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Proposal to replace the Central Preshower Detector and Central Crack Chambers with an integrated scintillator detector (CPR2)

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Abstract

We propose to replace the Central Preshower (CPR) and Central Crack (CCR) detectors with an integrated scintillator detector. This would happen when the silicon detector is replaced for Run IIb. The CPR performance is expected to degrade significantly due to the combination of high occupancy and integrating over several crossings. Reusing existing electronics, it is possible to replace both the CPR and CCR with a much improved, scintillator detector for $350-500K.

1 Executive Summary

We propose to replace the Central Preshower (CPR) and Central Crack (CCR) detectors with an integrated scintillator detector. This would happen when the silicon detector is replaced for Run IIb. There are many reasons to do this. 1) The CPR is a slow wire chamber that integrates over several crossings and has relatively poor segmentation. This combination will lead to very high occupancies in Run IIb, crippling electron and photon identification. 2) Even with modest occupancies in Run IIa, the current CPR segmentation makes it difficult to use in more sophisticated analyses such as improving jet resolutions. 3) With 10 fb^{-1} the CPR is expected to have collected 0.1 C/cm, where wire aging has typically caused significant degredation in performance, sometimes beginning much earlier. 4) The thin gas layers of the CPR and CCR have much worse pulse height resolution than a scintillator detector, which is important in electron identification and improving resolutions with a dead material correction. 5) We have an opportunity to build a much better detector for a small cost, \$300-400K. This is possible because we intend to reuse the Run IIa electronics and perhaps use Minos scintillator and other components for the detector.

2 Run I Physics Using the CPR and CCR

There are four potential uses for preshower detectors such as the CPR: 1) improving electron identification, 2) separating single photons from meson backgrounds, 3) improving electron and photon resolutions by correcting for dead material, and 4) estimating the energy deposited in the EM calorimeter by charged hadrons. The CPR has been used extensively in electron identification in CDF. It provides about a factor of two to three more rejection of charged pions that pass all other cuts using tracking, calorimetry, and shower maximum information. This extra rejection has been crucial in soft electron ID for b jet tagging, as was shown in the first top evidence paper and displayed in figure 1.

Secondly, the CPR has been used in numerous publications involving photon identification. The shower maximum detectors cannot resolve single photons from meson decays above 35 GeV since the angular separation between the two photons is too small. The CPR uses photon conversion rates which are energy independent. It was used initially to extend the QCD measurement of direct photons by more than 100 GeV in photon P_T, as shown in figure 2. More recently the CPR has been used to estimate backgrounds to signals of exotic physics that include photons. New physics is expected to come at higher P_T, the shower maximum detector cannot do this. It is crucial to maintain this capability for possible new signals in Run II. As the next section will show, with the luminosities possible in Run IIb, the occupancy of the current detector will be too large for photon identification.

The third possible use for a preshower detector is to improve electron and photon energy resolutions by correcting for dead material losses. This has not been done in CDF due to the relatively poor energy resolution of a thin gas detector. In the ZEUS experiment, their scintillator preshower detector has been used to correct for soft photon energy losses in jets, and improve their jet resolution by an impressive 17%[1]. Improving jet resolutions will be important in finding various new physics signals such as the Higgs.

Finally, a preshower detector can be used in other ways to improve jet resolutions in

algorithms incorporating charged tracking. Since the tracking resolution is so much better than the calorimeter, the main challenge is to estimate the remaining electromagnetic component of the jet. Charged tracks complicate this since they shower in the EM calorimeter, whereas preshower detectors can be used to estimate this contribution to the EM energy. The current CPR detector makes this difficult since a single cell spans five calorimeter towers, possibly collecting showers from other particles in the jet. A preshower detector where each cell is confined to a single calorimeter tower, such as the one in this proposal, is desirable for this purpose.

