Backscattering setup @ MiB

Matteo Biassoni
TRISTAN Workshop, KIT July 2022

Why backscattering measurements

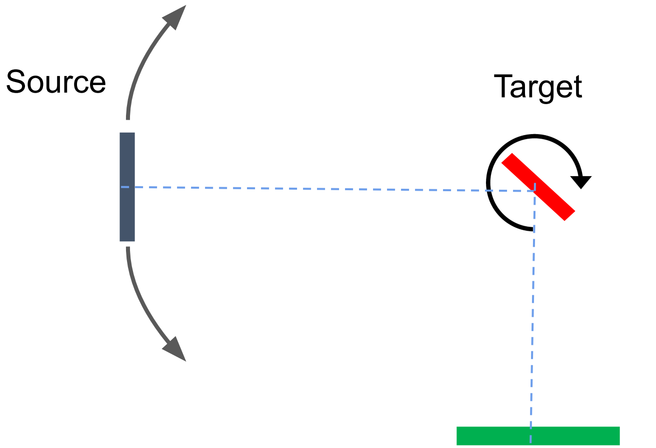
- backscattering has relevant impact on spectral shape and sensitivity
- mainly backscattering on Si (detector) but also other materials (RW)
- current approach is to model backscattering with same Geant4 simulations used to build detector response function, BUT
- backscattering coefficients and spectra are very sensitive to simulation parameters (physics lists, step limiter, etc…) → need for data-driven choice and validation

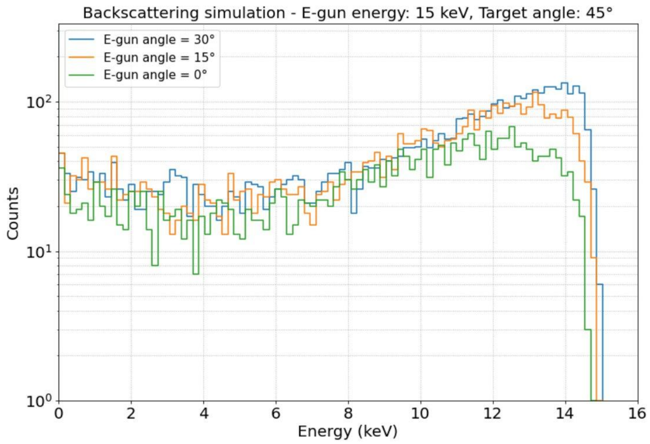
Why backscattering measurements

- data available in literature mainly backscattering coefficients:
  - primary coefficient = number of electrons entering the material that leave it before stopping
  - secondary coefficient = number of secondary produced electrons leaving the material
- only integral information on energy spectrum
- only integral information on angular distribution
- useful but limited amount of information to benchmark simulations
- energy and angular distributions are critical for Tristan (see talks on model)

Backscattering measurements with SDDs

Leverage knowledge of SDDs response to electrons to perform backscattered electrons spectroscopy!





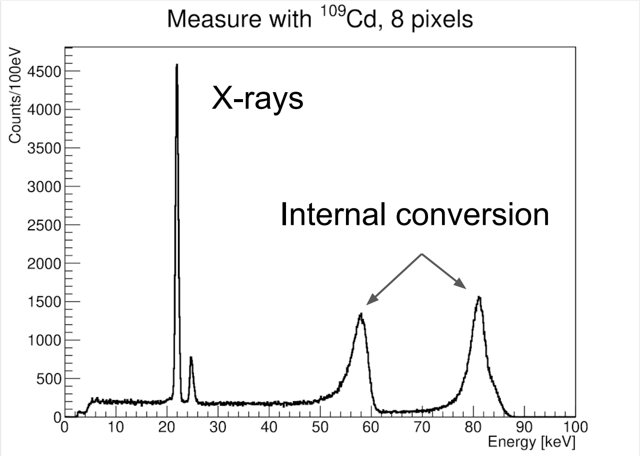
Compare data with simulation while changing: energy, incident angle, scattering angle

Internal conversion source

First attempt:

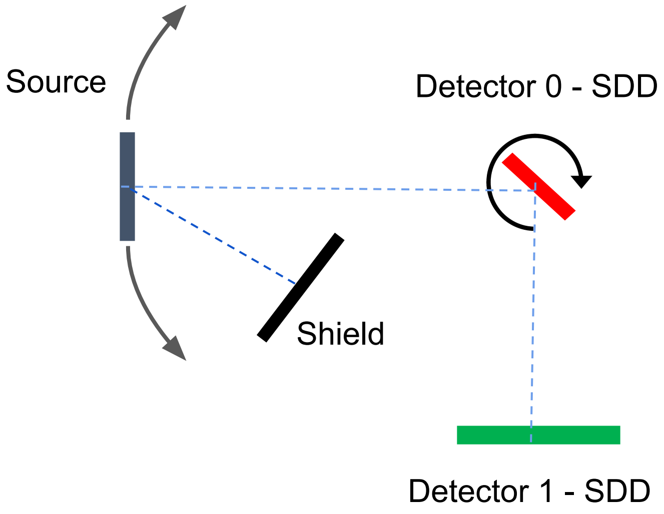
- radioactive source (109Cd)
- very small backscattering detection probability (small geometric efficiency)
- large background from direct detector illumination (isotropic source)

