WA105

A large DLAr TPC Prototype

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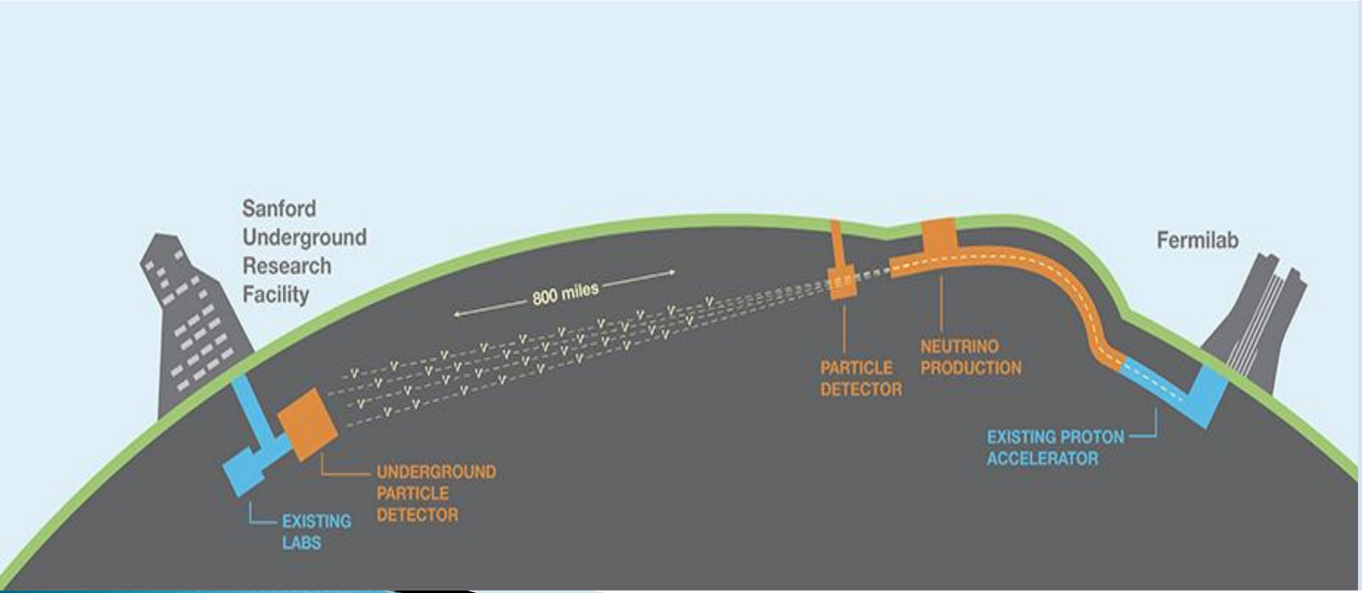
IFAE-BIST

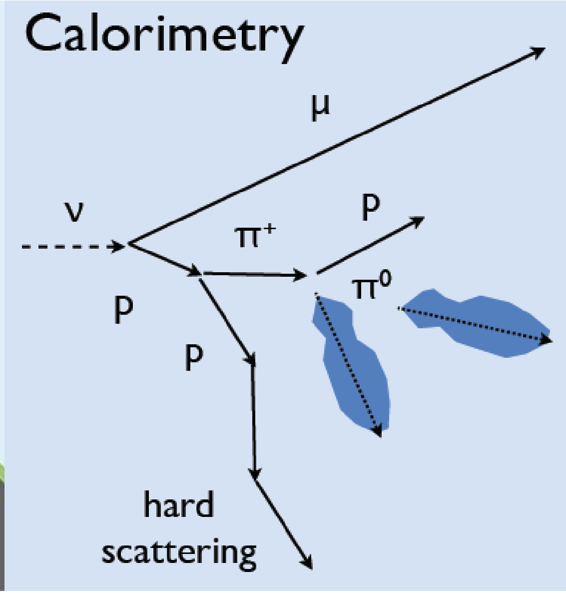
On behalf of the WA105 Collaboration

DUNE

DUNE is the next generation of long baseline neutrino oscillation experiments:

- Long baseline: 1300 km
- 1.2 MW neutrino beam (using Fermilab proton injector)
- wide band beam with maximum between 0.8 and 5 GeV
- Far detectors: huge LAr TPCs
- Start: 2025-2030





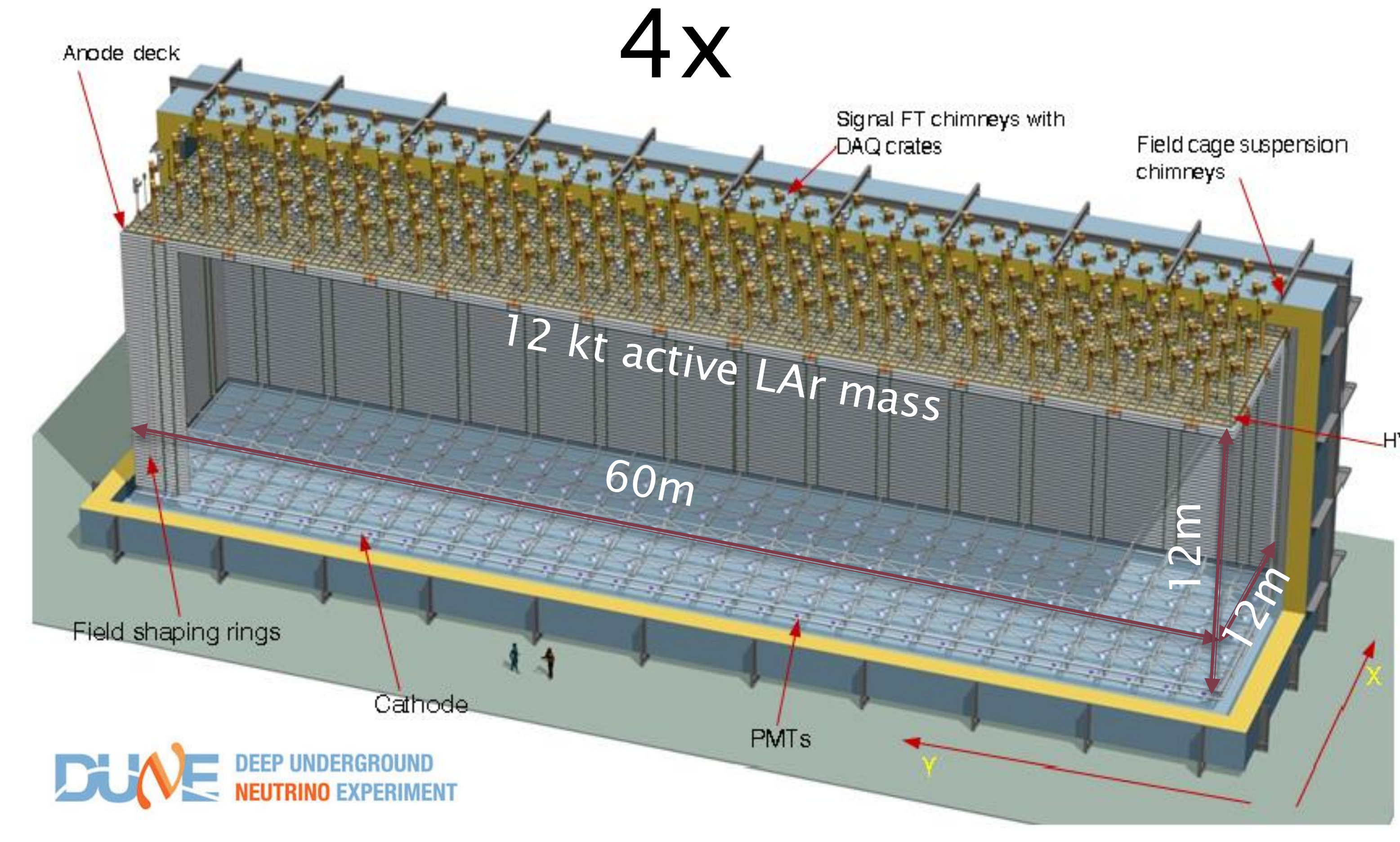
Open Neutrino Physics Questions:

Nobel Prize 2015 for discovery of neutrino oscillations

Arthur B. McDonald	Takaaki Kajita

- Is there any CP violation in the neutrino sector?
- Which neutrino mass hierarchy is realized in nature, normal or inverted?
- What happens in the core of supernovae?
- Precise measurement of oscillation parameters.
- Is the proton stable?

DUNE Detectors



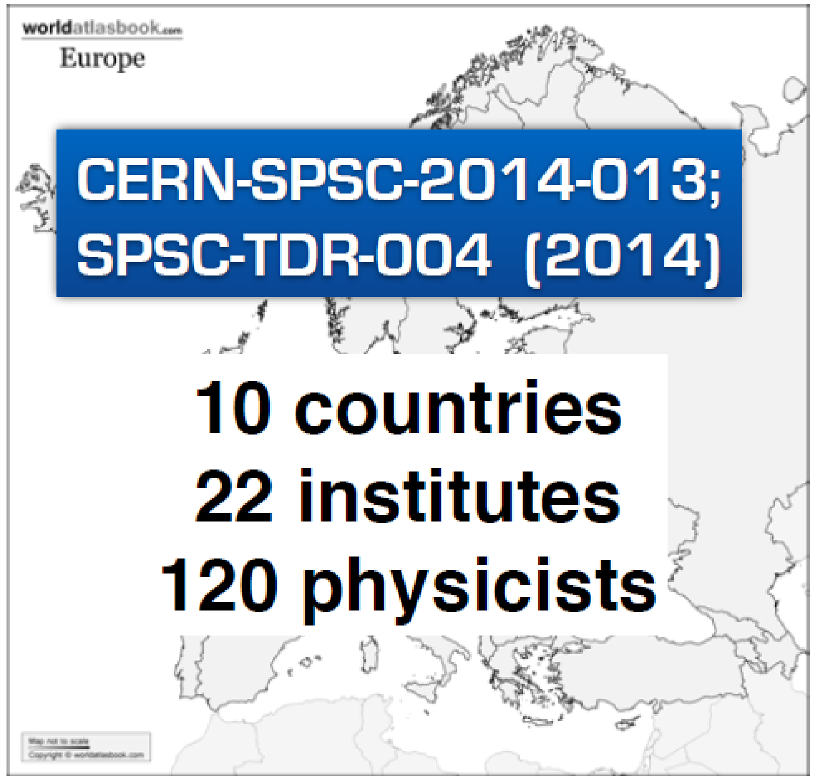
WA105 Collaboration

- 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

- 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

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

- INFN-Sezione di Pisa

- CERN

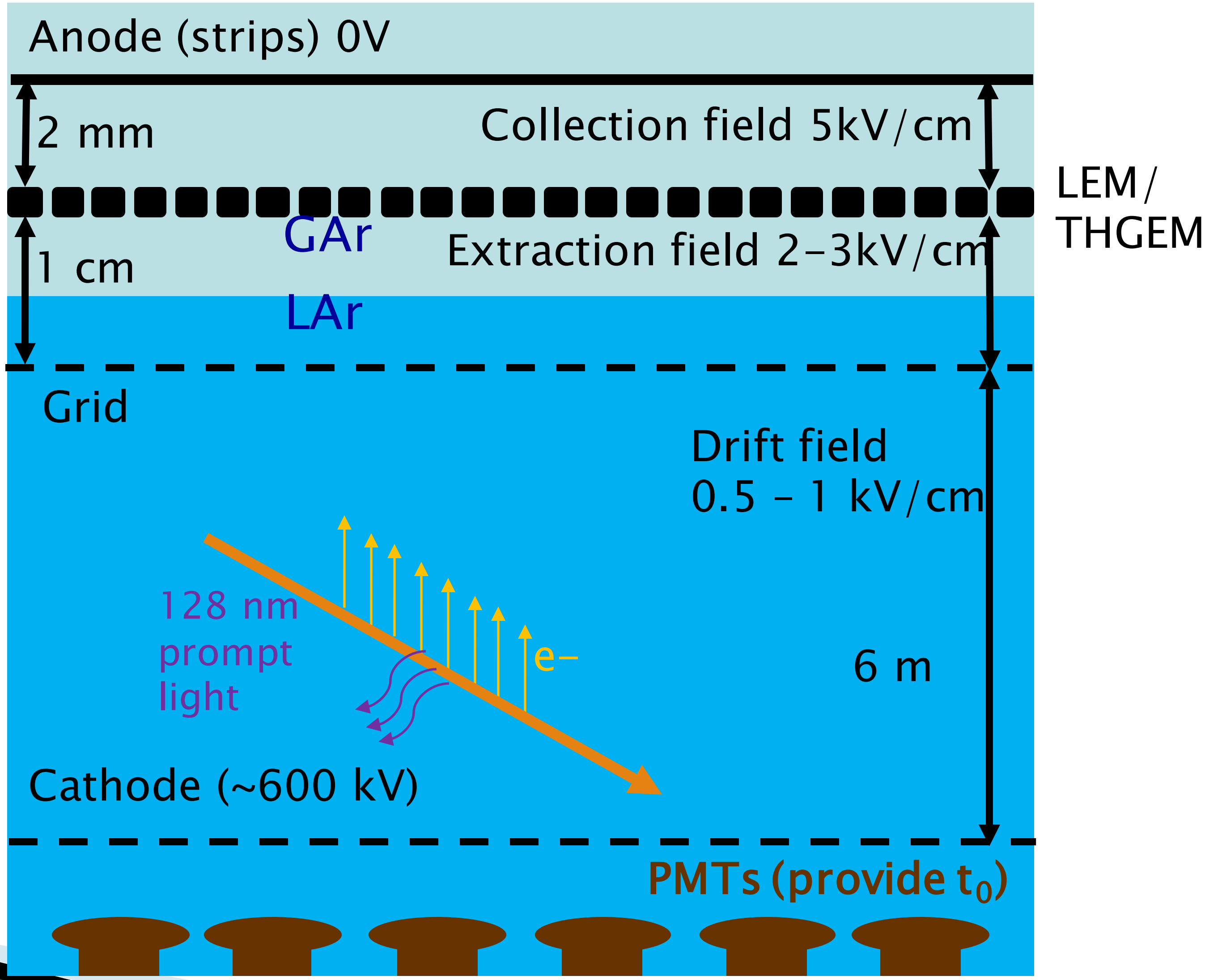
- Institut de Fisica d'Altes Energies (IFAE), Bellaterra (Barcelona)
- CIEMAT

