The CDF Calorimetry Upgrade

Steve Kuhlmann, Level-2 Manager
Joey Huston, Preshower Level-3 Manager
Dave Toback, Timing Level-3 Manager

Run IIB Upgrade Temple Review

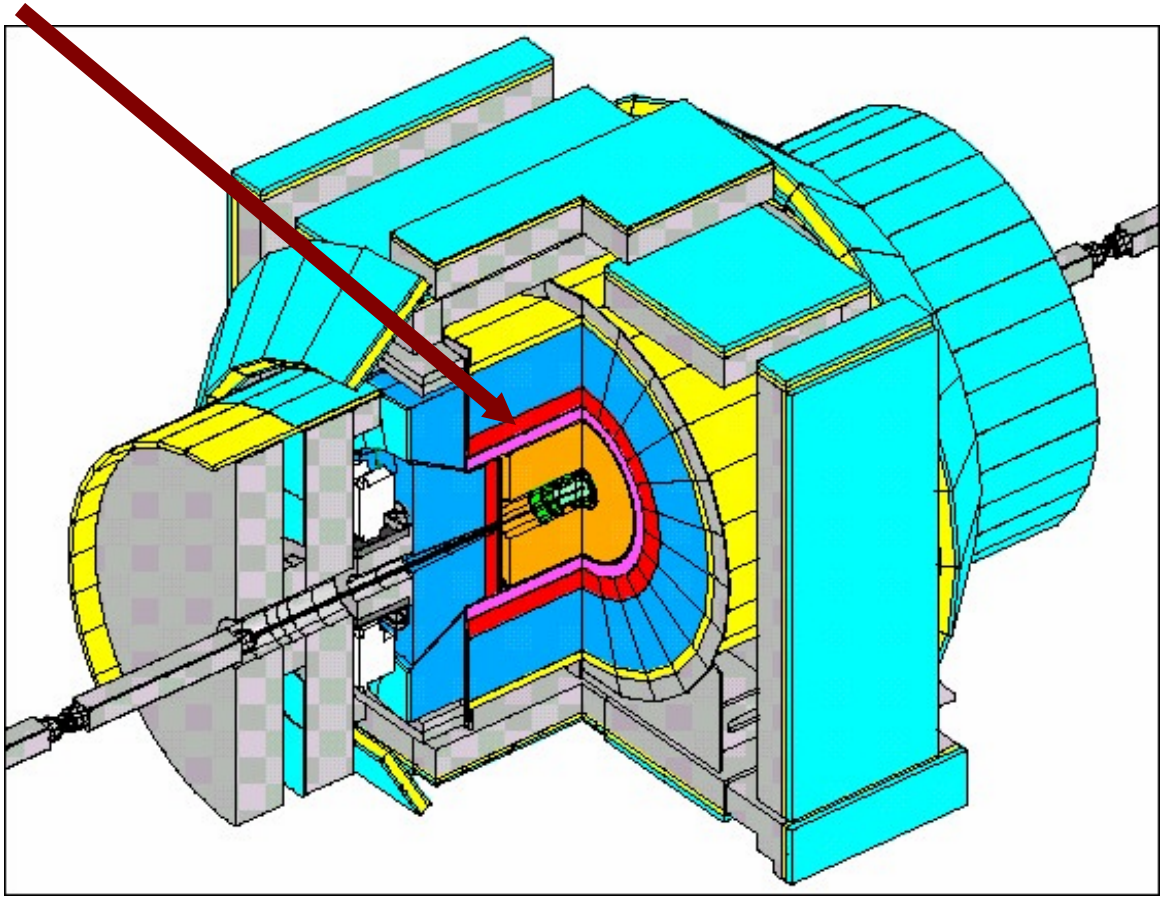
12 August 2002

Outline

- Overview of Calorimetry Upgrade
  - Central Preshower and Crack Detectors
  - Electromagnetic Timing
  - Institutions Involved
- Physics Motivation
  - Electron Identification for Higgs, Top, W, sin(2β)
  - Photon and Missing Energy Identification
  - Jet Resolutions for Higgs, Mass Bumps
- Project Technical Descriptions
- Costs, Schedules, Risk analysis
- Summary

Calorimetry Upgrade Overview

Most of the calorimetry upgrades related to the Central Electromagnetic Calorimeter



Calorimetry Upgrade Overview

Most of the calorimetry upgrades related to the Central Electromagnetic Calorimeter

Not Surprising:

Designed before Run -2 (1981)

Along with Central Tracking, Cornerstone of CDF Physics

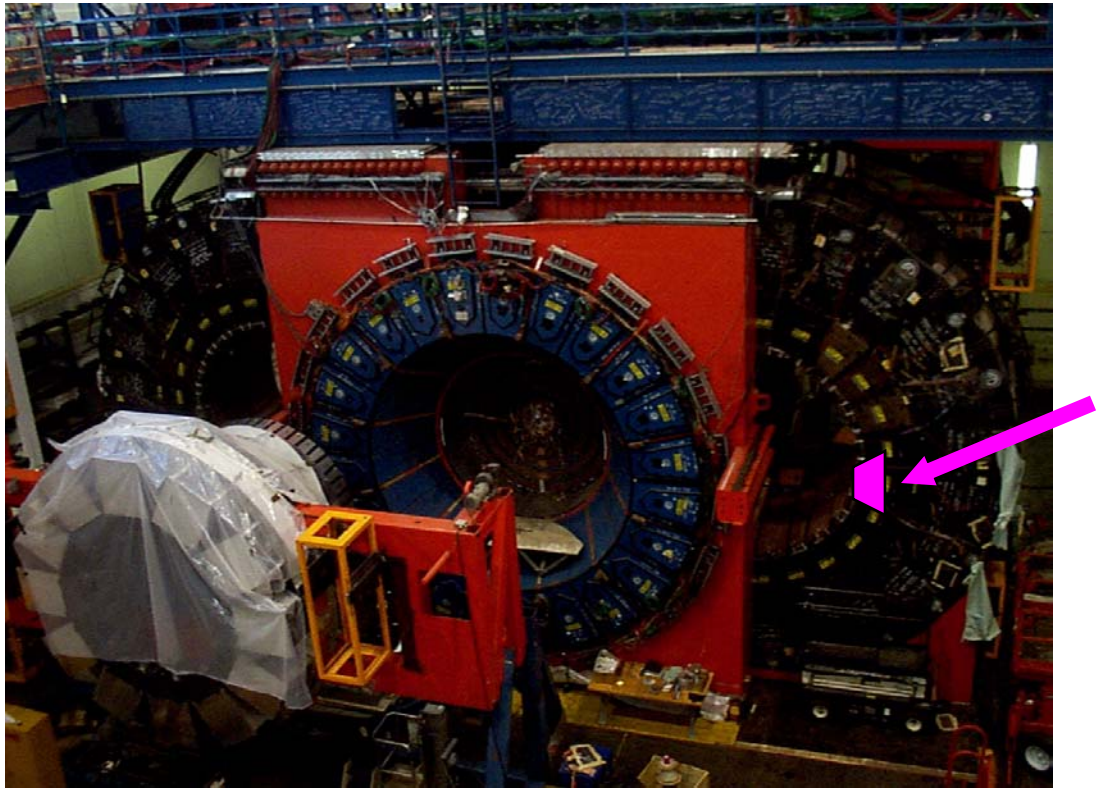
Designed for Instantaneous Luminosity = 10^{30}

