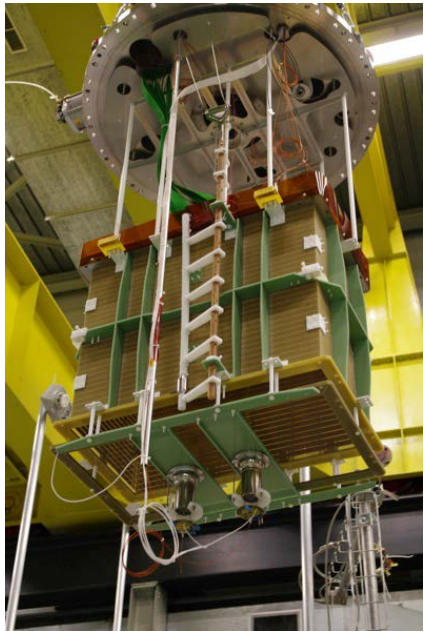
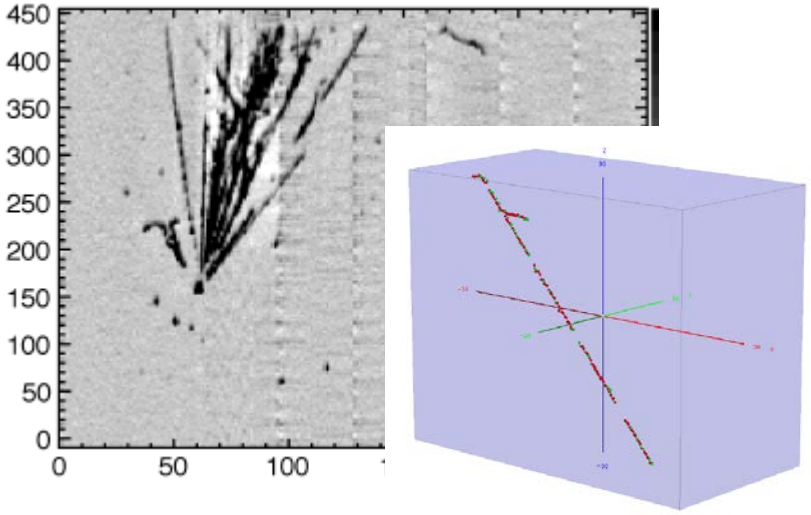
European Double-Phase LAr TPC R&D





Christos Touramanis

UNIVERSITY OF LIVERPOOL

LArTPC R&D Workshop Fermilab , 20-21 March 2013

OUTLINE

- The aim: ~100kt GLACIER double-phase TPC
- ETH group @ CERN:
  - 10x10cm^2 prototype
  - 40x76x60cm^3 prototype
- ArDM (1 ton) -> operational at CAFRANC
- Purification without evacuation of 6m^3 vessel “old news”
- Saclay: MicroMegas charge readout
- The Liverpool programme
- Reconstruction development:
  - at QMUL
  - at Warwick
  - at Cambridge
- Next step at CERN: A 6x6x6m^3 demonstrator

History and Disclaimer

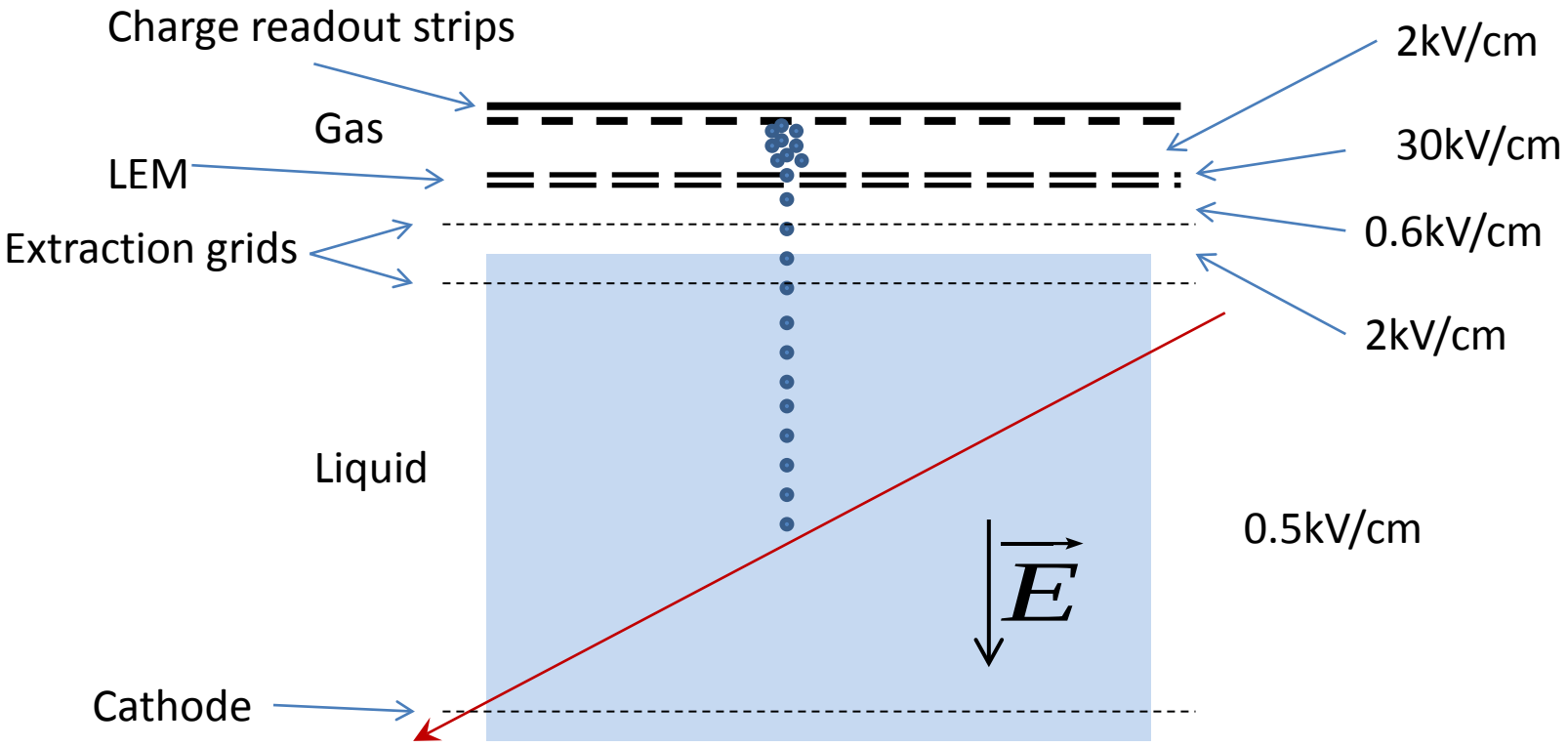
- 1977: Original proposal, C. Rubbia, CERN-EP/77-08
- 1985: ICARUS proposal to INFN, INFN/AE-85/7
- 1987-95: prototypes up to 3 ton at CERN
- 1997-99: 50 lt chamber in NOMAD neutrino beam
- 2001: operation on the surface of first 300 ton ICARUS module
- Since May 2010: continuous operation of ICARUS in LNGS

- Since 2000: Development of double phase concept
  - Up to 200lt (active) prototypes at CERN
  - 1ton ArDM TPC now operational in CAFRANC
- Next step: 6x6x6m^3 demonstrator, ~2016 @ CERN

35 years of LAr in Europe!