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

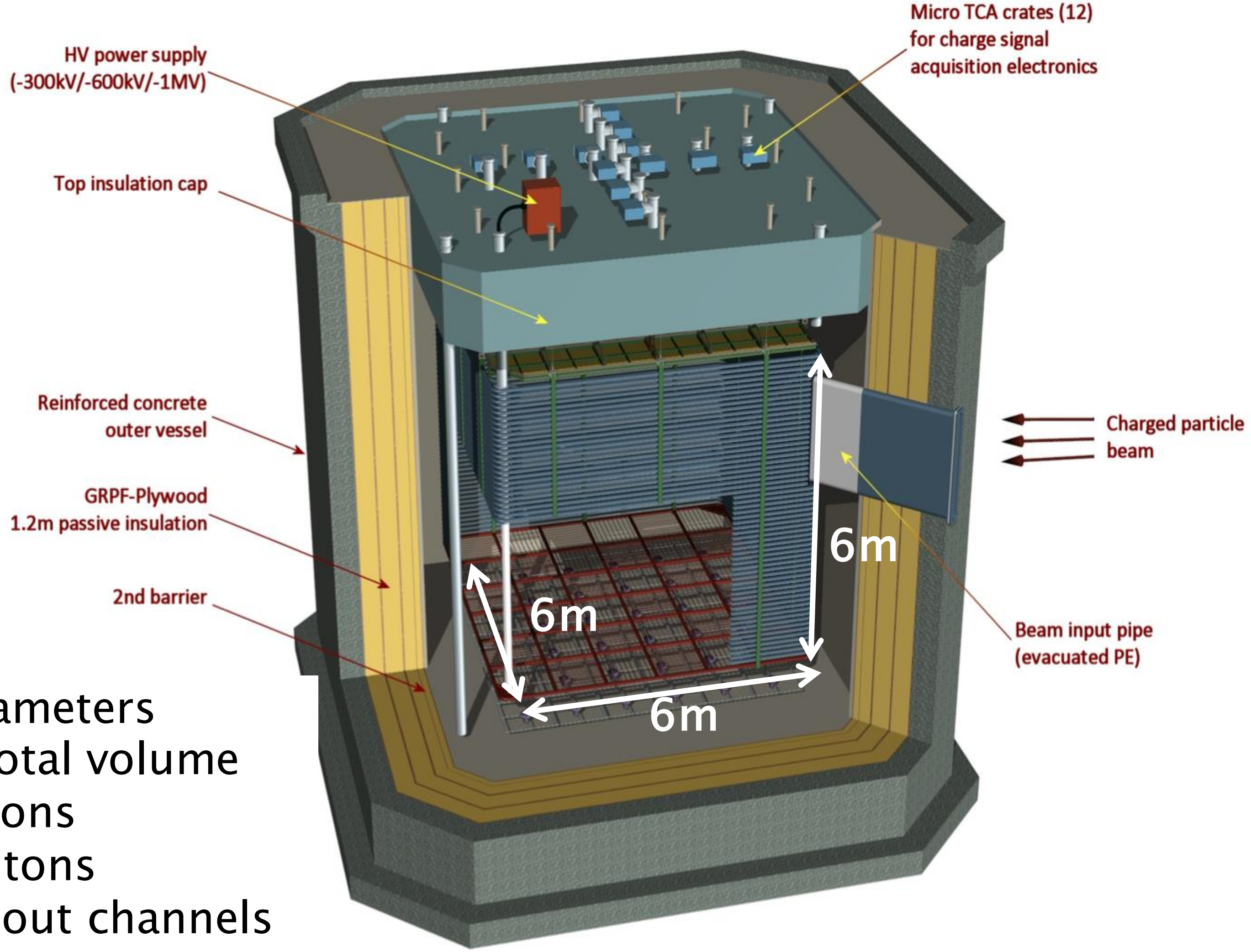
- Institute for Nuclear Research of the Russian Academy of Sciences, Moscow

- High Energy Accelerator Research Organization (KEK)

Double Phase TPC Concept

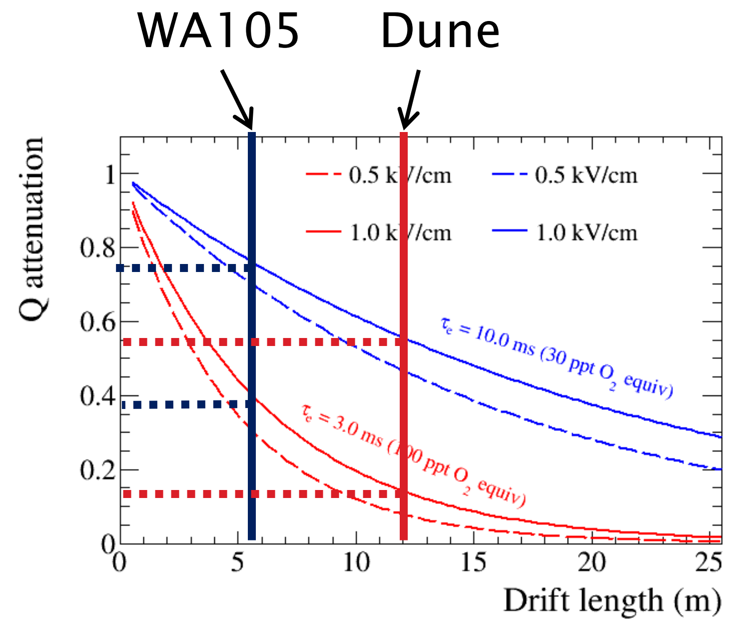


WA105 Detector



Some detector parameters
- 8.3x8.3x8.1 m^3 total volume
- Total mass: 705 tons
- Active mass: 300 tons
- 7680 charge readout channels
- 36 PMTs

WA105 Objectives



Technical:

• Construction of large cryostat providing excellent gas purity

• Industrial production of 36 m^2 of LEMs

• Handling of several hundred kV voltages

• Long term reliability of all components

Physics (with a testbeam):

