PEPITES

Measurement of secondary electron emission rates from ultrathin gold foil bombarded by protons at intermediate energies for the development of PEPITES, an ultra-thin beam monitor for hadron therapy.

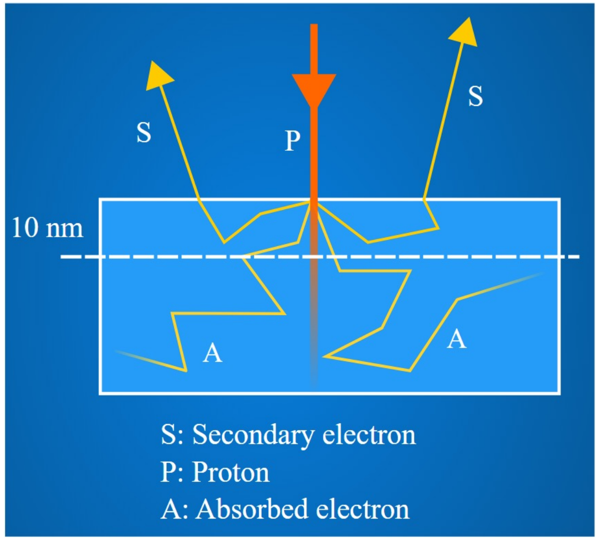
Tingzhen Xiao
Supervisor: Christophe Thiebaux
Co-supervisor: Alexandre Esper

Context

- **Hadron therapy**: Cancer treatment with hadron beams at intermediate energy (about 100 MeV).
- **Goal**: Continuous monitoring, minimal beam disturbance.
- **Innovative Monitor**: Ultra-thin, radiation-resistant for mid-energy accelerators.

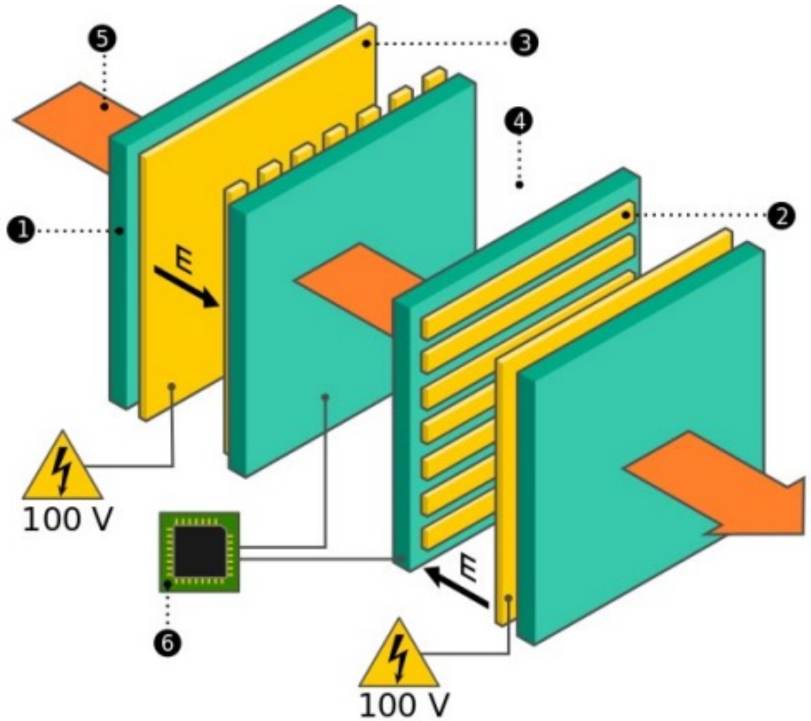
Principle

- **Signal**: Utilizes Secondary Electron Emission (SEE) for precise beam profiling which proportional to dE/dx of the charged beam particles since it is a **surface phenomenon**.
- **Design**: 50 nm Gold as electrodes, since its high Z(79) produces large number of SEE. Proton beam sensitivity, non-oxidizing.
- **Substrate:** 1.5 µm CP1 (colorless polyimide) membranes. High radiation tolerance.



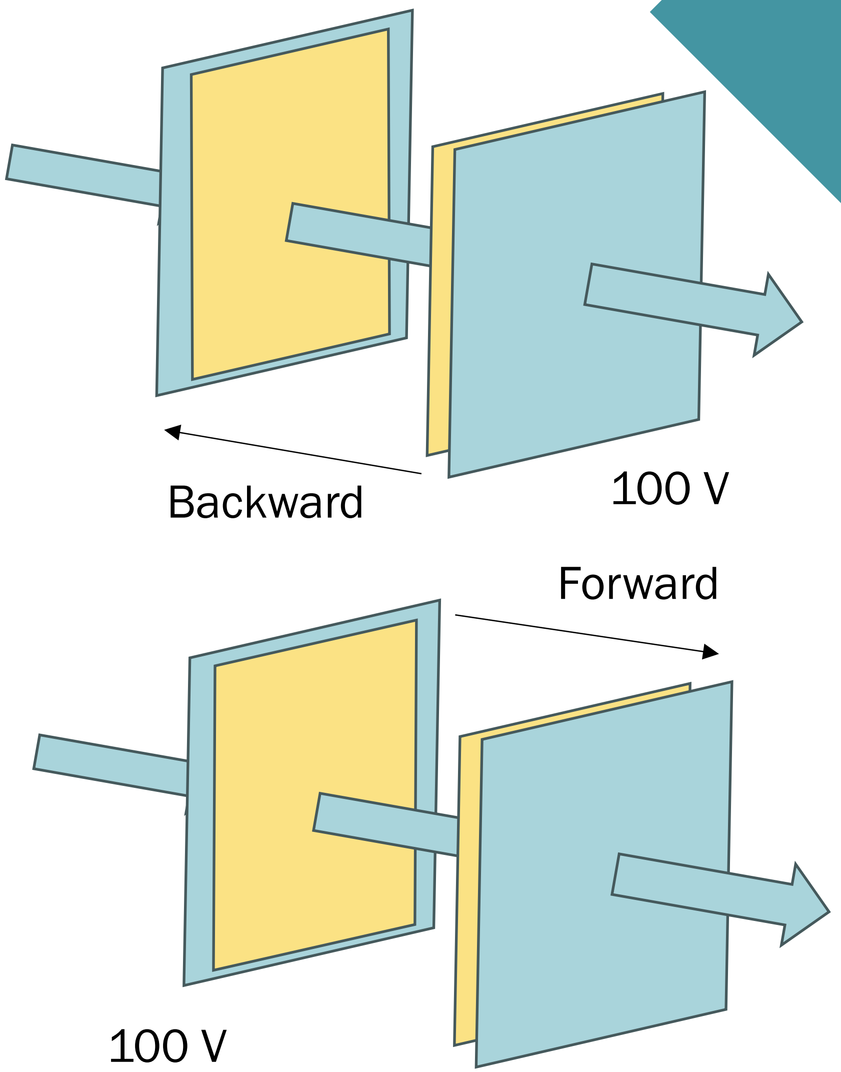
PEPITES Layout

- **Four Electrodes Design**: Two segmented cathodes, two anodes, 15 mm gap.
- **SEE Collection**: Anodes biased at 100 V.
- **Sensitive areas**: 32 gold strips for cathodes, fully metallized anodes.
- **Mechanically Independent Blocks**: For X and Y beam position and shape measurements..

