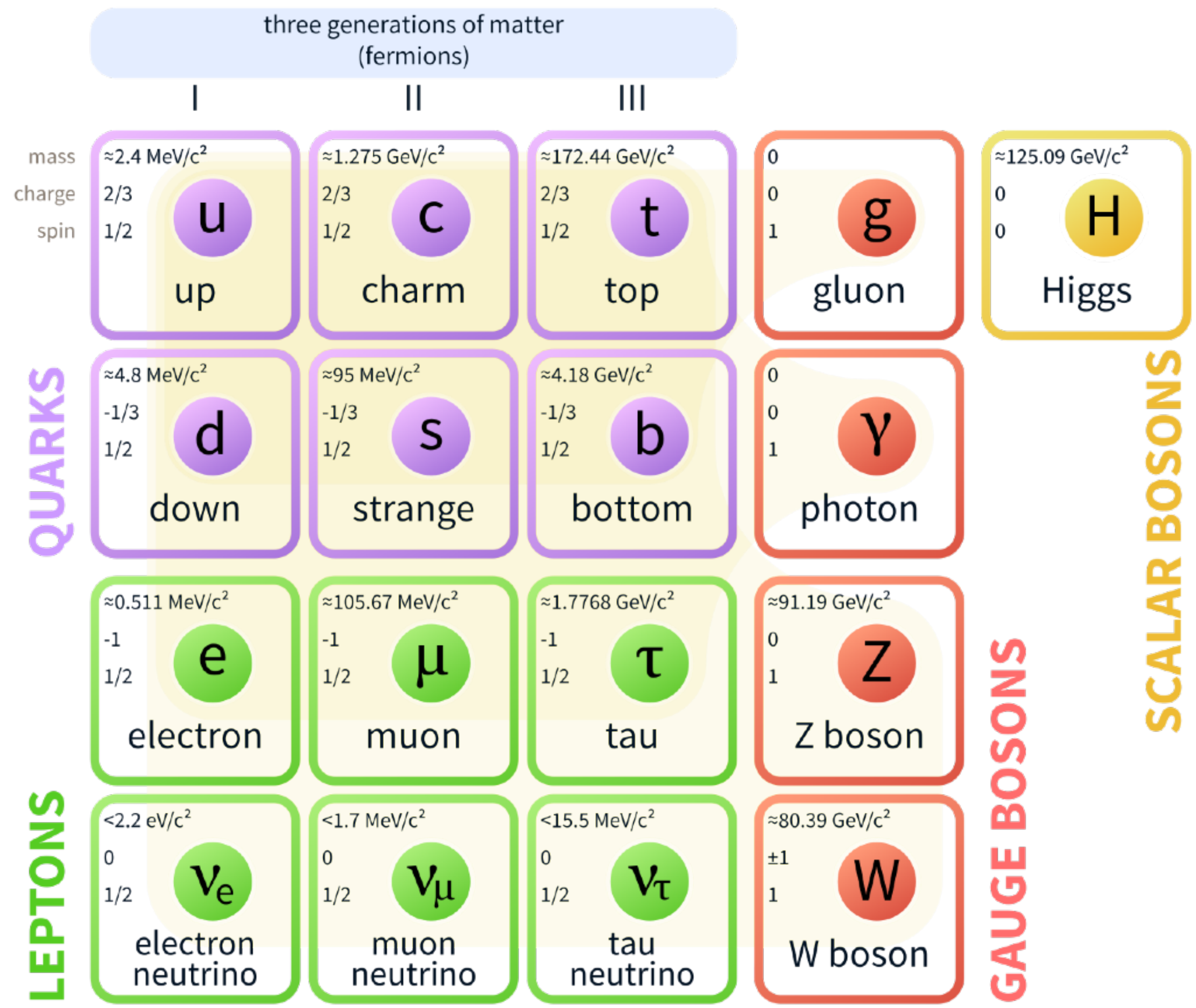
CERN efforts for future Neutrino Programs

Filippo Resnati (CERN EP-NU)

Seminar at Physics Department - UniGE - Geneva - 22/11/2017

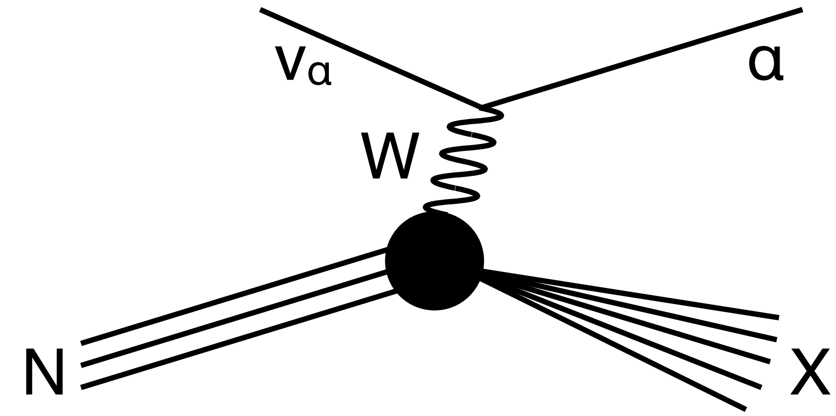
Why neutrinos?



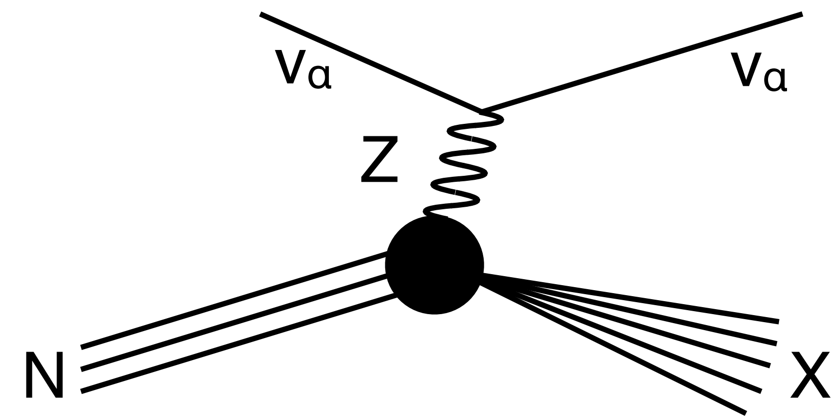
Classical Standard Model states:
- Neutrinos are massless
- Lepton flavour is conserved

Flavour and cross section

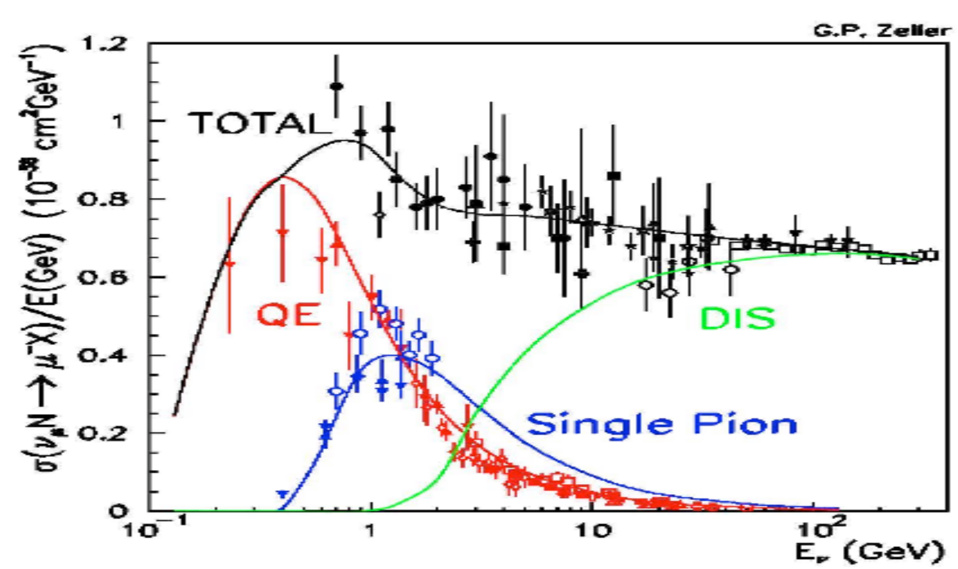
Charged current interactions (CC).
The flavour ν_α of the neutrino defined by the charged lepton α.



Neutral current interactions (NC).
The flavour of the neutrino cannot be determined.

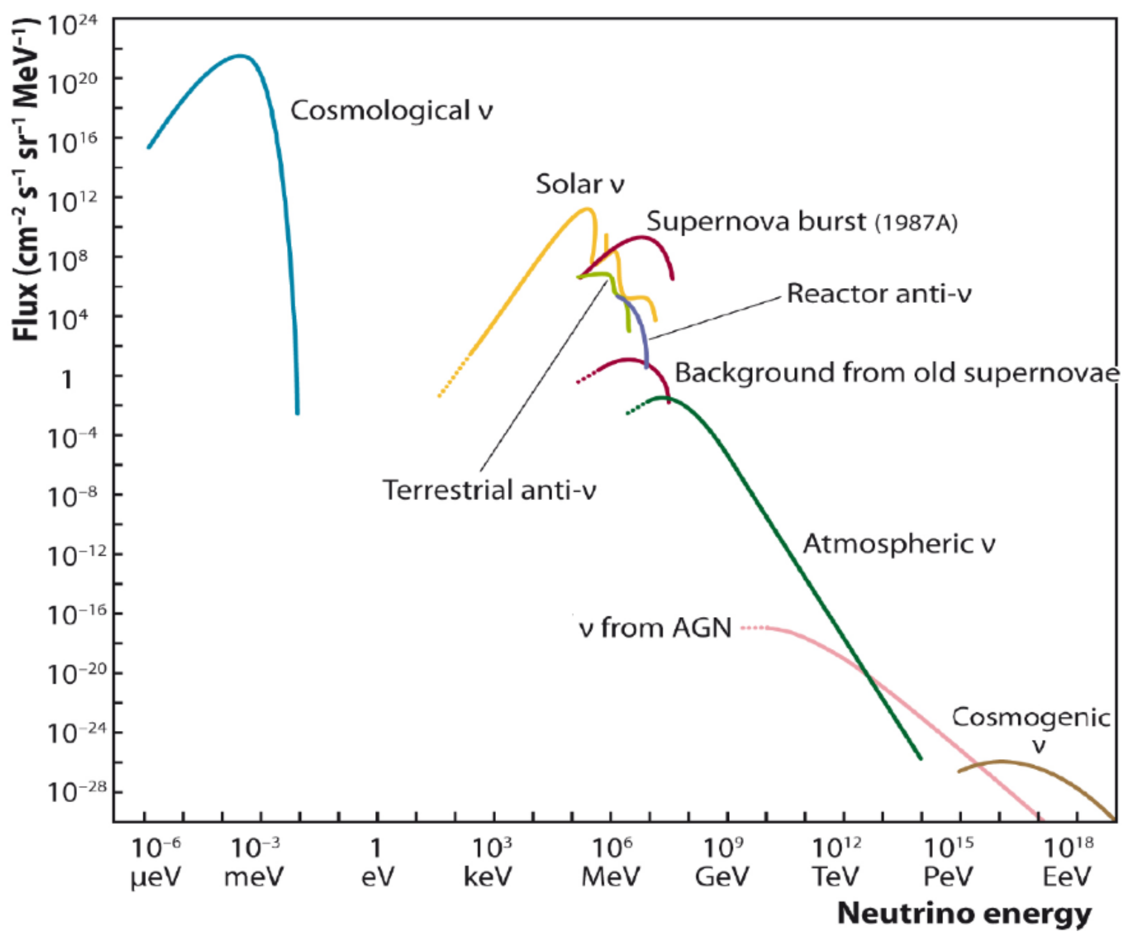


Weakly interacting.
Very light and interacting only weakly ($\sigma_{\nu\text{->}N}/E_\nu \approx 10^{-38}$ cm^2/GeV).
1 GeV neutrino mean free path in lead ≈ 10^{11} m.



Neutrino sources

Natural



Katz, U.F. et al. Prog.Part.Nucl.Phys. 67 (2012) 651

Artificial:

- Fission reactors O(MeV)
- Standard accelerators O(GeV)
- Radioactive sources
- *Neutrino factories*
- *Beta beams*

History

1930 - Pauli postulates the existence of neutrino (called neutron)
"I have done a terrible thing, I have postulated a particle that cannot be detected"
W. Pauli 1930

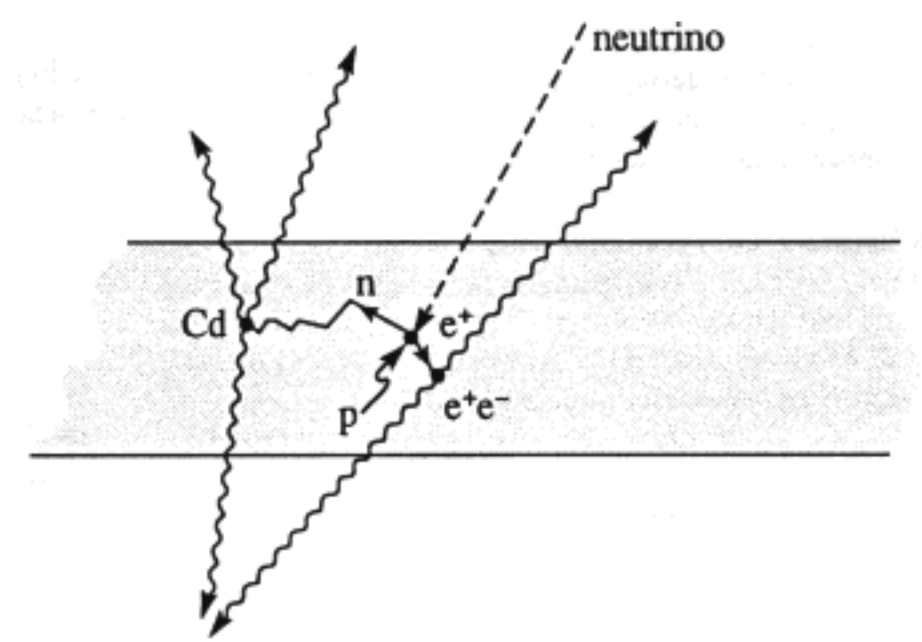
1932 - Chadwick discovers the neutron

1933/4 - Fermi proposes the name neutrino and publishes the beta decay theory

1956 - Cowan and Reines discover the (electron anti-)neutrinos

Cowan - Reines
anti-ν_e + p -> n + e^+
n + ^{108}Cd -> ^{109}Cd + γs
e^+ + e^- -> 2γ

reactor

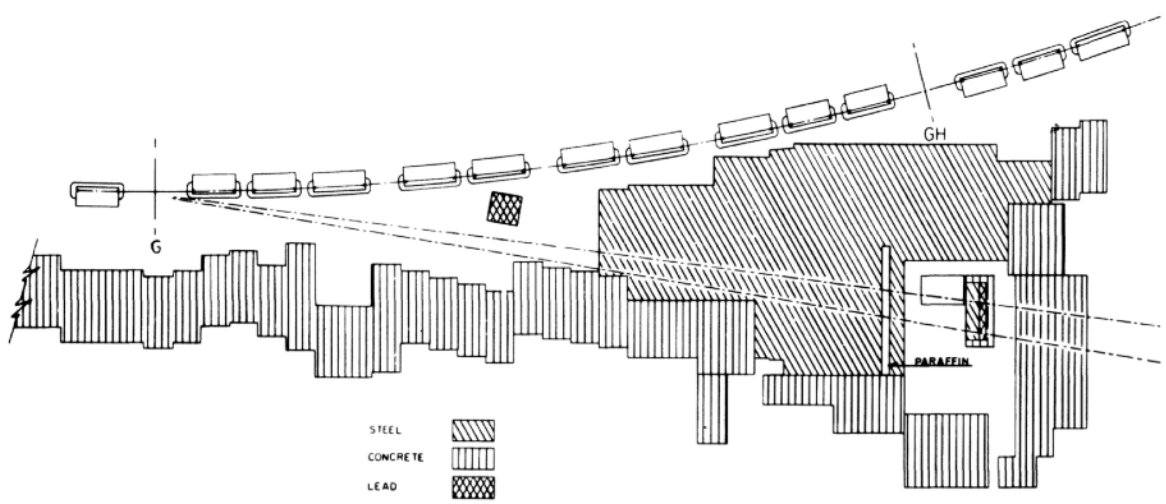


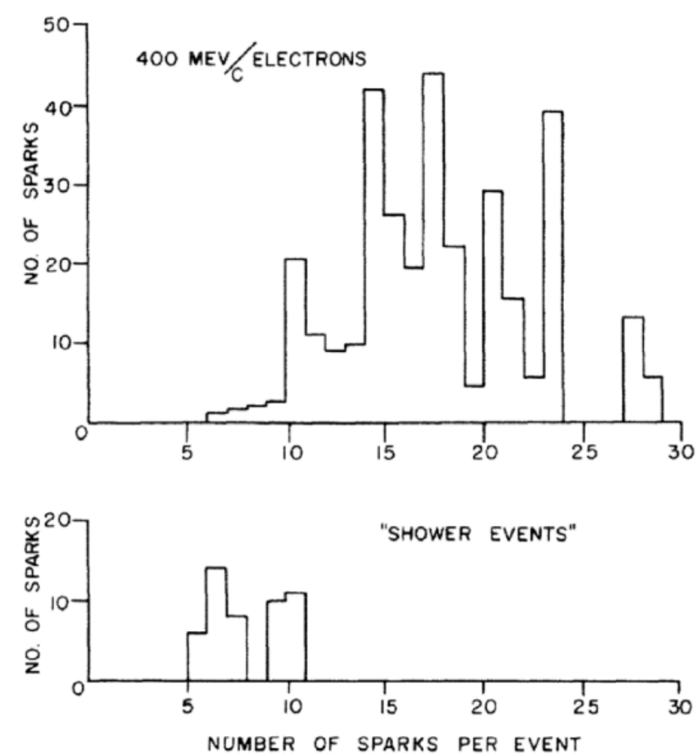
History

1959 Pontecorvo suggests the existence of two types of neutrinos

1962 Lederman, Schwartz and Steinberger discover muon neutrinos

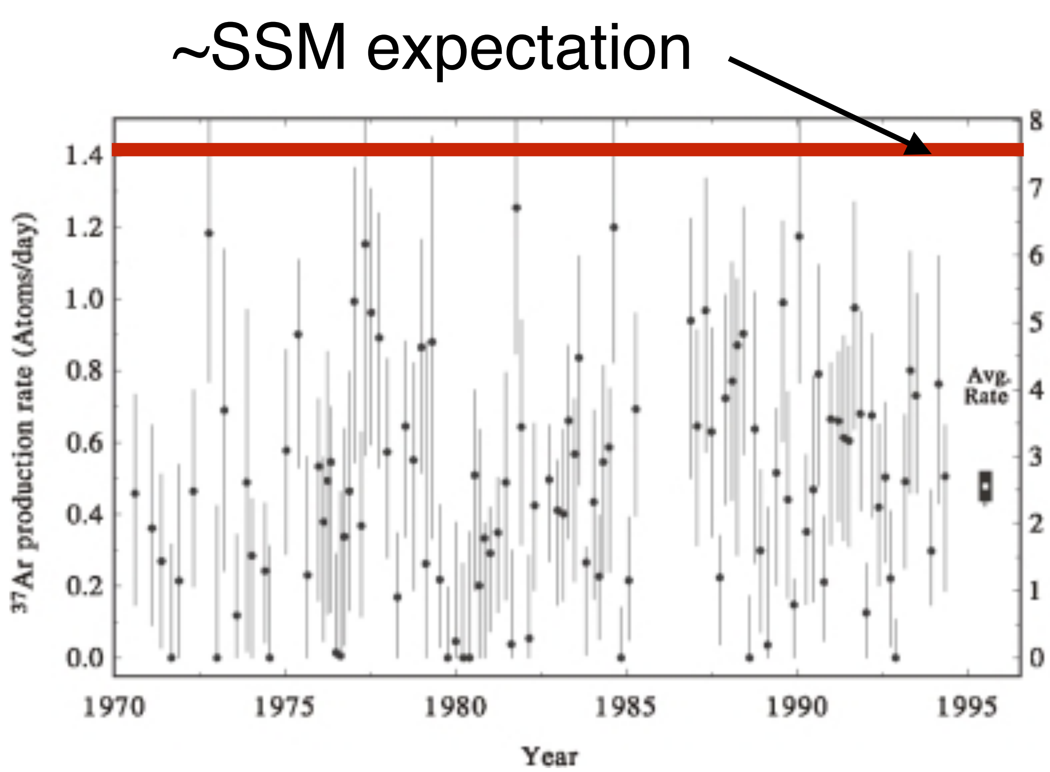
p accelerator
AGS at BNL



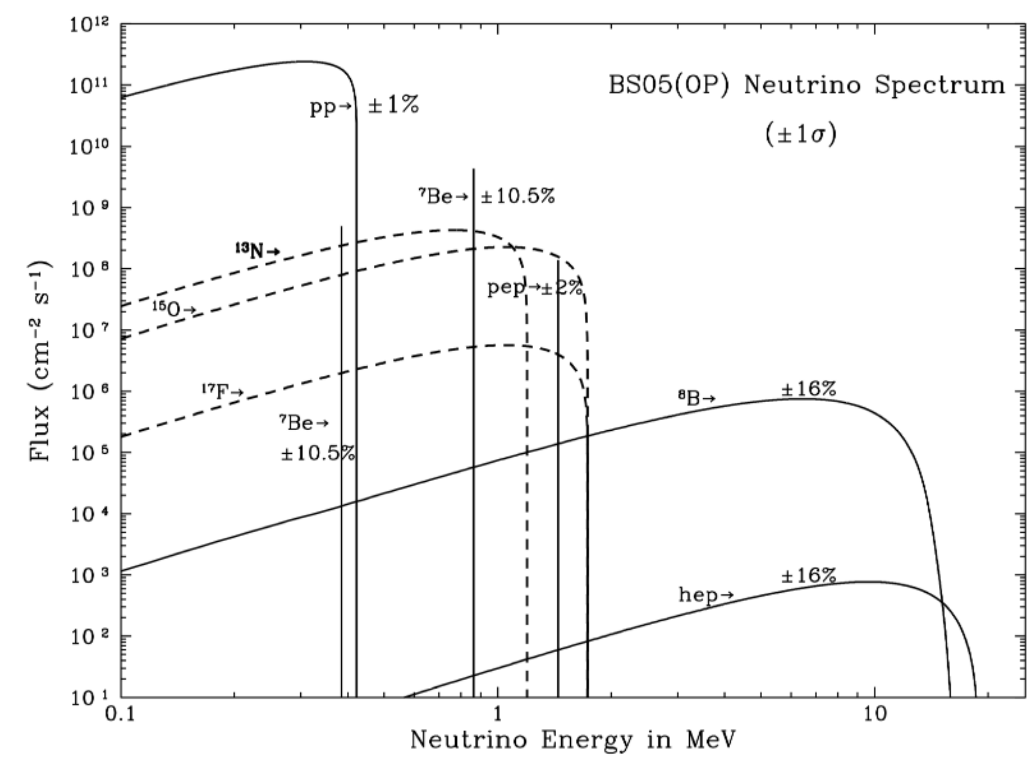


The solar neutrino problem

Homestake experiment (1970-1994)
$\nu_e + {}^{37}Cl \rightarrow {}^{37}Ar + e^-$
th ~ 0.814 MeV



$4\ {}^1H \rightarrow {}^4He + 2\ e^+ + 2\ \nu_e + 26.7$ MeV
heat flux at the hearth: 1.37 kW/m^2
64×10^9 ν/s/cm^2



Confirmations also from:

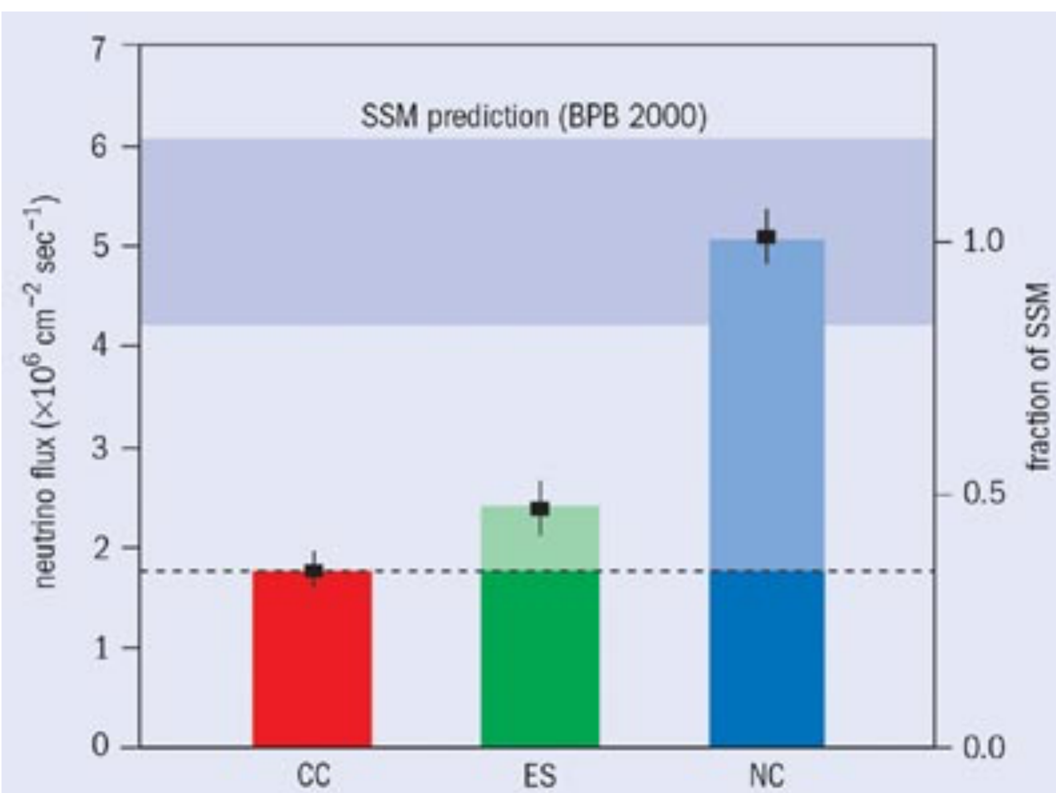
GALLEX (1991-1997) and SAGE (1990-2007)
$\nu_e + {}^{71}Ga \rightarrow {}^{71}Ge + e^-$
th ~ 0.233 MeV

