Final Technical Report
SISGR – Upgrades to the Asterix Polarized Neutron Reflectometer at LANSCE

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Abstract

We have upgraded the polarized neutron reflectometer, Asterix, at the Lujan Neutron Scattering Center at Los Alamos for the benefit of the research communities that study magnetic and complex-fluid films, both of which play important roles in support of the DOE's energy mission. The upgrades to the instrument include:

- A secondary spectrometer that was integrated with a Huber sample goniometer purchased with other funds just prior to the start of our project. The secondary spectrometer provides a flexible length for the scattered flight path, includes a mechanism to select among 3 alternative polarization analyzers as well as a support for new neutron detectors. Also included is an optic rail for reproducible positioning of components for Spin Echo Scattering Angle Measurement (SESAME). The entire secondary spectrometer is now non-magnetic, as required for neutron Larmor labeling.
- A broad-band neutron polarizer for the incident neutron beam based on the V geometry.
- A wide-angle neutron polarization analyzer
- A 2d position-sensitive neutron detector
- Electromagnetic coils (Wollaston prisms) for SESAME plus the associated power supplies, cooling, safety systems and integration into the data acquisition system.

The upgrades allowed a nearly effortless transition between configurations required to serve the polarized neutron reflectometry community, users of the 11 T cryomagnet and users of SESAME.

Equipment installed during the upgrade

The original sample mount and rotation stage for the secondary spectrometer was obtained from BNL when the HFBR was closed. The unit itself was originally a WW-II gun-mount and contained significant amounts of magnetic material, which was incompatible with the use of a very-high-field cryomagnet and with the use of Larmor labeling techniques. This unit was replaced by a stack of non-magnetic Huber units paid for with LANSCE BES-SUFD funding just before the project described in this reported was started, although the two upgrades were coordinated. The new Huber unit can be seen as the green unit in the CAD drawing in Fig 1.

The secondary spectrometer was designed as a rigid aluminum frame (gantry) that could be rotated by one of the Huber stages around the sample position. The weight of the whole secondary spectrometer is supported halfway along its length on a steel bearing that rolls on a steel track that is bolted to the floor. This track is the arced component at the bottom of Fig 1. On top of the aluminum frame grantry, components are mounted on a pair of Thompson rails, allowing distances between the components along the neutron beam line to be chosen at will. The drawing in Fig 1 (made at an early stage of the project) shows the Huber goniometer, the gantry and one of the main components of the secondary spectrometer in notional form – an elevator that can carry two different polarization analyzers and an optional empty position, each optimized for a different type of experiment, any one of which can be placed reproducibly in the scattered neutron beam via the instrument control computer.