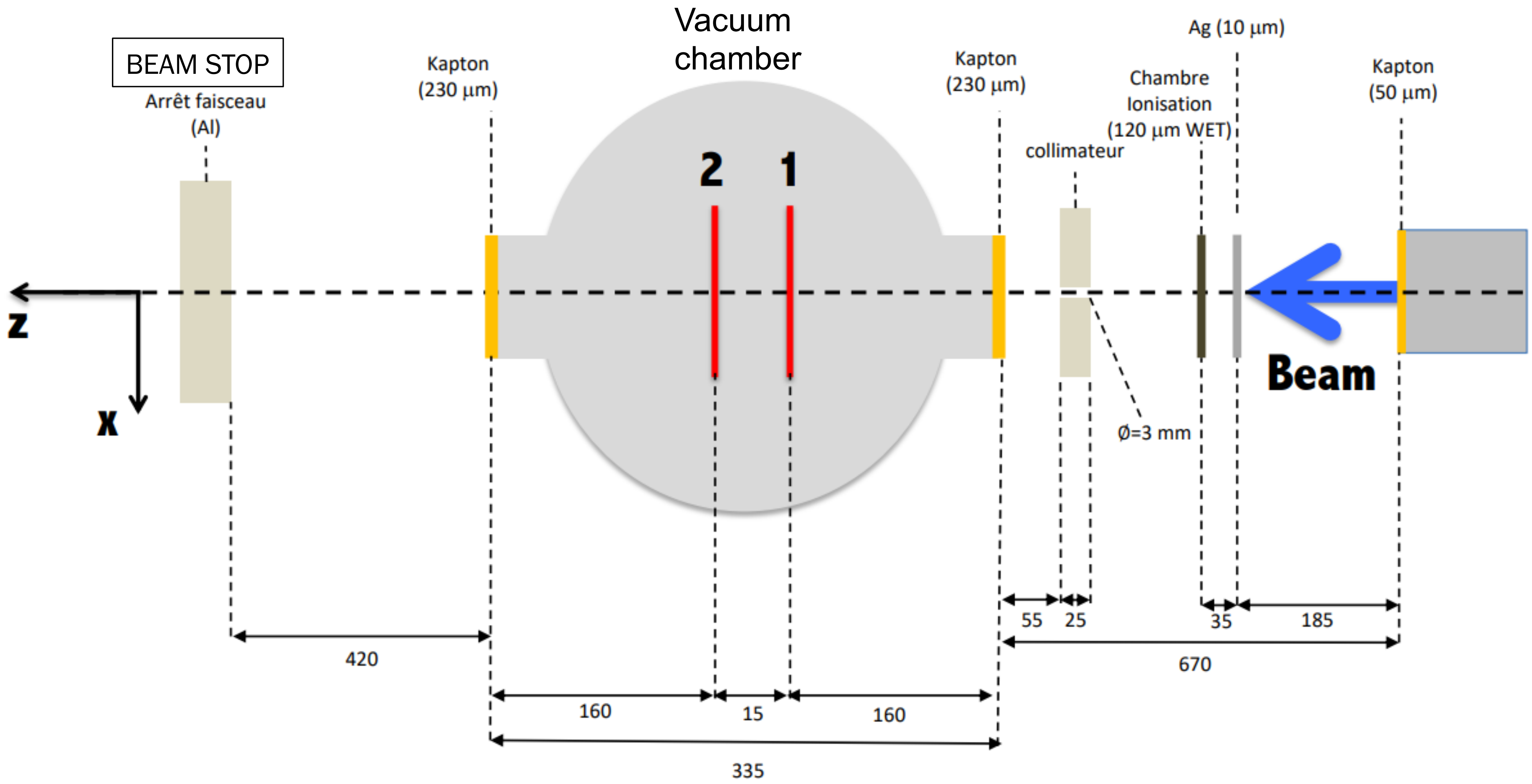


My Work—Measure SEE Rate

- **Why?** To calibrate the detector and for further development of PEPITES.
- Calculate with the test beam data from 13 and 14 December 2018 at ARRONAX.
- Electron going the same direction of the beam=**Forward**
- Electron going opposite direction of the beam=**Backward**
- **No measurement available for E>20MeV.**
- **Rate = Nse/Np**



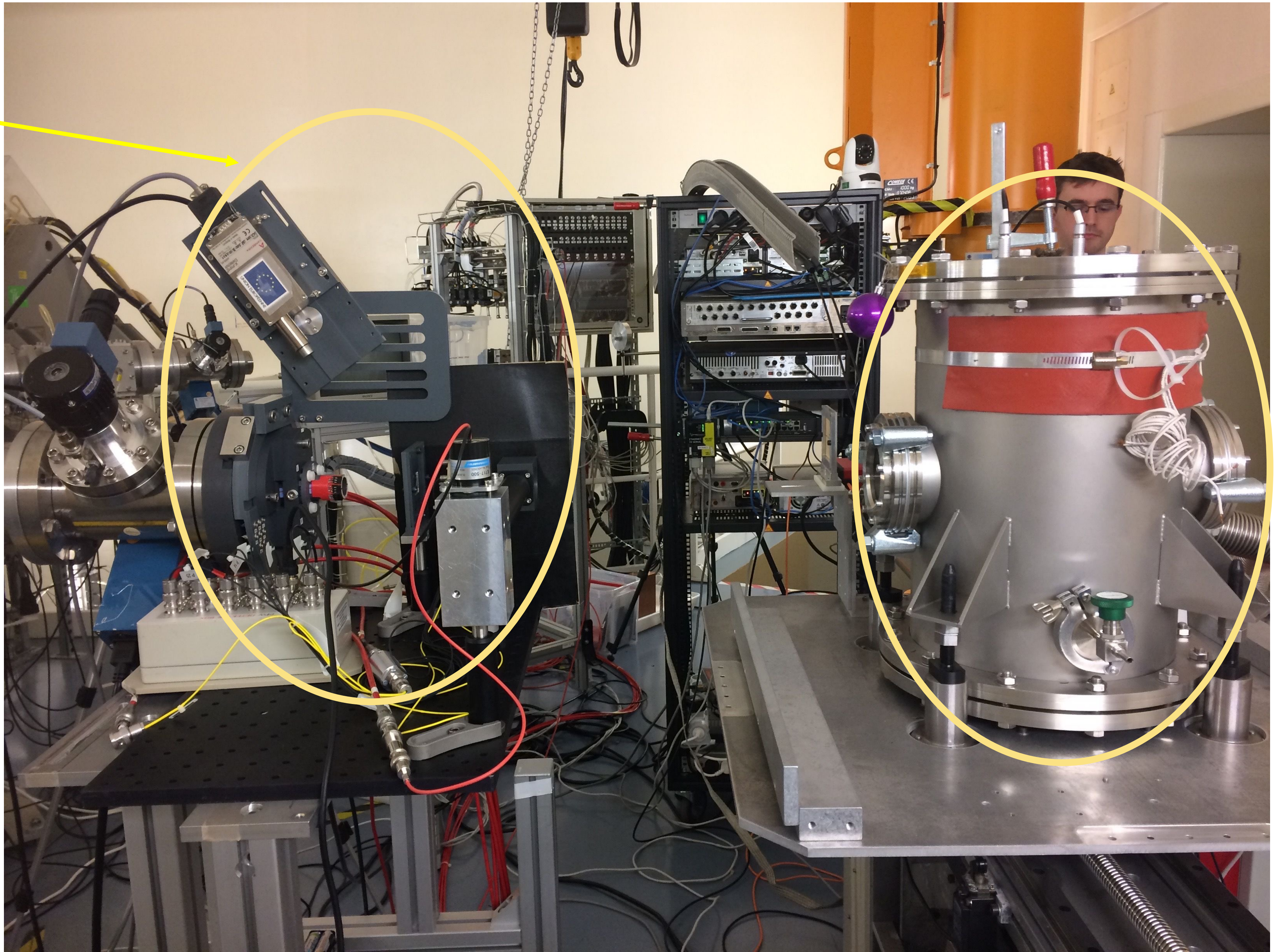
Experimental setup for SEE rate measurement



