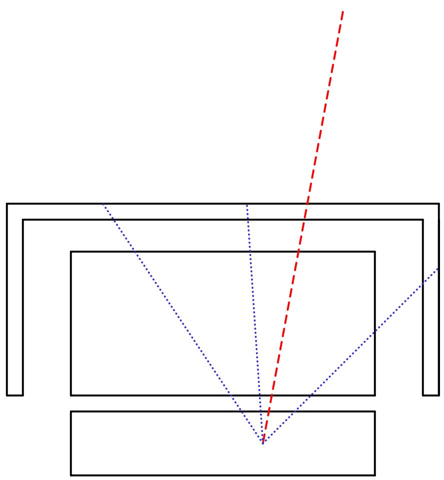
Backsplash study

Alex Moiseev 05/22/2001

Purpose

High energy particle instruments which contain a heavy calorimeter to measure the energy of detected particles produce radiation emitted backward from the calorimeter. This radiation is a small fraction of the cascade developed in the calorimeter by the primary high energy particle. This radiation is often called "backsplash", and could create problems in some measurements by creating background detections ("hits") in the instrument detectors. A good example is a gamma-ray telescope which is shielded by anticoincidence detectors (ACD) to veto the dominating charged cosmic rays. The backsplash particles can cause signals in the ACD and consequently false veto signals, potentially removing good gamma events. For gamma-ray detection, the backsplash consists mainly of low-energy photons which create signals in ACD through Compton scattering.



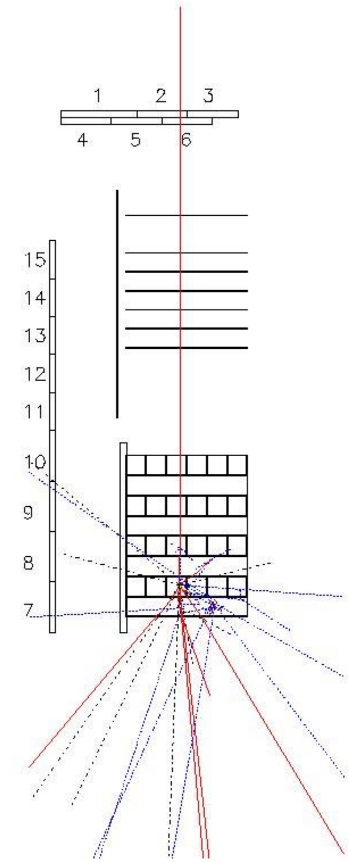
We have studied backsplash effects in application to the GLAST LAT. We know from EGRET experience that backsplash can dramatically reduce instrument efficiency for high energy gamma rays (above 20-50 GeV) if the ACD design is not adequate. The first approach was to simulate the cascade in the calorimeter and its propagation through the other detectors of the instrument, including the ACD. But we realized that we need reliable and accurate knowledge of backsplash because it drives the ACD design, and therefore decided to study it experimentally in beams, and combine those results with the simulation results.

1997 beam test at SLAC

The first our backsplash beam test was performed in the Fall of 1997 at SLAC. 15 scintillating tiles with wave-shifting fiber readout (WSF) were fabricated and tested for this experiment. The goal of the experiment was also to prove WSF technique for use in the GLAST ACD.

All tiles were made of 1 cm thick BC-408 scintillator, read out by 1 mm diameter BCF-91A single-clad fibers. The fibers in the scintillator were sitting in 1.5mm deep straight grooves spaced at 1 cm. Tile 1 is 12cm x 24cm, tiles 2 - 10 are 8cm x 24cm, and tiles 11-15 are 6cm x 24cm. The tiles are assembled in two light-tight boxes, #1 with the tiles 1-6 in 2 layers, and #2 a single layer (tiles 7-15). The boxes also contained the photomultipliers, Hamamatsu R647, one per tile.

Box #1 was placed in front of the silicon strip tracker, 50cm from the first CsI calorimeter plane; box #2 was on the side of calorimeter, 21cm from the calorimeter axis (see Atwood et al., NIM, for the detailed experimental setup). The calorimeter was 9 radiation lengths deep.



1997 beam test at SLAC (cont.)

Geometry of tiles in '97 beam test (tiles 13, 14 and 15 did not work in this test due to a readout problem). Tiles 3 and 6 are not included because they were crossed by the beam.

