Active Stoppers for Decay Experiments

Valencia, Spain, March 24-26 2025

March 24, 2025

Beta counting systems at the RIBF:

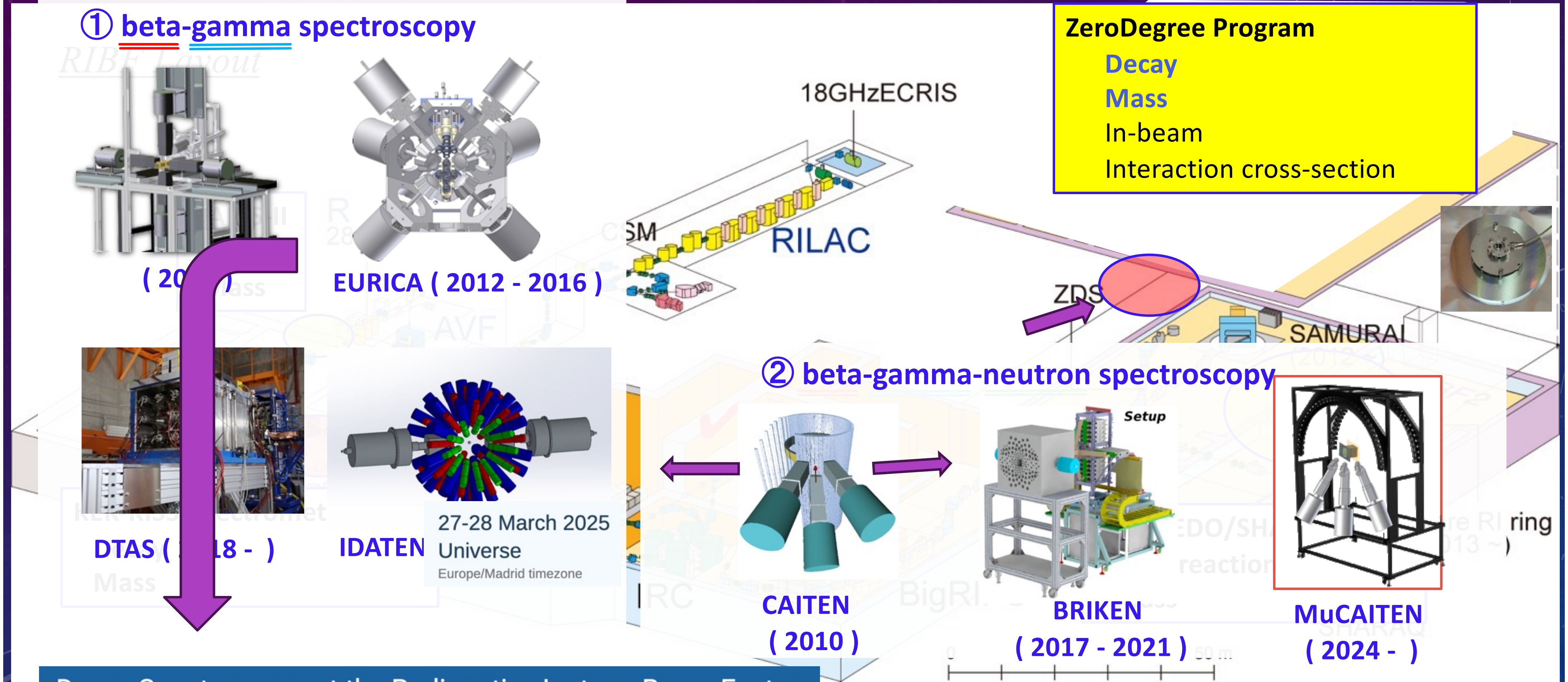
Requirements and options

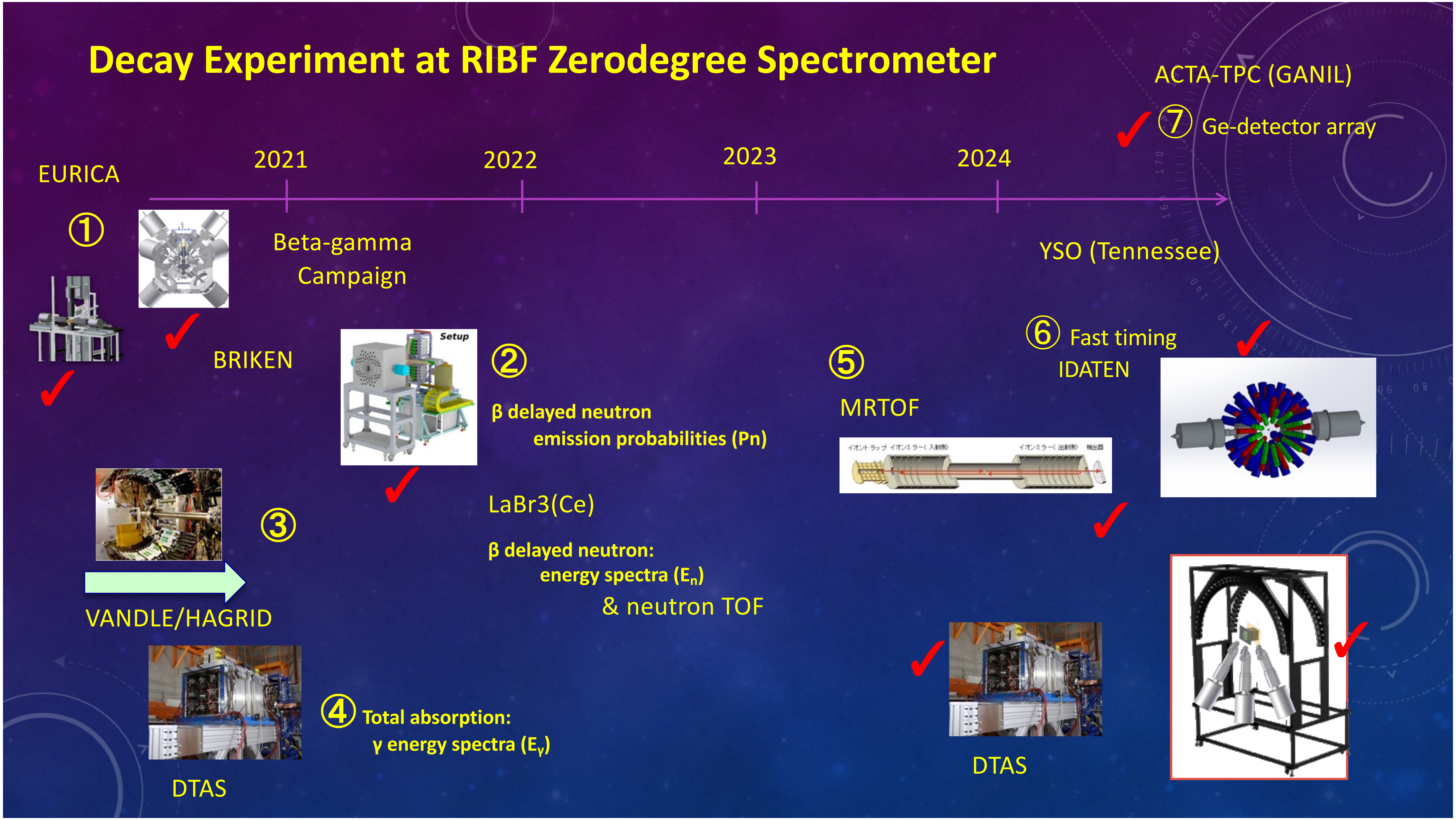
Shunji Nishimura (RIKEN)

Talks by
- V.H. Phong ... RIKEN
- T .T Yeung (Marco) ... U.Tokyo
- Q. Zeng ... IMP

