Dark Matter Searches with the ArDM detector

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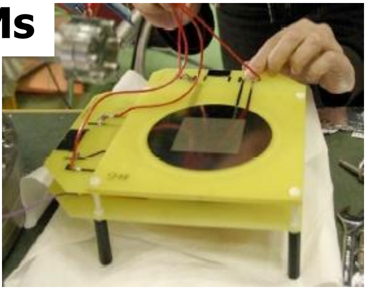
We are constructing a 1 ton argon prototype at CERN … the goal (1^{st} phase) is to demonstrate the validity of the design

It has been shown that liquid Xenon or Argon can act as a target for WIMP detection [NIM A 327 (1993) 205 & NIM A 449 (2000) 147]

Our aim is to detect the ionization charge and scintillation light independently:

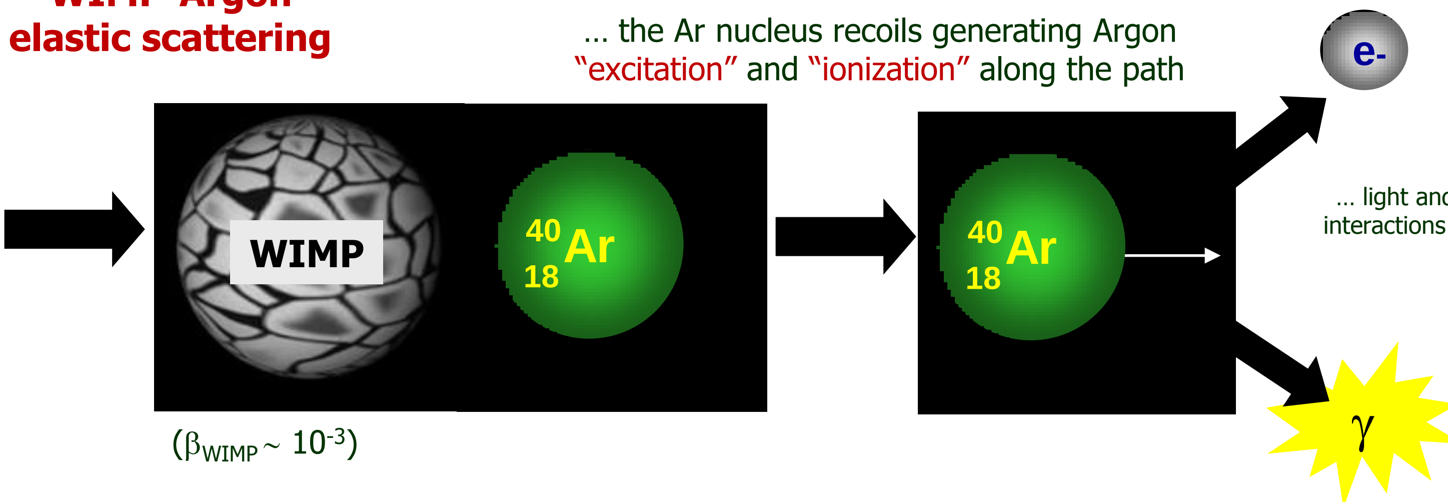
~ 42 000 e / MeV

LEMs



WIMP-Argon elastic scattering

… the Ar nucleus recoils generating Argon "excitation" and "ionization" along the path



($\beta_{WIMP} \sim 10^{-3}$)

… kinetic energy transfer to Ar nucleus …

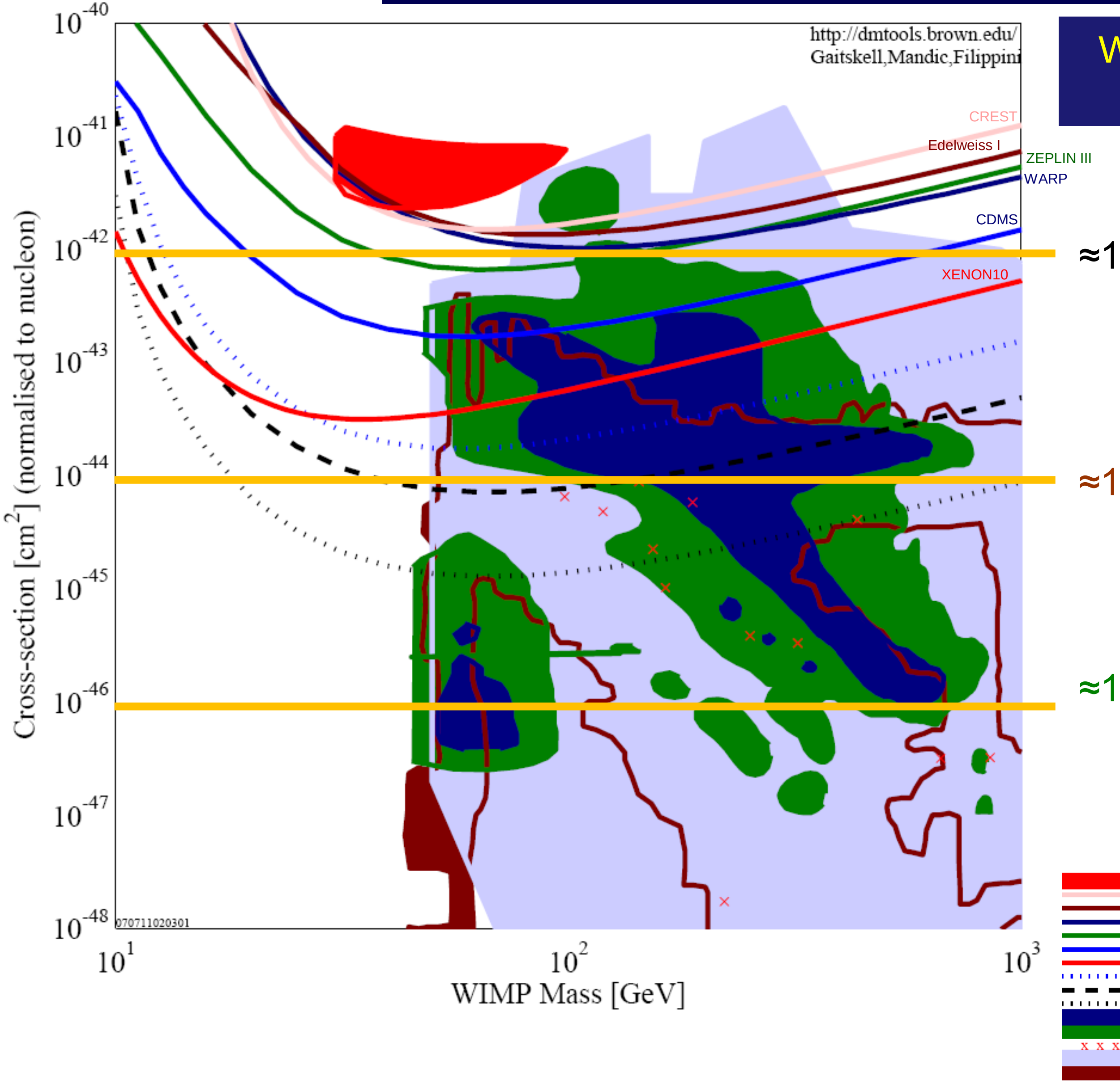
$T_{max} \sim 2\, M_{Ar}\, c^2\, \beta^2 \sim$ in the range of tens of keV

