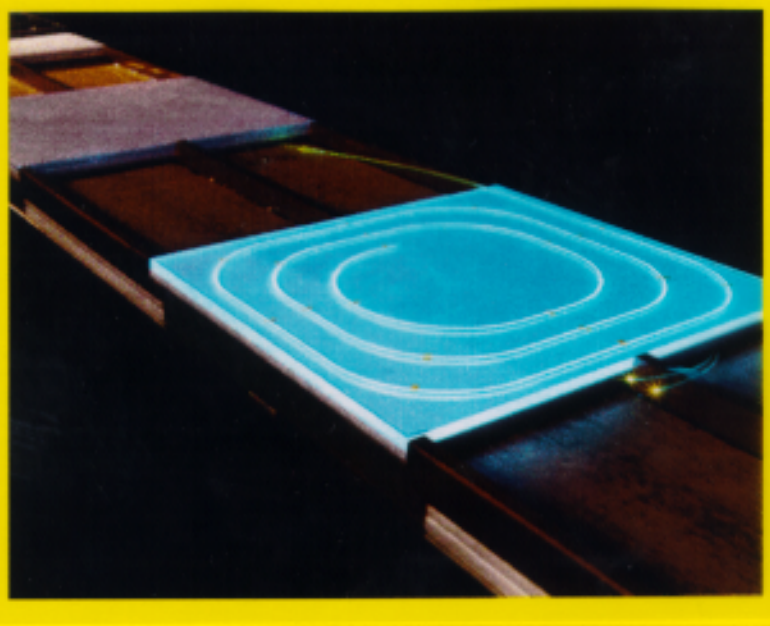
# The ZEUS Barrel PREshower Detector for Dummies™

2nd Edition

Includes :
MIP Calibration
Energy Corrections

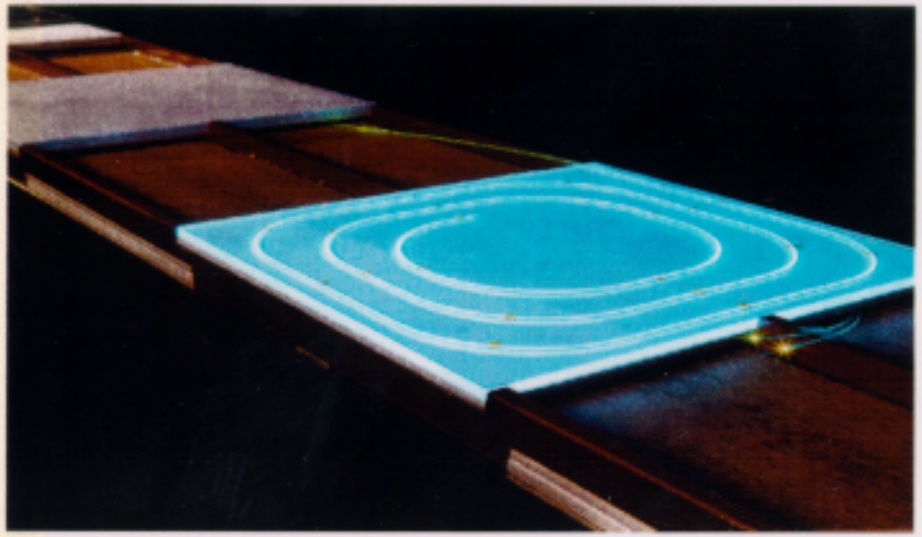
A Reference for the Rest of Us! ™



Sergei Chekanov

Steve Magill

# ZEUS Barrel Preshower Detector (BPRE)



*Installation -> January to June 1998*

*Commissioning -> Fall 1998*

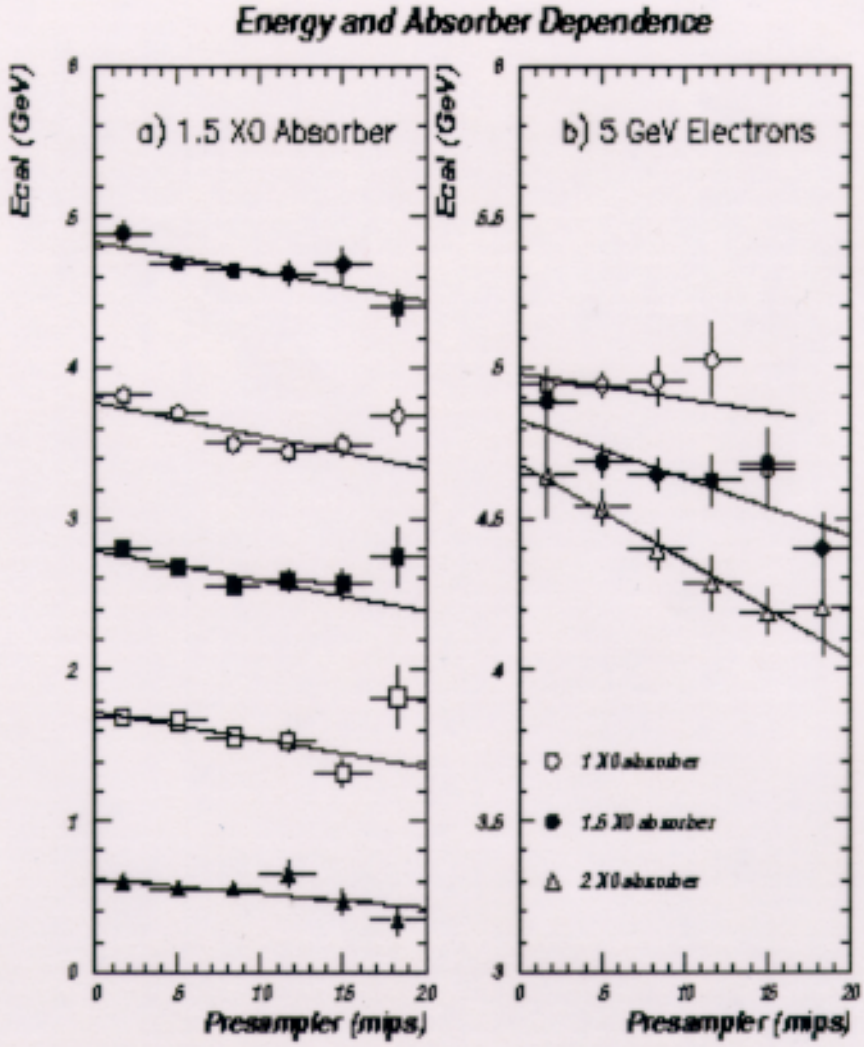
*Full Operation -> January 1999 to Present*
*80 pb-1 data so far*

- **Dead Material Map of Barrel Region**
  - use DIS scattered e+/e- to verify Monte Carlo simulation code
- **Calorimeter Energy Corrections**
  - **DIS Scattered e+/e-**
    - energy-independent BPRE corrections improve resolution by 4%
  - **Jets**
    - results - energy correction and resolution improvement
  - **Optimized detector objects**
    - towards ultimate use of tracks and preshower-corrected CAL clusters
- **Prompt Photons**
  - BPRE mips analysis independent of calorimeter

# How a Preshower Detector works:

Preshower signal $\propto X_0$, $\Delta E$ ← NOT E!

↳ Dead Material Map
↳ Energy Corrections




Constant $X_0$ Constant E

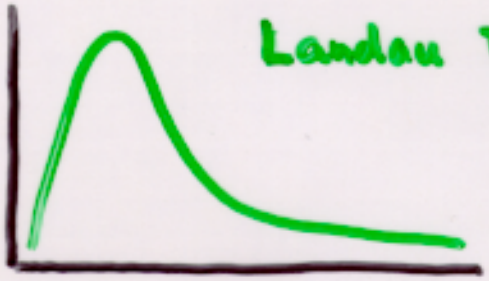
BPRE Test Beam Results

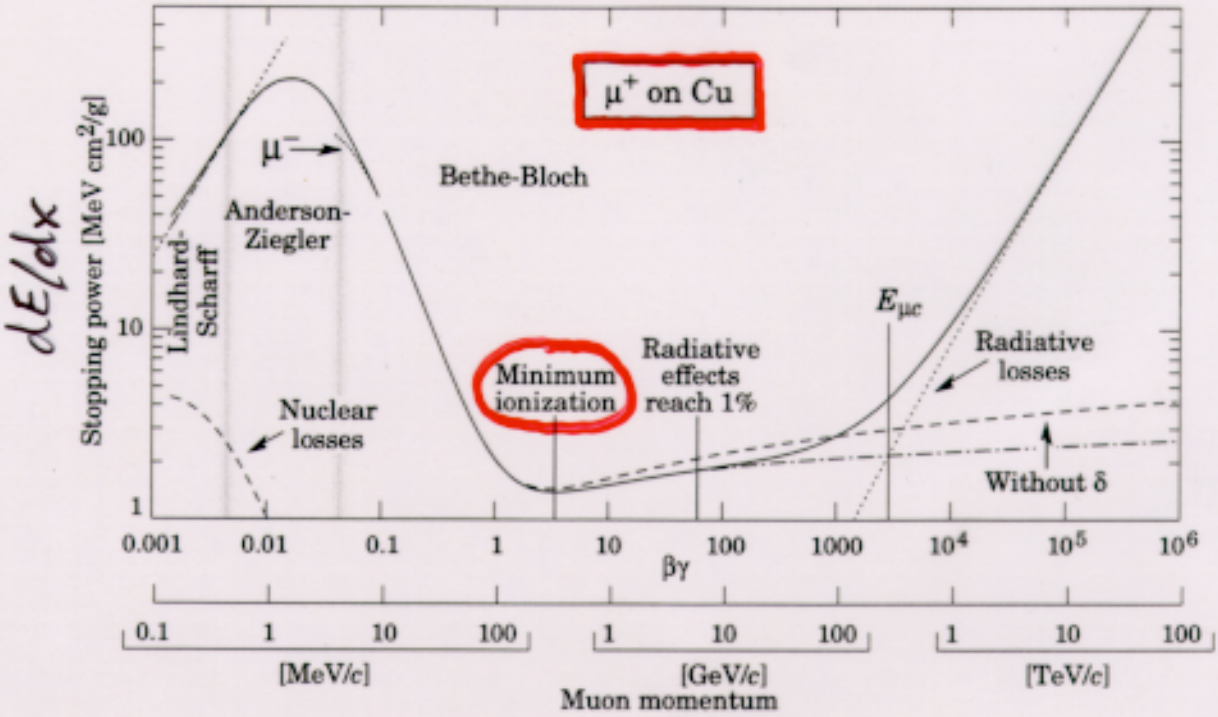
# What is a 'MIP'?

a) Minimum Ionizing Particle

b) the signal you get from a particle when it acts like a)

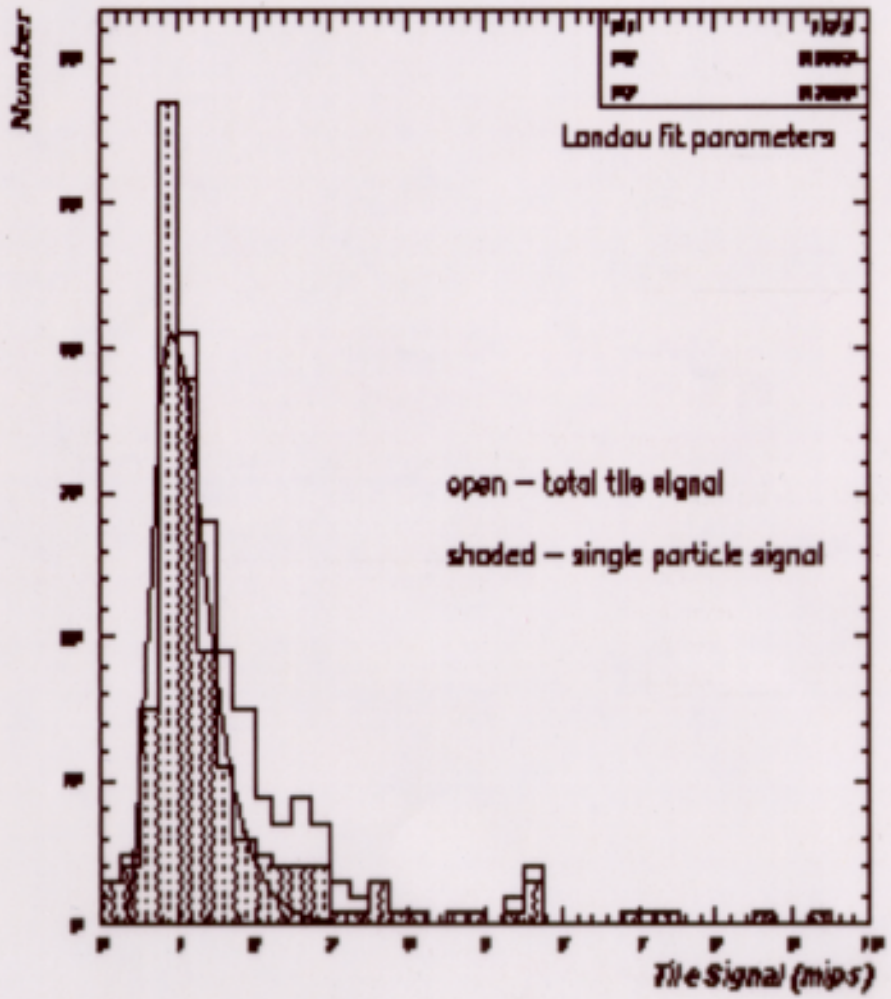
In scintillator, looks like →




PDG

# BPRE Calibration Procedure




from MC : fit inclusive tile signal around peak with Landau distribution :

