

# ***CERN Neutrino Platform***



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CERN  
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# Outline

- The European Strategy and neutrinos
- The Neutrino Platform
- Ongoing Projects
  - Icarus and FNAL SBL
  - Baby MIND (T2K)
  - Double Phase Lar (WA105)
  - ProtoDune
- The new EP neutrino group
- Summary

Based on M. Nessi's SPC talk 6/17

# 2013 European Strategy

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.*

2014: CERN announced that it will freeze all types of neutrino beam at CERN in favor of world wide activities (Japan/US)

## → CERN NEUTRINO PLATFORM

### CERN's role

CERN support for accelerator-based neutrino experiments, both short and long baseline

- ✓ 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



# We react on demands from the community : MOU frame

- 6 Projects presented to the SPSC and approved:

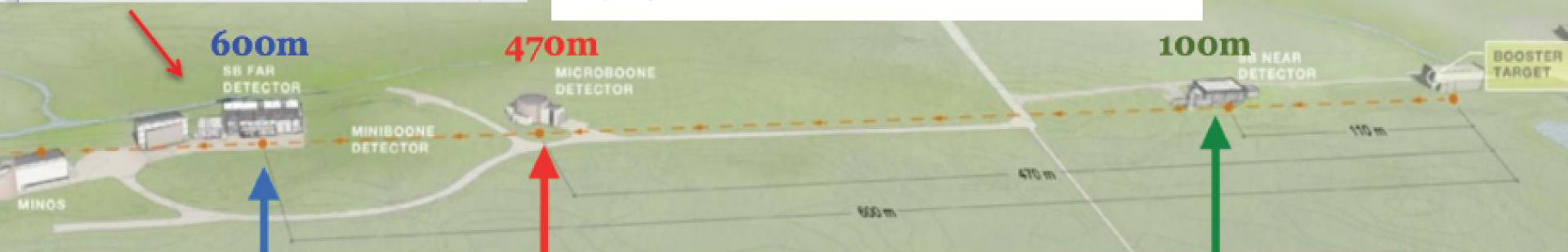
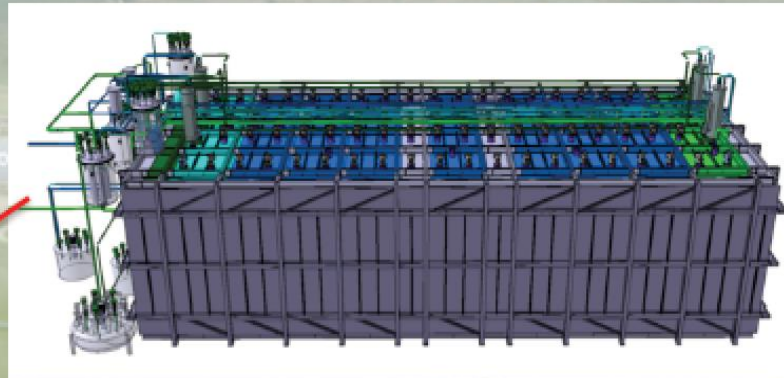
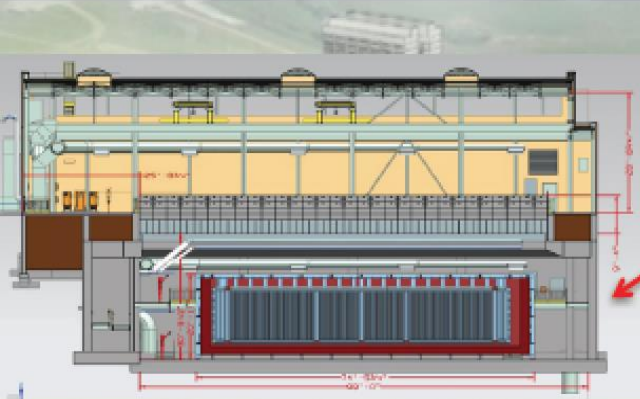
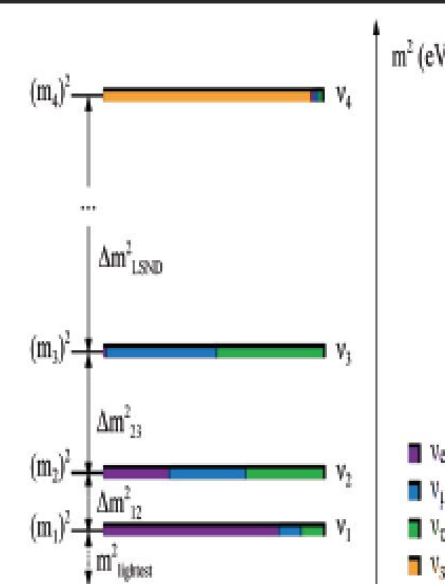
- ✓ *NP01: WA104, ICARUS as far detector for the US SBN*
- ✓ *NP02: protoDUNE WA105, demonstrator + engineering prototype for a double ph. TPC*
- ✓ *NP03: PLAFOND, an generic R&D framework*
- ✓ *NP04: ProtoDUNE, engineering prototype for a single phase TPC*
- ✓ *NP05: Baby Mind, a muon spectrometer for 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 just signed*)

# SBL @ FNAL

A Multi-detector program will address the unexplained anomalies which together could be hinting at new physics (steriles?)