PMTs

~ 40 000 γ / MeV

Estimated event rates on Argon

With true recoil energy threshold
≈ 30 keVr



≈100 event/ton/day

≈1 event/ton/day

≈1 event/ton/100 day

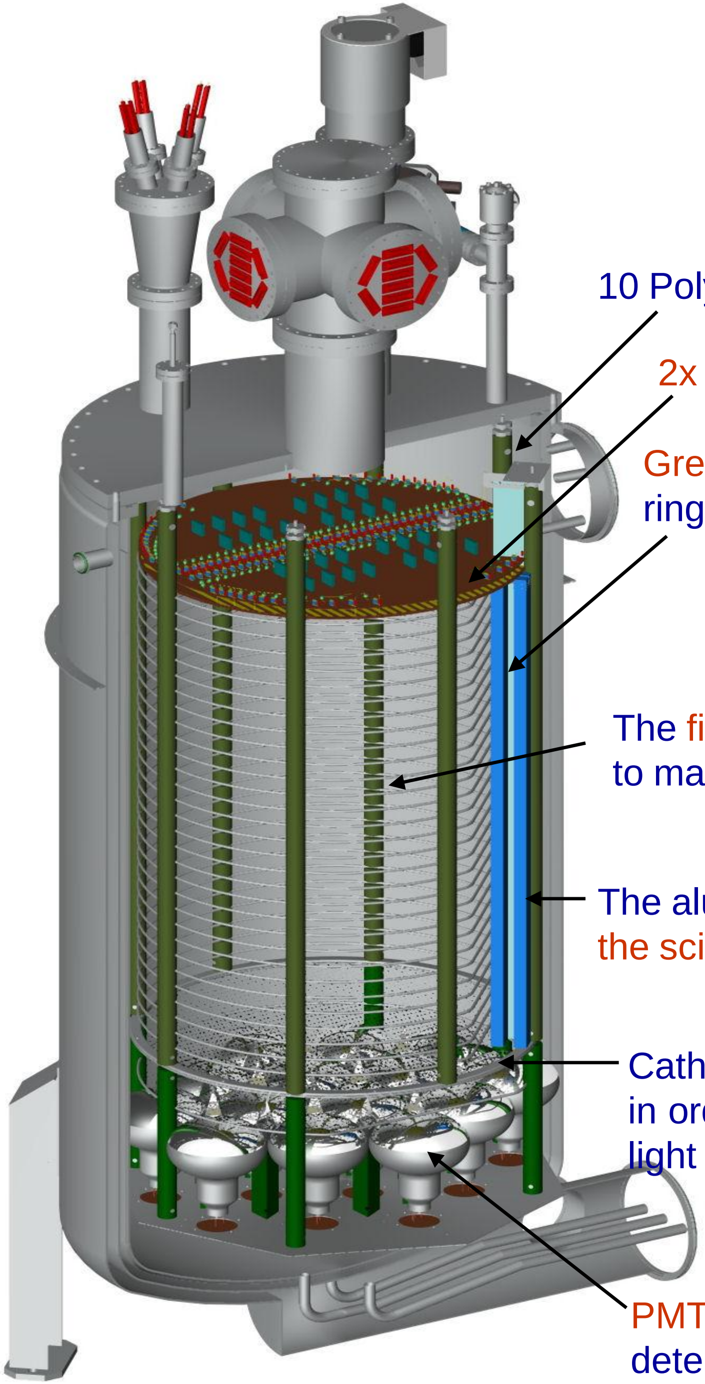
Assumptions for simulation:

- **Cross-section normalized to nucleon**
  - → $\sigma = 10^{-42}$ cm² $= 10^{-6}$ pb
  - → $M_{WIMP} = 100$ GeV
- **Halo Model**
  - → WIMP Density = 0.5 GeV/cm³
  - → $v_{esc} = 600$ km/s
- **Interaction**
  - → Spin independent
  - → Engel Form factor

S. Navas (U. Granada), EPS'07

Prototype layout

- Cylindrical volume, drift length ≈ 120 cm
- 850 kg LAr target



10 Polyethylene pillars as mechanical support.

2x LEM for the electron multiplication and readout (Gain ≈ $10^3 – 10^4$)

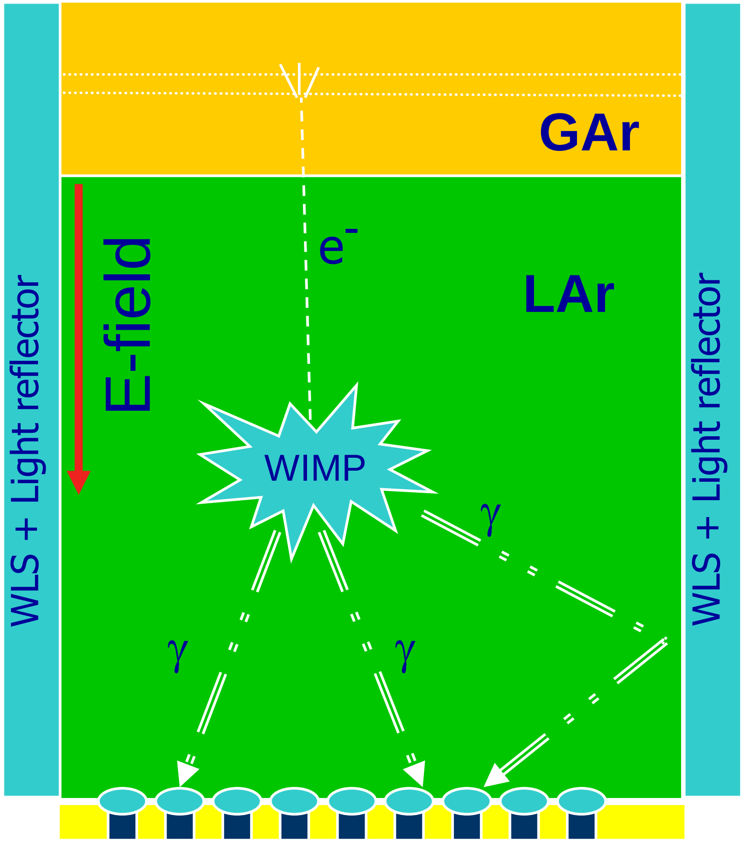
Greinacher chain: supplies the right voltages to the field shapers rings and the cathode up to 500kV → ≈ 4 kV/cm

The field shapers are needed to make an homogeneous $\vec{E}$

The aluminized Mylar reflects the scintillation light (>95%)

Cathode: semi-transparent in order to let the scintillation light pass trough …

PMTs below the cathode to detect the scintillation light.

