New electron scattering test

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In this talk...

1) Electron backscattering: comparison wrt Sandia80 experimental data

2) Results for various incidence angle and material

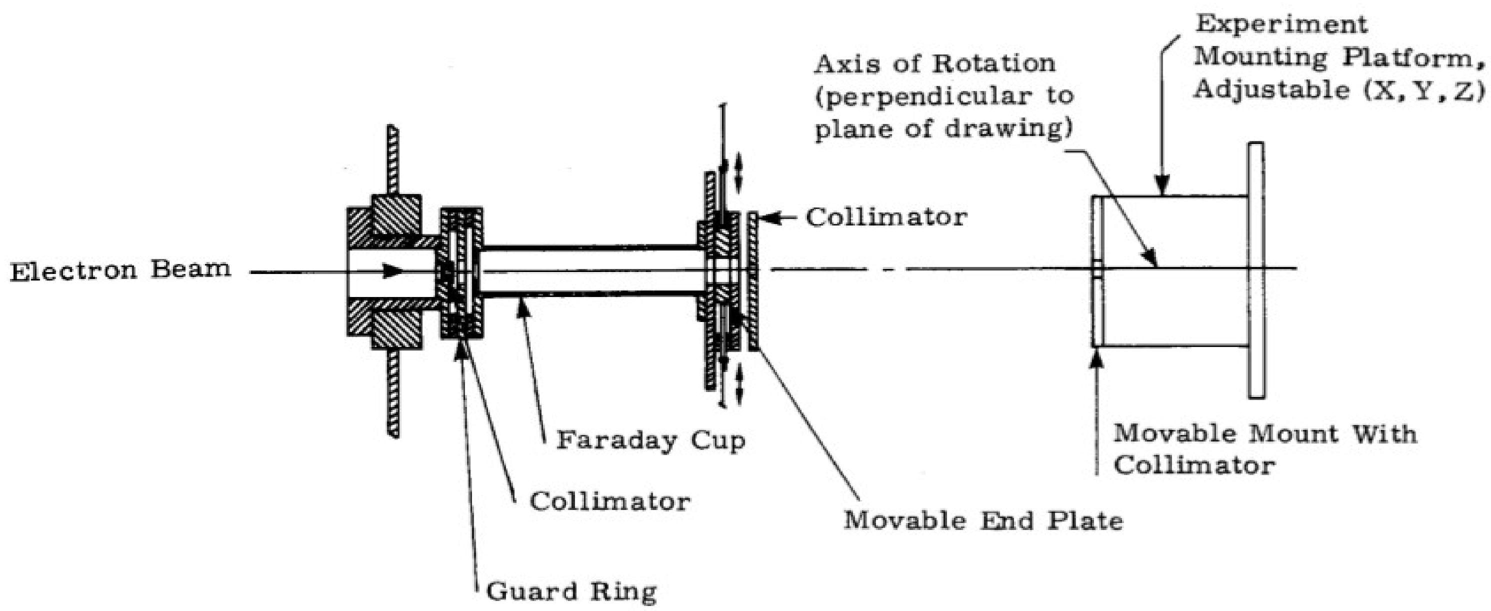
3) Low energy experimental data

4) Benchmark: Aluminium at normal incidence angle

5) Conclusions

Feedback, news and comments are welcomed!

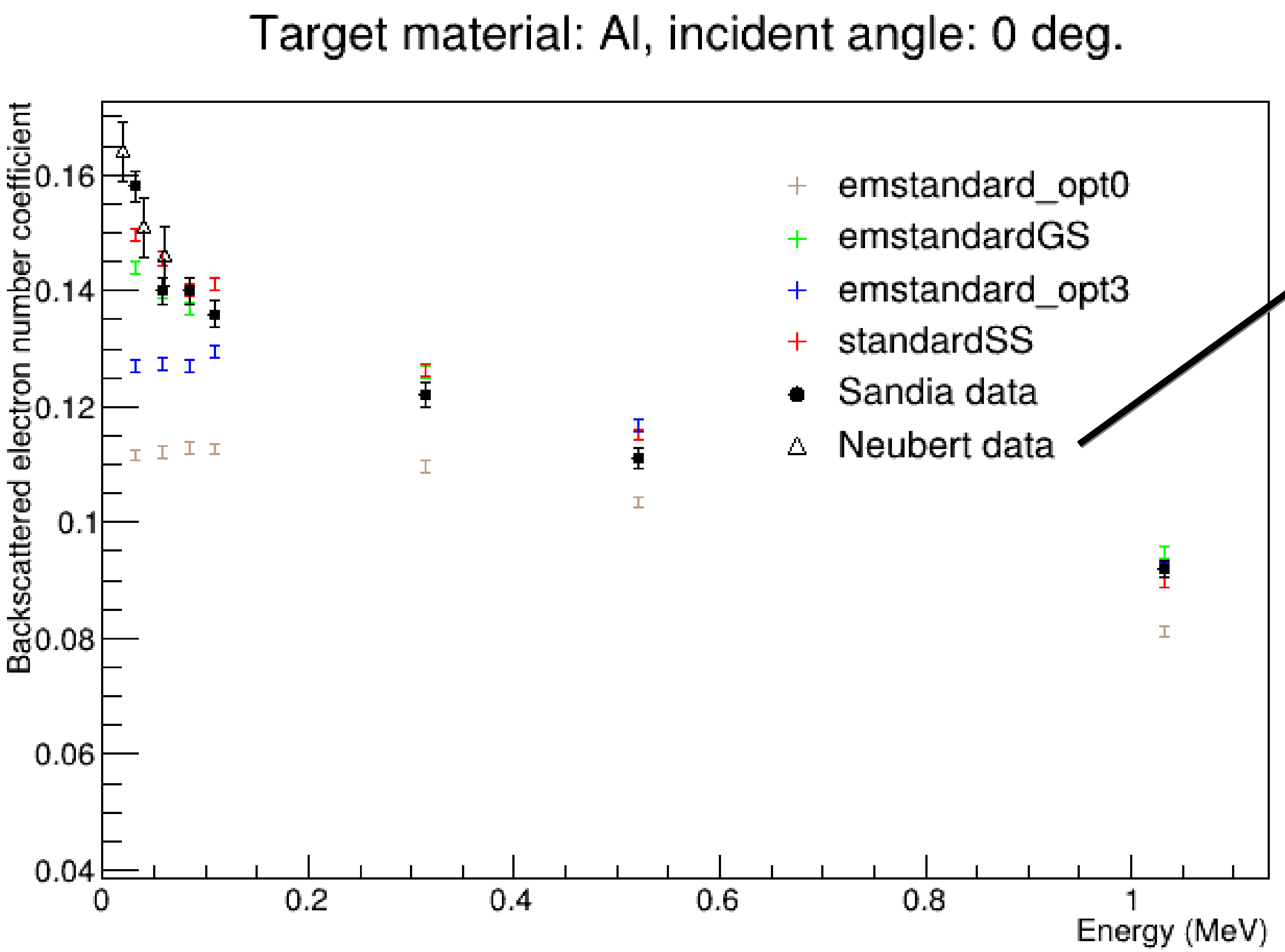
Sandia80 backscattering experiment



- Calorimetric measurement from Sandia Lab (Ref. [1]). Calorimeters are cylindrical and serve as targets.
- Various incidence angle from 0° to 75°
- Various materials (Al, Be, Ca, Ti...)
- Electron beam energies from 0.032 to 1.033 MeV
- Simulate this apparatus with a cylinder in vacuum using Geant4 10.2

We started from a suite by A. Lechner and V. Ivantchenko (thanks!).

