WA105 Experiment

a large demonstrator of LAr double-phase TPC

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on behalf of WA105 collaboration

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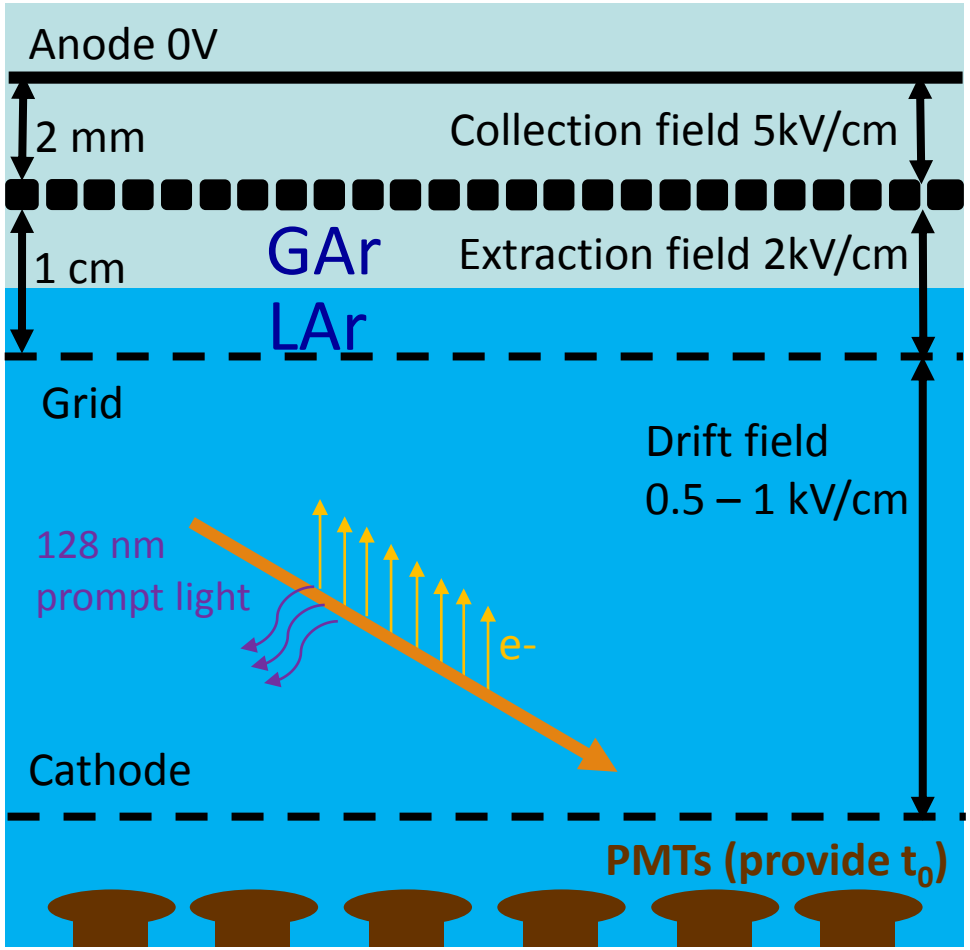
Large-scale liquid argon TPC

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

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

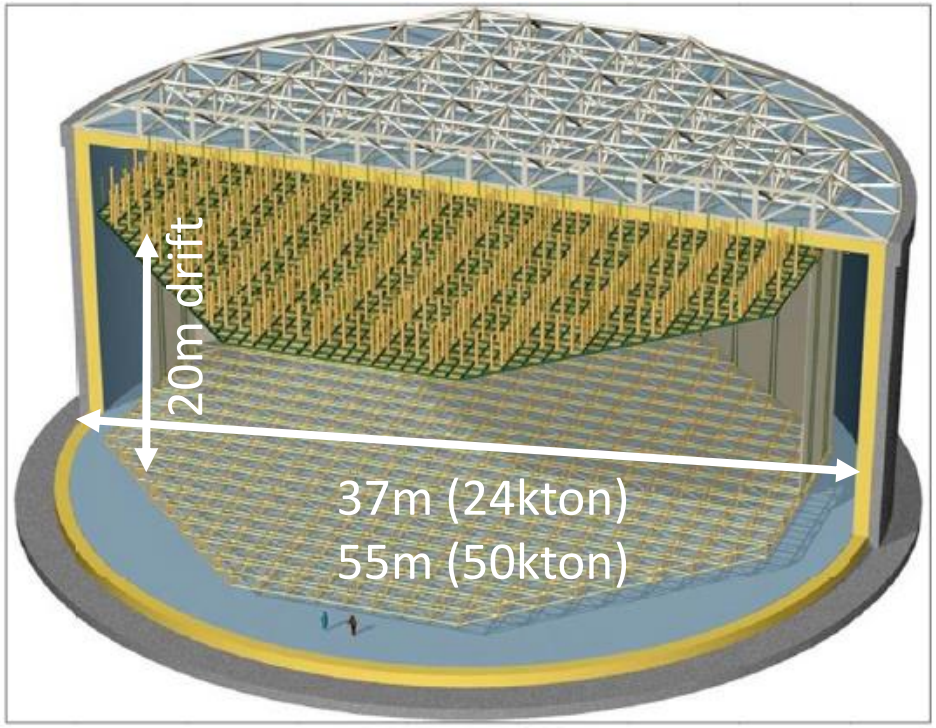


Large scale LAr TPC for LBL neutrino oscillation physics, astrophysics, and nucleon decay search (GUT physics)

- Cryostat based on industrial LNG solution to house O(10) kton of LAr mass
  - Fully active TPC volume with no dead material
- Double-phase for charge readout to achieve electron amplification:
  - Long drift distances
  - Low energy detection thresholds
  - Improved S/N ratio

LAGUNA-LBNO DLAr detector

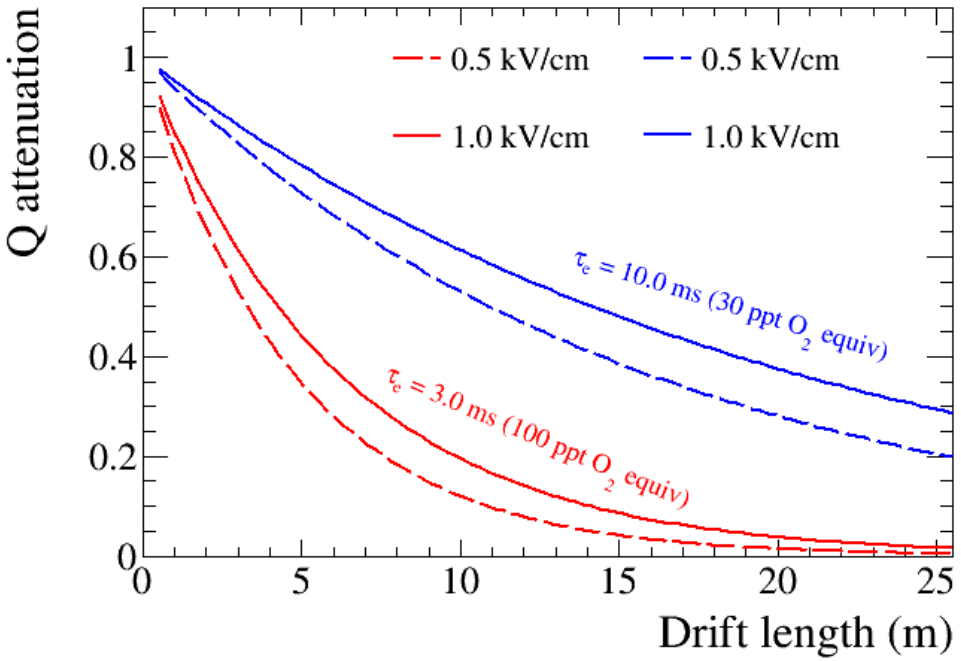
Fully engineered design for ~24kton and ~50kton detectors from LAGUNA/LBNO design study (2011-2014)



- Tank constructed using LNG technologies
- Affordable solution for underground installation
- 1MV voltage on the cathode → 0.5 kV/cm drift field
- Hanging field cage structure → no contact with the tank floor
- Charge collection in two views
- Tunable gain: 20 – 100
- Accessible front-end electronics

Technical aspects to be addressed

- Purity in non-evacuated tank
  <100 ppt of O_2 equivalent is required
- 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 concept for O(10) kton detectors

WA105 physics case

LAr TPC provide a fully active homogeneous medium

Rich physics program based on test beam data

- Development and validation of automatic event reconstruction in LAr
- Assessment of PID performance
- Validation of e/π^0 rejection
- Study of energy resolution and scale for calorimetric measurement of electronics and hadronic showers
- Charged pions and proton cross sections on Ar nuclei
- Characterization of hadronic shower development at unprecedented granularity scale
  - Readout out pitch gives an area resolution of 3x3 mm^2