Decay Experiments at RIBF

^{238}U beam
345 MeV/u, 90 pnA




Decay Experiment at RIBF Zerodegree Spectrometer
ACTA-TPC (GANIL)
⑦ Ge-detector array
2021
2022
2023
2024
EURICA
①
Beta-gamma Campaign
YSO (Tennessee)
BRIKEN
Setup
②
β delayed neutron emission probabilities (Pn)
⑥ Fast timing
IDATEN
⑤
MRTOF
LaBr3(Ce)
③
β delayed neutron:
energy spectra (E_n)
& neutron TOF
VANDLE/HAGRID
④ Total absorption:
γ energy spectra ($E_γ$)
DTAS
DTAS

Beta Counting System: Requirements and Options

Requirement	beta, alpha, gamma	Heavy Ion (RI)
Energy threshold	20 keV ～ 50 keV & self-trigger	Beam trigger
Energy resolution	20 ~ 30 keV@1MeV	σ < 0.2 %
Position association	Segmentation, size, layers	pixel size, layers
Energy dynamic range	2 ～ 10 MeV ～	0.5 ～ 20 GeV (Z, thickness)
Fast Recovery time	< 500 usec after Implantation	a few μsec
Timing resolution	100 psec ～ * nsec	30 psec ～
High Rate of RI	Signal / Background	Radiation damage

- Material
  - High stopping power for beta
  - Less absorption for gamma-ray
  - Quenching
- Fast speed DAQ for high statistics / rare events
- Stable operation
- Isomer tagging, conversion electrons

No perfect detectors... Silicon, Plastic, TPC, ...

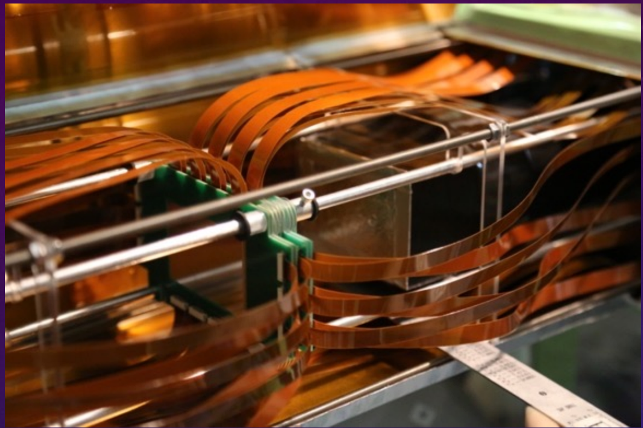
→ Flexible configuration for required physics cases and RI beams

WAS3ABi

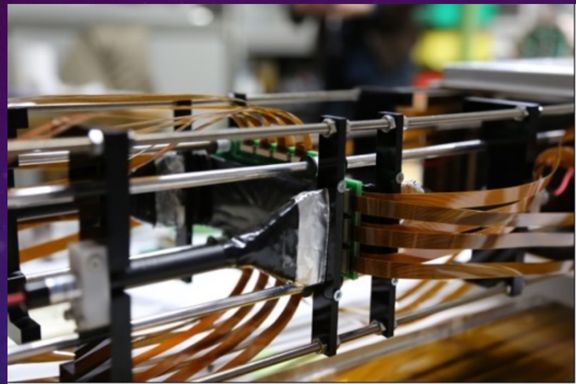
WAS3ABi Configuration for EURICA, BRIKEN, DTAS

Nitrogen air cooling ~ 10 degree.
Air cooling ~ 15 degree

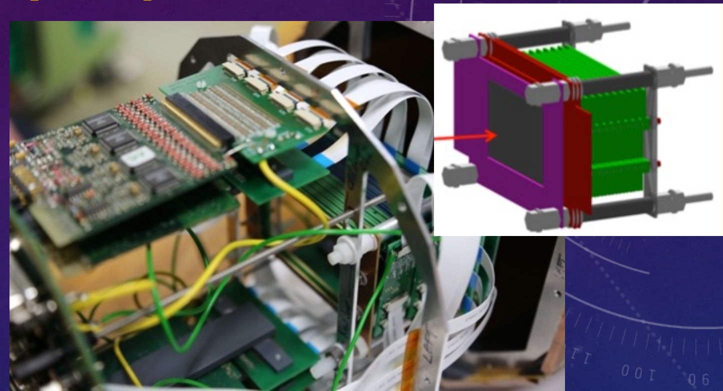
[60x40] x 8 + Plastic scintillator



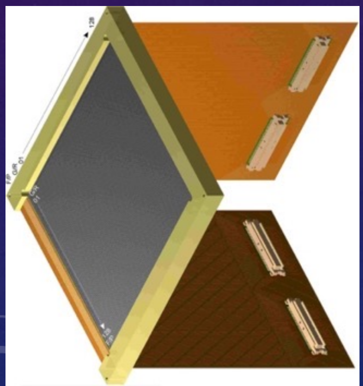
[60x40] x 4 + Plastic scintillator x 2



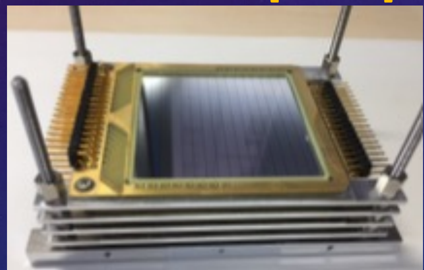
[60x40] x 3 + SSD x 10



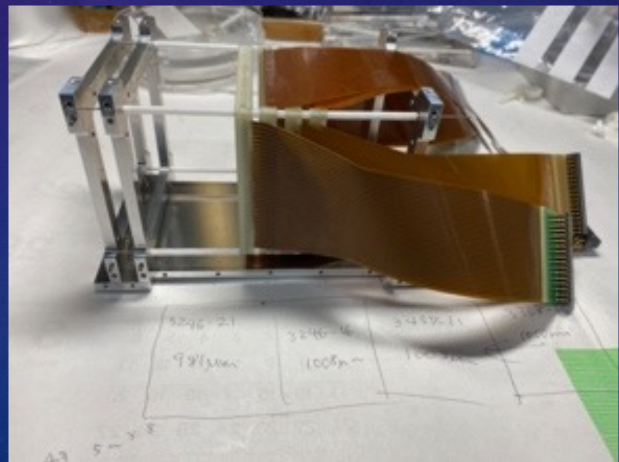
[128x128]（York Univ.)



