



15TH INTERNATIONAL BEAM INSTRUMENTATION CONFERENCE

High-intensity heavy-ion beam diagnostics over a nine-order-of-magnitude dynamic range

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1st September, 2026

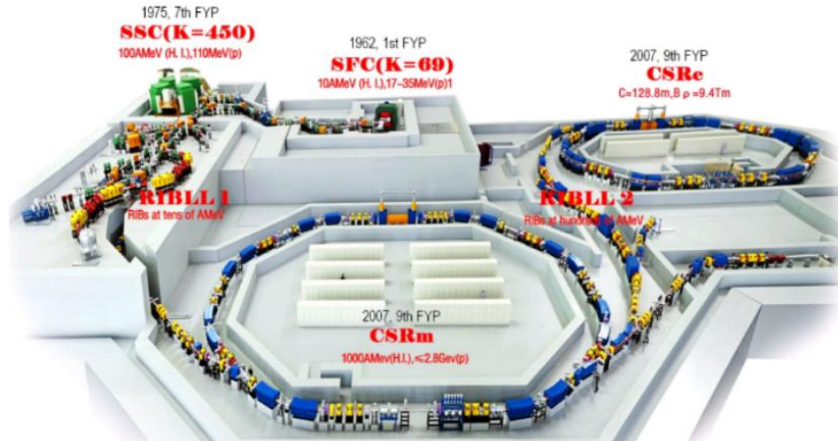


Institute of Modern Physics, Chinese Academy of Sciences

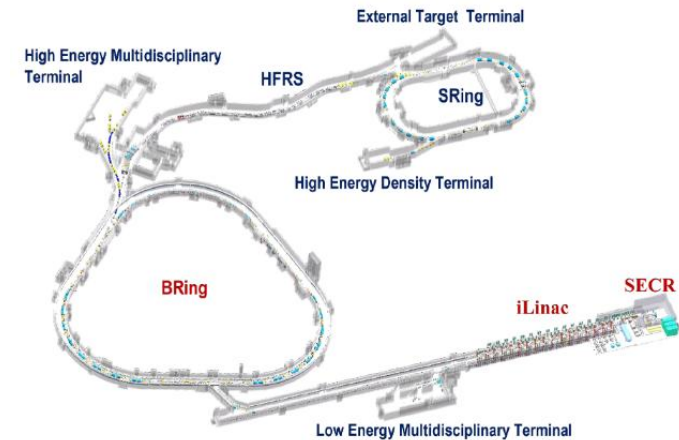
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Background



HIRFL(Heavy Ion Research Facility in Lanzhou)



HIAF(High Intensity heavy ion Accelerator Facility)

Synchrotron (CSR)

Ions	Energy	Stored Ions
$^{12}\text{C}^{6+}$	1 GeV/u	1×10^9
$^{16}\text{O}^{8+}$	300 MeV/u	1.1×10^9
$^{22}\text{Ne}^{10+}$	70 MeV/u	2.7×10^9
$^{209}\text{Bi}^{36+}$	170 MeV/u	1.2×10^7

Synchrotron (BRing)

Ions	Energy	Stored Ions
$^{16}\text{O}^{6+}$	2.6 GeV/u	2.5×10^{11}
$^{209}\text{Bi}^{31+}$	851 MeV/u	3.2×10^{10}

Fast Extraction Measurements

Ions	Max. stored ions	Max. Charge
p	6.0×10^{12}	960 nC
$^{238}\text{U}^{74+}$	1.1×10^{11}	1.18 μC

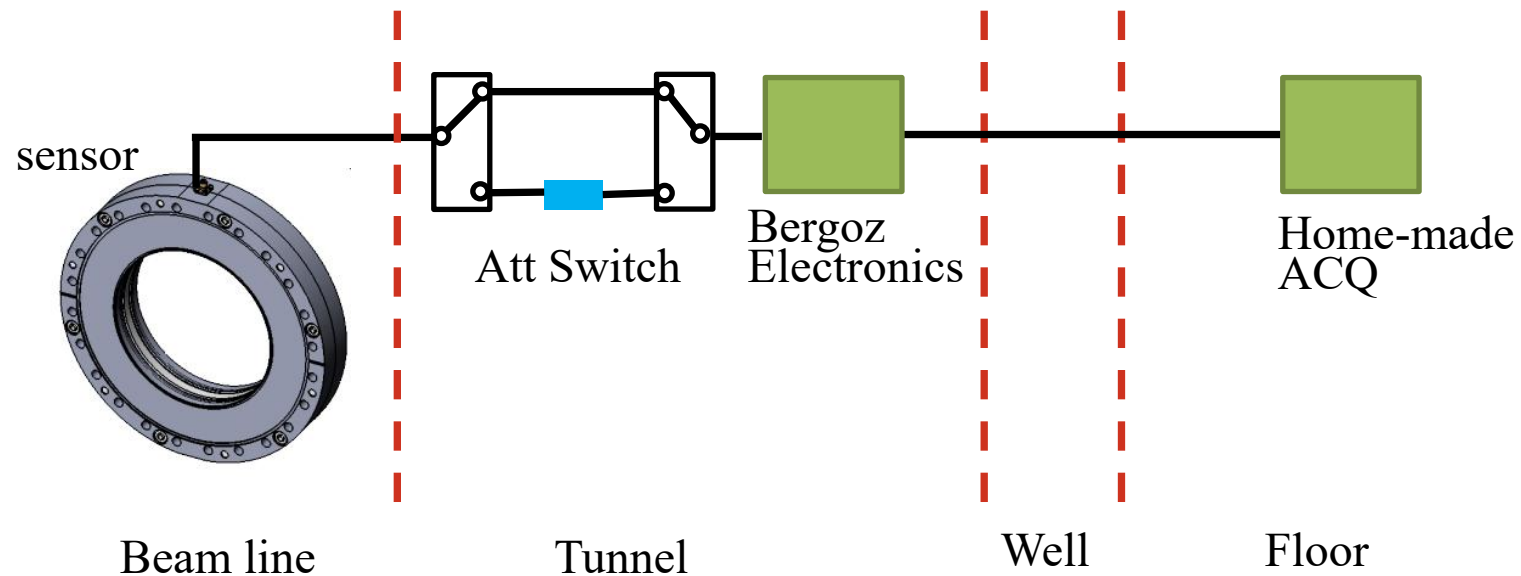
Full scales

Gain	Bits (Gain setting)	Full scale with ICT-...- 0.50	Full scale with ICT-...- 1.25	Full scale with ICT-...- 2.50	Full scale with ICT-...- 5.00	Full scale with ICT-...- 10.0
6 dB	H-H-H	400 nC	160 nC	80 nC	40 nC	20 nC

Bergoz electronics upper limit

Max. charge/pulse	2000	324	81	20	5	μC
Max. rms current ($f > 10\text{kHz}$)	2.7	2.7	2.7	2.7	2.7	A
Max. peak current (pulses = 1ns)	0.4	0.2	0.1	0.1	0.1	kA

ICT max. charge



Offline Tests

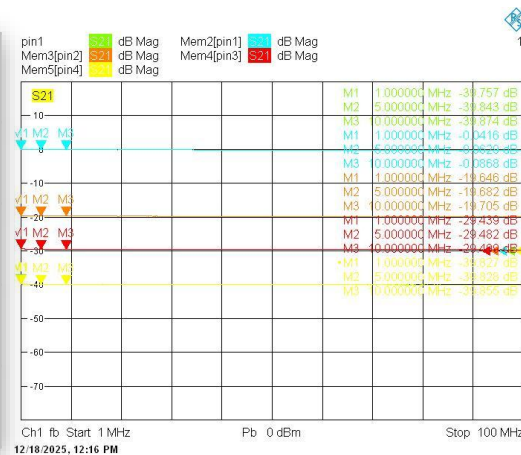
Max. charge = 20 nC $\times$ 97.6338 = **1.95 μ C**

$$\sigma_N = \frac{k \cdot \sigma_U \cdot k_{att}}{q \cdot e}$$

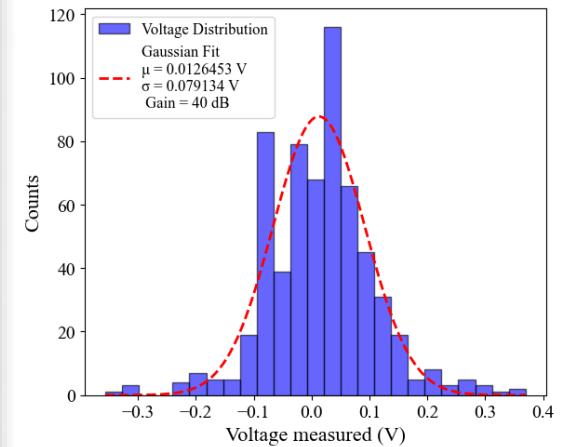
p	1.22 $\times 10^{13}$ ppp
$^{238}\text{U}^{92+}$	1.32 $\times 10^{12}$ ppp

