Development of coated electrodes with low quantum efficiency for the DARWIN experiment

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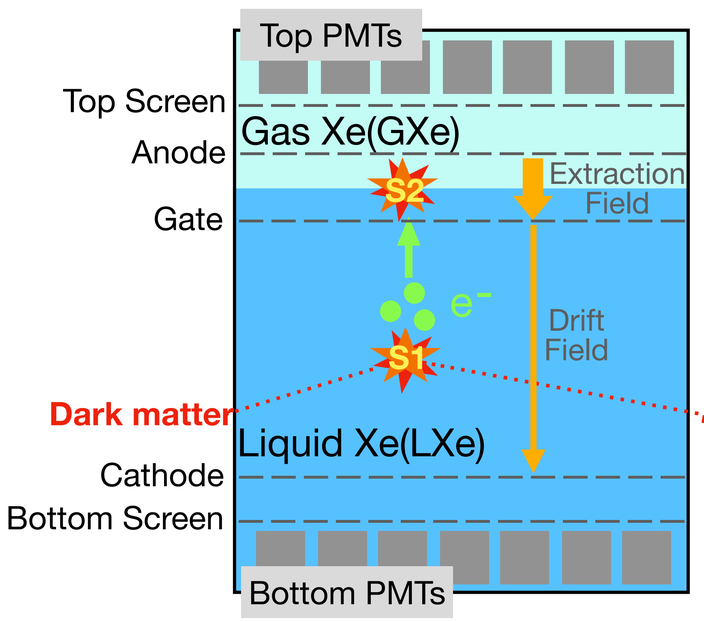
1. Direct dark matter search with liquid xenon

- **Purpose** :
  Observe the recoil of a target xenon nucleus induced by a collision with a dark matter.



S1 : Scintillation light (175nm)
S2 : Electroluminescence

- 3D Reconstruction
  x,y : S2 light distribution
  z : Drift time
- Particle identification based on S2/S1

- **Detection principle** :
  PMTs detect the scintillation light (S1) and the electroluminescence(S2) of the ionized electrons produced by the interaction between xenon nucleus and dark matter.

- **Motivation of this study :**
  The scintillation photon can produce a electron through photoelectric effect on electrode, which is one of the major S2 backgrounds in low mass dark matter search. For DARWIN, a future direct dark matter search experiment using 50 tons of liquid Xe, we are developing coated electrode with low quantum efficiency(QE) which can reduce such S2 background.

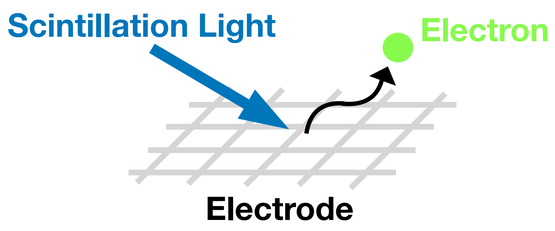
2. For low mass dark matter search

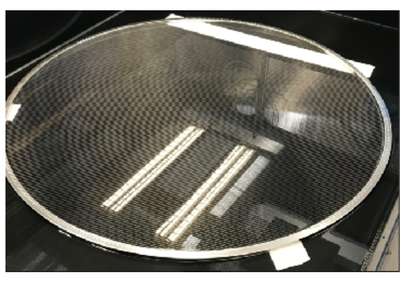
- Dark matter search based on S1 and S2 is limited by S1 which has small detection efficiency.

Improve sensitivity for low mass dark matter (<5 GeV/c) by using **S2-only** signal with higher detection efficiency!
[Detection efficiency : S2(~90%) > S1(~10%)]

However, there are lots of unknown S2 backgrounds

- One of S2 backgrounds
  - **Photoelectric effect on electrode**





From XENON collaboration

Electrode material of XENONnT :
Stainless steel wire (diameter: 200~300μm)

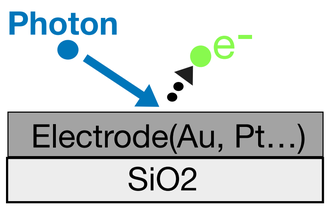
3. Coated electrode

- We're developing

new electrode with low QE coated on quartz glass

- **Low QE → Reduce S2 background from photoelectric effect**
- Coating on quartz glass → Prevent deflection of electrode

