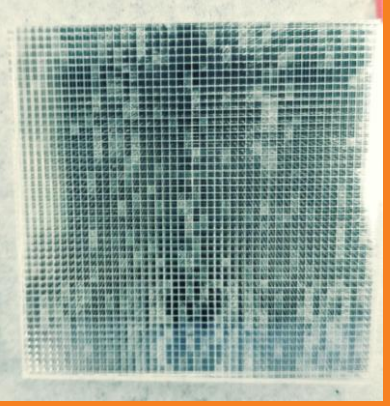
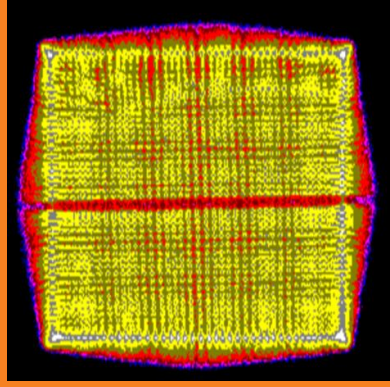
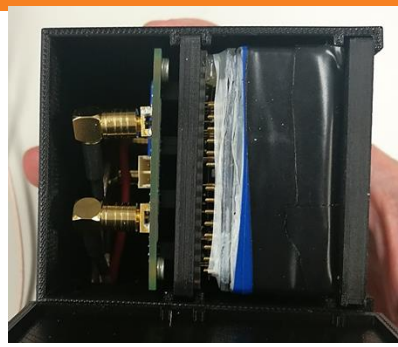




YSO fragment implantation and decay counter

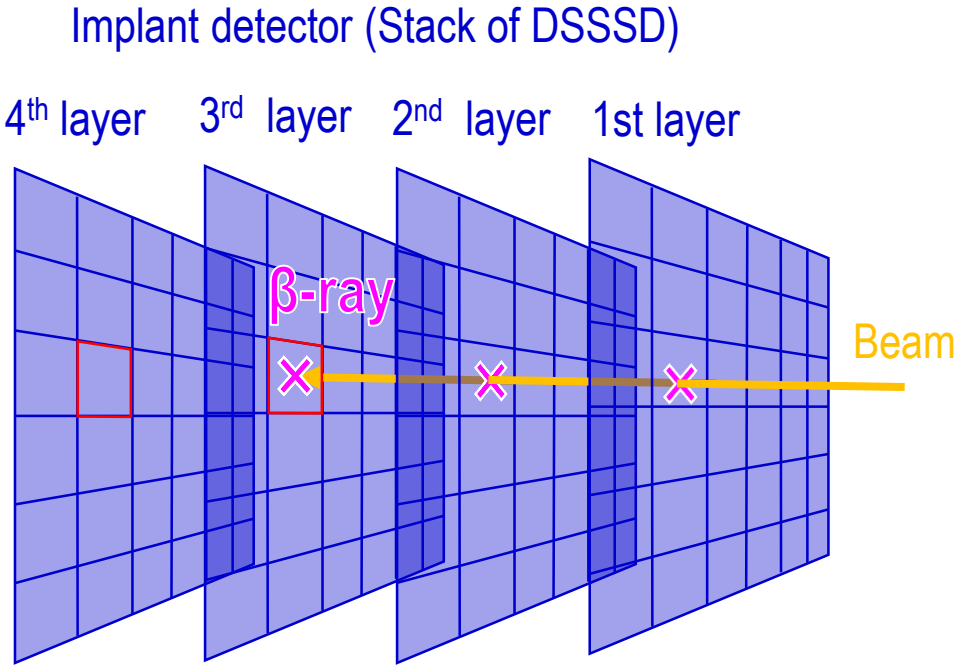


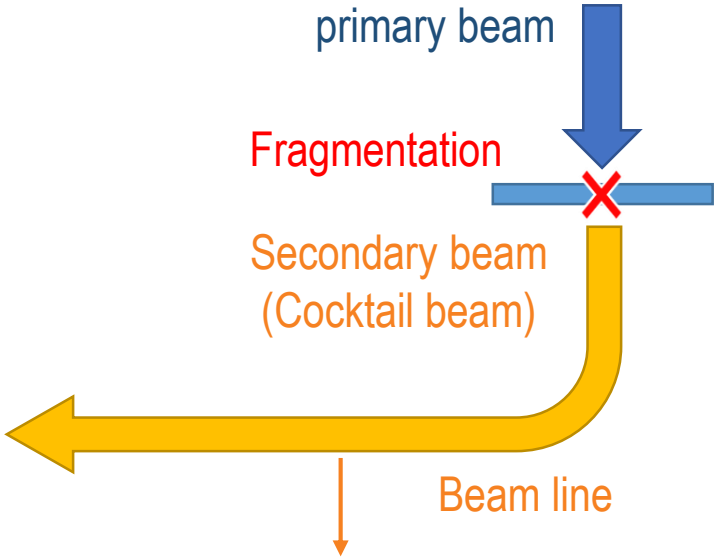
Rin Yokoyama

(*University of Tennessee, Knoxville*)

R. Grzywacz, M. Singh, T. King, S. Go, A. Keeler, J. Agramunt, N. Brewer, J. Liu, S. Nishimura, V. Phong, M. Rajabali, C. Rasco, K. Rykaczewski, J.L. Tain, A. Tolosa, and the Briken collaboration

