EXTRACTION OF PHYSICS

- DETECTORS ALLOW MEASUREMENT OF

MOMENTA	TRACK CHAMBERS CALORIMETERS
ENERGIES	CALORIMETERS

- TYPICALLY ONE MIGHT RECONSTRUCT

INVARIANT MASSES

$$D^- \rightarrow K^- \pi^- \pi^+$$

$$M^2 = \sum_i E_i^2 - \sum_i p_i^2$$

NEED MASSES OF INDIVIDUAL PARTICLES

$$E_i^2 = p_i^2 + m_i^2$$

PARTICLE IDENTIFICATION

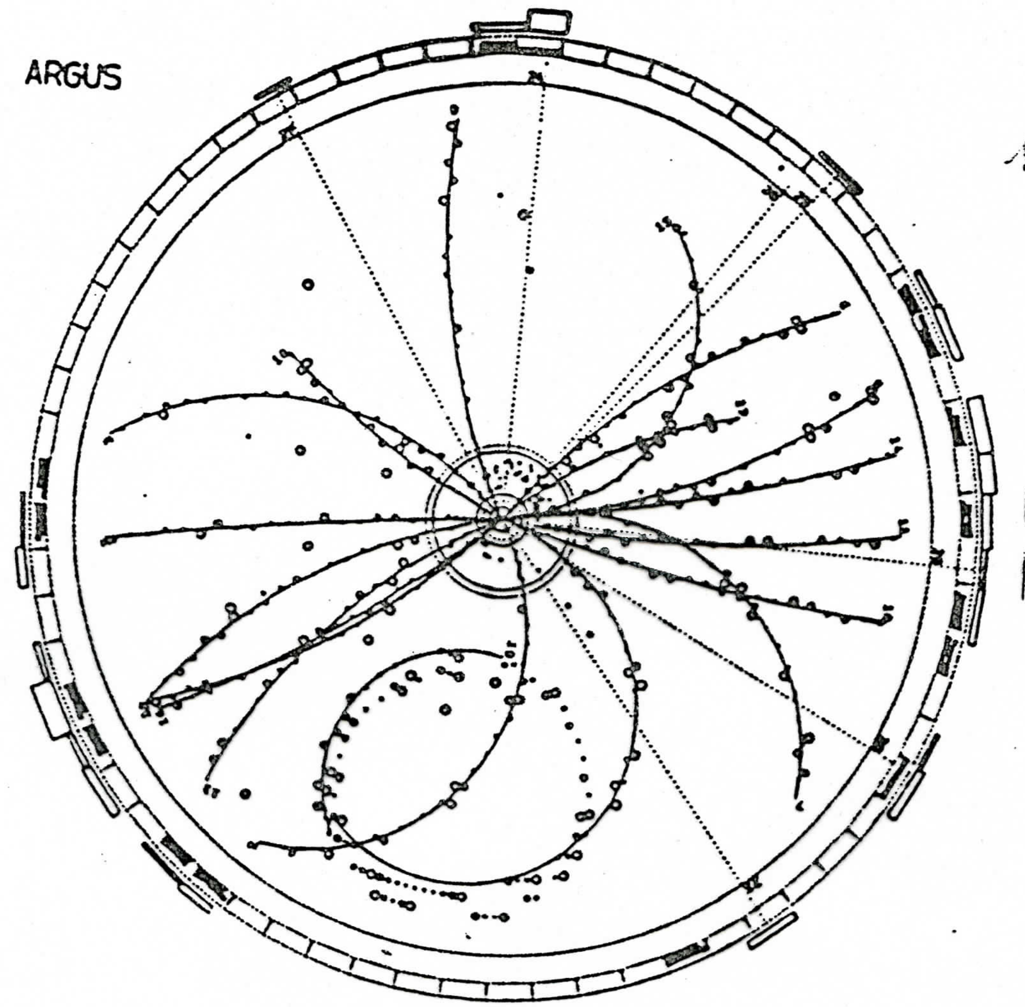
TWO METHODS OF PARTICLE IDENTIFICATION

- MEASURE INTERACTION IN MATERIAL
  - CAL:
    - LONGITUDINAL / LATERAL PROFILE OF ENERGY DEPOSITION
    - TOTAL ENERGY DEPOSITION COMPARED TO MOMENTUM (TRACKING)
  - TRANSITION RADIATION

- MEASURE VELOCITY ($m = \frac{p}{v}$) (p ← TRACKING)
  - IONIZATION (dE/dx)
  - TIME OF FLIGHT
  - ČERENKOV

- USUALLY NEED COMBINATION OF APPROACHES
  - COVER MOMENTUM RANGE
  - REQUIRED EFFICIENCY / REJECTION

FULLY RECONSTRUCTED $B\bar{B} \rightarrow$ HADRONS



18 CHARGED

7 NEUTRAL

[illegible]

$B^- \rightarrow D^{*+} \pi^- \pi^-$

$\quad \hookrightarrow D^0 \pi^+$

$\quad\quad \hookrightarrow K^- \pi^+ \pi^+ \pi^-$

$B^+ \rightarrow \bar{D}^0 \pi^+ \pi^+ \pi^+ \pi^+ \pi^+$

$\quad\quad \pi^- \pi^- \pi^- \pi^- \pi^0 \pi^0 \pi^0$

$\quad \hookrightarrow K^+ \pi^- \pi^0$

PARTICLE IDENTIFICATION REGIMES

Method	Domain for π/K separation		Requirements
	Fixed target geometry $L = 30$ m	Storage ring geometry $L = 3$ m	
Time-of-flight	$p < 4$ GeV/c	$p < 1$ GeV/c	$\sigma_t = 300$ ps
Threshold Cherenkov	$p < 80$ GeV/c	$p < 25$ GeV/c	10 photoelectrons
DISC-Cherenkov	$p < 2000$ GeV/c	–	achromatic gas counter
Ring imaging Cherenkov		$p < 65$ GeV/c	
Multiple ionization	$1.2 < p < 100$ GeV/c	$1.5 < p < 45$ GeV/c	$\sigma_E = 2.5\%$
Transition radiation	$\gamma > 1000$	$\gamma > 1000$	detection of >10 keV X-rays

PARTICLE ID USING CALORIMETERS

- EXPLOIT DIFFERENCE BETWEEN

  μ, EM, HADRON SHOWERS

  - HI Z ABSORBER e, γ SHOWER
  - MEASURE SHOWER SHAPE USING SAMPLING DETECTORS IN ABSORBER
  - COMPARE CALORIMETER ENERGY WITH MOMENTUM IN TRACK CHAMBER