Source reference spectrum

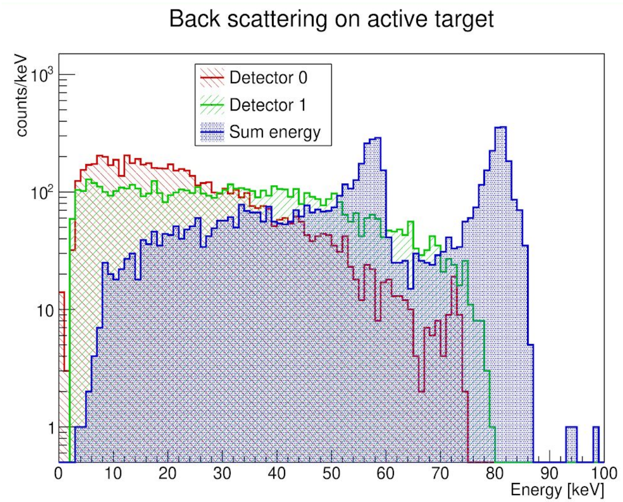


Internal conversion source

Leverage knowledge of SDDs response to electrons to perform backscattered electrons spectroscopy! Improved configuration

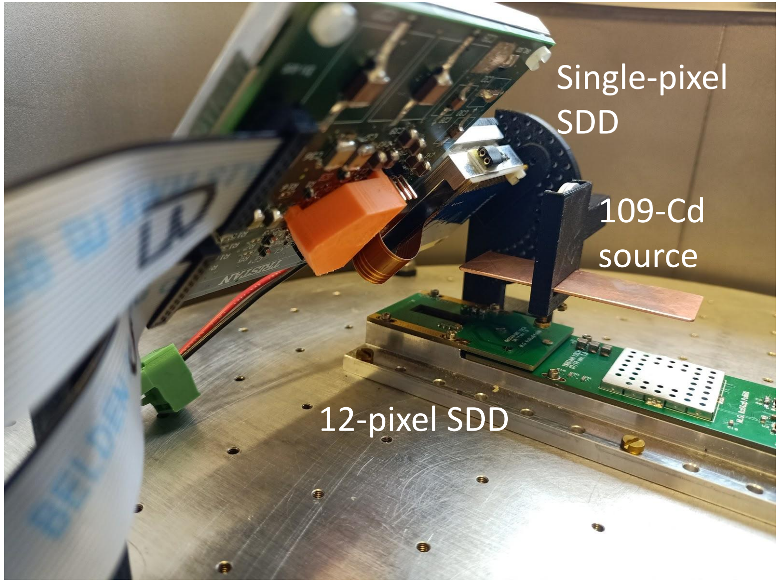


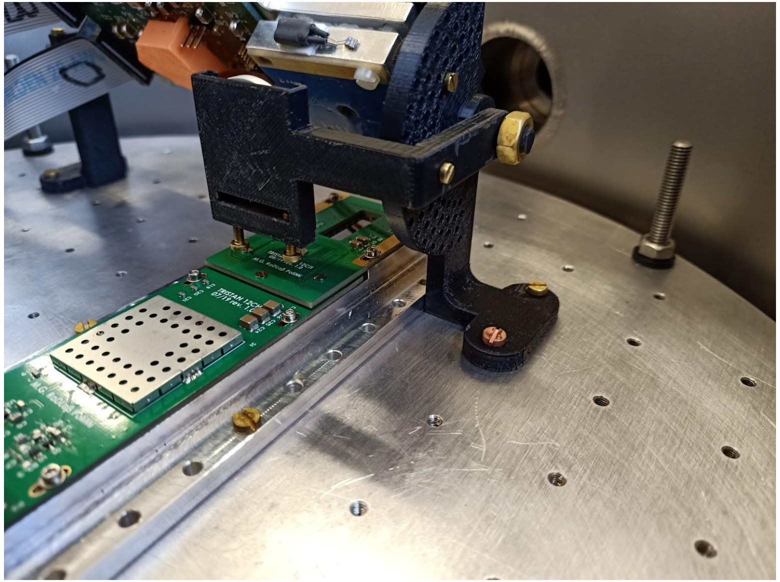
Detector 0 = single pixel SDD
Detector 1 = 12 pixel Tristan matrix
Selection of multiplicity 2 events (both detectors trigger)