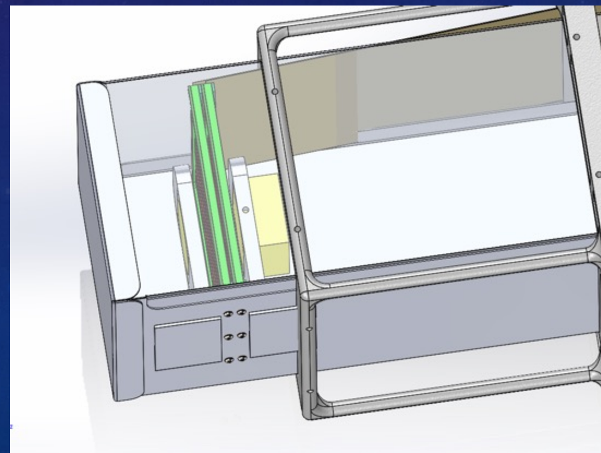
BRIKEN 2017 ... [16x16] x 4



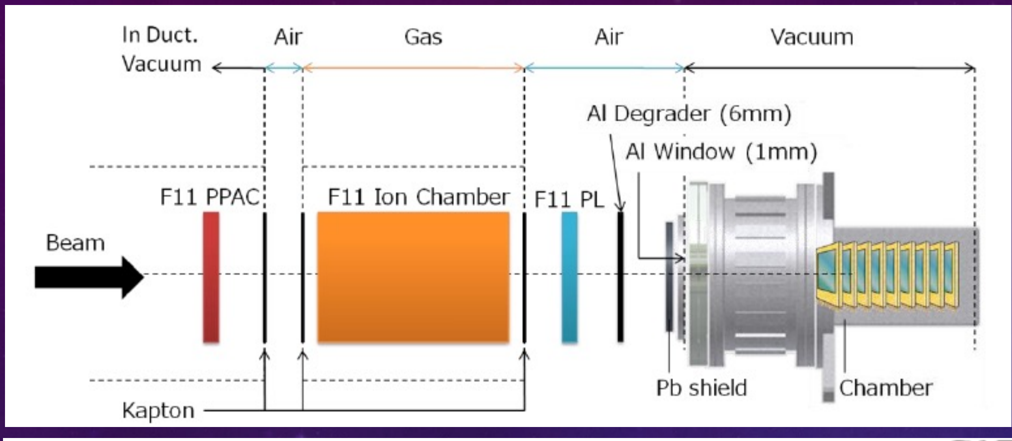
BRIKEN 2021 ... [32x32] x 4

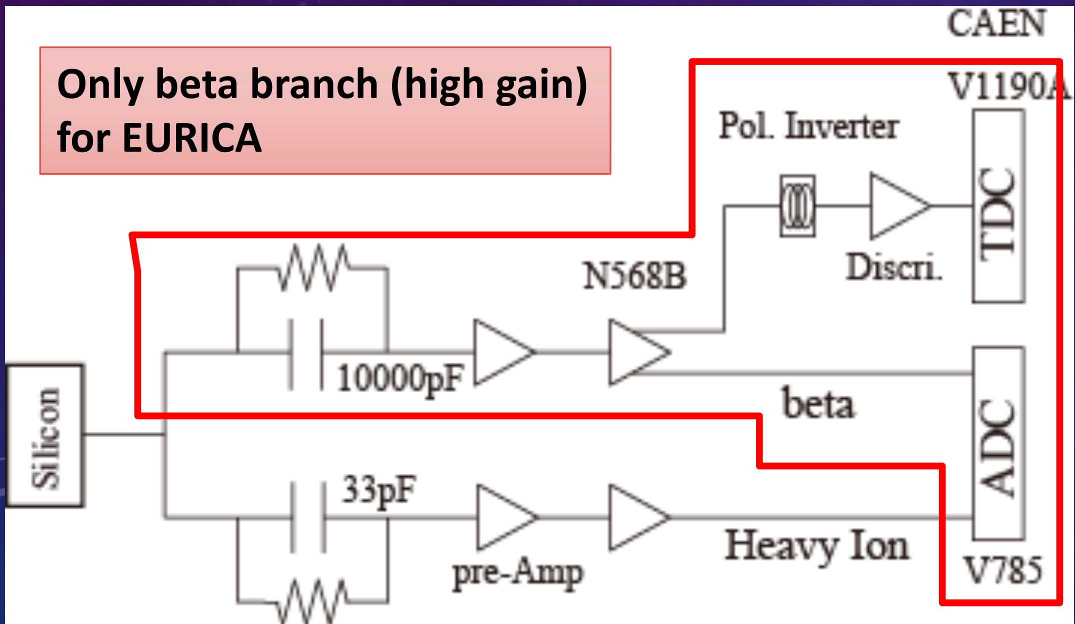


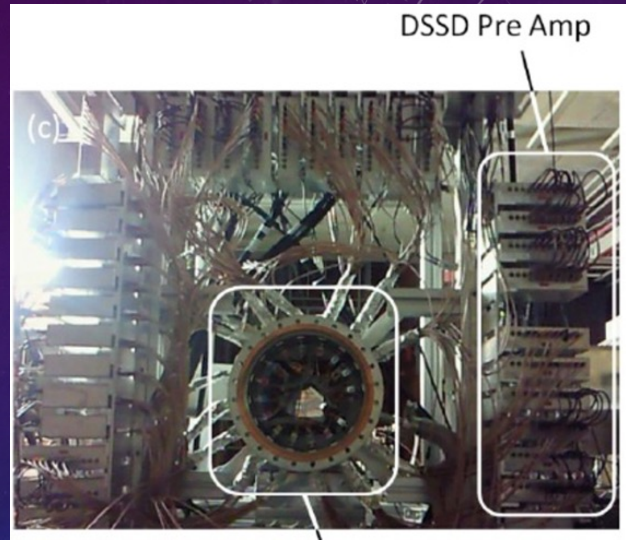
DTAS 2024 ... [64x64] x 2 (IFIC)



Readout system (2009 – 2015)





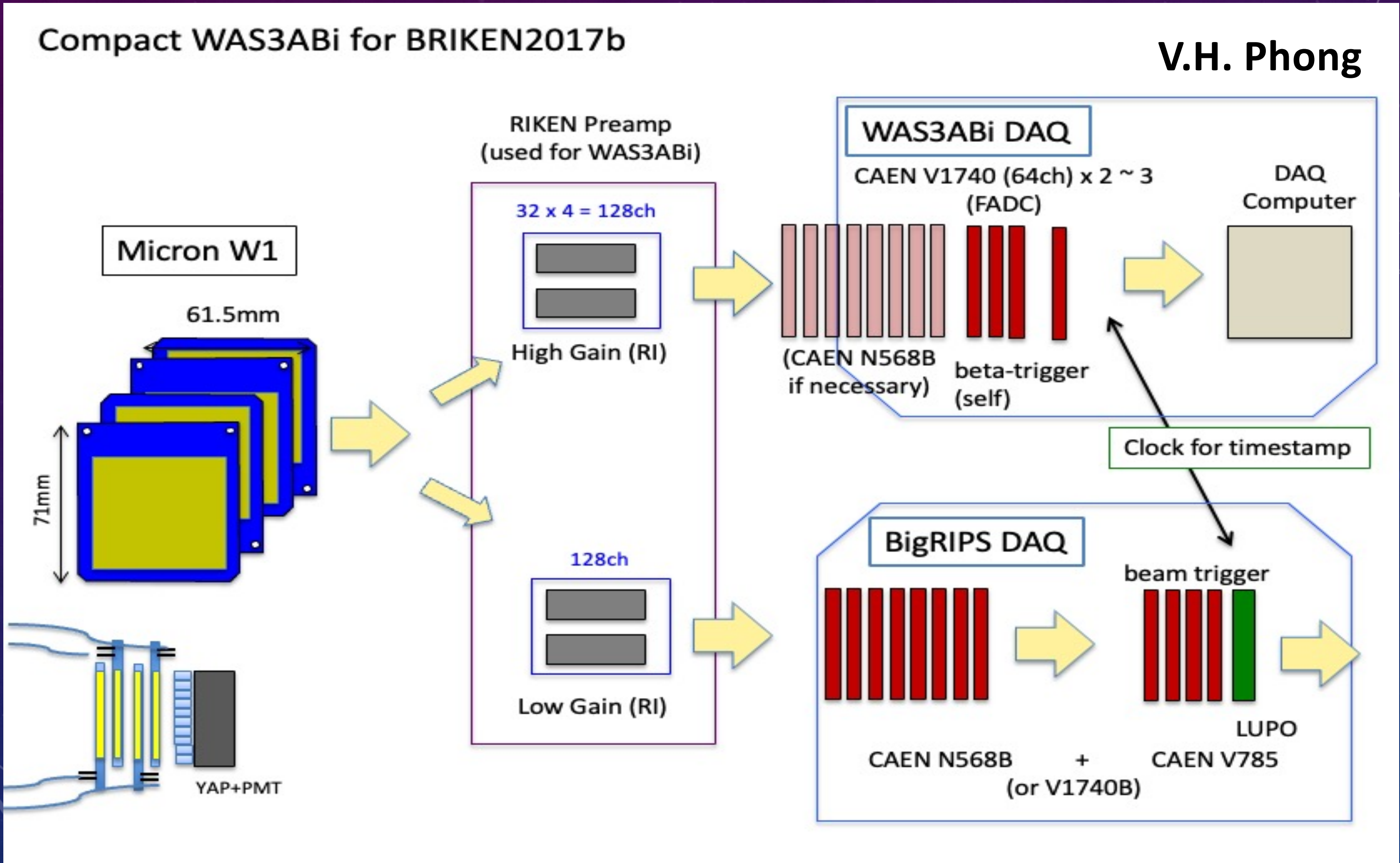


Dual preamplifier system for low/high gain.
→ High gain only (EURICA)

