

***** Accelerator based *****

EUROPEAN STRATEGY FOR FUTURE NEUTRINO PHYSICS

<http://indico.cern.ch/conferenceDisplay.py?confId=59378>

1. The questions
2. Question 1: the aims
3. Accelerator options
4. Detector options
5. Summary and going forward



CERN/SPC/912/Rev.
CERN/2815/Rev.
9 December 2008

Specific Request from Council to the Scientific Policy Committee

Relations between CERN and the ongoing development work regarding future neutrino facilities

„The UK delegation to the CERN Council notes that there is no European-wide strategy to engage in the precise determination of neutrino oscillation parameters for the period beyond ~2015, after the T2K and Nova experiments. Within the context of "Questions from Council to the SPC", it requests that the SPC gives its views on several issues pertaining to the physics of neutrinos"



Question 1

- What is the view of the SPC on the importance of precise measurements of the neutrino oscillation parameters, in particular the CP violating phase and mass hierarchy?

Question 2

One of the most promising techniques for such measurements is the neutrino factory and there is currently an International Design Study (IDS) to produce a conceptual design report for a neutrino factory by 2012. This is not site specific. What is the view of the SPC on the overall value of the IDS for the future of the subject? Should CERN take a more active role in enabling the study to reach its goals, irrespective of where such a facility would be sited?

Question 3

What other high intensity neutrino facilities are technically possible and how would they address the measurements above? What should be the involvement of CERN in studies of these facilities, in particular with regard to the planned LHC upgrades?

Question 4

What is the view of the SPC on the merit of a European strategy in this phase of neutrino experimentation and whether it should have a place on the future CERN road map?

This Neutrino Workshop

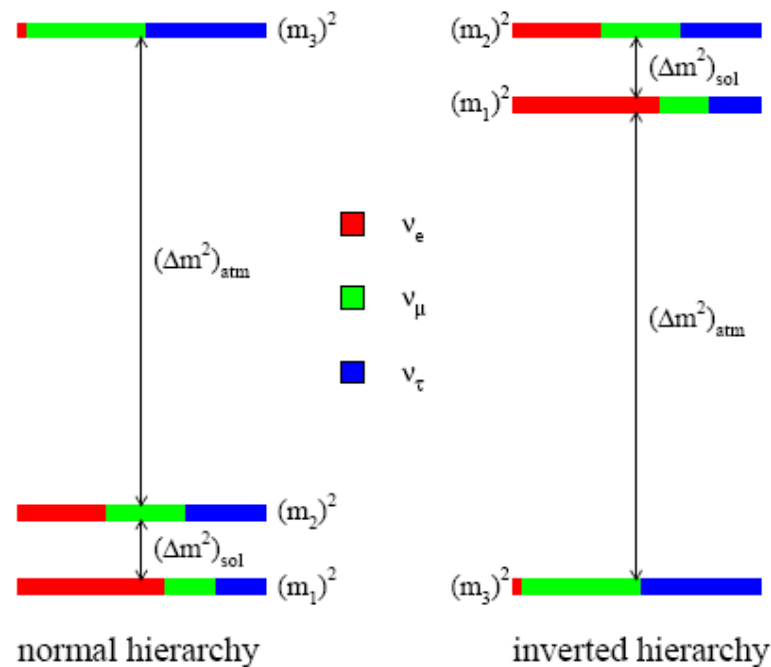
- Not a Neutrino Conference
- Brief Review of what can be expected over the next 5 years
 - Oscillation and non-oscillation neutrino physics
- Review theoretical ideas of the importance of lepton physics
- **Main Aim**
 - To position the European Particle Physics Community to be major players in the period 2015 – 2030
 - The emphasis will be on accelerator-based neutrino oscillation experiments - this requires substantial design, R&D and planning. Here CERN has much expertise.
 - Non-accelerator experiments and neutrino astrophysics will be reviewed only briefly. CERN has not traditionally been involved - but this could change.

Question 1

- What is the view of the SPC on the importance of precise measurements of the neutrino oscillation parameters, in particular the CP violating phase and mass hierarchy?

Talk by de Gouvea

What We Know We Don't Know (1): Missing Oscillation Parameters [Driving Force of Next-Generation Oscillation Program (see next three talks)]



- What is the ν_e component of ν_3 ? ($\theta_{13} \neq 0$?)
- Is CP-invariance violated in neutrino oscillations? ($\delta \neq 0, \pi$?)
- Is ν_3 mostly ν_μ or ν_τ ? ($\theta_{23} > \pi/4$, $\theta_{23} < \pi/4$, or $\theta_{23} = \pi/4$?)
- What is the neutrino mass hierarchy? ($\Delta m_{13}^2 > 0$?)

⇒ All of the above can “only” be addressed with new neutrino oscillation experiments

Ultimate Goal: Not Measure Parameters but Test the Formalism (Over-Constrain Parameter Space)

Important theoretical points:

- 3X3 neutrino oscillations account for what we see
- still parameters missing: θ_{13} mass hierarchy, CP phase
- strategy on oscillations still debated: do we really*) need to know the value of θ_{13} **before** deciding on the next step?

In other words:

case for neutrino factory or beta-beam in case of large θ_{13} is to be made.

- most fundamental questions in neutrino physics seem to be
 - majorana or not?
 - is CP violated?
 - values of θ_{13} , $\pm\Delta m^2_{13}$ θ_{23}
YES they are interesting to measure precisely in their own right
- **is framework complete? (unitarity tests)**

is there another measurement than

$$\nu_{\mu} \leftrightarrow \nu_{\tau} \text{ OPERA,}$$

$$\nu_{\mu} \leftrightarrow \nu_{\tau} \cdot \nu_e \leftrightarrow \nu_{\tau} \text{ and c.c.'s NEUTRINO FACTORY}$$

- importance of rare muon decays was stressed.

*) i.e. not only for politico/psychological reasons.



θ_{13} ?

Discovery: CP violation + hierarchy

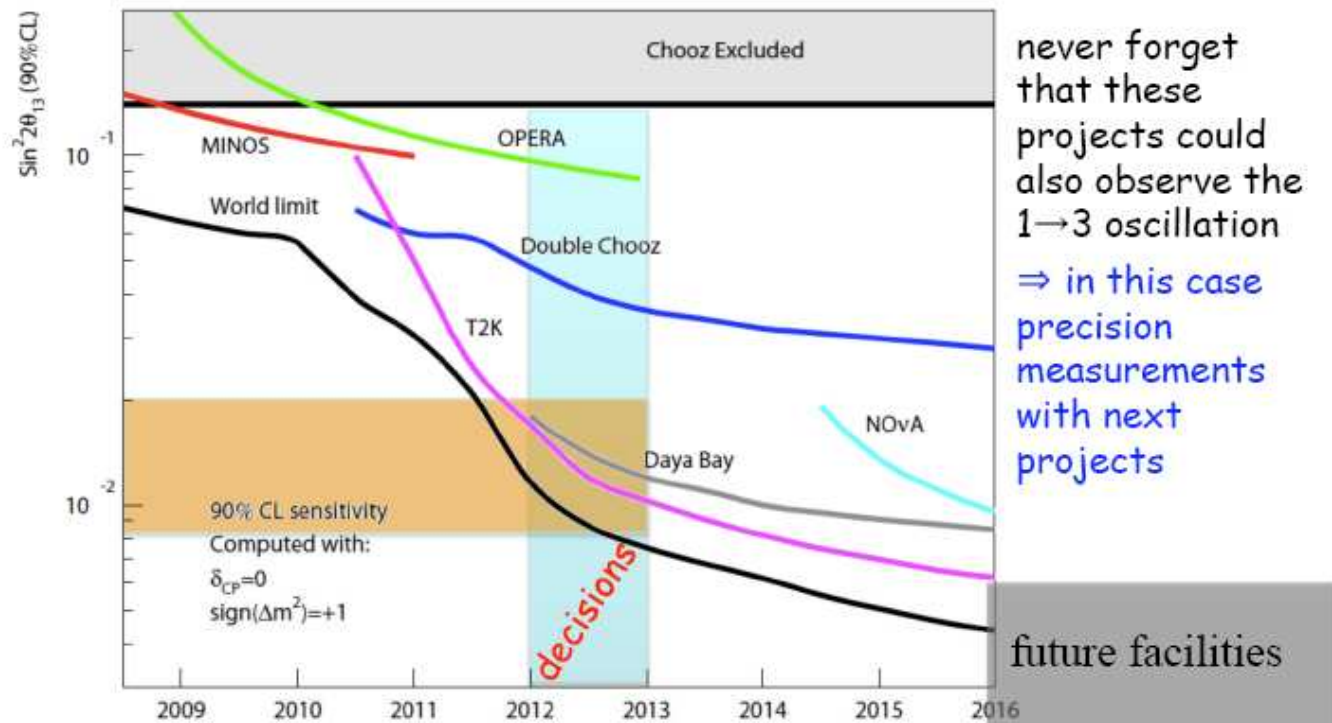
Would a superbeam e-g. T2HK, T2KK be enough ?
Do we need better beams ? Can we afford them ?

Less powerfull accelerators, one baseline,
better detectors: **Low-energy Nufact (T. Li)**
Low- γ $\beta\beta$ different ions (A. Donini)

Completely new ways ? **Mossbauer neutrinos (S. Parke)**



θ_{13} limit expectations up to 2016



2 Oct. 2009

M. Dracos

4



Keep an eye on new alternatives

Neutrino mass with radioactive ions ? **B. McElrath**

Neutrino mass hierarchy with reactors ? **S. Petcov**

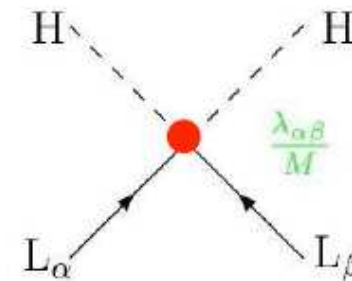


ν masses beyond the SM

The Weinberg operator

Dimension 5 operator:

$$\lambda/M \underbrace{(L L H H)}_{O^{d=5}} \rightarrow \lambda \nu^2/M (\nu\nu)$$



It's unique \rightarrow very special role of ν masses:
lowest-order effect of higher energy physics

This mass term **violates lepton number (B-L)**
 \rightarrow **Majorana** neutrinos

This is now well agreed and well explained....



