FOCAL PLANE POLARIMETER FOR THE GRAND RAIDEN

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In this year, two multi-wire proportional chambers (MWPC 1,2), whose effective areas are 760mm$^W\times$ 200mm^H, have been newly added to the focal plane polarimeter (FPP)[1] for the GRAND RAIDEN. They are placed just upstream from the carbon analyzer and employed to make the second-level trigger more effective, because the standard focal plane counters (two vertical drift chambers (VDC)) cannot be used for the fast second-level trigger signal. The development and construction of the FPP system has almost finished after the installation of these MWPC1,2. The whole FPP setup is shown in Fig. 1 for the case of the measurement of proton inelastic scattering at zero degrees. Since the horizontal angular range at the focal plane is rather large ($\theta_{\rm max} \sim 3^\circ$) for the full acceptance of the GRAND RAIDEN due to the ion optical features, the on-line rejection of small angle scattering, which has few contributions to the effective analyzing power, is insufficient in the case of only using the emitted angle obtained by the MWPC3 and MWPC4 after re-scattering from the carbon. On the other hand, vertical angle at the focal plane is so small ($\leq 1^\circ$) due to the large vertical magnification (~ 6) that we have neglected the vertical injection angle to the carbon analyzer in the stage of the second-level trigger and both the MWPC1 and MWPC2 are consist of only X-anode planes.

The second-level trigger logic is constructed by fully utilizing the standard CAMAC ECLine from the LeCroy modules i.e., the PCOSⅢ chamber readout modules, a Memory Lookup Unit (LRS2372), and a Universal Programmable Logic Modules (LRS2366). The last one is employed instead of Data Stacks (LRS2375), and Arithmetic Logical Units(LRS2378), because such a FPGA (Fast Programmable Gate Array) circuit is much flexible for applications. The scattering angle of u-direction and v-direction (u and v are the directions after the 45° rotation of horizontal(x) and vertical(y) ones) can be approximately calculated as follows:

$$\tan(\theta_u) \simeq \frac{u_4-u_3}{L_3}-\frac{u_2-u_1}{L_1}, \quad (1)$$

$$\simeq \frac{u_4-u_3}{L_3}+\frac{\sqrt{2}}{2}\frac{x_2-x_1}{L_1}-\frac{\sqrt{2}}{2}\frac{y_2-y_1}{L_1}, \quad (2)$$

$$\tan(\theta_v) \simeq \frac{v_4-v_3}{L_3}-\frac{v_2-v_1}{L_1}, \quad (3)$$

$$\simeq \frac{v_4-v_3}{L_3}-\frac{\sqrt{2}}{2}\frac{x_2-x_1}{L_1}+\frac{\sqrt{2}}{2}\frac{y_2-y_1}{L_1}. \quad (4)$$

Here, the L_1 and L_3 are distances between the MWPC1 and MWPC2, and between the MWPC3 and MWPC4, respectively. If we assume $(y_2-y_1)/L1 \ll \theta_{u(v)}$ and set the distances

