Nikokukan 2017/6/28 11:40-

Development of time-of-flight detector for mass measurements with R3

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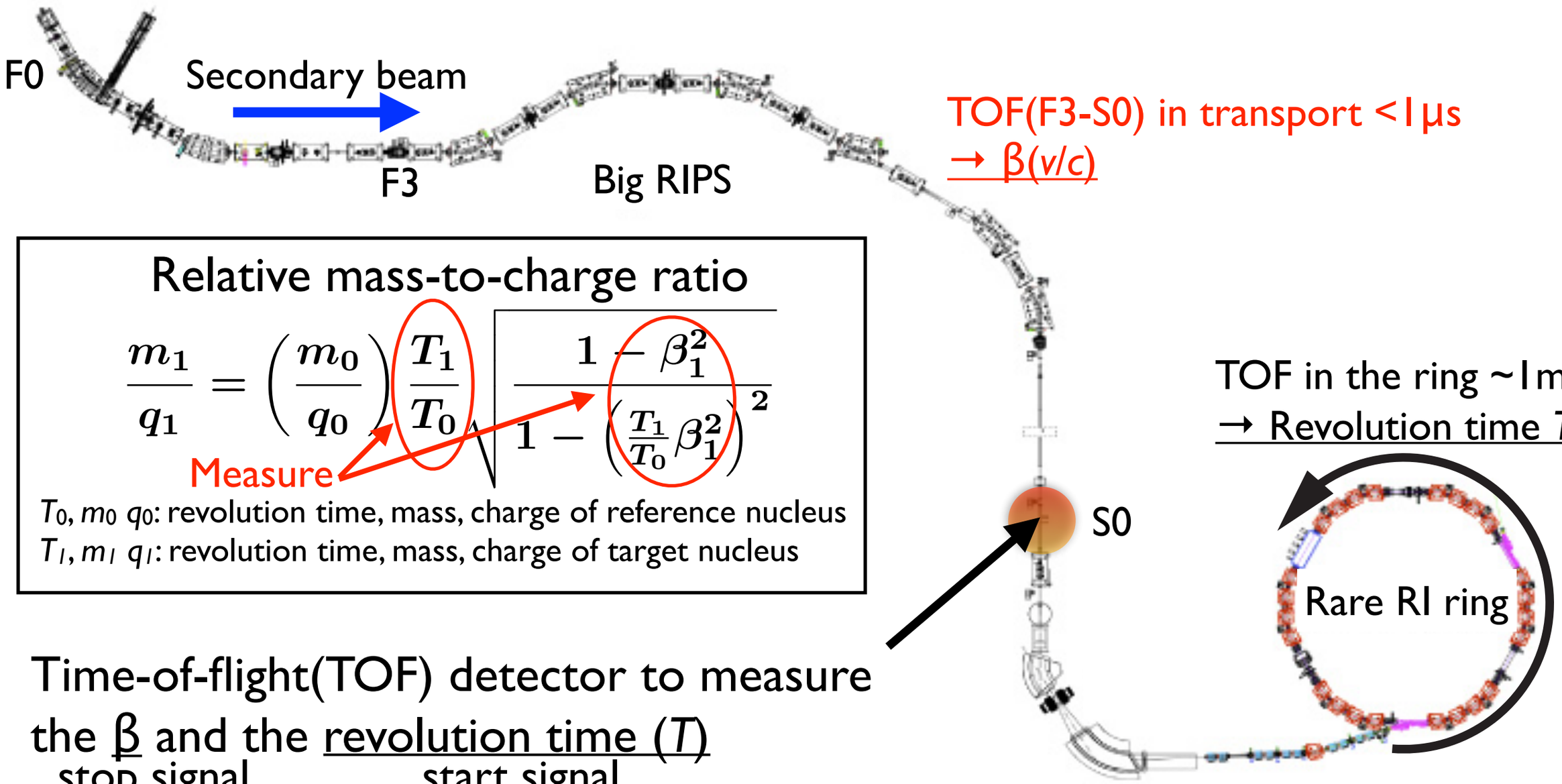
Contents

- Requirements for the time-of-flight detector
- Working principle
- Design of the present detector
- Performance test with the heavy ion beam

Rare-RI Ring (R3)

Mass-measurement tool for short-lived nuclei (half life < 1 ms)



TOF(F3-S0) in transport < 1 μs
→ β(*v*/*c*)

TOF in the ring ~1 ms
→ Revolution time *T*

Relative mass-to-charge ratio

$$\frac{m_1}{q_1} = \left(\frac{m_0}{q_0}\right)\frac{T_1}{T_0}\sqrt{\frac{1-\beta_1^2}{1-\left(\frac{T_1}{T_0}\beta_1^2\right)^2}}$$

Measure

T_0, m_0 q_0: revolution time, mass, charge of reference nucleus
T_1, m_1 q_1: revolution time, mass, charge of target nucleus

Time-of-flight(TOF) detector to measure the β and the revolution time (*T*)
stop signal start signal