→ LIMITATION $\pi^{\pm} p \to \pi^{0} n$

- CDF ELECTRON IDENTIFICATION

  - SHOWER SHAPE IN TOWERS
  - LONGITUDINAL PROFILE

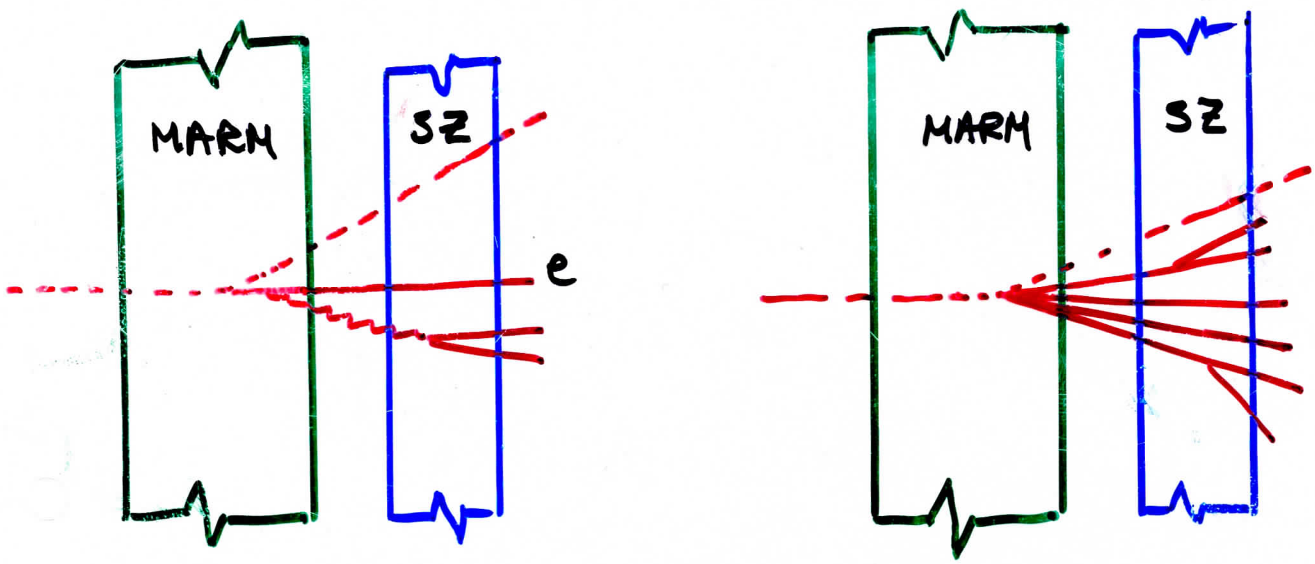
    EM / HAD CAL DEPOSITIONS

  - LATERAL SHOWER SHAPE FROM MWPC $\sim 6 X_0$
  - COMPARISON OF OBSERVED ENERGY DEPOSITION + MOMENTUM IN TRACKER

    $e/\pi < 1$?

