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A global R&D program on liquid Ar Time Projection Chambers under execution at the University of Bern

Marcello Messina
Albert Einstein Center for Fundamental Physics
Laboratory for High Energy Physics
University of Bern
on
behalf of
I. Badhrees, A. Ereditato, S. Janos, I. Kreslo, M. M., S. Haug, B. Rossi, C. Rudolf von Rohr, M. Weber, M. Zeller

LAr TPC concept

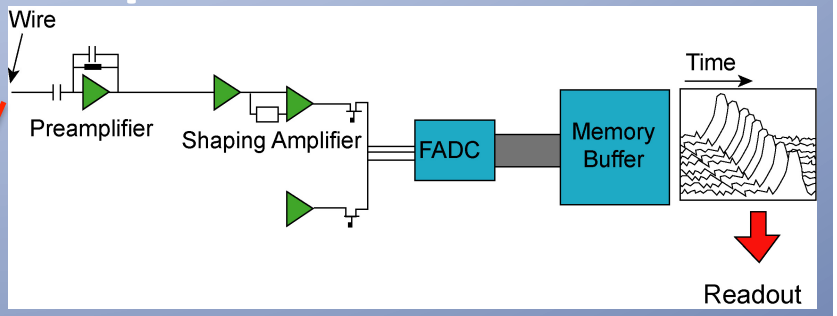
Features:

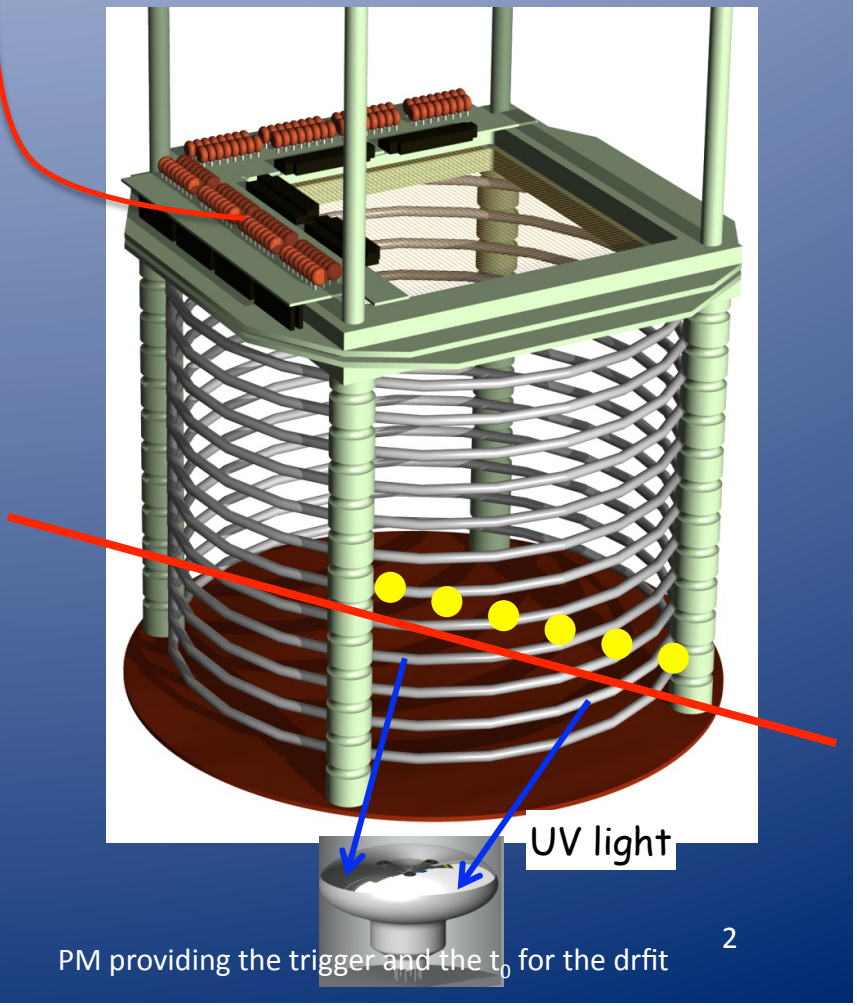
- Homogeneous sensitive volume
- Charge read out
- Collected charge proportional to the deposited energy
- Three dimensional tracker
- Fully homogenous

Charge yield (m.i.p.)	6000 e^-/mm
Photon yield (m.i.p.)	5000 photons/mm (128 nm)
Electron drift velocity	2mm/μs (@ 1kV/cm)

Peculiarities:

- Very good energy resolution for electromagnetic showers
- Good particle identification via the dE/dx measurements
- Good momentum resolution for passing through particles





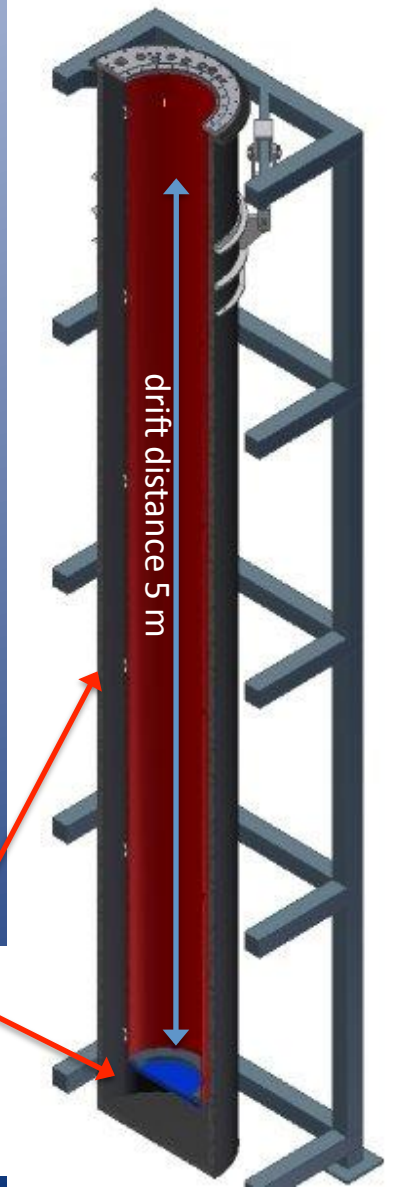
PM providing the trigger and the t_0 for the drfit

ARGONTUBE

Project aimed at proving the capability of drifting the ionization electrons on long distances in view of the construction of very large mass neutrino detectors

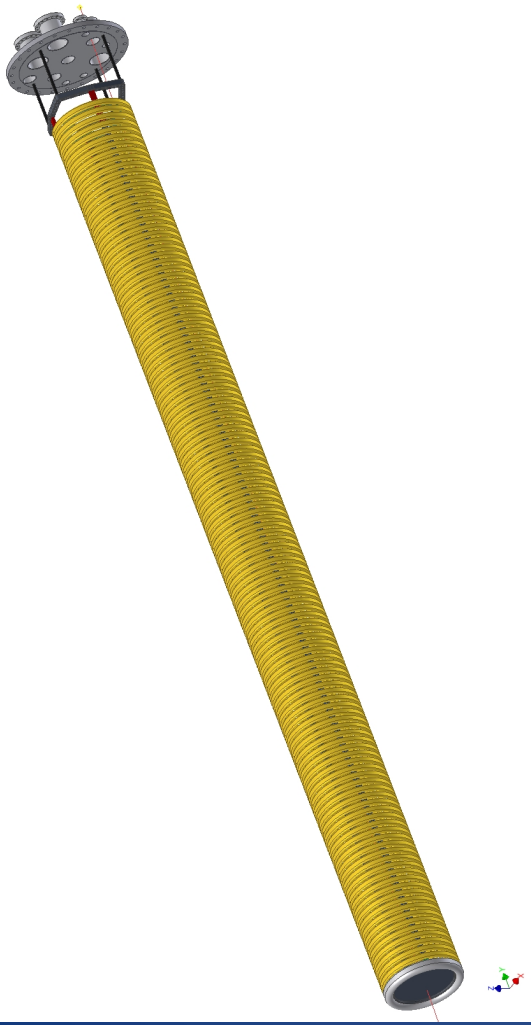
- Main issues
  - 500 kV in liquid Argon
  - Impurities at the level of < 0.1ppb (life time > 3000 ms)
  - Signal over noise ratio of at least a factor 10

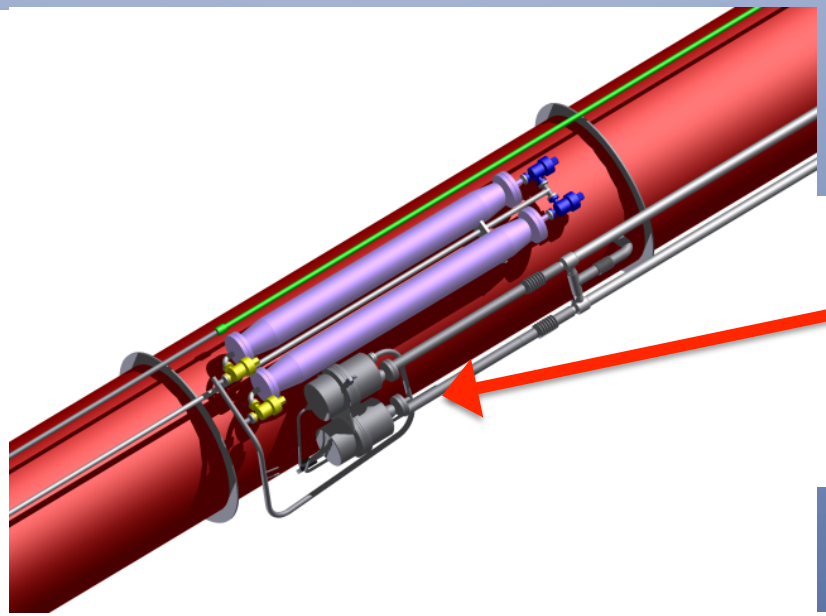
- Possible studies with ARGONTUBE:
  - Measure the purity limit
  - Study the UV-Laser as purity monitor and calibration method
  - Electron diffusion (parallel and perpendicular to E-field)
  - Test new readout system