Trigger by leading edge discriminators after shaping amplifiers (N568B)

Dead time ... 0.2 msec for beta
... 0.5 – 0.7 msec for ion

Upgrade of readout system with Flash ADCs (2017 – Present)



Energy Threshold

Silicon detector WAS3ABi ... 20 keV ～ 40 keV depend on adjustment

✓ Silicon detector: Micron (BRIKEN, DTAS), Camberra (EURICA)

✓ Trigger after shaping amplifier (shaping time : 0.2 – 3 μsec)

- Not sensitive to high frequency noise
- Slow time response

→ Position of RI using timing information

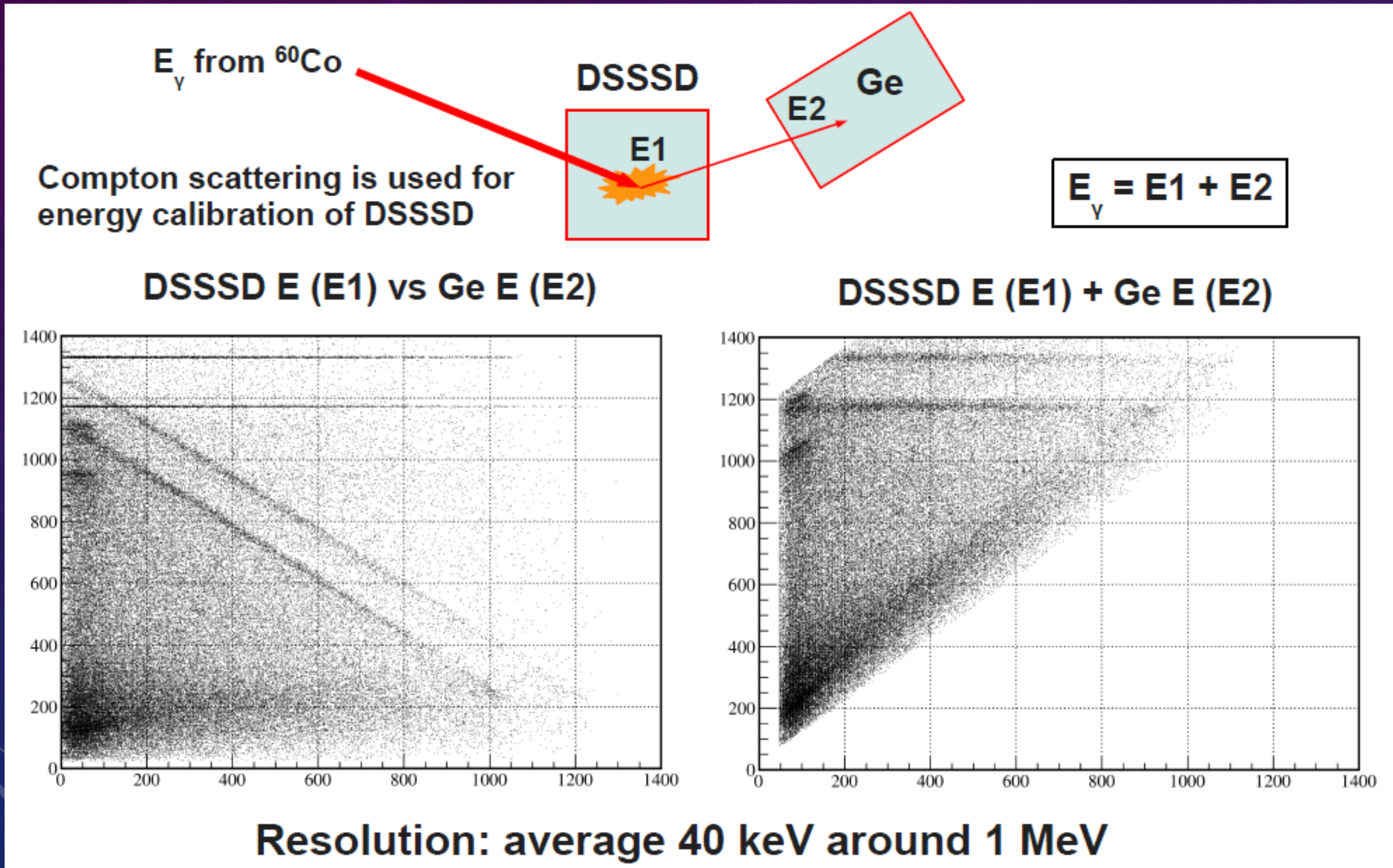
Scintillation detector CAITEN, GARi, MACi ... ～ 20 keV

✓ Scintillator (EJ228, EJ200) & Flat-panel PMT (H8500, H12700A)

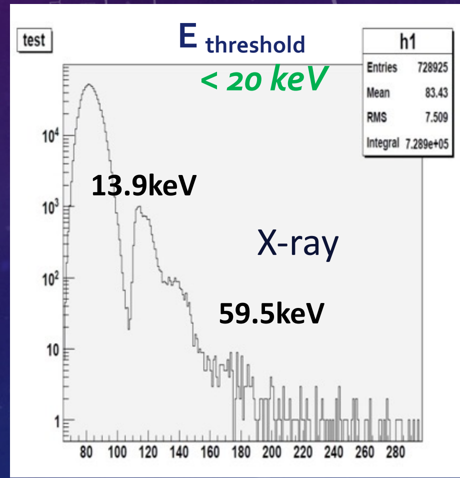
✓ Trigger after fast amplifier of dynode signal

Energy threshold, resolution, and calibration

EURICA



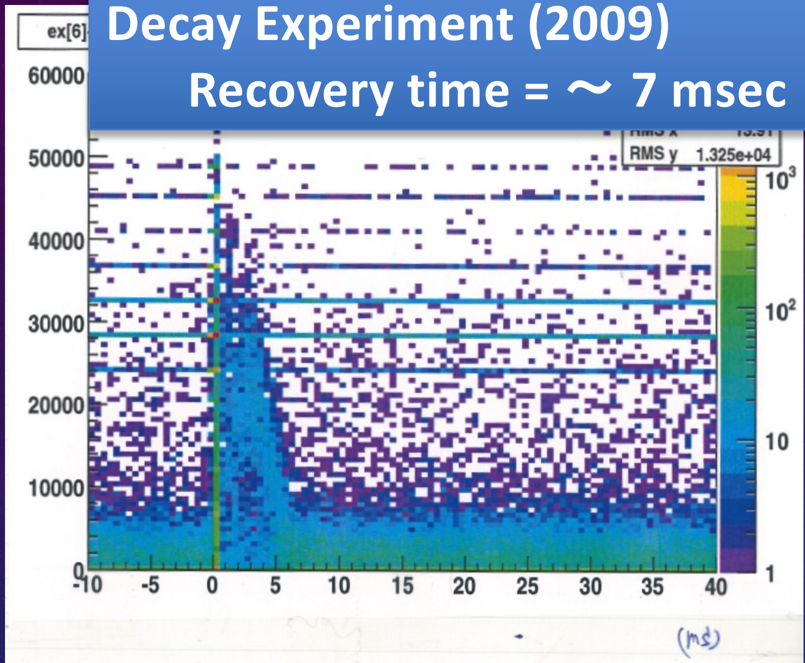
Bench test



Recovery Time after Implantation

Critical for short-lived isotopes (exotic)

Decay Experiment (2009)
Recovery time = ∼ 7 msec



Overflow of shaping amplifier (N568B)

Decay Experiment (2012 – Present)
Recovery time ~ 0.5 msec with small feedback resistance 1 MΩ.

