RIBF Detector Workshop 08

Beam line detectors for BigRIPS

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Collaborators

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BigRIPS

First stage:
Production and
Separation

Second stage:
Tagging

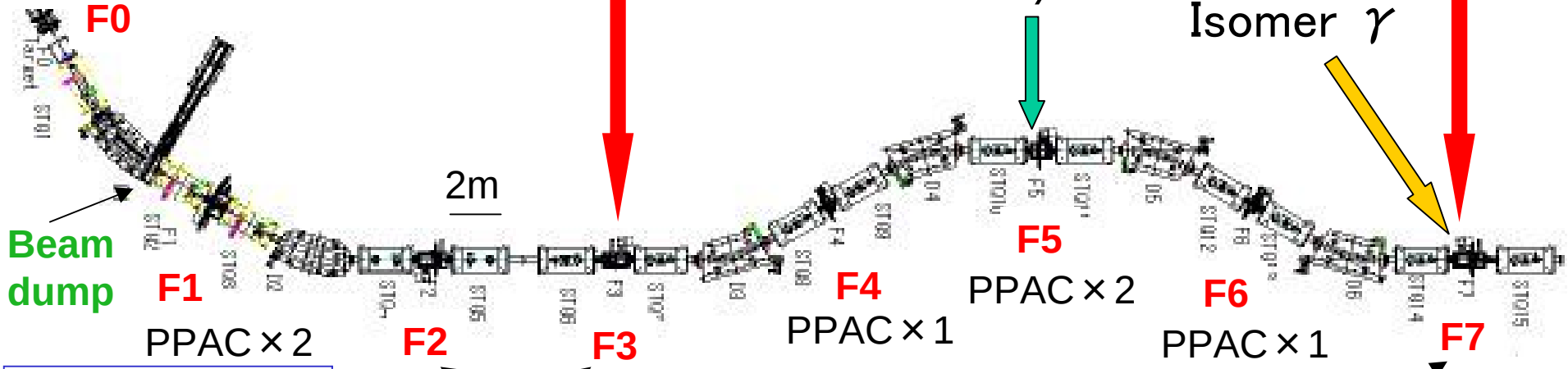
TOF

Target Intensity monitor

F0

$B\rho$

ΔE, E
Isomer γ



Beam dump

F1
PPAC × 2

F2

F3

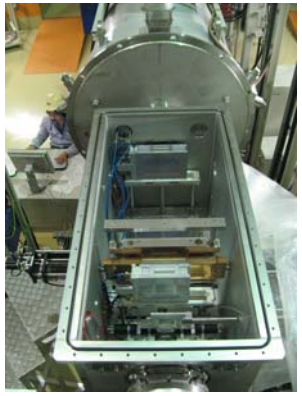
PPAC × 2
Plastic(0.2mm)
Si(325 μ m)

F4
PPAC × 1

F5
PPAC × 2

F6
PPAC × 1

F7



PPAC × 2
Plastic(0.2mm)
Si(50 × 50 mm^2 325 μ m) × 2
Ge(90 × 90 × 76mm^3;4 crystal)
NaI(3 inch × 60 mm)
TEGIC(ϕ 200 mm, 556mm)

Parameters:
$\Delta\theta$ = 80 mr
$\Delta\phi$ = 100 mr
$\Delta p/p$ = 6 %
Bρ = 9 Tm
L ~ 77 m
P/ΔP ~1300(1st)
3300(2nd)

- Requirements for ±3σ separation in A/Q, Z, A

BigRIPS

Pos res. σ < 0.5 mm
Timing res. < 64 ps (σ)
ΔE resolution σ: 0.66 %
E resolution σ: 0.12 %

- Other requirements
  - Large effective area 240 × 150 mm^2
  - Tolerance for high rate ～10^6 Hz

