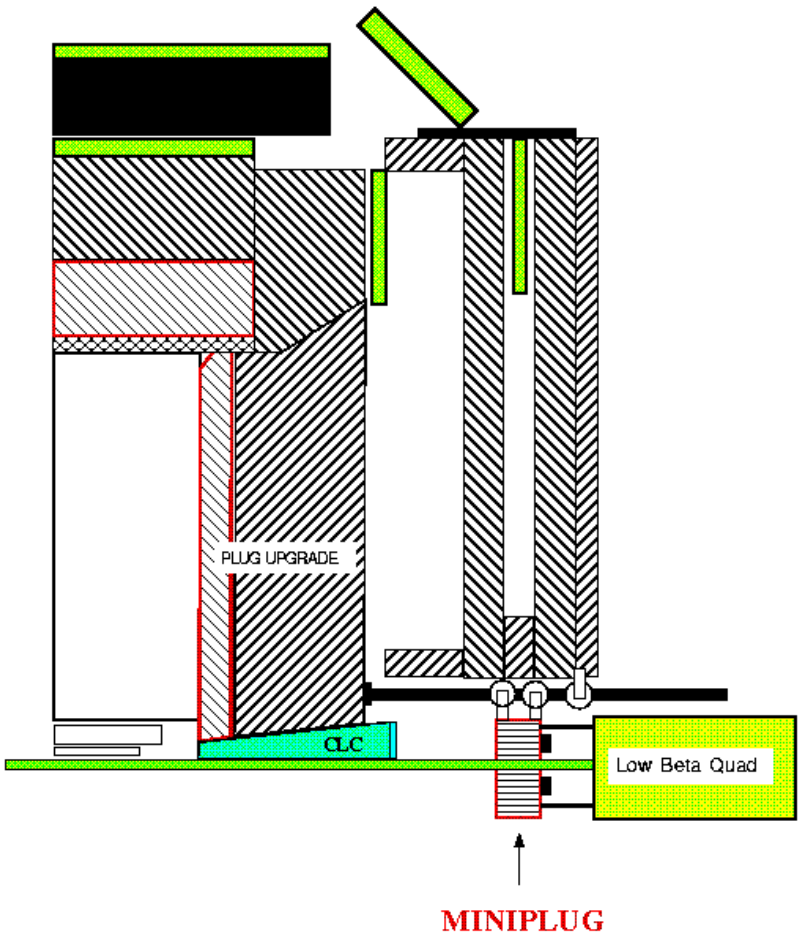
Forward CDF calorimeters

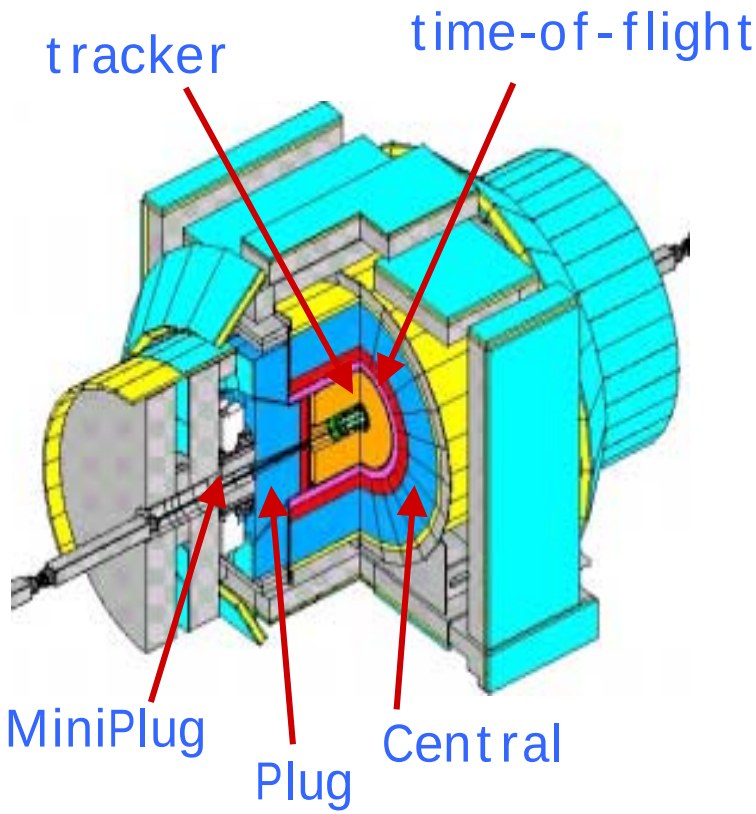
Michele Gallinaro (The Rockefeller University)



- ✓ Forward Physics
- ✓ Conceptual Design
- ✓ Prototype Results
- ✓ Final Design
- ✓ Cosmic Ray Test
- ✓ Run II Data

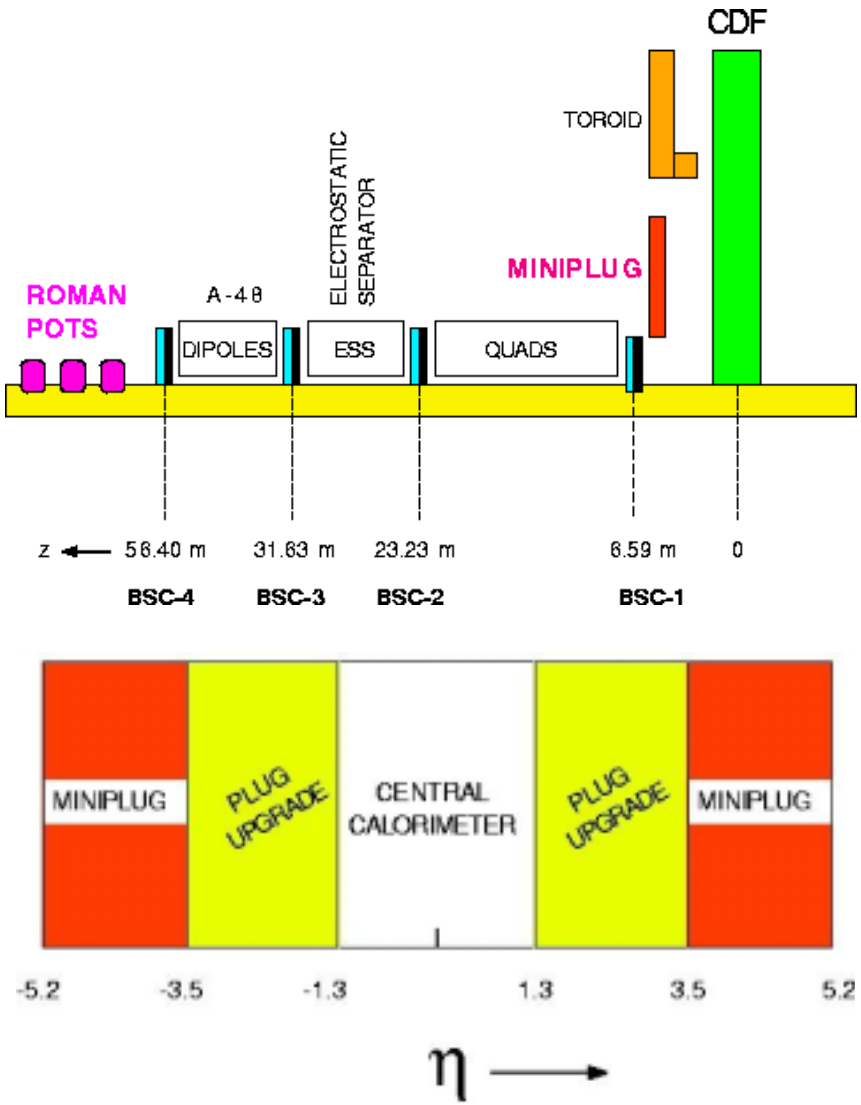
New Detectors for Run II

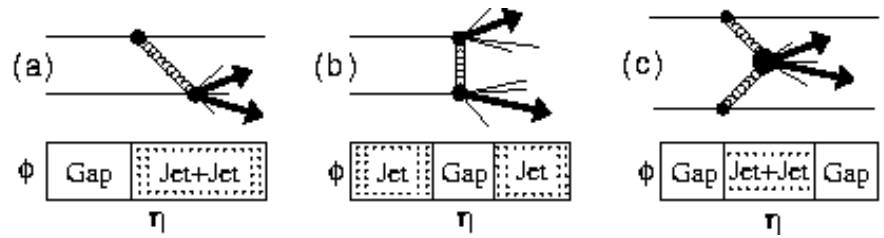
- Tracking
  - -Silicon
  - -Central Outer Tracker
- Time of Flight
- Expanded Muon Coverage
- Endplug Calorimeter
- **Forward Detectors**
  - -Beam Shower Counters
  - -Miniplugs
  - -Roman Pots (same as Run I)



All detectors are used in the diffractive program !

Forward physics



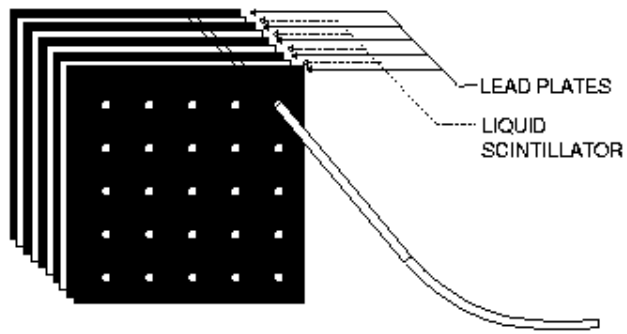


- Diffractive structure function
  - ✓ Q^2 and ξ dependence
  - ✓ process dependence
- Exclusive production in DPE (dijet, heavy flavor, low-mass)
- Forward jets (jet-gap-jet)

Conceptual design

Compact/simple/low-cost to measure energy and position

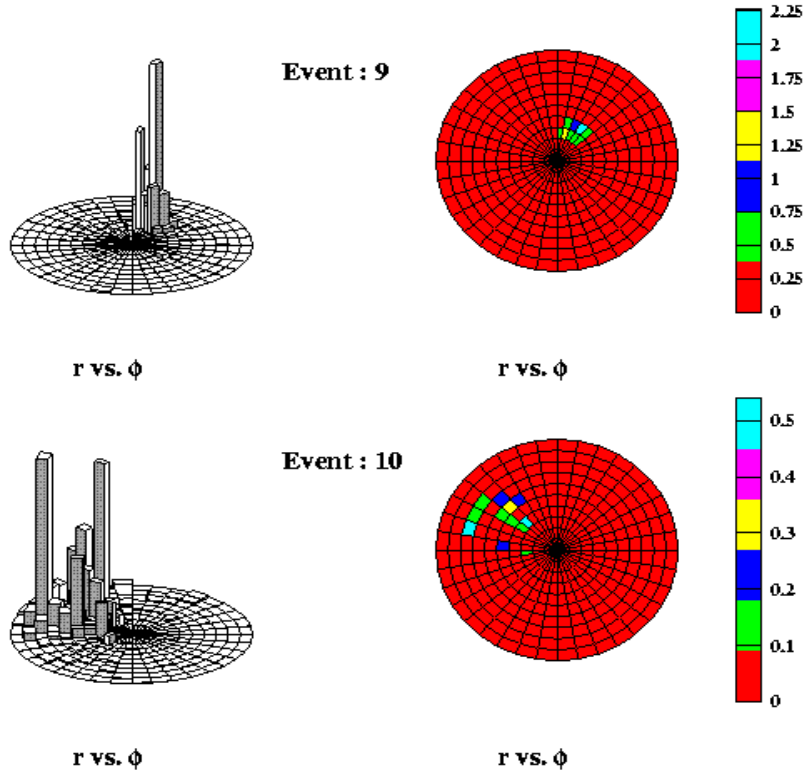
- Pb plates in liquid scintillator
- WLS fibers to MAPMT
- Flexible tower geometry
  (no mechanical boundaries)
- "Tower" size determined by fibers' grouping



