Investigation of new materials for higher secondary electron yields

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Agenda

- Introduction and usage of secondary electrons
- Production of secondary electrons by ions
- Nanorods as a promising candidate
- First test measurement
- Conclusion

Secondary electrons

- Definition: electrons produced by primary ionizing radiation
- Primary radiation: γ,δ (fast e-),Ions(p,α, heavy),…
- Production mechanism dependent on electronic structure of targets: metals, semiconductors(heterostructures), isolators; gasses
- Mainly a surface property
- Thin foils (ΔE<E)
  has to be treated differently

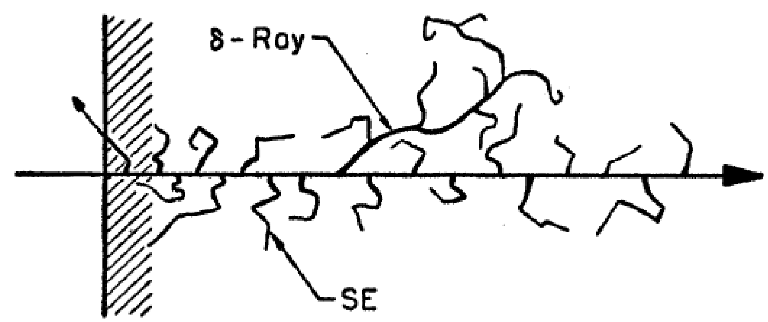


FIG. 1. Formation of secondary electrons (SE) and δ rays by heavy ion.

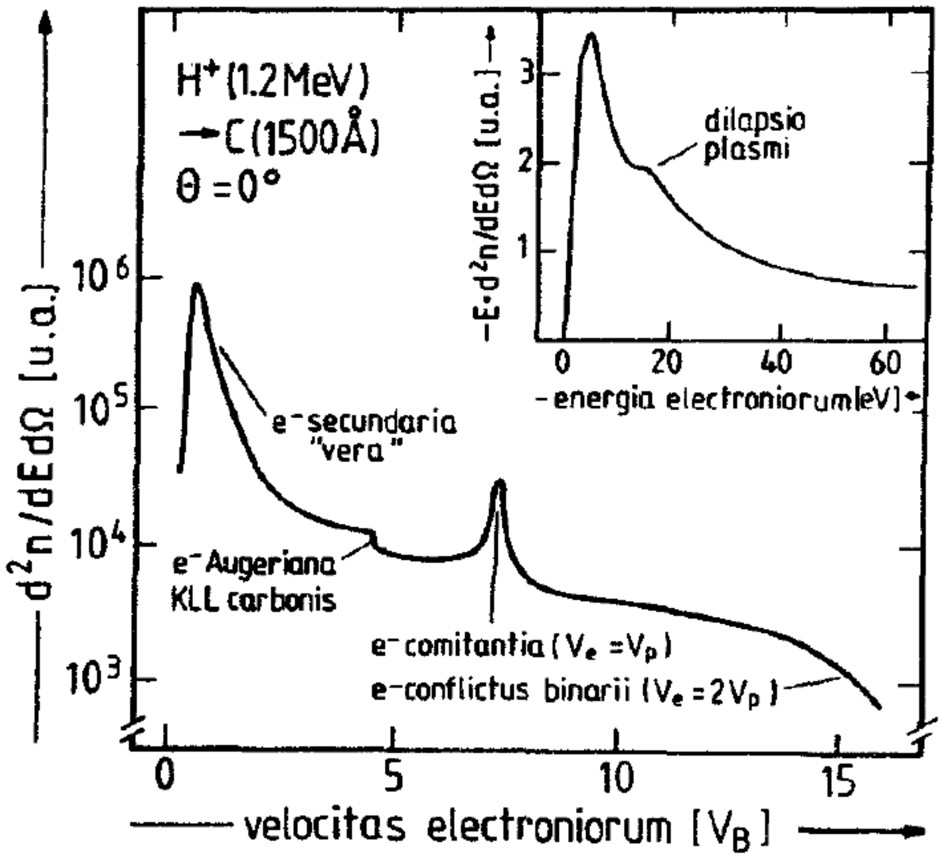
Theories of SE production

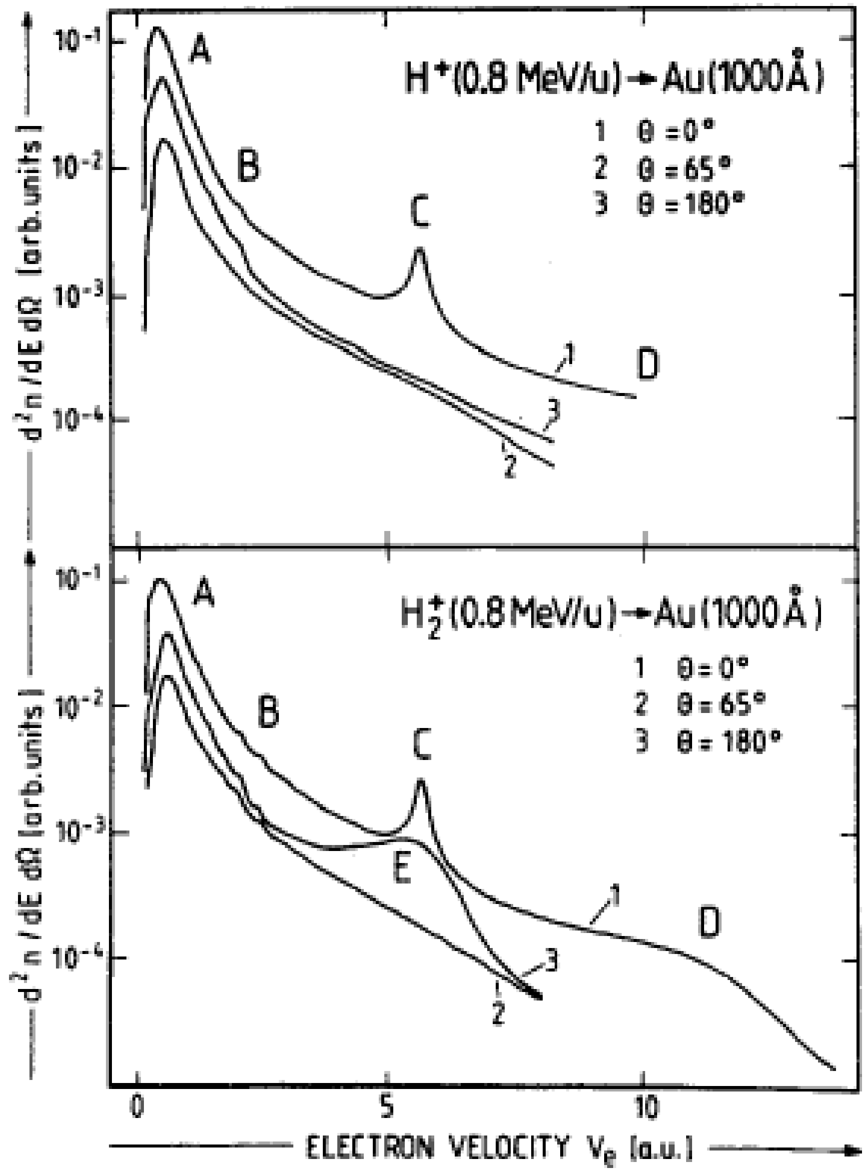
- Semi empirical treatments explain classes of observations quite well
- E.g. Sternglass (1957) for thick metals
- Most theories relate the yield y to the electronic stopping power of the material