Decay study at a fragmentation facility

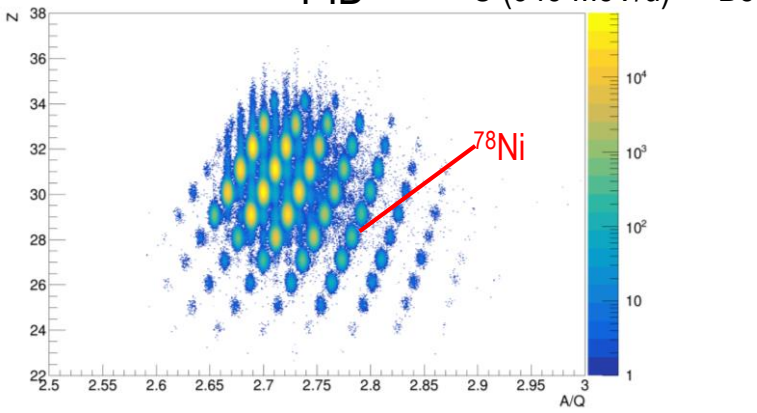




x-y position of an implant
x-y position of β-ray emission

} Correlate β events with PID

PID ^{238}U (345 MeV/u) + ^{9}Be



Implant detector requires

- **Good position resolution for both ions and beta**

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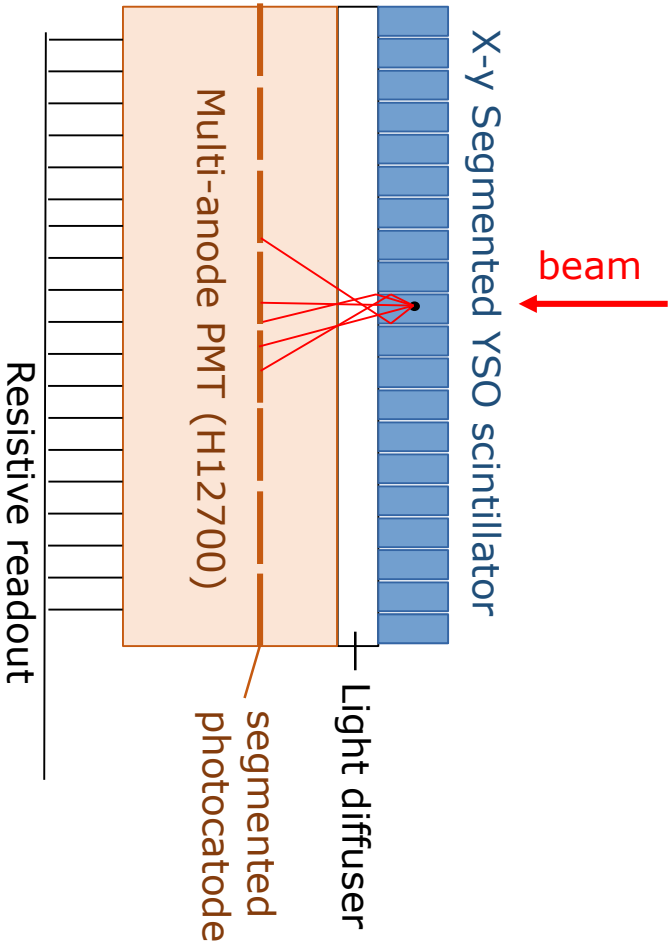
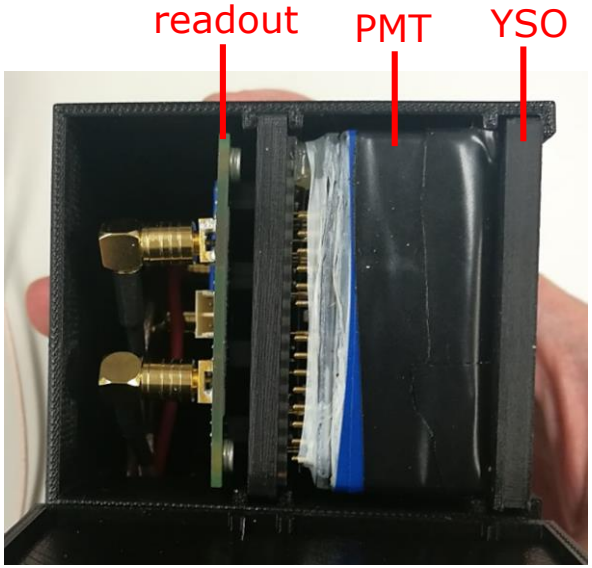
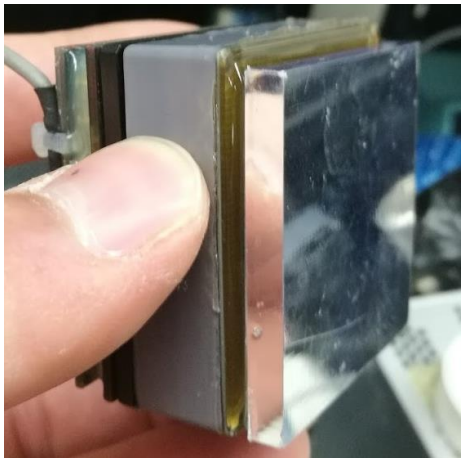
Segmented scintillation detector as an implantation and decay counter







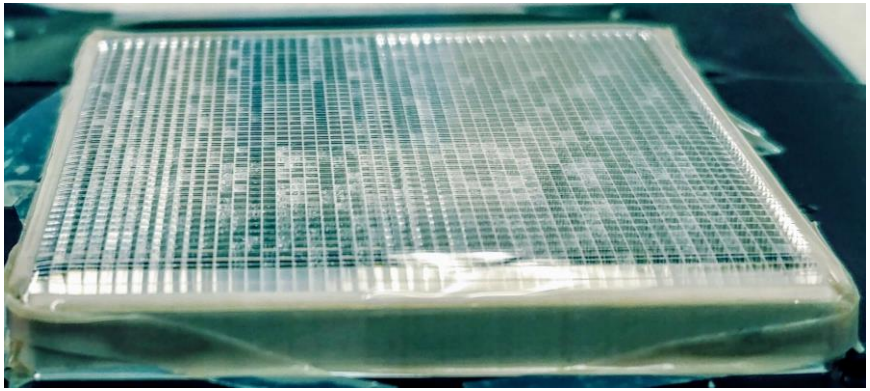
Compared to DSSSDs

- Fast response time (~300 ps)
- Hard to radiation damage
- High stopping power
  - High beta efficiency
  - Good position correlation
- Can be thick
- Simple and compact

