GET electronics for missing mass spectroscopy at RIBF

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Workshop on Active Targets and Time Projection Chambers for High-intensity and Heavy-ion beams in Nuclear Physics

January 17-19, 2018 Santiago de Compostela, Spain

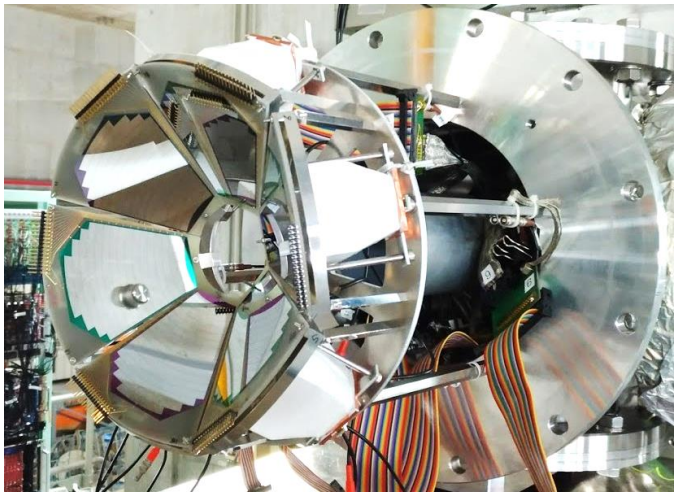
New devices for missing mass spectroscopy at RIBF

Active target ‘CAT-M’

→ Shinsuke Ota’s talk

Silicon array ‘TiNA’

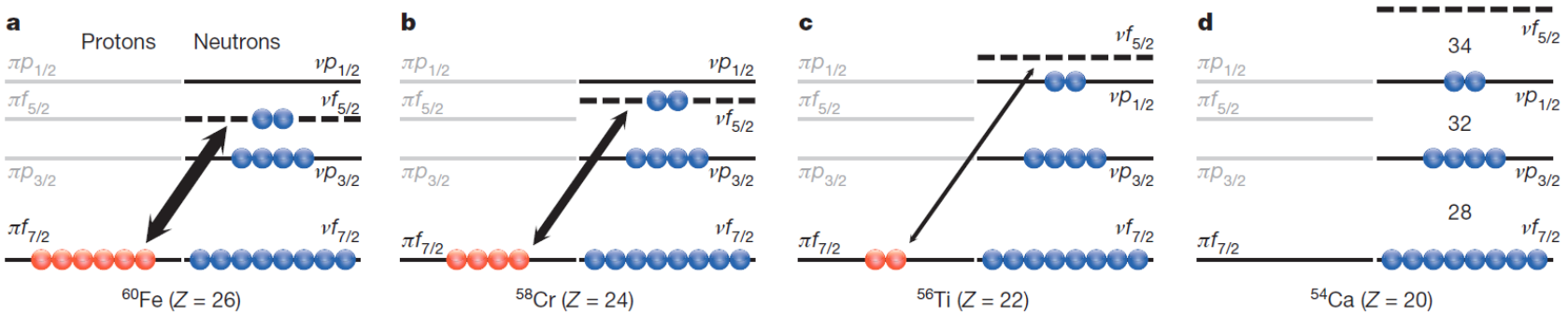
→ this talk



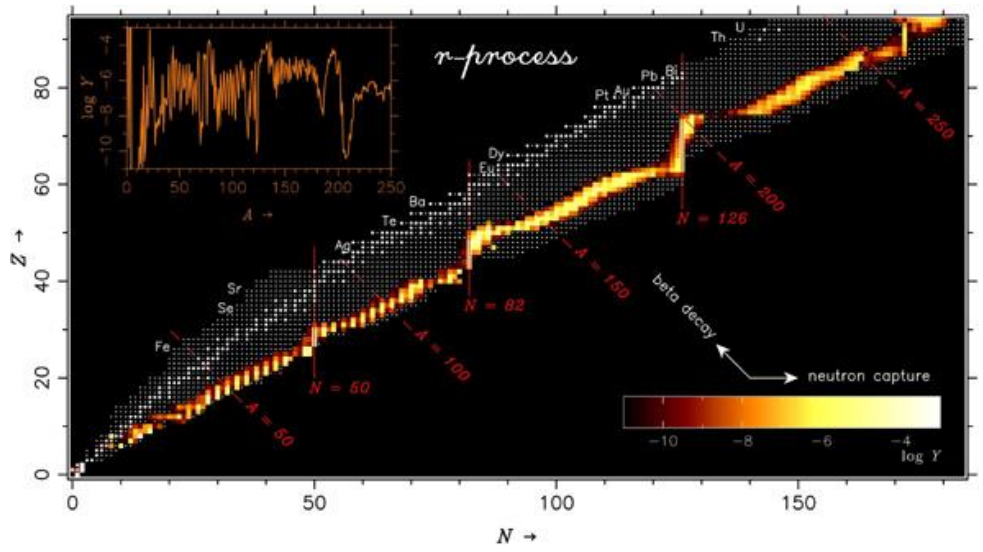
GET system

New silicon detector array TiNA

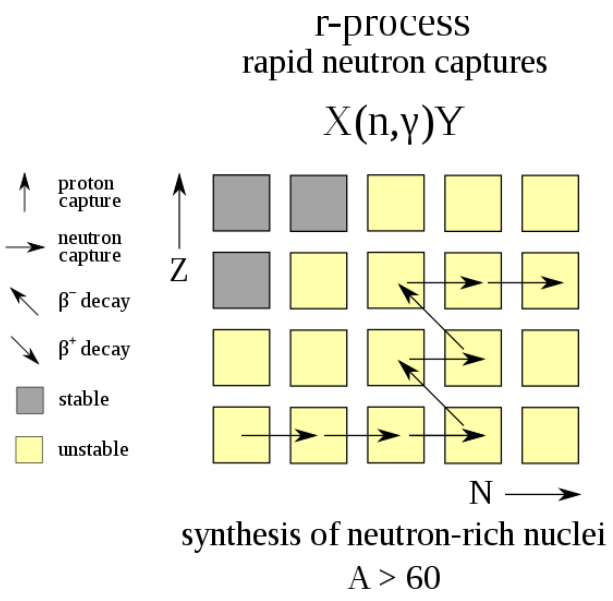
for transfer reactions (*d*,*p*), (*t*,*p*), (*d*,^{3}He)... at RIBF



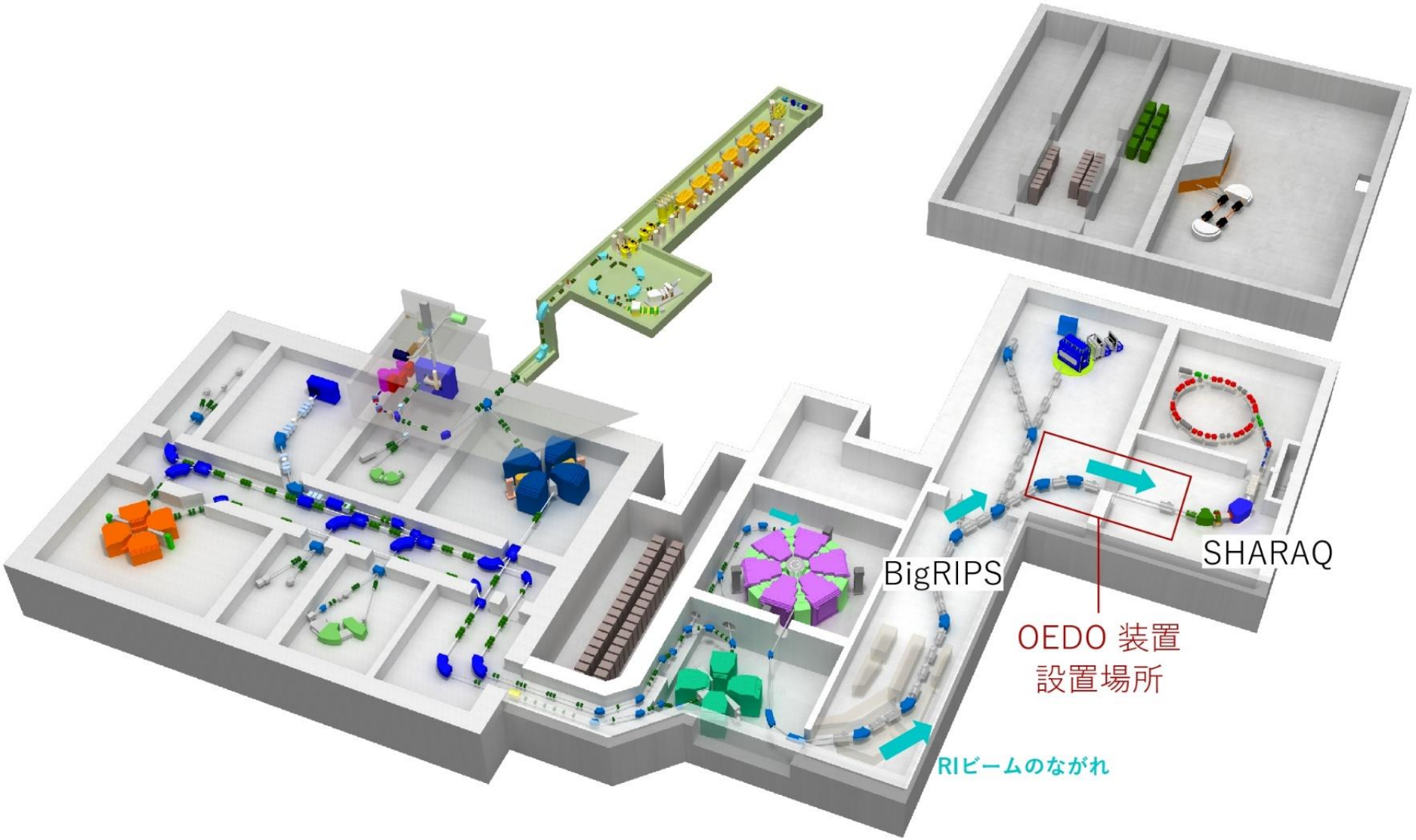
D. Steppenbeck *et al.*, Nature 502, 207 ('13)



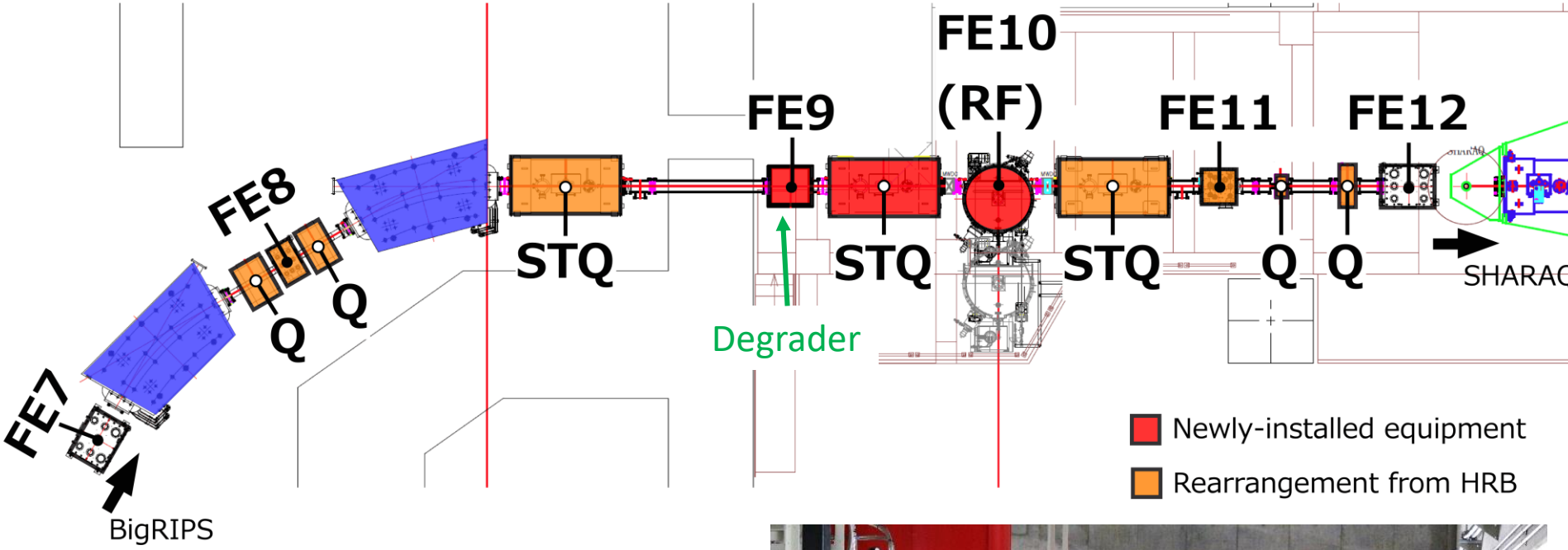
S. Wanajo *et. al.*, ApJ, 606, 1057 ('04)



