A Scintillating Tile/Fiber Preshower Detector for the CDF Central Calorimeter

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for the CDF Collaboration
CDF Preshower/Crack Detector Upgrade (CPR2)

- Preshower detector upstream of calorimeter to extend its capabilities

Replace old CPR and CCR (slow wire chambers) with detectors based on **scintillator tiles read-out by WLS fibers**, to confirm/extend Run I results

→ faster + finer segmentation in $\eta-\phi$
Physics with the CPR2

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

- High Pt Electron ID
- Soft Electron b-tagging
- Photon Background Subtraction (the only model-independent $\pi^0$ subtraction above 35 GeV)

Crack Detector detects photons in cracks that generate “fake” missing energy.

Inst $L = 2-3 \times 10^{32}$ causes significant degradation of current detector with 20-30% occupancies

Even with $L<1 \times 10^{32}$, segmentation of upgrade opens new window for improving jet energy resolution
CDF Preshower Detector in Run I

Photon ID: Conversion probability of $2\gamma$ from $\pi^0$ is higher than $1\gamma$

These probabilities are energy independent
Photons and Missing Energy

Identification important for New Physics Searches

Standard Model background estimate of $10^{-6}$
Jet Energy Reconstruction

Both 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% resolution improvement.

![Before and After comparison](GEANT)
Jet Energy Reconstruction

We developed a Particle Flow Algorithm that corrects Energy at Calorimeter Tower level rather than at Jet level – Tested on Run I γ-jet, it includes Tracking + Shower Max info

Better than 20% improvement vs. standard jet corrections with Calorimetry only

CPR2, with finer segmentation than Calorimeter towers, will be included in this algorithm
Project Overview

Scintillator tiles

- **Preshower Detector (CPR)**
  - 48 modules in front of CCAL

- **Crack Detector (CCR)** after 10 $X_0$ tungsten bar

<table>
<thead>
<tr>
<th>Institutions:</th>
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<tbody>
<tr>
<td>- Argonne</td>
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<tr>
<td>- INFN (Pisa, Roma1, Siena, Trieste)</td>
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<tr>
<td>- JINR (Dubna)</td>
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<td>- Michigan State Univ.</td>
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<tr>
<td>- Rockefeller University</td>
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<td>- University of Tsukuba</td>
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<table>
<thead>
<tr>
<th>Wedge</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPR</td>
<td>54</td>
</tr>
<tr>
<td>CCR</td>
<td>10</td>
</tr>
</tbody>
</table>

- Total n. of channels = 3,072
- CPR tile: 12.5 x 12.5 x 2 cm 2x3 ($\eta-\phi$)/Tower
- CCR tile: 22.5 x 5 x 0.5 cm 1 tile/Tower

Photomultipliers
- 16 channels per PMT (Hamamatsu R5900)
- 192 HV channels (CAEN HV SY527)
Project Overview

- 1mm dia WLS fiber into groove, spliced to clear fiber at tile exit, routed to optical connector
- Clear fiber cable (~4.5m) from connector to MAPMT
- We want to see MIPs in CPR, > 5 pe at PMT in specs, i.e. \textbf{>12 pe at tile exit}
  (splicing + connector + clear fiber)

- Room for Crack tiles limited to 5mm thickness (after tungsten bar)
- Bicron Crack tile gave ~ 7pe/MIP with mirrored fiber into straight groove
- Fine, we measure Showers in Crack
Preshower R&D Summary

Major Italian contribution to R&D of tile/fiber system

- **Comparison of Scintillators**
  - Bicron 408 and Dubna tiles light yield within +/- 5% \(\rightarrow\) bought Dubna

- **Study of the Groove Path and Cross Section**
  - Circle and \(\sigma\) (Sigma) grooves gave similar results for both light yield and uniformity \(\rightarrow\) \(\sigma\) groove (as in Plug Calorimeter)
  - N loops into square cross section later replaced by Keyhole Spiral

- **Comparison of Multi-Clad Fibers**
  - WLS PolHiTech and Kuraray Y11(250) gave similar light yield for 4 loops, but when we moved to 2-loops Keyhole Spiral \(\rightarrow\) Kuraray Y11(350) was preferred (spliced to Kuraray clear fiber inside module)
  - Mirroring: the fiber edge not read-out is important
  - \(\sim14\) Km of Clear Fiber for Optical Cable from Module to MAPMT. Similar Attenuation Length (~6m) for PolHiTech and Kuraray \(\rightarrow\) PolHiTech Clear

- **Study of Tile/Fiber Optical Coupling**
  - BC-600 Glue and BC-630 Optical Grease gave similar results, \(\sim40\)% better than air coupling in square cross section, \(\sim15\)% in Keyhole cross section
  - Response of glued tiles shows no decrease after ~ 9 months

- **Comparison of Reflectors**
  - Compared Aluminum, Tyvek paper and 3M VM2002 reflector. Tyvek \(\sim10\)% better than Al, 3M \(\sim15\)% better than Tyvek \(\rightarrow\) 3M VM2002
Test of the tile/fiber system

Cosmic Ray Test of the scintillator tile/fiber system candidates

- Compared for different configurations
  - In this plot: Non-mirrored PolHiTech fiber (4 loops) with grease + Tyvek wrapping

- Check optimal number of fiber loops, from 1 to 7
  - PolHiTech light yield reaches a plateau at N=4, Kuraray Y11 at N=5 (Kuraray atten. length ~50cm longer ~1 extra loop)