	Direction to tile (degrees)	Area, $degrees^2$	Area, 1000 cm^2 $degrees^2$	Solid angle from center of shower (steradian)	Correction factor for the tile thickness
Tile 1	168	239.8	69.1	0.074	1.02
Tile 2	177	167.2	32.1	0.052	1.0
Tile 4	166	154.8	29.7	0.048	1.03
Tile 5	173	165.0	31.7	0.052	1.01
Tile 7	53	674.6	129.5	0.209	1.25
Tile 8	69	1067.8	205.0	0.328	1.07
Tile 9	90	1297.1	249.0	0.390	1.0
Tile 10	115	1067.8	205.0	0.300	1.1
Tile 11	126	550	79.2	0.163	1.24
Tile 12	135	360.8	52.0	0.110	1.41

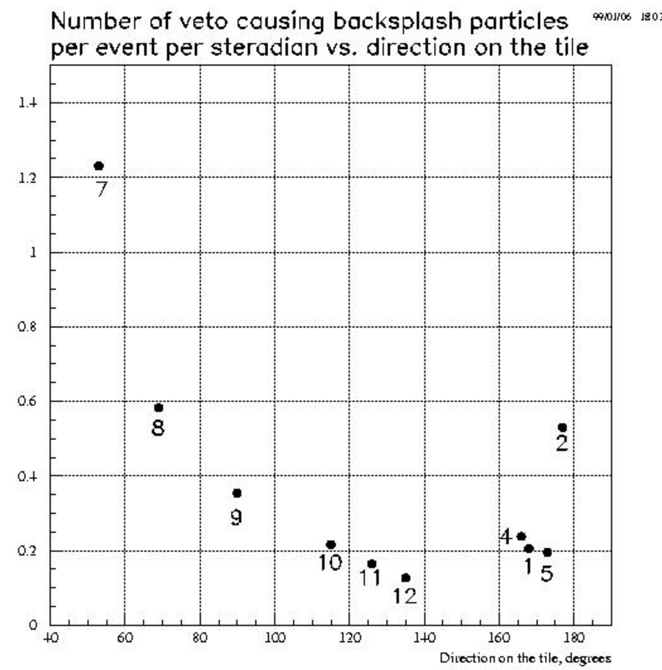
1997 beam test at SLAC (cont.)

The setup was exposed to a SLAC photon beam with maximum energy of 25-40 GeV. The events were selected as follows:

- To eliminate charged particle beam contamination, no hits were allowed in the first tracker plane (x or y layers).
- The energy of each photon was determined by a calorimeter. Events were divided into 4 energy ranges, 5-10 GeV, 10-15 GeV, 15-20 GeV, and 20-25 GeV.

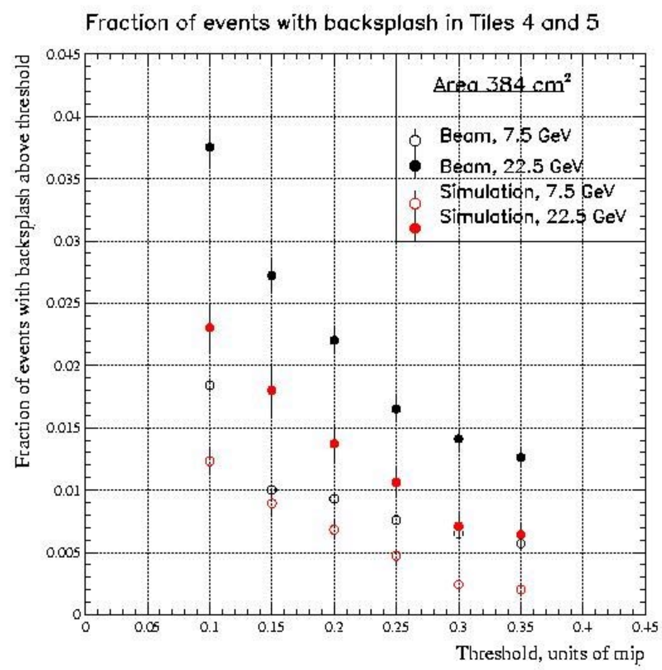
The pulse-heights from all 12 working scintillator tiles were digitized by CAMAC 2249A, gated by the beam trigger. The pulse-heights were used in units of minimum ionizing particle (*mip*), the mean pulse-height produced by a normally incident mip.