A non-unitary mixing matrix arises when leptons mix with heavy fermions

i.e. for heavy singlet neutrinos

$$|\epsilon|_{\alpha\beta} = \frac{v^2}{2} |c_{\alpha\beta}^{d=6,kin}| < \begin{pmatrix} 4.0 \cdot 10^{-3} & 1.2 \cdot 10^{-4} & 3.2 \cdot 10^{-3} \\ 1.2 \cdot 10^{-4} & 1.6 \cdot 10^{-3} & 2.1 \cdot 10^{-3} \\ 3.2 \cdot 10^{-3} & 2.1 \cdot 10^{-3} & 5.3 \cdot 10^{-3} \end{pmatrix}$$

Future bounds on $\epsilon_{\alpha\beta}$

$\nu_e \leftrightarrow \nu_\mu$: $\mu \rightarrow eee$, $\mu \rightarrow e\gamma$ ($\sim 10^{-5}$ MEG), μ -e conversion (PRISM/PRIME)

$\left. \begin{matrix} \nu_e \leftrightarrow \nu_\tau \\ \nu_\mu \leftrightarrow \nu_\tau \end{matrix} \right\}$ τ channels at ν factory $\sim 10^{-3}$

... or simpler?:

$\nu_e \leftrightarrow \nu_\tau$ with betabeams ? (Agarwalla, Huber, Link) disappearance

$\nu_\mu \leftrightarrow \nu_\tau$ even easier??

Gavela

"Near" detector in a high energy facility.

.....ndel Groupe Neutrino
Université de Genève



Relation with other fields of physics

- relation with astrophysics and cosmology is well known and was repeated.
- relation with LHC is far less necessary and 'lampost'

Equivalently, there are several completely different ways of addressing neutrino masses. The key issue is to understand what else the ν SM candidates can do. [are they falsifiable?, are they “simple”?, do they address other outstanding problems in physics?, etc]

Options include:

- modify SM Higgs sector (e.g. Higgs triplet) and/or
- modify SM particle content (e.g. $SU(2)_L$ Triplet or Singlet) and/or
- modify SM gauge structure and/or
- supersymmetrize the SM and add R-parity violation and/or
- augment the number of space-time dimensions and/or
- etc

Important: different options \rightarrow different phenomenological consequences

[talks by Altarelli, Strumia, Gavela]



Accelerators

- session described betabeam(s) superbeam (s) neutrino factory
- while we are asked to narrow down options, the devil keeps inventing new schemes!
- high Q beta-beam
- superbeam from PS2
- low energy neutrino factory

My comments:

1. as long as we are in this situation we will not be able to engage CERN in an important way.



Beta-beam

Talks by Elena Wildner, Thierry Stora, Semen Mitrofanov

My comments

HIGH $Q \neq$ HIGH gamma!

The high Q beta beam has the serious difficulty that in order to obtain as many 1st oscillation maximum events one needs a factor $Q/Q_0 \sim 5$ higher intensity wrt baseline beta-beam. (Flux goes like $1/Q^2$ (or $1/L^2$) and cross-section goes like Q) While with high gamma one gains a factor gamma for same number of ions.

(Issue with accelerator and storage ring activation)

The second oscillation maximum is at $E1/3$ and requires similar duty-factor-reduction issues than the normal betabeam.

Issue with accumulation and RF in the storage ring.

→ No real physics improvement from high Q beta-beam? High gamma is much better but also much more expensive and probably unrealistic. .

It does not help that the EURISOL design study with cost and schedule estimates is not out! And it may not help that the beta-beam may require different injectors than LHC. (SPL does not work)

It does not help either that the high Q fad has led to less effort on the ^{18}Ne production. → since 8B is very difficult, we have no assured baseline for neutrino production.

→ Must consider realistic scenarios and stop promising too much!





Production of ^{18}Ne ions for $\bar{\nu}_e$!!!



Other reactions (mainly coming from ^{18}F production for PET imaging):

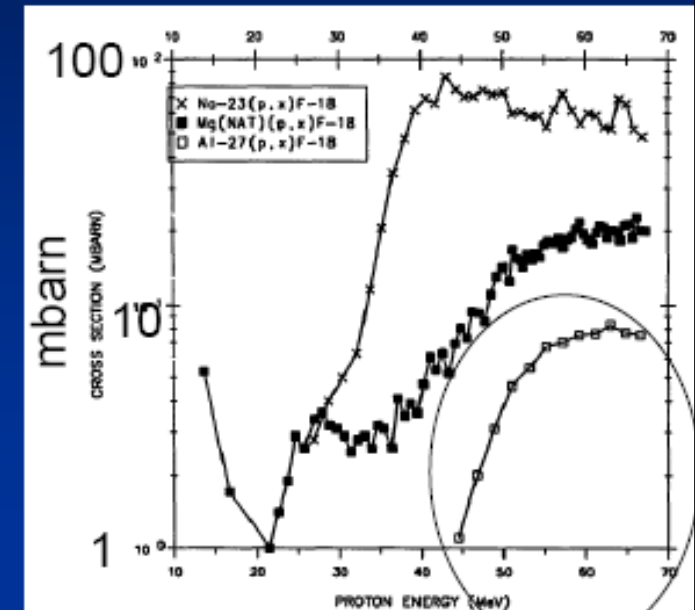
$^{19}\text{F}(p,pn)^{18}\text{Ne}$: threshold 16MeV, peak at 1.6mbarn @ 30MeV (M. Loiselet, S. Mitrofanof)

$^{24}\text{Mg}(p,\alpha p2n)^{18}\text{Ne}$: threshold 39 MeV, cross-sections ?

$^{27}\text{Al}(p,X)^{18}\text{Ne}$: ~ 4 mbarn @ 50-70 MeV (Lanulas-Solar, 1988&1992)

We need $\sim 30\text{mA}$, 70MeV p, and target R&D ($\sim 600\text{kW}$ to be dissipated) for $2 \cdot 10^{13} \text{ }^{18}\text{Ne}/\text{s}$

Production of $\bar{\nu}_e$
 $2 \cdot 10^{13} \text{ }^{18}\text{Ne}/\text{s}$











Nb which will deliver the required NEUTRINO intensity
This should be the priority.



Time schedule - ^8Li



- Start point: March 09 
- Prototype design study: June 09 
- Prototype technical drawings: July-October 09 
- Workshop manufacture: September-November 09 
- Off-line test: October ÷ November 09 
- First beam test (beam test in cabin): December 09 
- Background measurements: February 10 
- Full-time beam experiments: March ÷ April 10 
- ^8Li stage progress report: May ÷ July 10 

End of the summer 2010  we hope we will finish with ^8Li .





We have half of year to discover how to produce ^8B beam via ISOL method
and 1.5 year to develop the production technique

Comment(AB)→ No solution at hand for neutrinos

SUPERBEAM

Superbeam based on SPL is being studied by EUROnu (Dracos et al)

- 4-5 GeV protons \rightarrow 300 MeV neutrinos \rightarrow 150km 1st max = Frejus.
- Main issue is target + horn collection. Low energy \rightarrow high power needed and high power deposition (more protons per MW)
- solution with multiple horn?
(MY COMMENT much skepticism: reliability, geometry of further collections etc...)
- liquid target abandoned does not fit with horn

My Comment: Advantage of realism

Disadvantage that at this moment studying a scenario which makes sense IFF

- a) The Fréjus Megaton goes ahead
- b) The EURISOL beta beam allows CP, T, CPT tests

but is in direct competition with T2KK and DUSEL. Are we going to be on time?

The high power SPL is not in the CERN plans as of now. (but see later)



SUPERBEAM II

New and different ideas do come up:

for instance made the point (A. Rubbia oral comment) that a PS2 (60 GeV) With 200kW (X a few factors) to Pyhasalmi (2300 km, 1st osc. Peak at 4.6 GeV, 2d at may do as well than 4MW/4GeV SLP to Frejus

60GeV \rightarrow pion peak at $\sim 4-6$ GeV good match
Event rate increases like gamma

Well matched to... Liquid Argon detector! ;-)

First step towards Nufact to Pyhasalmi!

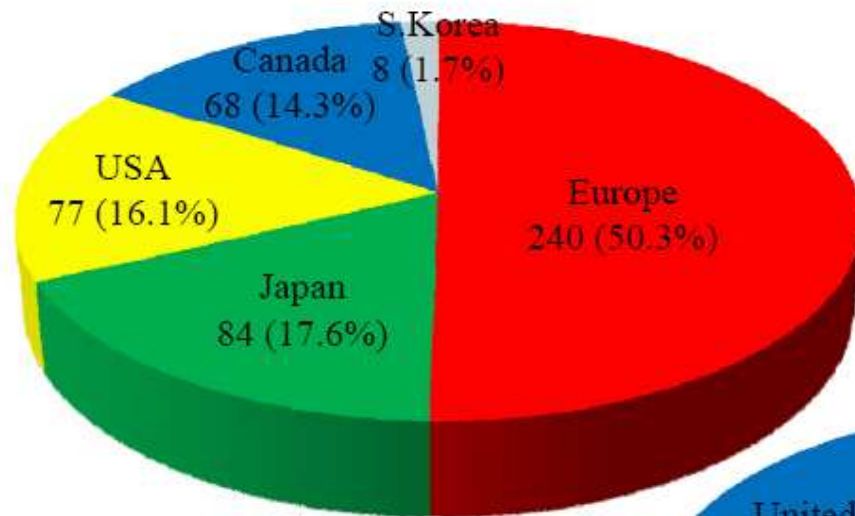
Is this realistic? LArg mass and PS2 power are real issues.





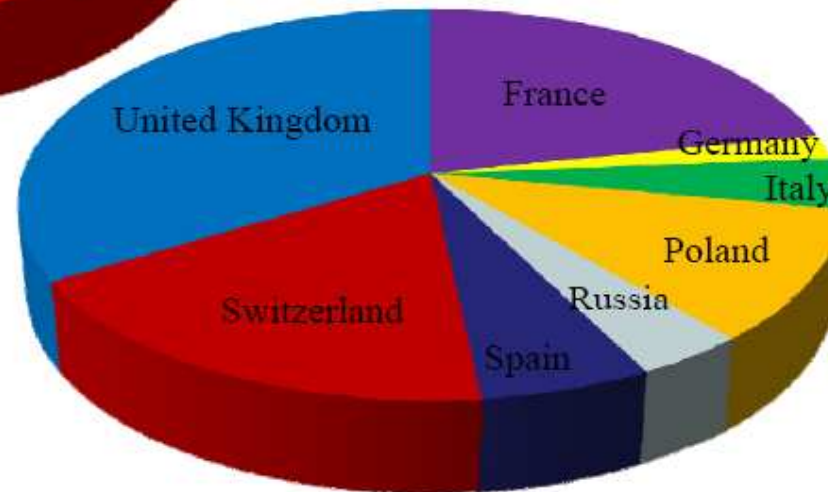
Superbeam (Japan)

Participants for T2K



ALL

Europe



Integrated power of $1 \sim 2 \text{ MW} \times 10^7 \text{ seconds}$
is
a turning point to decide

Next Project utilizing J-PARC Neutrino Beam

If **Significant** ν_e Signal \rightarrow
Proceed Immediately to CP Violation Discovery

Naturally, main neutrino detector
tends to be huge.

