WA105 experiment

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on behalf of WA105 collaboration
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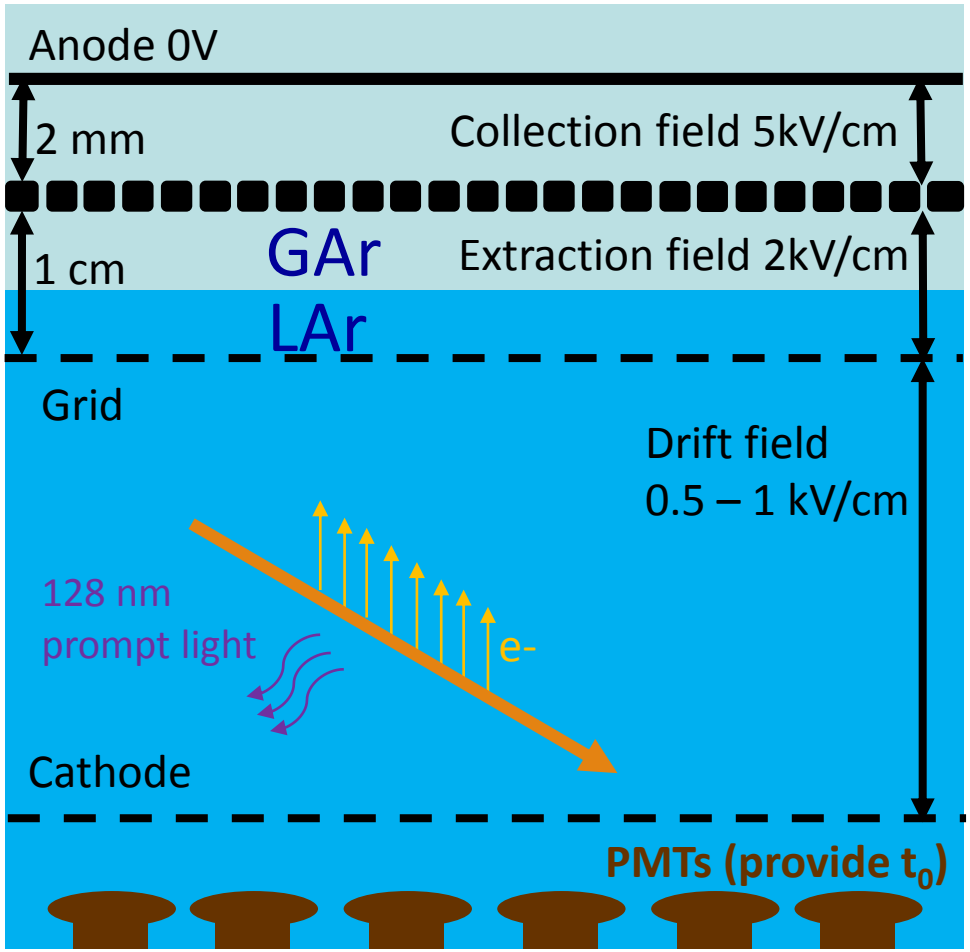
Nucleon Decay and Neutrino Detectors
Paris, November, 2014

Outline

- Introduction
- WA105 detectors
- LBNO-Demo technical description
- Conclusions

Large scale liquid argon TPC

Concept of double-phase LAr TPC (Not to scale)



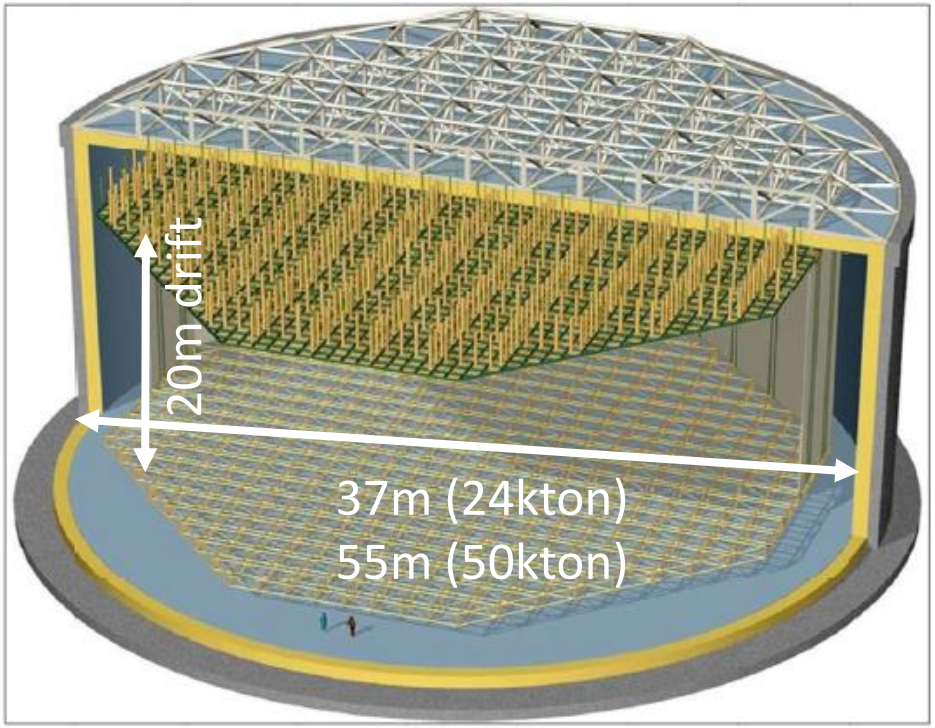
GLACIER (**G**iant **L**iquid **A**rgon **C**harge **I**maging **E**xpe**R**iment) concept
A. Rubbia hep-ph/0402110

Large scale LAr TPC for LB neutrino oscillation physics, astrophysics, and nucleon decay search (GUT physics)

- Single cryo-tank based on industrial LNG solution to house O(10) kton of LAr mass
- Double-phase for charge readout with amplification:
  - Long drift distances
  - Low energy detection thresholds

Goal: large scale DLAr detector

Fully engineered design for ~24kton and ~50kton detectors from LAGUNA/LBNO design study (2011-2014)



- Single tank constructed using LNG technologies
- Affordable solution for underground installation

- 1 – 2 MV voltage on the cathode

→ drift field 0.5 – 1.0 kV/cm

- Hanging field cage structure

→ no contact with the tank ground

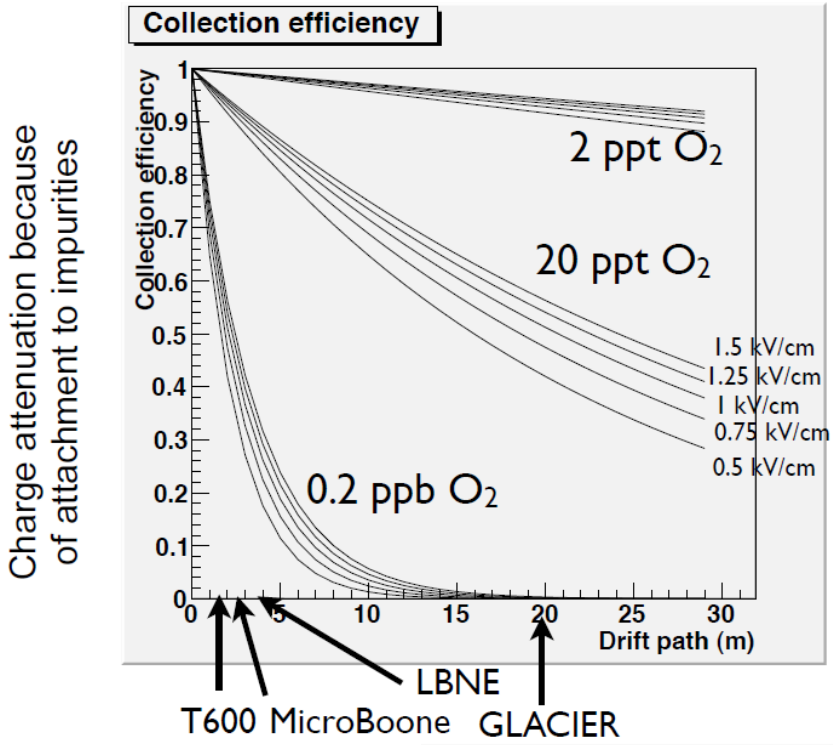
- Height adjustable anode deck

→ keep constant LAr level

- Instrumented area 824 m^2 for 24kton and 1845 m^2 for 50kton

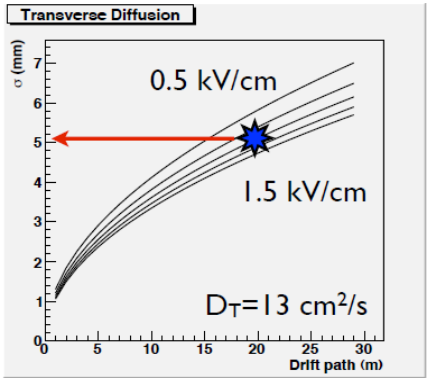
Towards large DLAr detectors

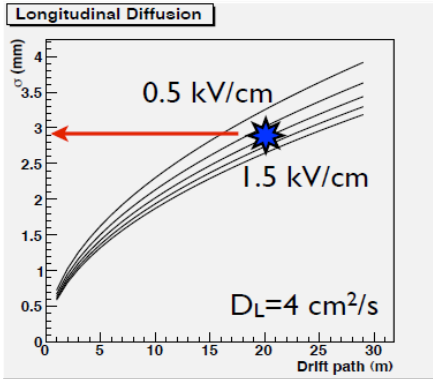
- Purity in non-evacuated tank
- Large hanging field cage structure
- Very high voltage generation
- Large area charge readout
- Accessible cold front-end electronics
- Long term stability of UV scintillation light readout



