Results and plans for LAr R&D in Switzerland

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Introduction

Next generation neutrino physics, nucleon decay (A. Rubbia talk) and direct Dark Matter search experiments (L. Baudis talk) require:

- Very large massive detectors (hundreds kiloton-scale for neutrino and proton decay and ton-scale for DM).
- Low background (underground).
- Good energy resolution.
- Low energy threshold.
- Particle identification capabilities.

R&D needed towards giant detectors:

- Readout method (charge amplification in double phase, proof of principle is achieved).
- High voltage system (successful test of small scale Greinacher circuit).
- LAr purity for non-evacuable dewars.
- Readout electronics (warm /cold solutions).
- LAr tank (LNG technique).

LAr R&D overview

Overview of the LAr R&D in Switzerland.

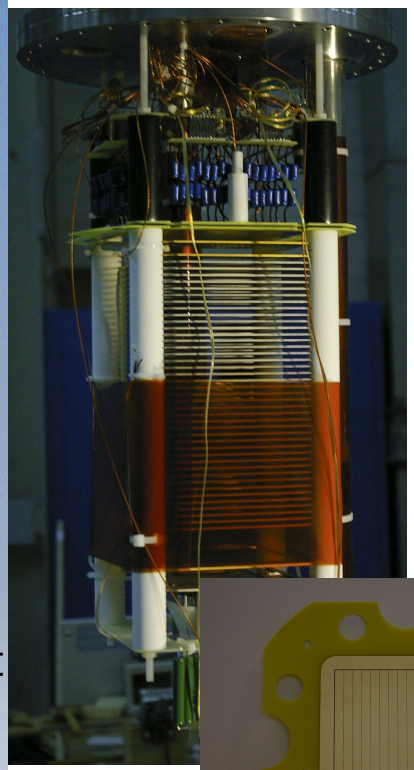
Ongoing:
- LEM-TPC test setup (ETHZ).
- ArDM experiment (ETHZ, UZH, University of Granada, CIEMAT, University of Sheffield, Andrzej Soltan Inst.).
- ArgonTube and UV laser LAr ionization (UniBe).

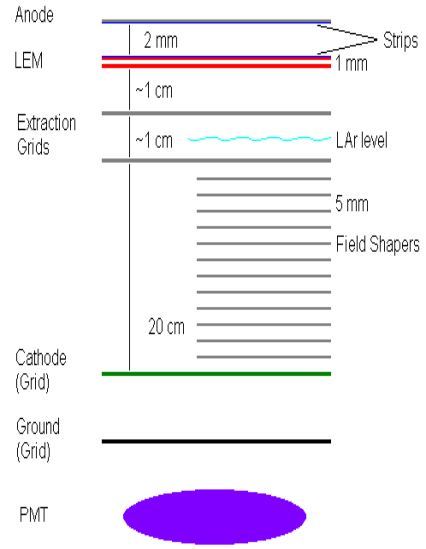
Near future (in collaboration with KEK):
- 250 Lt TPC (ETHZ, KEK).
- 80 Lt LEM-TPC (ETHZ).
- Purging test of ~6 m^3 (ETHZ).

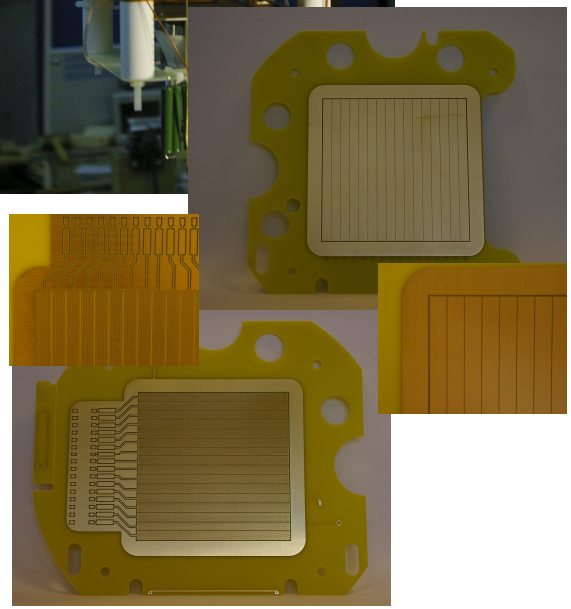
Future (ETHZ, KEK, ...):
- Test beam (e^-, π and μ) campaign.
- 1 kton full engineering demonstrator for giant detectors.