p	3.93 $\times 10^6$ ppp
$^{238}\text{U}^{92+}$	4.27 $\times 10^4$ ppp

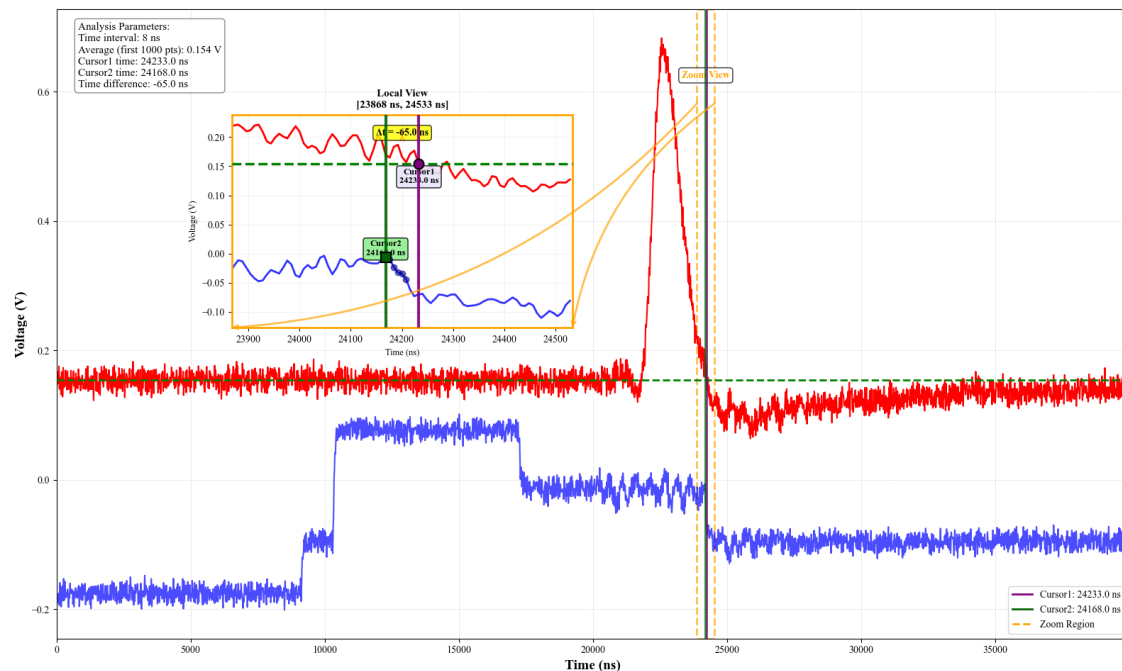
Att. dB	k_{att}
0	1.0048
-20	9.6006
-30	29.6449
-40	97.6338



Gain	k nC/V	σ_U V
6	2.5063	0.0016
12	1.2469	0.0028
18	0.6234	0.0056
20	0.5020	0.0070
26	0.2501	0.0127
32	0.1245	0.0297
40	0.0497	0.0126

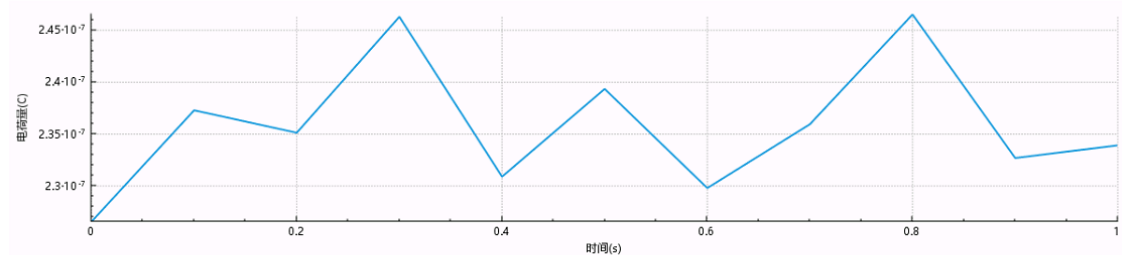


Auto time window: Droop

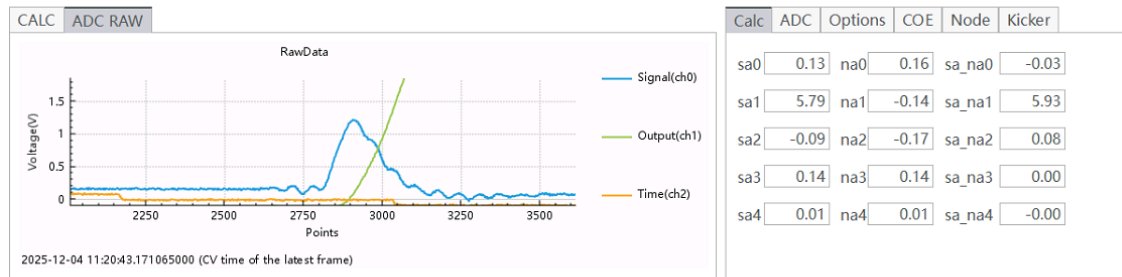


~**96%** extraction rate

HIAF:BL:BD51ICT01 电荷量 **233.92 nC** 电荷态 **6** 粒子数 **2.44e+11**



2025-12-04 11:20:43.171067000 (CV time of the latest frame)

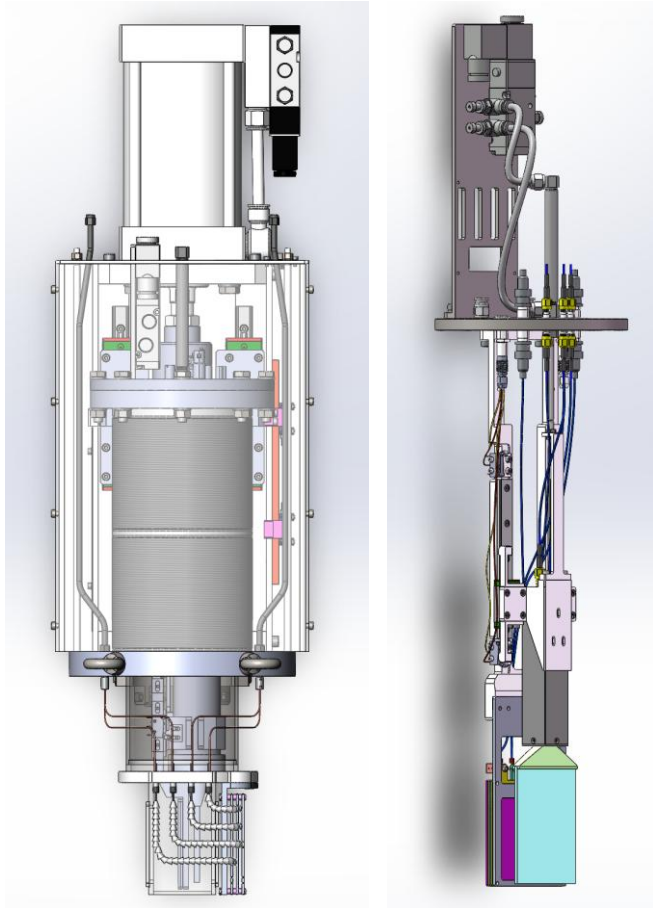


BD41ESVIDEO01CCD | Camera | Camera connecting (10.10.42.157), please wait...

