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Technical Note describing the experimental results of proton backscattering

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Rationale

The particle induced background of ATHENA is predicted with the use of Monte Carlo simulations (Geant4), and is induced by different physical processes: grazing incidence scattering of low energy protons (<100 keV) and secondary electrons backscattering efficiency. To achieve reliable predictions and to assess the uncertainty level of the expected background is therefore mandatory to validate the treatment of these processes inside the software. The lack of reliable experimental data regarding these processes has made necessary to issue measurement campaigns that are the object of this activity.

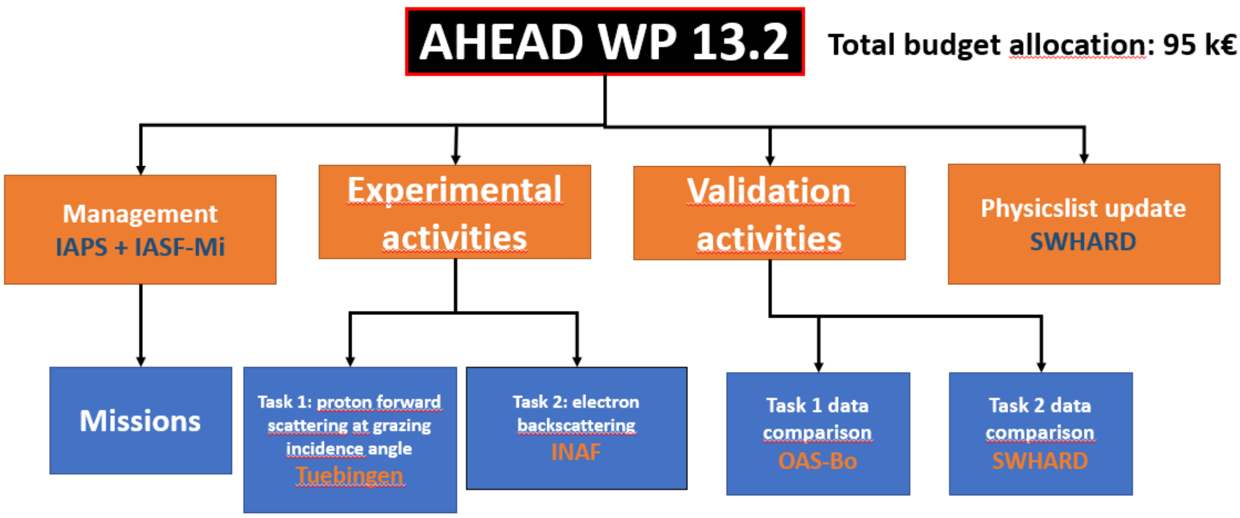


Figure 1 – Work Breakdown Structure of the activity

As shown in Figure 1, the activity is divided into two different experimental activities:

Task 1. Grazing incidence scattering of low energy protons
Task 2. Electrons backscattering

The results of the experimental activities will be compared to the results of validation activities aimed to refine the physics list used in the background simulations. Here below we report the status of the two experimental activities.

