ArDM, a 1t liquid argon detector for dark matter searches

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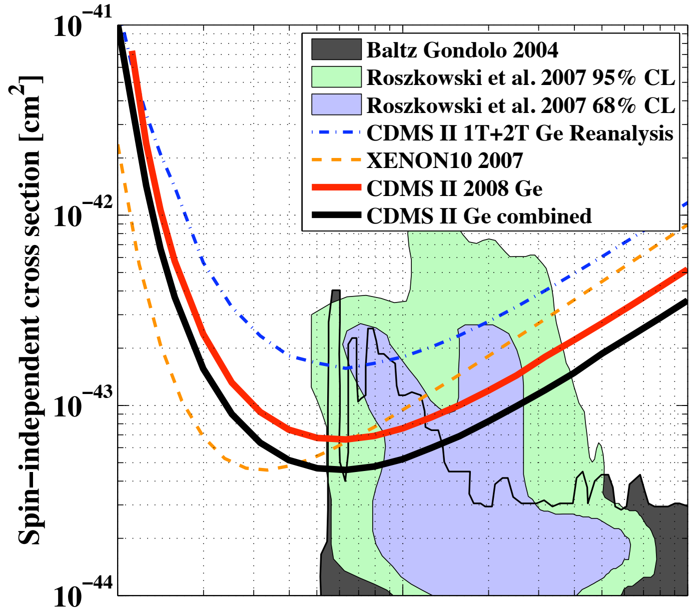
(on behalf of the ArDM Collaboration)

Abstract (nr. 711):

We are assembling a 1t liquid argon detector at CERN using the two-phase technique to detect both charge and luminescence produced by recoil nuclei from WIMP interactions. We have investigated background suppression capabilities and impurity effects in argon using the scintillation light and its decay time. We are studying ways to efficiently collect and detect the VUV-light to reach a detection threshold of 30 keV in a large liquid argon detector, and to efficiently suppress background from neutrons and electrons. First results for the light collection efficiency in the 1t detector will be presented.

Light collection system and efficiency (Uni. Zürich)

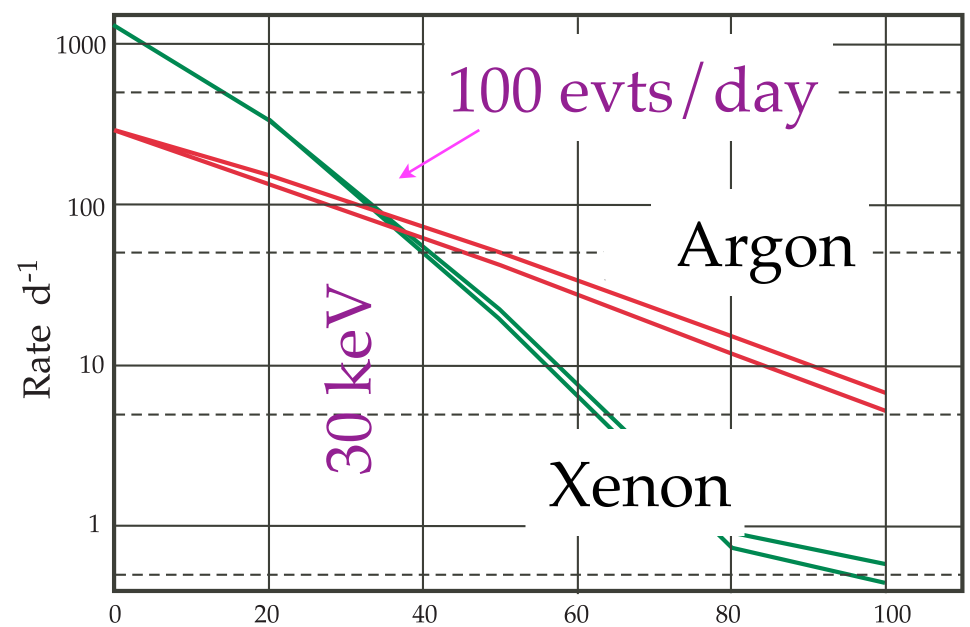


10 M(WIMP) 1000 GeV

Spin independent WIMP-N cross section

currently < ~ 4 x 10^{-44} cm^2 at 100 GeV

$1/v^2$ (large uncertainties)



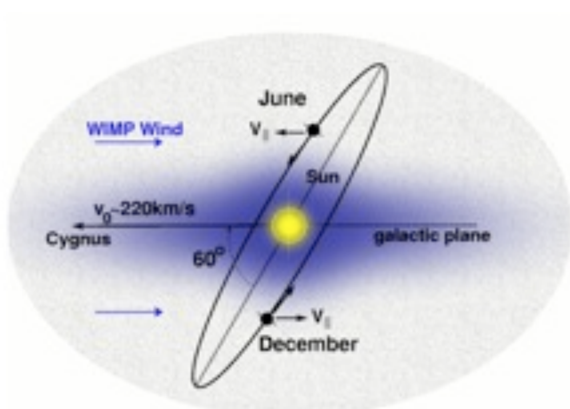
Nuclear recoil energy [keV]

Form factor

<u>Rate/day in a 1 ton liquid Ar detector</u>

0.3 GeV/cm^3, if DM a spherical halo:

v = 245 km/s (June), 215 km (December)



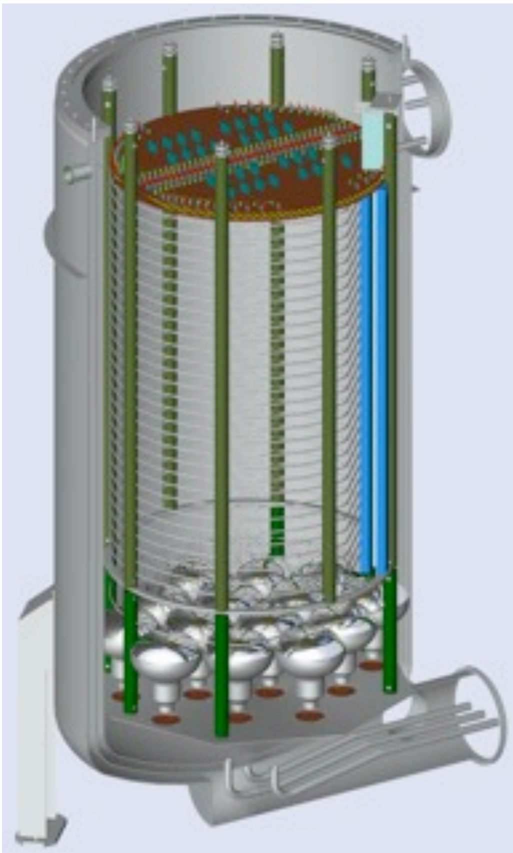
M(WIMP) = 100 GeV, $\sigma = 10^{-42}$ cm^2

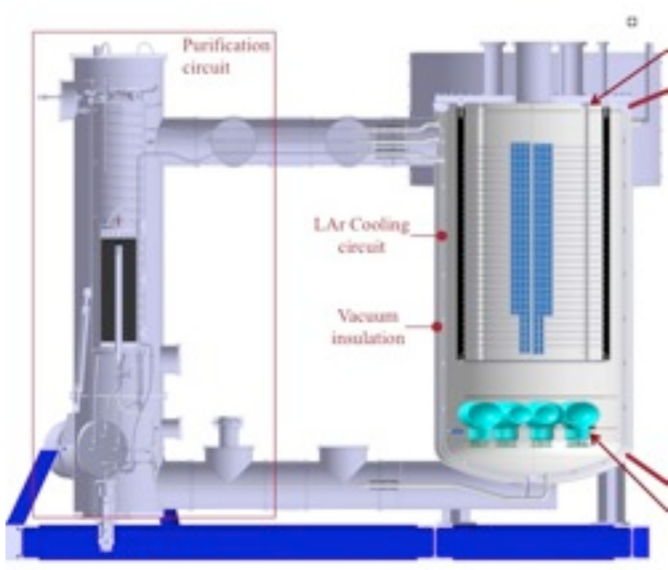
$$\frac{d\sigma}{dq^2} = \frac{G_F^2 C F^2(q^2)}{v^2}$$

