The CERN Neutrino Platform

Venezia, 14th March 2017, XVII Neutrino Telescopes 2017

Marzio Nessi, CERN & University of Geneva

Future Neutrino Accelerator Physics

- 2013- European Strategy : *"CERN should develop a neutrino program to pave the way for a substantial European role in future long-baseline experiments"*

- *2014-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)"

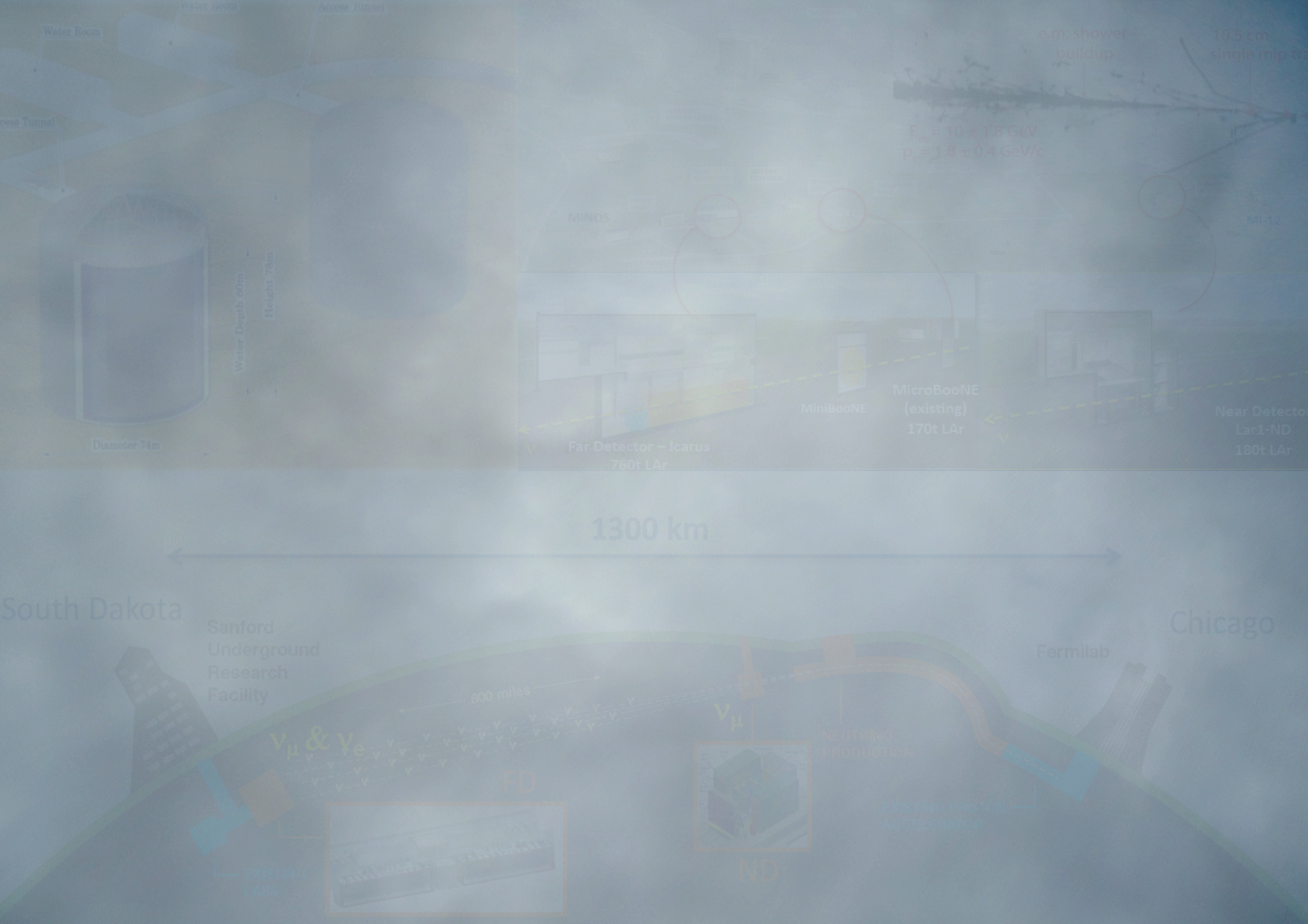
- *2015-CERN Council has released an important amount of resources for a CERN Neutrino Platform, as part of its medium term plan (next 5 years)*

Future Neutrino Accelerator Physics

- The June 2014 APPEC Paris meeting dedicated to Large Neutrino Infrastructures, where most FAs and leaders in the field where present, started drafting a possible future strategy
  - *CERN broke symmetry and announced that it will freeze for the moment all types of Neutrino beams at CERN (Short and Long Baseline) in favor of common activities in US and Japan*

- In July 2014 the FNAL management started the process for a new large international long and short baseline, first US green light in 2016
  - *Two parallel projects : infrastructure (LBNF), detectors+ physics (DUNE)*
  - *A US based international High Intensity Facility based on the LHC model*
  - *The short baseline program was approved by the FNAL PAC*

- Japan continues to plan for a future larger facility (Hyper Kamiokande) and an upgrade of the present T2K (beam and near)
  - *Today rated among the top scientific projects in Japan*


Water Room
Access Tunnel
Water Depth 60m
Height 78m
Diameter 74m
MINOS
MiniBooNE
MicroBooNE
(existing)
170t LAr
Far Detector – Icarus
760t LAr
Near Detector
Lar1-ND
180t LAr
1300 km
South Dakota
Sanford
Underground
Research
Facility
Chicago
Fermilab
800 miles
FD
ND

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 test facility of detectors and components (hardware and software)
- ✓ As a research group active at these facilities and later on physics experiments

→ CERN NEUTRINO PLATFORM

CERN ν Platform Initial Mandate (2015)

- Assist the various groups in their R&D phase (detectors and components) in the short and medium term and give coherence to a fragmented European Neutrino Community
- Provide to the ν community a test beam infrastructure (charged particles)
- Bring R&D at the level of technology demonstrators in view of major construction activities
- Continue R&D on ν beam, as a possible base for further collaborations
- Support the short baseline activities (infrastructure & detectors)
- Support the long baselines activities (infrastructure & detectors)

- LAr TPC (time projection chambers) technology is emerging as the solution to be adopted in both Short and Long baselines (in the US facilities)
- The technology for near detectors is more vague (both in US and Japan):
  - *Atmospheric or pressure TPCs*
  - *Modular liquid argon TPCs*
  - *Various trackers, calorimeters and muon spectrometers*
- All solutions need R&D and an approach in steps, given the size and the complexity

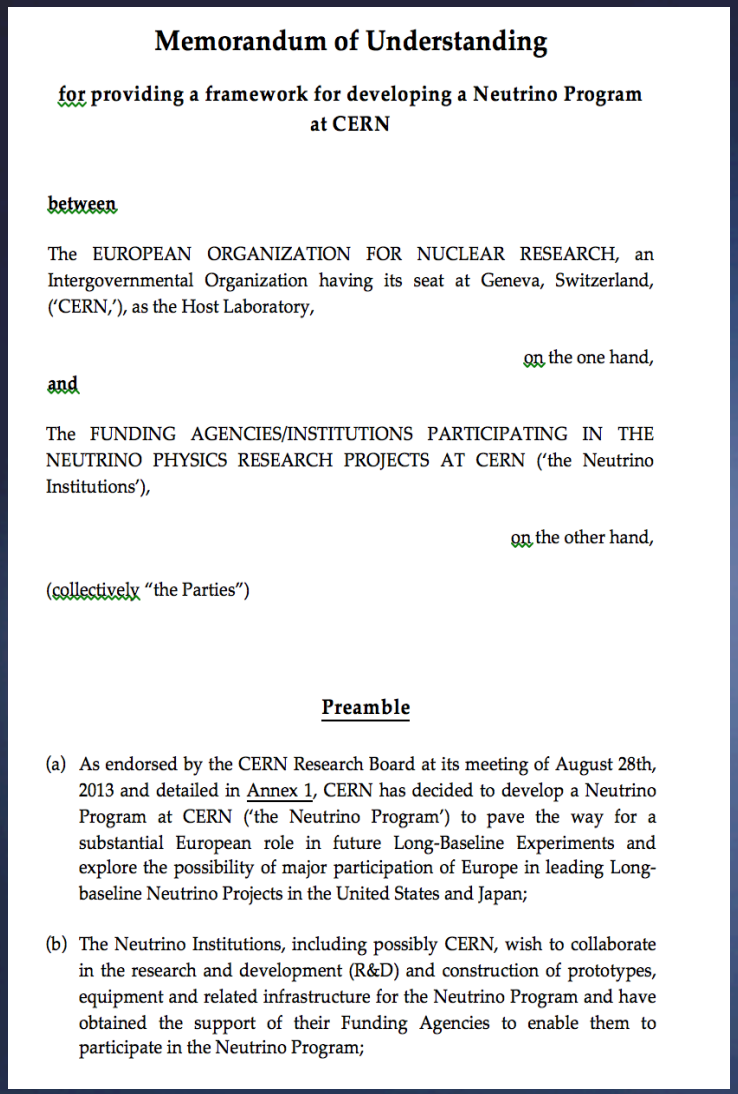
In steps for the next few years

- Optimize the TPC single phase technology, beyond what was done by ICARUS, MICROBONE and LArIAT
- *Prove the potential of a 2 phases LAr TPC*
- Gain experience on new techniques for light detection in LAr
- *Gain experience on gas TPCs*
- Calibrate the TPCs response to hadrons and leptons
- *Learn how to deal with all possible ν-e, ν-μ topologies (large samples of data)*
- Optimize the detector modularity and integration process
- *Gain experience on membrane cryostats construction*
- Learn the cryo-techniques necessary at the multi-kt scale
- *Exercise and learn about automatic data reconstruction and large data set handling (PBytes)*
- ….

In practice the CERN activity consists In :

- experimenting new technologies of large volume cryostats
- *creating a strong LAr cryogenics group at CERN working in strong cooperation with the FNAL one*
- preparing new test beam facilities for large cryogenic detectors
- *helping the Short Baseline detectors (ICARUS and later SBND) to be ready in situ for END 2017, data taking starts in 2018*
- supporting new R&D on single and double phases LAr detector for the Long baseline (large demonstrators and engineering prototypes)
- *supporting the R&D and later the construction of new ν detectors in general (near and far)*
- continue basic R&D on ν beam components
- *setting up a large and effective infrastructure for large procurements and investments on the benefit of the collaborations*
- Setting up an infrastructure for big data (DAQ, on-line processing, event reconstruction, physics analysis)

We react on demands from the community : MOU frame



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,

on the one hand,

and

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

on the other hand,

(collectively "the Parties")

Preamble

(a) As endorsed by the CERN Research Board at its meeting of August 28th, 2013 and detailed in Annex 1, 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;

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

~ 60 EU institutions

As of Today we have 6 MOU addenda active !!