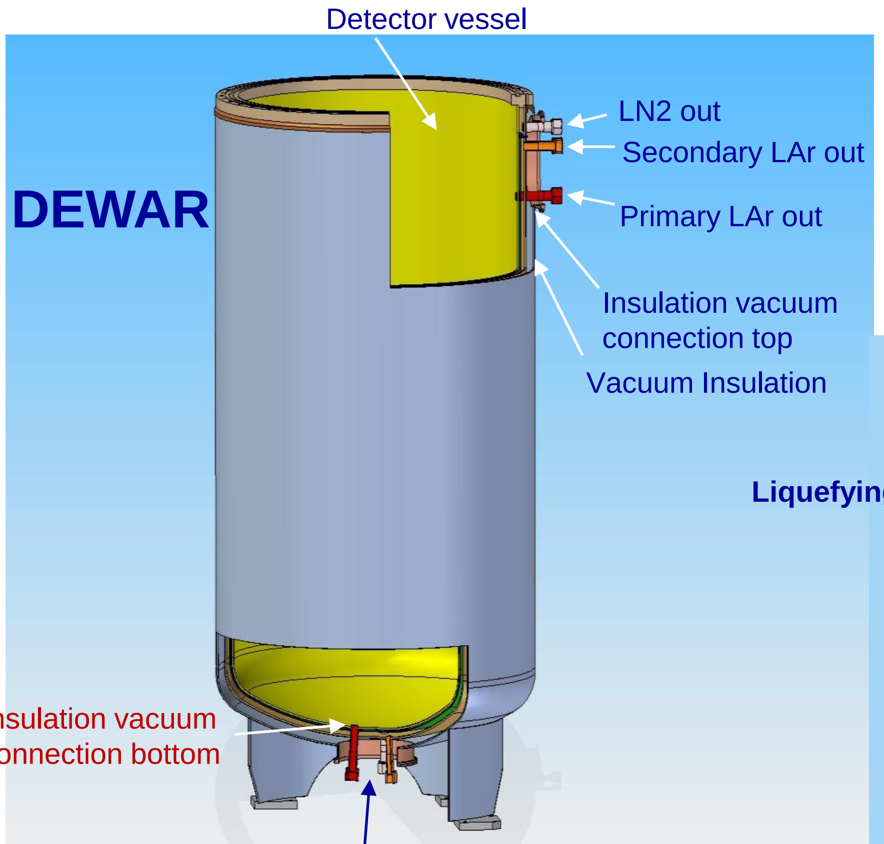


Cryogenics

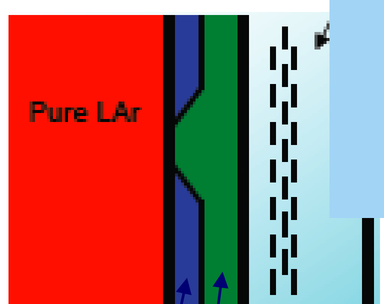
Liquid Argon should be kept

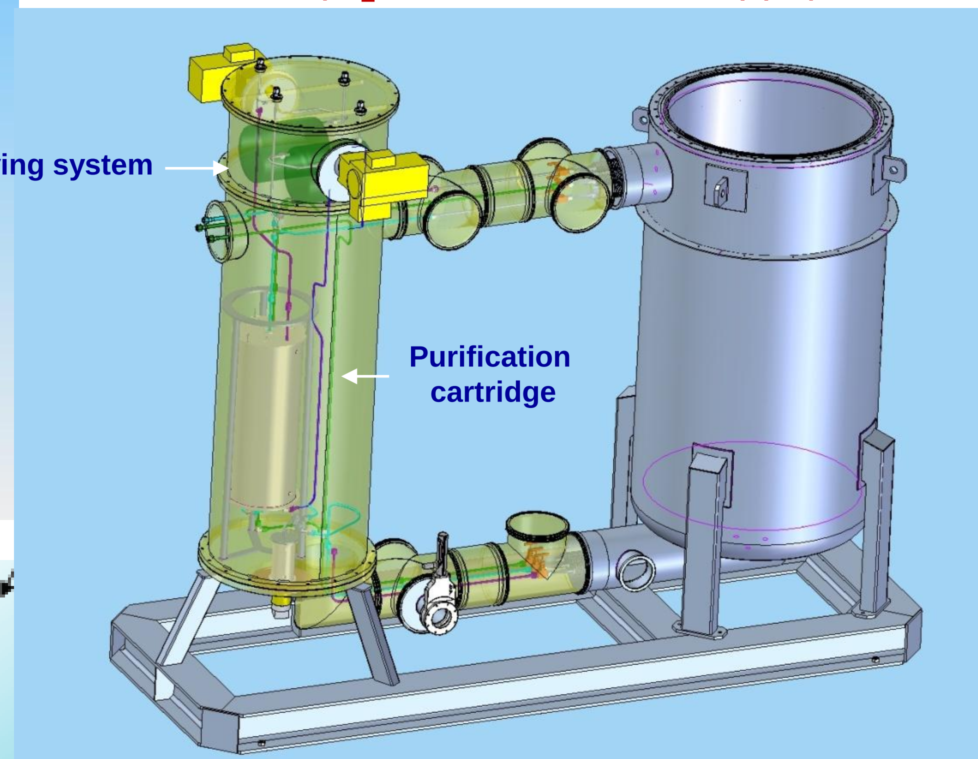
free from electronegative impurities

(O_2 contamination < 1 ppb)