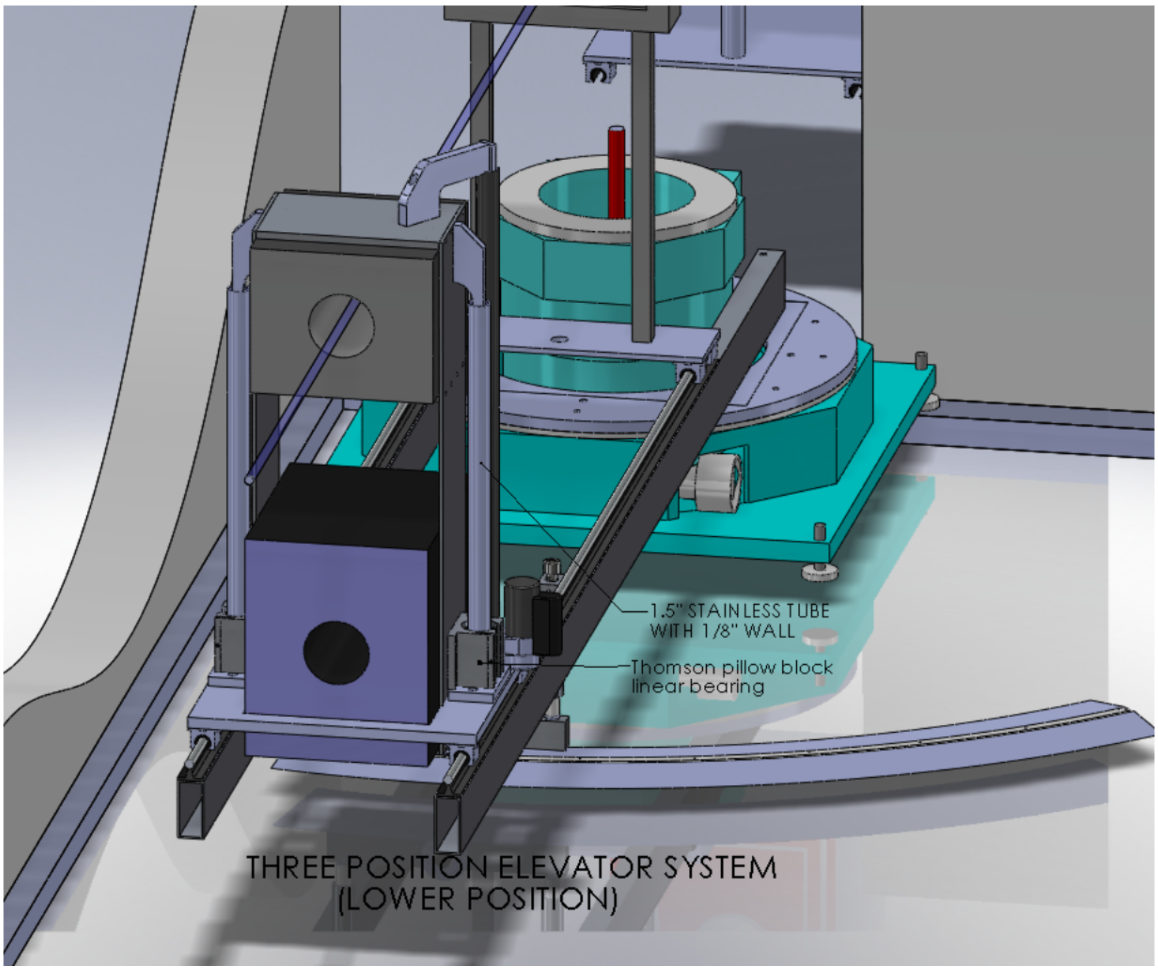

Fig 1: Early conceptual drawing of the Asterix secondary spectrometer showing the secondary spectrometer, driven by the green Huber unit, supported by a wheel running on a steel track

Figure 2 shows the secondary spectrometer in its final, as built form. The Huber goniometer shown clearly in Fig 1 is the green unit just to the right of the center of the picture. The large green parallelepiped to the left is the container for the neutron detectors that we is describe below. To the right of the detector is the elevator unit (shown notionally in Fig 1) with three polarization analyzers installed, one above the other. Between the elevator and the sample position is an adiabatic RF flipper that was available before this project started.

To accommodate different types of experiments we decided that several different detectors would be needed, essentially because 2-d detectors with high spatial resolution are not yet capable of counting neutrons at the full beam intensity of the LANSCE source. For this reason we designed a detector housing (the green object in Fig 2) that could shield each of the three detectors that we planned to use. Each detector can easily and quickly be removed from the shielding and replaced by a different detector at the experimenter's convenience.

Figure 2. Photograph of the new secondary spectrometer installed on Asterix as part of this project.

A CAD drawing of the detector shielding is shown in Fig 3. The unit is designed to rotate so that the high-resolution direction of a 1-d detector can be either vertical or horizontal. The pre-amps for one of the detectors we built (an array of sixteen 1-d PSDs with ?? mm positional resolution) are mounted on top of the detector shielding and are shaded in brown in Fig 3. The detector shielding itself is fabricated using 1" thick borated polyethylene sheets.

Close-up photographs of the detector housing and the elevator mechanism are shown in Fig 4.

