

DEVELOPMENT OF AN ION BEAM ANALYSIS SETUP AT THE BONN ISOCHRONOUS CYCLOTRON



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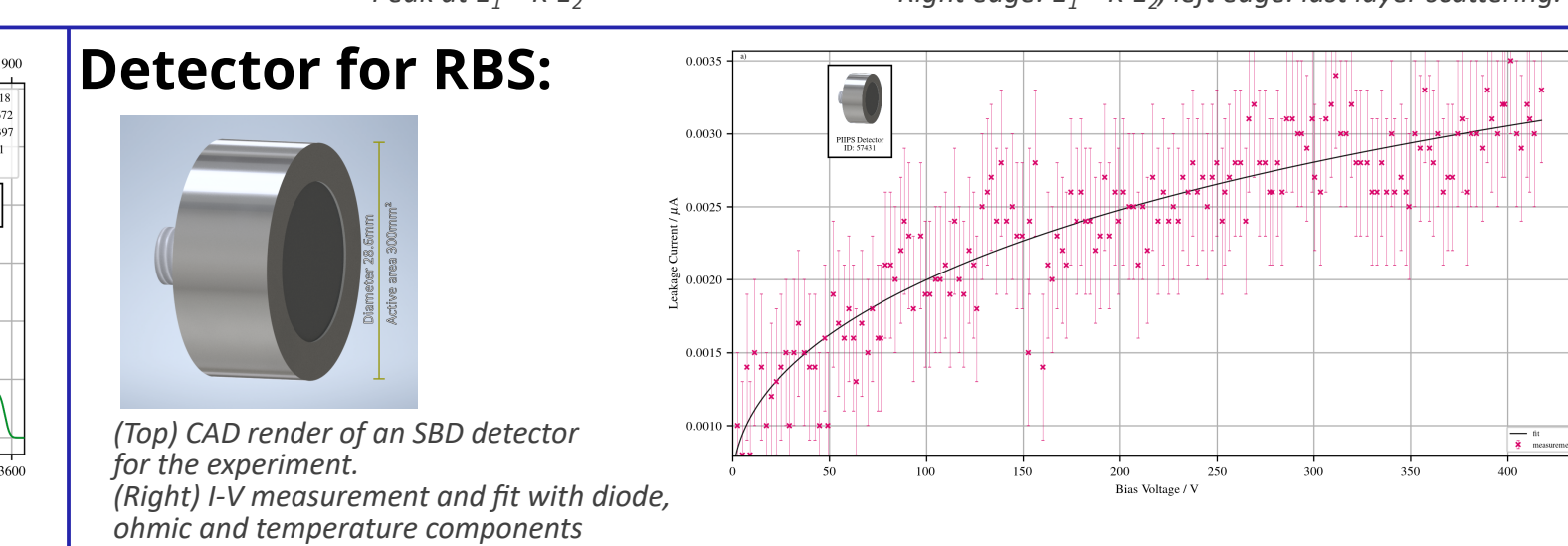
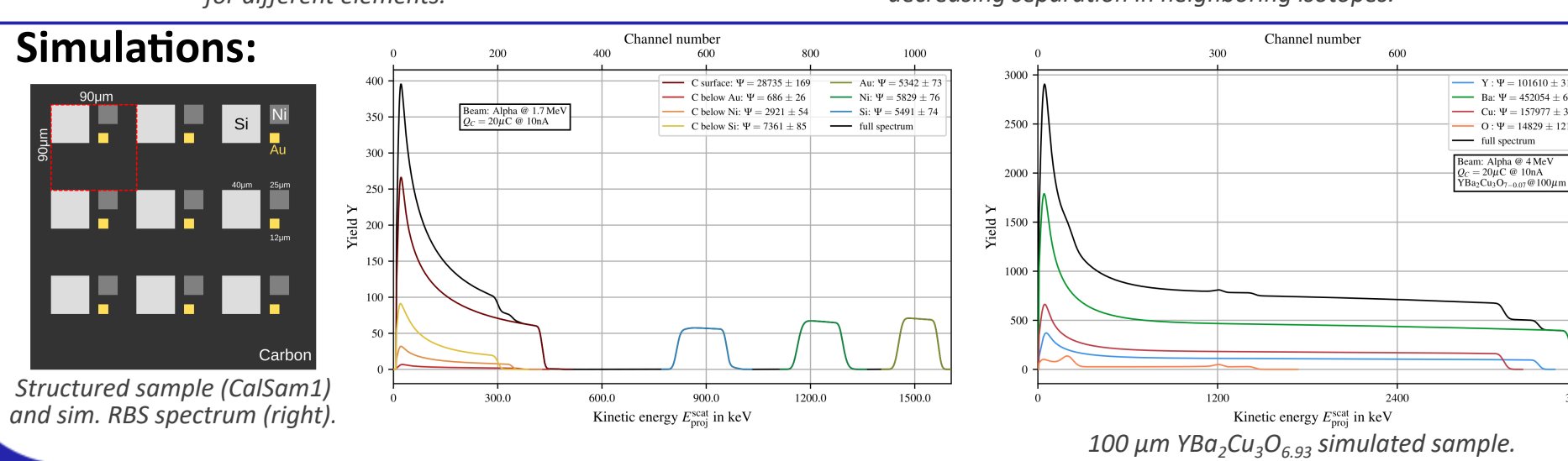
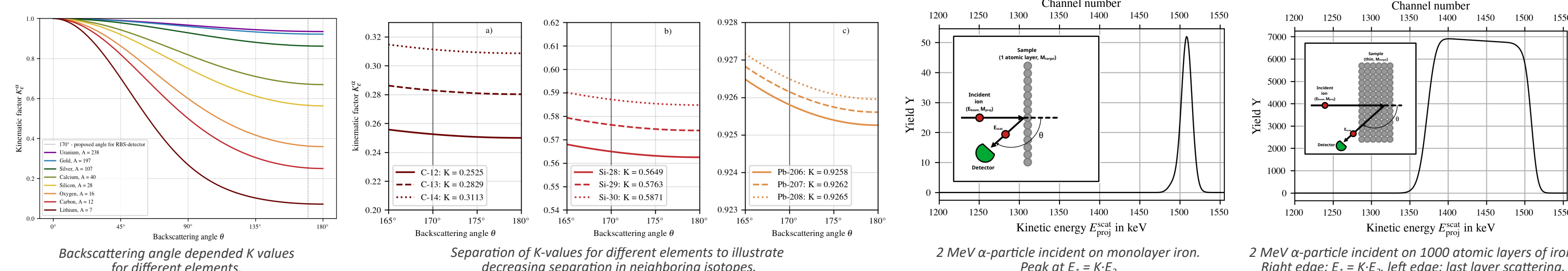
The Bonn Isochronous Cyclotron provides light ion beams with a charge-to-mass ratio $Q/A \geq 1/2$ and kinetic energies below 14 MeV per nucleon to one of five experimental sites. It is planned to extend the facility's analytic capabilities through the development and installation of an ion beam material analysis setup. It is intended to use low energy alpha particles with energies between 2 and 5 MeV, with investigations on whether to achieve this through a higher harmonics mode of the cyclotron or energy dispersive elements in the beamline currently under way. The analytic methods will be Rutherford backscattering (RBS), which is a method sensitive to the mass of a nucleus, and particle induced x-ray emissions (PIXE) which is used to detect characteristic x-ray emission lines to disambiguate isobars. The experimental setup is currently in development and will house a surface barrier detector (SBD) for RBS, a small number of SBDs for beam characterization and a silicon drift detector for PIXE measurements.