Kamiokande
$\nu_e + e^- \rightarrow \nu_e + e^-$

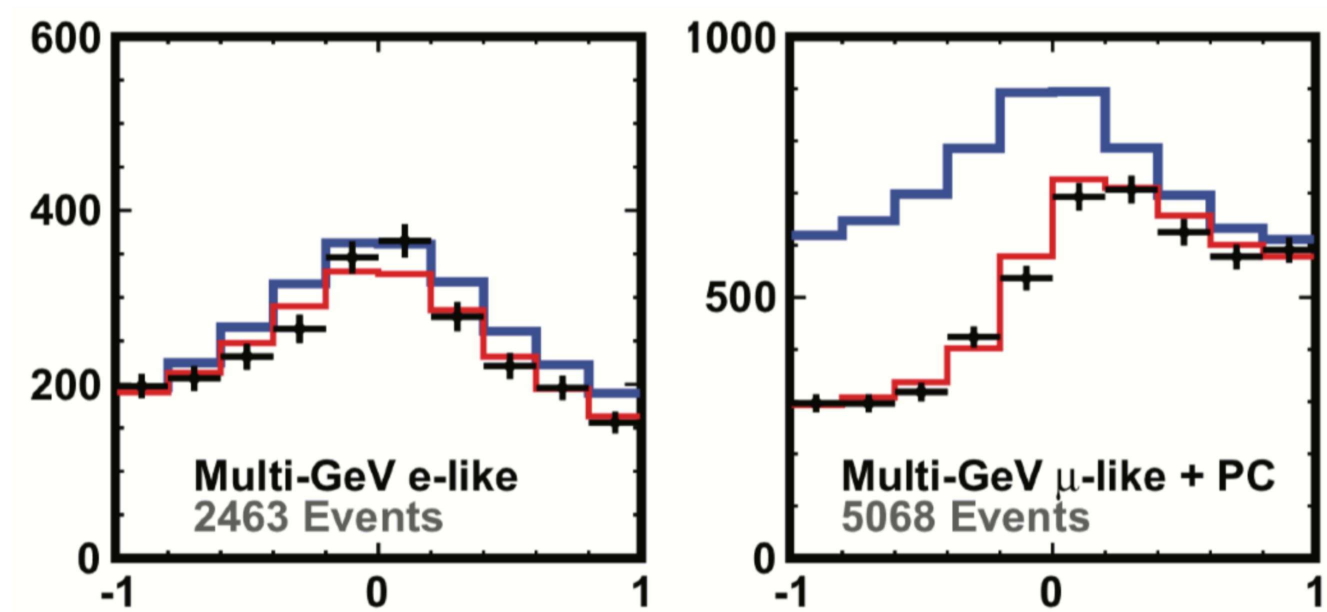
The solar neutrino solution

A. B. McDonald (SNO) and T. Kajita (SK) 2015 Nobel Prize winner

SNO
Solar neutrinos
CC: ν_e + d -> 2 p + e^-
NC: ν_x + d -> p + n + ν_x



Super-Kamiokande
Atmospheric neutrinos
Angolar resolutions
different baselines

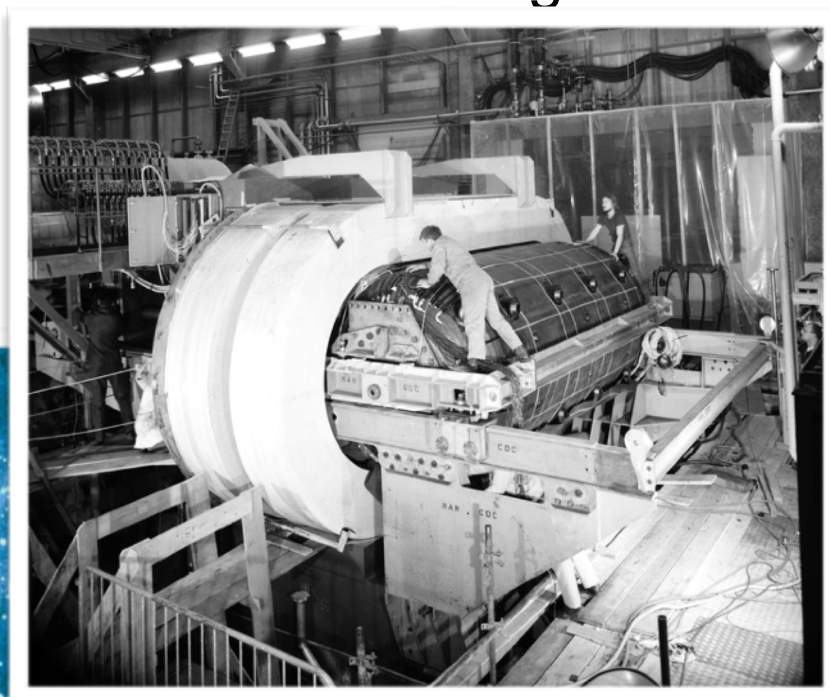


$\cos(\theta_{zenith})$ $\cos(\theta_{zenith})$

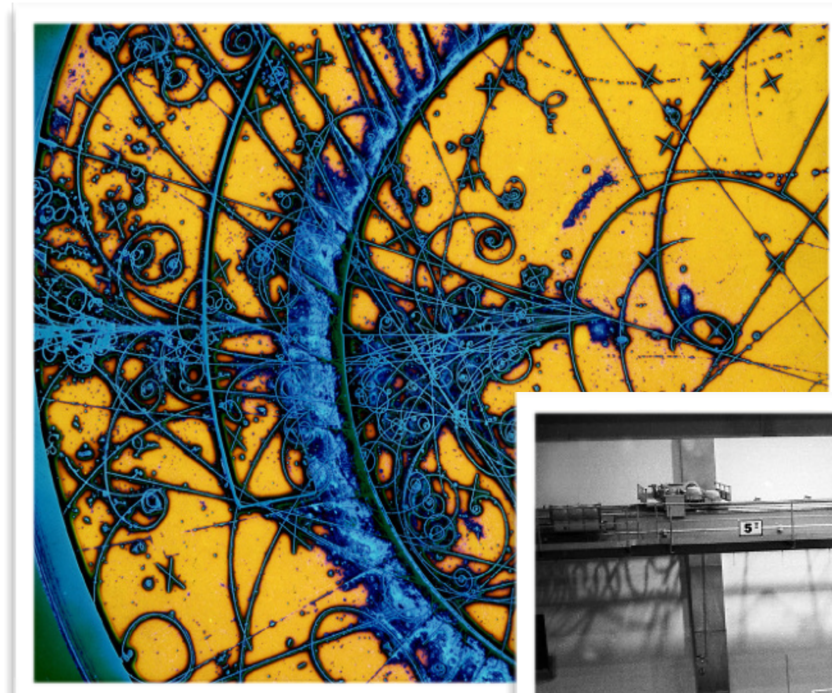
Neutrinos oscillate, change flavour along their flight
Flavour states are superimposition of mass states

At CERN

1970-1979 Gargamelle

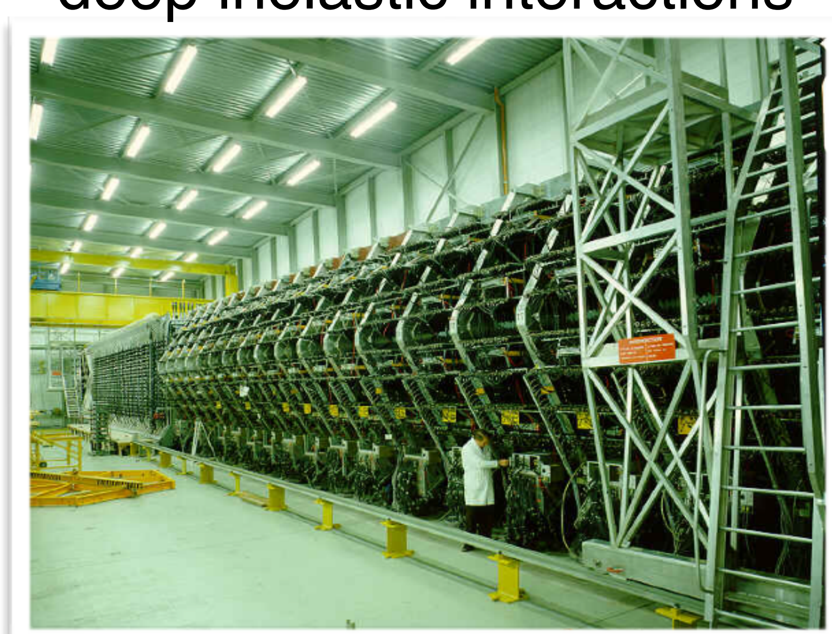


Discovery of neutral currents



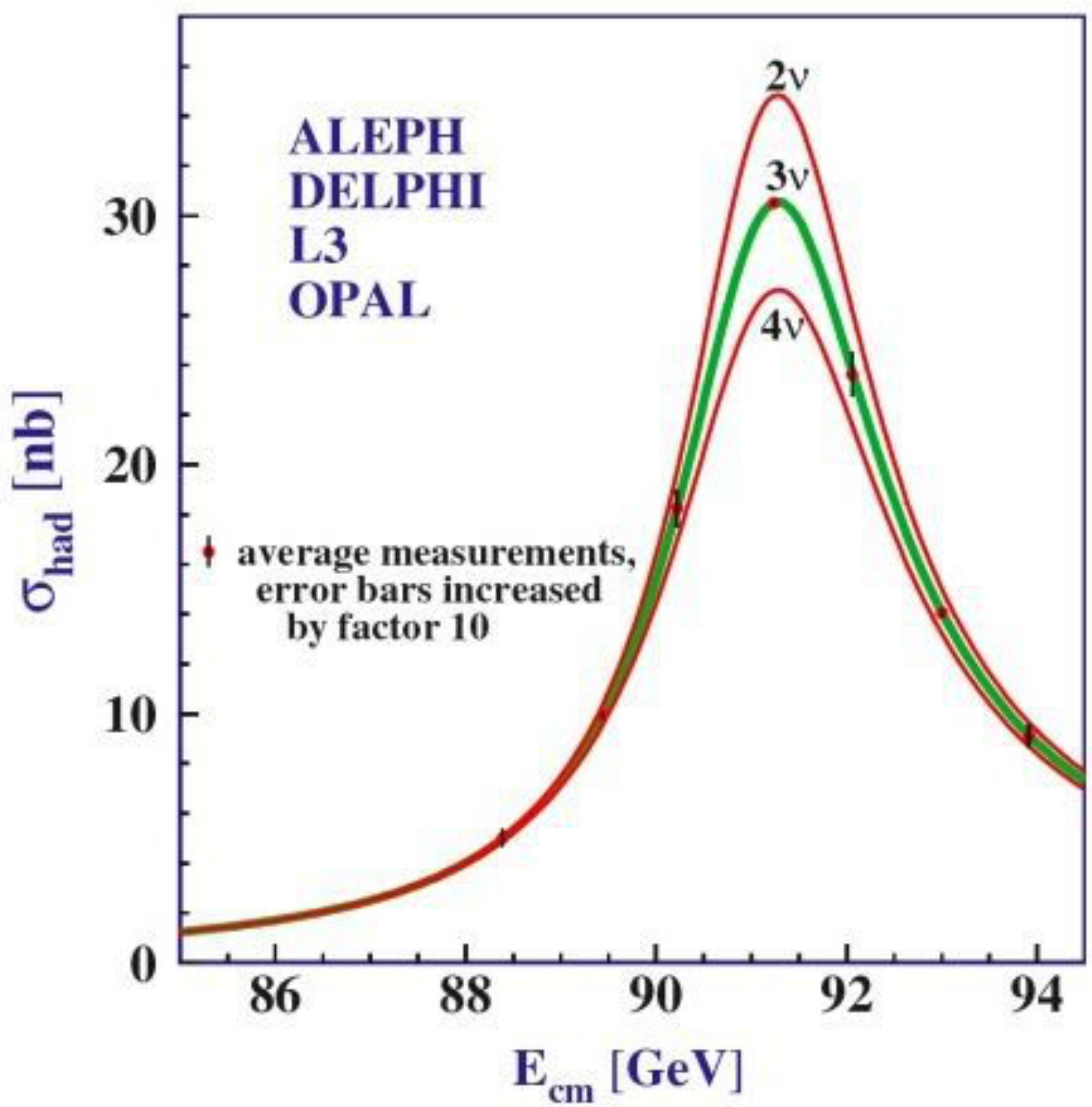
BEBC 1960-1984

1976-1984 CDHS,
deep inelastic interactions



At CERN

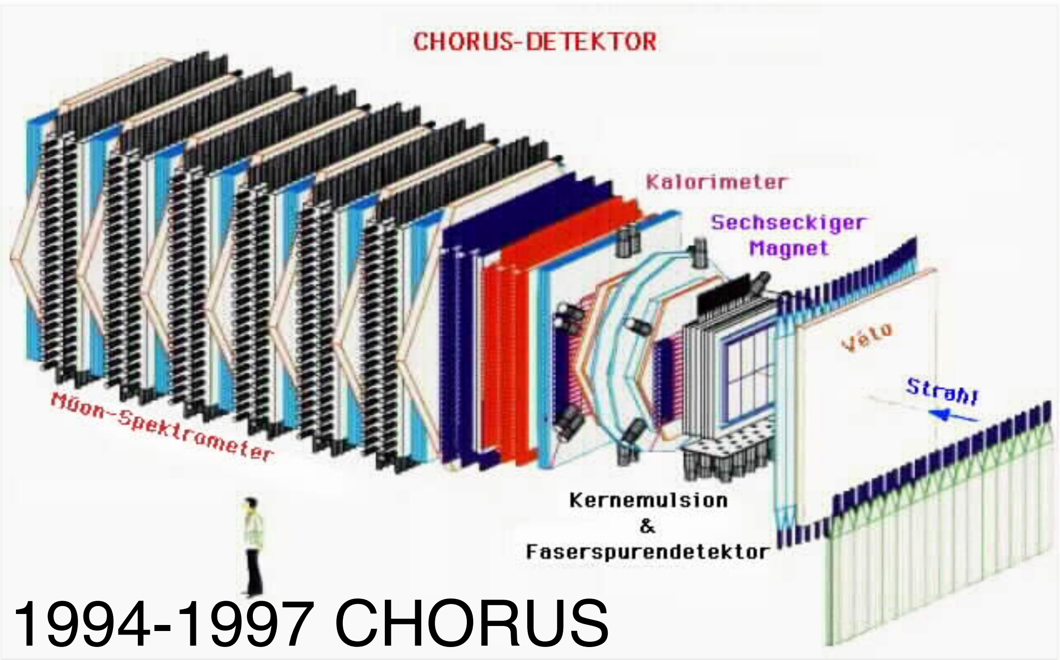
From the width of Z boson



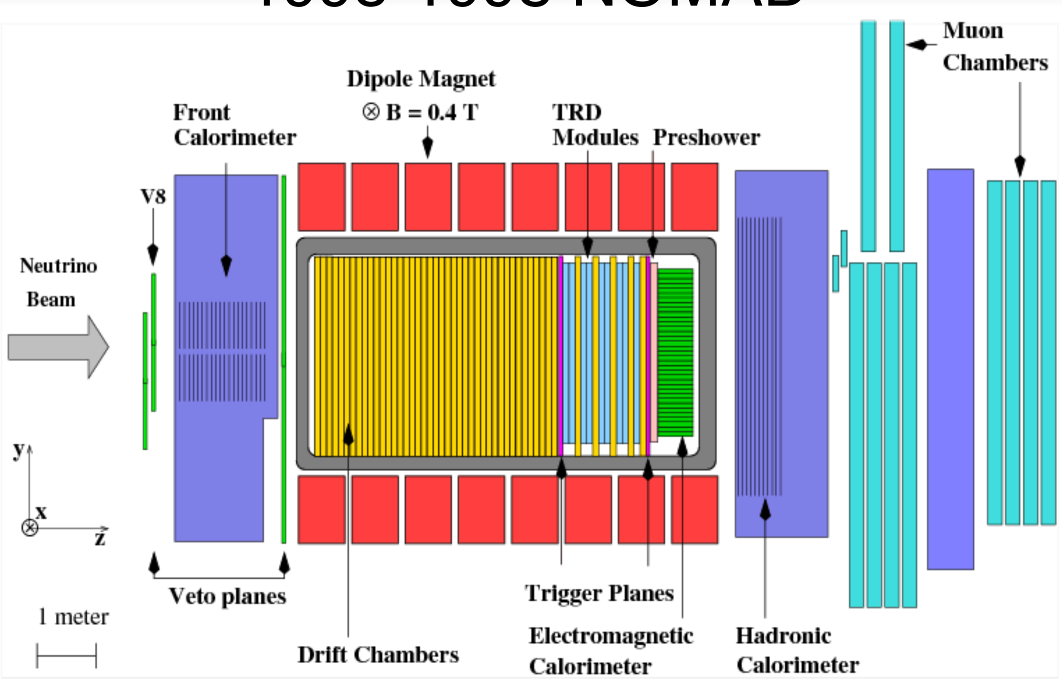
Number neutrino families (light and coupling with the Z): 2.9840 ± 0.0082

Oscillation at CERN

$\nu_\mu \rightarrow \nu_\tau$ oscillation



1995-1998 NOMAD



CNGS neutrino beam

Today's understanding

Flavour eigenstates superimposition of mass eigenstates
PMNS matrix: three angles and one phase (+ two Majorana phases)
Angles -> amplitude of the oscillation
Δm^2 -> frequency of oscillation

$$| \nu_\alpha \rangle = \sum_k U_{\alpha k} \mid \nu_k \rangle \qquad P(\nu_\alpha \to \nu_\beta) = |\langle \nu_\beta \mid \nu_\alpha \rangle|^2 \approx \left| \sum_k U^*_{\alpha k} U_{\beta k} e^{-i m_k^2 t/(2E)} \right|^2$$

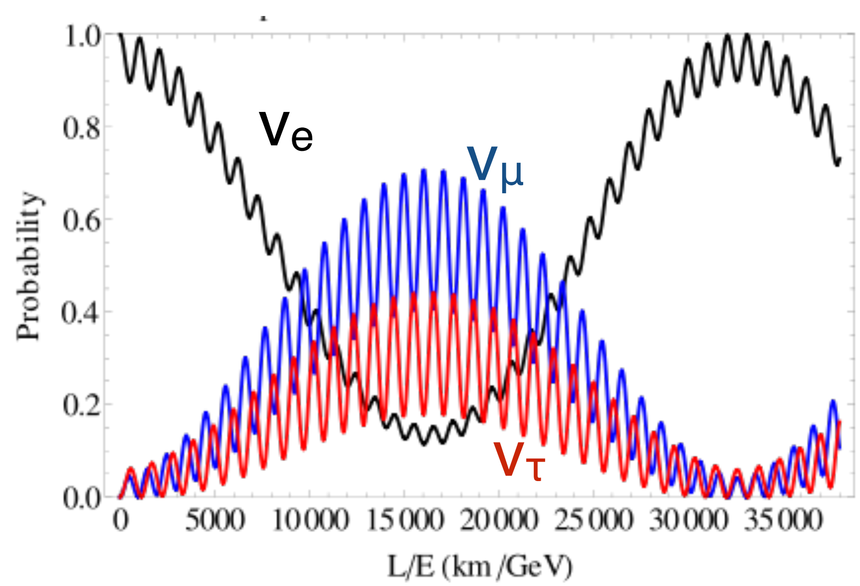
$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin(\theta_{13}) e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin(\theta_{13}) e^{i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

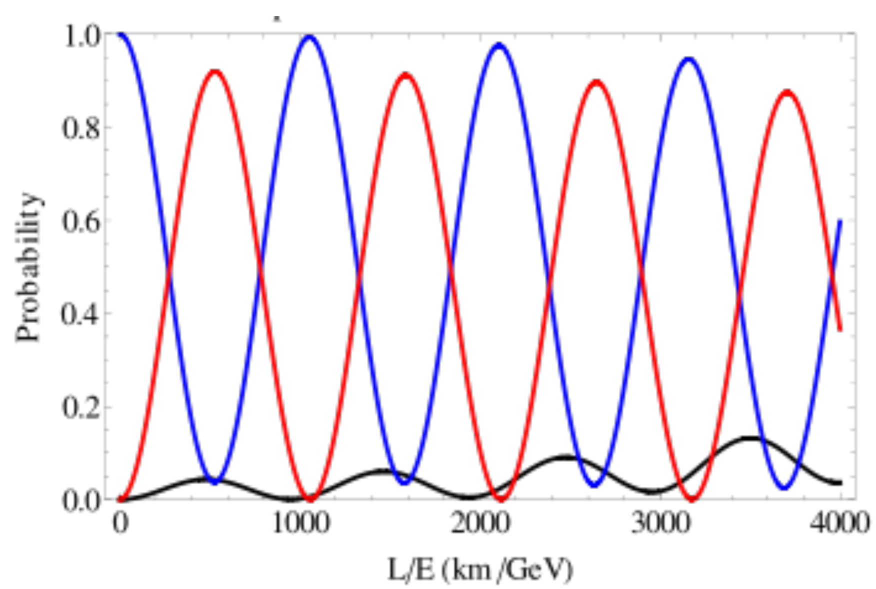
SK, K2K, T2K, MINOS, OPERA, NOVA

DChooz, DayaBay, RENO, T2K, MINOS, NOVA

S-K, SNO, KamLAND

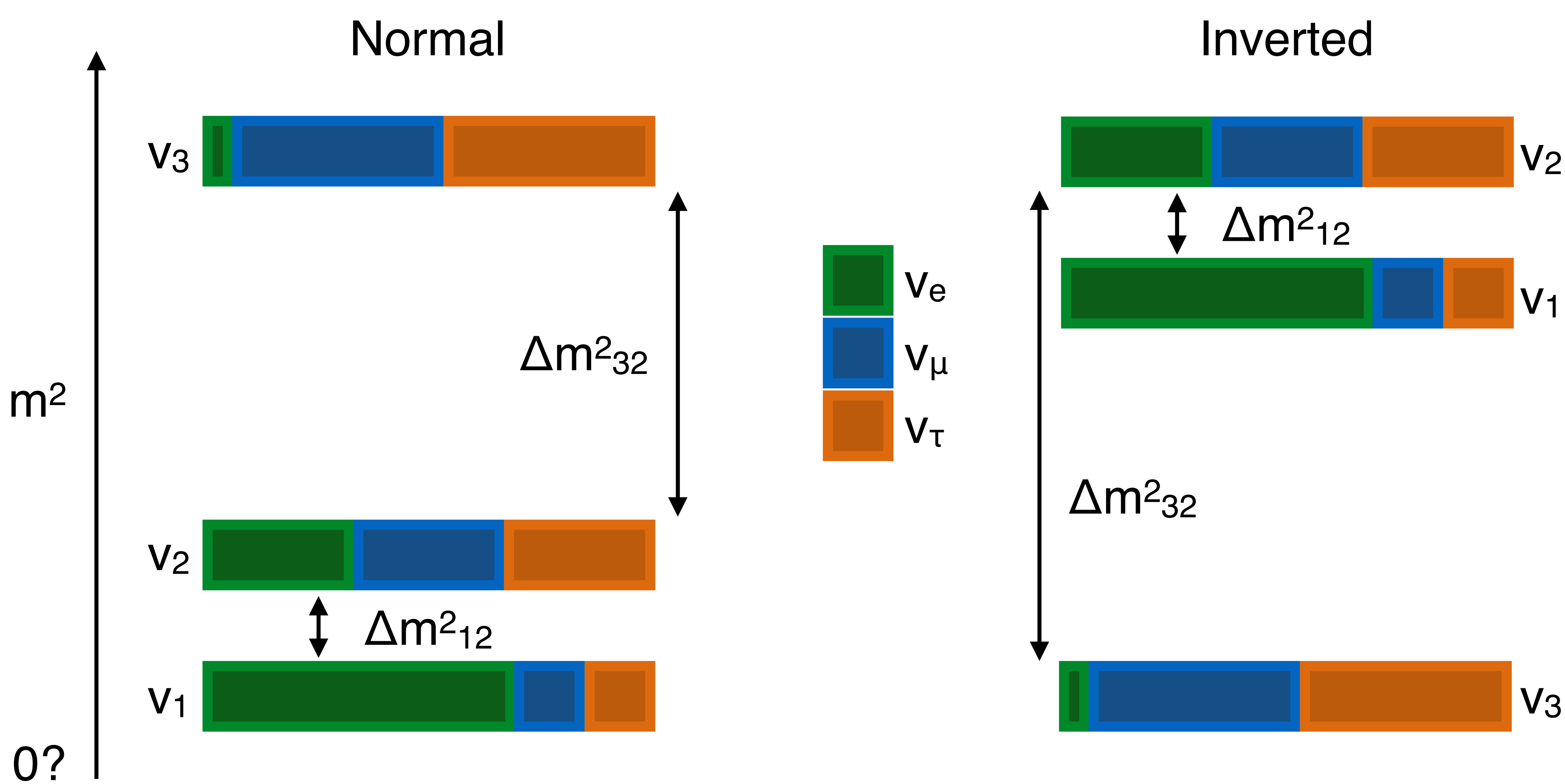
$\theta_{23} \sim 33^o$
$\theta_{13} \sim 45^o$
$\theta_{12} \sim 9^o$
$\Delta m^2_{12} \sim 7.5\text{x}10^{-5}$ eV^2
$|\Delta m^2_{13}| \sim 2.4\text{x}10^{-3}$ eV^2



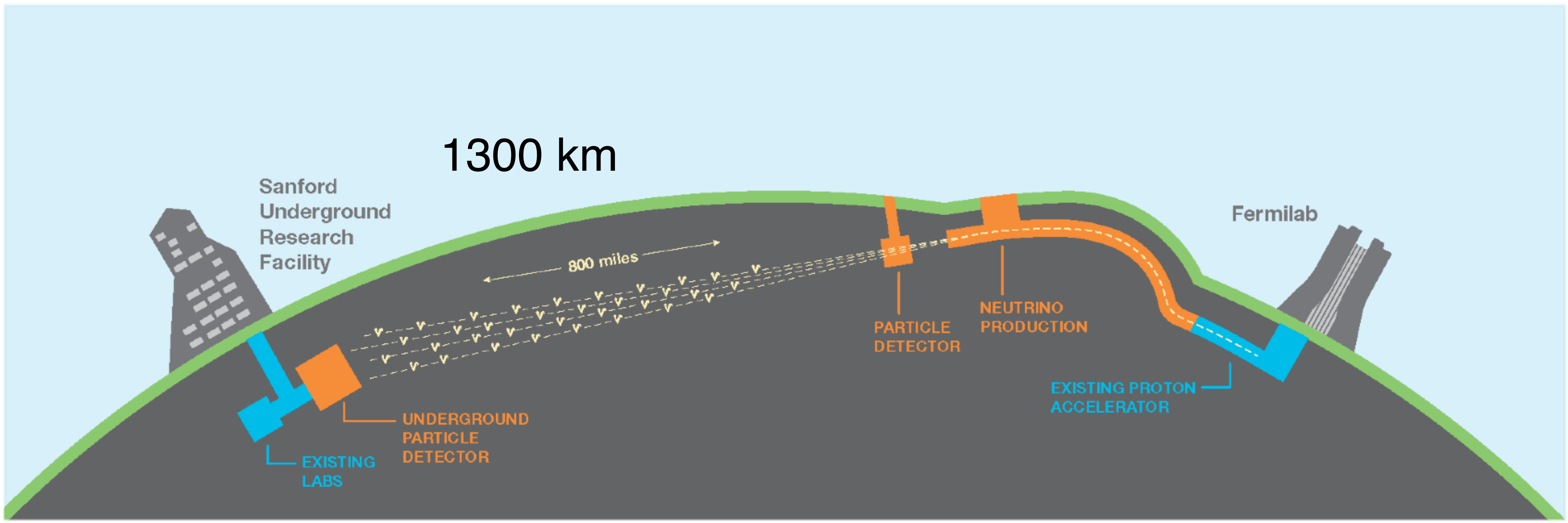


Open questions

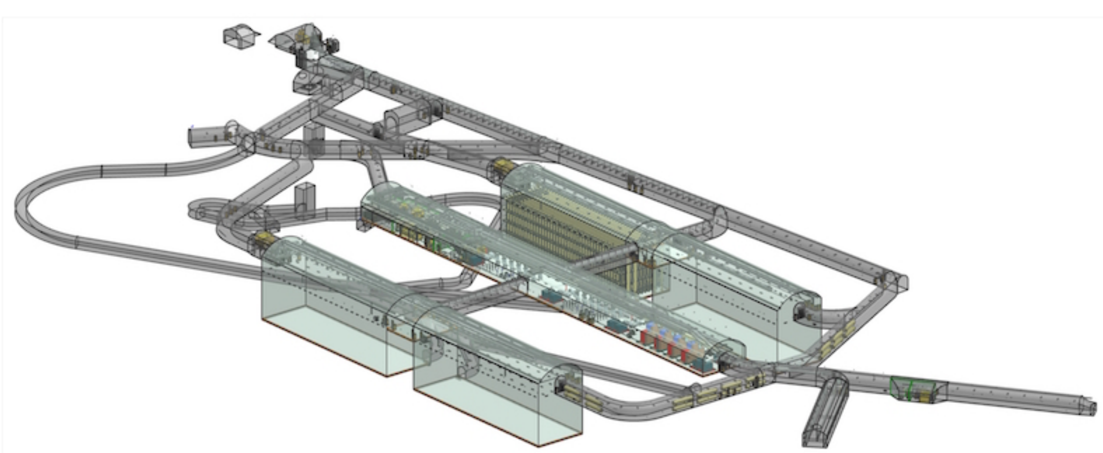
Unknowns:
- δ_{cp}, neutrinos and anti-neutrinos behave differently? LB
- mass hierarchy (sign of Δm^2_{32}), LB
- absolute mass scale,
- Dirac/Majorana, ν_L = anti-ν_R?
- sterile neutrino, forth (or more) generation(s)? SB



