WARP

WIMP ARGON PROGRAMME

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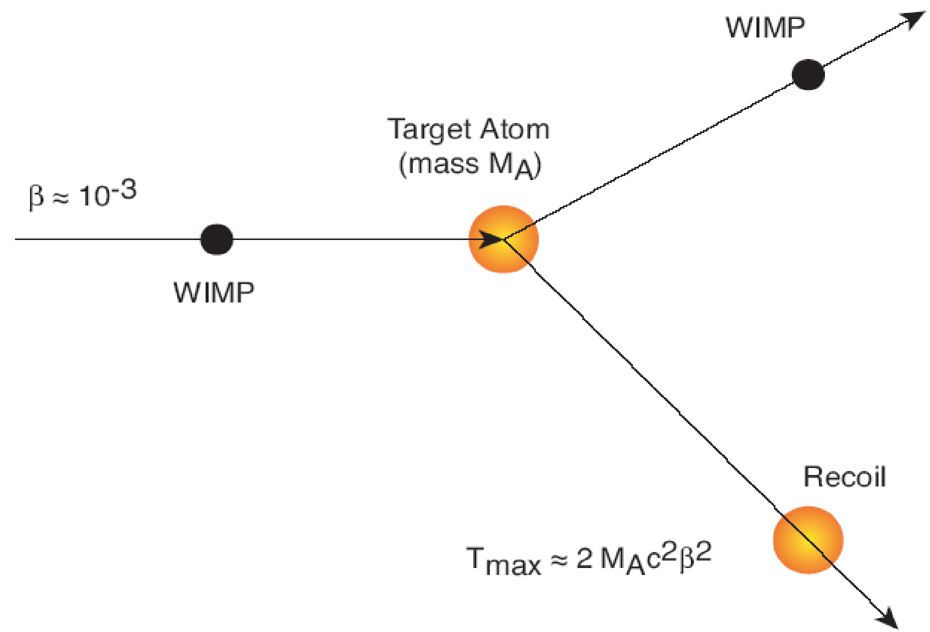
Direct Dark Matter Detection

Direct detection looks for recoil energy deposited by a WIMP interaction with one of the detector nuclei.



WIMPs should be present in the galactic halo and have a mass of the order of (50-1000 GeV).

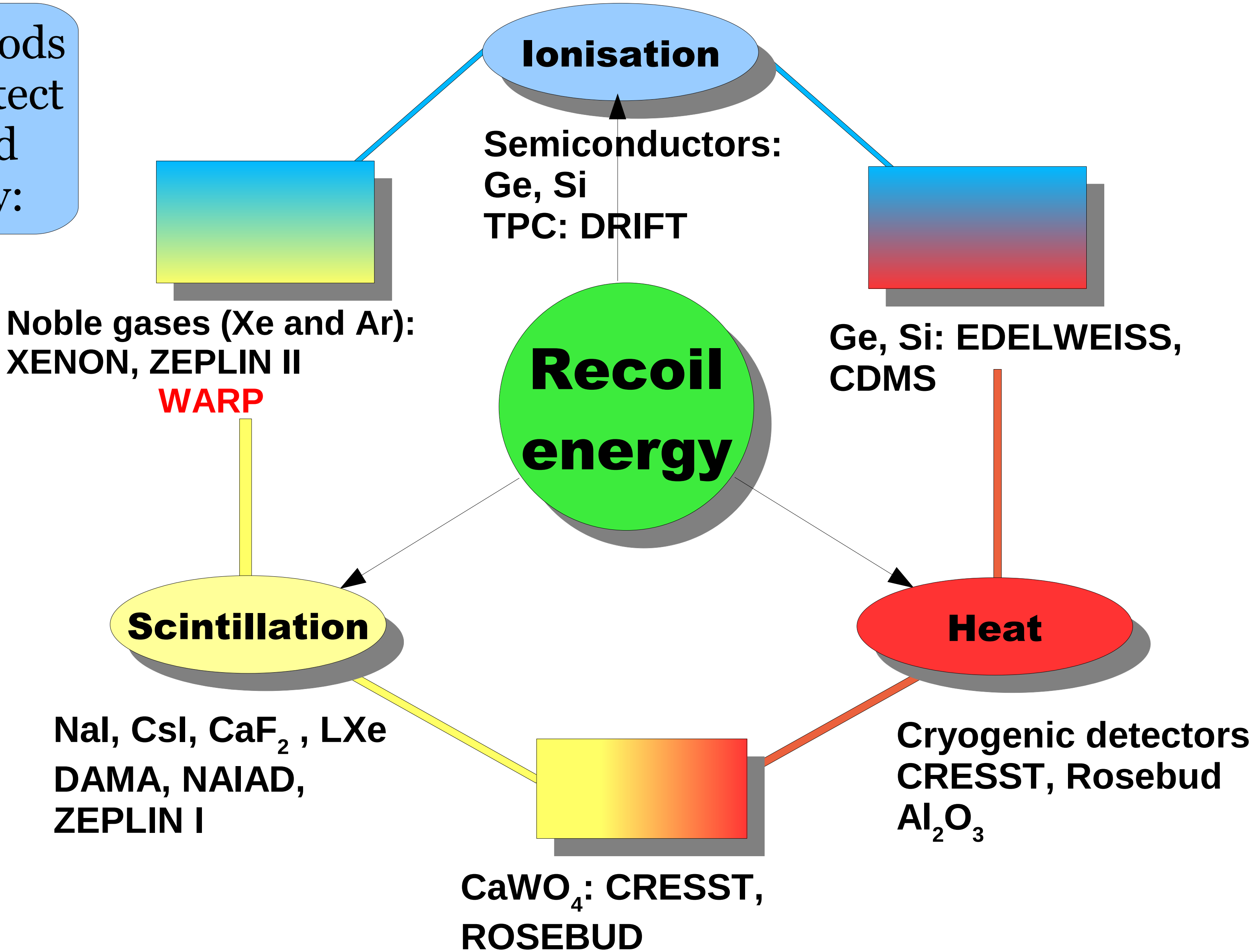
The predicted recoil energy is of the order of tens of keV (depending on the WIMP and detector nuclei masses).

The predicted cross-sections are of the order of 10^{-6}pb and smaller

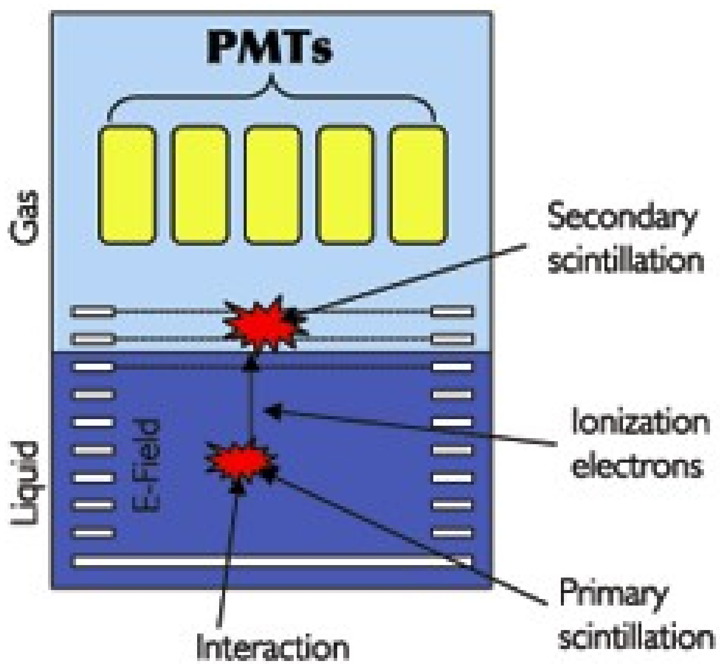
Low background and a very good understanding of the detector are essential.