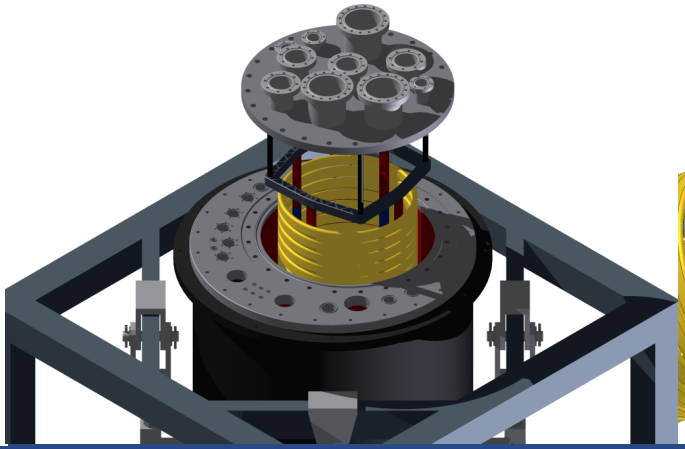
- Outer volume: 1.6 m^3
- Inner volume : 1. m^3
- Active volume: 0.5 m^3
- Active mass: 280 kg

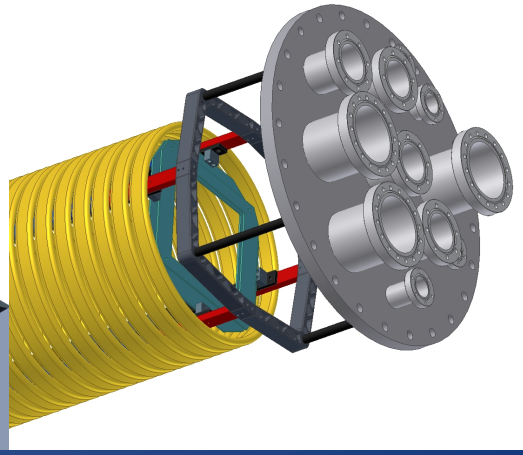
Drawings of the ARGONTUBE



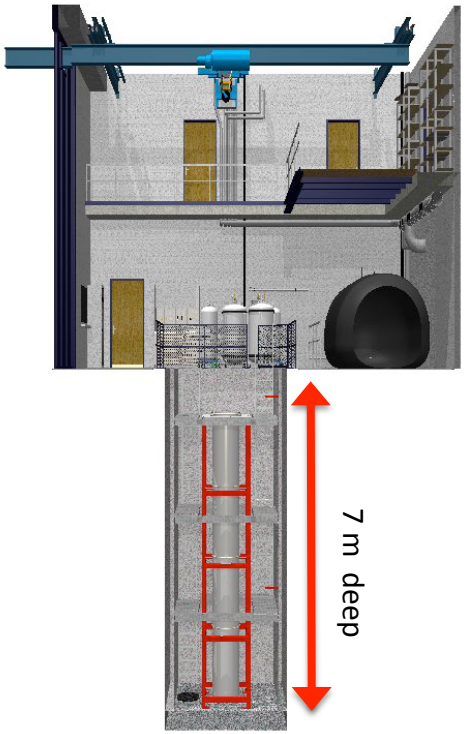


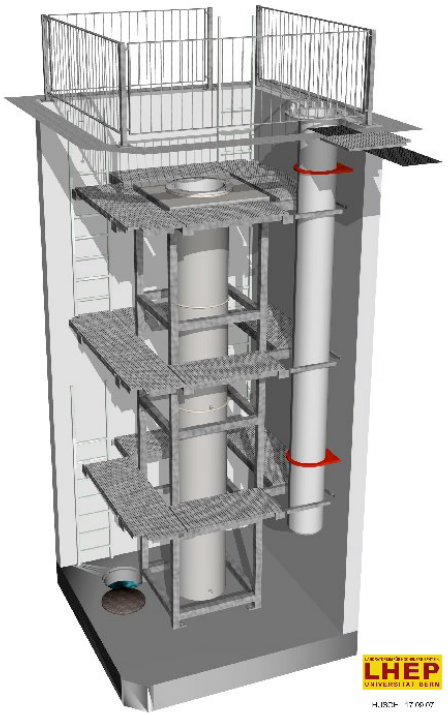
Pneumatic pump for recirculation of the LAr driven with pressurized nitrogen (developed in collaboration with ETHZ and realized by CRIOTEC , ITALY)

