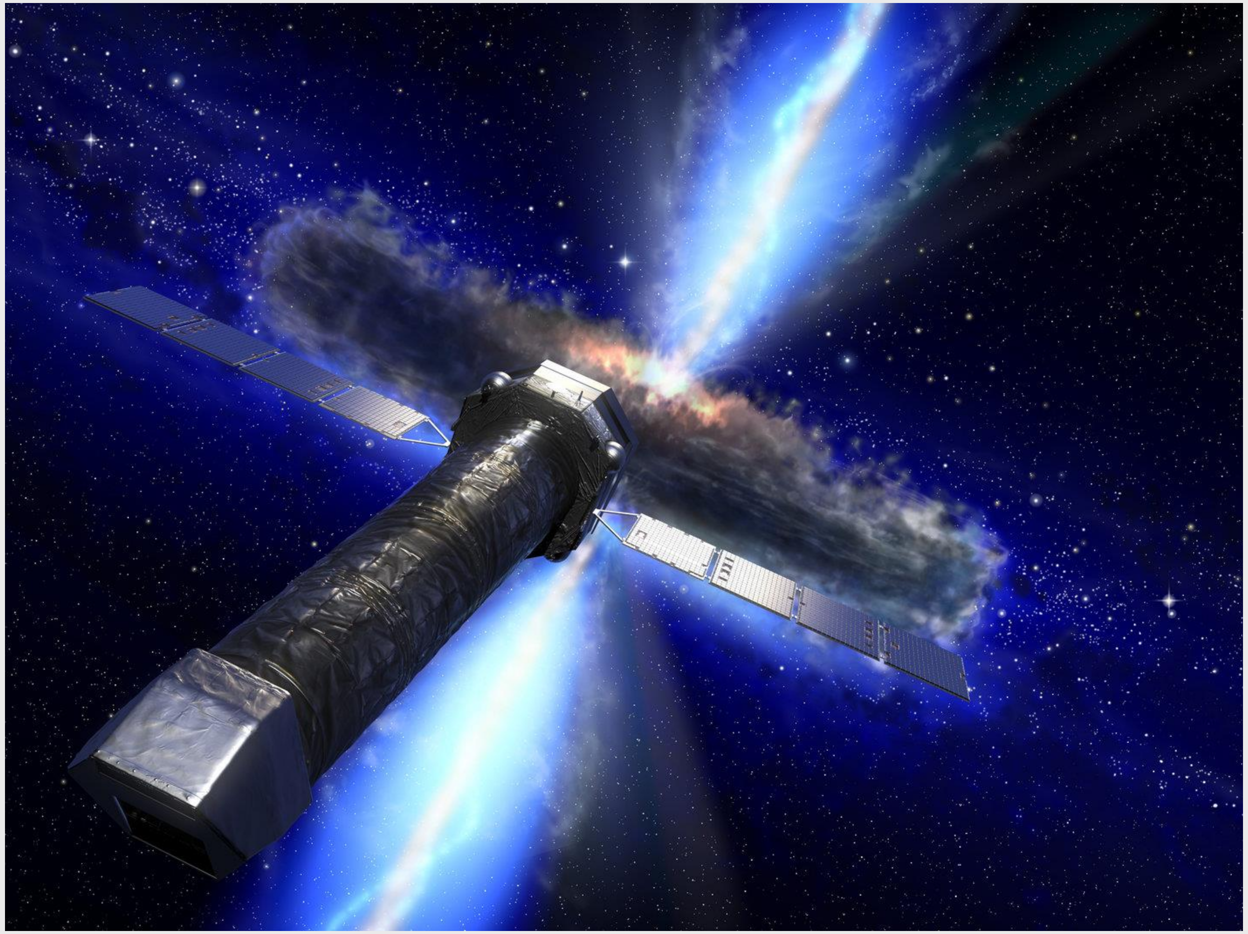
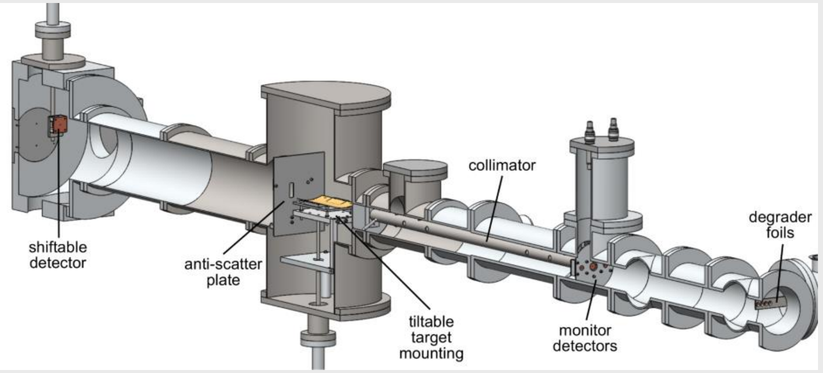
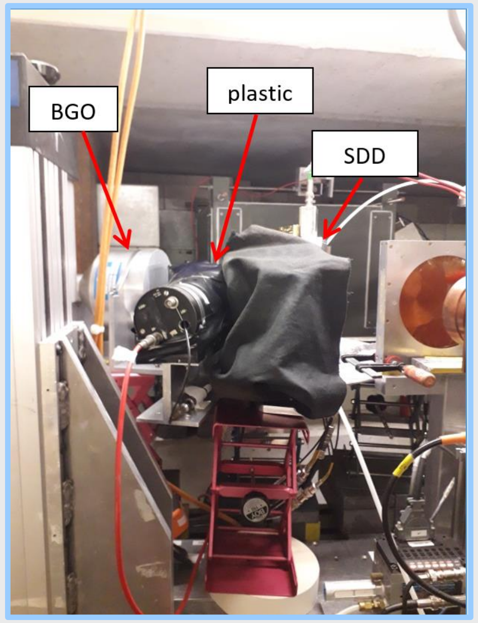
The EXACRAD Project in context







Silvano Molendi INAF/IASF-Milano

EXACRAD

Experimental Evaluation of ATHENA Charged Particle Background from Secondary Radiation and Scattering in Optics

Activity dedicated to an improved understanding of physical processes responsible for the instrumental background on ATHENA

Why are interested in the instrumental bkg?

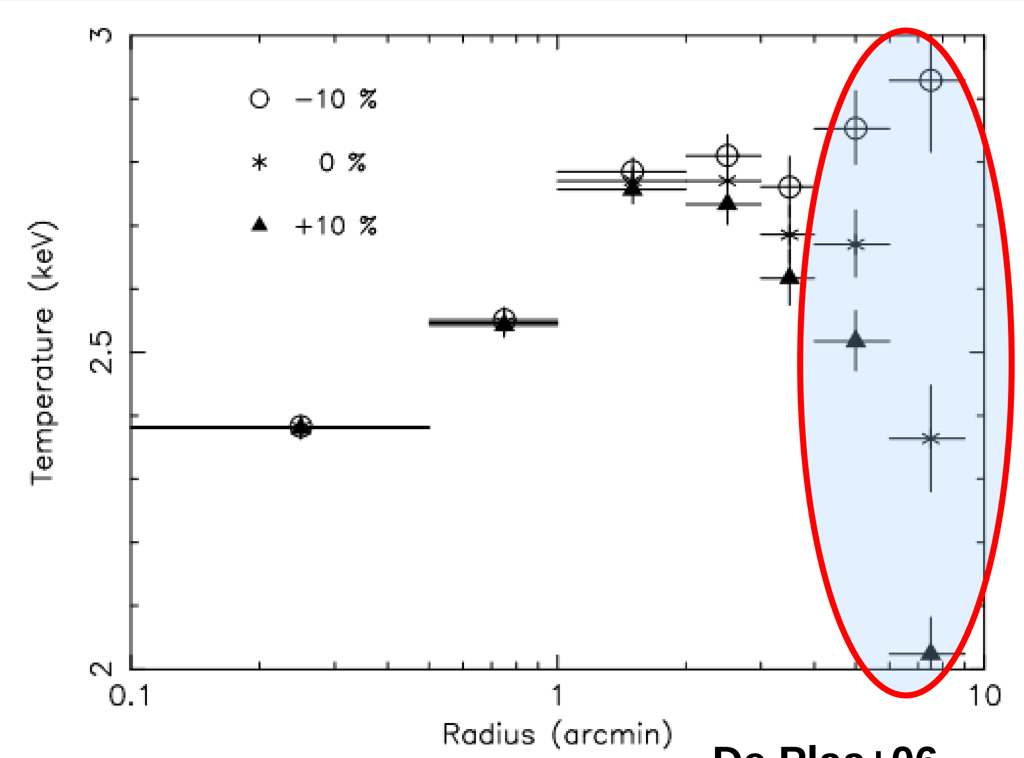
ATHENA's ability to carry out designated Science Goals will depend critically upon the properties of the instrumental background

An example from XMM-Newton

Radial Temperature profile of a Galaxy Cluster measured with XMM-Newton

3 different profiles measured adopting 3 different values for the instrumental bkg

Huge Systematic errors, much larger than statistical ones



De Plaa+06

Bkg is the major issue

Reduce or better characterize bkg → More science

Why EXACRAD?