$$y = a e^{\left[-(x-b)/c - e^{-(x-b)/c}\right]}$$

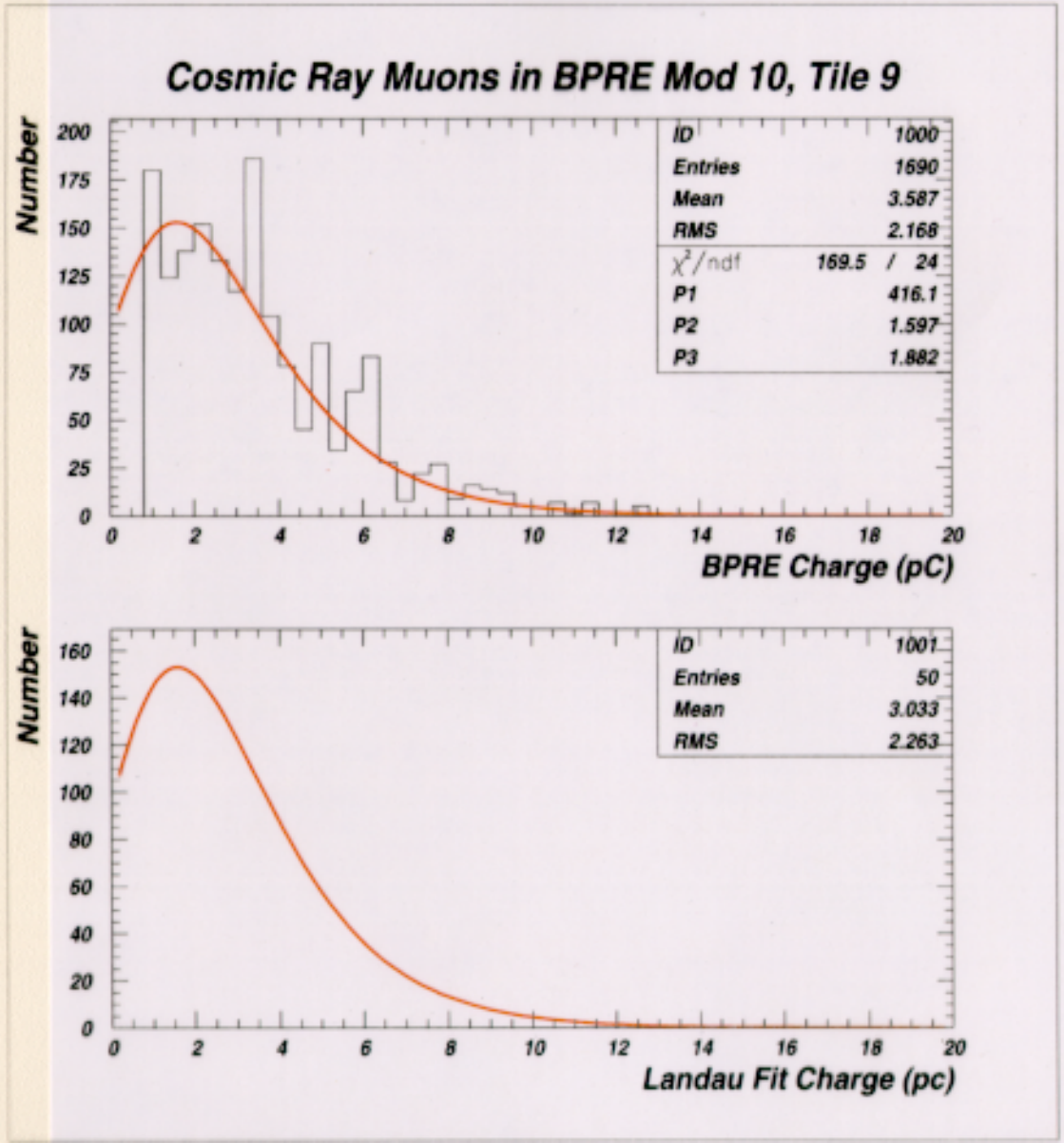
3-parameter fit (a, b, c)

---> use fit parameters to determine calibration constant . . .
needs ~1 pb-1, works for all channels

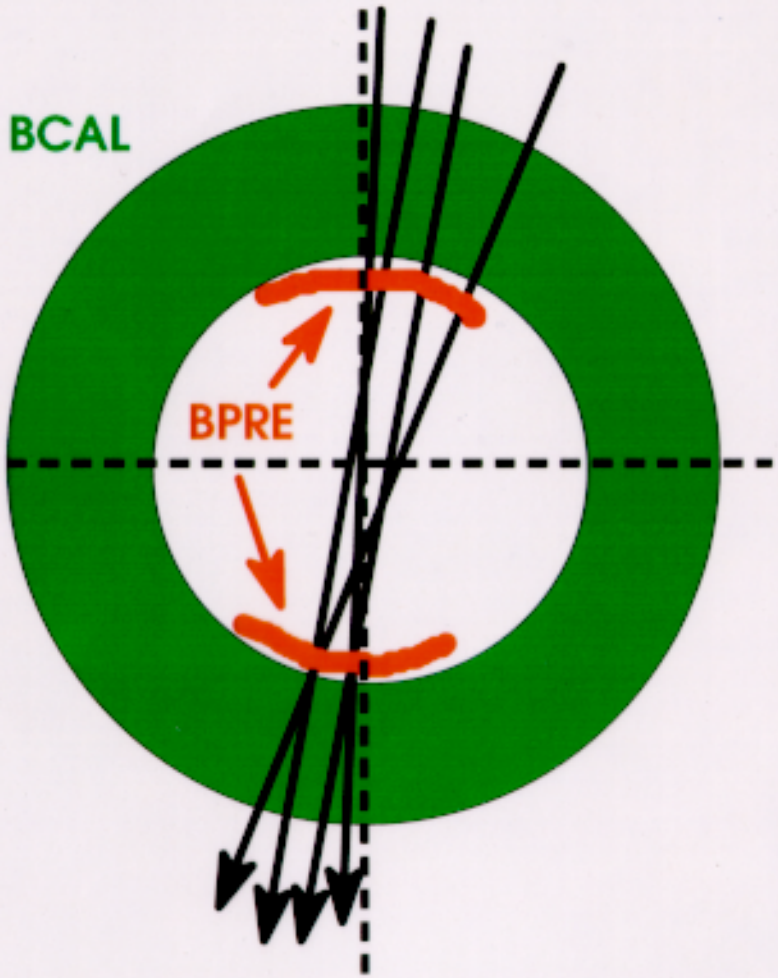
from Data : inclusive tile signal much broader than in MC (more showering in data . . .

---> good news : why we built BPRE in the first place
---> bad news : how are we going to calibrate?

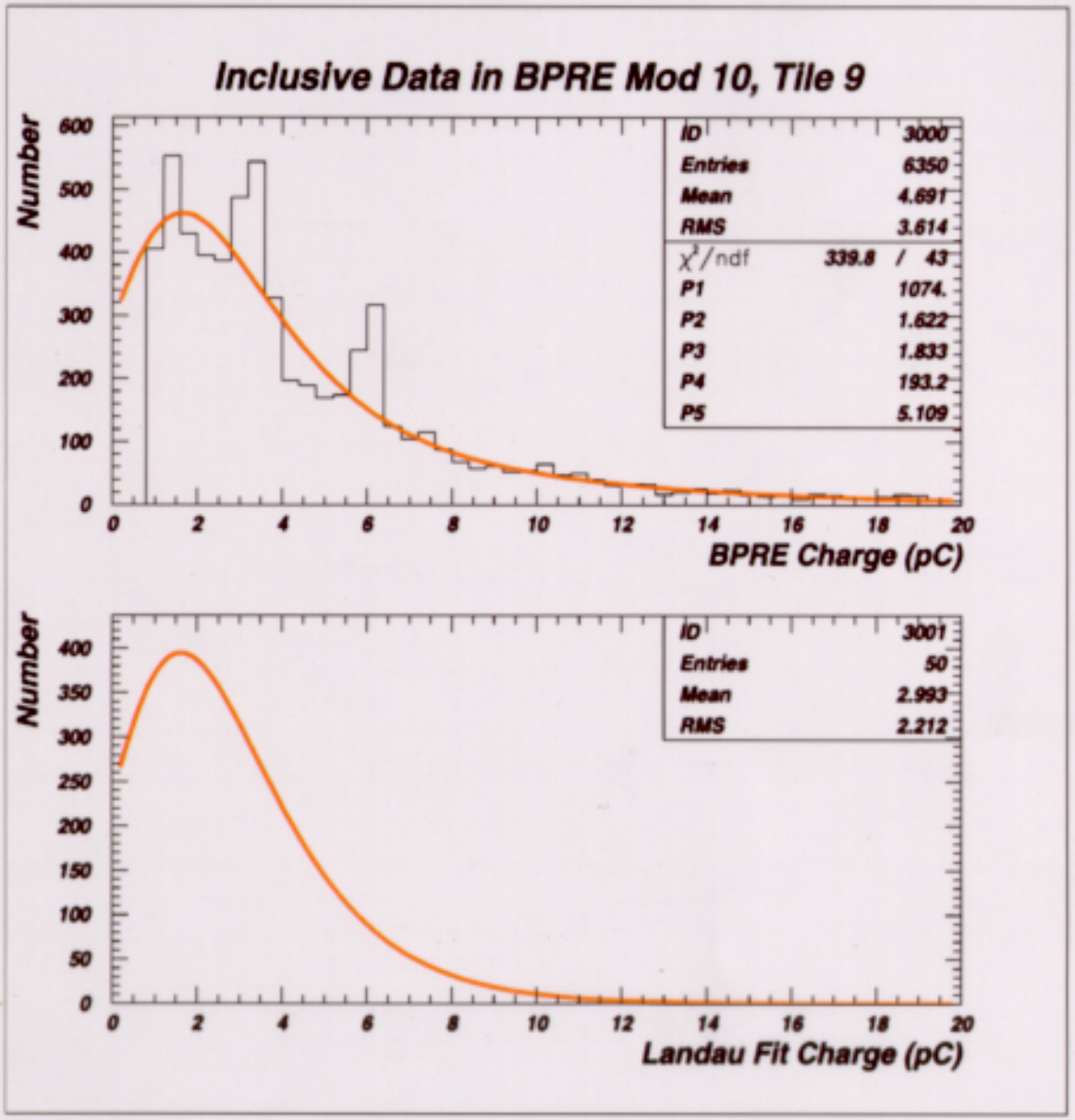
# CR Muons in BPRE




## CR Trigger in BCAL :



# Inclusive Data in BPRE




## 2-MIP fit of inclusive data :

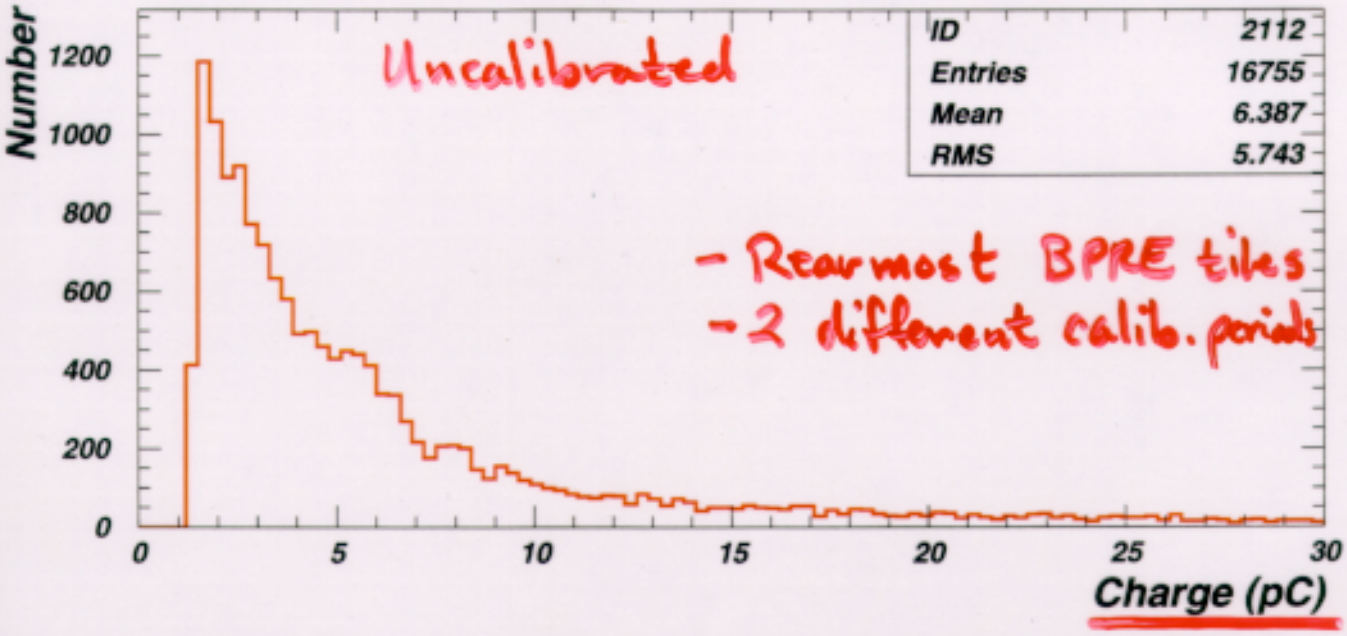
$$y = a e^{\left[-(x-b)/c - e^{-(x-b)/c}\right]} + d e^{\left[-(x-2b)/f - e^{-(x-2b)/f}\right]}$$

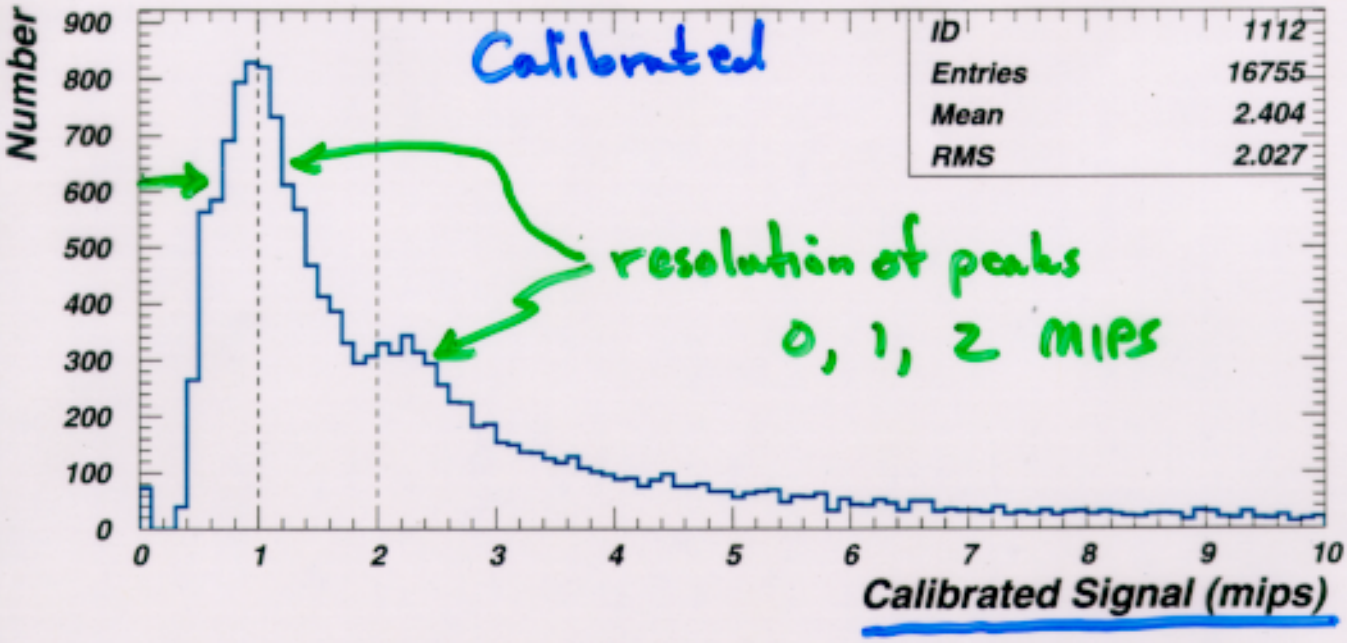
5-parameter fit

**Bottom plot : histogram of single MIP fit parameters :**

| | Inc. Data | CR Muon |
|---|---|---|
| peak | 1.62 | 1.60 |
| width | 1.83 | 1.88 |
| mean | 2.99 | 3.03 |