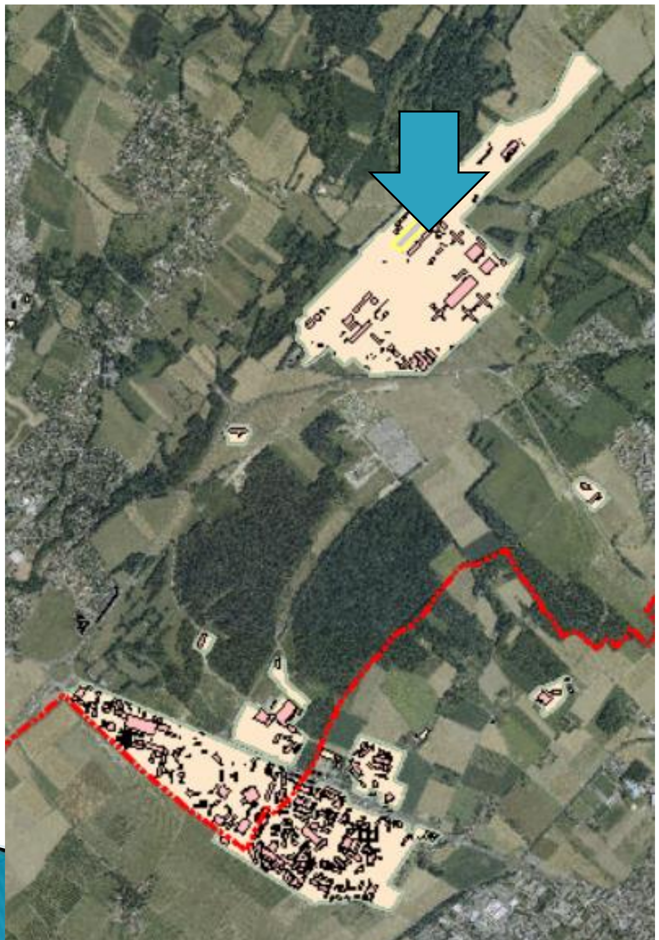
• Development of event reconstruction, especially $\pi^{\pm}/e$ separation

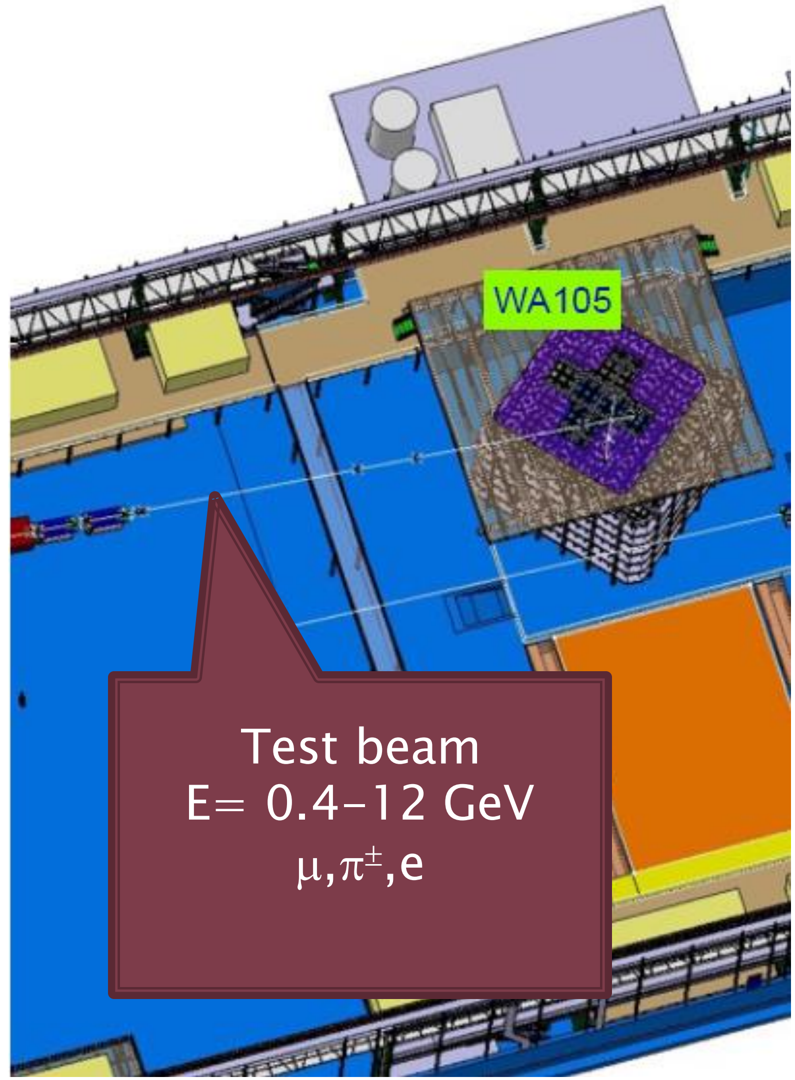
• Testing the performance in respect of neutrino energy reconstruction

• Characterization of hadronic show development and tuning of existing MCs with it