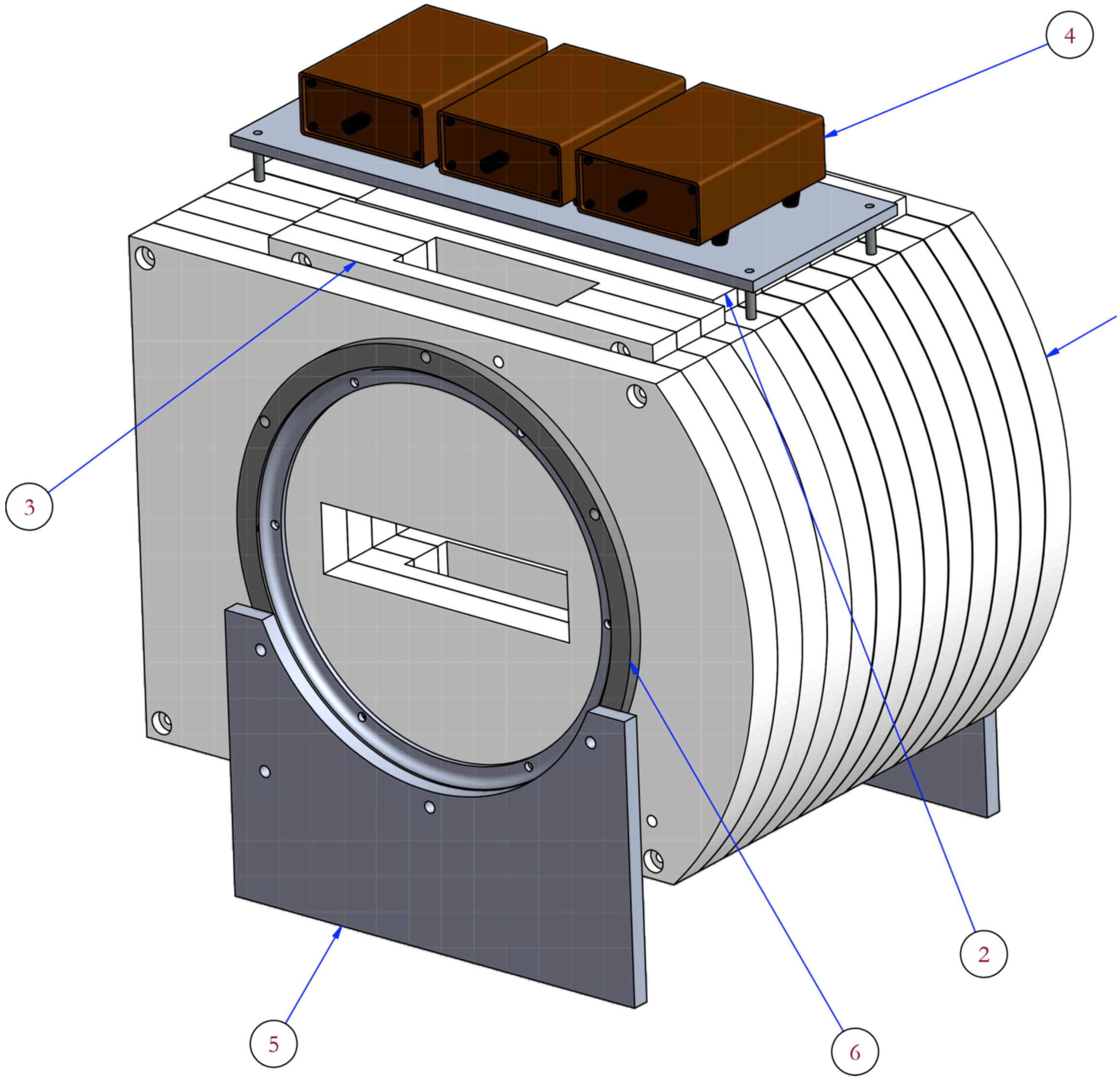

Figure 3: CAD drawing of the detector shielding unit. The labeled components are: 2—a removable plug with one of the 3 possible detectors attached; 3 – a removable plug for another detector that can be placed in a slot close to the front of the shielding; 4 – detector preamps for one of the detectors we built (an array of 12 single-ended 3He detector tubes); 5 – detector support; 6—bearing allowing detector to be rotated about an axis coincident with the neutron beam.