Internal conversion source

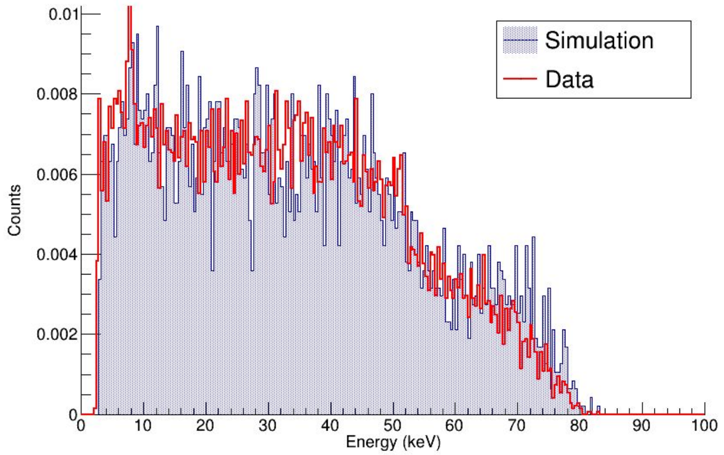
Leverage knowledge of SDDs response to electrons to perform backscattered electrons spectroscopy! Improved configuration



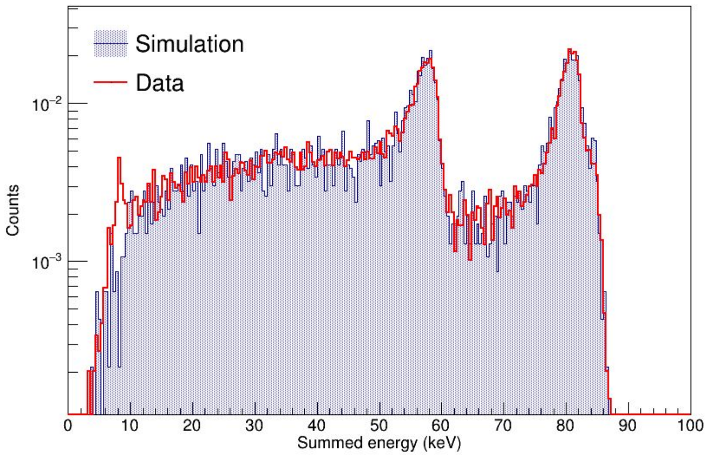


Internal conversion source

Detector 1



Sum energy

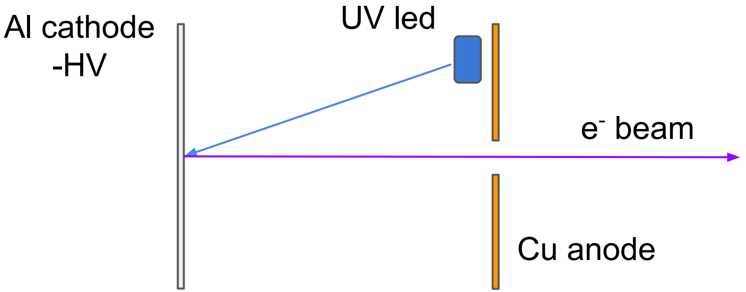


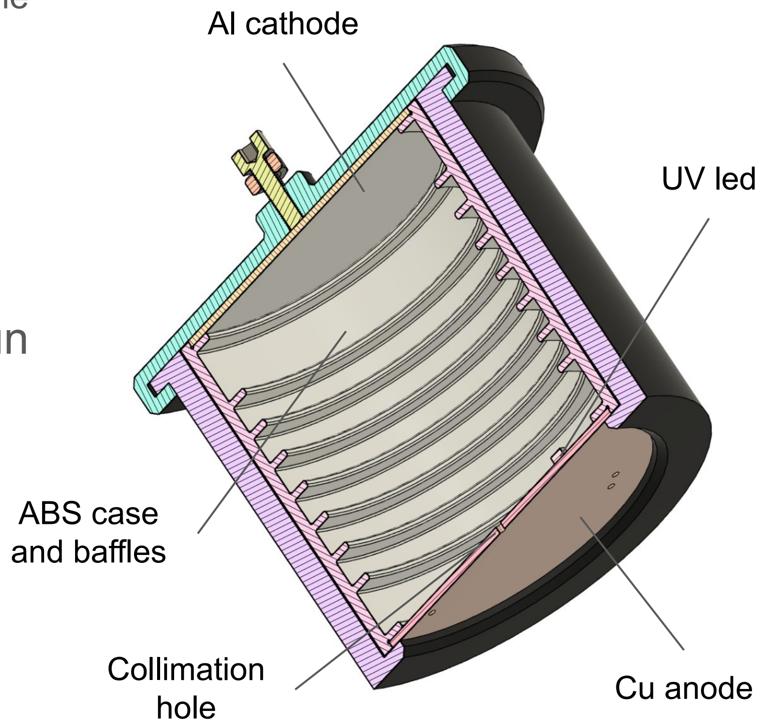
Very good agreement between data and simulation, but **source self-absorption** and **low geometrical efficiency** is limiting the sensitivity

