Test Matrix for the Photon Beam for the LAT Calibration Unit

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1. Introduction

We used as input to this discussion the note from Steve Ritz *Verification tests for LAT PS Science Requirements, 15 March 2001.* We limit the tests to maximum energy of 10 GeV, and leave either to the Engineering Model or the Monte Carlo simulation to address values at higher energies.

The plan in the photon beam is taken using the numbers from the SLAC 1999/2000 beam test. We emphasize on runs at different incident angles since most of our events will come between 20 and 60 degrees. The discussion on the run time (number of photons) is dominated by the PSF studies. If statistics are enough for this measurement, they will be for the other parameters. **We estimate a total of 6 months in a photon beam plus and additional month for setups.** Clearly we need either to descope of find an alternative to the incoherent photon beam

2. BTEM - number of events

For the BTEM 99/00 analysis we obtained an average of 2000 Monte Carlo events per energy bin which translated into an statistical error on the PSF for 68% and 95% containment of about 4% and 6% , respectively. The **total error estimated for the Monte Carlo corresponded to 6% and 10% respectively**. For the **BTEM data** (with 400 to 1000 events per bin) the total error was estimated to be from **10 to 15%** and was probably overestimated due to incomplete knowledge on all systematic effects. Note that for the BTEM analysis we did not use tagged photons, but rather required the energy of the calorimeter and the tagger to be correlated and applied a cut on this variable. Therefore we did suffer from multiple photons. The reason for this approach was that if we had use the tagger the number of photons in each energy bin would have been down to 200 to 500 events, which is not adequate for the PSF measurements. **Therefore we claim that 5000 tagged events per energy bin is the minimum required so that we are not statistics limited**. As Steve points out the 68% containment can be checked in orbit whereas the 95% is hard to do so. Therefore to validate the Monte Carlo 95% we propose 10000 tagged events per bin. *It is desirable to run Monte Carlo simulations to check the effect of 5000 versus 10000 events per bin on the 95% containment*

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3. BTEM – number of bins

From BTEM 99/00 an average run of 200000 events at 0 degrees polar angle and 0 degrees azimuth with 2.7% radiator to generate photons, yielded 16000 reconstructed photons *(not tagged !)*. If we had required the tagger alone we would have a factor of 2 less. These were divided into many energy bins. Note that the large bins may be tolerable at higher energies because the PSF changes slowly, whereas at lower energies we may have to constrain more the bin width (requires more run time) because the PSF changes rapidly.

So 16000 reconstructed photons = 2 hours of run at 2.7% radiation length (200K triggers) this number is adequate for effective area calculations. However for the PSF the calculation the situation became worse since we used from 400 to 1000 reconstructed photons per beam.

For a 1.6 GeV incident beam we could only use 0.5% of the total number of L1T triggers in 3 energy bins with photon energies from 0 to 600 MeV where the highest bin had a factor of 2 less statistics than needed for a reasonable measurement (reasonable is defined as 1000 photons).

For a 5 GeV incident beam we could only use 0.6% of the total number of L1T triggers in 6 energy bins with photon energies from 800 MeV to 2800 MeV. At this time the statistics were adequate

For a 20 GeV incident beam we could only use 0.6% of the total number of L1T triggers in 2 energy bins with photon energies from 3 GeV to 6 GeV. The last bin had barely enough statistics.

The numbers discussed here assume the PSF 68% for the front section of the tracker (smaller effective area than that at the back)

4. BTEM – run time

Based on the discussion form the previous section our reference for the calculations will be

1h of beam = 100 000 L1T triggers for 2.7% radiator thickness

Typically we had **a little less than 1 e/pulse.**

For the BTEM we obtained

20 MeV = 1000 photons = 8 hours of beam = 800 000 L1T triggers (comfortable)
100 MeV = 1000 photons = 8 hours of beam = 800 000 L1T triggers (lower limit)
1 GeV = 1000 photons = 4 hours of beam = 400 000 L1T triggers (comfortable)
10 GeV = 1000 photons = 16 hours of beam = 1 600 000 L1T triggers

Since we need 5000 events per bin the number above shall be multiplied by 5 leading to