- More γ absorption
- ~10% energy resolution for ions

Position sensitive detector with a segmented scintillator

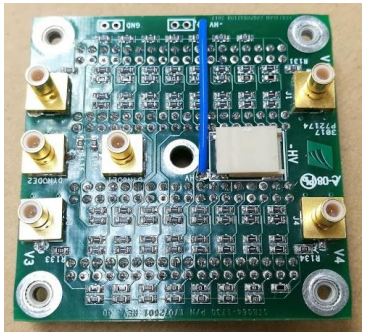
Surface of the segmented YSO



- YSO (Yttrium Orthosilicate, Y_2SiO_5) crystal
  - Effective atomic number: Z~39
  - Density: ~4.5 g/cm^3
  - Wavelength: 420 nm
  - Decay time: ~70 ns
- 48 x 48 segments
- Each segment: 1 x 1 mm
- Thickness: 5 mm
- Reflective material: ESR

Multi-anode PMT Hamamatsu H12700

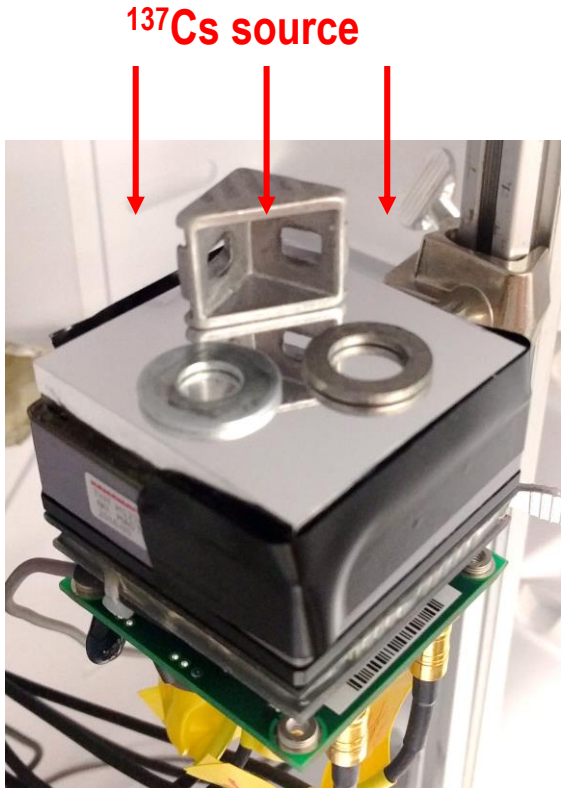
- 48.5 x 48.5 mm effective area
- 8 x 8 anodes