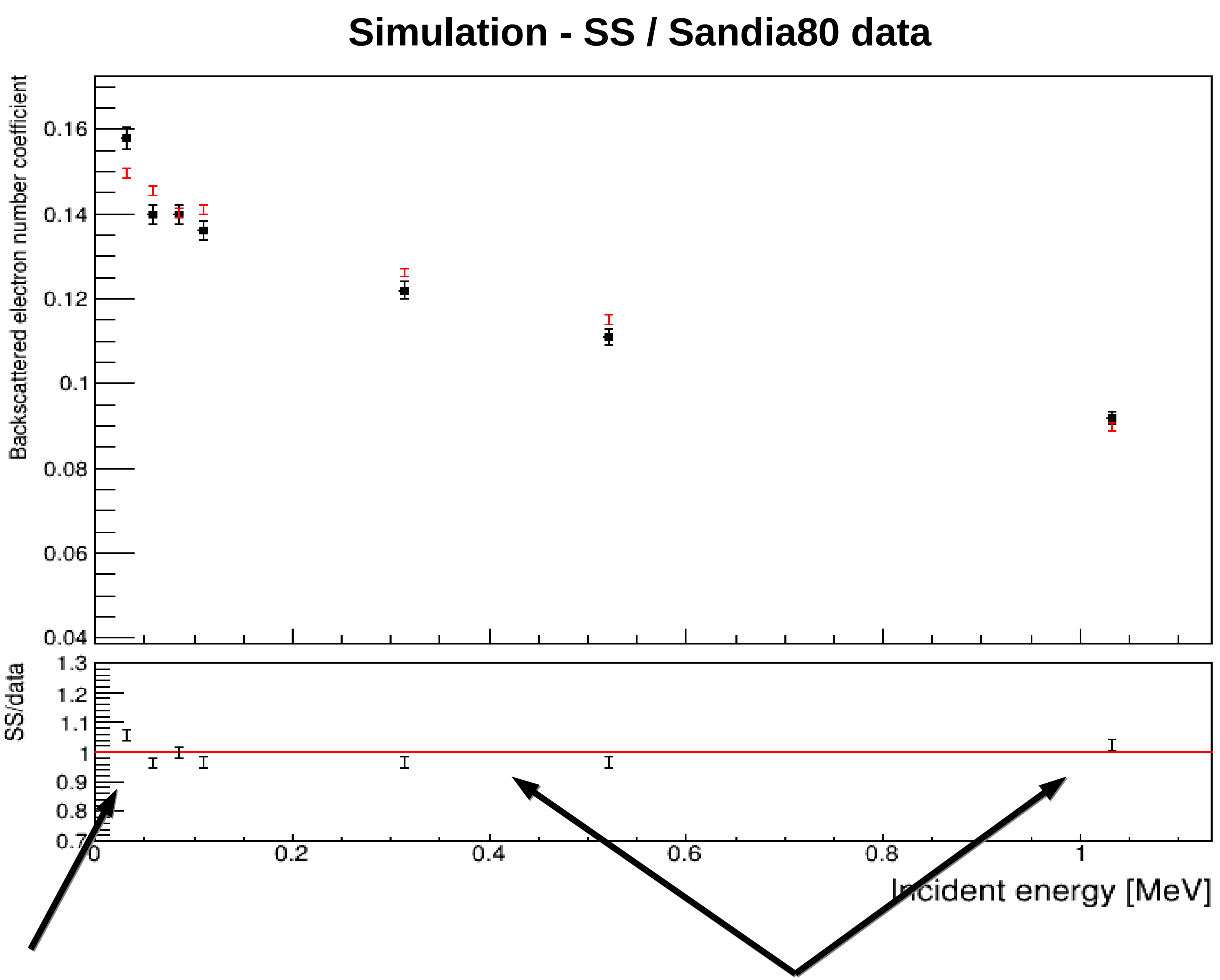
Sandia80 backscattering experiment



Another dataset [2] for various materials and angles added for comparison. Points only at low energy.

Excellent agreement above ~0.2 MeV. For lower energies different behavior between GS/SS and opt3/opt0.

Sandia80 backscattering experiment



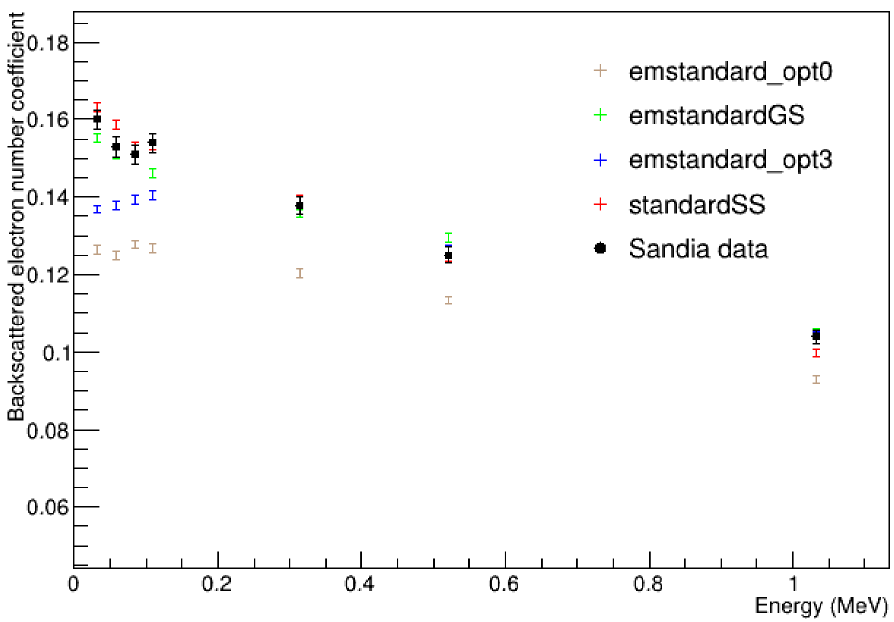
Small deviations (max ~5%) al low energies

Compatible within ~1.5 sigma (stat. error on simulation, syst+stat on exp data).