WLS - FIBER
(to multi-channel phototube)

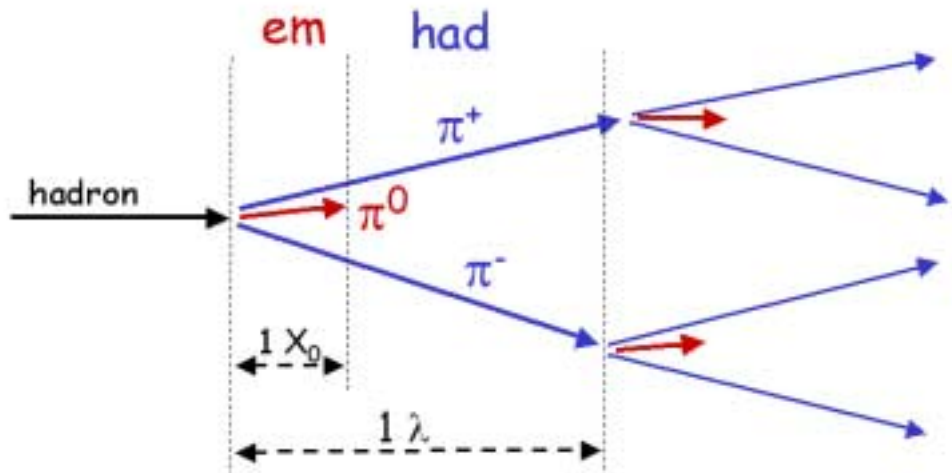
Design simulation

- Measure charged and neutrals
- Measure energy and position of both EM and hadron showers
- GEANT simulation ($56X_0$, 2λ):
  - ✓ $\sigma/E(e^+) = 18\%/\sqrt{E}$
  - ✓ $\sigma/E(\pi^+) = 30\%$ independent of E
- Hadron tagging fibers after 24 r.l.



Hadron shower

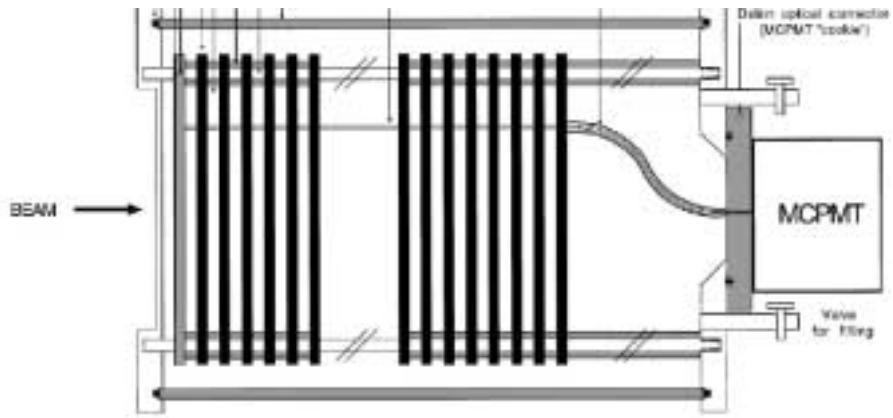
When interacting, hadrons release on average 1/3 energy as π^0

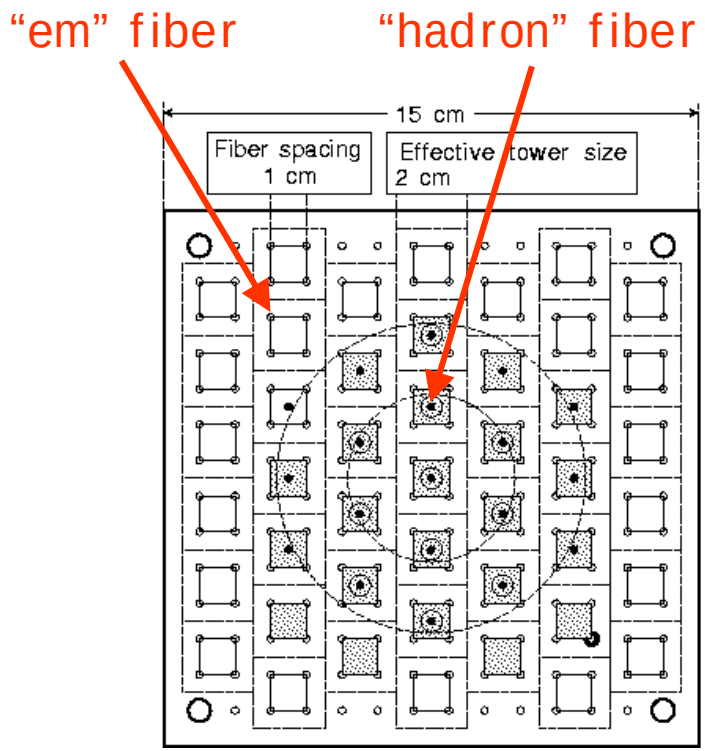


Shower lateral spread:
EM ~X_0 (=2-3 cm)
Had ~λ (=60 cm)

MP prototype

- Detector:
  - ✓28 X_0 (1 λ) long
  - ✓30 plates (15x15 cm^2)
  - ✓Bicron 517 L liquid scintillator
  - ✓Kuraray Y-11 WLS fibers

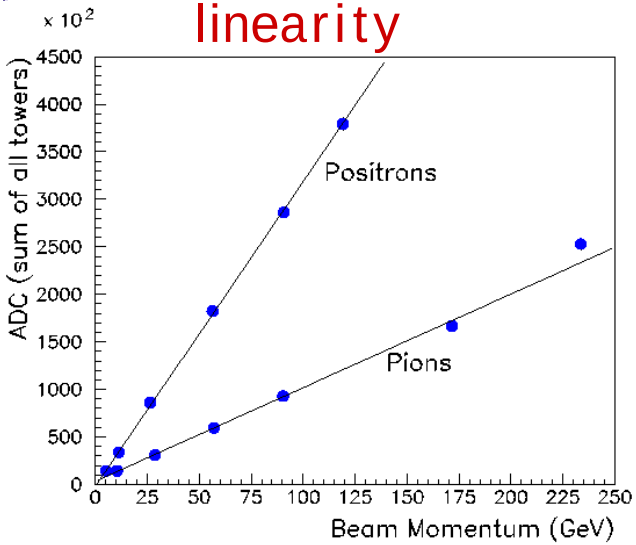




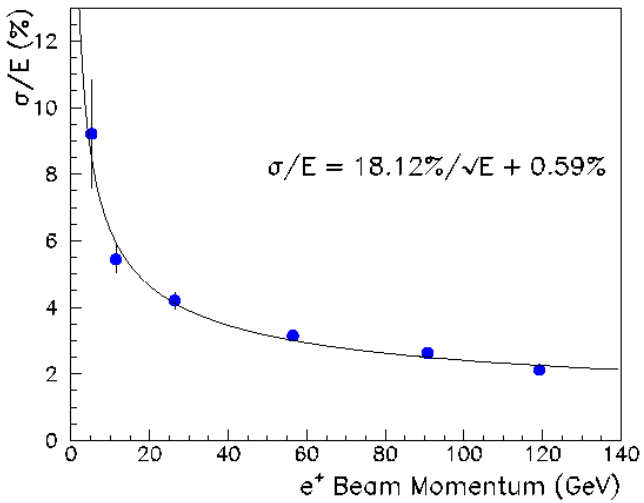
- Test-beam:
  - ✓ low energy pions and electrons at BNL (1994): NIM A 372 (1996) 117
  - ✓ high energy beams at Fermilab (1997): NIM A 430 (1999) 34