The current CDF central crack chambers (CCR) have not been directly involved in a CDF publication, but they have been checked for large pulse heights in all of the rare events CDF has observed. Their lack of use has been more due to a lack of software tools than their intrinsic usefulness. This was recently illustrated by looking for a Z peak in dielectron events where one electron goes into the crack[2]. Figure 3 shows a comparison of the Z peak when using the electron + track 4-vector and when one uses the electron + crack energy 4-vector. This shows the capability of tagging high energy photons in the crack detector in events of new physics. The crack covers about 8% of the central detector, and in events with multiple EM objects such as the famous $ee\gamma\gamma Met$ event the possibility of one object hitting the crack is quite high. If we are lucky enough to get a sample of such events then doing measurements of this physics will require crack tagging of photons. Irrespective of the source of this single event, if SUSY is producing signals with photons, as some suggest, there will be a large variety of new physics with photons and missing E_T and other objects. Crack tagging of high-energy photons will be even more important. The current crack chamber is a very thin gas layer that would be much improved with a scintillator replacement and it could be integrated with the new preshower detector.

The CDF preshower and crack detectors are expected to play important roles in Run II physics such as soft electron tagging of b jets, photon identification in SUSY events or other new physics, and improving jet resolutions for mass bump searches such as the Higgs. The next section will explain why the CPR in particular will be severely degraded or completely useless in the high-luminosity Run IIb era.

3 Occupancy Issues

The occupancy and segmentation issues discussed in this section are only relevant for the preshower detector, the crack chambers are not sensitive to MIPS or soft photons like the CPR and the proposed crack chambers have the same segmentation as the previous ones. The CPR is a slow wire chamber and based on early results from the engineering run it appears that integrating over three or four crossings will be needed. One concrete example of a problematic scenario is if peak Run IIb luminosities reach $6\text{x}10^{32}$ with 108 bunches and 132ns spacing. This gives rise to 5 minimum bias events per crossing, with the CPR integrating over 4 crossings it is integrating over 20 minimum bias events! A second concrete example is the TDR example of luminosities reaching $2\text{x}10^{32}$ but with 36 bunches and 396 ns spacing. This gives 6 minimum bias events per crossing, but with the CPR only integrating over two crossings in this case, the total is 12 minimum bias events per crossing. With these two examples it is possible to extrapolate to any other possibility. We present

figure 4 as evidence of the serious difficulties the CPR could have in Run IIb. The top plot in figure 4 shows the run Ib pulse height distribution from photons above 35 GeV. The way to identify photons at high P_T is to count the fraction of events in the zero bin, since single photons convert less often than multiple photons. In the bottom plot, we took random towers in Run Ib W events (ignoring the electron towers) and overlapped CPR pulse heights from seven of these. Since in Run Ib the average number of interactions per crossing was 1.5, this corresponds to 10 minimum bias events. But since W events are more energetic than the typical minimum bias event (by roughly 50%), this plot falls in between the two examples given above. The occupancy of the CPR is 85%, and there is no discrimination possible between these two plots, rendering the CPR completely useless for photon identification under these conditions. Similar difficulties arise for electron identification. Obviously there is a continuous degradation of performance with increasing luminosities, here we have only mapped out one possibility. But it shows that the occupancy problems in Run IIb are real.

4 Upgraded Detector Design for Run IIb

The relatively limited budget available for the Run IIb upgrades necessitates a limited budget for the CPR upgrade. In this spirit, we plan to re-use the existing electronics channels currently employed in the readout of the existing CPR and CCR detectors, thus removing one of the largest components of the cost for any new detector system. At the time that the present CPR was constructed, the technology did not exist for the convenient design of a scintillator-based device to fulfill the same purpose. In the intervening years, advances in the production of wavelength-shifting and clear plastic optical fibers have allowed for the design of scintillator detectors with WLS fiber readout with almost arbitrary segmentation and essentially complete hermeticity. Such a design has already been implemented in CDF in the plug electromagnetic and hadronic calorimeters and in the plug preshower detectors, as well as in many other experiments such as CMS and MINOS.

The new CPR will be placed in the space currently occupied by the old CPR and CCR. The basic design of the new CPR involves scintillator strips, segmented in η and in ϕ, read out by WLS fibers embedded in a groove in one surface of the scintillator. After exiting the strips, the WLS fibers will be routed to the high eta edge of each wedge, where they will be glued into a number of plastic shell optical connectors. The light signals will be routed from these optical connectors through the gap between the central and endwall calorimeters to the back of each wedge of the central calorimeter. There the light signals from each fiber will be coupled to the pixels of the MAPMT's.