Cryogenic connections bottom
LN2 in / Secondary Argon in / Primary Argon in



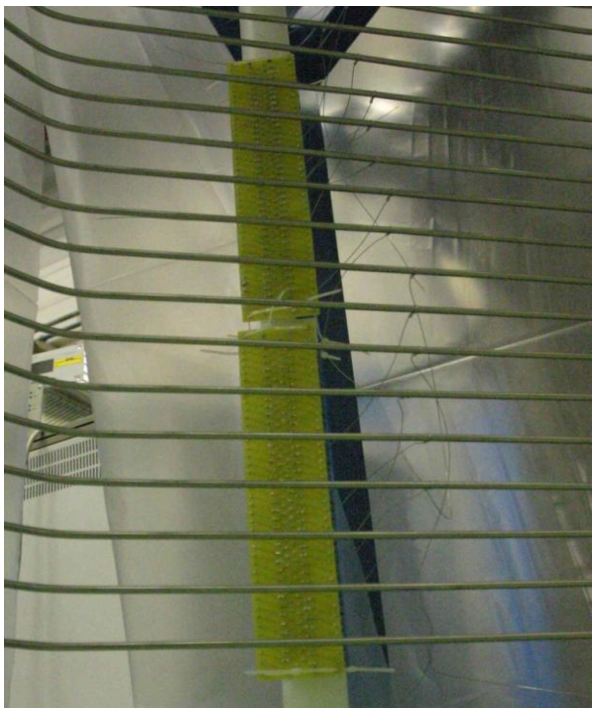


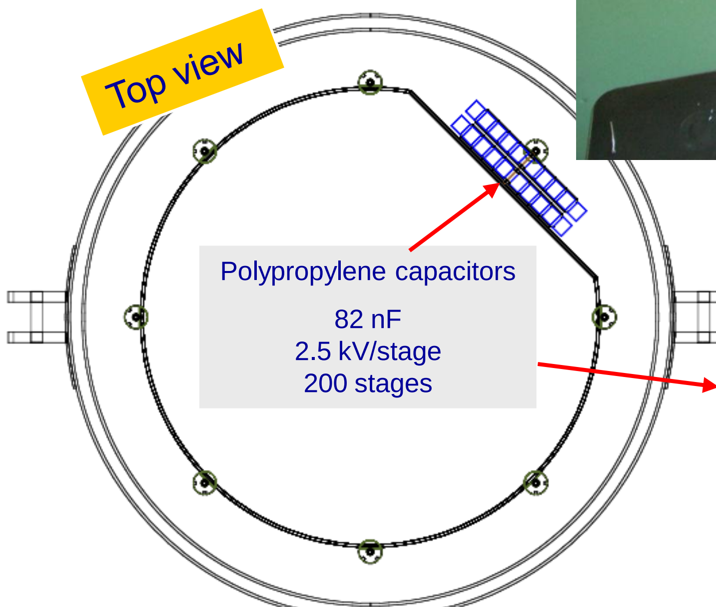
DEWAR
Delivered at CERN on April, 26

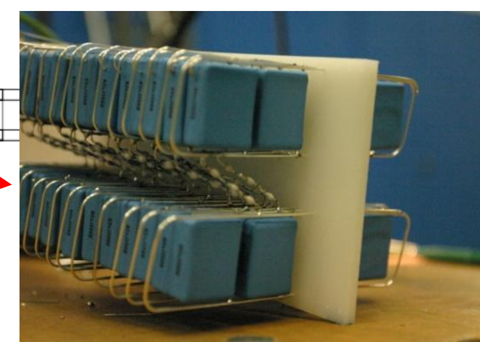
High Voltage system for drift field generation

- A cascade of rectifier cells (Greinacher/Cockroft-Walton circuit) used
- The total voltage we aim to reach is V_{tot} = 500 kV, i.e. ≈ 4 kV/cm
- Tests in liquid nitrogen have been performed
- The largest system successfully operated consists of 80 stages and reached stable operation at up to 120 kV ≈ 2 kV/cm

