COOLER MAGNETIC SPECTROMETER

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The plan for the Cooler Spectrometer as described previously[1] has been modified to accommodate several new experimental modes and to improve the technical design.[2] The original design was presented to the Long Range Planning Committee in December 1989, and the new modifications were prepared for the LRPC meeting scheduled for June 6, 1991. A formal funding proposal is presently in preparation. The following summarizes modifications and further details of the equipment design developed during the past year.

Figure 1 shows the IUCF Cooler S-region with the proposed chicane magnets CM-1,2,3 and the quadrupole-dipole (QD) K300 spectrometer system at the maximum chicane angle of 12°. This angle can be changed between 0° and 12° by moving CM-2 on rails (see Fig. 2) perpendicular to the undeflected beam direction. The spectrometer will accept reaction products over a range of scattering angles and momenta. It can be rotated around pivot 1 (notice new location) and pivot 2 to vary the accepted angle and momentum range according to experimental requirements. Neutrons with a range of forward angles emerge between the yokes of CM-2 and CM-3, and can be measured with neutron detectors close by or by time-of-flight techniques over larger distances.

Reaction products can also be extracted along the circular opening of CM-2 with detector systems other than the K300. For this purpose the K300 can be decoupled and removed from the chicane, or an additional detector can be moved up on a separate platform using the mounting in Fig. 2. This figure shows the side view of CM-2 and the K300 system. The spectrometer is leveled on three precision leveling feet and can be lifted on four air pads for positioning or removal.

Several experiments and operational modes are included in the design of the present Cooler Spectrometer. A new and most intriguing mode, which will be described below in more detail, is a two-proton detection mode where the neutron-tagging proton and the (n,p) reaction proton are both detected simutaneously in the K300 spectrometer. This mode eliminates the need for a second (n,p) spectrometer. It requires the neutron-production and (n,p) targets to be at separate locations in front of and inside the gap of CM-2. The option to increase the gap of CM-2 from 4 to 6 inches is proposed to facilitate target installations inside the gap. The planned (d,^{2}He) experimental program is, from an ion-optical standpoint, a special case of this two-proton mode with both protons emerging from the same target. While the two measured protons are correlated and provide true coincidences in the (d,^{2}He) case, they originate from different processes in the case of tagged (n,p) experiments.

Tagged neutrons can also be used for (n,n) studies in the angular range from 20°to 60°. In this mode the neutron production by deuteron break-up will occur 30 cm downstream from the entrance of CM-2, and the (n,n) target will be 50 cm still further downstream, where the neutron beam is clear of the deuteron beam and the tagging proton. In this case, the tagging proton can be measured in a large momentum and solid angle detector array without using the spectrometer, because the overall resolution for these experiments