Direct Dark Matter Detection (cont.)

Different methods are used to detect the deposited recoil energy:



The WARP detection technique

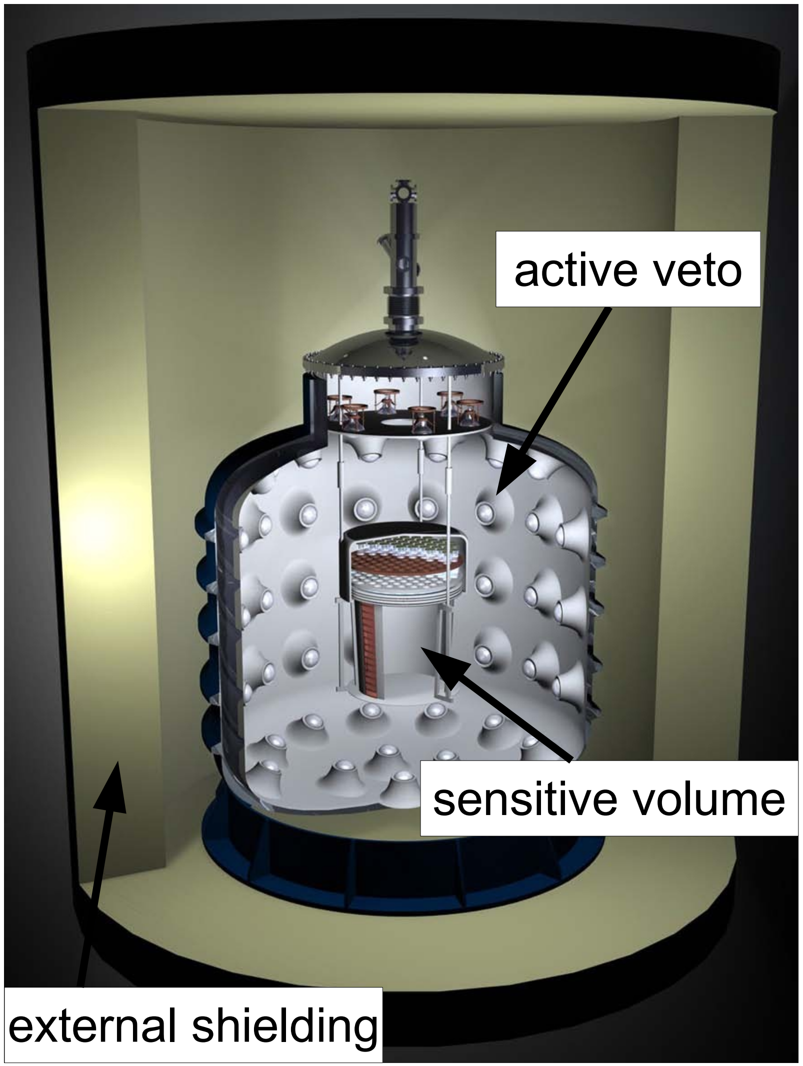


- The primary scintillation light (128nm) is detected by the PMTs (TPB as a wavelength shifter)
- The electrons coming from the ionisation are drifted to the gas-liquid interface.
- After extraction they are accelerated in the electric field shaped by wire grids.
- The resulting proportional scintillation is also detected by the PMTs.

The scintillation light yield is of the order of 1 phe/keV.

The expected energy window for recoil events is 30-100 keV.

The WARP detector

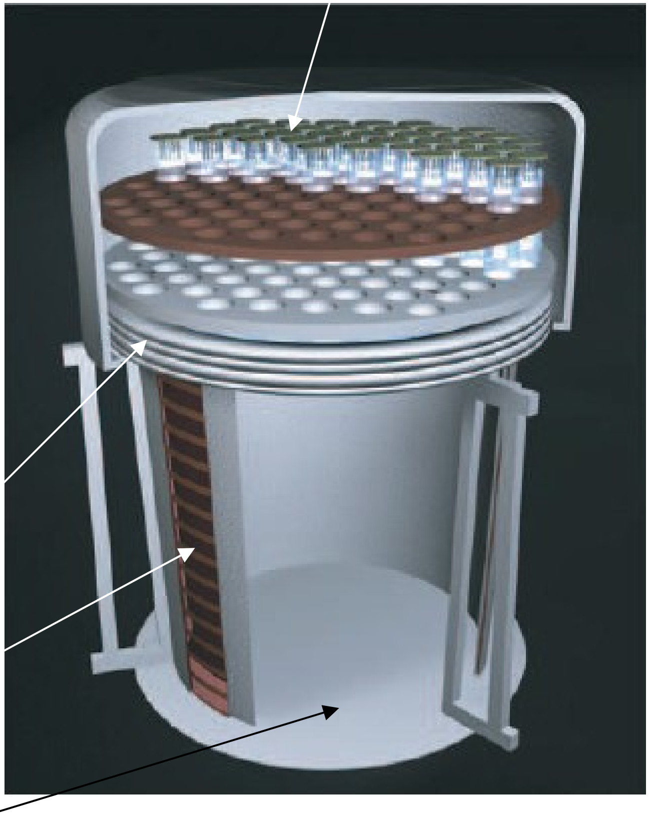


The WARP detector is expected to be operational in 2006.

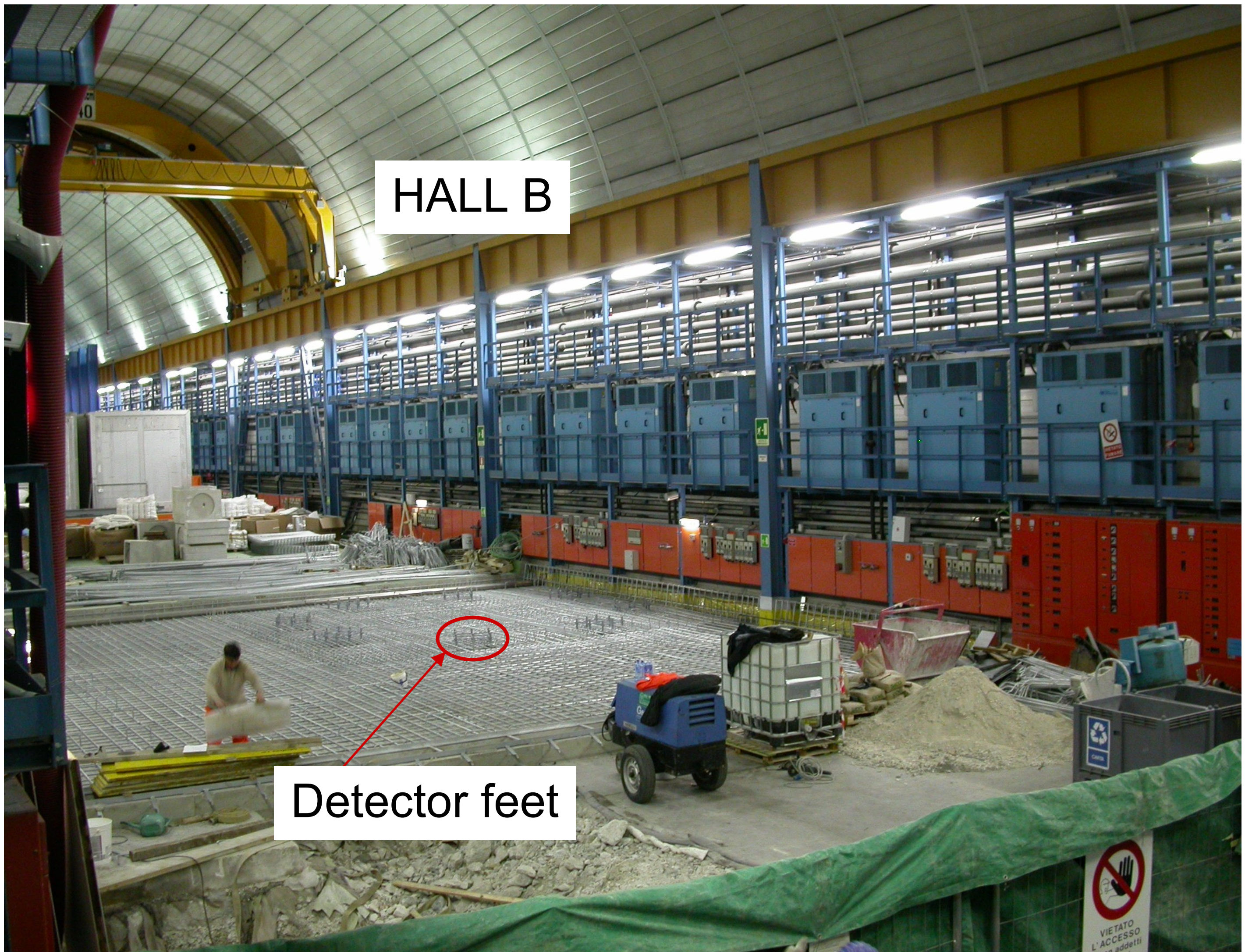
- 100 l of Argon resulting in 140 kg sensitive mass
- Active veto system
- passive neutron and gamma shielding
- 3d event localization