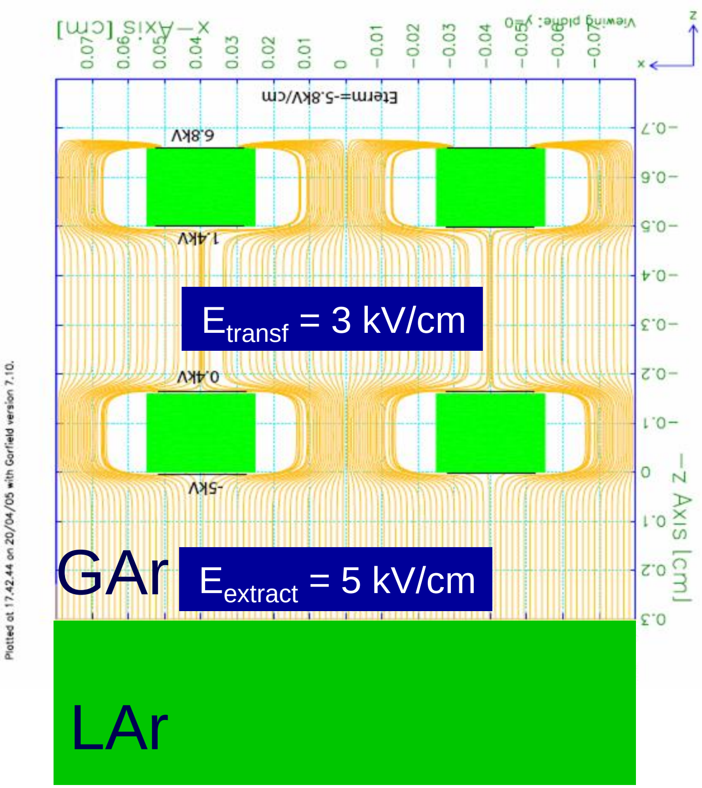
Mounted on field shaper rings

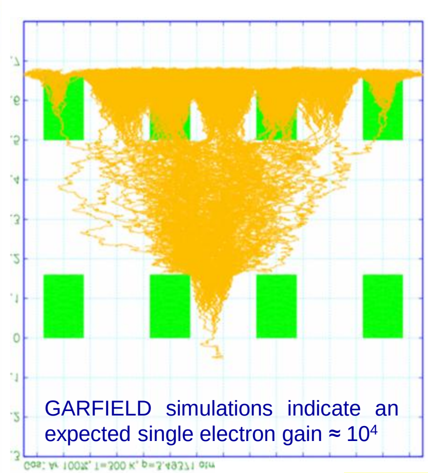


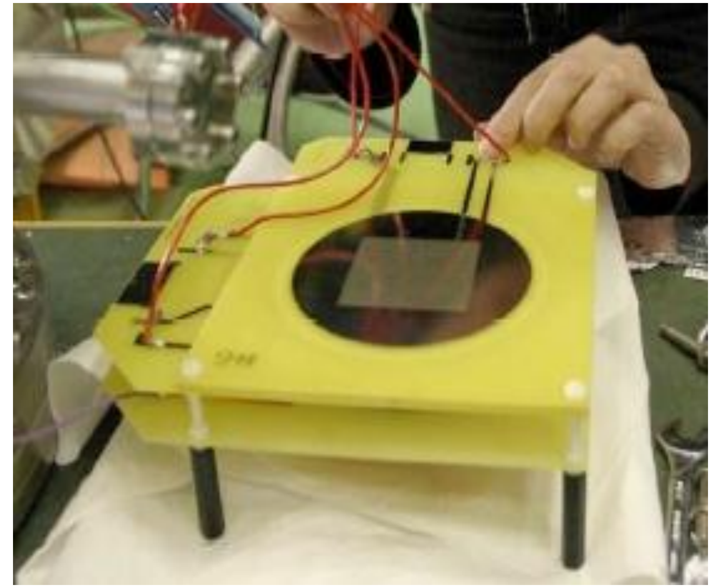


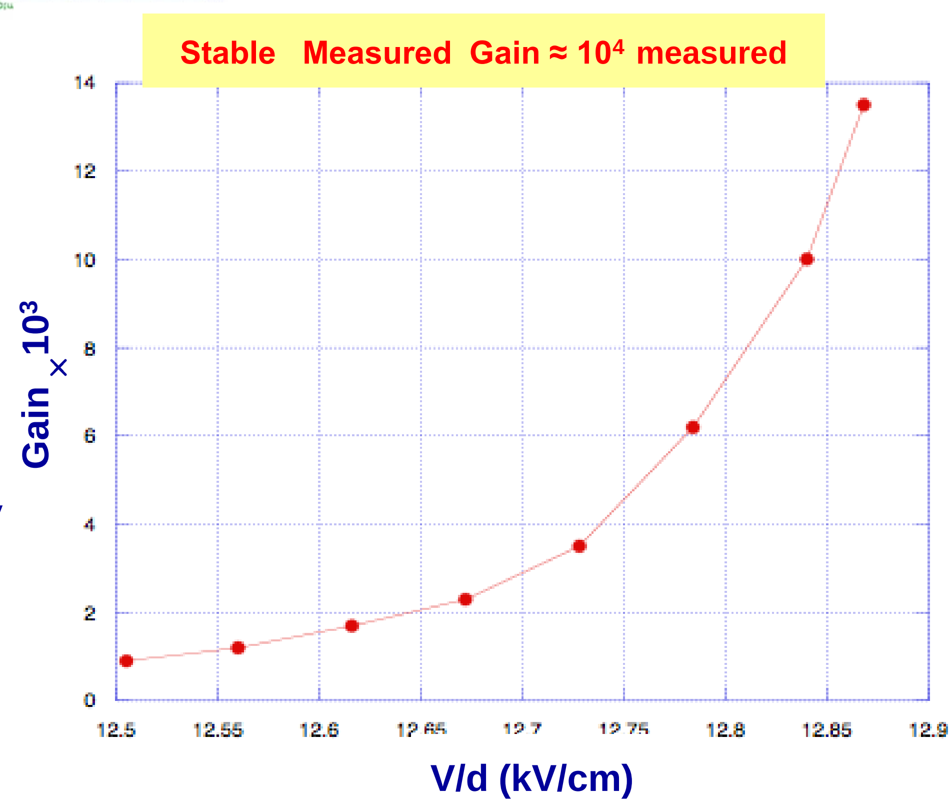


Layout of the charge readout system





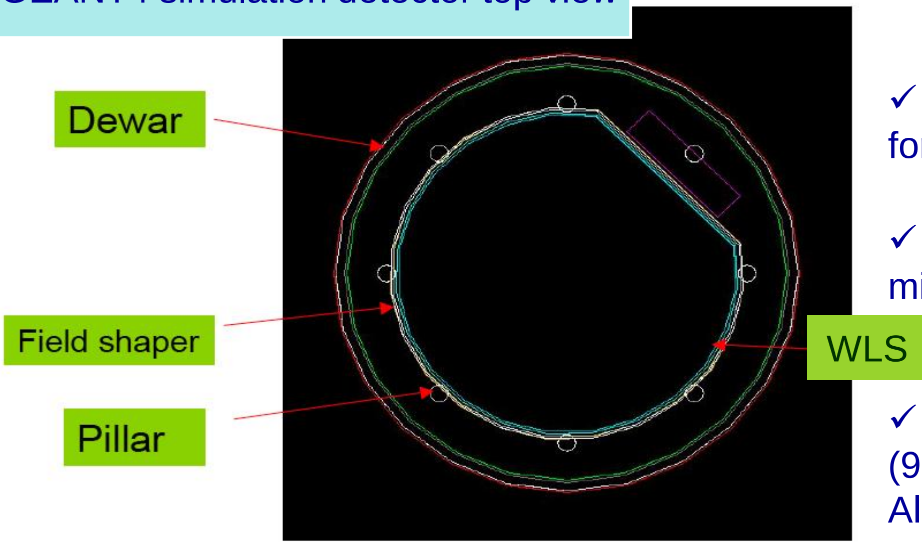




- → Distance between stages: 3 mm
- → Avalanche spreads into several holes at second stage
- → Higher Gain reached as with one stage, with good stability
- → Hole dimension: 500 μm diameter, 800 μm distance.
- → Thickness of PCB: 1.6 mm

Layout of Light Readout system and PMT

GEANT4 simulation detector top view



Scintillation light detection via PMTs and WLS reflector in mirror walls

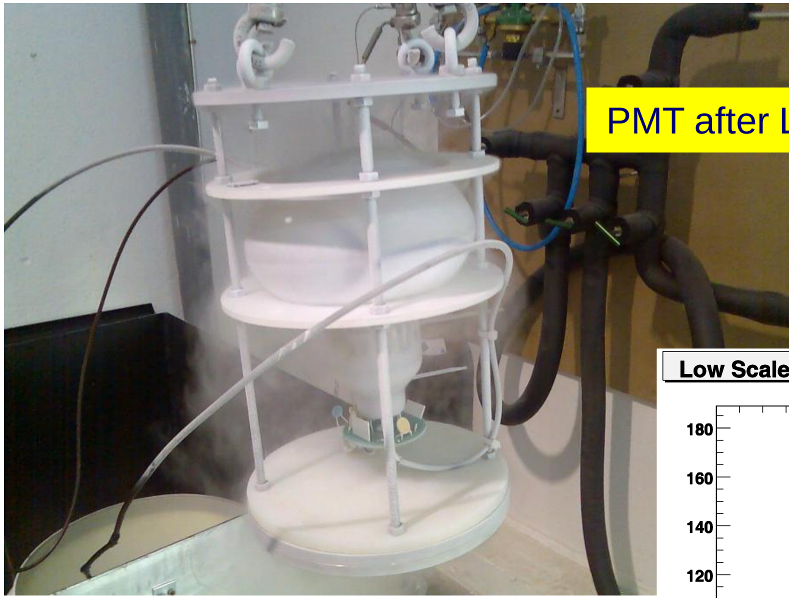
- ✓ Advantage: easier to find materials with high reflectivity for visible light than for UV light
- ✓ 128 nm γ produced in fiducial volume, hits the WLS mirror $\rightarrow$ diffuse reflection at 430 nm.
- ✓ Two layer WLS cylinder: outer to reflect visible light (99%), inner thin WLS added. Mylar foils coated with thin Al+MgF_2 layers (CERN)

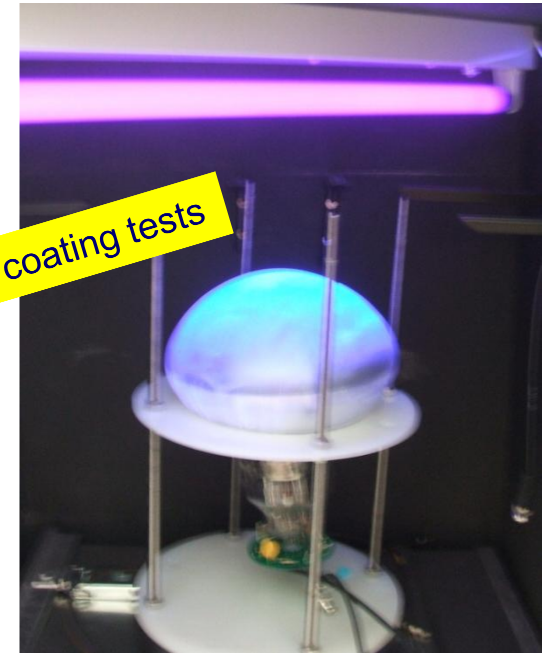
ETL 9357KFL (low background configuration) potential PMT candidate to detect scintillation light