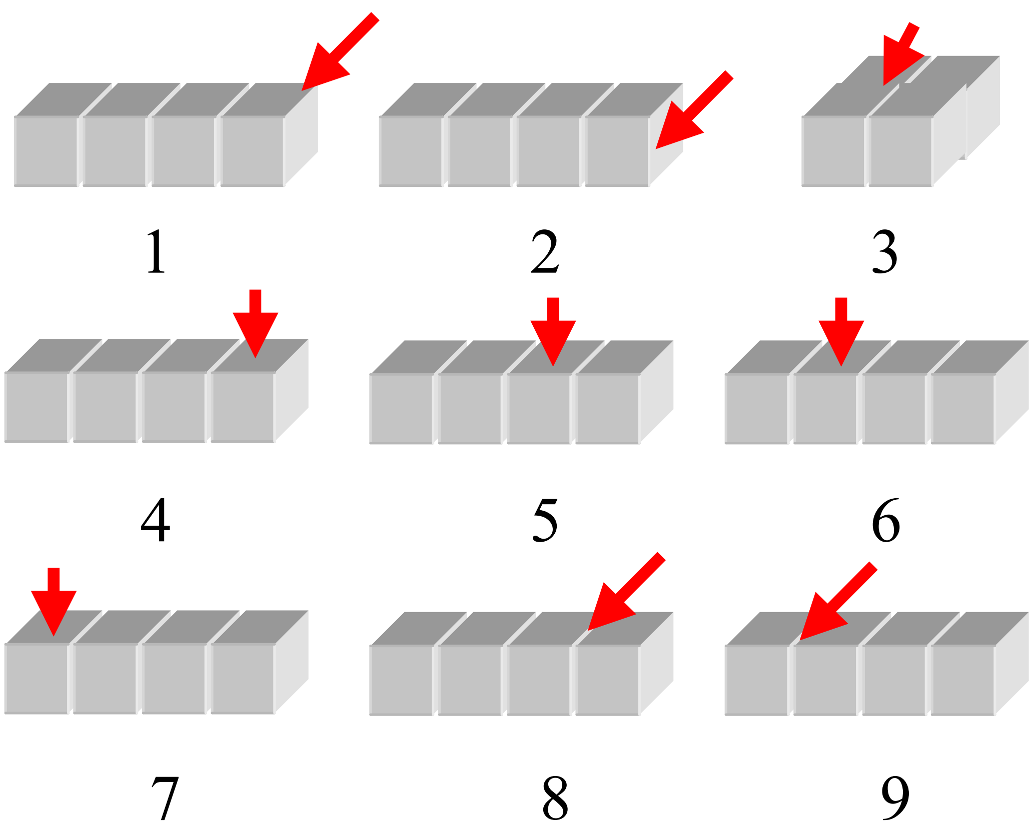
20 MeV = 5000 photons = 40 hours of beam = 4M L1T triggers (comfortable)
1100 MeV = 5000 photons = 40 hours of beam = 4M L1T triggers (lower limit)
1 GeV = 5000 photons = 20 hours of beam = 2M L1T triggers (comfortable)
10 GeV = 5000 photons = 80 hours of beam = 8M L1T triggers

The 10 GeV bin deserves a comment, most of the useful statistics were below 5 GeV for an incident beam of 20 GeV. One could increase the beam energy to 30 GeV and try to get more statistics closer to the 10 GeV bin. We will assume a conservative approach and stay with the assumptions above.

If we lose any run (it happened in the beam test) the statistics may be compromised so we will add another 2 hours of run for every energy setting. **So for 4 energy bin we need 188 hours (~8 days) at a fixed polar and azimuth angles.**

5. Configurations

There are 9 configurations we envisage adding up to 64 points for the test matrix if we take into account proposed energy and angles (see Appendix).



