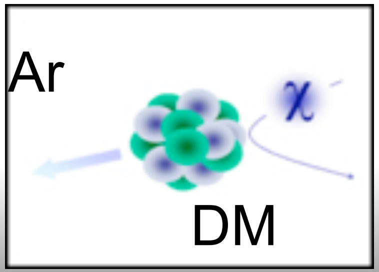
ArDM (CERN RE18)

A Liquid Argon Dark Matter Experiment

Lukas Epprecht on behalf of the ArDM-collaboration



Who Are We?

<u>Collaboration</u>

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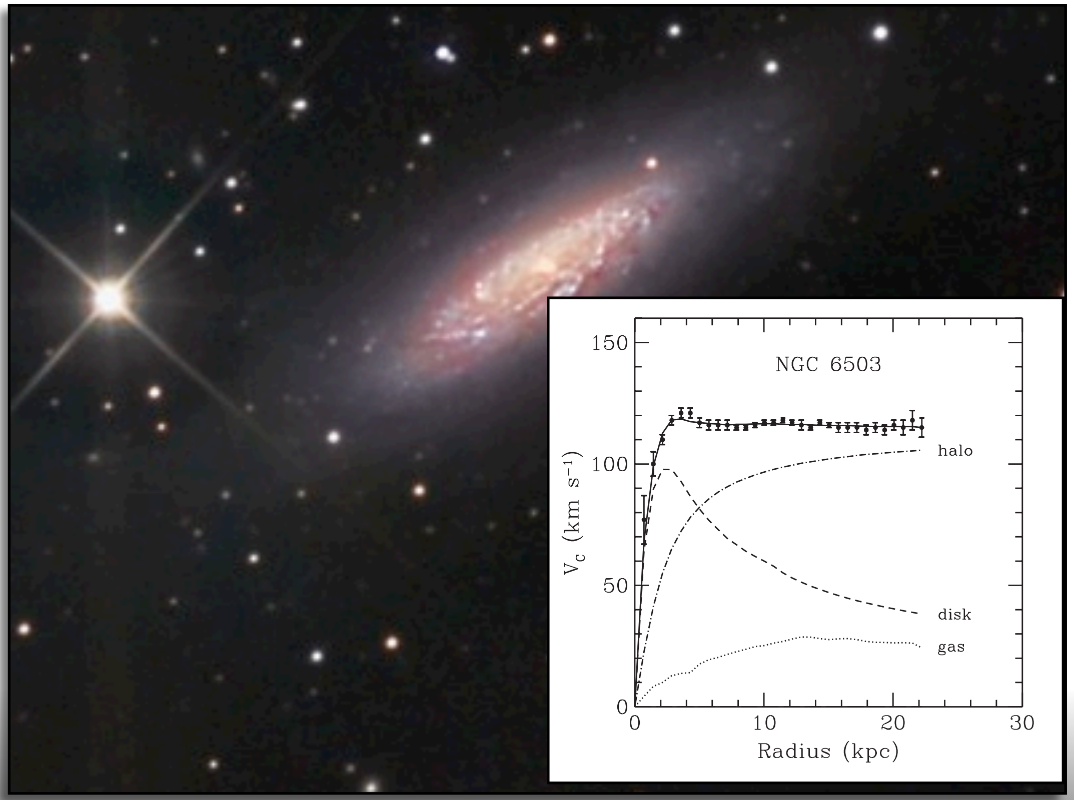
CERN: N. Bourgeois, G. Maire, S. Ravat

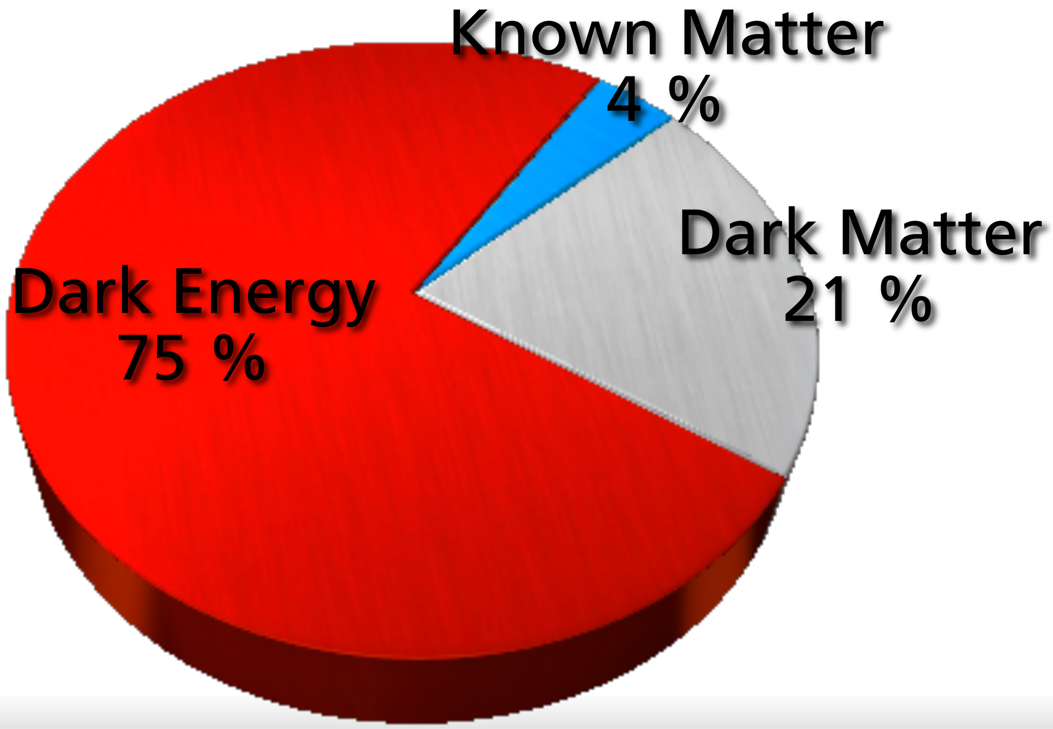
Why we look for Dark Matter ?

- **Rotation of galaxies:** Radial velocity distribution of stars in outer halo can't be described only by the mass of the visible stars in the galaxy. There must be additional mass to keep it constant. What is it? We don't know --> Dark Matter



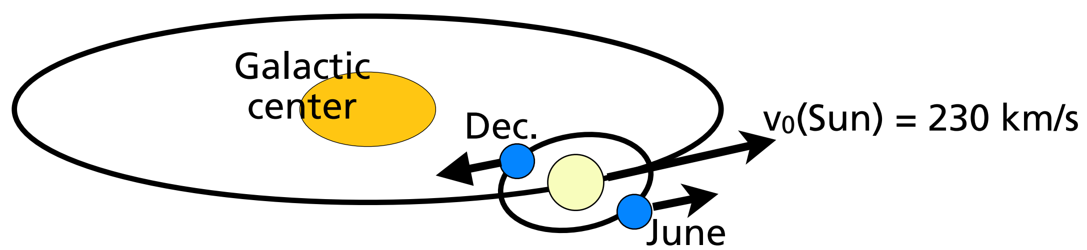
K.G. Begeman et al.; *MNRAS 249 (1991)* 523.

- Composition of the Universe:



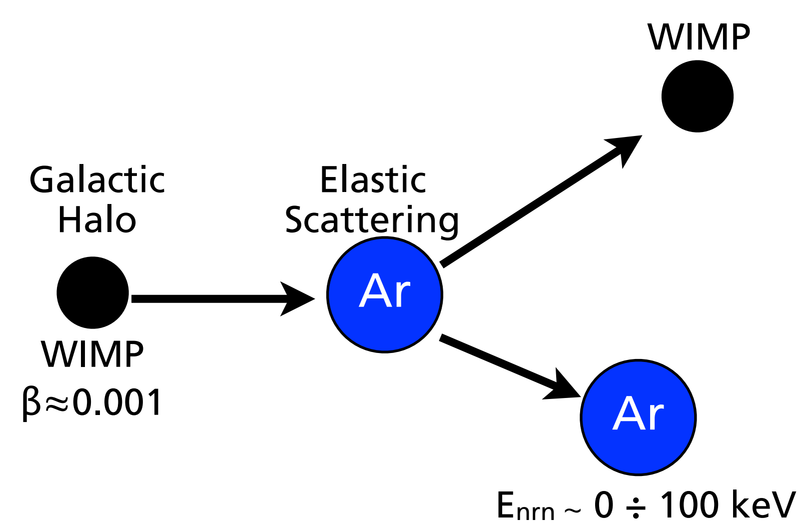
How Do WIMP's Interact with LAr?