**NB: this view point was
not universally agreed**

As a consequence, main neutrino detector gives
us rare and important opportunity to

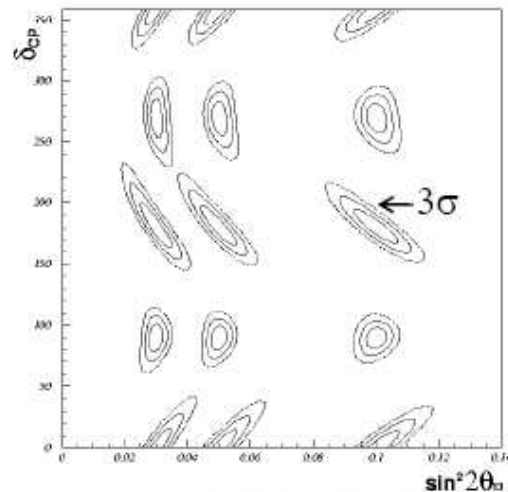
Discover Proton Decay



Scenario 1

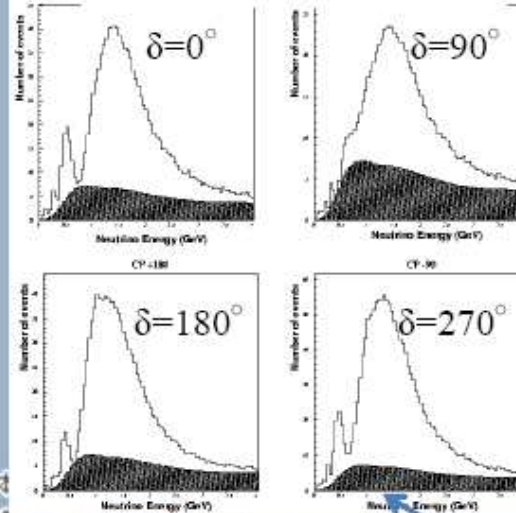
- Cover 1st and 2nd Maximum
- Neutrino Run Only 5Years \times 1.66MW
- 100kt Liq. Ar TPC
 - Good Energy Resolution
 - Good e/π^0 discrimination
- Keeping Reasonable Statistics

CP Measurement Potential



ν_e Spectrum

$\sin^2 2\theta_{13} = 0.03$, Normal Hierarchy



Okinoshima

658km

0.8deg. almost On-axis

Beam ν_e
Background

NP08, arXiv:0804.2111



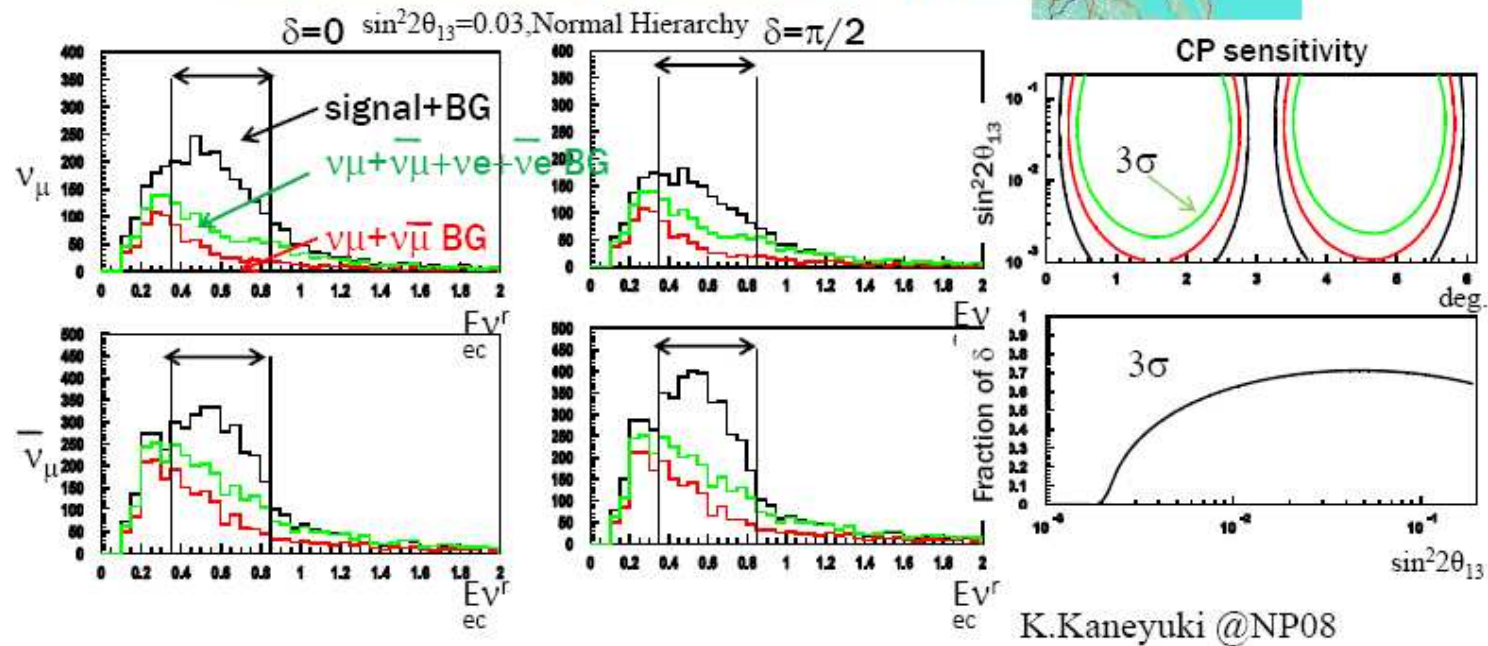
Scenario 2

- Cover 1st Maximum Only
- 2.2 Years Neutrino + 7.8 Years anti-Neutrino Run 1.66 MW
- 540 kt Water Cherenkov Detector

Kamioka

295 km
2.5 deg. Off-axis
 $\langle E_\nu \rangle \sim 0.6 \text{ GeV}$

Tokai

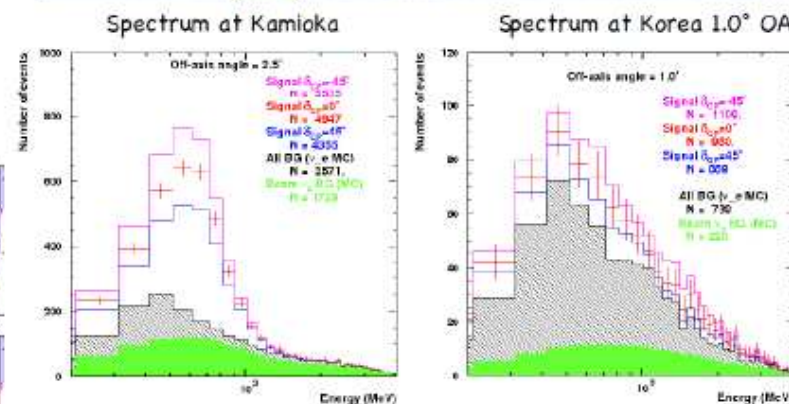
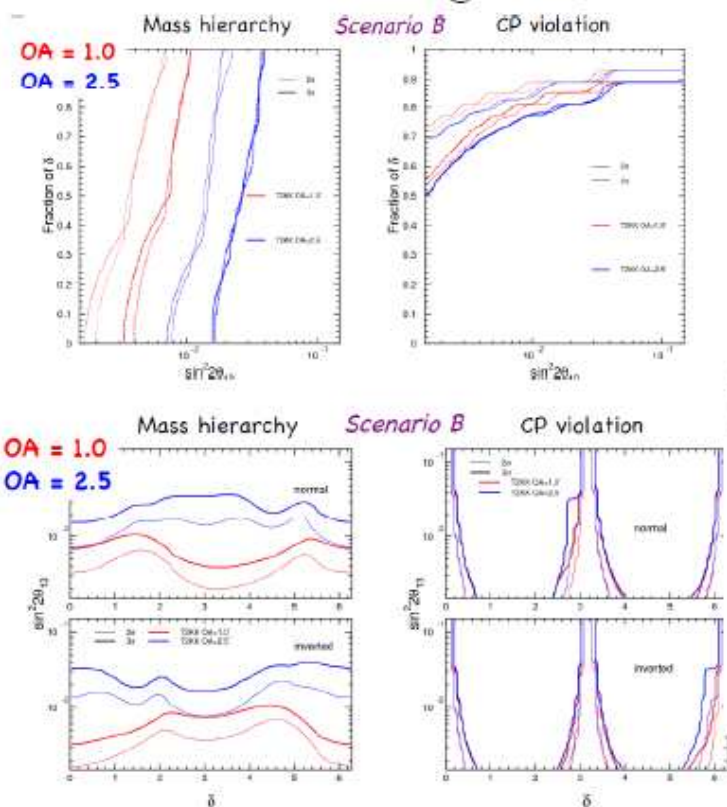


K.Kaneyuki @NP08



Scenario 3

- Cover 2nd Maximum @ Korea
 - Cover 1st Maximum @ Kamioka
 - 5 Years ν + 5 Years $\bar{\nu}$ Run 1.66MW
 - 270kt Water Cherenkov Detector each
- @ Korea, Kamioka



$\sin^2(2\theta_{12})=0.04$, neutrino, normal hierarchy, Scenario B
F.Dufour@NP08
(study is initiated by M.Ishitsuka et. al. hep-ph/0504026)



Comparison of Each Scenario

	Scenario 1 Okinoshima	Scenario 2 Kamioka	Scenario 3 Kamioka Korea
Baseline(km)	660	295	295 & 1000
Off-Axis Angle($^{\circ}$)	0.8(almost on-axis)	2.5	2.5 1
Method	ν_e Spectrum Shape	Ratio between $\nu_e \bar{\nu}_e$	Ratio between 1 st 2 nd Max Ratio between $\nu_e \bar{\nu}_e$
Beam	5 Years ν_{μ} then Decide Next	2.2 Years ν_{μ} 7.8 Years $\bar{\nu}_{\mu}$	5 Years ν_{μ} 5 Years $\bar{\nu}_{\mu}$
Detector Tech.	Liq. Ar TPC	Water Cherenkov	Water Cherenkov
Detector Mass (kt)	100	2×270	270+270

Study is continuing to seek for optimum choice



What we think important for Accelerator Based Neutrino Project in Japan

- Deliver high quality experimental output from T2K as soon as possible
- Quick improvement of accelerator power toward MW-class power frontier machine
- Validate beam line components tolerance (especially pion production target related issues) toward MW proton beam
- R&D on realization of Huge Detector
 - Liq. Ar TPC
 - Water Cherenkov Detector

We welcome cooperation in any aspects



Neutrino beam from 120 GeV MI

Best Δm^2_{23}
 θ_{13} ?
...

