INPC2016 L3 9/16 11:25-11:40

Development of time-of-flight detector for isochronous mass measurements with the rare-RI ring

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Contents

Rare-RI ring for ion storage

Mass-measurement tool for short-lived nuclei (half life <1ms) with Isochronous Mass Spectrometry (IMS)

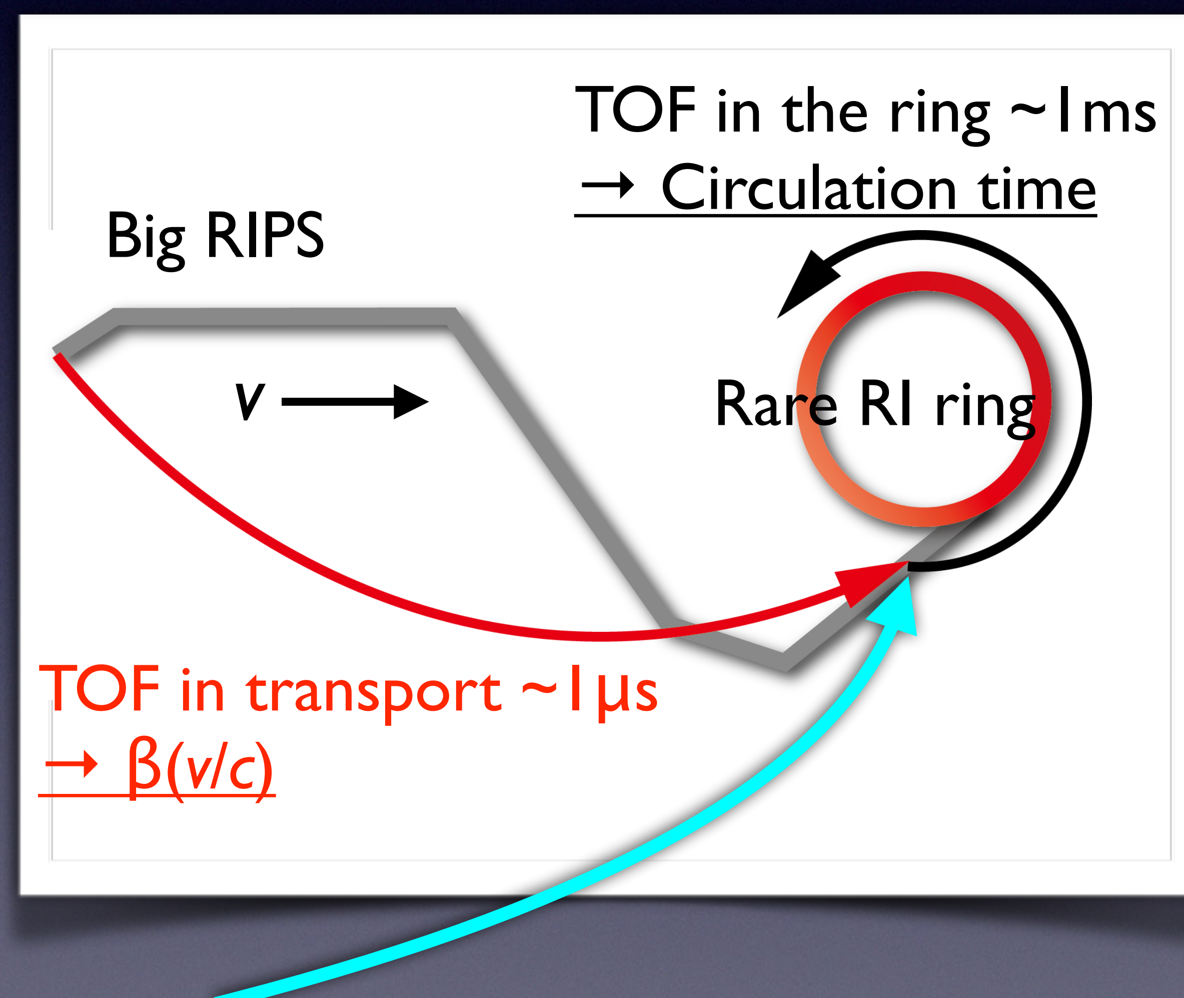
Yoshitaka Yamaguchi presented at Tuesday session

measure relative mass-to-charge ratio by isochronous magnetic field

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

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

Prog. Theor. Exp. Phys., 2012 (2012) 03C009.



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

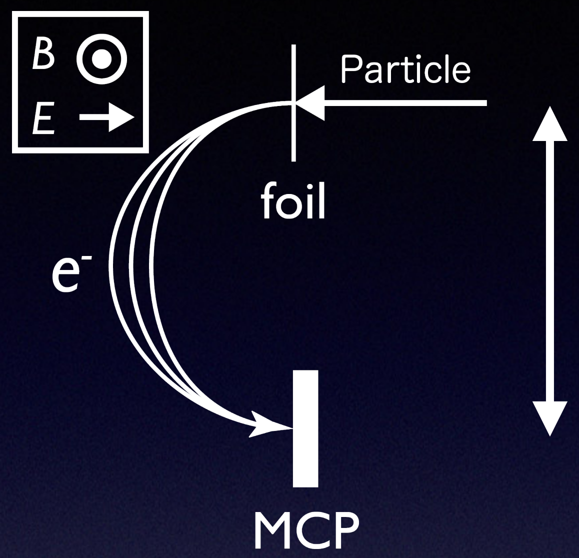
Requirements for TOF detector

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%

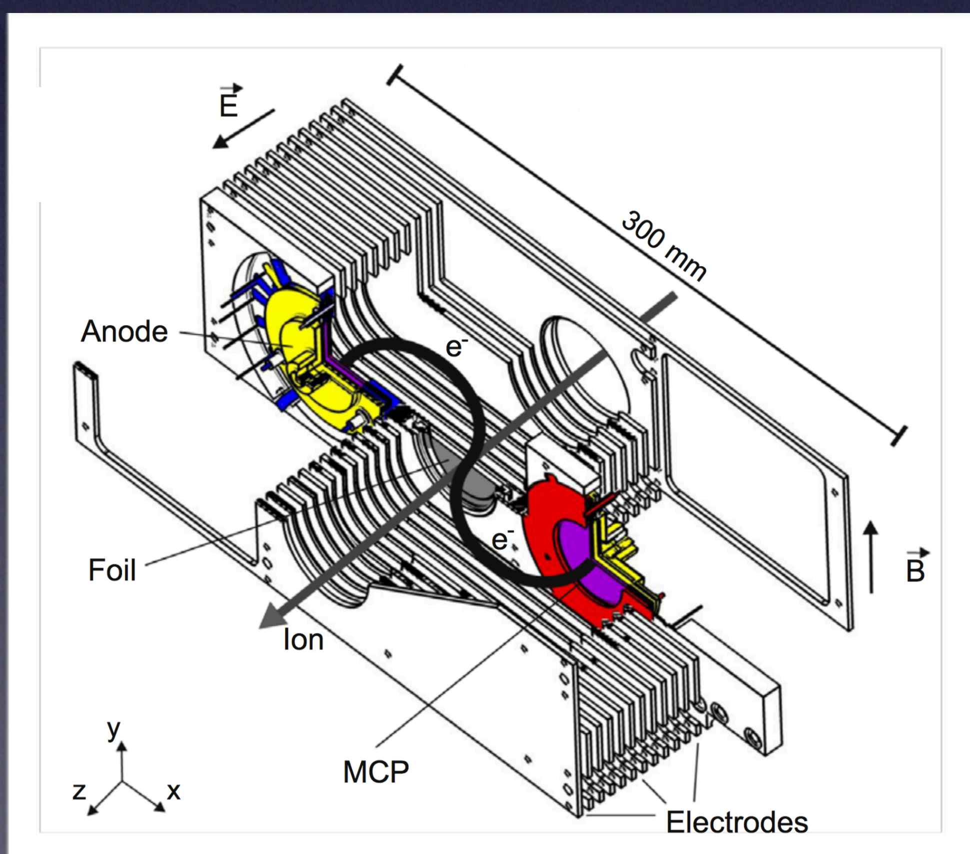
3. Detector should be as thin as possible
   Minimize of change of velocity by energy loss

