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Design of a Synchrotron Radiation Absorber for the H1 Luminosity Detector

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In order to detect 0° bremsstrahlung photons the photon detector has to be protected against the very high flux of synchrotron radiation. This will be done by a bulk material absorber of about one radiation length thickness in front of a water Cerenkov counter. The material for the absorber has to be chosen such that not only the low energy component of the synchrotron radiation ($E_\gamma < 50$ keV), but also medium energies are well shielded. This is achieved by using a low Z absorber (Carbon), if necessary, completmented by a thin lead absorber. This conclusion is reached by comparing photon absorption in carbon and lead.

The attenuation of a monoenergetic photon beam follows an exponential law

$$I = I_0 \cdot e^{-\mu/\rho \cdot x}$$

where μ/ρ is the mass absorption coefficient. This formula is a measure of the average number of interactions between the incident photon and material. It does not properly take into account the energy degredation of photons in bulk material and thus overestimates the absorption effect.

The energy absorption of photons in material follows a similar exponential law

$$E = E_0 \cdot e^{-\mu_{en}/\rho \cdot x}$$

This formula is a measure of the average fractional amount of incident photon energy transferred to kinetic energy of charged particles. It underestimates the attenuation properties of bulk material. Therefore the number of particles leaving an absorber will be somewhere between the attenuation coefficient for monoenergetic photons and the energy absorption coefficient.

The photon attenuation in carbon and lead has been calculated for various photon energies. The results of these calculations are summarized in a table. Comparing lead and carbon absorbers of one radiation length thickness it is clearly visible that for low energies the attenuation is unnecessarily high in lead, while at medium energies above some hundred keV carbon is definitely superior to a lead absorber. Therefore the best choice of a photon absorber is a carbon absorber which could be implemented by a thin lead absorber of the order of 0.5 mm at the exit.

Photon Absorption in Carbon

	Attenuation		Energy Absorption	
E_γ	μ/ρ [cm^2/g]	$e^{-\mu/\rho \cdot x}$	μ_{en}/ρ [cm^2/g]	$e^{-\mu_{en}/\rho \cdot x}$
50 keV	$1.9 \cdot 10^{-1}$	$3.1 \cdot 10^{-4}$	$2.4 \cdot 10^{-2}$	$3.6 \cdot 10^{-1}$
100 keV	$1.5 \cdot 10^{-1}$	$1.7 \cdot 10^{-3}$	$2.1 \cdot 10^{-2}$	$4.1 \cdot 10^{-1}$
500 keV	$8.7 \cdot 10^{-2}$	$2.5 \cdot 10^{-2}$	$3.0 \cdot 10^{-2}$	$2.8 \cdot 10^{-1}$
1 MeV	$6.4 \cdot 10^{-2}$	$6.6 \cdot 10^{-2}$	$2.8 \cdot 10^{-2}$	$3.0 \cdot 10^{-1}$
5 MeV	$2.7 \cdot 10^{-2}$	$3.2 \cdot 10^{-1}$	$1.7 \cdot 10^{-2}$	$4.8 \cdot 10^{-1}$
10 MeV	$2.0 \cdot 10^{-2}$	$4.3 \cdot 10^{-1}$	$1.4 \cdot 10^{-2}$	$5.5 \cdot 10^{-1}$

Radiation length x $= \rho \cdot X_0 = 2.26 \cdot 18.8 = 42.6 \cdot g/cm^2$

Photon Absorption in Lead

	Attenuation		Energy Absorption	
E_γ	μ/ρ $[cm^2/g]$	$e^{-\mu/\rho \cdot x}$	μ_{en}/ρ $[cm^2/g]$	$e^{-\mu_{en}/\rho \cdot x}$
50 keV	8.0	$7.4 \cdot 10^{-23}$	6.8	$1.5 \cdot 10^{-19}$
100 keV	5.5	$6.1 \cdot 10^{-16}$	2.2	$8.2 \cdot 10^{-7}$
500 keV	$1.6 \cdot 10^{-1}$	$3.6 \cdot 10^{-1}$	$9.6 \cdot 10^{-2}$	$5.4 \cdot 10^{-1}$
1 MeV	$7.1 \cdot 10^{-2}$	$6.4 \cdot 10^{-1}$	$3.8 \cdot 10^{-2}$	$7.8 \cdot 10^{-1}$
5 MeV	$4.3 \cdot 10^{-2}$	$7.6 \cdot 10^{-1}$	$2.6 \cdot 10^{-2}$	$8.5 \cdot 10^{-1}$
10 MeV	$6.2 \cdot 10^{-2}$	$6.7 \cdot 10^{-1}$	$3.4 \cdot 10^{-2}$	$8.0 \cdot 10^{-1}$

Radiation length x $= \rho \cdot X_0 = 11.35 \cdot 0.56 = 6.37\ g/cm^2$

Ratio of attenuation coefficients Carbon/Lead (Absorber thickness = 1 radiation length)

E_γ	Attenuation	Energy Absorption
50 keV	$2.3 \cdot 10^{-19}$	$4.2 \cdot 10^{-19}$
100 keV	$3.6 \cdot 10^{-13}$	$2 \cdot 10^{-6}$
500 keV	14	1.9
1 MeV	9.7	2.6
5 MeV	2.4	1.8
10 MeV	1.6	1.4