WA105
Purity Monitor

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Outline

- Purity in LAr TPCs
- Purity Monitor: how it works
- Schematic design
- Design in detail
- Current status
- Planned tests

Purity in LAr TPCs

- In LAr TPCs high electron collection efficiency is crucial to achieve fine spatial resolution when reconstructing the particle's track
- Electronegative impurities can trap electron on their way up to the liquid-gas interface
- LAr needs to be extremely pure, below the part-per-billion (ppb) level
- Commercial argon contains Oxygen impurities to the ppm level
- Recirculation is necessary

Purity Monitor: how it works

- Decrease in e- concentration due to electronegative impurities capture is given by:

$$\frac{d[e(t)]}{dt} = -k_S\,[S]\,[e(t)]$$

solve

$$[e(t)] = [e_0]\exp(-t/\tau_d)$$

$[e(t)]$ e- concentration in mol/L (or ppb w/w or w/V)

k_S electron attachment rate constant given in L/(mol*s)

$[S]$ concentration of electronegative impurities in units of mol/L

drift time

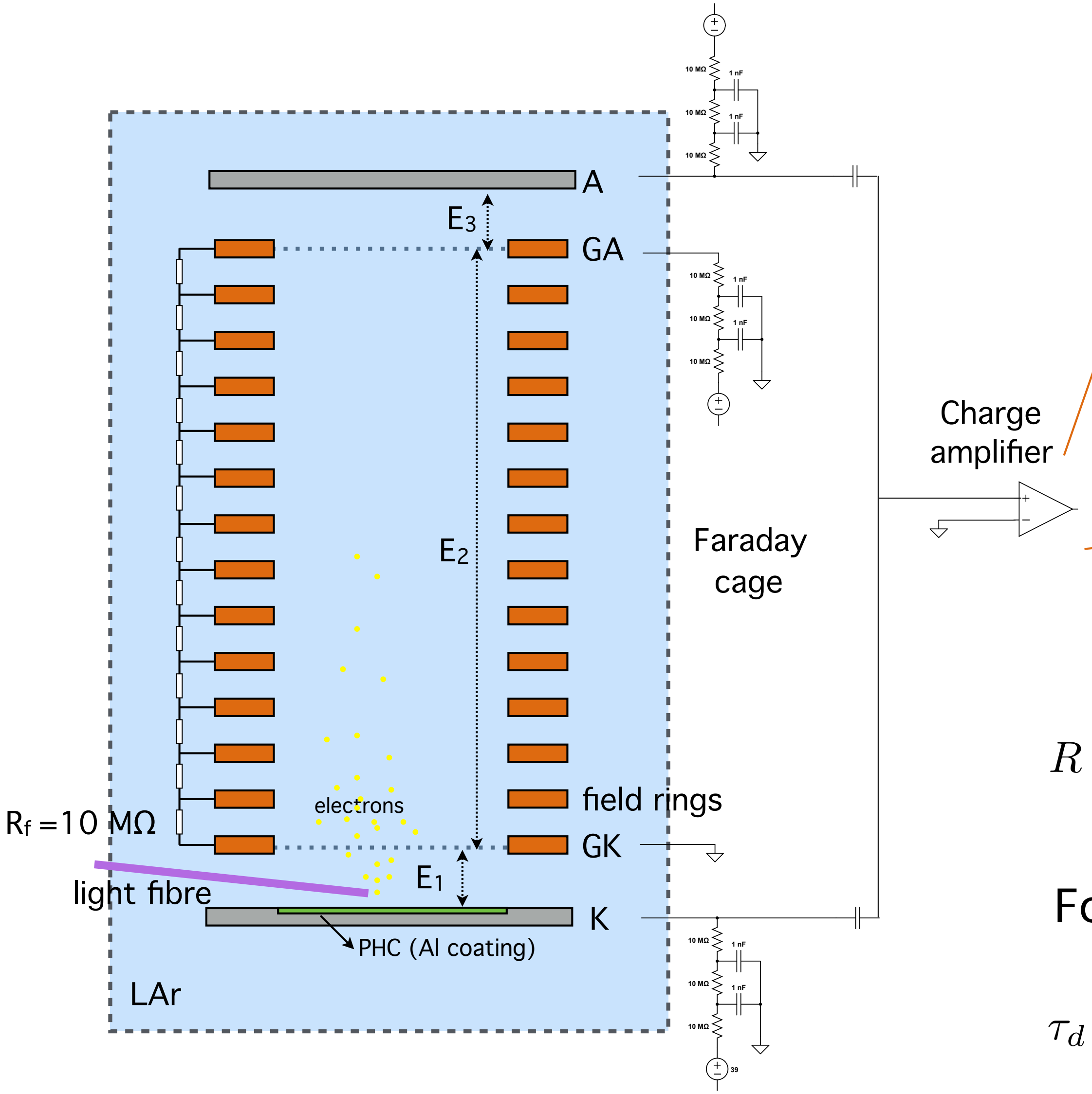
$$\tau_d = \frac{1}{(k_S\,[S])}$$

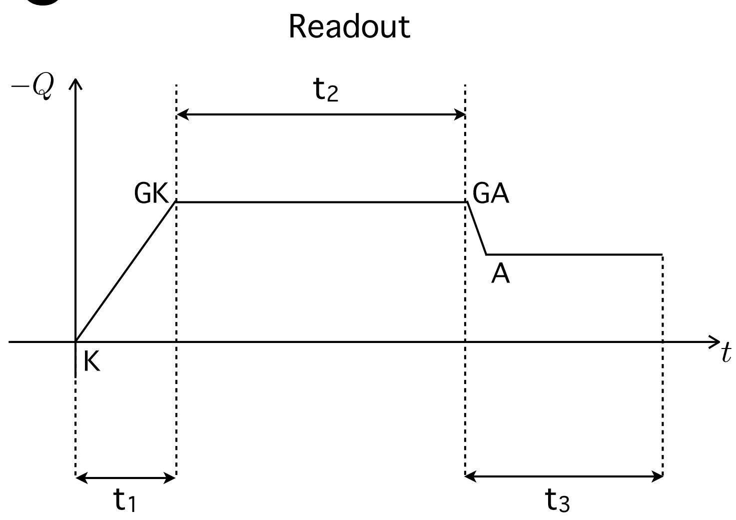
Aprile, E. and Doke, T. (2010). Liquid xenon detectors for particle physics and astrophysics. Reviews of Modern Physics, 82, 2053

- Drift time gives indirect measurement of argon purity

How can we measure τ_d ?