This contribution will give an overview over the development process, some preliminary detector tests and a preparatory benchmark x-ray measurement.

Rutherford Backscattering (RBS)

Theory: The ion-atom interaction is based on the Rutherford cross section formalism combined with kinematic scattering theory.

The K-factor describes the ratio between measured (E_1) and initial energy (E_2) of incident ion. Through this relation the mass of the scattered atom in the sample (M_2) can be inferred. K increases with higher M_2 but neighboring M_2 (in units of amu) grow smaller in separation.



Samples and Setup

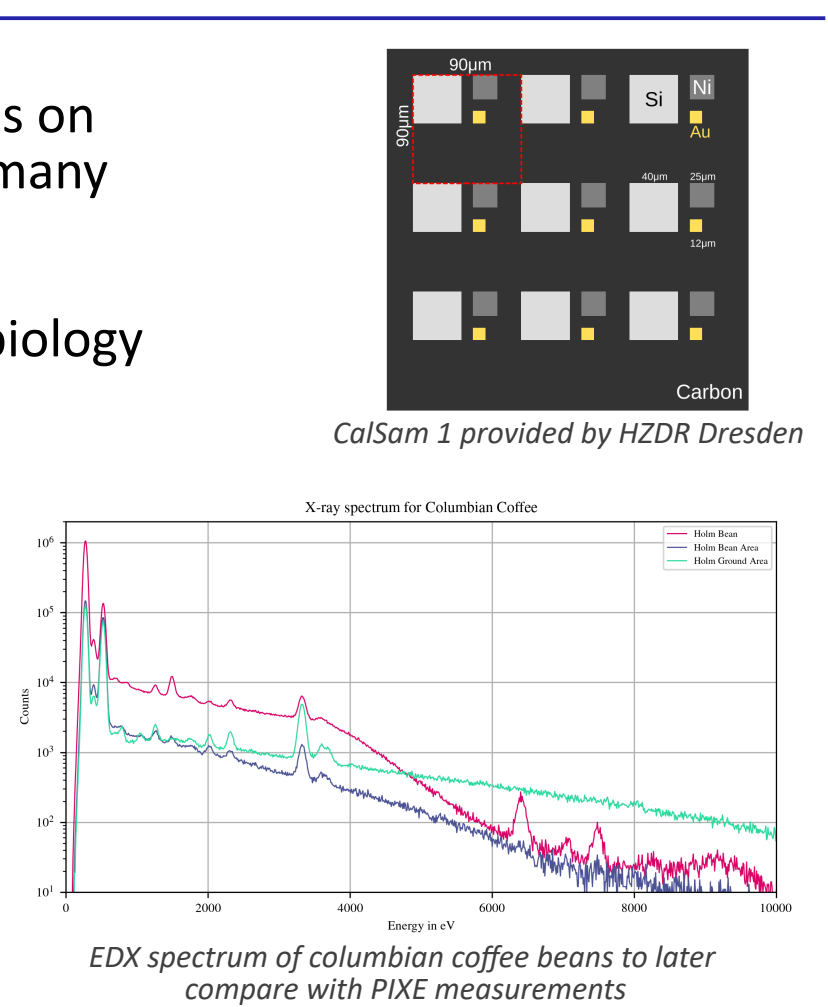
Samples:

As RBS is most useful for thin films or surfaces, a sample is usually less than 1 μm in depth if studied in its entirety or has a layer of interest in that thickness. The techniques employed work complementarily, such that RBS is sensitive where PIXE lacks in detector efficiency and vice versa. Furthermore are they non-destructive, if the applied beam current is feasibly low, so even delicate samples can be considered. Therefore a wide array of possible samples is imaginable, including:

- compound materials (e.g. ceramics, glass, microelectronics)
- organic substances (e.g. insects, tissue, liquids, crops)
- historic objects (e.g. artefacts, artworks, remains)