WIMP: Isothermal Halo (No co-rotation)



Wimp velocity: 230 km/s → non relativistic energy range; recoil pattern similar to the one of low energetic neutrons

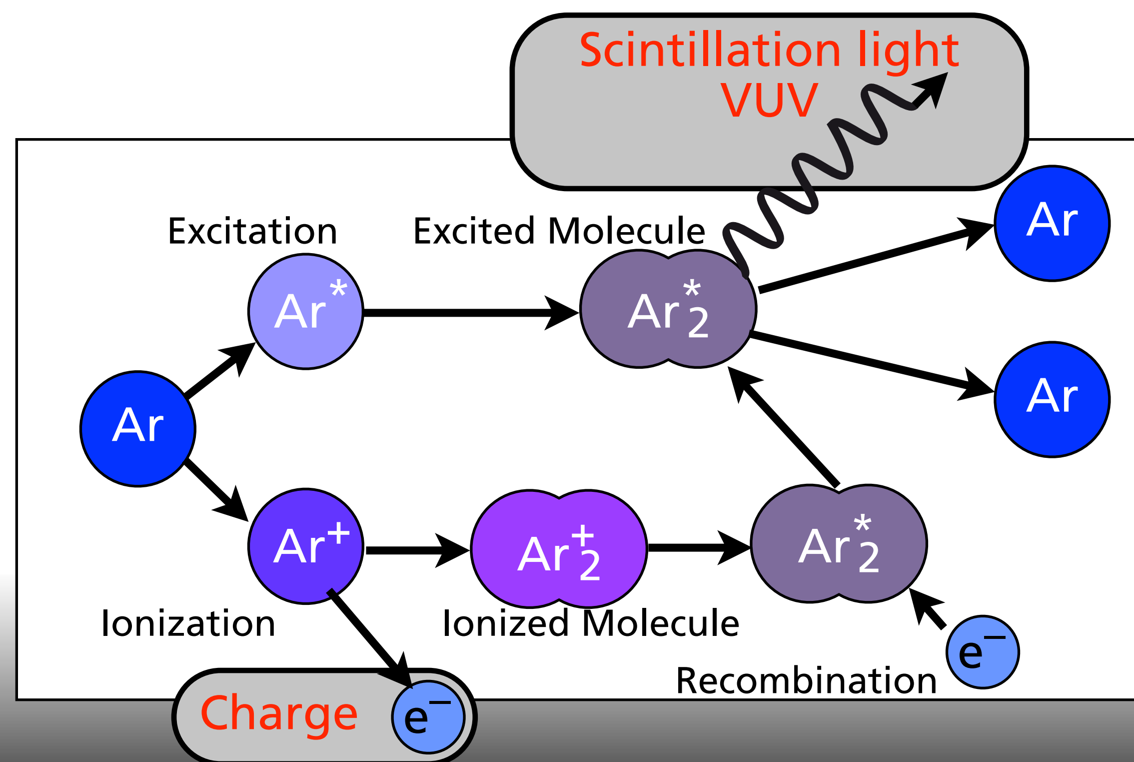
Recoil energy: 30-100 keV → excitation and ionization



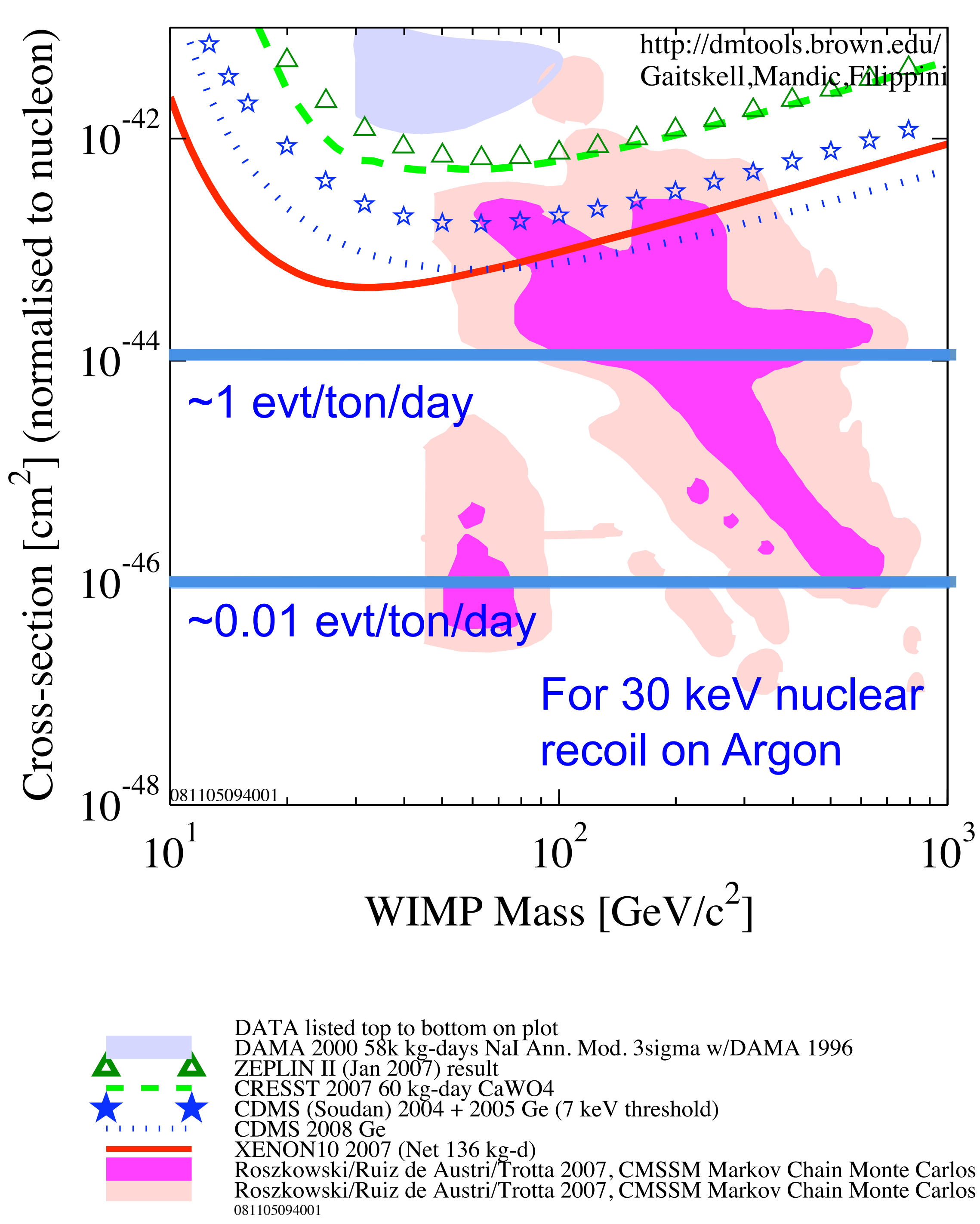
Strategy for ArDM:

Light: shifted from VUV (128 nm) to visible light and detected with low radio-activity PMTs. (~100 photons in UV)

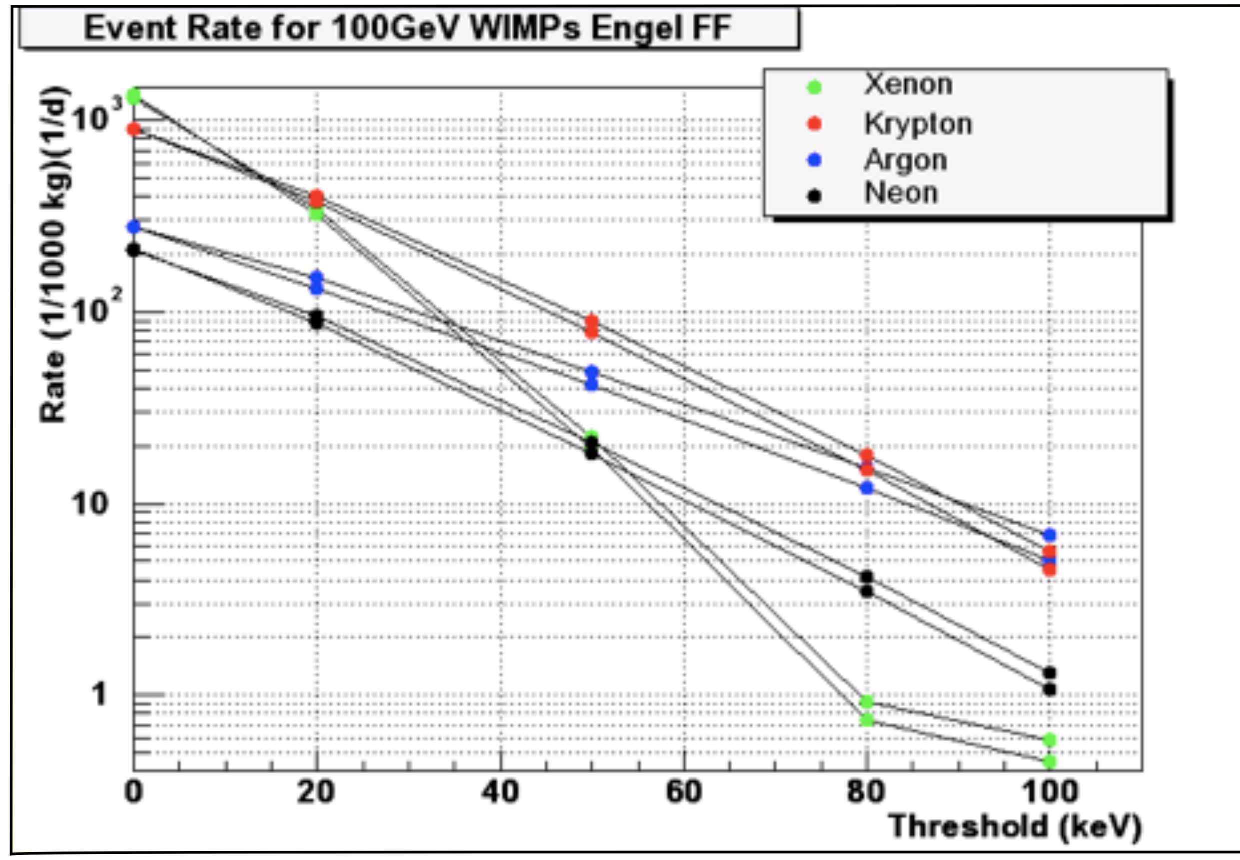
Charge: drifted upwards and read out in argon gas with a LEM charge readout system. (~100 electrons)



Design Parameter of ArDM



$$\frac{dR}{dE_{nr}} \propto S(E_{nr}) \times [F^2(q^2 = 2M_{WIMP}E_{nr})] \times I \approx e^{-E_{nr}/E_0} F^2 I$$



Event rate above recoil energy threshold per day and per ton of Xe/Kr/Ar/Ne

Assumptions for simulation:

- Cross-section normalized to nucleon
  - $\sigma = 10^{-42}$ cm^2 = 10^{-6} pb
  - M_{WIMP} = 100 GeV
- Halo Model
  - WIMP Density = 0.5 GeV/cm^3
  - Galactic escape velocity v_{esc} = 600 km/s
- Interaction
  - Spin independent
  - Engel Form factor