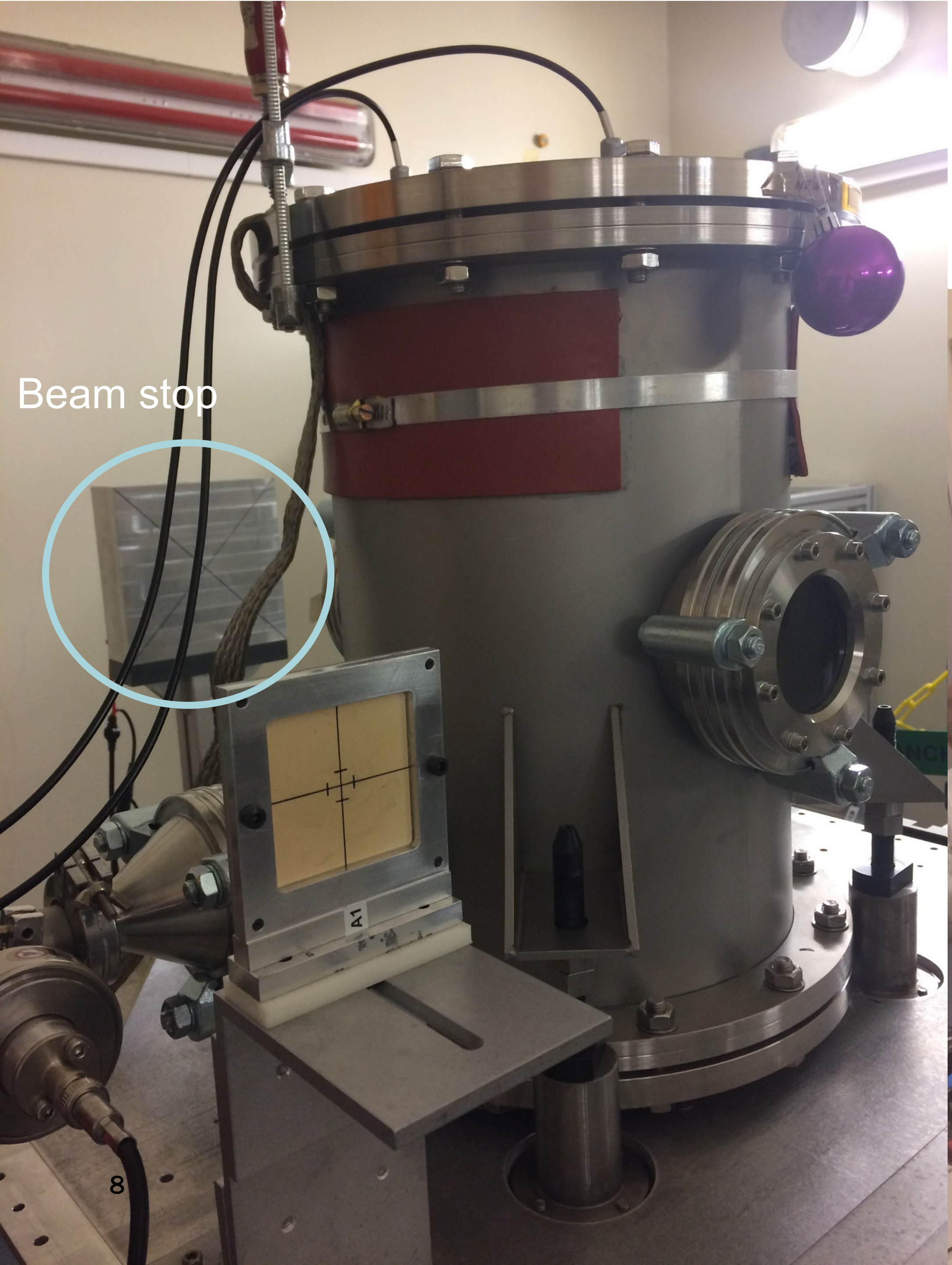
ARRONAX experimental setup

Charge measurement systems

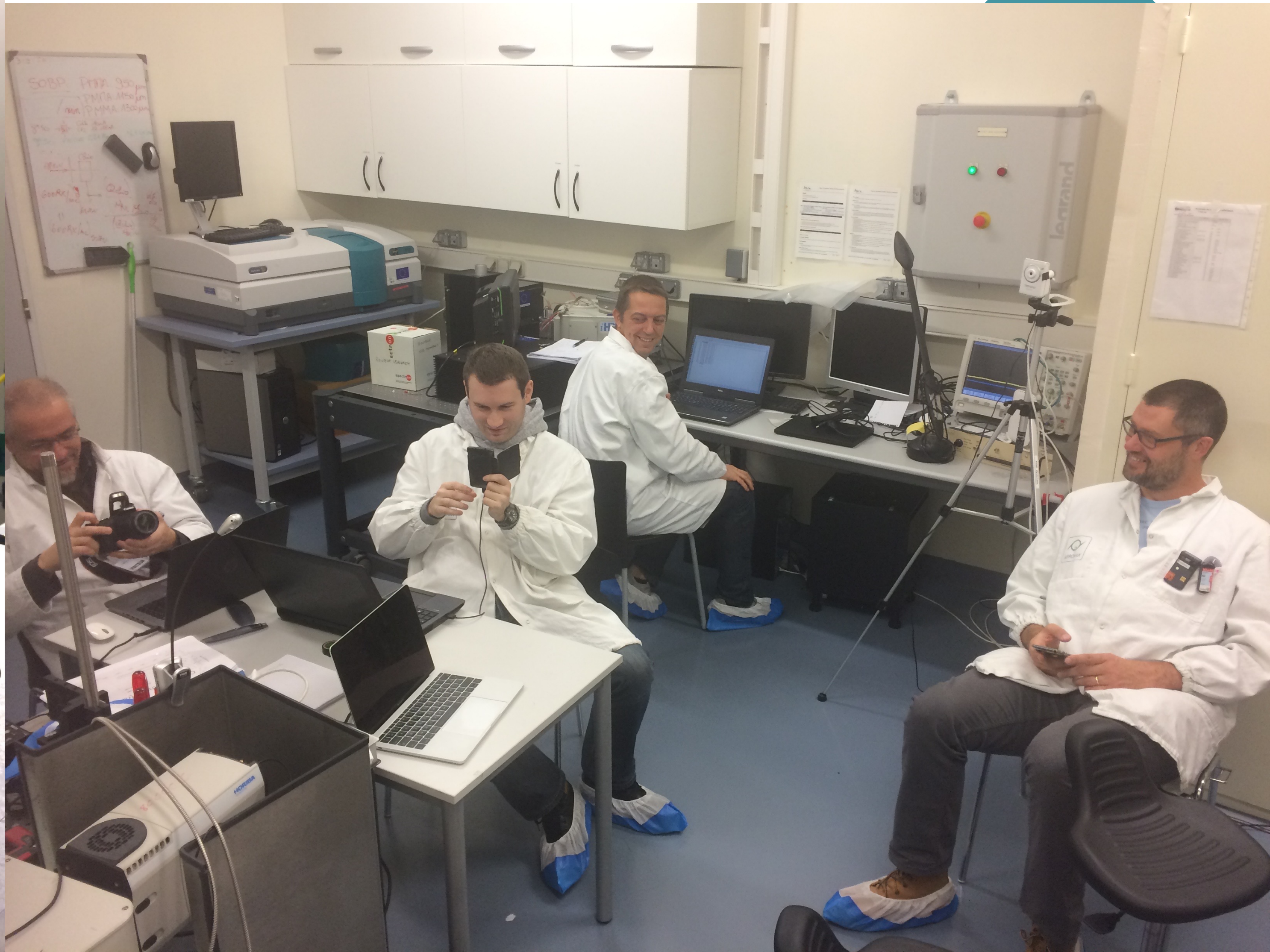
protons