Double phase LEM-TPC

A.Badertscher et al., IEEE Nuclear Science Symposium Conference Record, (2008), 1328.







It is a LAr TPC (10x10x20 cm^3) with charge amplification readout by means of Large Electron Multiplier (LEM) devices in Ar vapour.

LEM:

- mm-size hole charge amplifier.
- Standard PCB methods.
- Double sided copper-cladded FR4.
- Precision hole by drilling.
- Thickness: 0.8-1.6 mm.
- Holes diameter: 500 μm.
- Pitch: 800 μm.
- Segmented readout: 2x16 strips (6 mm wide).

Aim:

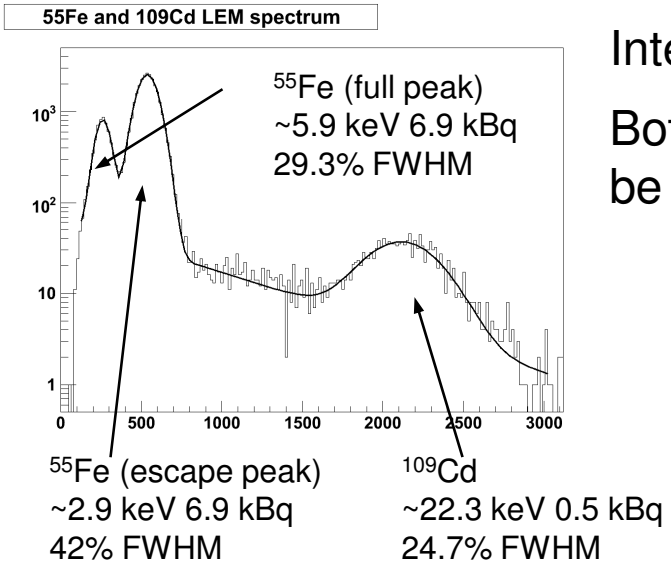
- Amplification of the charge from a LAr TPC (lower the energy threshold, compensate the charge loss in long path, increase the S/N).

Challenges:

- Controlled avalanches in pure argon gas.

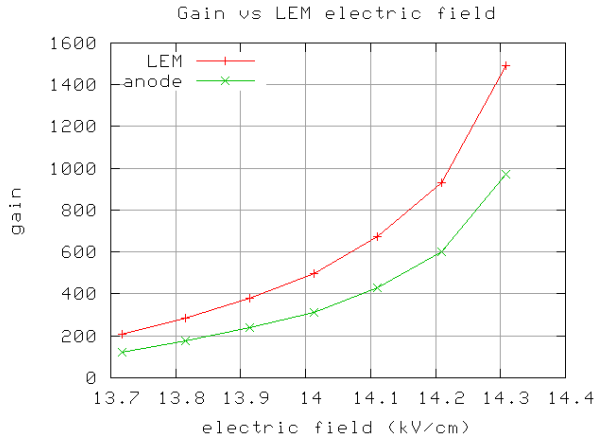
LEM-TPC results

Pure argon gas operation, room temperature, 1.2 bar.
Double stage LEM and anode readout.



