Heavy ion dosimetry and experiments in CHARM

Part 1: 2018 beam intensity calibration

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https://indico.cern.ch/event/971222

Introduction

- Heavy ions of very-high (0.1-5 GeV/n) and ultra-high (>5 GeV/n) energy are available in few facilities outside CERN (GSI, NSRL).
- Key features for R2E tests: **long range, stable LET**
  → can test in air and without de-lidding the components
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- **Focus of this talk: 2018 Pb ion campaign at CHARM (IEEE 8939371, 2020) - see also A. Coronetti's talk.**
- Not covered: 2018 Pb campaign at SPS-NA, 2017 Xe ion campaigns.

TABLE I
ION SPECIES, TOTAL ENERGY AND VOLUME-EQUIVALENT LET VALUES DURING THE 2017 AND 2018 CERN UHE HEAVY ION TEST CAMPAIGNS

	CHARM		SPS-NA	
	2017 ^{129}Xe	2018 ^{208}Pb	2017 ^{129}Xe	2018 ^{208}Pb
Energy (GeV/nucleon)	6.38	5.49	19-75	150
Volume eq. LET (MeVcm^2/mg)	3.6	8.0	3.7-3.9	8.8

The 2018 CHARM Pb ion campaign

- First R2E campaign with Pb ions at CHARM in 2018 (≈3 weeks):
  - E=5.5 GeV/n (LET ≈ 8 MeV·cm^2·mg^{-1})
  - Spills of ≈200 ms ('slow extraction' from PS) with ≈10^8 ions every 20-40s.
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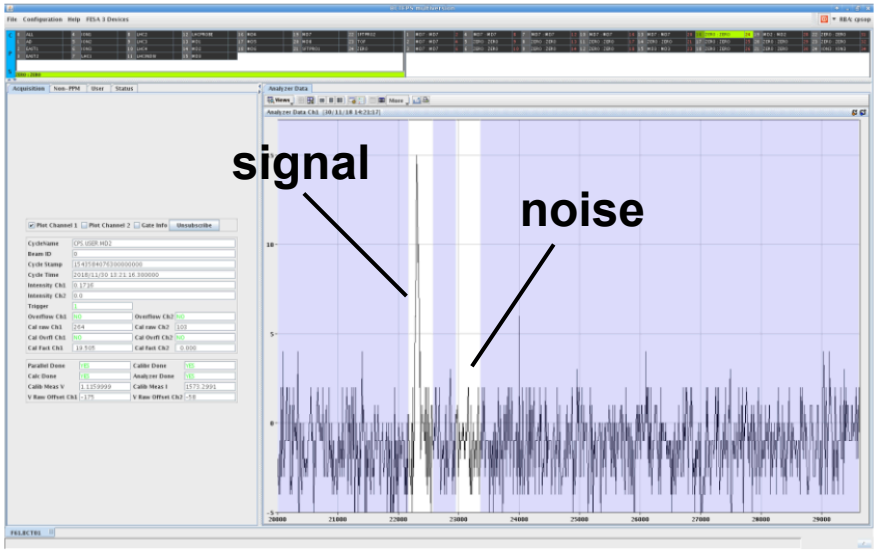
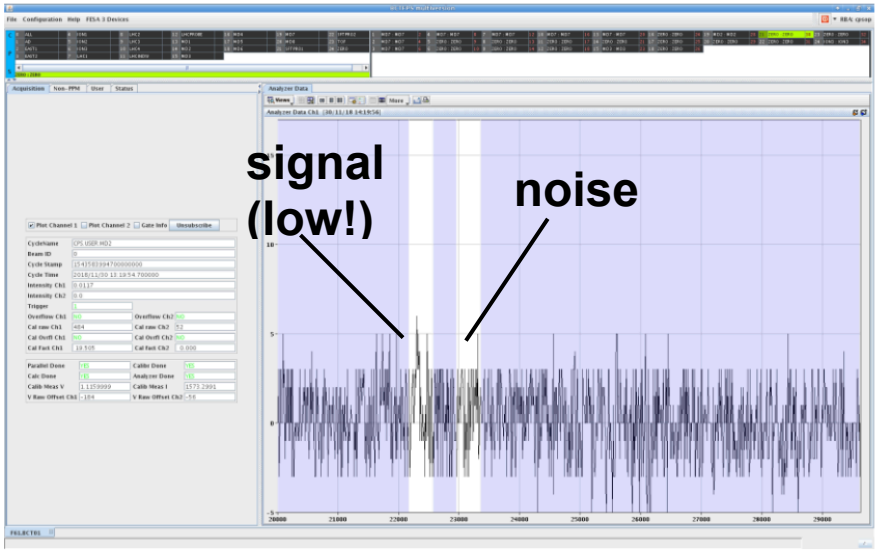
  - Devices typically exposed to the primary beam with variable profile (i.e. width).
- Key beam parameters:
  - **Beam intensity** → measured with a **fast Beam Current Transformer (fBCT)** and two **Secondary Emission Counters (SECs)**.
  - **Beam width** → measured with a Multi-Wire Proportional Chamber (MWPC).

Intensity measurement (1): fBCT





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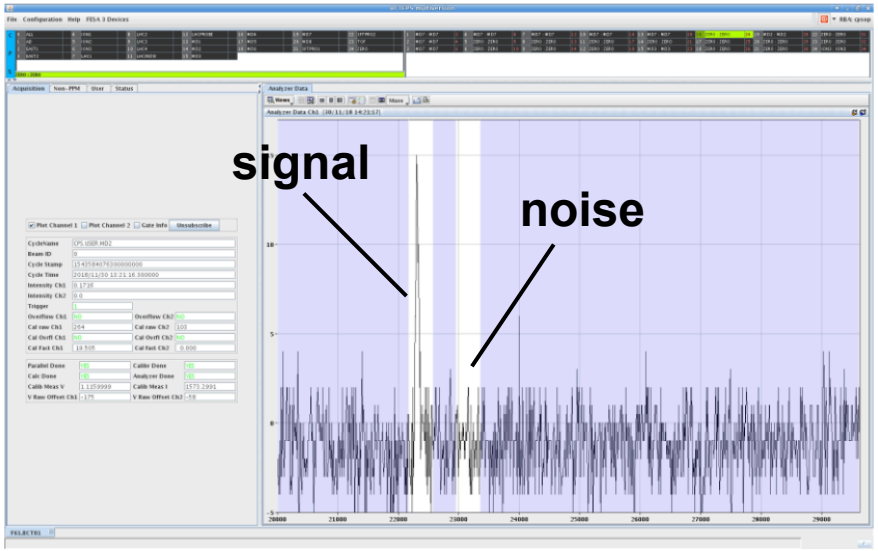
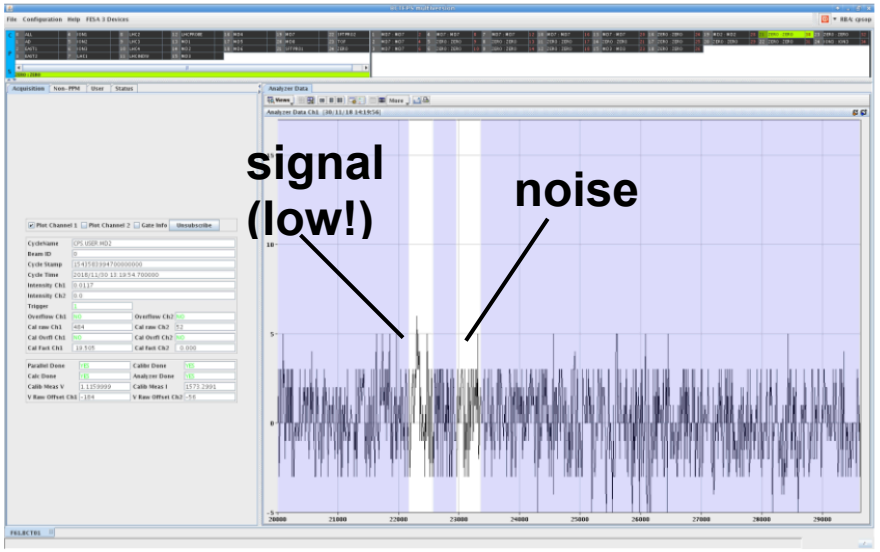