- In this test: Dubna+Grease+3M wrapping
Test of the tile/fiber system

No time decay observed yet for glued tiles

However, to reduce assembly time and remove the concern about glue damaging fibers, we recently proposed a new **Keyhole+Double-Spiral Groove**

(increased light yield to 38 pe/MIP without optical glue/grease)

- Keyhole cross section to better trap the light and reduce need of glue/grease
- Two-loop spiral, outer R=5cm, inner R=4.5cm
Test of the tile/fiber system

Keyhole groove, 2loops vs. Square groove, 4-loops glued
(Mirrored PolHiTech + Tyvek)

Keyhole Groove vs. Glued 4-loops

Constant 2.506e+04
MPV 29.37
Sigma 2.753

Lami 2004
Test of the tile/fiber system

Comparison for Spiral 2-loops into tile with Keyhole groove:

- Kuraray Y11(250) ~ PolHiTech
- Kuraray Y11(350) vs Kuraray Y11(250): + 17%
- 3M reflector vs Tyvek: + 15%
- Mirrored vs Non-mirrored: + 20%
- Grease vs No-grease into Keyhole: + 15% (Not essential)

Mirrored Kuraray Y11(350) into 2-loop spiraling keyhole groove on Dubna tile wrapped with 3M reflector is our final choice
Status CPR2

- All material procured
- Module production started at Argonne in May 04
  - Italian INFN + ANL techs at work
  - ~1 Module/day
- Timeline:
  - Installation starts September 04
  - Module construction ends in July
Status CPR2

- Performance of first two (prototype) modules as expected
  - Production at full speed

16 pe/MIP after full optical path

Source scan

Not corrected for Attenuation Length, MAPMT Calibration
Conclusions

- CDF Calorimeter Upgrades needed to do the physics of Run II, including New Physics signatures involving photons

- Hardware choices made to minimize costs, minimize R+D, and minimize technical risks

- A light yield of \(~38 (~16) \text{ pe/MIP}\) at the Preshower tile exit (after full optical path) exceeds design requirements

- Preshower/Crack detectors ready to install by Fall 2004
Backup slides
Use of CPR to improve e/γ energy resolution at low P_T

- **Impact on jet energy resolution**

- Previous experiences with scintillator tile preshowers very promising (~17% improvement at ZEUS)

Preliminary study in Run II with jets in Plug Calorimeter are showing an energy resolution improvement ~ 7% when EM energy (PEM) redefined including E from the preshower (scintillator tiles)
CPR2 Fiducial Coverage

Discrimination $\pi^0/\gamma$ with CPR only in its fiducial region

The CPR2 will increase it accepting more photons

Limit due to Tungsten bar
Holder is 20.3 cm. CPR2 will have full coverage to 20.0 cm

There will be no Z crack in CPR2,
And full coverage past $|Z|<9$ cm
Clear fiber attenuation length

![Graph showing light yield vs fiber length with data points for PolHiTech and Kuraray.]
Test of the tile/fiber system

Comparison for Spiral 2-loops into tile with Keyhole groove

<table>
<thead>
<tr>
<th>Test</th>
<th>WLS Fiber into Spiral</th>
<th>Mirror</th>
<th>Reflector</th>
<th>pe/MIP</th>
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<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<td>3</td>
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<td>4</td>
<td>Kuraray Y11(350)</td>
<td>No</td>
<td>Tyvek</td>
<td>28.7</td>
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<td>5</td>
<td>Kuraray Y11(250)</td>
<td>No</td>
<td>3M</td>
<td>28.1</td>
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<tr>
<td>6</td>
<td>Kuraray Y11(350)</td>
<td>No</td>
<td>3M</td>
<td>32.9</td>
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</tbody>
</table>

- Kuraray Y11(250) ~ PolHiTech (test 1 vs 3)
- Kuraray Y11(350) vs Kuraray Y11(250) (test 6 vs 5): +17%
- 3M reflector vs Tyvek (test 6 vs 4): +15%
- Mirrored vs Non-mirrored (test 1 vs 2): +22%
Test of the tile/fiber system

Looking for best configuration with Kuraray Y11(350)M into Spiral 2-loops with Keyhole groove:

<table>
<thead>
<tr>
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<tr>
<td>6</td>
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<td>3M</td>
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<td>3M</td>
<td>43.9</td>
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</tbody>
</table>

Grease vs no grease into Keyhole groove (test 8 vs 7): + 15%

Configuration of test 7 is our final choice:
Mirrored Kuraray Y11(350) into 2-loop spiraling keyhole groove on Dubna tile wrapped with 3M reflector

With Bicron BC-630 optical grease

Cosmic ray test of CPR2 tile

Constant 2.73e+04
MPV 43.89
Sigma 3.128
Latest prototype Dec 2003

- 12.5X12.5 cm²

**keyhole sigma groove**
- Inner circle:
  - 4.5 cm radius
- Outer circle:
  - 5.0 cm radius
- 2 loops of green 1mm diameter fiber
- Splice to clear at exit
- 3M wrapping ($\lambda=570\text{nm}$)
Spiral and keyhole groove

Emission angle

Angle of blue light emitted by scint (deg)

Incident angle

0 10 20 30 40 50 60 70 80 90

0 50 100 150 200 250 300 350

inner

outer

n=1.59
critical angle 1.4°

vertical track:
critical angle 35°
Test Multi-Anode to verify if is adequate to CPR2

- H6568 16-pixel multianode
- Uniformity of 10%
- Cross talk 3% on direct neighbors