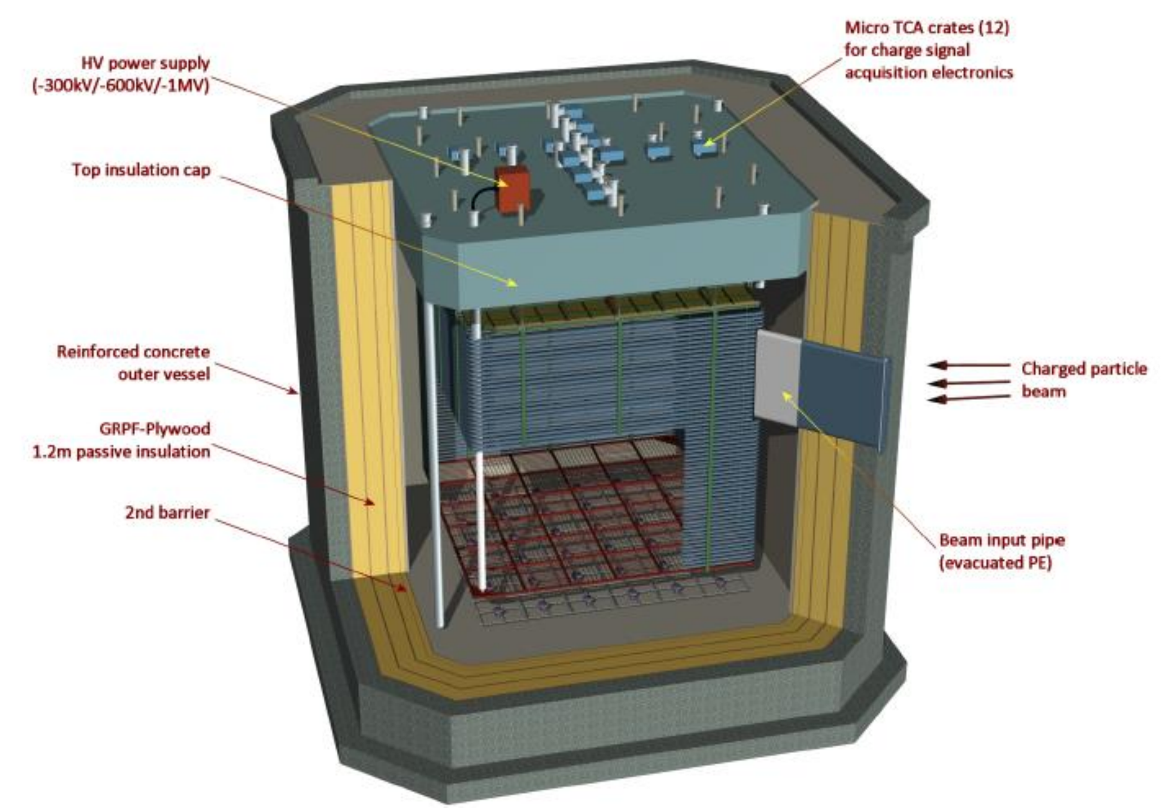
Status and plans of the WA105 Project

117th Meeting of the SPSC

CERN, April 14th, 2015

D. Autiero (IPNL Lyon)

on behalf of the WA105 Collaboration



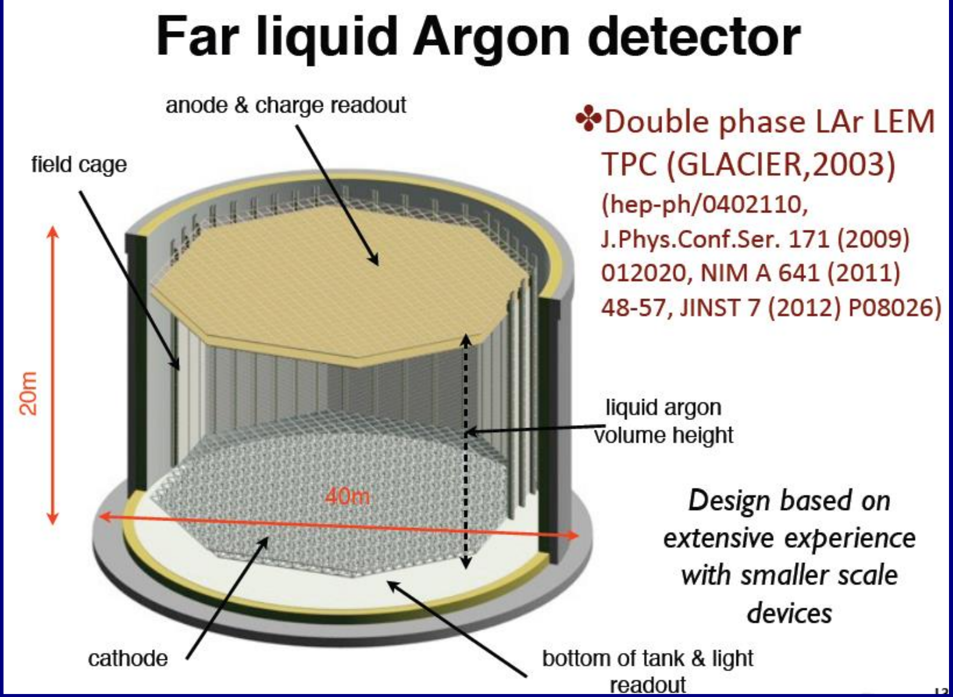
LAGUNA-LBNO DS

Design study for LBL neutrino experiment
2 EU programs: 2008-2011/2011-2014
~17 Meur investment
Completed August 2014

- LBNO EOI June 2012 (CERN to Pyhasalmi)

http://cdsweb.cern.ch/record/1457543
224 physicists, 52 institutions
Physics program:

- Determination of neutrino mass hierarchy
- Search for CP violation
- Proton decay
- Atmospheric and supernovae neutrinos



Far liquid Argon detector

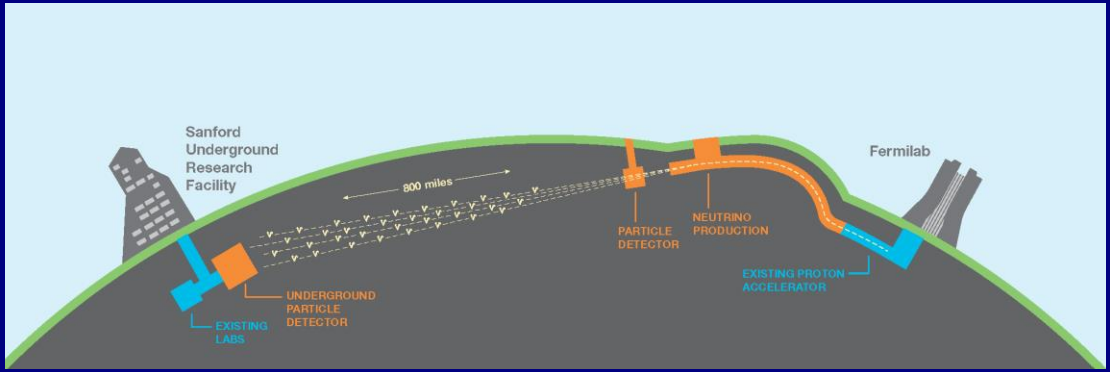
✤Double phase LAr LEM TPC (GLACIER,2003) (hep-ph/0402110, J.Phys.Conf.Ser. 171 (2009) 012020, NIM A 641 (2011) 48-57, JINST 7 (2012) P08026)

Design based on extensive experience with smaller scale devices

20 kton double phase LAr TPC

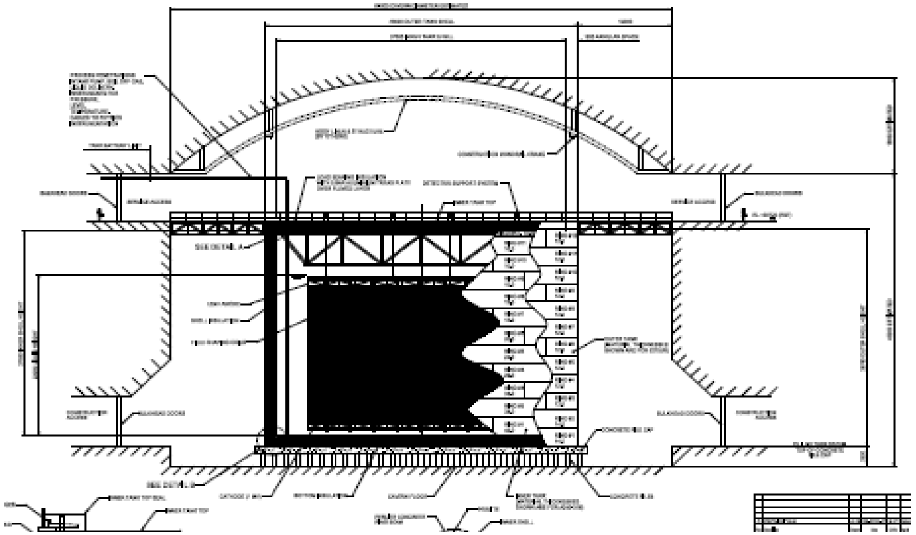
- ELBNF (now DUNE) LOI, January 2015 (P1062)

http://www.fnal.gov/directorate/program_planning/Jan2015Public/LOI-LBNF.pdf
503 physicists, 142 institutions
LBL and underground physics (as rec. by P5): 40 kton LAr at Homestake + 1.2(2.4) MW beam

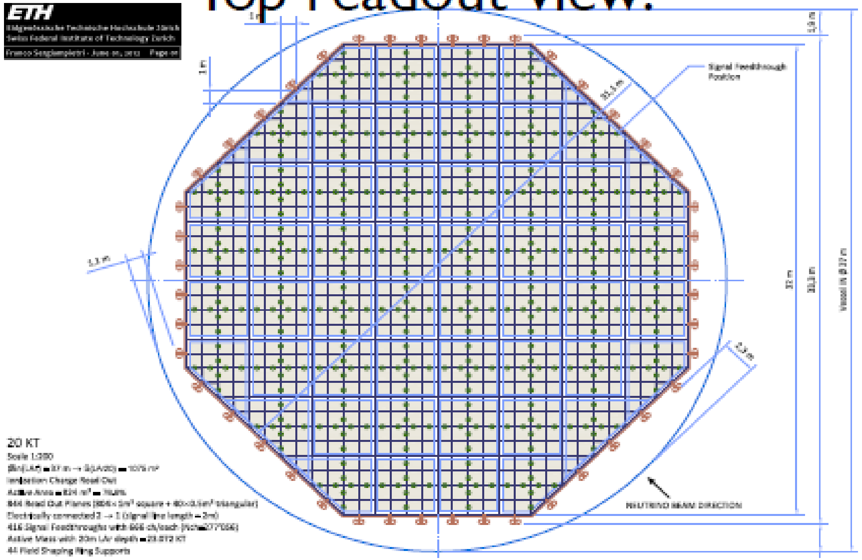


GLACIER detector design

- ★ Concept unchanged since 2003: Simple, scalable detector design, from one up to 100 kton (hep-ph/0402110)
- ★ Single module non-evacuable cryo-tank based on industrial LNG technology
  - industrial conceptual design (Technodyne, AAE, Ryhal engineering, TGE, GTT)
  - two tank options: 9% Ni-steel or membrane (detailed comparison up to costing of assembly in underground cavern)
  - three volumes: 20, 50 and 100 kton
- ★ Liquid filling, purification, and boiloff recondensation
  - industrial conceptual design for liquid argon process (Sofregaz), 70kW total cooling power @ 87 K
  - purity < 10 ppt O_2 equivalent
- ★ Charge readout (e.g. 20 kton fid.)
  - 23'072 kton active, 824 m^2 active area
  - 844 readout planes, 277'056 channels total
  - 20 m drift
- ★ Light readout (trigger)
  - 804 8" PMT (e.g. Hamamatsu R5912-02MOD) WLS coated placed below cathode
- ★ The concept and the designs are reaching the required level of maturity for submission to SPSC.

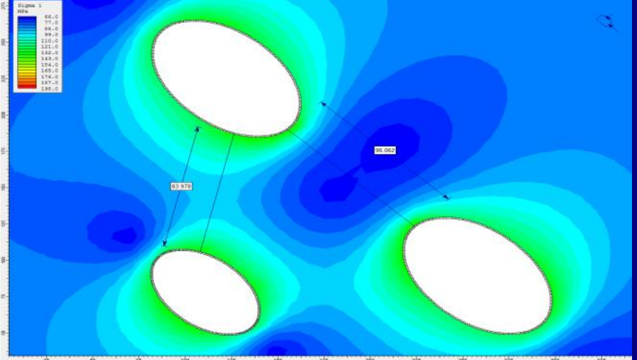


Top readout view:



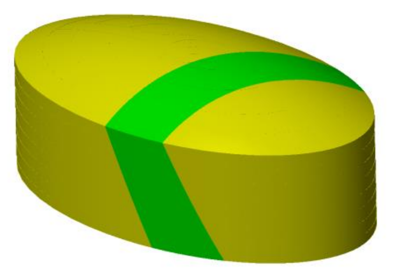
Technical aspects finalized in the LAGUNA-LBNO study as deliverables including detailed costing → August 2014

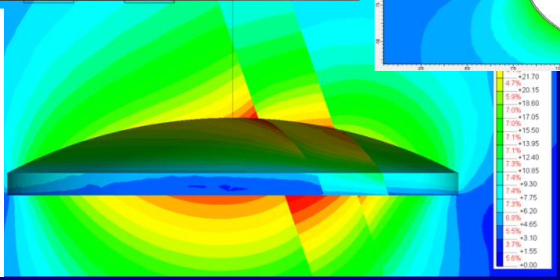
Affordable underground detector



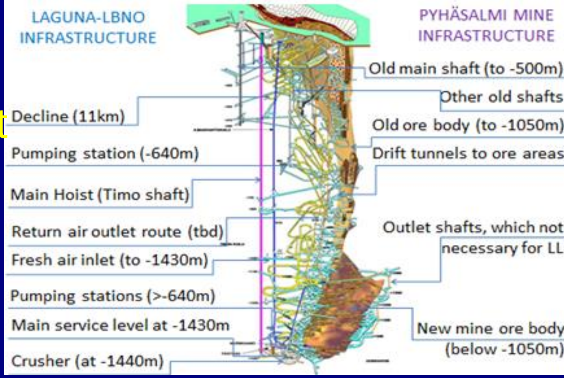
Rock engineering Caverns:
- ✓ 64m span,
- ✓ 100 m length,
- ✓ 38 m height

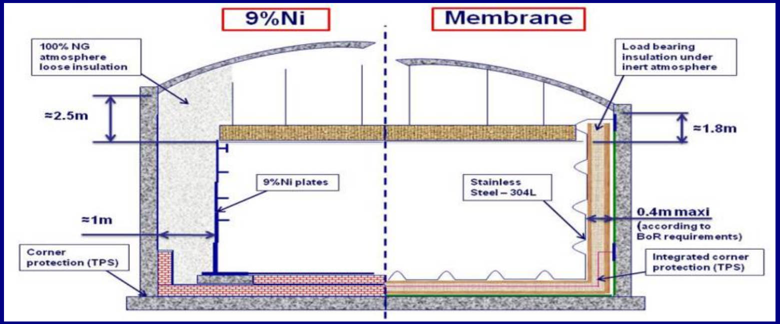
at 1400 m dept.





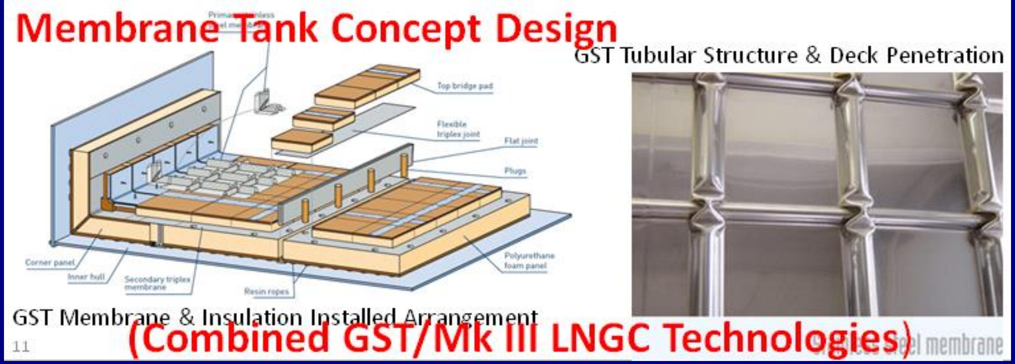
- Infrastructure integration with mine environment
- Concrete production

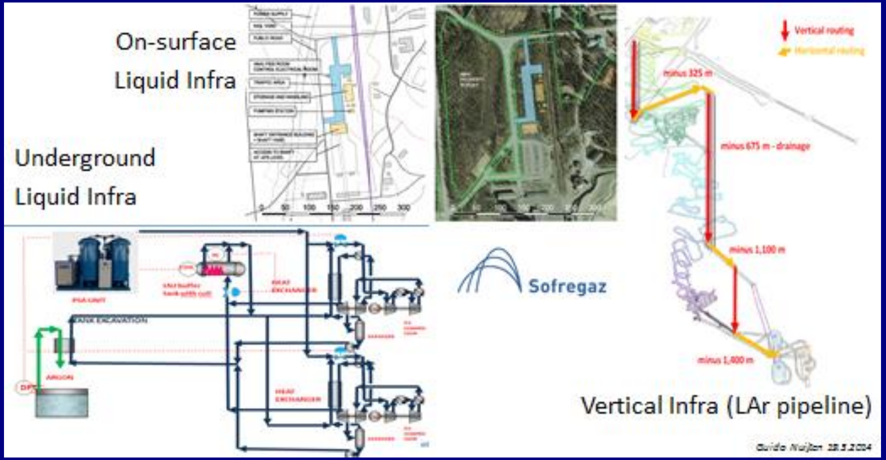




- Study of single/double containment underground

→ Membrane tank double containment

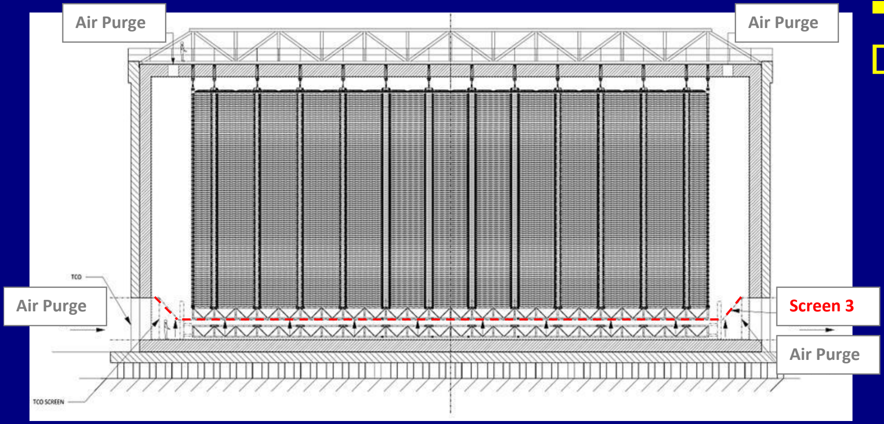


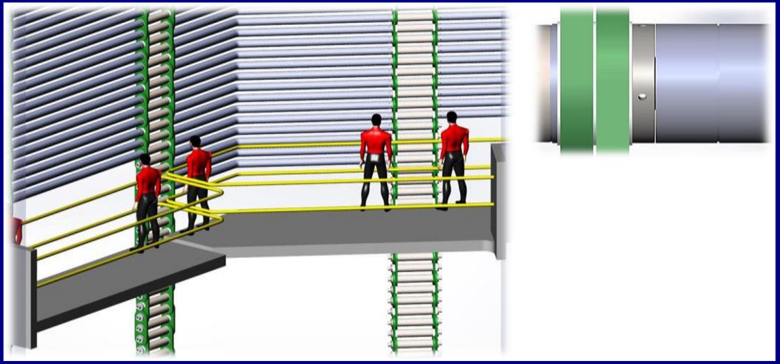


- Design and integration of the liquid handling infrastructure
- Liquid procurement, safety, risk assessment

- Construction/Installation

Design and detailed logistics of the construction steps

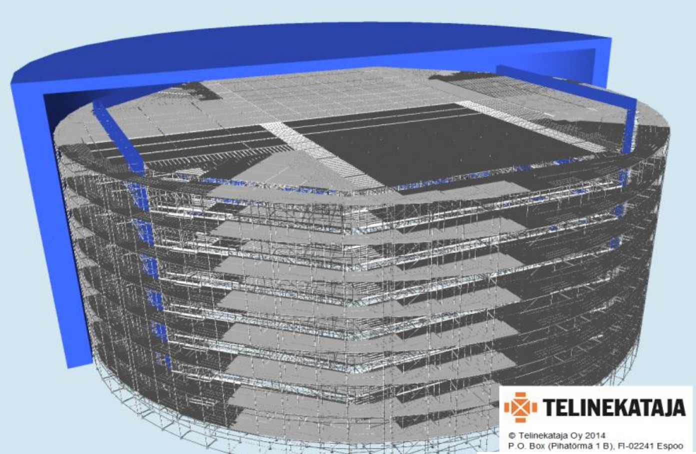


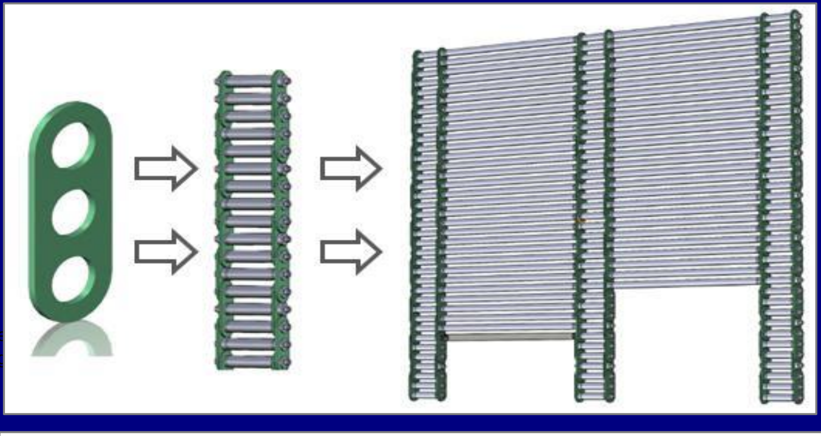


- Special construction materials and demands

Field cage, cathode, anode deck and feed-throughs

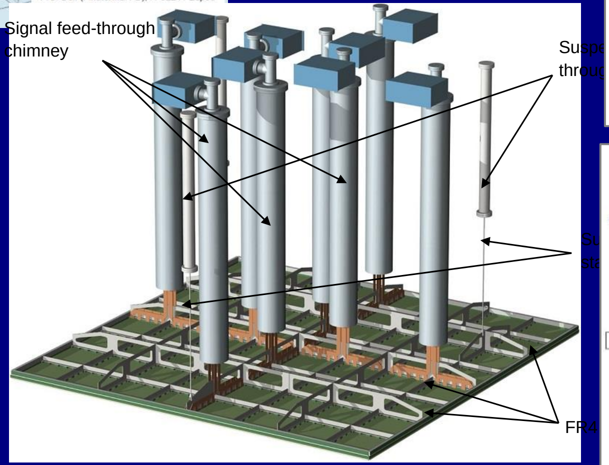
- Scaffolding
- Clean room integration

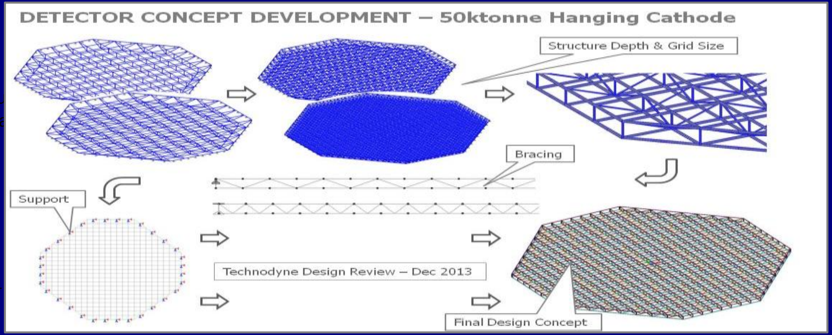




And last but not least:

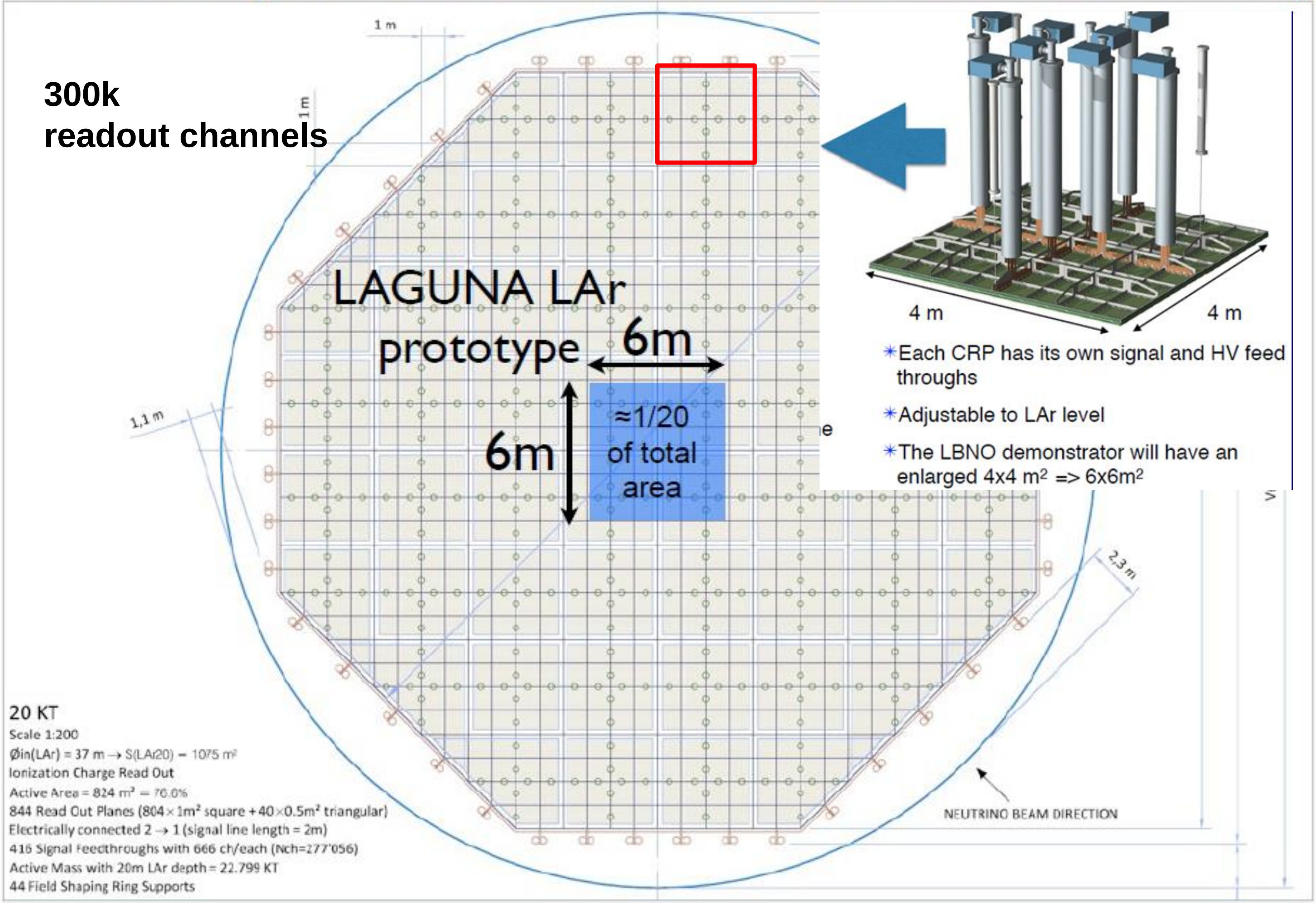
- Double phase detectors design and integration
- FE electronics and DAQ
- VHV





Compared to GLACIER 20 kton

300k readout channels



LAGUNA LAr prototype

6m

6m

≈1/20 of total area

- Each CRP has its own signal and HV feed throughs
- Adjustable to LAr level
- The LBNO demonstrator will have an enlarged 4x4 m^2 => 6x6m^2

20 KT

Scale 1:200

Øin(LAr) = 37 m → S(LAr20) = 1075 m^2

Ionization Charge Read Out

Active Area = 824 m^2 = 76.0%

844 Read Out Planes (804 × 1m^2 square + 40 × 0.5m^2 triangular)

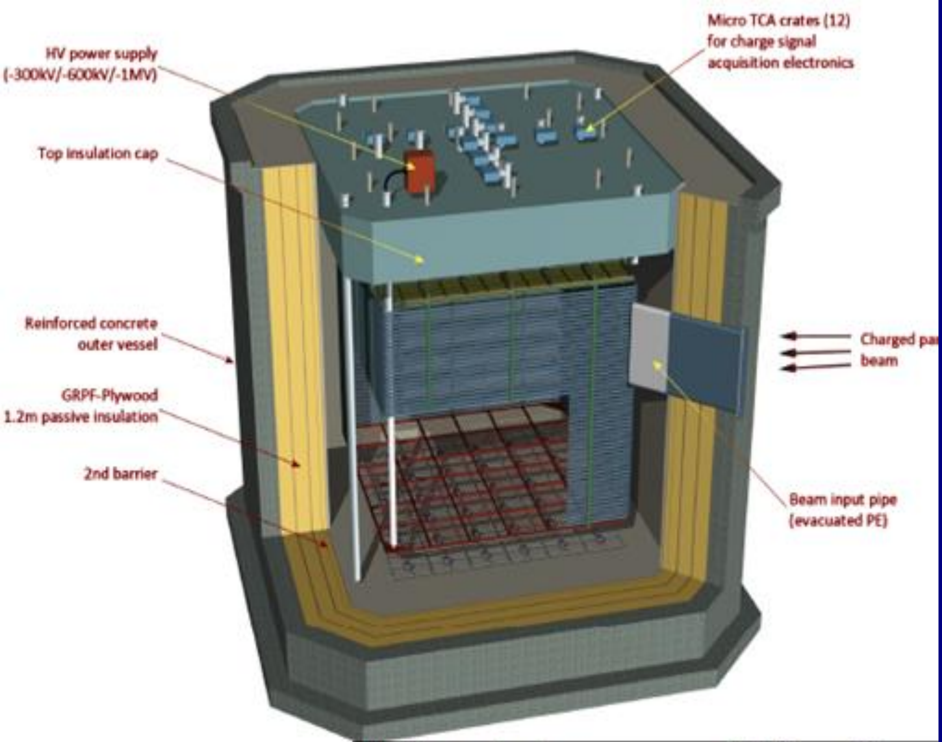
Electrically connected 2 → 1 (signal line length = 2m)

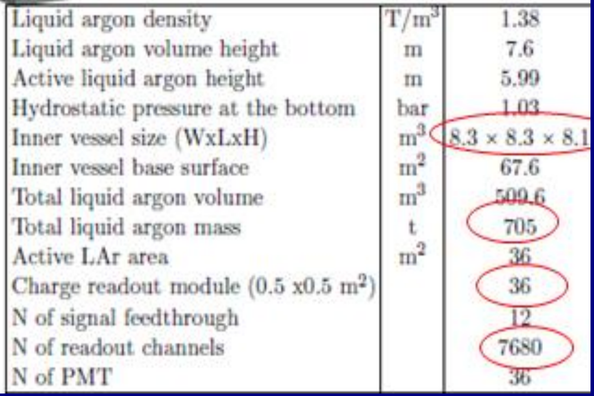
416 Signal Feedthroughs with 666 ch/each (Nch=277'056)

Active Mass with 20m LAr depth = 22.799 KT

44 Field Shaping Ring Supports

The LBNO-DEMO/WA105 experiment at CERN





Liquid argon density	T/m^3	1.38
Liquid argon volume height	m	7.6
Active liquid argon height	m	5.99
Hydrostatic pressure at the bottom	bar	1.03
Inner vessel size (WxLxH)	m^3	8.3 × 8.3 × 8.1
Inner vessel base surface	m^2	67.6
Total liquid argon volume	m^3	509.6
Total liquid argon mass	t	705
Active LAr area	m^2	36
Charge readout module (0.5 x0.5 m^2)		36
N of signal feedthrough		12
N of readout channels		7680
N of PMT		36

→ 1/20 of 20 kton LBNO detector

6x6x6m^3 active volume, 300 ton , 7680 readout channels, LAr TPC (double phase+2-D collection anode): DLAr
Exposure to charged hadrons, muons and electrons beams (0.5-20(10) GeV/c)

Full-scale demonstrator of all innovative LAGUNA-LBNO technologies for a large LAr detector:

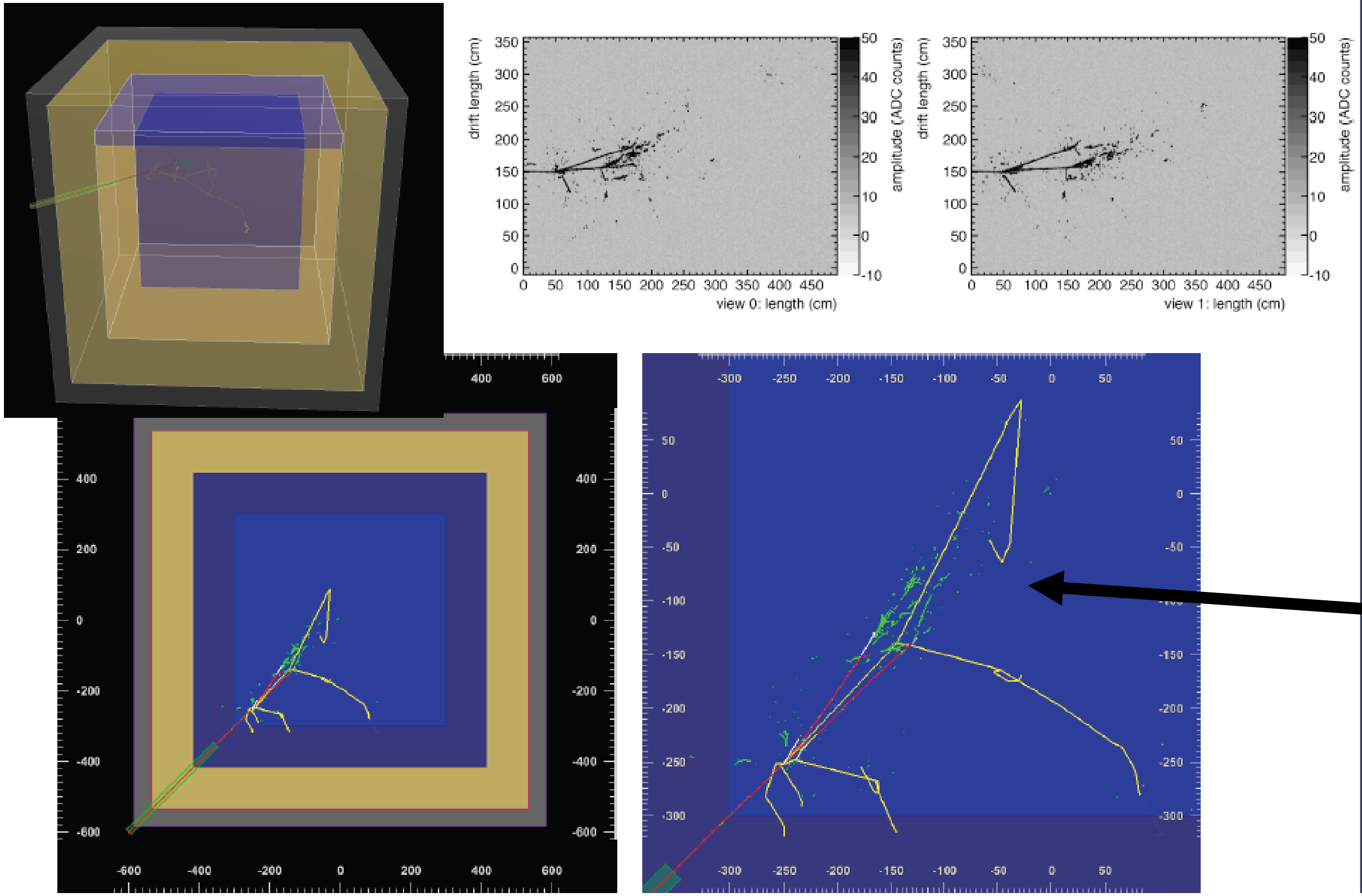
- **LNG tank construction technique (with non evacuated vessel)**
- **Purification system**
- **Long drift**
- **HV system 300-600 KV, large hanging field cage**
- **Large area double-phase charge readout**
- **Accessible FE and cheap readout electronics**
- **Long term stability of UV light readout**

Assess performance in reconstructing hadronic showers (most demanding task in neutrino interactions):

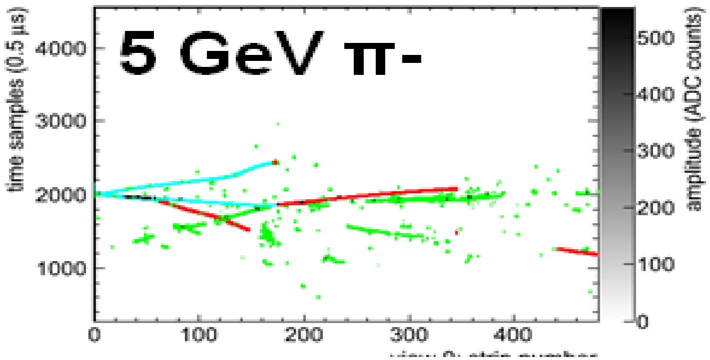
- **Measurements in hadronic and electromagnetic calorimetry and PID performance**
- **Full-scale software development, simulation and reconstruction to be validated and improved**

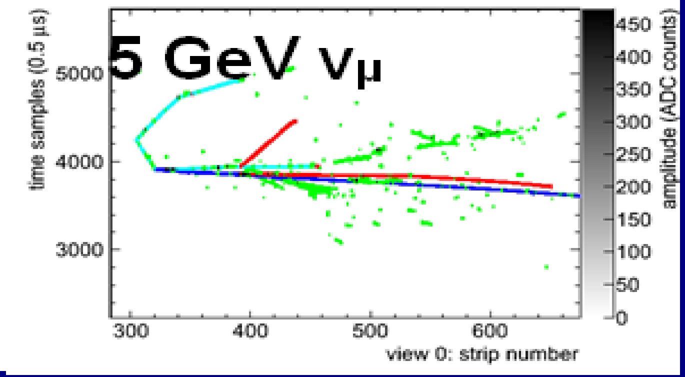
Installation in the CERN NA EHNA extension, data taking in 2018
→ Fundamental step for the construction of a large LAr detector

5 GeV π⁺ simulation in 6x6x6m³



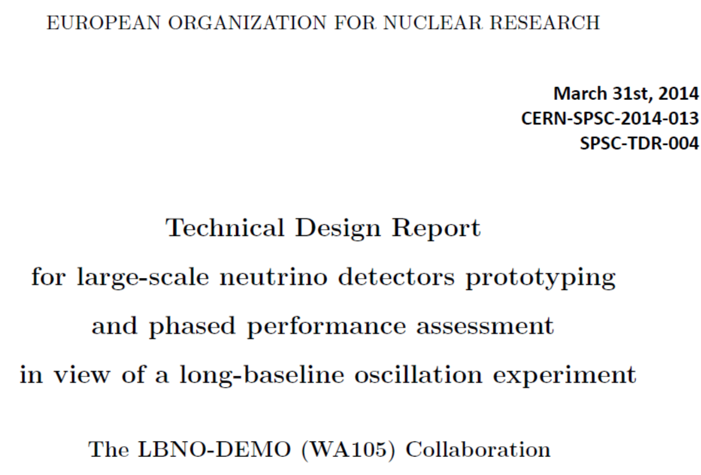
Hadronic showers fully contained in the 4x4 m2 Glacier readout unit





Reconstructed pion and neutrino interactions in DLAr

WA105 Technical Design Report:

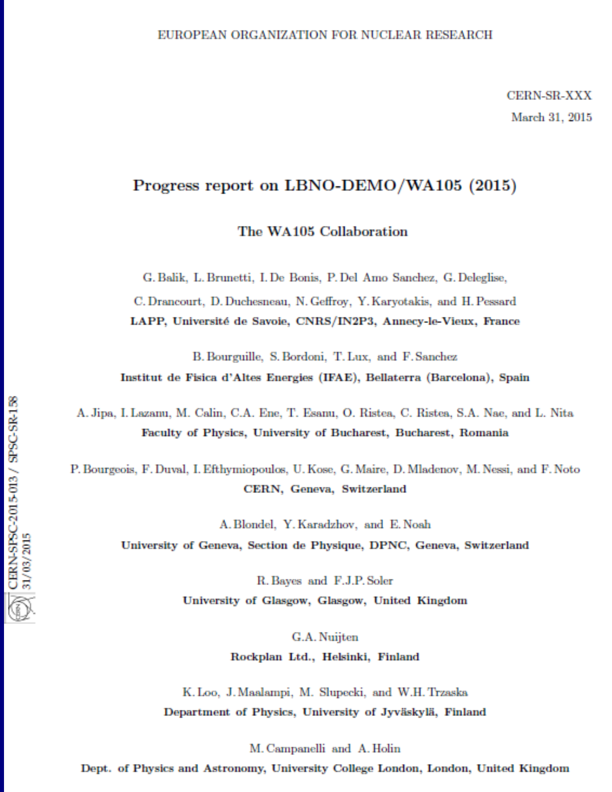


EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

March 31st, 2014
CERN-SPSC-2014-013
SPSC-TDR-004

Technical Design Report
for large-scale neutrino detectors prototyping
and phased performance assessment
in view of a long-baseline oscillation experiment

The LBNO-DEMO (WA105) Collaboration



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-SR-XXX
March 31, 2015

Progress report on LBNO-DEMO/WA105 (2015)

The WA105 Collaboration

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CERN-SPSC-2015-013 / SPSC-SR-158
31/03/2015

TDR presented to the SPSC one year ago (217 pages)

- During this year W105 set up its formal collaboration structure and organization which is fully operative
- A lot of progress was done on the preparation for the DLAr detector construction
- Software/analysis organization and developments were started as well

These progresses are the subject of this presentation and they are fully documented in (>50 pages) Status Report document submitted to the SPSC (SPSC-SR-158) on March 31 2015

The WA105 Collaboration:

WA105

21 institutes 122 physicists

UNIVERSITY of OULU

UCL

CERN

Sofia University St. Kliment Ohridski
Bulgaria

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Ciemat
Centro de Investigaciones
Energéticas, Medioambiental
gicas

KEK
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

UNIVERSITY OF JYVÄSKYLÄ

ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ
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INSTITUTE FOR NUCLEAR RESEARCH
OF RUSSIAN ACADEMY OF SCIENCES

nstitut de Física
d'Altes Energies IFAE

LPNHE
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lapp

University of Glasgow

UNIVERSITÉ DE GENÈVE

cea
SACLAY

IPNL

APC

IN2P3
INSTITUT NATIONAL DE PHYSIQUE NUCLÉAIRE
ET DE PHYSIQUE DES PARTICULES

~50 FTE at the moment (excluding CERN)

WA105 ORGANIZATION (completed in January 2015):

Spokesperson : A. Rubbia (Deputy: M. Zito)
Institution Board: 21 Institutions, T. Patzak (Chair)
Executive Board: D. Autiero, A. Blondel, Y. Kudenko, I. Gil-Botella, M. Nessi, A. Rubbia, T. Patzak, M.Zito
Dissemination Board: Y. Maalampi (Chair), D. Duchesneau, I. Gil-Botella, Y. Kudenko, I. Iazanu + ex officio members
GLIMOS: S. Murphy

Technical Board (TB)
Chair: D. Autiero

DLAr detector coord. : S. Murphy
Infrastructure coord.: I. Efthymiopoulos
Trig. planes coord.: E. Noah

Scientific Board (SB)
Chair: T. Hasegawa

Physics TF coord. : V. Galymov
Soft and simulations coord.: S. Di Luise
Software manager: E. Pennacchio

+ fine structure coordination roles (about 30)

The TB coordinates all the aspects of the detector developments, procurement, construction and installation. The SB coordinates the software developments and the preparation of the physics measurements. → The TB and SB have regular weekly meeting activity

Detailed WBS defined for DLAr detector construction. MoU in phase of finalization and signature

Summary of core construction WBS for DLAr (6x6x6)

Detector covered by WA105 collaboration institutes:

Subsystem	IFAE and CIEMAT	IRFU CEA	ETHZ	KEK	IPNL	LAPP	APC	LPNHE	Finnish groups	UCL
CRP		🟩	🟩	🟩						
CRP hanging syst. and movement						🟩				
Drift cage			🟩							
HV FT&PS			🟩					🟩		
Light readout	🟩					🟩	🟩			
Power supplies			🟩	🟩						
Charge readout FE and DAQ					🟩					
Online data processing									🟩	
Cryogenic plant			🟩							
Cryogenic vessel			🟩							
Slow control			🟩							
LAr purity monitoring										🟩
Eng. and P. management.									🟩	

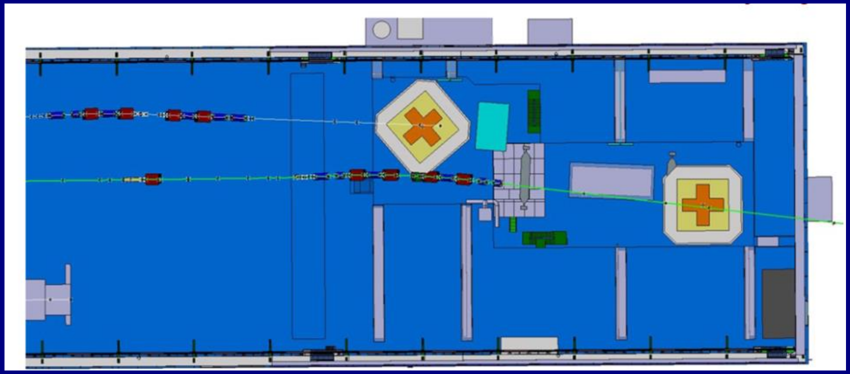
All WA105 institutes (more than in the above table) contributing to software and analysis efforts

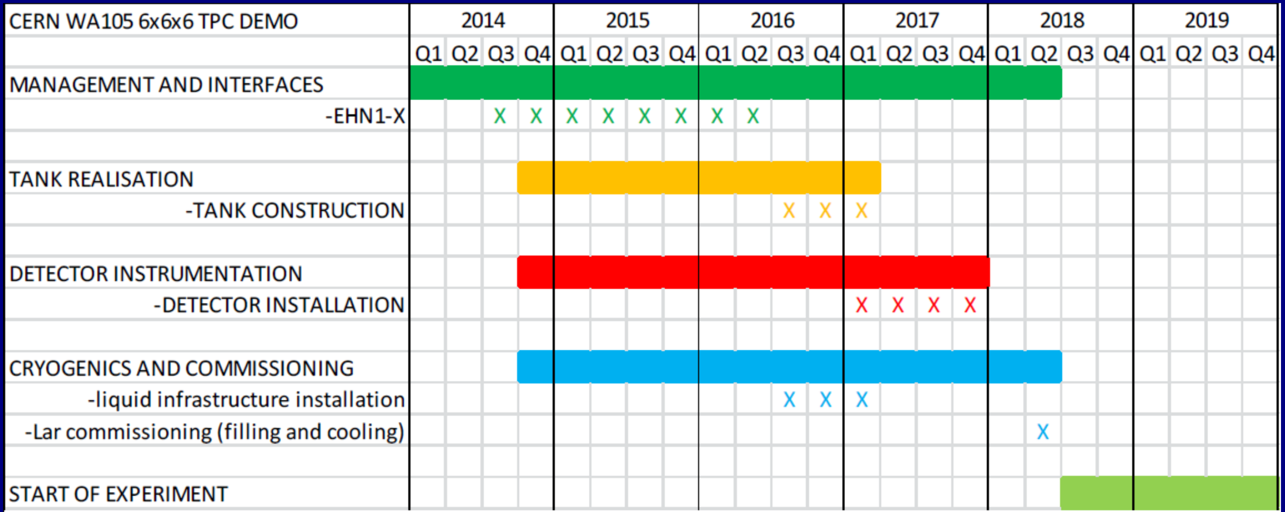
CERN major support on detector infrastructure: Cryogenic Vessel, Drift cage, Cryogenic plant, Supporting structure, Online data processing, Detector slow control, Clean room for about 50% of core costs of the project.