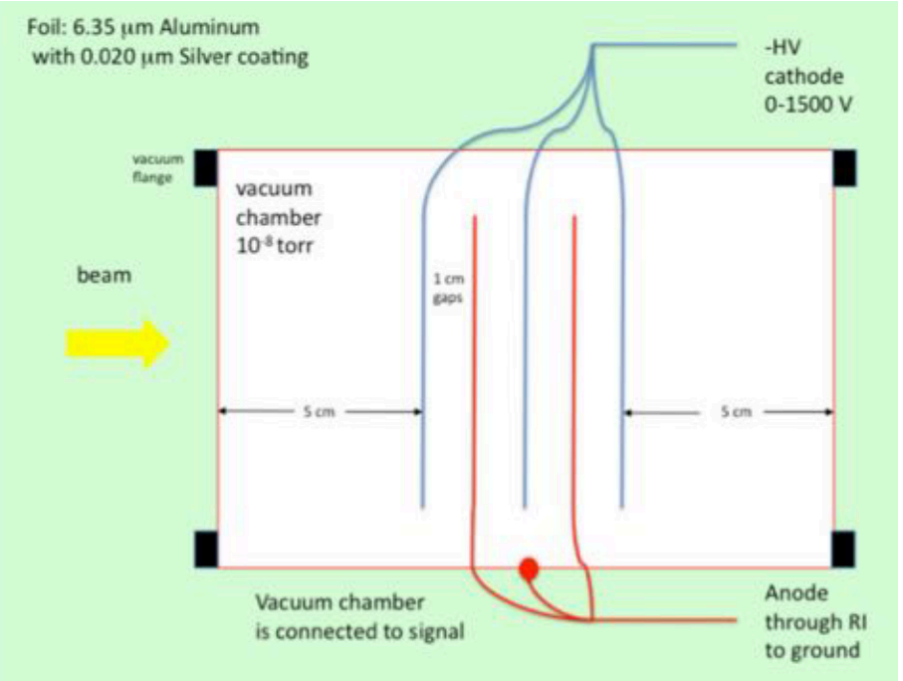


- The **fast Beam Current Transformer (fBCT)** measures the absolute beam intensity by subtracting the current in 'signal' and 'noise' time windows (in- and off-sync with the spill).
- Limitations:
  - Low signal/noise ratio → large uncertainties.
  - Only working for fast extraction (spill duration < 1μs)
    → requires dedicated calibration runs.

Intensity measurement (2): SEC counters

- The Secondary Emission Counters (SECs) measure the beam intensity by counting the electrons emitted by the passage of the beam through thin foils.

S. Bonaldo Master thesis



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$$I = r \cdot N_{SEC}$$

Beam intensity

r coefficient, to be computed for Pb ion beams.

Number of SEC counts

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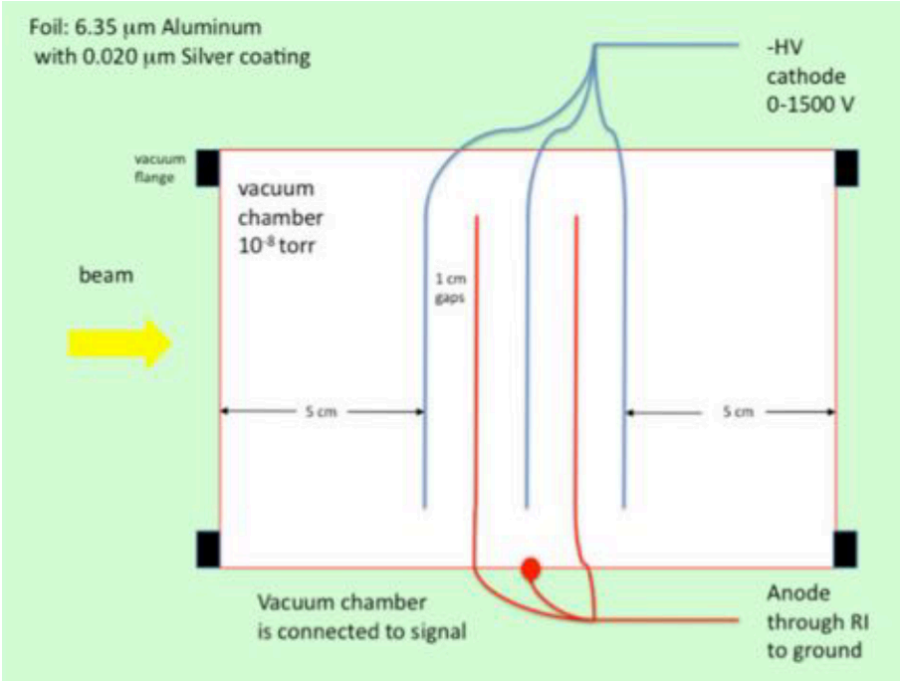

