Development of gaseous Xe scintillator for particle identification of high-intensity and heavy-ion beams

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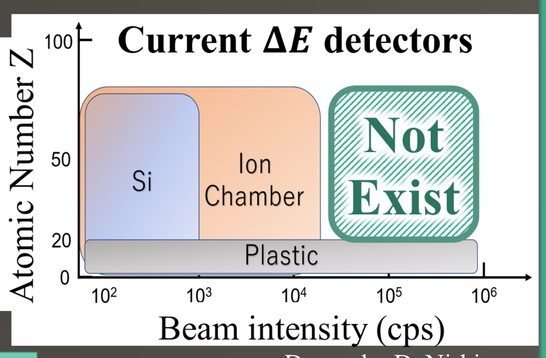
1. Purpose

- Production of high-intensity RI beams
  thanks to development of accelerators @RIBF, RIKEN.
- But, can't use maximum-intensity beam
  due to beam-PID (Particle Identification) detectors, especially ΔE detector.
- Requests under high-intensity beam : Good radiation hardness & Fast response

Current ΔE detector	Problem
Ion Chamber (Standard @RIBF)	Slow response
Si detector	Bad radiation hardness
Plastic scintillator	Insufficient energy resolution for large Z beams.



Drawn by D. Nishimura

Development of new ΔE detector : **gaseous Xe detector**

Characteristics of Xe gas
- Gas state = structureless
  - ➢ Good radiation hardness
- Small decay time constant : ~100 ns (Ion Chamber : μs order)
  - ➢ Fast response
- Need small energy for production of scintillation photon (~20 ev/photon)
  - ➢ Good energy resolution

Previous research

separate $\delta Z \sim 0.2$ (5σ) for $Z \sim 50$ beams with prototype chamber.
(1 mmt Al window + 4 atm. Xe gas = 800 mg/cm^2 : too thick!)

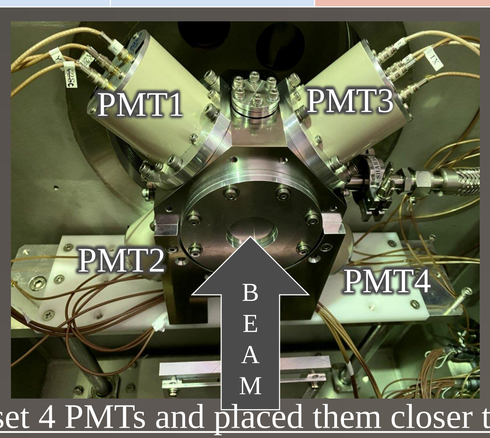
Requested performance
- Thickness : ~130 mg/cm2 (comparable to Ion Chamber)
- Energy resolution : separate Z from Z+1 with (at least) 3σ.

2. Design of New Detector

Configuration of Detectors.

	Ion Chamber	Prototype	New
Gas, pressure [atm.]	P10 1	Xe **4**	Xe **2**
Total thickness [mg/cm^2]	130	800	134
Beam-axial length [cm]	60	12	9

Prototype



In order to capture more light, set 4 PMTs and placed them closer to center.

3. Performance test

@BigRIPS beam line, RIBF

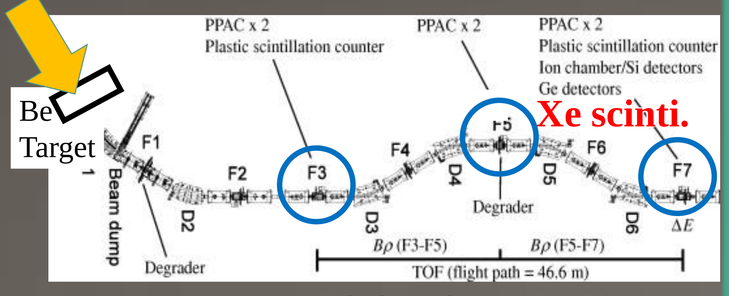
TOF-$B\rho$-ΔE method

$$\mathrm{TOF} = \frac{L}{\beta c}$$
$$\frac{A}{Q} \propto \frac{B\rho}{\beta\gamma}$$
$$\frac{\mathrm{d}E}{\mathrm{d}x} \propto \frac{Z^2}{\beta^2}$$