Requirements for TOF detector

1. Time resolution σ < 100 ps for $\Delta(m/q)/(m/q) \sim 1\times10^{-6}$

   TOF for injection line <1 μs → $\Delta\beta/\beta \sim 1\times10^{-4}$

2. Detection efficiency should be 100%

3. Detector should be as thin as possible

   Minimize change of velocity by energy loss

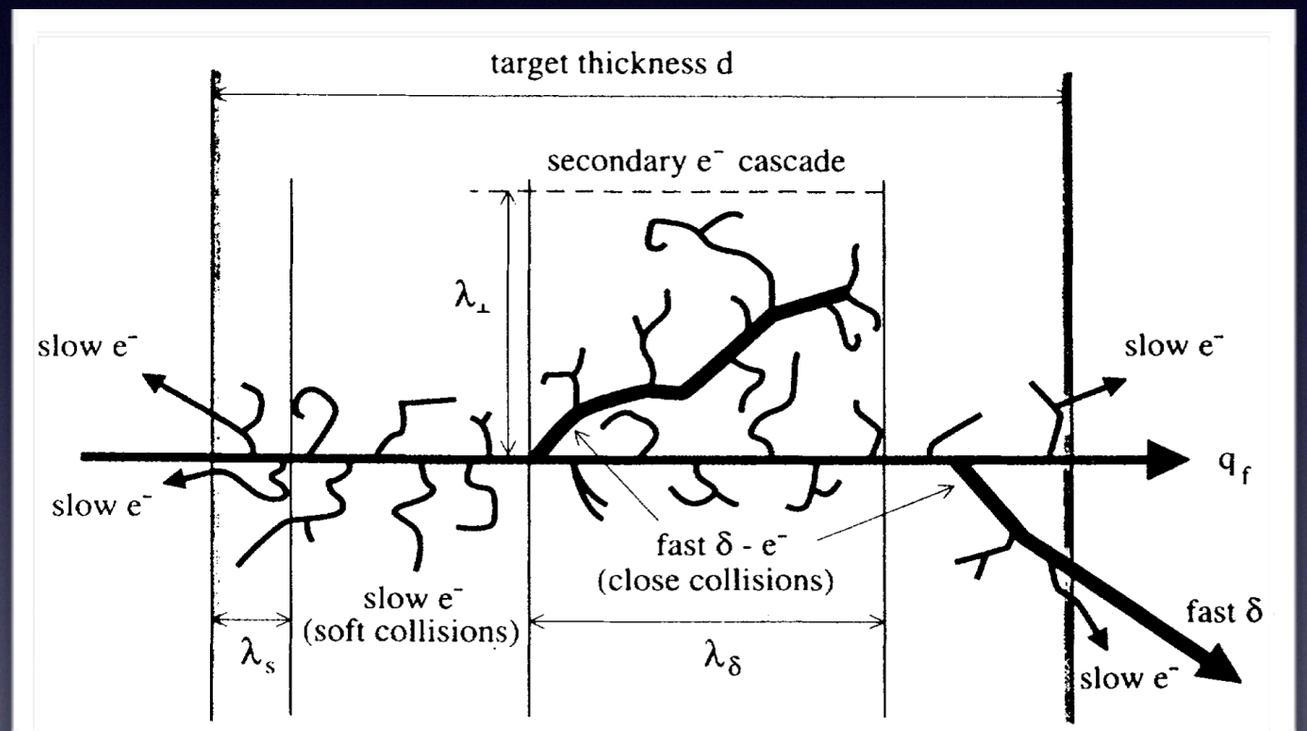
4. Large acceptance

   Expected beam size at focal plane is <Φ30mm

We are developing the TOF detector witch uses secondary electrons emitted from thin foil

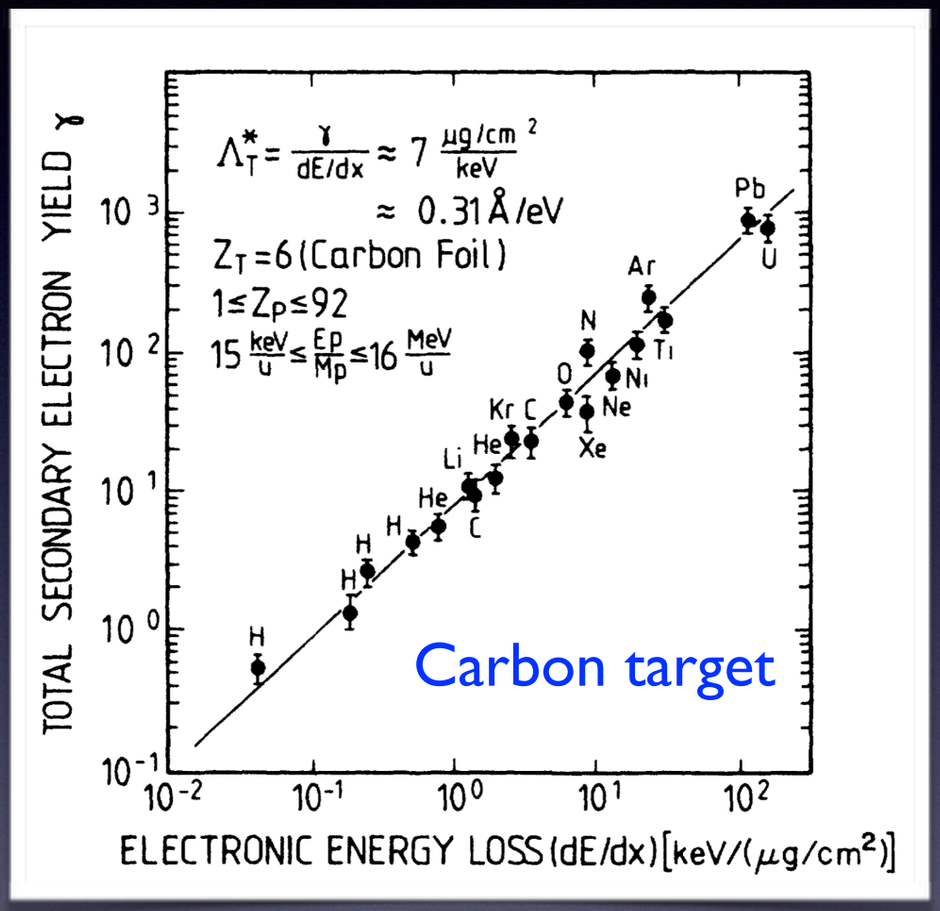
Secondary electron emission

Production mechanism of electrons



Phys. Rev.A 51(1995)3066

dE/dx dependence of SE yield per impinging ion



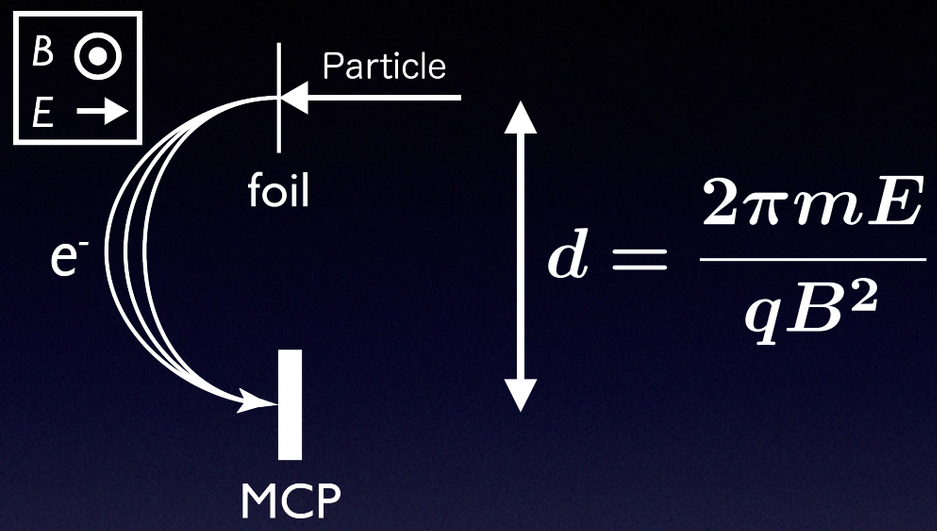
Phys. Rev.A 41(1990)2521

$$N_{\mathrm{SE}} \simeq \Lambda \frac{dE}{dx}$$

dE/dx : stopping power [keV/(μg/cm²)]