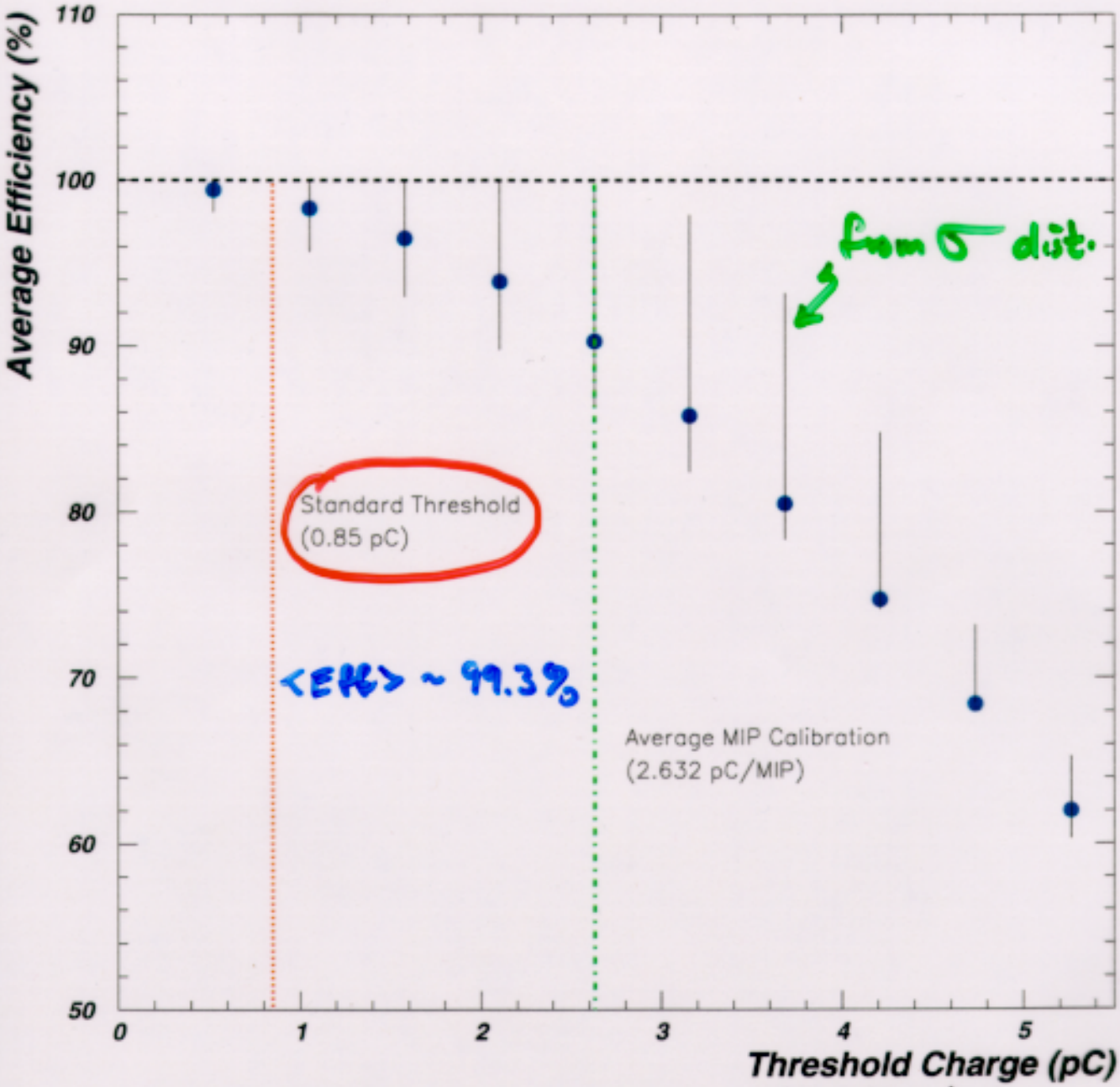
# MIP Resolution in BPRE :



Use MIP Calibration to calculate <Eff>

- integrate Landau dist. above threshold

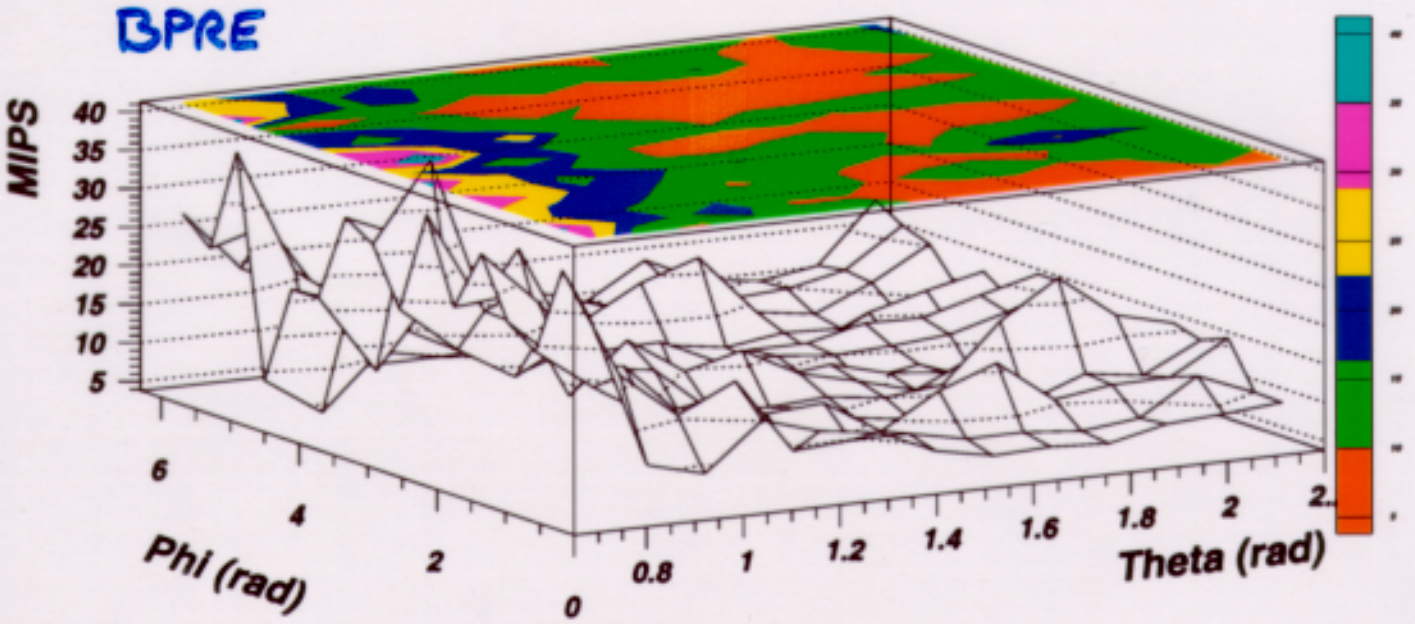


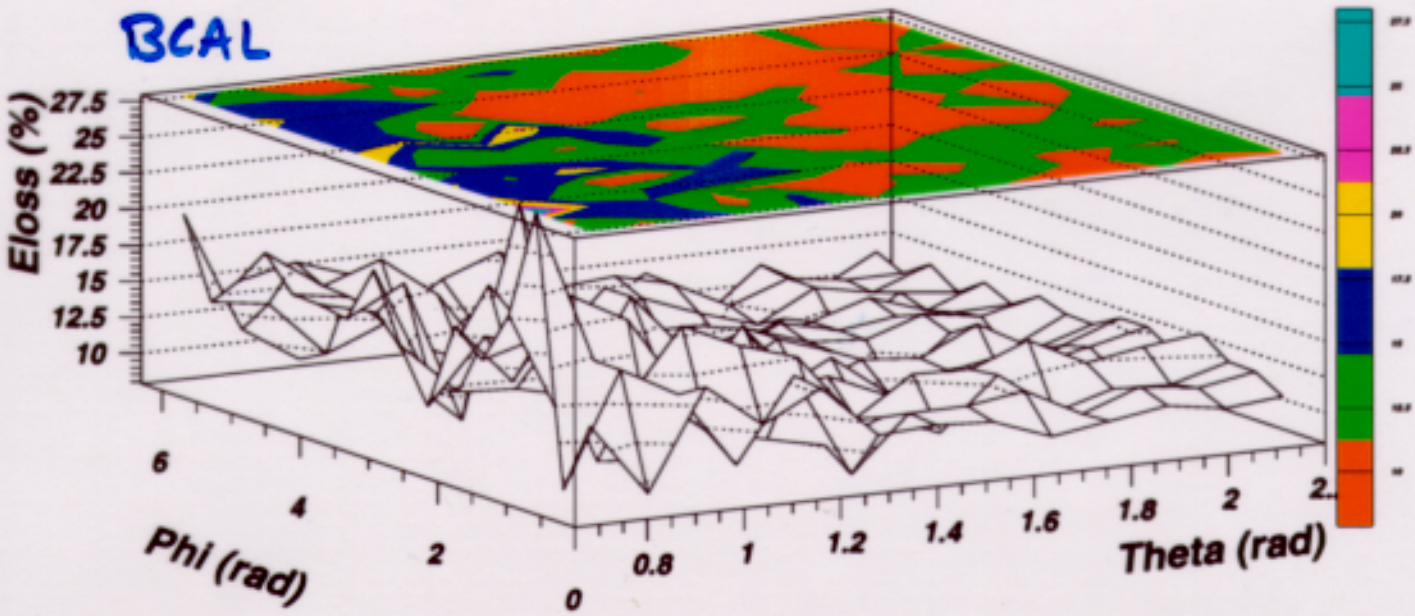

<NPE/MIP> ~ 5.5 $\left(\frac{\langle \text{MIP Charge} \rangle}{\text{e charge} \times \text{Gain}}\right)$