LBNF/DUNE



1500 m underground facility



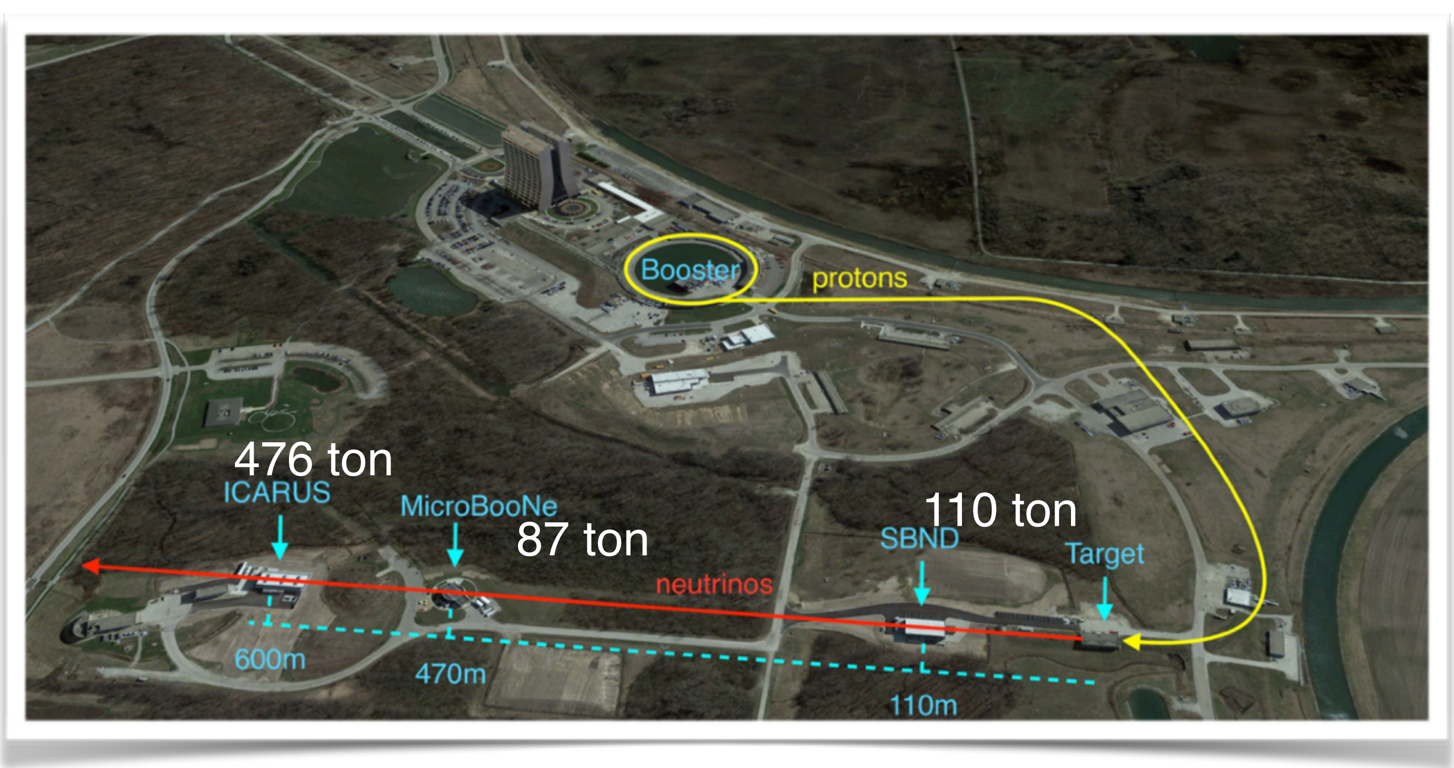
LBNF is the facility, DUNE is the experiment
- World most intense neutrino beam (wide energy)
- 4 x 10 kton active mass underground LAr TPCs

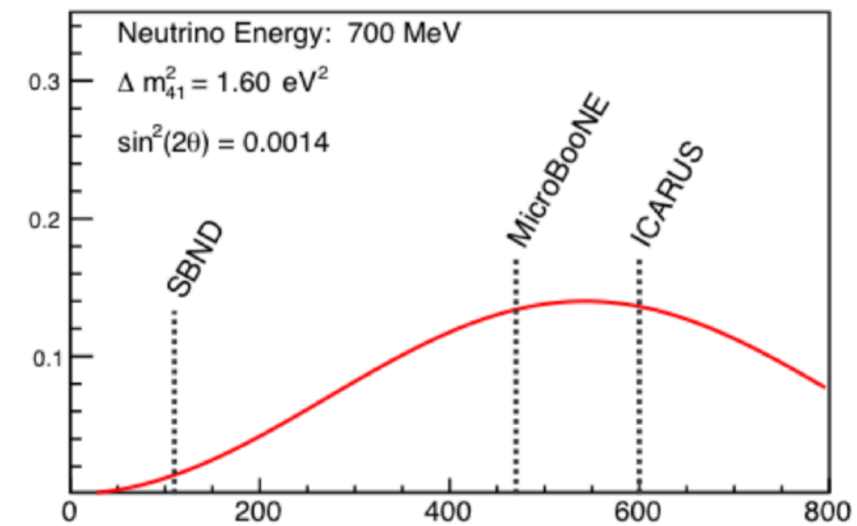
Goals:
- neutrino mass hierarchy through MSW effect
- δ_{cp} from oscillation pattern and ν/anti-ν
- proton decay search
- neutrino from supernovae

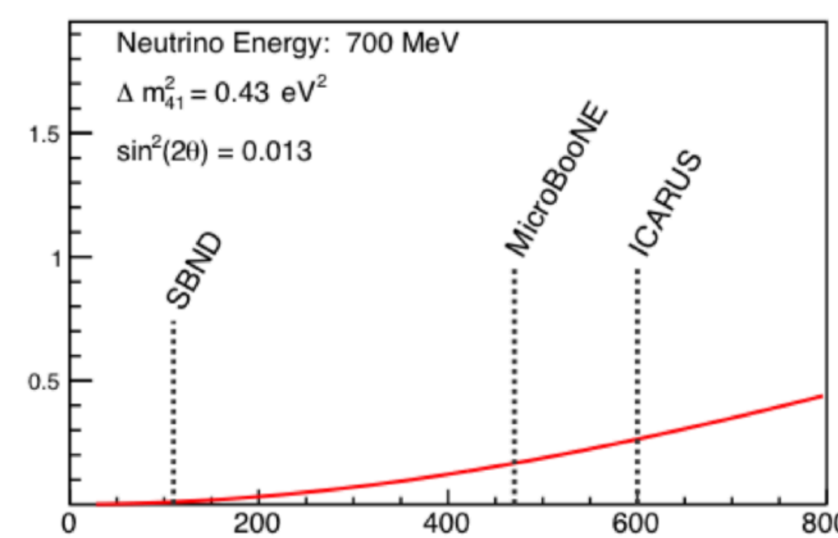
SBN program

A physics program with 3 LAr TPCs in the Fermilab Booster Neutrino Beam:
- Explore neutrino oscillations beyond three-neutrino mixing
- Search for eV mass-scale sterile neutrinos in both appearance and disappearance channels
- Resolve the LSND and MiniBooNE anomalies
- Measure ν-Ar cross-sections in the sub-GeV to few-GeV region
- Further advance LAr TPC technology and build up experience relevant for the (LBNF/DUNE)

three baselines -> redundancy and oscillation pattern
same target -> minimise cross section systematics
same technology -> minimise detector systematics







2013 European Strategy

High-priority large-scale scientific activities

"Rapid progress in neutrino oscillation physics, with significant European involvement, has established a strong scientific case for a long-baseline neutrino programme exploring CP violation and the mass hierarchy in the neutrino sector. ***CERN*** *should develop a* ***neutrino programme 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****."*

2013 European Strategy

In other words:

- No neutrino beam at CERN

- Neutrino beam in US and Japan (maybe also in EU ESS?)

- A structure at CERN to foster an active involvement of Europe and CERN in the US and Japanese new programs

This led to the establishment of the CERN Neutrino Platform part of the CERN Medium Term Plan since 2015

NP mandate

- **Assist** the various groups in their R&D phase in the short and medium term and give **coherence** to a fragmented European Neutrino Community

- Provide a charged particle test beam **infrastructure** for tests and R&D

- Bring R&D programs to the level of **technology demonstrators** in view of major construction activities

- Continue **neutrino beam** R&D, as possible basis for further collaborations

- Support the **short baseline** activities (infrastructure & detectors)

- Support the **long baselines** activities (infrastructure & detectors)

- Be a partner in the **physics exploitation**

MoU framework

Memorandum of Understanding for providing a framework for developing a Neutrino Program at CERN https://edms.cern.ch/document/1353815

NP reacts on **input from the community**

As of October 2017, **106** institutes signed the MOU

CERN SPS Committee (SPSC) as an entry point

NP participations

Acad. of Sciences, Czech Republic; AGH University of Science and Technology, Krakow, Poland; Alikhanian National Science Laboratory (YerPhi), Armenia; Argonne National Laboratory, United States; Boston University Study Abroad Program Geneva, Switzerland; Brookhaven National Laboratory, United States; Campinas University, Brazil; CEA/IRFU,Centre d'études de Saclay Gif-sur-Yvette – IRFU, France; Centre d'études nucléaires de Bordeaux-Gradignan, France; Centre National de la Recherche Scientifique - LAPP-Laboratoire d'Annecy-le-Vieux; France; Centro de Investigaciones Energéti cas Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain; Colorado State University, United States; Czech Technical University, Czech Republic; Dipartimento de Fisica e Astronomia, Universita di Roma, Italy; Dipartimento di Fisica E. Pancini, Università di Napoli Federico II, Italy; Dipartimento di Fisica, Universita di Bari, Italy; Dipartimento di Fisica, Universita di Bologna, Italy; Dipartimento di Matematica e Fisica, Universita del Salento, Lecce, Italy; Dipartimento di Matematica e Fisica, Universita Roma Tre, Italy; Duke University, United States; ETH Zurich Institute for Particle Physics, Switzerland; European Organization for Nuclear Res. (CERN), Federal University of ABC, Brazil, Fermi National Accelerator Lab., United States; High Energy Accelerator Research Organization, Tsukuba, Japan, Indiana University, Bloomington, United States; INFN e Laboratori Nazionali di Frascati, Italy; INFN, LNGS, Assergi, Italy; INFN, Rome, Italy; INFN, Sezione de Bari, Italy; INFN, Sezione di Lecce, Italy; INFN, Sezione di Pavia, Italy; Institut de Fisica d'Altes Energies (IFAE), Bellaterra, Barcelona, Spain; Institute of Theoritical Physics and Modeling, Armenia; Joint Institute for Nuclear Research (JINR), Dubna, Russia; Justus-Liebig-Universität Gießen, Germany; Kansas University, United States; Laboratoire de physique nucléaire et de hautes énergies Paris (LPNHE), France; Laboratori Nazionali del Gran Sasso, Italy; Lancaster University, United Kingdom; Lawrence Berkeley National Lab., Berkeley, United States; Lebedev Physical Institute of Russian Academy of Science, Moscow, Russia, Lomonosov Moscow State University, Russia; Los Alamos National Laboratory, United States; Louisiana State University, United States; Michigan State University, United States; Middle East Technical University (METU), Ankara, Turkey, National Centre for Nuclear Research, Otwock, Poland, National Taras Schevchenko University of Kyiv, Ukraine, National Technical University of Athens, NTUA, Greece; OMEGA Ecole Polytechnique IN2P3 / CNRS, France; Princeton University, United States; Roma 2, Italy; Ruder Boskovic Institute, Zagreb, Croatia, Russian Academy of Sciences - Institute for Nuclear Research, Russia; SLAC National Accelerator Laboratory, United States; South Dakota School of Mines and Technology, Rapid City, United States; Southern Methodist University, Dallas, United States; State University of New York (Stonybrook), United States; STFC - Rutherford Appleton Lab. - Rutherford Appleton Laboratory, United Kingdom; Theoretical Nuclear Physics Research Group, Department of Physics and Astronomy, Ghent University, Belgium; Univ. of Valencia and CSIC - Instituto de Fisica Corpuscular (IFIC), Spain; Universita & INFN, Milano-Bicocca, Italy; Università degli Studi e INFN Milano - Sezione di Milano, Italy; Universita e INFN, Bologna - Sezione di Bologna (INFN) , Italy; Universita e INFN, Catania - Sezione di Catania, Italy; Universita e INFN, Napoli - Sezione di Napoli (INFN) , Italy; Universita e INFN, Padova, Italy; Universitaet Bern - Laboratorium fuer Hochenergiephysik, Switzerland; Universite Claude Bernard-Lyon I - Institut de Physique Nucleaire de Lyon, France; Universite de Geneve - Dept. de Phys. Nucl. et Corpuscul., Switzerland; Universite de Paris VII - Laboratoire APC - Astroparticules et Cosmologie, France; Université Paris Diderot, France; Université Pierre et Marie Curie (UPMC) et Paris Diderot, France; Université Savoie Mont Blanc, France; University of Bristol, United States; University of California Davis, United States; University of California Los Angeles, United States; University of California, Berkeley, United States; University of California, Irvine, United States; University of Cambridge, United Kingdom; University of Glasgow, United Kingdom; University of Hawaii, Honolulu, United States; University of Houston, United States; University of Jyvaskyla - Department of Physics, Finland, University of Liverpool, United Kingdom; University of London - University College London, United Kingdom; University of Manchester, United Kingdom; University of Minnesota, United States; University of Minnesota, Duluth, United States; University of Oulu, Finland, University of Oxford - Particle Physics, United Kingdom; University of Pennsylvania, Philadelphia, United States; University of Pittsburgh, United States; University of Seville, Spain; University of Sheffield, United Kingdom; University of Sofia, Department of Physics, Bulgaria, University of Sussex, United Kingdom; University of Texas, Arlington, United States; University of Warwick, United Kingdom; University of Wisconsin, Madison, United States; Virginia Tech, United States; Warsaw University of Technology, Poland, William & Mary College, United States; Yale University, United States;

October 2017

NP activities

Project already *approved* by the SPSC:

NP01 (WA104): ICARUS detector as far detector for the SBN program in the US

NP02 (WA105/ProtoDUNE-DP): R&D program, large size demonstrator and prototype on a charge particle beam of the double-phase LAr TPC technology

NP04 (ProtoDUNE-SP): Large size engineering demonstrator and prototype on a charge particle beam of the single-phase LAr TPC technology

NP05 (BabyMIND): Magnetised muon spectrometer for the WAGASCI experiment in Japan

NP03 (Plafond): Generic R&D framework

In addition:

- Near detector studies for T2K and DUNE
- Performance study and requirement assessment of neutrino near detectors
- Participation in the design and construction of the DUNE cryostats
- Active participation in FNAL-SBN program
- Active participation in the DUNE program

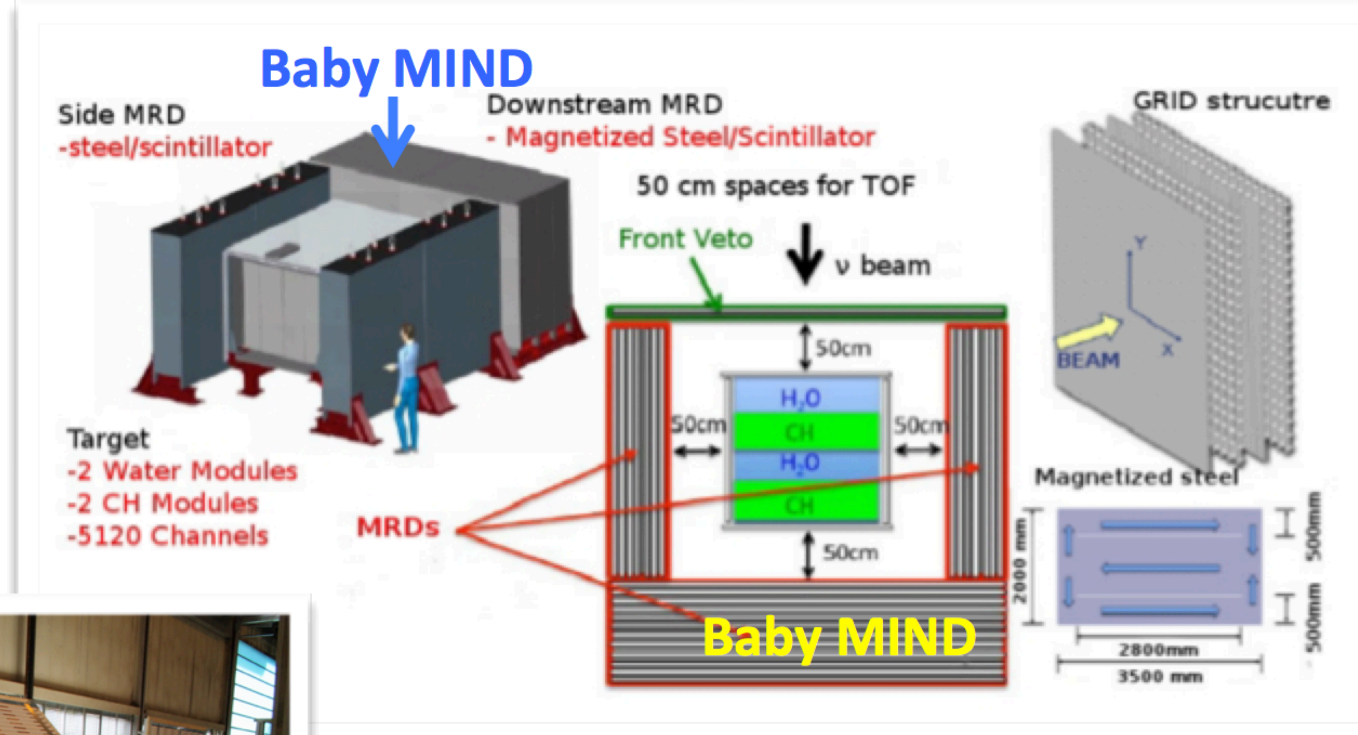
NP05 / BabyMIND

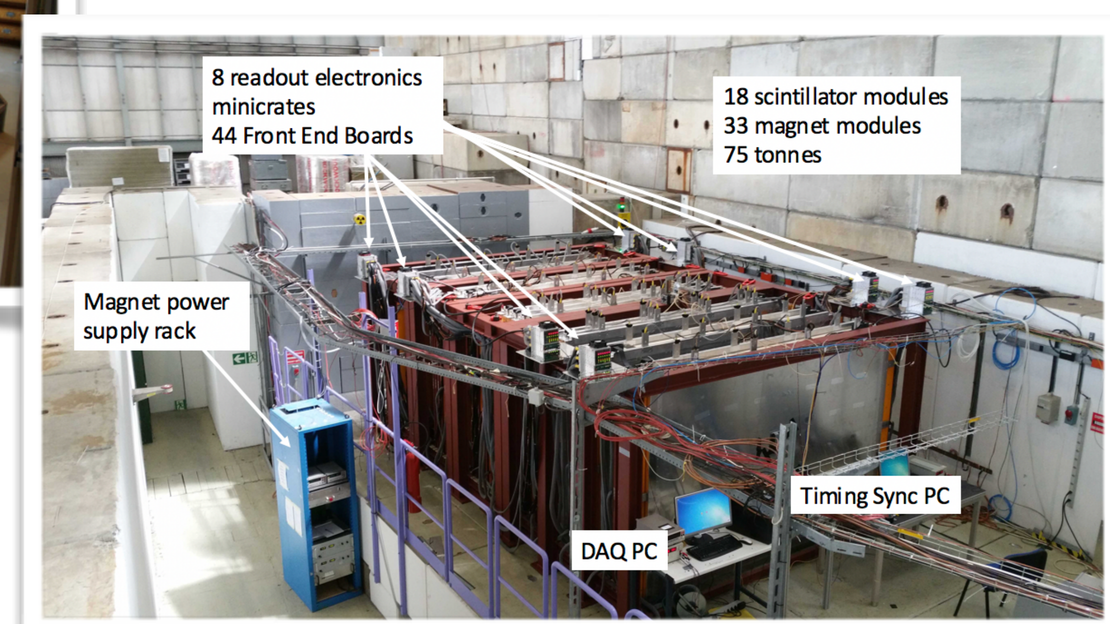
NP05 / BabyMIND Collaboration:
Instituto de Fisica Corpuscular (IFIC), Spain - Institute for Nuclear Research (INR), Russia - University of Geneva, Switzerland - University of Glasgow, United Kingdom - University of Sofia, Bulgaria - European Organisation for Nuclear Research (CERN), Switzerland

NP05 / BabyMIND

Magnetised muon spectrometer for the WAGASCI experiment (T2K beam line)
Interleaving of magnets (33) and scintillator (18) modules

Main systems:
- Magnet modules (CERN)
- Scintillator modules (JINR and UniGe)
- Readout electronics (UniGe and Sofia)
- Support mechanics (UniGe)





Baby MIND beam tests at PS in July 2017
Results recently presented at NuFact2017:
https://indico.uu.se/event/324/session/6/contribution/72/material/slides/0.pdf

On its way to Japan

NP01 / WA104

NP01 / WA104 Collaboration:
Argonne National Laboratory (ANL), USA - Brookhaven National Laboratory (BNL), USA - European Organisation for Nuclear Research (CERN), Switzerland - Colorado State University, USA - Fermi National Laboratory (FNAL), USA - INFN Catania and University Catania, Italy - INFN GSSI, Italy - INFN LNGS, Italy - INFN Milano and Milano Bicocca, Italy - INFN Napoli, Italy - INFN Padova and University, Italy - INFN Pavia and University, Italy - Los Alamos National Laboratory (LANL), USA - Pittsburgh University, USA - SLAC, USA - Texas University, USA

NP01 / WA104

ICARUS T600 LAr TPCs successfully operated underground at LNGS on CNGS neutrino beam from 2009 to 2013.

Refurbish ICARUS T600 as far detector for the SBN program in the US (on surface at Fermilab):
- New cold (extruded aluminium) and warm (passive isolation) vessels
- Upgrade of light detection system (more sensitive, more coverage, new calibration system)
- Cabling and connectivity re-done (light and charge signals)
- Faster and higher performance electronics (FE, digitisation, DAQ systems)
- Refurbishing of the central cathode
- Design and construction (ongoing) of the top Cosmic Ray Tagger
- Proximity cryogenics re-design and presently in production.

