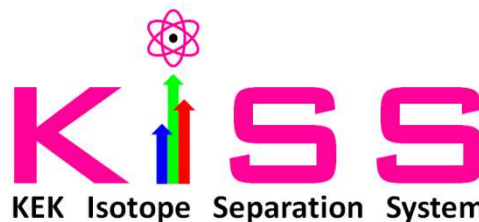


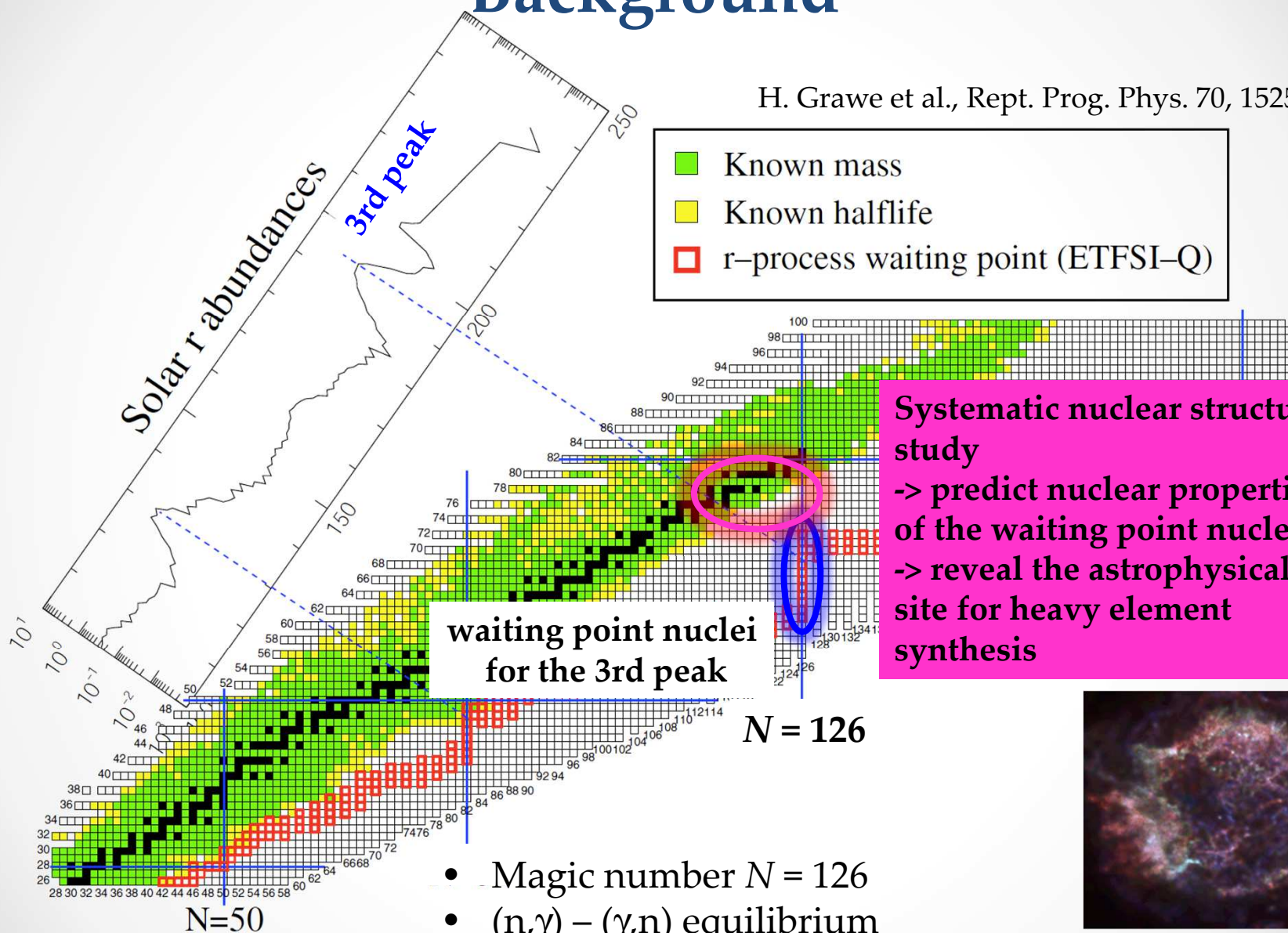
Development of a multi-segmented proportional gas counter for β -decay spectroscopy at KISS

Momo Mukai
University of Tsukuba



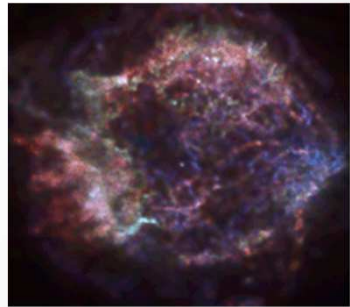
Background

H. Grawe et al., Rept. Prog. Phys. 70, 1525 (2007).



■	Known mass
■	Known halflife
□	r-process waiting point (ETFSI-Q)

Systematic nuclear structure study
 -> predict nuclear properties of the waiting point nuclei
 -> reveal the astrophysical site for heavy element synthesis



- Magic number $N = 126$
- $(n, \gamma) - (\gamma, n)$ equilibrium
- Astrophysical environment \leftarrow β -decay half-life, mass
- Unexploited nuclei

KEK Isotope separation system (KISS)

Requirements for the β -ray detector:

Yields of extracted ions from KISS: < 1 cps

⇒ **Low-background: < 0.1 cps**

⇒ **High-efficiency: > 40% @ $Q_\beta = 1$ MeV**

Origins of background events:

Compton scattering of environmental γ -rays

→ Low density material

Cosmic-ray

→ Tracking

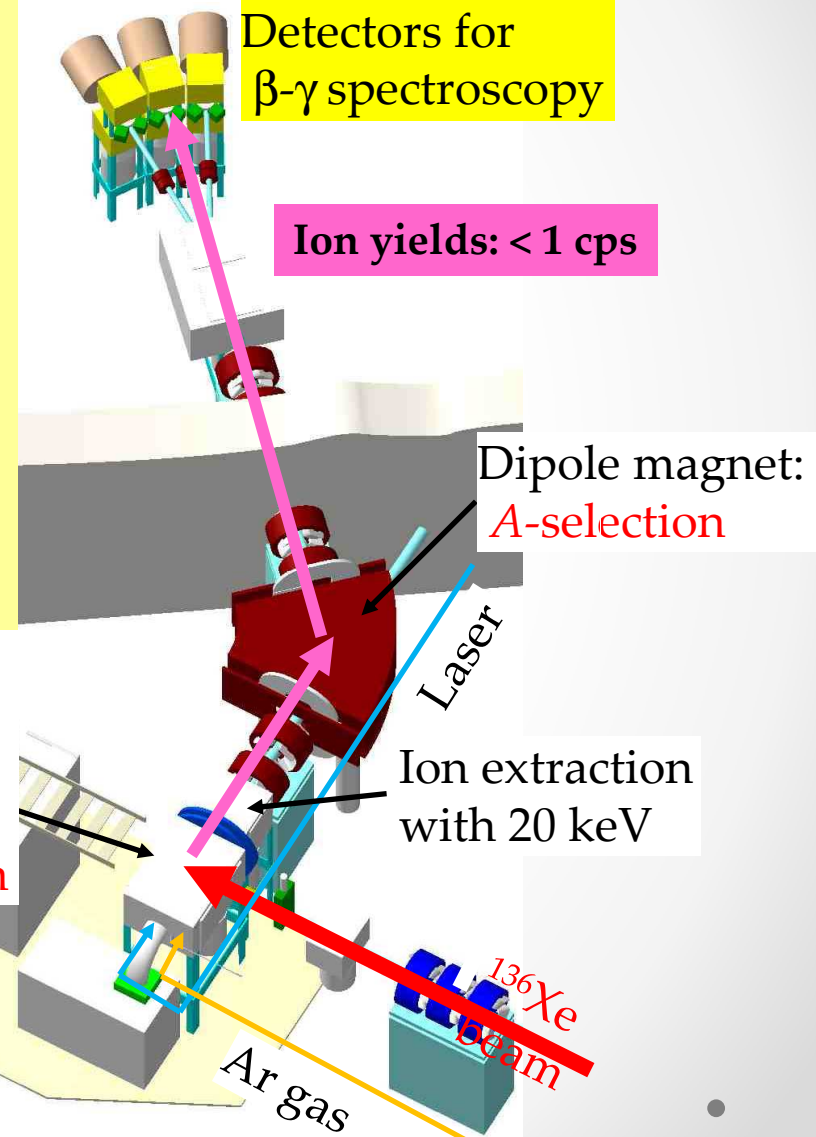
⇒ **Multi-segmented proportional gas counter**

Gas cell system

MNT reaction: $^{136}\text{Xe} + ^{198}\text{Pt}$

Ar gas cell: Neutralization

Laser resonance ionization: **Z-selection**



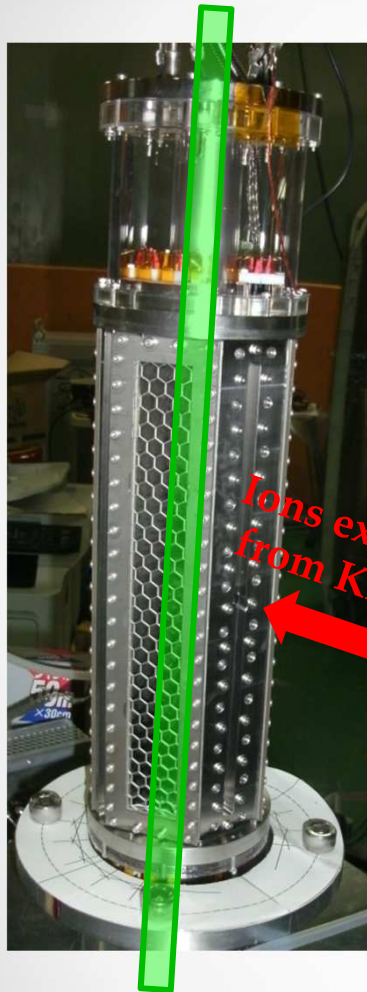
Y.X. Watanabe et al., Phys. Rev. Lett. 115 (2015) 172503.