Global fit:

$\theta_{13} = 0$ disfavored by $\sim 2\sigma$
Central value $\sin^2 2\theta_{13} = 0.08$

Lead, SD

Nebraska

iron mine
at Soudan

MINOS (Far Det.)

735 km
2.5 msec

Wisconsin

Michigan

Milwaukee

MiniBooNE
SciBooNE

MINOS (Near Det.)

Chicago

MINOS
MINERvA
ArgoNeUT

ArgoNeUT

MINERvA

MINERvA: Ops. w/ Partial Det.(2009)
 ν – Matter Interactions

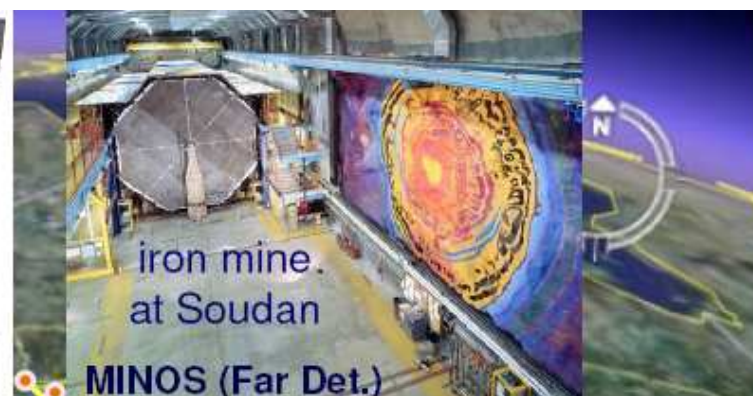
LAr TPC:
Collaborating with Italy

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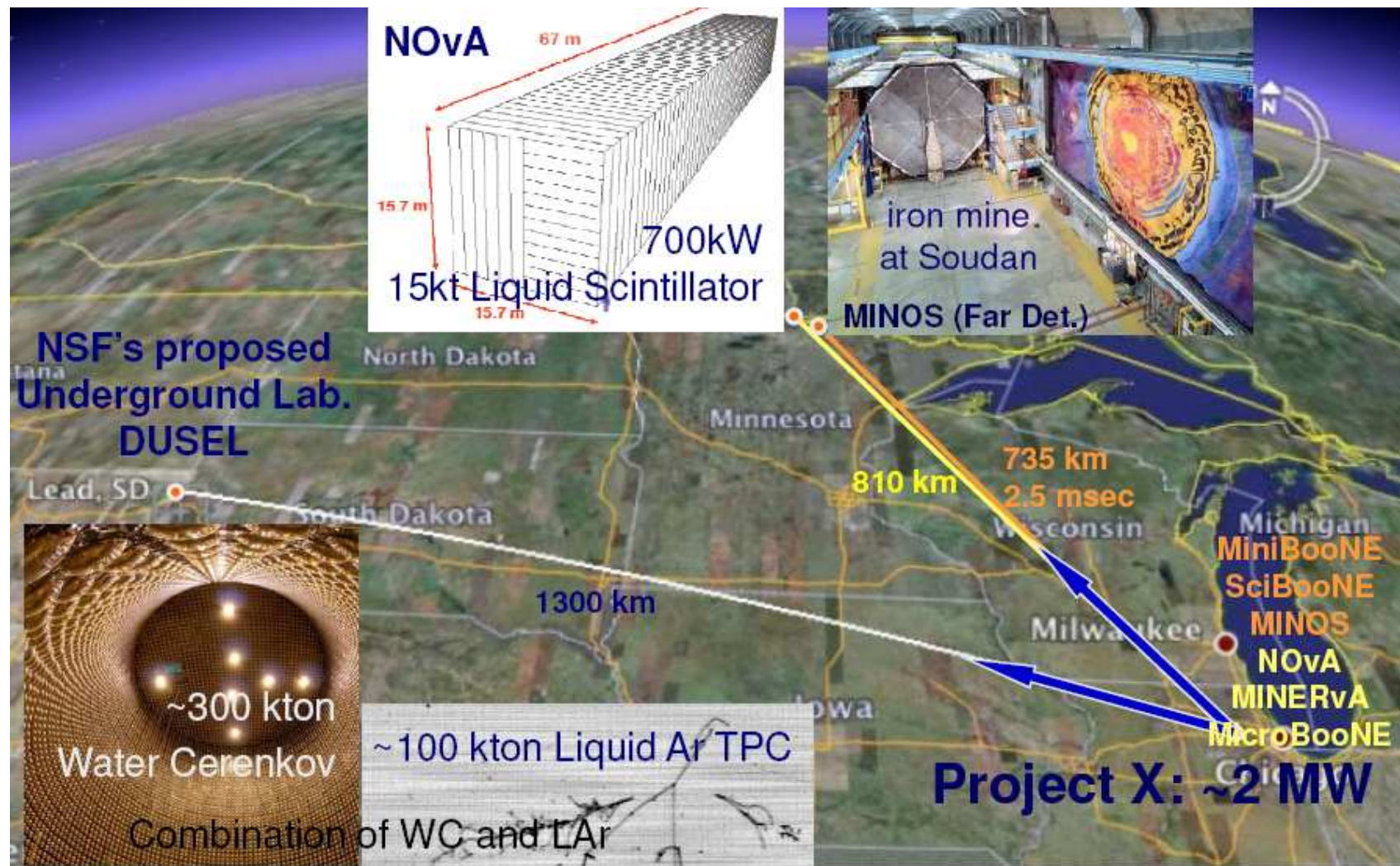


- NOvA: Data Taking in FY12-13
- θ_{13}
 - Mass Ordering:
the only near term project in the world sensitive to mass ordering
 - improved precision: 2-3
 - ...



MINERvA: Ops. w/ Full Det.(2010)
 ν – Matter Interactions





Matter – Antimatter Asymmetry with Neutrinos
Proton Decay
Supernovae Neutrinos

operation with **BOTH**
is envisaged



CERN ideas?

Carlo Rubbia rejuvenated the I216/P331 proposal of 10 years ago by proposing the same experiment with Liquid Argon detector.
(was plastic scintillator readout with WLS)

NB this is a two detector version of MiniBooNE and should clarify a number of (possible) issues unambiguously

This seemed to be viewed positively by the CERN management as a way to restart a CERN based activity (there is NO CERN-based neutrino physics group at the moment)

Carlo took advantage of the situation to deliver a little sermon:



The future of the LAr

A number of possible future experiments with masses much larger than T600 have been discussed by a number of authors and are a subject of discussion for the long range future of neutrino physics and perhaps proton decay.

These authors have presented masses of 5'000 and up to 100'000 tons, namely between 10x and 200x the today's T600.

But containing the LAr is not enough: for instance purity levels of 10^{-11} O₂ equivalent must be created and maintained. (NDLR: !!!)

In our view, before translating more or less generic R&D into a detector of such an enormous magnitude, intermediate steps must be performed, consolidating realistically the physics already possible with detectors of the present size.

Gargamelle has already shown that remarkable results may be obtained with a very sensitive detector even if much smaller than the one of larger and coarser calorimeters of that time.

There may be a similar opportunity in the future, paving on the same time the way to the much larger ultimate facilities.

Neutrino Factory

Several presentations by Geer (US), Zisman(US), Pozimski(UK), Edgecock(UK)

- ONE remarkable achievement: the MERIT experiment.
- ONE essential but remarkably delayed project : MICE
- Baseline scenarios are being drawn for cost estimate.
- Propose to take out tau detector at long baseline from baseline study: does not teach enough (but only way to over-constrain oscillation mechanism?)
- IDS-NF (in Europe: EUROnu-NF) proposes to present a cost estimate in 2010 to within 50% and in 2012 within 30%

Requests help from CERN in areas of

- target infrastructure and safety aspects
- RF for MICE (within TIARA?)
- cost estimate
- accelerator physics

My comment: cost estimate was made in US in 2004 (1.3-2B\$)
Effort is really too small to be very credible without CERN and I suspect this is the origin of the initial UK question to council.

Not shown at workshop: CERN Pyhasalmi +INO is a very good set up

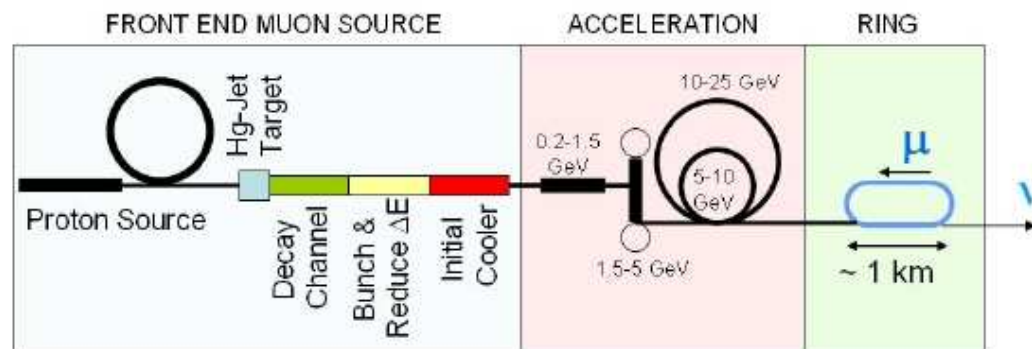
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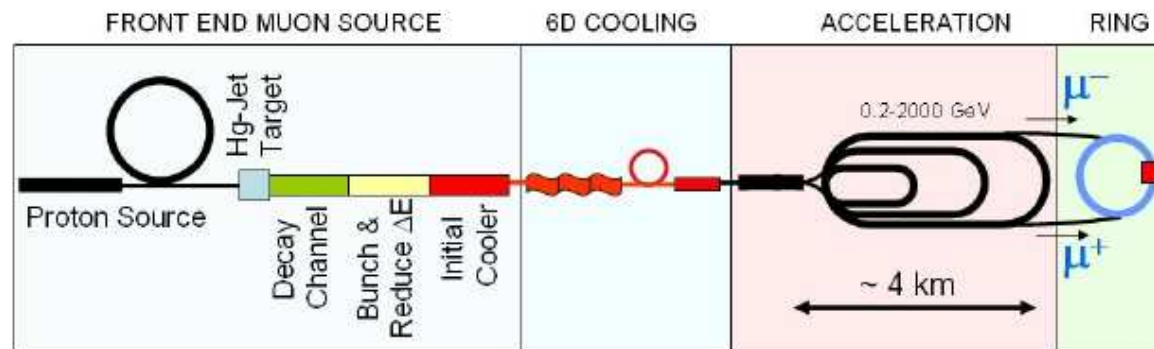
The main comments for Neutrino Factory