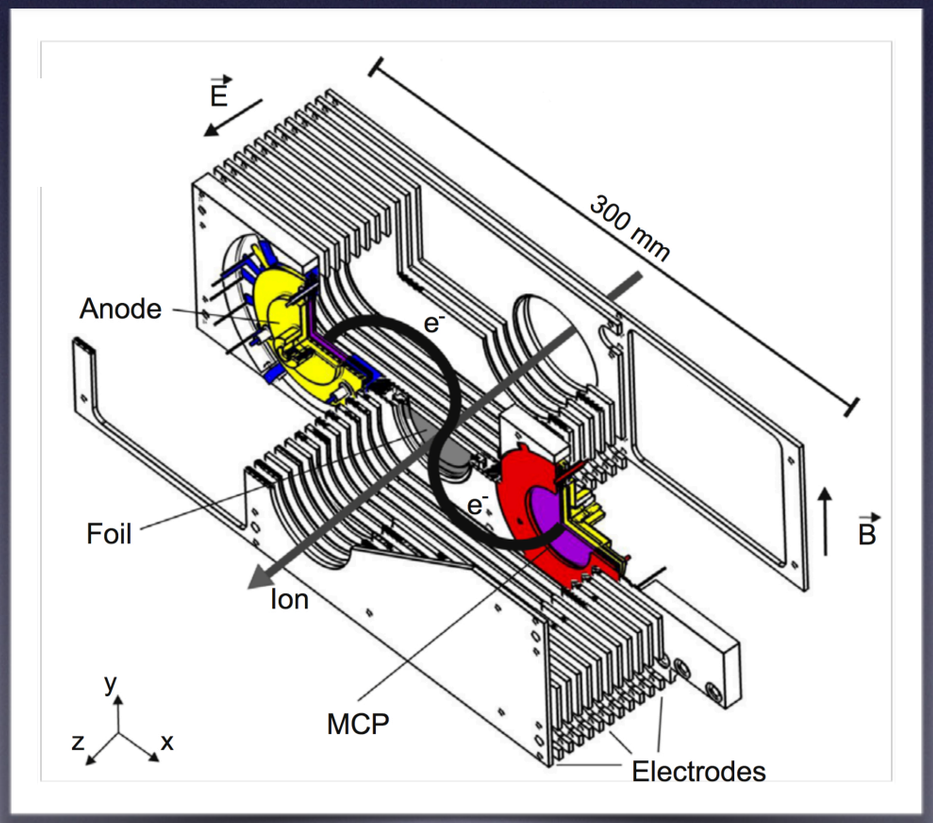
Λ : constant of proportionality [(μg/cm²)/keV]

TOF detector with secondary electrons



$$d = \frac{2\pi m E}{qB^2}$$

Nucl. Inst. Meth. 148 (1978) 503



Nucl. Inst. Meth. A 821 160 (2016)

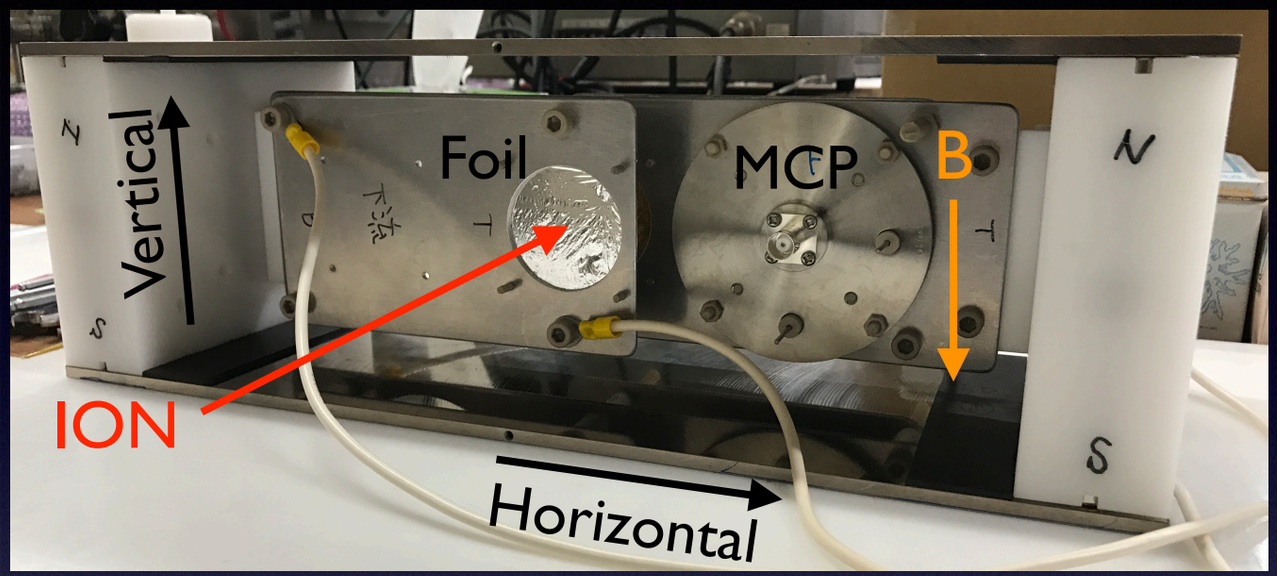
Performance of the former detector

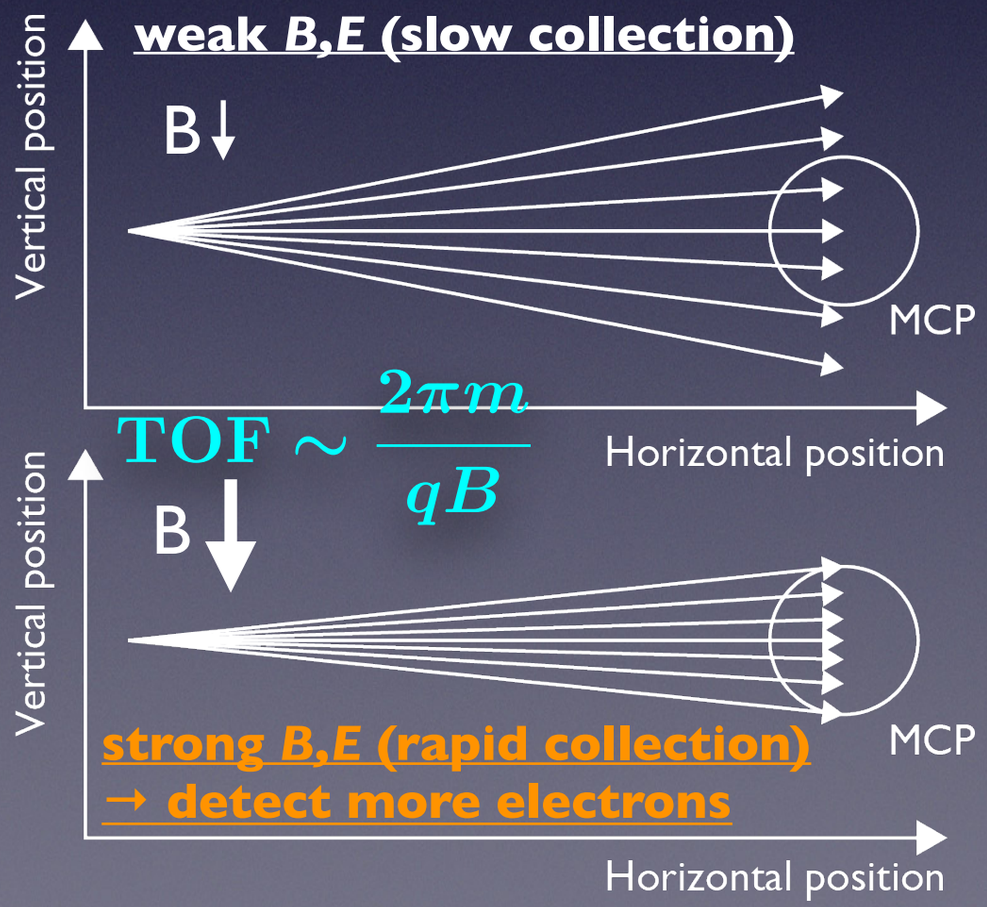
	ESR / CSRe
Foil	Carbon (10-19 μg/cm^2)
Magnetic field [Gauss]	~84
Electric field [V/mm]	160 - 180
Time resolution σ [ps]	~30
Detection efficiency [%]	70 - 83