Results presented in this poster



- **Use metal with low QE**
  Candidates : **Au, Pt** (high work function)

	Au	Pt
Work function[eV]	5.1	5.7

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Another idea for improvement

- **Coating metal-surface with insulator** Candidates : **MgF2+Al …**

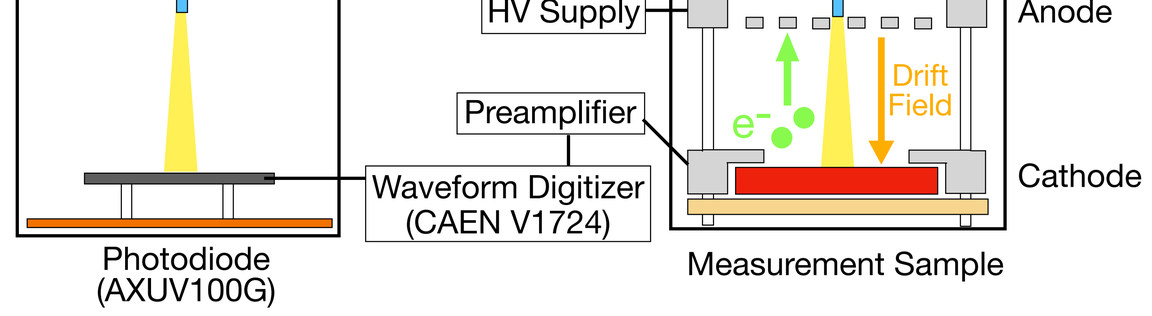
Another study of QE for other detector components

Candidates : PTFE, Quartz, PEEK (insulator)
→ Study the impact of them on the S2 backgrounds

4. Measurement setup

- **Measurement value : QE =** $\frac{N_{el}}{N_{ph}}$

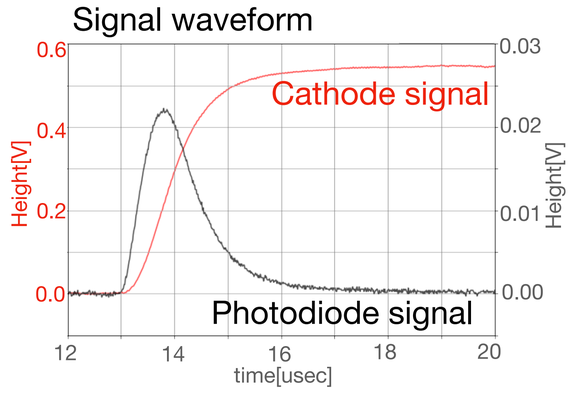
Light Source
Xe Flash Lamp(Hamamatsu L12746) + Bandpass filter[217 nm]
or
H2D2 Lamp(Hamamatsu L15094) + Bandpass filter[172 nm]



Measured samples

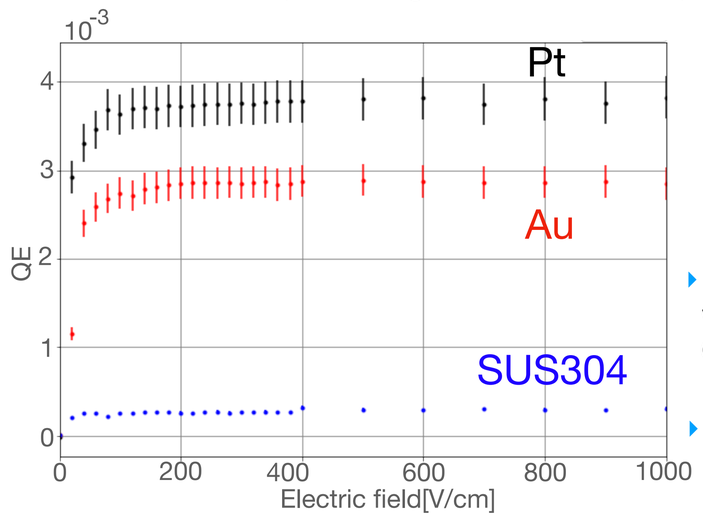
SUS304 (Electropolished)	Au / Pt (Sputtered)
SUS304 — 2mm, □12mm	Au / Pt — 100nm, 10nm(Cr); SiO2 — 2mm, □12mm