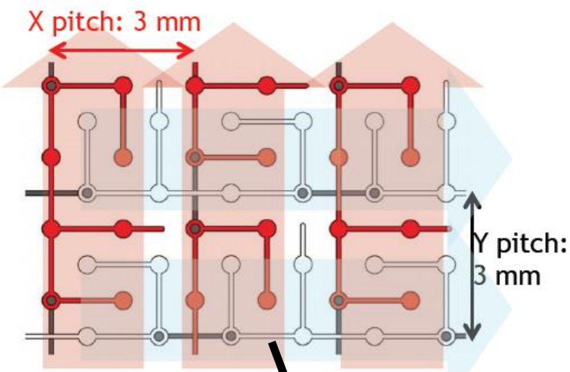
WA105@CERN

Bldg 887 (EHN1), Prevessin Site

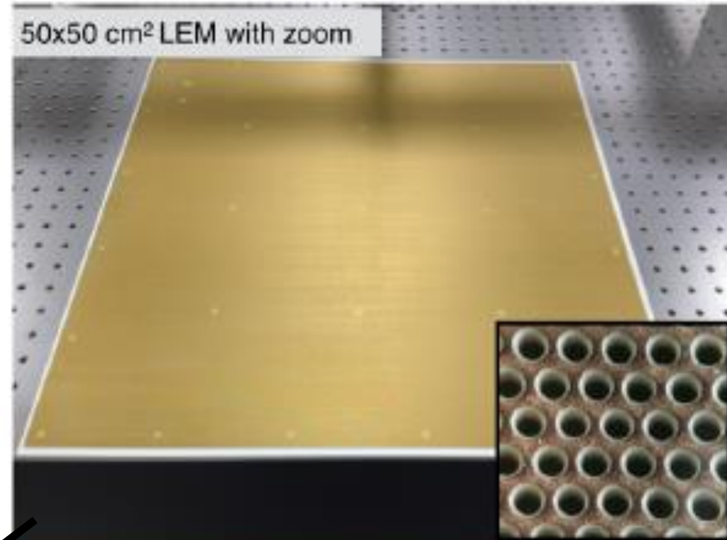


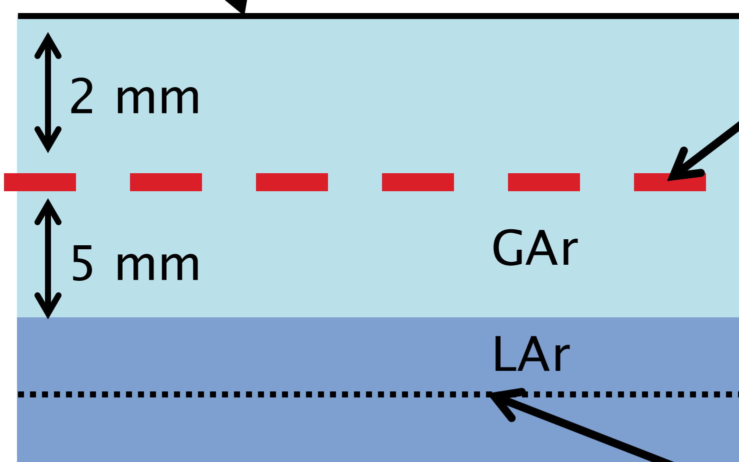


Charge Readout

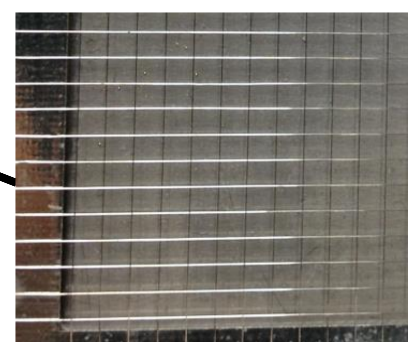


- XY strips
- optimized for charge sharing and capacitance
- 3840 channels per view





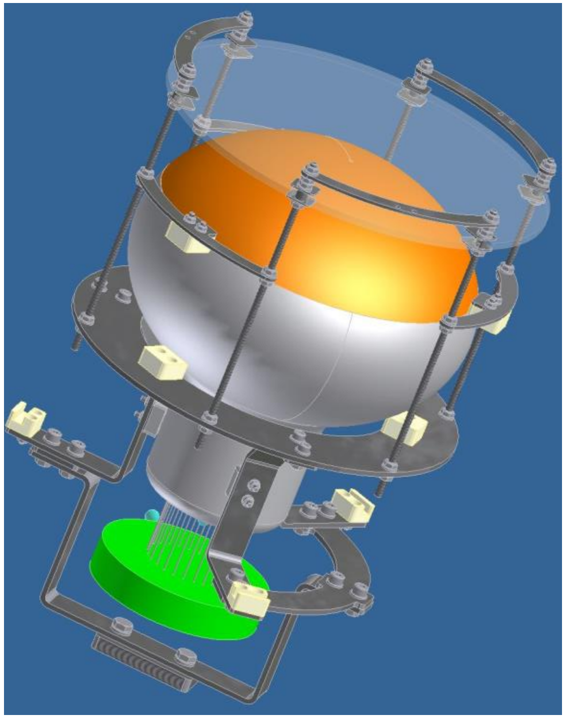
- 50x50 cm² large
- 144 LEMs in total
- 1 mm thick FR4, hole diameter 0.5 mm, pitch 0.8 mm

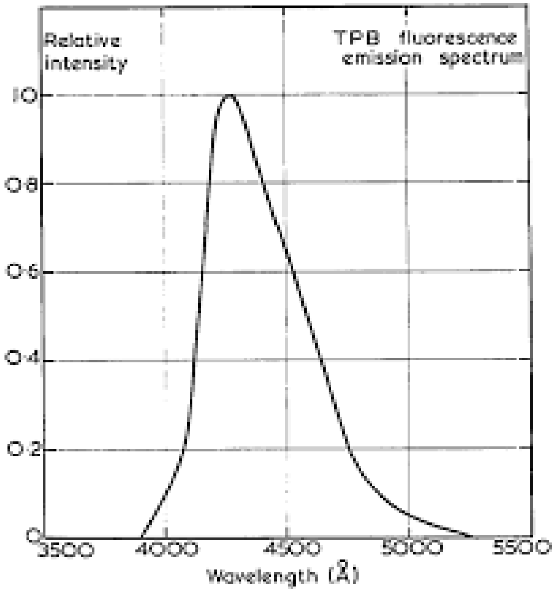


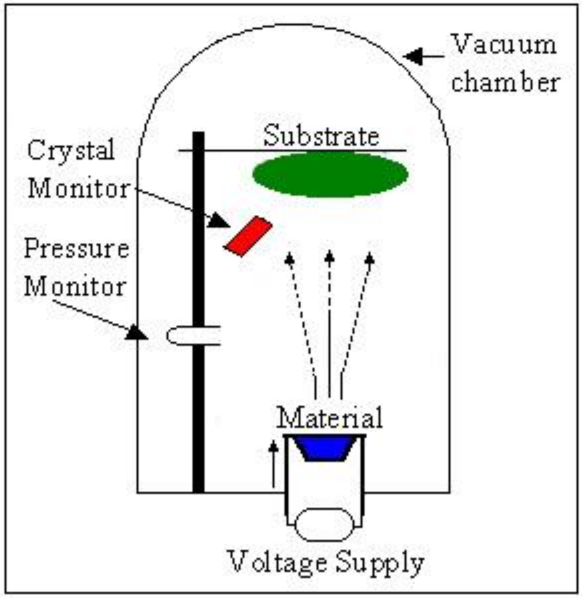
- 100 μm stainless steel
- 3 mm pitch

Light Readout

• Commercial PMTs not directly sensitive to 128 nm => need to use wavelength shifter
• Tetraphenyl-Butadiene (TPB) shifts light to about 430 nm
• Coating of acrylic plates instead of PMTs
• 36 R5912-02mod 8" PMTs from Hamamatsu
• Sensor coverage behind cathode: ~3%