$$y = \alpha * S_e$$

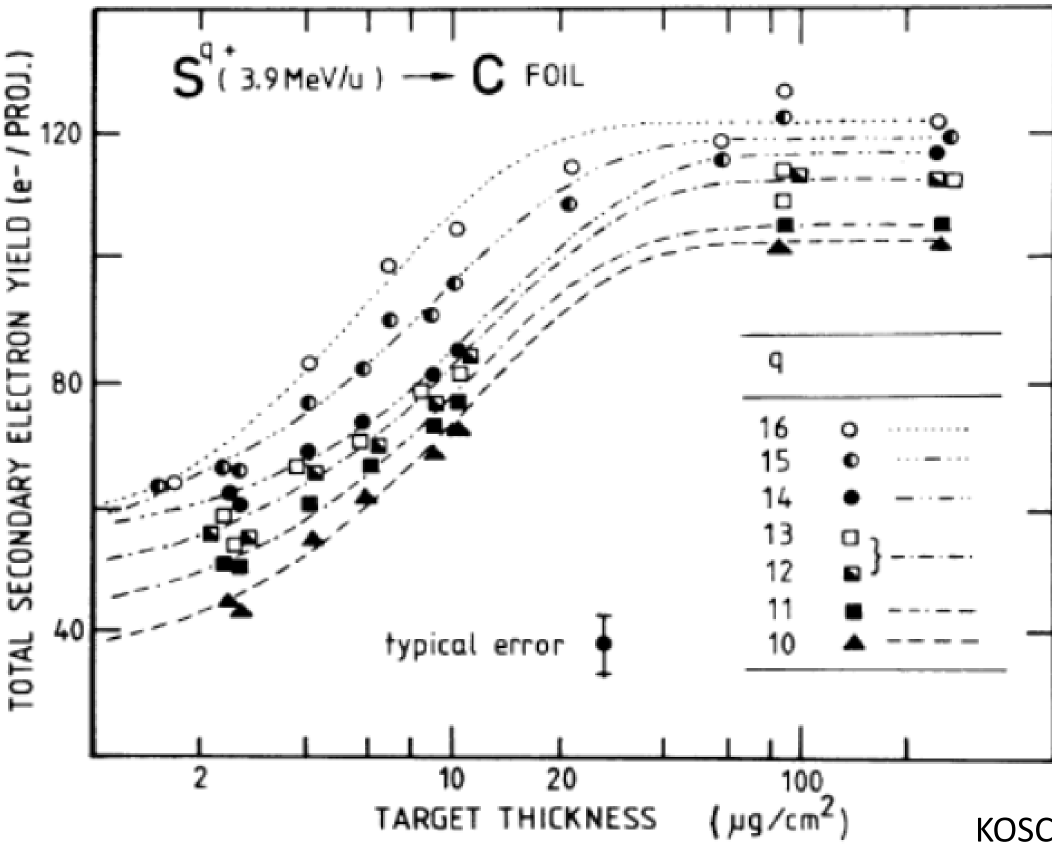
- Most theories distinguish two steps:
  - production
  - transport (and release from surface)
- No modern full picture theory availabel