↳ $\langle \text{EFF} \rangle = 1 - e^{-NPE} \sim 99.6\%$

Comparison: BPRE MIPS vs. BCAL $E_{Loss}$

— use 1999-2000 DIS scattered $e^+, e^-$

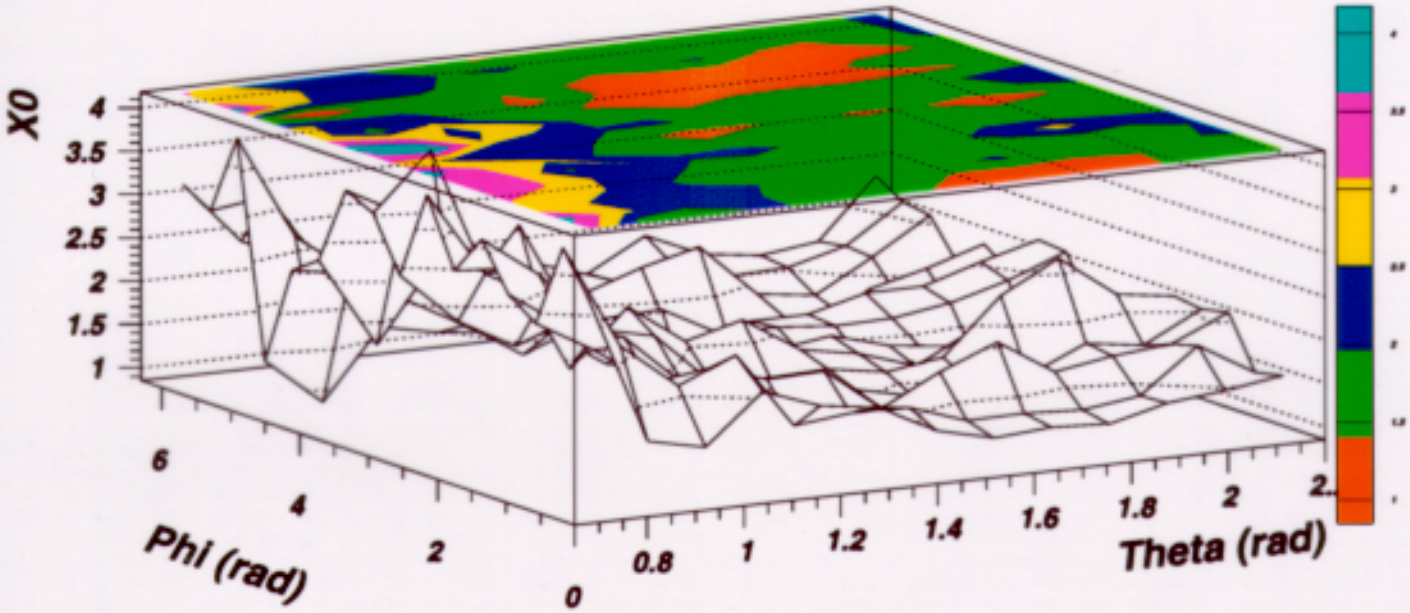


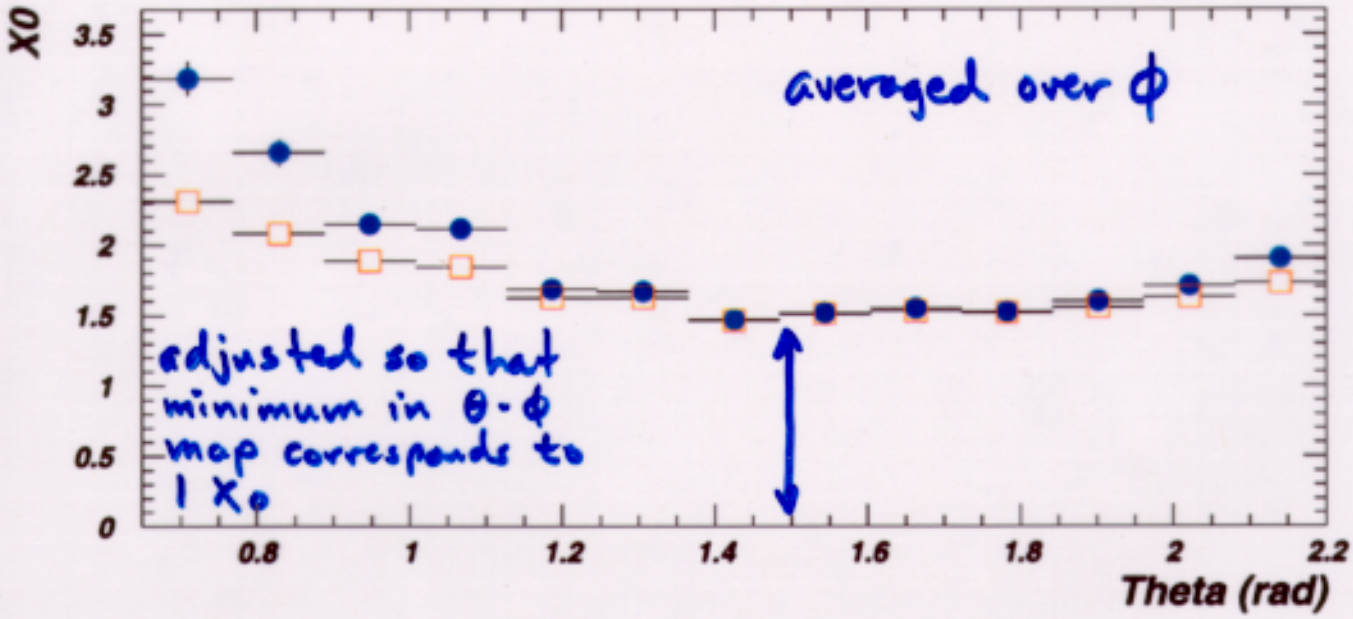




Correlation between $E_{Loss}$ and BPRE

— good calibration

# Dead Material Map in $X_0$

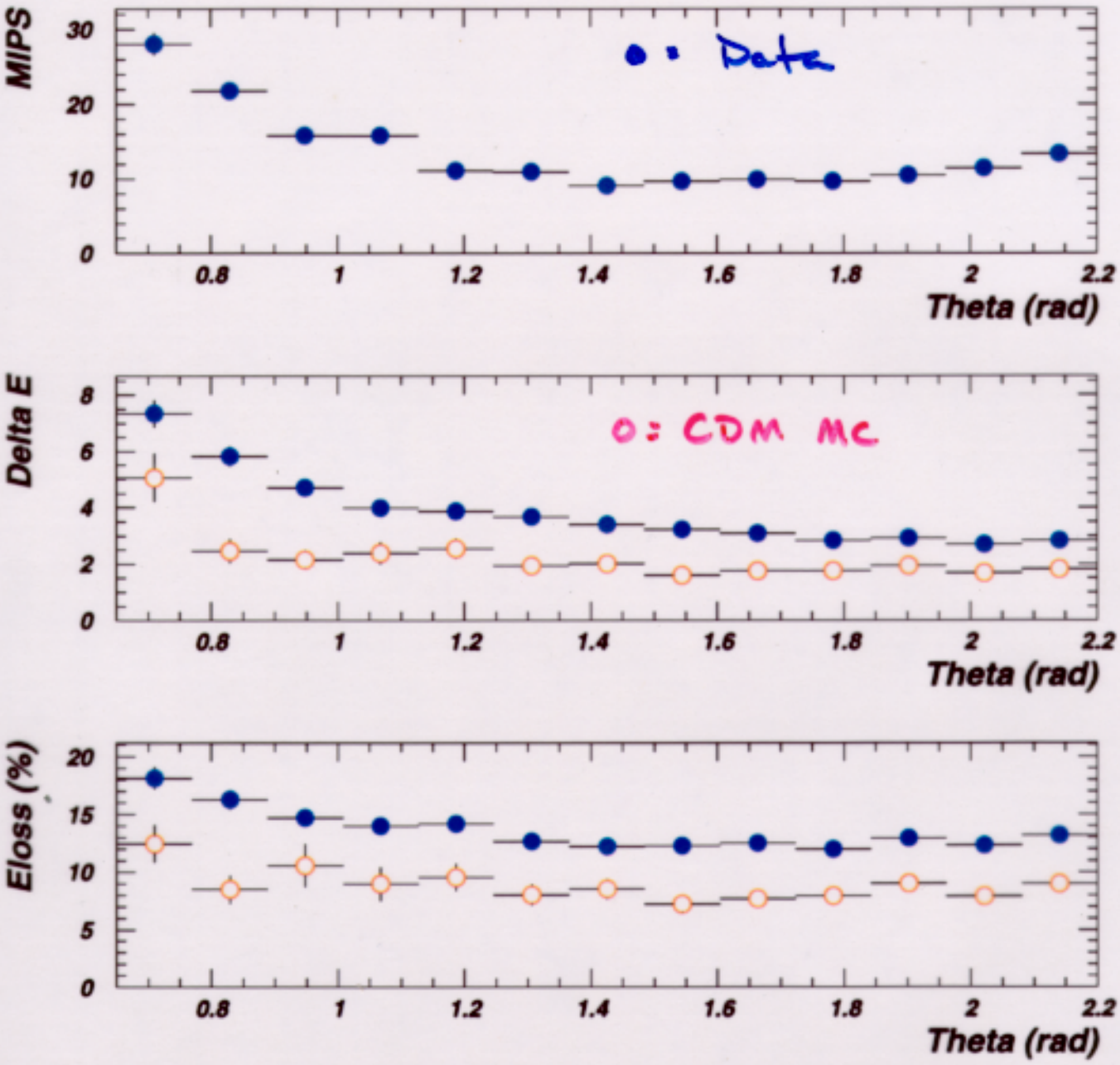



● = conversion from BPRE MIPs to $X_0$ based on test beam/$e^+,e^-$ energy corrections in ZEUS data (S. Chekanov)

□ = based on simple shower propagation model (S. Magill)

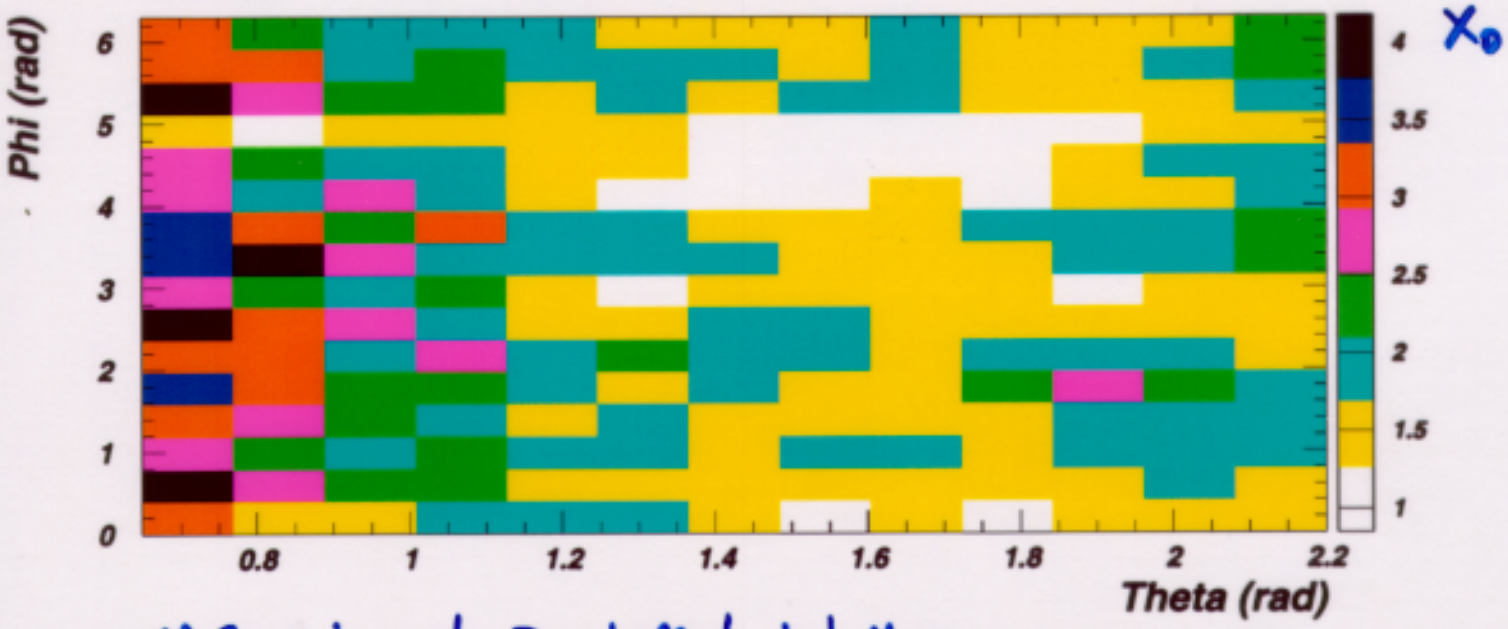
BPRE MIPs, Comparison of $\Delta E$ and $E_{loss}$ in Data and MC for scattered $e^+, e^-$



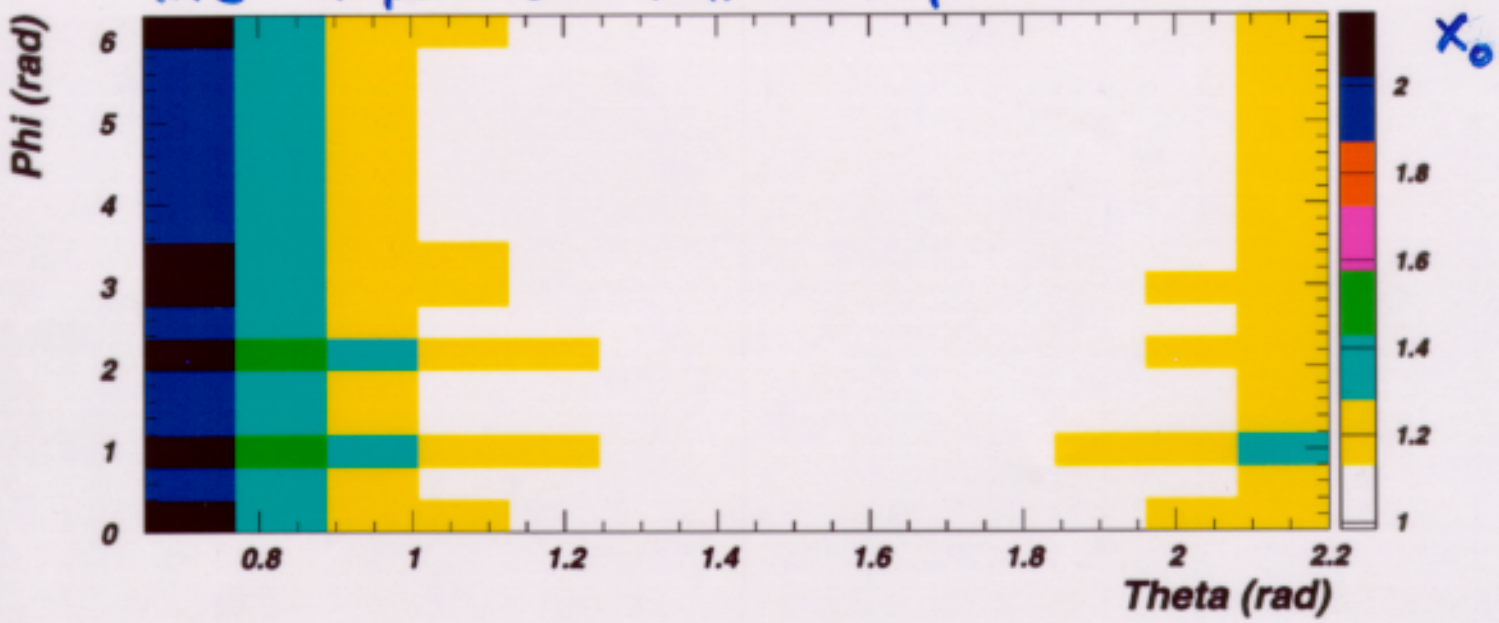

- MC $E_{loss}$, $\Delta E$ always smaller than Data
- Not enough dead material in MC?

