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AEC
ALBERT EINSTEIN CENTER
FOR FUNDAMENTAL PHYSICS

The Argontube detector – HV in LAr

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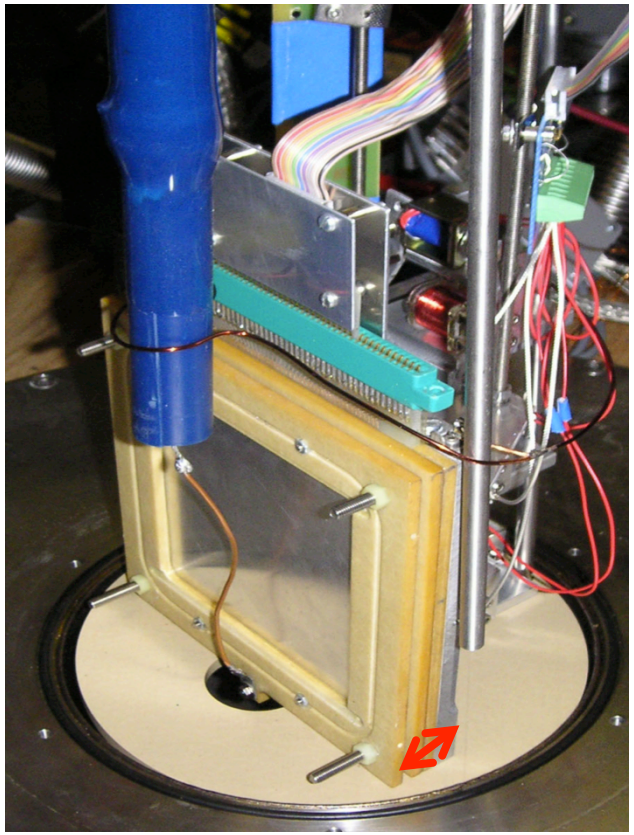
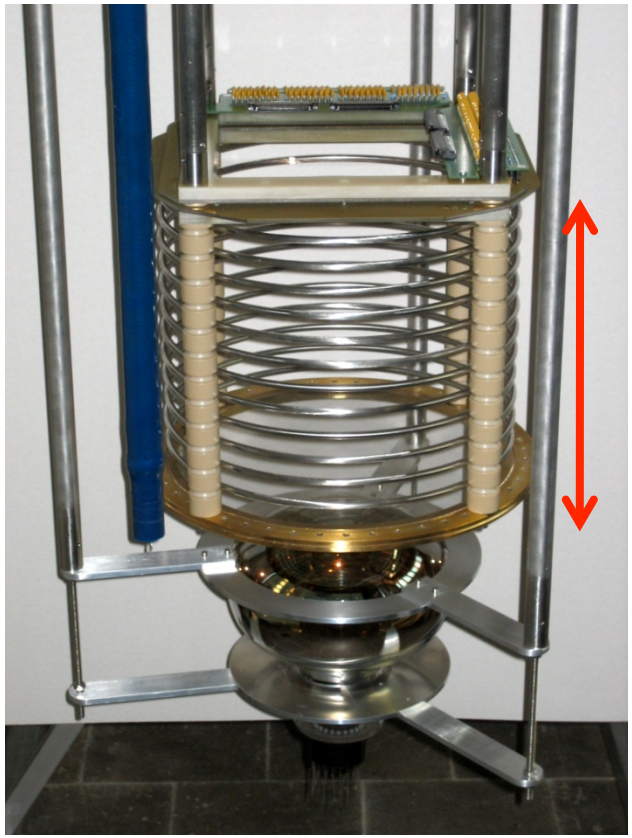
Evolution of LAr TPCs in Bern

Mini Argontube



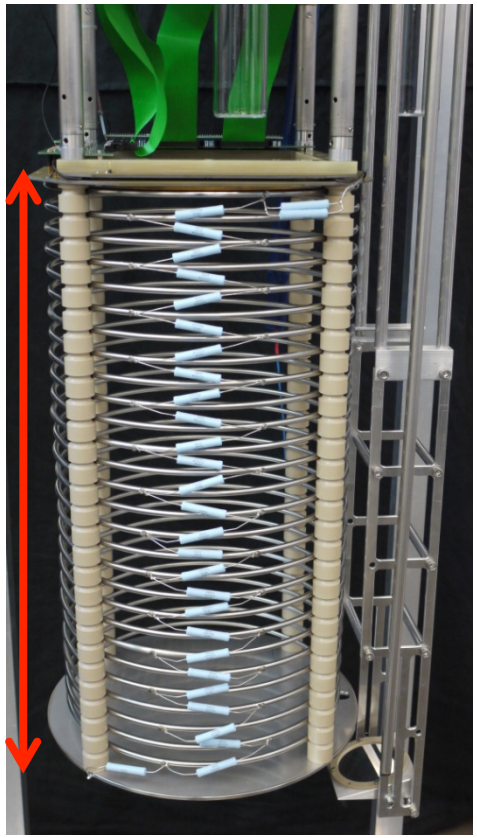
0.5 cm

Medium Argontube



25cm

Medium Argontube +



57cm

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 < 0.1ppb
- 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)

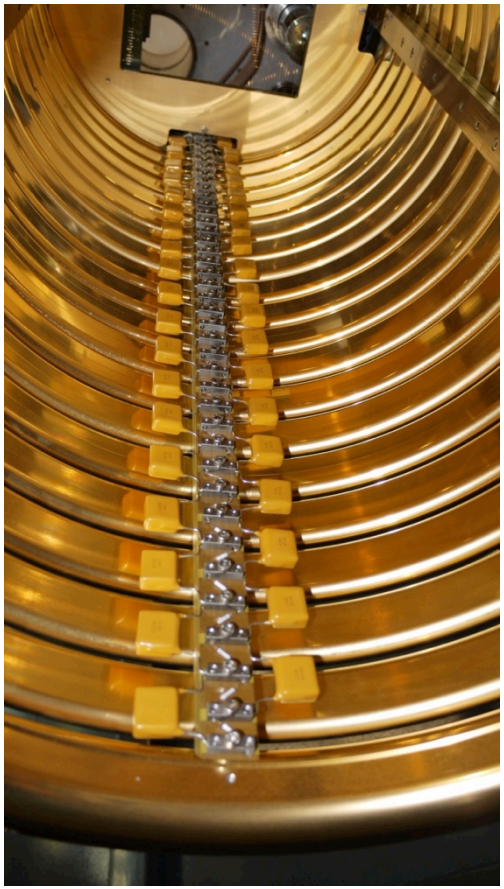
•Outer volume: 1.2 m³
•Inner volume : 1.1 m³
•Active volume: 0.2 m³
•Mass of active volume: 280 kg

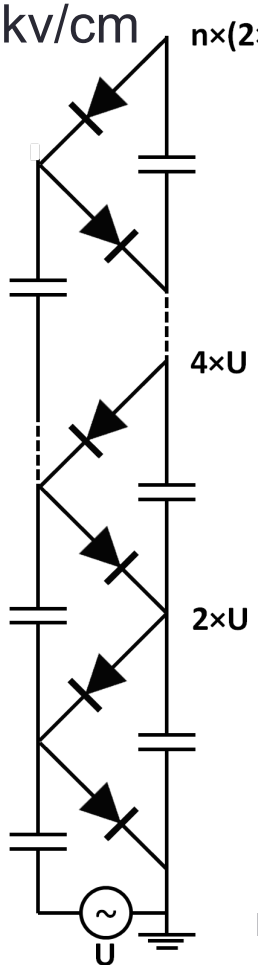
JINST 7 (2012) C02011

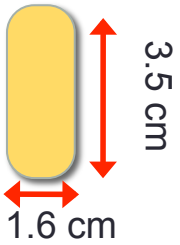
High Voltage

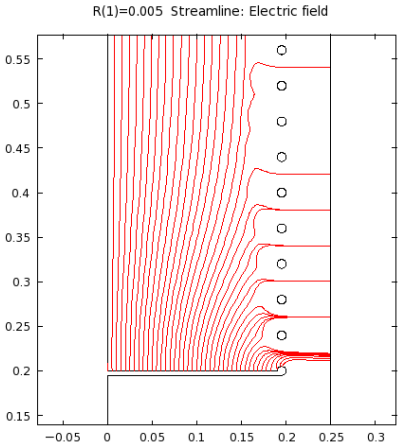
J.Phys.Conf.Ser. 308 (2011) 012027

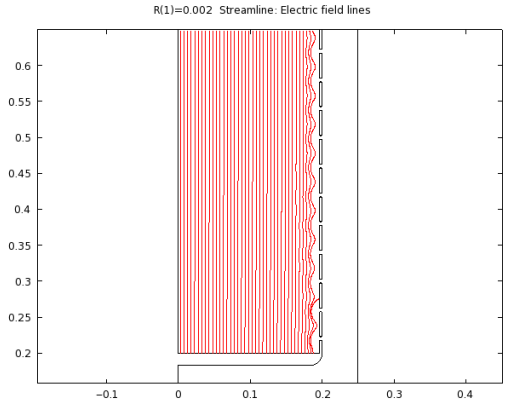
- Cockcroft/Walton – Greinacher circuit for charge multiplication (125 stages, input 4kV AC)
- Comsol (Finite element analysis software) to obtain best field rings shapes
- Goal: drift field of 1kv/cm

