Purity monitor and TPC design for Xenoscope

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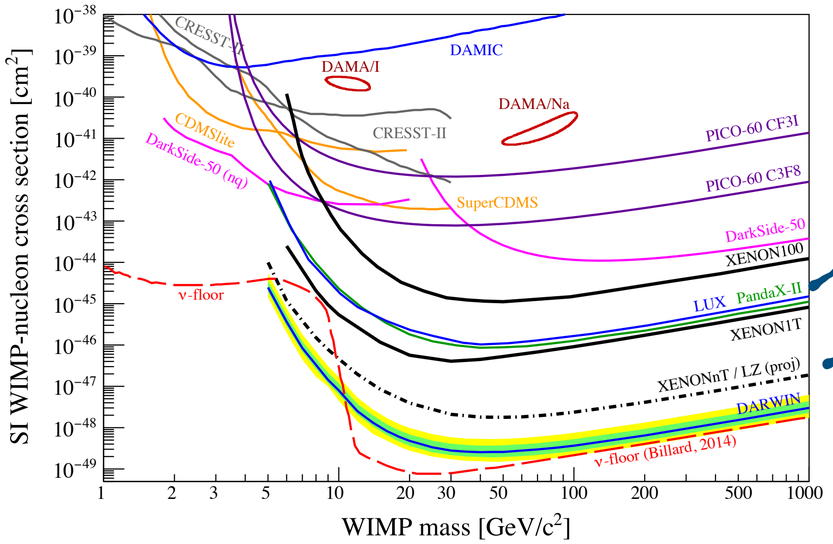
WIMP dark matter and DARWIN

University of Zurich[UZH]

Spin independent Cross Section for WIMPs

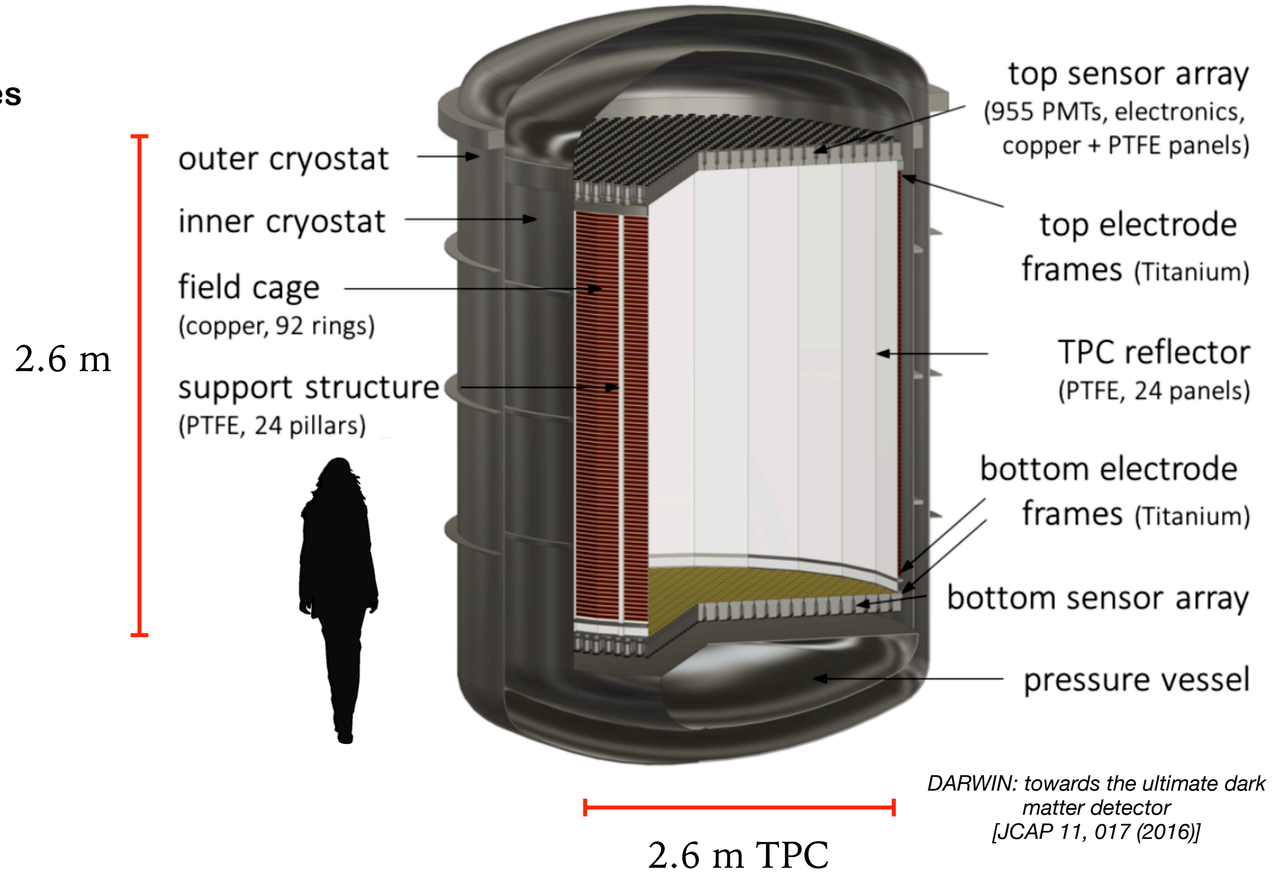


The highest sensitivity to WIMPs above 5 GeV/c² comes from experiments using liquid targets (Xe,Ar).

Current limits

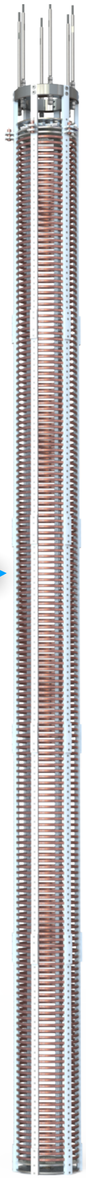
Future sensitivities

- **Dual-phase Time Projection Chamber (TPC)**
- **50t total (40 t active) of liquid xenon (LXe)**
- **Outer shield filled with water (12 m diameter)**
- **Neutron veto**
- **Drift field ~0.2 kV/cm**

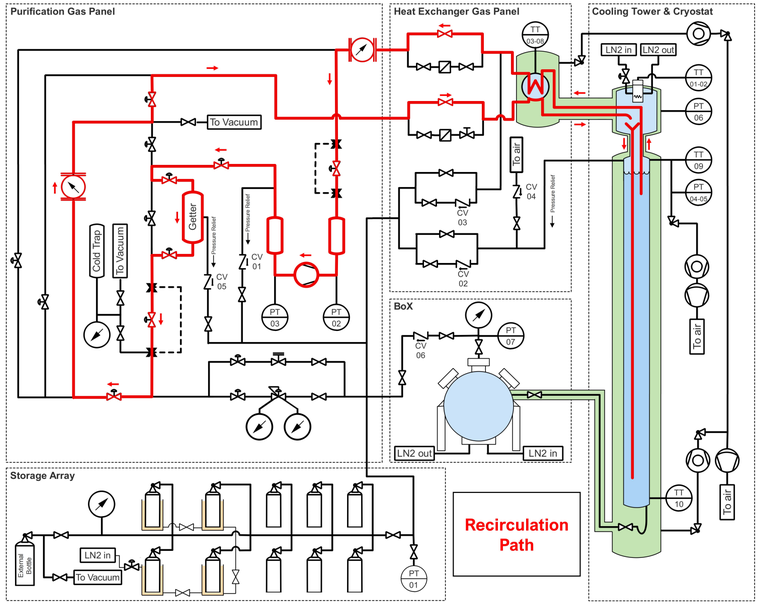


DARWIN: towards the ultimate dark matter detector [JCAP 11, 017 (2016)]