1. 4 energies and 5 polar angles , 0 azimuth , impact point with respect to the top corner of the tower at the end of the 1 x 4 stack = 5 x 188 = **940** hours of beam.
2. 4 energies and 5 polar angles , 0 azimuth , impact point 30 cm (TBR) below the top corner of the tower at the end of the 1 x 4 stack = 5 x 188 = **940** hours of beam.
3. 4 energies and 5 polar angles , 22.5 azimuth, impact point with respect to the top corner of the tower at the center of the 2 x 2 stack = 5 x 188 = **940** hours of beam.
4. 4 energies and 1 polar angles (0), 0 azimuth, impact point at center of tower 1 = **188** hours of beam.
5. 4 energies and 1 polar angle (0) , 0 azimuth , impact point at center of tower 2 = **188** hours of beam.
6. 4 energies and 1 polar angles (0), 0 azimuth , impact point at center of tower 3 = **188** hours of beam.
7. 4 energies and 1 polar angles (0), 0 azimuth, impact point at center of tower 4 = **188** hours of beam.
8. 4 energies and 1 polar angles (20), 0 azimuth , impact point at the center of first two adjacent towers 1 x 4 stack or 2 x 2 stack = **188** hours of beam.
9. 4 energies and 1 polar angles (20), 0 azimuth , impact point at the center of last two adjacent towers 1 x 4 stack or 2 x 2 stack = **188** hours of beam.

6. Run time planning

From the previous section the total number of hours needed = **3760 hours (157 days**). As happened for the beam test some runs were not useful due to technical problems so I will add some 20% contingency here to bring this number **to 4512 hours = 188 days** assuming **beam is up ~ 80% of the time.**

Now we sum it all up to get **7 months for the photon beam only.**

Here is the time estimated

- 6 months run time in a beam
- 2 weeks to safely change from 1 x 4 to 2 x 2 configuration.
- 1 week to debug beam line
- 1 week to debug instrument and DAQ.

Note that we used a 2.7% radiator in the beam line, it is desirable to use 1% and this will increase the beam time by a factor of 2. If we need two points to apply the same correction method for the PSF (used in BTEM 99/00) then we need a factor of 4 in beam time.

7. Discussion

To reduce the run time we can

1. Reduce the time it takes to change between two possible configurations 1 x 4 and 2 x 2 to save 168 hours
2. eliminate 2 x 2 configuration to save 524 hours
3. use a coherent beam , we could probably could reduce the run time by a factor of 3
4. eliminate a 2 hour run added as a back up for every run to save 128 hours
5. use 2500 reconstructed tagged photons instead of 5000 to reduce the run time by a factor of 2
6. run the beam at > 20 GeV to get more events in the 10 GeV energy bin
7. Study if there is anything that could be learned on cosmics ? Effective area ?
8. reduce number of configurations

But run time will also increase if

9. we assume the same efficiency as we had for the previous tagger/reconstruction (factor of 2 increase)
10. We decide to run more at angles where we expect more data (between 20 and 60 degrees) ?
11. In case we stay in the incoherent beam, we may consider to get PSF with 1% radiator instead of 3% to minimize contamination (factor of 2 increase in time)
12. The method of having different radiators so that we understand how to correct for the target is excluded by time constraints background rejection needs.

APPENDIX

A.1 Polar Angle

We choose 5 angles for the baseline program 0, 20, 40, 60 and 70 degrees. The largest angle proposed before was 80 degrees but we feel we need to look at Monte Carlo events to justify that at this angle we can make use of the events. So we propose to this committee to use 70 degrees instead. The 60 degree angle was motivated by having ½ of Effective Area on axis at 55 degrees. Since there are uncertainties in that , we rounded the number for practical reasons. The justification for 20 and 40 degress is because most of our events will be between 20 and 60 degrees and 3 data points in this range give us enough confidence for extrapolations.

A.2 Azimuth

We propose 2 angles as a baseline. 0 degrees and 22.5 degrees since the instrument has a symmetry around 45 degrees. Let';s leave the 3rd point as optional if we have time.

A,3 Impact point

The impact point at the top of the last tower in the 1 x 4 configuration should be the baseline. We would like to check at 0 degrees every tower, hitting at the center so that we can prove that the performance of modules is actually reproducible. One more impact point would be 20 degrees (TBR) in between 1st and 2nd and 3rd and 4th towers in the 1 x 4 stack, so that one can evaluate how much the effective area reduces as we reach the boundaries of each tower. In addition we need another configuration with the impact point below the top of the corner of the tower (maybe 30 cm TBR) to understand the effects when effective are starts to drop. It is important that we simulate that in the Monte Carlo as soon as possible.