# Proton Spectrometer Monte-Carlo simulation program

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In the past year we have completed code development for the Proton Spectrometer Monte-Carlo simulations. The Monte-Carlo (MC) will generate the acceptance functions required in the process of building the cross-sections for the measured (d,$^2$He) data.

A simplified version of the Monte-Carlo was written during design and prototype studies [1]. It included an event generator based on Migdal-Watson final state interaction in $^2$He's, magnet transport routine using matrix elements generated by RAYTRACE, primitive event tracking in the drift chambers and scintillator hodoscopes. Multiple scattering was effectively added to the resolution calculated based on optics simulation. In this form, the Monte-Carlo was used to optimize the proton spectrometer for intermediate energy (120-160MeV) diprotons and to estimate the flat regions of spectrometer acceptance. Thus the acceptance limits were chosen to be 105mrad by 35mrad.

To produce the acceptance functions, the Monte-Carlo program, PSPMC, was upgraded to completely simulate the spectrometer. First of all, the energy loss and multiple scattering off the internal structure elements, like vacuum and drift chamber window foils, window support bars, the chamber gas, the wires in the DCs, and the scintillators, was implemented. The angular deflection and energy loss were calculated with Los Alamos ELOSS package. This allowed to account for particles stopped inside the detectors, majority of which were lost in 4mm wide steel window support bars, and to record the energy deposited in the scintillators. This required keeping track of exact geometric coordinates and momentum of each particle.

Next, the time-of-flight tracking was added to allow measurements of the trigger time and the DC times that included the drift time in the chamber gas. This permitted to generate the events fully equivalent to the events taken during the experiment. The MC data were analyzed with the data analysis code written for reconstruction of the real data. The usual routine of tuning timing parameters was followed and produced expected resolution.

After this the hardware uncertainties were superimposed on good triggers to emulate the limited resolution of the TDC's and specifics of the drift chamber design that permits some protons to be trapped in the corner of the drift chamber cells. During this stage some final details, like time delay in cables and missing wires, were put in. Again, the predicted broadening of spectra occurred, but it also improved the acceptance slightly, probably because the analysis code was created using real, not ideal, tracks.

Then we have added the reaction kinematics based on RELKIN tables. So that PSPMC can assign the energy corresponding to the angle of the $^2$He pair that is generated randomly in a given angular range. Typical theta range is 16 degrees around spectrometer angle; typical

vertical spread is 6 degrees about zero. This allows covering entire spectrometer acceptance region without losing excessive numbers of particles on the magnet slits.

Only now we could attempt to understand how good are the algorithms that the analyzer uses to reconstruct initial $^{2}$He energy and angles. Knowing precisely the angle and the beam energy, we found that some non-negligible matrix elements were missed in the analysis code, creating the problems similar to what we have met in the past and that we thought was part of experimental uncertainties. We have also found the limitations on the solution of the inverse problem. We cannot resolve initial phi and theta angles of the $^{2}$He pair simultaneously. However, this can be corrected empirically in the MC analysis by adjusting the spectrometer angle.

## References

1. A.C. Betker, C.A. Gagliardi, Nucl. Inst. Methods **A283** (1989) 79.