1. Particle production with 4 GeV (kinetic) 4MW SPL is OK
(in spite of effort by Dydak to claim otherwise)
2. → No bad surprise to be expected from source
3. Lot of effort remains to be done to understand/optimize cooling!
Issue of RF cavities operated in magnetic fields
Combination of Phase rotation and cooling appears possible.
MICE effort should be increased
4. Acceleration of muons requires understanding of a new type of accelerator,
the FFAG → interest for other fields, but definitely a risk
5. It is the only machine that can fulfill the Long baseline neutrino mission.
6. It is NOT a coherent step with proton decay and supernova neutrinos!
Unless one designs a magnetized liquid argon or TAsD (NOVA-like) far detector
7. It is a coherent step towards high energy frontier with MUON COLLIDER (Geer)
8. is this an appropriate step for CERN (which is not working on muon collider!)?





**NEUTRINO
FACTORY**



**MUON
COLLIDER**

In present MC baseline design, Front End is same as for NF

Bunching and Phase Rotation

Beam from target unsuitable for downstream accelerators

must be "conditioned" before use

reduce energy spread

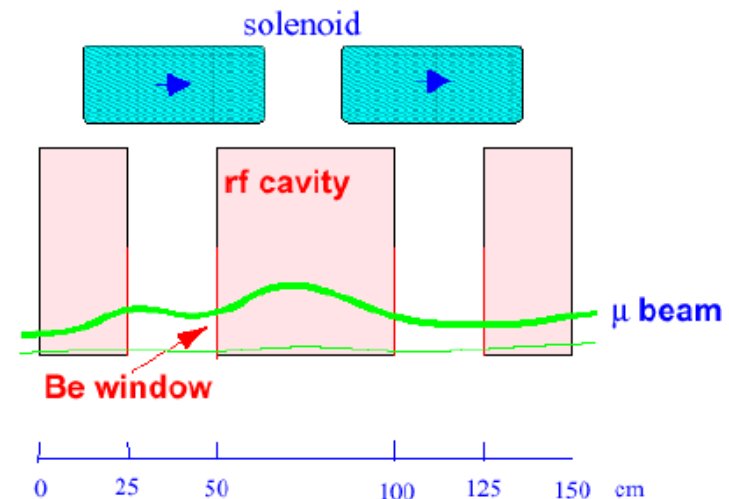
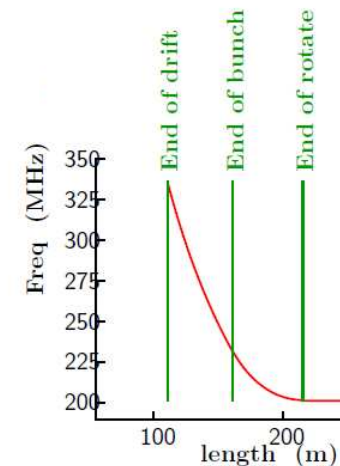
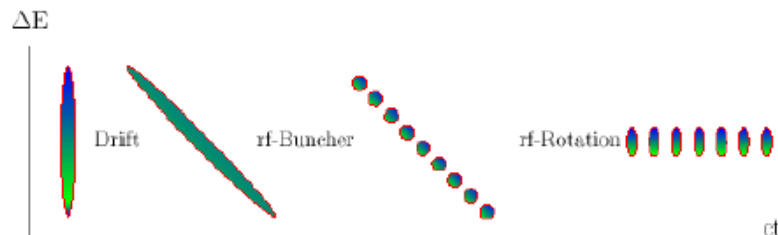
create beam bunches for RF acceleration (201 MHz)

accomplished with RF system with many frequencies

RF issues as cooling channel (covered later)

optimization of length and performance under way

Neuffer scheme





Possible Future Role for CERN

A natural CERN contribution would be participation in the design and testing of a prototypical neutrino factory target system with an intense proton beam.

This would take explicit advantage of CERN's expertise, capabilities and facilities



European Neutrino Physics Oct. 2-3. 2009

Harold G. Kirk

Alain Blondel Groupe Neutrino
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ν specific (Europe)

- Reach a shared decision on the next step(s).
- Narrow down the choice of the far detector location
- Narrow down choices for new accelerators.
- Keep stepping up synergies in Europe and abroad for accelerator and detector R&D.



ν specific (@CERN)

- Specify the LHC injector consolidation/upgrade and its coupling to ν roadmap.
 - **Strategy retreat end November**
- Increase support for coordinated R&D, within reality
- An oscillation experiment/R&D at PS?
 - LOI being submitted shortly to the SPSC
 - A possible way to attract local physicists?
- Keep working on accelerator R&D, contributing to the world effort.



The role of CERN

8

- EU FP projects and networks are very useful...
- But more support from CERN would be very welcomed:

- Technical R&D: electronics, PD, scintillators, LAr, ...
- Test beams
- R&D followup

example for LHC
detector R&D

Detector Research and Development Committee
(1990-1995)

R&D projects and proposals

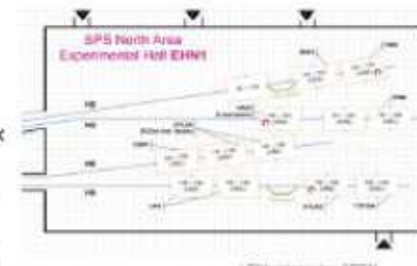
- RD-1 (E1) Scintillating fibre calorimetry at the LHC
- RD-2 (E2) Proposal to study a tracking/vertex detector for the LHC
- RD-3 (E3) Liquid argon calorimetry with LHC-performance specifications
- RD-4 (E4) Study of liquid argon detectors for LHC hadron calorimetry
- RD-5 (E5) Study of silicon trigger and momentum reconstruction in a strong magnetic field for a muon detector at LHC
- RD-6 (E6) Integrated high-rate transition radiation detector and tracking chamber for the LHC
- RD-7 (E7) Proposal for Research and Development on a central tracking detector based on scintillating fibres
- RD-8 (E8) Proposal to develop GEM detectors for physics at the LHC
- RD-9 (E9) A demonstrator analog signal processing circuit in a radiation hard CMOS-CHOC

RD1, ..., RD50, ...

TEST BEAMS AT CERN FOR DETECTOR R&D

SPS North Area

- H2, H4, H8 : 10 + 400(450) GeV/c
 - H8 : attenuated proton beam
 - H2 and H8 : have a VLE branch → beams 1-9 GeV/c
- H6 10-200 GeV/c
- Particle types: electrons, hadrons, muons
- Intensity : max 1+2 × 10⁸ particles/spill
 - Flat top : 4+9 sec
 - Cycle : 16.8 +49s



Courtesy of I. Efthymiopoulos (CERN)

<http://committees.web.cern.ch/Committees/DRDC/Projects.html>

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In summary

We will need

- Flexibility
- Preparedness
- Visionary global policies

.....and

Choices



Conclusions

THE WORKSHOP WAS QUITE A SUCCESS, WITH HIGH ATTENDANCE AND LOTS OF DISCUSSION

IT WAS ONLY A BEGINNING. WE HAVE A PROGRAM OF RESEARCH (EURONU, ETC...) WHICH INCLUDES PROVIDING INPUT FOR DISCUSSIONS

I BELIEVE IT WOULD BE MOST USEFUL TO CONTINUE THE INTERACTION WITH CERN MANAGEMENT TO HELP NARROWING DOWN TO **REALISTIC OPTION(s?)**

THE POSSIBILITY OF USE OF THE OLD CERN GGM BEAM WOULD BE A POSSIBILITY - ANYONE INTRESTED?



A CERN possibility?

Once upon a time (in 1999 with extruded scintillator WLS readout) and more recently (LArg) at the workshops in May and in October it has been suggested to refurbish the old Gargamelle neutrino beam to do short distance neutrino physics
-- (final word?) LSND oscillations with two detectors is the argument given
-- my take: near detector \rightarrow neutrino cross sections?

References

EUROPEAN LABORATORY FOR PARTICLE PHYSICS

CERN-SPSC/99-26

SPSC/P311

August 30, 1999

PROPOSAL

SEARCH FOR $\nu_\mu \rightarrow \nu_e$ OSCILLATION
AT THE CERN PS

35 years after Gargamelle:
the Renaissance of the "Bubble
chamber" neutrino physics