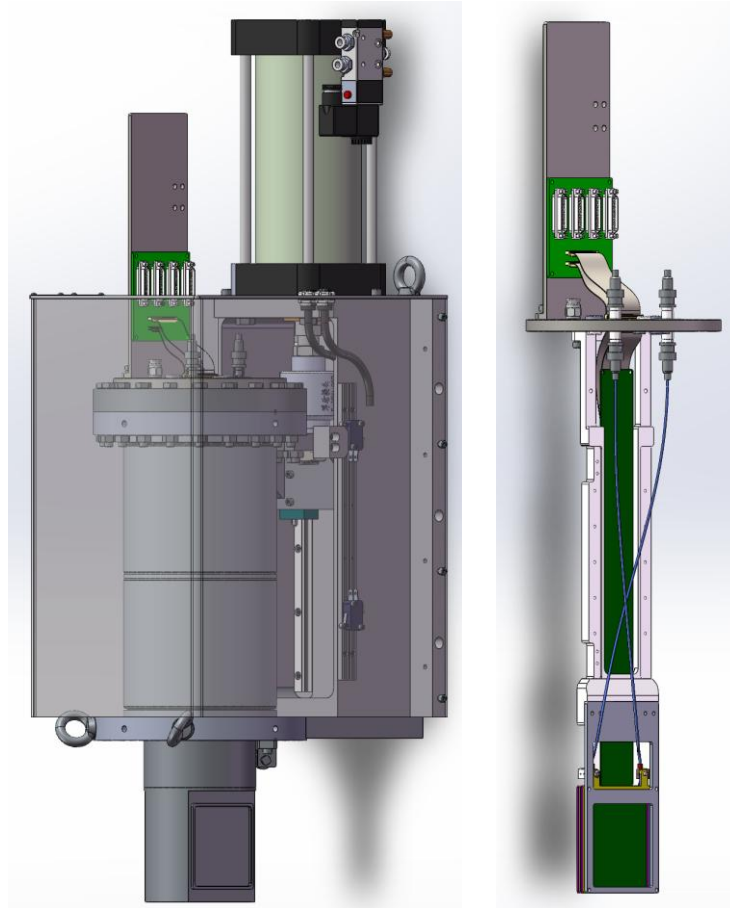
运行 E:99+ W:99+ 2025-12-04 11:20:43

Slow Extraction Measurements

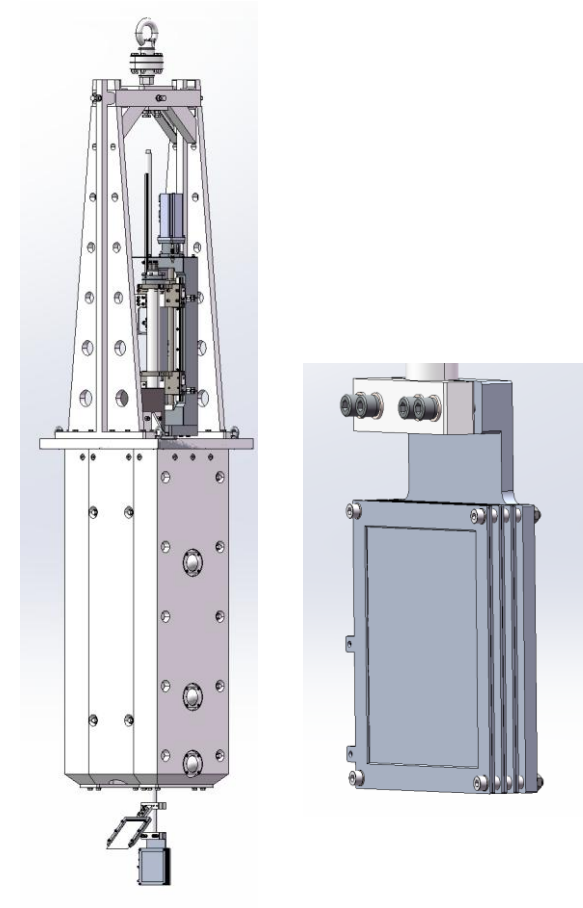
SXIM:SC+IC+SEM



Multi-strip Ionization Chamber



SEM integrated with VS

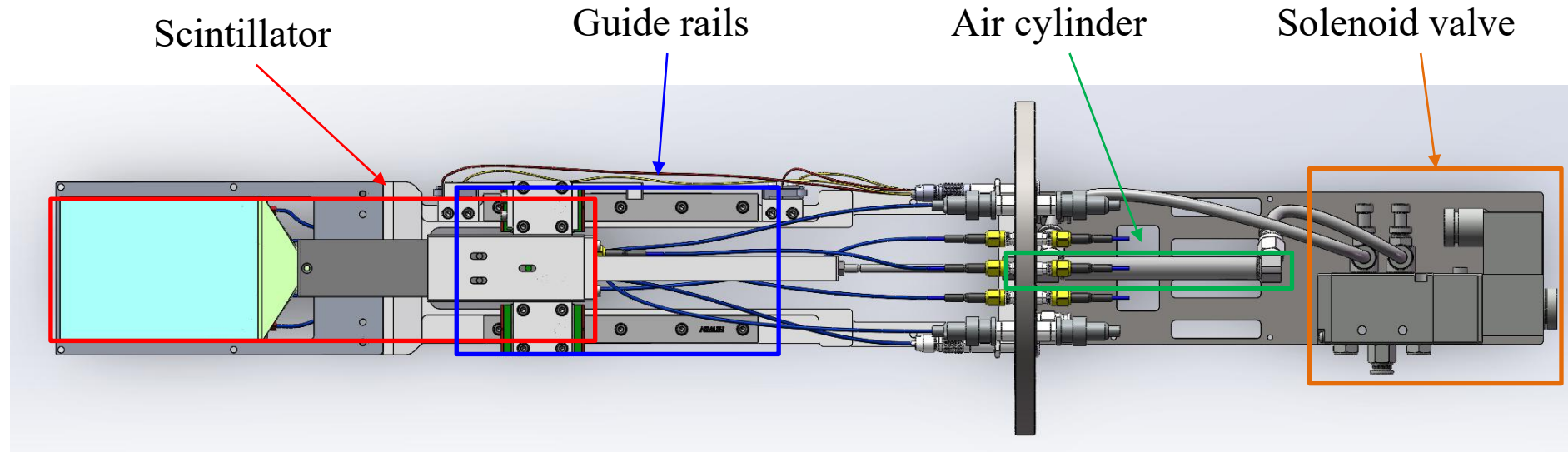


Independent pneumatic control

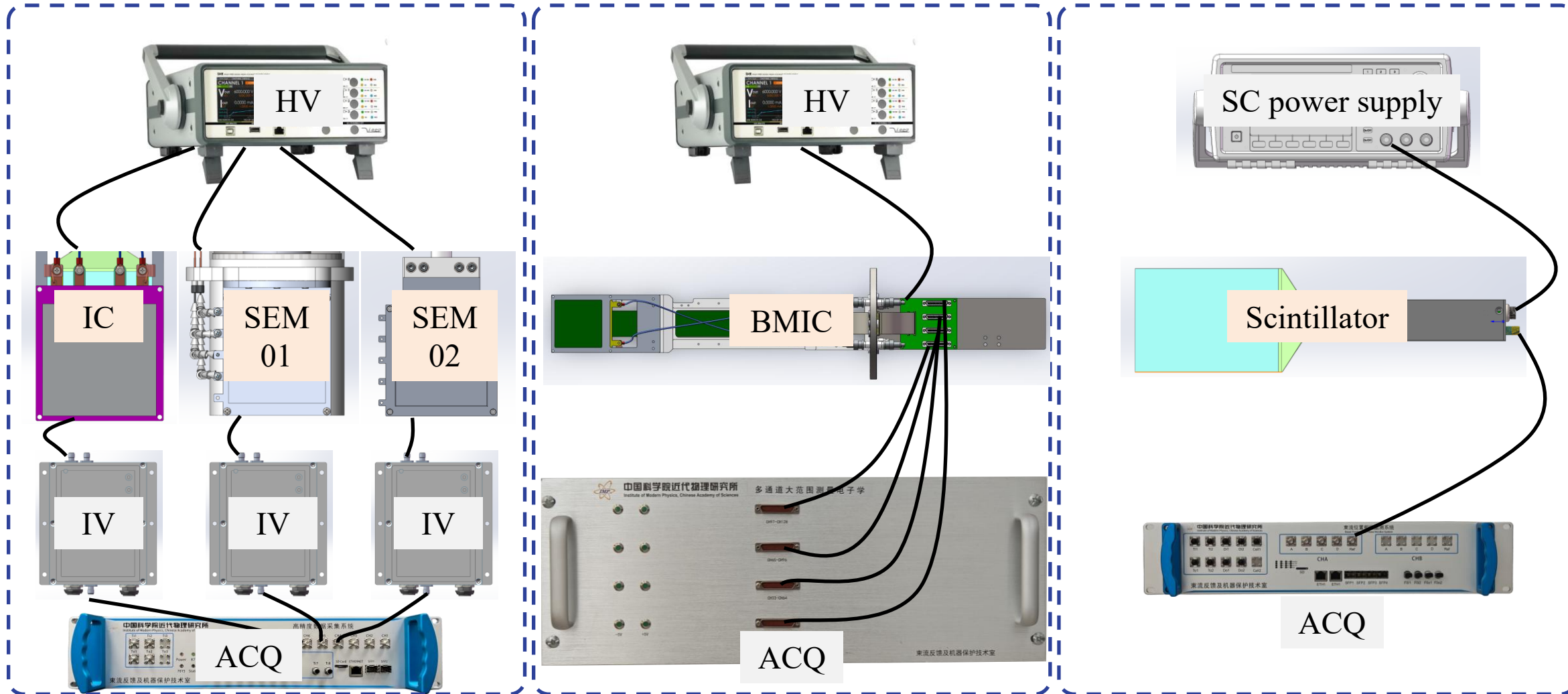