Prototype results

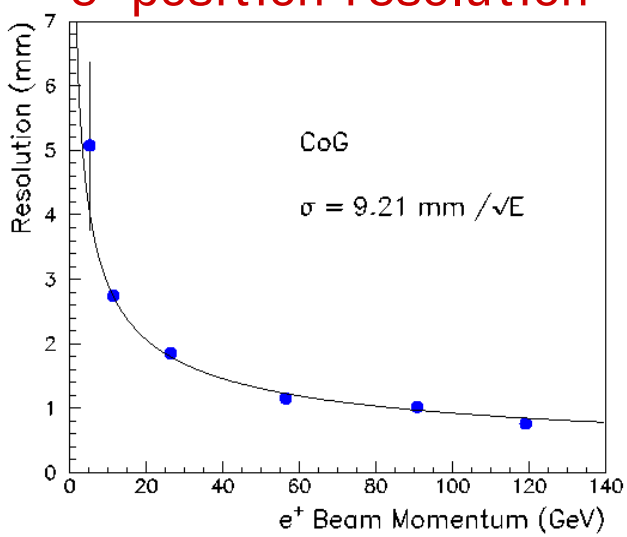
linearity



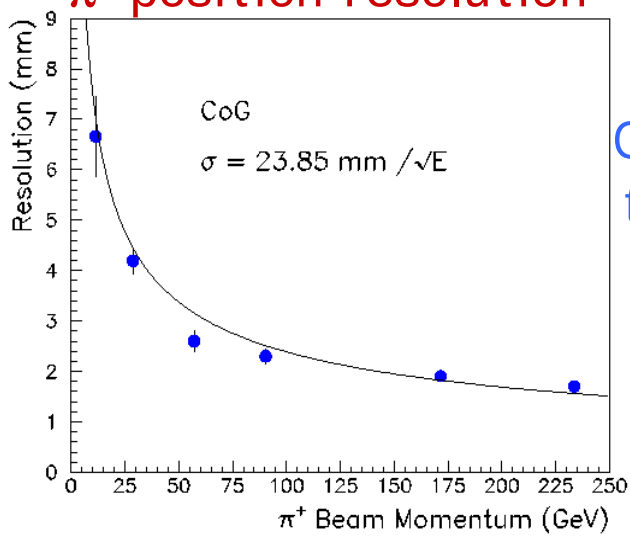
EM energy resolution



e⁺ position resolution

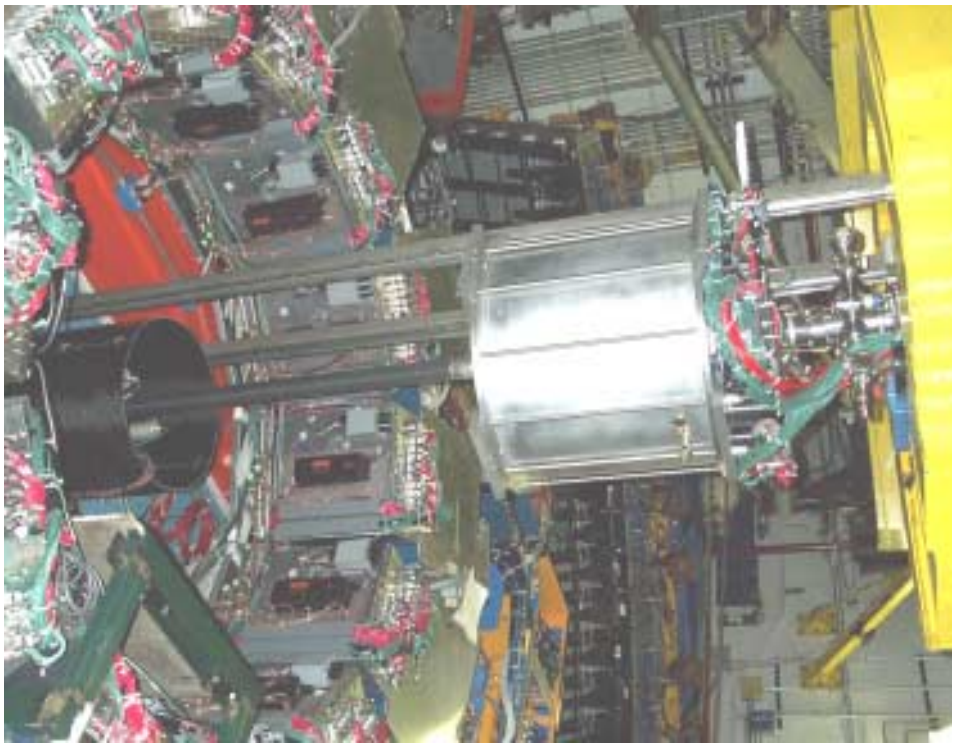


π⁺ position resolution



Good fit down to low energy

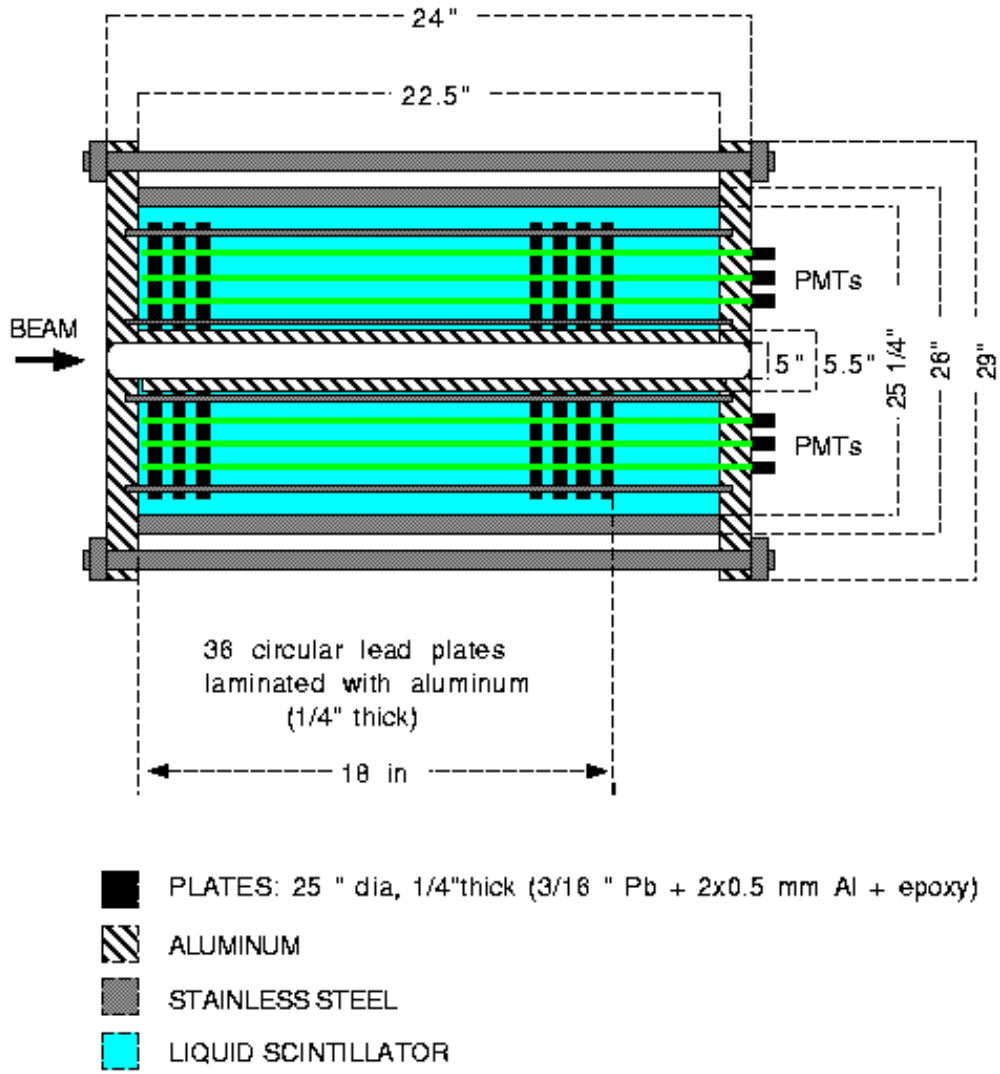
MiniPlugs at CDF



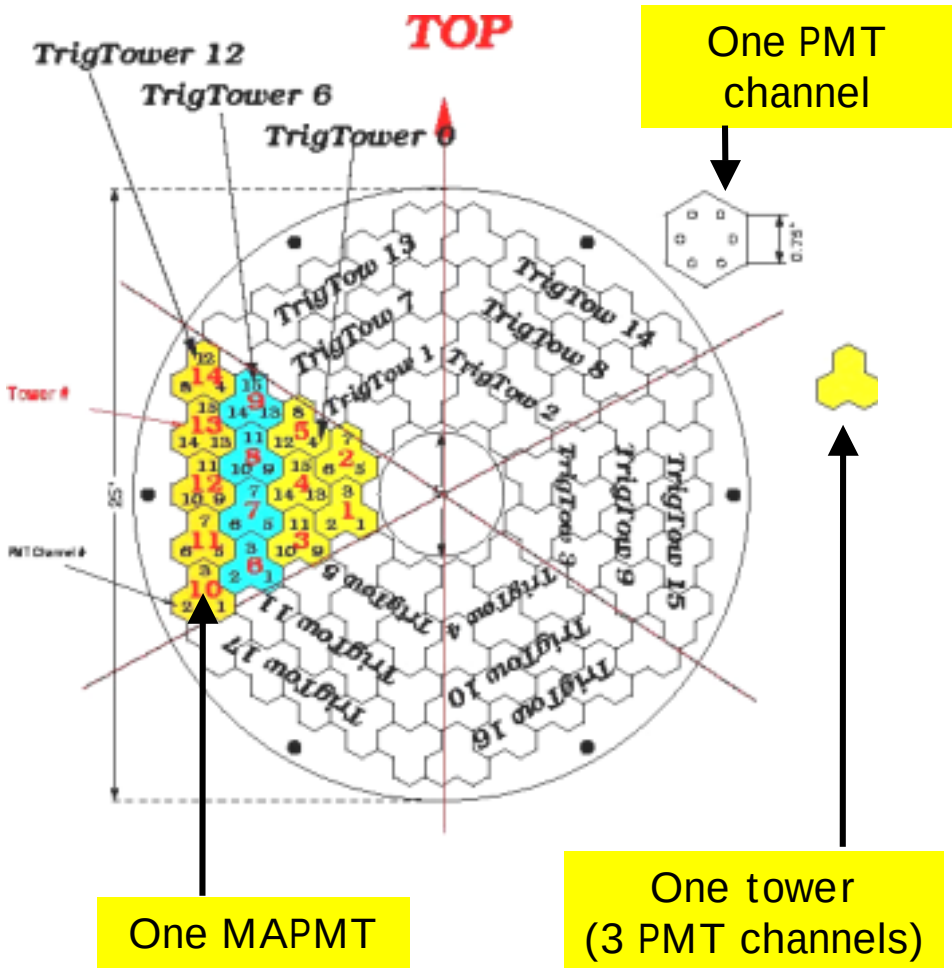
- Due to space constraints when Plug in "open" position, MPs are 61 cm long (32 r.l. and 1.3 i.l.)
- Same plate/gap thickness, scintillator as prototype
- Larger hexagonal cell structure, balanced by increasing:
  - ✓ Number of fibers (6 vs. 4)
  - ✓ Fiber dia. (1 mm vs. 0.8 mm)

Nucl. Instr. Meth. A 496 (2003) 333

Final design



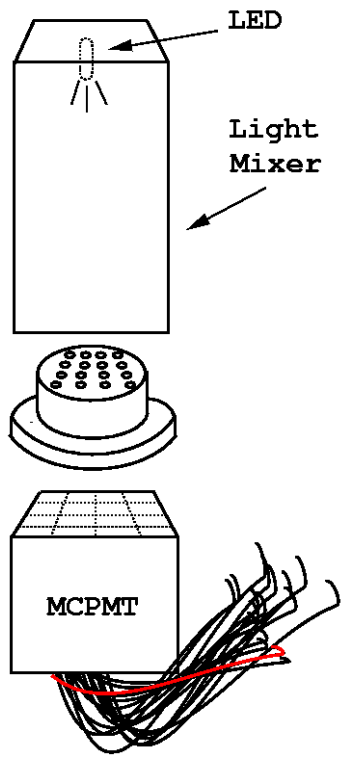
Final design



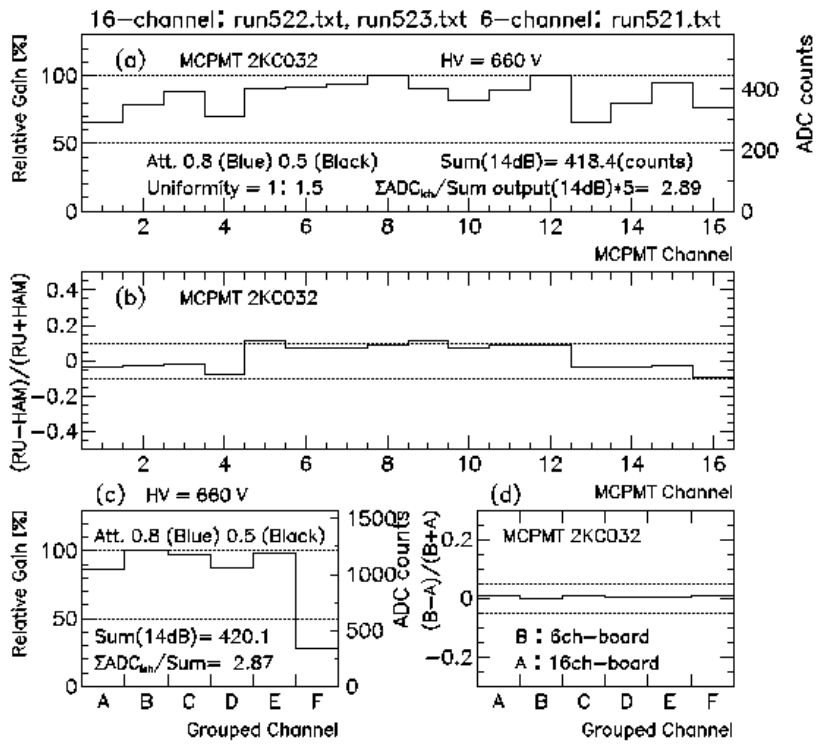
- 6 WLS fibers = hexagon
  ⇒ 1 MAPMT pixel
- 1 clear fiber to LED
- 252 hexagons viewed by 18 16-channel MAPMT
- 3 MAPMT outputs added
  ⇒ 84 calorimeter "towers"
  (to reduce electronics' cost)
- 4 η rings: $3.6<|\eta|<5.1$
- 18 "trigger-towers"