TOF detector with secondary electrons



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

Nucl. Inst. Meth. 148 (1978) 503



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

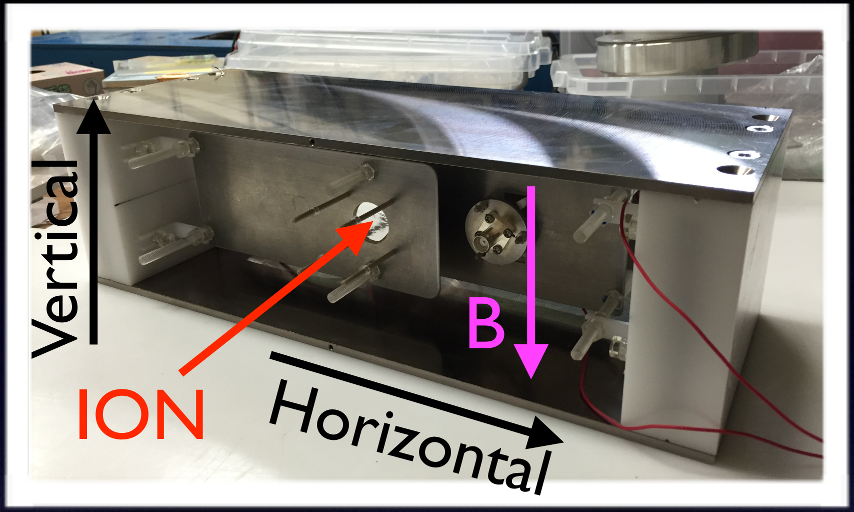
Performance of the previous detector

	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

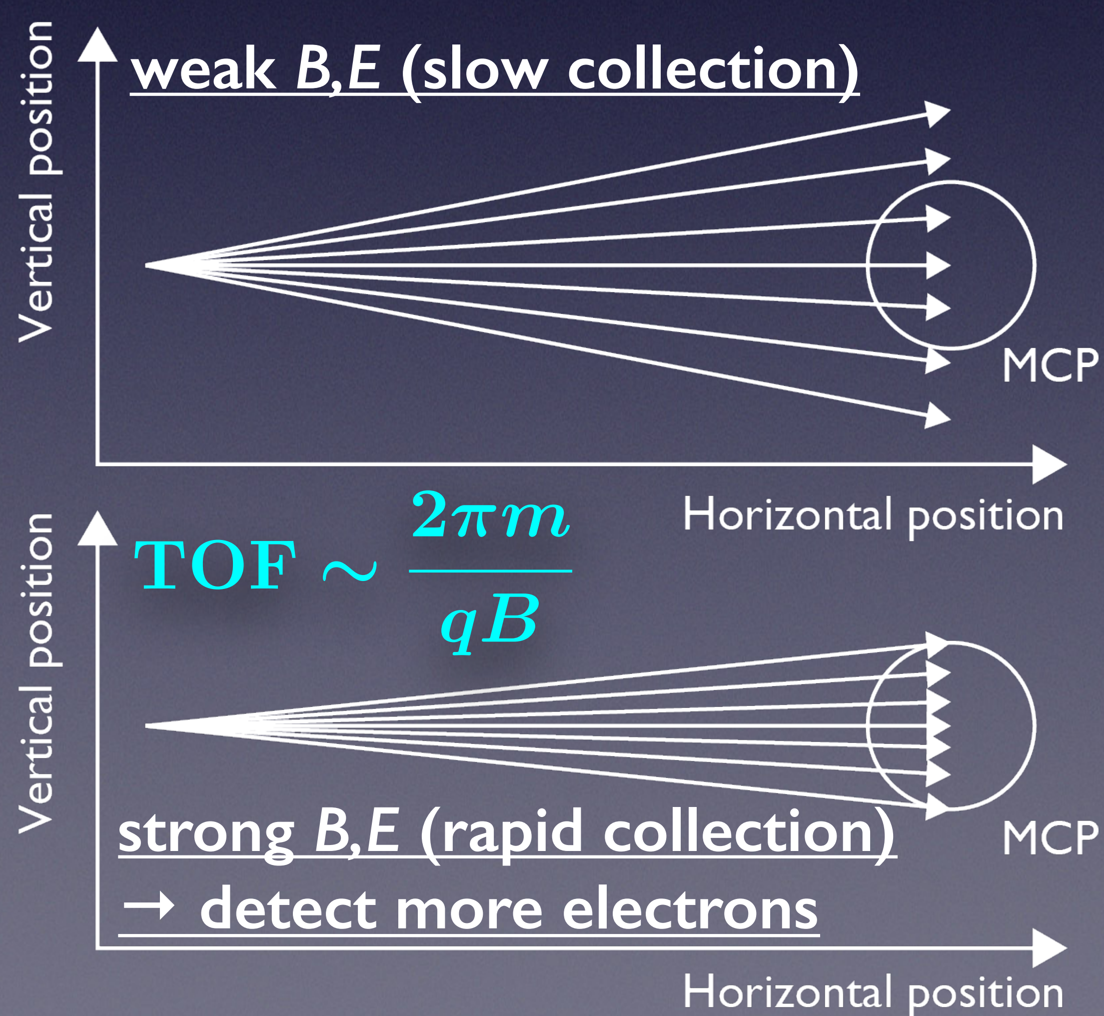
Nucl. Inst. Meth. A 821 160 (2016)
Nucl. Inst. Meth. A 756(2014) 1
Nucl. Inst. Meth. A 624(2010) 109