Design Parameter of ArDM

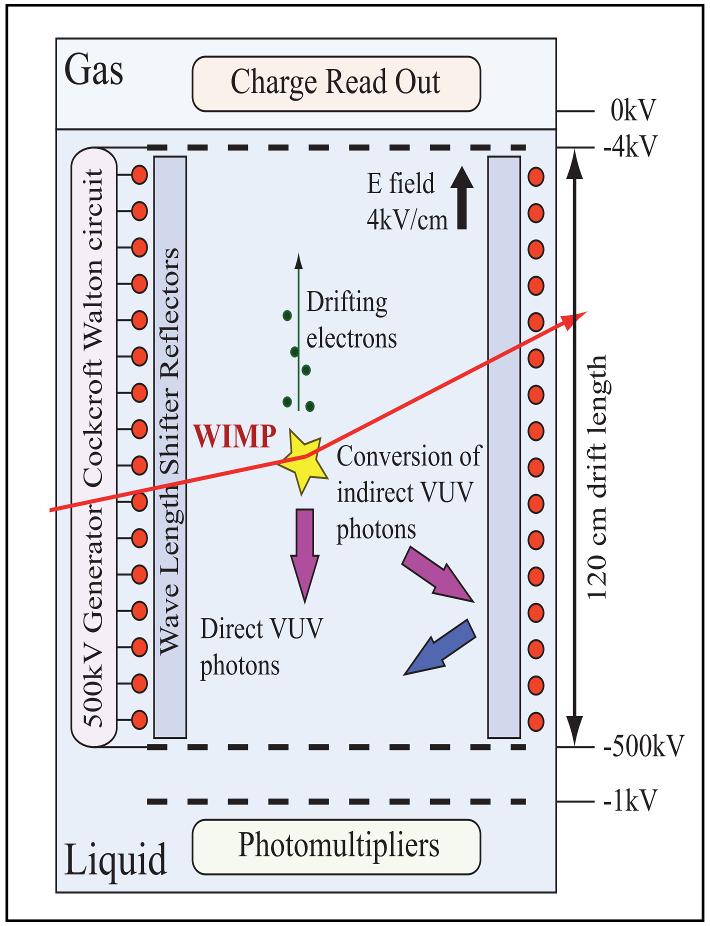
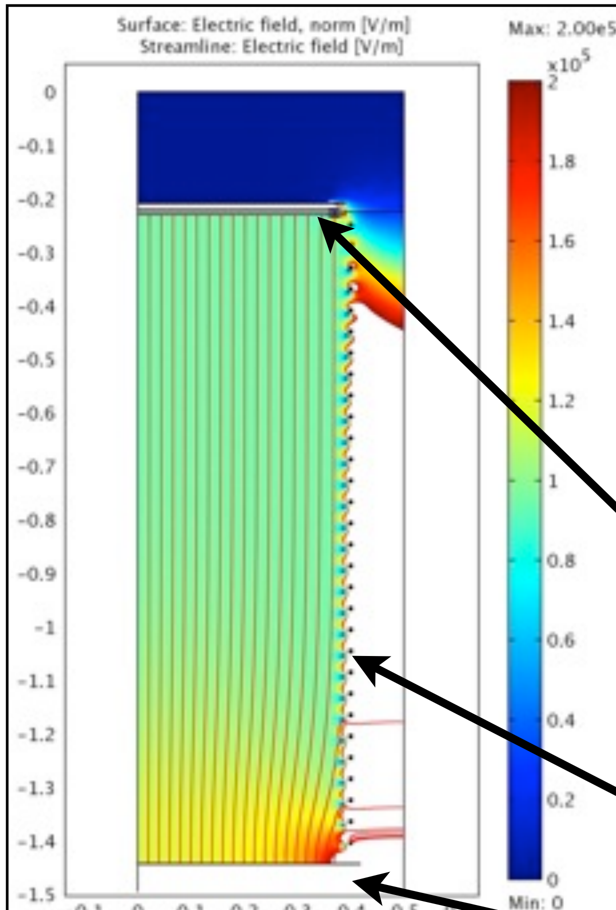
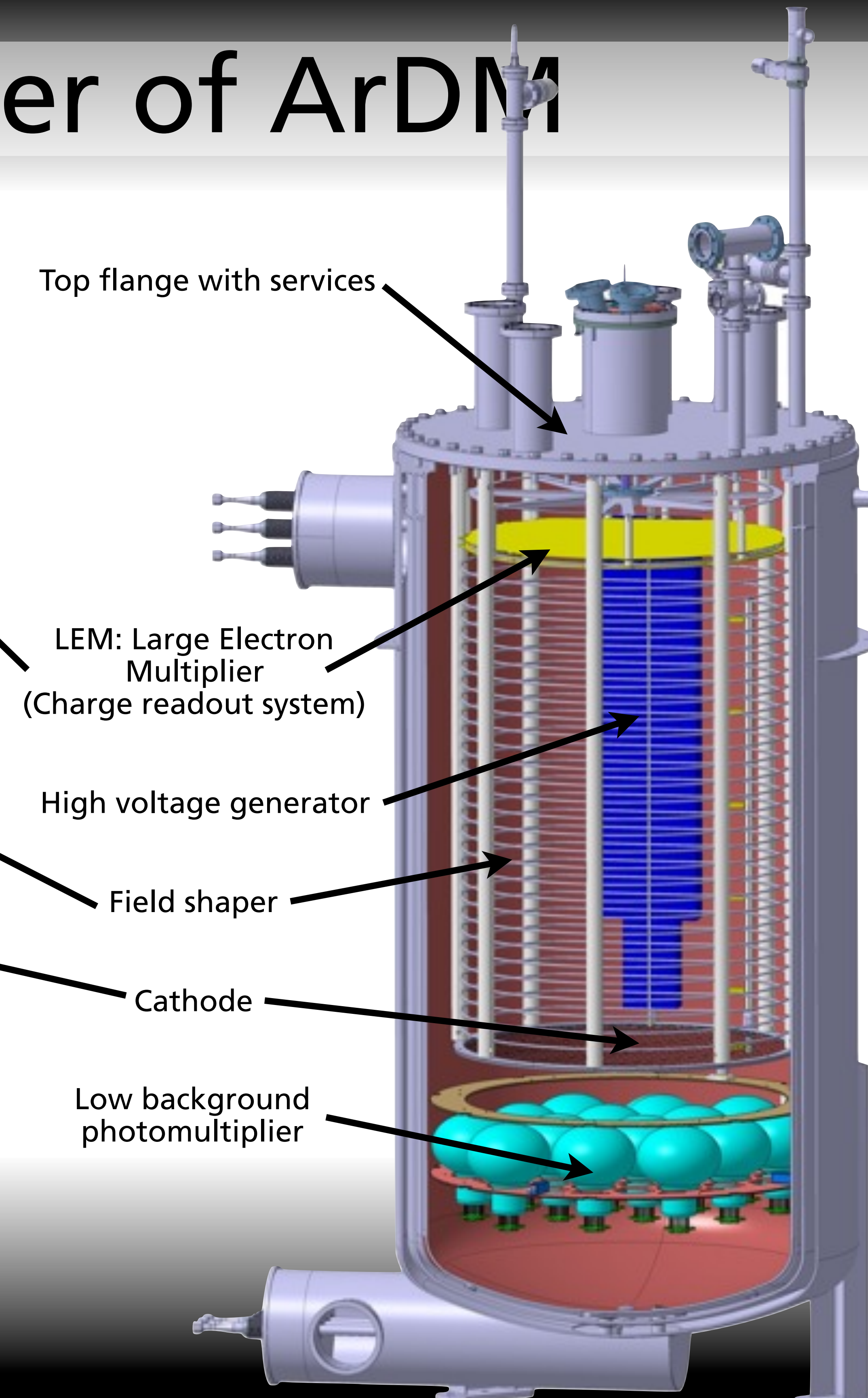