WA105

Build and operate a large scale prototype (LBNO-Demo) to demonstrate the feasibility of LAGUNA/LBNO DLAr TPC design for O(10) kton detectors



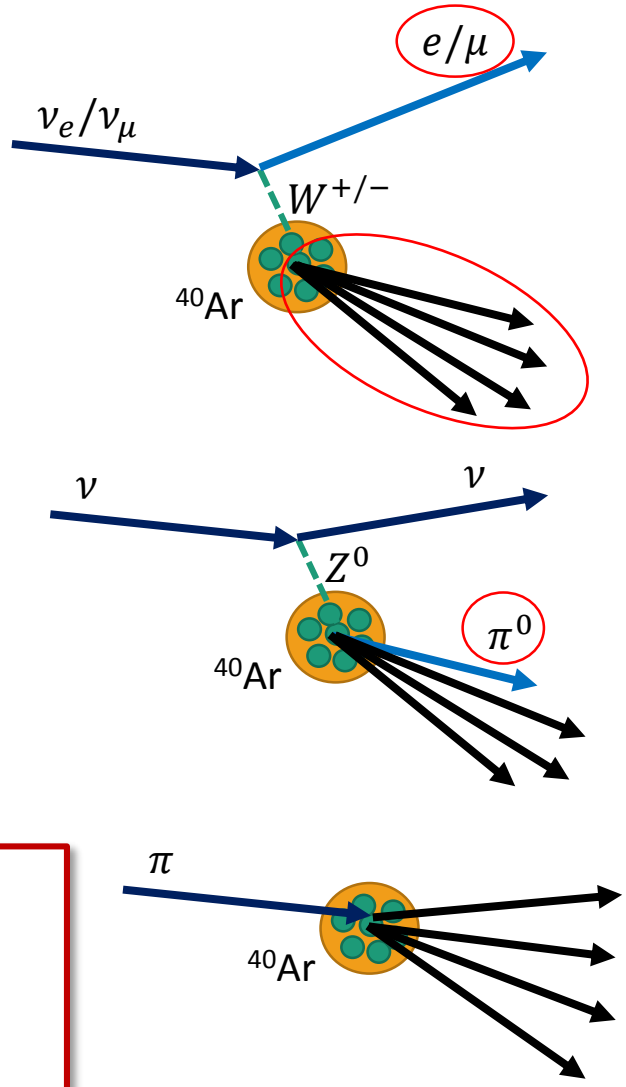


The physics case for DLAr demo

- Development and validation of automatic event reconstruction in LAr
- Assessment of PID performance
- Test e/π^0 rejection
- Study of energy resolution and scale for calorimetric measurement

$$E_{reco} = \alpha E_{had} + \beta E_{EM}$$

  - Resolution constant term: $\sigma/E = A/\sqrt{E} \oplus B$?
- Charged pions and proton cross sections on Ar nuclei (input to modelling of FSI in nuclear environment)



Dedicated data-taking campaign with charged particle beams of well-known momenta and type

Measurement of hadronic showers

- LAr TPC provide a fully active homogeneous medium
- High granularity 3x3 mm^2 ← two orders of magnitude better than most granular calorimeters
  - e.g., CALICE AHCAL prototype has 3x3 cm^2
- Additional handle from dE/dx

Opportunity to provide unprecedented measurements of hadronic shower development to HEP community

WA105 collaboration

WA105

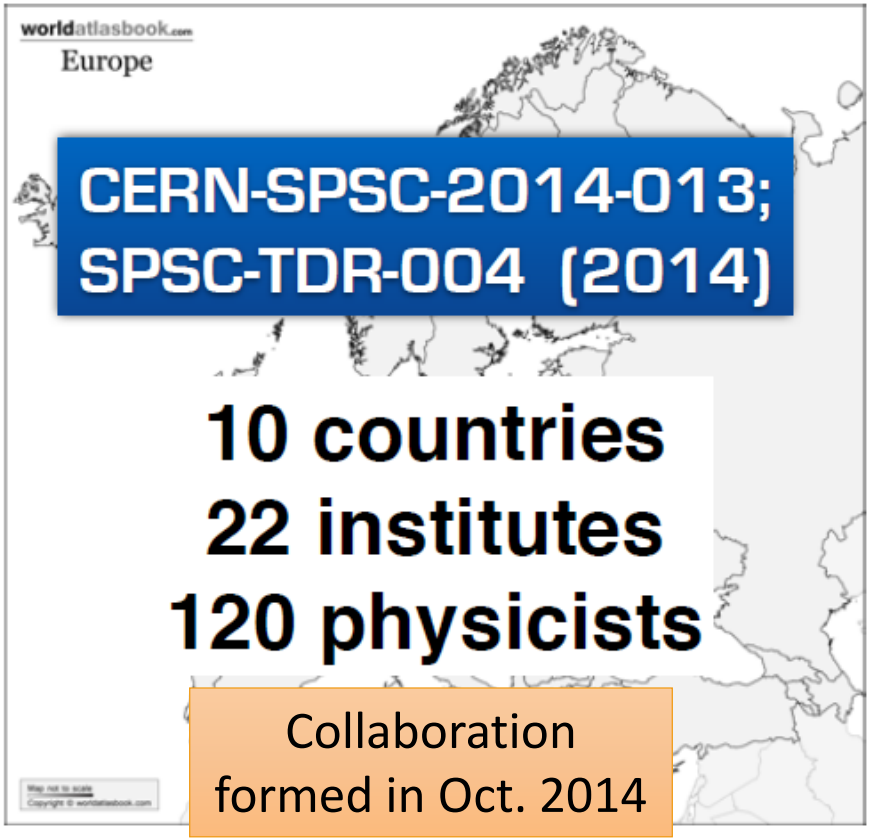
- LAPP, Université de Savoie, CNRS/IN2P3, Annecy-le-Vieux
- OMEGA Ecole Polytechnique/CNRS-IN2P3
- UPMC, Université Paris Diderot, CNRS/IN2P3, Laboratoire de Physique Nucléaire et de Hautes Energies (LPNHE)
- APC, AstroParticule et Cosmologie, Université Paris Diderot, CNRS/IN2P3, CEA/Irfu, Observatoire de Paris, Sorbonne Paris Cité
- IRFU, CEA Saclay, Gif-sur-Yvette
- Université Claude Bernard Lyon 1, IPN Lyon

- Institut de Fisica d'Altes Energies (IFAE), Bellaterra (Barcelona)
- CIEMAT

- University of Glasgow
- University College London

- University of Jyväskylä
- University of Oulu
- Rockplan Ltd

- Horia Hulubei National Institute (IFIN-HH)
- University of Bucharest



CERN-SPSC-2014-013; SPSC-TDR-004 (2014)