Integration of the 6x6x6 WA105 DLAr detector in the EHN1 extension

- Ongoing civil engineering works for the construction of the EHN1 hall extension on schedule (~2 weeks delay)

- EHN1 Hall integration design in progress as well as beamline instrumentation design (3 Cerenkov + counters for TOF)
- Hadrons + pure electrons (0.5-20(10) GeV/c) beamline requirements described in TDR, flux optimizations in progress in target/optics design





CERN WA105 6x6x6 TPC DEMO	2014				2015				2016				2017				2018				2019			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
MANAGEMENT AND INTERFACES	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩						
-EHN1-X			X	X	X	X	X	X	X	X														
TANK REALISATION				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨											
-TANK CONSTRUCTION											X	X	X											
DETECTOR INSTRUMENTATION				🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥								
-DETECTOR INSTALLATION													X	X	X	X								
CRYOGENICS AND COMMISSIONING				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦						
-liquid infrastructure installation											X	X	X											
-Lar commissioning (filling and cooling)																		X						
START OF EXPERIMENT																			🟩	🟩	🟩	🟩	🟩	🟩

Goal:
Data taking with beam in 2018, possible given the advanced status of the WA105 experiment construction preparation

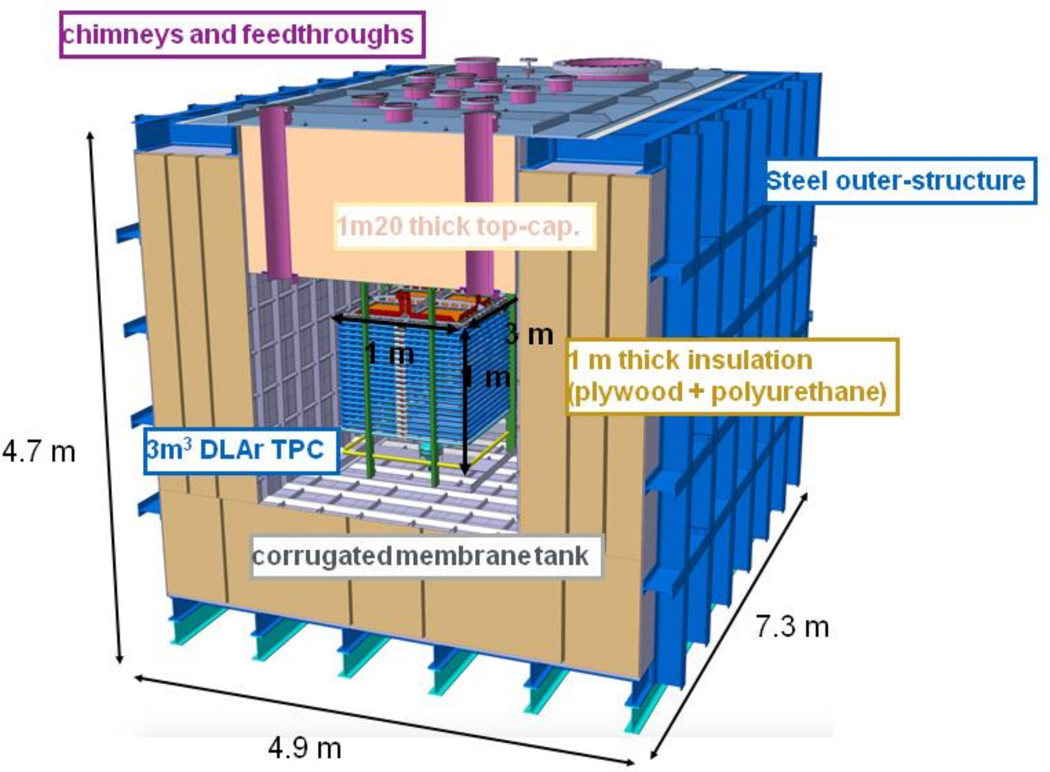
Progress on WA105 DLAr detector 6x6x6 m^3:

- Membrane vessel design and procurement
- Cryogenics
- Charge Readout Plane (CRP) detectors
- CRP structure and hanging system
- Feedthroughs
- HV and field cage
- Charge readout FE electronics + digital electronics
- Light readout system + electronics
- DAQ and online processing
- Slow Control

Advanced state of design, prototyping and production preparation

For many items huge benefit from immediate application of a smaller 3x1 prototype LAr-proto (minimal size of RO unit in 6x6x6)

- ✓ Fully engineered versions of many detector components with pre-production and direct implementation (installation details and ancillary services)
- ✓ First overview of the complete system integration: set up full chains for Quality Assessment, construction, installation and commissioning
- ✓ Anticipate legal and practical aspects related to procurement, costs and schedule verification
- ✓ Dedicated weekly meeting to follow up construction progress



3x1x1 is a technical playground to speed-up the preparation of the WA105 6x6x6 demonstrator:

- Routine procedure for mass production, QA tests and calibration of the LEMs.
- Cryogenic installation, feedthroughs, thermodynamic conditions of the membrane tank, prototyping and integration, …
- Anticipation of all the legal and technical aspects related to the contracts for the realization of a membrane cryostat at CERN under the GTT license → much easier and smoother tendering procedure for the 6x6x6 m^3
- Allowed us to reconfirm the cost estimates and production schedule for the 6x6x6 m^3

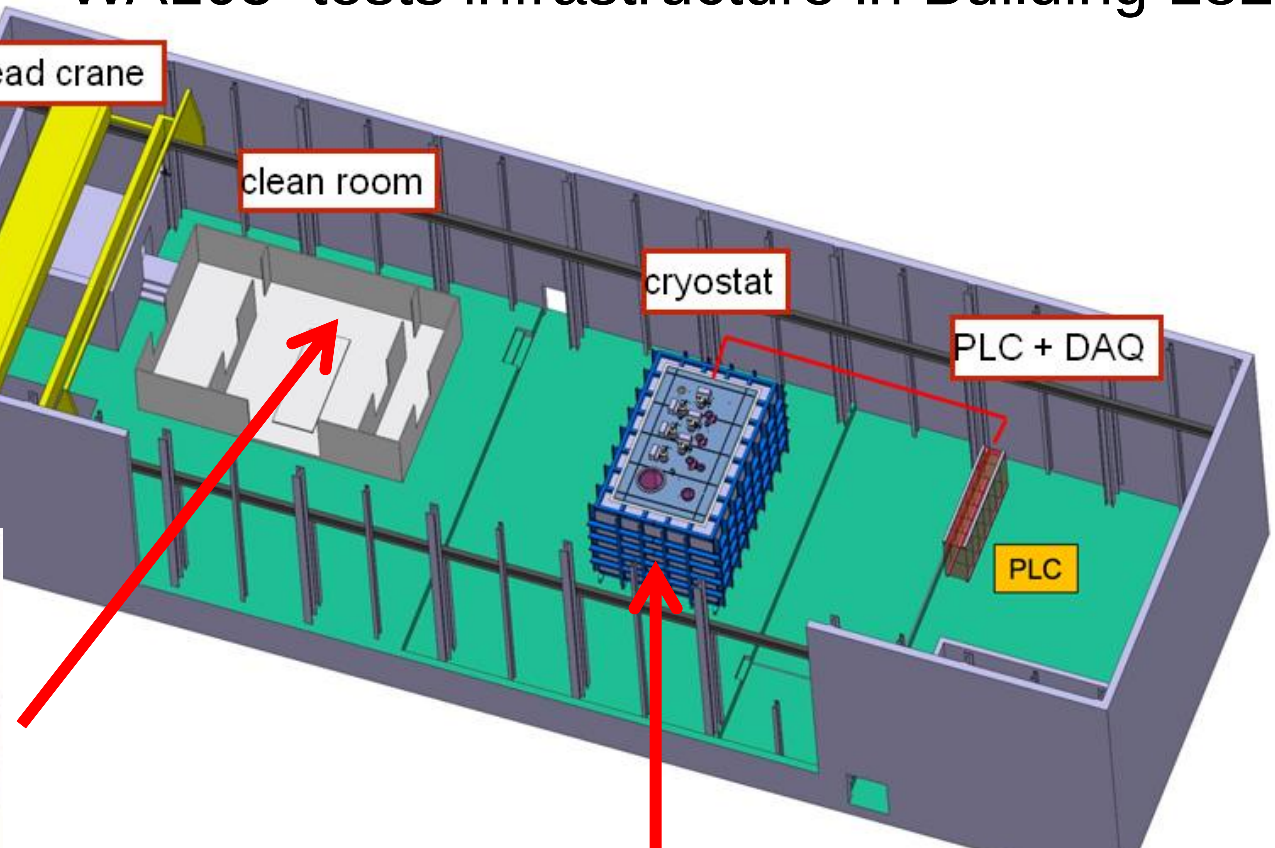
The 3x1x1 prototype is extremely useful as a technical tool but, given its small active dimensions, it does not answer to the questions for which the WA105 6x6x6 DLAr demonstrator is foreseen:

- No very large vessel and field cage
- No large surface CRP instrumentation
- No long drift (purity, diffusion assessments)
- No VHV generation
- No events containment and exposure to hadronic beam

→ No demonstration of feasibility of a large scale detector and no associated physics program for the LBL neutrino experiment systematics

WA105 tests infrastructure in Building 182

Clean room for LEM tests + CRP production and assembly



the clean room inside b. 182

3x1x1 cryostat ($17\ m^3$)

WA105 vessel design and procurement:

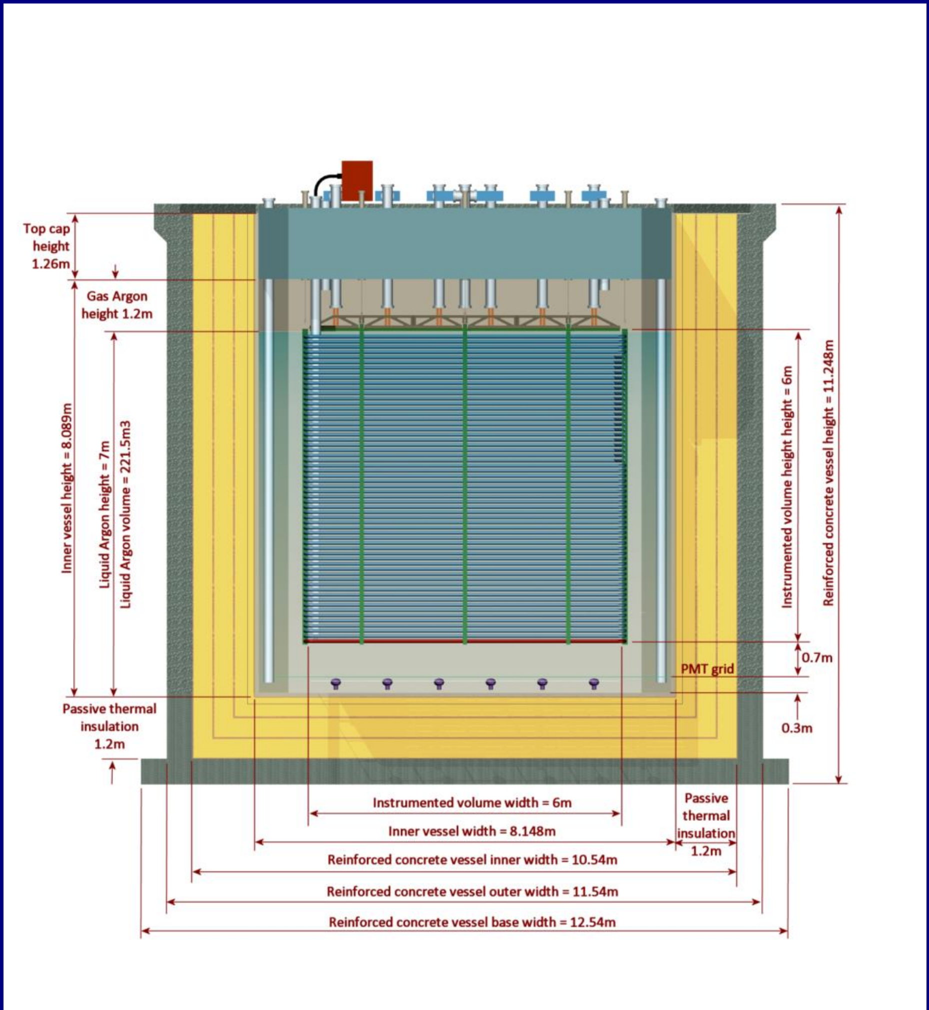
LNG industrial technology based on cost effective corrugated membrane technology (licensed by GTT/France)

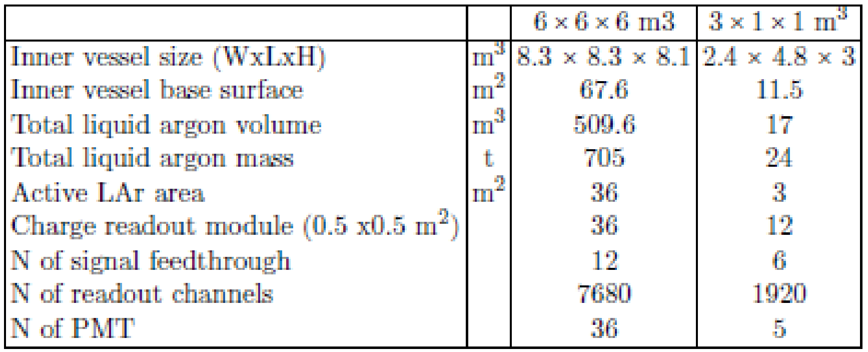
3 main functions of structural support, thermal insulation and liquid containment by separate elements:

(a) Outer supporting structure
(b) Specially designed insulating panels with plywood and GRPF foam (<5W/m^2)
(c) Thin layer of steel membrane

Exercise on 3x1 prototype essential to solve vessel procurement issues !

- Attempts for all in one executive design, procurement and assembly via GTT licensed companies unsuccessful
- Final solution: CERN responsible for construction of outer structure. Executive engineering of membrane cryostat by GTT. Panels installation and welding of membrane by outfitter company (GABADI/Spain) specialized in LNG ships repair





		$6 \times 6 \times 6$ m3	$3 \times 1 \times 1$ m^3
Inner vessel size (WxLxH)	m^3	$8.3 \times 8.3 \times 8.1$	$2.4 \times 4.8 \times 3$
Inner vessel base surface	m^2	67.6	11.5
Total liquid argon volume	m^3	509.6	17
Total liquid argon mass	t	705	24
Active LAr area	m^2	36	3
Charge readout module (0.5 x0.5 m^2)		36	12
N of signal feedthrough		12	6
N of readout channels		7680	1920
N of PMT		36	5

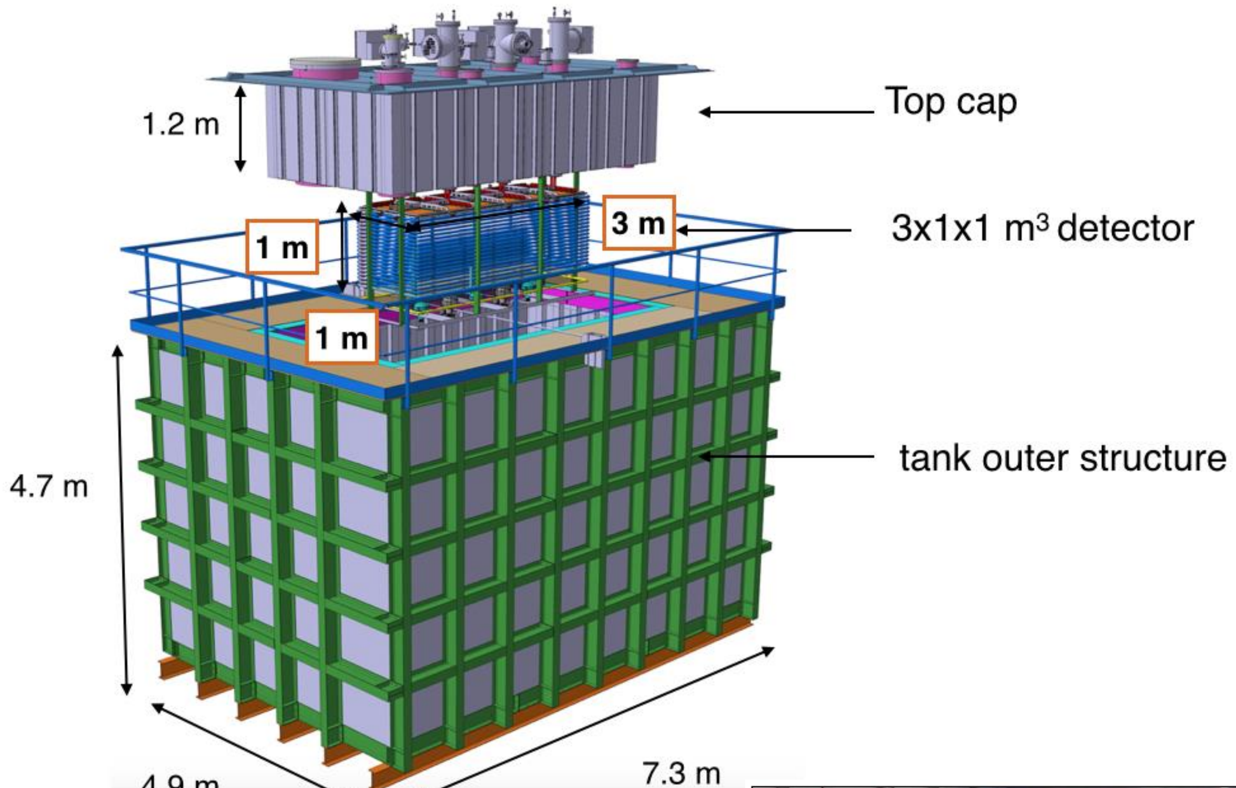
The 3x1 Vessel

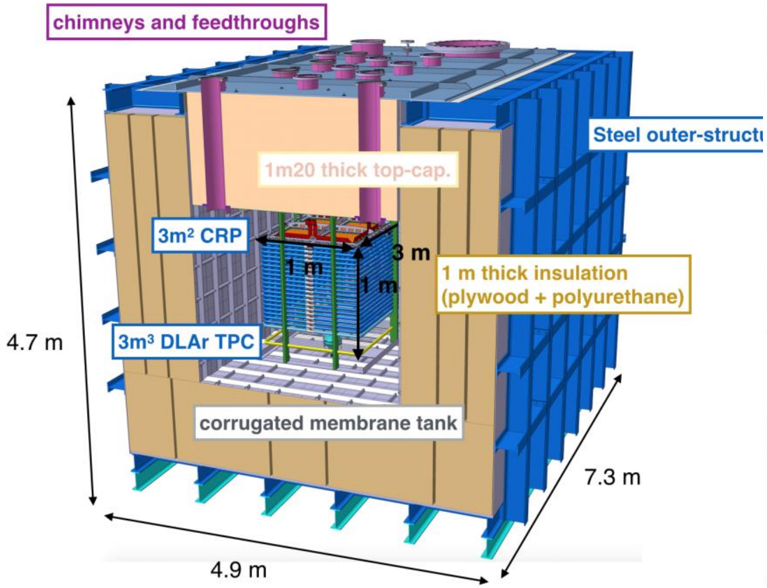
Tank outer structure:
completed

Panels installation:
September 2015

TOP cap closure:
November 2015

Gas purity measurement:
December 2015



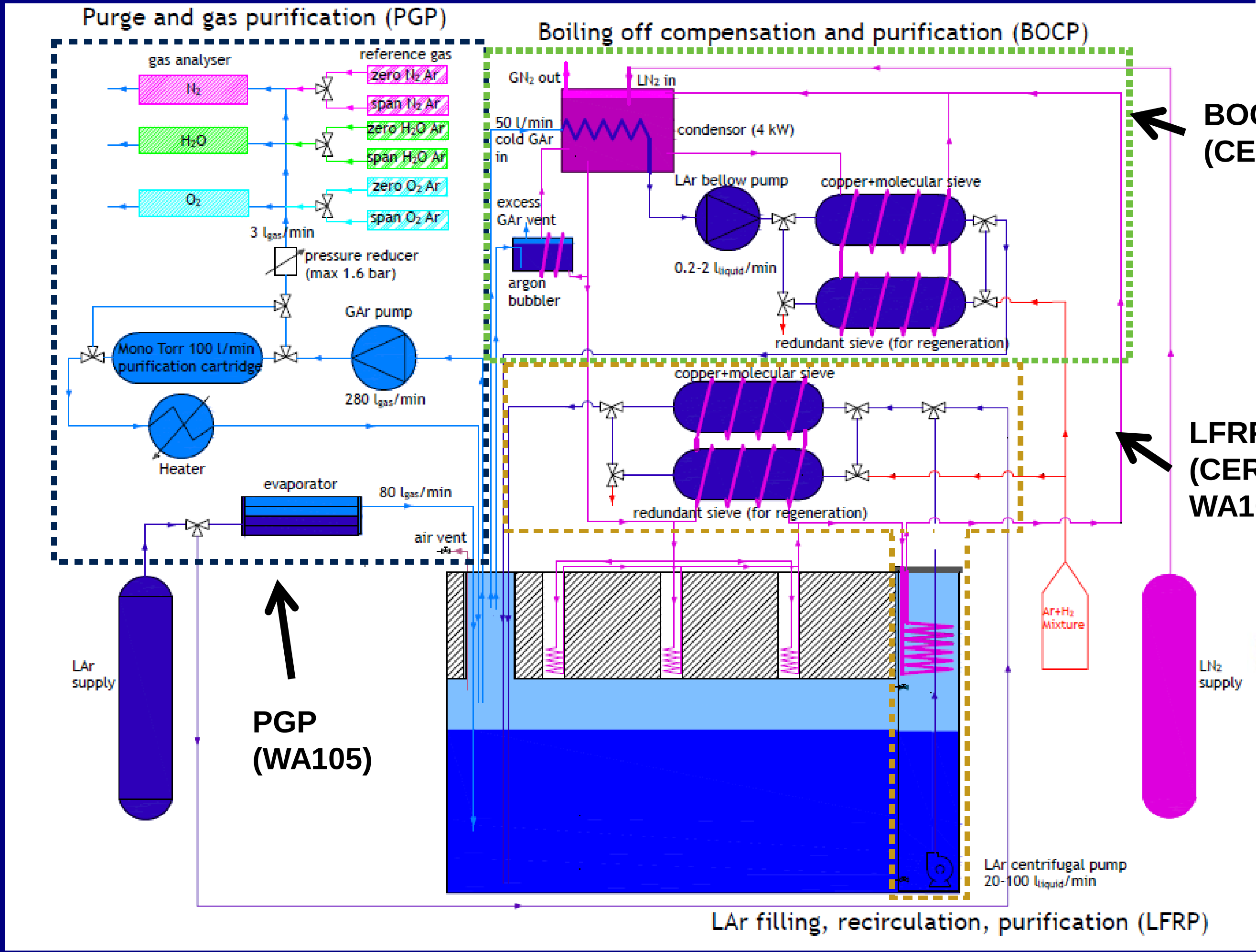


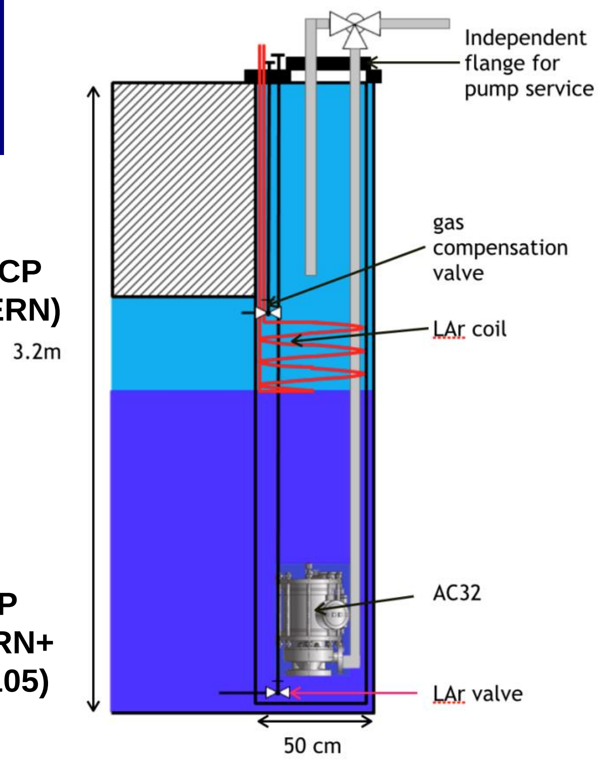
Cryogenic system:

→ building block for 6x6 fully designed for 3x1 in collaboration with CERN cryogenic group

3 sub-systems:

- Purge and gas purification (PGP)
- Boil-off compensation and purification (BOCP)
- LAr filling recirculation and purification (LFRP)

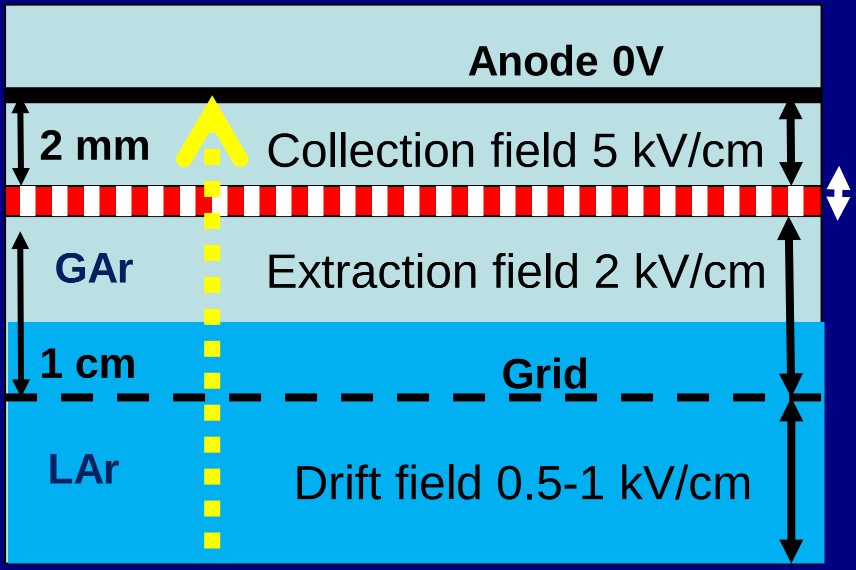




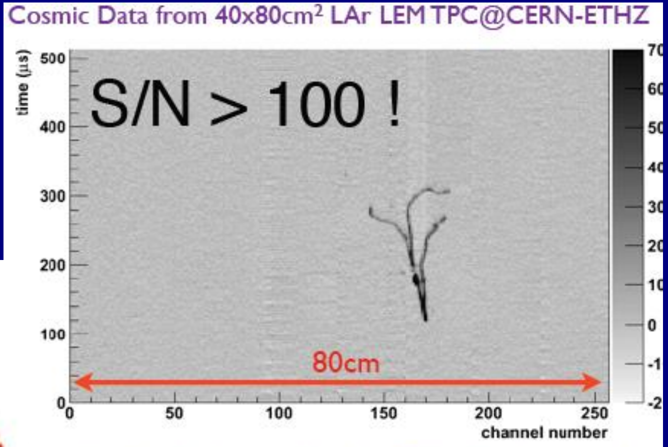
LFRP centrifugal submersed pump TC34.2

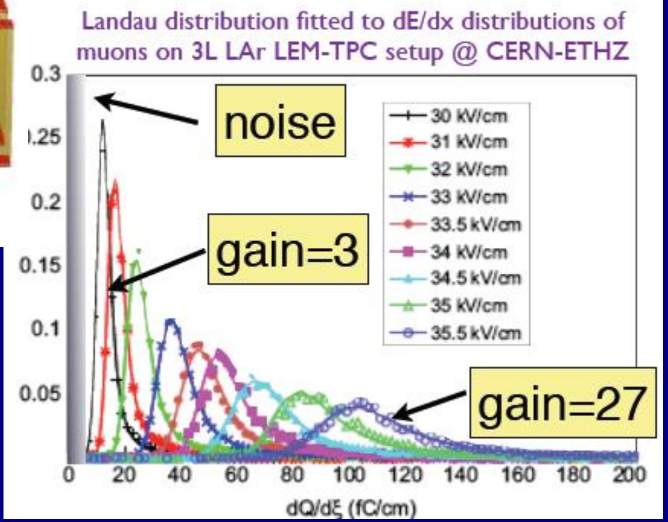
Double-phase readout:

Compensate for long drift: extraction of electrons from the liquid and multiplication with avalanches in pure argon with micro-pattern detectors like LEM (Large Electron Multipliers)
Low gain (~20), coupling to cold electronics in integrated modules

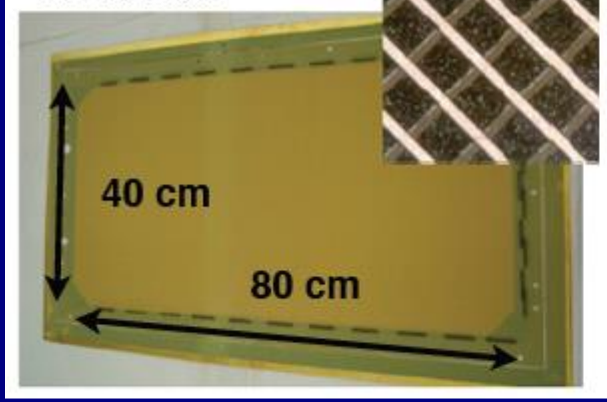


LEM
25-35 kV/cm

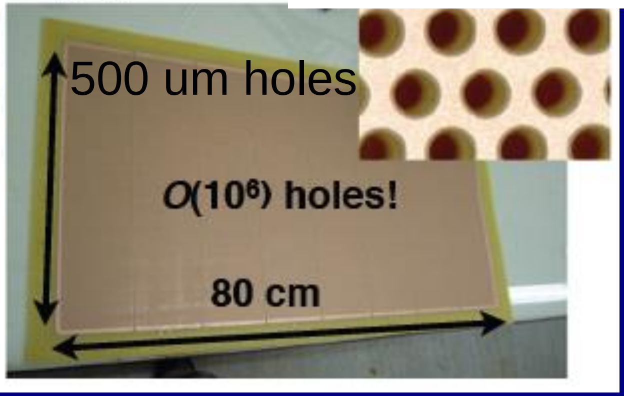

Cosmic Data from 40x80cm² LAr LEM TPC@CERN-ETHZ


Landau distribution fitted to dE/dx distributions of muons on 3L LAr LEM-TPC setup @ CERN-ETHZ

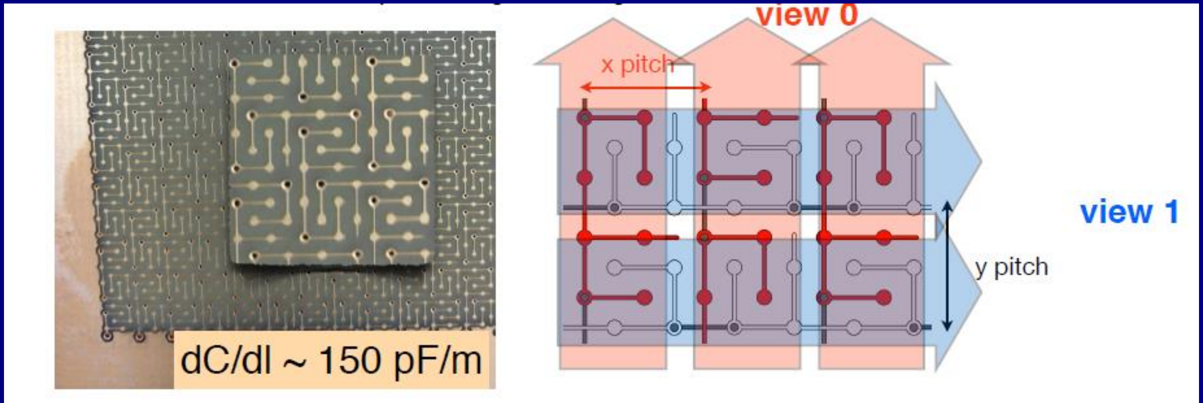
2D anode



LEM

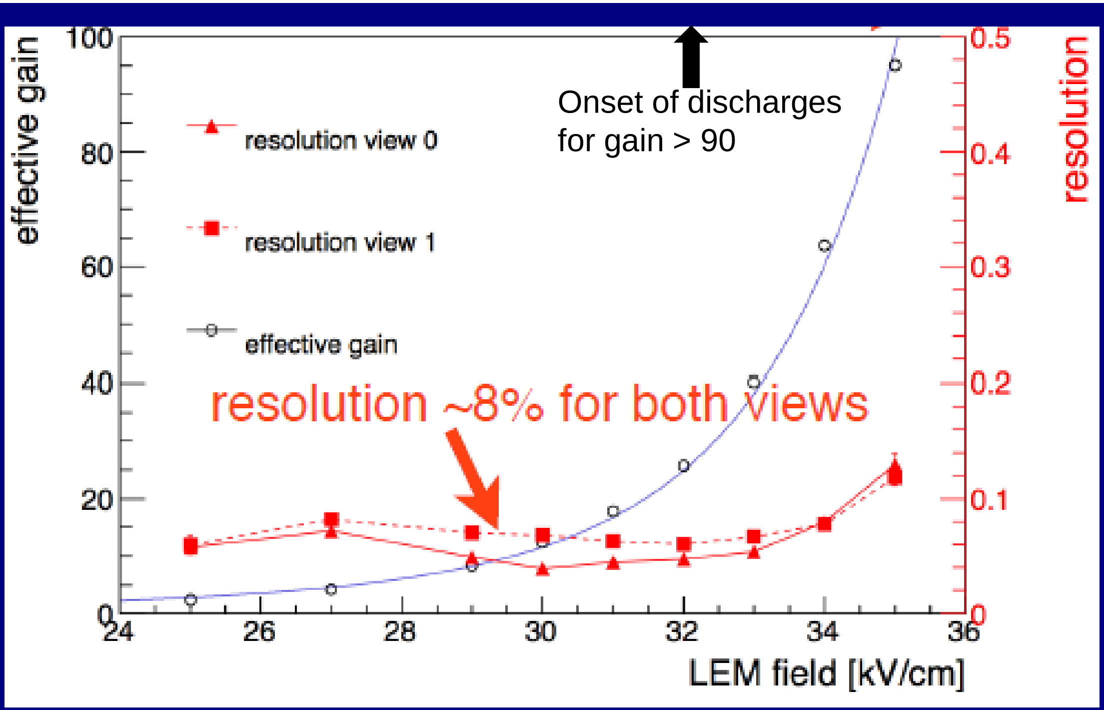


LEM charge readout: R&D results from long-standing prototyping tests



dC/dl ~ 150 pF/m

Multi-layer PCB anode with symmetric x-y charge sharing



Onset of discharges for gain > 90

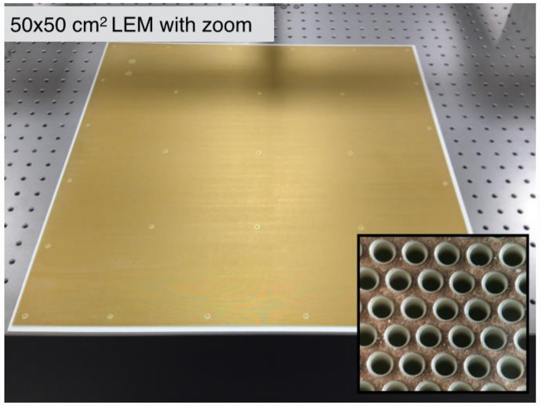
resolution ~8% for both views

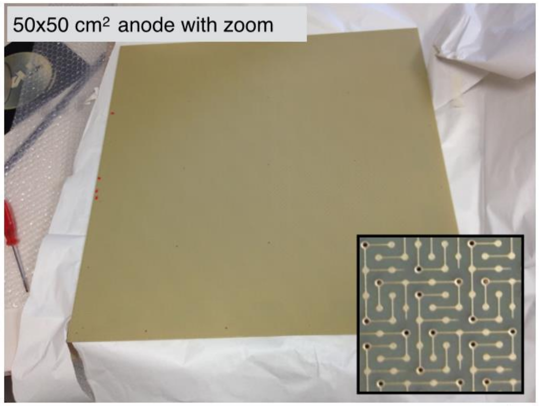
Gain and resolution for different LEM fields

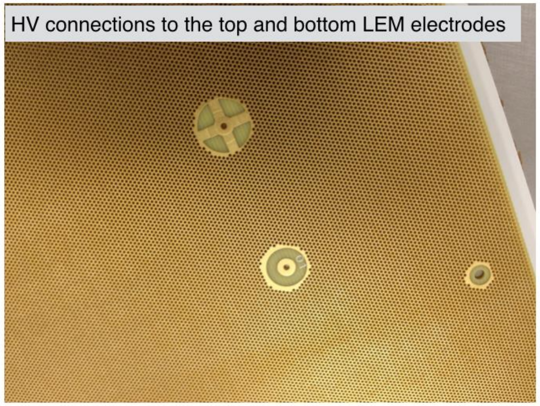
Gain stability reproduced over several months
JINST 9 (2014) P03017

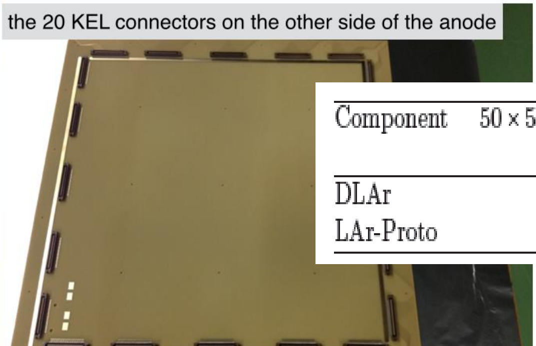
Geometry optimization:
JINST 10 (2015) 03, P03017

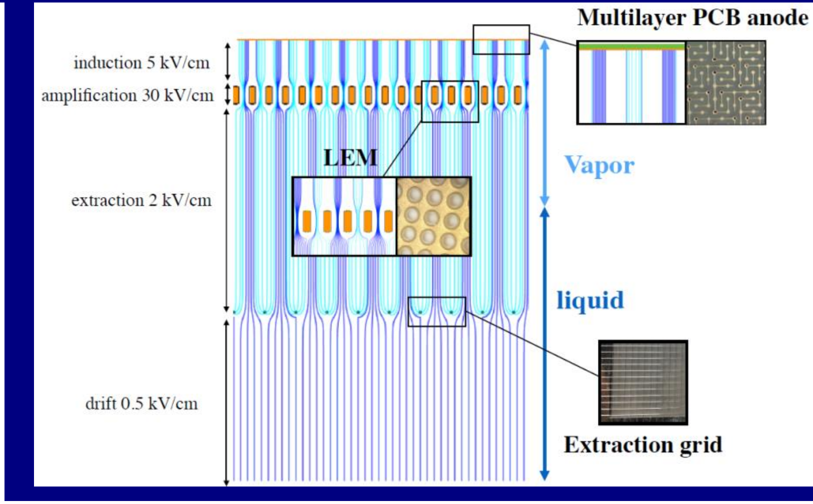
Charge Readout Plane (CRP) 50x50 cm^2 LEM-Anode Sandwich (LAS)


50x50 cm^2 LEM with zoom


50x50 cm^2 anode with zoom

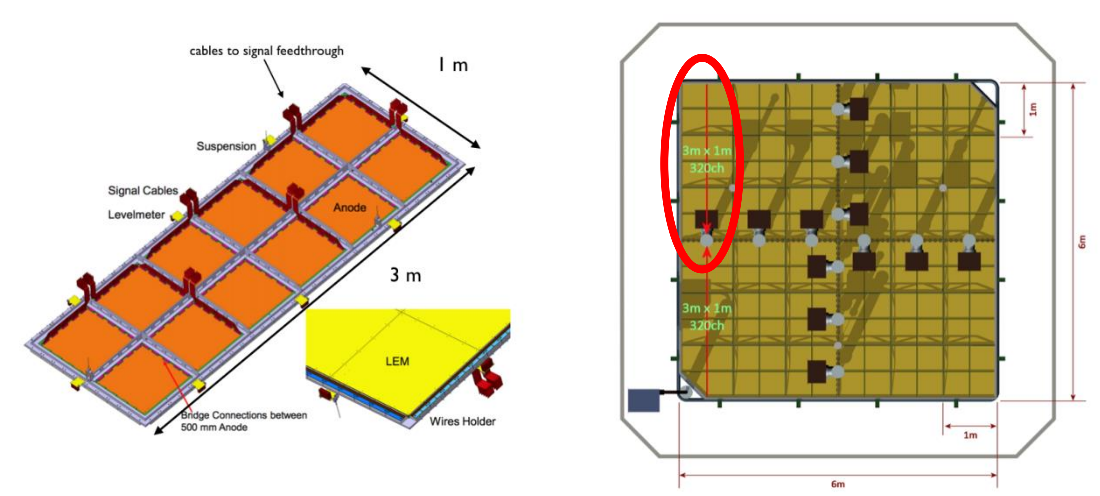

HV connections to the top and bottom LEM electrodes


the 20 KEL connectors on the other side of the anode



Component	50×50 cm^2 Anode panels	50×50 cm^2 LEM panels	Signal feddthrough	Suspension feddthrough	readout strip length (m)
DLAr	144	144	12	3	3
LAr-Proto	12	12	6	3	1 or 3

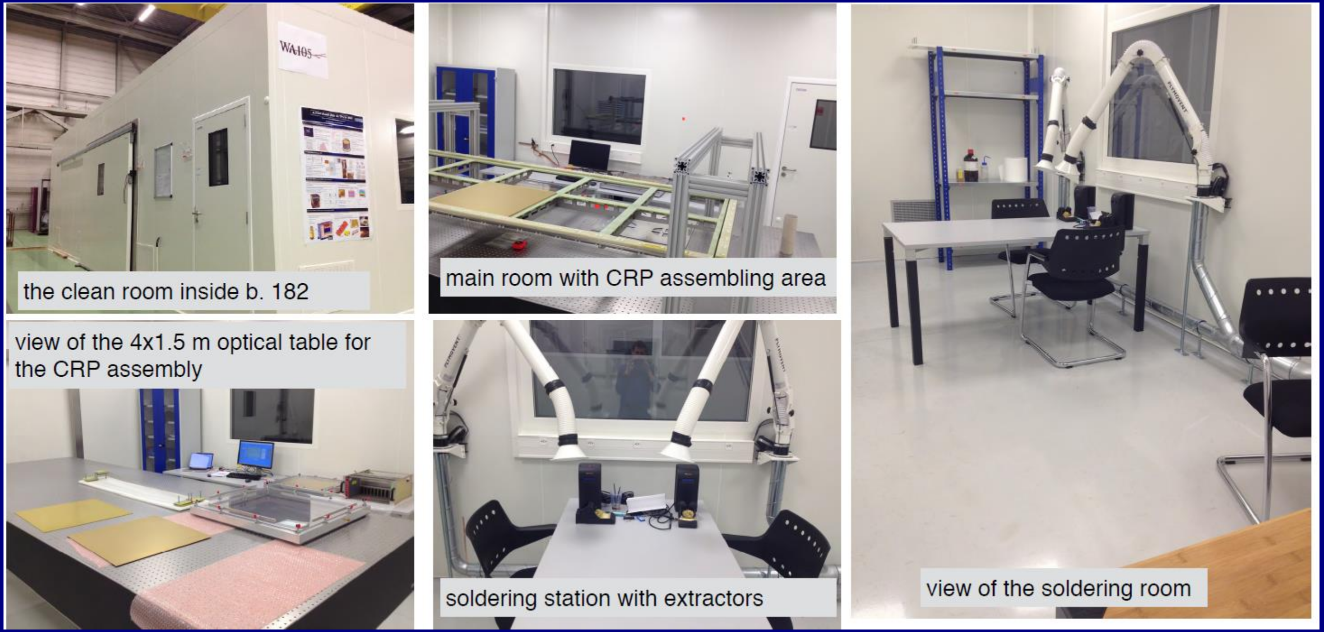
3m readout units in 6x6



LEM and anodes produced by ELTOS

- **LEM: 500 um holes spaced by 800 um, 40 um rim**
- **Anodes: 2D collection views, 3.125 mm pitch, 150 pF/m**

CRP components production and assembly chains:


the clean room inside b. 182

main room with CRP assembling area

view of the 4x1.5 m optical table for the CRP assembly

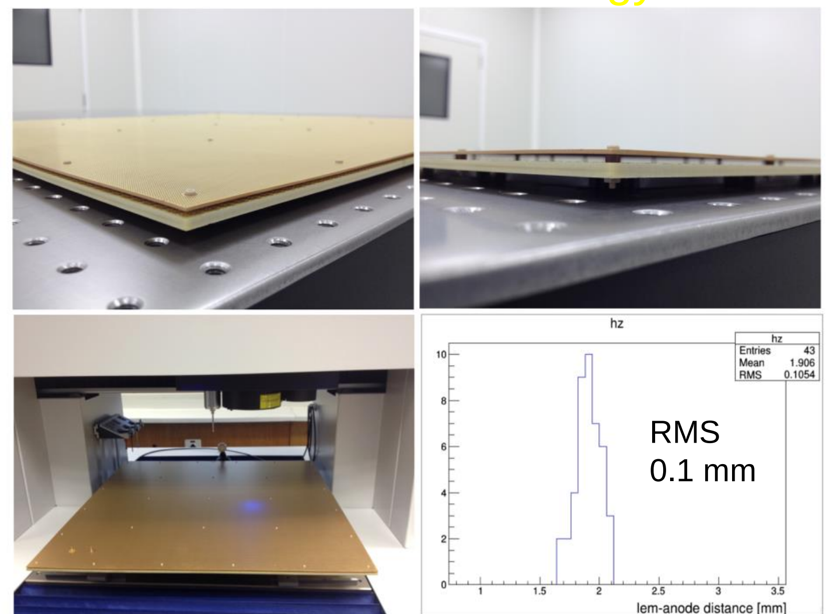
soldering station with extractors

view of the soldering room

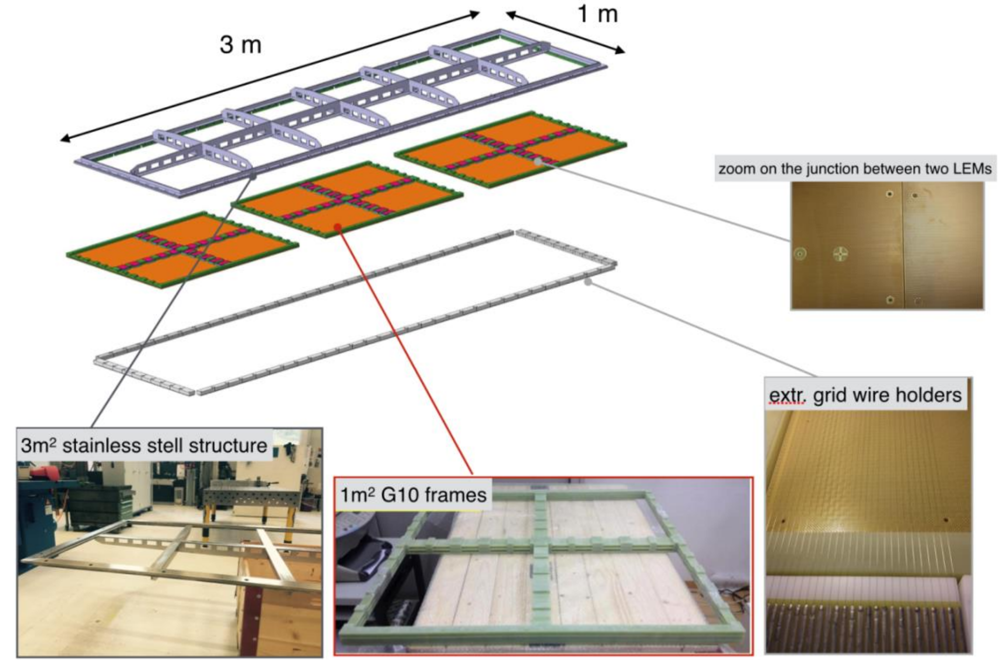
- Clean room ad hoc infrastructure (ISO-8 class) in Bld. 182
- Full production/QA chains set up
- Immediate application for 3x1 setup:

→ 12 LEM/anode 0.5x0.5 m^2 LAS integrated in 3x1 m^2 CRP frame (pre-production of 20 LAS)

LAS sandwich metrology



RMS 0.1 mm



zoom on the junction between two LEMs

extr. grid wire holders

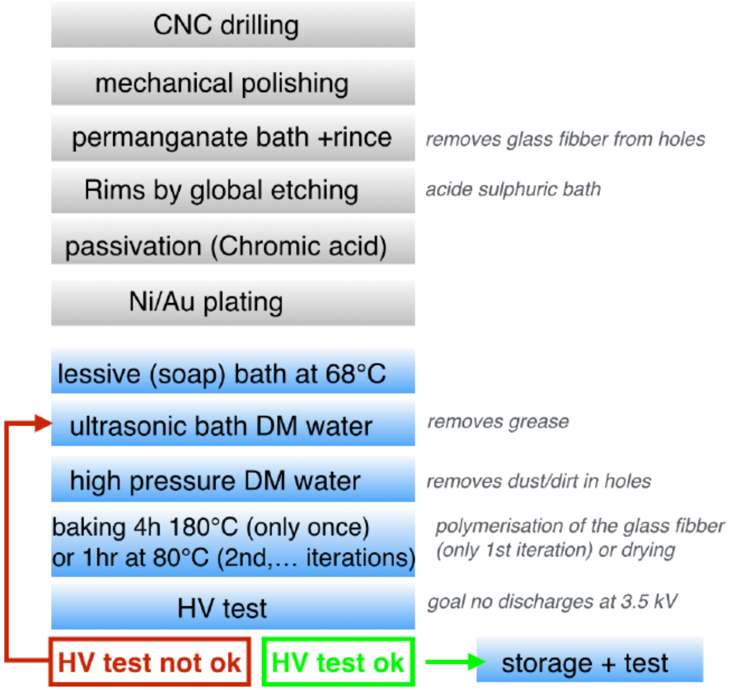
3m² stainless stell structure

1m² G10 frames

LEM production:

cleaning and commissioning chain

(in collaboration with CERN PCB lab, R. De Oliveira)



CNC drilling

mechanical polishing

permanganate bath +rince — *removes glass fibber from holes*

Rims by global etching — *acide sulphuric bath*

passivation (Chromic acid)

Ni/Au plating

lessive (soap) bath at 68°C

ultrasonic bath DM water — *removes grease*

high pressure DM water — *removes dust/dirt in holes*

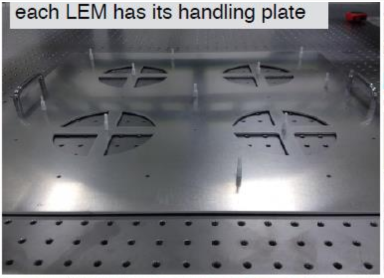
baking 4h 180°C (only once) or 1hr at 80°C (2nd,… iterations) — *polymerisation of the glass fiber (only 1st iteration) or drying*

HV test — *goal no discharges at 3.5 kV*

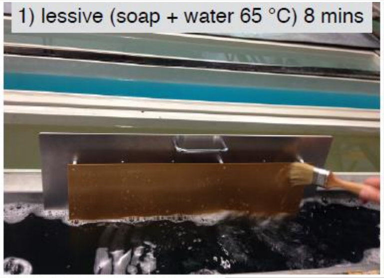
HV test not ok **HV test ok** → storage + test

- at ELTOS: one machine with 6 independent drills each capable of ~7 holes per second. They can drill six 50x50 cm^2 LEM in 24 hours. The timescale for the rest of the procedure depends on the organisation of production line.