Illustration of working principle



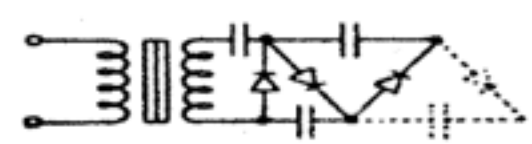
Field lines in the drift area



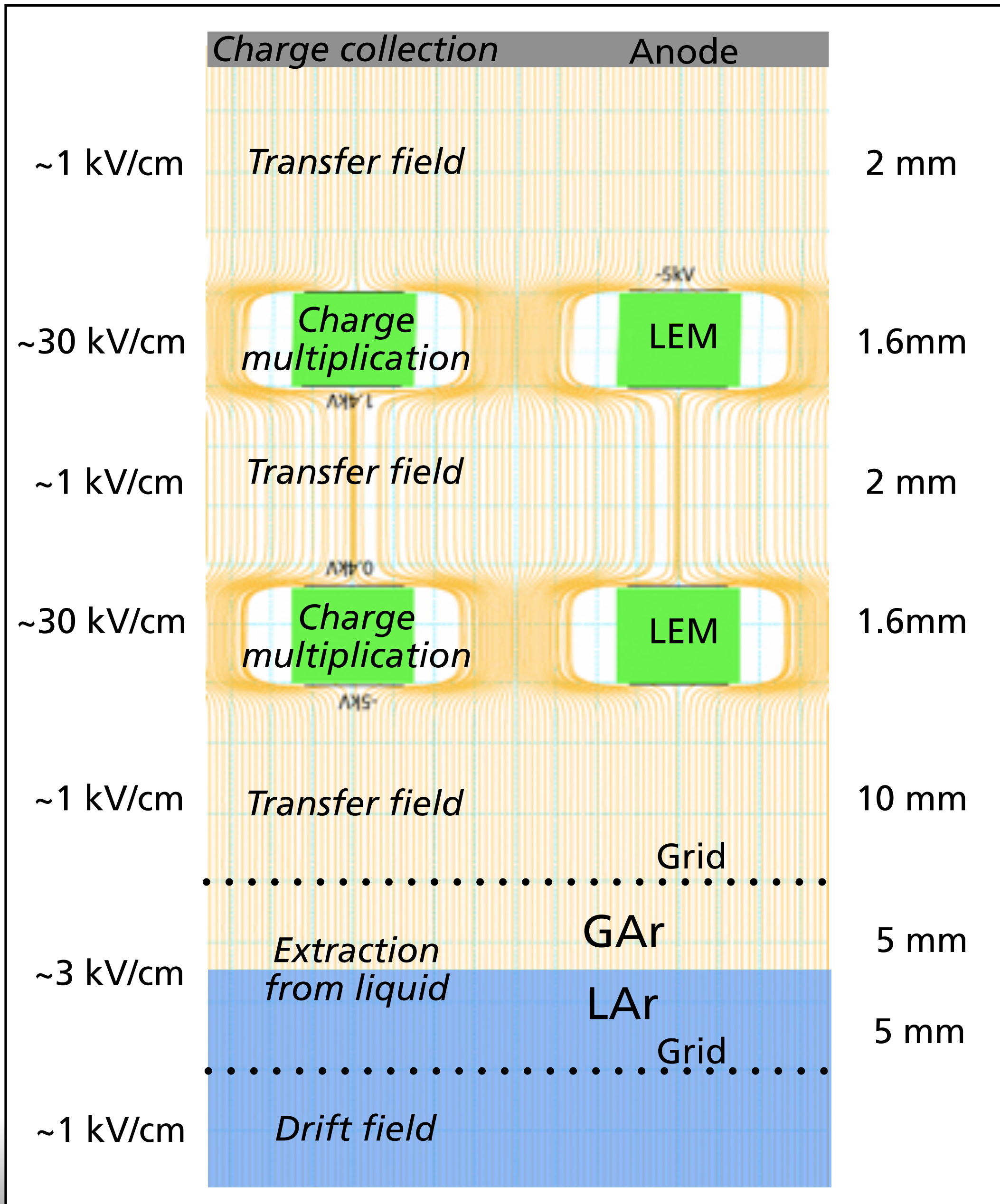
Total drift length:	120 cm
Radius:	80 cm
Target:	850 kg
Drift field:	1–4 kV/cm
Shielding with 100 mm LAr	
Temperature control of detector with LAr cooling jacket	

Uniformity of drift field controlled by 30 field shaping rings

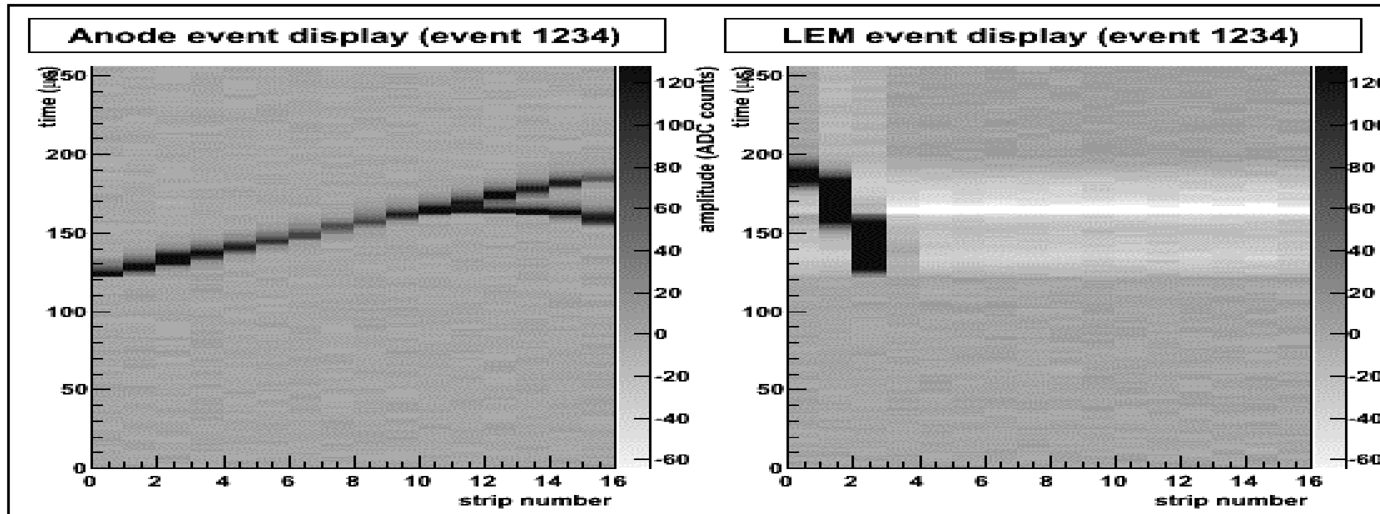
High voltage must be generated inside the detector with a Greinacher circuit.



How do we read out the charge?



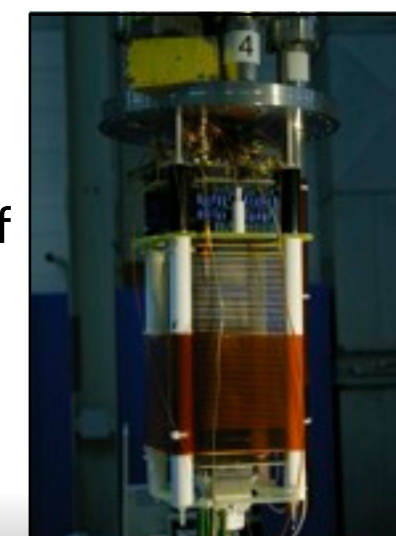
Double phase liquid Argon LEM TPC (still in R&D phase)



Track of a cosmic muon with a delta electron in 3l prototype

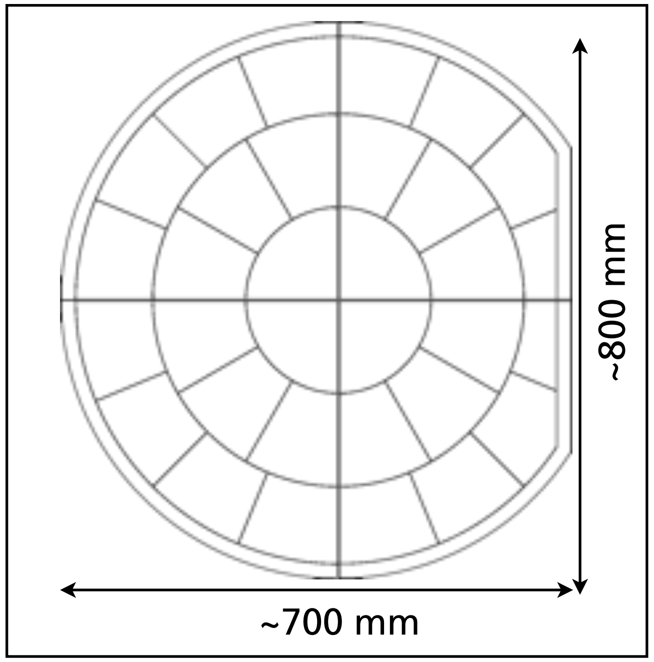
Principle of operation

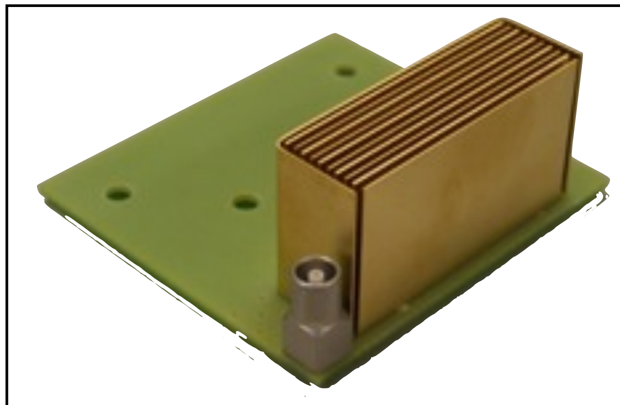
- Electrons drift up in liquid
- 2 grids squeeze the field lines and electrons can pass the surface potential of the liquid
- In the high field of the LEM planes, an electron avalanche occurs. (multiplication factor: 10^2–10^3)
- Multiplied charge induces a signal in the anode