Status of Task 1: Proton forward scattering

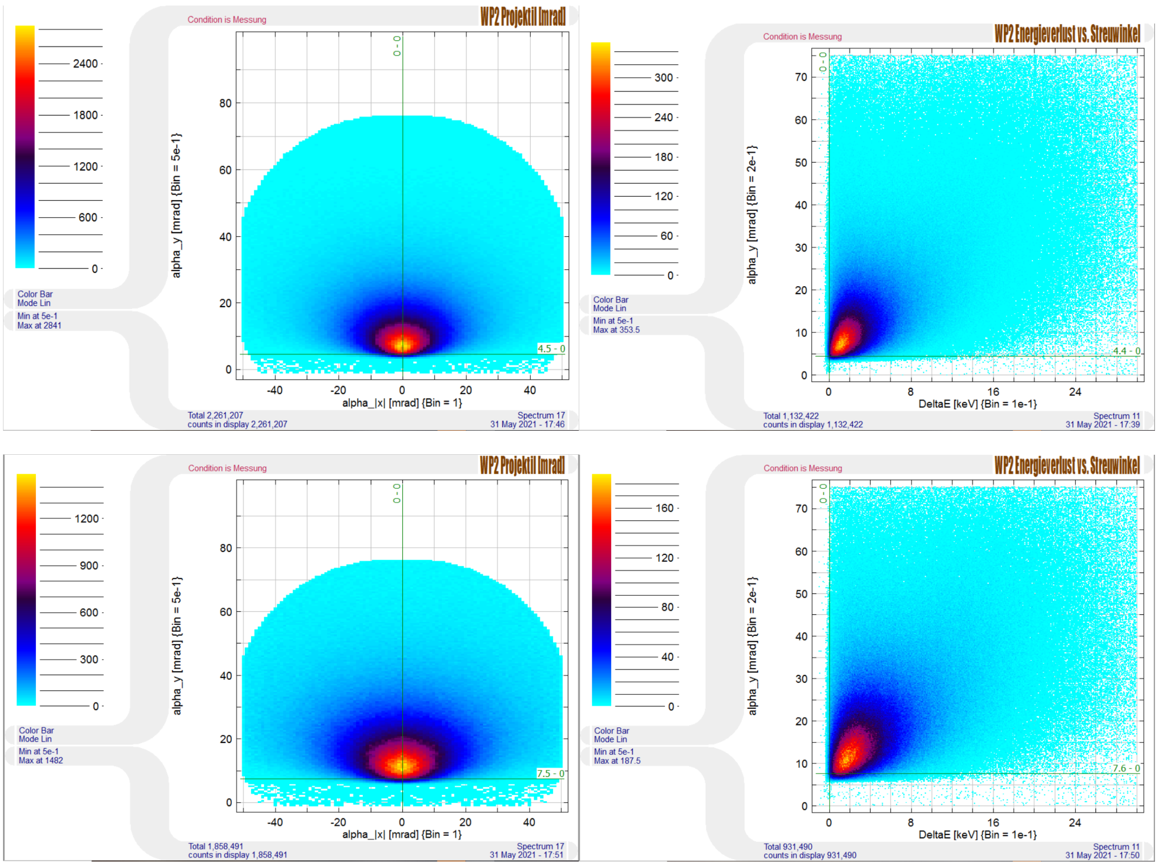
The Tuebingen university has performed measurements with following setup **incidence angles** with a **50 keV proton beam**:

- V1: 4.3 mrad
- V2: 7.5 mrad

- V3: 8.6 mrad
- V4: 14.0 mrad
- V5: 18.3 mrad

These corresponds roughly to **angles between 0.25° to 1-2°.**

The detector is a fixed position 2D micro channel plate, that allows accurate measurement of the 2D scattering distribution of the protons and of the energy lost in the scattering. In Figure 2 some preliminary results are shown. Data analysis is still ongoing, and normalization of the intensity is still to be done. The energy loss resulted to be roughly proportional to the scattering angle, which is in contrast with previous understanding of the process and will need to be investigated.
There is probably a systematic on the measured angle still to be addressed in the next months.
The parallel validation activity has prepared a list of information needed to prepare and run the simulations.



