WEP17

# Physical design of an online beam monitor for heavy-ion single event effects tests

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## ◆ INTRODUCTION

Single event effects (SEE) of integrated circuits are one of the main threats faced by spacecrafts, and heavy-ion accelerators are commonly used for SEE studies on Earth.In irradiation experiments, the parameters of greatest concern to users are the flux rate and its uniformity at the irradiation terminal. Therefore, real-time, direct measurement of these key parameters during the irradiation process is essential. However, online monitoring of low-energy heavy-ion beams presents considerable challenges, and commonly used detectors such as parallel ionization chambers, semiconductors, and scintillators are no longer suitable for use as non-destructive beam monitors.

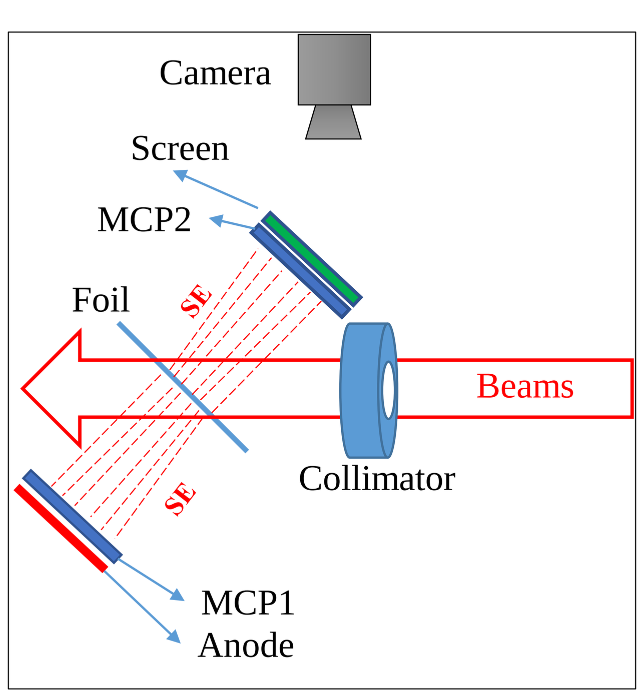
**Some difficulties in heavy-ion beam monitoring for SEE tests:**

- **low intensity:** less than 1E6 /s
- **low energy:** 5~10 MeV/u
- **on-line monitoring:** requirement of SEE tests

**SLIM might solve these difficulties**

(Secondary emission for Low-Interception Monitoring )

## ◆ PHYSICAL DESIGN




Conceptual illustration of the SLIM

**Key Features**

- **Thin foil is oriented at a 45°angle**
- **Thickness of foil is far less than ion range**
- **SEs emitted from both sides**
- **MCP1 with anode**
- **MCP2 with fluorescent screen**
- **Both intensity and profile can be measured**
- **Dose rate and uniformity at various positions can be acquired**

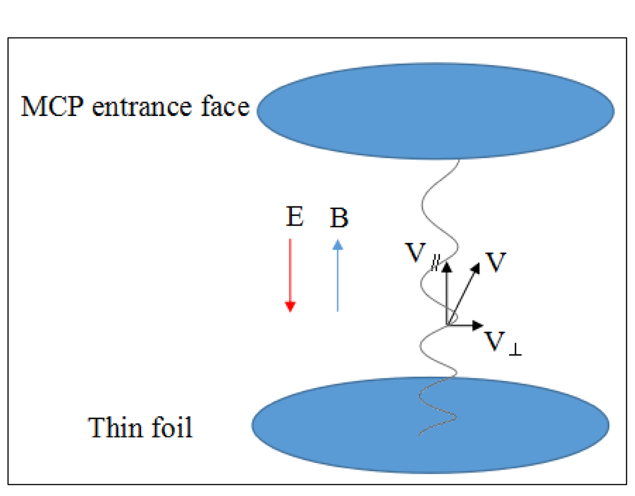
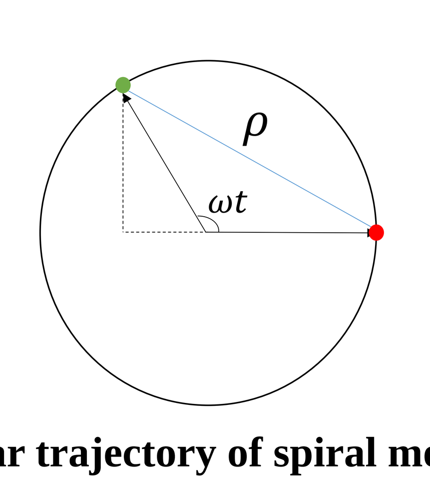



Diagram of a constrained electron

The confinement of SEs is a key issue due to their initial emission angle distribution.This article abandons the use of wire mesh and only applies negative high voltage to the thin foil. By utilizing the potential difference between the thin foil and MCP entrance surface, the SEs are accelerated. Besides, permanent magnets are introduced with its polarization direction perpendicular to the foil surface.




