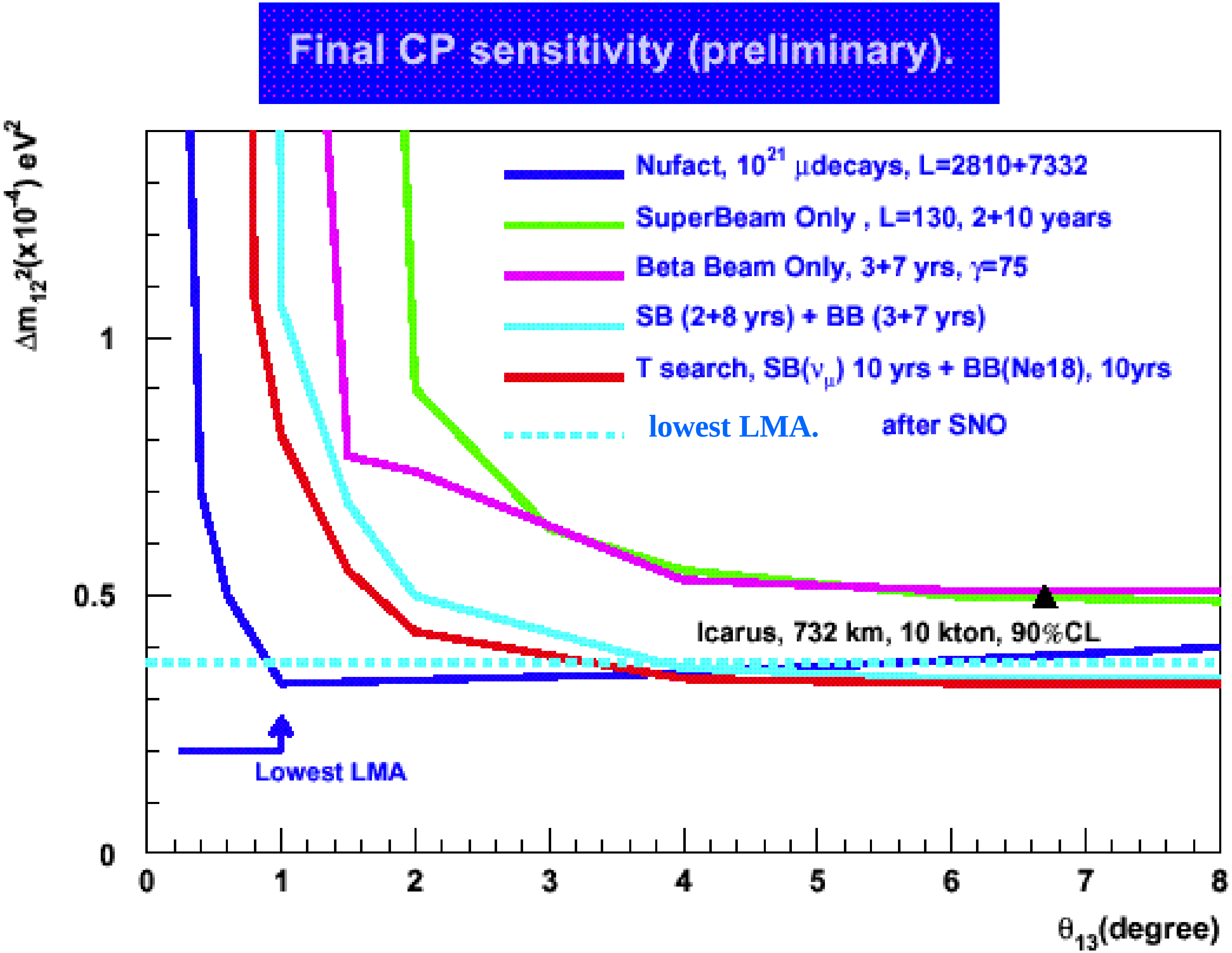
n_e ® n_m (b+) **(T)** n_m ® n_e **(**p^+**)**

(CP)

$\overline{n}_e$ ® $\overline{n}_m$ (b-) **(T)** $\overline{n}_m$ ® n_e **(**$\overline{p}^-$**)**

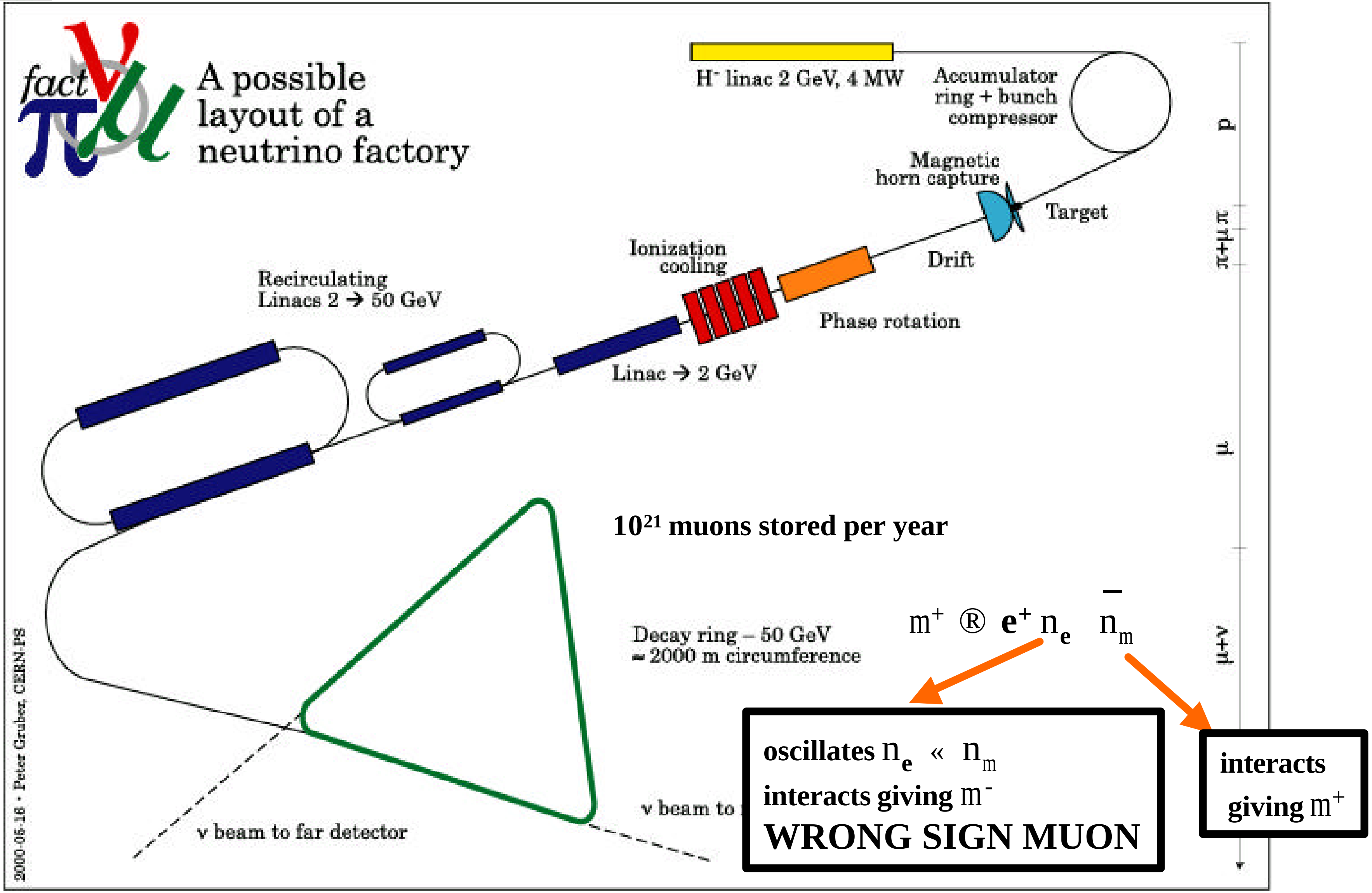
Can this work???? accelerator **theoretical studies now on beta beam**
intensity of Neon 18 achievable?
ion stacking at high energy

Combination of Beta beam and superbeam is in the same ballpark of performance as neutrino factory …
(bewrare of systematics for low Energy neutrino events, though)



M.Mezzetto, CERN workshop NNN02, january 2002

Nufact CERN layout



Neutrino fluxes m^+ -> e^+ n_e n_m

n_m/n_e **ratio reversed by switching** $m^+/\ m^-$

n_e n_m **spectra are different**

No high energy tail.