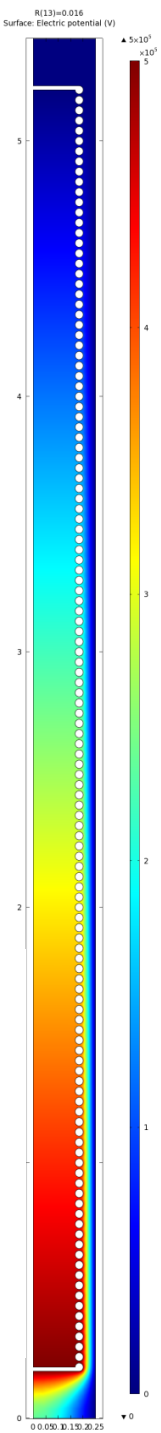












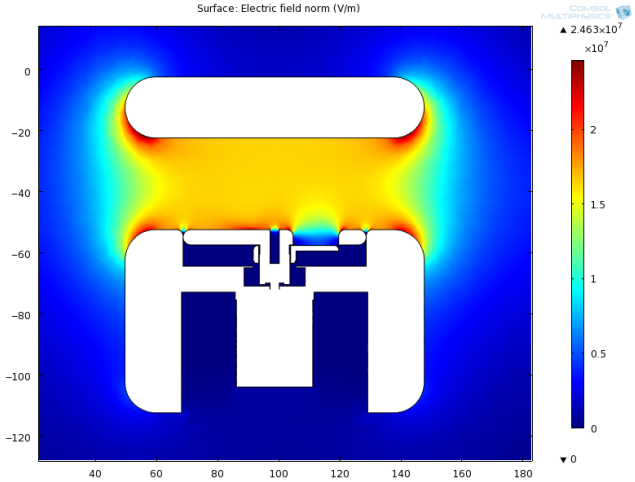
Proc Phys Soc 78 448 (1961) measured 1.1 MV/cm for gold/gold