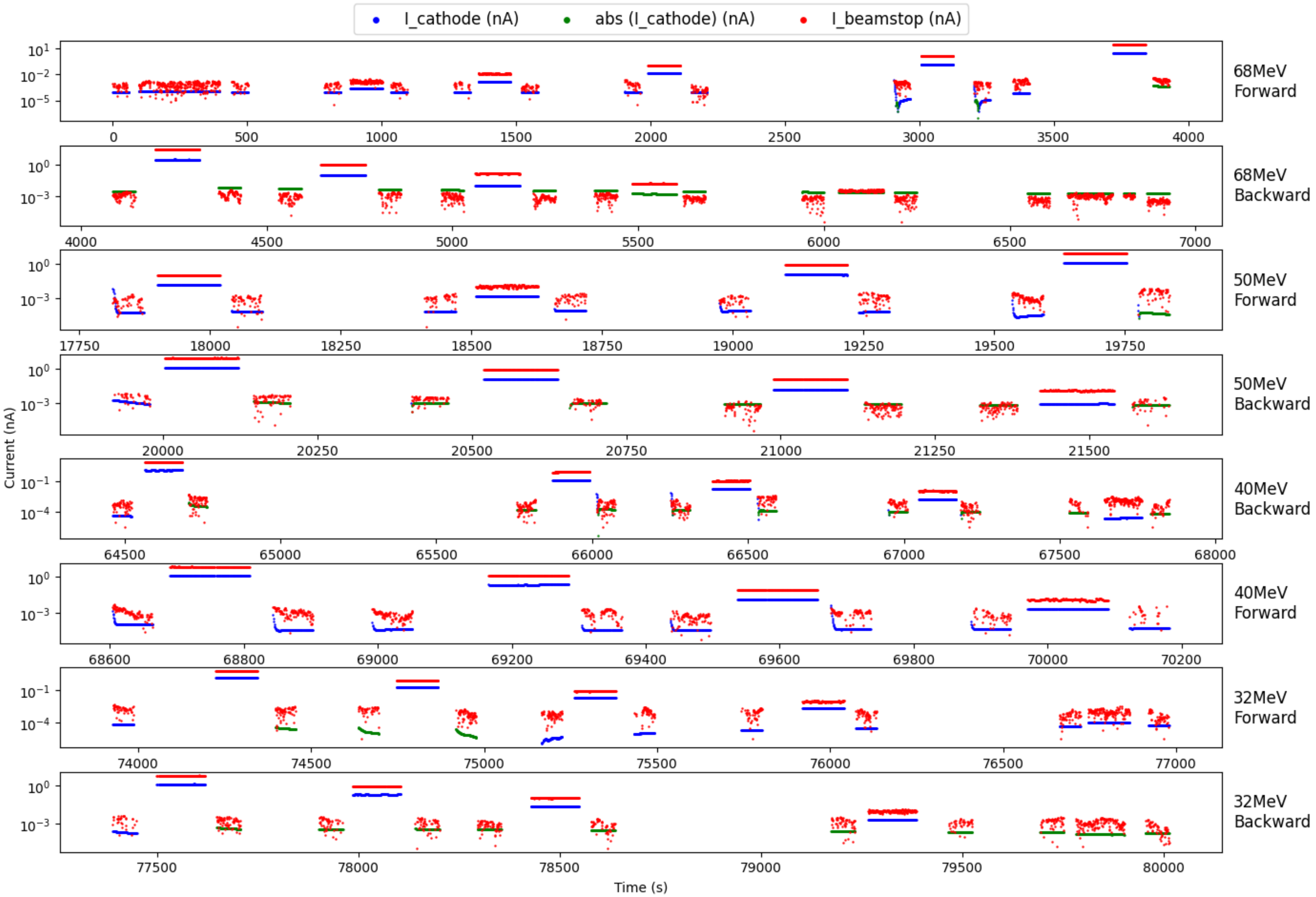
Vacuum chamber



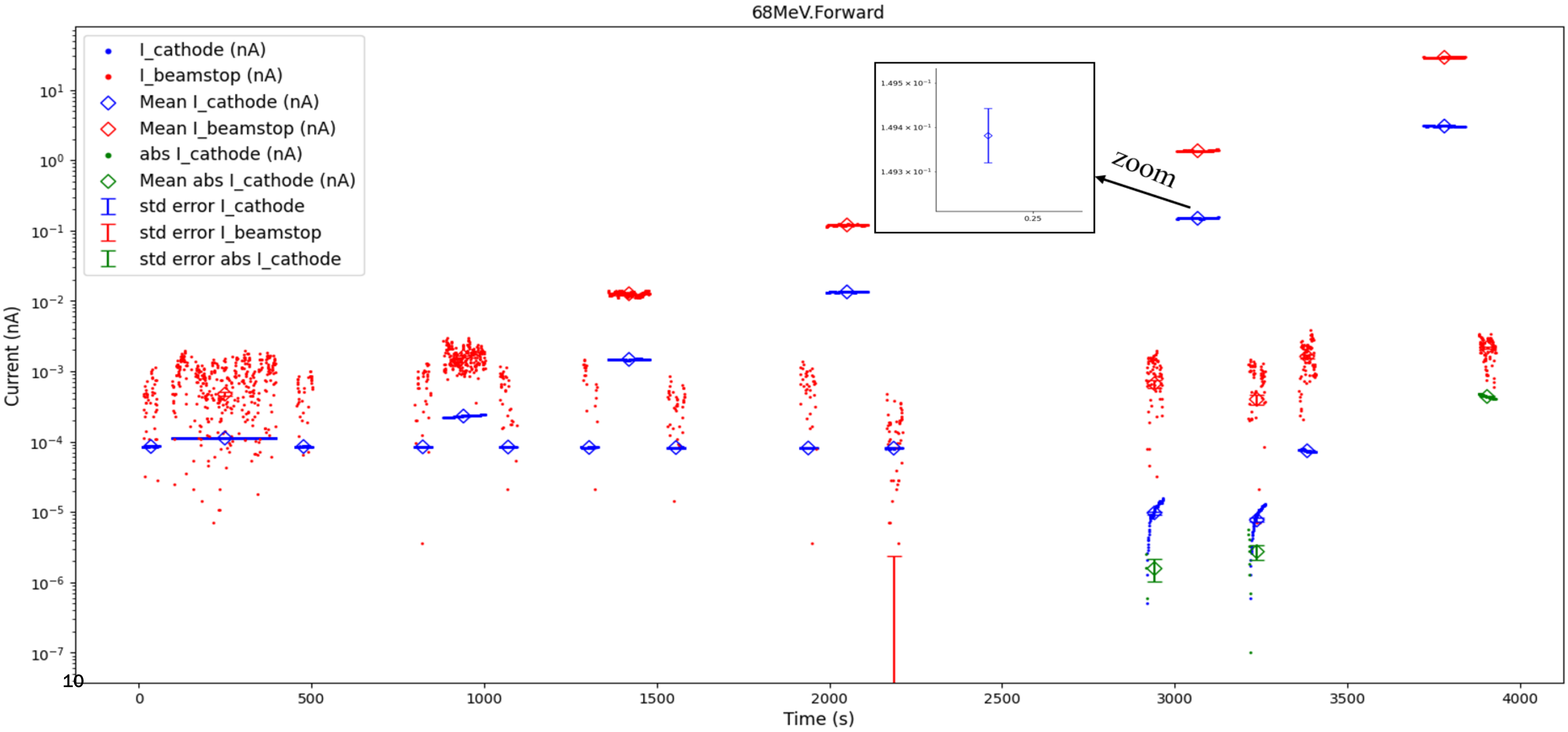
Beam stop



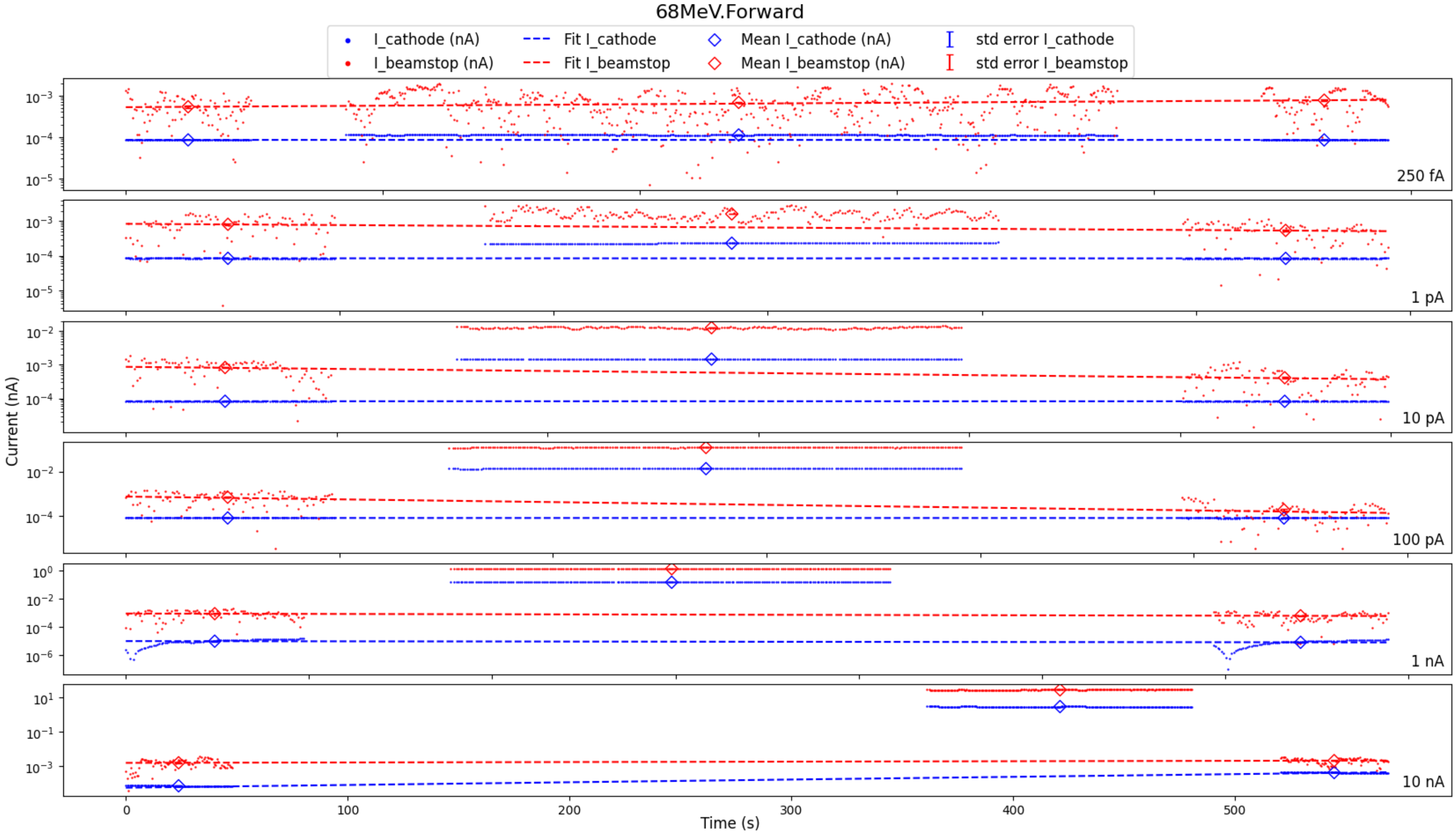
Result: Data Taking "History"