Goal of ArDM ≈ 10^{-45} cm^2:
0.1 event /day
@ 30 keV threshold

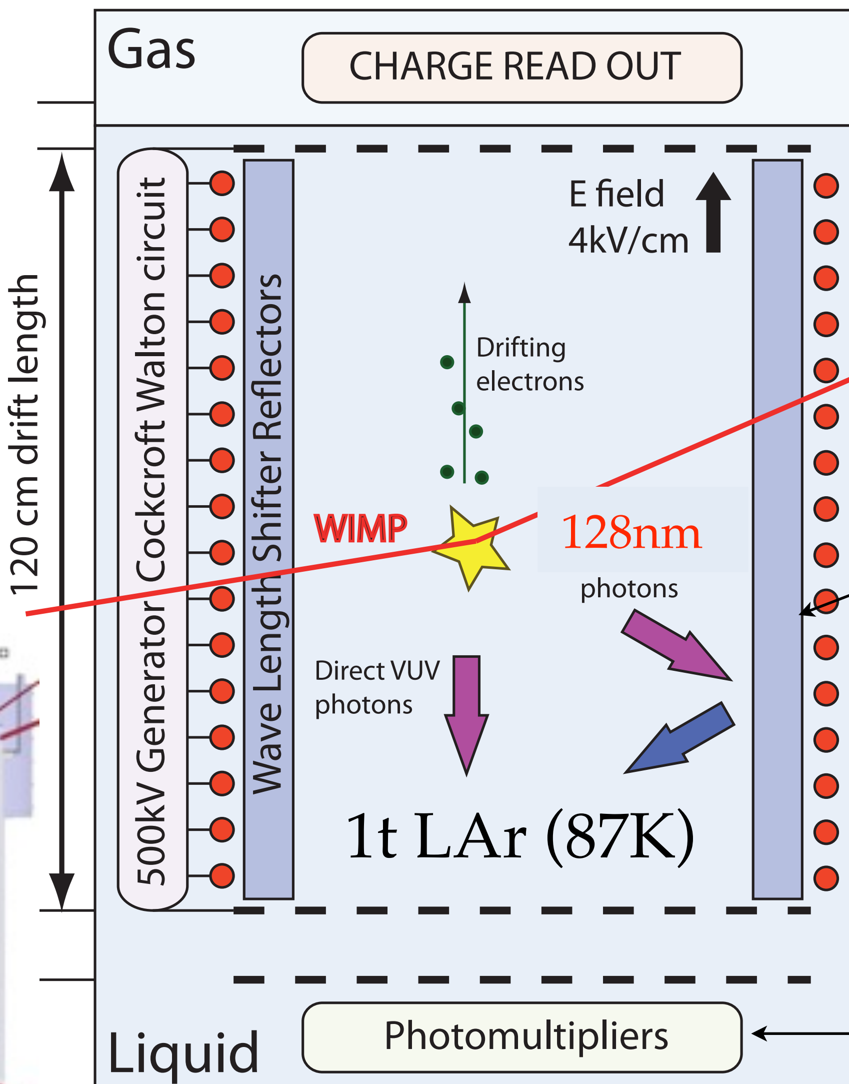
ArDM Experiment (CERN recognized RE18)

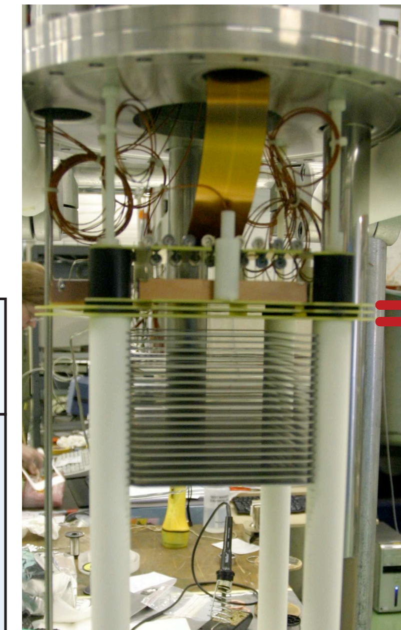
500 kV, 210 stages





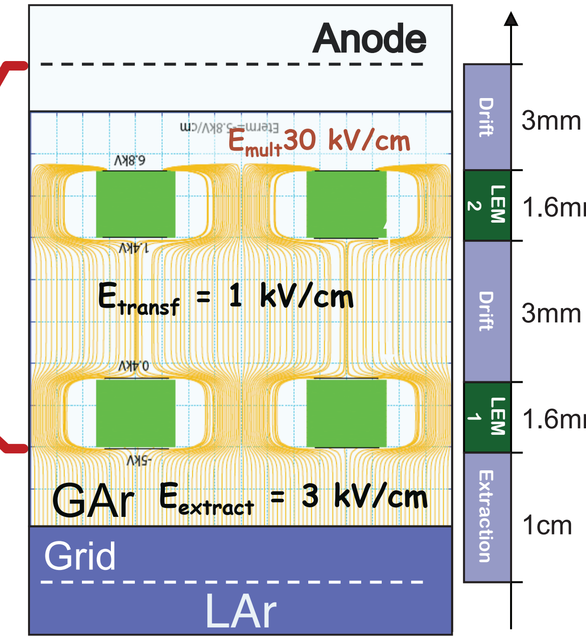
CHARGE + LIGHT





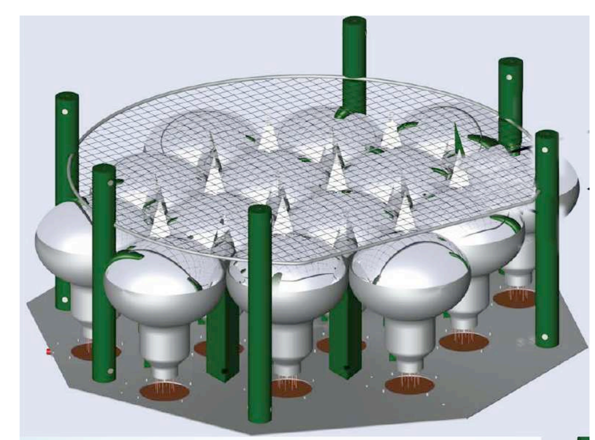
LEM

small prototype



Wavelength shifter
128nm -> 430 nm

TPB on Tetratex



14 x 8″

Hamamatsu R5912-02MOD, Pt-underlay, evaporated, low radiation

ArDM: Strategy

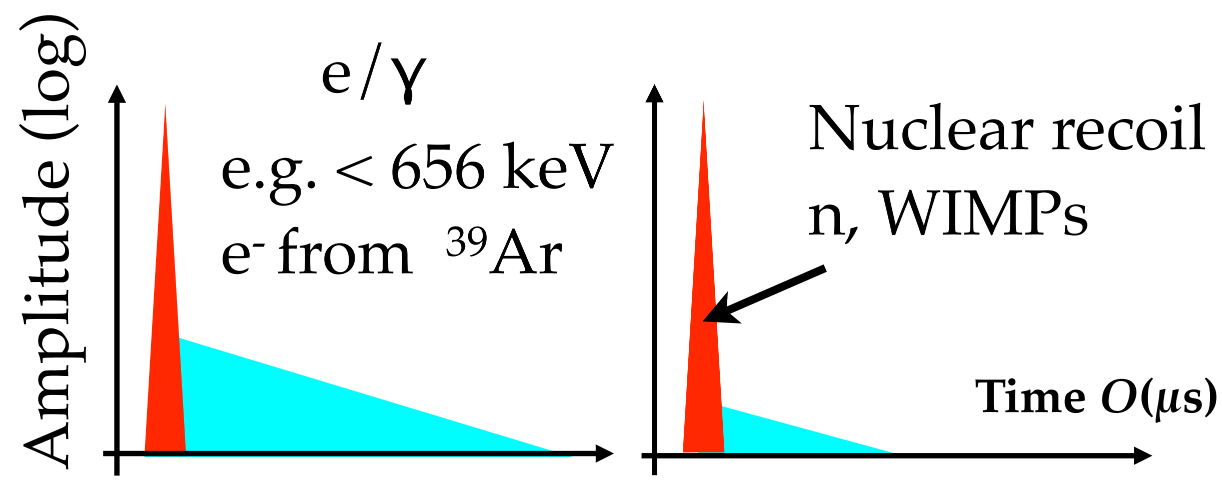
1. Assemble the detector and test its performance on the surface (at CERN).
1. Study the response of the detector to γs, electrons and neutrons
2. Particle identification

} Summer 2009

3. Underground (low background) operation (2010), three optional sites

Background rejection is based on:

- Population ratio of $^1\Sigma$ to $^3\Sigma$ excimers are different for nuclear recoils and e/γ-events (excellent in argon).