Radiation Reduction

Compact

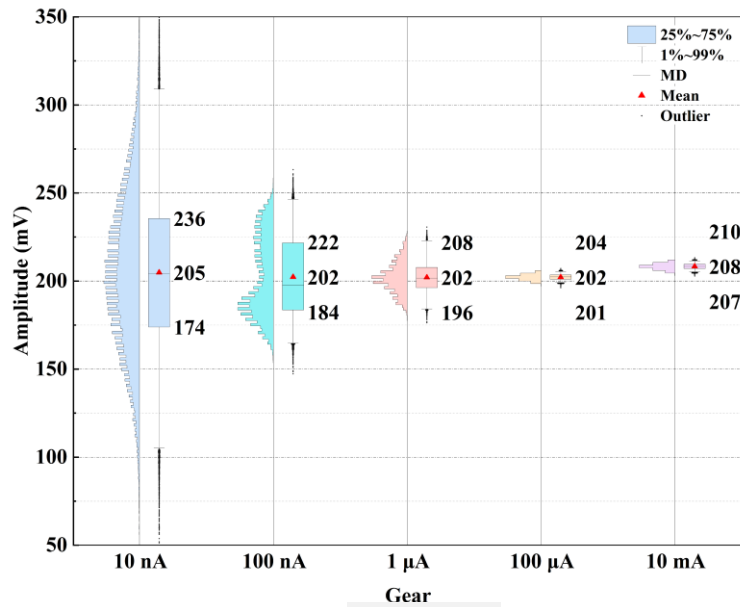
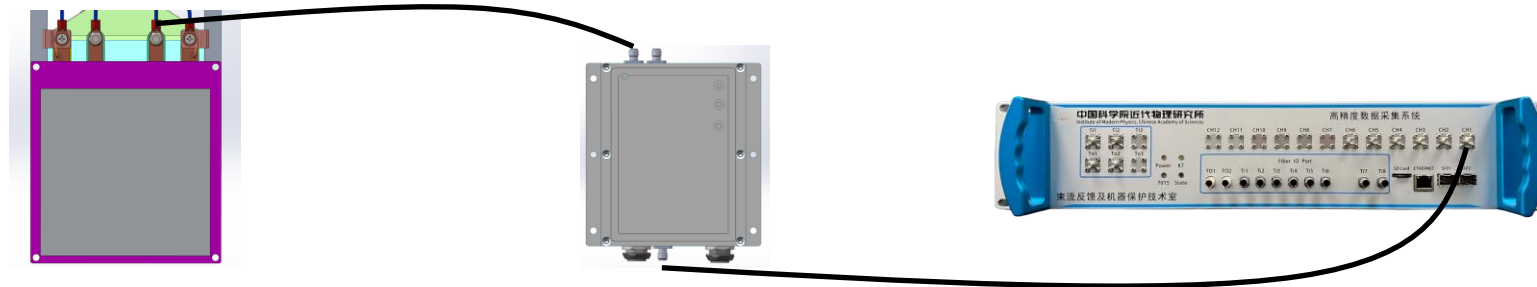
Long-term operation



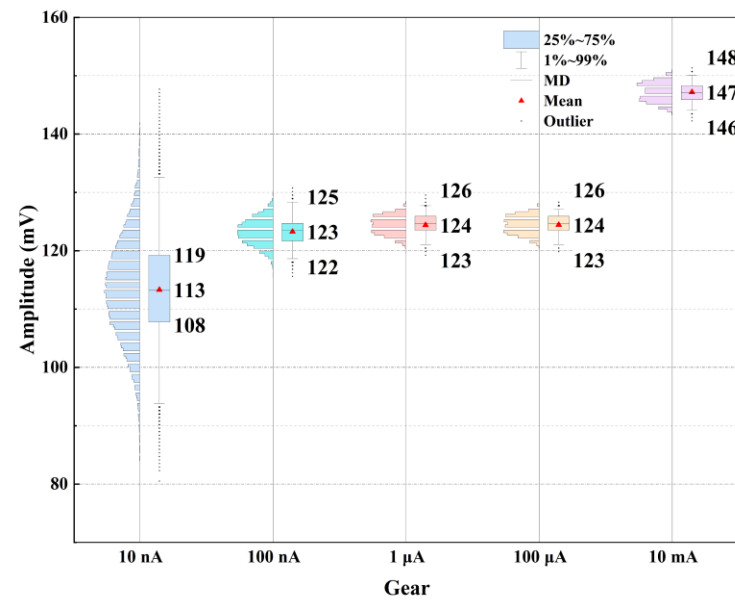
Schematic Design



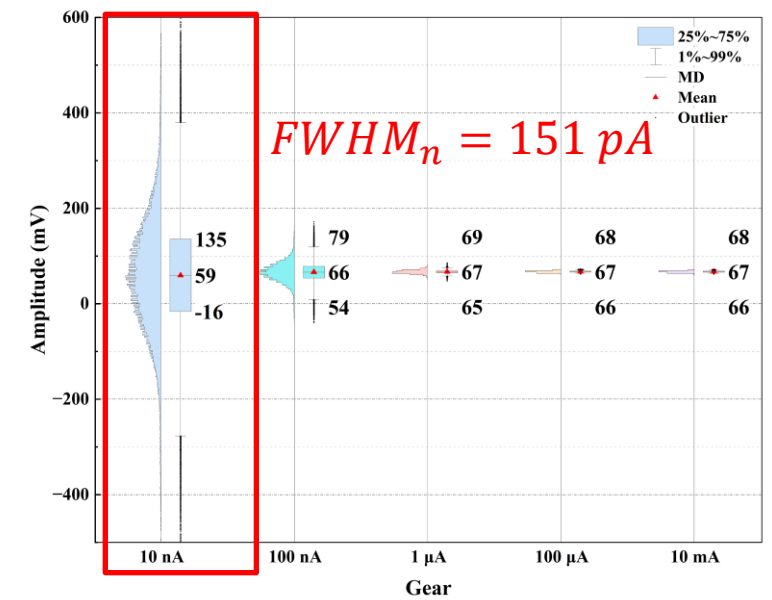
Offline Tests – Noise



IC

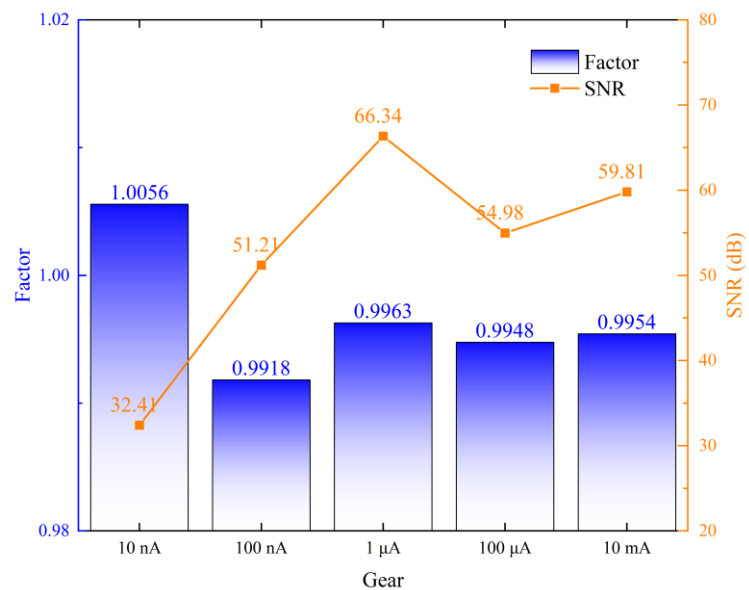
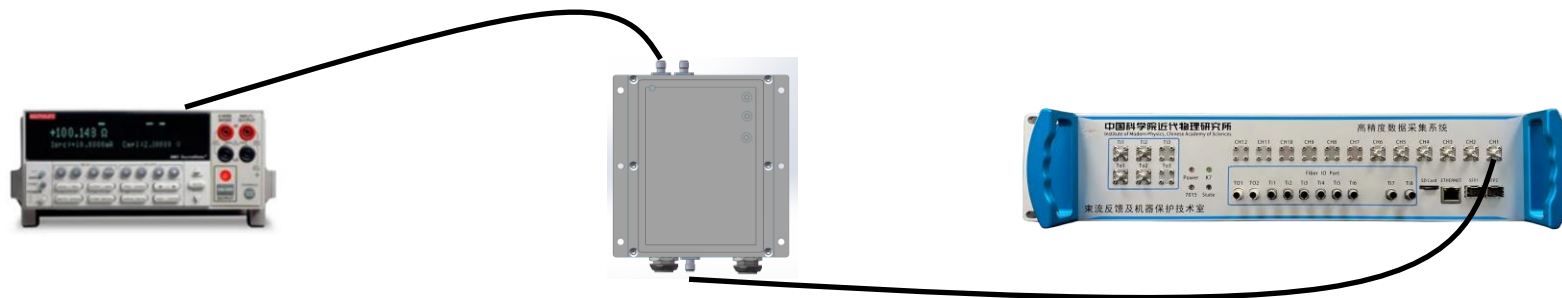