- Position: PPAC
- ΔE: Si, TEGIC
- TOF: Plastic
- E: NaI
- PID confirmation: Ge

DL-PPAC for BigRIPS

DL-PPAC: Delay Line Parallel Plate Avalanche Counter

H. Kumagai et al., Nucl. Instr. and Meth. A470(2001)562.

DL-PPAC in RIPS : 10^6Hz

Gas: C_3F_8 10～30 Torr

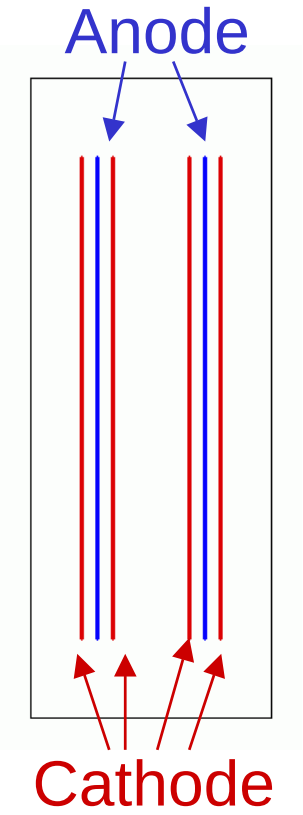
HV: 800 ～1800 V

Anode/Cathode:
2/4 μm Mylar

Anode-Cathode:4mm

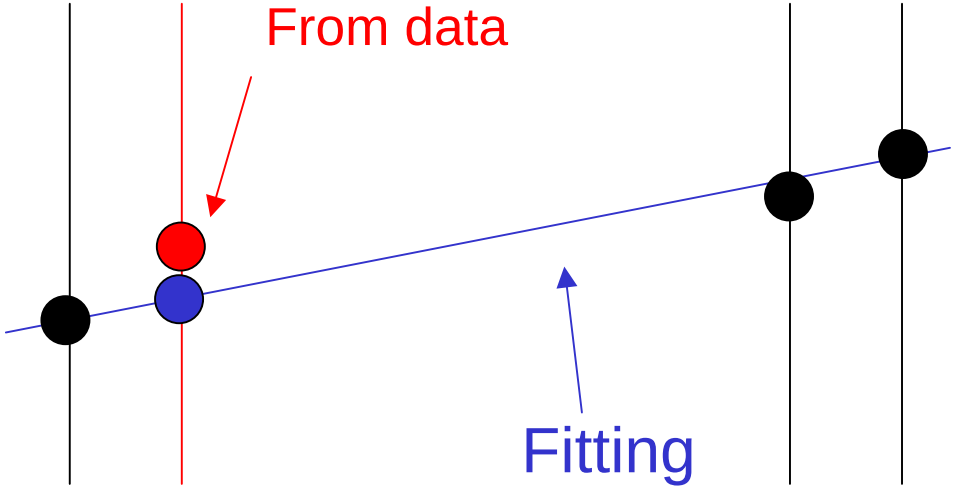
Window:
12 μm Al-Mylar

Effective area: 240×150 mm^2



To avoid the effect of δ-ray,
we set the double layer.
→ High efficiency

Position Resolution



U+Be 7mm

B ρ 01= 7.438 Tm

Controlled Pressure 11.0 Torr

Operating bias

F3-1 870V

F3-2 890V

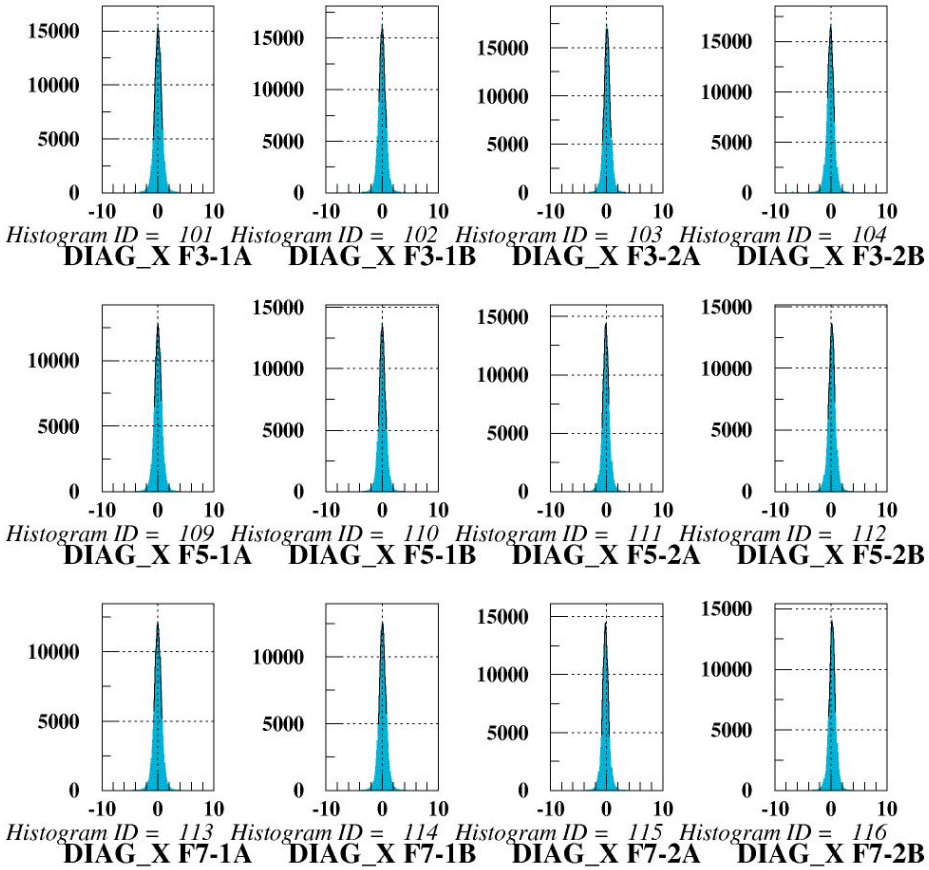
F5-1 890V

F5-2 890V

F7-1 880V

F7-2 880V

Residu σ : 0.48 ~ 0.57 mm