LAr: two decay times: 5ns ($^1\Sigma$) and 1.6μs ($^3\Sigma$)

(strong recombination)

↓

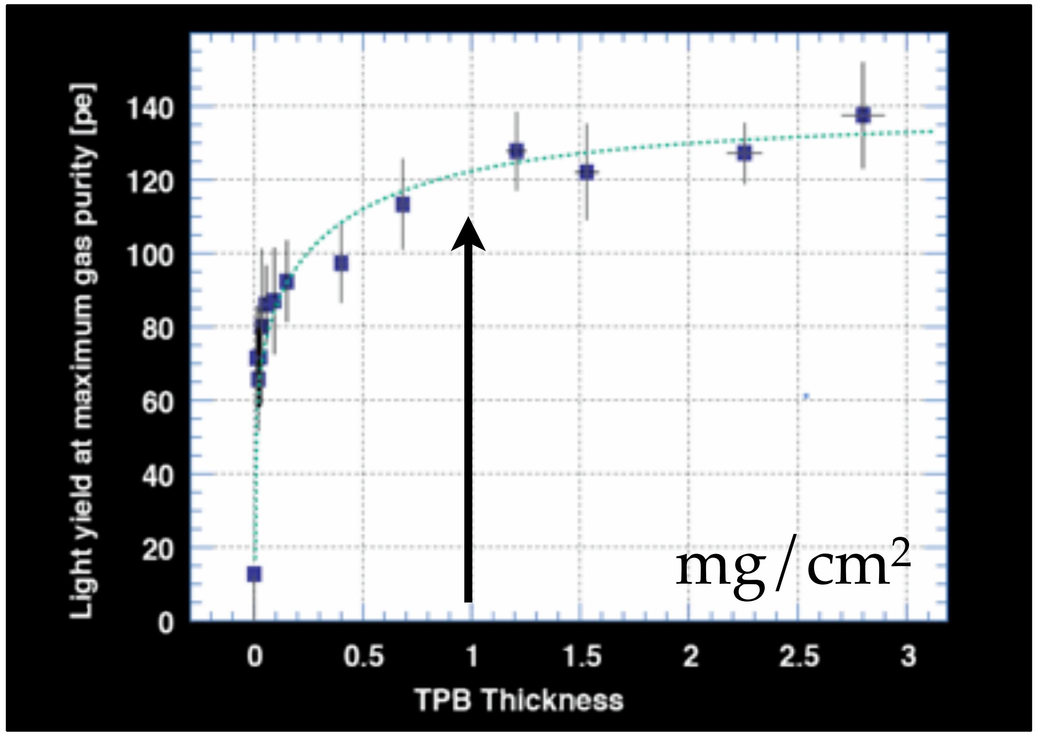
- Different primary charge/ light ratios for WIMPs and e/γ-like events

1e/1γ for e, γ (~600 e @ 30 keV)

1e/100 γ for WIMPS, n (~ 3 e @ 30 keV)