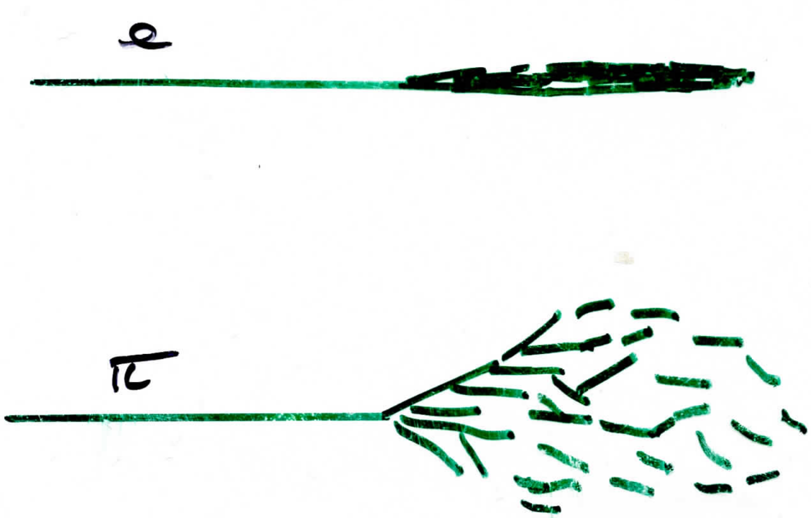
SEPARATION OF E/M AND HADRON SHOWERS

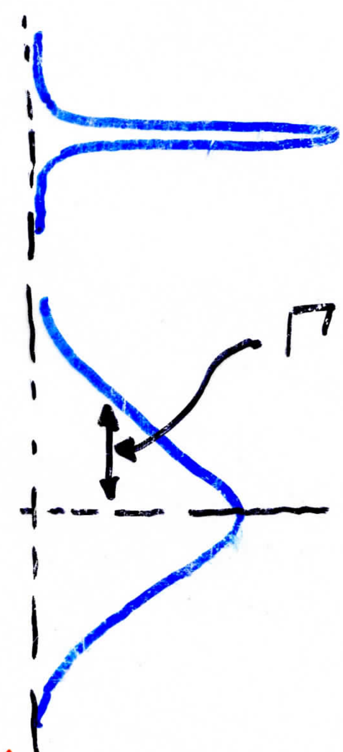
- PARTICLE MULTIPLICITY AT VERTEX



EM HADRONIC

2) TRANSVERSE SHOWER DEVELOPMENT



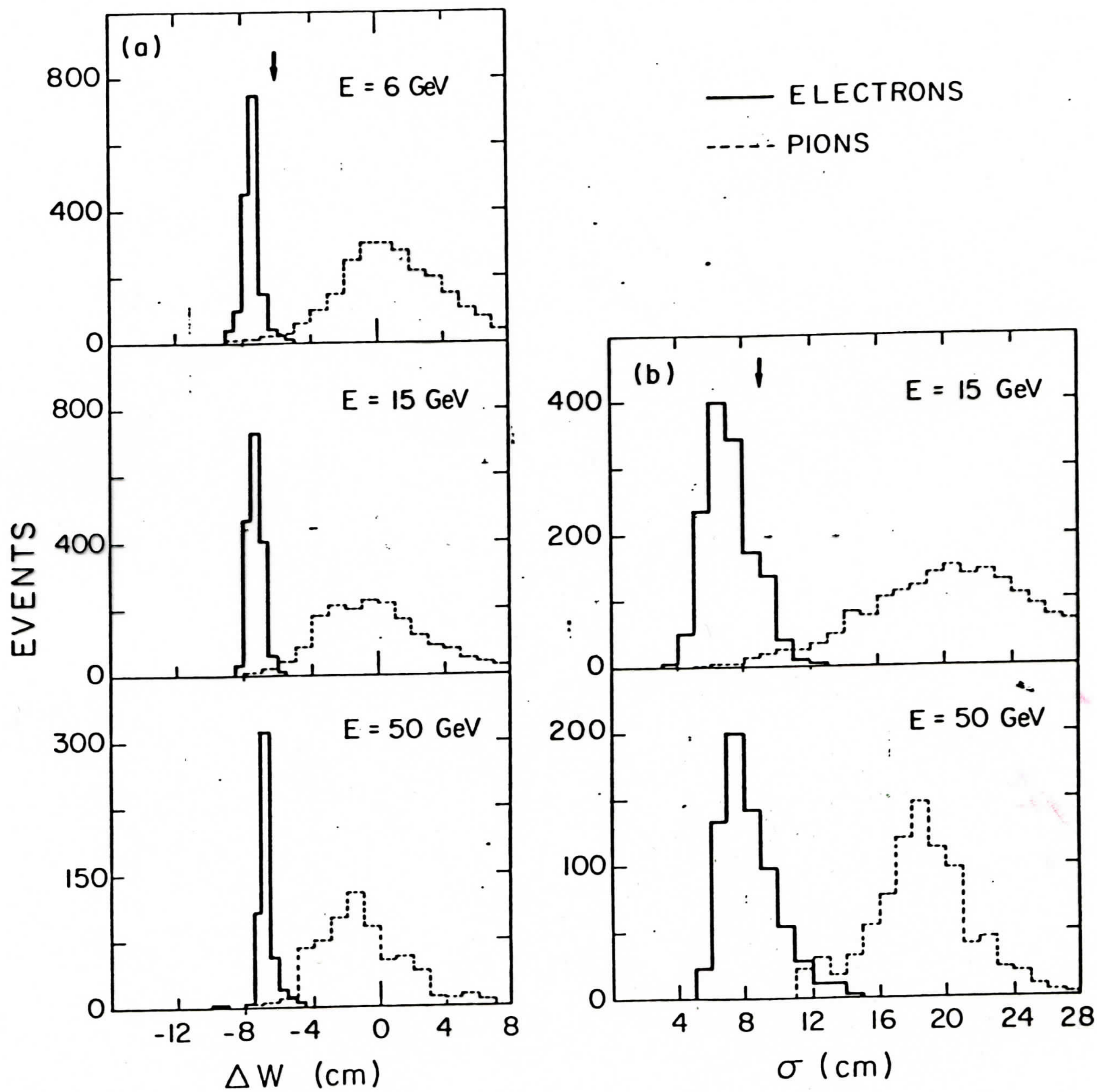


CAUCHY SHAPE — Γ

CALIB. ACCEPT 95% EM

REJECT 99% HADRON

