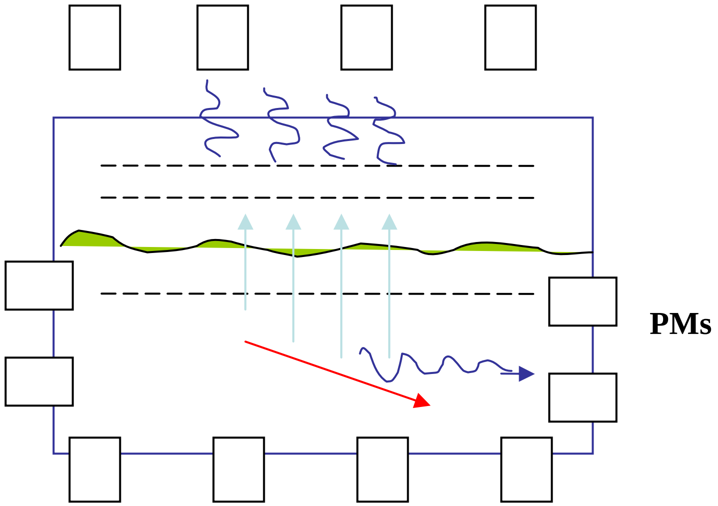
Photosensitive Gaseous Detectors for Cryogenic Temperature Applications

- L. Periale[1], V. Peskov[2], C. Iacobaeus[3], B. Lund-Jensen[4], P. Picchi[1], F.Pietropaolo1, Rodionov[5]
- *[1]CERN, Geneva, Switzerland*
- *[2]Pole University Leonardo de Vinci, Paris, France*
- *[3]Karolinska Institute, Stockholm, Sweden,*
- *[4]Royal Institute of Technology, Stockholm, Sweden*
- *[5]Raegent Research Center, Moscow, Russia*

Introduction

A concept of the LXe WIMP detectors based on the extraction of the tracks from the LXe.



Light multiplication between two metallic meshes.

- There are several proposals and projects to build LXe detectors for dark matters (Weakly Interacting Massive Particles-WIMP) search.
- The concept of this detector is illustrated in the Figure. It is a LXe TPC which has the possibility is to extract the electrons from the track into the gas phase, where they can be detected by producing a scintillation light in the vapours.
- This concept is implemented in the ZEPLIN and XENON projects.

- An important component of the TPC is the photo-detector.

- Until now vacuum photo-multipliers (PMs) were usually used. Some preliminary tests were also done with solid–state avalanche detectors (see for example, E. Aprile et al ., Phys/0501002 and 0502071, 2005).

- In recent Conferences (Vienna Wire –Chamber Conf.- 2003, IEEE-2004 and Beaune- 2005) we presented some preliminary results demonstrating that gaseous detectors with solid photo-cathodes can operate at low temperatures. This opens the possibility of replacing the costly and bulky PMs or costly solid state detectors with **cheap and simple photosensitive gaseous detectors.**

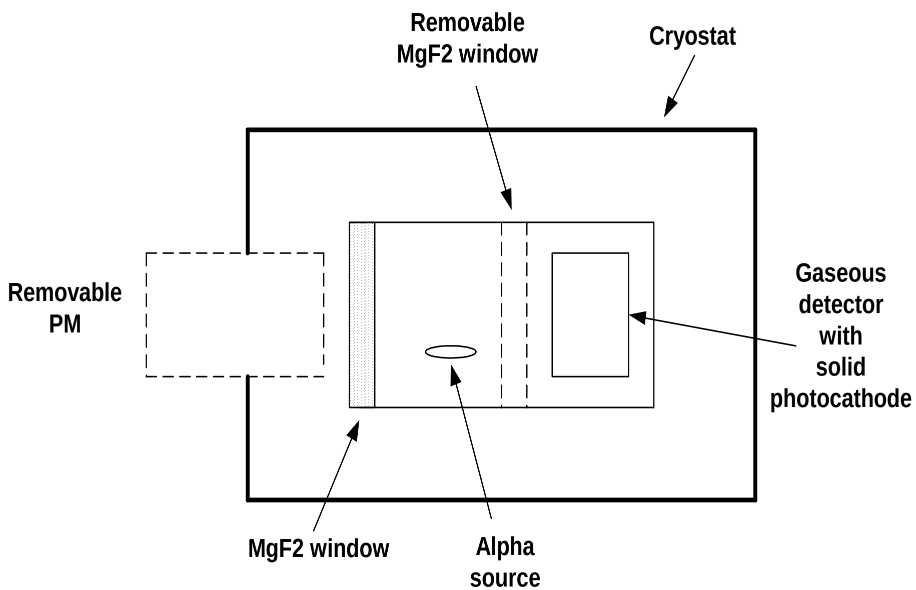
- In this report we present new unpublished yet results from the systematic studies of the operation of the gaseous detectors combined with reflective and semitransparent CsI photocathodes in the temperature interval 300-165 ^{o}K (LXe).

- Special focus was drawn on the studies of their long-term stability, which is an important issue for their real applications.