Xenoscope Project at UZH

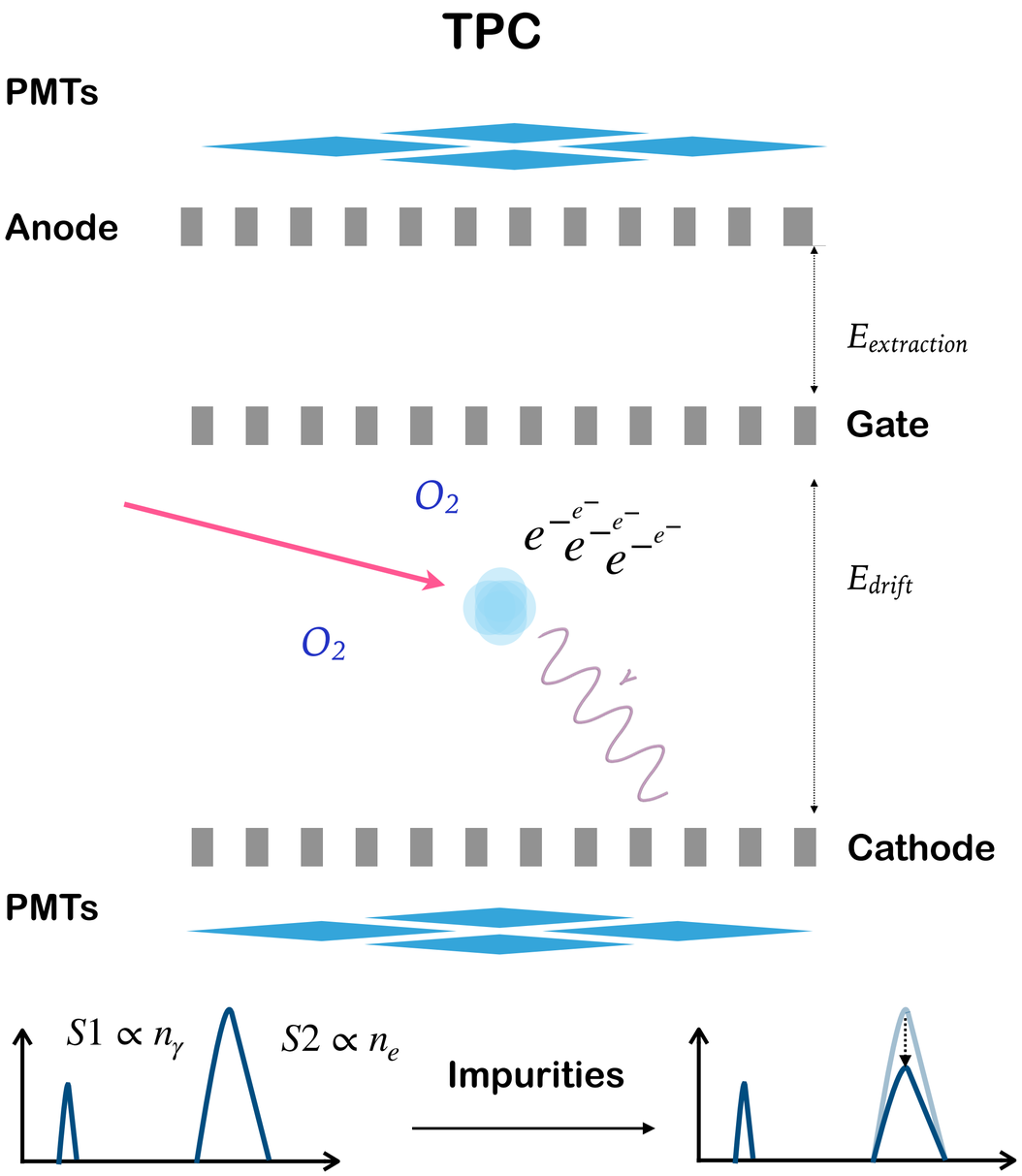


- 2.6m Time projection chamber
- Gas recirculation
- -50kV in the cathode

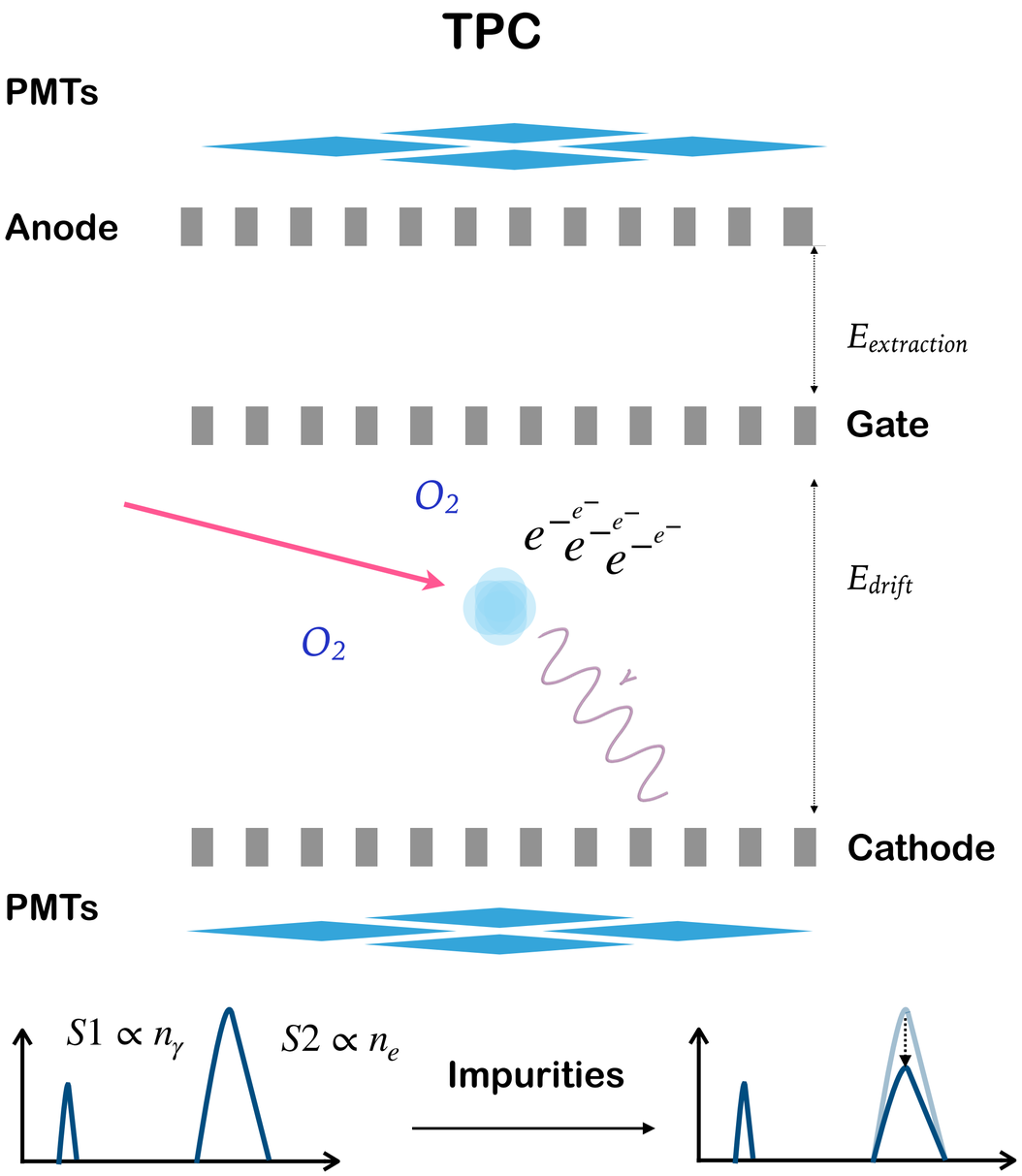


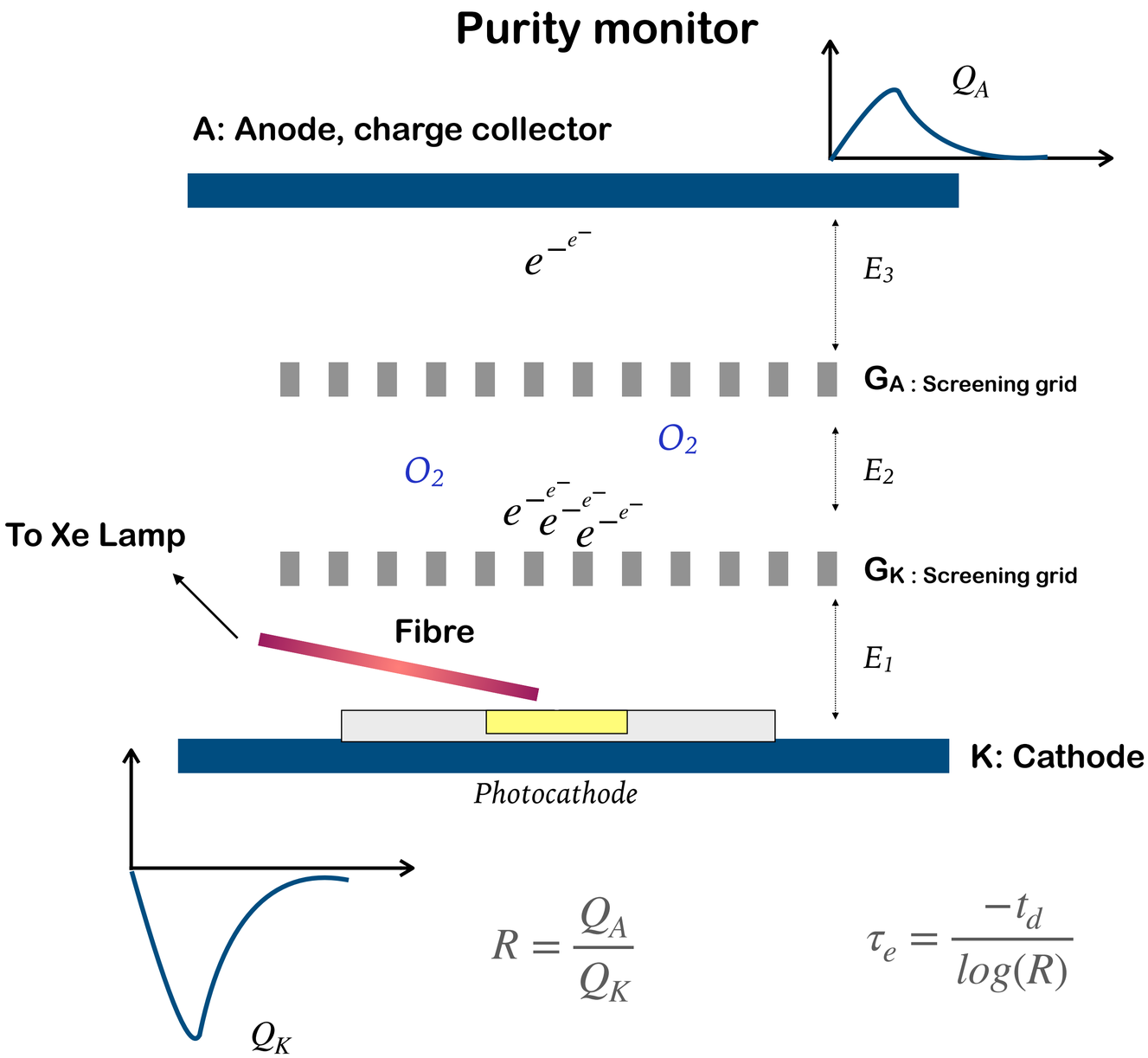
- Drift electrons over 2.6 meters
- Modular design compatible with the integration of different photosensors and technologies
- Facility to study LXe properties (diffusion, optic attenuation…)
- HV systems in LXe (Power Supply, HV feedthrough, filters, connections)