CHARM TEST BEAM



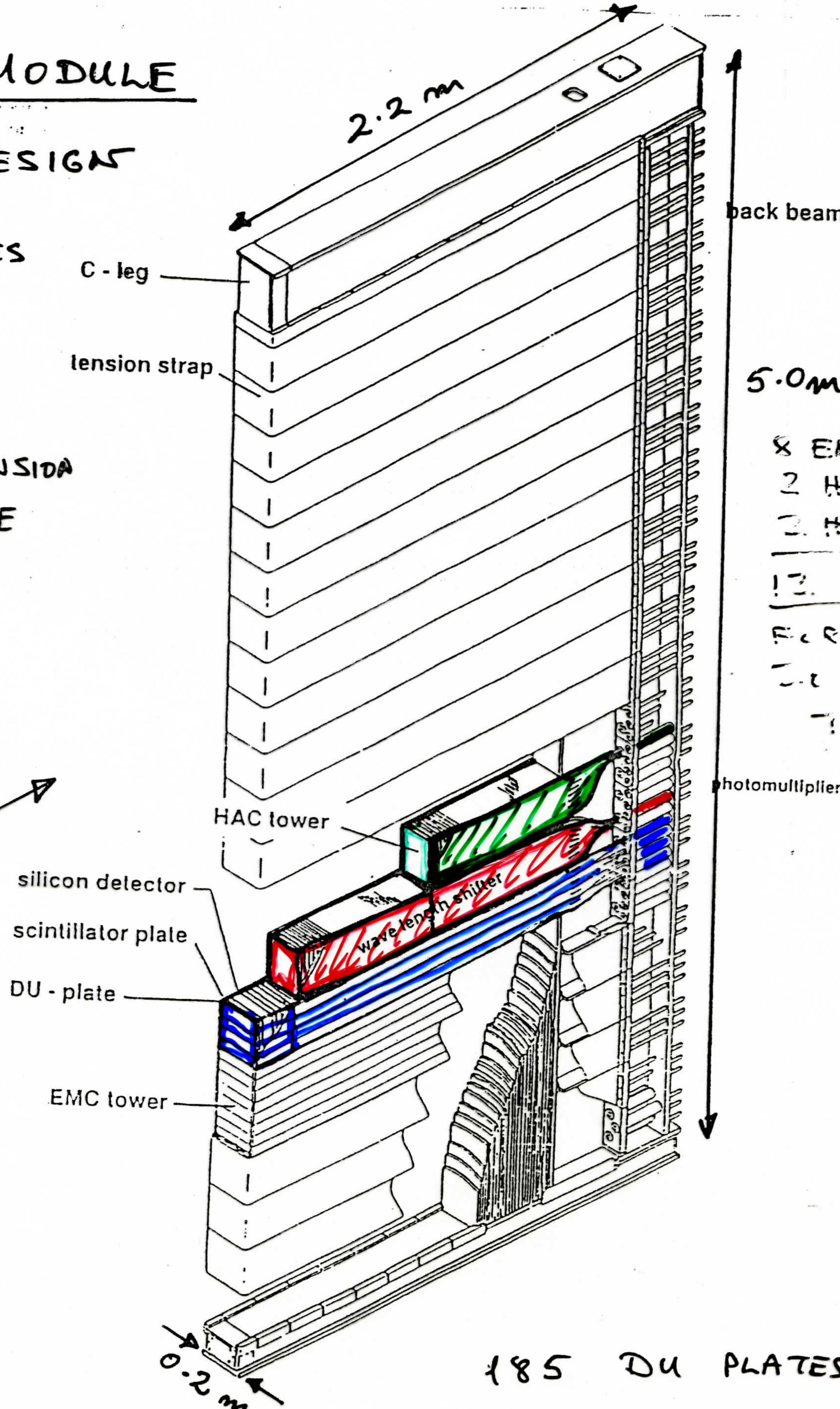
Γ σ

FCAL MODULE

CDN DESIGN

~ 11 TONNES

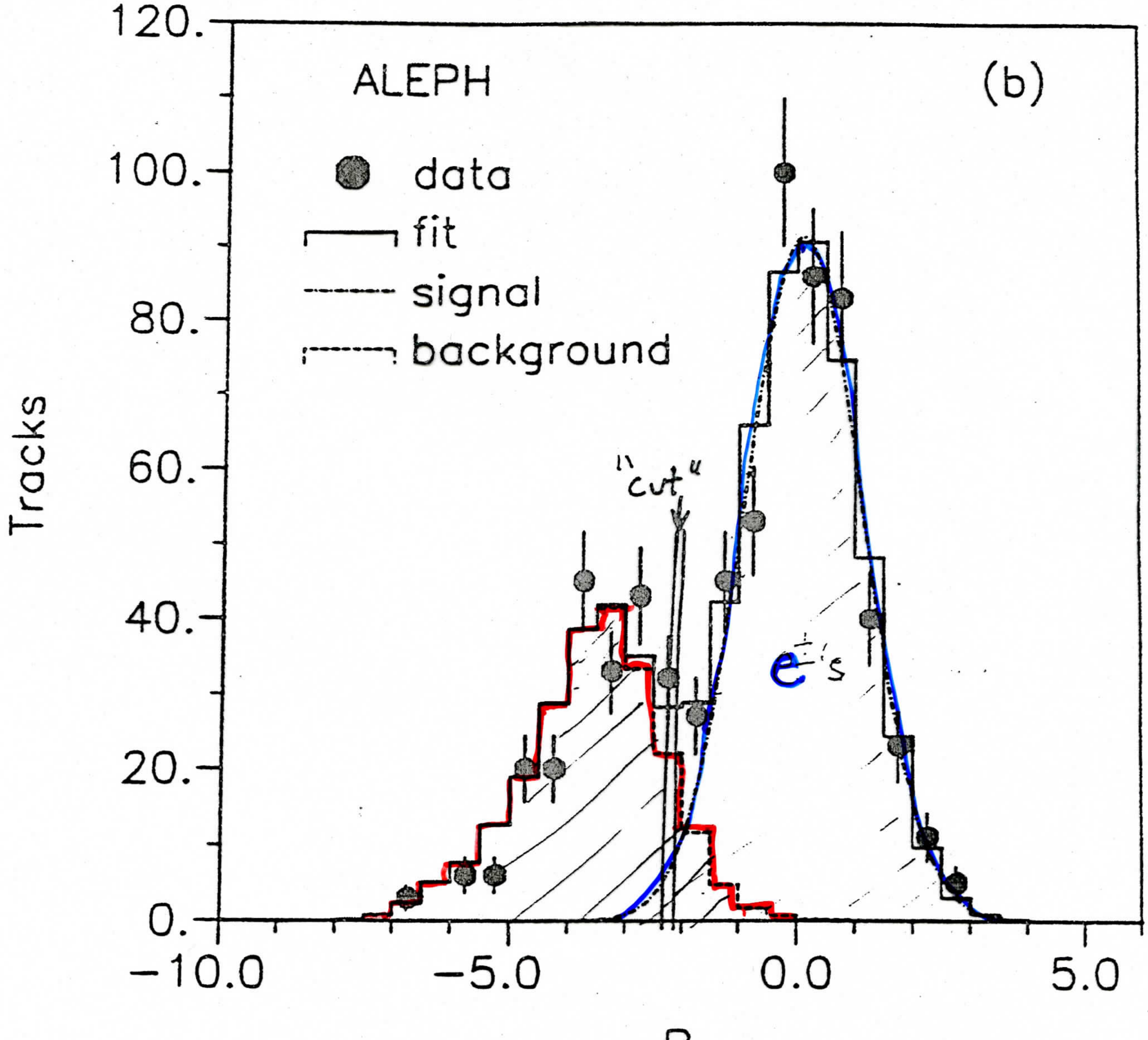
STRAP TENSION
~ 1 TONNE



8 EMC
2 HAC1
2 HAC2
12 PMT
FOR EACH
20x20 cm
TOWER

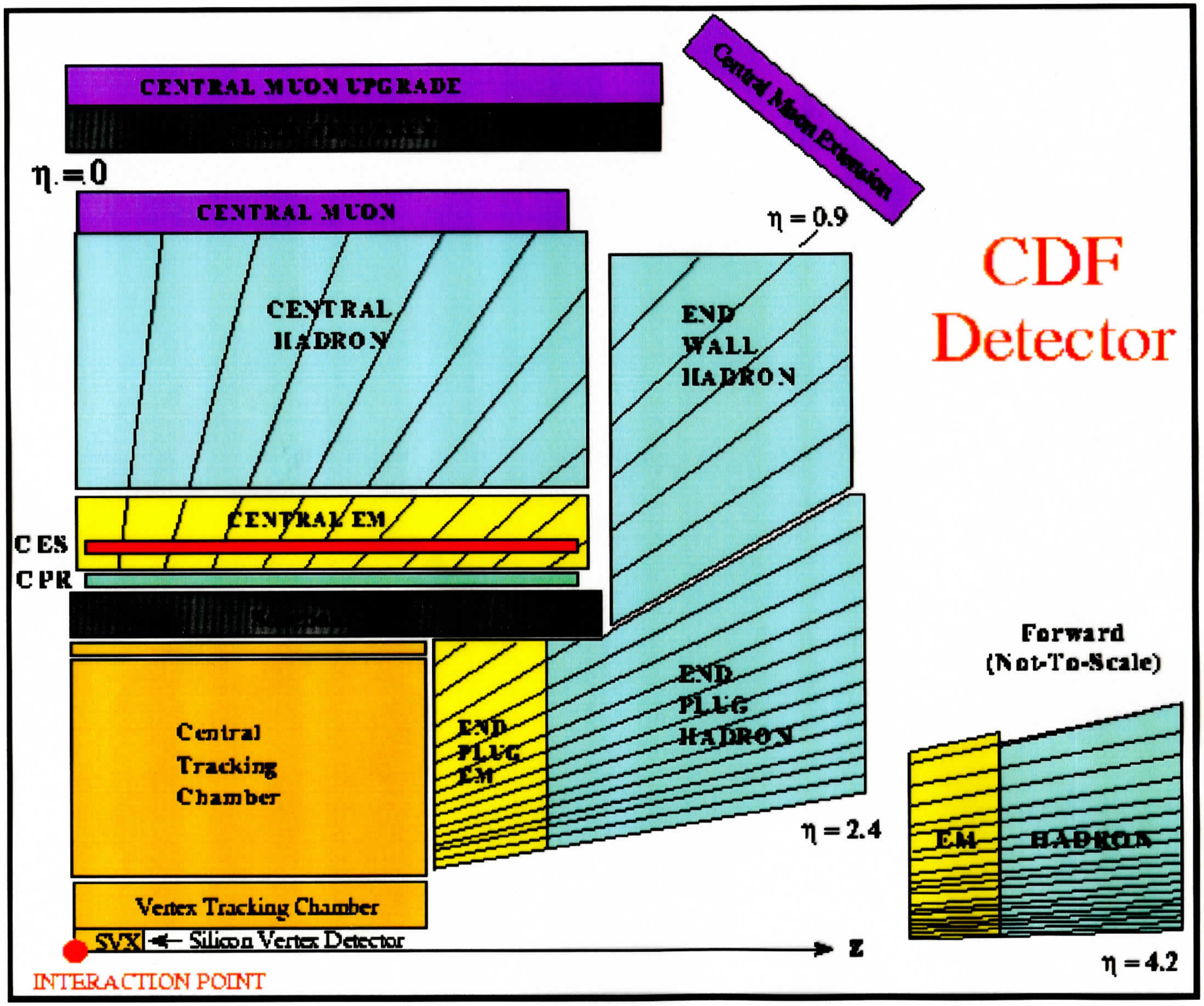
185 DU PLATES
4.6m x 20cm x 0.33cm.