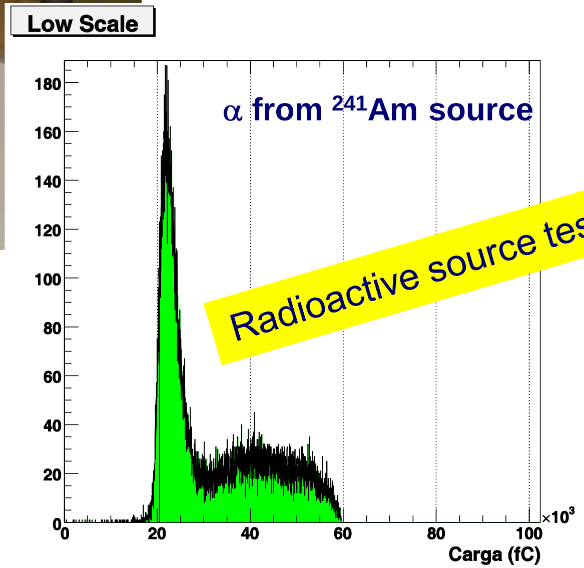
ETL 9357FLA works at
liquid Ar temperature NIM A556 (2006) 146

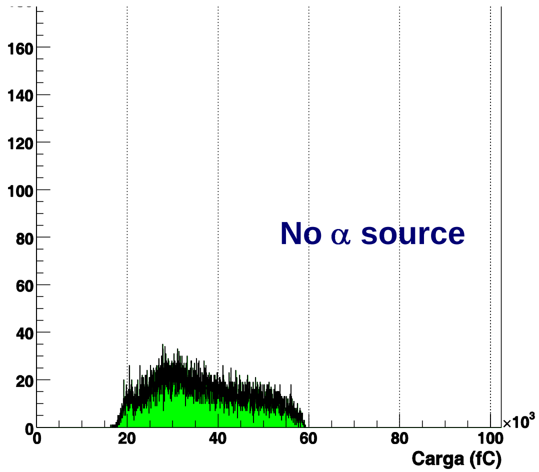
- ✓ On average, 50% of the produced photons hit PMTs

PMT tests in LAr









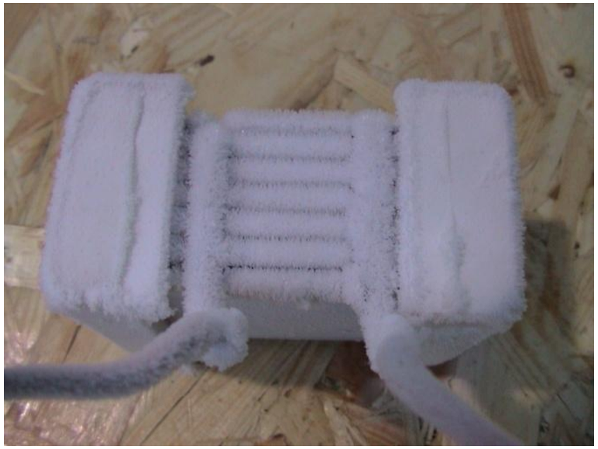
Slow Control Devices

- A series of **custom designed Slow Control devices** have been built, tested and installed to monitor temp., level, pressure …

PT10K resistors

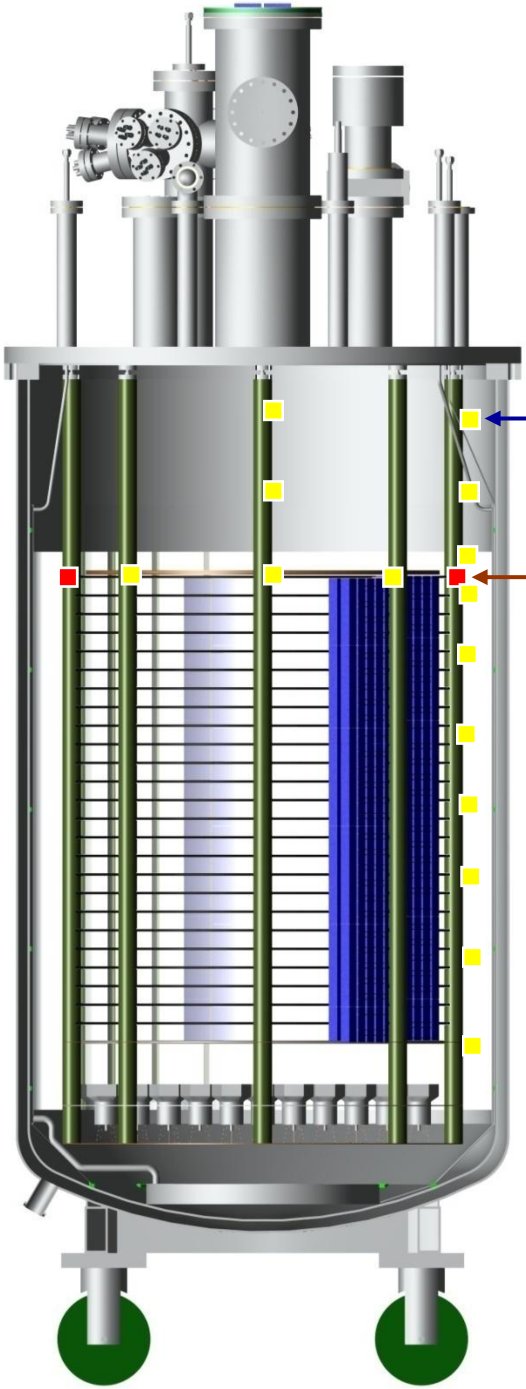
10 KΩ at 0ºC
Range: -200 to 400ºC

Capacity levelmeter



~ 0.7 pF/mm
precission of ~ 0.03 mm

Electronic circuits



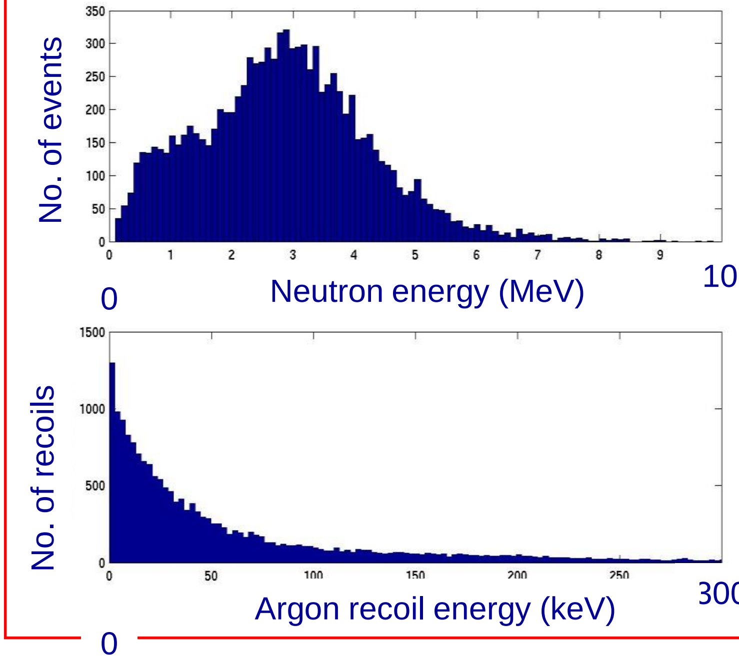
Neutron Background from detector components

Neutron sources:

- Uranium and Thorium contamination (spontaneous fission) of the detector components and the surronding rock:
  - flux about 3.8×10^{-6} cm^{-2} s^{-1} (at 2450 m.w.e.)
  - can be shielded, e.g. by a hydrocarbon shield
- Muon-induced neutrons from surrounding rock, shielding and detector components

High energy neutrons penetrate shielding, are thereby moderated and can cause WIMP-like events.

