Aiglon: A Magnetic Spectrometer for Low Energy Electrons

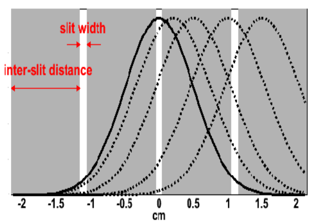
R. Battiston[1,2], W.J. Burger[1], A. Ostaptchouk[3] and S. Schael[3]

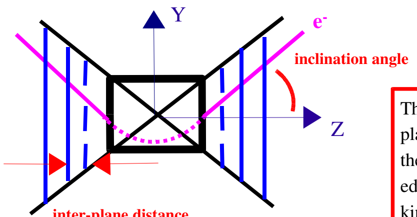
[1]*INFN Sezione di Perugia, I-06123 Perugia;* [2]*Dipartimento di Fisica, Università di Perugia, I-06123 Perugia;* [3]*I. Physikalisches Institut B, D-52056 RWTH Aachen*

Abstract

The magnetic spectrometer is designed to detect low energy electrons (5-50 MeV) with good energy (10%) and angular (~2^0) resolutions, and sufficiently large acceptance (~10 cm^2sr), to monitor short term changes of the electron population trapped in the Earth's magnetic field. The influence of multiple scattering is reduced by the use of active collimators composed of "edgeless" silicon microstrip detectors. The incident and exit particle trajectories are reconstructed in four planes of scintillating fibers. The relatively limited amount of material allows to measure non-relativistic protons (30-500 MeV) with a large acceptance (75-130 cm^2sr) and an energy resolution of 2-8% *via* time-of-flight (time resolution ~50 ps). The spectrometer is a "digital" device in the sense that the notion of sampling is omnipresent: at the level of the collimator (filter) planes, which suppress large multiple-scattered electrons, and at the level of the frontend readout electronics, where silicon photomultipliers (SiPM) are used.

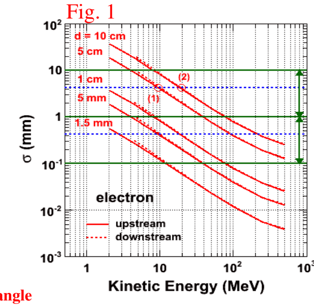
Principle of Operation

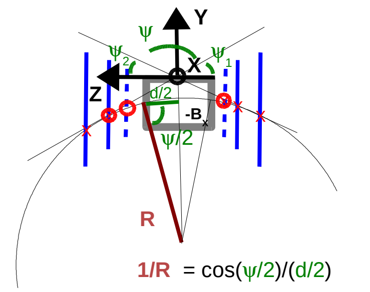




The relevant parameters are indicated above. For a given inter-plane distance, the slit width should be be smaller than the projected track error in the plane, and the inter-slit distance sufficiently large to limit contamination from large scattering angles. (*cf.* Fig.3).

Fig. 1

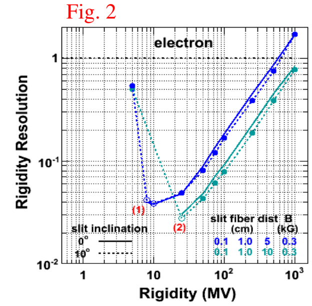




$1/R = \cos(\psi/2)/(d/2)$

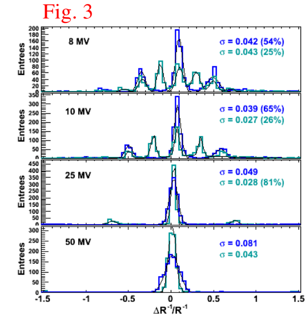
1 Slit Event – 3 point reconstruction

Fig. 2



The particle rigidity is obtained by a measurement of the incident / exit directions in six tracking planes. The planes closest to the magnet are segmented filters. When the particle passes by a slit in the filter, its direction is reconstructed using the closest predicted slit position and the position recorded in the nearest tracking plane. The projection error at the filter planes as a function of the electron kinetic energy are shown for several different inter-plane distances in Fig. 1. Two intervals are indicated on the vertical axis corresponding to different combinations of inter-slit distance and width. With an inter-slit distance of 10 mm and a slit width of 1 mm, the optimum "2-slit" resolution is observed at a width/separation ratio of 0.425, i.e. at an inter-plane distance of 5 (10) cm for an electron rigidity of 10 (25) MV (*cf.* Fig.2). The open circles in Fig. 2 indicate the presence of multiple slit contributions (the "central" slit contribution represents ≥ 50% of the total). The corresponding reconstructed rigidity distributions from the Geant3 simulation are shown in Fig. 3.