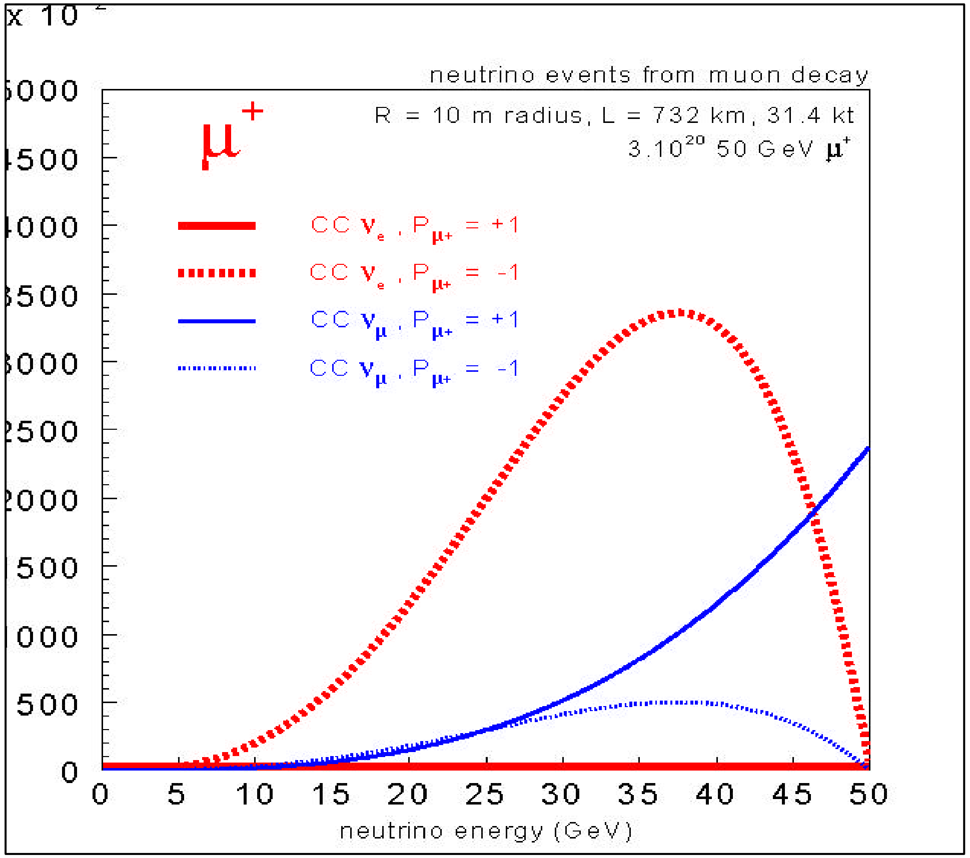
Very well known flux ($\pm\ 10^{-3}$)

-- E& s_E **calibration from muon spin precession**

-- angular divergence: small effect if $q < 0.1/g$
measurable with an imaging Cherekov

-- absolute flux measured from muon current
or by $n_m\ e^-$ **->** $m^-\ n_e$ **in near expt.**

-- in triangle ring, muon polarization precesses and averages out.



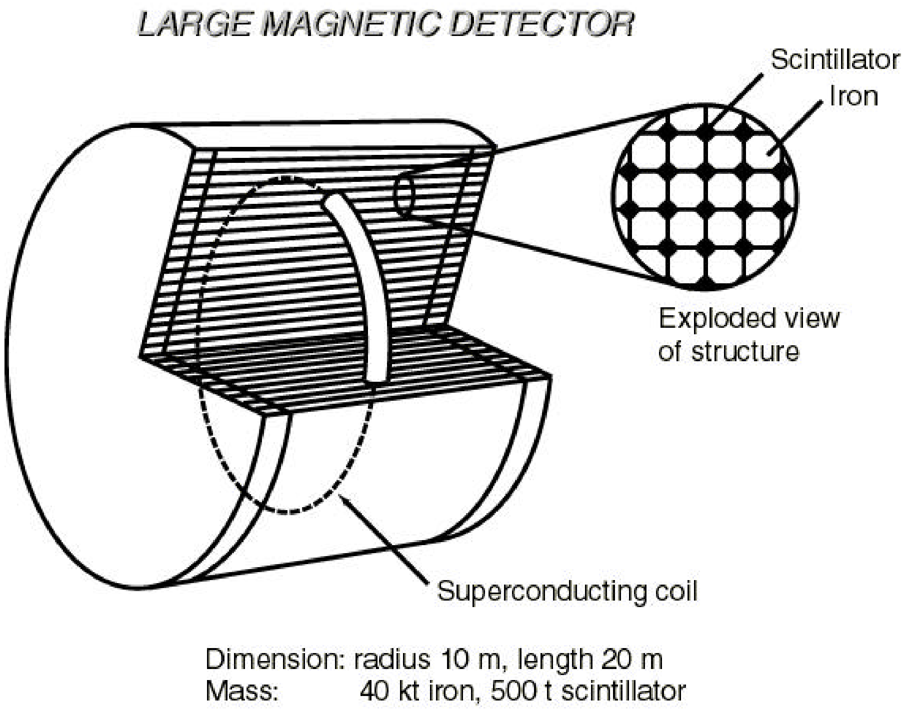
m **polarization controls** n_e **flux:**