The figure shows the backsplash dependence vs. angle at which the tile is seen from the calorimeter, for a 0.2 mip threshold and photon energy 20-25 GeV



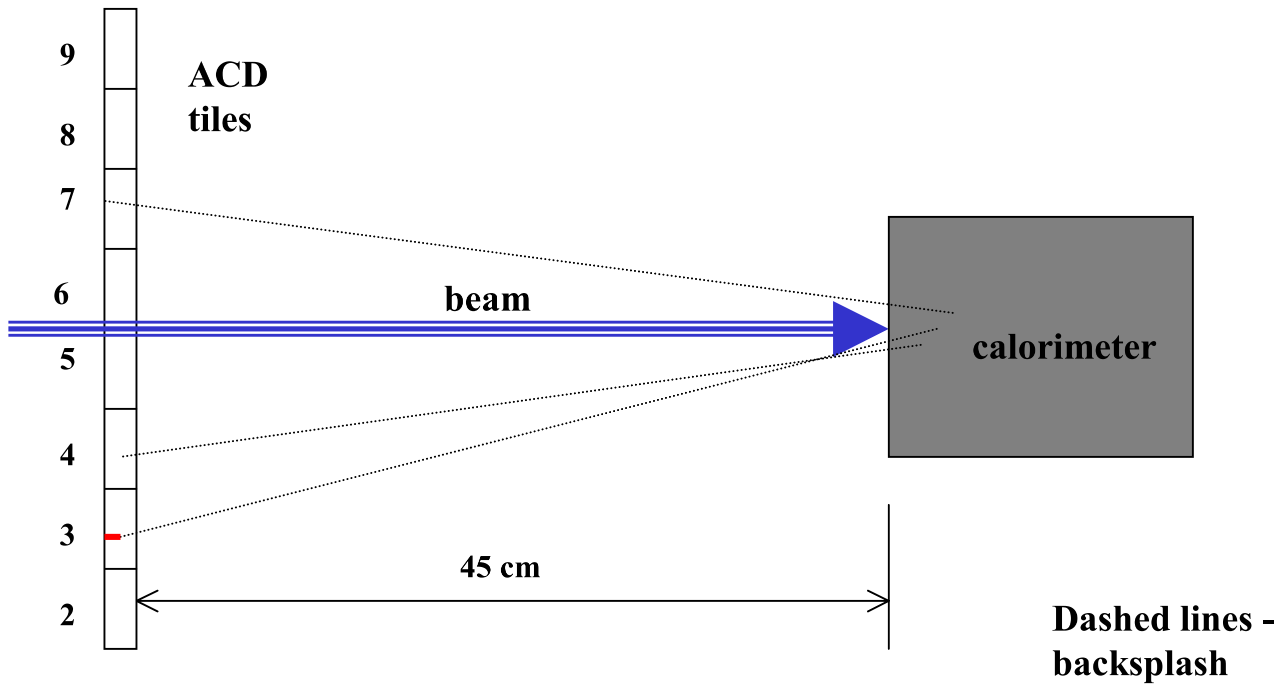
1997 beam test at SLAC (cont.)

- **The experimental results are compared with the simulations by GEANT/GHEISHA for the tiles positioned near the beam direction (tiles 4&5 combined). Experimental data are factor of 1.5-2 above those from the Monte-Carlo simulations.**



1999 beam test at CERN

- **The tiles used in 1997 beam test at SLAC were refurbished and tested at SPS CERN in the summer of 1999. The task was to measure the backsplash up to 300 GeV, which is the upper limit for GLAST. Measurements were done in both electron and proton beams. Here results are given for the electron beam, for which backsplash is the same as for photons (with the only difference that there is always a signal in the tile crossed by the incident electron).**



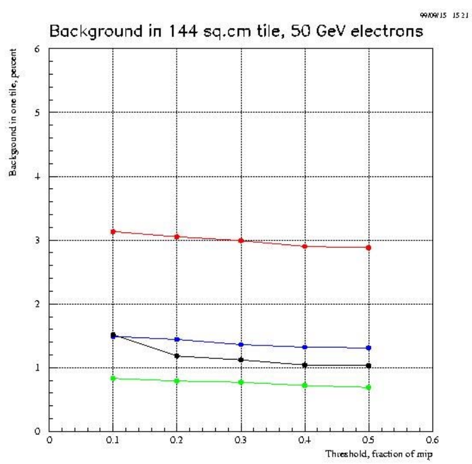
1999 beam test at CERN (cont.)