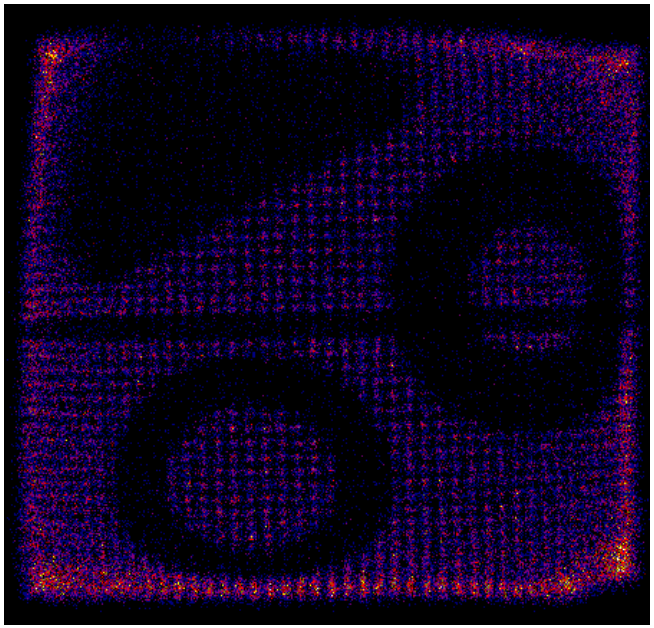


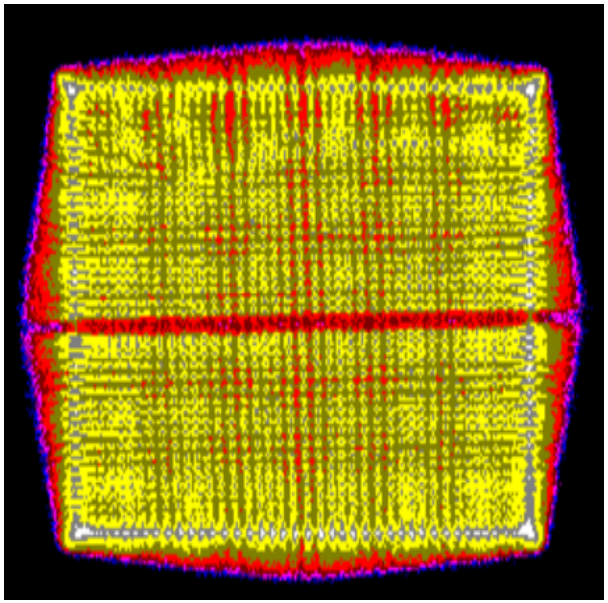
Resistive readout board

- 4 ch for position
- 1 ch (dynode) for timing

Gamma-ray image

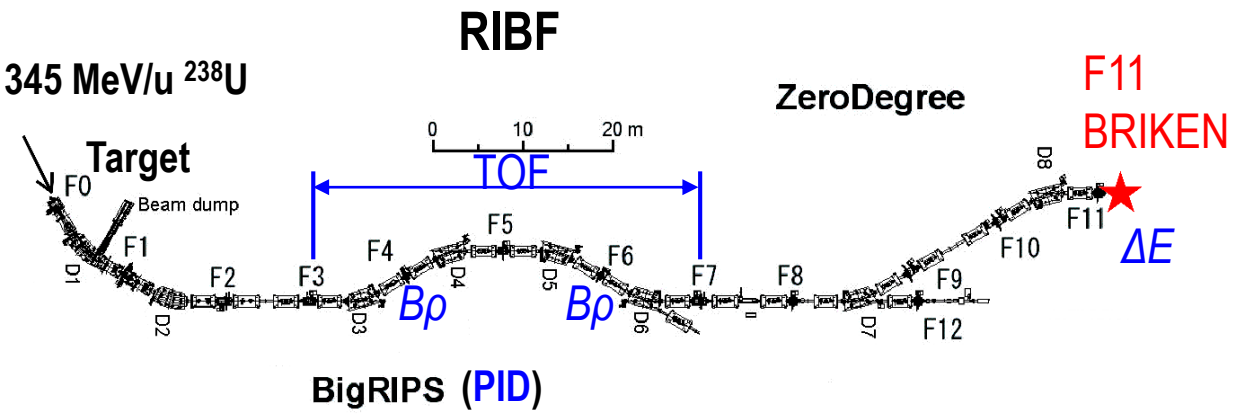


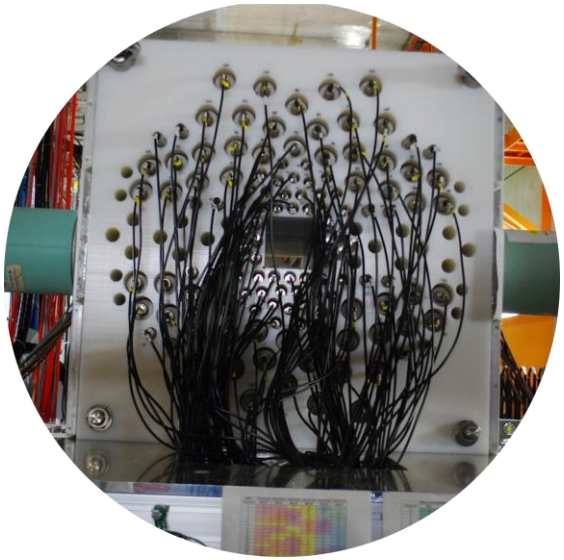


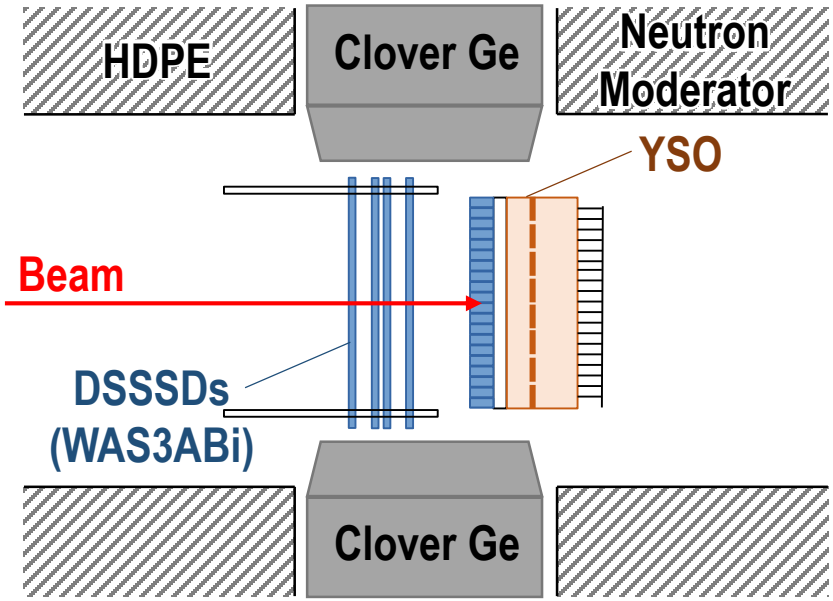


- Enough resolution to see 1 x 1 mm segments
- The image is linear except along the edge

