

First Measurement with Argontube, a 5m long drift Liquid Argon TPC

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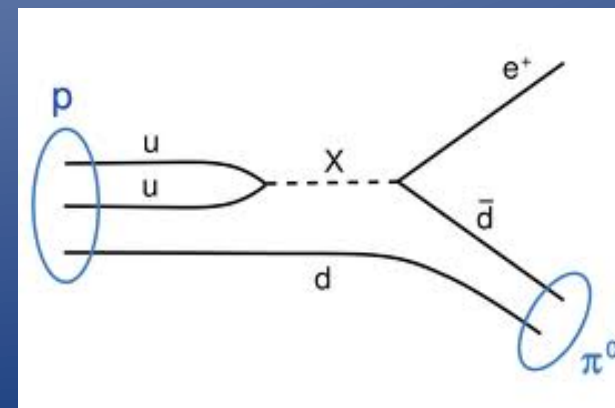
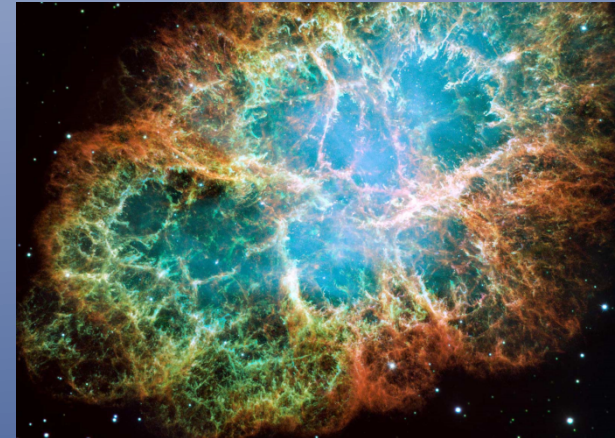
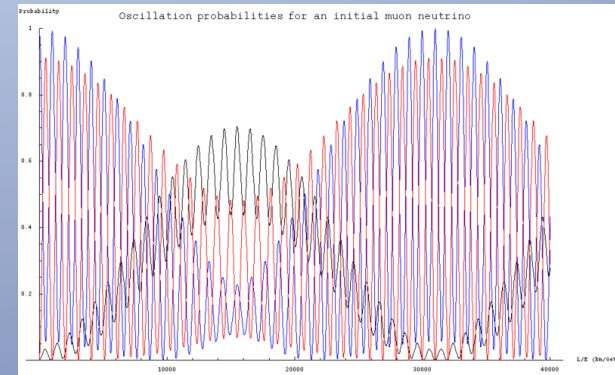
A. Ereditato, S. Haug , C. Hsu, S. Janos, I. Kreslo, M. Messina, C.
von Rohr, B. Rossi, T. Strauss, M. Weber, M. Zeller

Outline

- Physics
- LAGUNA
- LAr TPC technique
- Argontube (LAr TPC with 5 m drift)
- Conclusions

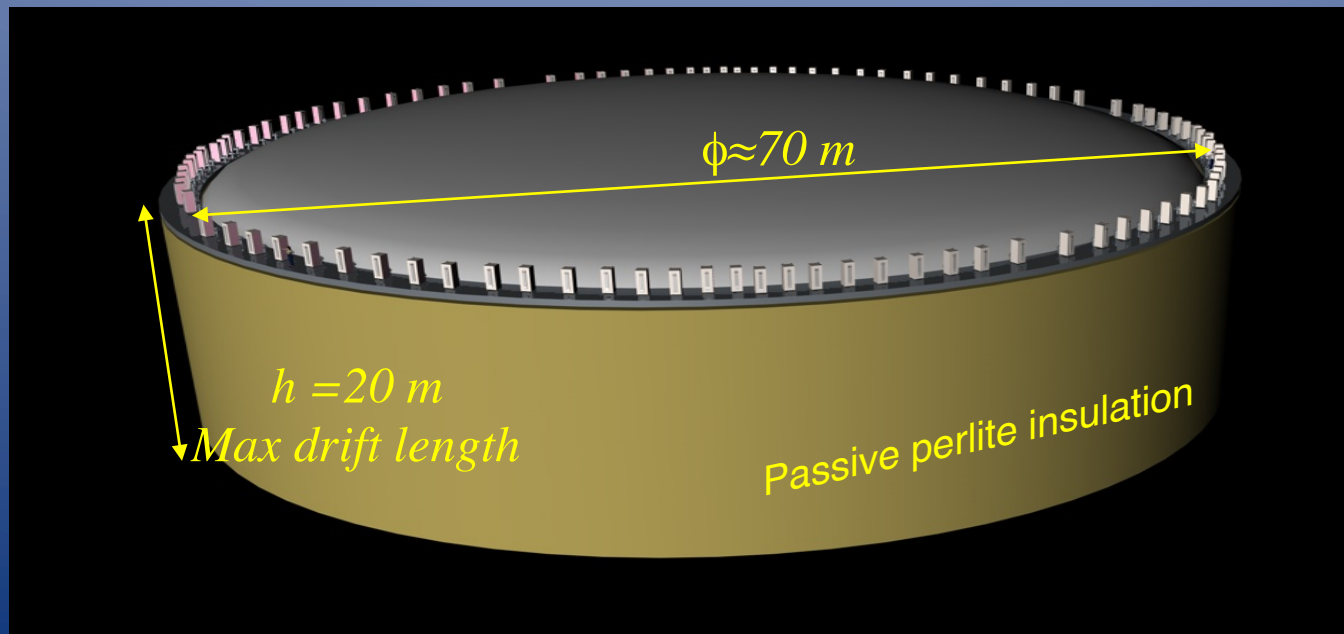
Physics

- Neutrino properties
 - θ_{13}
 - C_p violation (lepton sector)
 - Mass hierarchy
- Neutrinos as probes
 - Supernova Neutrinos
 - Solar Neutrinos
 - Other neutrinos sources
- Proton decay (GUT)



LAGUNA (Large Apparatus for Grand Unification and Neutrino Astrophysics)

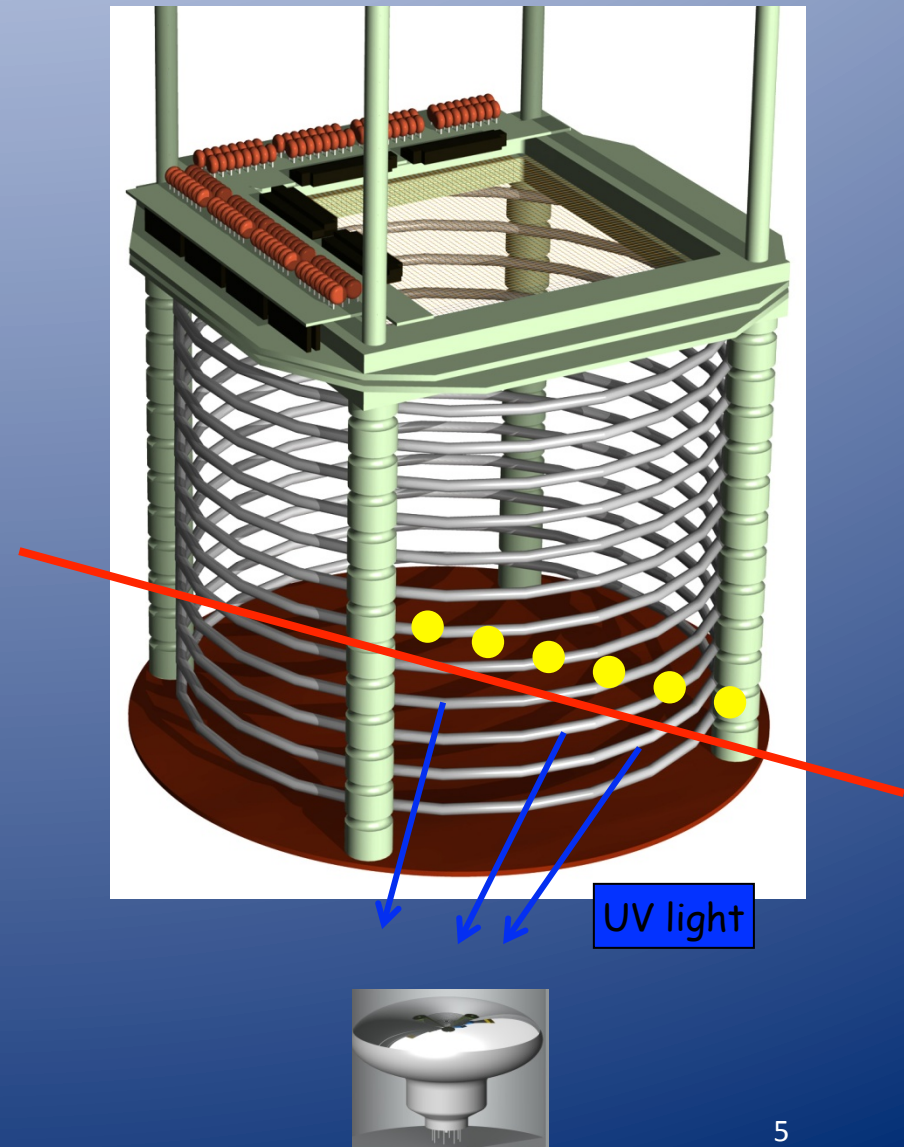
- **MEMPHIS**
500kt Water Cherenkov
- **GLACIER**
100kt Liquid Argon
- **LENA**
50kt liquid Scintillator



LAr TPC technique

- Three dimensional tracking device
- Readout of the charge is only on surface
- Read out charge corresponds to the energy deposited in the detector
- Momentum estimation via multiple scattering
- The detector is 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)

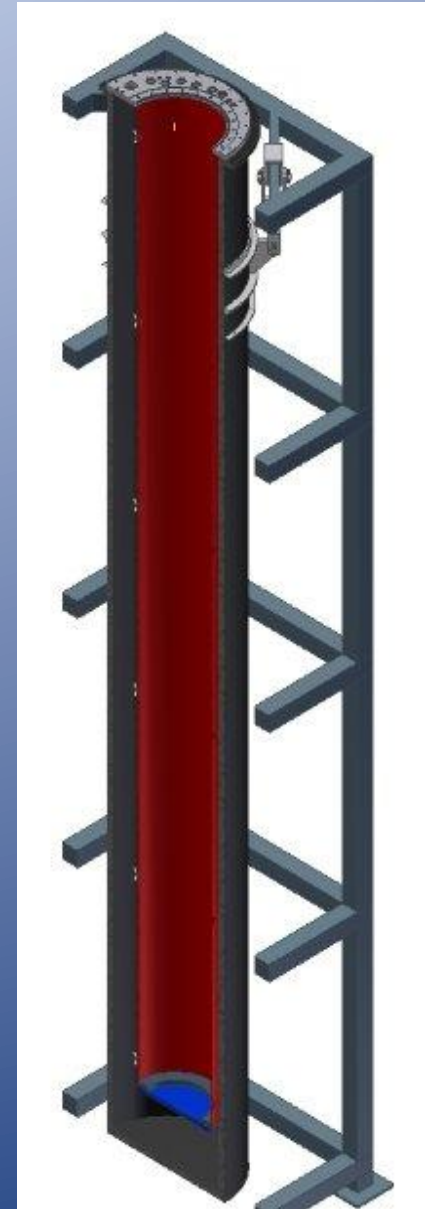


Argontube

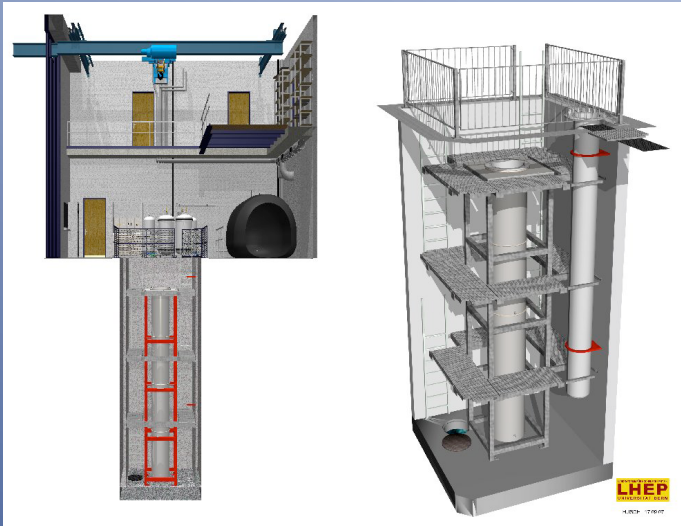
Prove the feasibility of 5 m drift

- Main technological issues
 - 500 kV in liquid Argon
 - Signal over noise ratio at least factor 10
 - Impurities at the level of $< 0.1\text{ppb}$
- Possible studies
 - 5 m particle tracks
 - Measure the purity (Charge loss along the drift)
 - Electron diffusion (parallel and perpendicular to E-field)
 - Test new readout system and electronics
 - Muon decay (Michel spectrum)

- Outer volume: 1.2 m^3
- Inner volume : 1.1 m^3
- Active volume: 0.2 m^3
- Mass of active volume: 280 kg