Experimental Set Up

- Two experimental set ups were used in this work

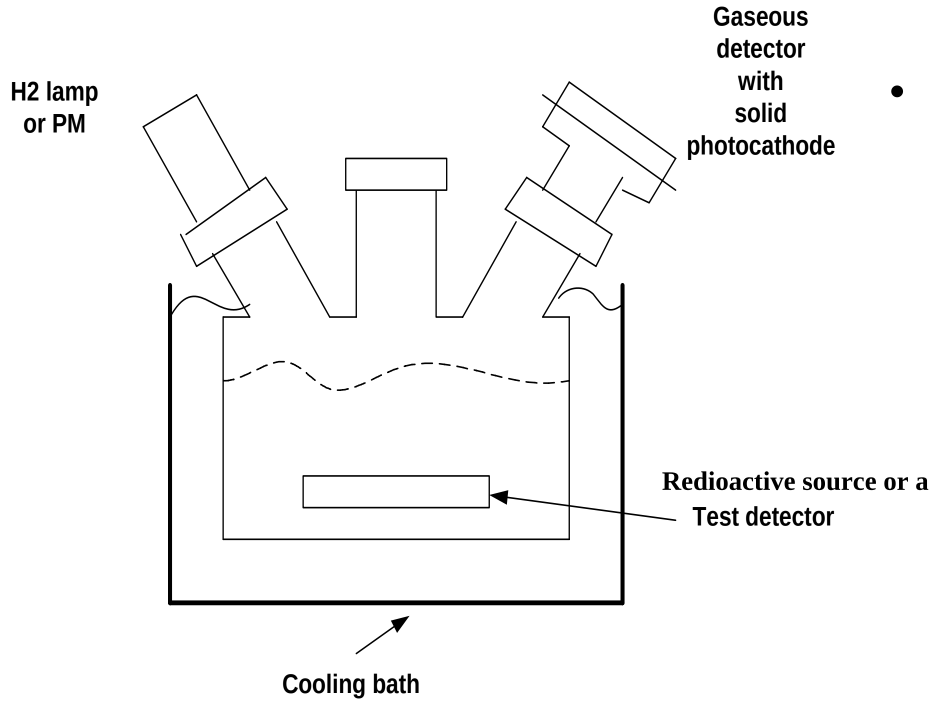
First Experimental Set Up:



- It consists of a cryostat, inside which a test vessel was installed. The test vessel consisted of: a gas "scintillation" chamber filled with noble gases (Ar or Xe) and contained an alpha source (^{241}Am) , a gaseous detector with CsI photocathodes attached to the "scintillation" chamber and the PM monitoring the primary scintillation light produced by the radioactive sources.

- Two types of photosensitive defectors were tested: sealed detectors with MgF_2 windows and windowless detectors able to operate in cooled noble gases.

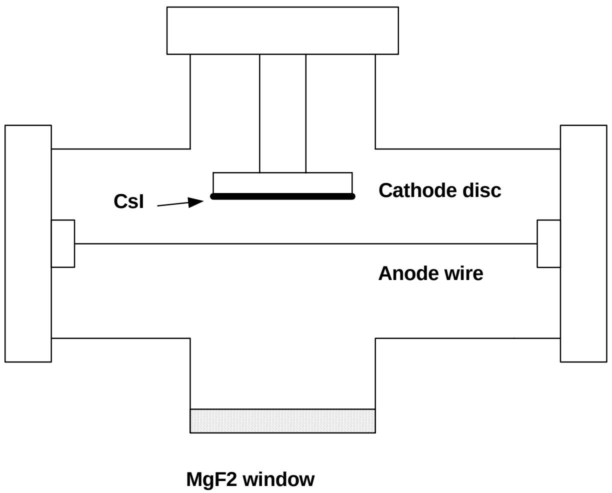
Second Set Up:



- **The second set up was a chamber which could be immersed into the bath cooled with the LN_2 or other liquids. It allowed several independent studies to be carried out, for example, detection of the scintillation lights from (175 nm) LXe by a PM or by a gaseous detector with CsI photocathodes.**

Detectors used : a single wire counter (a), capillary plates (b)

a)



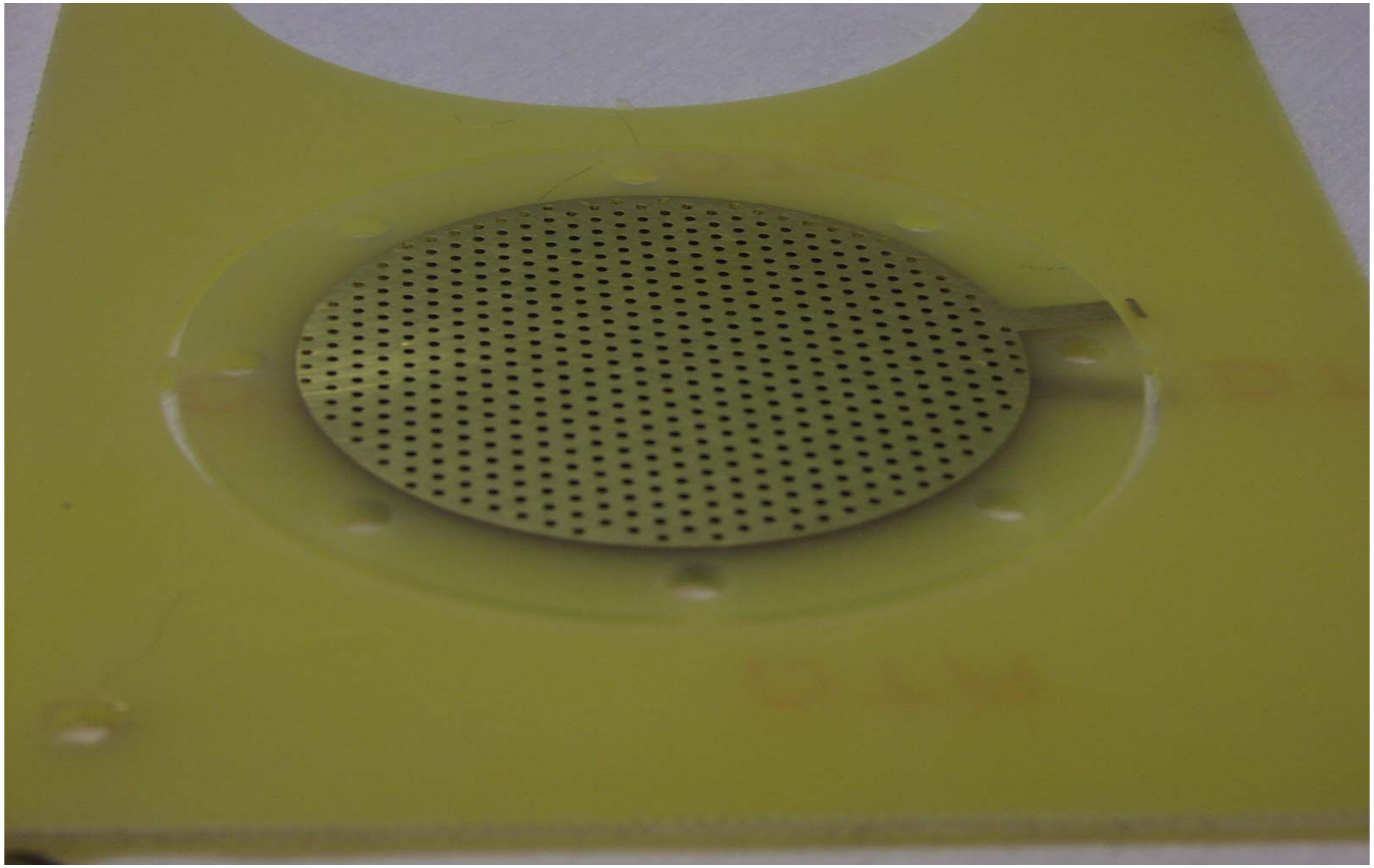
In case of semitransparent CsI photocathode
It was was evaporated on the MgF_2 window.

b)

Hamamatsu capillary plate.

