He-3 target lessons/status for SIDIS

- Lessons learned during GEn-II
- Quick look at the original target we used for Transversity in 2008/2009
- Design features to consider for the SBS SIDIS polarized 3He target.

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Highlights of lessons learned and/or a wish list

- Don't lose and the lessons-learned document from GEn-II and read it carefully when preparing for the next He-3 experiments !!!
- Have target cells ready early (actually, we tried, and I will examine what it might take to do so).
- Put more emphasis on designing a target enclosure that better facilitates mounting cells, survey and alignment, magnetic field measurements, and other tasks.
- More real-time diagnostics !!! Beam position, magnetic field strength and direction, etc.
- A more robust optics system - extra optical fibers, additional diagnostics, etc.
- Establishing a system so that a cell rupture is easy to clean up would be tremendously valuable.
- For SBS SIDIS - look carefully at the special demands of a He-3 target meant for SIDIS, and FIND the lessons learned from the Transversity experiment !!!

First the good news

- We have managed to develop polarized 3He targets with increasingly high figures-of-merit over the course of 3He experiments at JLab.

- Shown at right are the luminosities, weighted by the square of polarization, for a succession of experiments first at SLAC and subsequently at JLab.

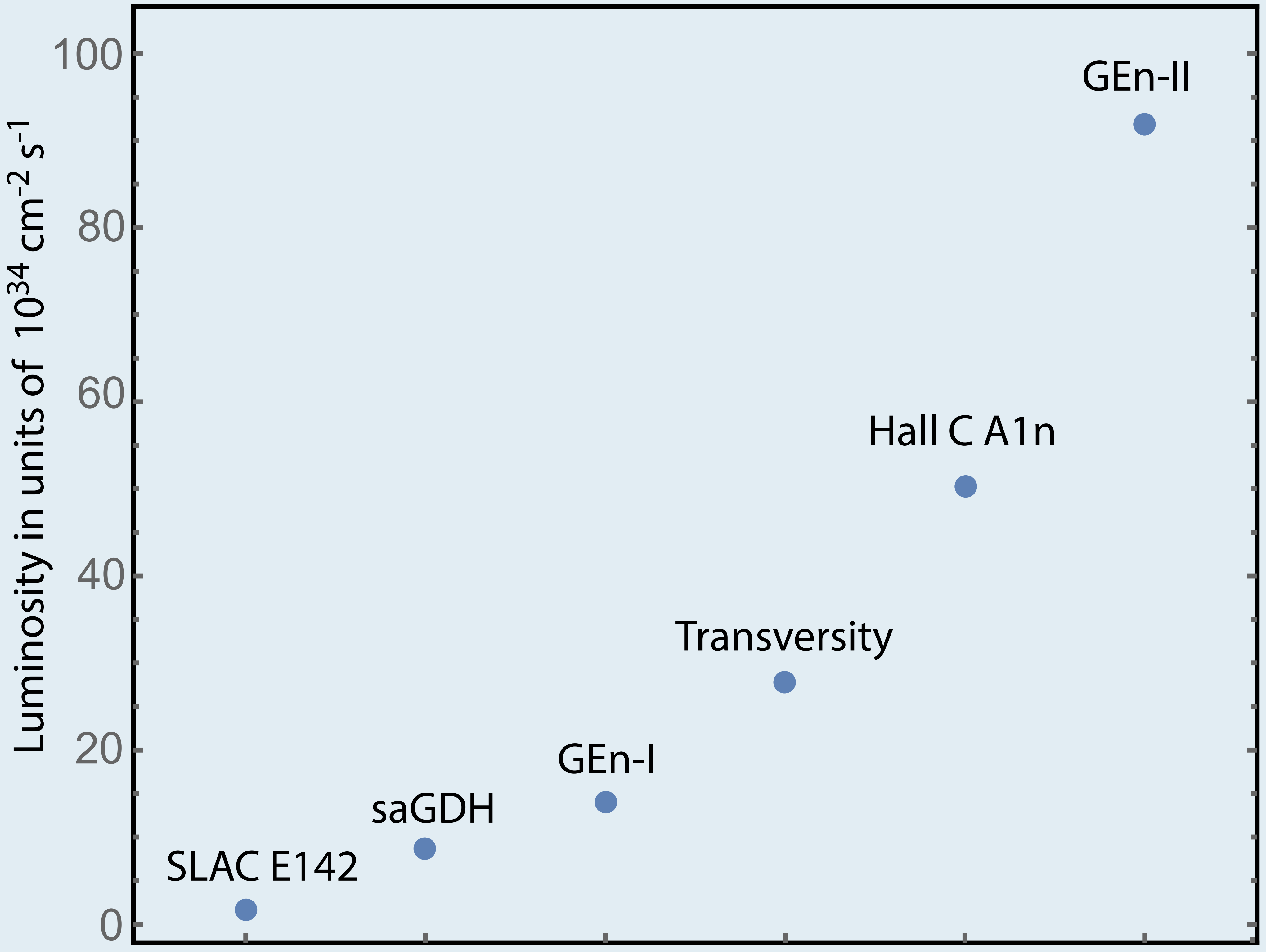
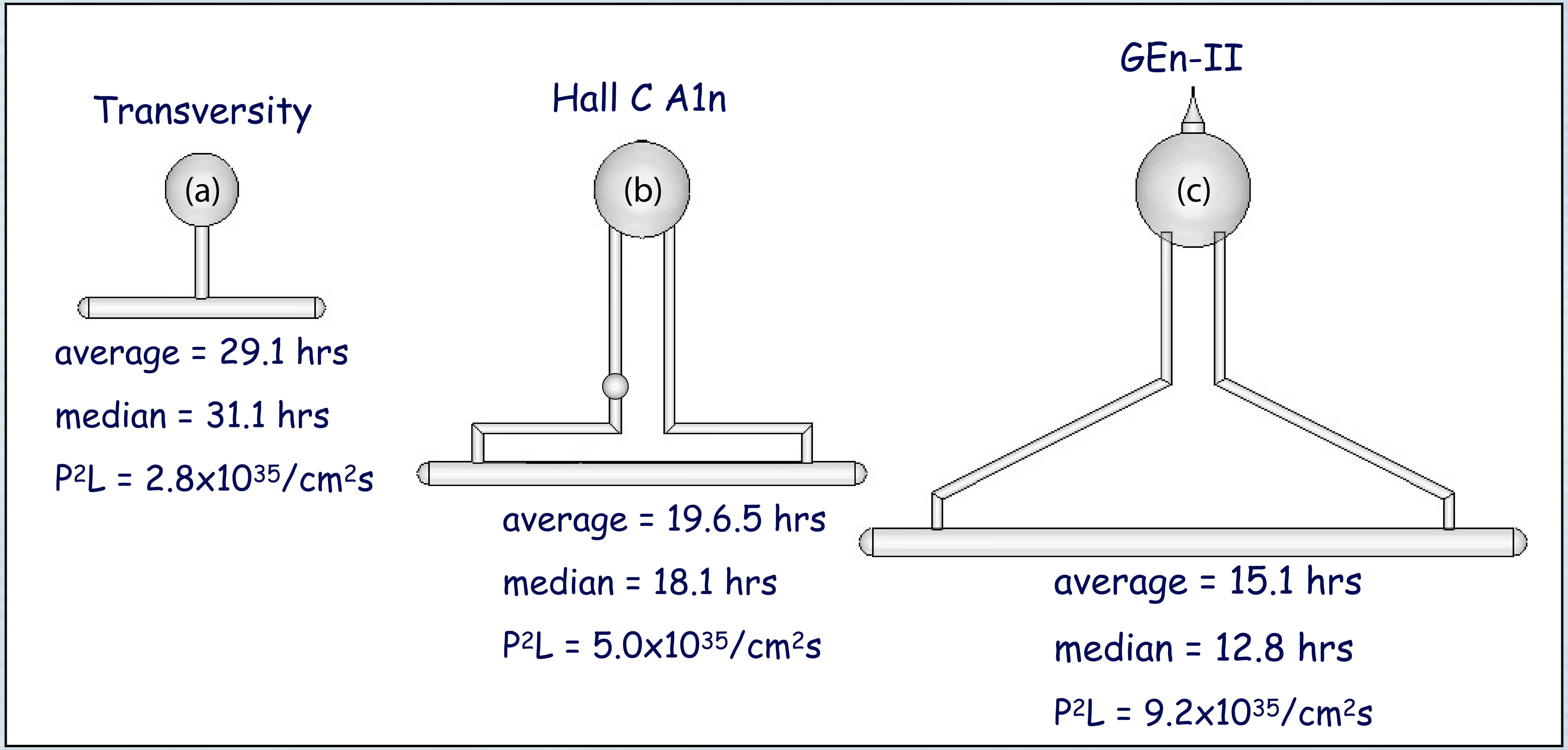