m^+ **-X>** n_e **in forward direction**

Alain Blondel, ICFA @cern - 2002

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

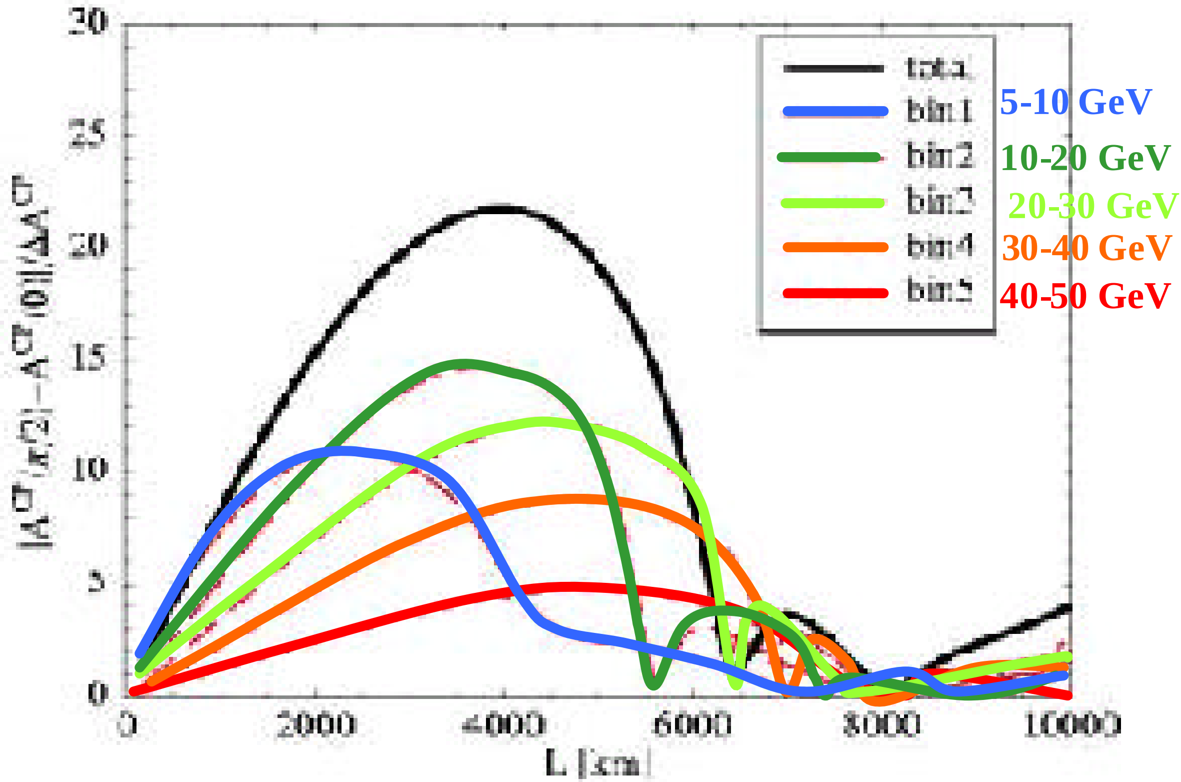
Events for 1 year

Baseline	$\bar{n}_m$ CC	n_e CC	n_m signal (sin^2 q_{13}=0.01)	
732 Km	3.5 x 10^7	5.9 x 10^7	1.1 x 10^5	
3500 Km	1.2 x 10^6	2.4 x 10^6	1.0 x 10^5	(cf 40 in JHF-SK)

CP violation

Cervera et al, de Rujula et al, Burget et al,
Yellow report to be finalized

Matter effect must be subtracted. One believes this can be done with uncertainty Of order 2%. Also spectrum of matter effect and CP violation is different
⇒It is important to subtract in bins of measured energy.
⇒knowledge of spectrum is essential here!



40 kton L M D
50 GeV nufact
5 yrs 10^{21}m /yr

In fact, 20-30 GeV
Is enough!

Best distance is
2500-3500 km

e.g. Fermilab or BNL
-> west coast or …

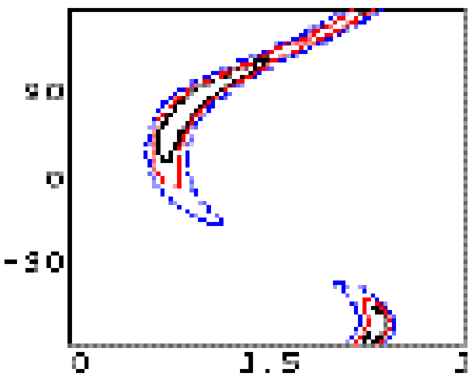
Silver channel at neutrino factory

A. Donini et al
hep-ph/0206034
ROMA-1336/02

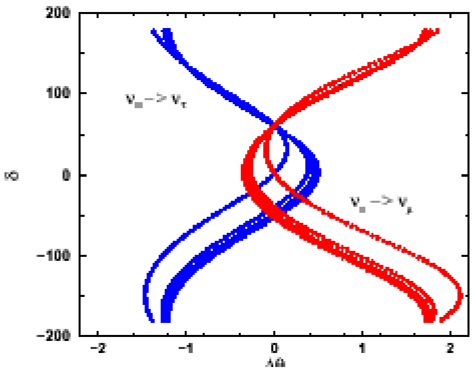
High energy neutrinos at NuFact allow observation of n_e ® n_t
(wrong sign muons with missing energy and P^). UNIQUE

Liquid Argon or OPERA-like detector at 3000 km.

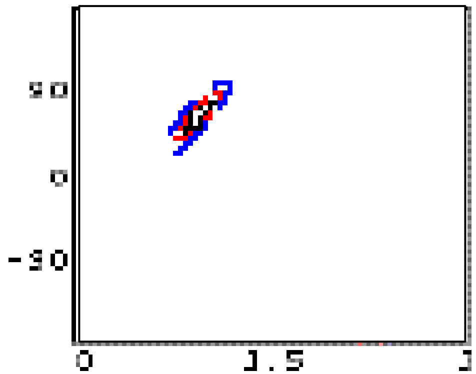
Since the sind dependence has opposite sign with the wrong sign muons, this solves ambiguities that will invariably appear if only wrong sign muons are used.



ambiguities with only wrong sign muons (3500 km)

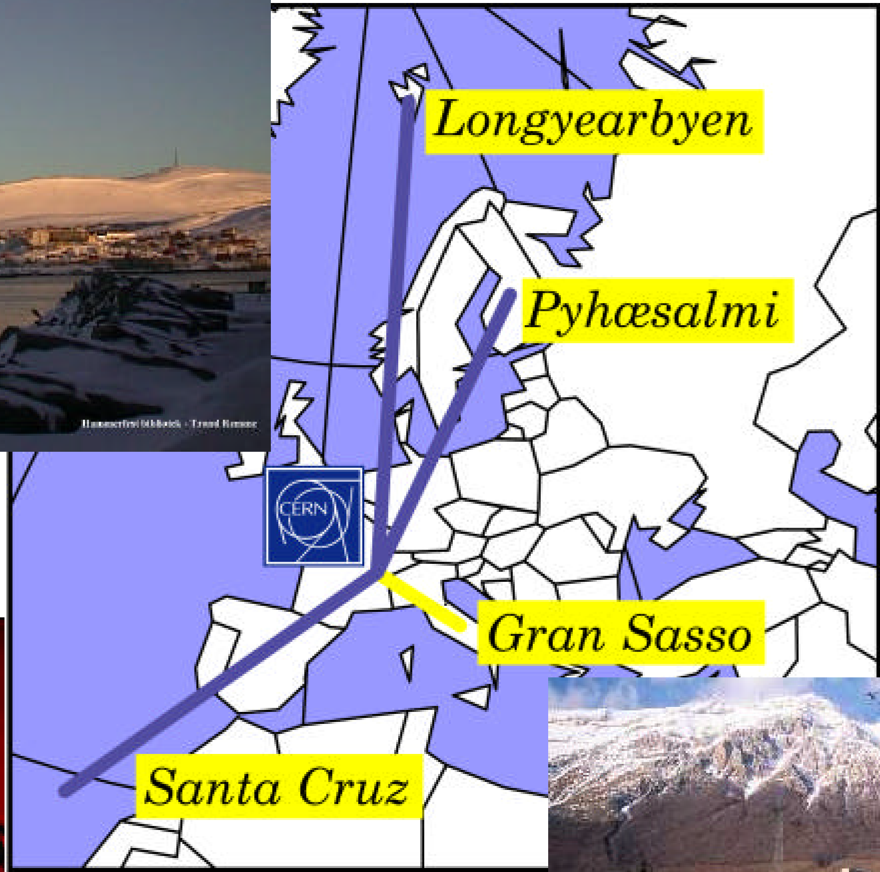


equal event number curves muon vs taus



associating taus to muons (no efficencies, but only OPERA mass) studies on-going

Where do you prefer to take shifts?



m^+ -> e^+ n_e $\bar{n}_m$

Expected Physics outcome of a Long base Line program at a Neutrino factory

High energy n_e essential & unique

- **Measurements of**
  q_{13} , q_{23} **with precision of 10^{-3} or limit at about 10^{-6}**
  Dm_{13} **with relative precision of 1%**

- **establish matter effect -> sign of Dm_{13}**

- **Will be sensitive to CP violation over the whole Large Mixing Angle solution of the Solar neutrinos (favored now) and can do both n_e®n_m and n_e®n_t**

- **(50 KT, 5 years, 10^{21} muons per year, 3000 km)**

R&D for future neutrino beams

US: Muon Collider and Neutrino Factory Collaboration

EU: ECFA and CERN studies of a Neutrino Factory Complex

Neutrino Factory studies and R&D

USA, Europe, Japan have each their scheme. Only one has been costed, US study II:

System	Sum ($M)	Others[a] ($M)	Total ($M)	Reconciliation[b] (FY00 $M)
Proton Driver	167.6	16.8	184.4	179.9
Target Systems	91.6	9.2	100.8	98.3
Decay Channel	4.6	0.5	5.1	5.0
Induction Linacs	319.1	31.9	351.0	342.4
Bunching	68.6	6.9	75.5	73.6
Cooling Channel	317.0	31.7	348.7	340.2
Pre-accel. linac	188.9	18.9	207.8	202.7
RLA	355.5	35.5	391.0	381.5
Storage Ring	107.4	10.7	118.1	115.2
Site Utilities	126.9	12.7	139.6	136.2
Totals	1,747.2	174.8	1,922.0	1,875.0

Neutrino Factory CAN be done…..but it is too expensive as is.