10 countries
22 institutes
120 physicists

Collaboration formed in Oct. 2014

- University of Geneva, Section de Physique,
- ETH Zürich

- INFN-Sezione di Pisa

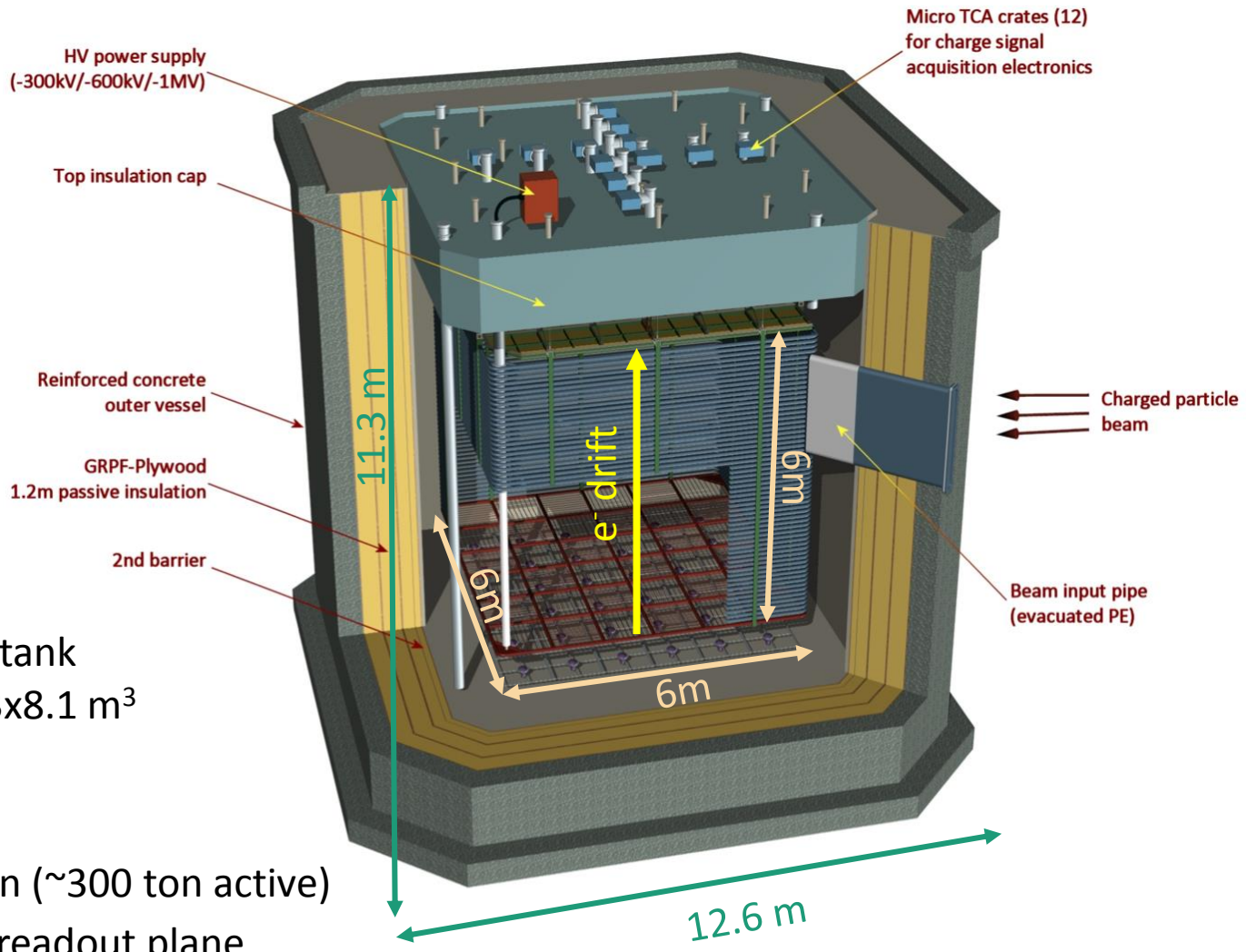
- CERN

- Faculty of Physics, St.Kliment Ohridski University of Sofia

- Institute for Nuclear Research of the Russian Academy of Sciences, Moscow

- High Energy Accelerator Research Organization (KEK)

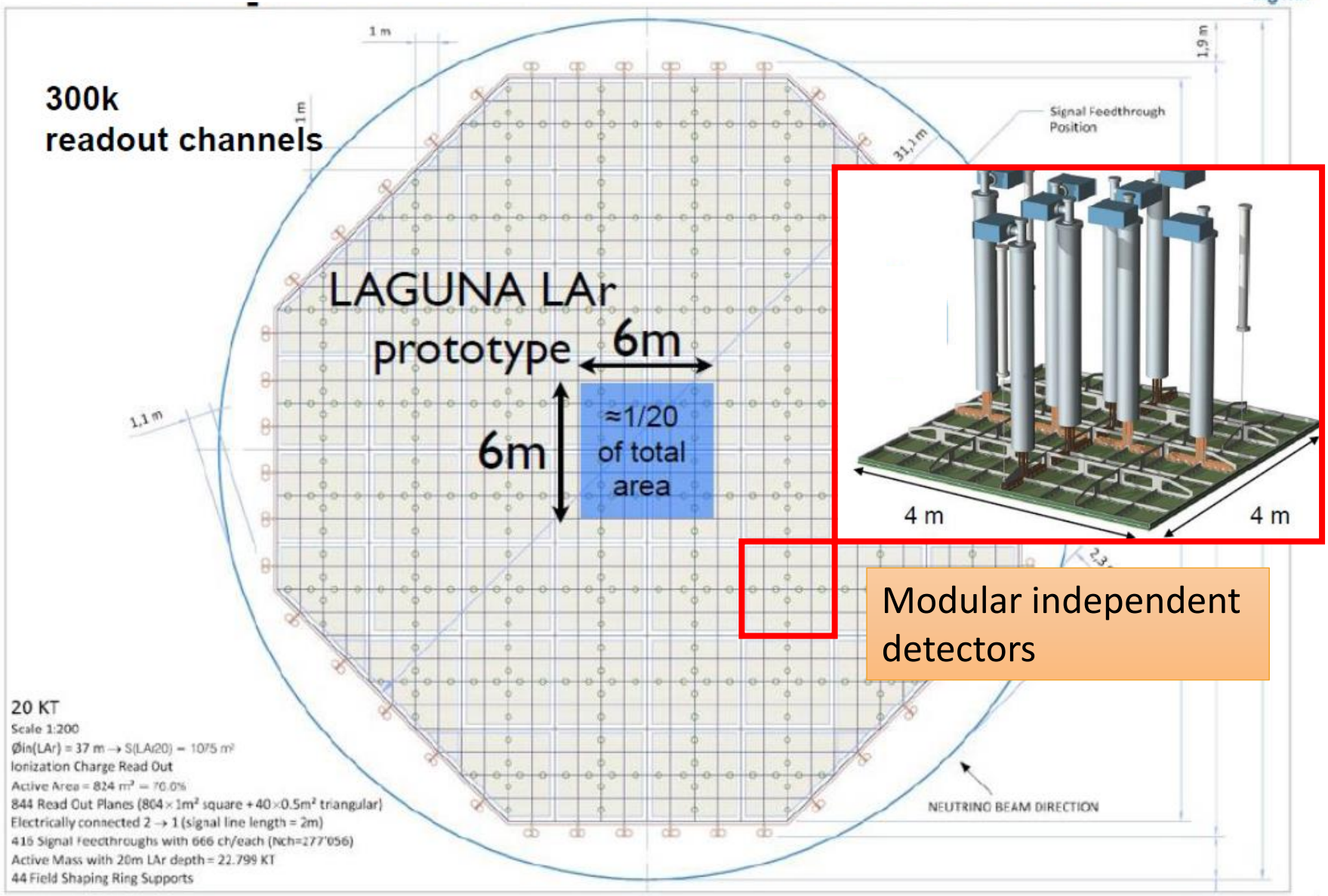
WA105 DLAr detector



Some detector parameters:

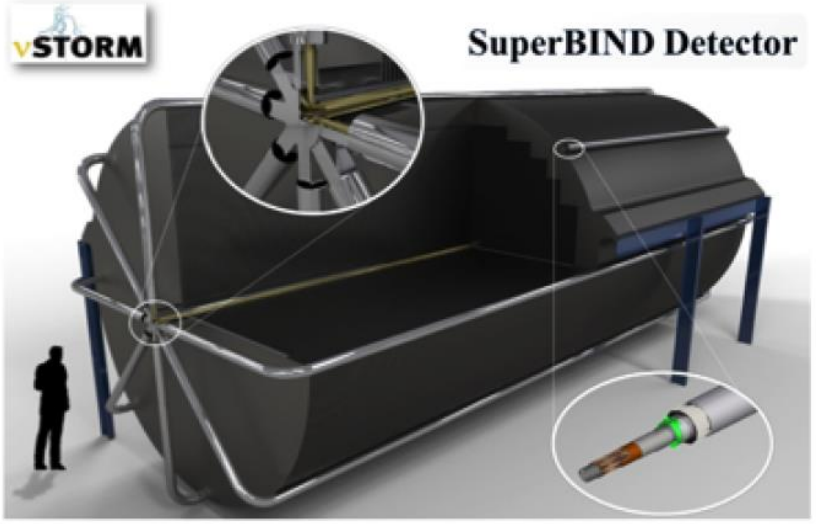
- Insulated membrane tank
  → inner volume 8.3x8.3x8.1 m^3
- Active area 36 m^2
- Drift length 6 m
- Total LAr mass 705 ton (~300 ton active)
- Hanging field cage & readout plane
- # of signal channels: 7680 in 12 signal FT
- # of PMTs: 36

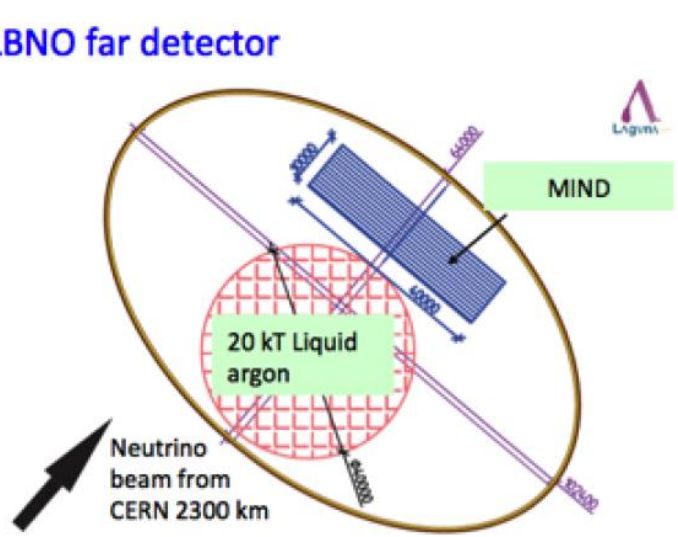
Compared to LAGUNA/LBNO 20 kton DLAr



WA105 MIND

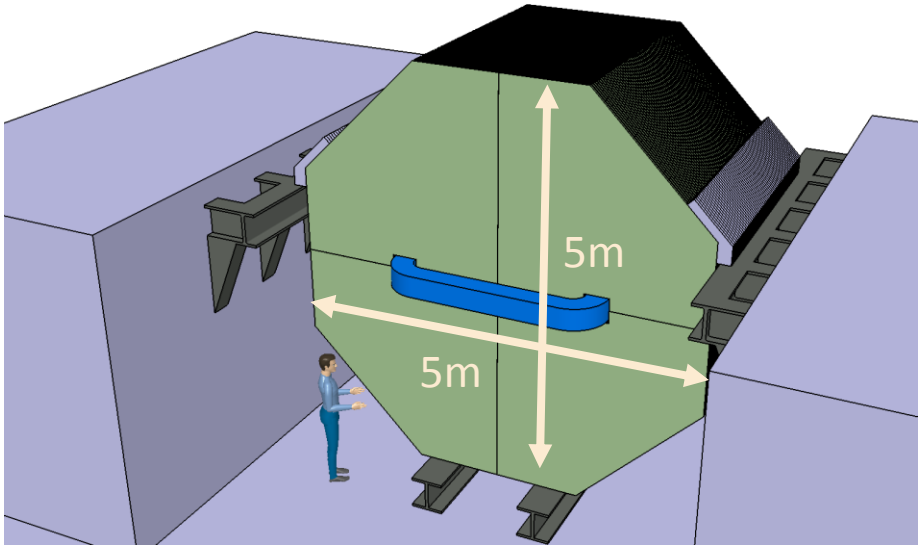
MIND = Magnetized Iron Neutrino Detector