The inner detector.

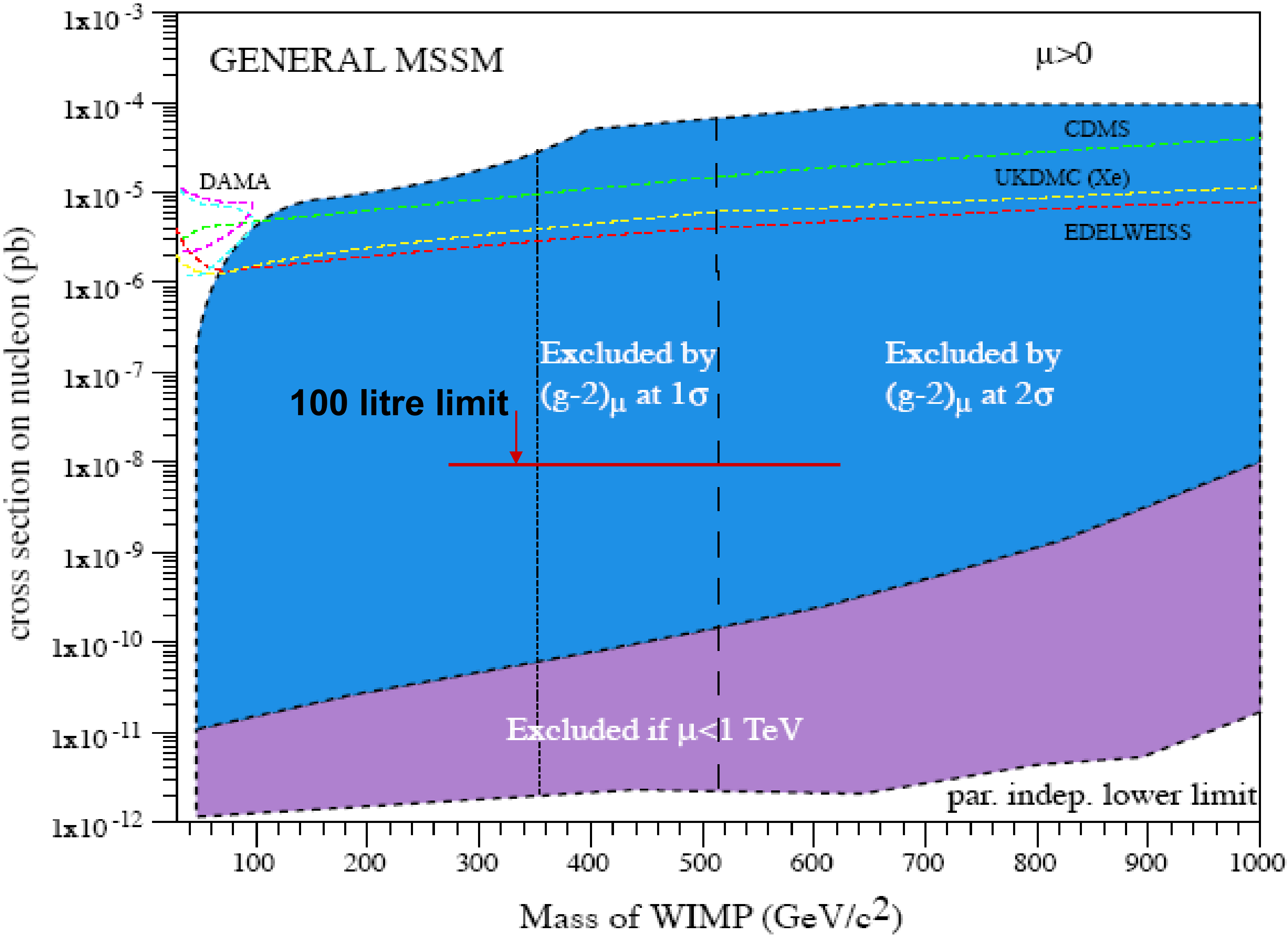
- **Sensitive mass = 140 kg**
- **Height = 60 cm, Radius = 25 cm**
- **a set of UV sensitive cryogenic PMTs placed in the gas phase on top of the last grid for a total photocathode coverage of about 10%**
- **Drift field = 1 kV/cm**



