Swiss Neutrino Programme

Laura Baudis
Nicola Serra

Alain Blondel
Teresa Montaruli

Antonio Ereditato

André Rubbia

Swiss Neutrino Programme

Basic Neutrino Properties **Neutrino Oscillation Physics**

(supported by relevant theoretical activities)

Year 2015 FTE:

19 PhD students,
21.5 PostDocs,
10.25 Senior,
9 Technicians.

(30 June 2015, CHIPP)

Past results from experiments on neutrino properties

Search for **Majorana neutrinos** with the first two years of
EXO-200 data,
J. B. Albert et al, (EXO collaboration), Nature 510, (2014) 229–234

First Search for **Lorentz and CPT Violation** in Double Beta Decay
with **EXO**-200,
J. B. Albert et al, (EXO collaboration), arXiv:1601.07266 (2016) 6 pp.

Results on **Neutrinoless Double-β Decay** of Ge76 from
Phase I of the **GERDA** Experiment
M. Agostini et al. (GERDA Collaboration) Phys. Rev. Lett. 111 (2013) 122503

Past results from neutrino oscillation experiments

Measurement of **Neutrino Oscillation** by the **K2K Experiment,**
M. H. Ahn et al. (K2K Collaboration), Phys. Rev. D 74 (2006), 072003

Indication of **Electron Neutrino Appearance** from
an Accelerator-Produced Off-Axis Muon Neutrino Beam
*K. Abe et al. (**T2K** Collaboration), Phys. Rev. Lett. 107 (2011) 041801*

Observation of **Electron Neutrino Appearance** in a Muon Neutrino Beam
*K. Abe et al. (**T2K** Collaboration), Phys. Rev. Lett. 112 (2014) 061802*

Measurements of **π± differential yields** from the surface of the **T2K replica target** for incoming 31 GeV/c protons with the **NA61/SHINE** spectrometer at the CERN SPS
N. Abgrall et al., CERN-EP-2016-057, arXiv:1603.06774

Discovery of **tau neutrino appearance** in the CNGS neutrino beam
with the **OPERA** experiment,
N. Agafonova et al. (OPERA), Phys. Rev. Lett. 115 (2015) 12180.

Determining **neutrino oscillation parameters** from atmospheric muon neutrino disappearance with three years of **IceCube DeepCore** data
M. G. Aartsen et al. (IceCube Collaboration) Phys. Rev. D 91 (2014) 072004

The Nobel Prize in Physics 2015

Photo: A. Mahmoud

Takaaki Kajita

Prize share: 1/2

Photo: A. Mahmoud

Arthur B. McDonald

Prize share: 1/2

The Nobel Prize in Physics 2015 was awarded jointly to Takaaki Kajita and Arthur B. McDonald *"for the discovery of neutrino oscillations, which shows that neutrinos have mass"*

*"Super-Kamiokande's oscillation results were later confirmed by the detectors MACRO and Soudan, the long-baseline accelerator experiments **K2K**, MINOS and **T2K** and more recently also by the large neutrino telescopes ANTARES and **IceCube**. Appearance of tau-neutrinos in a muon-neutrino beam has been demonstrated on an event-by-event basis by the **OPERA** experiment in Gran Sasso, with a neutrino beam from CERN."*

Koichiro Nishikawa and the K2K and T2K Collaboration

Affiliation when awarded Breakthrough Prize: KEK: High Energy Accelerator Research Organization

Citation: For the fundamental discovery and exploration of neutrino oscillations, revealing a new frontier beyond, and possibly far beyond, the standard model of particle physics.

Science goals for the future

- Pattern of mixing angles and masses (CP-violation phase)
- Sterile neutrinos
- Absolute neutrino mass scale
- Nature of neutrino mass
- Search for right-handed neutrinos

14 November 2015

Experimental neutrino physics: Switzerland in the global context, a white paper

Editors: L. Baudis, A. Blondel, A. Ereditato, T. Montaruli, A. Rubbia, N. Serra

A) first priority for Swiss funding, notably FLARE, should be given to the approved WA105 and SBN projects. ← Bern, ETHZ

B) The Swiss involvement in DUNE will be developed in the coming years within the international context. A coherent Swiss DUNE proposal for FLARE will be eventually submitted. ← Bern, ETHZ

C) The evolution of the Hyper-K project might also lead to a proposal to be submitted to FLARE, which will propose upgrades of the T2K experiment and participation to the Hyper-K construction. ← Geneve

D) After approval by CERN and pending more precise timescales, SHiP will also request support from FLARE. ← Zurich,Geneve

E) The evolution of a ton-scale double beta decay experiment might also lead to a proposal to be submitted to FLARE. ← Zurich

Future projects on neutrino properties

GERDA Phase -II

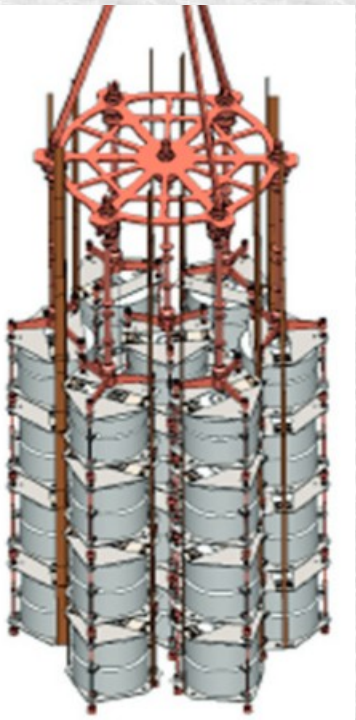
Majorana-Dirac mass dilemma ($0\nu2\beta$ decay $T_{1/2}>2\times10^{26}$ years)

Inverted mass hierarchy

GERDA+Majorana (USA)

B. Majorovits / Physics Procedia 61 (2015) 254 – 259

15 kG



35 kG

Future projects on neutrino properties

SHiP experiment

Heavy Neutral Leptons (right-handed neutrino)

Dark matter

Tau neutrino interactions

(wait for CERN decision on approval of beam and experiment)

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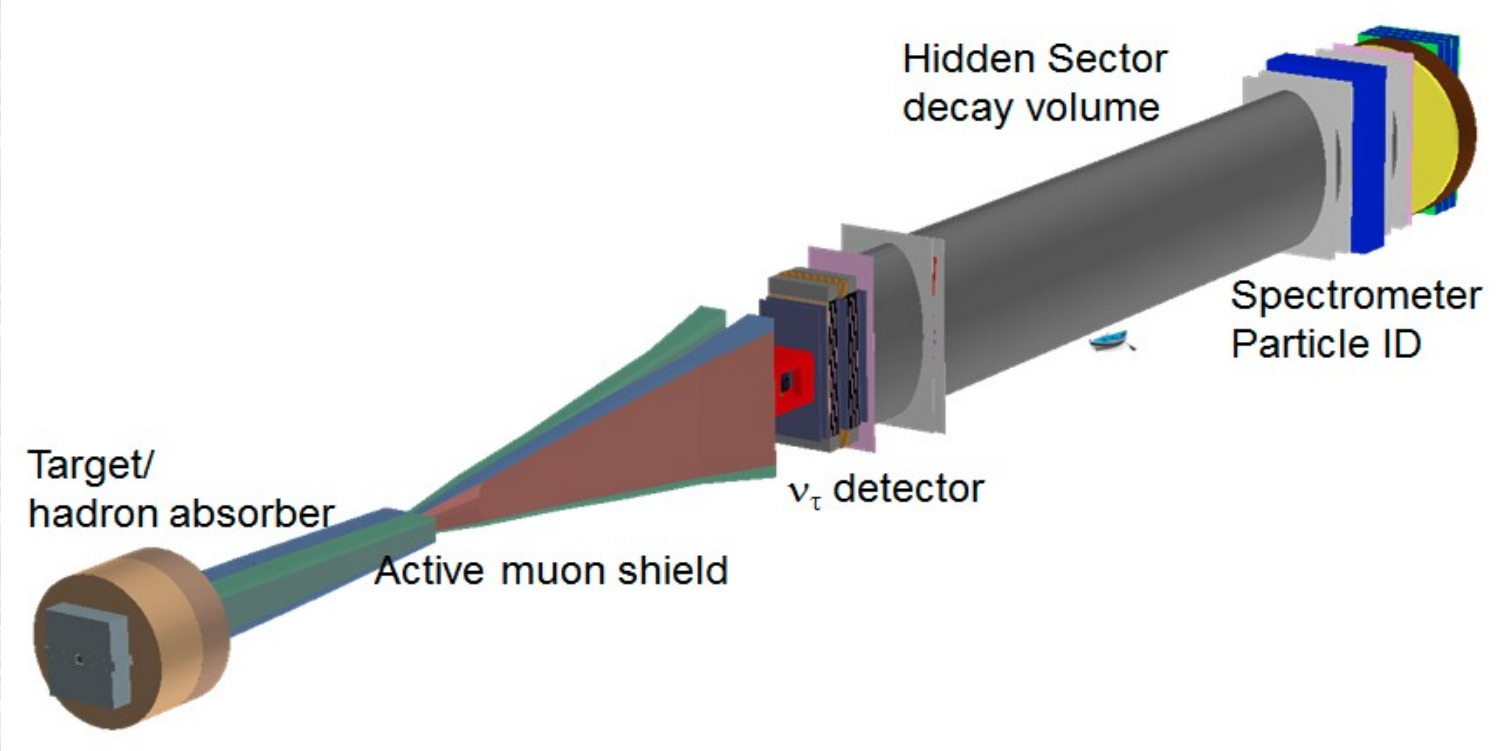
Universität Zürich[UZH]

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Theory



Future in neutrino oscillation experiments : PINGU

Precision IceCube Next Generation Upgrade (PINGU)