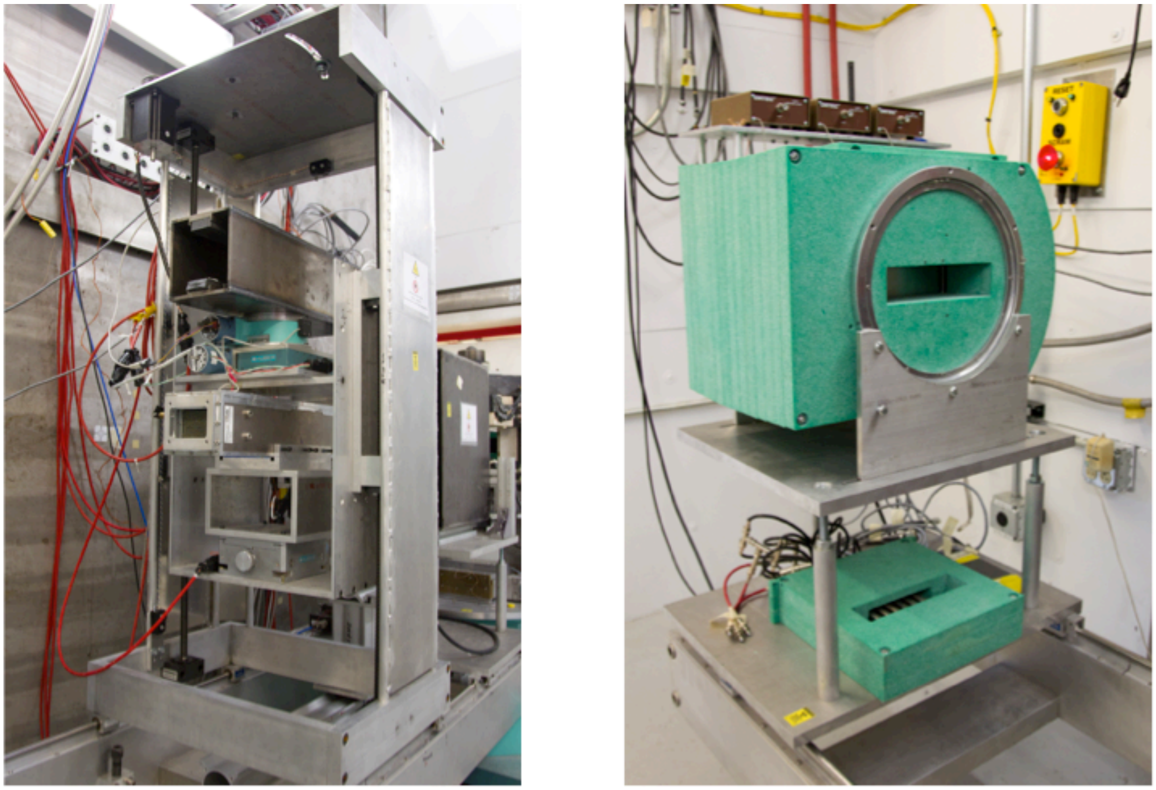

Figure 4: Left: more detailed view of the elevator that allows two different polarization analyzers and an empty beam pipe to be placed in the neutron beam. The 2 polarization analyzers are (from the top): a single-supermirror polarization analyzer with new mirrors purchased as part of this project and a wide-angle polarization analyzer obtained from the IPNS.
Figure 4: Right: Close up view of the new detector housing mounted on the secondary spectrometer gantry. One of the detectors that is not is use is seen on the shelf below the main detector housing.