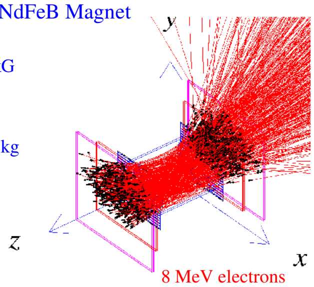
Fig. 3



Technologies Employed

Cylindrical NdFeB Magnet

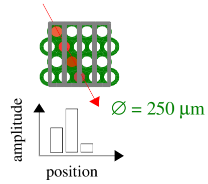
B_x = 0.64 kG
L = 24 cm
∅ = 20 cm
mass = 6.5 kg



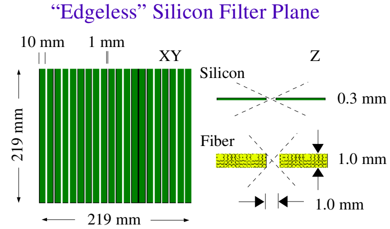
Scintillating Fiber Tracker

channels /mm /coordinate = 4
total number of channels = 12 520
position resolution ~ 40 μm

SiPM readout



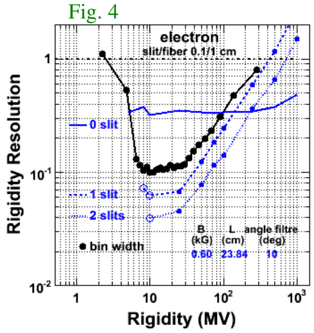
"Edgeless" Silicon Filter Plane



The magnetic field is orientated perpendicular to the axis of the cylinder; the net dipole moment is zero. The satellite payload will include two spectrometers to view in orthogonal directions. With a near polar orbit, the 0° detector would sample 0° (90°) pitch angle at the pole (equator), while the 90° detector would view in permanence in the direction perpendicular to the local magnetic field line. The simulation results presented are based on a position resolution of 80 μm for the fiber / filter planes.

Expected Performance

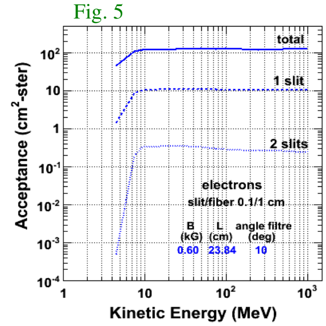
Fig. 4



Comparison with Existing Detectors

Detector	geometric factor (cm^2sr)	aperture	pitch angle	range e^- (MeV)	range p (MeV)
SAMPEX PET	1.7	58°	0°-90°	4-20	28-64
DEMETER IDP	1.2	32°	90°	0.07-2.4	
NOAA MEPED	0.1	30°	0°-90°,90°	0.03-2.5	0.03-6.9
AIGLON	10 / 75-130	40° Δ2°,Δ0.8°	0°-90°,90°	5-50	30-500

Fig. 5



The 0, 1 and 2 slit electron rigidity resolutions are presented in Fig. 4; the corresponding acceptances are shown in Fig. 5. The bin widths in Fig. 4 are normalized to the rigidity value of the center of the bin. The widths were adjusted to limit the migration to adjacent bins due to differences between the generated and reconstructed rigidities to less than 50%. Electrons were generated over the full geometric acceptance using a power law in energy E^{-3} between 2-200 MeV. The data of the detectors quoted in the above table have been used to study the correlation between particle flux variations and disturbances of solar, meteorological, seismic and anthropogenic origin.

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