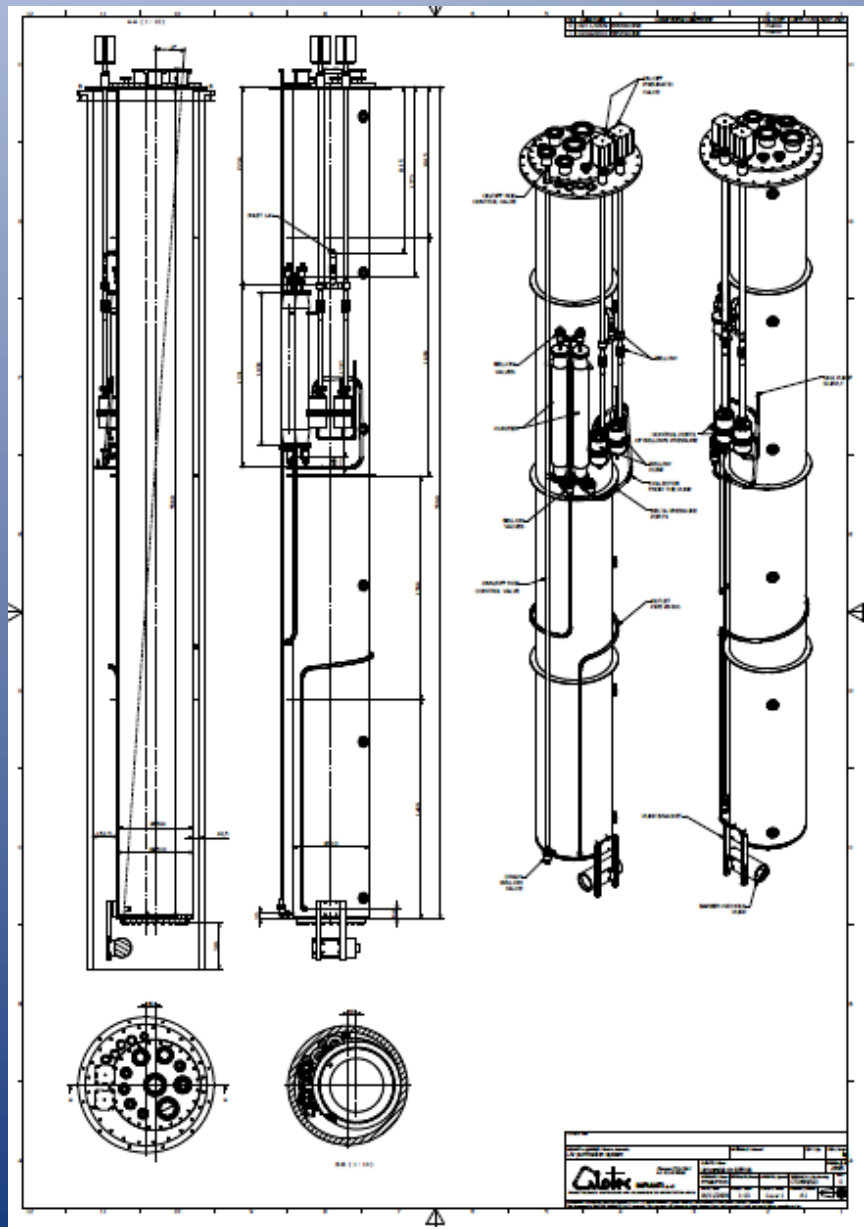




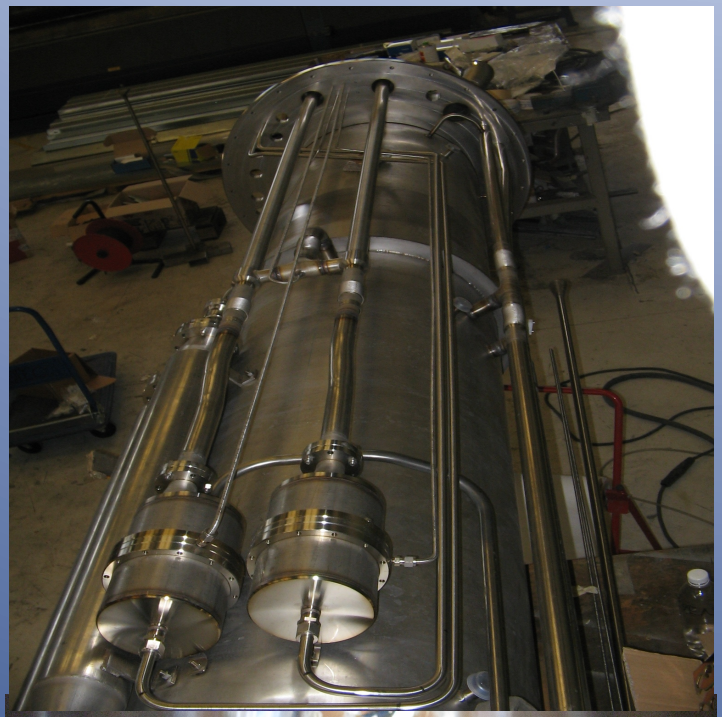
Design and construction







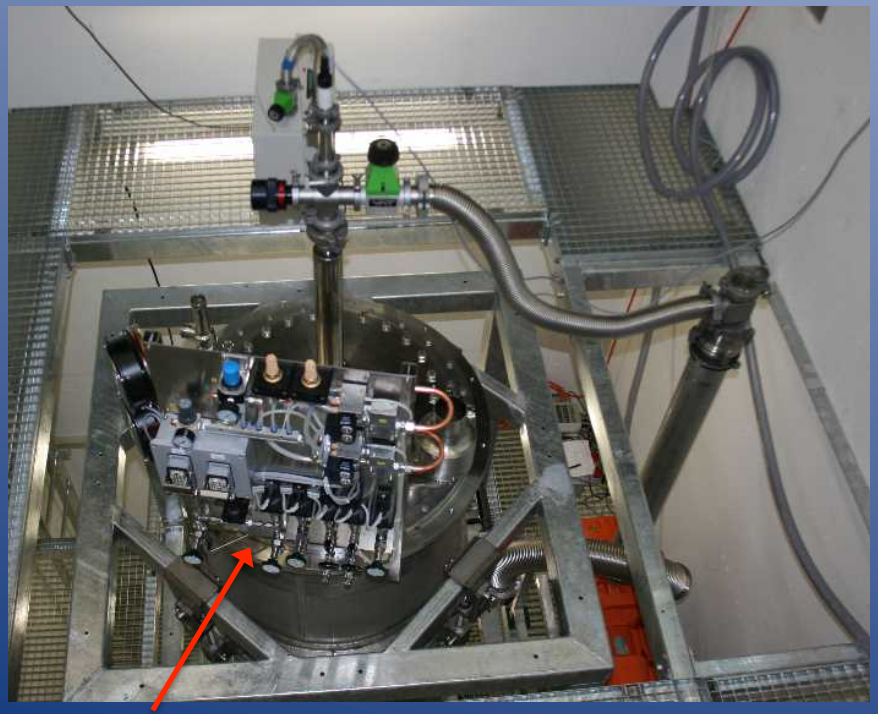
Installation of the inner vessel



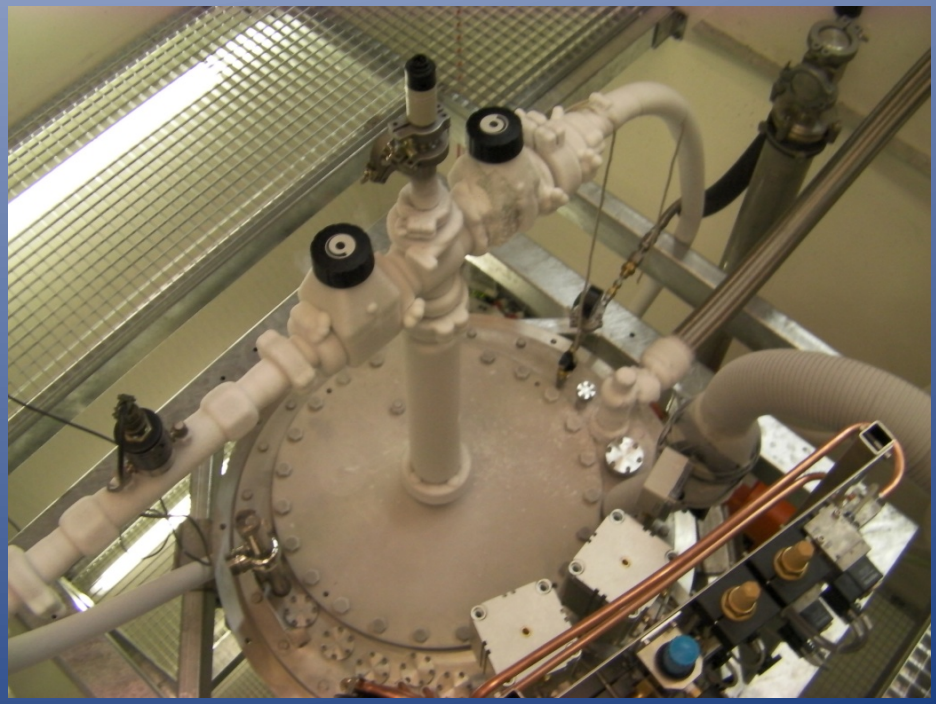
First vacuum and cold test

Vacuum
- rotational pumps
- 12 h of pumping
- vacuum: 7×10^{-5} mbar

Filling
- 6 h
- 2600 litres of Argon
- recirculation system tested at 100 litres/h

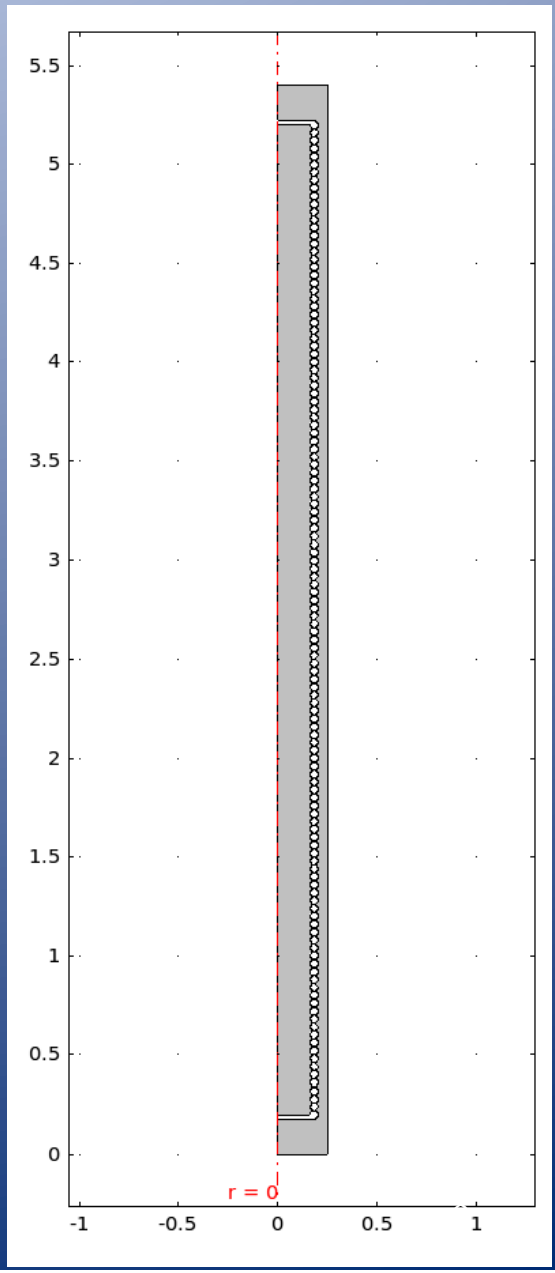


Panel where all the valves to control the recirculation circuit are mounted. Everything is controlled with a PLU accessible via Ethernet.



Electric field simulation (2d axis-symmetric)

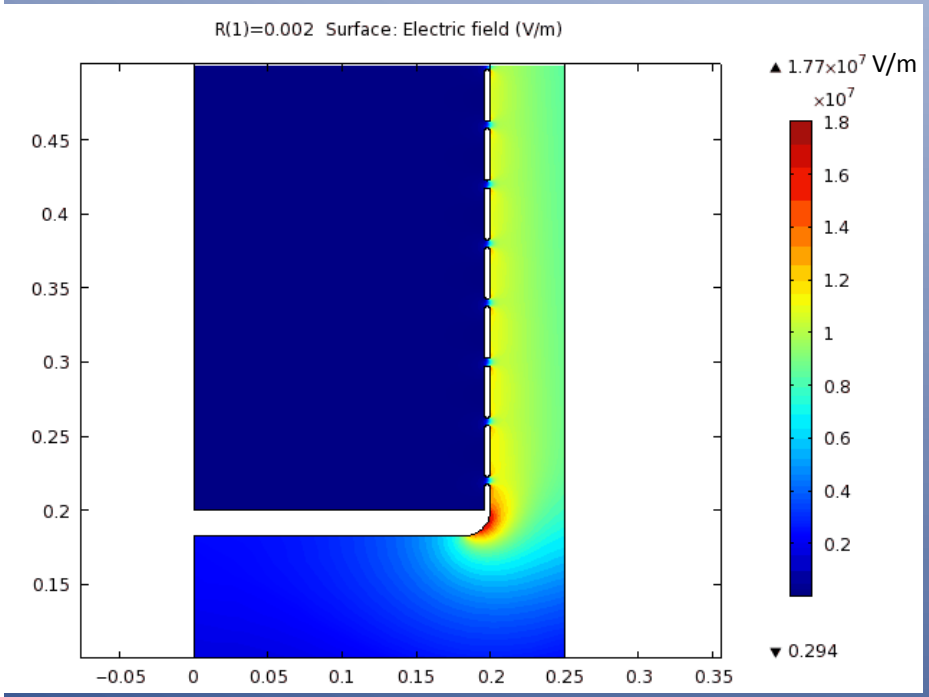
- COMSOL (Finite element analysis software)
- Outer diameter of field shaping rings : 400 mm
- Pitch distance between two rings: 40 mm
- Different thickness and forms of field shaping rings have been considered

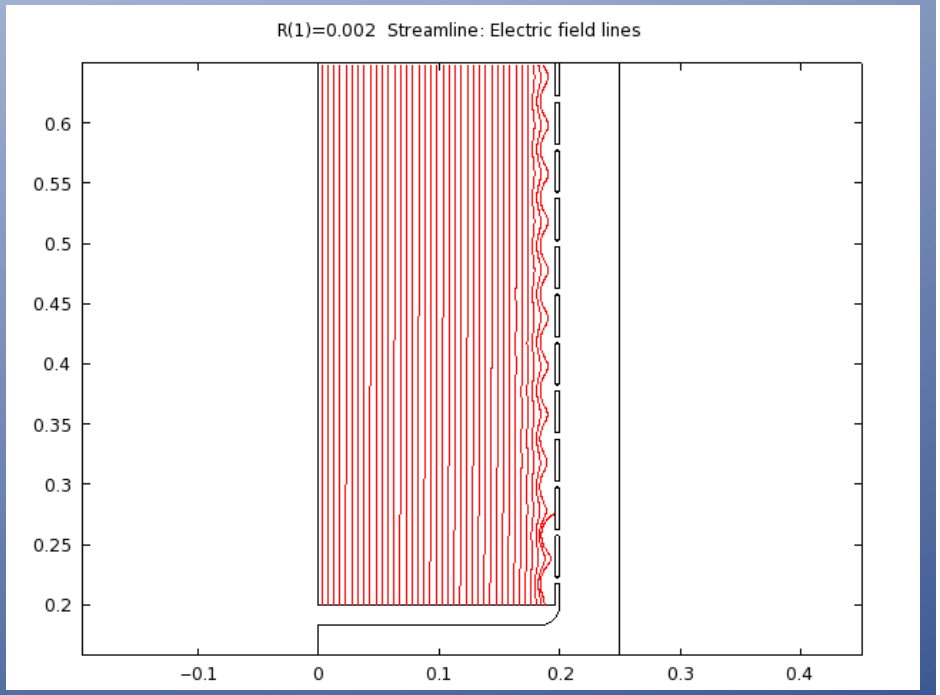


Electric field (V/m)