- Interaction point, self shielding of LAr

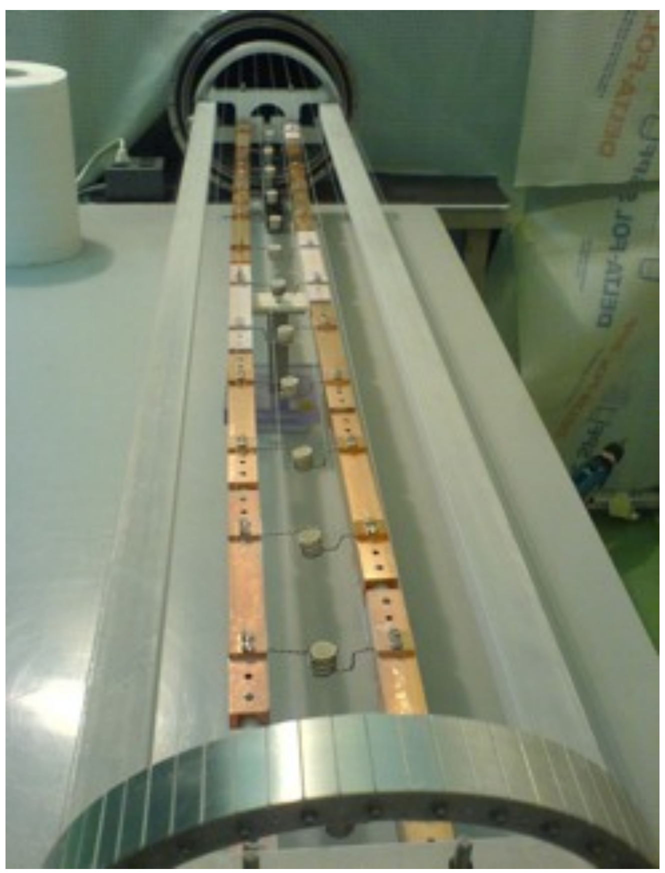
Goal: 1 photoelectron / keV ee



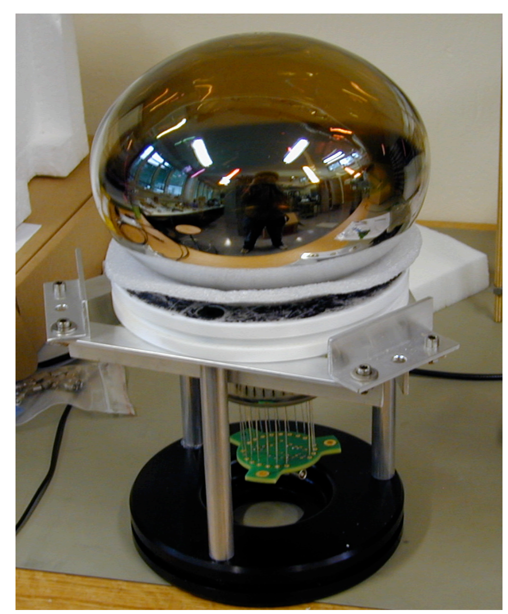
Detector insertion

Exp. area at CERN

Large scale evaporator

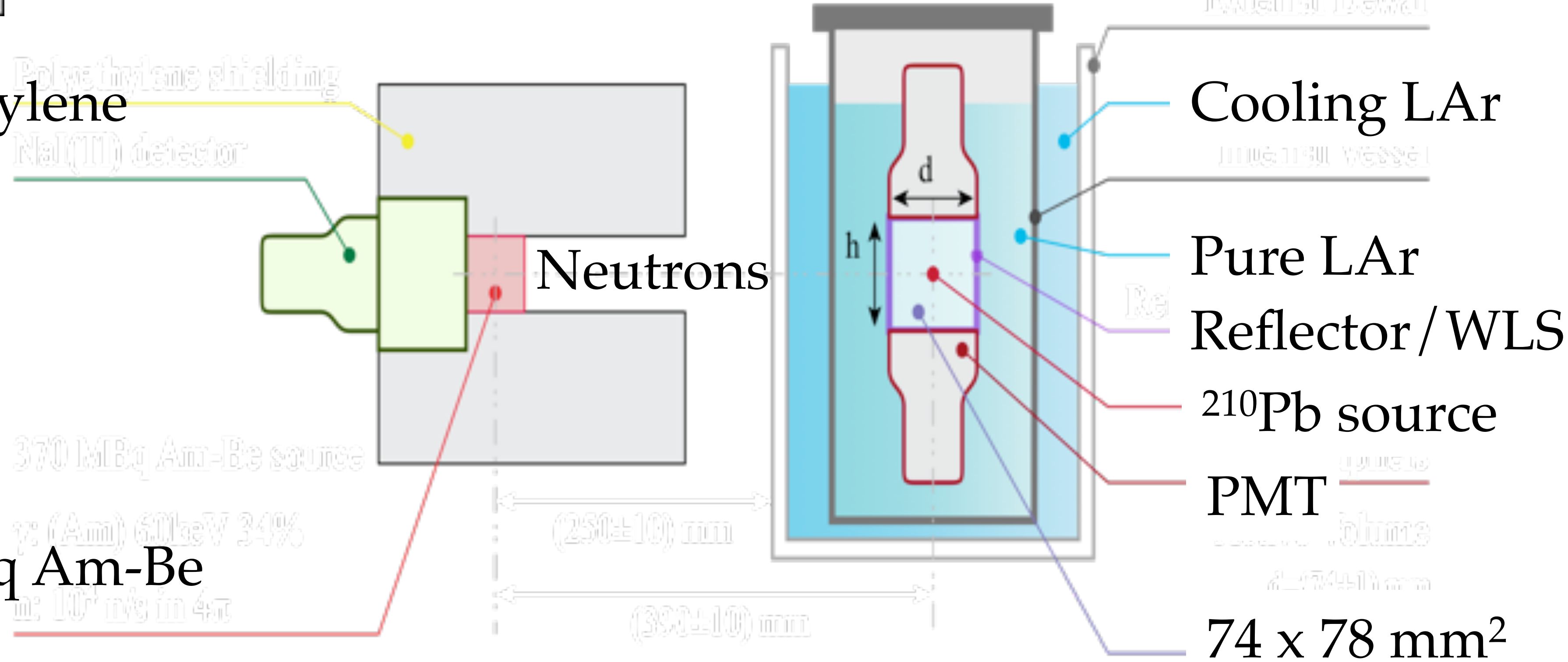


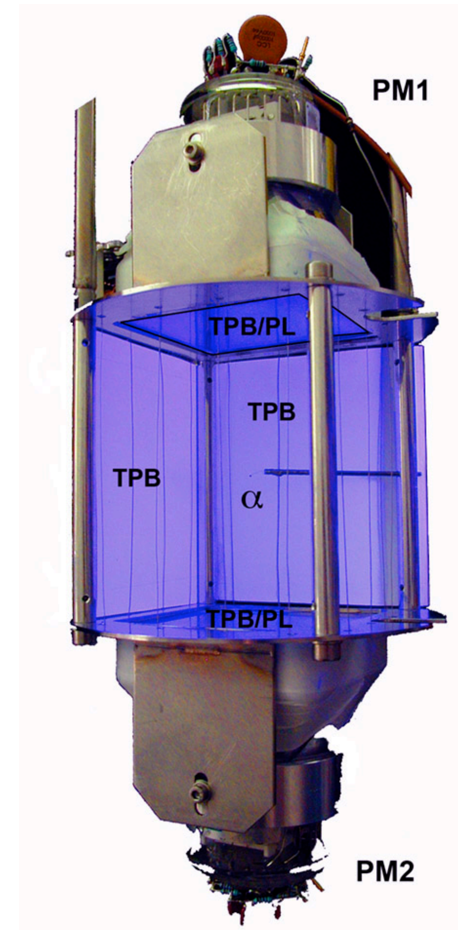
8” PMT



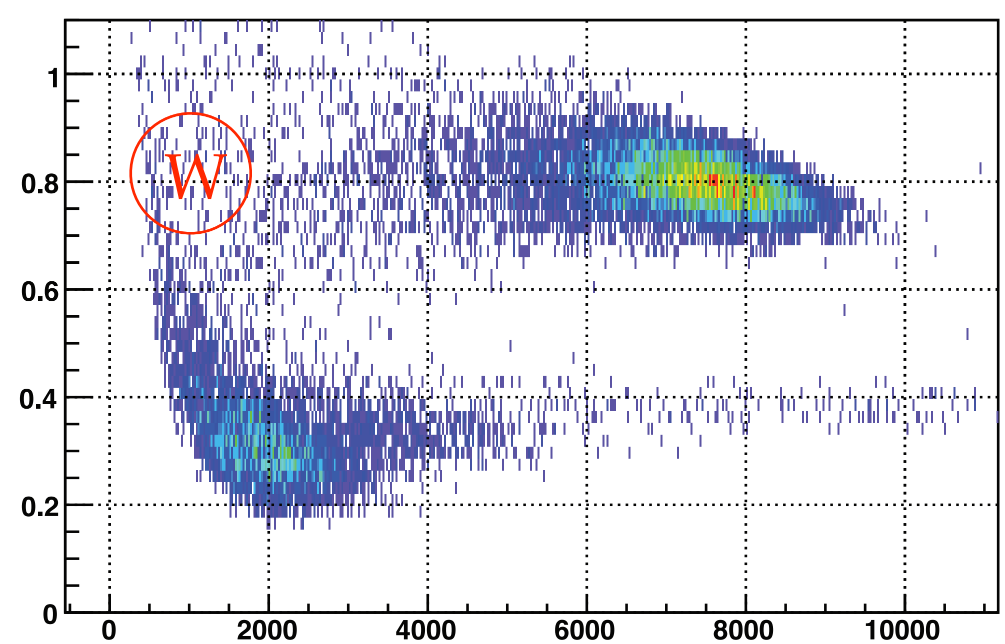
Top flange

R & D with small LAr cell





Ratio of fast (<50ns) to total light yield



Integrated pulse height [photoelectrons]

from ^{210}Pb -> ^{210}Bi -> ^{210}Po -> ^{206}Pb source

5.2 MeV α (heavily ionizing)

1.2 MeV e$^-$

Purity monitor

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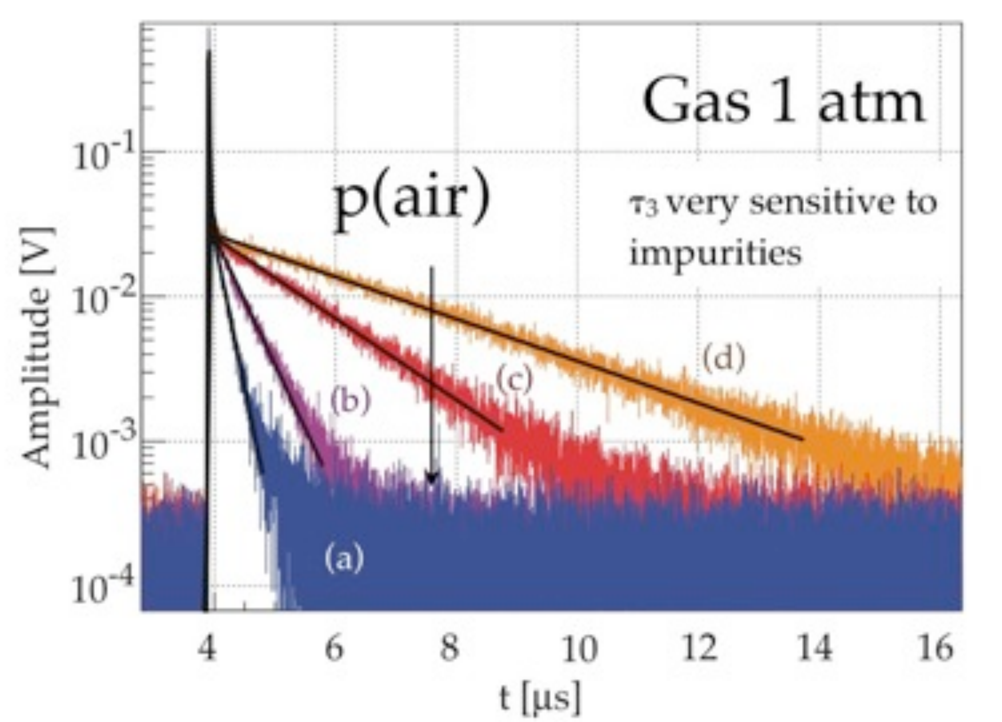
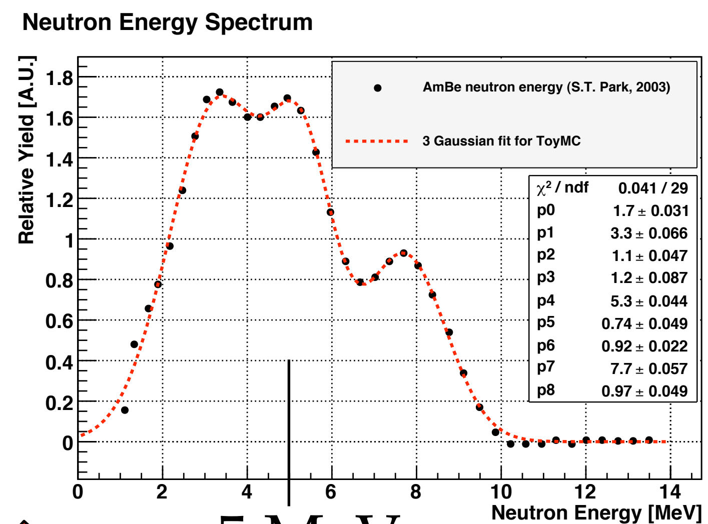