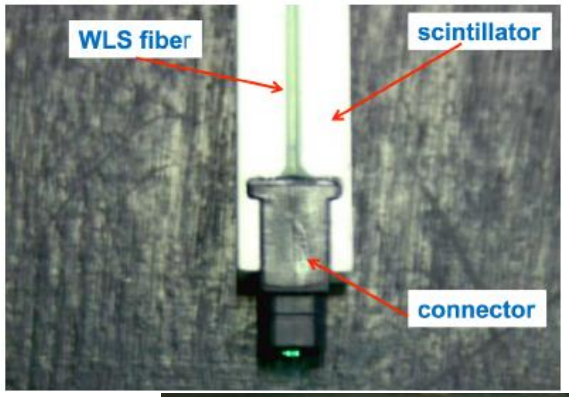


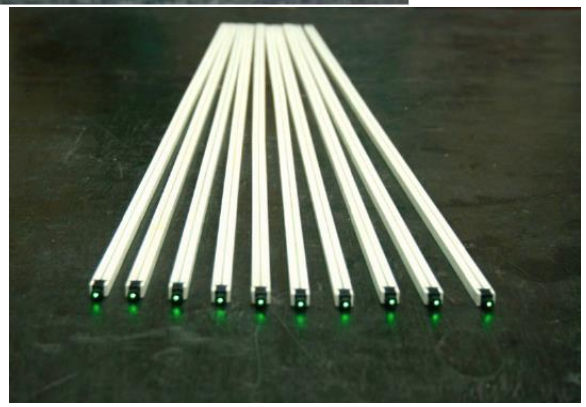
500 ton magnetized iron detector demonstrator installed after LBNO-Demo

- Track secondaries escaping from DLAr
- Complement momentum reconstruction of high energy muons
- Study reconstruction for charge ID of low energy muons (<1 GeV)



MIND activities



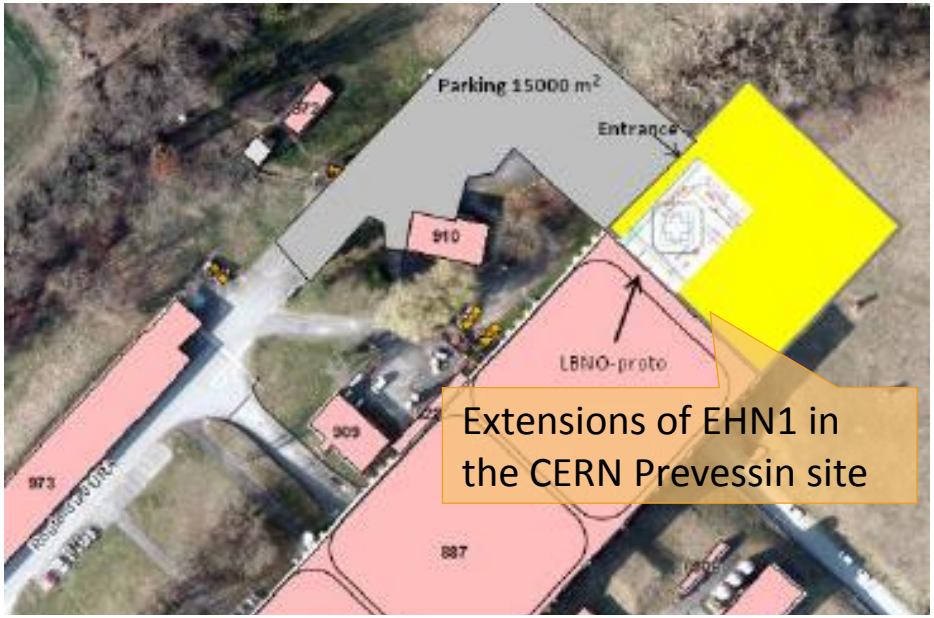


Detector modules R&D

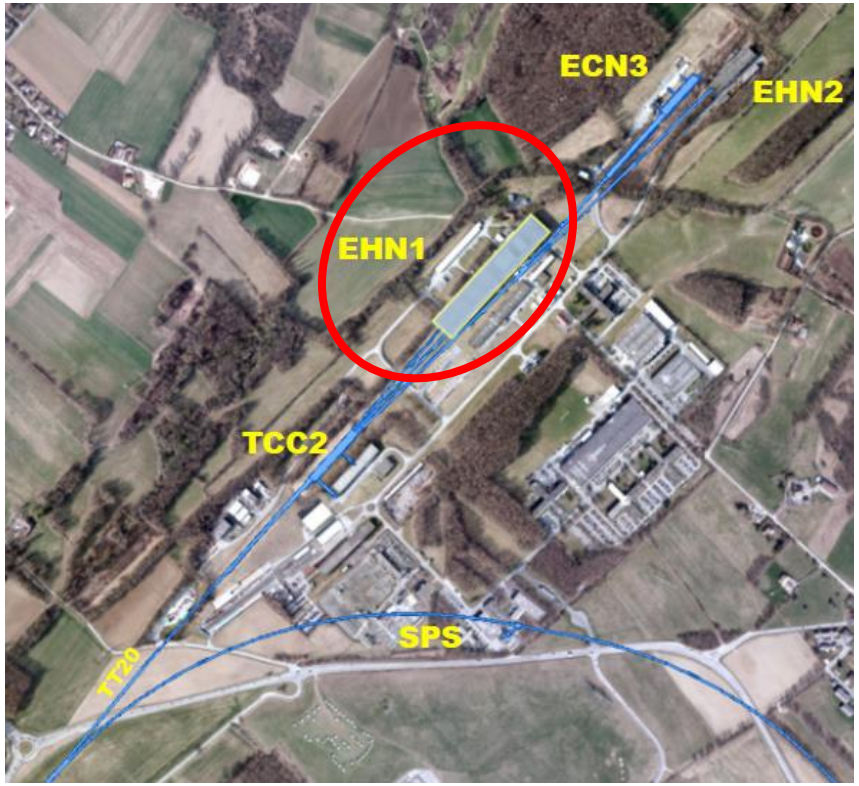
- SiPM photosensors
- Plastic scintillators
- Wavelength shifting fiber
- Integrated electronics & DAQ

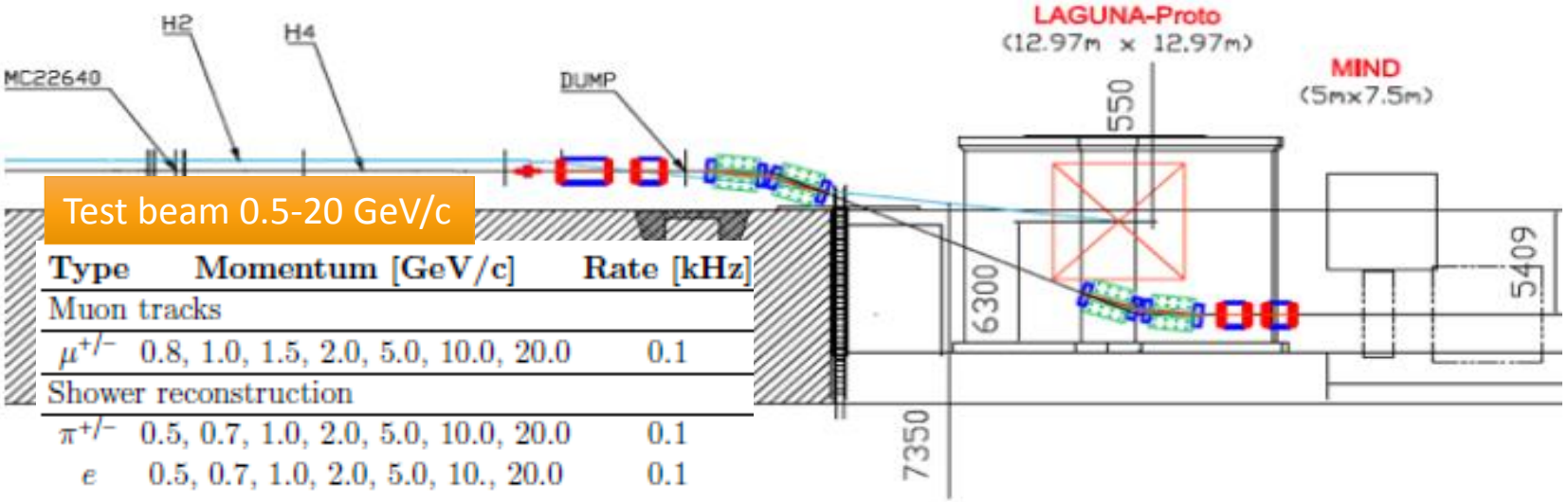
- Optimization of detector performance & costs
- MIND prototype 50 ton detector (“Baby MIND”) for test beam in SPS H8 beamline (0.5 – 9 GeV/c range)