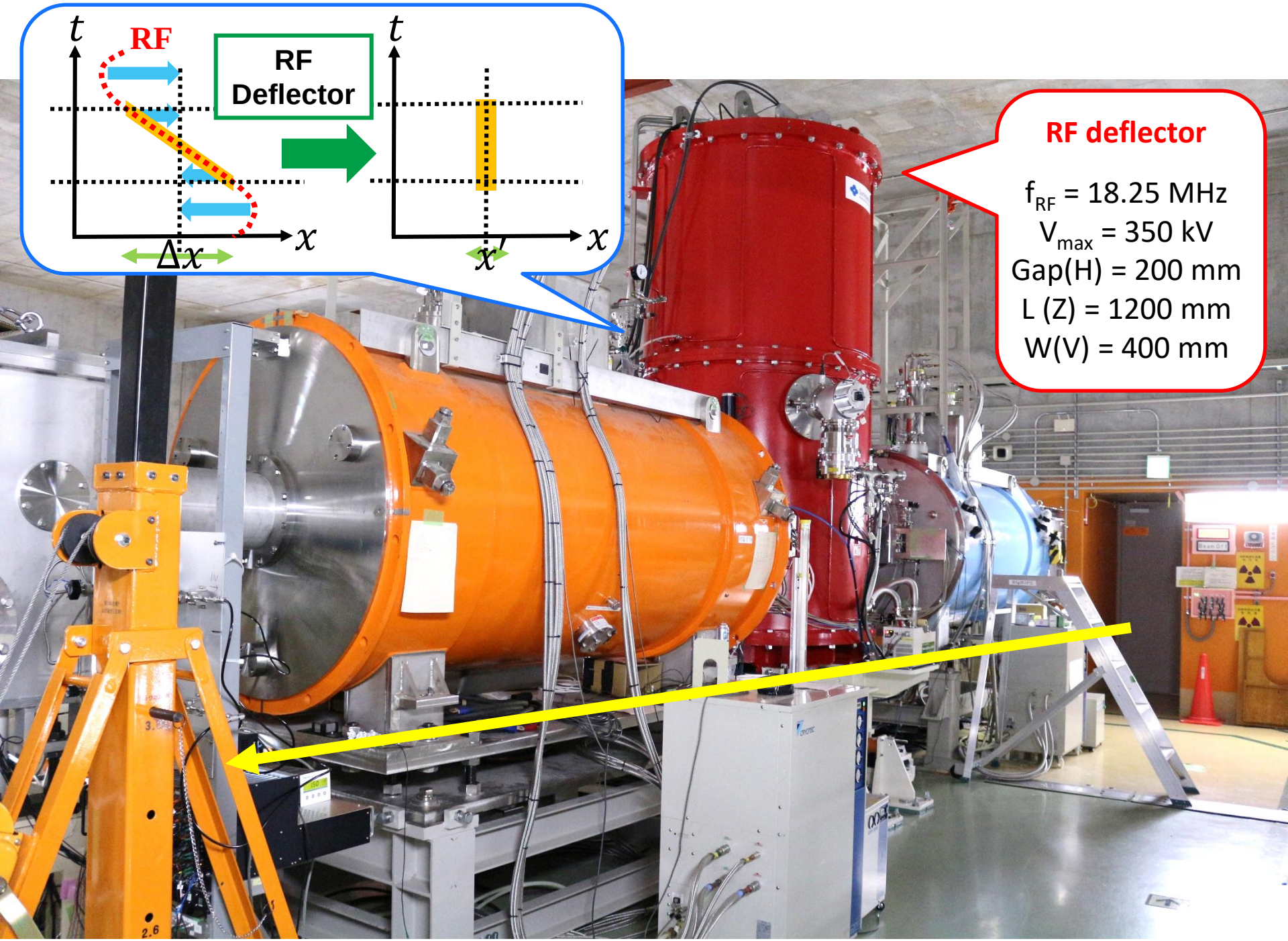
From 250 MeV/*u* down to 10 ~ 50 MeV/*u*.



OEDO beam line (complete 2017)

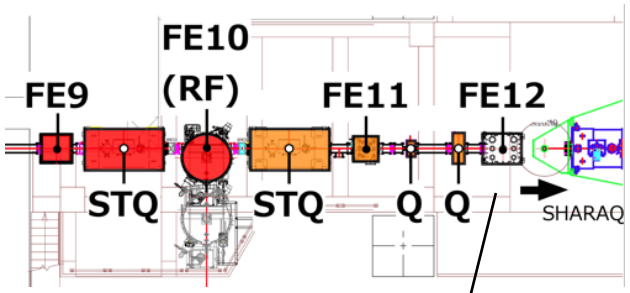


Courtesy N. Imai


t
RF
RF Deflector
x
Δx
t
x
x'
RF deflector
f_RF = 18.25 MHz
V_max = 350 kV
Gap(H) = 200 mm
L (Z) = 1200 mm
W(V) = 400 mm

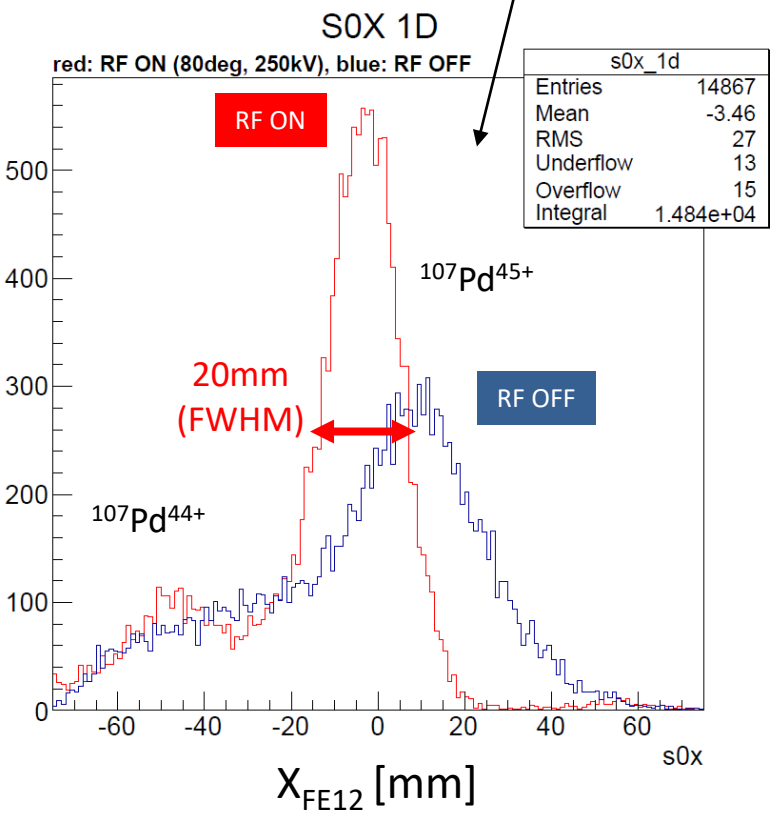
Commissioning: ^{107}Pd slowed from 170 to 33 MeV/u

^{107}Pd @ 170MeV/u

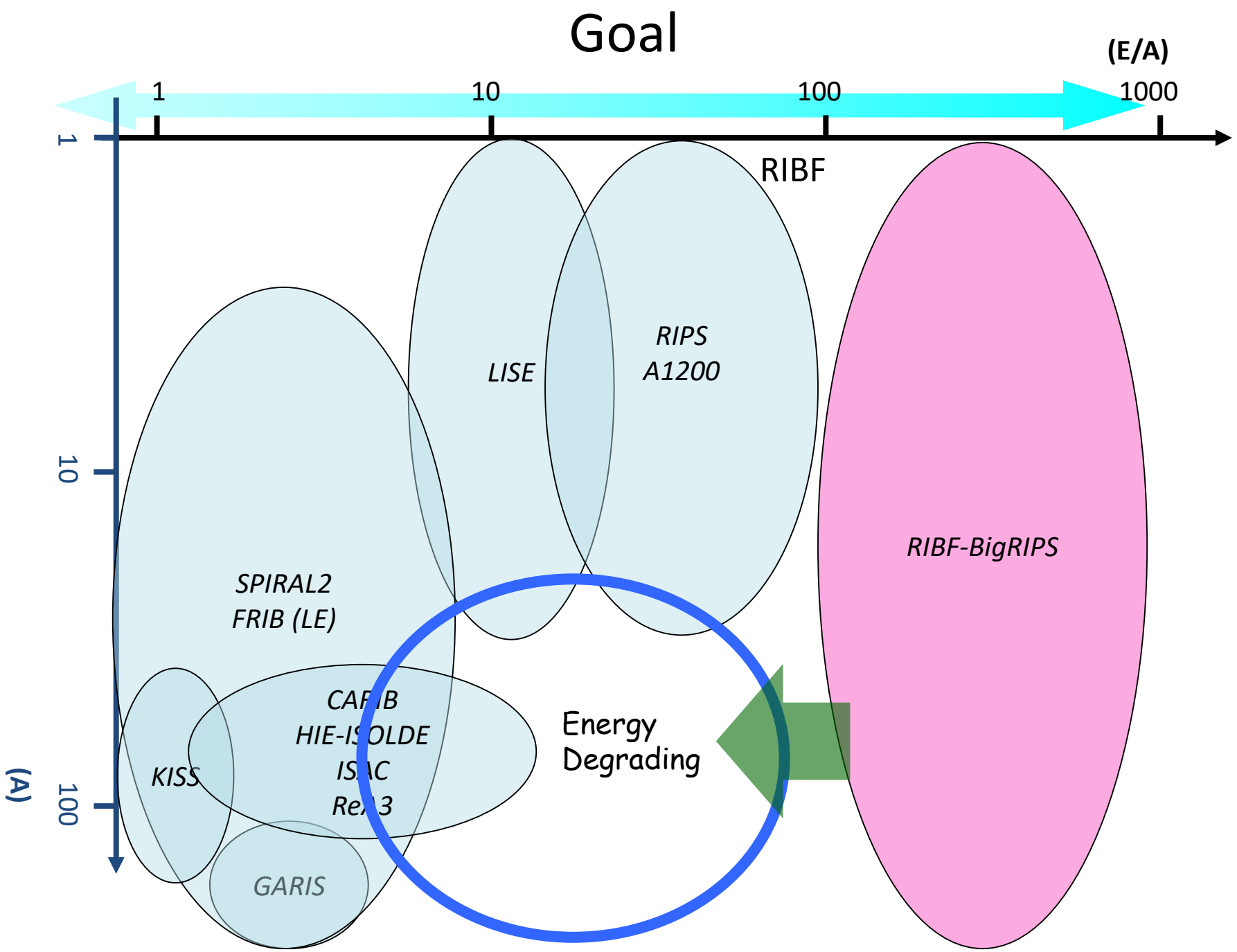


^{107}Pd@ 33MeV/u

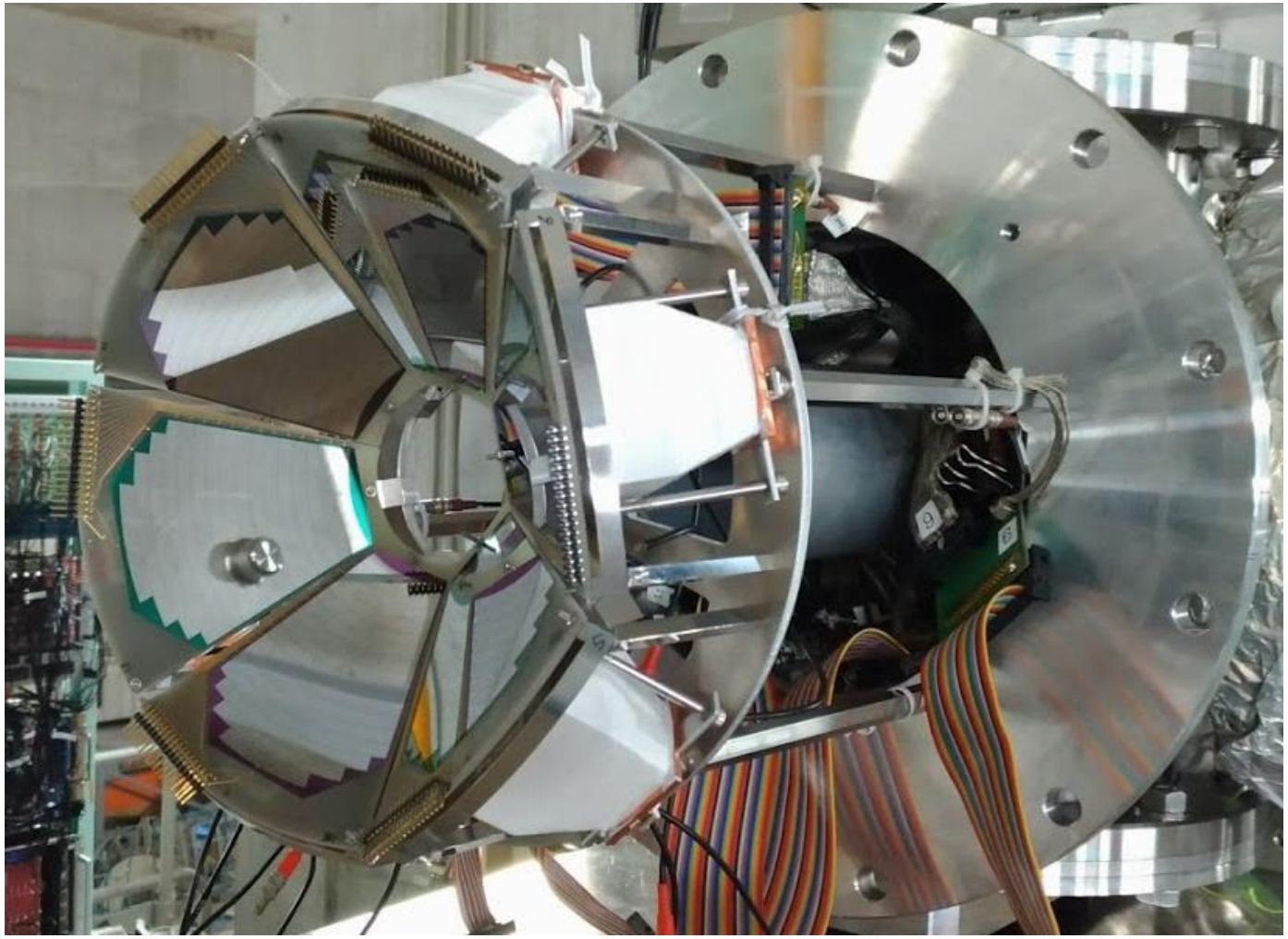
RF HV: 250kV
Phase: 80 deg.