Reusing the electronics for CPR/CCR implies two SMD cards per wedge or 64 channels. Since the CCR cards are only half occupied, this would be reduced to 48 channels if spares are not available. A possible design for the 64 channel case would be to retain ten CCR channels and allocate six to each of the nine fiducial calorimeter towers. Tower-based information could be used in the optimized jet resolution algorithm. If the six panels per tower were overlapped, one could reach eleven ϕ bins per wedge, at the expense of a larger occupancy. These tradeoffs of position resolution versus occupancy will be studied early in Run IIa before the CPR2 design is finalized.

4.1 Scintillator

The amount of scintillator needed for the new CPR is relatively modest, of the order of 50 m^2. The maximum thickness of the scintillator in the crack region is 0.7 cm due to spacial constraints, while in the rest of the detector the scintillator will be at least 1 cm thick to improve light yield. We are currently exploring several options for the procurement of the scintilator needed, with an eye to optimize both the performance and the cost. The three options are: 1) MINOS scintillator, 2) ITEP Group scintillator, and 3) Bicron scintillator.

MINOS has adopted the technology of (polystyrene-based) scintillator strips read out by WLS fibers for both their near and far detectors. Because of the large volume of scintillator needed, they have chosen the technology of extruding their scintillator into strips of width 4.1 cm and thickness 1 cm with a groove for a 1.2 mm diameter fiber running along one of the large surfaces of the strip. Each strip is coextruded with a TiO2 coating which serves both to trap the light inside the scintillator as well as allowing for much greater durability and ease of handling. MINOS will produce a total of 700,000 m of extruded scintillator of this type. Our requirements will be less than 0.2% of this total. The strip width being used for MINOS may not be optimal for the CPR. A change of extrusion size is easily possible with the production of a new die, at the cost of \$5-10K. The new CPR will require approximately 500 kg of polystyrene at a cost of \$5/kg. The WLS dyes needed to dope the polystyrene will cost an additional \$10K. The TiO2 will cost \$2K and the cost for producing the extrusion will be on the order of \$3K. Testing and handling will add another \$20K, leading to a total cost of less than \$50K.

The Russian ITEP group on CDF has the ability to produce 1 cm thick scintillator either by the processes of extrusion or injection molding. The scintillator brightness typically is on the order of 70% of that of Bicron BC404. The cost for production is not currently available but should be cheaper than Bicron.

The third scintillator option is to purchase 1 cm thick scintillator sheets from Bicron of approximate size 0.75 X 2.5 m^2 and then to cut and polish the scintillator strips using the existing facilities in Lab 8. At the same time, a groove for the WLS fiber would be machined. The cost for the scintillator sheets would be approximately \$60K. This is the most expensive option but is still a relatively small fraction of the total detector cost and is available if the other two options do not work out.

4.2 Phototubes

The readout of the detector would be by the use of multi-anode PMT's (MAMPT's). The current choice would be to use the R5900 tube manufactured by Hamamatsu, which is the same tube used for the endplug shower maximum detector. This is a 16 channel device with pixel size of 4.5X4.5 mm^2. With one fiber per pixel, each wedge of the CPR would require 4 MAPMT's, for a total of 192. If we allow for approximately 5% spares, then the total need would be for approximately 200 MAPMT's. The cost for an order of this size from Hamamatsu is on the order of \$1500/tube, for a total of \$300K. However, MINOS is ordering a large number of these phototubes (on the order of 1500) at a cost of \$700/tube and it may be possible to tie the CDF order into theirs, leading to a cost of the order of \$150K. Each tube will also require a base and mounting at an additional cost of \$100/tube, making the

total cost between $160K and $320K depending on whether we can order with MINOS. We are also exploring the option of using a 64 channel MAPMT produced by Hamamatsu.

4.3 Cost Summary

The cost estimate of this detector varies significantly depending on how much we can benefit from the MINOS production lines in both scintillator and phototubes. If both detector and readout can be tied to MINOS the total cost of scintillator + phototubes will be about $200K. In addition, design and R&D is $50K. Labor costs for detector construction are estimated to be $100K, leading to a total cost of $350K. If neither the detector nor readout can be tied to MINOS then the cost is expected to be closer to $500K.