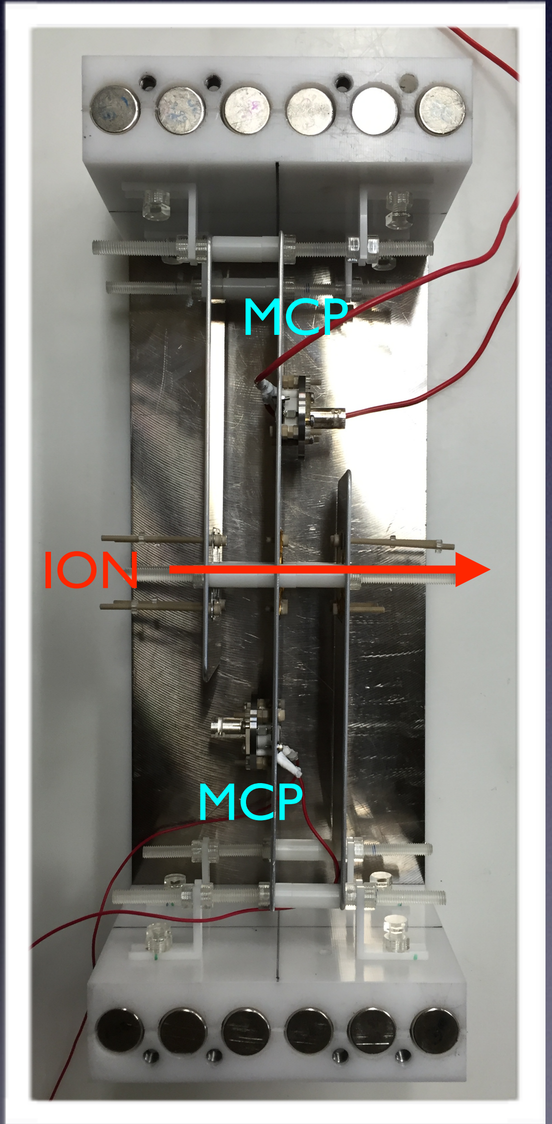
Prototype TOF detector

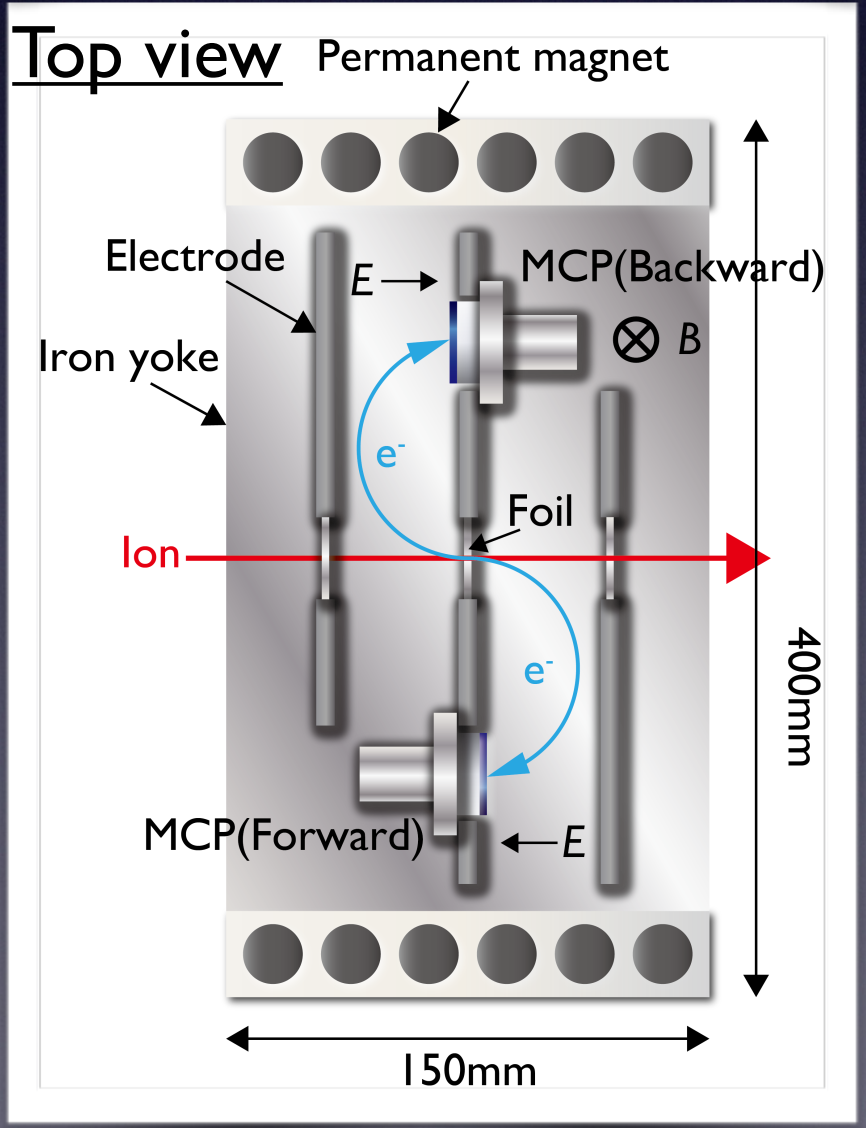
Magnetic field : ~172 Gauss increase!
Electric field : <670 V/mm increase!
Foil (1) : Carbon (50 μg/cm^2)
Foil (2) : Gold coated (168 μg/cm^2) per side on 2μm mylar
Effective area of MCPs : Φ14.5 mm