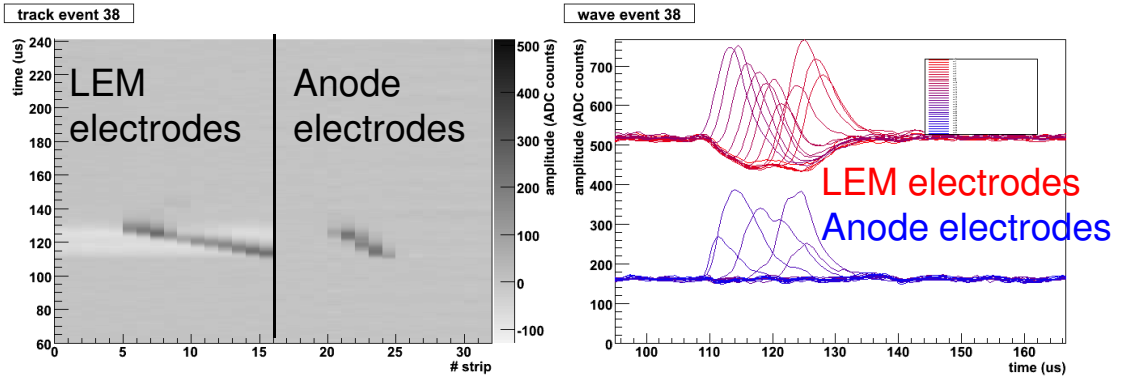
Internal ^{55}Fe and ^{109}Cd sources.

Both anode and LEM signals can be used for the energy evaluation.



Cosmic muons tracks.

Drift field: 400 V/cm.
LEM field: 14 kV/cm.
Gain: ~1000.



LEM-TPC results

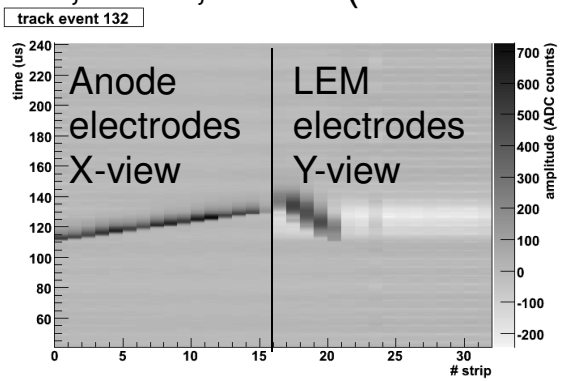
ETH Institute for Particle Physics

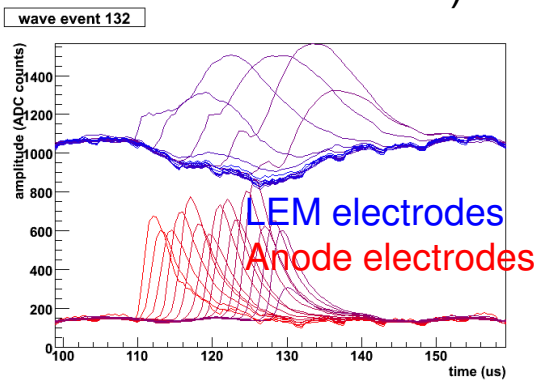
Double phase operation, 87 K, 1 bar (~3.5 times denser than at STP).

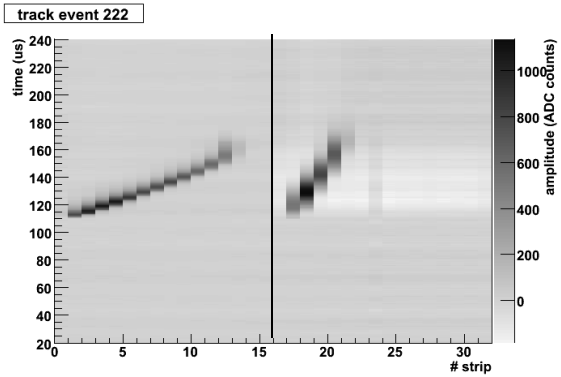
Double stage LEM and anode readout.

