LAST FEW YEARS have been very intense

- A new set of measurements have characterized with precision some of the Oscillation parameters
- New experimental facilities have become or are becoming operational worldwide
- Neutrino physics experience a new revival (see Nobel Price 2015).

Japan, China, Europe and then the USA have revealed their priorities for particle physics for the medium and long term future
Three major statements/events

• European Strategy: “CERN should develop a neutrino program to pave the way for a substantial European role in future long-baseline experiments”

• US P5 Report: “The U.S. will host a world-leading neutrino program that will have an optimized set of short- and long-baseline neutrino oscillation experiments, and its long-term focus is a reformulated venture referred as the Long Baseline Neutrino Facility (LBNF)”

• In the 2014 and 2015 councils, CERN has released an important amount of resources for a CERN Neutrino Platform, as part of its medium term plan (next 5 years)
The future possible landscape for new Neutrino Accelerator Infrastructure (as far we understand today!)

3 facilities

✓ no beams at CERN!
✓ Beams in the US and/or Japan?
SBN at the FNAL ~ 0.8 GeV $\nu$ Booster Beam

<table>
<thead>
<tr>
<th>Detector</th>
<th>Mass Total</th>
<th>Mass Active</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAr1-ND</td>
<td>220t</td>
<td>112t</td>
</tr>
<tr>
<td>MicroBooNE</td>
<td>170t</td>
<td>89t</td>
</tr>
<tr>
<td>T600</td>
<td>760t</td>
<td>476t</td>
</tr>
</tbody>
</table>

ICARUS
T600

MINOS

NOvA

600m – Far Detector
ICARUS/T600

110m – Near Detector
SBND

NuMi Line

BNB Target

MicroBooNE

SciBooNE

LAr1-ND
SBN Physics Program

- A Multi-detector program will address the unexplained anomalies which together could be hinting at new physics (sterile?)
  - MicroBooNE will address MiniBooNE low energy excess but is not designed to explore the complete sterile neutrino oscillation parameter space on its own
  - Plans to have all 3 detectors in operation in 2018 (LOI submitted in 2014, proposal submitted in January 2015)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Type</th>
<th>Channel</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSND</td>
<td>DAR</td>
<td>$\bar{\nu}_\mu \to \bar{\nu}_e$ CC</td>
<td>3.8σ</td>
</tr>
<tr>
<td>MiniBooNE</td>
<td>SBL accelerator</td>
<td>$\nu_\mu \to \nu_e$ CC</td>
<td>3.4σ</td>
</tr>
<tr>
<td>MiniBooNE</td>
<td>SBL accelerator</td>
<td>$\bar{\nu}_\mu \to \bar{\nu}_e$ CC</td>
<td>2.8σ</td>
</tr>
<tr>
<td>GALLEX/SAGE</td>
<td>Source - e capture</td>
<td>$\nu_e$ disappearance</td>
<td>2.8σ</td>
</tr>
<tr>
<td>Reactors</td>
<td>Beta-decay</td>
<td>$\bar{\nu}_e$ disappearance</td>
<td>3.0σ</td>
</tr>
</tbody>
</table>

The Long Baseline Facility in the US (LBNF)

- ~ 1’500 m underground
Hyper-Kamiokande in Japan

L=295km OA=2.5deg

LoI: The Hyper-Kamiokande Experiment  arXiv:1109.3262v1

The beam is from J-PARC
Scientific Priorities

→ CP violation in the neutrino sector
→ CP phase measurement regardless of its value
→ Neutrino Mass Hierarchy determination
→ Determination of $\theta_{23}$ octant and precision parameter measurements
→ Precision tests of 3-flavor neutrino model.
→ Atmospheric neutrino measurements (confirmation of mass ordering with independent data)
→ Proton decay
→ Supernova burst neutrinos
How does CERN fit in all this?