Neutron background

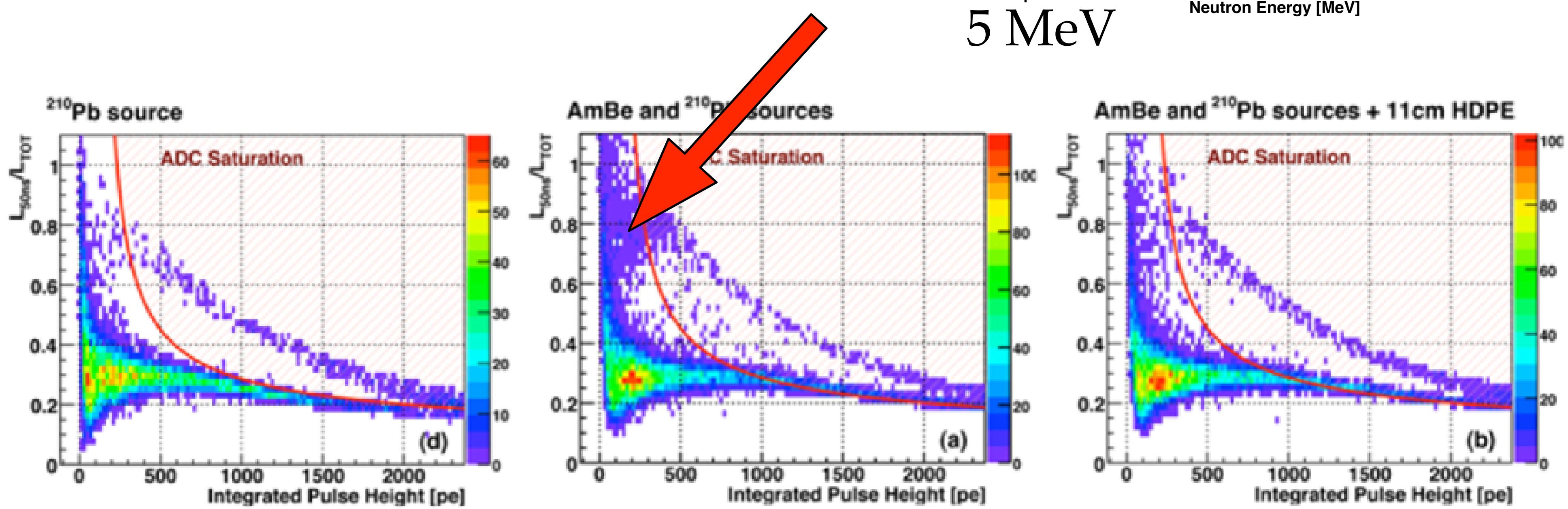
Neutrons from the rocks (spallation) can simulate WIMPs!
$\sigma(\text{WIMP A}) \sim 10^{-18}\,\sigma(\text{n A})$!!

