Barrel Calorimeter for the Hall D Spectrometer

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Abstract. The barrel calorimeter for the hall D spectrometer is discussed for standard pointing geometry and a parallel geometry using Lead Scintillating fibres as active material. A comparison with a CSI spectrometer is shown.

If we want to measure events with several photons in the final state a hermetic calorimeter is of great importance. The forward calorimeter needs a high segmentation a threshold energy of 50-100 MeV and has to be very fast. A Cerenkov based calorimeter like lead glass seems to be a good choice because it has the advantage that it does not see neutrons generated by charged pions. The barrel calorimeter can be slower but it should have a threshold energy of about 20 MeV. A good energy resolution is always desired. But for the reconstruction of η's and particularly π^o one needs both good energy and position resolution. It is very important, that the barrel region and the forward region of the calorimeter overlap. Even a small hole there could reduce the acceptance for final states with more than 2 photons dramatically.

A Lead Scintillating Fibre (PbSciFi) Calorimetry

The advantage of a PbSciFi calorimeter are a rather moderate cost (about \$0.5 per cm^2·radiation length. We will need about 3 m^3 of active material, which makes that an important consideration. The construction principle is shown in figure 1. Coated scintillating fibres are embedded in grooves of the lead sheets, which contain 6% Antimony per weight. A specific amount of glue is applied and the sheets are pressed together to form the calorimeter blocks. This procedure can produce in principle any size (and form) of calorimeter block. Calorimeters were made for 2 experiments with slightly different parameters, see table 1 [1]. In the following I will assume a density similar to the one used in Jetset.

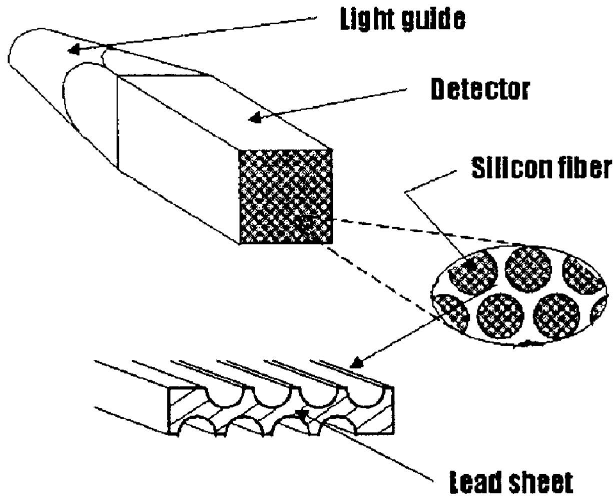

FIGURE 1. Construction principle of a PbSciFi calorimeter

Table 1: Parameters and performance of PbSciFi calorimeter

	Radiation Length	Moliere Radius	Attenuation Length	Lead	Fibre	Signal Rise Time	Energy Resolution
Jetset:	1.6 cm	3.5 cm	85-100 cm	35%	50%	3.5 ns	$6\%\sqrt{(E(GeV))}$
g-2:	1.1 cm	3.5cm	85-100 cm	50%	35%	3.5 ns	$10\%\sqrt{(E(GeV))}$

B Barrel Calorimeter in parallel geometry

A calorimeter with 5 m long PbSciFi blocks sitting parallel in the solenoid is shown in figure 2. It has the advantage of a very small number of readout channel (cost). It uses minimal radial space (24cm for 15 radiation length). If necessary the forward endcap can be segmented further in radius, in order to separate photons which are emitted close in direction. An excellent polar segmentation can be achieved with a resonable amount of channels. A three degree segmentation results in a ploar position resolution of about 0.4 degree [1]. Photon showers can be distinguished if they are separated by at least 10 degrees, as experience from the Crystal Barrel experiment shows. Both sides of the calorimeter are read out and the time comparision results in a azimutal position resoution of about 6 degrees. Because this is a very fast calorimeter (signal rise time 3.5 ns) it is possible to distinguish 2 photon clusters (2 photons went into the same segement) if they are separated by at least 40 degrees. Channel count and cost are shown in table 2. I would like to point out, that the attenuation lenght of about 1 m is too small for a 5 m long calorimeter block and has to be improved.

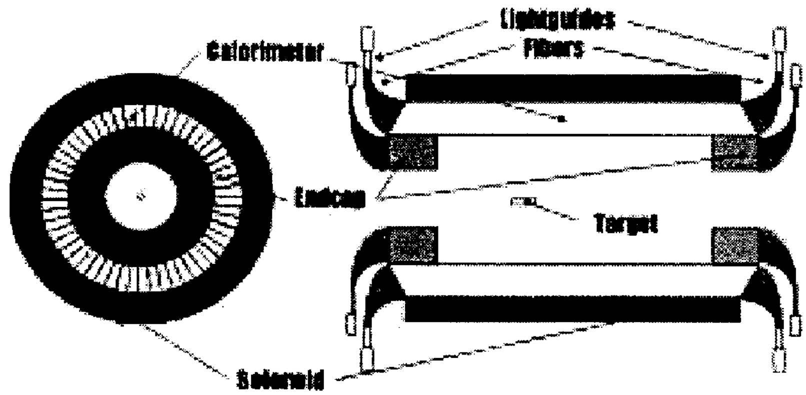

FIGURE 2. Barrel Calorimeter in parallel geometry.