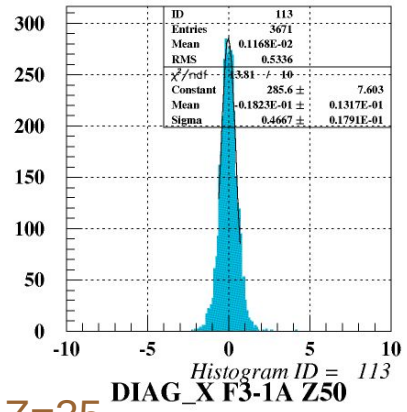


Propagation of error, Geometry of PPAC

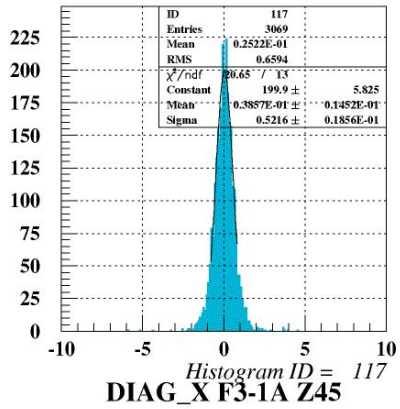
Position res. σ : 0.35 ~ 0.46 mm

Z dependence of position resolution

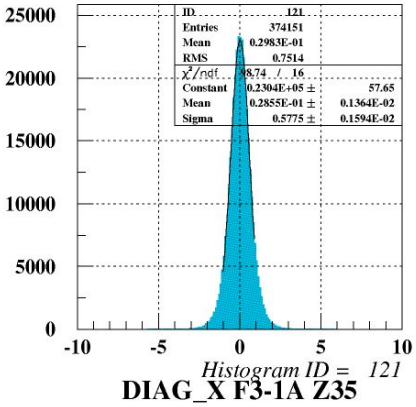
Z=50



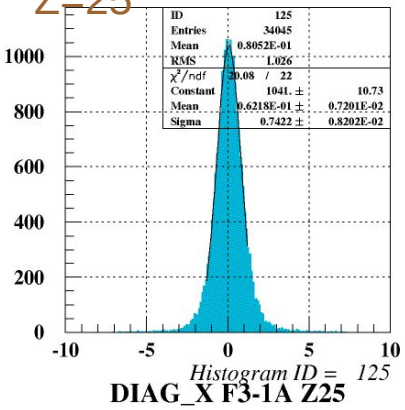
Z=45



Z=35

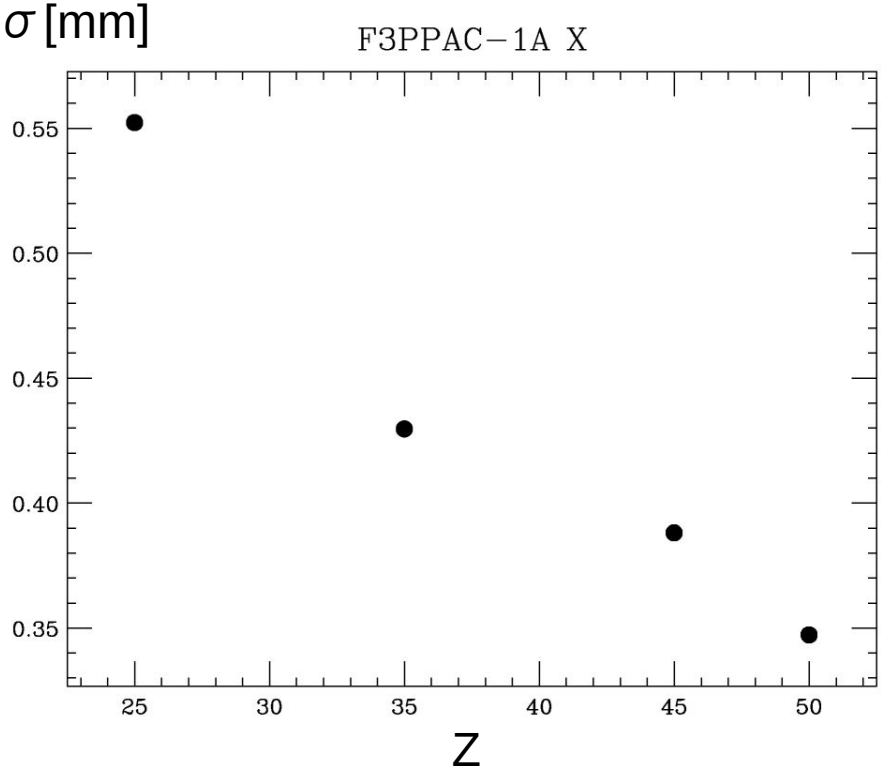


Z=25



Position resolution

σ [mm]



For light nuclei: Fine tuning of gas pressure and bias

σ [mm] ^{8}B,^{7}Be: 0.51mm, ^{12}C: 0.38 mm@300MeV,GSI

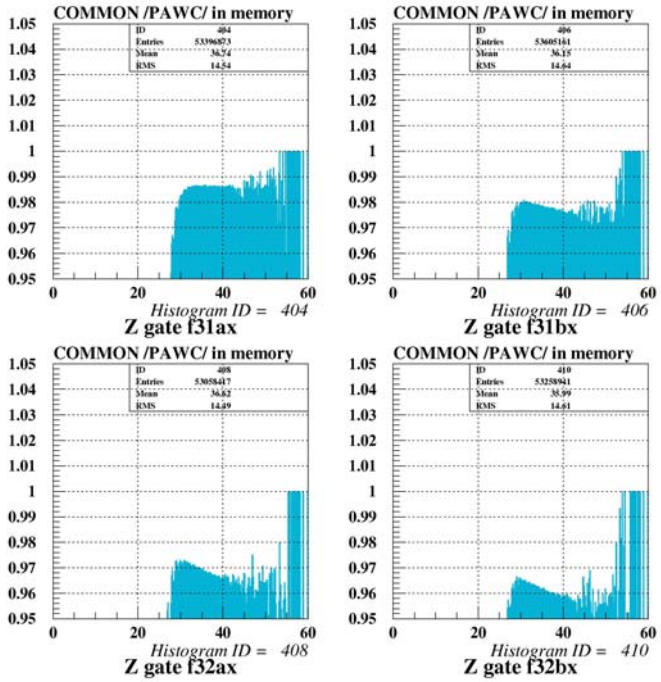
Z dependence of tracking efficiency

U+Be 7mm, Bρ 01= 7.438 Tm Controlled Pressure 11.0 Torr

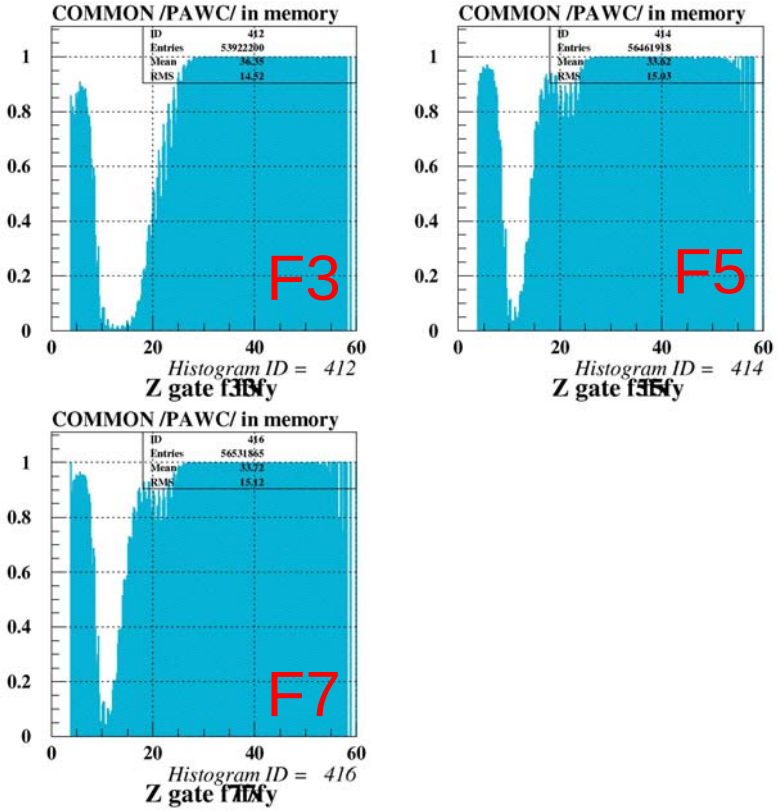
Operating bias F3-1 870V, F3-2 890V,F5-1 890V,F5-2 890V
F7-1 880V, F7-2 880V

