High resolution TOF measurements with plastic scintillators

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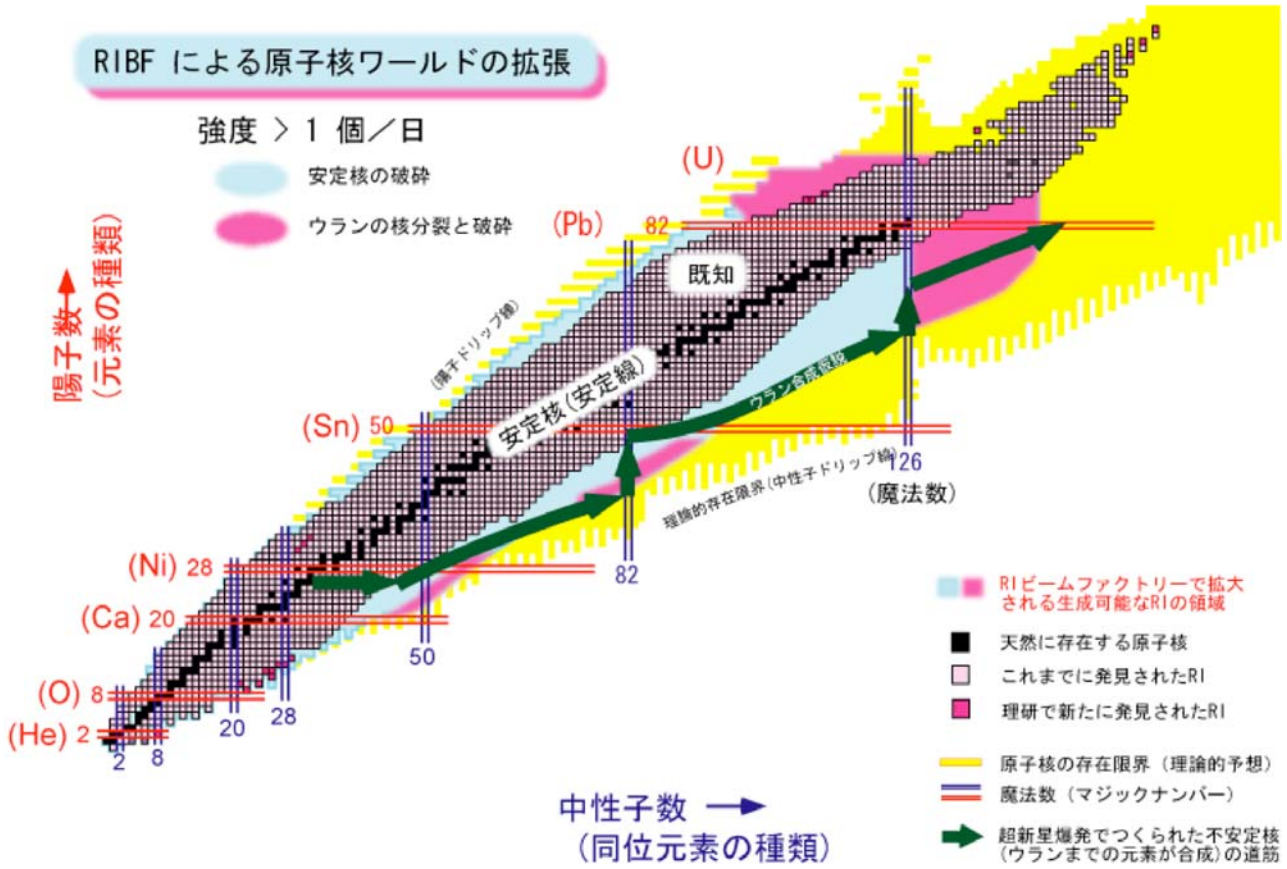
for “Rare RI Ring” collaboration

RIBF Detector Workshop 08
17-18 Mar. 2008

What is Rare RI Ring?