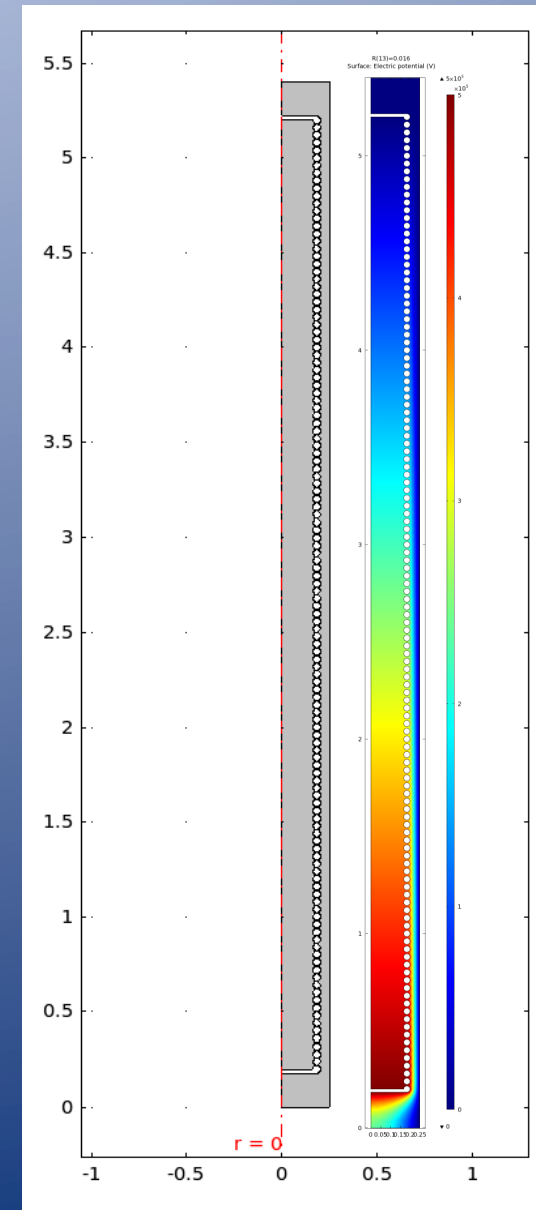


Design and construction

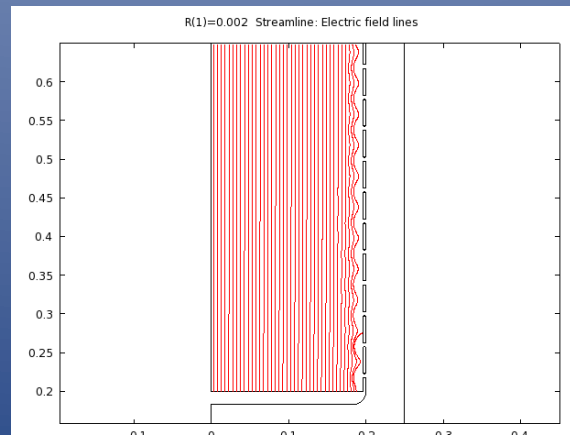
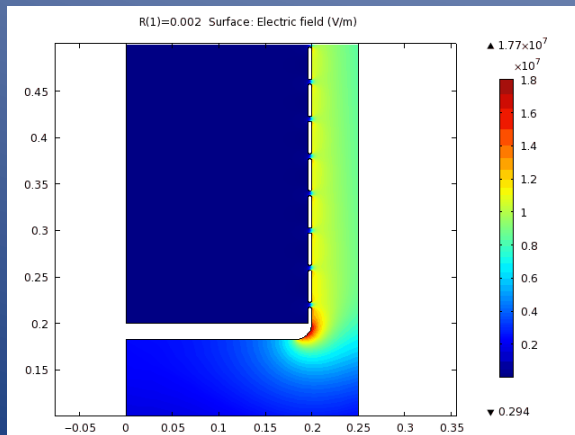
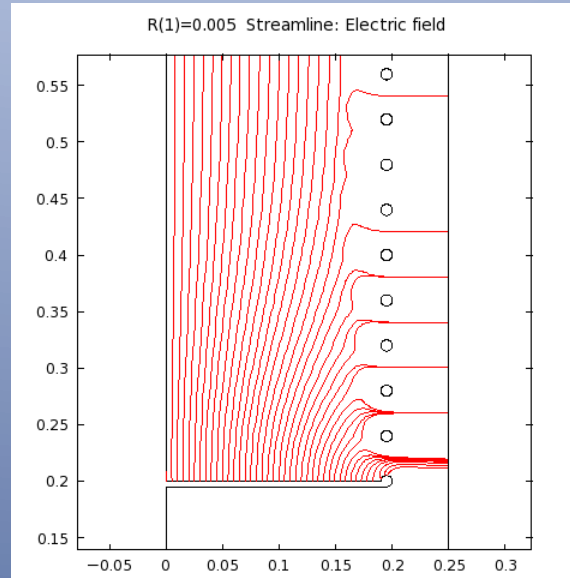
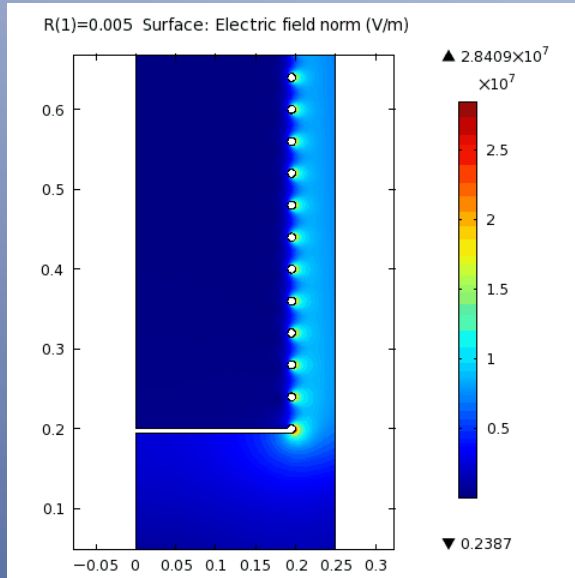


Electric field simulation (2d axis-symmetric)

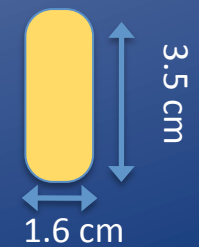
- Comsol (Finite element analysis software)
- Dimensions of cryostat: 0.5m x 5.6m
- Dimensions of the drift chamber : 0.4m x 5m
- Pitch between two rings: 4 cm
- Different thickness and forms of field shaping rings have been simulated



Electric field simulation

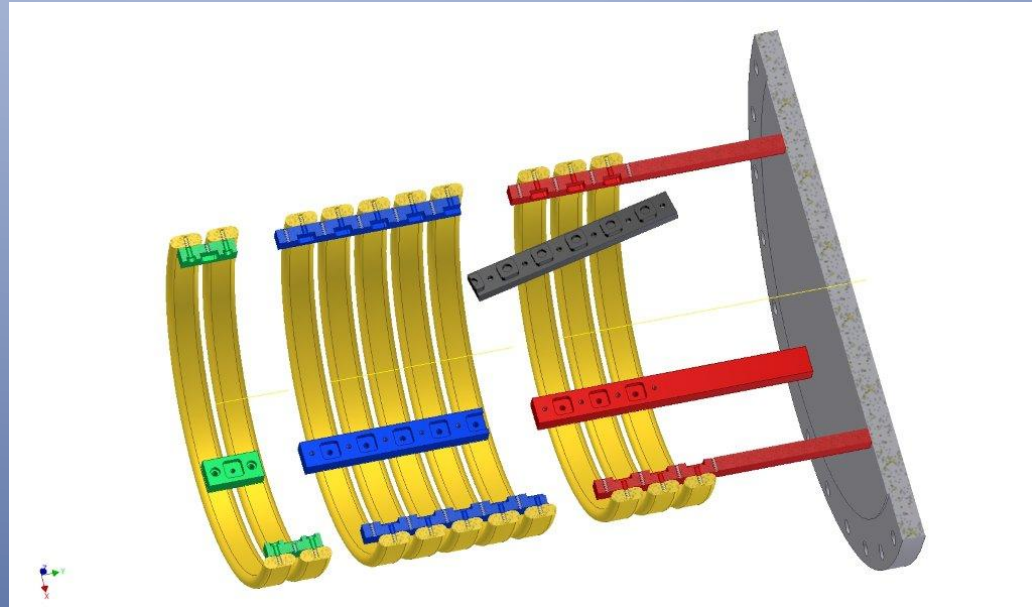


Rings cross section:



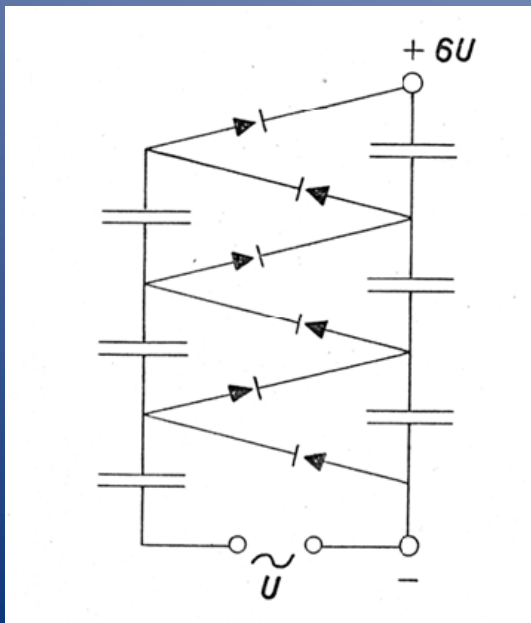
breakdown voltage in LAr : 1.1-1.4 MV/cm

Detector design and construction

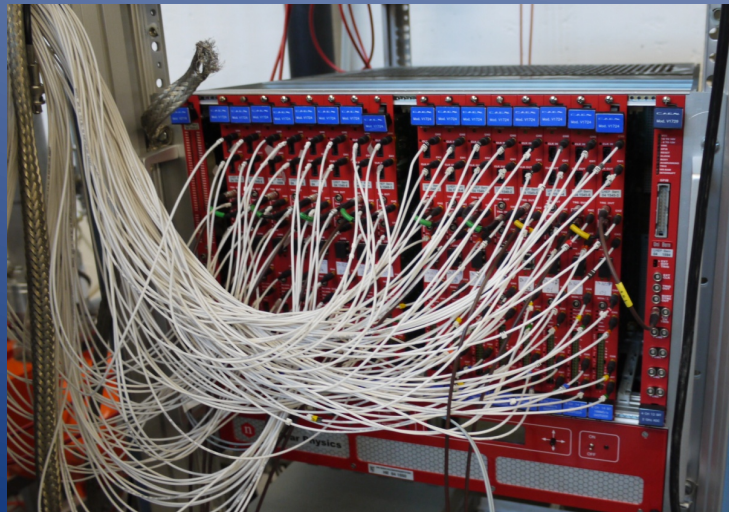
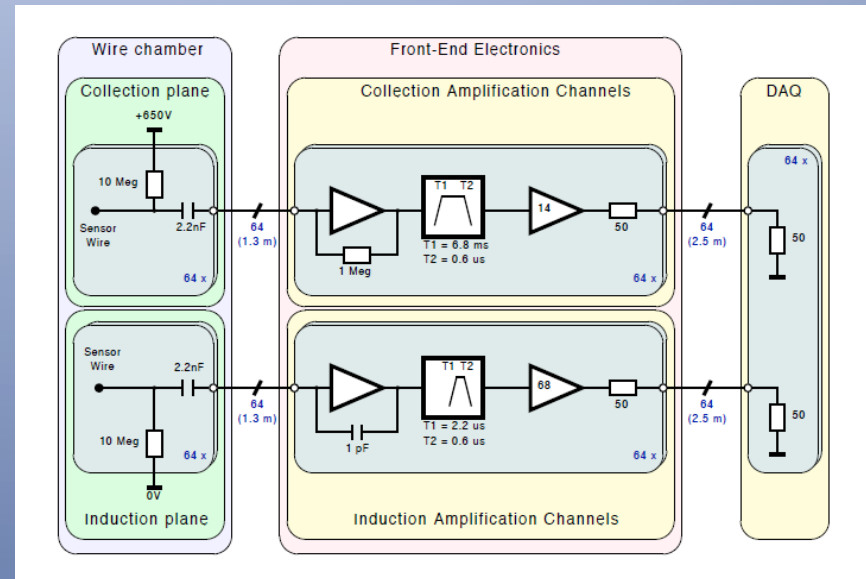
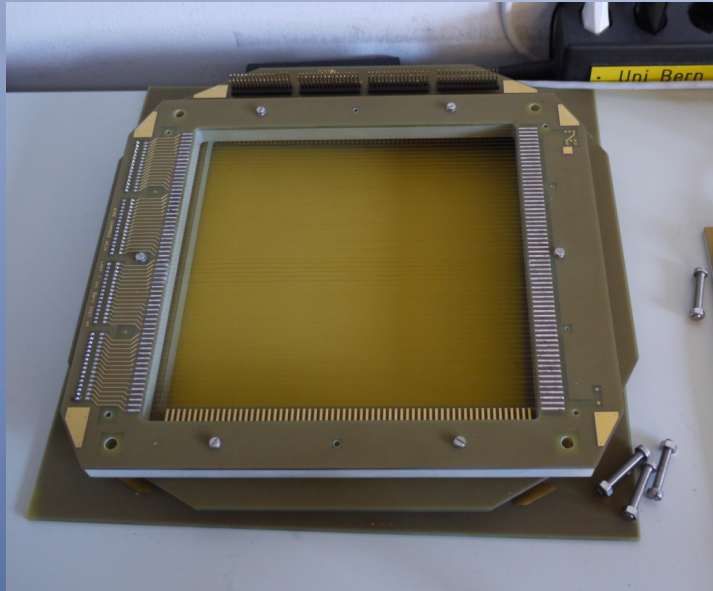


High voltage system (Cockcroft-Walton or Greinacher multiplier)

- 125 stages installed
- Maximum AC input voltage is 4kV peak to peak
- Sinusoidal input voltage 50 Hz
- 500 kV should be reached providing a drift field of 1 kV/cm



TPC, pre-amplifiers and DAQ



Max Drift Distance: 5000 mm
 e^- Velocity: 2mm/ μ s
 Max Drift Time: 2500us

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

First test of Argontube

Vacuum

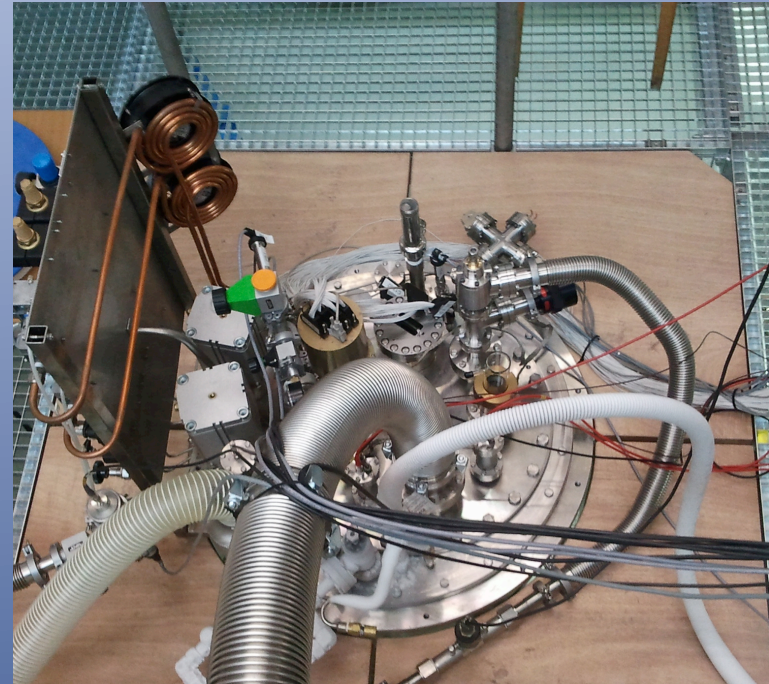
- Pumping with pre-vacuum- and roots-pump
- 5 days of pumping
- Vacuum: $4.8E-5$ mbar

Filling

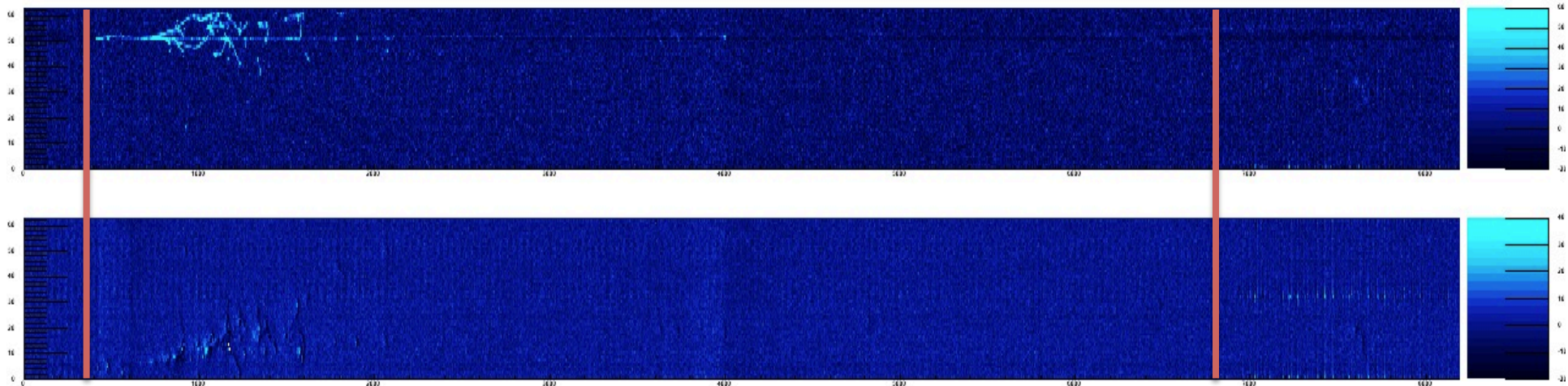
- 6 h to fill ARGONTUBE
- 2600 l of Argon used
- Filtered Argon was injected (Oxygen trap)
- Before taking data one night of liquid recirculation through oxygen trap

Operation

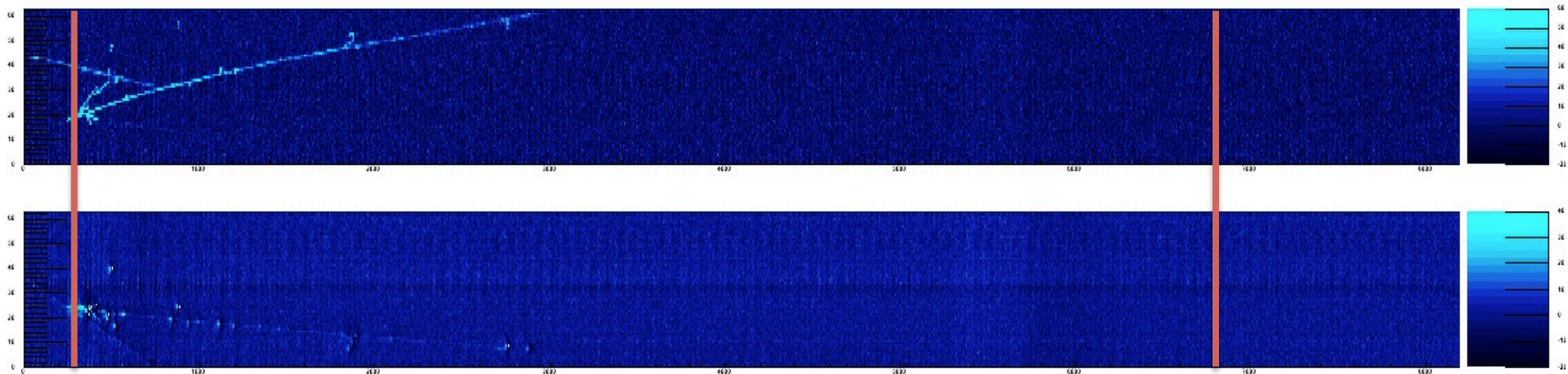
- HV was ramped up to 1.2kV AC input voltage (150 kV) -> discharges
- Stable conditions at 1 kV AC input voltage (125 kV)
- Cosmic muon tracks
- Laser induced signals
- Drift field not homogenous (from 250V/cm-150V/cm)
- Measured voltage 100kV
- 2 Weeks of operation (about 10'000 events)