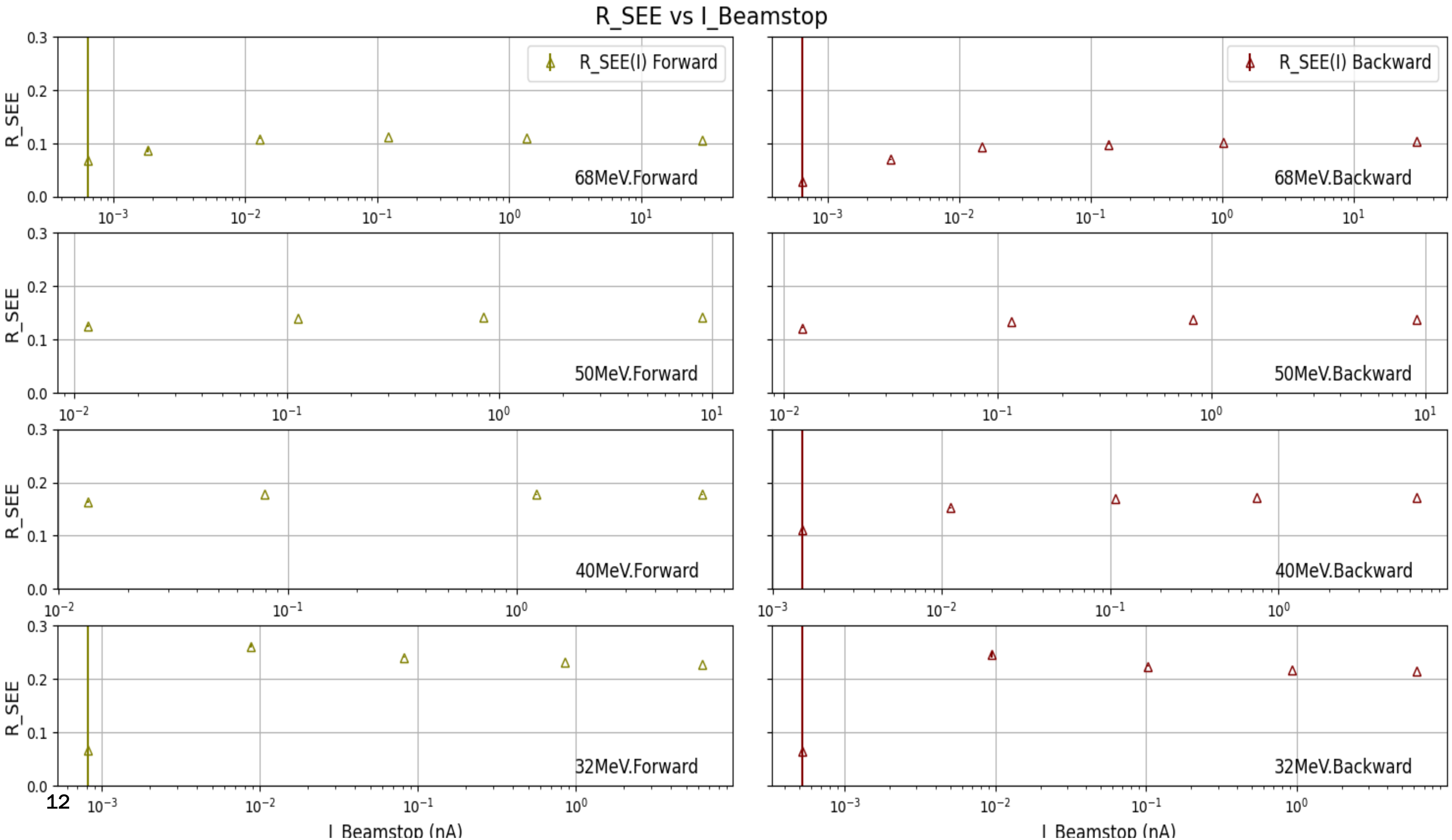
Result: Current values of SEE in forward direction at 68 MeV for Proton beam



Result: Beam’s current measurements for different current

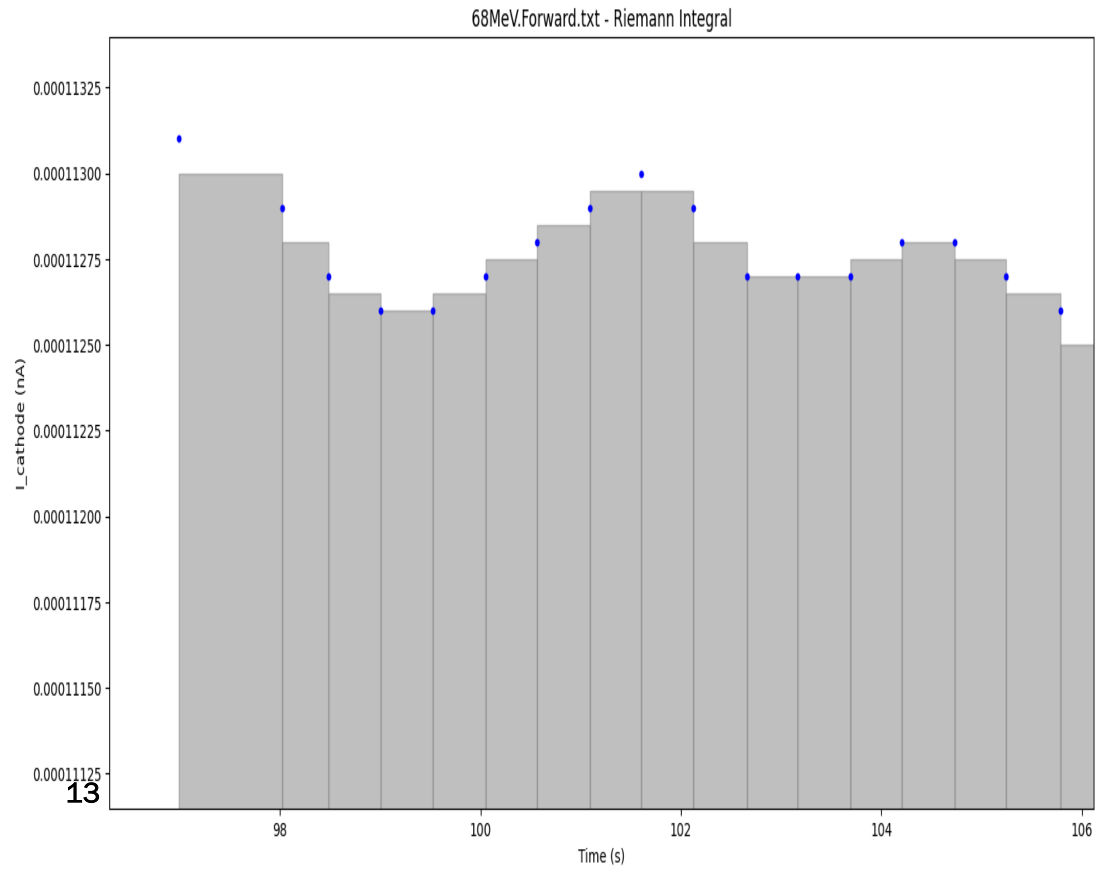


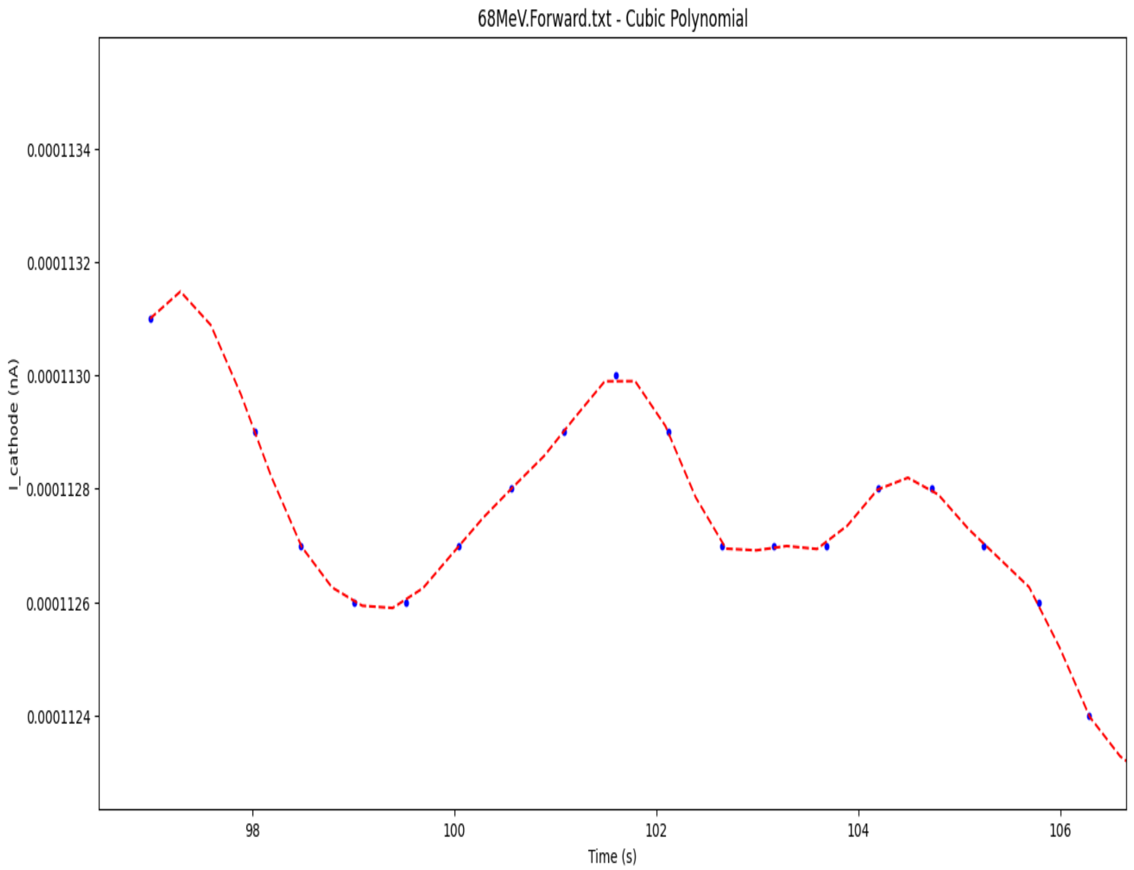
Analysis: SEE(I) Rate Forward vs. Backward