**ICARUS T600**  
476t Active Mass

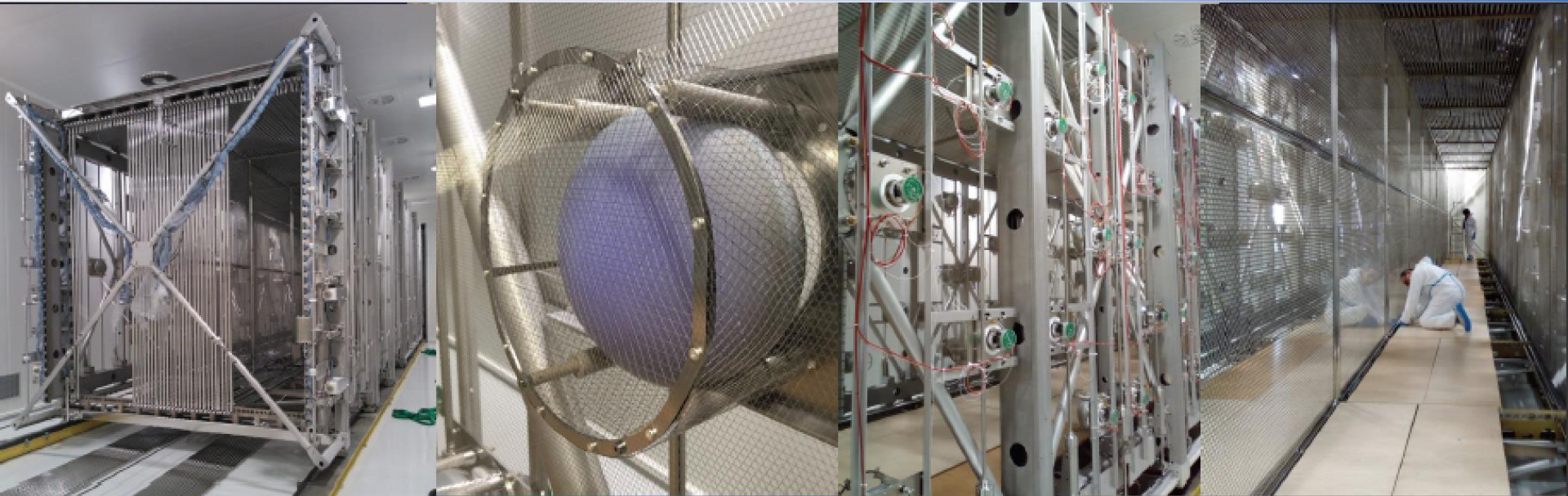
**MicroBooNE**  
89t Active Mass

**SBND**  
112t Active Mass

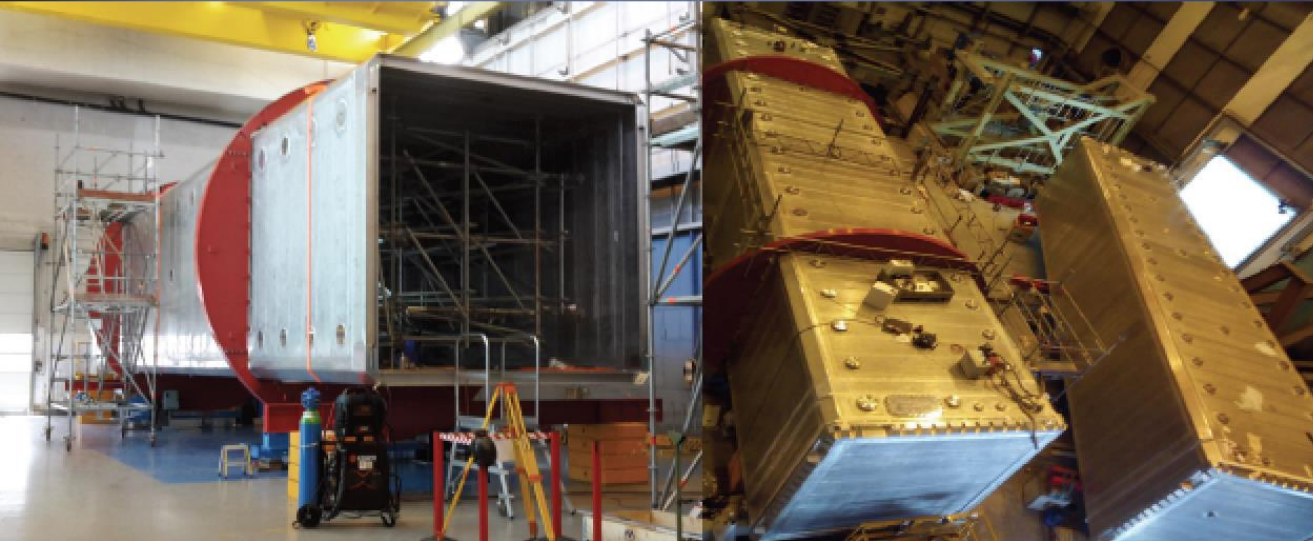
**Protons**



# NP01: ICARUS Refurbished @ CERN



- new PMTs - new cabling - rework on cathodes - new cryostats
- new electronics - .....