Test setup 10cmx10cm

Temporary Charge Readout



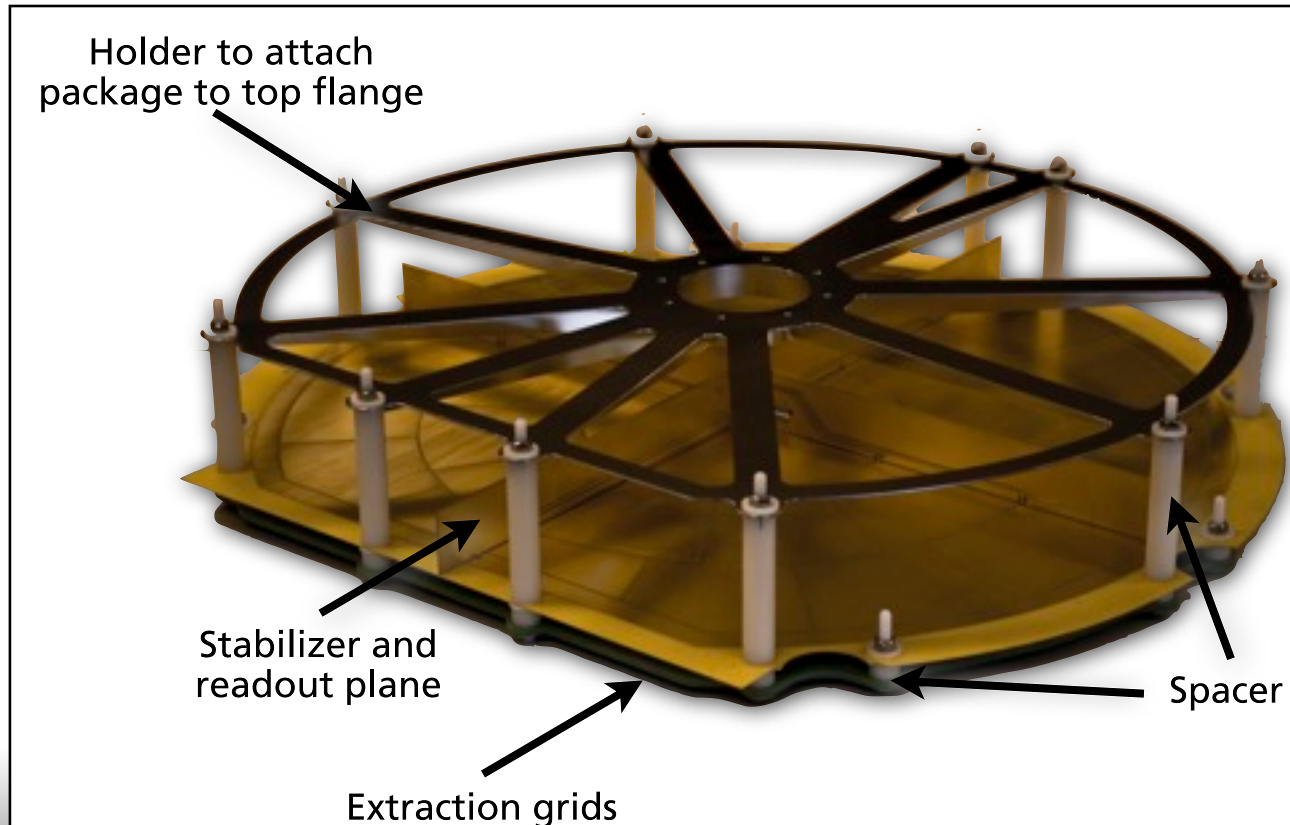


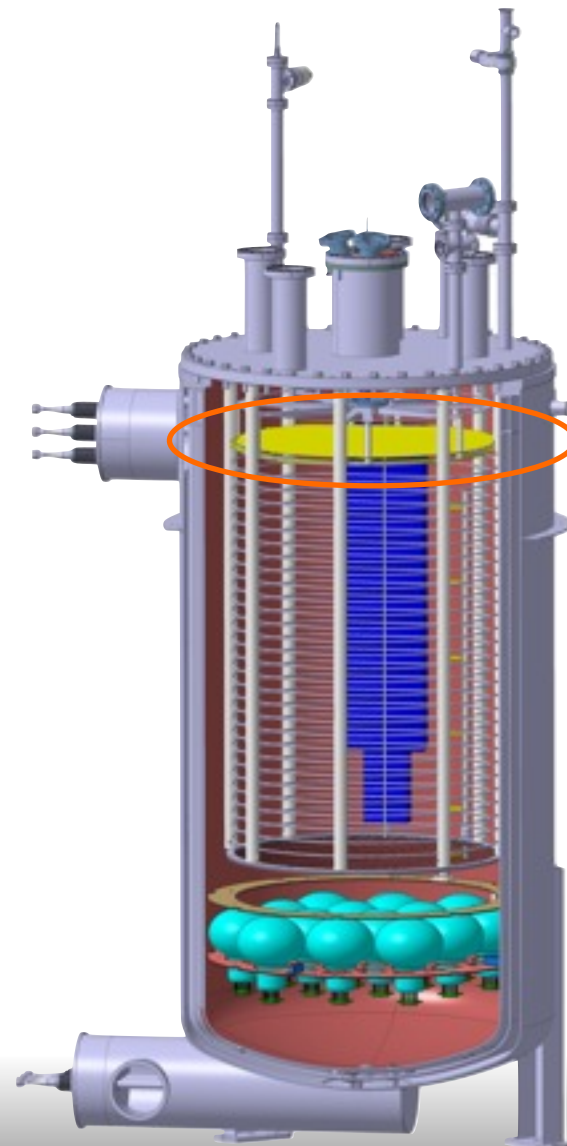
Capacitive level meter

Segmented anode:

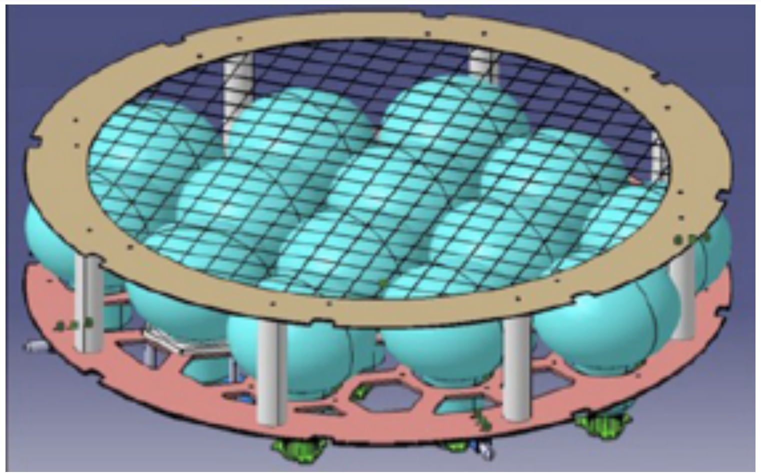
- Standard PCB technique
- Glued together from 4 parts
- 32 channels

- Capacitive readout
- Movable in z-direction
- Tilting possible in the plane
- Adjusting to the level by 3 capacitive level meters



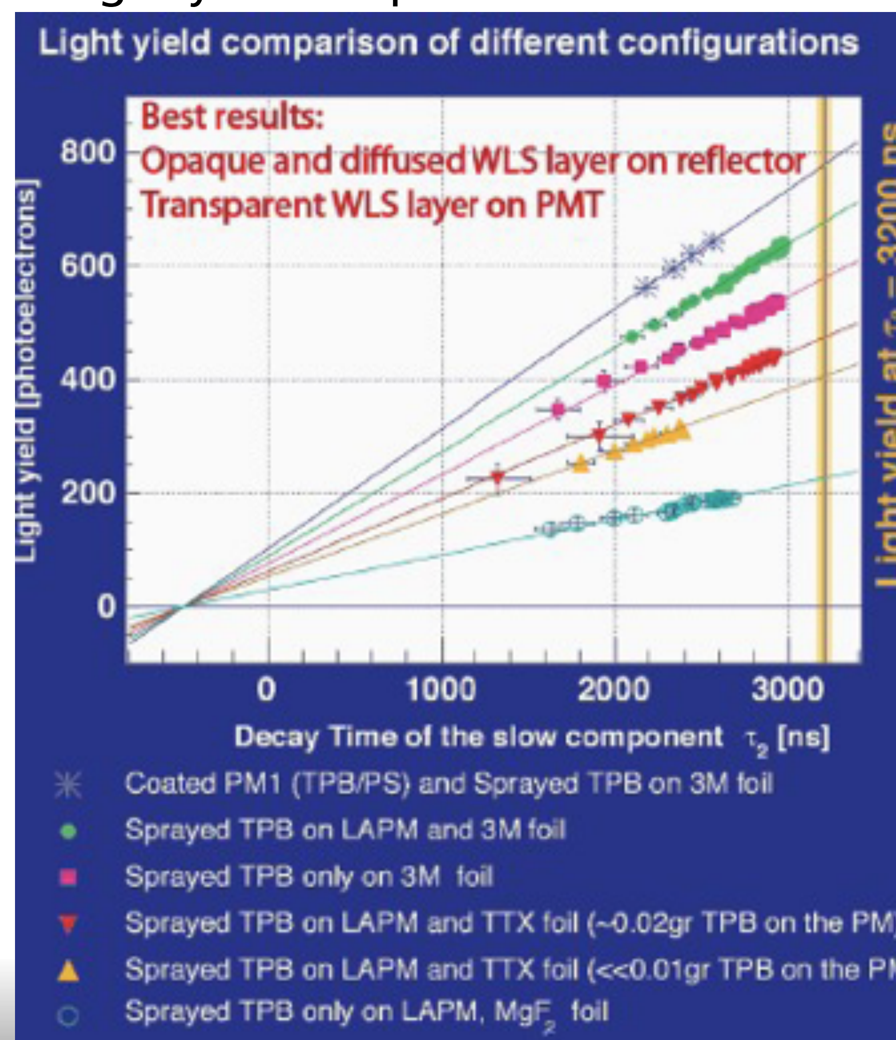


How to read the light?



- Scintillation light in argon has 128 nm
- Glass is not transparent in VUV range
  - →Wavelength shifter is needed
- Wavelength shifter: TPB 128 nm → 430 nm
- Coating of the PMTs in order to detect the direct light
- Coated reflector foil around fiducial volume to guide indirect light to the readout system

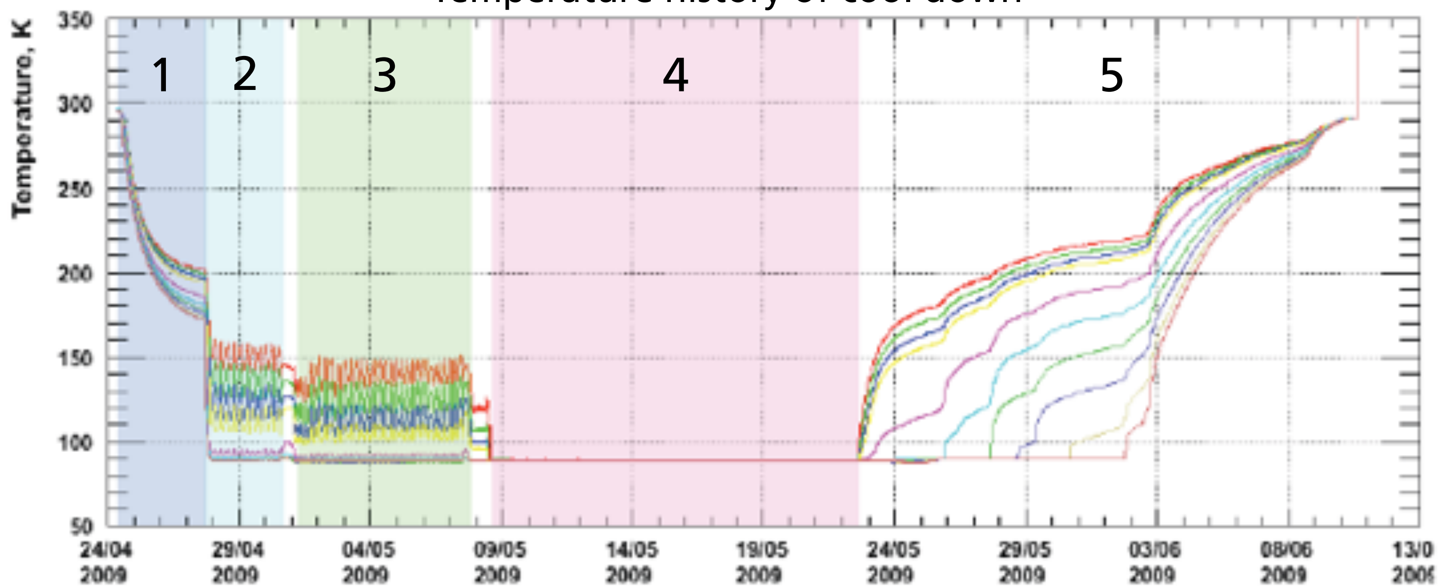
- Light readout at the bottom of the detector
- It contains 14 8 inch low radioactivity PMTs from Hamamatsu
- Light yield 0.5 phe/keV