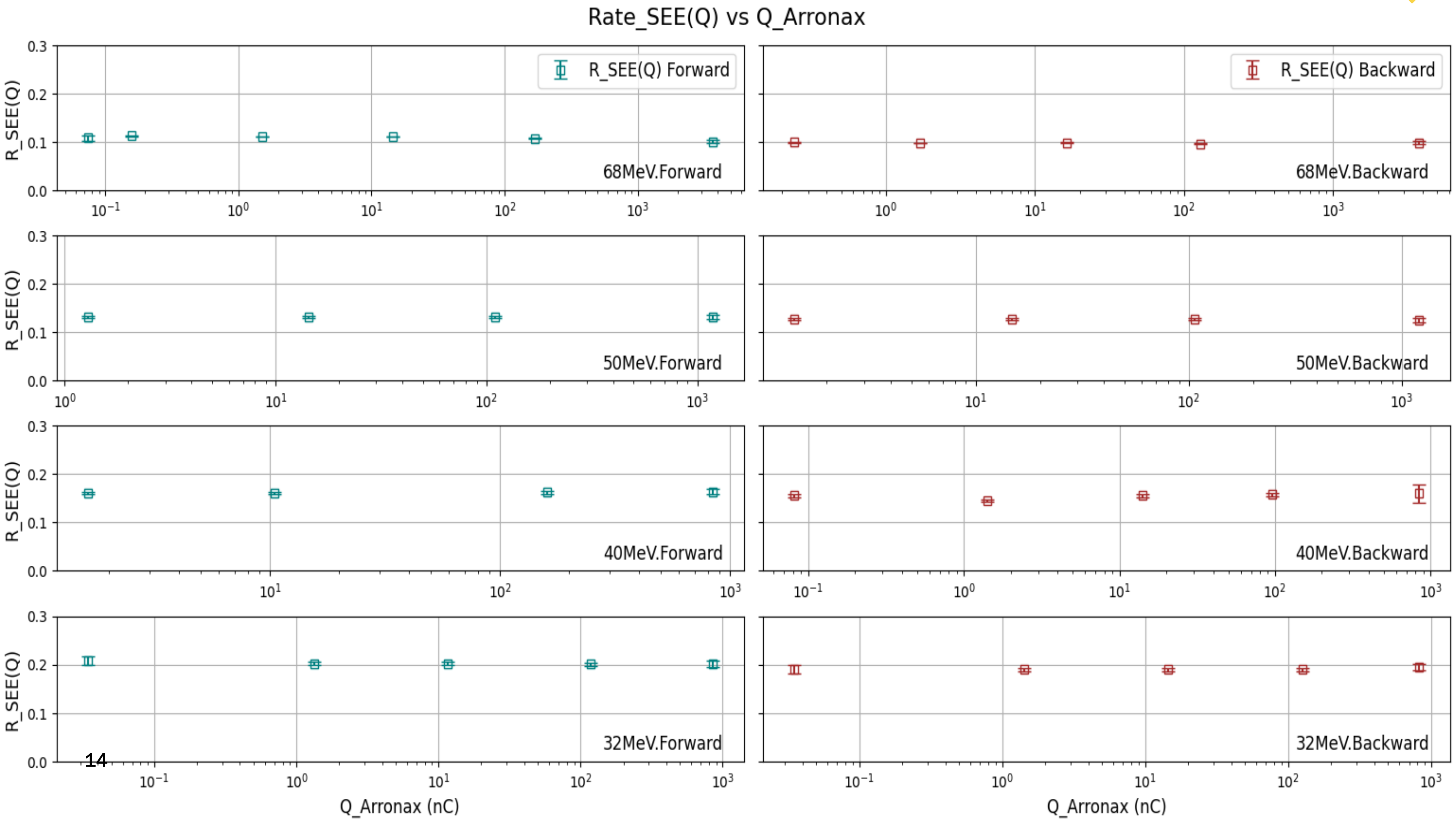
A different way measure the rates

- Use of ARRONAX charge (Q) measurements system instead of beam stop
  - Avoid « bad » Beam Stop measermet at low current
- We need to transform the measured intensity I_cathode into a charge Q_cathode
  - Q = I * T

