Silicon PIN Diodes as Particle Flux Monitors for the MERIT Experiment

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A simple detector for the very high flux of secondary particles from *p*-mercury interactions in the MERIT experiment is a silicon PIN photodiode, such as the Hamamatsu S3590, http://sales.hamamatsu.com/index.php?id=13183087 . PIN diodes are used as beam-loss monitors in almost every accelerator nowadays. In extreme environments, the trend is to use CVD diamond diodes, but this should not be necessary for us. A commercial PIN diode loss monitor is available from Bergoz:
http://www.bergoz.com/Products/BLM/BLM-downloads/files/BLM.flyer.PDF .

Such a device does NOT need to be coupled to any scintillator or Čerenkov counter, as there will be plenty of signal due to ionization in the silicon junction itself. Of course, they could also be used with a scintillator or Čerenkov counter, but then there would be the issue of what part of the signal comes from the scintillator/Čerenkov counter and what part from the diode itself.

The diode junction has an active depth of ~ 300 μm (less in some models). A minimum-ionizing particle that passes through the diode at normal incidence deposits about 240 keV, producing a signal of 66.3k electrons. The rise time of the resulting pulse is less than 50 ns, so the voltage into a 50-Ω cable is $R\,Q\,/\,\Delta t \sim 50 \bullet 7e4 \bullet 1.6e\text{-}19/5e\text{-}11 \sim 1\,\mu V$.

As shown on p. 7 of *Particle Flux Calculation III* by S. Striganov,
http://www.hep.princeton.edu/~mcdonald/mumu/target/Striganov/flux2-1.pdf ,
a detector of 1 cm^2 area placed at 45° to the proton beam and 3 m from the Hg target experiences a flux of about 1e8 charged particles and about 1e9 soft γ's per pulse of 1e13 protons. A 300-μm layer of silicon constitutes about 1/300 of a radiation length, so the signal from the soft photons will be equivalent to about 3e6 charged particles, a small correction to the signal from the latter.

Thus, the signal in a 1 cm^2 PIN diode will be about 10V for a pulse of 1e13 protons. This signal is less than the depletion voltage of the diode, and so the diode should not saturate, although there is not a lot of margin in this respect. It might be prudent to consider use of a diode of area, say, only 0.1 cm^2, such as the Hamamatsu S2684,
http://sales.hamamatsu.com/index.php?id=13183033 ,
or even only 1 mm^2, such as the Hamamatsu S1336,
http://sales.hamamatsu.com/index.php?id=13182998 .

I recommend use of 4 or 8 such devices, arrayed over several angles. Perhaps pairs of Hamamatsu S1336 and S3590 could be used to provide low and high sensitivities. A simple and sufficient data-acquisition system could consist of 1 or 2 Tek digital scopes such as TDS2004/14/24, interfaced to a control PC.