The SEparator for CApture Reactions (SECAR): An Update on Commissioning

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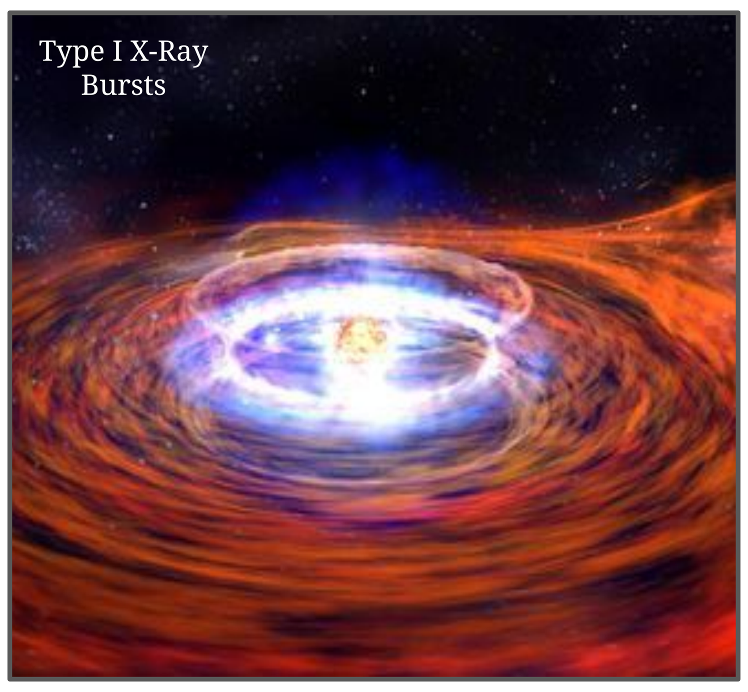
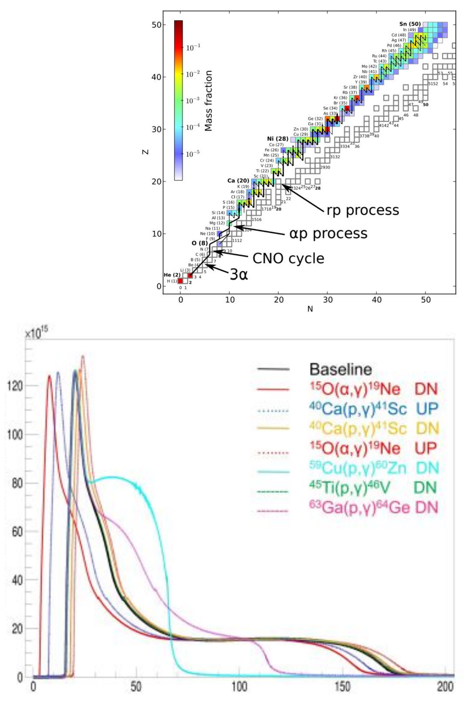


Astrophysical Motivation

While we can learn much about fundamental nuclear physics through studying exploding stars, the opposite is also true. Accreting compact stars (shown to the left) may experience violent thermonuclear outbursts and core-collapse supernovae (shown to the right) are sites of many nucleosynthetic processes. Of these are the **rp process**, **νp process**, **weak r-process**, and more.

While some reactions are well-known in the lower mass range, many intermediate reactions are yet to be measured. SECAR was designed to study reactions relevant to exploding stars up to **A ~ 65** in the **0.2 - 3.0 MeV** energy range. Sensitivity studies (pictured to the right) help identify which reactions need to be constrained to improve our models.