Purity Monitor concept



Purity Monitor concept

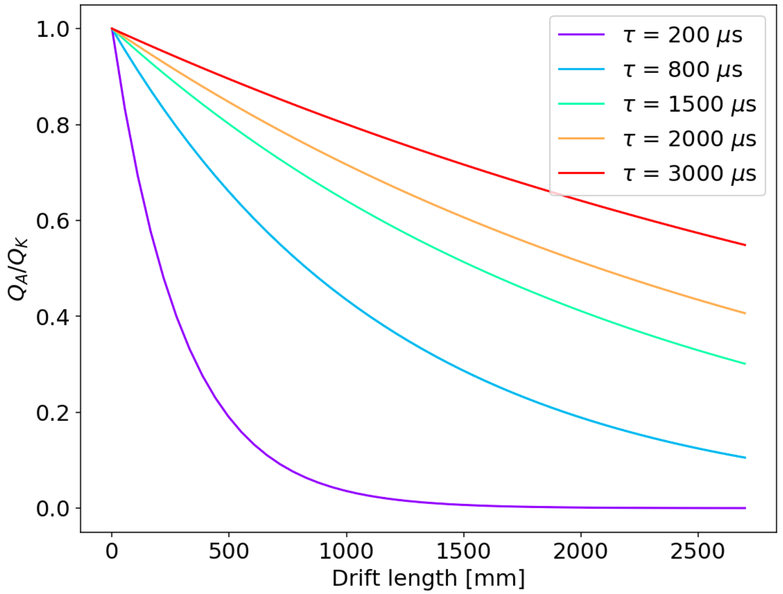




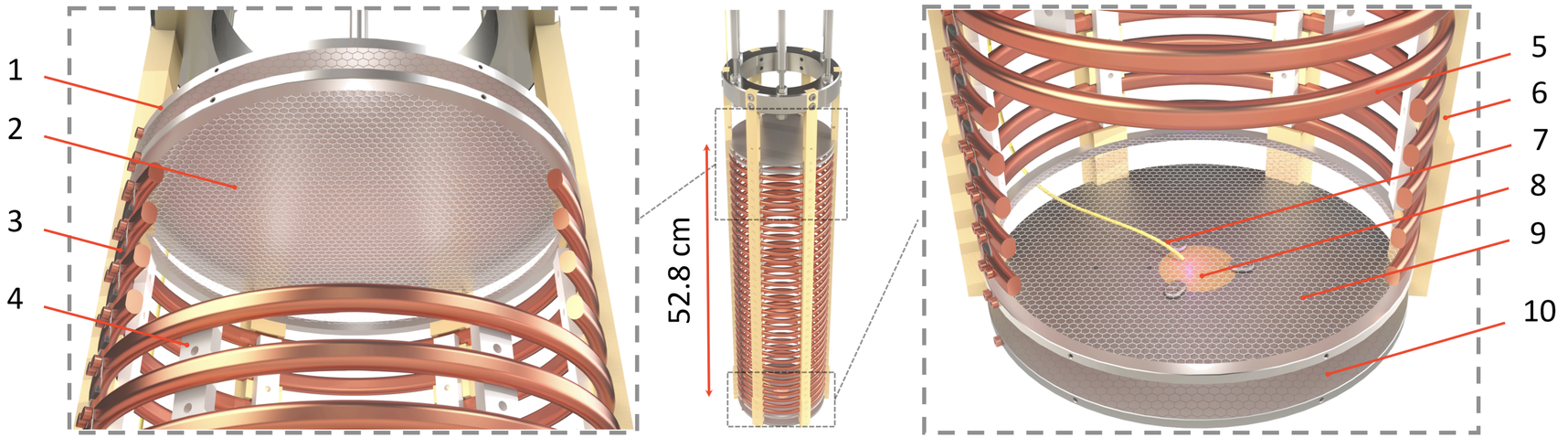
Purity Monitor design for Xenoscope

Integrated Purity monitor

- Easy and instant monitoring of the LXe purity
- Electron arrival times can be used to estimate electric field homogeneity
- No necessity of PTFE walls
- Provides a clear trigger
- Compatible with adding the GXe phase