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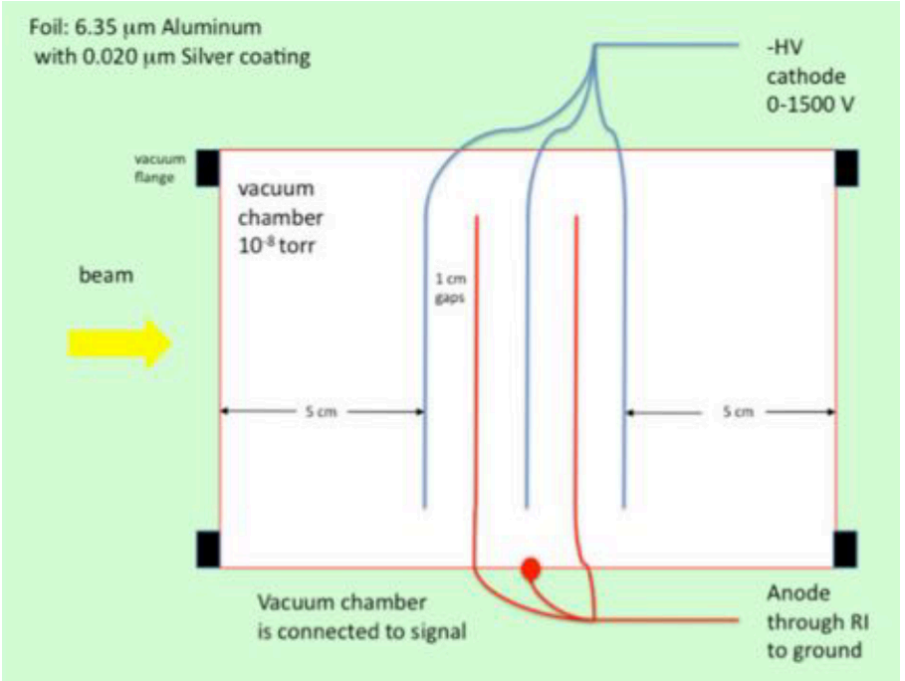
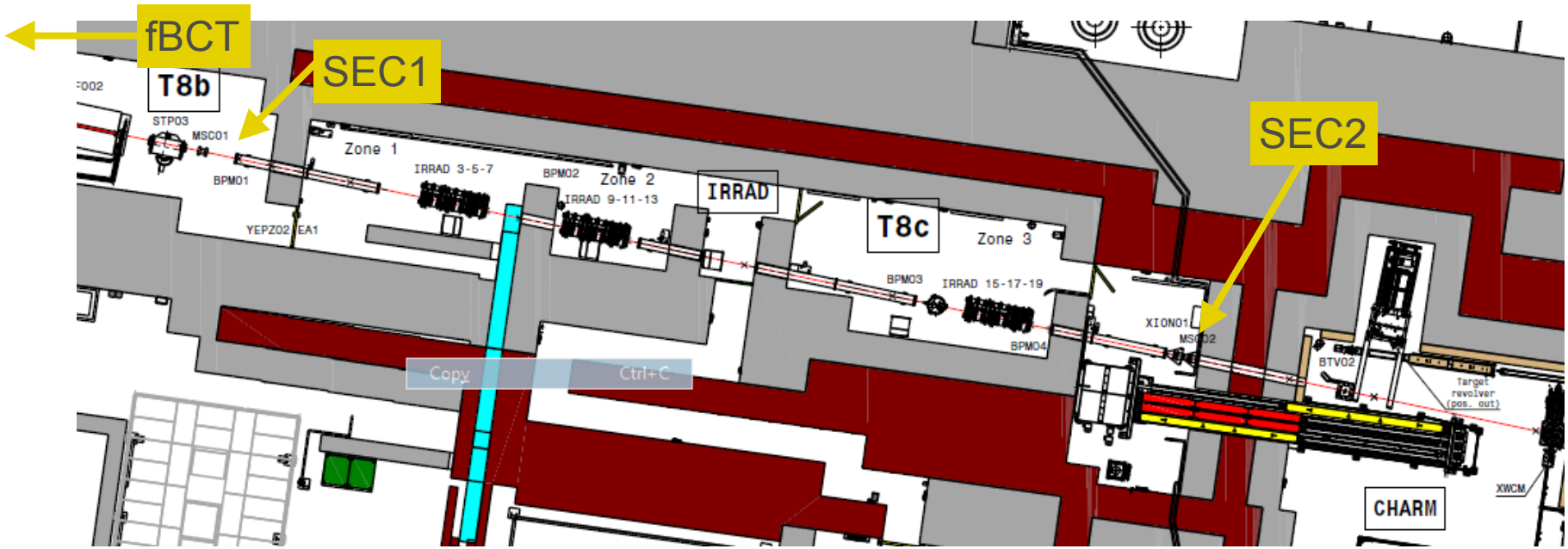
- They work for both fast and slow extraction (not necessarily with identical efficiency)

S. Bonaldo Master thesis



IRRAD-CHARM layout

- Position of SEC1 and SEC2 upstream and downstream of IRRAD on the CHARM beam line.
- The fBCT is placed further upstream along the beamline.



Intensity calibration: fast and slow extraction

- Approach to beam intensity measurement:
  1. Measure the SEC calibration factors (i.e. r-coefficients) during calibration periods with fast beam extraction.
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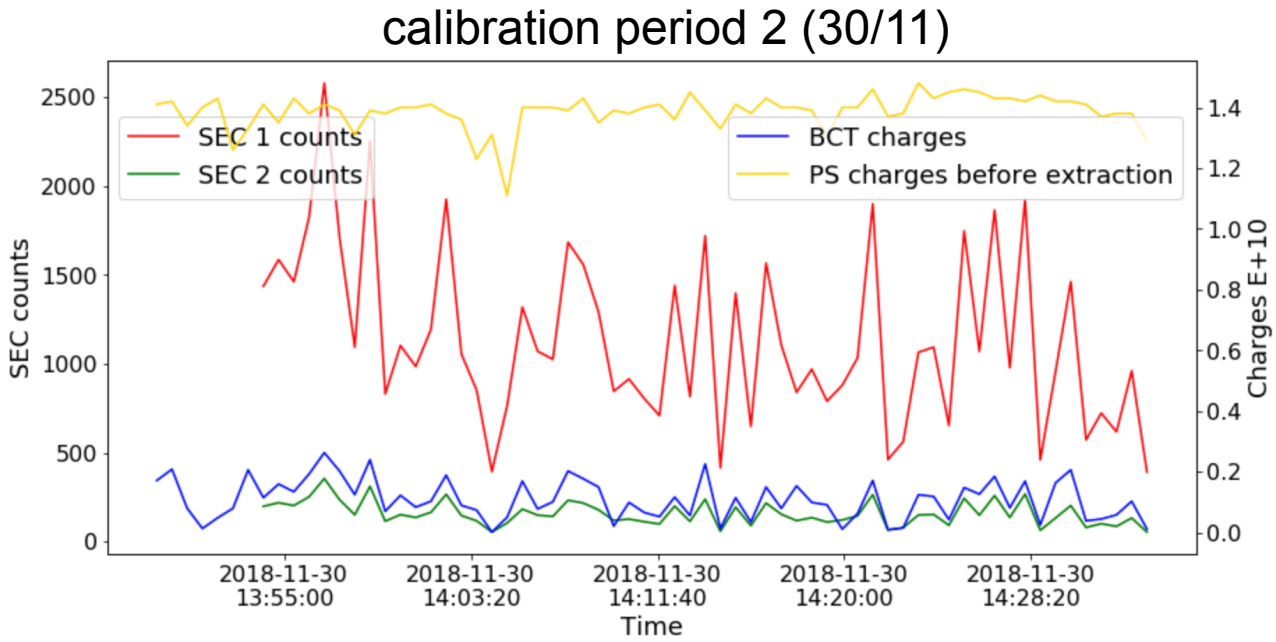
- Two calibration periods:
  - 1 (13/11)
  - 2 (30/11)
- $N_{ions} = N_{charges}/82$ for fully-stripped Pb ions.