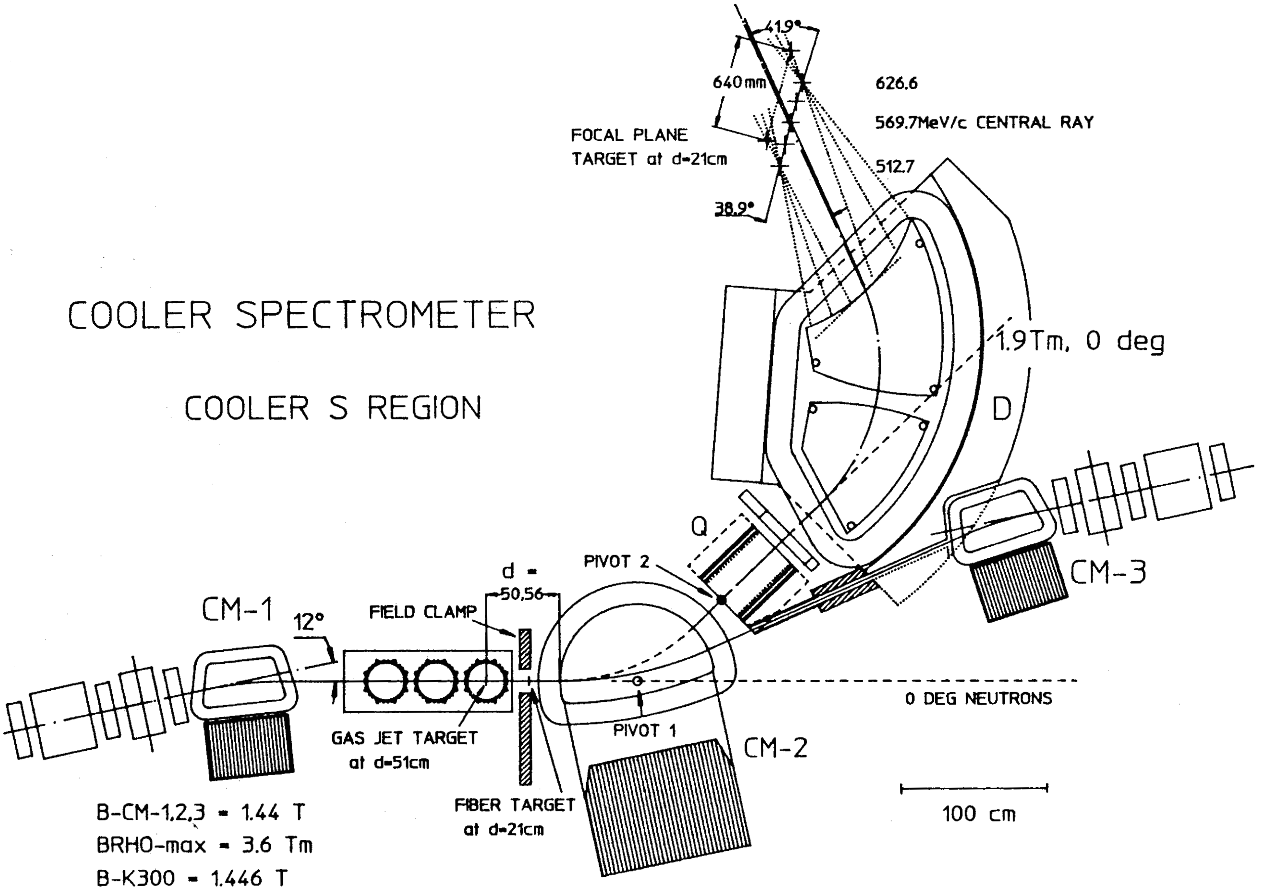

Figure 1. Cooler Spectrometer with chicane magnets CM-1,2,3 and spectrometer QD. Two target locations are indicated and the gas jet target box is inserted for space comparison.

is limited by the resolution of the scattered neutrons measured in a neutron detector consisting of a veto, active converter, two wire chambers and a ΔE,E plastic array. The (p,pn) reaction represents another class of experiments which can be studied by placing an internal target at a location 80 cm downstream from the entrance of CM-2. Protons and neutrons can be detected at angles between about 30° and 70° in the K300 and by time of flight techniques, respectively.

The requirements for a variety of experiments and targets initiated a study of the ion optics for different sample target locations. The original target location[2] which was chosen 21 cm upstream from the front of chicane magnet CM-2 may provide enough room for a solid skimmer, fiber or dust target, but a gas jet target will require more space. To demonstrate another case as an example, Fig. 1 shows the existing gas jet target box installed in front of CM-2. The center of the gas jet in this case is located at a distance 51 cm upstream of CM-2. (For reference, the maximum available length for a target and

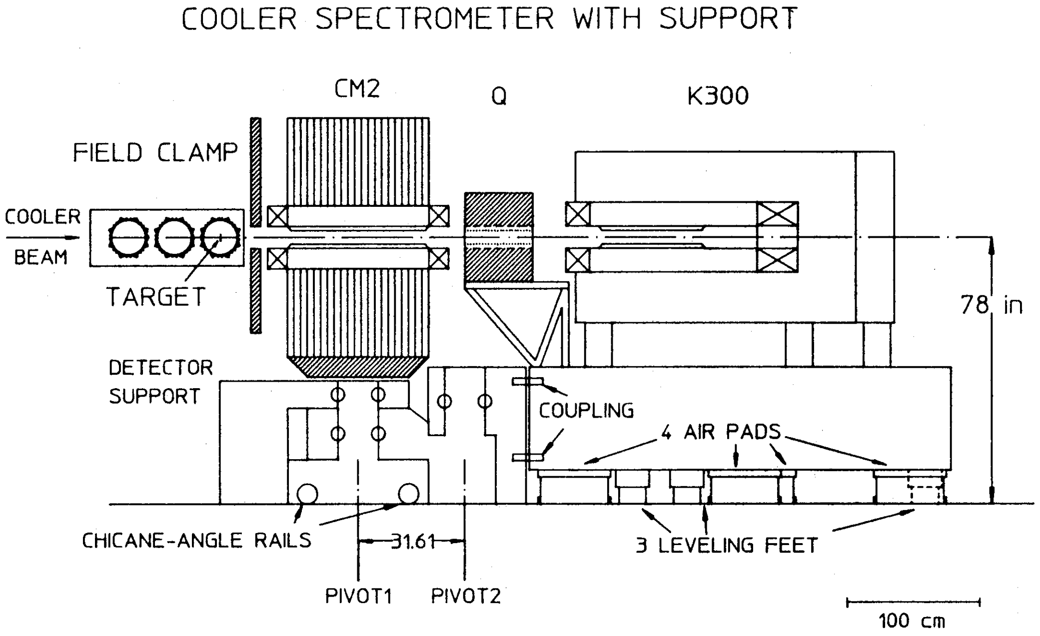

Figure 2. This side view shows schematically the mounting of chicane magnet CM-2 and the spectrometer. CM-2 can move on rails which define the chicane angle (0°– 12°). The spectrometer can rotate around pivot 1 and 2. Also shown are the lifting and leveling system of the spectrometer and the coupling to remove the spectrometer.

necessary pumping stations is about 150 cm between CM-1 and CM-2.) Special space-saving construction will be necessary for polarized gas cell targets. For these targets a field clamp is necessary to eliminate fringe field effects of CM-2, because a small and precise holding field for target spin is required.