Circular trajectory of spiral motion

- **SEs are acceleratored by E-field,** $v \gg v_0$
- **Drift time t is only related to the E-field (foil voltage)**
- **In lateral circle,the cyclotron frequency is** $\frac{qB}{m}$ **,while the cyclotron radius is** $\frac{mv_\perp}{qB}$
- **Lateral distance is**

$$\rho(B,t)=\left\{\left(\frac{mV_\perp}{qB}\right)^2\left[\left(\cos\left(\frac{qB}{m}t\right)-1\right)^2+sin^2\left(\frac{qB}{m}t\right)\right]\right\}^{1/2}$$

- **when** $\frac{qB}{m}t=2\pi n$ **is satisfied,** $\rho$ **will be zero**

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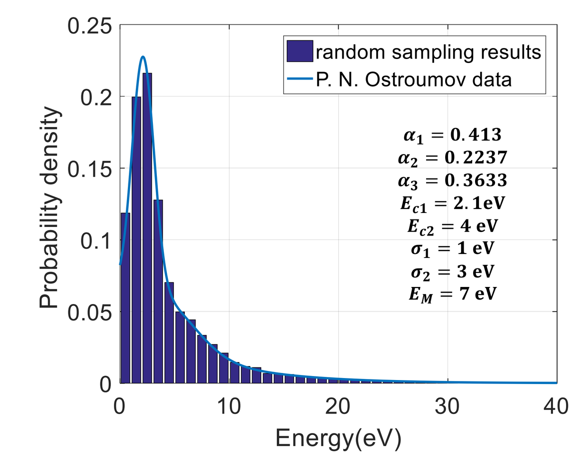
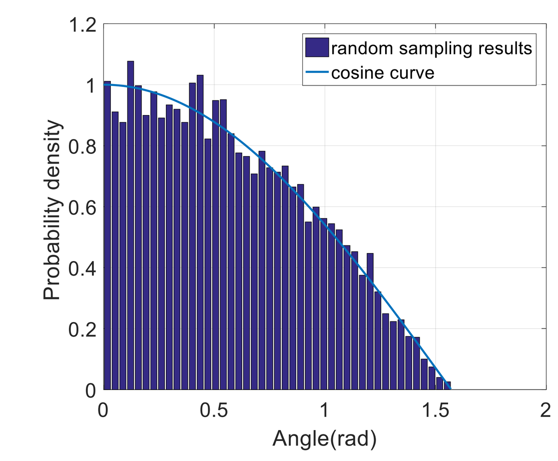
## ◆ SIMULATION AND RESULTS