First implementation of YSO detector at RIKEN w/ BRIKEN



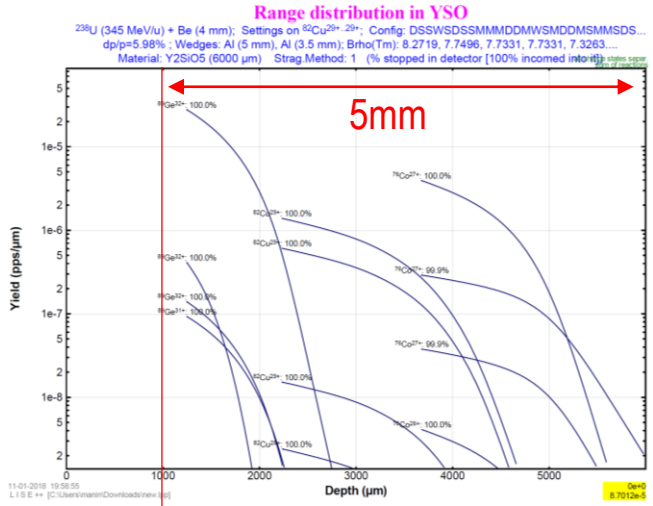




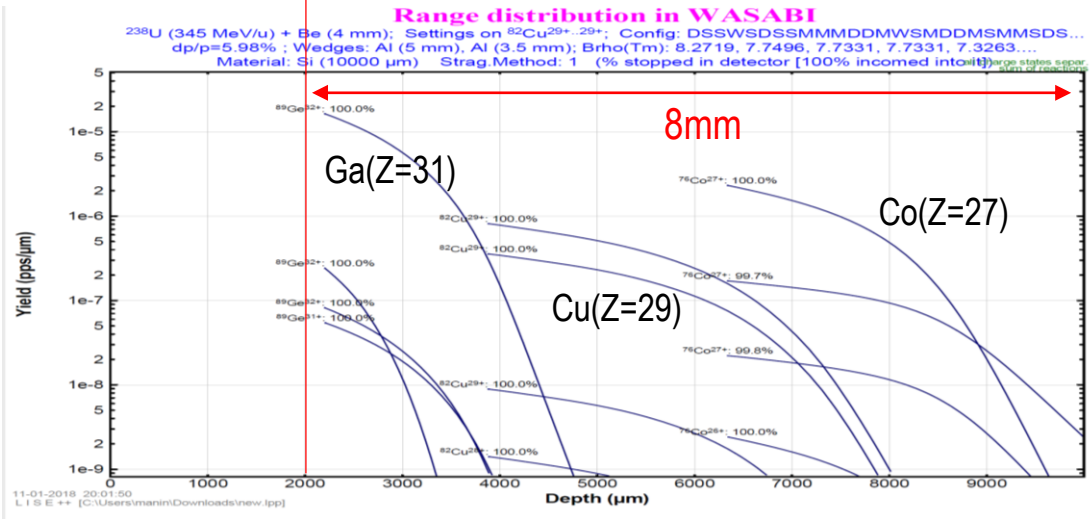
BRIKEN exp. in Oct./Nov. 2017 at RIBF

- In-flight fission of 345 MeV/u ^{238}U
- Region around and beyond 78Ni
- 140 ^{3}He counters for Pn measurement
- Two ORNL clover detectors
- Shared implantation between DSSSDs and YSO

Ion ranges in YSO and Si



5 mm of YSO stops all the ions between Z=27 to 31



8 layers (8 mm) of Si are required to stop all the ions

- **4 mm Si + 5 mm YSO are installed in this experiment**

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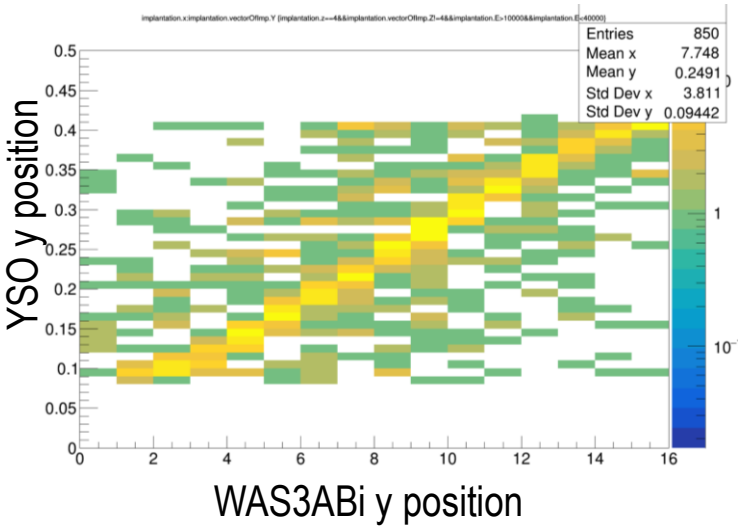
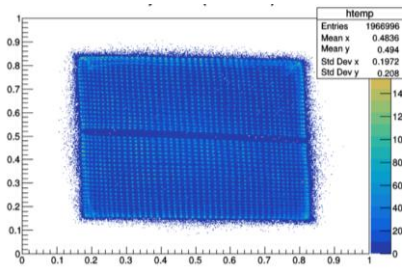
Position correlation

Position correlation between YSO and WAS3ABi(DSSSDs) (Ions that punched through)

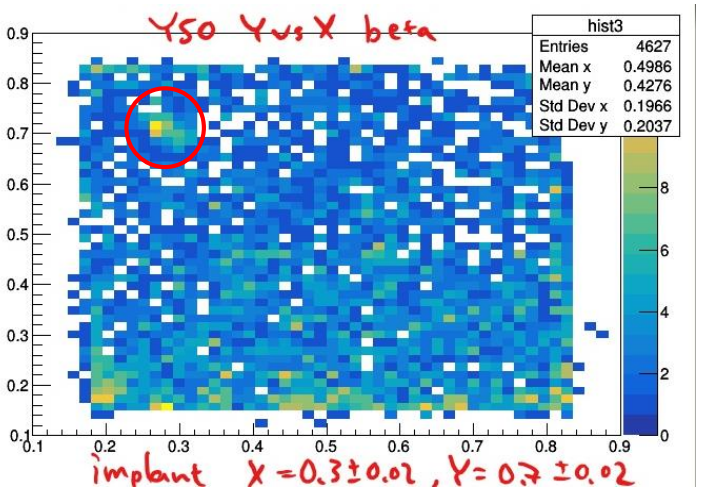


Position correlation between implantation and beta

x-y images of beta events gated by implant position $(T_\beta - T_{imp} < 1\text{s})$