Need a better source
Electron gun

Electron gun

- Ideal source features
  - monochromatic (at the ~10 eV level or better) in the relevant range (few to few tens of keV)
  - collimated (known incident angle and increase geometric efficiency)
  - controllable electron flux
  - compact and easy to move (change angle and position)
- current implementation: UV-led based e-gun



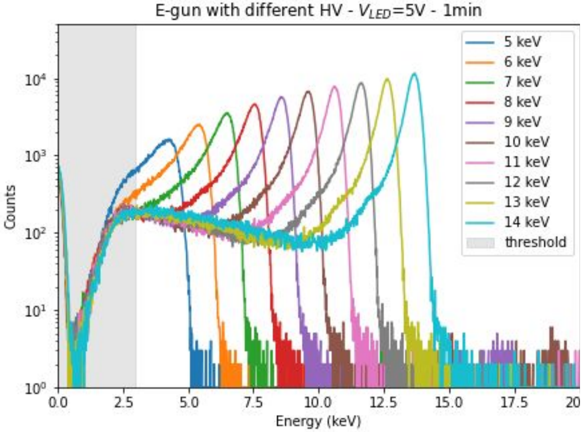


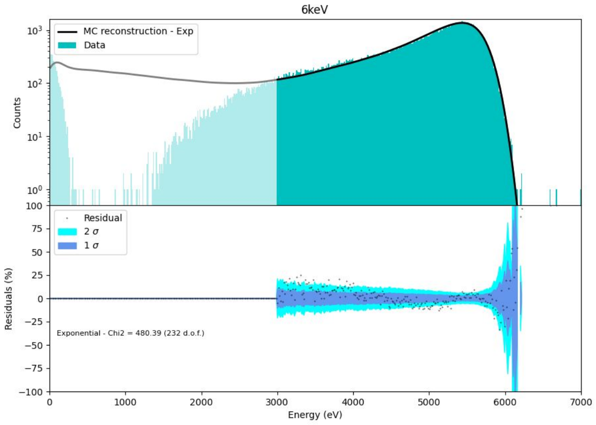
Electron gun - spectra for detector response

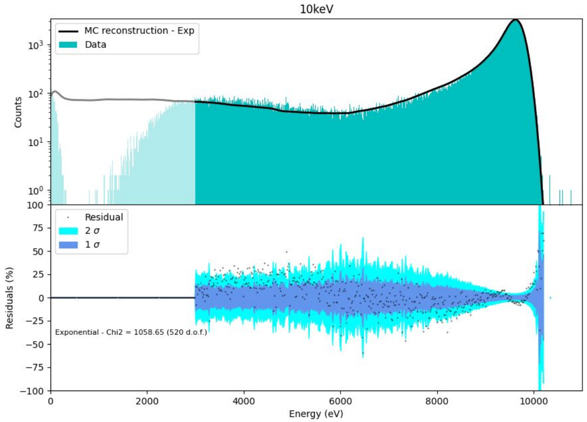
- Data with beam pointed directly at SDD (used for detector response fits, charge sharing, etc…) show very promising spectral shape