SPSC committee as an entry point

We react on demands from the community : MOU frame

- 6 Projects presented to the SPSC and approved:

✓*NP01: WA104, ICARUS as far detector for the US SBN*
✓*NP02: protoDUNE WA105, demonstrator + engineering prototype for a double ph. TPC*
✓*NP03: PLAFOND, an generic R&D framework*
✓*NP04: ProtoDUNE, engineering prototype for a single phase TPC*
✓*NP05: Baby Mind, a muon spectrometer for the WAGASCI experiment at T2K*
✓*Argon Cube : a modular TPC R&D*

- A few Projects in the pipeline : *T2K near detector, DUNE near detector, HPgas TPC, ENUBET, ….*

- COOPERATION PROTOCOL with the US Neutrino Program *(Neutrino Protocol signed in 2015, Addendum 1 is being finalyzed)*

Laboratory infrastructure at CERN : EHN1-1

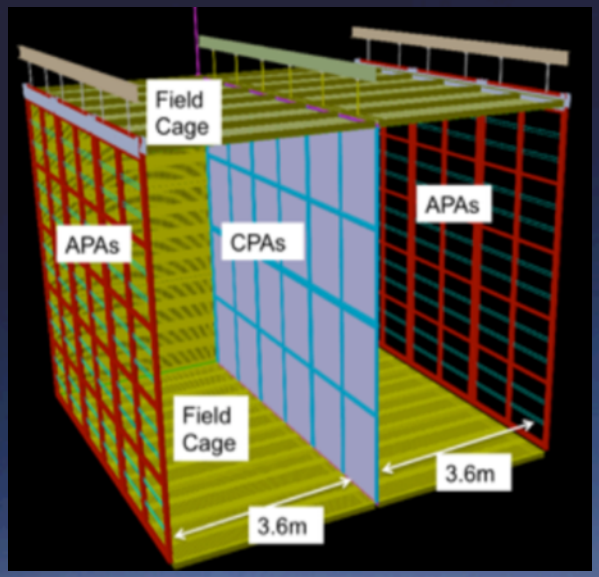
Status Sept 2016

+ 4 large clean rooms (b182, b185, EHN1-1), assembly areas (b185, b191, b182, EHN1-1), R&D labs (b182, b3179)

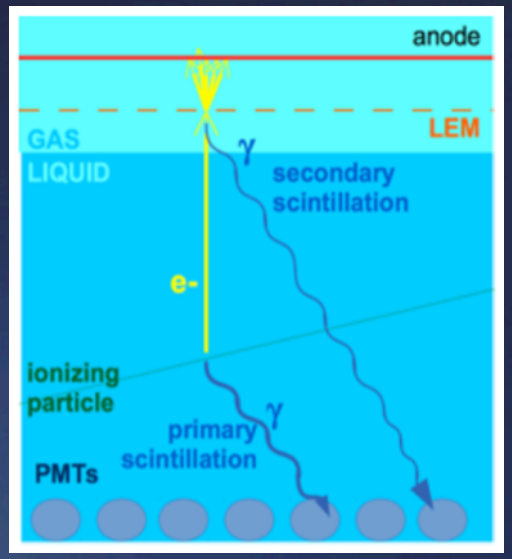
Laboratory infrastructure at CERN : EHN1-1

NP02 and NP04 DUNE LAr TPC prototypes

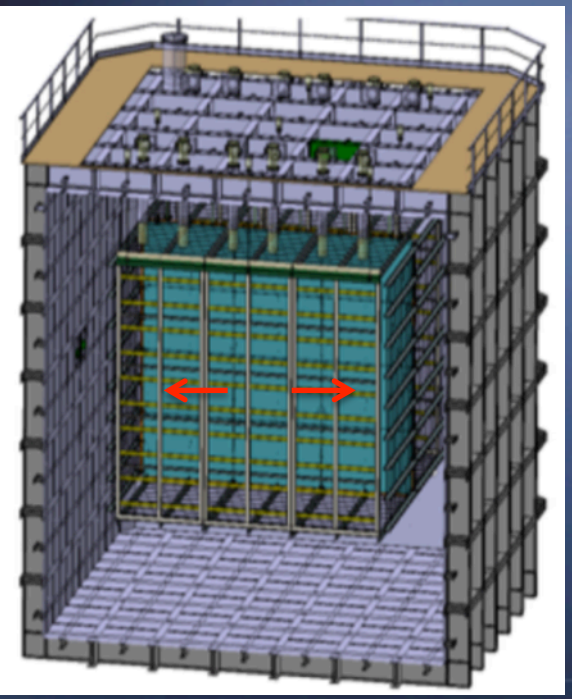
Single Phase TPC



N.P. active in several components design, procurement and installation



Double Phase TPC



NP04

Active volume

~ 6 x 6 x 7 m^3

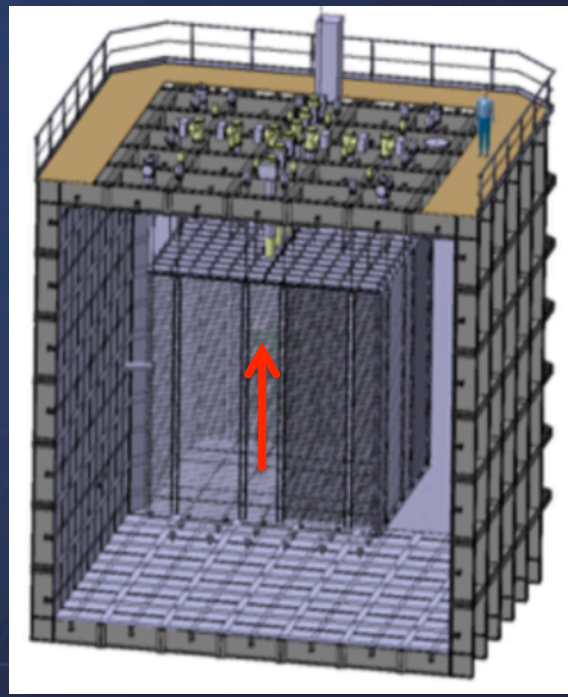
~770 tons of LAr

NP02

Active volume

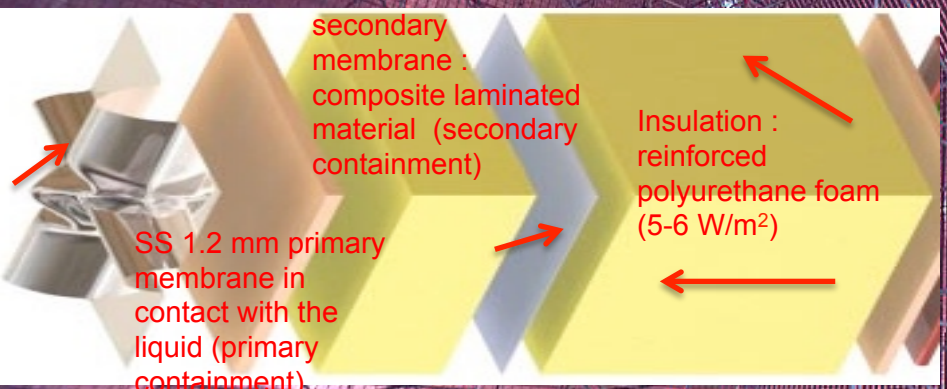
~ 6 x 6 x 6 m^3

~770 tons of LAr

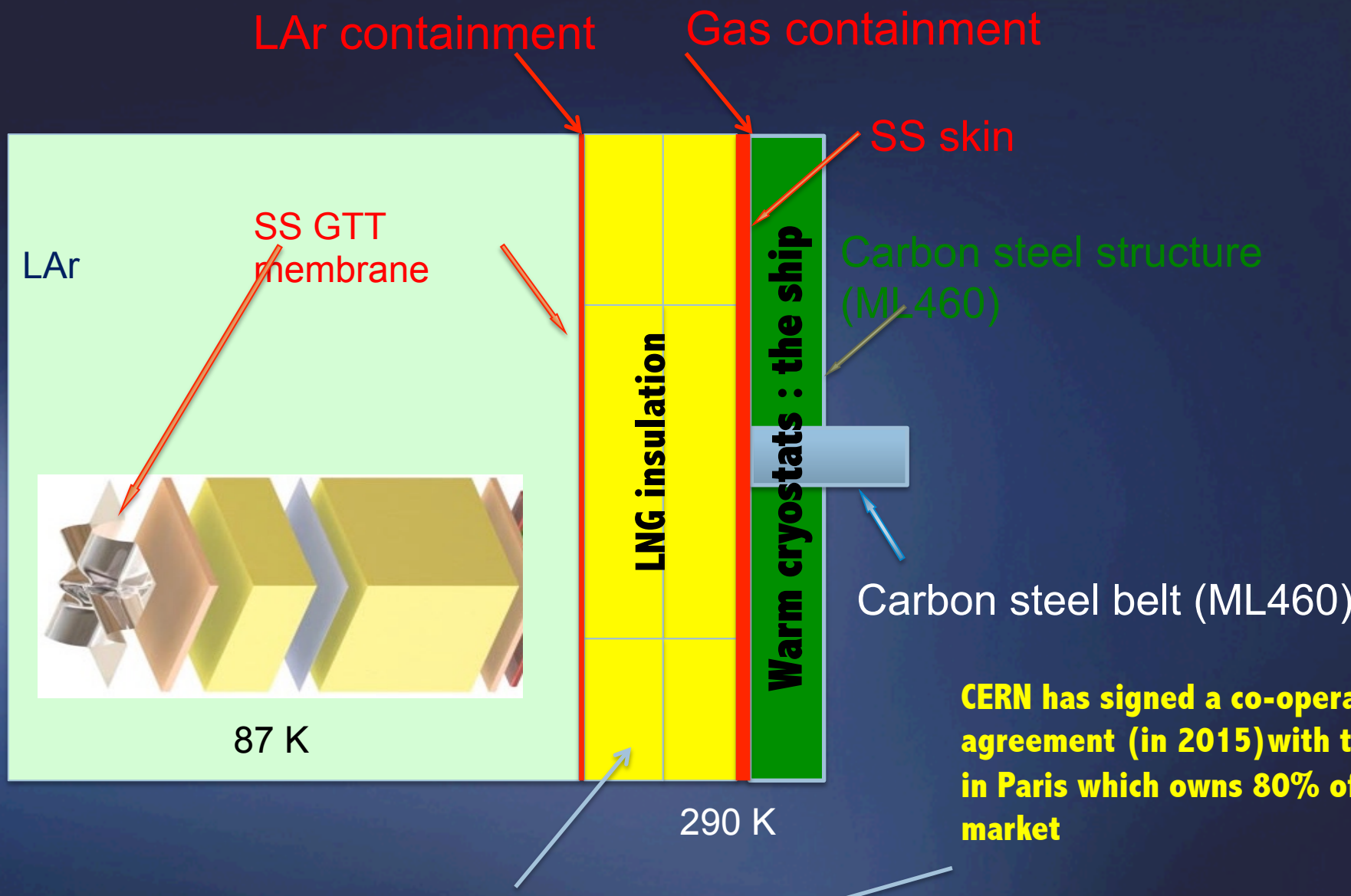


In the CERN SPS beams in April 2018

Membrane cryostats (LNG industry technology)



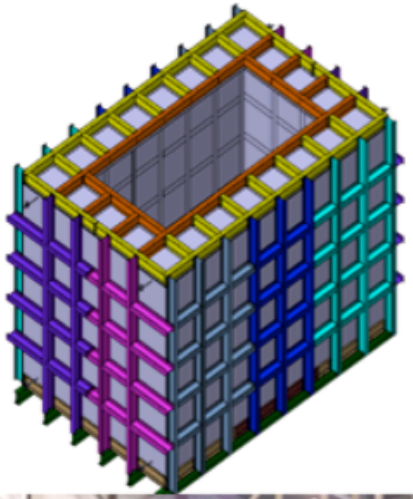
Membrane cryostats LNG concept

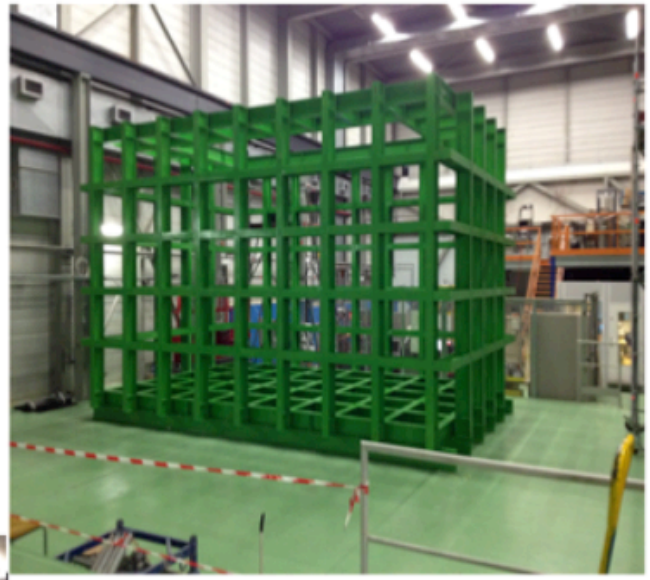


CERN has signed a co-operation agreement (in 2015)with the firm GTT in Paris which owns 80% of the market