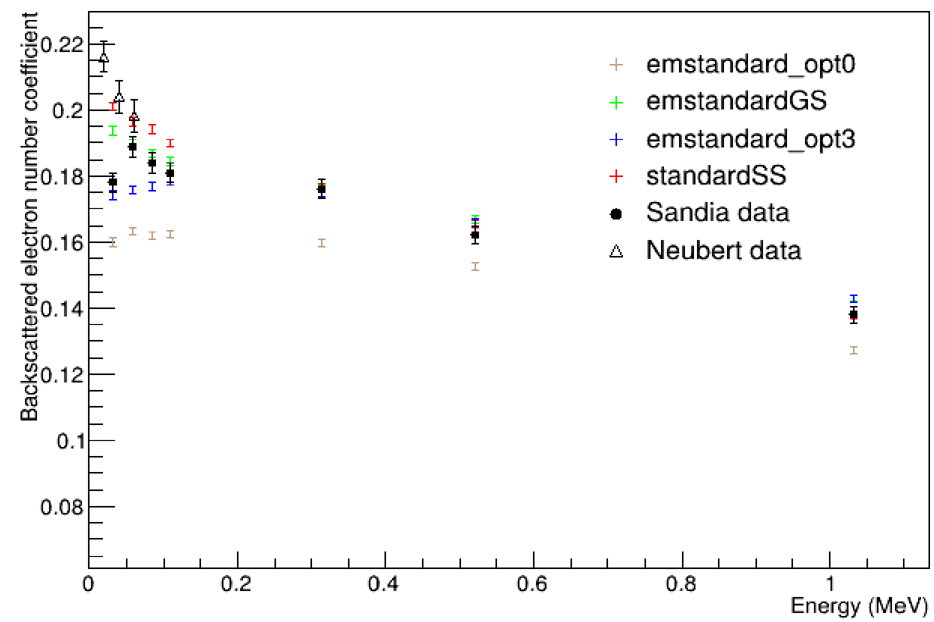
Sandia80 backscattering experiment

Incident angle dependency

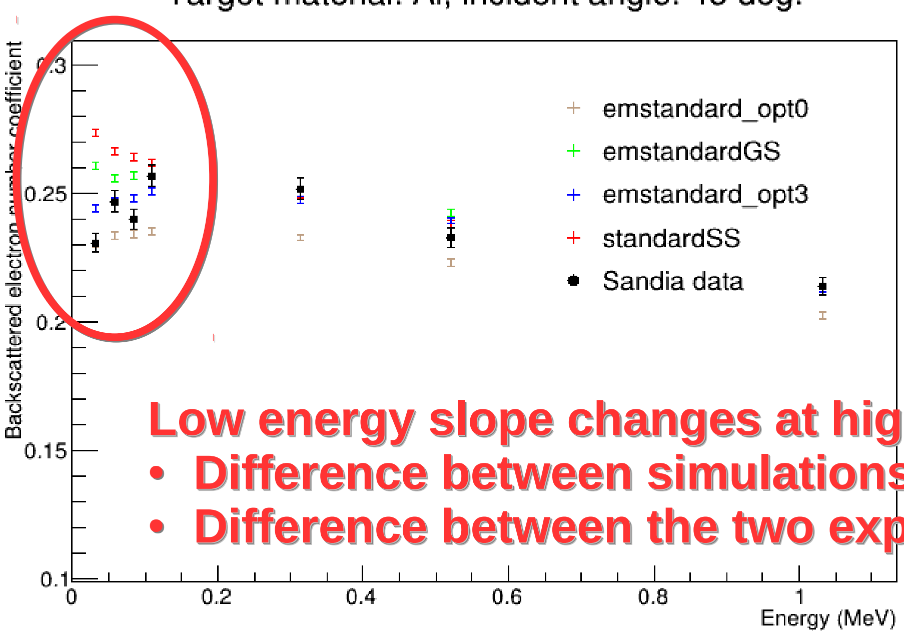
Target material: Al, incident angle: 15 deg.



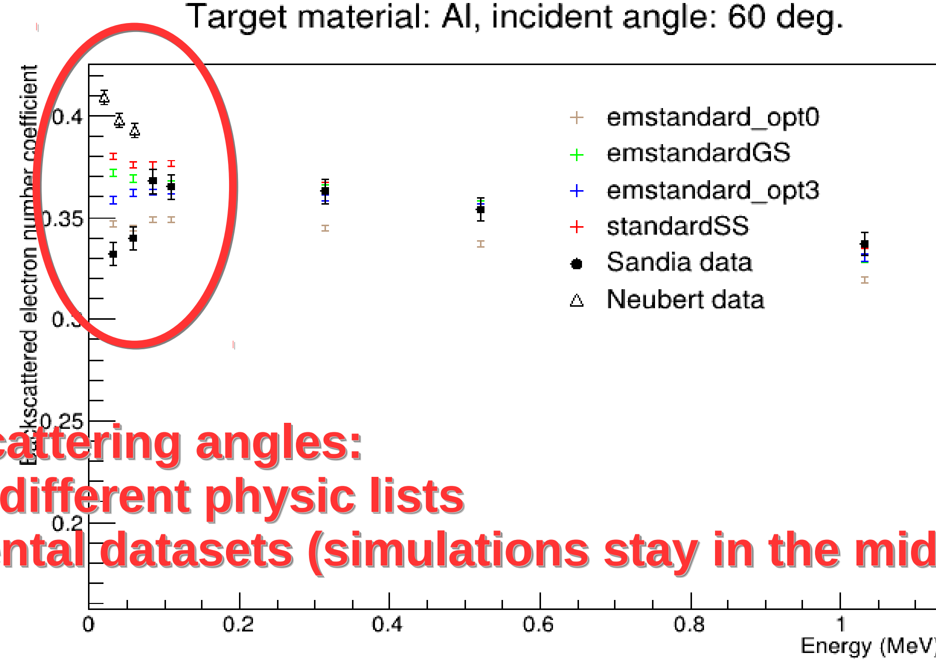
Target material: Al, incident angle: 30 deg.



Target material: Al, incident angle: 45 deg.



Target material: Al, incident angle: 60 deg.



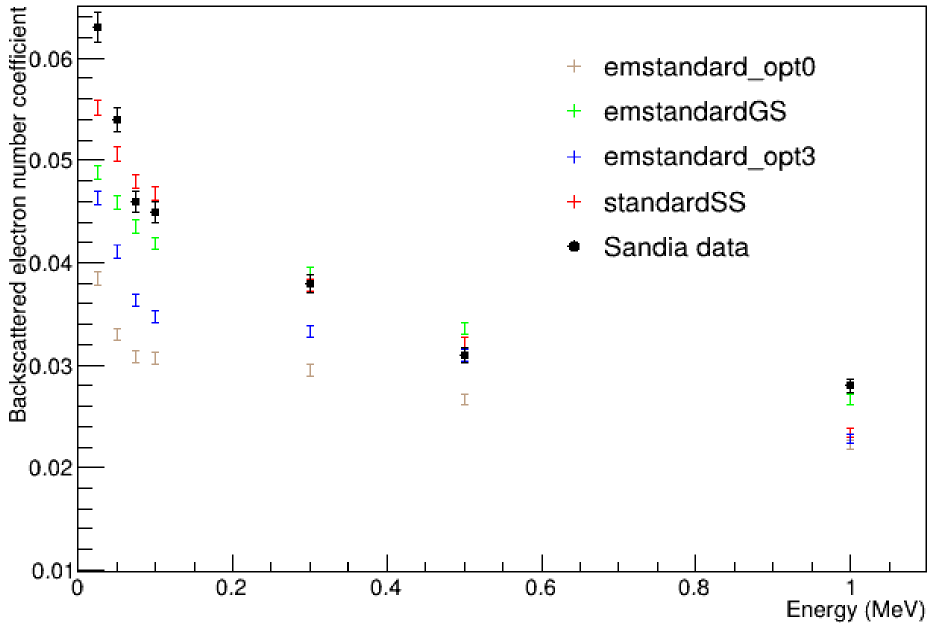
Low energy slope changes at higher scattering angles:

- **Difference between simulations with different physic lists**
- **Difference between the two experimental datasets (simulations stay in the middle)**

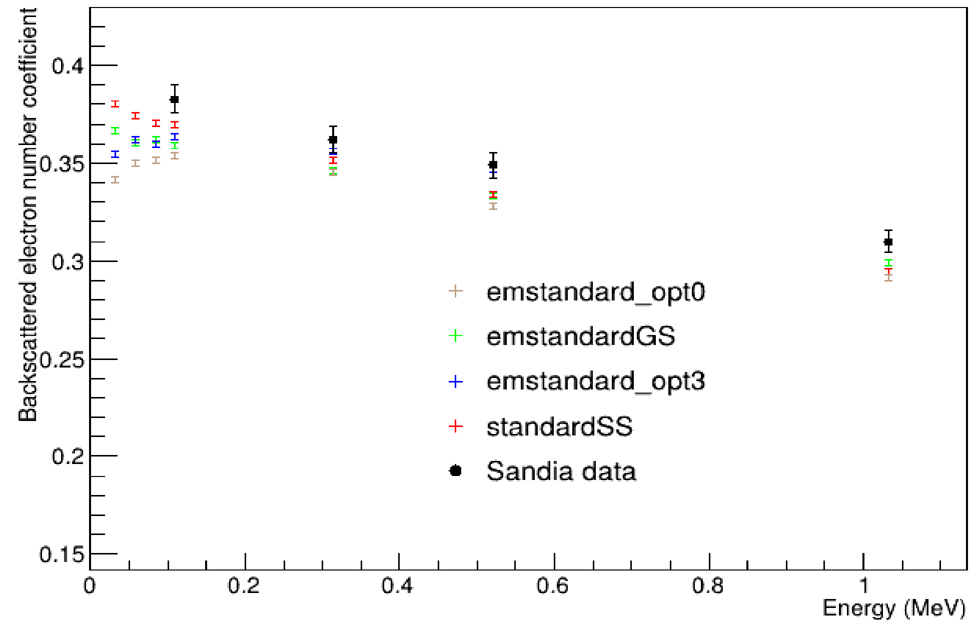
Sandia80 backscattering experiment

Different materials normal incidence

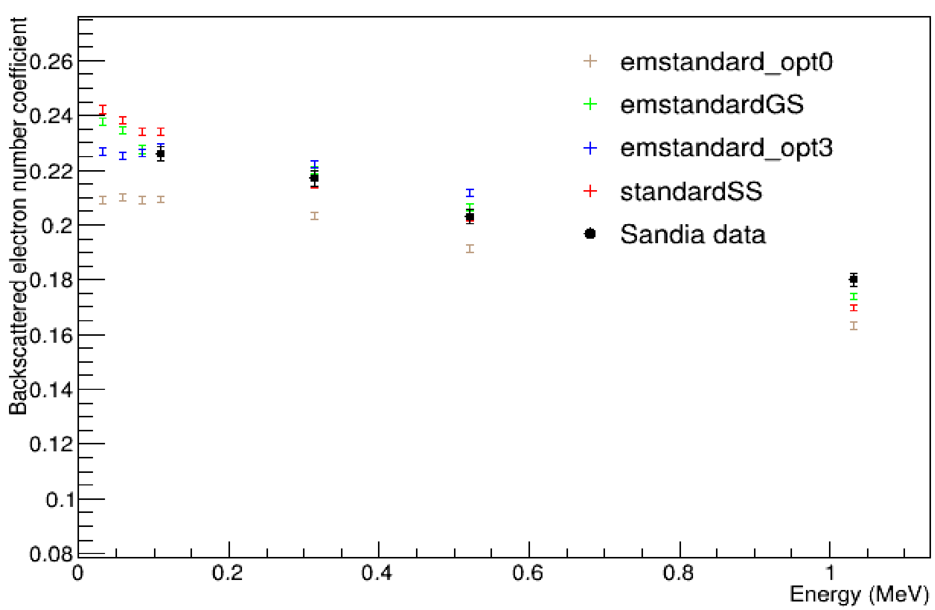
Target material: C, incident angle: 0 deg.



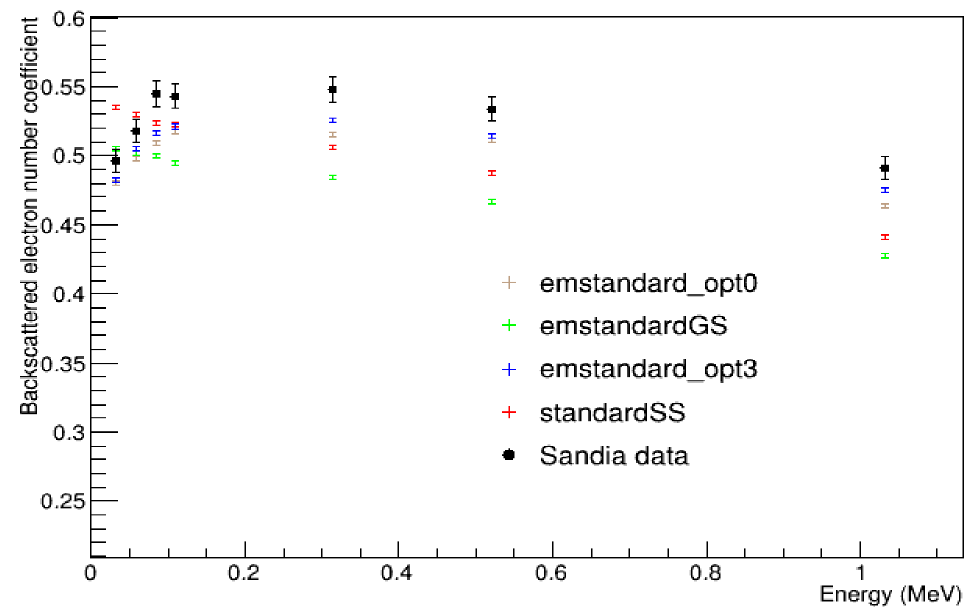
Target material: Mo, incident angle: 0 deg.



Target material: Ti, incident angle: 0 deg.