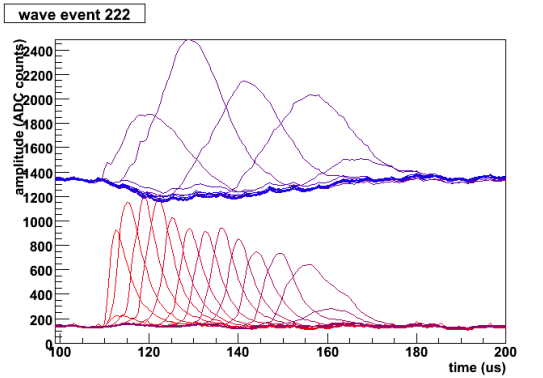
Drift field: 700 V/cm.
LEM field: 26 kV/cm.

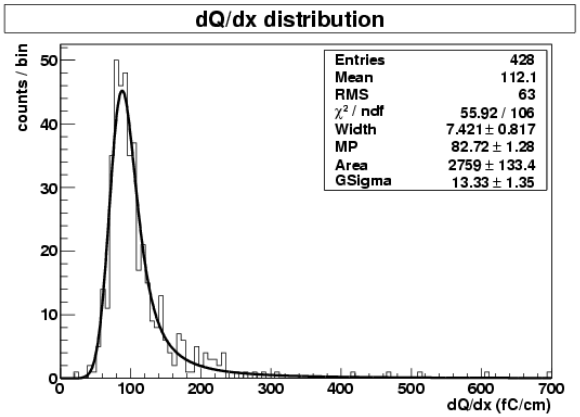
Calibration with cosmic muons:
- Gain ~10.
- Resolution 12%.
- Raw images.
- S/N ~800/10.

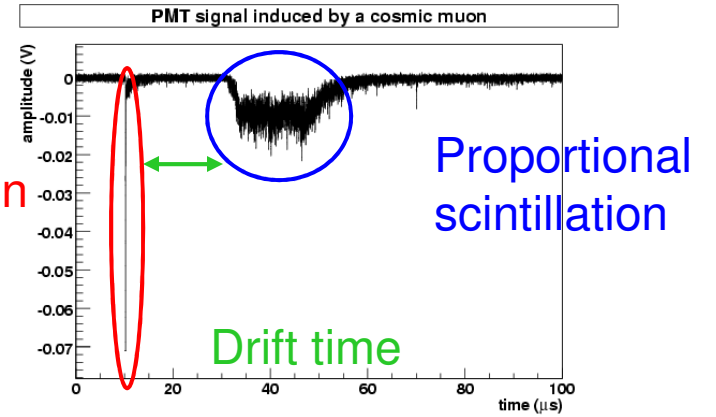












Argon Dark Matter experiment

See L. Baudis talk tomorrow.

ArDM (CERN recognized experiment RE18) is a double phase pure argon TPC (850 kg active volume) for the direct detection of Dark Matter.

Aim:

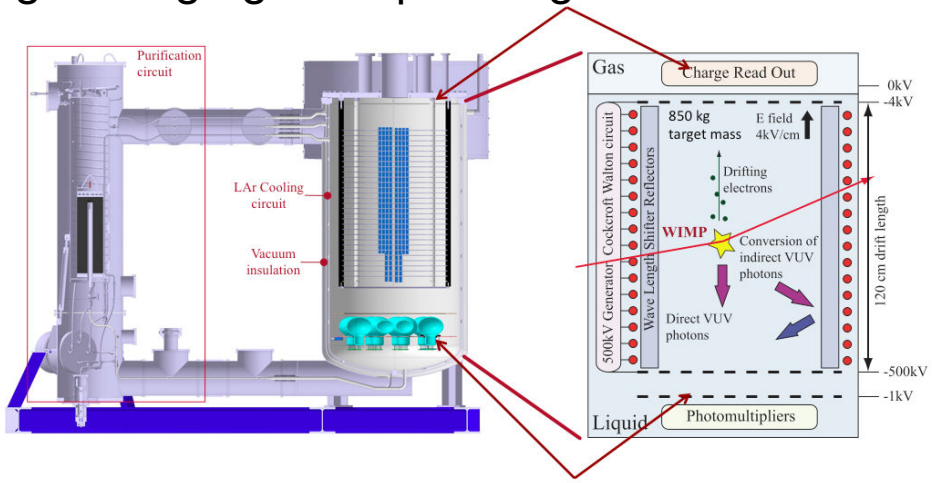
• Detect nuclear recoils induced by WIMPs.