SE in thin foils



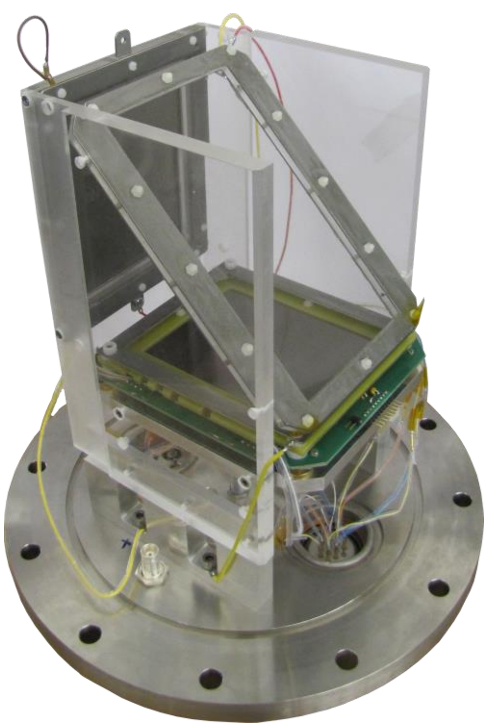


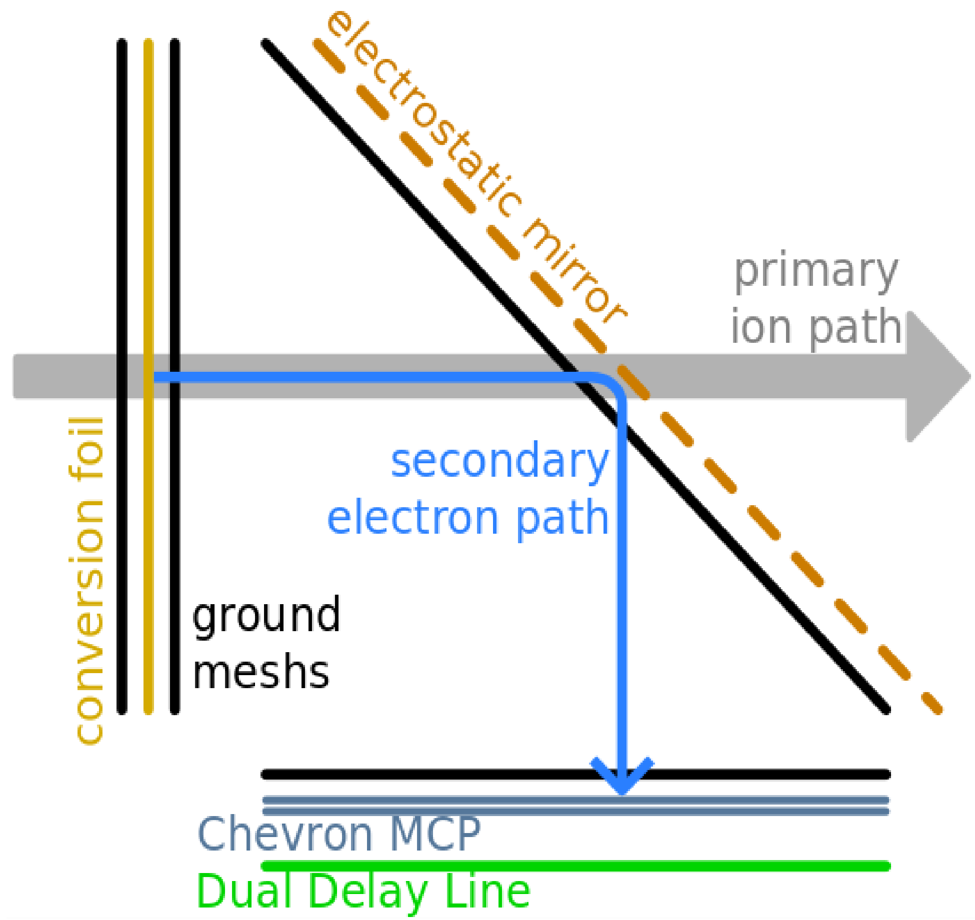
Thickness and yield



KOSCHAR, ET AL.; Phys. Rev. A (**1989**); 40, 3632–3636

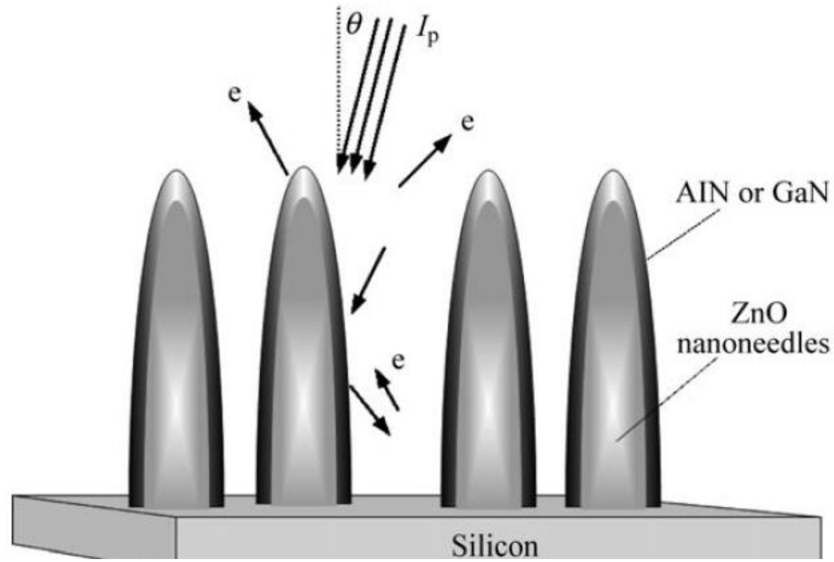
Example usage of SE-
Thin Foil Beam Tracking Detectors