Electric Field Mill

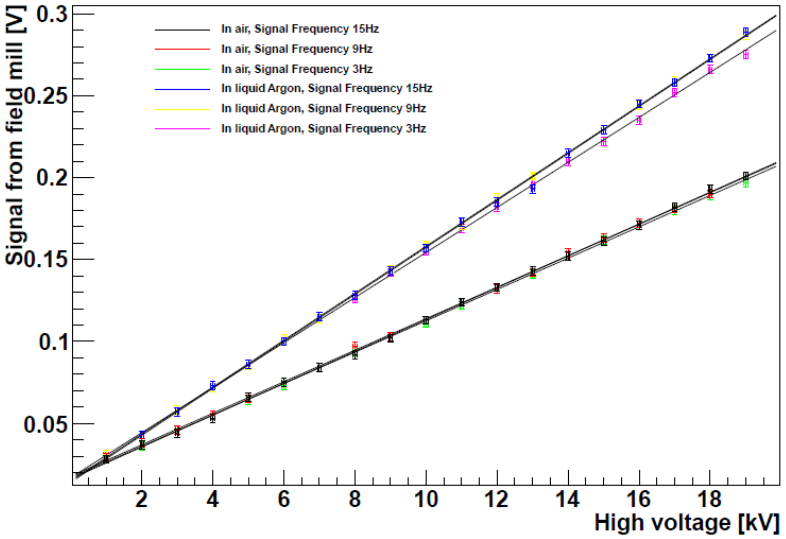
$$Q = CU$$

$$C = \varepsilon_0 \varepsilon_r \frac{A}{d}$$

$$S \propto Q = \frac{U}{d} \varepsilon_0 \varepsilon_r A$$



Calibration curve of the field mill



Dielectric constant of liquid argon

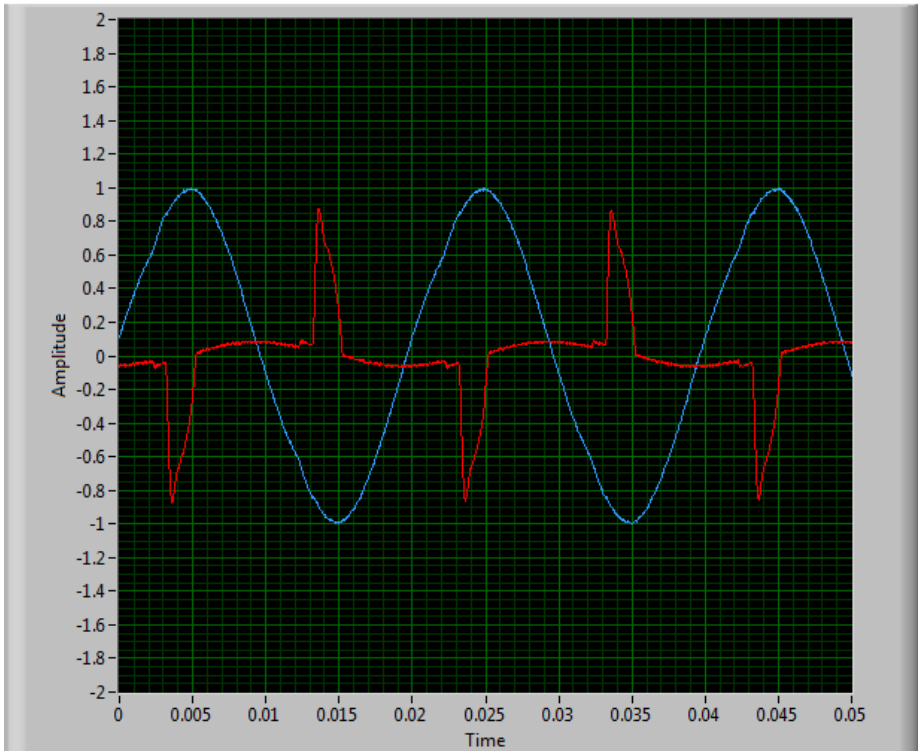
Literature :1.52

Measured :1.48±0.03

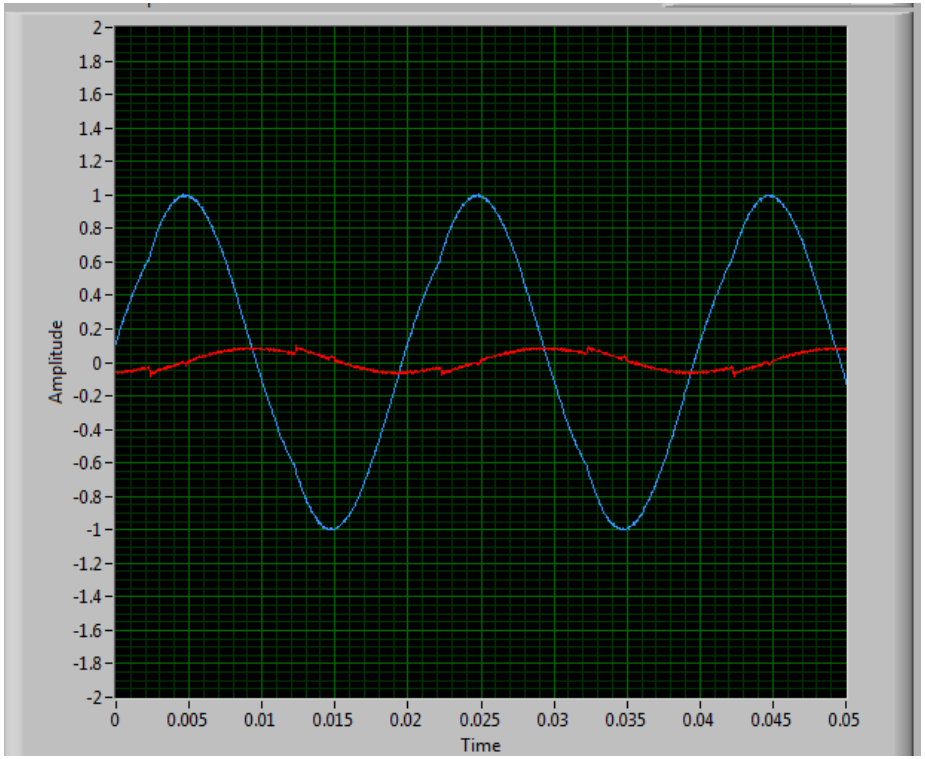
Power supply

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

GC is charging up

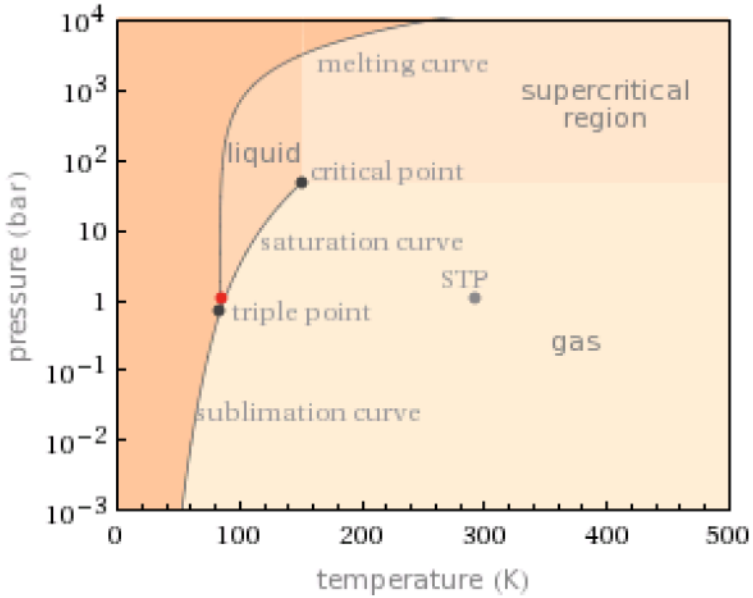


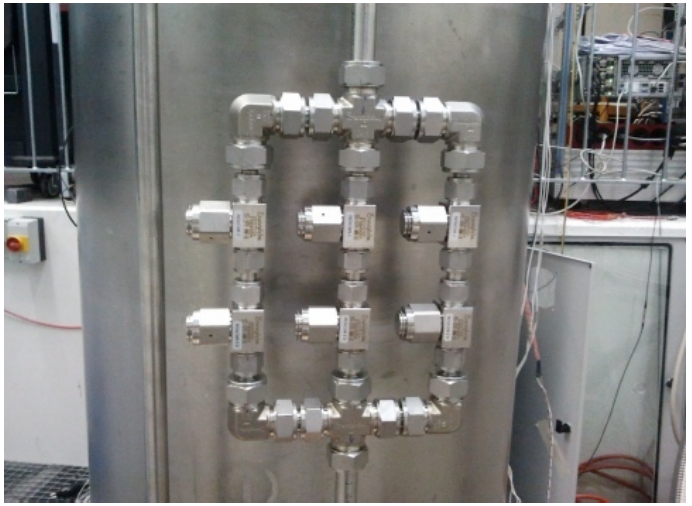
GC is charged



HV breakdowns

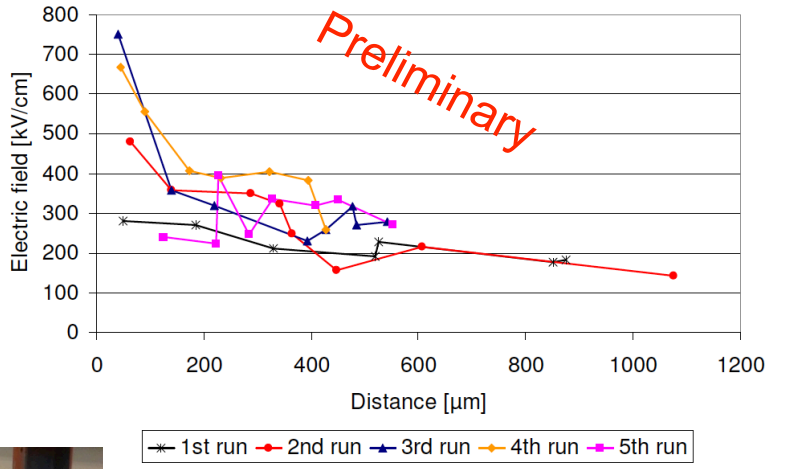
- Max stable HV achieved 100kV
- Around 100 kV spontaneous discharges of the Greinacher ~ **30kV/cm@5cm** (max field to ground)
  - Run 1: Few discharges, one broken capacitor
  - Run 2: O(100) discharges, one broken capacitor
  - Run 3++: New capacitors, discharges at ~150kV, no destruction of Greinacher
- candidates for discharges
  - Argon bubbles (triple point close)
    - Change pressure
    - Enrich Argon Gas with He
  - Dust from filters
    - Copper powder <0.5μm
  - Electrostatic forces
    - 5m leverage in case of small misalignment along drift axis
  - Breakdown voltage << 1MV/cm
    - Proc Phys Soc 78 448 (1961) measured 1.1 MV/cm for gold/gold