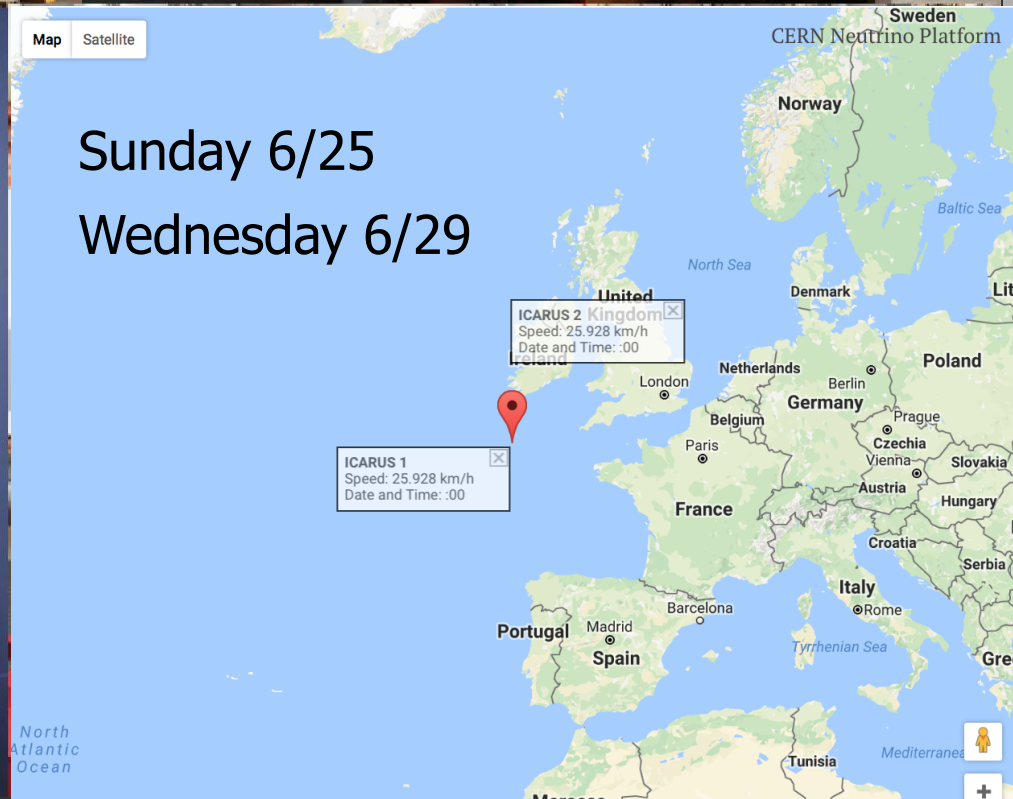


# ...And now on its voyage to FNAL



Route Planning	Route Schedule
Dep. CERN	12 June 2017
↓ truck	
Arr. Basel (CH)	14 June 2017
Dep. Basel (CH)	15 or 16 June 2017
↓ barge	
Arr. Antwerp (BE)	21 June 2017
Dep. Antwerp (NL)	earliest/latest on 23/30 June 2017
↓ ship	
Arr. Burns Arbor (USA, IN)	appr. 23-24 days after departure from Antwerp
↓ truck	
FERMILAB	appr. 2 days after dep. from Burns Arbor

<http://cern-wa104.web.cern.ch/wa104.org/icarus-transportation-cern-fnal>



# NP05: Baby MIND

A muon spectrometer for the WAGASCI experiment at T2K

## Baby MIND moved to East Hall

by Stefania Pandolfi

- A 75-tonne neutrino detector with a new magnetization scheme
- A prototype for a Magnetised Iron Neutrino Detector (MIND)
- Baby-Mind will be transported at the end of July to Japan



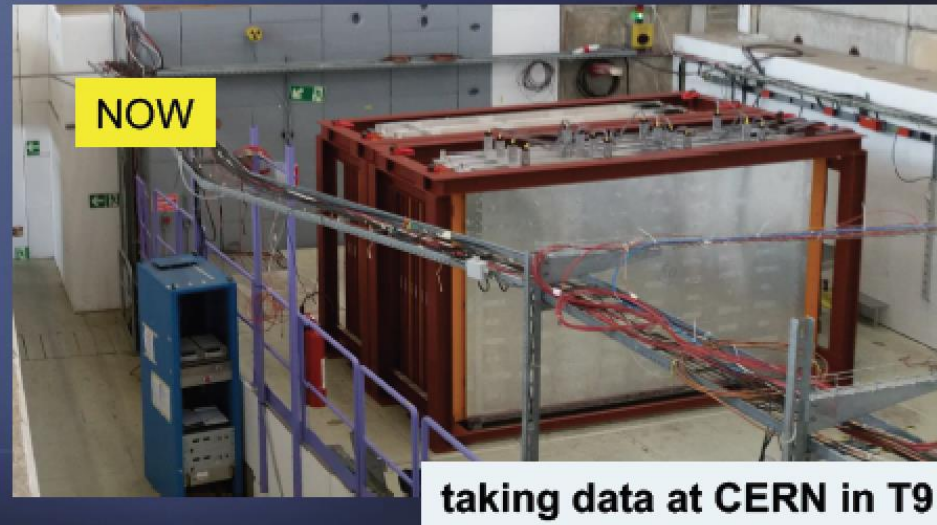
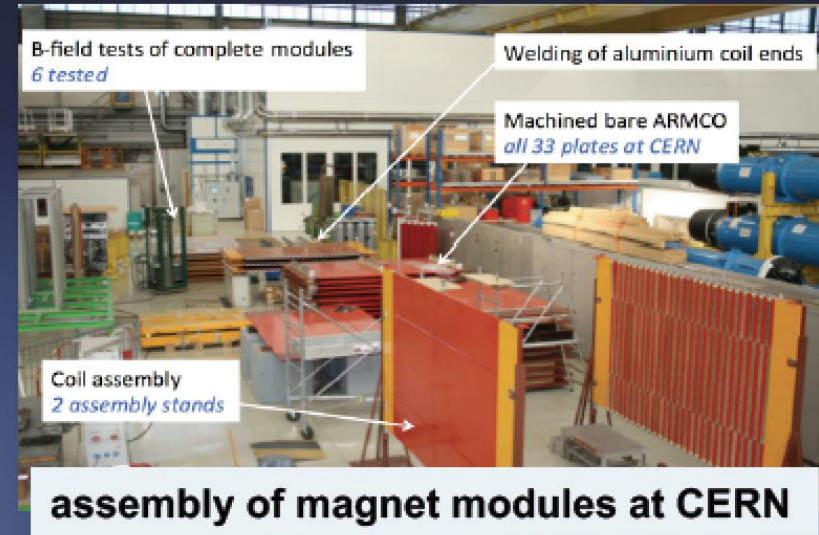
On 14 June, the Baby MIND neutrino detector was moved, module by module, from Building 180 to Building 157 (East Hall). The succession of coil windings and (red) iron plates is clearly visible. (Image: Etam Noah/University of Geneva)