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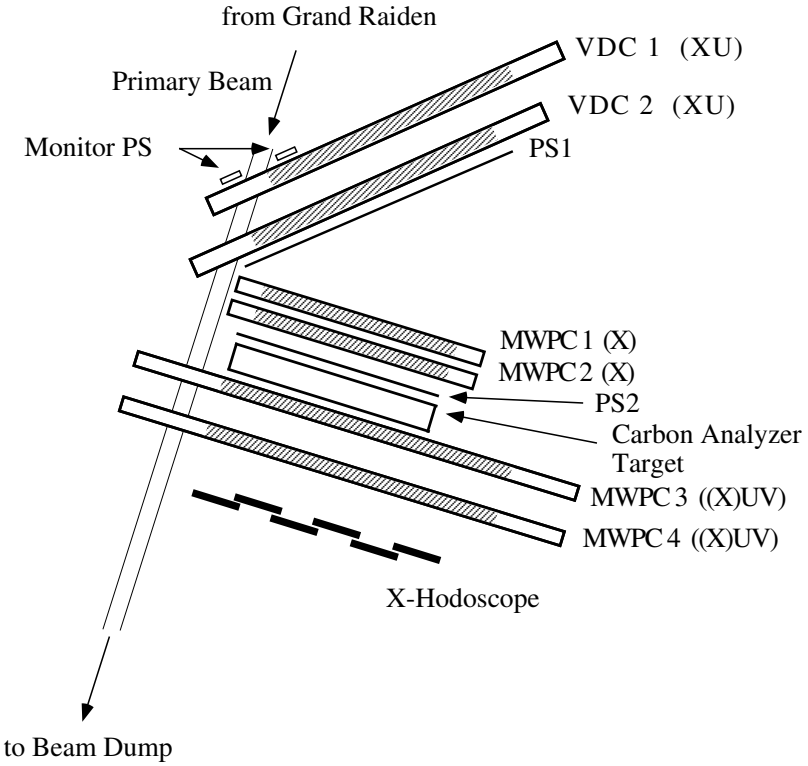

Figure 1: Setup of the Focal Plane Polarimeter (FPP) for the measurement of proton inelastic scattering at zero degrees. The primary beam passes through the beam pipe at the highest momentum side in each chamber and is lead to the external beam dump.

L_1 and L_3 as $L_3 = \sqrt{2}L_1$, then

$$\tan(\theta_u) \propto (u_4 - u_3) + (x_2 - x_1), \quad (5)$$

$$\tan(\theta_v) \propto (v_4 - v_3) - (x_2 - x_1). \quad (6)$$

The scattering angle can be obtained by easy operations of additions, subtractions and bit-shifts in the FPGA modules, using the information of the hit-patterns of X1,X2,U3,V3,U4 and V4 anode planes. A typical result of the second-level cut is shown in Fig. 2. When the cutting angle is about 4°, the trigger rate is reduced about one order of magnitude.

Two kinds of polarization transfer experiments have been performed in this year; the measurements of the polarization transfer coefficients D_{NN} and D_{LL} in zero-degree proton inelastic scattering at 392 MeV[2, 3] and of spin rotation parameters (Q) for proton elastic scattering [4]. Updated second-level trigger system above mentioned has been especially effective in the measurement of zero-degree inelastic scattering, in which large background events originated by the primary beam itself (i.e., the beam halo and the multiple Coulomb scattering) have restricted the data-acquisition rate although we have also developed a fast data acquisition (DAQ) system[5].

Some experimental results of proton inelastic scattering at zero degrees and analysis are presented in other papers in these reports by A. Tamii *et al.*[2] and by T. Kawabata *et al.*[3].

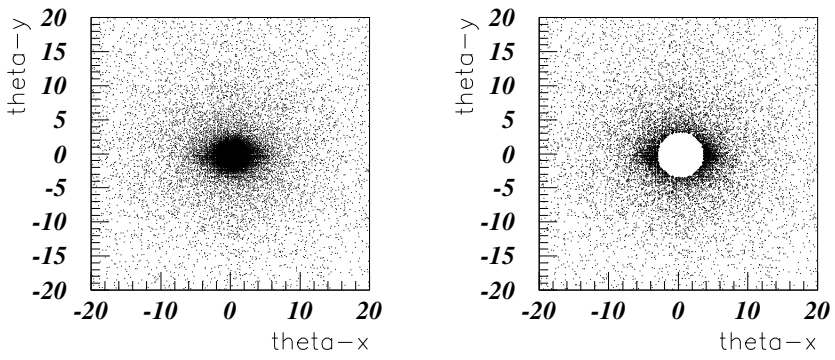

Figure 2: Two-dimensional scatter plots of horizontal angle versus vertical angle of second scattering (neglecting incident vertical angle). Left) Plot for the first-level trigger (no rejection). Right) Plot for the second-level trigger.

References

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