SEM01

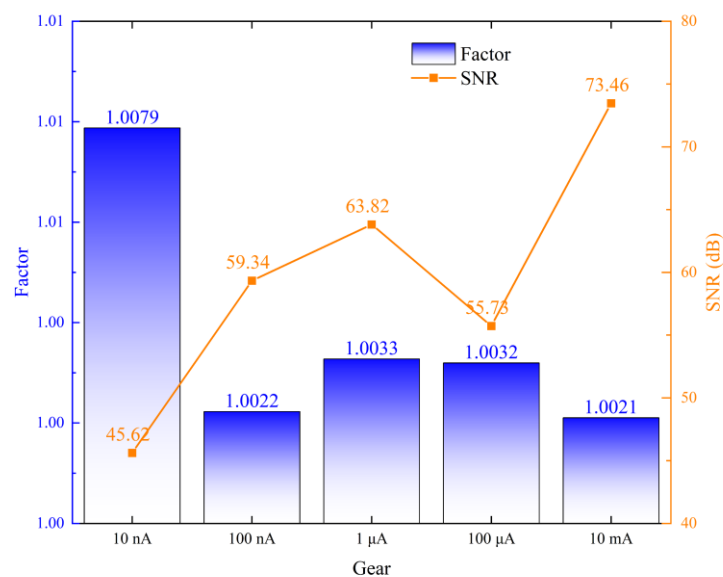


SEM02

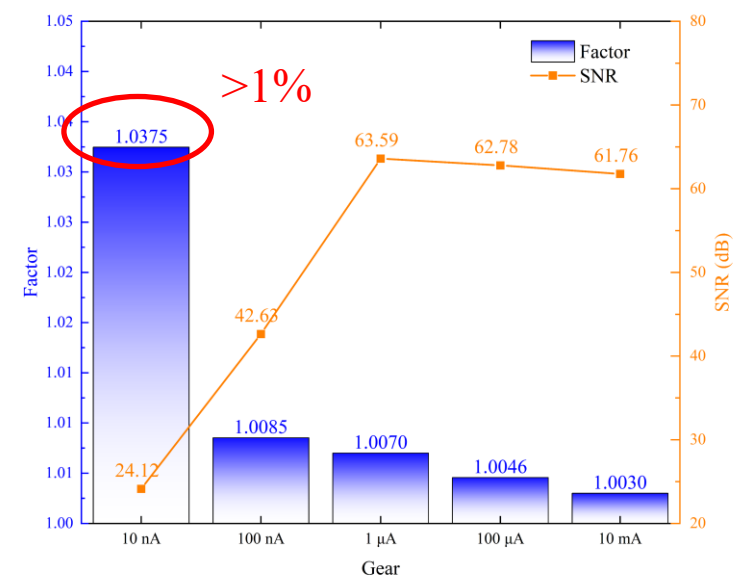
IV calibration



IC

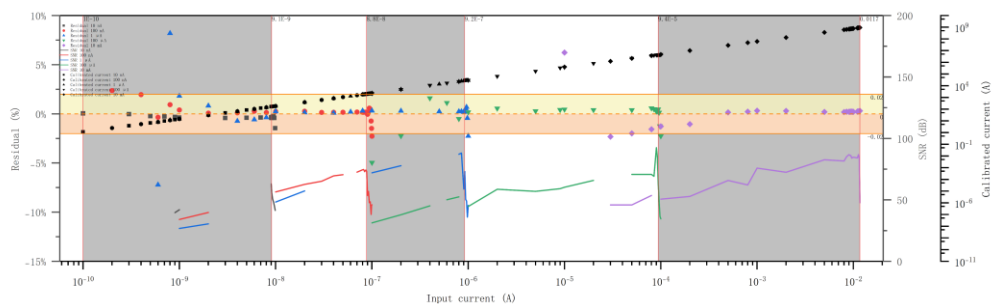
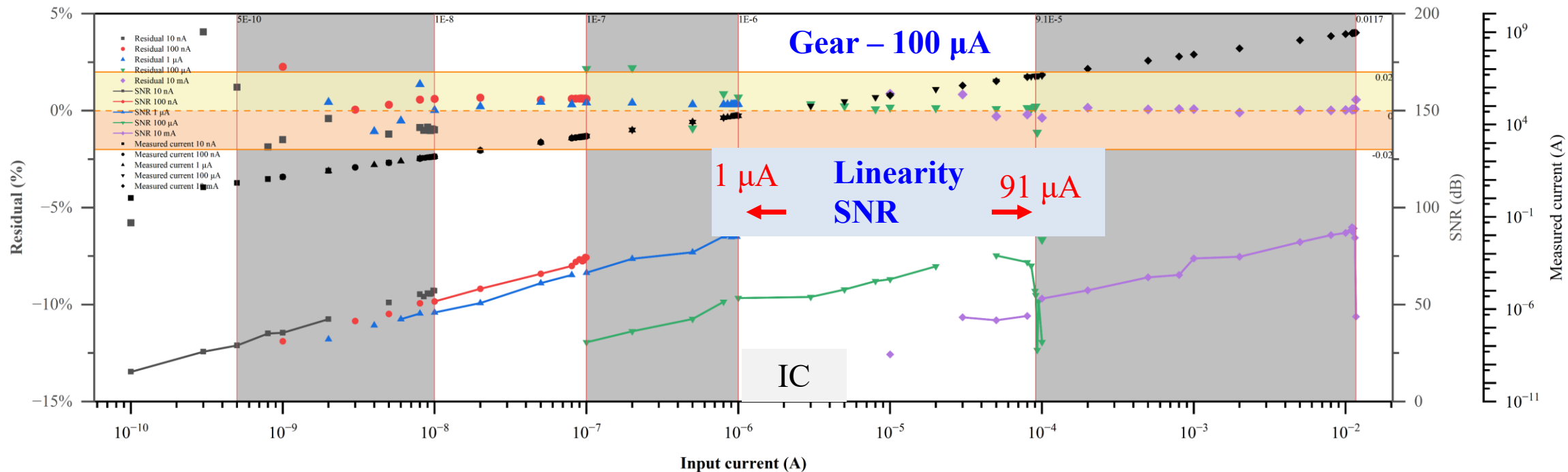