Geant4 simulation



Event numbers per year

Component	n per year	WIMP-like recoils
Container	~ 400	~ 30
LEM (std. materials)	~ 10000	~ 900
LEM (PEEK)	< 18	< 1
PMTs (std. materials)	~ 12000	~ 1000
PMTs (screened)	~ 600	~ 50

Nuclear recoils:

→ 70% scatter more than once within the fiducial volume → advantage of large detectors

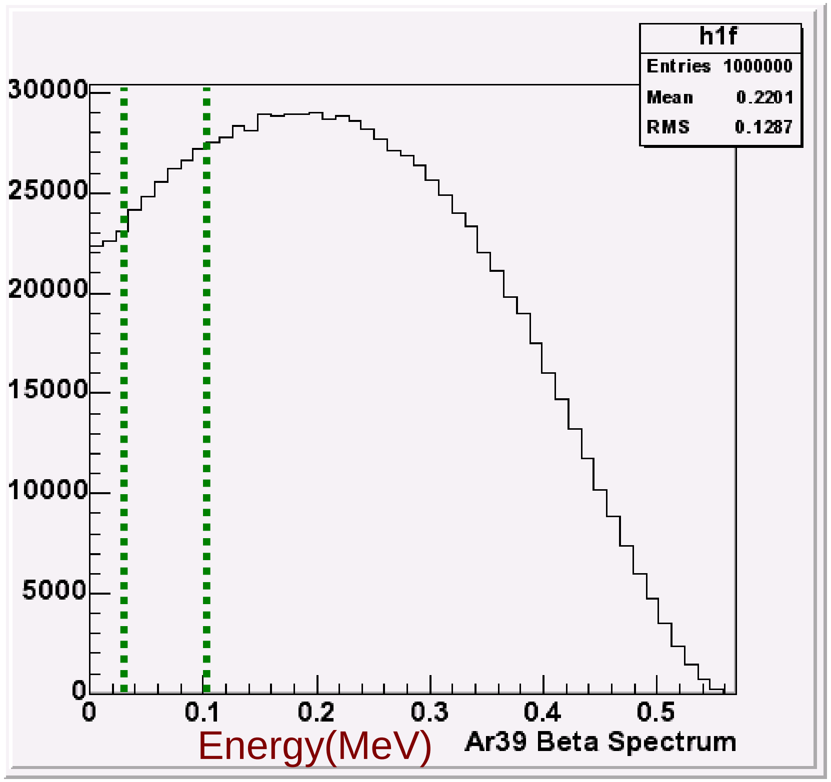
→ 10% produce a WIMP-like event (single scattering, recoil energy ∈ [30,100] keV)

Compared with ~ 3500 WIMP events at $\sigma = 10^{-43}$ cm^{-2}

Low Background Materials are crucial

Intrinsic background from Argon 39 isotope

Natural argon from liquefaction of air contains small fractions of ^{39}Ar radioactive isotope (well known to geophysicists)



- Induced in atmospheric argon by cosmic rays
- Concentration in natural Ar: 8.1×10^{-16} ^{39}Ar/Ar

  [H.H. Loosli, Earth and Planetary Science Letters, 63 (1983) 51 and "Nachweis von ^{39}Ar in atmosphärischem Argon" PhD thesis University Bern 1968]

- $T_{1/2}$ = 269 years, Q=565 KeV , <E>= 218 keV
- Integrated rate in 1 ton LAr ~ 1kHz

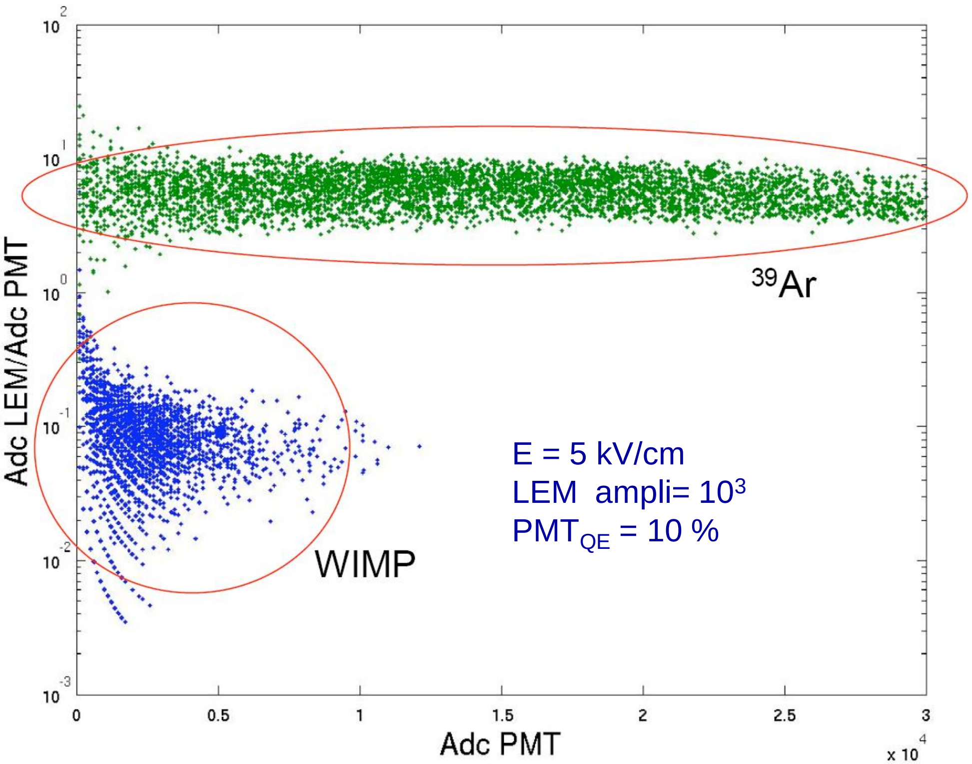
  [WARP Coll.] astro-ph/0603131

To suppress ^{39}Ar fraction we consider using Ar extracted from well gases (extracted from underground natural gas). On the other hand, this source, evenly distributed in the target, provides precise calibration and monitoring of the detector response.