Motion of SE

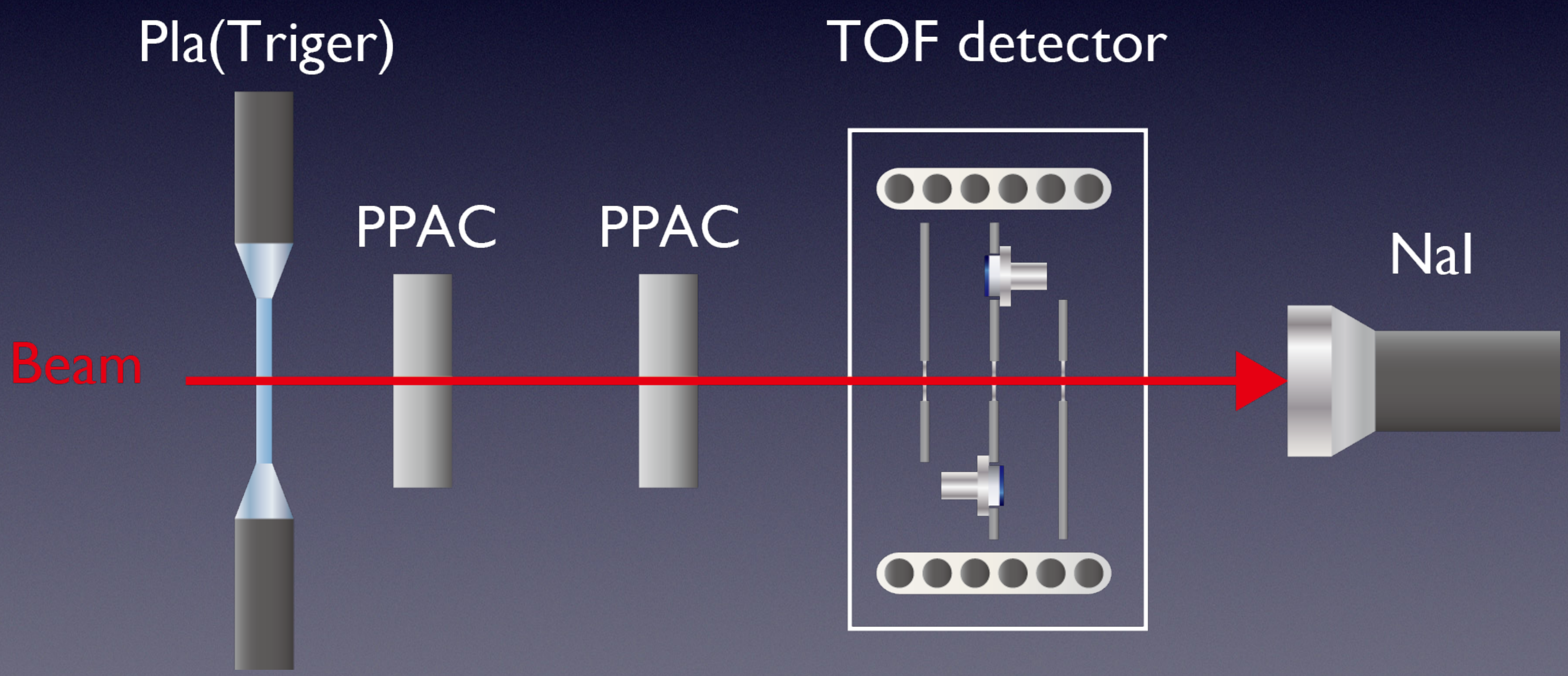






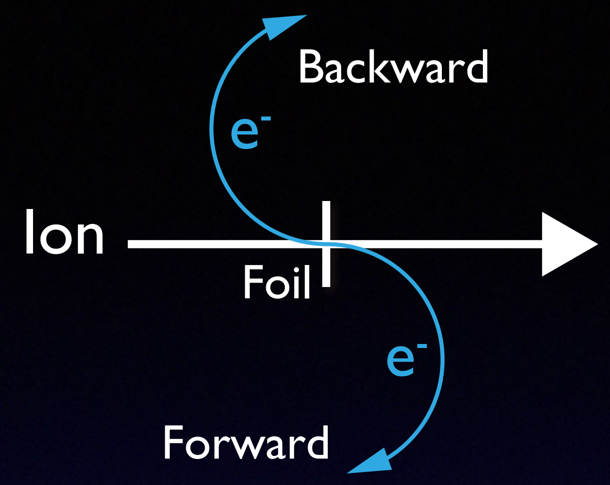
Performance test with heavy ion

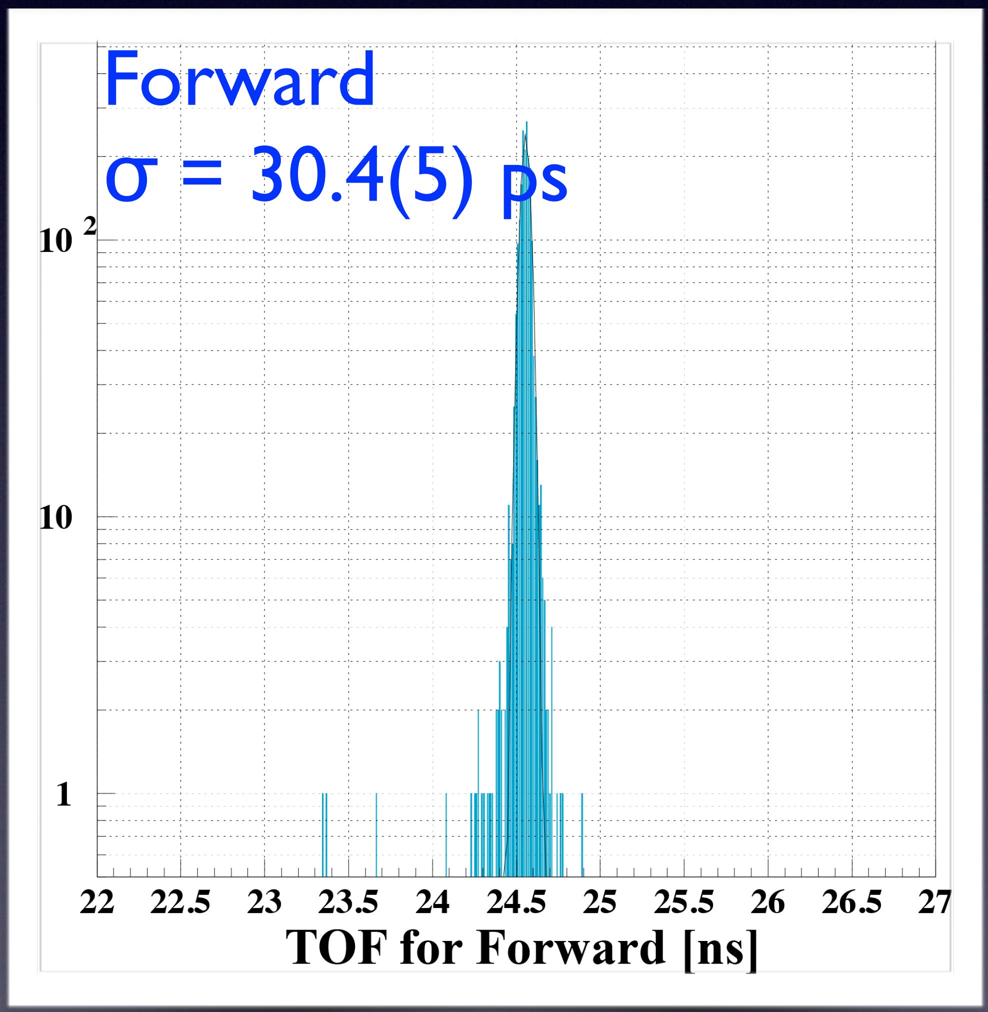
$^{84}Kr(36+)$ of 200 MeV/nucleon provided by HIMAC (Heavy Ion Medical Accelerator in Chiba) at NIRS