WA105 collaboration

WA105

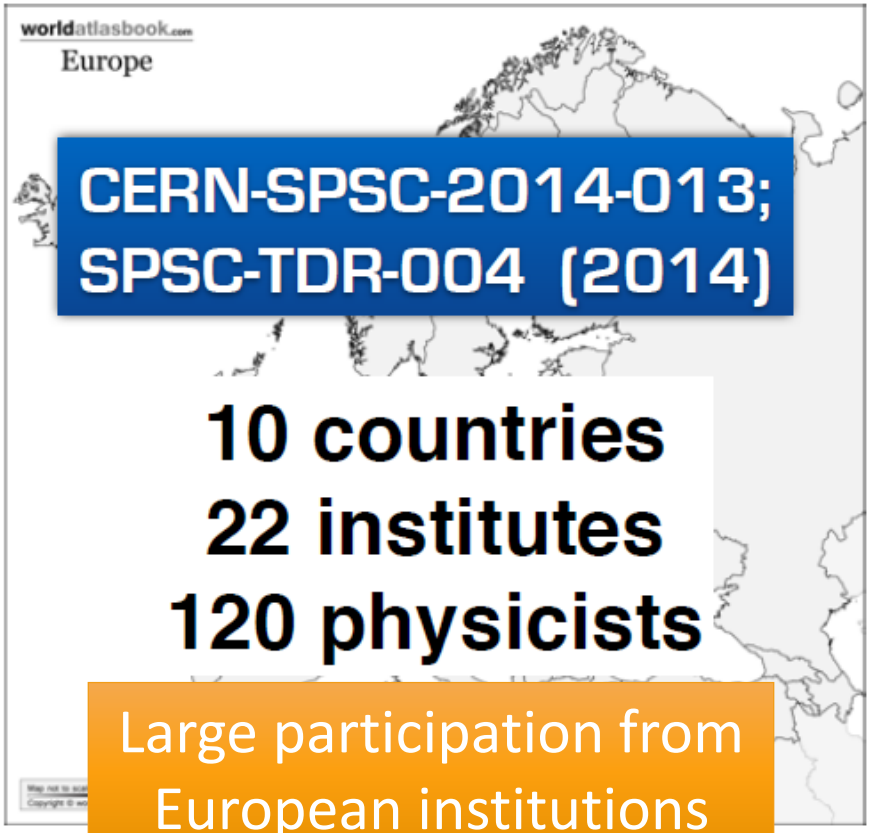
- LAPP, Université de Savoie, CNRS/IN2P3, Annecy-le-Vieux
- OMEGA Ecole Polytechnique/CNRS-IN2P3
- UPMC, Université Paris Diderot, CNRS/IN2P3, Laboratoire de Physique Nucléaire et de Hautes Energies (LPNHE)
- APC, AstroParticule et Cosmologie, Université Paris Diderot, CNRS/IN2P3, CEA/Irfu, Observatoire 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