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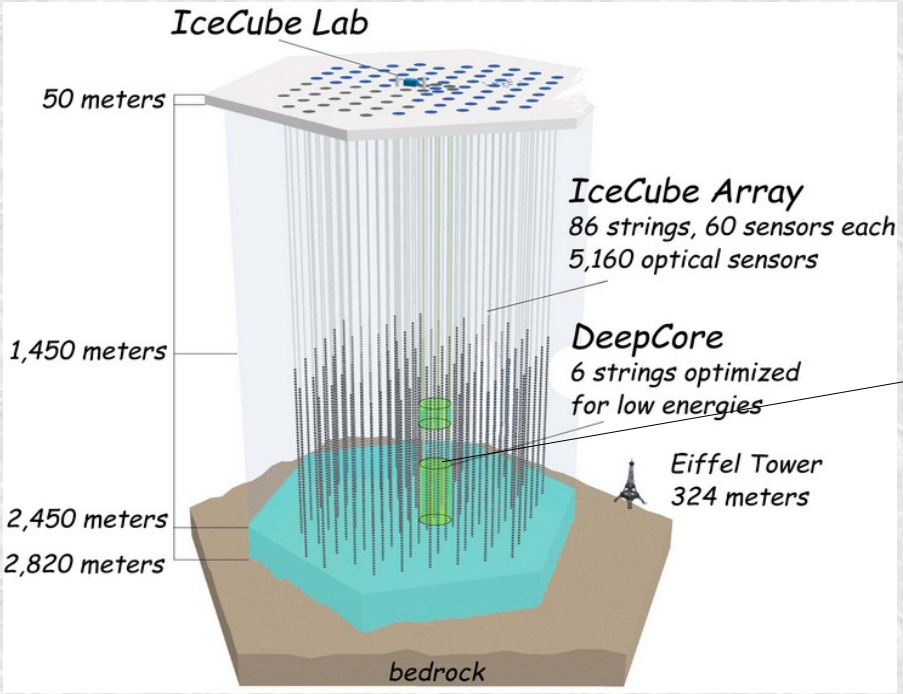
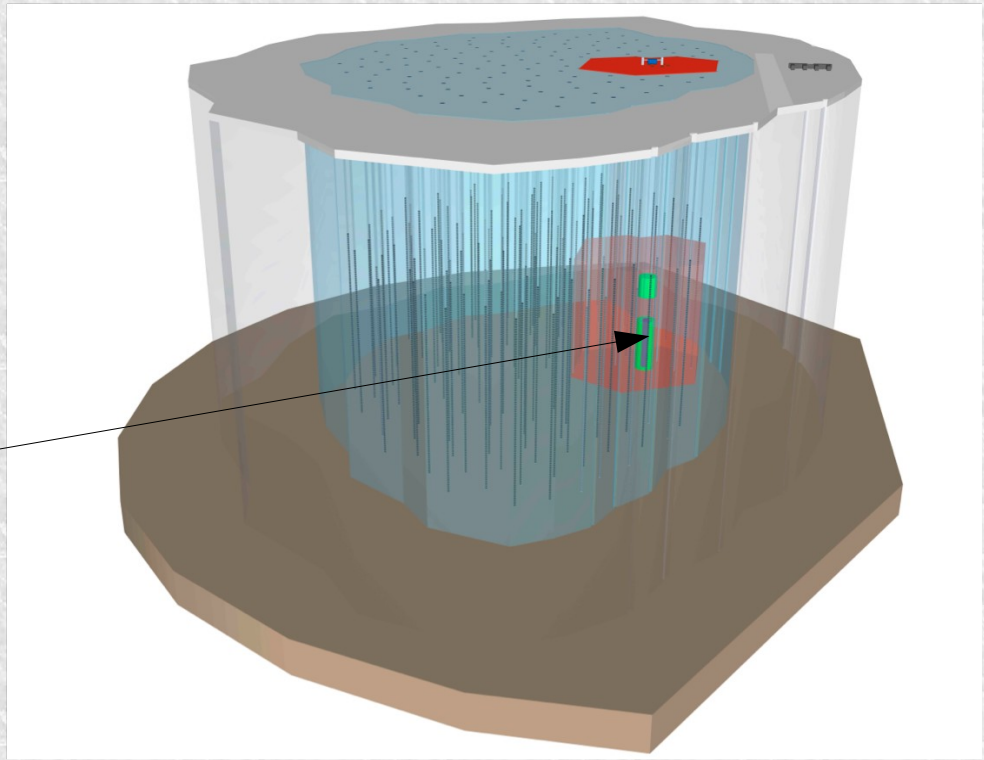
Normal or Inverted neutrino mass hierarchy

Dark matter

Supernova neutrinos

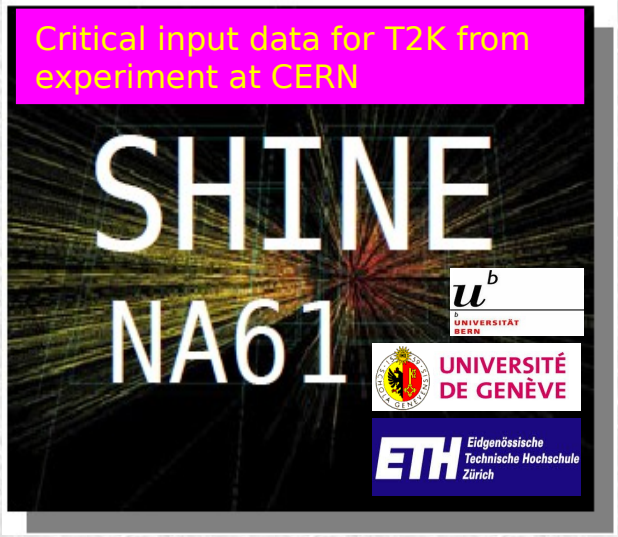
Neutrino Earth tomography

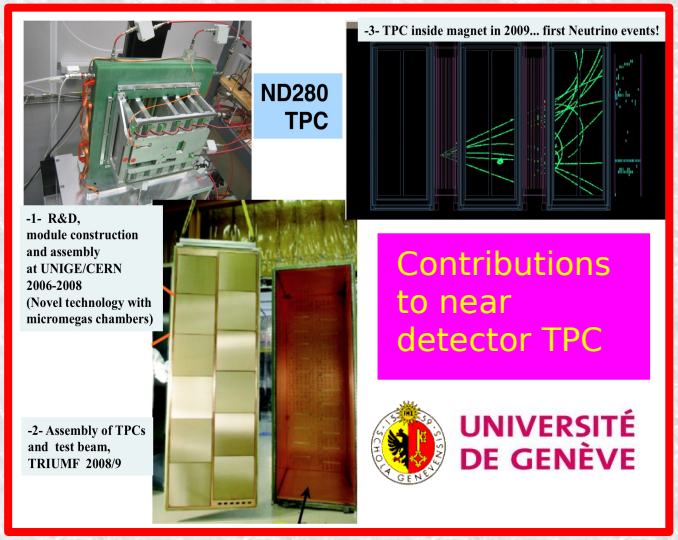


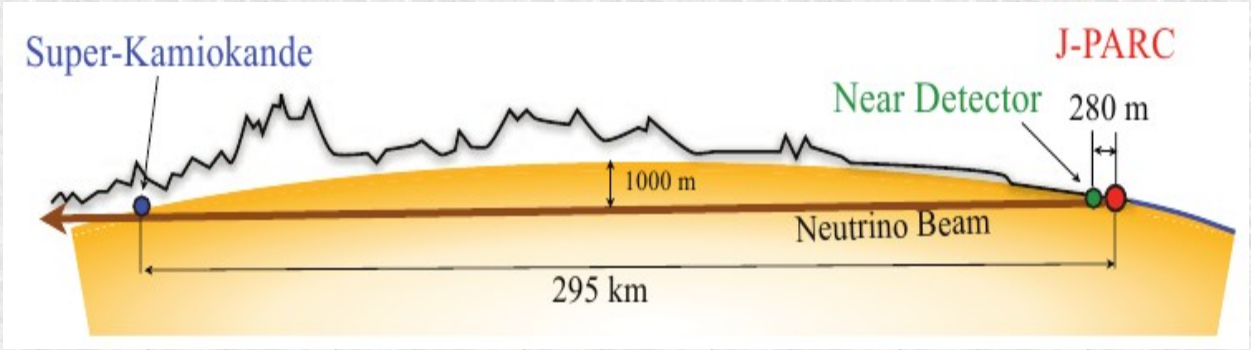


The running T2K neutrino oscillation experiment

Swiss contributions:

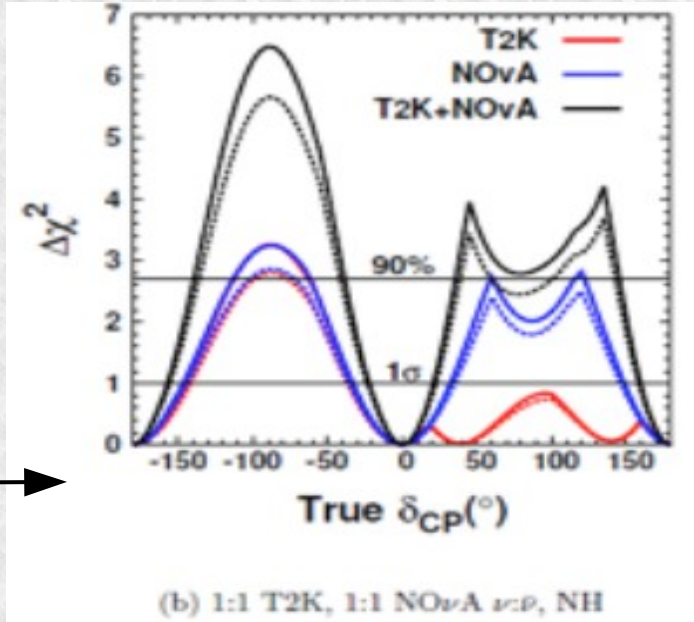






Search for $\nu_\mu \rightarrow \nu_e$ oscillations in accelerator beam

By 2020 possible indication of CP-violation
(combined with NOVA results)