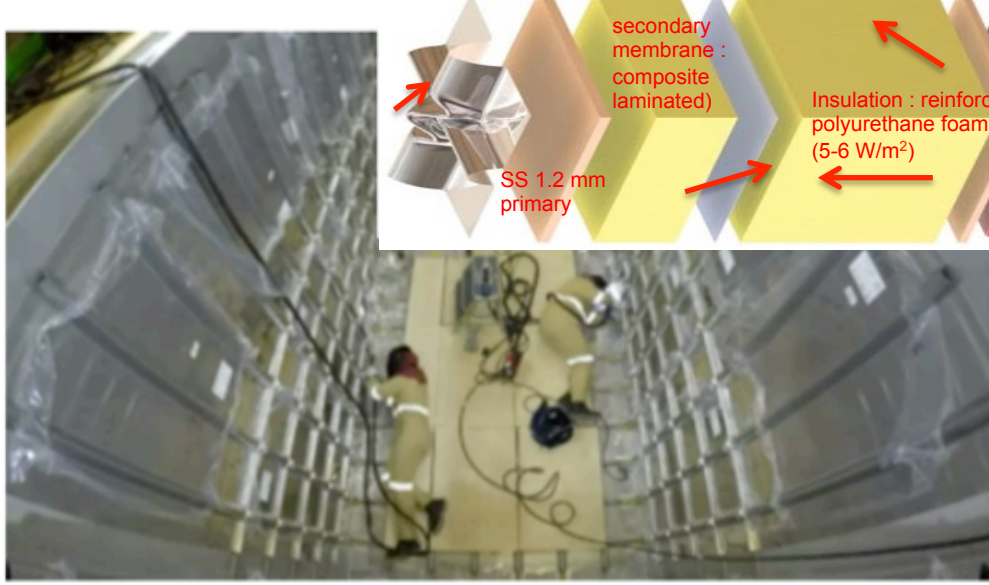
LNG proprietary technology

2015-2016 : WA105 DP first cryo demonstrator



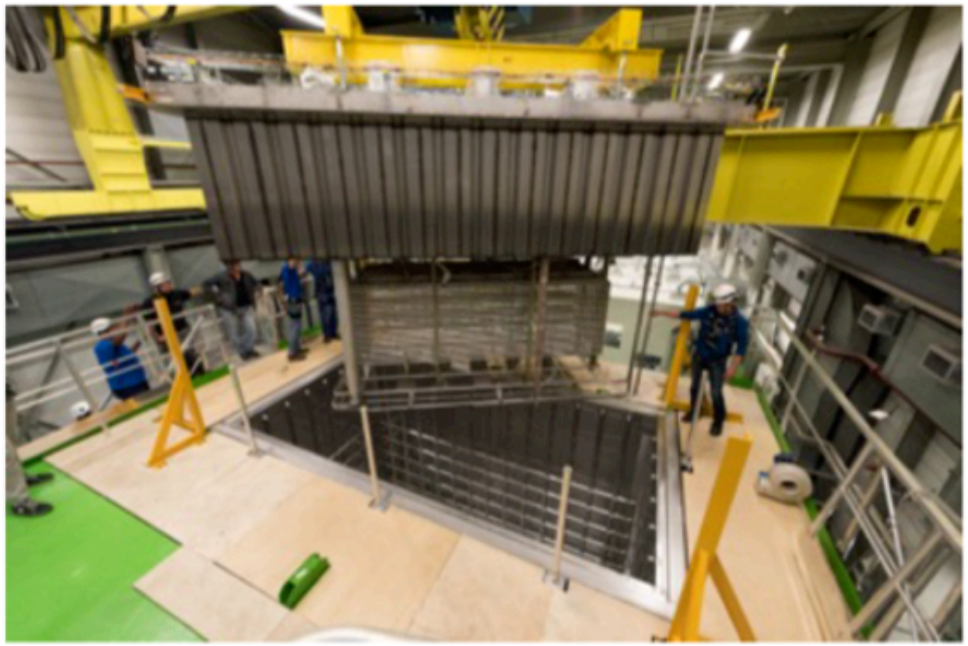


The stainless steel plates (form inside)