Large participation from European institutions

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

- INFN-Sezione di Pisa

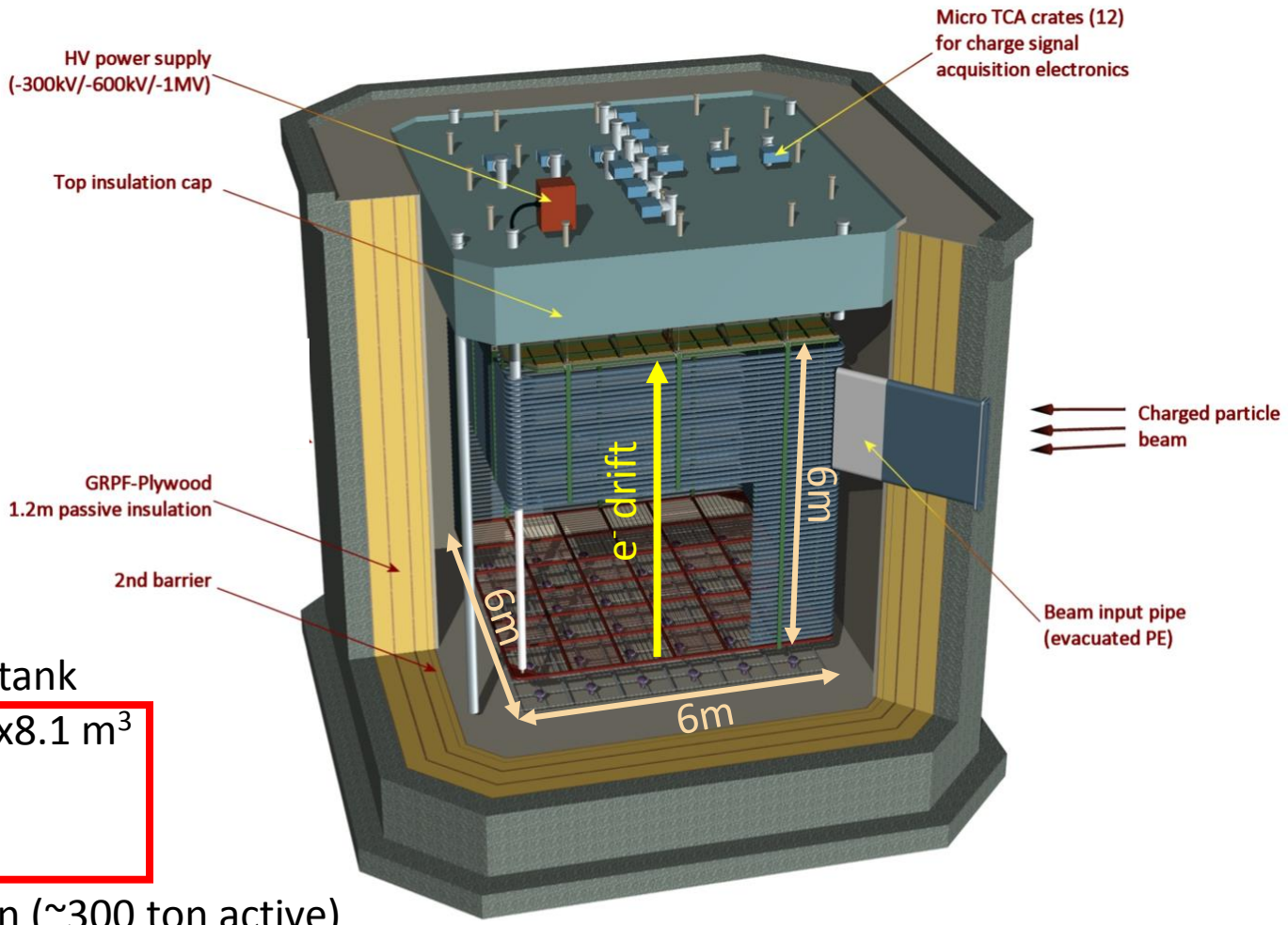
- CERN

- 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

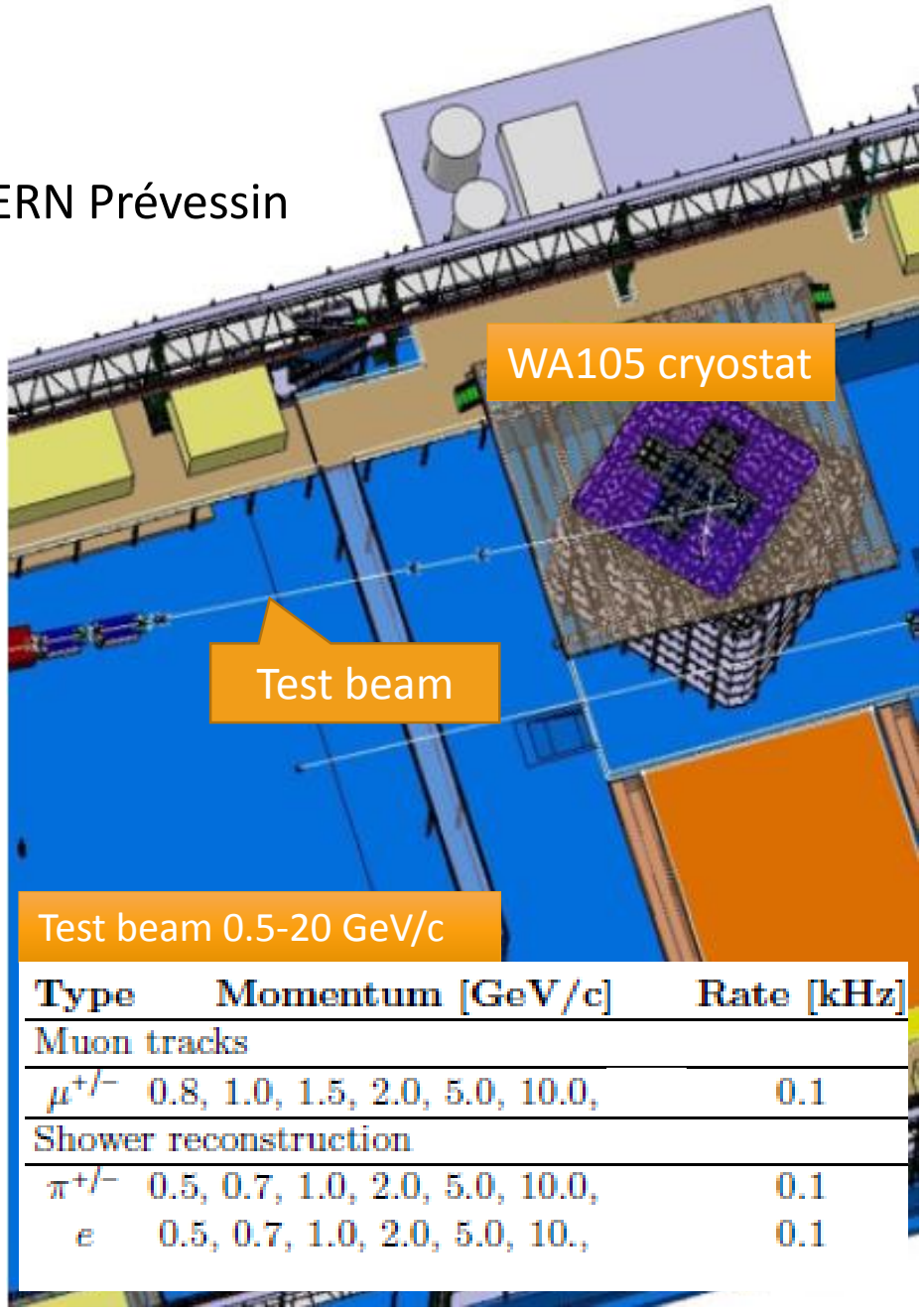


Some detector parameters:

- 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

WA105 at CERN

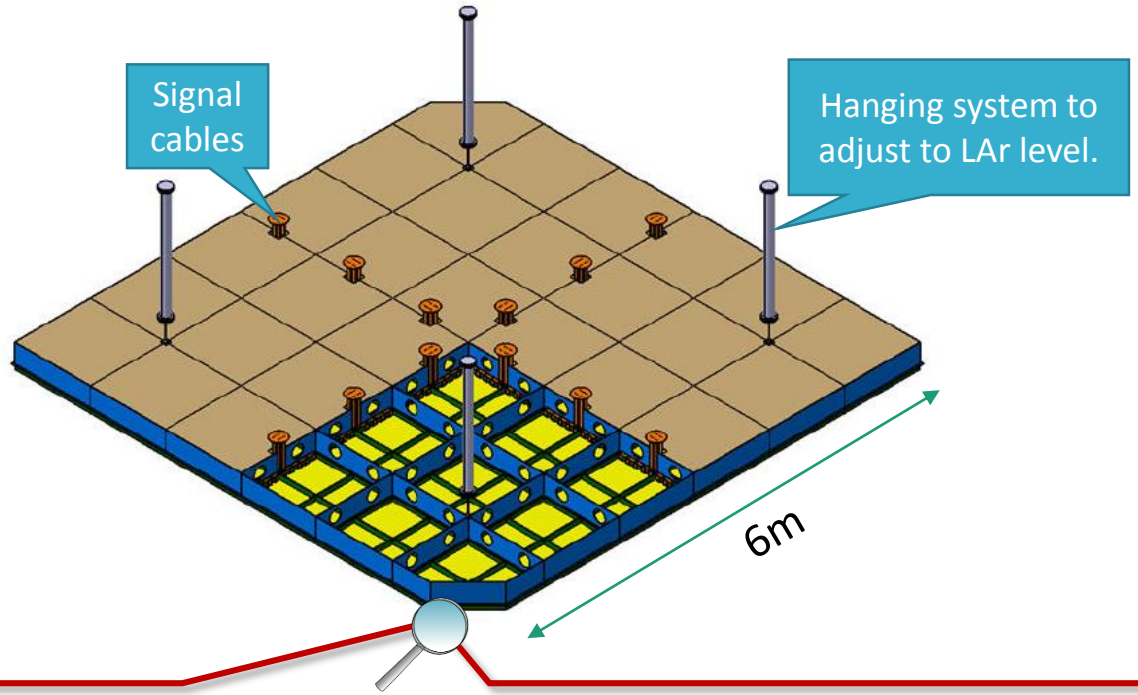
Extensions of EHN1 test beam facility at CERN Prévessin



