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A SPECTROMETER COUPLED TO AN ELECTRON STORAGE RING FOR TAGGING LASER BACKSCATTERED GAMMA RAYS

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A spectrometer has been designed to momentum-analyze electrons, from the 2.5-3.0 GeV 'X-RAY' storage ring of the National Synchrotron Light Source at Brookhaven National Laboratory, that have lost energy from the production of high-energy γ-rays by Compton scattering of laser light. The electrons detected in the focal plane will provide a "tag" for the backscattered γ-rays, determining their energy (to 2.3 MeV), and timing. This design utilizes the fact that, due to kinematics, the Compton scattered electrons have a transverse phase space negligibly different from that of the stored beam. It is constrained by the requirement of not altering any of the existing elements of the storage ring. In particular, no structures or fields interfere with the large aperture of the storage ring that is required for loading the ring.

The spectrometer will consist of four dipole magnets (D1 thru D4 in Fig. 1). The first magnet (D1) is one of the existing storage ring dipoles, located 5.5m from the center of electron-laser interaction region. The second dipole (D2) is a specially designed septum magnet, located just outside the existing ring vacuum chamber, to obtain the maximum dynamic range ($E_\gamma > 175$ MeV). This magnet, which is described below, has shaped pole tips, a current sheet septum and trimming coils to cancel the fringe field at the circulating beam. Two dipoles of conventional construction (D3 and D4) complete the spectrometer.

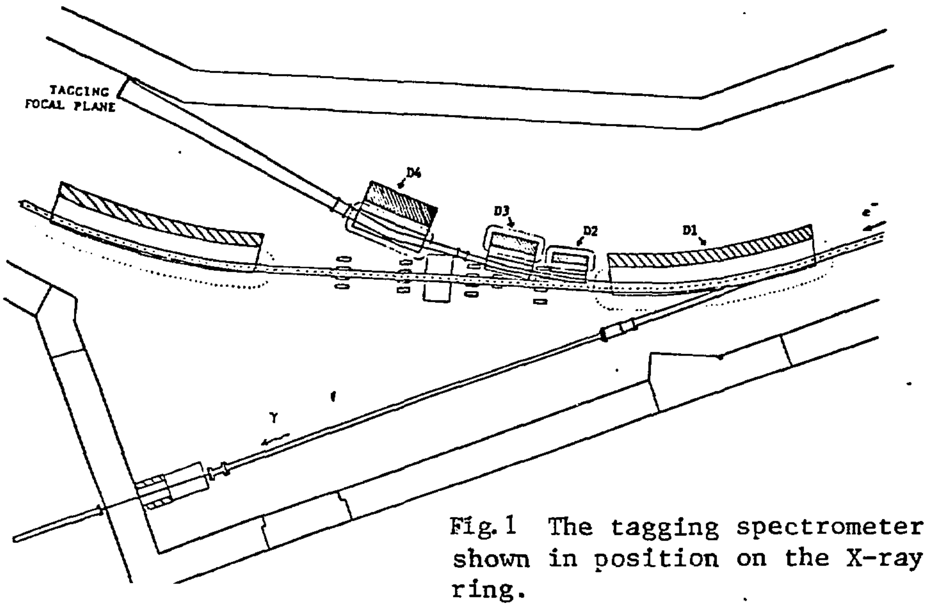

Fig. 1 The tagging spectrometer shown in position on the X-ray ring.

The septum magnet D2 is an unconventional design, in that the current septum has been removed from the magnet gap and placed just outside the edge of the poles. This has been done in order to reduce the width of the septum (by increasing its height) while maintaining an acceptable current density (4000 A/cm^2). The narrow width is essential to obtain a large dynamic range since the dispersion at D2, due to D1, is only 0.30 mm/MeV. This septum geometry results in an increased leakage field, but since the magnet is constrained by the existing vacuum envelope to be 8 gap lengths (5.5cm) from the beam, the actual field is less than 40 gauss. This field will be cancelled by trim coils located above and below the beam. Figure 2 is a cross section of the proposed magnet.