Diameter of 25 mm,
thickness of 0.8 mm,
diameter of holes - 100 μm

c) Home-made “capillary plate”

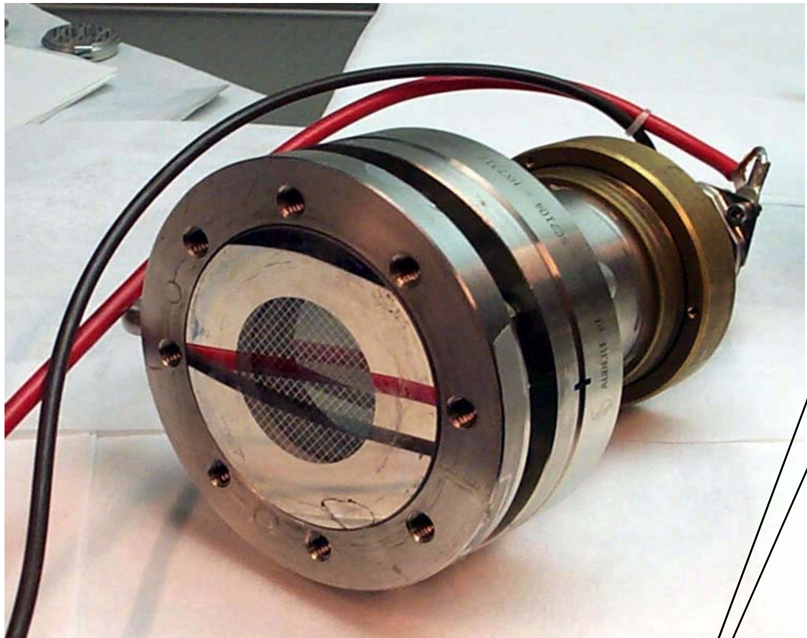


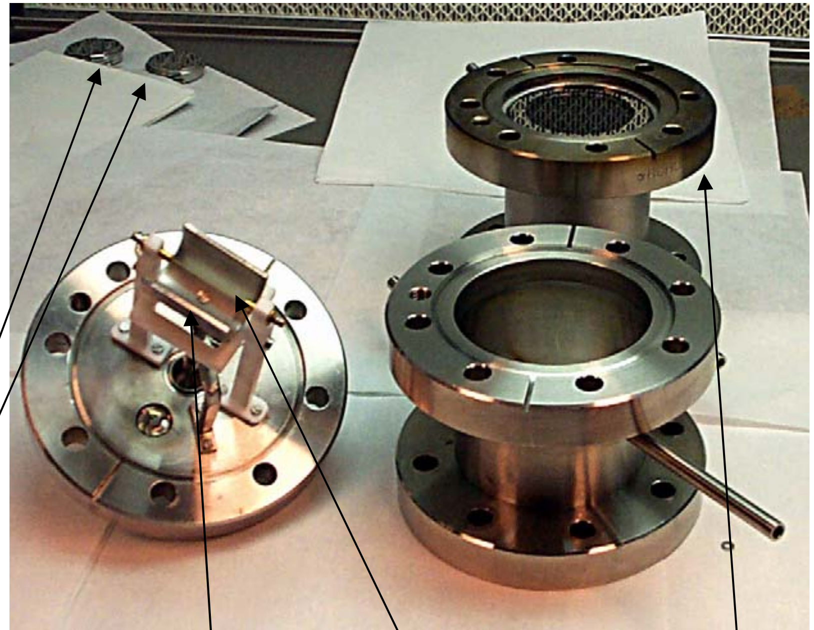
Circut board G10, with drilled holes, coated with CsI.

- **In this work two types of CsI photocathodes were tested: a reflective and a semi-transparent one.** See details below.

- In the case of the reflective photocathode, the CsI (0,4 μm in thickness) layer was deposited on the cathode's surface.
- The semi-transparent CsI photocathodes (20 nm in thickness) were evaporated on to the inner surface of the MgF_2 window(coated by a Cr film), separating the detector's volume from the scintillation chamber.

Photos of the main parts from the first set up.