Designed for Integrated Luminosity = 1 pb^{-1}

Run IIB Physics Agenda not envisioned

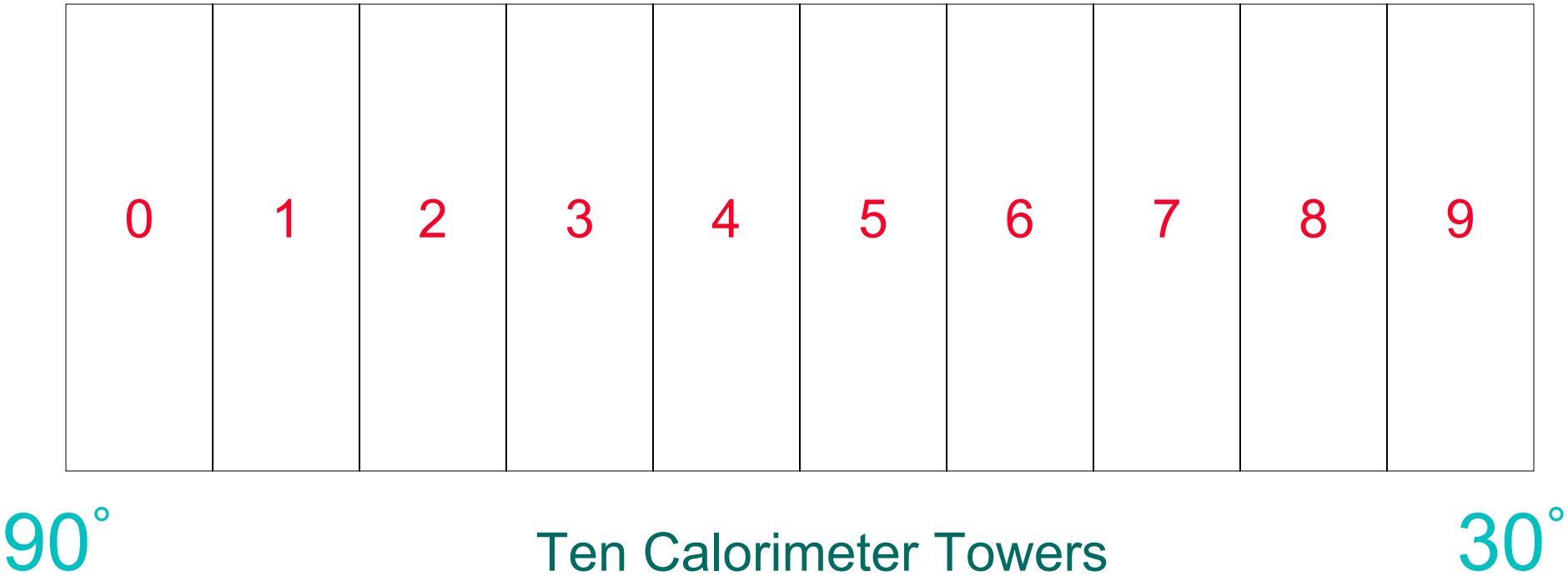
Calorimetry Upgrade Overview

1 Wedge of Central Electromagnetic Calorimetry (out of 48)

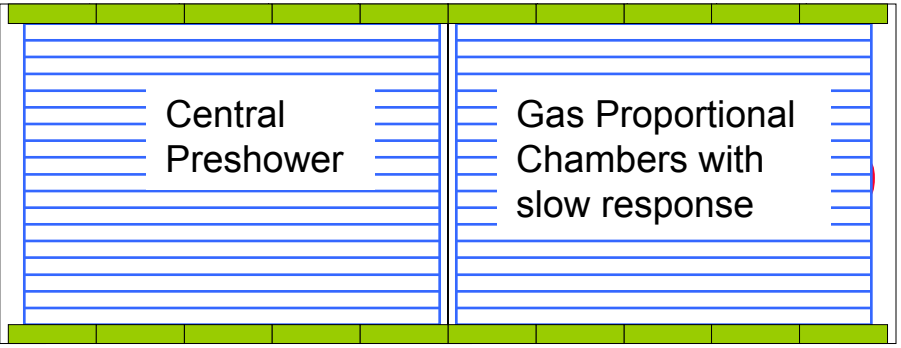


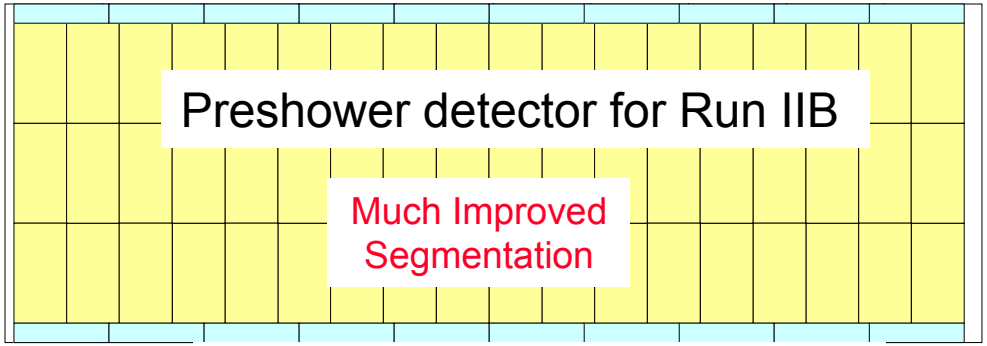
Calorimetry Upgrade Overview

Front Face of 1 Wedge of Central Electromagnetic Calorimetry (out of 48)



Calorimetry Upgrade Overview





Central Crack Detectors behind 8 X_0 Tungsten bar

More Gas Proportional Chambers with slow response

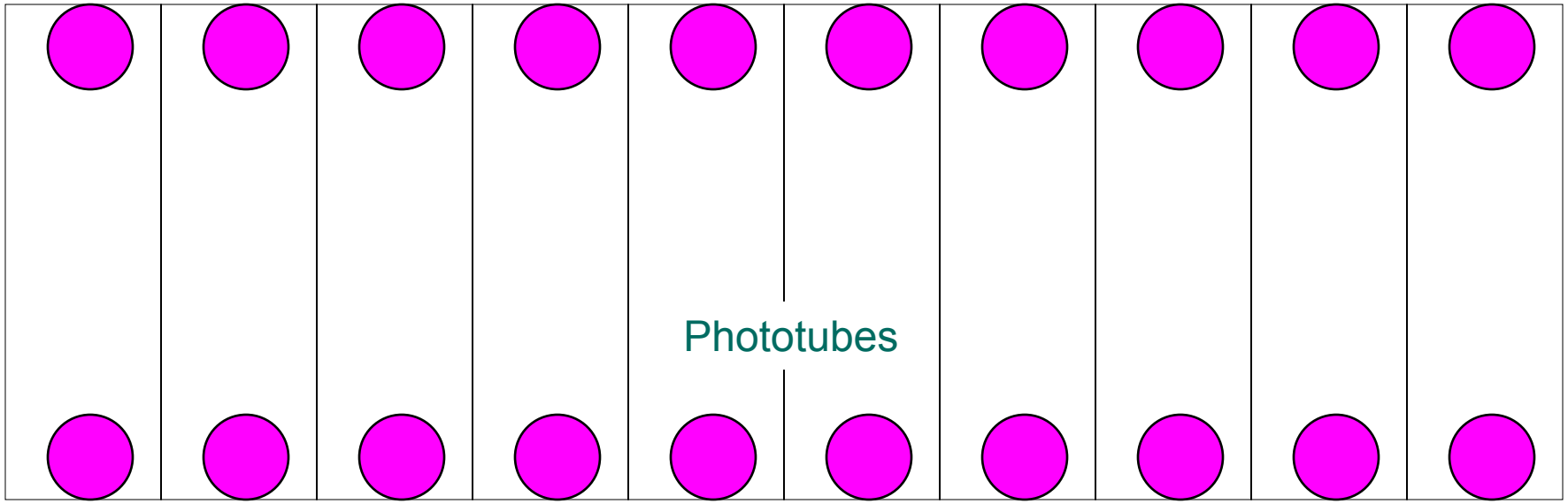
Crack Detectors for Run IIB

Current Detectors

Replace with scintillator+fiber detectors

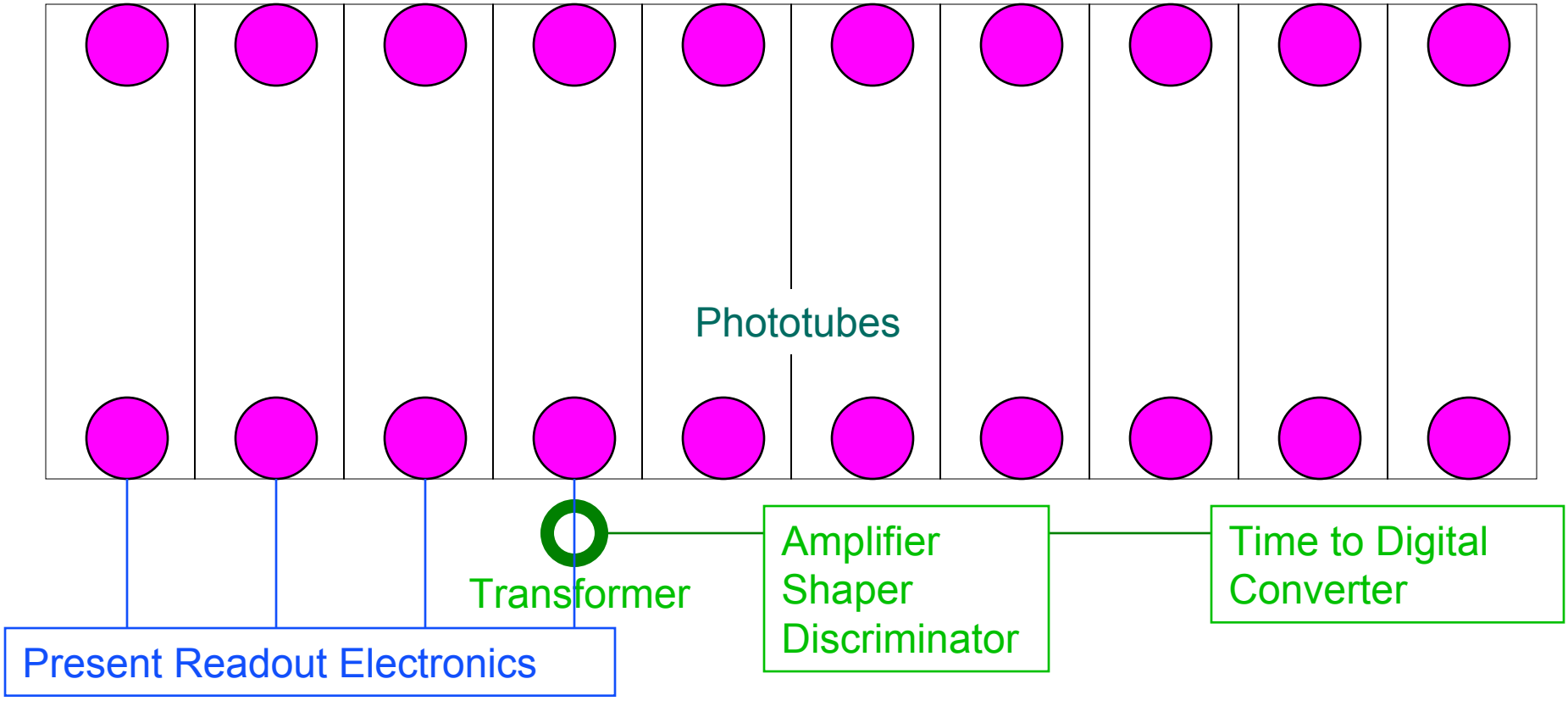
Calorimetry Upgrade Overview

Cartoon of Rear Face of 1 Wedge of Central Calorimetry



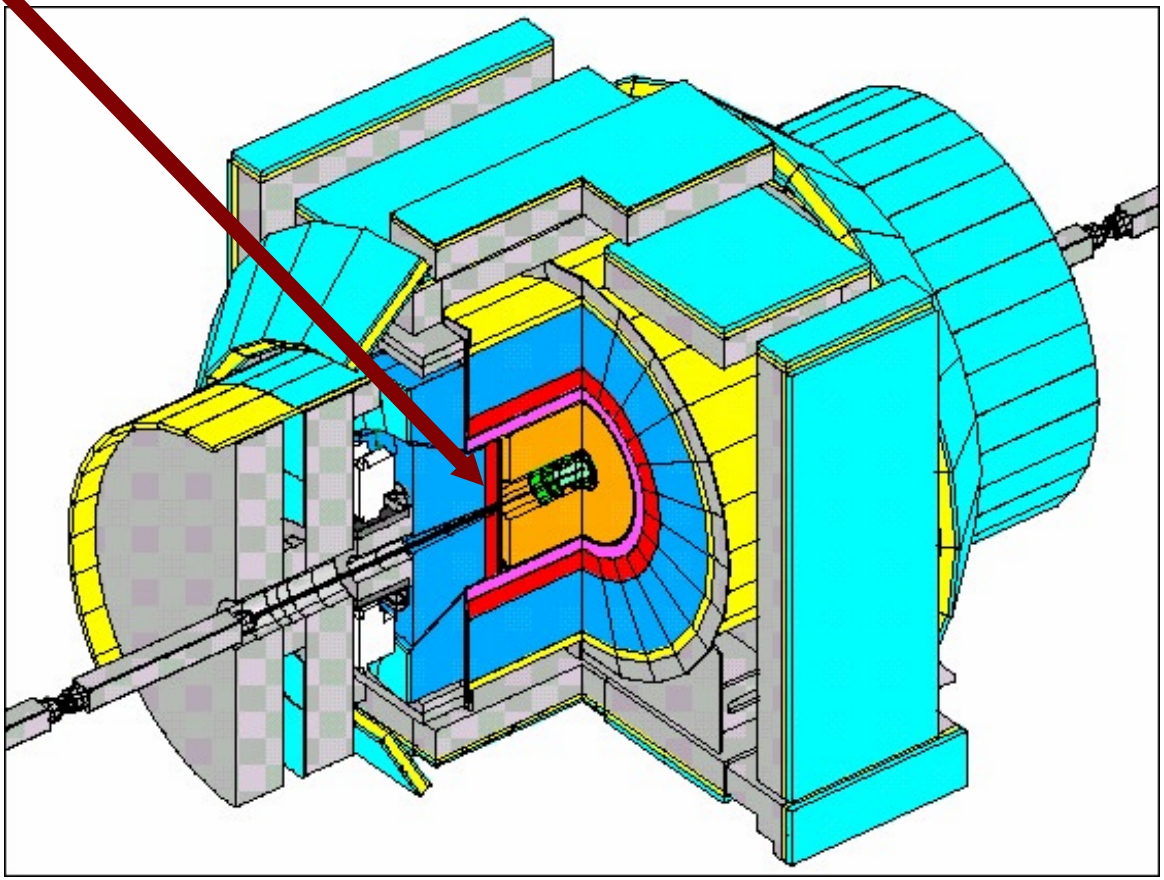
Calorimetry Upgrade Overview

Add timing information to the readout of the Central Electromagnetic Calorimeter



Calorimetry Upgrade Overview

Timing would be added to the End Plug Electromagnetic Calorimeter as well



Institutions

Preshower/Crack

- University of Tsukuba
- INFN (Pisa, Rome)
- JINR (Dubna)
- Argonne National Laboratory
- Michigan State University
- Rockefeller University
- FNAL