WARP 100 l site at LNGS



WARP 100 l sensitivity

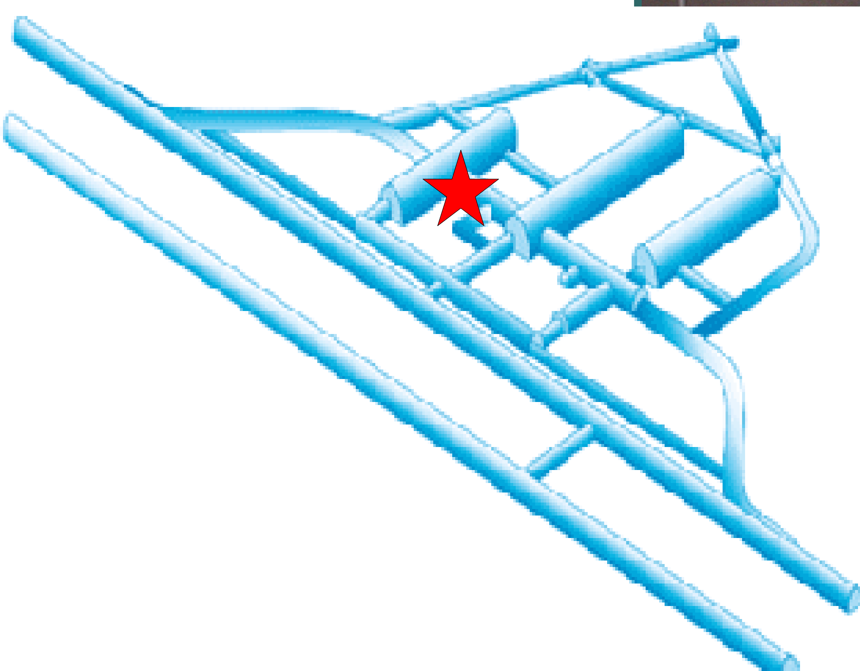


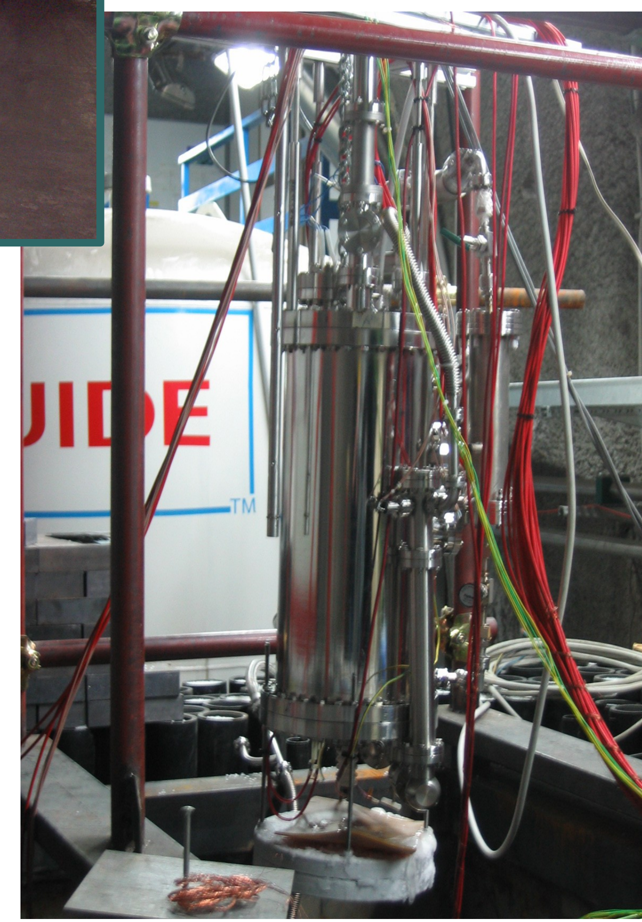
The 2.3 liter test chamber

The 2.3 liter test chamber has been operational in LNGS since April 2004.

- 2 setups: 7x2" or 4x3" PMTs (ETL)
- same scheme as the 100l detector.
- maximum electron drift time: 40 µs (10 cm chamber height)
- argon purity maintained by constant recirculation

The Test Chamber in LNGS





The signal discrimination

The events are selected based on two parameters:

- The ratio of light in the secondary and primary scintillations (s2/s1)
- The rise time of the primary scintillation

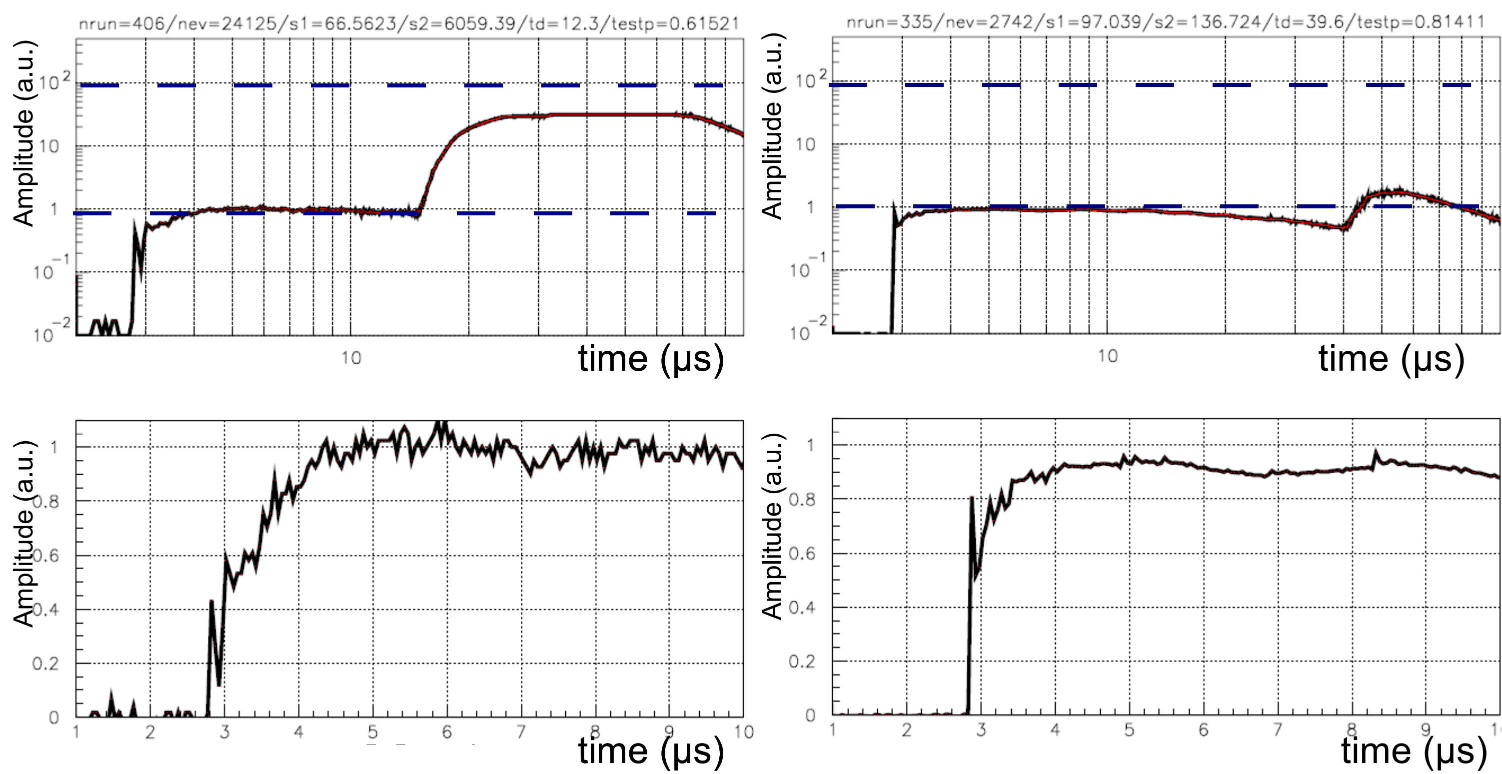
The pulse ratio depends on the columnar recombination, different for recoil-like events and minimum-ionizing-like ones.