WA105 at CERN



Extensions of EHN1 in the CERN Prevessin site



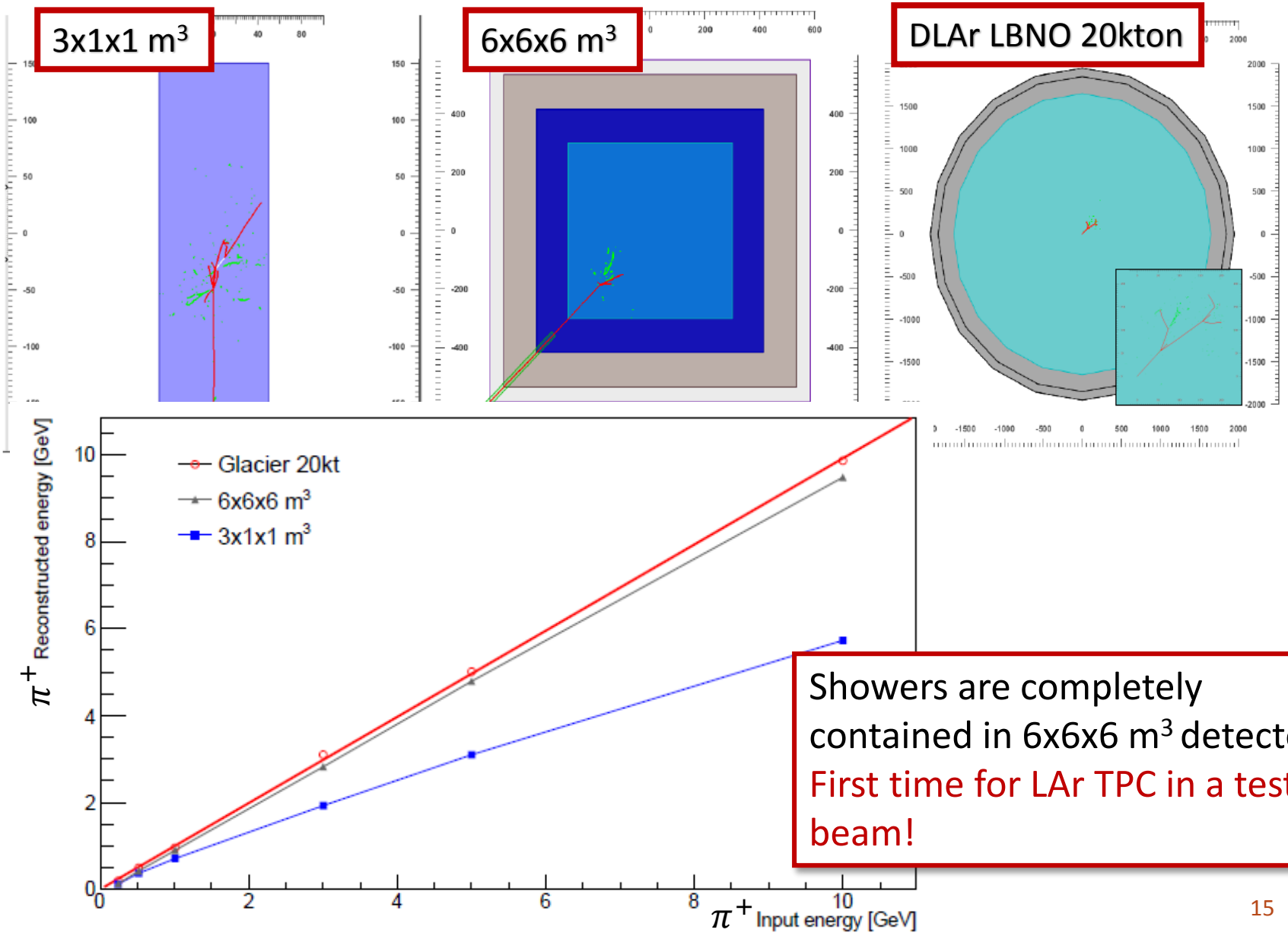


Test beam 0.5-20 GeV/c

Type	Momentum [GeV/c]	Rate [kHz]
Muon tracks		
$\mu^{+/-}$	0.8, 1.0, 1.5, 2.0, 5.0, 10.0, 20.0	0.1
Shower reconstruction		
$\pi^{+/-}$	0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 20.0	0.1
e	0.5, 0.7, 1.0, 2.0, 5.0, 10., 20.0	0.1


The EHN1 extension - 28 October 2014
LBNO-Demo

Particle containment in LBNO-Demo

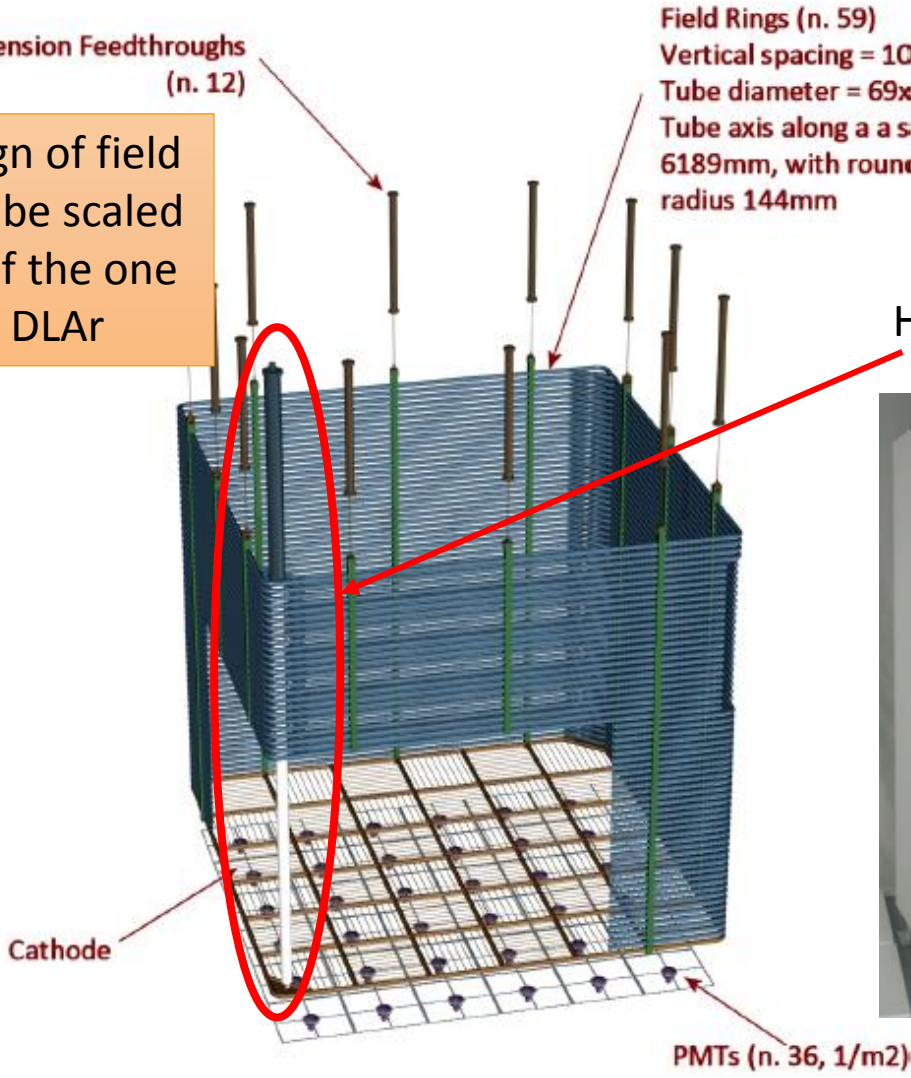


Showers are completely contained in 6x6x6 m^3 detector

First time for LAr TPC in a test beam!