Future neutrino oscillation experiments : T2K upgrade

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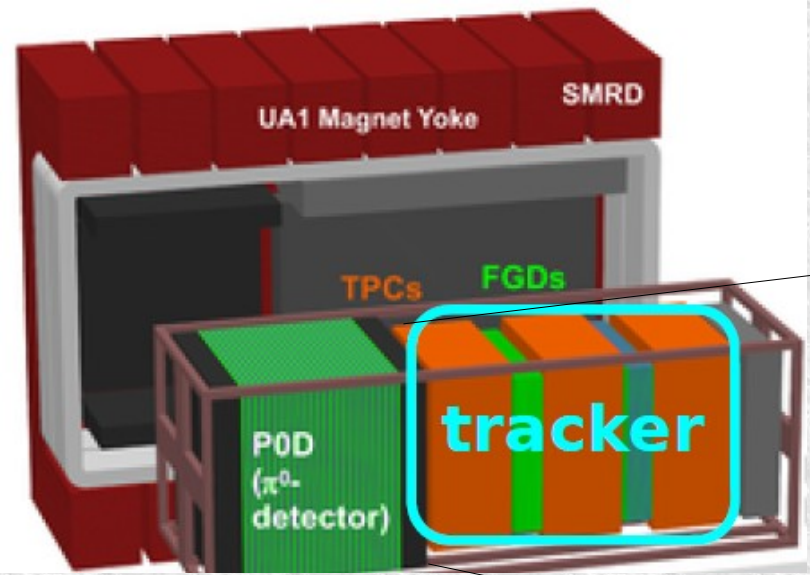
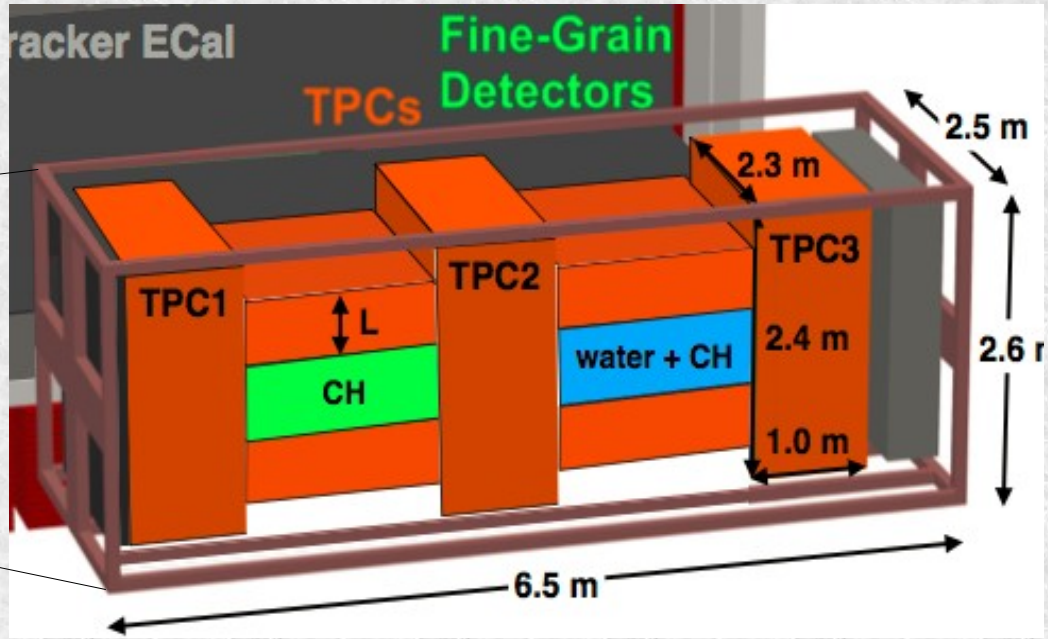
ND280 tracker upgrade (waiting for approval)

J-PARC accelerator upgrade aims at: 371 kW => 750 kW by 2019,
with the final goal of 1.3 MW





Neutrino oscillation ancillary experiments : NA61 upgrade

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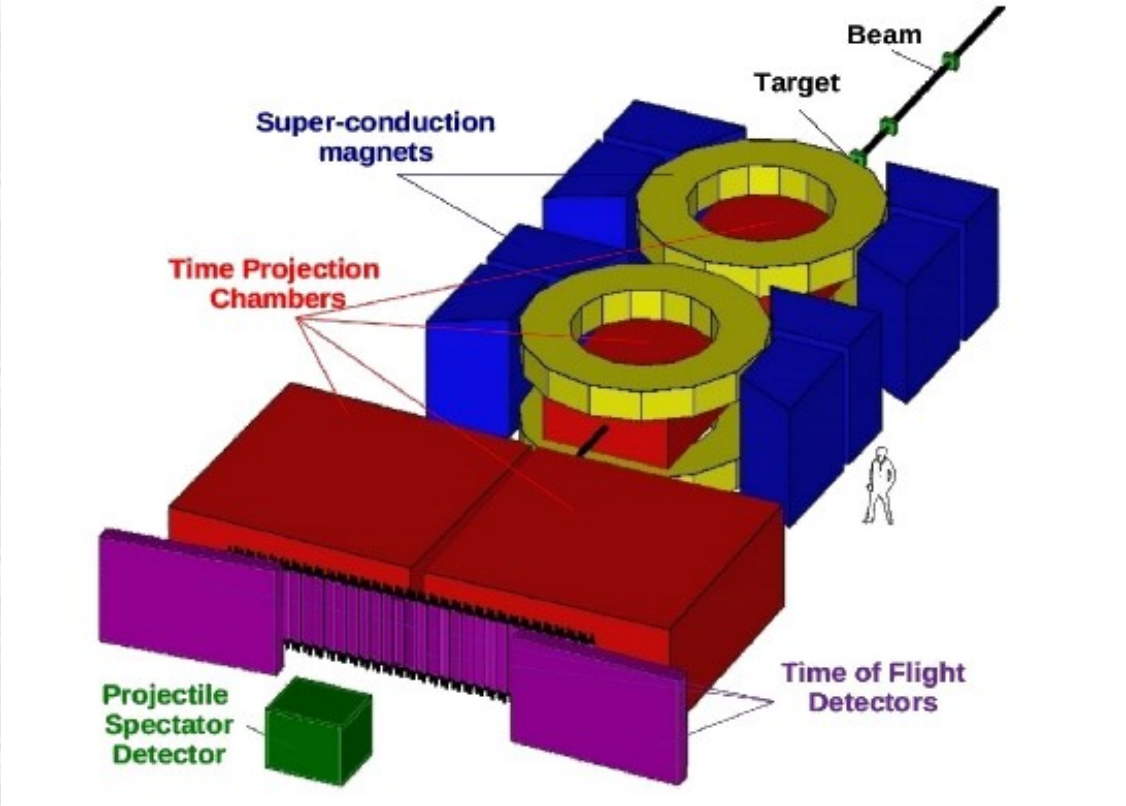
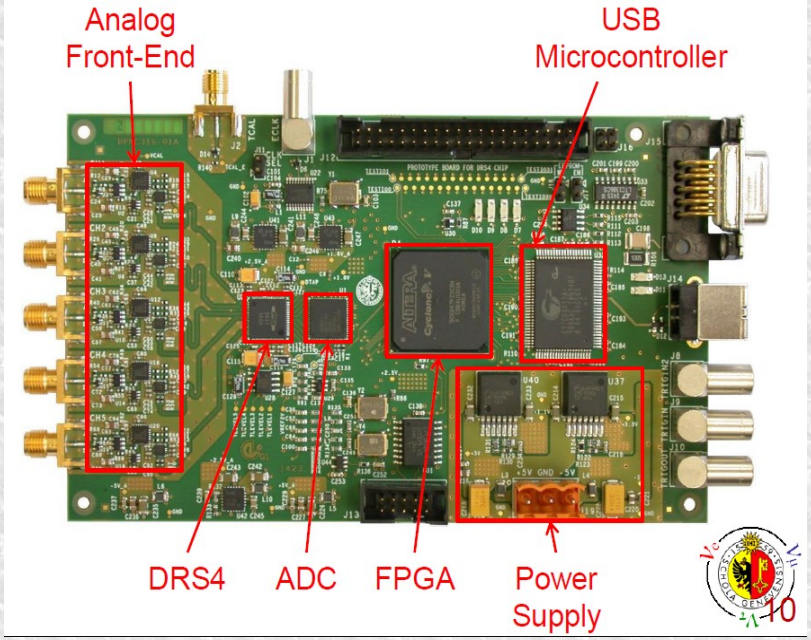
(Hadron production in proton interactions at fixed target)

Upgrade electronics with DRS4 (PSI)
Precise characterization of neutrino flux for T2K and Hyper-K





Future in oscillation physics : Hyper-K

Hyper-K
(Megaton-scale water Cherenkov detector with upgraded J-PARC beam)

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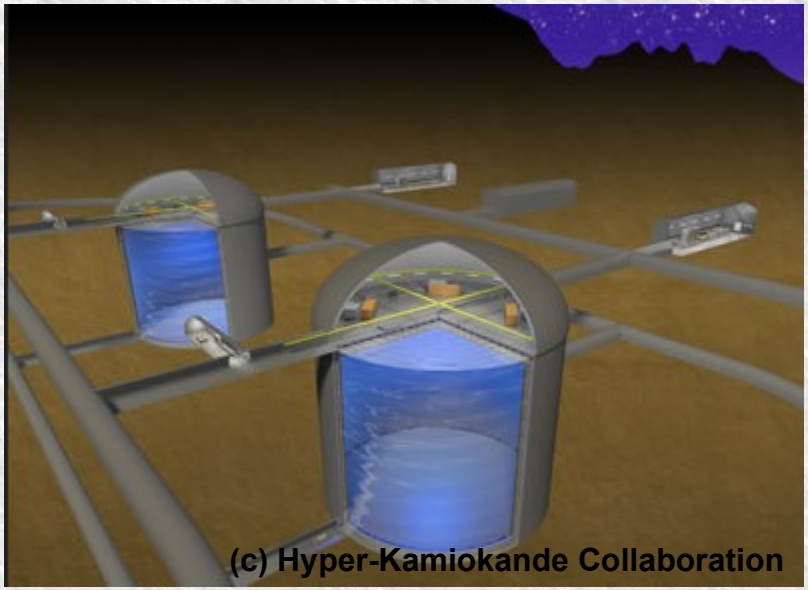
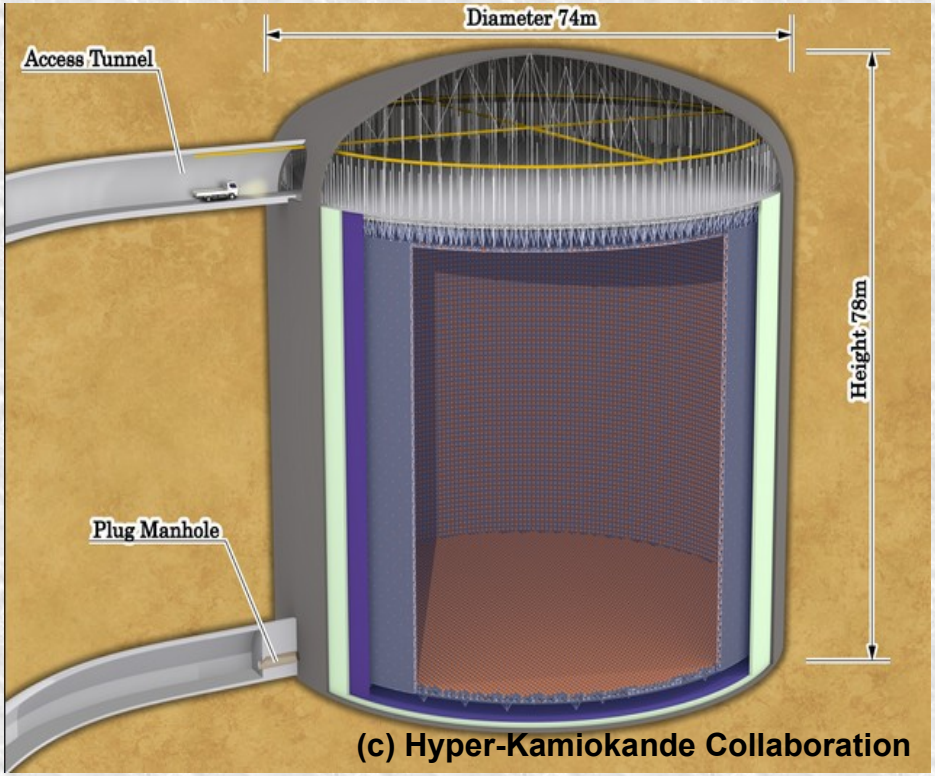
x25 larger than Super-Kamiokande