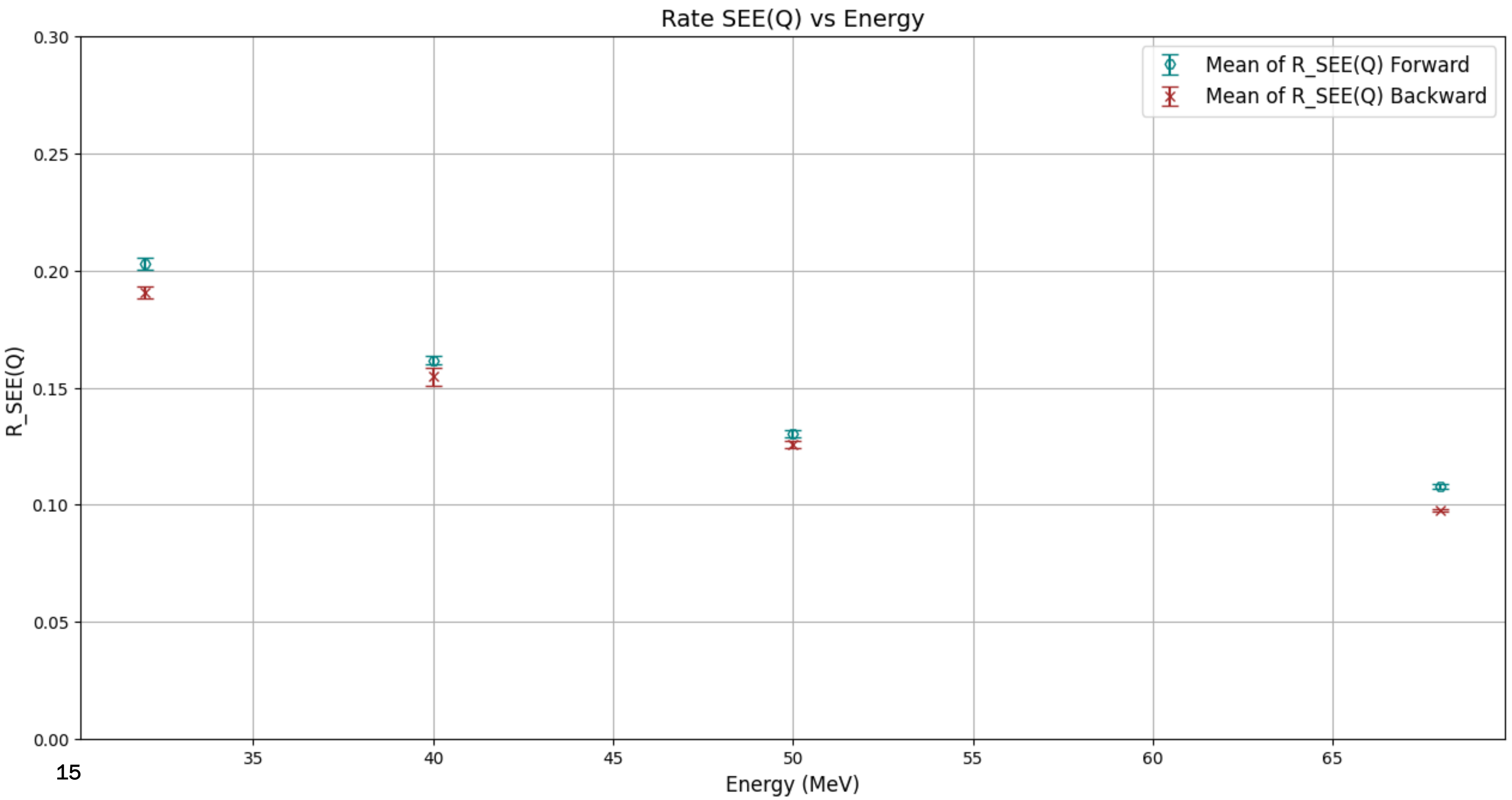




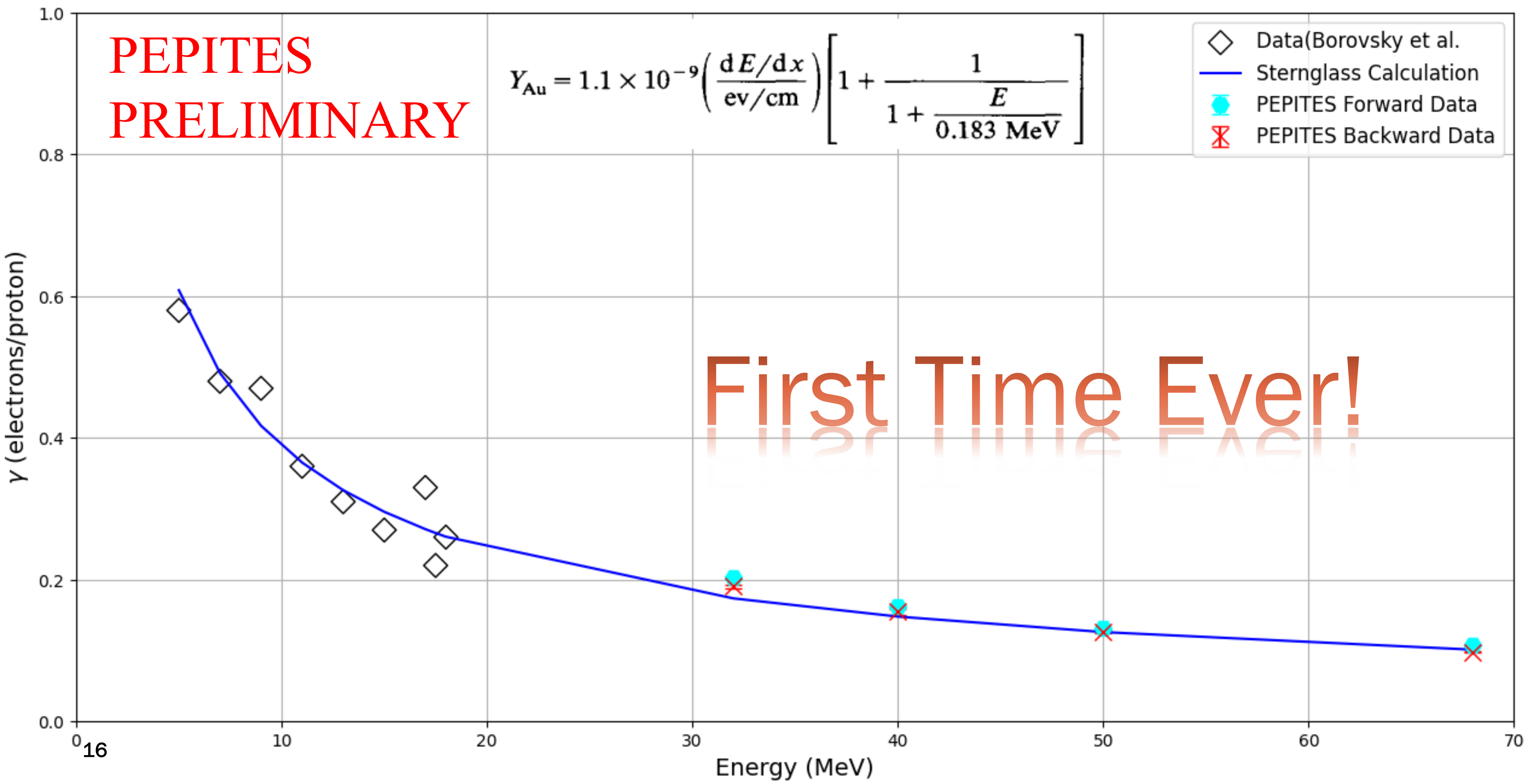
Analysis: SEE(Q) Rate Forward vs. Backward



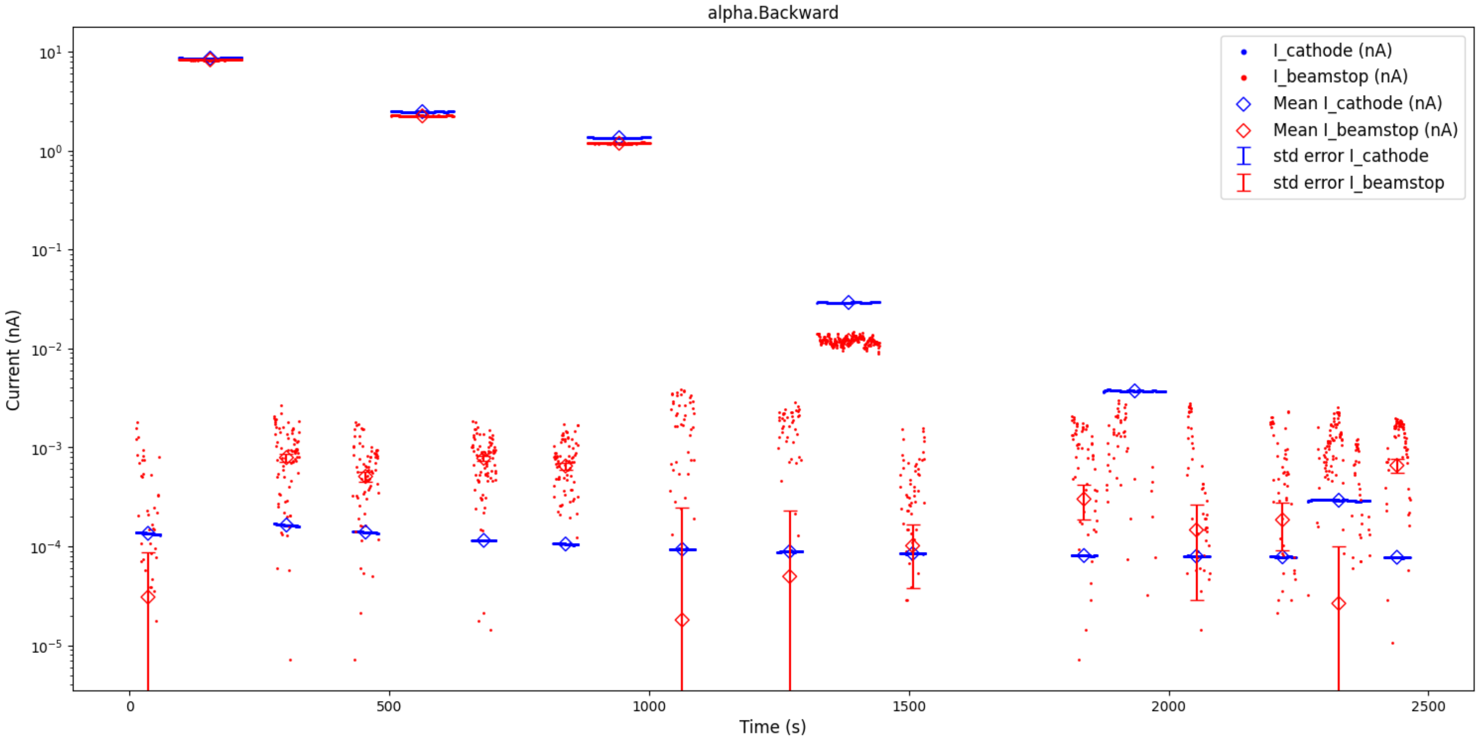
Analysis: SEE(Q) Rate for different Energies