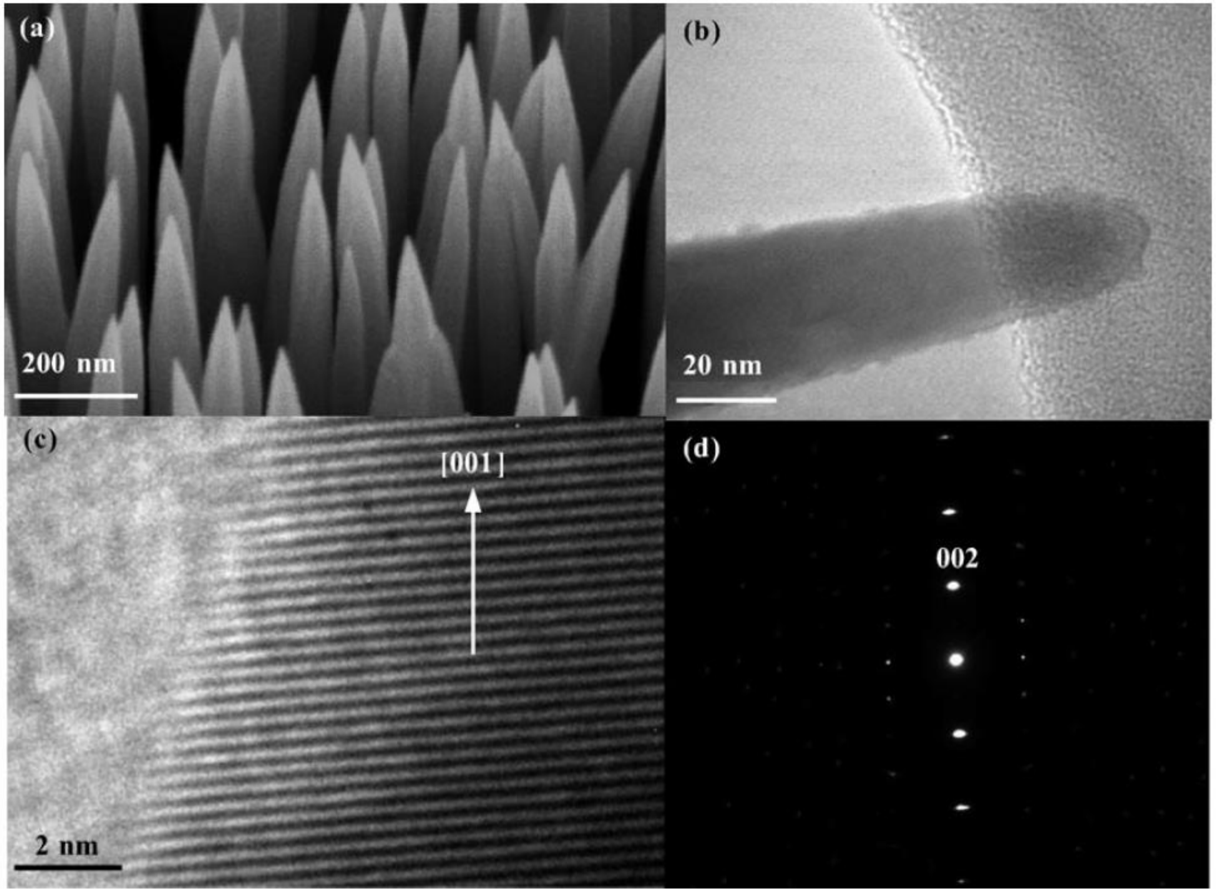
AlN/GaN on Zn nanorods

- Product of industry for flat screens
- interest in high field effect electron emission
- Heterostructure, i.e. interface between dissimilar semiconductors
- AlN/GaN have low or even negative electron affinity
- Epitaxial growth on 1D ZnO nanorods



Shu Ping Lau et al., Small 2006, Vol. 2, No. 6, 736

Zn nanorods



a) Scanning Electron Microscop (SEM)
b) Transmission Electron Microscop (TEM)
c) High Resolution TEM (HRTEM)
d) selected-area electron diffraction (SAED)

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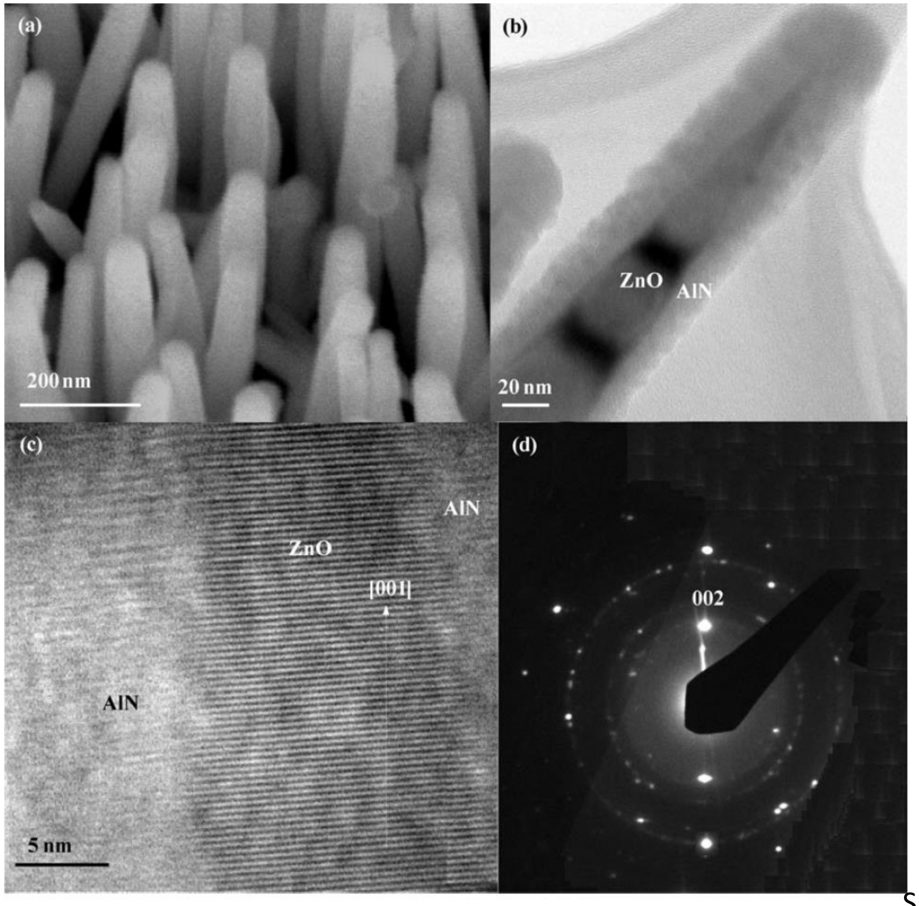
Zn nanorods coated with AlN