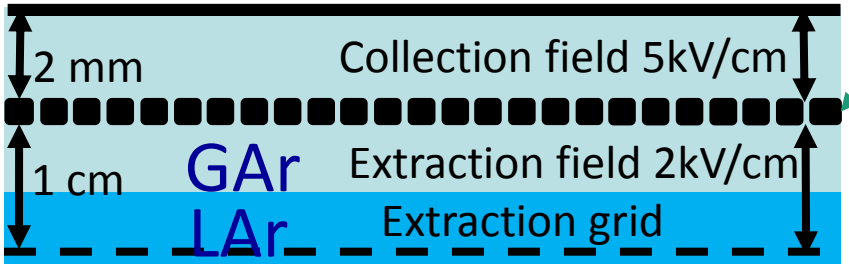
Test beam 0.5-20 GeV/c

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

Charge readout deck

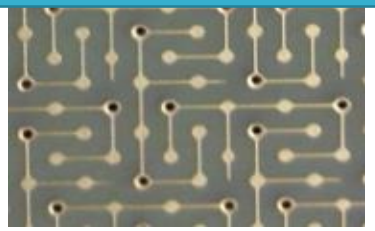


CRP (Charge Readout Plane) structure

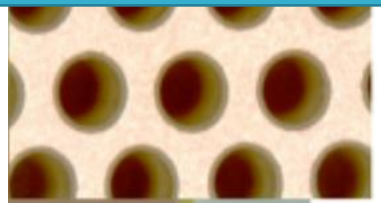


1mm thick LEM (Large Electron Multiplier) 25-35 kV/cm

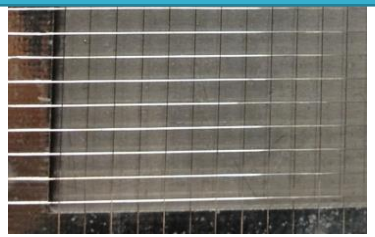
Multilayer PCB anode. 3.125 mm pitch



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

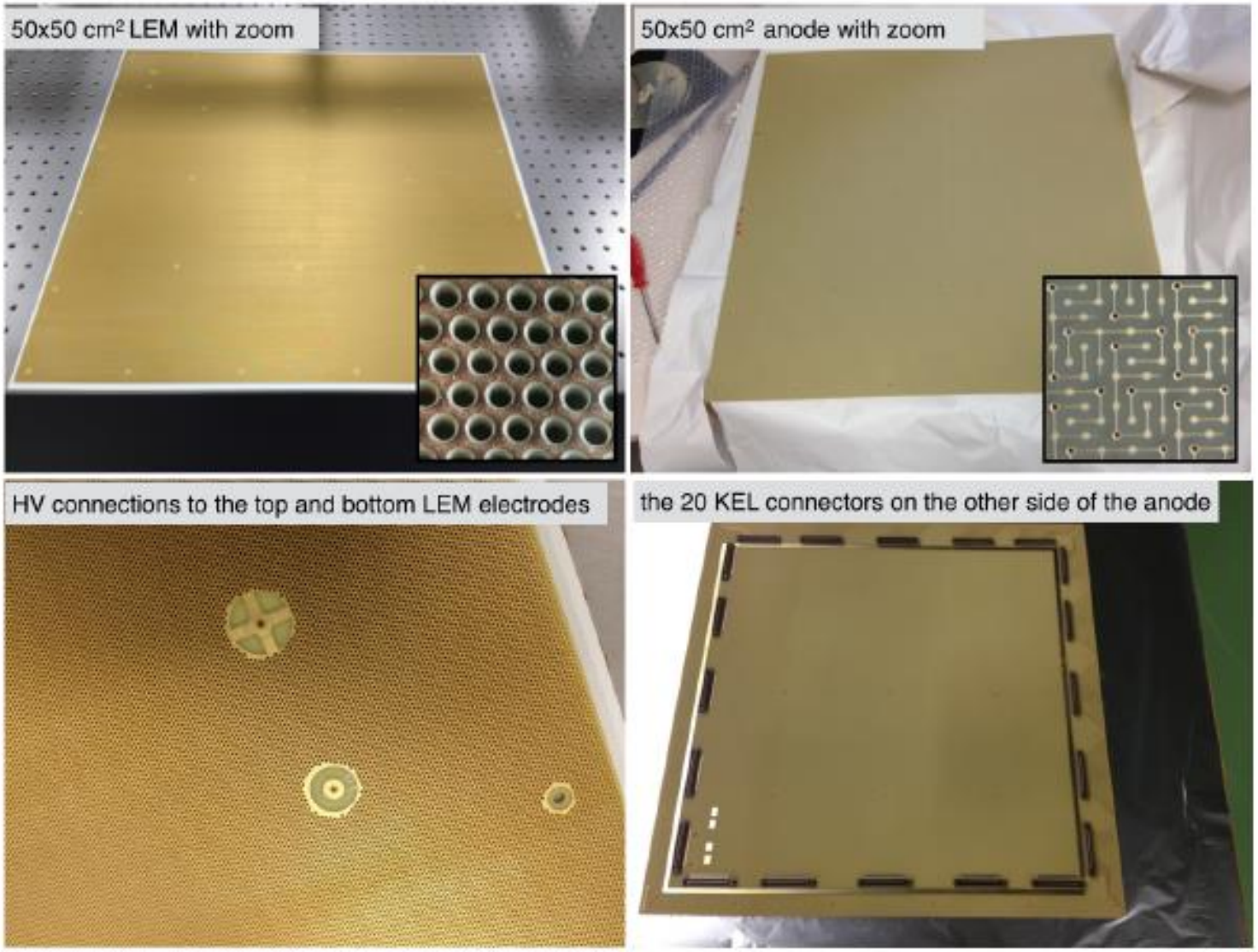


Extraction grid: 100 μm stainless still wires 3mm pitch in x and y

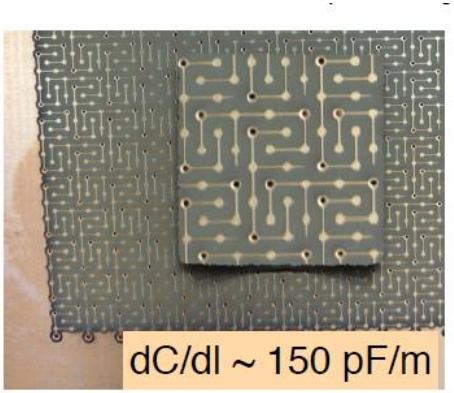


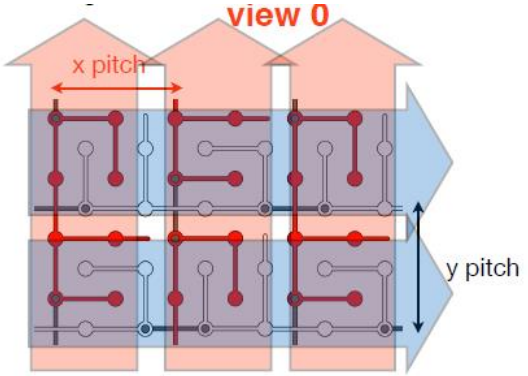
LEM and Anode

The charge readout plane is built from 50x50cm^2 LEMs and anode PCBs

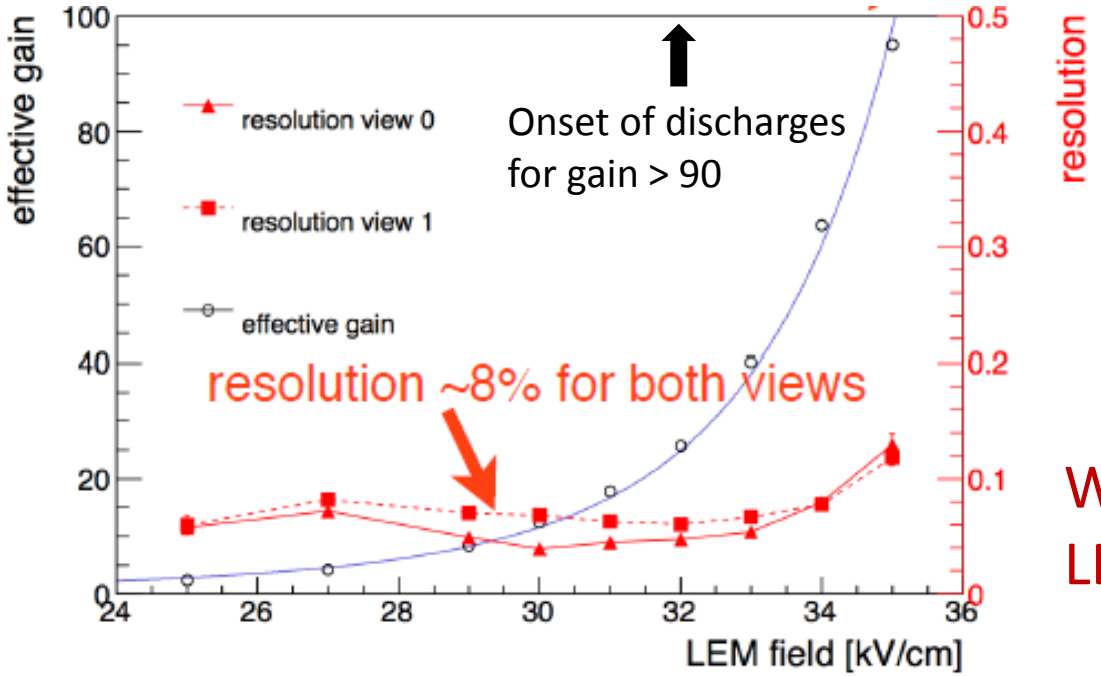


Charge readout based on long-standing R&D efforts





Anode: multi-layer PCB with symmetric charge sharing between x-y views



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

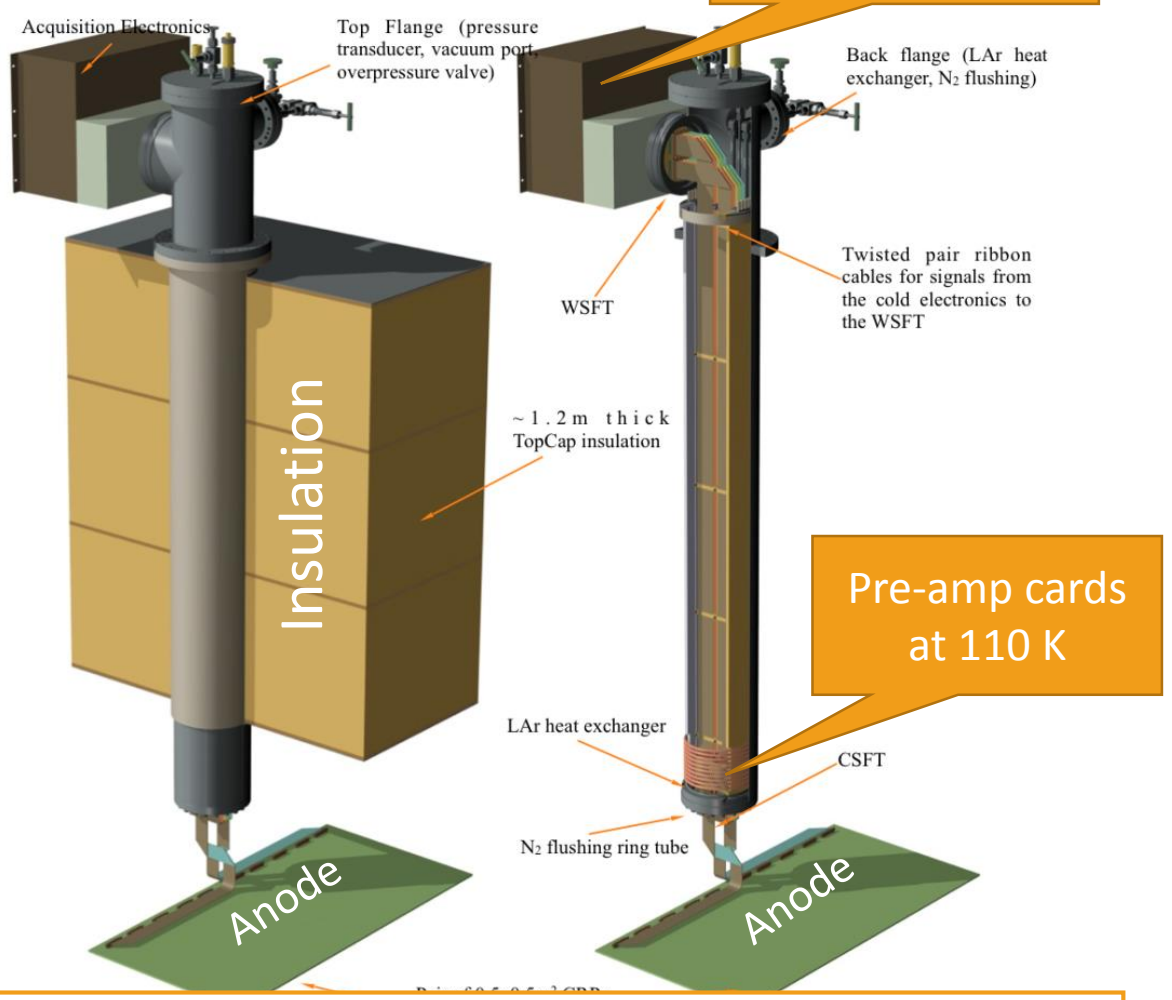
Geometry optimization:
JINST 10 (2015) 03, P03017