New response function fits

1 min runs



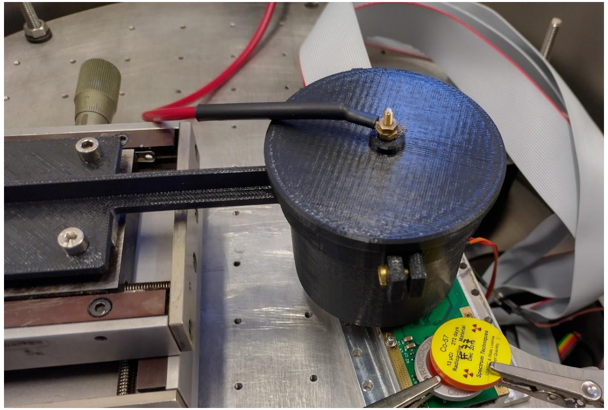


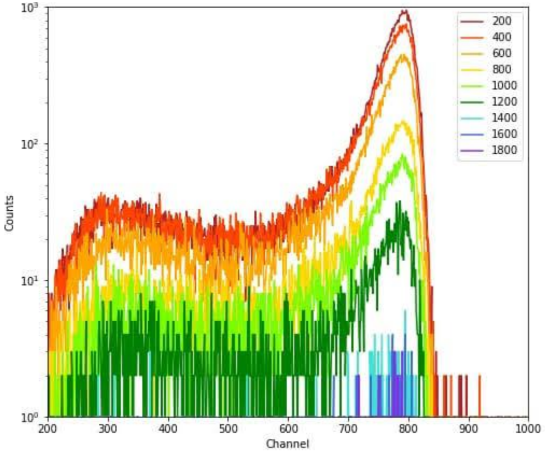


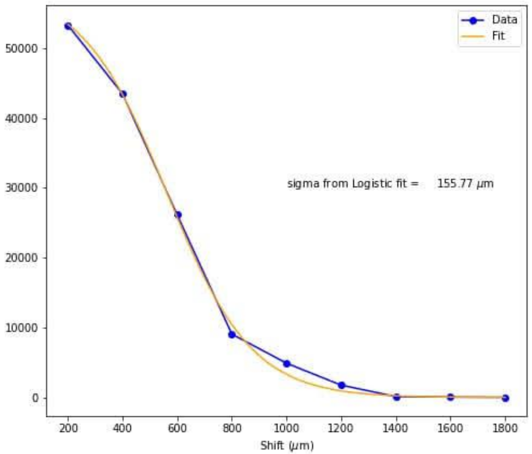
Electron gun - spectra for detector response

- Data with beam pointed directly at SDD (used for detector response fits, charge sharing, etc…) show very promising spectral shape

Beam cross section study



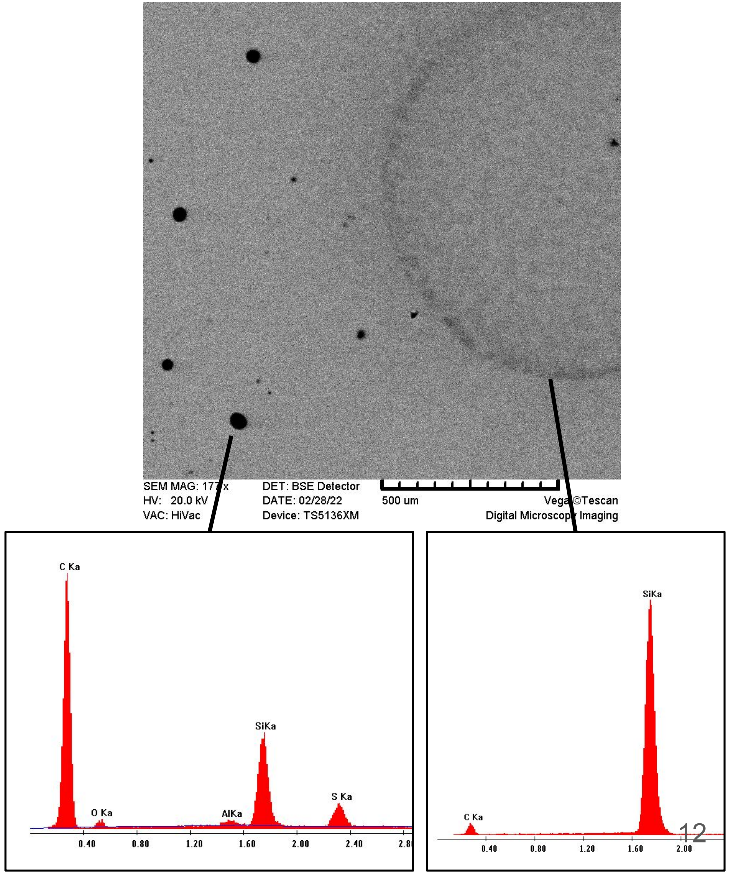




Electron gun - spectra for detector response

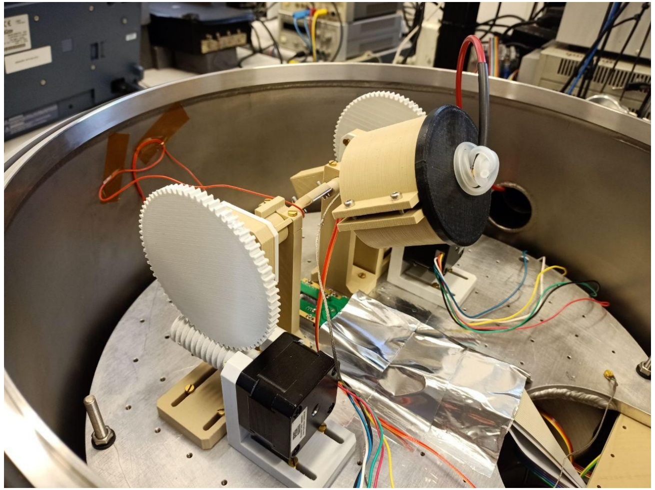
- PROBLEM: instability at large acceleration potentials (>15 kV)
  - large electron rate fluctuations/spikes
  - large current from HV generator
  - electronics misbehaviours
- after one of these “traumatic” events the pixel where the beam was pointing was damaged (larger leakage current) and had visible “halo” on the surface
- performed micro-analysis at SEM: coating of C-reach material plus C particles with small amount of Al
- most likely explanation: residual gas from solvents (electrical tape was being used, now replaced with kapton tape)
- after this tests second stage of Ettore ASIC stopped working → no more acquisition with CAEN multi-channel DAQ (new Ettore on its way as also first stage stopped working after some more tests!)