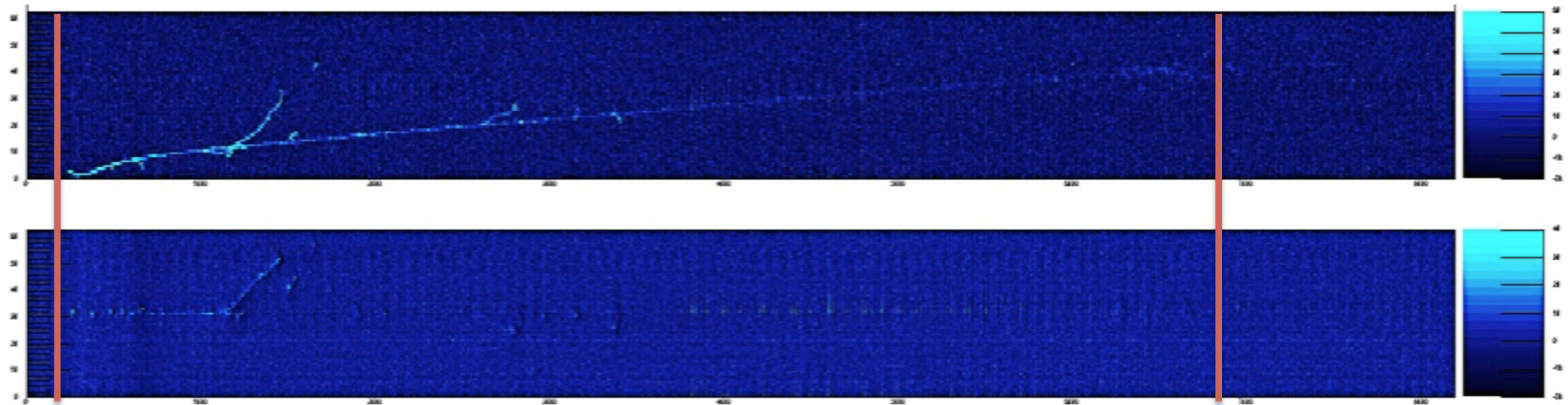
Cosmic muon tracks at 100kV



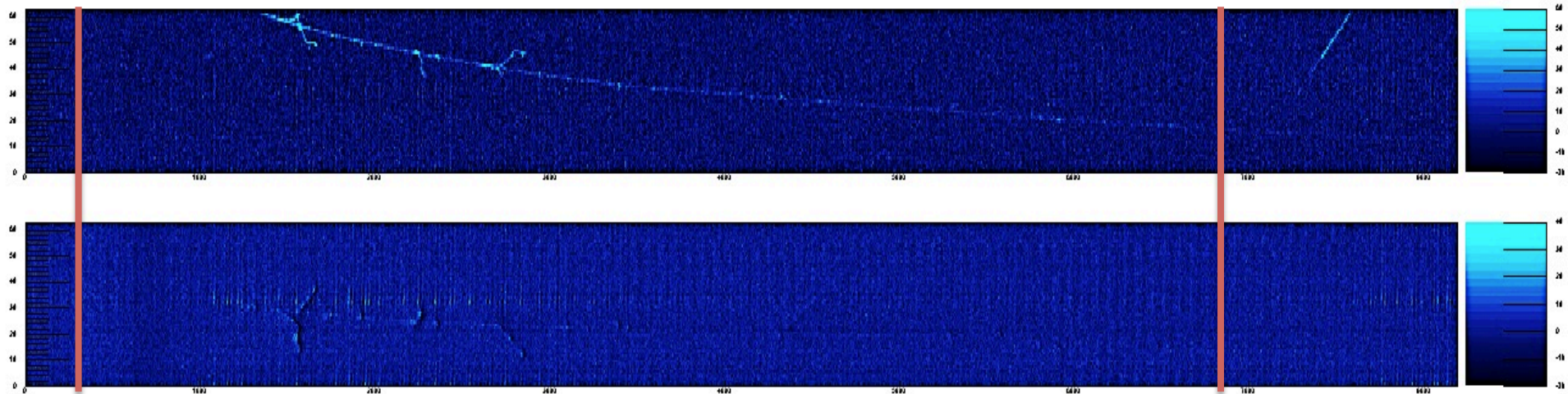
6.1 ms corresponds to 5m drift



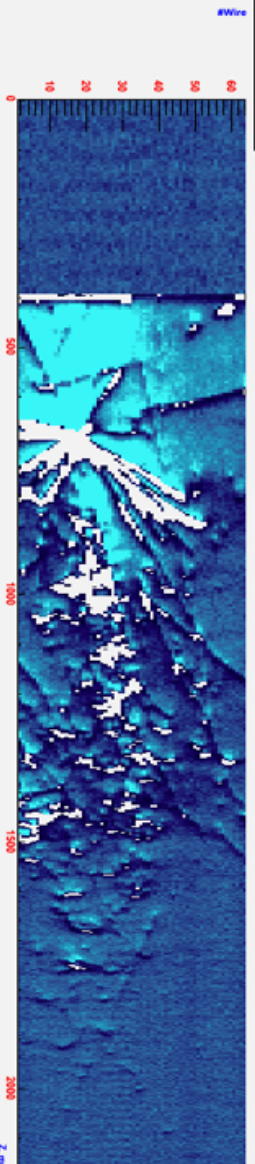
Cosmic muon tracks at 100kV (200 V/cm)



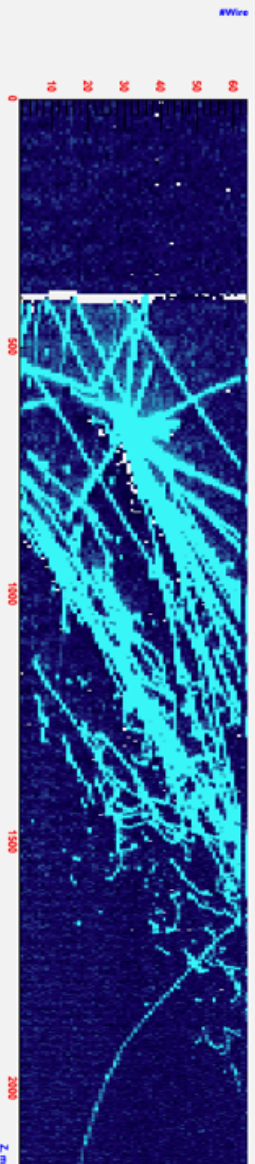
6.1 ms corresponds to 5m drift



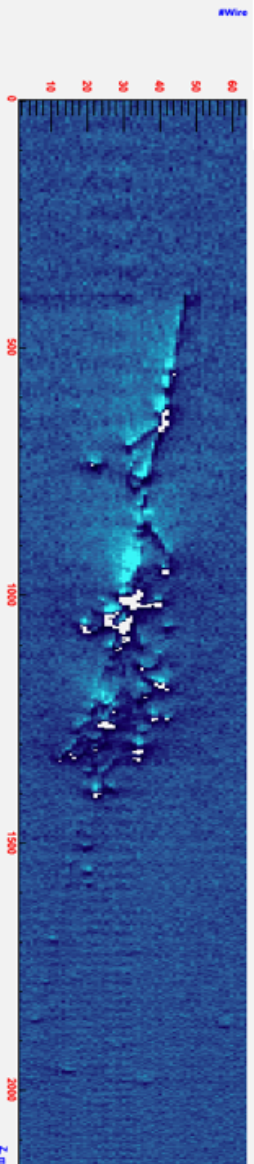
Induction view, Event 675



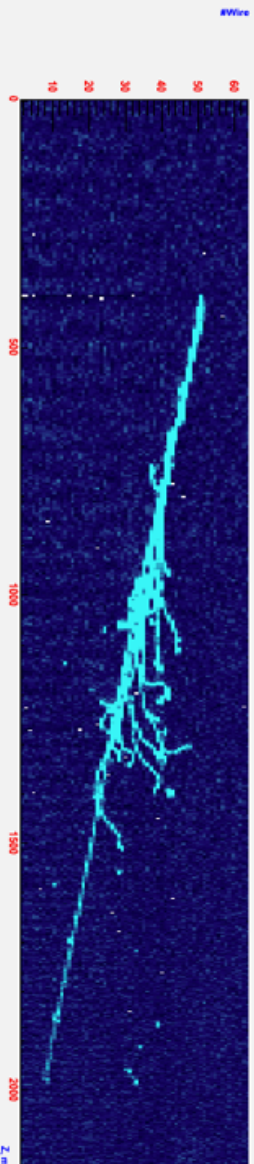
Collection view, Event 675



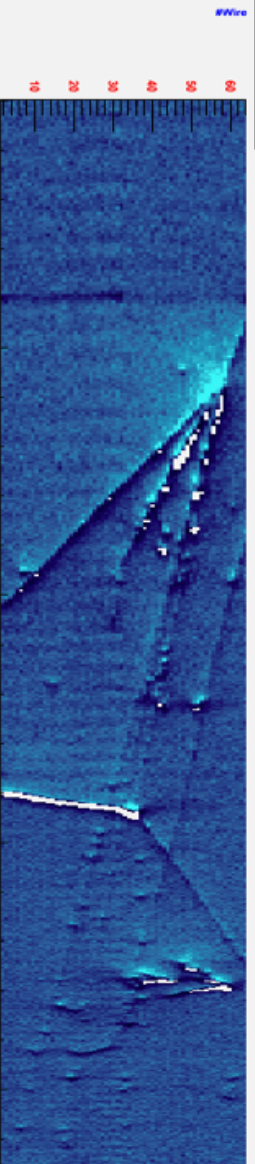
Induction view, Event 598



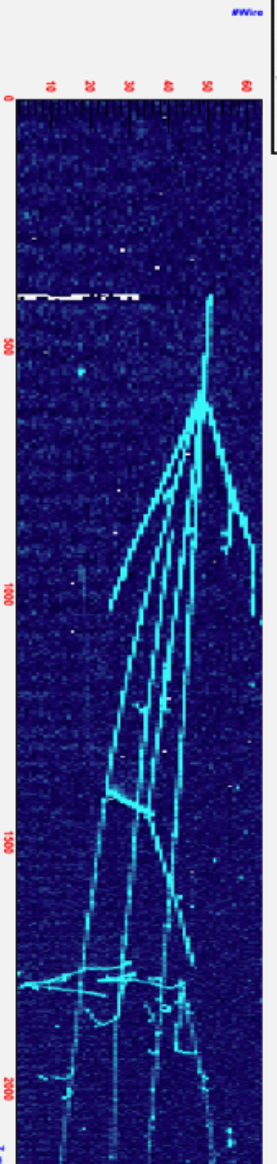
Collection view, Event 598



Induction view, Event 529

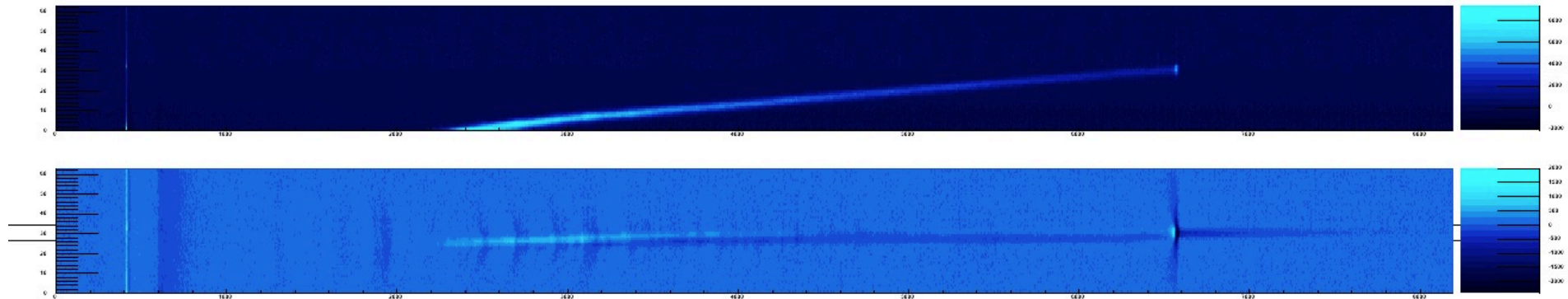


Collection view, Event 529



UV-Laser tracks

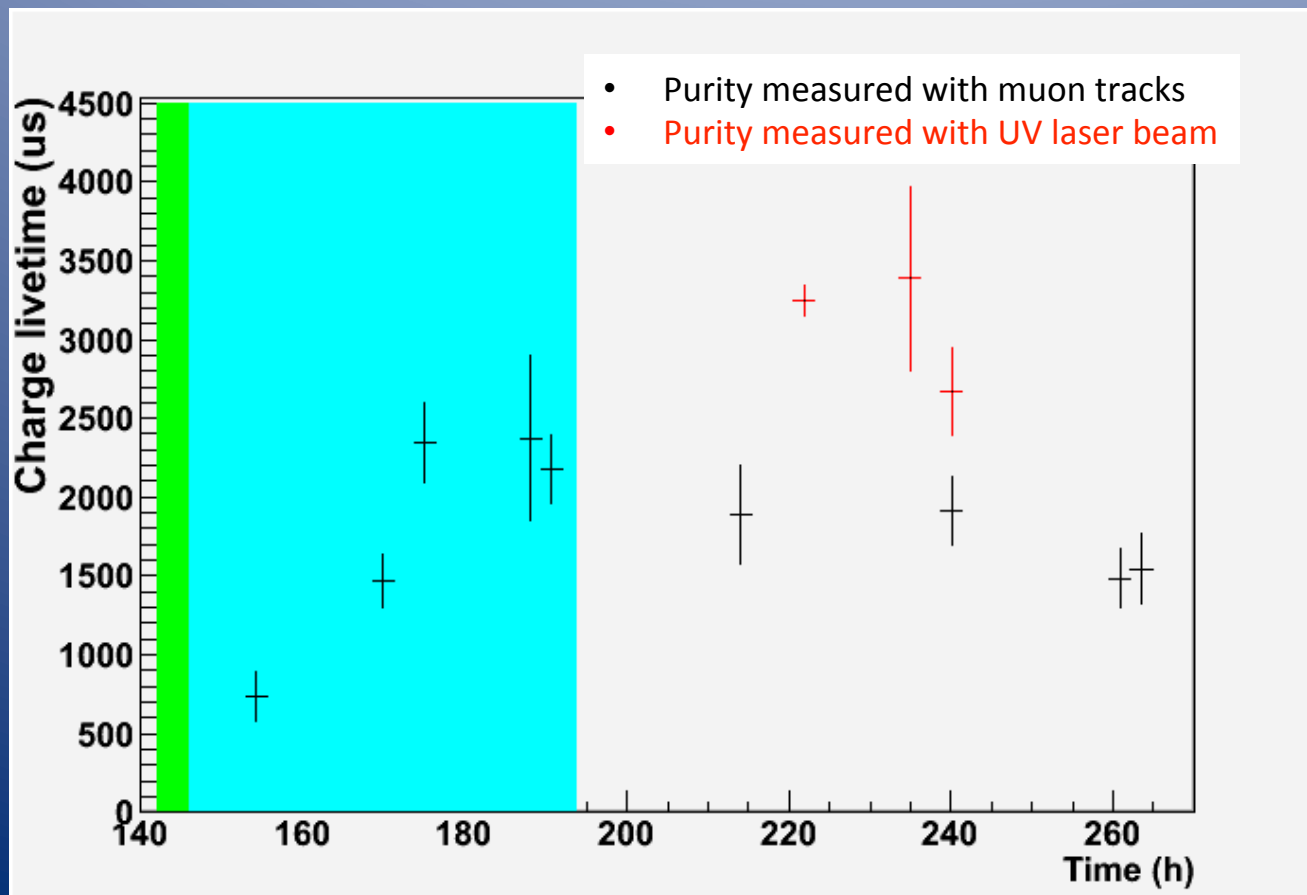
- Laser wavelength 266 nm
- 4 mJ per pulse
- Feed through on the top
- Argon is ionized via 3 photon absorption