WA105 plans to operate the LEMs at minimum gain of 20

Signal readout

Leak testing signal FT

µTCA crates with digital electronics



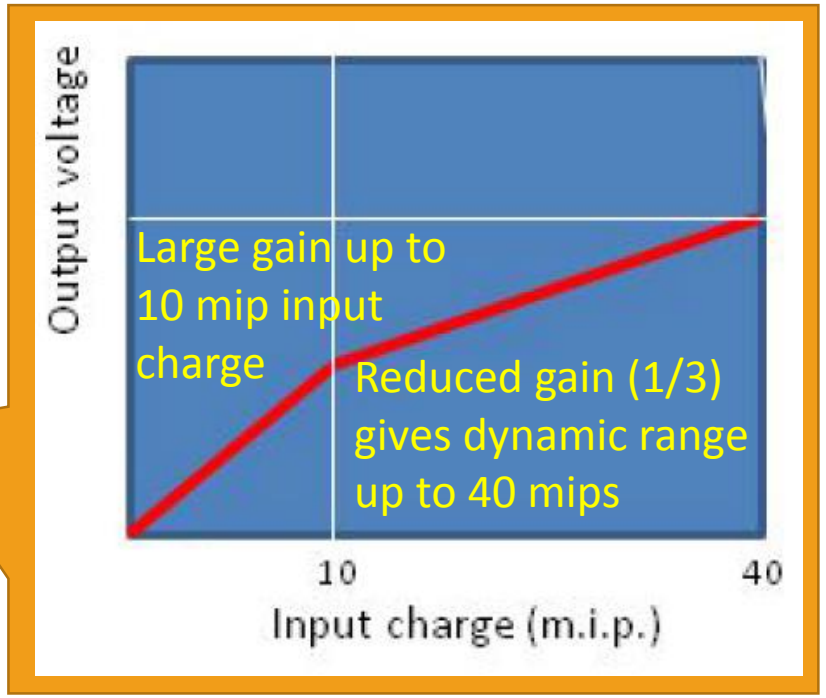
12 signal feed-through chimneys each collecting data from two 3x1 m^2 group of anodes (640 ch / chimney)

Provide access to the FE electronics without opening the main cryostat volume

Front-end and digital electronics

16 channel ASIC with CMOS-based pre-amplifiers

- Low noise due to ambient temperature of 110 K and proximity to anode(short cables)
- Power consumption 18mW/ch
- Large dynamic range up to 40 mip using double slope structure of the gain
- R&D since 2006



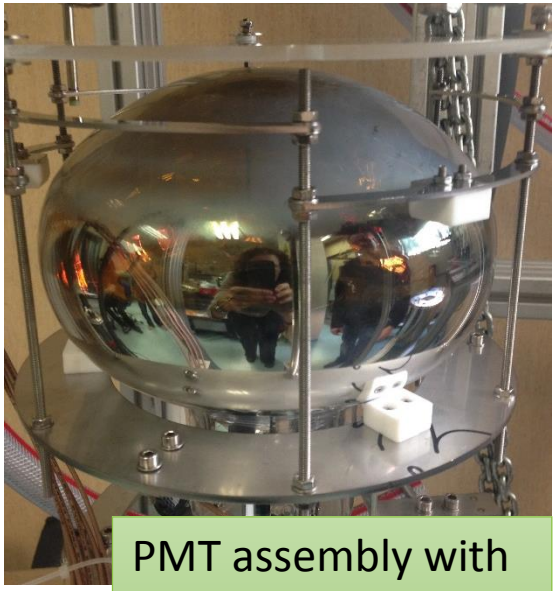
Digital electronics in warm zone on the tank deck

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

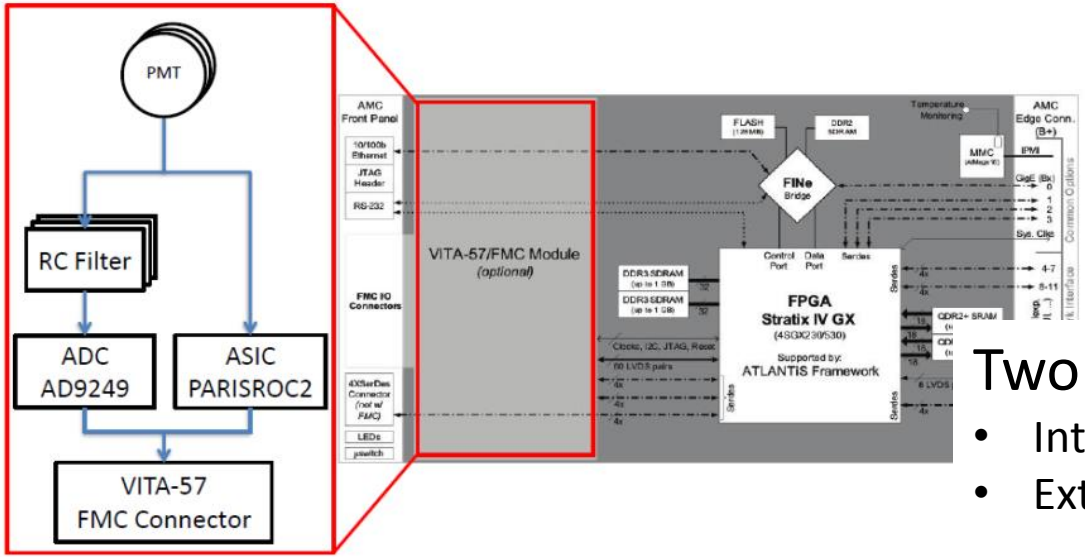
Scalability to large detectors (150k ch for 10 kton) at low cost

Light readout system

- Primary goal to provide T0 (and for underground operation trigger) for events
- For WA105 (surface operation) critical to tag cosmic ray muon arrival time
- 36 x 8” Hamamatsu R5912mod2 PMTs
- TPB coating to shift 128 nm to visible wavelengths



PMT assembly with TPB coated window



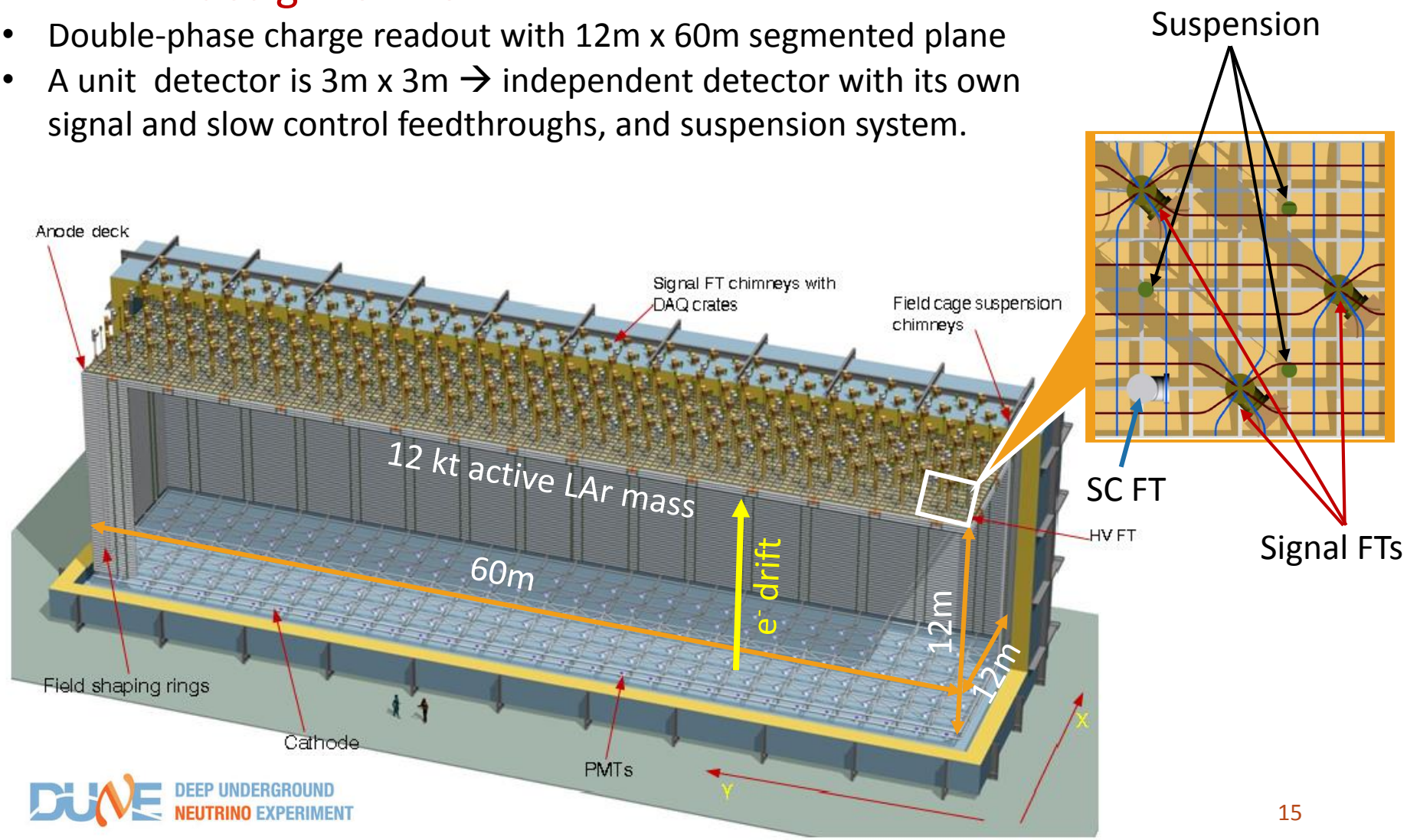
Two modes of acquisition:

- Internal trigger from PARISROC2 ASIC
- External beam trigger

WA105 in the global context

DLAr TPC design for DUNE

- Double-phase charge readout with 12m x 60m segmented plane
- A unit detector is 3m x 3m → independent detector with its own signal and slow control feedthroughs, and suspension system.