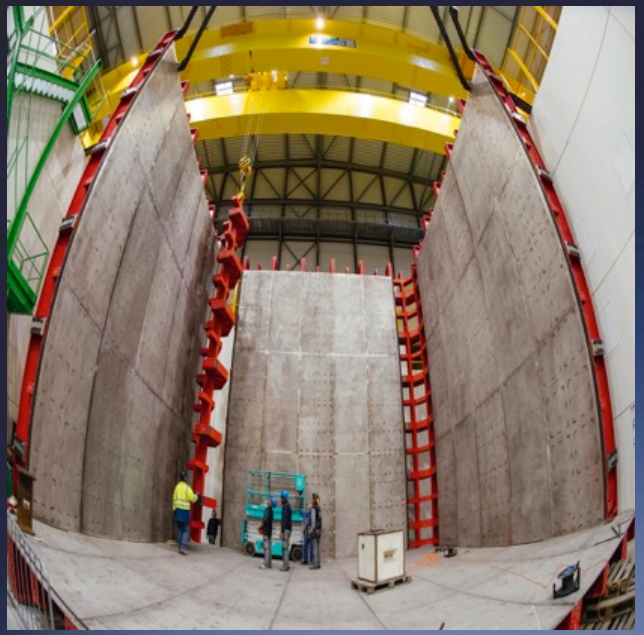


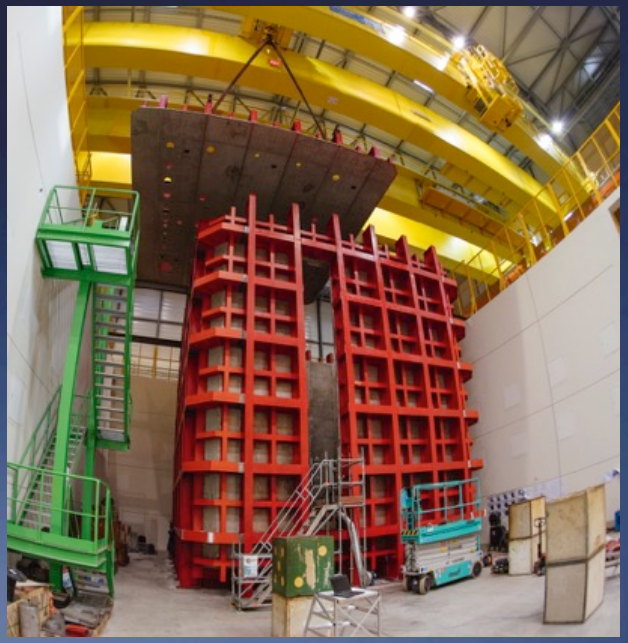
First GTT type membrane cryostat

LAr TPC double Phase demonstrator inserted

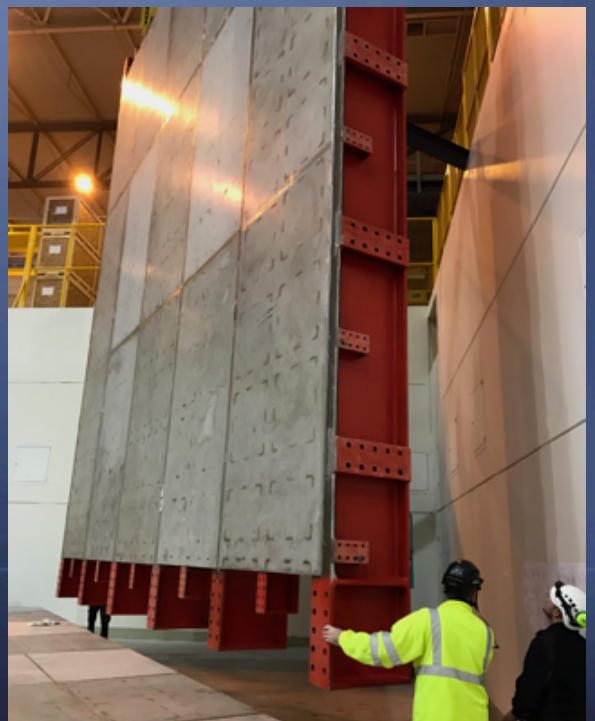


2016-2017 : ProtoDUNEs ~800 tons warm cryostats





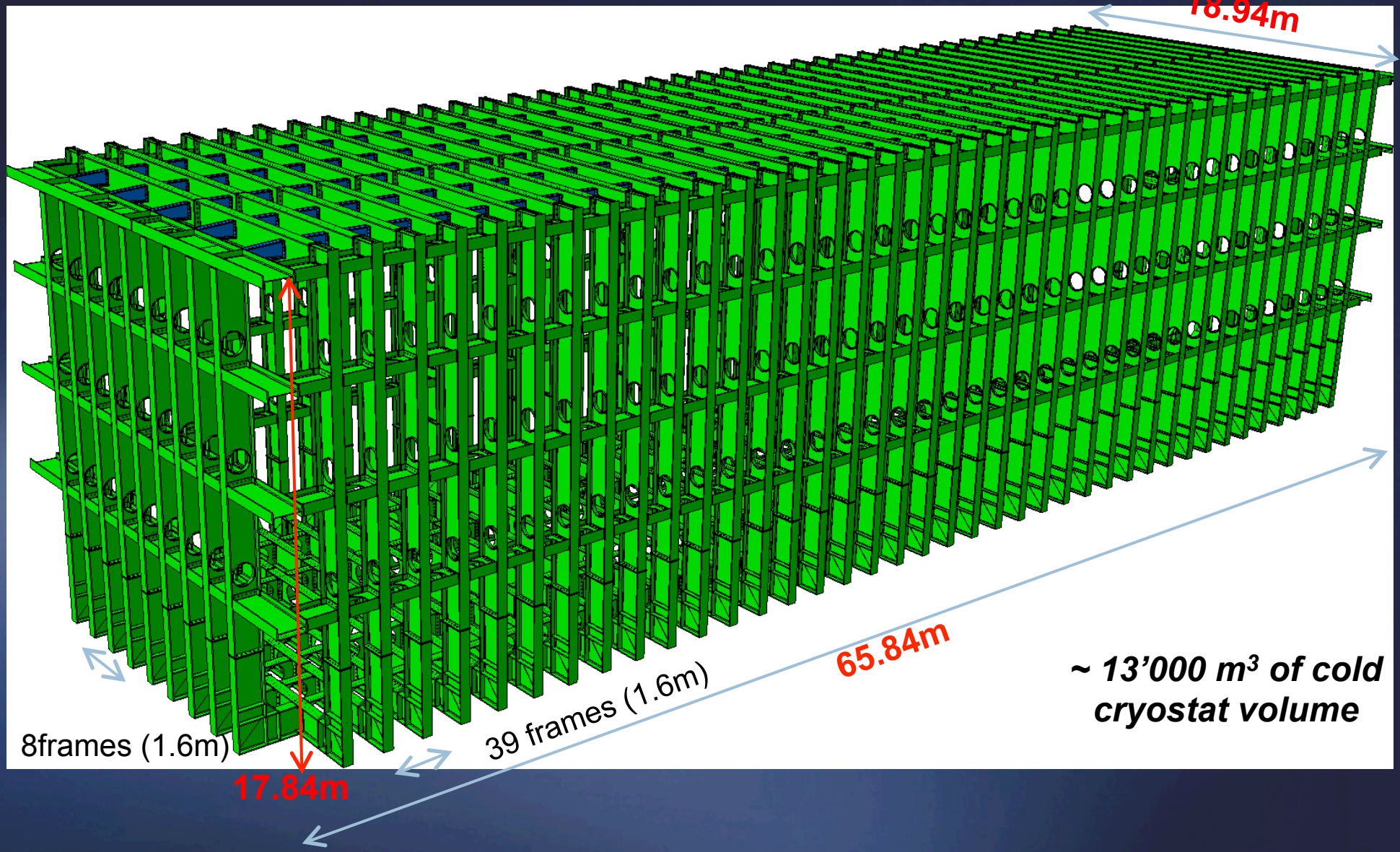
NP04: single phase



NP02: double phase

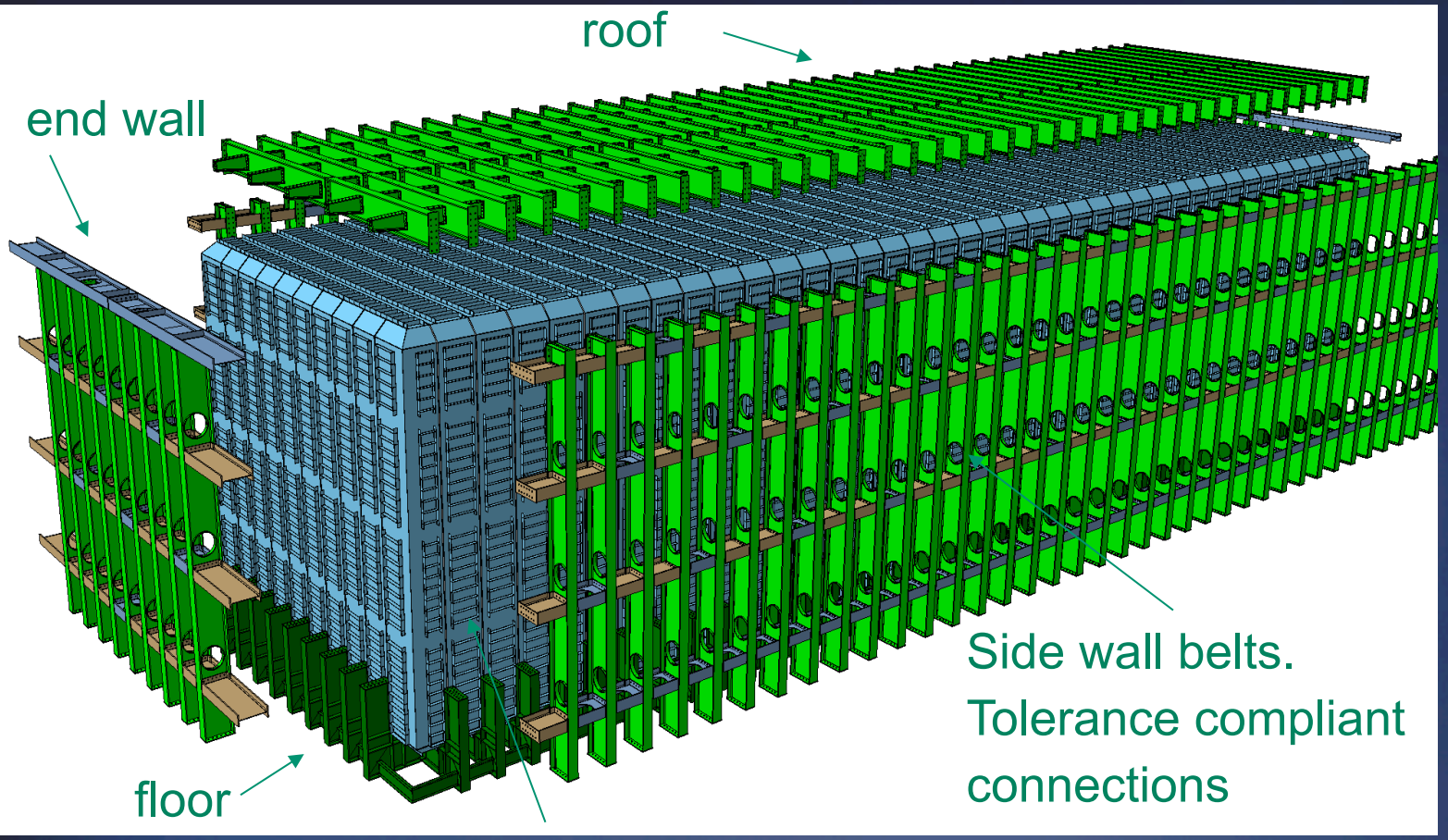
2016-2017 : ProtoDUNEs ~800 tons cold cryostats

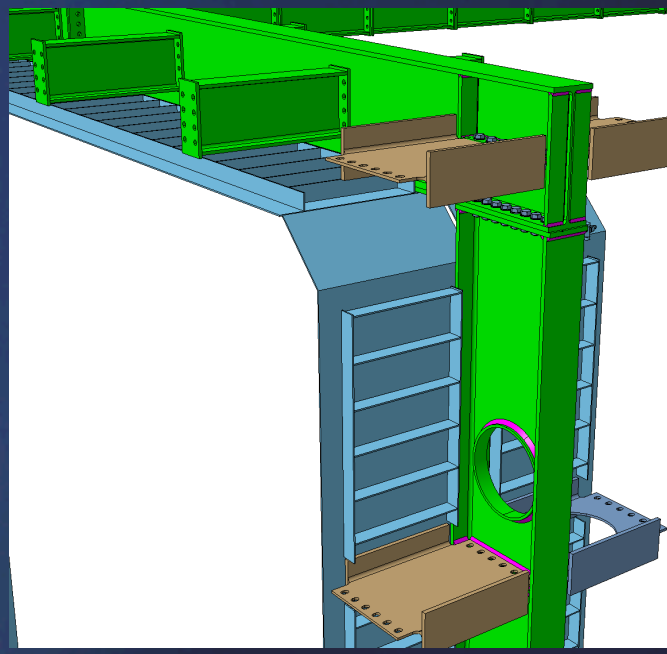
LBNF cryostats design, first cryostat financed by CERN



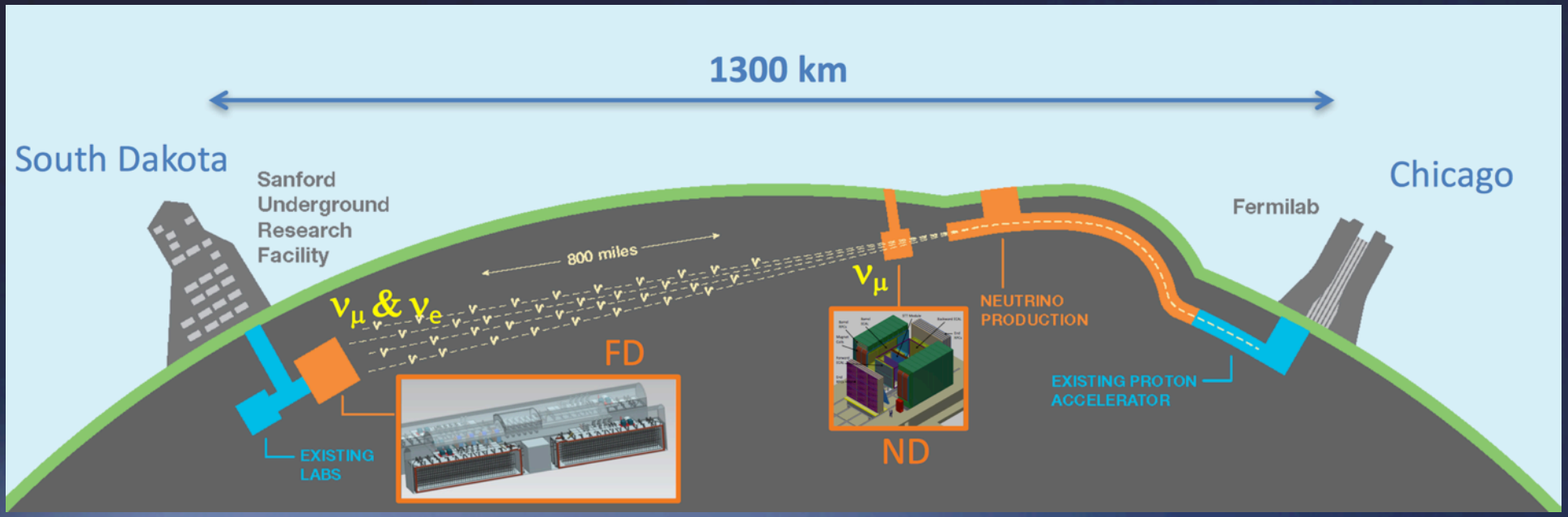
LAr = 17'432 tons (95% liquid)

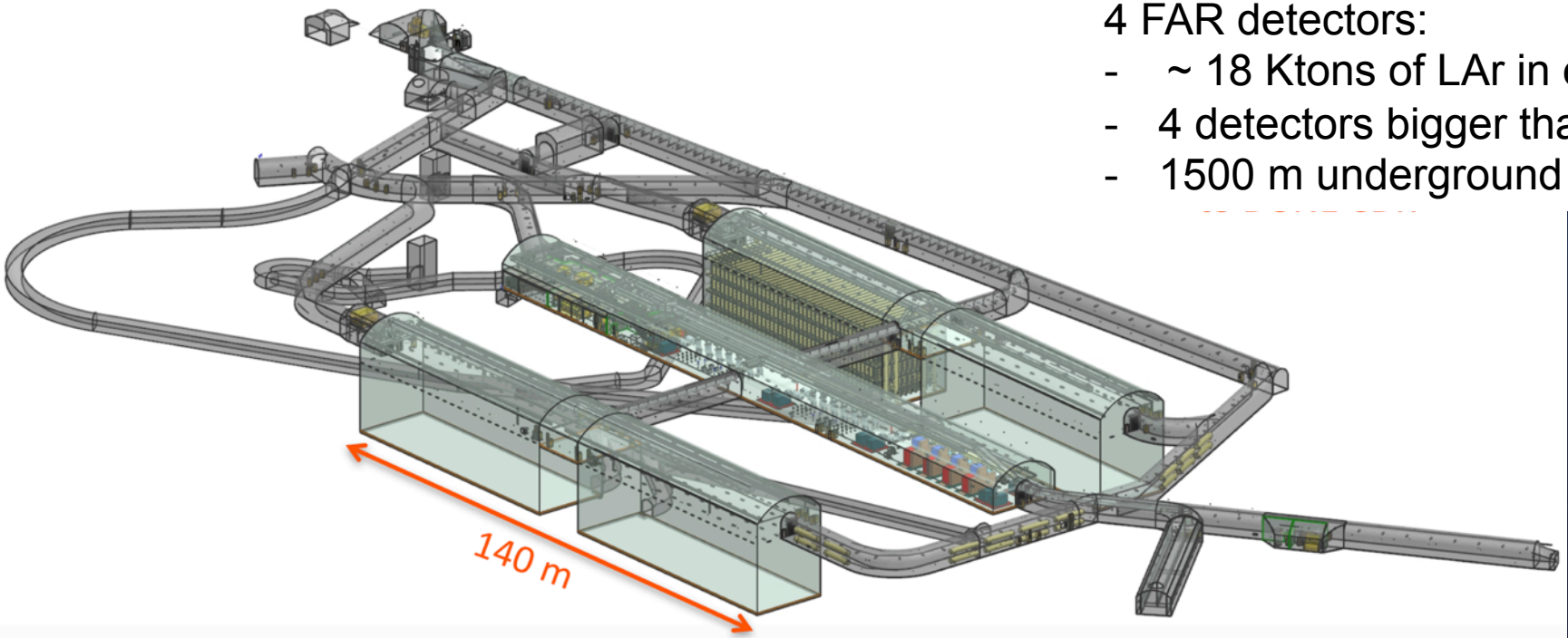
LBNF cryostats design, first cryostat financed by CERN