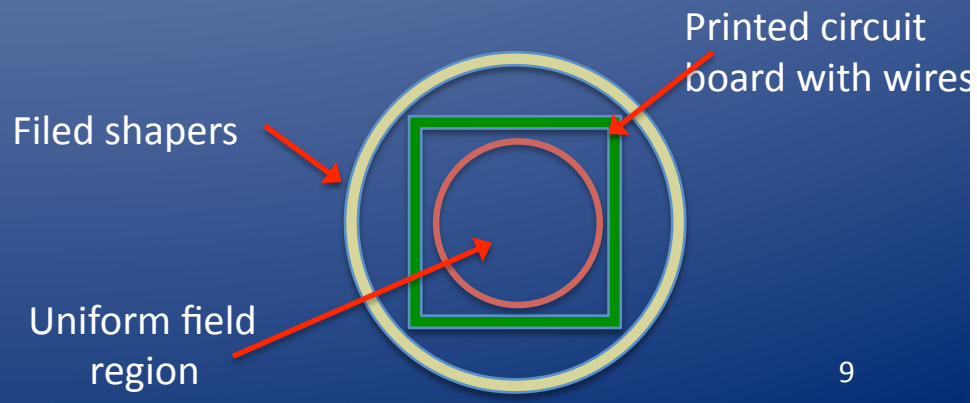
Breakdown voltage in LAr : 1.1-1.4 MV/cm ~10^8 V/m

The field is uniform at level of 10^{-3} in a cylindrical (h= 5m and diameter= 0.2 m) in the middle of the instrumented region





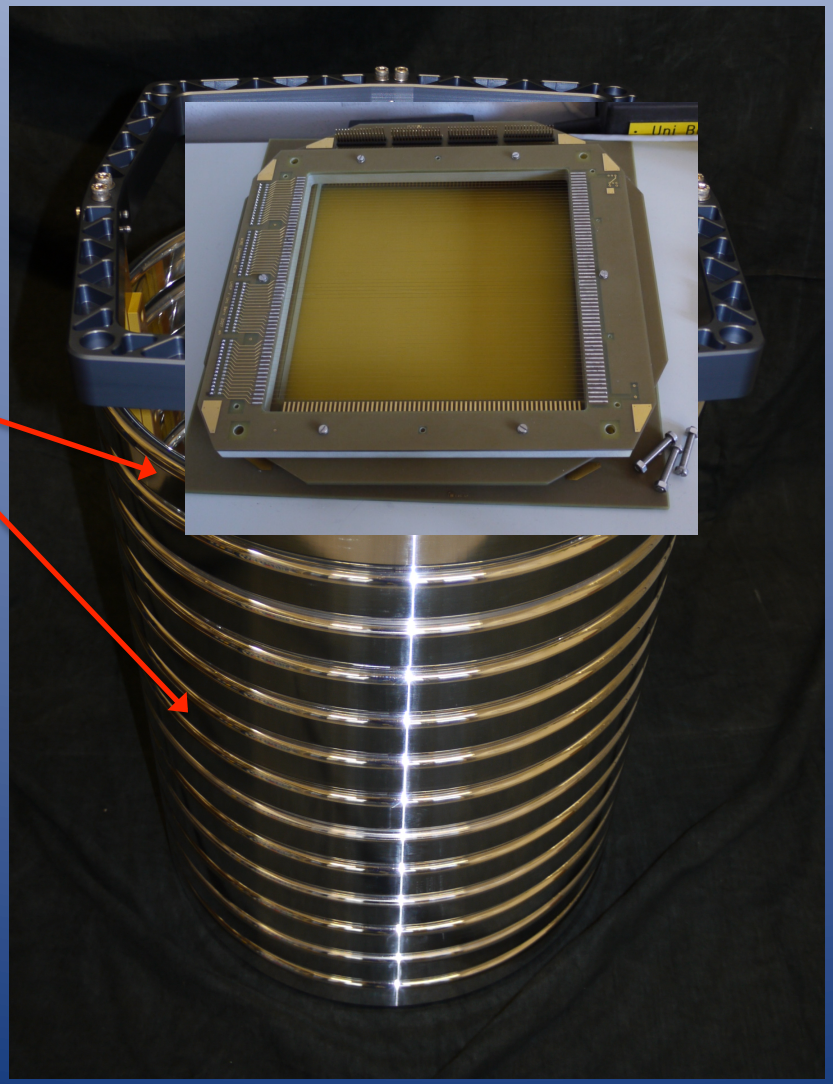
Maximum voltage is largely below the breakdown limit



ARGONTUBE detector

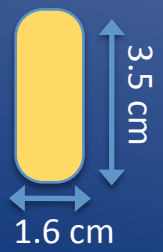
first 4 modules assembled

Gold plated aluminum field shapers.



A standard wire chamber will be used as first read out option. New read out device with amplification capability will be tested in a second step.

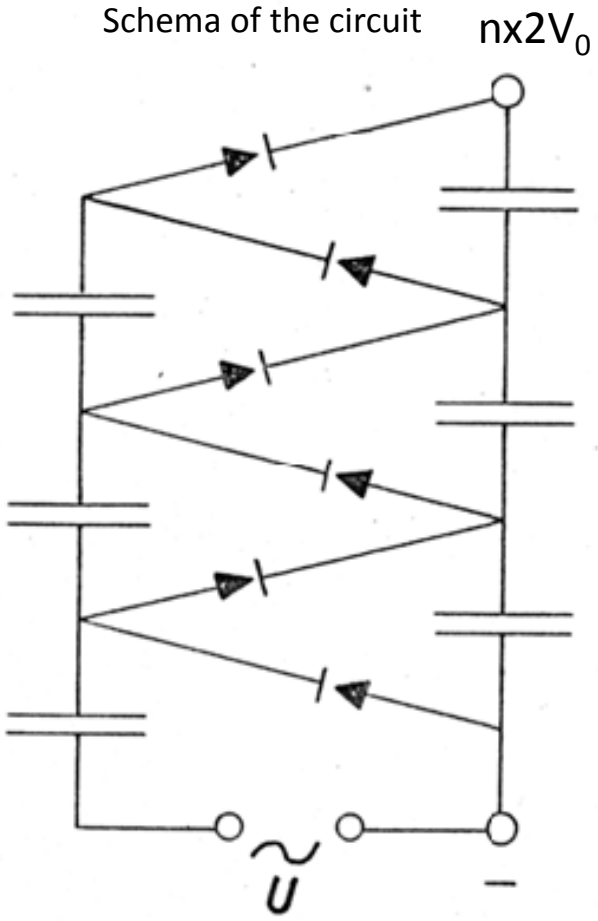
Rings cross section:



High voltage system

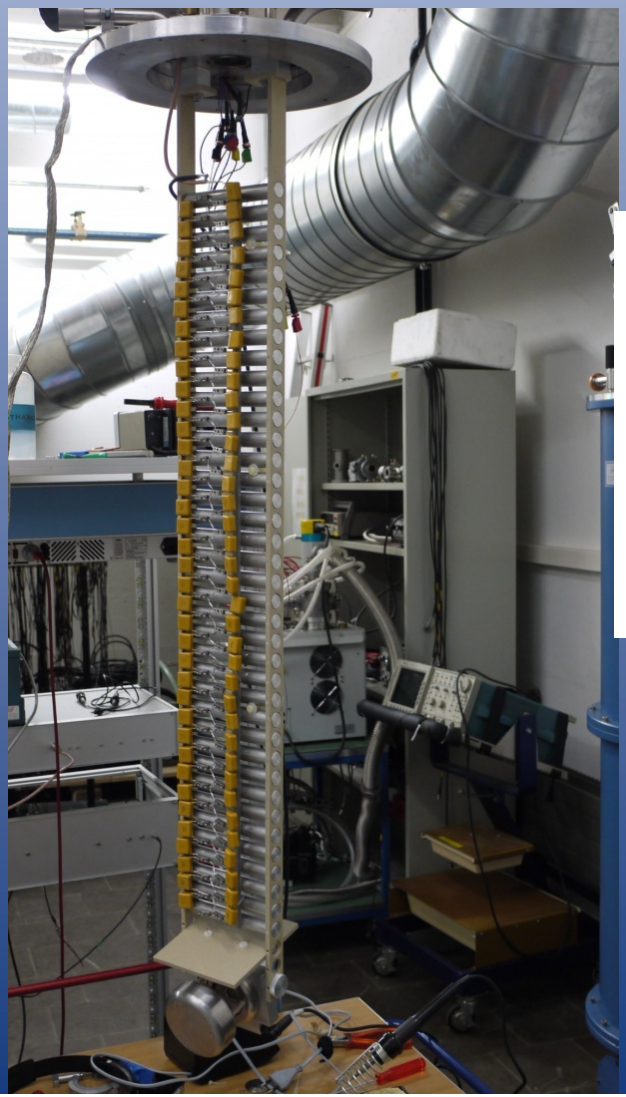
Greinacher/Cockcroft-Walton circuit: chain of rectifying cells installed in liquid