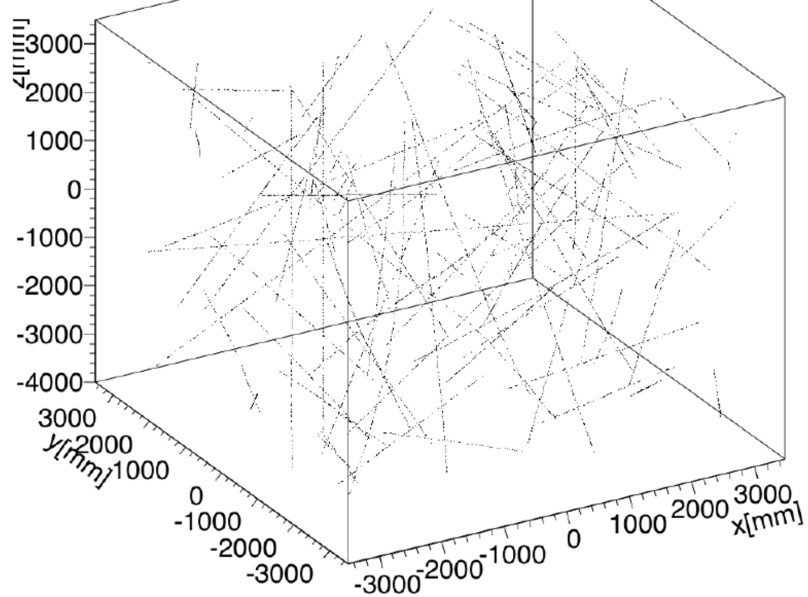
Operation Challenges: Cosmics

Cosmics are normally great for detector characterization but in our case also a challenge ....

~10 kHz of cosmics
$\Rightarrow$ ~40 cosmics overlapping in 4 ms readout window
$\Rightarrow$ reconstruction of beam event a challenge

dE/dx (MIP): ~2 MeV/cm
$\Rightarrow$ 50.000 e/ions, 50.000 γ per cm
$\Rightarrow$ 30 million e/ions and γ per MIP in 600 cm

Building 8ms of Cosmics

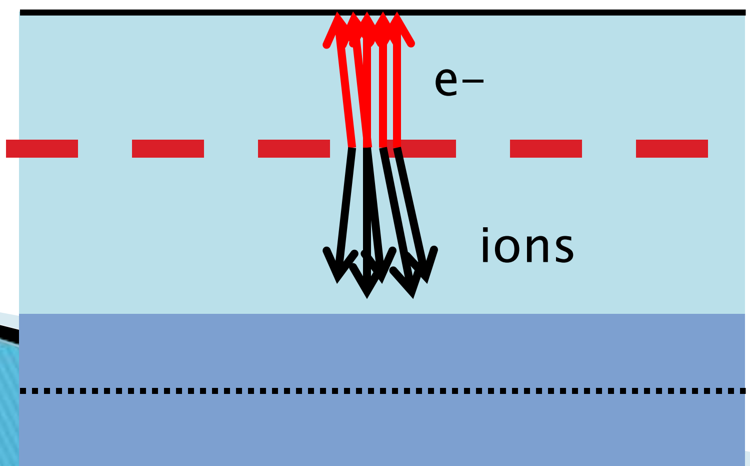


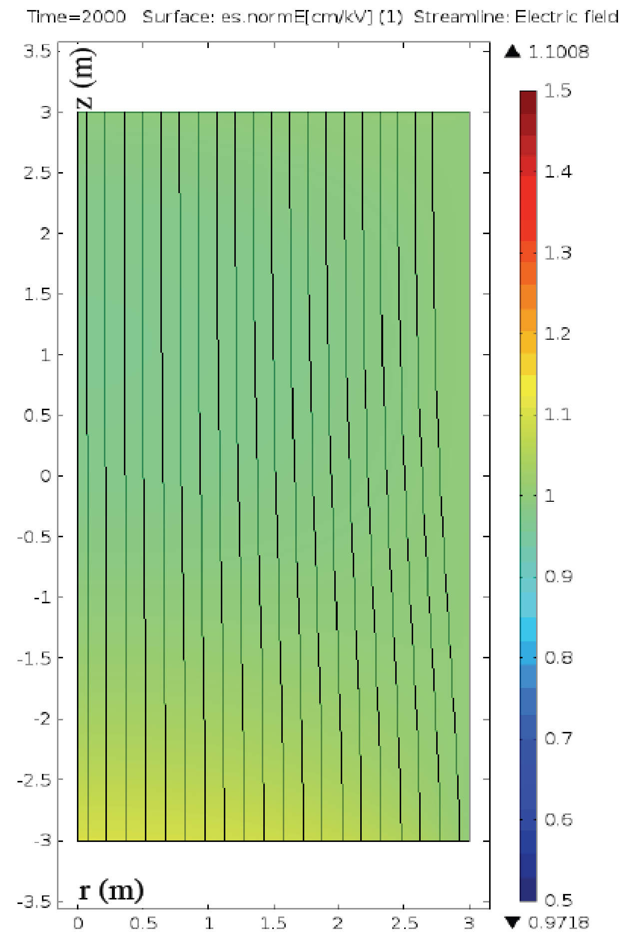
Space Charge Effects

Primary charge is one issue but there is also charge amplification ...

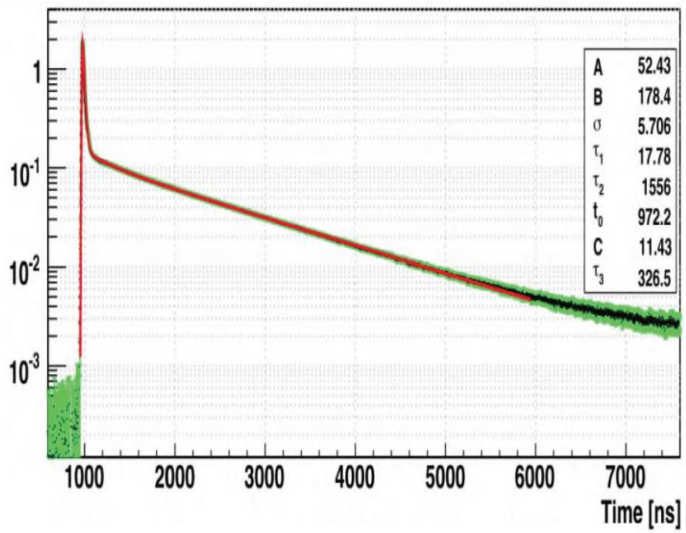
Electron gain is moderate: ~20
but we have many primary electrons and ions are really slow: ~1 cm/s in LAr.