SECAR Layout

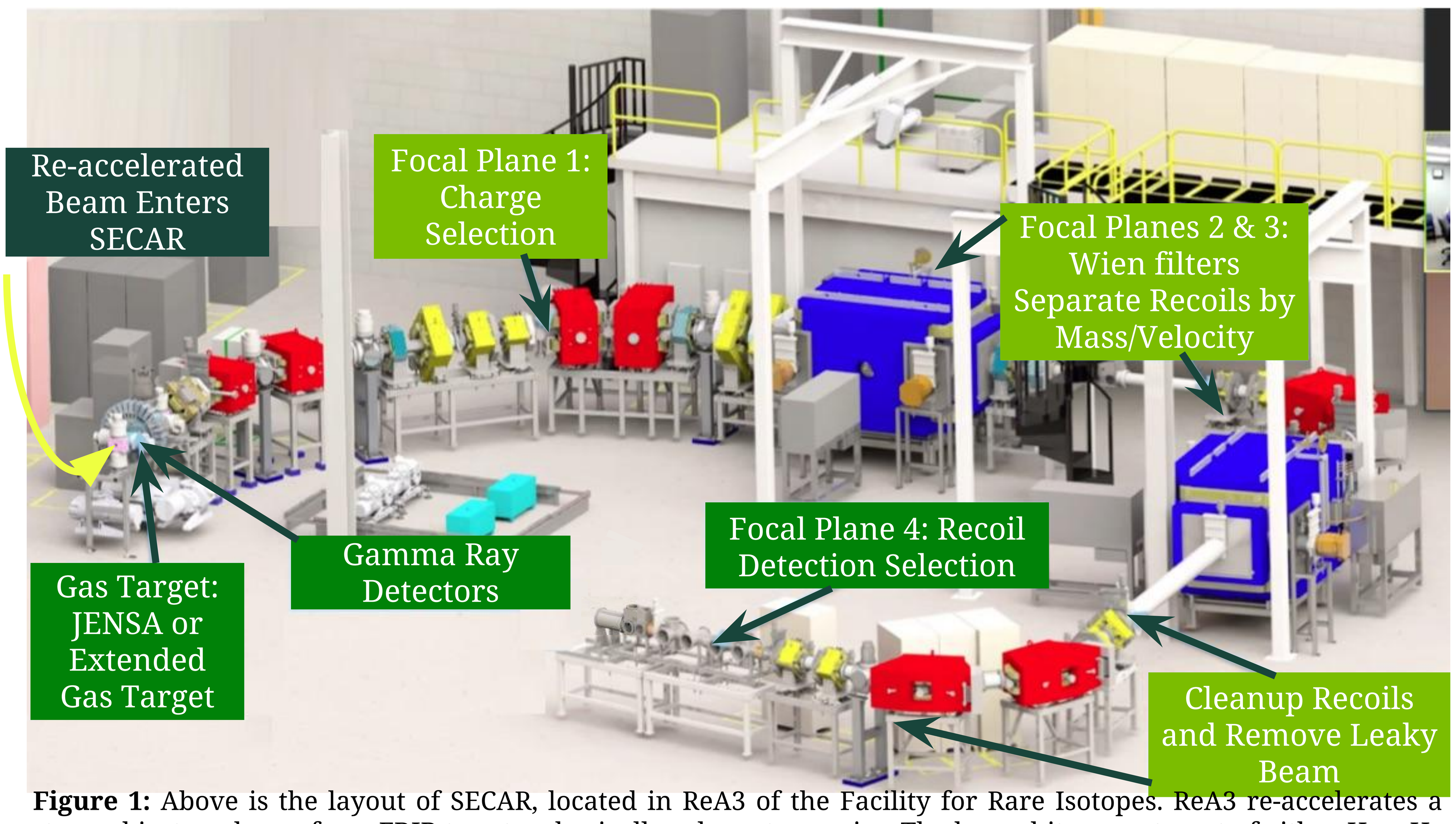


Figure 1: Above is the layout of SECAR, located in ReA3 of the Facility for Rare Isotopes. ReA3 re-accelerates a stopped isotope beam from FRIB to astrophysically relevant energies. The beam hits a gas target of either H or He gas before entering the recoil separator. The separator functions through a series of magnetic and electrostatic devices designed to first select the charge state based on magnetic rigidity, followed by various mass separation tools, and detecting recoils that reach focal plane 4 with a combination of particle detector systems. Recoils can further be gated around gamma ray detection in the case of (p,γ) and (α,γ) capture reactions. For reference, red devices are dipole magnets, yellow devices are quadrupole magnets, blue devices are Wien filters, and blue devices are higher order magnets.