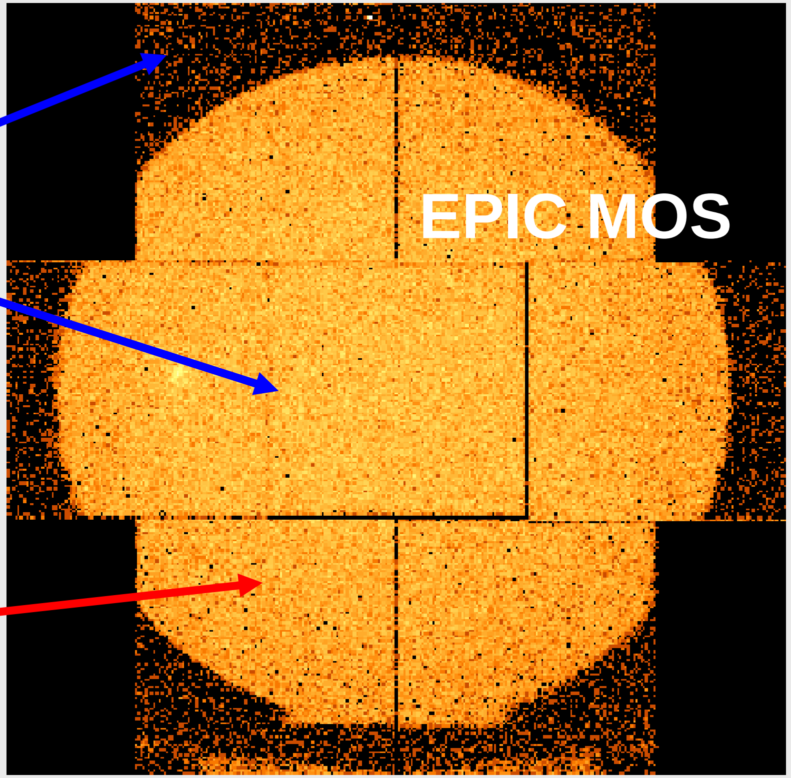
ATHENA's ability to carry out designated Science Goals will depend critically upon the properties of the instrumental background

ATHENA instrumental background is due to particles interacting with the detectors, its surrounding and the X-ray optics

EXACRAD

Major ATHENA Bkg components as seen with XMM-EPIC MOS

- Secondaries generated by high energy particle (E>100 MeV) mostly Cosmic Rays p+
- Low energy ions (E<100 KeV) concentrated by mirrors, often refered to as Soft Protons

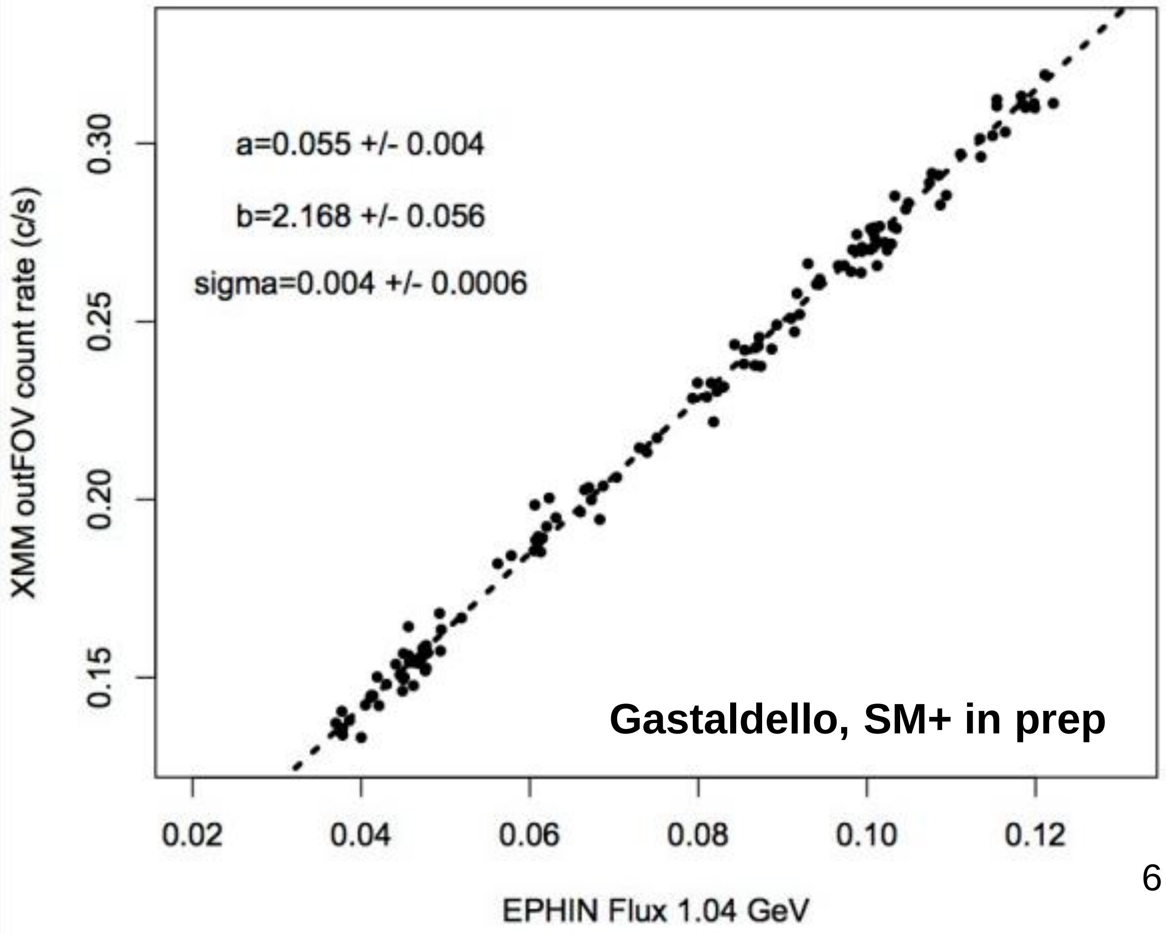


Major components GCR

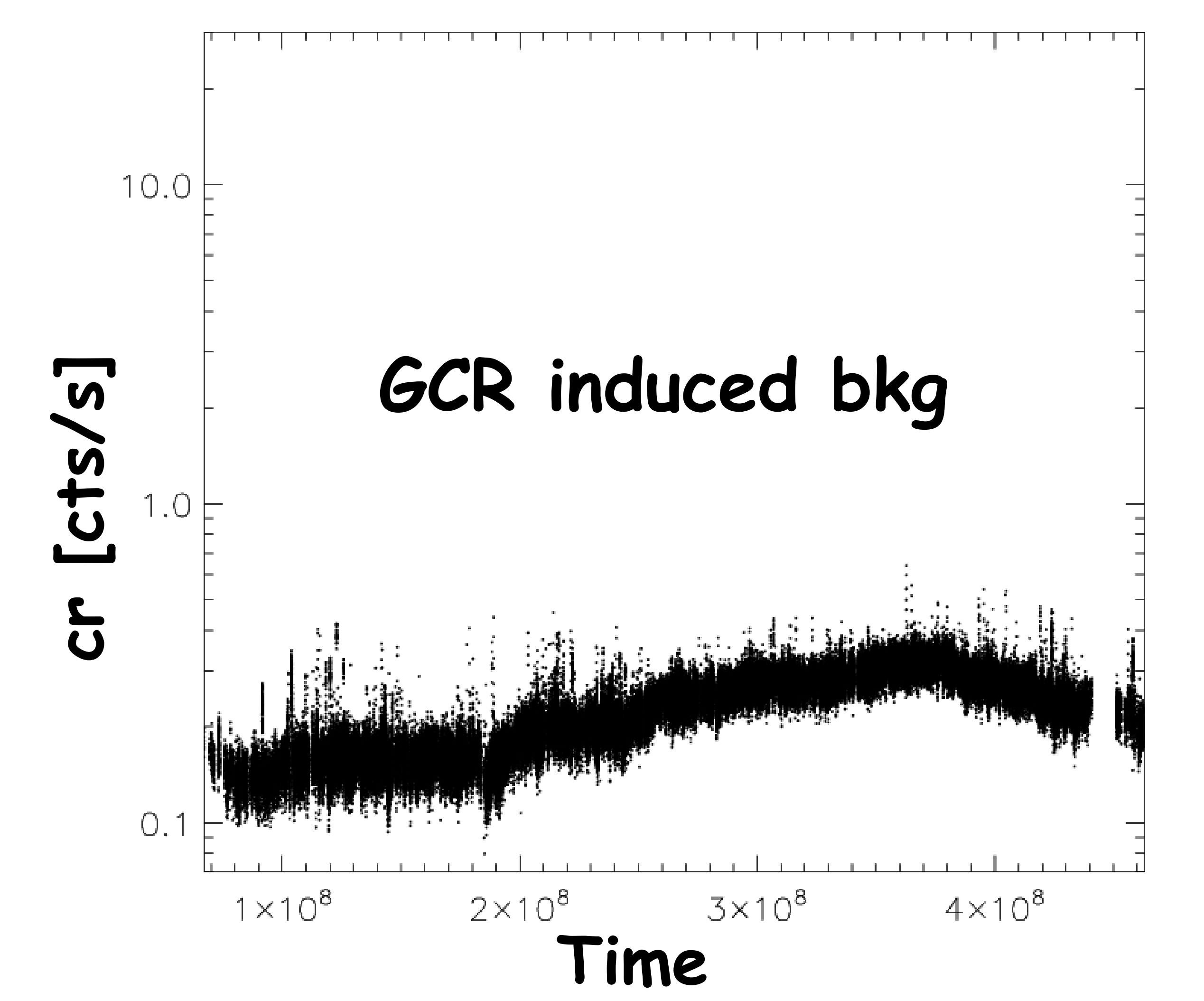
- GCR p+ e- α

- EPHIN on board SOHO which is @ L1

- Very tight correlation btwn EPIC instrumental background and EPHIN measurements firmly establishes GCR as cause



