Memo on FPPA specifications.

C. Seez, 5 August 2002

All simulation plots produced by A. Nikitenko

Introduction

During the last ECAL Week (July 2002) it was formally decided to proceed with a fallback FPPA design in 1/4 µ technology. In view of this development a few possibilities for modifying the specification of the FPPA have been suggested. This memo presents related simulation results and arguments, and summarizes conclusions. Briefly, the spec should remain largely unchanged.

Dynamic range

The best current estimate of barrel crystal output from twin APDs is 6 p.e./MeV [1]. Using the nominal gain of 50 for the APDs, one obtains a charge of 48 pC for 1 TeV.

To arrive at a figure for the maximum charge to be accepted by the FPPA it is reasonable to assume that for the top end of the dynamic range we are interested only in electron and photon physics (i.e. we do not considering damage to jet energy measurement or missing E_T measurement). The obvious channel to consider is a massive Z’ decaying to two electrons. The discovery limit at LHC for such an object is about 3 TeV/c^2. The energy deposition in the crystals can be modelled using the simple distribution shown in Fig. 1, which shows the probability for the maximum crystal in a shower to contains a given fraction of the energy contained in a 5x5 array of crystals. This distribution is obtained by approximating what is found in full simulation of unconverted photons is the barrel. The probably falls approximately linearly from 80% to 30%, with the probability of 80% being approximately twice that at 30%.

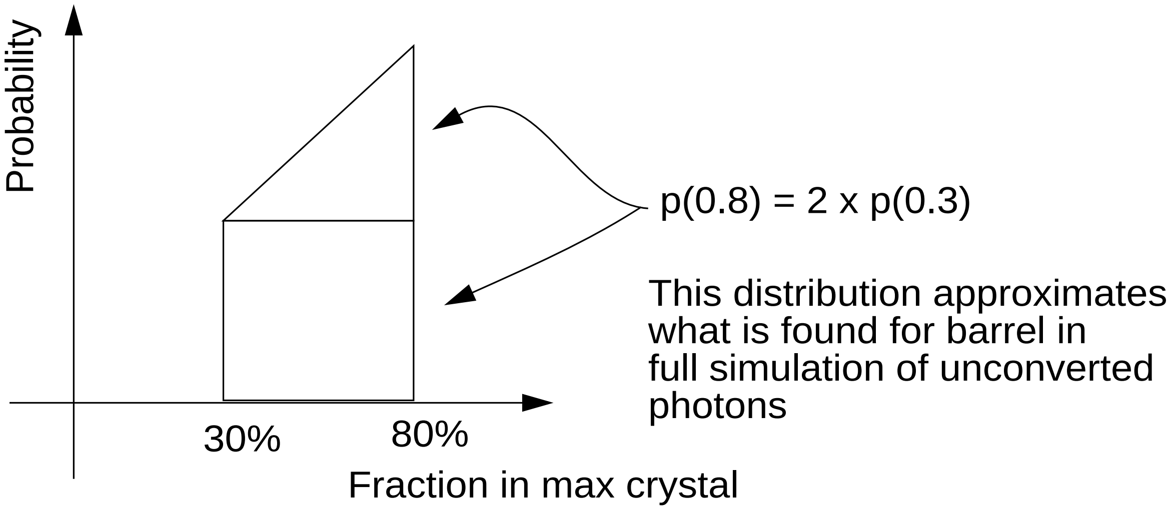

Fig. 1: Probability for the maximum crystal in a shower to contains a given fraction of the energy contained in a 5x5 array of crystals

The energy of electrons coming from heavy Z’s, with masses $m_{Z'} = 2$, and 3 TeV/c^2 generated with Pythia have been convoluted with this distribution. Fig. 2 shows the probability that a Z’ event contains a barrel electron with an energy greater than a given cutoff, E_{cut}. It can be seen that it is not possible to relax the FPPA specification of 60pC for the full range if the fraction of 3 TeV Z’ events containing an electron which saturates the FPPA is to be kept small.

In the endcap the mean charge output from the VPT will be less than 5pC/TeV. So it is not necessary to consider the endcap upper cutoff in any detail.