LONGITUDINAL PROFILE
IN ALEPH



$$R_L = -\sum_{1}^{3} \frac{E_i - E_i^{e\,expect.}}{\sigma_E}$$

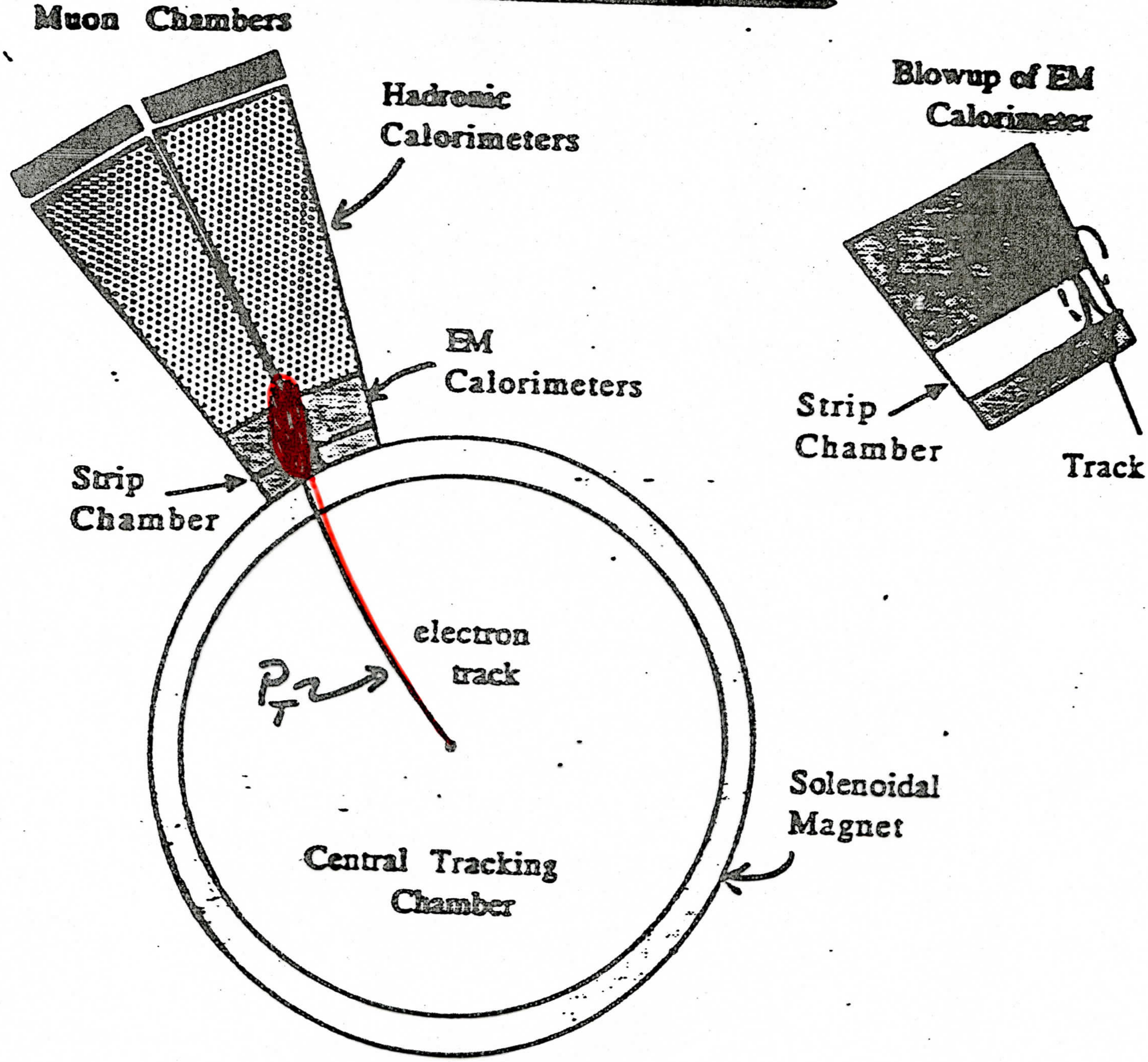
E_i^e = ENERGY AT THAT DEPTH EXPECTED OF ELECTRON



CENTRAL MUON UPGRADE
Central Muon Extension
$\eta = 0$
CENTRAL MUON
$\eta = 0.9$
CDF Detector
CENTRAL HADRON
END WALL HADRON
CENTRAL EM
CES
CPR
Forward (Not-To-Scale)
END PLUG HADRON
Central Tracking Chamber
END PLUG EM
$\eta = 2.4$
EM
HADRON
Vertex Tracking Chamber
SVX
Silicon Vertex Detector
z
$\eta = 4.2$
INTERACTION POINT

ELECTRON ID IN CDF

CDF Central Calorimeter



CDF Central Electron Variables:

- E_T
- Had/EM
- Lateral Sharing (LSHR)
- Strip χ^2
- Strip-Track Match (δx, δz)
- E/P
- Isolation/Border Tower Energy

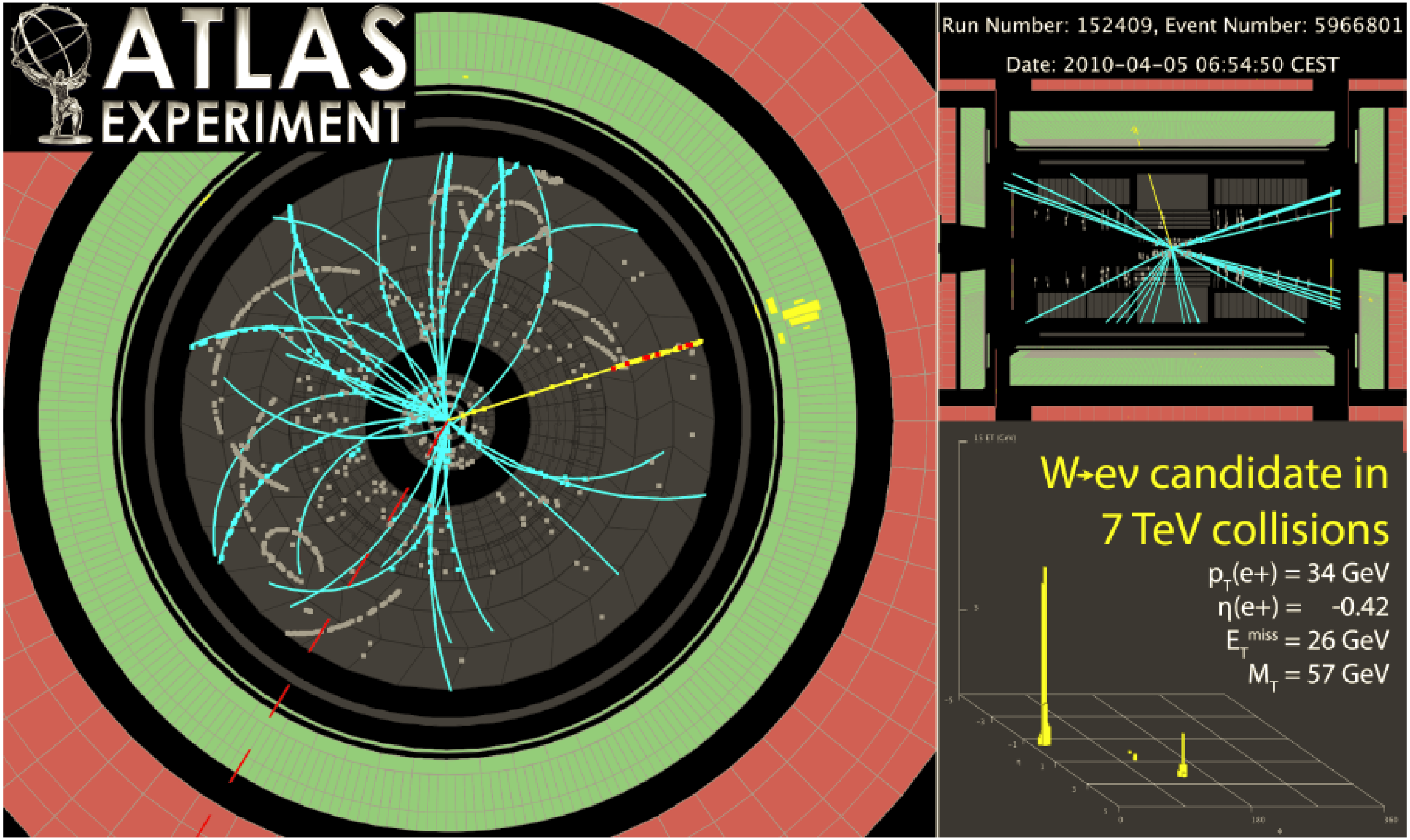
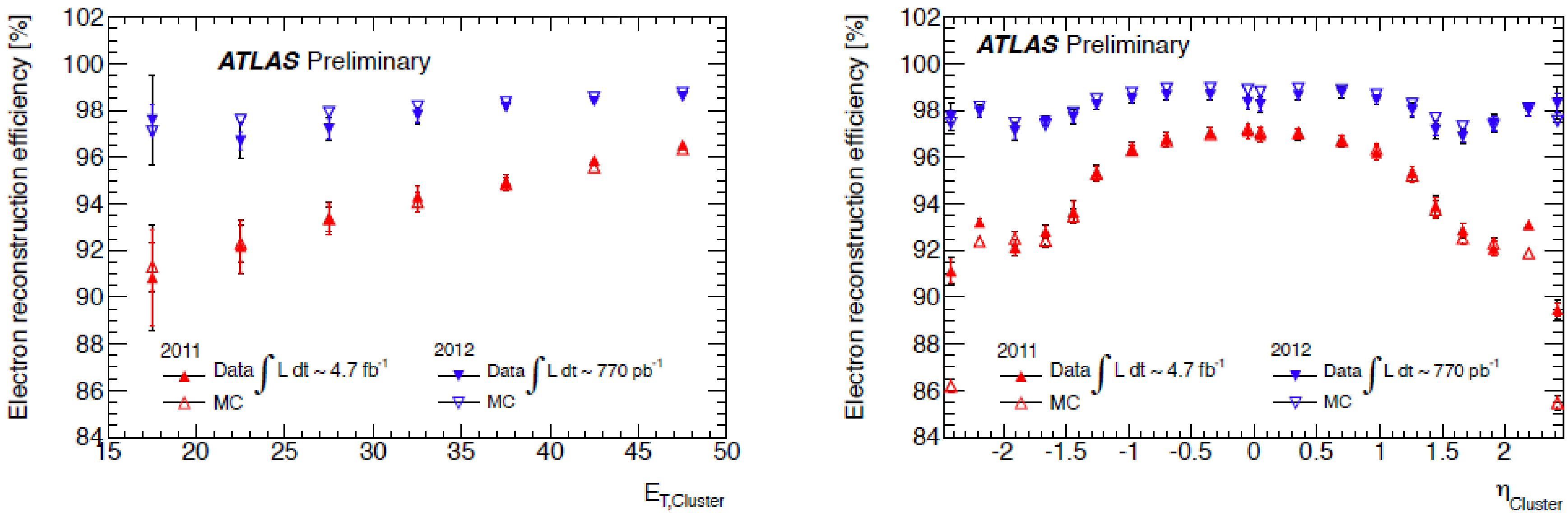