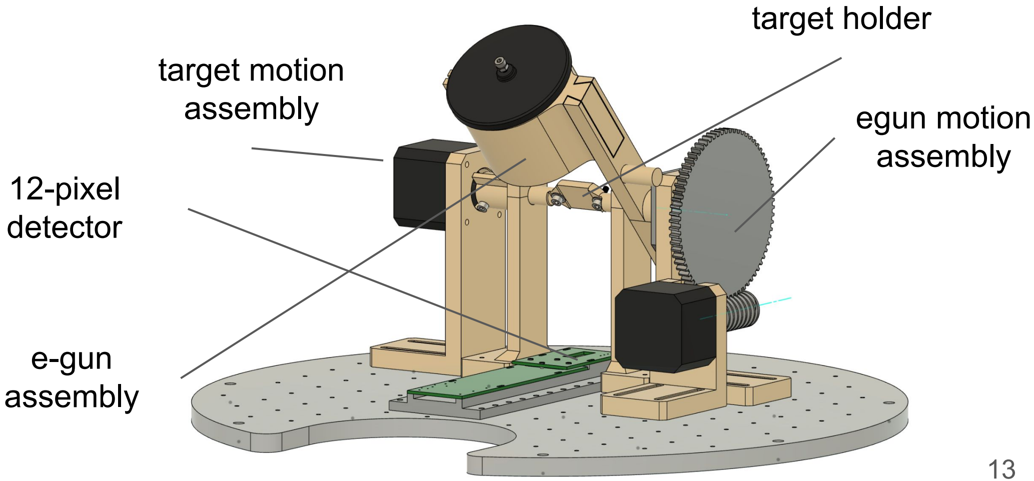
Decision to switch to backscattering measurements with E < 15 keV to avoid damaging more pixels



Electron gun - backscattering setup

- Build setup for backscattering measurement with passive target:
  - passive target to test different materials (possible thanks to higher geometric efficiency)
  - move egun and target without breaking vacuum → fully motorized movements of source and target



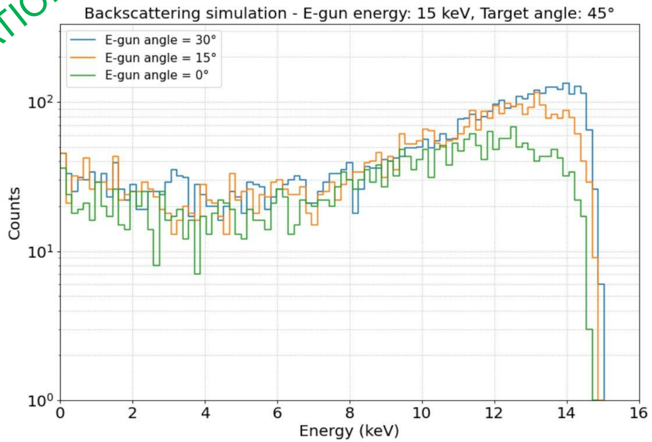


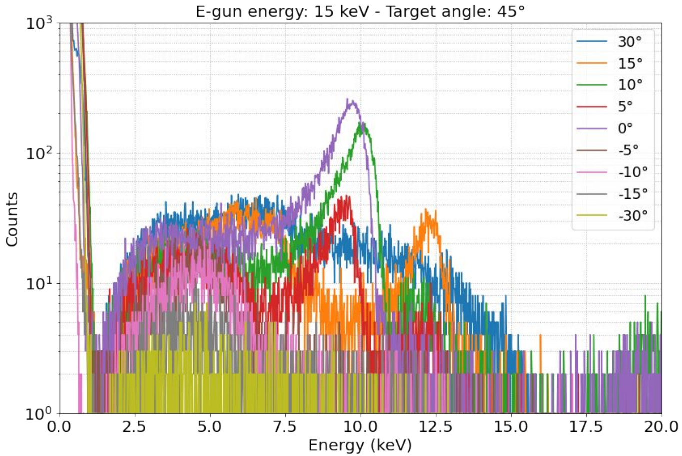
Electron gun - backscattering setup

Data clearly show unexpected structures and features:

- not compatible with expected BS spectra (present also in runs without target)
- strong angular dependence
- peak-like structures at unexpected energy
- very low rate (many orders of magnitude smaller than “main beam” rate)