- for WIMP-like recoil events:
  s2/s1 ~ 1-10
- for γ- and β – like events:
  s2/s1 ~ 100

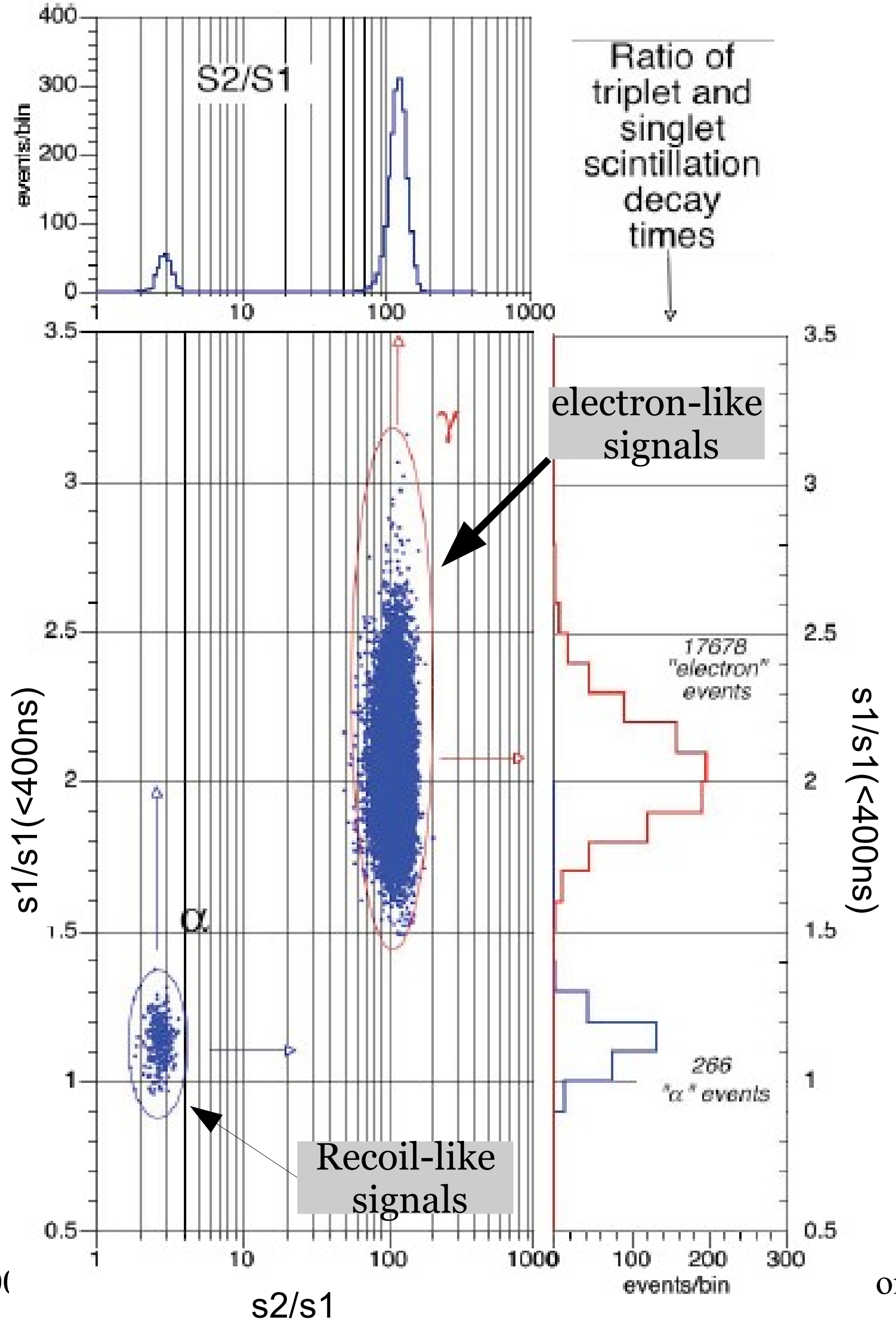
Excited argon forms molecular states with very different transition times:
singlet (~10ns),
triplet (~1.6 μs).

The difference in pulse shapes results from the different composition of these states

a) electron-like **b) R-like**



The signal discrimination (cont.)



The combination of the two parameters results in very good background rejection power

a rejection better than $1/10^8$ can be achieved.

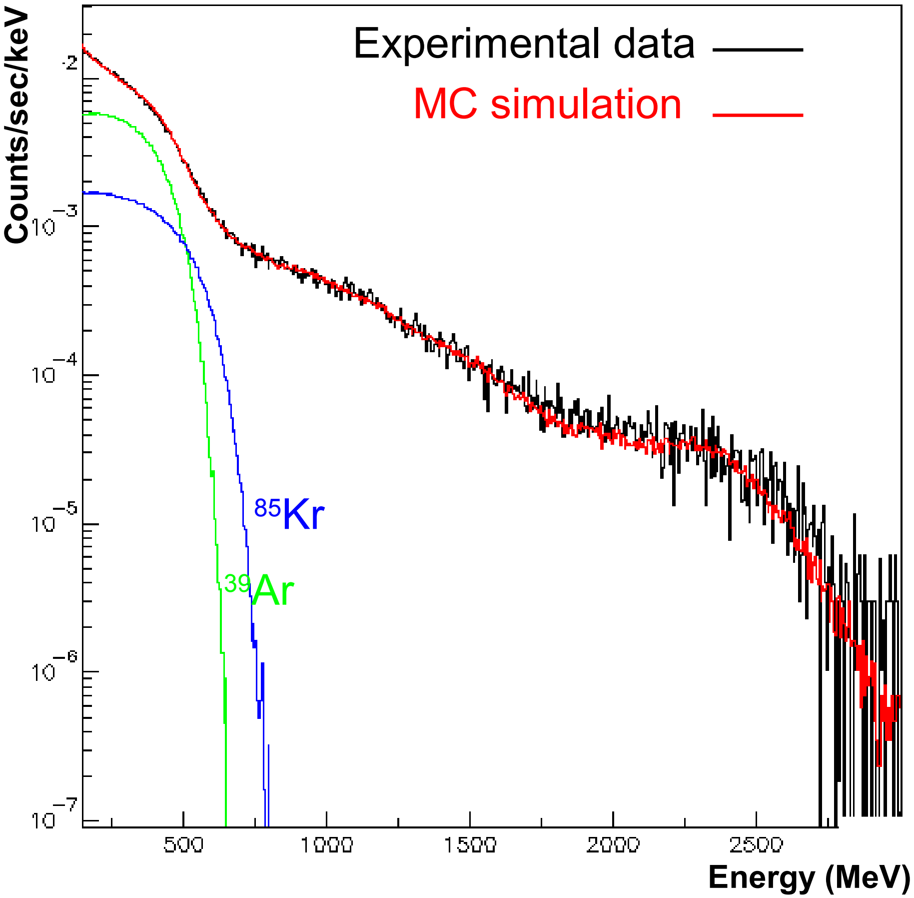
The β and γ Background

The collected data sample is in very good agreement with a MC simulation of the environmental background

The main source of background are ^{39}Ar and ^{85}Kr. Also notable are the ^{238}U and ^{232}Th chains:

The composition of the background:

Total rate:	6.48 Hz
• ^{232}Th chain	26.2%
• ^{238}U chain	19.8%
• ^{60}Co	5.6%
• ^{40}K	1.2%
• ^{39}Ar + ^{85}Kr	46.8%



^{39}Ar abundance Measurement

The ^{39}Ar is a constant background in an argon detector...