Y. Hirayama et al., Nucl. Instrum. and Meth. B 353 (2015) 4.

Y. Hirayama et al., Nucl. Instrum. and Meth. B 376 (2016) 52.

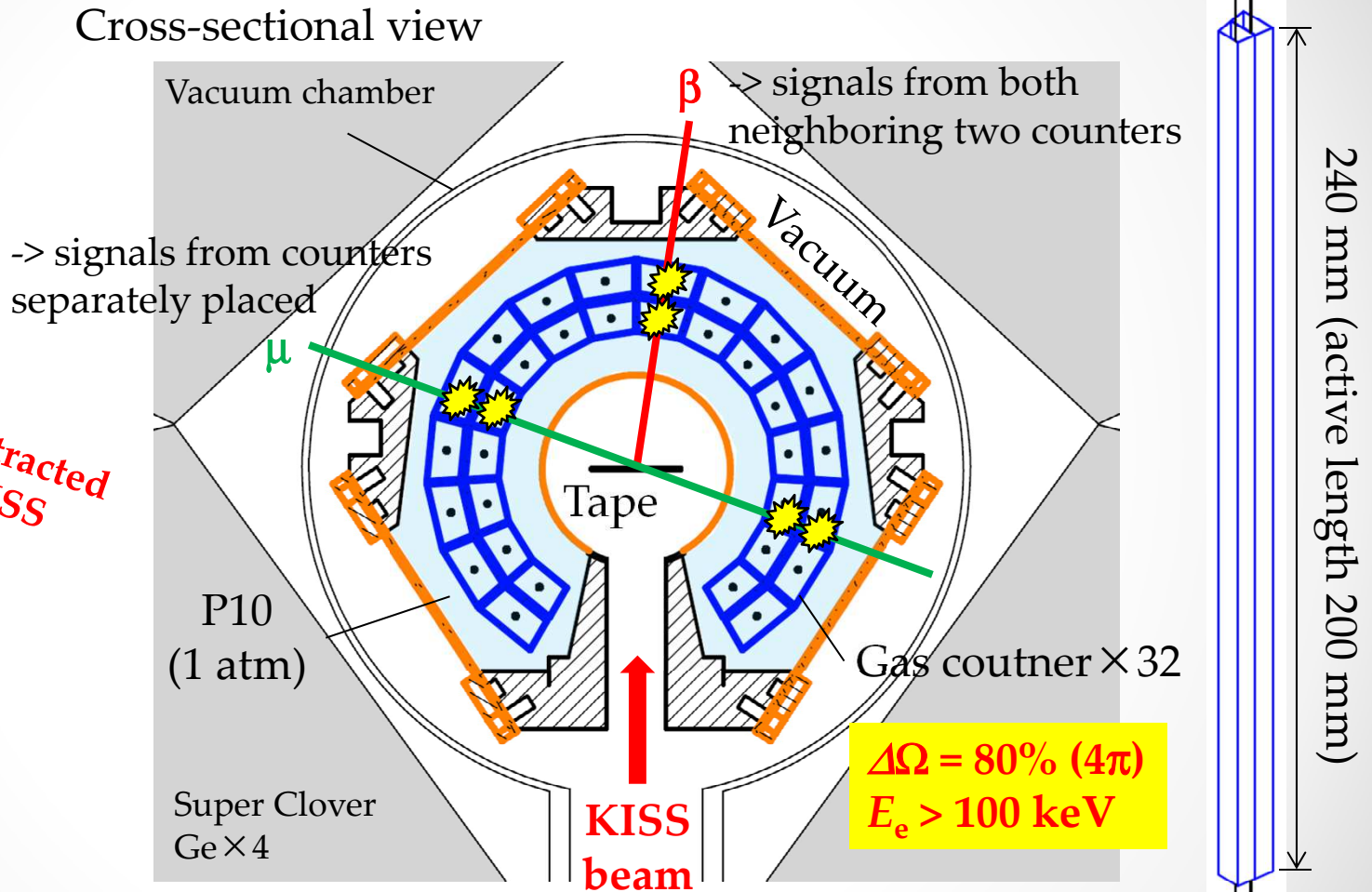
Y. Hirayama et al., Nucl. Instrum. and Meth. B 412 (2017) 11.

Multi-segmented proportional gas counter



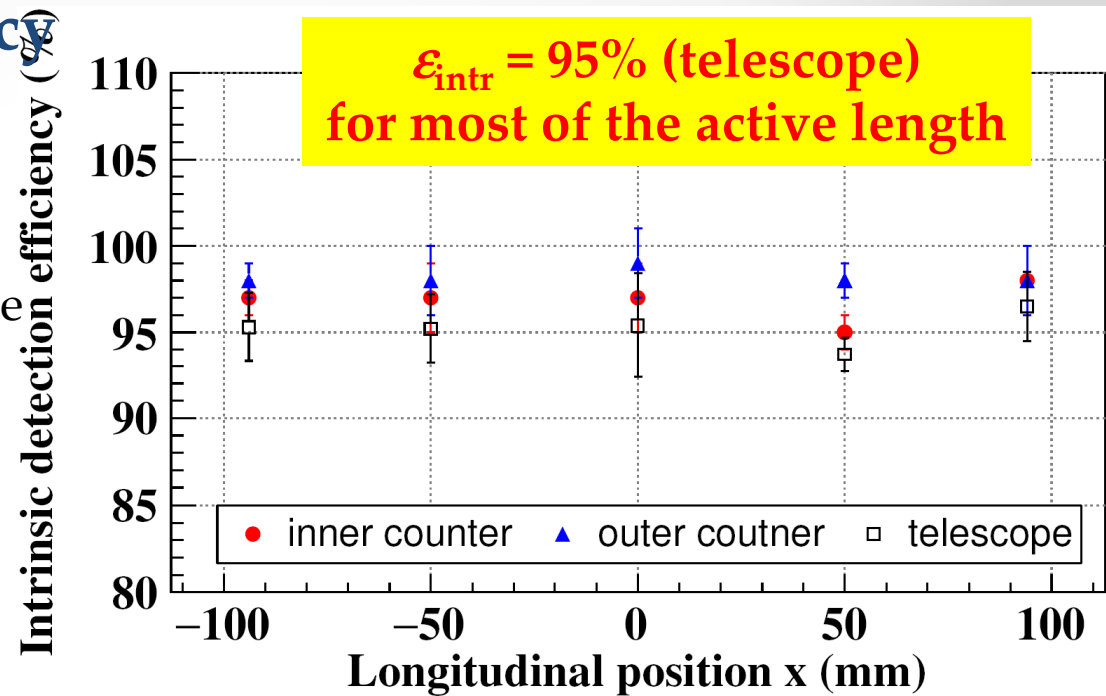
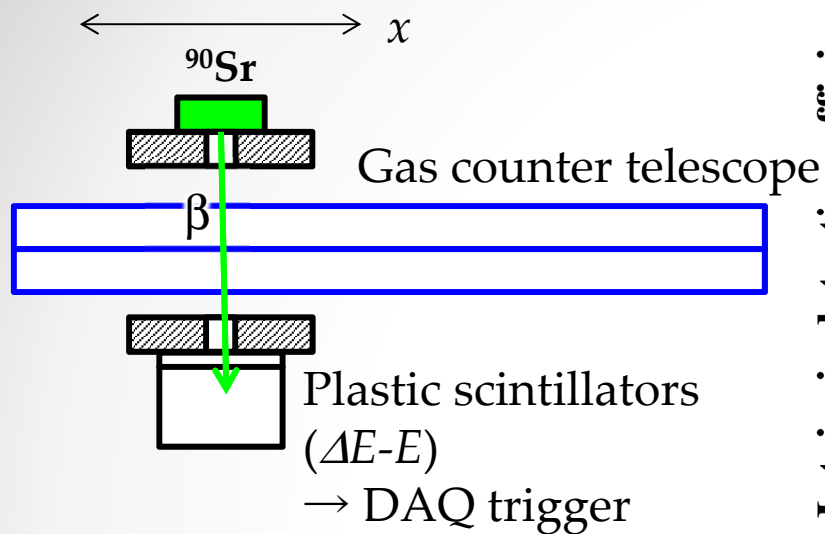
Al-Mylar tape