Carlo Rubbia

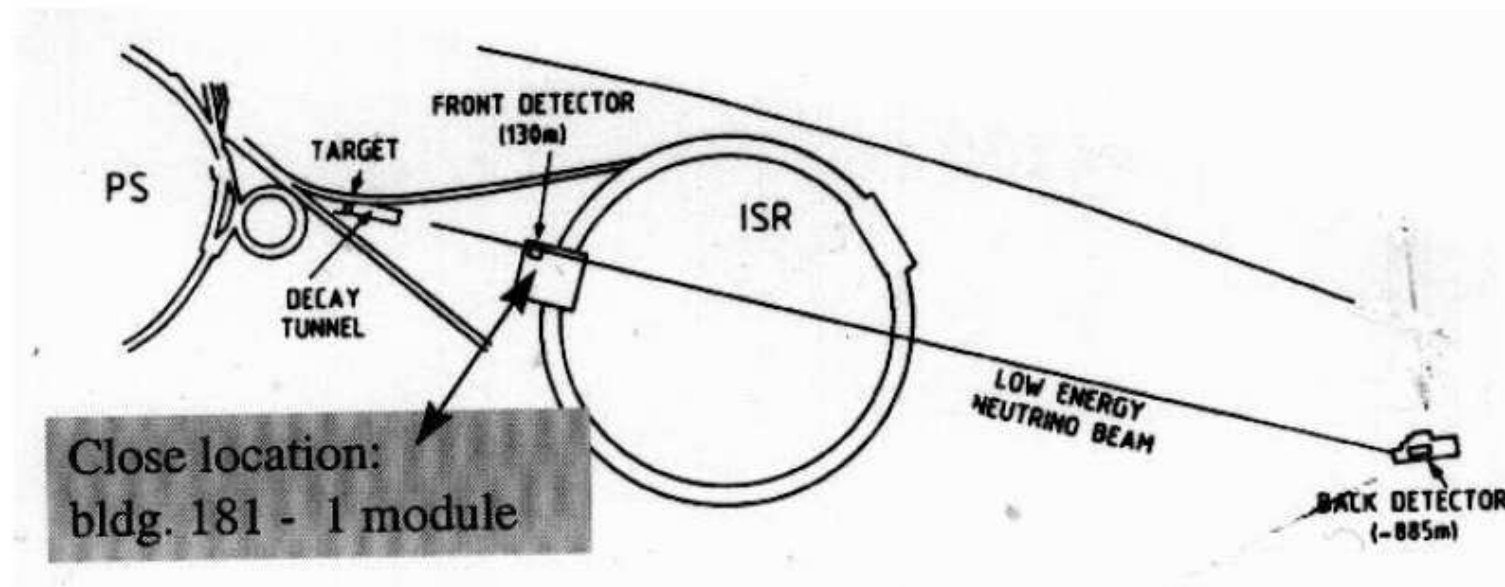
CERN, Geneva, Switzerland

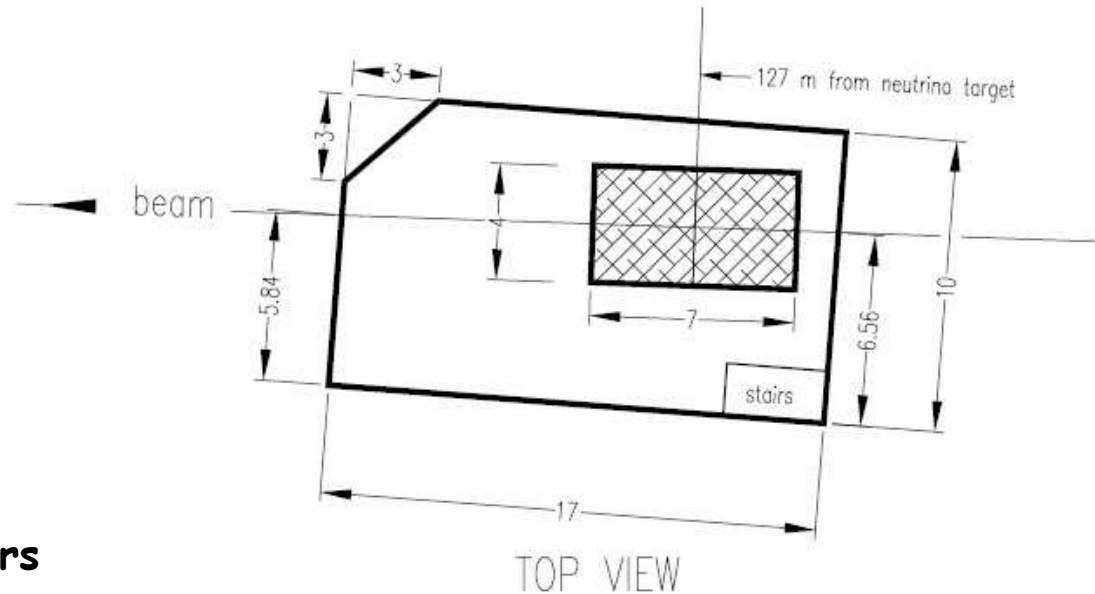
INFN-Assergi, Italy

European Strategy for Future Neutrino Physics
1-3 October 2009 CERN

Alain Blondel Groupe Neutrino
Université de Genève







**NB: 6 meters at 127 meters
is 50mrad ~3 degrees
from beam axis
 $E_\nu = 500 \text{ MeV to } 2 \text{ GeV}$
Across the detector**

**Measurement of cross sections
in that energy range.**

Is magnet necessary?

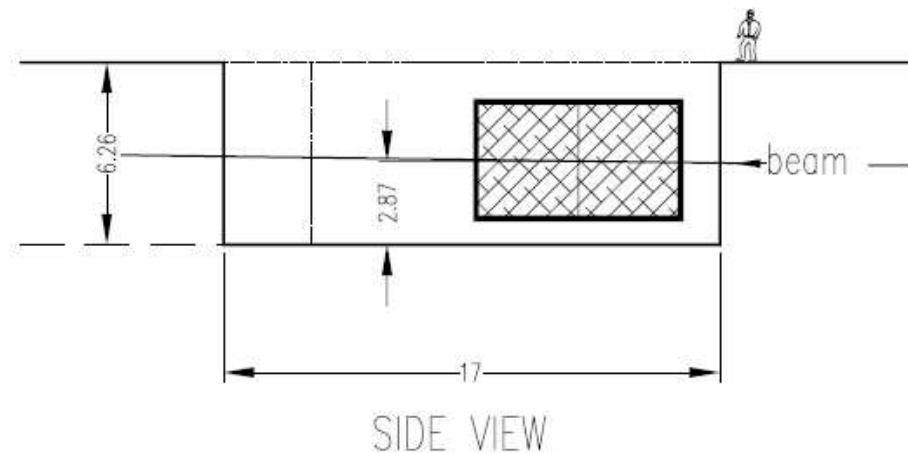
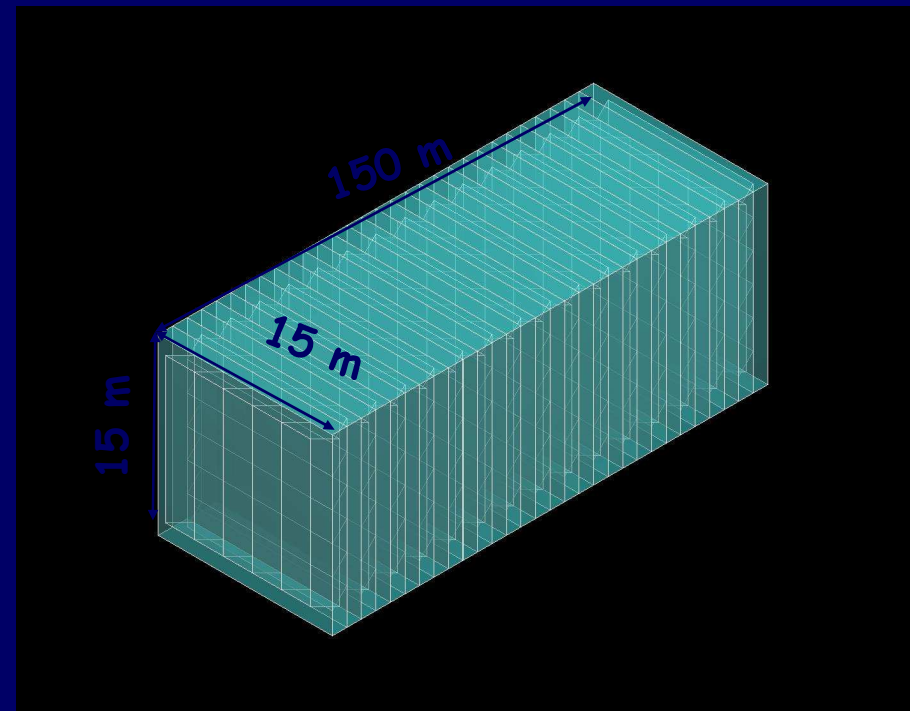
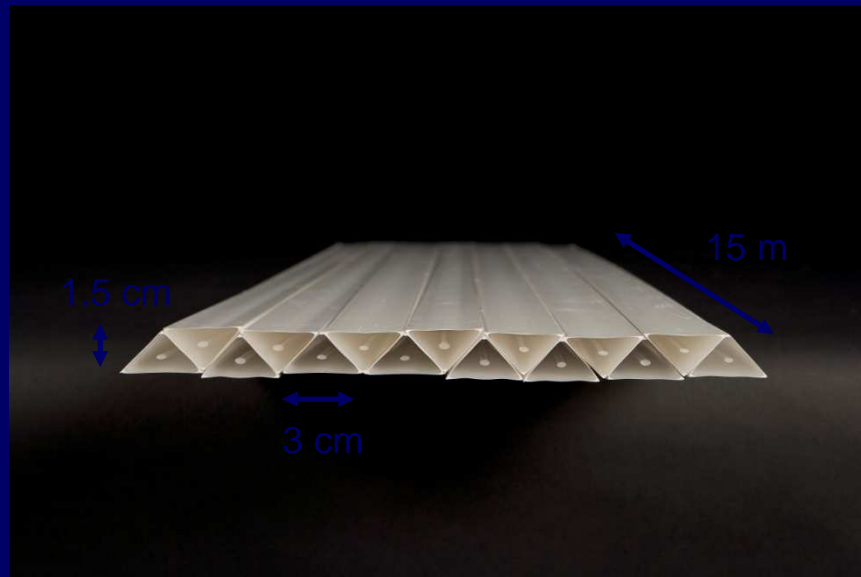


Figure 11: Top view and side view of the neutrino pit in Hall 181, showing schematically the location of the near detector.