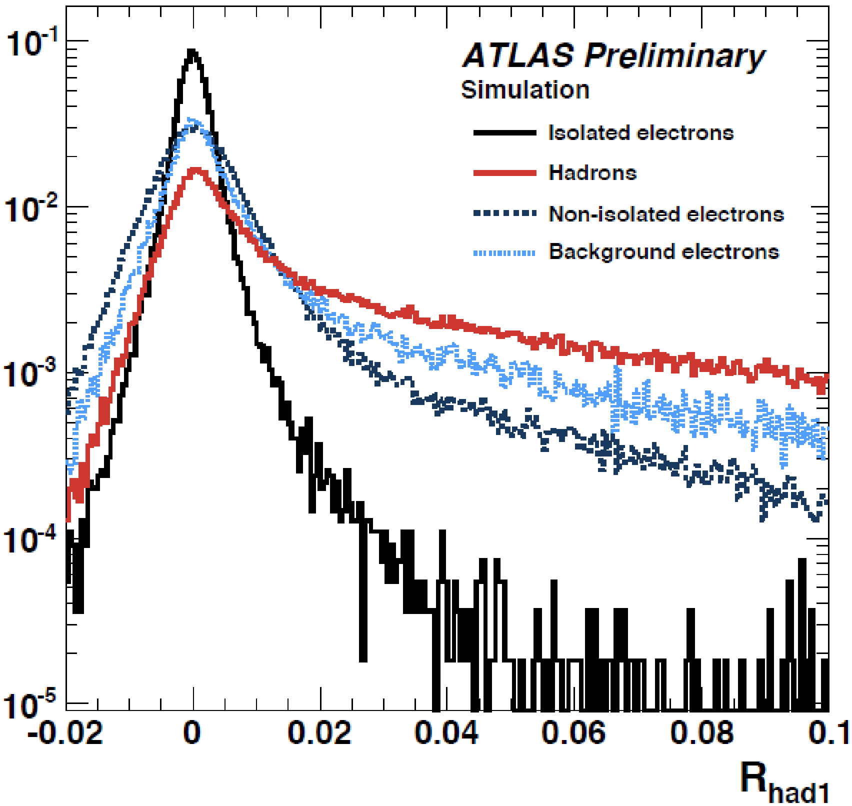
Figure 7.1: Event display of a reconstructed electron from a candidate W decay. The reconstructed electron track is indicated in yellow. The electron cluster is shown in yellow, in the green EM calorimeter. The red points along the electron track indicate measurements of transition radiation. The red dashed line indicates the direction of the momentum imbalance.

ELECTRON RECONSTRUCTION



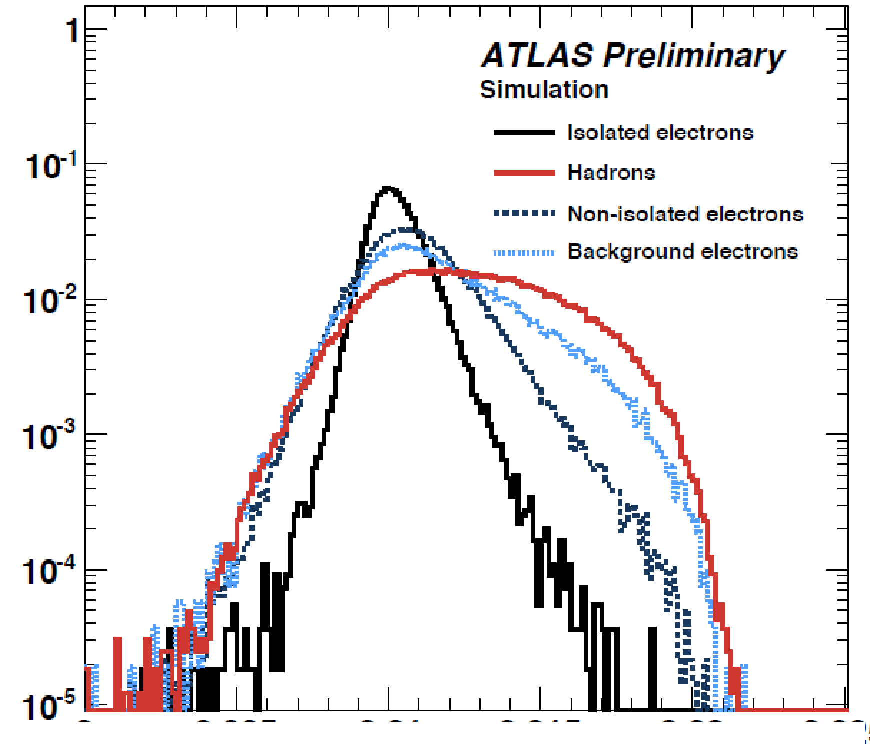
(a) (b)