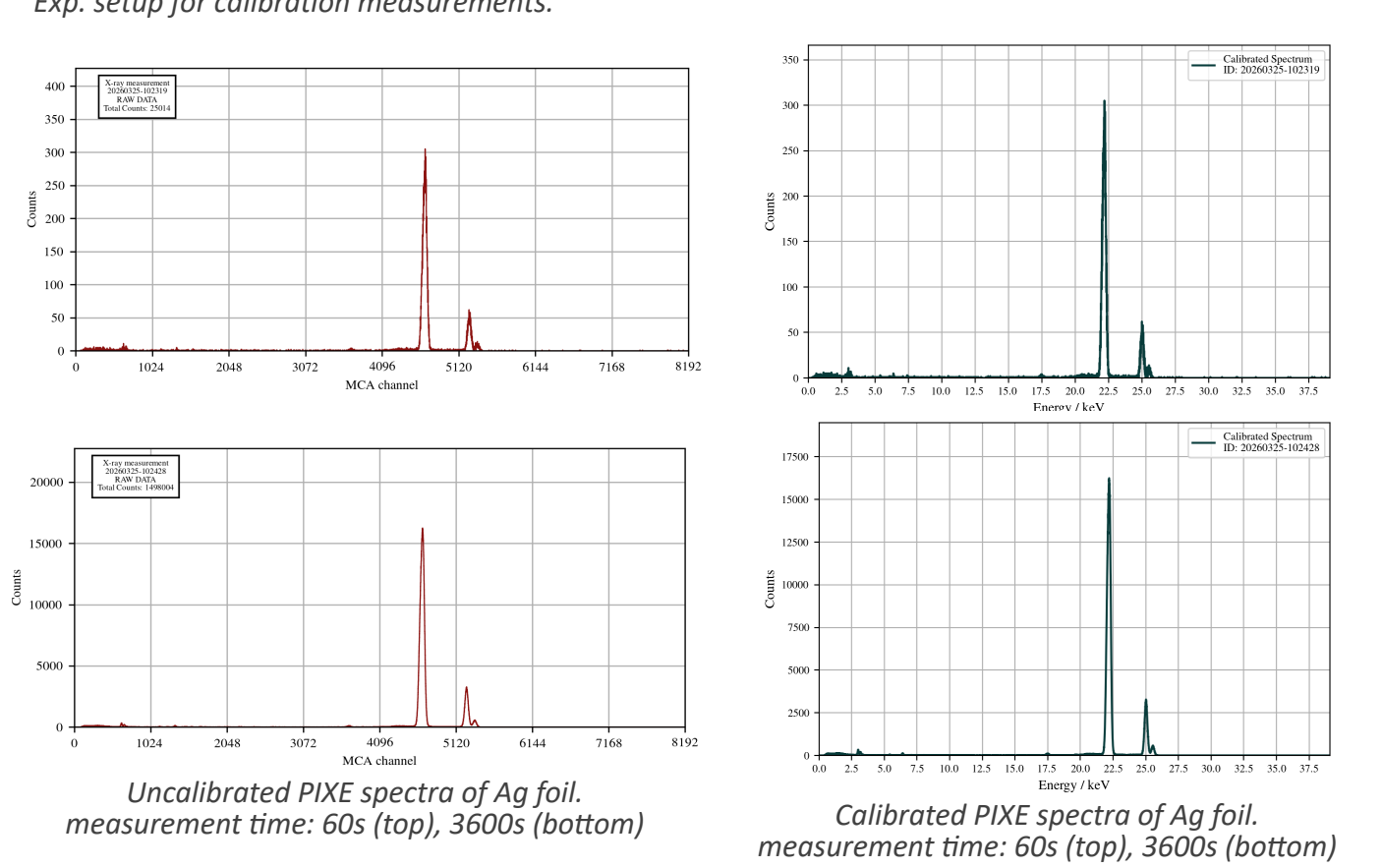
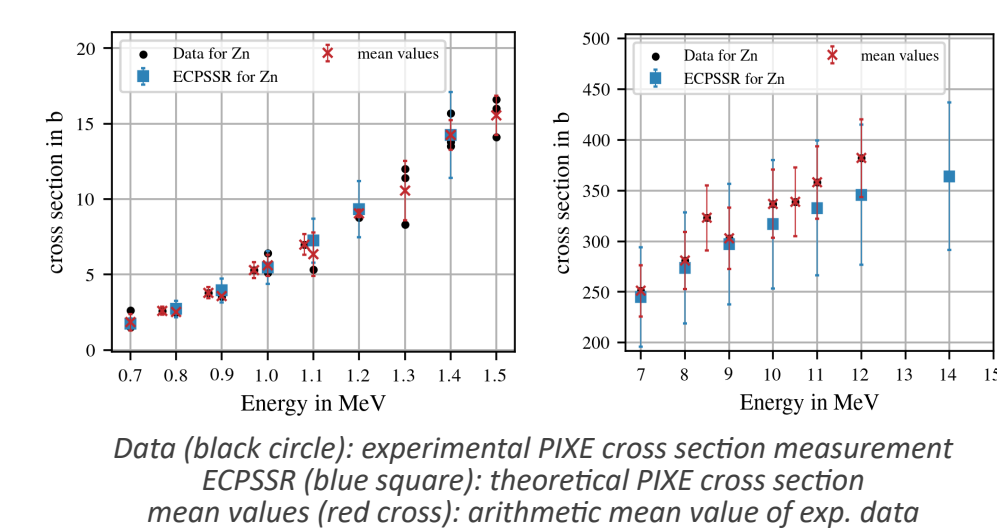
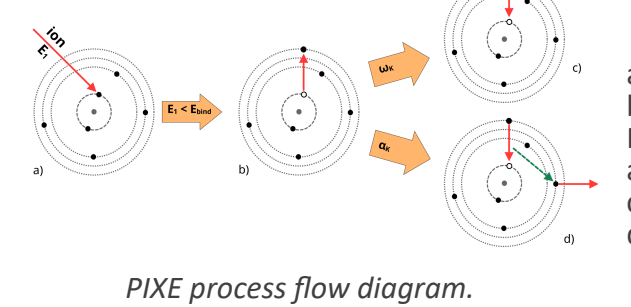
Planned studies in Bonn:

- Calibration Sample 1 (CaSam1): structured sample with Si, Ni and Au patches on a C matrix, provided by HZDR Dresden, Germany
- Coffee beans: a preparatory study was performed with a biology lab at the University of Bonn
- Silicon semiconductor detectors: in collaboration with the LHCb group at Uni Bonn to investigate surface doping and radiation damage
- Detection limit studies: samples are still in evaluation

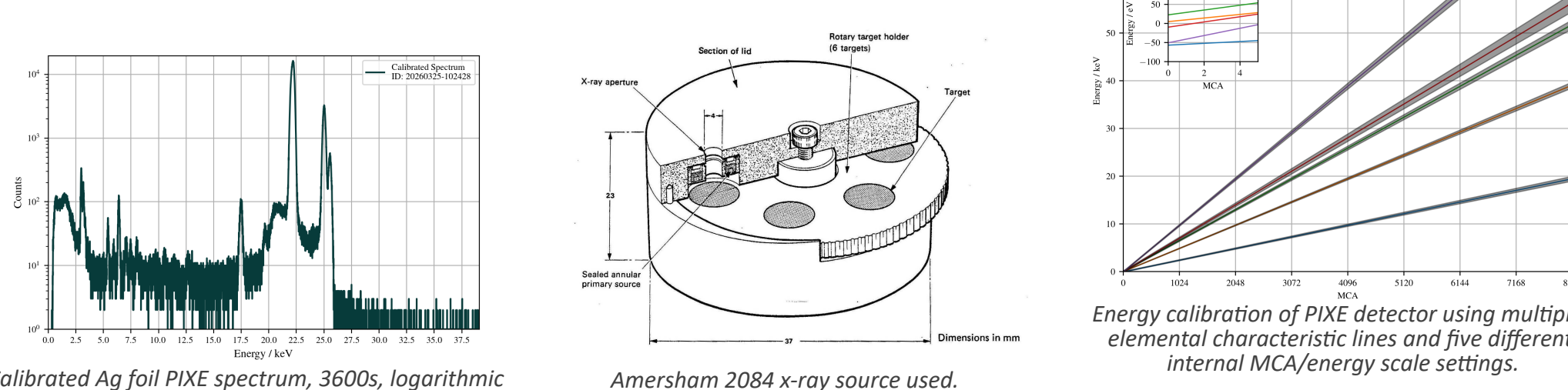


Particle Induced X-ray Emission (PIXE)

Theory: The ion-electron interaction is modelled using ECPSSR theory as well as Hartree-Slater formalism to describe energy transitions.