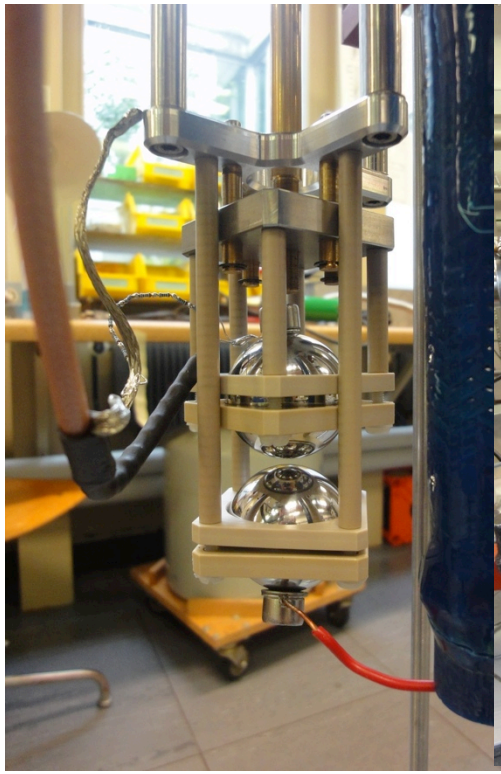


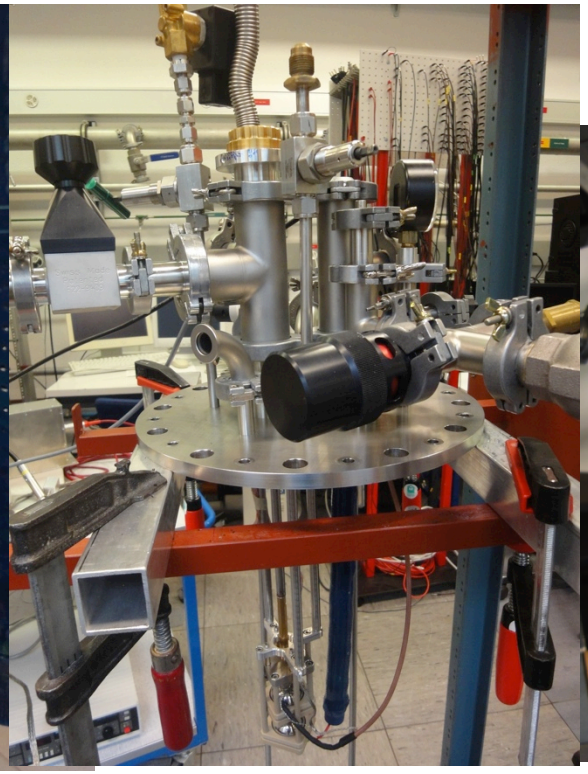


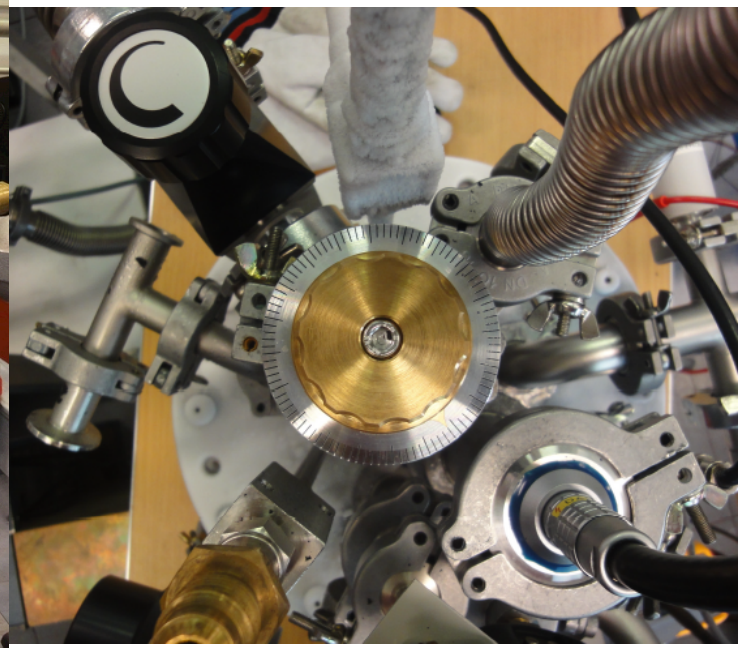
Breakdown Voltage

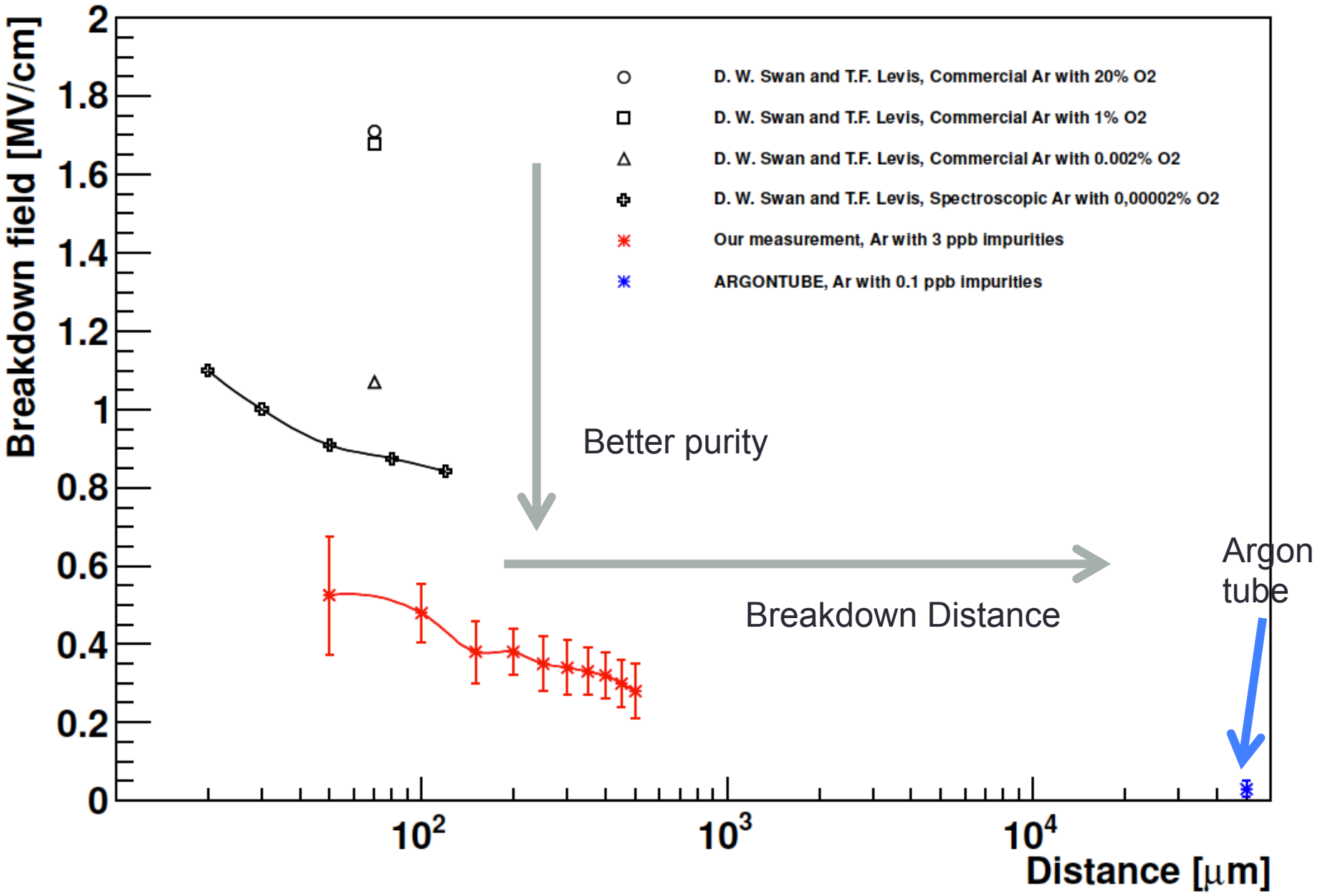
- Breakdown voltage measurement
- Micro Argontube with a 30kV HV feed through JINST 5:T11002 (2010)
- 2 spheres (d=4cm), one moveable with 5μm precision
- Few micron to 1mm range









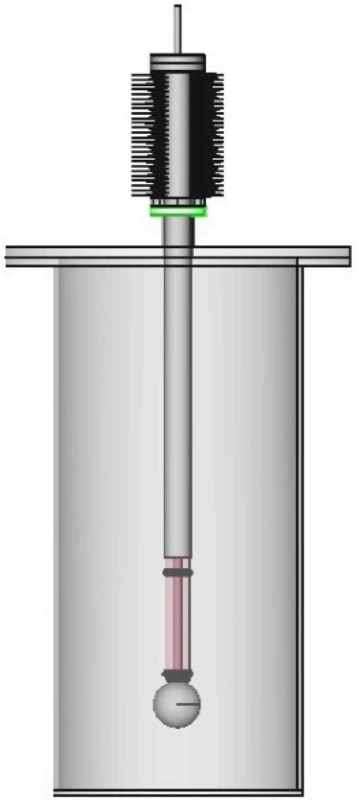

Breakdown field [MV/cm]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10^2
10^3
10^4
Distance [μm]
D. W. Swan and T.F. Levis, Commercial Ar with 20% O2
D. W. Swan and T.F. Levis, Commercial Ar with 1% O2
D. W. Swan and T.F. Levis, Commercial Ar with 0.002% O2
D. W. Swan and T.F. Levis, Spectroscopic Ar with 0,00002% O2
Our measurement, Ar with 3 ppb impurities
ARGONTUBE, Ar with 0.1 ppb impurities
Better purity
Breakdown Distance
Argon tube