Instrumenting the first module of the TPC as a PM as a proof-of-concept

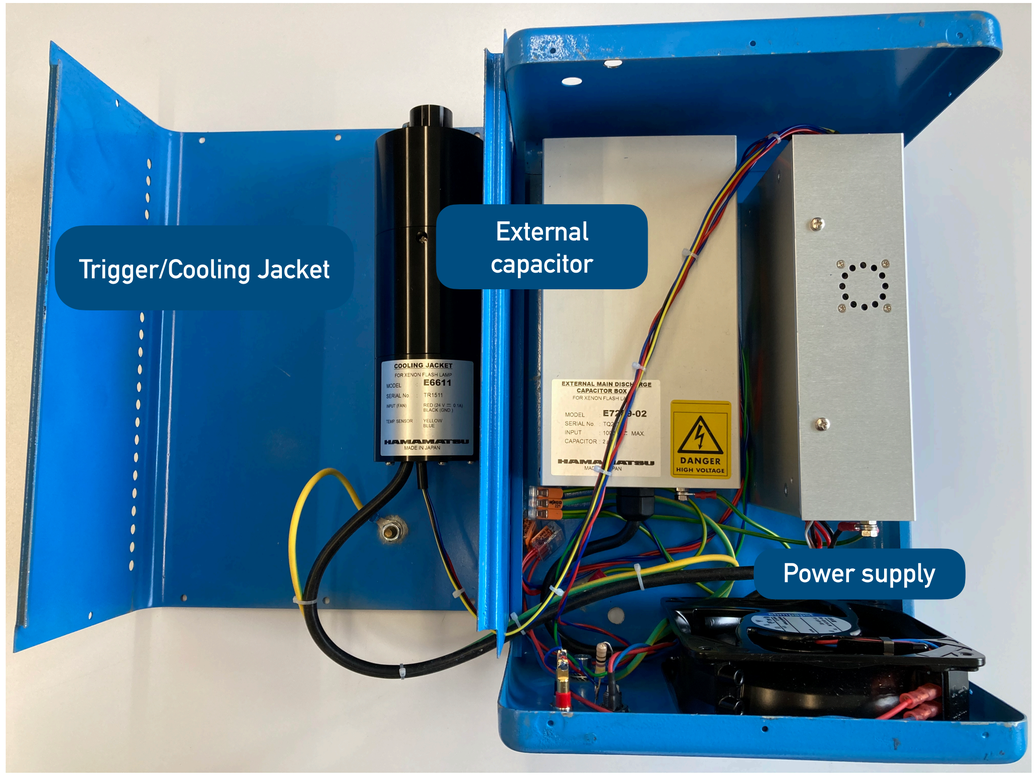


1. Charge Collector
2. Screening Mesh
3. Resistor chain
4. Interlocking PTFE blocks
5. Field Shaping Ring
6. Torlon pillars
7. Optical Fibre
8. Thin film photocathode
9. Screening Mesh
10. Cathode (up-to -10kV first)

Xenon lamp

University of Zurich[UZH]

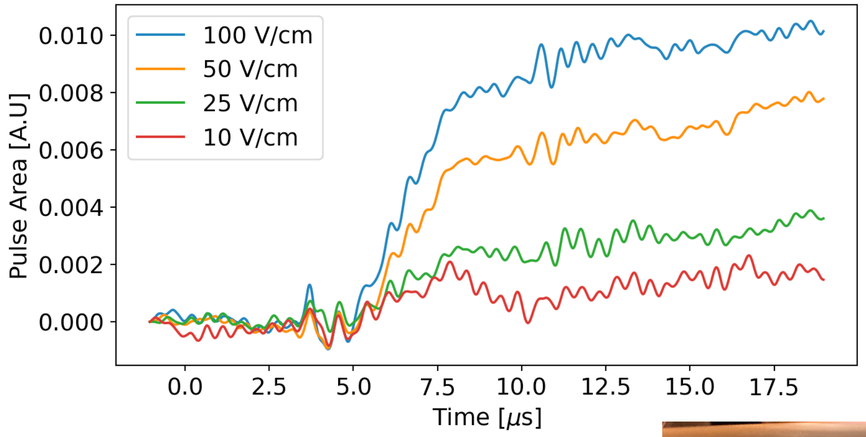
Hamamatsu xenon flash lamp



Discharge of up-to 1kV

Adjustable internal trigger but can be triggered externally

However: Extremely noisy! Roughly to signal level (~1V). The initial aluminium housing wasn't enough to prevent the noise in other devices

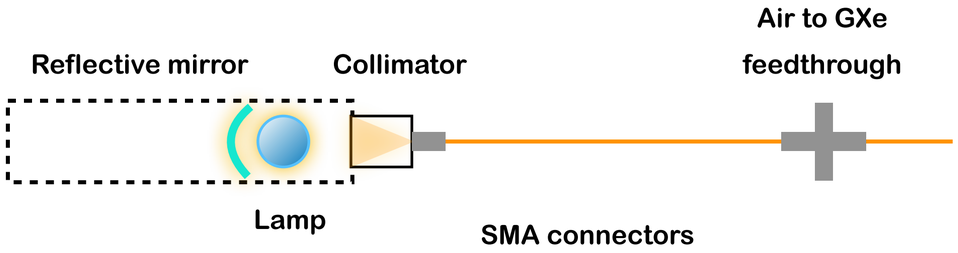


Rehoused in stray electromagnetic interference box

UV sapphire lens with a SMA connector (Hamamatsu) to increase the light collected by the fibre

Expected charge and readout circuit

Estimating photoelectrons



1J

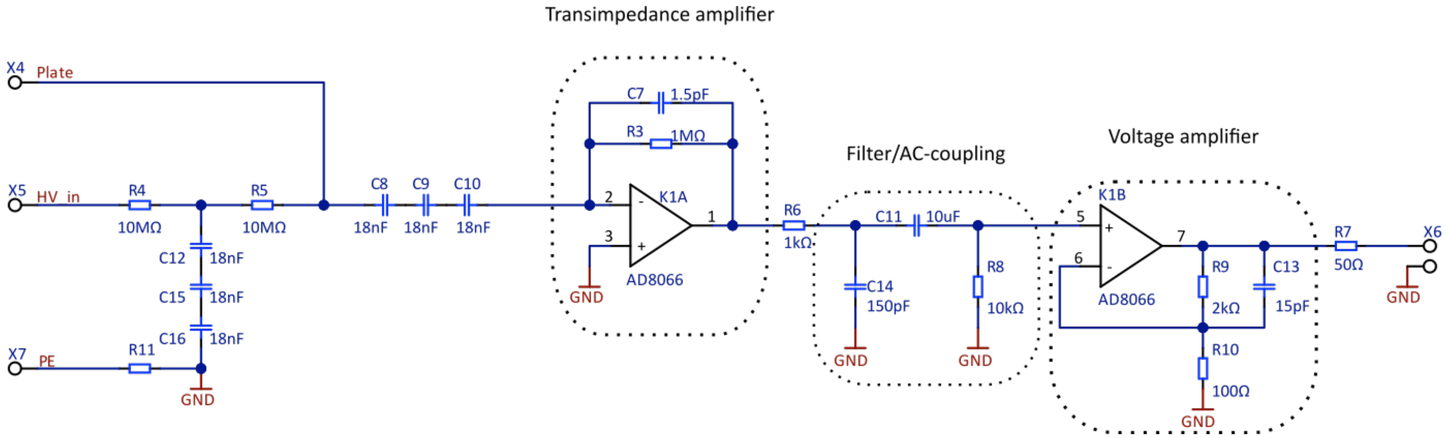
Attenuation, coupling

$$\text{Charge} \propto \text{Ps} \times \frac{\Omega}{4\pi} \times \text{QE} \times \text{losses}$$