DEEP UNDERGROUND NEUTRINO EXPERIMENT

Summary

WA105 experiment will construct a double-phase LAr TPC with a ~300 ton fiducial mass

- Demonstrate double-phase technology for large LAr detectors
- Validate the technical designs developed by LAGUNA/LBNO
- Study detector performance with dedicated charged particle beam
- Start data taking by the end of 2017

Successful operation will open a door to exploiting double-phase LAr TPC detectors within the DUNE program

Thank you

Back-up material

WA105 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

DUNE double-phase LAr TPC fact sheet

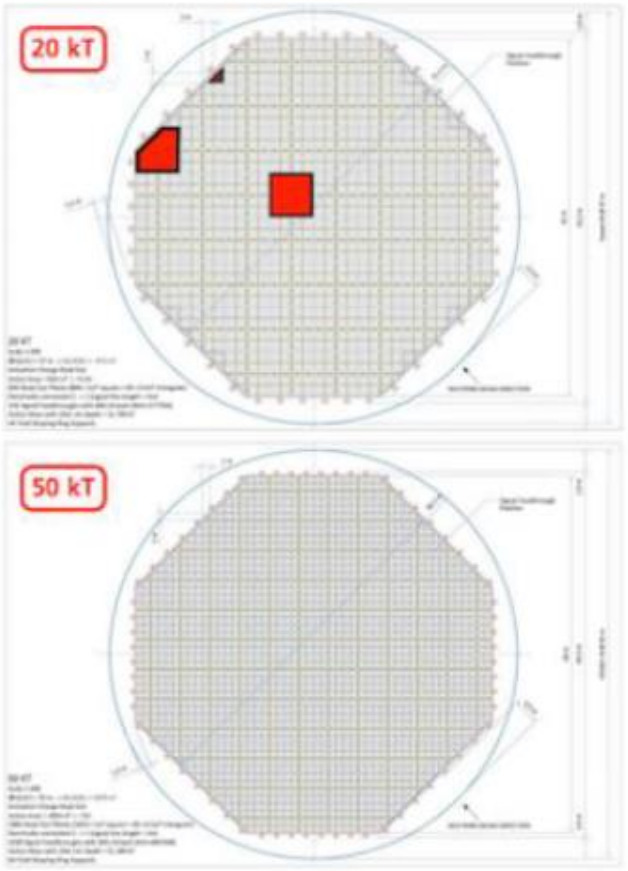
Parameter	Requirement	Achieved Elsewhere	Expected Performance
Gas phase gain	20	200	20-100
Electron Lifetime	3 ms	$>$ 3 ms 35-t prototype	$>$ 5 ms
Minimal S/N after 12 m drift	9:1	$>$ 100:1	12:1-60:1

Item	Value(s)	
Active volume width and length	W = 12 m	L = 60 m
Active volume height	H = 12 m (H = 15 m)	
Active volume/LAr mass	8,640 (10,800) m^3	12,096 (15,120) metric ton
Field ring vertical spacing	200 mm	
Field ring tube diameter	140 mm	
Anode plane size	W = 12 m	L = 60 m
CRP unit size	W = 3 m	L = 3 m
HV for vertical drift	600–900 kV	
Resistor value	100 MΩ	

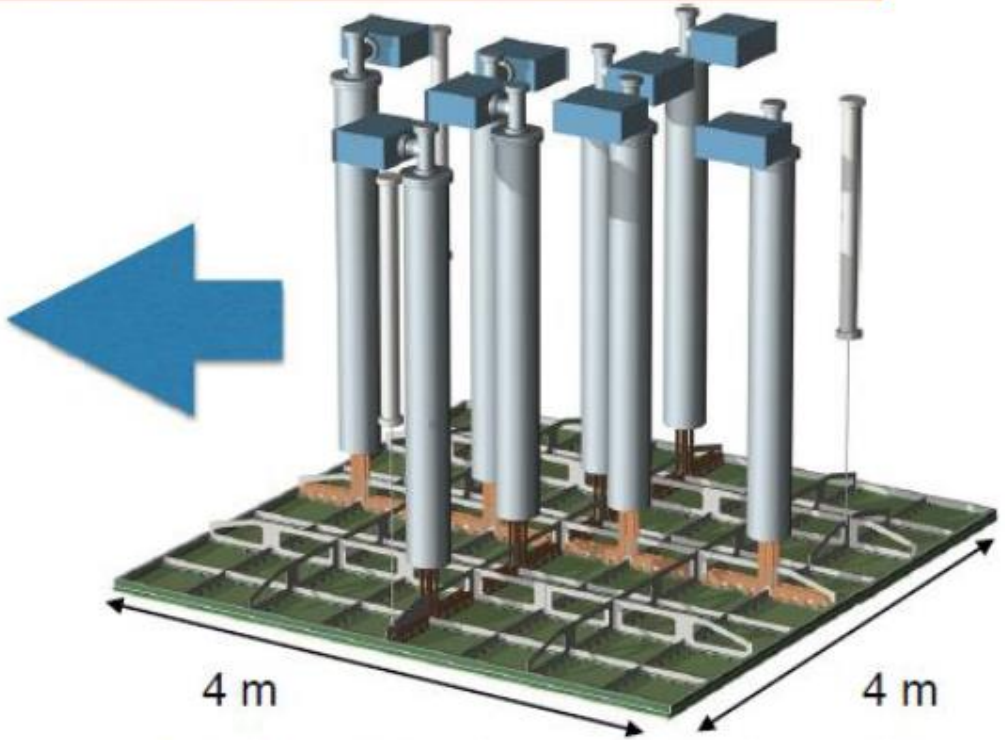
Item	Number
Field rings	60 (75)
CRP units	4 × 20 = 80
LEM/Anode sadwiches per CRP unit	36
LEM/Anode sandwiches (total)	2,880
SFT chimneys / CRP unit	3
SFT chimneys (total)	240
Readout channels / SFT chimney	640
Readout channels (total)	153,600
Suspension FT / CRP unit	3
Suspension FTs (total)	240
Slow Control FT / sub-anode	1
Slow Control FTs (total)	80
HV feedthrough	1
Voltage degrader resistive chains	4
Resistors (total)	240 (300)
PMTs (total)	180 (1/4 m^2)

GLACIER 20kt, 50kt: 4x4 m² modules

Each Charge Readout Plane is an independent detector

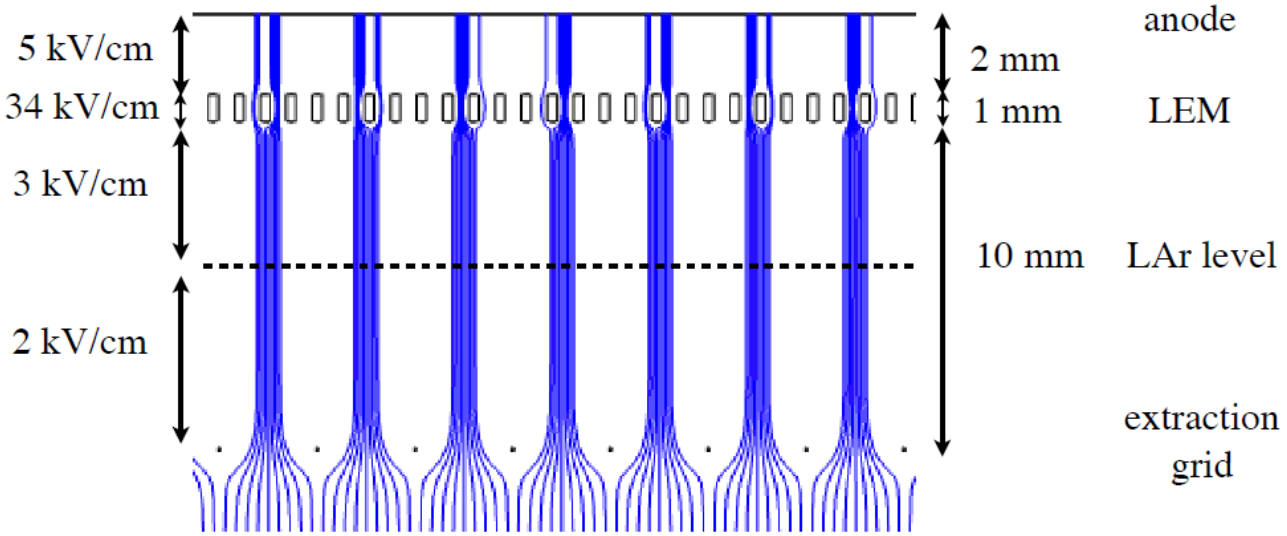


different geometries but all with the same functionality and identical construction sequence.