# Status of WAGASCI/Baby MIND

- All magnetic and detector modules assembled
- Full detector designed as 4 blocks
- First tested in T9 test beam at CERN in May'17
- Full detector assembled and tested June-July'17
- Ship to Japan in Jul'17 /Nov'17
- Installation in B2 starting in Sep'17
- Commissioning Oct'17-Mar'18

→ Start full data taking WAGASCI+ BabyMIND Apr'18



# Preparation for DUNE

## Demonstrator and Prototypes

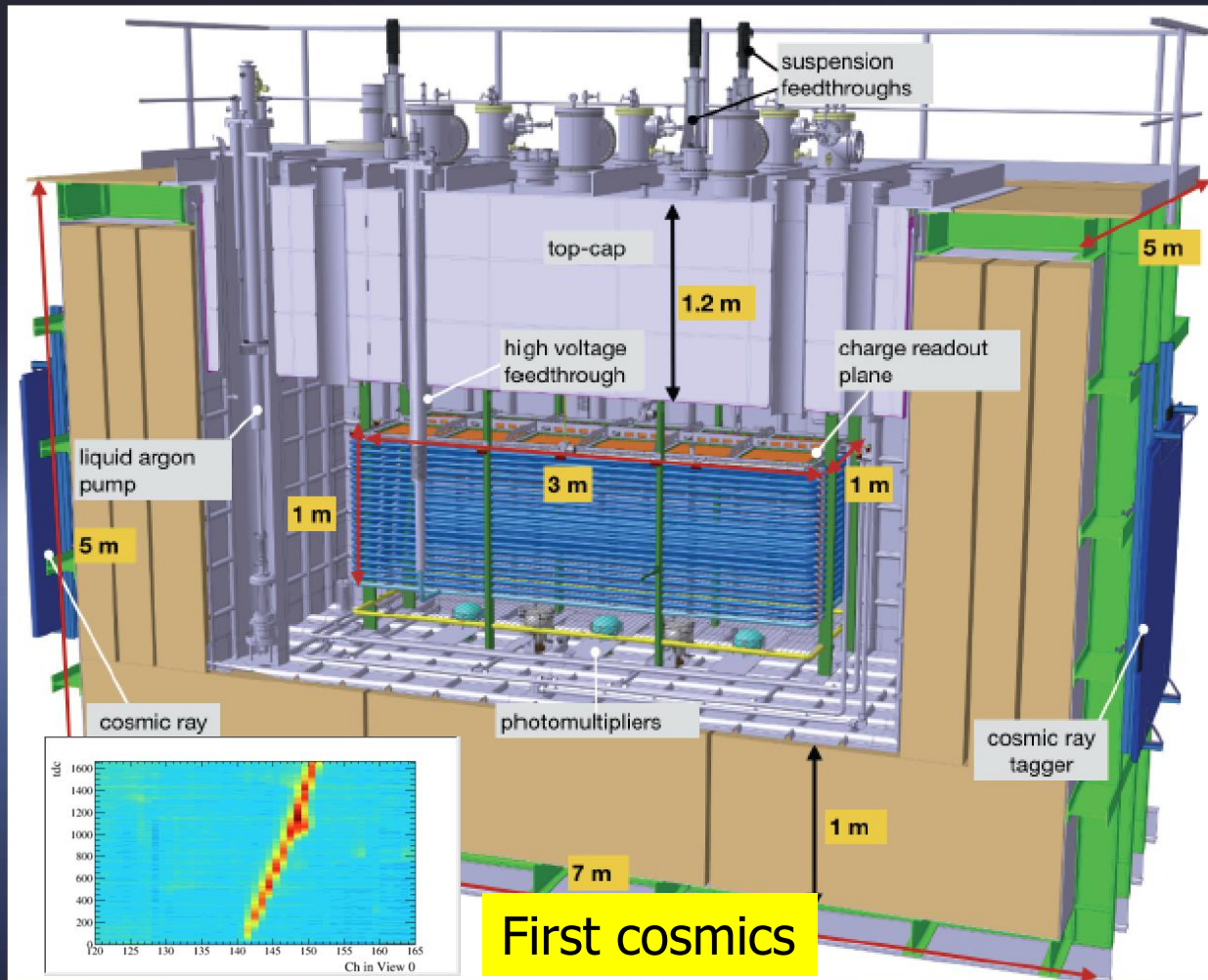
- Cryostats and Cryogenics need to be demonstrated and the techniques acquired
- Single phase LAr detectors have to be extrapolated to the new scale (x 100), starting from the ICARUS and MicroBooNE experience. Cold electronics and automatic data reconstruction are the next challenges
- Double phase LAr detectors have to be proven as concept and then extrapolated to the new scale



# WA105 (3x1x1m Demonstrator)

## DOUBLE PHASE Demonstrator (WA105/NP02)

LNG and cryogenics first lesson!