Schema of the circuit



In the ARGONTUBE project
125 stages will be installed

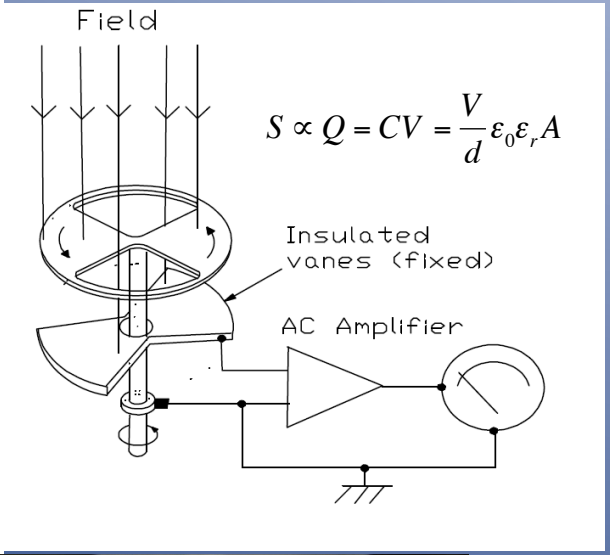
Test setup



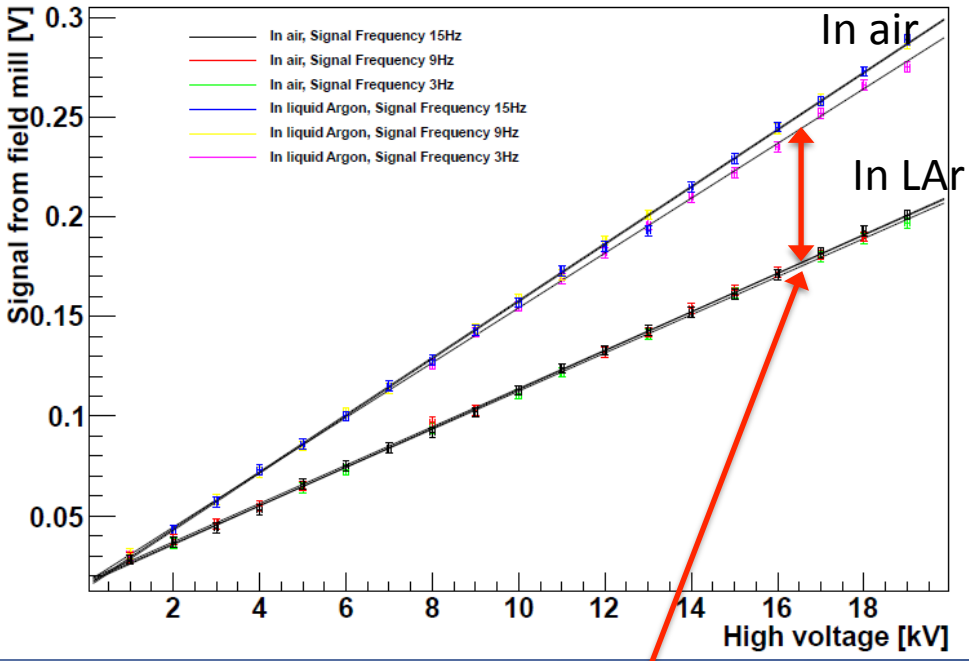
- 37 stages
- AC input voltage 4kV
- Tested in liquid Argon
- Field monitor at the bottom

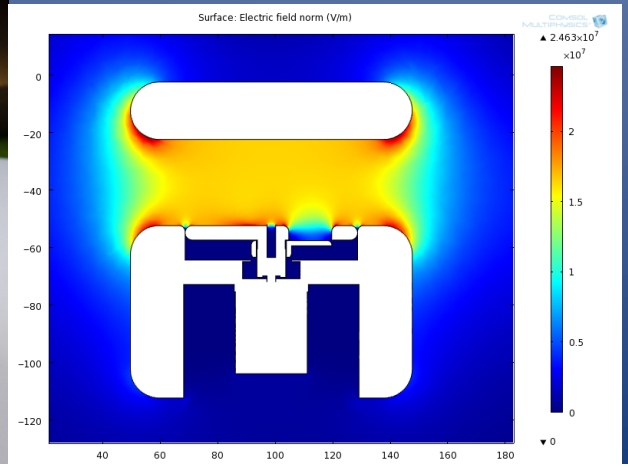
Field mill

Idea developed in collaboration with ETHZ and realized at the LHEP (University of Bern)