Maximal drift: 6.1 ms
Corresponds to 100kV

Purity measurement with UV-laser and muons

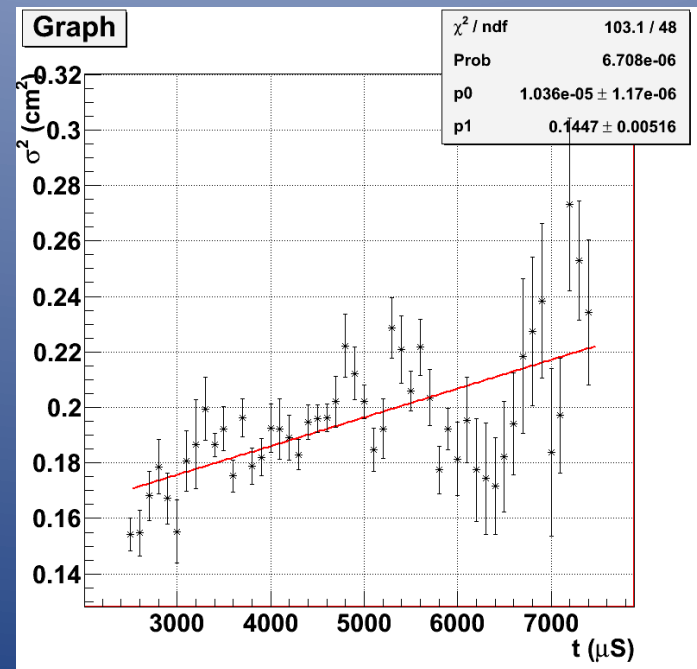
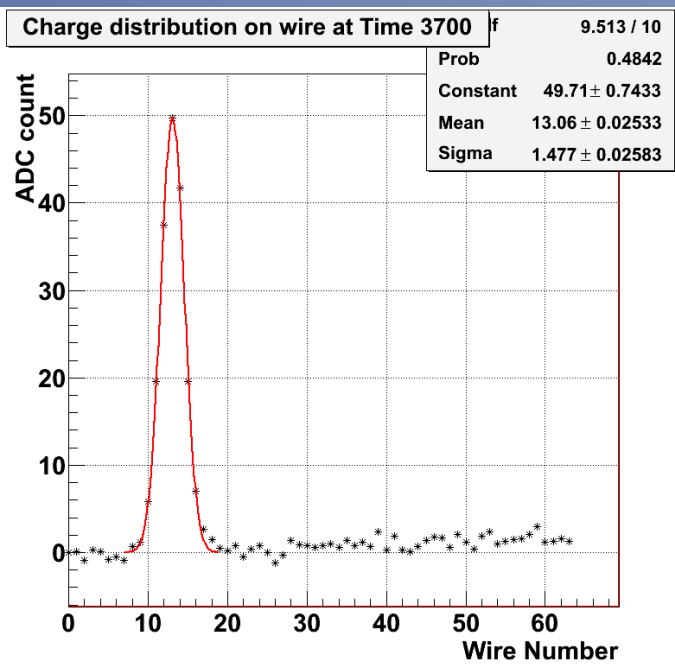
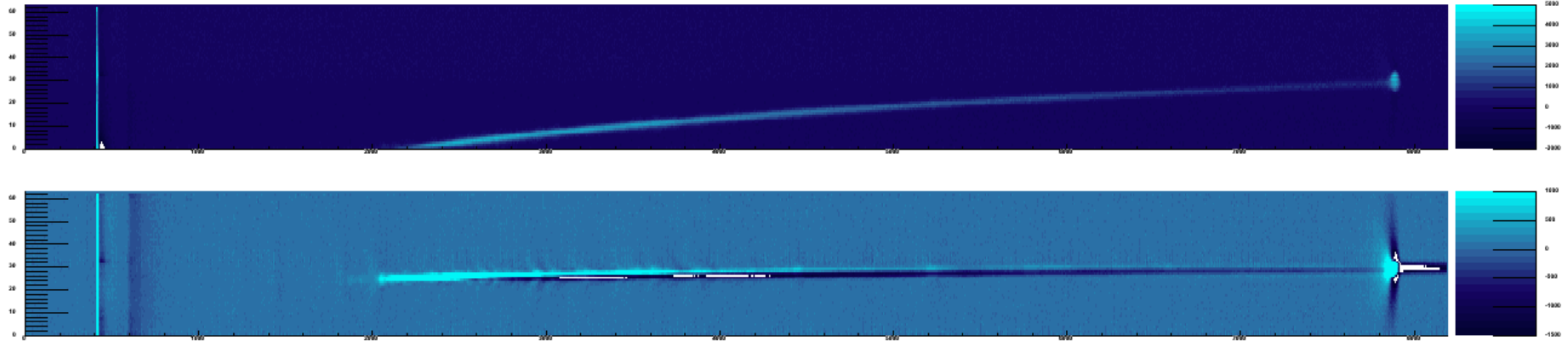
- Electronegative molecules absorb drifting electrons (Oxygen or Water)
- Charge attenuation along the drift is called charge live time



$$P[ppb] = \frac{300}{\tau[\mu s]}$$

2500 ms of live time
corresponds to our 0.12
ppb of oxygen equivalent

Diffusion Measurements



$$\sigma^2/t = 2 * D$$

$$D = 5.18 \pm 0.58 \text{ cm}^2/\text{s}$$

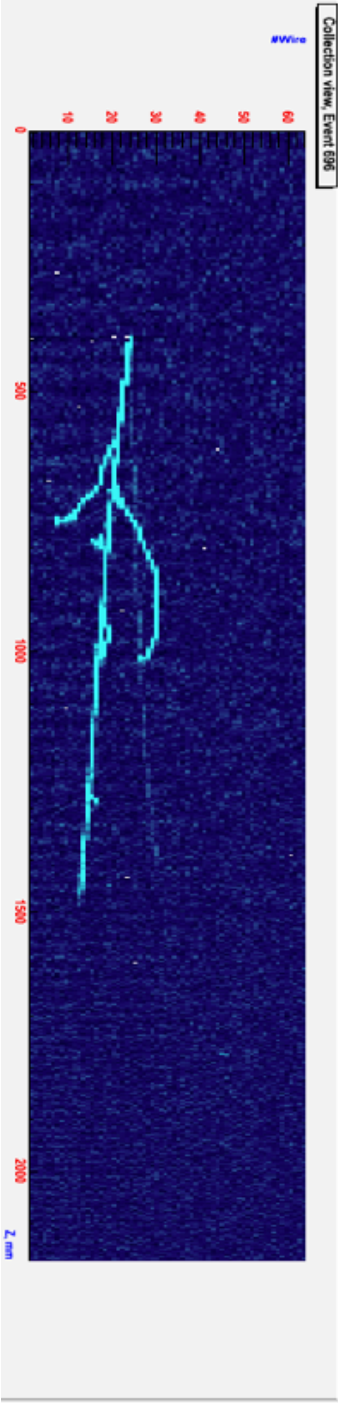
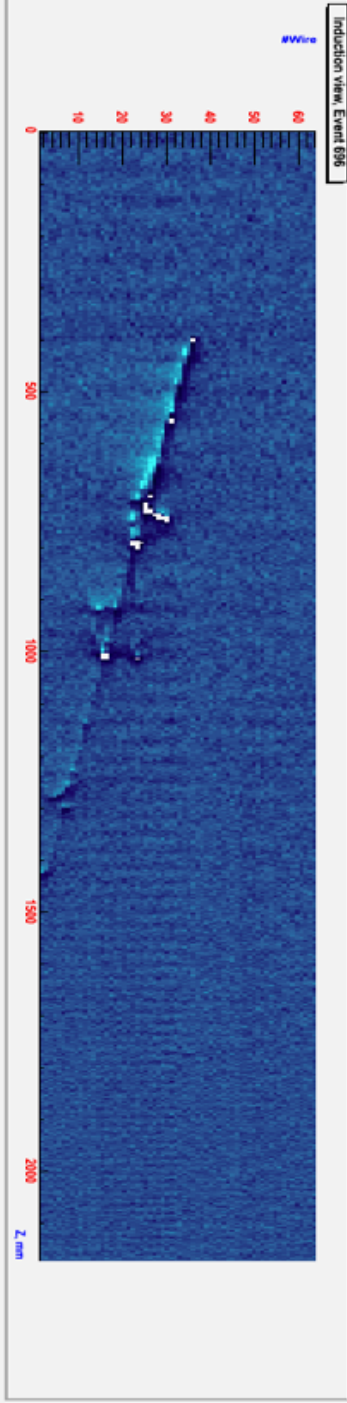
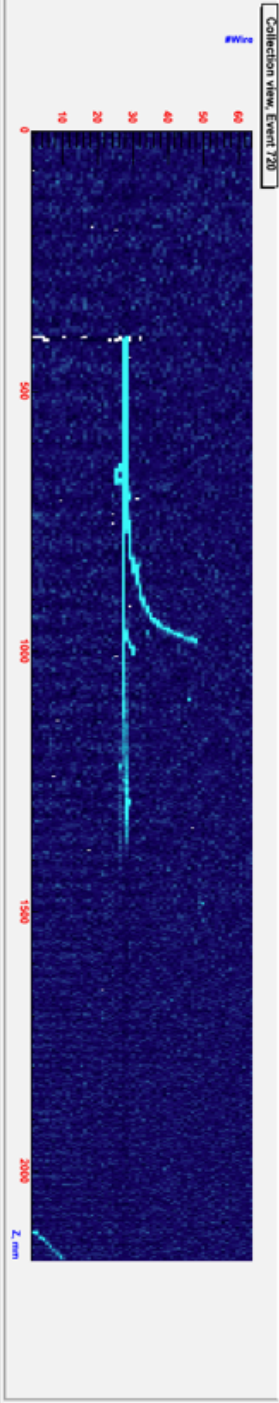
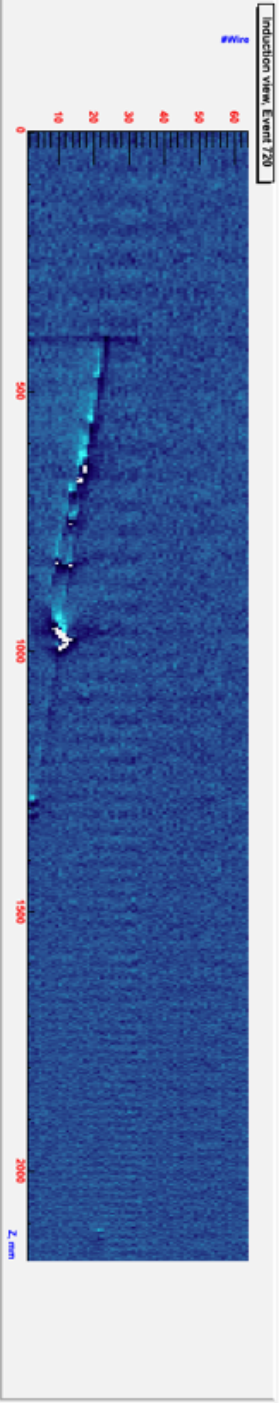
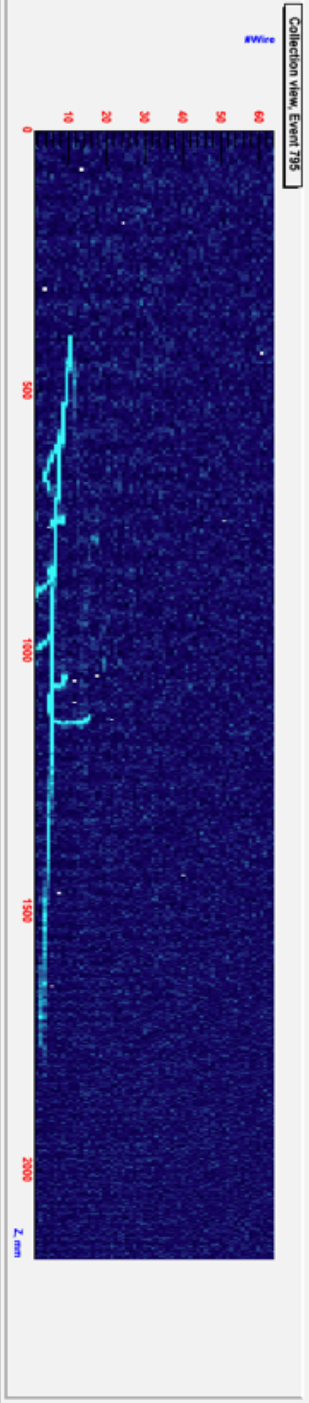
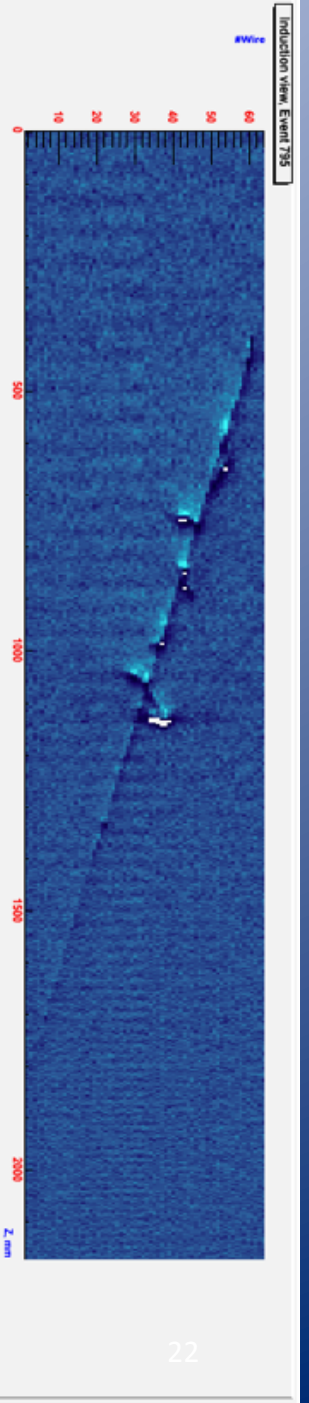
The Icarus Collaboration
measured: $4.8 \text{ cm}^2/\text{s}$