TOF & position $\Rightarrow A/Q, \beta$

$\Delta E + \beta \Rightarrow Z$

^{238}U beam @345 MeV/u



N. Fukuda, et al., NIM B 317 (2013) 323.

Since β resolution is much better than that of ΔE, we estimate ΔE resolution of the Xe scintillator by using Z resolution.

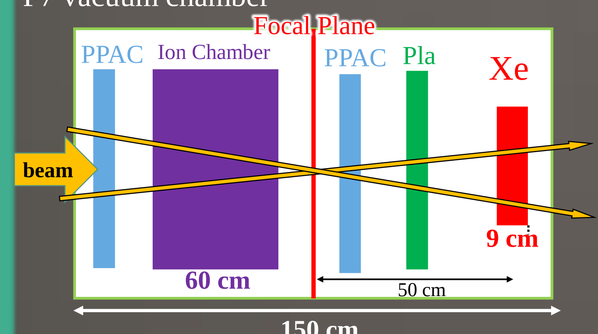
4. Result

Beam Information

Atomic Number	$Z \sim 35, 55$(secondary beams) $Z = 92$ (primary beams)
Intensity [kcps]	$\leqq 1$

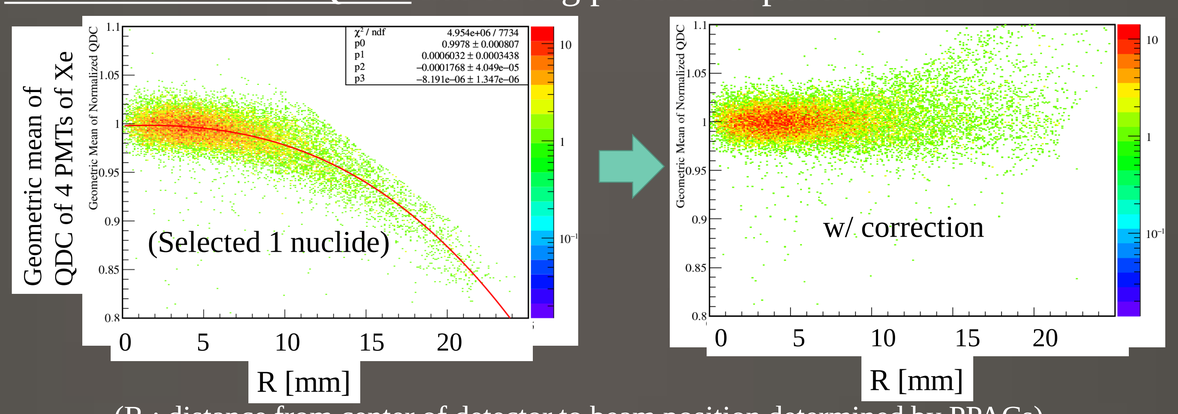
(Analysis for high-intensity beam is future work.)