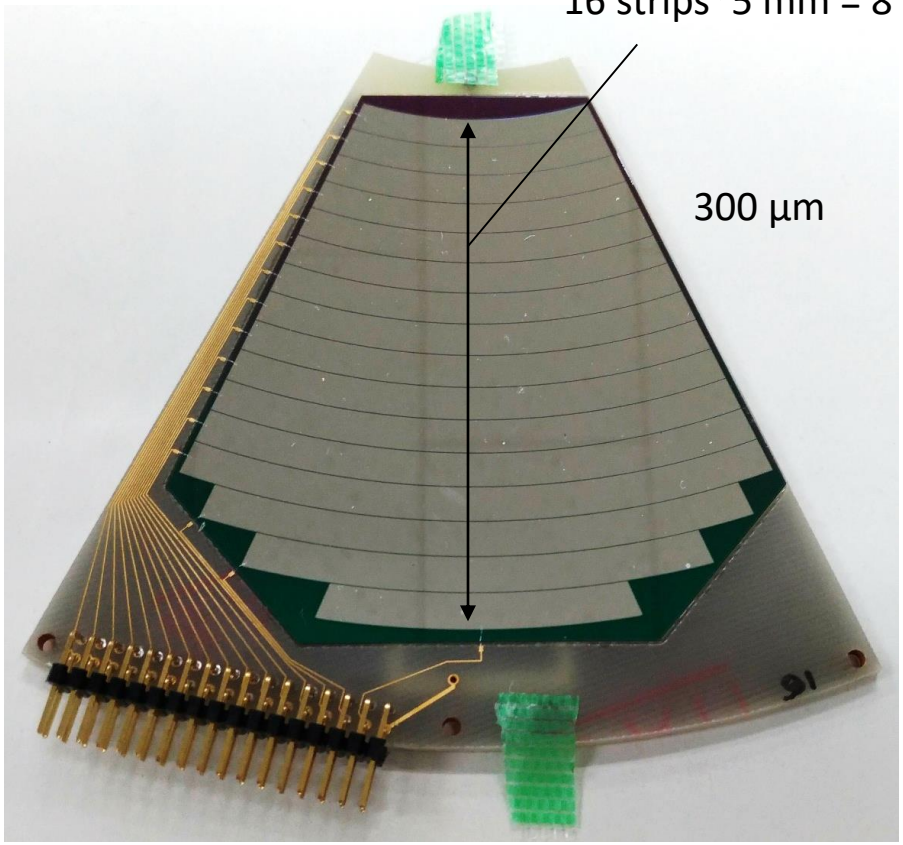
Courtesy N. Imai


Goal
(E/A)
1
10
100
1000
RIBF
1
10
100
(A)
RIPS
A1200
LISE
RIBF-BigRIPS
SPIRAL2
FRIB (LE)
CARIB
HIE-ISOLDE
ISAC
ReA3
KISS
GARIS
Energy
Degrading