4.4 Schedule

R&D/Final Design	Jan 2001 - Dec 2001
Construction	Jan 2002 - Dec 2002
Phototube Procurement	Oct 2002
Phototube Testing	Jan 2003 - Dec 2003
Installation	Run IIB Shutdown

References

[1] S. Magill/ZEUS talk at CALOR2000

[2] CDFNote 4798

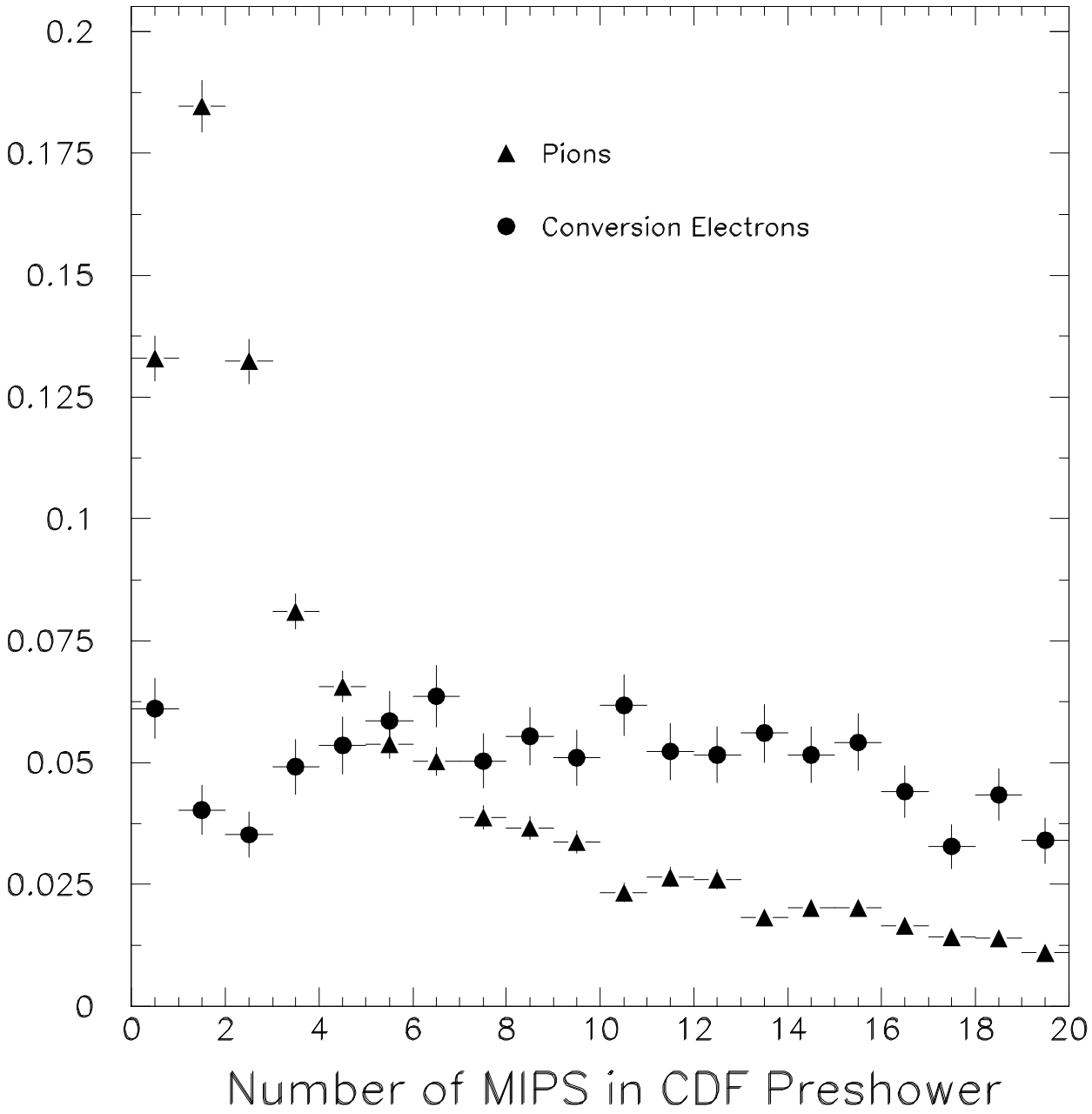

Figure 1: CPR response to electrons and charged pions as shown in the top "evidence" PRD.