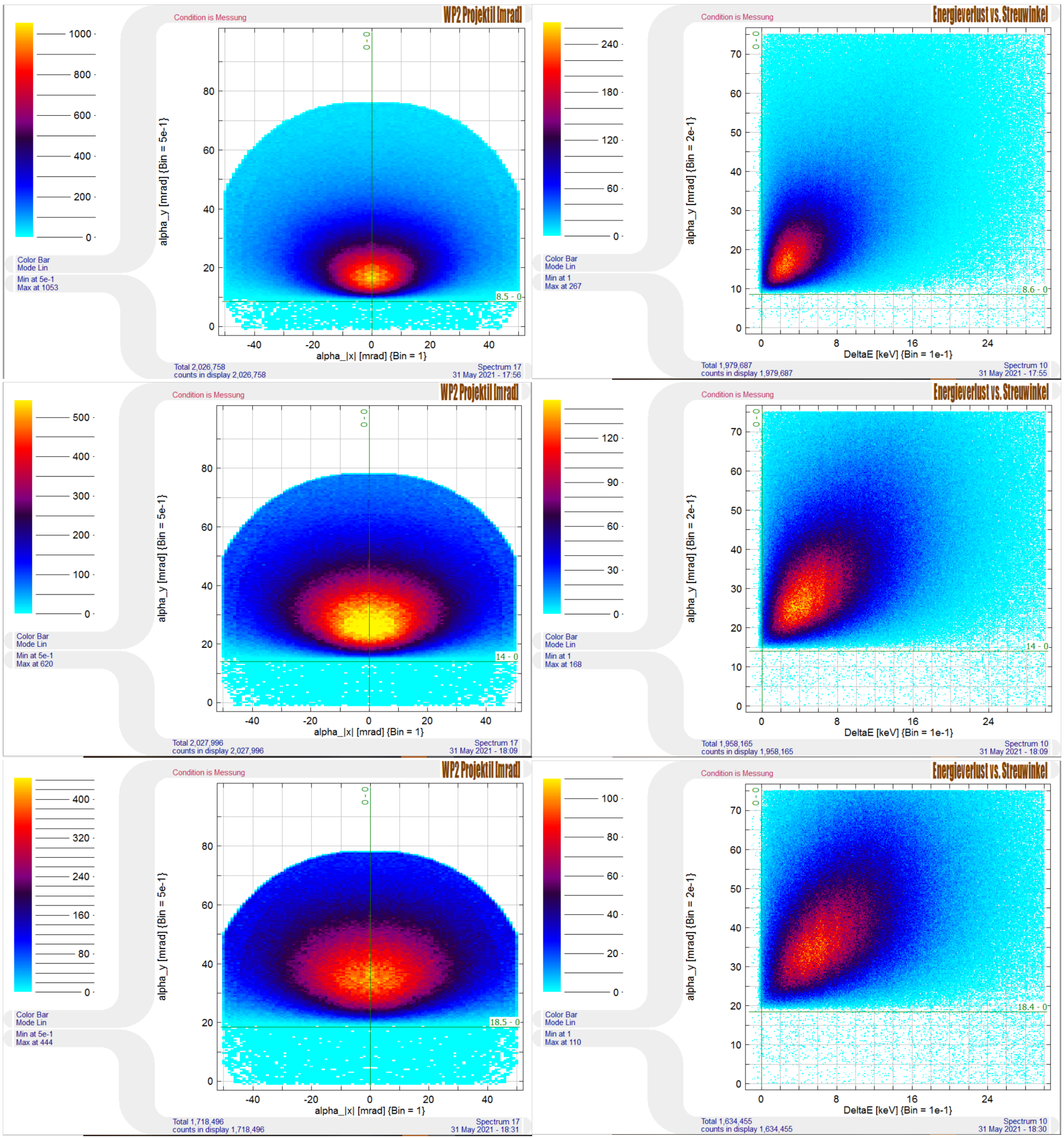


Figure 2 – Preliminary 2D intensity distribution across the plate (left). Scattered y-angle vs. energy loss (right). Red lines indicate the reconstructed incidence angle. Axes are in mrad from the origin (unscattered beam direction).

Optical Blocking Filter measurements

In the framework of WP13 activities a possible test of an optical blocking filter (OBF) sample is under investigation. OBFs play a major role in determining the rate of soft protons reaching the detectors with an energy in the band. In fact, energy loss in the OBF modifies the spectrum of the protons focused by the mirror, so that the critical energy range for the instrumental background strongly depends on the OBF specifications. For X-ray detectors in the low-to-medium energy band up to 10 keV very thin (less than 1 micron) OBFs are normally used to guarantee high X-ray transmissivity. In such thin layers, the energy loss mechanism may be affected more significantly by straggling, that is the random variation in the number of scattering events the protons undergo traversing the layer. In order to verify this effect and validate the results of simulations, a measurement of the energy loss in an OBF sample is desirable. To perform the test, the same setup used to measure the proton scattering on the SPO sample could be exploited. The OBF sample should be mounted at the exit of the collimator perpendicularly to the beam. Using a chopped beam, the mean energy loss of protons passing through the OBF could be reconstructed by their time-of-flight onto the MCP detector, provided that the reference time-of-flight of protons in absence of the OBF is calibrated. We are currently studying a technical solution for the housing of the OBF sample inside the tube.

Status of Task 2: Electron backscattering

In task 2 we assess the backscattered electron emission yield on a composite material representative of the X-IFU detector structure at one incident angle (30° in regard of the normal of the sample) and three energy levels below 100 keV: 35 keV (electron gun was not stable below this energy level), 60 keV and 90 keV. The assessment of backscattered electron emission yield is based on the measurements of electron current emitted by the irradiated samples. For this kind of measurements at a specific angle, a dedicated sample holder was designed, developed and then tested and validated within the irradiation facility.