Electromagnetic Timing

- Texas A&M
- INFN (Frascati)
- University of Chicago
- University of Michigan
- Argonne National Lab
- FNAL

Preshower Detector in Run I

Preshower used in >100 papers, about 1/2 of all Run I publications

Higgs Search, Sin(2β), High Pt Photons, Top Quark Mass

<u>Three principle uses so far:</u>

High Pt Electron ID

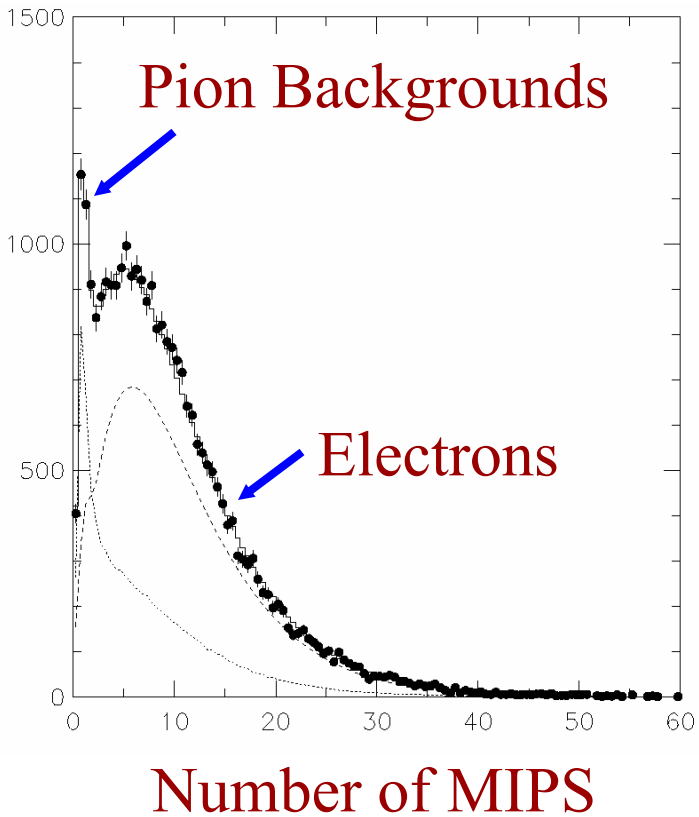
Soft Electron b-tagging

Photon Background Subtraction

Preshower Detector in Run I

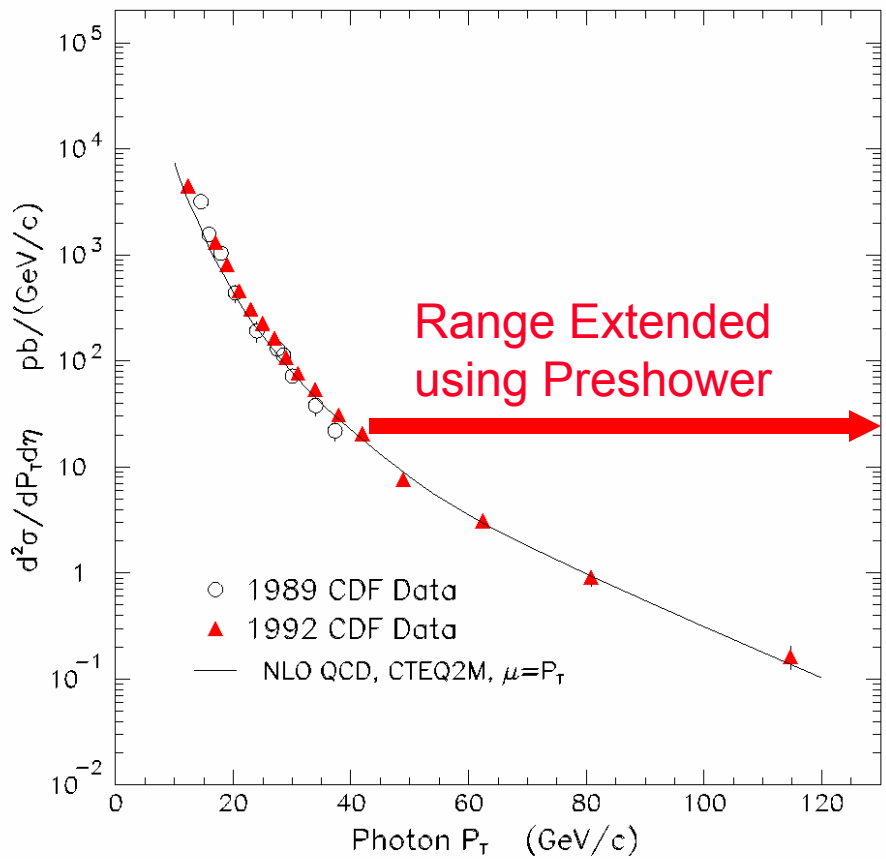
Electron Identification

Preshower MIPs give a remarkably clear picture of backgrounds



Preshower Detector in Run I

For Photon Identification, the Preshower detector offers the only model-independent π^0 subtraction above 35 GeV.



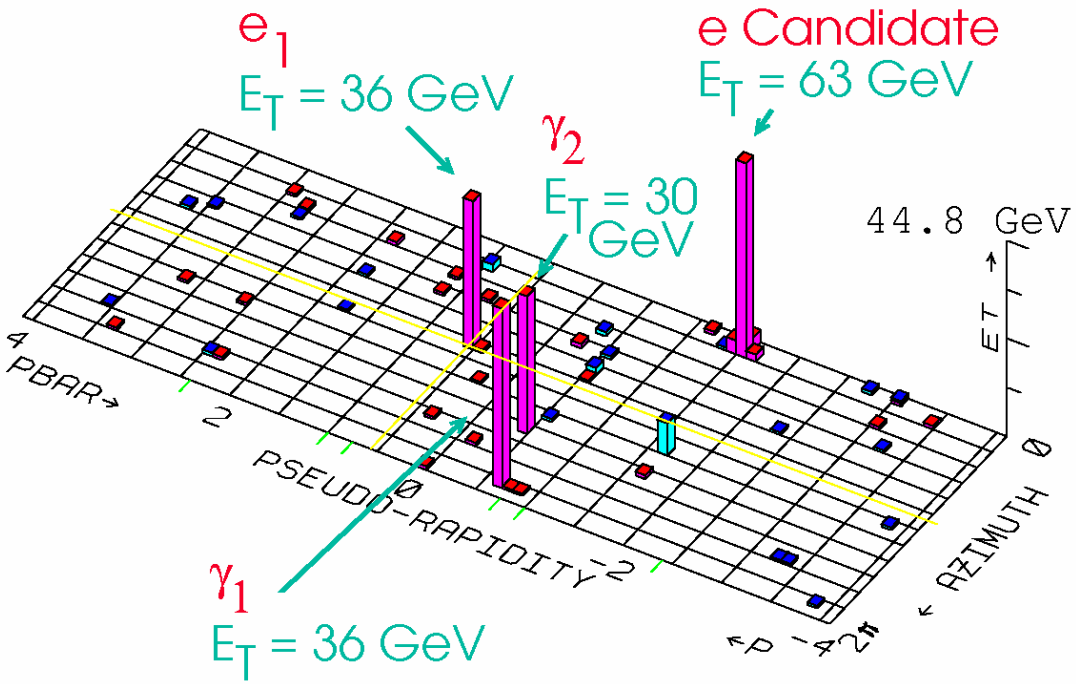
Uses fact that conversion probability of 2 γ from π^0 is higher than 1γ.

These probabilities are energy independent.

25 Run I photon papers using preshower

Photons and Missing Energy

$ee\gamma\gamma\not{E}_T$ Candidate Event



$\not{E}_T$ = 55 GeV

Photon and Missing Energy Identification important for New Physics Searches

Standard Model background estimate of 10^{-6}

Photons and Missing Energy

$$\tilde{C}_1\tilde{N}_2 \rightarrow (jj\tilde{N}_1)(\gamma\tilde{N}_1) \rightarrow \gamma jj\not{E}_T$$

$$\tilde{C}_1\tilde{N}_2 \rightarrow (\tilde{t}_1 b)(\gamma\tilde{N}_1) \rightarrow (c\tilde{N}_1 b)(\gamma\tilde{N}_1) \rightarrow \gamma bc\not{E}_T$$

$$\tilde{g}\tilde{C}_2 \rightarrow (q\bar{q}\tilde{N}_2)(\tilde{t}_1 b) \rightarrow (jj\gamma\tilde{N}_1)(cb\tilde{N}_1) \rightarrow \gamma bcjj\not{E}_T$$

$$\tilde{g}\tilde{N}_2 \rightarrow (q\bar{q}\tilde{C}_2)(\gamma\tilde{N}_1) \rightarrow (jj\tilde{t}_1 b)(\gamma\tilde{N}_1) \rightarrow \gamma bcjj\not{E}_T$$

$$\tilde{g}\tilde{g} \rightarrow (q\bar{q}\tilde{C}_2)(q\bar{q}\tilde{N}_2) \rightarrow \gamma bcjjjj\not{E}_T$$

If an early sign of New Physics, then expect many other channels with photons.