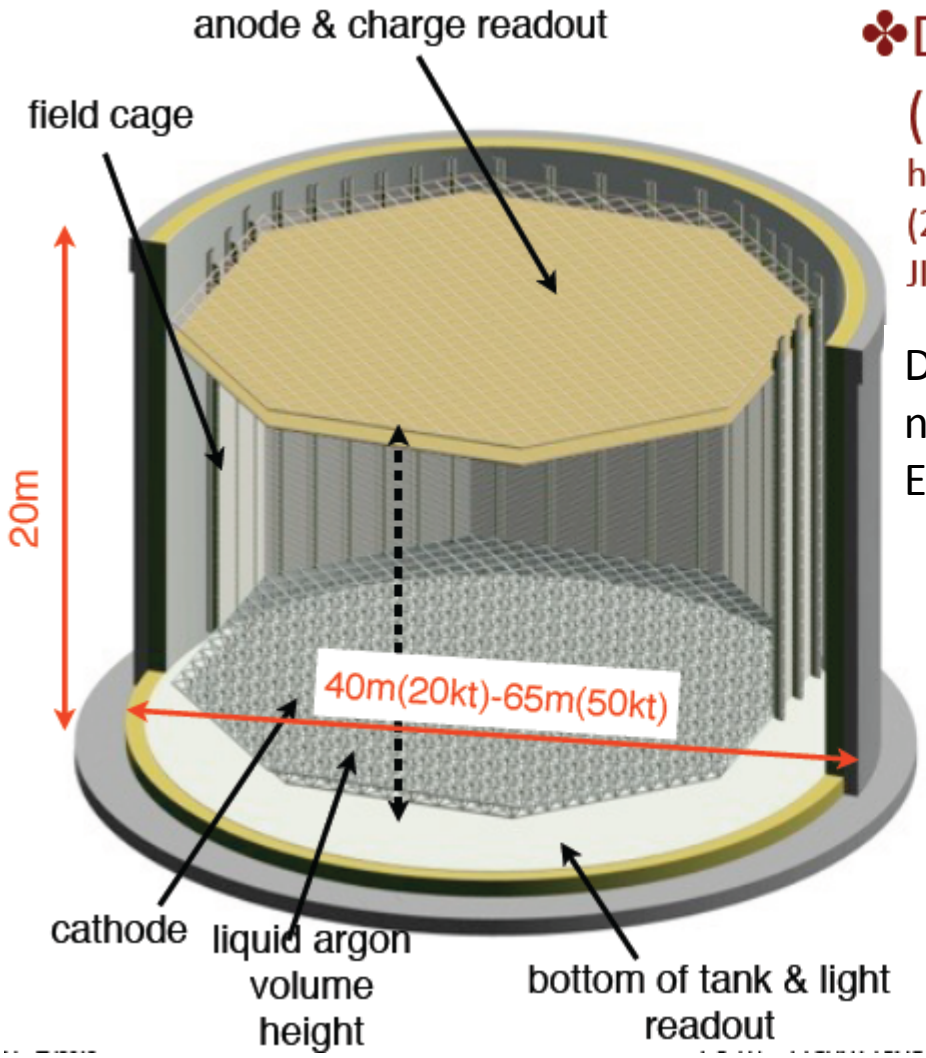
This talk is concerned only with items in the lower part.

Double-phase LAr TPC operation



- Distances between layers at the top ~2cm
- LEM thickness ~1mm
- Charge Amplification through LEM ~30

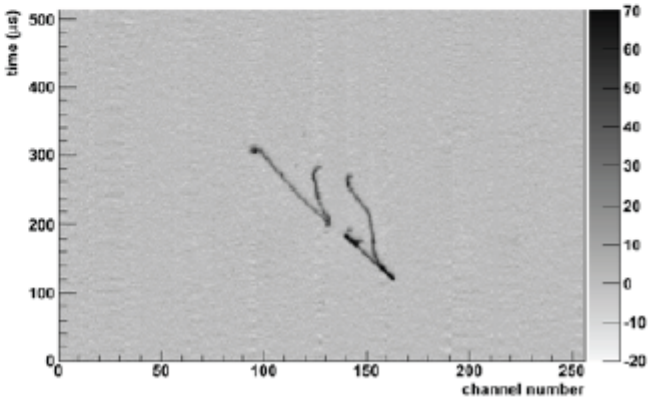
20-50kt GLACIER detector



- Double phase LAr LEM TPC (GLACIER,Venice 2003 !)

hep-ph/0402110; J.Phys.Conf.Ser. 171 (2009) 012020; NIM A 641 (2011) 48-57; JINST 7 (2012) P08026; arXiv:1301.4817

Diffusion coefficients not well known. At 20m drift Expect transv. ~5mm, long. ~3mm



Design Studies

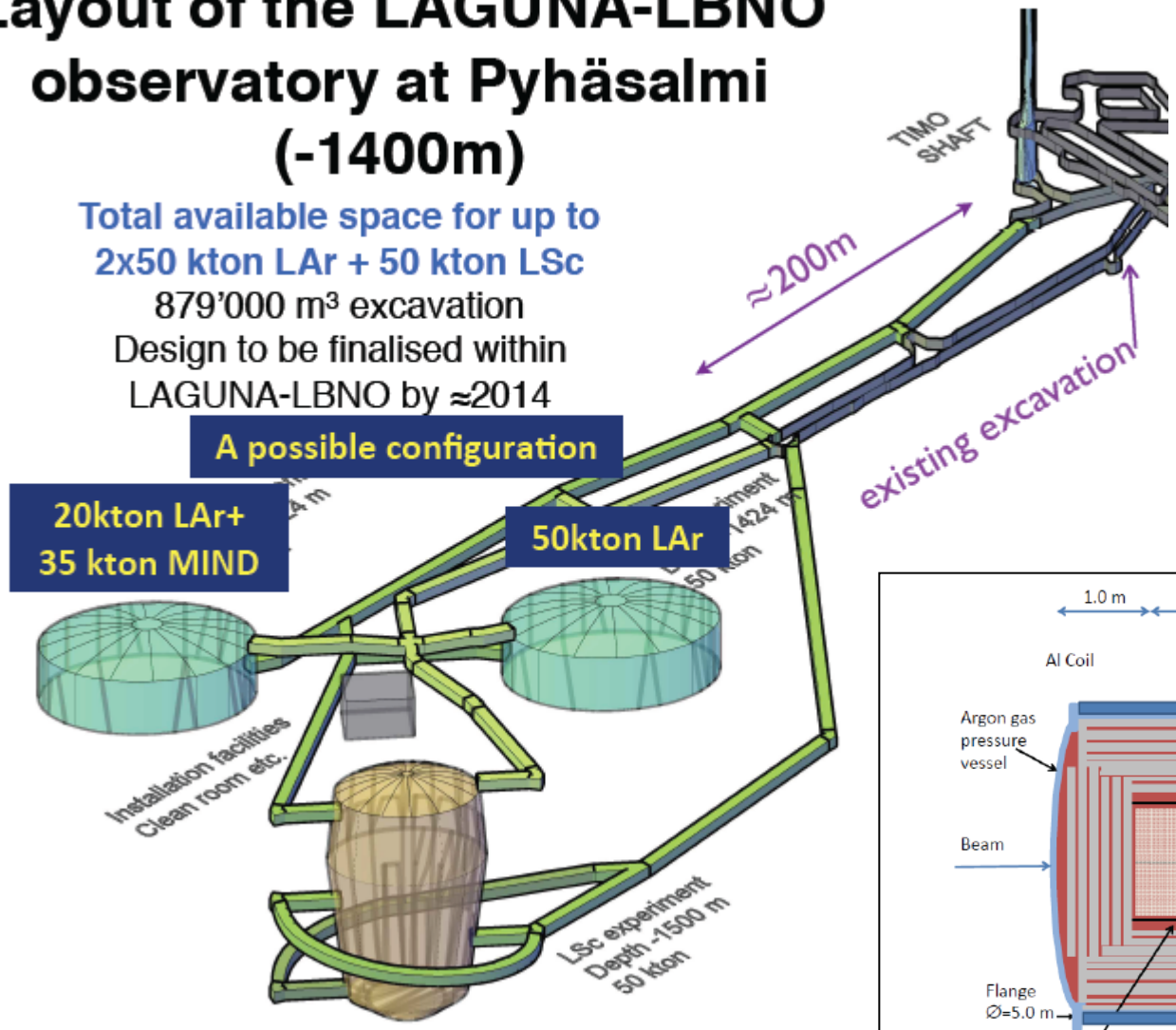
- LAGUNA (100 members) 2008-11
- LAGUNA-LBNO (300 members) 2011-14
- Site studies; beam facility (CERN)
- Extensive Industrial participation
- Detector Design (LAr), Near Detector design
- Project planning, detailed costing
- LBNO: EoI submitted to CERN SPSC, under review