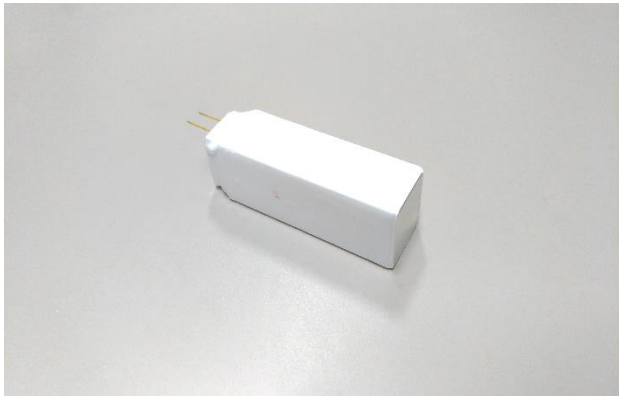
Silicon detector array TiNA-Phase 1



Phase 1: Micron YY1 + CsI + NIM circuit

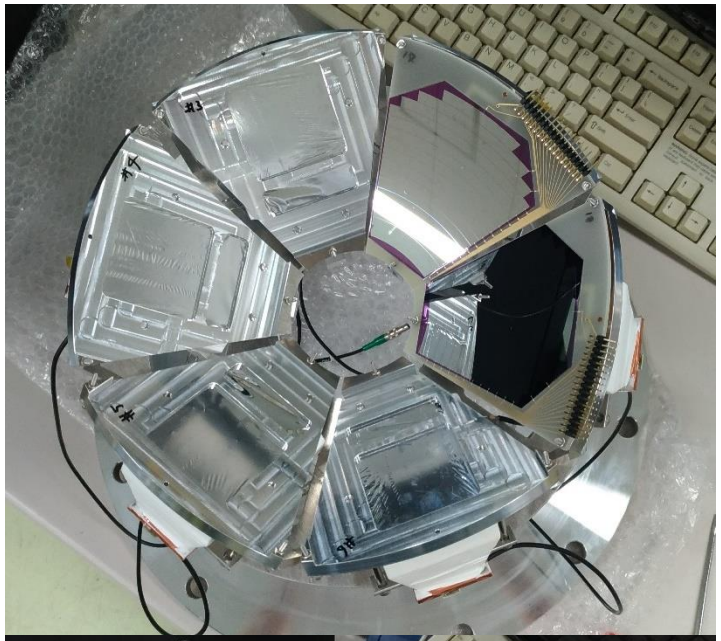


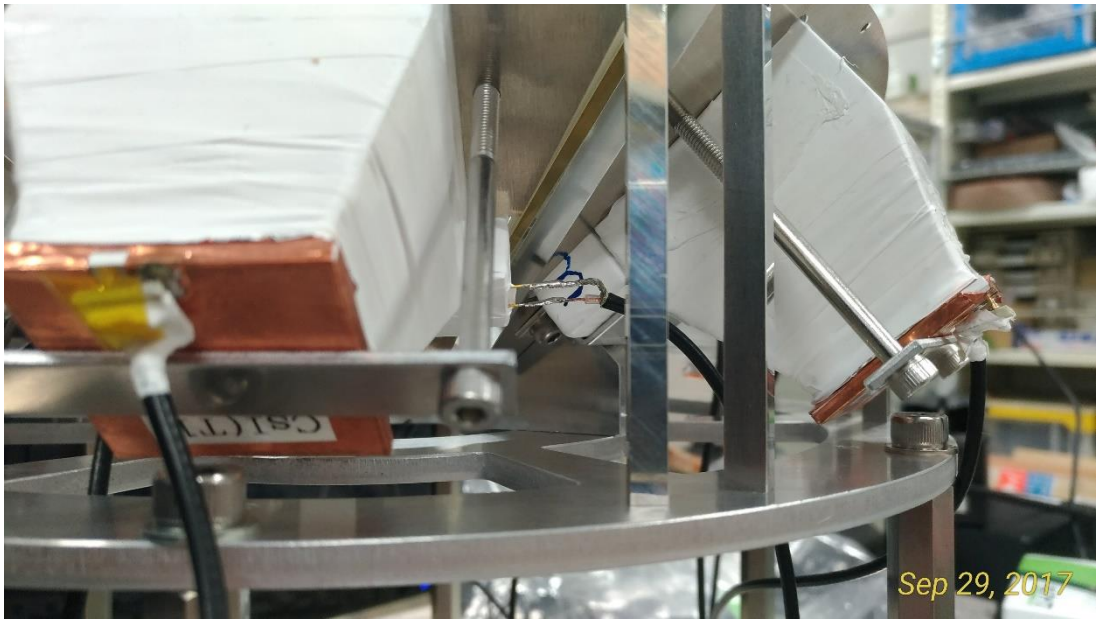
5*5*2.5 cm^3

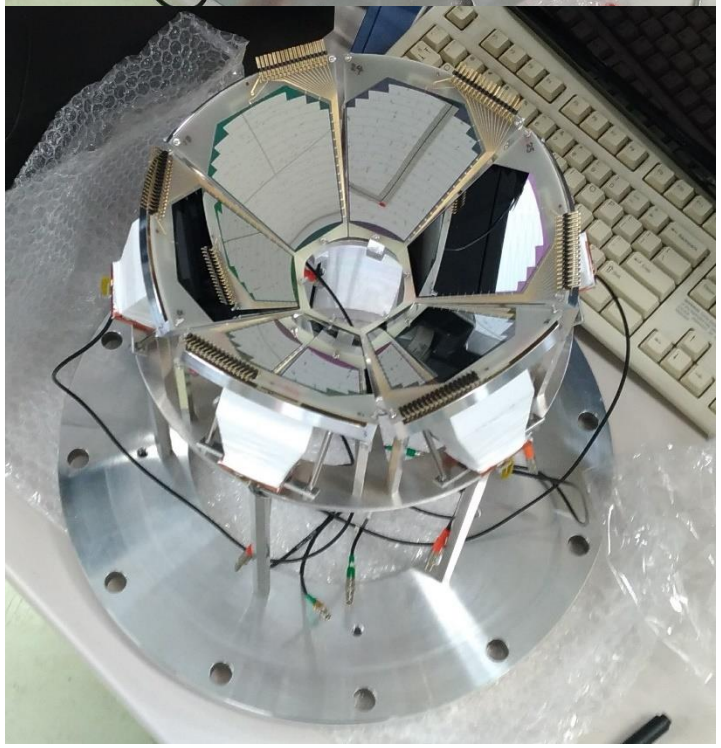


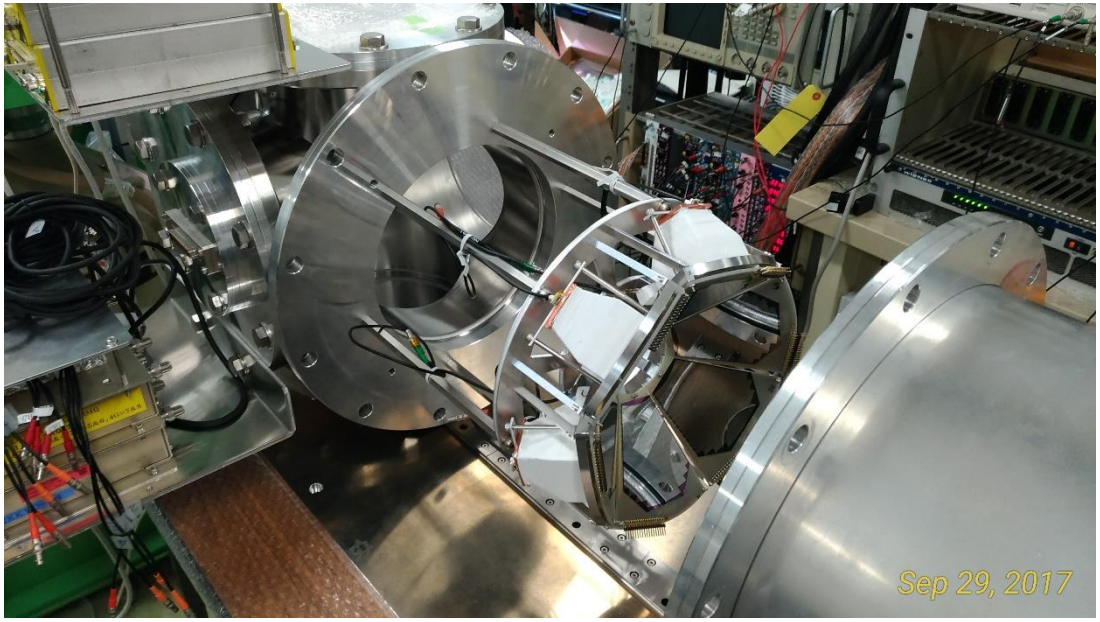
1.8*1.8*5 cm^3

16*6 (YY1) + 12 (CsI) = 48 channels in total



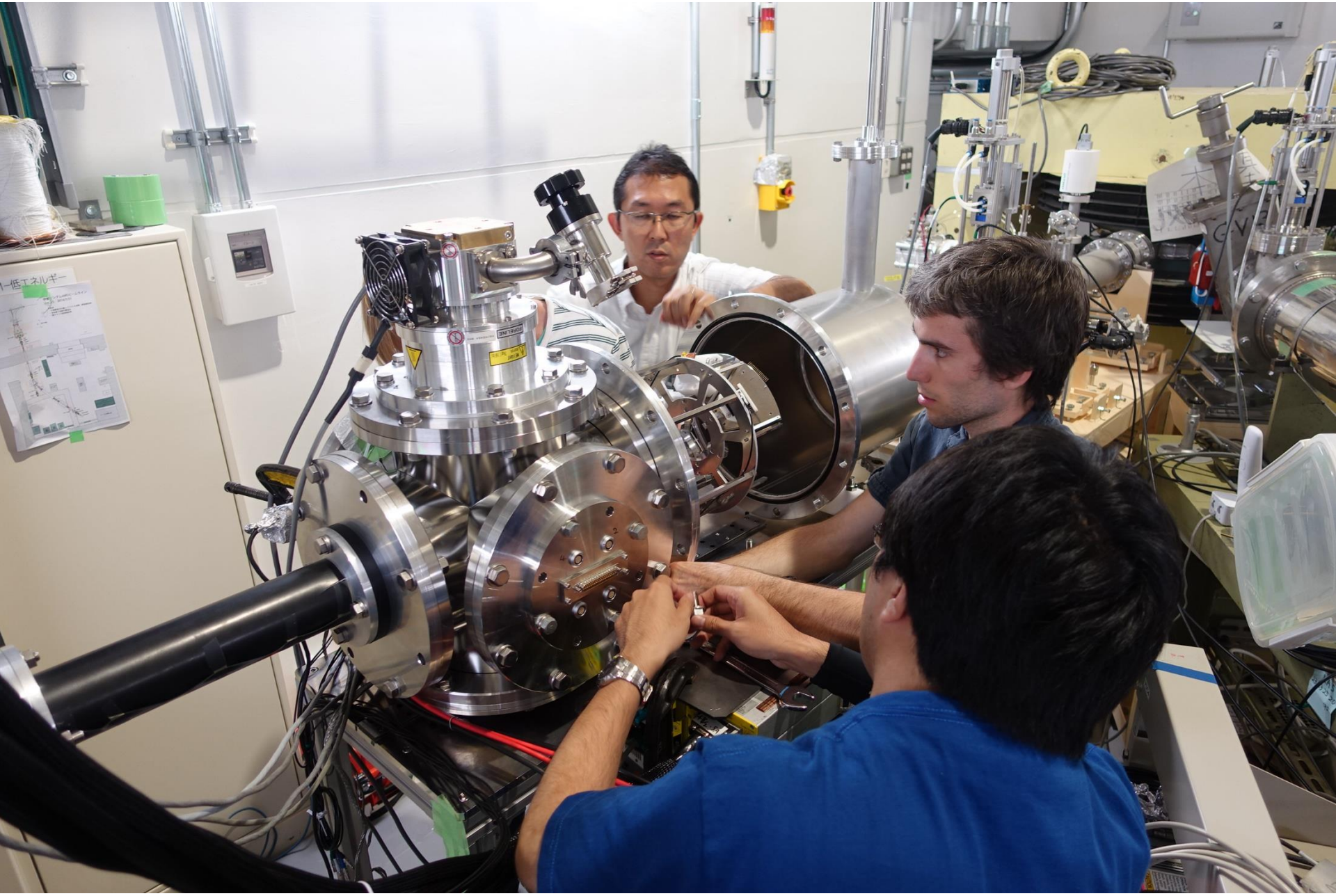

Sep 29, 2017



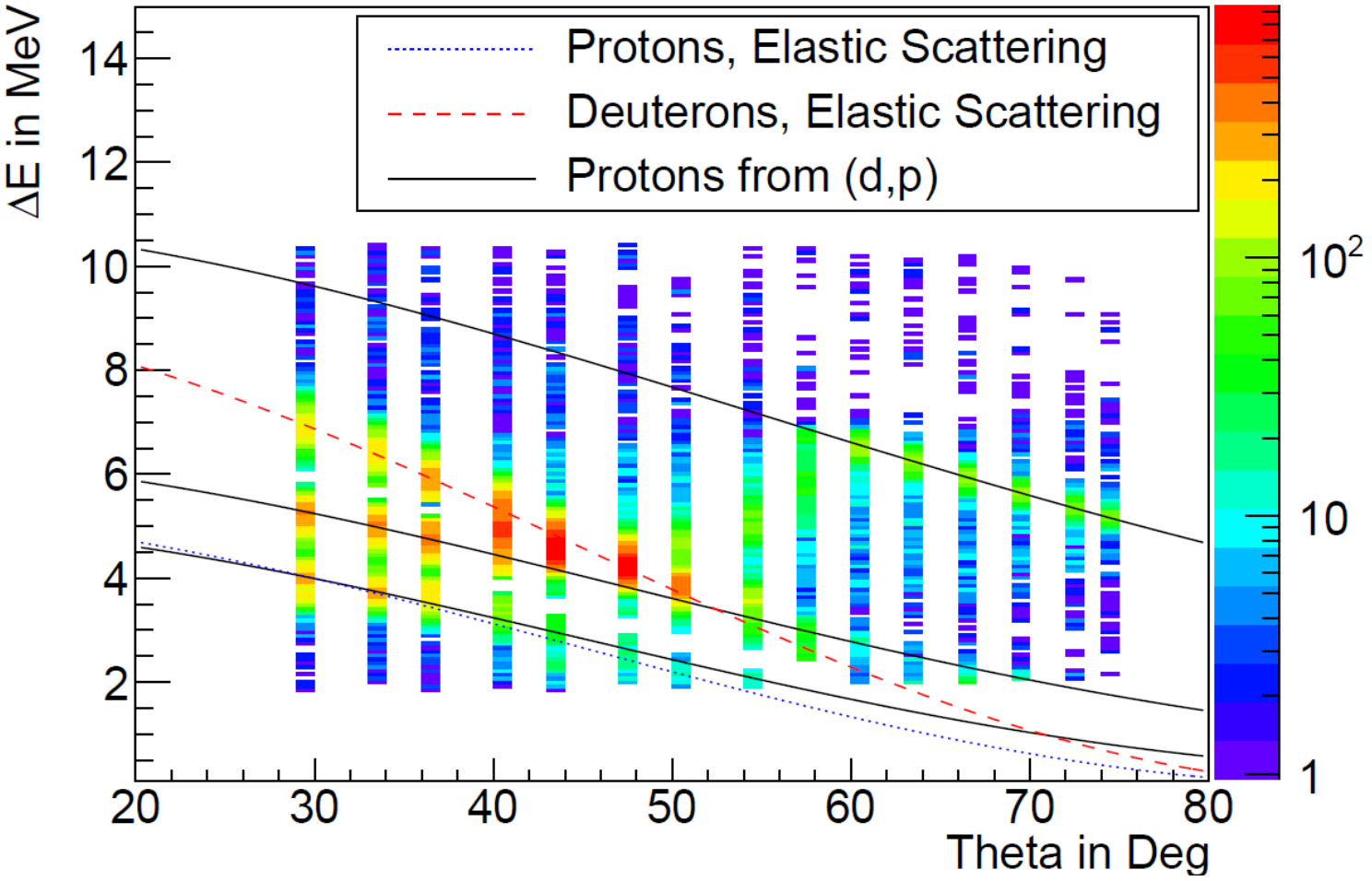

Sep 29, 2017

In-beam test (July 2017)

@ Tandem facility of the Kyushu University



^{12}C @20 MeV + TiD_2 target



Courtesy P. Schlock, K. Wimmer

First (*d*,*p*) experiment at OEDO (Nov. 2017)

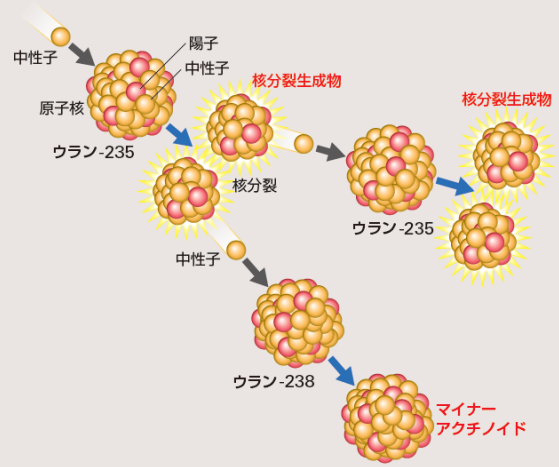


図1　原子力発電で発生する高レベル放射性廃棄物とその主な核種

高レベル放射性廃棄物は、核分裂生成物とマイナーアクチノイドに分けられる。核分裂生成物のうち、半減期が10万年以上の主な長寿命核分裂生成物（LLFP）は7種類ある。

核分裂生成物（FP）

	核種	半減期	線量換算係数	含有量（使用済み核燃料1トン当たり）
LLFP（長寿命核分裂生成物）	ヨウ素-129（^{129}I）	1570万年	1.1×10^{-7}	0.2 kg
	パラジウム-107（^{107}Pd）	650万年	3.7×10^{-11}	0.3 kg
	セシウム-135（^{135}Cs）	230万年	2.0×10^{-9}	0.5 kg
	ジルコニウム-93（^{93}Zr）	153万年	1.1×10^{-9}	1 kg
	セレン-79（^{79}Se）	29万5000年	2.9×10^{-9}	6 g
	テクネチウム-99（^{99}Tc）	21万1000年	6.4×10^{-10}	1 kg
	ズズ-126（^{126}Sn）	10万年	4.7×10^{-9}	30 g
	セシウム-137（^{137}Cs）	30.1年	1.3×10^{-8}	1.5 kg
	ストロンチウム-90（^{90}Sr）	28.8年	2.8×10^{-8}	0.6 kg

マイナーアクチノイド

核種	半減期	線量換算係数	含有量（使用済み核燃料1トン当たり）
ネプツニウム-237（^{237}Np）	214万年	1.1×10^{-7}	0.6 kg
アメリシウム-243（^{243}Am）	7,370年	2.0×10^{-7}	0.2 kg
アメリシウム-241（^{241}Am）	432年	2.0×10^{-7}	0.4 kg
キュリウム-244（^{244}Cm）	18.1年	1.2×10^{-7}	60 g

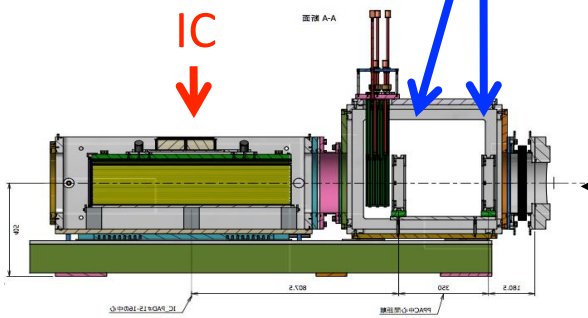
日本原子力研究開発機構の資料より

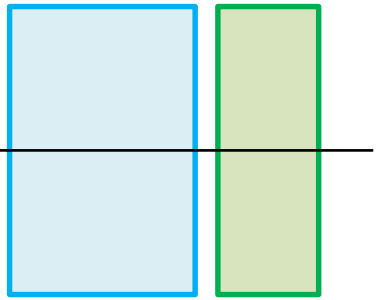
- Transmute Long-Lived Fission Product (LLFP)
  ^{79}Se ($t_{1/2}$ = 3 × 10^5 years) to ^{80}Se (stable)
- Surrogate method:
  σ(*d*,*p*) → σ(*n*,γ)

^{79}Se(d,p)^{80}Se reaction at 20 MeV/u

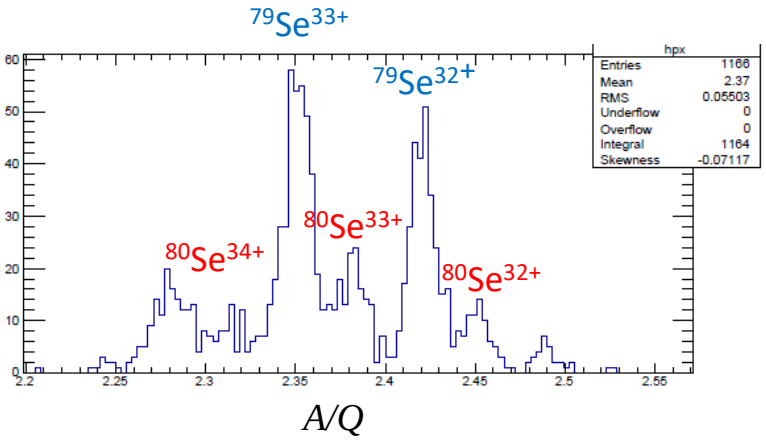
Courtesy N. Imai

4 mg/cm^2 CD_2
(GANIL)