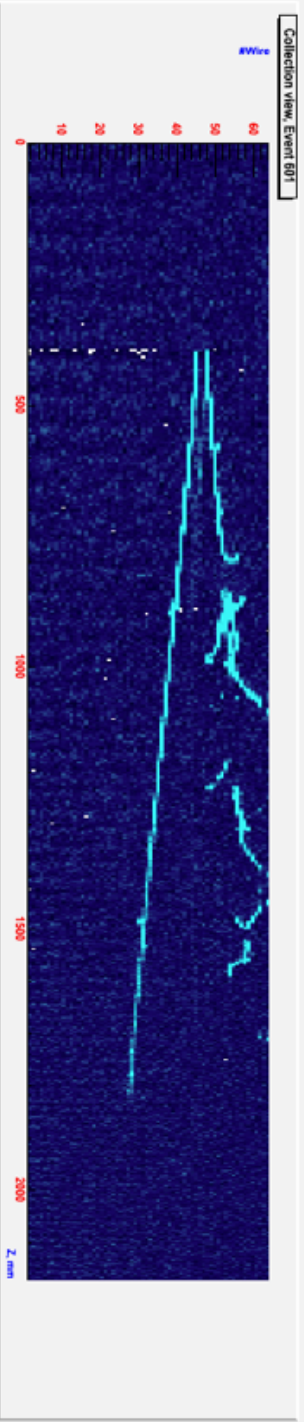
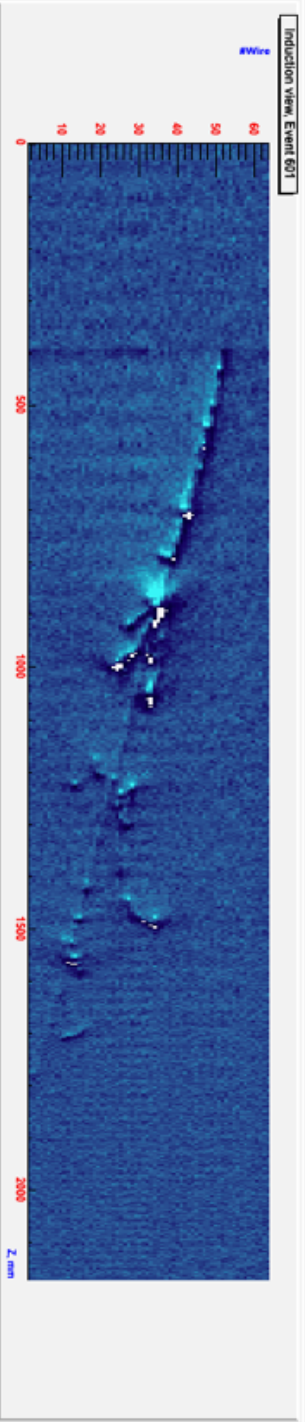
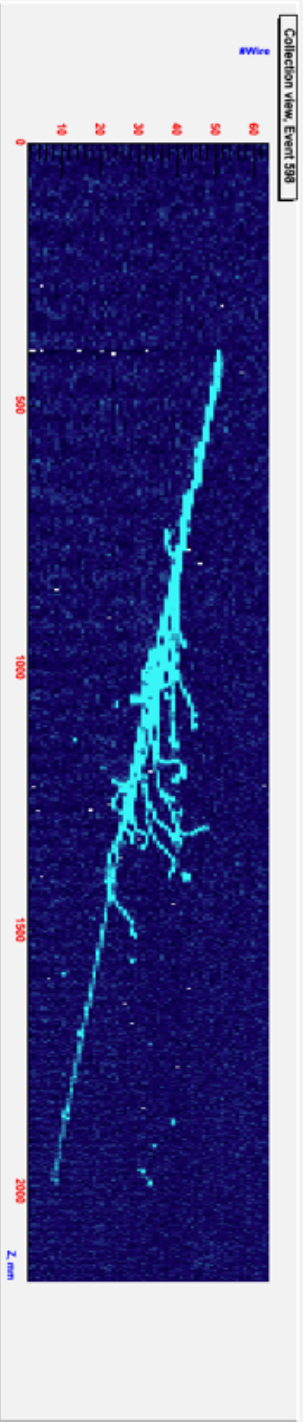
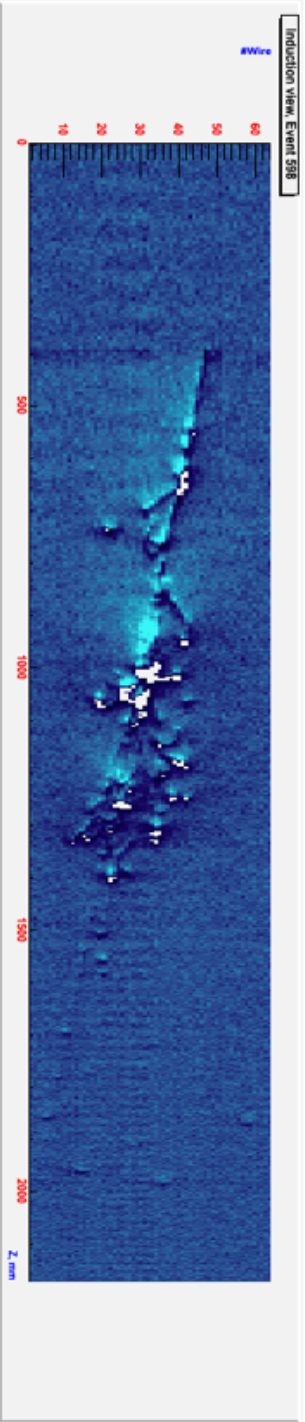
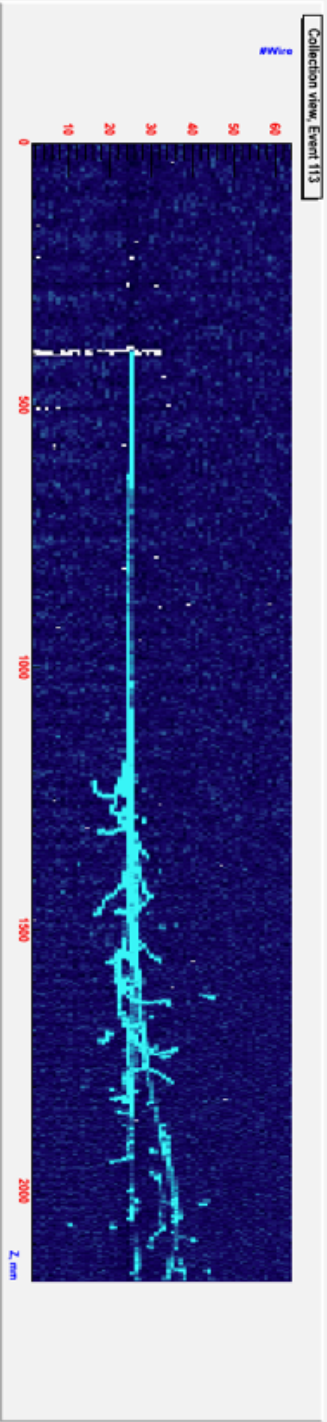
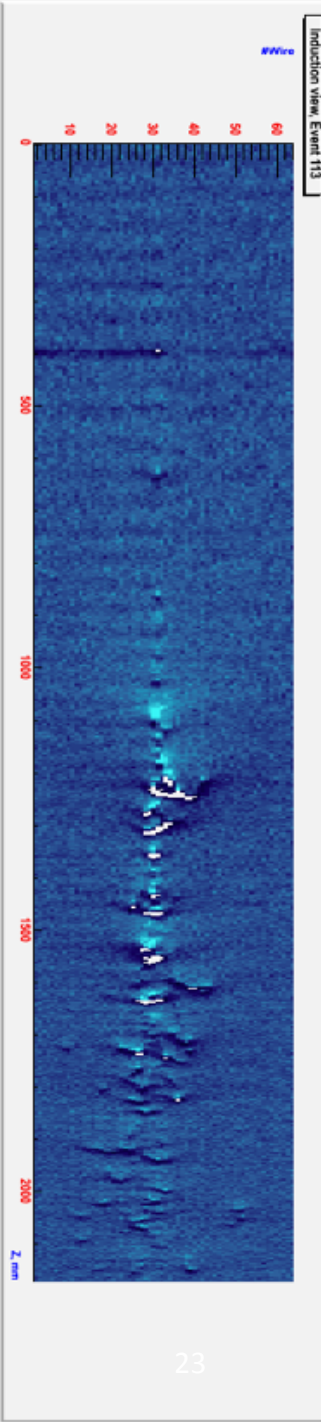
Conclusions

- Dewar and inner vessel installed
- Design, construction and installation of the detector is finished
- Vacuum and filling was successful
- Recirculation system for Argon purification is working
- HV about 100kV (500kV nominal Voltage)
 - 3 candidates for discharges (bubbles, dust from filters and electrostatic force)
- Muon tracks of almost 5m drift
- Laser tracks with 5m drift
- Purity of about 2.5ms
- Transversal electron diffusion Dt 5.2 cm²/s