TPC drift cage and HV

The design of field cage will be scaled version of the one for LBNO DLAr

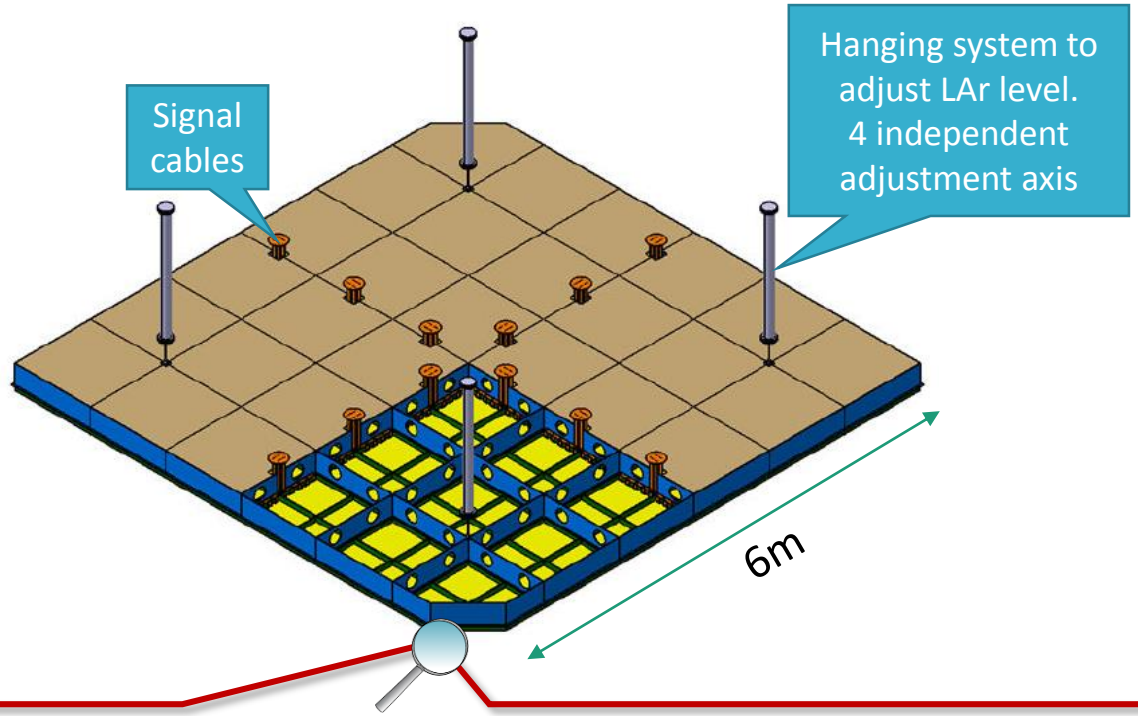


High voltage feed-through

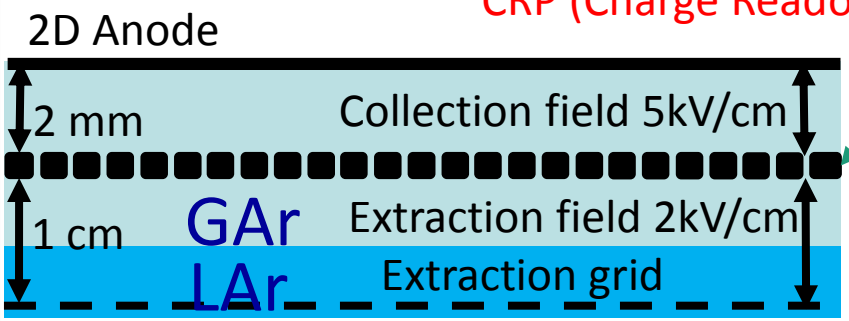
Off-shelf 300kV PS from Heinzinger GmbH
→ can operate with 0.5 kV/cm drift field over 6m

R&D with industry to find a solution to get to 1kV/cm (600 kV PS)