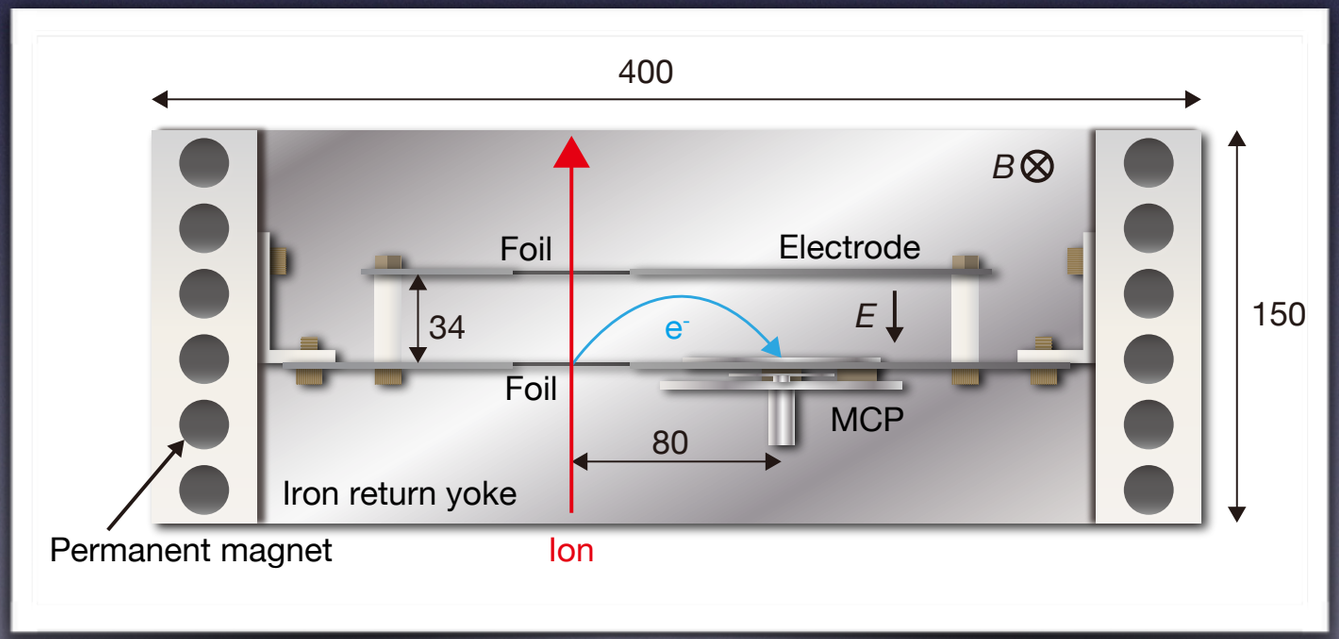
Nucl. Inst. Meth. A 821 160 (2016)
Nucl. Inst. Meth. A 756(2014) 1
Nucl. Inst. Meth. A 624(2010) 109

TOF detector

Magnetic field : ~172 Gauss increase!
Electric field : ~712 V/mm increase!
Foil (1) : Polymer (30 μg/cm^2) coated
on carbon (30 μg/cm^2)
Foil (2) : Aluminum coated (~100 nm)
on 1μm mylar
Effective area of foil and MCP : ~Φ40 mm