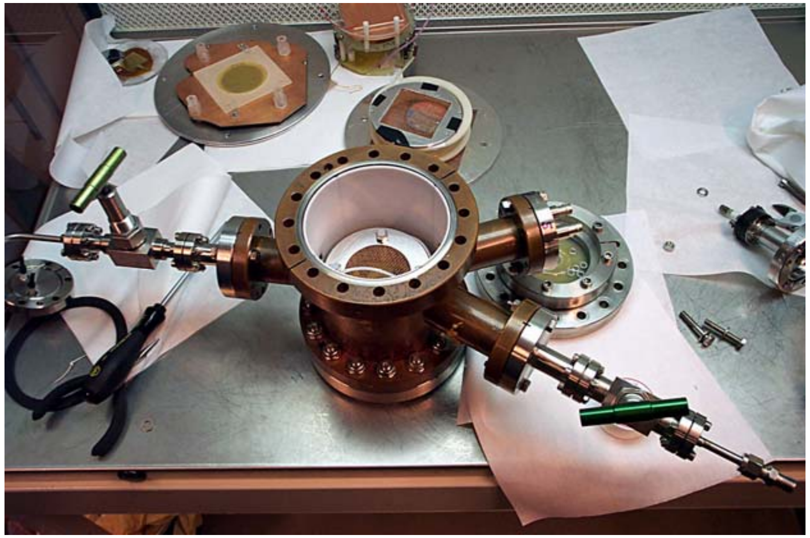


PM with a MgF_2 window

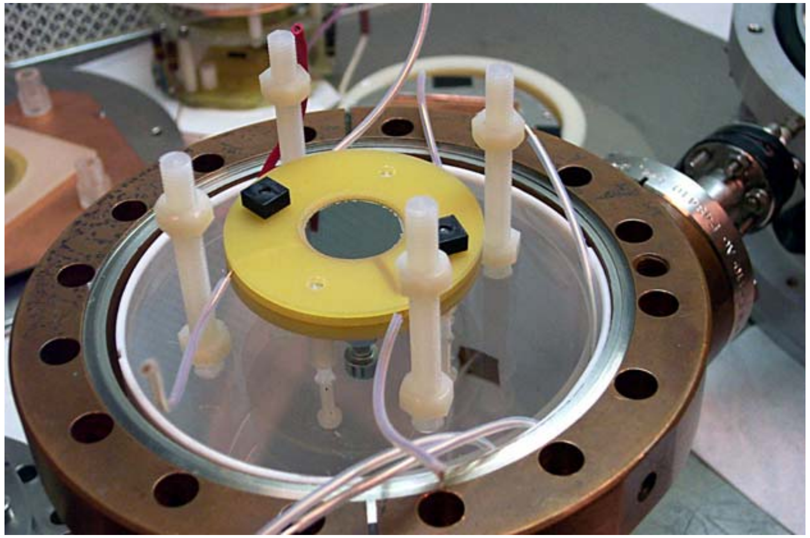
Capillary plates

One of the designs of a single wire detector
with a reflective CsI photocathode.
On the back of the picture-a scintillation chamber.

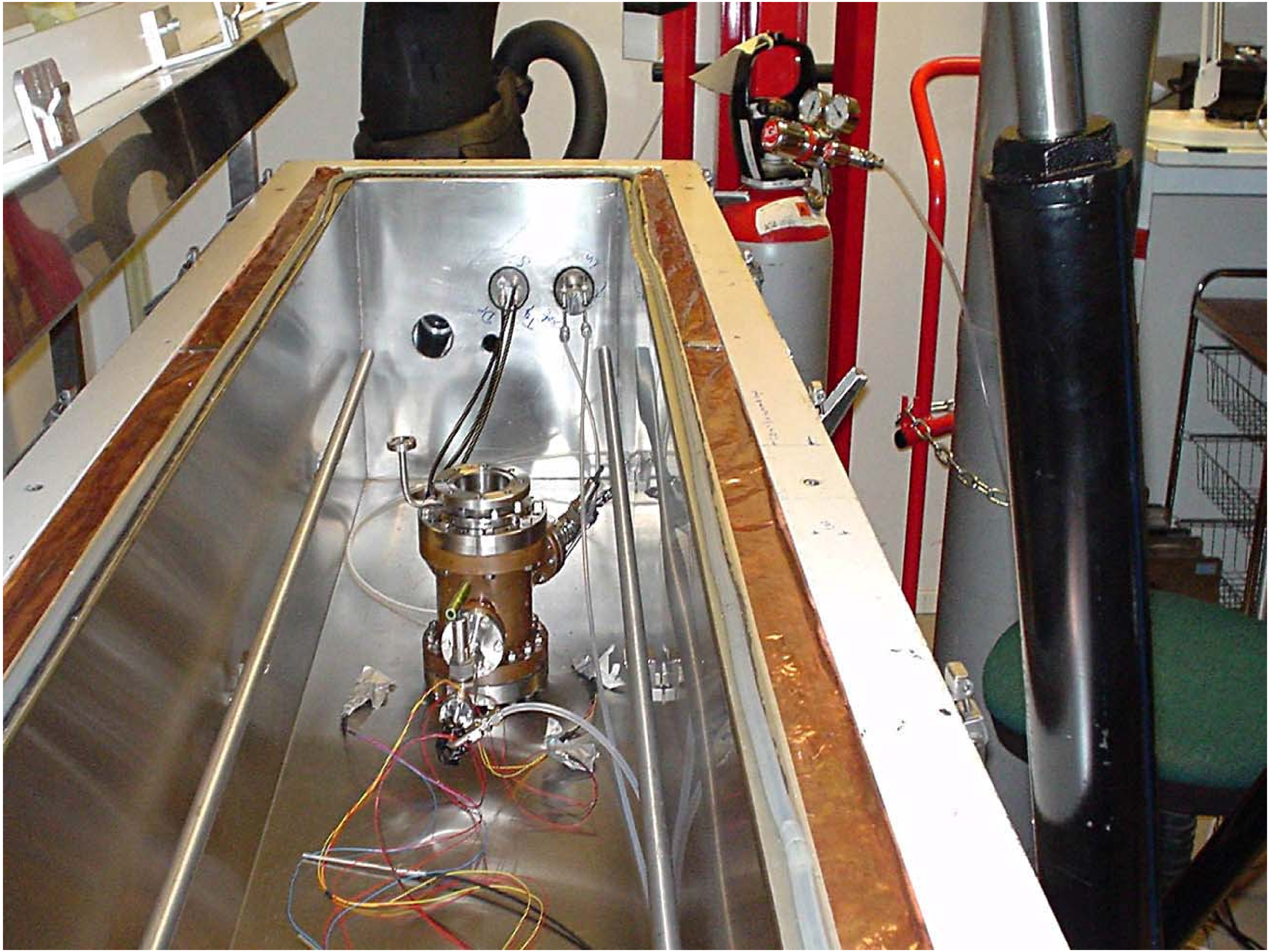
Photo of the chamber with capillary-type detectors (CPs) inside:

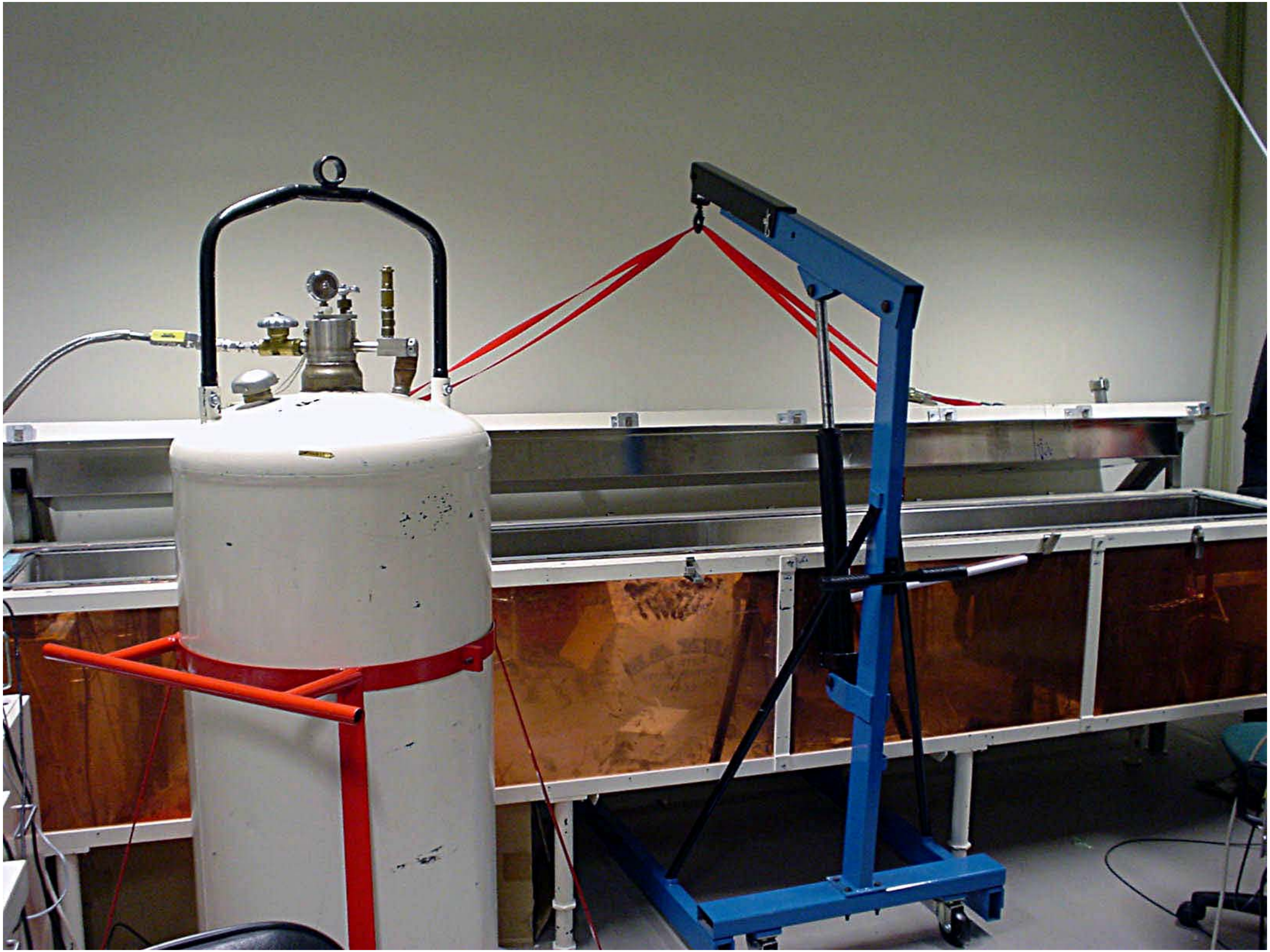


A chamber which could be immersed to the bath cooled with LN_2 or other liquids



Double capillary plate before being installed inside the chamber





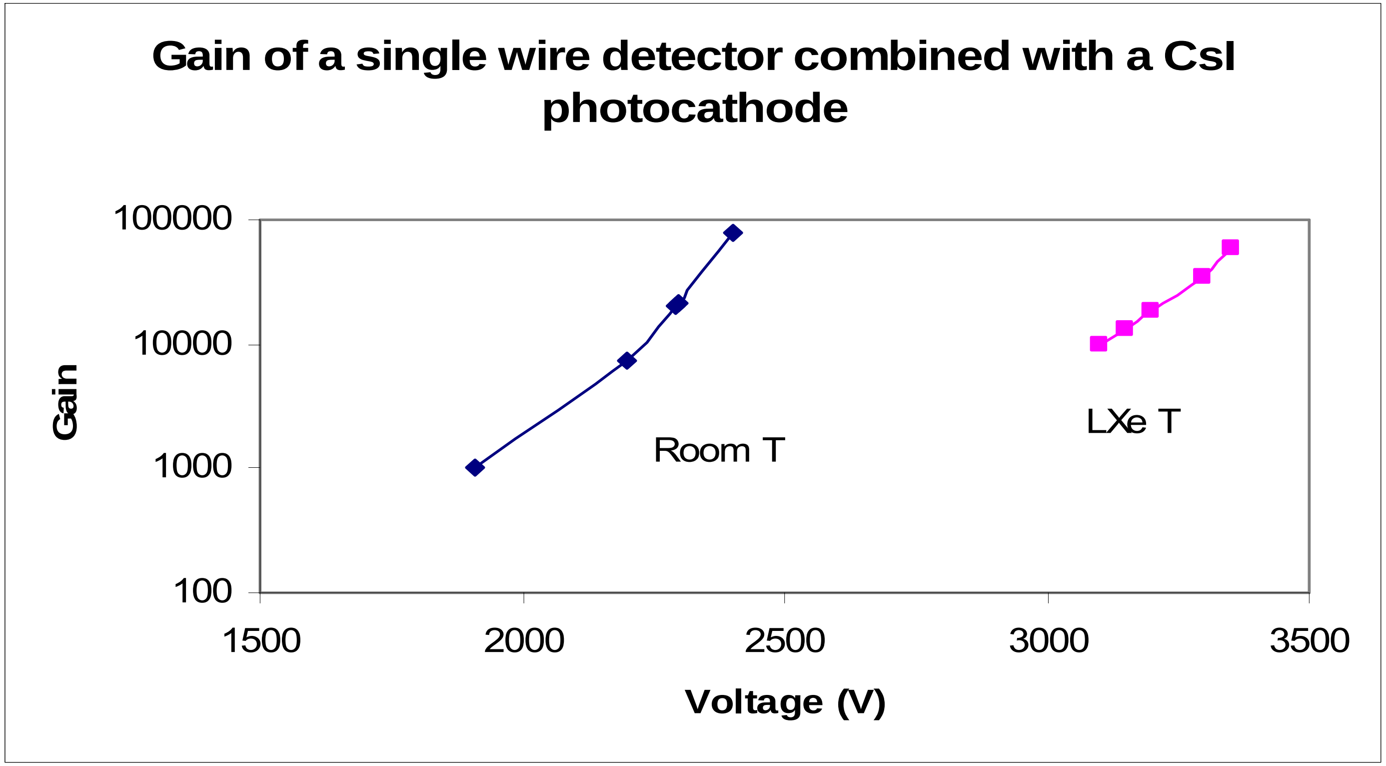
Power supplies with floating high voltages:

- Designed and manufactured by us (C.Iacobaeus)
- christian.iacobaeus@radfys.ki.se
- Price for 6 supplies (with two HV outputs 2 kV each) ~$13000

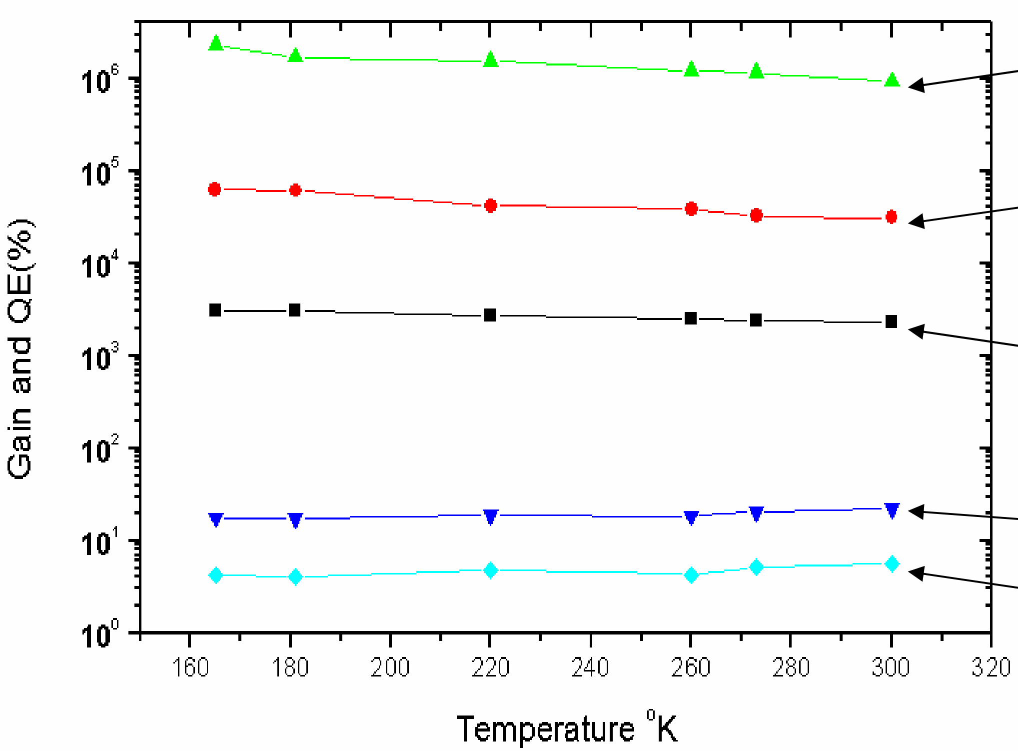
Results

- Results obtained with single-wire detectors

Example: gains vs. voltage for a single-wire counter flushed with Ar+10%CH_4 gas mixture at P=1 atm



Gain, voltage and QE vs. temperature in the case of a single-wire detector flushed with Ar+10%CH_4 at p=1atm



Maximum gain before corona discharge appears

Gain at which of first visible feedback pulses appeared(~10% from the main pulse)

Voltage vs. temperature at gain A=100

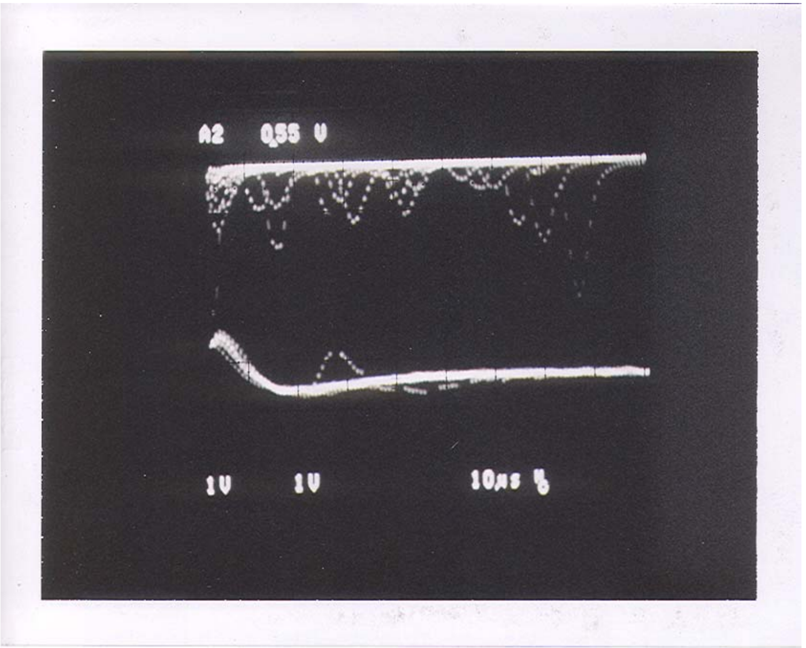
QE of a reflective CsI photocathode

QE of a semitransparent CsI photocathode

- **The QE of these photocathodes both in the vacuum and in a gas at some temperature intervals, including those which corresponded to LXe or LAr. For this a pulsed H_2 or a continues Hg lamp, was used with a system of UV filters. The absolute intensity of the light beam was measured by a calibrated Hamamatsu vacuum photodiode and the calibrated CFM-3 counter.**