Figure 7.2: Electron reconstruction efficiency, including the requirements on the track quality, ($N_{pix} \geq 1$ and $N_{Si} \geq 7$) as a function of (a) E_T and (b) η. The plot vs η is shown for electrons with E_T between 30 and 50 GeV.



hadronic leakage variable, R_{had_1}

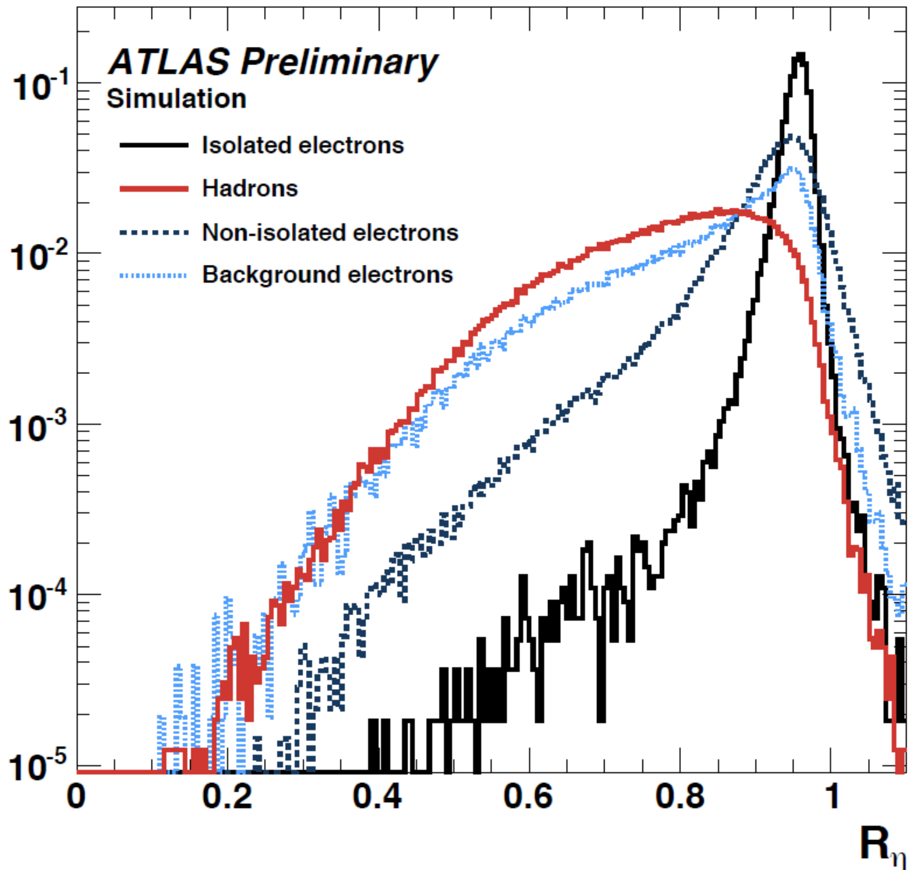
$\frac{E^{e}_{\text{CLUST}} \text{ IN EM}}{E^{\text{1ST SAMPLE}} \text{ IN HAD}}$



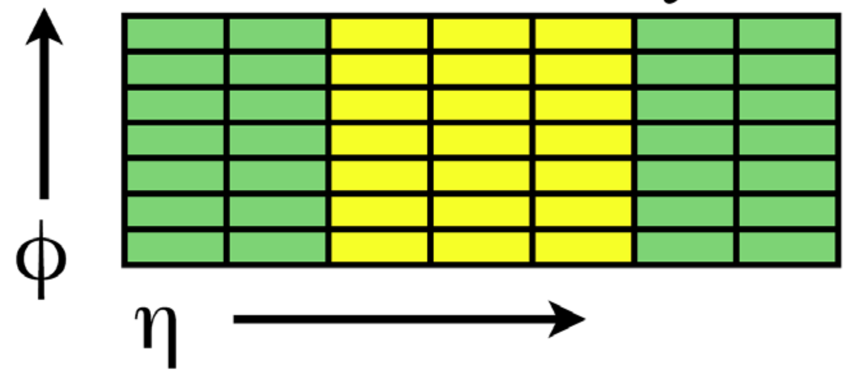
$$w_2 = \sqrt{\frac{\sum_i (E_i \eta_i^2)}{\sum_i E_i} - \left(\frac{\sum_i E_i \eta_i}{\sum_i E_i}\right)^2},$$