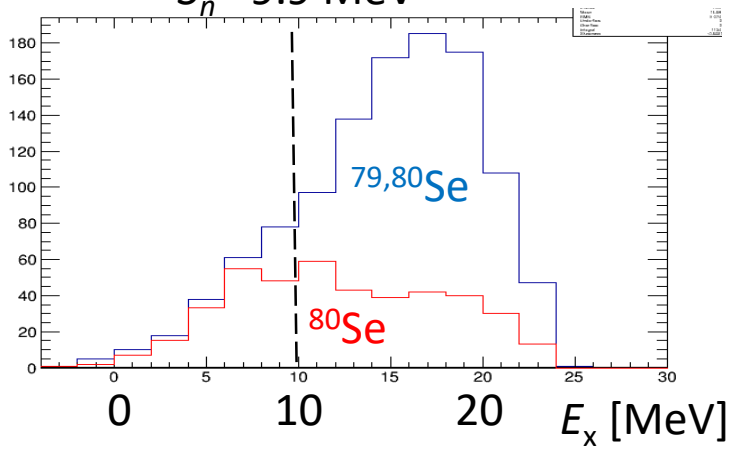




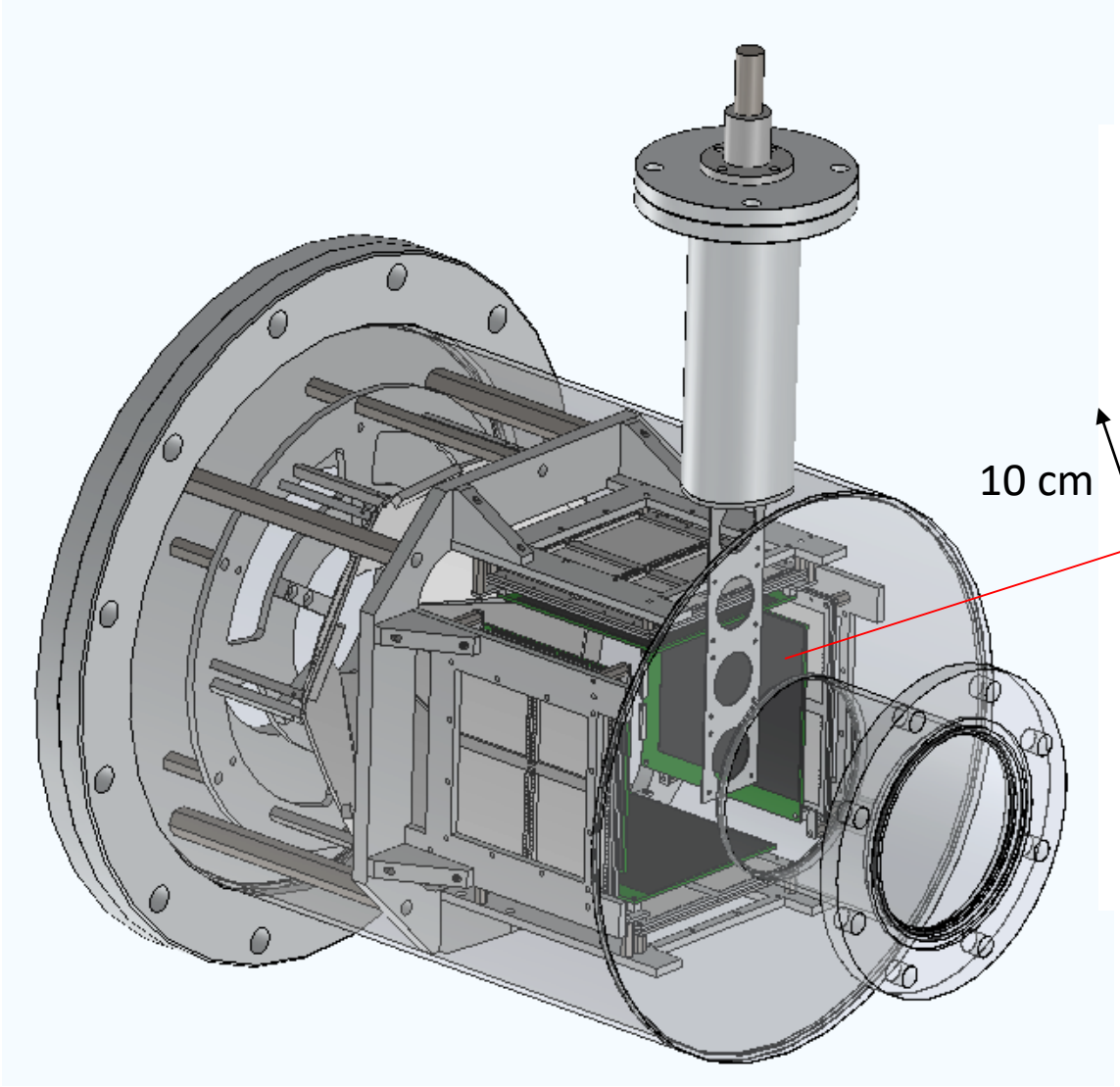
Dipole Quadrupole

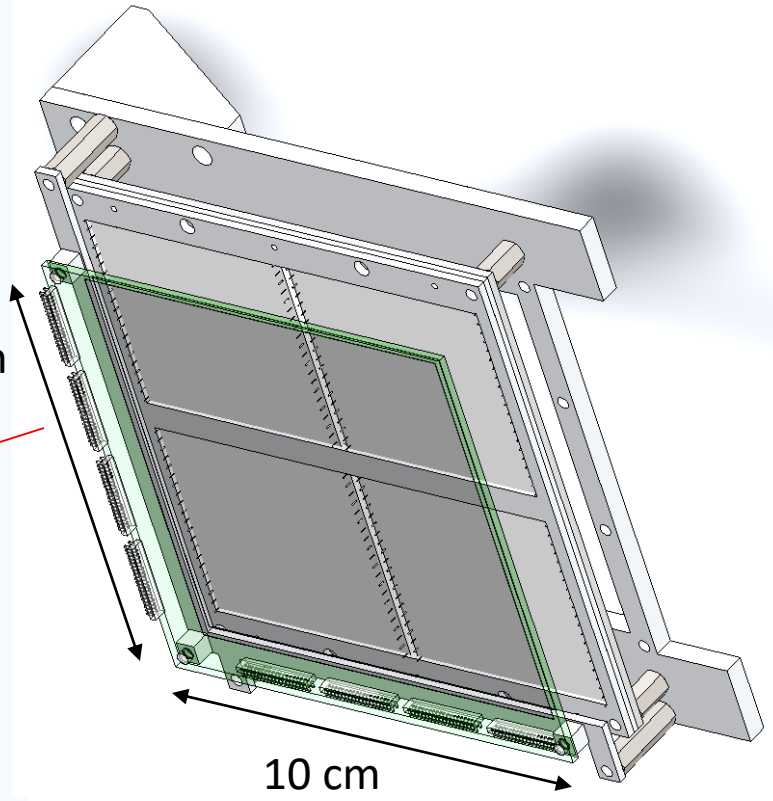


S_n= 9.9 MeV



TiNA-Phase 2 upgrade

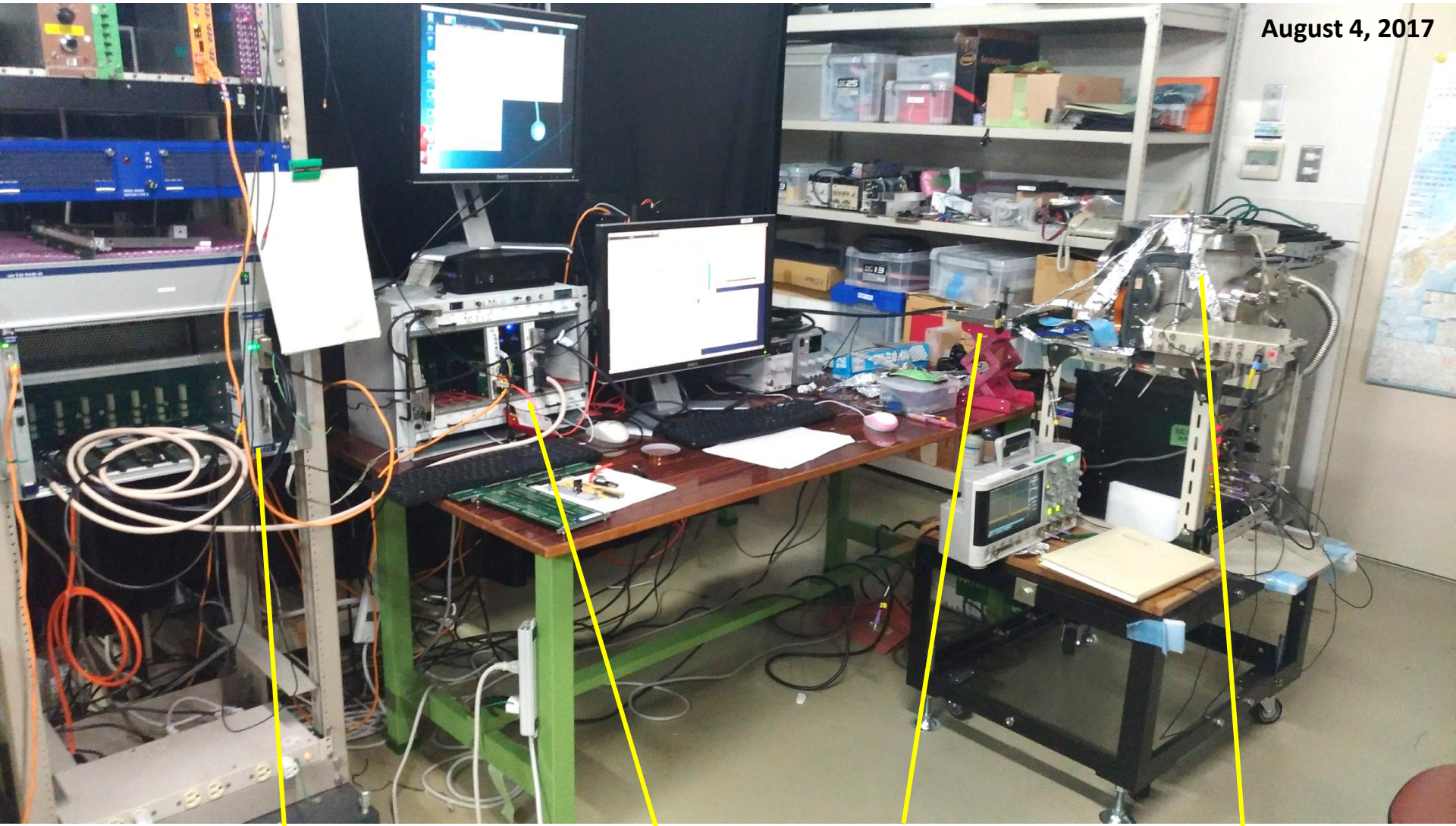


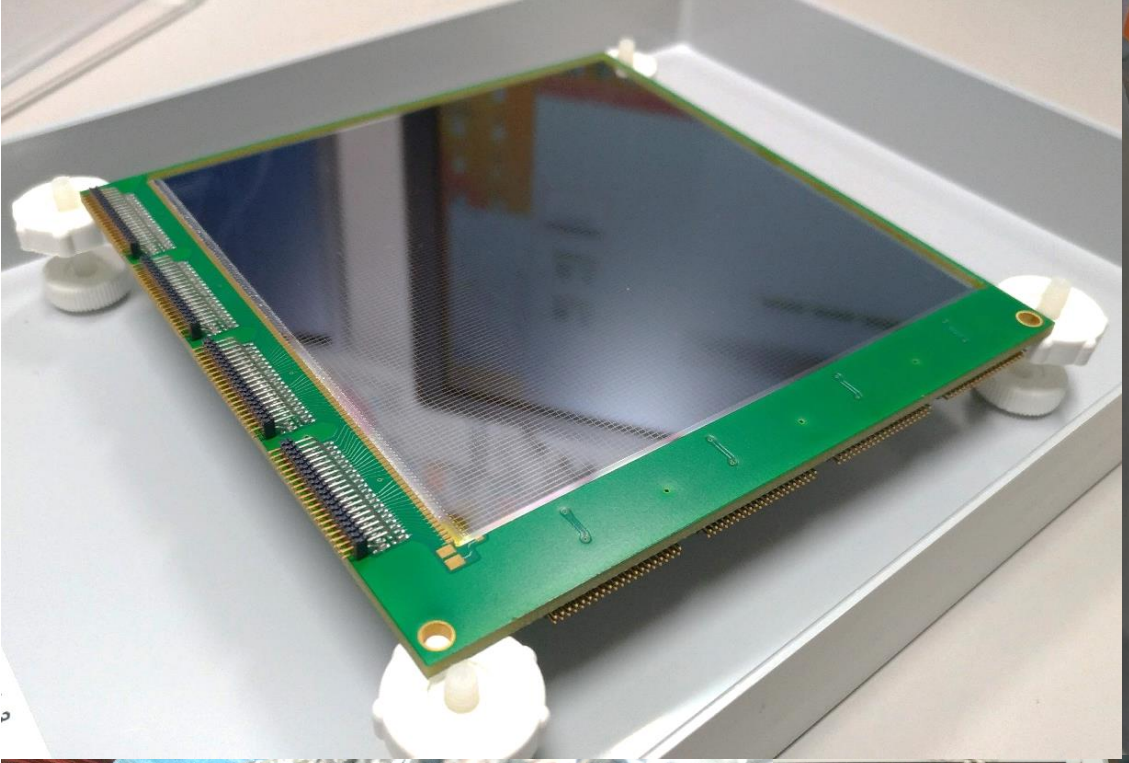


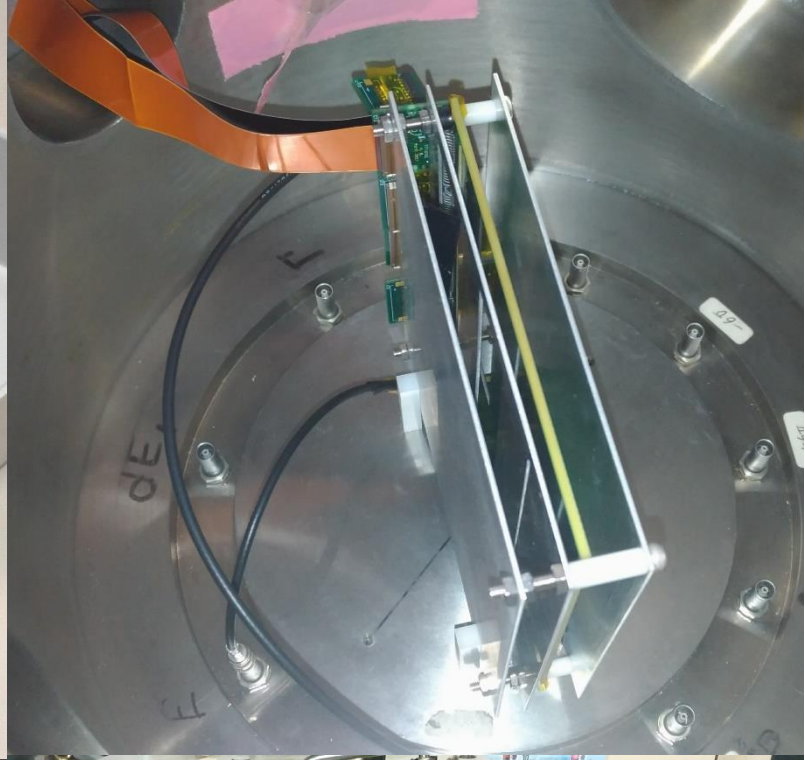
Micron Type TTT (DSSD of MUST2)
128 strips on each surface