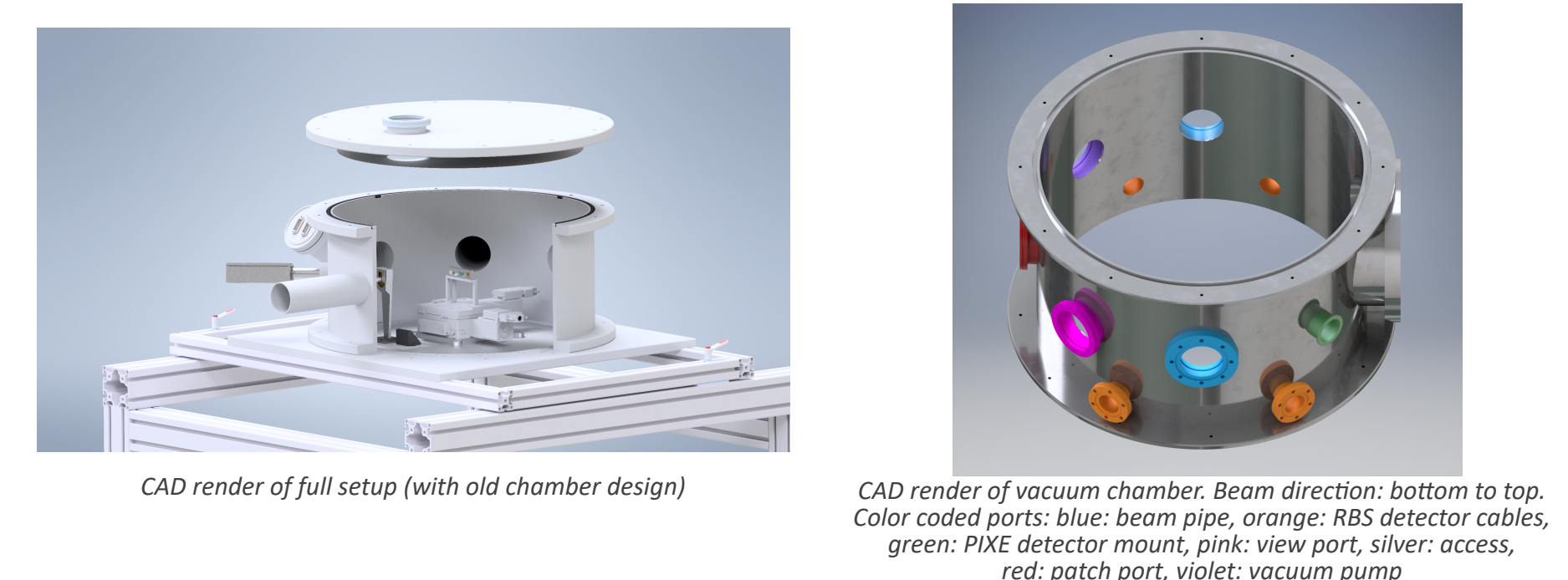


Because PIXE uses α -particles or protons, the background from bremsstrahlung is greatly reduced.