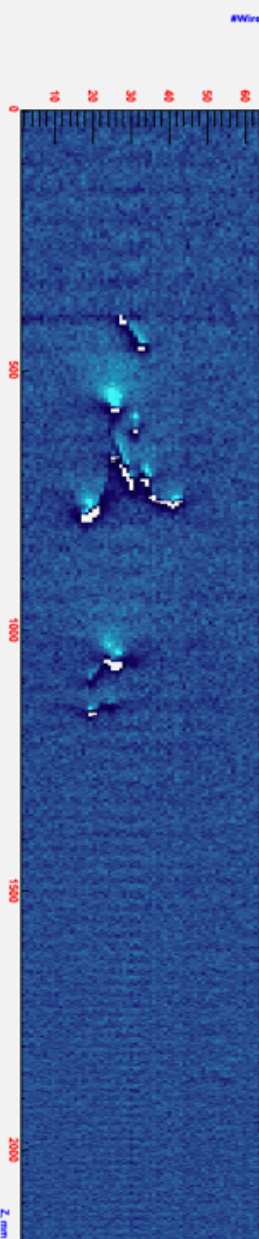
Thank you



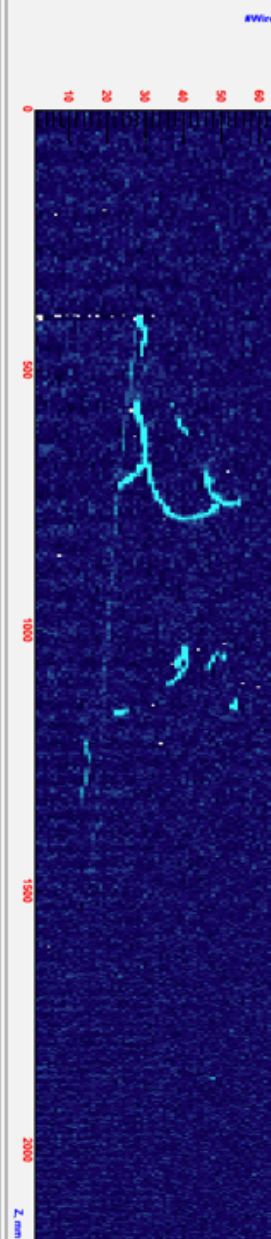




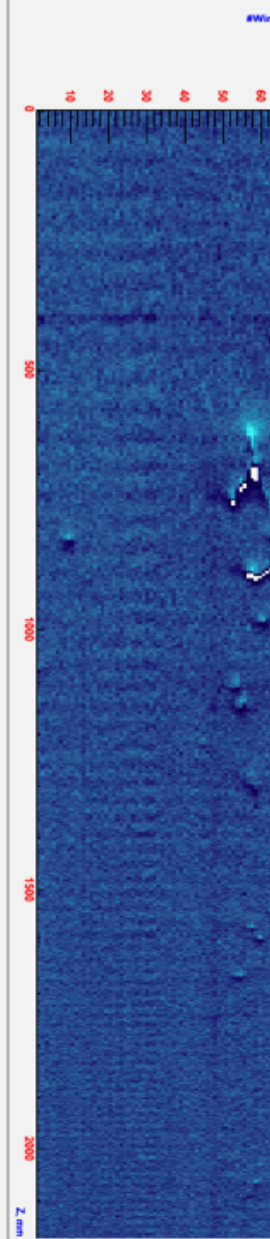
Induction view, Event 338



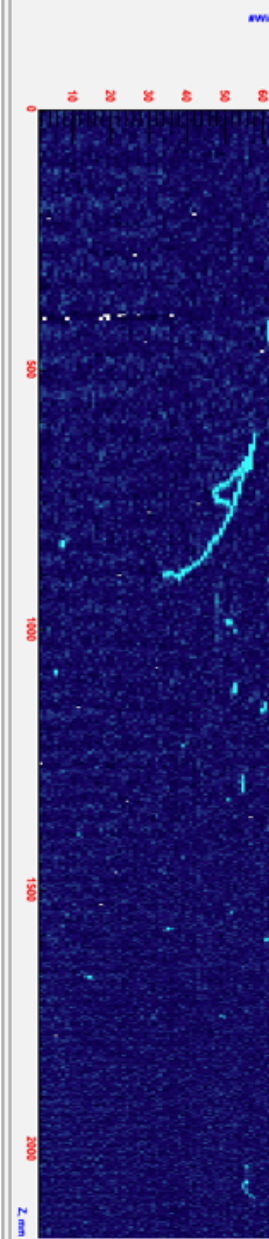
Collection view, Event 338



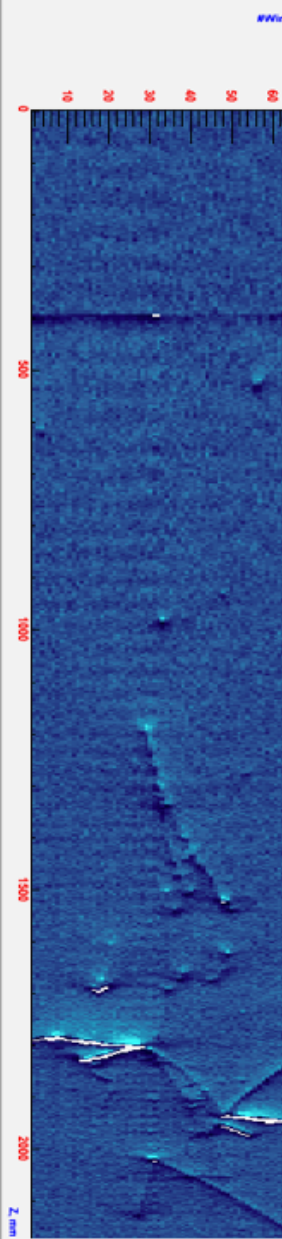
Induction view, Event 633



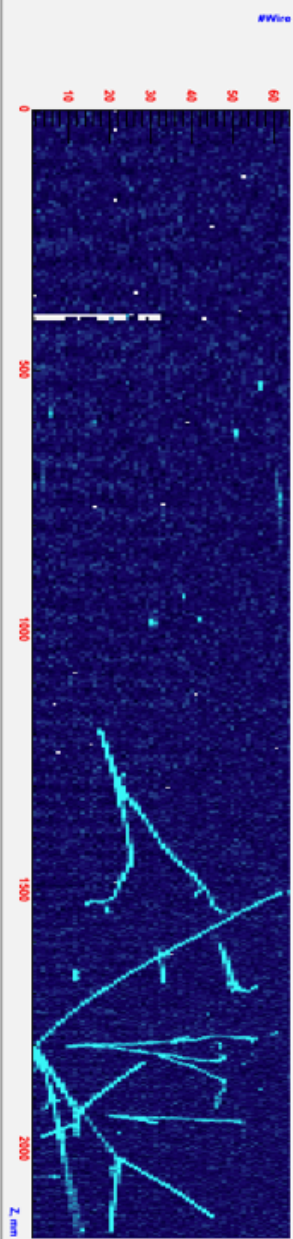
Collection view, Event 633

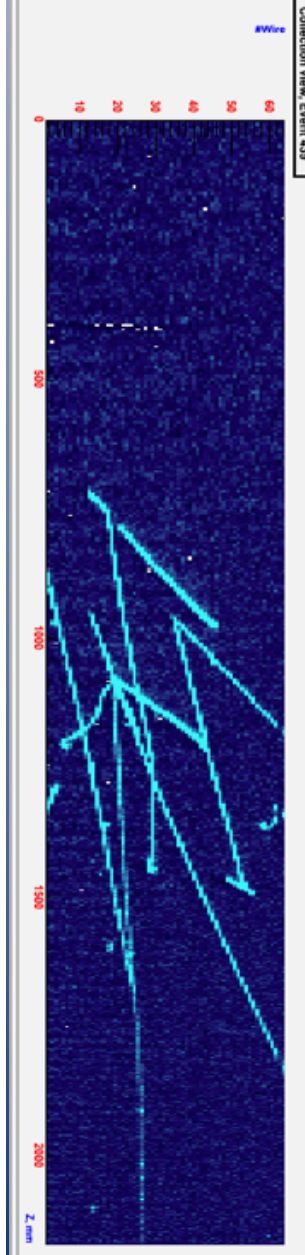
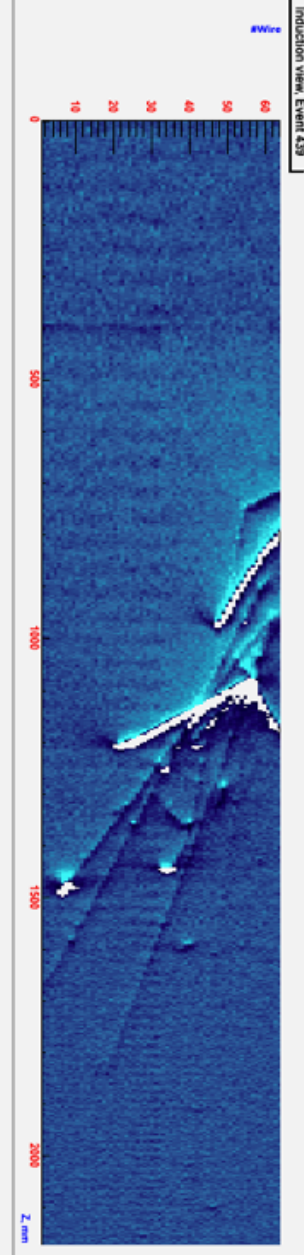
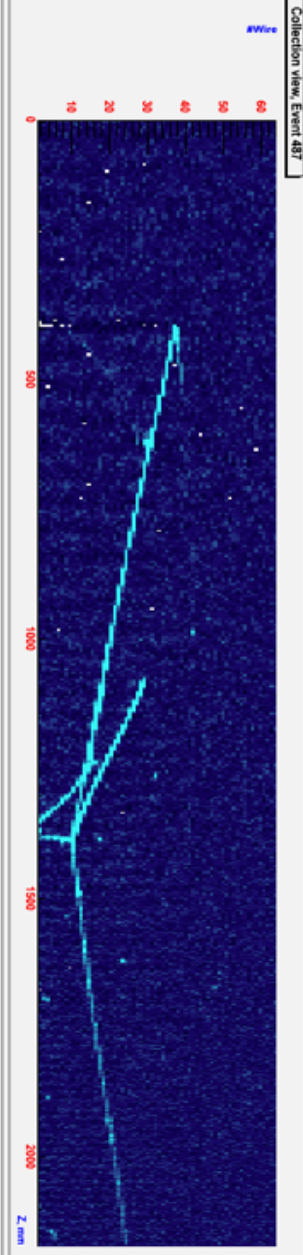
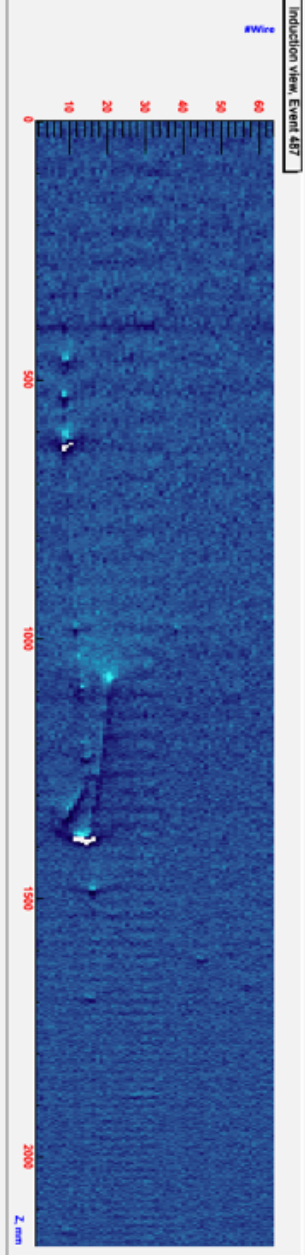
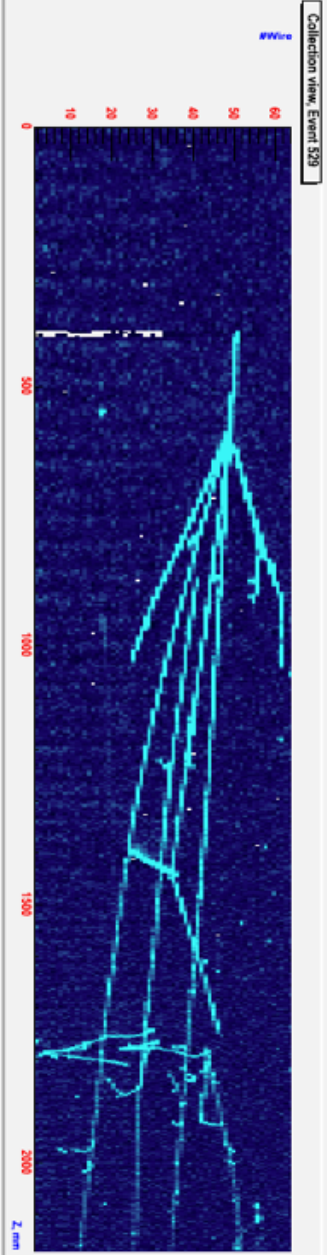
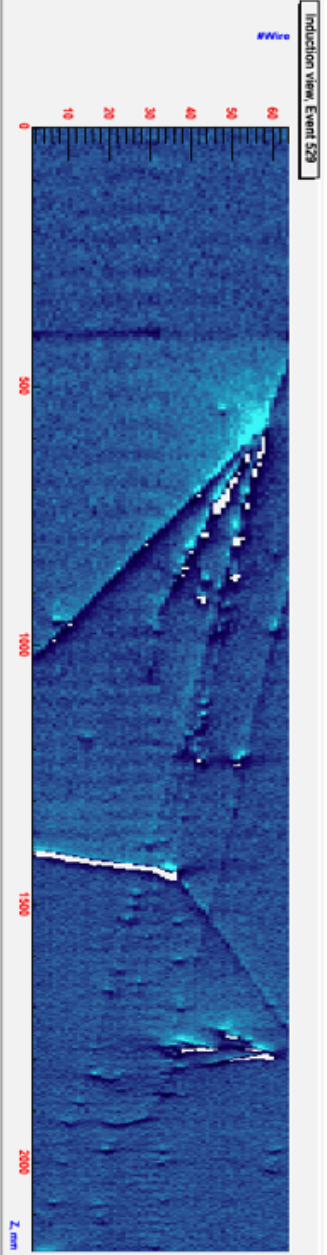


Induction view, Event 708

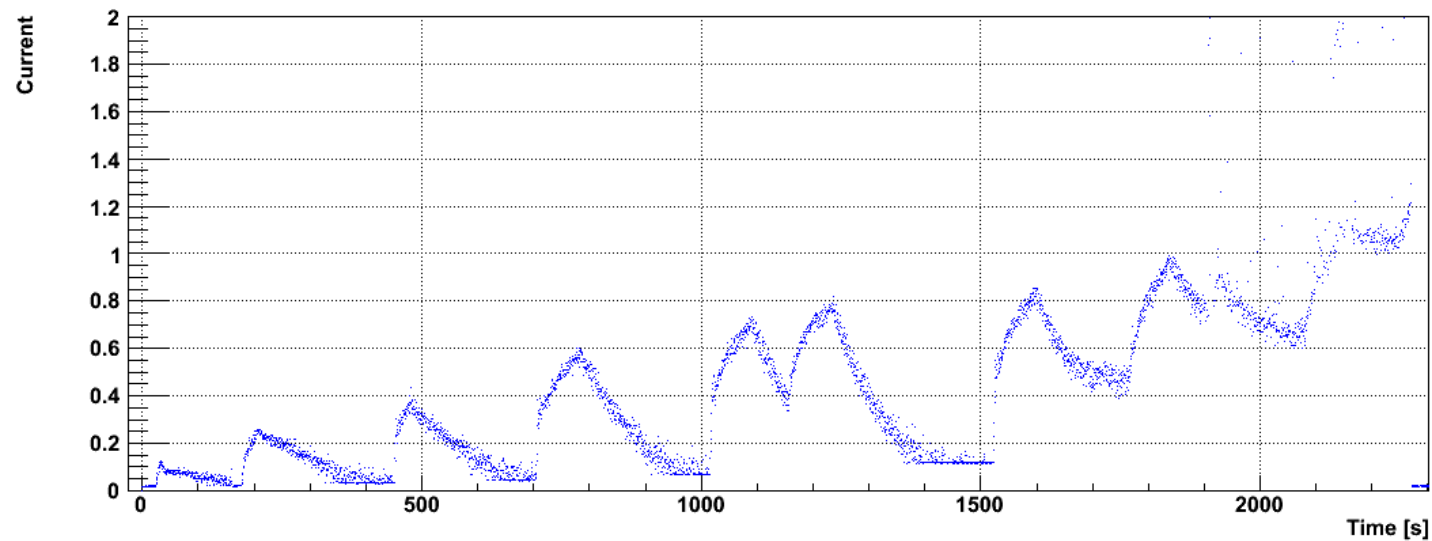
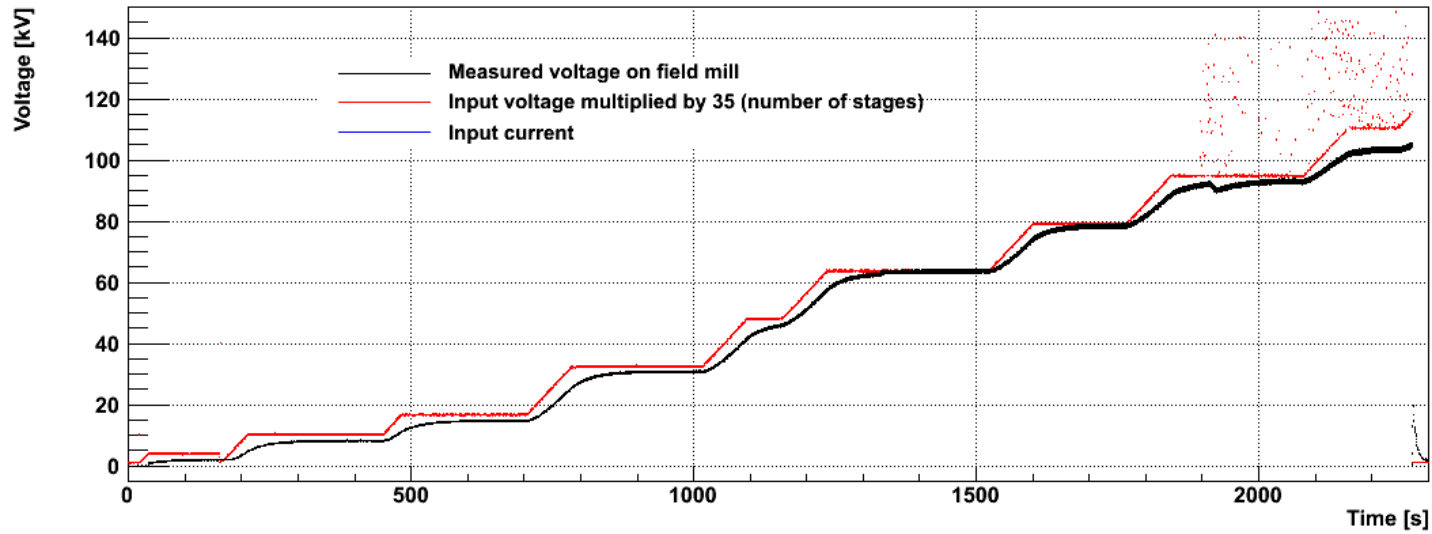


Collection view, Event 708



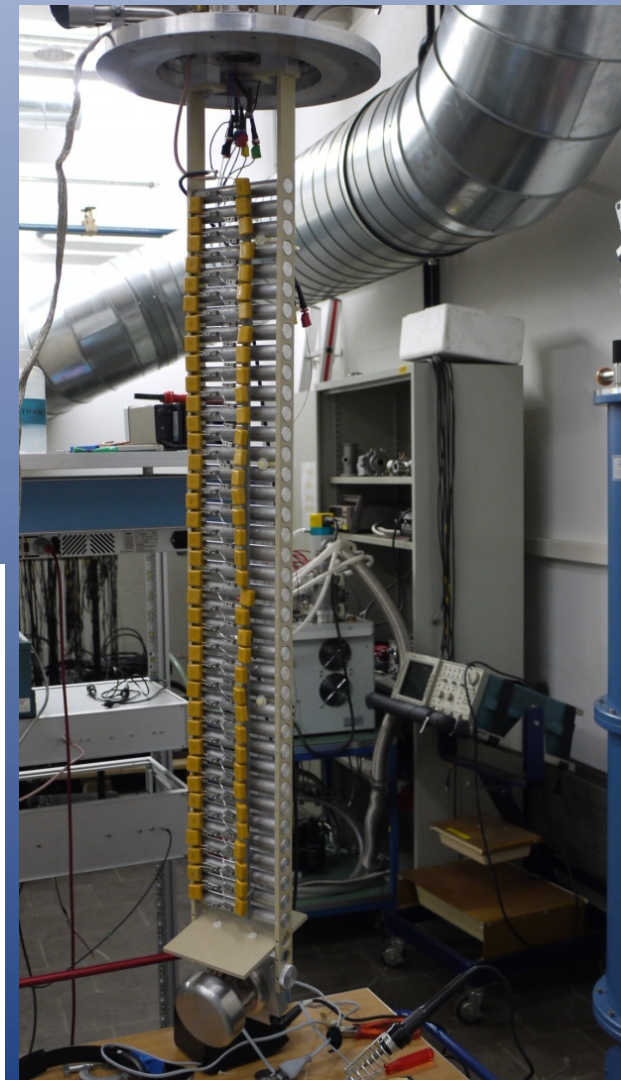
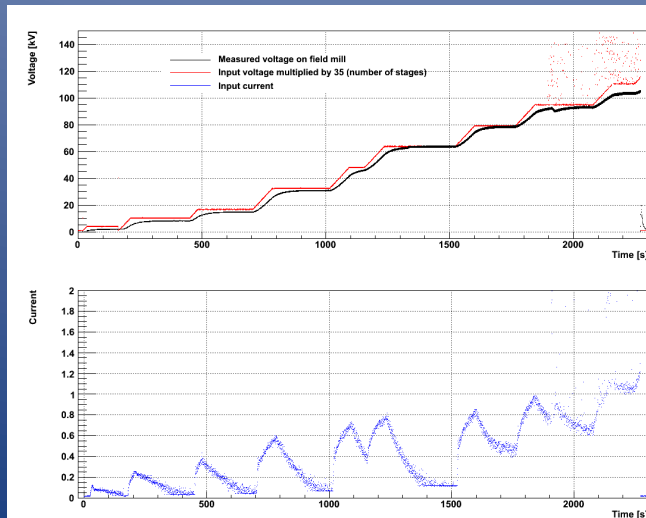
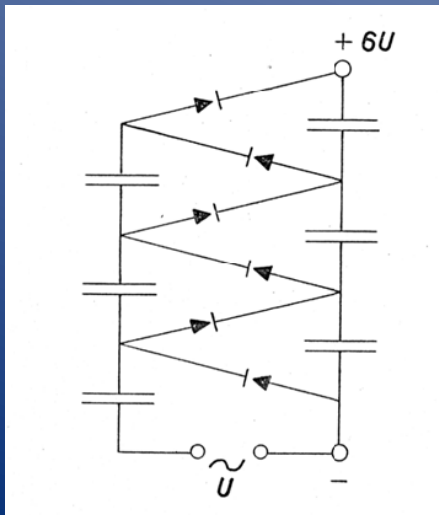


High voltage reached



High voltage system test (Cockcroft-Walton or Greinacher multiplier)

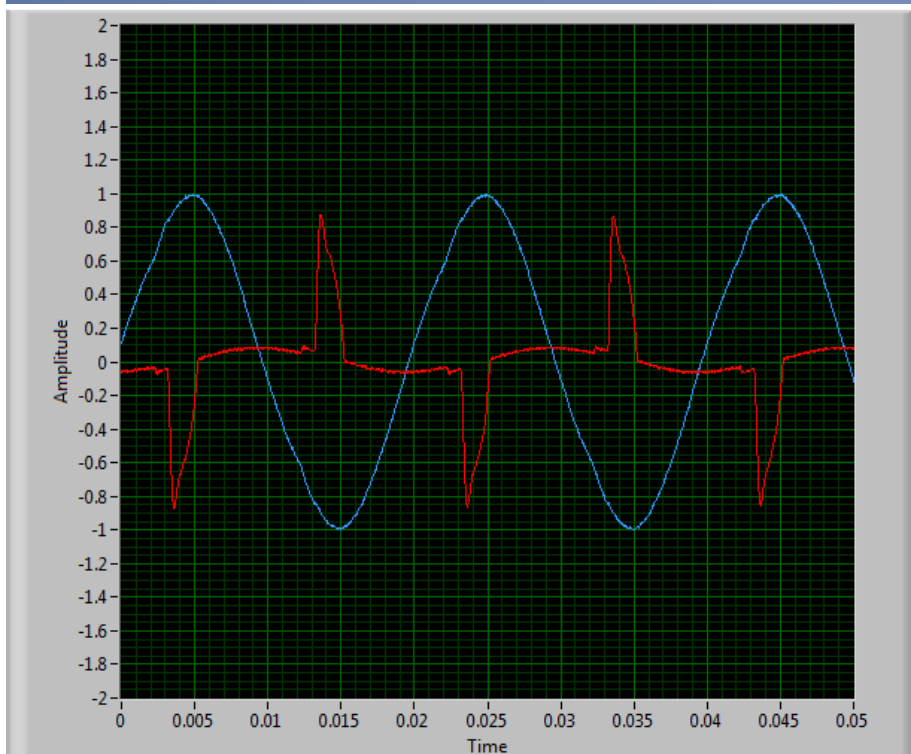
- Prototype: 35 stages installed
- Electric field mill on the bottom
- Filled with liquid Argon
- AC input voltage 4kV
- 140kV should be reached
- Reached voltage 110kV