Charge readout deck

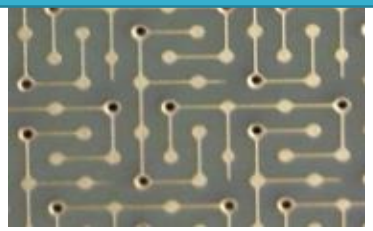


CRP (Charge Readout Plane) structure

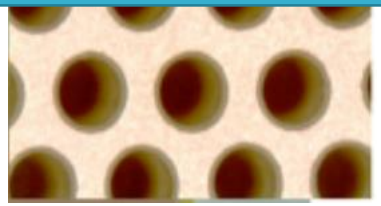


1mm thick LEM (Large Electron Multiplier) 25-35 kV/cm

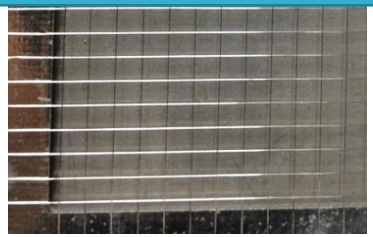
Multilayer PCB anode. 3.125 mm pitch



LEM: 500 μm holes, 800 μm pitch, 1mm thick FR4

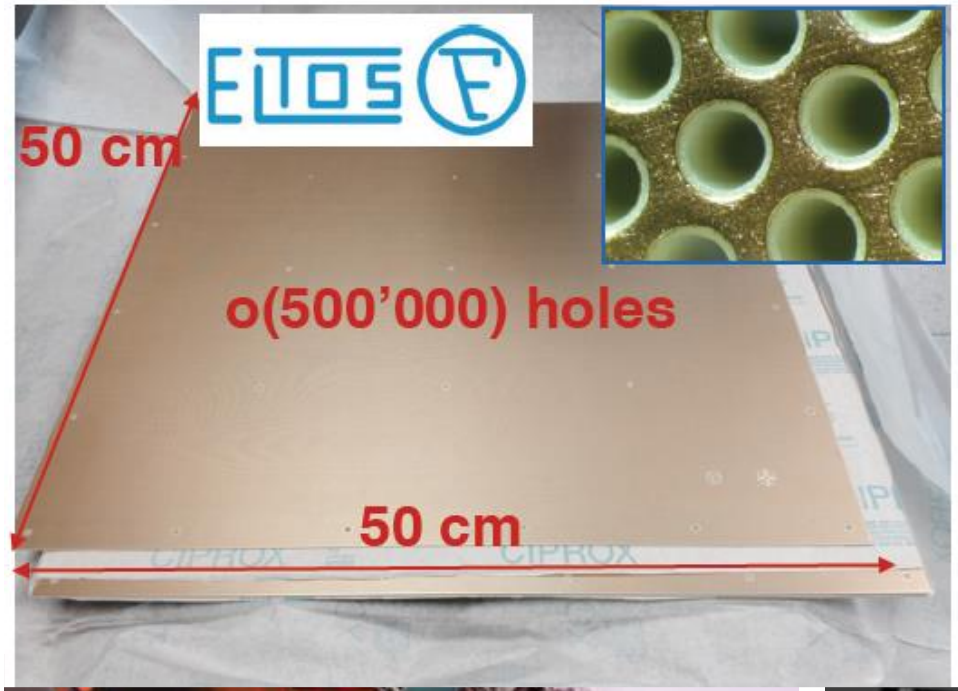


Extraction grid: 100 μm stainless still wires 3mm pitch in x and y



CRP based on years of extensive R&D → See S. Murphy talk

Large area LEMs

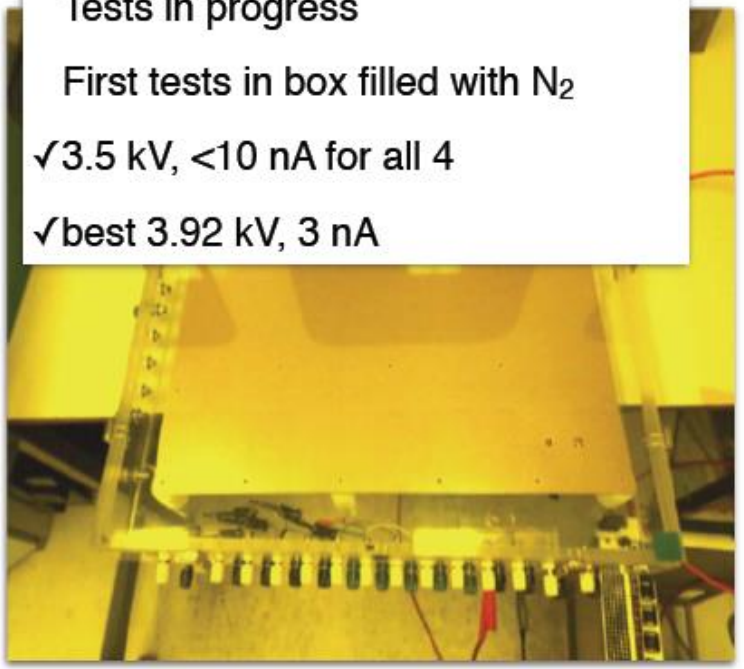


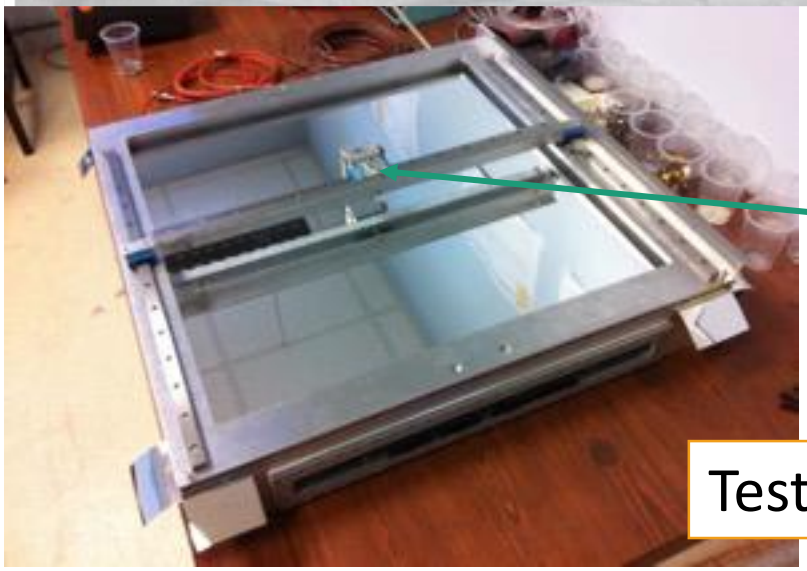
Tests in progress

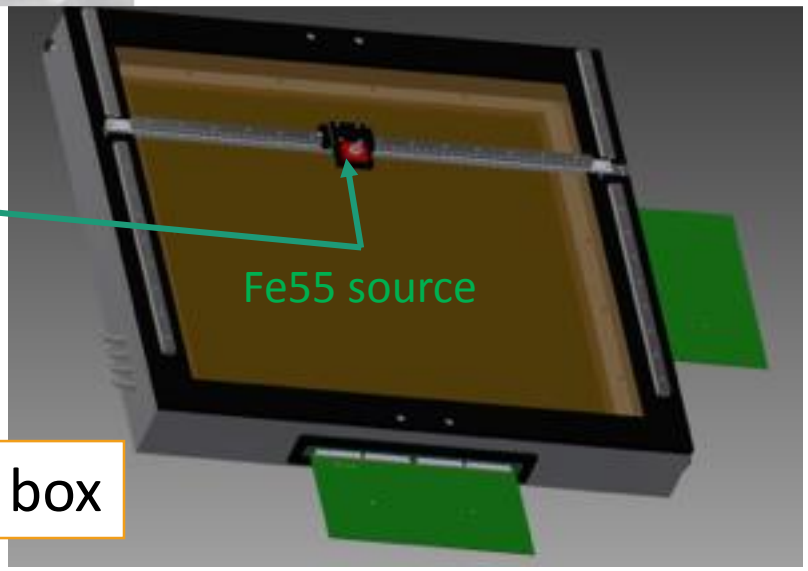
First tests in box filled with N_2

✓3.5 kV, <10 nA for all 4

✓best 3.92 kV, 3 nA



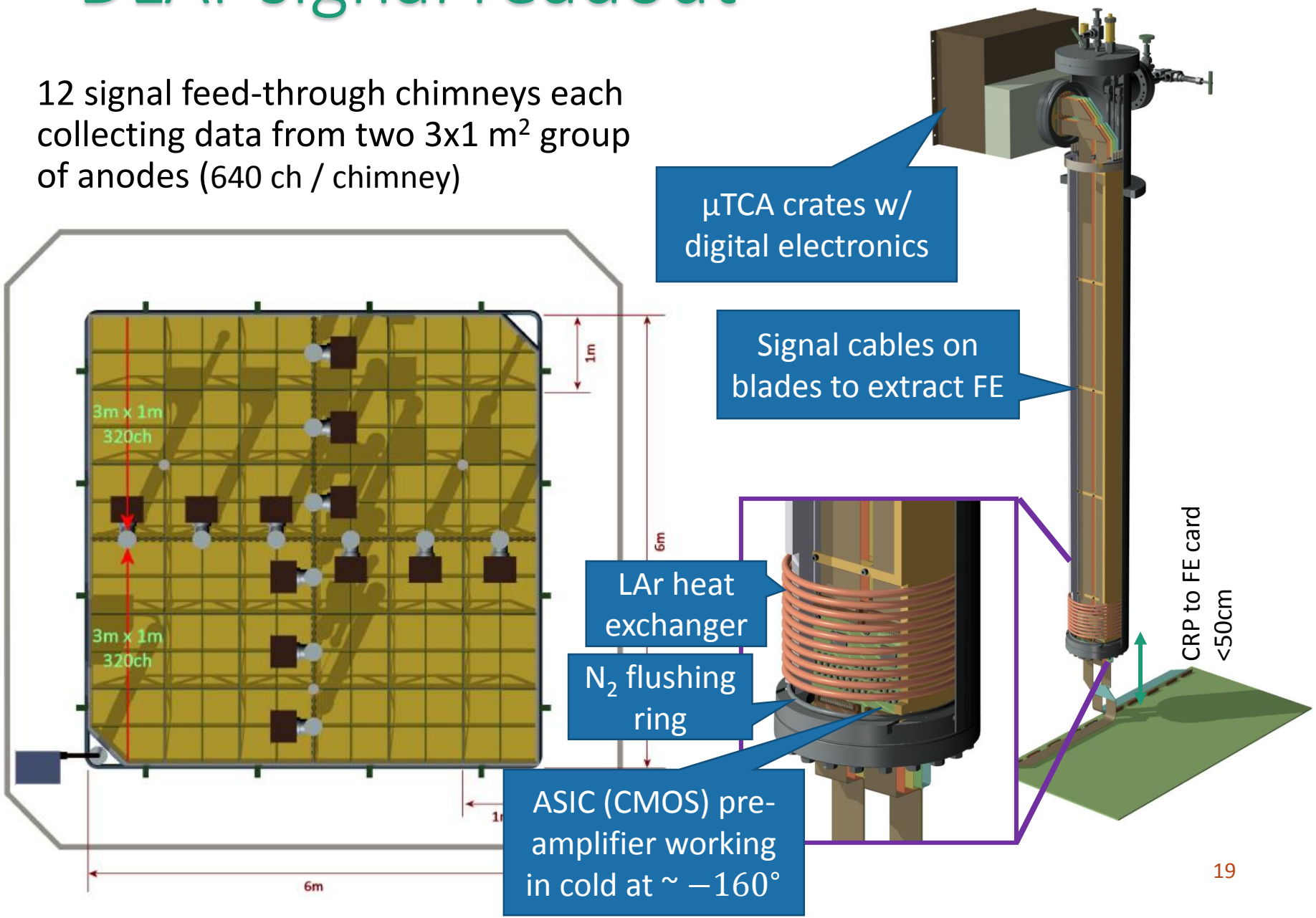




Test box

DLAr signal readout

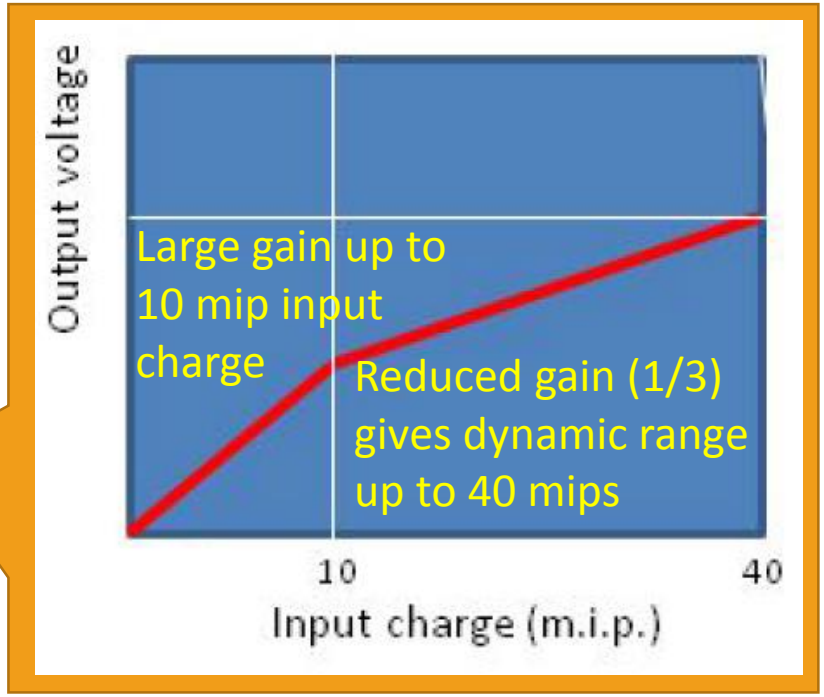
12 signal feed-through chimneys each collecting data from two 3x1 m^2 group of anodes (640 ch / chimney)



Front-end and back-end electronics

16 channel ASIC with CMOS-based pre-amplifiers

- Low noise due to ambient temperature of 110 K and proximity to CRP (short cables)
- Power consumption 18mW/ch
- Large dynamic range up to 40 mip using double slope structure of the gain

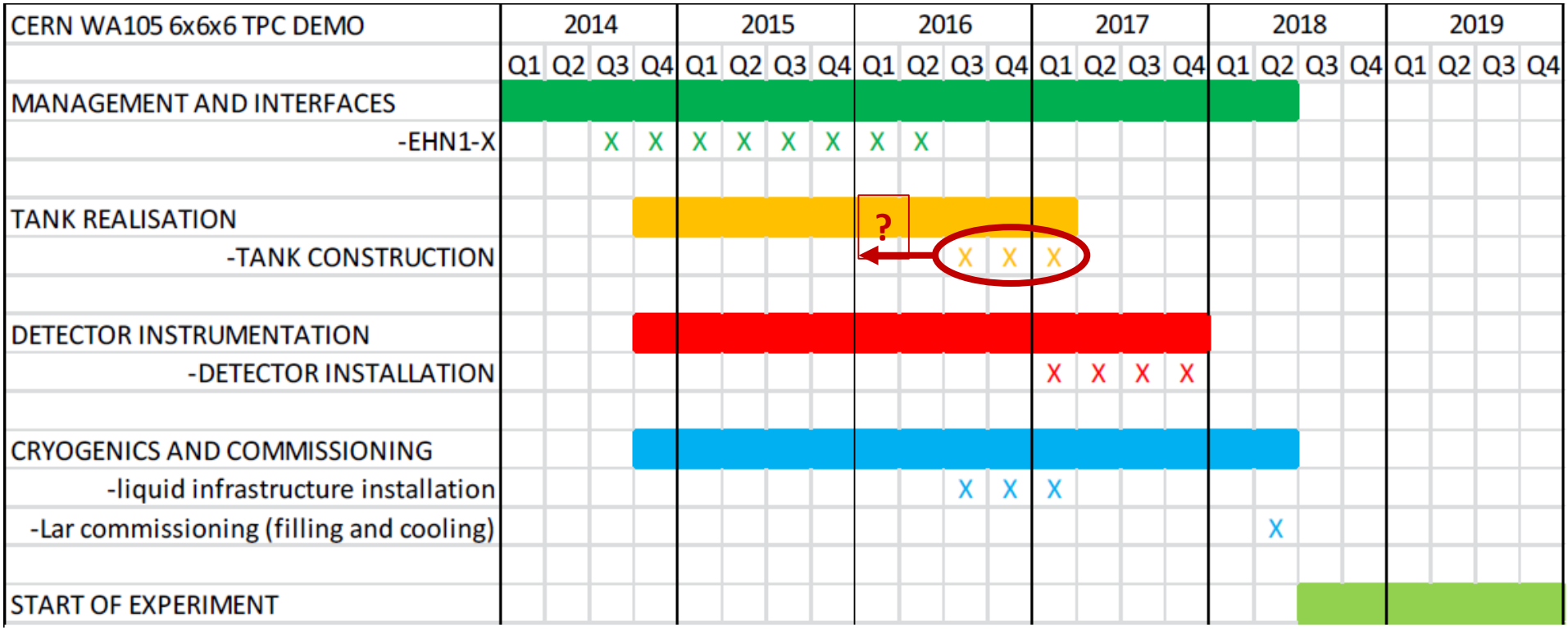


Back-end electronics in warm zone on the tank deck

- DAQ system based on micro-TCA standards
- Readout frequency 2.5MHz
- Total time window of 4000 usec ← covers completely 6 m of drift