F7 vacuum chamber



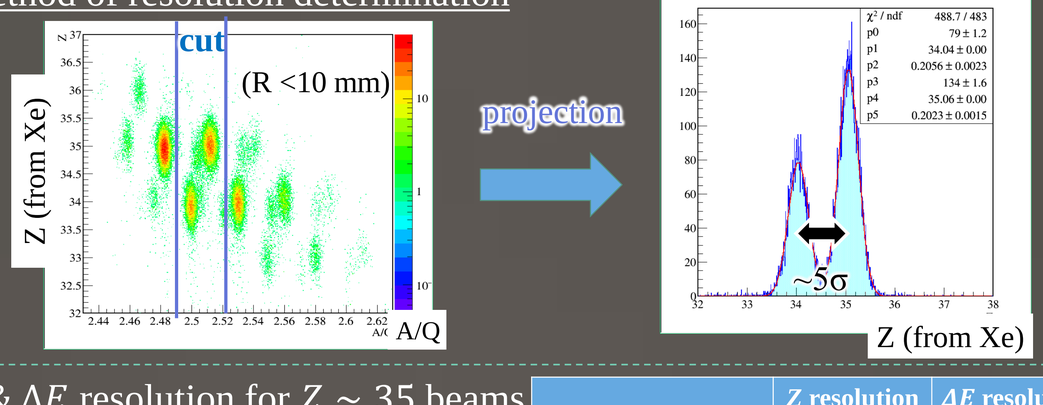
PPAC	Beam position on Xe.
Ion Chamber	ΔE (Reference of Xe evaluation.)
Plastic scintillator	Timing.
Xe gas scintillator	ΔE (Development in this work.)

Geometric mean of QDCs has strong position dependence



(R : distance from center of detector to beam position determined by PPACs)

Method of resolution determination



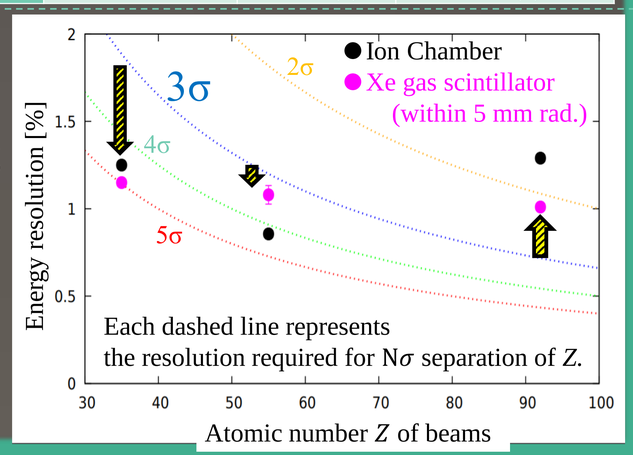
Z & ΔE resolution for $Z \sim 35$ beams

- Overall, the resolution of the Xe scintillator is close to that of IC.
- The resolution near the center is better than Ion Chamber

		Z resolution	ΔE resolution [%]
IC		0.218(1)	1.27(1)
Xe	Within 5 mm rad.	0.194(3)	1.13(2)
	Within 10 mm rad.	0.204(2)	1.18(1)
	Within 15 mm rad.	0.231(2)	1.34(1)
	All	0.255(2)	1.48(1)

Summary of the ΔE resolution

- In $Z < \sim 60$, achieve 3σ separation.
- The reason for the resolution plateauing at ~1% is under investigation.



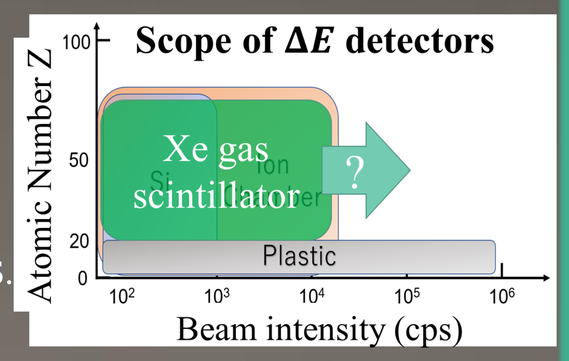
5. Extra Performance

- Timing resolution : 74 ps (σ) for 238U
- Position resolution : 0.39 mm (σ) for 238U

(Both are preliminary result and expected to improve with further analysis)

4. Summary

- We are developing **Xe gas scintillator** as a new detector which can work under high-intensity & heavy RI beams.
- We developed a new chamber with small material thickness to introduce it in BigRIPS.
- Achieved good resolution close to that of Ion Chamber in the $Z < \sim 60$.



Collaborators

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