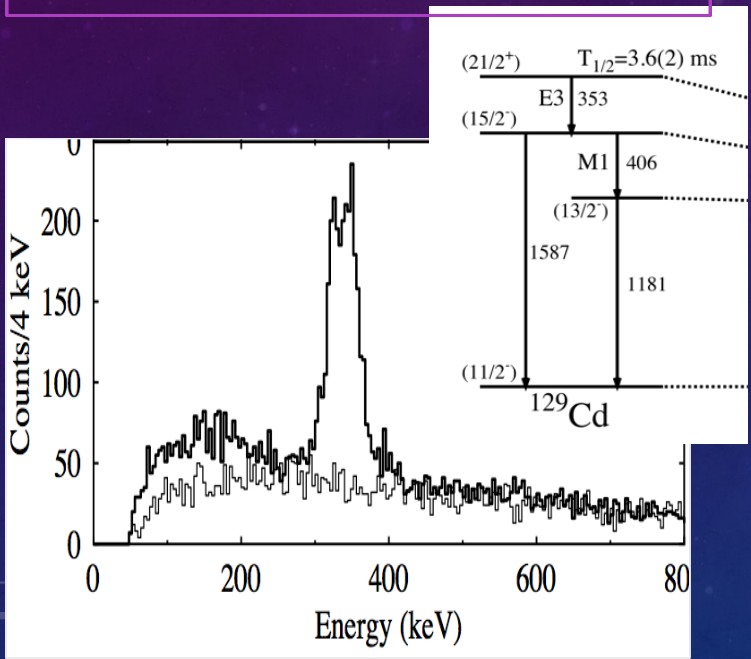
Several options of faster recovery below 0.1 msec (to be tested)

→ pole-zero adjustment
→ Reduction of gain
→ Thinner DSSD (0.6 mm)
→ Mesytec logarithmic amp

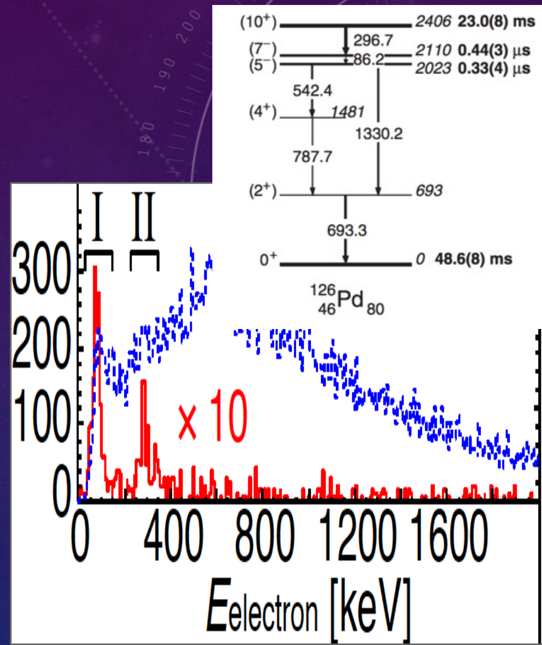
Energy Resolution & Recovery Time

⇒ Identification of Conversion Electrons

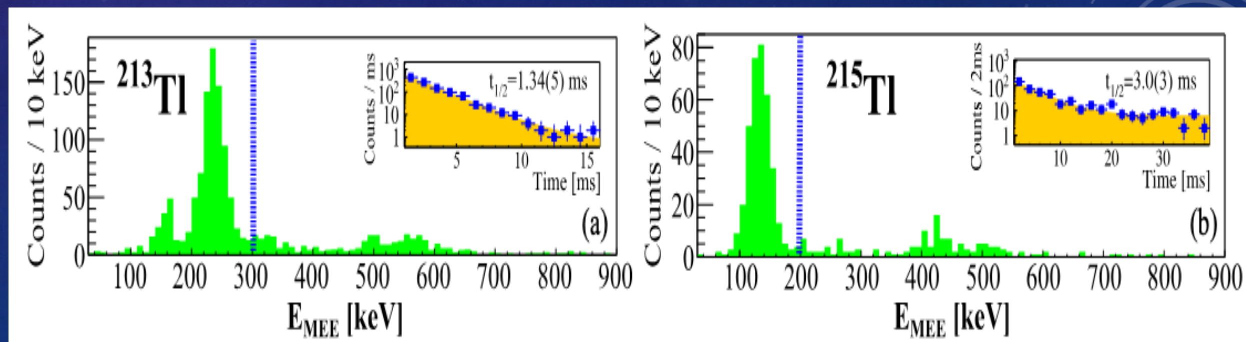
J.Taprogge, A.Jungclaus et al.
Phys. Lett. B 738 (2014) 223.



H.Watanabe et al.
Phys. Rev. Lett. 113
042502 (2014)



T.T. Yeung, A.I. Morales et al.,
PRL 133, 072501 (2024) (BRIKEN 2021)

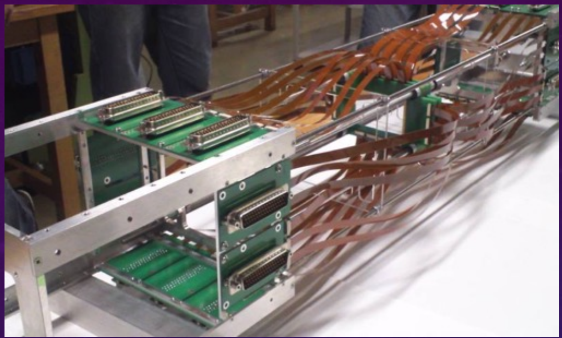


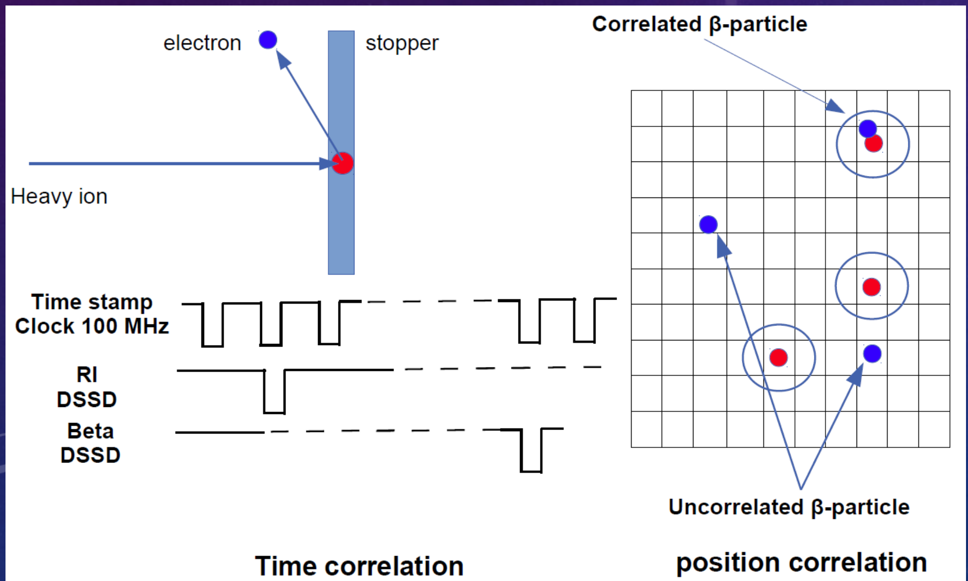
Reconstruction of RI (Position)