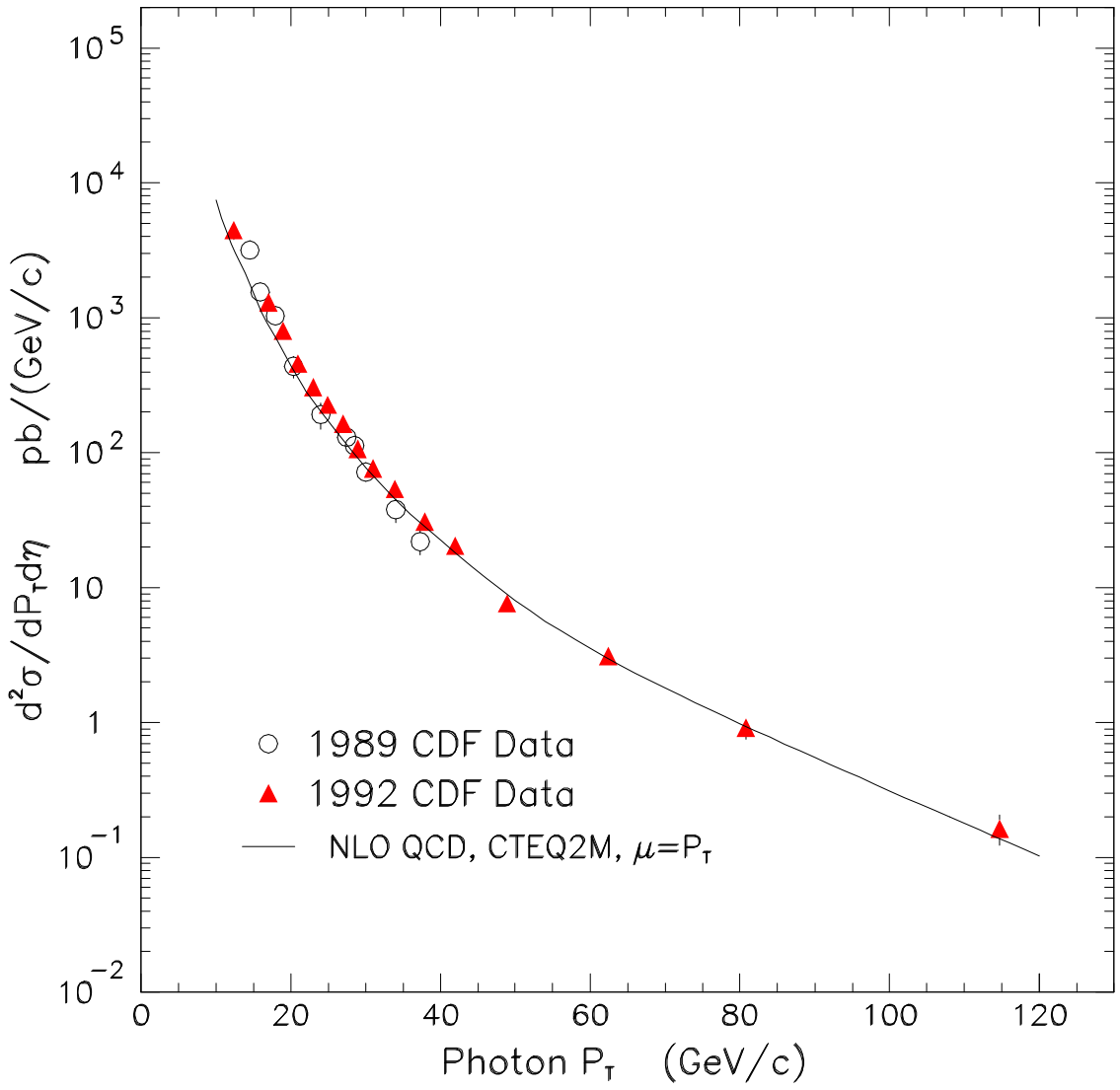

Figure 2: Direct photon cross section from 1989 (before CPR installation) and from 1992 using the CPR. The cross section was extended by almost 100 GeV in photon Pt.