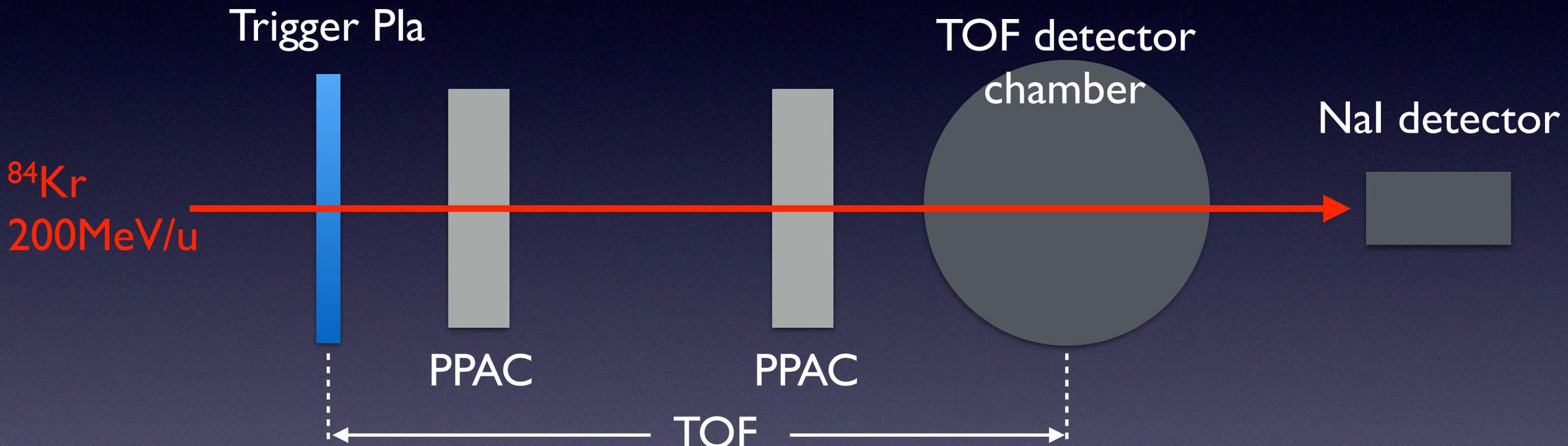


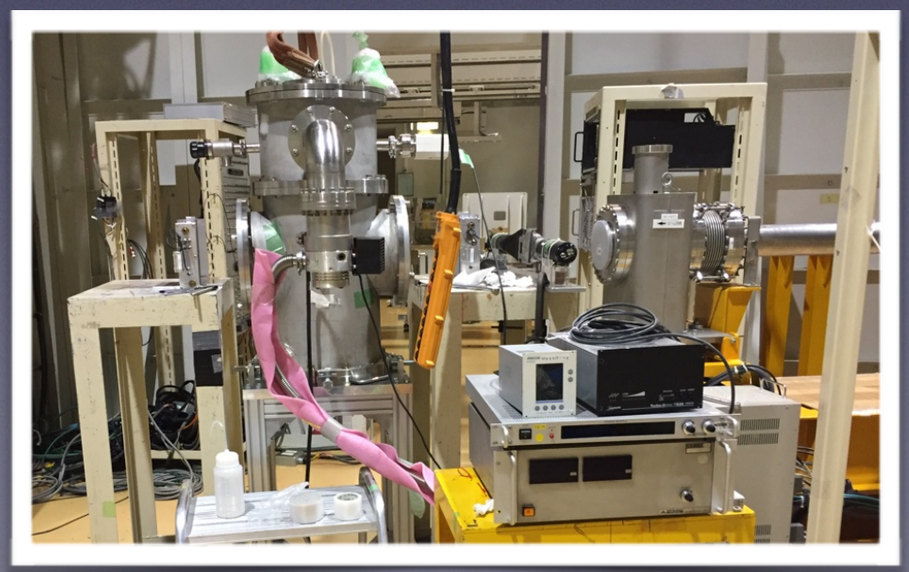


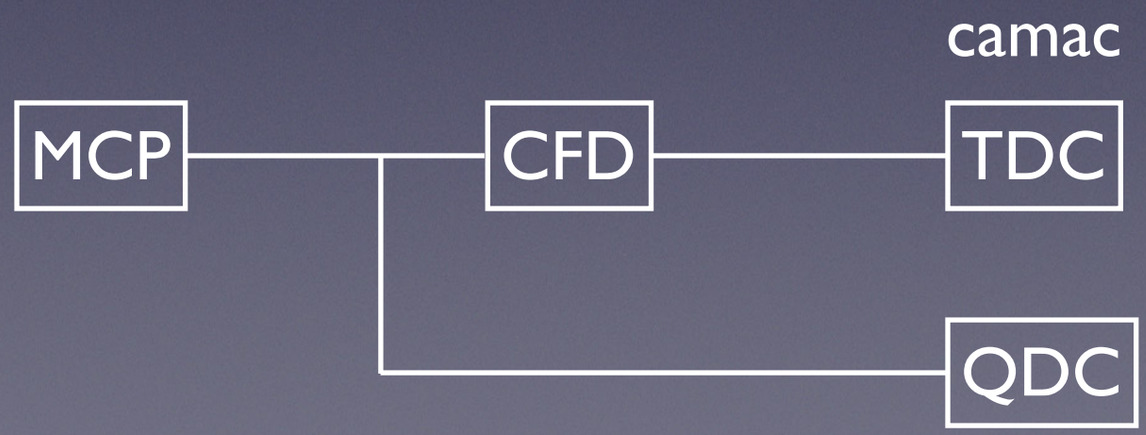
Experimental setup

^{84}Kr(36+) of 200 MeV/nucleon provided by HIMAC (Heavy Ion Medical Accelerator in Chiba) in NIRS