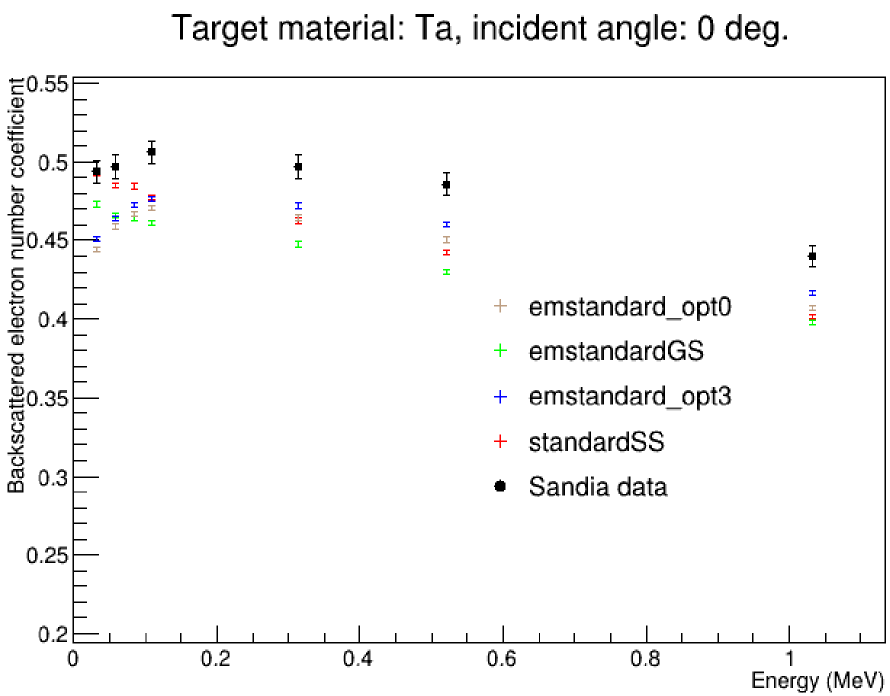
Target material: U, incident angle: 0 deg.

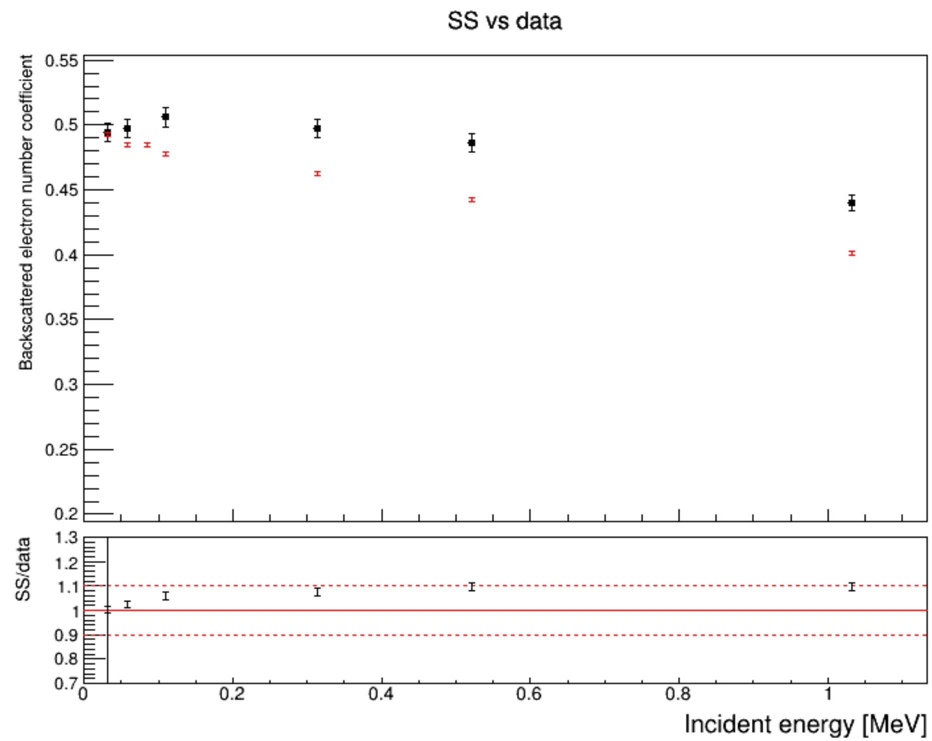


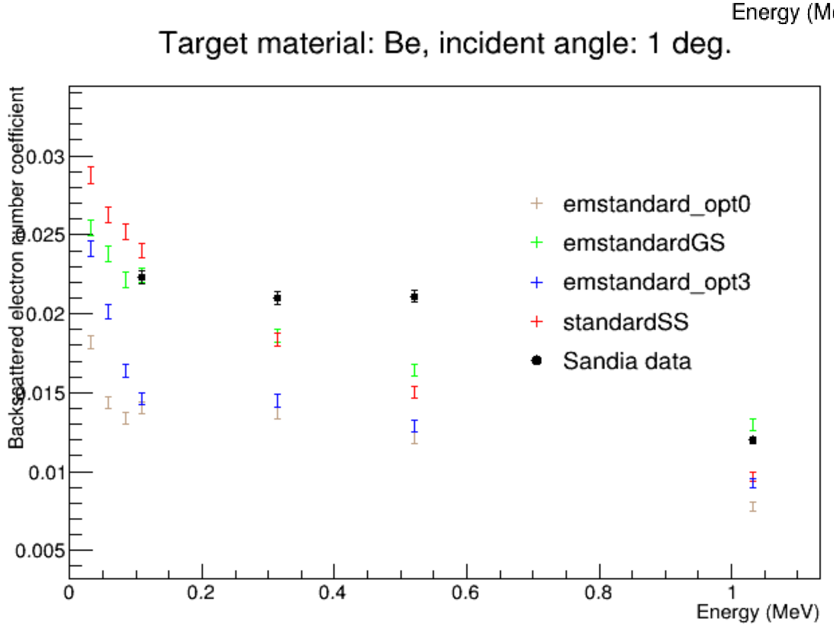
Sandia80 backscattering experiment

Different materials normal incidence

Tantalium: deviations up to 10%.