Schematic design





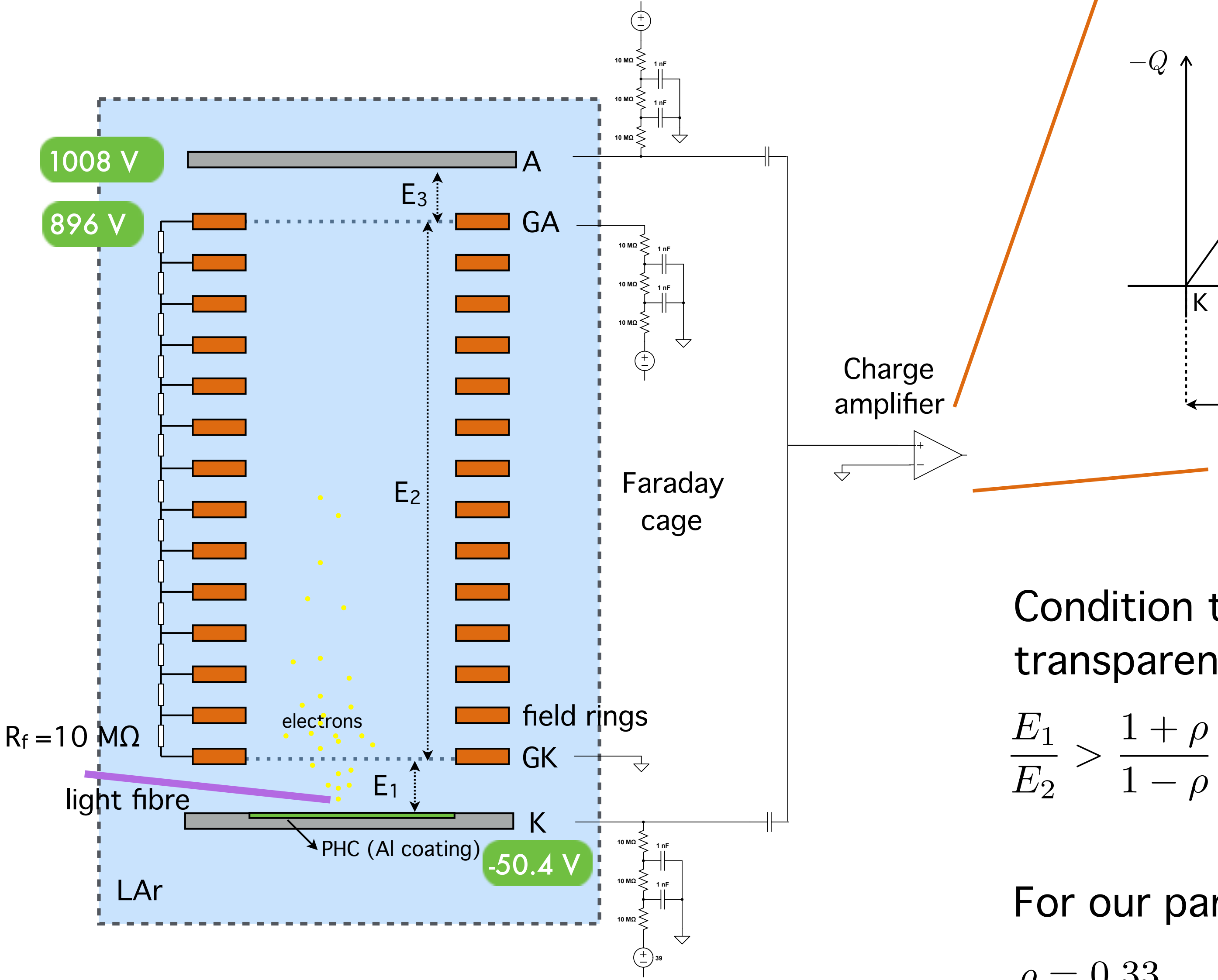
$$R = \frac{Q_A}{Q_K} = \frac{t_1 \sinh(t_3/2\tau_d)}{t_3 \sinh(t_1/2\tau_d)} \exp\left(-\frac{t_2 + \frac{t_1+t_3}{2}}{\tau_d}\right)$$

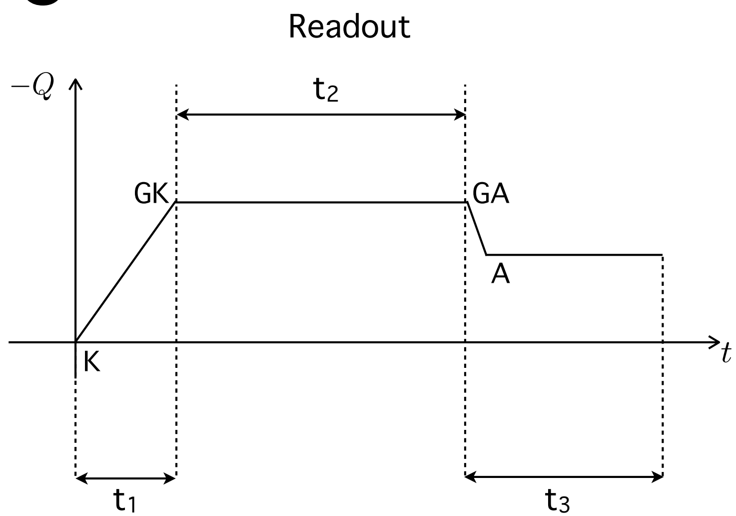
For t_1 and t_3 smaller than t_2

$$\tau_d = \frac{1}{\ln(R)}\left(t_2 + \frac{t_1 + t_3}{2}\right) = \frac{-T_d}{\ln(R)}$$

