Detector concept development for the spin-filtering experiment at COSY

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The main objective of recently proposed spin-filtering experiments at COSY [1] and AD-CERN [2] relate to physics of the polarization build-up in a stored proton (antiproton) beams. Two scenarios of stored beam polarization passing through polarized internal target exist. Understanding to which one is really work is crucial to progress towards the goal to produce stored antiproton beam. The polarized antiproton beam is the main necessary component to realize the PAX project [3].

The simulation study has been carried out in order to design and optimize a common detector to measure the polarization observables in pp and $\bar{p}p$ elastic scattering. The detector has to be optimized to detect the scattered particles in the energy range $40 < T_{p(\bar{p})} < 500\,MeV$. For the detector performance estimate we used Geant3 and Geant4 packages. To generate events according to the differential cross section we used the flat p.d.f. for the variable $cos\vartheta_{cm}$. It reproduces SAID [4] predicted $d\sigma/d\vartheta$ at $40\,MeV$ beam energy with good approximation. For some special purposes we used the SAID generated spectrum.

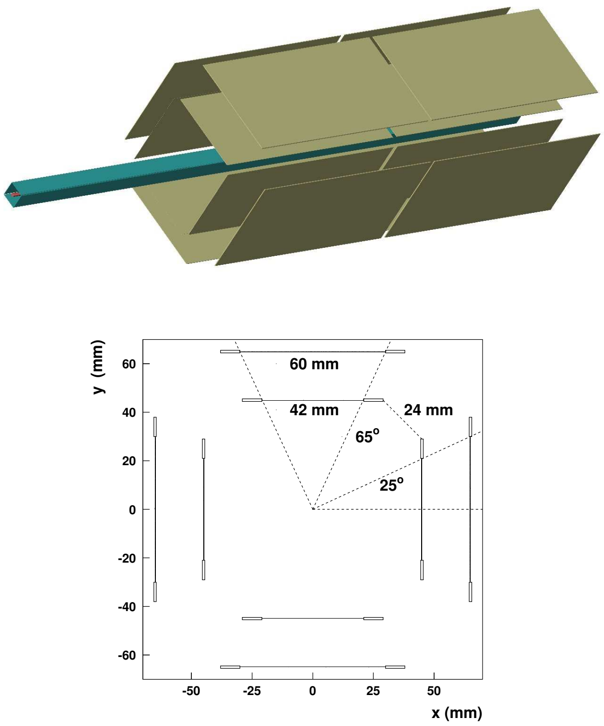

Fig. 1: (*Top panel*) The two-layer silicon detector geometry used by the simulation code. Each layer consists of four adjacent modules. The target cell of $40\,cm$ length is shown. (*Bottom panel*) xy -view of the detector (rotated for convenience).

For simulation we used the detector set-up shown in Fig 1. The detector covers the scattering angle range $10^o < \vartheta_{lab} < 45^o$. The target cell of $10 \times 10\,mm^2$ section and $40\,cm$ length is made of teflon foil with thikness of $10\mu m$. The detector is made of four sets of two-layer silicon strip modules, as shown in Fig 1. The first layer plane is located at a distance of $40\,mm$ away from the beam axis and the second one at $60\,mm$. The first layer modules have a dimensions of active area $42 \times 60\,mm$ and the second layer modules $60 \times 60\,mm$, respectively [5]. The outer layer is staggered by $+11\,mm$ along the beam to match better the elastic scattering geometry. The gaps of $24\,mm$ are foreseen between the inner modules in the x, y -plane (see Fig. 1) to keep a free space for the target communications, supporting mechanics, and connections. At the event generation stage we used the layers consisting of 7 adjacent modules with $4\,mm$ gap inactive area between the modules. However, at the analysis stage the acceptable detector configuration varied depending on particlular task.

We considered two classes of "reconstructed" events:

(A) two hits per track were detected. The interaction vertex is defined as a cross-point of forward and recoil tracks. The requirement is efficient for large-angle scattering events, with high energies for forward and recoil particles;

(B) two hits of the forward track and one hit in the first layer for recoil particles were detected, i.e. the low energy reciol particle stopped in first layer. The interaction vertex is defined as the intersection between forward particle and the beam line.