C PbSciFi Calorimeter in Pointing Geometry

The problem with a PbSciFi calorimeter in pointing geometry as shown in figure 3 is, that one needs phototubes in the magnetic field. One solution might be, that the light can be brought out thru the gaps in the solenoid. However a careful study has to show, if the geometry allows a large enough light yield. Photo diodes have a typical noise of 400-800 photo electrons to much for the photon yield of 15 ph/MeV in a PbSciFi calorimeter. The only solution would be to use the new (DEP) hybrid phototubes. A proximity focused hybrid tube has a gain of 3500 a quantum efficiency of 25% and excellent photo electron resolution [3]. The magnetic field does not affect the gain, as long as the tube is parallel to the field. This would mean that the light guides have to bent by 90°. This would require a relative large amount of space radialy (35cm).

Using blocks with a side length of 6cm results in almost 7000 channels. To save cost one would like to use pixelated tubes, but the energy resolution becomes poor because of photo statistics. Coupling the fibers in closesed packaging and including an adiabatic reduction on the lightguide one finds that one could read out 3 blocks with a 1 inch tube and still finds an aceptable energy resolution of 8% (6.5% in case of 1 block per tube). The position resolution is about 0.7 degree and the geometrical shower seperability is 10 degrees polar and azimuthal.

D CSI Calorimeter in Pointing Geometry

A CSI calorimeter would be ideal. Not only can it be read out with photo diodes, as the Crystal Barrel experiment has shown [2], it has also a much better energy resolution $(2\%\sqrt[4]{E(GeV)}$. The detector would look similar like the PbSciFi detector in pointing geometry (figure 3), where the hybrid tubes are replaced with photo diodes which leads to a slightly more compact design. At least in the forward

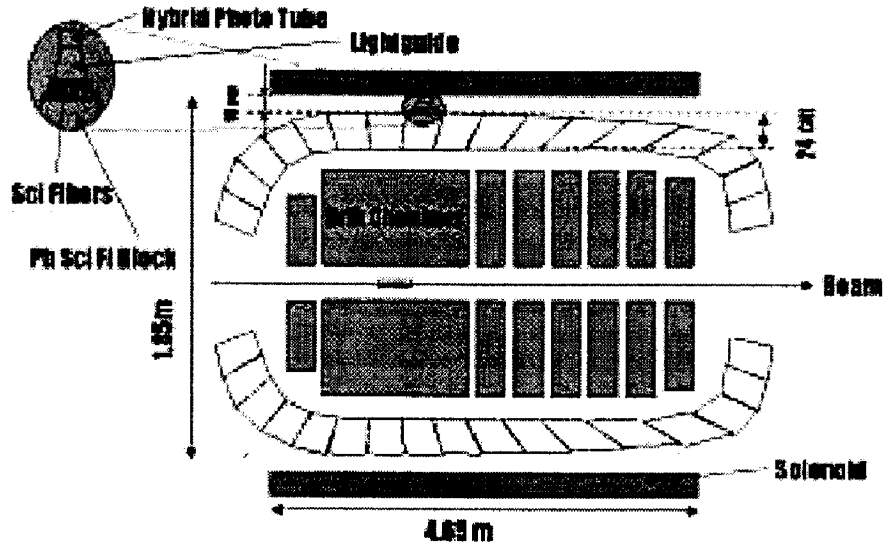

FIGURE 3. Barrel Calorimeter in pointing geometry. In order to get good gain in the magnetic field the tube has to be parallel to the field. The necessary bend of the light guides is not shown.

direction one would need pure CSI crystals, which have a smaller light output than the doped CSI crystals. A study would be required to proof, that a good energy resolution still can be achieved. The high cost of the material (about \$7.5 per cm^2·radiation length) is the main problem with this calorimeter.

E Channel Count and Cost Estimate

Table 2 shows the channel count and rough cost estimates for the 3 suggested detectors. About \$700 was included for ADC, phototubes and bases per channel.

Table 2: Comparision of different calorimeters. The costs are only rough guesses.

	PbSciFi Parallel	PbSciFi Pointing	3 channels/tube	CSI
Nr of blocks:	Barrel: .120 Endcap: 80 + 60	6920	6920	6920
Energy Resolution:	$9\%/\sqrt{E(GeV)}$	$6.5\%/\sqrt{E(GeV)}$	$8.0\%/\sqrt{E(GeV)}$	$2.0\%/\sqrt[4]{E(GeV)}$
Position Resolution:	pol: 0.4^o az: 6^o	0.8^o	0.8^o	0.8^o
Cost:	\$2.5 Mio	\$11 Mio	\$7 Mio	%25 Mio

REFERENCES

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3. Delft Electronische Producten (DEP) technical information.