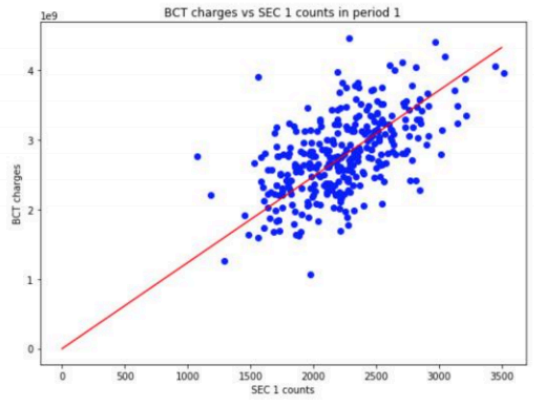


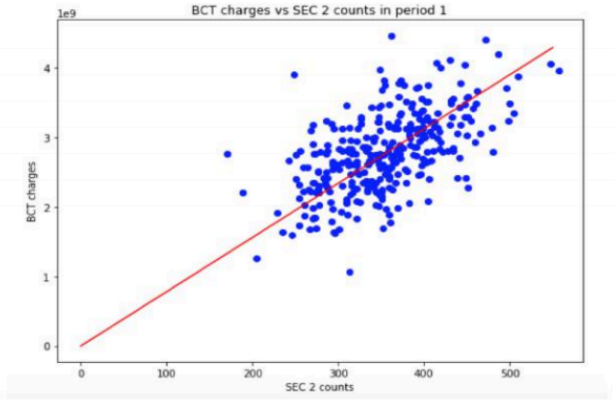
Intensity calibration: results

- Visible correlation between BCT charges and SEC1-2 counts, despite the large BCT uncertainty.

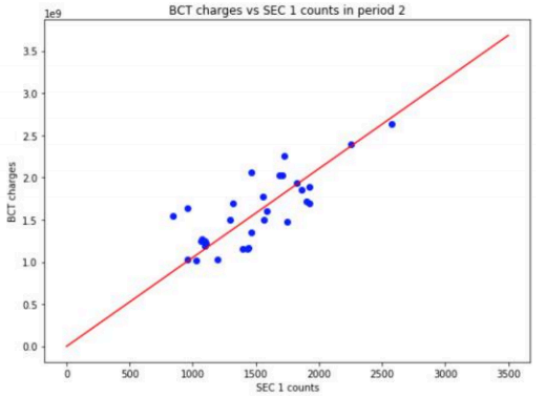
SEC1 SEC2

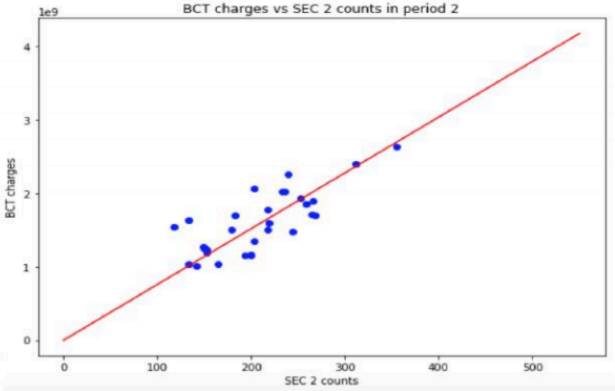
period 1





period 2





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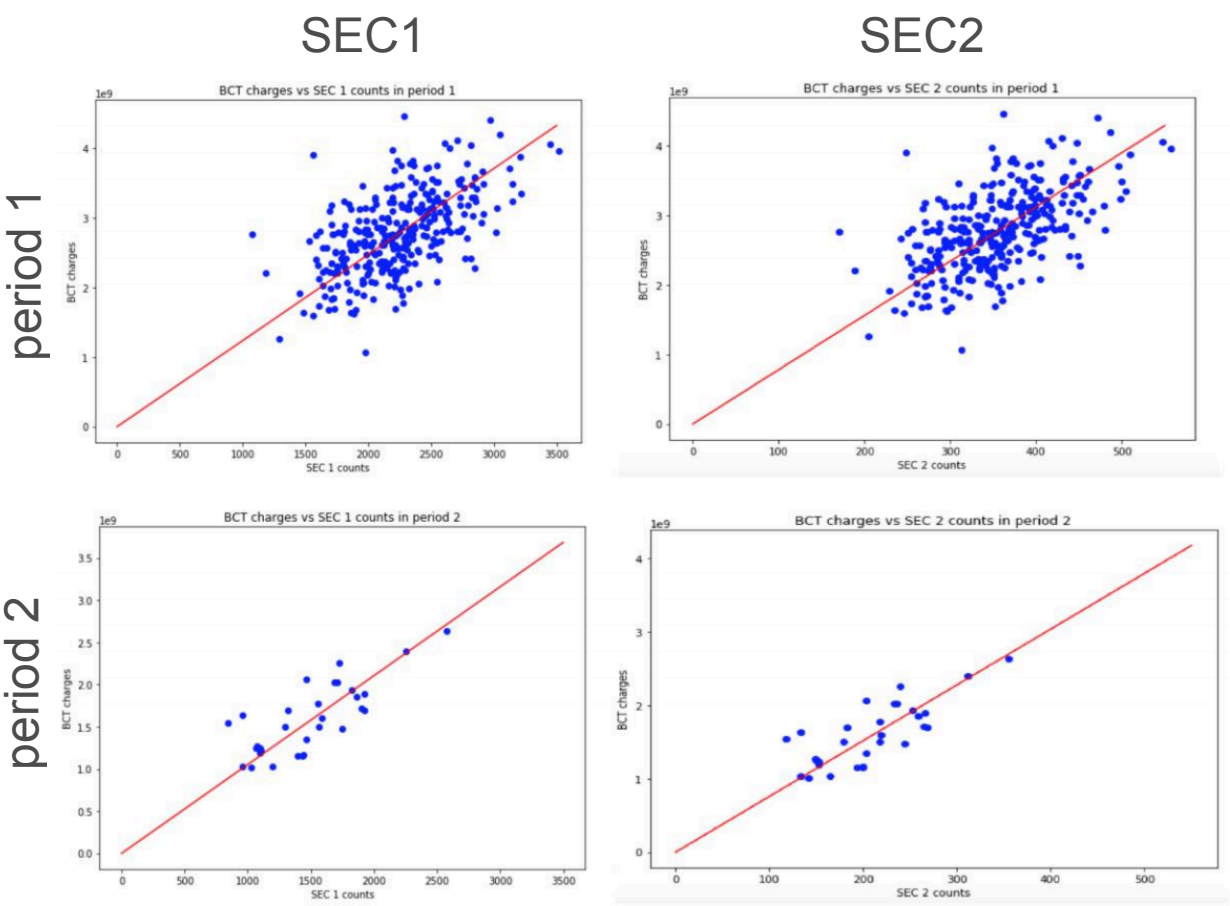
Calibration Factors