# Dead Material Maps : Data vs. MC

Data - from BPRE MIPS

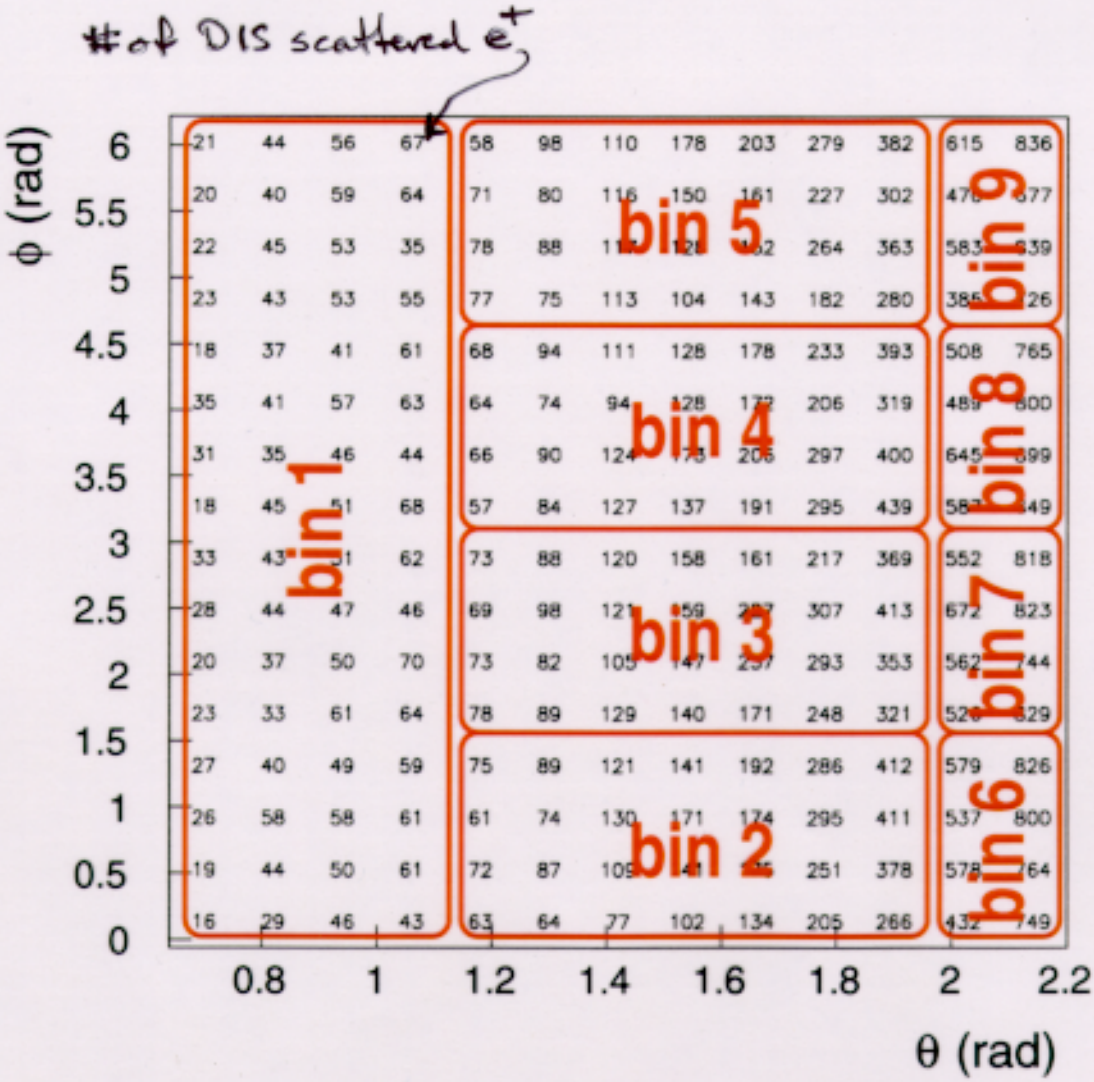



MC - input Dead Material Map



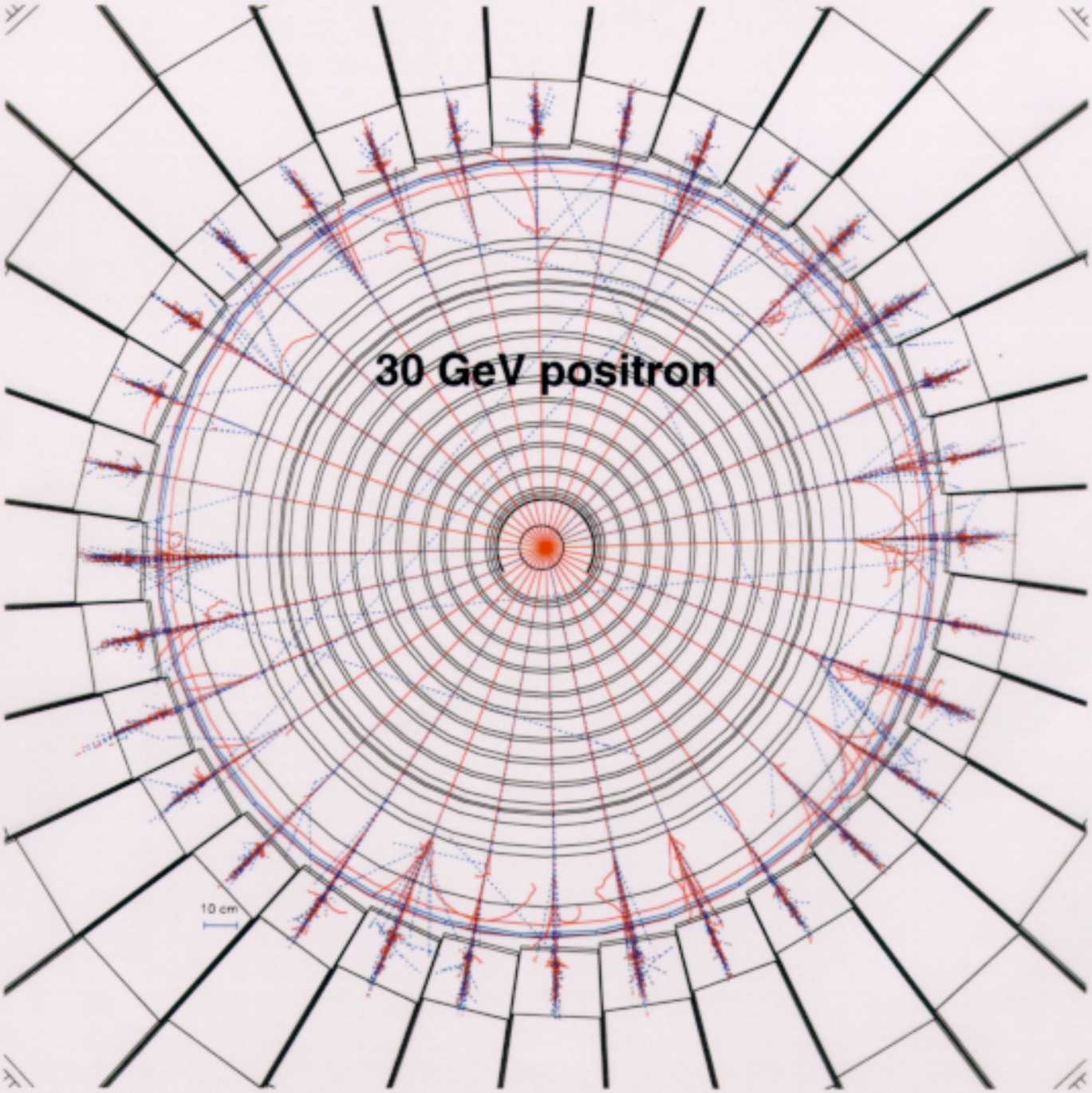

- overall magnitude of $X_0$ in data > MC (using S. Chekanov's method)
- ∅ structure differences? → more data needed

# Bins in Barrel for BPRE E corrections




- decrease bin size as data ↑

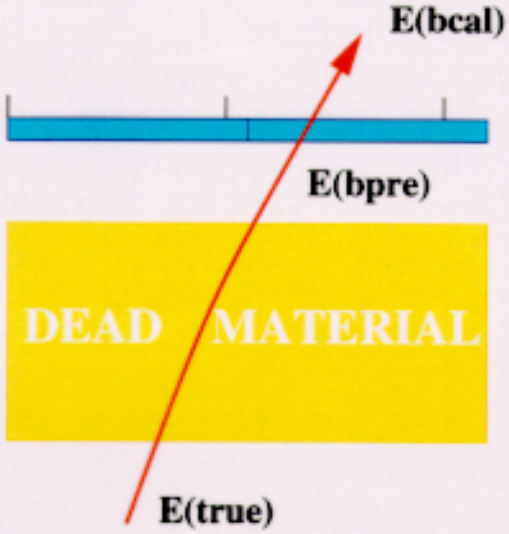
# BPRE Geometry




: "BPRE performance .."

(H1 has 4 events like this from $e^+p$)

# Derivation of BPRE Correction




- Find $E(bpre)$ (in MIPS), $E(bcal)$ and $E(true)$ $(= E_{DA})$
- Fit to a straight line in bins of $E(true)$:

$$E(bcal) = A0 + A1 * E(bpre)$$ → plot

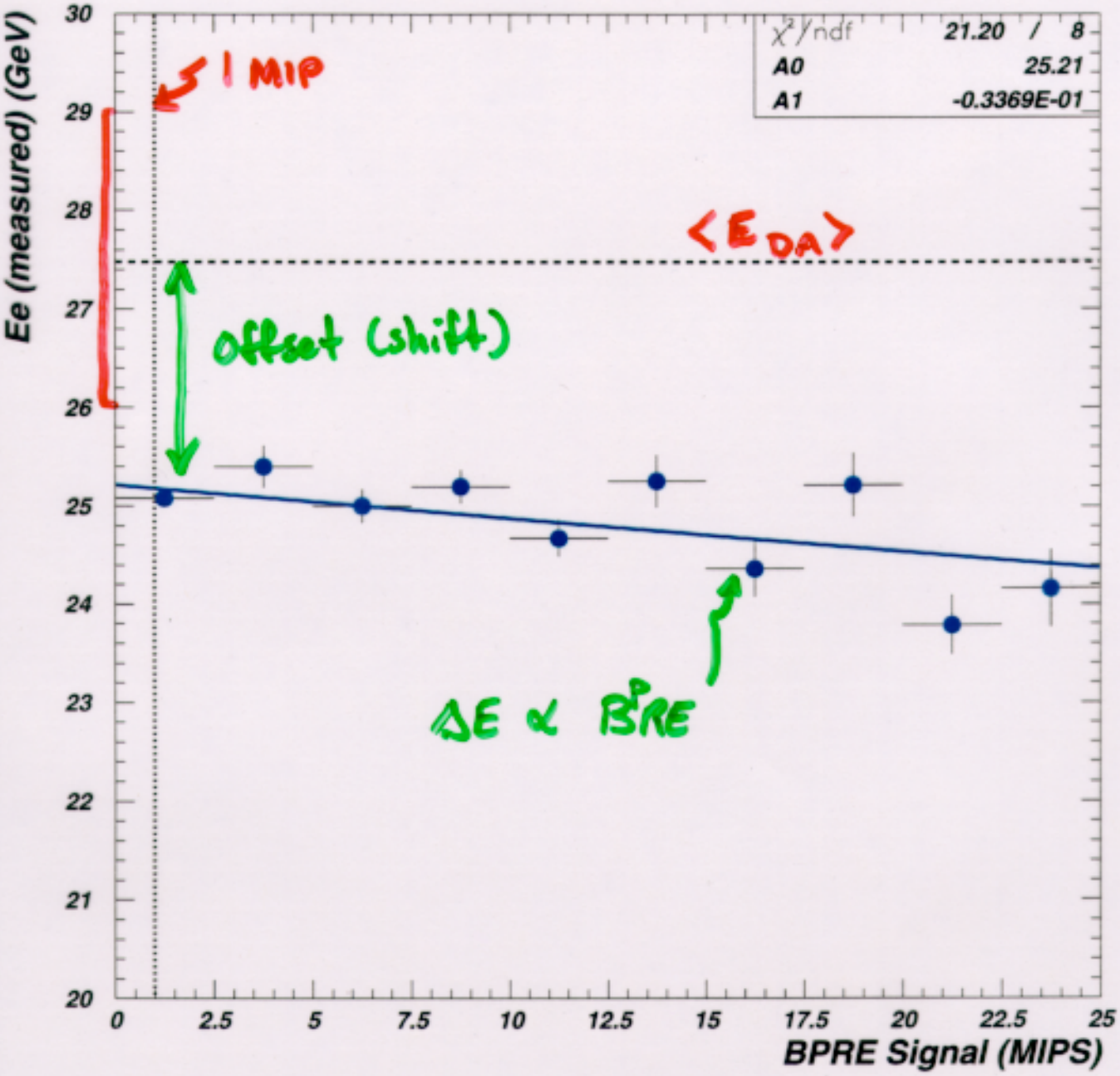
with

$$A0 = a0 + b0 * E(true) \qquad A1 = a1 + b1 * E(true)$$

- Solve all pairs of equations for parameters $a0$, $a1$, $b0$, $b1$
- Histogram and fit (Gaussian) to obtain:
  $< a0 >$, $< a1 >$, $< b0 >$ and $< b1 >$ → plot
- Do the same for different BCAL regions;
- Calculate corrected energy:

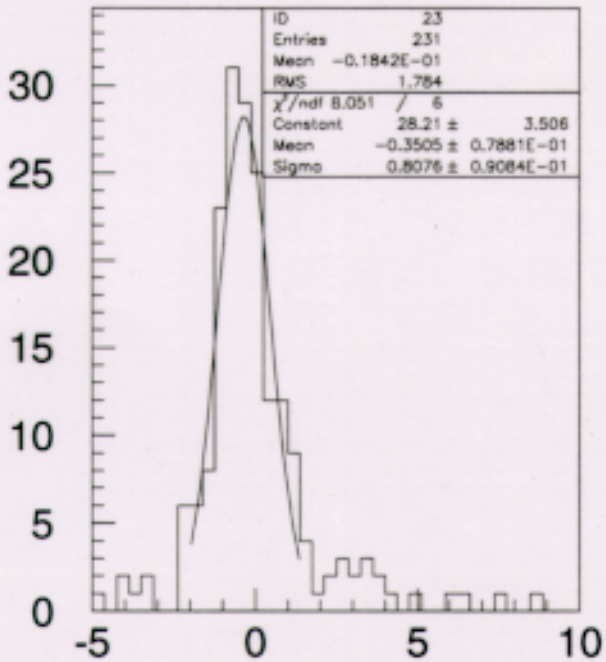
$$E(CORR) = \frac{E(BCAL) - < a0 > - < a1 > * E(BPRE)}{< b0 > + < b1 > * E(BPRE)}$$