Z information: F7 Si detector

Efficiency = Event(Si,X,Y)/Event(Si)



Efficiency of 1 plane at F3PPAC
Z>30 Efficiency >95%

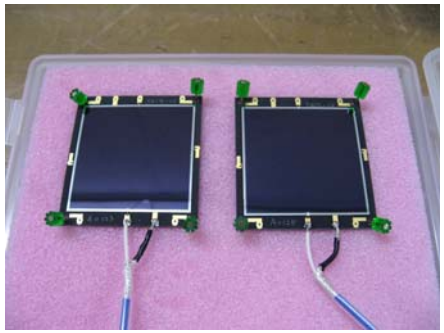


Efficiency of X and Y
using 4 planes for each direction

Z>30 Efficiency ～100%

ΔE detector(Si, IC)

Si:



Tilted-Electrodes-Gas-Ionization-Chamber

Stacked structure

K. Kimura et al., Nucl. Instr. and Meth. A538(2005)608

Setting U + Be 7mm, Bρ01 = 7.215 Tm

PPAC: F3,F5,F7

Plastic: F3, F7

Si: F7 50×50mm^2 325 μm ×2

TEGIC: F7 ϕ200 mm

P10 425mm at 760 Torr

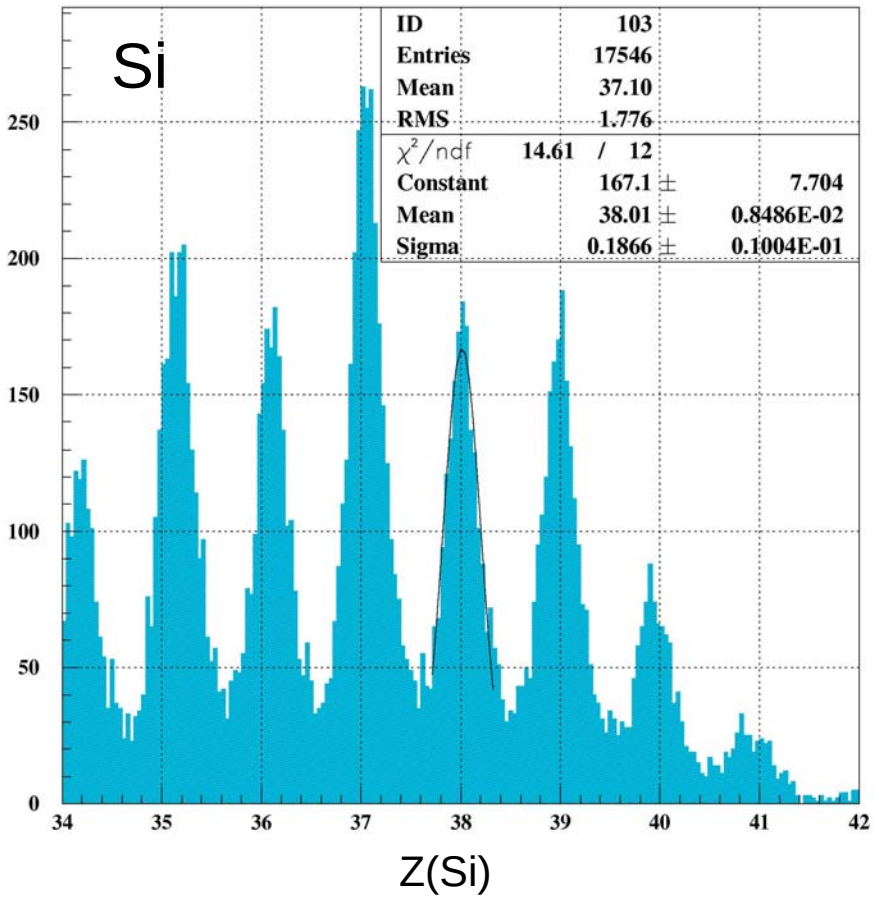
Electrodes(anode/cathode) 4μm×25 Mylar

Distance(anode-cathode) 2cm

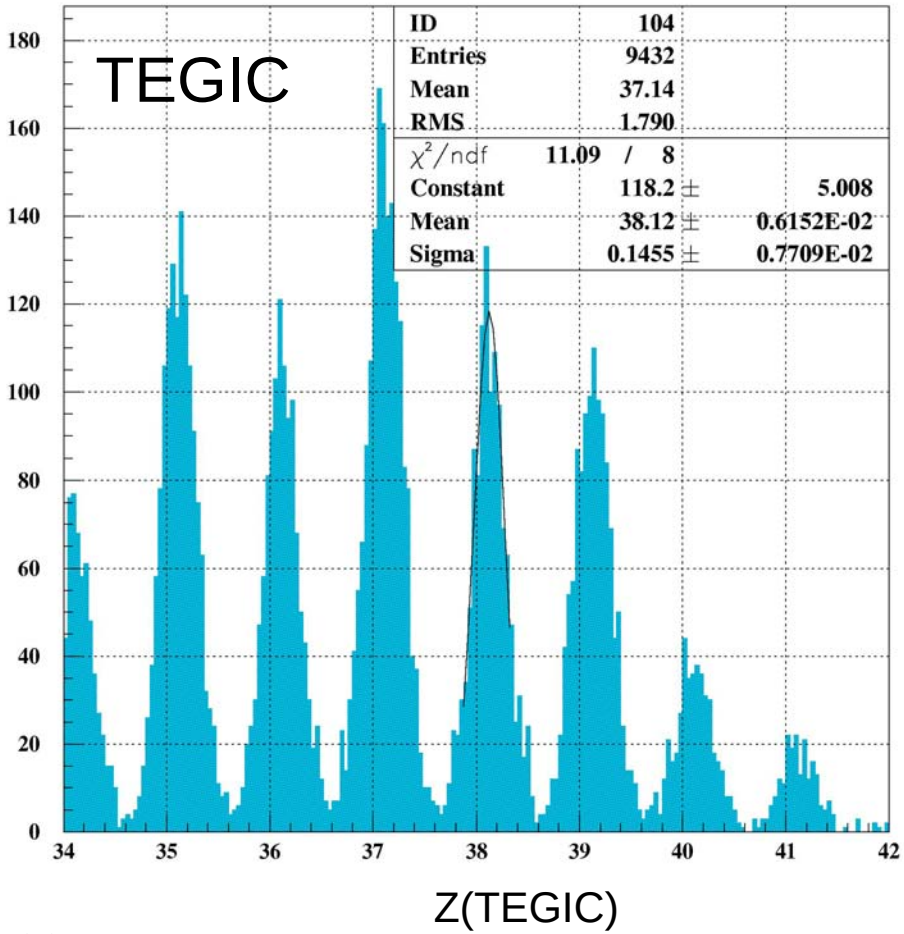