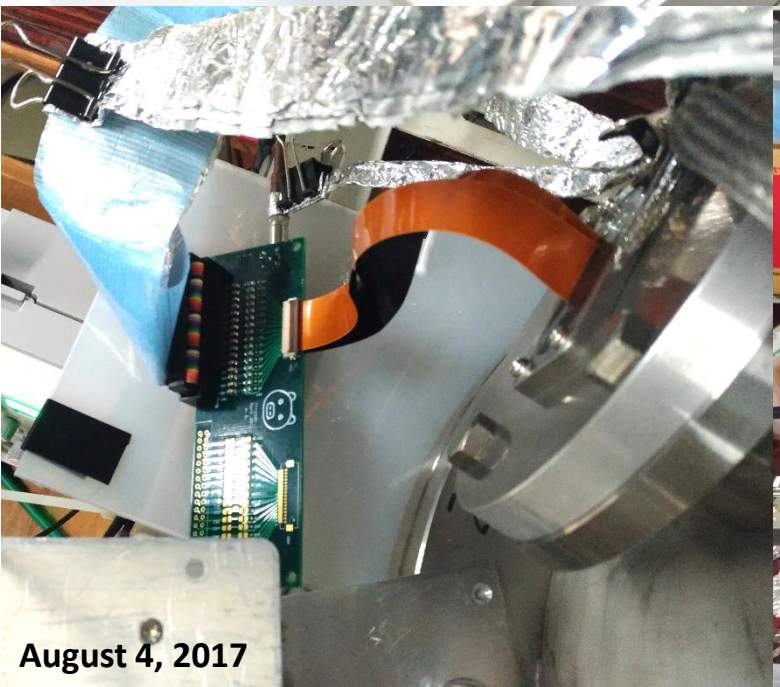
More than 1,000 channels in total

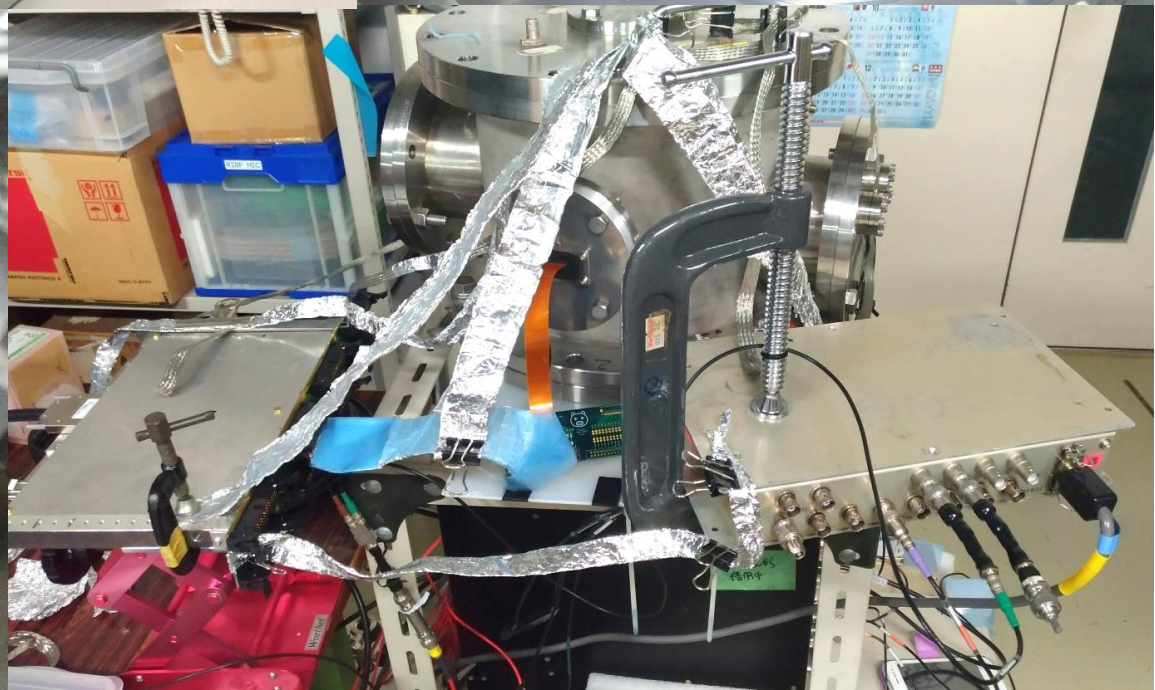
TTT + GET electronics @RIBF-3F





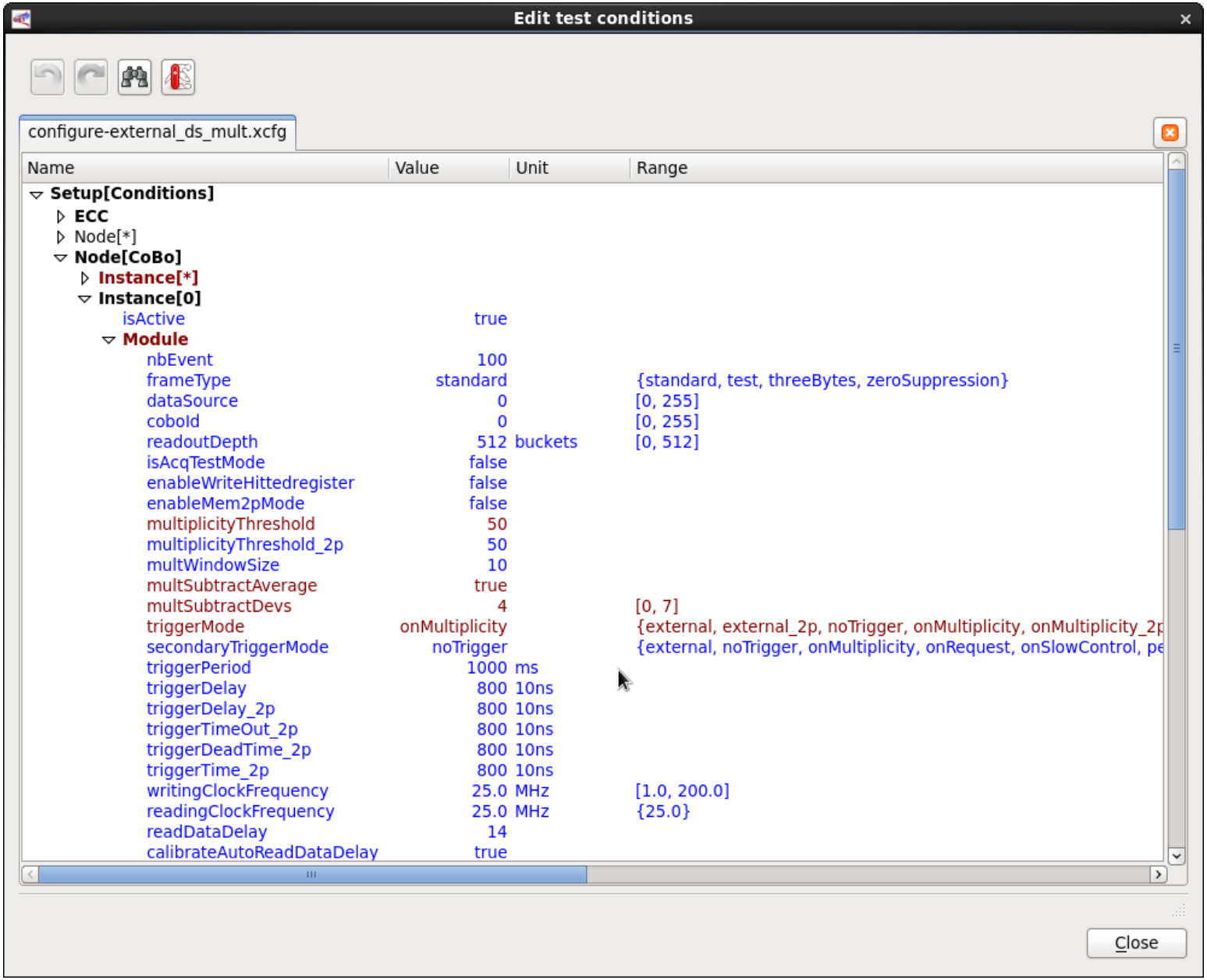






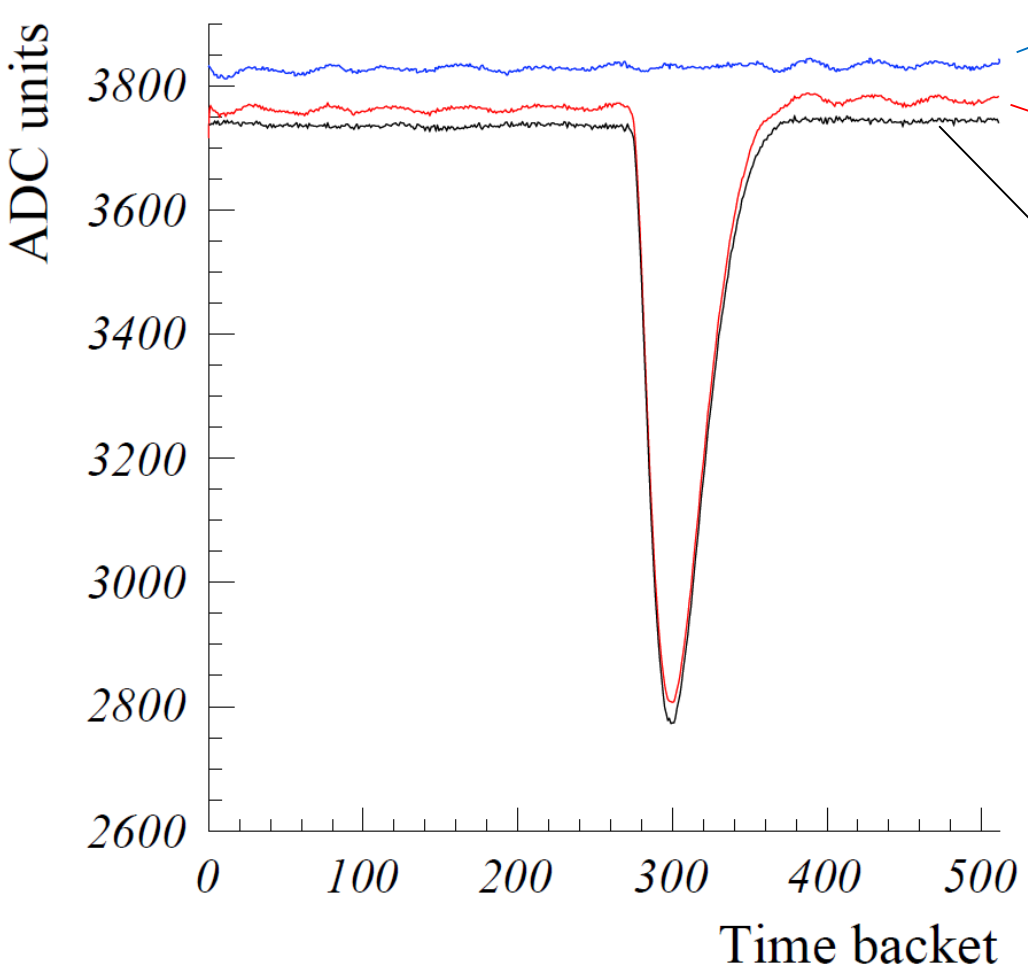
August 4, 2017

Data taking by internal trigger



Name	Value	Unit	Range
Setup[Conditions]			
ECC			
Node[*]			
Node[CoBo]			
Instance[*]			
Instance[0]			
isActive	true		
Module			
nbEvent	100		
frameType	standard		{standard, test, threeBytes, zeroSuppression}
dataSource	0		[0, 255]
coboId	0		[0, 255]
readoutDepth	512	buckets	[0, 512]
isAcqTestMode	false		
enableWriteHittedregister	false		
enableMem2pMode	false		
multiplicityThreshold	50		
multiplicityThreshold_2p	50		
multWindowSize	10		
multSubtractAverage	true		
multSubtractDevs	4		[0, 7]
triggerMode	onMultiplicity		{external, external_2p, noTrigger, onMultiplicity, onMultiplicity_2p