Aim: ascertain challenges can be met + cut cost in half.

Recent developments

CERN cuts….   and EMCOG initiative

MICE LOI received encouragement at RAL

Cooling rings

European Muon Concertation and Oversight Group (EMCOG)

CERN:	Carlo Wyss (chair), Helmut Haseroth, John Ellis
CEA-DAPNIA:	Alban Mosnier, François Pierre
IN2P3:	Stavros Katsanevas, Marcel Lieuvin
INFN:	Marco Napolitano (Napoli), Andrea Pisent (Legnaro)
GSI:	Oliver Boine-Frankenheim, Ingo Hofmann
PSI:	Ralph Eichler, Albin Wrülich
Geneva:	Alain Blondel (secretary)
RAL:	Ken Peach
PPARC:	Ken Long

EMCOG : 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 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, 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 four areas:

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 120 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. GSI…. EMCOG will invite a specific report on the status of the studies and a proposal for the implementation process.

2. Target studies

. This experimental program is already well underway with liquid metal jet studies. Goal: explore synergies among the following parties involved: CERN, Lausanne, Megapie at PSI, EURISOL, etc…

3. Horn studies.

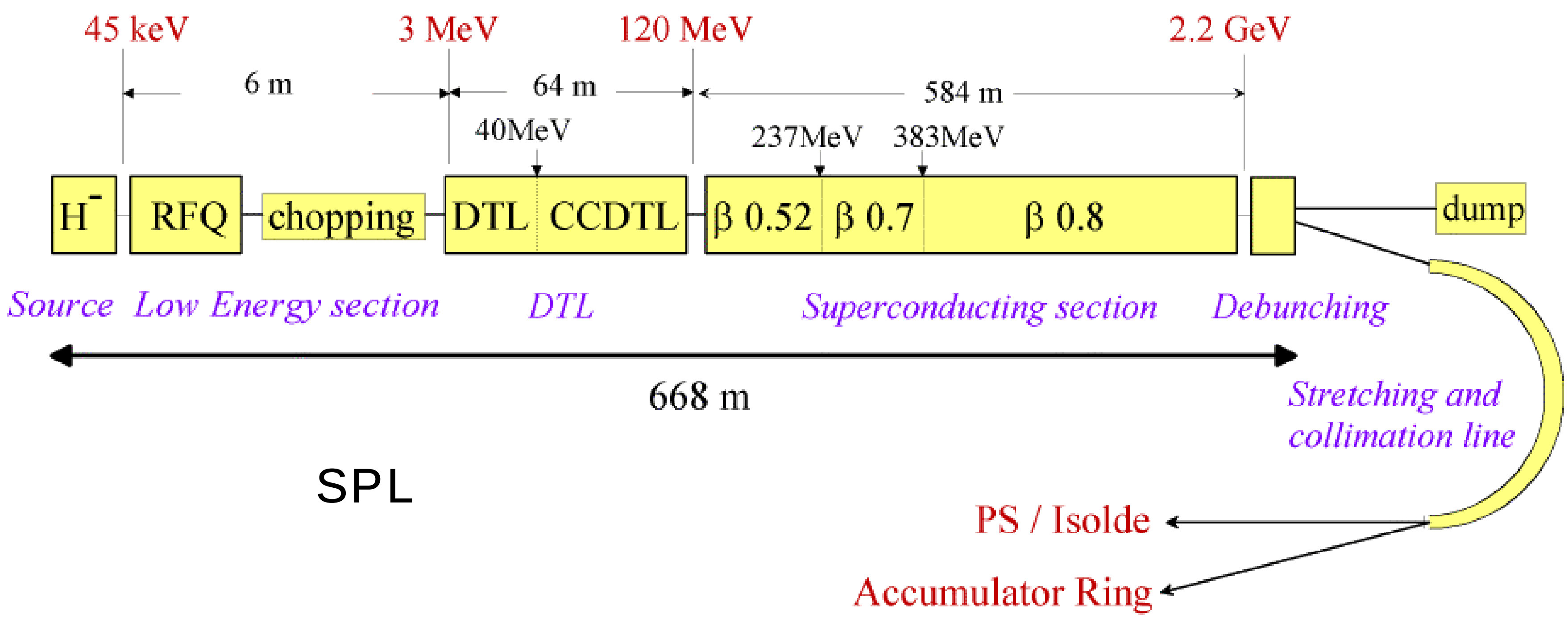
A first horn prototype has been built and is being equipped for pulsing at low intensity.
5 year program to reach high intensity, high rep rate pulsing, and study the radiation resistance of horns. Optimisation of horn shape. Explore synergies between CERN, IN2P3 Orsay, PSI (for material research and fatigue under high stress in radiation environment)

4. MICE. A collaboration towards and International cooling experiment 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 been encouraged to prepare a full proposal at RAL, with technical help fro RAL. PSI offers a solenoid muon beam line and CERN, which as already made large initial contributions in the concept of the experiment, could earmark some very precious hardware that could be recuperated. A summary of the requests should be presented by the collaboration.

It is noted that the first three items are also essential for a possible initial neutrino program with a high intensity low energy conventional neutrino beam (superbeam).