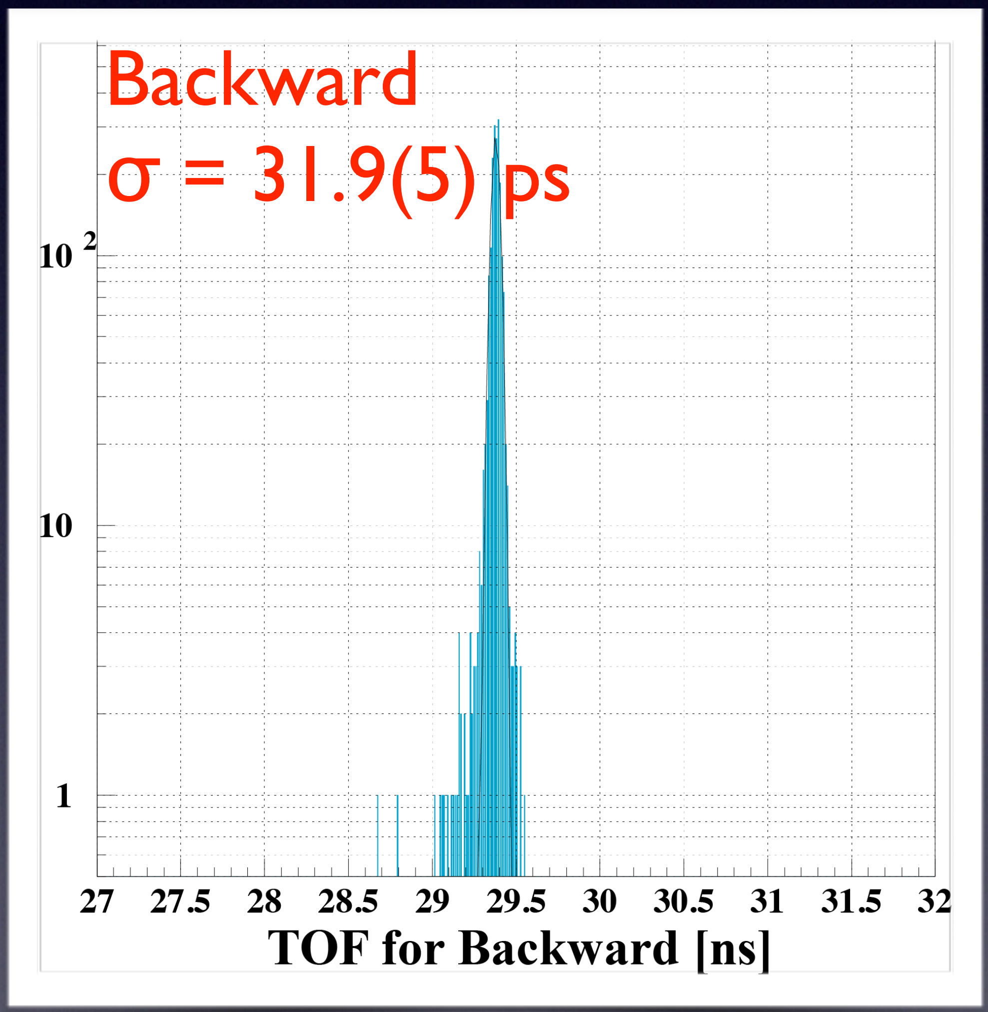
Results

Foil : Carbon 50μg/cm^2
B = 172 Gauss
E = 606 V/mm





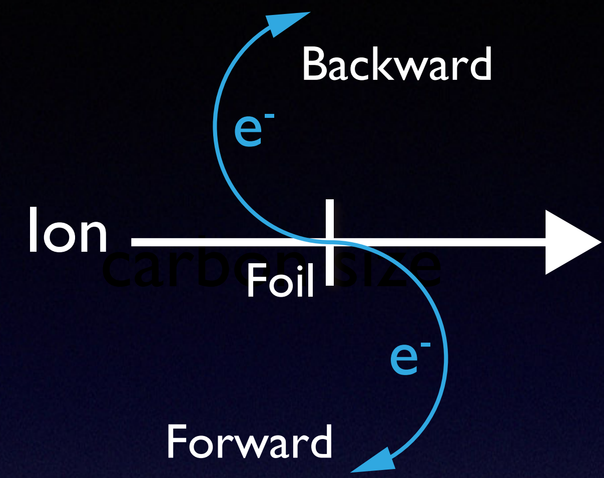
Detection efficiency
Forward : 99(3)%,



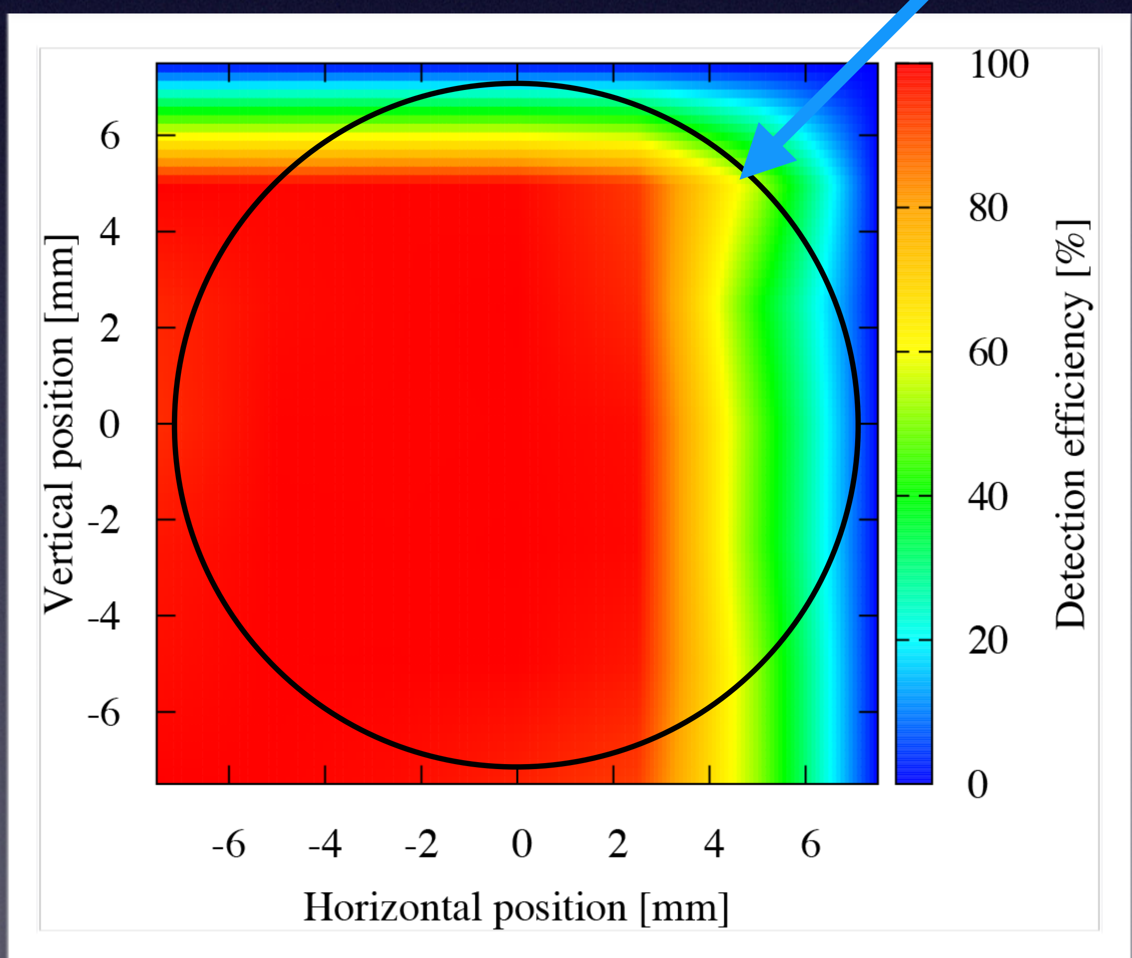
Detection efficiency
Backward : 99(3)%

Position dependence of efficiency

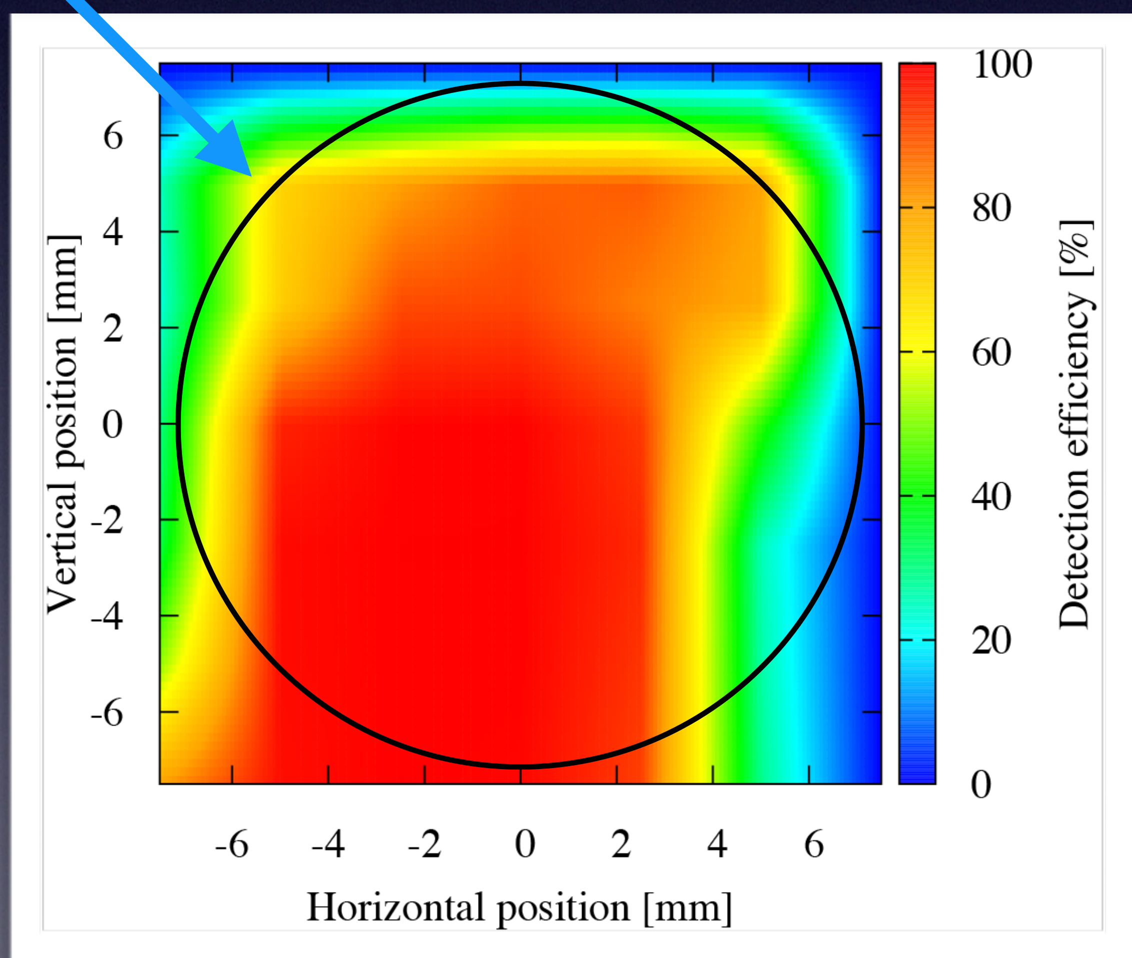
<ins>Carbon foil</ins>



Size of MCP



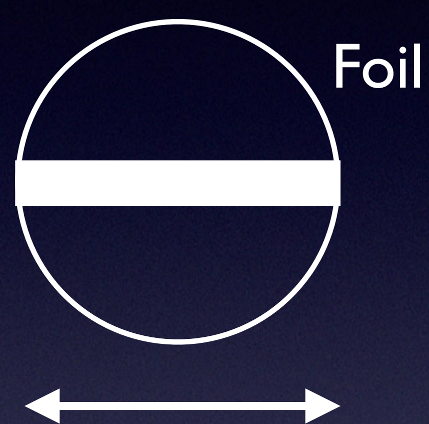
Forward

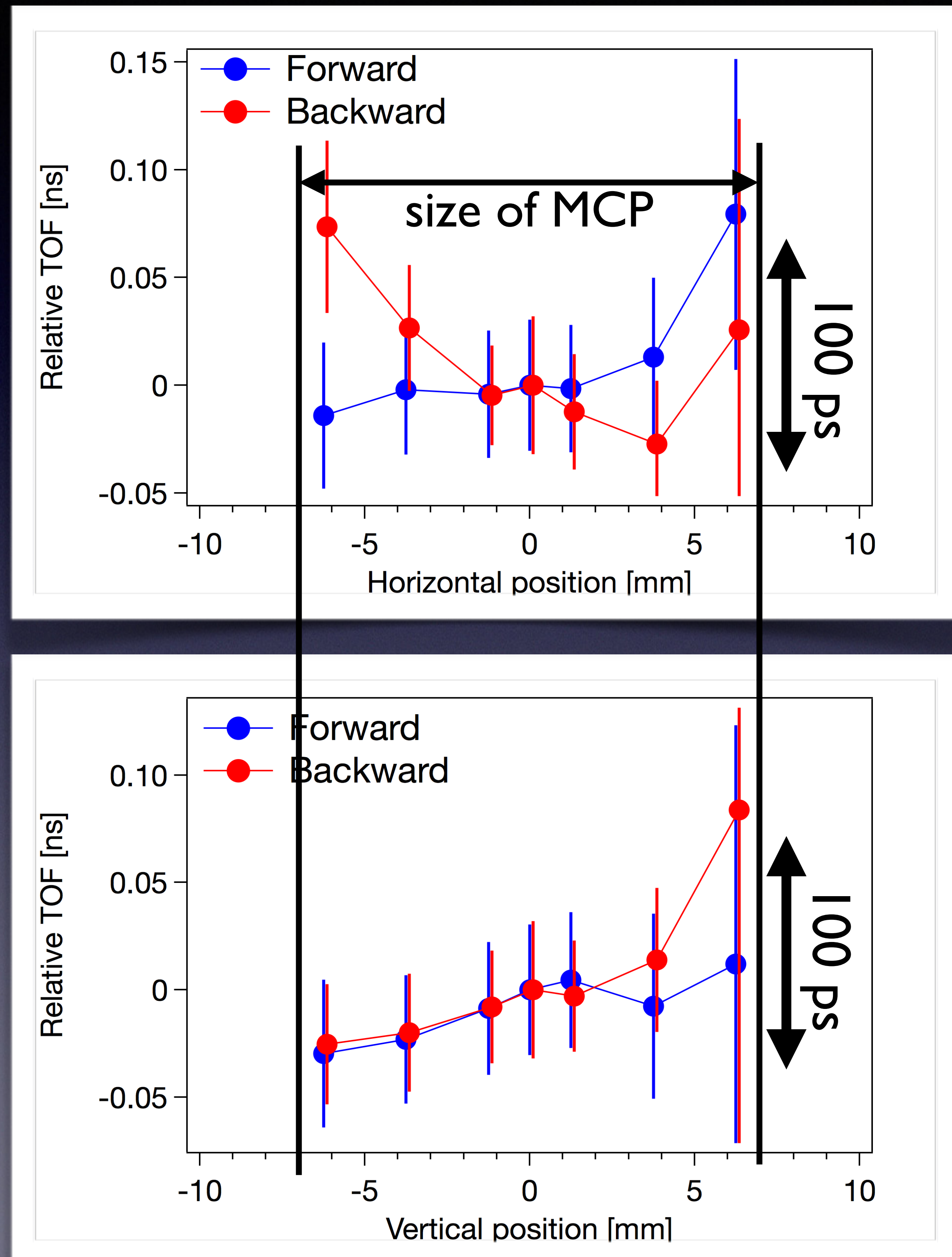


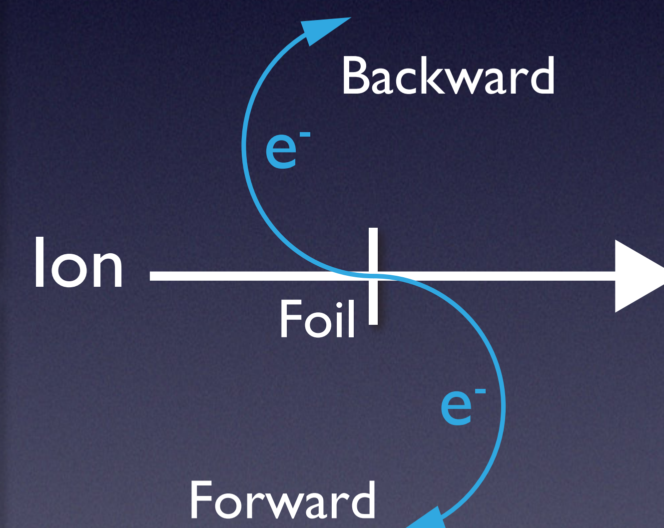
Backward

Position dependence of total TOF

Horizontal







Vertical

Conclusion and further development

- Sufficient detection efficiency of 99% was obtained by thin carbon. No need to use thick gold coated mylar.
- Time resolution was achieved σ <100 ps.
- No serious position dependence of detection efficiency and TOF.