Calibration curves





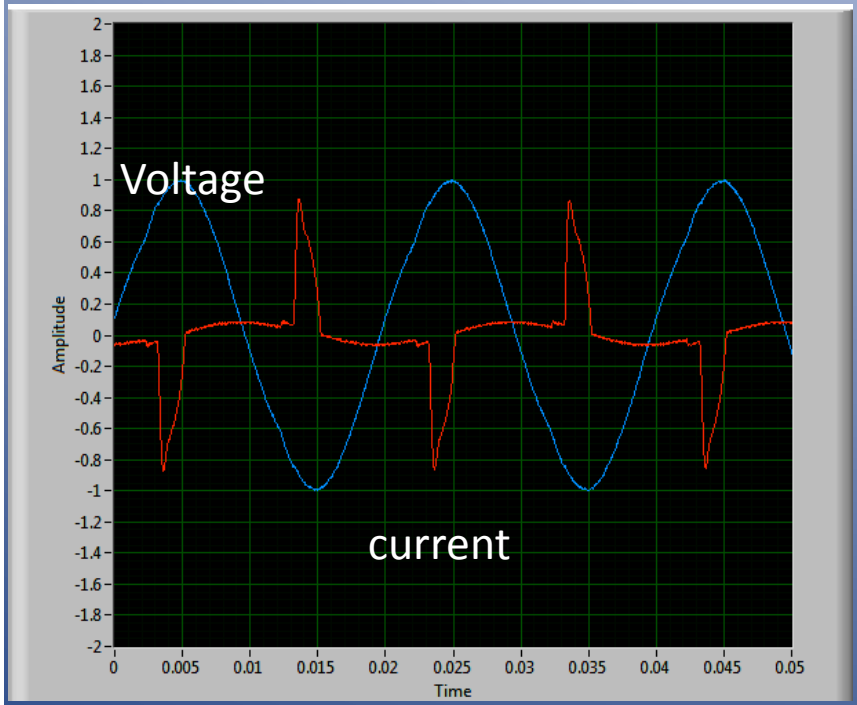
Dielectric constant of liquid argon

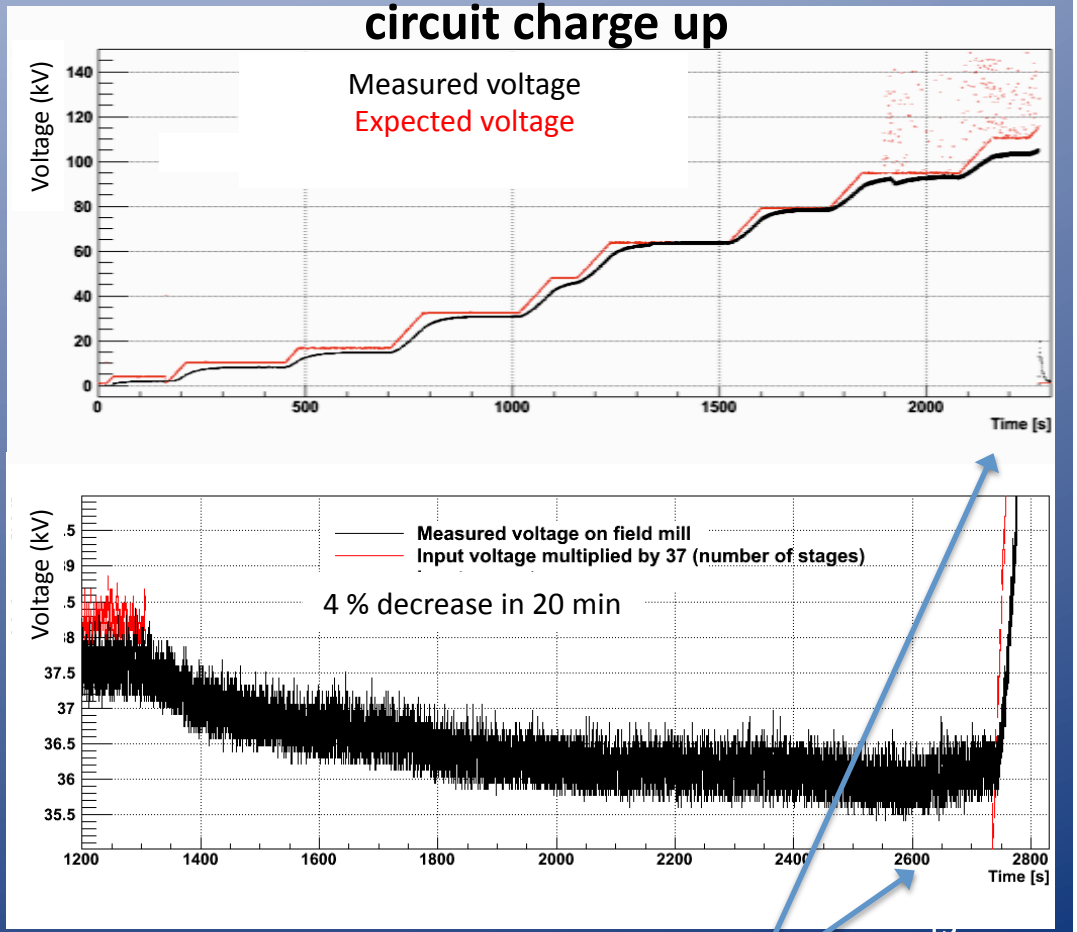
Literature :1.52

Measured :1.48±0.03

CHARGE up test

Monitoring of the injected signal



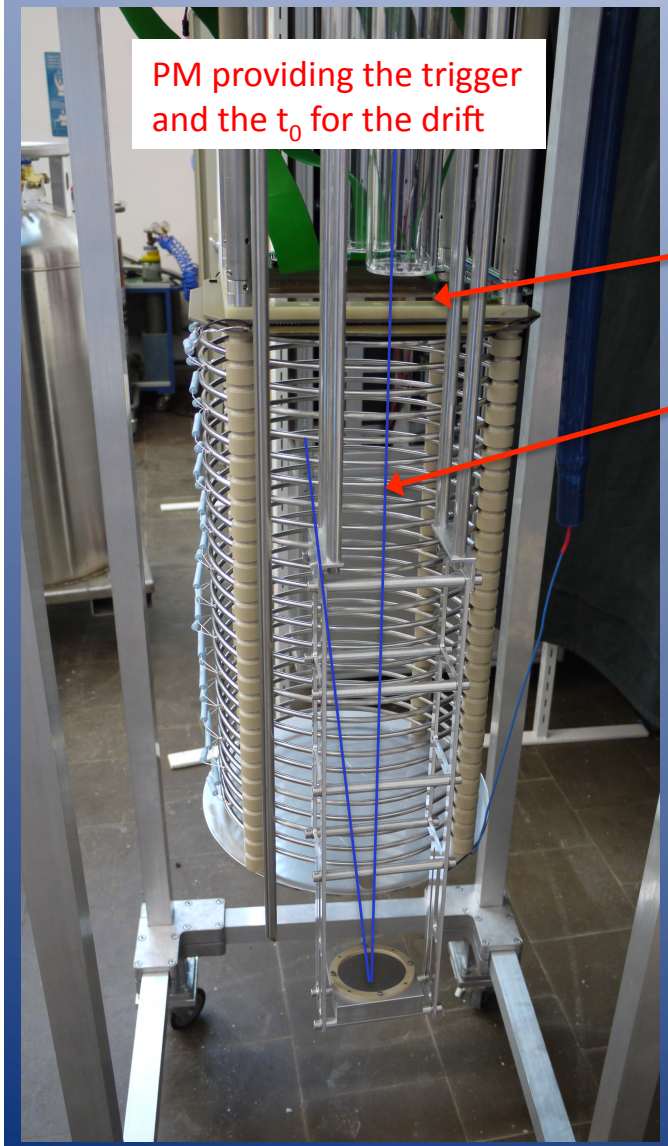


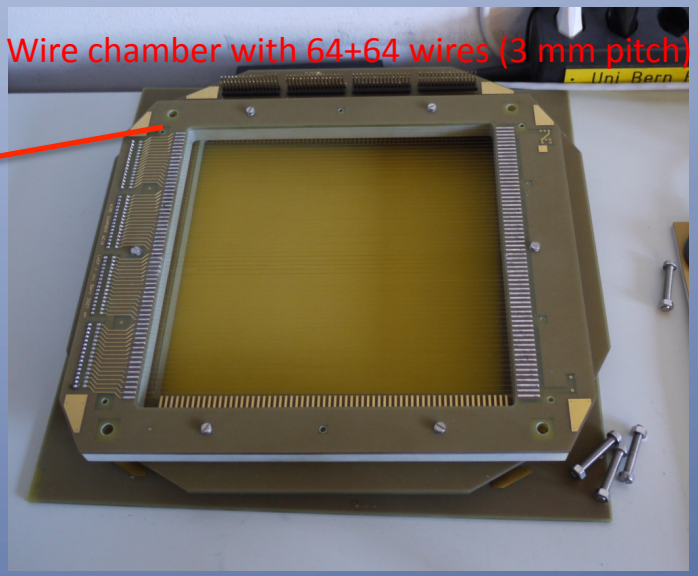
- Max Output : 4 kV peak to peak
- Frequency: 50 Hz
- Measuring system of output voltage and current

Charge up time scale

medium ARGONTUBE

a bench-test for the ARGONTUBE and even more[1,2]





Then main issues studied with medium ARGONTUBE:

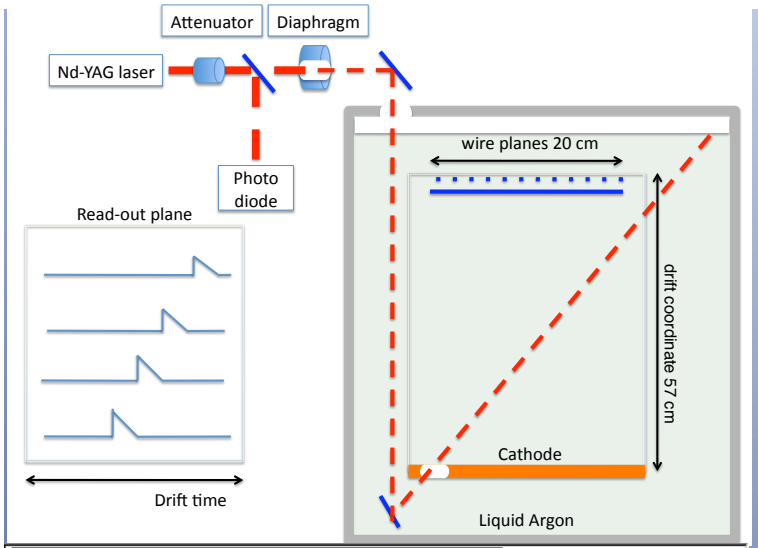
1. Purity monitor using a laser beam.
2. Recirculation system based on bellow pumps and TRIGON filters (twin system as the one for ARGONTUBE)
3. DAQ based on VME standard, fully developed at LHEP. Front-end pre-amplifiers, custom made in collaboration with CNRS (Lyon) and ETH (Zurich).

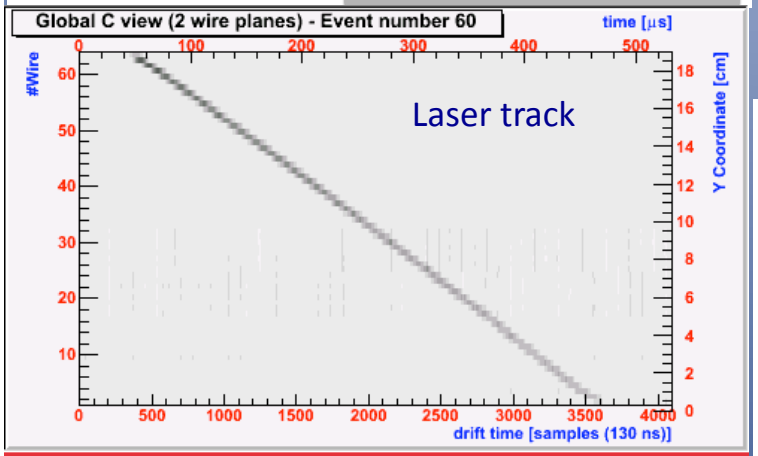
1. Measurement of the two-photon absorption cross-section of liquid argon with a time projection chamber. New J.Phys.12:113024,2010
2. A prototype of liquid Argon Time Projection Chamber for the study of UV laser multi-photonic ionization. JINST 4:P07011,2009.

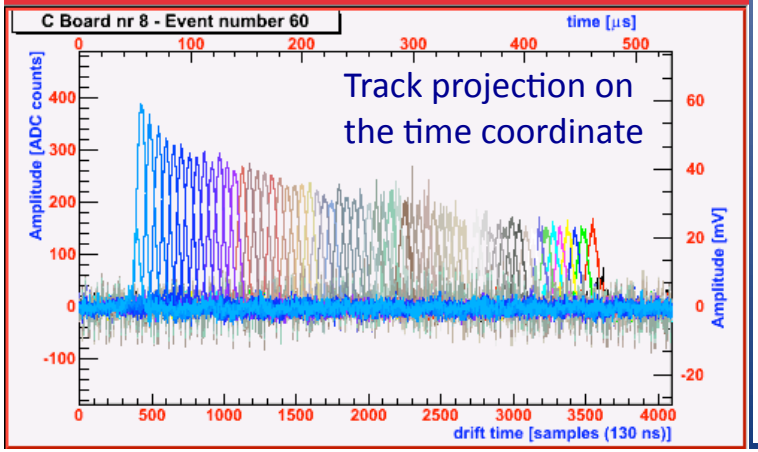
Laser beam

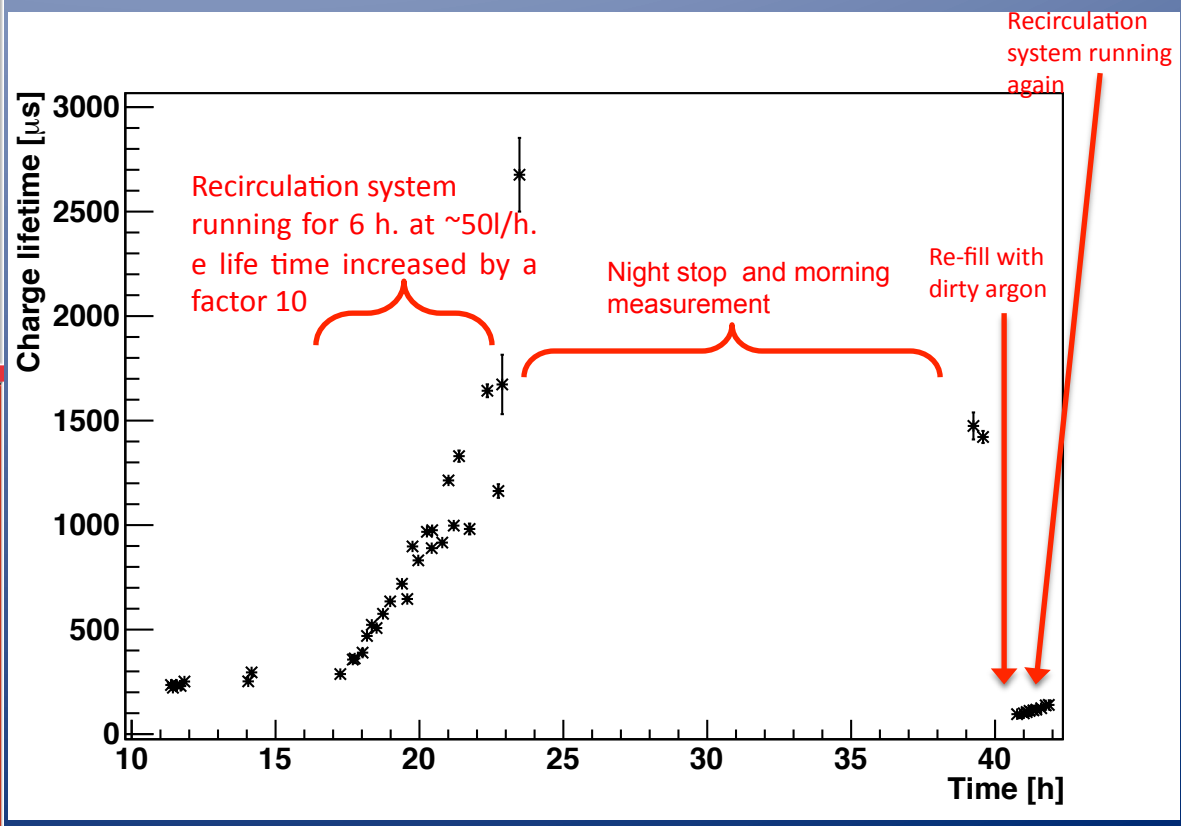
to monitor the purity of the LAr

Longest life time 2500 μs (~ 0.1 ppb) hitting the sensitivity limit of the detector. Longer life time can only be measured with the ARGONTUBE