LBNF cryostats design, first cryostat financed by CERN

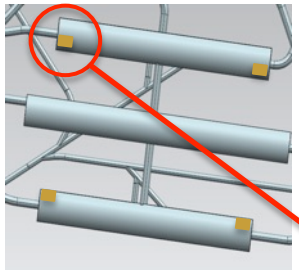


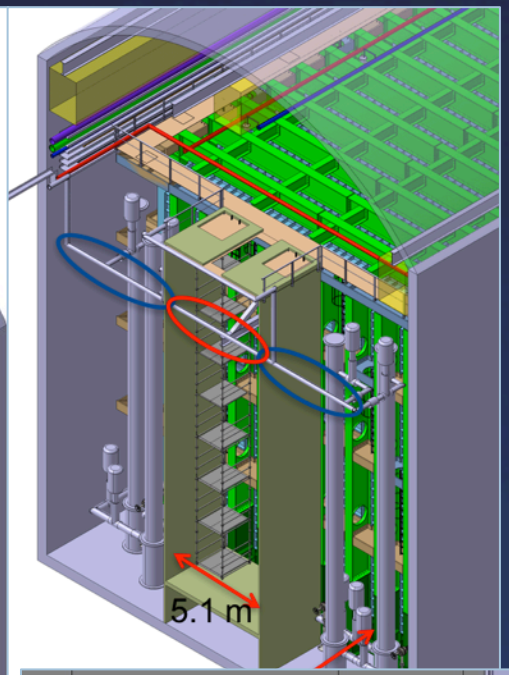


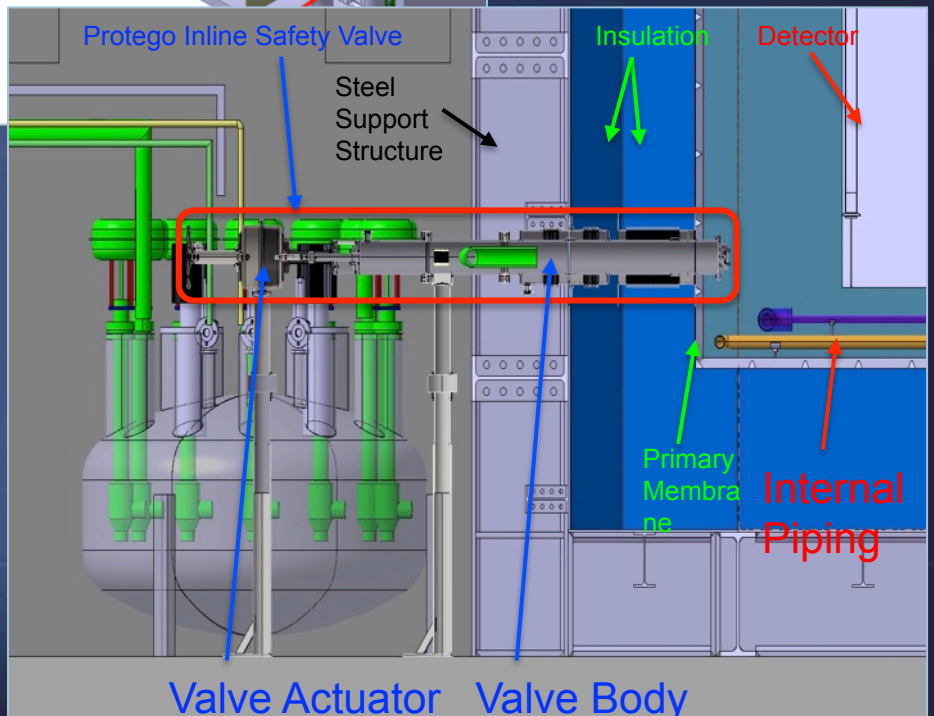
4 FAR detectors:

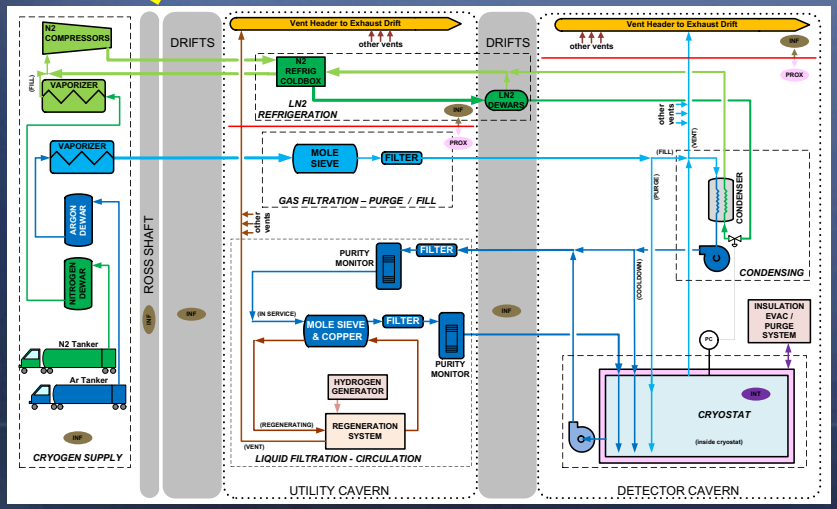
- ~ 18 Ktons of LAr in each one
- 4 detectors bigger than ATLAS
- 1500 m underground

LBNF LAr proximity cryogenics design



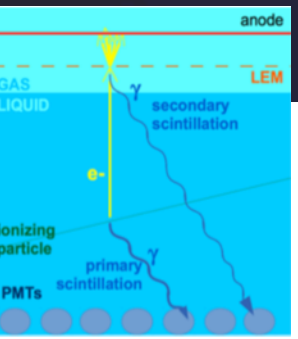






NB: External cryogenics designed by FNAL

LAr proximity cryogenics to be built for the CERN prototypes



DP protoDUNE

Condenser LAr Filters

LAr Filters Regeneration (NP-02/NP-04)

LAr Phase sep.

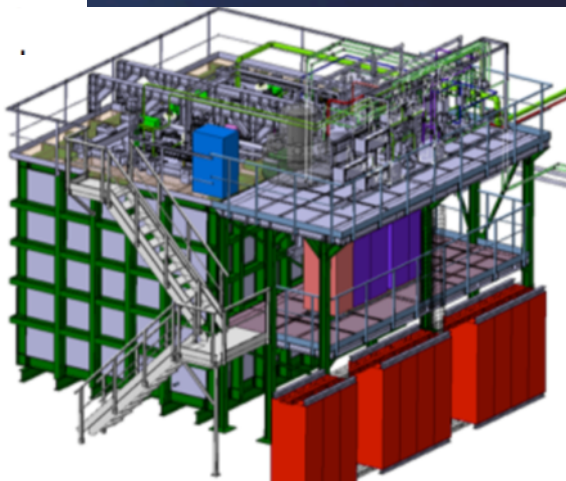
LN2 storage tank (NP-02/NP-04)

LN2 Phase sep.

LAr storage tank (NP-02/NP-04)

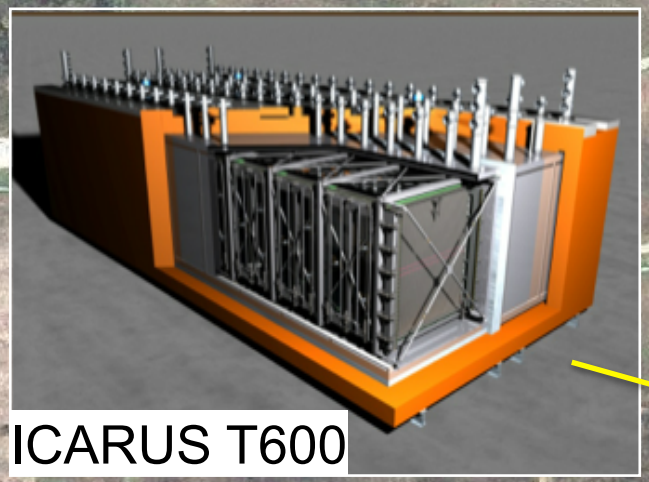
LAr circulation pumps

3x1x1 demonstrator



A strong LAr cryogenics engineering group has been created between CERN and FNAL

Short Baseline at FNAL ~ 0.7 GeV ν Booster Beam



ICARUS T600

	LAr Mass	
	Total	Active
SBND	220t	112t
MicroBooNE	170t	89t
T600	760t	476t

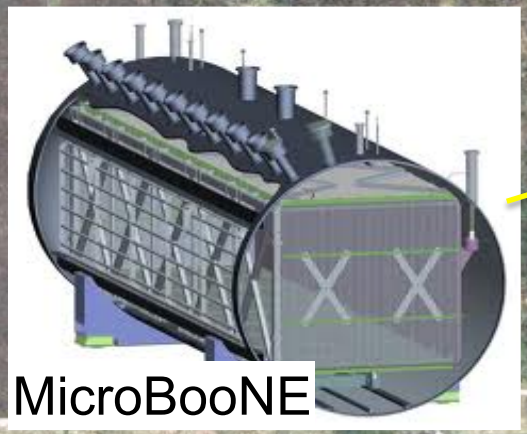
MINOS

NOvA

600m – Far Detector
ICARUS/T600

MiniBooNE

MicroBooNE



MicroBooNE

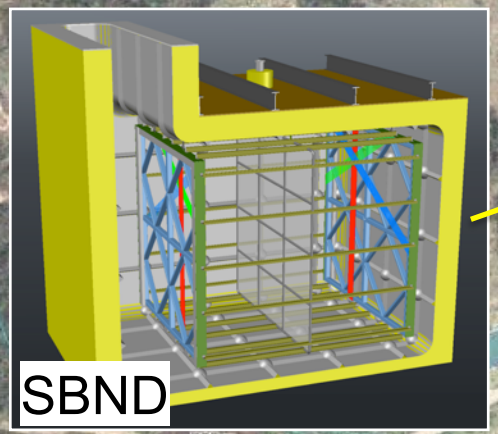
NuMi Line

– 8 GeV proton beam
– ν flux peaks ~700 MeV !
– Robust target and horn system!
– Neutrino fluxes well understood 10+ years of study by MiniBooNE and SciBooNE!
– Beam near surface (~10m) => modest civil construction cost!

SciBooNE

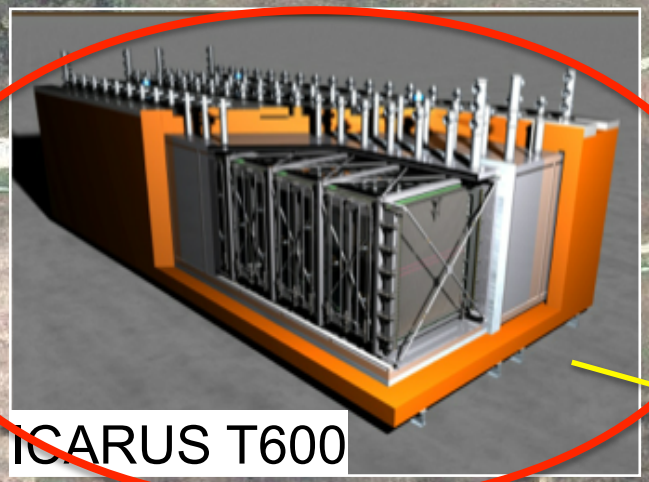
110m - Near Detector
LAr1-ND

BNB Target



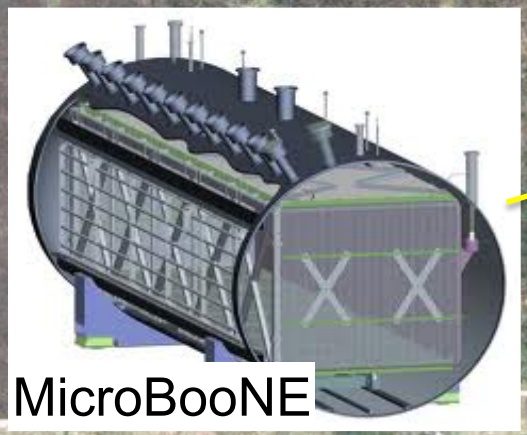
SBND

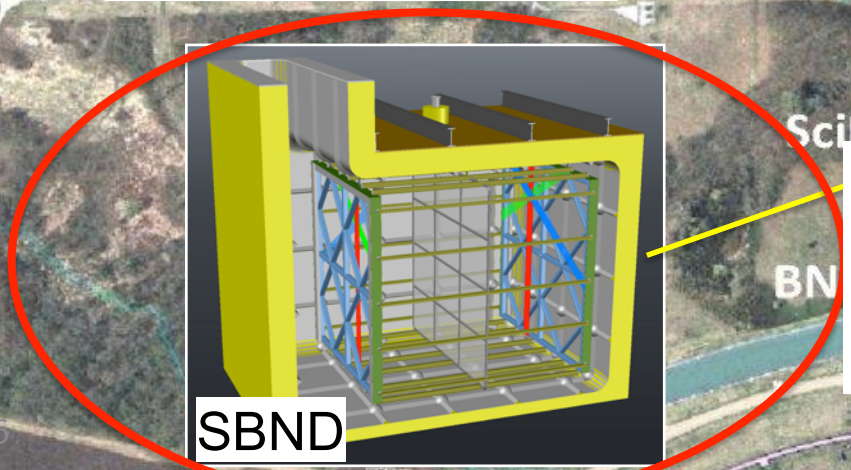
Short Baseline at FNAL ~ 0.7 GeV ν Booster Beam



detector reshaping + cryostats and LAr cryogenics (INFN+CERN)