- 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

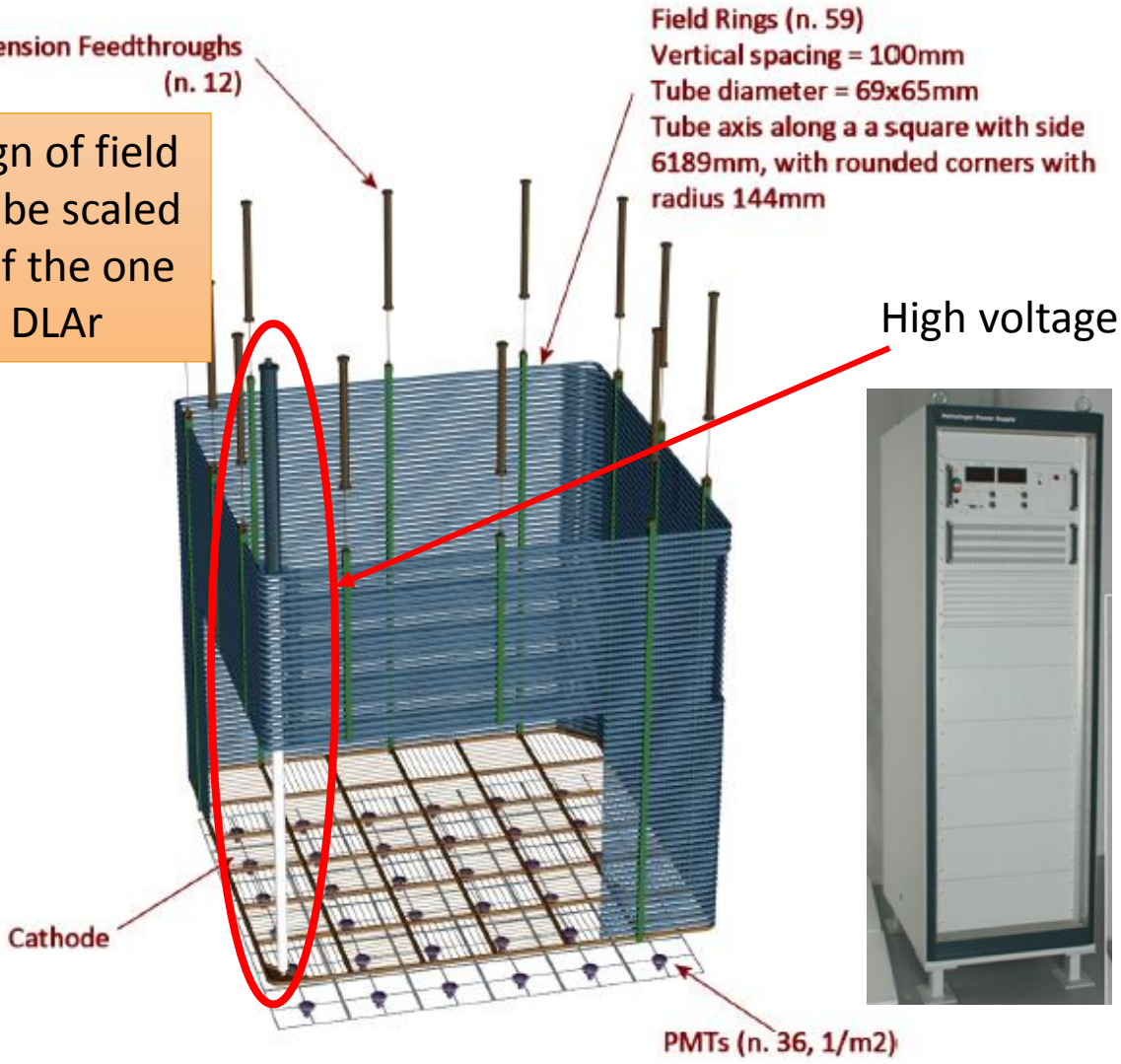


Tolerances are calculated to keep gain stability <5%

	[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

TPC drift cage and HV

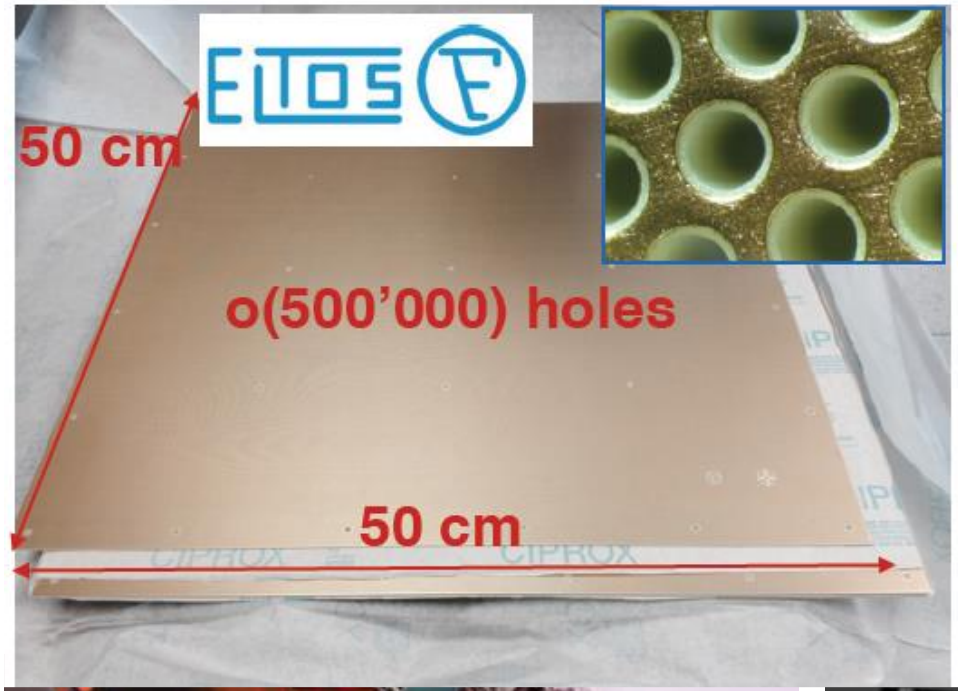
The design of field cage will be scaled version of the one for LBNO DLAr



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)