CP-violation discovery (5-sigma) for 58% of parameter space

CP-violation phase to better than 19 degrees

(target for approval: 2017, first run in 2025-2026)





Comprehensive LAr-based program in USA

European Strategy for Particle Physics (2013):

CERN should develop a neutrino program to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan.

Strategic USA «P5» report:

In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab (LBNF).

Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S.
To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text. LBNF is the highest-priority large project in its timeframe.

Select and perform in the short term a set of small-scale short-baseline experiments that can conclusively address experimental hints of physics beyond the three-neutrino paradigm. Some of these experiments should use liquid argon to advance the technology and build the international community for LBNF at Fermilab.

Comprehensive LAr-based program in USA

Sterile neutrinos

CP-violation phase

Mass hierarchy

Accelerator beam

Supernova neutrinos

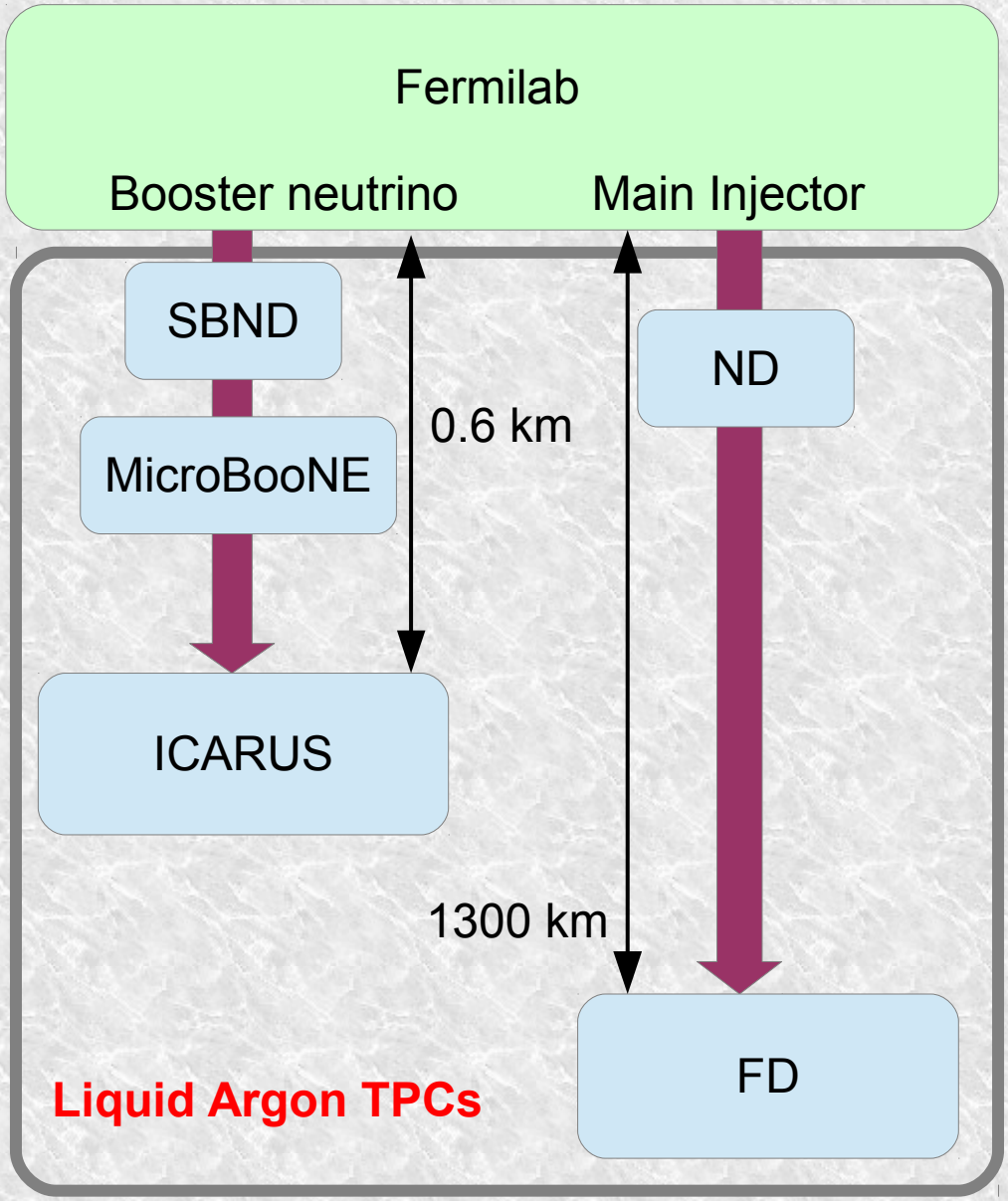
Atmospheric neutrinos

Proton decay

Dark matter

...

Astroparticle



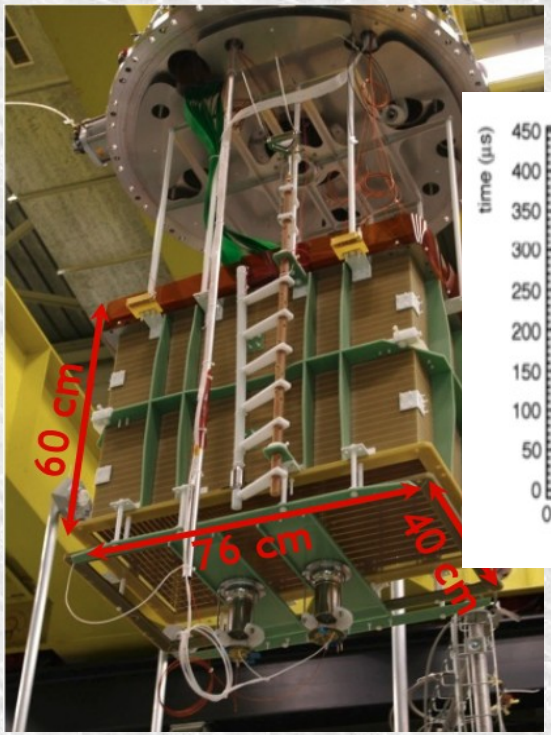
LAr TPC technology experience in Switzerland

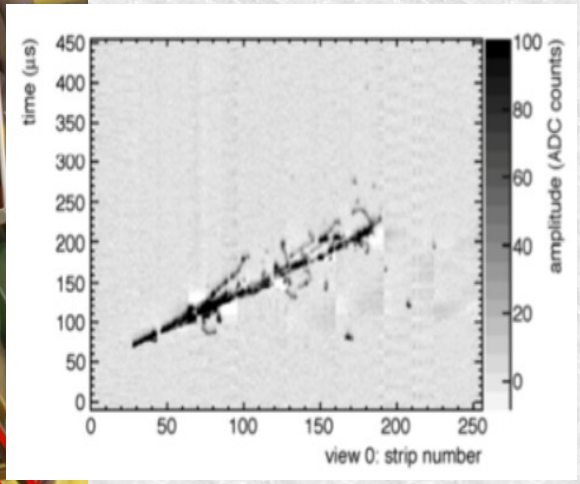
LAr technology initially developed in Europe
Substantial part of front-line knowledge is hosted in Switzerland
(> 10 years, Bern & ETHZ)

UNIVERSITÄT BERN

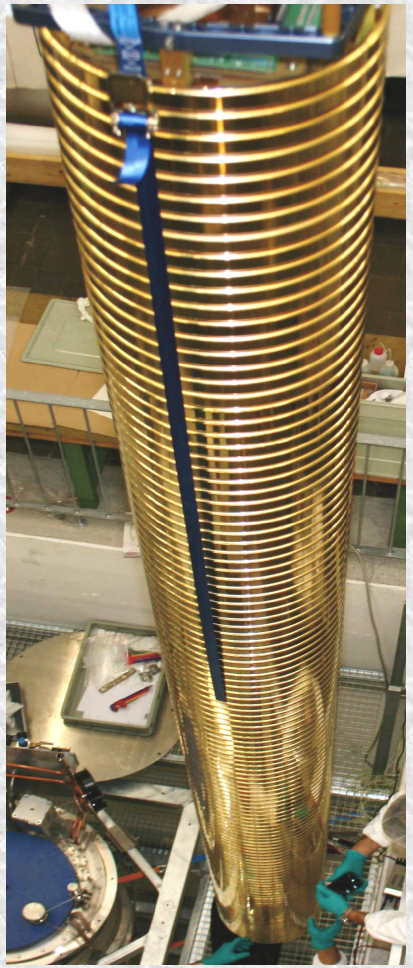
ETH Eidgenössische Technische Hochschule Zürich