… Cyclotron-like storage ring
for mass measurements

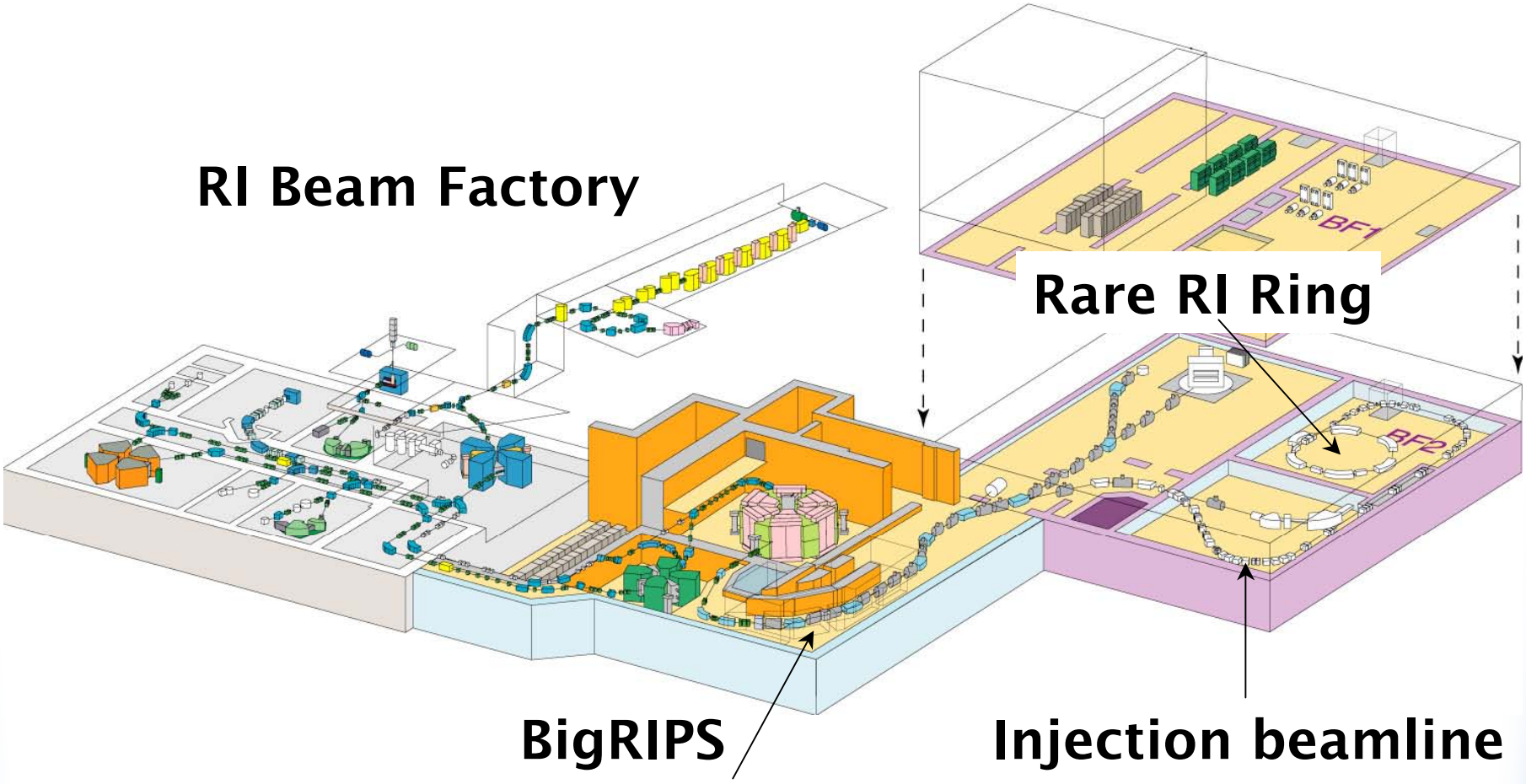
Rare RI on the r-process



The masses of exotic nuclei on the r-process should be measured precisely to shed light on the nucleosynthesis.

Rare RI Ring at RIBF

~ precision mass measurements ~



Experimental Principle

~ a comparison with GSI ~

Mass measurements in storage rings

FRS–ESR (GSI)

Method:

SMS/IMS

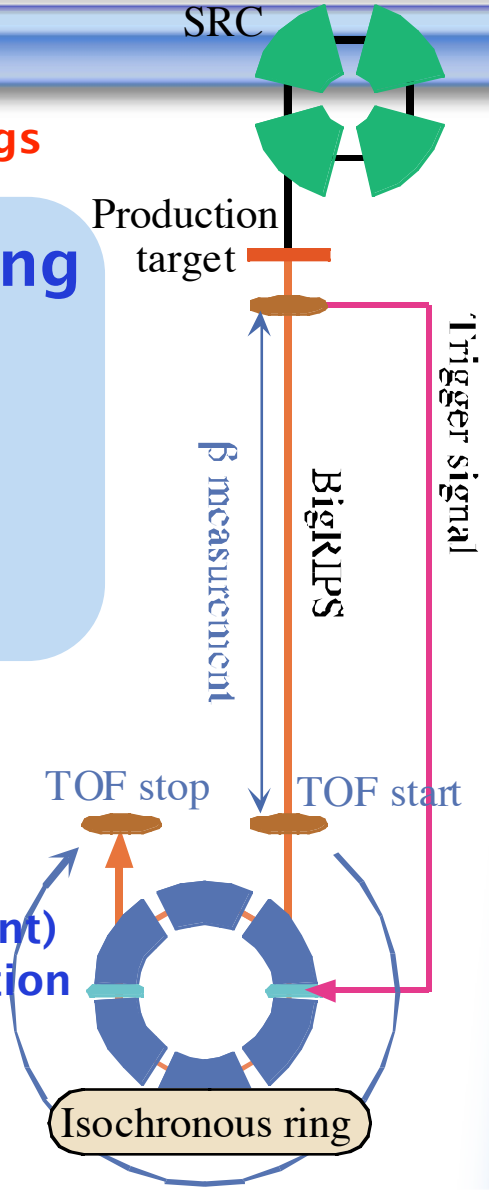
Feature:
Synchrotron
(Fast ext.)
No calibration

Rare RI Ring (RIBF)

Method:

IMS

Feature:
Cyclotron
(event by event)
Velocity correction



New scheme at Rare RI Ring

In-flight particle identification
Fragment separator BigRIPS
Long injection beamline
Precision velocity measurement

→ Injection “one by one”

Isochronous optics for storage ring
m/q proportional to revolution frequency
TOF measurement
Revolution frequency in the ring

→ IMS (GSI)

High resolution TOF detectors need to be developed.