Preliminary tests and technical amendments have been performed on a conventional and known material (Aluminium) to comply with the measurement requirements, prior to measurements on the composite material. The experimental tests on the composite materials were then performed, followed by a thorough analysis on outcoming results.

Below are reported the experimental results for Backscattered electron emission yield measured on the composite sample (Figure 3, Table 1) and, for validation, on the Si sample (Figure 4, Table 2).

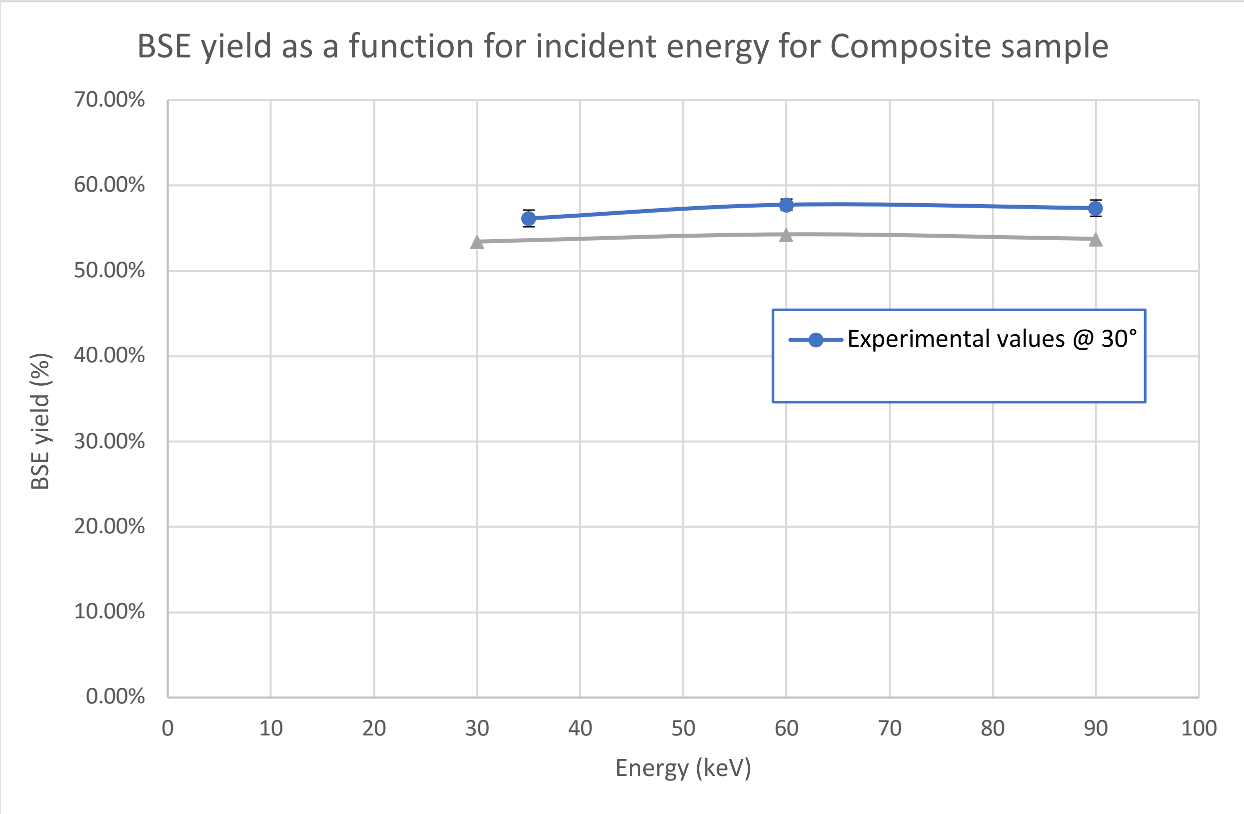


Figure 3 – Backscattering electron yield average values as a function of energy for the composite sample for electrons impacting at 30° from the surface normal, with 3 different energies

Table 1 - Backscattering electron yield values for the composite sample for electrons impacting at 30° from the surface normal