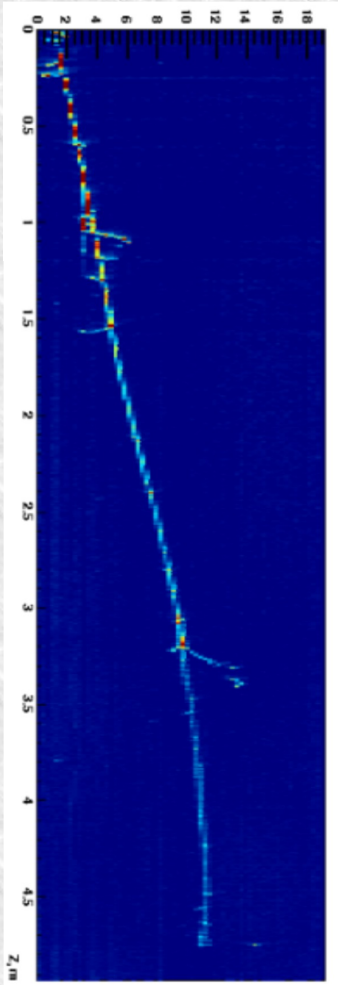
Double-phase TPC with LEM





Long-drift TPC: ARGONTUBE

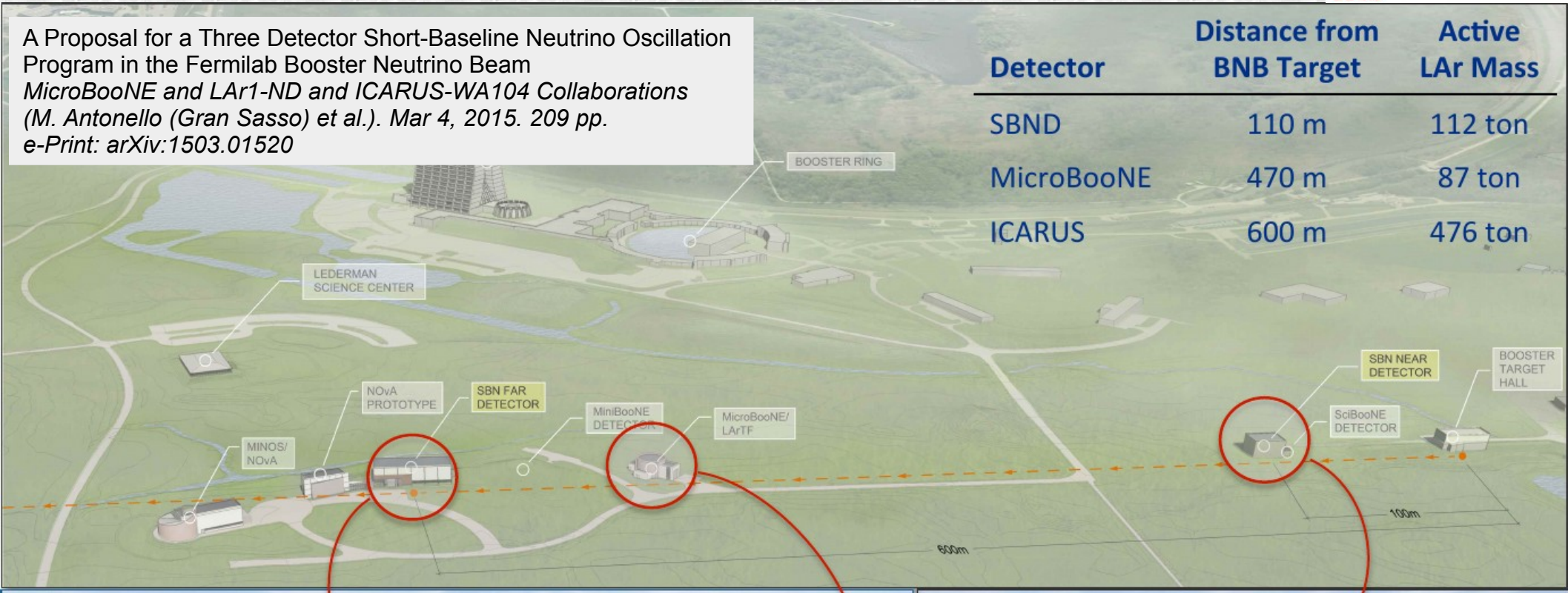


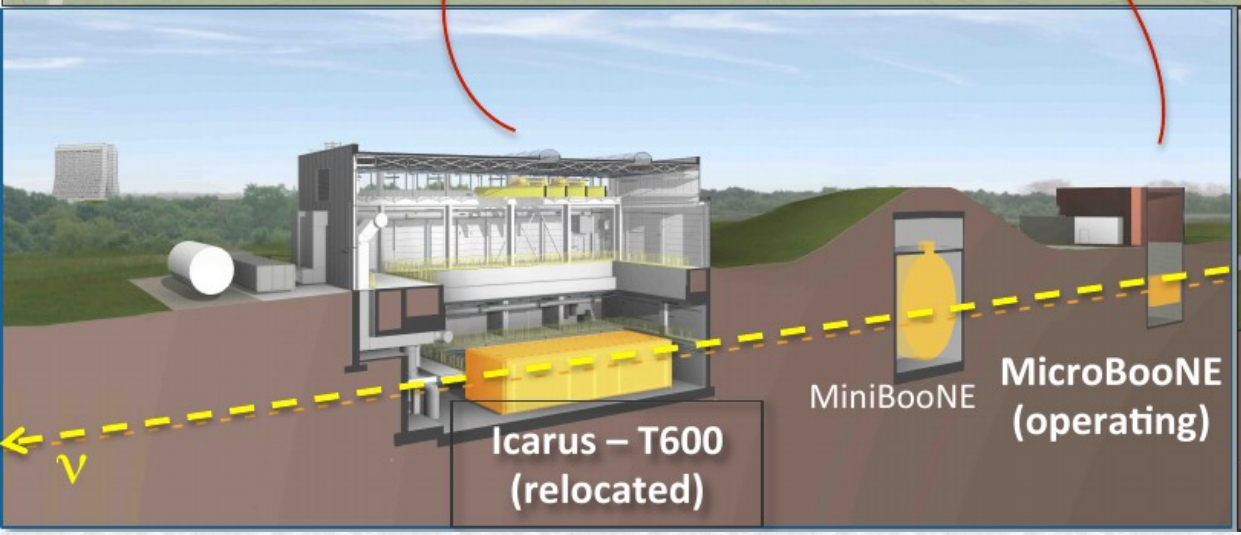


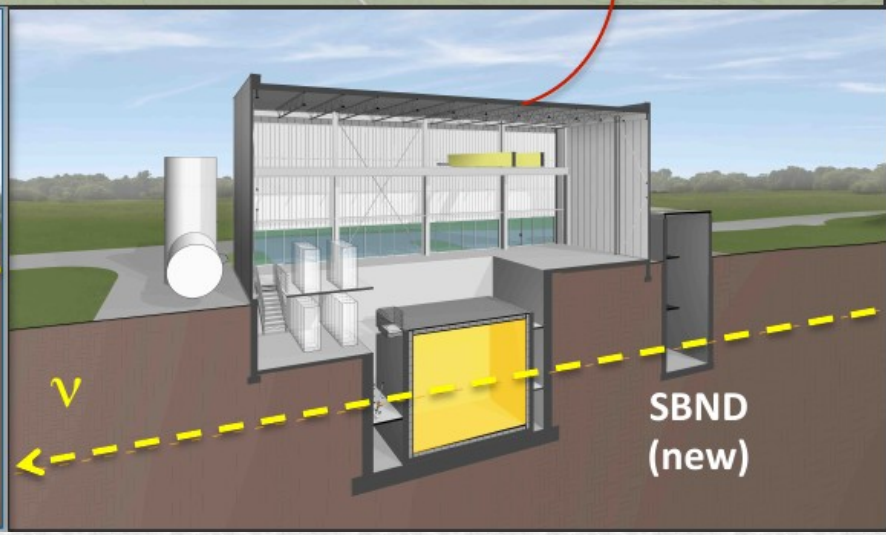
Short-Baseline Program (SBN)

A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam
MicroBooNE and LAr1-ND and ICARUS-WA104 Collaborations (M. Antonello (Gran Sasso) et al.). Mar 4, 2015. 209 pp.
e-Print: arXiv:1503.01520

Detector	Distance from BNB Target	Active LAr Mass
SBND	110 m	112 ton
MicroBooNE	470 m	87 ton
ICARUS	600 m	476 ton