Proton Drivers

- **For CERN, two possibilities:**



SPL

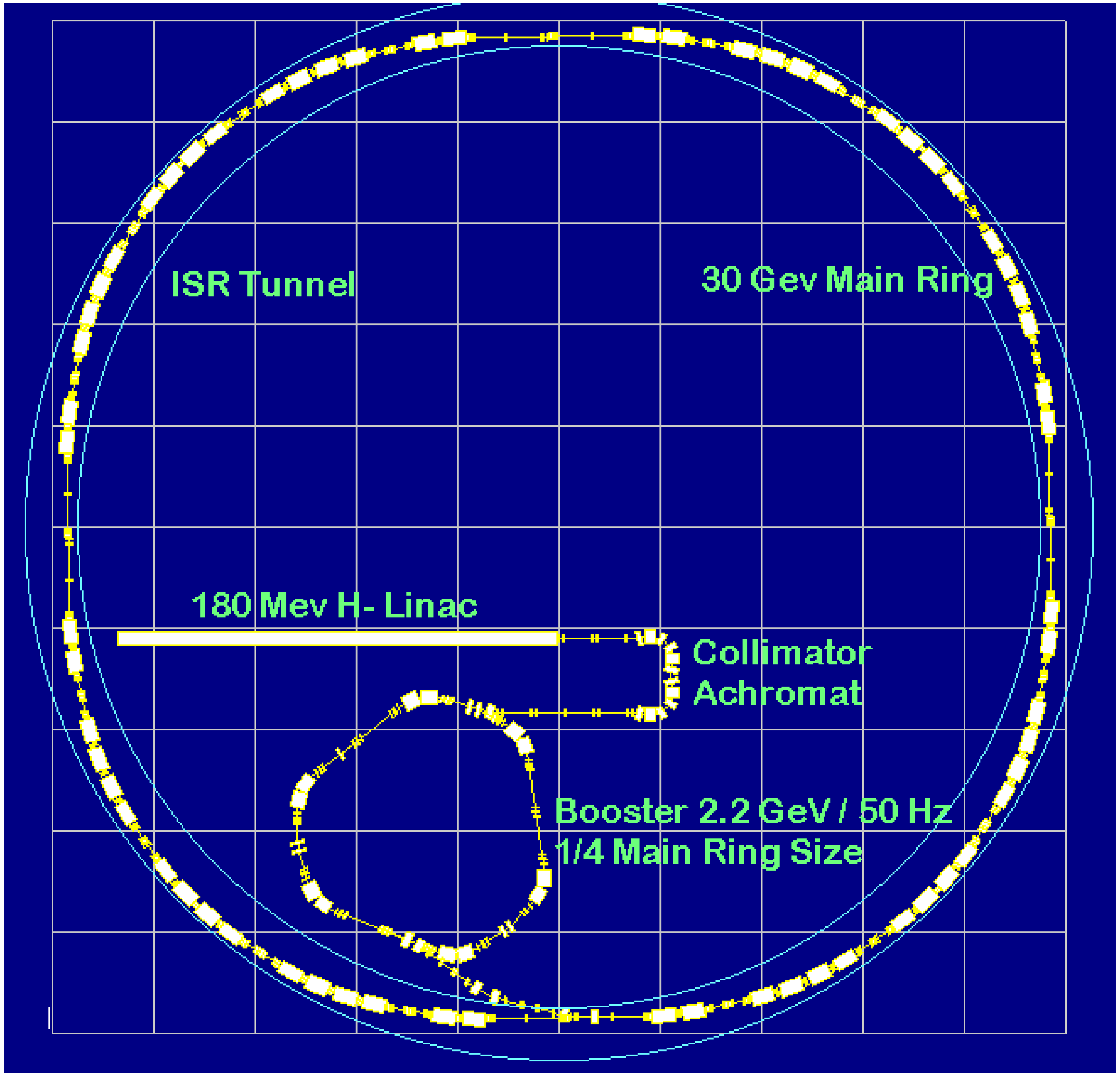
Uses LEP RF system

(capable of >20 MW ….)

a CW machine, needs accumulators

Proton Drivers

30 GeV Rapid Cycling Synchrotron in the ISR tunnel



Proton Drivers

Cost comparison

	PDAC		*RCS*
	MCHF		MCHF
SPL	**350**	**Linac**	**110**
Accumulator	**63**	**Booster RCS**	**88**
Compressor	**50**	**Driver**	**233**
TOTAL	**463**	***TOTAL***	**431**

Schönauer

SPL: driver for a conventional superbeam to Frejus
driver for b-beams
R&D already started with CEA

RCS: replacement for PS

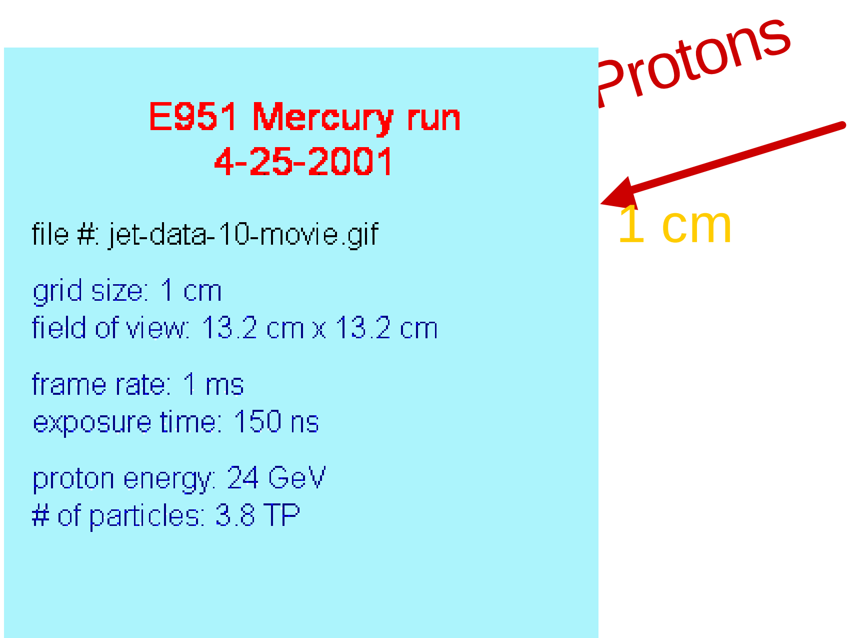
NUFACT R&D: Target station

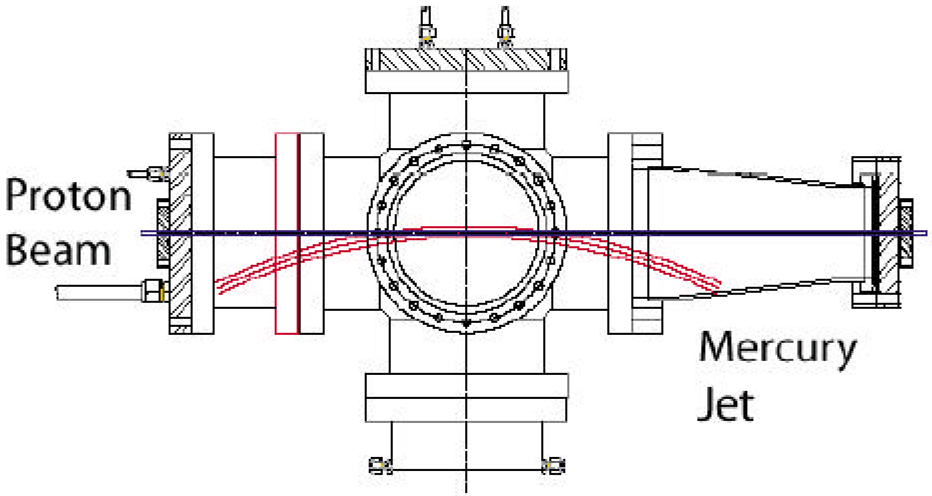
- Target:
  - Dimension: L ≈ 30 cm, R ≈ 1 cm
  - → **4 MW proton beam into an expensive cigar…**
  - → High Z → small size good for optics
  - → Liquid → easy to replace ($v_{//} \approx$ 20 m/s) → Mercury

