Internal Amplification Ge(GeIA)

Theory of predicting the necessary gain

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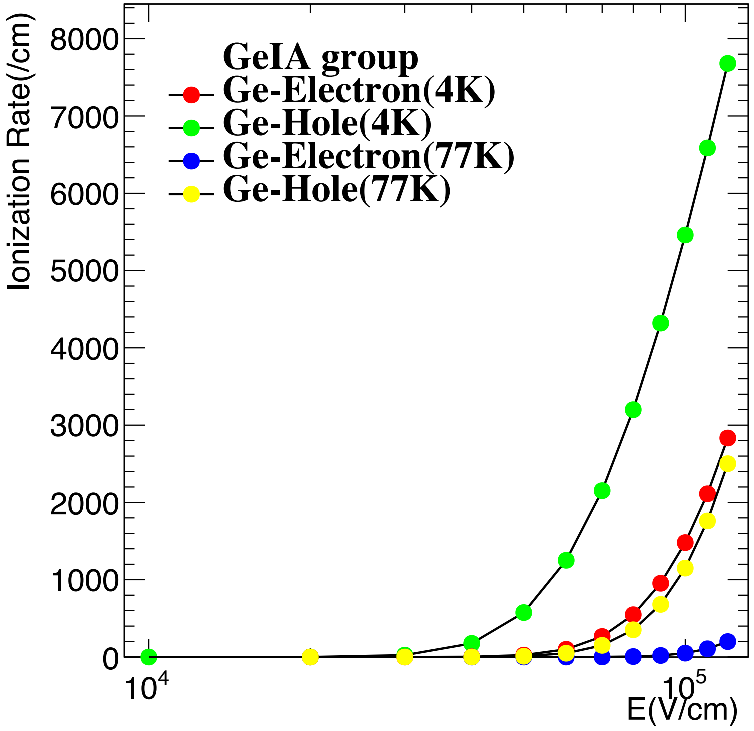
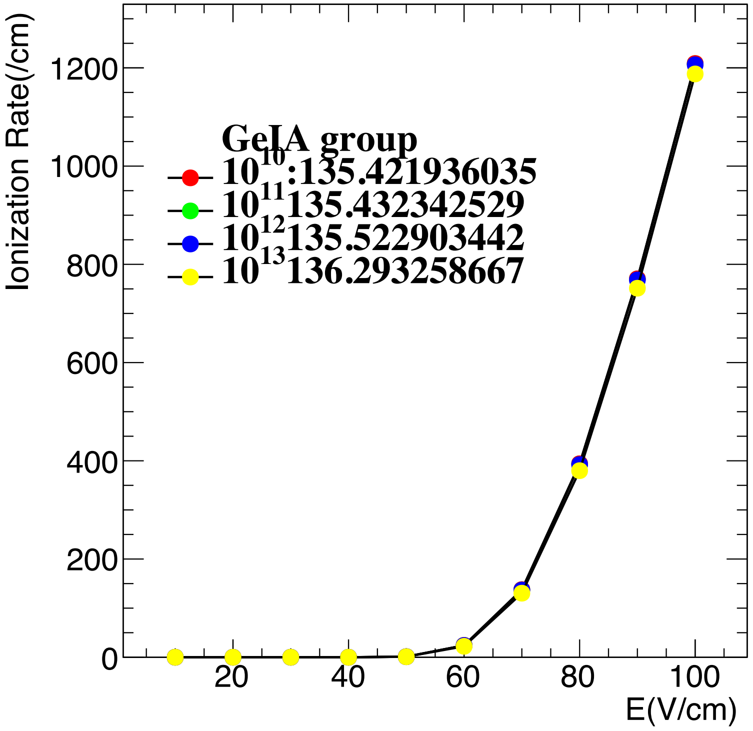
The reminder of the previous results

- At the first place, the ionization rates of electron and hole were predicted by some of the formulae:

Signal(Ge)



Signal(Impurities)



Ionization rate

➔ Give us the “Gain” in the end.

➔ Great! But what‘s the next?

➔ Debut of our “BKG”!!

➔ Umm…It seems complicated!

➔ Let me map out the blueprint first!