secondaryTriggerMode	noTrigger		{external, noTrigger, onMultiplicity, onRequest, onSlowControl, pe
triggerPeriod	1000	ms	
triggerDelay	800	10ns	
triggerDelay_2p	800	10ns	
triggerTimeOut_2p	800	10ns	
triggerDeadTime_2p	800	10ns	
triggerTime_2p	800	10ns	
writingClockFrequency	25.0	MHz	[1.0, 200.0]
readingClockFrequency	25.0	MHz	{25.0}
readDataDelay	14		
calibrateAutoReadDataDelay	true		

Example of waveform taken with ^{241}Am



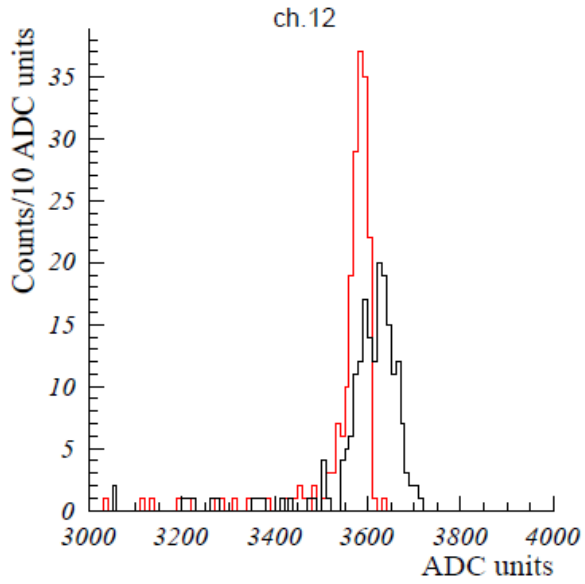
(2) Channel without hit

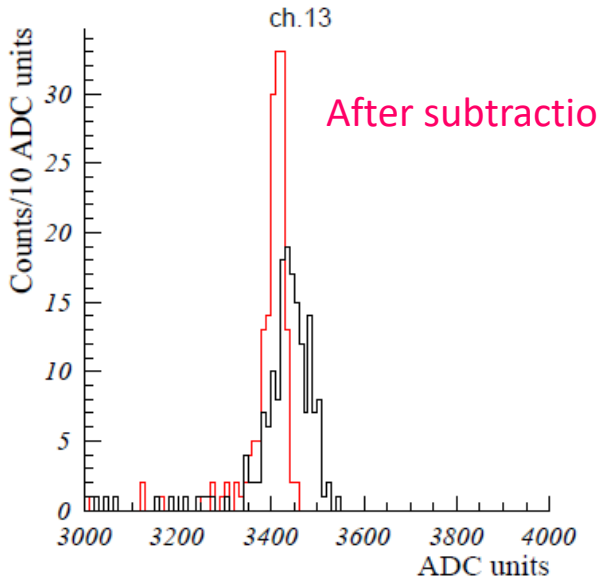
(1) AGET channel 12

After subtraction: (1) – (2)

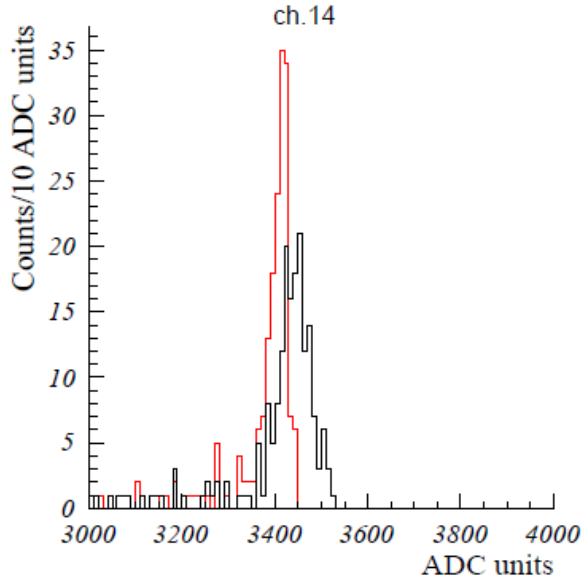
- Sampling 25 MHz or 4 ns/time bucket
- Gain 1 pC
- Peaking time 1 µs

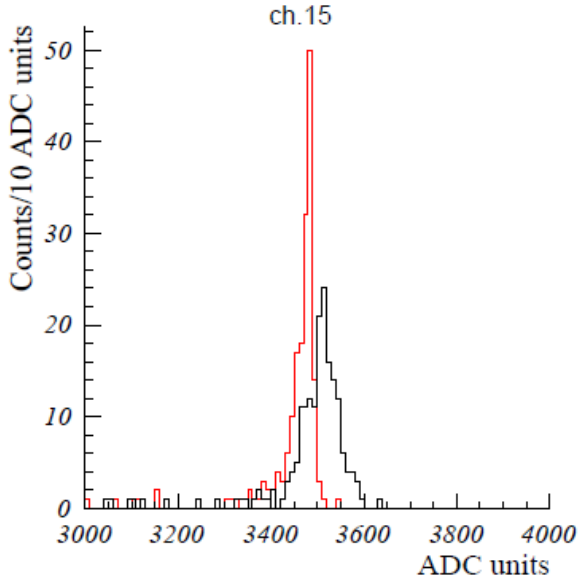
Energy spectra





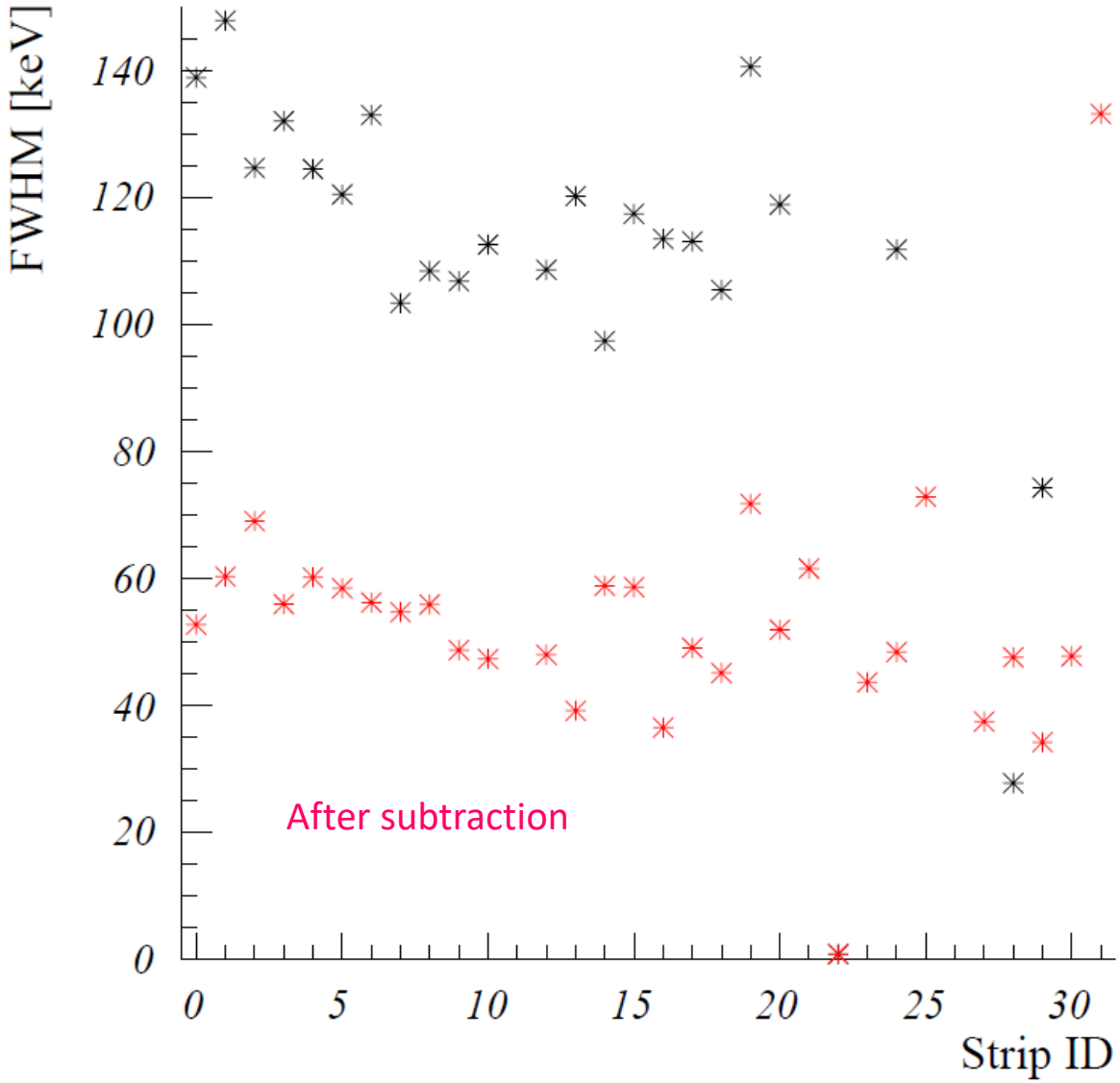
After subtraction





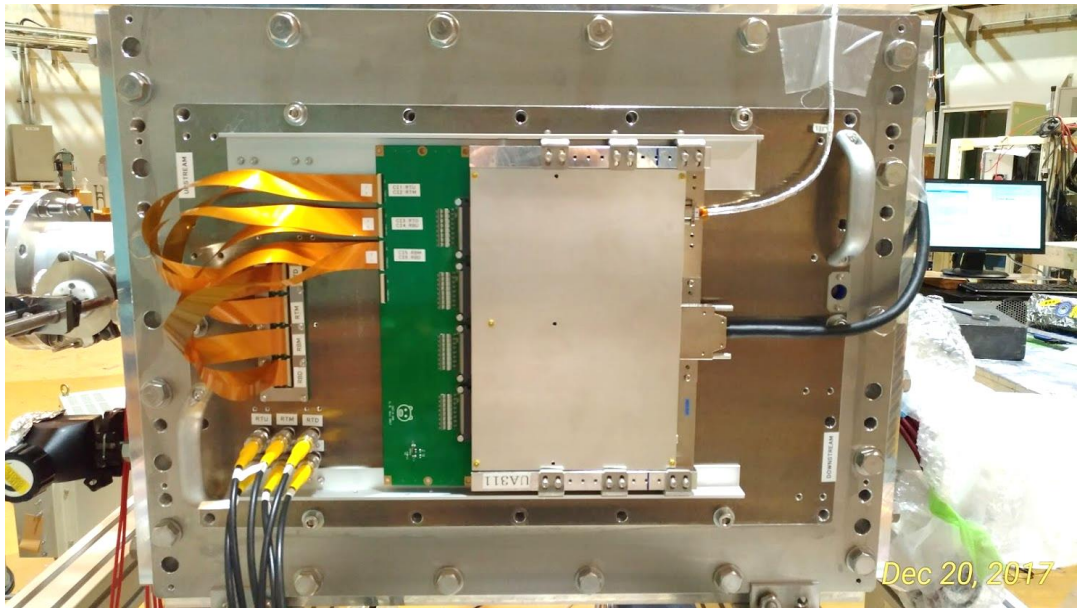
CoBo0_AsAd0_2017-08-04T14:27:57.615_0000.graw