a) SEM
b) TEM
c) HRTEM
d) SAED

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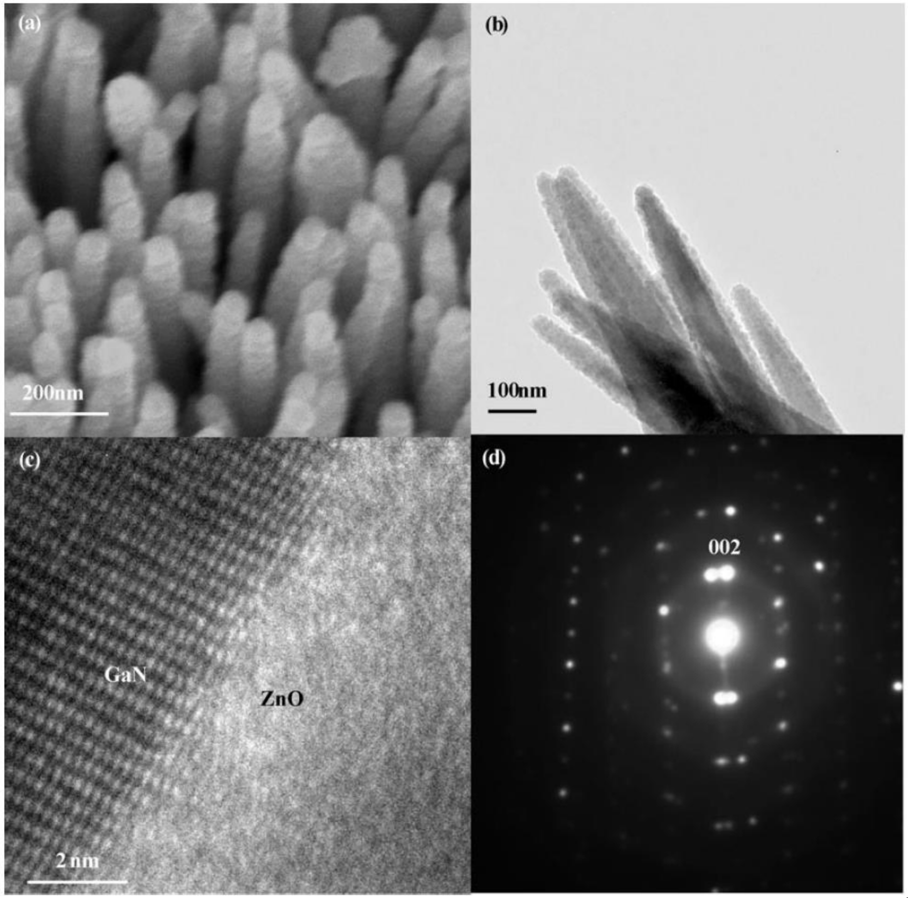
Zn nanorods coated with GaN



a) SEM
b) TEM