	LAr Mass	
	Total	Active
SBND	220t	112t
MicroBooNE	170t	89t
T600	760t	476t



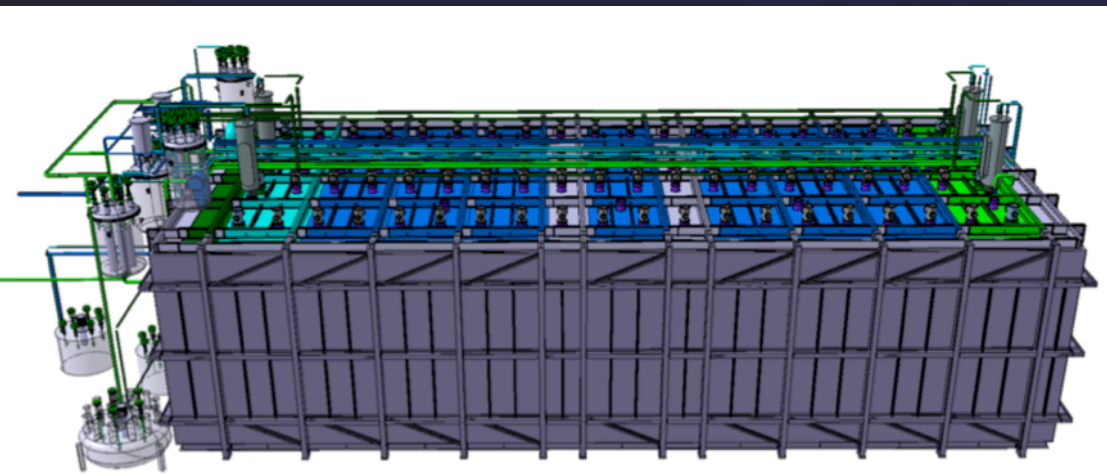


cryostat and LAr cryogenics (INFN+CERN)

ar Detector
ICARUS/T600
MiniBooNE
MicroBooNE
NuMi Line
110m - Near Detector
SciBooNE

– 8 GeV proton beam
– ν flux peaks ~700 MeV !
– Robust target and horn system!
– Neutrino fluxes well understood 10+ years of study by MiniBooNE and SciBooNE!
– Beam near surface (~10m) => modest civil construction cost!

ICARUS : FNAL short baseline



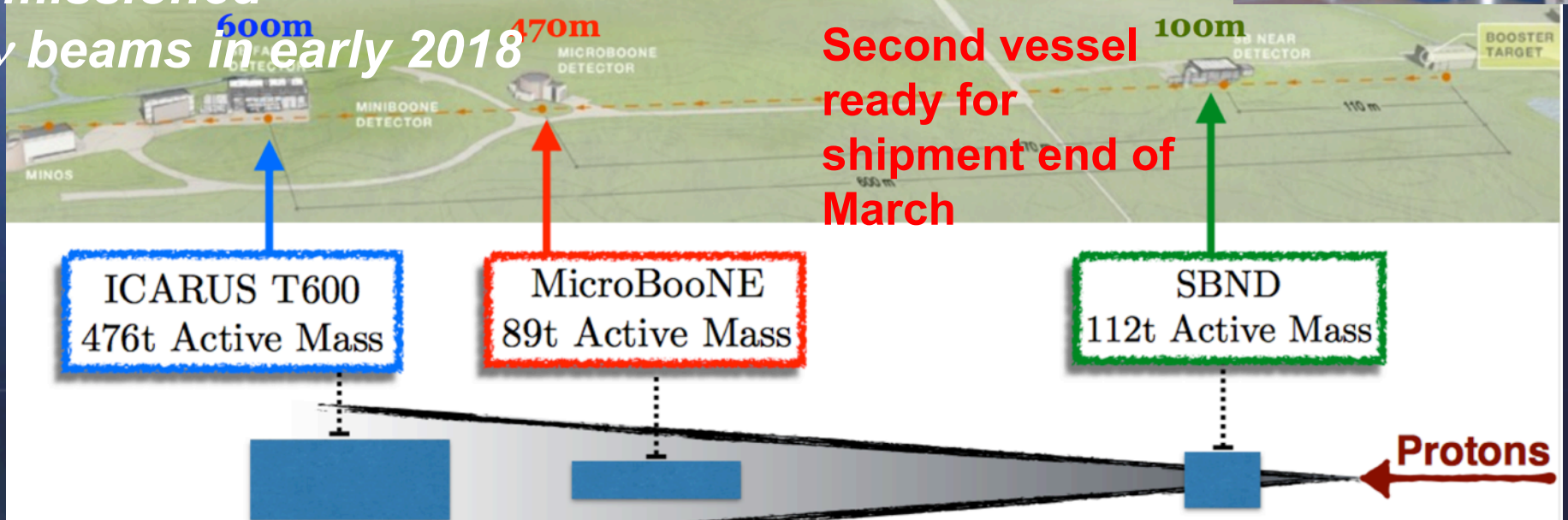
b185 detector reshaping activities (INFN+ CERN)

New aluminium cold vessels

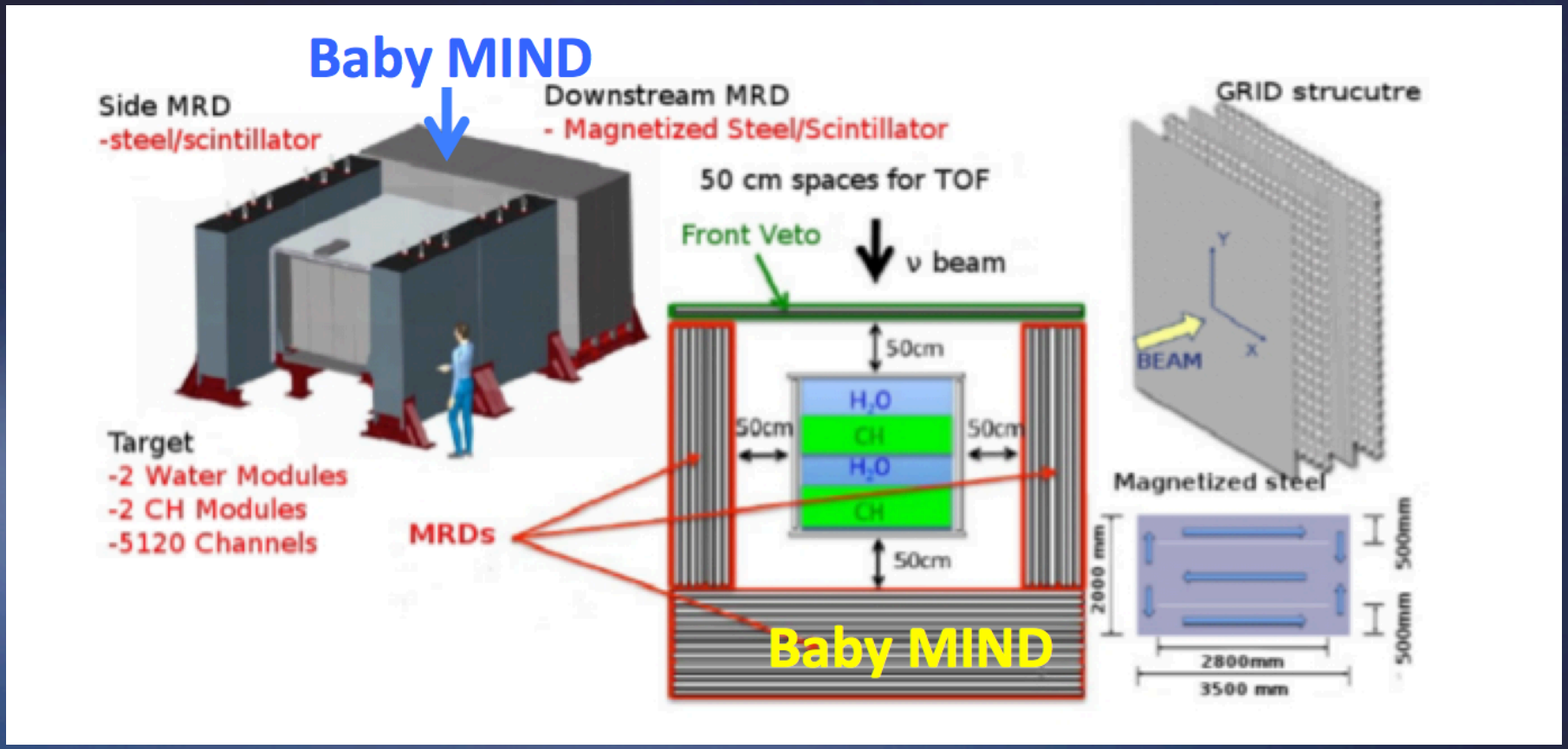
- *ICARUS as far detector is being re-shaped at CERN (WA104/NP01)*
- *ICARUS will be moved to FNAL in April 2017, installed and commissioned*
- *On ν beams in early 2018*