Ions extracted from KISS

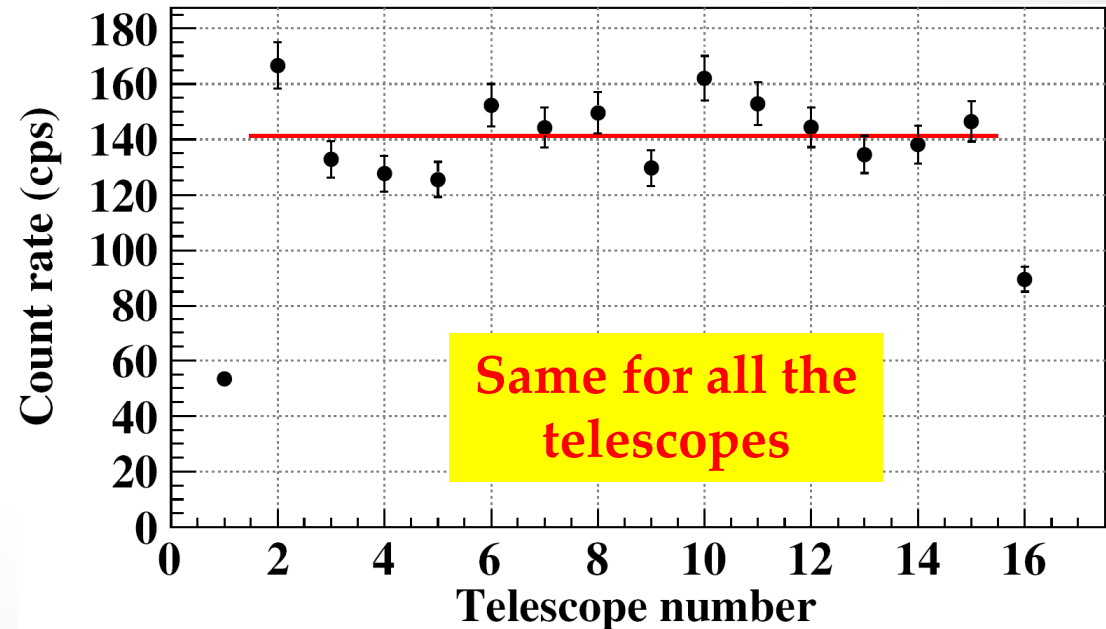
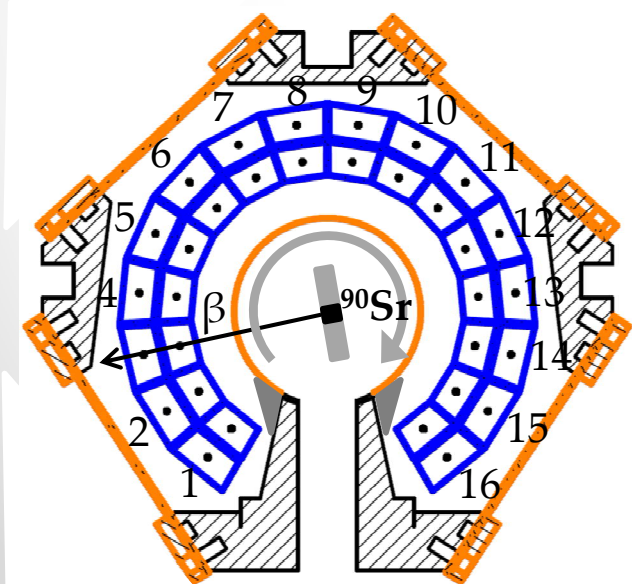


Anode: Be-Cu wire, $\phi 100\mu\text{m}$
 Cathode: Al-Mylar foil, $t 25\mu\text{m}$