Requirements for TOF detector

- **Excellent time resolution**
  - **100 ps or even better**

    (Total TOF~1ms leads to $\Delta T/T \sim \Delta m/m \sim 10^{-7}$.)

- **Thin materials in the beamline**
  - **to avoid emittance growth**

    (Acceptance of the injection line and the ring is relatively small, <10 π mmmrad.)
  - **to keep charge state**

    (Non-fully stripped ions are used to tune the ring to the isochronous setting.)

➡ **Test the "thinnest" plastic scintillators as a first trial.**

Beam test at HIMAC

- **Time resolution of plastic scintillators**
  - **Plastic: ELJEN 500/100/50/10 μm**
  - **PMT: Hamamatsu H2431/H1949 (both std.)**
- **Heavy ions with 200MeV/u available at HIMAC**
  - **Xe^{42+}**
  - **Kr^{31+}**
  - **Fe^{20+}**
- **(Charge state distributions, Hybrid Photo Sensors)**

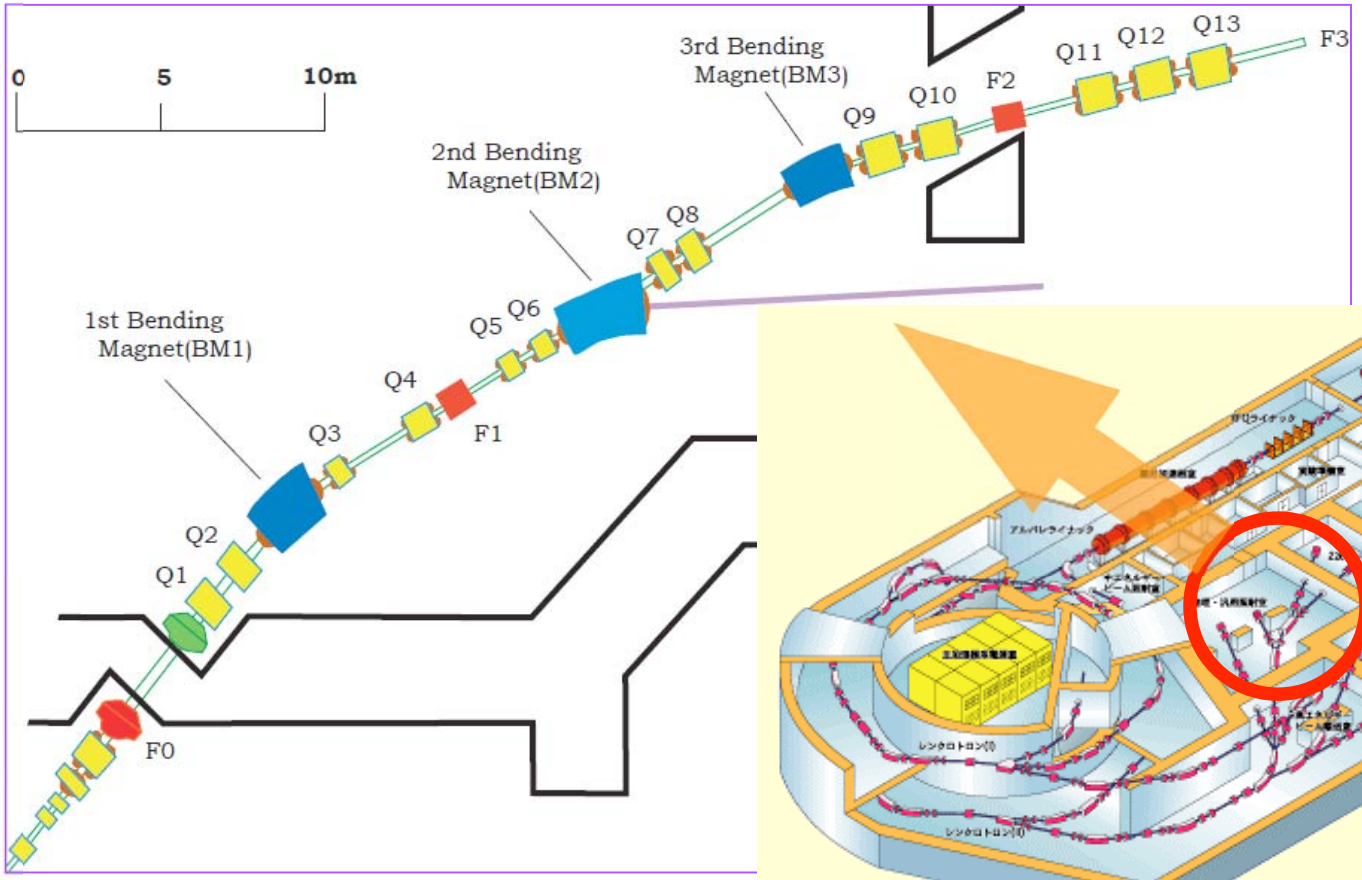
Specifications

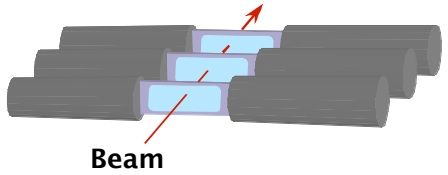
Scintillator	Rise time (ns)	Decay time (ns)	Light output (%)	Attenuation length (cm)
BC418/BC420 (EJ230)	0.5	1.4	67	100
BC422	0.35	1.6	55	8
EJ232	0.35	1.4	55	–