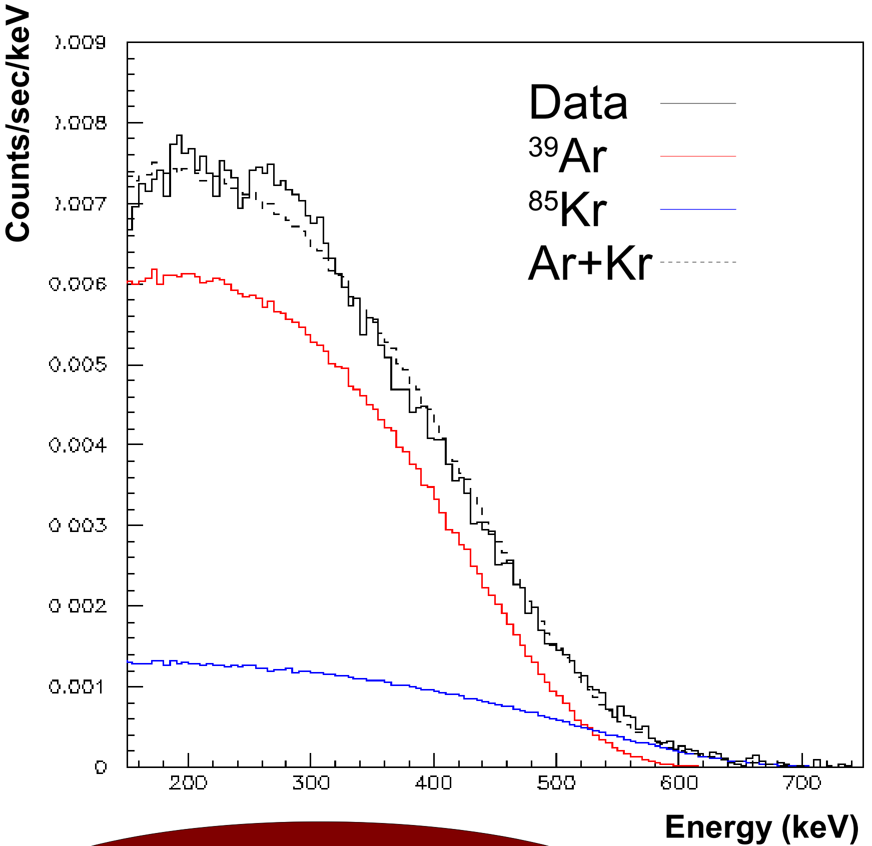
$^{39}Ar \rightarrow {}^{39}K + e^- + \overline{\nu}_e$ (Q = 565 keV)

Measured activity in agreement with the abundance of ^{39}Ar in natural Argon gas from:
H.H.Loosli, Earth and Plan. Sci. Lett., 63 (1983) 51-61

only 3% of ^{39}Ar decays will produce an event in the signal energy range (30-100 keV).

The expected rate due to ^{39}Ar in the 100l/140kg setup in the ion recoil evergy window is ~ 3.3 Hz

Spectrum after subtracting events from U and Th chains.



Measured Activity of ^{39}Ar (1.18 ± 0.11) Bq/liter

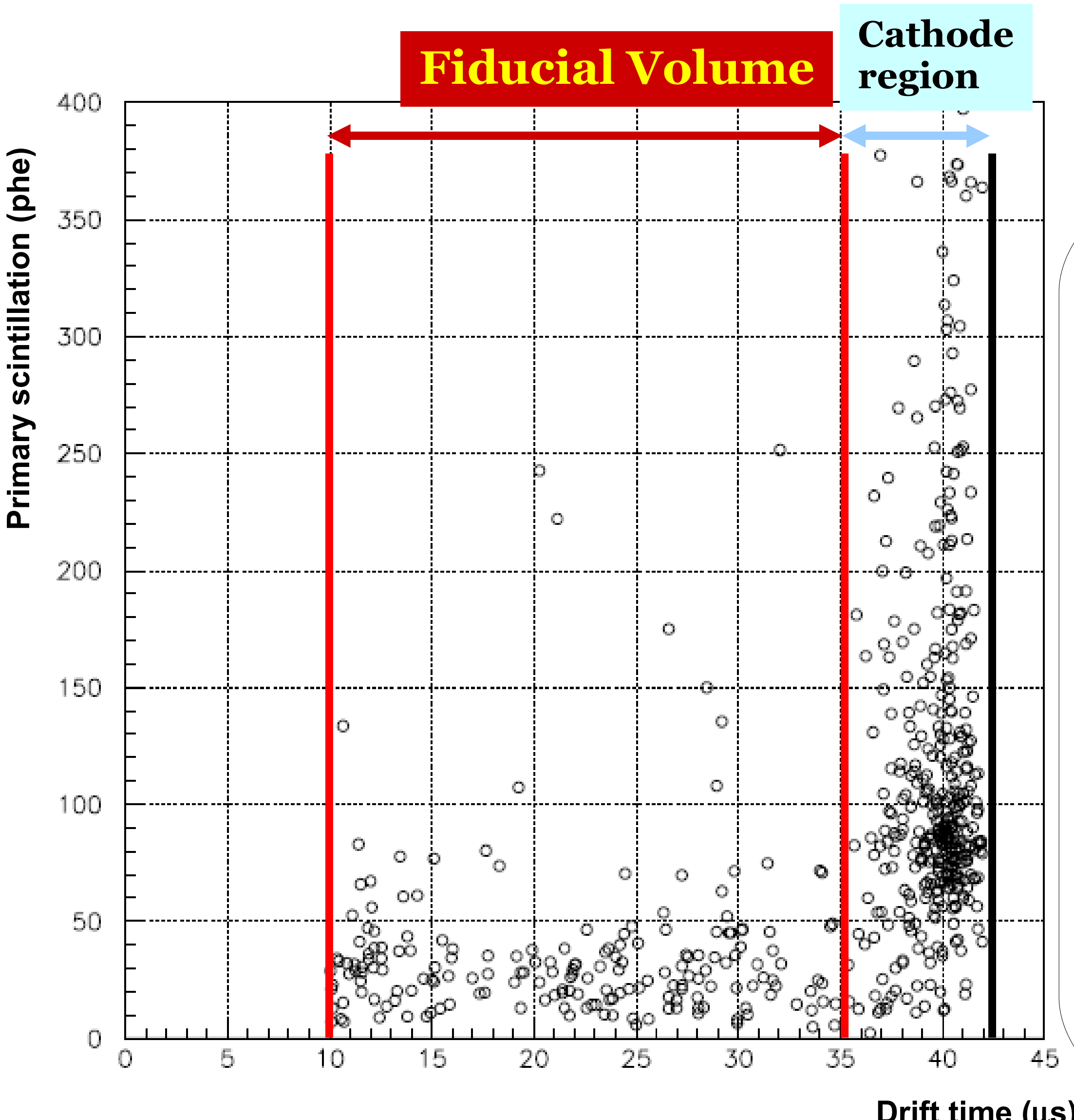
The ^{39}Ar Background in the 100l detector

In the full detector (100l/140kg) ^{39}Ar is expected to induce about 3.3 evts/s.

To reduce this rate to less than 1 evts/100 days one needs, a total rejection power of the order of **3×10^{7}.**

An additional possibility is isotopic separation.
One can reduce the abundance of ^{39}Ar by two to three orders of magnitude. This could further increase the sensitivity.

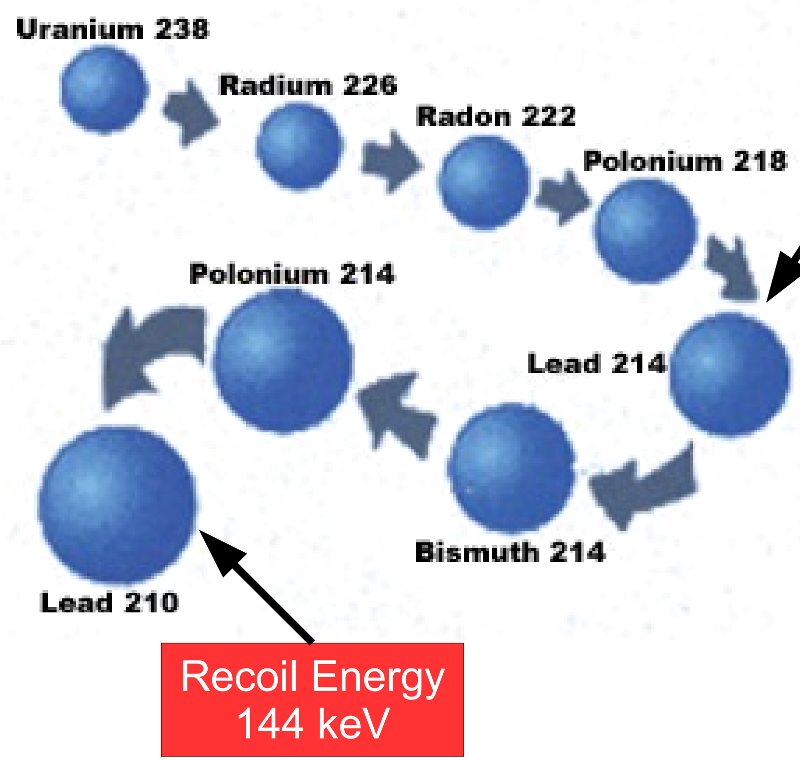
Analysis of Recoil-like events.