Five examples of other photon channels from Supersymmetry

Related physics:

- Large Extra Dimensions
- Excited leptons
- New dynamics
- W/Z+Higgs → W/Z+γγ
- W/Z+γ production

Photons and Missing Energy

Pick one example from Supersymmetry and illustrate the possible backgrounds...

$$\tilde{C}_1\tilde{N}_2 \rightarrow (jj\tilde{N}_1)(\gamma\tilde{N}_1) \rightarrow \gamma jj\not{E}_T$$

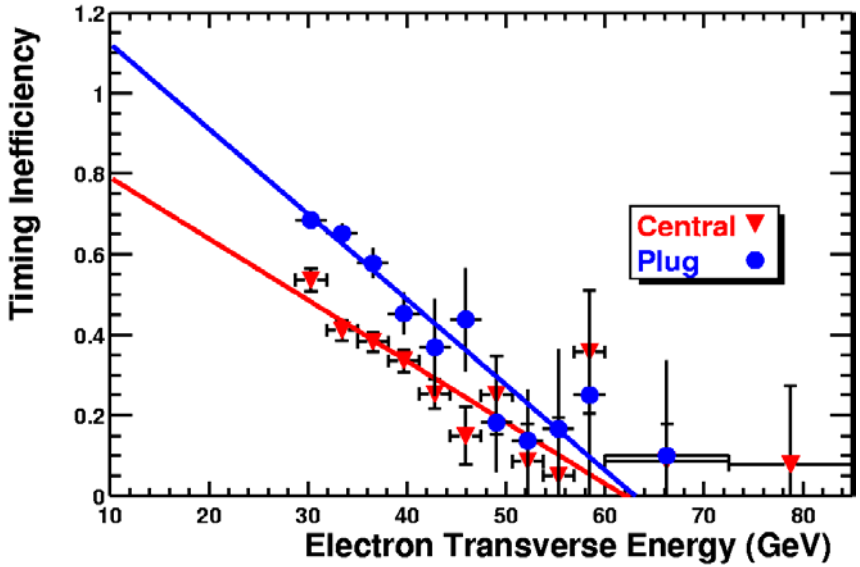
Prolific jet+jet production + 1 cosmic $\rightarrow \gamma jj\not{E}_T$ (Timing)

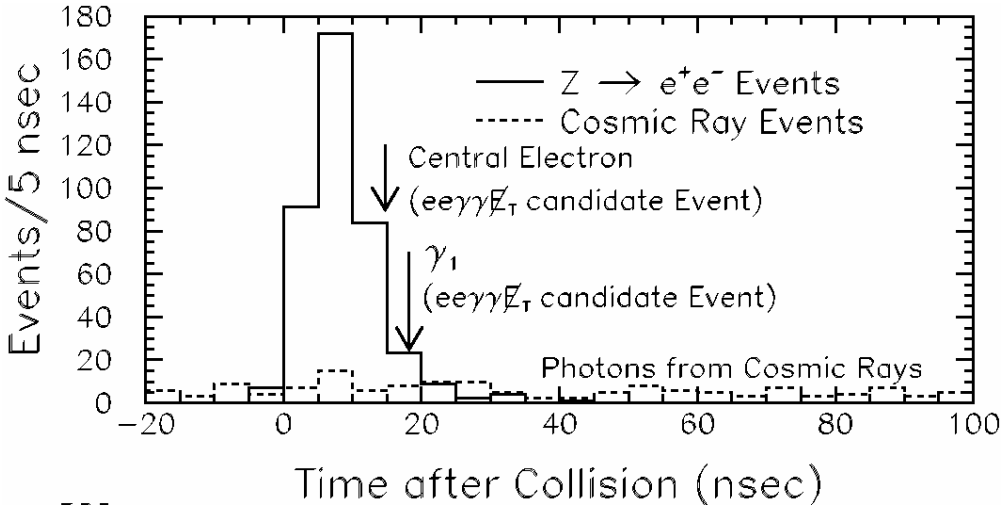
$\gamma\gamma$+jet+jet with one photon in crack $\rightarrow \gamma jj\not{E}_T$ (Crack)

jet+jet+jet with jet $\rightarrow \pi^0$ + resolution $\rightarrow \gamma jj\not{E}_T$ (Preshower)

Photons and Missing Energy

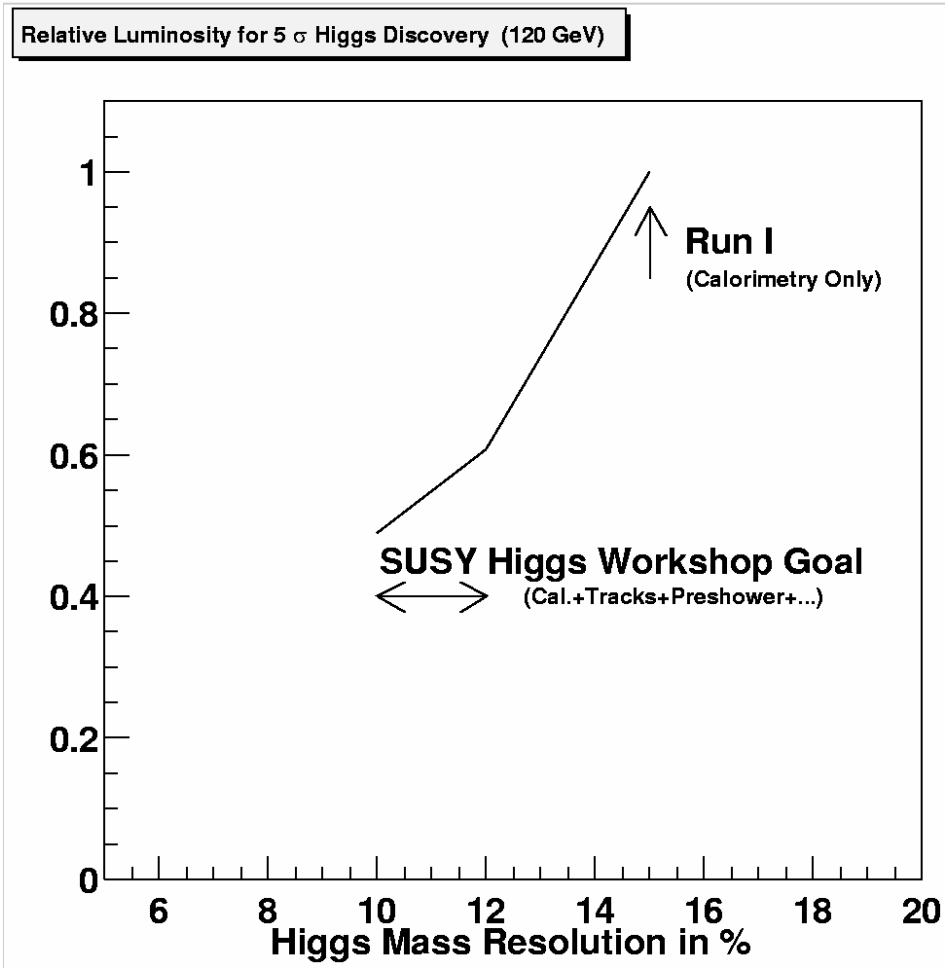
Currently use leakage into hadron calorimeter timing, very inefficient





Then there's the Higgs...

Jet Resolutions are Important for a Higgs Discovery



Then there's the Higgs...

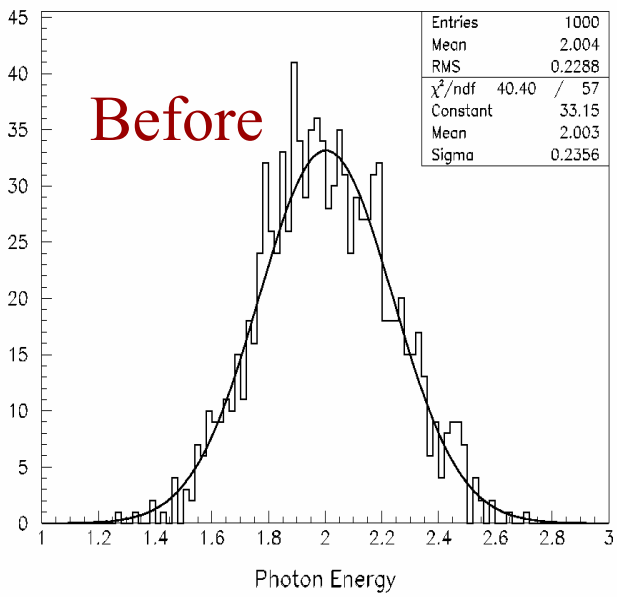
Both the Preshower and Crack Detectors will play a role in improving jet resolutions

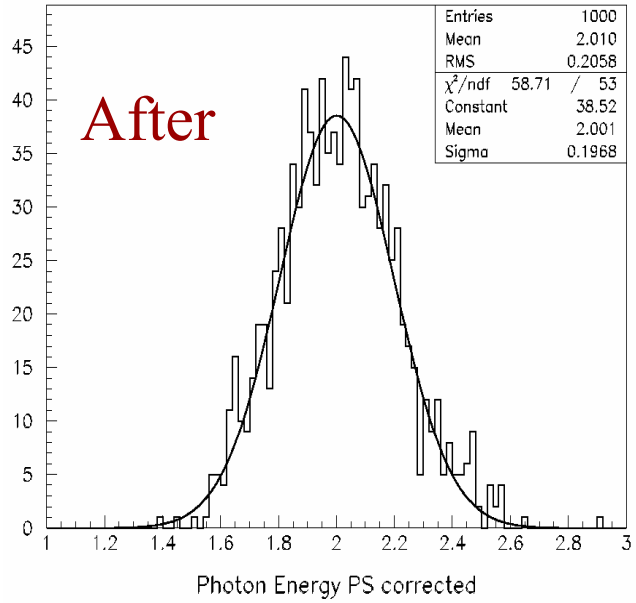
- Already used in Run I: neutrino correction for b jets with soft electrons
- Dead material correction for soft photons
- Tagging soft tracks that deposit all energy in solenoid magnet
- Estimating track deposits in electromagnetic calorimeter
- Tagging large energy losses of photons in cracks

These studies are still in the early stages, but it's likely that Preshower/Crack alone will provide 5-10% of needed 20-30% resolution improvement.

Then there's the Higgs...