To focus the Compton scattered electrons onto the spectrometer focal plane, a quadrupole field is desirable before D3. Since there is no space for a separate element, a gradient (450 gauss/cm) will be introduced into D2, so that the field decreases from 11 kG at the septum to 9 kG at the inside. The horizontal focal length is 3.2 m. The increased fringing which would accompany such a design can be reduced by using a pole tip shape, known as a floating pole, which was developed for use in shaping field gradients in isochronous cyclotrons[2]. These pole tips are attached to the pole root at the inside edge of the magnet and are separated from it by a secondary gap that increases toward the outside edge. The main gap decreases similarly to provide the desired gradient (see Fig. 2). The low reluctance path from the inside edge, through the floating pole and across the main gap at the outside edge, causes field lines to move inward, reducing fringing at the outside edge.

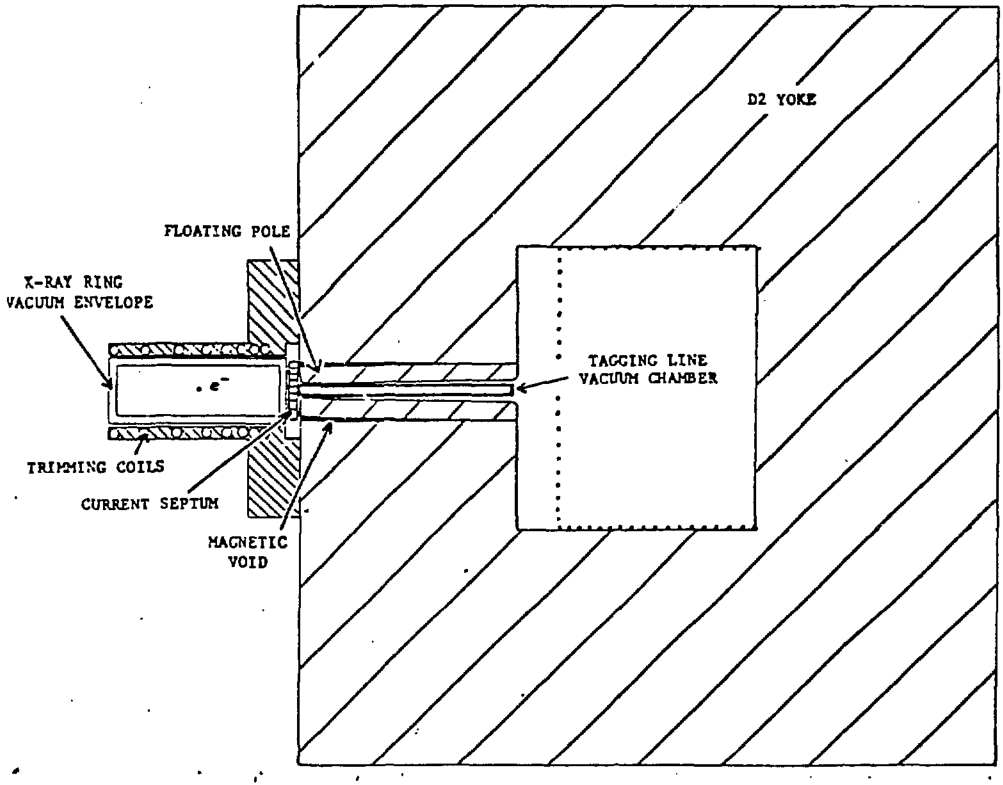

Fig. 2: Cross section of the unconventional septum magnet, D2.

Calculations with the code TRIM[3] have been made to design the septum and trim coils for D2. The magnitude and shape of the leakage field at the stored beam can be adjusted by varying the height of the septum (Fig. 3). The septum height (2.5 cm) is chosen to make the quadrupole field zero at the beam. Two sets of trim coils will be used to cancel higher multipoles. One set (COIL 1 in Fig. 4) has current symmetry chosen to produce only even multipoles (dipole, sextupole,...) and geometry and current (350 ampere turns) chosen to cancel both dipole and sextupole components of the leakage field. A second coil (COIL 2 in Fig. 4) has only odd multipoles with geometry selected for no quadrupole field and current (26 ampere turns) chosen to cancel the octupole component. The trimmed fields calculated for the region near the beam are shown in Fig. 4. With both coils (1+2) the field is less than 0.5 gauss within 1 cm of the beam.