Intrinsic detection efficiency

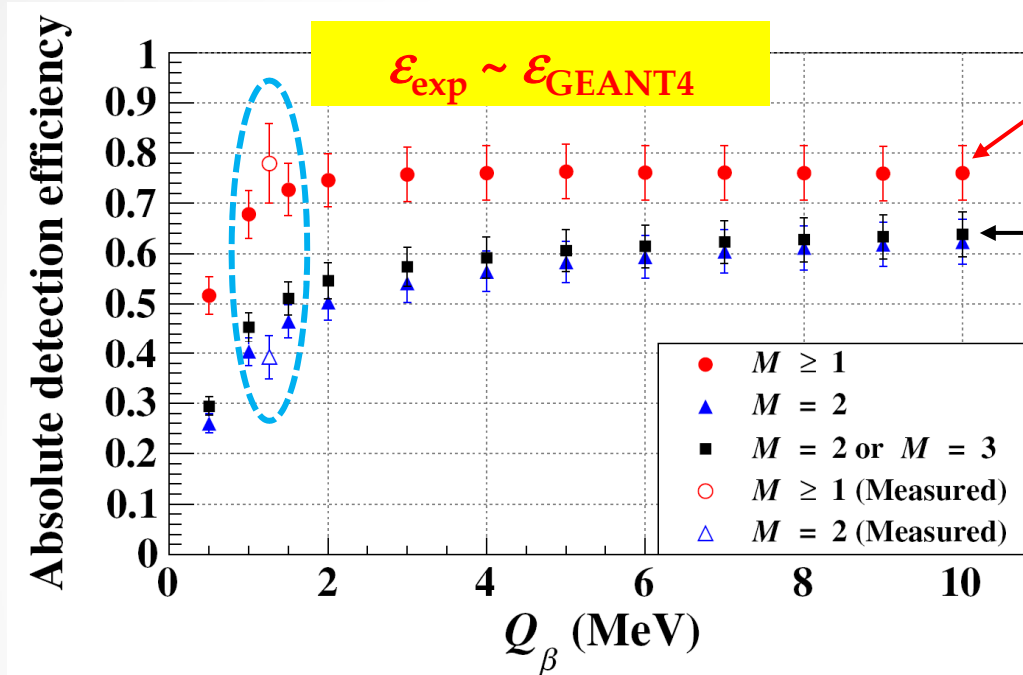


Relative detection efficiency



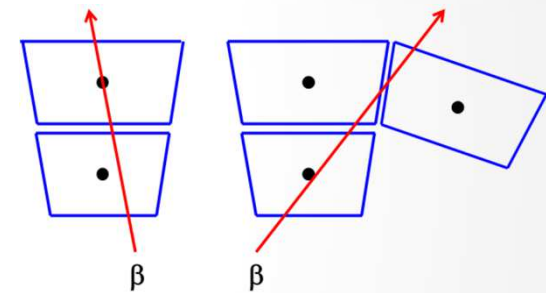
Absolute detection efficiency

- GEANT4 simulation



$M \geq 1$
 $\epsilon_{\beta} = 75\%$

$M = 2$ or $M = 3$
 $\epsilon_{\beta} = 45\% @ Q_{\beta} = 1 \text{ MeV}$



- β - γ spectroscopy of ^{199}Pt

$^{199}\text{Pt } T_{1/2} = 30.80(21) \text{ min}$

$Q_{\beta} = 1161.6 \text{ keV}$
 $I_{\beta} = 0.1201$

$Q_{\beta} = 1704.6 \text{ keV}$