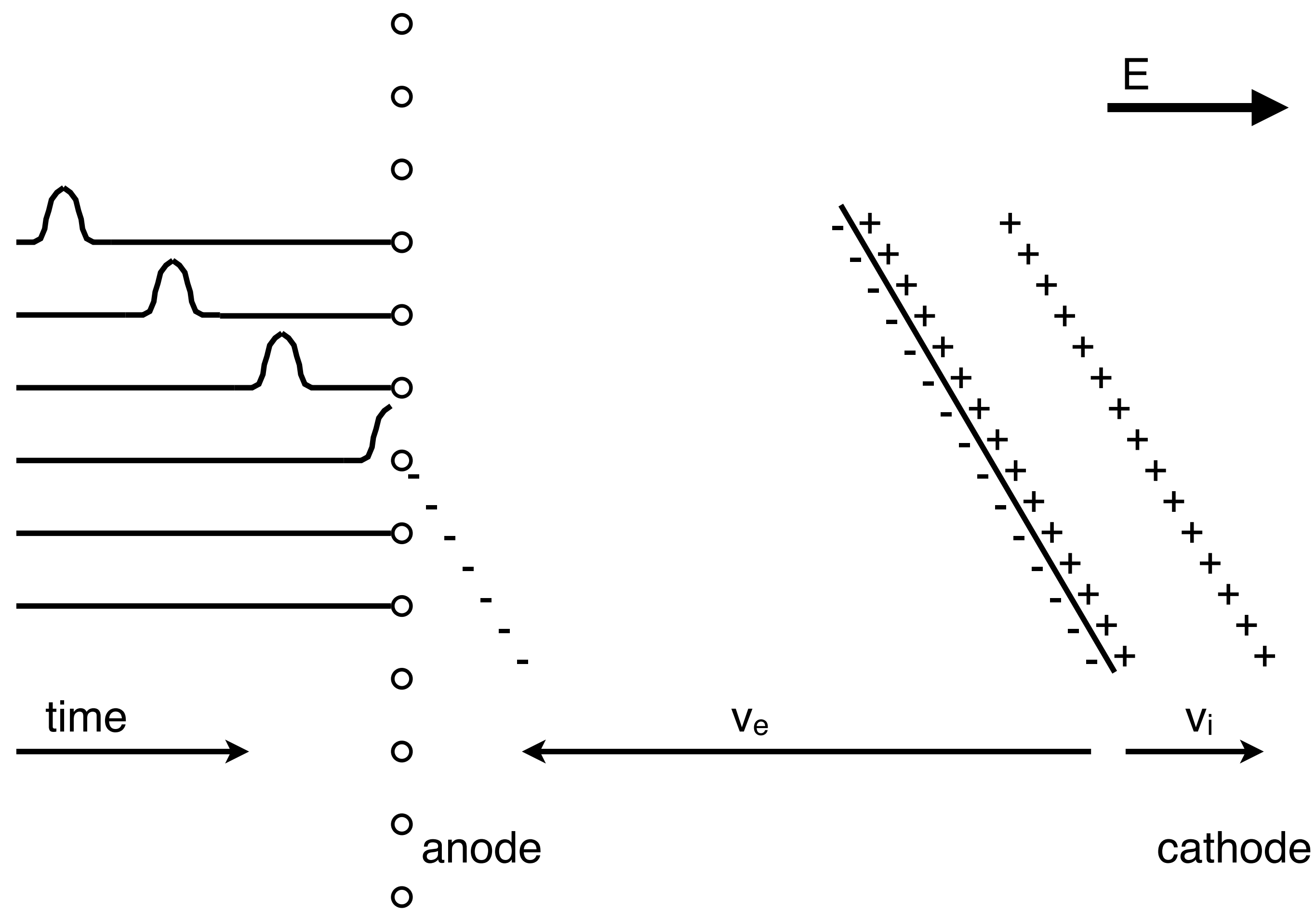
These activities were conducted at CERN from December 2014 until June 2017
Transport of the ICARUS modules to Fermilab from 12 June to 26 July 2017

LAr TPC

Homogeneous calorimetric, 3D tracking and imaging device

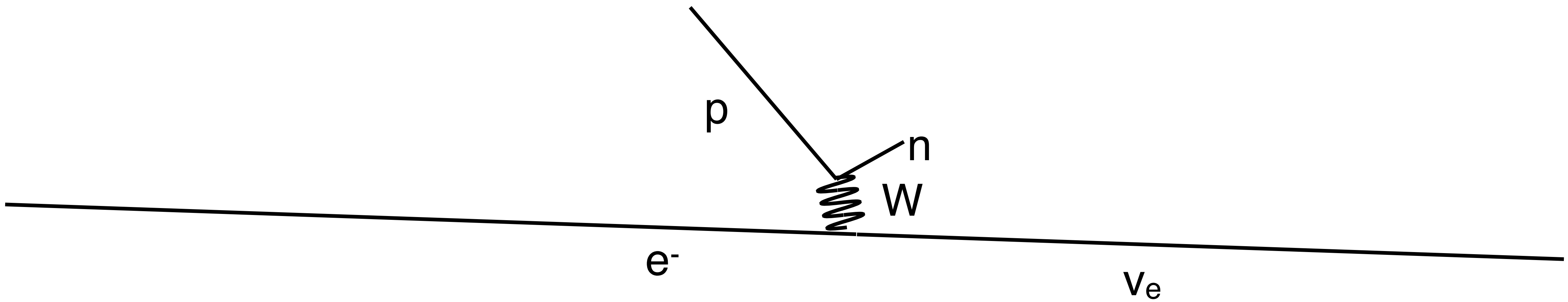
Liquid argon as active medium:
- inert
- dense 1.4 kg/l
- not too expensive (1% of atmosphere)
- good scintillator in the VUV
- quasi-free electron able to drift
- Cryogenic, but simple

Ionised electrons along the track move 'rigidly' at a constant speed under the action of a uniform electric field.
Moving charge induce current pulses on sensing electrodes.
Drift direction projected on time domain

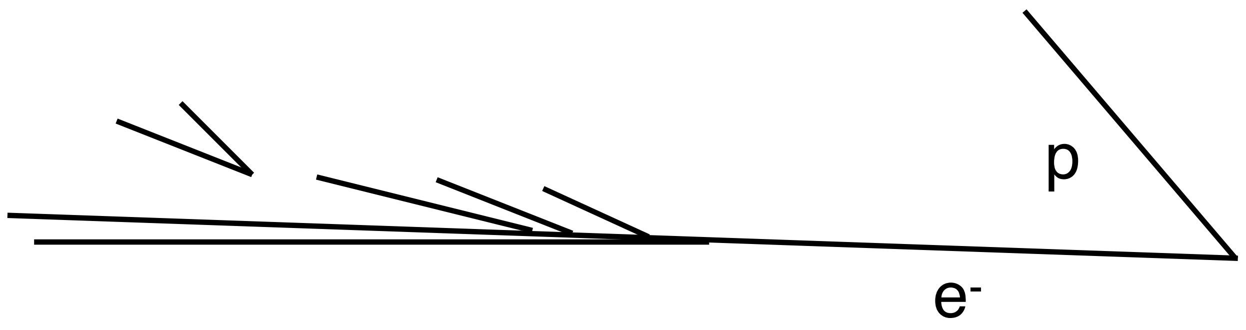


PID capabilities:
- charge density ~ dE/ds
- topology of the event

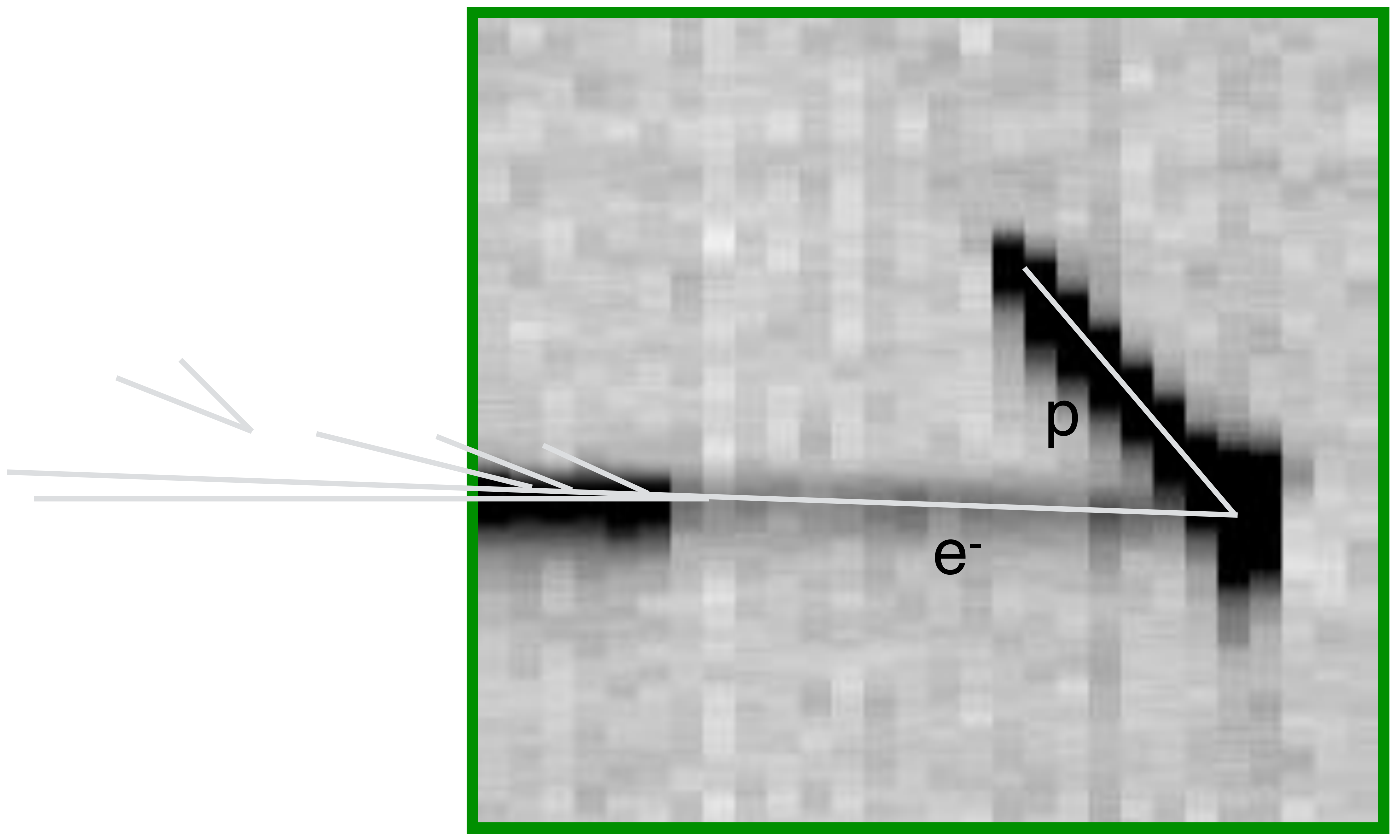
LAr TPC in action



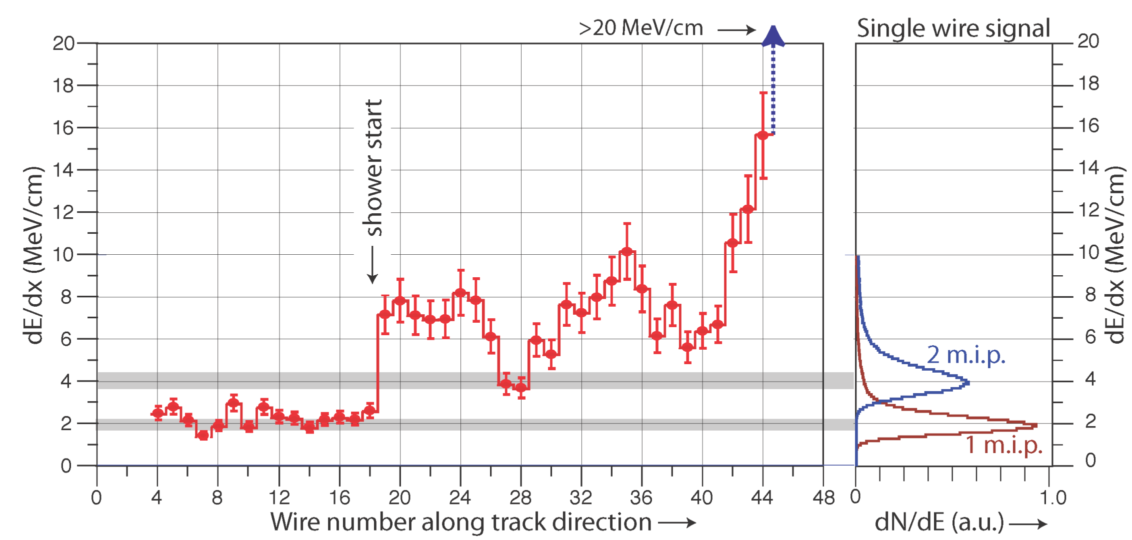
LAr TPC in action

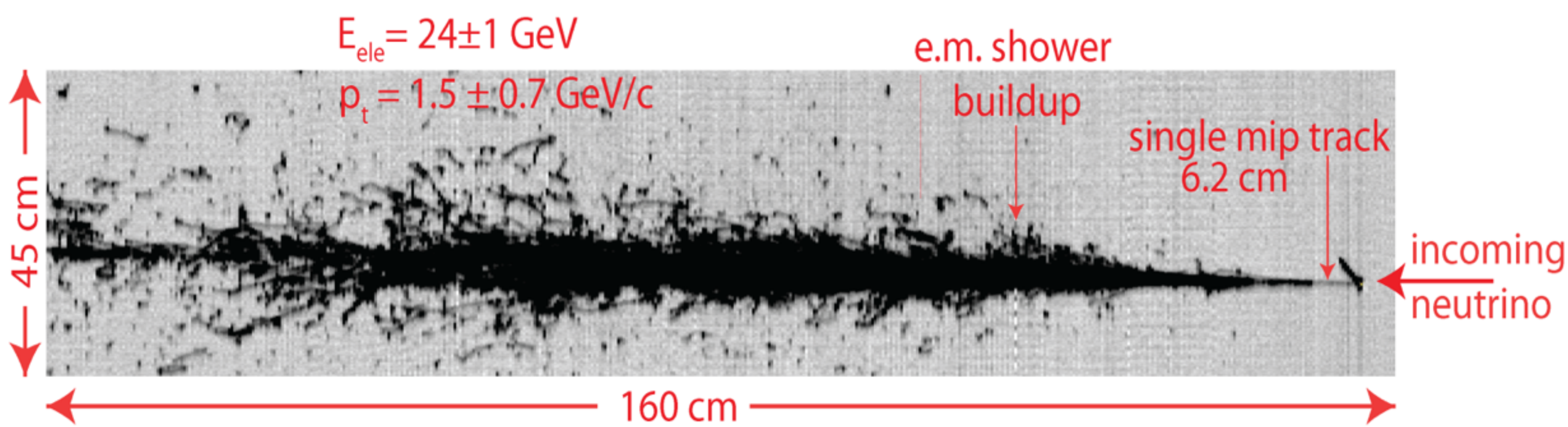


LAr TPC in action

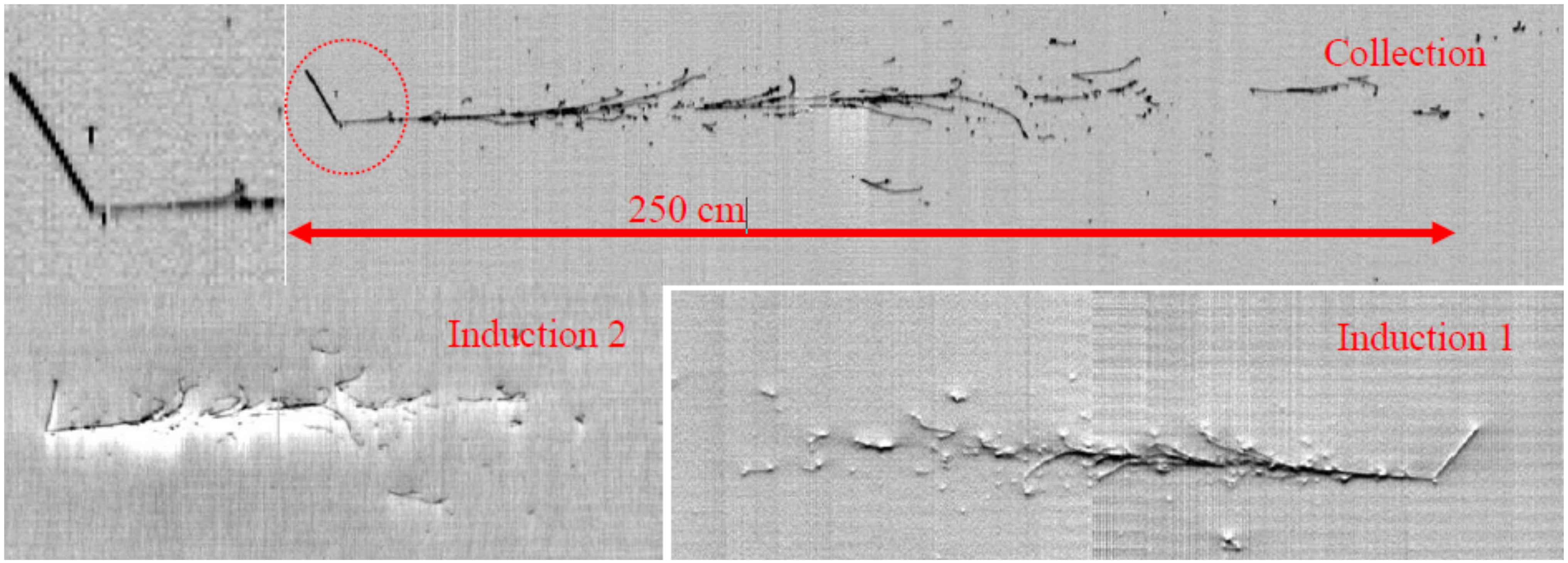


ν_e candidate recorded by ICARUS on LNGS neutrino beam



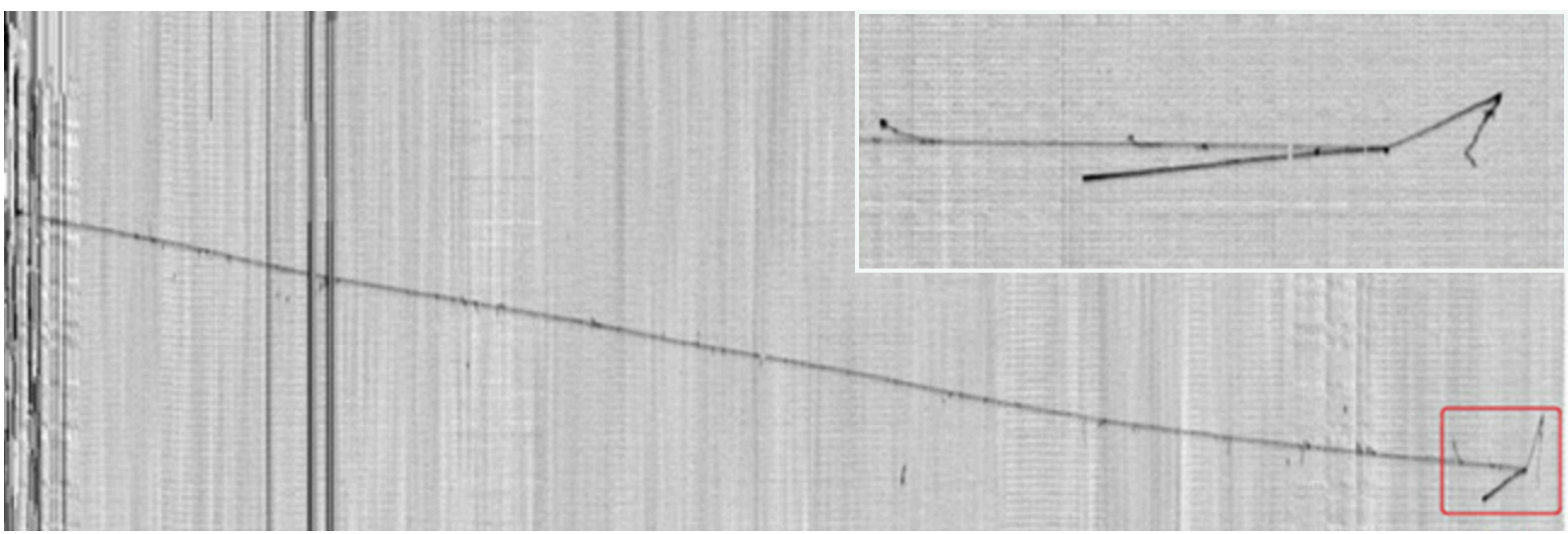


LAr TPC in action



ICARUS events

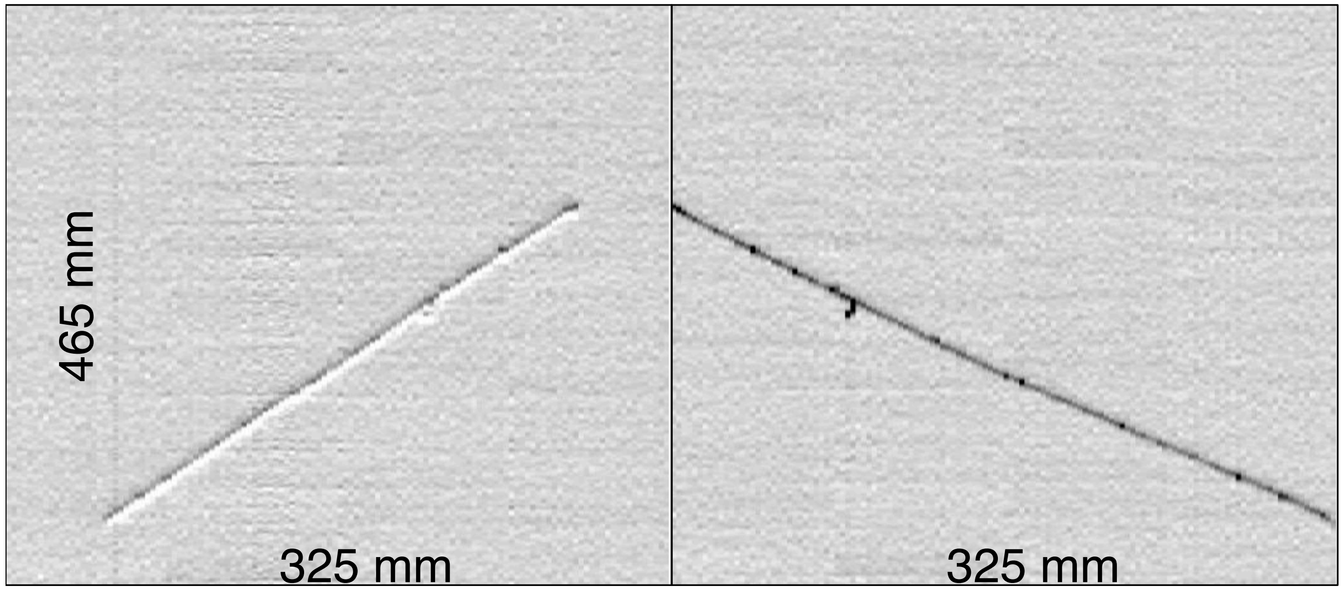
QE atm ν_e candidate,
E_{tot} ~ 2.1 GeV
E_p ~ 115 MeV

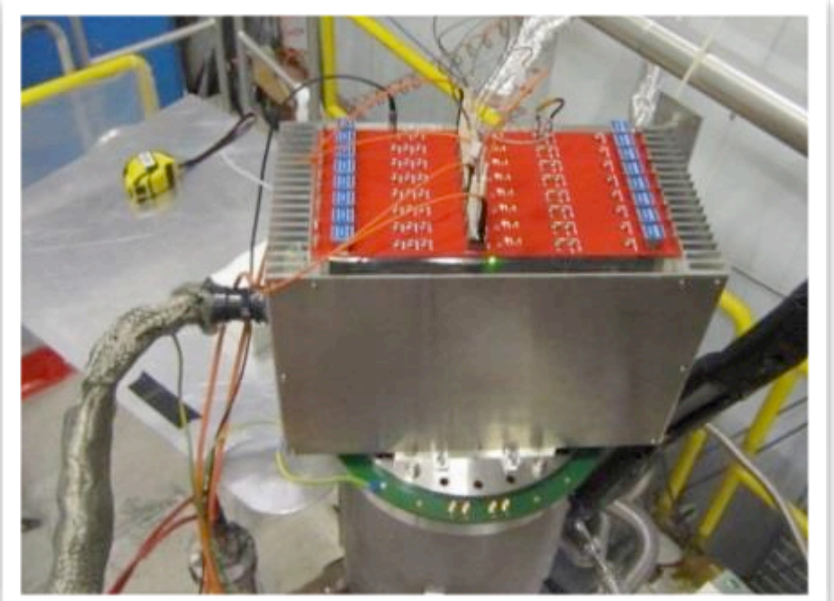


ν_μ from CNGS,

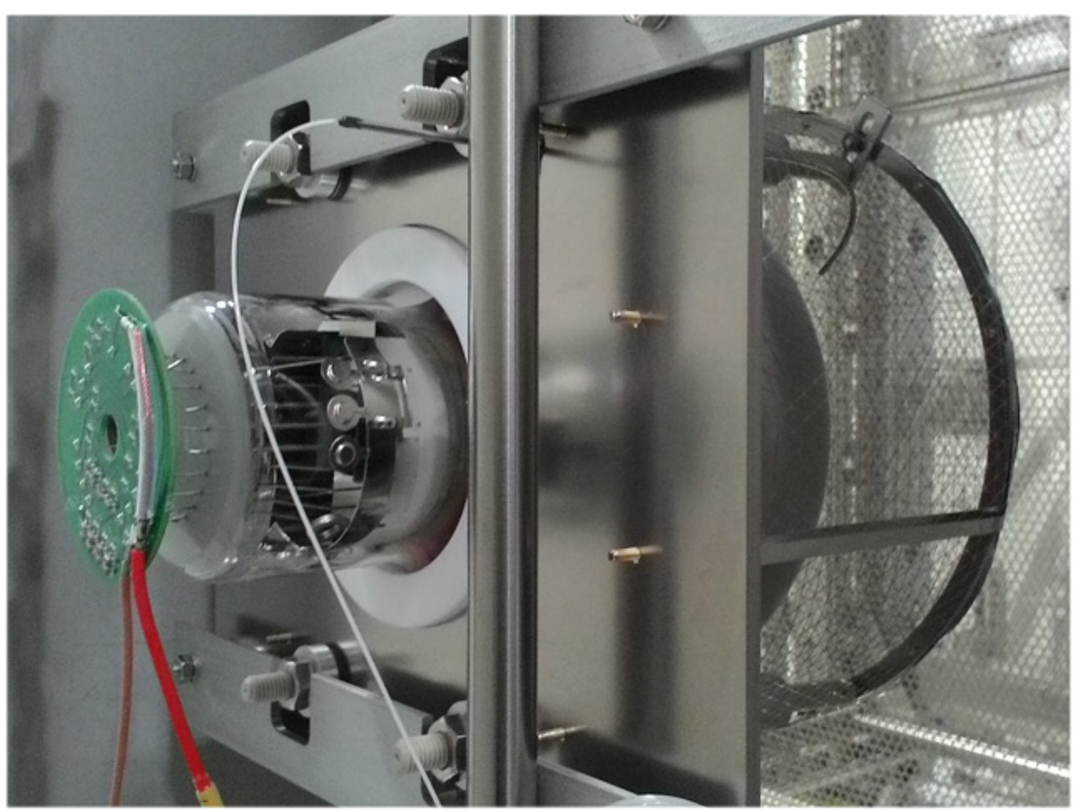
NP01 / WA104

New electronics, heavily tested with cosmic rays in the 50l ICARUS chamber at CERN