Part of the project involved equipping Asterix for Spin Echo Scattering Angle Measurement (SESAME). The technique that we chose to implement is based on the use of water-cooled magnetic Wollaston prisms. Figure 5 shows the aluminum bodies used for winding the coils for these prisms. These units have internal water cooling (the cooling channels can be seen in the upper picture in Fig 5) that was provided by a 20 kW ??? chiller purchased for this project. Fabrication of the Wollaston prisms turned out to be a technical challenge that became a principal part of the thesis of a graduate student. The lower part of Fig 5 shows the grooves that are machined into the aluminum bodies of the coils to ensure uniform winding. The windings were made from aluminum wire that was coated with a special insulation that has limited incoherent scattering for neutrons. Working with a manufacturer we were able to get the coils wound in the way we needed to ensure performance.

Current for the Wollaston prisms is supplied by four 20V/20A Lambda-TDK power supplies that were installed as part of this project. Two smaller units supply current to the π and $\pi/2$ flippers required for the spin echo method. A programed unit cuts the power to the coils if their temperature diverges beyond a set point or if an interruption of cooling water flow is detected. All of these units were chosen for their stability and a special direct current-current transformer (DCCT) was implemented to measure the current in the various coils so that its constancy could be monitored.

The Wollaston prisms and flippers are mounted on an X-95 optic rail mounted on the gantry carrying the secondary spectrometer. This rail and the supported prisms are clearly seen in Figure 7.

The SESAME equipment installed on Asterix allows desnity correlation functions for be measured in strongly scattering systems over length scales from about 20 nm to 2 microns. This is accomplished using equipment that can be installed in a space of less than 2 m on both the incident and scattered neutron flight paths. The only prerequisite is that the instrument be equipped with a polarization analyzer that is spatially uniform.