First vessel ready for shipment with the detector inside

Second vessel ready for shipment end of March



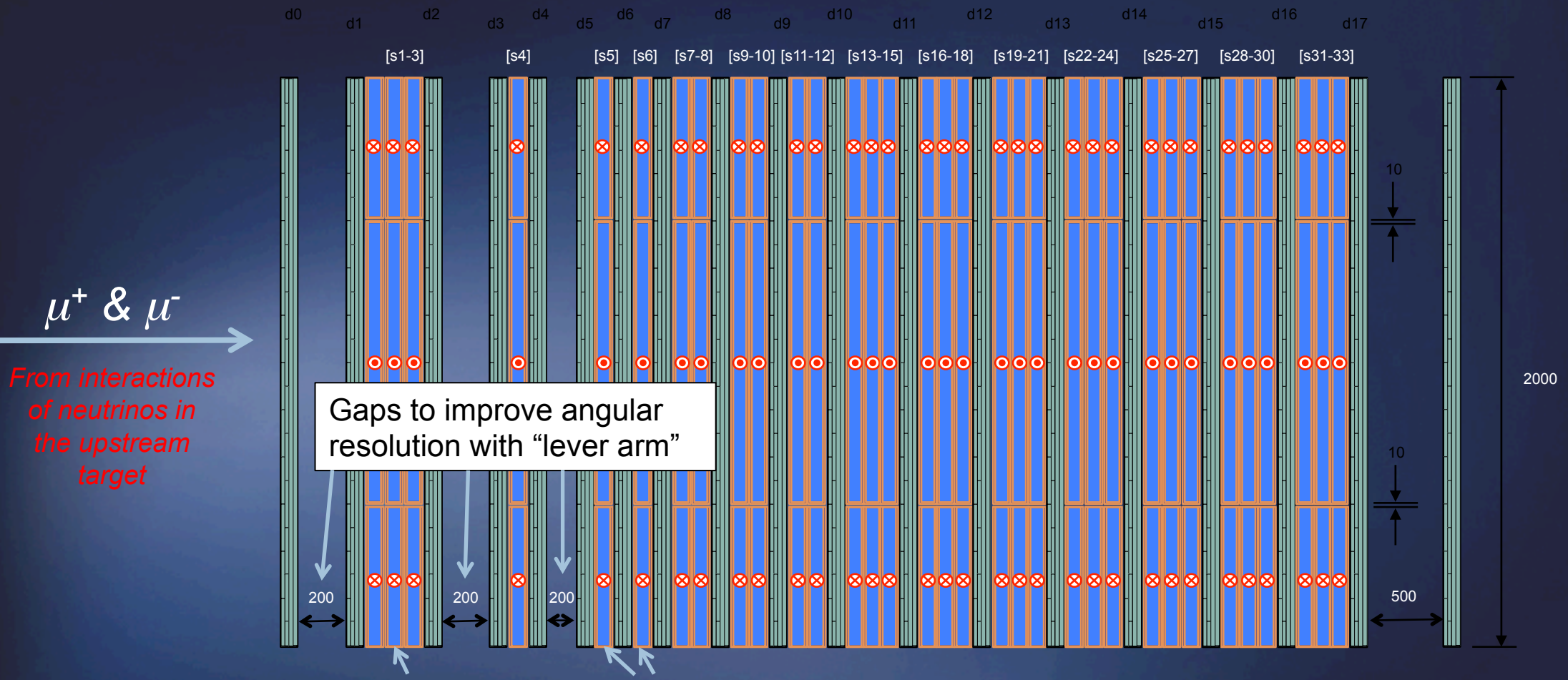
Baby Mind : a muon spectrometer for the WAGASCI ND



WAGASCI at J-PARC (2016 onwards) : rejection of nu-mu background in anti-nu mu beam: anti-nu selection efficiencies > 90% for P_{μ}>300 MeV/c.

Baby Mind : a muon spectrometer for the WAGASCI ND

Interleaving of Magnet and Scintillator Modules

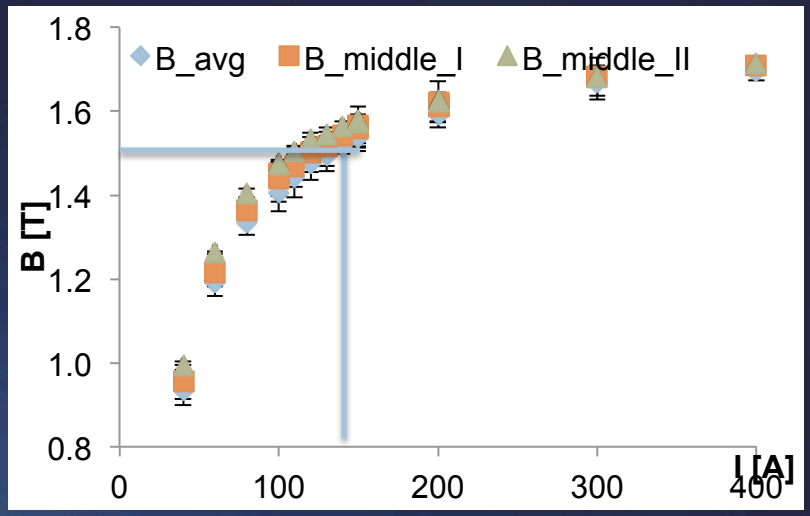


d: detector module (x 18 modules)
s: steel magnet module (x 33 modules)

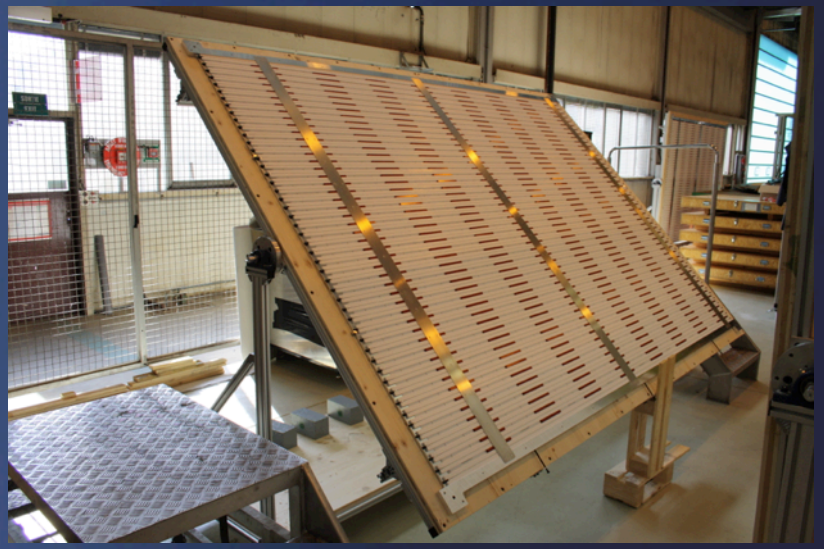
Baby Mind : a muon spectrometer for the WAGASCI ND

Novel magnet design

x 33 modules



18 Custom scintillator modules



It will sent to Japan in summer 2017 after a CERN SPS test run

Near detectors generic R&D on gas TPCs (pressure and not)

- Strong T2K and DUNE interest in a new generation of near detectors, based on atmospheric TPCs
- With some additional interest on high pressure TPCs

→ *First workshop on gas TPCs for ND 8-9 November at CERN. ~ 80 participants*

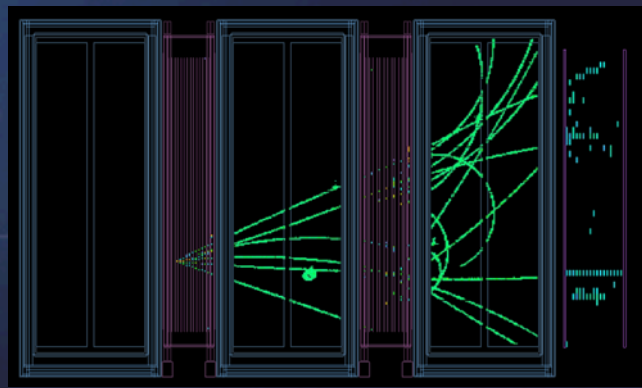
→ *EoI presented to the CERN SPSC committee*

→ *Next WS 20-21 March at CERN*

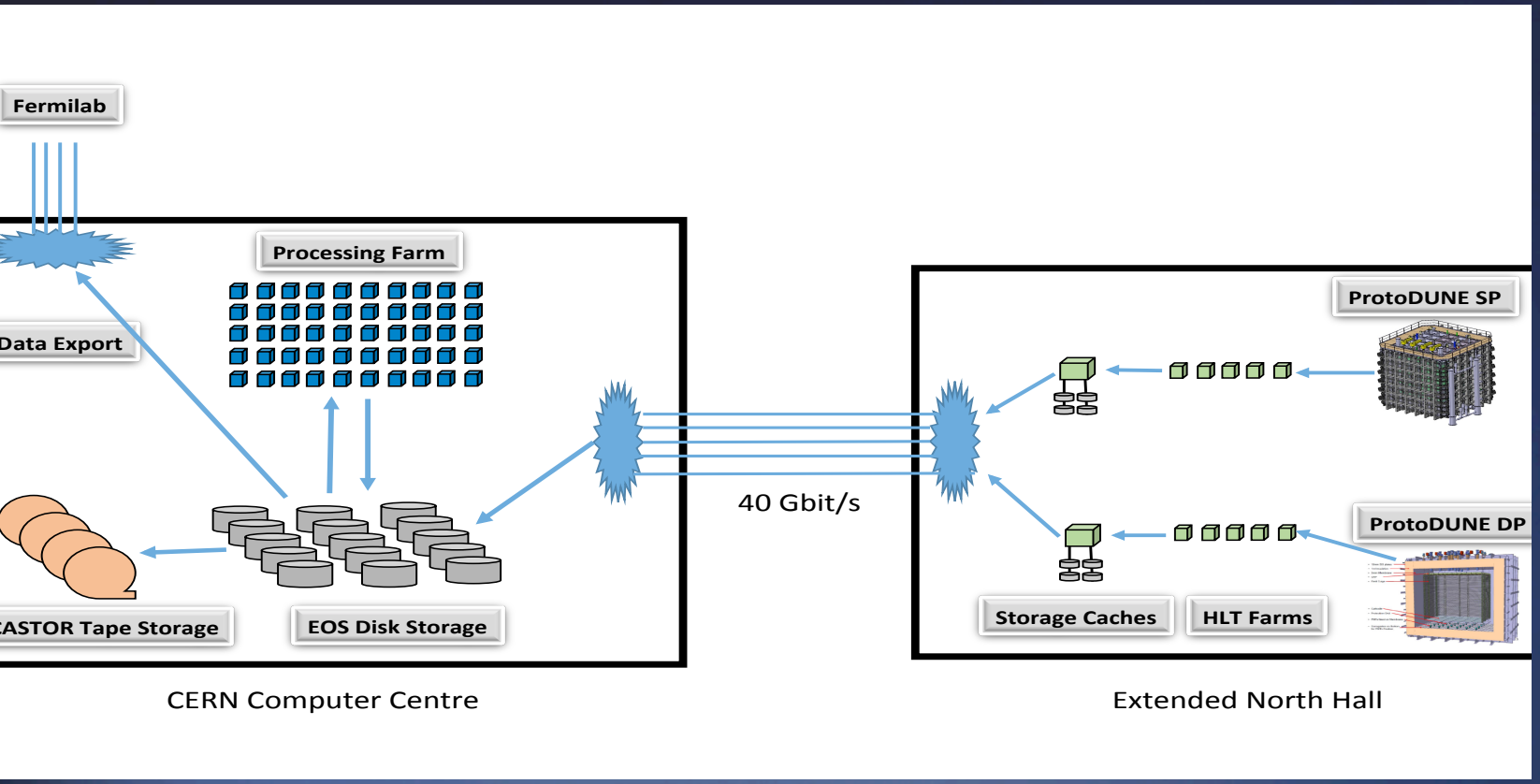
→ *Possible convergence of EU contributions to the design and construction of NDs*