Galactic Cosmic Rays induced bkg



Galactic Cosmic Rays induced bkg

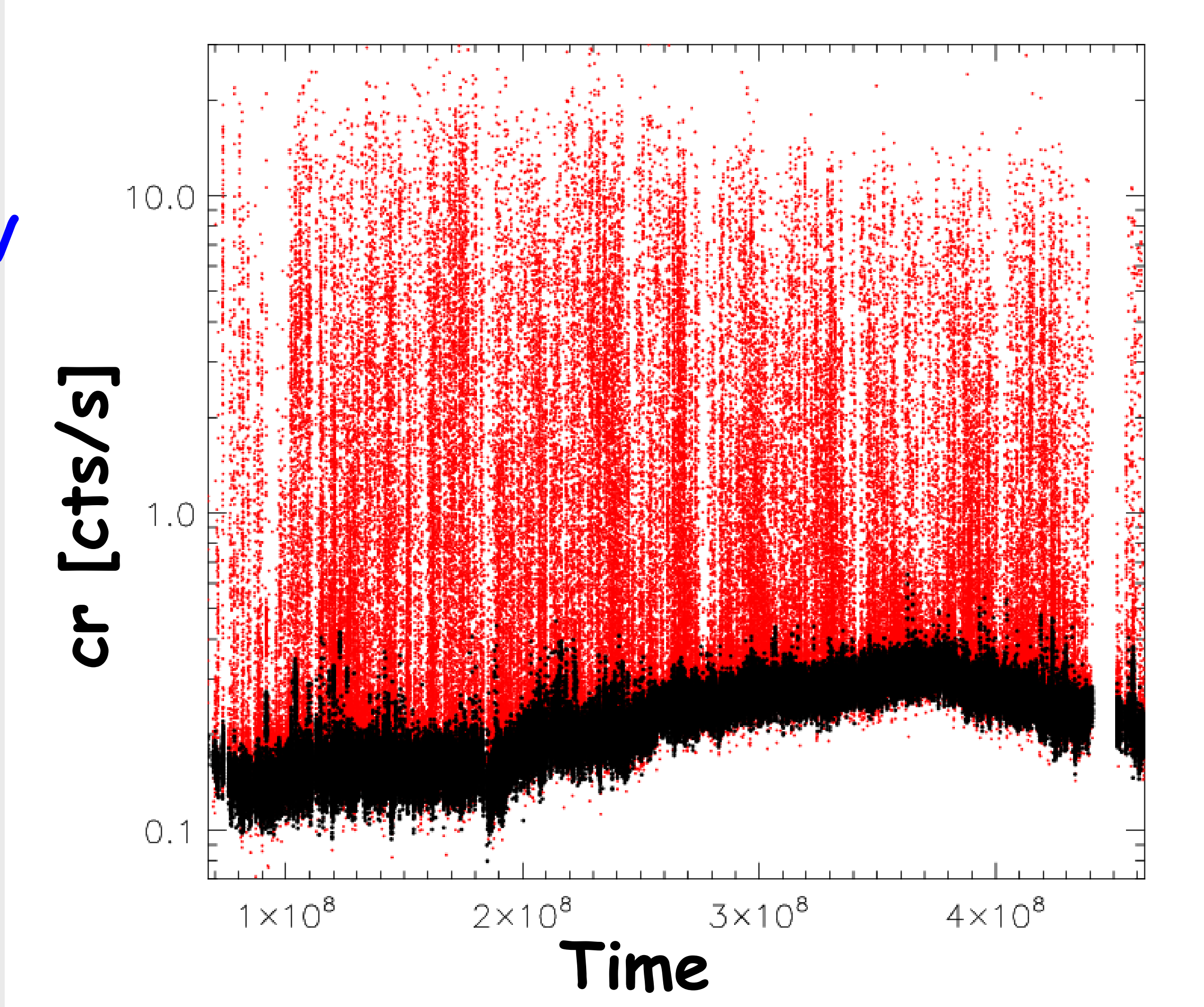
Soft protons
highly variable

Supra-thermal ions with energies few 10 few 100 keV scattered off X-ray optics in a quasi-specular fashion

X-ray telescopes act as concentrators

The larger the telescope the more the concentrated protons

ATHENA largest X-ray telescope



Activities

Several activities have been undertaken

- Study of Archival data from X-ray missions
- Study of particle environment non X-ray missions SOHO etc.
- Laboratory Experiments to investigate key physical processes
- Proposed a dedicated ATHENA particle monitor AHEPaM
- Development of Magnetic Diverter
- Optimizing instrument design (graded shielding, Anti-Coincidence , Self Anti-Coincidence…)

AREMBES

Study of background data from active X-ray missions

Study of particle environment in L1 and L2 & comparison btwn 2

Definition of SPACE Physics list to be adopted when performing GEANT4 simulations of ATHENA instruments

EXACRAD

Within AREMBES identified 3 key physical interactions btwn particles and matter for which experimental data is scarce or inconclusive.
EXACRAD has been set up to investigate them

Goal is include results in Physics List to improve simulations

- Soft proton Scattering off X-ray optics
- Secondary electron production
- Electron Backscattering

WBS

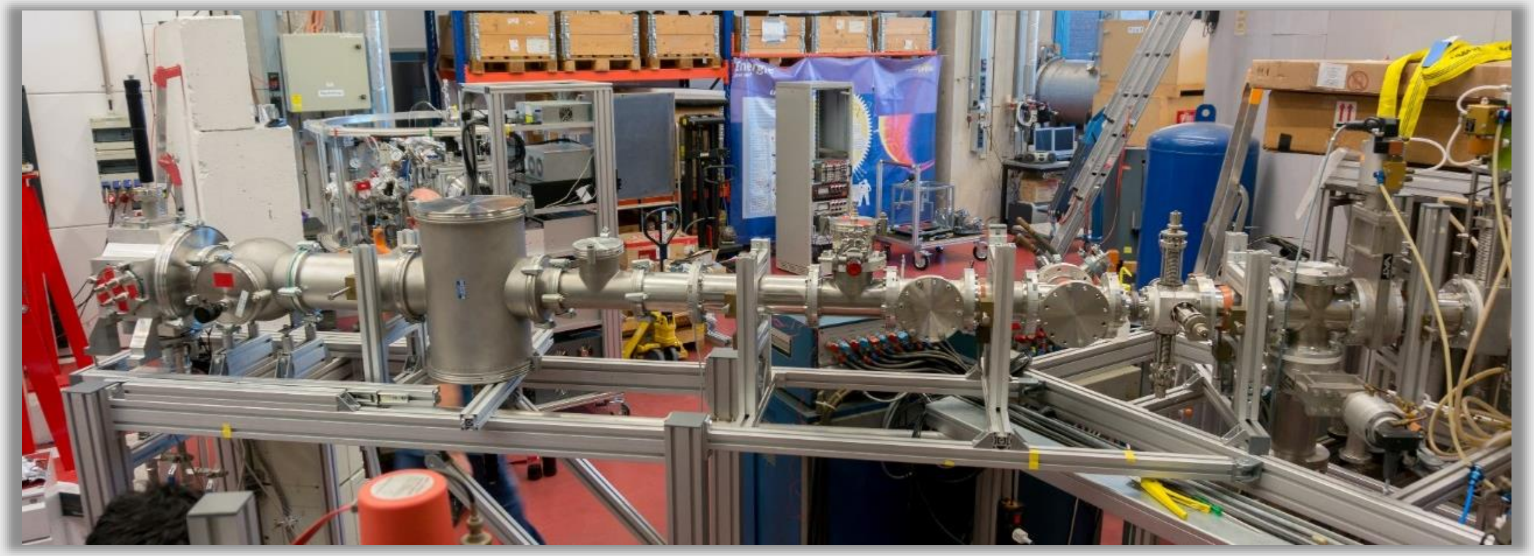
INAF	UT	CEA	ONERA	RADMOD	SWHARD

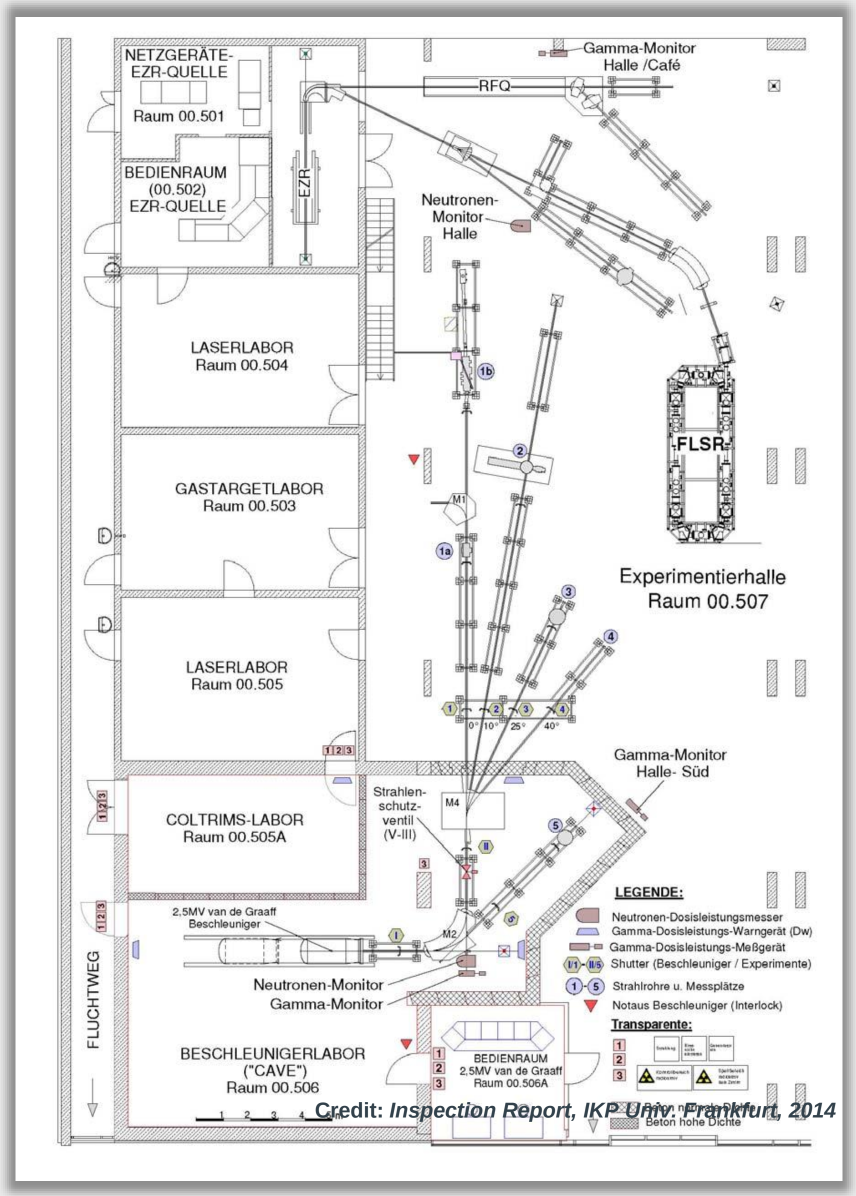
- EXACRAD
  - WP0 Project Management INAF/IASFMI
  - Part 1
    - WP1 ESA TASK1 INAF IASFMI+IAPS
      - 1.1 Low-energy particle forward scattering UT
      - 1.2 Secondary particle generation CEA
      - 1. 3 electron backscattering ONERA
    - WP2 ESA TASK2 INAF IASFMI+IAPS
      - 2.1 Low-energy particle forward scattering UT
      - 2.2 Secondary particle generation CEA
      - 2. 3 electron backscattering ONERA
  - Part 2
    - WP3 ESA TASK3 UT
      - 3.1 Experiment Set up UT
      - 3.2 Measurement Campaign UT
    - WP4 ESA TASK4 CEA
      - 4.1 Experiment Set up CEA
      - 4.2 Measurement Campaign CEA
    - WP5 ESA TASK 5 ONERA
      - 5.1 Experiment Set up ONERA
      - 5.2 Measurement Campaign ONERA
    - WP6 ESA TASK6 RADMOD
      - 6.1 Sim task3 INAF/IASFBo
      - 6.2 Sim task4 INAF/IAPS
      - 6. 3 Sim task5 RADMOD
      - 6.4 physics list technical consulting SWHARD
    - WP7 ESA TASK7 INAF/IAPS
      - 7.1 Format and content definition SWHARD
      - 7.2 Low-energy particle forward scattering UT
      - 7.3 Secondary particle generation CEA
      - 7. 4 electron backscattering ONERA
  - Part 3
    - WP8 Data Analysis ESA TASK8 SWHARD
      - 8.1 Data Analysis Task3 INAF/IASFMi
      - 8.2 Data Analysis Task4 INAF/IAPS
      - 8.3 Data Analysis Task 5 RADMOD
    - WP9 Model Validation ESA TASK8 SWHARD
      - 9.1 Mod Val Task 3 INAF/IASFBo
      - 9.2 Mod Val Task 4 INAF/IAPS
      - 9.3 Mod Val Task 5 SWHARD
      - 9.4 Technical cosulting SWHARD