Layout of the LAGUNA-LBNO observatory at Pyhäsalmi (-1400m)

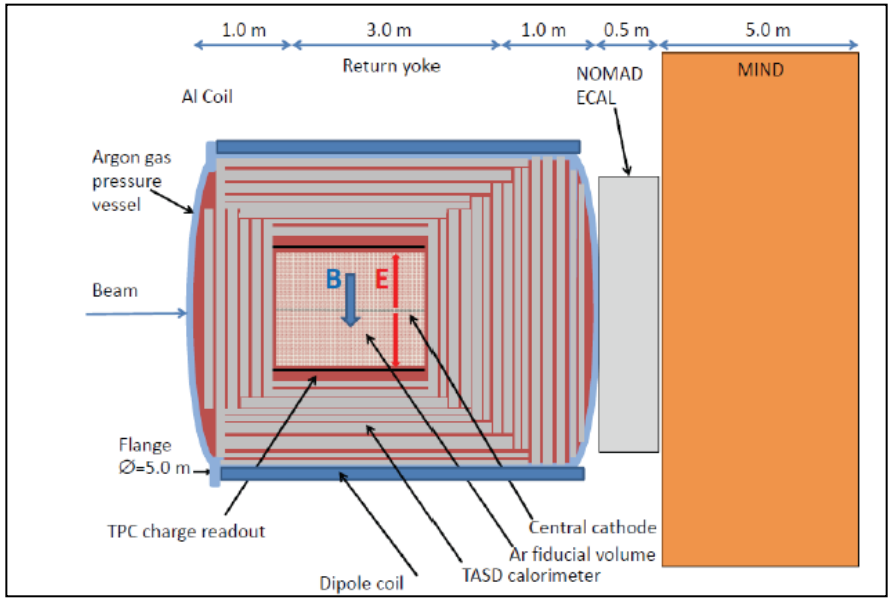
Total available space for up to 2x50 kton LAr + 50 kton LSc

879'000 m³ excavation

Design to be finalised within LAGUNA-LBNO by ≈2014

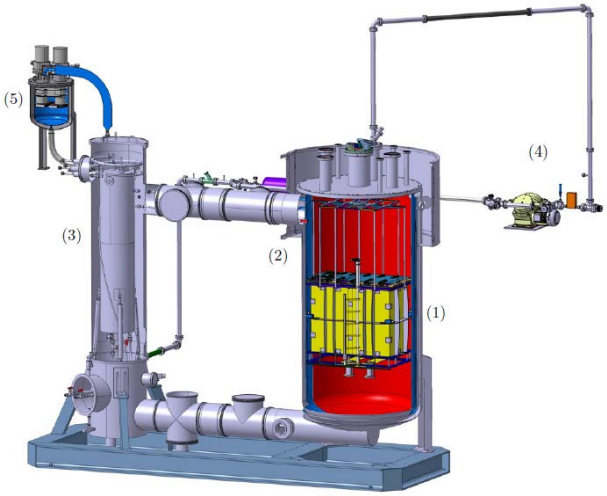


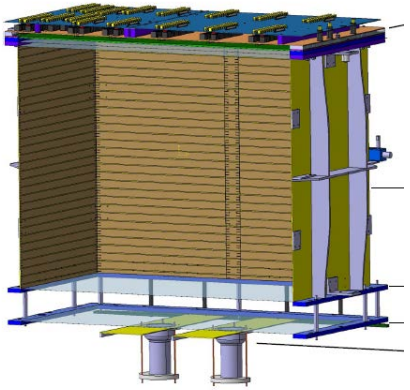
Near Detector

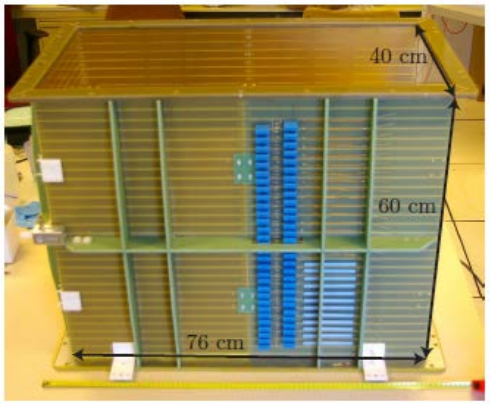


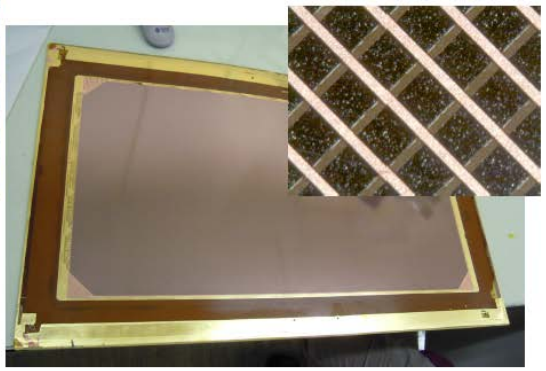
200lt prototype (ETH)

- 1ton ArDM vessel
- 76x40cm^2 readout surface
- 60cm max drift
- 2 TPB-coated PMTs
- LEM (left) with 0.5M holes
- 2D anode (right)
- CAEN (hot) electronics