- We are now developing large acceptance detector using larger MCP (Φ42mm) for mass measurements with the rare-RI ring.

Corroborators

University of Tsukuba
A. Ozawa, T. Moriguchi,
M. Amano, D. Kamioka,
Y. Ichikawa, Y. Tajiri,
K. Hiraishi, T. Matsumoto,

RIKEN Nishina Center
D. Nagae, Y. Abe, S. Naimi,
Z. Ge

Saitama University
T. Yamaguchi, T. Suzuki,
S. Ohmika, Y. Takeuchi,
N. Tadano, K Wakayama,
I. Kato, T. Nishimura

National Institute of Radiological Sciences (NIRS)
A. Kitagawa, S. Sato

Yield of secondary electrons

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

dE/dx : stopping power [keV/(μg/cm^2)]

Λ : constant of proportionality [(μg/cm^2)/keV]

Number of SEs by ^{84}Kr of 200MeV/u

Carbon

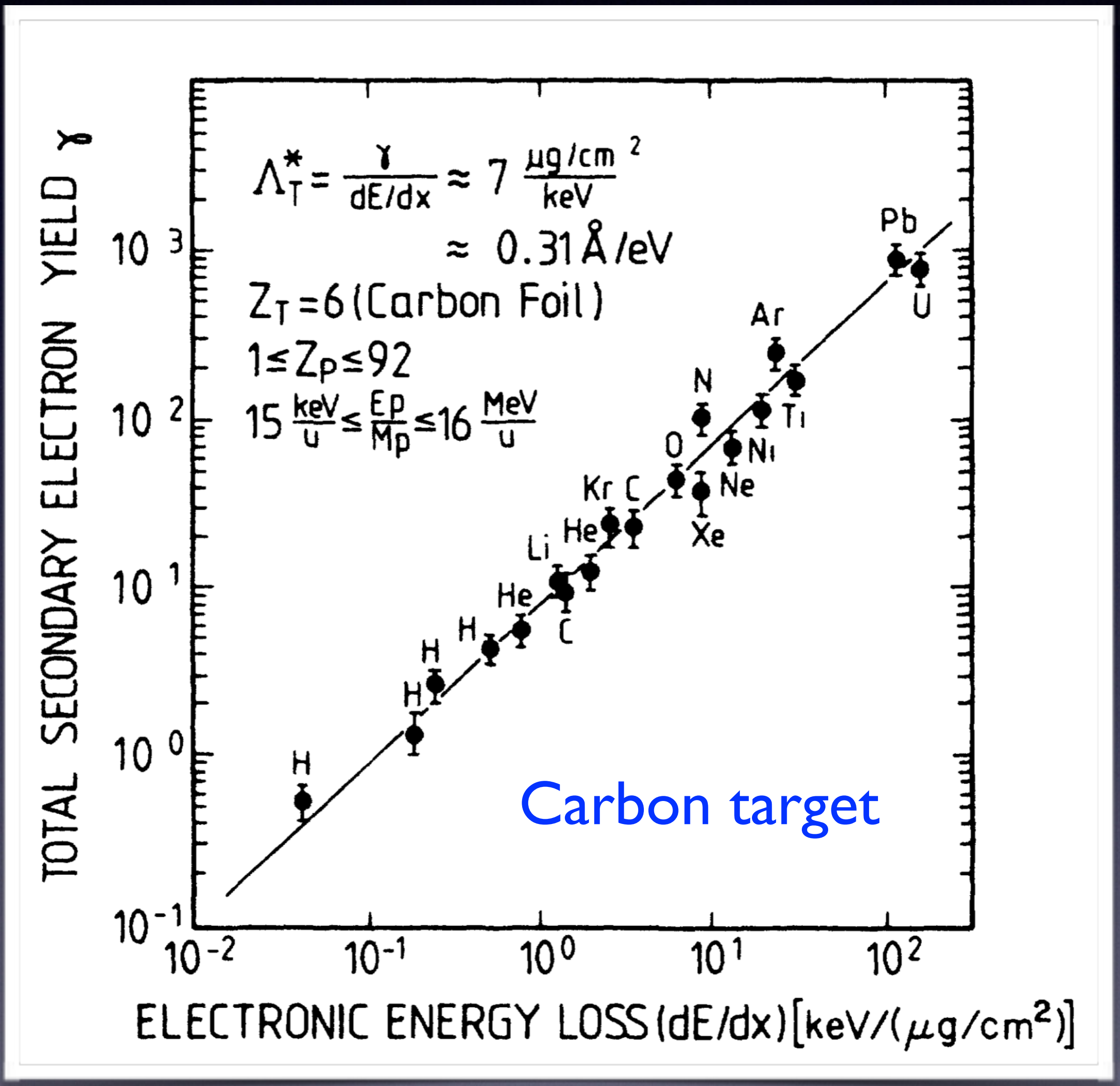
Λ = 7

Nse ~ 40

Gold

Λ= 60 (Ref. Phys. Rev. B 39, 6316)