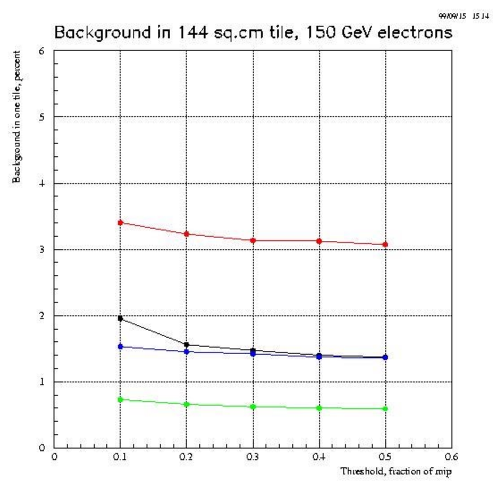
- **Measurements were done with two similar calorimeters, ICA and TTU, both of which are prototypes for the ACCESS mission.**
- **ICA calorimeter (Washington University - MSFC) is scintillating fiber - W sampling calorimeter, 25 X_0 in total depth**

- **Backsplash measurement: Pulse height measurement for each of 8 ACD tiles was gated by the beam trigger. Events for analysis were selected by energy deposited in the calorimeter.**

1999 beam test at CERN (cont.)
ICA calorimeter

- **Background measurement. In order to account for background present in the beam (which for the electron beam is mainly bremstralung photons), several runs were done without the calorimeter. In these runs, ACD tiles detected the background, to be subtracted later when deriving the backsplash from the calorimeter.**
- **The figures show the background in a single tile for 50 GeV and 150 GeV electrons.**





Background for 150 GeV is slightly higher than for 50 GeV beam due to a larger number of brem photons.

Tile 3 (black)

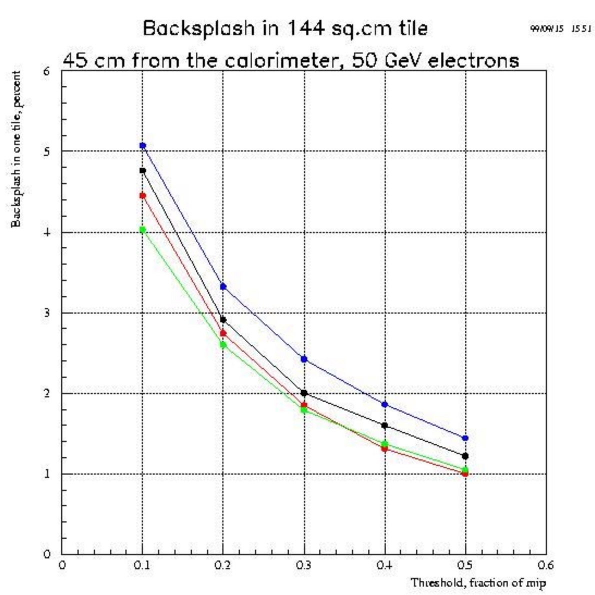
Tile 7 (red)

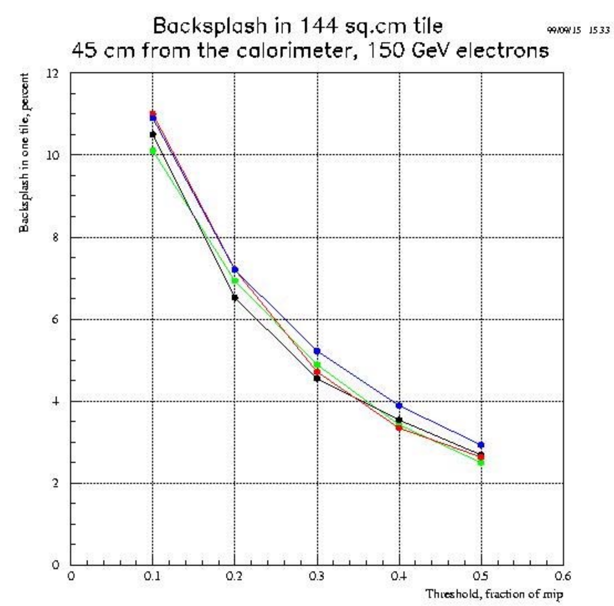
Tile 8 (blue)

Tile 9 (green)

1999 beam test at CERN (cont.)
ICA calorimeter

- **Backsplash measurement: With the calorimeter in the beam, the same measurements were done. Background previously determined was deducted from the measurements with the calorimeter, resulting in the backsplash caused by the calorimeter. The results for 50 GeV and 150 GeV electrons are given in the figures.**