Data sample from 13.4 days of live time, (June 2005)

- Expect to see environmental neutrons(external gamma bckgd. reduced by 10 cm lead shielding).
- Events selected using s2/s1 and primary rise time
- Drift time cuts applied to select fiducial volume
- Events visually scanned
- 6.5 mil. triggers, 190 evts in fiducial volume 388 in cathode region
- R-like cathode events mostly ^{222}Rn and daughters, fiducial volume are neutron like

^{222}Rn and daughters



Recoil Energy
110 keV

Natural Argon is contaminated with ^{222}Rn. Whenever the Ar is exchanged in the chamber an amount of Rn is also introduced.

Daughter nuclei of Rn are produced in an ionized state and are drifted to the cathode or stick on the walls of the chamber.

Their decay may lead to either the α, β particles or the Heavy Ion entering the LAr.

In the second case a R-like event is observed. (most are expected near the cathode region)

^{222}Rn has the longest half-life (3.8 days)

The daughters' decay time is of the order of minutes

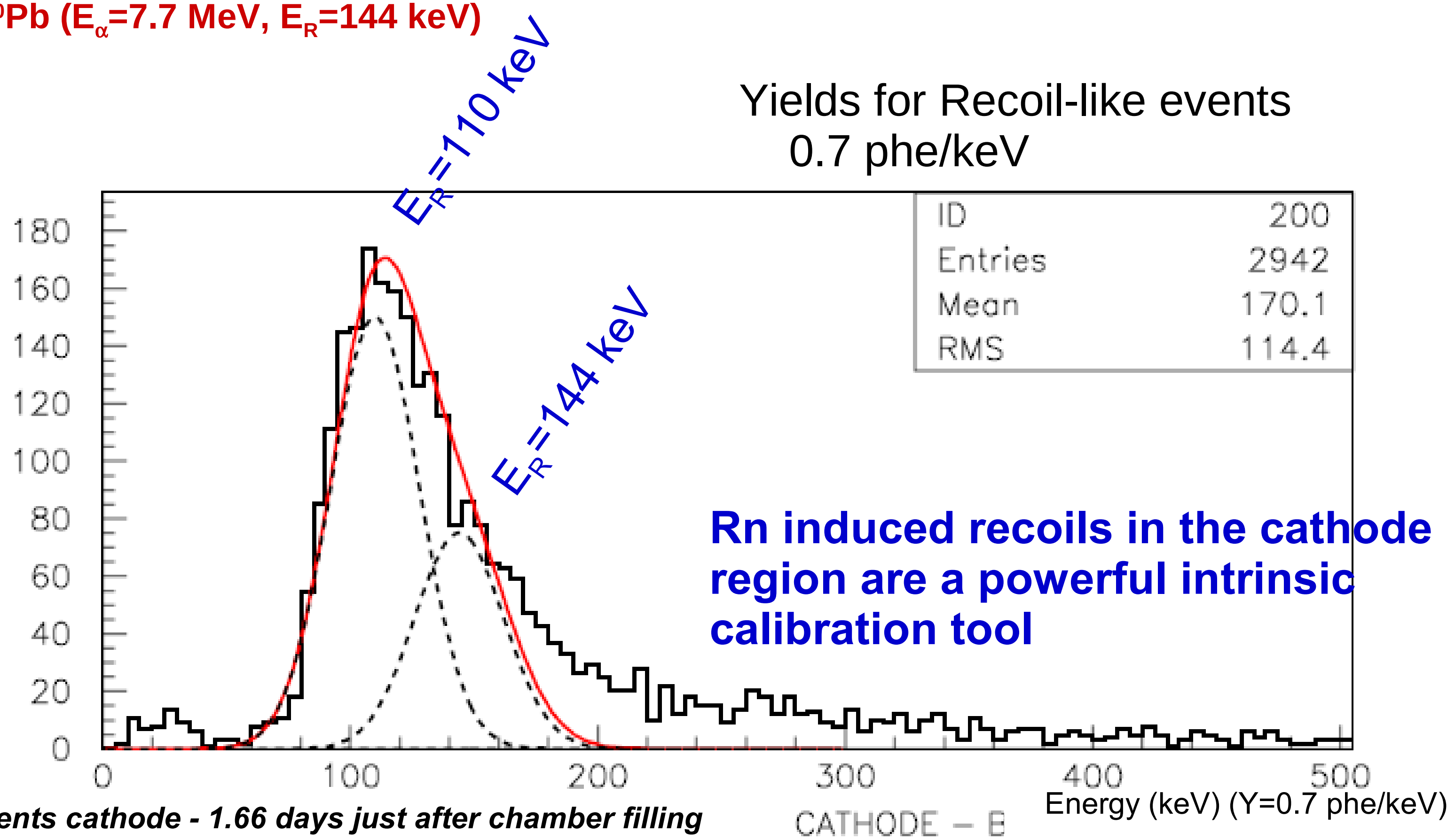
Cathode events as a calibration tool

The decays in the Cathode region can be fitted with gaussians of expected energy. This gives a very good calibration of the detector.

$^{218}Po \rightarrow {}^{214}Pb$ (E_α=6.0 MeV, E_R=110 keV)

$^{214}Po \rightarrow {}^{210}Pb$ (E_α=7.7 MeV, E_R=144 keV)