Three steps

SIG estimation

Ionization rate
Gain(E,T)

Know our predicted gain for signal
Under the certain T and E

BKG estimation

Theory of BKG
Signal threshold

Know the threshold of the signal
(Signal → Gain)
Predicted by BKG (Theory)

Gain

Type of the detector?
Temperature?
Electric field?

Raw/Observable

No Amplification
Raw SIG/BKG

With Amplification
Obs SIG/BKG

(SIG) > (3 * sigma of BKG)

$$(S * G) > 3 * \sqrt{(B * G)}$$

S	S*G
B	B*G

$$S > \frac{3 * \sqrt{(B * G)}}{G}$$

Various thresholds (Given the dark matter energy) → All can be predicted.

Confirm the circumstance

	G	S(GS)	B(GB)	Threshold
(1)USD	1	1(1)	1(1)	3
(2)China-THU	100	1(100)	100(10000)	3

(SIG) > (3 * sigma of BKG)

$$(S * G) > 3 * \sqrt{(B * G)}$$

$$S > \frac{3 * \sqrt{(B * G)}}{G}$$

Purpose of this study

- *The important issue:
- Can we predict "the necessary gain" by the signal we expect?

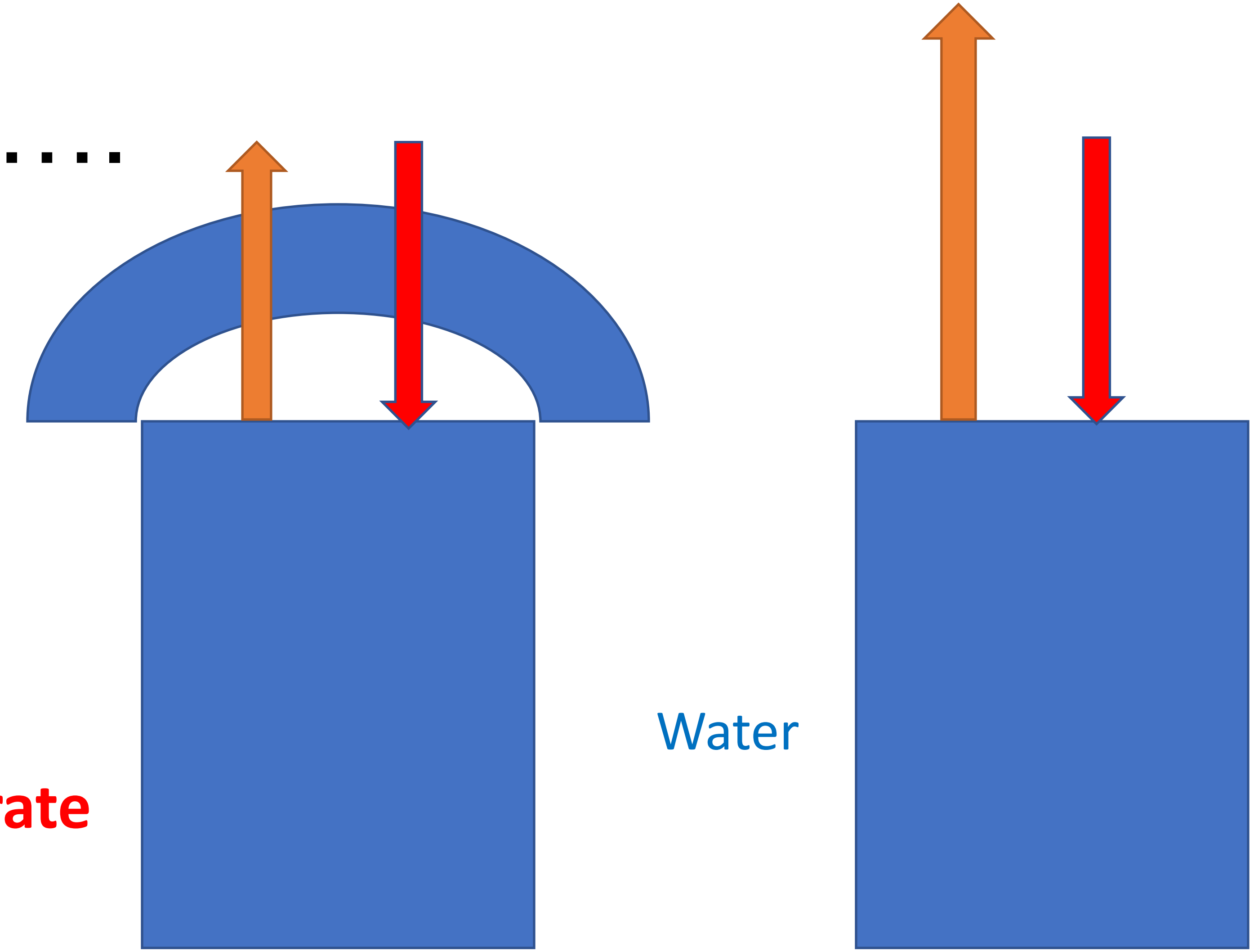
- Next step:
- Find out the right BKG and find out the right threshold plots.
- → Then, we can apply it on our detector
- → Even design the different type of the detector compared with other people.

