Solid Targets for MOLLER - Initial Thoughts

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June 22, 2020 (Rev. 1)

1 Overview

Considerations for initial specifications for the solid targets to be used in MOLLER are presented. After discussion, this document can be revised to become the Solid Target requirements Tech Note required by a previous review.

2 Target System Hardware Constraints

The MOLLER cryotarget will have a single axis vertical motion system, (unlike some other JLab targets, such as the Qweak target system, which also had horizontal motion).

We will be able to have a total of between 40 and 45 cm of vertical travel, which can accomodate up to 6 solid targets, 4 of which could accommodate high beam power. The solid targets could be located at different z locations, *eg.* some could be at the z location of the upstream (entrance) window of the lH_2 target and some at the downstream (exit) window. In addition, an "optical table" can accomodate a set of (uncooled) thin targets for use in spectrometer optics/kinematics studies; since there is no horizontal motion, the targets in place would again be selected by vertical motion.

A sketch of the general solid target configuration is in Fig. 1.

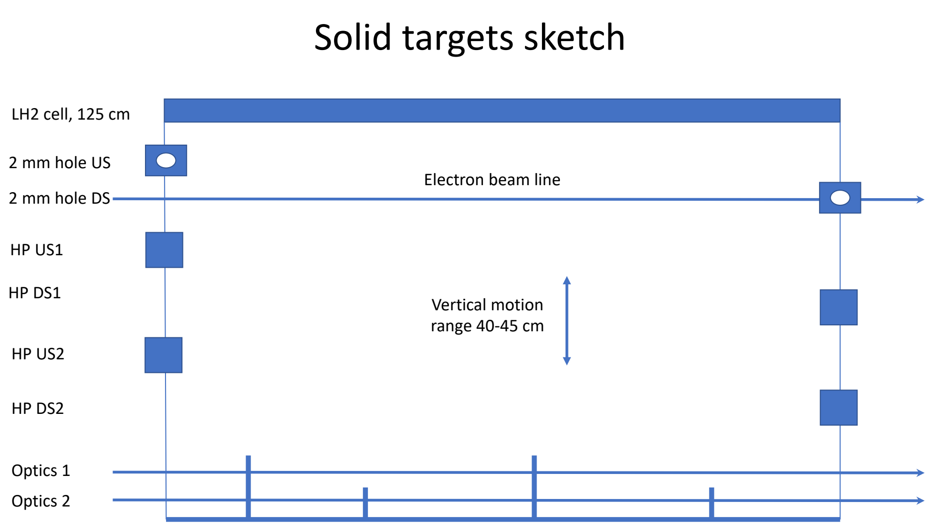

Figure 1: Sketch of MOLLER target layout (courtesy of Silviu Covrig Dusa).

3 Alignment Targets

We will need "hole" targets for the purpose of aligning the beam on the target system at low beam current. These would be thin carbon targets with 2 mm diameter circular holes in each one. As is standard practice in Hall A, one can then send rastered beam at low current on the targets, and in event-mode data taking, "image" the rastered beam on the holes by triggering on scattered electrons and analyzing the data binned by the rastered beam's position.

Having the hole targets rigidly attached to the mounting structure for the hydrogen cell is important, so that any "cold motion" undergone by the cyrogenic target would then be accounted for by aligning the beam to the hole targets - aligning to the holes should be equivalent to aligning to the lH_2 cell, as long as we know the vertical distance between the cell and the hole targets.

Given the length of the MOLLER lH_2 target, and the need to align both the beam position and angle on the target, we probably want hole targets at both +62.5 cm and -62.5 cm (entrance and exit window locations) where 0 cm is the center of the LH_2 target cell.

Jay had suggested that we consider using only a single vertical location for both of the hole targets, *i.e.* using up only 1 of the 6 target vertical positions. In that concept, both hole targets are in-beam simultaneously. A possible disadvantage is that the raster "image" would be smeared out somewhat if there is a significant "tilt" to the beam, making interpretation more difficult. However, imaging an individual hole to much better than 0.2 mm is difficult (PRex/CRex experience), and a 0.2 mm mis-alignment over 125 cm is 0.16 mrad, which seems rather large to me, so this option could be a good one.

For the purposes of beam alignment, the thickness of the hole targets, (since they will be used at low beam current $\approx 2\ \mu$A) is not important, so they could be chosen be selecting whatever is simplest mechanically (3 mm?).

However, if we make them large enough in the vertical direction, then simply by having two vertical "stop" locations for each hole target, one could choose to enable the beam to miss the holes, and use them as optics targets as well. For this use, we would not want to have both upstream and downstream targets in use at the same time, so this would argue against the idea of having the two hole targets occupy just one vertical slot. This then would provide us with two "backup" optics targets.

4 Kinematics/Spectrometer Optics

For this purpose all measurements will be done with very low beam current ($<$ 100 nA, with some measurements as low as 100 pA), dictated by the rate capability of the Tracking system. Thus the targets do not need to be high-power.

The initial spectrometer optics plan (devised primarily by S. Riordan and R. Silwal) required measurements of e-nucleus elastic scattering from thin foil targets (these data also need to be taken at several lower beam energies in order to map out the scattered momentum/θ phase space of the Moller electrons).

The reason for these targets to be thin is simply to ensure a defined z-location for scattering events; combined with the sieve-hole collimator, this then allows us to produce events with a known scattering angle θ (recall - there are no tracking elements upstream of the spectrometer magnets). They do not really need to be thin foils, as the angles would be determined sufficiently even if they are several mm thick. It would be an desirable to have them be a $\approx$ factor of two different in thickness than the alignment hole targets - one could then compare results from them to the hole targets (when hole targets are used as optics targets) to benchmark multiple-scattering effects on our optics studies.