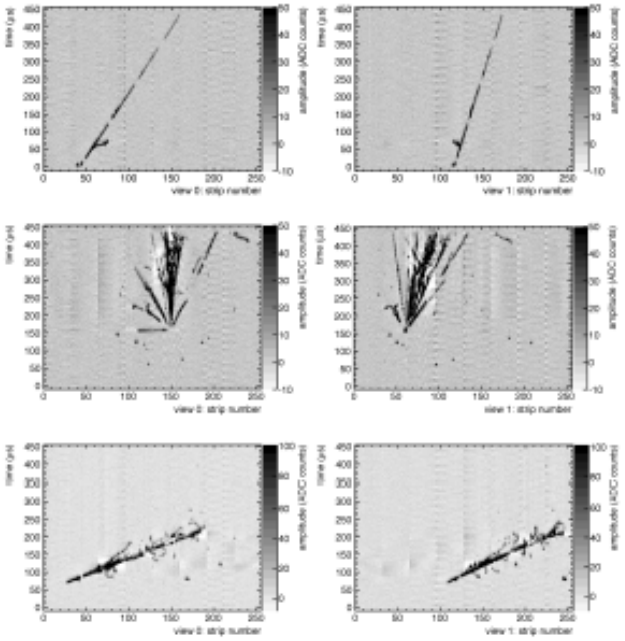






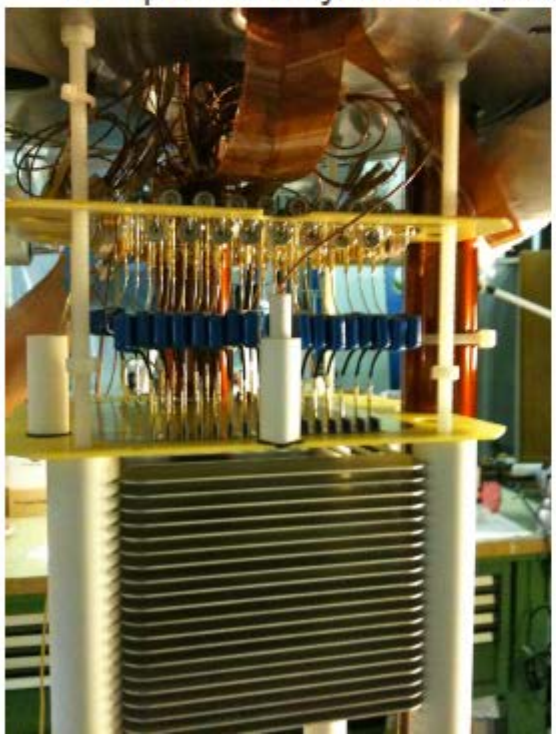
200lt prototype (cont.)

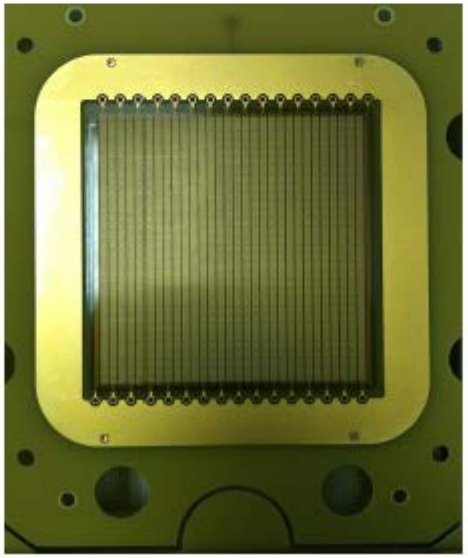
- Stable operation for 1 month
- Muon, had. shower, EM shower:
- Coherent noise filtering, QSCAN reconstruction
- Effective gain: 14, s/n > 30 (MIP)
- A. Badertscher et al., JINST 7 (2012) P08026

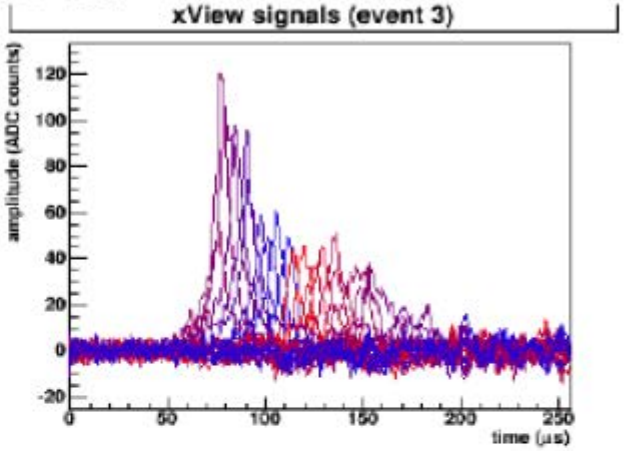


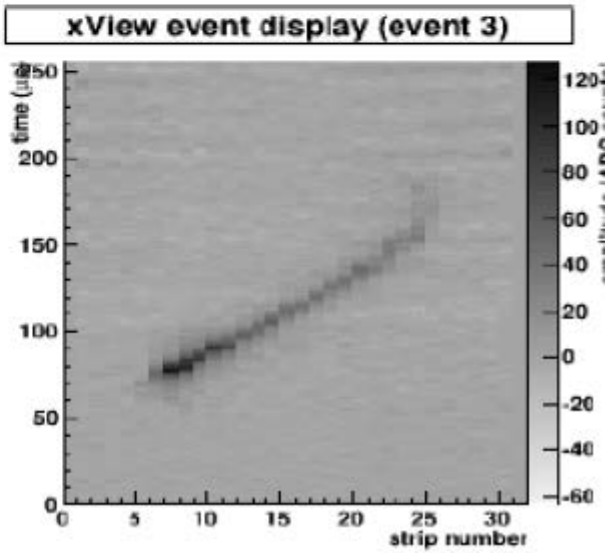
ETHZ-Saclay test of Micromegas for charge readout

Test done in the 3l ETHZ setup at CERN
Bulk Micromegas, 32 strips 3.1 mm pitch, 100 µm gap
Proof of principle : stable operation reached, cosmic ray tracks observed,
Gain ~5. Further steps in collaboration with U. of Liverpool and Lyon. New tests this year.



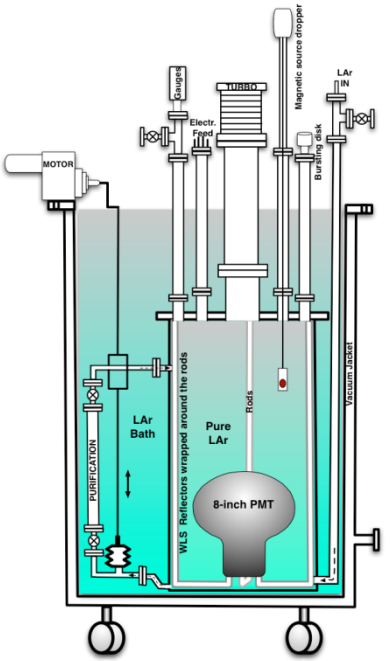


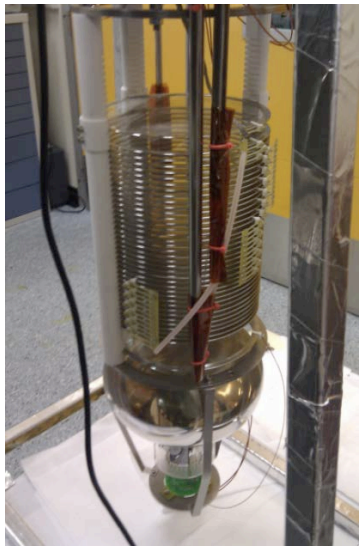


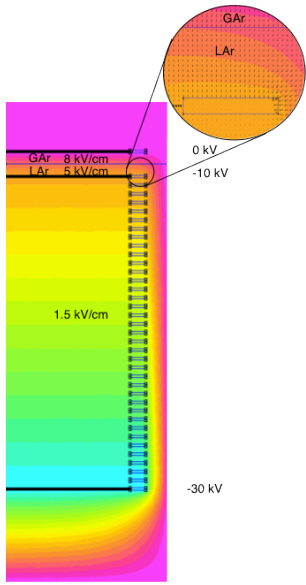


LAr at Liverpool

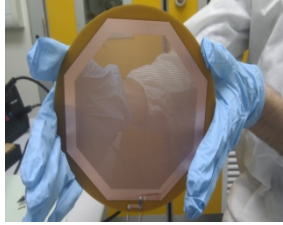
- Design & construction in-house
- 250lt bath, 40lt chamber
- Recirculation, filtering
- Drift voltage up to 1kV/cm
- TPB-coated cryo PMTs
- Purification, electron lifetime, absolute calibration done (K. Mavrokoridis *et al 2011 JINST 6 P08003*)