T_d defines actual “drift time” of the electrons inside the PrM drift volume

Schematic design





Condition to maximise grid transparency (Bunemann et al. 1949):

$$\frac{E_1}{E_2} > \frac{1+\rho}{1-\rho} \qquad \rho = 2\pi r/d$$

wire radius

distance between wires

For our particular choice of grid:

$$\rho = 0.33 \qquad E_1 > 2E_2 > 2E_3$$

$$(E_1 = 28\mathrm{V/cm}; \quad E_2 = 56\mathrm{V/cm}; \quad E_3 = 112\mathrm{V/cm})$$

Design details

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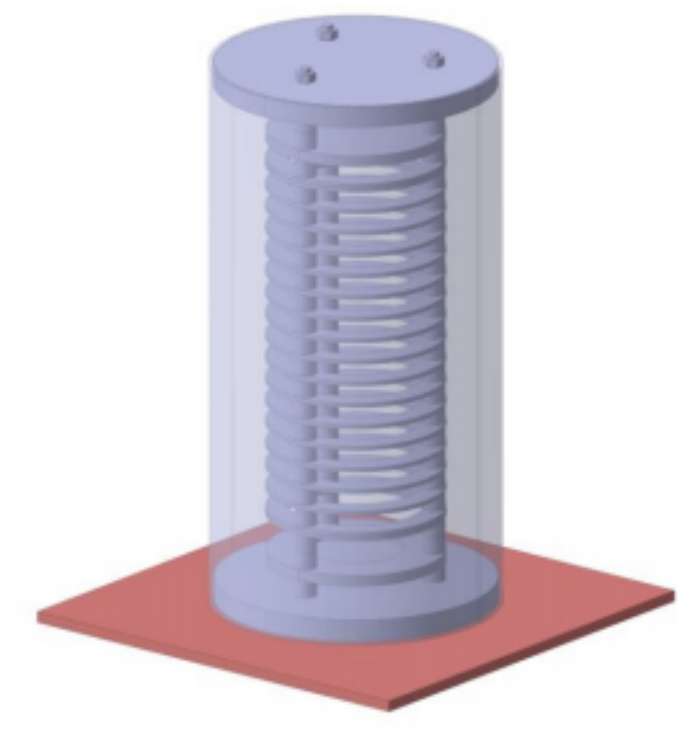
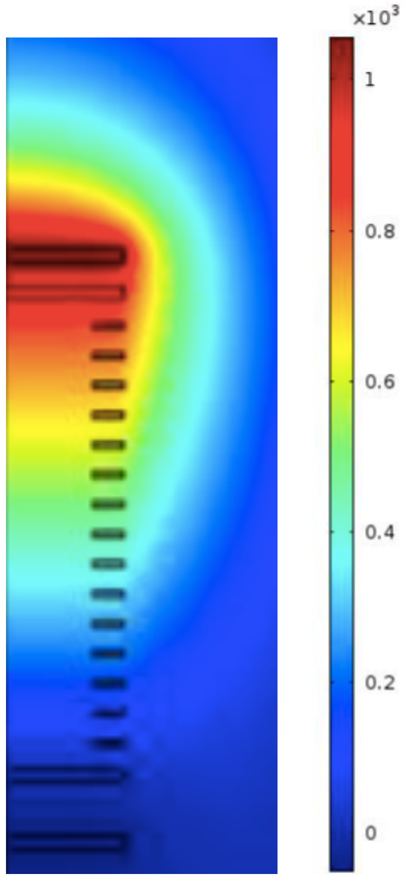
- Design follows ICARUS PrM design





