Performance of a Prototype Position Sensitive Towerless Calorimeter at the 1997 CDF Test Beam

- Conceptual Design
- The MiniPlug Prototype
- Test Beam Results:
  - Calibration and Linearity
  - Electron Energy and Position Resolution
  - Response to Pions
- MiniPlugs in CDF II
- Conclusions

Stefano Lami
The Rockefeller University
Calor97, 12-Nov-97
Desired Features of an Ideal Calorimeter

- Energy Determination
- Position Determination
- Works for EM and Hadron Showers
- Provides EM/Hadron Identification

How to optimize/compromise in the very forward region of collider detectors?
Conceptual Design

Pb plates in liquid scintillator
WLS fibers to MCPMT

Towerless geometry: no discrete towers.
Principle of Hadron Shower Position Determination

Upon interaction hadrons release on average $1/3$ energy as $\pi^0$s
MiniPlug Prototype

Front view of the MiniPlug Prototype:
4 fibers grouped for readout.

In ≈70 RL (2.4 IL) final design, hadrons are tagged by WLS fibers which do not sample the first 24 RL.
The MCPMT Calibration

Setup with green LED:

Light mixer (lucite: 32x28x102 mm)

64 hole array (2 mm spacing)

Optical connectors: fibers glued in delrin "cookies"

Clear fiber light guides (1 mm dia.)

Rotate MCPMT to cross-calibrate channels

Hamamatsu 5828
Test Beam Setup

MiniPlug moved to MT6 in May 1997

Beam drift chambers $\sigma_{x,y} = 290 \mu m$, $\delta p/p = \pm 0.5\%$

e$^+$, $\pi^+$, $\mu^+$ particles within $\pm 1.5\sigma$ from $\langle p_{beam} \rangle$

Read 64 MCPMT central channels
ADC count sum around Seed Tower in circle of radius 3, 5, 7, 8(all towers) cm

Miniplug centered on beam and $\pm 1$ tower
and at angles $0^0$, $3^0$ and $10^0$
(Beam spot $1/2'' \times 1'').
Calibration

$\chi^2/\text{ndf} = 60.61 / 27$

P1  1636.3
P2  307.0
P3  203.7

100 GeV $\mu^+$, all towers

MCPMT HV=1.8 KV, $G \approx 0.6 \cdot 10^6$

110 pe's/GeV (e)

All towers ($\mu$): 55 pe's/MIP, or 1.8 pe's/MIP/layer

Seed Tower ($\mu$): 13 pe's/MIP,
or 0.43 pe's/MIP/layer
Linearity

MiniPlug Electron Linearity

\[ \langle \text{ADC} \rangle = -2257.4 + 3205.6 \times E \]

TB 97, All Towers

MiniPlug Pion Linearity

\[ \langle \text{ADC} \rangle = 3136.3 + 984.8 \times E \]

TB 97, All Towers
Electron Energy Resolution

$$\frac{\sigma}{E} = 18.1\%/\sqrt{E} + 0.6\%$$ for 5–120 GeV $e^+$

MiniPlug Electron Energy Resolution

TB 97, All Towers
$$\frac{\sigma}{E} = 18.12\%/\sqrt{E} + 0.59\%$$
Electron Position Resolution

CoG of the Shower Profile: best results with

- Weighted CoG over a raw of 5 towers
- Lorentzian lineshape fit over 3 towers

\[ <x> = x_{seed} + \frac{(1/R_1 - 1/R_2)}{[2(1/R_1 + 1/R_2 - 2)]} \cdot W \]

Where \( R_1 = \frac{Q_{-1}}{Q_{Seed}} \), \( R_2 = \frac{Q_{+1}}{Q_{Seed}} \), \( W = \text{tower size} \)

\[ \sigma = 1.15 \text{ mm for 50 GeV } e^+ \]
**Electron Position Resolution**

**MiniPlug Electron Spatial Resolution**

TB 97, CoG

\[ \sigma = 9.21 \text{ mm } / \sqrt{E} \]

**MiniPlug Electron Spatial Resolution**

TB 97, Profile Fit

\[ \sigma = 9.47 \text{ mm } / \sqrt{E} \]
Response to Pions

MiniPlug prototype is 1 interaction length deep
→ MIP peak + gaussian tail from $\pi^0$'s

Select interacting pions by rejecting the Landau MIP peak in the Seed Tower ADC spectrum
$\sigma/E = 43\%$, constant over 10–230 GeV range.
(fluctuation in $\pi^0/\pi^\pm$, independent of $E_\pi$ if $\pi^\pm$ escape)

In $\approx 70$ RL (2.4 IL) final design, GEANT simulation provides $\sigma/E \approx 30\%$ for single pions.
Pion Position Resolution

$\chi^2/\text{ndf} = 20.10 / 13$

Constant = 128.7
Mean = 0.2197E-01
Sigma = 0.1876

$\sigma = 1.88 \text{ mm for 150 GeV } \pi^+$

150 GeV $\pi^+$

$R \text{ MiniPlug-Beam Chambers (cm)}$
**Pion Position Resolution**

**MiniPlug Pion Spatial Resolution**

TB 97, CoG

\[ \sigma = 23.85 \text{ mm } / \sqrt{E} \]

**MiniPlug Pion Spatial Resolution**

TB 97, Profile Fit

\[ \sigma = 24.18 \text{ mm } / \sqrt{E} \]
Typical single event ADC counts:

30,000 (e)  
ADC

8000 (π)

50 GeV e⁺

50 GeV π⁺

500 (μ)

100 GeV μ⁺
CDF II

2 MiniPlugs

3.5 < |\eta| < 5.5
Test Beam Data Mixing

2 50 GeV $\pi^+$

2 50 GeV $e^+$
Conclusions

We successfully tested a prototype of the proposed CDF II MiniPlug Calorimeter

- Good Energy Resolution for electromagnetic showers:
  \[
  \sigma/E = 18.1\%/\sqrt{E} + 0.6\%
  \]

- Electron Energy Linearity better than 1.5%

- High precision in measuring the lateral position of both electromagnetic and hadronic showers:
  - \( \sigma = 9.2 \text{ mm} / \sqrt{E} \) for positrons,
  - \( \sigma = 23.9 \text{ mm} / \sqrt{E} \) for pions