Beta image without the gate

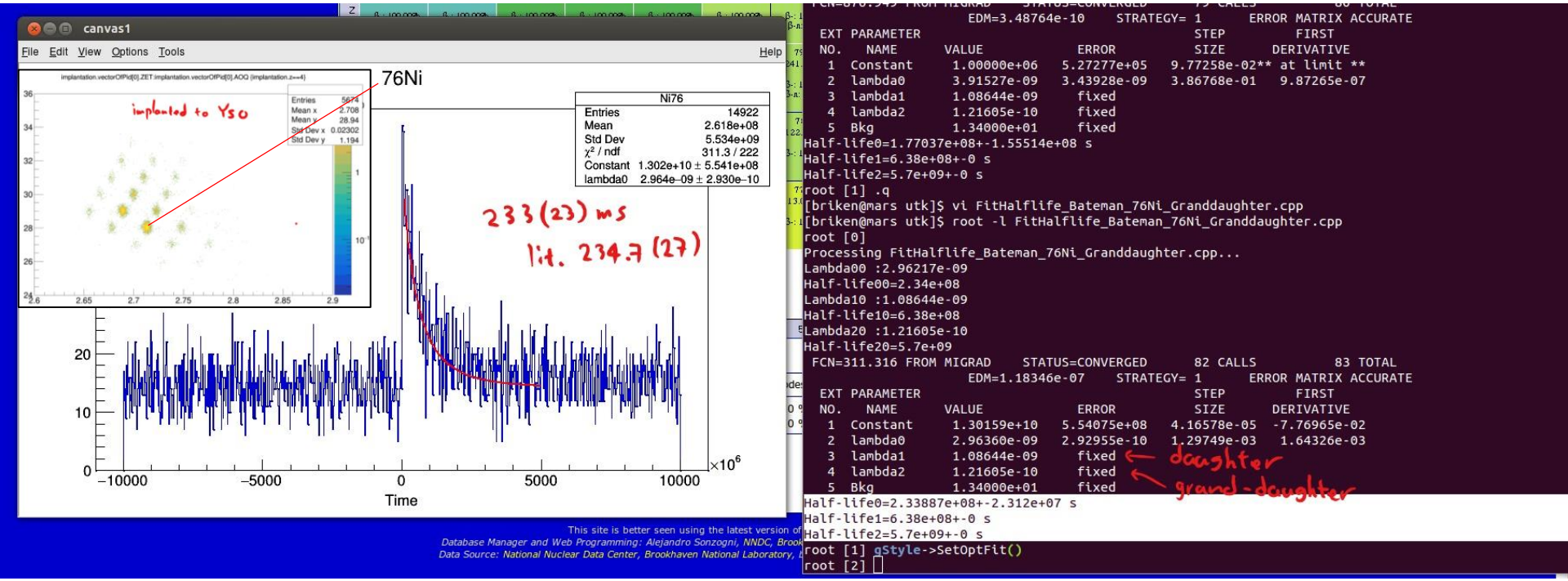


Implanted at the top left corner

- **Implant positions obtained from YSO were consistent with those obtained from WAS3ABi.**
- **Observed position correlated events between beta events and implant events.**

Decay of ^{76}Ni

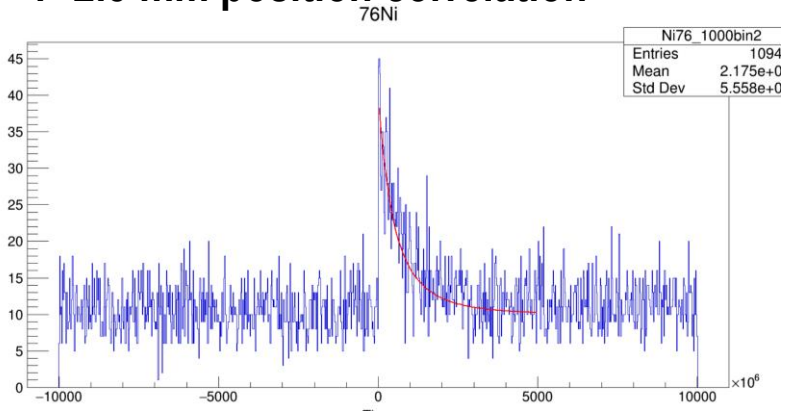
Decay curve of ^{76}Ni implanted into YSO



- The decay curve was fit with a function including the daughter and grand-daughter decays.
- Obtained half-life of ^{76}Ni was consistent with a literature value.

Beta efficiency

Decay spectrum of ^{76}Ni with r<2.5 mm position correlation



$$A_0 = N_0 \int_{0s}^{10s} \lambda_0 e^{-t\lambda_0} dt$$

$$A_1 = N_0 \int_{0s}^{10s} \lambda_0\lambda_1 \left(e^{-t\lambda_0} - e^{-t\lambda_1}\right)/(\lambda_1 - \lambda_0) dt$$

$$A_2 = N_0 \int_{0s}^{10s} \lambda_0\lambda_1\lambda_2 \left\{\frac{e^{-t\lambda_0}}{(\lambda_2-\lambda_0)(\lambda_1-\lambda_0)} + \frac{e^{-t\lambda_1}}{(\lambda_2-\lambda_1)(\lambda_0-\lambda_1)} + \frac{e^{-t\lambda_2}}{(\lambda_0-\lambda_2)(\lambda_1-\lambda_2)}\right\} dt$$

Number of detected beta from ^{76}Ni:
{(Integral 0 to 10s) – (Integral -10 to 0s)} * $A_0/(A_0+A_1+A_2)$
= 6232 * 0.35 = 2170 events