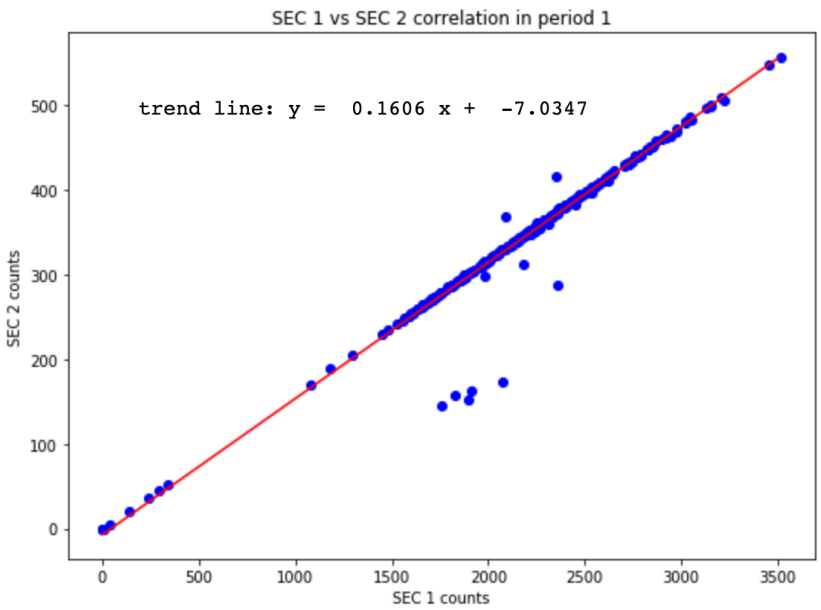
- SEC1
  - **1.23E6** fBCT charges/SEC counts (13/11/18)
  - **1.05E6** fBCT charges/SEC counts (30/11/2018)
- SEC2
  - **7.80E6** fBCT charges/SEC counts (13/11/18)
  - **7.60E6** fBCT charges/SEC counts

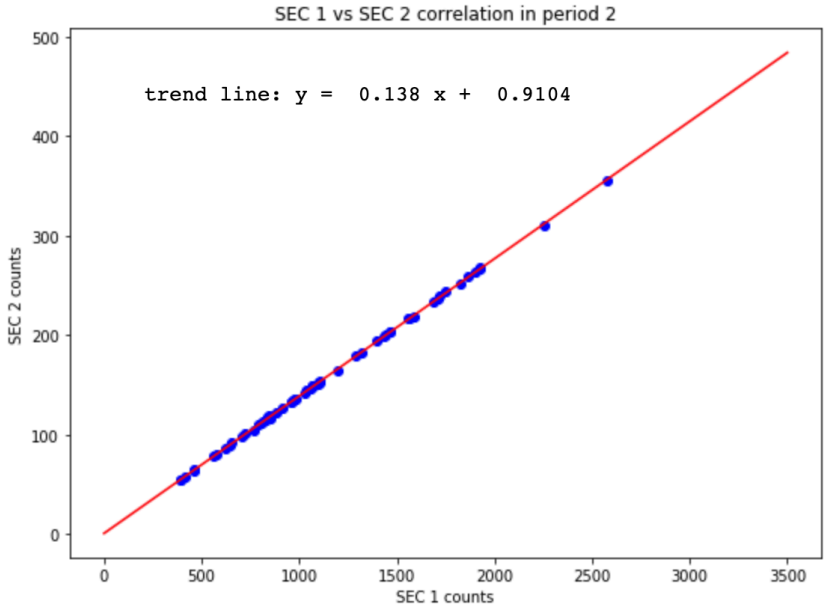
given to users



- Period 1-2 coefficients consistent within <20%

SEC1-2 correlation and beamline transmission





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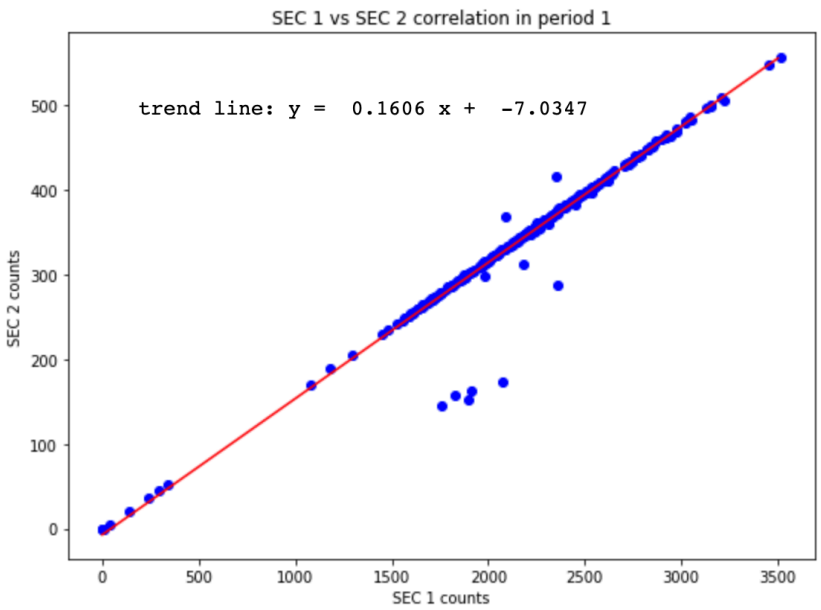