MAPMT test

- Channel-to-channel response Hamamatsu R-5900 (16 channels)

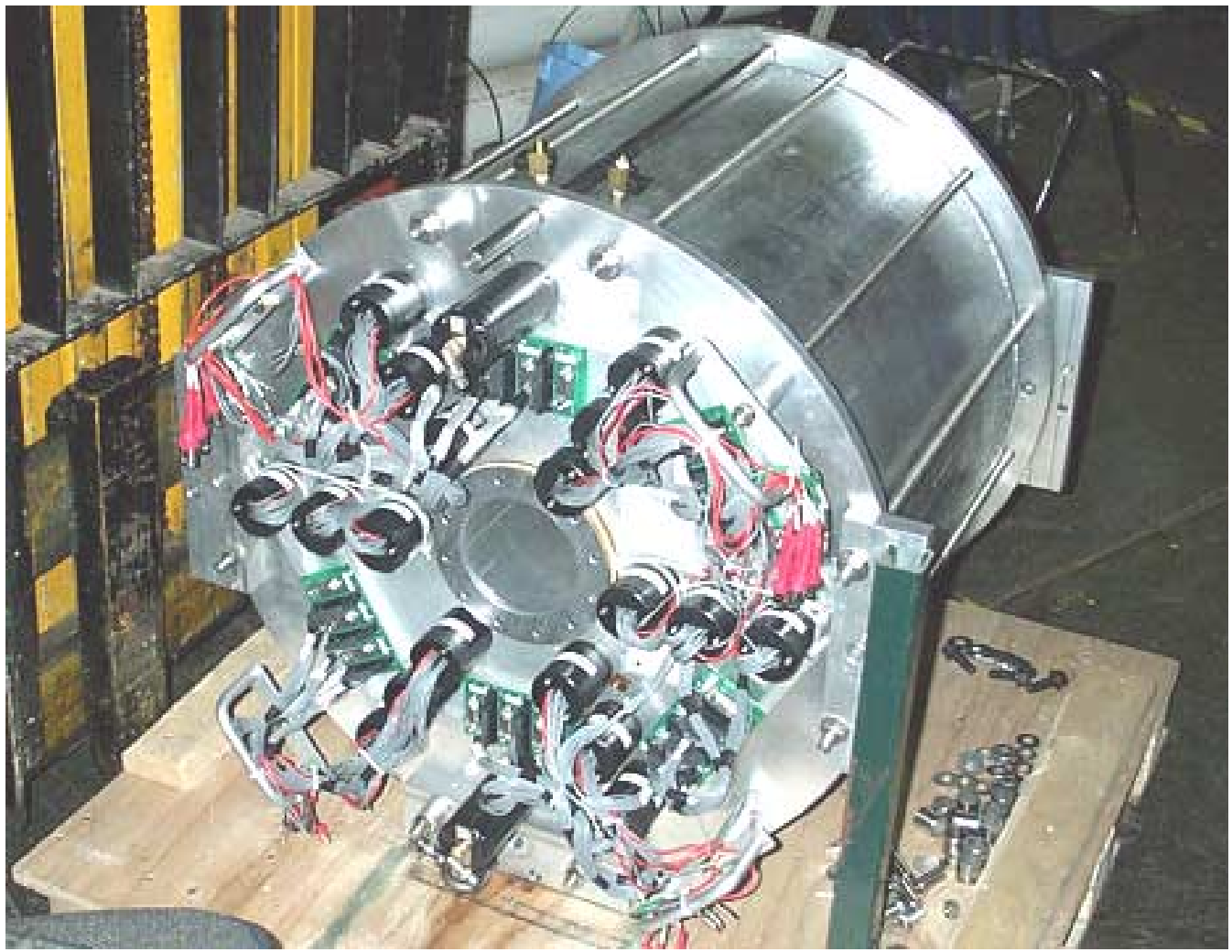


MAPMT test setup



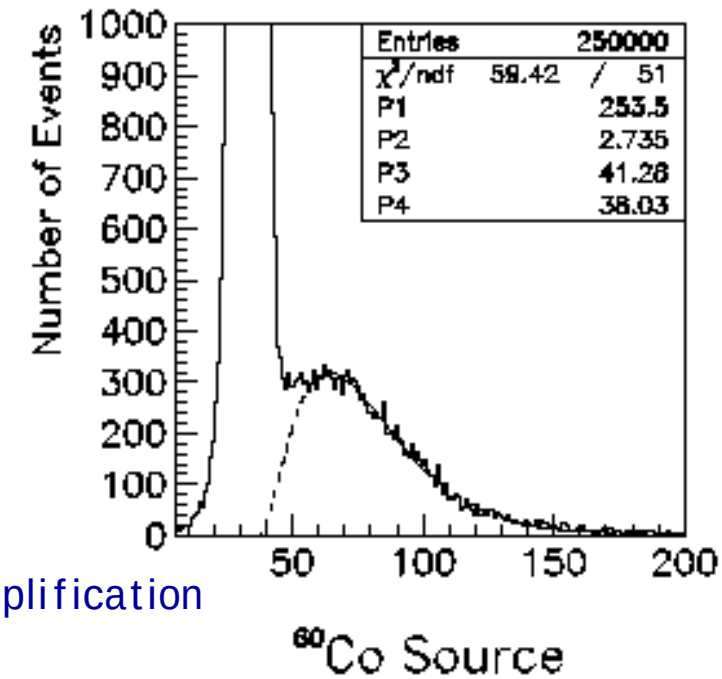
MiniPlug assembly

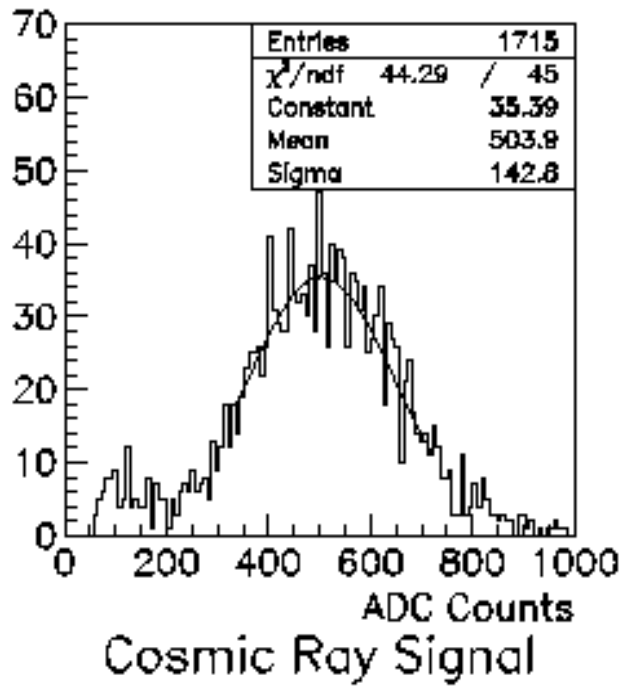
MiniPlug assembly



Cosmic ray test

- Measure response to single photoelectrons (Co^{60} source)
- Trigger on cosmic rays for 60^{o}-section of one MP



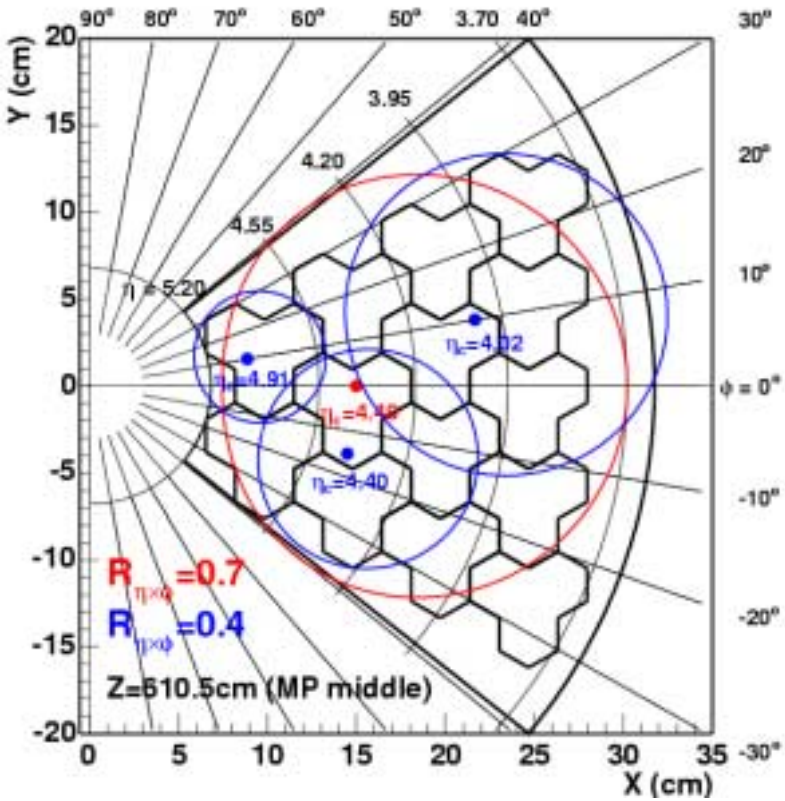


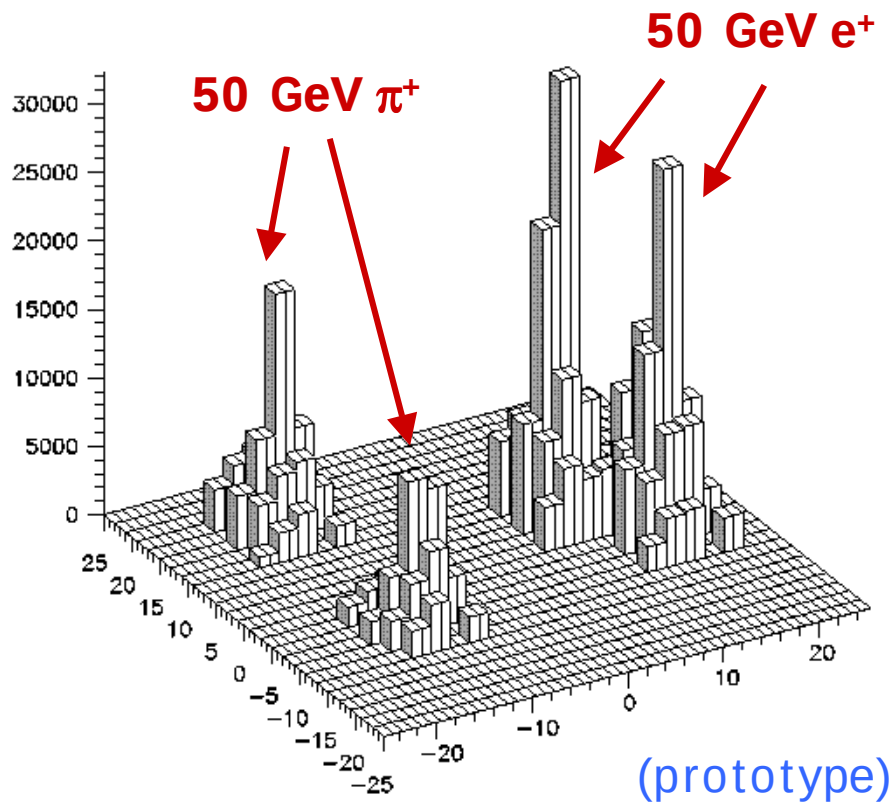
⇒ **Average response is ≥ 100 p.e./MIP**