1999 beam test at CERN (cont.) TTU calorimeter

- **Similar measurements were done with TTU calorimeter prototype (45 X_0 deep, with about the same geometrical size and shape), positioned 50cm from the ACD tiles.**
- **Electron beam energies were 20, 50, 100, 150, 200, 250, and 300 GeV.**
- **No runs were done without the calorimeter, so the background data from the ICA runs were used.**

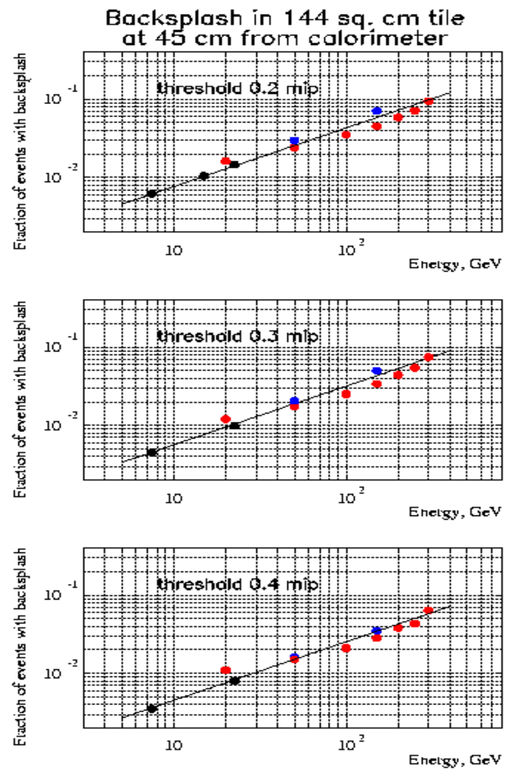
1999 beam test at CERN (cont.)

Backsplash formula

- **The data collected in the 1997 SLAC test and the 1999 CERN test were combined.**
- **We assumed that the backsplash particle originated from the shower center (maximum), which was approximately taken to be 10cm from the front plane inside the calorimeter. Backsplash particle density was assumed to be proportional to $1/r^2$, where r is the distance from the shower center**
- **Data for different ACD thresholds were fitted**
- **Energy dependence was fitted, resulting in a $E^{0.75}$ power law**

$$P_{backsplash} = \left(0.85 \times \frac{0.3}{E_{thr}} + 0.15\right) \times 10^{-3} \times \frac{A}{144} \times \left(\frac{55}{x+10}\right)^2 \times E^{0.75}$$

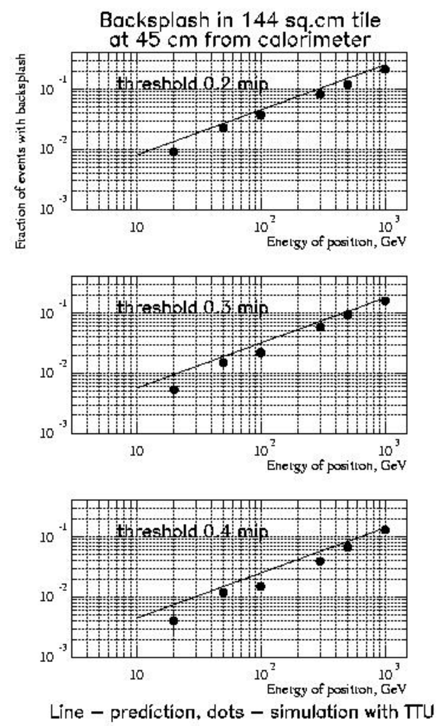
Where E is the energy of incident electron/photon in GeV
E_{thr} is the threshold value in units of *mip*
X is the distance from the top of calorimeter
A is area in cm^2
$P_{backsplash}$ is the probability that there was an energy deposition above E_{thr} in 1cm scintillator



- **- 1997 SLAC**
- **- 1999 CERN/ICA**
- **- 1999 CERN/TTU**

Comparison with simulations

- Backsplash prediction from the formula obtained was compared with simulation results. This figure shows the consistency between the GEANT3/FLUKA simulations for CERN/TTU runs and the experimental backsplash obtained for this configuration.



Remaining Concerns

- **The main concern is the backsplash dependence on distance. It requires more tests combined with MC simulations. Knowledge of this dependence is especially important for GLAST side-entering events when the path between ACD and calorimeter is short.**