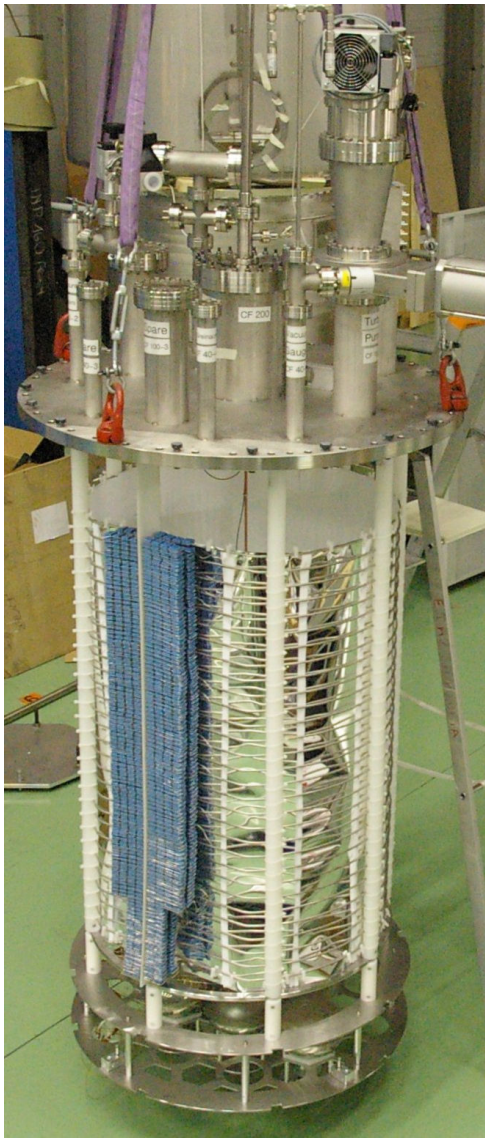
How:

• primary scintillation light (cryogenic PMTs).
• ionization charge (LEM readout).

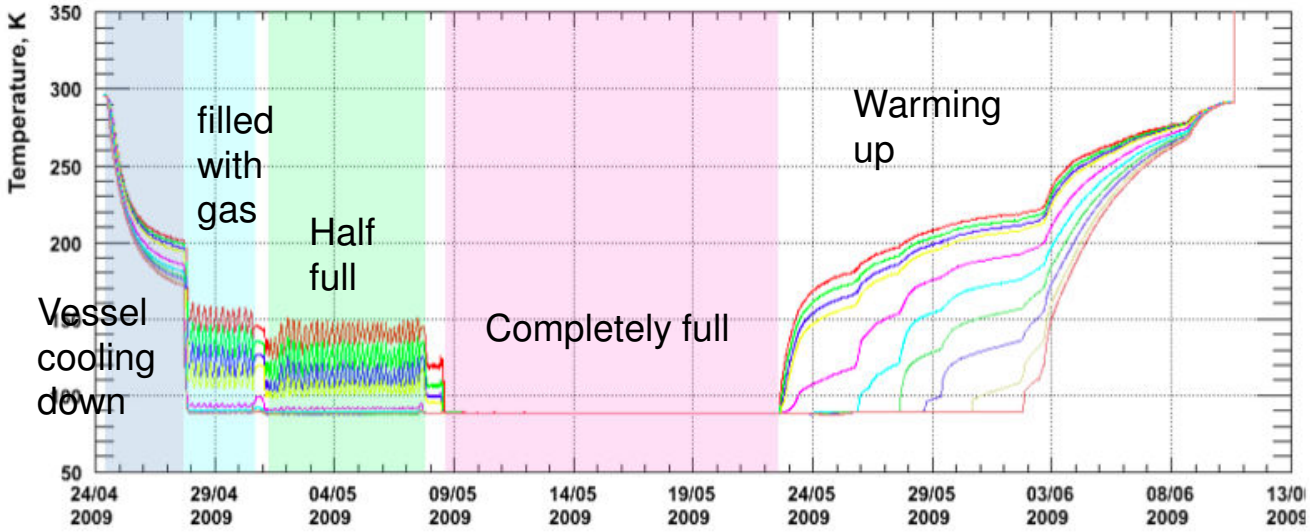
Challenges:

• High voltage for the long drift.
• Low threshold for the scintillation light.
• High charge gain in pure argon.





ArDM status



- First filling with LAr in May 2009.
- More than 3 weeks of data taking.
- LAr purity stable without purifying.
- Analysis is ongoing:

Light yield (preliminary) > 0.5 phe/keV$_{ee}$ (7/14 PMT installed with different WLS coatings).

ArDM next test is planned for November 2009.
Possible underground laboratories for the end of 2010:

- Canfranc, Spain (2450 mwe).
- SUNLAB, Poland (2200 mwe).
- Prahova salt mine, Romania (600 mwe).

ArgonTube & laser ionization

ArgonTube is a 5 m long LAr TPC in Bern.

Aim:

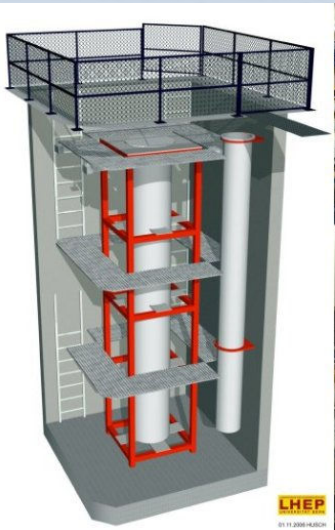
• Proof the possibility to drift electrons for very long distances (simulate 20 m).

• Study the electron diffusion.

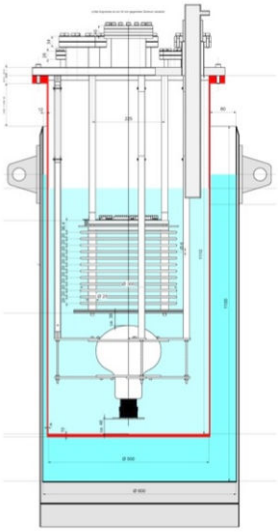
Challenges:

• LAr purity.

• High Voltage supply (Greinacher ~500 kV).



B. Rossi et al., arXiv:0906.3437



The detector is a LAr TPC (20x20x26 cm^3) with wires readout (64+64 channels). Tracks are produced by UV laser (266 nm) multi-photonic ionization.

Aim:

• New monitor of the free electron lifetime.

• Calibrate the TPC with the laser (no Landau fluctuations).

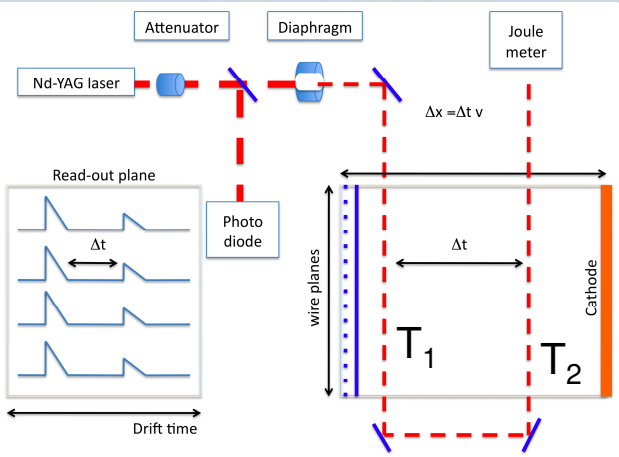
Challenges:

• New ionization technique.