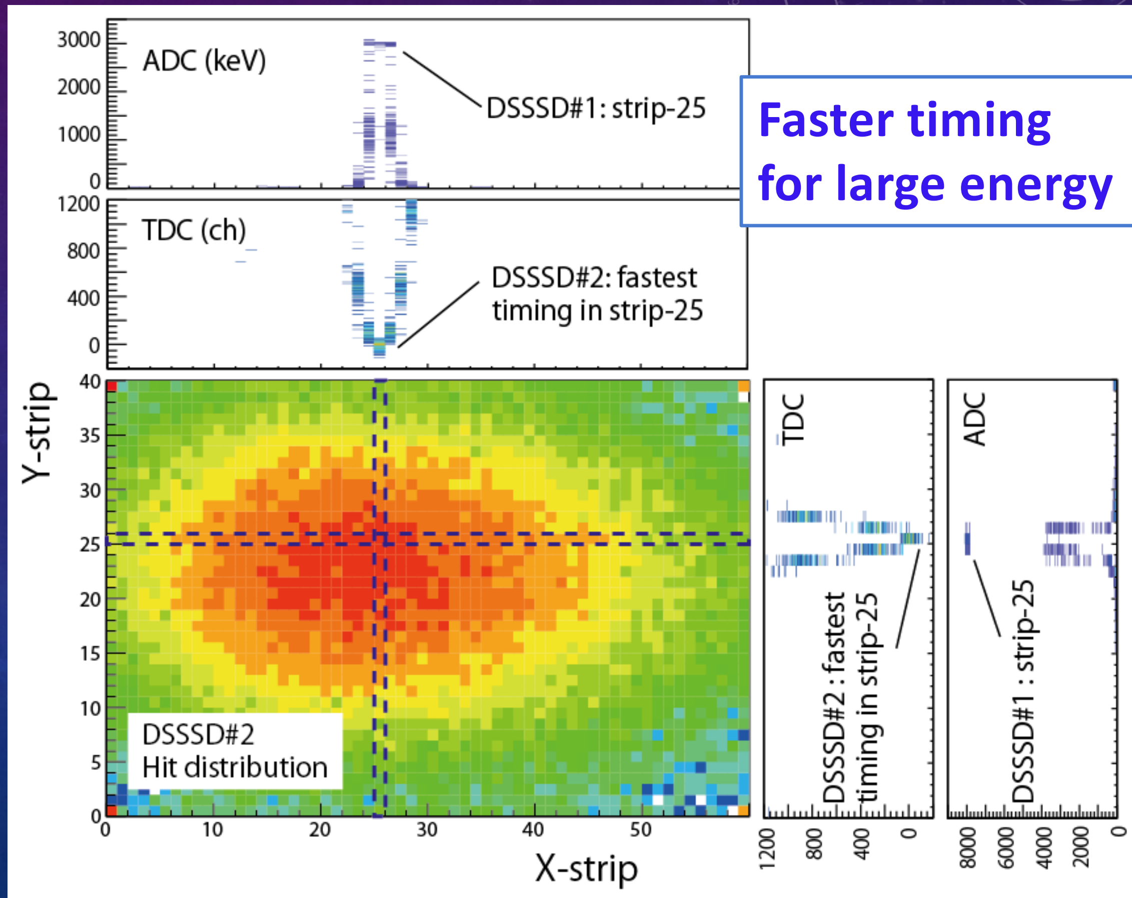
Energy loss of RI in 1mm Si: ~ 1GeV ~ 20 GeV

Leading edge discriminator for beta trigger

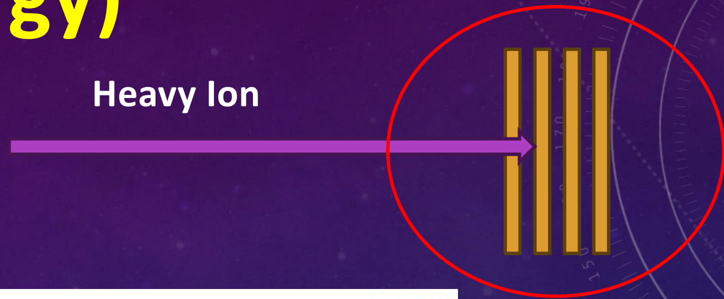
Timing information is used for reconstruction of RI position. (Time walk eff.)



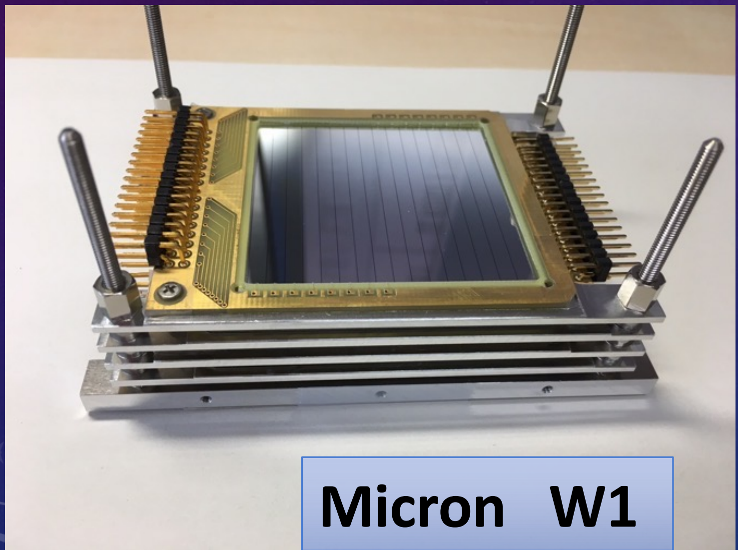




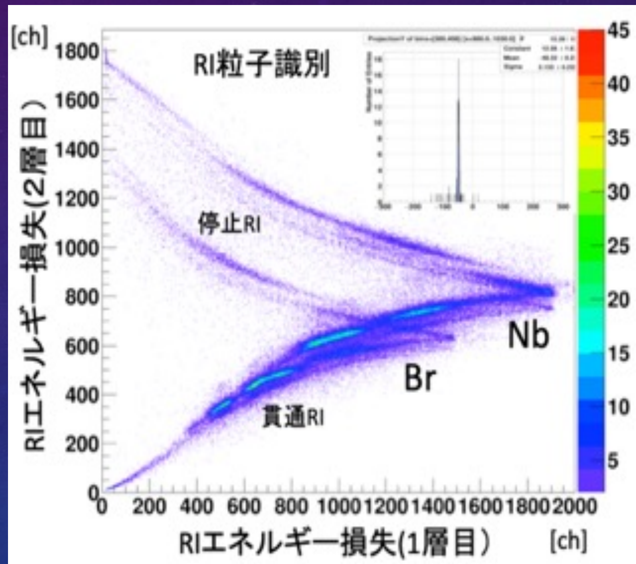
Reconstruction of RI (Energy)