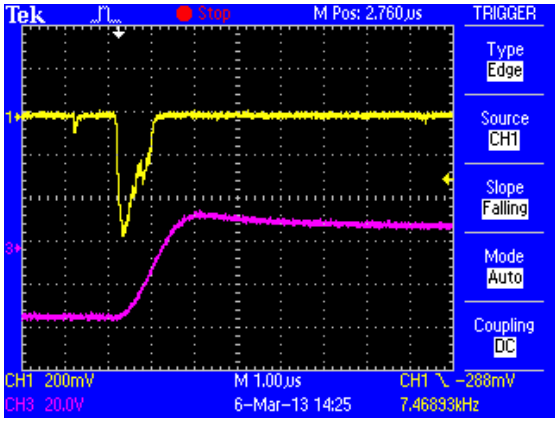




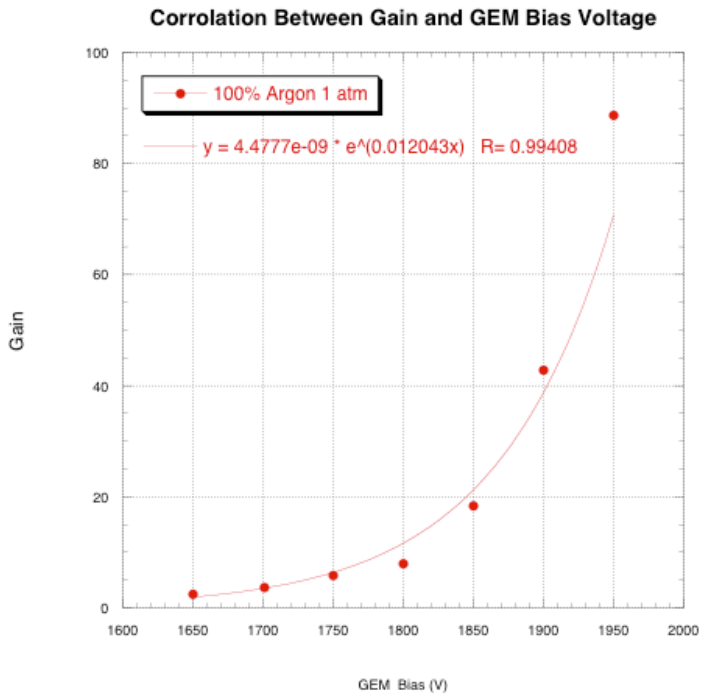


Liverpool - Saclay plans





- Demonstrated drift, extraction, amplification, Q readout using TGEM (picture)
- See S2 light (yellow) and charge preamp signal (purple)
- Gain 100 in gas (1Atm)
- Saclay prepares MicroMegas and provides readout
- 2013 plan: campaign of different micromegas measurements at Liverpool

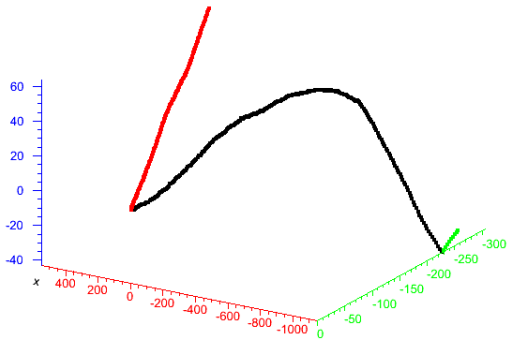


Event Reconstruction Software

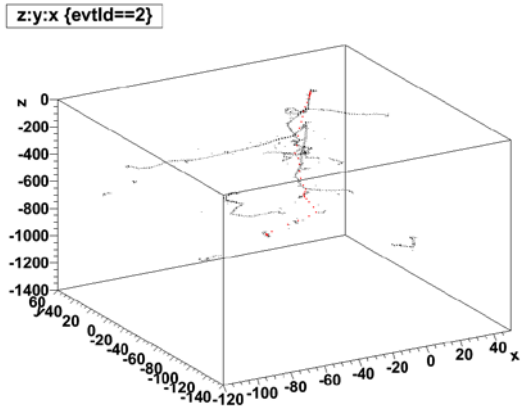
- QSCAN used by ETH group
- UK effort:
  - Development of new algorithms and tools
    - Simulation chain, Reconstruction with CA and LPC, PID tools by Warwick group
    - PANDORA by Cambridge group
  - Integration, performance evaluation, cross-checks
    - Led by QMUL group, Warwick coming on board
  - Anything to be gained from ICARUS?

Software development at Warwick

- Home-grown LATTE package includes
  - LAMU: MC package using GENIE and G4
  - Full reco chain: pre-processing tools, track/cluster finding and separation using Cellular Automaton and Local Principal Curves, full "physics" objects output
  - PID tools
- See: B. Morgan, JINST 5 (2010) P07006; arXiv:1210.2215



CA: robust for tracks



LPC: versatile for low-E electrons

Cambridge

Automated LAr Reconstruction

- **There is now an advanced effort at Cambridge to write fully automated event reconstruction for LAr detectors.**
  - Cambridge are world leaders in fine-grain reconstruction, having developed Particle Flow Calorimetry for ILC/CLIC.
    - ◇ Techniques are readily applicable to LAr detectors.
  - Recently released Pandora Software Development Kit
    - ◇ Package of analysis tools and template algorithms.
- **Have used Pandora to build a chain of LAr algorithms.**

Reconstruction Strategy:

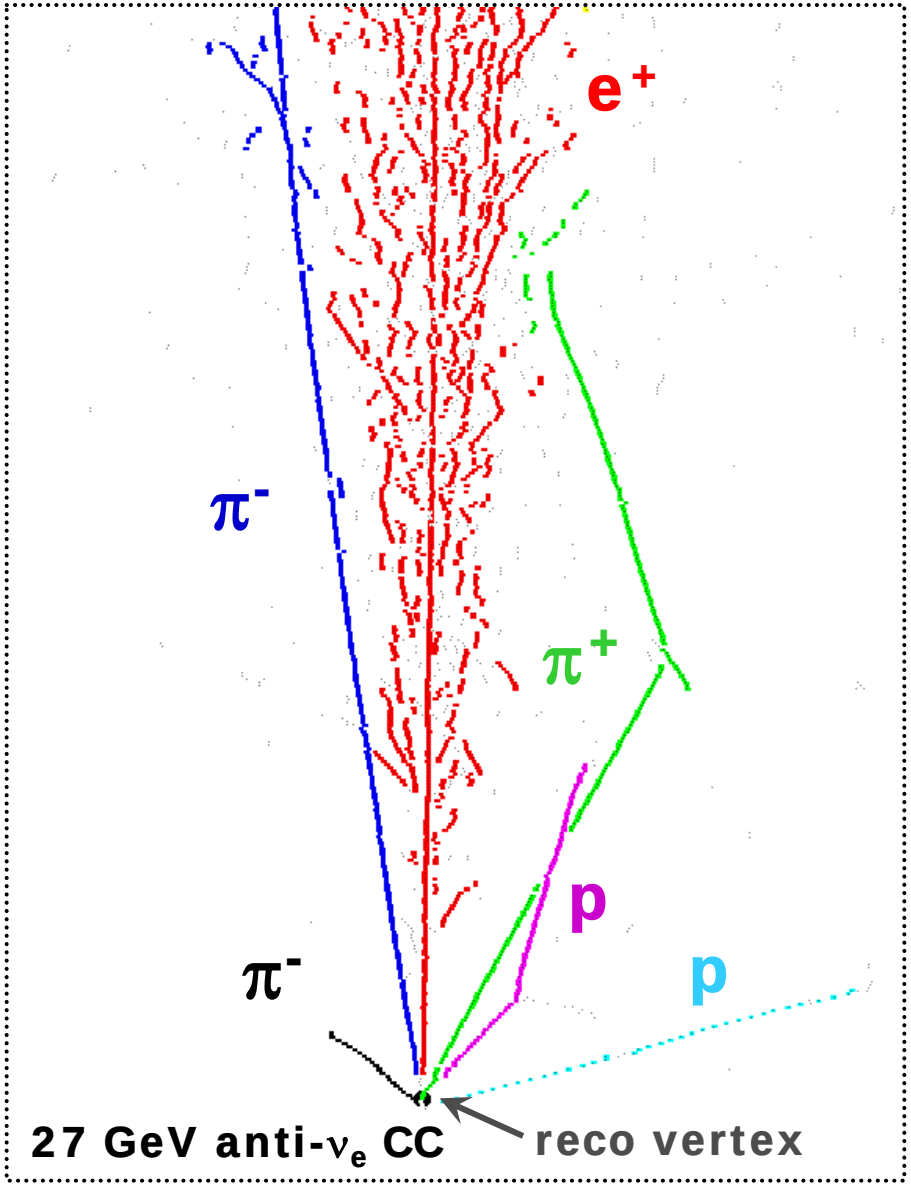
Clusters: Use topological associations between hits to build 2D clusters (these are building blocks for particle tracks and showers).