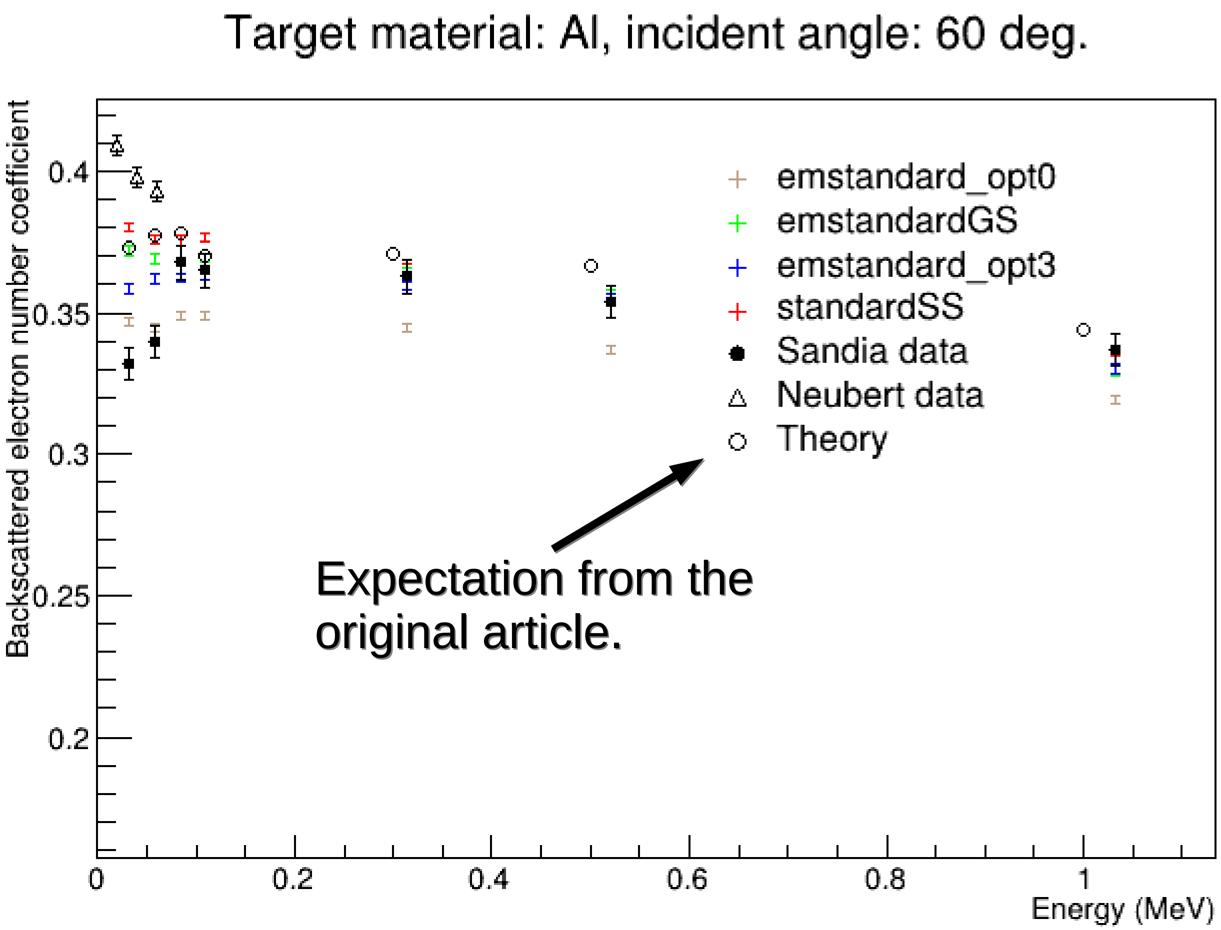




Also Be not very good, but strange slope in data...

Sandia80 backscattering experiment

- Good agreement for Al, C, Mo, Ti, U at normal incidence
- Differences for Ta and Be



- Experimental data slope different at low energies, particularly at higher angles
- Sandia80 authors expected higher values at low energies (see circles in plot) and discussed possible experimental systematics affecting the measurements.

Sandia80 backscattering experiment

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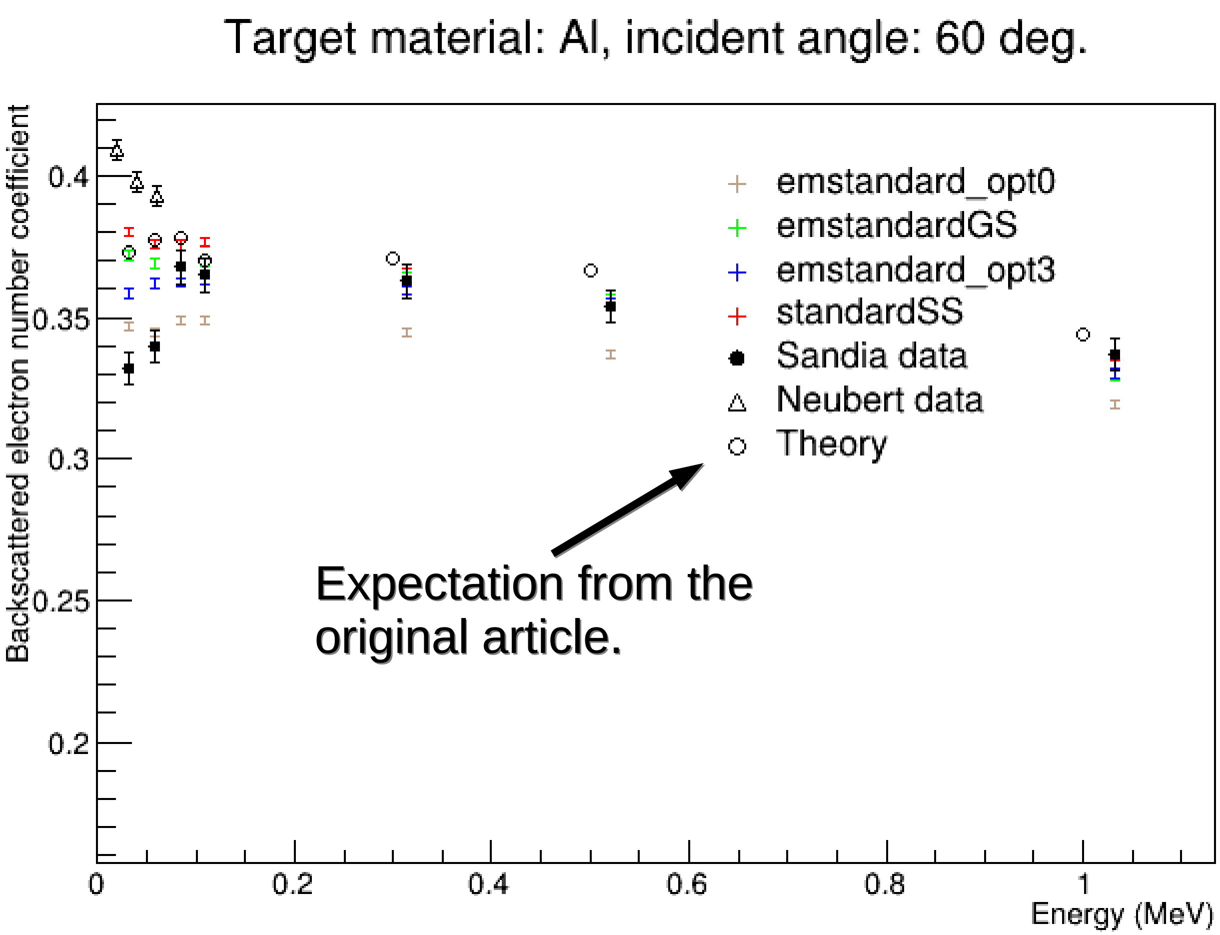

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Find other experimental datasets for further comparisons...

Backscattering datasets at low energy

Find other experimental datasets for further comparisons...

Collection of electron-solid interactions experimental datasets by C. Joy [3]. Large database, different materials, energies and experimental conditions.

Backscattering coefficient conventionally defined as $\eta = I_B/I_P$.