WP3 Soft proton Scattering off X-ray optics
E.Perinati UT

2.5 MV single-ended Van de Graaff (HVEC ANS/200)

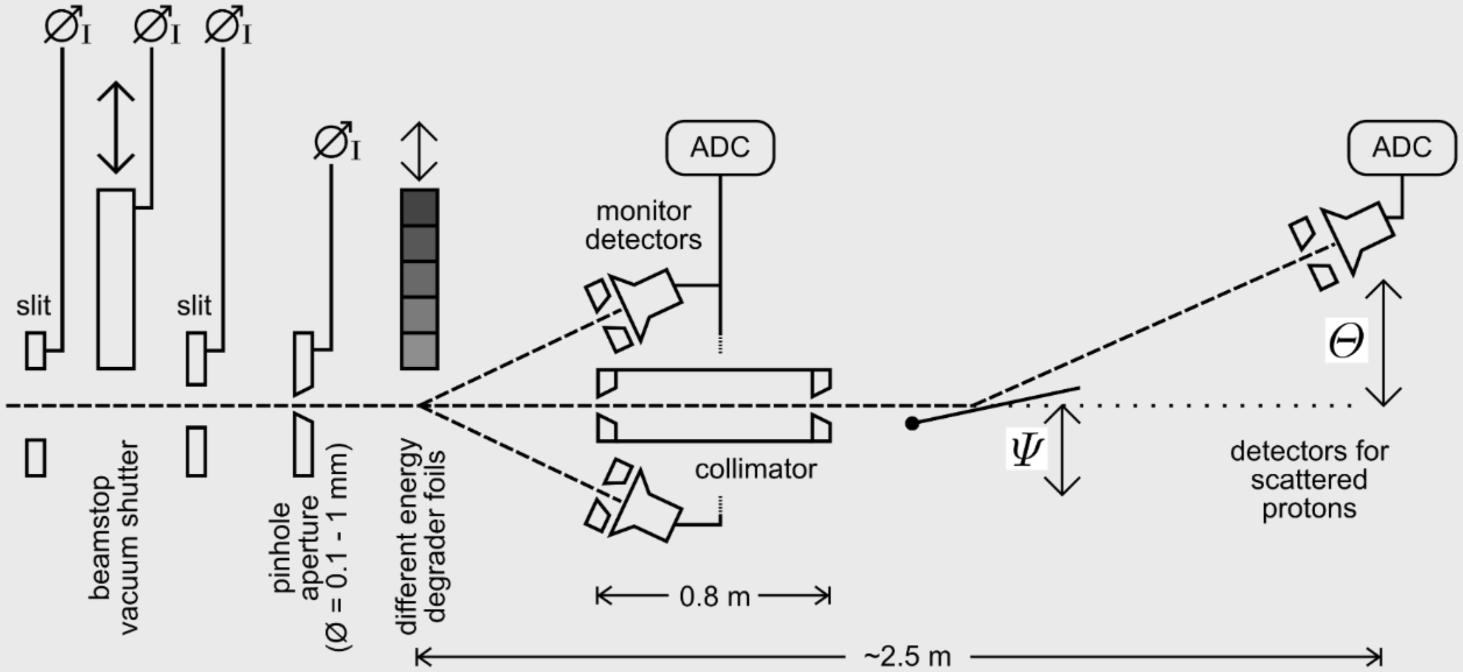
- Located at the *Stern-Gerlach-Zentrum* of Univ. Frankfurt/Main
- Nominal operating voltage 0.3–2.5 MV
- Available ion types: p, d, ^{3}He, ^{4}He, C, O





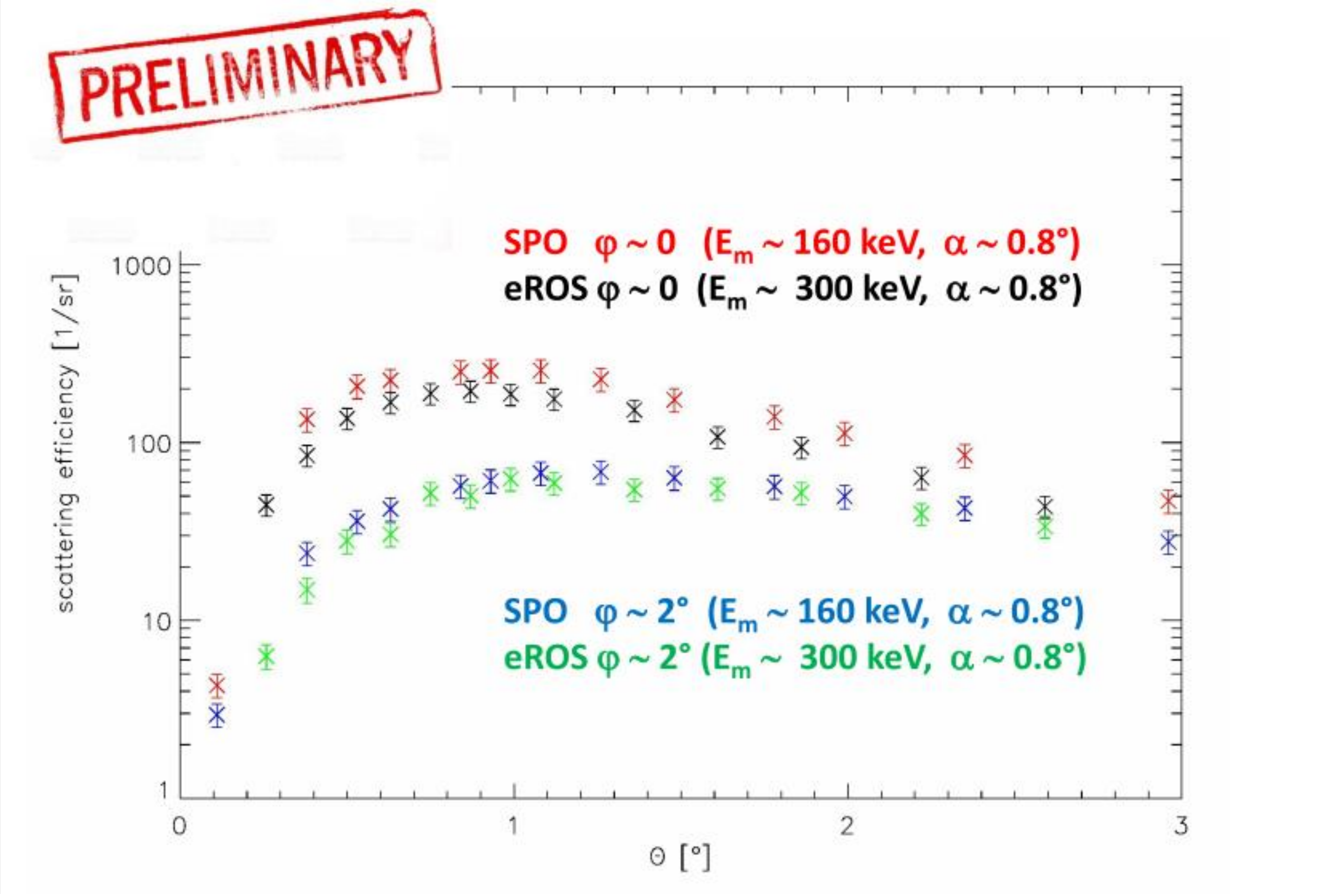
Credit: *Inspection Report, IKP Univ. Frankfurt, 2014*

Geometry & Conventions



Measurements

α [°]	~150 keV	~250 keV	~350 keV	~450 keV
0.5	X	X	X	X
0.65	X (?)	X(?)	X(?)	X(?)
0.82	X (?)	X(?)	X(?)	X(?)
0.9	X (?)	X(?)	X(?)	X(?)
1.16	X(?)	X(?)	X(?)	X(?)



Difficulties with normalization
Review of WP3 activities by EXACRAD managemet Nov 2019
New normalization strategy agreed upon
4 calibration runs by March 2020

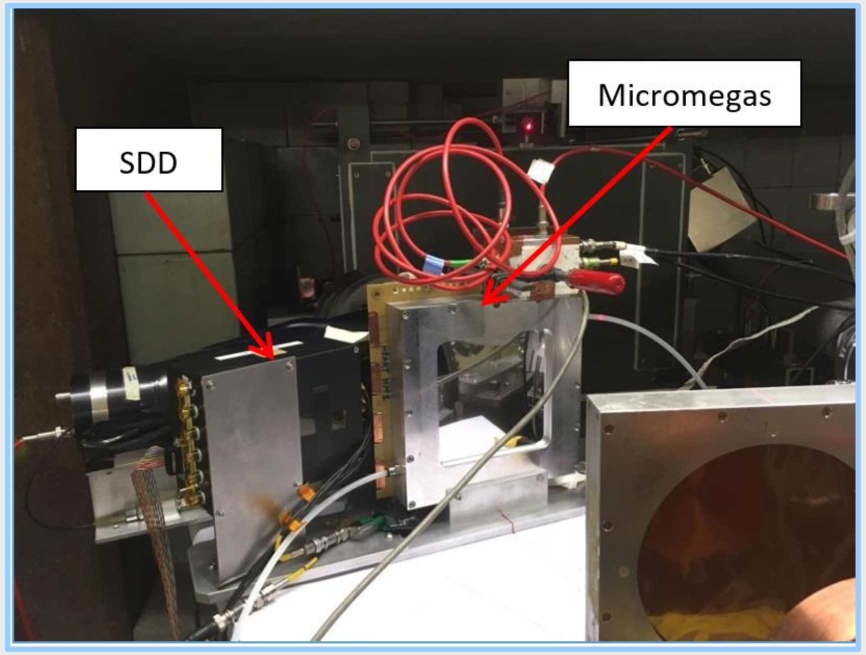
WP4 Secondary electron production - P.Laurent CEA