- Cleaning is performed at the CERN PCB laboratory . Procedure takes about 6 hrs per LEM (mainly due to baking time)

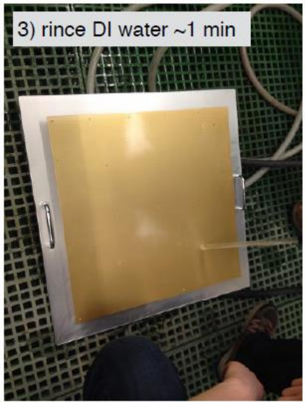


each LEM has its handling plate

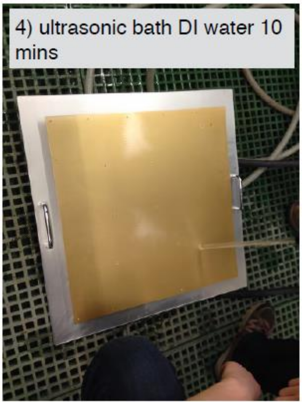


1) lessive (soap + water 65 °C) 8 mins

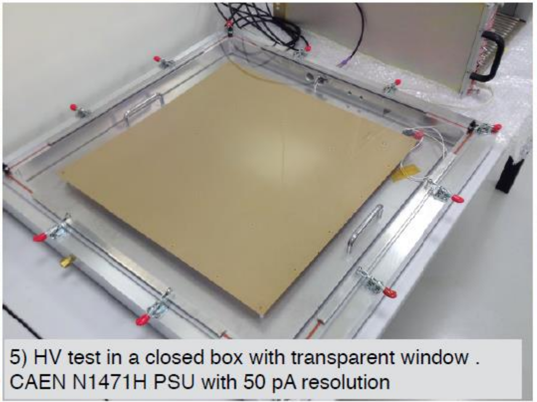
2) high pressure water DI water 3 mins



3) rince DI water ~1 min



4) ultrasonic bath DI water 10 mins



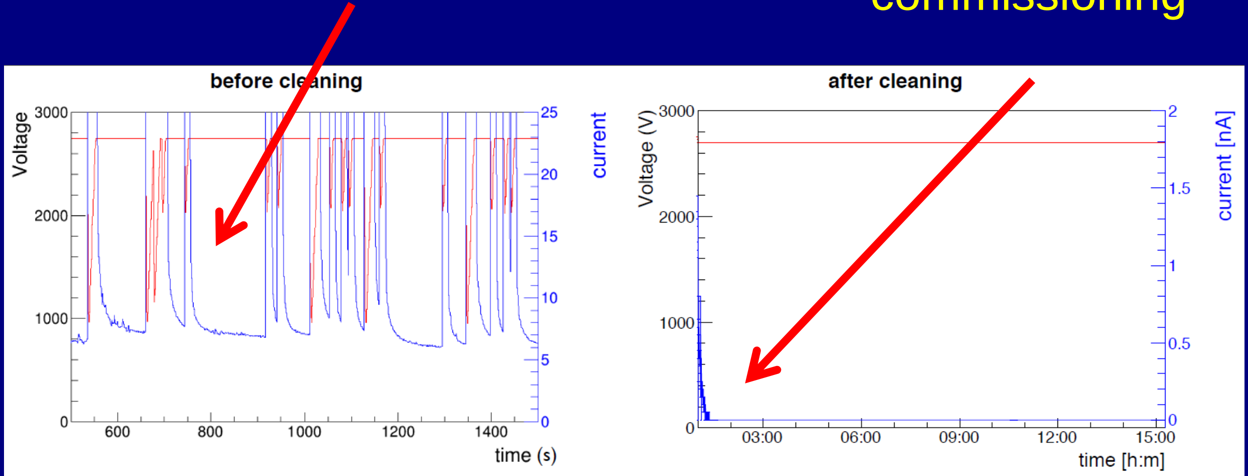
5) HV test in a closed box with transparent window . CAEN N1471H PSU with 50 pA resolution

6) storage in custom made box designed to hold 20 LEMs with their handling plates.

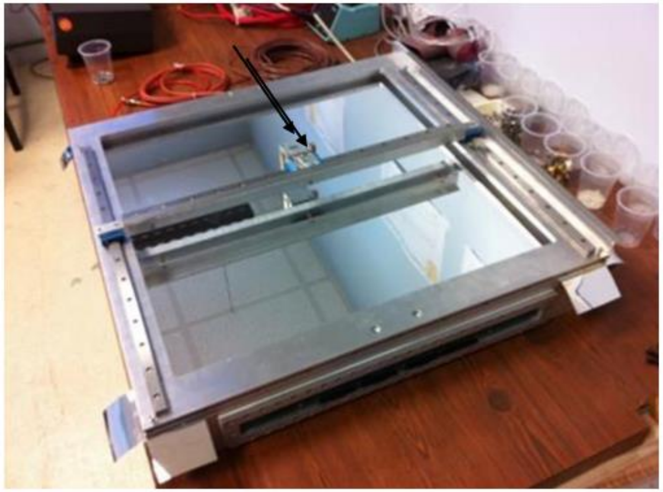
LEM commissioning:

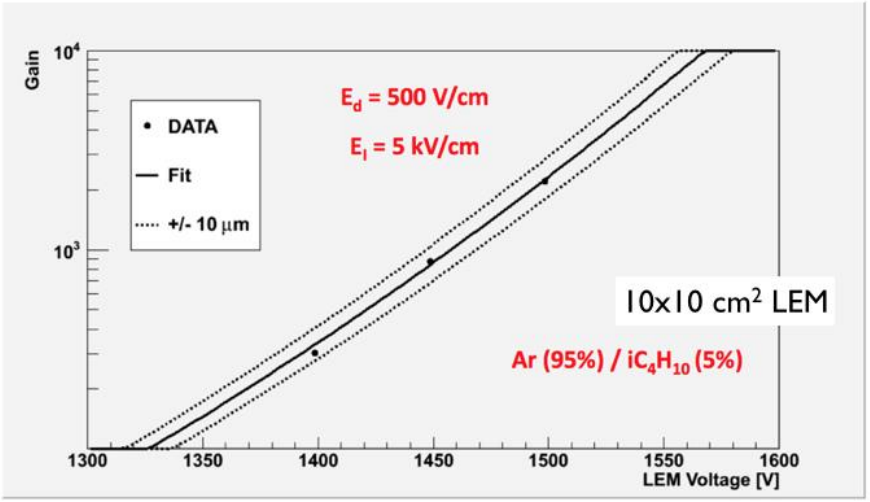
HV commissioning in air
LEM surface cleaning by initial sparks

Dark current (measured with ~pA resolution) well below nA after commissioning



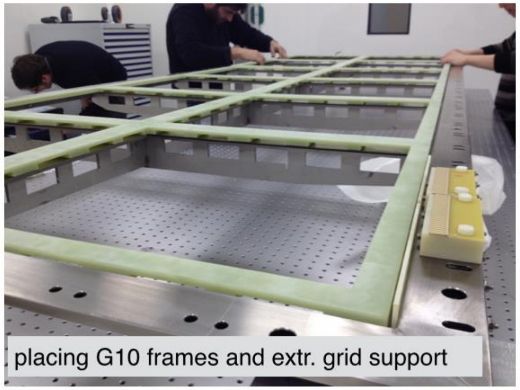
Uniformity gain scan gas chamber with 55Fe source for 50x50 LEM (Ar gas mixture)

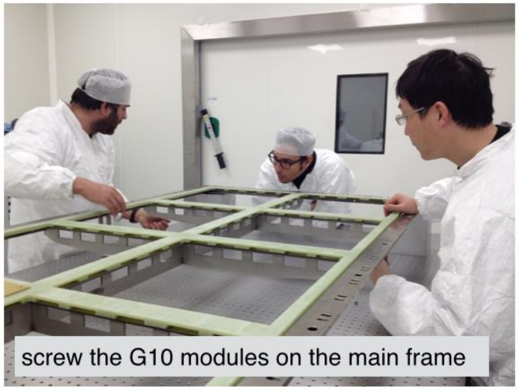


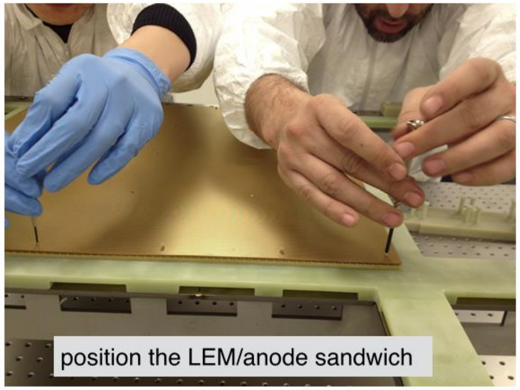


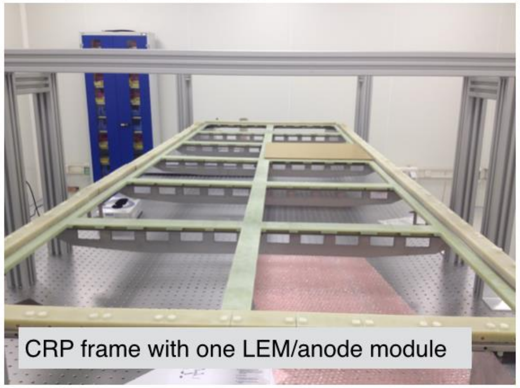
LEM-Anodes Production:

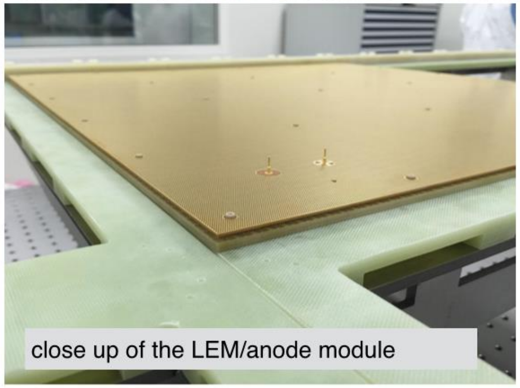
Assembly chain

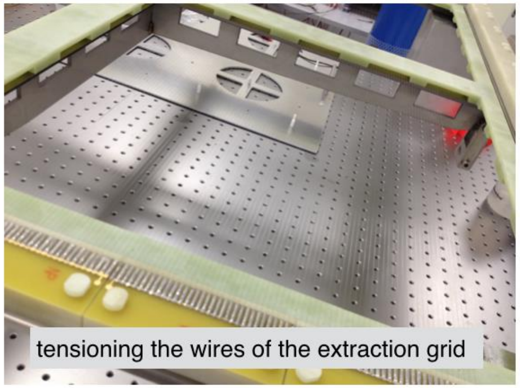

placing G10 frames and extr. grid support

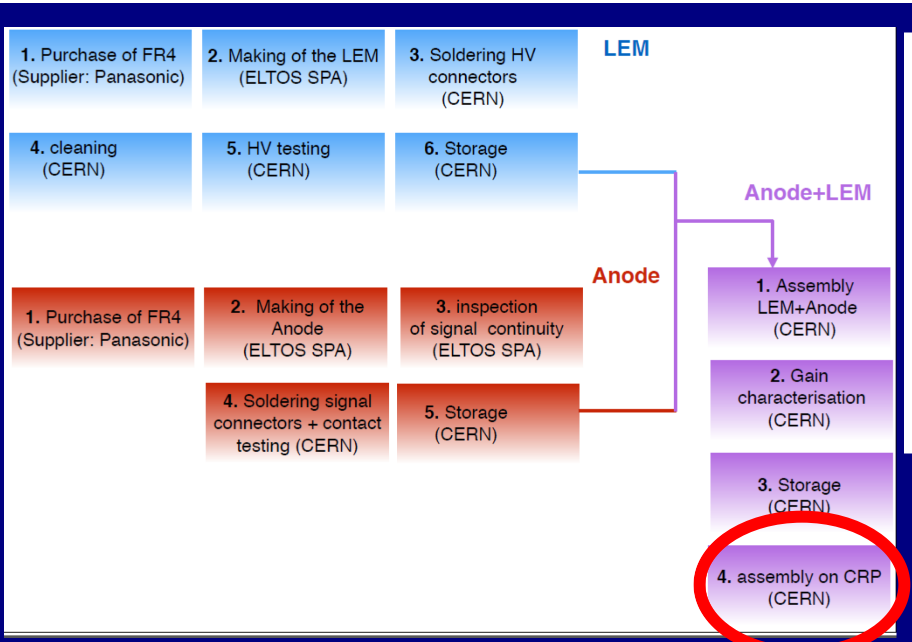

screw the G10 modules on the main frame


position the LEM/anode sandwich


CRP frame with one LEM/anode module


close up of the LEM/anode module


tensioning the wires of the extraction grid


LEM

1. Purchase of FR4 (Supplier: Panasonic)

2. Making of the LEM (ELTOS SPA)

3. Soldering HV connectors (CERN)

4. cleaning (CERN)

5. HV testing (CERN)

6. Storage (CERN)

Anode

1. Purchase of FR4 (Supplier: Panasonic)

2. Making of the Anode (ELTOS SPA)

3. inspection of signal continuity (ELTOS SPA)

4. Soldering signal connectors + contact testing (CERN)

5. Storage (CERN)

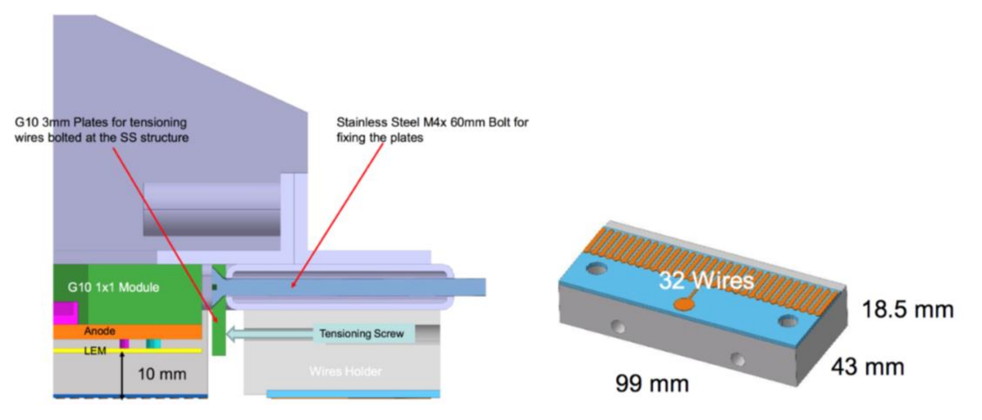
Anode+LEM

1. Assembly LEM+Anode (CERN)

2. Gain characterisation (CERN)

3. Storage (CERN)

4. assembly on CRP (CERN)



Extraction grid wire holders

Cost effective cold front-end electronics and DAQ for WA105

Remove long cables and their capacitance, exploit intrinsic noise reduction at low T

ASIC (CMOS 0.35 um) 16 ch amplifiers working ~110 K to profit from minimal noise conditions:

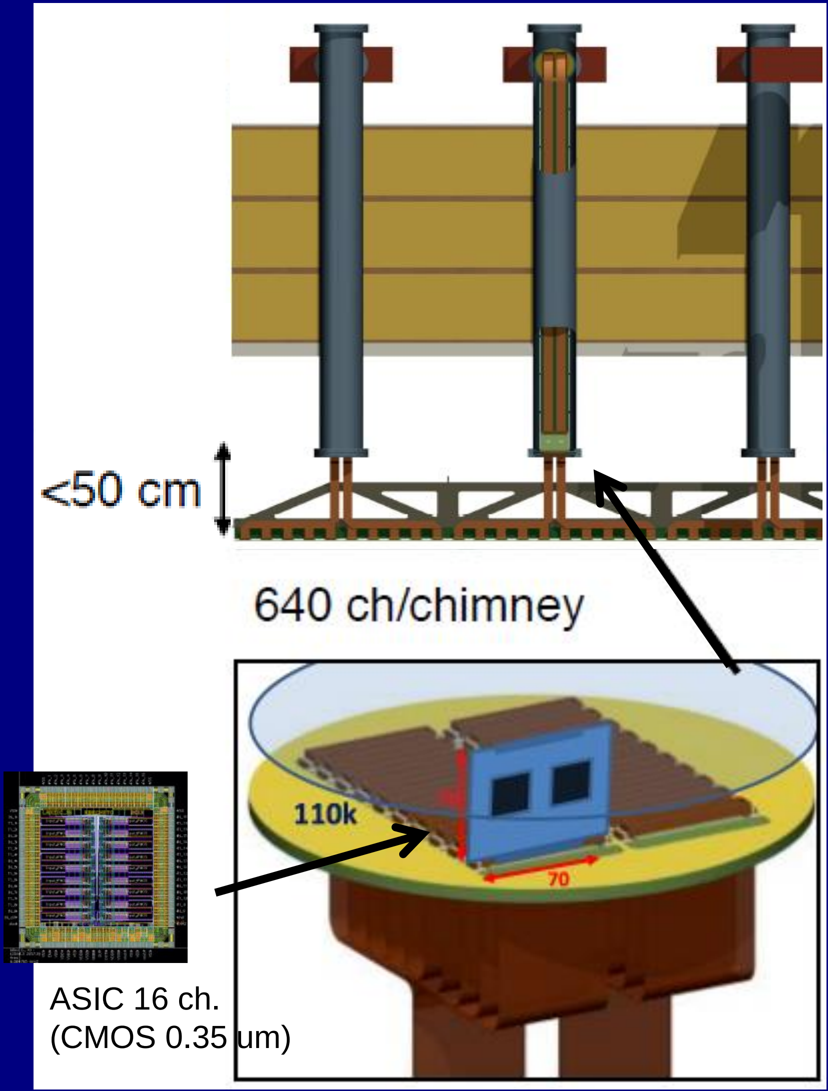
- FE electronics inside chimneys, cards fixed to a plug accessible from outside
- Distance cards-CRP<50 cm
- Dynamic range 40 mips, (1200 fC)

(LEM gain =20)

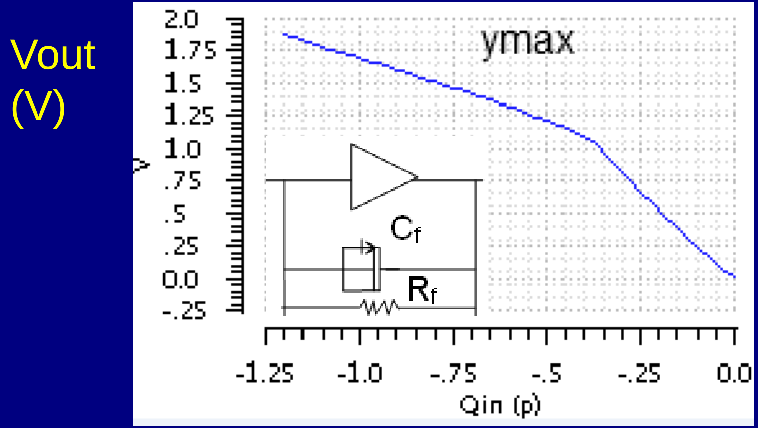
- 1300 e- ENC @250 pF, 100 keV sensitivity
- Single and double-slope versions
- Power consumption <18 mW/ch

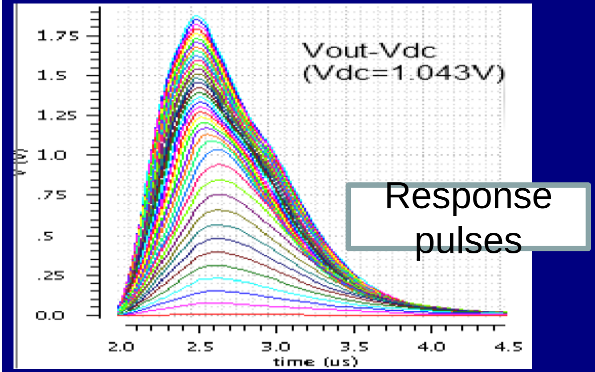
DAQ in warm zone on the tank deck:

- architecture based on uTCA standard
- local processors replaced by virtual processors emulated in low cost FPGAs (NIOS)
- integration of the time distribution chain (improved PTP)
- Bittware S5-PCIe-HQ 10 Gbe backend with OPENCL and high computing power in FPGAs



Electronics production for 6X6x6 starting in Fall 2015, first batch can be used on 3x1

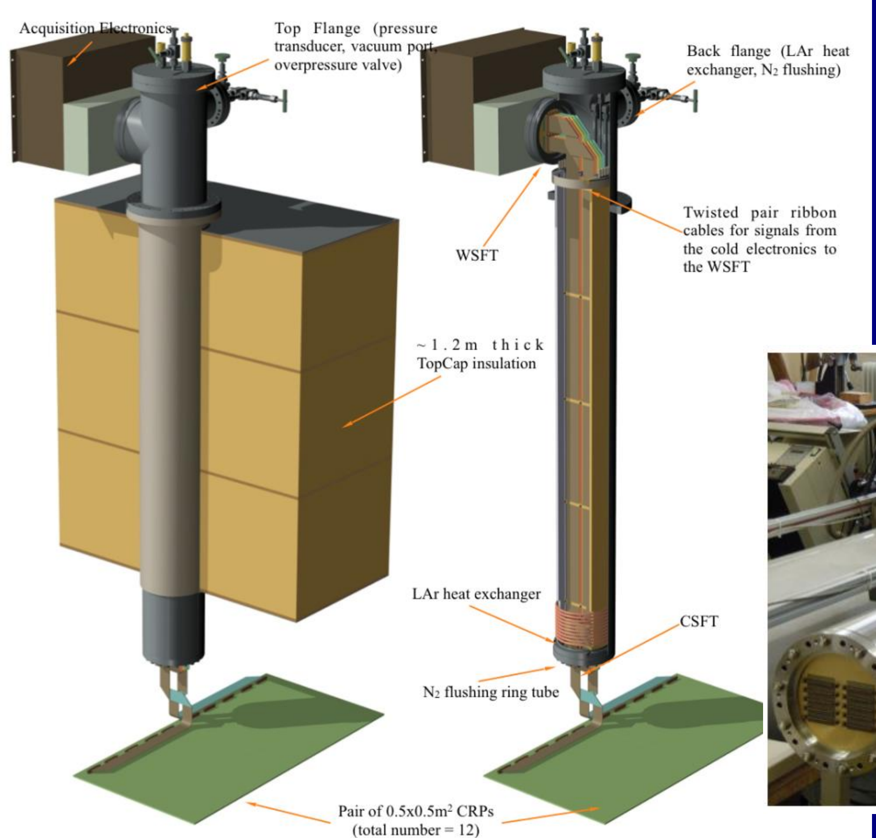




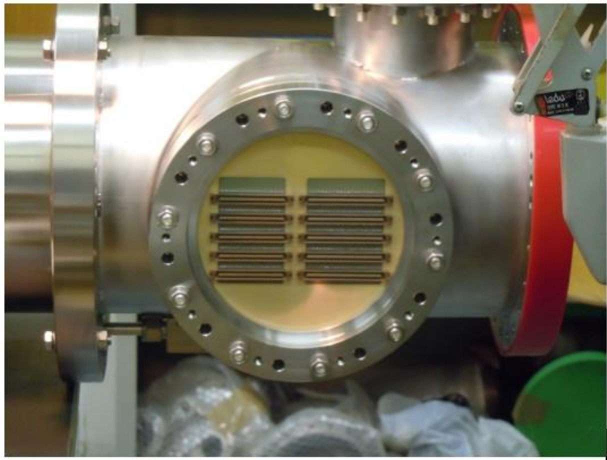
Double-slope version of cryogenic ASIC 16 channels with MOSCAP feedback

Input charge pC (kink point at ~350 fC, 11.5 mip, max 1200 fC)

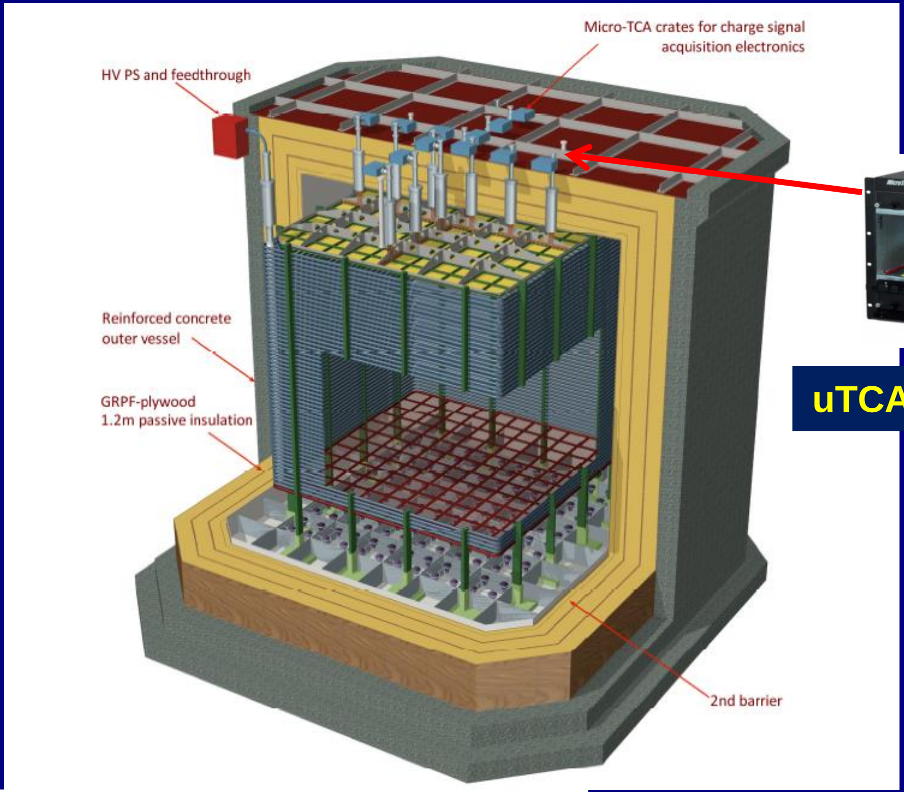
- Extensive tests of surge arrestor components on FE cards for sparks



- Fully engineered signal chimneys for accessible electronics in pre-production for 3x1
- (insertion/extraction of FE cards tested)