Detector Window 150μm Kapton

F5x: ±2mm = ΔP/P ±0.06% gate

TOF 225 – 226 ns



^{96}Sr Z resolution: $4.9 \times 10^{-3}(\sigma)$



^{96}Sr Z resolution: $3.82 \times 10^{-3}(\sigma)$

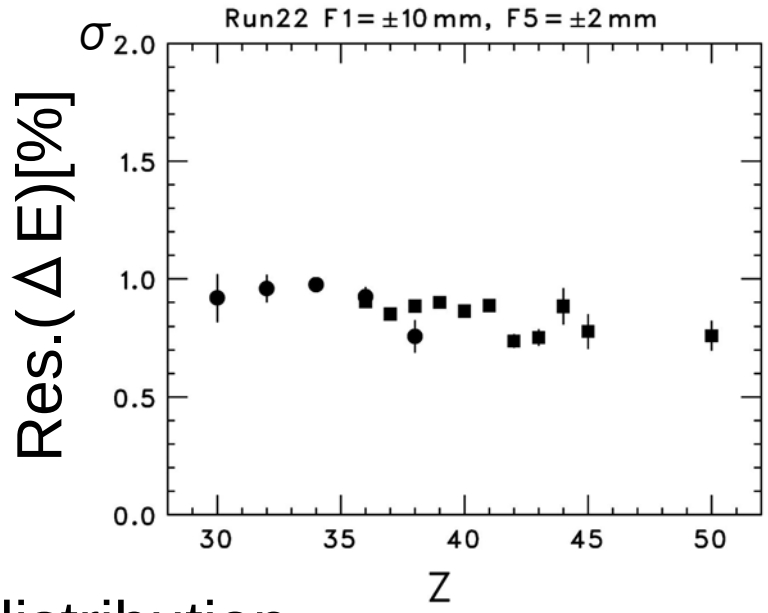
16%

Required $\sigma = 3.3 \times 10^{-3}$

Property of TEGIC

Z dependence of energy resolution

U + Be 7mm, Bρ 01 = 7.215 Tm

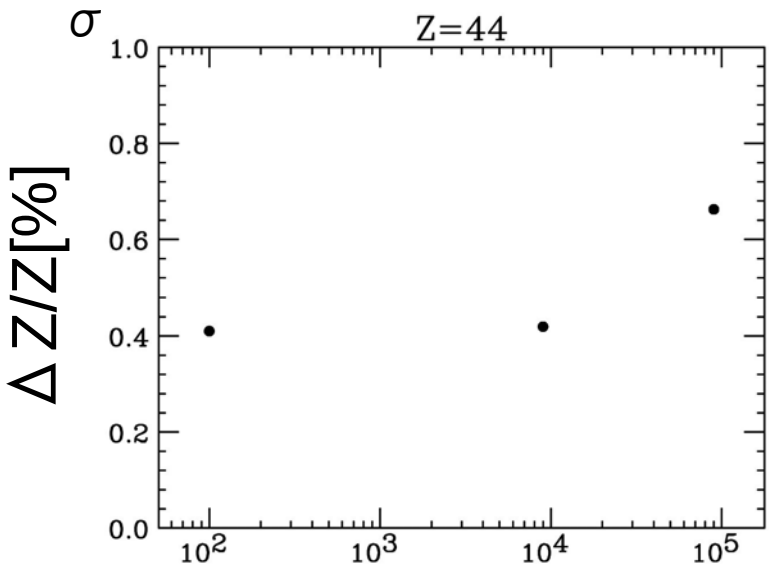


Rate dependence

U + Be 5mm, Bρ 01 = 5.8567 Tm

F1: ±6.4mm, F2:±60mm

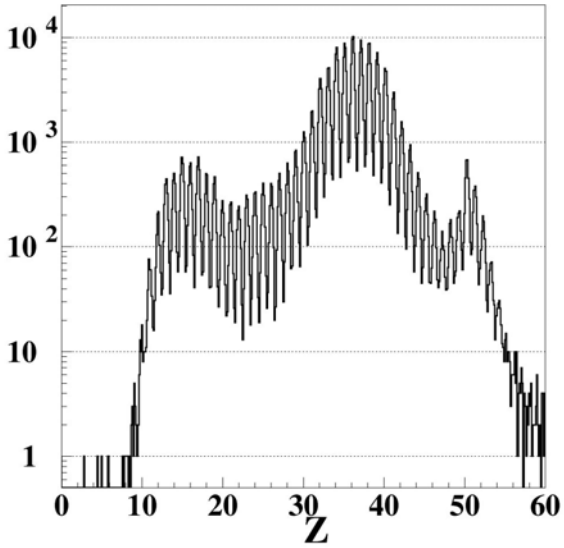
P10 gas TOF 243−245ns



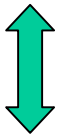
Yield distribution

U + Be 7mm

Bρ 01 = 7.215 Tm



ΔZ=0.43(FWHM)