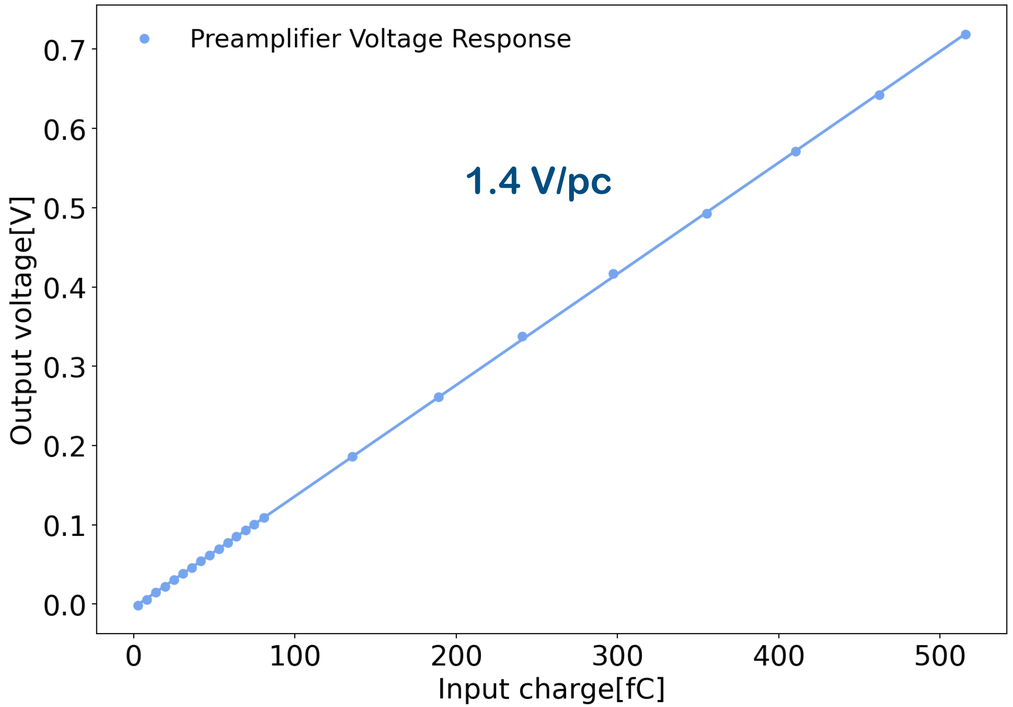
1e-7 1e-4?

Readout circuit designed by our UZH electronics workshop, placed in LXe.

Commercial capacitors tested rated to 50kV are not suited for this cryogenic temperatures (ceramic bulk). Replaced momentarily with smaller 10kV rated capacitors in parallel



Good linearity in the expected charge region



Photocathodes

Photocathode: We want as many as possible photoelectrons with a reasonable low ageing

Sputter

Coating Material	WF [eV]
Au	5.1
Ag	4.26-4.73
Al	4.08

Electron escape probability

Optical penetration

Thin Film → Oxide layer

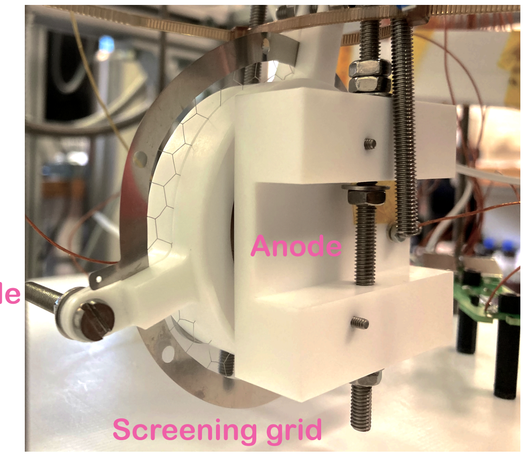
Substrate → Not absorbent of UV photons

Substrate → Reflectivity enhances the e^- production

Thicker films allow more optical penetration
Thinner films increase the electron escape probability (~inelastic scattering length)

Thin films with 100 nm and 40 nm: >4x amount of photoelectrons in Au, Ag

The photocathode signals are tested in a cryostat in vacuum, GXe and LXe



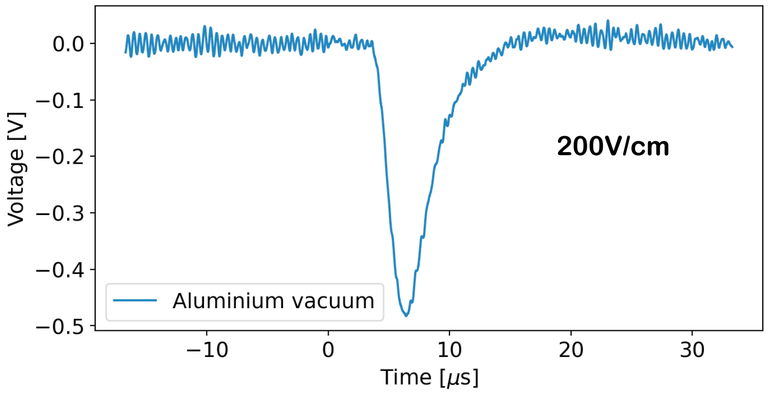
Cleaning procedure: Acetone, Isopropyl in ultrasonic bath and then blow dried with nitrogen

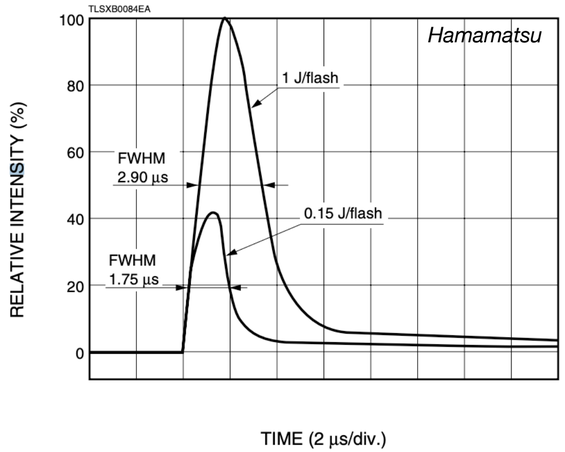
Very hard to clean to negligible dust level