c) HRTEM
d) SAED

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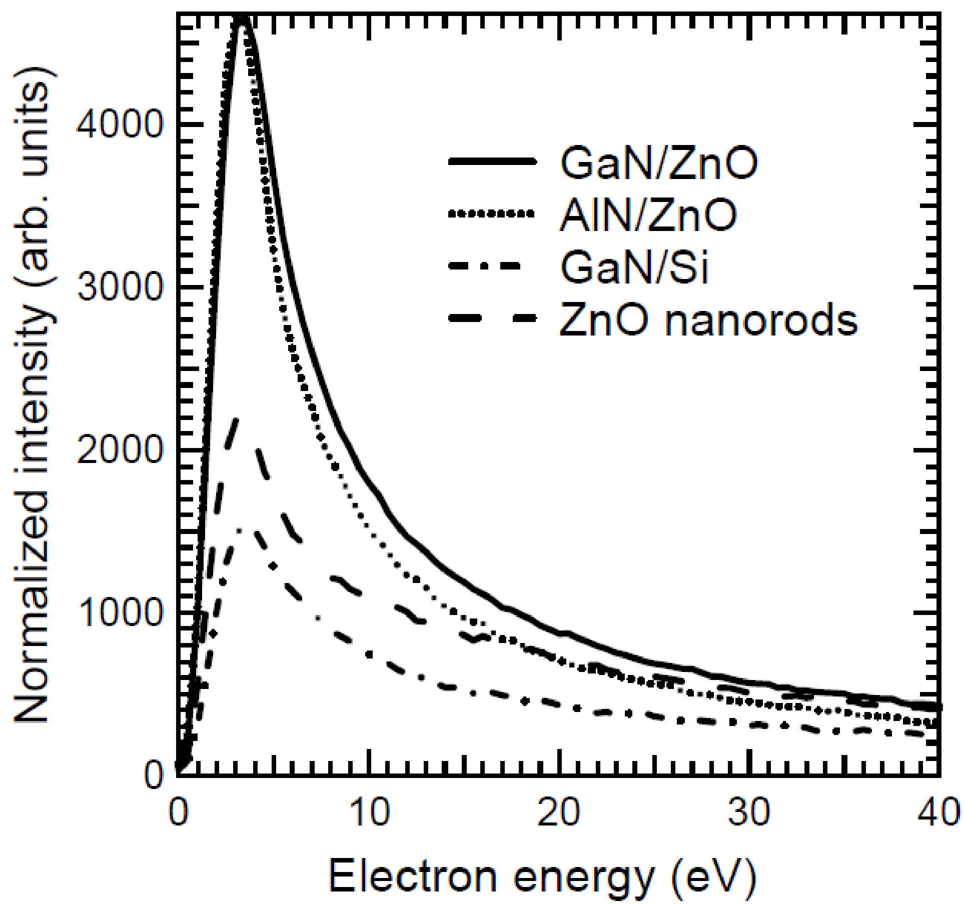
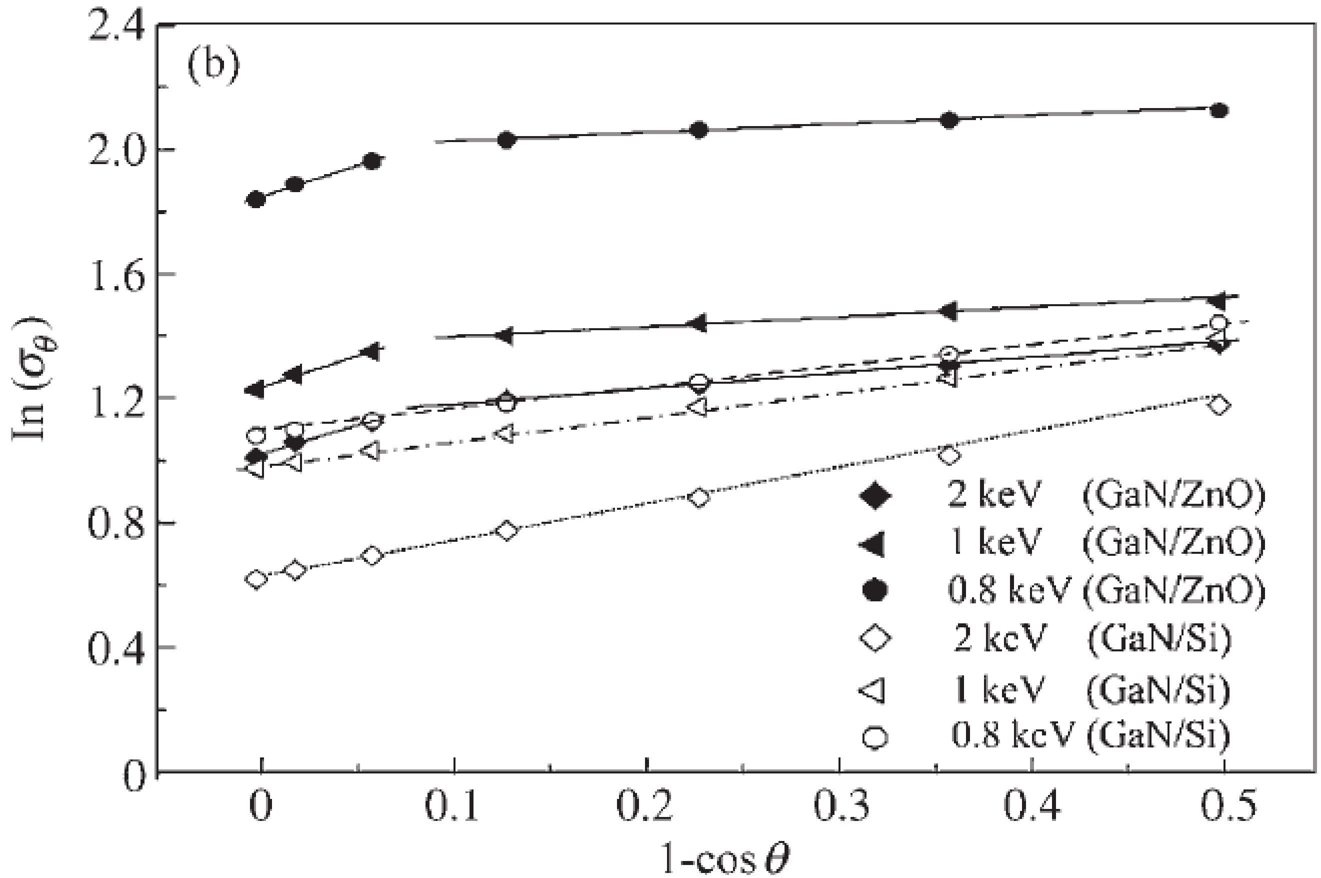
SE Yield