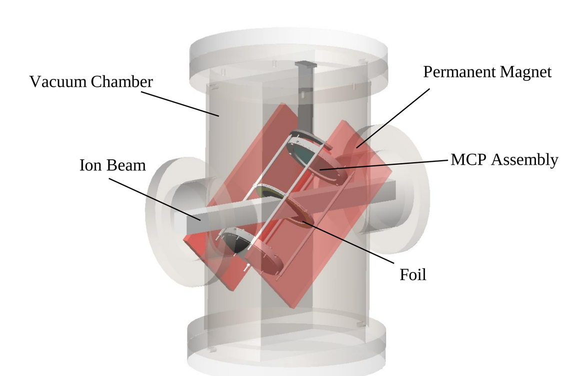



**Energy**

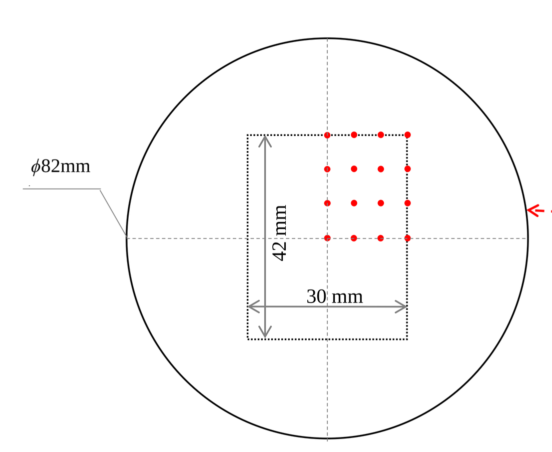



**Angle**

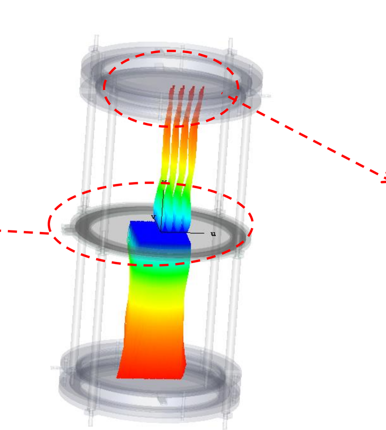
- **Acceptance-rejection sampling method to generate SEs**
- **Particle Tracking simulation within CST Studio Suite**
- **Maximum beam size is 30×30 mm²**
- **Electron point sources and area source are emitted**



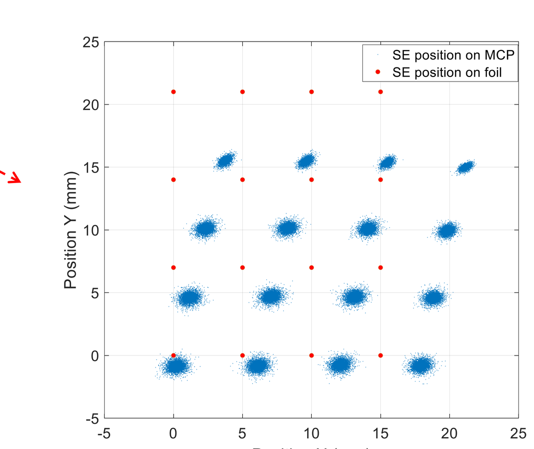

The CST geometric model includes major components such as vacuum chamber, permanent magnets, foil, MCP assemblies, and support rods.



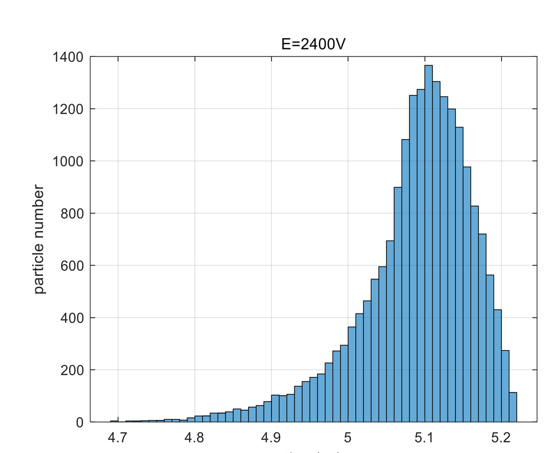

**Point sources**



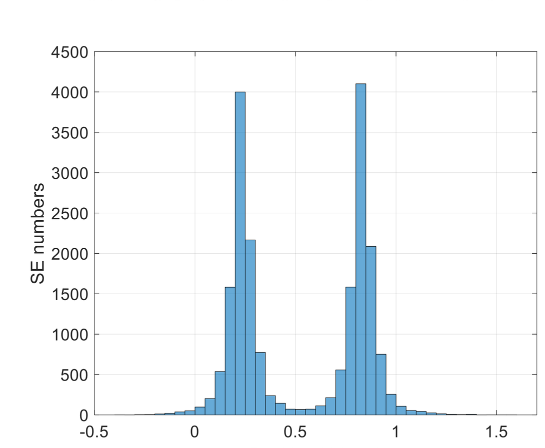
**CST simulation results**




**Position distribution**




**Distribution of the drift time**




1D distribution on MCP

**SLIM characteristics**

- Space resolution can be adjusted by scanning the foil voltage;
- There is a distortion in the imaging, which can be corrected by position calibration;
- A fast detector-the time resolution of this detector will be better than 1ns. This allows it to work in count mode or current mode according to the beam intensity ;
- Space resolution is better than 0.5mm, meeting the monitoring requirements of SEE tests adequately;
- On-line, low-interception monitoring.

## ◆ CONCLUSION

This paper presents a novel approach that utilizes SEs from the front and back surfaces of a thin foil to simultaneously measure beam intensity and profile, thereby enabling online monitoring of the flux rate. This method offers several advantages over traditional monitoring techniques, including high resolution, reduced mass thickness, and the capability for **multi-parameter measurements**.

Additionally, by employing adjustable electrostatic fields and constant magnetic fields to constrain SEs, a configuration without an accelerating wire mesh and with lateral rectangular permanent magnets is proposed. The beam only traverses a thin layer of foil, and space resolution optimization can be achieved by adjusting the voltage. Simulation results show that the space resolution is better than **0.5mm**, while the time resolution is better than **1ns**.