The first order optical properties of this tagging spectrometer have been computed with TRANSPORT[4], and are shown in Fig. 5 for two different tunes of the storage ring. The optics tune will be the standard mode for the x-ray ring; the high β tune is a special mode which is optimized for use of the ring for Compton scattering of laser photons. In either case, the energy resolution is better than

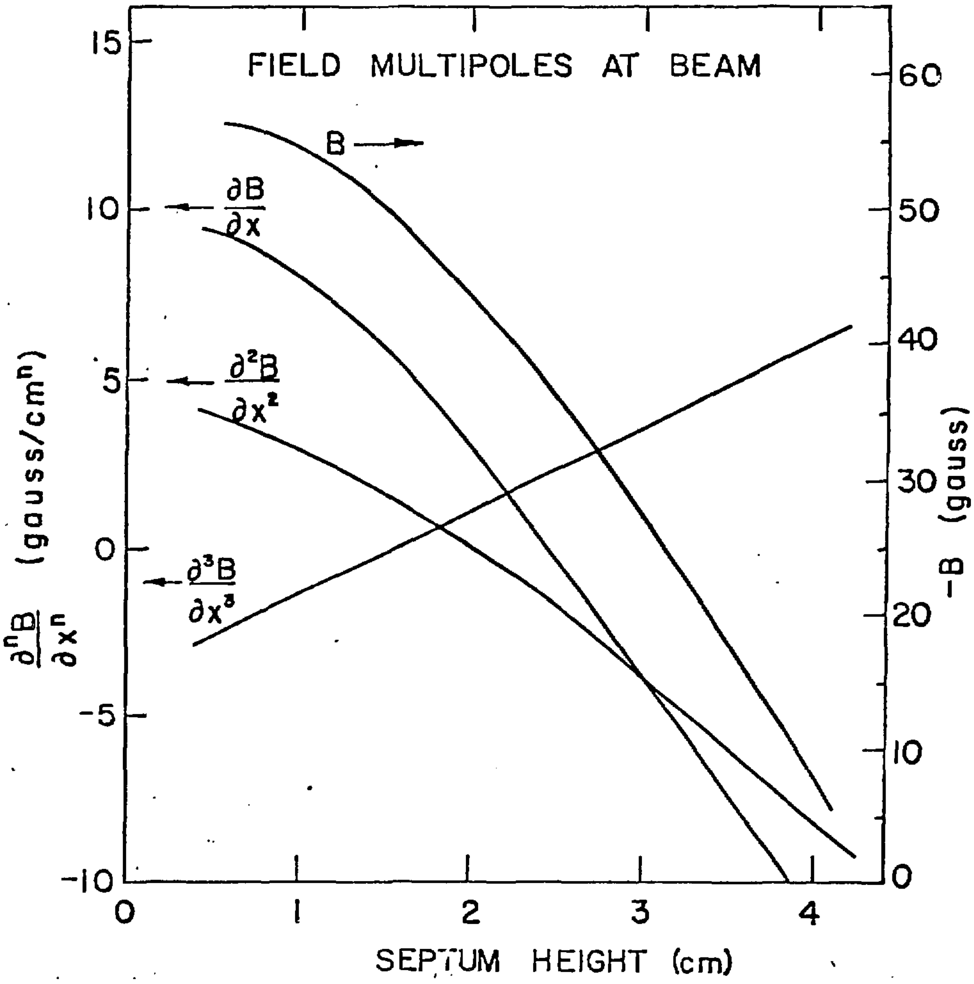

Fig. 3: Magnetic multipoles in the stored beam region as a function of septum height, before trimming.