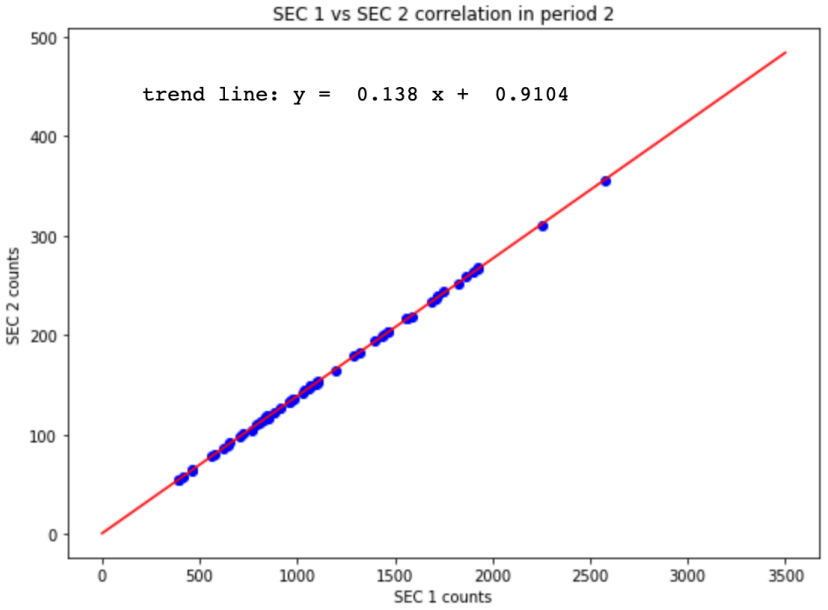

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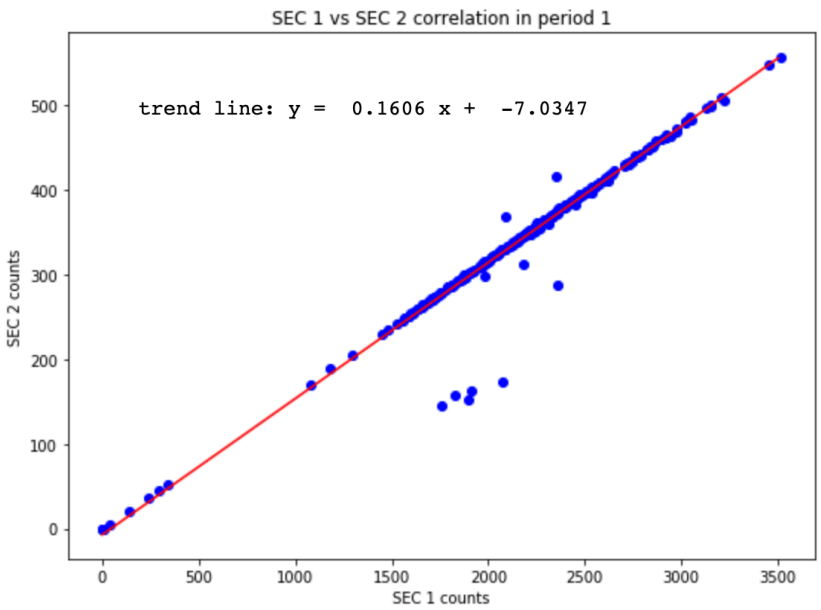
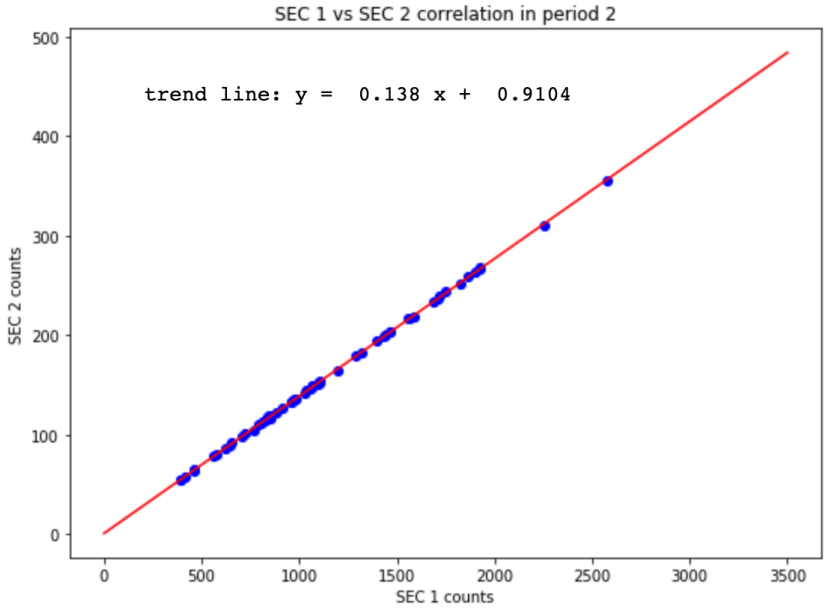
SEC1-2 correlation and beamline transmission





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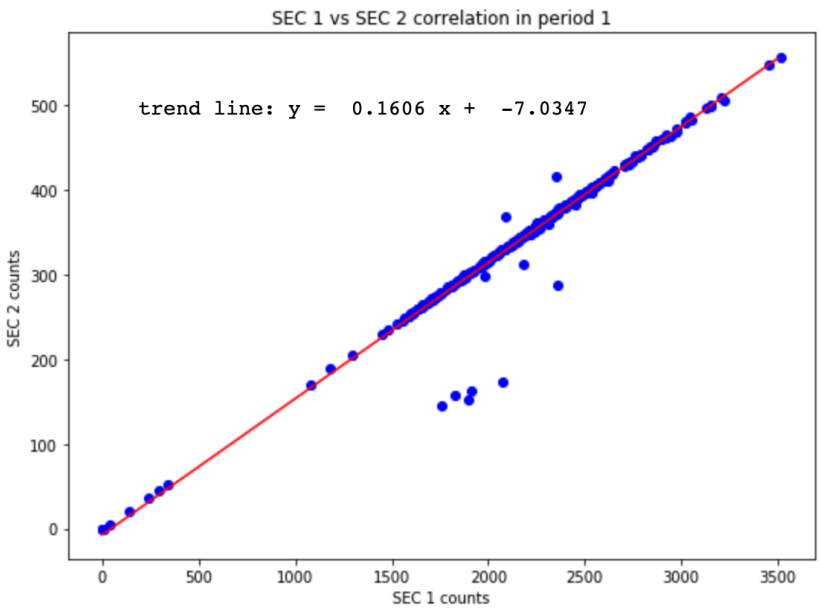