Theory of BKG

Image….

Generate rate (Evaporate)

Recombination rate (Condensate)



T equilibrium

G=R

Take off the cover

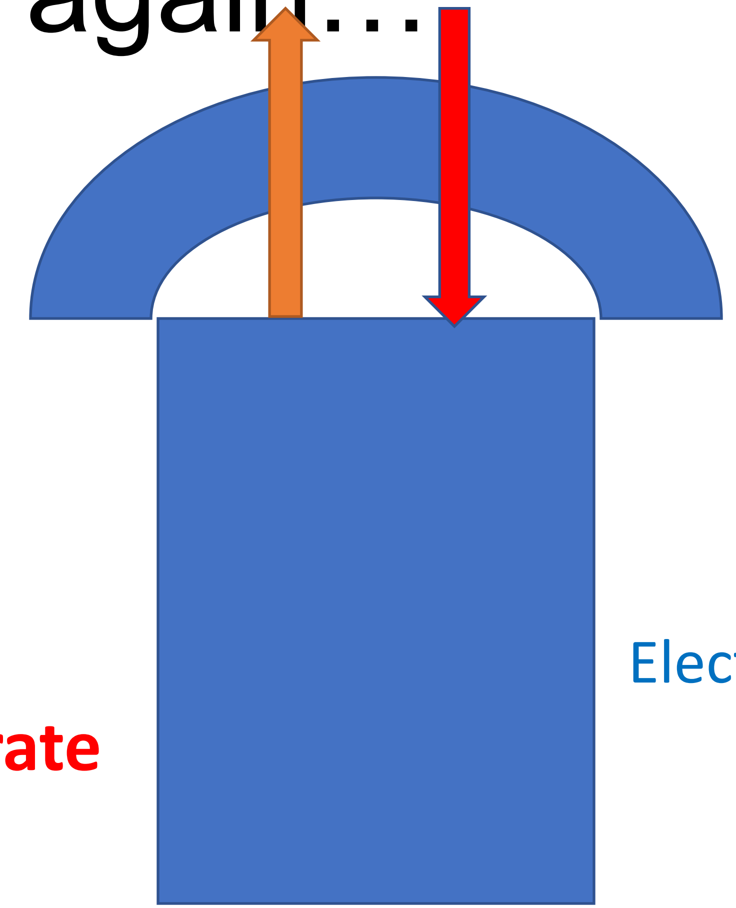
G>R

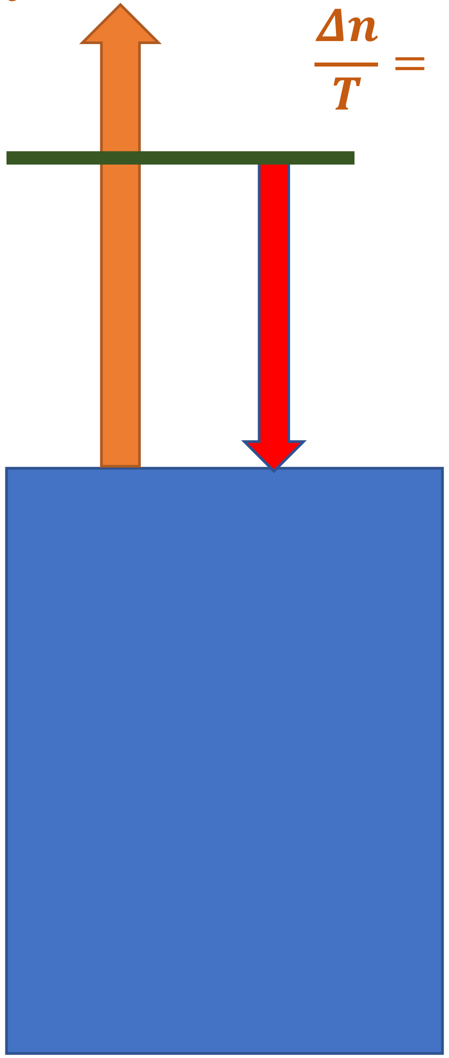
The same as our experiment!