Large area LEMs

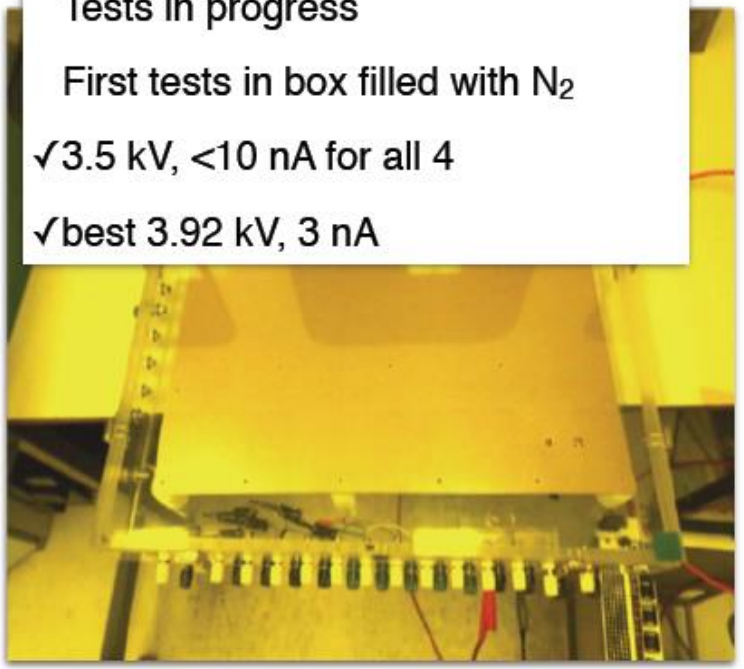


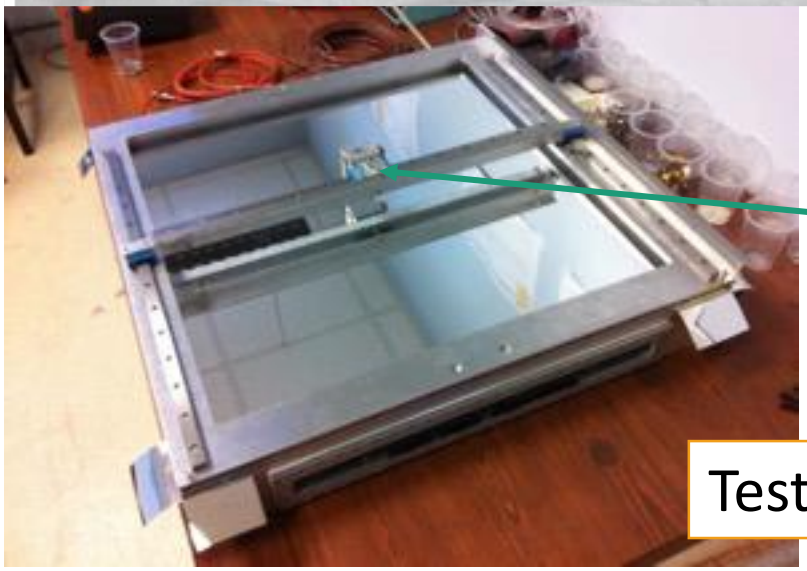
Tests in progress

First tests in box filled with N_2

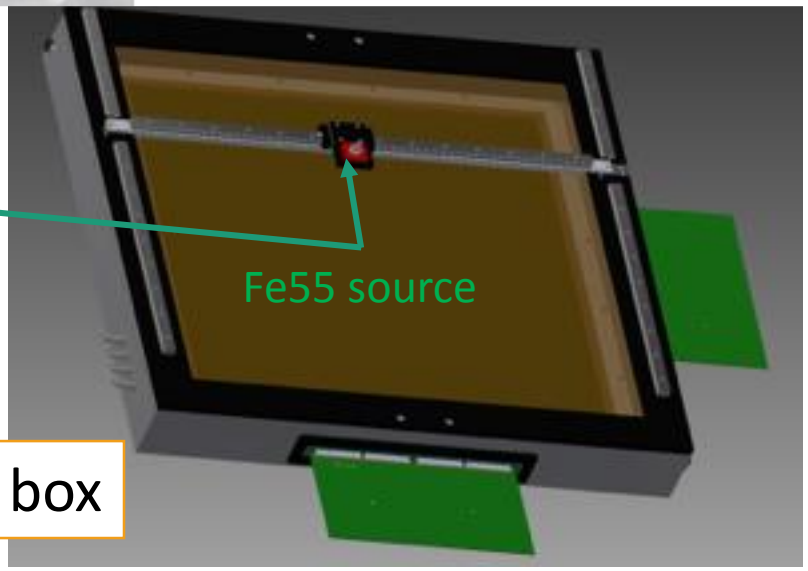
✓3.5 kV, <10 nA for all 4

✓best 3.92 kV, 3 nA

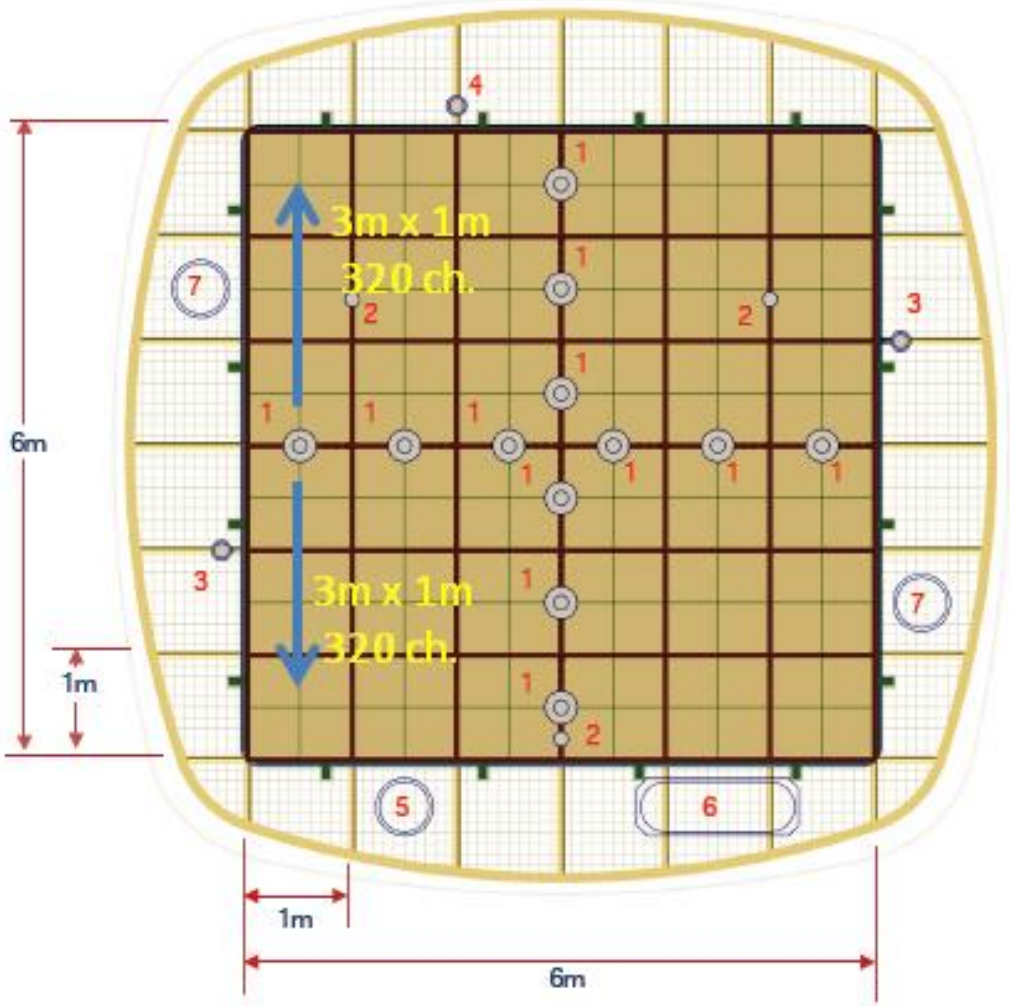




Test box



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



top view

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

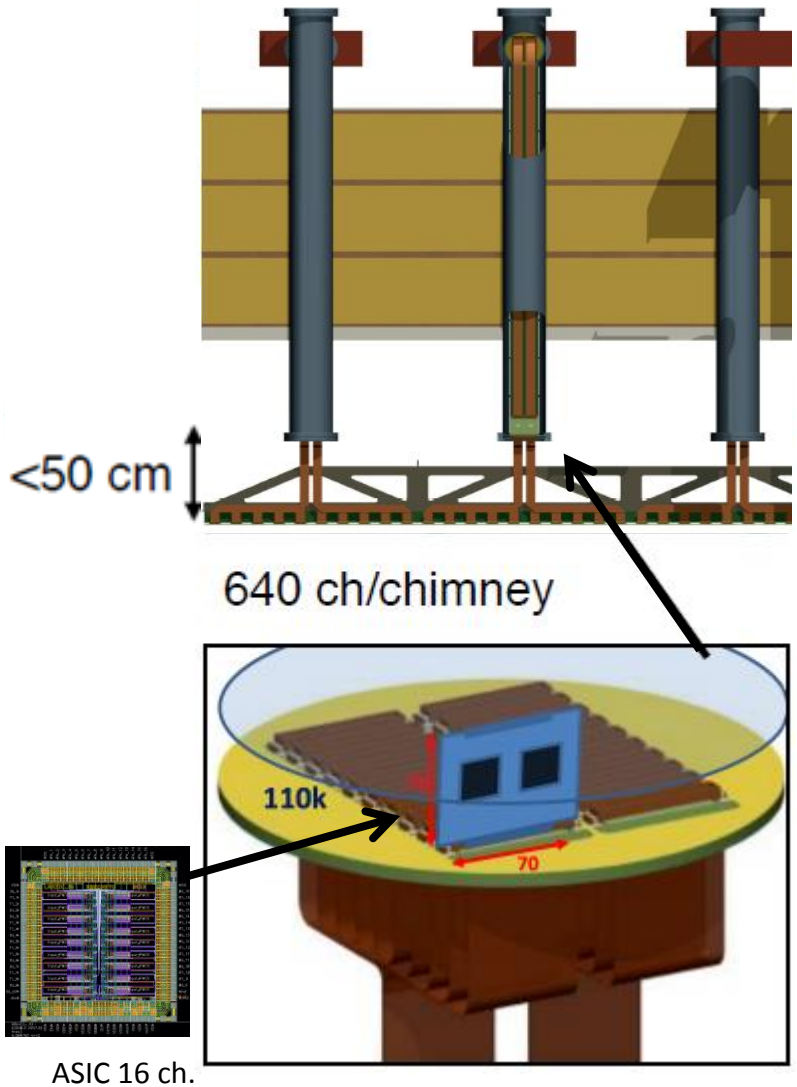
- FE electronics inside chimneys, cards fixed to a plug accessible from outside
- Distance cards-CRP<50 cm
- Dynamic range 40 mips, (1200 fC)

(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



ASIC 16 ch.
(CMOS 0.35 um)