Vertex: Use fast likelihood fit to determine interaction vertex.

Particles: Use particle-growing algorithms to build tracks and showers, based on clusters, vertex and topology.

- **Current status: have 2D prototype. Now extending to 3D.**

Automated LAr Reconstruction (contd.)



- **Use GENIE and LArSoft to simulate neutrino interactions.**
  - LBNE beam spectrum.
  - MicroBooNE detector geometry.
- **Run the LArSoft hit-finder. Then, pass hits to PANDORA for pattern recognition and event reconstruction.**
- **Prototype 2D reconstruction uses 18 algorithms.**
  - Each algorithm grows event in a particular way.
- **2D results look promising.**
  - Vertex resolution is 1.5 cm.
  - Able to handle quite complex final states (see display left).
- **Full 3D reconstruction chain now in development.**

Glacier Reconstruction

ν beam → ν interactions → Hits → Particle Flows → Analyses

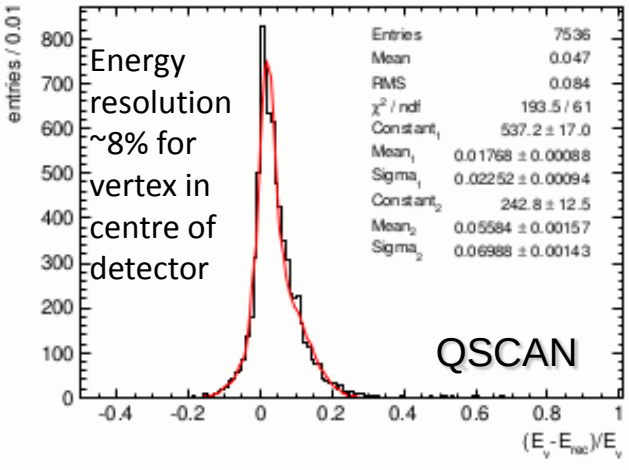
Genie
(few studies w/ NEUT as well)

QSCAN
(cross checks with LAMU: no charge drift/readout)

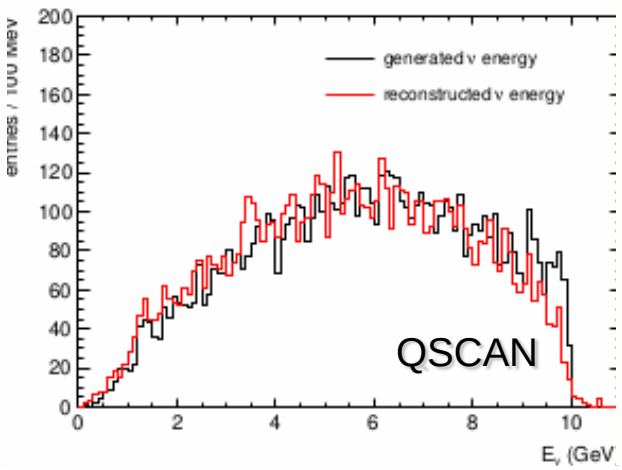
PANDORA
(particle flow algorithm. It reconstructs each particle in the event)

- ν_μ, ν_e, ν_τ analyses
- Proton decay
- Migration matrices
- ...

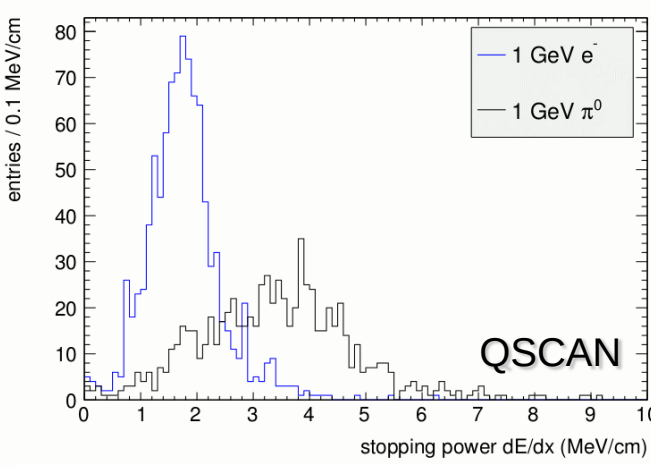
CCν_e Energy Resolution



CCν_e Energy Spectrum

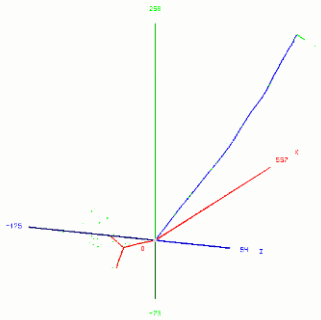


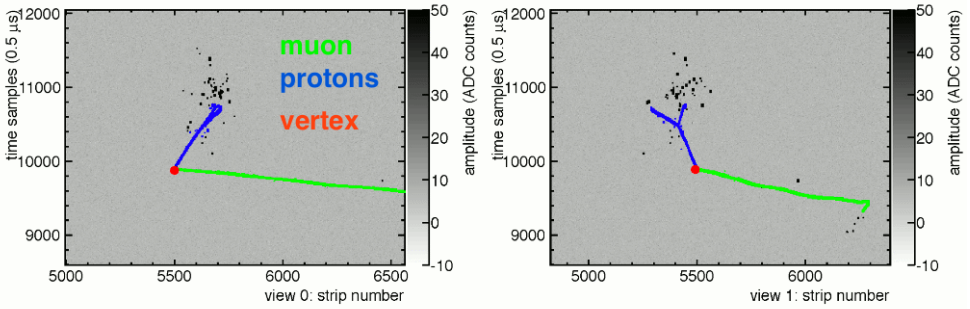
e^- / π^0 Separation



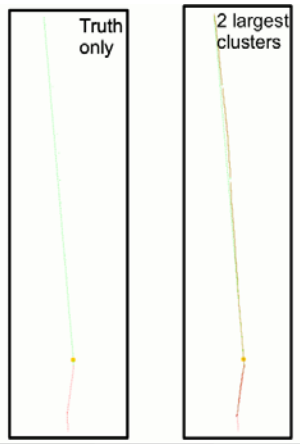
PANDORA events displays with QSCAN input