→ *ν cross-section program planning*

https://indico.cern.ch/event/613107/



BIG data … DAQ, event reconstruction

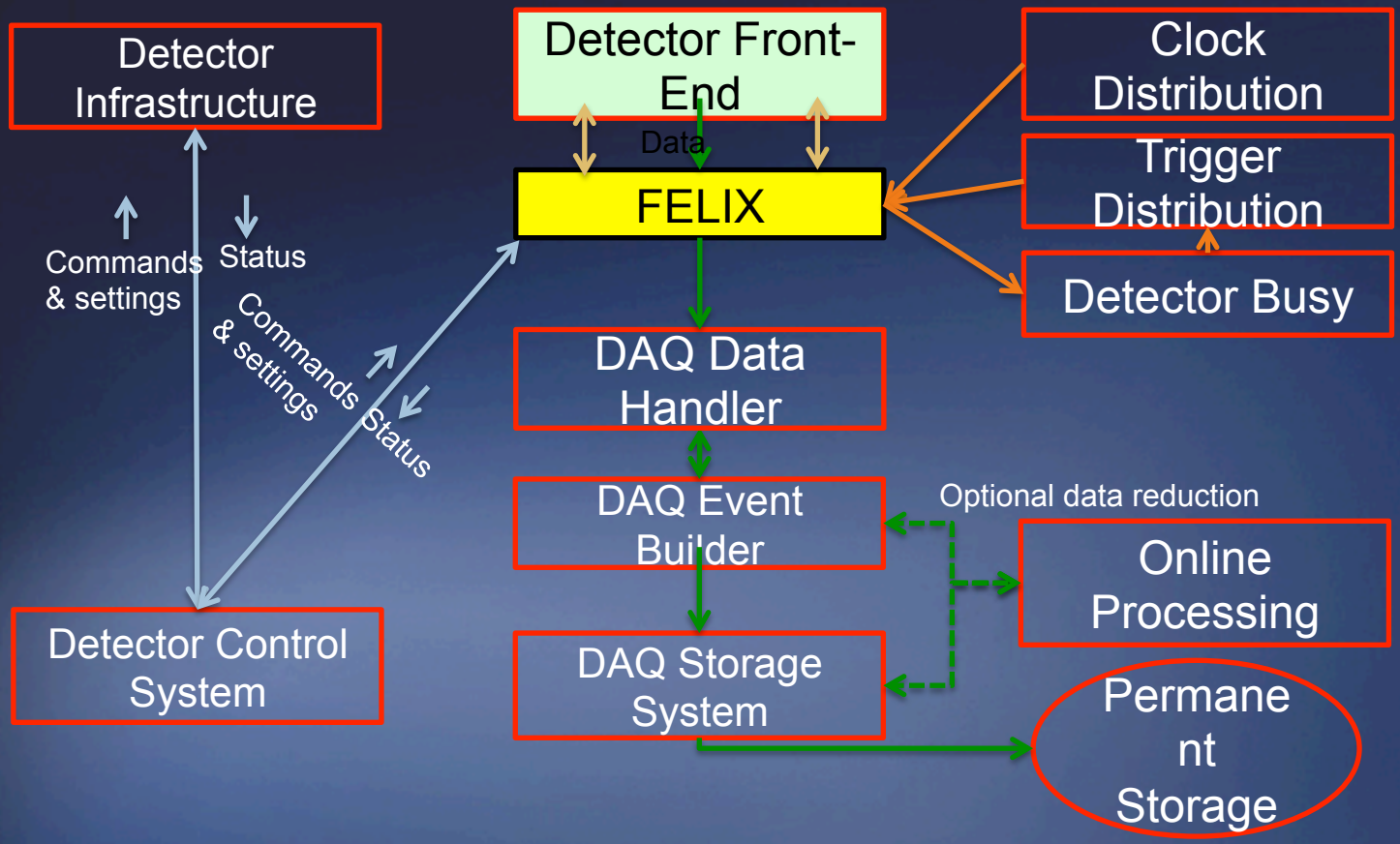


several PB data / year

Similar to LHC

✓ **CERN TIER0 infrastructure as a CERN NP deliverable**

BIG data ⋯ DAQ, event reconstruction

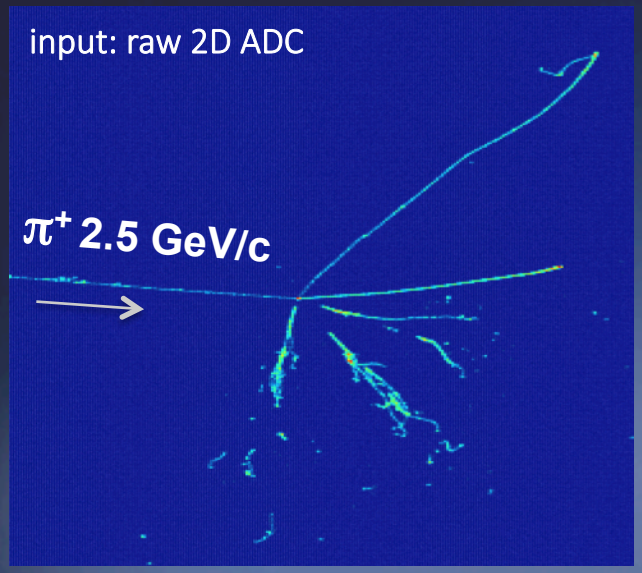


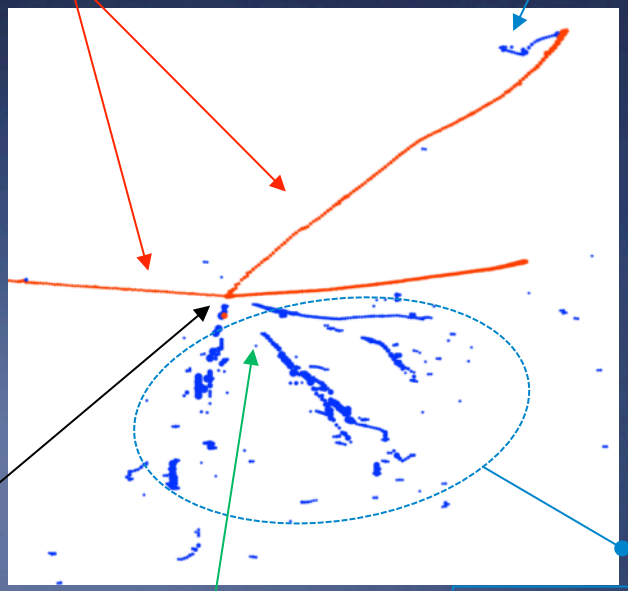
- ✓ CERN TIER0 infrastructure as a CERN NP deliverable
- ✓ **New DAQ in synergy with LHC upgrade developments (ATLAS FELIX=Front End Llink eXchange)**

BIG data ⋯ DAQ, event reconstruction

3. hadron tracks reconstruction:
→ once EM separated, efficient standard algorithms

2. Michel selection: advanced
→ labeling with CNN





CNN (Convolutional Neural Network)

1. EM selection: quite done
→ labeled with CNN

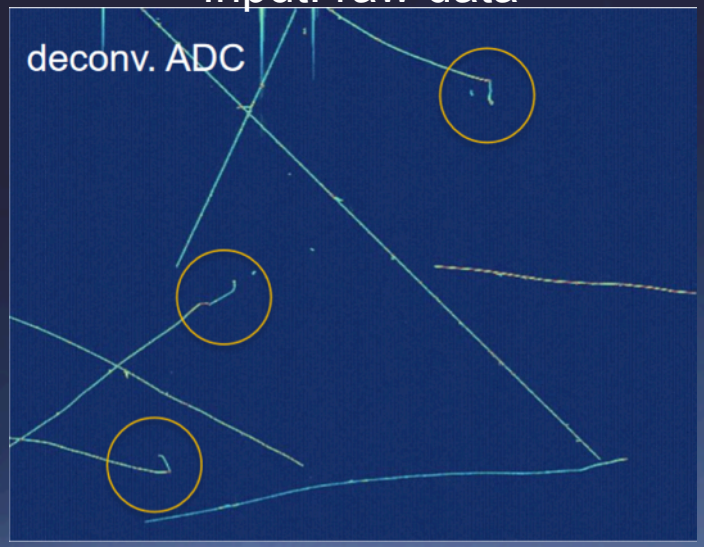
4. interaction vertex:
→ reconstructed with standard tracking
→ or labeled with CNN

5. EM cascade start finding
→ most significant for e/γ separation and ν_e selection
- EM shower displacement from the vertex
- 1m.i.p. vs 2m.i.p. dE/dx in the initial part

✓ **First steps in automatic event reconstruction and pattern recognition**

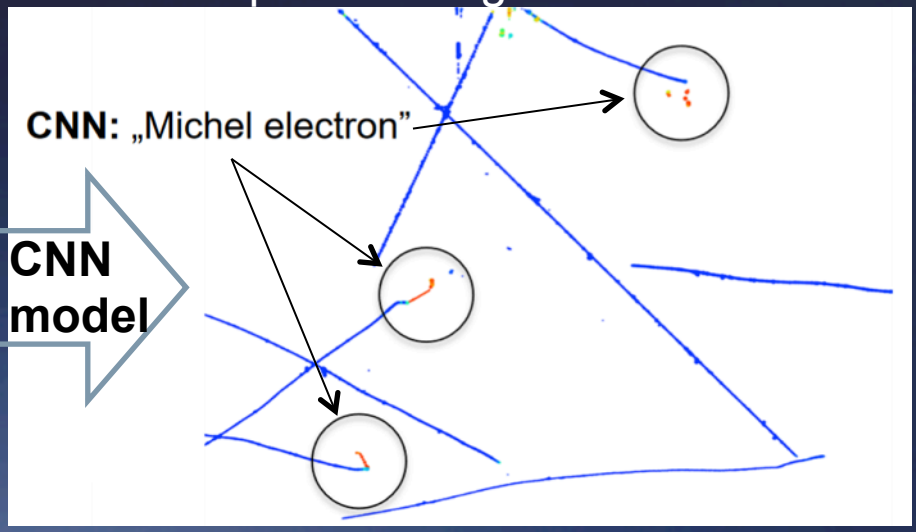
BIG data ⋯ DAQ, event reconstruction

Input: raw data

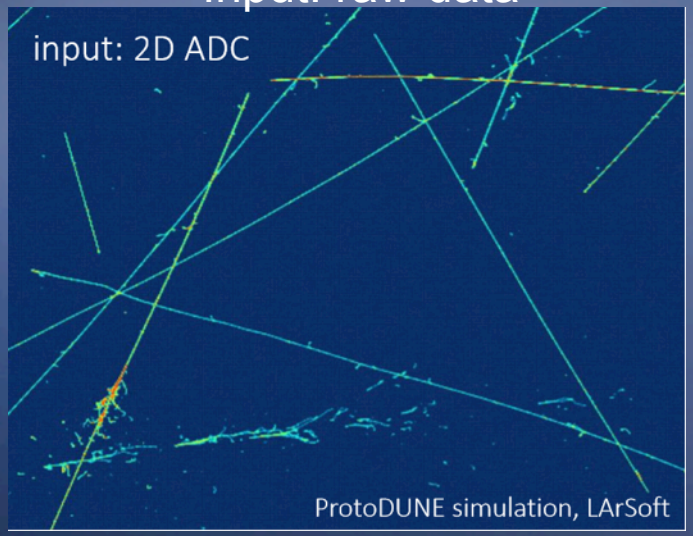


CNN model

Output: labeling Michel electron



Input: raw data

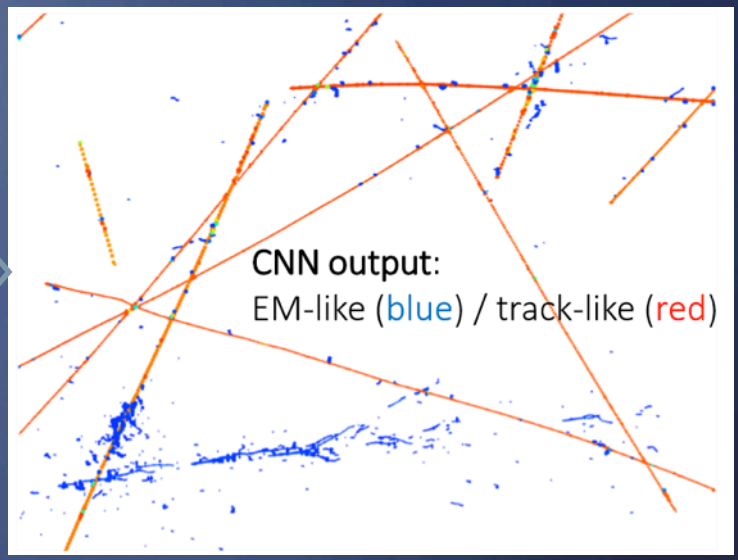


Drift time

Channel number

CNN model

Output: labeling EM-like / track-like



MACHINE LEARNING TECHNIQUES

✓ **First steps in automatic event reconstruction and pattern recognition**

Summary:

- ✓ The landscape for future ν accelerator physics is shaping up in a global environment !
- ✓ CERN offers a platform for Neutrino detectors R&D and later construction. CERN will support this platform in an active way both for the infrastructure and for the detectors construction, installation and commissioning
- ✓ A large neutrino test area (EHN1-1 extension) with charged beams capabilities has been constructed and is being made operational
- ✓ 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. CERN is reacting on demands from the community
- ✓ In the short term, the CERN Platform is helping in getting a Short Baseline operational at FNAL with an agreed physics program … and later a Long Baseline. Near detector are now appearing as new R&D projects.