Am-Be source
Energy distribution



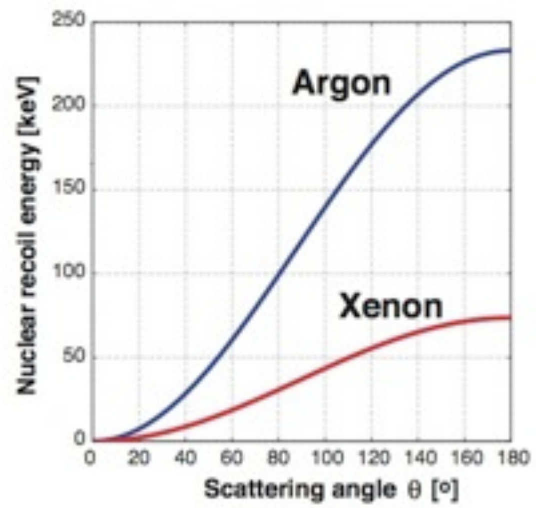
5 MeV

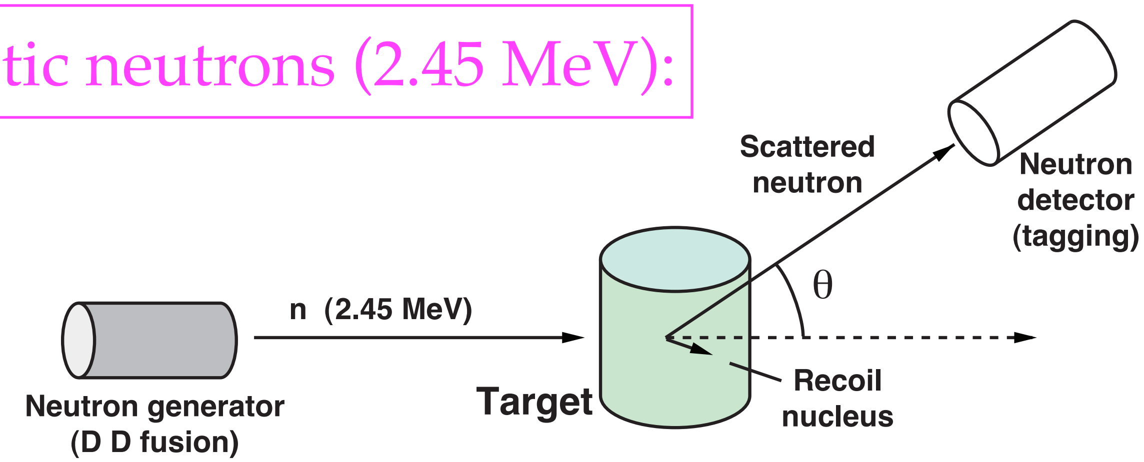
fast (<50ns) to total light yield

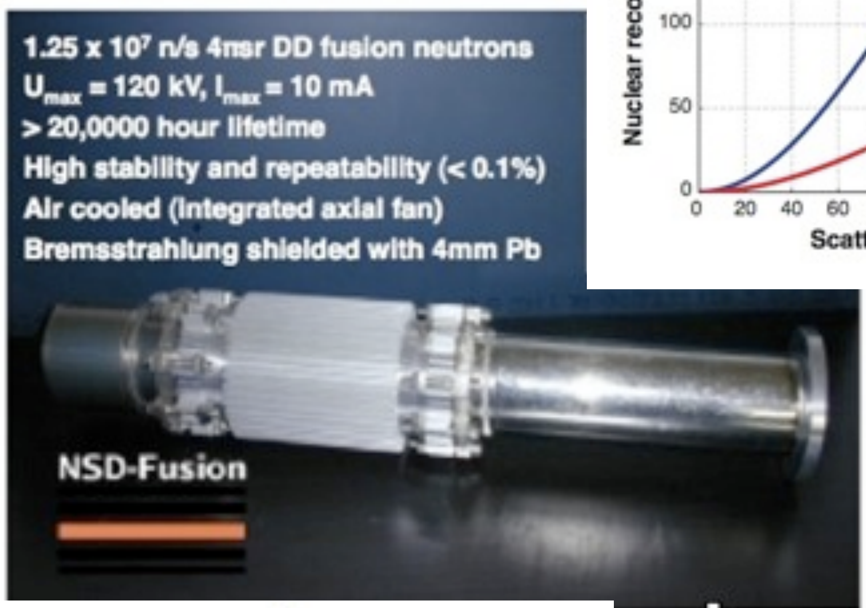


Pb source only (low energy region) | with Am-Be | polyethylene absorber

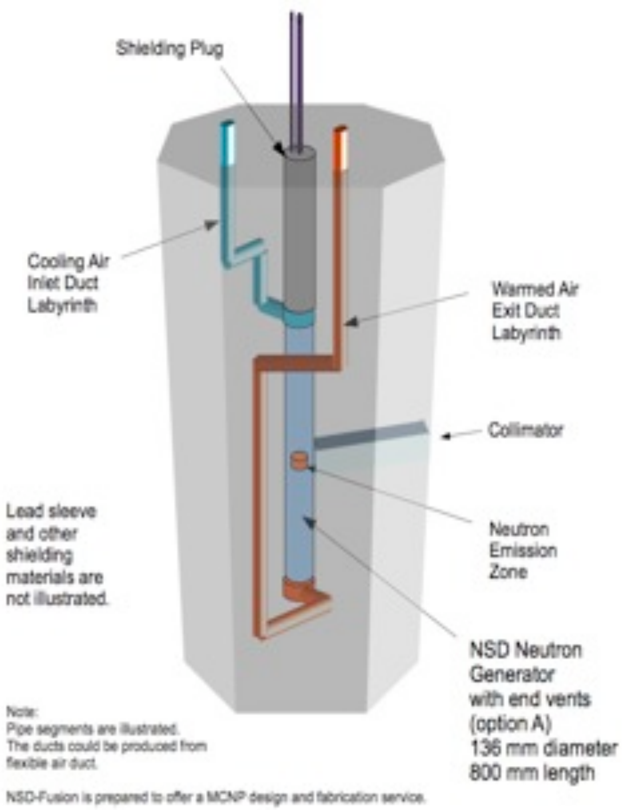
Source of monoenergetic neutrons (2.45 MeV):





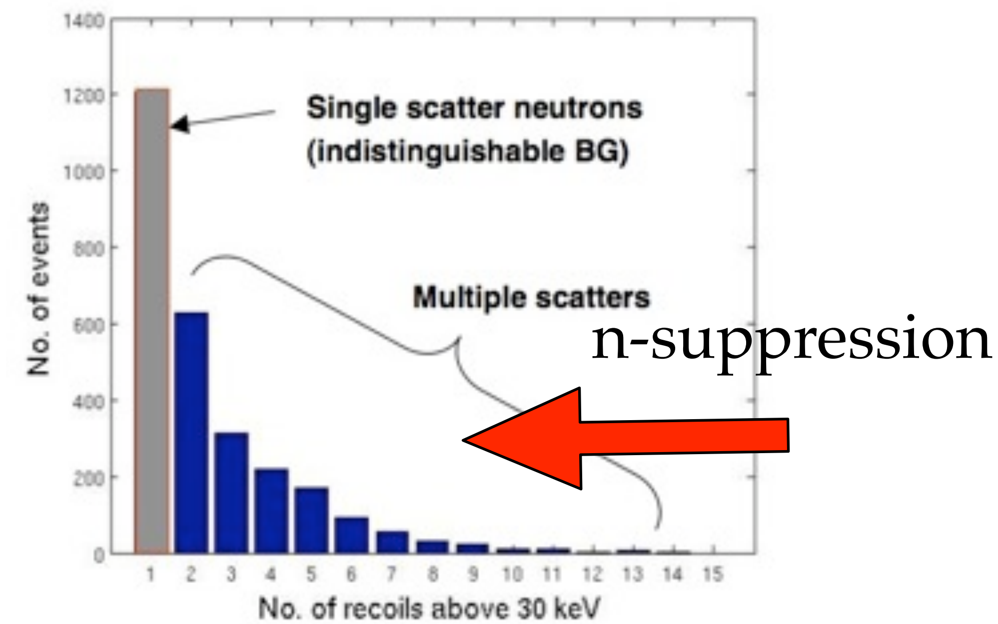


- Calibration of recoil energy (quenching!)
- Determination of the multiplicity distribution for neutron interactions



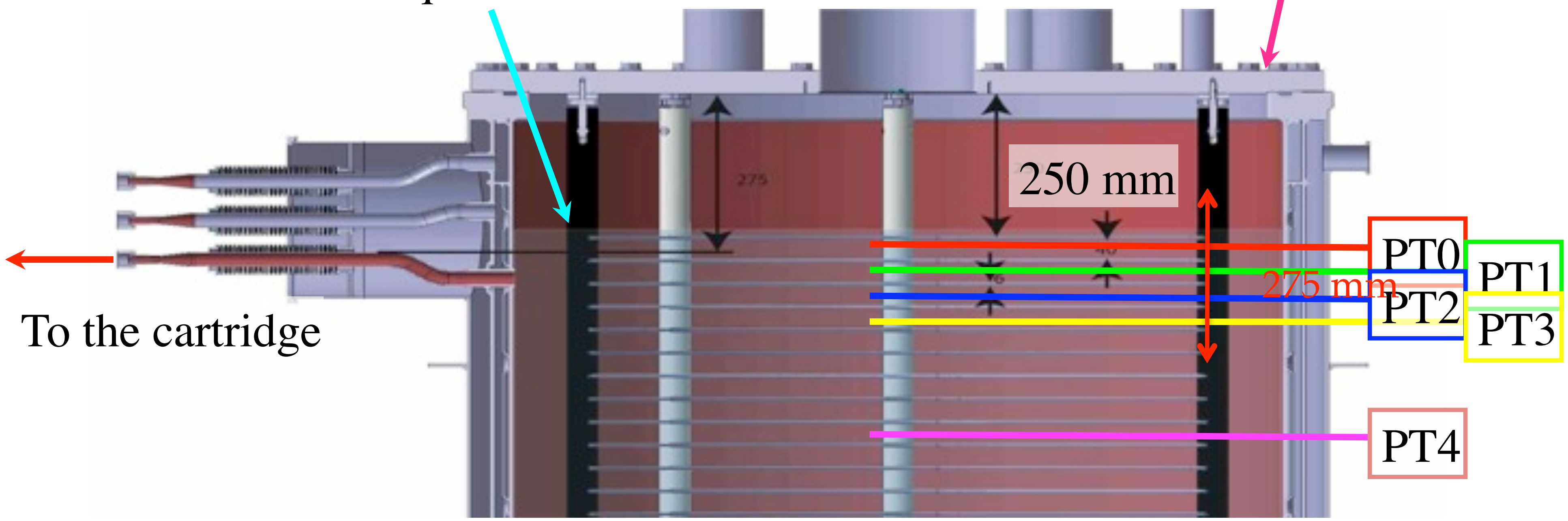
Radiation level below 1 μSv/h at places of human access