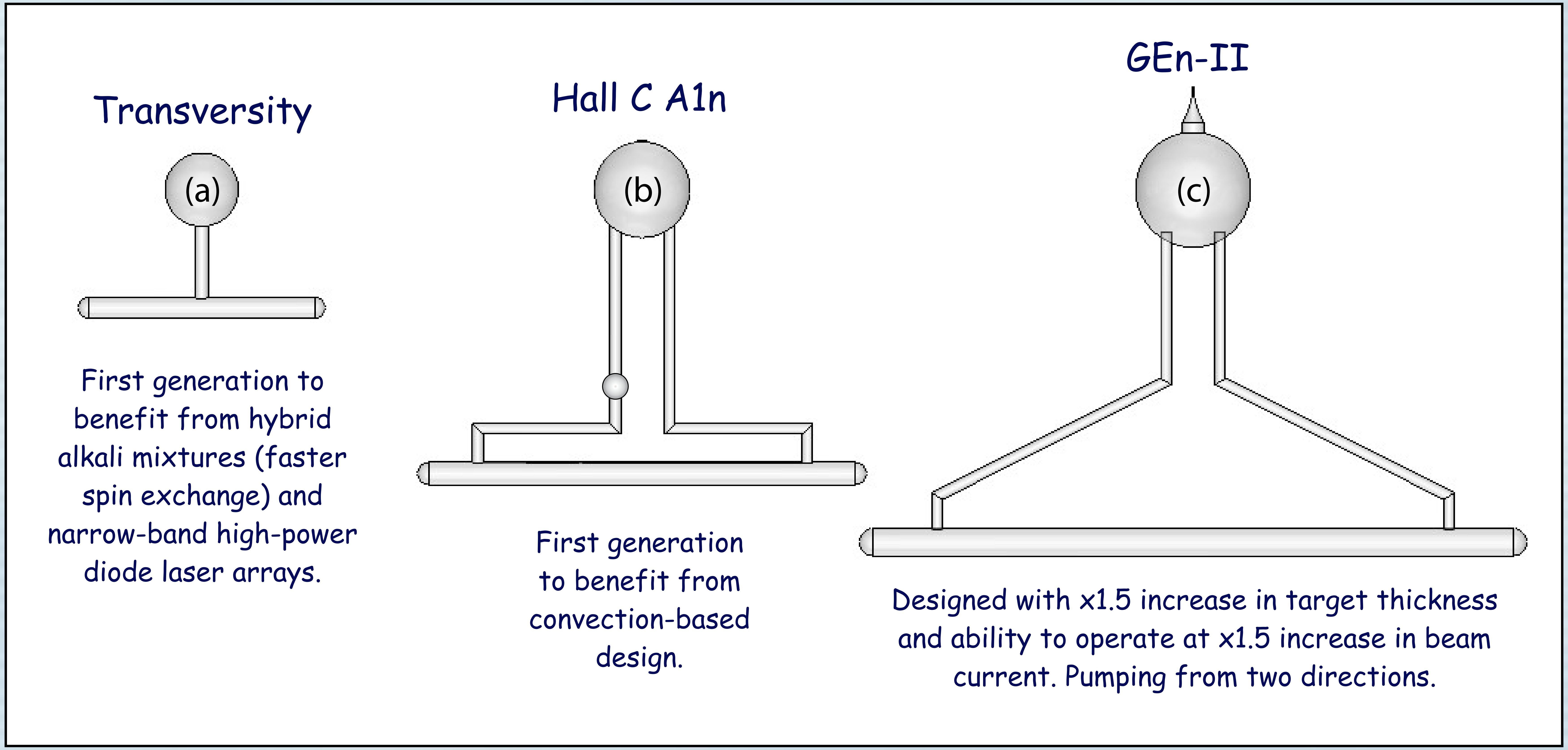
Figure 3. Luminosity, weighted by the square of polarization, is shown for the polarized ^3He targets used in various experiments dating back to SLAC E142 (published in 1991).

