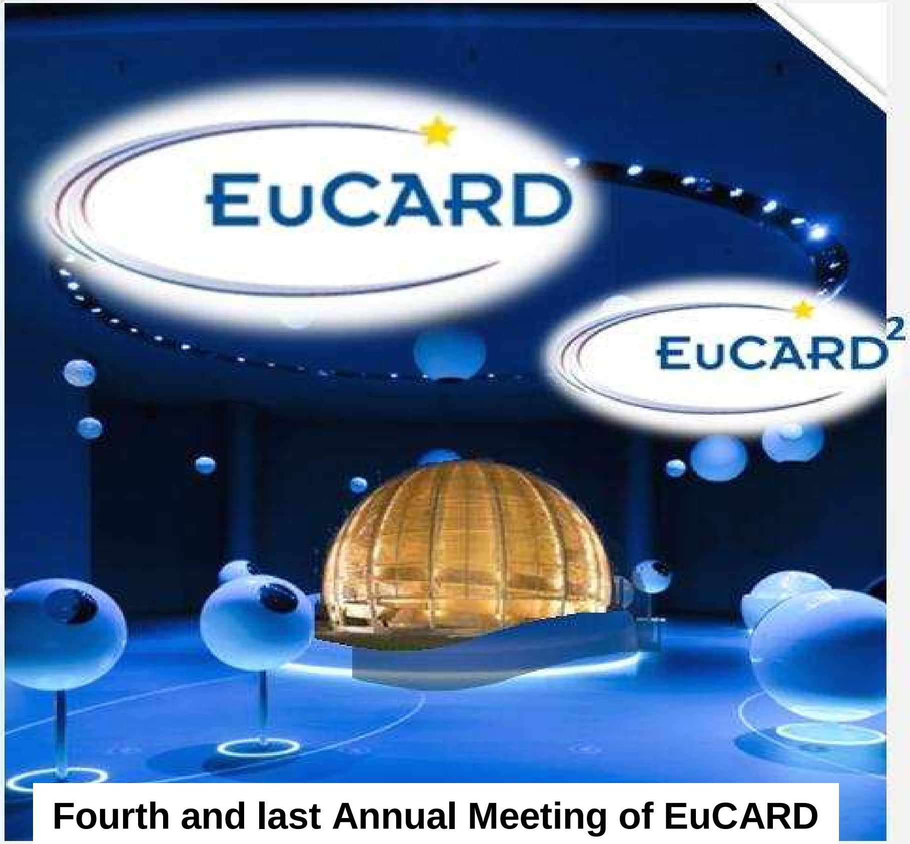
WP3-NEu2012

Neutrinos for Europe in 2012

V. Palladino
Univ & INFN Napoli
EuCARD13 plenary
10 June 2012

Structuring the accelerator neutrino community



Fourth and last Annual Meeting of EuCARD

CERN June 10-14 2013

WP3-NEu2012

Neutrinos for Europe in 2012

Networking Activity (continuing BENE,
along with EUROnu & LAGUNA-LBNO FP7 DS)

within Integrating Activity EuCARD (continuing CARE)

EUROnu : A High Intensity Neutrino Oscillation Facility in Europe 2009-12 Longer term

http://www.euronu.org/

MW protons * ν/p

Neutrino Factory (NF) ….. in the larger context of NF-IDS International Design Study
Superbeam (SB) 4 MW conventional beam SPL to Frejus
Betabeam

LAGUNA - **Large Apparatus for Grand Unification and Neutrino Astrophysics 2009-11**

http://laguna.ethz.ch/laguna-eu/

0.1-1.0 MTon detector !!!!

Seven Eu underground **sites** …. Pyhäsalmi, Frejus and 5 more
Three liquid detector **technologies** (500 KT Water, 100 KT Li-Ar, 50 KT Li-Sci)

LAGUNA-LBNO - **Large Apparatus also for Long Baseline Neutrino Oscillations 2012-4**

Conventional beams SPS (and possibly HP 2 MW PS) to Pyhäsalmi
Superbeam (SB) SPL to Frejus

Medium term

Network on υ facilities
preparing the update of the ESPP

Eu strategy for particle physics

WP3= υEu2012 ..

a NA organized in view of the ESPP 2012 update

Support for discussions of accelerator, detector, phenomenology experts
in a relatively small (~ 750) community vs cost of this physics
of growing recognition from serial discoveries in υ oscillations from 1998→
to the 3rd last υ mixing angle θ_{13} in 2012, promisingly large

meetings, workshops, "lobbying" for finally revived CERN support

synthesis papers D3.3.1 our proposal to ESPP (next slide)	Jul	2012
D3.2.1 survey of the facilities studied	Apr	2013
D3.1.2 outlook after the ESPP	Jun	2013

Impact: 1)**full recognition** by ESPP of LBL υ physics case

2)**way open** to adequate ESPP LBL υ implementations in Europe and/or America & Asia

A European strategy for accelerator-based ν physics (D3.3.1)

In preparation for the CERN strategy meeting in Cracow NEu2012 as part of EuCARD project activities has delivered a cohe proposal for the next accelerator neutrino facility in Europe, as a result of two complementary design studies. The program calls for the continuation of neutrino beams at CERN after the CNGS, and for a high priority support from CERN and the me states to the experiments and R&D programme.

CERN to Pyhäsalmi baseline, 2300 km.

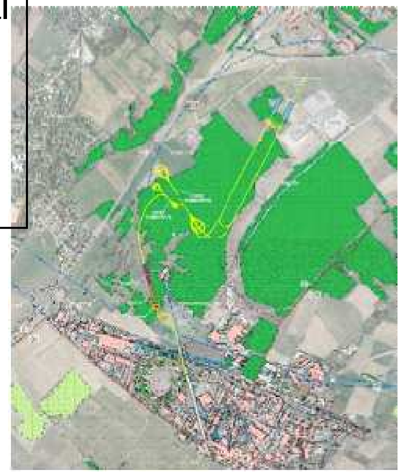
1) A giant Mm^3 underground **home for giant ν detectors** in Finland (Sweden?)

2) North Bound **MW CERN ν beams** over a **2000 km or so long baseline (LBL)**

conventional SPS and possibly 2 **MW** HPPS **beam first**
needs support for 2014 proposal
novel 4 MW p driven **10 GeV Neutrino Factory** beams, **ultimately**, when ready
vital support for R&D and design for 2018 or so proposal

NB **Foster** also local **synergetic SBL opportunities** for sterile neutrinos
within local CERN short baselines (SBL)
ICARUS/Nessie, NuSTORM ....