Initial studies were based on using a single ^{12}C foil target located at $z = 0$ (location of hydrogen target center). From those studies, there did not seem to be a requirement to have foil targets at multiple z locations.

Of course, targets at different z locations would allow us to get two different θs for the same sieve-hole.

Locating these targets 1.25 m apart, however, would only provide a difference in scattering angle between the two targets of about 10%. Still, this could be an additional useful diagnostic.

With only the ability to change the foil target height, at at least one height one has to have multiple foil targets in the beam. A simple choice would be to have one height where only the upstream foil is in the beam, and at the second height, both the upstream and downstream foils are in the beam - the distribution from the downstream foil can then be extracted by a subtraction of the two data sets.

It might be useful also to consider a higher-Z material. This is because the optics measurements are using the e-nucleus scattering, the cross section for which scales like Z^2, while the Moller cross section scales like Z, so a higher-Z target like W would have better signal/background for the optics measurements.

5 High Power Targets

Aside from kinematics/spectrometer optics studies, solid targets can be used for:

1. *An alternative source of Moller-scattered electrons*: in case of issues with the hydrogen target, and for the ability to commission aspects the detectors and spectrometer without the need for the hydrogen target (of course, some cryogenic cooling is still needed for high current operation). For this purpose, a thick ^{12}C target appears the logical choice (ability to withstand high beam currents).

   If we choose the same areal density for the C target as for lH_2 target, i.e. 8.9 g/cm^2, this would imply a 4 cm thick target (20.7% of X_0, compared to the 14.6% of X_0 lH_2 target). Silviu could presumably tell us about the challenges of cooling such a very thick carbon target.

2. *Benchmarking of the GEANT 4 simulation*: radiative effects in the target, the spectrometer optics, the collimator location and apertures, *etc.*. The rationale is that our extraction of the Moller asymmetry from the ep and inelastic backgrounds relies on our understanding of the radial and azimuthal distibution of these events at the main detector “focal plane”. These distributions, as measured with the Tracking system, should match our simulations. Given the 14.6% radiation length of our lH_2 target, radiative effects in the target have significant effects on these distributions. If there is any discrepancy between our measured focal plane distributions and the simulations, we would want additional “handles” to debug the discrepancy - is it due to instrumental artifacts in the Tracking system hardware or software, imperfect handling of radiative effects in the simulation, or incomplete or imperfect geometry in the simulation? This benchmarking can be done using several nuclear targets, with different thicknesses.

3. *Studying the Al window dilution.* In the case of Qweak, the contribution to the measured asymmetry due to the Aluminum target windows was substantial, and so a measurement of the e-nucleus asymmetry was essential. In the case of MOLLER the aluminum window background is expected only to be about a 1.5% correction to the Moller asymmetry. The dominant contribution is e-Al elastic scattering. The asymmetry from this will be measured to sufficient precision ($\approx 30\%$) during the main measurement using our multi-ring simultaneous fit procedure (see MOLLER backgrounds report, Appendix L of the CDR). It will also be even better known than this ($\approx 10\%$) from the Qweak measurement of the ^{27}Al asymmetry (Kurtis Bartlett’s PhD thesis, to be published)

   Thus, we do not require the ability to make a measurement of the elastic asymmetry from ^{27}Al (although having at least one high-power Al target available would enable us to make such a measurement, should we choose to for some reason).

   However, will likely be useful to verify that the rate distribution (in both R and ϕ) of the Al events are as expected, so that we can be confident in the “dilutions” from the Al in the various detectors rings, as this is essential for our fit procedure.

Of course, due to the energy-loss and radiative losses in the liquid hydrogen, it would not be possible to devise an aluminum target which has the same z-position and kinematics as the cryotarget windows, so the verification of the scattering distributions from the Al windows will require a "bootstrap" process: compare simulated and measured scattering distributions from different Al targets; when simulation and measurement agrees, then we have confidence that the simulated Al window distributions should also agree with reality.

Thus we would want thick ^{27}Al targets of different thicknesses at both upstream and downstream locations.

I propose a modest thickness (few mm) Al target at the upstream location, and two different thickness Al targets at the downstream location: one also of a few mm in thickness, and the second one being thicker, perhaps as much as 10% of X_0 (9 mm), to mock the radiative effects of the entire target.

To ward off any paranoid issues (see the $np \to d\gamma$ experience), we should use the identical Al alloy as we use for the windows on the lH_2 target, of course.

6 Summary

My initial solid target inventory would be:

- ^{12}C Alignment hole targets at upstream and downstream window locations. 2 mm diameter holes. Perhaps 3 mm thick? Uses up two height locations (as in Fig. 1). Can function as "spare" optics targets.
- Optics targets (uncooled optics table): One height with single foil at upstream location, at second height foils at both upstream and downstream locations. Material ^{12}C (or tungsten?). Different thickness than hole targets.
- High Power targets:
  1. Thick (4 cm?) ^{12}C target for posible asymmetry measurements.
  2. ^{27}Al target upstream location, 2% of X_0 (1.8 mm)
  3. ^{27}Al target downstream location, 2% of X_0 (1.8 mm)
  4. ^{27}Al target downstream location, 10% of X_0 (9.0 mm)

Questions: what needs to be specified before CD-1 review? What studies are required after CD-1 review?