Although only two silicon layers are used, the elastic event is overconstrained when the recoil stops in both (A) and (B) -type events.

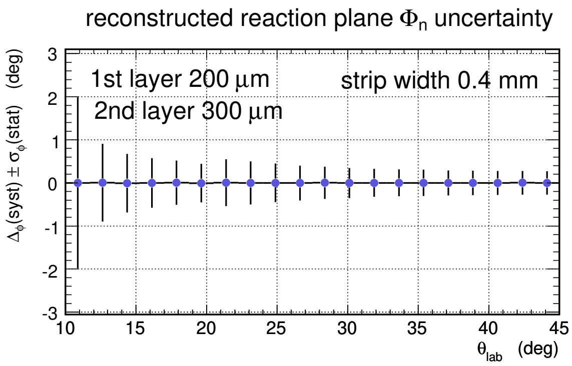

Fig. 2: The reconstructed reaction plane normal uncertainty. The multiple scattering and the energy losses are accouted. The detector resolution (x, y strip widths) is assumed to be both equal to $0.4\,mm$. Cut on χ^2 has not been applied.

Most important reaction parameters (kinematicaly independent) are ϕ_n - the reaction plane normal, and ϑ - the scattering angle. Reliable and precise reconstruction of these parameters in each event makes possible to measure any spin observable using the beam and the target of appropriate directions of polarization. The reaction plane reconstruction algorithm has been developed in order to define the expected uncertainties caused by the multiple scattering and the energy losses. The reaction plane is reconstructed using 3D -coordinates of 4 (or 3) hits (A and B -type events). The plane is built with a severe constraints, to be parallel to the beam axis (z), and minimum distance to z axis to be less than the beam radius. The reconstruction algorithm is based on

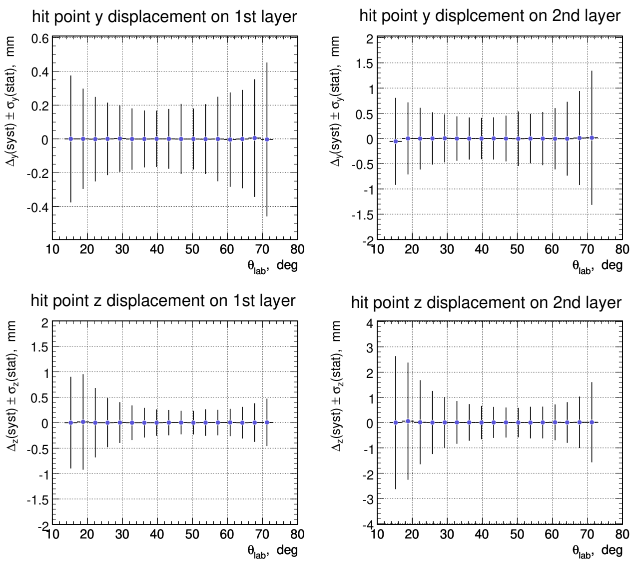

Fig. 3: Silicon hit y and z coordinate displacement due to multiple scattering for 1st and 2nd layers (the thickness of 1st layer is equal to $100\,\mu m$.)

the *orthogonal regression method* providing a parameter characterizing 'goodness of fit' (χ^2).

The local displacement of each track in 1st and 2nd layers due to multiple scattering is shown in Fig. 3. ϑ_{lab} corresponds to the track lab angle, for the scattered protons up to 45^o and for the recoil - above 45^o. The displacement values depend not only on the deflection but also on the hit angle, e.g. σ_z increasis at small scattering angles (long tracks and small hit angles) and at large angles (low energies).