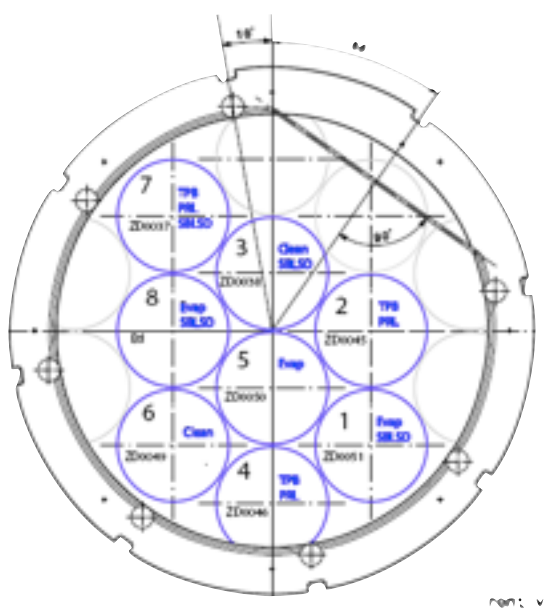
PMTs and reflector foil, illuminated with a UV-lamp.

Cool Down Test 2009

Temperature history of cool down

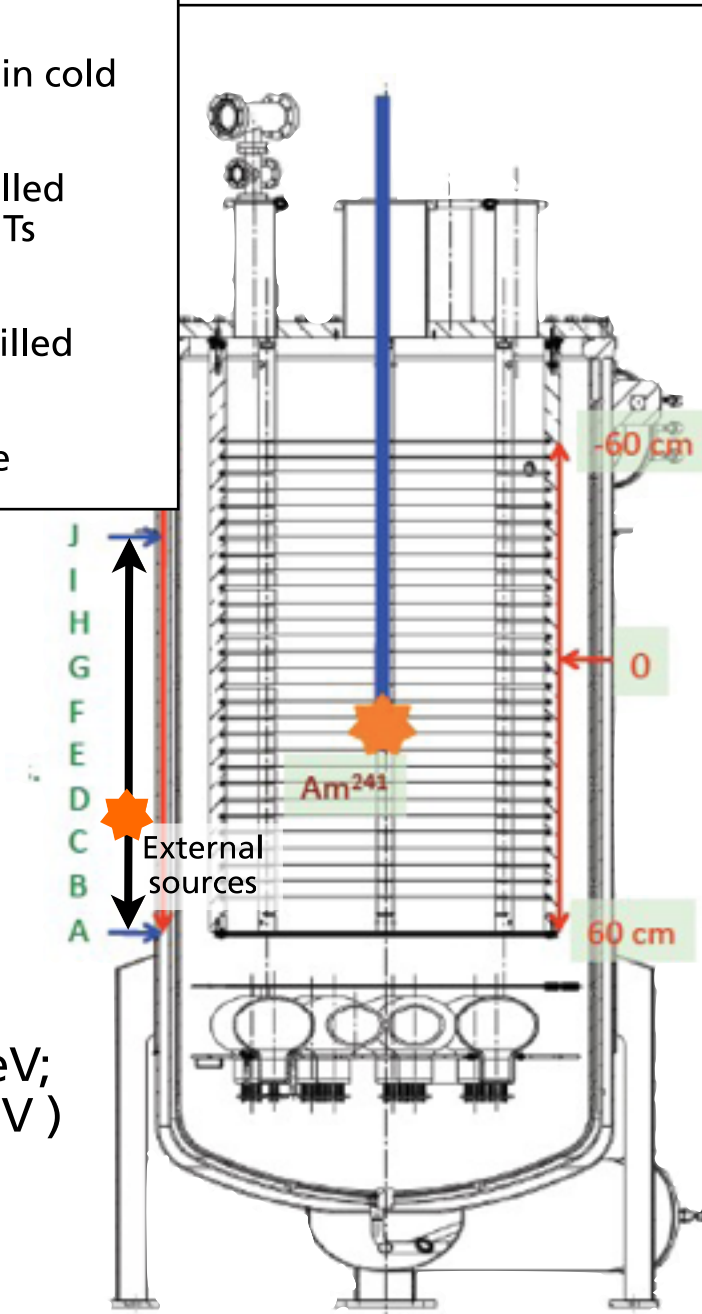


1) Cool down detector walls. Detector is still under vacuum.
2) Measurements in cold pure argon gas
3) Detector half filled with liquid (PMTs immersed)
4) Detector fully filled with liquid.
5) Warm-up phase



Test setup:
- 8 PMTs from different brands and different coating.
- No drift field
- No charge readout

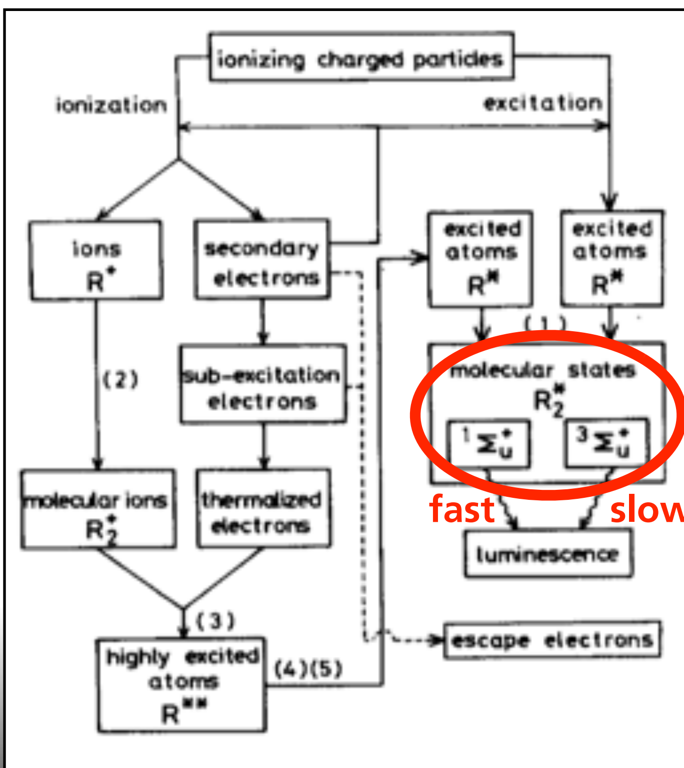
Sources:
- Internal:
  - Movable ^{241}Am
- External:
  - ^{22}Na (20 kBq, 511 keV & 1270 keV)
  - ^{137}Cs (190 kBq, 661 keV)
  - Am-Be (neutrons 2-8 MeV; gamma: 370 MBq, 60 keV)



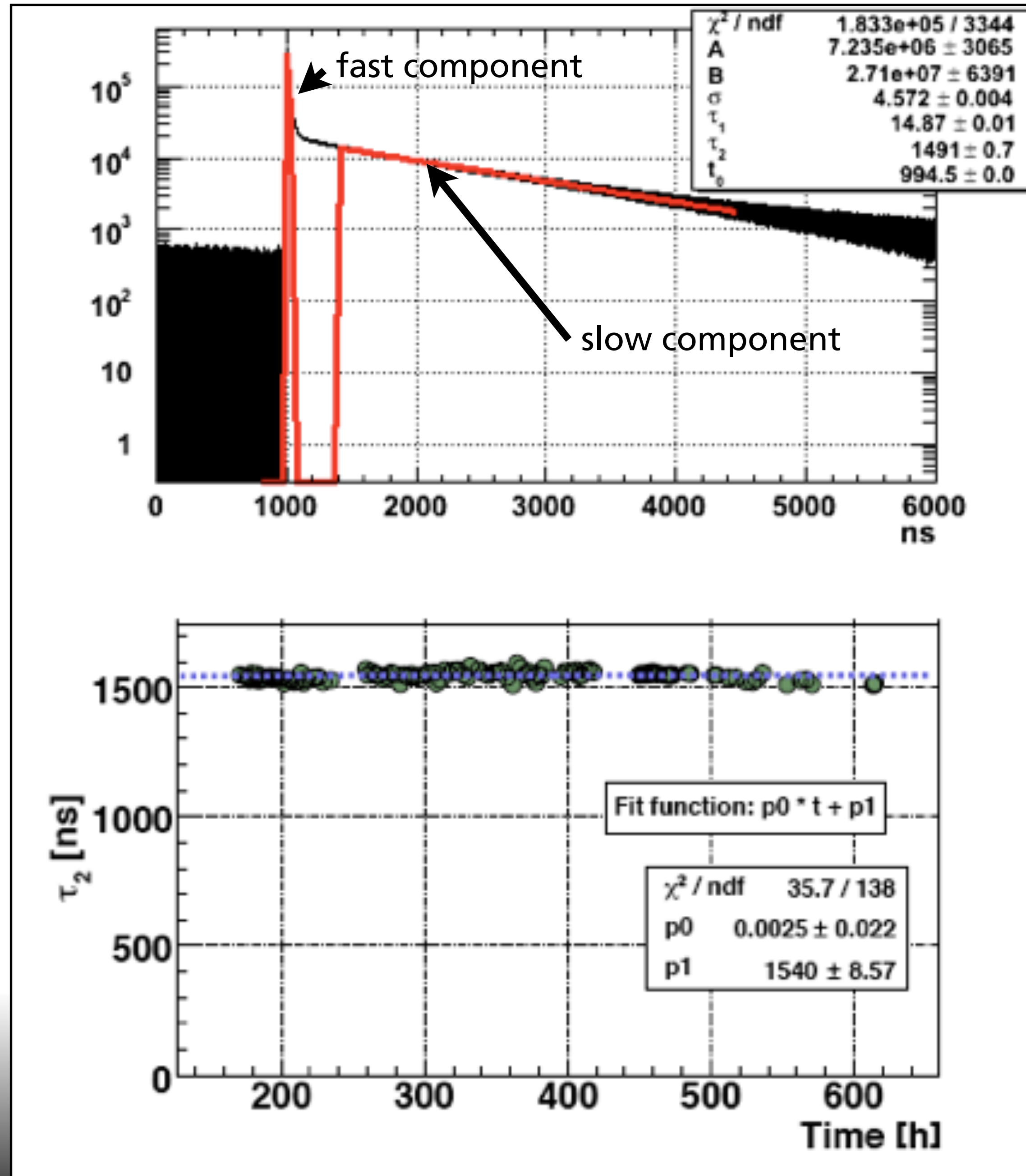
Measurements in Liquid Argon (1)