SPSC-P347 CENF



preliminary layout of a 10 GeV Neutrino Factory on the CERN site, with straight sections pointing at Pyhäsalmi.

Introduction

NEu2012 background

massive υ' s today, the **only** experimental compelling **evidence beyond** the Standard Model (**SM**)
demanding, among a few other decisive ones,

a **measure**ment of **a new, possibly large**, source of CPV in LBL υ **accelerator** appearance experiments δ_{CP}^{lepton}

and, via matter effects, see below, of the **mass hierarchy** (**MH**), the sign of the larger mass split

whether υ_3 is heavier or lighter than the other two, those with small mass split.

NEu2012 mission "**an agreed program** of accelerator neutrino experiments,
based on upgrade of existing infrastructures and/or the proposal of a new one"
in 2012, year of the second ESPP update.

A Networking Activity because

LBL experiment = KTons * MW * υ/p

assembling the largest neutrino detector mass **KTons** , with the finest affordable grain

the highest possible proton power **MW** driving a neutrino beam option well matched to the detector technology.

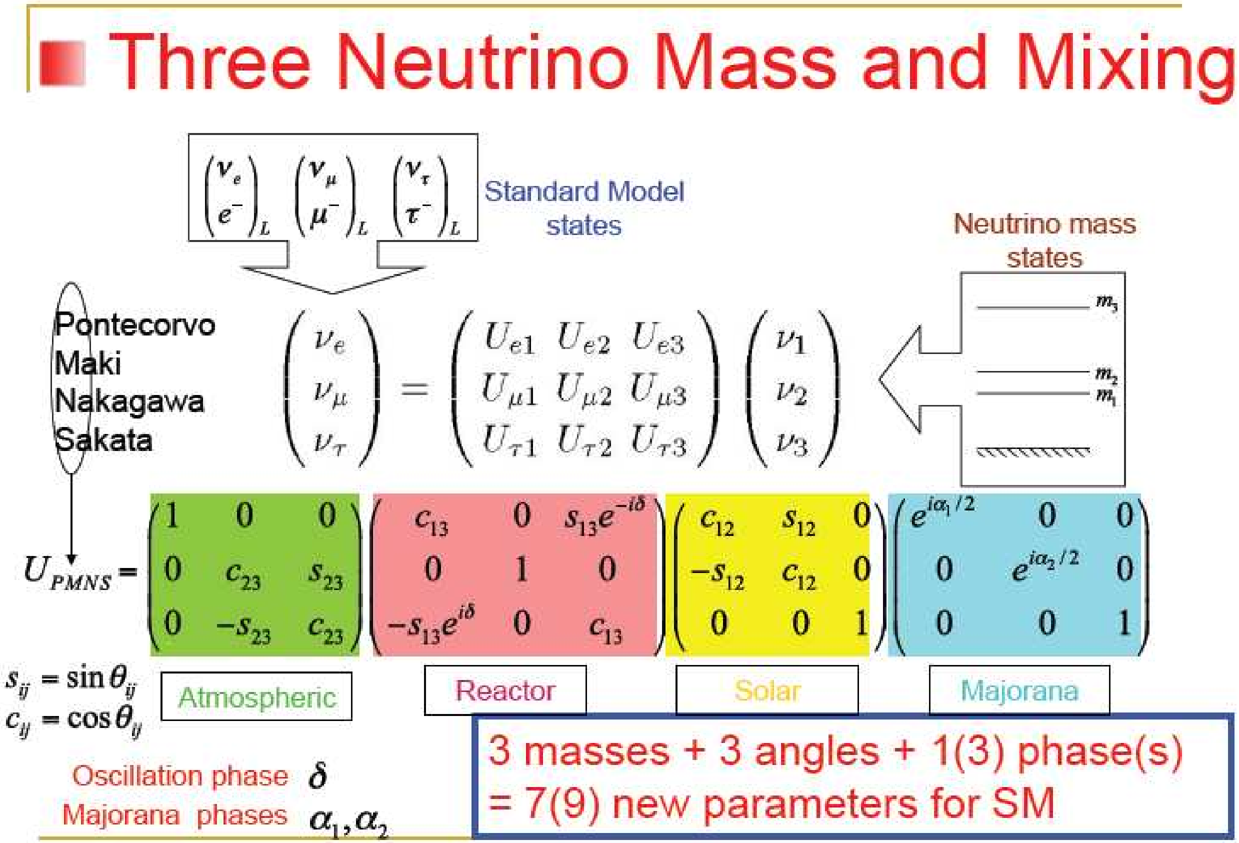
novel options, **neutrino factory** = storage and decay ring of accelerated muon beams
betabeam = storage and decay ring of accelerated beta ion beams
storage and decay ring of accelerated υ parents instead of a conventional decay tunnel
promise to contribute an additional gain in **υ/p** yield

at the most convenient **baseline**, source to detector distance, must be identified.

The product (network) of neutrino **phenomenology, detector and accelerator experts** is therefore needed.

From many years of intense networking, already in the FP6 CARE/BENE Network,
in close connection to all world studies and, particularly, two FP7 Design Studies (LAGUNA and EUROnu)
in a second 'European Strategy for future neutrino physics' workshop at CERN 14-16 May 2012,
the draft of **a consensual "proposal of the next global accelerator υ facility for Europe to build or help build**".
This was then finalized for the ESPP 2012 Symposium (**NEu2012 D3.3.1**).

Meaning of θ_{13} and its size



The Mixing Matrix is indeed at least 3*3

θ_{13} **being large, the far reaching CP violation phase δ can be measured !!!!!**

by ν / $\bar{\nu}$ asymmetries in appearance experiments

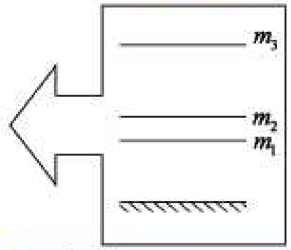
the future belongs to accelerator neutrinos

More ("sterile") neutrinos?

Three Neutrino Mass and Mixing

$\begin{pmatrix}\nu_e \\ e^-\end{pmatrix}_L \begin{pmatrix}\nu_\mu \\ \mu^-\end{pmatrix}_L \begin{pmatrix}\nu_\tau \\ \tau^-\end{pmatrix}_L$ Standard Model states

Neutrino mass states



Pontecorvo
Maki
Nakagawa
Sakata

$$\begin{pmatrix}\nu_e \\ \nu_\mu \\ \nu_\tau\end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3}\end{pmatrix} \begin{pmatrix}\nu_1 \\ \nu_2 \\ \nu_3\end{pmatrix}$$

$$U_{PMNS} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23}\end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13}\end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1\end{pmatrix} \begin{pmatrix} e^{i\alpha_1/2} & 0 & 0 \\ 0 & e^{i\alpha_2/2} & 0 \\ 0 & 0 & 1\end{pmatrix}$$

Atmospheric | Reactor | Solar | Majorana

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

Oscillation phase δ
Majorana phases α_1, α_2

3 masses + 3 angles + 1(3) phase(s)
= 7(9) new parameters for SM

Beyond 3 X 3

$m_\nu > 0$

ν_R must exist

ν_L only, so far

A new home for giant υ detectors

much larger than the present Gran Sasso halls

The challenge of assembling the immense detector mass required,
50 to 1000 Kilotons depending on the technology,
will dominate the pace of progress in this sector.