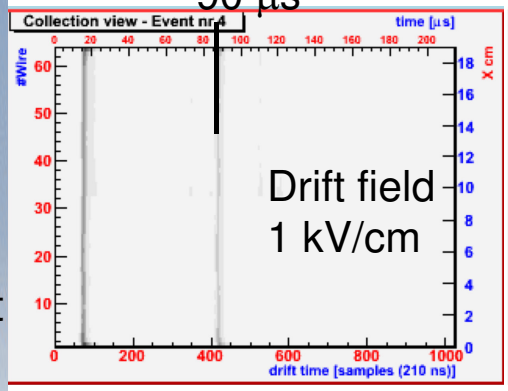
UV laser ionization results

UV laser ionisation:

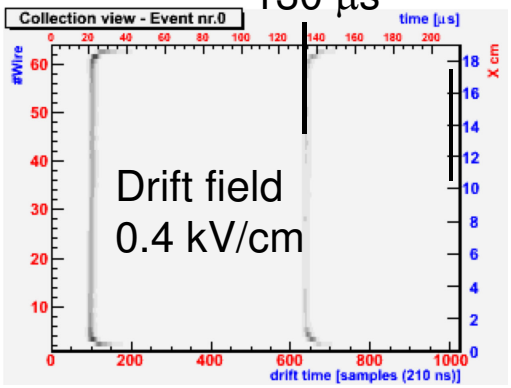
- Two tracks perpendicular to the drift path (T_1 and T_2).
- e^- lifetime (τ_{e-}) is measured by T_2/T_1 ratio.
- A more precise measure of τ_{e-} is done by changing the drift field.



~90 μs

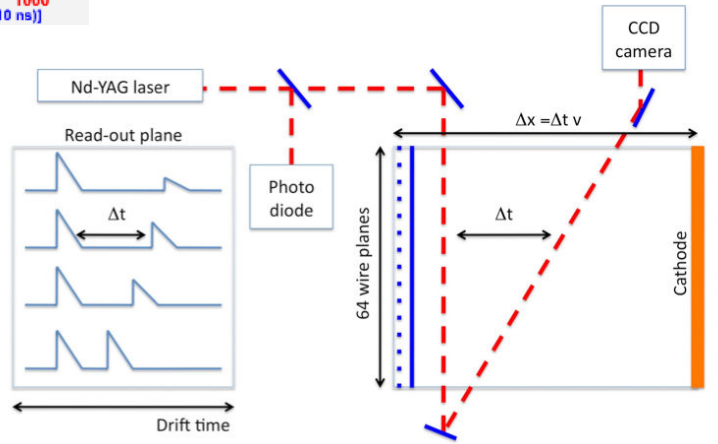


~130 μs



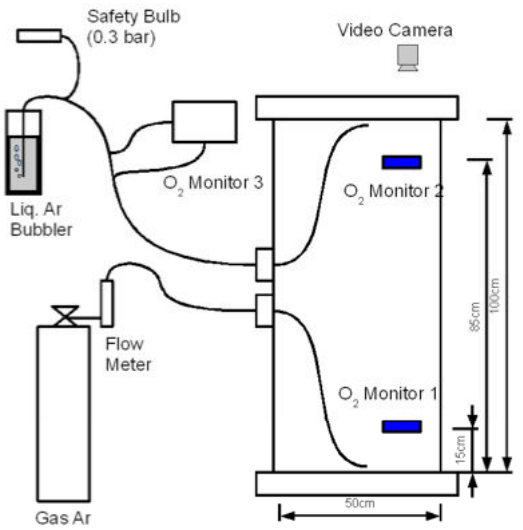
New UV laser configuration.
Two tracks, one parallel to the drift path and one inclined:

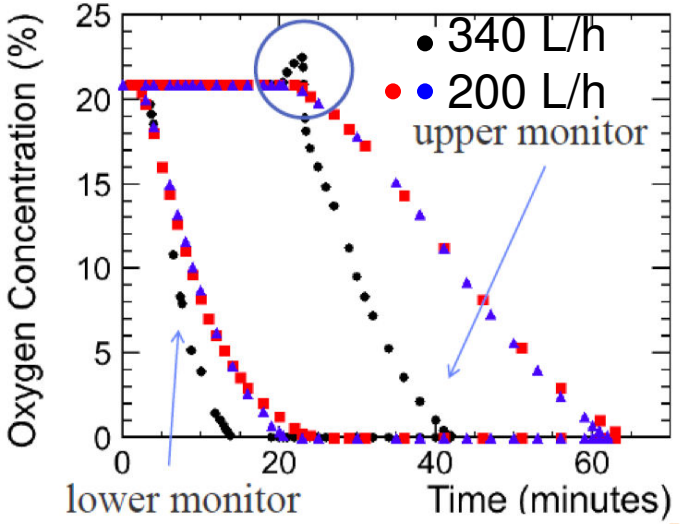
- Precision measurement of the electron lifetime without changing the drift field.
- Not only R&D: measure the multi-photonic ionization cross section.



In collaboration with KEK

Purging test without pumping the vacuum in 200 Lt vessel.



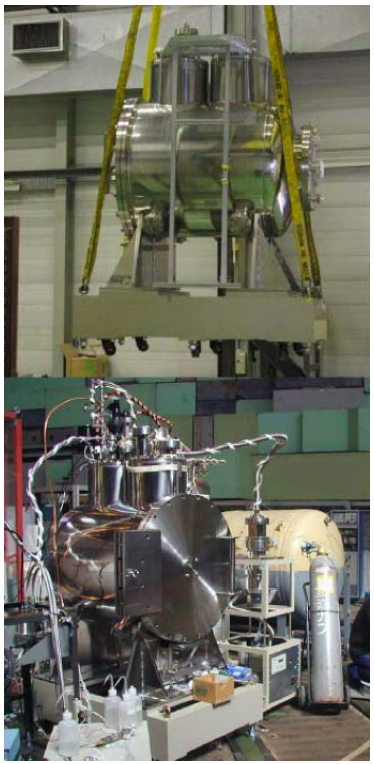


Purity acieved: ~3 ppm (O_2) after 10 volume changes.

250 Lt cryostat from MEG experiment sent to Japan:

- Transfer technology for building LAr TPC of ~500 ch.
- LAr TPC on charged particles beam

(PID performance, calorimetry, vertex reconstruction).



Planned tests at CERN

Vacuumless purge test of a 6 m^3 dewar.

Aim:

• Proof the possibility to achieve high LAr purities (~ppm O_2 equivalent).

Challenges:

• Remove the air by "flushing" argon (new technique on large scale vessels).

• Outgassing of the material inside.

80 L double phase pure argon LEM-TPC, being designed, to be tested on e^-, π and μ beam.

Aim:

• Test the largest (~50x50 cm^2) available LEM.

• Test imaging capabilities on interaction vertex reconstruction (refine the spatial resolution, strip width < 3 mm).

Challenges:

• Largest LEM ever produced.

Summary

Extensive R&D in Switzerland towards next generation liquid argon detector for neutrino physics, proton decay and direct DM search.

All the R&D programs are complementary:

LAr-TPC embedded in magnetic field (not covered here)
• address the sign to the charge.

Double phase pure argon LEM-TPC
• New technique for amplification of charge signals from LAr TPC.

Argon Dark Matter Experiment
• Surface tests ongoing, underground for the end of 2010.

UV laser LAr ionization
• New TPC calibration and LAr purity monitor techniques.

ArgonTube
• Study very long electron drift.

ETHZ-KEK collaboration
• Vacuumless purging tests.
• LAr detector test beam campaign