LAr TPC double phase demonstrator

The 3x1x1 m<sup>3</sup> dual phase LAr TPC

# ProtoDUNE Area

Next step : ~800 ton LAr prototypes

External cryogenics

SPS : new EHN1-1 experimental area

NP04 proximity cryogenics

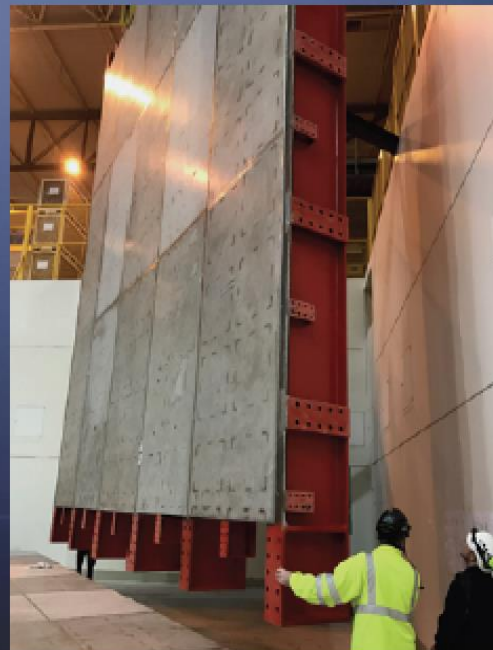




# 2016-2017 : ProtoDUNE ~800 ton LAr cryostats



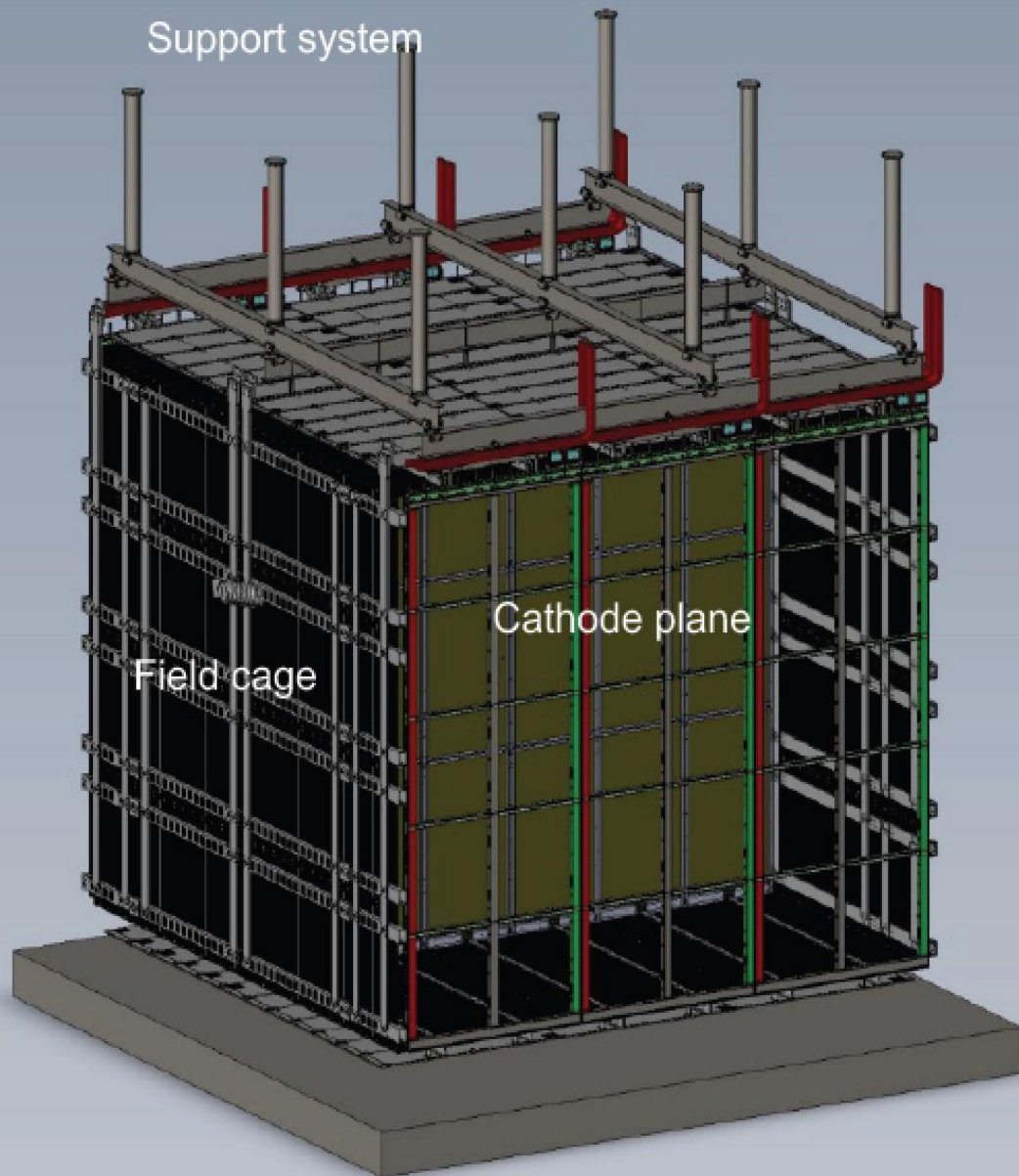
NP04: single phase



NP02: double phase



# SP detector components



Field cage made out of Al extruded profiles



# DOUBLE PHASE DUNE prototype (NP02)

Charge Readout Plane (CRP) X and Y charge collection strips  
3.125 mm pitch, 3 m long → **7680 readout channels**