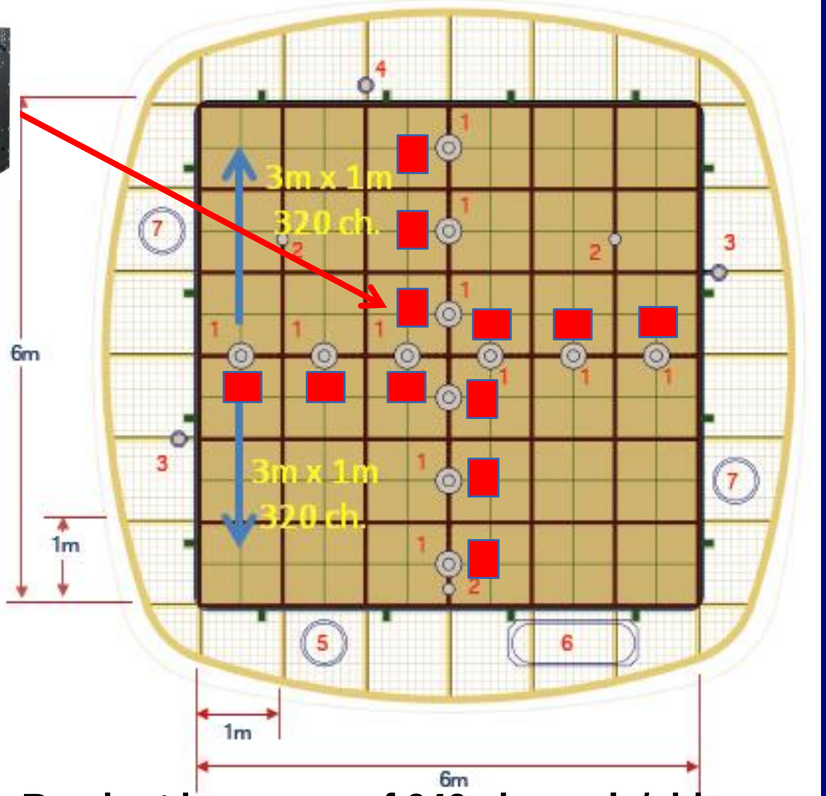


uTCA charge readout architecture



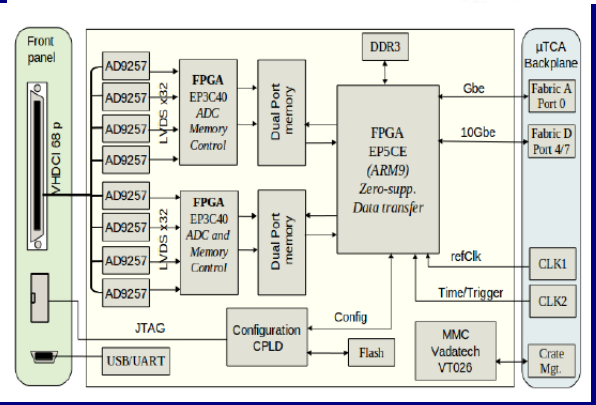
uTCA crates

View from anode with signal (1), suspension (2), HV(3), PMT(4), manhole (5), detail insertion (6), clean room IN/OUT (7) nozzles

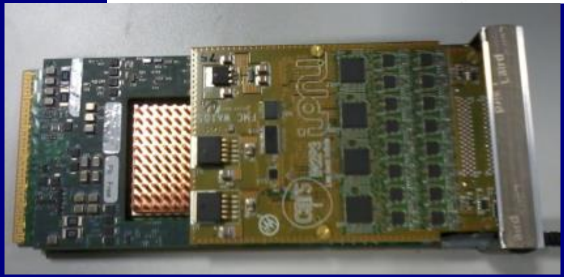


Readout in groups of 640 channels/chimney

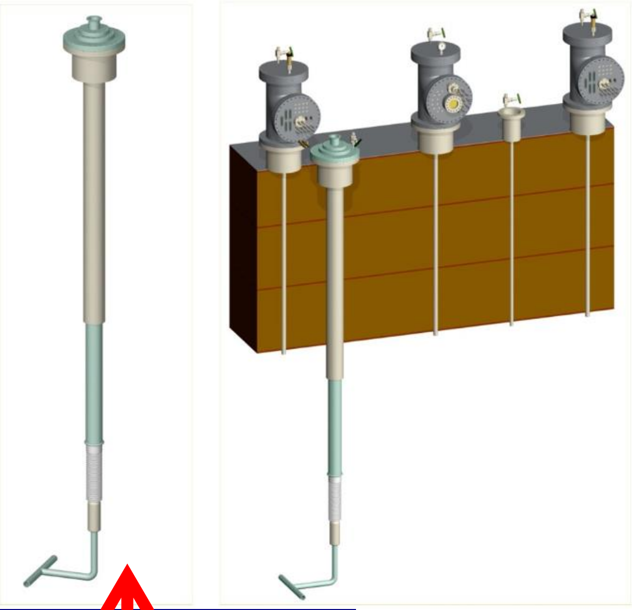
top view

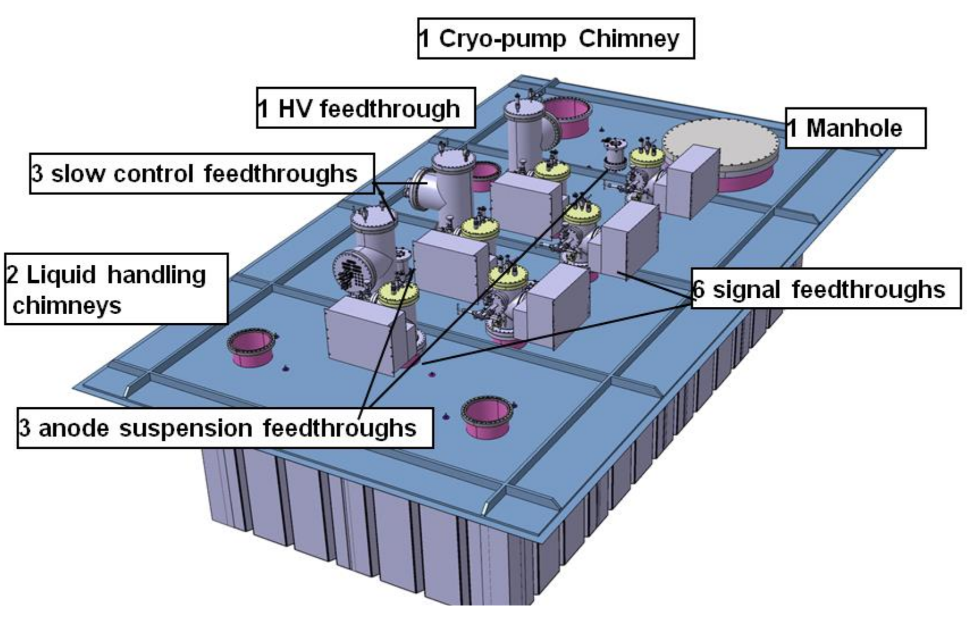


64 channels AMC digitization (2.5-25 MHz, 14 bits) card prototype based on Bittware S4AM 10 GbE output



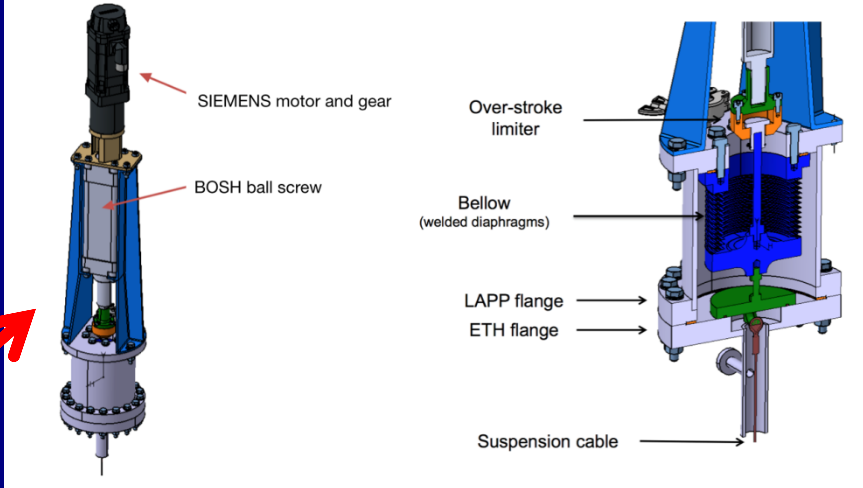
Full design, prototyping and integration of WA105 feedthroughs/chimneys



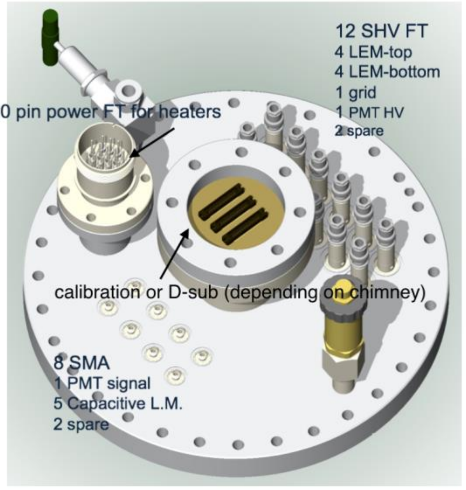


Studied and implemented in 3x1 TopCap

Cathode HV feedthrough

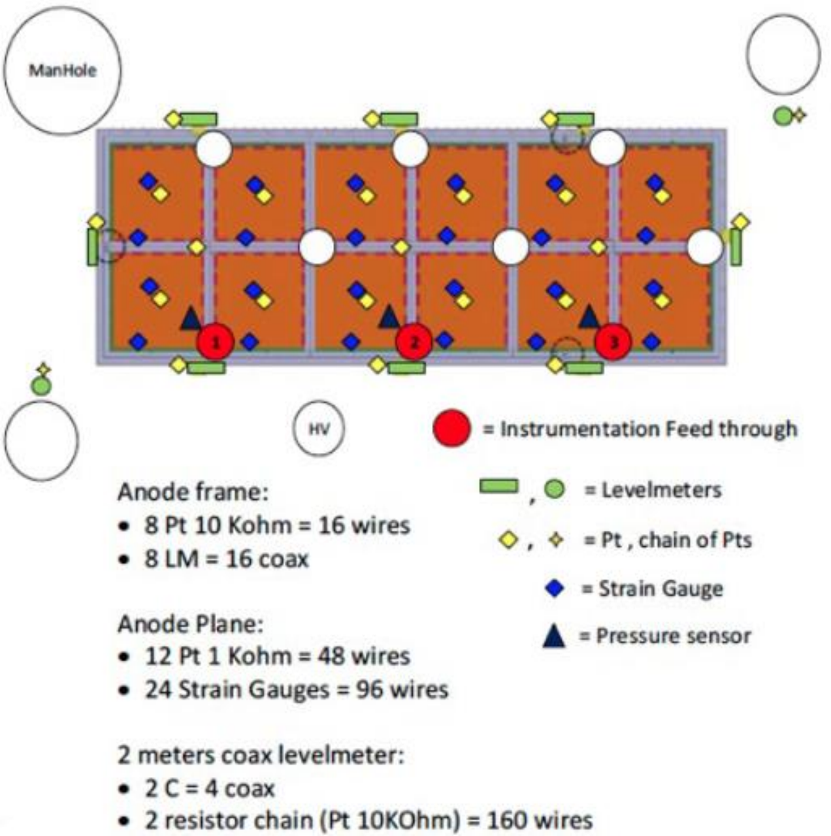


Design of slow control/services feedthroughs



CRP hanging system feedthroughs and motorization system (adjust CRP distance and parallelism to LAr level)

WA105 Slow Control (PCS/DCS/DSS)



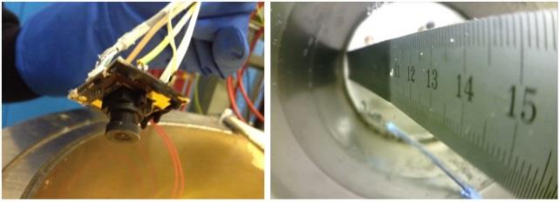
3x1 CRP sensors instrumentation (highly redundant)

Fully engineered system designed for 3x1 as building block easy to extrapolate to 6x6 in collaboration with CERN PH-DT (G. Maire)

→ Based on National Instruments compact RIO modules + UNICOS supervisor + single LabView interface

Integrates controls of level meters, temperature and pressure sensors, strain gauges, cryocamera + safety

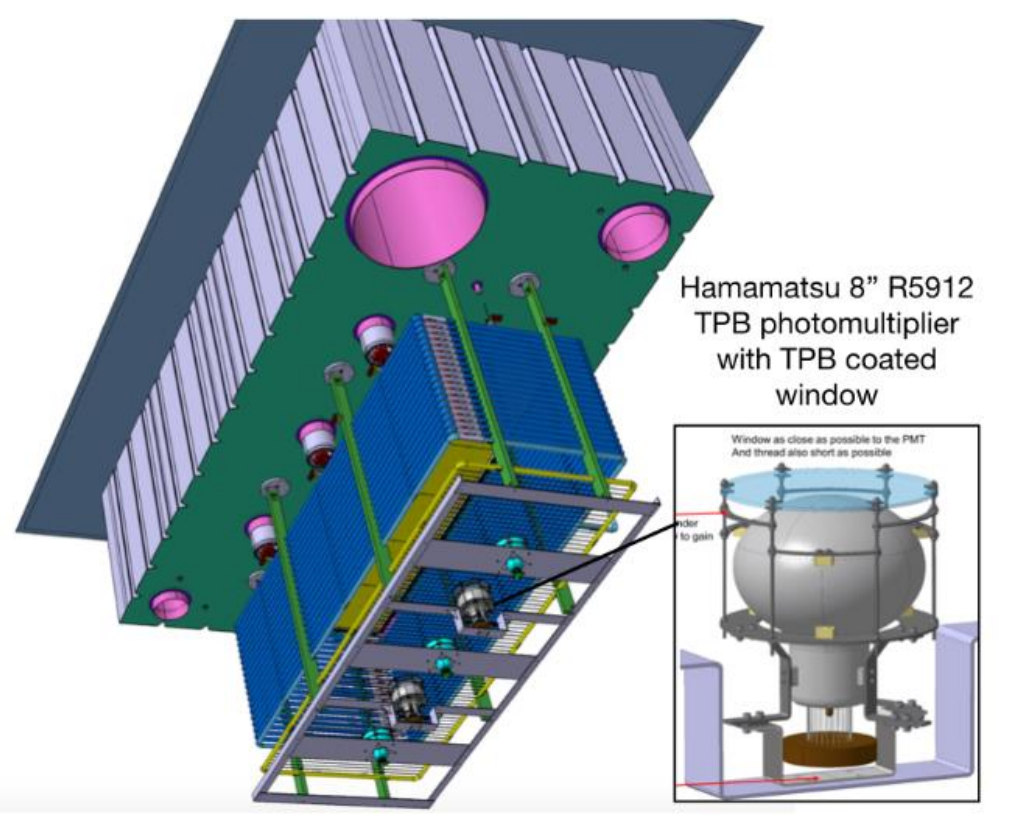
High accuracy (100 um)
and standard (1 mm) level meters

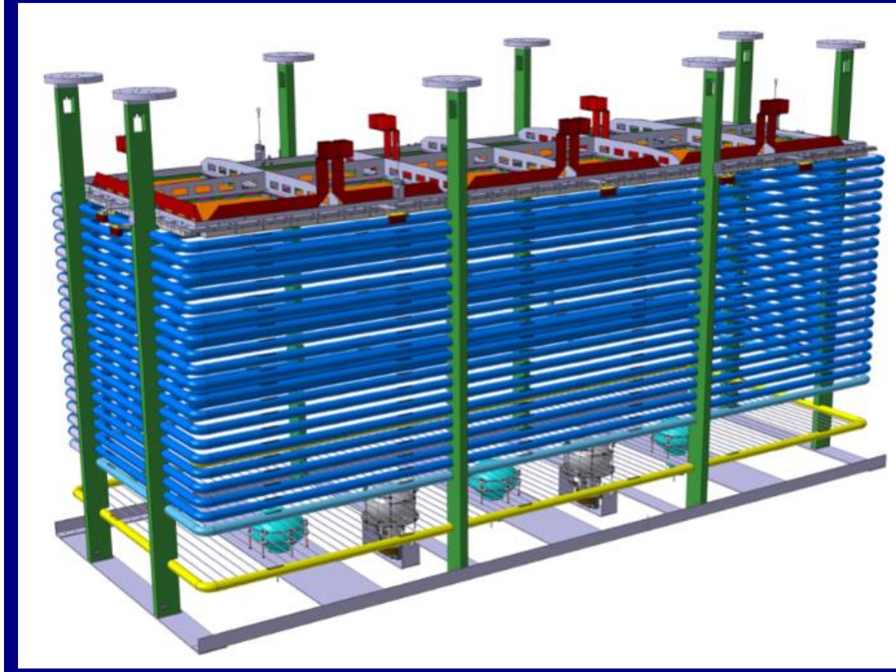


Cryocamera

SC
Test rack

Light readout

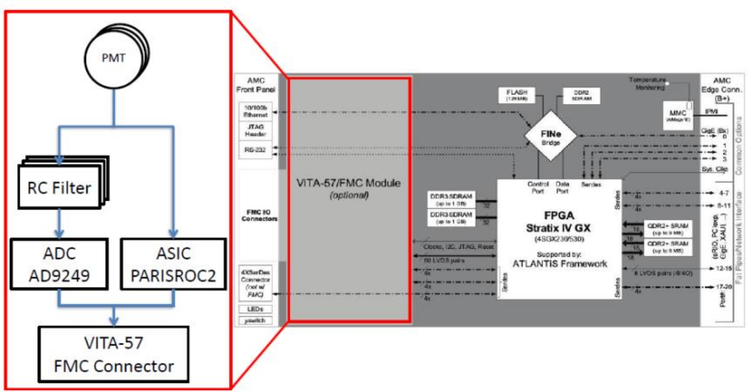




Mechanical supports for PMTs + different TPB coating options implemented in 3x1. Single coax for HV+signals

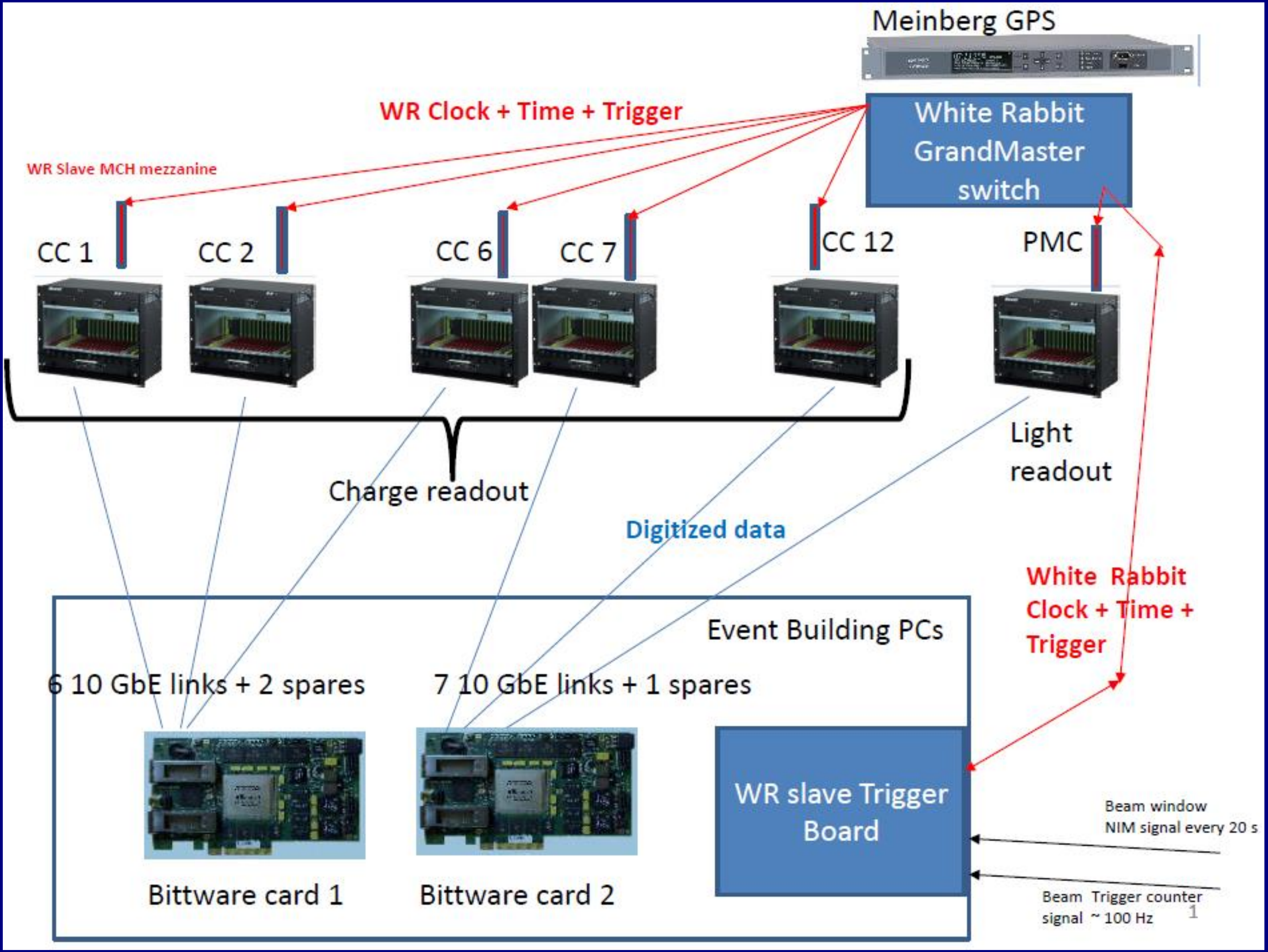
Development prototype of uTCA light readout digitization boards based on Bittware S4AM, 9 channels/card, 36 PMTs in 6x6x6

Trigger from PARISCROC2 ASIC



Global uTCA DAQ architecture

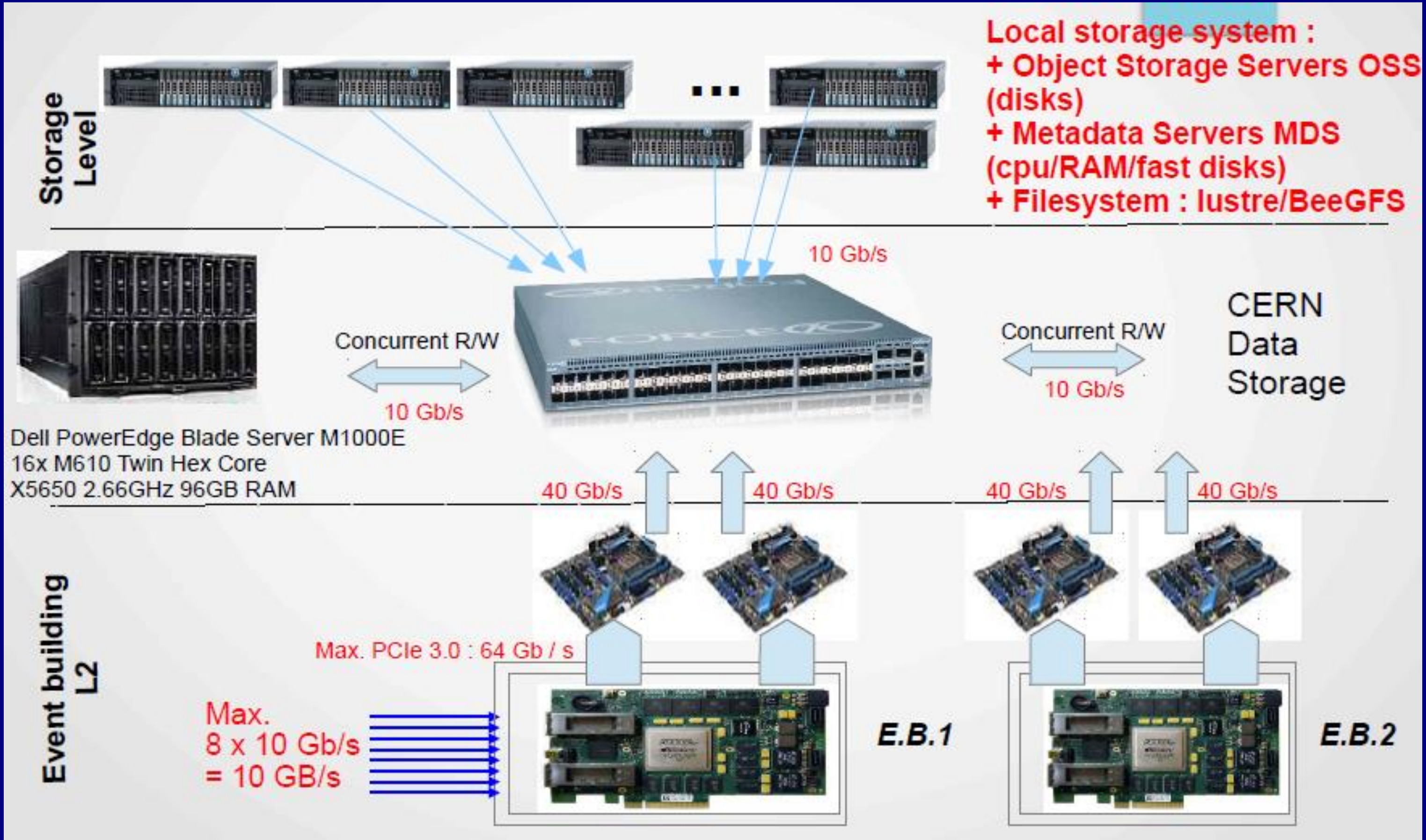
integrated with « White Rabbit » (WR) Time and Trigger distribution network
+ WR MCH slaves in uTCA crates



Online storage and data processing

Defined basic architecture for local network, storage and computing:

- Possibility to run with the beams without zero suppression at 100 Hz, event size 150 MB 15 GB/s, Huffman lossless compression under study
- Online buffer storage up to ~PB
- Online processing farm for event reconstruction, purity and gain analysis from cosmic ray tracks overlapped to beam events in a +-4ms window around the beam triggers

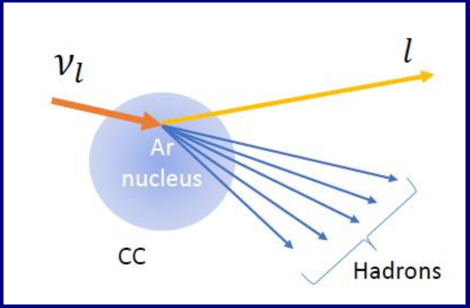


Software and Analysis developments

- Software for simulation and reconstruction from all past developments in LAGUNA-LBNO (QSCAN, light simulation) has been collected in a coherent production release at CCIN2P3 which is the basis for the next reconstruction developments for the analysis of the hadronic interactions samples.