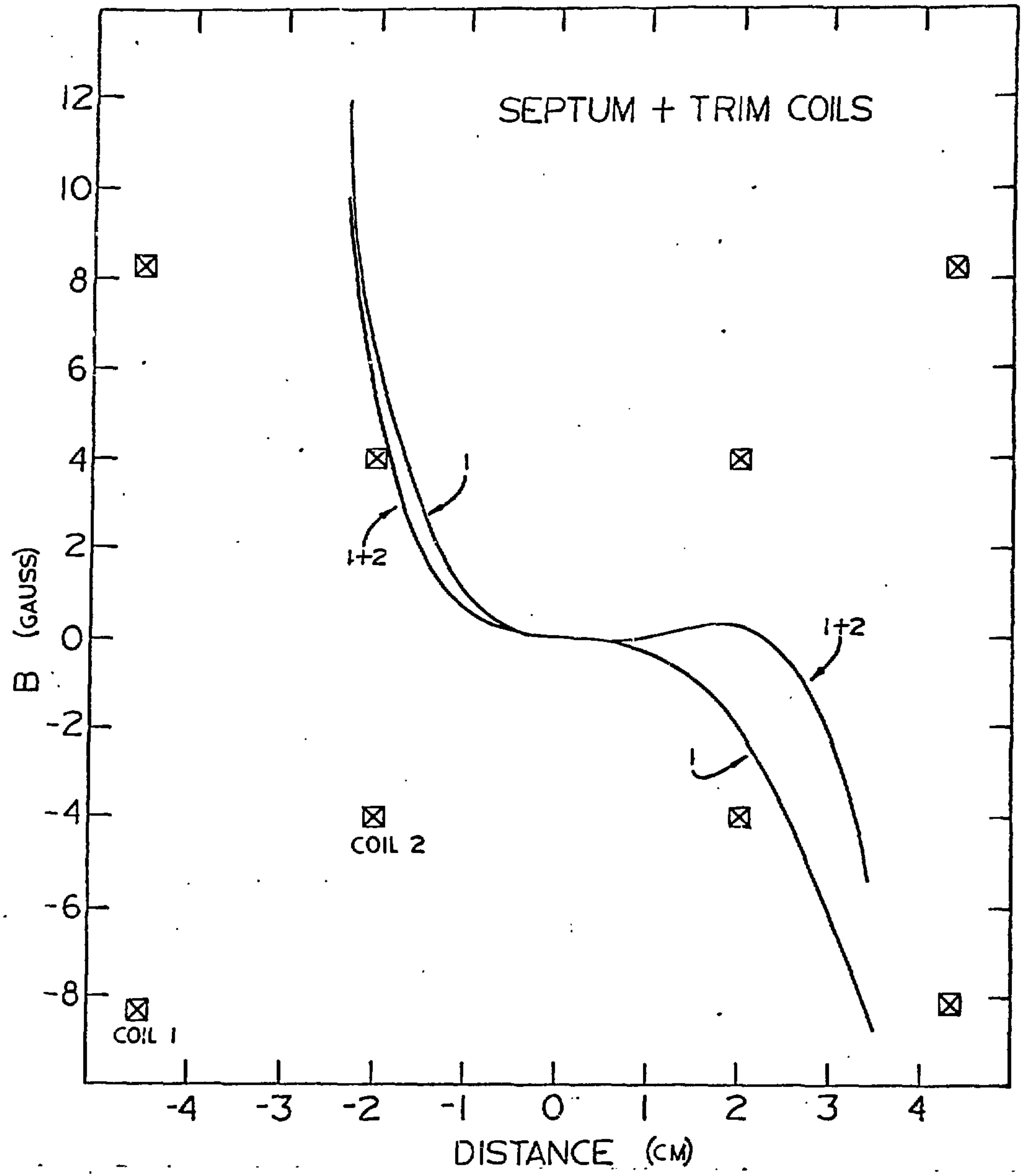

Fig. 4: Magnetic induction in the stored beam region with trim coils.

1.5 MeV which, when combined with the energy resolution of the ring, 8×10^{-4}, gives a total resolution of 2.3 MeV. Second order aberrations have been estimated and are negligible, principally because of the small divergence of the stored beam (<0.1 mr).

The focal plane detector will be a 96 element lead glass hodoscope array capable of counting at 3×10^{5} Hz per element. The microstructure of the synchrotron beam (1 ns bunches every 17 ns) makes it possible to resolve beam bunches and reject multiple events per bunch. This results in a background-free tagging efficiency of 100%.