Fine-Resolution Totally Active Segmented Detector

Totally Active Scintillating Detector (TASD) using Nova and Minerva concepts with Geant4

- ♦ 35 kT (total mass)
- ♦ 10,000 Modules (X and Y plane)
- ♦ Each plane contains 1000 cells
- ♦ Total: 10M channels



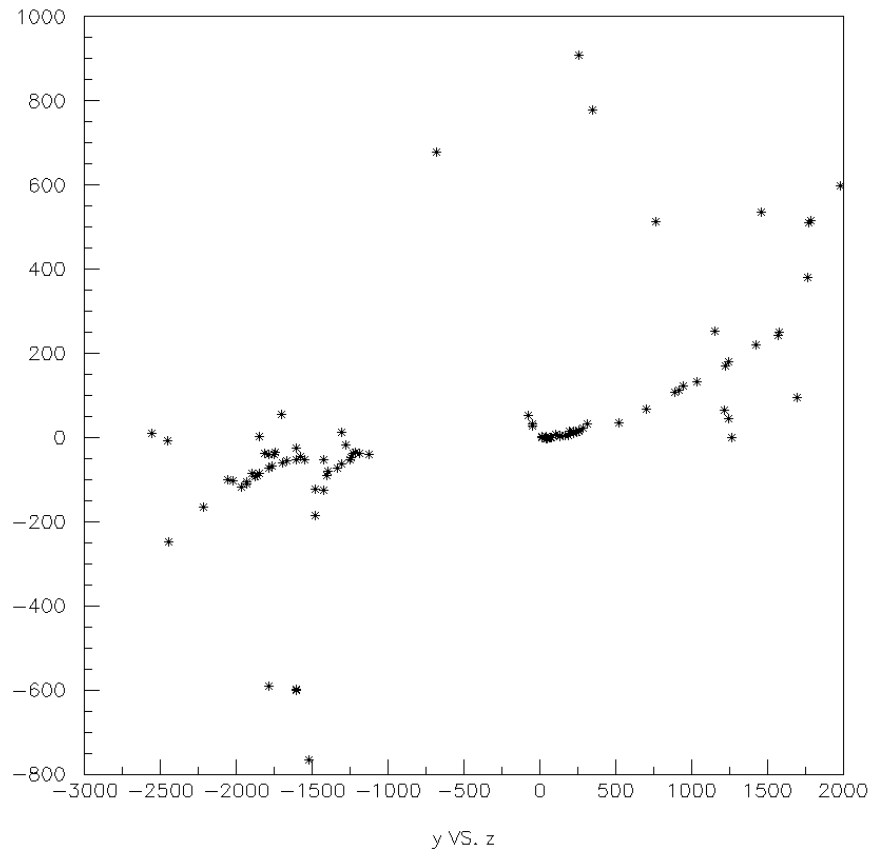
- Momenta between 100 MeV/c to 15 GeV/c
- Magnetic field considered: 0.5 T
- Reconstructed position resolution ~ 4.5 mm

B = 0.5T

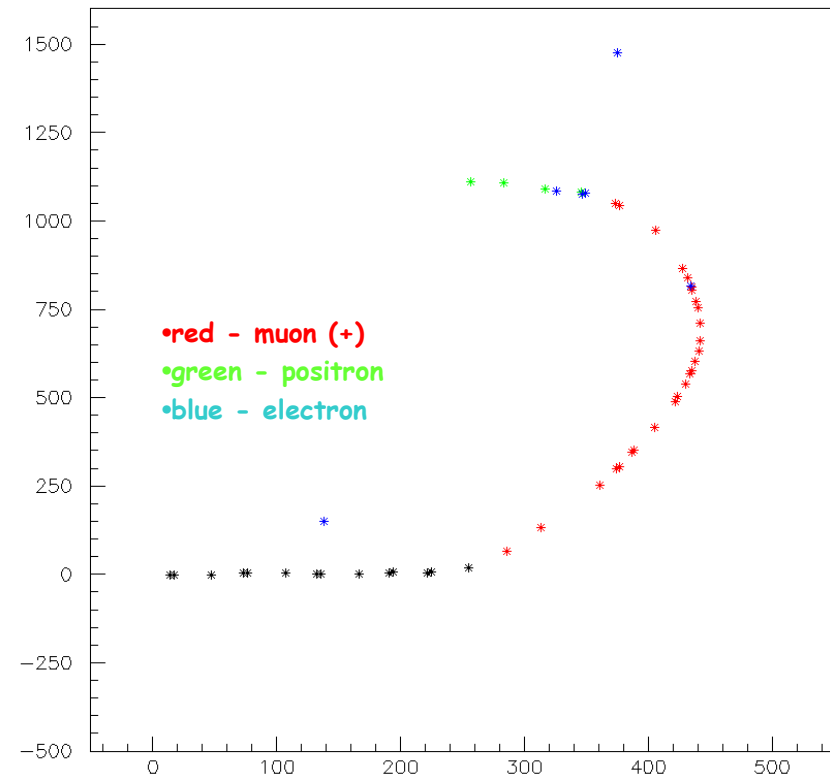


Proton Decay

$$p \rightarrow \pi^+ \pi^0$$



$$p \rightarrow K^+ \nu$$



Physics issues:

- Stopping properties of pions and muons in Minerva detector
This will be studied in the MICE EMR
- Charge separation for electrons in Minerva - like detector
(with lower density?) in magnetic field
This can be studied in the MORPURGO magnet at CERN
- Charge separation in MIND-like detector
This can be studied in a baby-MIND detector at CERN
- hadronic shower angular and transverse momentum resolution in
TASD and MIND (tau detection in superbeam or high energy neutrino factory)
this requires about 2m deep MIND and 5m deep TASD (!) in test beam
but could be tested at CERN



The following institutes have expressed interest:

Fermilab (A. Bross)

Virginia (J. Nelson)

CERN (For the test beam) (I. Efthymiopoulos)

University of Geneva (A. Blondel, S. Bravar)

Imperial College (D. Wark, K. Long),

RAL (A. Weber),

Brunel (M. Ellis),

Liverpool (C. Touramanis),

Glasgow (P. Soler)

Valencia (A. Cervera)

Sofia (R. Tsenov)

INFN Como (M. Prest),

Trieste (E. Valazza),

Milano (Bonesini) RomaIII (Tortora)

INO (N. Mondal)

Y. Kudenko (INR Moscow)

Anyone else I forgot...



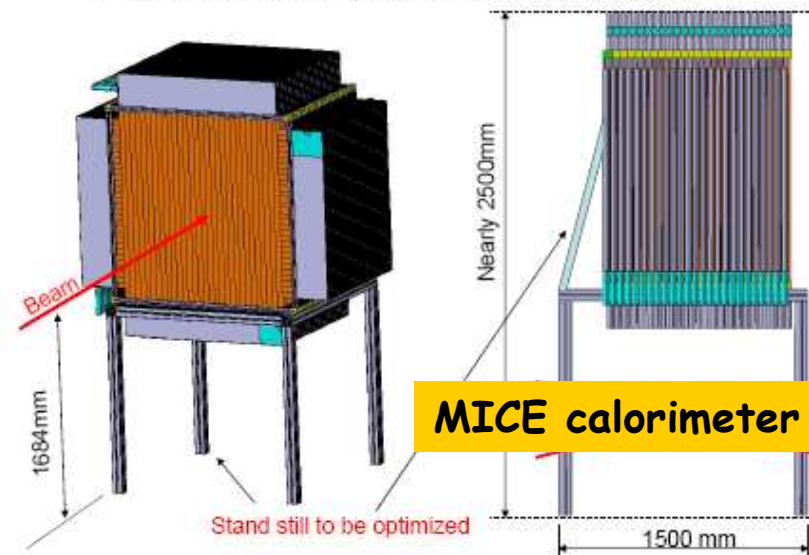
Fast detectors for magnetized near detectors in Superbeam, beta-beam, neutrino factory



Triangular shaped bars (1.1m long, from Fermilab)

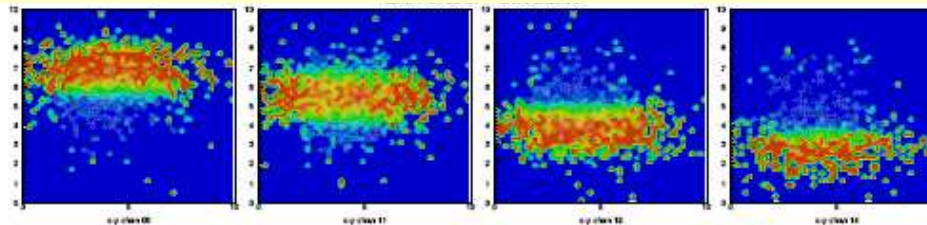
Accurate position resolution (mm)
→ triangular shaped scintillator bars
Magnetic field → si-PMT readout

➤ EMR Module concept : the whole assembly (25 modules...)

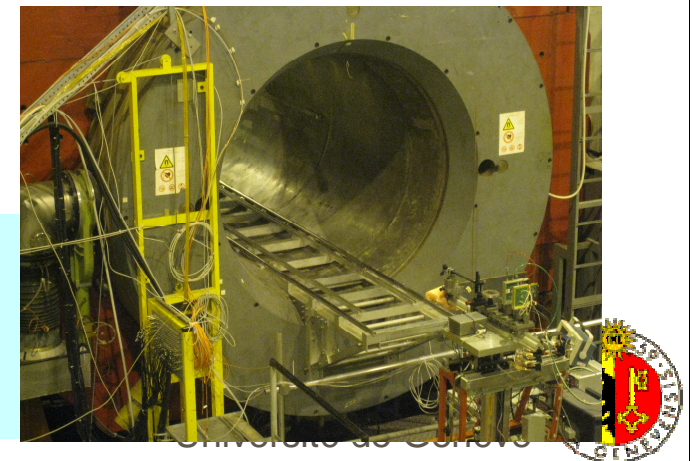


14

First test in T9 beam at CERN – position resolution few mm



Next step: test at CERN in Dipole magnet in H8 →
1.6m diameter. Variable density by spacing planes
-- reconstruction of showering electrons
-- stopping properties of pions and muons



Materials

For 48 planes of 64 scintillator about 1m long bars

- scintillator: assume Fermilab can provide as for EMR
- SiPM and electronics in a first iteration can use spacers from the T2K EMCAL
(contacts D. Wark, C. Touramanis)
- ibid for electronics with 48 front-end and 2 back end boards.
- not fast electronics (not suited for MICE beam, OK for CERN beam)

Construction in independent planes mounted on a extendable frame, allowing density from 1 to ~ 0.4 (air gaps)

Aims:

- expose to 250 MeV/c to 10 GeV/c particles (e, pi, mu)

Charge ID for electrons, stopping ID for charged mu and pi and protons.

Interactions of pions

Shower energy and angle?

- contact at CERN with Ilias Efthymiopoulos (NEU2012) for beam line.