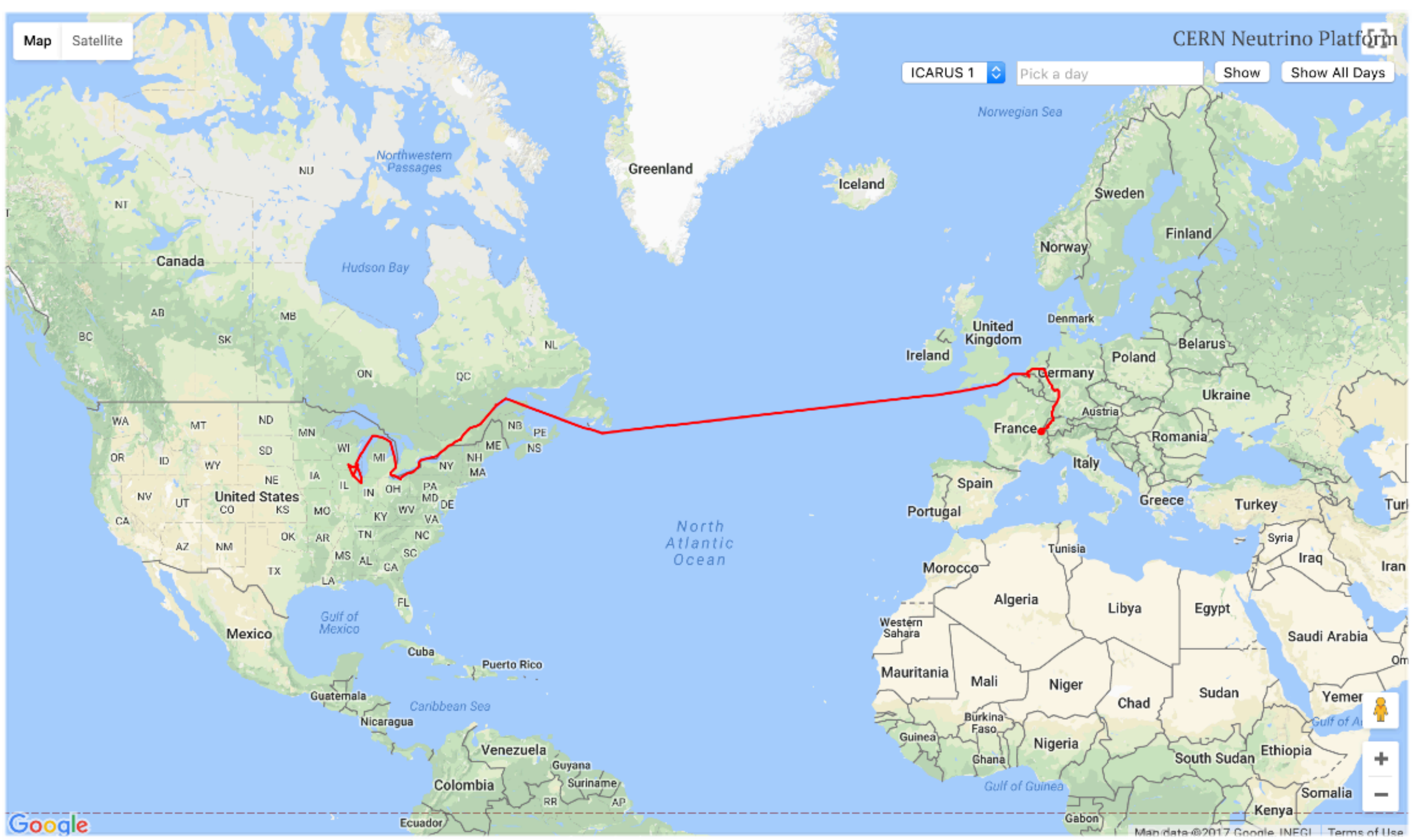


Dedicated clean room to host the two ICARUS modules



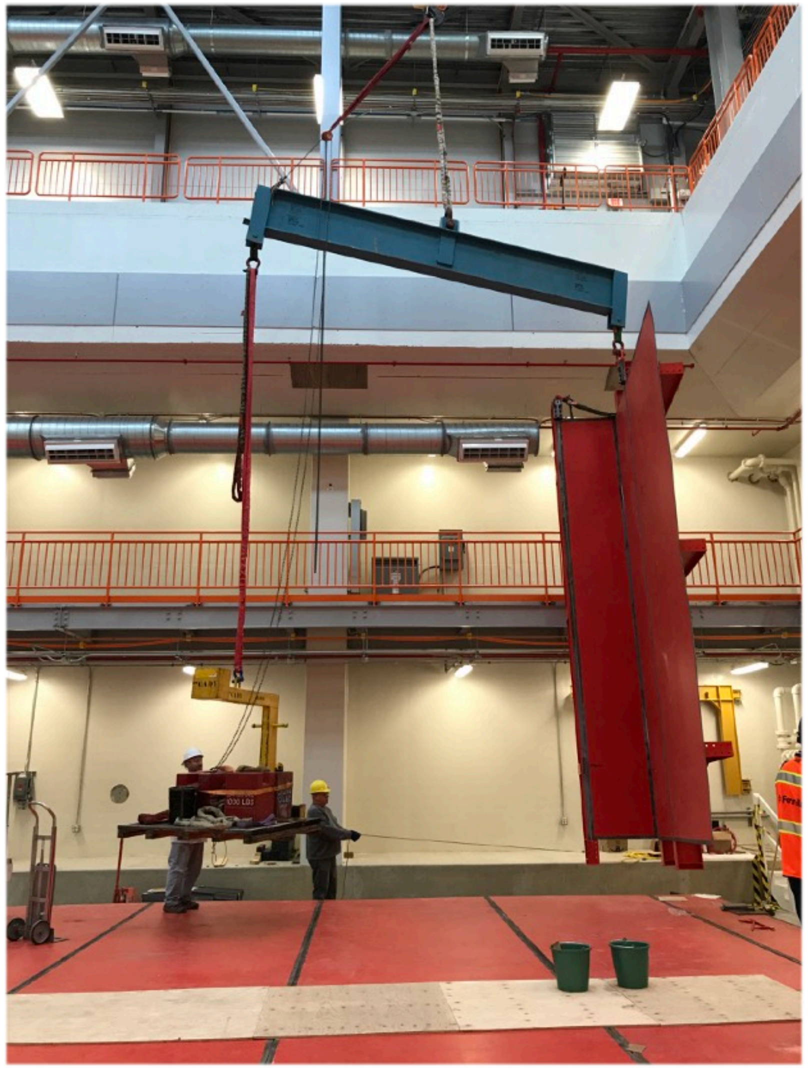
ICARUS trip

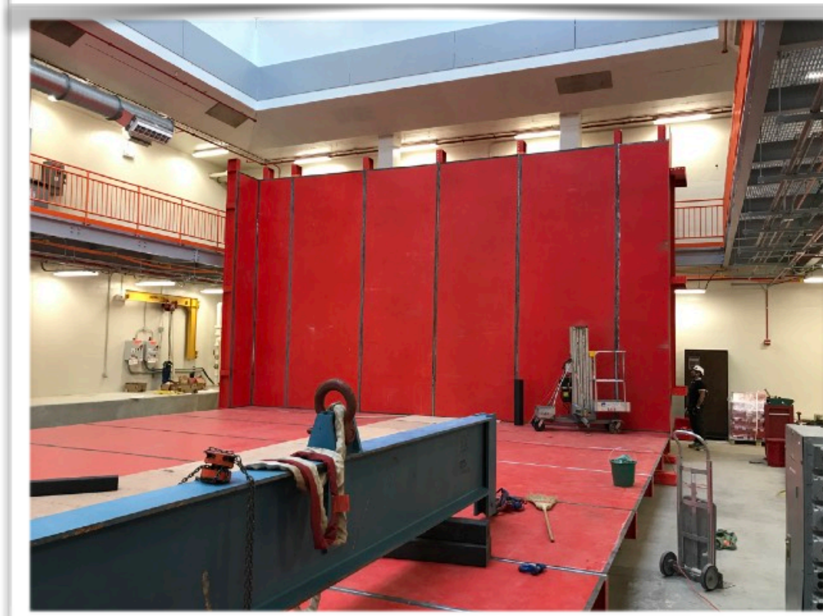
Dep. CERN	12 June 2017
↓ truck	
Arr. Basel (CH)	16 June 2017
Dep. Basel (CH)	16 June 2017
↓ barge	
Arr. Antwerp (BE)	20 June 2017
Dep. Antwerp (BE)	22 June 2017
↓ ship	
Arr. Burns Harbor (USA, IN)	10 July 2017
Dep. Burns Harbor (USA, IN)	24 July 2017
↓ truck	
Arrival at FERMILAB	26 July 2017
Photos from the transportation	



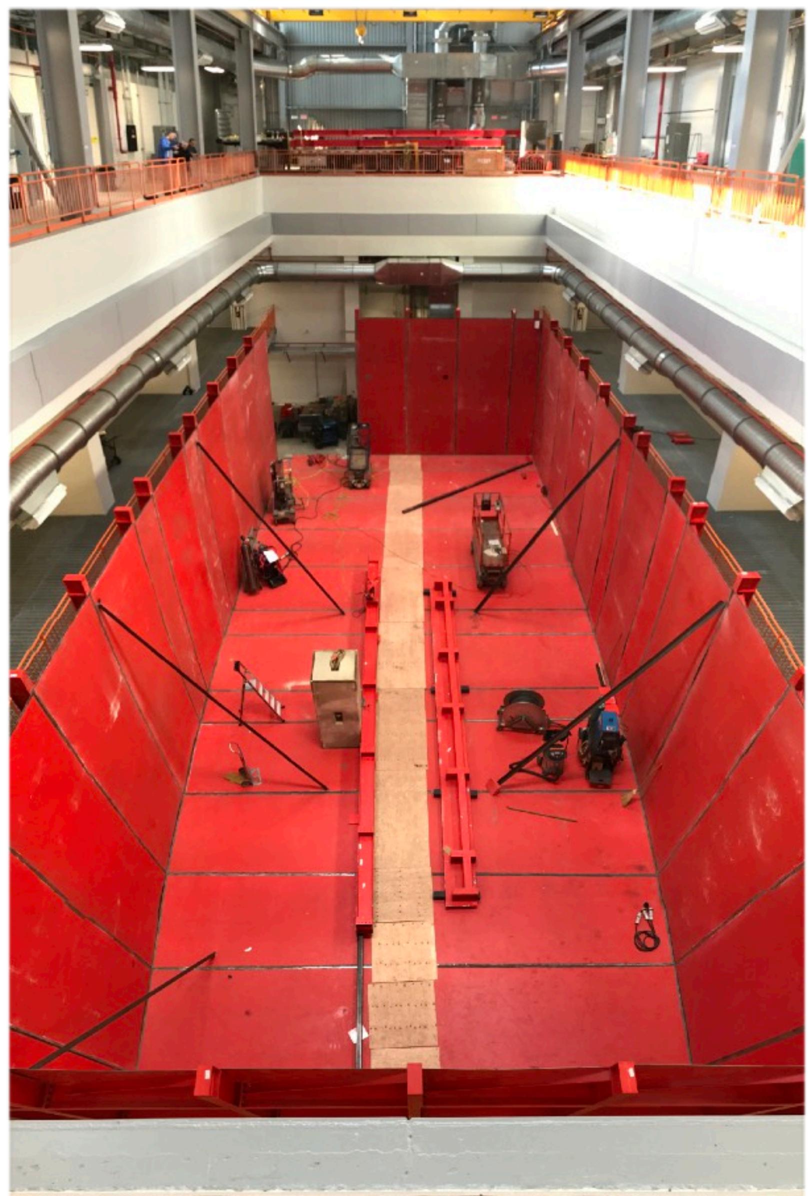
http://icarustrip.web.cern.ch

NP01 / WA104





Warm vessel construction at Fermilab by CERN
Ready to host ICARUS. Next steps:
- Insertion of the two cold cryostats in the warm vessel
- Construction of the cryogenics by CERN contractors



NP02 & NP04: ProtoDUNEs

NP02 and NP04 ProtoDUNEs Collaborations:
very large subset of the LBNF-DUNE Collaboration

Single vs doble phase

Single Phase (**SP**) à la ICARUS

Pro

- demonstrated functioning underground for years
- drift in any direction with respect to gravity
- sensing electrodes are simple wires
- stable thermodynamic conditions of the detector
- no need of HV in gas

Cons

- signal to noise limited by the electronics and wire length
- very different induction and collection view signals

Double Phase (**DP**) liquid and vapour

Pro

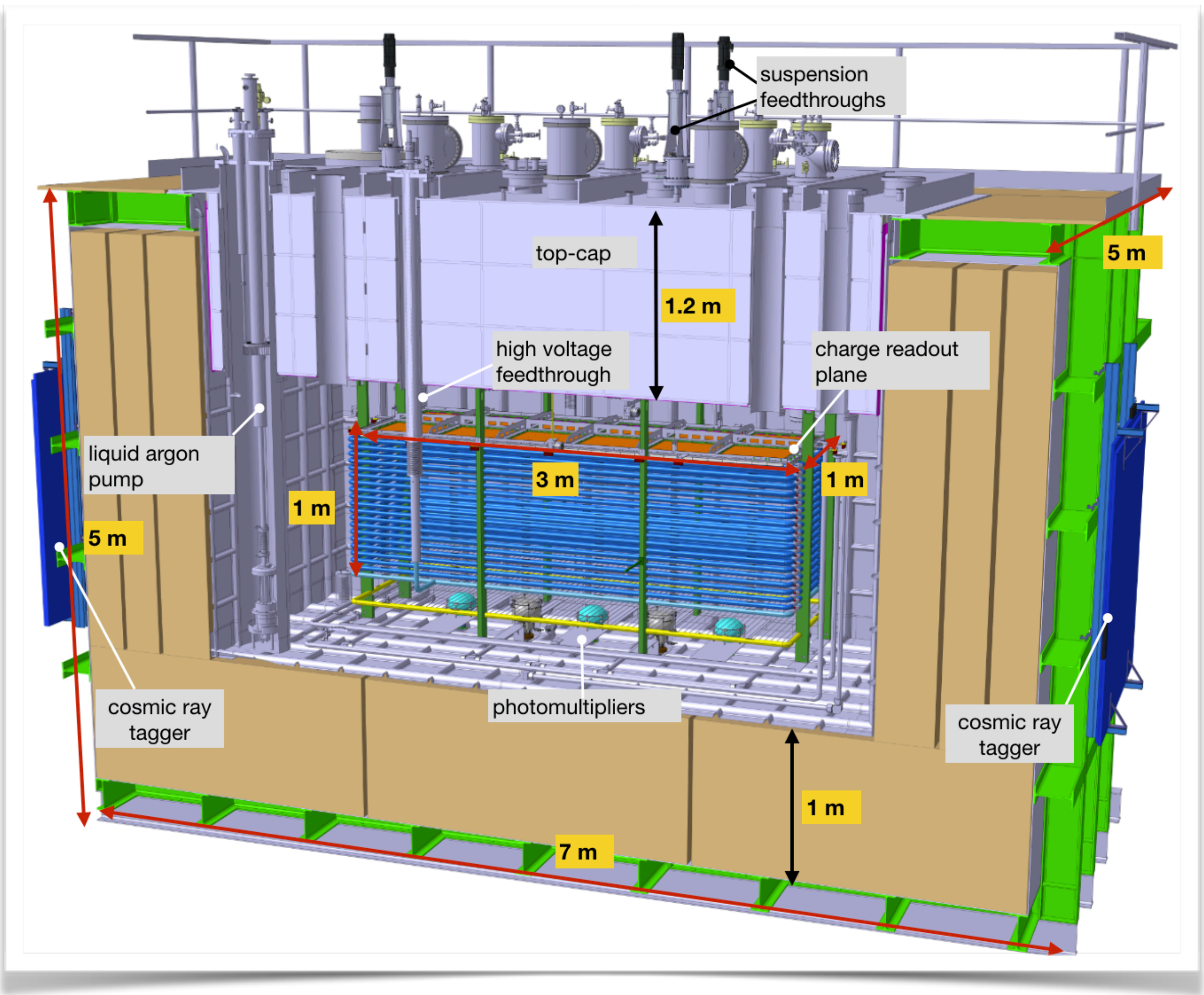
- signal amplification during just before signal formation
- electronic noise less important with respect to the SP
- completely analogous signals on the views
- possibly fewer electronic channels for the same volume
- accessible electronics

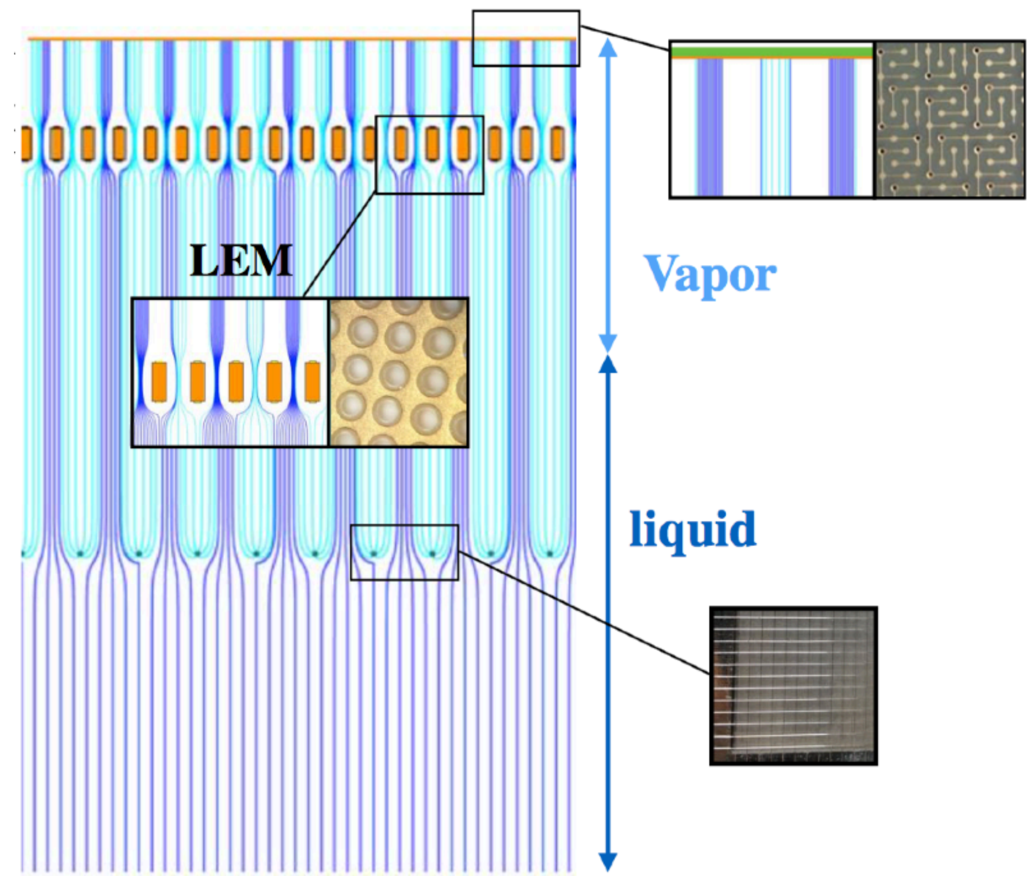
Cons

- stability and uniformity of the charge amplification
- generally larger HV needed

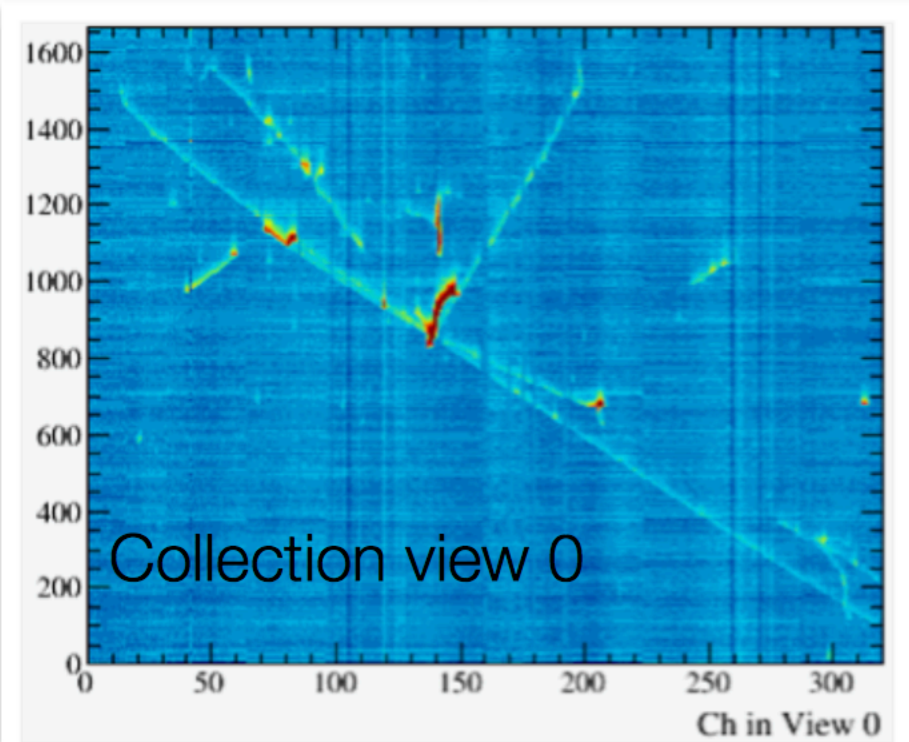
Double phase argon TPC

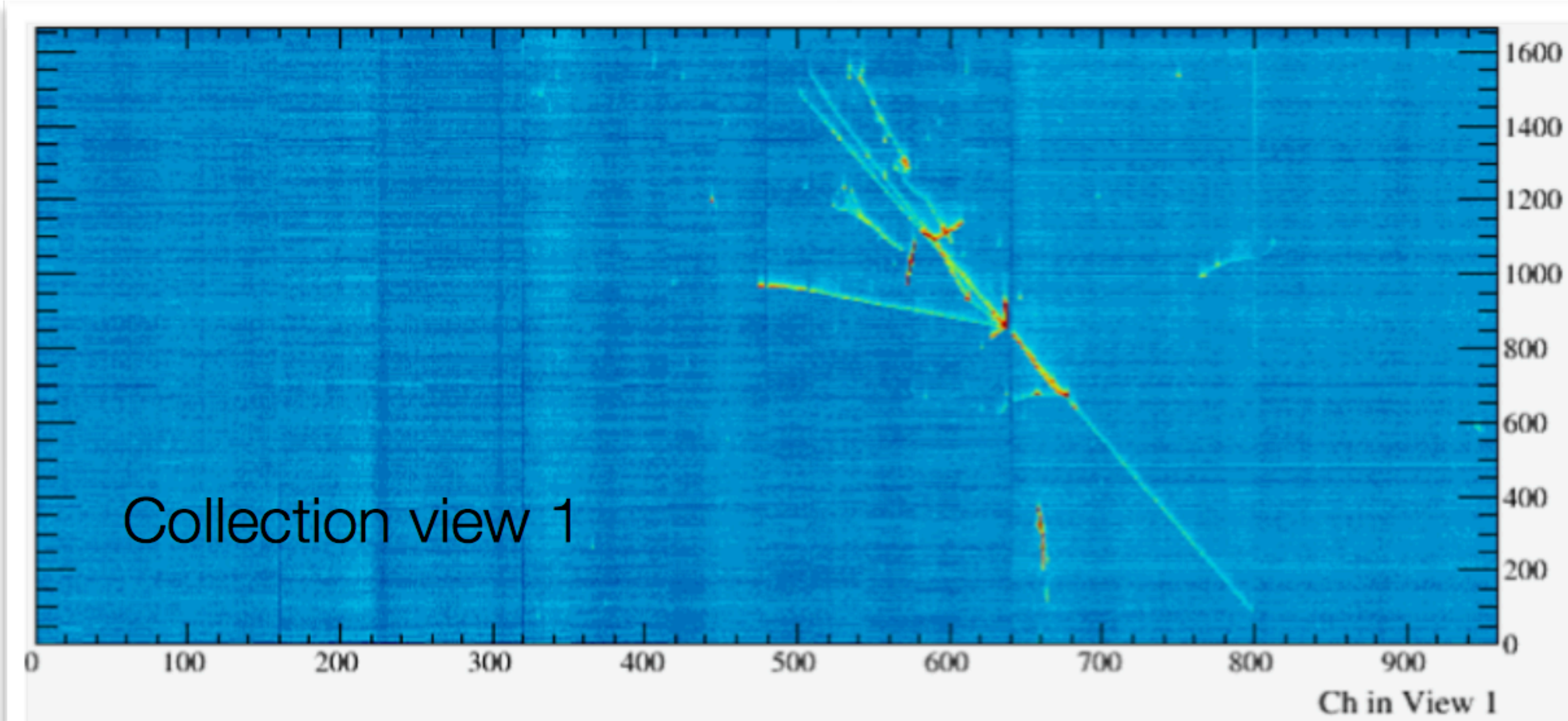
3x1x1: Largest DP LAr TPC ever operated:
3 m³ active volume prototype and scalability demonstrator
In operation at CERN since spring 2017





3x1x1 double phase TPC





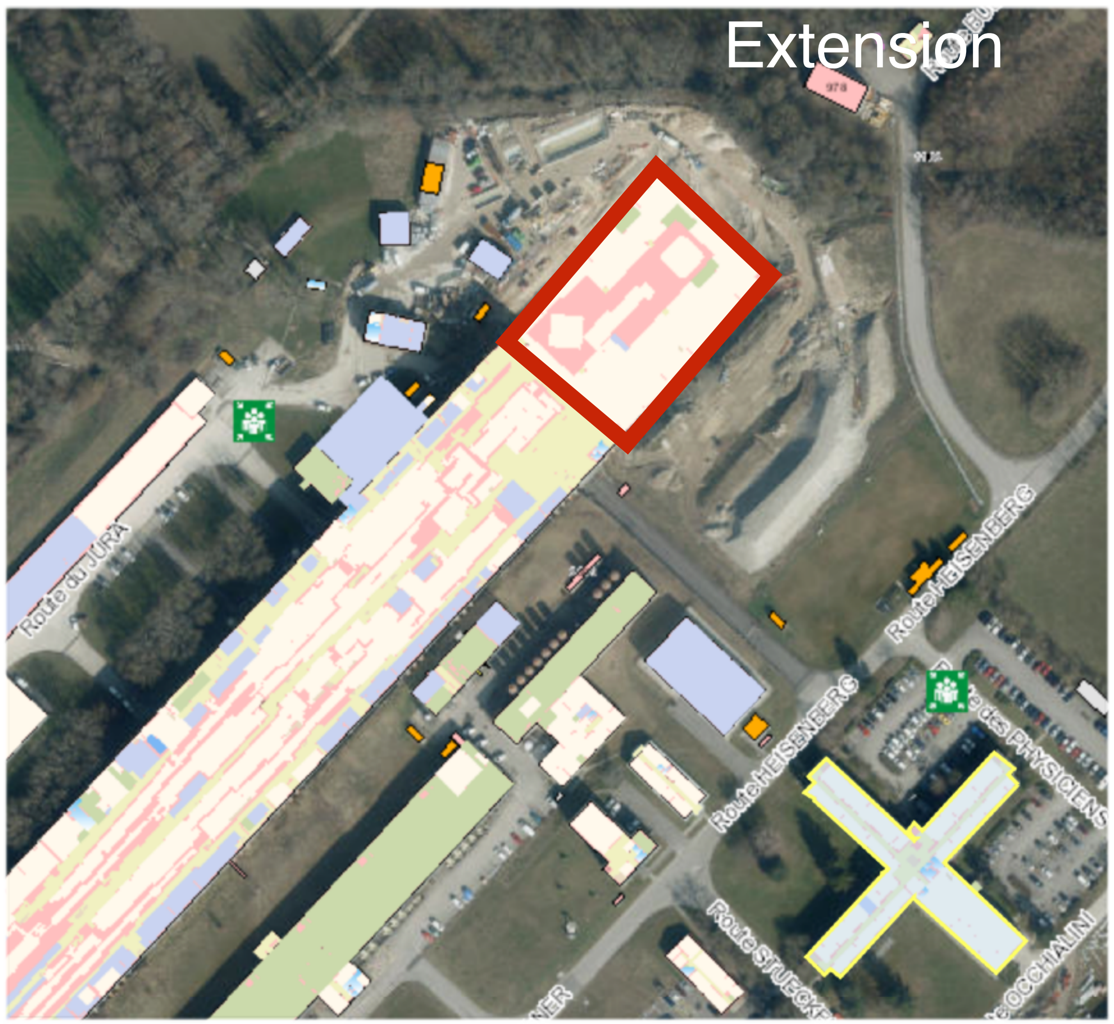
High quality data illustrates the state of the art imaging of the dual phase technology:

- About 350 k cosmic events collected.
- Stable 500 V/cm drift field over one meter.
- Excellent performance of liquid argon pump.
- Liquid argon purity compatible with 10-20 ms free electron lifetime.
- First time achieved at CERN with a membrane cryostat.
- Liquid argon level stable at sub-mm scale.
- First time ever electron extraction over 3 m^2
- LEM amplification demonstrated on the 50x50 cm^2 (final design for DUNE)
- Good S/N ratio on two collection views (3 meter and 1 meter strips)
- Some stability problems still under investigation and clarification

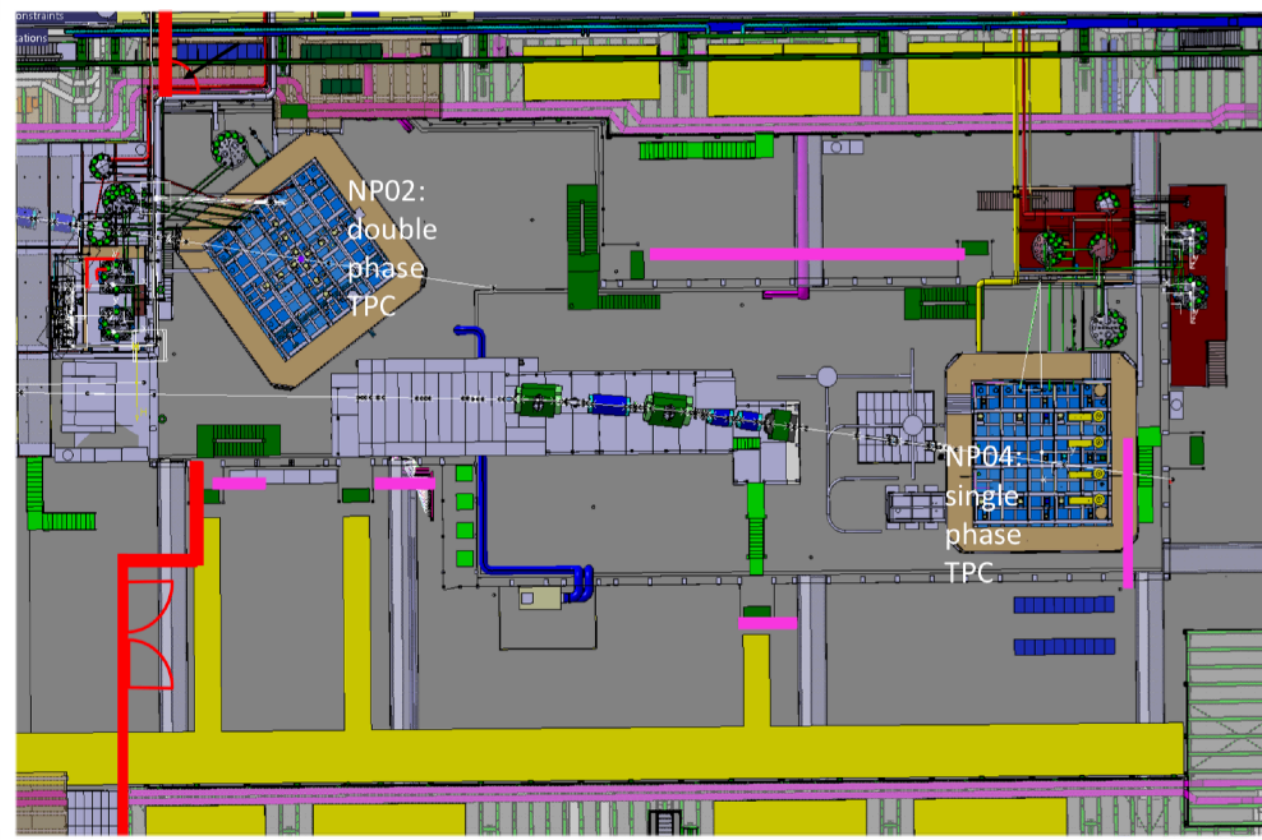
EHN1 extension

Extension of the EHN1 building in the CERN North Area to host the two ProtoDUNEs.