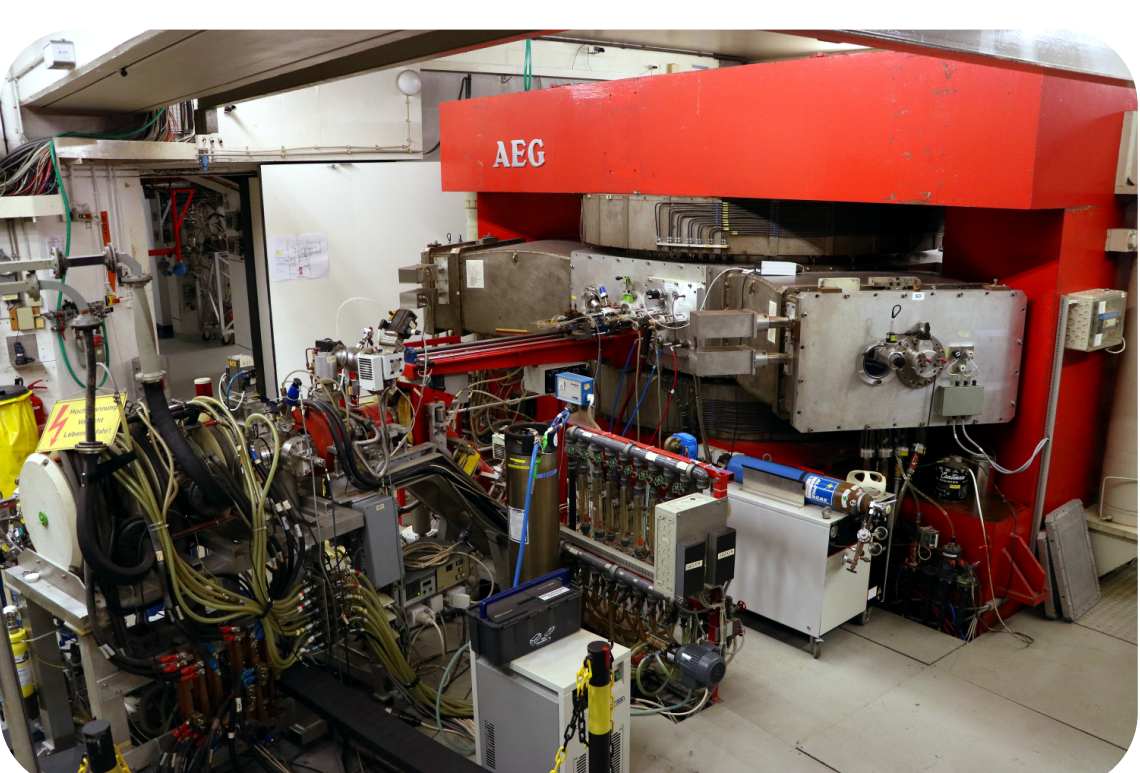


Experimental Setup

For the realisation of the experiment is a vacuum chamber imperative as energy loss of ions and attenuation of x-ray photons in air are to be minimized as much as possible to ensure large statistics and reliable energy measurements respectively. For compatibility with existing infrastructure as well as for radiation protection reasons, it will be made from stainless steel.