M. Cholewa et al. Nucl. Instrum. & Meth. B 254 (2007) 55-58.

Angular dependence



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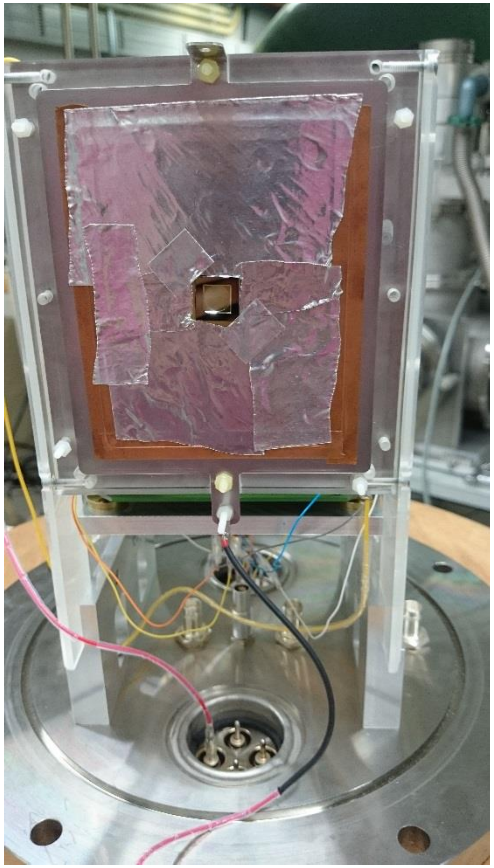
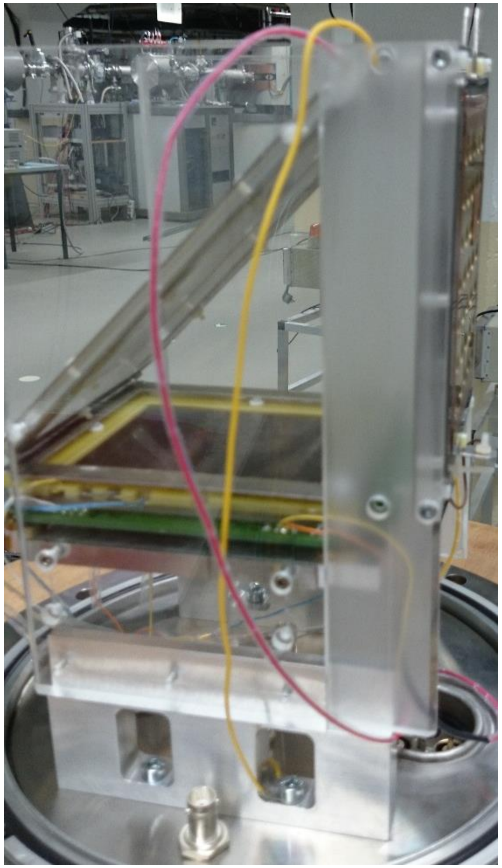
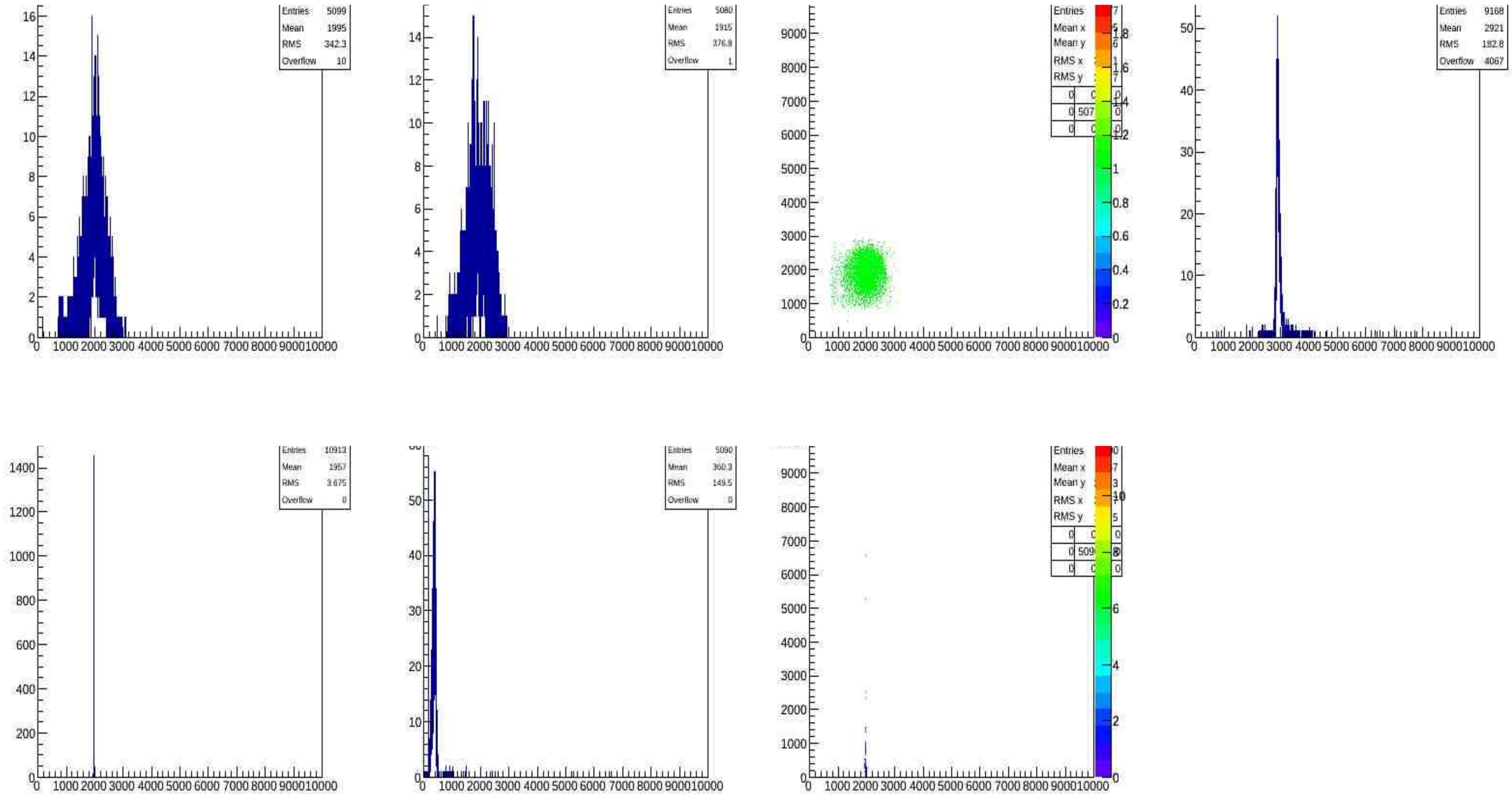
First test setup in Cologne

- Thin foil detector in coincidence with Silicon detector and mask
- 241Am α source
- Number of MCP events in coincidence with silicon is related to the quantity of SE
- U_{acc} =2kV U_{ref} =3kV U_{mcp} =1.65kV



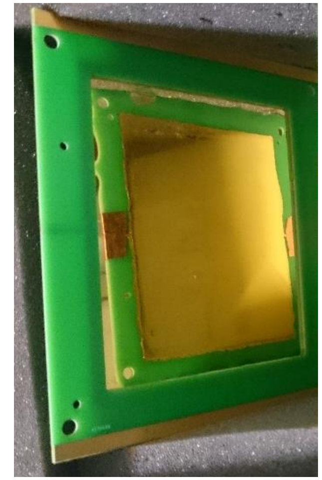


Results

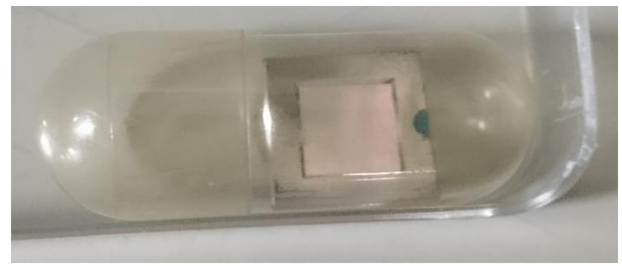


Entries 5099
Mean 1995
RMS 342.3
Overflow 10
Entries 5080
Mean 1915
RMS 376.8
Overflow 1
Entries 9168
Mean 2921
RMS 182.8
Overflow 4067
Entries 10913
Mean 1957
RMS 3.675
Overflow 0
Entries 5090
Mean 360.3
RMS 149.5
Overflow 0
Entries
Mean x
Mean y
RMS x
RMS y