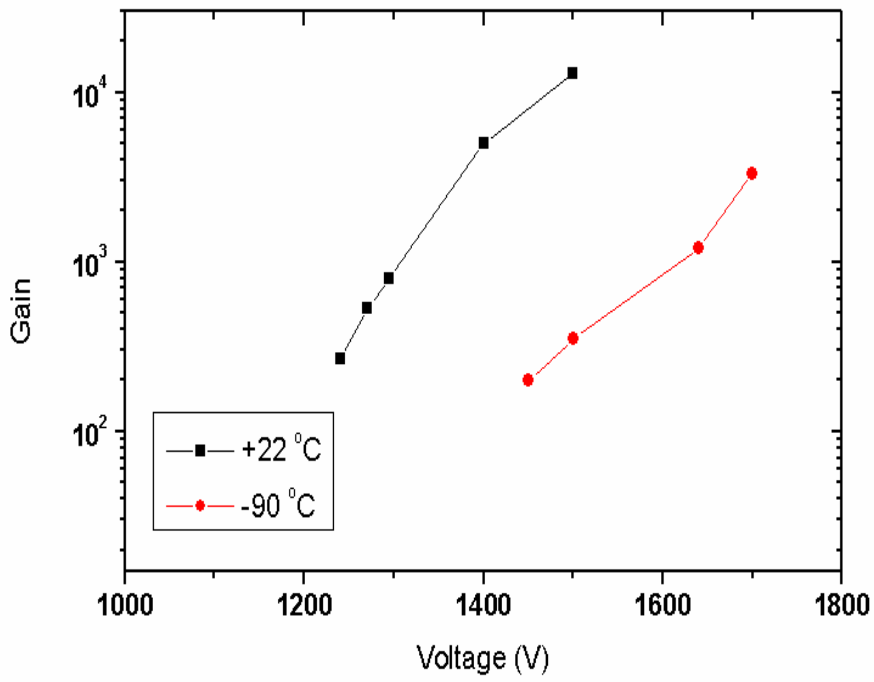
  See for detailes **physics/0403087** February 2004.

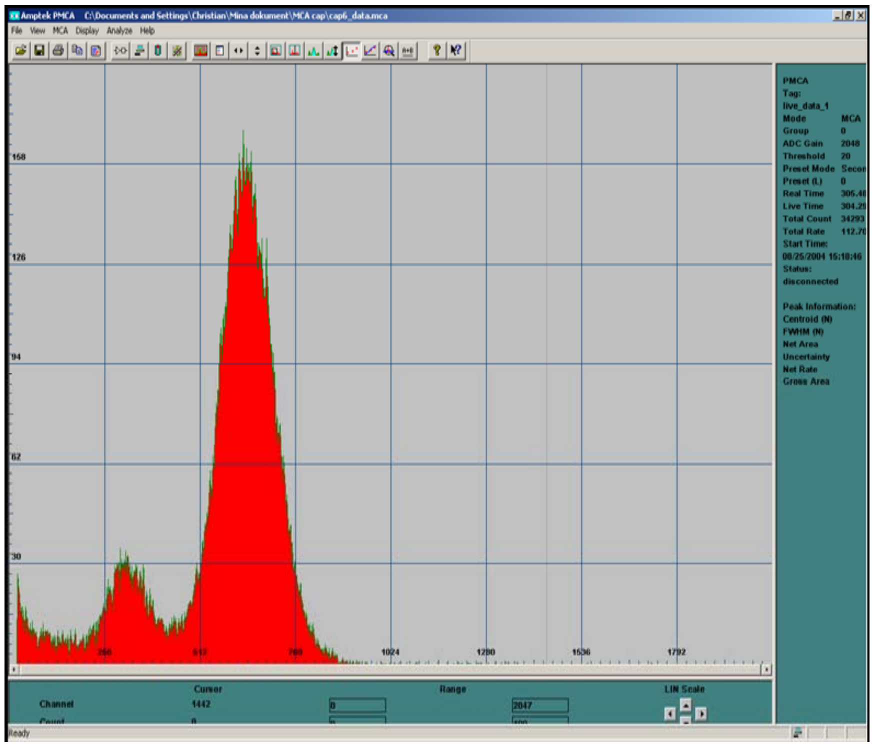
Simultaneous detection of the scintillation light (175 nm) from LXe (second set up) by a single-wire detector with CsI photocathode and by a PM (Schlumberger 541F-09-17)



- Upper beam-signals from the PM
- Lower beam –signals from the single –wire counter with a CsI photocathode
- Conclusion: the photosensitive gaseous detector offers a much better signal to noise ratio
- (for more details see: J.G. Kim et al., NIM 534 2004 376)