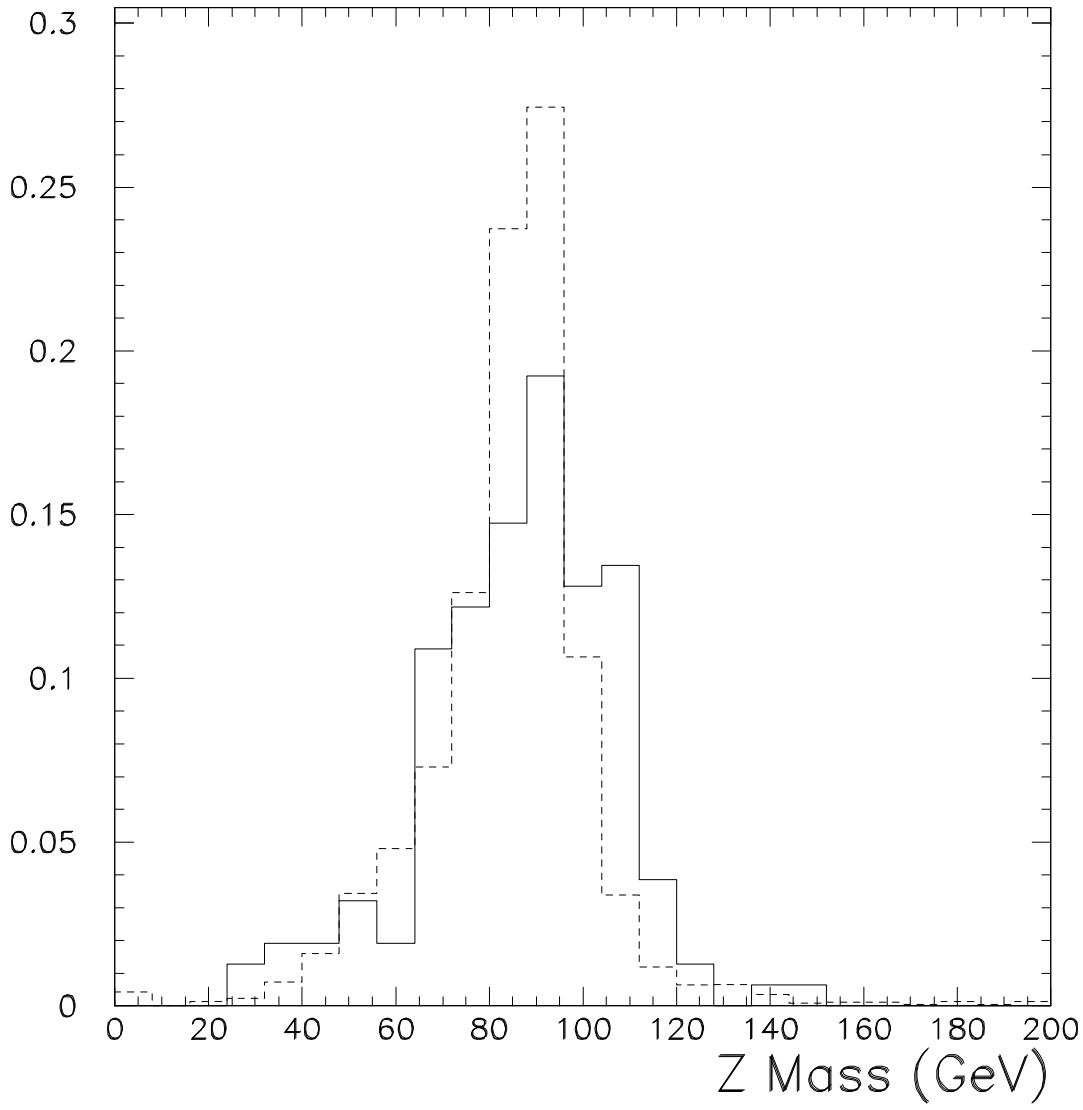

Figure 3: Dashed line is Z peak using electron + track, the solid line is electron plus Crack Chamber pulse height for electrons that went into the ϕ crack.