An appropriate giant laboratory to house these detectors is a prerequisite
to any long baseline neutrino beam.

The LAGUNA study proved that such caverns are feasible and
pointed, among many other sites,
to a 1440 m deep mine in Pyhasalmi, Finland, 2300 Km from CERN.

Assembling detector mass in the far Pyhasalmi site (SPSC-EOI-007)
would begin with
a 20kton Li-Ar TPC, of the double phase GLACIER technology and
a 40 kton magnetized iron detector (MIND).
to be prototyped and validated in a **smaller CERN neutrino home**
to be set up as detector prototyping and R&D test area.

Long term

<u>MW CERN υ beams</u>

over a **<u>2000 km or so long baseline</u> (LBL**)

the EuROnu study identified

the few GeV clean multi-flavor υ_μ and υ_e WB beams

from a 10 GeV muon ring (Neutrino Factory LENF)

travelling 2000 Km or so,

driven by a 4 MW or so 5-15 GeV proton source,

as the **long term** optimal **facility** to establish CPV,

precisely and completely map the neutrino transition matrix,

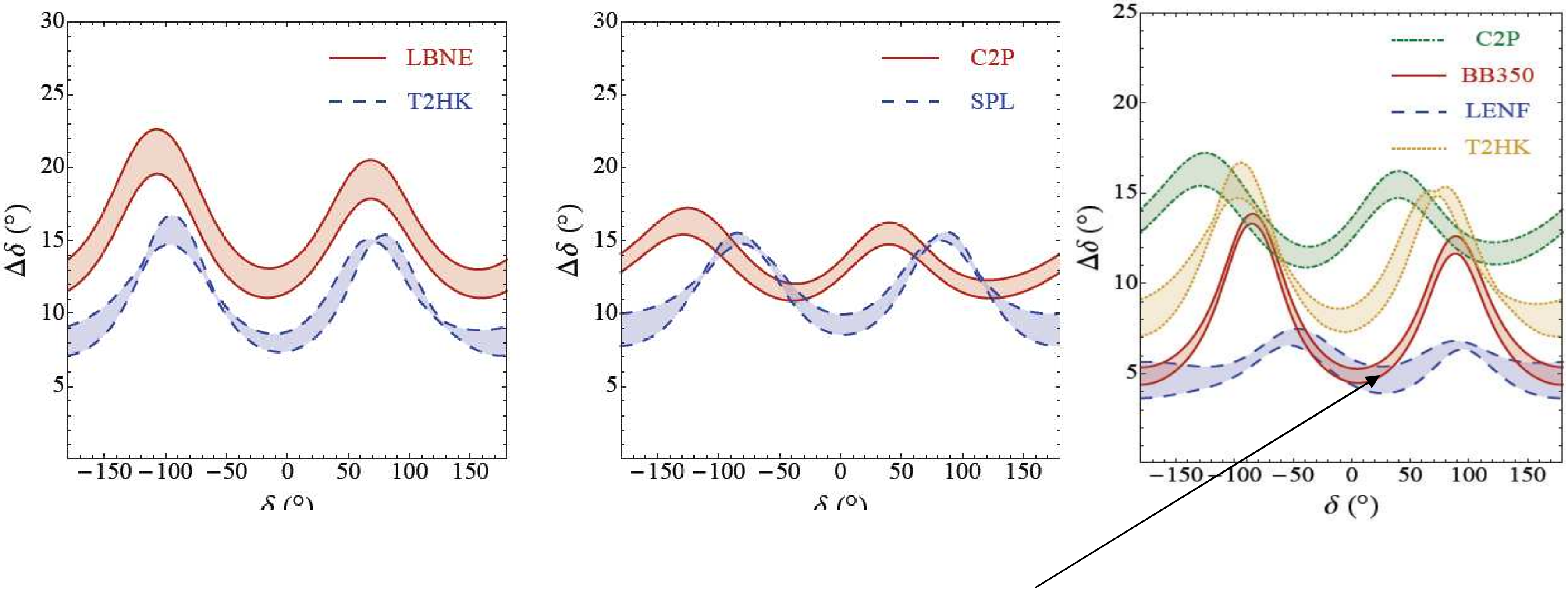
establish its 3*3 nature, test its unitarity.

this 10 GeV neutrino factory (LENF) promises the smallest

uncertainties in the measurement of the CP violating phase δ

at the bottom of the rightmost of the three graphs

$\Delta\delta$ uncertainty (in degrees)



10 GeV Neutrino Factory LENF

Comparison of the $\Delta\delta$ uncertainties (in degrees) in the measurement of the CP violating phase δ from different facilities [Coloma]. $\Delta\delta$ varies in he [-180, +180] range of δ. The 10 GeV neutrino factory setup, in the bottom of the right graph, promises the smallest $\Delta\delta$ for all values of δ.. Uncertainties from conventional beam projects, in particular the three present medium term projects, T2HK in Japan (shown both in the left and right graph), LBNE in the USA and C2P in Europe (both in the centre and right graph) are larger and comparable

Medium term

MW CERN υ beams

over a **2000 km or so long baseline (LBL**)