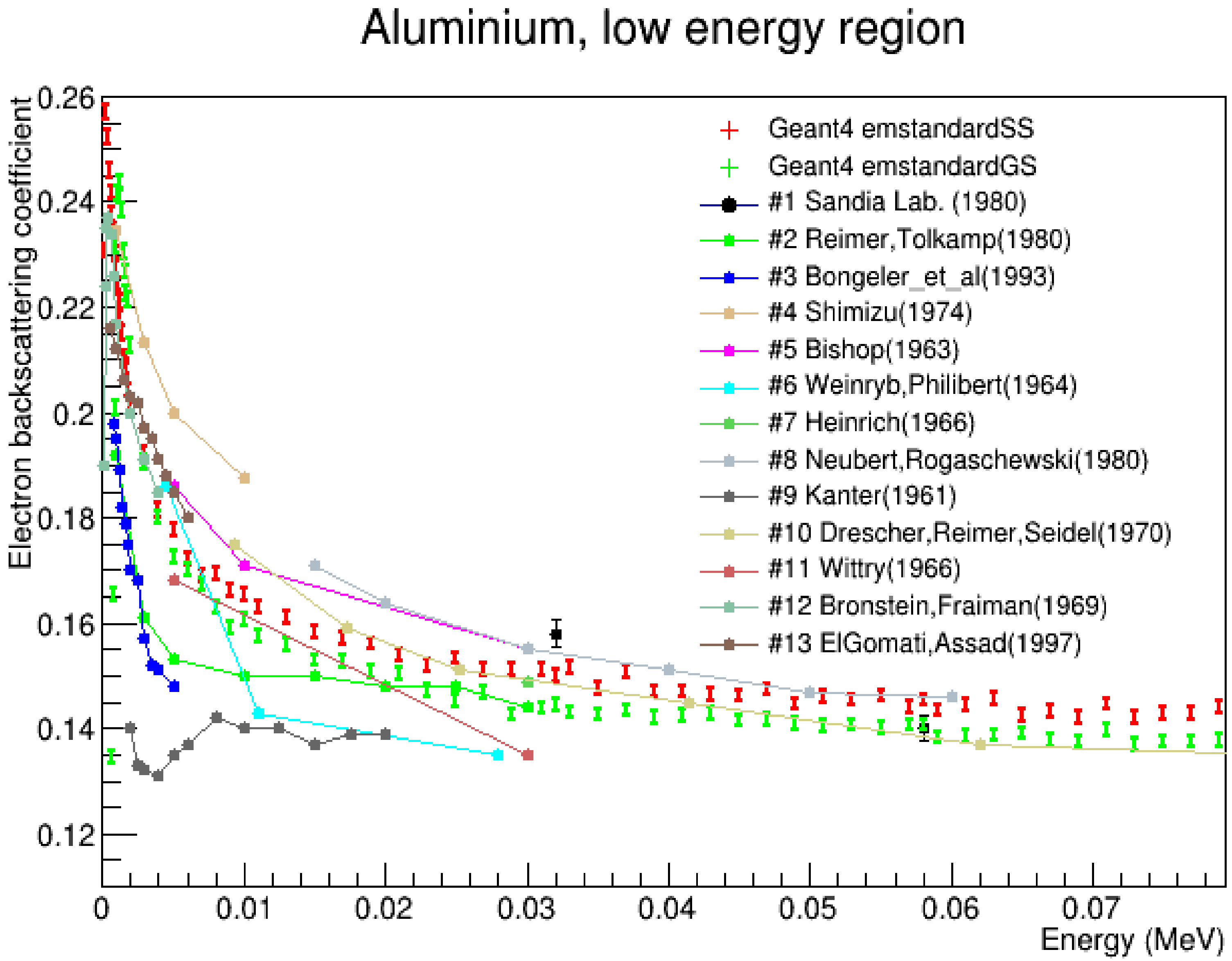
- number of electrons backscattered from the sample surface measured through the current I_B (with an energy greater than 50 eV)
- total number of the incident electrons (current I_P).

- Take Aluminium as benchmark (relevant for AREMBES project)
- 14 datasets reported
- Discard 2 of them because very lack of information on experimental techniques and systematics

Differences between the measured values reported due essentially by the different experimental techniques and condition of measure.

Backscattering datasets at low energy

ALERT!: Out of boundary use!
SS down to 50 eV !
(LowEnergy limit 1keV)

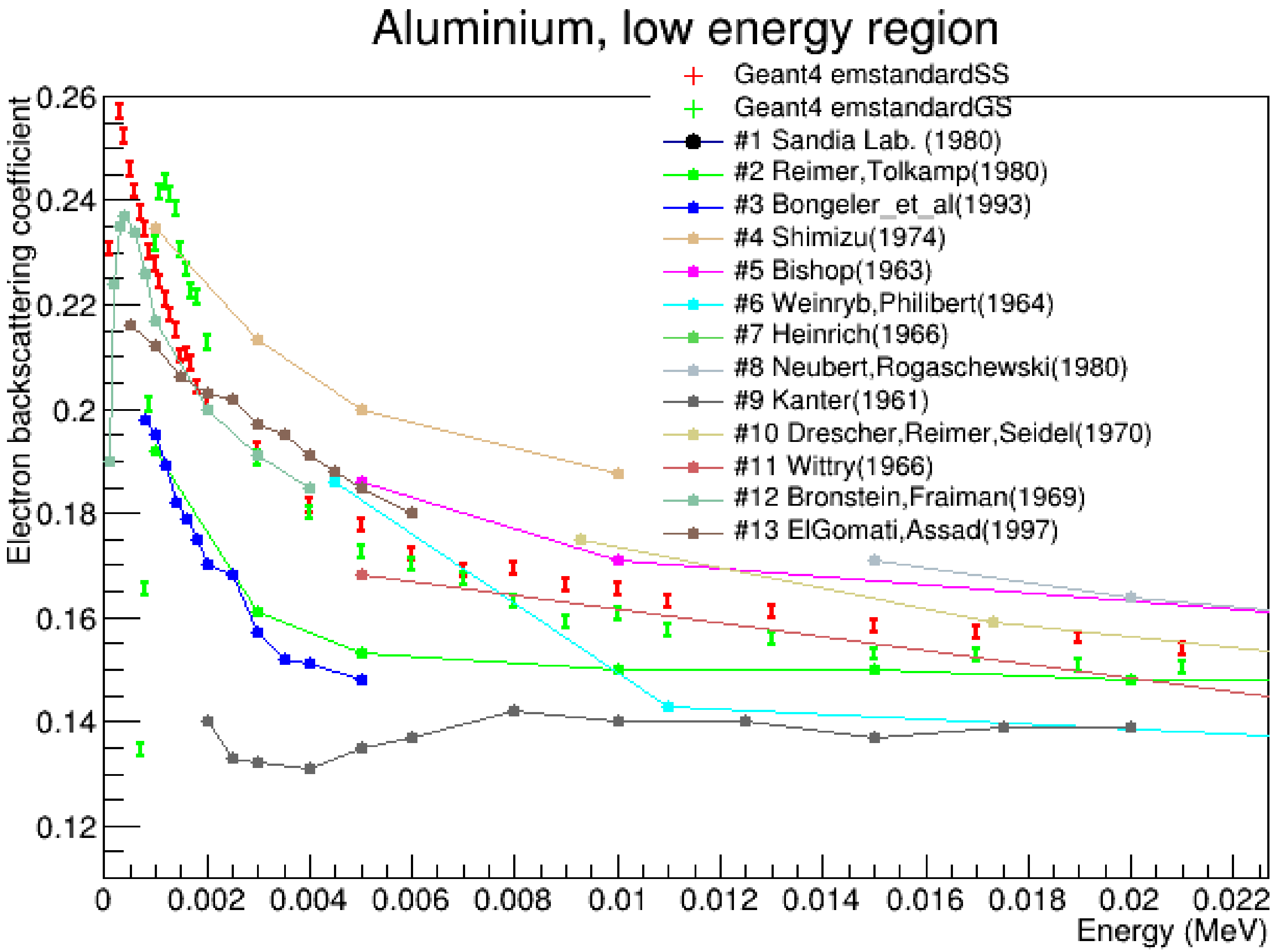


Normal incident electrons on Aluminium target. Compared with SS and GS standard physics lists. Geant4 10.2 used.