width in eta in the second sampling w_2

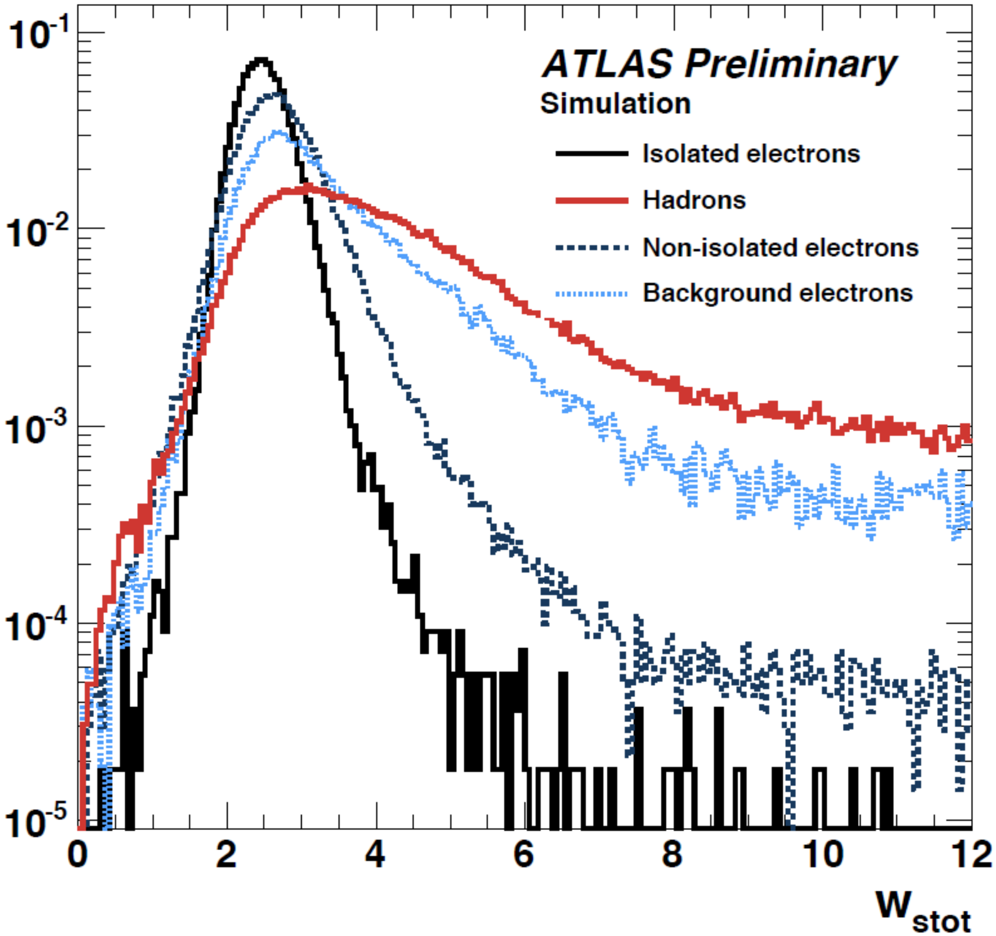
SHOWER WIDTH in η



Cells in 2nd Layer



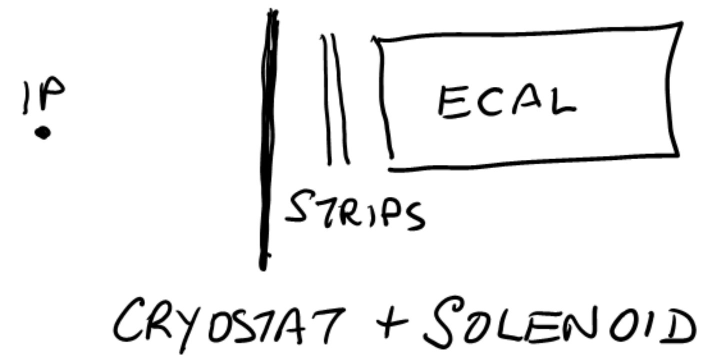
$$R_\eta = \frac{\text{ENERGY IN YELLOW}\ (3\times7)}{\text{ENERGY IN GREEN}\ (7\times7)}$$



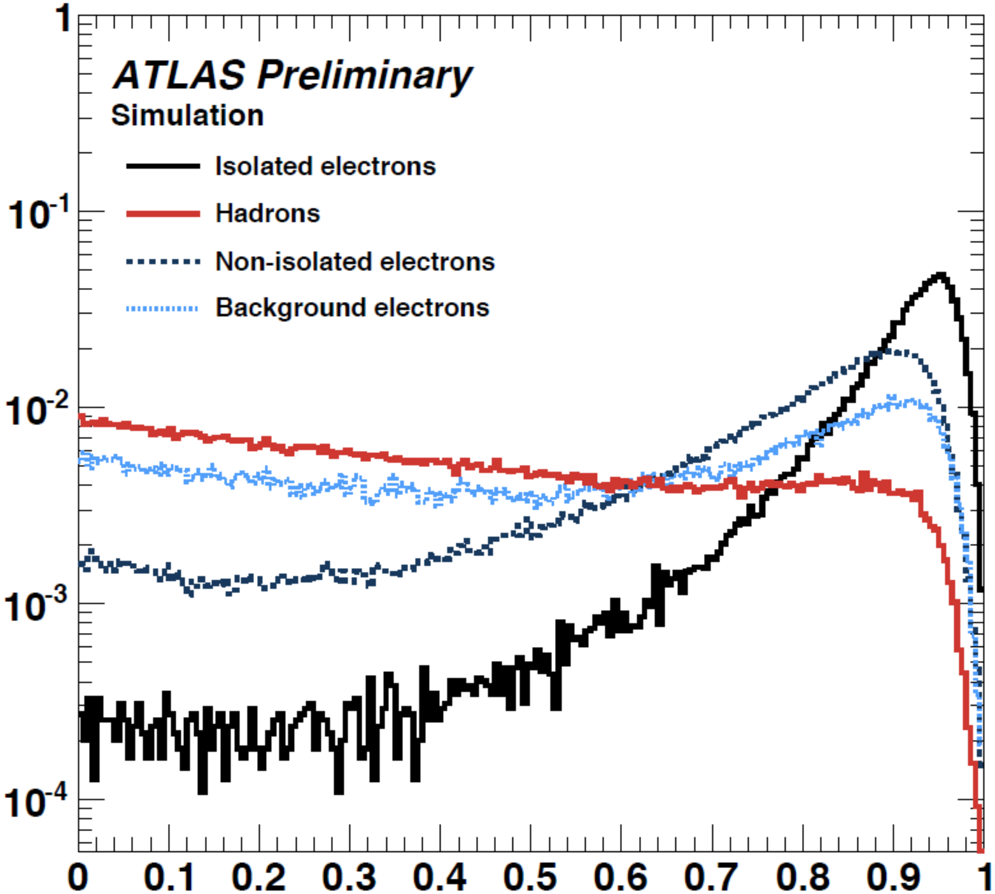
$$w_{s,\mathrm{tot}} = \sqrt{\frac{\sum_i E_i (i - i^{\max})^2}{\sum_i E_i}}$$

STRIP INDEX

STRIP WITH MAX ENERGY



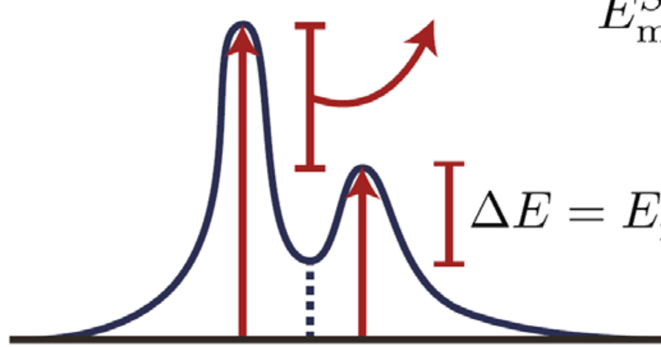
SHOWER WIDTH IN STRIPS



JET BACKGROUNDS HAVE MULTIPLE HADRONIC SHOWERS

TRUE ELECTRONS ARE VERY NARROW & HAVE SINGLE MAXIMUM.

$$E_{\text{ratio}} = \frac{E^{S1}_{\max,1} - E^{S1}_{\max,2}}{E^{S1}_{\max,1} + E^{S1}_{\max,2}}$$



$$\Delta E = E^{S1}_{\max,2} - E^{S1}_{\min}$$

PERFORMANCE OF CALORIMETER PID.

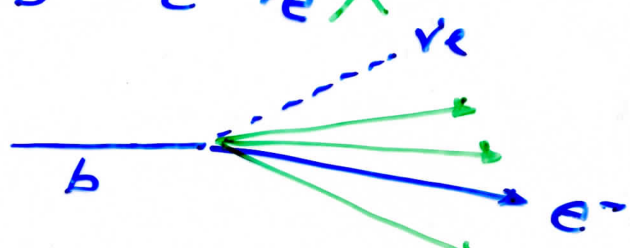
- PERFORMANCE LIMITED BY
  (ASSUMING ELECTRONS ARE SIGNAL)
  - CHARGED HADRON & π^0 OVERLAP
  - INTERACTING $\pi^\pm$
  - CONVERSION $\gamma \rightarrow e^+e^-$

- TYPICAL e PERFORMANCE
  - HADRONIC JET REJECTION $< 10^{-3}$
  - EFFICIENCY FOR ISOLATED e
    $> 75\%$

- NOTE "ISOLATED"

THIS MAY LOWER e EFFICIECY IN LEPTONIC HEAVY FLAVOUR DECAY

$$b \rightarrow e^- \nu_e X$$



EFFICIENCY ~40% IN CDF

→ ATLAS ?