 $I_{\beta} = 0.707$

543 keV

543 keV, $I_{\gamma} = 0.1174$

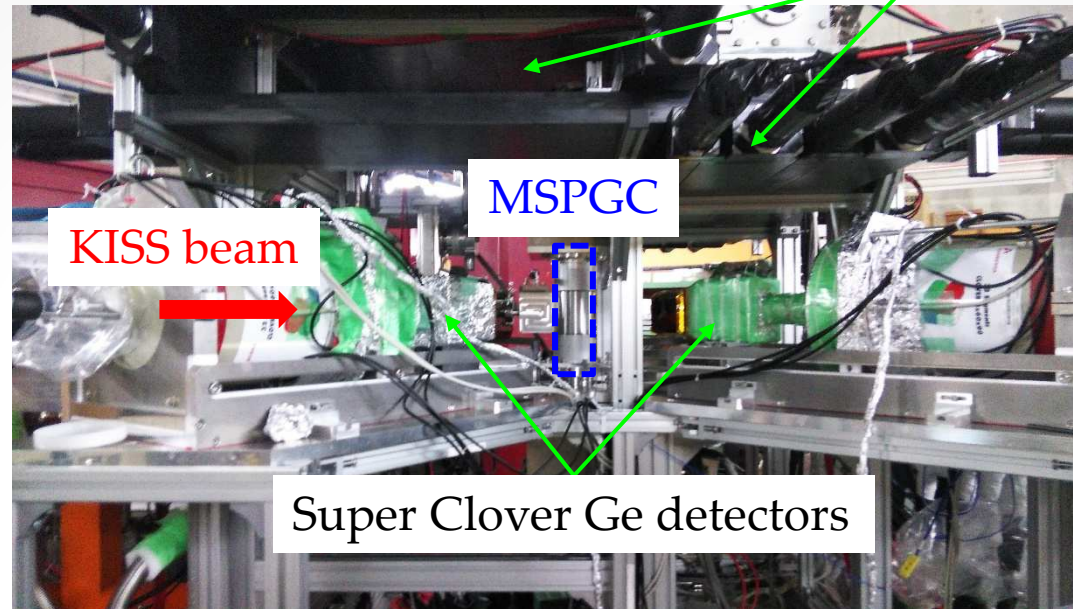
gs

$^{199}\text{Au } T_{1/2} = 3.139(7) \text{ d}$

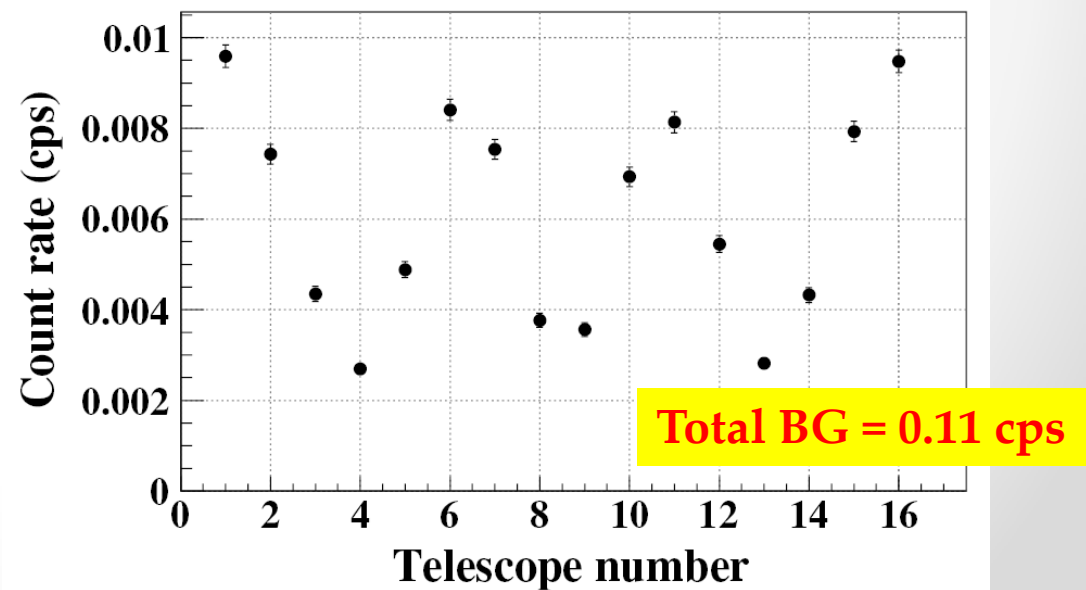
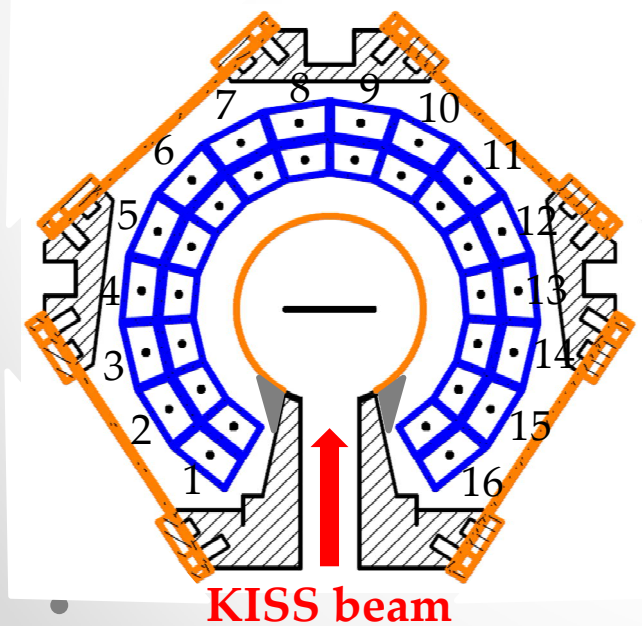
$$\epsilon_{\text{GC}} = \frac{N_{543}(\beta - \gamma)}{N_{543}(\text{single})}$$

Background event rate

Side view of the detector station

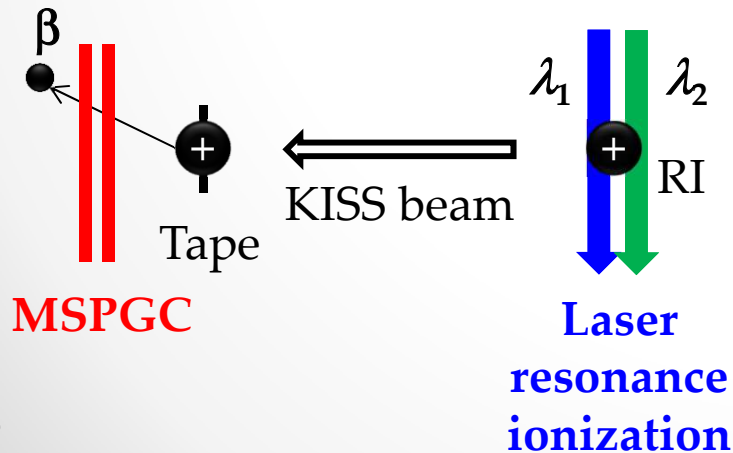
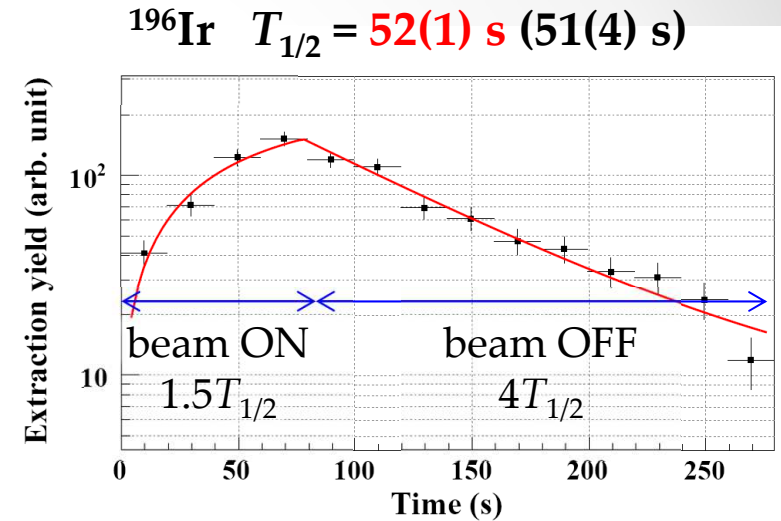
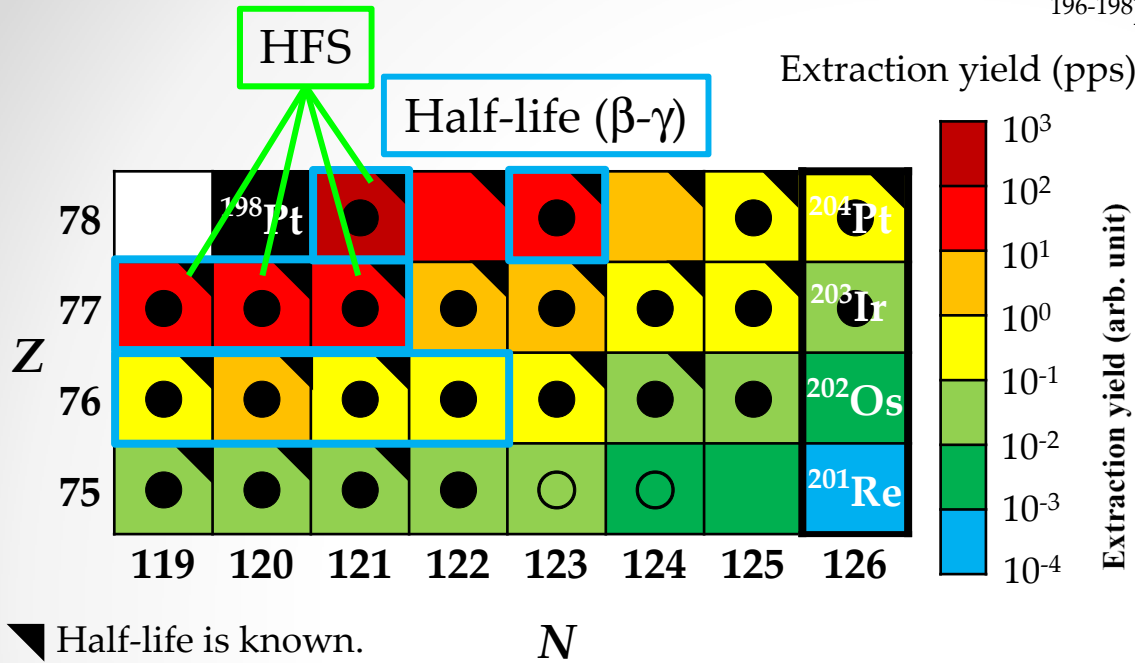