# $E_{measured}$ vs. BPRE

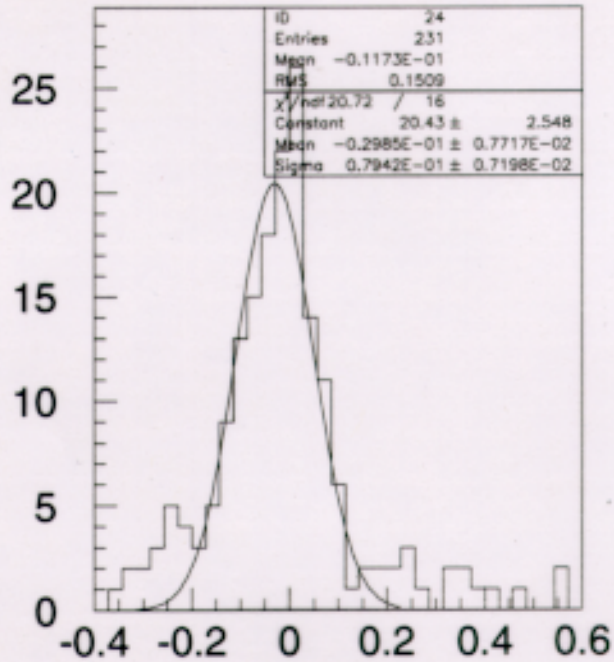



E correction is offset (shift) + MIP dependence

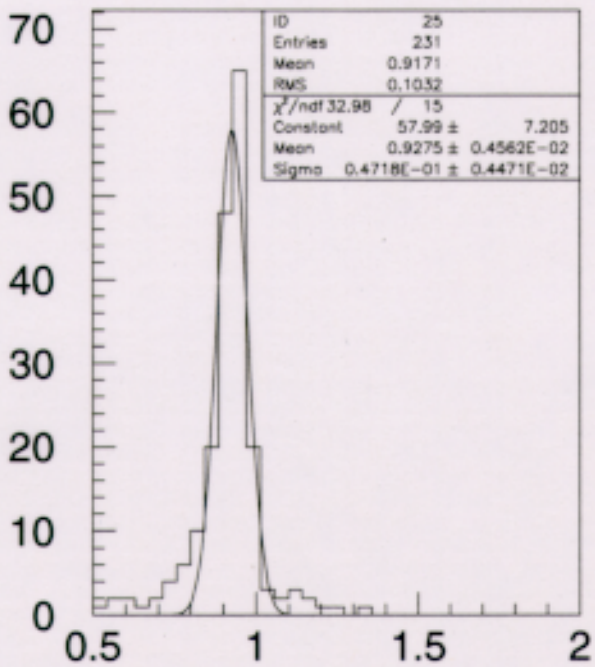
# Bin 9



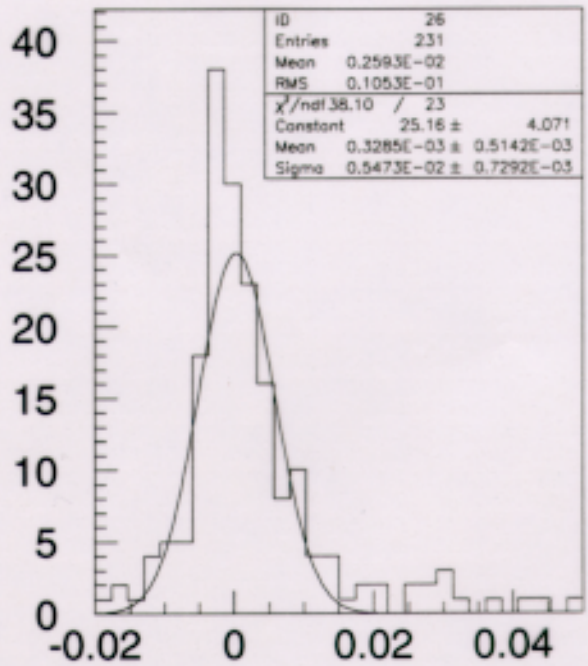

a0




a1

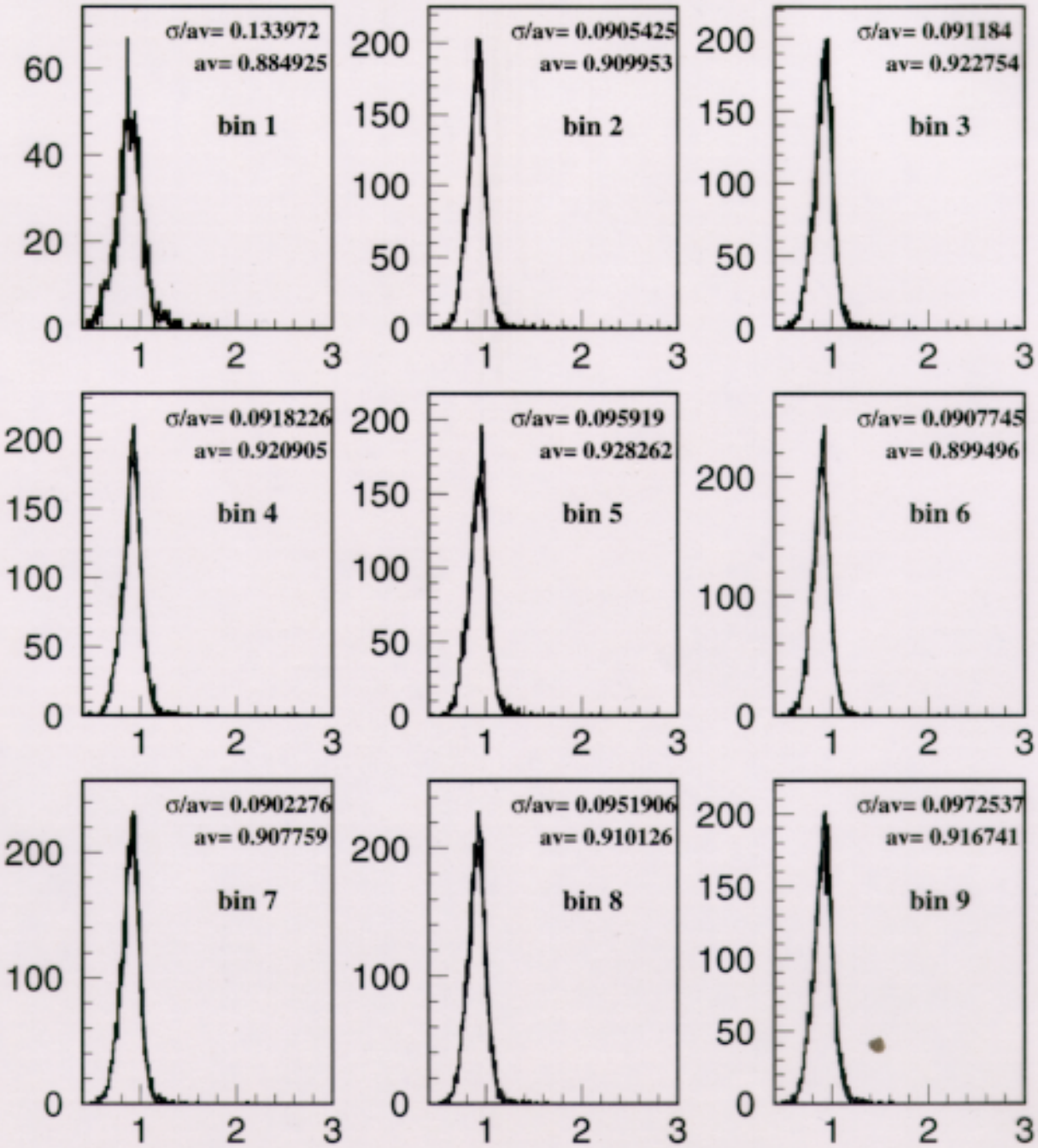



b0

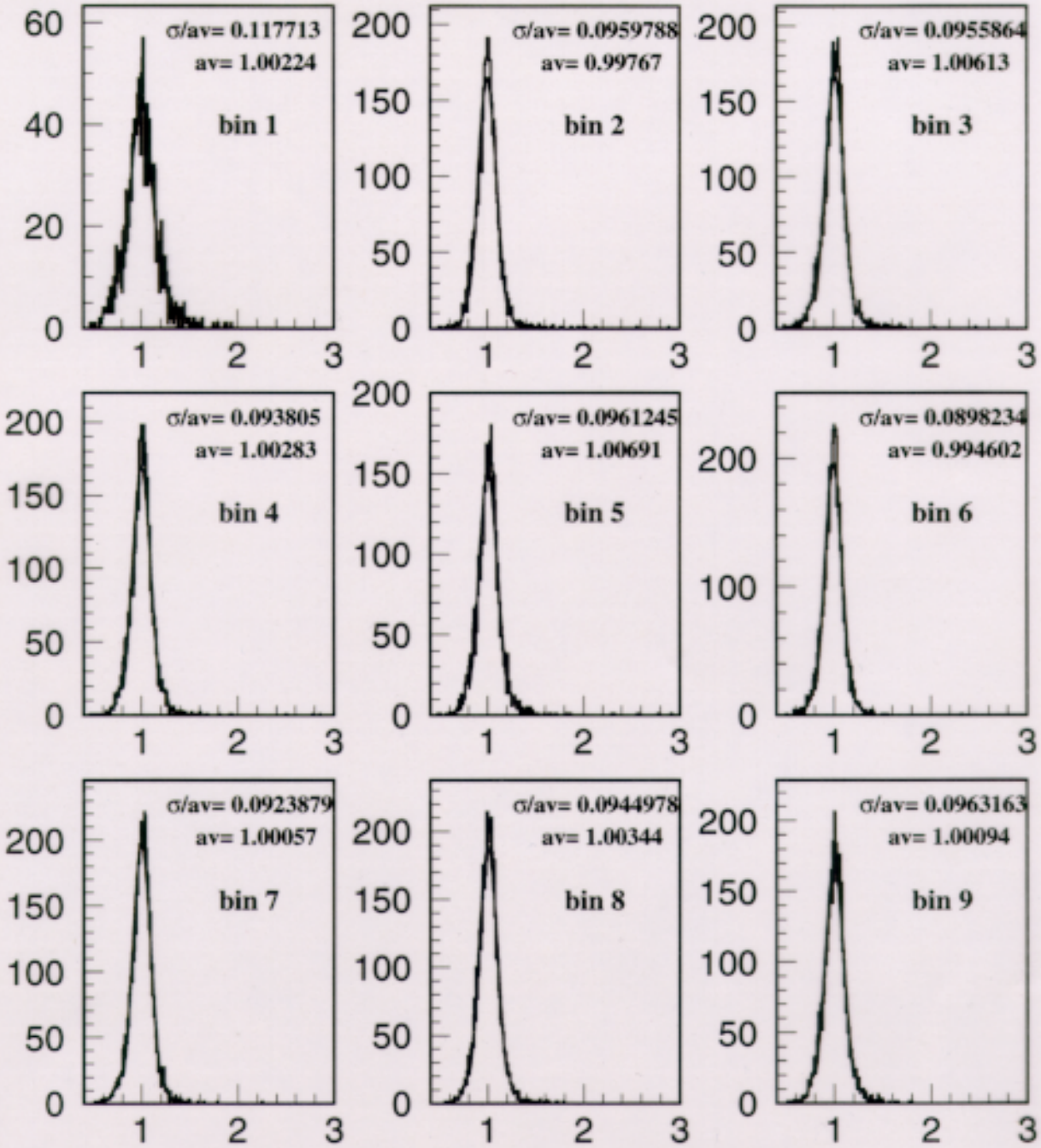



b1

# Esir/Eda


σ/av= 0.133972
av= 0.884925
bin 1
σ/av= 0.0905425
av= 0.909953
bin 2
σ/av= 0.091184
av= 0.922754
bin 3
σ/av= 0.0918226
av= 0.920905
bin 4
σ/av= 0.095919
av= 0.928262
bin 5
σ/av= 0.0907745
av= 0.899496
bin 6
σ/av= 0.0902276
av= 0.907759
bin 7
σ/av= 0.0951906
av= 0.910126
bin 8
σ/av= 0.0972537
av= 0.916741
bin 9

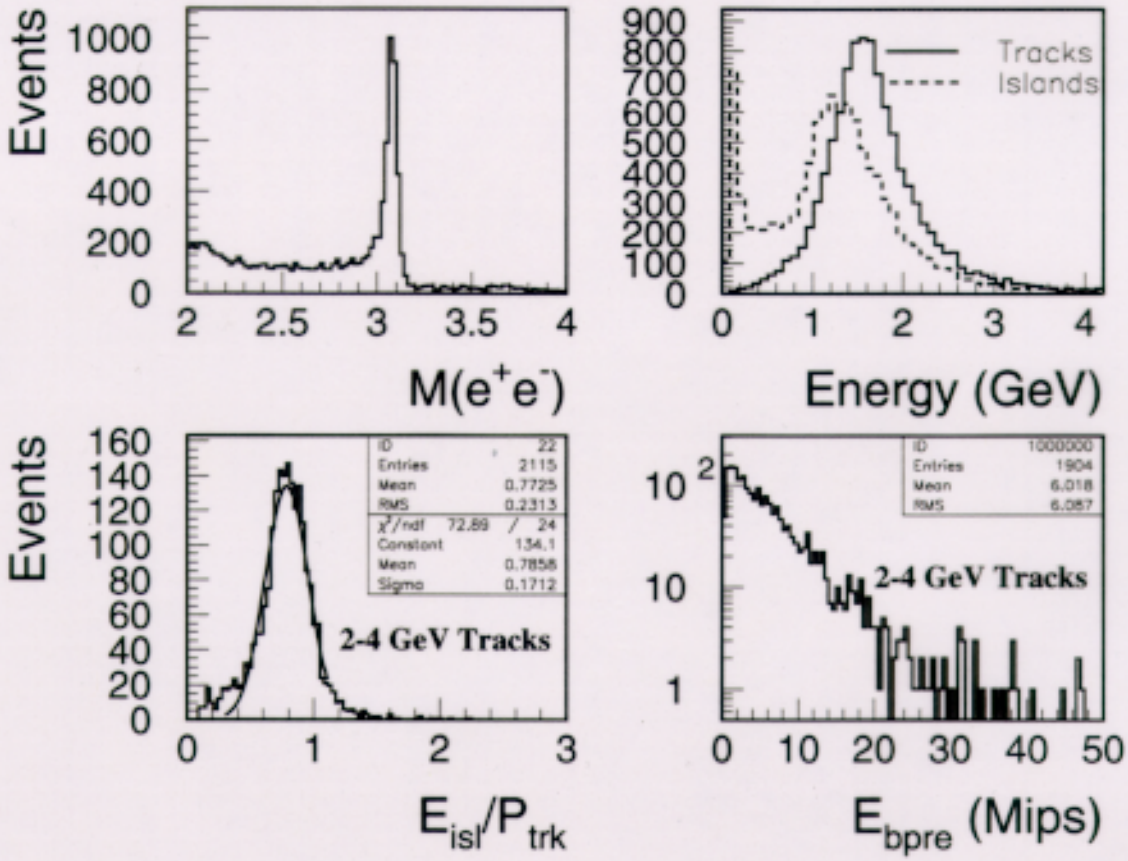
# Ecor/Eda distributions



# Energy dependence of BPRE correction

Can BPRE correction be used for low energies ?

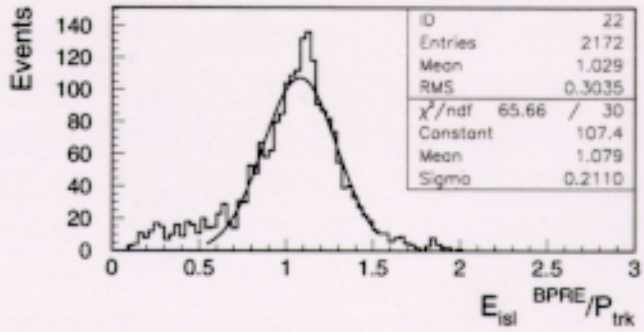
Look at $J/\Psi$ electrons:

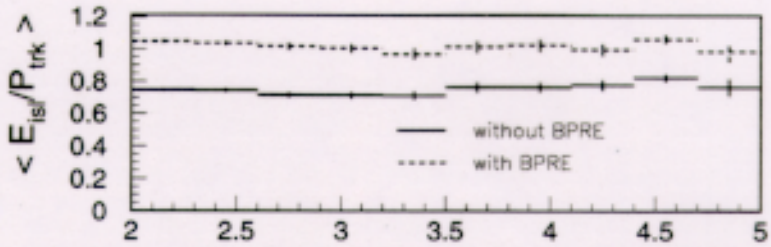


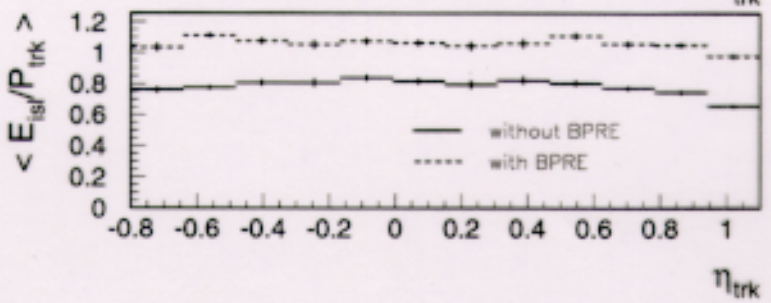

~ 22% difference between energies of islands and tracks

## Correction for electromagnetic islands (2 – 4 GeV)

use the same correction as for DIS electrons



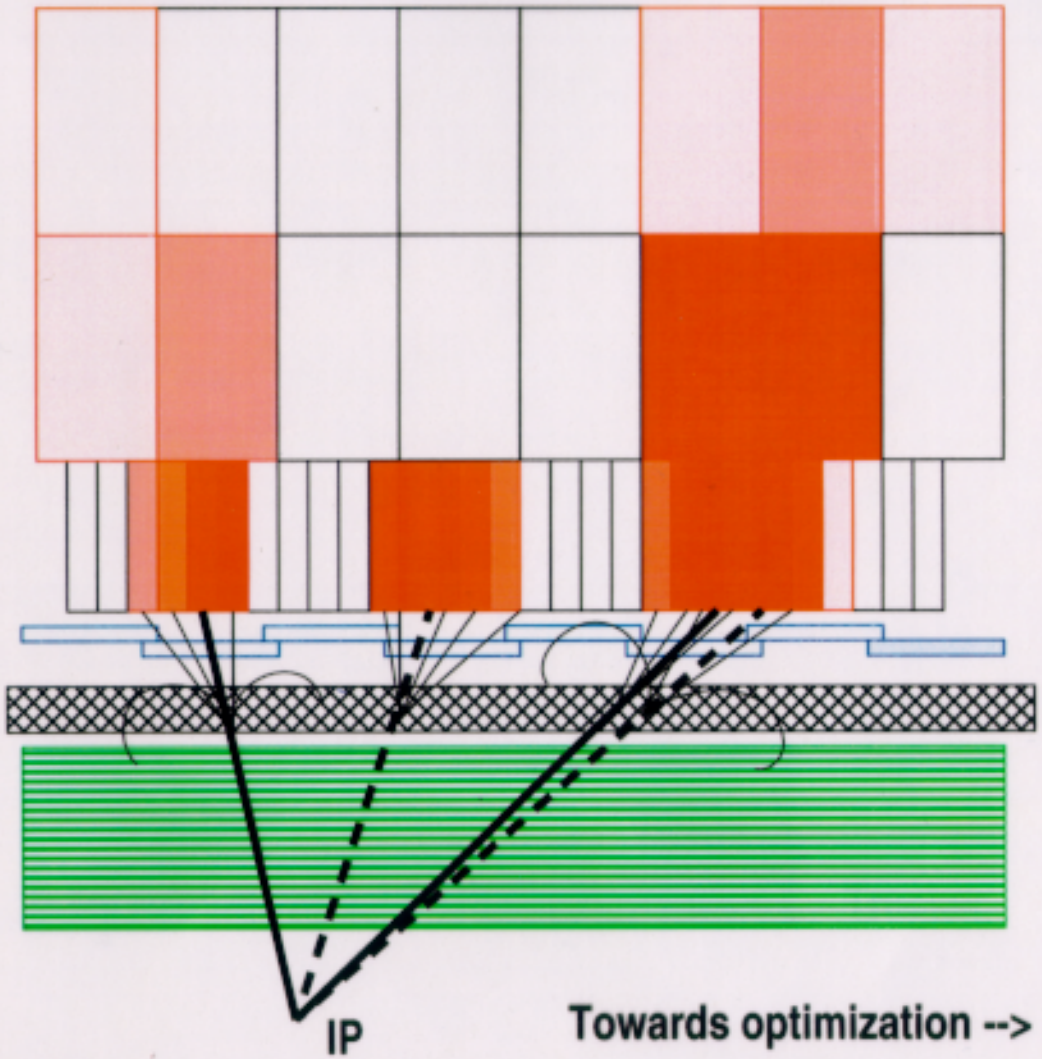

## BPRE Correction improves

- agreement with $P_{trk}$
- resolution by 11%

BPRE correction is energy independent

: *"BPRE performance .."*

# Optimized Detector Objects




HAC II

Jets : collection of low E hadrons and photons

HAC I

Energy loss in coil --> Preshower Detector

EM Cal

Track Substitution requirements :

1. 1:1 unique match
2. Ptrack > Ecluster

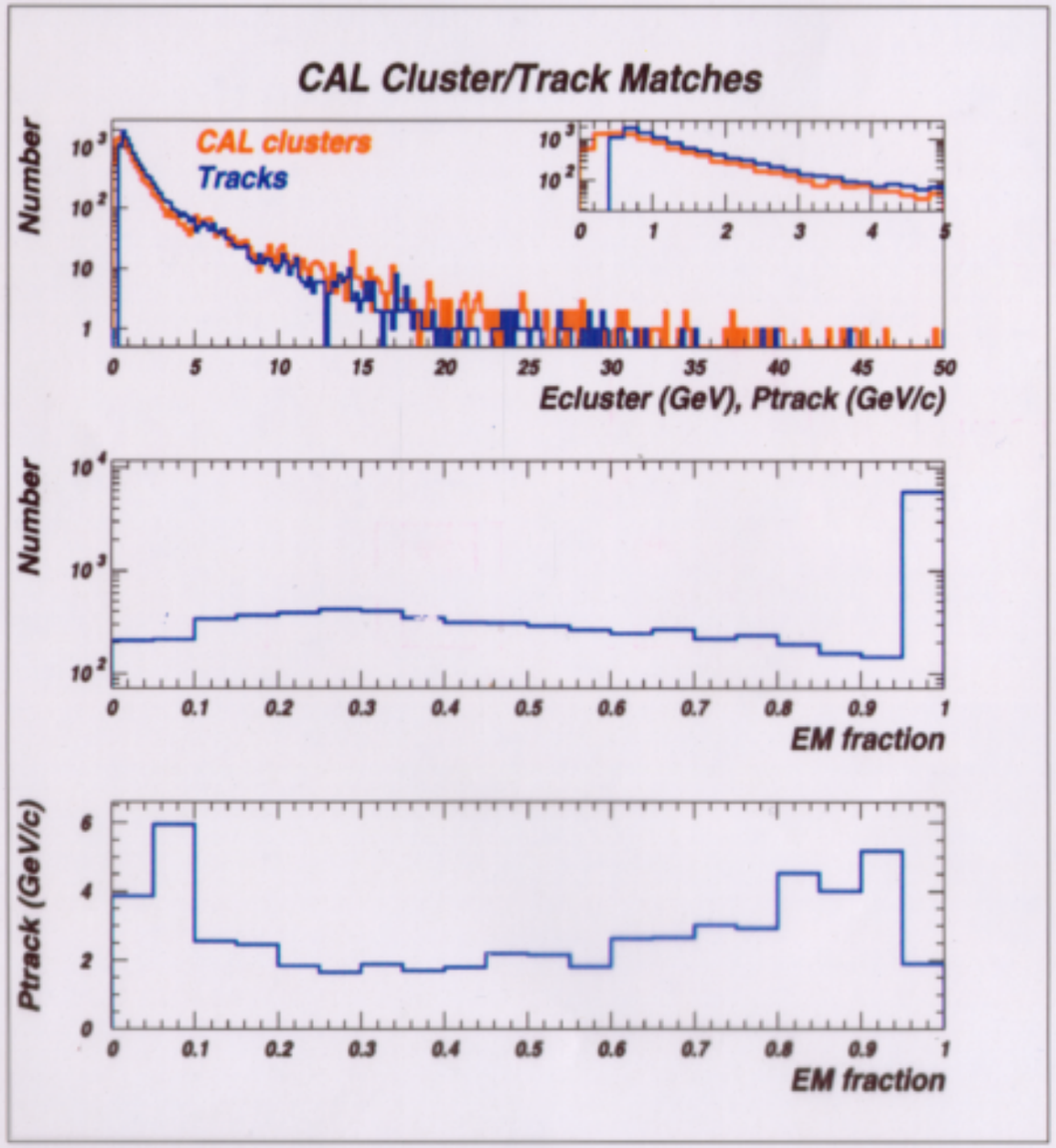
Preshower Detector

Magnet

Tracker

Towards optimization --> Tracks for hadronic clusters ($\pi$+-)
Preshower-corrected EM clusters (photons)

# Track substitution for CAL clusters




**Cluster/Track Match Characteristics**

*7 Cal clusters per jet*
*5 tracks per jet --> 1.4 clusters/track*
*jet size <~1*

Energy, momentum comparison - typically P>E

Matches dominated by clusters with EM fraction > 95%

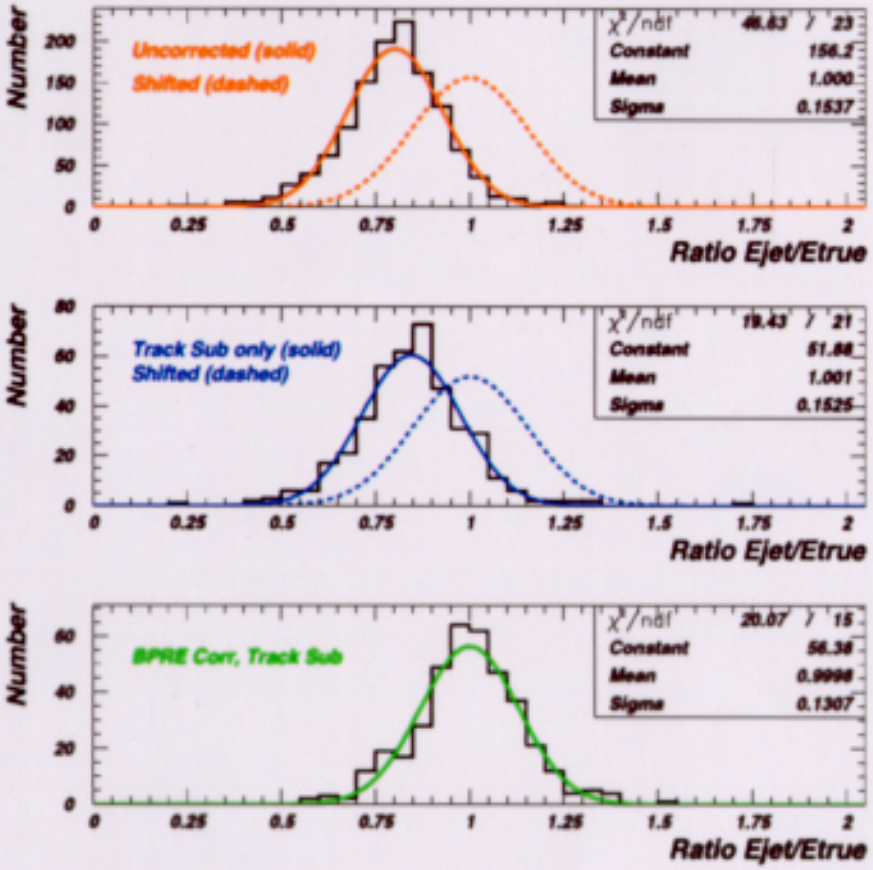
But, hadronic cluster/track matches typically have more momentum than EM clusters

*for tracks : sigma/$P_T$ ~ .005 $P_T$*

*for clusters : sigma/E ~ .35/$\sqrt{E}$*

*Tracks <------ 17 GeV ------> Cal*

# Summary - results using optimized inputs




First results combining track substitution and EM cluster preshower correction :

NO JET ALGORITHM DEPENDENCE

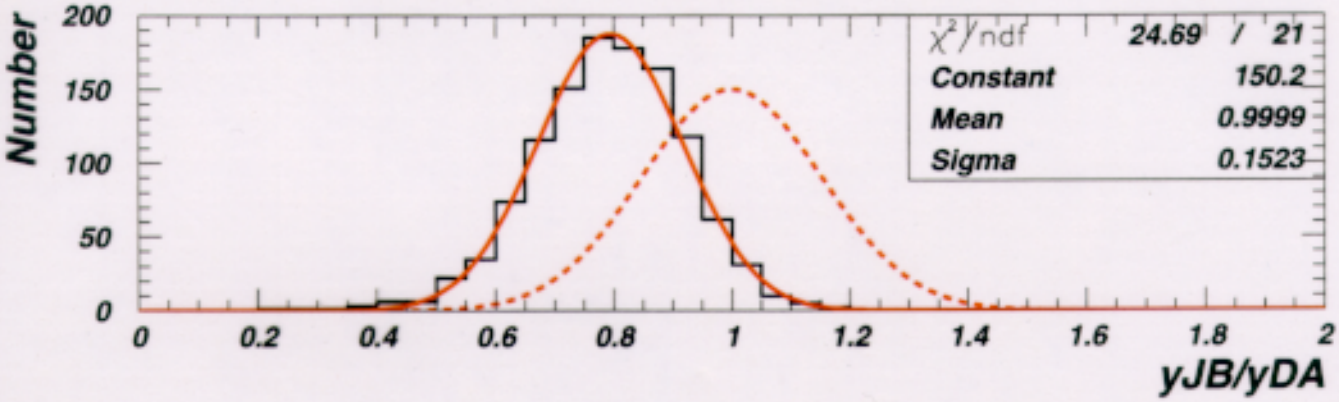
Track sub only partially corrects for energy loss and with marginal resolution improvement

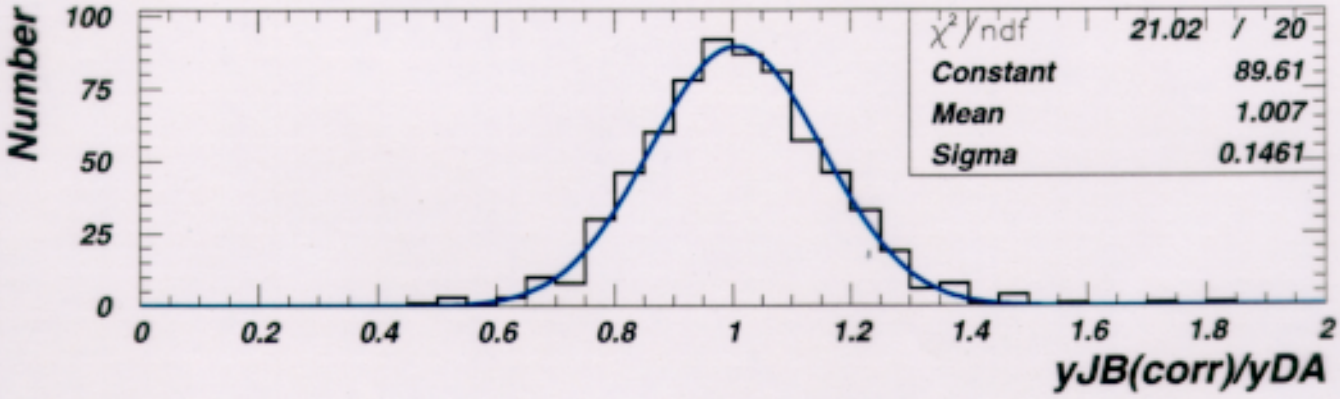
Combining track substitution and preshower correction results in ~17% improvement in the jet resolution of fully-corrected jets - a 5% improvement over jets corrected using only the preshower correction method

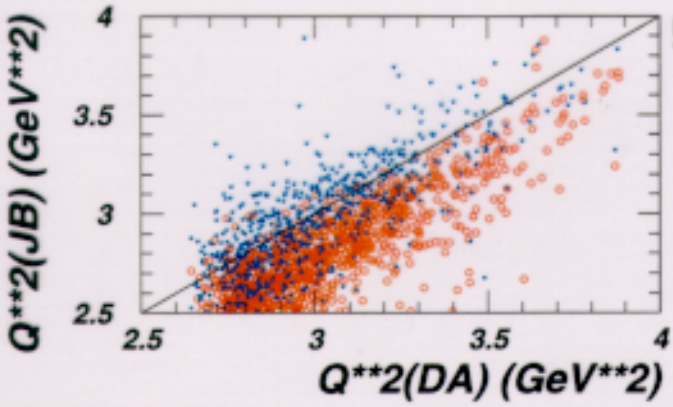
# Correction of JB Kinematic Variables :