NUFACT R&D: Target station

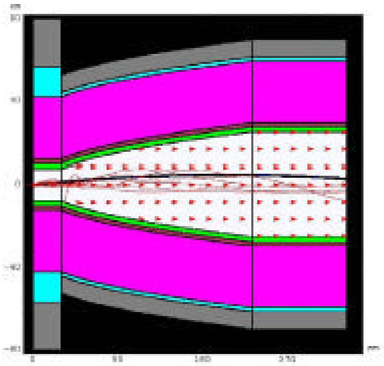
Experiment @BNL and @CERN

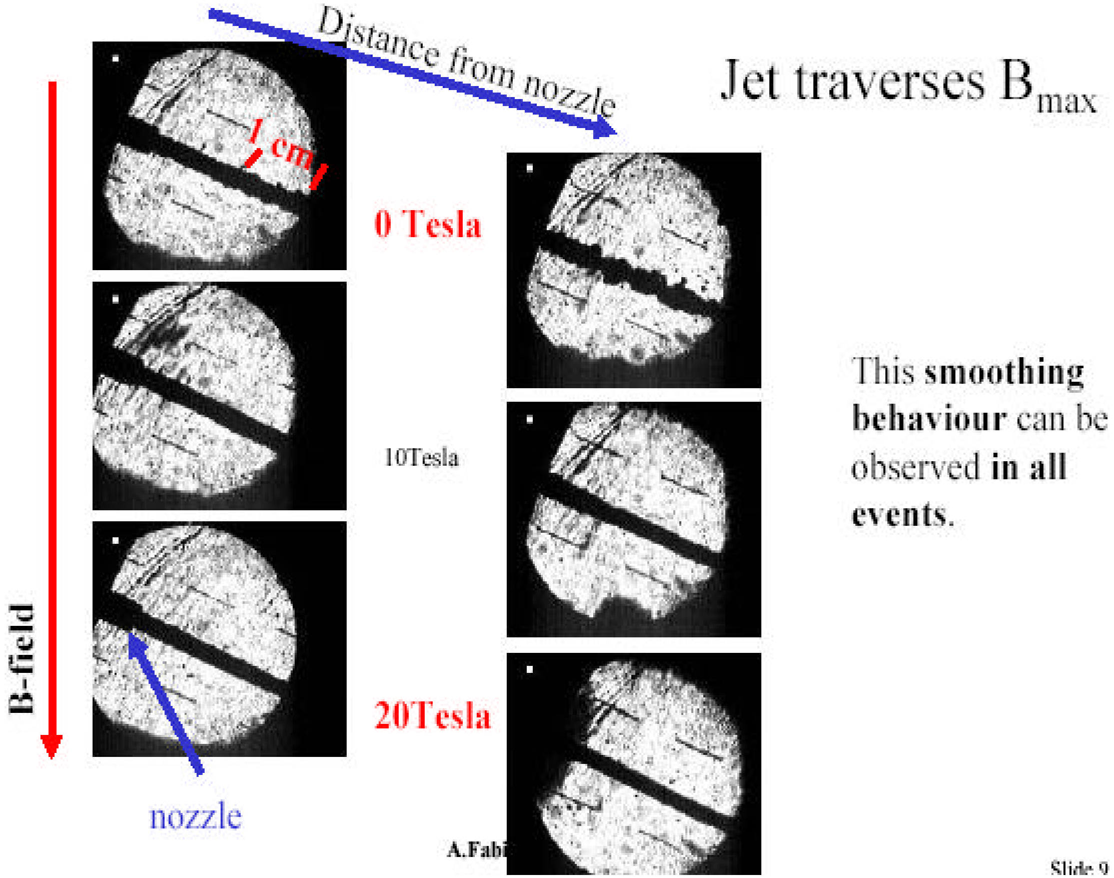
- Speed of Hg disruption
- Max $v_{\perp} \approx$ 20 m/s measured
- $v_{//} \approx 3$ m/s
- jet remains intact for more than 20 microseconds.





US scheme:
jet is inside a very high field tapered solenoid (20 T max)

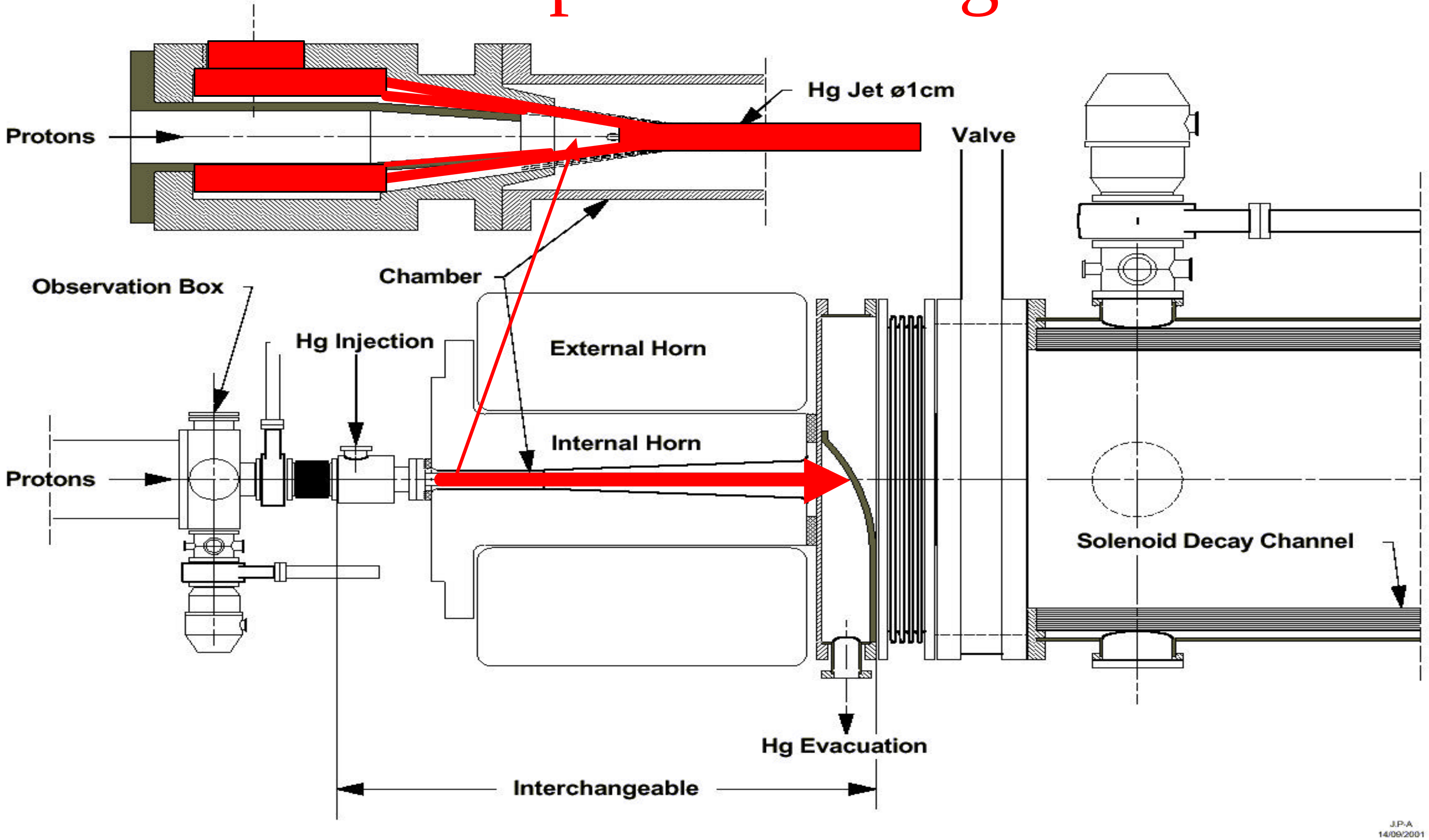




this was tested at the Laboratoire de Champs Intenses (Grenoble)

A. Fabich et al– CERN-BNL-Grenoble

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



HORN STUDIES

horn is built at CERN
mechanical properties will be measured
(can it be pulsed at 350 KA and 50 Hz?
important for basic choice of proton driver)

This is the neutrino factory horn,
SPL-superbeam one will have different shape.