It is worth remarking that the specification for linearity in the top half of the FPPA range need not be constrained to the very tight specification which has been demanded for lower energies. There will be, in any case, a non-linearity of ~3%, between 0.5 and 1 TeV, coming from longitudinal shower leakage.

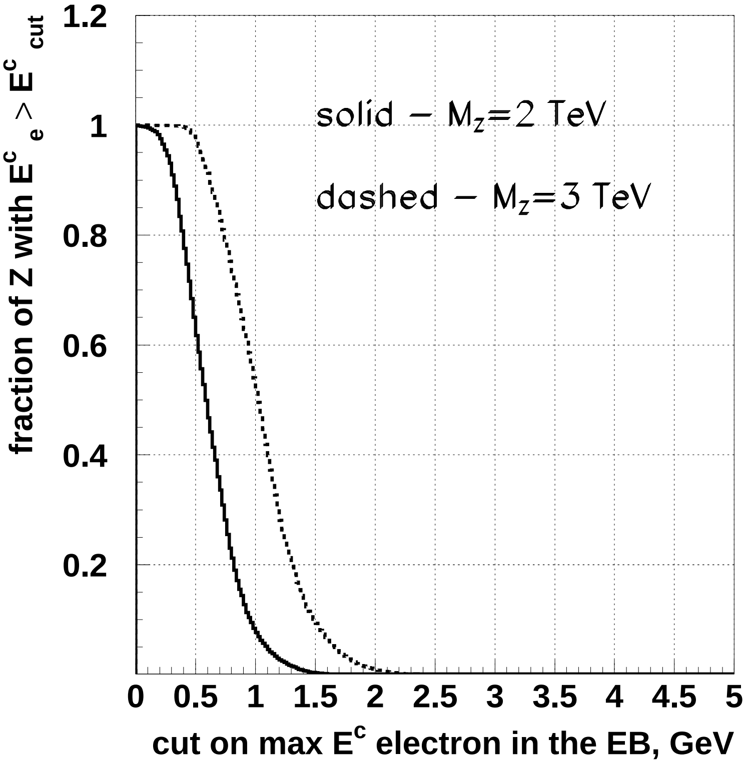

Fig. 2: Probability that a Z’ event contains a barrel electron with an energy greater than a given cutoff, E_c

Change of range

In view of possible problems associated with change of range, it might be of some advantage if all precision physics could be fitted into the first (highest gain) range. To obtain some indications on this question, $H\rightarrow\gamma\gamma$ events were simulated using Pythia, for m_H = 120 and 150 GeV/c^2. The same energy deposition approximation was used. Fig. 3a shows the probability that a barrel photon in a $H\rightarrow\gamma\gamma$ event (after standard kinematic cuts) has an energy greater than a given cutoff, E_{cut}. If the mean LSB size is set to be 40 MeV (i.e. equal to the noise spec), and the range is considered to be 3500 counts (assuming a pedestal of ~500 counts, and no margin at the top of the range — since choice of ADC used would be after digitization), then the top of the highest gain range is 140 GeV. A very small fraction of unconverted photons from $H\rightarrow\gamma\gamma$ events would require a change of range. There is even some margin for the ~20% spread of photo-electron yield. Provided that the digitization noise is not significantly larger than 1 LSB, this is a desirable configuration.