Nse ~ 180



Phys. Rev. A 41(1990)2521

Energy spectrum of secondary electron

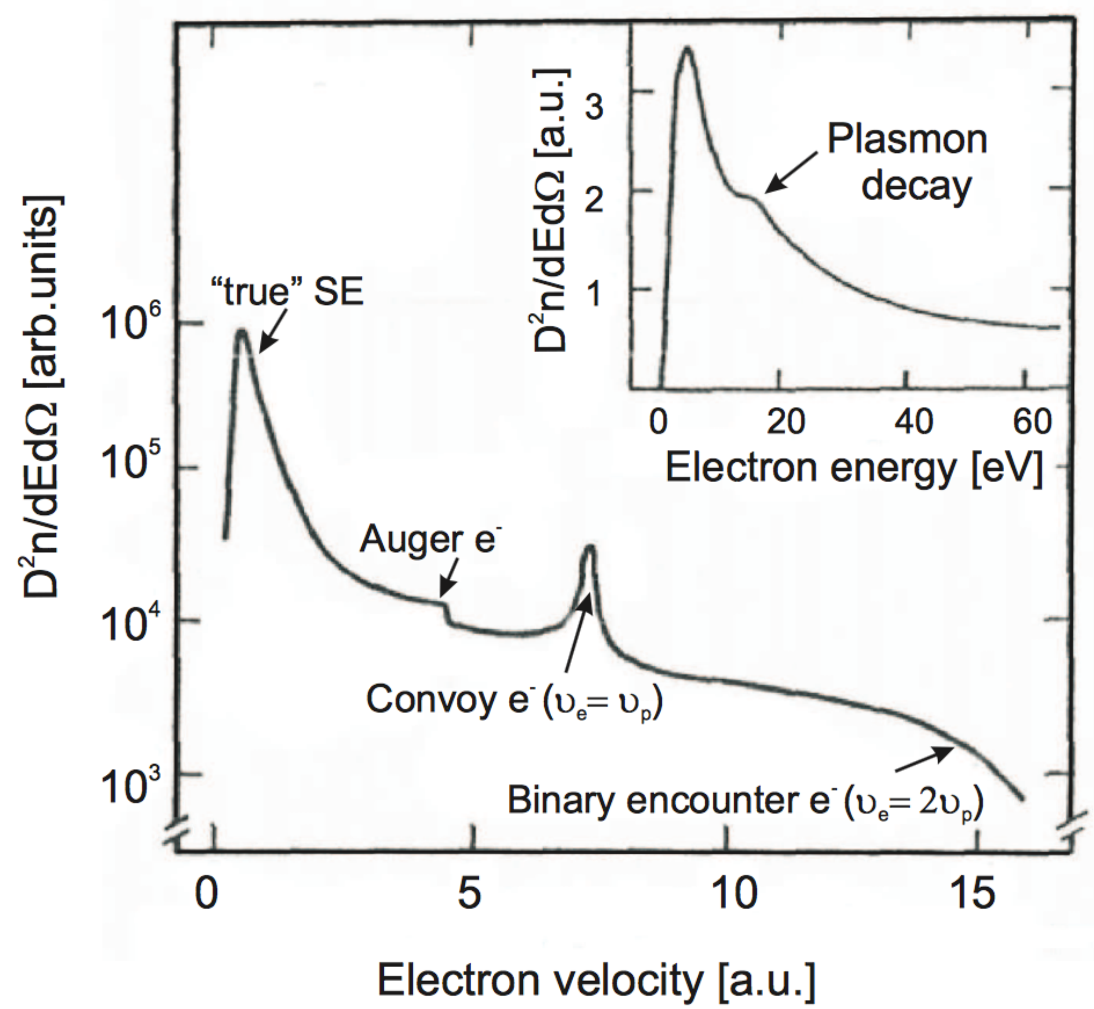
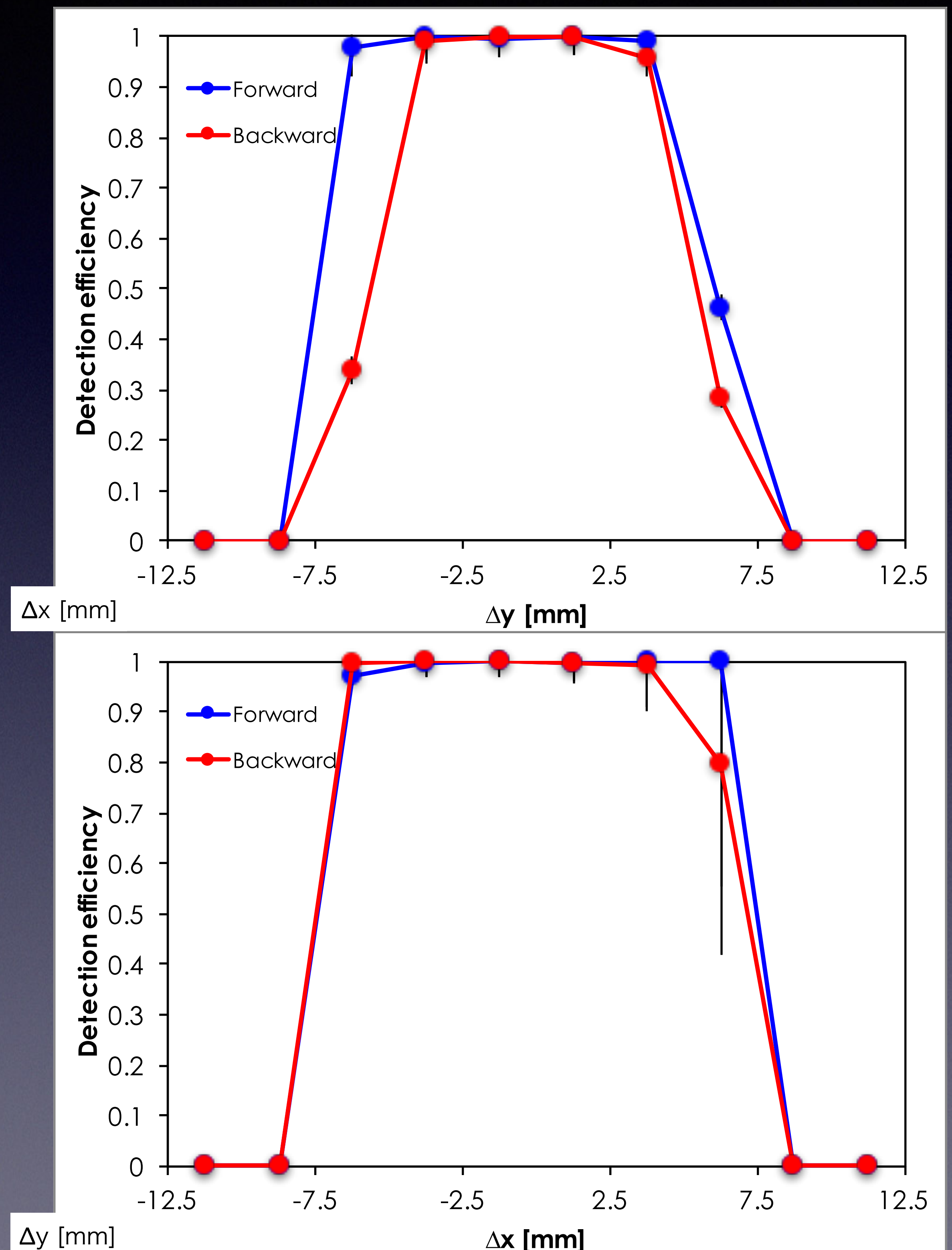