EXPECTATION





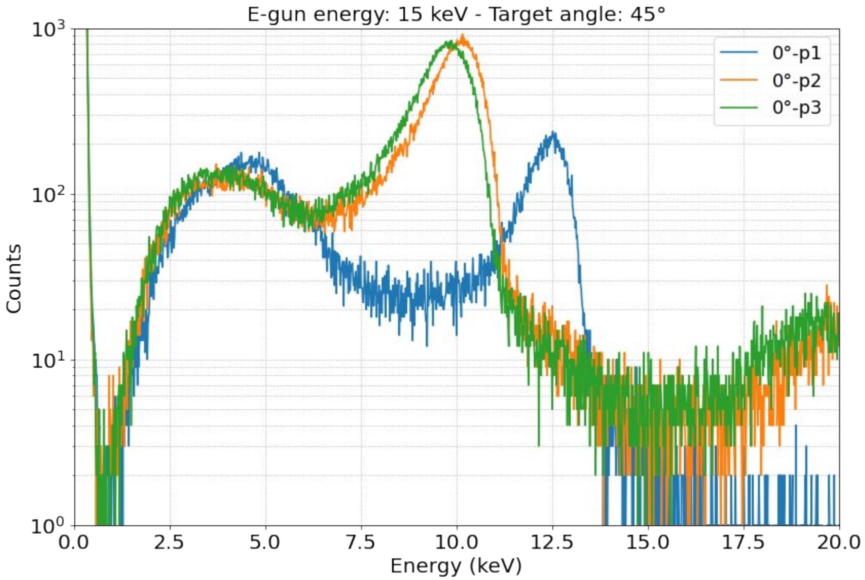
DATA

24 h runs

Electron gun - backscattering setup

Data clearly show unexpected structures and features:

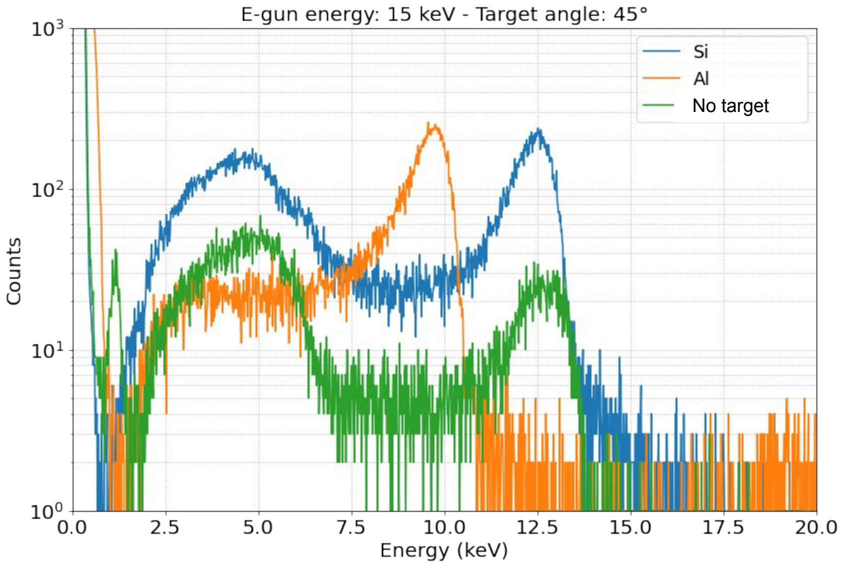
- relatively (but not completely) repeatable



Electron gun - backscattering setup

We performed many test to exclude:

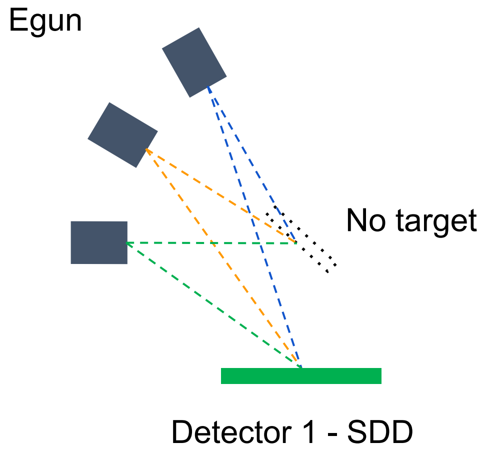
- polarization of target (replace original Si target with grounded Al sample)
- transient effects
- correlation with LEDs or HV instabilities