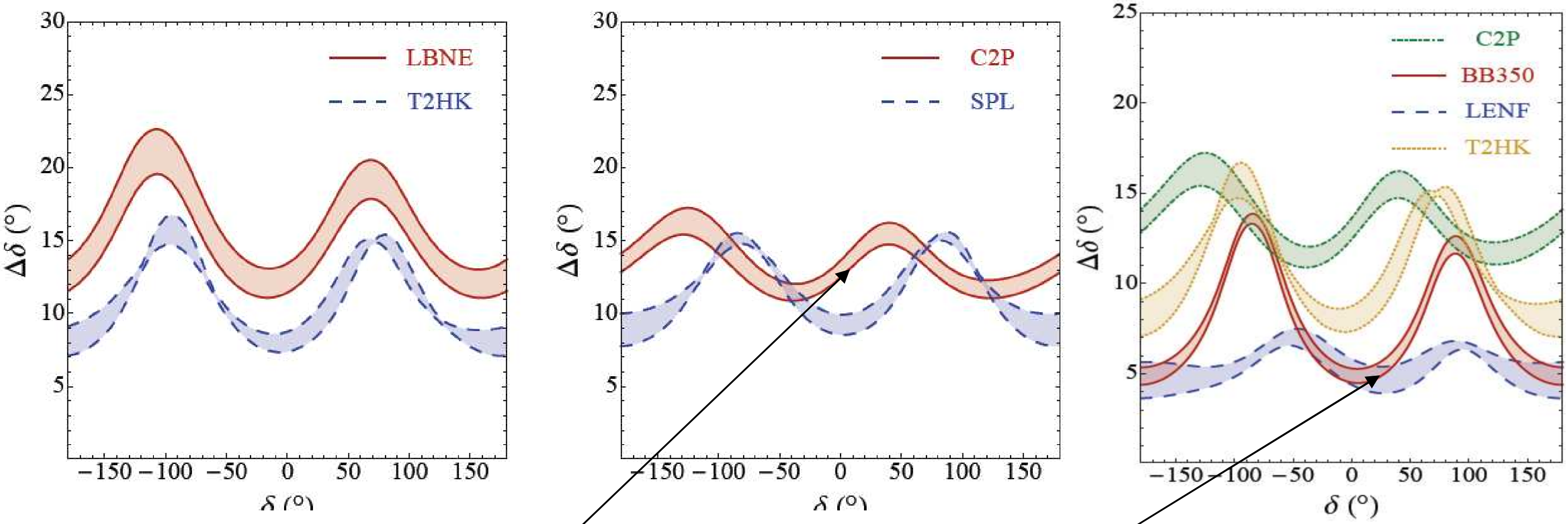
LAGUNA/LBNO is now promoting and studying a similar

few GeV υ_μ WB conventional beam from the SPS in the North Area
< 1 MW 400 GeV protons,
with far more modest performance,
capable over the 2300 Km baseline of
a **medium term**
conclusive statement on neutrino mass hierarchy and
first attempt at detection of CP violation
(SPSC-EOI-007).

Under study also the option of raising beam intensity, before a neutrino factory,
by driving the facility with a new **50-70 GeV 2 MW** power proton synchrotron (HPPS)
instead of the SPS

It could be built **next and in synergy with** the short baseline SPS North Area
SBL CENF facility already in advanced phase of study
in view of Technical Proposal (SPSC-P-347)
an equally fundamental search of sterile υ
based on the operating 0,6 Ton Li-Ar single phase technology ICARUS TPC

Δδ uncertainty (in degrees)



SPS C2P 100 KT

10 GeV Neutrino Factory LENF

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<u>fewGeV/few1000Km</u> vs <u>subGev/few100Km</u>

L/E~500 Km/GeV~ λ

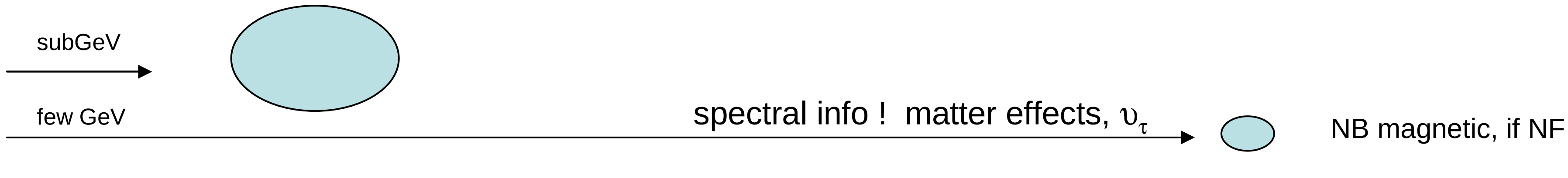
merits and complementarities

a second also very attractive option, of both EUROnu and LAGUNA
intense sub-GeV beams travelling only the 130 km
CERN to Fréjus baseline:

a "super" (4 MW) <u>conventional beam</u> from the 5 GeV HP SPL
complemented later by a <u>γ=100 beta-beam</u>,
in the EUROnu longer term vision.

Asymmetries between ν and anti ν oscillation probabilities come from
1) leptonic CP violation (CPV)
2) matter effects, as neutrinos find in matter electrons, but not positrons, to interact with.
depend on and do provide sensitivity to the mass hierarchy.

subGev/few100Km small or no matter effects …. only CPV !
subGeV ν events rates and energy deposit low ….. must approach a MTon transparent
water !! MEMPHIS 440 KT FV
atmospheric ν useful for matter effects and thus mass hierarchy, p decay …..
similar, including the Water Cerenkov MEMPHYS detector, to the Japanese approach



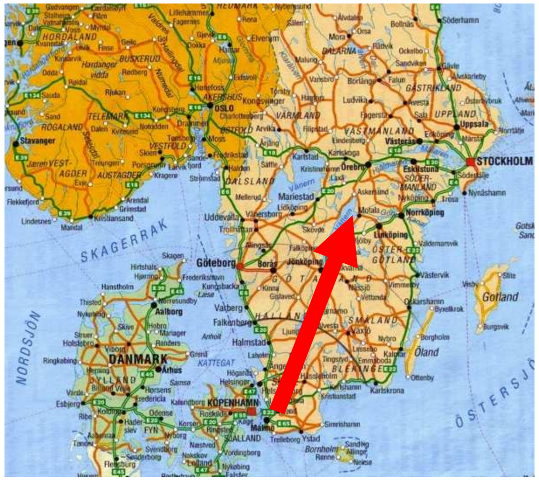
The recent ESS neutrino option

the subGev option lives on

a super beam is also possible from the 5 MW, 2.5 GeV
ESS superconductive proton linac in Sweden
to be by 2023 the most intense, MMW, proton driver on earth