SEM01

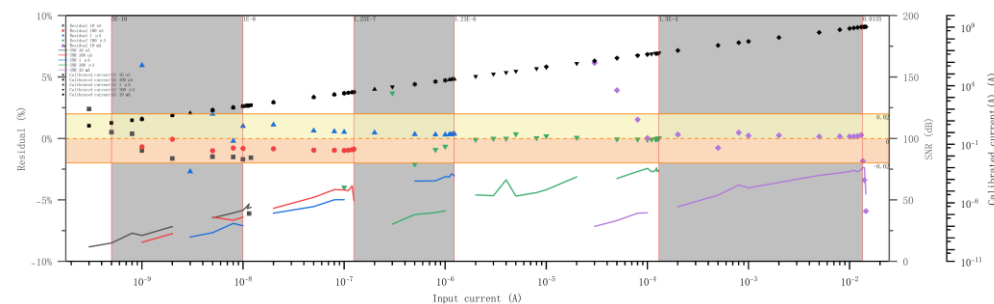


SEM02

Linearity & Strategies

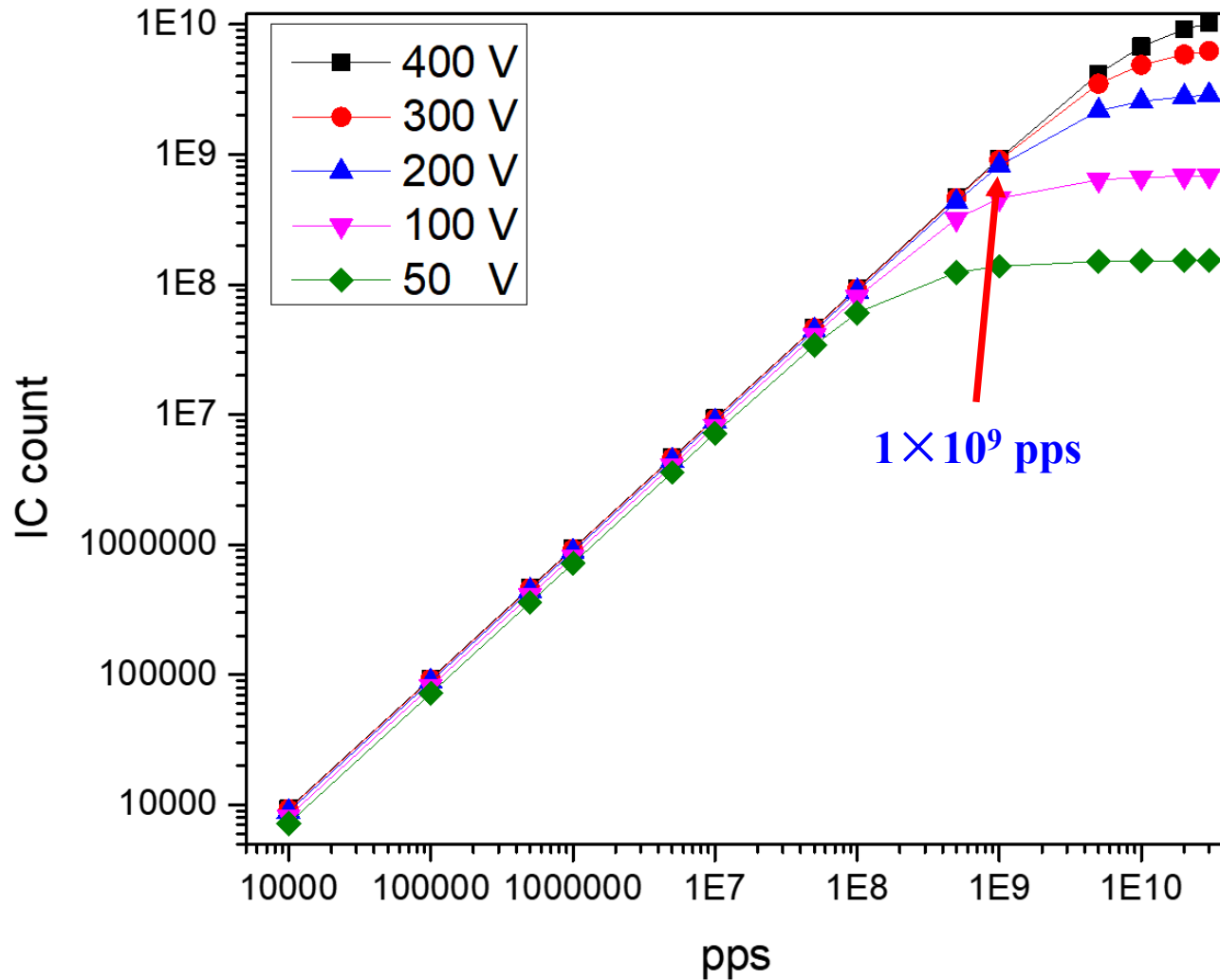


SEM01



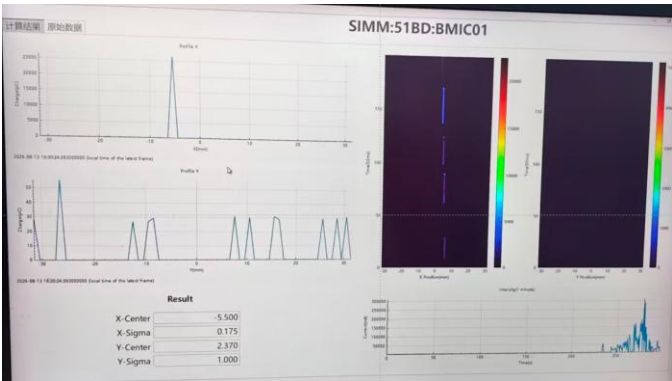
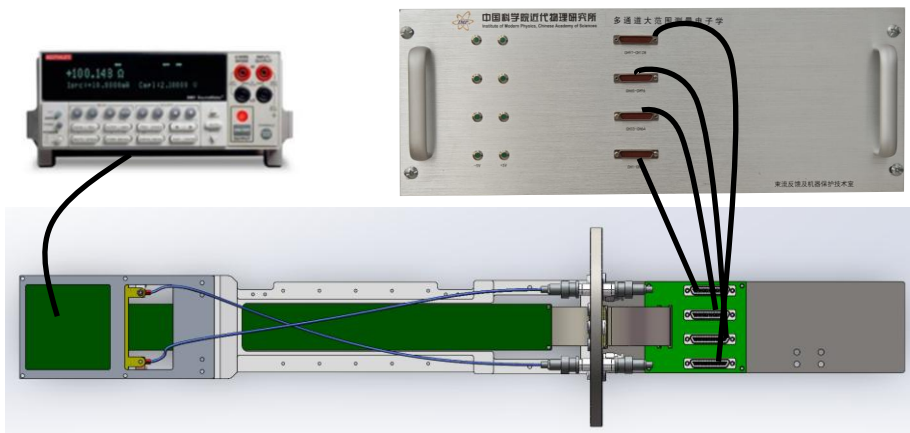
SEM02

IC simulation

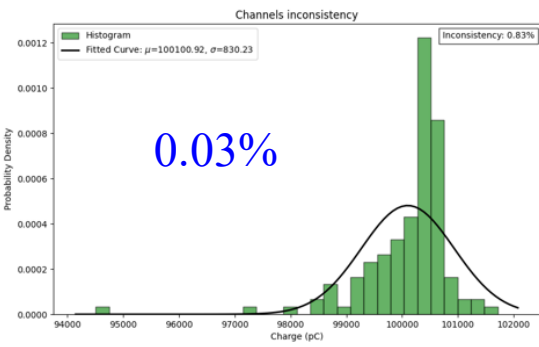


Parameters	Value
Ion	$^{209}_{83}\text{Bi}^{31+}$
Energy	850 MeV/u
Max. intensity	3×10^{10} pps
Gas	Air
Thickness	2 mm
Area	60×60 mm
Voltage	50/100/200/300/400 V

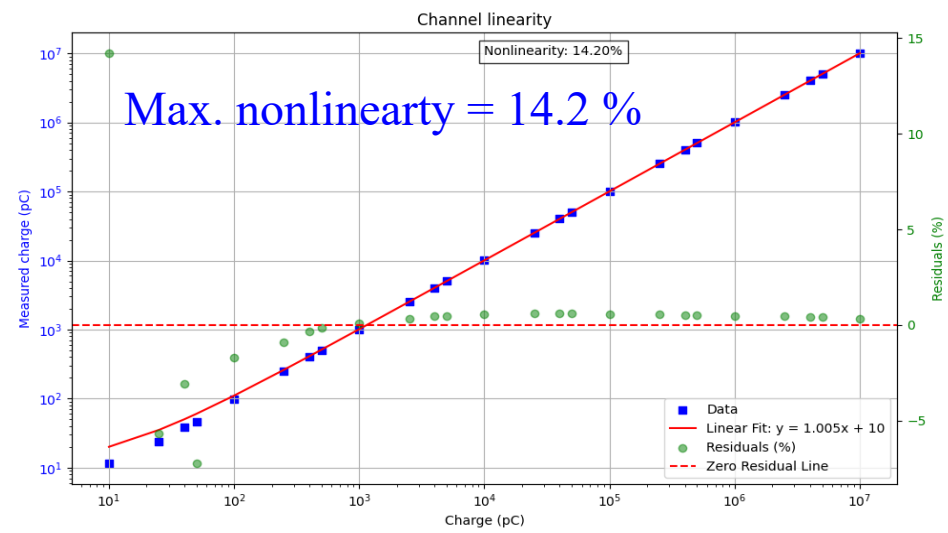
BMIC Test



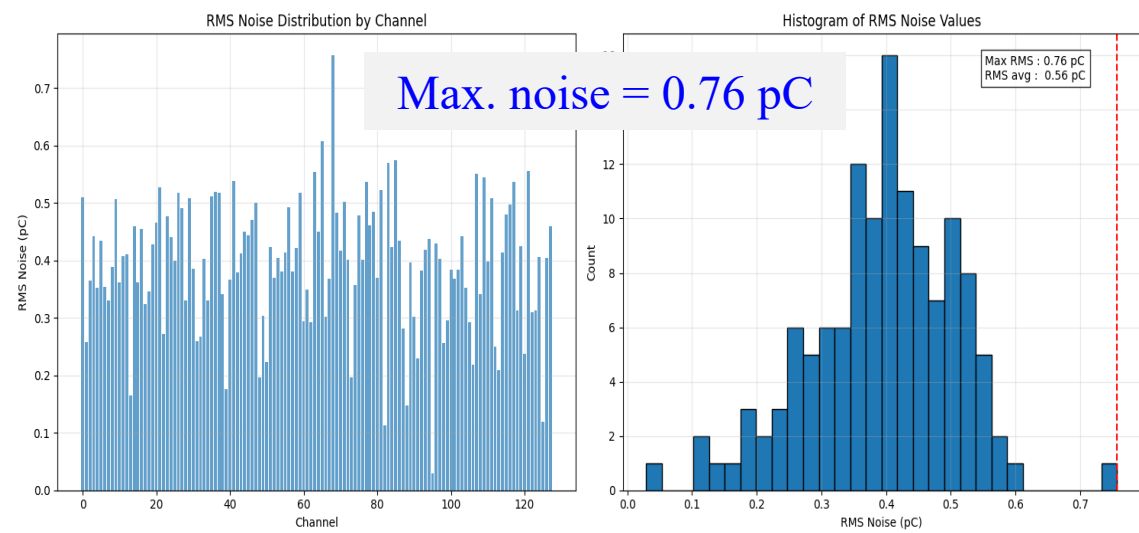
Order & Connection



Channels inconsistency



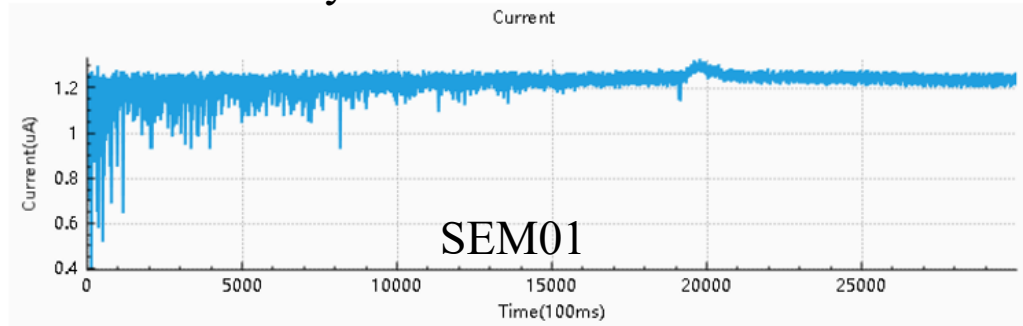
Linearity



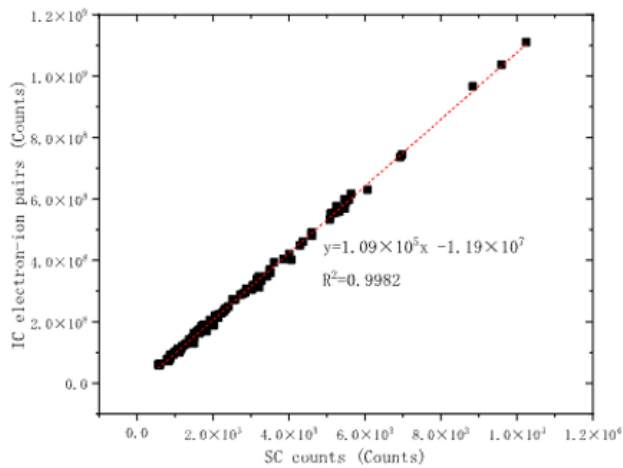
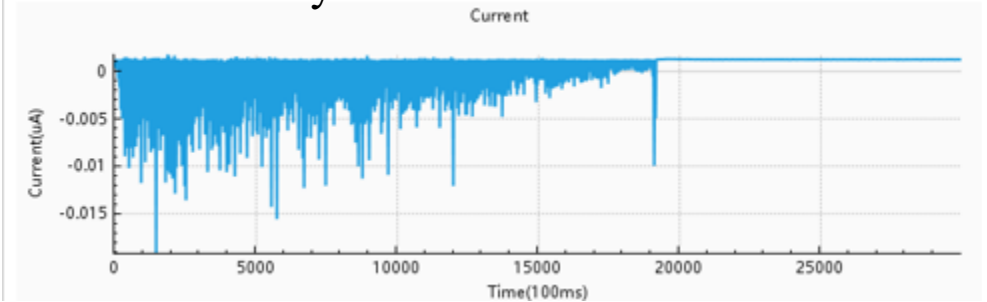
Noise