The bad news - each improvement in figure-of-merit has proven quite challenging



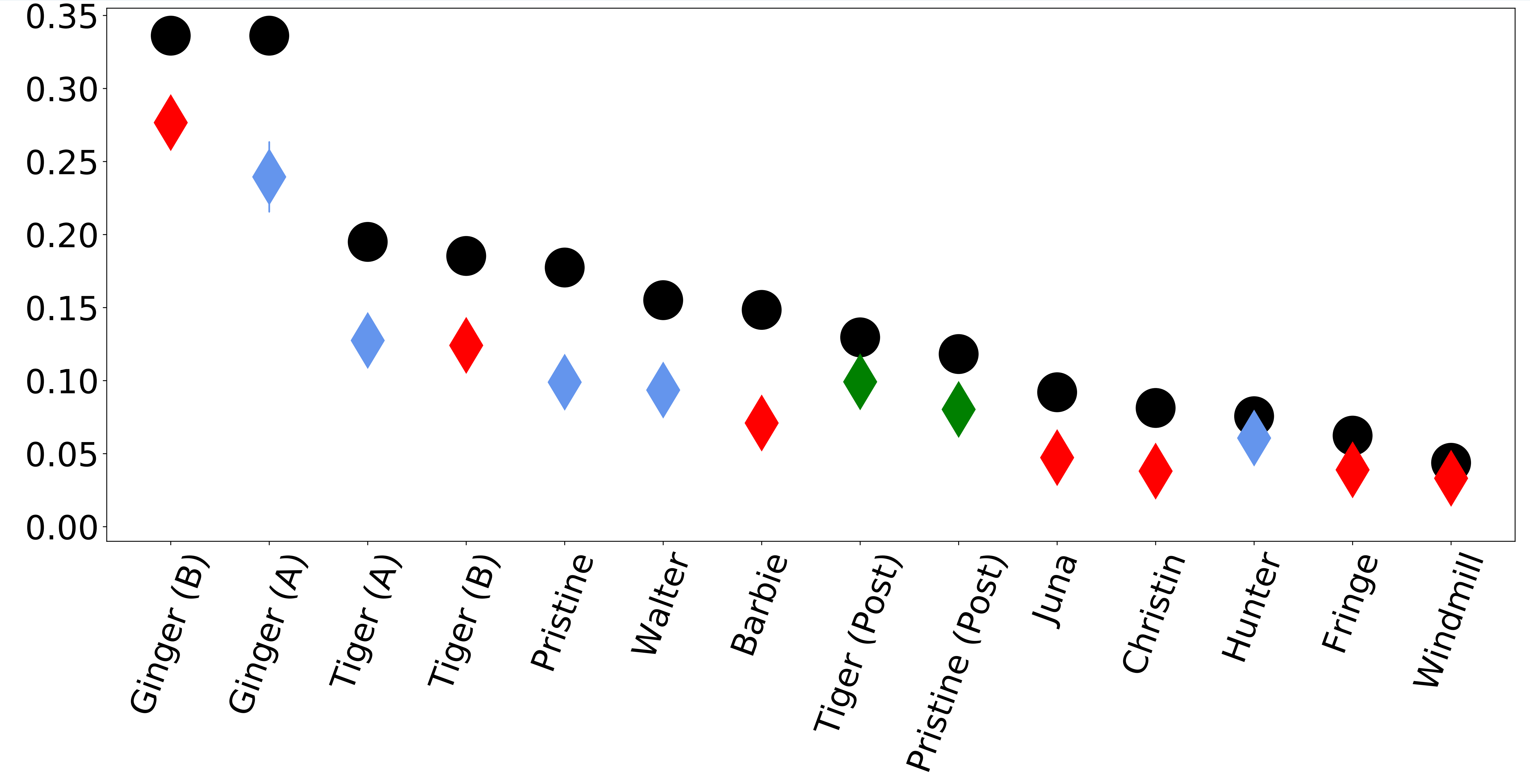
- Shown above are the geometries of the three most recent generations of polarized ^{3}He targets
- Also shown are the average and median lifetimes of the cells produced for the corresponding experiments.
- The average figure-of-merit achieved for each experiment is also shown.

Innovations incorporated into each generation



- Compared to Transversity, the targets for A1n and GEn-II were larger and more complicated.
- Larger size means more stress, which opens up "micro-fissures" on the interior surface of the glass.
- The micro-fissures increase surface area, and importantly, expose the 3He to contaminants in the bulk that are not as prevalent in a smooth interior surface.

Hysteresis in the GEn-II target cells



- Shown above with the black points is the relaxation rate, in hrs^{-1}, of each target cell, either during its first test after production, or after being degaussed.
- Shown with diamonds are the relaxation rates measured after the cell was rotated by 180 degrees.
- In <u>every</u> case the relaxation rate after the 180 degree rotation was lower.

Hysteresis in the GEn-II target cells

- Prior to GEn-II, we had not particularly noticed hysteresis effects in our cells although such effects have been reported by other groups.
- It is likely that the larger more complex cells built for GEn-II were more susceptible to such effects because stress around the glass joints in cells developed microfissures.
- We note that spherical test cells with < 1atm pressure consistently had lifetimes of 100 hours or more (significantly larger than our high pressure target cells), and experienced much smaller absolute differences depending on orientation, although the relative changes were not insignificant.