Backscattering datasets at low energy

ALERT!: Out of boundary use!
SS down to 50 eV !
(LowEnergy limit 1keV)

Focus in the low-energy part of the plot.



- SS and GS stay in the middle of experimental results
- Up to 50% difference at lower energies between different datasets
- Caveat: different experimental conditions

Conclusions

- In general good agreement between Geant4 10.2 and experimental data
- Best are SS and GS (GS faster)
- Opt0 and opt3 tend to underestimate data at low energy
- A couple of “problematic” materials (Ta, Be)
- At low energy SS and GS stay in the middle of the experimental data spectrum

Plans for the future...

- Systematic treatment of the various angles data: backscattering coefficient vs angle at fixed energy for the available materials
- Low energy detailed plot with the available datasets from Joy collection for different materials and other physics lists

Backup

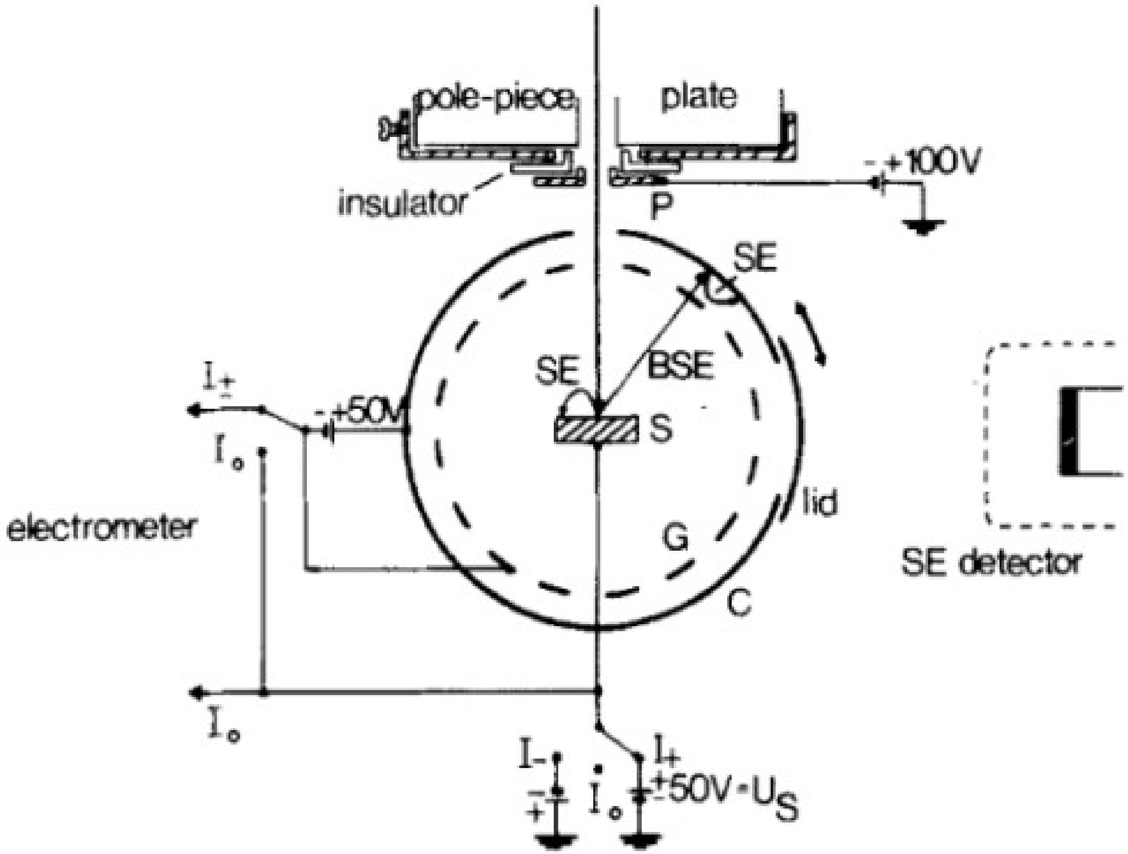
References

[1] G J Lockwood and G H Miller and J A Halbleib, "Electron Energy and Charge Albedos - Calorimetric Measurement vs Monte Carlo Theory", SAND80-1968 UC-34a.

[2] Measurements of the back-scattering and absorption of 15-60 keV electrons for transparent solid films at various angles of incidence, 1984 J. Phys. D: Appl. Phys. 17 2439 (http://iopscience.iop.org/0022-3727/17/12/012)

[3] David C. Joy. A database of electron-solid interactions, 2008

Polarized grid

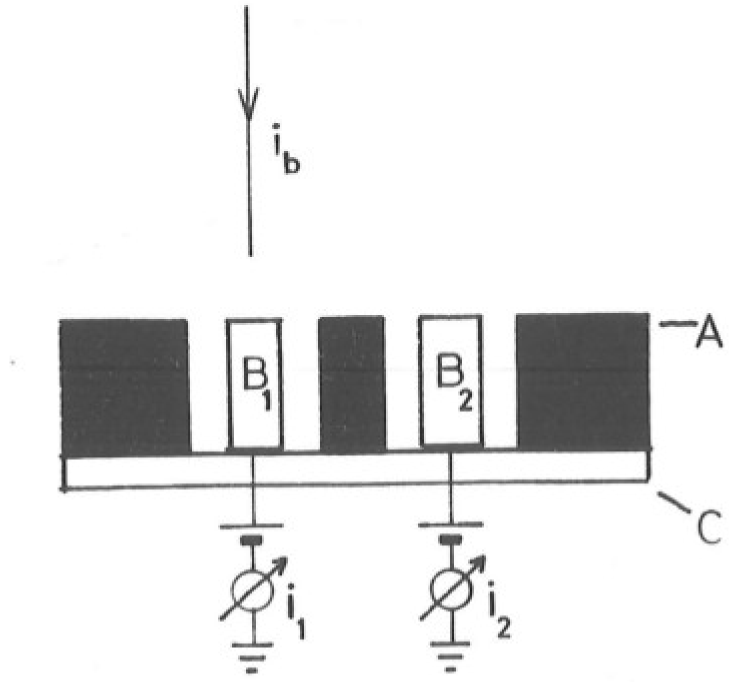


- S specimen
- G polarized grid (-50V)
- C collector
- P negatively biased plate for retarding the secondary electrons coming down the column.

Thanks to the grid the electron backscattered at the collector should not hit the specimen again and the secondaries from the specimen will not escape and reach the collector.

When the specimen is positively biased a current I^+ is measured at the collector and when the bias is negative I^- is measured (50 V can be neglected compared to the accelerating voltage, of the order of 10 kV). If C, G and S are electrically connected the total electron incident probe current I^0 can be measured. So the backscattering coefficient and secondary yield δ can be expressed as the following: $\eta = I^+ / I^0$ and $\delta = (I^- - I^+) / I^0$.

Double target



When the incident electron beam scatters on the first target B1, the second target B2 is used to measure the background current from the chamber walls.