Magnet Cycling

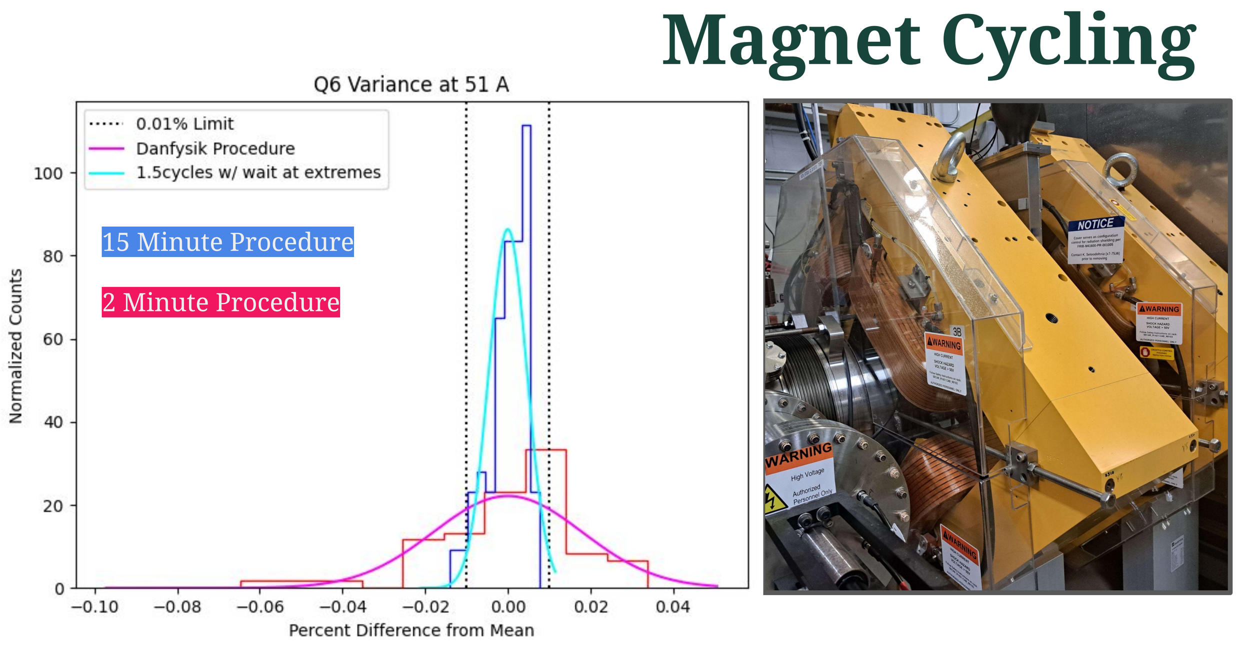


Figure 5: *Right:* As the largest quadrupole magnet in the beamline, it requires the longest cycling procedure to ensure magnetic field reproducibility. *Left:* Graph show two procedures for cycling, one that provides reproducible fields within .004% at the cost of a long cycling time, and one faster procedure that reproduces fields within 0.018%. Finding a procedure that minimizes the time and provides reliability is underway.