$$\textit{Net impurity concentration} = \Delta n$$
$$\textit{Carrier lifetime} = T$$

$$\frac{\Delta n}{T} = \frac{\frac{10^{10}}{cm^3} * (F)}{100\mu s} = \frac{10^8 * F}{cm^3 * \mu s}$$

Image again…





Generate rate
(e pop up)

Recombination rate
(e absorbed)

Electron sea

T equilibrium
(Electric field off)

G=R

Take off the cover
(Electric field on)

G>R

Give us the sense

$$\frac{\Delta n}{T} = \frac{\frac{10^{10}}{cm^3} * (F)}{100\mu s} = \frac{10^8 * F}{cm^3 * \mu s}$$

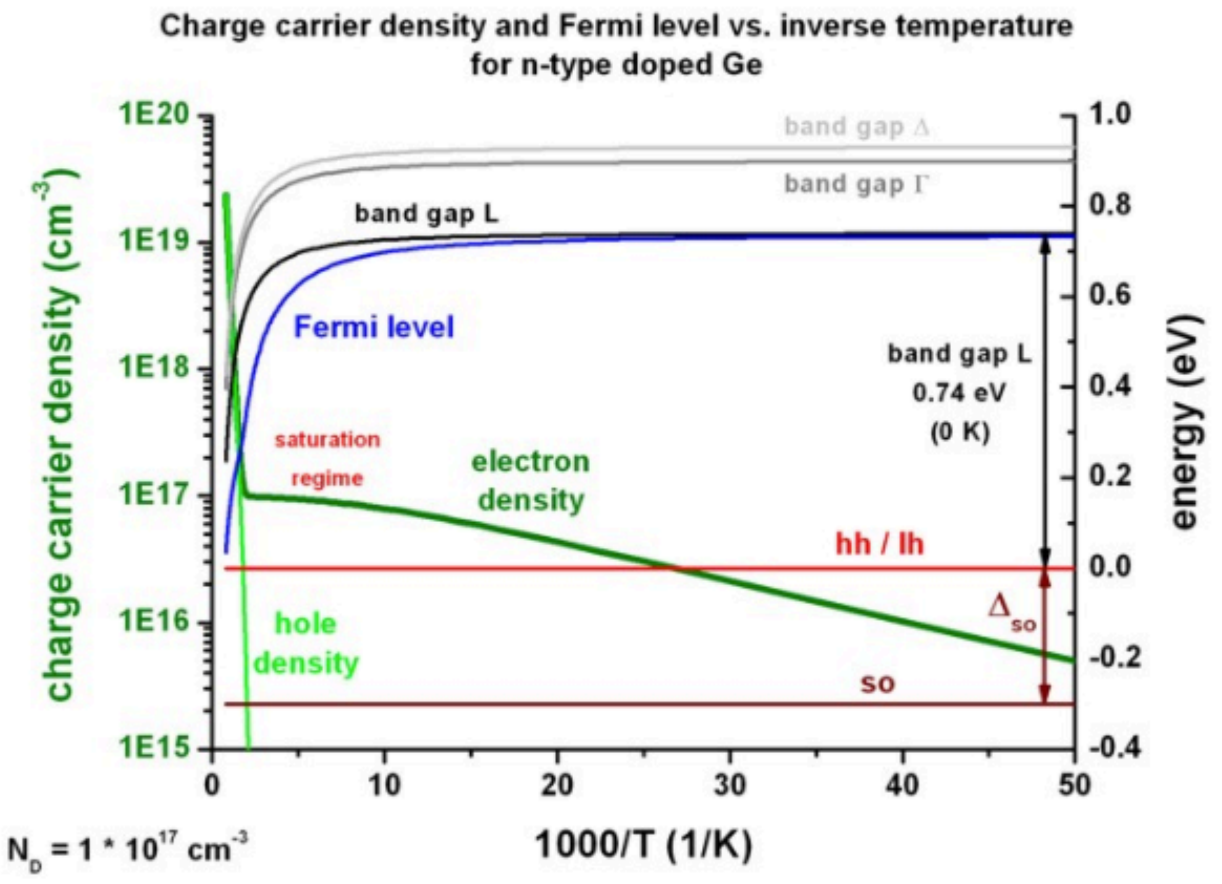
- Since we don't know the explicit physics in the detector
- ➔ Do some approximation.