- As a support structure for all these activities, where CERN expertise can be a VALUE
- As the support Laboratory for all European Groups interested in a collaborative effort
- As a unique R&D and tests facility of detectors and components (hardware and software)
- As a research group active at these facilities

→ NEUTRINO PLATFORM
NEUTRINO CERN PLATFORM (LAr)

• LAr TPC detector are emerging as large scale precision detectors

Precise imaging capability in 3D
~ few mm scale

Excellent energy measurement capability:
totally active calorimeter
LAr TPCs challenges

- Large detector mass reach ~ 15-18 ktons of LAr
- Deep underground activities
- Large cryostats ~ 13’000 m³
- Long drifts > 3.5 m
- High liquid purity at the ppt level
- High temperature stability ~0.3°-0.5°
- Cold front end electronics or electrons amplification in the gas to maximize S/N
- Low threshold signals
- Large data handling capabilities
- Automatic tracks reconstruction and pattern recognition
- ……
New cryostat paradigm

- Cold cryostats technology based on LNG transport techniques

- SS 1.2 mm primary membrane in contact with the liquid (primary containment)

- Secondary membrane: composite laminated material (secondary containment)

- Insulation: reinforced polyurethane foam (5-7 W/m²)

- Warm structure: support structure
Membrane cryostats (GTT licence)
NEUTRINO CERN PLATFORM (LAr TPCs)

- .... the large scale is a big and new challenge
The new test beam facility at the CERN SPS
EHN1 extension : CE contract active

CE construction started in December 2014

- Target dates:
  - CE works completed : July 2016
  - Infrastructure completed : April 2017
  - Experiments ready for beam for 2017/2018 SPS run
Two large TCPs prototypes: protoDUNE

Single phase LAr TPC

Operational in 2017,
SPS calibration beams in 2018-19

Active volume \( \sim 7 \times 7 \times 6 \text{ m}^3 \)
Two large TCPs prototypes: WA105

Double phase LAr TPC

Operational in 2017,
SPS calibration beams in 2018-19

Active volume 6x6x6 m³
To be cooled down in summer 2016
WA105 3x1x1 prototype
LBNF far detector goals

4 detectors in 4 caverns
1'500 m underground
~ 17’400 tons of LAr / detector

Inner dimension (liquid+gas):
- L = 62.00 m
- W = 15.10 m
- H = 14.00 m

Excavation starts in 2017
First detector ready in 2022
All 4 detectors in 2026
Neutrino beam in 2026
Proximity cryogenics mezzanine
The FNAL short baseline (SBN)

ICARUS T600
476t Active Mass

MicroBooNE
89t Active Mass

MicroBooNE
112t Active Mass

600m

470m

100m

Protons
CERN ν Platform and SBND

Plate A: TPC support and detector feedthroughs
Plate B: Cryogenic Services
SS Inner Membrane
Foam Insulation (60cm)
Steel outer cryostat and support structure

LAr cryogenics
cryostat
WA104 : ICARUS detector overhauling

ICARUS Collaboration with INFN and CERN help

- Move the detector from the GS Laboratory to CERN
- Prepare at CERN all the necessary infrastructure (clean rooms, cryogenics, …)
- Reshape the detector with new components (more PMTs, new cathode, new inner cabling, new electronics, …)
- Construct a new generation of Aluminum cryostats
- Reshape, maintain and modernize the cryogenics plant
- Reassemble the 2 T300 detectors inside their cryostats
- Construct a new outer vessel, GTT insulation
- Make it ready for shipment to FNAL early 2017
-Cooldown should start in summer 2017
ICARUS Detector at Gran Sasso being dismantled
and moved to CERN (10 days trip)
ICARUS Detector arrived at CERN (first T300) and is now in the CERN dedicated clean room

New:
- flat cathodes
- 200 new 8” PMTs (coated) / T300
- new cabling, new warm electronics and FE crates, new DAQ
ICARUS new cryostats

Aluminium extruded panels
Physics opportunity

• This will represent for young physicist an opportunity to perform a real accelerator physics experiment in the next 2-3 years, starting from scratch

• All ingredient will have to be present : DAQ, controls, safety systems, simulation, reconstruction software, computing, data visualization and data analysis ..... 

• This effort will happen at the same time as the large DUNE prototypes calibration at CERN and will require a good coordination and a sharing of resources
A very modular TPC? (ArgonCube Collaboration)
A very modular TPC?