Photocathodes

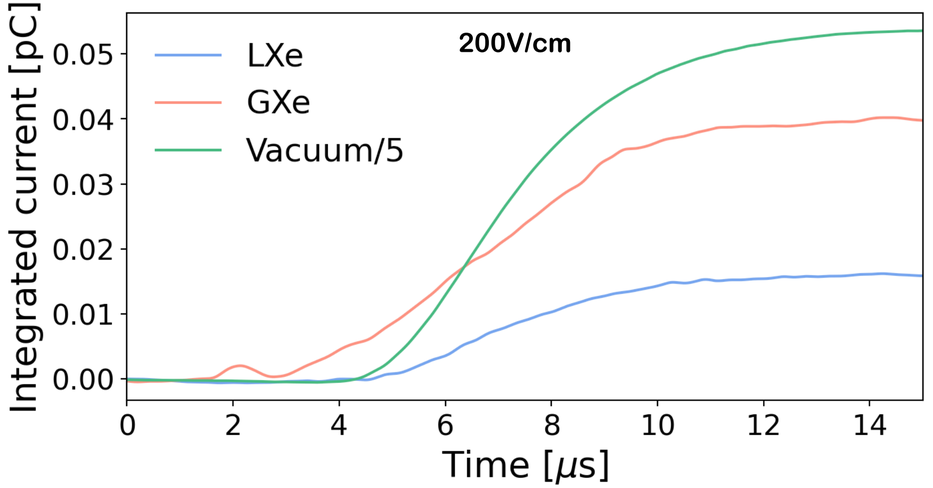
The signals from the photocathode are acquired with an oscilloscope, using the internal trigger of the lamp

The width of the photocathode signal is dominated by the lamp signal width

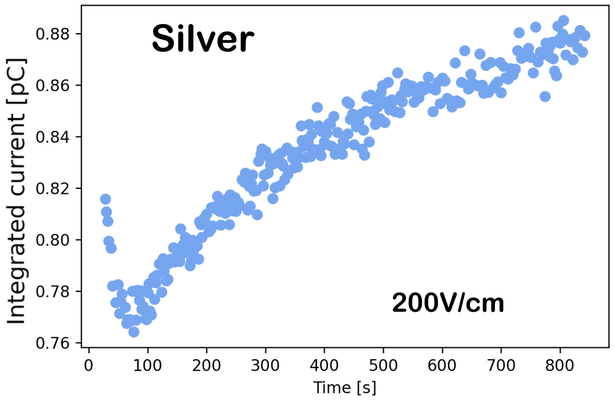




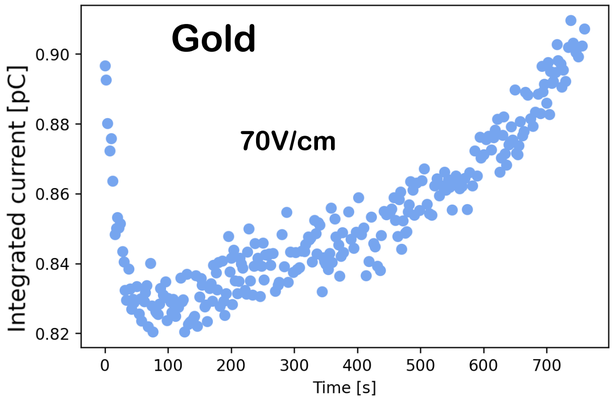
Silver, 100nm



Gold and silver have a clear improvement over time: photoelectric outgassing?

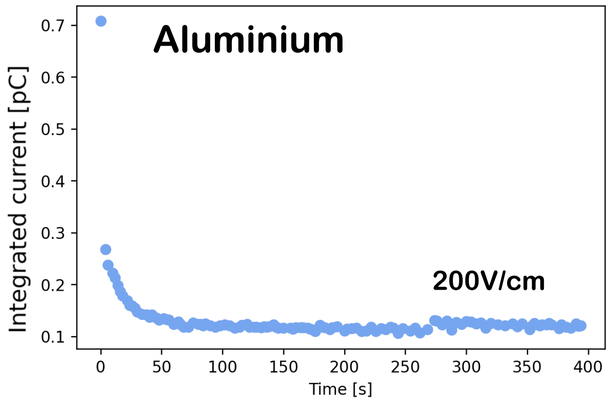


40nm



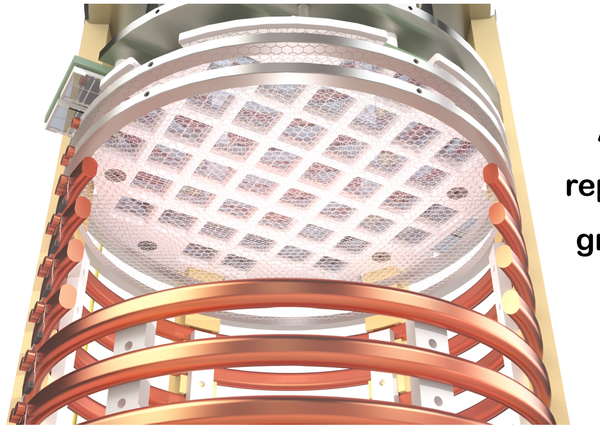
40nm

Aluminium only tested with 100nm



Future measurements

Purity monitor 50 cm → Dual Phase TPC 1m → TPC 2.6m



Anode (collector) replaced by hex mesh grid (stainless steel)

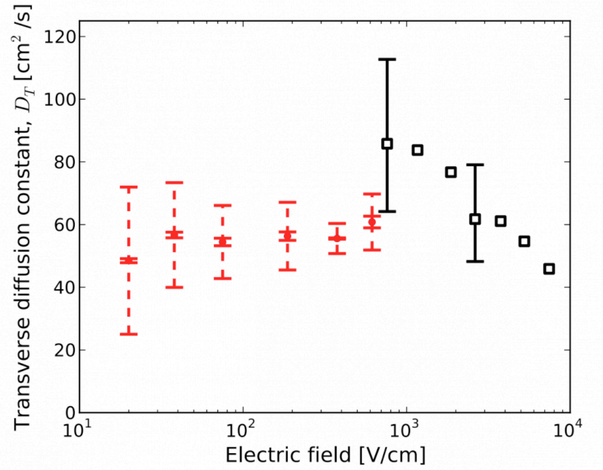
Implement liquid level control and an SiPM array readout

Gas scintillation by photoelectrons

Diffusion at long drifts with the Purity Monitor photoelectrons?

First opportunity to study this effect in meters scale

Transverse diffusion



Measurement of the drift velocity and transverse diffusion of electrons in liquid xenon with the EXO-200 detector J. B. Albert et al

The SiPM array has to be able to see the broadening of the deposition pattern

1. Take the hit pattern of the 0.5m, 1m and 2.6 m array and compare its broadening

Longitudinal diffusion

Place screening meshes, compare the broadening of the signal.