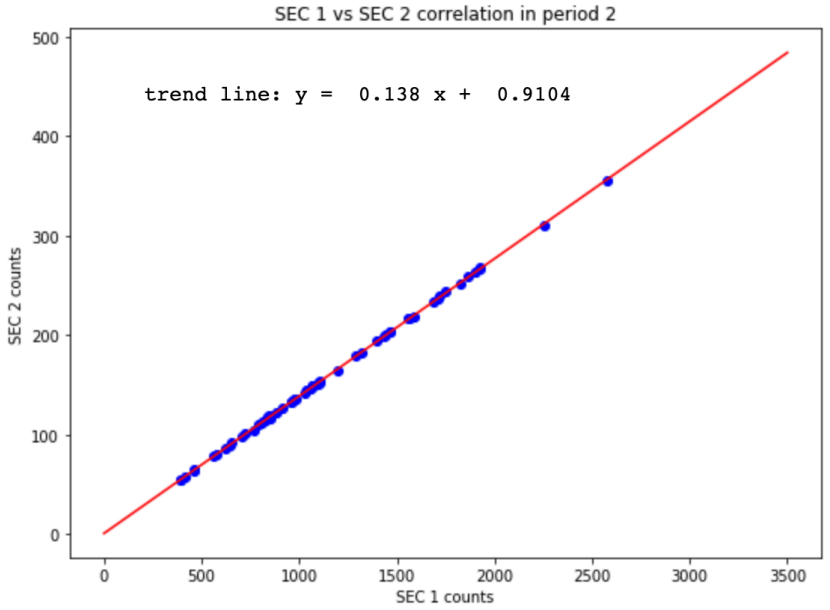

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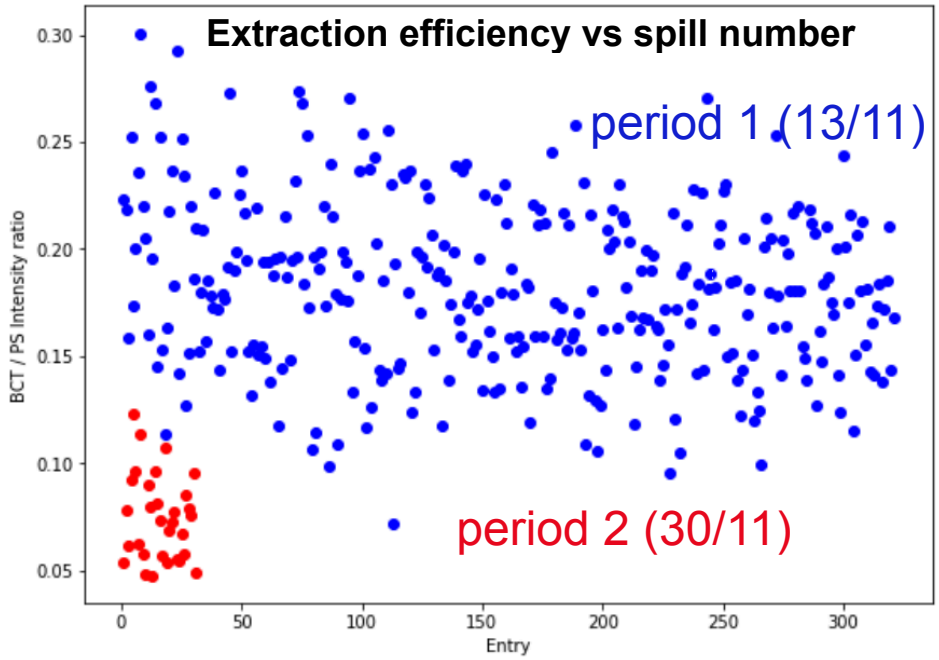
➡Possible explanation: the **beamline transmission** changes with beam properties (e.g width).

PS extraction efficiency

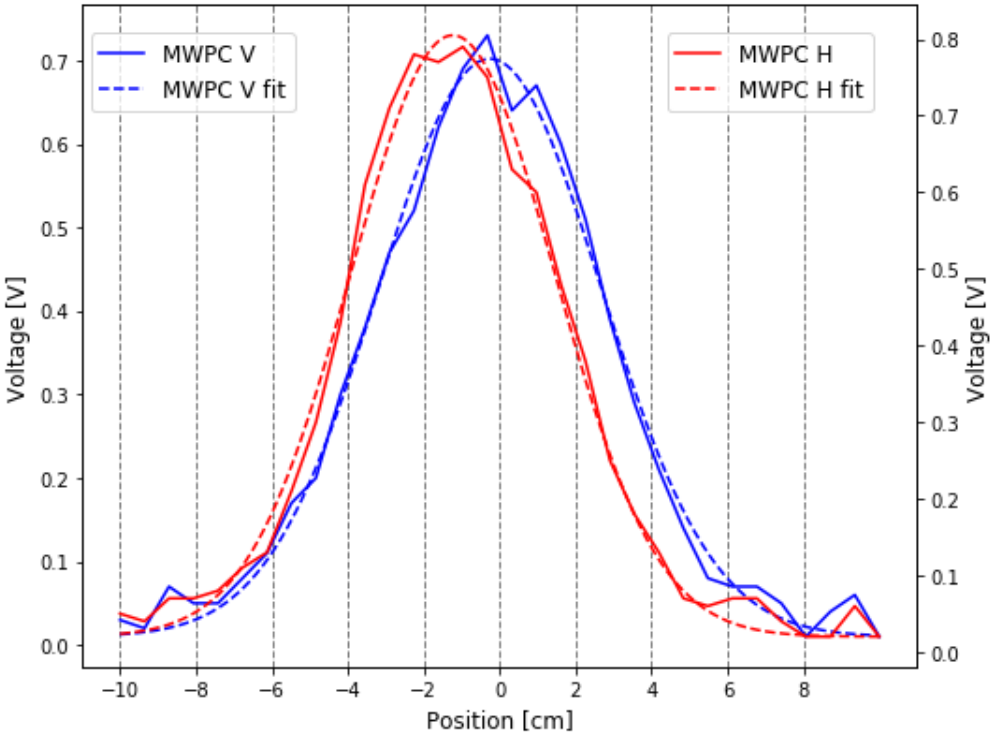
- Ratio of the fBCT measurement in the CHARM beamline and the PS intensity before extraction.
- Using ion charge states:
  - PS: 54+
  - East area: 82+



- Large fluctuations due to fBCT measurement uncertainties.
- Different average efficiencies with different beam settings.
- Further investigations are needed to better understand the observed patterns.

Beam profile measurements: the MWPC

- **Multi Wire Proportional Chamber (MWPC)** to measure the beam profile in front of the devices under test.
- Gaussian fit to extract the **beam center** and the **Full Width Half Maximum (FWHM)** in the horizontal and transverse planes.



- Typical FWHM values in the **4.5-9cm range** in different periods.