Each module 2m x 2m x (5 or 10) m

First prototypes 2016!
A fully magnetized TPC?
The B2 experiment: WAGASCI (T2K near location)

Place

B2 floor of T2K near detector hall
Off axis angle = 1.6°

νμ flux
black: ND280
red: B2
similar spectrums

ND280 floor
SS floor
B2 floor

Off-Axis Detector (ND280)
On-Axis Monitor (INGRID)

INGRID

νμ

top view of B2 floor
B2 experiment offaxis 1.6°
The B2 experiment: WAGASCI (T2K near location)
Baby MIND detector/spectrometer
MOU frame, How to get in?

Memorandum of Understanding

for providing a framework for developing a Neutrino Program at CERN

between

The EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH, an Intergovernmental Organization having its seat at Geneva, Switzerland, (‘CERN,’), as the Host Laboratory,

and

The FUNDING AGENCIES/INSTITUTIONS PARTICIPATING IN THE NEUTRINO PHYSICS RESEARCH PROJECTS AT CERN (‘the Neutrino Institutions’),

(collectively, “the Parties”)

Preamble

(a) As endorsed by the CERN Research Board at its meeting of August 28th, 2013 and detailed in Annex I, CERN has decided to develop a Neutrino Program at CERN (‘the Neutrino Program’) to pave the way for a substantial European role in future Long-Baseline Experiments and explore the possibility of major participation of Europe in leading Long-baseline Neutrino Projects in the United States and Japan;

(b) The Neutrino Institutions, including possibly CERN, wish to collaborate in the research and development (R&D) and construction of prototypes, equipment and related infrastructure for the Neutrino Program and have obtained the support of their Funding Agencies to enable them to participate in the Neutrino Program;

How to get in?

- Present to the CERN SPSC a LOI or an expression of interest
- When approved we prepare together an MOU (addendum) which defines all responsibilities and resources needed
- Then a CERN experiment is created (WA104, WA105, …), with all privileges and requirements

https://edms.cern.ch/document/1353815
STATUS

6 Projects presented to the SPSC and approved:

- PLAFOND : an generic R&D framework
- WA104 : ICARUS as far detector for SBN
- WA105 : demonstrator + engineering prototype for a double ph. TPC
- ProtoDUNE : engineering prototype for a single phase TPC
- Baby MIND : a muon spectrometer for the WAGASCI experiment

Few projects in the pipeline:

- HKK detector components R&D
- Darkside
- ARIADNE

LBNF & SBN activities approved by CERN (as part of the DOE-CERN agreement)

- LBNF cryostat and LAr cryogenics
- SBND cryostat and LAr cryogenics
- CERN member of DUNE
European Institutions who are signing ν Platform MOUs (today 49)

CERN, CIEMAT Madrid, ETH Zurich, Gran Sasso Science Institute, IFIC Valencia, IN2P3, including IPNL, LPNHE, LAPP, APC, OMEGA, INFN Bari, INFN Bologna, INFN Lecce, INFN LNF Frascati, INFN LNGS, INFN Milano, INFN Milano Bicocca, INFN Napoli, INFN Padova, INFN Pavia, INFN Roma, Institut de Fisica d’Altes Energies (IFAE) Barcelona, Institute College of London, IRFU CEA Saclay, Lancaster University, National Center for Nuclear Research Otwock, NTUA Athens, Ruder Boskovic Institute Zagreb, STFC Rutherford Appleton Laboratory, Università di Bari, Università di Bologna, Università di Padova, Università di Roma ‘La Sapienza’, Università di Salento, University of Bern, University of Cambridge, University of Geneva, University of Glasgow, University of Jyvaskyla, University of Liverpool, University of Manchester, University of Oulu, University of Oxford, University of Sheffield, University of Sofia, University of Sussex, University of Warwick, UST Cracow
Summary:

✓ CERN offers a platform for Neutrino detectors R&D. This platform is now part of the CERN MTP.

✓ CERN is constructing a large neutrino test area (EHN1 extension) with charged beams capabilities, available in 2017.

✓ CERN will assist the EU neutrino community in their long term common plans. For the moment CERN is not committing to any neutrino beam at CERN, in view of an agreed road map between all partners.

✓ In the short term, CERN is helping in getting a Short Baseline operational at FNAL with an agreed physics program ... and later a Long Baseline.