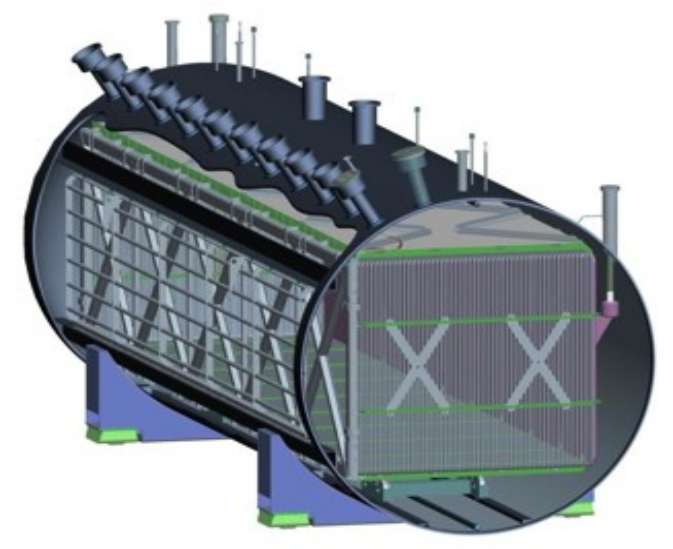


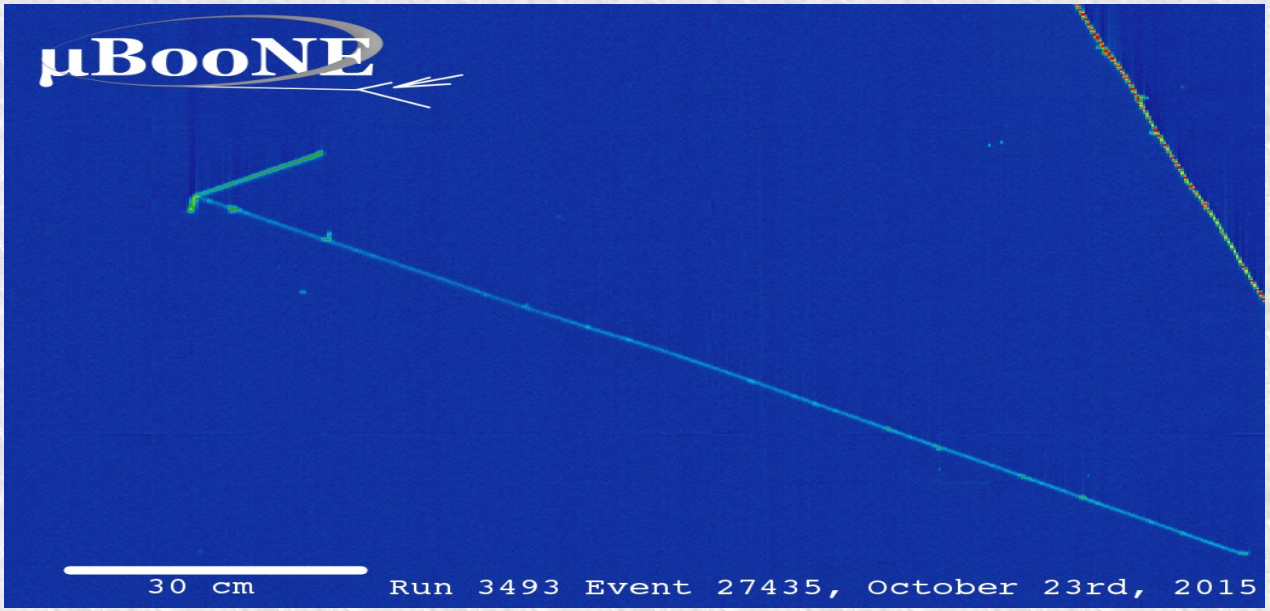


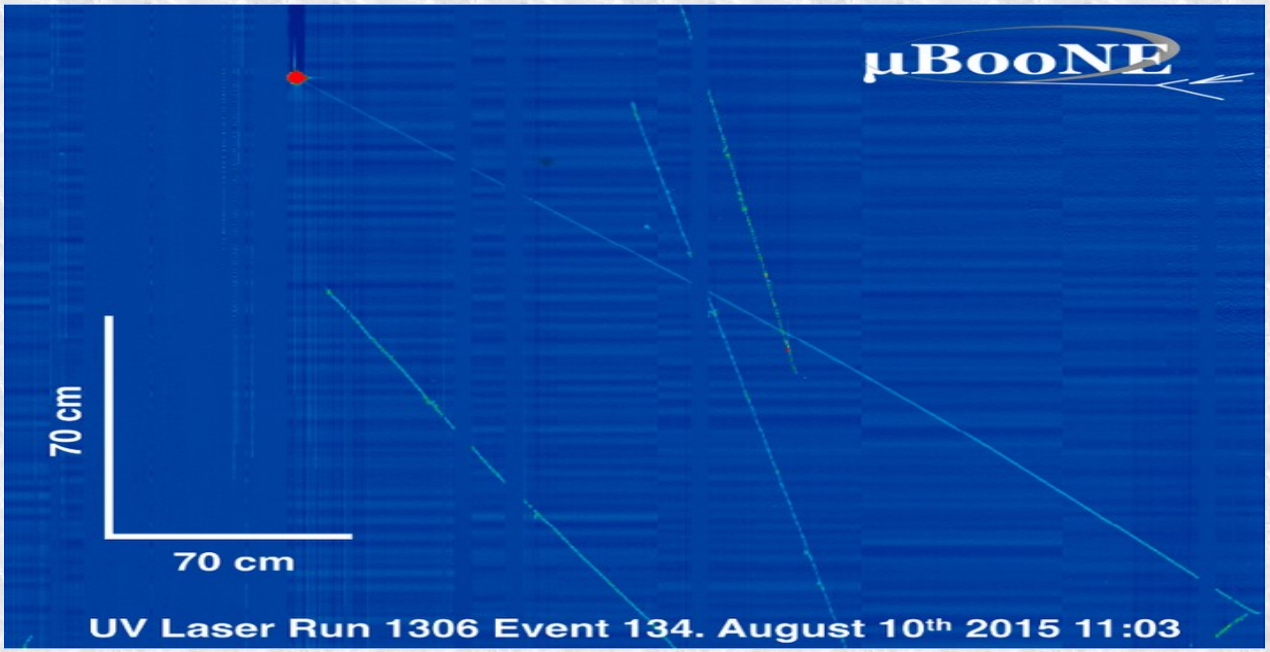


Short-Baseline Program (SBN) : MicroBooNE

Taking neutrino data since Nov 2015 ...

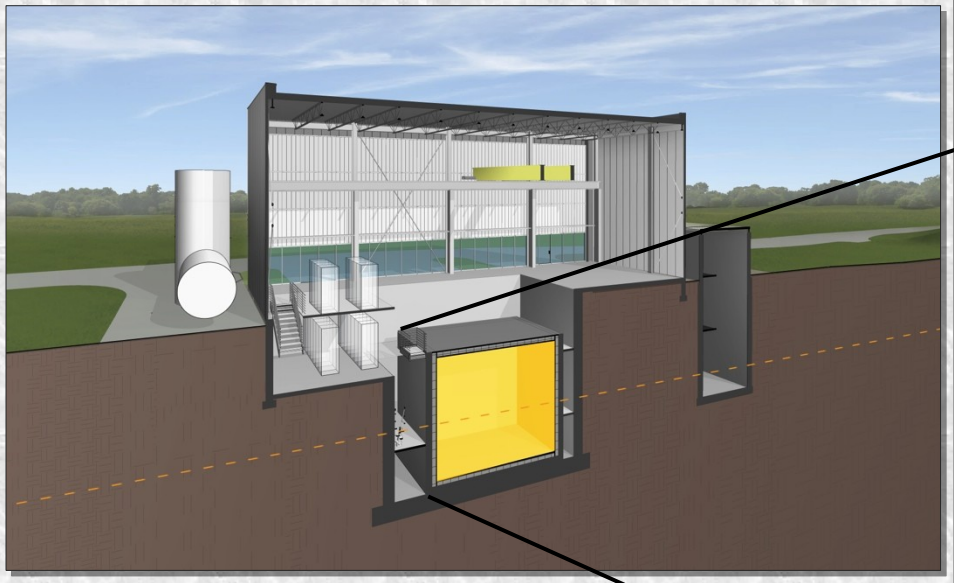


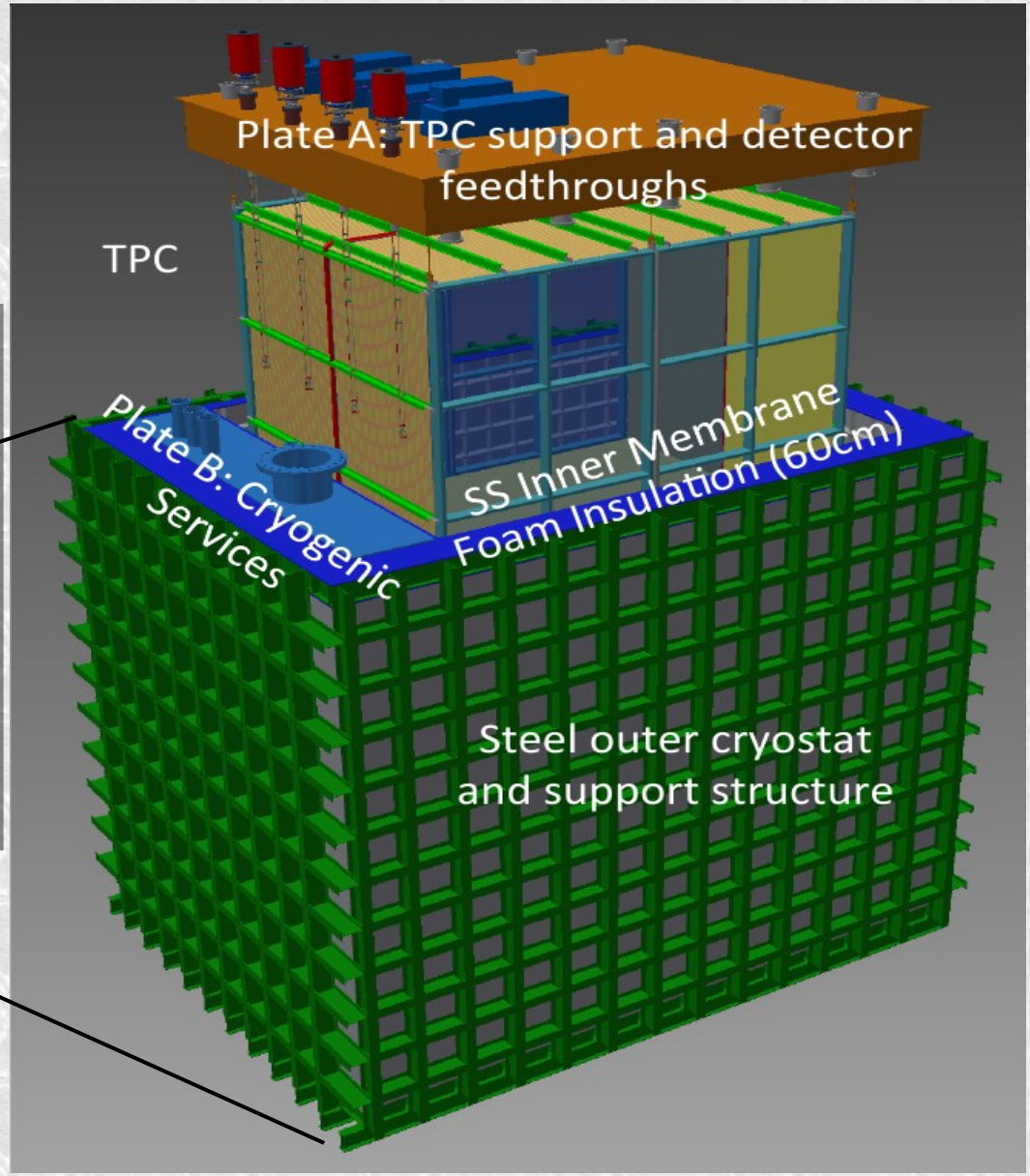




Short-Baseline Program (SBN) : SBND

Building ready Nov 2016, commissioning in Q3 2018.