Significant field distortions expected
⇒ intensive simulation studies ongoing
⇒ field distortions are being included in event reconstruction





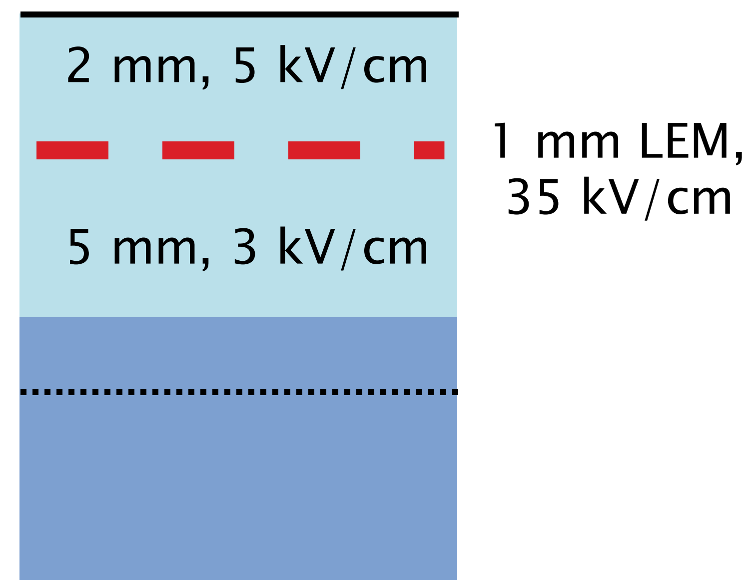
Light Background



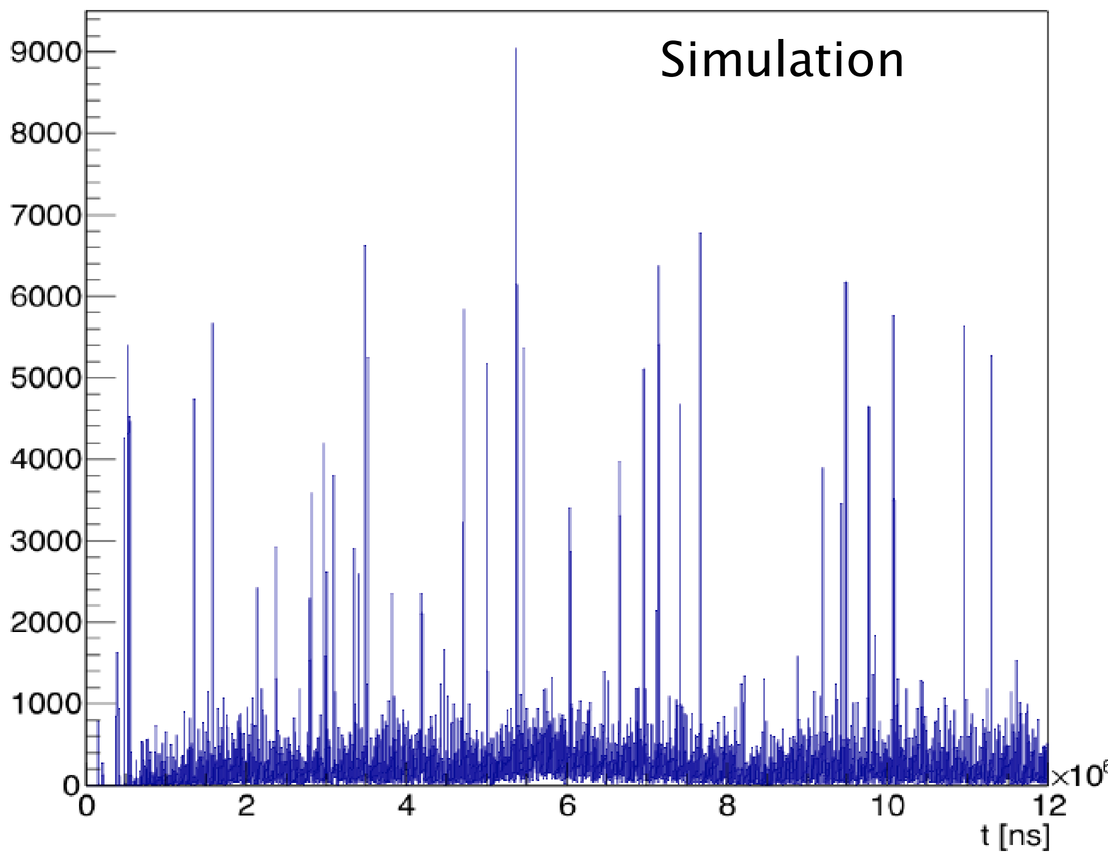
- primary light has 2 components:
  - fast component, singlet: $6 < \tau < 18$ ns
  - slow component, triplet: ~1.6 μs
- 30 million photons for straight cosmic
- most of light for MIPs in fast component => perfect for triggering

But we have light background …

- electroluminescence (EL) in gas phase
- each e- will produce some hundreds γs
- "constant" background



Light Background

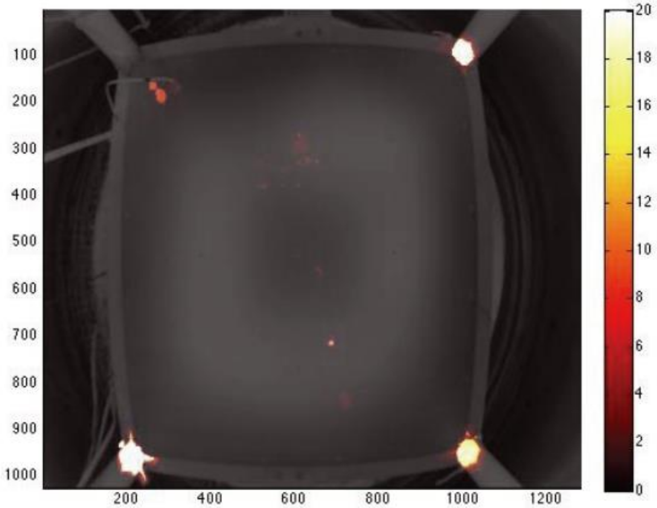


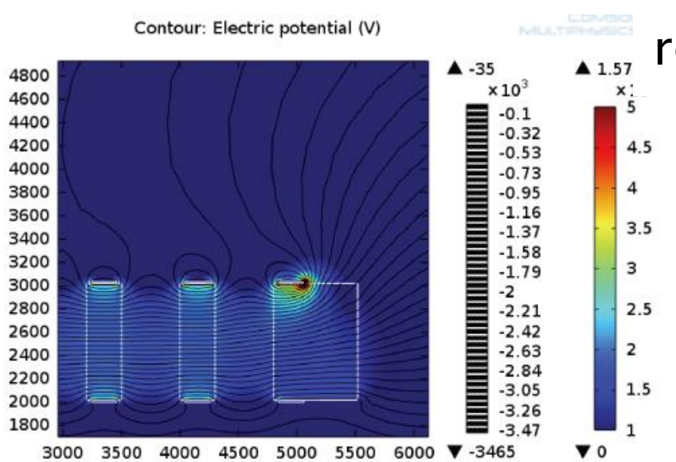
Related to talk from A. Sokolov from yesterday.

ppm level of N2:
• reduces primary light peaks
• increases EL induced background

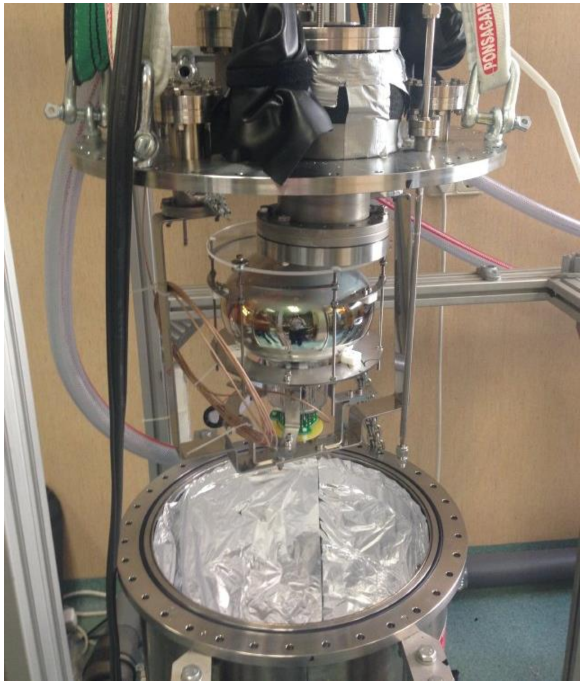
But these challenges only exist for WA105 …
Underground operation reduces cosmics by 10^4 to 10^5!