NEW Test setup

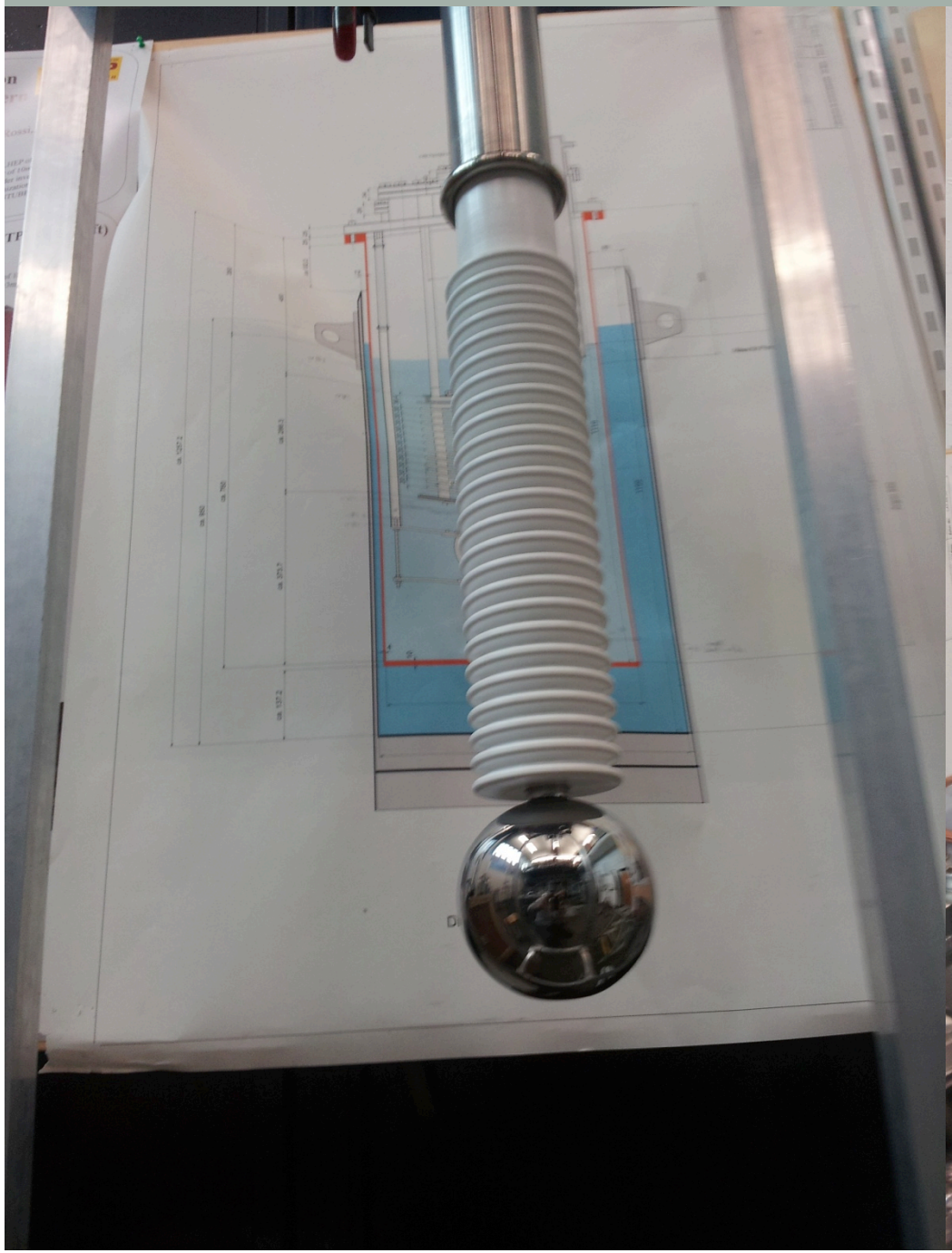
- Discharge to flat surface
- Up to 10cm
- Micrometric resolution
- New dedicated HV feed through by LHEP