J.-M. Maugain, et al

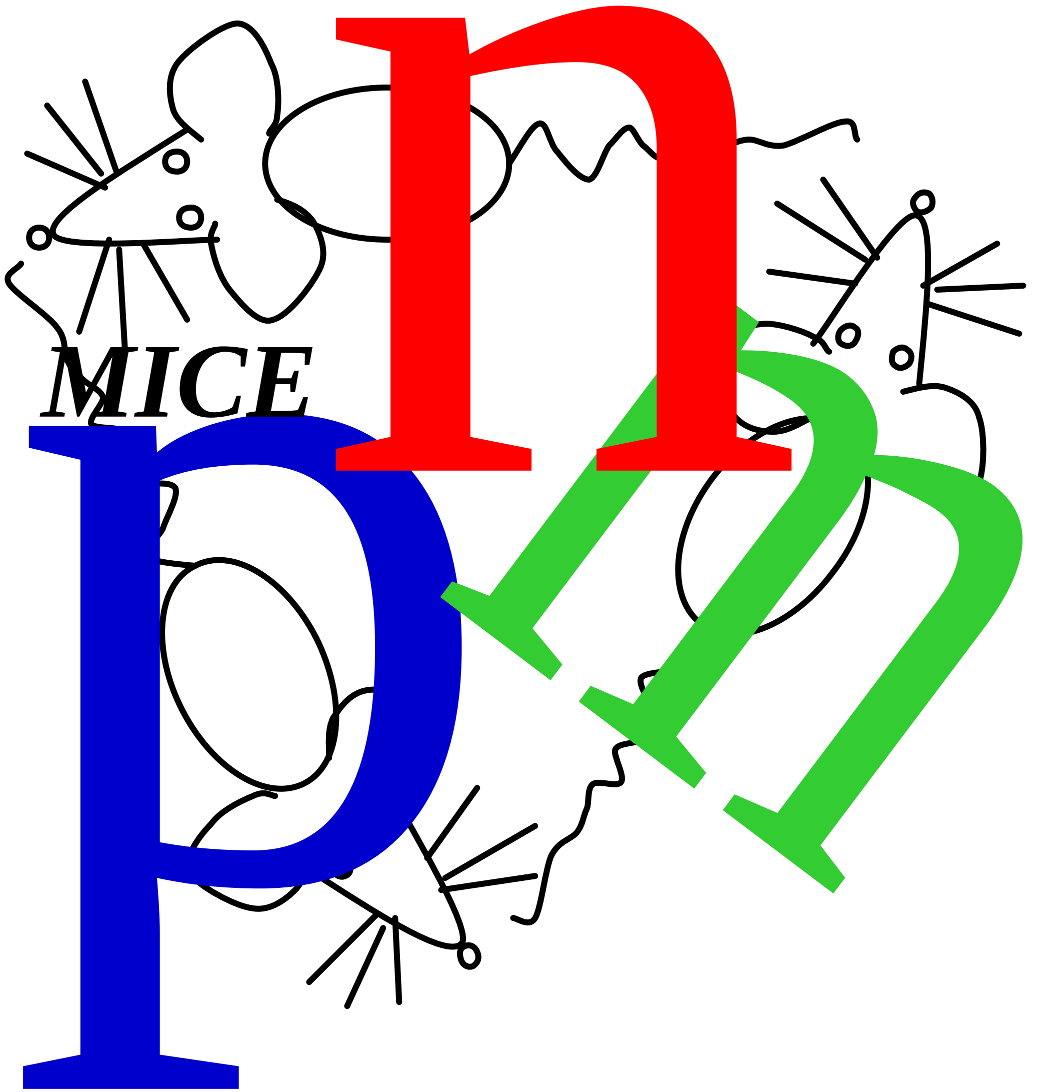
What muon cooling buys

MUON Yield without and with Cooling

	NOCOOL	with cooling
long. emittance	0.05 eVs	0.05 eVs
rotation	6.7×10^{19}	6.7×10^{19}
44 MHz	6.8×10^{19}	
88 MHz	7.3×10^{19}	1.2×10^{21}
176 MHz	5.5×10^{19}	1.0×10^{21}

exact gain depends on relative amount of phase rotation
(monochromatization vs cooling trade off)

cooling of minimum ionizing muons has never been realized in practice
involves RF cavities, Liquid Hydrogen absorbers, all in magnetic field
dsigns similar in EU and US Nufact concepts



An International **M**uon **I**onization **C**ooling **E**xperiment

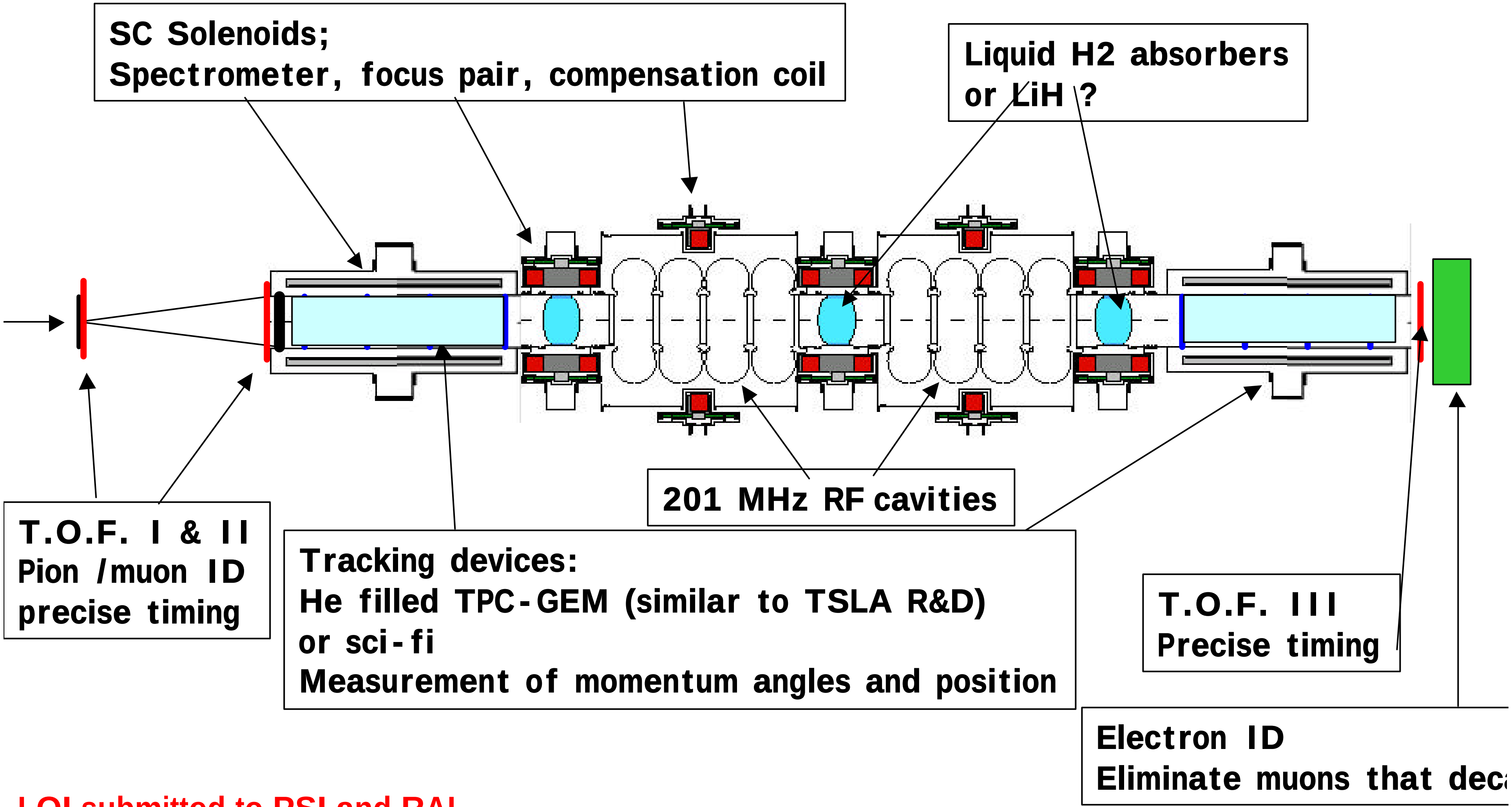
Builds on results of CERN and US studies,

as well as compnonet development by the MUCOOL collaboration

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

single particle measurements =>

measurement precision can be as good as $D (e_{out} / e_{in}) =$:



LOI submitted to PSI and RAL.
The two labs agreed to collaborate and RAL encourages submission of proposal. 2002: prepare prop