(prototype was ~55 p.e./MIP)

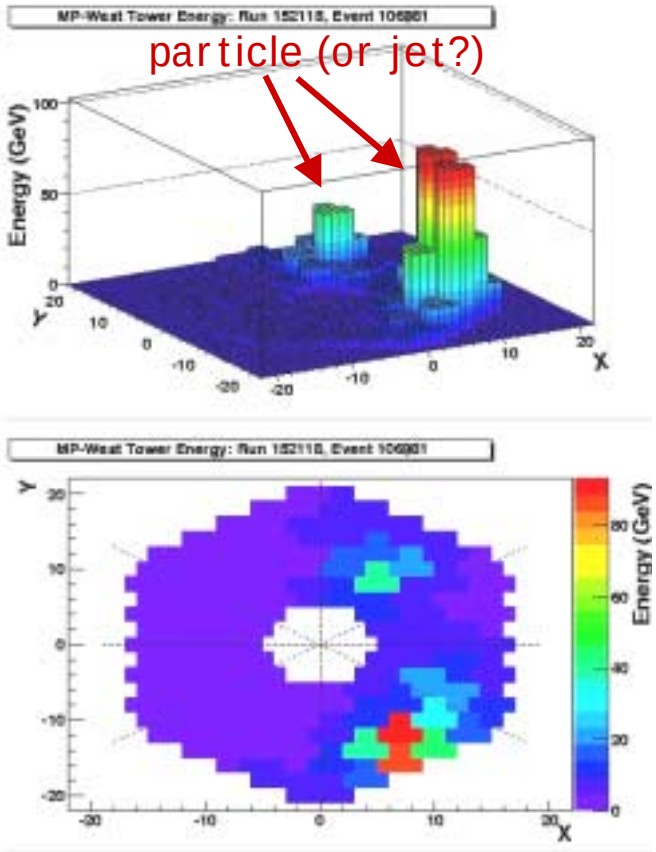
MP segmentation

determine shower centroid
(electron/pion separation)

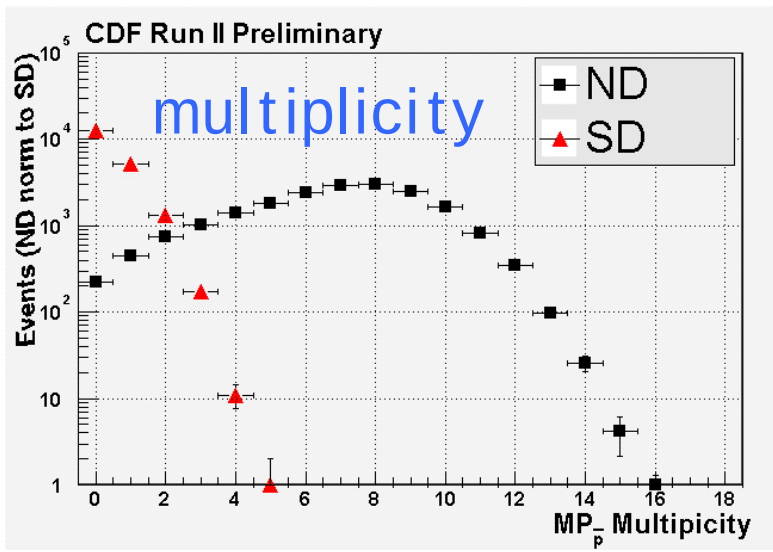




Particles/jets in MP

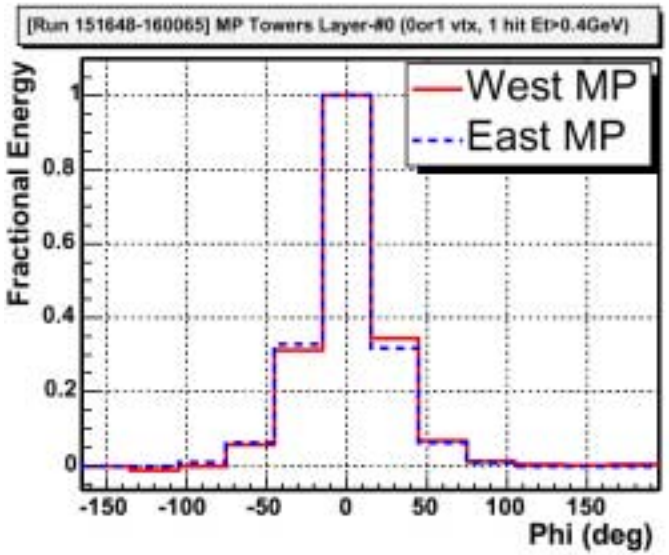


ADC counts in MP towers:
approximately 1000 counts = 1 GeV

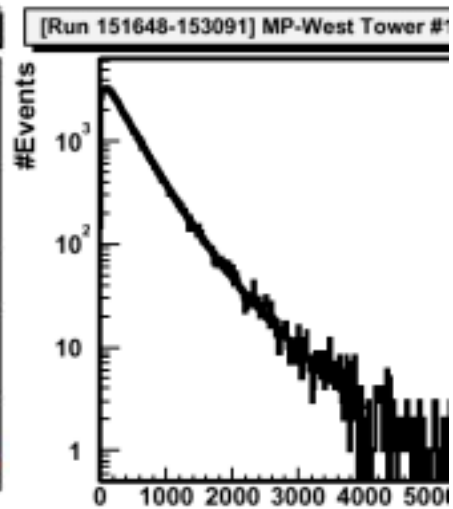


Position/energy resolution can be improved by instrumenting all 252 towers

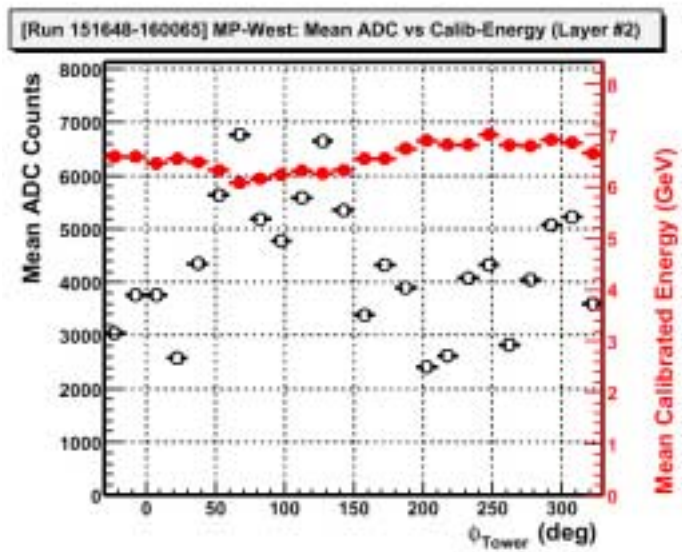
MP calibration



"Seed" and neighbor towers in ϕ

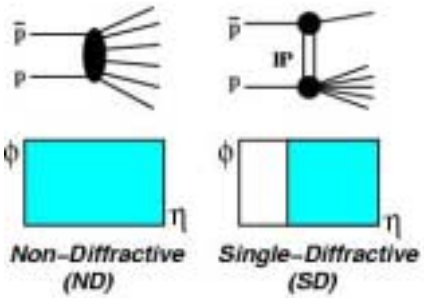


"Seed" tower ADC counts



ADC counts vs ϕ before/after calib.

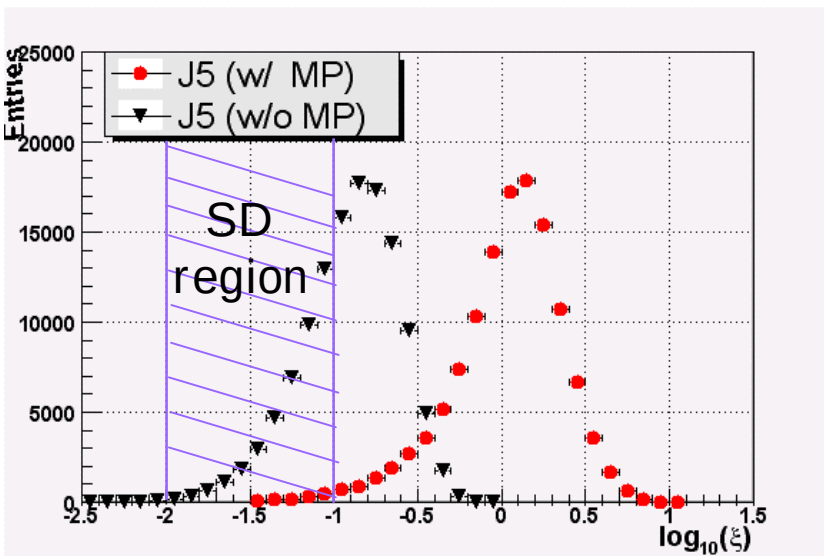
- ✓ use data for relative calib. of towers at same η
- ✓ use MC for relative calib. vs η and overall energy scale