Fig. 3 shows the maximum solid angle as function of available momentum range for the two target locations discussed in the previous paragraph. The reduction of solid angle with increasing momentum range comes from the fact that the dispersive magnet CM-2 precedes the first quadrupole of the spectrometer. RAYTRACE calculations were used to calculate these limits which come from the dipole spacers in the split K300 dipoles shown in Fig. 1.

The Cooler spectrometer configuration with a leading dispersive element (CM-2) is an unusual spectrometer operation requiring particular attention. The widely-varying target positions, in particular involving the measurement of two protons simultaneously from the same and different locations, set even more stringent requirements on the detection system to measure momentum and scattering angles at high count rates. Tests with existing IUCF wire chambers have shown that single event rates of up to 300 kHz per wire can be measured. An appropriate scintillator array is also needed to measure timing and ΔE,E information at these high count rates. The readout system has to allow for

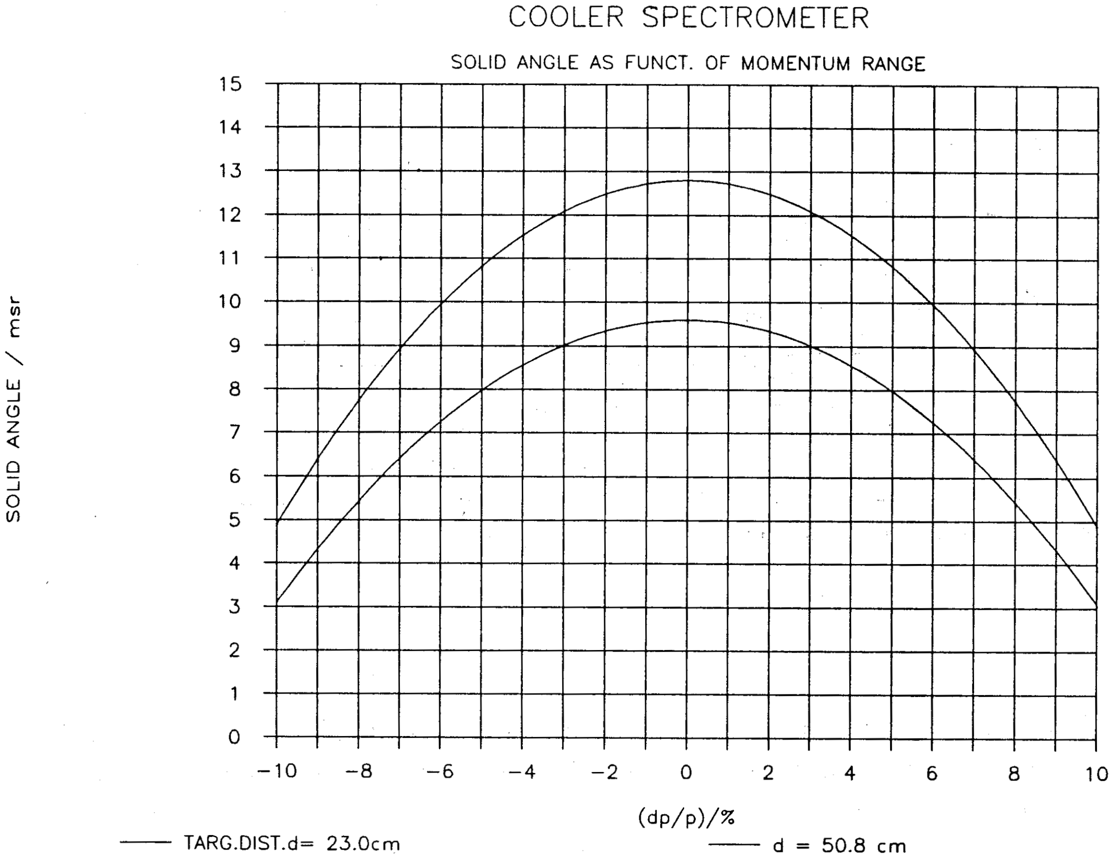

Figure 3. Solid angle as function of the available momentum range. This dependence is caused by the dispersive properties of CM-2.

measurement of two coincident protons, and the spatial and angular resolution must allow raytracing capability horizontally and vertically for both protons. Detailed RAYTRACE calculations for all different modes are being performed to define the needed detector design parameters. Properties of vertical rays for simultaneous protons from different locations have been shown to range between a focus close to the downstream end of the K300 dipole, and point to parallel focussing.

1. D.W. Miller and G.P.A.Berg, A.I.P. Conference Proceedings, No. 221, p. 303 (1990).
2. Report of the IUCF Cooler Magnetic Spectrometer Working Group, 2 December 1989, IUCF Internal Report #487, G.P.A. Berg, *et al.*