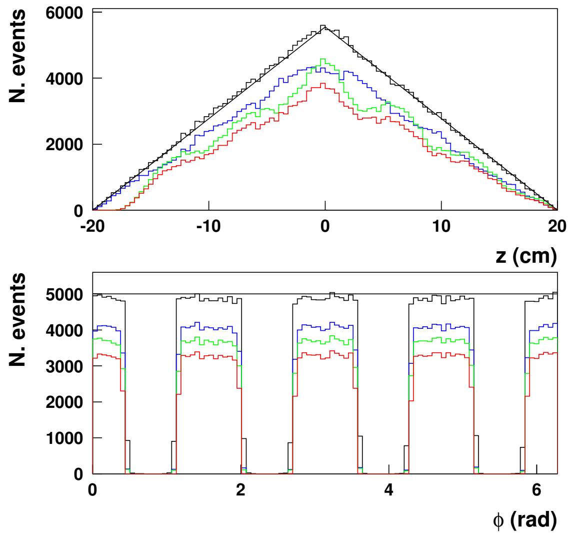

Fig. 4: Geometrical acceptance of the silicon detector at 40 MeV beam energy: accepted events as a function of z coordinate (Top) and ϕ angle (Bottom).

Fig. 4 shows the geometrical acceptance of the detector. The black lines shows events with at least one hit into the silicon. The blue (green) lines shows events where the forward (recoil) track is reconstructed. The red lines shows events where both tracks are reconstructed: the modulation is due to the 4 mm gaps between silicon active areas.

Fig. 5 shows the event distribution of reconstructed event as a function of the scattering angle and the typical deposit energy into the silicon layers. On top-left panel,

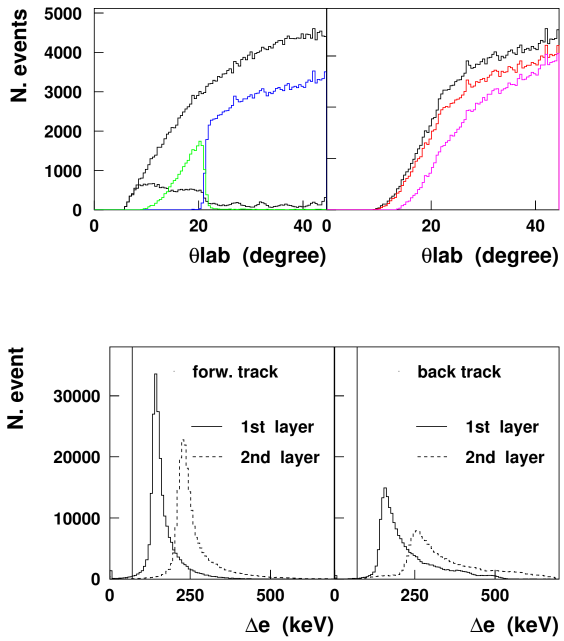

Fig. 5: **Top panel:** Event distribution as a function of the laboratory scattering angle. **Bottom panel:** Energy deposited into the silicon layers by forward (Left) and recoil (Right) particle.

the black lines shows the events with at least one silicon hit. The blue lines shows the events (class A) with 2 silicon hits per reconstructed track. The green lines shows events (class B) where the recoil track, stopped in the first silicon layer, was reconstructed using the energy information. The dashed black lines shows events with no reconstructed track (lost). On top-right panel, the black lines shows the reconstructed events (class A and B). The red lines shows the reconstructed events when the upstream recoil telescopes is disregarded. The green lines shows the reconstructed events when in addition the two downstream forward telescopes are disregarded and only the central 4-modules detector is used. On bottom panel the energy deposition of forward and recoil particle into the two silicon layers is plotted. The signals are all above the detection threshold, of the order of 70 keV.

In case we consider the central part of the detector (4 adjacent modules), the geometrical acceptance equals to 25 %. If we assume an expected luminosity of $10^{29} cm^{-2} s^{-1} = 100 mb^{-1} s^{-1}$, a total cross section for pp scattering $\sigma_{tot} = 70 mb$, a dead-time correction factor equal to 0.9, a detection efficiency equal to 80 %, a reconstruction efficiency equal to 70 %, and a trigger efficiency equal to 70 %, the estimated event rate is about $600\, s^{-1}$.

References:

[1] *Spin-Filtering Studies at COSY*, 2006
[2] *Measurement of the Spin-Dependence of the $\bar{p}p$ Interaction at the AD-Ring*, 2005
[3] PAX Proposal, **arXiv:hep-ex/0505054**
[4] **http://gwdac.phys.gwu.edu**
[5] A. Mussgiller, Ph.D. thesis, Univ. of Cologne, 2006

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