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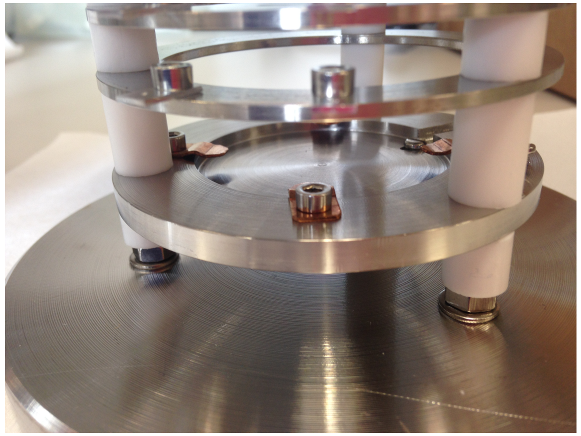
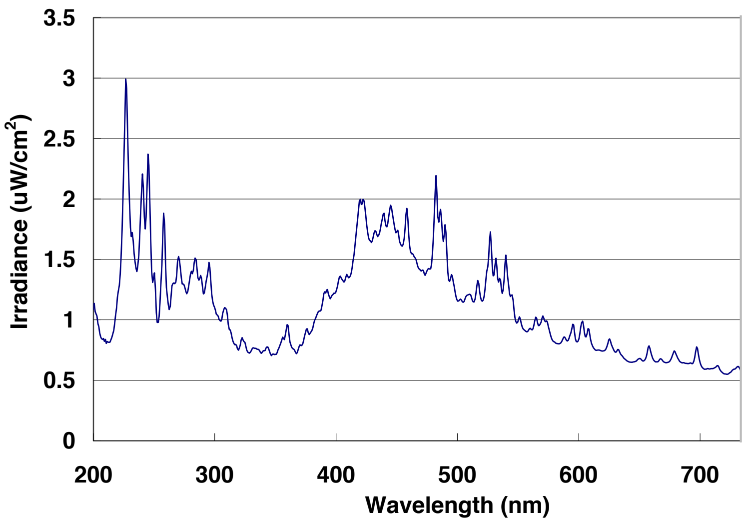


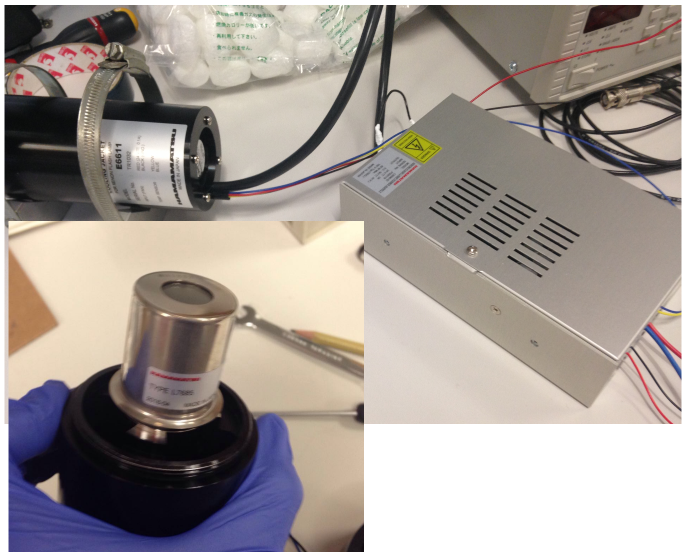
- Design follows ICARUS PrM design
- Hamamatsu Xenon lamp
- Photocathode:

- fused silica window (λ/4 quality surface at 632 nm, i.e. < 0.1 μm surface irregularities)

- 500 nm Al coating (at London Centre of Nanotechnology)

- photoelectric effect: Al work function 4.08 eV (~300 nm)





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  - photoelectric effect: Al work function 4.08 eV (~300 nm)
- 600 μm Cu cladded UV fibre guides the light onto the PHC
- SS fields shaping rings
- Nickel mesh
- Al Faraday cage
- Amptek charge amplifier

Planned tests

- Mechanical tests in LAr.
- Given LARA at UCL has no recirculation system yet, it is not possible to test the PrM in LAr at UCL. Plan is to test the charge read out in GAr using an alpha source.

LARA - Liquid ARgon Apparatus at UCL

Purity Monitor in WA105

PrM in WA105