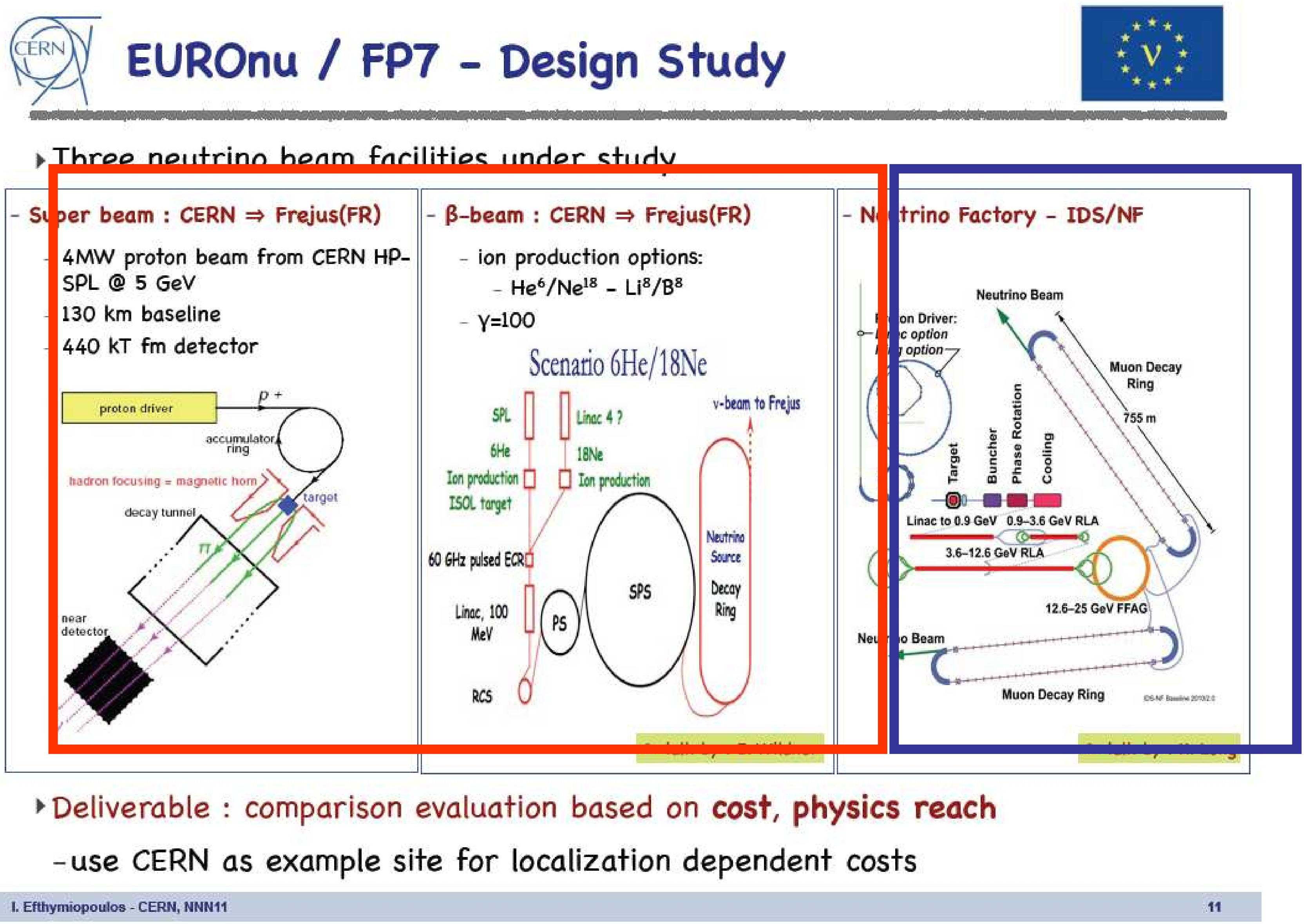
concept circulated around the ESPP Symposium,
based essentially on the EUROnu SPL sub-Gev superbeam
MEMPHYS detector studied for Frejus

in one of a few Swedish mines,
few 100 Km away, perhaps of interest also for the LBNO proposal



This concrete opportunity
for a LBL experiment in Europe
is being seriously considered
by a small enthusiastic group

The 3 EUROnu options



The EUROnu Costing Report

Dec 2012

achieved more solid, and quite sobering, notion
of the high cost of these facilities, including detectors,

cost brackets

[5.3,7.3] B€ for the Neutrino Factory baseline project
[1.0,1.3] B€ for the SPL 4 MW proton linac
[1.0,1.2] B€ adding instead the Frejus Superbeam project } [3.4,4.8]B€
[1.4,2.3] B€ for adding the Betabeam on top of that.

It is evident that funding a new facility will take many many years

is conceivable only if realistic cost reduction
as well as staging approaches
can and will be found.

Scientific Policy

the Finnish government announced Dec 18 that Finland cannot commit
to host the Pyhasalmi underground laboratory
because of the heavy costs involved,
its stringent public budgets being hardly able
to finance even its most highly prioritized scientific infrastructures.
Can Pyhasalmi can still be the home of European neutrino detectors,
with reduced costs for Finland?
Another home has to be found, perhaps in Sweden?

Mid January, the CERN SPSC summarized its recommendations

support SPSC-P-347 (CENF SBL) and SPSC-E-007 (LBNO)

the SPS SBL **CENF** facility could be **adequate**
to foster the necessary focus beyond ongoing approved programs,
provided that it can also **contribute** significantly **to** the preparation of future **LBL** projects.

supported the focus on the Li-Ar TPC technology,
noted the similar focus in the USA and
recommended close contact in anticipation of collaboration.

requested from SPSC-P-347 a comprehensive TDR
SPSC-E-007 a TP of the R&D on the double phase Li-Ar

The ESPP update

Late January the Draft ESPP 2012 Strategy Upgrade Document dixit:

"with significant European involvement, a strong scientific case is established for a long-baseline (LBL) υ programme …..

CERN should develop a neutrino programme to pave the way **for** a **substantial European role** in future LBL experiments.

Europe should explore the possibility of **major participation** in leading υ projects in the US and Japan."