Energy (keV)	Average experimental BSE yield	Standard deviation
35	56.14%	0.98%
60	57.75%	0.66%
90	57.35%	0.95%

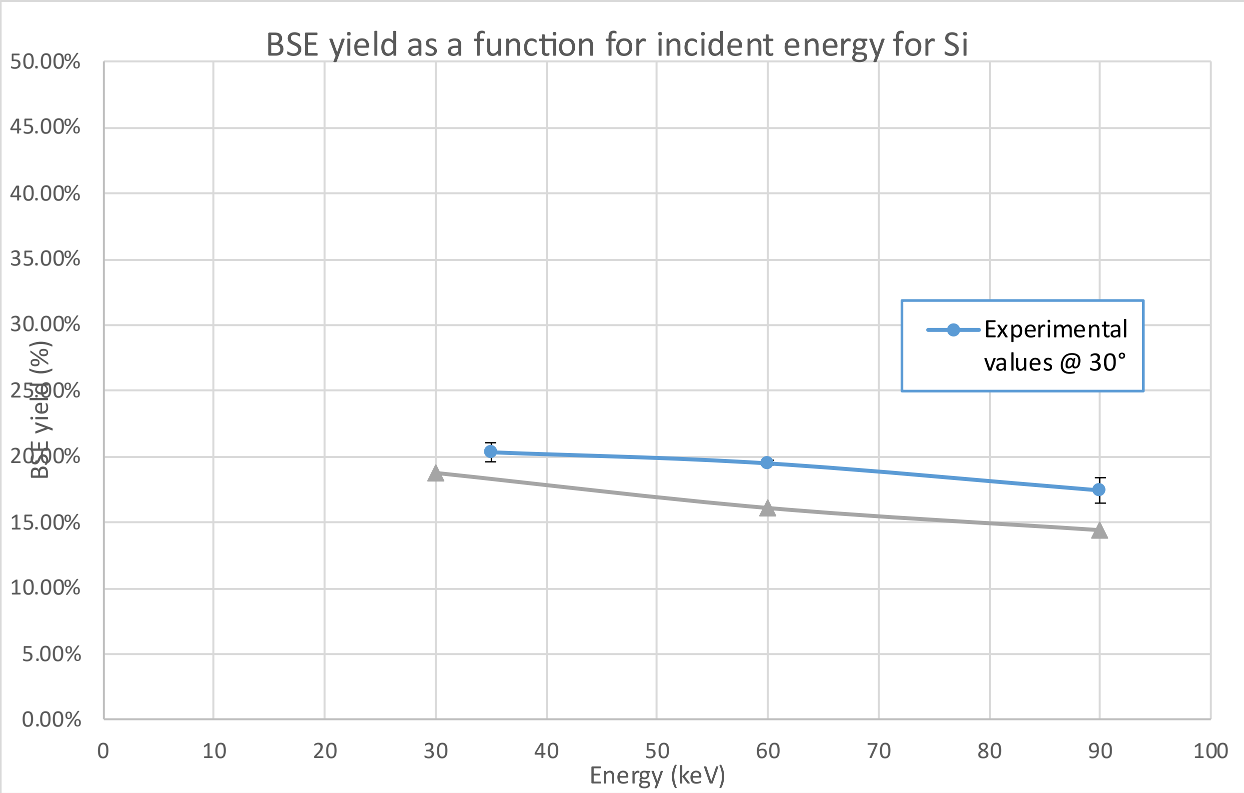


Figure 4 – Backscattering electron yield average values as a function of energy for the Si sample for electrons impacting at 30° from the surface normal, with 3 different energies

Table 2 - Backscattering electron yield values for the Si sample for electrons impacting at 30° from the surface normal

Energy (keV)	Average experimental BSE yield	Standard deviation
35	20.34%	0.69%
60	19.50%	0.17%
90	17.48%	0.95%

Comparing the results obtained at 30° with the ones coming from the previous EXACRAD project at 5.6° for the incident angle the BSE yield is higher at 30°, in agreement with the predictions and the numerical results obtained with independent simulations performed with the Monte Carlo CASINO code. This can be explained by the fact that increasing the incident angle reduces the penetration depth of the incident electrons, which reduces the energy lost by BSE and enhances the probability for the incident electrons to come back to the surface and be backscattered.