Dynamic Range： ～ 5 GeV



Size：　50 x 50mm2, 1mm thickness



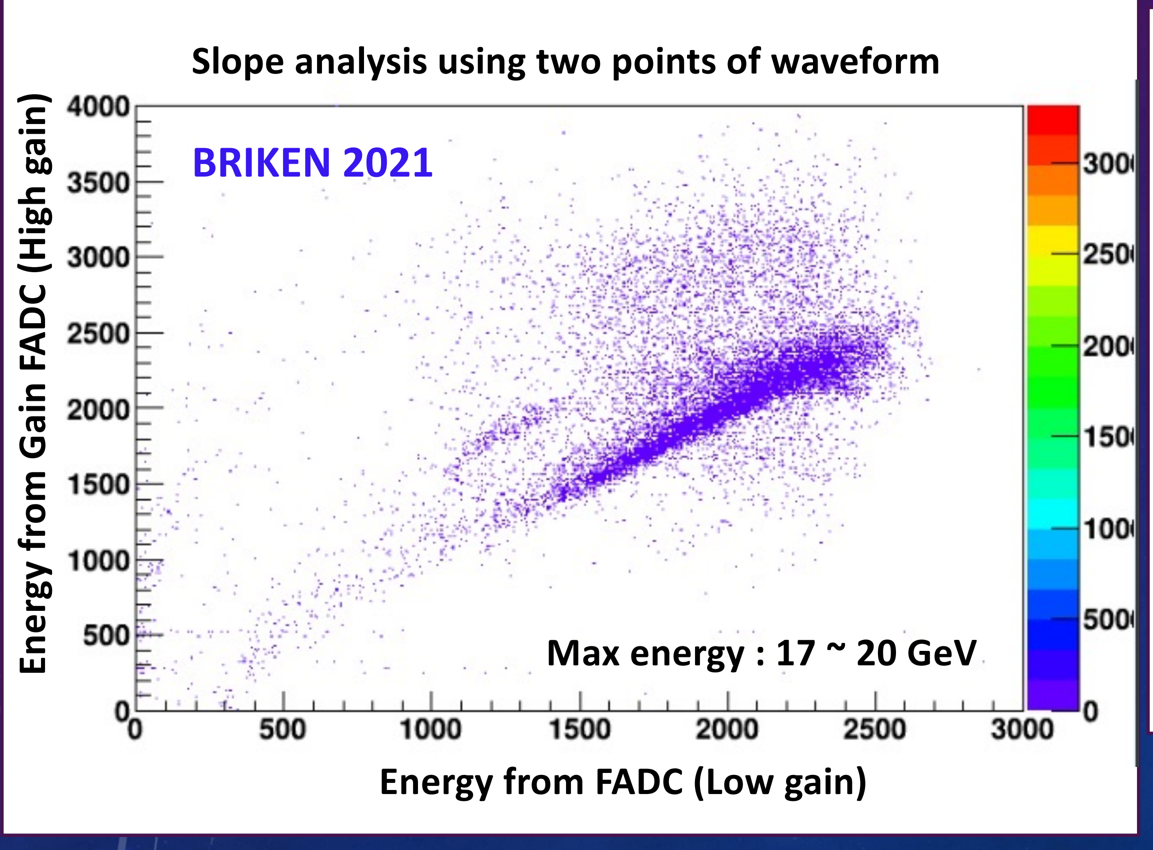
Energy resolution：σ = 0.21 %

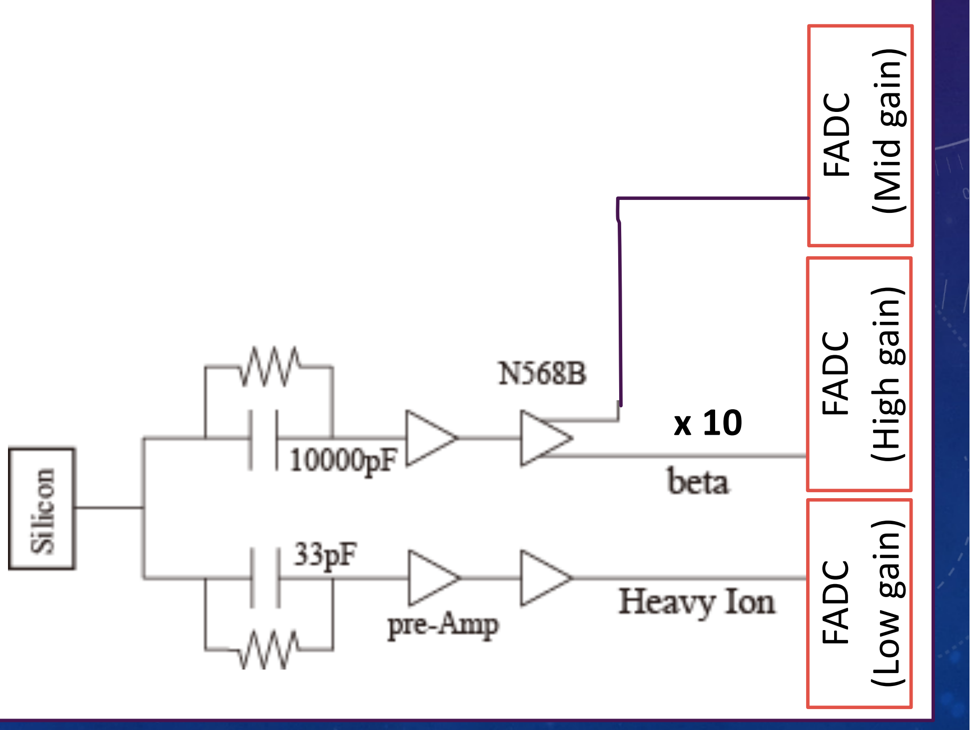
(16 + 16) x 4
= 128 ch

Demonstration of energy reconstruction for all the strips and layers (BRIKEN 2017)

Reconstruction of RI (Energy)

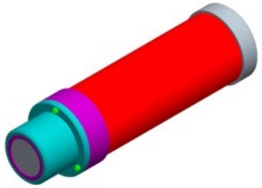
Demonstration: Reconstruction of Implantation Energy using waveform of high-gain beta branch





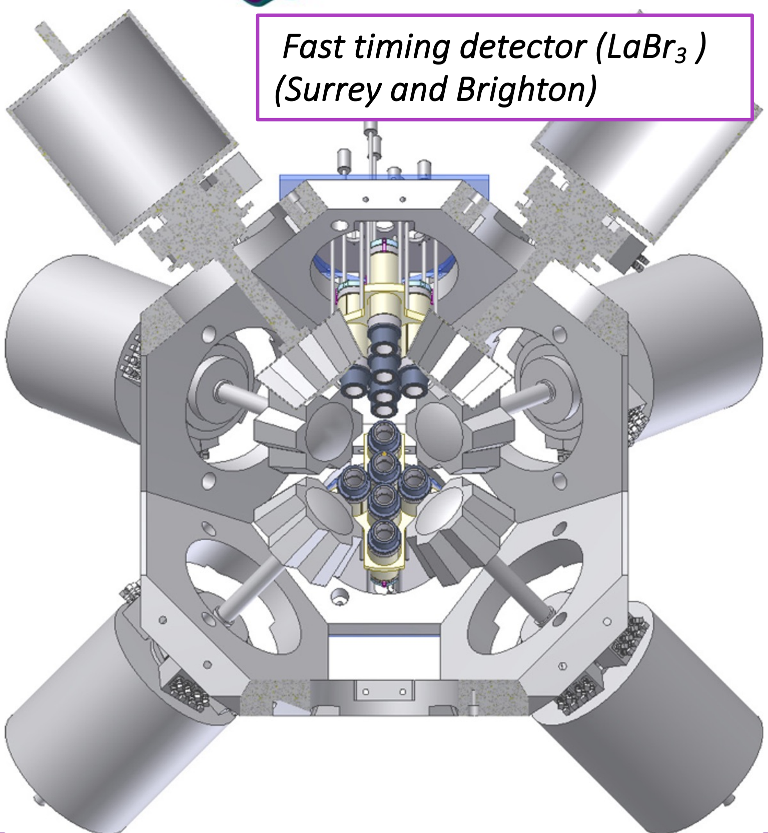
T.T. Yeung's talk

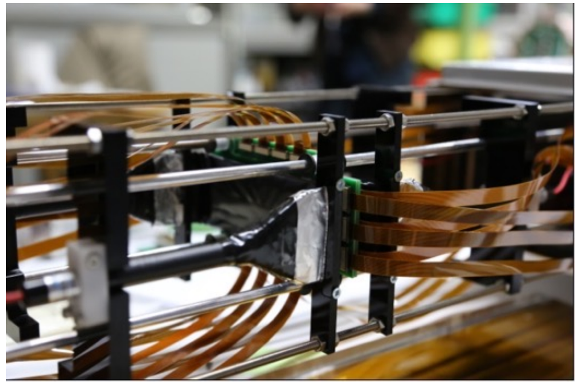
EURICA with LaBr3(Ce) detectors: WAS3ABi + Plastic Scintillators