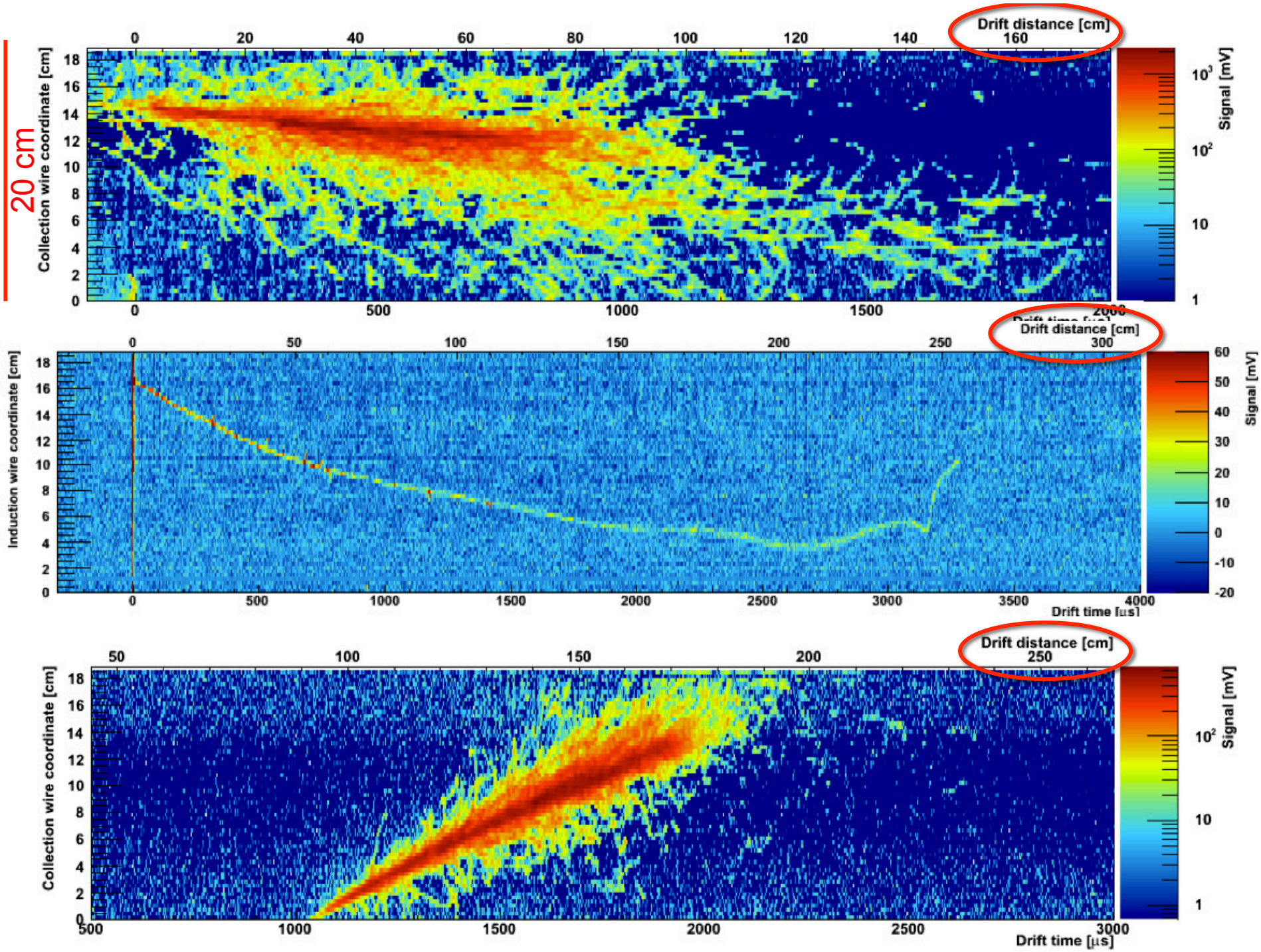
- HV protection by >10MΩ resistor

- Test starts next Monday



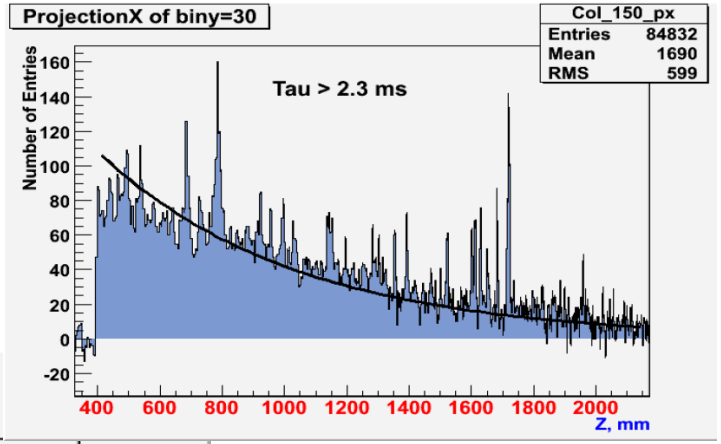
New test setup



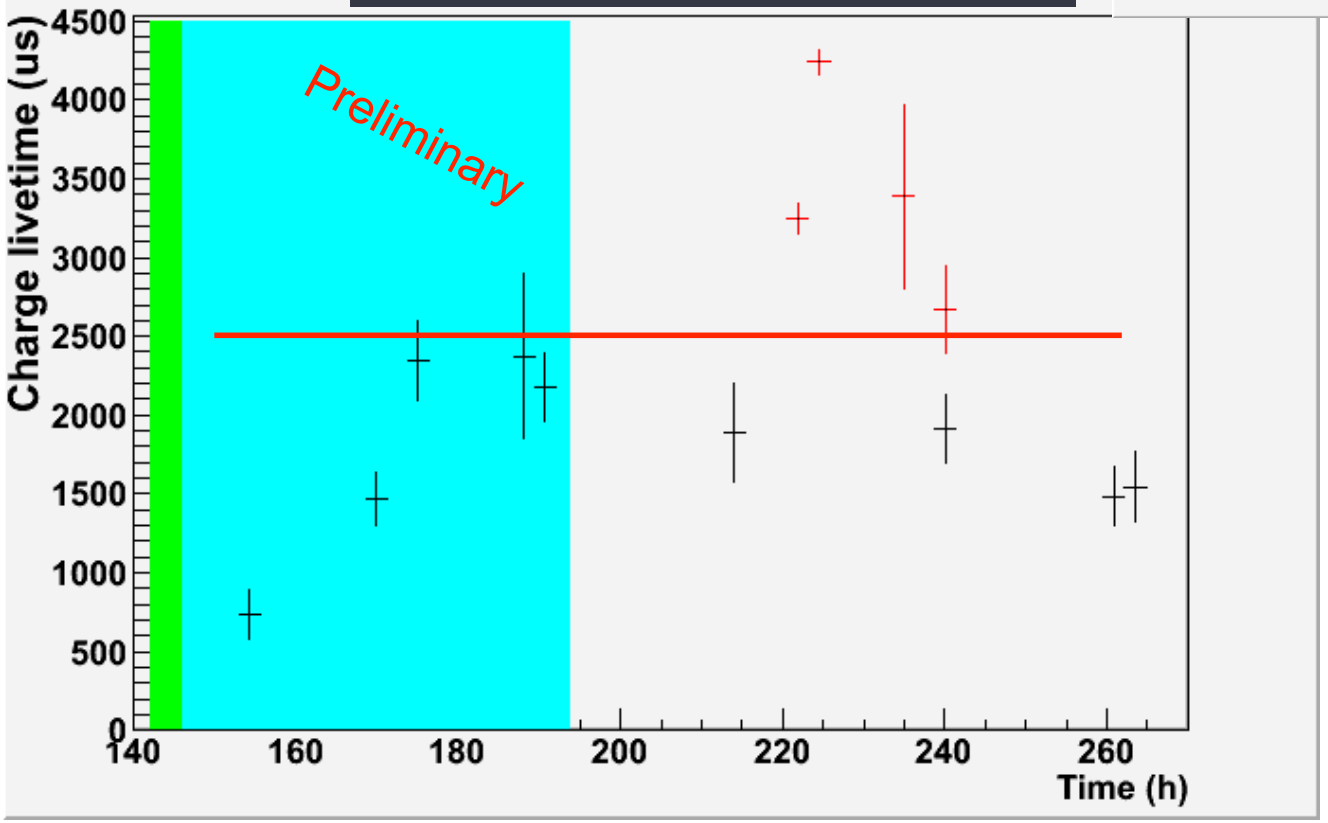

20 cm
Drift distance [cm]
Collection wire coordinate [cm]
Signal [mV]
Induction wire coordinate [cm]
Drift time [µs]

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
- Recirculation system to reduce oxygen impurities



- Purity measured with muon tracks
- Purity measured with UV laser beam



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

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

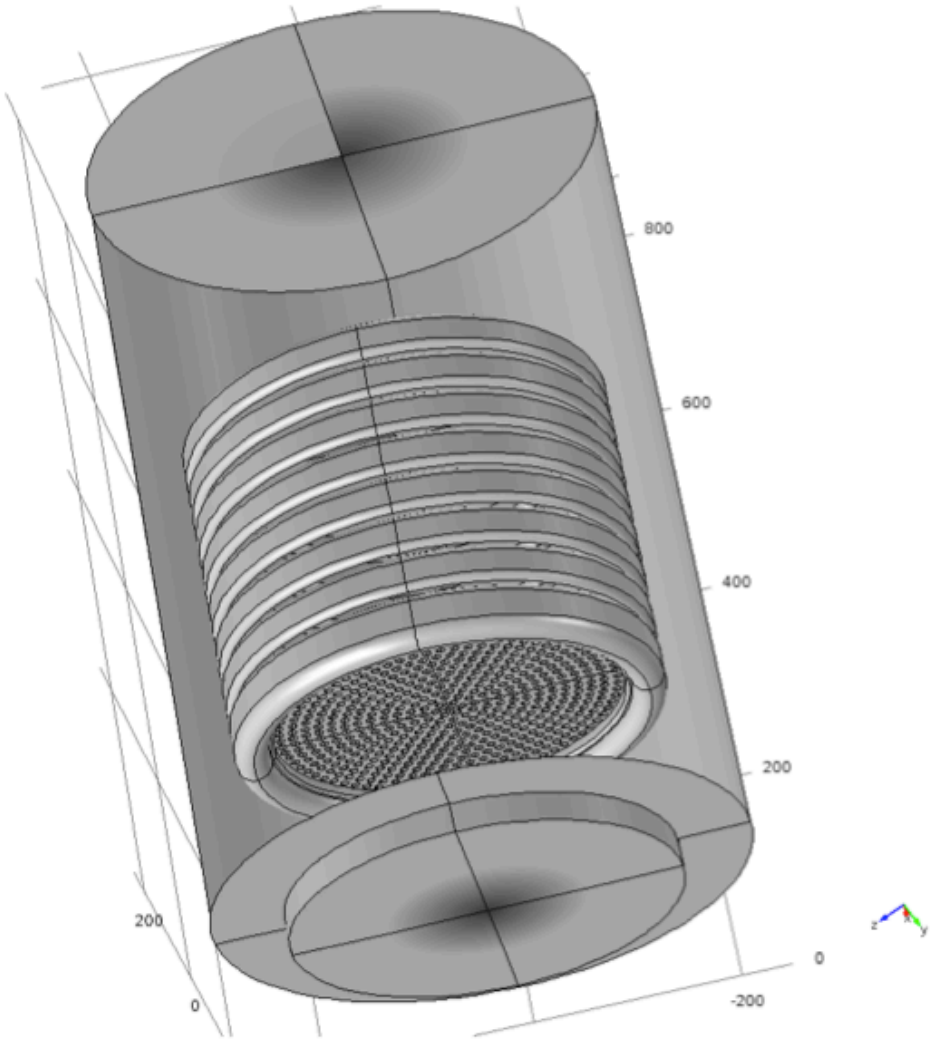
Conclusions

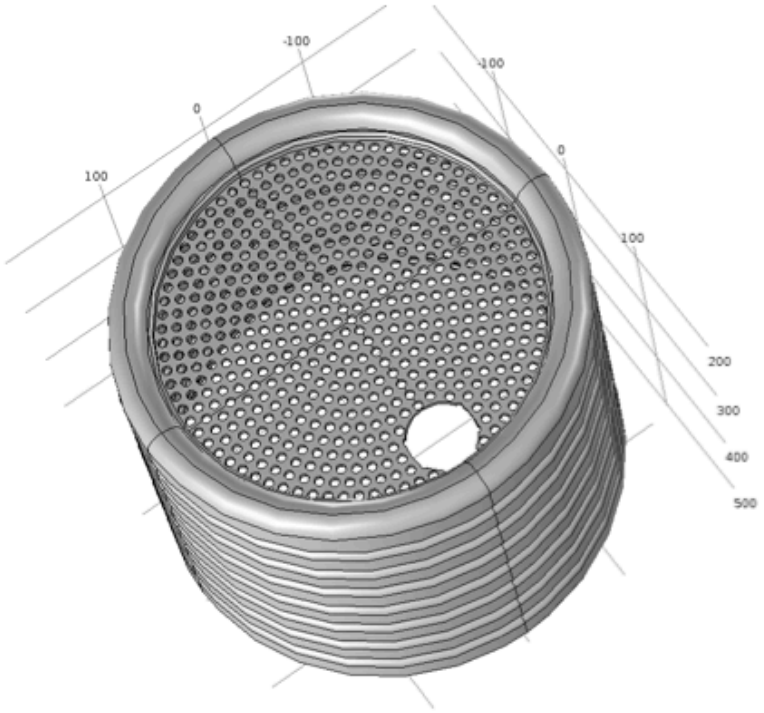
- Very long drift successfully demonstrated at AEC Bern
  - Recirculation system for Argon purification
  - Stable HV ~ 125kV with Greinacher multiplier (Cockcroft Walton)
    - Reason for discharges are understood, more R&D needed to optimize for larger HV and study LAr properties
  - Muon tracks of almost 5m drift
  - Purity of about 2.5ms
  - Measurements HV breakdown vs. Distance as function of purity in progress

  - Read more PhD M. Zeller: “Advances in liquid Argon TPC’s for particle detectors”