PMT	size	Rise time (ns)	Transit time spread (ps)	Gain (10^6)
R4998 (H6533)	ϕ1”	0.7	160	5.7
R2083 (H2431)	ϕ2”	0.7	370	2.5
R1828 (H1949)	ϕ2”	1.3	550	20

Heavy Ion Medical Accelerator in Chiba
~ HIMAC ~

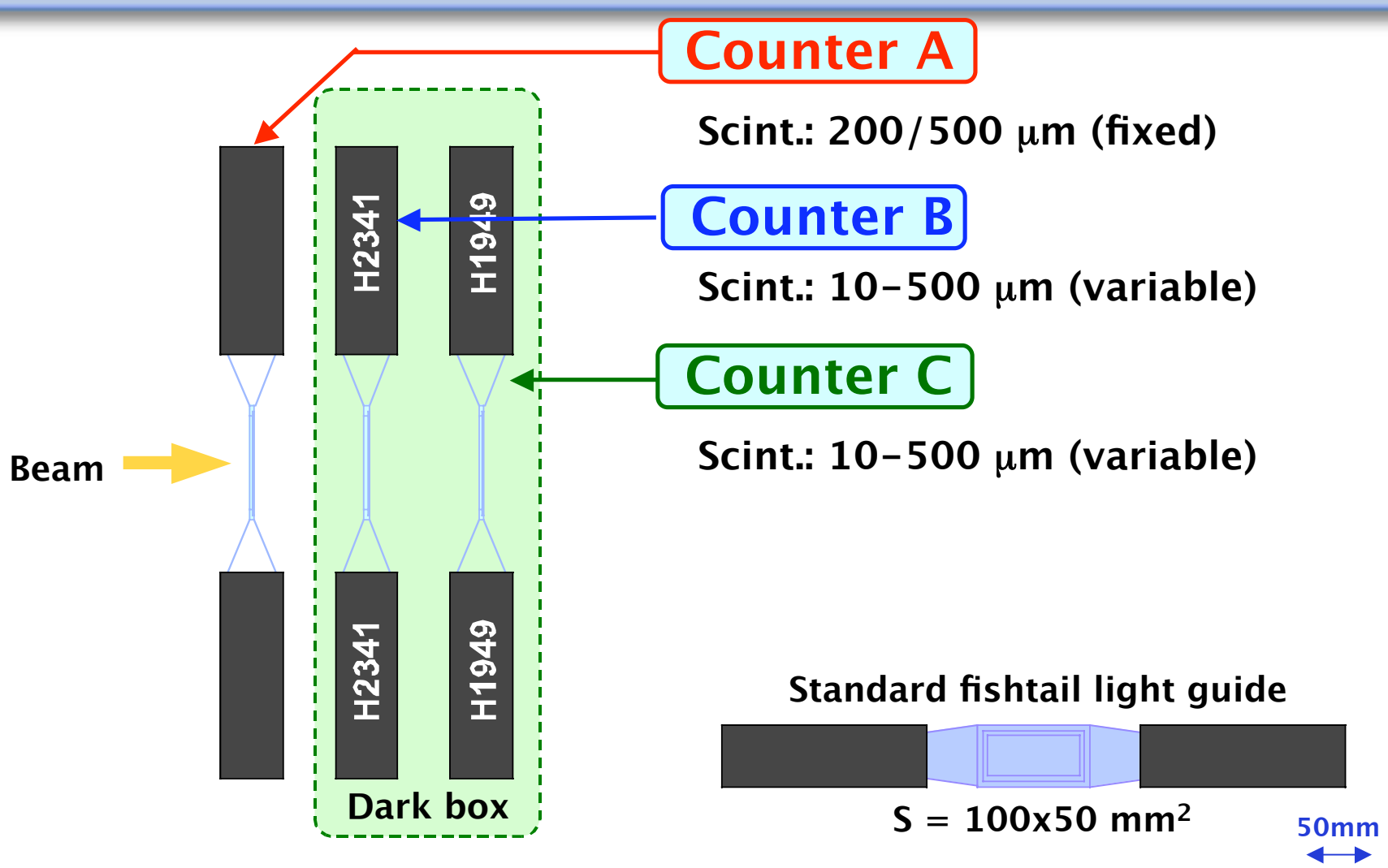
Secondary beam line (SB2)





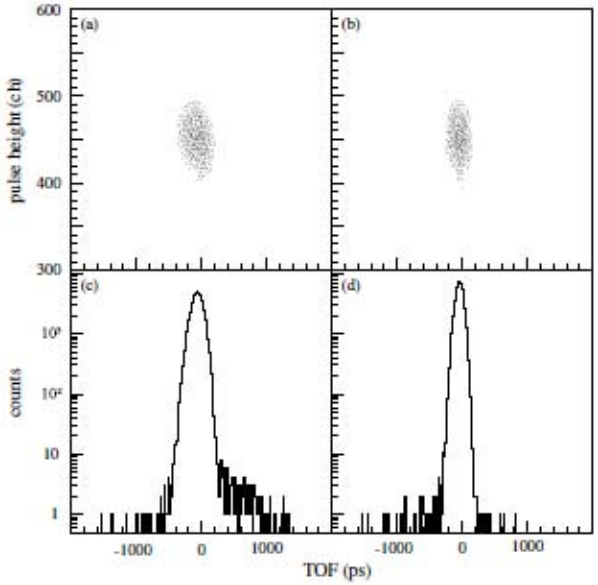
http://www.nirs.go.jp/research/division/charged_particle/himac/himac_01.shtml