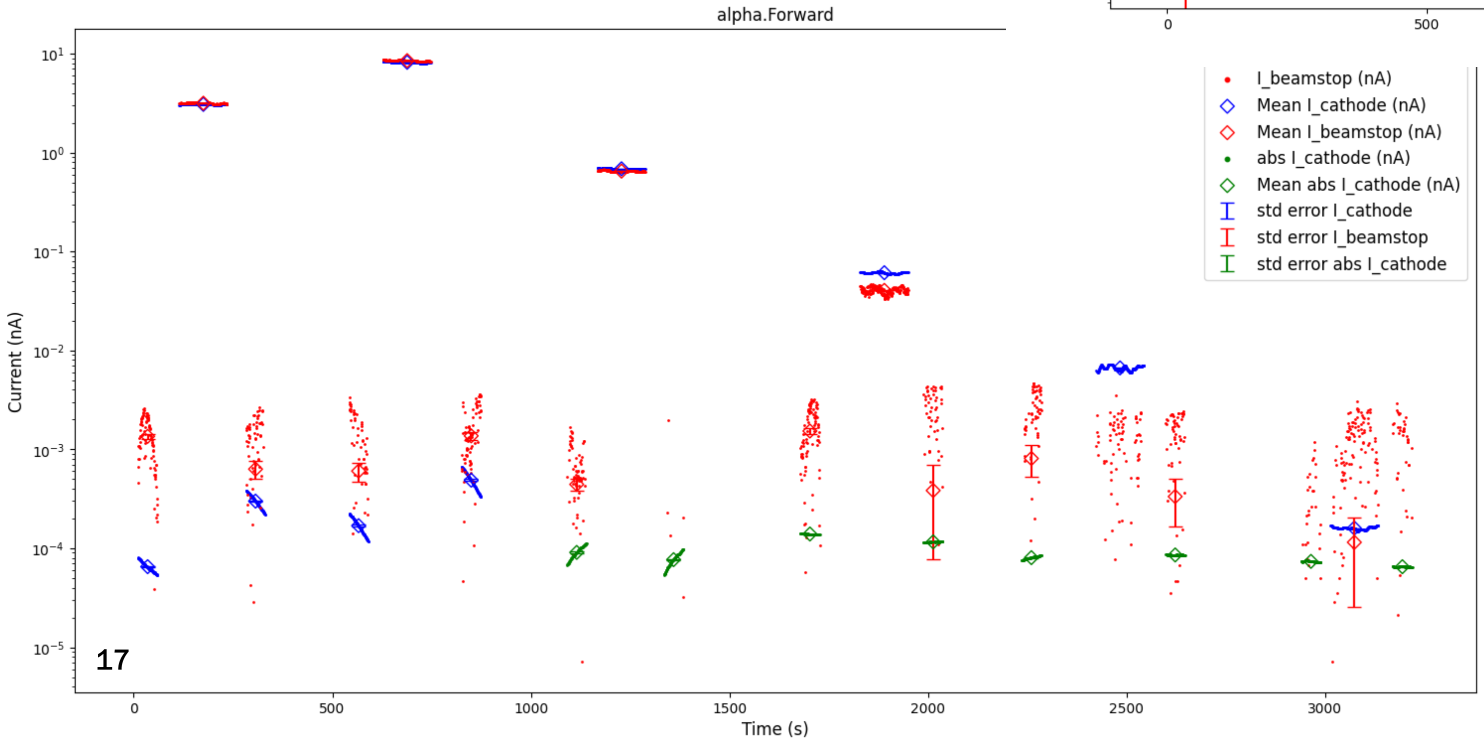


Analysis: SEE(Q) Rate compared with Sternglass calculation

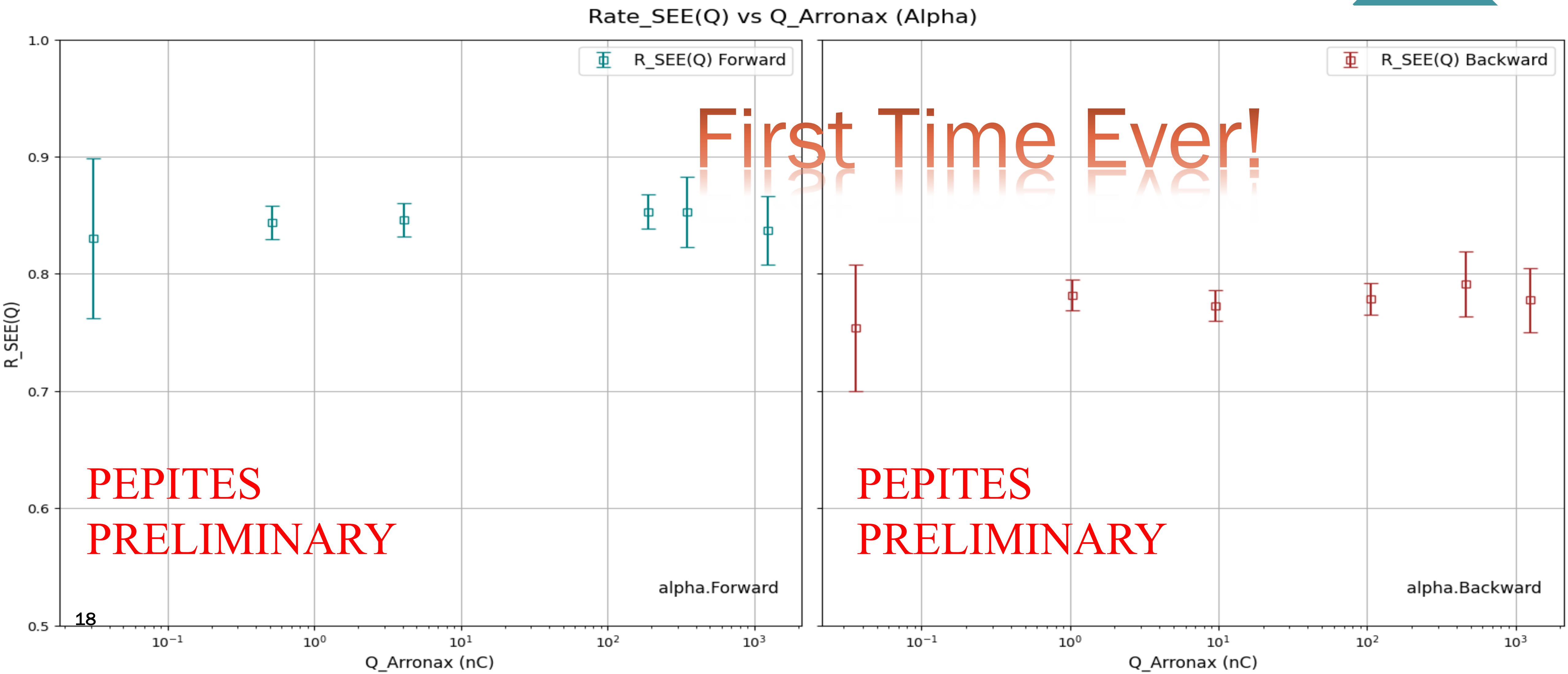


Alpha Particles





Analysis: SEE(Q) Rate Forward vs. Backward



Conclusion

- **Consistency in R_SEE Calculations:**
  - Both current (I) and charge (Q) based methods provided consistent R_SEE values, Charge-based calculation shows reduce error margins.
- **Linearity**
  - Secondary electron emission rate does not depend on beam intensities.
  - PEPITES could still work with very high beam intensities.
- **SE Directional Flow Dependence:**
  - For both protons and alpha particles, the R_SEE in the forward direction was consistently higher than in the backward direction for all energy levels.
- **Energy Dependence:**
  - As the energy increased, the R_SEE values for protons decreased.
- **Particle Type Differences:**
  - Alpha particles exhibited significantly higher R_SEE values compared to protons at the same energy levels.

Thank you

BACKUP SLIDES

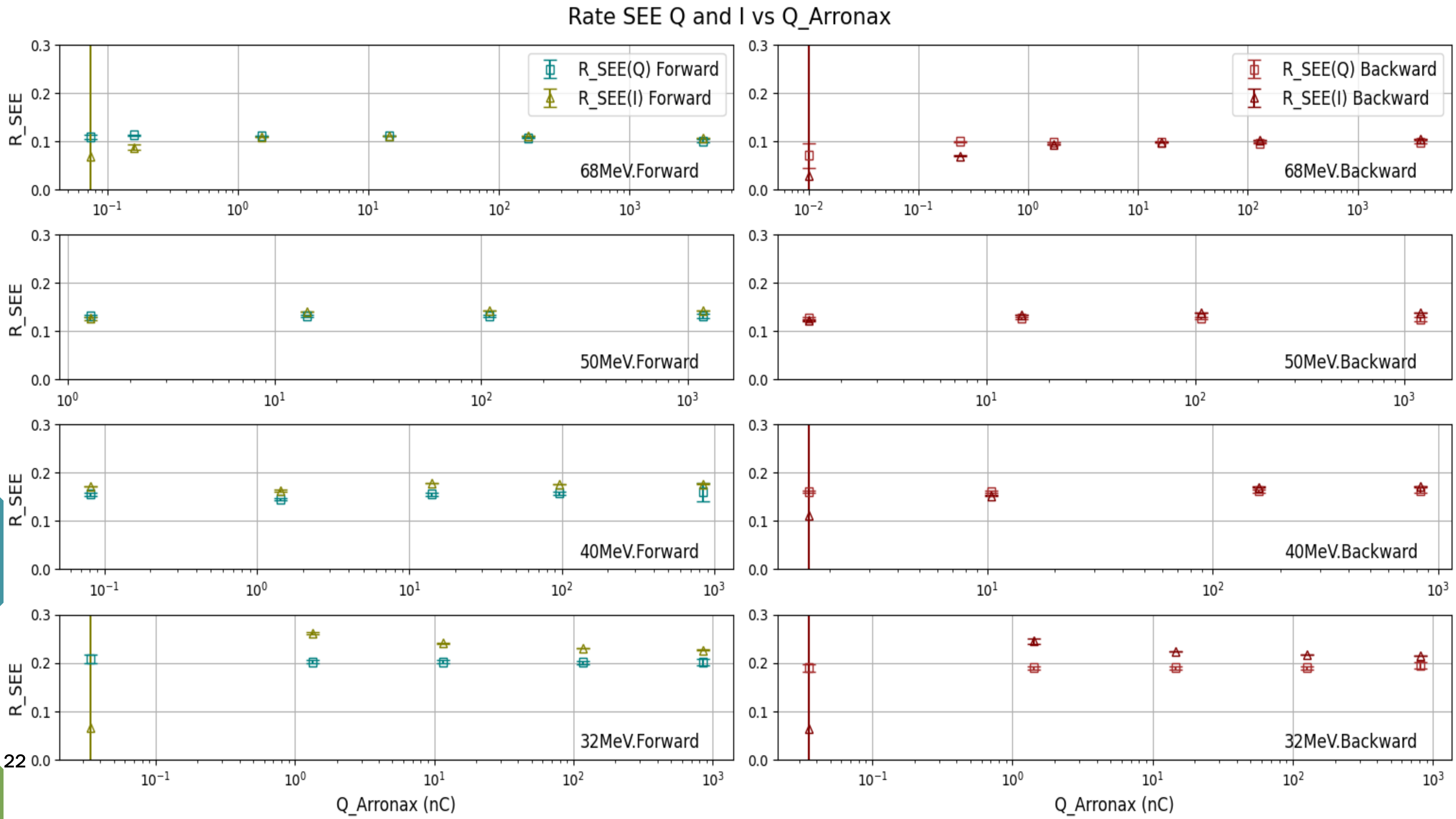
PEPITES Prototype

Installation: ARRONAX, vacuum chamber with a translation system for beam path engagement.

Advantage: Detector is free of mechanical constraint.

Implementation: Proven success at ARRONAX, paving the way for long-term applications.

Comparing the 2 methods



Analysis : SEE(I) rate for different Energies