- We suppose the whole crystal can give us the BKG estimation.
- ➔ In μs

- $7.5 \times 7.5 \times 3 (cm^3)$

How do we know we are right?
The standard case as follows:

Charged concentration density



Temperature-dependent
charged concentration density

Lower than "ionization energy"
120K
Density of the charged concentration will get smaller since the insufficient fluctuation.

$$\propto \frac{1}{e^{\frac{E}{2k_BT}}}$$

$$1 : \frac{1}{e^{\frac{0.0106}{2k_B * 120}}} = x : \frac{1}{e^{\frac{0.0106}{2k_BT}}}$$

We can get the charged concentration correlated with the temperature!

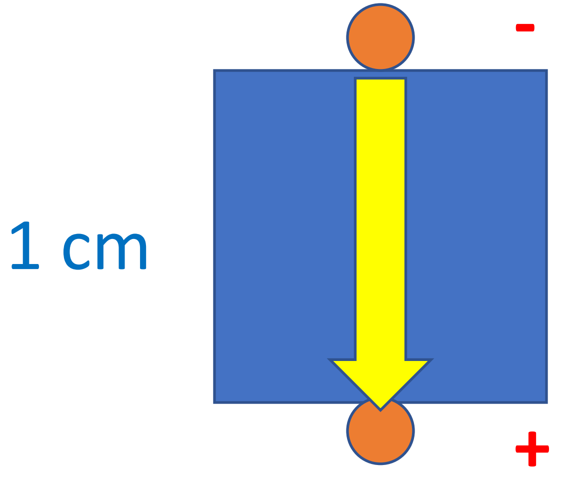
The standard Germanium

- **1 x 1 x 1 (cm^2)**

- 10^{10}(Net impurity) : $\frac{1}{e^{\frac{0.0106}{k_B * 120}}}$(Minimum ionization) = $\boldsymbol{F}$: $\frac{1}{e^{\frac{0.0106}{k_B T}}}$ (Certain temperature)

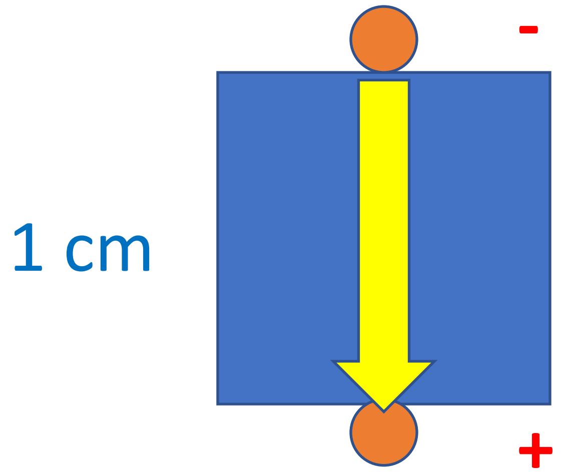
- 77K
- F = 7.5×10^9

- 4K
- F = 3.5×10^3



The standard Germanium

- **1 x 1 x 1 (cm^2)**
- "No Gain"➔ Apply the small field
- $\frac{1\ cm}{10^7 \frac{cm}{s}} = \mathbf{0.1\mu s}$



$$\frac{\Delta n}{T} = \frac{(F)}{100\mu s} = \frac{0.01 * F}{cm^3 * \mu s} = \frac{10^{-3} * F}{cm^3 * 0.1\mu s} = 10^{-3} * F\ \ (/cm^3 * 0.1\mu s)$$

Threshold

$$(S * G) > 3 * \sqrt{(B * G)}$$

$$S > \frac{3 * \sqrt{(B * G)}}{G}$$