Scalability to large detectors (300k ch for 20 kton) at low cost

Timescale



Construction of EHN1 extension on the critical path

Optimization of construction schedule

Currently aim to start data taking by mid 2018

Summary

WA105 will construct a ~700 ton DLAr detector (LBNO-Demo) at CERN

- Demonstrate double-phase technology for large LAr detectors
- Validate the technical designs developed by LAGUNA/LBNO
- Study detector performance with dedicated charged particle beam

Successful operation of LBNO-Demo opens the door towards large and affordable underground DLAr observatory for LBNO/LBNF

Thank you

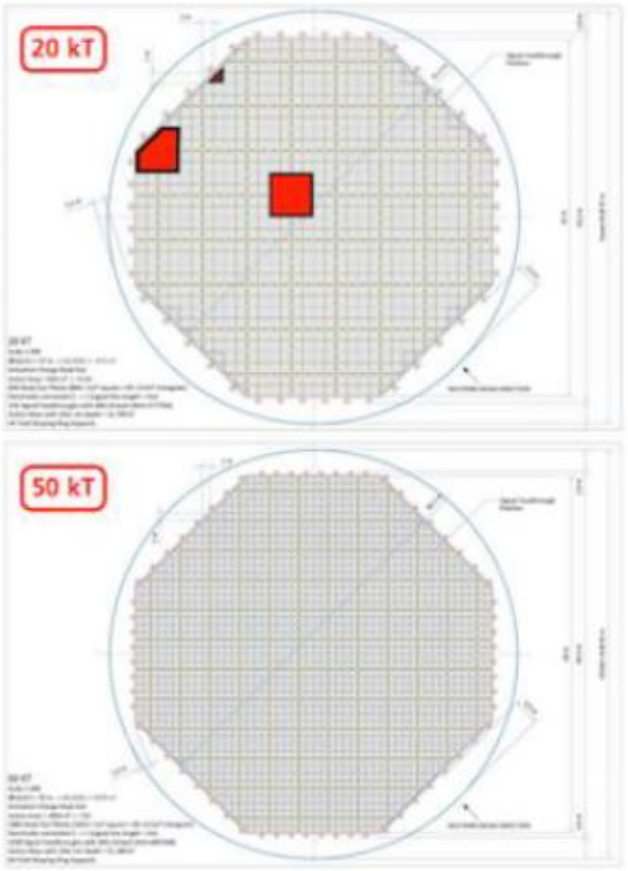
Back-up material

LBNO-DEMO detector fact sheet

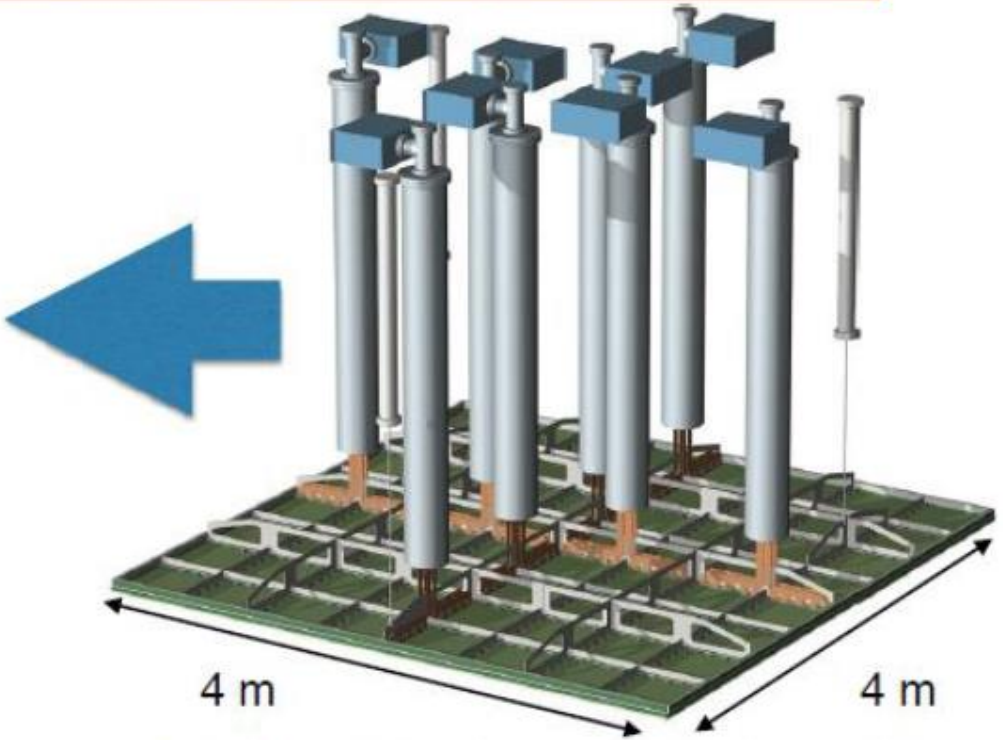
Liquid argon density	T/m^3	1.38
Liquid argon volume height	m	7.6
Active liquid argon height	m	5.99
Hydrostatic pressure at the bottom	bar	1.03
Inner vessel size (WxLxH)	m^3	$8.3 \times 8.3 \times 8.1$
Inner vessel base surface	m^2	67.6
Total liquid argon volume	m^3	509.6
Total liquid argon mass	t	705
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

GLACIER 20kt, 50kt: 4x4 m² modules

Each Charge Readout Plane is an independent detector

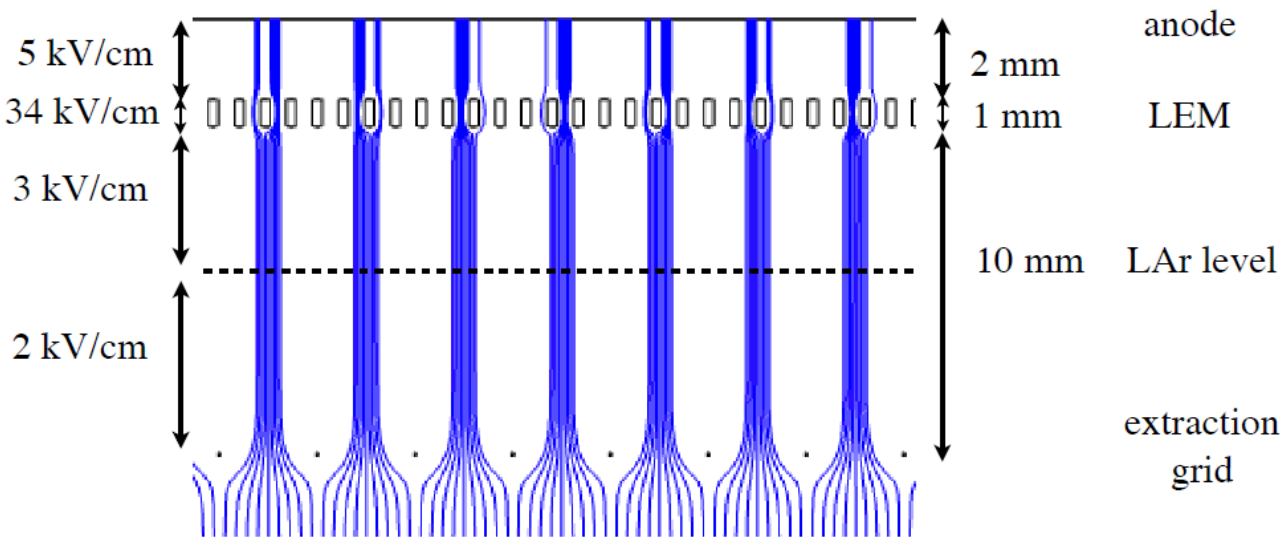


different geometries but all with the same functionality and identical construction sequence.



- Each CRP has its own signal and HV feed throughs
- Adjustable to LAr level
- The LBNO demonstrator will have an enlarged 4x4 m² => 6x6m²

CRP alignment requirements



Tolerances are calculated to keep gain stability <5%

	[mm]	electric field [kV/cm]	tolerance [mm]
anode-LEM	2	5	0.1
LEM	1	34	0.01
LEM-grid	10	2	1
liquid level	5 (from grid)	-	1

Charge deposition