+ Pb shield



Half-life and HFS measurements

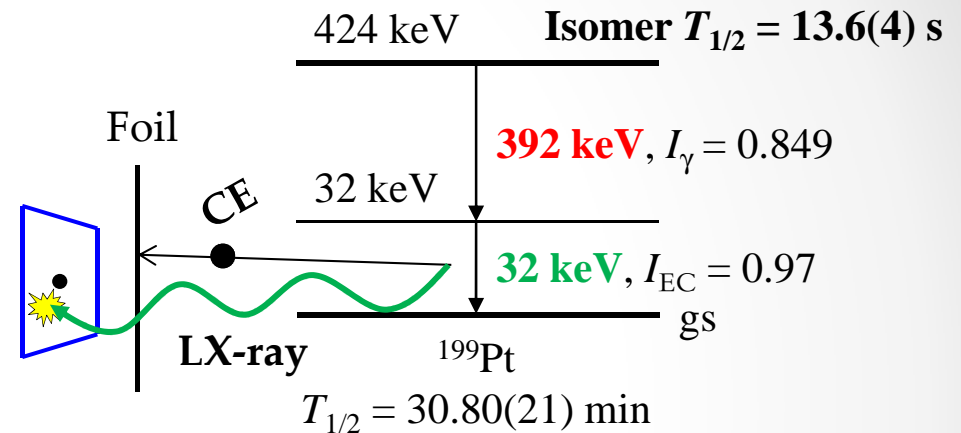
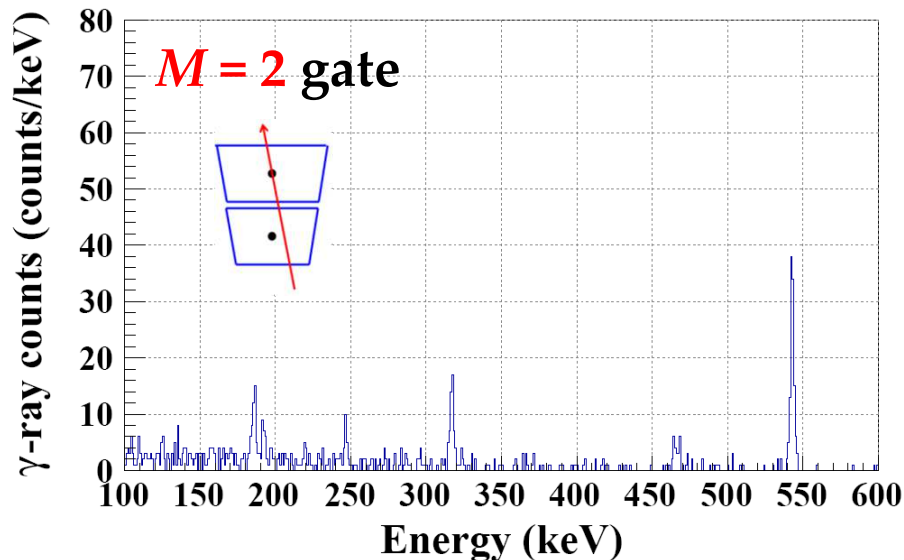
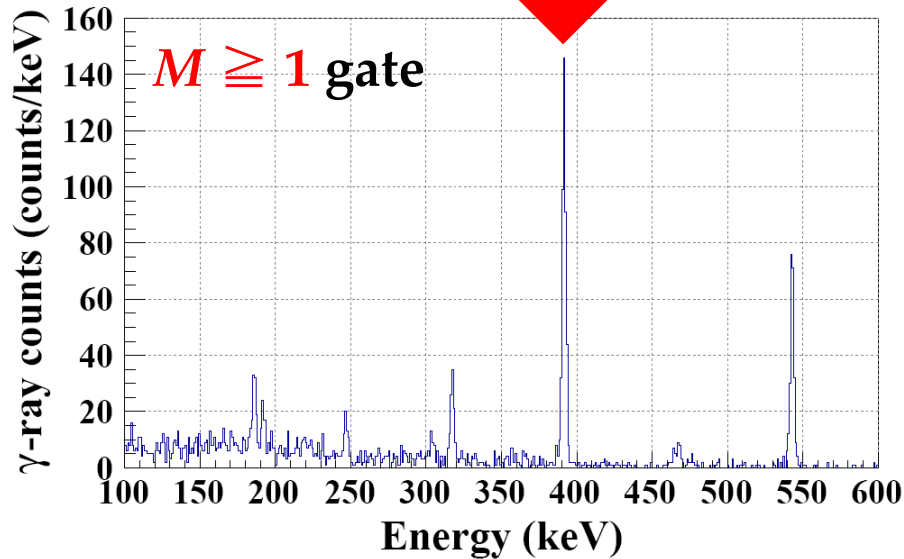
^{199}Pt : Y. Hirayama et al., PRC 96, 014307 (2017).
 $^{197,198}\text{Os}$: Y. Hirayama et al., PRC 98, 014321 (2018).
 $^{196-198}\text{Ir}$: M. Mukai et al., in preparation.