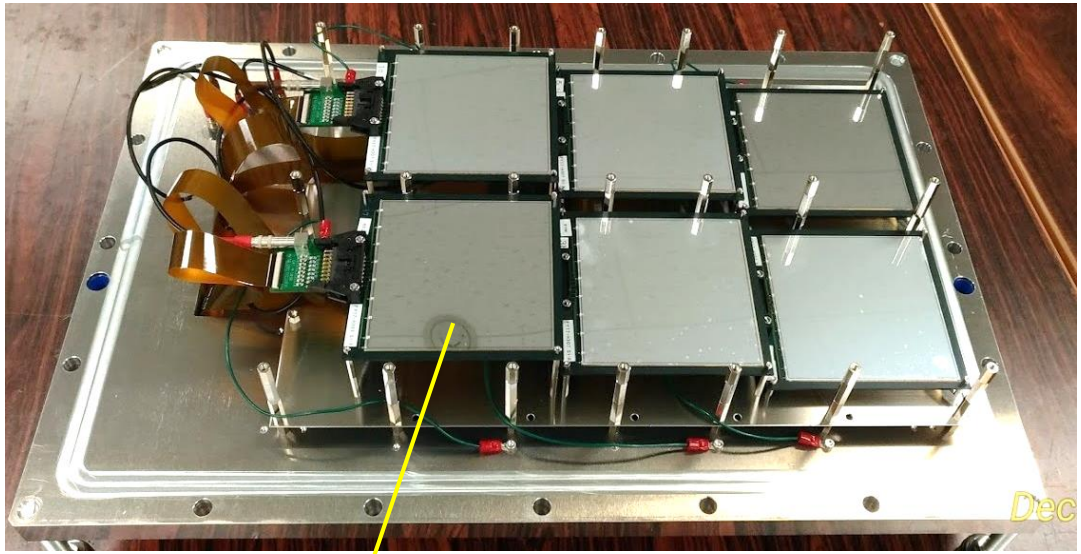
Energy resolution for ^{241}Am



CoBo0_AsAd0_2017-08-04T14:27:57.615_0000.graw

CAT-M test with 200 MeV/u ^{136}Xe beam (HIMAC)





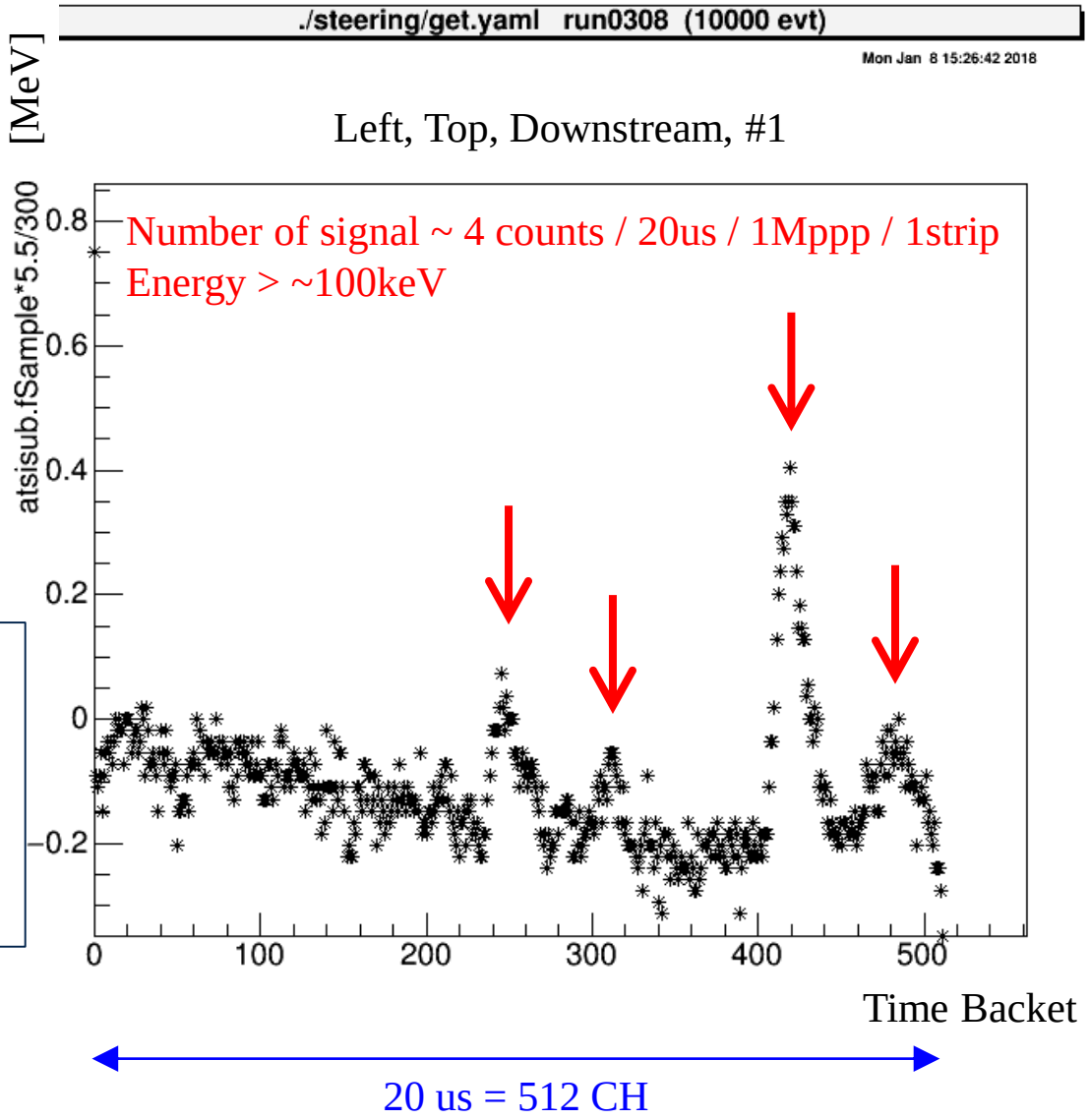
Hamamatsu S10938-9340(X) 9 × 9 cm^2, 8 strips

Overview of GET electronics

Courtesy N. Kitamura

Number of delta-ray

- Delayed Down Scale Beam trigger
- Beam Intensity: 1Mppp
- Full readout mode
- Sampling Rate: 25MHz
- Multiple threshold = 50 (M=1)
- Silicon position: LTD-1
- Event #: 9547



Counts rate

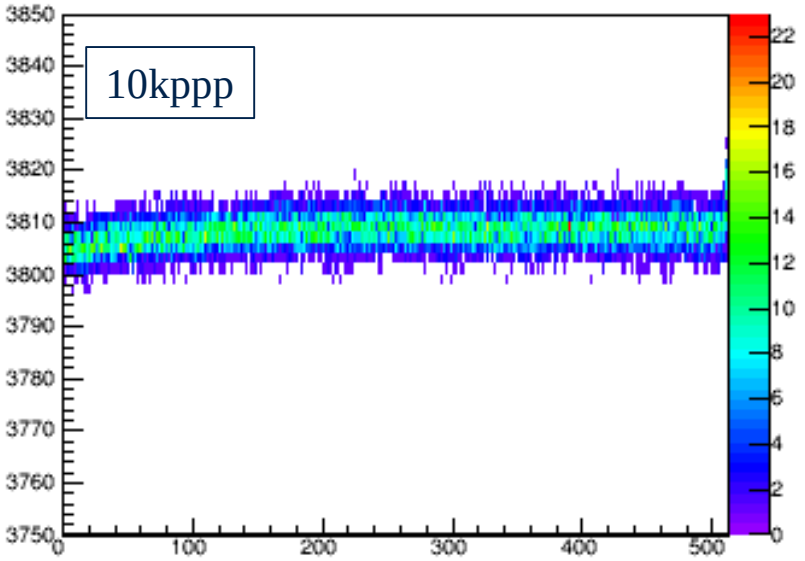
- 0.1 counts / 0.5 us /1strip @ 1Mppp
  → Pile-up event will be small enough
- 19 x 10^6 counts / s / all Si det. @ 1Mppp
  → Too much for trigger rate
  need to cut

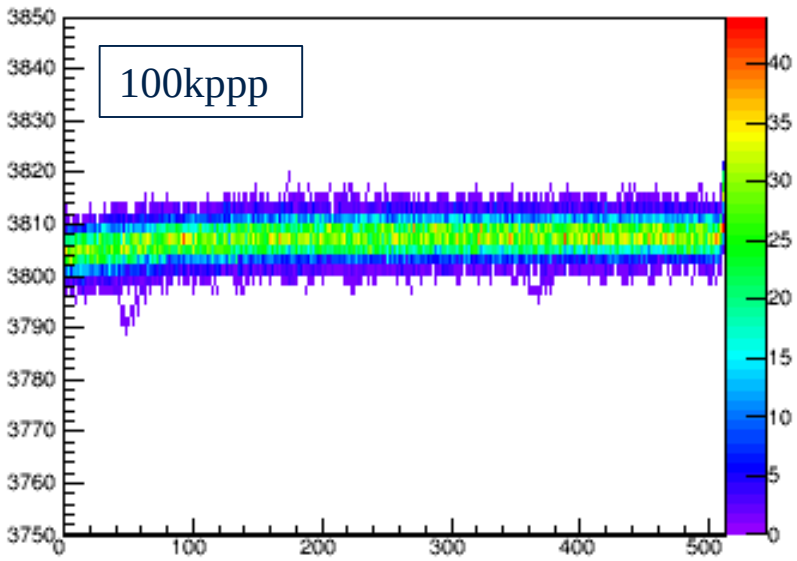
Courtesy C. Iwamoto

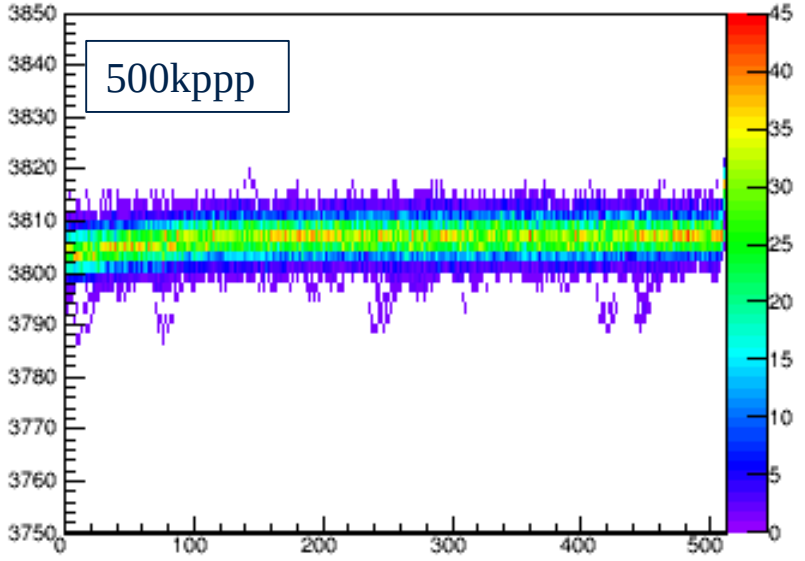
Beam intensity dependence of delta-ray

Wave form (Sample VS Time backet)

- Delayed Down Scale Beam trigger
- **Full readout mode**
- Sampling Rate: 25MHz
- Multiple threshold = 50 (M=1)
- Silicon position: LTD-1







Summary

- New active target CAT-M and silicon detector array TiNA are being developed for future missing mass studies at RIBF
- These new devices are equiped with GET electronics.
- Reduced version of TiNA was successfuly operated to measure ^{79}Se(*d*,*p*) reaction at 20 MeV/*u* at the new OEDO beam line of RIBF.
- GET system was tested with a TTT silicon detector for the full version of TiNA. Internal trigger for M = 1 was successful.
- CAT-M and GET system were tested using a 200 MeV/u ^{136}Xe beam. Delta ray spetra were obtained from waveform data of silicon detectors.

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H307-8 (CAT-M test at HIMAC)

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