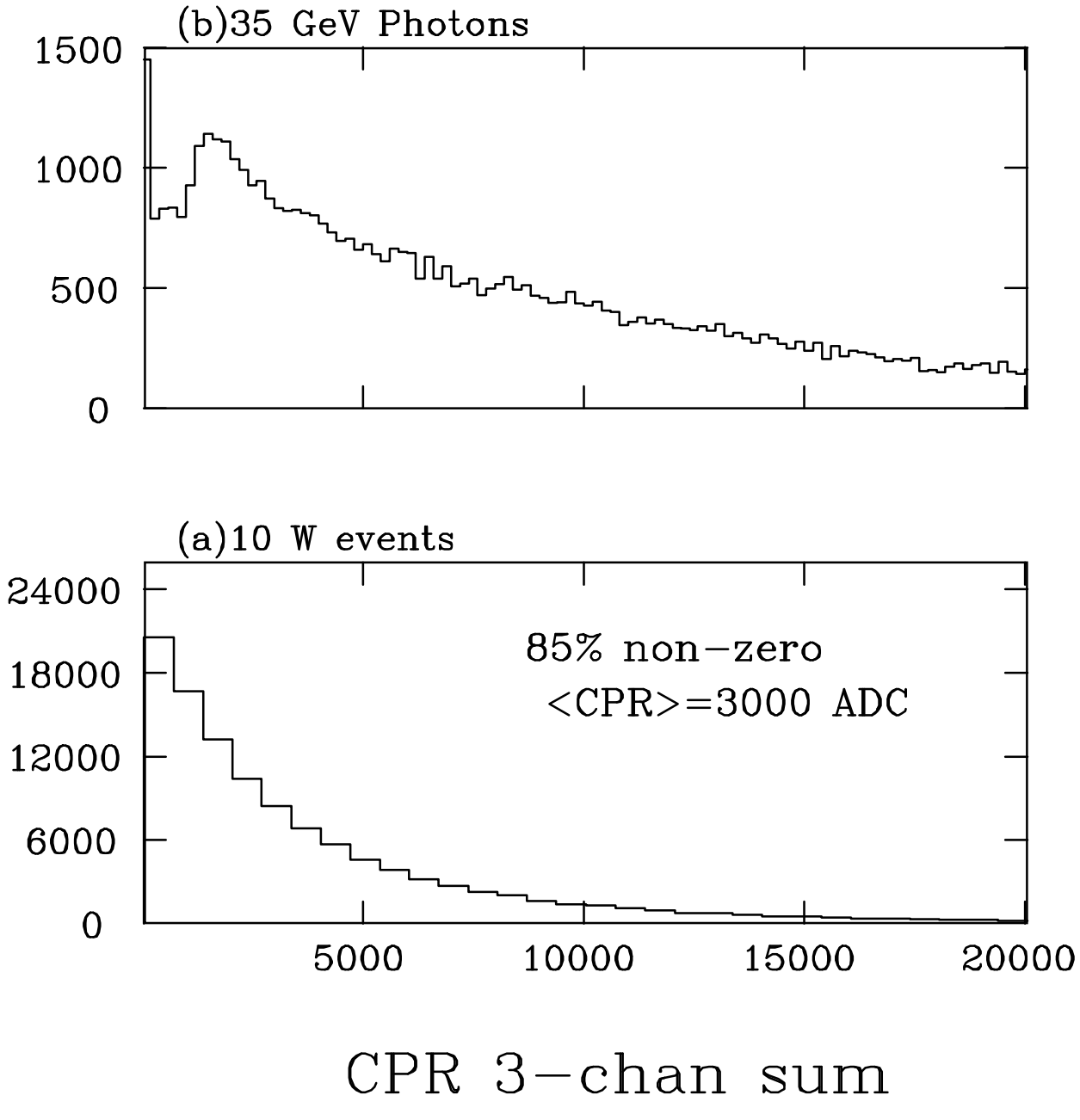

Figure 4: CPR run 1B pulse height distribution for 35 GeV photons (top), compared to an estimated underlying event pulse height distribution at high luminosity. (see text for explanation). The photon cross section is derived from counting the fraction in the zero bin. The 85% occupancy of the estimated underlying event will make this very difficult.