ESA monitor cross section at CHARM

- The measurement of the ESA monitor SEU cross section uses as input:
  - beam intensity
  - beam width (to measure the beam fraction on the monitor surface)
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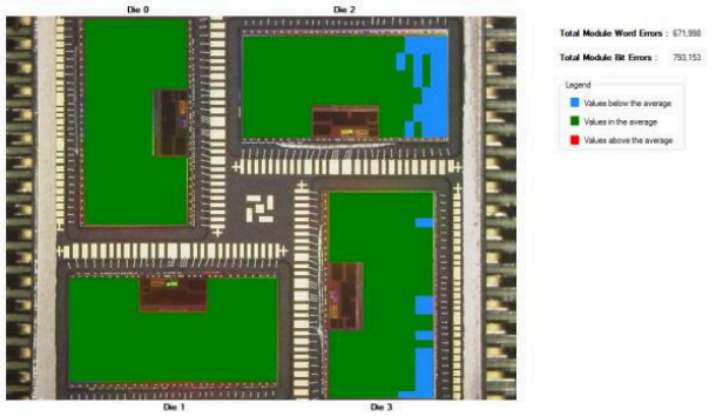

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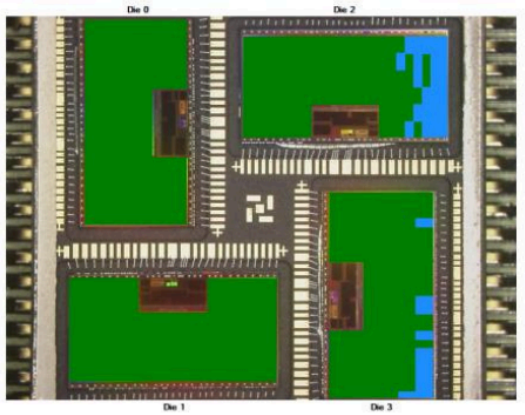
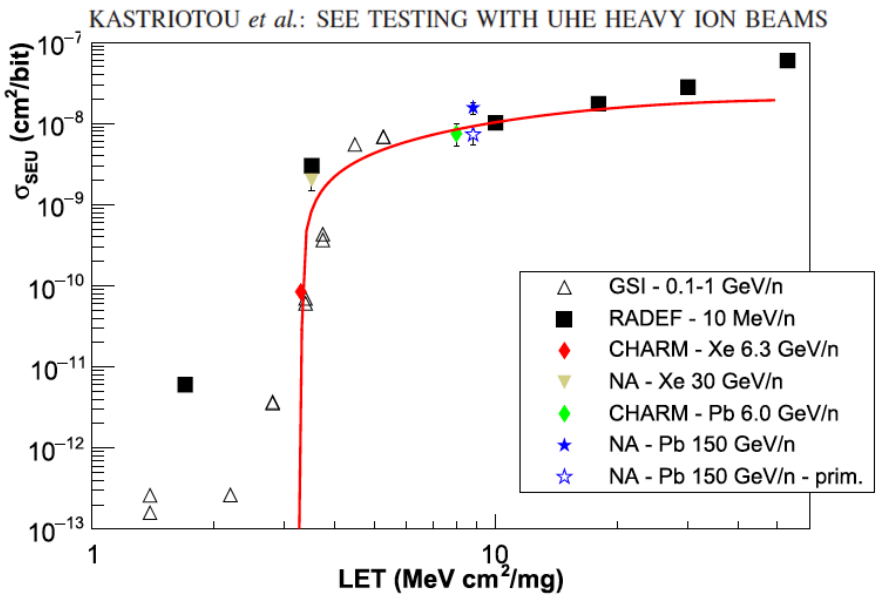
- **Result: σ_{SEU} = 6·10^{-9} cm^2/bit**
- Consistent with expected LET dependence, serving as validation of the beam intensity calibration.





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  - Possible difference in SEC response in fast and slow spills.

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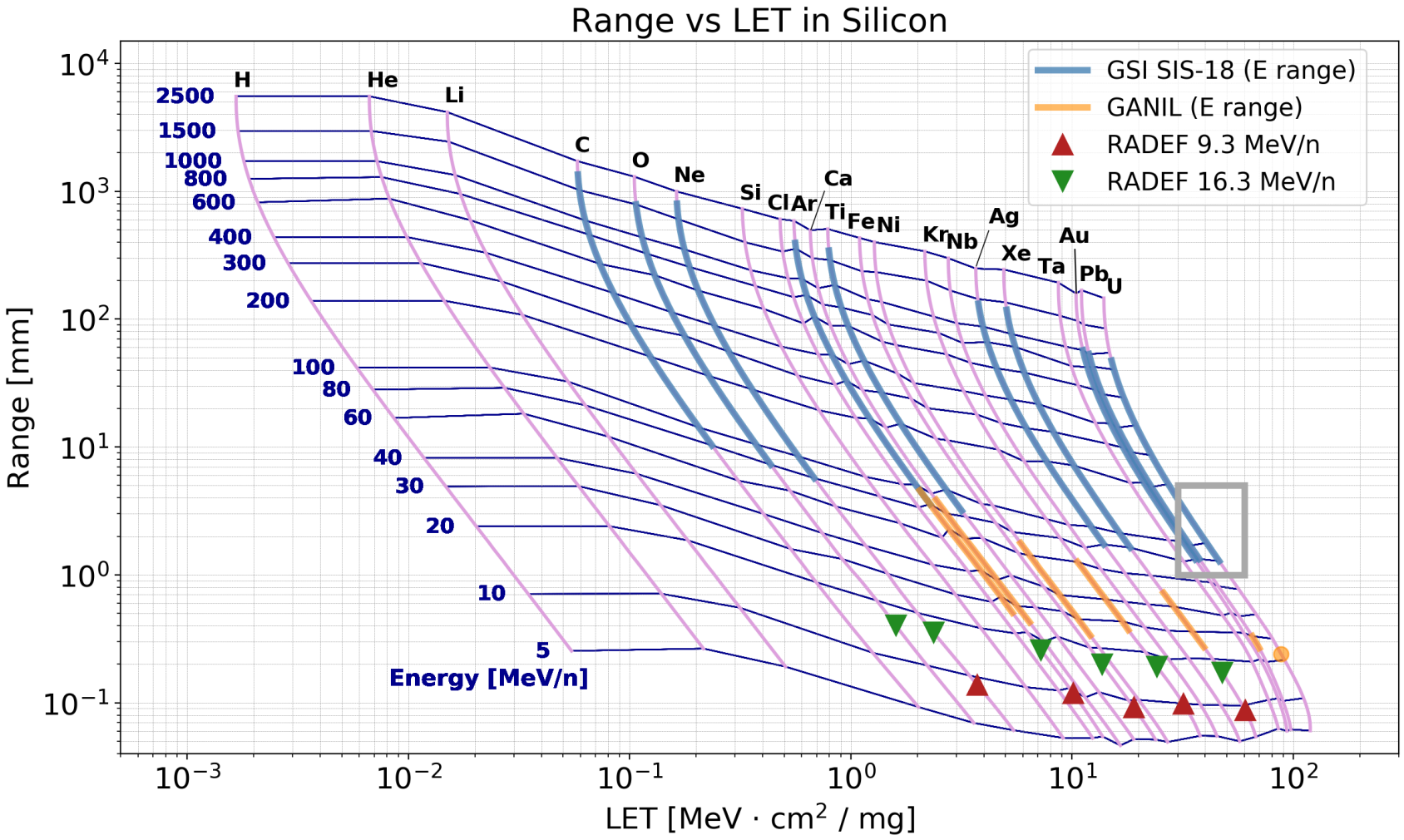
  - Tuning of beam profile, up to e.g. 20x20cm.

BACKUP

Heavy ion range vs LET



Calibration period 1 (13/11)