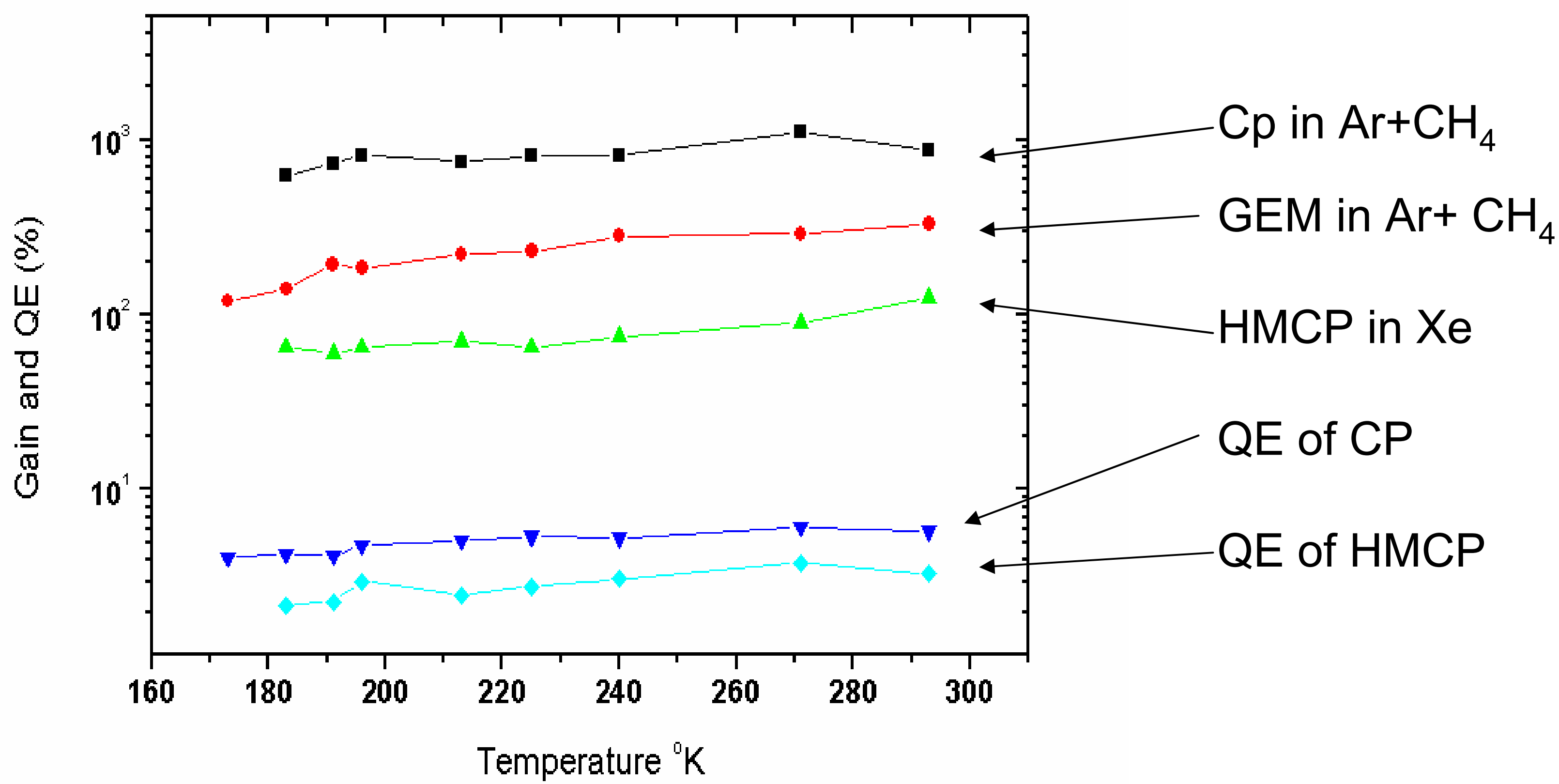
Example: gains vs. temperature for CPs flushed with Ar+10%CH_4 at p=1atm



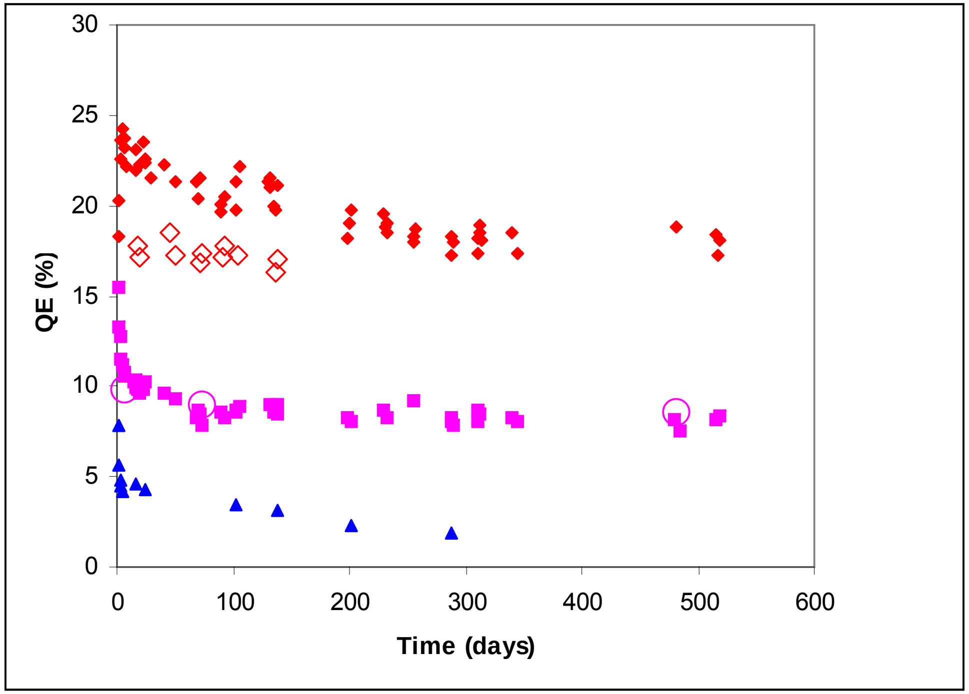


^{55}Fe

Combined results for hole type detectors coated with CsI layer.
Maximum achivable gain and QE.



Some results of long-term stability tests for single wire counters.



Single wire,flushed with Ar+CH4,reflective CsI photocqthode,
Room temperature

The same singlewire,
165K

Sealed singlewire,reflective CsI photocqthode,
Room temperature

The same detector at 165K

Single wire flushed,semitransparent CsI photocqthode,
Room temperature

Hole type detectors were tested for 160-200 days only and results were simillar (see Preprint Physics/0509077, Sept.2005)

Conclusions:

- For the first time it was demonstrated that sealed photosensitive gaseous detectors (single wire and hole-type) combined with semitransparent CsI photocathodes can operate at LXe temperatures. Semitransparent CsI photocathodes allow much a better light collection to be achieved in interface liquid-window.

- Single wire detectors combined with semitransparent CsI photocathodes can reach gains sufficient to detect single photoelectrons.

- HMCP with reflective CsI photocathodes can operate in pure Xe and thus could be used in vapors above the liquid Xe. However, several of such detectors operating in cascade mode are required to reach high gains. One should also demonstrate that HMCPs will be able to operate stably in the turbulent atmosphere above the liquid.

- For the first time long-term tests (of up to 1,5 year) for photosensitive detectors (sealed and flushed by gas) were performed.

- Obtained results show that photosensitive gaseous detectors (with windows and without) could be a cheap and simple alternative to PMs or avalanche solid-state detectors in LXe TPCs. The other potential advantage could be the possibility to manufacture them from low level radioactivity materials.