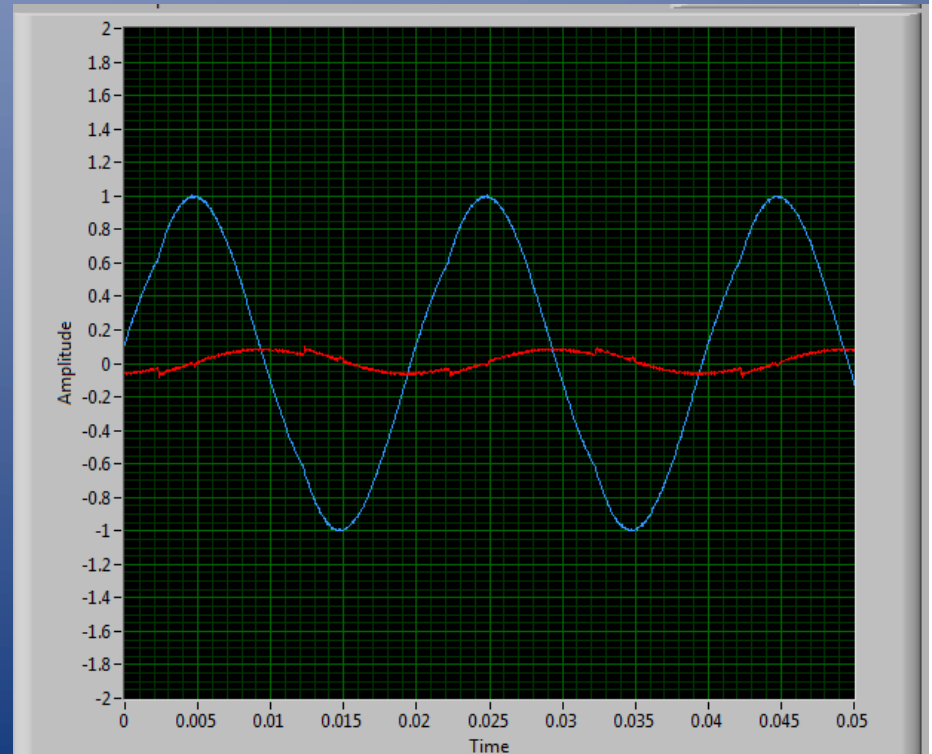
Power supply

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

GC is charging up



GC is charged

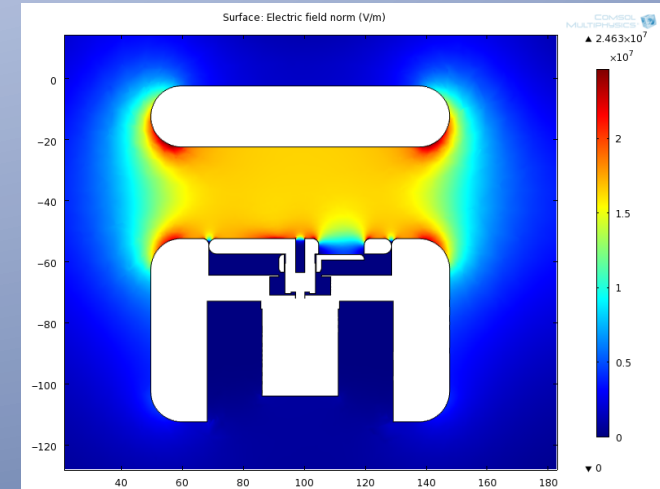


Electric Field Mill

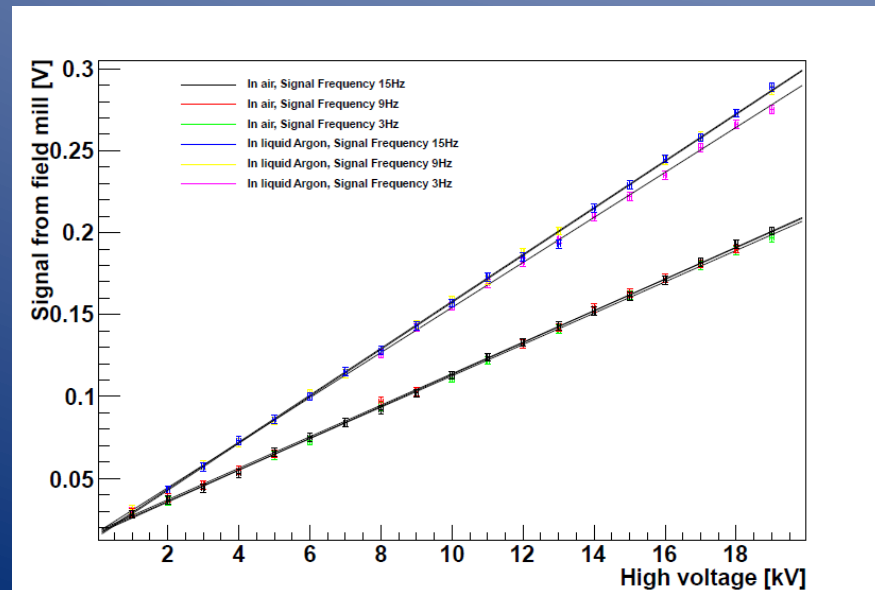
$$Q = CU$$

$$C = \epsilon_0 \epsilon_r \frac{A}{d}$$

$$S \propto Q = \frac{U}{d} \epsilon_0 \epsilon_r A$$

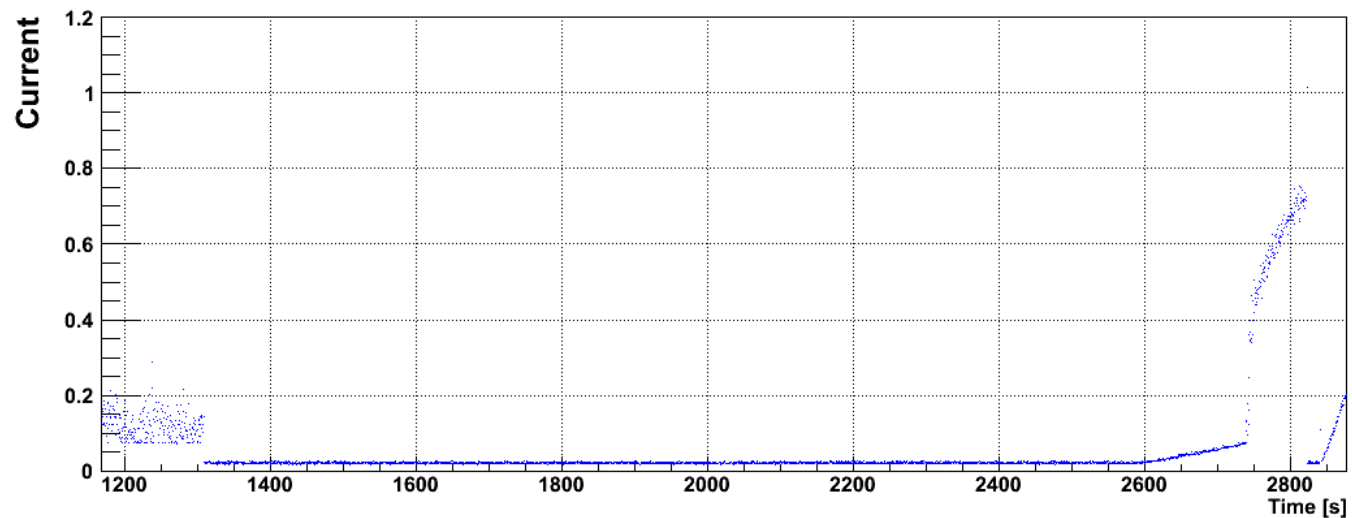
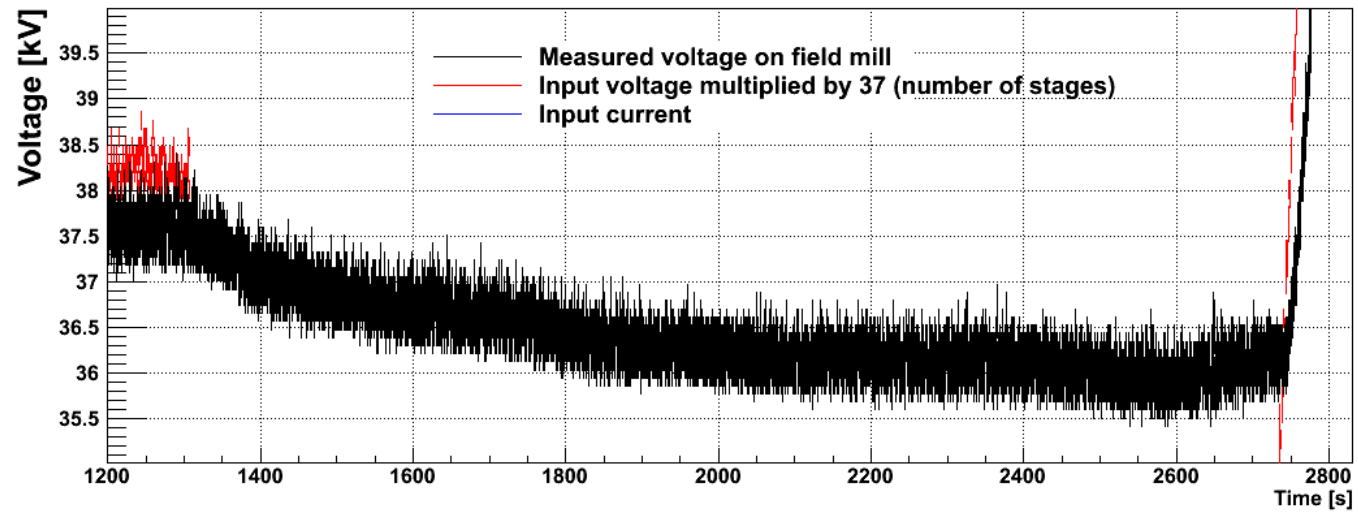


Calibration curve of the field mill



Dielectric constant of liquid argon
Literature :1.52
Measured :1.48±0.03

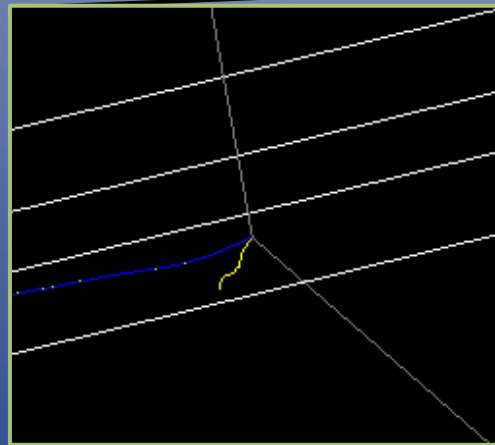
Discharging GC



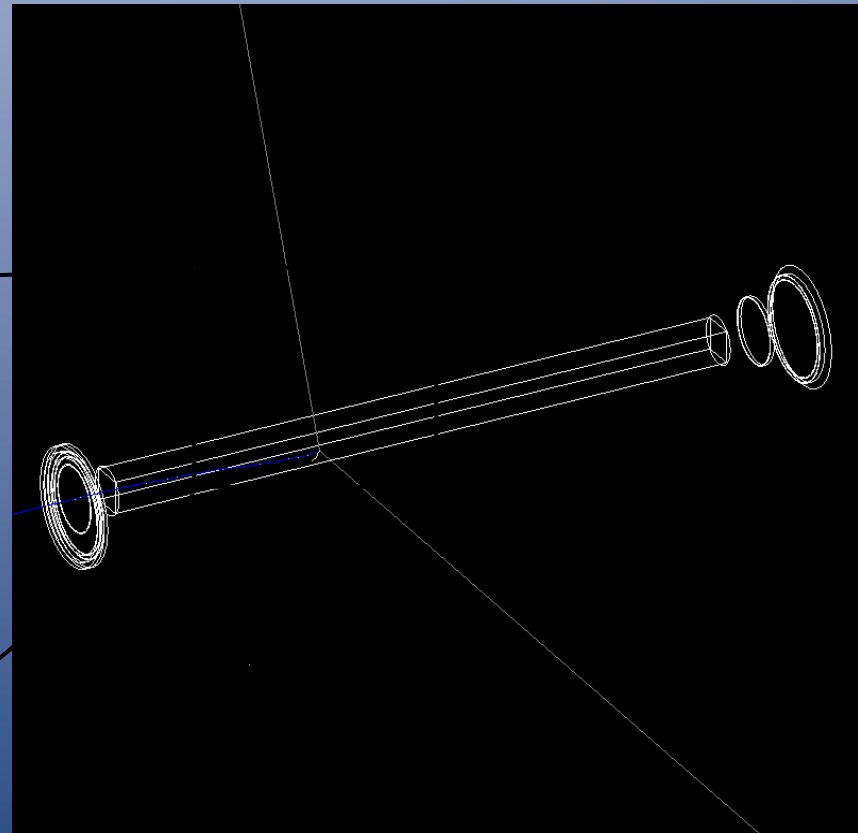
Monte Carlo of cosmic muons (GEANT4)

MC Results

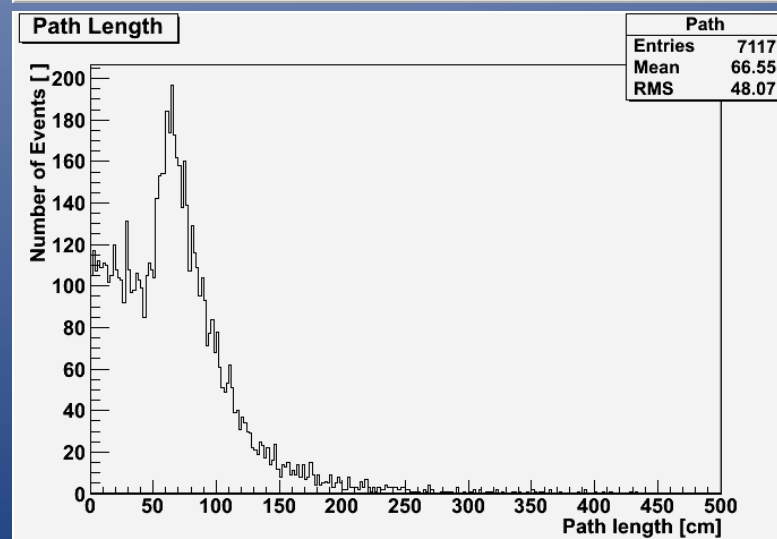
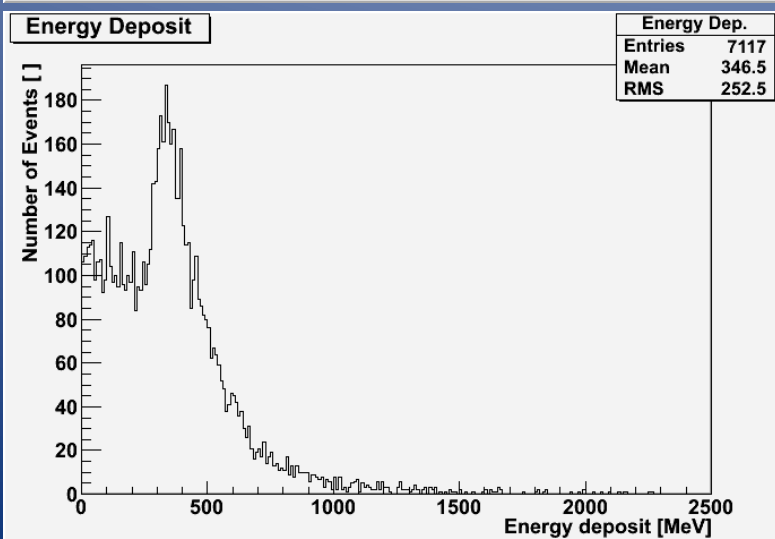
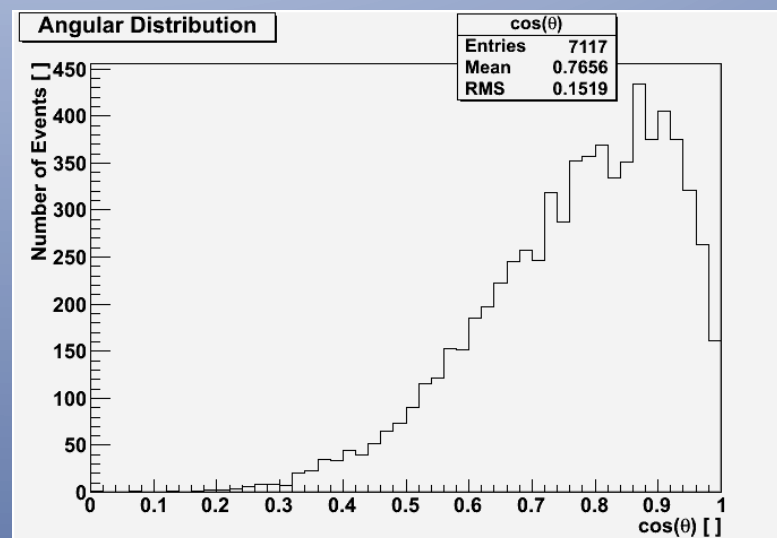
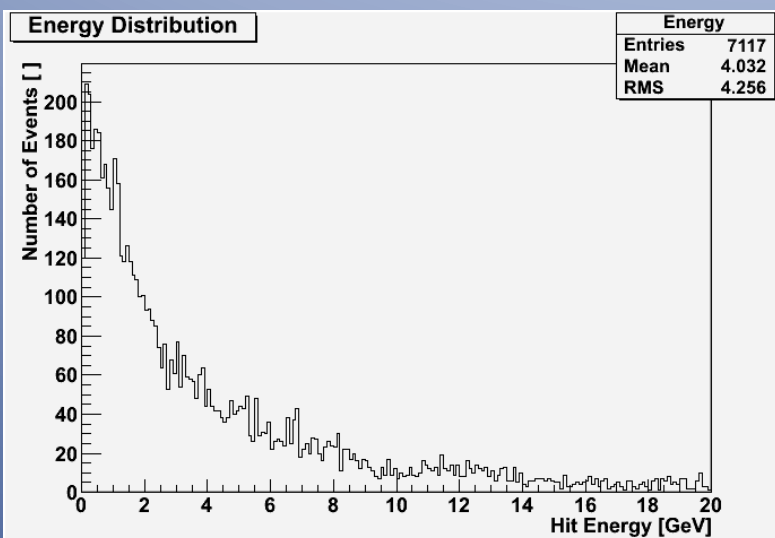
- Simulation time: 90.8s
- Muon hit rate: 78.4s^{-1}
- Muon decay rate: 1.8s^{-1}