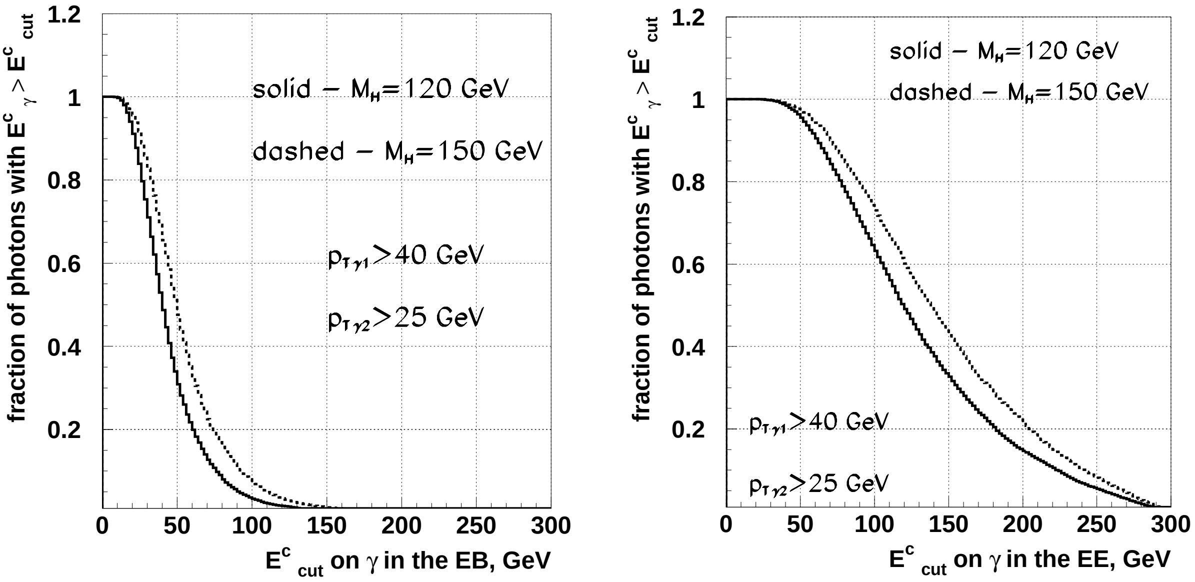

Fig. 3: Probability that a photon in a H→γγ event (after standard kinematic cuts) has an energy greater than a given cutoff, E_{cut} for a) barrel photons, b) endcap photons

Fig. 3b shows the equivalent result for the endcap. Taking a mean LSB of 150 MeV and a range of 3500 counts would put the top of the highest gain range at 525 GeV. Clearly there is room for a smaller LSB (~100MeV ?) even if the large (~30%) spread of endcap charge yield is borne in mind.

Endcap noise

A recent draft memo circulated by Dave Cockerill raised questions about the encap noise specification. A noise figure of 150 MeV was used in the ECAL TDR H→γγ performance simulation, giving a noise performance in the endcap at |η|=2 similar to the barrel value of 40 MeV when expressed in E_T. The current best estimate for mean VPT charge output in a field of 1.8T is 34 e/MeV. Table 1 shows the further factors which degrade this (at high luminosity). The combined factors, excluding the crystal light yield loss, give an overall factor of 0.9 x 0.9 x 0.95 x 0.9 = 0.69.

Table 1: Factors resulting in reduction of VPT charge output

Source of reduction	factor
VPT in 4T field	0.9
VPT run at reduced HV	0.9
VPT faceplate “early darkening”	0.95
VPT burnin	0.9
Crystal light yield loss (high luminosity at h=2)	0.76

The expected crystal light yield loss, at high luminosity, varies with |η|. Table 2 shows the mean factor for this loss for different |η| values between |η|=1.6 and |η|=2.5, (in column “crystal loss”). To minimize noise, expressed in E_T, the VPTs can be selected so that the highest gain tubes are at smallest |η|, reserving the very worst for |η| > 2.5. The column “VPT factor” estimates the factors, relative to the mean output, that could be obtained by selecting from the distribution (which was included in Dave’s memo) in this way. Then multiplying the 34 e/MeV by the three factors — 0.69, the crystal light yield loss, and the VPT factor — gives the resulting signal charge per MeV shown in the table. In the final two columns, this signal charge is converted to energy equivalent noise and transverse energy equivalent noise, assuming the standard FPPA spec of 3500e noise. In terms of energy the noise rises from 120 to 330 MeV. In terms of transverse energy the noise is close to 50 MeV over the entire |η| |η|range. These values seem very acceptable for high luminosity performance.

Table 2:

η	**1/sinθ**	**crystal loss**	**VPT factor**	**charge/ MeV**	**3500e E^{noise}**	**3500e E_T^{noise}**
1.6	2.58	0.87	1.40	28.6	122	47
1.8	3.11	0.83	1.18	23.0	152	49
2.0	3.76	0.76	1.00	17.8	197	52
2.2	4.57	0.73	0.82	14.0	250	55
2.5	6.13	0.70	0.65	10.7	327	53

References

[1] CMS NOTE-2000/009