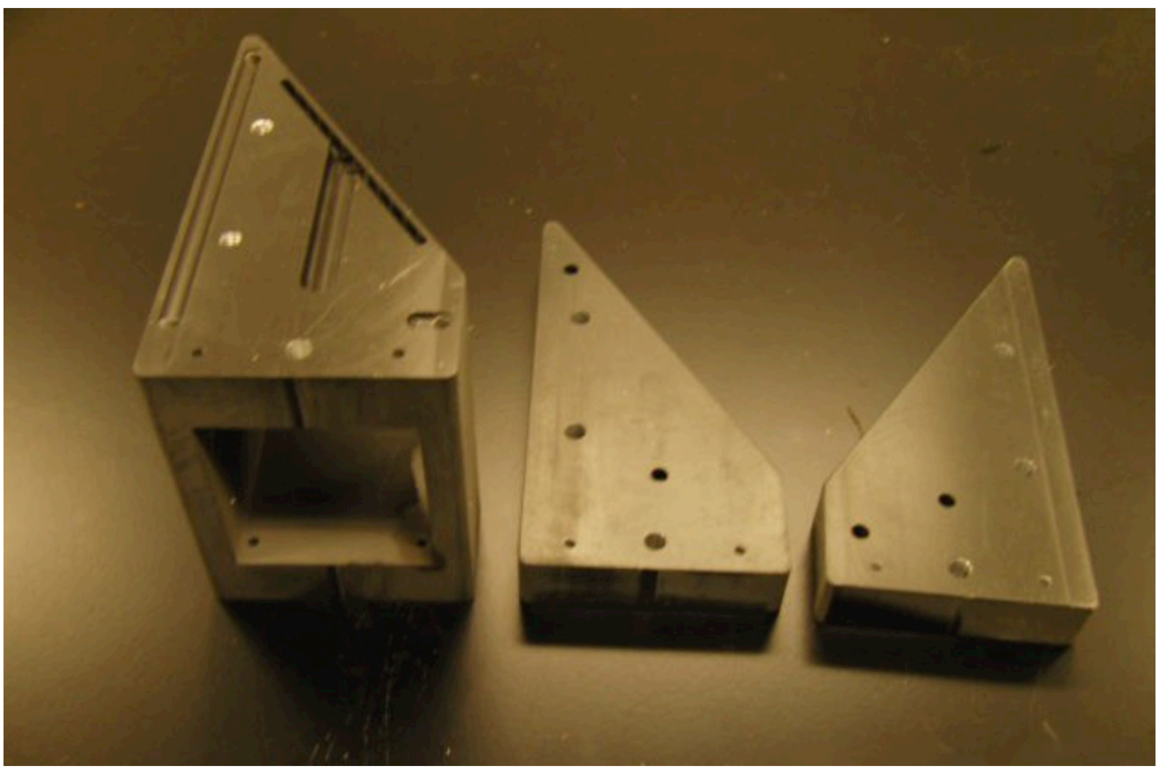

Figure 5: One of the coil-bodies for the Wollaston prisms before assembly. The internal cooling channels are visible in the leftmost image. The top and bottom of the coil-body (the two objects to the right) are glued on to the main part of the body using a special adhesive. Note the large aperture in the main part of the coil-body through which the neutron beam passes.

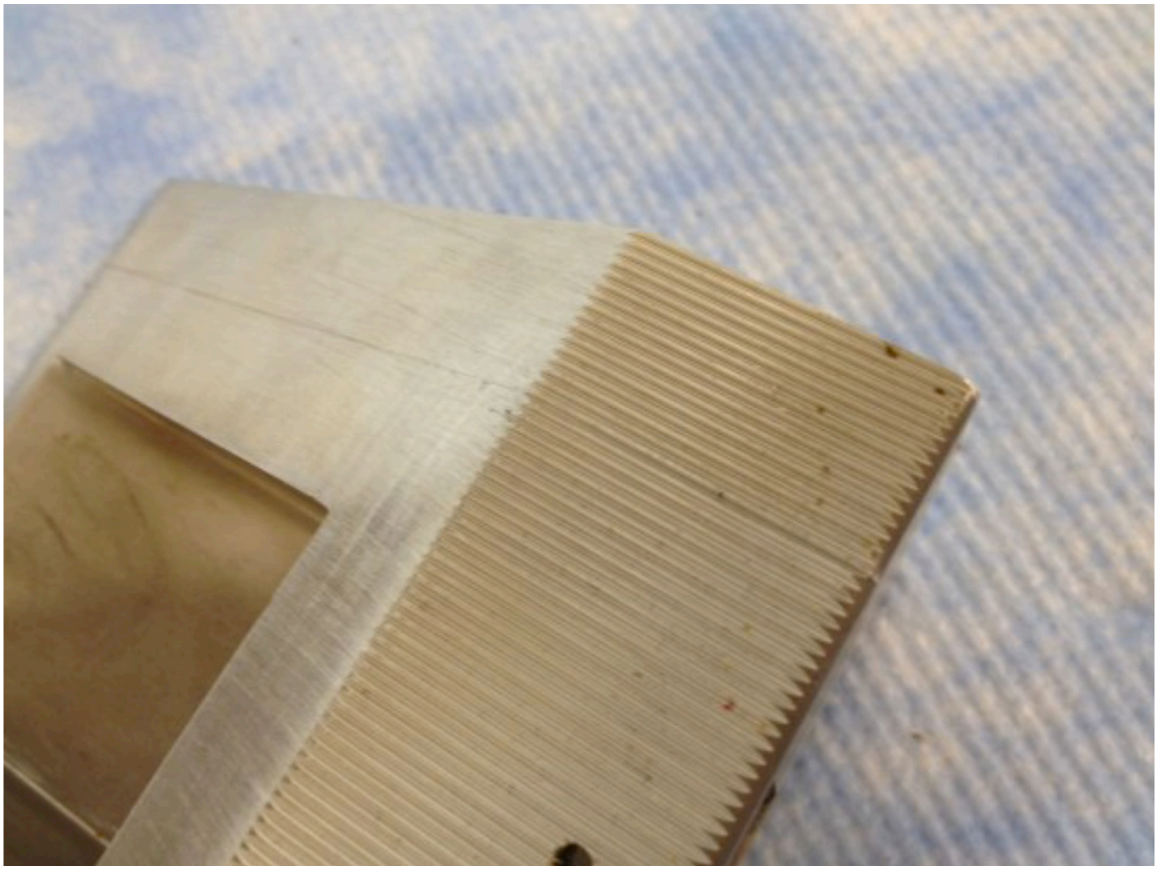

Figure 6: Two edges (one shown here) of each coil-body have machined grooves to guide the wires during winding. The glue joint between the main coil-body and one of its end units is just visible in the image.