ΔZ=0.42(FWHM) at GSI

A. Stolz et al.: GSI Scientic Report 1998, p.174

Timing detector(Plastic)

Plastic BC-420+H1949(current booster)

Run120 F3,F7 Plastic

U86+ 345MeV/u + Be 2 mm

Bρ 34 = 7.239 Tm

F3Pla – F7Pla : 46.978 m

Calc TOF = 237.169ns

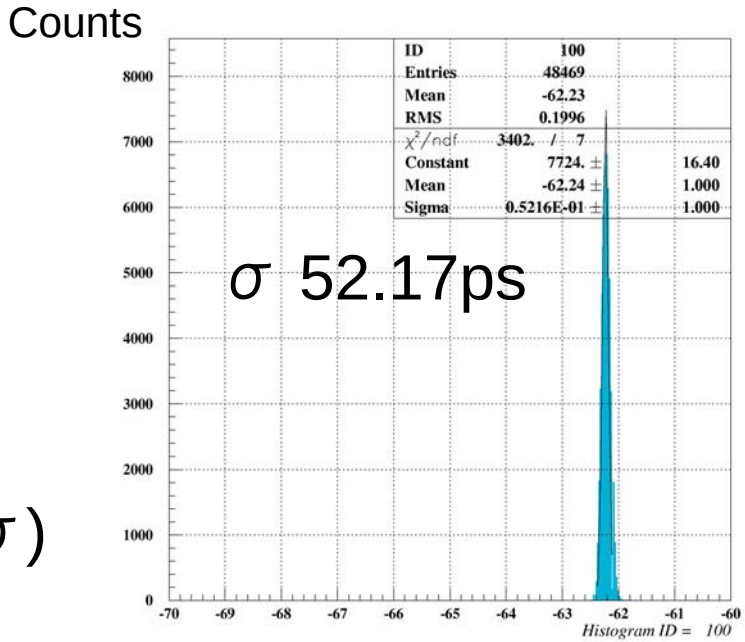
Straggling inside target: σ 28.73ps

Fitting 52.17 ps(σ)

→ Res(Pla) = 30.8 ps(σ)

↕

Required Timing res. 64 ps (σ)



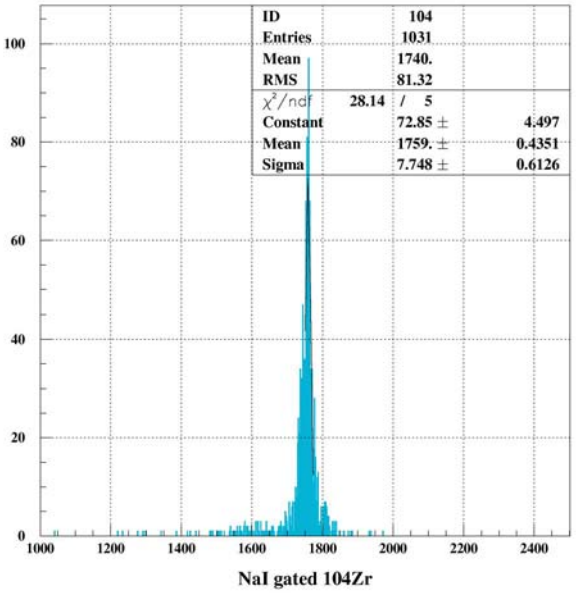
ToF37

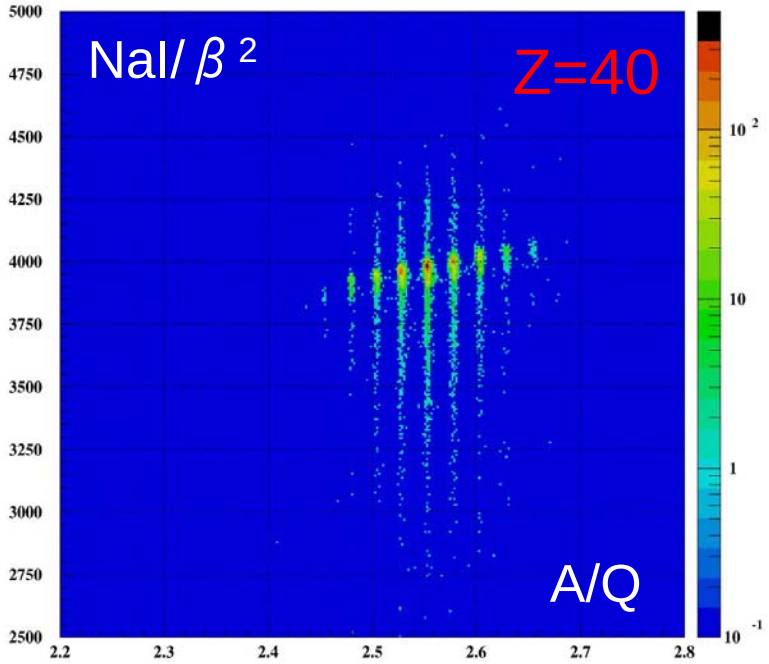
Total E detector

NaI $B\rho$ 01=7.215 Tm
$B\rho$ 35=7.138 Tm

U + Be 7mm

^{104}Zr





Energy resolution
0.47 %(σ)

ΔA=1 separation
Required E resolution σ=0.12%

A information for PID
Help of A/Q information

A is identified.