Nse ~ 37 for carbon
Nse ~ 60 for aluminized Mylar

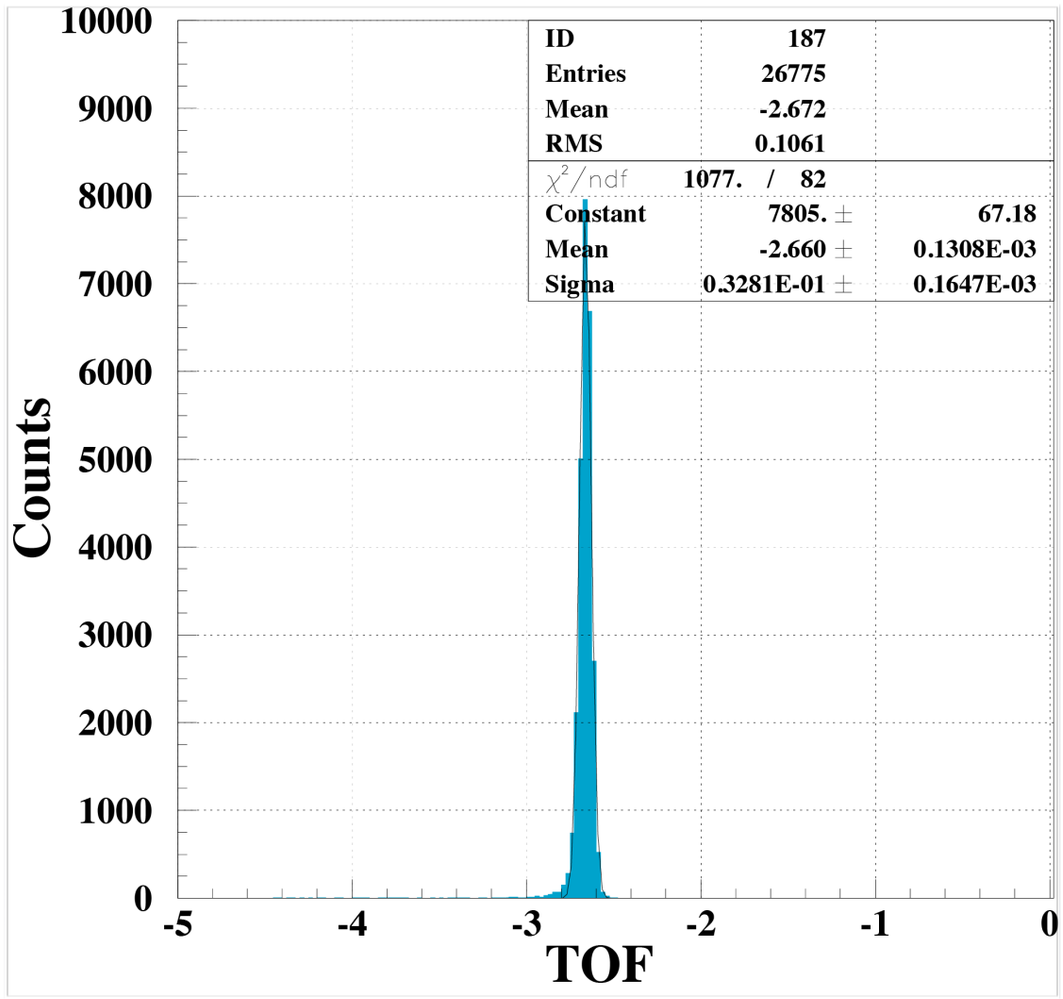






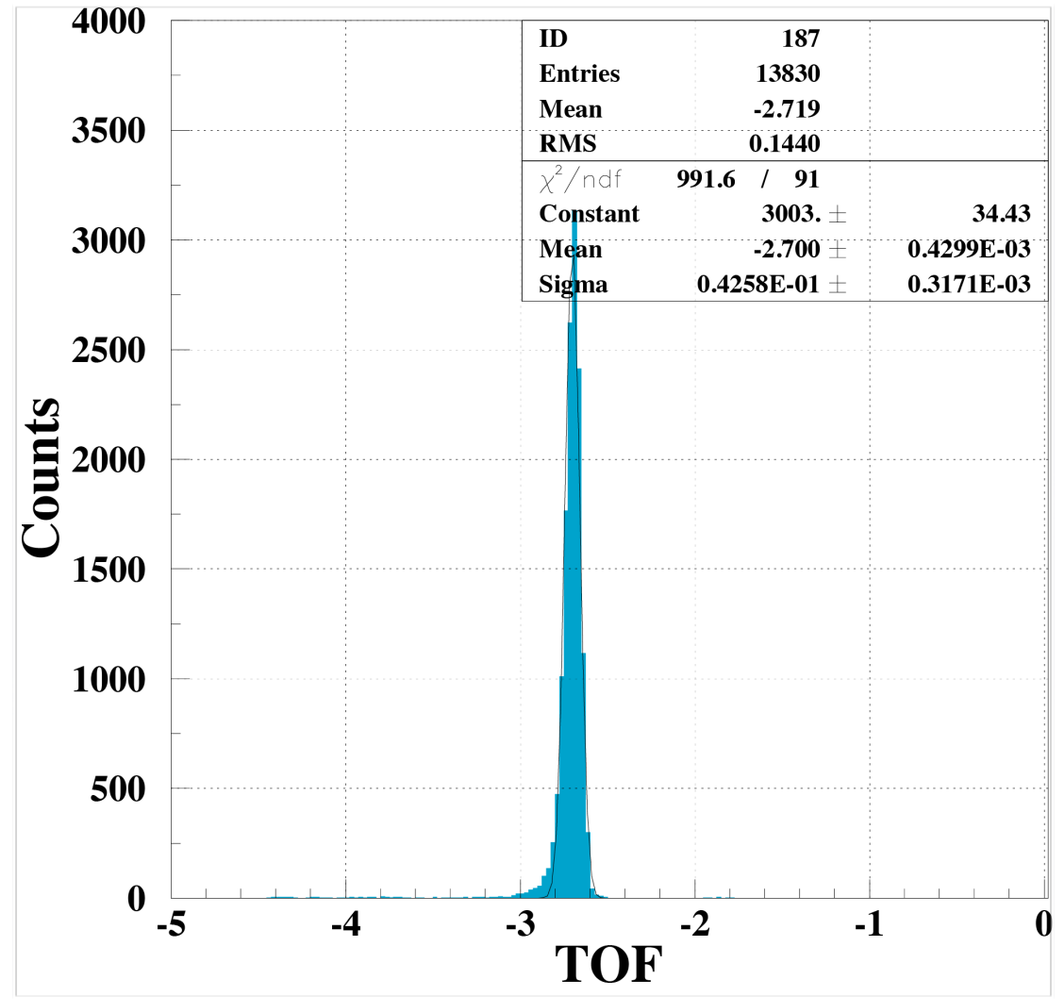
Timing and efficiency performance

Aluminized Mylar



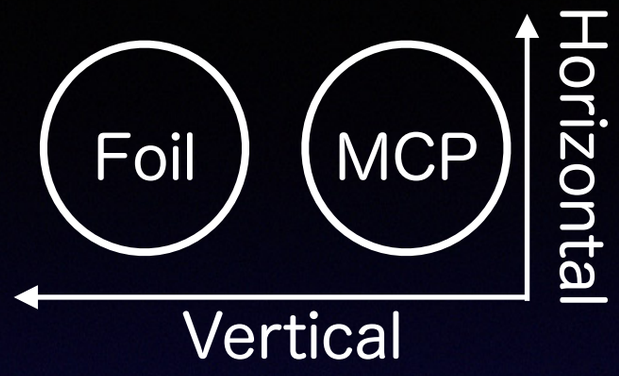
Sigma = 33 ps
Det. Eff. = 100.0(0.8)%

Carbon

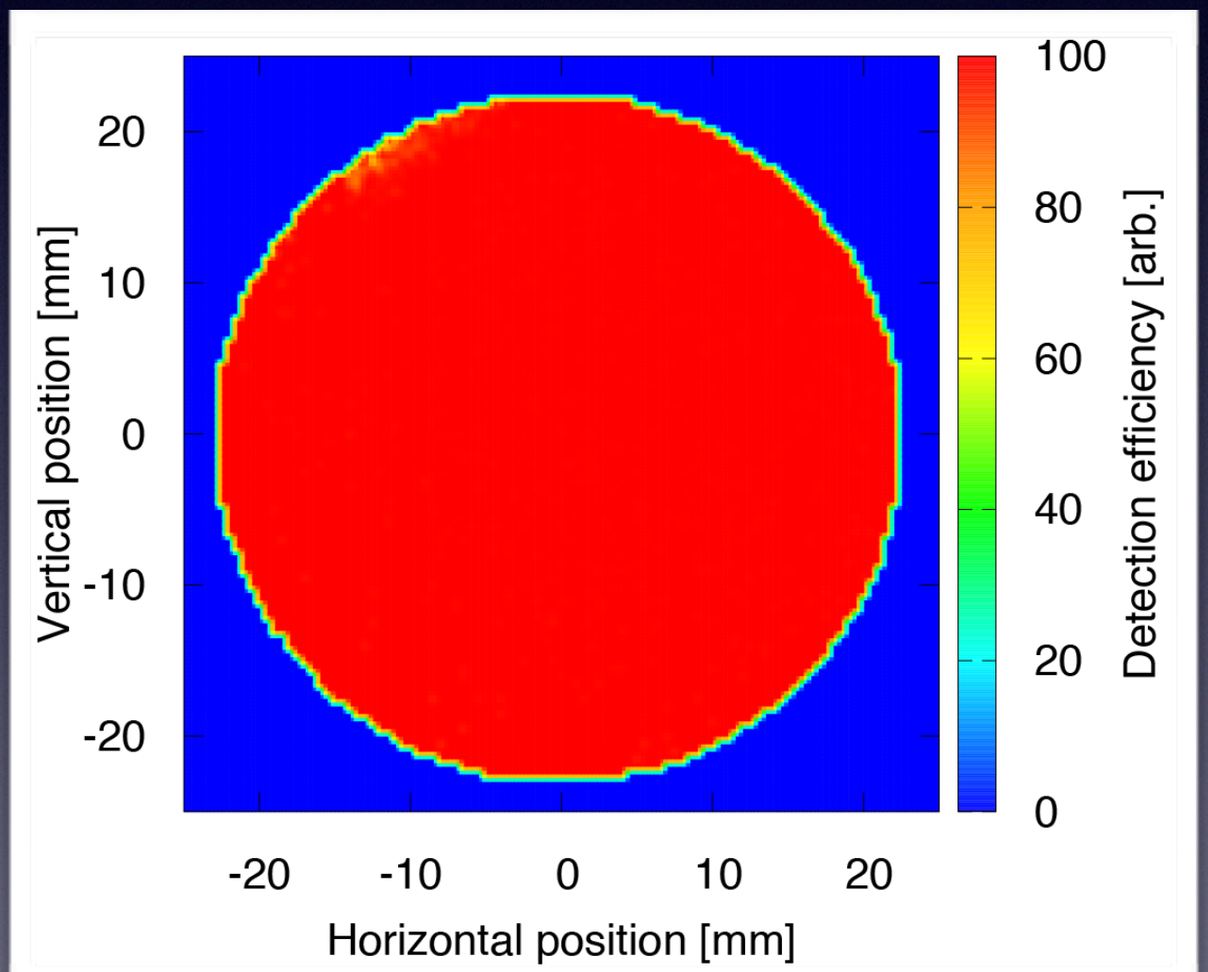


Sigma = 43 ps
Det. Eff. = 99.2(1.2)%

Position dependence of efficiency

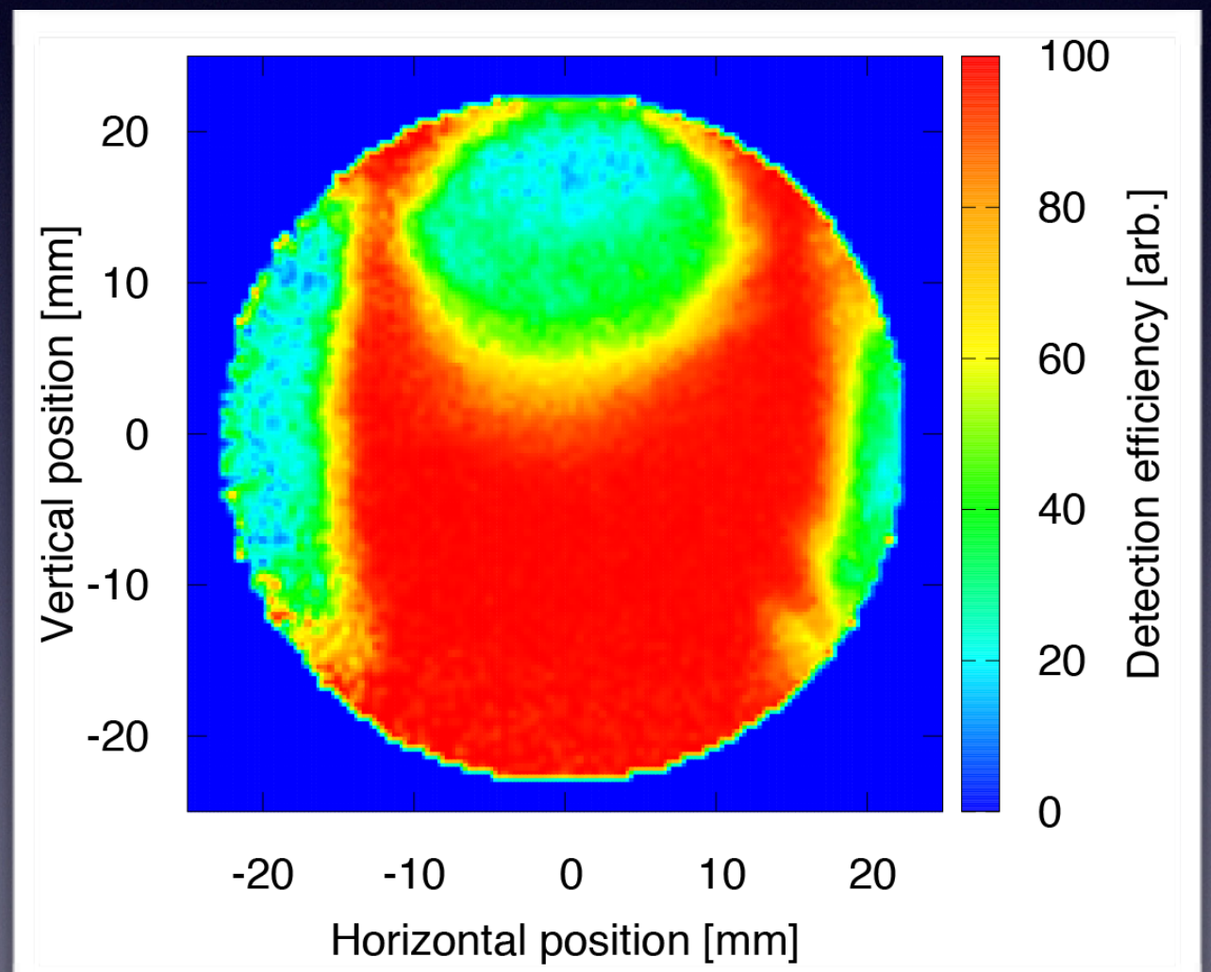


Aluminized Mylar



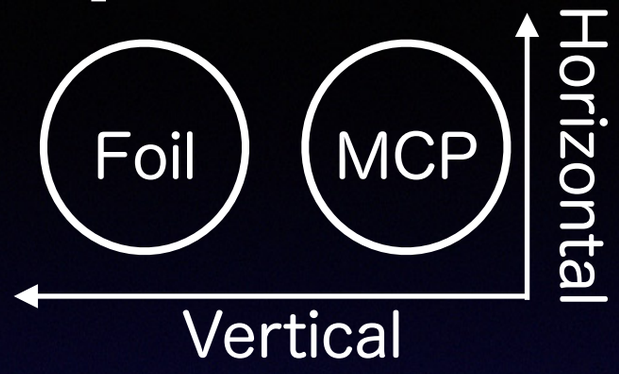