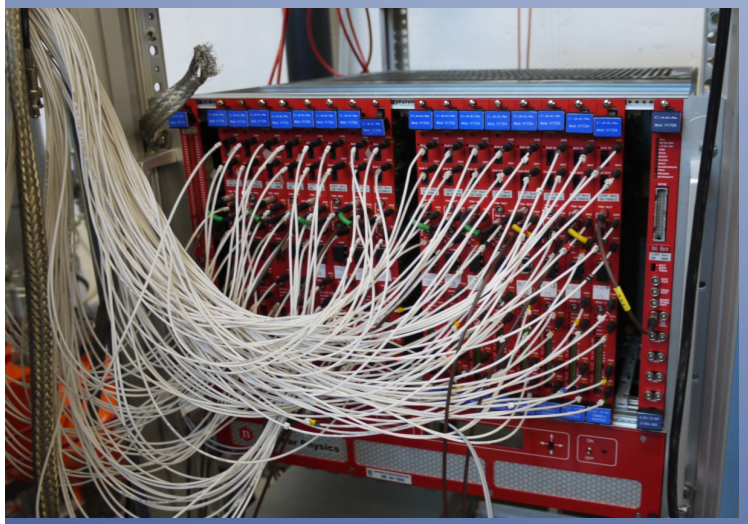






DAQ

Already tested on medium ARGONTUBE and ready to work for ARGONTUBE

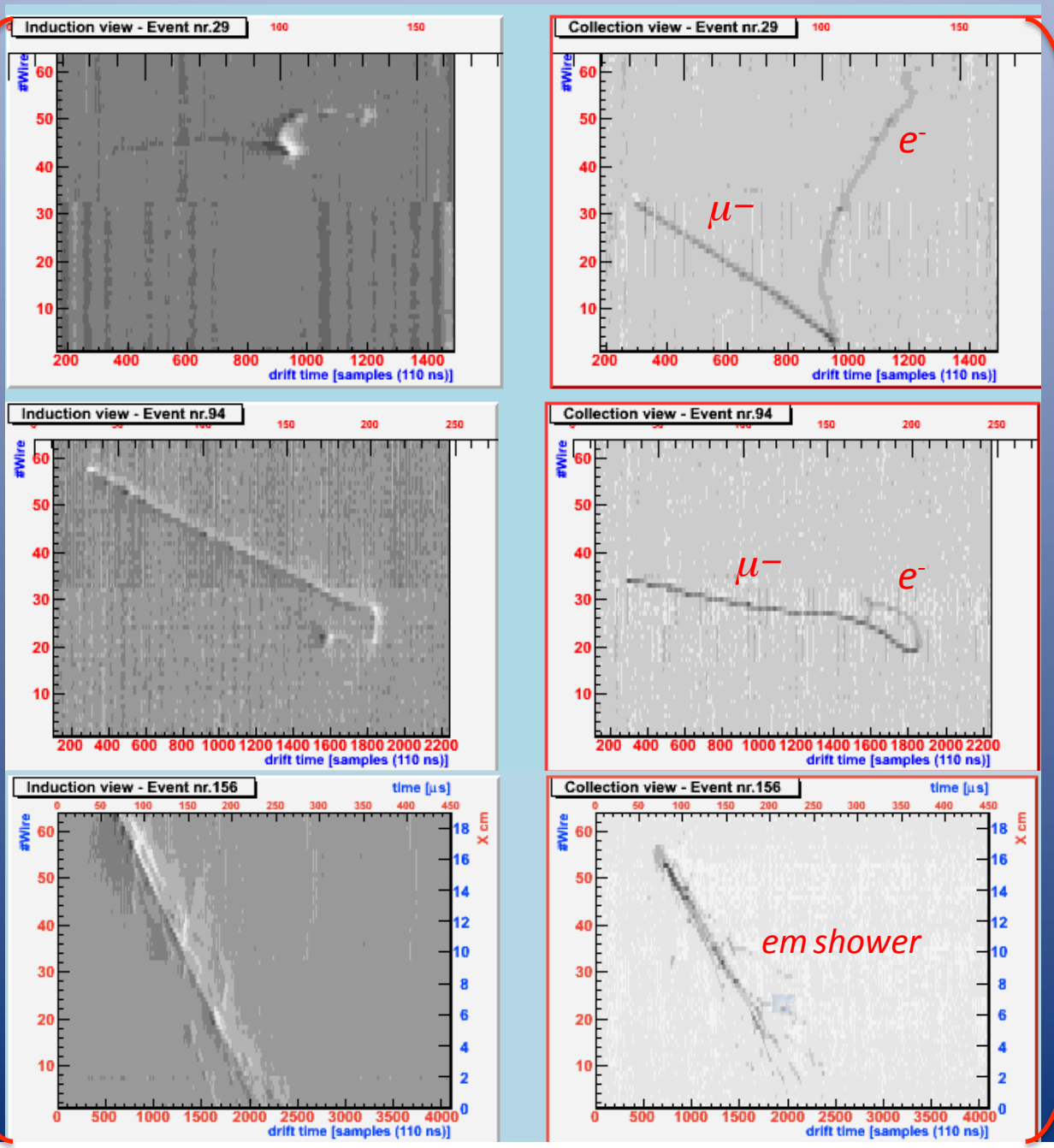


Sampling: 10 ns
DAQ window: 256kSamples/ch = 512kb/ch
Event Size = 512kb/ch * 128ch = 65MB/e

Sampling: 100 ns
DAQ window: 32kSamples/ch = 64kb/ch
Event Size = 64kb/ch * 128ch = 8MB/ev

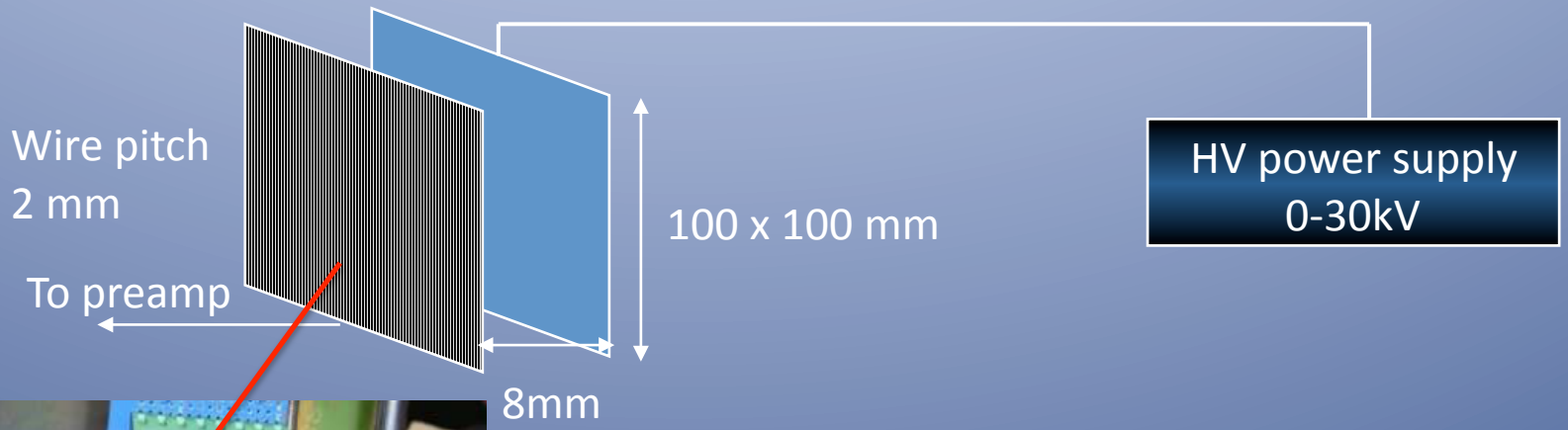
- 1 Crate
- 16 ADC boards V1724 (CAEN) with 8 channel each and 128 channels overall
- 4MB memory per board
- VME controller V2718 (CAEN) with a max data flow 70MB/s (optical link)