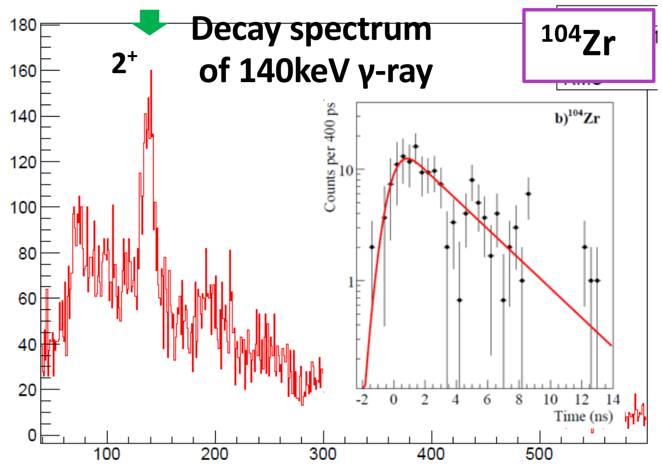
- **For short life-times a $LaBr_3$ array for fast timing has been installed to complement the HPGe detectors**

Fast timing detector ($LaBr_3$) (Surrey and Brighton)





^{104}Y beta-decay is used as start.

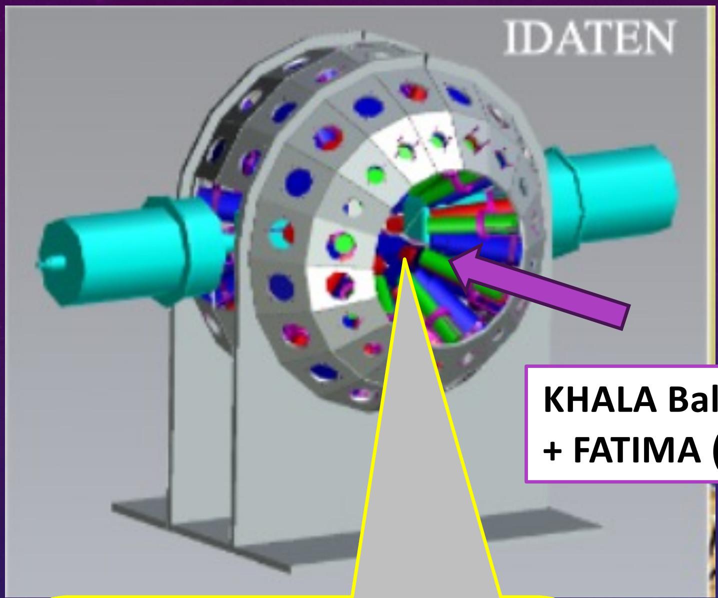


F.Browne

Scintillation Base Detectors for

Fast-timing Beta Counter

Simplified Version of CAITEN : No Rotation / Compact



KHALA Ball (Korea)
+ FATIMA (UK)

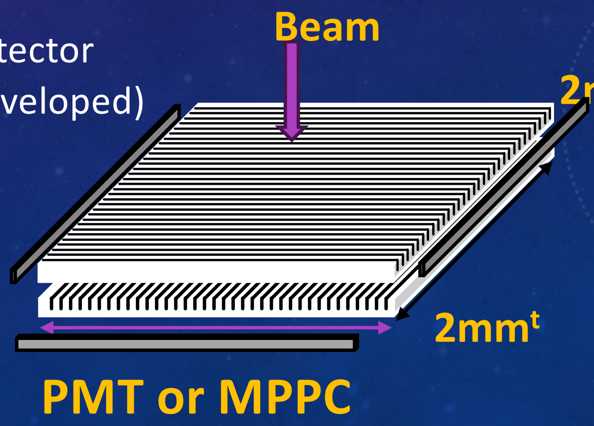
Absorption of
gamma-rays in the PMTs..

PMTs & Charge-divider used for CAITEN (H8500B)

Passive stopper

KHALA Ball (Korea)
+ LBC/LaBr3 (RIKEN)

MACi Detector
(to be developed)



Isomeric Ratio Reconstructed in WAS3ABi

Eur. Phys. J. A (2020) 56:159
https://doi.org/10.1140/epja/s10050-020-00171-3

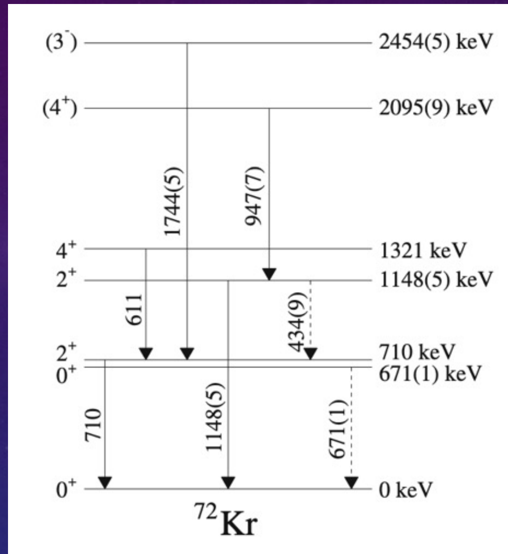
The European Physical Journal A

Regular Article - Experimental Physics

Shape coexistence revealed in the $N = Z$ isotope ^{72}Kr through inelastic scattering

K. Wimmer[1,2,3,a], T. Arici[4,5], W. Korten[6], P. Doornenbal[2], J.-P. Delaroche[7], M. Girod[7], J. Libert[7], T. R. Rodríguez[8], P. Aguilera[9], A. Algora[10,11], T. Ando[1], H. Baba[2], B. Blank[12], A. Boso[13], S. Chen[2], A. Corsi[6], P. Davies[14], G. de Angelis[15], G. de France[16], D. T. Doherty[6], J. Gerl[4], R. Gernhäuser[17], T. Goigoux[12], D. Jenkins[14], G. Kiss[2,11], S. Koyama[1], T. Motobayashi[2], S. Nagamine[1], M. Niikura[1], S. Nishimura[2], A. Obertelli[6], D. Lubos[17], V. H. Phong[2], B. Rubio[10], E. Sahin[18], T. Y. Saito[1], H. Sakurai[1,2], L. Sinclair[14], D. Steppenbeck[2], R. Taniuchi[1], V. Vaquero[3], R. Wadsworth[14], J. Wu[2], M. Zielinska[6]

the isomeric ratio was measured in a separate setting, where the beam was implanted into the WAS3ABi silicon detector array at the final focal plane of the ZeroDegree spectrometer [24]. The isomeric ratio was determined from the number of ^{72}Kr nuclei implanted in the first layer of WAS3ABi and the number of 0^+ decays which were obtained by comparing the energy spectrum of the second layer with GEANT4 [25] simulations. The isomeric ratio obtained this way amounted to 4(1)% comparable to the isomeric ratio of 5.5(19)% in an experiment at lower energies at GANIL [26].



K. Wimmer

^{72}Kr has a low-lying isomeric 0+ state at 671 keV with a lifetime τ = 38 ns.

Check next Layer of DSSD

Summary

There is no perfect beta counter.

- Material
  - High stopping power for beta
  - Less absorption for gamma-ray
  - Quenching
- Fast speed DAQ for high statistics / rare events
- Stable operation
- Isomer tagging, conversion electrons

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