Expected to be ~10 times lower than transverse diffusion

More plans in the future: optical attenuation measurements, photosensor testing and high voltage systems test

Conclusions

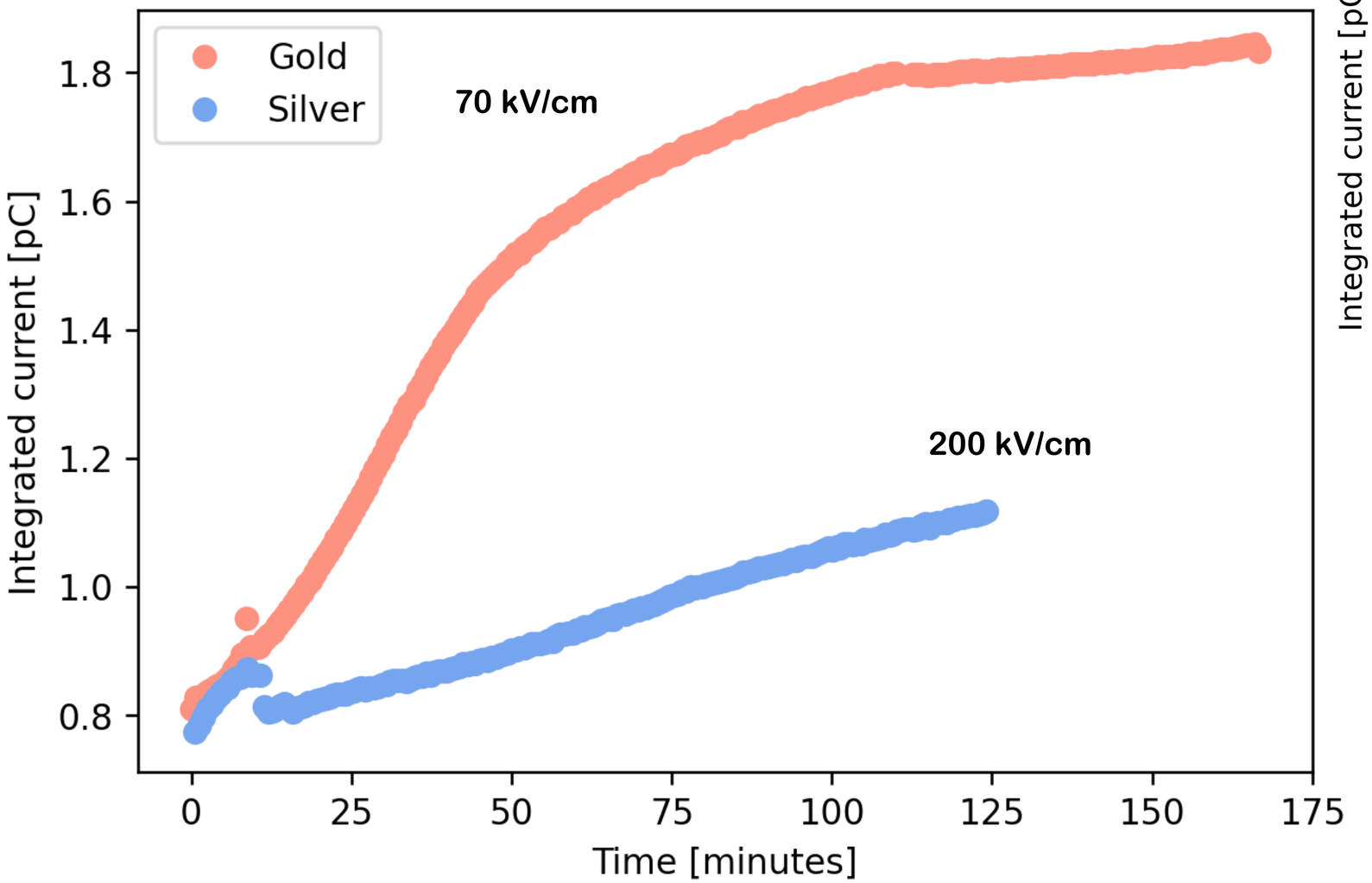
- Designed a PM, that will be commissioned very soon in LXe
- The electronics developed are working as designed
- The Xenon lamp works as expected, the noise was reduced by rehousing (~1 V to >10 mV)
- The photocathodes provide a clear signal that can be used for the signal, gold looks stable and provides the higher amount of photoelectrons at the times observed
- Improvement of photocathodes over time needs to be investigated long term (outgassing?)
- Promising signals for the next step of integrating the PM in the Xenoscope facility

Thank you for your attention!

Backup Slides

Photocathodes

The signals from the photocathode are acquired with an oscilloscope, using the internal trigger of the lamp



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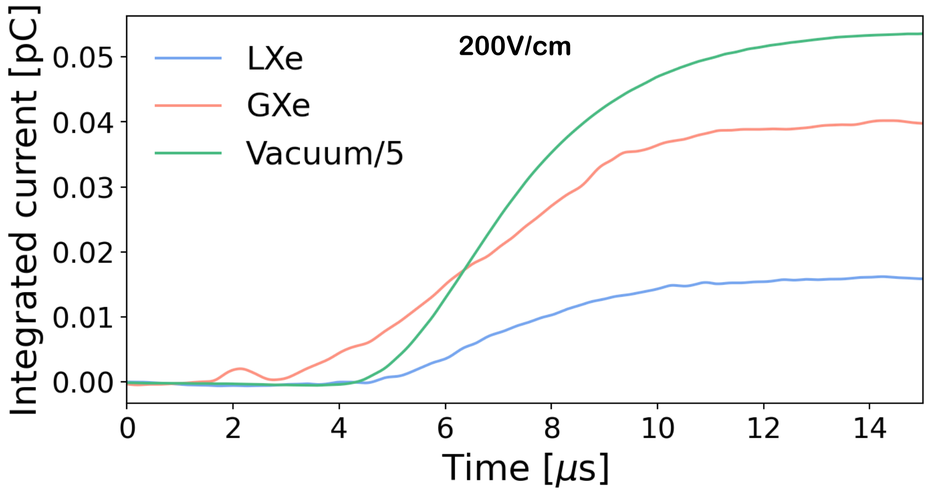
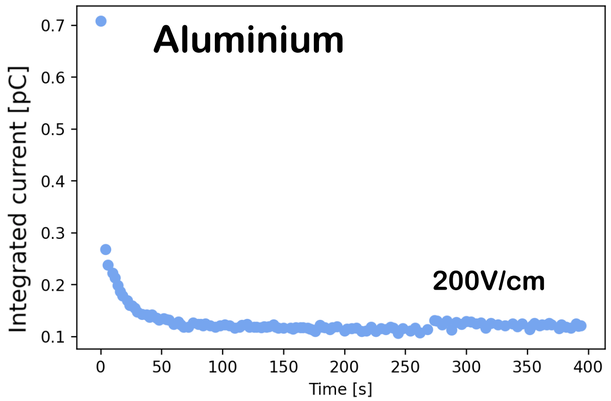


Aluminium only tested with 100nm



The gold photocathode shows stability and higher photoelectron production at a lower field (it can still be increased)

Fibre and Optic feedthrough

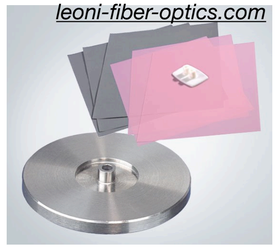
UV photons in the light guide: Protection against photo darkening:
Hydrogen infused into the silica.

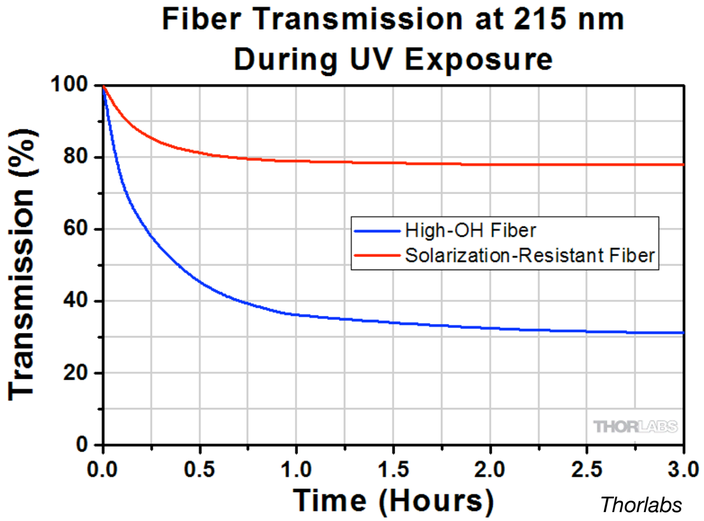
Typical NA of 0.22, 600 μm

Not fragile, easy to handle!