<u>officially approved on May 31</u>

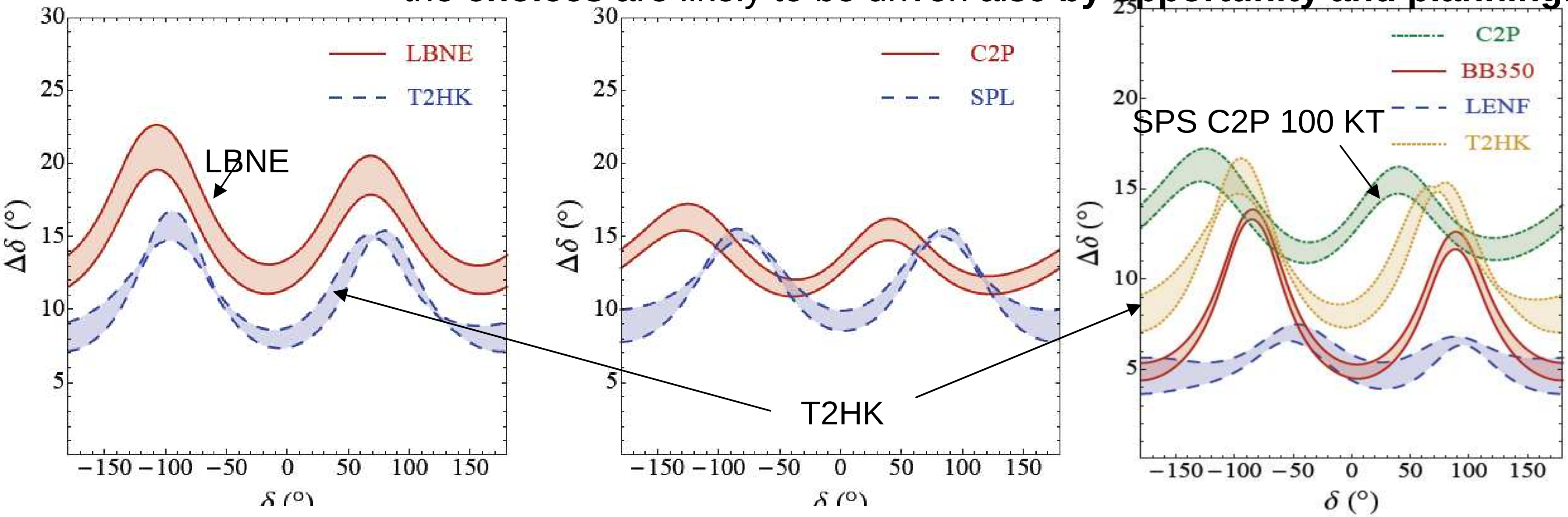
A CERN SPC neutrino working group
has also been since set up to make recommendations about
a CERN neutrino programme
that would satisfy the European Strategy.

Eu participation
in international programs

has long been a reality, well before the ESPP strategy statements.

T2HK and **LBNE** are the corresponding next generation experiments
on the same time scale as **LBNO** scale.

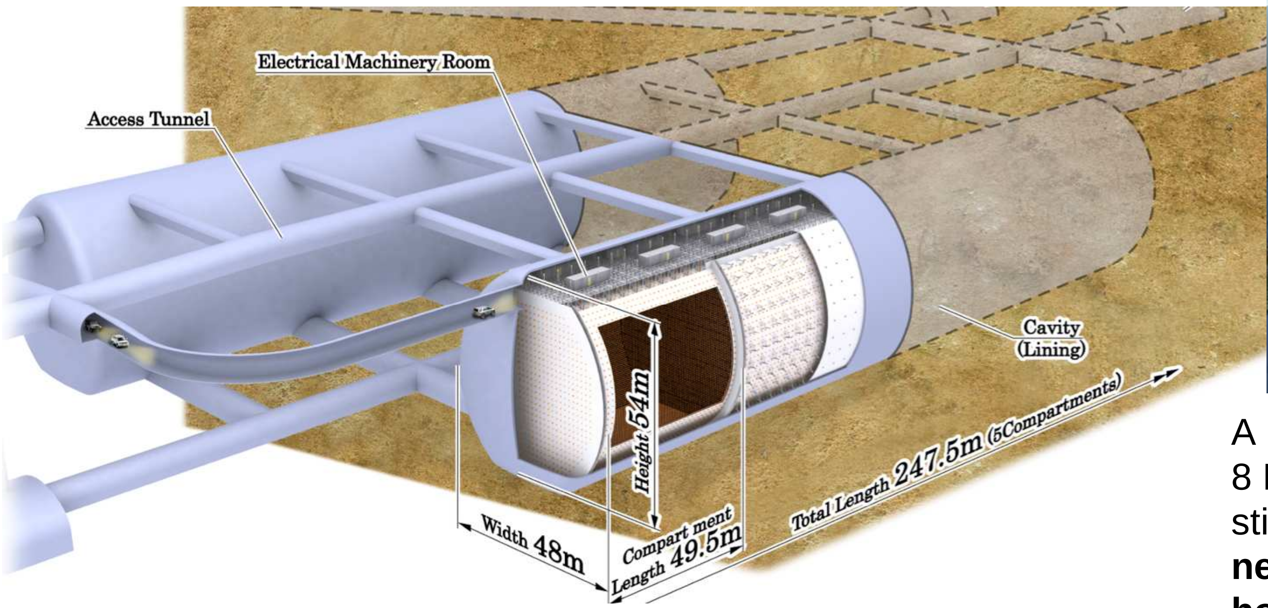
The three expected $\Delta\delta$ uncertainties **are comparable**
the **choices** are likely to be driven also **by opportunity and planning**.

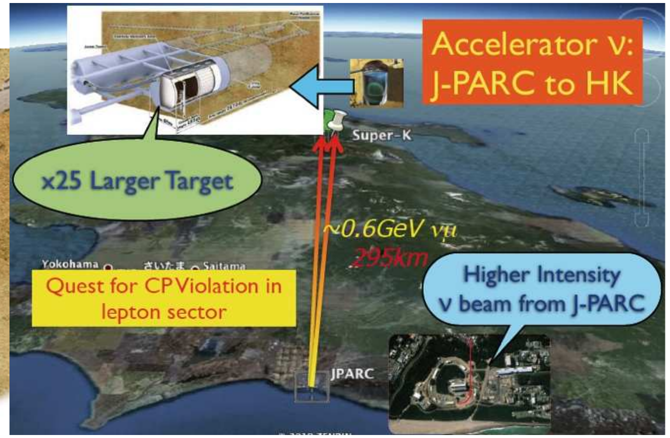


Comparison of the $\Delta\delta$ uncertainties (in degrees) in the measurement of the CP violating phase δ from different facilities [Coloma]. $\Delta\delta$ varies in he [-180, +180] range of δ. The 10 GeV neutrino factory setup, in the bottom of the right graph, promises the smallest $\Delta\delta$ for all values of δ.. Uncertainties from conventional beam projects, in particular the three present medium term projects, T2HK in Japan (shown both in the left and right graph), LBNE in the USA and C2P in Europe (both in the centre and right graph) are larger and comparable

T2HK

250 Eu υ physicists invested in the T2K near detector,
running for several more years ahead.
some heve long been active on Water Cerenkov and
the International Open Working Group Hyper-Kamiokande and T2HK
. More will.





A cavern in the **Nijungo-yama mountain**,
8 Km south of the Kamioka
still 295 Km from JPARC,
new much larger underground (650 m)
home for Japanese neutrinos

HK is **two 500 KTons** Water Cerenkov detector tanks, 20 times bigger than SuperK, ultimately **1.6 MW** perhaps.
Eu groups will be thriving on the work done **for** the **Frejus** option **and** being done now for the **ESS** option.

NB ILC competitive context.