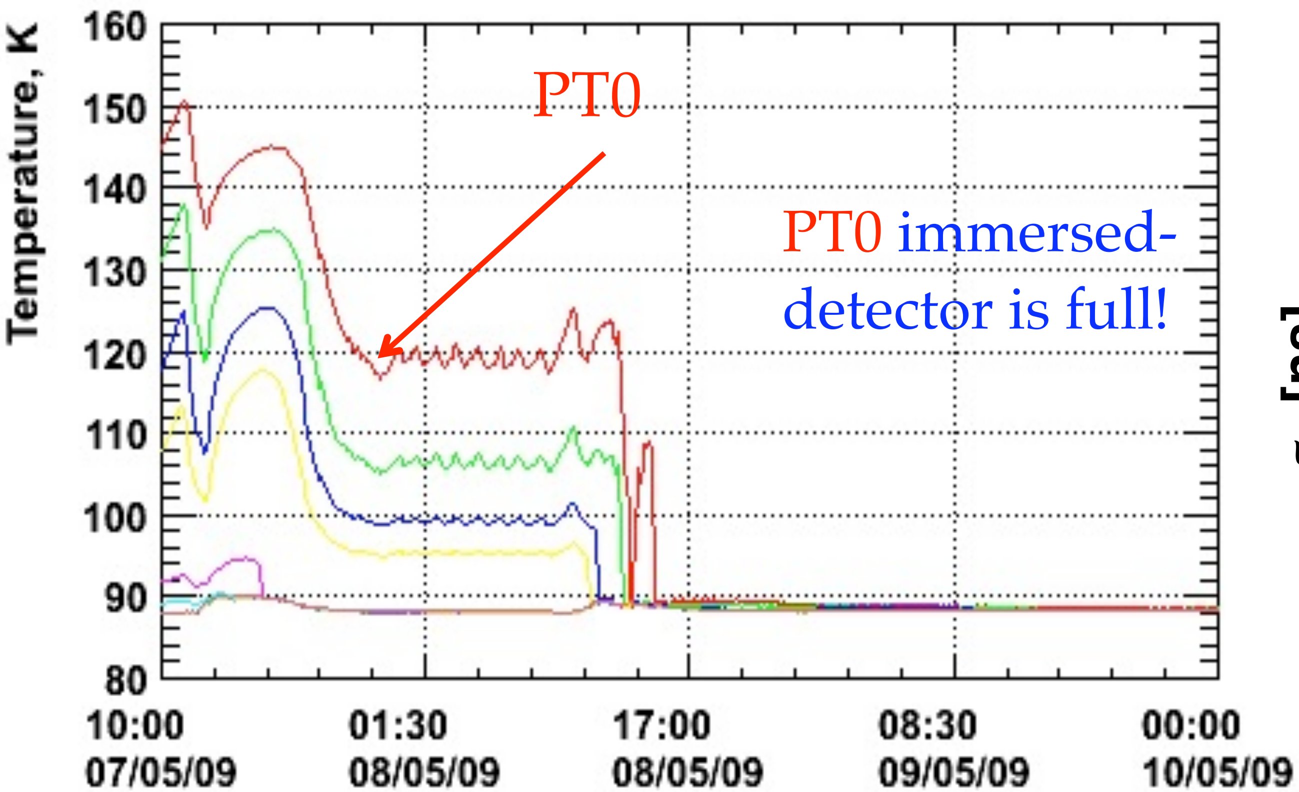
Delivery expected in August



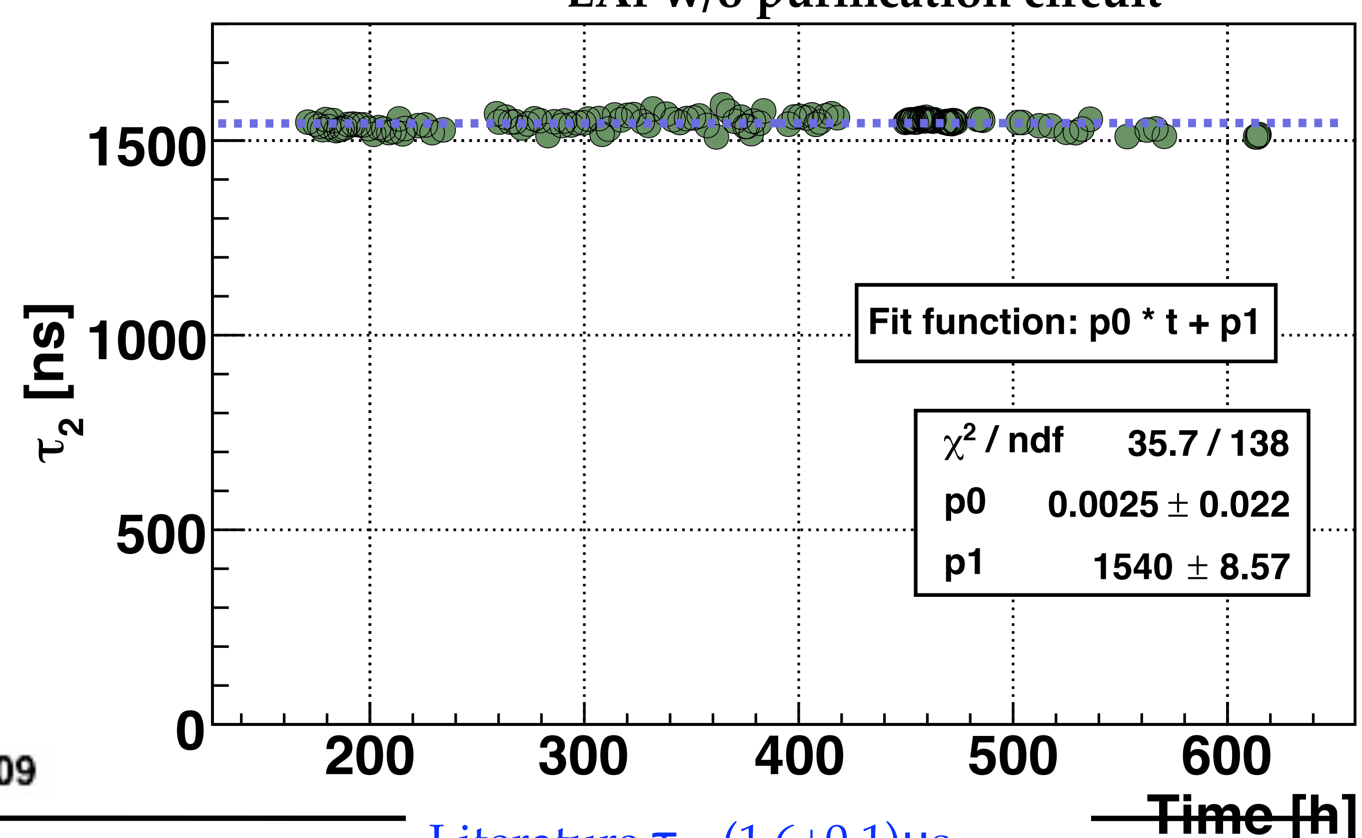
Multiple scattering (simulation)