Number of ^{76}Ni ions implanted to YSO: 3307 ions

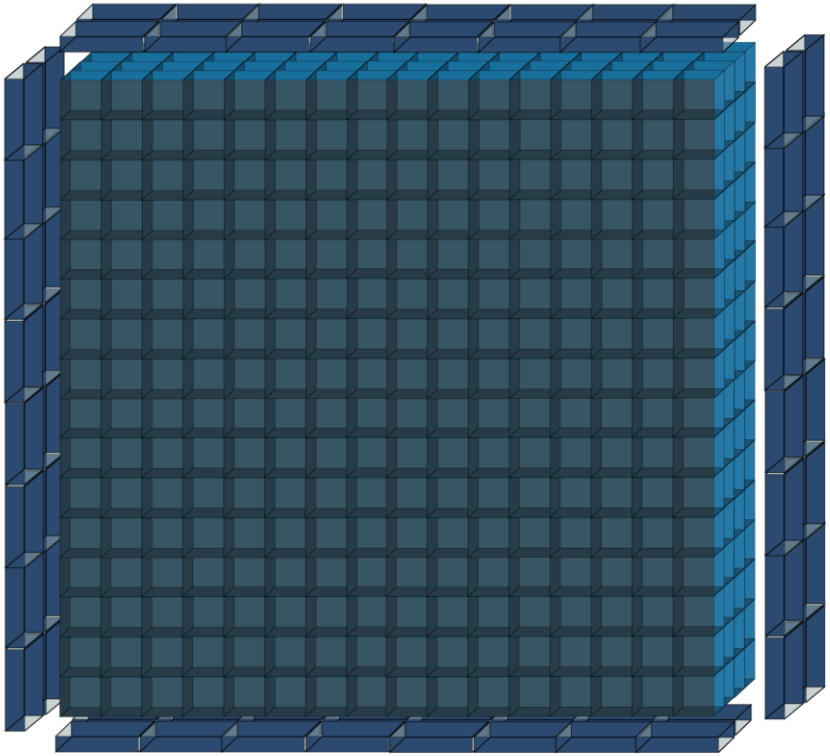
Beta efficiency of ^{76}Ni with 2.5 mm correlation: ~65%

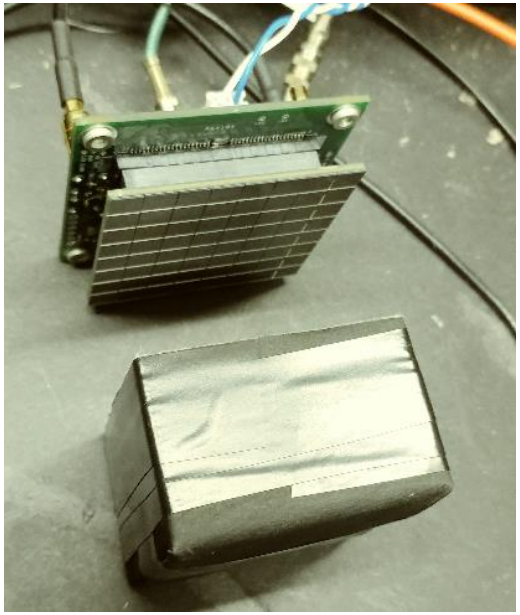
- **Ni isotopes are expected to be implanted in the very front part of YSO.**
- **Higher efficiency is expected for an ion implanted deeply.**

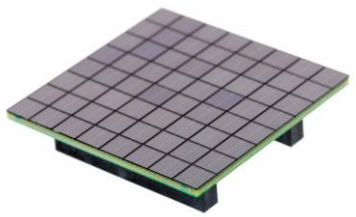
Future design

3D readout will be enabled with SiPM

Large arrays possible to fit the size of the beam spot.