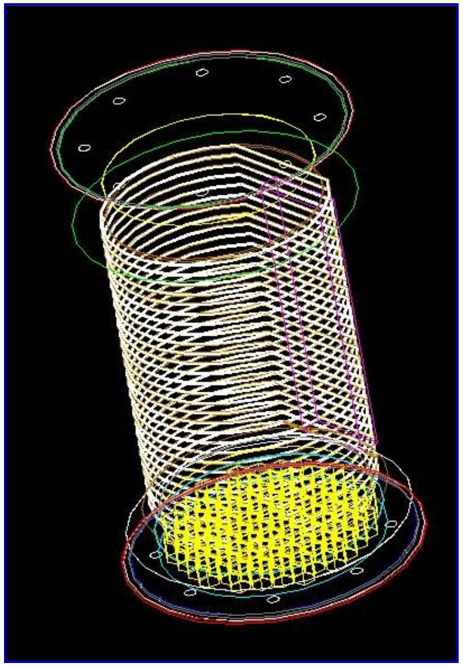
WIMPs vs. ^{39}Ar background discrimination

This is MONTE CARLO, thisrelies heavily on MC, there is no reason to belive this is OK, this is exactly what the 1 ton test at CERN should prove.

Charge/Light ratio



Full GEANT4 simulation



~0.7 phe / keV

CUTS:
True recoil energy > 30 keV
Q > 2000 electrons
light ≥ phe

phe = 2 : ~91 WIMP evts/day
phe = 4 : ~85 WIMP evts/day

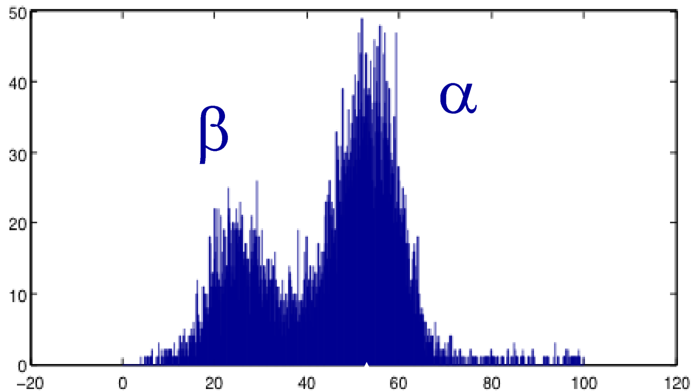
(If Quenching = 0.28)

phe = 2 : ~39 WIMP evts/day
phe = 4 : ~9 WIMP evts/day

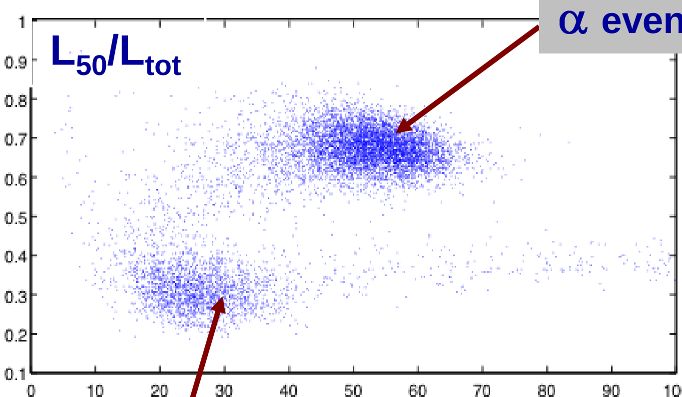
Light measurements in Liquid Argon (preliminary)

real data

Event separation in liquid argon



Por un lado hay más luz de centelleo DETECTADA de alphas que de betas



$$\frac{I_S}{I_T} =$$

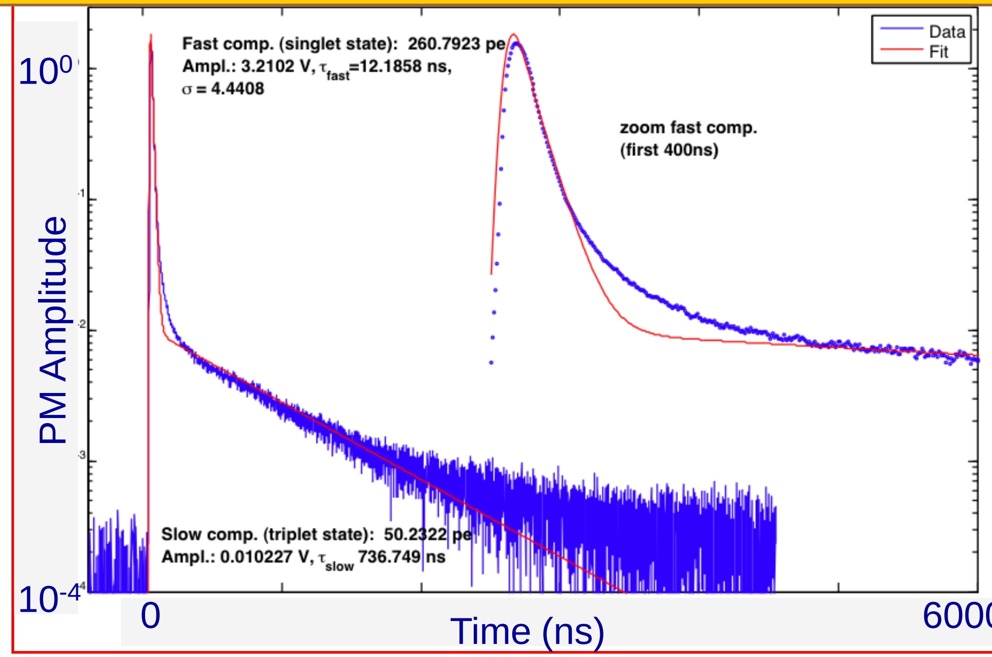
~ 0.3 for β particles

~ 1.3 for α particles

[Phys.Rev.B27 (1983) 5279]

^{210}Po radioactive source: α (5.4 MeV) + β (Q = 1.163 MeV)

Scintillation light from α in 1200 mbar liquid argon



→ α events separate well from γ,e events

→ Fast and slow light components distinguishable

Ar_2^*
- $1\Sigma_u^+$ (singlet) t=6 ns (fast)
- $3\Sigma_u^+$ (triplet) t=1.7 μs (slow)

#photo-electrons	Rejection (@E=0V/cm)
>10	> 10^2
>20	> $5x10^3$
>30	> 10^5

The experimental R&D roadmap

- We are constructing a 1 ton prototype at CERN to demonstrate the validity of the design.

- Surface test at CERN (From July to December, 2007)
  - Verify LEM performance and light collection efficiency in cold
  - Test purification technology, HV system at low temperature for long periods
  - Calibrate with γ and n sources
  - Study pulse shape and light/charge ratio discrimination power

- Underground test in 2008
  - Canfranc Lab. As potential location? EOI submitted; Scientific Committee very supportive.
  - Study the detector performance and background rejection capabilities in realistic conditions