- SB is working on the program for the exploitation of the hadronic interaction samples (its own general physics interest with this unprecedented granularity and resolution for the study of hadronic interactions and nuclear effects) and for the reconstruction aspects related to detector operation on surface (tagging and subtraction of cosmic ray tracks)

- An ambitious program for the analysis of the hadronic interactions sample is under work in order to provide significant the systematics for the next generation LBL neutrino experiments:



  - ✓ Impact on physics capabilities of better detector performance vs proposed LBL single phase LAr TPC: high S/N ratio, 3 mm pitch, absence of materials in long drift space, two collection views, no ambiguities

  - ✓ Reconstruction of the hadronic system (resolution and energy scale) , electron id efficiencies and pi0 rejection. Particles dE/dx identification for proton decay

Conclusions:

- The WA105 experiment completed its collaboration structure. The Technical Board and Science Board are fully actives with weekly meetings and are coordinating the detector preparation and the analysis preparation and software developments.
- Since the TDR submission large progress has been achieved on the preparation for the 6x6x6 DLAr detector construction in the EHN1 hall thanks to the possibility of using as playground a 3x1x1 detector prototype which allowed to anticipate the technical work and to mitigate possible problems.
- 3x1x1 allowed to setup the full chains for components procurement and production/assembly and to work out a full engineering integration of many parts of the detector. Reconfirmed the costs and time estimations for the 6x6x6.
- Work for the EHN1 hall integration and installation is in progress as well as for the beamline definition and its instrumentation in collaboration with CERN. The advanced state of preparation for the detector construction puts W105 in a good situation to achieve the 2018 beam data-taking goal for the 6x6x6 demonstrator.
- The software for simulation and reconstruction from all past developments has been collected in a coherent production release at CCIN2P3 which is the basis for the next high level reconstruction developments. An ambitious program for the analysis of the hadronic interactions sample is under work in order to impact significantly the systematics for the next generation LBL neutrino experiments.
- All these developments are being included in the DUNE CDR (DOE CD1 refresh July 2015)

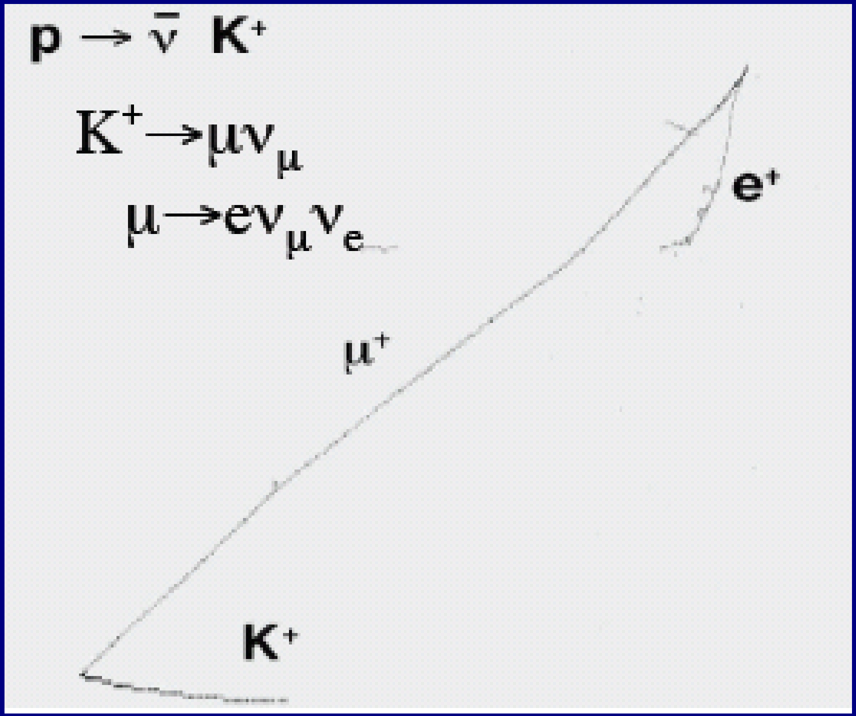
The LAr TPC as an electronic bubble chamber

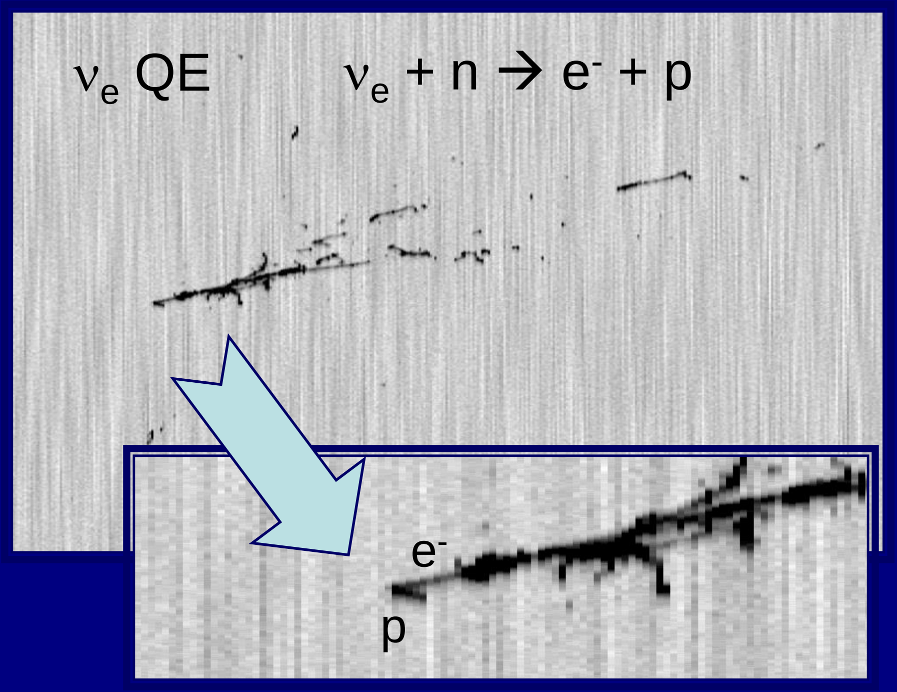
- Large mass, homogeneous detector, low thresholds, exclusive final states
- Tracking + calorimetry (0.02 X0 sampling)
- **Electron** identification, π^0 rejection, particles **identification with dE/dx**

→ Neutrino physics (electron identification, reconstruction of event kinematics, identification of exclusive states, excellent energy resolution from sub GeV to multi GeV)

→ Supernovae neutrinos

→ Proton decay search (large mass, particles id.)

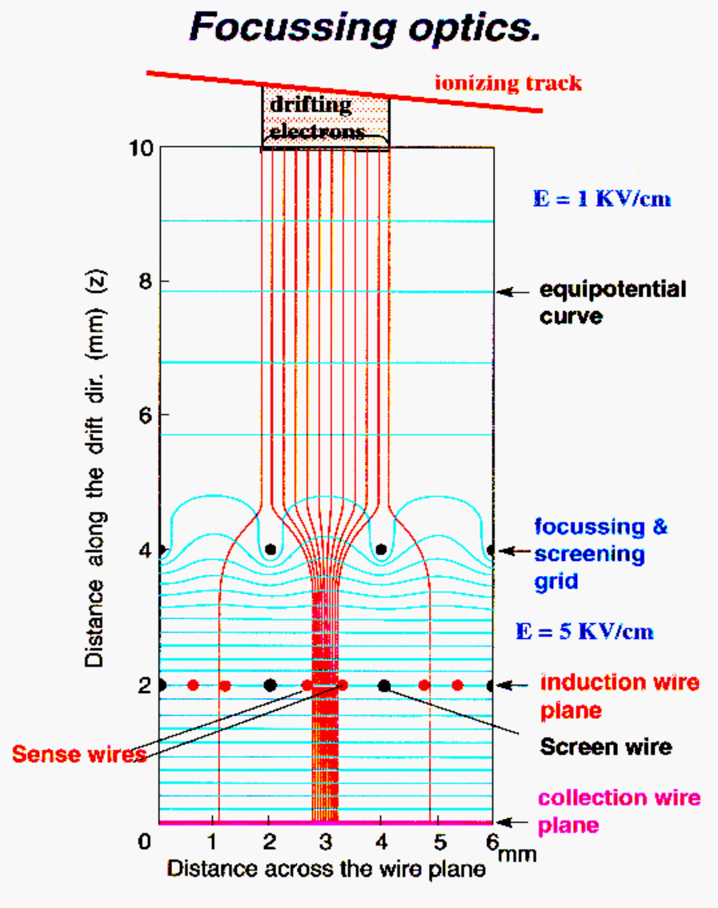


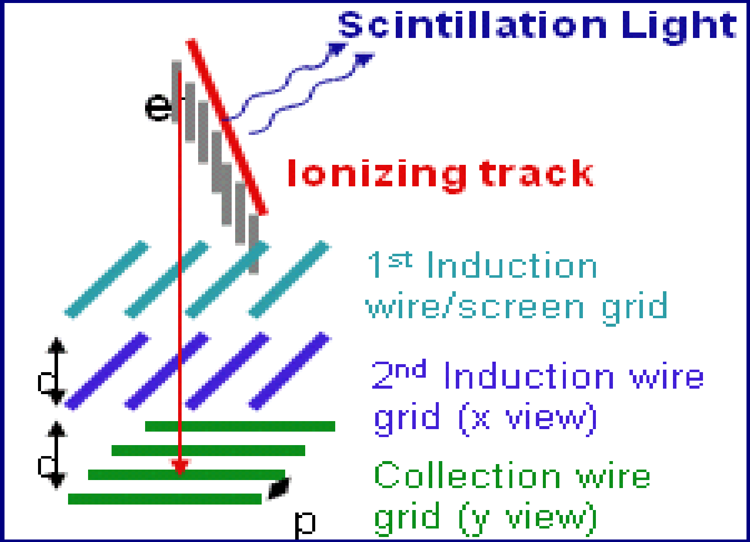


The Liquid Argon Time Projection Chamber (C. Rubbia 1977)

- Homogeneous massive target and ionization detector → electronic bubble chamber
- 3D event reconstruction with ~1 mm resolution, Surface readout of instrumented volume
- High resolution calorimetry (electromagnetic and hadronic showers)
- Primary ionization in LAr: 1 m.i.p. ~20000 e- on 3 mm
- Detection of UV scintillation light in LAr (5000 photons/mm at 128 nm) to provide t = 0 signal of the event

Ideal detector for neutrino oscillations, supernovae neutrinos and proton decay





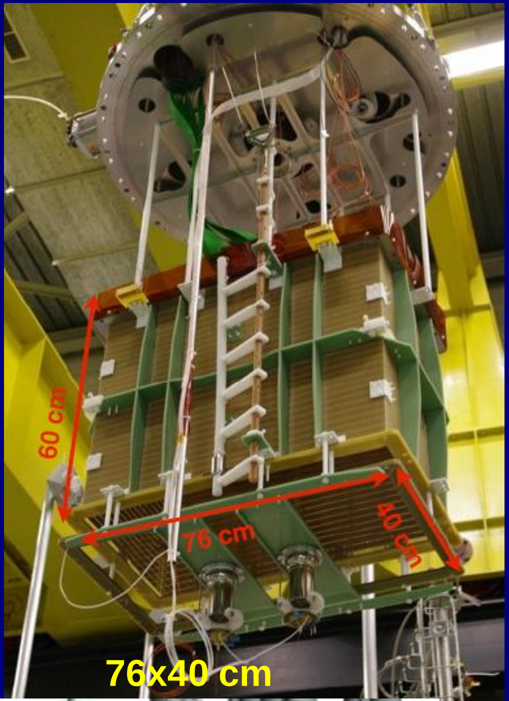
X,Y
Non-destructive multiple readout with induction planes

Z = drift time

Drift Field: 0.5-1 kV/cm
Drift time:
2 m/ms @1 kV/cm

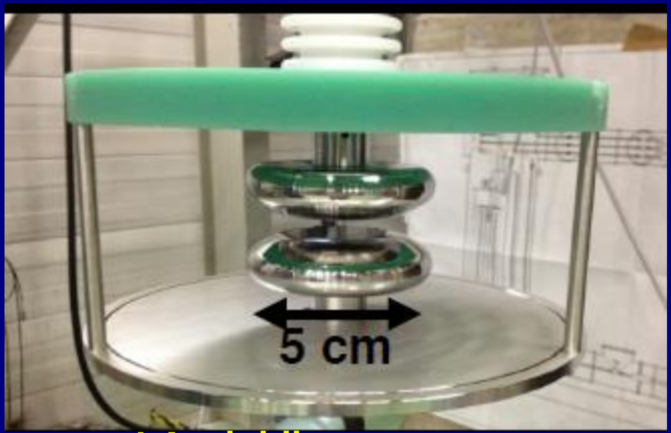
→ drift requiring < 0.1 ppb O_2 equiv. impurities

Parallel ongoing technical R&D activities:

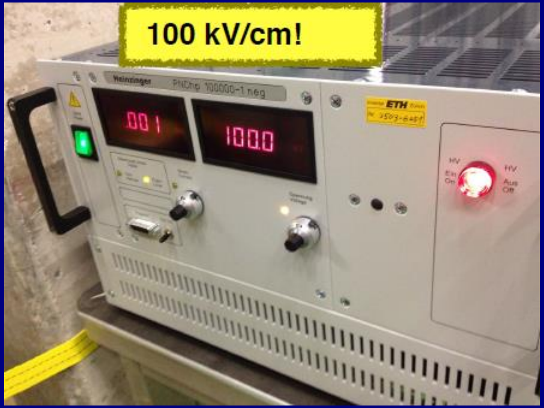


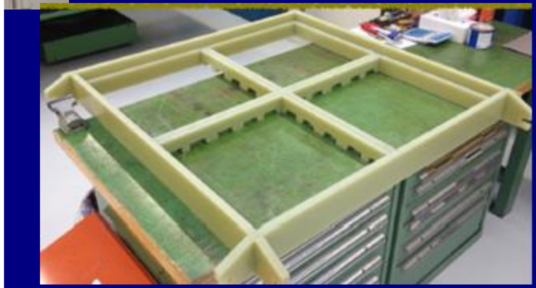
76x40 cm

10x10x20 cm
LEM-anode fast test setup

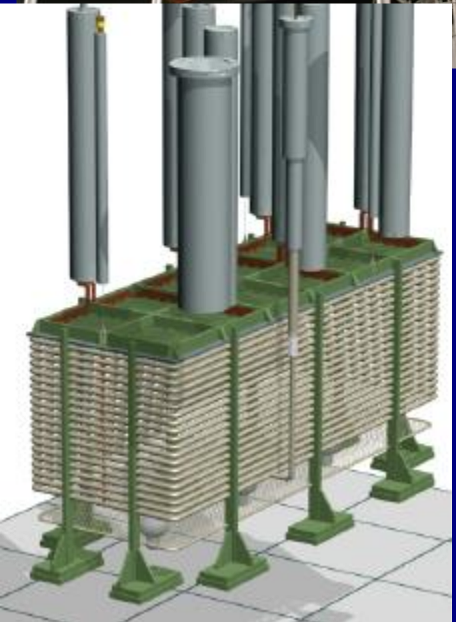


LAr rigidity test setup





CRP mockup



3x1x1 m mockup
(3 CRP)

Readout test setup in Lyon

Technical challenges for the construction and operation of a large and affordable LAr TPC with long drift length to be assessed with the WA105 demonstrator

- **Very high purity:** Drift of electrons over 20 m distance requiring very clean environment, with impurities ~100 ppt O2 (electron lifetime of 3-10 ms). Achieved so far on small prototypes. This will be the first test with a large scale non-evacuable prototype and the same tank construction technique foreseen for the far detector.

- **Large field cage:** This is a large structure with demanding requirements on its mechanical precision and capable of sustaining a large potential difference (up to 500 kV).

- **Very high voltage generation:** Very low noise and stable power supply able to reach 600 kV to generate an uniform drift field of 1 kV/cm (300 kV power supplies within specifications are commercially available).

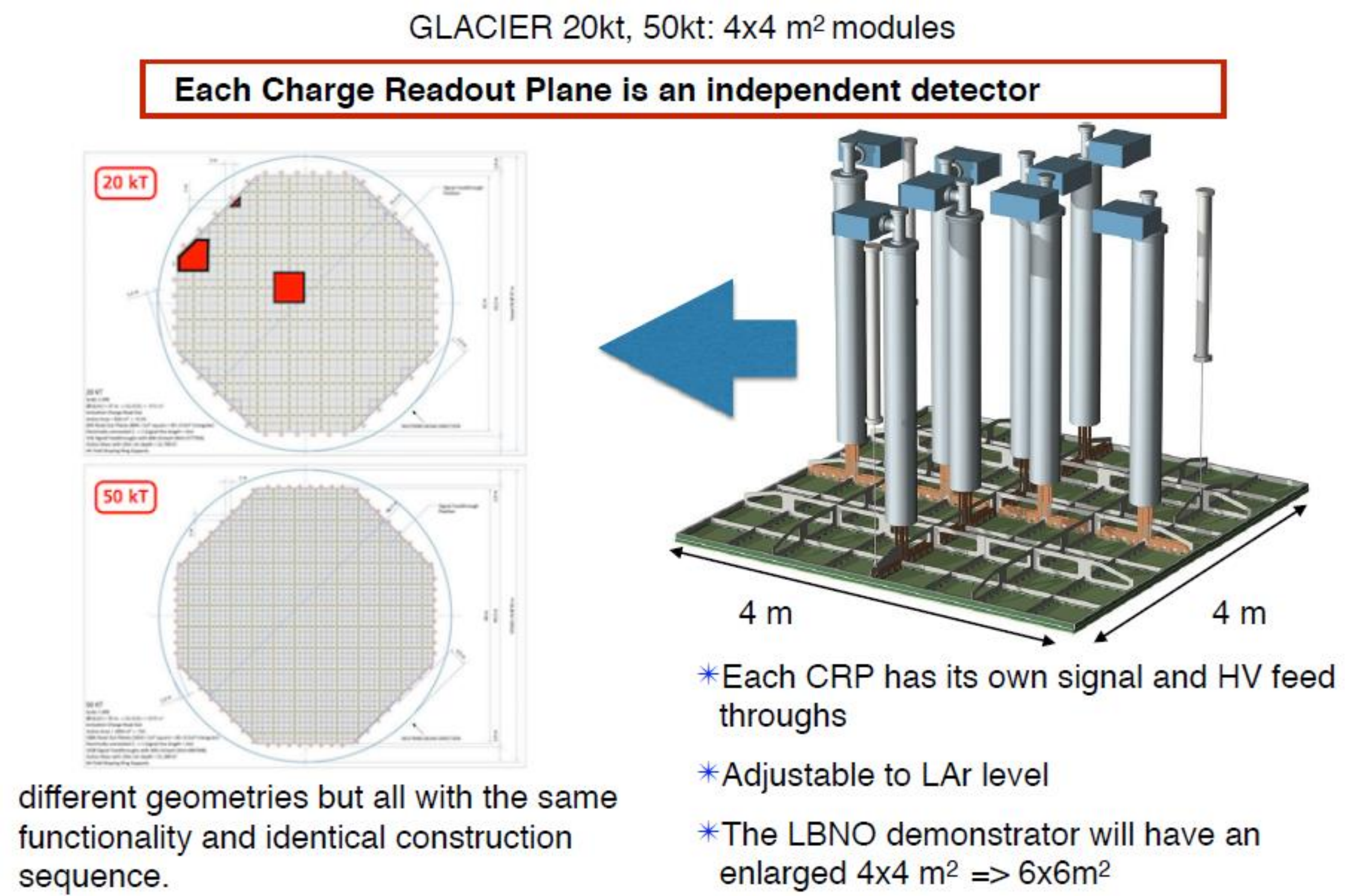
- **Large area micro-pattern charge readout:** A 36 m^2 surface will be instrumented with a charge sensitive device providing gas amplification in ultra pure argon vapors.

- **Cold front-end charge read-out electronics:** Good S/N is crucial to reach the required physics performances, especially for the low energy neutrino physics. Innovative solution with preampliers located as close as possible to the charge-sensitive anode, but yet accessible without opening the inner vessel, will be tested.

- **Long term WLS coating:** A method based on WLS deposition with very long stability (> 10 years) will be implemented and tested.

- **Integrated light readout electronics:** New integrated devices will be developed for the digitization of argon scintillation light, scalable to very large detectors.

GLACIER readout units from LAGUNA-LBNO design study



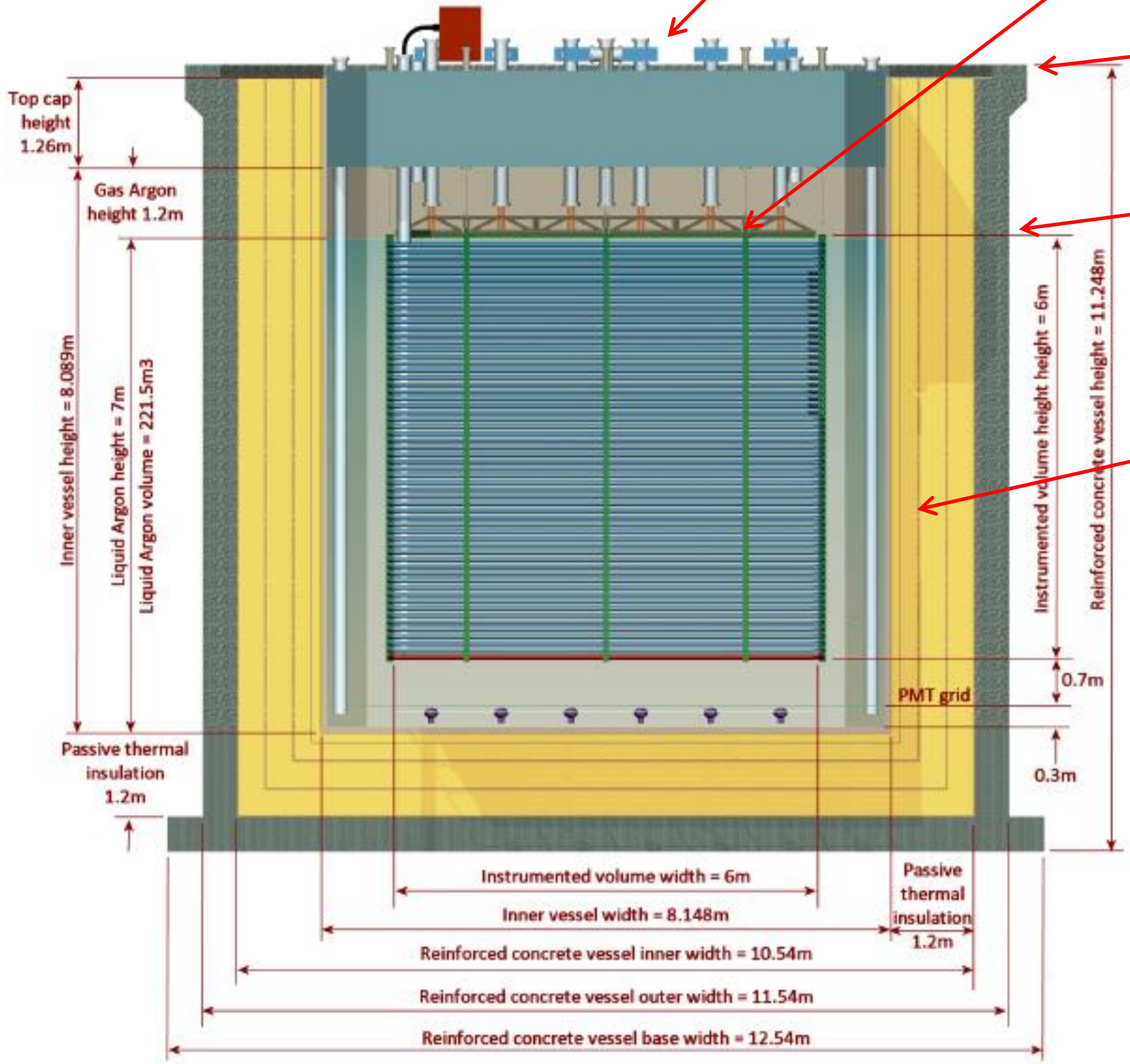
GLACIER 20kt, 50kt: 4x4 m^2 modules

Each Charge Readout Plane is an independent detector

different geometries but all with the same functionality and identical construction sequence.