Target performance during GEN-II

Despite the challenges, with a luminosity more than twice that achieved during A1n, the target had record-breaking performance.

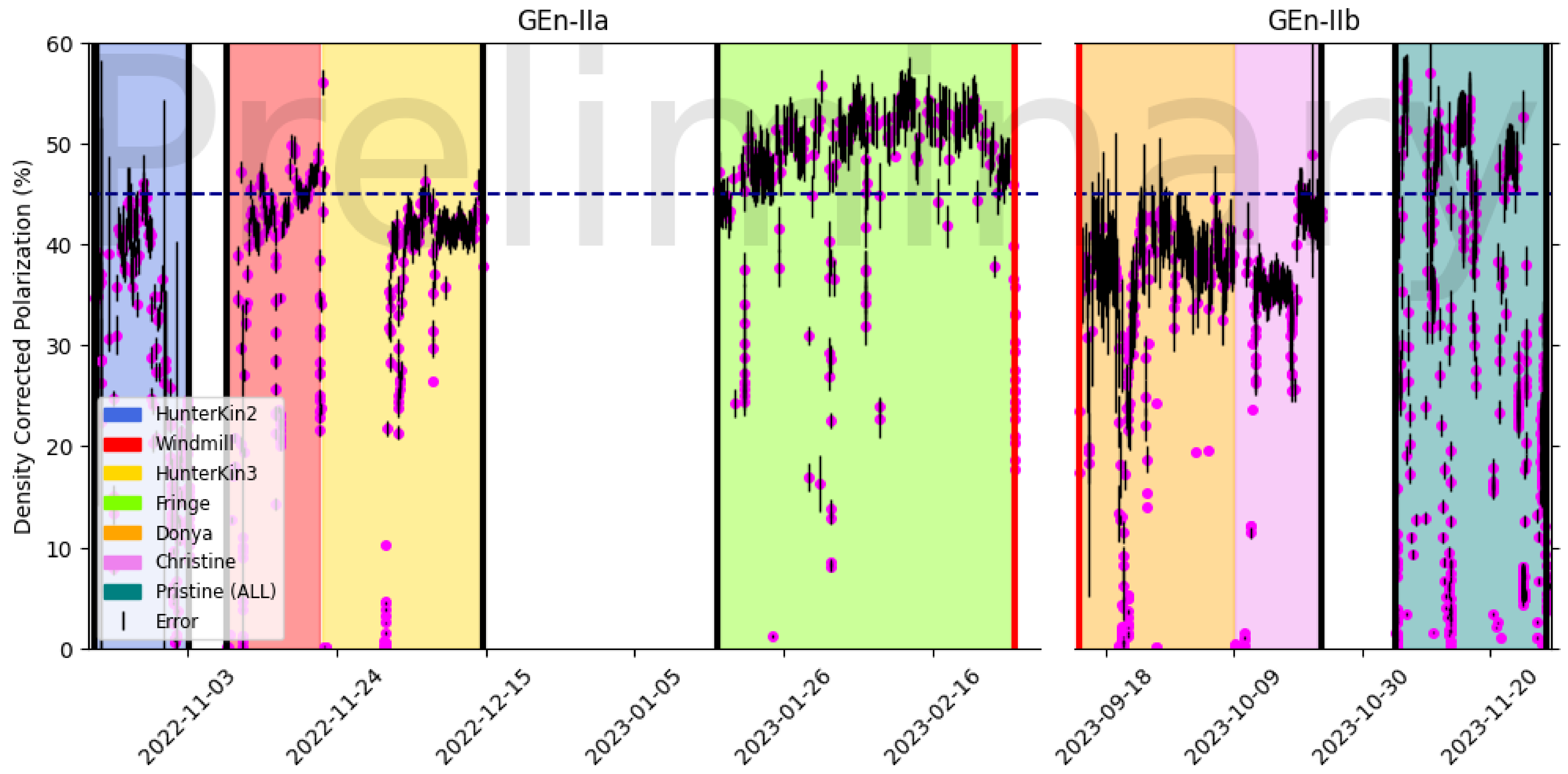


Figure 4. Shown above are the results of every NMR measurement on the polarized ^{3}He target during both the GEN-II and A_LL runs. The dashed line indicates a polarization level of 45%, which we treated as our nominal goal. Note that during the period prior to Nov. 11, 2022, we were collecting data at our lowest kinematic setting where we had very high event rates and could thus use the time to optimize the target. Note finally that during the period starting October 30, 2023 through the end of the run we had little to no beam and thus conducted numerous target-related tests when not taking data. Thus, the fluctuations in polarization during that time period were *not* during production running. The steady state polarization of that final target was well over 50%.