Isommer γ detector

Confirmation of PID

Ge detector

Two clover-type (90 × 90 × 76mm3)

50mm off beam center

Photo peak efficiency(add-back) 3.5%@1MeV

Timing gate

1～2 μ s from prompt

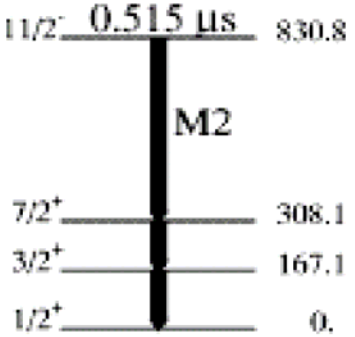
Energy gate

200 keV ～ 500 keV

Z=38, A/Q = 2.55 ^{97}Sr

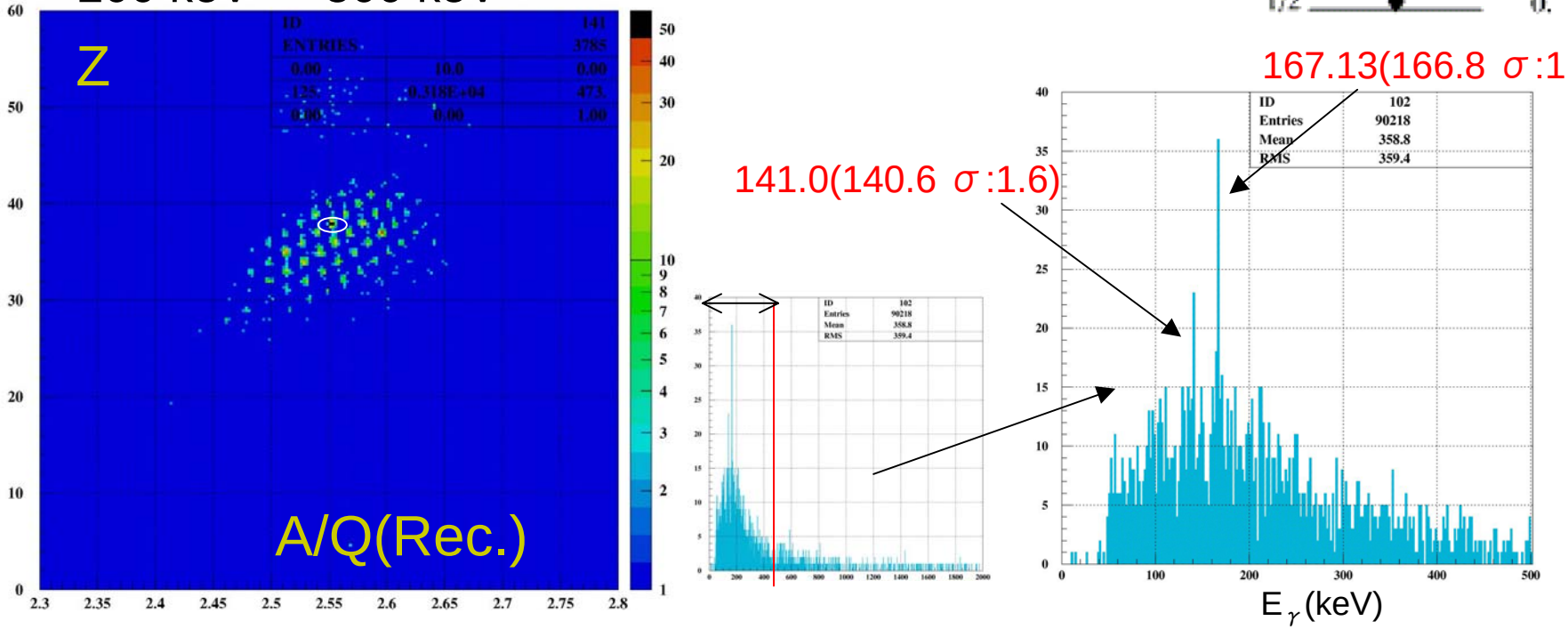
Z=35, A/Q = 2.51 ^{88}Br

PRC59(1999)82



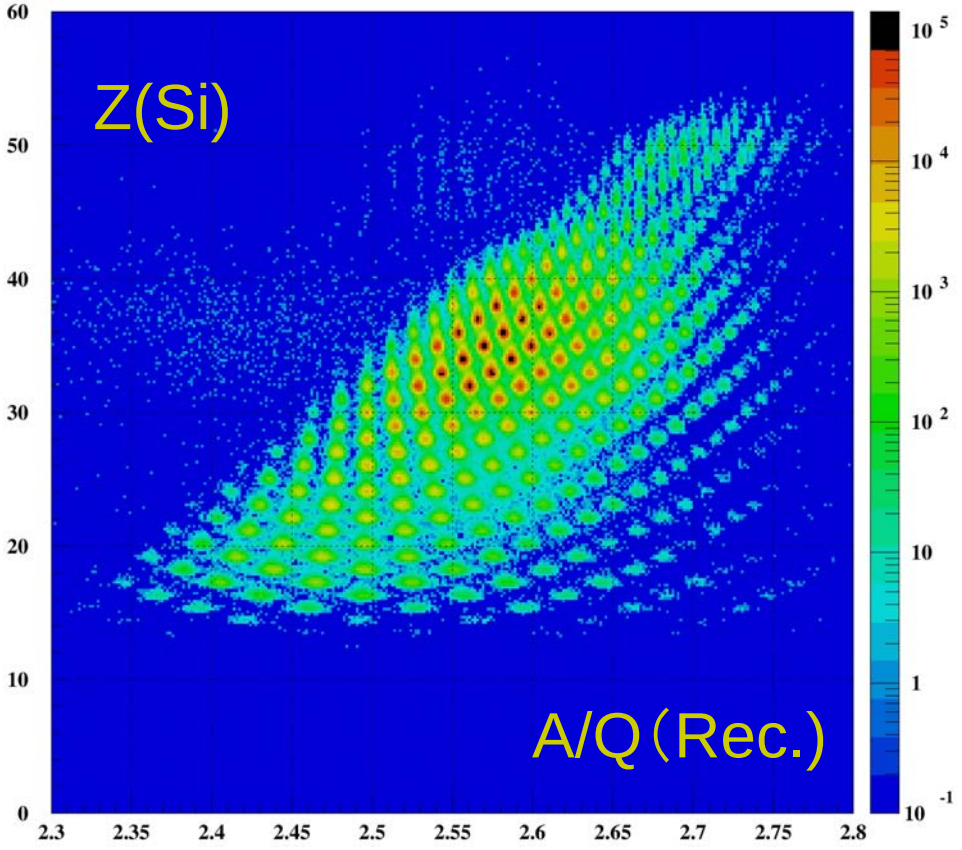
167.13(166.8 σ:1.6)