Possibility of isomer search by X-ray detection

e.g. ^{199m}Pt

Coincidence with γ -ray and LX-ray (~ 10 keV)



$$\varepsilon_X = \frac{N_{392}(\beta_{M \geq 1} - \gamma)}{N_{392}(\text{single})} \frac{1}{P_L} = 12(1)\%$$

P_L : Averaged L-shell fluorescence probability

Comparison of γ -ray energy spectra
between $M \geq 1$ and $M = 2$
 \Rightarrow Identification of γ -ray transition
originated from isomer

Development status of 3D tracking MSPGC

The background rate below 0.01 cps is necessary to perform β - γ spectroscopy of even more neutron-rich nuclei ($\Upsilon < 0.1$ cps).

-> **Carbon (resistive) anode wire** to measure the **longitudinal hit-positions** for identifying β -rays.

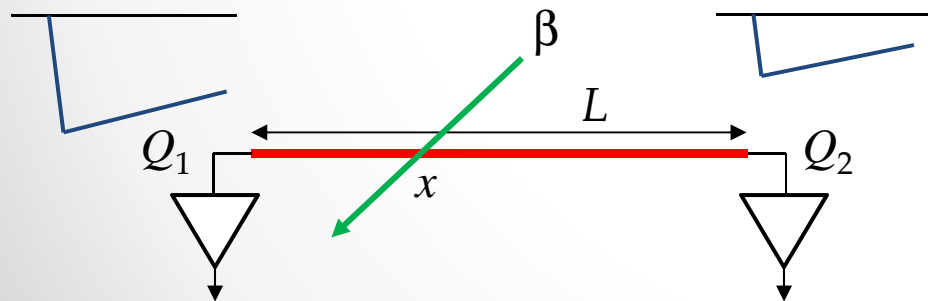
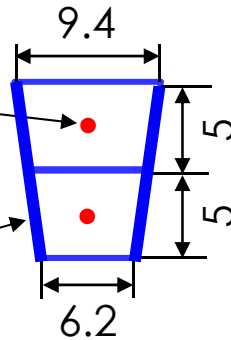
Top view of 1 telescope

Anode :

**Carbon wire, $\phi 10 \mu\text{m}$
XN-P9-60Z, 3 k Ω /cm**

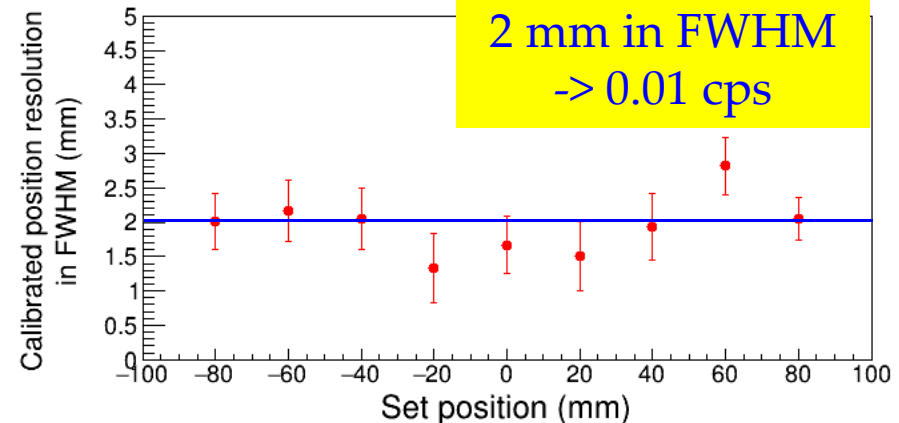
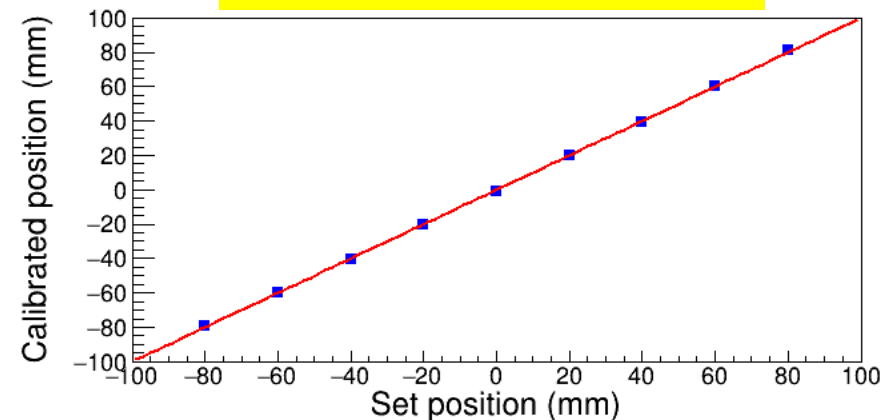
Cathode:

**Aluminized Mylar ($t 25 \mu\text{m}$)
and SUS wall ($t 0.3 \text{ mm}$)**



$$x = L \times \frac{Q_1 - Q_2}{Q_1 + Q_2}$$

One proto-type counter



Summary

- MSPGC was developed as low-background and high-efficiency β -ray detector in KISS
 - 2 layers \times 16 counters \rightarrow hit-pattern analysis
- Absolute detection efficiency = 45% @ $Q_{\beta} = 1$ MeV
- Background rate w/ VETO + Pb = 0.11 cps
- Application:
 - HFS measurement, isomer search
- The three-dimensional tracking MSPGC by using resistive carbon wire as the anode is under development to reduce the background event rate down to 0.01 cps.

Thank you for your attention.