Detector arrangement

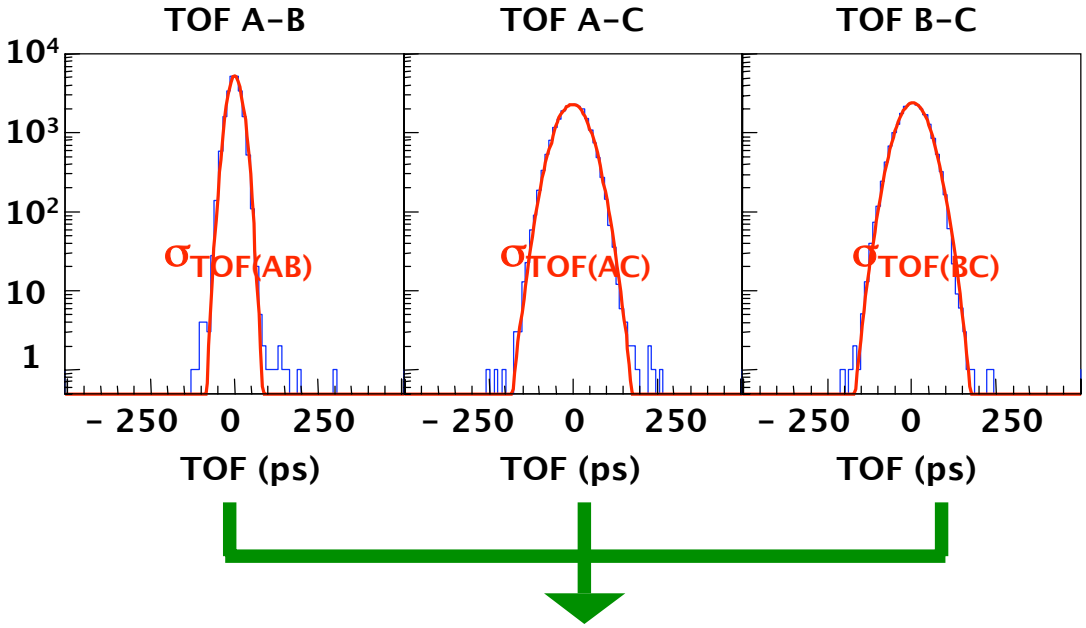


Data analysis

walk effect correction



$$T = T_{\mathrm{raw}} - \frac{\mathrm{Coeff}}{\sqrt{\mathrm{pulse\,height}}}$$



$$\sigma^2_{\mathrm{TOF_{AB}}} = \sigma^2_{\mathrm{T_A}} + \sigma^2_{\mathrm{T_B}}$$
$$\sigma^2_{\mathrm{TOF_{AC}}} = \sigma^2_{\mathrm{T_A}} + \sigma^2_{\mathrm{T_C}}$$
$$\sigma^2_{\mathrm{TOF_{BC}}} = \sigma^2_{\mathrm{T_B}} + \sigma^2_{\mathrm{T_C}}$$