- Measurement of secondary electrons production yield
- Several materials/thicknesses tested
- The test at PSI occurred from March 13th to 18th, 2019. The irradiation lasted 32 hours. The beam had an energy of 230,3 MeV and a Gaussian profile with a FWHM of 1,5 cm. The beam was stable and the mean proton flux was 1.5×10^7 p/s/cm2

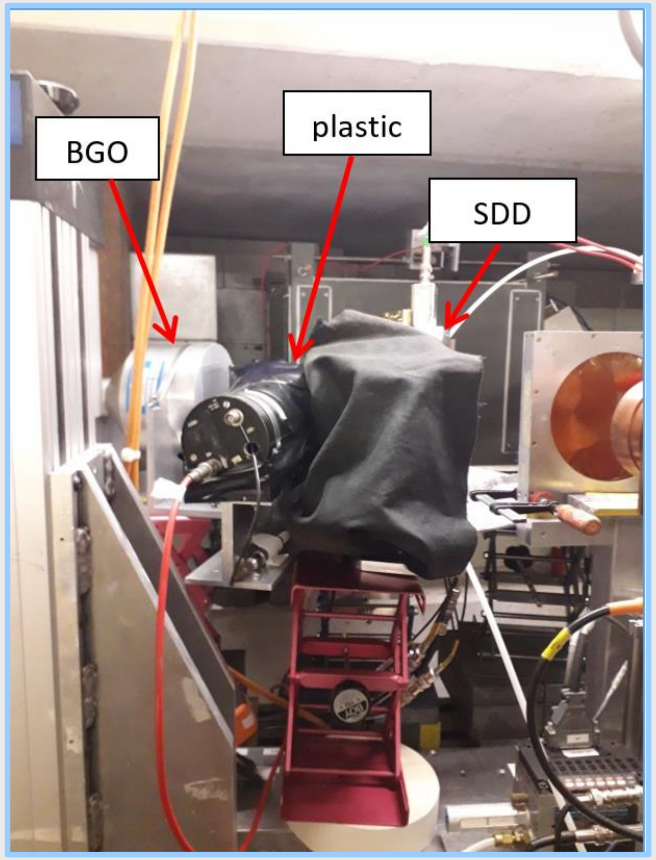
Name	Thickness (µm)	Purity (%)
Aluminum	10	99.0
	100	99.0
	1000	99.0
Niobium	10	99.9
	500	99.9
	1000	99.9
Carbon	75	99.8
	125	99.8
	1000	99.8
Kapton	13	DuPont™ Kapton
	250	DuPont™ Kapton
	500	DuPont™ Kapton
Titanium	10	99.99
	100	99.99
	1000	99.99
Copper	10	99.99
	100	99.99
	1000	99.99

DETECTOR HARDWARES

All detectors worked well during the runs, with some minor problems. Also used a plastic racket to monitor the particles background in the room which was found to be high but stable.



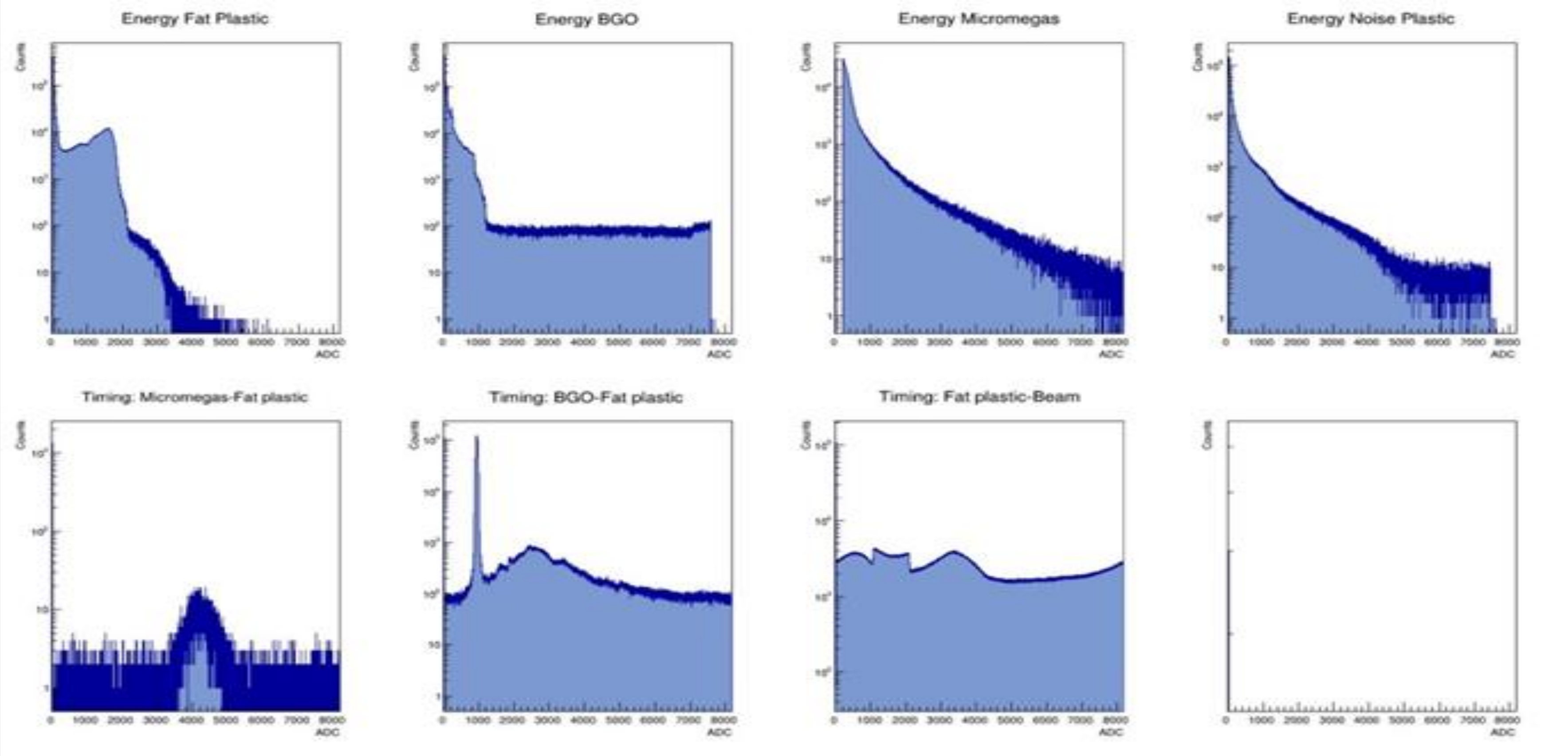
Measurement at 22,5°



Measurement at 70°

DATA

For each run, got spectra of the detectors (Si, BGO, Plastic and Micromegas) and timing info of the delay between the plastic (fastest detector) and the others.



PRE-TREATMENT

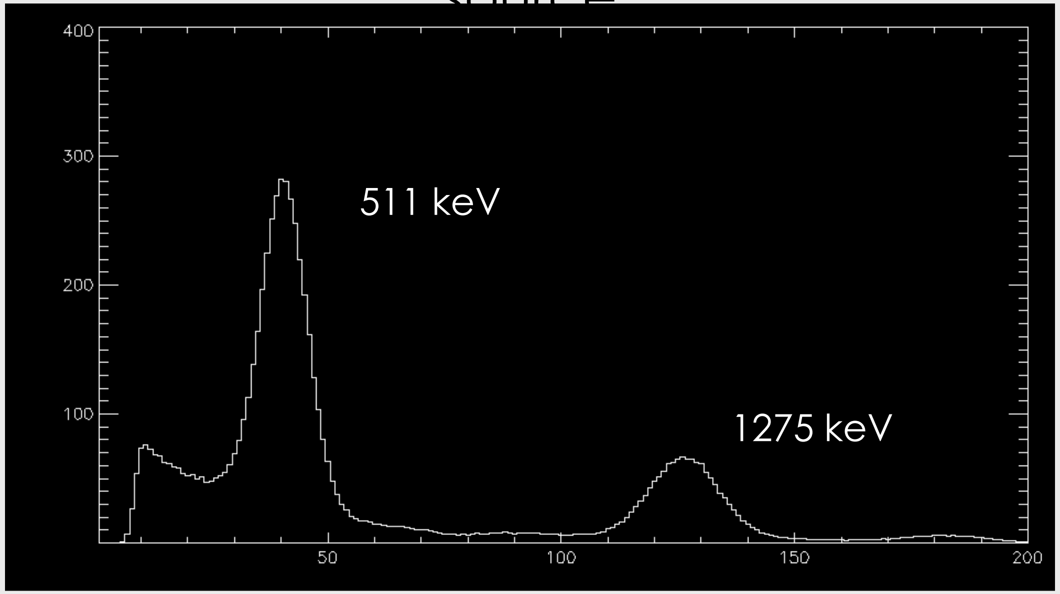
1. Energy calibration :

- Detector calibrations with radioactive sources at the start, middle and end of the test.

- Gain/offset value for each detector (Energy = gain*Channel + Offset) were computed from these measurements.

- These values were shown to vary by about 10 % during the tests.