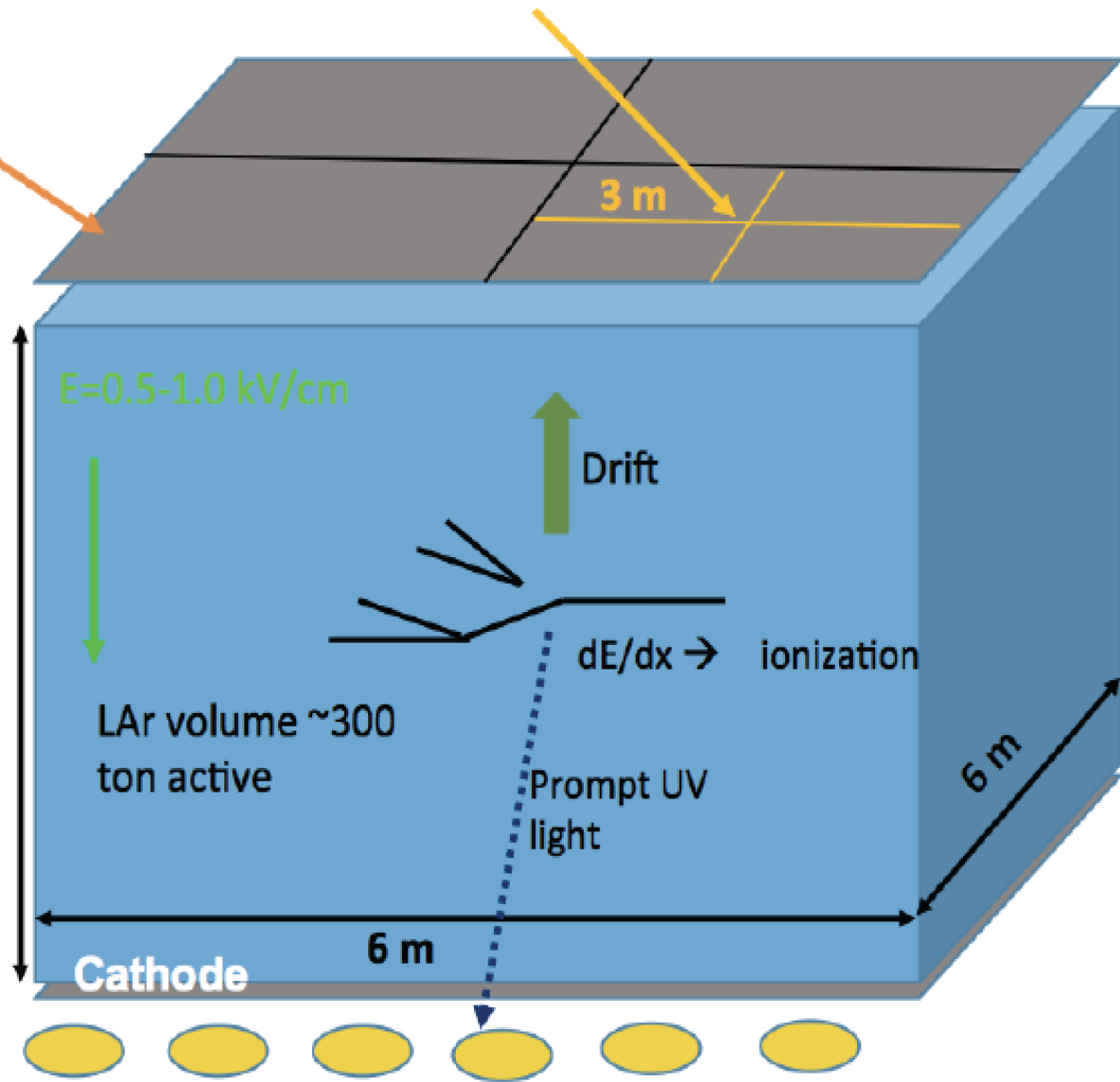
Readout in gas phase:  
charge is amplified and  
collected on a 2D anode

Drift coordinate 6 m = 4 ms sampling  
2.5 MHz (400 ns), 12 bits → **10000  
samples per drift window**

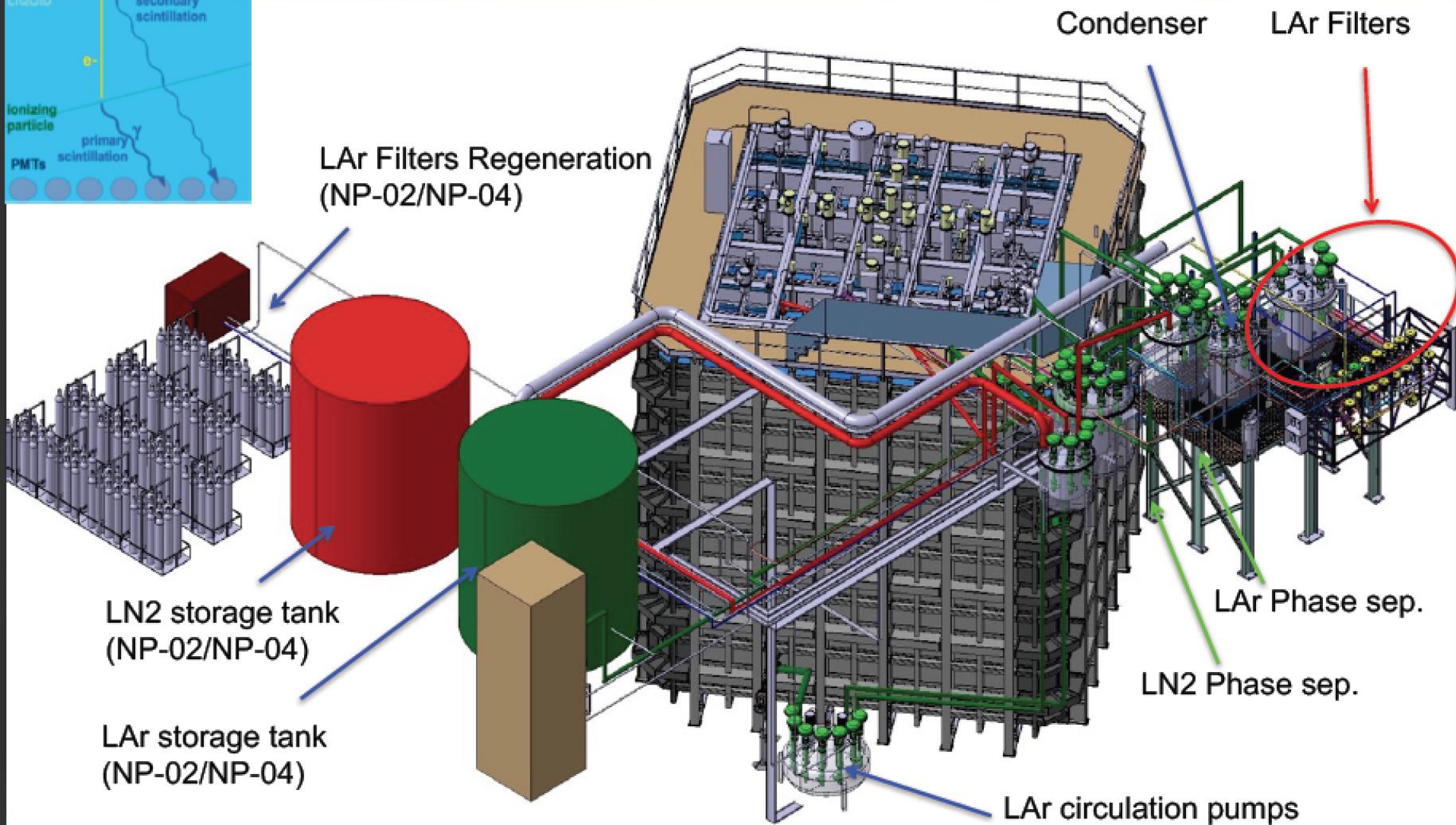
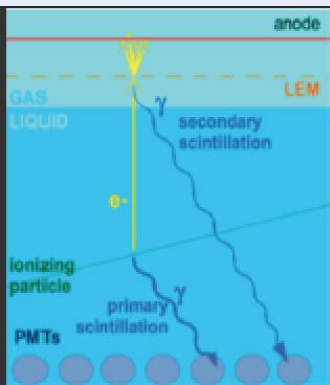
Total event size 148MB  
Data rate 15GB/s (at 100 Hz trigger)  
→ DAQ bandwidth on 20 GB/s scale