First filling of 1t detector in May 2009





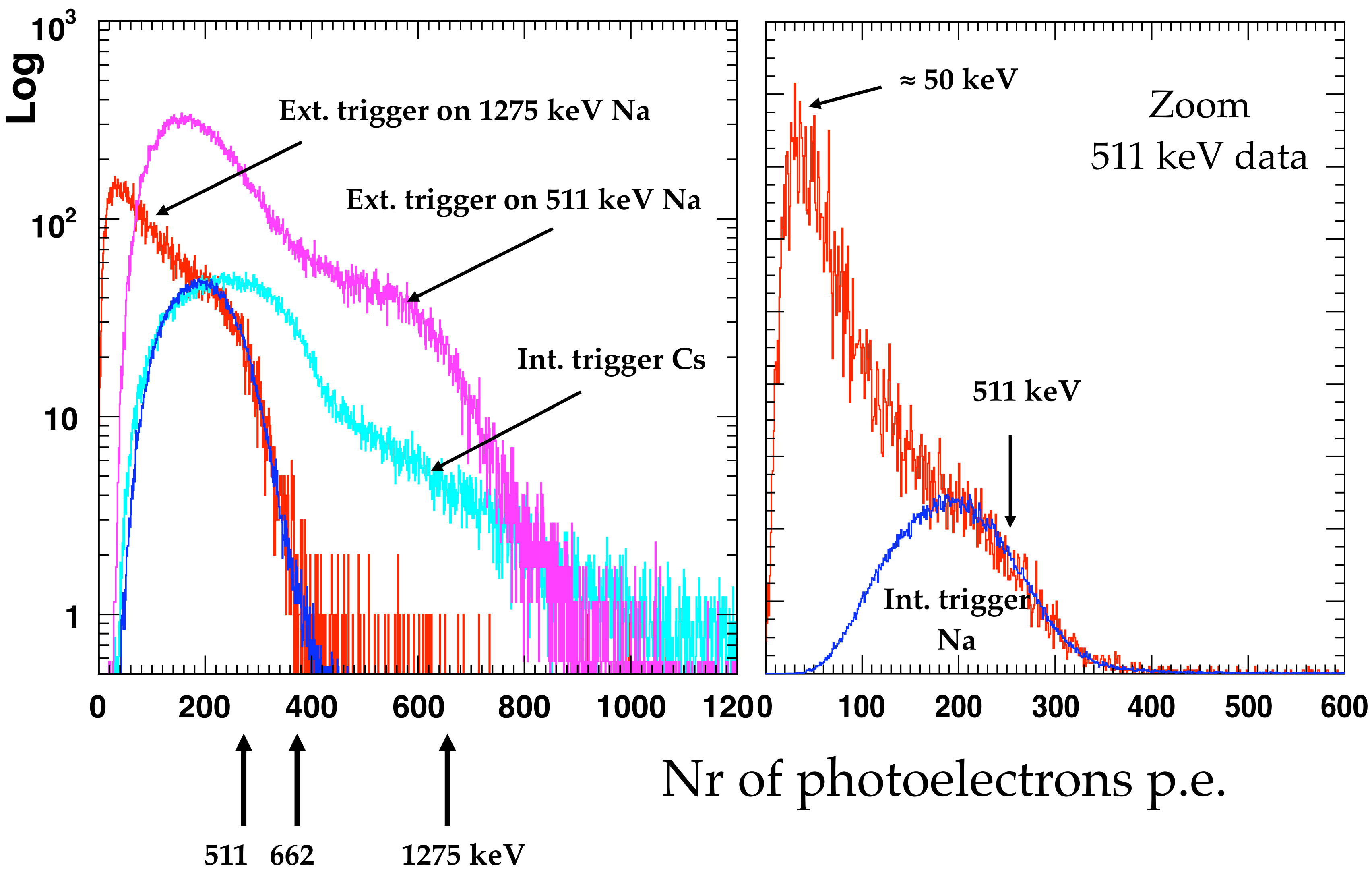
τ_2~1.5μs for >30days with bulk LAr w/o purification circuit



Literature τ_2=(1.6±0.1)μs

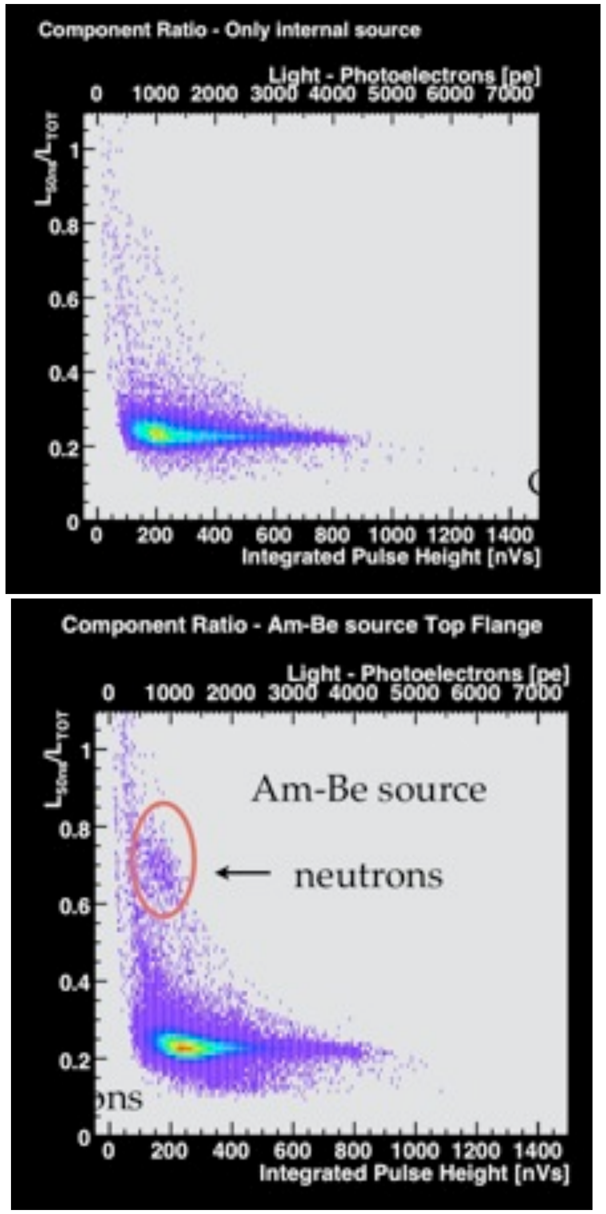
Preliminary results 1t LAr

- Triggered on combinations of PMTs and/or external NaI crystal
- ^{22}Na and ^{137}Cs sources
- Only half (7) of the PMTs were installed



Neutrons (preliminary)

Ratio fast/total



≈ 1pe/keV ee
(with 14 PMTs)

about 0.3 p.e. / keV WIMP, hence 9 p.e. for 30 keV
400 VUV photons, hence detection efficiency is about 2%

Conclusions

- ArDM is preparing the detection of DM induced nuclear recoils with a large LAr TPC (goal $\sigma \sim 10^{-45}$ cm^2)

- For the first time ArDM (1t) was operated on the surface:

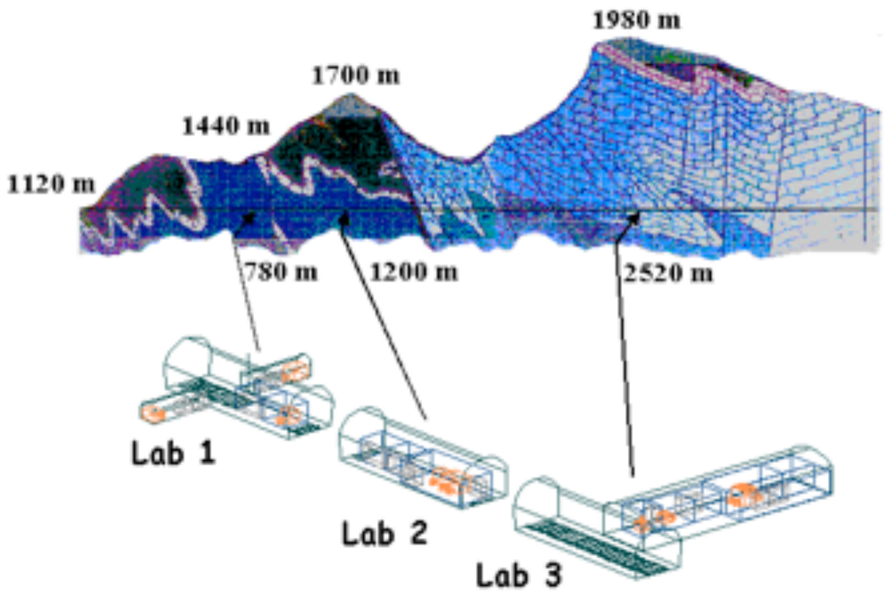
- Light yield is consistent with expectations (0.5 p.e./keV ee with 7 PMTs);
- First successful detection of 50 keV energy in 1t detector;
- Evidence for nuclear recoils (from neutrons).

- Next test foreseen in autumn 2009, 14 PMT, drift electric field to also measure ionization.

- The detector will then be moved to an underground location.

Three possible underground sites (end of 2010?)

Canfranc underground laboratory (2450 mwe)



Planned for end of 2010?

Unirea salt mine in the slanic mine of the Prahova region (Romania)

SUNLAB. Sieroszowice mine, Poland; (2200 mwe)

Participants

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