^{86}Kr(α,xn)$^{...88,89}$Sr Experiment

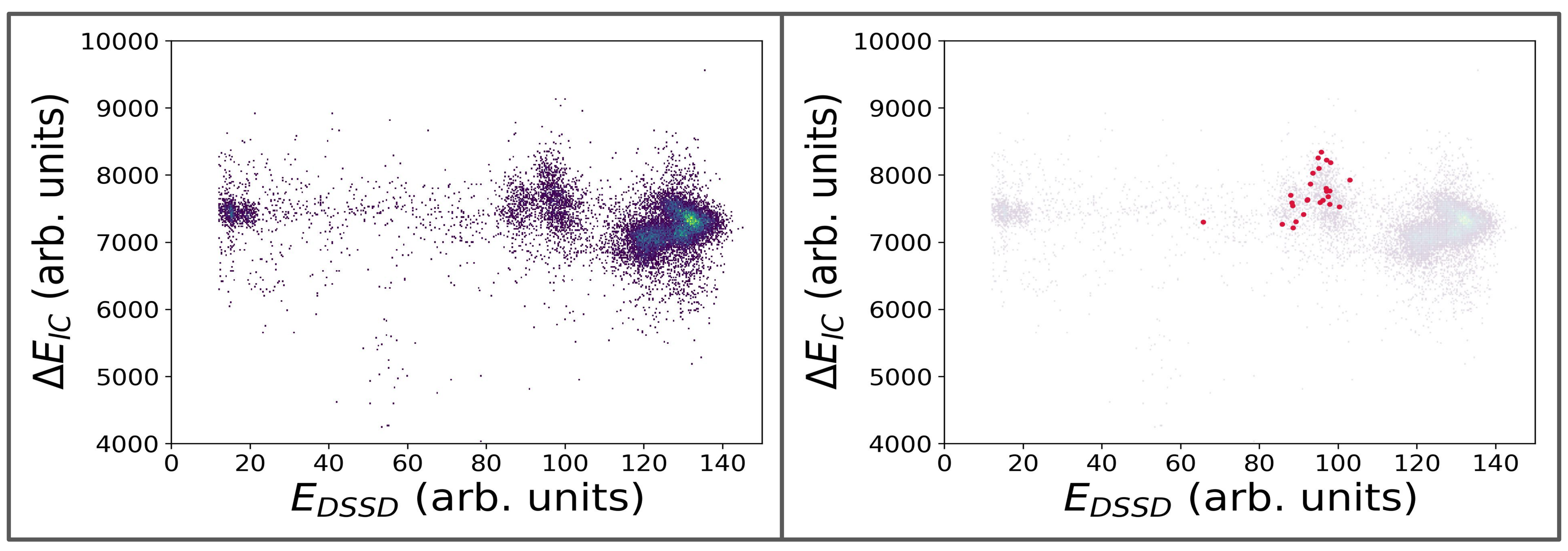


Figure 7: This experiment was performed with the use of the Low Energy Neutron Detector Array (LENDA) located at the target chamber. *Left:* Particle Identification (PID) plot of Strontium recoils made through the combination of an ionization chamber and a DSSD. *Right:* Shows the recoils gated on neutron detection from the LENDA bars.

Windowless Extended Gas Target

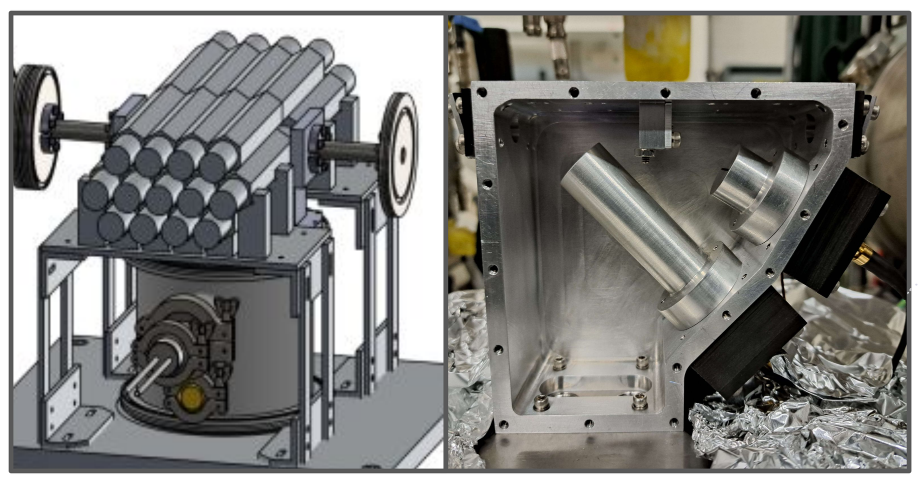


Figure 2: *Left:* Target chamber at the beginning of SECAR with the 26 Bismuth Germanate Oxide (BGO) Detectors surrounding the target symmetrically along the beam axis. (Image courtesy of Colorado School of Mines) *Right:* Inside look of the windowless extended gas target. The chamber is 10cm long filled with H or He gas with two Silicon surface barrier detectors beneath.

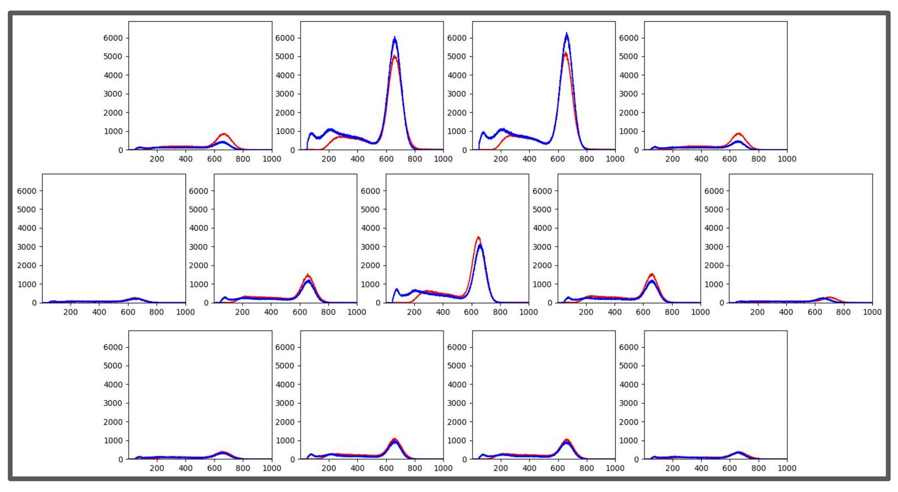


Figure 4: GEANT4 Simulation vs. in-lab calibration test of a Cs-137 source placed on top and in the center of the target chamber. The blue curves are the GEANT4 runs and the red curves are the lab runs. This graph shows only the 13 BGO detectors on the beam left side of the chamber.