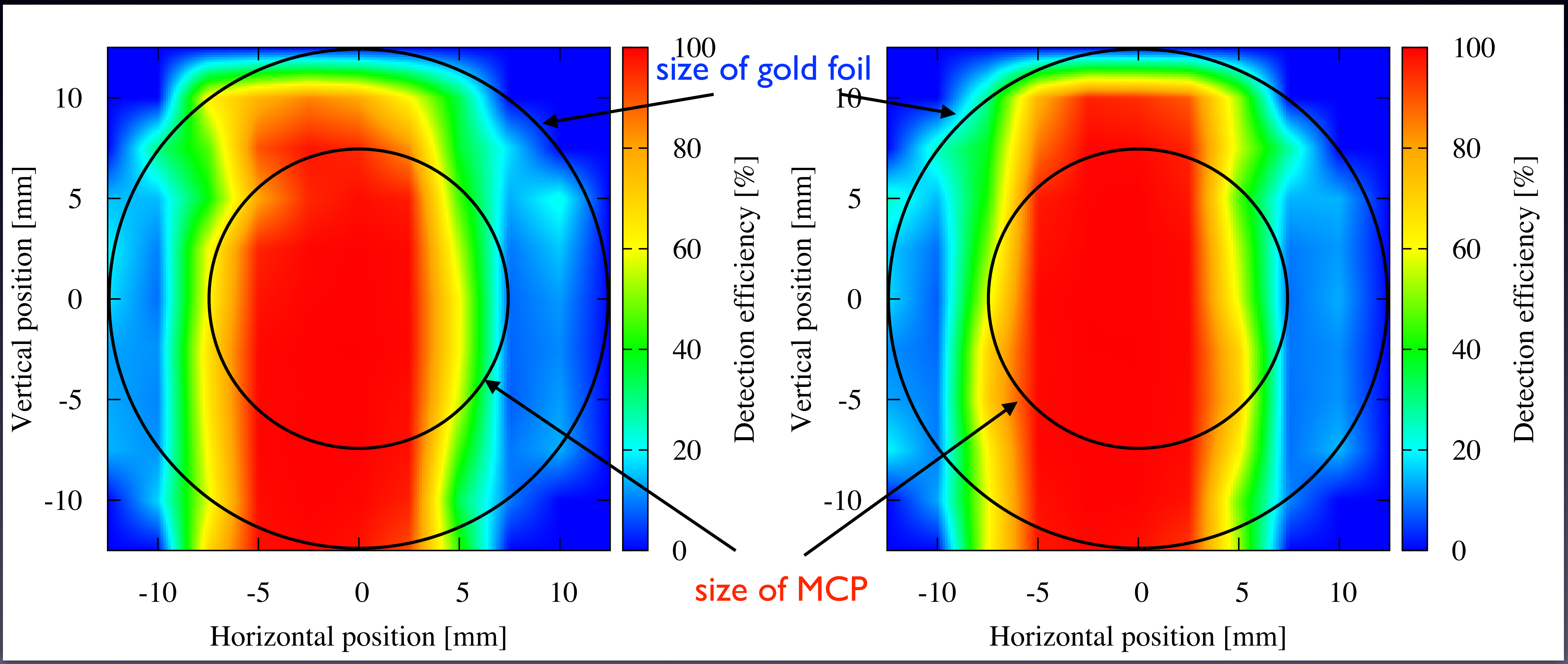
Figure 2.4: Typical secondary electron spectra from carbon foil of thickness 1500 Å induced by 1.2 MeV protons according to [Rot 90]. The spectra has been recorded at observation angle $\Theta = 0°$. The structures indicated in the figure as "true" SE, Auger electrons, convoy electrons, binary encounter electrons and electrons from plasmon decay (shown in the inset) are discussed in the text.

Ref. Springer Trac. Mod. Phys. 123, "Particle Induced Electron Emission II" (1992) [cited at p.109]

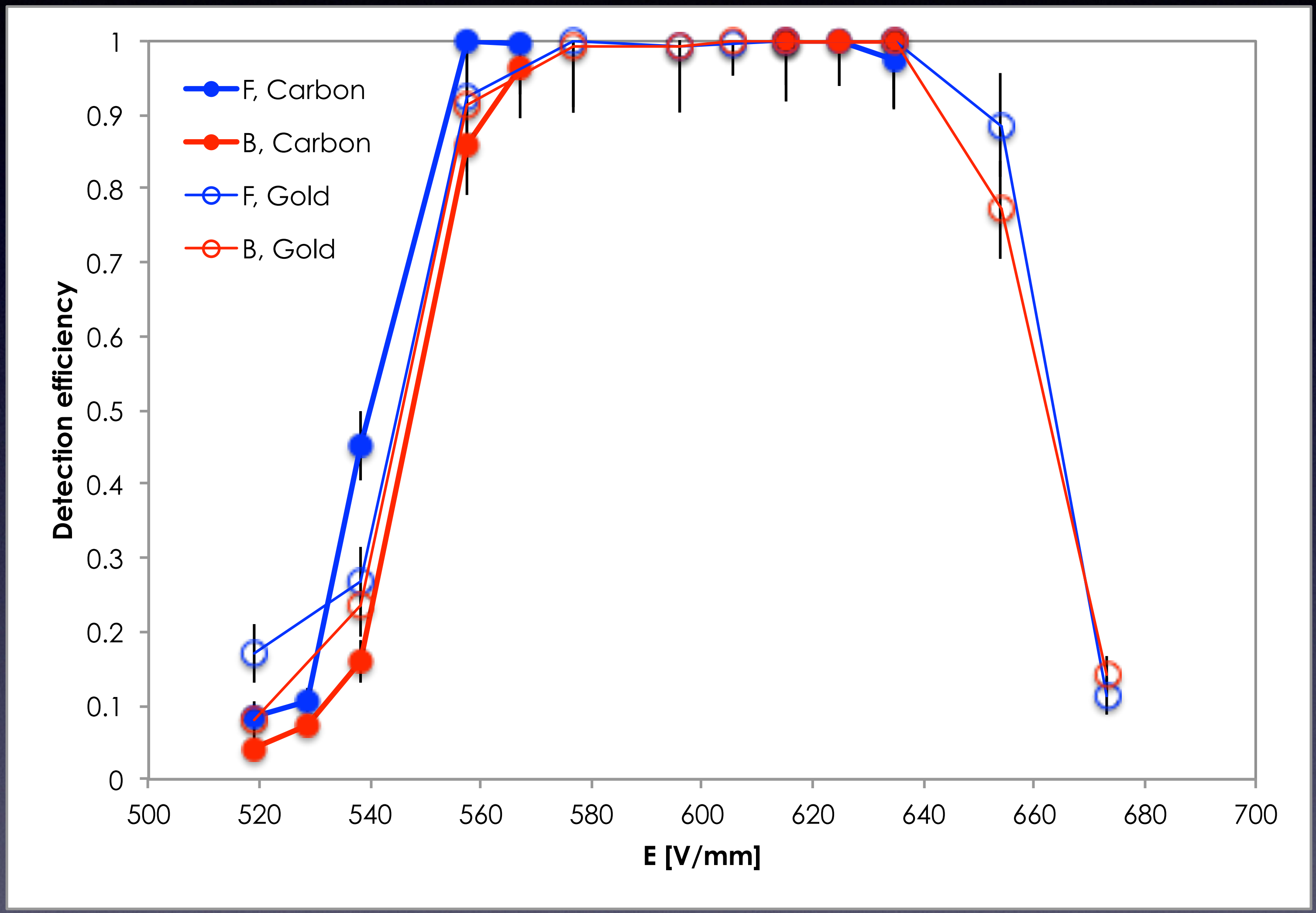
Position dependence of efficiency



Position dependence of efficiency



Electric field dependence of efficiency



In the case of carbon at E = 606V/mm,

<u>Forward : efficiency 0.9993(3), σ = 32.2 (2) ps</u>

<u>Backward : efficiency 0.9984(4), σ = 27.0(2) ps</u>