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

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on behalf of
LAr TPC concept

Features:

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

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
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<tbody>
<tr>
<td>Charge yield (m.i.p.)</td>
<td>6000 e⁻/mm</td>
</tr>
<tr>
<td>Photon yield (m.i.p.)</td>
<td>5000 photons/mm (128 nm)</td>
</tr>
<tr>
<td>Electron drift velocity</td>
<td>2 mm/µs (@ 1kV/cm)</td>
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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 t₀ for the drift
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 m³
• Inner volume: 1. m³
• Active volume: 0.5 m³
• 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

7 m deep
Installation of the inner vessel

Electro-polished internal surface
真空
- 轴向泵
- 12 h 的抽气
- 真空: 7x10^{-5} mbar

注满
- 6 h
- 2600 升的氩气
- 再循环系统测试每小时 100 升

面板，所有控制再循环电路的阀门都安装在这里。所有内容都可以通过以太网访问的PLU进行控制。
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

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.
High voltage system
Greinacher/Cockcroft-Walton circuit: chain of rectifying cells installed in liquid

Schema of the circuit

Test setup

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

In the ARGONTUBE project 125 stages will be installed
Idea developed in collaboration with ETHZ and realized at the LHEP (University of Bern)

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

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

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
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</thead>
<tbody>
<tr>
<td>Measured voltage</td>
<td>Expected voltage</td>
</tr>
</tbody>
</table>

- 4% decrease in 20 min

Charge up time scale
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).

Laser beam to monitor the purity of the LAr

Longest life time 2500 $\mu$s (~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

Induction views

Collection views

Induction view - Event nr. 25

Collection view - Event nr. 25

Induction view - Event nr. 94

Collection view - Event nr. 94

Induction view - Event nr. 156

Collection view - Event nr. 156

em shower
micro ARGONTUBE

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

Wire pitch
2 mm

To preamp

100 x 100 mm

HV power supply
0-30kV

The content of Nitrogen is monitored by resonant density sensor.
\[ \rho_{\text{LAr}} = 1.4 \text{ g/cm}^3 \]
\[ \rho_{\text{LN}} = 0.8 \text{ g/cm}^3 \]
Density sensor developed at LHEP:
Electron yield

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

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 Nitrogen) are made of.

\[ \gamma + ^{14}\text{N} \rightarrow ^{13}\text{C} + p \]
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 5 m.
• medium ARGONTUBE
  ✓ continue to work as bench test for ARGONTUBE
• micro ARGONTUBE
  ✓ show definitively the feasibility of the gamma ray radiography