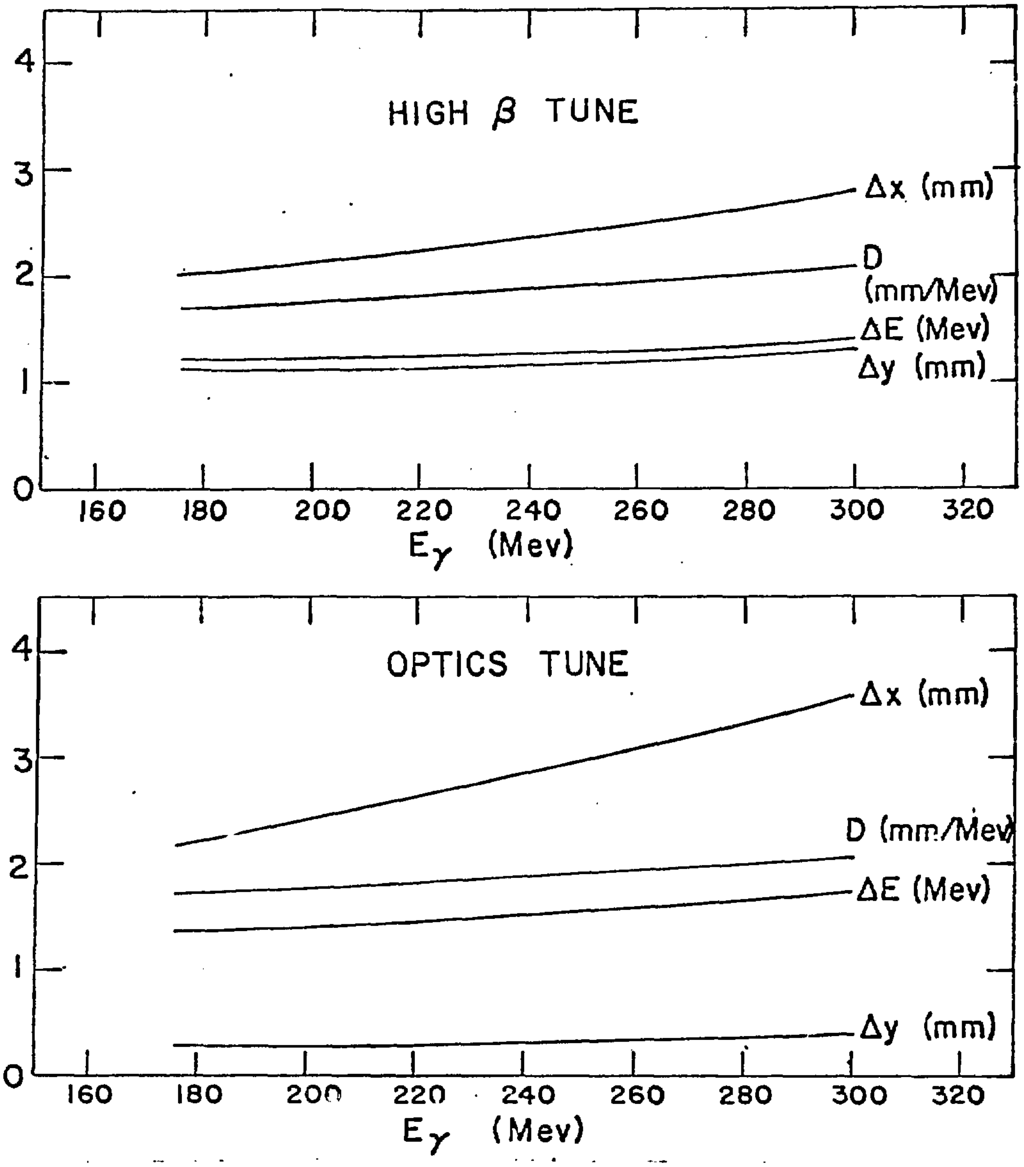

Fig. 5: Characteristics of the tagging spectrometer in both the normal (optics) tune and the high-β (single-user) tune of the storage rings.

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