Detector is built from 4 independent  
3x3 m<sup>2</sup> units. (The same as for multi  
kiloton detectors)

Photomultipliers



# Double Phase DUNE Prototype





# protoDUNE strategy

- ✓ Modular structure that will be repeated many times inside DUNE
- ✓ ProtoDUNE prototypes as DUNE module 0, as basis for the final detector construction and assembly
- ✓ Full engineering done as a basis for the final production (PRRs), both for detectors and cryostat/cryogenics
- ✓ Check detector response with cosmics (DCS, DAQ, Computing, Reconstruction, ...)
- ✓ Calibrate with charged beam the response to leptons and hadrons

## Very ambitious program :

- detectors cooled by April 2018
- in beam in 2018 before LS2 shutdown

# New: EP- Neutrino Group @ CERN

- No Neutrino Experimental Physics (EP) group at CERN since 2001!
- In view of the effort in the established neutrino forum a new group was created in fall 2016
- EP group focus at present
  - Experimental neutrino physics -> take part in experiments. So far DUNE and SBL at FNAL. T2K/T2HK on the radar.
  - Focal point for activities for the neutrino community in Europe
  - Collaborate with the neutrino platform on ProtoDUNE (data analysis, computing, simulations, reconstruction, beamline optimization, physics analysis...)
  - Collaborate with the platform on detectors R&D, test beams
  - Liaise with CERN-TH neutrino group on the physics program
  - Organize workshops for the Neutrino community
  - Recently: **Special focus on near detector challenges**



# BIG data ... DAQ, event reconstruction

3. hadron tracks reconstruction:

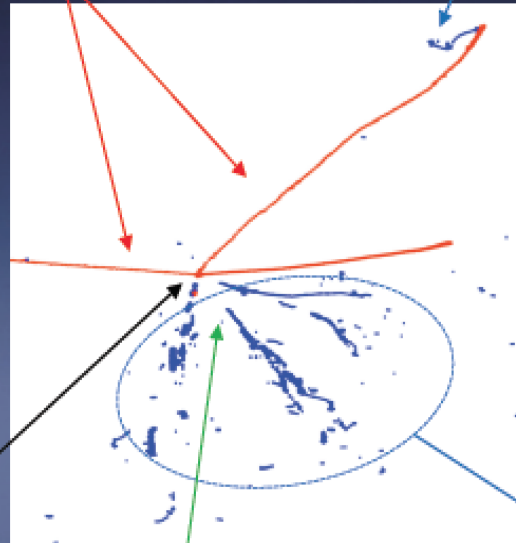
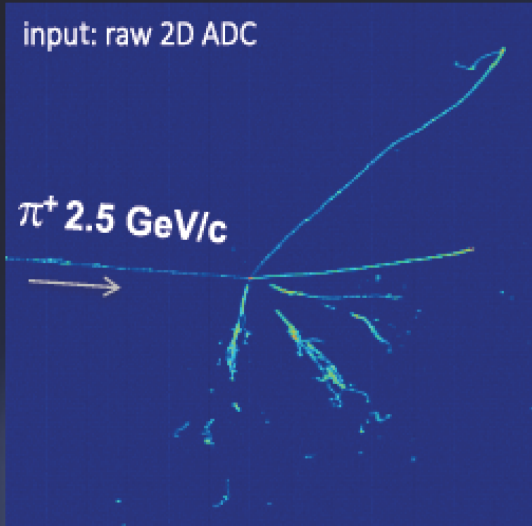
→ once EM separated, efficient standard algorithms

2. Michel selection: advanced

→ labeling with CNN

input: raw 2D ADC

$\pi^+$  2.5 GeV/c



**CNN (Convolutional Neural Network)**

4. interaction vertex:

→ reconstructed with standard tracking  
→ or labeled with CNN

1. EM selection: quite done

→ labeled with CNN

5. EM cascade start finding

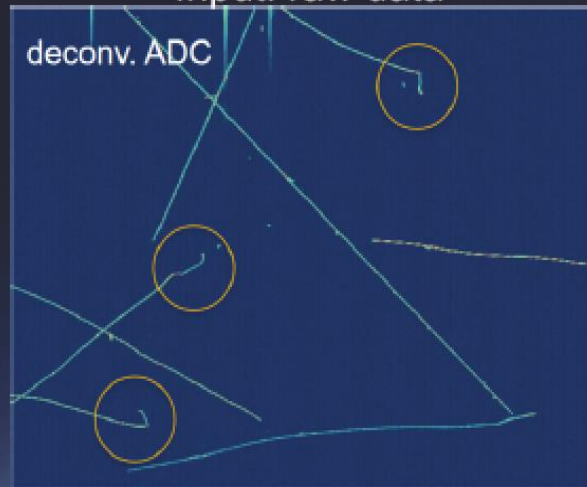
→ most significant for  $e/\gamma$  separation and  $\nu_e$  selection