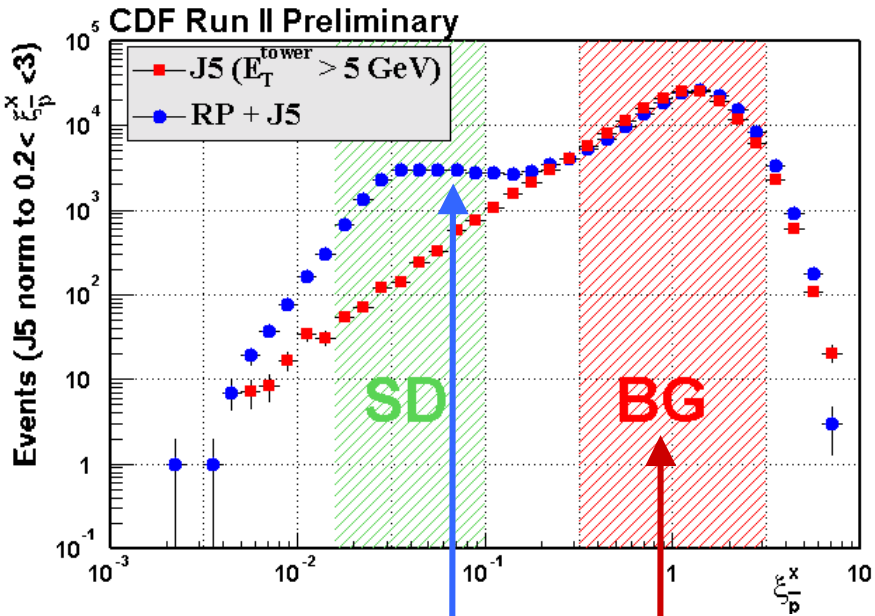


Diffractive dijets

ξ : momentum loss fraction of pbar

$$\xi = \frac{\Sigma_{\text{(all towers)}} E_T \, e^{-\eta}}{\sqrt{s}}$$





Approx. flat at ξ<0.1

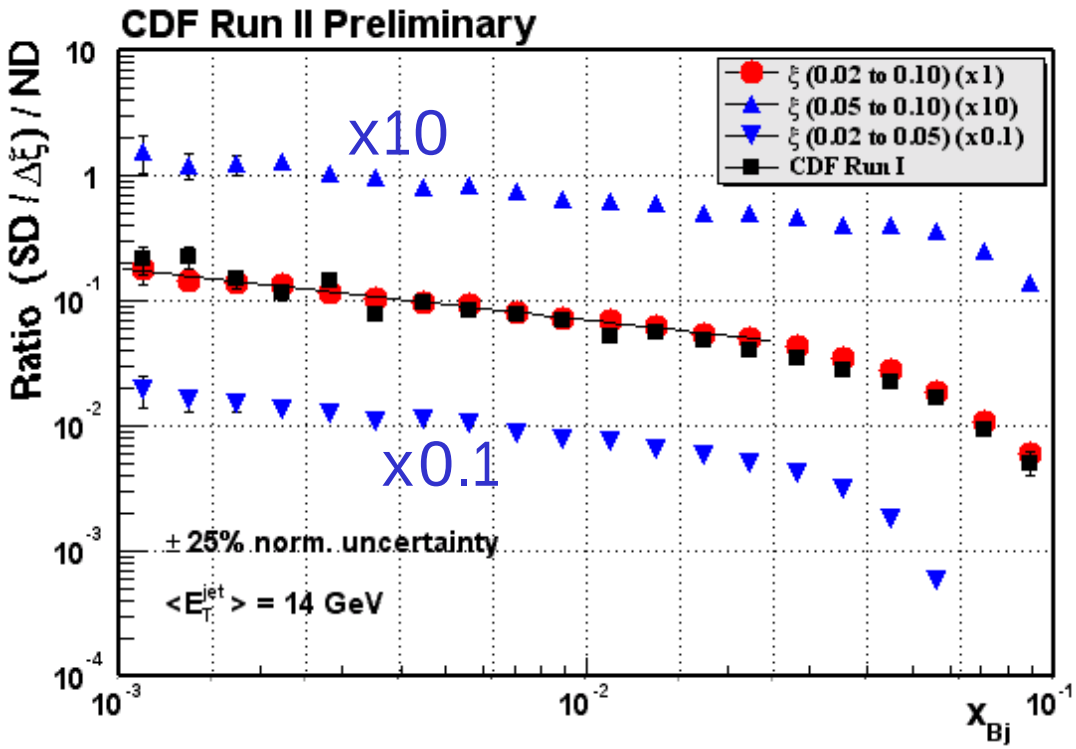
$$\frac{d\sigma}{d\xi} \propto \frac{1}{\xi} \rightarrow \frac{d\sigma}{d(\log \xi)} = \text{const}$$

overlap events

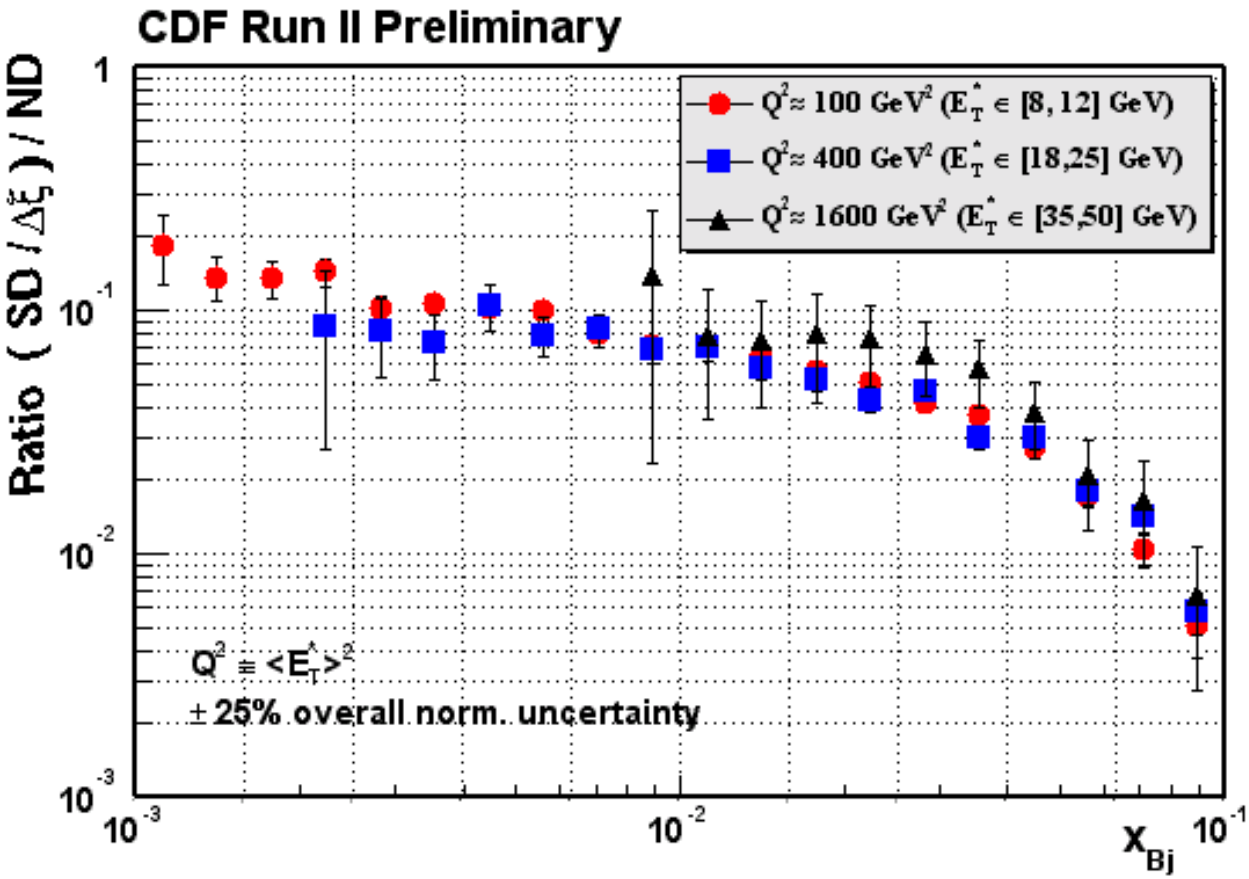
Ratio of SD/ND Events

$$x_{Bj} = \frac{\Sigma_{jet} E_T e^{-\eta}}{\sqrt{s}}$$

- slope and normalization agree with Run I result
- no ξ dependence observed within $0.03 < \xi < 0.1$
  ⇨confirms Run I results



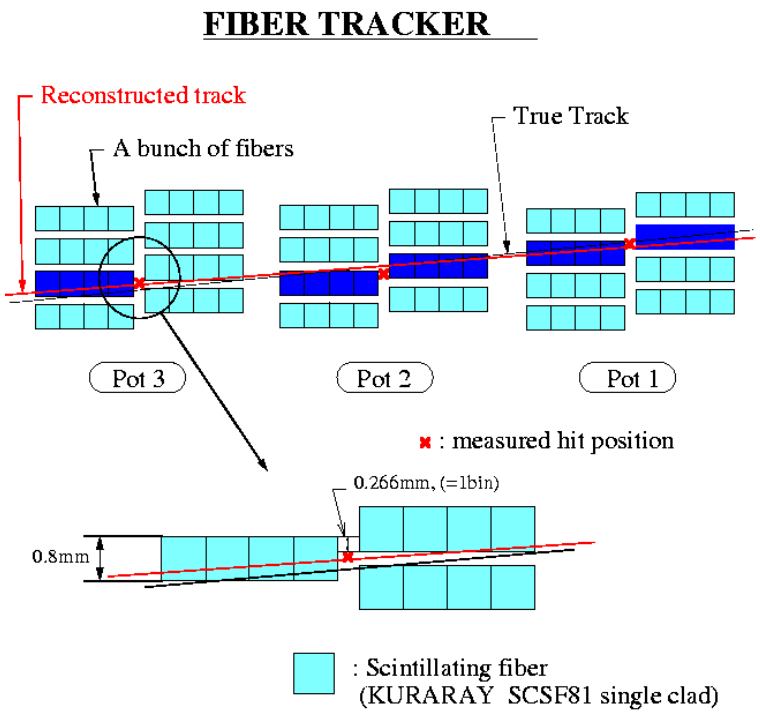
Q^2 dependence



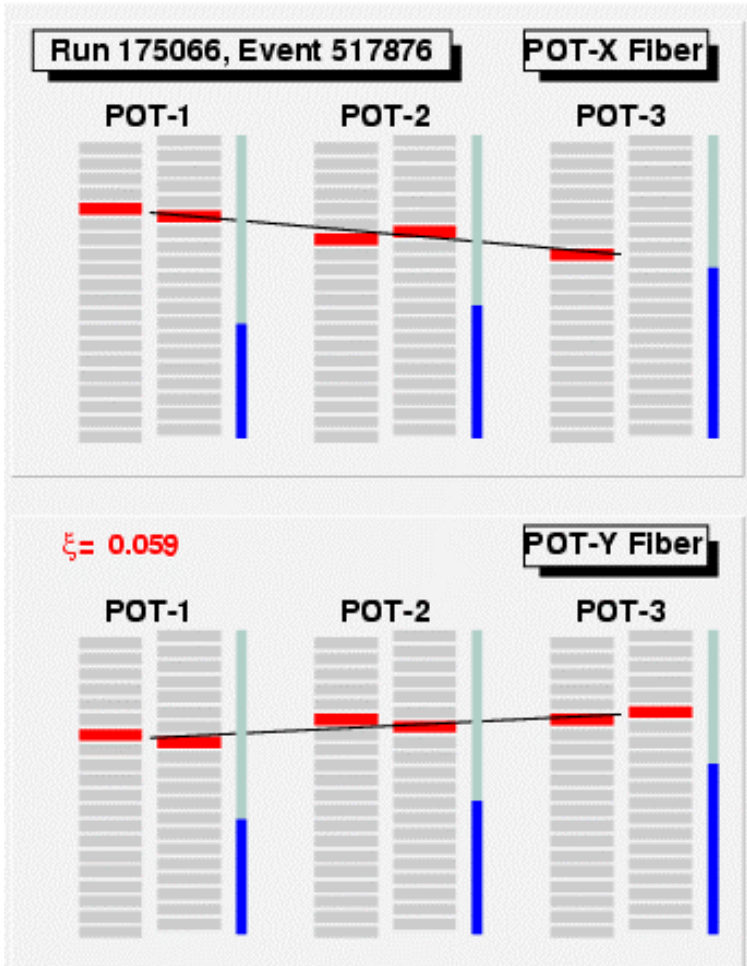
No appreciable Q^2 dependence observed within $100 < Q^2 < 1{,}600$ GeV^2