Thanks for your attention

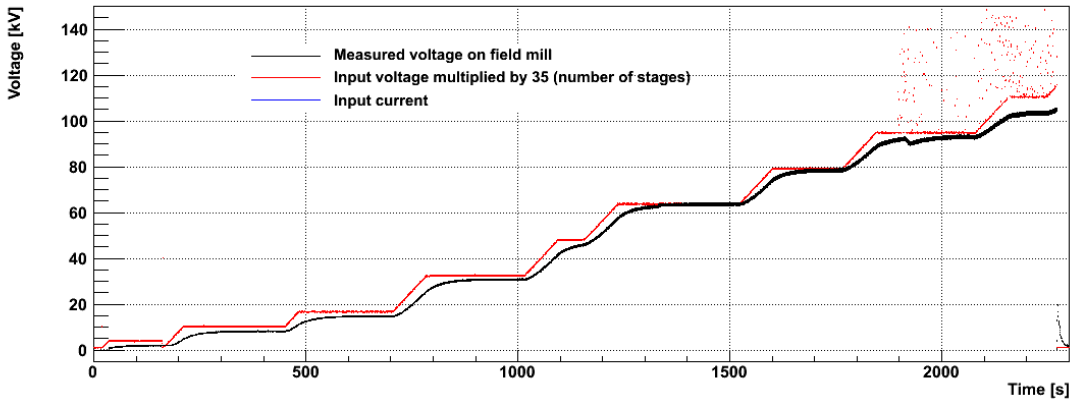
Cathode of Argontube

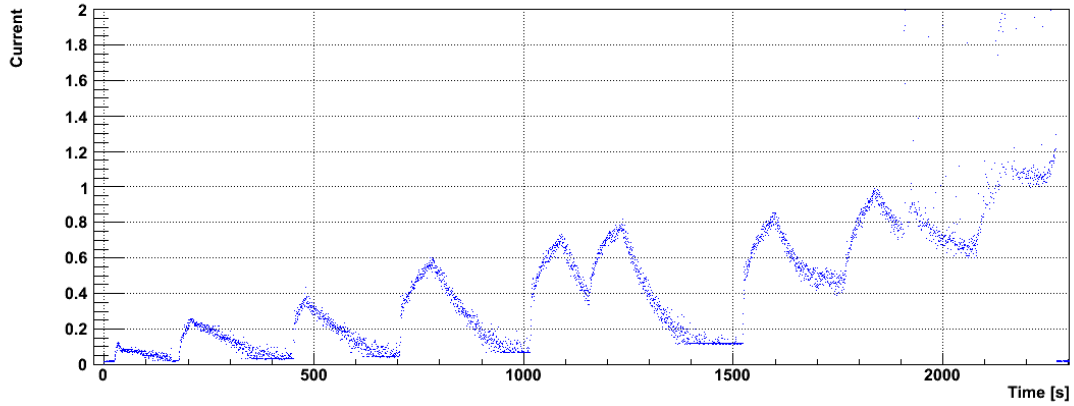




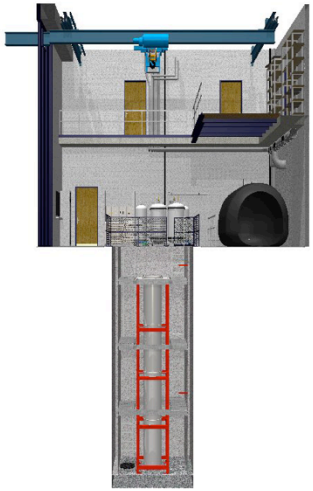
High voltage system test (Cockcroft-Walton or Greinacher multiplier)

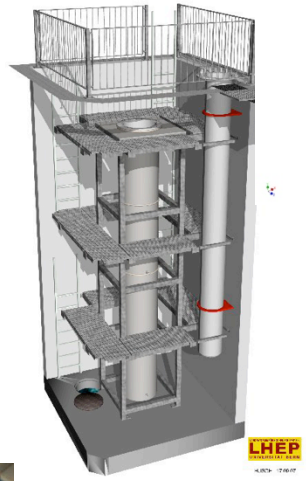
Prototype: 35 stages installed
Electric field mill on the bottom
Filled with liquid Argon
AC input voltage 4kV
Reached voltage 110kV