For feedthroughs I found two options:

- **Feedthroughs were the fibre is coupled through SMAM connectors: Versatile. Coupling losses. Not rated for overpressure, requires extra testing.**





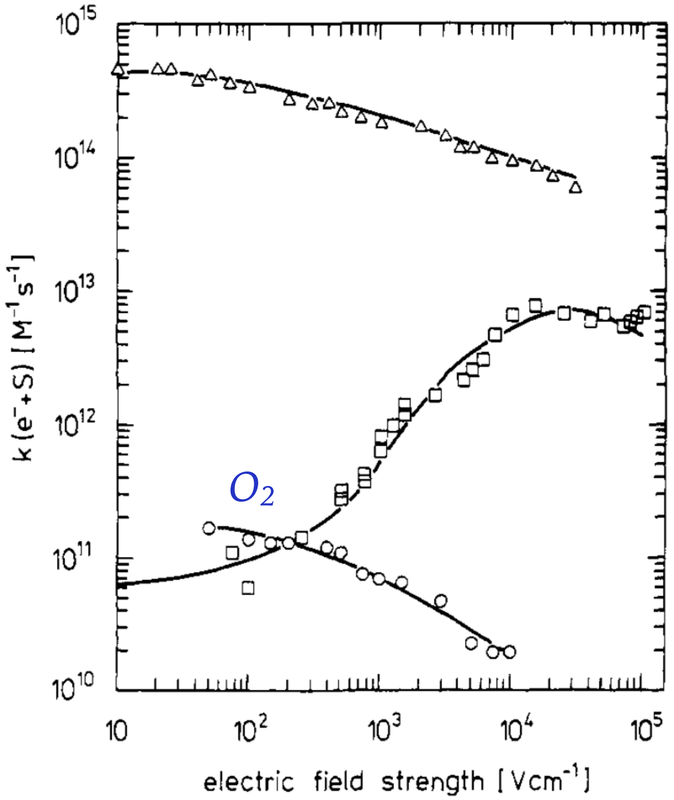
Thorlabs

Thorlabs

- **Feedthroughs that either the company produces as well the fibre or you need to provide the fibre with a specified length: no coupling losses, no connector polishing.**
  Requires special care in the welding. Very customised.


Art Photonics

Purity monitor working principle

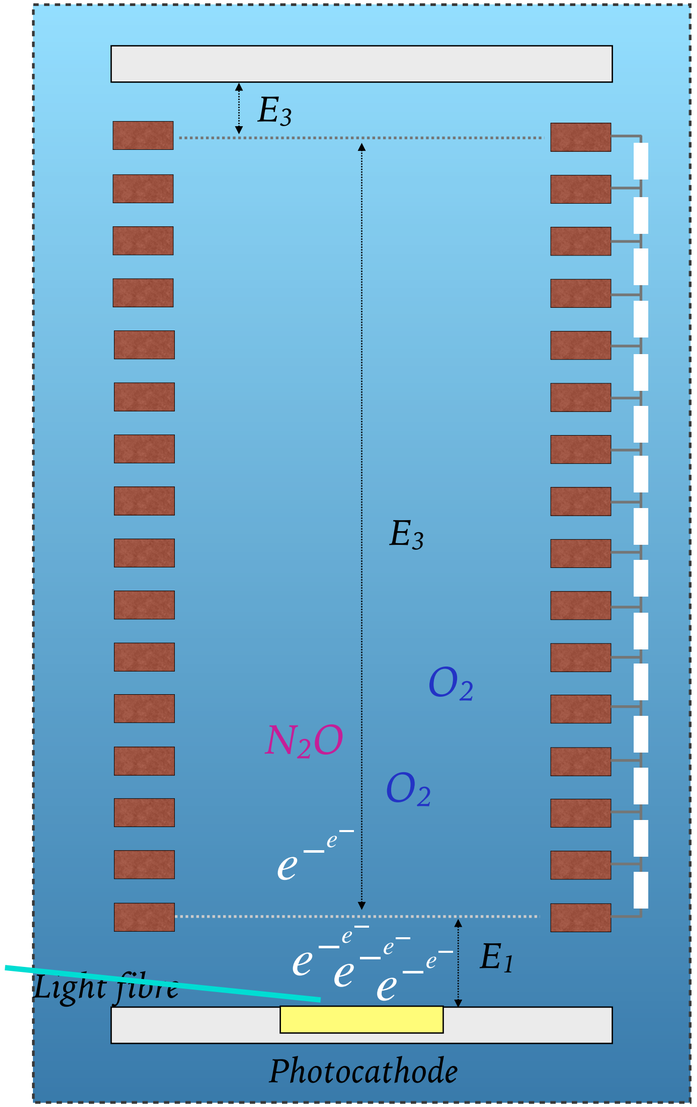


G.Bakale U.Sowada and W.F.Schmidt,
J.Phys. Chem. 80 (1976) 2556

$$N(t) = N_0\, e^{-t/\tau}$$

$$\tau = \frac{1}{K_s N_s}$$

Xenon Lamp



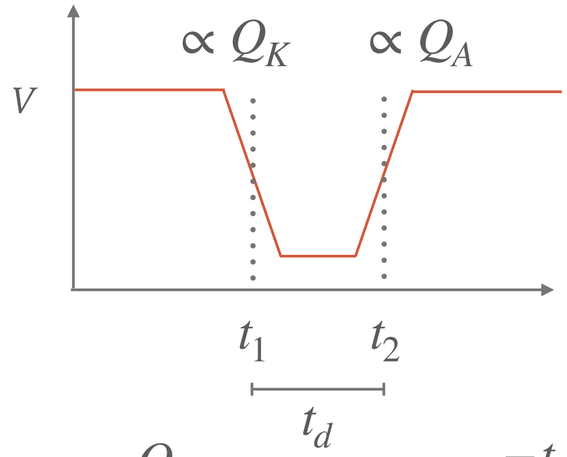
To charge amplifier
A →
GA

$R_f = 50M\Omega$

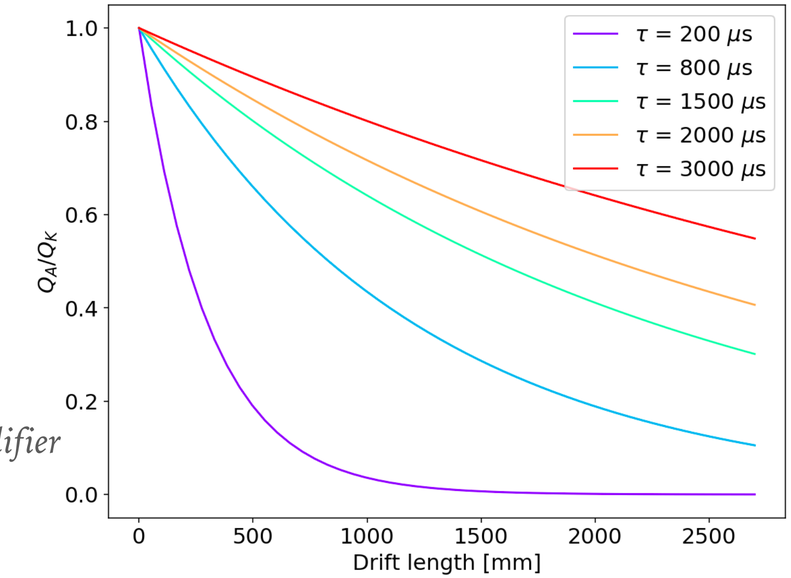
FSR

GK

To charge amplifier
K →



$$R = \frac{Q_A}{Q_K} \qquad \tau_e = \frac{-t_d}{log(R)}$$



SiPMs