Operation in liquid:

- 7 PMTs with different coating installed
- calibration with external sources
- no purification during the operation



M. SUZUKI, J. RUAN and S. KUBOTA, NIM 192 (1982) 565



Argon purity:

- Excited argon has two decay channels. A fast one and slow one, depending on if the excited atom was in a singlet or a triplet state.
- The lifetime of the slow component depends on the purity of the argon.
- Lifetime measured in ArDM for the slow component: 1.49 µs. Literature: 1.2 – 1.6 µs

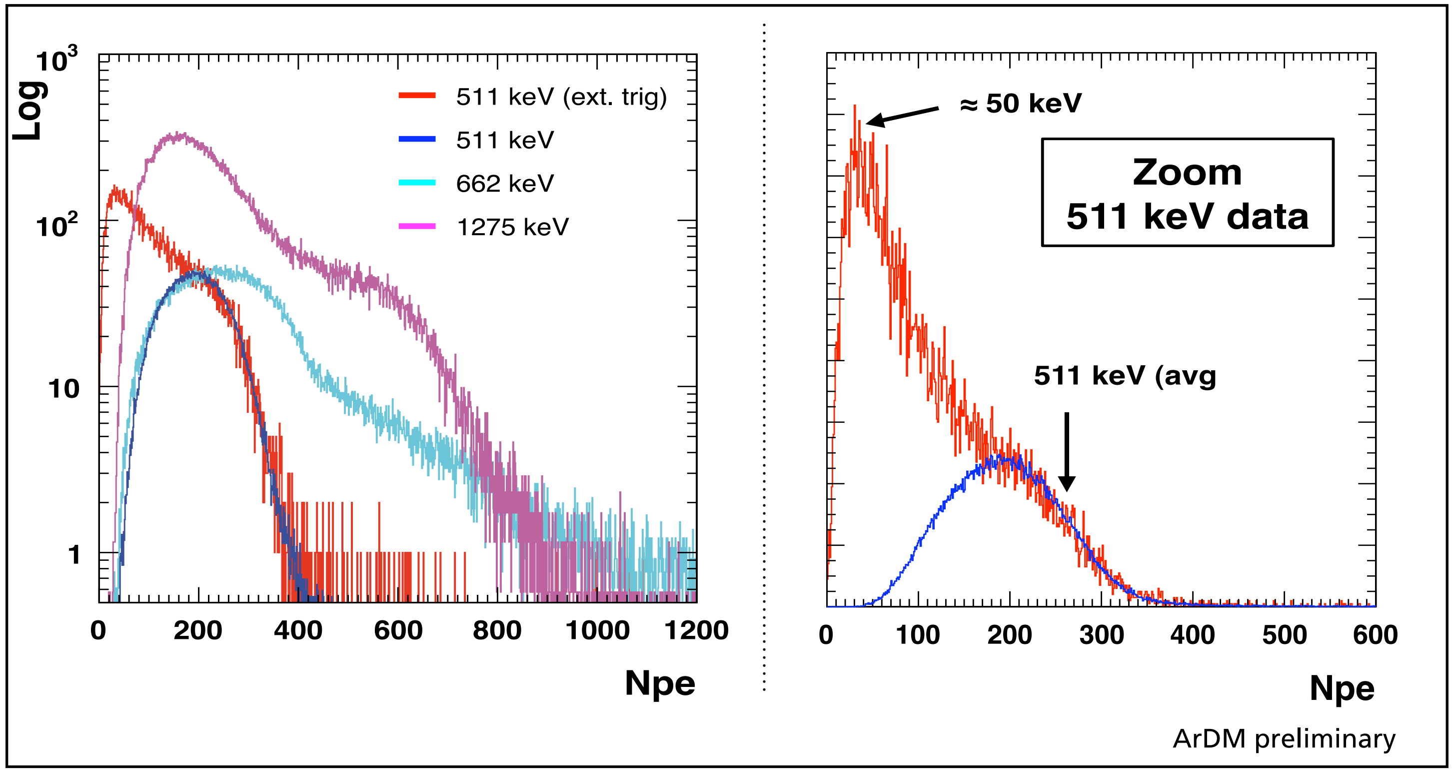
→ Argon is very pure!

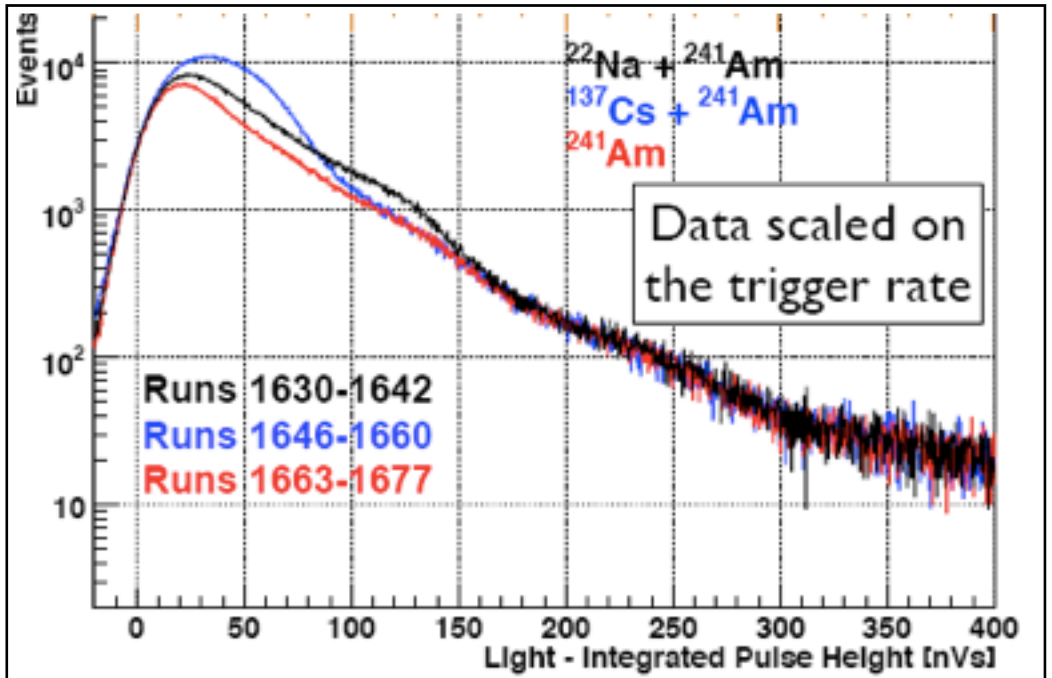
- Lifetime stays constant over 25 days!

→ No leak in the cryogenic system

- Better measurements of the purity are possible with the drift field.

Measurements in Liquid Argon (2)





^{241}Am is the internal source → background

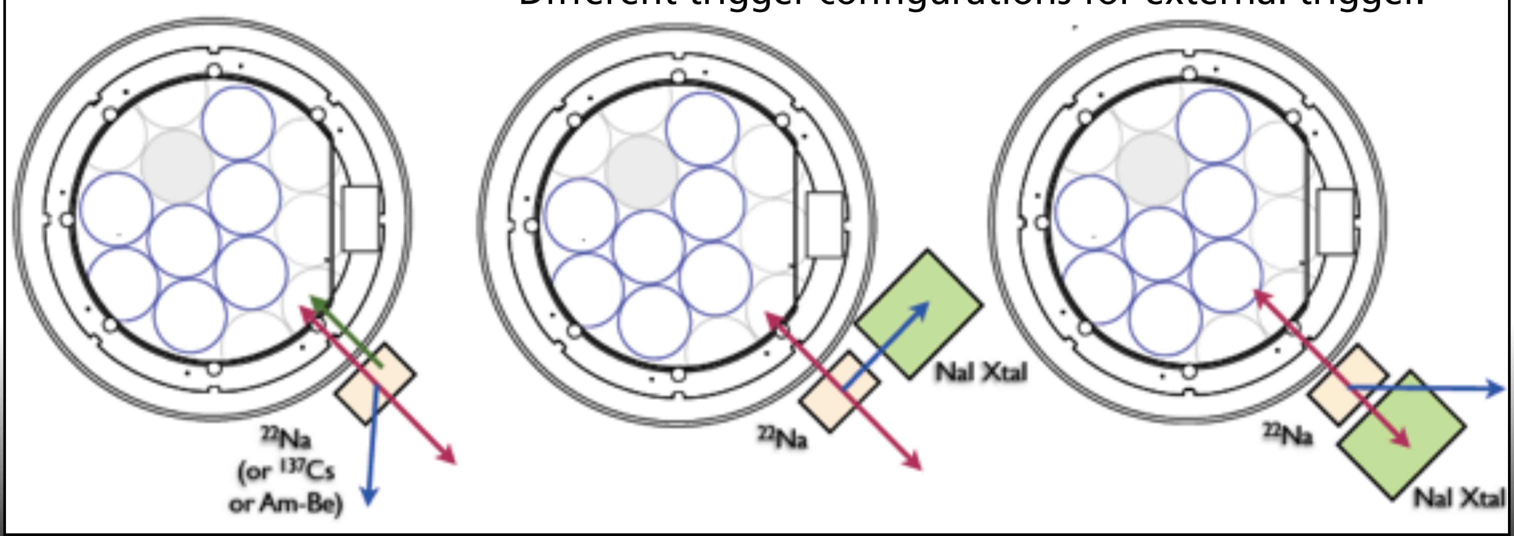
Measurements with external sources:

- ^{22}Na (511 keV; 1275 keV)
- ^{137}Cs (662 keV)
- Internal trigger: ≥2 ; thresh 150 keV

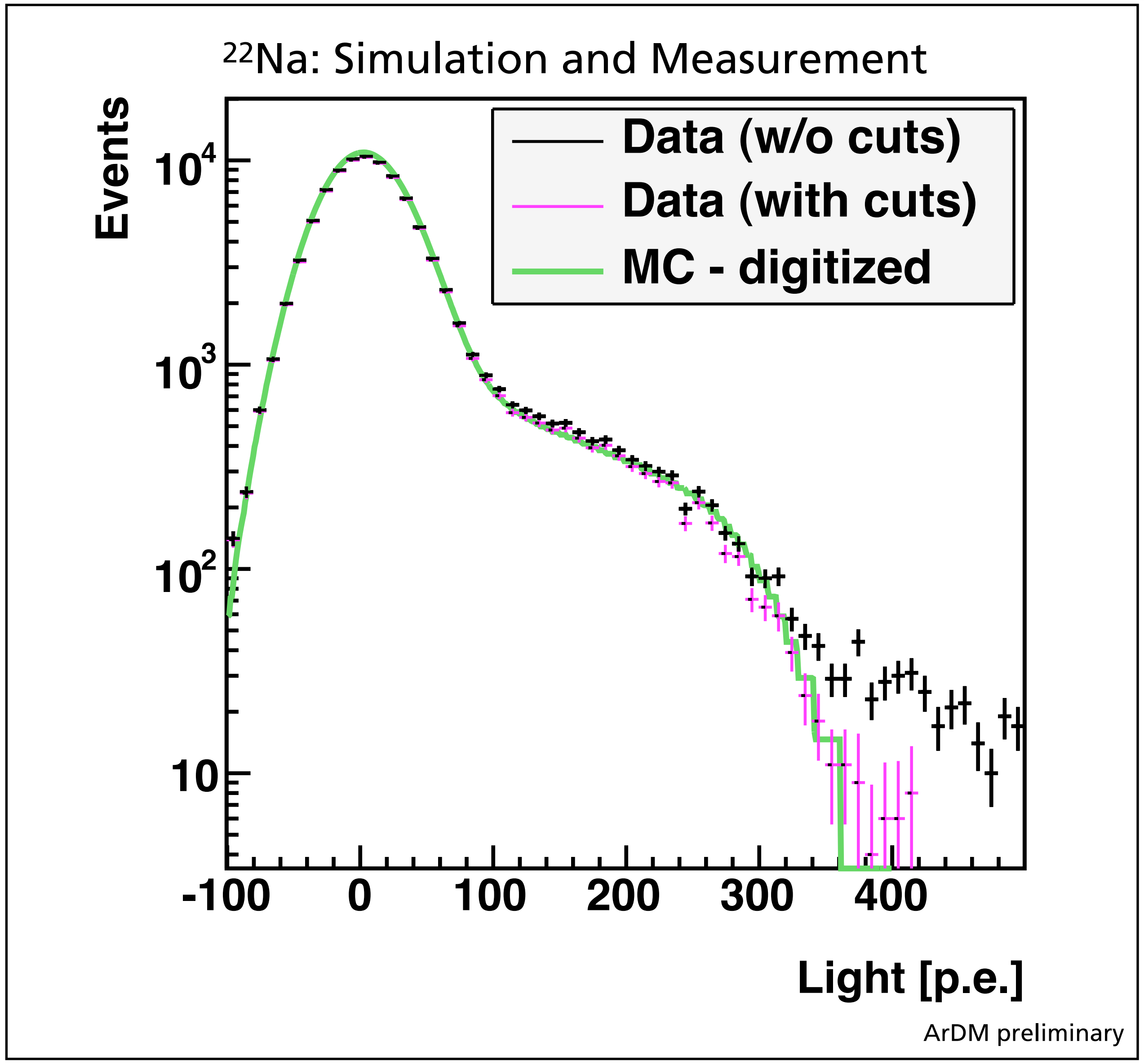
All results are preliminary

We can see about 0.5 phe/keV!

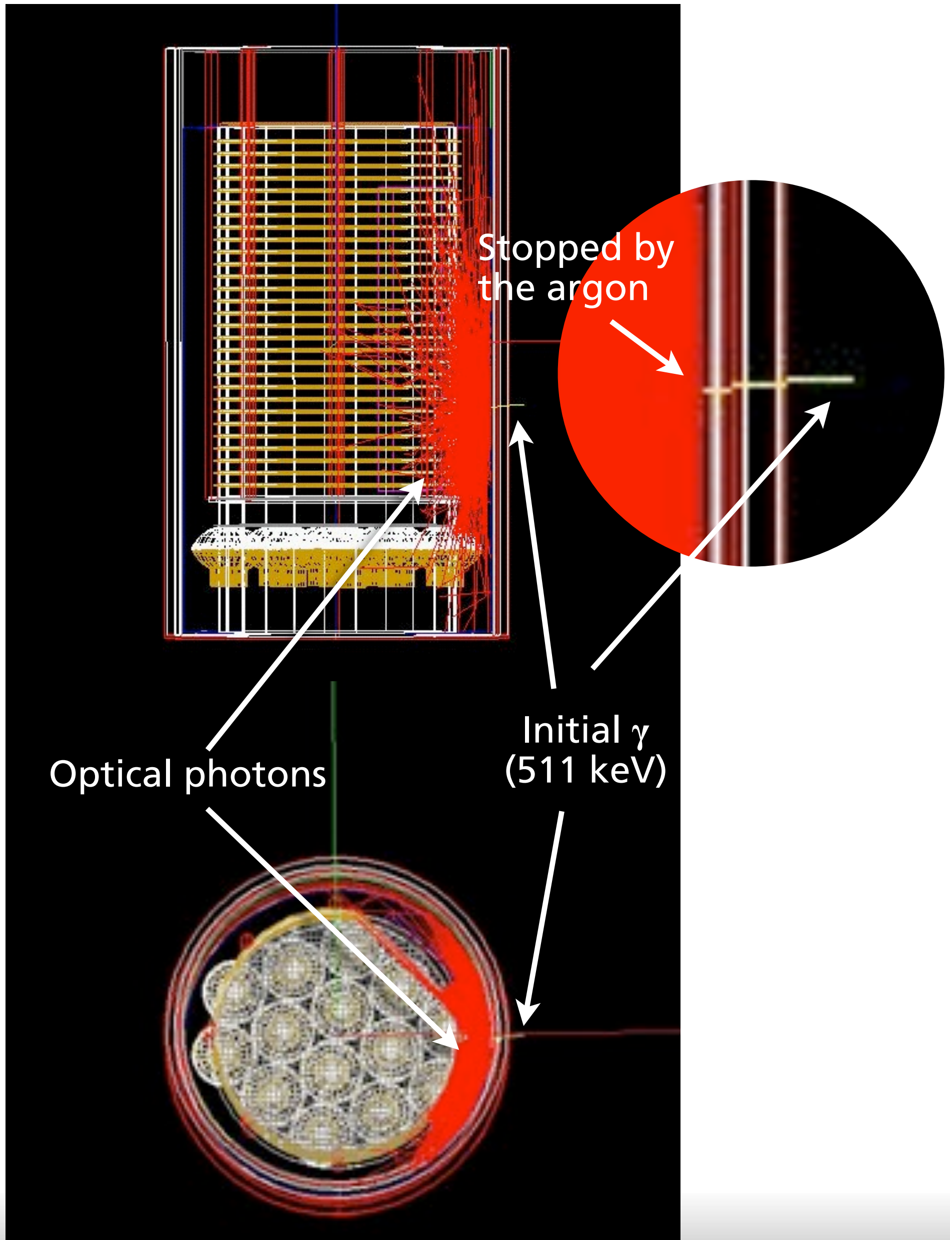
Different trigger configurations for external trigger.



Comparison between MC-data and Measurements



- All optical photons are tracked in the simulation including reflection and shifting properties of materials !



Detector acts as shield for **γ-particles.** External optical photons are blocked by reflector foil.

Summary & Outlook

- The first cool down run in 2009 was successful.
  - First data were taken.
  - Analysis is still ongoing.
  - Good argon purity during the whole run.

- Great parts of the detector development have been accomplished.
  - Light readout system has been optimized and the final configuration is installed and tested in argon gas.
  - A first charge readout system with 32 channels (without amplification) is installed.
  - R&D is still on going for the final charge readout. (1028 channels and charge amplification of a factor 10^3 with LEMs) → Talk of Devis Lussi.

- Start of the next run in the coming weeks.
  - Calibration of the 14 new installed low background PMTs.
  - Understanding of the neutron background (Use of a neutron source?)
  - First run with a drift field and a charge readout system.
  - Better measurements of purity with the amount of charge reaching the anode.

- **We hope to start to transfer the experiment to an underground location in 2010.**

- **We aim at underground physics run 2011 (?)**