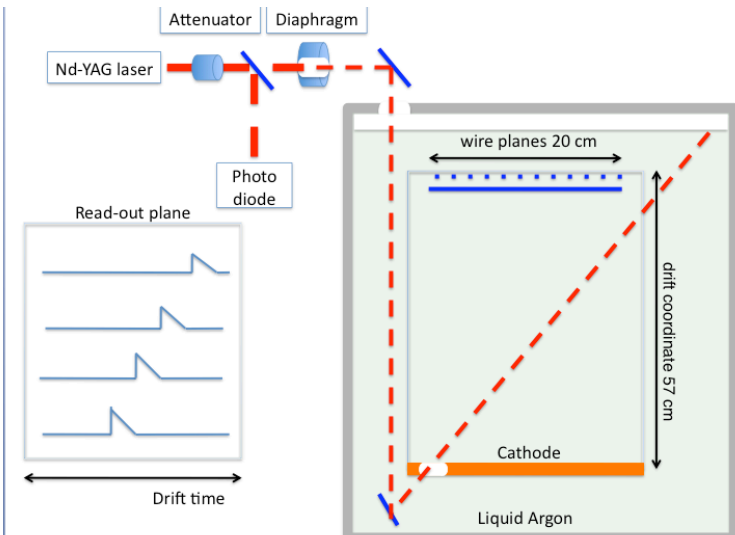


Muon decay event



Monte Carlo of cosmic muons (Geant4)

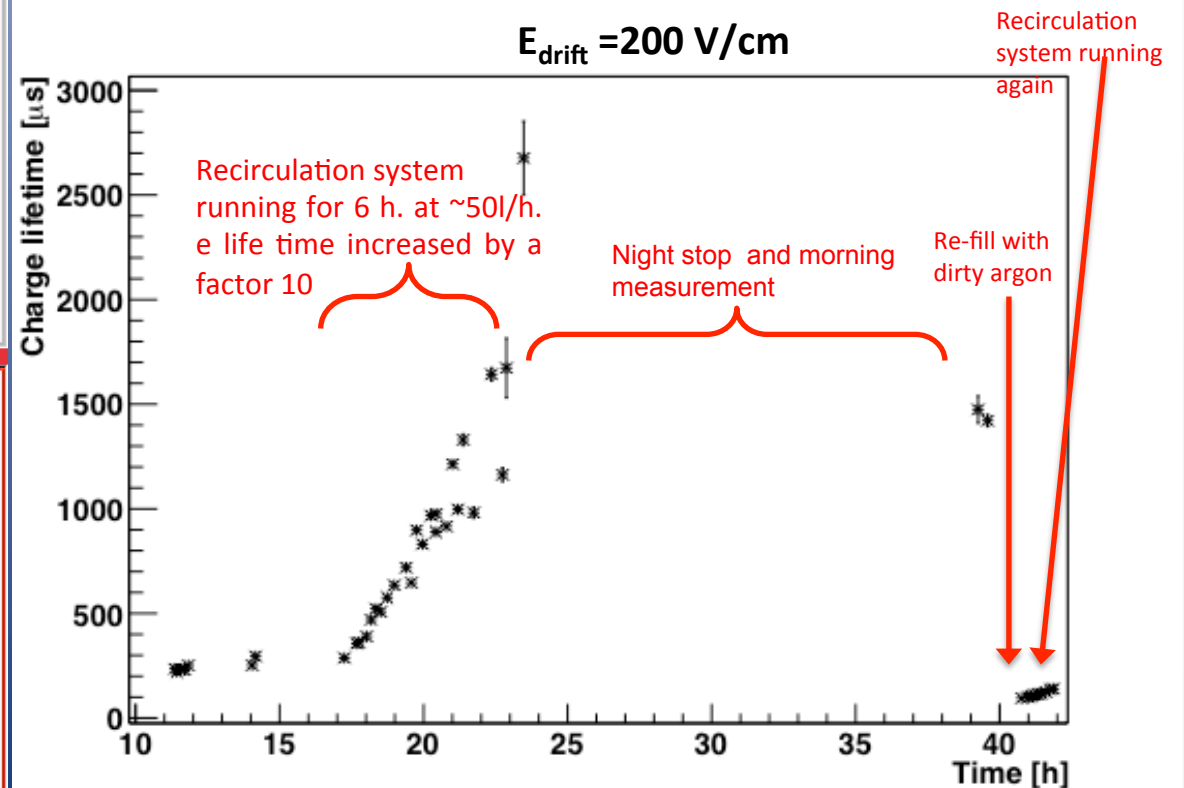
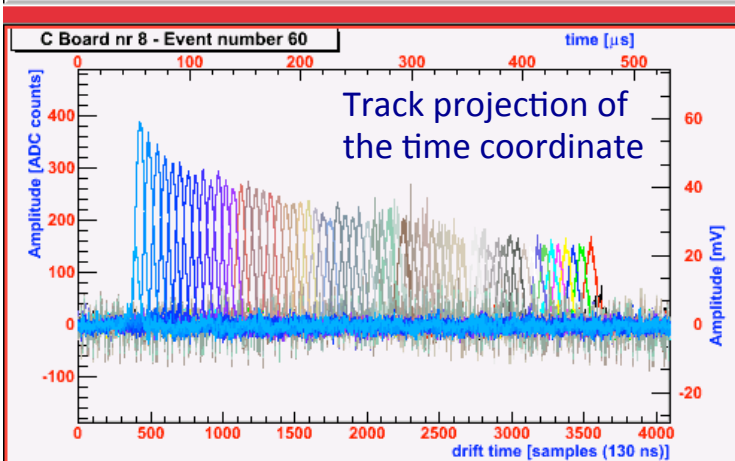
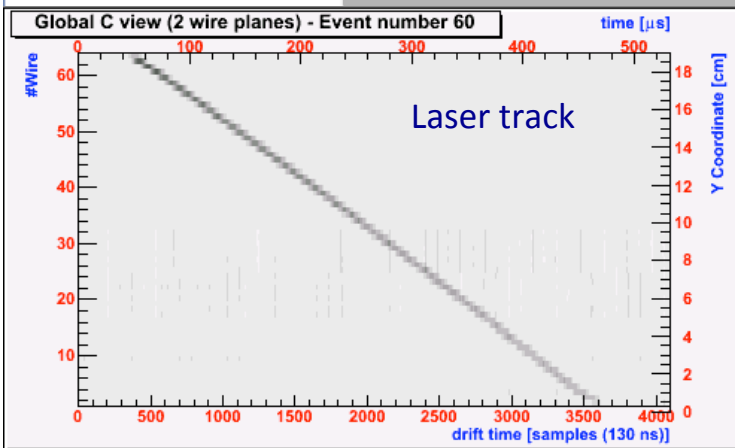




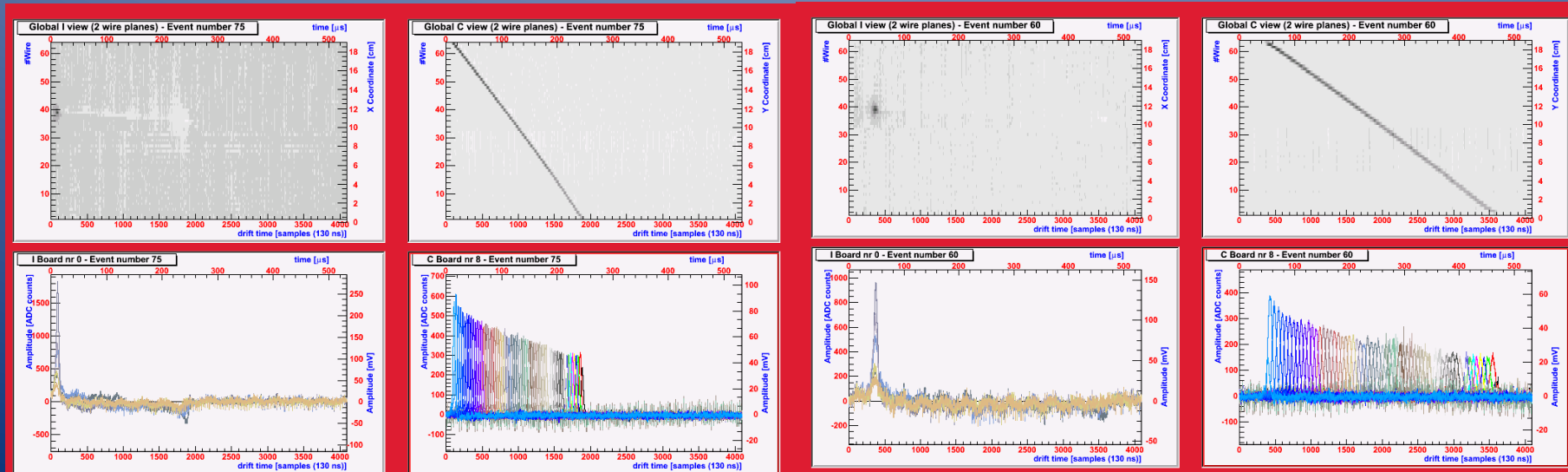
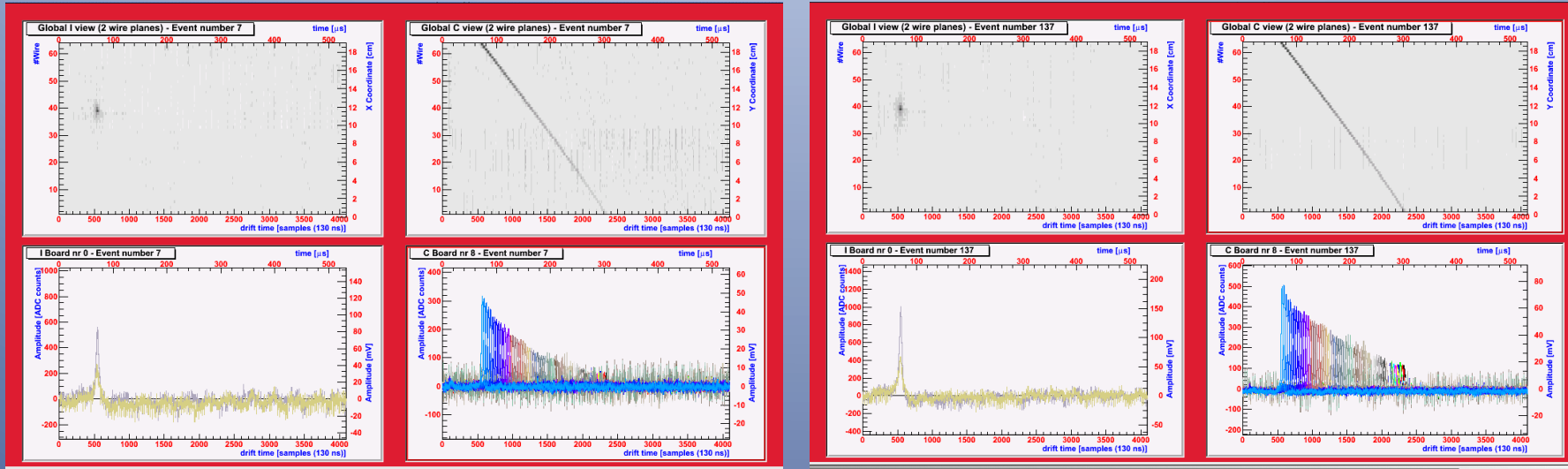
Laser beam

to monitor the purity of the LAr

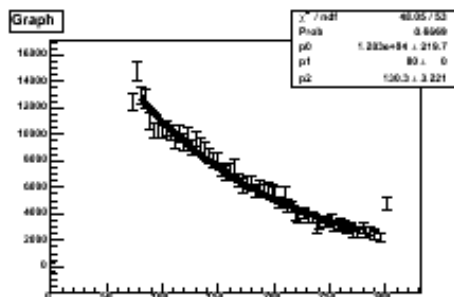
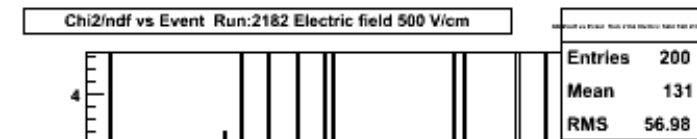
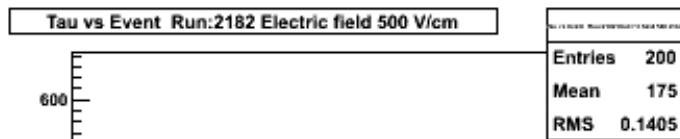
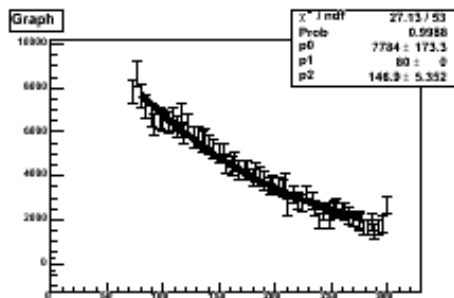
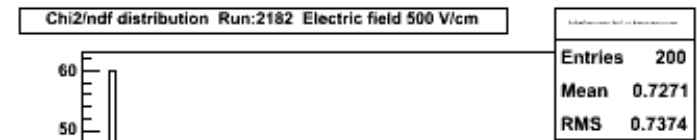
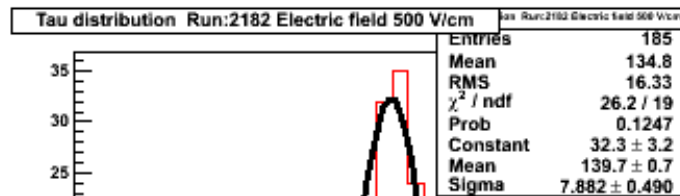
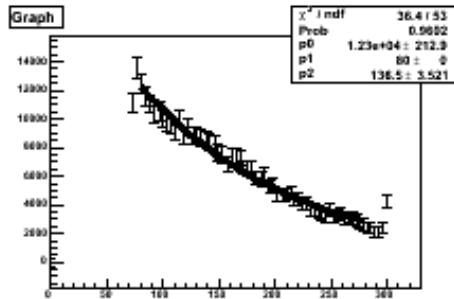
Longest life time $2000 \mu\text{s}$ ($\sim 0.1 \text{ ppb}$) hitting the sensitivity limit of the detector. Longer life time can only be measured with the ARGONTUBE



Purity measurements with UV Laser



Purity measurements with UV Laser (500 V/cm)



Purity measurements with UV Laser