2.3 GeV ν_μ CC





PANDORA events displays with LAMU input

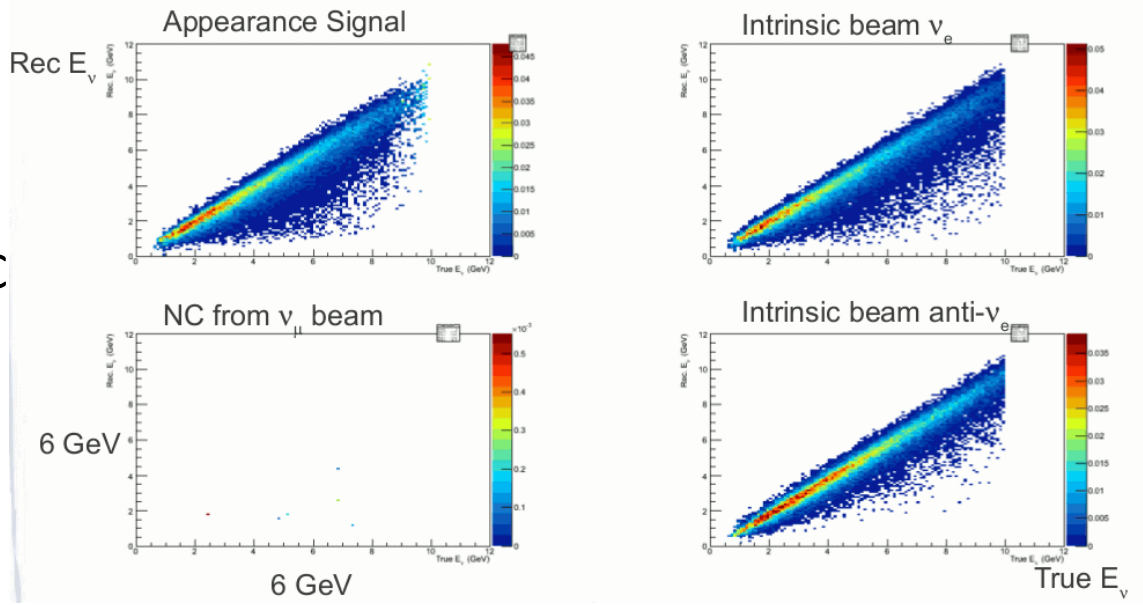


Investigating w/ Pandora: reconstruction efficiency versus theta, opening angle between two tracks and vertex reconstruction – reasonable results.

Working w/ Pandora developers to address reconstruction of tracks parallel to the strips (perpendicular to the beam direction)

Physics: analysis and migration matrices done using smeared MC true events.

Moving to reconstructed events.



The next big step in Europe:

The LAGUNA 6x6x6m^3 Demonstrator at CERN

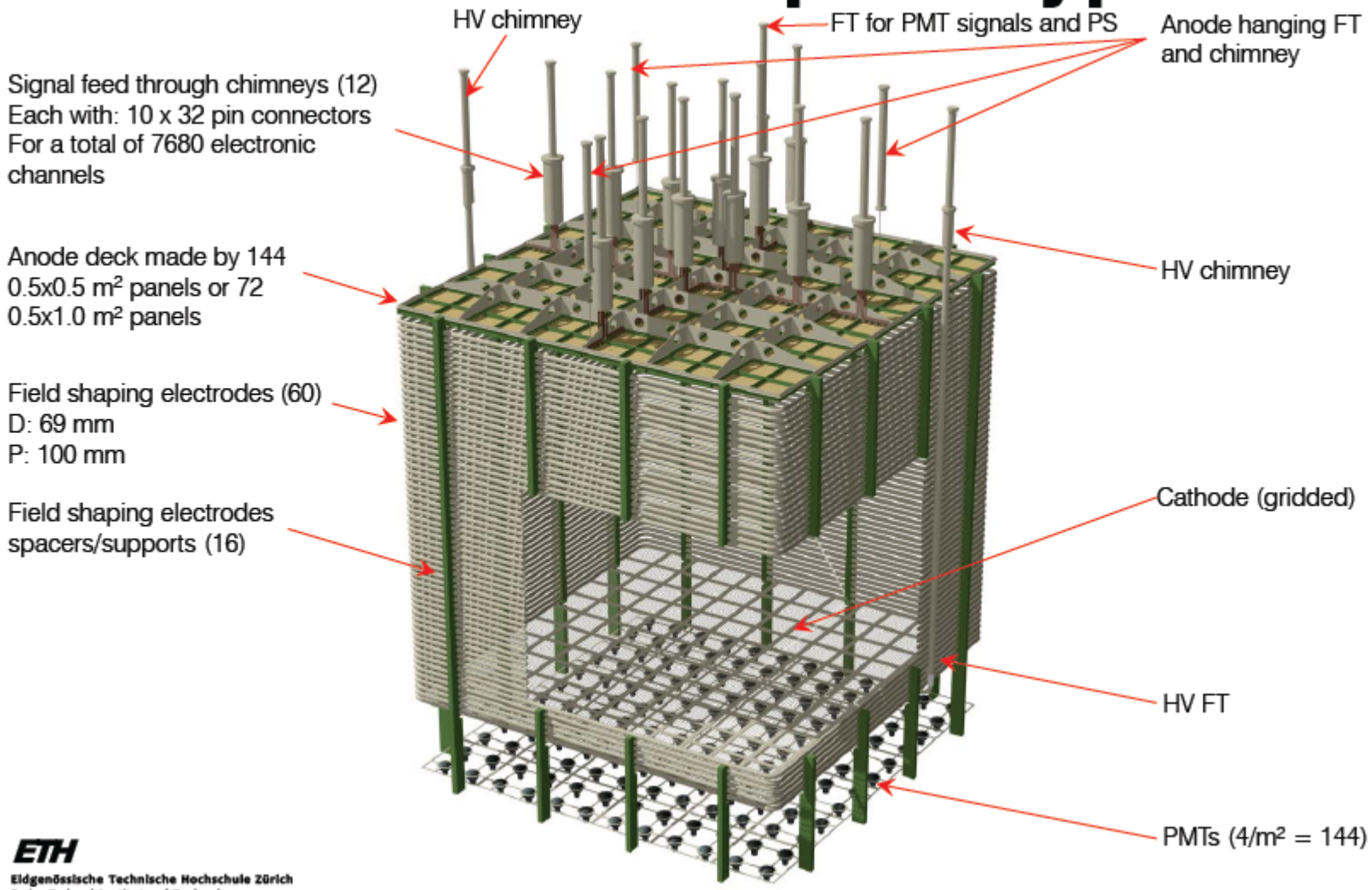
using charged particle testbeams and possibly neutrinos

aiming to be operational in 2016

The LAGUNA Prototype

- Industrial prototype to validate construction and operation methods for the 20kt Far Detector (LAGUNA-LBNO).
- Use charged particle testbeams to validate simulation, measure EM/Had calorimetry and tracking performance, bring reconstruction tools to physics readiness
- Position: CERN N.A., EHN1 extension (ready in 12 months?)
- To be operational < 2016
- May be exposed to neutrinos if CENF is built
- Highly relevant beyond Europe (LBNE, Okinoshima)