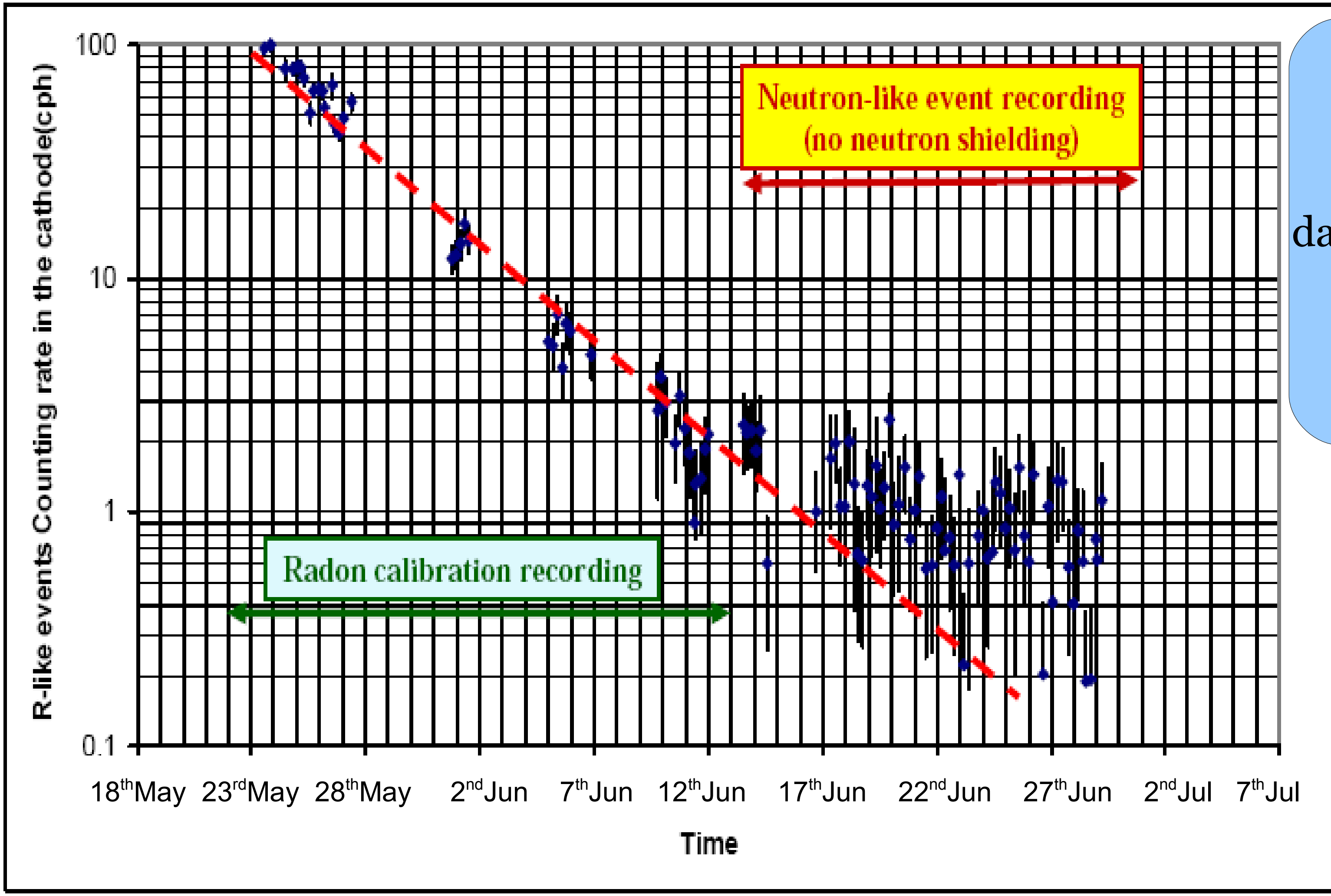
Yields for Recoil-like events
0.7 phe/keV



Rn induced recoils in the cathode region are a powerful intrinsic calibration tool

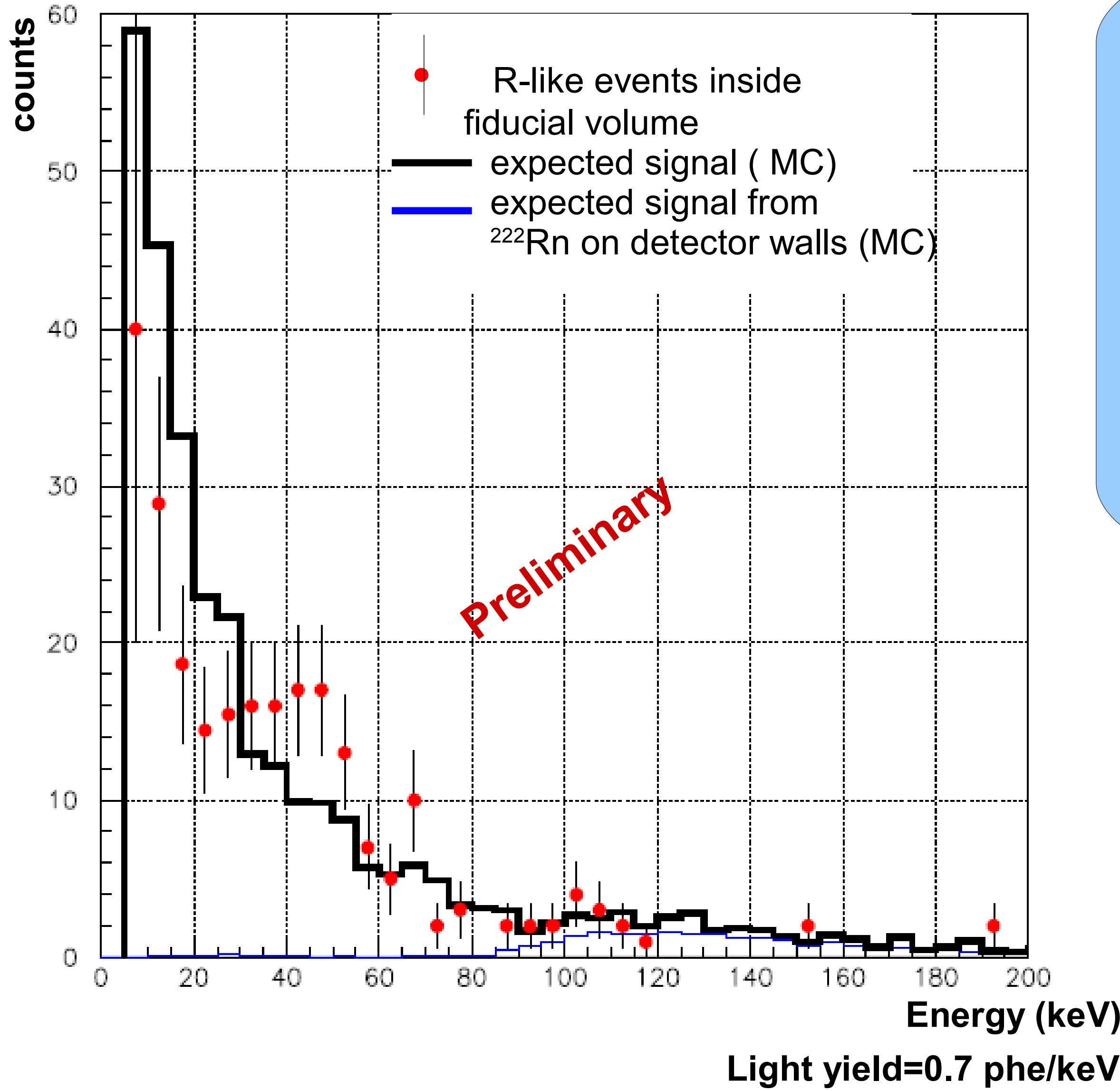
R-like events cathode - 1.66 days just after chamber filling
The sample is enriched in Rn induced signals

^{222}Rn background in time



Short decay times of Radon and its daughters, make them insignificant after about 1 month

neutron-like events



The energy spectrum of recoil events is compared to the signal expected from the environmental neutron background in LNGS
(Astrop.Phys. 22(2004) 313)
The light yield (0.7 phe/keV) is deduced from Radon events.

The event rate and the shape of the energy spectrum are in good agreement with a signal expected from the neutron background in the underground laboratory (Monte Carlo simulation).

current status

The Run with the test prototype ending in December lasted 149 days

44 days done with full neutron shielding.

about 80 kg day live time.

Data currently being analyzed.

In January, the prototype will be refurbished and setup again.

The construction of the main detector also begins.

Conclusions

The WARP programme's next phase will be the construction of the 100 l detector at LNGS

The runs with the current prototype have been successful in providing input for the main detector as well as physics results on its own.

The data with the neutron shielding are being analyzed.

For further information:
http://warp.pv.infn.it/

Based in part on talks by
N.Ferrari
and A. Cocco