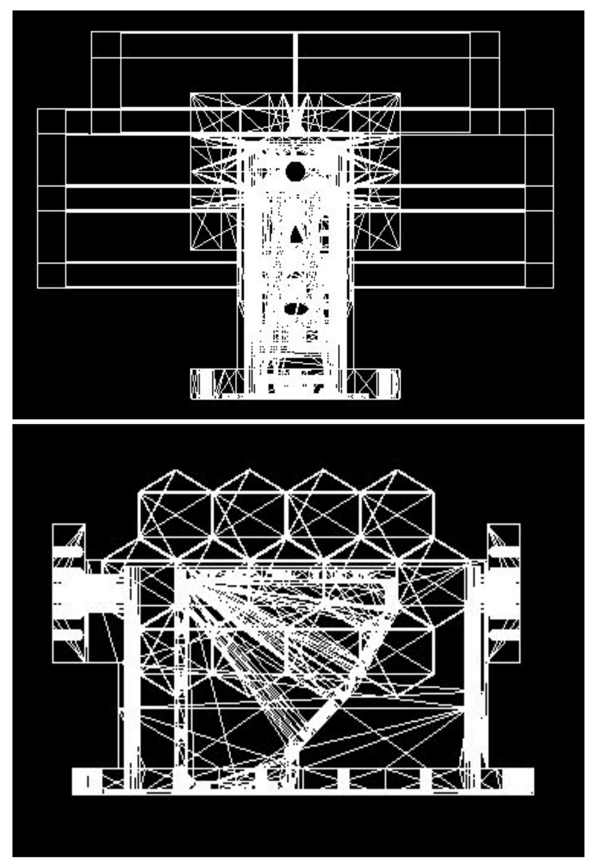


Figure 3: This figure shows the GEANT4 detector construction for the extended target with all detectors. *Top:* Shows the view in the downstream direction. *Bottom:* View from beam right.

Alignment of Target and Diagnostics

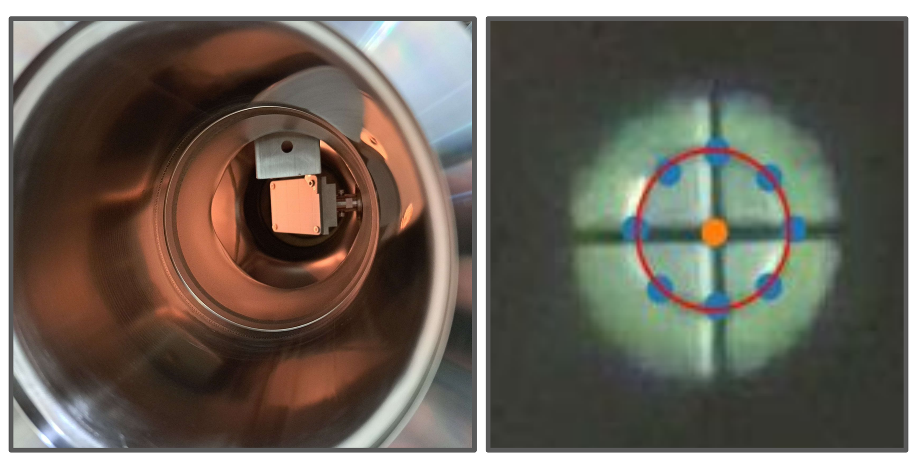


Figure 6: Alignment of the target chamber and diagnostics systems to the optical axis of SECAR is crucial to experiments running properly. *Left:* Upstream diagnostics box containing an insertable viewer and aperture. *Right:* An alignment telescope is set up after the first bend of SECAR to take pictures and analyze the offset with a circle fitting program.

Future Plans

SECAR has successfully measured reactions in inverse beam kinematics for (α,γ) and (p,n) beam optics with an (α,n) experiment currently being analyzed. While a (p,γ) resonance measurement is planned, other tests are planned first. Some goals for SECAR in the near future are listed below:

- Test beam optimization procedures and tuning methods with well-defined beams;
- Develop a model through GEANT4 to determine the location of reactions in target chamber based on BGO detection;
- Understand the transmission of SECAR with alpha source measurement;
- Characterize the acceptance of SECAR with a large energy and angular spread;
- And first (p,γ) resonance measurement with a ^{20}Ne beam. This will also be the first measurement with the extended gas target.

Image courtesy of Mackenzie Styers and Cierra Tinson[1,2,3]

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