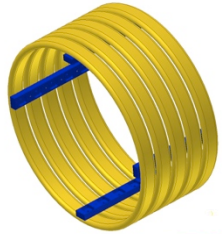


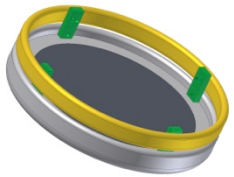


Design and construction

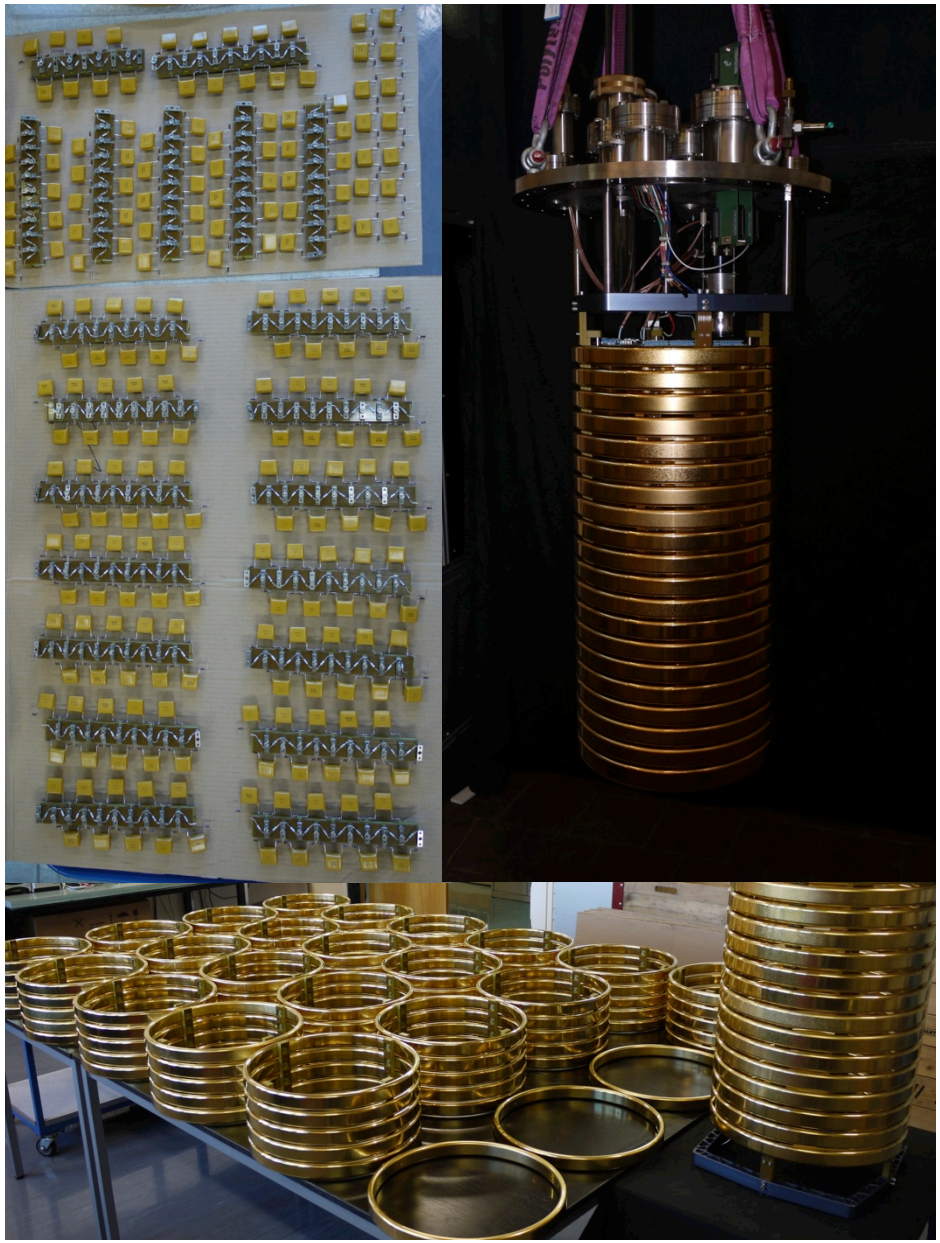




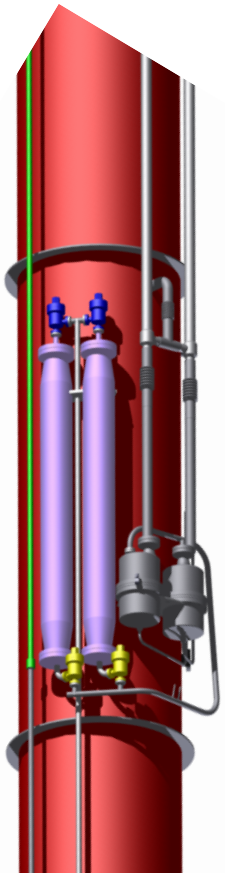


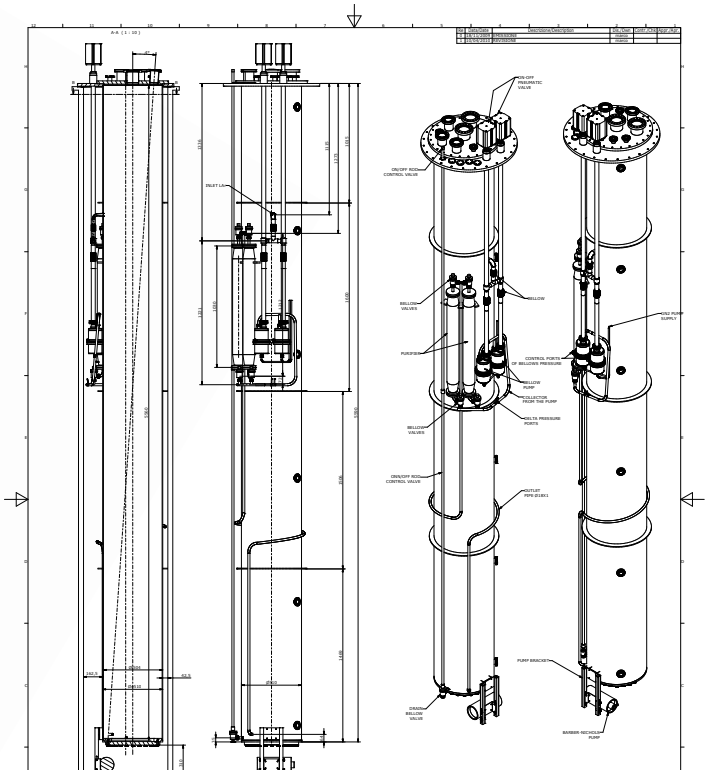


Construction, recirculation



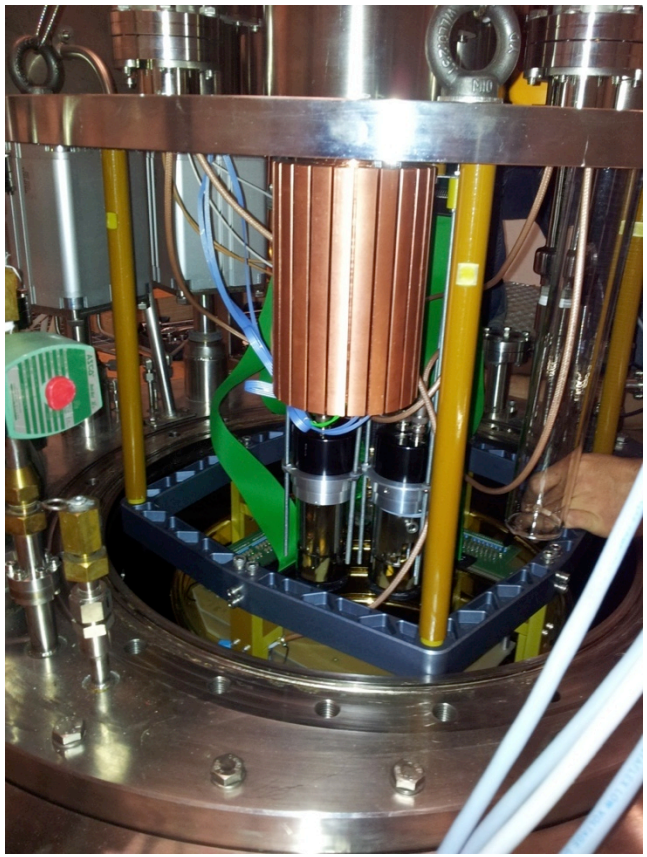
To ensure the required purity, a Argon recirculation system was installed.
First cleaning stage filling
2nd stage with bellow pumps



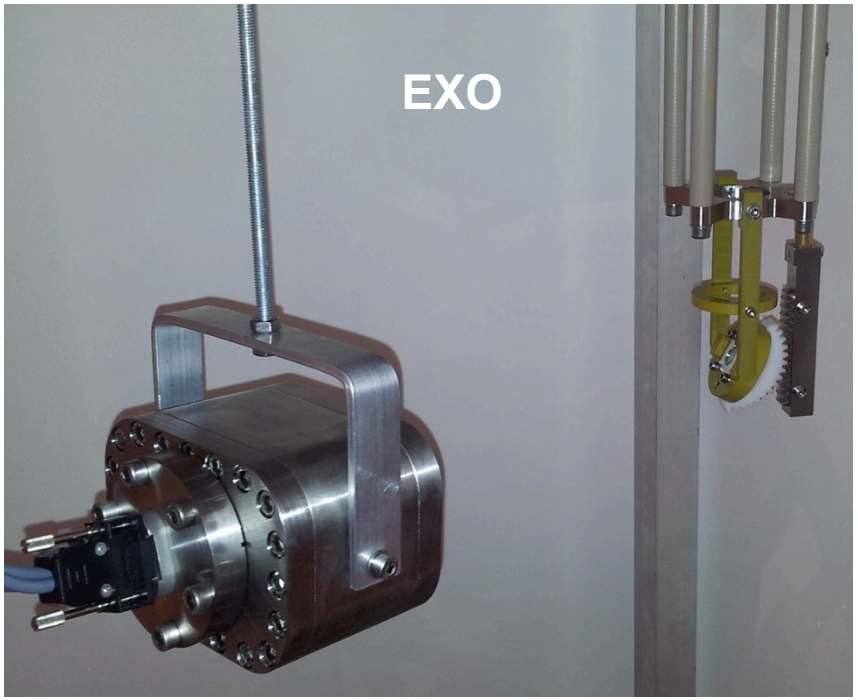


Other features of Argontube

Trigger on cosmic tracks (2 PMT's) or on UV laser (see later talk)



Cryo-cooler to run 24/7 long term without refilling

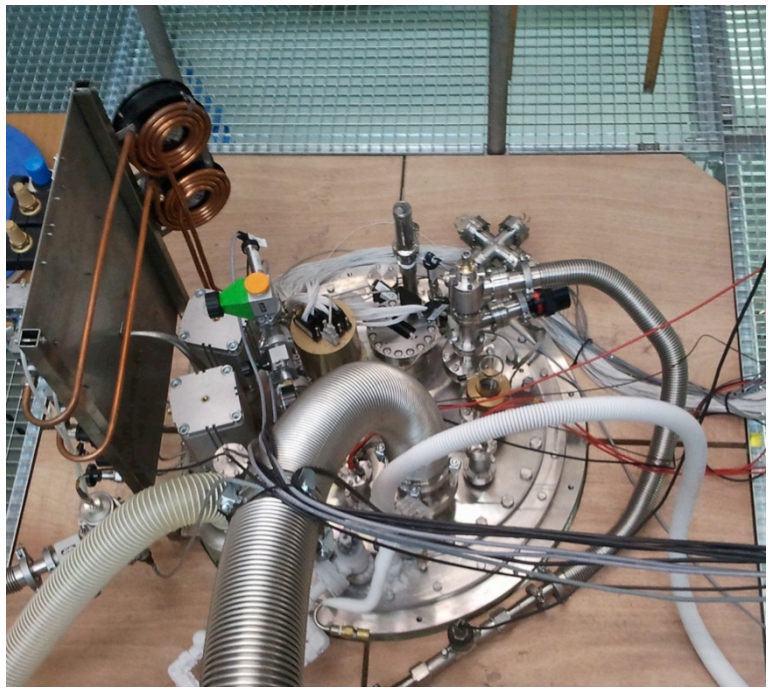


Cold camera to observe movements and conditions inside the cryostat

Data run

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 (copper filter)
- Before taking data one night of liquid recirculation through copper filter



Operation (last run)
- HV was ramped up to 1.3kV AC input voltage (170 kV) -> discharges
- Stable conditions at 1 kV AC input voltage (Drift field ~125 kV)
- Collect cosmic events
- Collect UV laser induced signals
- 2 Weeks of operation (about 10’000 events)
- Next run: max purity, new filters (regeneration in progress)