887 building



Civil e completed in September 2016



EHN1 extension

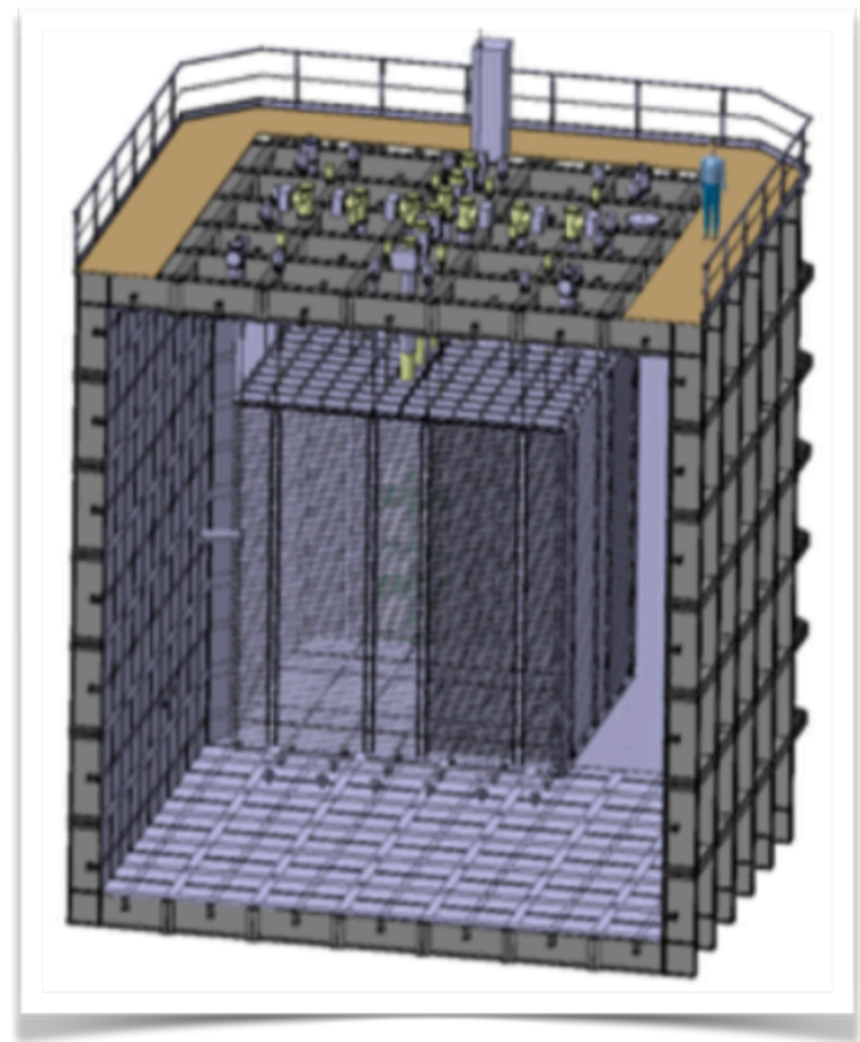
Prototypes of the DUNE far detectors
Two almost identical cryostats, two 700 ton liquid argon TPCs, two very different technologies:
- double phase (NP02) and single phase (NP04) LAr TPC prototypes (full size components)
- on charge particle beam before LS2 (end 2018)

Approximate external dimensions 11x11x11m^3
Approximate internal dimensions 8x8x8 m^3

ProtoDUNEs

Engineering and functional prototyping and detector performance studies
The critical components are fully representative of what will be in DUNE
For instance the new technology for large volume cryostats.

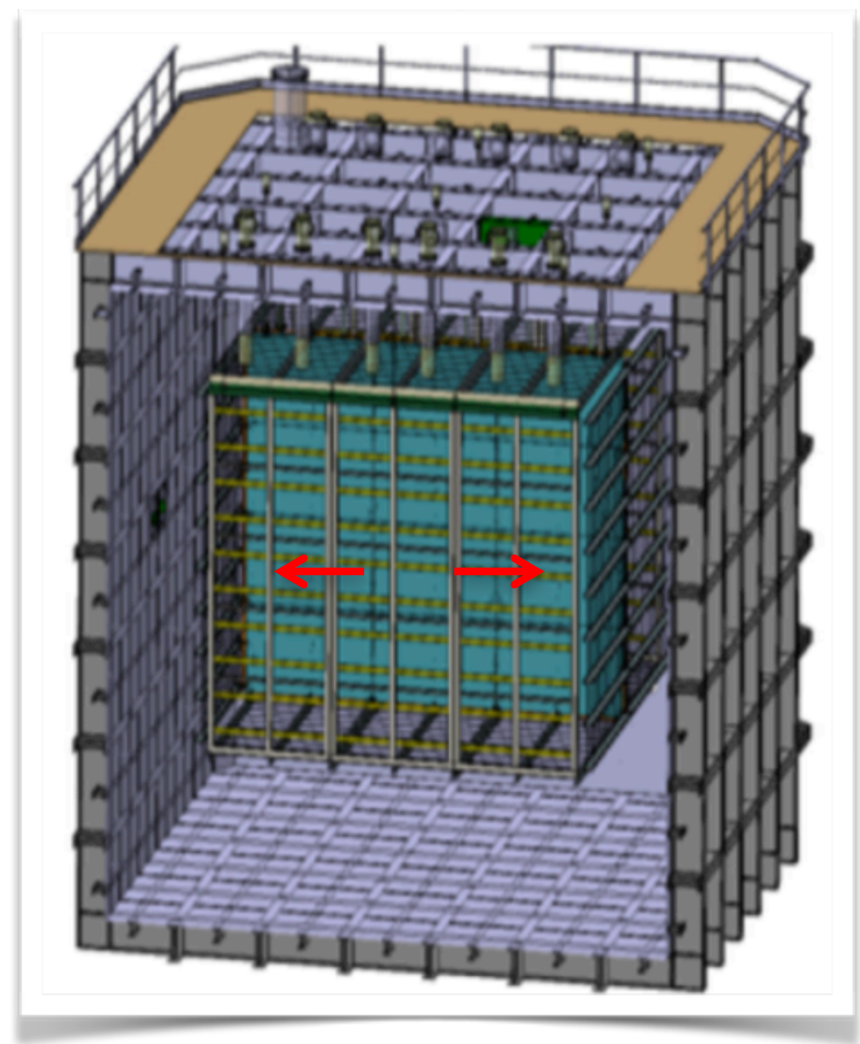
Double phase LAr TPC (NP02)
- The 3x1x1 is the prototype
- Active volume 6x6x6 m^3
- Electrons drift vertically (6 m -> 300 kV at the cathode)
- Electrons are extracted in the vapour phase
- Electrons undergo charge amplification in the LEM holes
- Charge is equally shared between two orthogonal sets of strips on an anode
- Extraction, amplification and readout is modular 3x3 m^2 CRP
- Electronics is cold but extractable (special chimneys developed)



ProtoDUNEs

Engineering and functional prototyping and detector performance studies
The critical components are fully representative of what will be in DUNE
For instance the new technology for large volume cryostats.

Single phase LAr TPC (NP04)
- Active volume ~6x6x7 m^3
- Electrons drift horizontally orthogonal to the particle beam
- two drift length of 3.6 m -> 180 kV at the cathode
- Electrons drift in liquid and induce signals on wires
- Wires wrapped around APAs (full DUNE size) to gain modularity
- Electronics installed in liquid argon -> improve S/N ratio
- Light readout modules embedded in the APA system



LAr purity

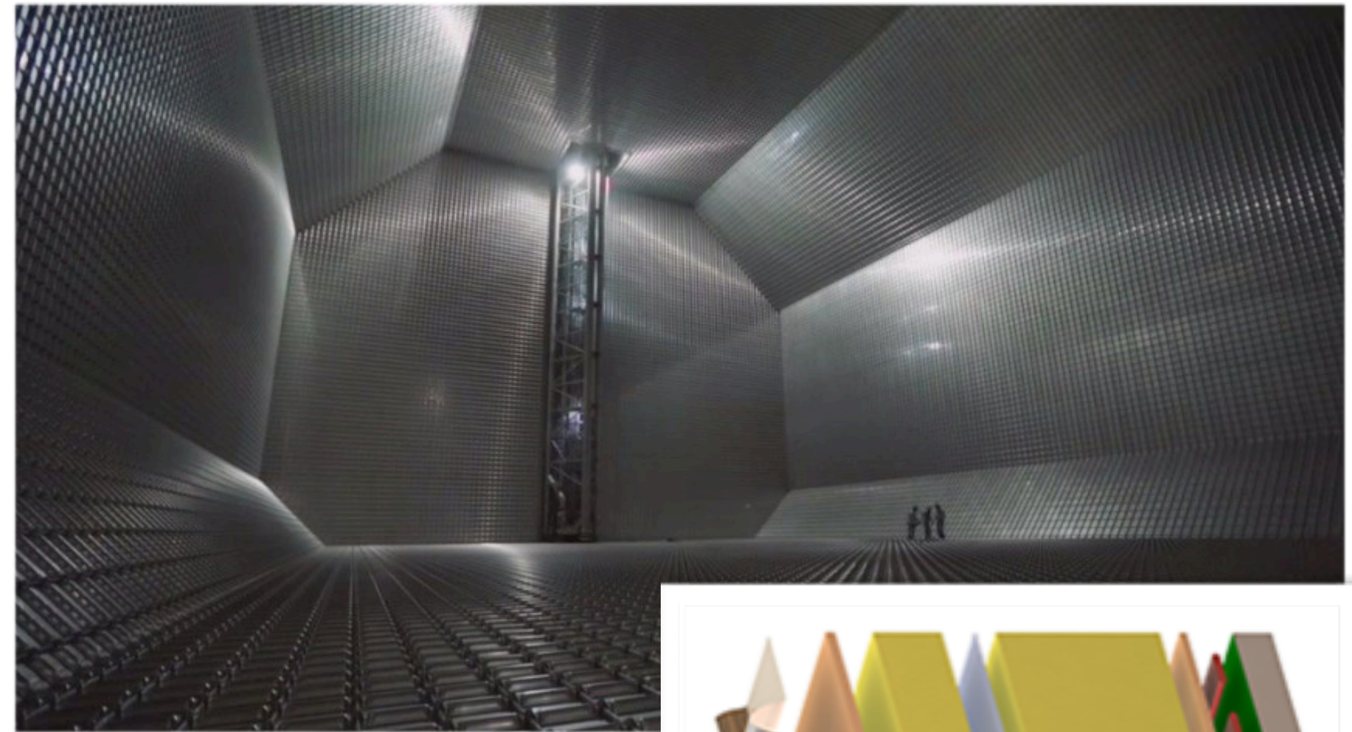
Electronegative contaminants spoil the LAr TPC signals
O_2 molecules attach to drifting electrons slowing them down

HV and UHV to clean the TPCs is the classical solution:
- remove the air at the beginning
- improve the outgassing of the material
- simple to find leaks towards the atmosphere

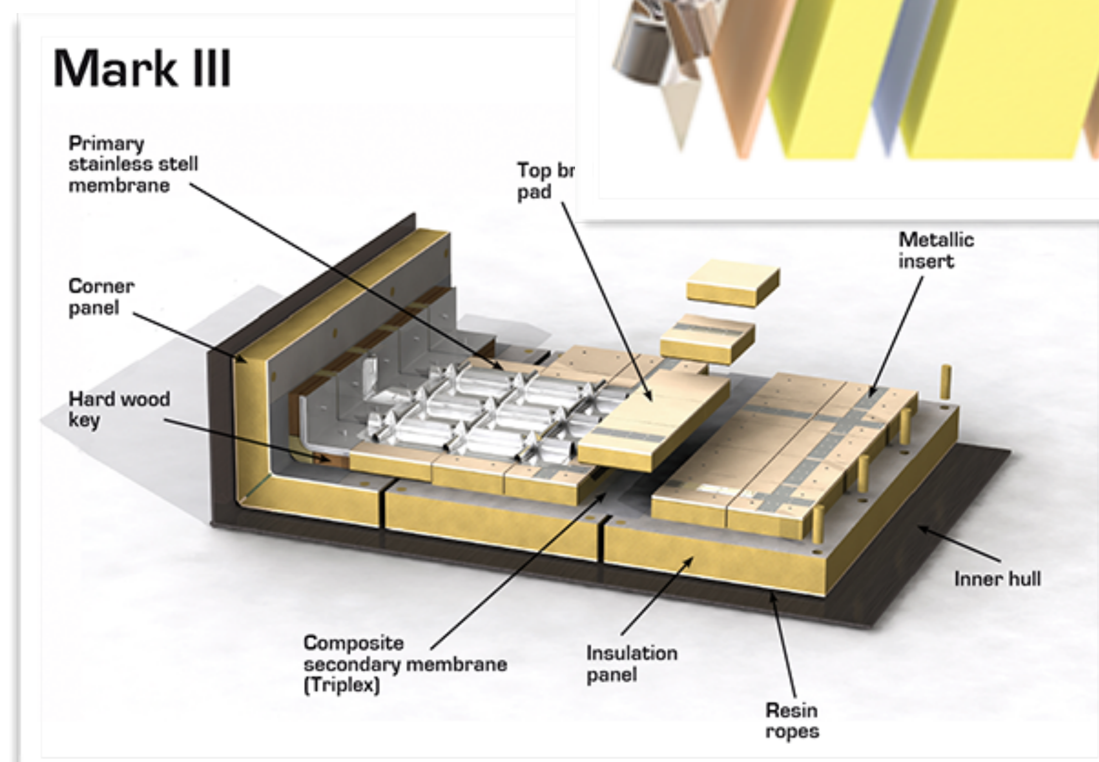
Not feasible within the budget to build large cryostat that can be put under vacuum
The same is valid for the vacuum insulation. Approach:
- Air is evacuated at the beginning gently flowing pure gas argon from the bottom
- Argon gas is recirculated through getters to maintain the purity in warm
- Leaks must be found in another way

The technology

Royalties owner: GTT (France)
Licensee: Gabadi (Spain) among several
Applications:
- LNG carriers (>200000 m^3 in 5 sub-tanks)
- Floating storages and re-gasification vessels
- Land storage tanks
- Fuel tank for vessels
- Cryostats for LAr TPCs



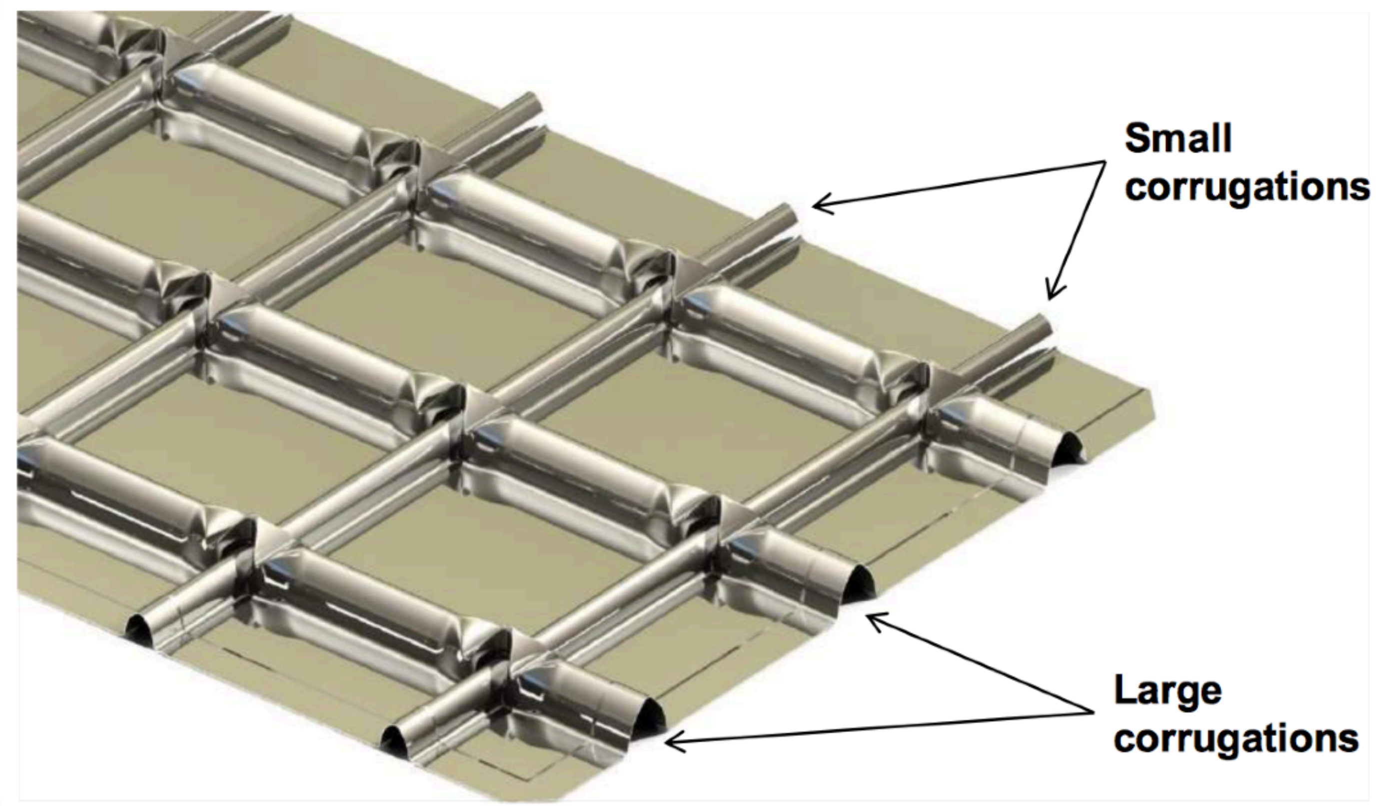
- Primary membrane: in contact with the liquified gas. Flexible and elastic to accomodate wave impacts, vessel deformation, thermal expansion and contraction. Not self supporting.
- Thermal insulation: passive, in between and directly connected to the primary membrane and the hull.
- Hull: the warm structure, sustains and support the entire system.

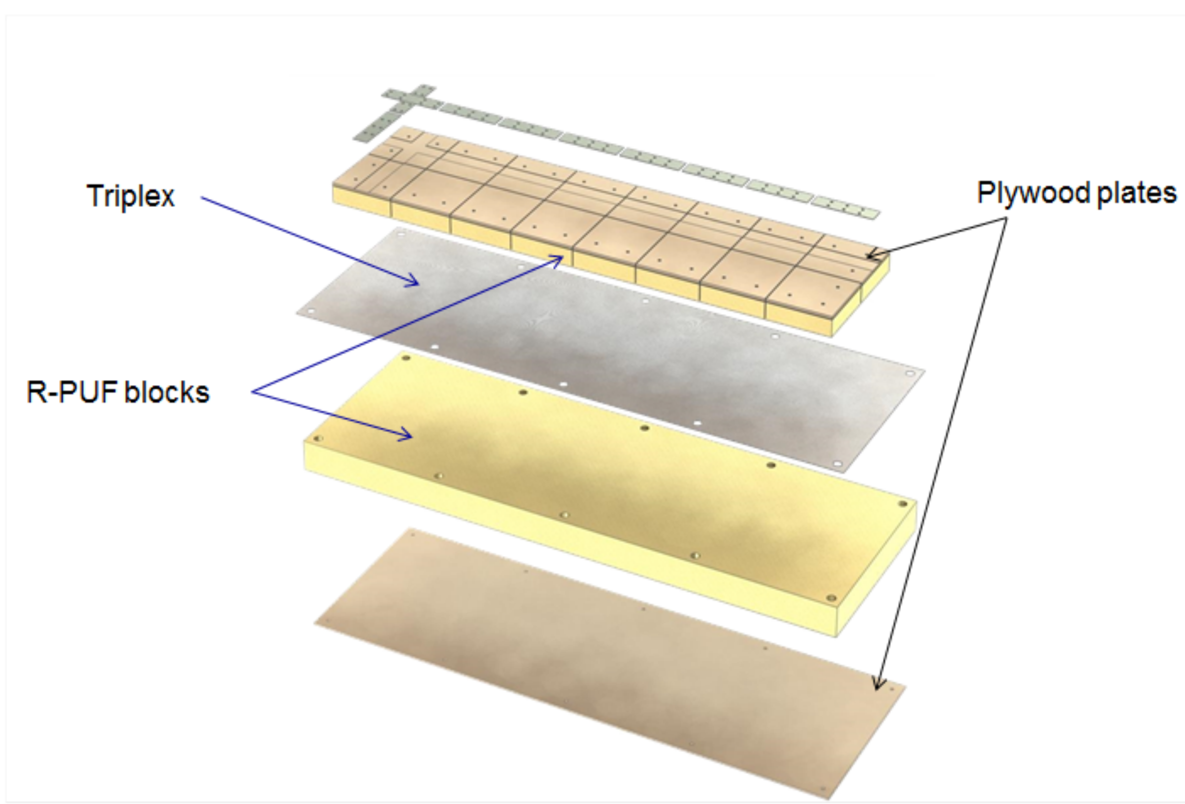


www.gtt.fr

GTT Mark III technology

Primary membrane:
Stainless Steel 304L, 1.2 mm thick, 1mx3m 'tiles' (eventually welded together), with corrugation (acting as springs) along the two orthogonal directions (340 cm pitch). Highly standardised components, constructed in Korea. Special components for angle and corner pieces.

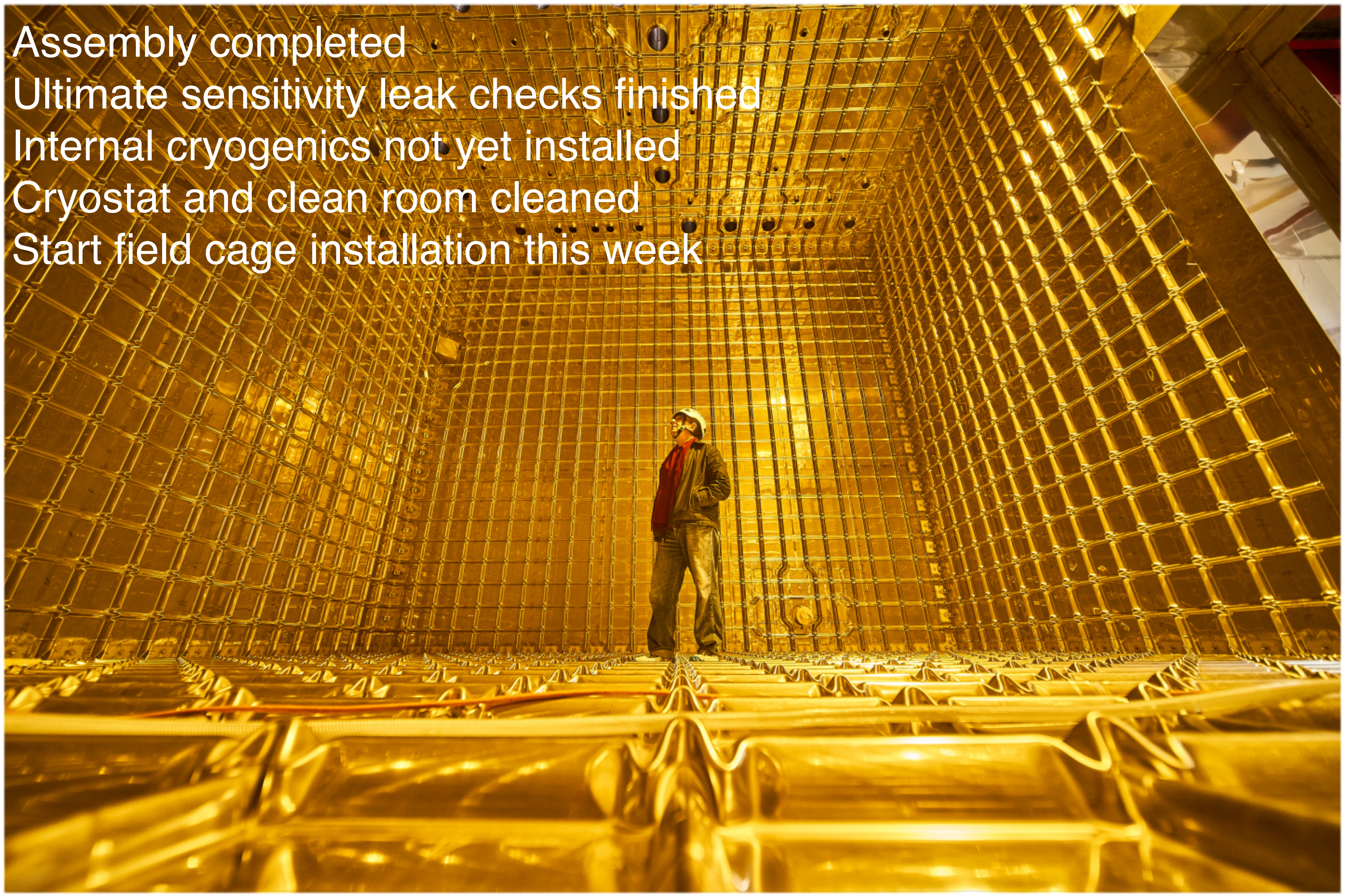




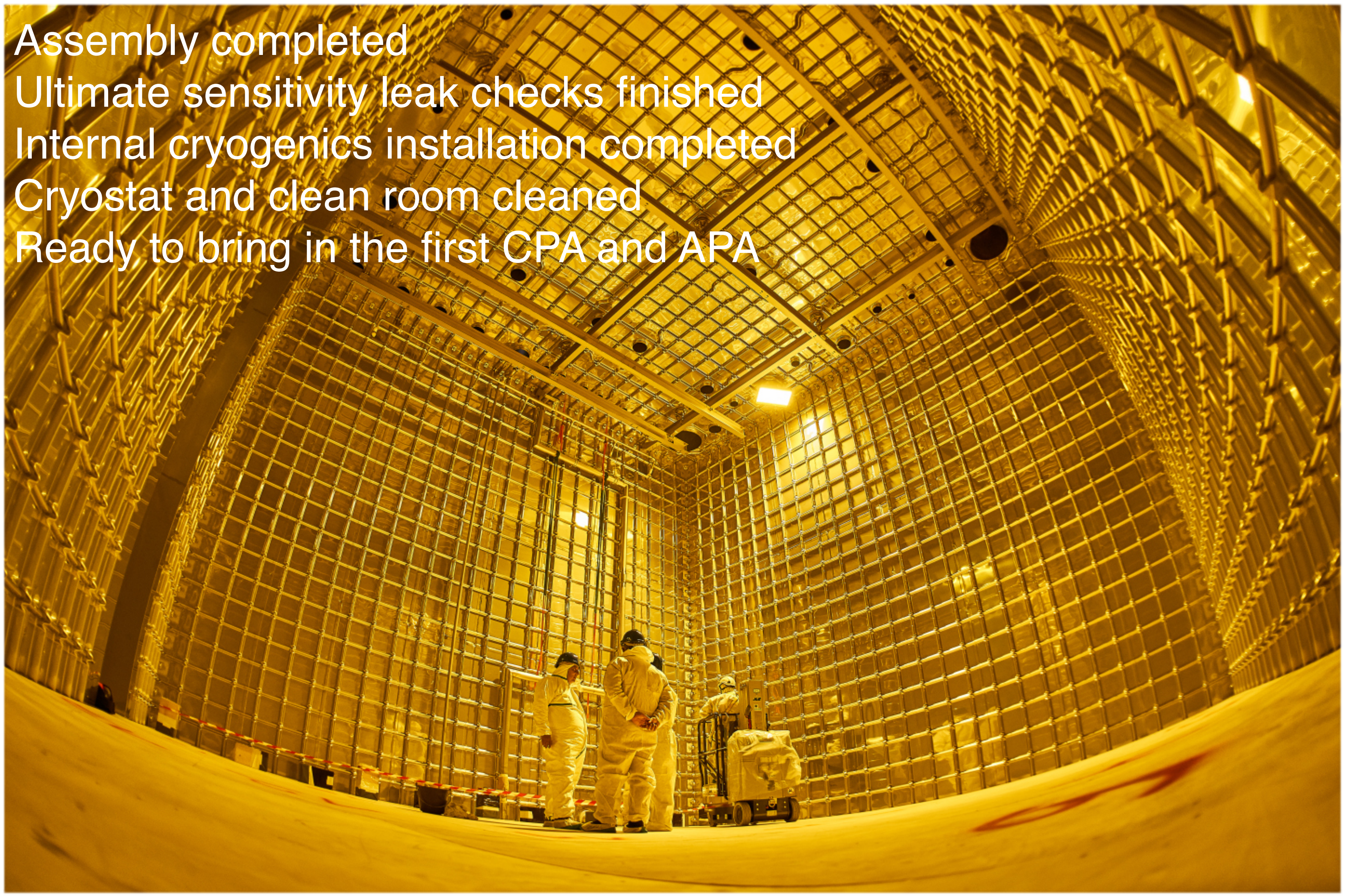
Insulation:
Typically 27 cm think, two polyurethane foam layers separated by the secondary membrane. Metal inserts on the plywood serve as welding points for the primary membrane. No direct metal contact between warm structure and primary membrane. Highly standardised prefabricated components, constructed in Korea. Special components for angle and corner pieces.