BGO calibration with 22Na source

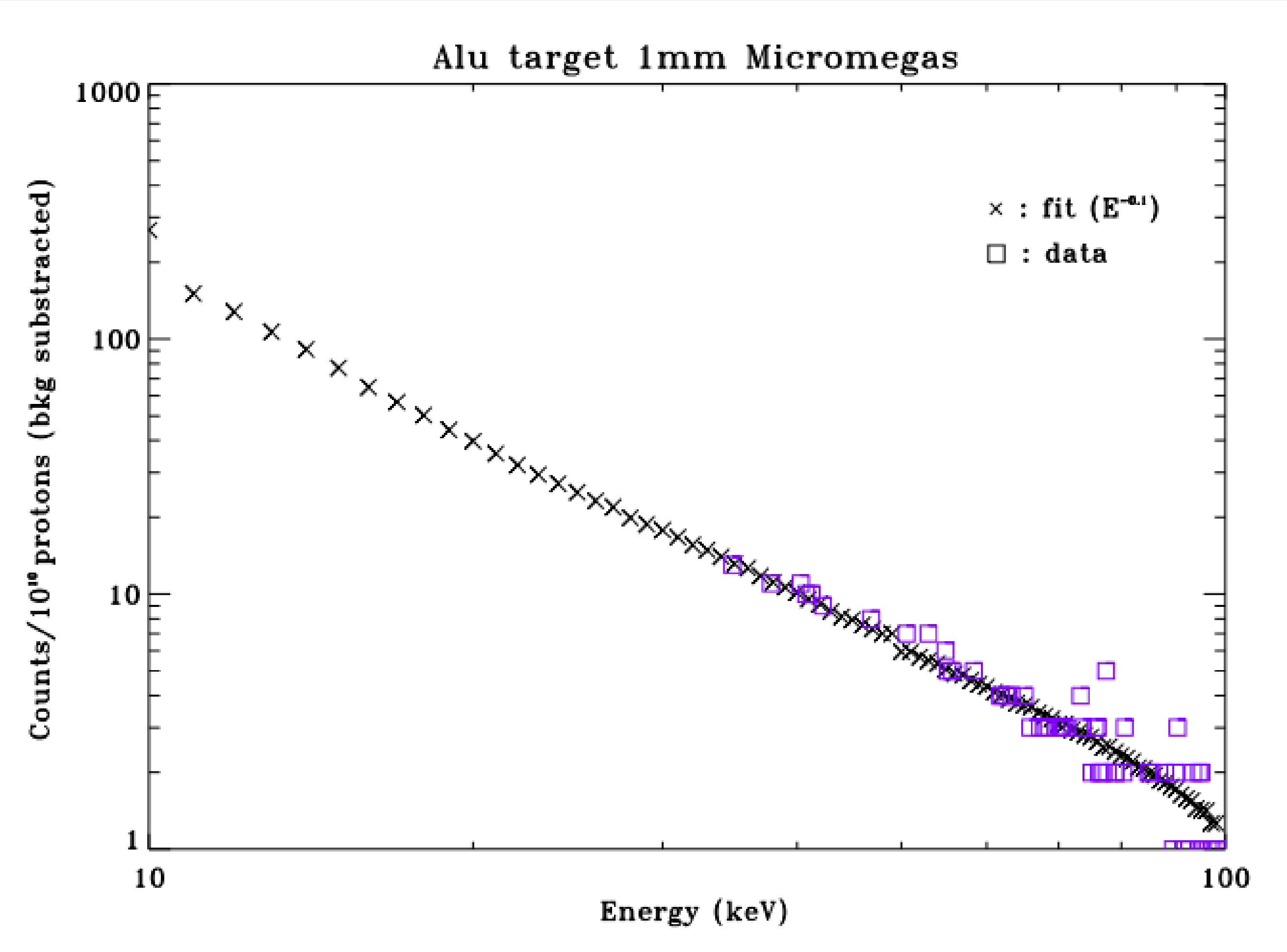


PRE-TREATMENT

2. Background subtraction:

- Tests without the target holder and with an empty target holder to see the effect of this holder. It was shown that the spectra were not affected by the holder presence.
- These runs were used to subtract the background from the on-target runs. Again, for each run, used the closest background file.
- During this pre-processing phase, it was shown that the BGO detector was completely blinded by the background, probably induced in the beam stopper.