⇨ Pomeron evolves similarly to proton

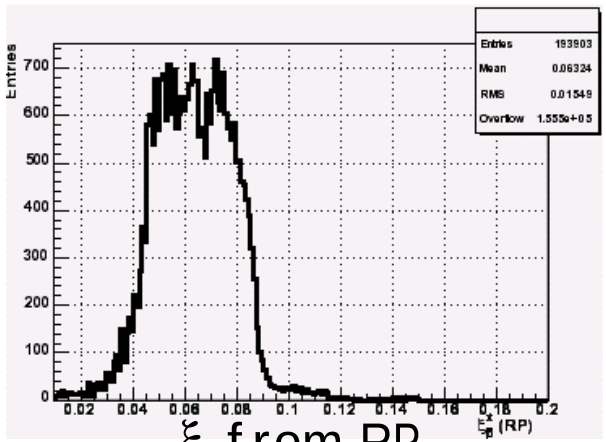
Roman Pot tracking

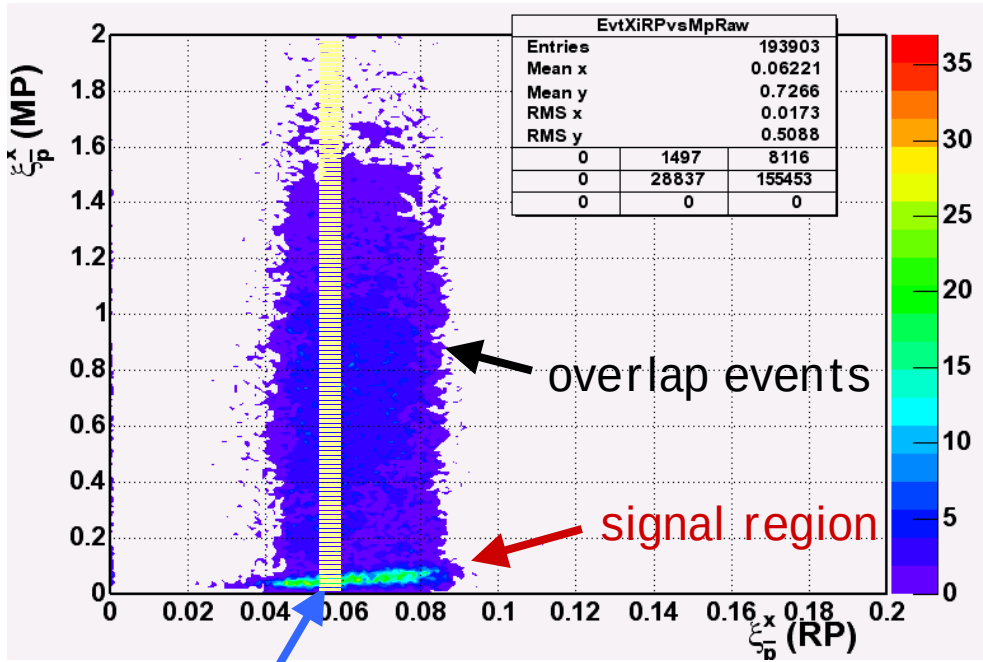


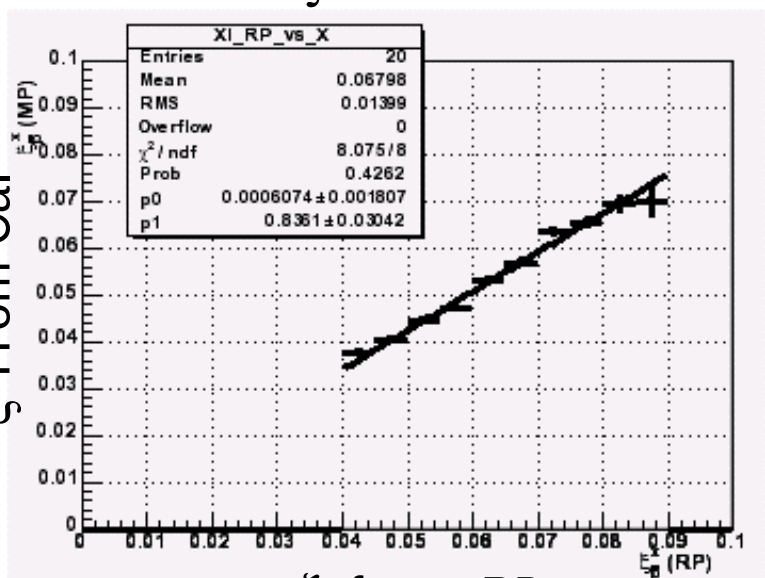
Expected position resolution	**80 μm**
Expected angle resolution	**60 μrad**

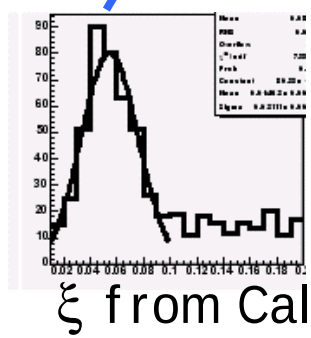


ξ: RP vs calorimeter





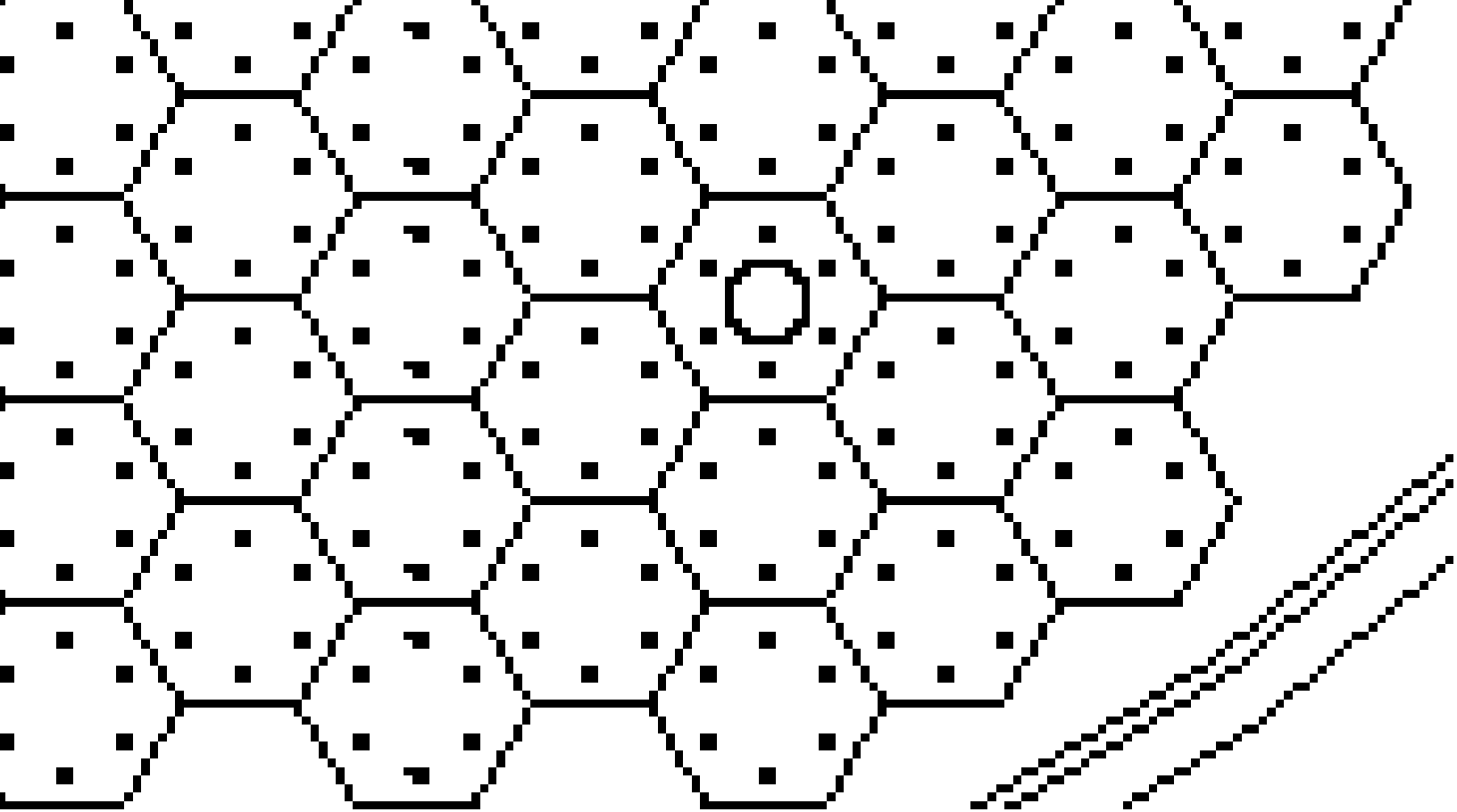




ξ^{cal} distribution for slice of ξ^{RP}

Conclusions

- two MP calorimeters (Pb/liquid scintillator) installed at CDF
- MPs measure energy and position of particles ($3.6<|\eta|<5.1$)
- cosmic ray test resulted in light yield of ~100 pe/MIP per tower, exceeding design requirements
- measure energy and position (count particles/gaps)
- MP powerful detector to separate SD/ND events
- produced first results of Run II diffractive analyses



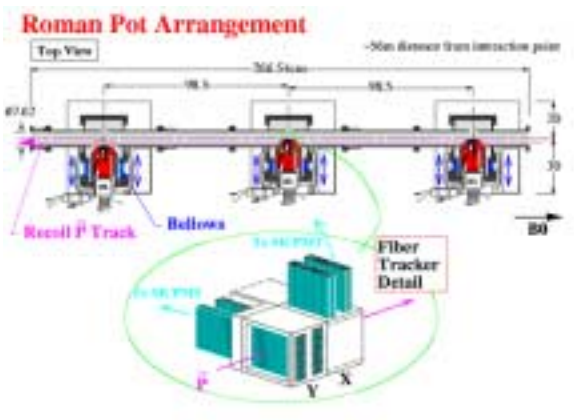
"The universe (…) is composed of an indefinite and perhaps infinite number of hexagonal galleries.(…) There was no personal or world problem whose eloquent solution did not exist in some hexagon."