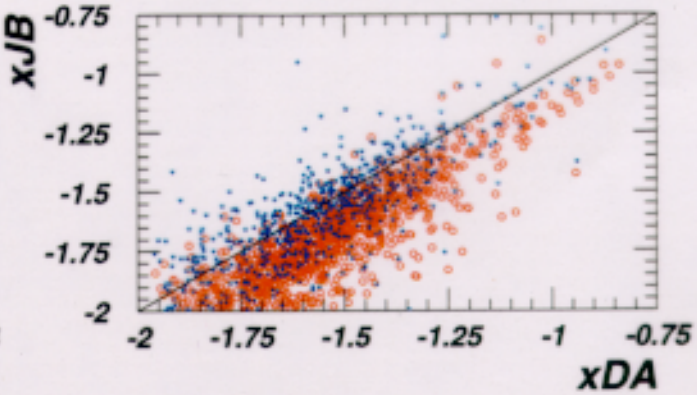
for 2002+ CC events:

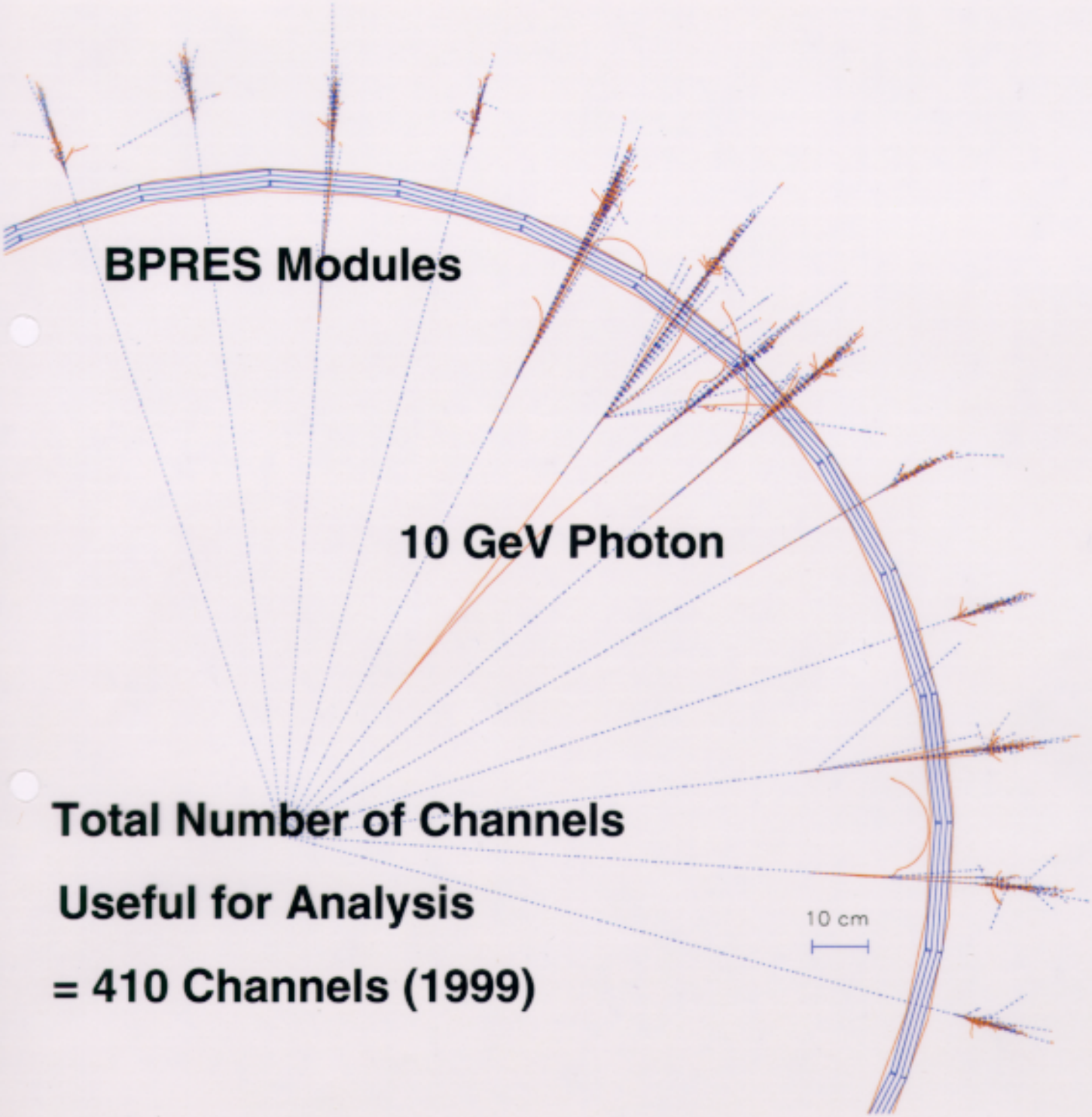
- No NC
- No MC





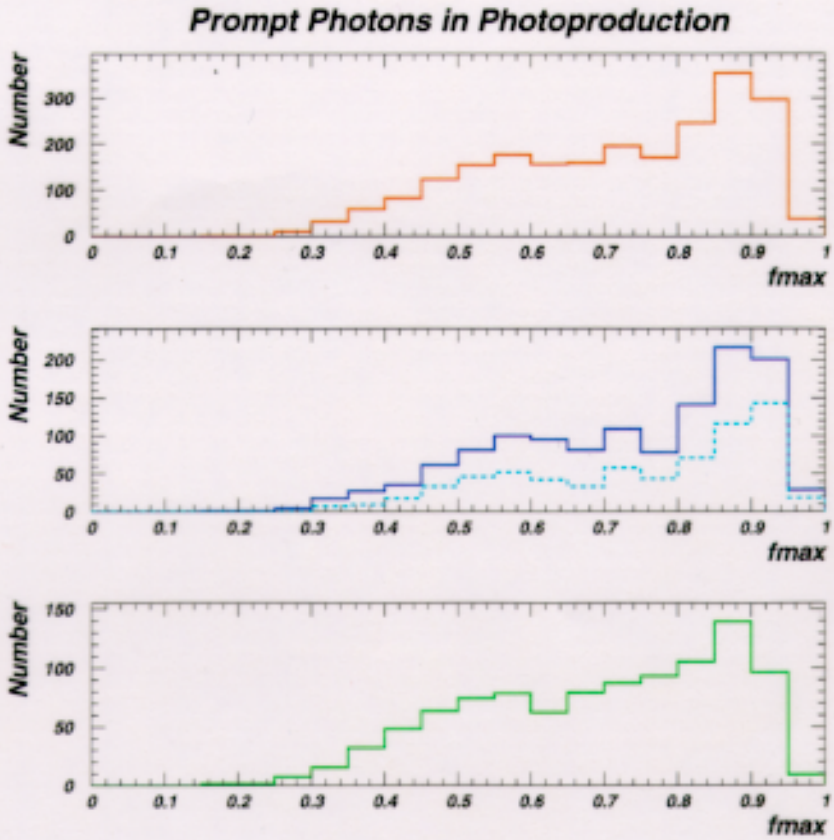

**Total Number of Channels**

**Useful for Analysis**

**= 410 Channels (1999)**

# Prompt Photon Studies

Selection criteria: $\langle \delta Z \rangle < 0.65$




No BPRE
< 2.5 Mips from BPRE
> 2.5 Mips from BPRE
No BPRE signals

Peak for $f_{max}$ is enhanced by the low BPRE Mip requirement

BPRE Goal: Independent PP analysis
↳ no $E_\gamma$ dependence

Sergei Chekanov (ANL): *"BPRE performance .."*

ZEUS HP → Detector Components
→ Barrel Presampler

# ZEUS BPRES HOME PAGE

**Off-Line and On-Line DQM Reports from BPRES**

**BCAL PreSampler Upgrade Information from Steve Magill 's Home Page**

**BPRES News**

**What to do When**

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## Physics analysis using BPRES:

ZEUS Note 00-006 – Initial Performance of the ZEUS BPRE

ZEUS Note 00-039 – Jet Energy Corrections with the ZEUS BPRE

**How to use the BPRES to correct the energy of BCAL electrons and the X0 map**

**How to use the BPRES to correct the energy of jets in BCAL**

**Prompt photon analysis (S.Lee)**

**Studies of e+e-, mu+mu- , pi+pi- (T.Tsurugai)**

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## Fortran BPRES Library:

**bprestool.fpp Version 2.7 (Jun 4, 2000) Copy to your "src" directory.**

**bpredat.inc Copy to your "inc" directory**

Starting from the 99 data, you should always fill the BPRES mip signals into your ntuple. To do this, copy bprele.fpp subroutine which is used together with bprestool.fpp and bpredat.inc. To get the mip signals, just put bprele.fpp after any electron finder if you know a run number and XYZ of the electron. The correction can be done off-line if the BPRE signals in mips are known.

Note that bprele.fpp subroutine can also be used to find any BPRE object related to BCAL if the variable RAD is optimized.

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### BPRES group:

**Coordinator : Steve Magill (non-resident) srm@hep.anl.gov**

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# DIS Scattered Lepton Energy Correction and X0 Reconstruction

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**How to correct the energy of the BCAL electrons/positrons**

Starting from the 99 data, you should always fill the BPRE mip signals into your ntuple. To do this, copy subroutine bprele.fpp which is used together with bprestool.fpp and bpredat.inc . To get the mip signals, just put bprele.fpp after any electron finder if you know a run number and the XYZ of the electron. The variable "bmips" gives the BPRES mip signal. Once you have the BPRE mip signal, the energy of the BCAL electron and its pseudorapidity, you can correct the energy of the electron using the subroutine CELE, which can be used in your off-line program.

This BPRE correction is inferred from the studies discussed below:

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**Systematic checks**

First, look at Steve's studies of the BPRE corrections.

The studies of BPRES efficiency for positrons can be found here.

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**Data used for BPRE corrections**

**To determine BPRE correction parameters in the BCAL region, the following steps are necessary:**

Select DIS events with electrons in BCAL using cuts: DST bit 12, 40 < (E-pz) < 60, abs(Zvertex) > 50, Yel < 0.95, Yjb > 0.01, Eda > 7.5, Sinistra is used with option 4, Prob > 0.9 and theta between 0.65 and 2.20 rad.

Data: 80 pb-1 (1999-2000 data)

Using the DJANGOH MC model, it was found that at present the best reconstruction of the positron energy can be obtained using the DA method. Fig.00 shows comparisons of the true positron energy with that reconstructed using the DA and Electron (EL) methods. Typical difference between DA and EL methods is 4-5 %. For data, this difference is on the level of 8%. The use of CALCORR reduces this difference to 4%. (see Fig.01)

Non-uniformity correction for the BPRE correction is not used. Using the EM corrections (subroutine ***emEnergyCorrection*** after excluding a correction for dead material), it was found that there is a negligible contribution from non-uniformity correction. Fig.02 shows that, in average, non-uniformity correction changes the energy of the electron by about 1-2%. No improvement in resolution is seen with respect to the DA method. Therefore, the non-uniformity correction is not used in the further analysis, since the same shift in the energy can be taken into account using the BPRE correction.

## Dead Material Map reconstruction

**Dead Material Map** can be reconstructed from the BPRE counting numbers of MIPs for different BCAL regions. This figure shows the dead material map from 96 Monte Carlo. For the data, this figure shows the average BPRE signals and the numbers of DIS electrons for different BCAL regions. After taking into account the dependence of the energies of electrons for different BCAL regions (see figure) and normalizing the average BPRE signal using a BCAL region with small and most understood dead material amount (phi: 5-6 rad, theta: 1.57 - 1.7), one obtains the X0 dead material map shown in figure.

## BPRE Scattered Lepton Energy Corrections

First, all barrel region was divided into 9 bins which have similar dead material amounts. Fig.03 shows the definitions of these bins and numbers of DIS positrons for 80 pb-1 (99e-00p data).

The differences between the measured energies of DIS electrons and the energies determined using the DA method are shown in Fig.1 for the 9 bins determined in Fig.03 and, in Fig.2, for 4 bins in the DA energy (integrating the data over all 9 bins).

The range of the DA energies between 10 and 32 GeV was divided into 22 bins of size 1 GeV. For each bin, a fit of the measured electron energy vs BPRE signal is performed. An example of such a fit for one bin is shown in Fig.3.

To determine the BPRE correction, the parameters a0, a1, b0, b1 can be found from the equations given in ZEUS Note 00-006 for 2 independent fits. For 22 bins used, there are 22*19/2 solutions and each solution gives a0,a1,b0,b1 parameters. These solutions can be histogramed and peak positions of the histograms give average values of the a0, a1, b0, b1 parameters. This histogram shows the distribution of parameters a0,a1,b0,b1 for bin 9 which has the largest statistics.

**This correction is implemented in the subroutine CELE which can be used in your off-line program.**

Figure 4 shows the results of a comparison of the BPRE corrected positron energies for 9 bins with the DA method (+ Gaussian fits to each distribution). A similar Figure 5 shows the same but for 4 bins in the DA energies, integrating the data over these 9 BCAL regions. Comparing these figures with Figure 2 and Figure 3, an improvement of about **8-9%** is obtained. This Figure shows improvements in the resolution after the use of BPRE for each BCAL region.

Fig.6a and Fig.7a show the ratios as functions of eta and Eda, before and after BPRE and CALCORR corrections. Fig.6b and Fig.7b are the same but for the DJANGOH Monte Carlo. Note that the Monte Carlo does not reproduce energy dependence of the BPRE correction.

Thus a preliminary conclusion is : The electron energy corrected with BPRE should be compared to the Monte-Carlo electron energies corrected by 5%. The BPRE simulation looks unrealistic for present version of the Mozart. Fig.8 illustrates this conclusion. Fig.9 gives the ratio between data (with

CALCORR and BPRE correction) and MC predictions. The EL+BPRE energies are well described by Djangoh with the 5% correction (in fact, CALCOR applied to MC gives the same). This agreement is slightly better than that between EL+CALCORR method (for data) and the EL method for a Monte Carlo.

## First look on J/Psi with BPRE:

To understand the applicability of BPRE to low energy electrons, a sample with 2 tracks coming from J/Psi was selected using DST bit 83. Fig.10 shows the mass distributions of the electrons, energies of tracks and islands matched to tracks from J/Psi in BCAL (using cone algorithm with the radius 0.25), the ratio of the energy of islands to the track total momenta and BPRE signal in MIPS associated to the islands (using a cone algorithm with the radius 0.5). A typical difference between the energies of islands and tracks is 22%. Note that only tracks in the energy range 2-4 GeV were used, to avoid a bias due to requirement on the minimum value of energy of the islands, which is 0.3 GeV for this study (tracks with momenta less than 2 GeV often correspond to islands with energies lower than 0.3 GeV).

A similar studies have been performed using 7 bins of size 0.1 GeV in the track momenta of J/Psi, from 2.0 GeV to 2.7 GeV which have largest statistics (more than 100 entries). Fig.11 shows the distributions of the parameters from the 7 fits. The parameters are close to those obtained for the scattered electrons in the forward region. The latter plot suggests that one can apply the same correction to the low energy electrons from J/Psi as it was done for the high-energy scattered electrons. Fig.12 and Fig.13 illustrate the BPRE correction applied for islands. In general, there is a good agreement between energies of the tracks and energies of islands corrected by the BPRE. An improvement in the resolution seen from Fig.13 is about 11%, with respect to that without the BPRE correction.

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