Signal waveform



5. Results

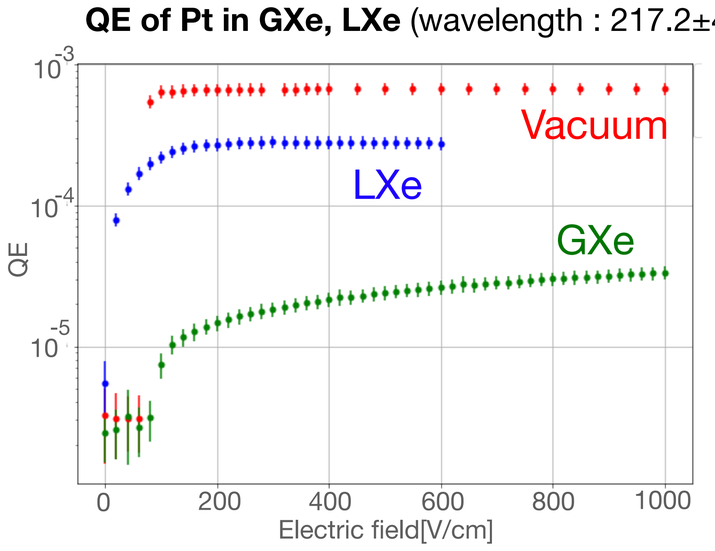
QE in vacuum (wavelength : 178.0±7.0 nm)



	QE @ 200 V/cm
: Pt	$(3.72 \pm 0.24) \times 10^{-3}$
: Au	$(2.85 \pm 0.18) \times 10^{-3}$
: SUS304	$(2.59 \pm 0.16) \times 10^{-4}$

- Both Au and Pt, which have the highest work function among metals, show less QE than SUS.
- We will study other electrode materials coated by insulator such as MgF2+Al.

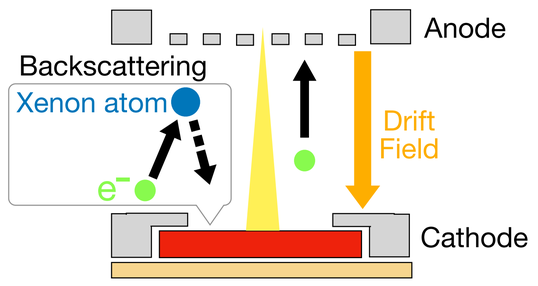
QE of Pt in GXe, LXe (wavelength : 217.2±4.8 nm)



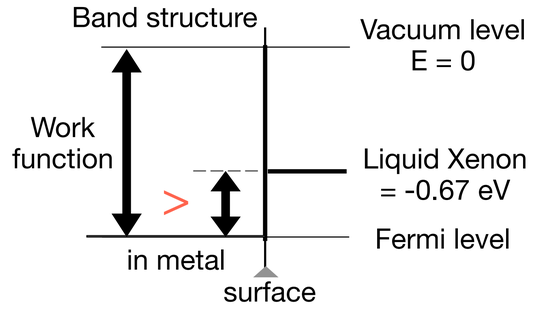
	QE @ 200 V/cm
: Vacuum	$(6.40 \pm 0.56) \times 10^{-4}$
: LXe	$(2.65 \pm 0.24) \times 10^{-4}$
: GXe	$(1.56 \pm 0.17) \times 10^{-5}$

- QE : Vacuum > LXe > GXe
- Previous CsI measurement have similar tendency. NIM A 338(1994),328-335

QE : Vacuum > LXe, GXe
Backscattering by xenon atoms



QE : LXe > GXe
Change of effective work function



6. Summary & Outlook

- Instrumental S2 backgrounds limit the sensitivity for low mass dark matter, and reducing them are currently under studied.
- Coated electrode with low QE can reduce such S2 backgrounds.
- QE of SUS304 in vacuum is measured to be lower than that of Au and Pt.
- QE of Pt in LXe, GXe has been measured, and QE in LXe is the highest.
  This result can be explained by the reduction of work function in LXe and less impacts of backscattering compared to GXe.
- We will measure QE for other electrode candidates (Au ,MgF2+Al…) in LXe, and detector components such as PTFE, Quartz, PEEK.

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