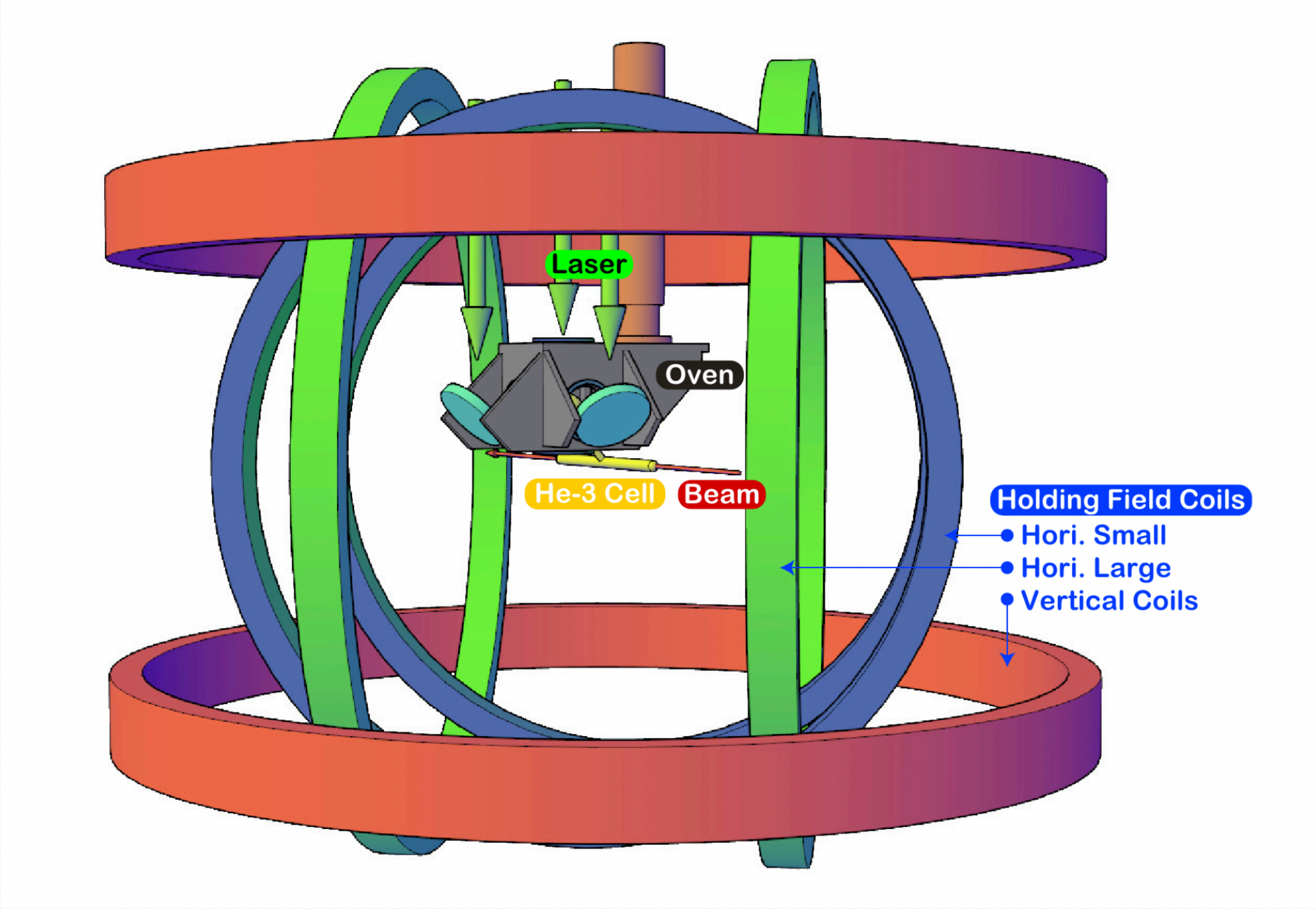
Lessons learned pertaining to hysteresis effects

- Hysteresis effects are clearly correlated with pressure.
- Hysteresis effects are also increased with size and complexity.
- Several changes may prove useful in minimizing hysteresis.
  - We should identify glass the is largely free of ferromagnetic particles and test whether or not the use of such glass would be to our benefit.
  - If possible, we should consider simpler geometries.
  - Given the timescales involved, we should start on the this development project right aways

To be ready for SBS SIDIS within several years, we need to begin developing and testing the next generation of target cell soon!!!

Polarized ^{3}He target for Transversity (E06-010)

Shown at right are some of the components that were used for the Transversity experiment (E06-010) that ran from November 2008 - February 2009.



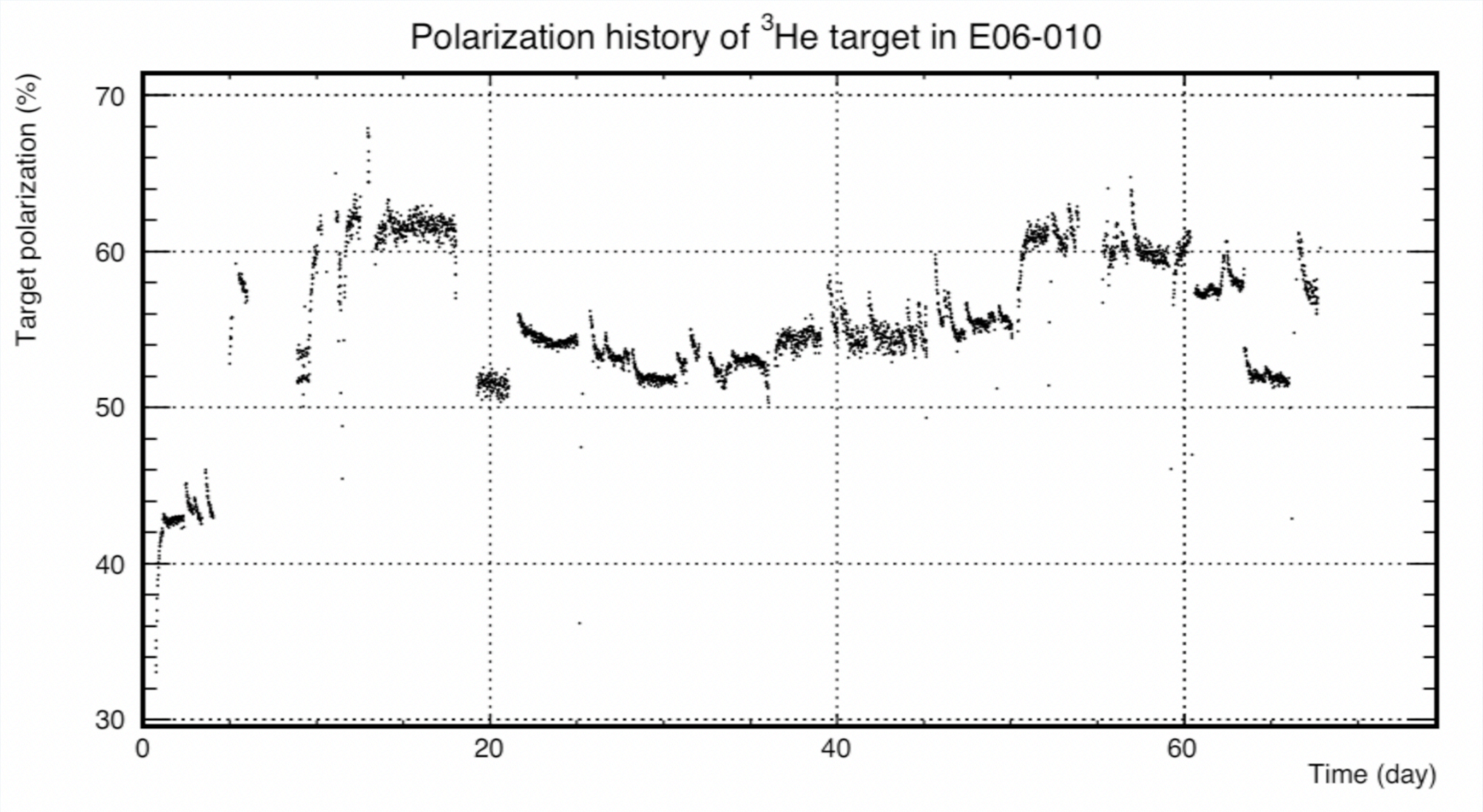
Requirements include:

- The ability to run with vertical polarization (notice direction of lasers above).
- The ability to reverse the direction of polarization quickly.

Performance of the polarized ^{3}He target during Transversity

- Average polarization of gas in the beam of 55.4 +/- 2.8%
- Gas was distributed using diffusion resulting in significant polarization gradient of ~5% between the pumping and target chambers.
- Without beam, polarizations as high as 70% were observed.
- Current was typically 12 uA with a 40 cm long target chamber.
- Vertical polarization was reversed every 20 minutes using AFP with reasonably low losses.
- Gas was distributed using diffusion resulting in significant polarization gradient between the pumping and target chambers.

Performance of the polarized ^{3}He target during Transversity

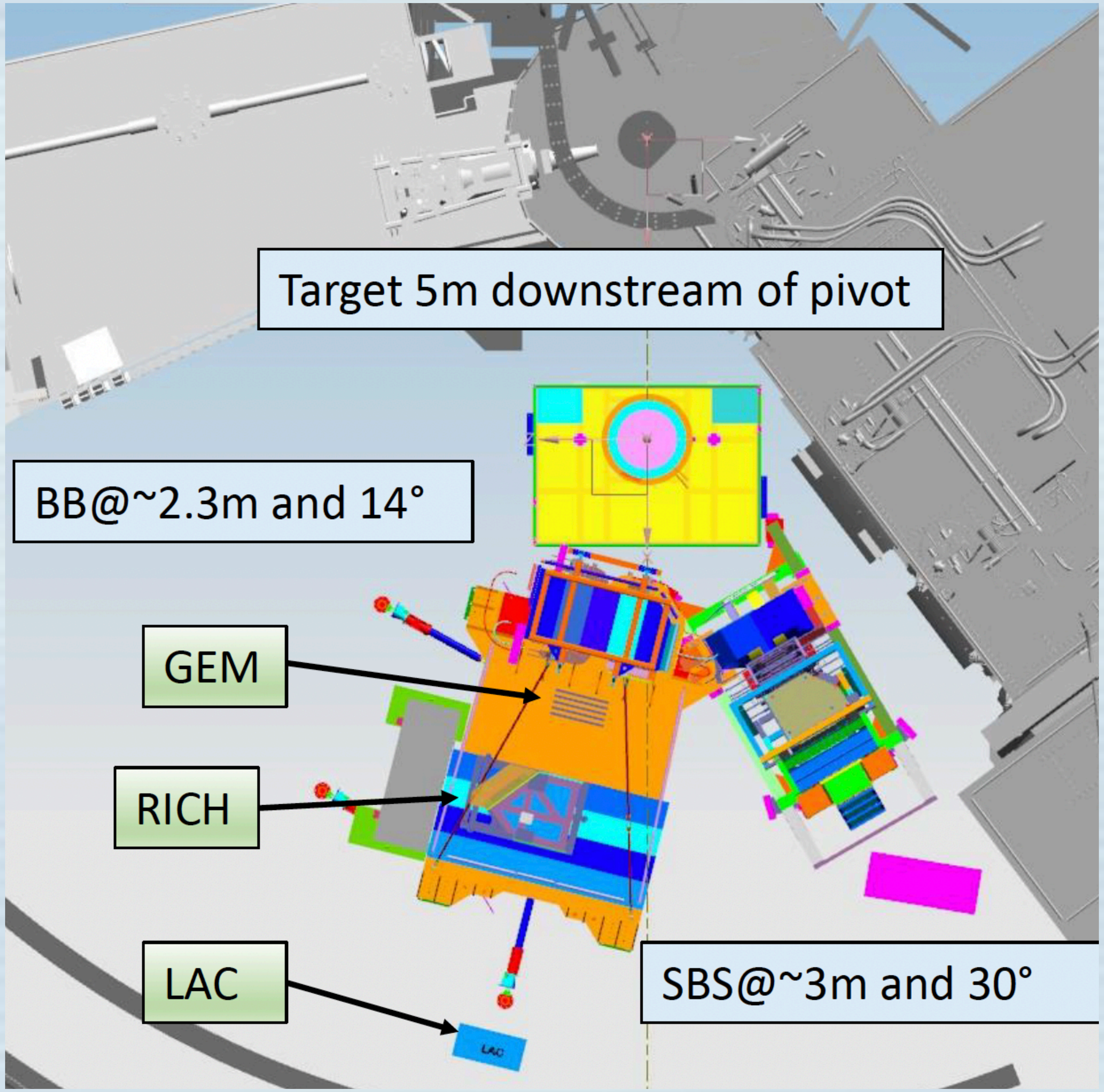


Important differences for SBS SIDIS

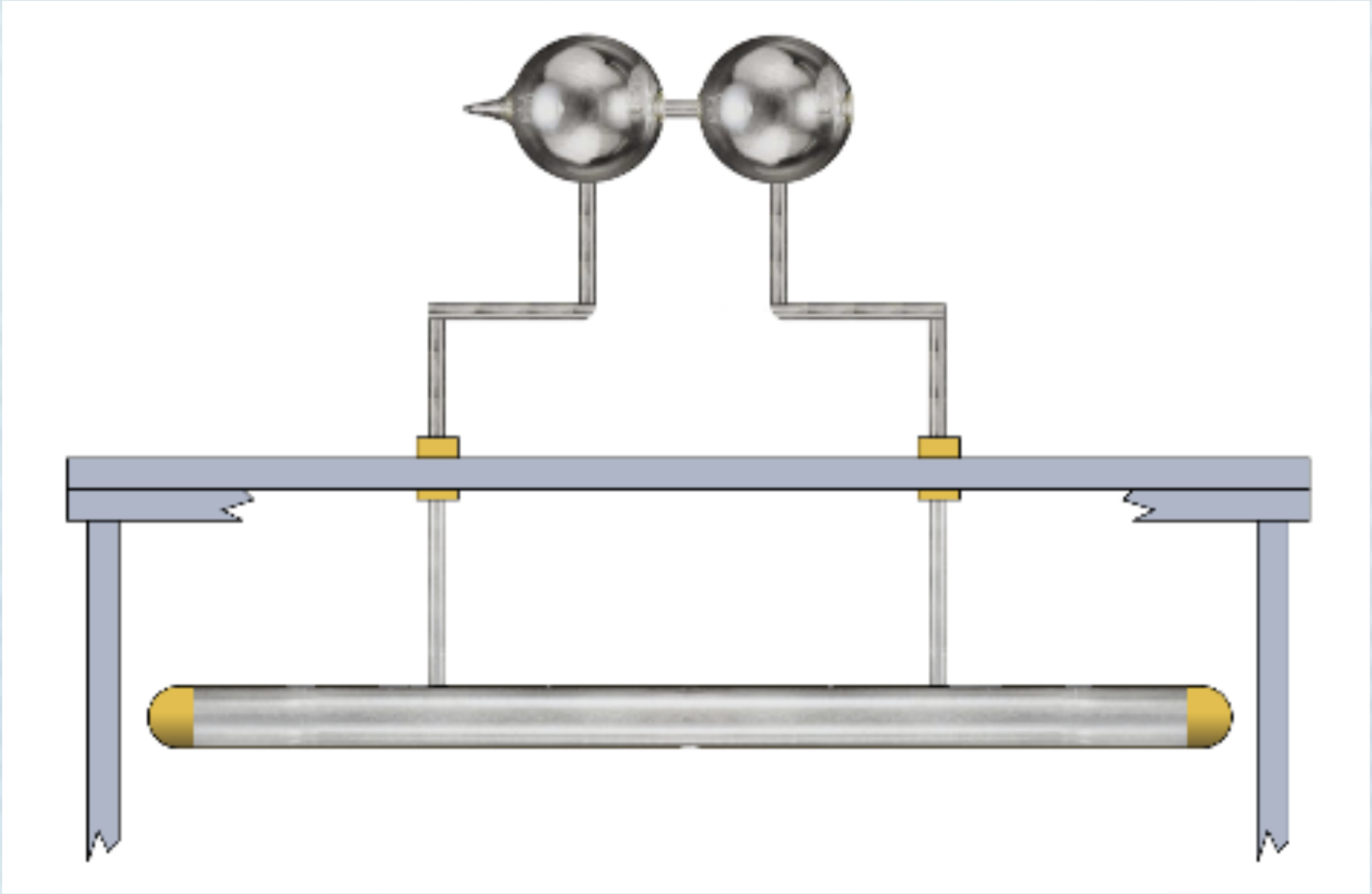
- SBS SIDIS will require much higher beam current while maintaining high polarization.
- A significantly larger quantity of 3He must be polarized to run at high luminosity.
- As was the case with Transversity, we will need to accommodate vertical polarization, which was NOT the case during GEn-II.
- We will need to minimize hysteresis effects which, without mitigating measures, will be an issue with the larger targets.
- Significant conceptual and engineering work needs to occur to realize the target.