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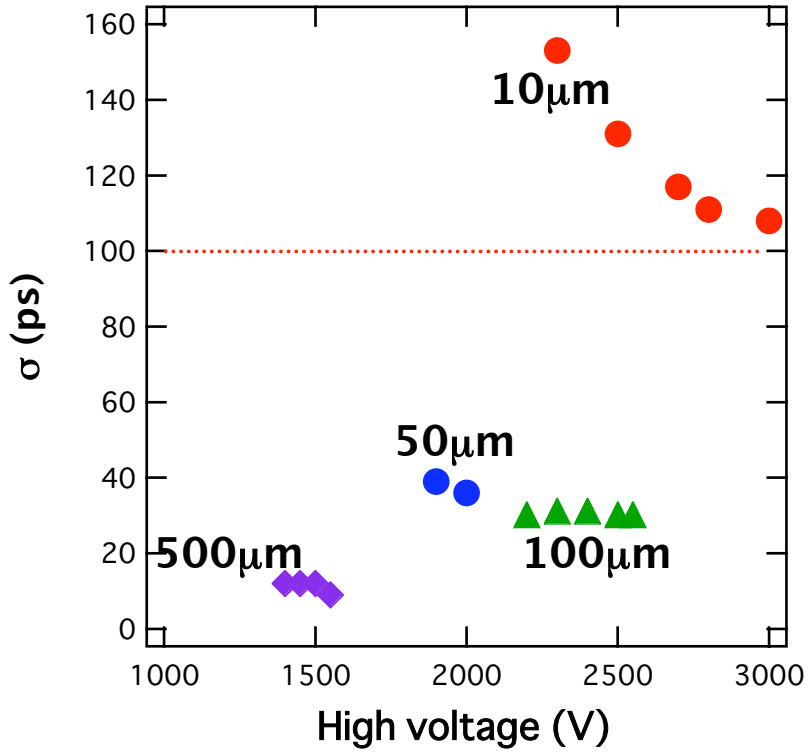
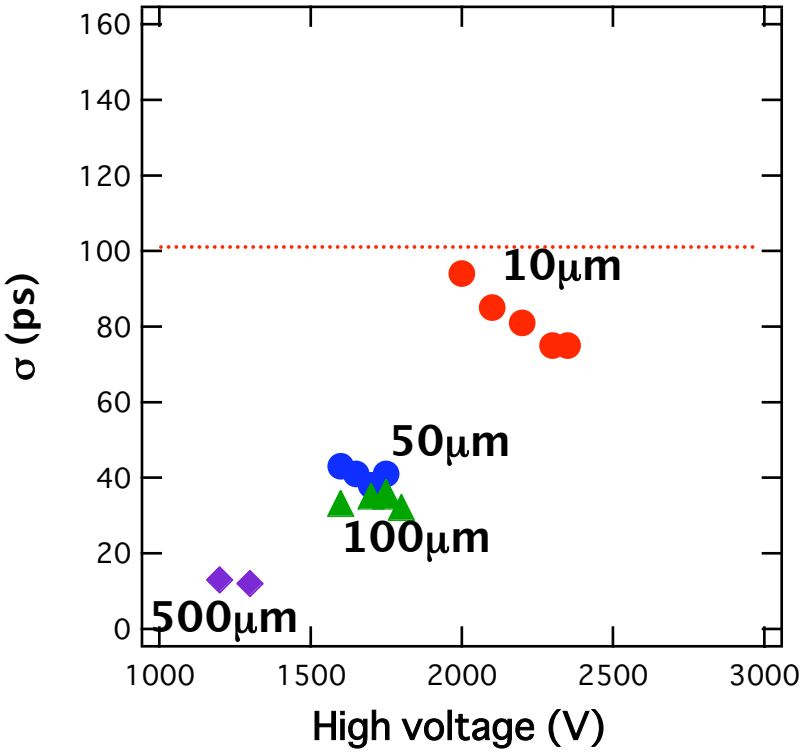
PMT dependence

~ Kr beam ~

H2431



H1949



H1949 is better for thin plastics.