141.0(140.6 σ:1.6)



PID

U+Be 7mm Bρ =7.4 Tm ΔP/P=$\pm$1%



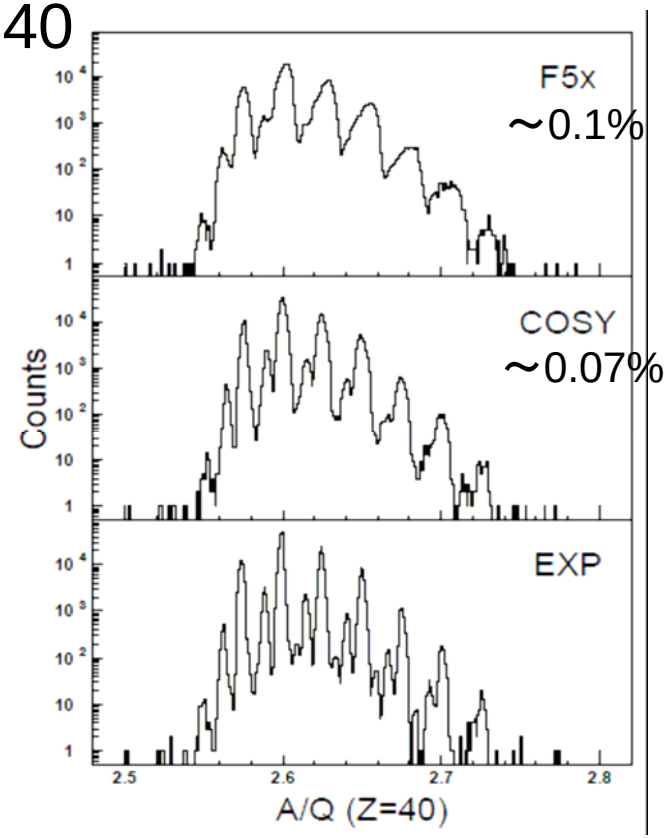
$\Delta Z/Z$ (Si): $\sigma = 5.5 \times 10^{-3}$

→ $\pm 1.8\sigma$ separation

Bρ Reconstruction

- Track at the dispersive focal plane
- Optical matrices of BigRIPS

Z=40



A/Q resolution:0.05%(r.m.s)

→ $\pm 1.8\sigma$ separation

Limit of A/Q resolution (Detector)

$$\left\{\frac{\Delta\left(\mathrm{A}/\mathrm{Q}\right)}{\left(\mathrm{A}/\mathrm{Q}\right)}\right\}^2 = \left\{\frac{\Delta(B\rho)}{(B\rho)}\right\}^2 + \gamma^4\left(\frac{\Delta\beta}{\beta}\right)^2$$

$$\mathrm{B}\rho = (\mathrm{B}\rho)_0(1+\delta) \quad \Rightarrow \quad \frac{\Delta(\mathrm{B}\rho)}{\mathrm{B}\rho} = \frac{\Delta\delta}{1+\delta} \sim \Delta\delta$$

1st order $$\delta = \frac{1}{\det}\left[(a|a)\{f_{5x} - (x|x)f_{3x}\} - (x|a)\{f_{5a} - (a|x)f_{3x}\}\right]$$

det = (x|d)(a|a)-(x|a)(a|d)

$$(\Delta\delta)^2 = \frac{1}{\det^2}\left[(a|a)^2(\Delta f_{5x})^2 + \{(a|a)^2(x|x)^2 + (x|a)^2(a|x)^2\}(\Delta f_{3x})^2 + (x|a)^2(\Delta f_{5a})^2\right]$$

$$(\Delta\delta)^2 = \frac{1}{(34.63)^2}\left[1.33(\Delta f_{5x})^2 + 1.20(\Delta f_{3x})^2 + 0.151(\Delta f_{5a})^2\right] \ [\%^2]$$

PPAC resolution $(\Delta f_{5x})^2 = (\Delta f_{3x})^2 = 0.08\mathrm{mm}^2, (\Delta f_{5a})^2 = (0.832)^2\,\mathrm{mrad}^2$

$$\frac{\Delta(\mathrm{B}\rho)}{\mathrm{B}\rho} = 0.016 \ [\%]$$

ToF σ:0.013% Bρ =7.4 Tm γ =1.36

$$\left\{\frac{\Delta\left(A/Q\right)}{\left(A/Q\right)}\right\}^2 = \left\{\frac{\Delta(B\rho)}{(B\rho)}\right\}^2 + \gamma^4\left(\frac{\Delta\beta}{\beta}\right)^2$$

$$= (0.016)^2 + 3.42(0.013)^2$$

Detector only $\dfrac{\Delta\left(A/Q\right)}{\left(A/Q\right)} = 0.028[\%]$ → $\pm 3.1\sigma$ separation

Optical Matrix

Overestimation of detector's resolution…

Measured A/Q resolution 0.05[%]

$\pm 1.8\sigma$ separation

Summary

Beam line detectors for BigRIPS

1) ±1.8 σ separation in Z, A/Q
2) Identification of A: 2D plot E/β^2 vs A/Q
3) ± 2.6σ separation in Z by TEGIC

Future

- Development of Timing detector
  Timing resolution, Radiation hardness
- Higher order correction for optical matrix
- More Development of ΔE, E detectors for High rate
- Development of detector, amplifier, and circuits for E