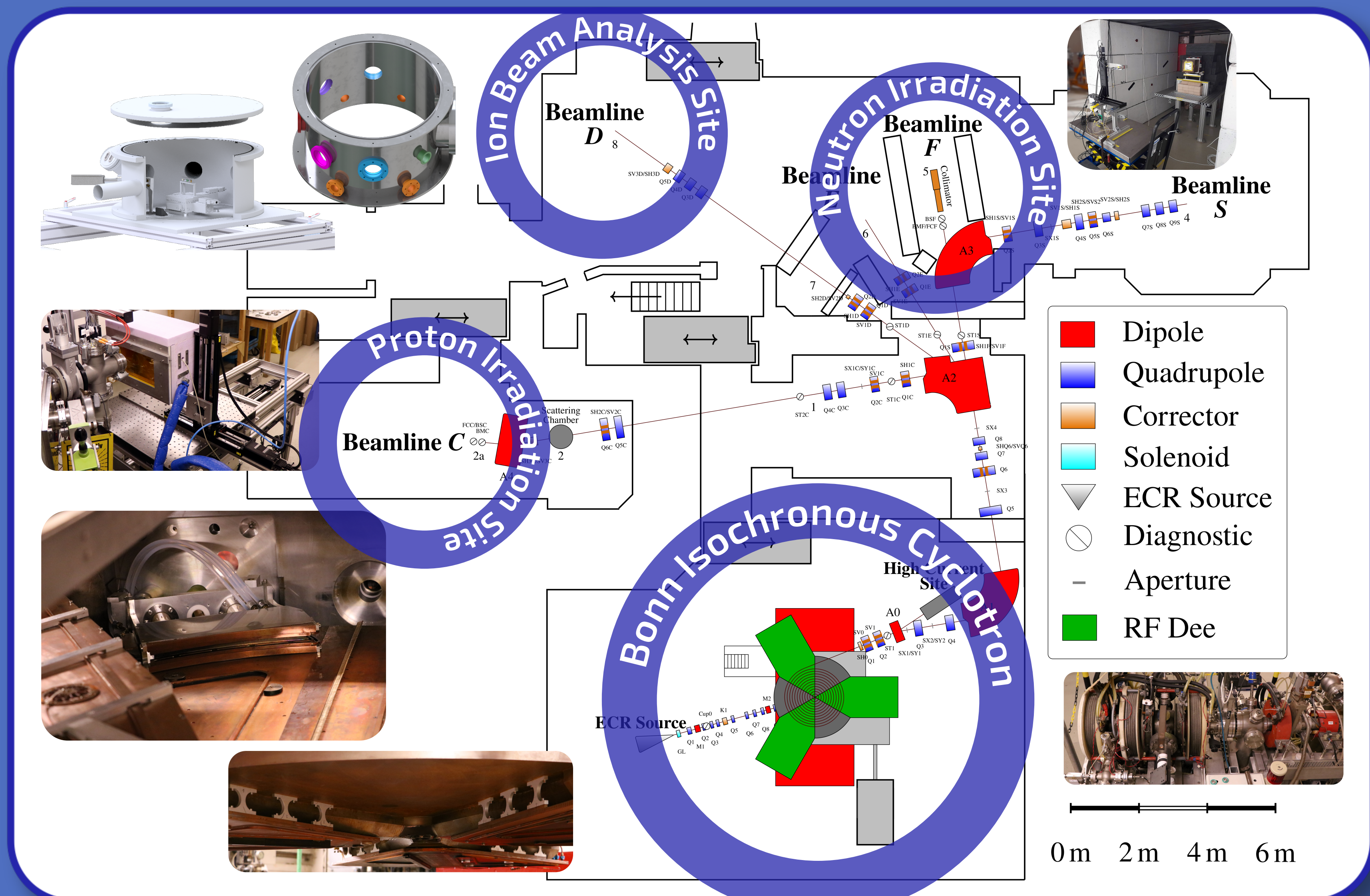


Bonn Isochronous Cyclotron



providable ions	p, d, α , ..., $^{16}\text{O}^{6+}$
energy ($h = 3, Q/A \geq 1/2$)	7 to 14 MeV/A
beam current (ext.)	$\leq 1 \mu\text{A}$
injection / extraction radius	38 mm / 910 mm
number of revolutions	approx. 120
hill sectors	$3 \times 40^\circ, 0^\circ$ spiral angle
hill / valley field strength	1.9 / 0.7 T (max.)
flutter	0.62
dees	$3 \times 40^\circ, 40 \text{ kV}$ (max.)
cyclotron harmonic h	3, 9
rf frequency ν_{rf}	20.1 to 28.5 MHz
hor. / vert. emittance	16 / 22 mm mrad
relative energy width	4×10^{-3}

Beam Preparation: A two-stage 5 GHz or a single-stage 2.5 GHz polarized ECR source (2 to 8 keV)
Injection: Vertical injection into the magnetic center of the cyclotron via a low-energy beam line, using an electrostatic hyperboloid inflector
Cyclotron: Isochronous AVF cyclotron with three Hill-and-Valley sectors
 Three broadband dees with maximal acceleration voltage of 40 kV (min. gap 23 mm)
 Single-turn extraction into compensated-field channel via electrostatic septum
 Position and angle stabilization of extracted beam via slit apertures
Beam Handling System: Symmetric/asymmetric double-bend monochromator or achromator



Contact