A sampling of recent jet resolution studies using Preshower/Crack

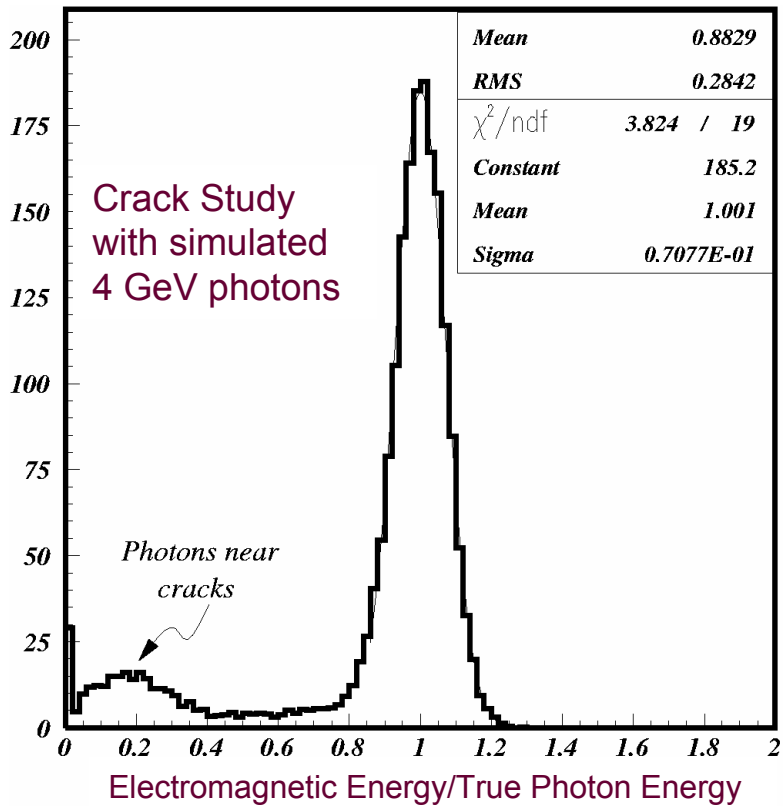




Improve 2 GeV photon resolution by 20% → Possible 6% Jet resolution improvement

Then there's the Higgs...

A sampling of recent jet resolution studies using Preshower/Crack



Cracks change the beautiful 7% resolution into a 28% RMS. This changes the jet resolution component from 2% to 8%. Will use the Crack Detectors to recover some of this.

Luminosity/Segmentation

- Current Preshower/Crack detectors integrate over four crossings.
- Will see 20 overlapping minimum bias events if 132 ns spacing.
- Will see 12 minimum bias events if 396 ns spacing.
- Current Preshower occupancies will be 38-65% from overlaps alone.
- Preshower is expected to suffer wire aging, more than 0.1 C/cm.
- Wires running over 5 calorimeter towers not optimal for jet resolution uses, Run IIb detector is optimized for Higgs.

Now for Technical Details...

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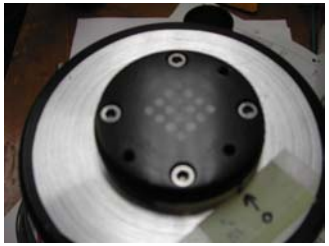
** Note the only acronym used so far is CDF!

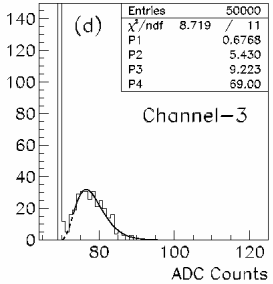
Preshower Design Choices

- Reuse electronics
- Well-established technologies
- R5900 16-channel PMTs
- 2.8 cm of space, use 2 cm scintillator used for CDF Muons
- Scintillator and fiber preparation done in FNAL shops

Preshower/Crack Phototubes

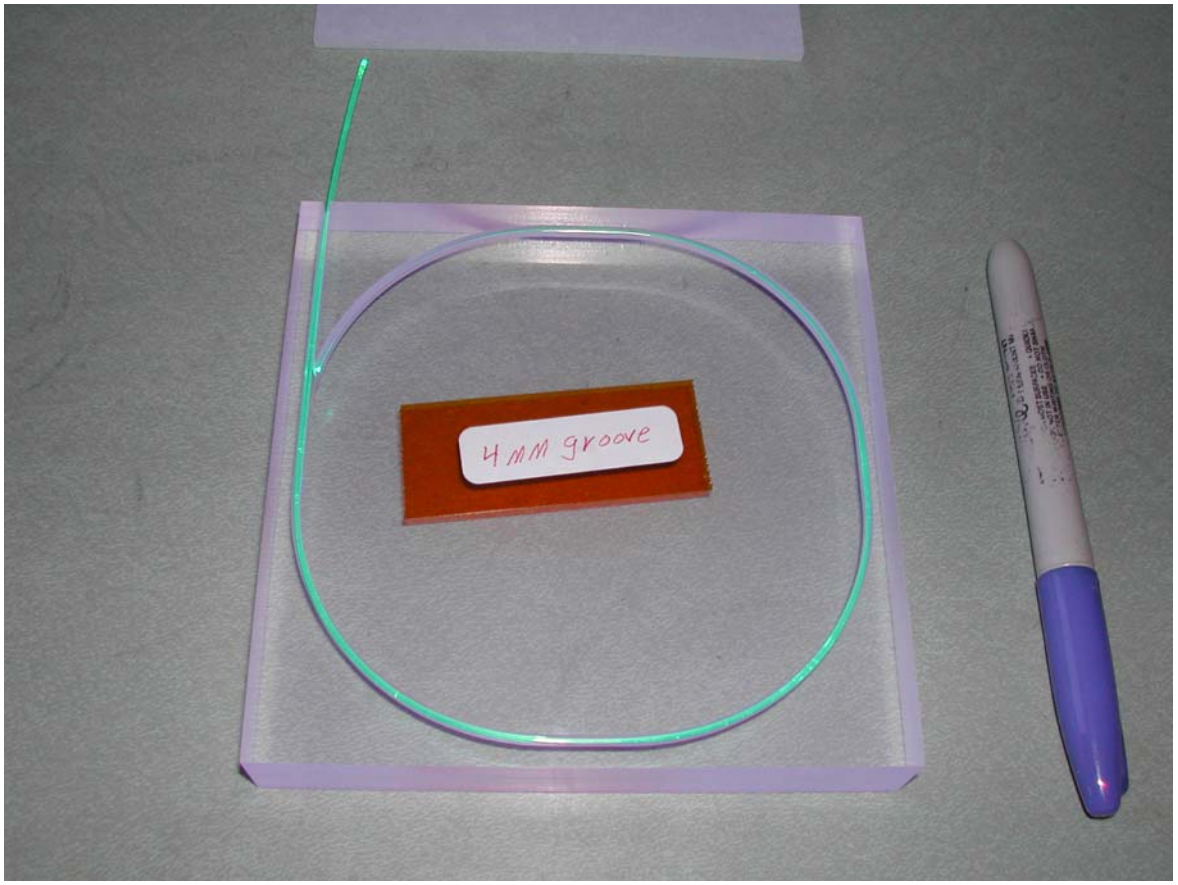
- R5900 16-channel Phototubes
- Used in CDF Endplug shower maximum and preshower
- Used in MINOS
- Many others…
- Tests at Rockefeller and soon at Tsukuba