www.gtt.fr

NP02 double phase



NP04 single phase

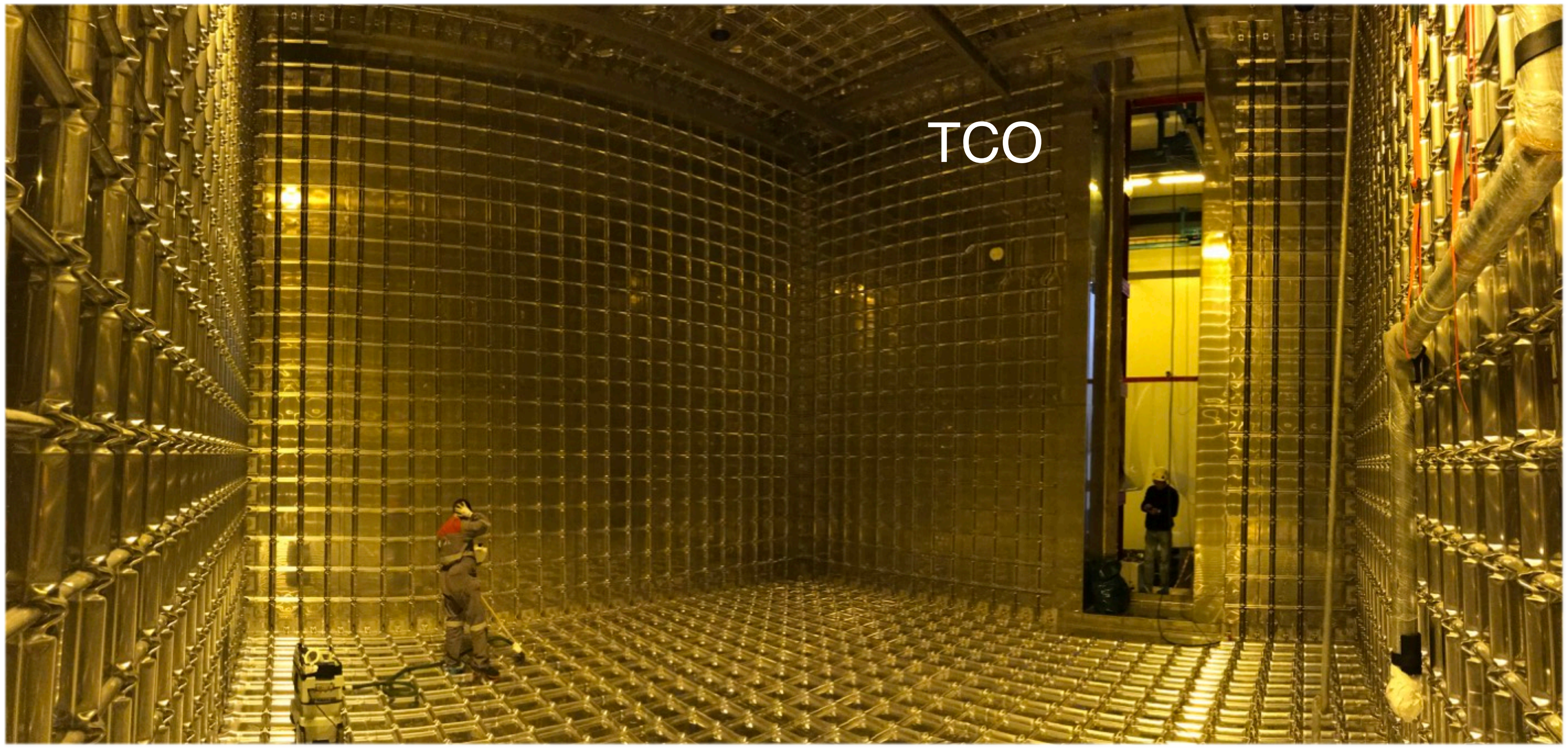


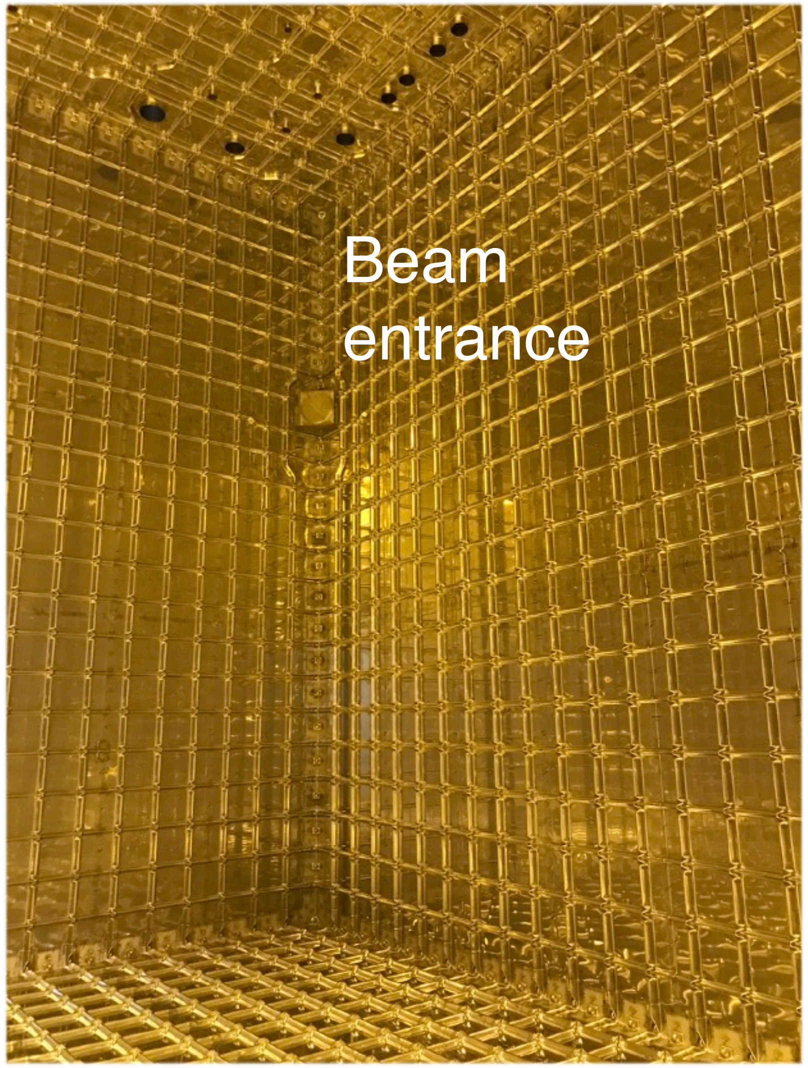
ProtoDUNE cryostats

Differences with LNG tanks:

- LAr instead of LNG (LAr is denser)
- Smaller (~8x8x8 m^3 compared to ~30x30x40 m^3)
- No sloshing issues except in case of earthquake (anyway minor waves)
- Several openings - typically on the roof - for feedthroughs, detector support, cryogenic lines, …
- Beam entrance (missing insulation to minimise beam perturbations)
- More stringent requirement on heat input (5-7 W/m^2) -> 79 cm thick insulation
- Installation of the detector: activities going on inside the cryostat for months after the cryostat is ‘completed’
- Temporary Cryostat Opening (TCO) that is closed at the very end

ProtoDUNE features





Roof openings (from inside)

Roof openings (from outside)

Warm structure

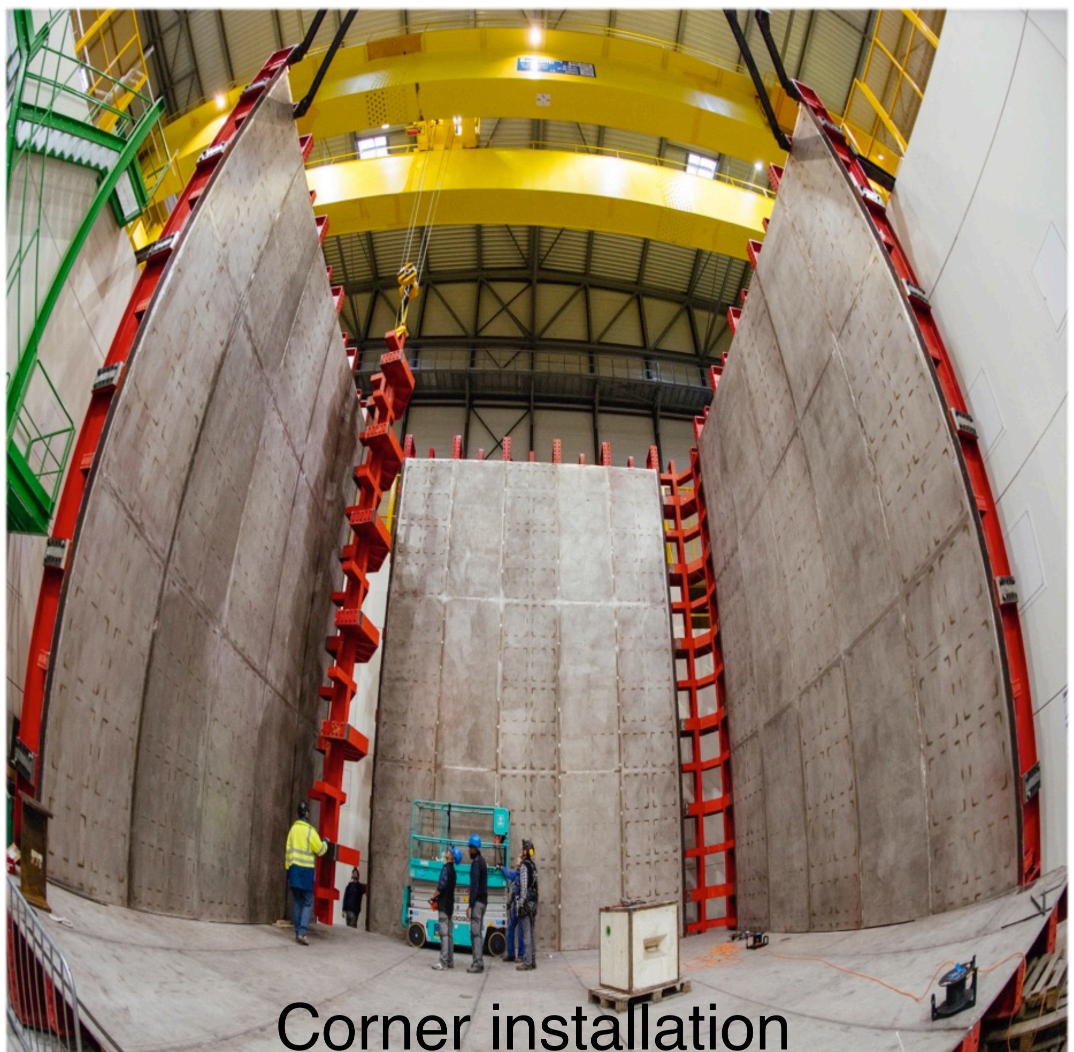
About 250 ton of steel in total
Support structure: carbon steel IPE600 1.6 m pitch interleaved with IPE240
Warm skin: 10 mm think stainless steel 304L (gas tight welded)
Rated for: weight of the detector + weight of LAr + 350 mbar overpressure

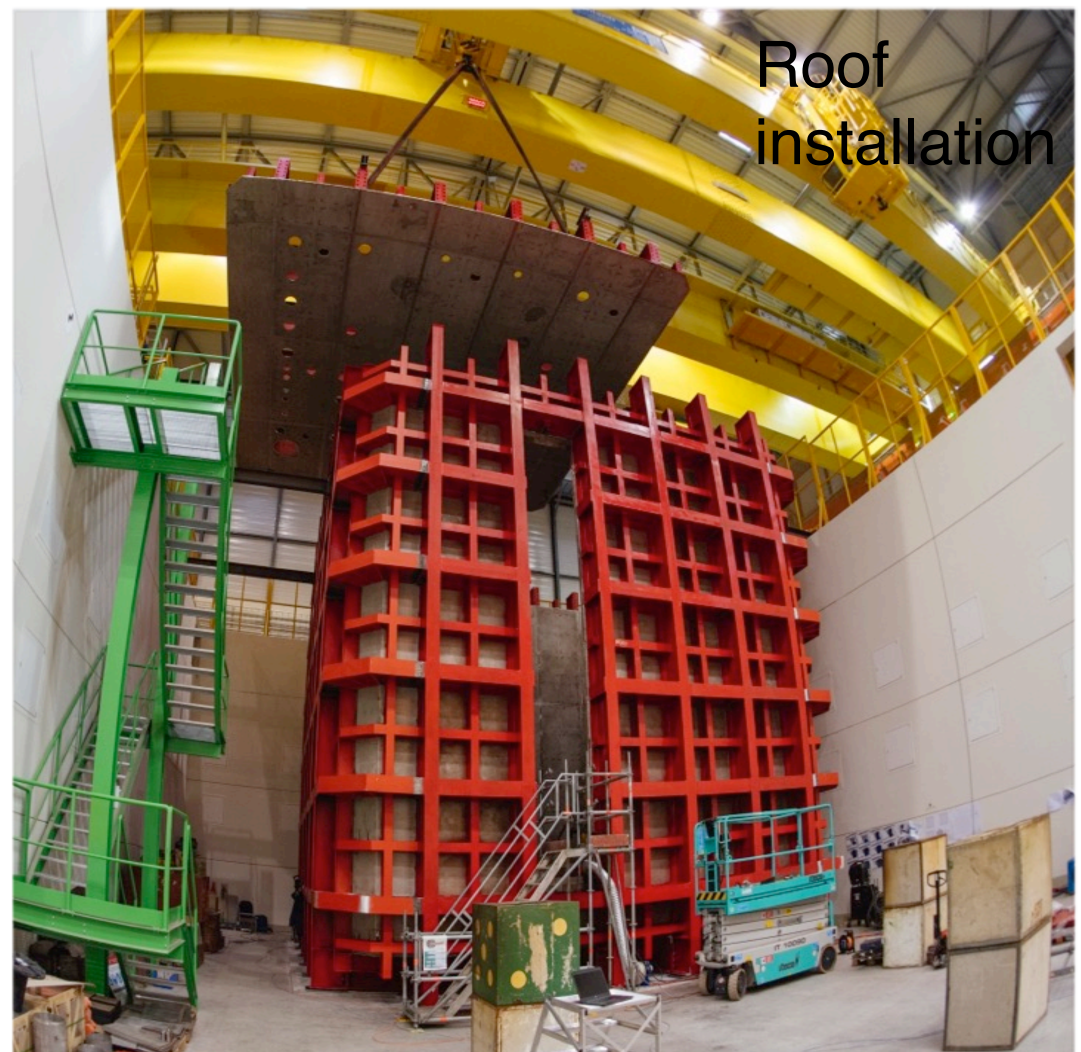
NP04: started 15 August 2016 finished 7 January 2017 -> 21 weeks
NP02: started 7 January 2017 finished 13 March 2017 -> 9 weeks
Manpower: 10 Technicians, 9 welders and 4 crane drivers

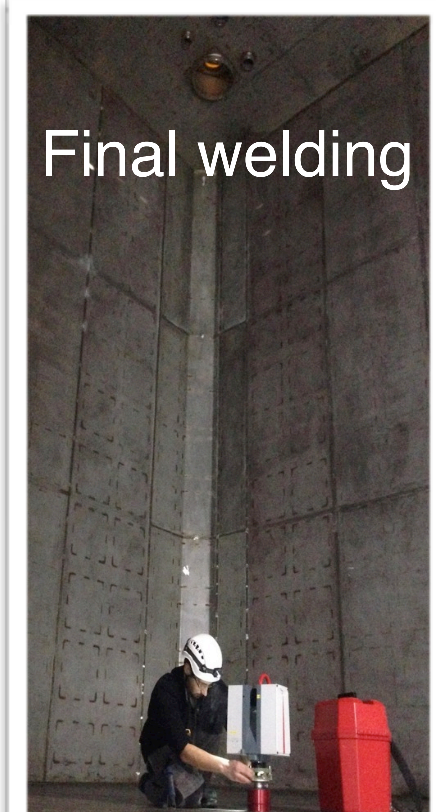

Components
welding


Floor preparation


Wall
handling


Corner installation


Roof
installation

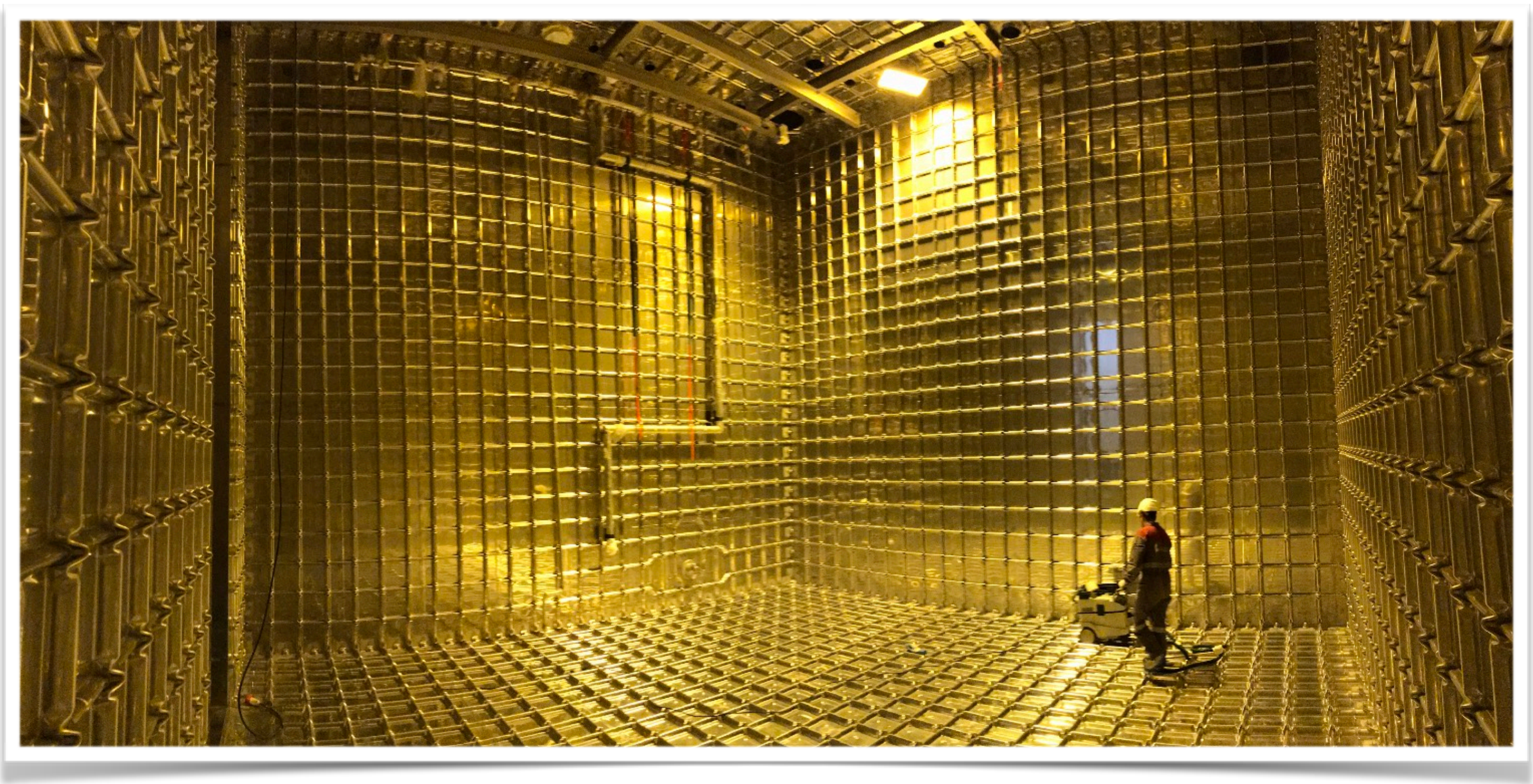

Final welding

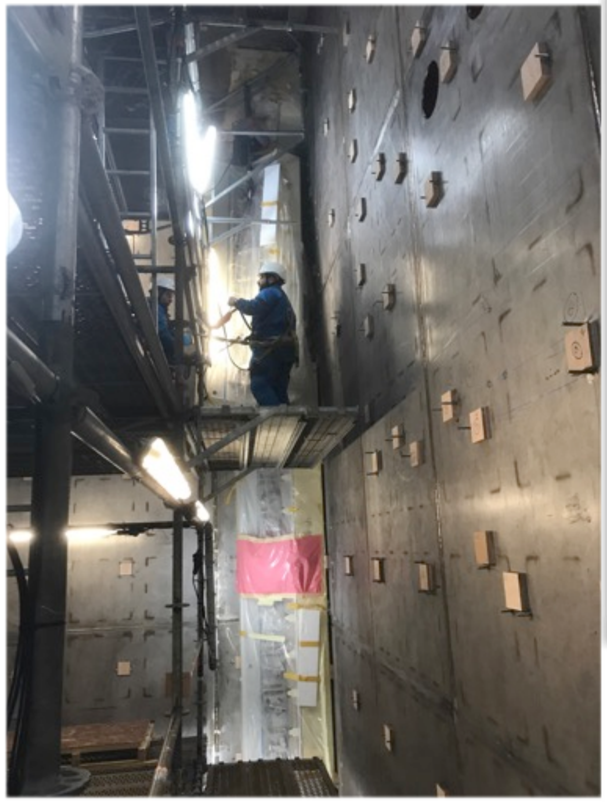
Insulation and membrane

Up to about 60 workers (engineers, carpenters, welders, foreman, technicians, scaffolders):
- Gabadi for construction work, welding, and management
- GTT for quality control and supervision

NP04 (handover on 7th January)
start date 9th of January
last welding 1 September (34 weeks)
Scaffolding removal 11 October

NP02 (handover on 13th March)
start date 13th of March
last welding 22 September (28 weeks)
Scaffolding removal 10 October






SCS-05

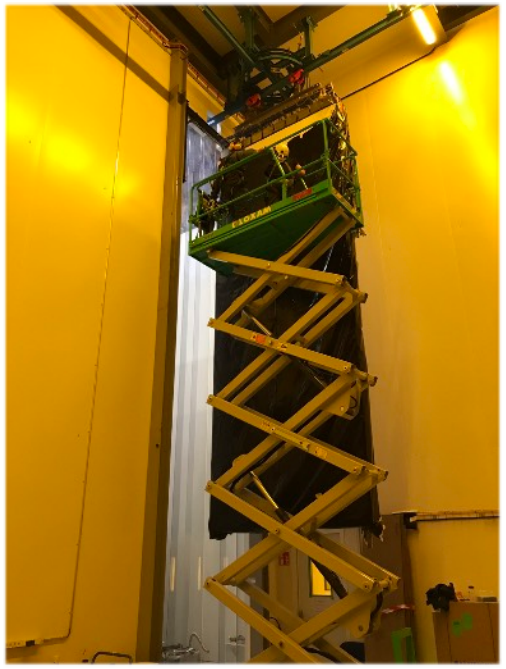
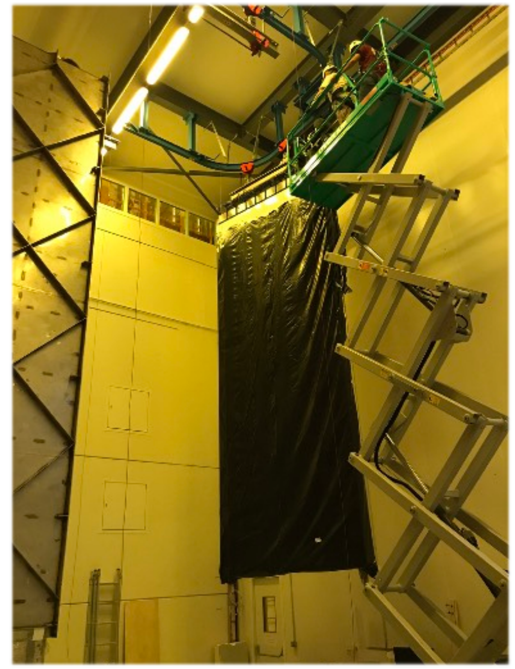
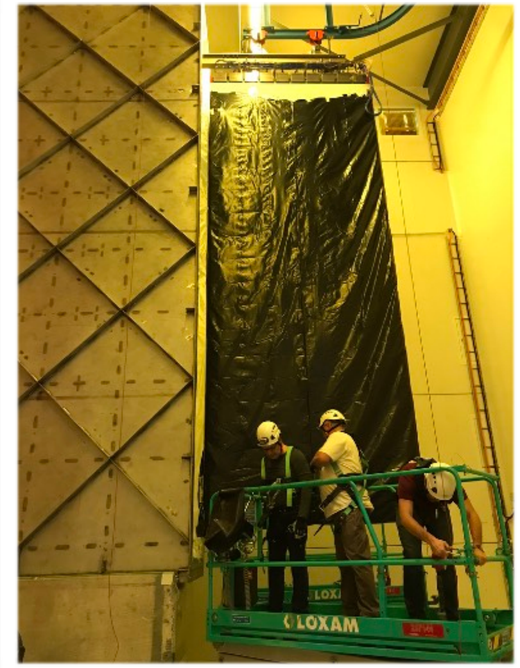
Cold test box