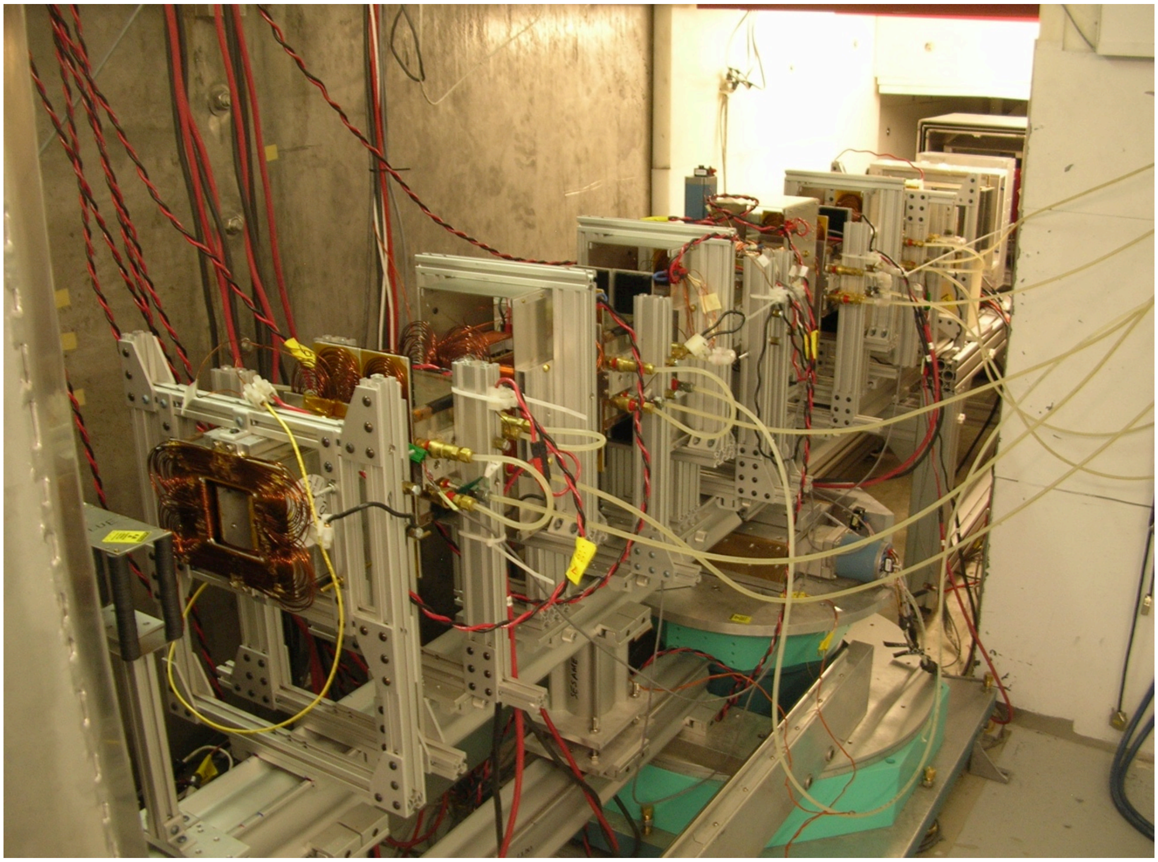

Figure 7: Asterix equipped with Wollaston prisms for SESAME. The two X95 optic rails that support the water-cooled prims are clearly visible. These rails allow the prisms to be mounted reproducible on the reflectometer and removed when not needed.