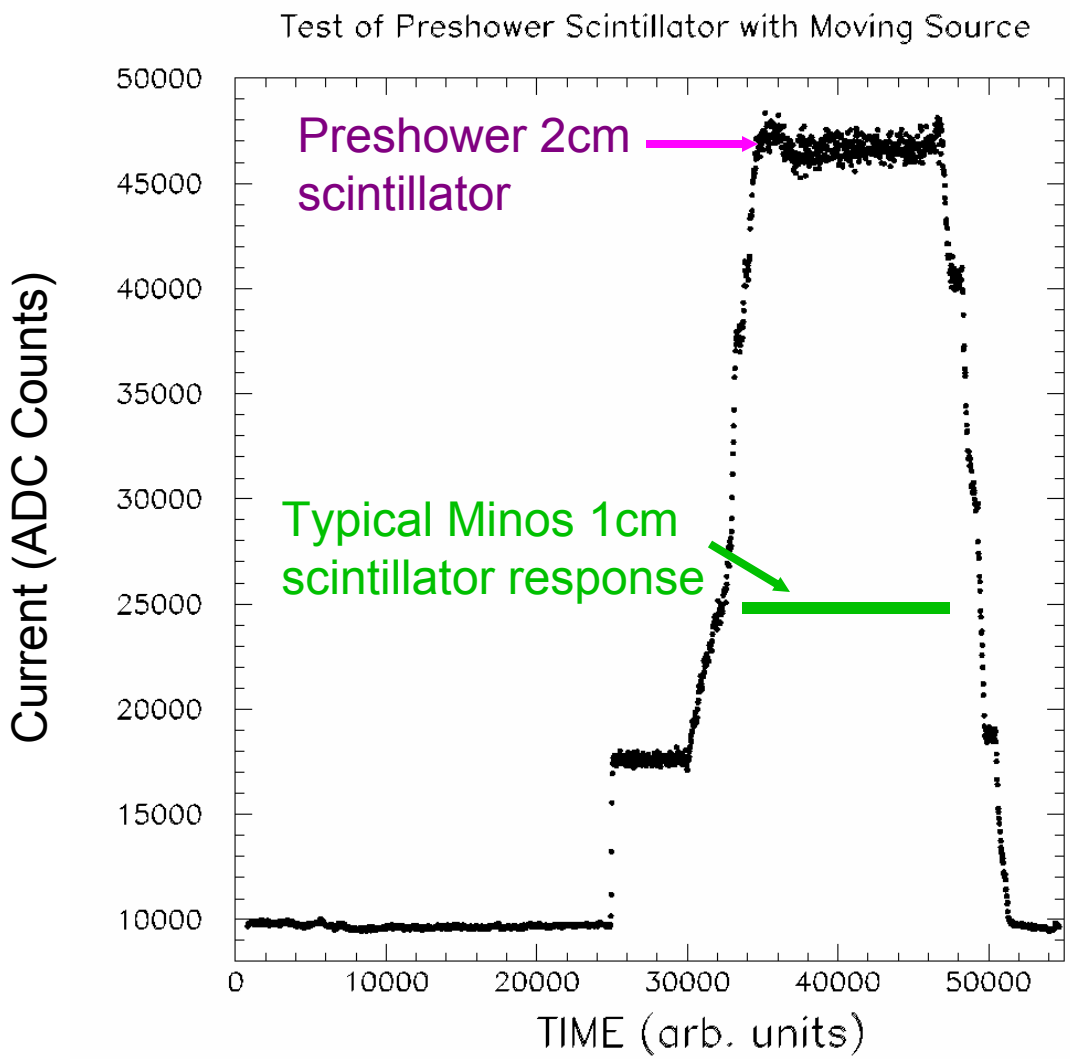


Preshower Scintillator

Dubna 2 cm scintillator with groove cut at FNAL

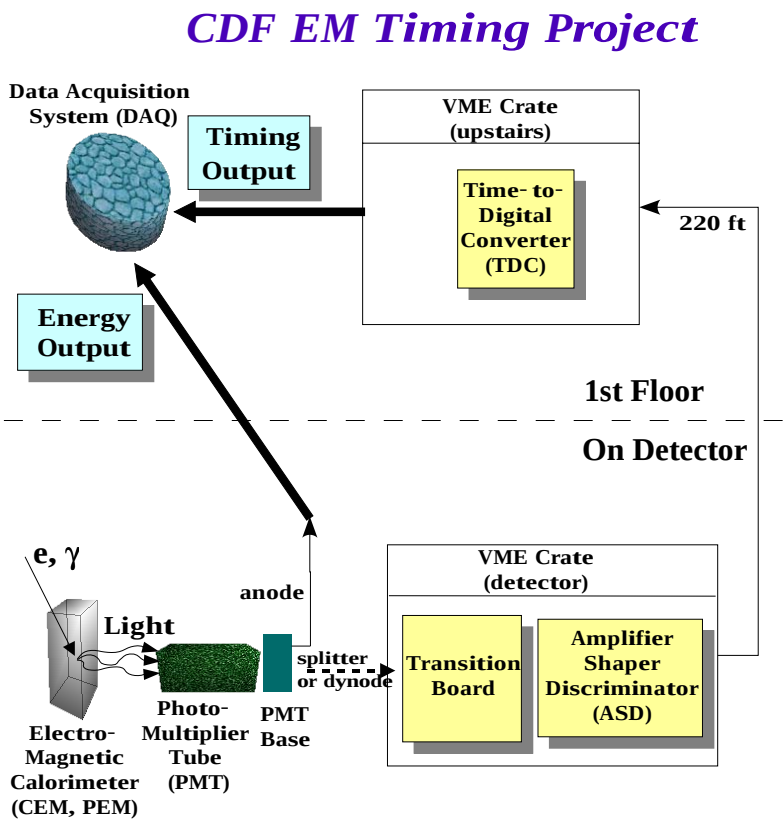


Preshower Tests



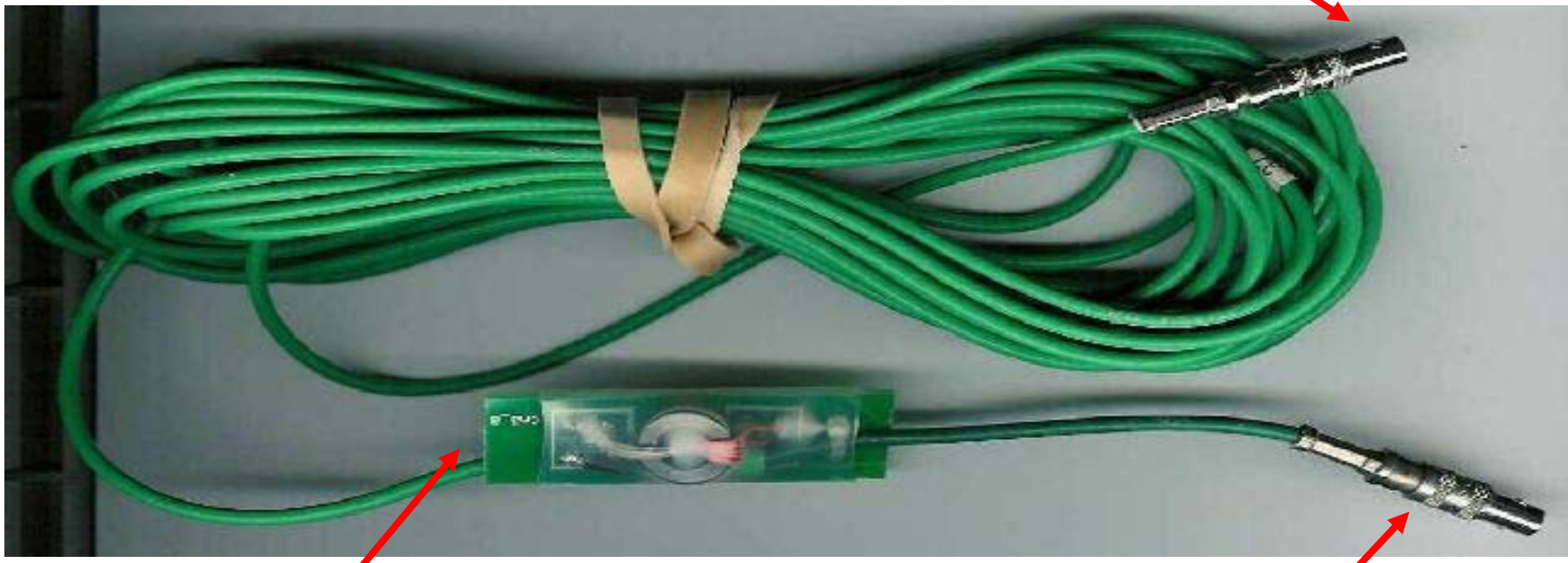
Electromagnetic Timing Design Choices

- Reuse electronics
- Well-established technologies
- Virtually identical to existing system on hadron calorimeter
- Plug phototubes have dynode output already
- Use inductive pickup on central, no noticeable effect on energy signal



Electromagnetic Timing Splitter

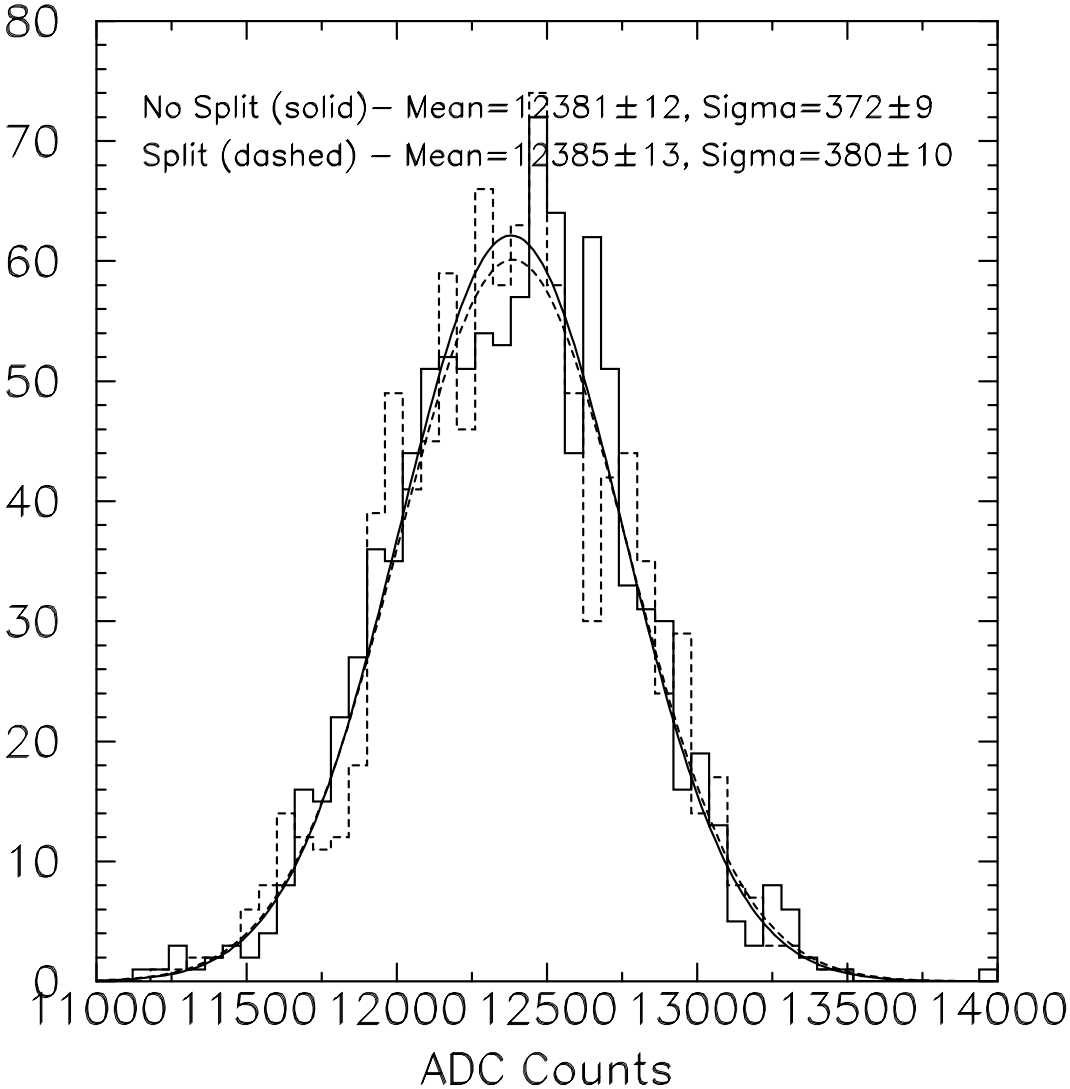
Male LEMO to ASD transition board



Female LEMO to ADMEM input (on back)