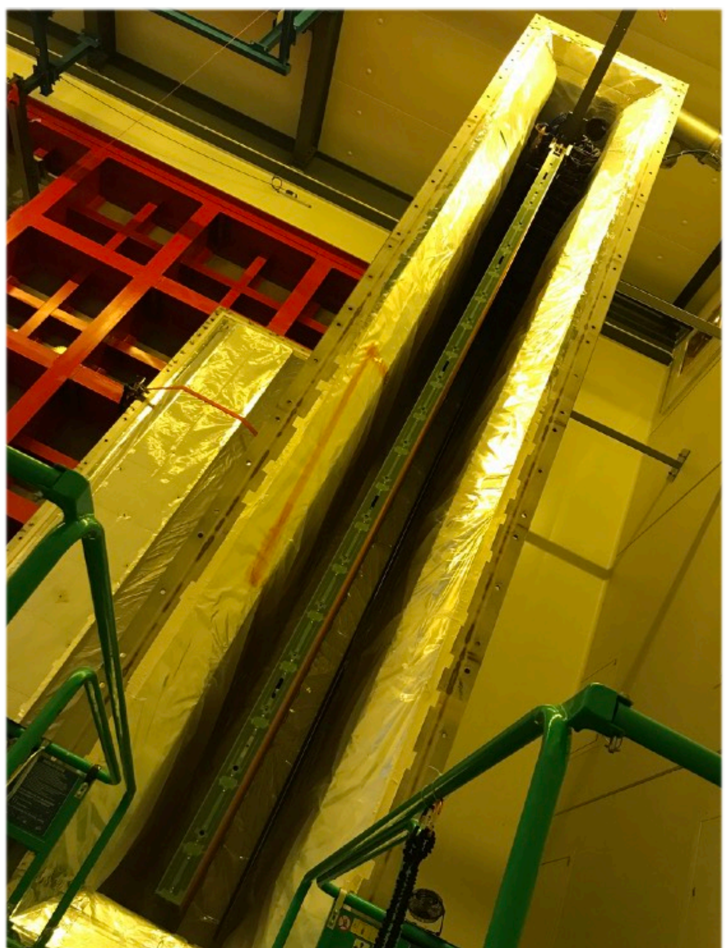
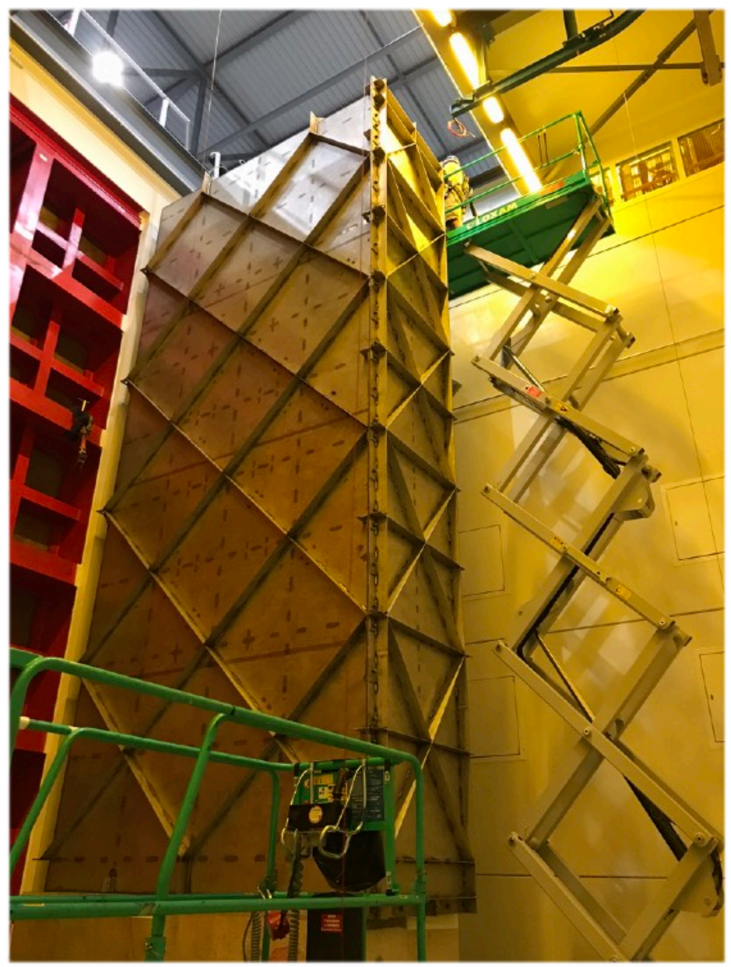
Cryogenic plant next to the NP04 clean room

- SS structure with passive thermal insulation
- Installed in the NP04 clean room
- DSS beam to hold the APA
- 7 m tall door gives access to the APA
- Cooled (~150K) flushing cold GN_2
- 17 m^3 LN_2 dewar provides the cold gas
- Cryo-control integrated in the DCS


Cold box open inside the NP04 clean room

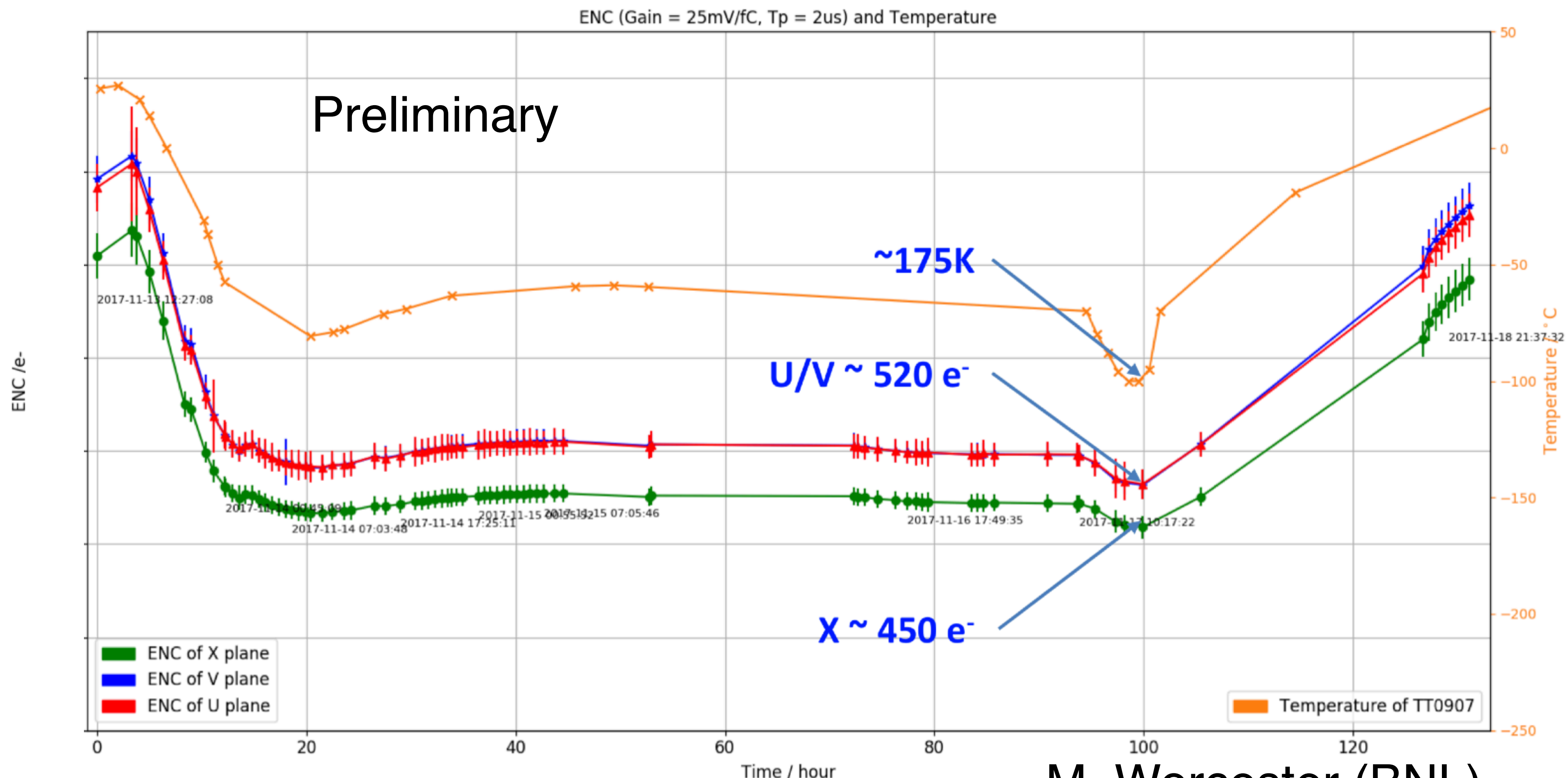
APA in cold box

APA in cold box

First cool down of the cold box with the APA inside finished last weekend



M. Worcester (BNL)

Additional activities

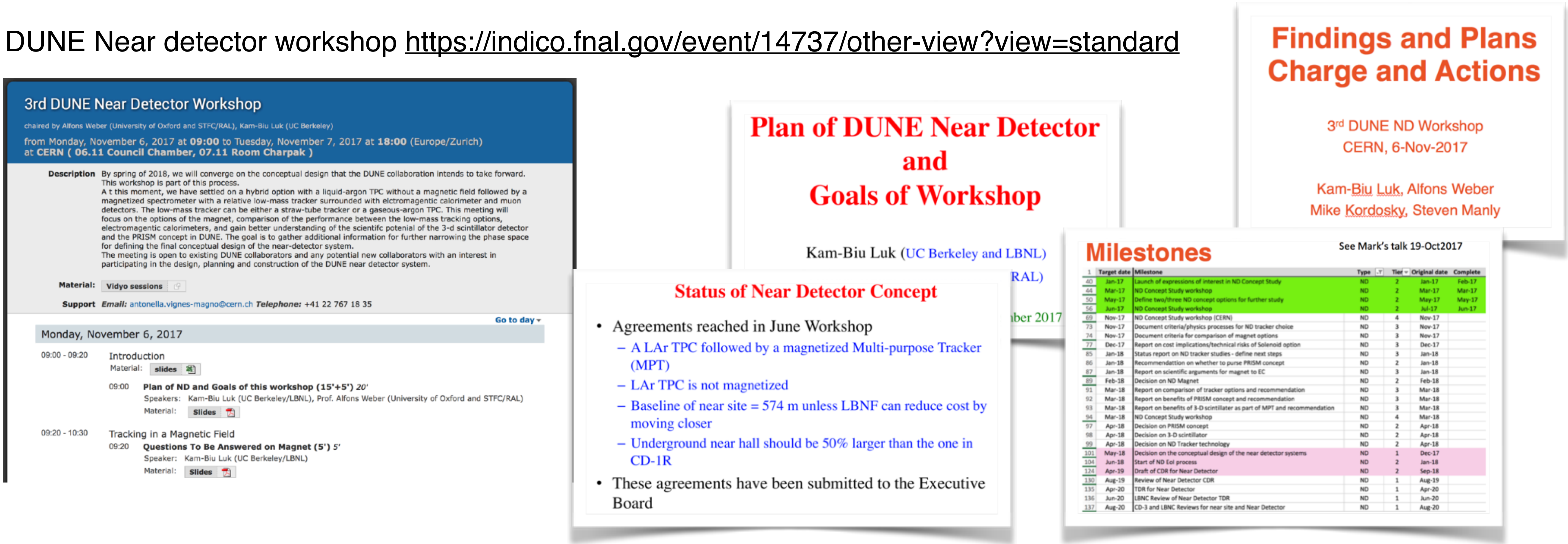
Combine **DCS and DAQ**, exporting the Front-End-Link-EXchange (FELIX) technology (à la ATLAS) from collider experiments to neutrino experiments

Online **computing farm**
(more than 1000 cores)
Data storage based on EOS
Tier0 for protoDUNE data

Production of the **field cages** for both NP04 and NP02
HV systems (aluminium field shaping rings, resistive cathode, HV feedthrough, …)
Production of the single phase **cathode** system
Technical infrastructure (cooling, ventilation, electricity, building, safety, cranes, access, …)
Two new **beam lines** (extension of H2 and H4 beam lines)
Activities in event **reconstruction**, **simulations**, **data analysis** with CERN EP-NU

Near detector related work

DUNE Near detector workshop https://indico.fnal.gov/event/14737/other-view?view=standard



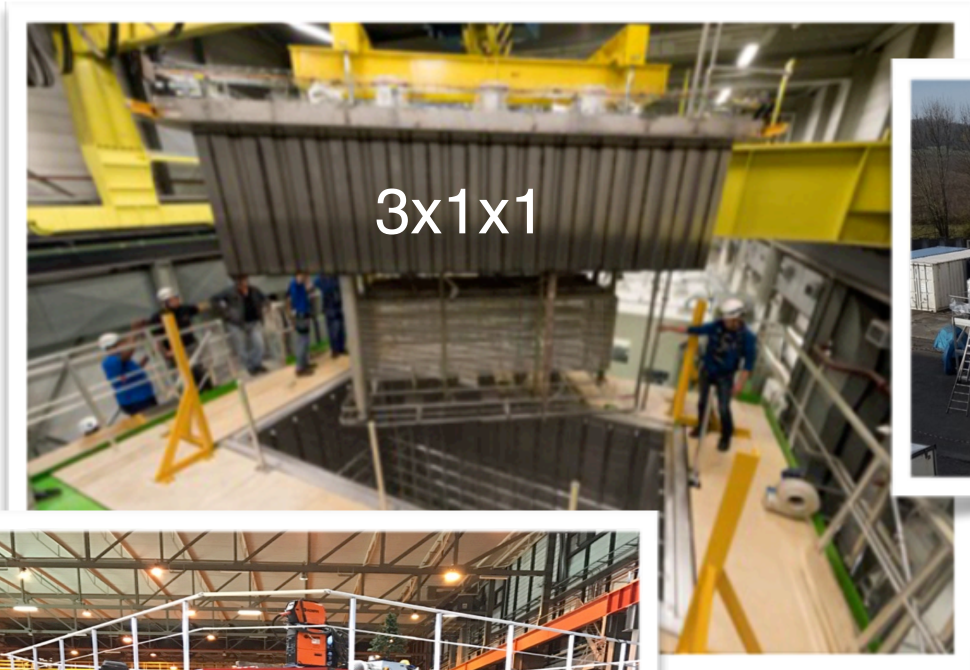
The **CENF-ND forum** is set to provide **support** to the ongoing efforts of the **DUNE** and **HK** collaborations, strength the European support, attract new institutes, endorse participation from Japanese and American Institutes.

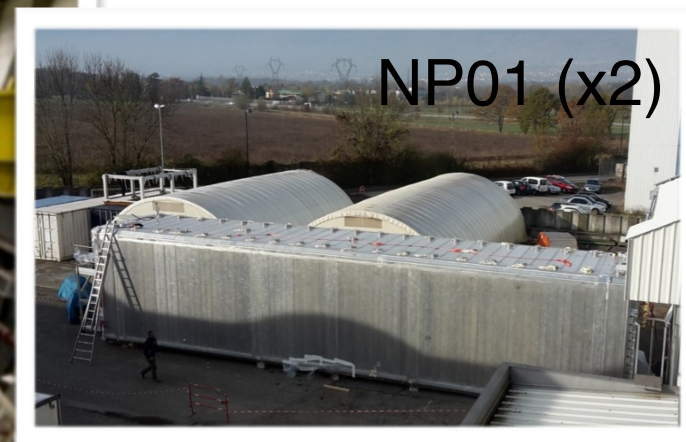
The effort started in July and growing up. 1 steering group and 5 Working Groups
Steering group: P. Sala (CERN/INFN-Mi), S. Bordoni (CERN), A. Weber (U. Oxford/RAL), M. Zito (CEA, Paris)
WG1 - Flux: M. Diwan (BNL), B. Popov (LPNHE, Paris)
WG2 - Cross-section (TH): M. Martini (CEA,Paris), F. Sanchez (IFAE, Barcelona)
WG3 - Cross-section (Exp): S. Bolognesi (CEA,Paris), TBD (expected from LAr community)
WG4 - Sensitivity studies: L. H. Whitehead (CERN), D. Meloni (Roma 3)
WG5 - R&D: E. Radicioni (INFN-Ba), T. Lux (IFAE, Barcelona)

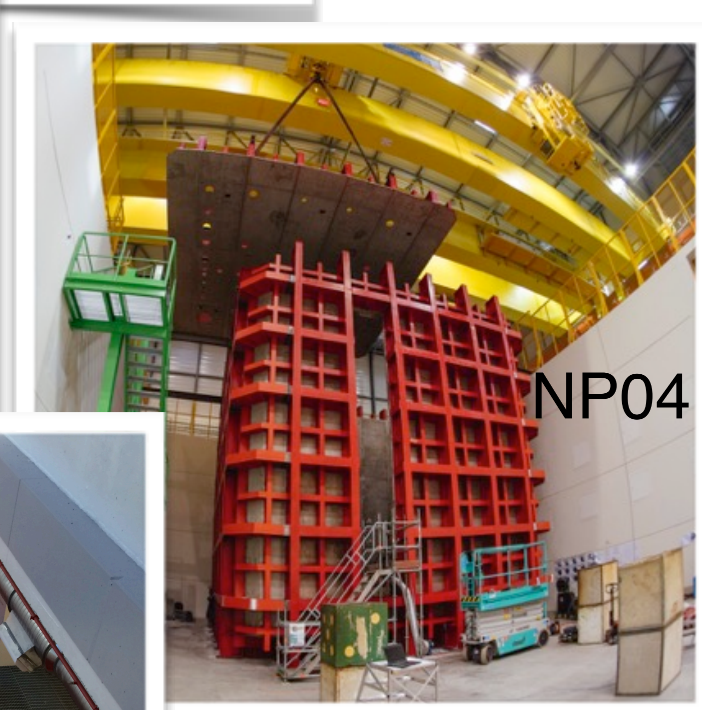
Convenors from both T2K and DUNE and in connection with NA61/SHINE and NuSTEC

https://twiki.cern.ch/twiki/bin/view/CENF/NearDetector

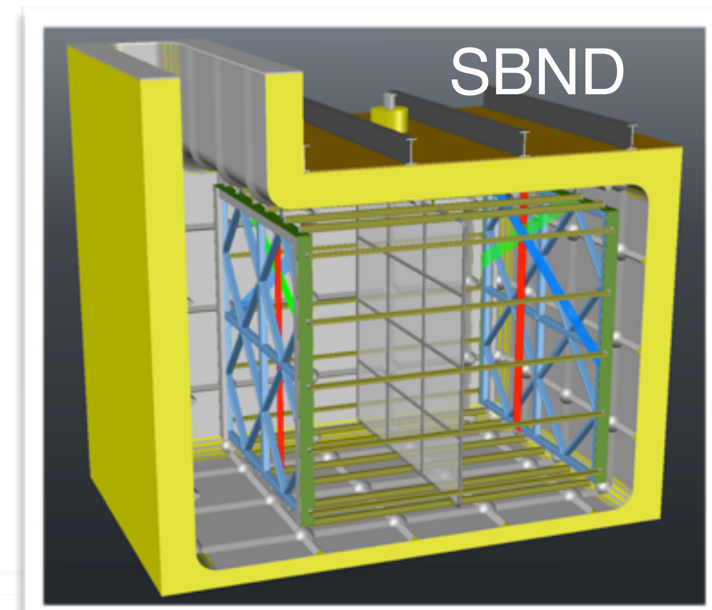
Recap on cryostats

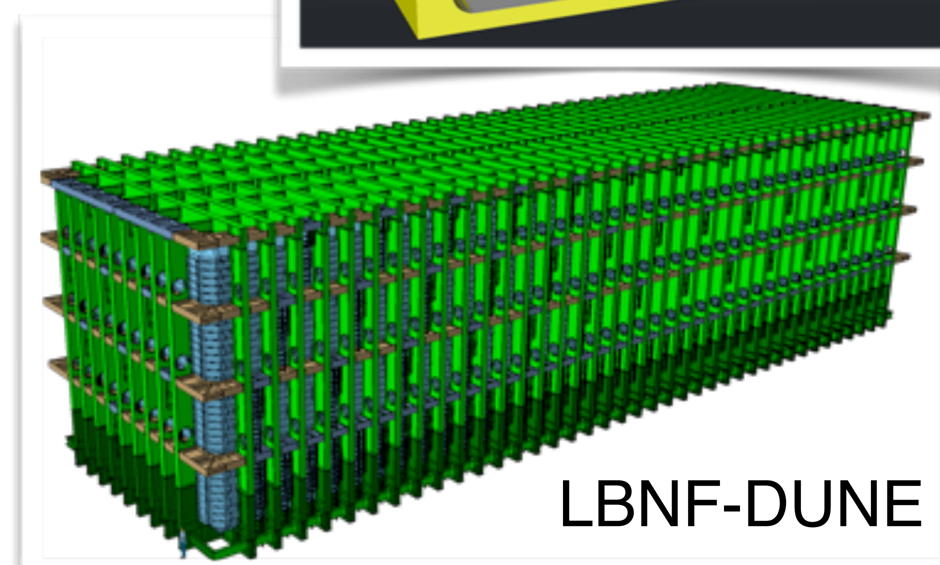






Design phase



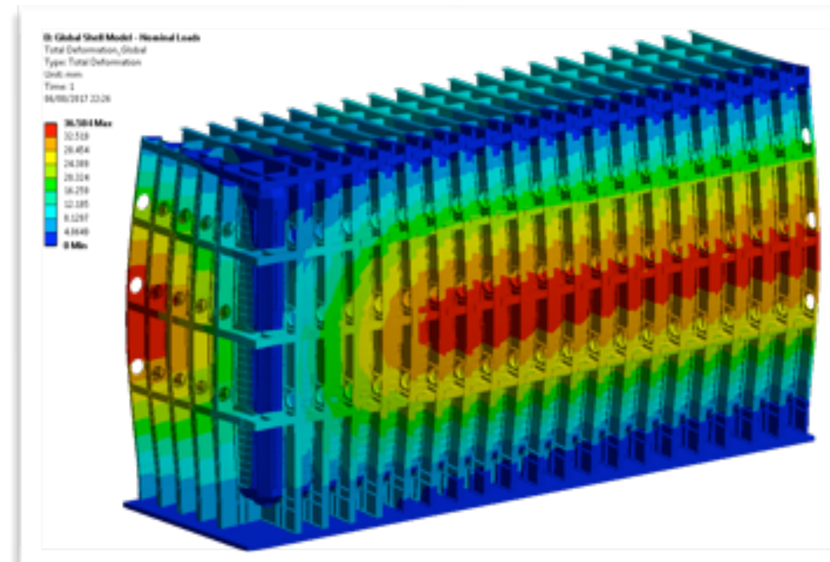


LBNF-DUNE

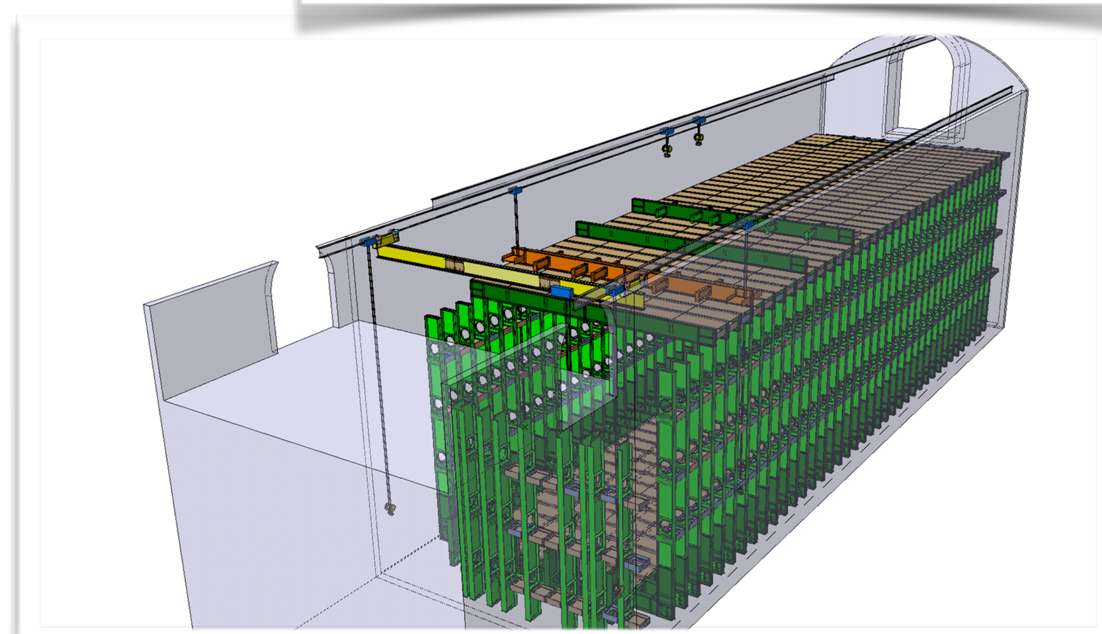
Warm structure final review done and ok:
- Final warm structure design
- Drawings and models repository
- Detailed structural analysis
- Plans for destructive tests and QA
- Analysis of installations scenarios
- Requirements on tools and infrastructure
- Requirements on host lab responsibilities
- Access, safety and construction codes aspects

Warm structure Final Design review at SURF on 21-22 August 2017

https://web.fnal.gov/project/LBNF/ReviewsAndAssessments/LBNF%20Cryostat%201%20Steel%20Structure%20(Warm%20Structure)%20Final%20Design%20Review/SitePages/Home.aspx



CERN approved to issue a Design Contract with GTT
Contract should be ready before end of 2017.
Design work in 2018 with following deliverables:
- Cold vessel final design
- Table of materials to be ordered
- Detailed installation procedure
- Structural and thermal analysis
- QA plans
- List of firms to be contracted for the execution
- Overall schedule compatible with start of installation at SURF in 2021



Conclusions

The CERN Neutrino Platform is very active on several fronts.

NP offers to the neutrino community support for detector R&D, tests and construction for both US and Japanese activities.

At EHN1 extension two LAr TPC prototypes for LBNF-DUNE will be operated on a charge particle test beam starting from next year.

NP is involved in installation and commissioning of LAr detectors in Europe and in US.

NP has major responsibility towards cryostats. The first LBNF cryostat should be ready for installation by end of 2020.

CERN is also strongly committed to the FNAL short baseline program.

More activities to assist DUNE and T2K/HK in the definition of their future near detector are being planned.