Beam Tests – Beam Intensity

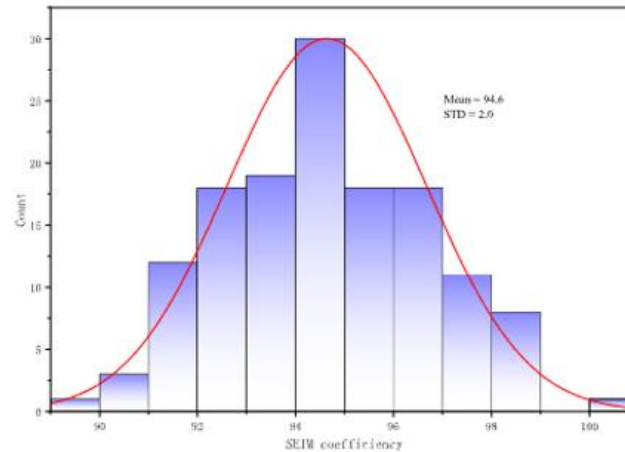
Efficiency: 76.6% Number: 3.5×10^9



Efficiency: 66.9% Number: 1.79×10^8

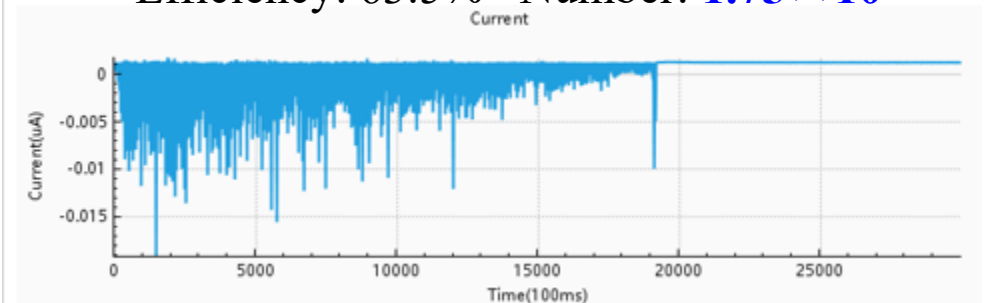


IC calibrated by scintillator



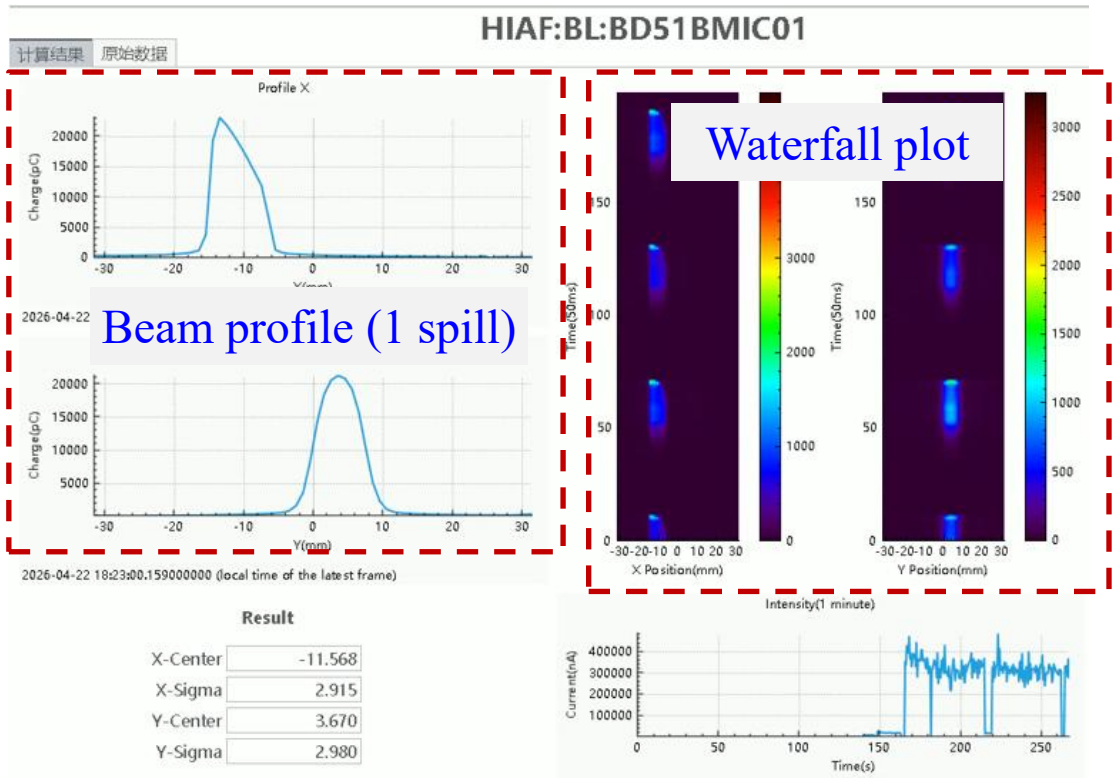
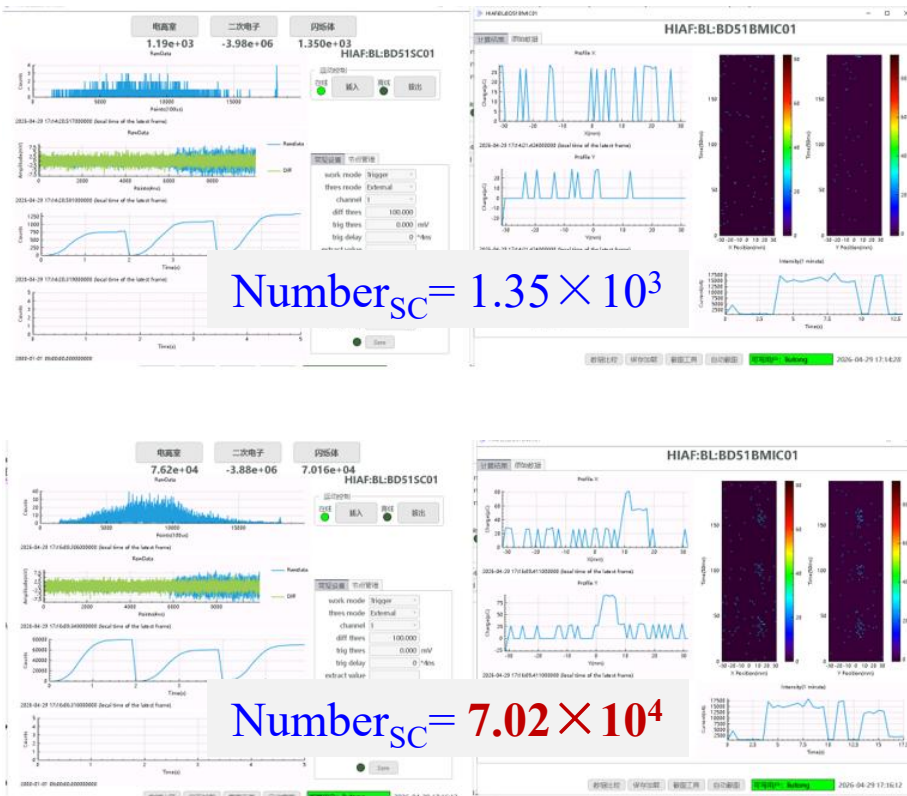
SEM calibrated by IC