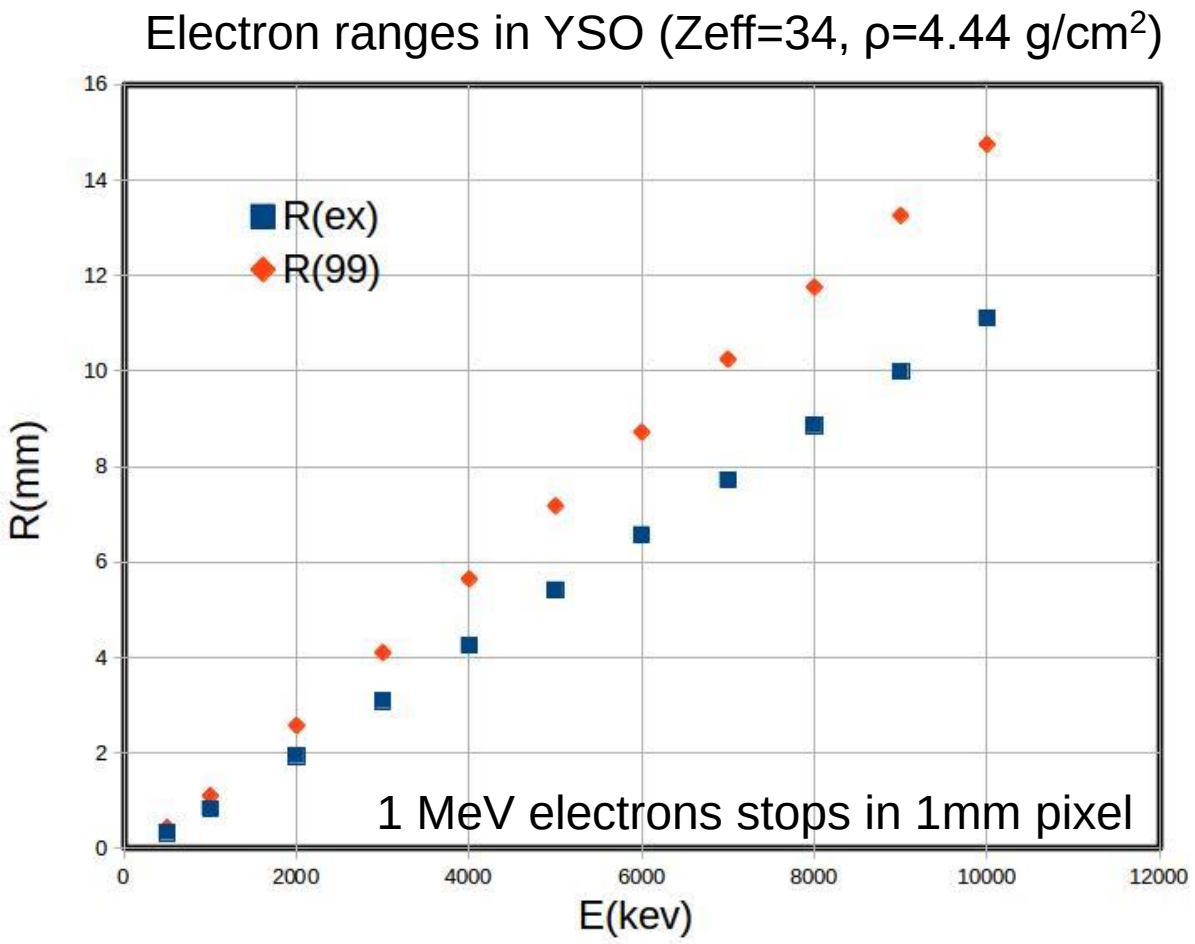
Summary

- We are developing a YSO scintillation detector as an implantation and decay counter for fragmentation facilities.
- Implemented in an experiment at RIKEN RIBF (~78Ni region).
- The Ion-beta correlation by YSO was successful
  - The decay curve of ^{76}Ni was consistent with a literature.
- The online analysis shows ~65% beta efficiency with 2.5mm position window.

TODO

- Study of the light yield of YSO to various ions for the better way of gain adjustment.
- Testing fast timing for the future neutron-ToF measurements.
- 3D readout with SiPM

Beta range in YSO



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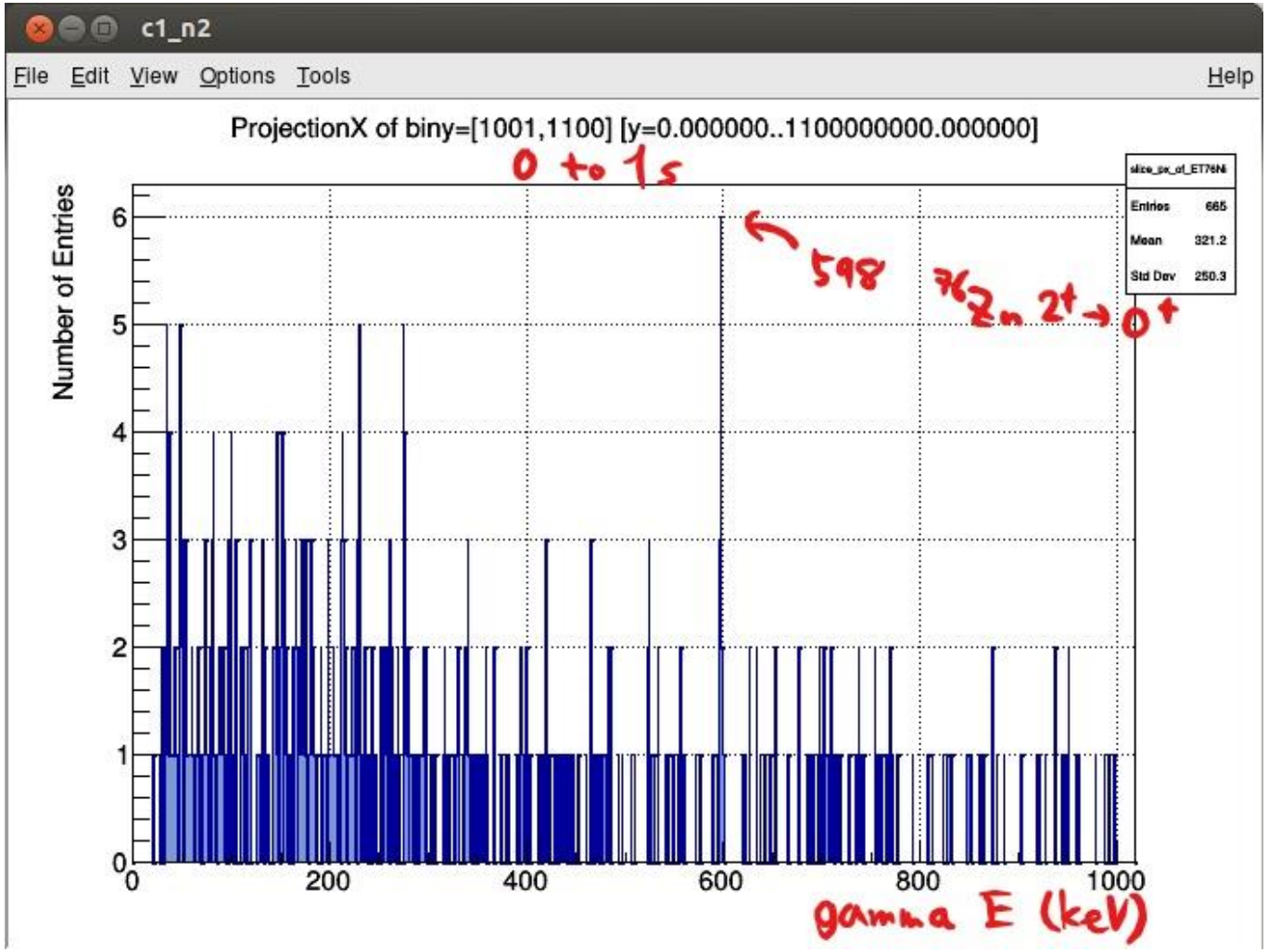
Gamma-ray



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Position distribution of implant and beta events