Layout of SBS SIDIS in Hall C

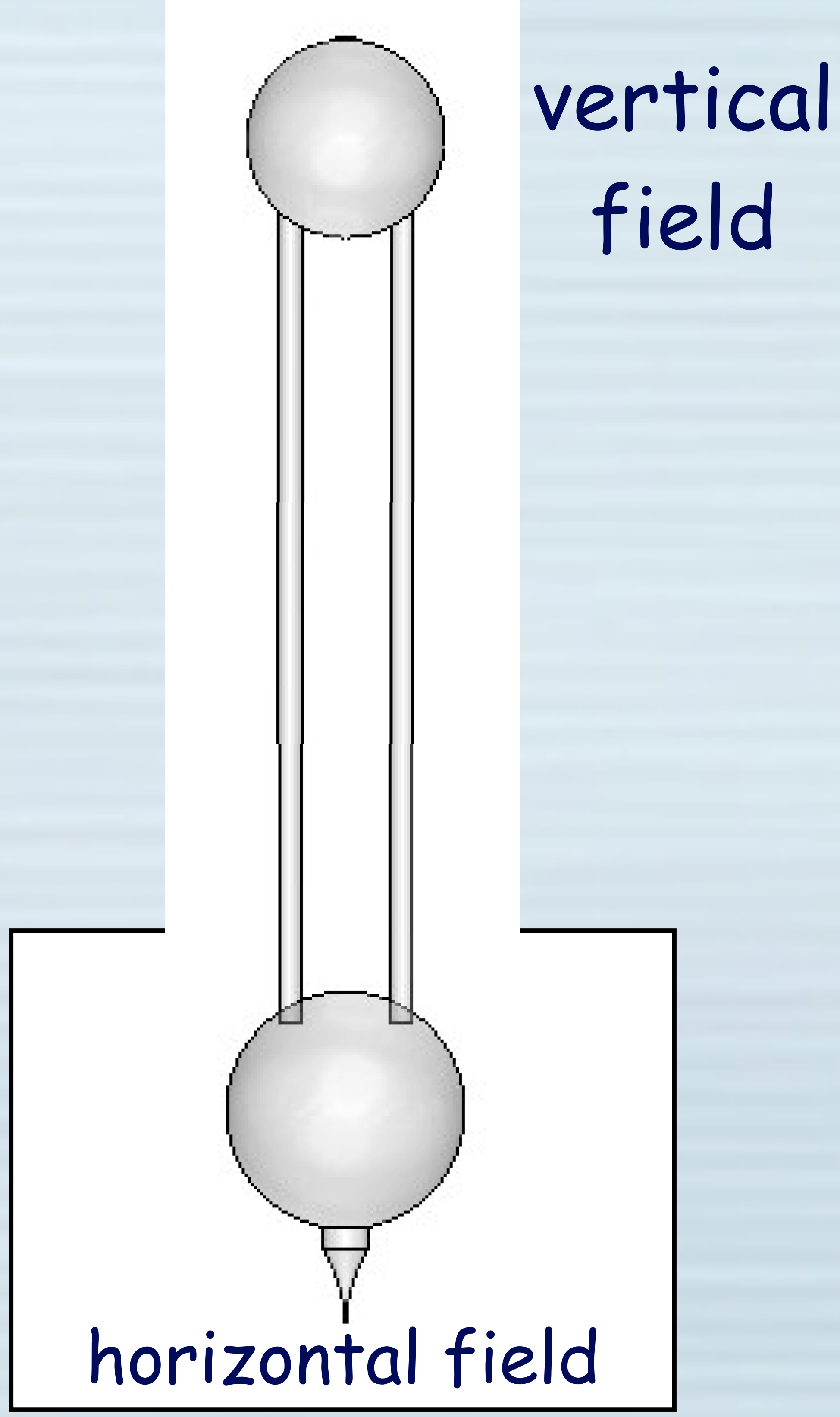
- The available footprint for the polarized 3He target is larger in Hall C than was the case for the GEn-II target in Hall A.
- This is important because of several issues:
  - Unlike the original Transversity experiment, we will need magnetic shielding.
  - In contrast with GEn-II, we will have a vertical set of Helmholtz coils, which take up significant space.
  - One lesson learned during GEn-II was that additional space inside the magnetic shielding would be advantageous.



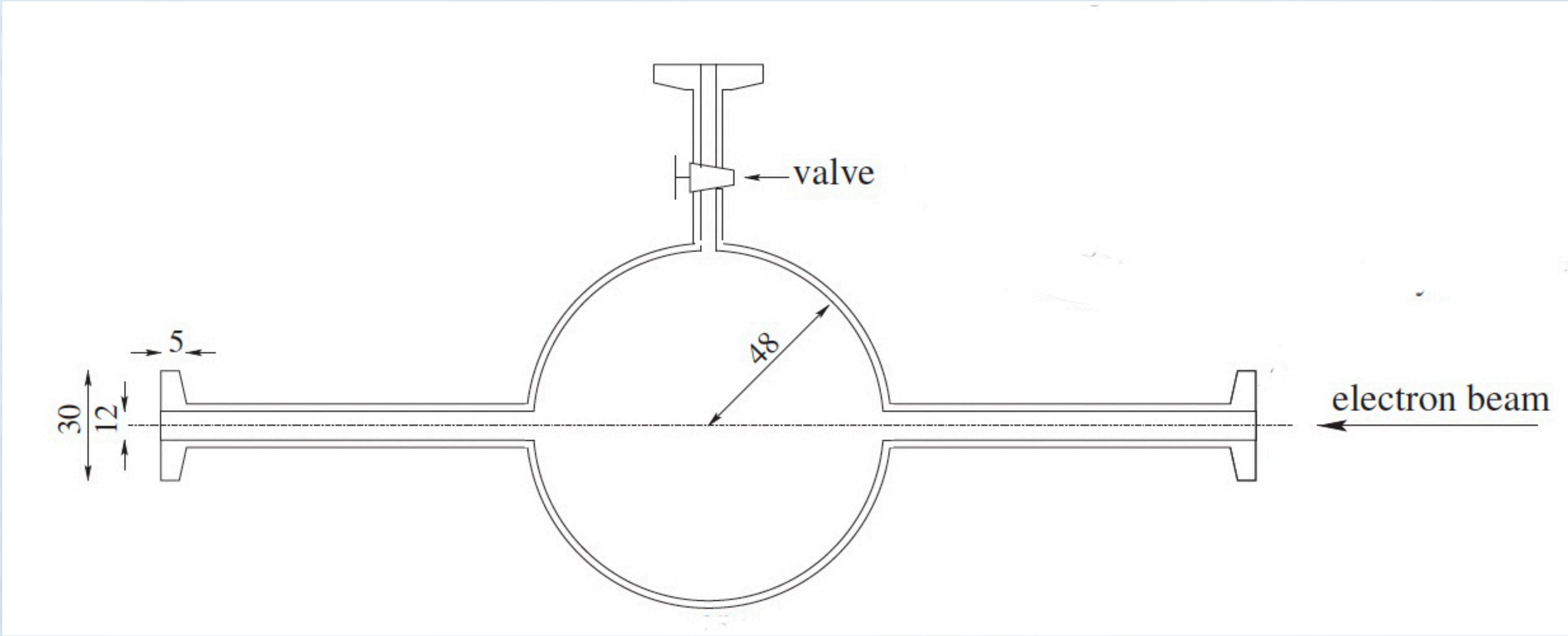
Three concepts for vertical optical pumping



Pump vertically with two chambers to avoid excess laser intensity on glass



Polarize in separate space with fixed magnetic field



Adopt Mainz approach where polarized cells are brought in and allowed to decay in the beam

Summary

- The SBS SIDIS experiment can build off of the highly successful Transversity experiment, both in terms of hardware and concepts.
- The conceptual design needs to proceed in parallel with some of the engineering to establish the most efficient way forward.
- Target cell development needs to proceed to insure performance exceeds that achieved during GEn-II. Luckily, that path is fairly well defined.
- Finally - as we get into the detailed phase of design, we need to find and read the lessons-learned document from GEn-II !!!