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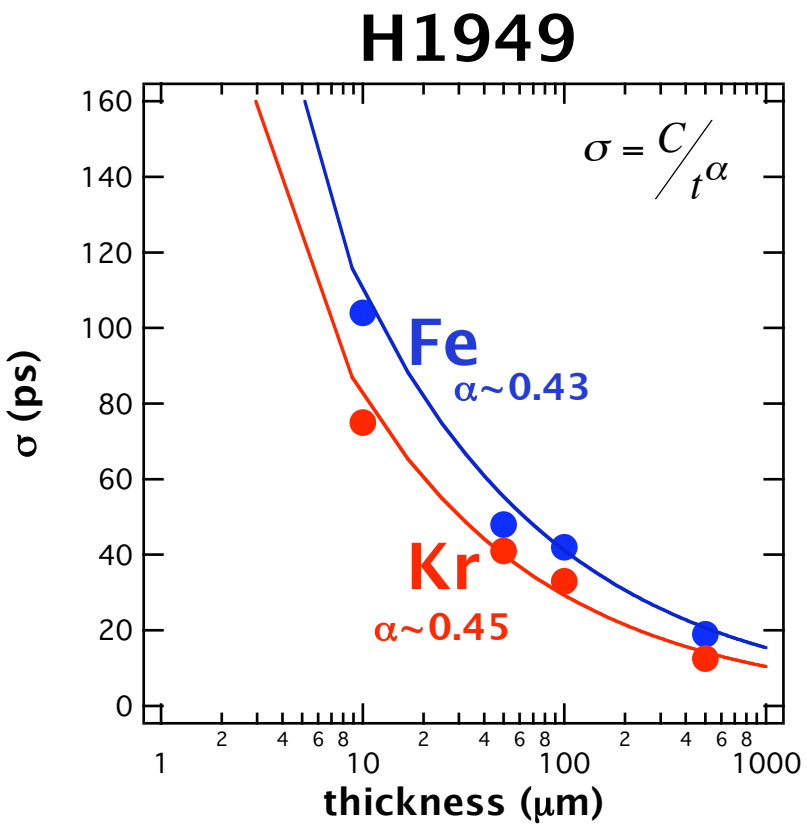
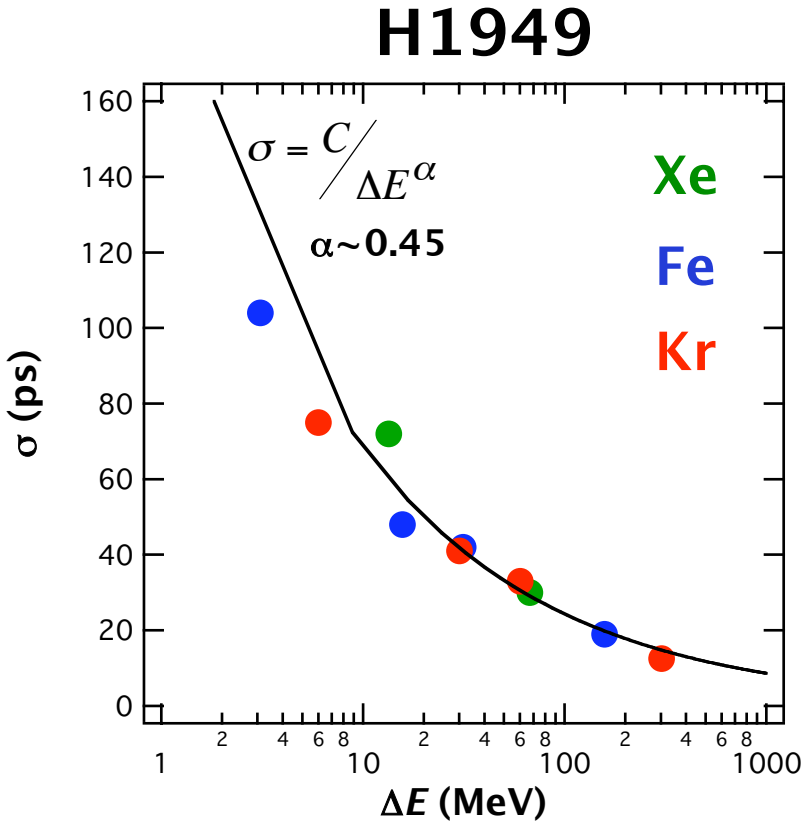
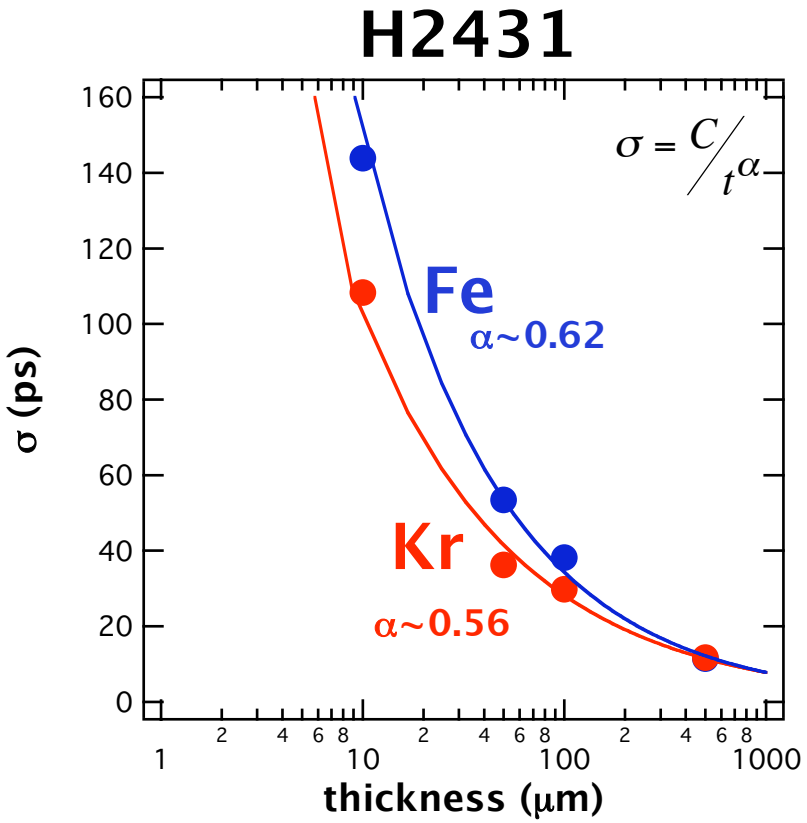
Thickness and energy-deposit dependence for H1949