PRELIMINARY RESULTS

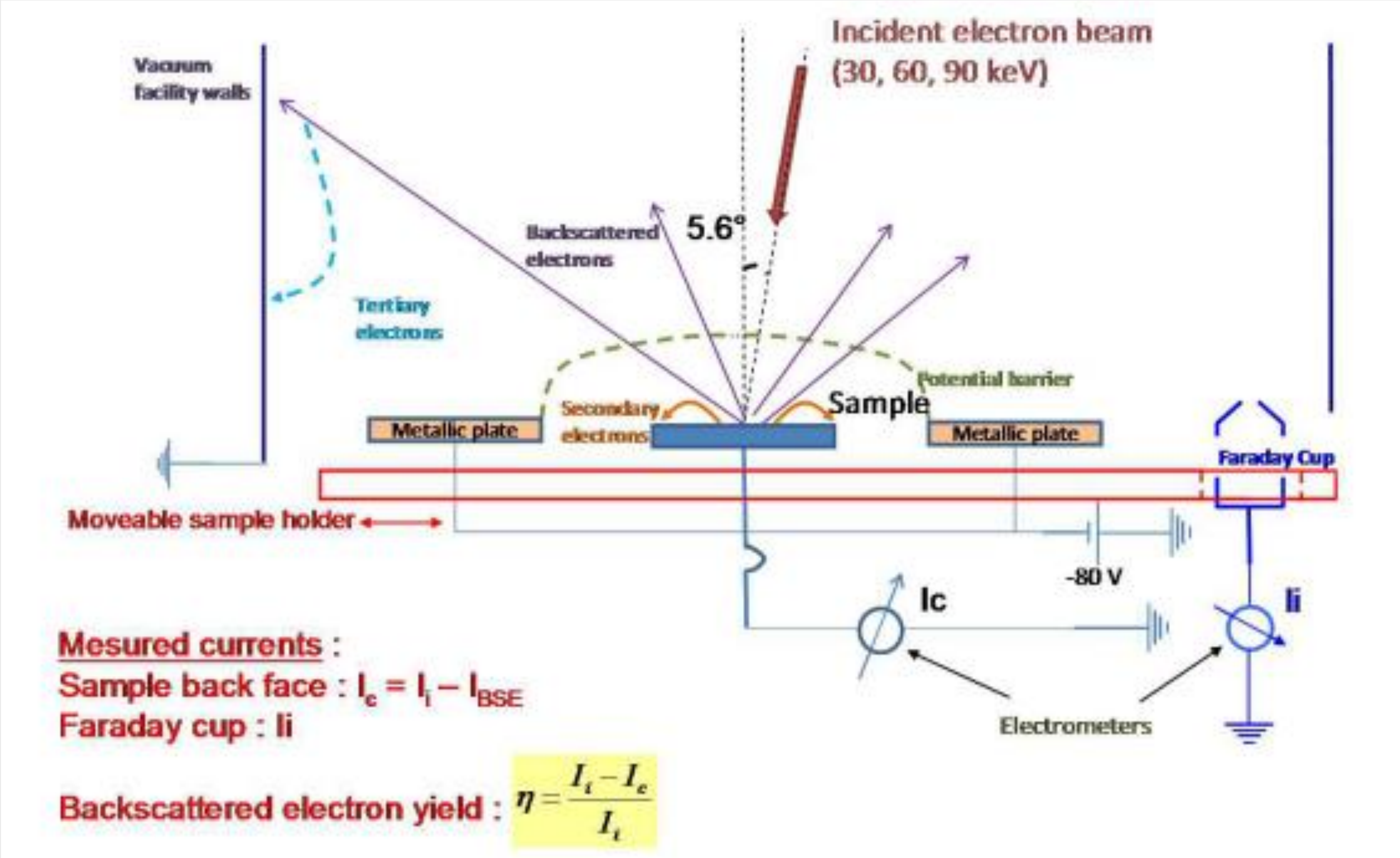


Fit of data with power-law model convolved with response matrix for instrument

WP5
ELECTRON BACK SCATTERING
T. Paulmier ONERA

- Induced current on sample
- Incident current measured by Faraday cup

Yield is relative diff. btwn the two



Experimental setup

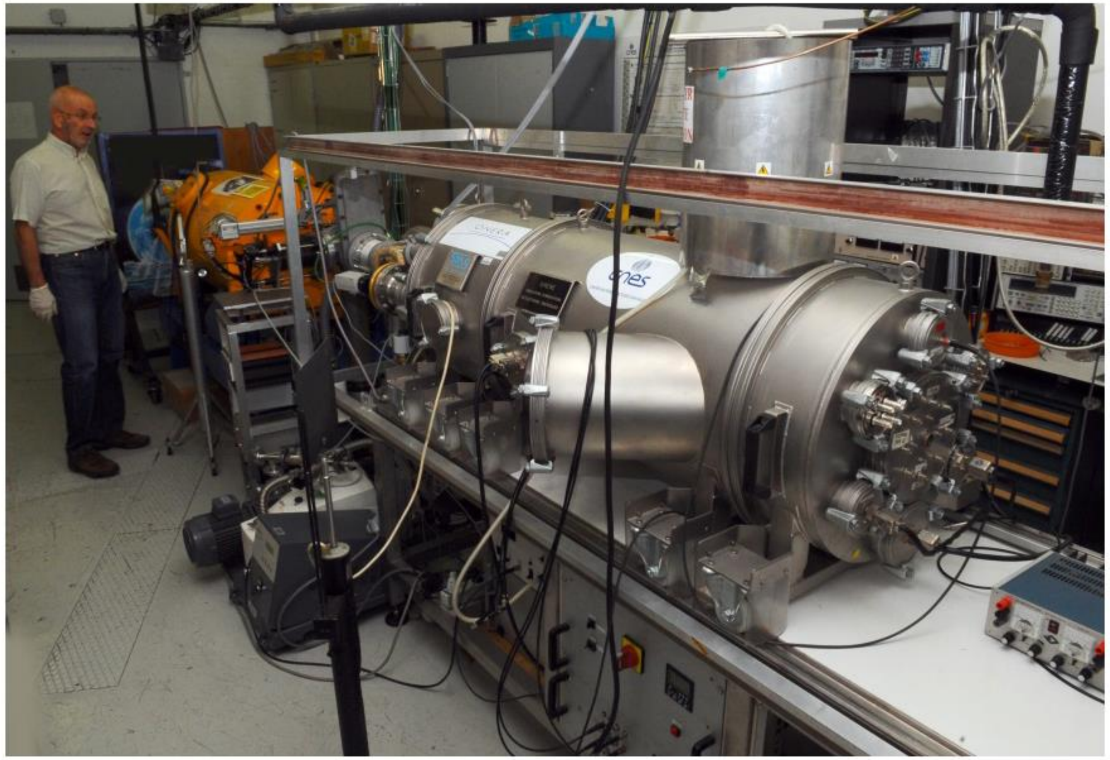


Figure 1. The SIRENE irradiation test facility

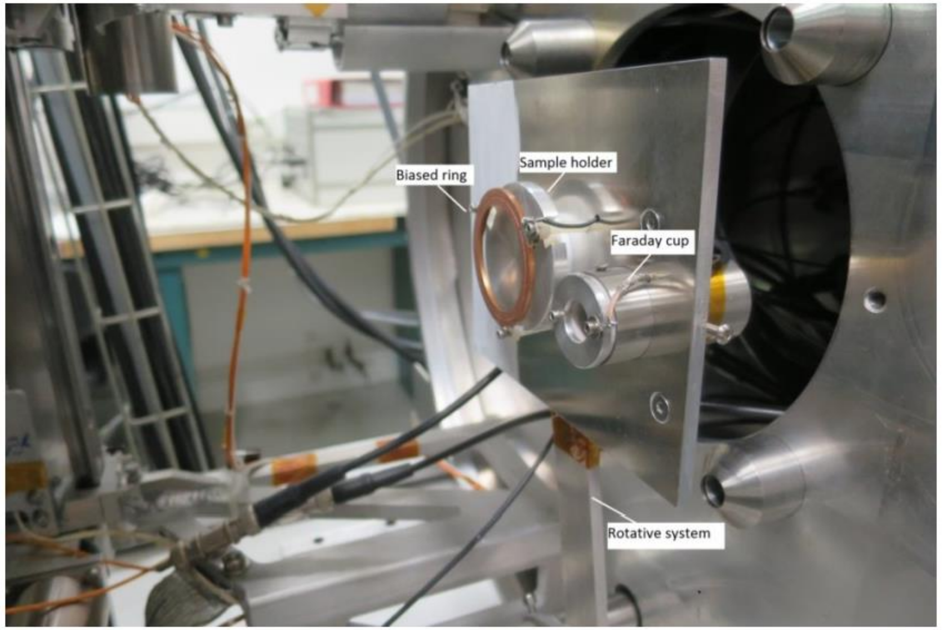
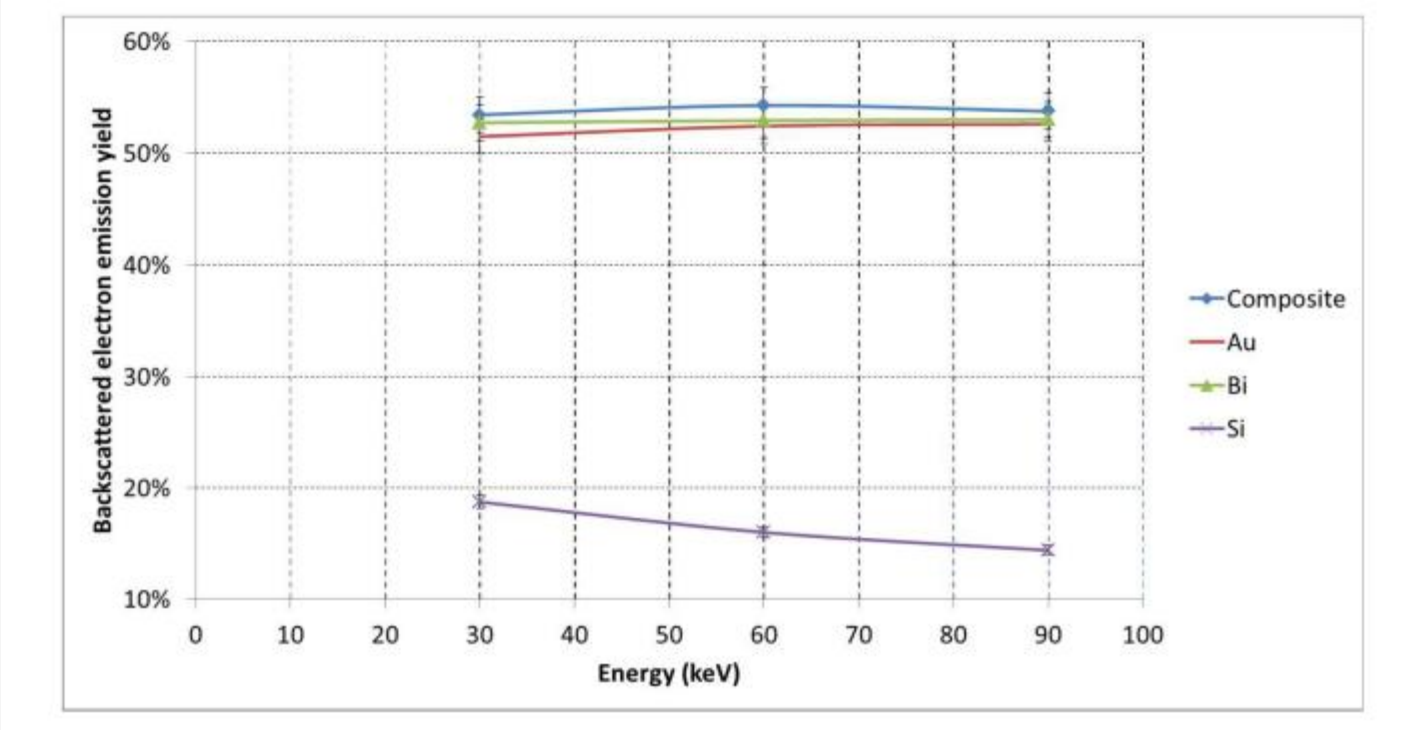


Figure 3. View of the rotative sample holder with Faraday cup, sample and biased system

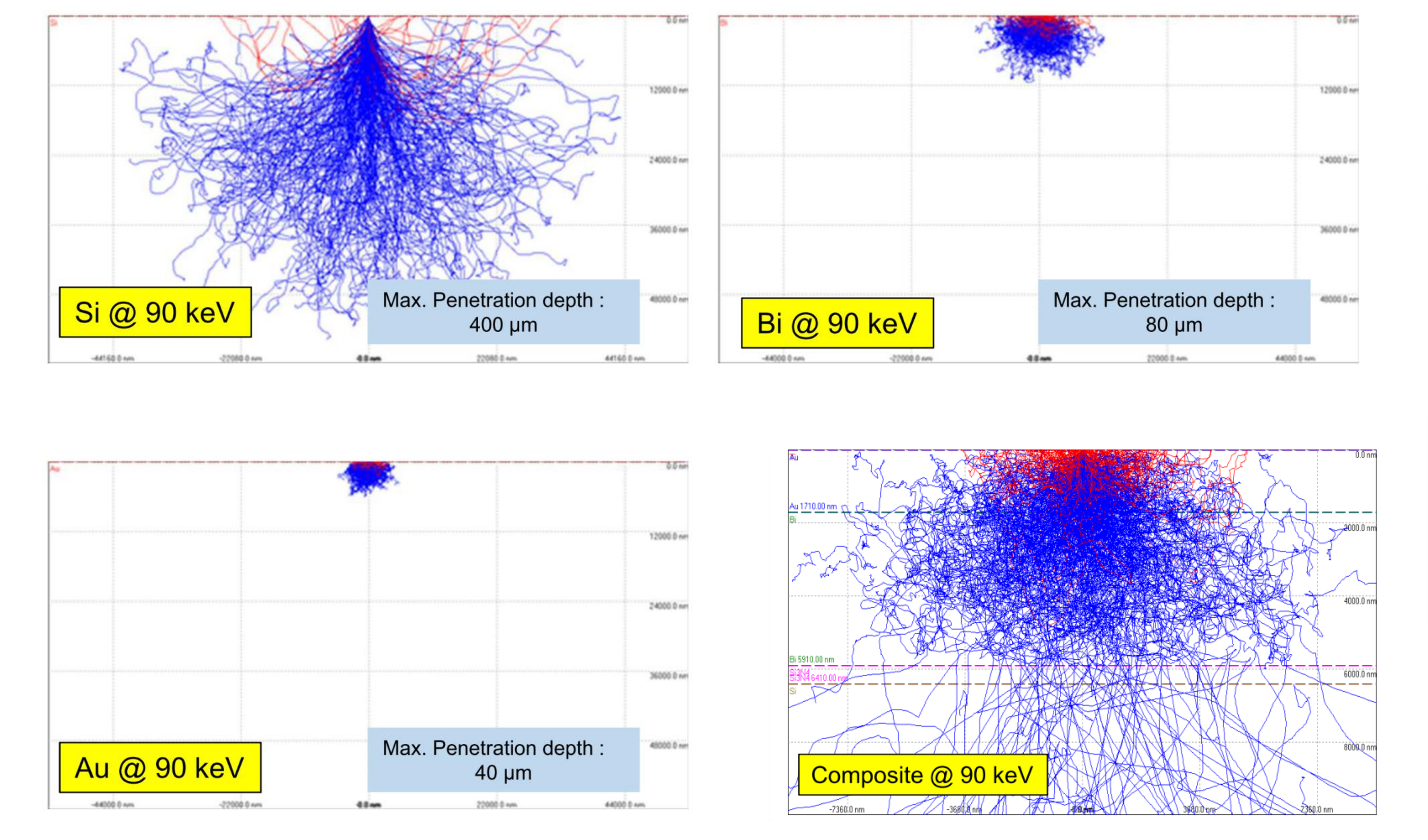
SIRENE facility in ONERA: 7-400keV monochromatic e- beam

Results

- Difference btwn high Z/density and low Z/density material
- Composite material behaves like highZ/dendity