- Each CRP has its own signal and HV feed throughs
- Adjustable to LAr level
- The LBNO demonstrator will have an enlarged 4x4 m^2 => 6x6m^2

Vertical cross-section



Electric, electronic, cryogenic instrumentation

Anode deck

Top roof supporting the anode deck

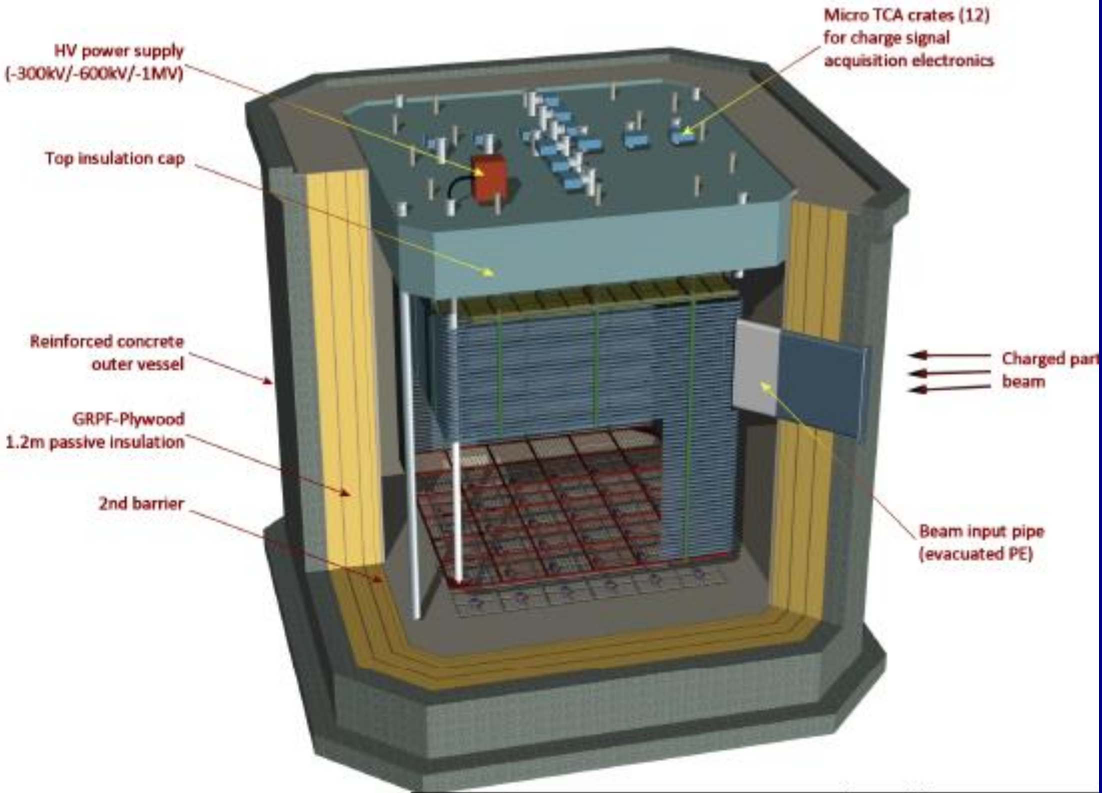
Concrete 0.5 m

Insulation 1.2 m

8.3 m inner vessel
Active size 6 m
External size 12.5 m

DLAr 6x6x6m^3 design

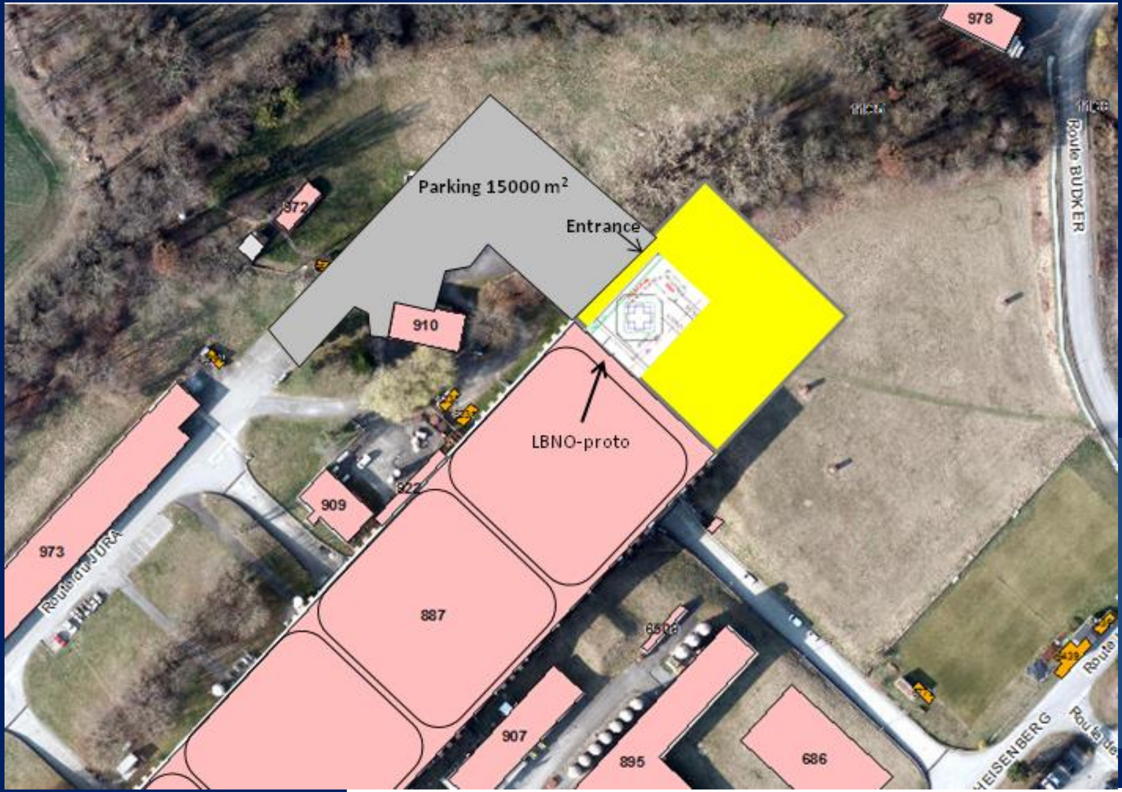
- Membrane GTT® tank with passive insulation
- Top deck with chimneys and insulation
- **6x6m^2 anode large readout area, 6m long drift length** (3ms max drift time @ 1kV/cm)
- Charged particle beam window
- 300 ton LAr instrumented: 7680 charge readout channels, 36 PMTs (baseline layout)

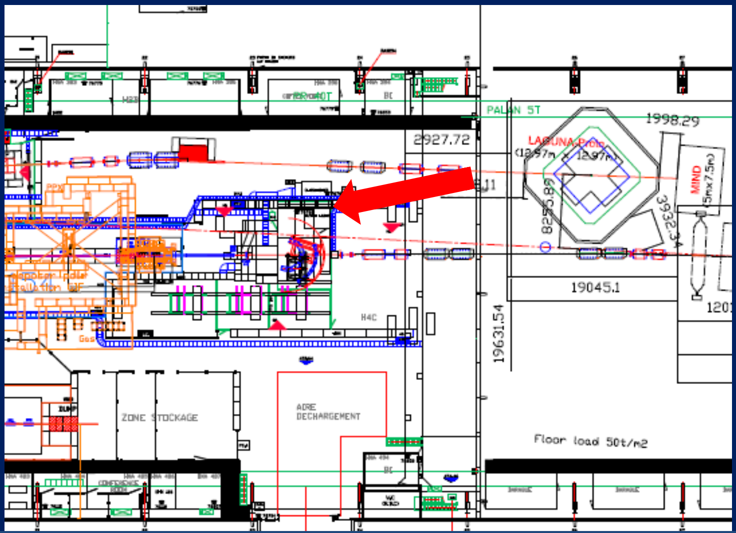


Liquid argon density	T/m^3	1.38
Liquid argon volume height	m	7.6
Active liquid argon height	m	5.99
Hydrostatic pressure at the bottom	bar	1.03
Inner vessel size (WxLxH)	m^3	8.3 × 8.3 × 8.1
Inner vessel base surface	m^2	67.6
Total liquid argon volume	m^3	509.6
Total liquid argon mass	t	705
Active LAr area	m^2	36
Charge readout module (0.5 x0.5 m^2)		36
N of signal feedthrough		12
N of readout channels		7680
N of PMT		36

7680 readout channels, ICARUS T300 for similar fiducial mass had 27000 channels

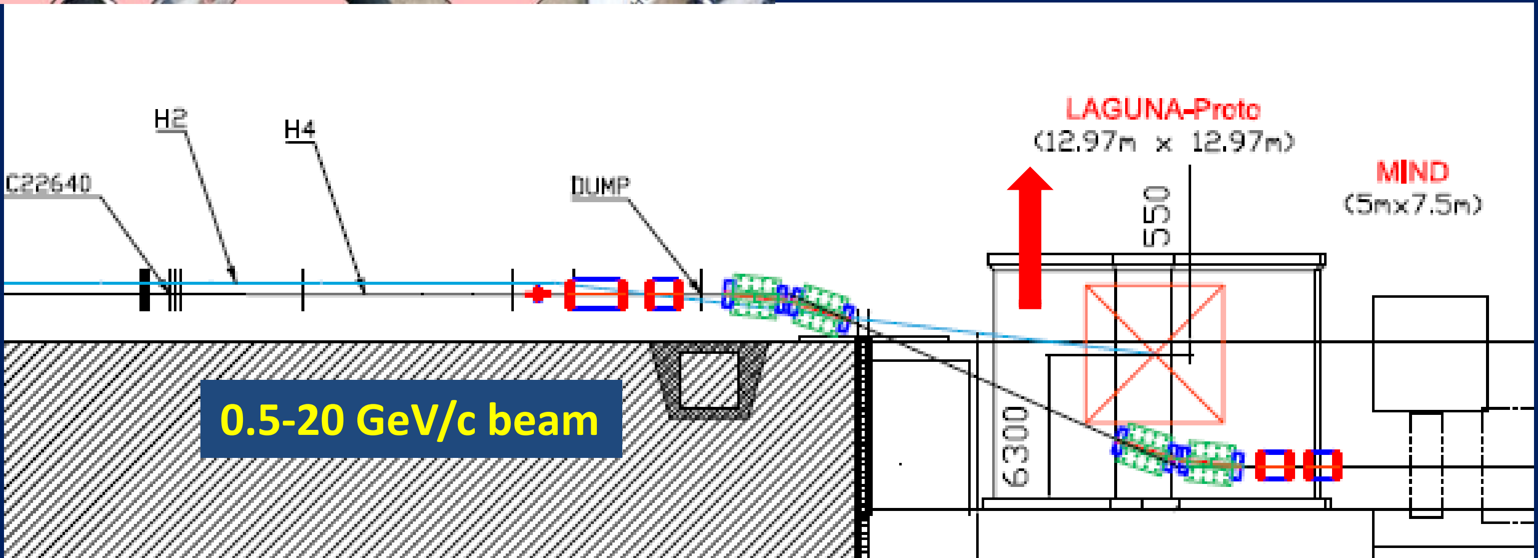
WA105 in the CERN North Area EHN1 extension





Requirements:
20×30 m^2, 2m deep pool

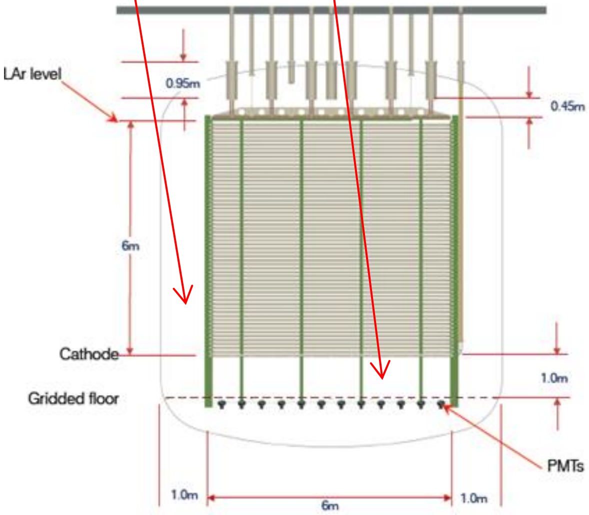
→ Fitting in half of the EHN1 extension



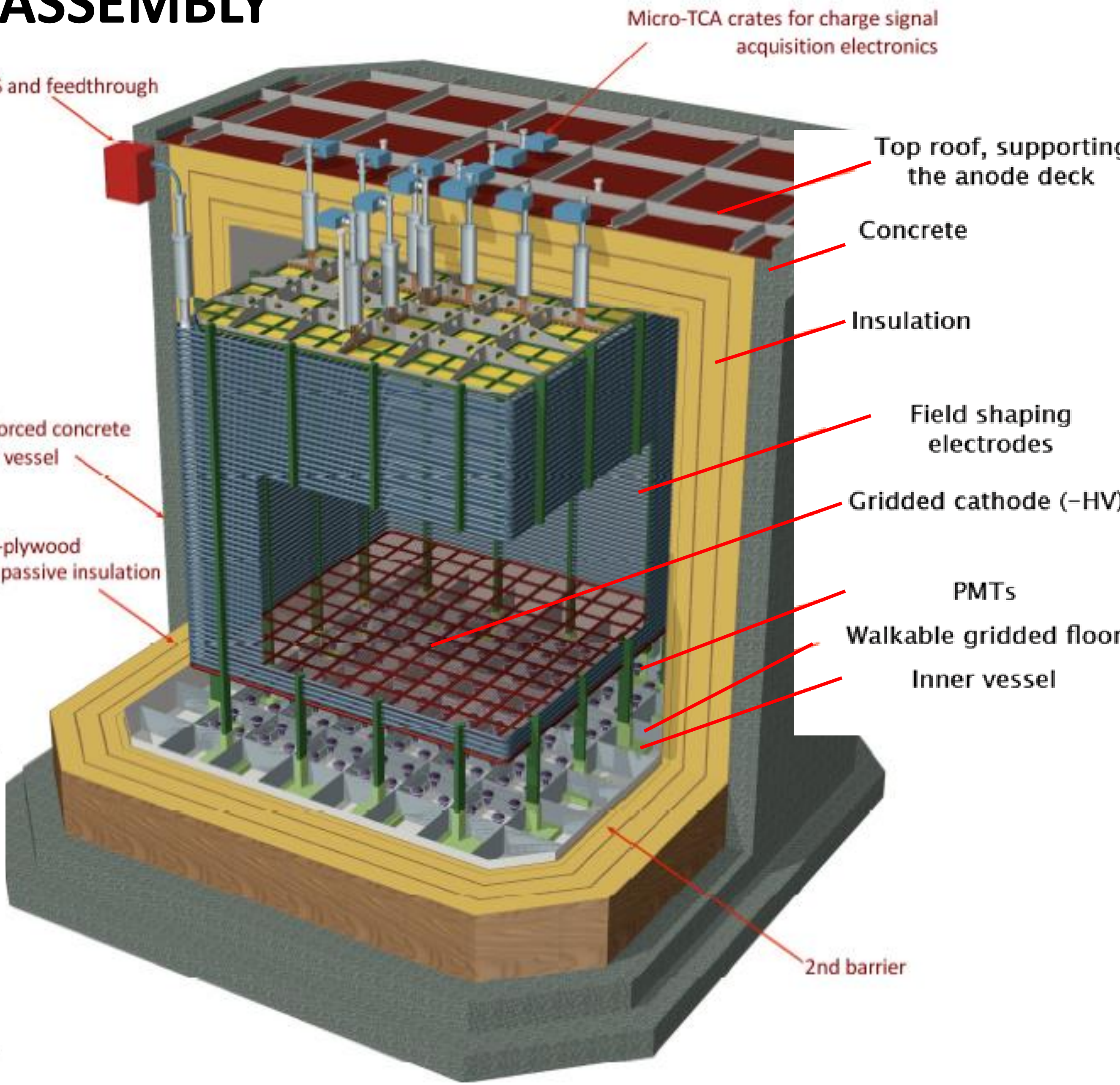
0.5-20 GeV/c beam

FINAL FIELD CAGE ASSEMBLY

- **1 m distance field cage - walls**
  - **1 m distance cathode-PMTs**



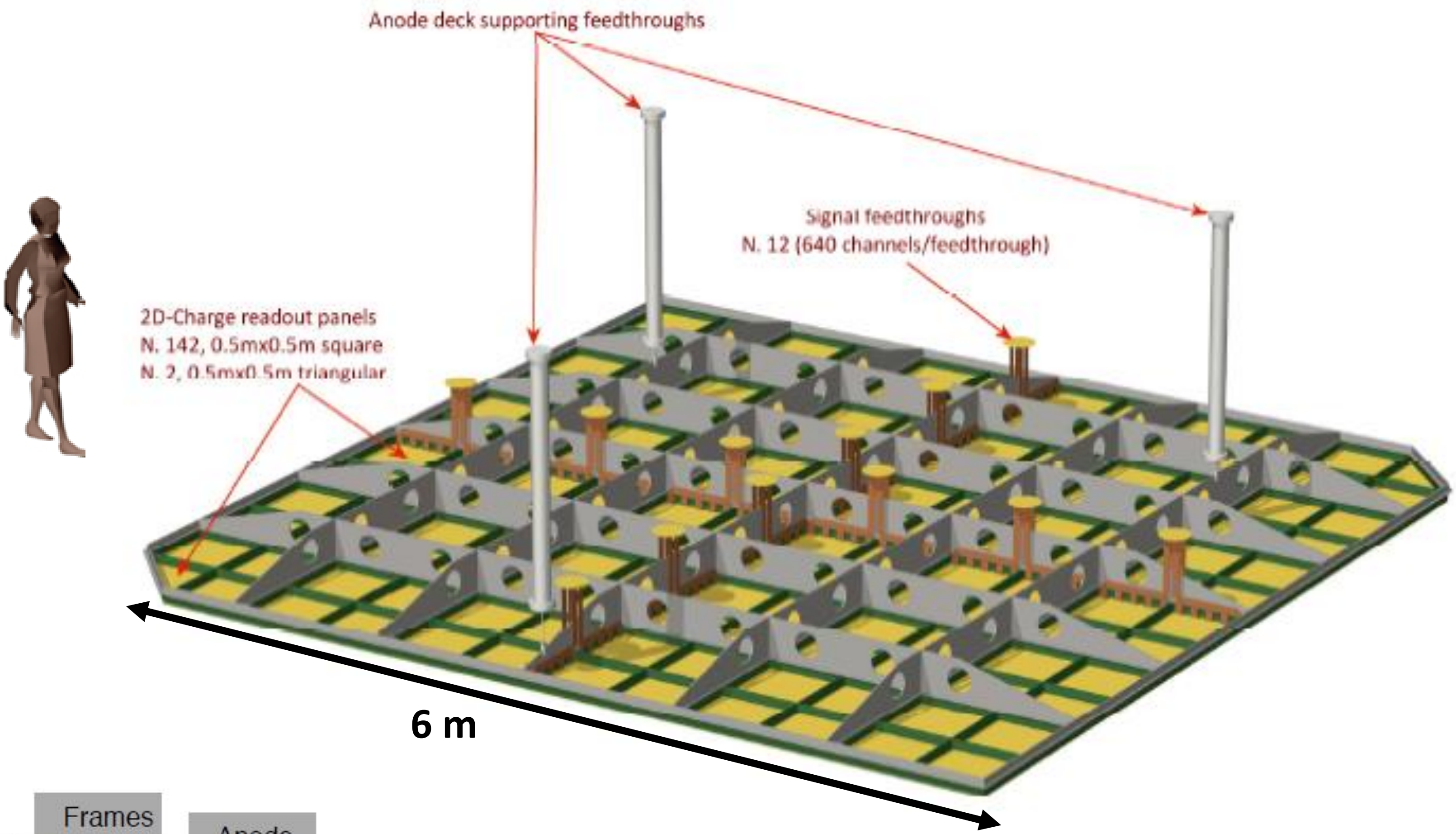
side view

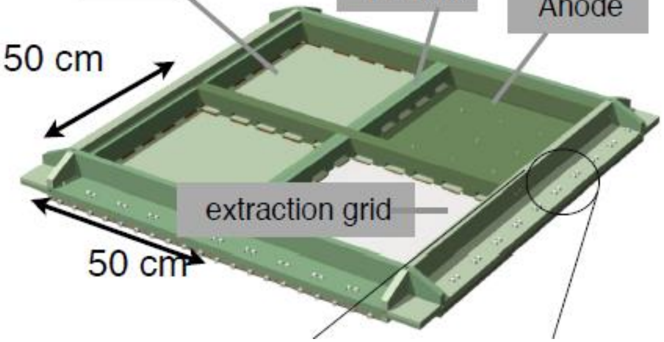


WA105

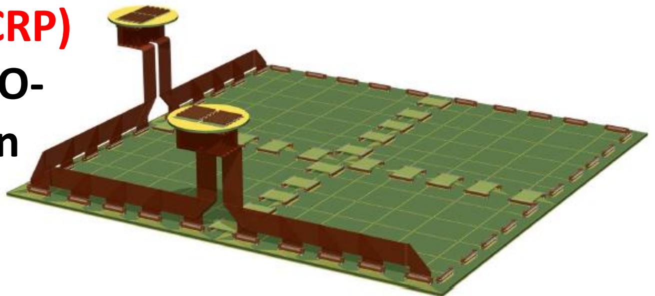
Charge readout anode deck

144 Readout Modules 0.5x0.5 m2
Two anode coordinates, 3 mm pitch





4 Readout Modules assembled in a Charge Readout Plane (CRP) unit 1x1 m2 common to LBNO-proto and Glacier 20/50 kton



LAGUNA-LBNO DESIGN CONTENT

FULLY COVERED CONCEPTUAL DESIGN STUDY

→ INCLUDING:

-GENERAL DESIGN

- -COMPLETE AND COHERENT LAYOUT DESIGN OF THE UNDERGROUND
- -DESIGN OF ON-SURFACE INFRASTRUCTURE
- -LOGISTIC DESIGN + EQUIPMENT OF THE DIFFERENT CONSTRUCTION STAGES
- -IMPLEMENTATION INTO CURRECT INFRASTRUCTURE (MINE / ROAD)
- -SAFETY (H&S) DESIGN FOR REALISATION AND OPERATION

-DESIGN OF THE CAVERNS

- -ROCK ENGINEERING AND EXCAVATION
- -CIVIL WORKS (HVAC + AUXILIARY CONSTRUCTIONS)

-DESIGN OF EXPERIMENT

- -TANK CONSTRUCTION DESIGN + SCAFFOLDING
- -DETECTOR DESIGN AND INSTRUMENTATION
- -ELECTRONICS
- -LIQUID INFRASTRUCTURE, HANDLING + COMMISSIONING

-CONSTRUCTION PROGRAMMES OF ALL STAGES

-RISK ASSESSMENTS + PROJECT RISK REGISTRY + CONTINGENCY

-CONSTRUCTION + OPERATIONAL COSTINGS

LAGUNA-LBNO FIELDS OF INNOVATION

DESIGN (REALIZATION STEPS)

- GEOLOGICAL ENGINEERING
- ROCK ENGINEERING
- MINE ENVIRONMENT
- HEATING, VENTILATION, AIR CONDITION

- TANK TECHNOLOGY UNDERGROUND
- CONCRETE WORKS
- MEMBRANE TECHNOLOGY
- SIGNAL FEED-THROUGHS
- CONSTRUCTION LOGISTICS + CRANEAGE
- INSTALLATION LOGISTICS

- LIQUID ARGON DETECTOR
- SCAFFOLDING
- CLEAN ROOM DEMANDS
- INSTALLATION TOLERANCES
- SPECIAL CONSTRUCTION MATERIALS
- ELECTRONICS + DATA AQUISITION

- LIQUID INFRA-STRUCTURE
- LIQUID TRANSPORT
- LIQUID HANDLING
- SLIM STEEL CONSTRUCTION
- HIGH VOLTAGES (UP TO 2MV)

- HEALTH AND SAFETY QA
- RISK ASSESSMENTS QA
- COST OPTIMIZATION
- PROJECT MANAGEMENT

- LBNO design phase concluded

→ Outcome: optimized configuration for a LBL experiment studied in Europe (as recommended by CERN, APPEC) with associated technological developments, innovative solutions and full costing

- Deliverables to the EC, outcome of the design study, documented in >4000 pages (0.5 GB)

- Final design study meeting in Helsinki (24-28 August 2014)

→ Explore the application of all these developments for a US hosted experiment

Industrial partners

GTT

50 years of membrane

France

LNG Membrane tank technology

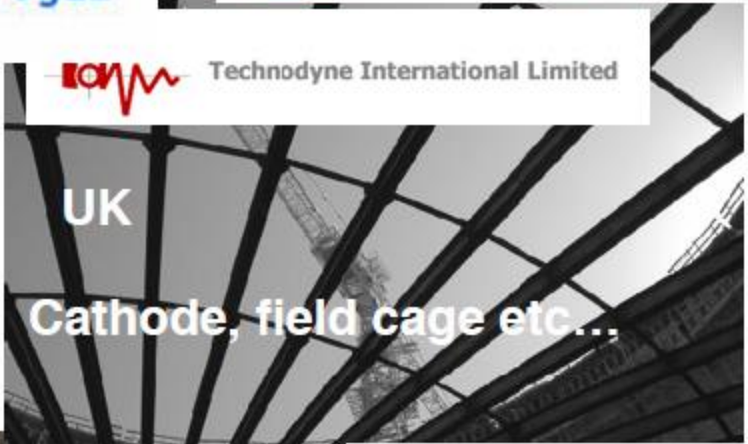
Sofregaz

France

UK

Alan Aul

GROUP LTD



Technodyne International Limited

UK

Cathode, field cage etc…

20 m

AGT INGEGNERIA

Italy

ROCKPLAN

Finland

Underground excavation etc..

RHYAL ENGINEERING

U

Greece

ΔΗΜΟΚΡΙΤΟΣ

Risk assessment

Lombardi

Switzerland

Underground excavation