LAGUNA LAr prototype

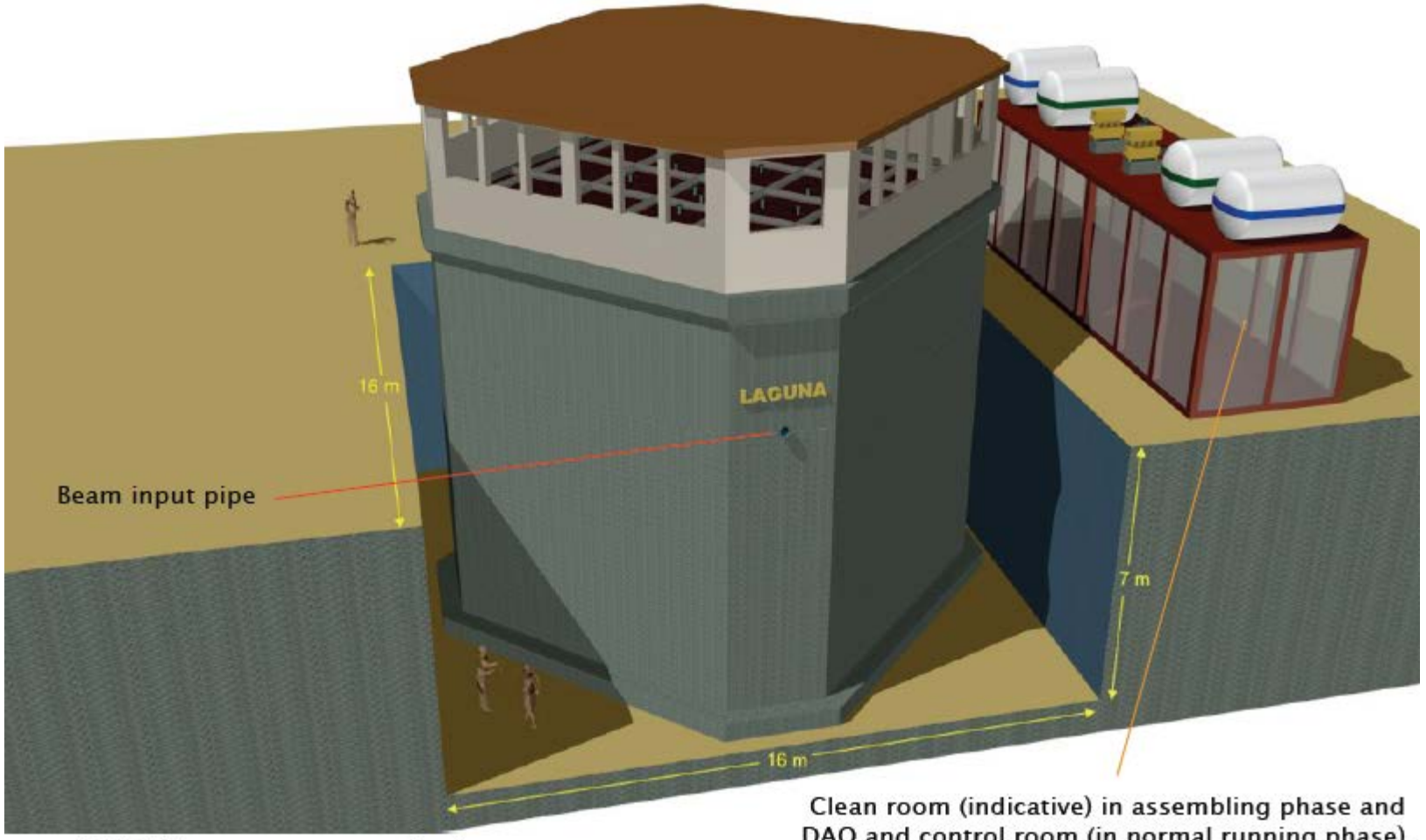


ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology

Overview of parameters

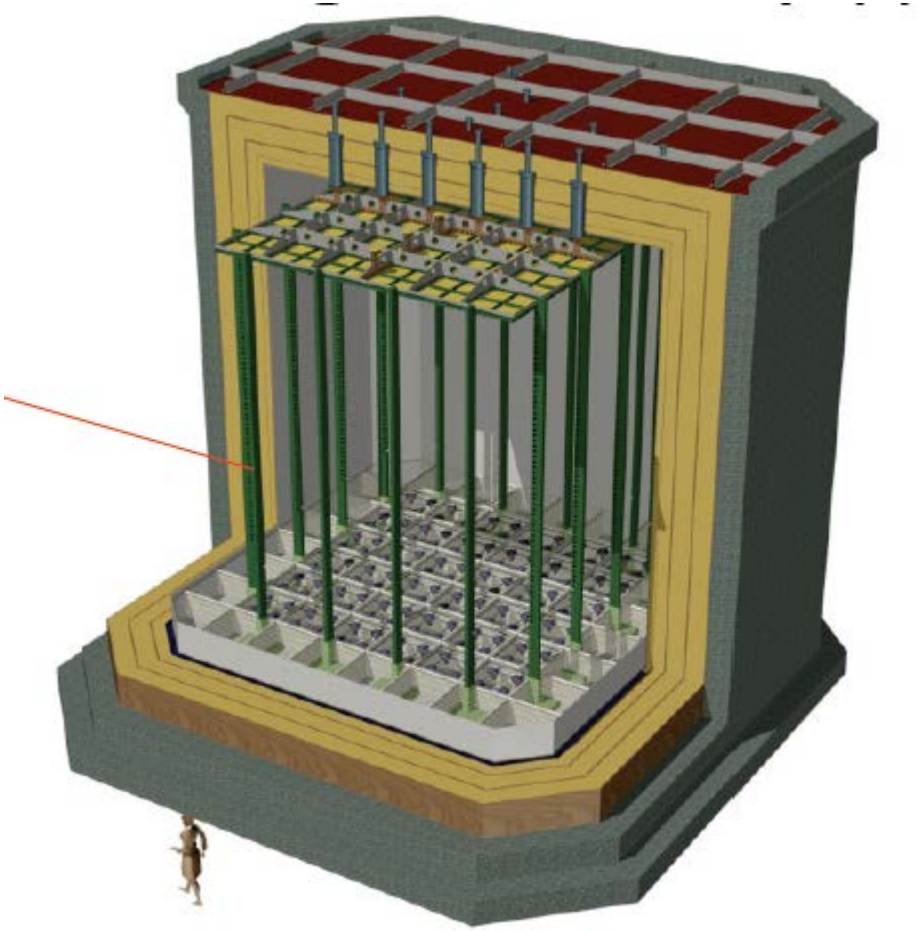
Liquid argon density at 1.2 bar	[T/m^3]	1.38346
Liquid argon volume height	[m]	7.6
Active liquid argon height	[m]	5.992
Pressure on the bottom due to LAr	[T/m^2]	1.05 (≡ 0.1 MPa ≡ 1.031 bar)
Inner vessel size (W x L x H)	[m x m x m]	8.288 x 8.288 x 8.108
Inner vessel base surface	[m^2]	67.6
Total liquid argon volume	[m^3]	509.6
Total liquid argon mass	[T]	705.0
Active LAr area (percentage)	[m^2]	36 (53.3%)
Active (instrumented) mass	[T]	298.2
Charge readout square panels (0.5m×0.5m)		144
Number of signal feedthroughs (640 channels/FT)		12
Number of readout channels		7680
Number of PMT (area for 1 PMT)		144 (0.5m×0.5m)

General overview



SPSC recommendation:
"validate large scale"

Clean room (indicative) in assembling phase and DAQ and control room (in normal running phase). Eventually used as support for cryocoolers and cryogenic liquid storage vessels



- Vessel to be “membrane” technology (GTT/FR)
- Passive GRPF insulation
- Foreseen to demonstrate the baseline options (LEM) and also allow for alternative charge readout methods to be tried

Summary

- LAr, originally proposed by Carlo Rubbia in 1977 at CERN, is the technology of choice for most proposed/planned LBL experiments
- European experts in single-phase largely working with US (LBNE) community
- The rest of the European neutrino community is working on double-phase technology
- We are poised to establish double-phase as a credible option for (far) giant LAr detectors
- ☺ .....and actually to prove that it is the best..... ☺

Thank you very much