Almost 100% in the whole area

Carbon

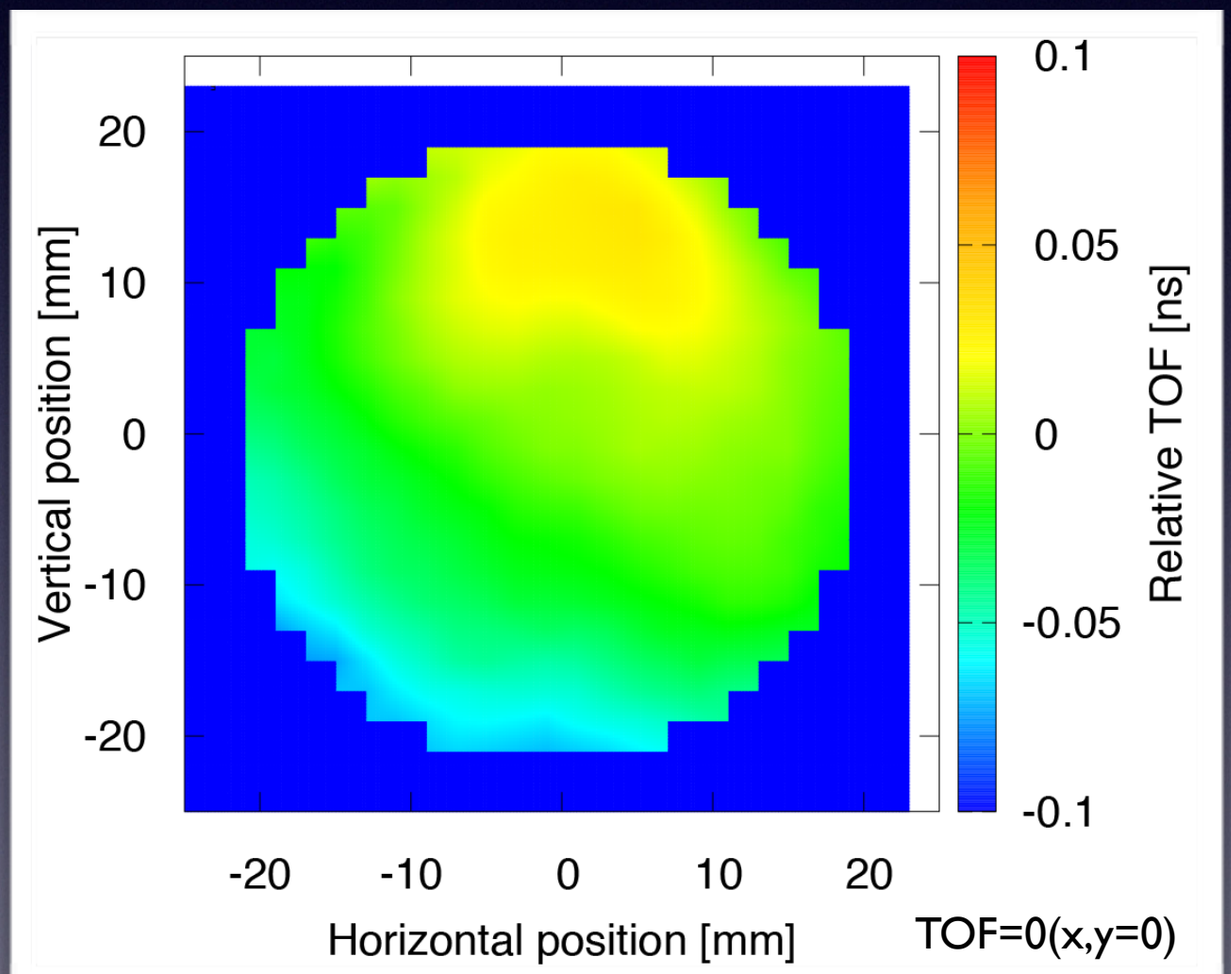


Efficiency at upper area was cheap
→Electric field was not optimum…

Position dependence of TOF

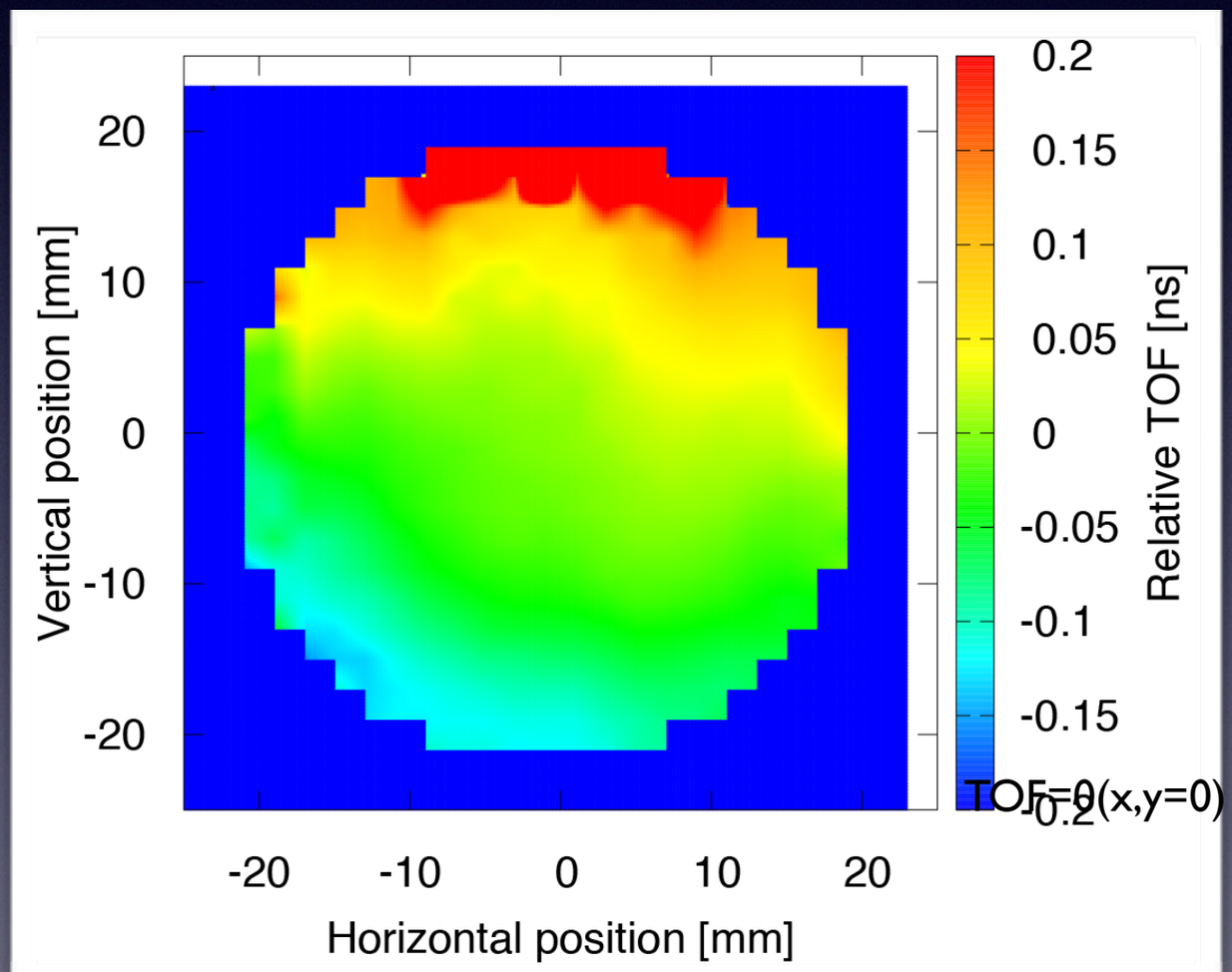


Aluminized Mylar



ΔTOF < 100 ps (-20 < y < 20)

Carbon



ΔTOF ~ 200 ps (-20 < y < 20)

Summary

- We are developing the TOF detector for mass measurement with R3. The TOF detector uses secondary electrons emitted from a thin foil.
- With the strong magnetic field, sufficient detection efficiency (~100%) was obtained by both of aluminized Mylar and carbon.
- Timing resolution was achieved σ <100 ps.
- No serious position dependence of measured TOF.
- We will optimize the electric field in the case of carbon.

Corroborators

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RIKEN Nishina Center

D. Nagae, Y. Abe, S. Naimi

National Institute of Radiological Sciences (NIRS)

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