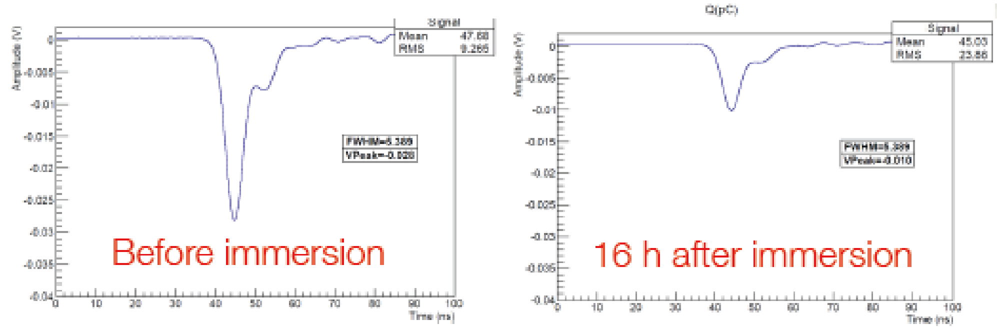
Ongoing Work





- Optimization of LEM geometry
- Current design sparks at corners
- Electric field simulation ongoing
- PMTs tested in LN2
- Development of PMT readout optimization ongoing
- SiPM based light readout



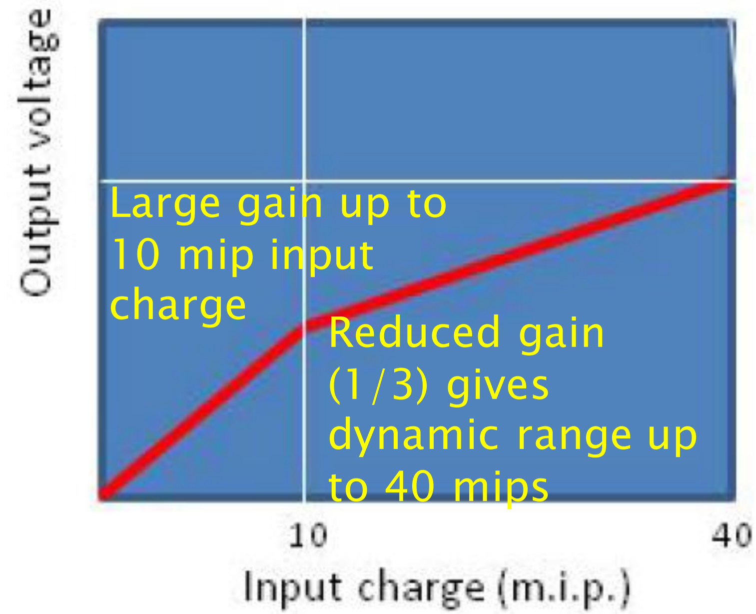


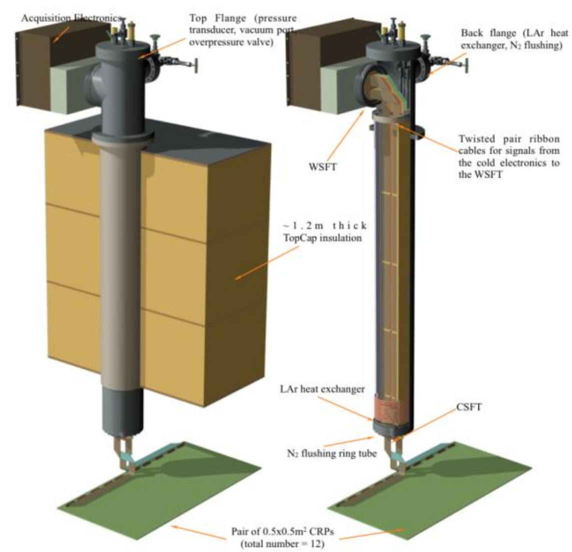
* For more details about LEM R&D see slides from Mr. WU (Thursday 15 October 2015 10:00)

Ongoing Work

Electronics:

- R&D development since 2006
- Design allows exchange of electronic cards without opening the cryostat
- 16 channel ASIC with CMOS-based pre-amplifiers
- Suitable for operation at 110 K
- Low power consumption
- Large dynamic range (up to 40 MIPs)
- Total time window of 4 ms => covers completely 6 m of drift
- scalable to # of readout channels required by DUNE (~150 kChannels)





Ongoing Work

Construction of a 3x1x1 m3 prototype -> Start data taking 04/2016

Ongoing Work

Long Baseline Neutrino

- Neutrino flux
- Neutrino interaction simulation
- Detector(including trigger logic) simulation and reconstruction
- Analysis tool
- Evaluation on Mass Hierarchy and Lepton CP sensitivity (based on experimentally validated energy resolution, e/pi0 separation, etc.)

Nucleon decay & Atmospheric neutrino

- Nucleon decay simulation
- Atmospheric neutrino simulation
- Neutrino interaction simulation
- Detector(including trigger logic) simulation and reconstruction
- Background (Atmospheric neutrino etc.) evaluation
- Analysis tool
- Evaluation of nucleon decay discovery potential & Mass Hierarchy sensitivity

Several MC studies ongoing

Supernovae neutrino

- Supernovae neutrino simulation
- Neutrino interaction simulation
- Detector(including trigger logic, elec. noise) simulation and reconstruction
- Background (including elec. Noise, radio active source) evaluation
- Analysis tool
- Evaluation of measurement potential

Detection threshold: ≤ 5 MeV

Hadron propagation/shower evolution in the medium

- Establish reliable simulation
- Evaluate impact on neutrino measurement systematics at foreseen large scale detectors

Conclusions

- WA105 will be the largest DLAr TPC ever built (~300 ton fiducial mass)
- Operation with testbeam will allow to study detector performance
- Surface operation will add challenges
- Crucial step towards 10 kton detectors of DUNE
- Intensive work ongoing
- Data taking will start 2018