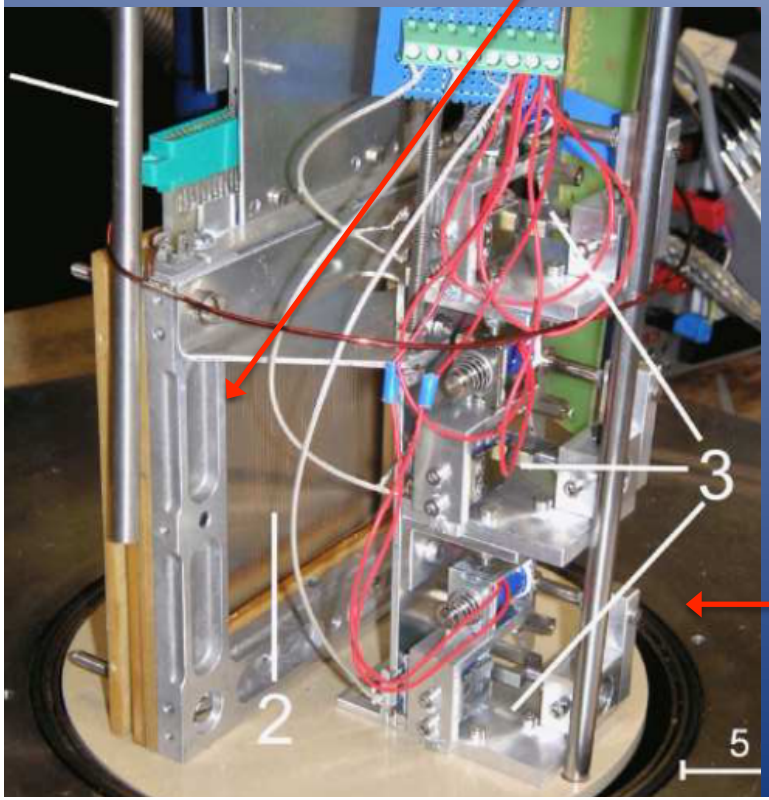
Events gallery



micro ARGONTUBE

A short distance TPC where the drift properties of the electrons in a mixture of LN-LAr are studied



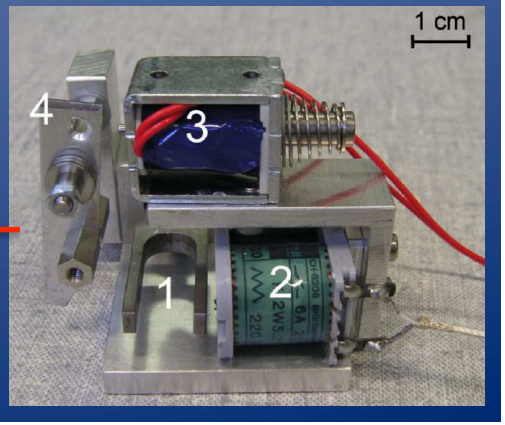


The content of Nitrogen is monitored by resonant density sensor.

$\rho_{LAr} = 1.4\ g/cm^3$

$\rho_{LN} = 0.8\ g/cm^3$

Density sensor developed at LHEP:



Electron yield

TPC response to alpha and beta particles as function of the E_{drift} with different Nitrogen concentration.

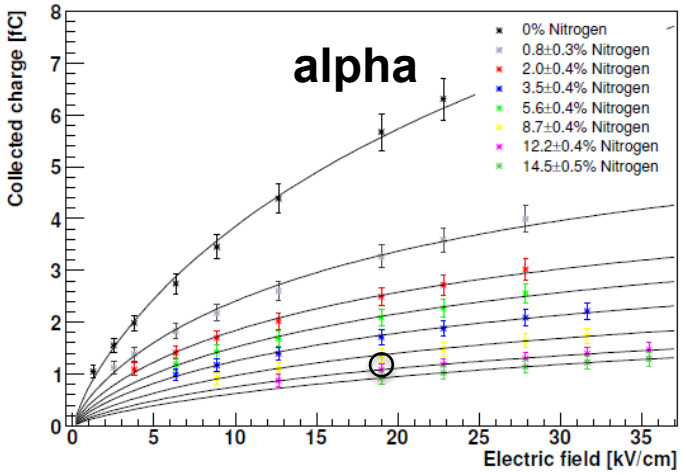


Figure 9. Collected charge produced by an ^{241}Am source for different drift-field intensities and Nitrogen concentrations. The ^{241}Am source is placed directly at the cathode plate of the TPC, so that the drift distance is 7.9 mm. The calibration procedure described in the text is applied. Points are fitted with the Box model.

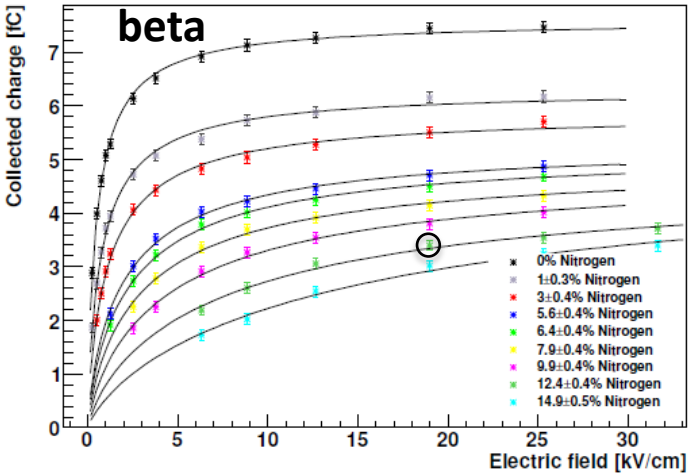


Figure 12. Collected charge corresponding to the Compton edge from ^{60}Co for different drift field intensities and different Nitrogen concentrations. Experimental data are fitted with the "Box model".

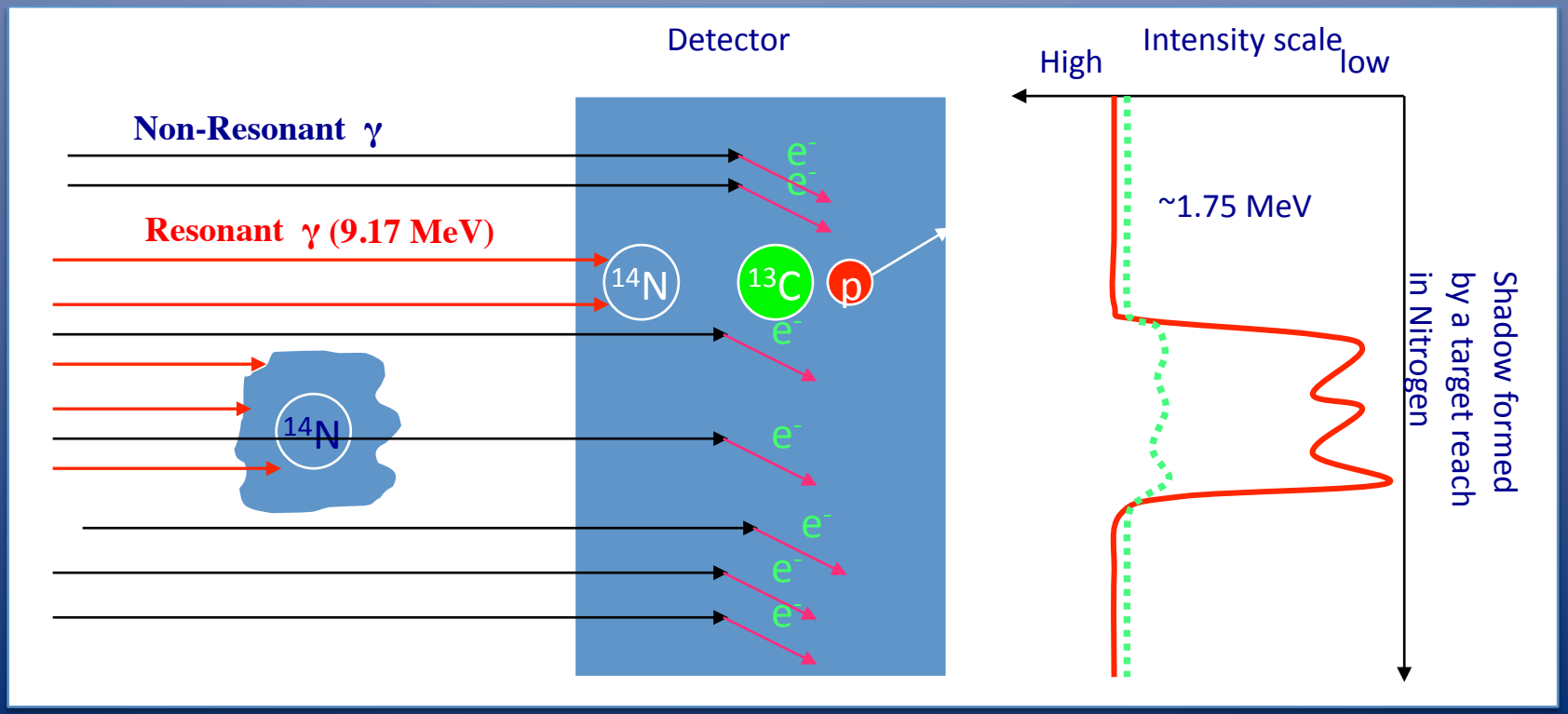
1. Ionization signals from electrons and alpha-particles in mixtures of liquid Argon and Nitrogen: Perspectives on protons for Gamma Resonant Nuclear Absorption applications. JINST 5:P10009,2010.
2. Study of ionization signals in a liquid Argon TPC doped with Nitrogen. JINST 3:P10002,2008.

Gamma Nuclear Resonant Absorption

on Nitrogen nuclei proposed by Soreq National Research Center (Israel) in 1985

X-ray cargo radiography are sensitive to high density objects of peculiar shape and not particularly sensitive to specific chemical compositions such as the one of which many explosives (reach in Nitorgen) are made of.

$$\gamma + {}^{14}N \rightarrow {}^{13}C + p$$



Conclusions and outlook

- In the R&D program under development at the LHEP (UniBern) two LAr TPCs have been constructed and tested successfully. The third one, ARGONTUBE, with a drift length of 5 m (the longest so far) is under construction.

- All the most important issues of the ARGONTUBE have been addressed

Next steps:

•ARGONTUBE

- ✓ Complete the construction of the TPC .
- ✓ Detect a muon track as long as 5m.

•medium ARGONTUBE

- ✓continue to work as bench test for ARGONTUBE

•micro ARGONTUBE

- ✓ show definitively the feasibility of the gamma ray radiography