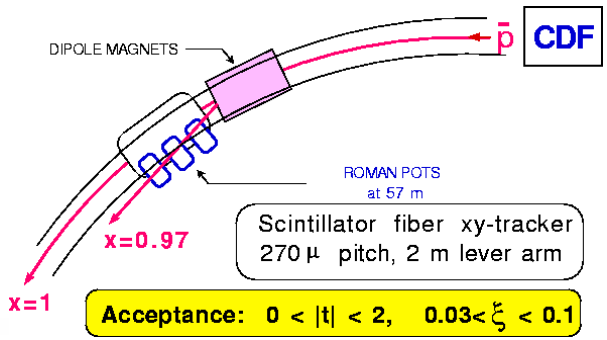
Jorge L. Borges *in The Library of Babel*

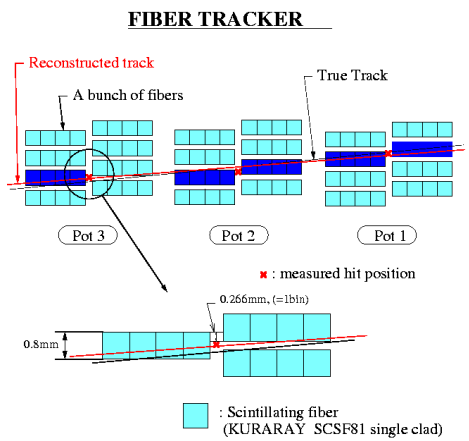
Roman Pot Fiber Tracker

Fiber Tracker

✓3 stations
✓57 meters from IP

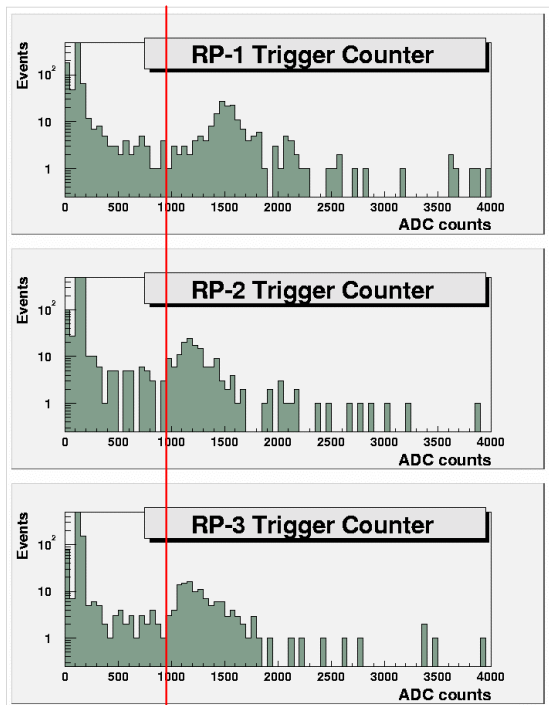






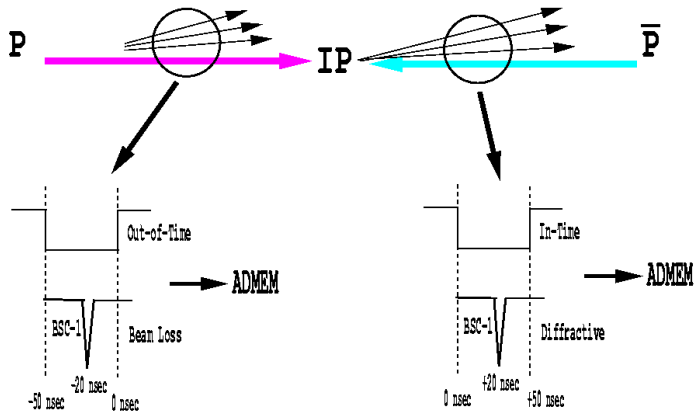
Expected position resolution	80 μm
Expected angle resolution	60 μrad

✓3 trigger counters
✓240 channels

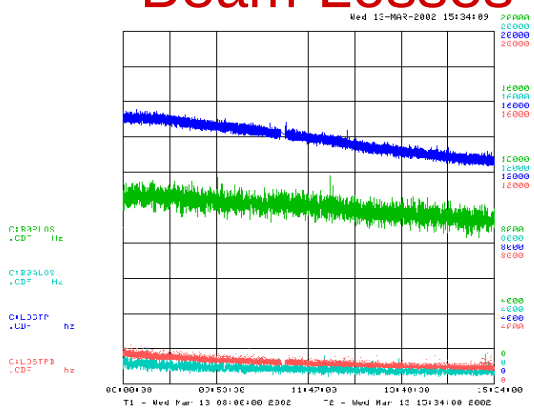


MIPs (> 1000 counts)

Beam Shower Counters

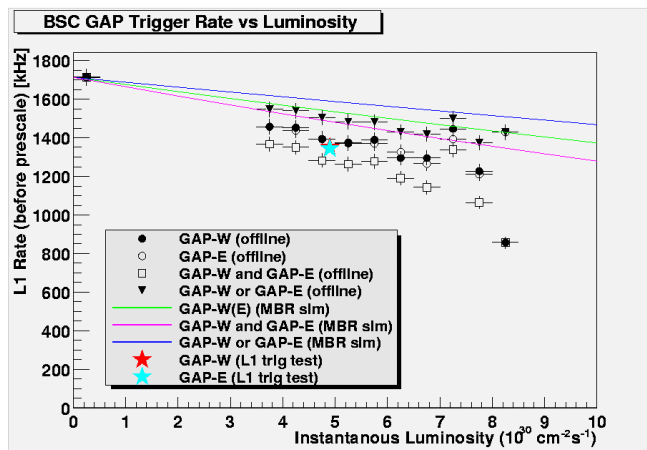


Beam Losses



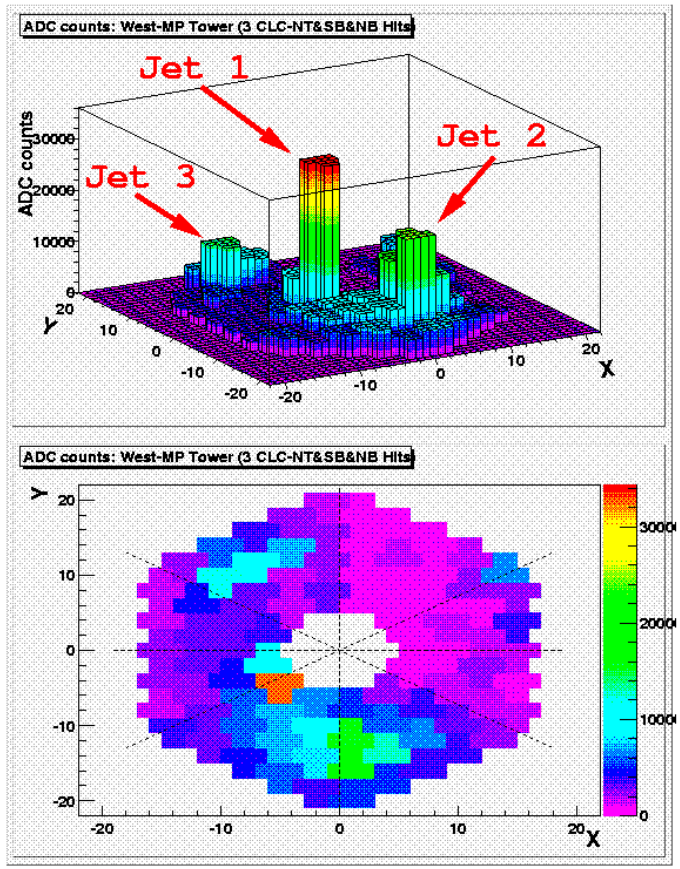
L1 Trigger

(veto E/W, minimum bias)



MP Collider Data

ADC counts in MP towers:
approximately 1000 counts = 1 GeV



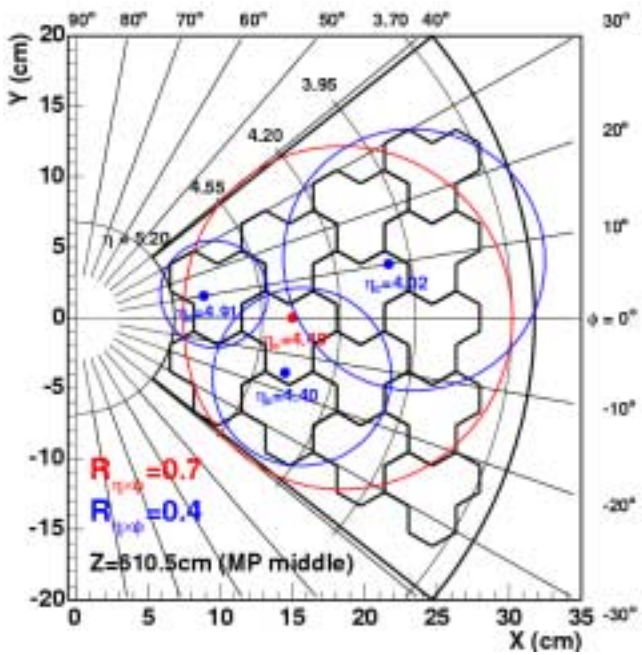
Radiation damage

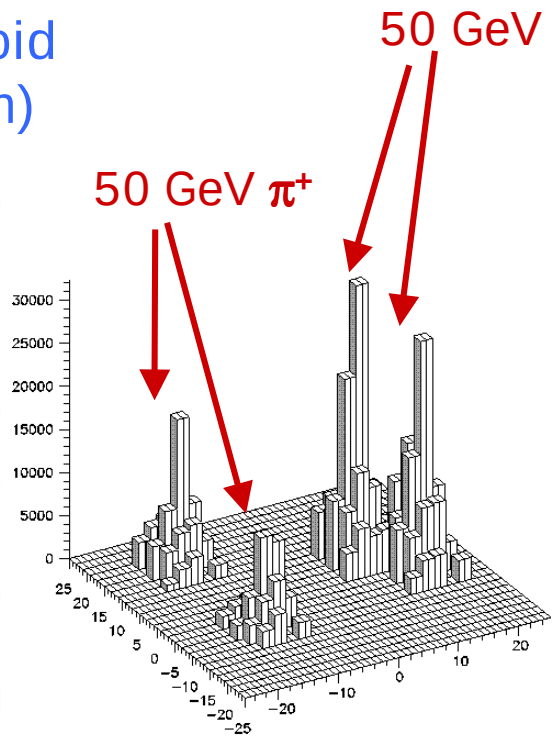
Radiation damage at MP: ~3 Mrad/year ($L=10^{32}$ cm^{-2} sec^{-1})

liquid scintillator: ~unaffected
WLS fibers: ~10% loss after 6.4 Mrad
PMTs: quartz window improves radiation hardness

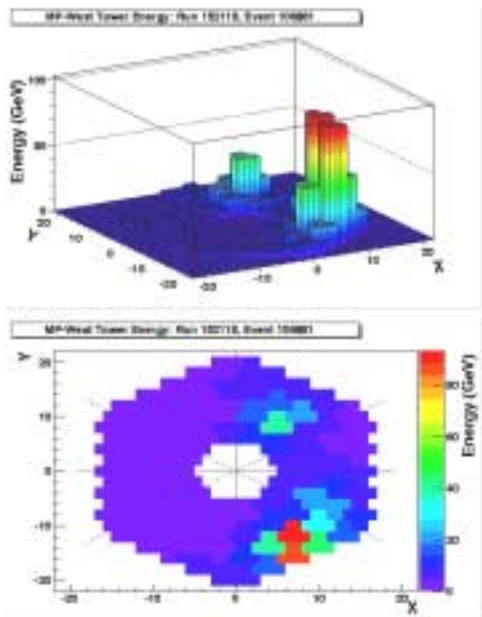
Particles/jets in MP

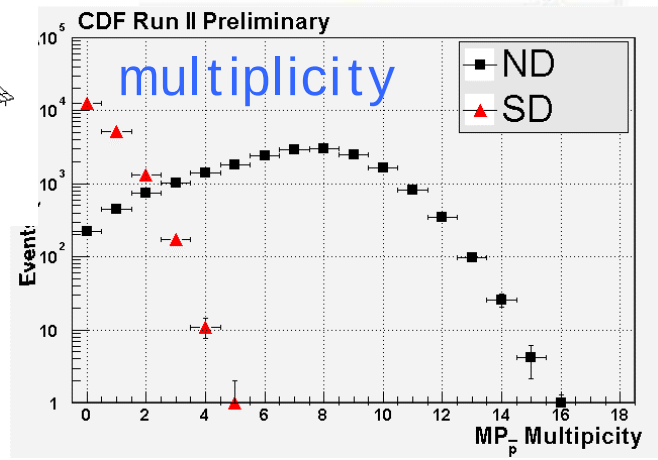
determine shower centroid
(electron/pion separation)





(prototype)





Position/energy resolution can be improved by instrumenting all 252 towers