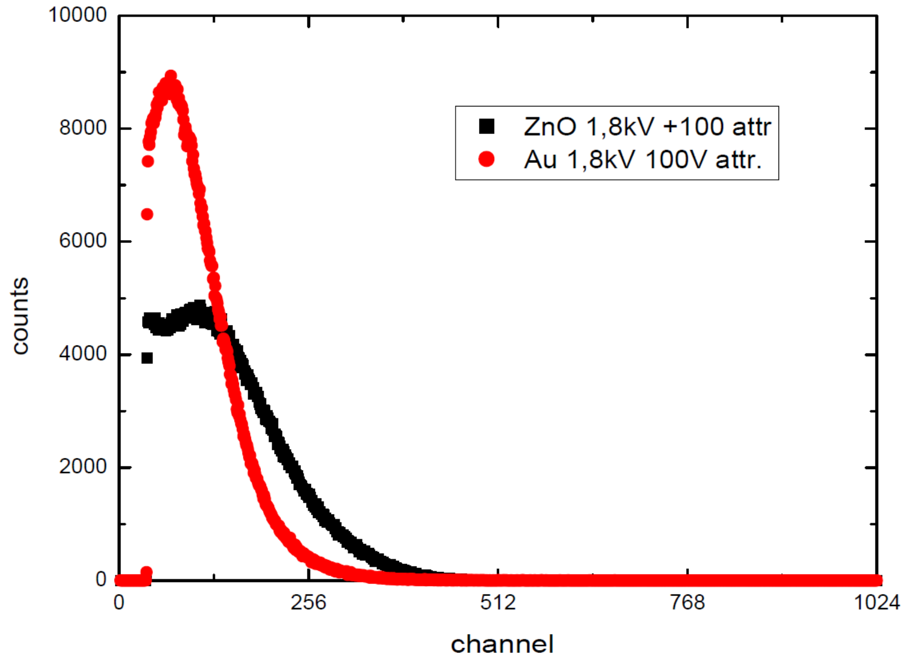
Results

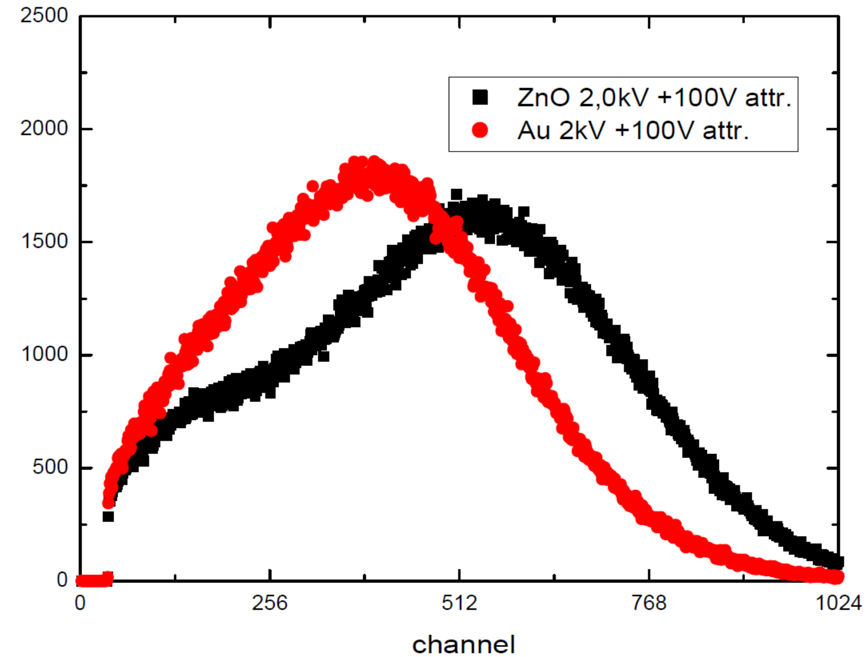


- Gold (0.03 µm) on Mylar(0.9µm) 46,5%
- Mylar(0.9µm) with Gold (0.03µm) 58,6%
- Gold(0.01µm) on SiNi(1µm) 60,7%
- SiNi(1µm) with Gold (0.01µm) 63,7%
- Carbon Foil (0.18µm) 66,4%

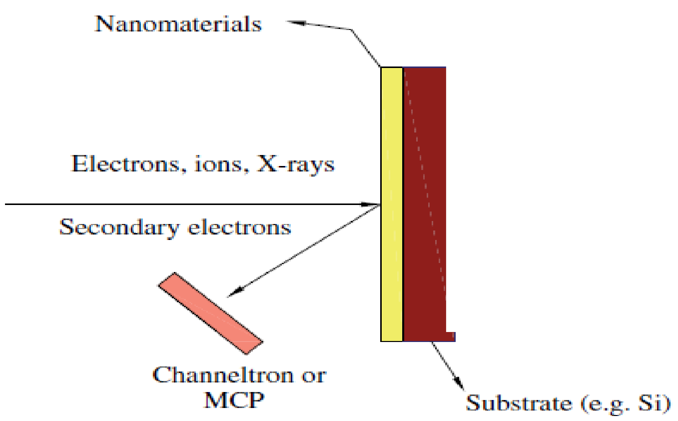


First test of the new material





- Performed @ GSI by Dr. Kay-Obbe Voss using a channeltron
- 2 MeV α beam
- Shift to higher channels indicate better yield



Outlook

- reproduce the measurements
- measure the new material
- (empiric) theory
  - systematic studies to identify relevant parameters (geometry, electronic structure, temperature)
- need a more sophisticated setup for energy and angular distribution measurement
- alternative materials
- data base

Thank you for your attention!

Problems with the test

- Geometric losses of alphas
- Possible losses of SE
- Different electrostatic fields
- Thickness of the materials
- Thresholds could cut off Signals
- No pulse height distribution
- No clean surface (but they will never be in nuclear physics experiments)