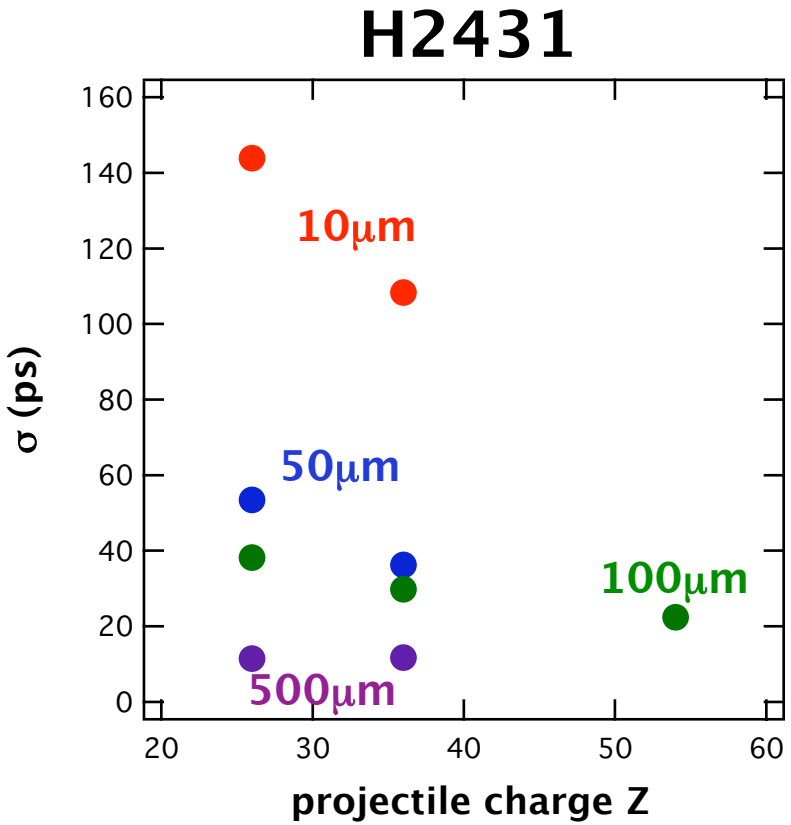




Kuboki

Thickness and Z dependence for H2431





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Kr beam at FRS

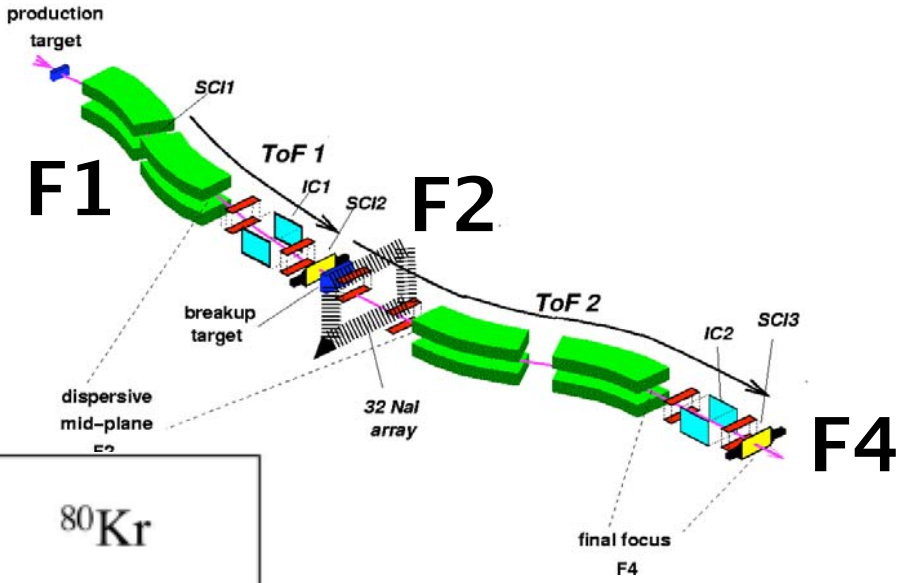
~ an application ~

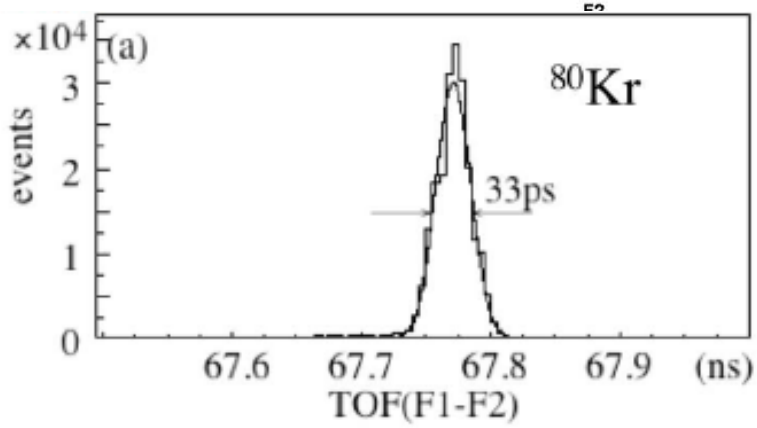
^{80}Kr 1.05GeV/u

size: σ~1mm

ΔE=800~900MeV

FWHM (TOF12)=33ps





T. Yamaguchi et al. Phys. Rev. C74 (2006) 044608.

World Record of Plastic

- ^{40}Ar (95MeV/u) primary beam, ϕ<10mm
- Scintillators
  - BC422Q(0.5%): short attenuation length
  - 50×40 × 0.5mm^3: relatively small
  - ΔE~120MeV
- Light guide:
  - No (direct coupling to PMT)
- PMT:
  - R4998
- Time resolution: **RMS = 6.8ps**
  - **The number of photoelectrons is important.**

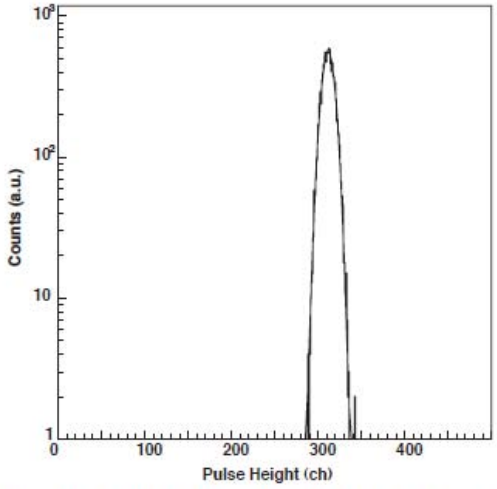


Fig. 2. Pulse height spectrum of the T0. Solid line shows the fitting result assuming Gaussian distribution. The variation of pulse height is evaluated to be about 2.2% in sigma.

Nishimura et al., NIM A510 (2003) 377.

Summary

- **Thin plastic scintillation detectors were tested using 200-MeV/u Fe, Kr and Xe beams.**
- **Systematic data for designing the “Rare RI Ring” detectors and also for the general use in the heavy-ion beam experiments are obtained.**