International Muon Ionization Cooling Experiment

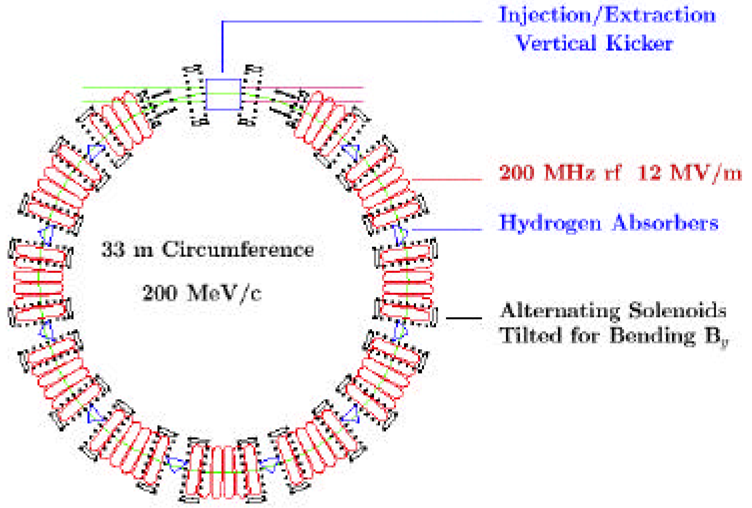
Steering committee:
A. Blondel* (University of Geneva) H. Haseroth (CERN**) R. Edgecock (Rutherford Appleton Laboratory)
Y. Kuno (Osaka University)
S. Geer (FNAL) D. Kaplan (Illinois Institute of Technology) M. Zisman (Lawrence Berkeley Laboratory)
* convener for one year (June 2001-2002)

Conveners of Technical teams:
a) Concept development and simulations : Alessandra Lombardi (CERN **) Panagiotis Spentzouris (FNAL) Robert B Palmer (BNL)
b) Hydrogen absorbers: Shigeru Ishimoto (KEK) Mary-Anne Cummings (Northern Illinois)
c) RF cavities and power sources Bob Rimmer (LBNL) Roland Garoby (CERN**)
d) Magnets Mike Green (LBNL) Jean-Michel Rey (CEA Saclay)
e) Particle detectors Vittorio Palladino (INFN Napoli) Alan Bross (FNAL)
f) Beam lines Rob Edgecock (RAL) Claude Petitjean (PSI)
g) RF radiation Jim Norem (Argonne) Ed McKigney (IC London)

Participating institutes (40 Institutes across the world)
INFN Bari INFN Milano INFN Padova INFN Napoli INFN LNF Frascati Roma
INFN Trieste INFN Legnaro INFN Roma I Roma II Roma III
Rutherford Appleton Laboratory University of Oxford Imperial College London
DAPNIA, CEA Saclay
Louvain La Neuve
NESTOR institute University of Athens Hellenic Open University
CERN** (H. Haseroth)
** only some limited simulation work and lend of used or refurbished equipment
University of Geneva University of Zurich ETH Zurich PSI
KEK Osaka University
Argonne National Laboratory Brookhaven National Laboratory Fermi National Accelerator Laboratory
Lawrence Berkeley National Laboratory University of California Los Angeles University of Mississippi
University of Indiana/ U.C. Riverside, Princeton University
University of Illinois University of Chicago – Enrico Fermi Institute
Michigan State University Northern Illinois University
Illinois Institute of Technology

COOLING RINGS

Two goals: 1) Reduce hardware expense on cooling channel
2) Combine with energy spread reduction (longitudinal and transverse cooling)



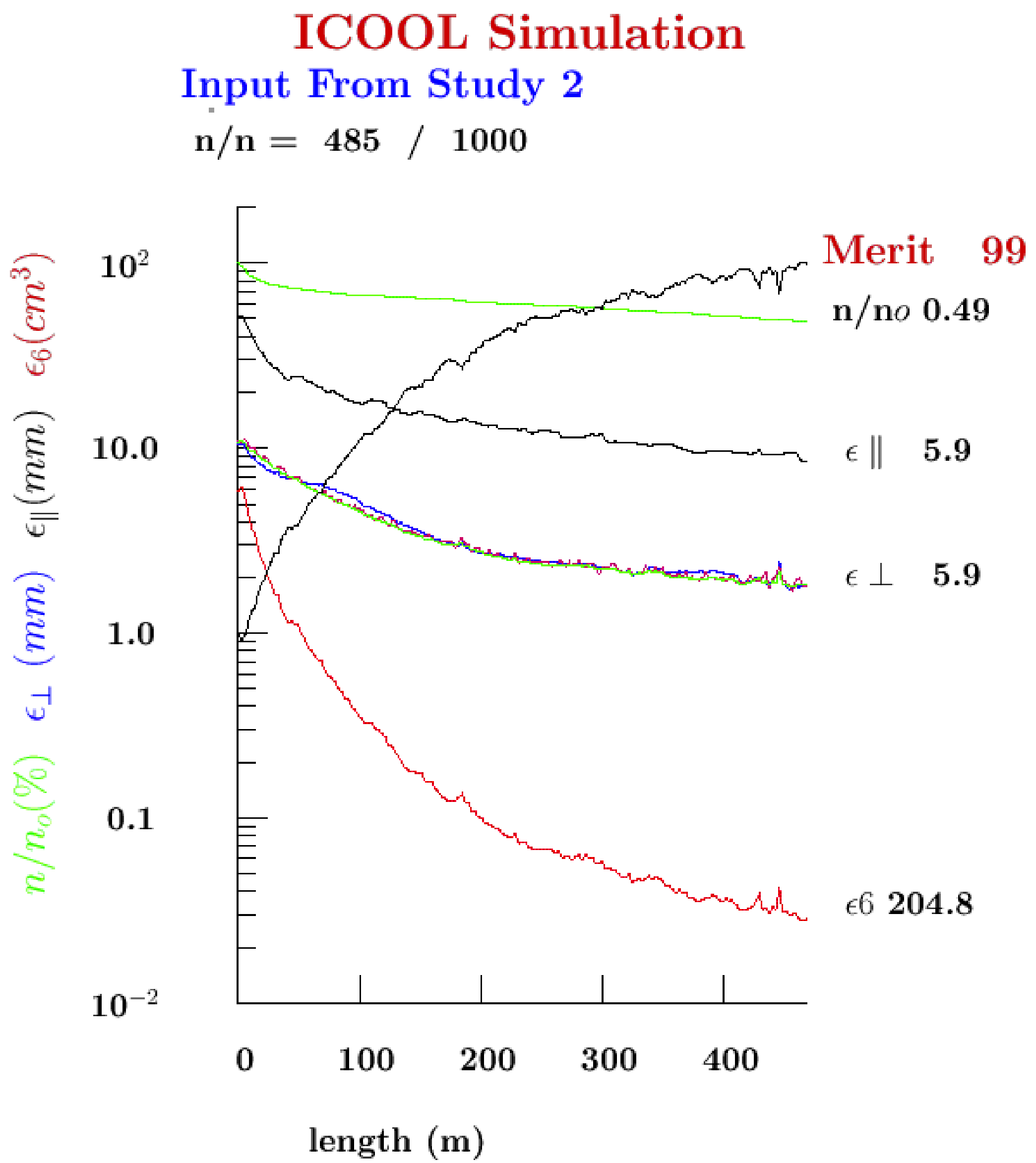
Simple but Sinful:

- Rf in dispersive location

major problem: Kickers!

(Similar problem occurs in Japanese acceleration scheme with FFAG)

Palmer et al



Conclusions

Neutrinos have mass and they mix.

This is a NEW FORCE, (beyond the SM)
possibly implying phenomena at the GUT scale
that could also generate baryon decay
the baryon asymmetry of the universe,

These issues cannot be addressed by LHC or a lepton collider, but they will need powerful and precise tools

A Neutrino Factory Complex (and in a first step a high intensity superbeam) would offer the possibility to discover/measure precisely leptonic CP violation and to measure the mass and mixing properties of neutrinos very precisely.
It would offer a very versatile physics program on the side as well + first step to muon coll..

We know that such a machine can be build and work.
Cost would be too high today and techniques have never been tested in practice.

Requires R&D! Ascertain designs and find new ideas.
Will follow also carefully beta-beam + super-beam combination

Following ECFA/B&B recommendations, an International coordinated effort is being build in Europe and across the world. Goals and priorities are set.