- EM shower displacement from the vertex
- 1m.i.p. vs 2m.i.p.  $dE/dx$  in the initial part

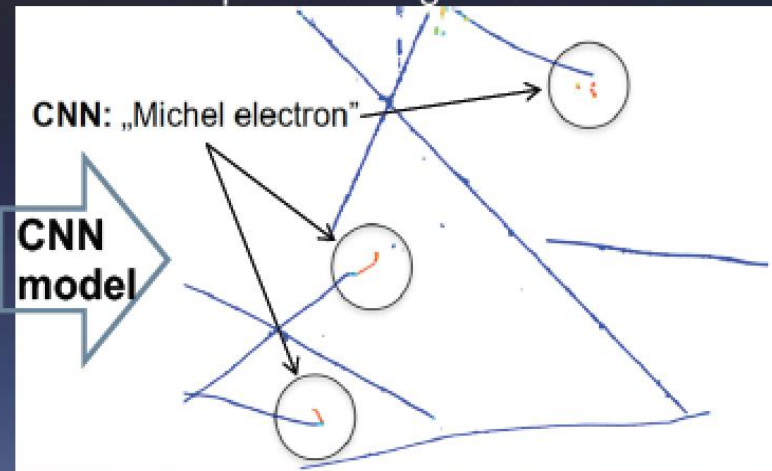
✓ First steps in automatic event reconstruction and pattern recognition

# BIG data ... DAQ, event reconstruction

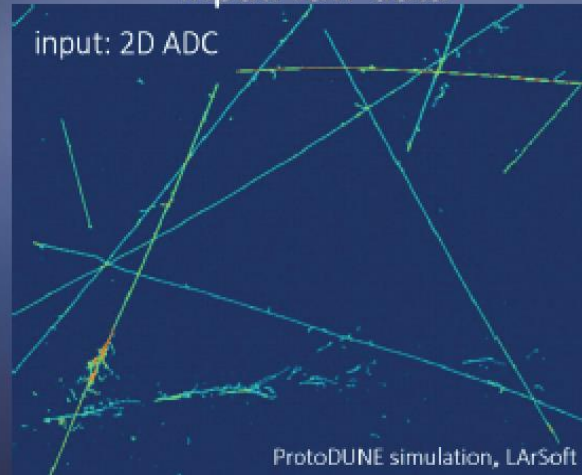
Input: raw data



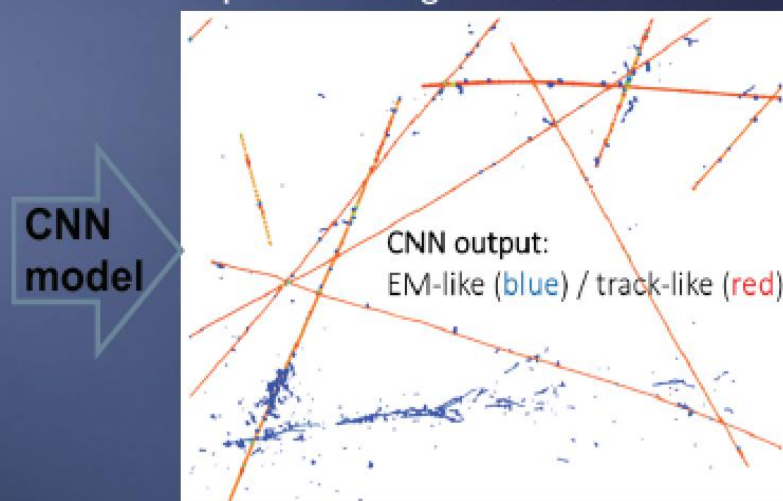
Output: labeling Michel electron



Input: raw data



Output: labeling EM-like / track-like



MACHINE LEARNING TECHNIQUES

✓ First steps in automatic event reconstruction and pattern recognition



# Analysis of the ProtoDUNE data

- Beams of e, mu, and hadrons (pions, proton, kaons)
- Beam energies from 0.5 to 7 GeV
- Inclusive and exclusive pion-Argon cross sections
- ...proton-Argon cross sections
- ...electron-Argon cross sections

Momentum Bins (GeV/c)	# of Spills per Bin	# $e^+$ per Bin	Beam Time per Bin (days)
0.5, 0.6, 0.7, 0.8, 0.9, 1, 2, 3, 4, 5, 6, 7	5000	300K	1.4

Possible run scenario

P (GeV/c)	# of Spills	# of $e^+$	# of $K^+$	# of $\mu^+$	# of p	# of $\pi^+$	Total # of Events	Beam Time (days)
1	70K	84K	$\approx 0$	70K	689K	625K	1.5M	19.4 days
2	16K	19K	9K	36K	336K	572K	1.0M	4.4 days
3	13K	16K	26K	17K	181K	540K	780K	3.6 days
4	11K	13K	19K	16K	107K	510K	660K	3.1 days
5	11K	13K	29K	13K	96K	510K	660K	3.1 days
6	11K	13K	36K	12K	94K	510K	660K	3.1 days
7	11K	13K	42K	8K	87K	510K	660K	3.1 days
Total	143K	171K	161K	172K	1.6M	3.8M	5.9M	39.7 days

# Summary:

- ✓ CERN offers a platform for Neutrino detectors R&D and later construction. CERN is supporting 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
- ✓ We will assist the EU neutrino community in their long term common plans. We are reacting on demands from the community, in particular for many R&D aspects.
- ✓ 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 detectors are now appearing as new R&D projects.