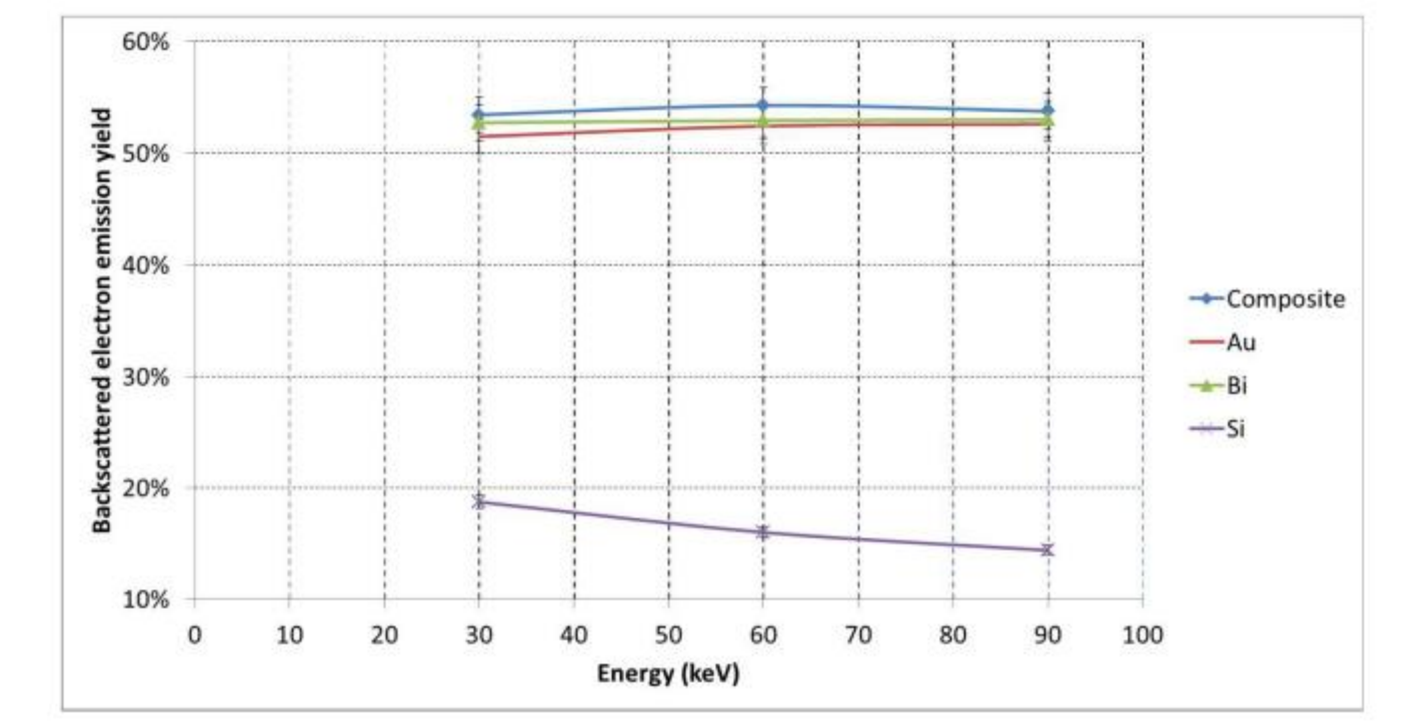


Simulations of penetration



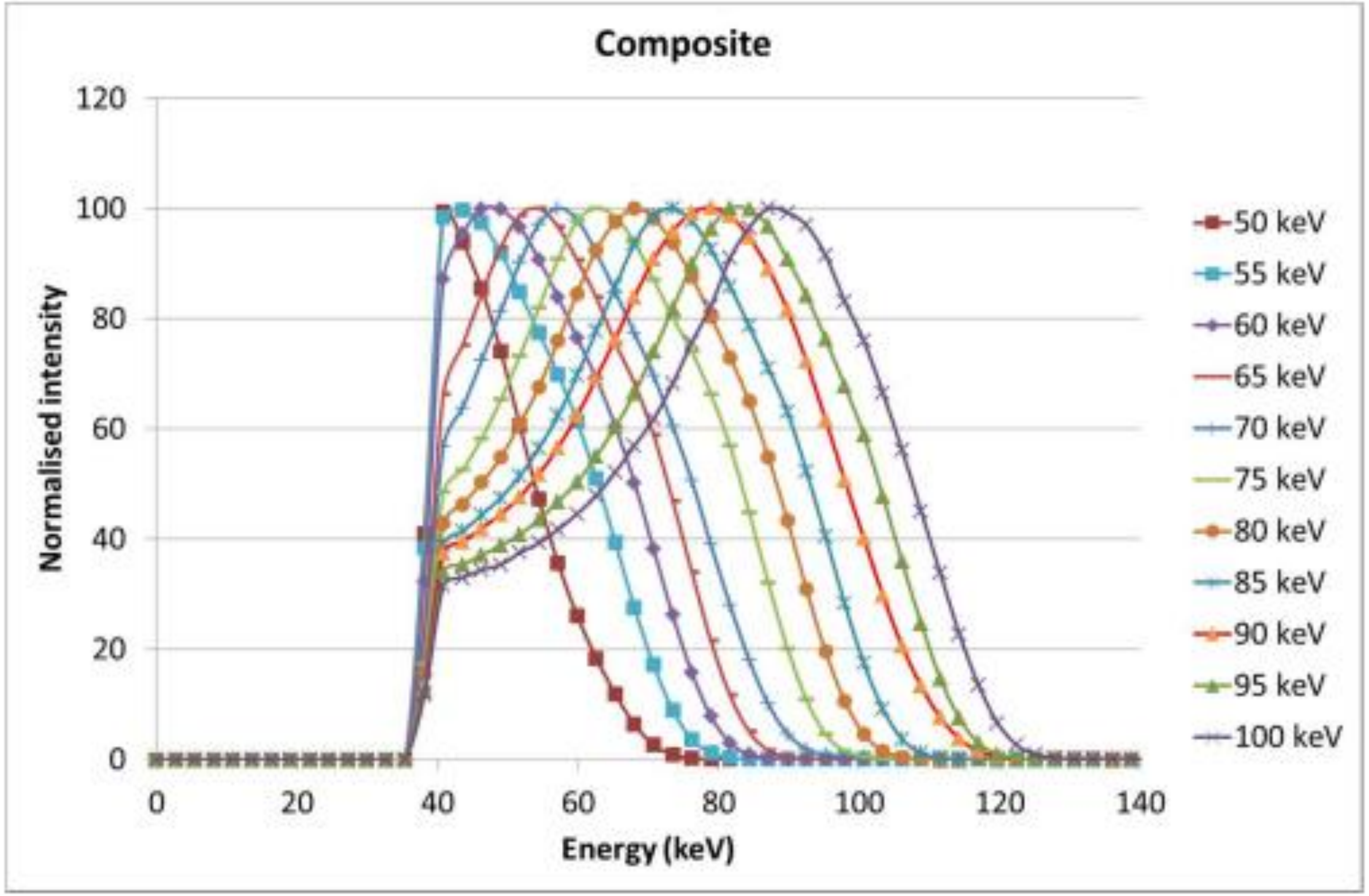
Results

- Difference btwn high Z/density and low Z/density material
- Composite material behaves like highZ/dendity



G4 simulations by Fan Lei in excellent agreement

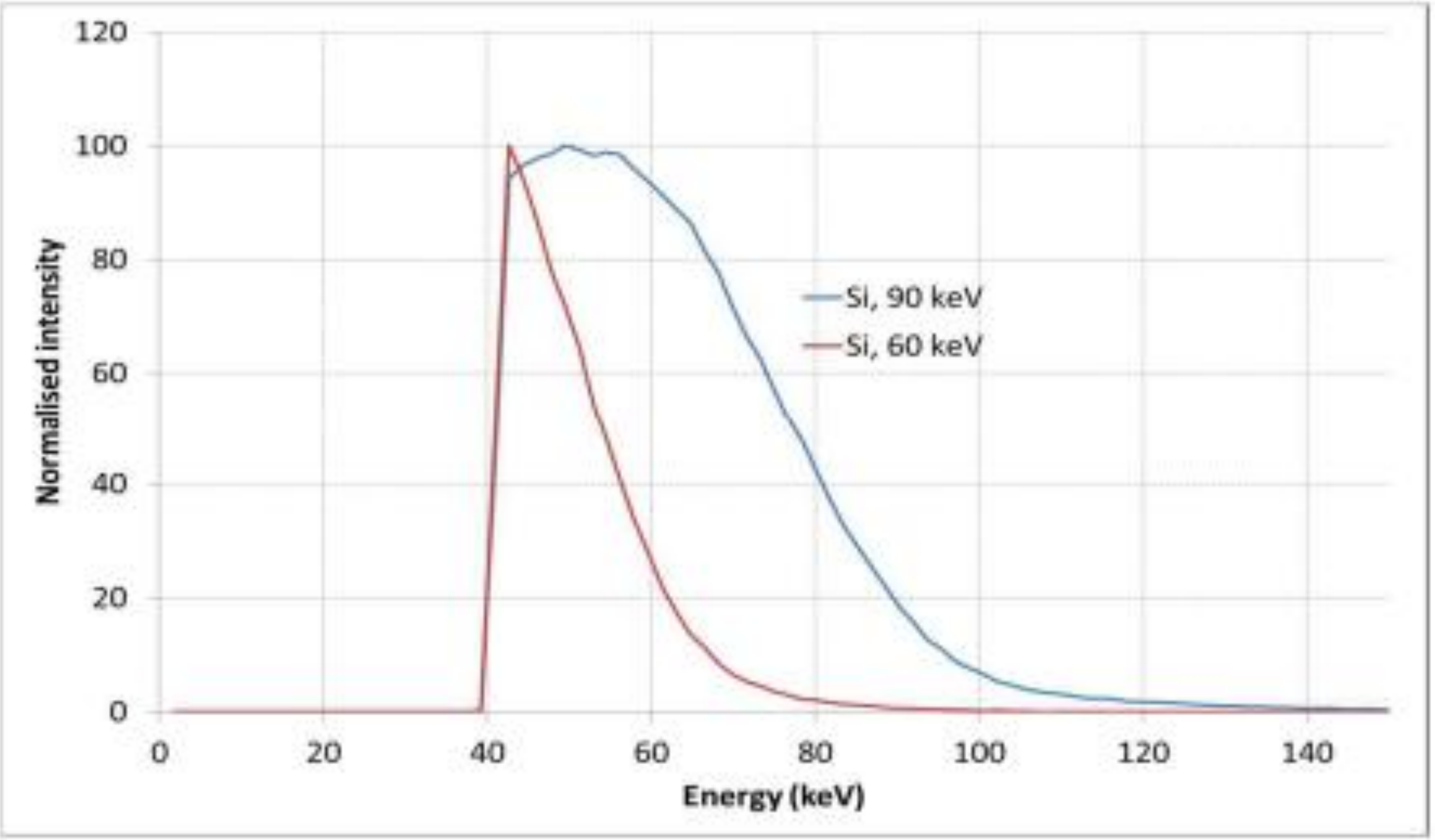
BSE Spectrum



BSE energy spectra measured on the composite sample at incident energies ranging between 50 and 100 keV

backscattered electrons suffer only modest energy loss

BSE Spectrum



backscattered electrons suffer siginficant energy lossese

BS: implications for XIFU and WFI

Composite sample ~ XIFU sensors

- ~ ½ e- are backscattered
- only small fraction of energy ~ keV left on sensor

Si sample ~ WFI sensors

- <20% e- are backscattered
- substatial fraction of energy left on sensor

Unrejected background associated to BSe- much larger for XIFU than WFI

Outlook

Measures within EXACRAD vital but not complete

- electron backscattering at small angles to surface not performed
- soft proton measures limited to E > 100 keV

Summary

A solid characterization of instrumental background is key to carrying out several ATHENA science goals

Predictions for ATHENA instrumental background rely heavily on understanding of physical processes

AREMBES - Defintion of SPACE Physics list

EXACRAD - Carrying out experiments to characterize key physical interactions btwn particles and matter

These activities are part of a larger and coherent structure whose ultimate goal is to afford a low and highly reproducible background for ATHENA instruments