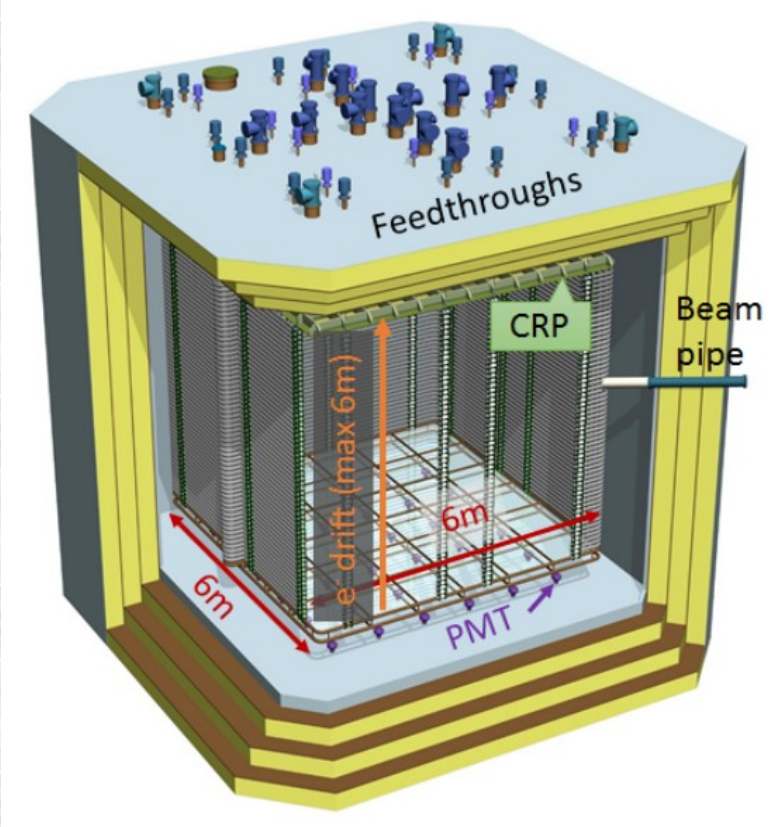


Towards the DUNE detector

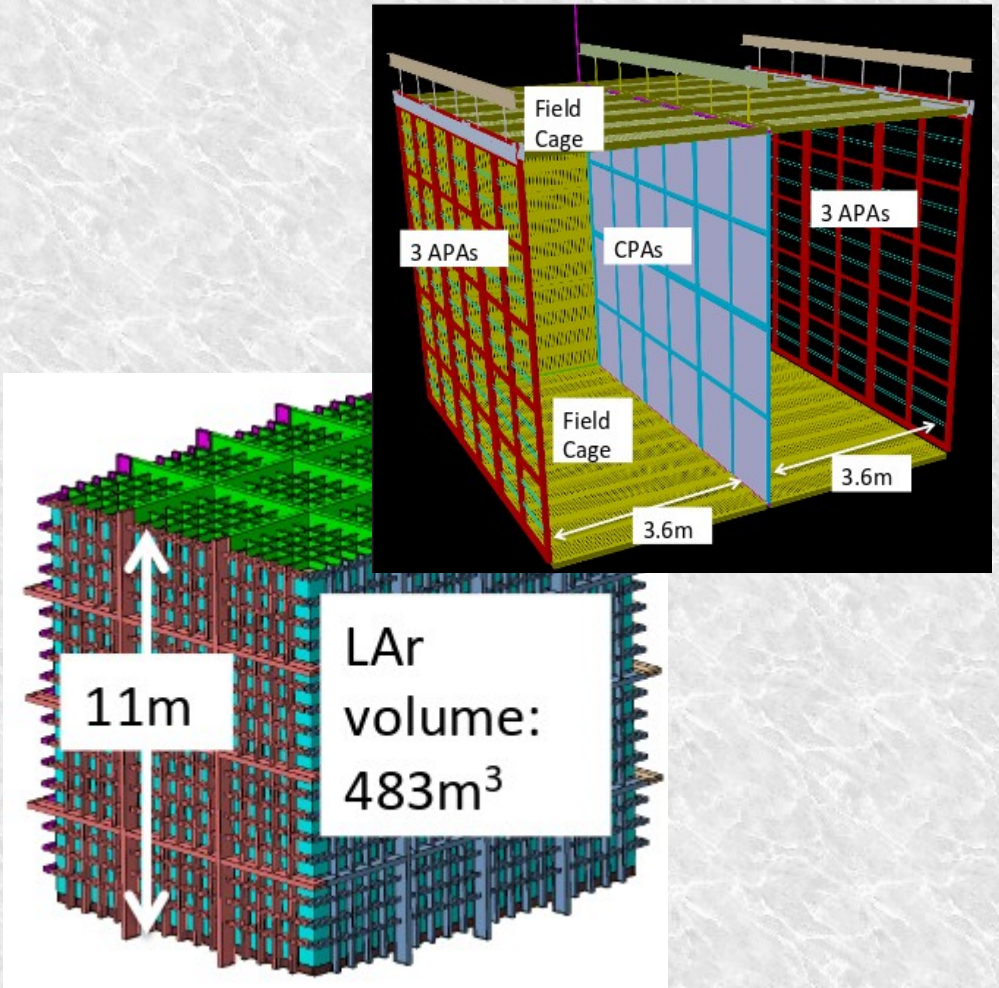
Prototypes at CERN Neutrino Experimental Facility (CENF)

Double-phase LAr TPC (WA105)

Eidgenössische Technische Hochschule Zürich



Single-Phase LAr TPC (Proto-DUNE)



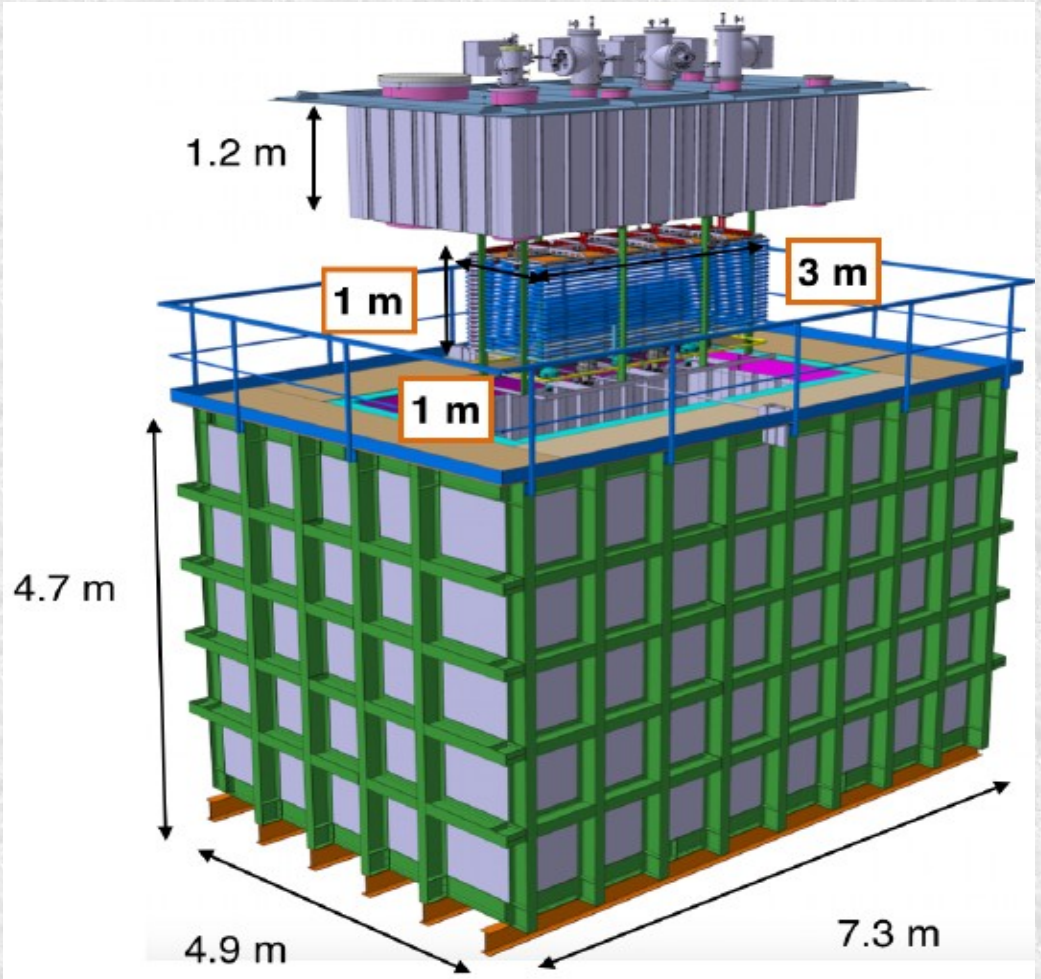
Towards the DUNE detector

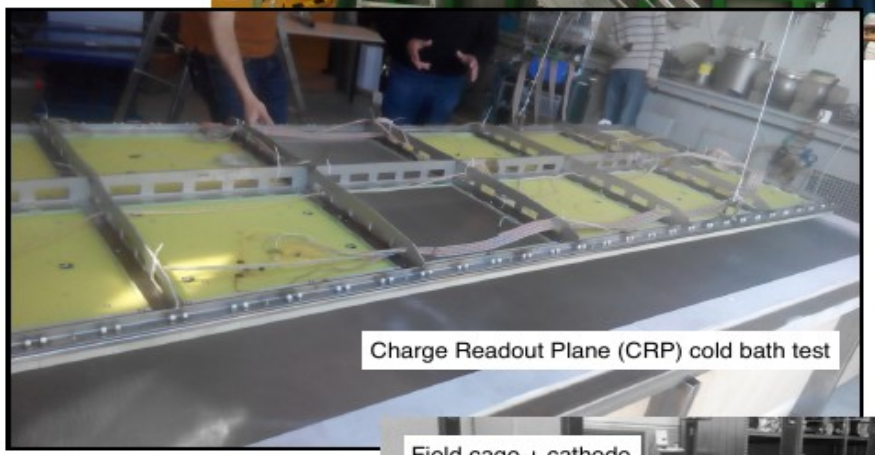
Prototype at CERN PS East Area, b182

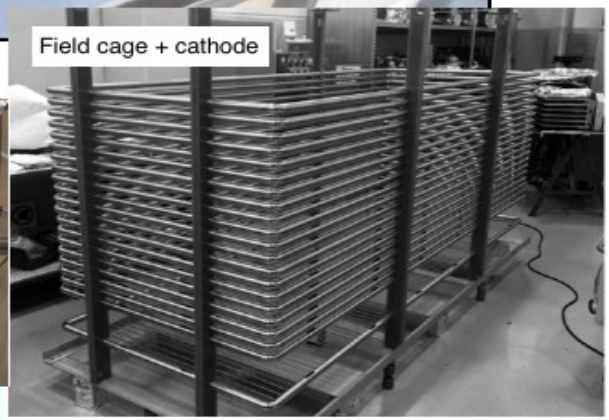
10-ton scale Dual Phase LAr TPC

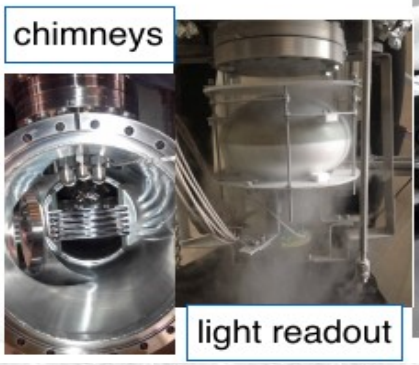
(3x1x1 m³ active 24 ton LAr total)