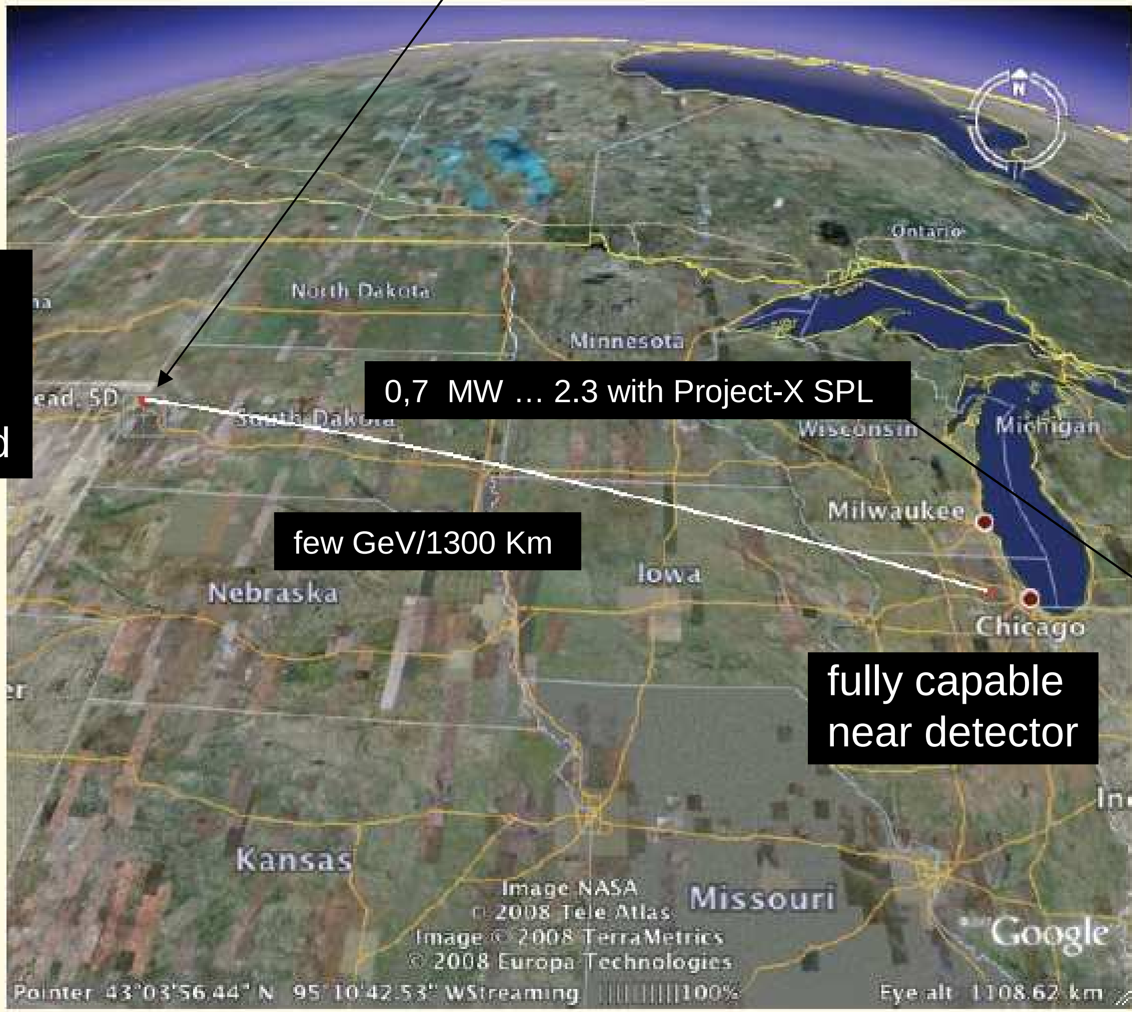
Europe should assemble a very sizeable contribution, under CERN coordination, both to detectors and beams

US LBNE = Long Baseline υ Experiment

NuMI

new much larger underground (4850 ft)home SURF Sanford Underground Research Facility

Fermilab to Homestake DUSEL (1290km)



attractive project facing financial difficulties

35 Ktons
Li Argon
Detector
underground

0,7 MW … 2.3 with Project-X SPL

few GeV/1300 Km

fully capable near detector

NB X-Project SPL only a strategic study, for the moment

LBNE10 dramatic reconfiguration

NuMI

chose to invest in the longer baseline, to some extent a second similarity of focus, along with Li-Argon, with Europe

10 Ktons
Li Argon
Detector
on surface

LBNE10

867 M$

CD1

high priority goal
to create the
underground lab
and build the
34 KTons detector

full 5σ MH → 3σ level for 75% of all values of δcp
3 σ CPV 60% of all δcp values → 25% at 2.5σ level

Significant international collaborators and resources being sought aiming at recovering the full LBNE performance.
From Europe, UK groups and the ICARUS INFN team may be getting involved.
Much more international help is needed for a really attractive option to take credible shape.

Europe should assemble a very sizeable contribution, under CERN coordination, both to detectors and beams

Longer term EU collaborations in international programs (US MAP)

A leading υ project in the US is the longer term effort towards a Neutrino Factory *and Muon Colliders*

The UK leads the NF International Design Study (NF IDS),
one big EUROnu work package was devoted to it.
R&D: HARP and MERIT were at CERN, MICE is in the UK.