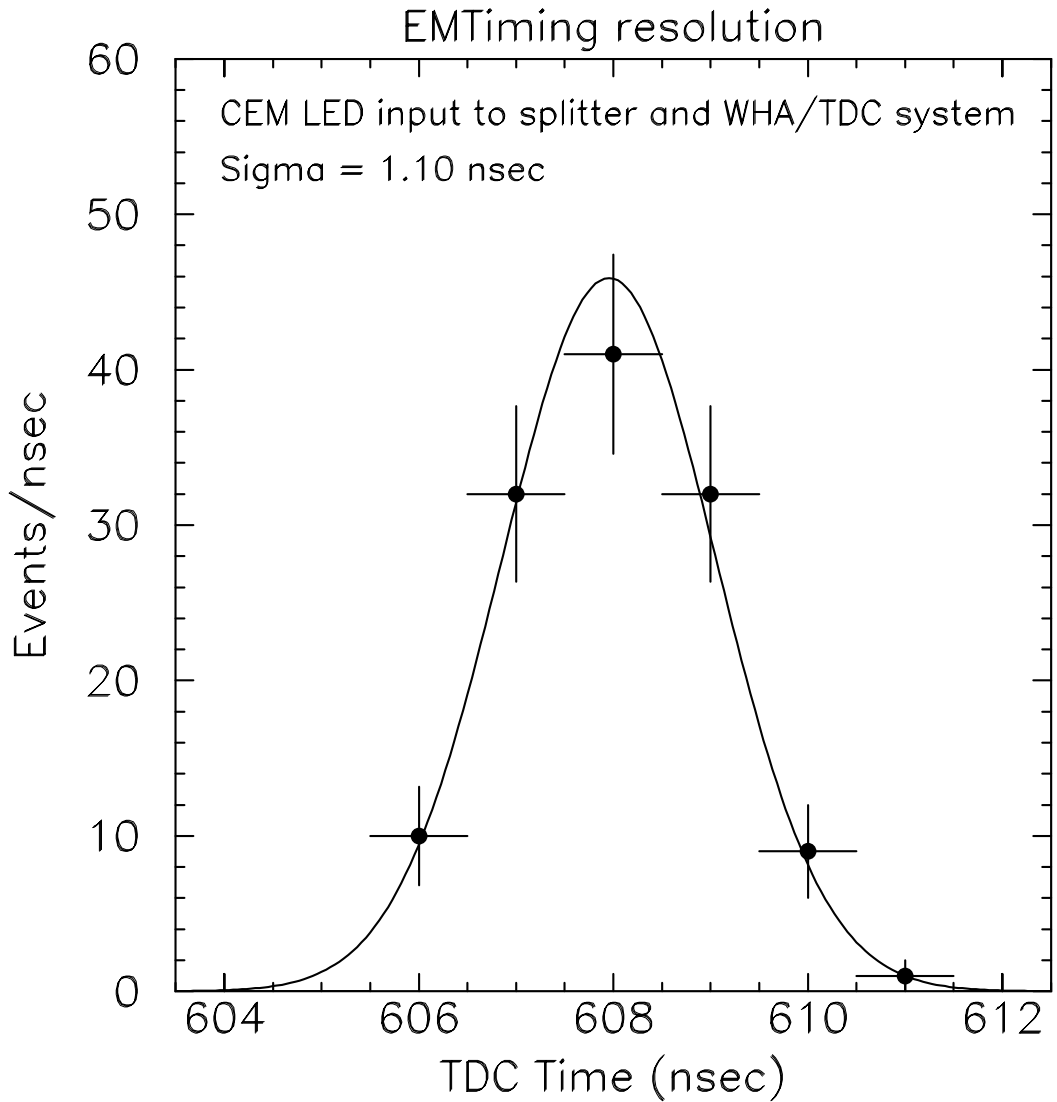
Male LEMO to PMT anode

Electromagnetic Timing Test Results on the Detector



As expected, energy output doesn't change

Electromagnetic Timing Test Results on the Detector



Timing resolution quite good, about 1 ns

Now for Costs and Schedules...

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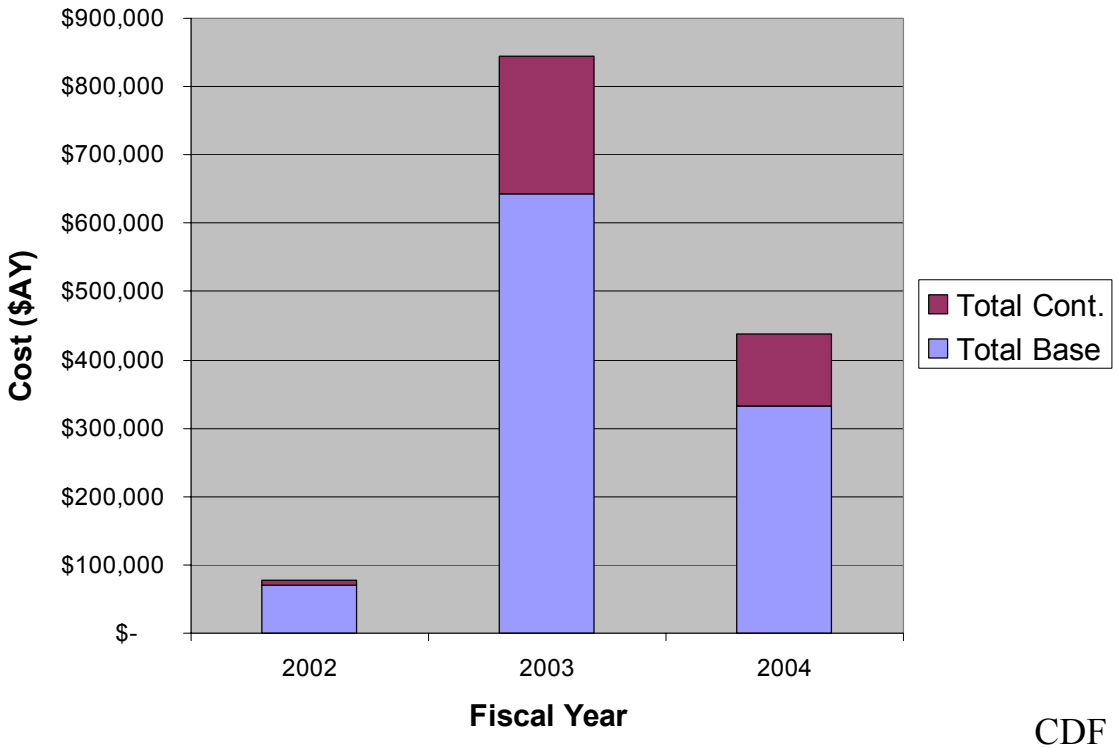
Total Calorimetry Costs

	2002	2003	2004	2005	2006	Totals
Total Base	$ 70,141	$ 642,468	$ 333,244	$ -	$ -	$ 1,045,853
Total Cont.	$ 6,580	$ 202,356	$ 105,565	$ -	$ -	$ 314,501
Total	$ 76,721	$ 844,823	$ 438,809	$ -	$ -	$ 1,360,353

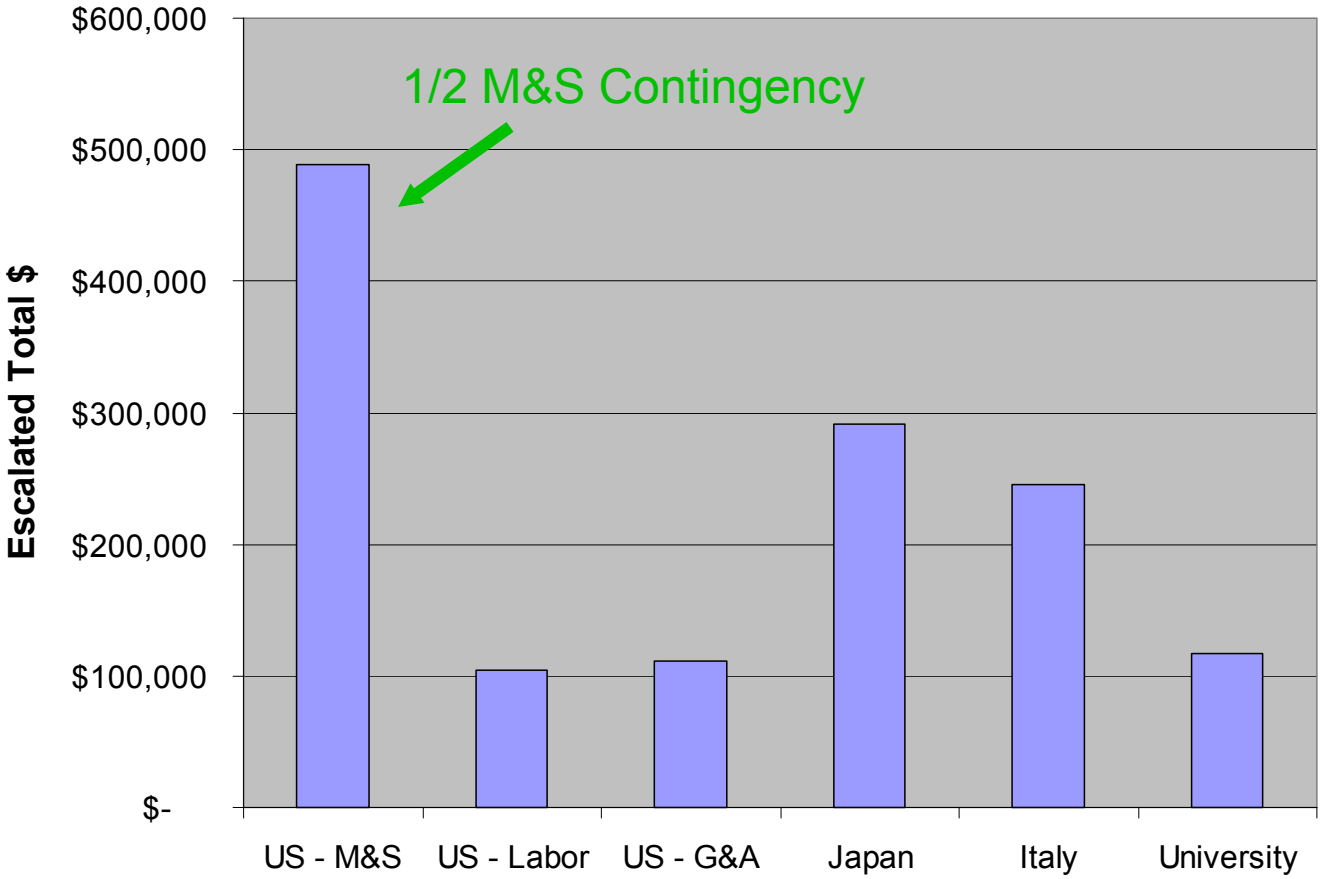
- 73% Preshower
- 27% Timing



Costs

M&S	$	903,755
M&S Cont.	$	240,237
Labor	$	78,136
Labor Cont.	$	26,655
G&A	$	63,962
G&A - Cont.	$	47,609
Total Base	$	1,045,853
Total Cont.	$	314,501
Total	$	1,360,353

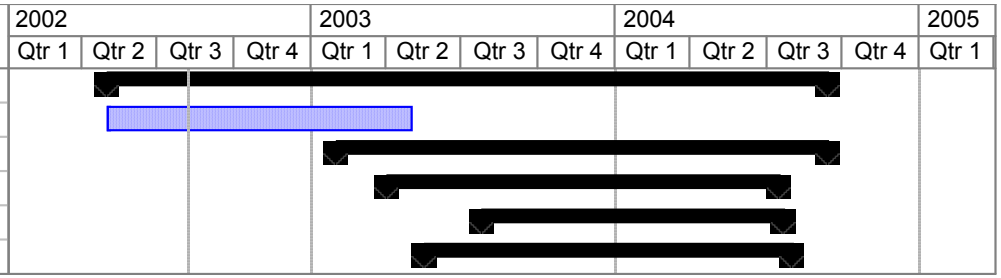
Funding Sources



US - M&S	$	489,046
US - Labor	$	104,790
US - G&A	$	111,571
Japan	$	291,812
Italy	$	246,073
University	$	117,061
Total	$	1,360,353