Detector integration in progress
Cryogenic Operation: September 2016







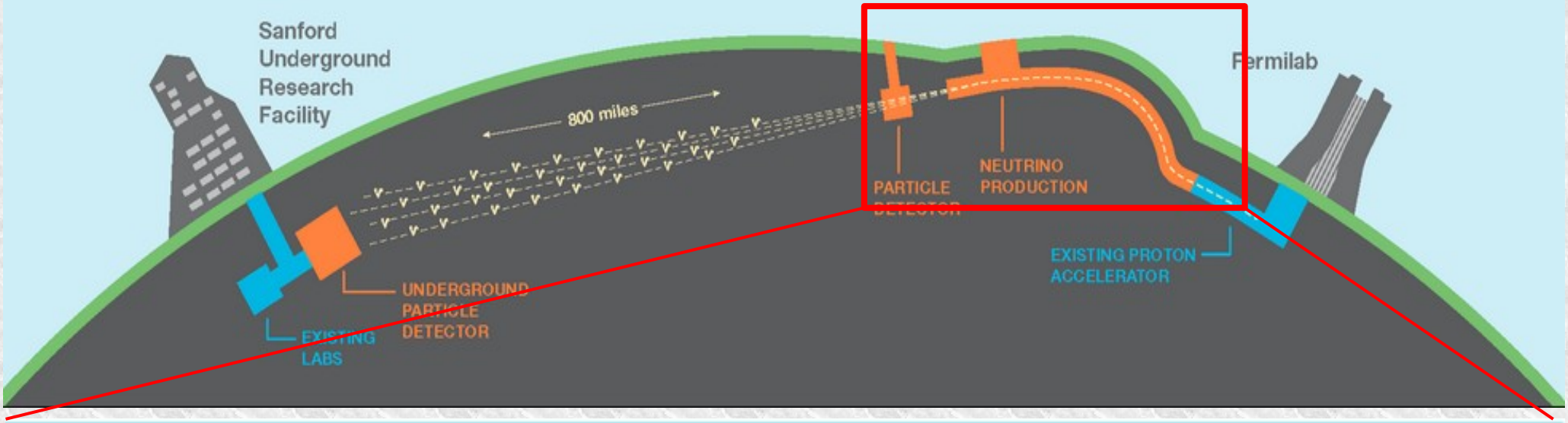


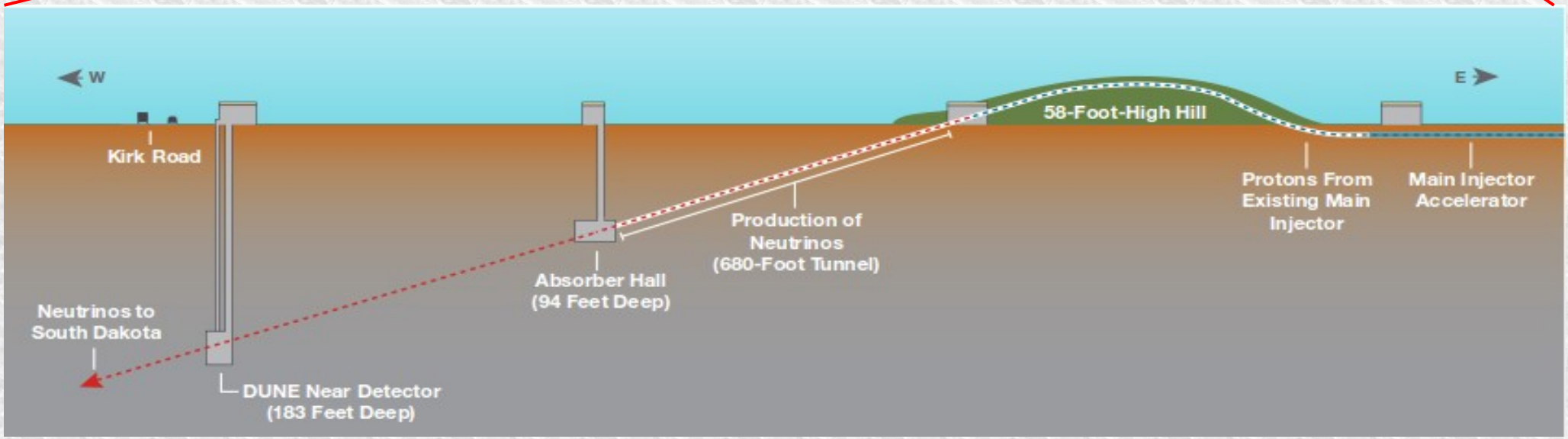
Long-Baseline Program

Deep Underground Neutrino Experiment (DUNE) at LBNF

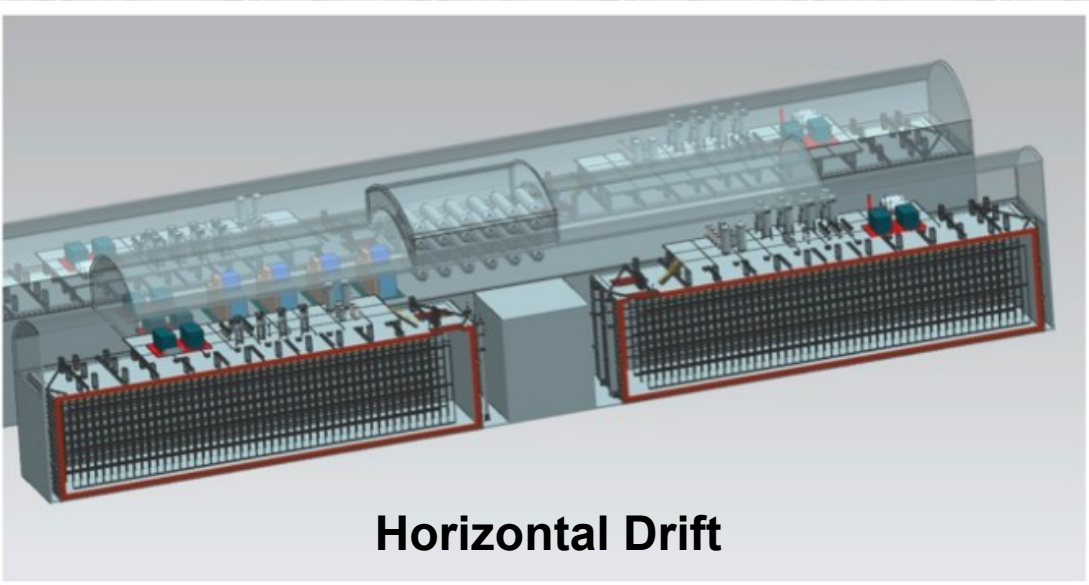
~150 International Institutions, ~800 physicists from 27 countries

Long-Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE)
Conceptual Design Report Volume 2: The Physics Program for DUNE at LBNF
R.Acciarri et al., DUNE collaboration, arXiv:1512.06148

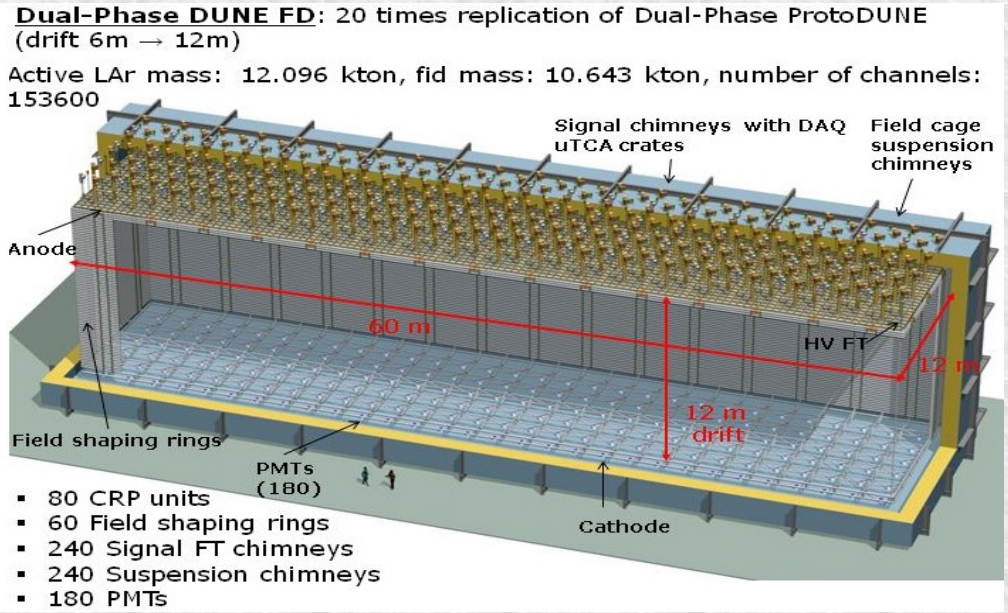




Long-Baseline Program (DUNE)



Horizontal Drift



Far Detector

Goal: 40 kton active LAr mass

Single phase and Dual phase TPC

- Pattern recognition
- Energy measurement
- Particle ID

} O(MeV) to O(GeV)

Near Detector

aim at LAr TPC (ARGONCUBE technology)

Excavation complete by 2021, first 10-kt cryostat equipped by 2023, 1.2 MW beam by 2025

Conclusions

The Swiss community has been very successful in neutrino physics. Discoveries were made and experimental results were obtained in the last years.

Strong visibility of Swiss researchers

Coordinated effort in accordance with the Swiss Particle Physics Road Map: Recent White Paper with identified priorities

Unique knowledge and experience accumulated over past years on key technologies for the future projects: base for success

New generation of young scientists