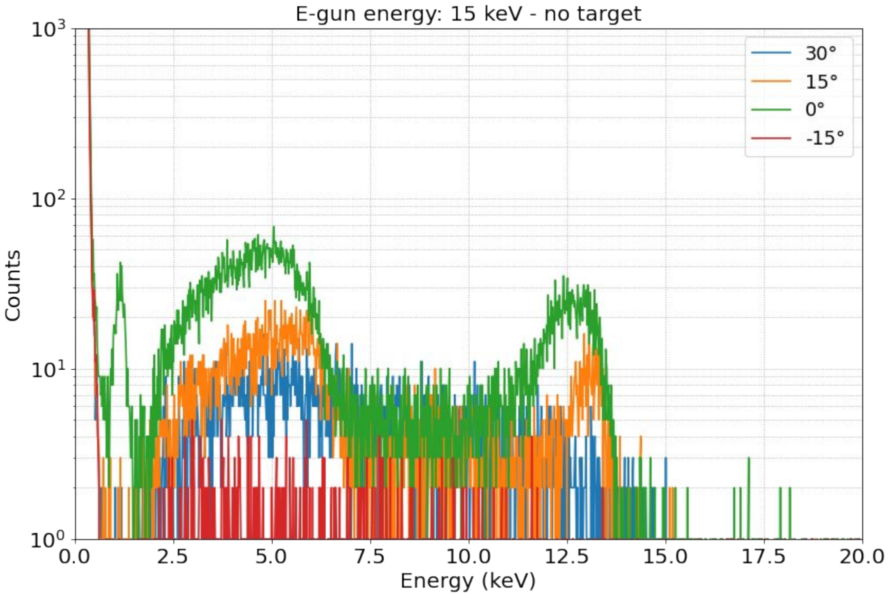


Electron gun - backscattering setup

We performed many test to exclude:

- perform angular scan without target
- effectively corresponds to looking at off-axis electrons



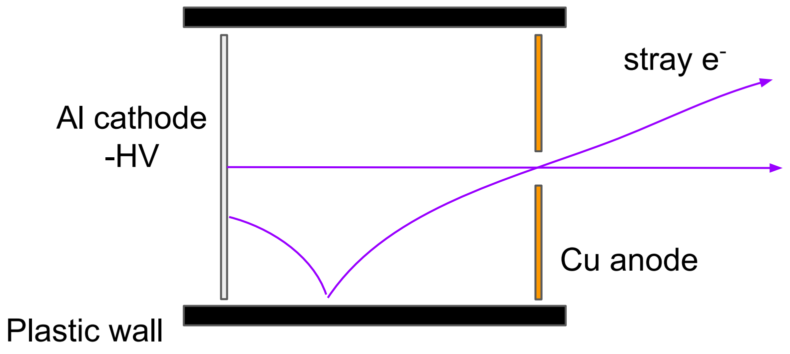


Electron gun - backscattering setup

Current most likely explanation (but not very convincing): stray electrons diverging from main beam, produced in a different position w.r.t. the cathode:

- diffused from inner egun walls (plastics) when charged during operation
- from residual gas ionization

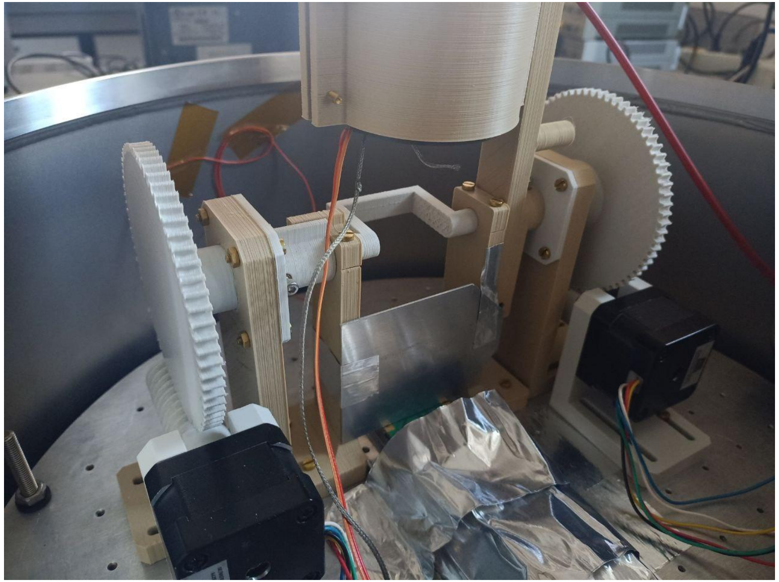
Not clear if really this electrons can be guided through the hole in the anode, would need a simulation of the fields with dielectric components (not available at the moment)



Electron gun - proposed solution

Three solutions to confirm the origin and fix the problem:

- add baffle to block direct line of view to the detector. Temporary solution to go on with the measurements



Already implemented but not tested as ASIC stopped working right before this…

Electron gun - proposed solution

Three solutions to confirm the origin and fix the problem:

- reduce UV-illuminated portion of the cathode with Kapton tape to emit electrons only on the axis of the e-gun and reduce inner wall charging
- complete redesign of the egun with:
  - removal of plastic parts
  - replace all-metal cathode with kapton PCB with small cathode at the center (and possible guard rings towards grounded casing)

Conclusion and outlook

- backscattering setup built and working with motorization of electron source and passive target
- backscattering setup with manual positioning of active target and source
- e-gun currently working, but clear evidence of time and position-dependant off-axis electrons to be understood
- 12 pixel setup currently non-operational (ASIC to be replaced in the next weeks)
- 47 pixel setup parts all available, installation planned in September