Efficiency: 63.5% Number: 1.75×10^8

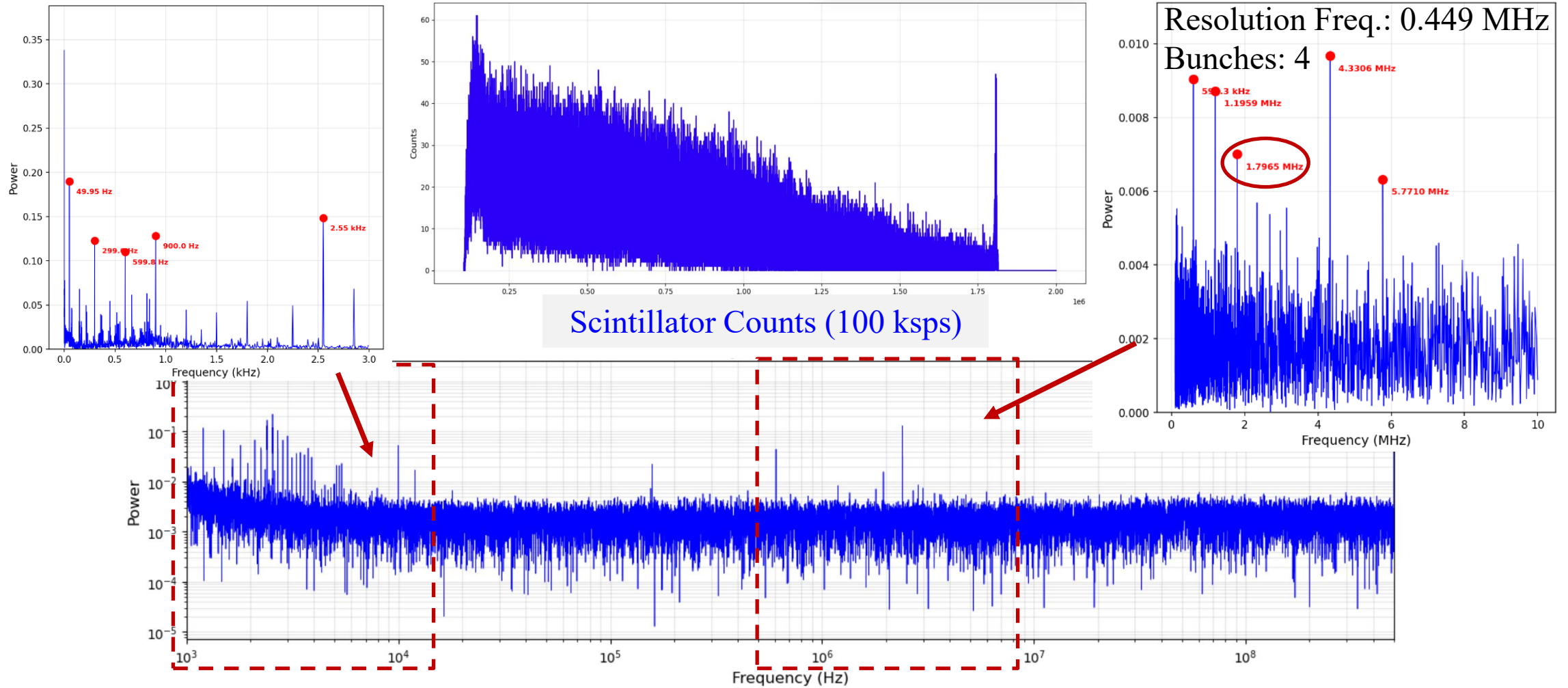


IC

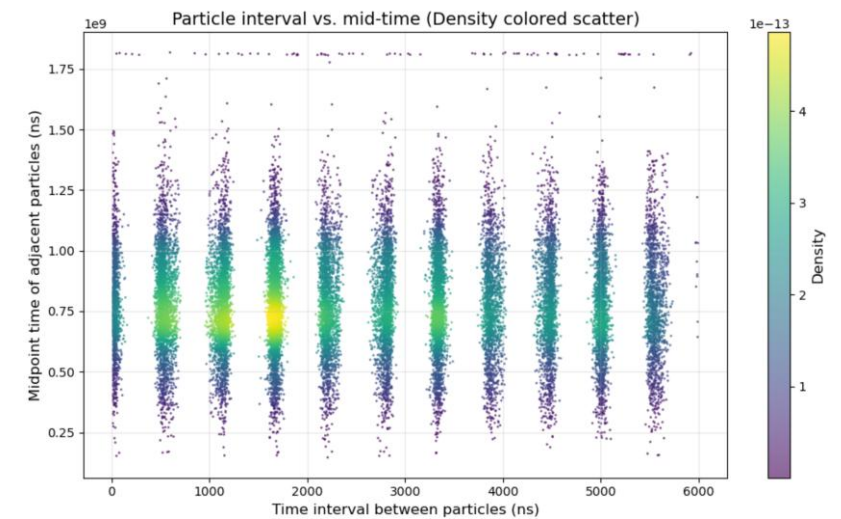
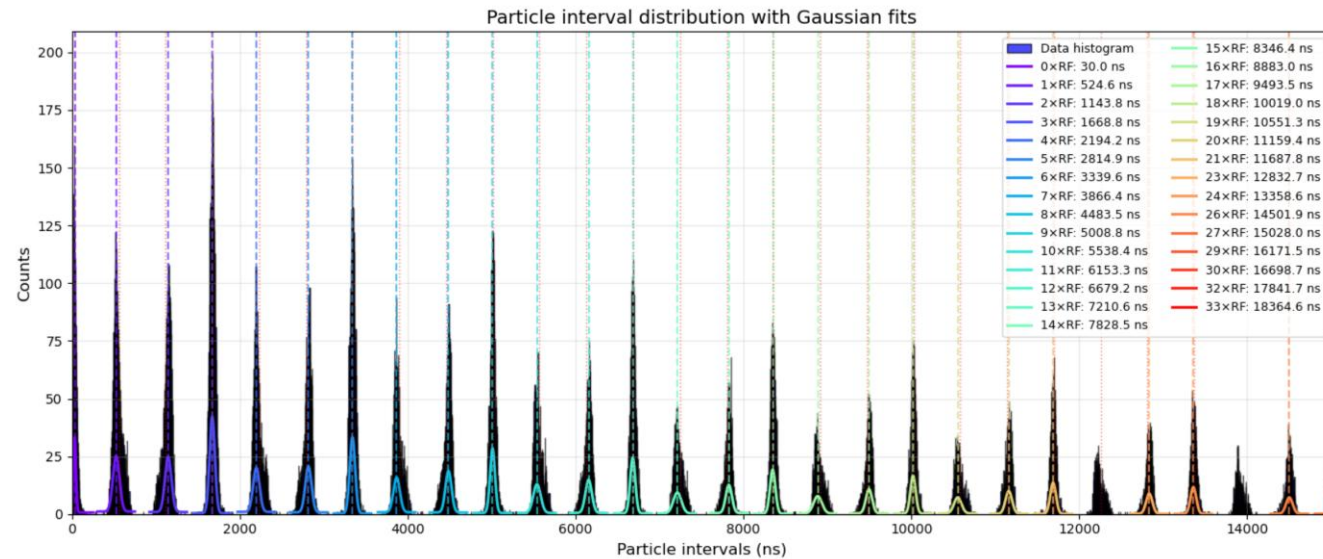
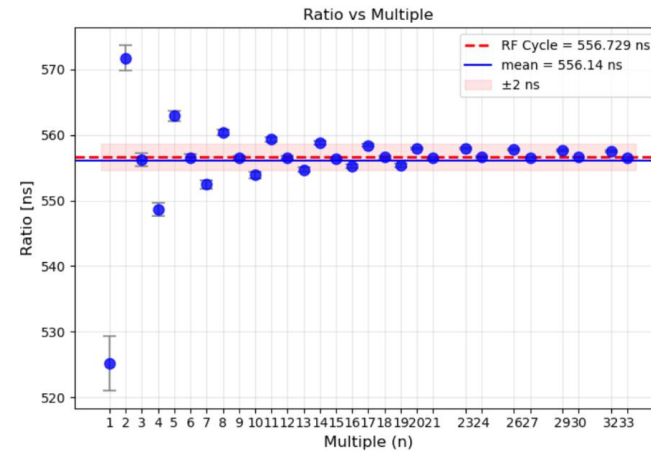
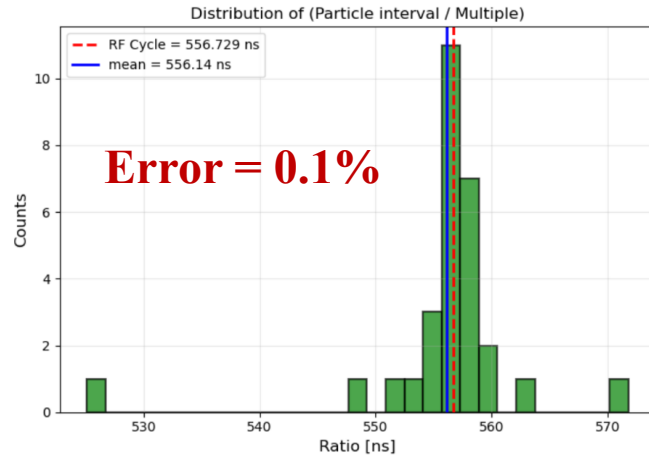
Beam Profile



Micro-structure



Nano-structure



Conclusion

1. ICT with the ability of **nine-order-of-magnitude** for fast extraction.
2. Up to 1.8×10^9 pps for slow extraction.
3. Offline tests: calibration, linearity, noise.
4. Beam profile and the **lower limit of slow extraction**.
5. **Micro-structure and nano-structure** measurements.

Thanks for your listening!