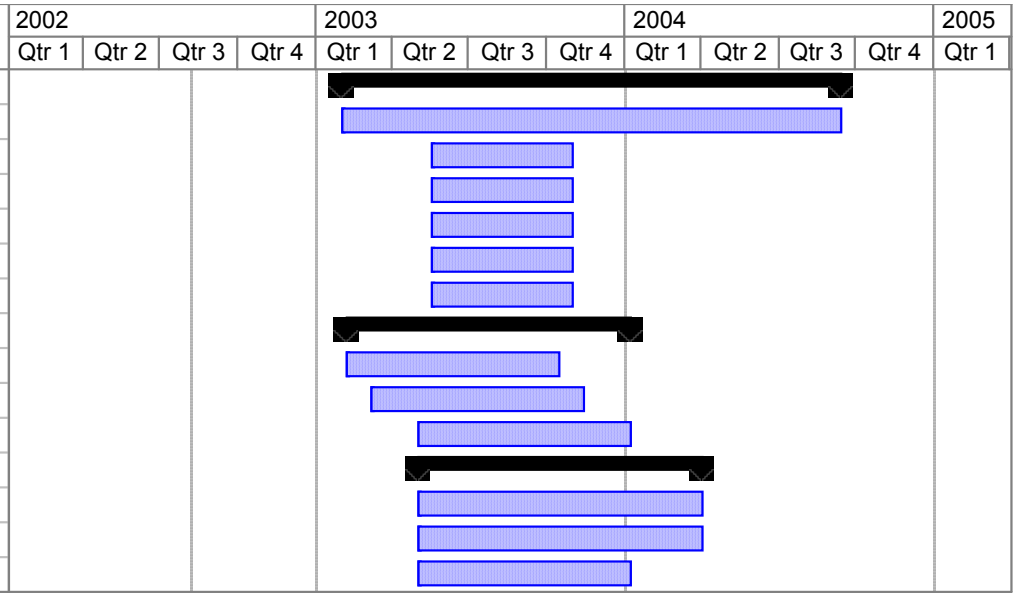
Preshower/Crack Schedule

WBS	Name
1.2.1	**Central Preshower Subproject**
1.2.1.1	Research and Development
1.2.1.2	**Procure parts**
1.2.1.3	**Preshower Detector Assembly**
1.2.1.4	**Crack Detector Assembly**
1.2.1.5	**Fiber Bundle Assembly**



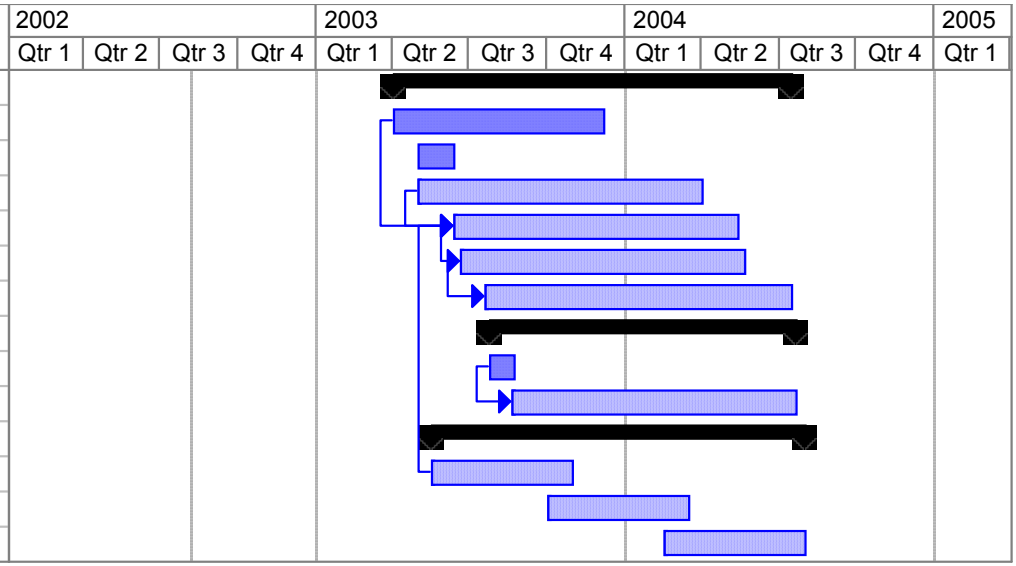
Preshower/Crack Procurement

WBS	Name
1.2.1.2	**Procure parts**
1.2.1.2.1	Phototubes and bases
1.2.1.2.2	Electronics Transition Card
1.2.1.2.3	HV Supplies and cables
1.2.1.2.4	Clear Fiber Bundle parts
1.2.1.2.5	Wavelength-shifting fiber holder parts
1.2.1.2.6	Phototube box parts
1.2.1.2.7	**CPR Detector parts**
1.2.1.2.7.1	Scintillator
1.2.1.2.7.2	Optical Fibers
1.2.1.2.7.3	Sheet metal and misc. supplies
1.2.1.2.8	**CCR Detector parts**
1.2.1.2.8.1	Scintillator
1.2.1.2.8.2	Optical Fibers
1.2.1.2.8.3	Sheet metal and misc. supplies



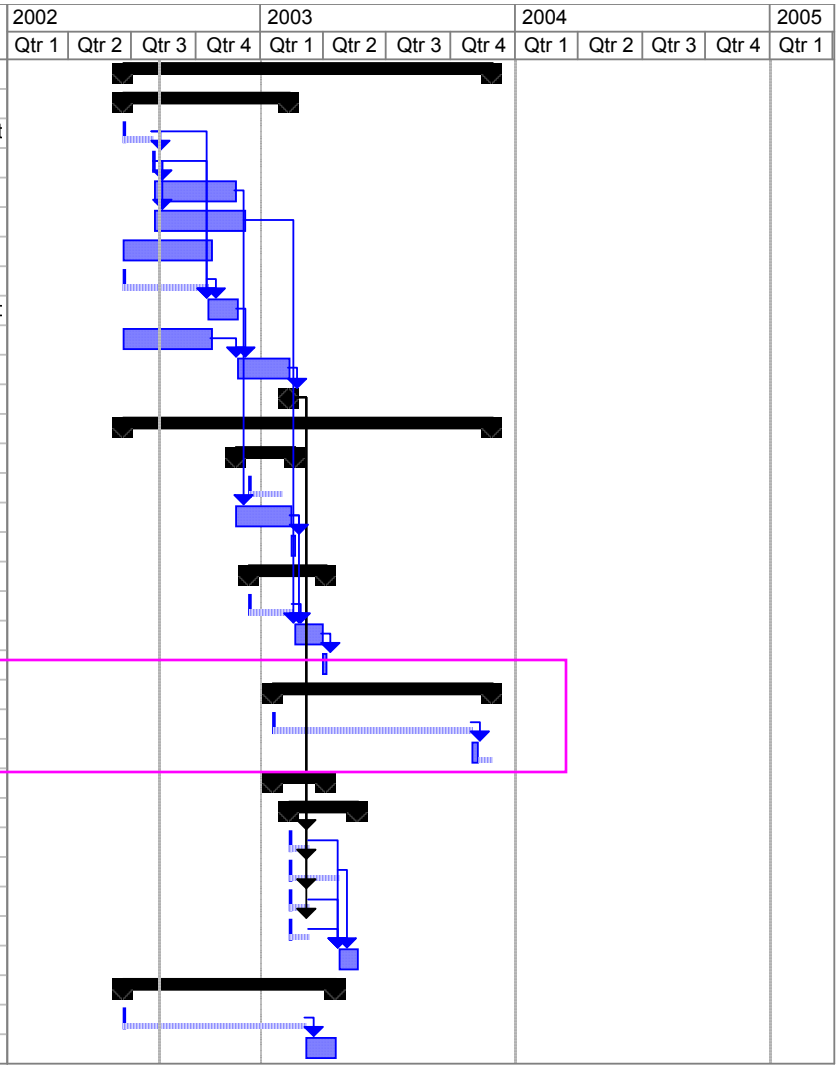
Preshower/Crack Assembly

WBS	Name
1.2.1.3	**CPR Detector Assembly**
1.2.1.3.1	Prepare scintillator tiles
1.2.1.3.2	Prepare optical fibers
1.2.1.3.3	Assemble bottom of module
1.2.1.3.4	Installing fibers into tiles
1.2.1.3.5	Assemble module top
1.2.1.3.6	Quality control
1.2.1.4	**CCR Detector Assembly**
1.2.1.4.1	Prepare scintillator tiles
1.2.1.4.2	Assemble detector with CPR procedure
1.2.1.5	**Fiber Bundle Assembly**
1.2.1.5.1	Assemble WLS fiber holders
1.2.1.5.2	Assemble phototube fixtures
1.2.1.5.3	Assemble clear fiber bundles



Timing Schedule

WBS	Name
1.2.2	**Electromagnetic timing**
1.2.2.1	**Research and Development**
1.2.2.1.1	Procure parts for splitters & cable prototypes, misc test
1.2.2.1.2	Assemble Splitter and PEM harness prototypes
1.2.2.1.3	Tests to finalize CEM Splitter
1.2.2.1.4	Tests to finalize PEM Harness
1.2.2.1.5	Finalize ASD->TDC cable tests
1.2.2.1.6	Build ASD/TB Prototypes and test
1.2.2.1.7	Prototype ASD tests with CEM Splitter, TDC cable, anc
1.2.2.1.8	Assembly of wedge test stand
1.2.2.1.9	Wedge test using all components
1.2.2.1.10	Prototype Testing Complete
1.2.2.2	**Purchase parts for components and Produce**
1.2.2.2.1	**CEM Splitter**
1.2.2.2.1.1	Procure Splitter parts
1.2.2.2.1.2	Build Splitters
1.2.2.2.1.3	Test CEM Splitter Cables
1.2.2.2.2	**PEM Cable Harness**
1.2.2.2.2.1	Procure PEM Harness Parts
1.2.2.2.2.2	Build PEM Harnesses
1.2.2.2.2.3	Test PEM Harnesses
1.2.2.2.3	**ASD and Transition Boards**
1.2.2.2.3.1	Produce ASD and Transition boards
1.2.2.2.3.2	Test ASDs and Transition boards
1.2.2.2.4	**ASD->TDC Cables**
1.2.2.2.5	**VME Crate for TDCs**
1.2.2.2.5.1	Procure VME Crate for TDCs
1.2.2.2.5.2	Procure VME Crate Power Supply
1.2.2.2.5.3	Procure VME Crate Processor
1.2.2.2.5.4	Procure Tracer
1.2.2.2.5.5	Test crate, PS, processor and Tracer
1.2.2.2.6	**TDC Boards**
1.2.2.2.6.1	Recycle TDC Boards
1.2.2.2.6.2	Test TDC Boards



Calorimetry Risk Analysis

Only 2 entries with >5% Risk, both are 8% Schedule Risk

1) Final phototube purchase and testing

2) Fiber preparations before counter assembly

Both have 20% probability of >10% (3 month) delay in overall calorimeter schedule.

Calorimetry Risk Analysis

Final Phototube purchase will be our fourth, will watch for delays in the previous purchases and testing cycles.

Main goal of remaining R+D phase is to work out the kinks in fiber preparation steps.

Summary

- CDF Calorimeter Upgrades needed to do the physics of Run IIB, including the Higgs.
- Hardware choices made to minimize costs, minimize R+D, and minimize technical risks.
- Upgrades should be finished and ready to install by the end of 2004.