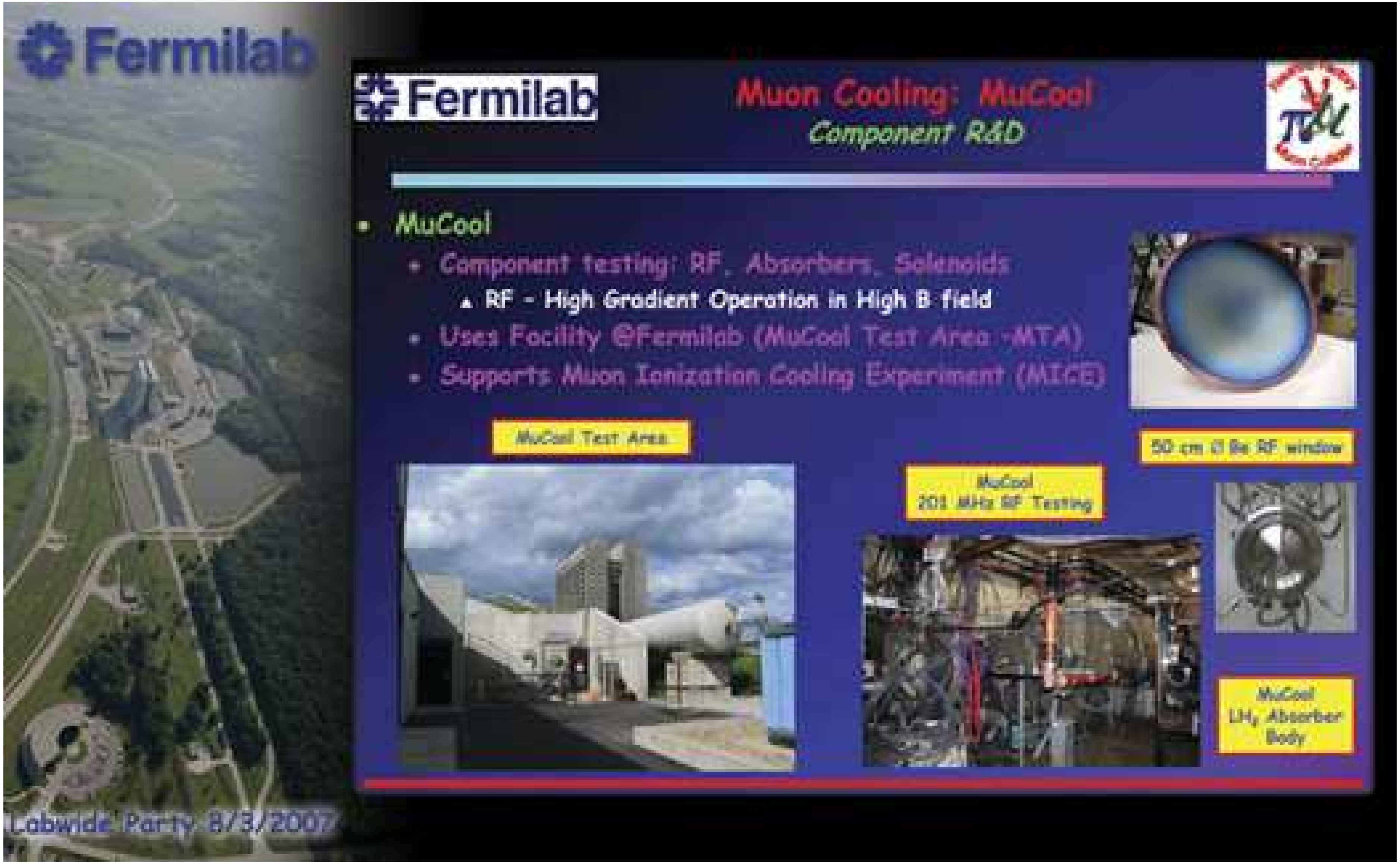
The strongest Muon Accelerator Program (MAP) remains thou
the <u>collaboration of major US labs and universities</u> clustering
around the R&D in progress in the dedicated <u>Muon Test Area</u> and
the regular DOE/NSF funding profile run by Fermilab.

The goal is a Neutrino Factory pointing towards SURF

ESPP support implied for these European collaborations?

1) MICE, in progress
2) the completion of the IDS RDR (Reference Design Report) soon
3) effort to proposal(s) of a Factory for Fermilab and/or CERN.

US Muon Acceleration Program



A first Muon Storage Ring: NUSTORM

Next major milestone on this muon path
both an FNAL *LOI* (arXiv:1206.0294) and CERN *SPSC*-EOI-009,
calling for an internationally concerted decision

a mini, low intensity and thus SBL only, neutrino factory

fully stripped down NF front end

A pilot facility first to deliver ν_e and ν_μ beams from the decay of a stored μ beam with a central momentum of 3.8 GeV/c and a momentum spread of 10%.

Unique service to the future long- and short-baseline neutrino-oscillation programmes
1) definitive % measurements of νe and $\nu\mu$ scattering cross sections
2) searches for sterile neutrinos of exquisite sensitivity to be carried out

essential step in the incremental development of μ accelerators

CERN SPSC-EOI-009 requests the resources required to: investigate in detail
how it could be implemented at CERN
what Eu contributions wherever it were sited.
A 2-year programme to a Technical Design Report.

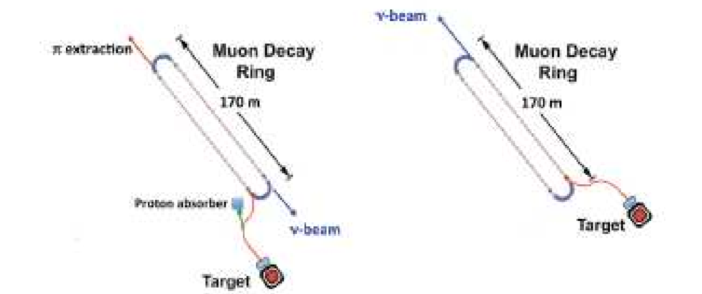


Figure 9: The νSTORM facility, with a Decay Ring having 150 m straights and 25 m, 180° arcs. The left figure shows a possible CERN layout where injection of pions produced from the full 10 μs spill of 100 GeV protons from the SPS would correspond to ~ 7 turns of the muon beam in the storage ring. The FNAL option, to the right, injects pions produced during only 1 μs 60 GeV proton extraction from the Main Ring.

scheduled at
SPSC 26 June

Final Recommendations

CERN Medium Term Plans this year and later should **accommodate** the necessary **resources and attract more from the national agencies** for a **Eu neutrino program adequate to fulfil the ESPP.**

Europe should keep following through its own opportunities of a site and MW beams
competitive with or superior to those in other continents, themselves far from being established .
rescue the Finnish option? a Swedish option? .

A neutrino detector home and test area at CERN is just as essential
for detectors in Europe as in South Dakota or in the Japanese Alps. **!!!!**
Both Li-Ar technologies must prove capable of really big tanks.
And build one or more for any international program that will manage to fly.
So should other technologies, iron-scintillator spectrometers, fully active scintillator detectors and more.

Major European participation in leading ν projects as HyperK and/or in the USalso very expensive and challenging
Contribution to their neutrino accelerator complex will also be decisive.
A catalyzing and steering CERN kernel of a global Eu concerted effort should be set up.

Europe should structure a stronger contribution to the international R&D and design work:
high power HP SPL driver work must continue, strategic, world wide.
high power targets and collection systems for conventional and novel beams,
ionization cooling, NuFact-IDS, NuSTORM, muon acceleration and more.

a vigorous coordinated multi-facet combination of European participations
in the international neutrino accelerator and detectors programs:
next generation experiments and, in parallel,
R&D and design work for long term experiments

It is too early to drop European based options.
And, in any case, any Eu option for Japan/USA demands a just as ambitious vision.

Thank you