To be checked: incoming particle ID. (TOF, CKOV)

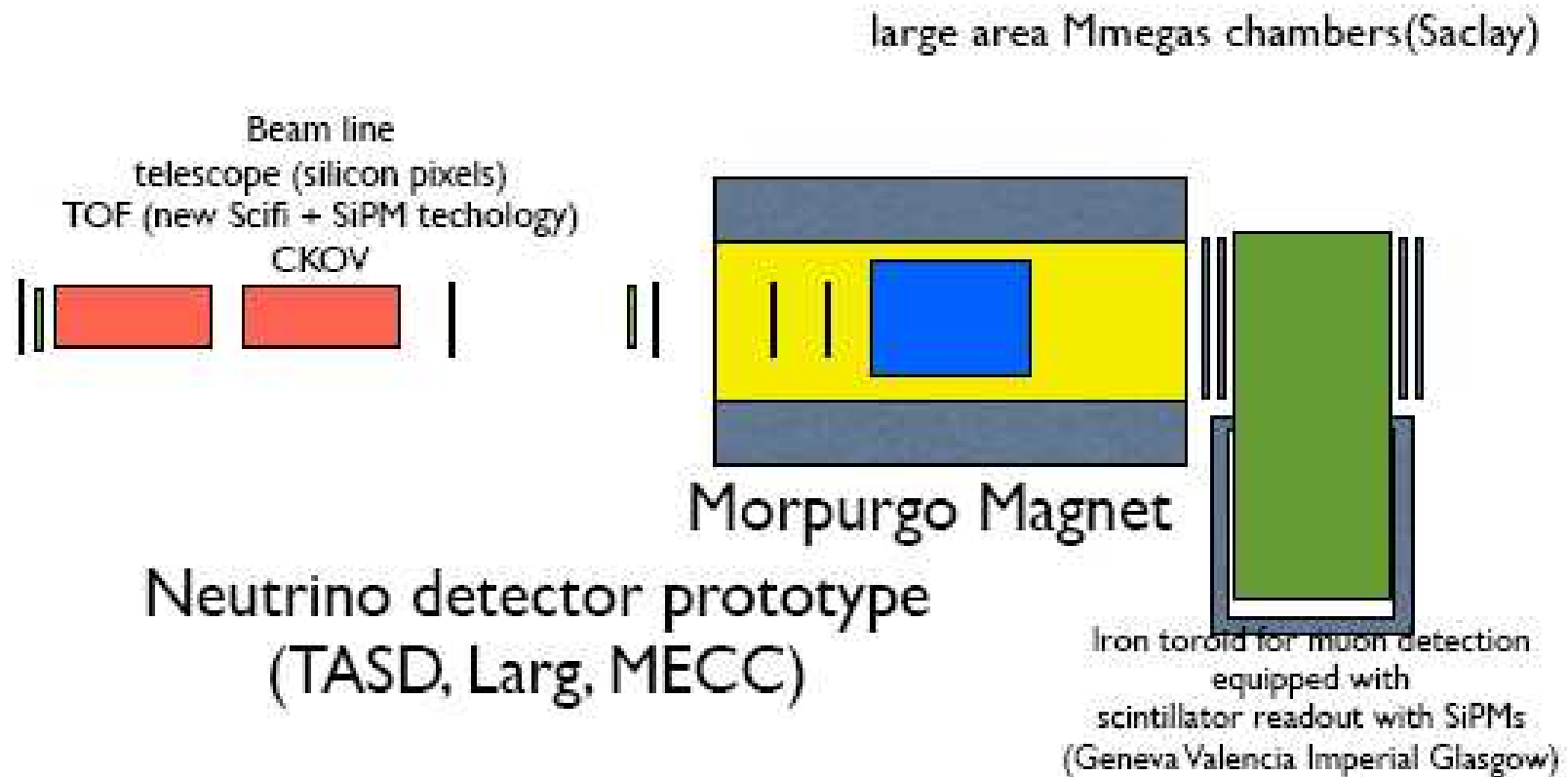
For stopping particles could prefer MICE beam.

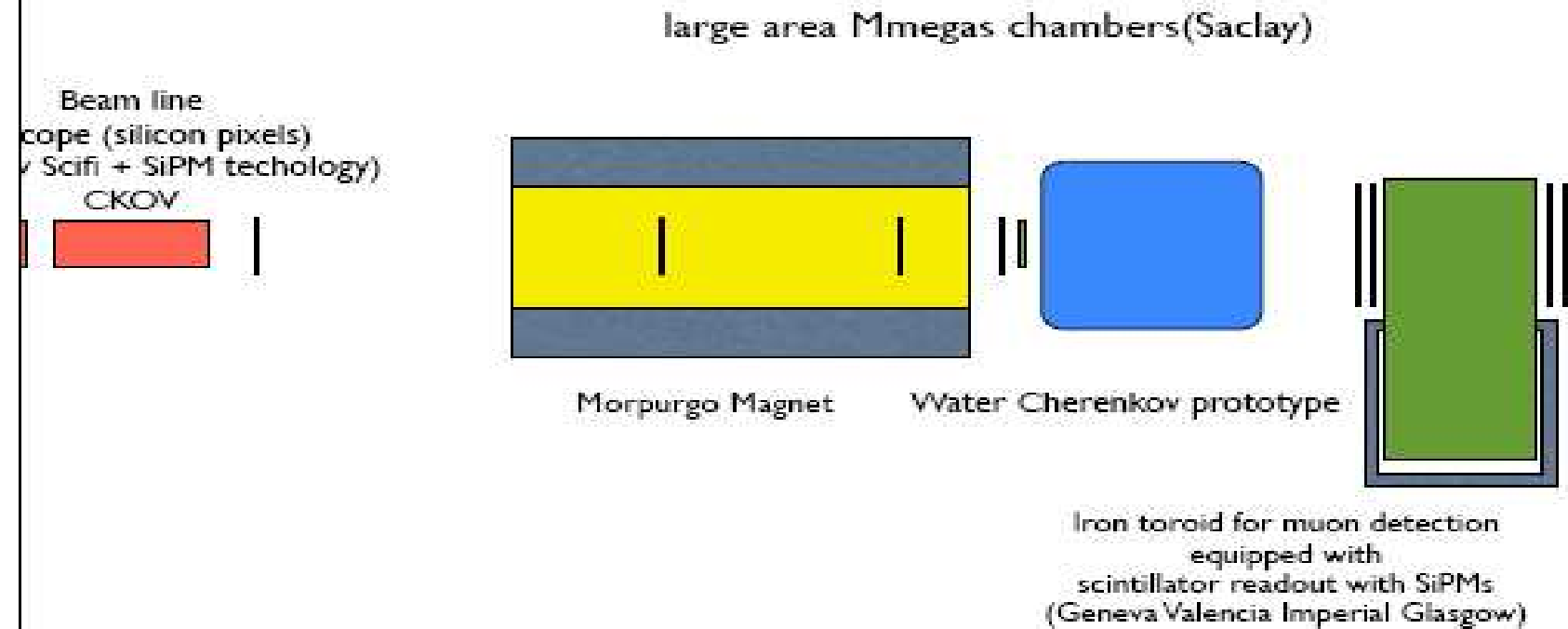


Following steps:

- use same or similar planes as detector for MIND situated outside magnet
 - develop cheap electronics to envisage mass production
 - develop >15 m long scintillator bars
-
- software for test beam simulation and analysis
 - simulation of electrons in density $d=1, \frac{1}{2}, \frac{1}{3}$
 - which is your predicted optimum?



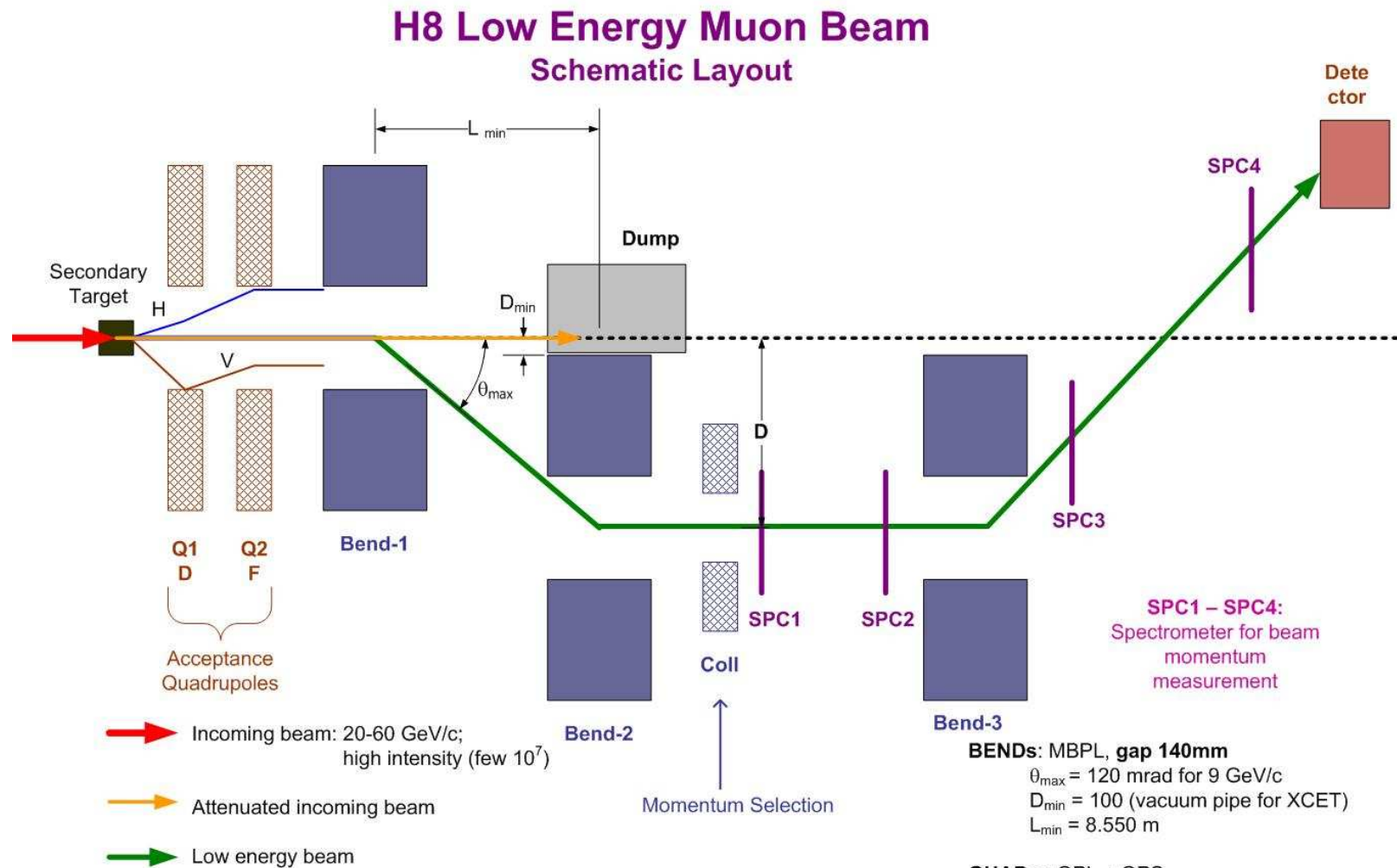




A Low Energy Muon beam in H8 line

55

Beam design principle



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