# A short study of EM + HA Total Absorption Dual Readout Crystal Calorimeter

- Hadron shower containment & Energy resolution
  Interaction Lengths & Shower Energy Leakage

  started this study with CCAL02 BGO

  Hans Wenzel added CCAL02_PbWO4

  Hans W. and Adam P. convert script to enable varying

Density e.g. 7.13 8.3 15 20

Tranverse Segmentation
$(15 \times 15, 25 \times 25)$
$(30 \times 30, 50 \times 50)$
$(45 \times 45, 75 \times 75)$ mm$^2$

At Muon Collider, the Calorimeter should have $> 8$ Interaction Lengths.

- Calorimeter Segmentation
  Important to study Longitudinal Segmentation
  Should have more realistic simulation of the calorimeter

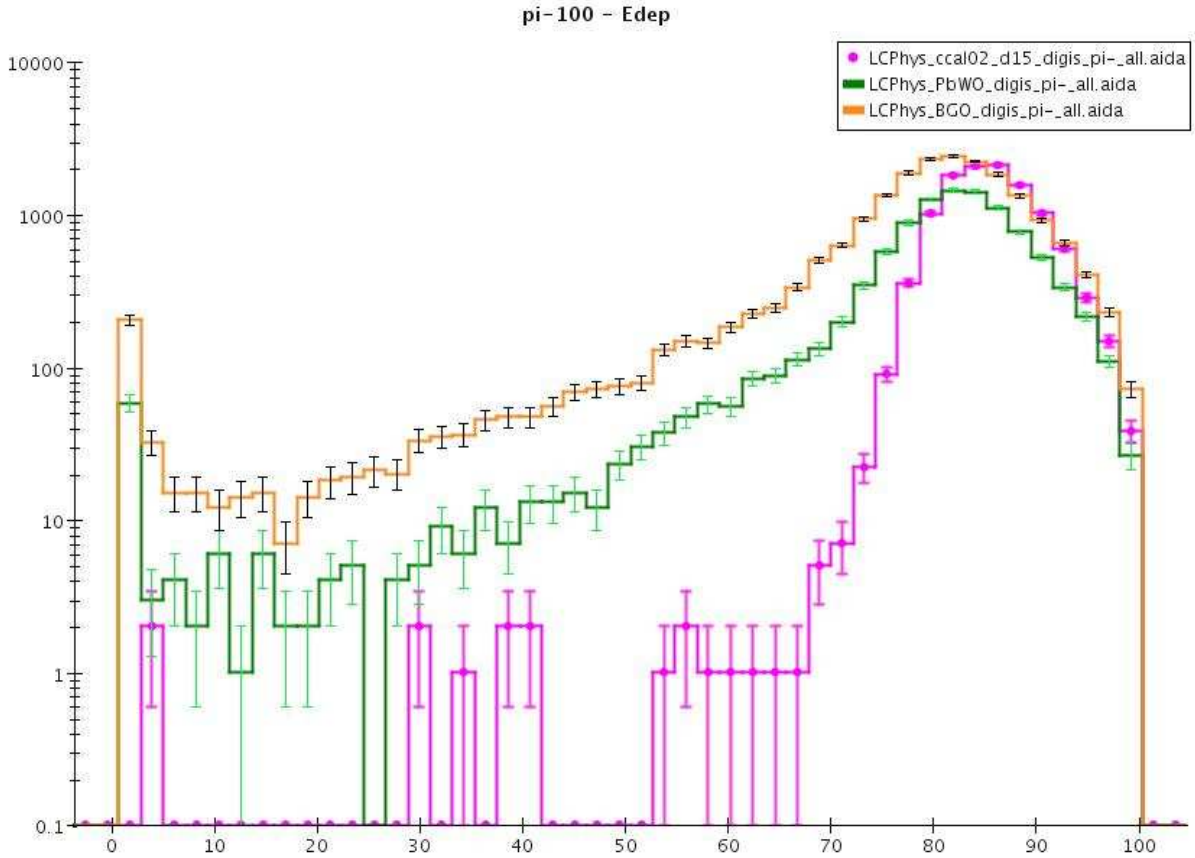


FIG. 1: Leakage also observed by Hans Wenzel

.

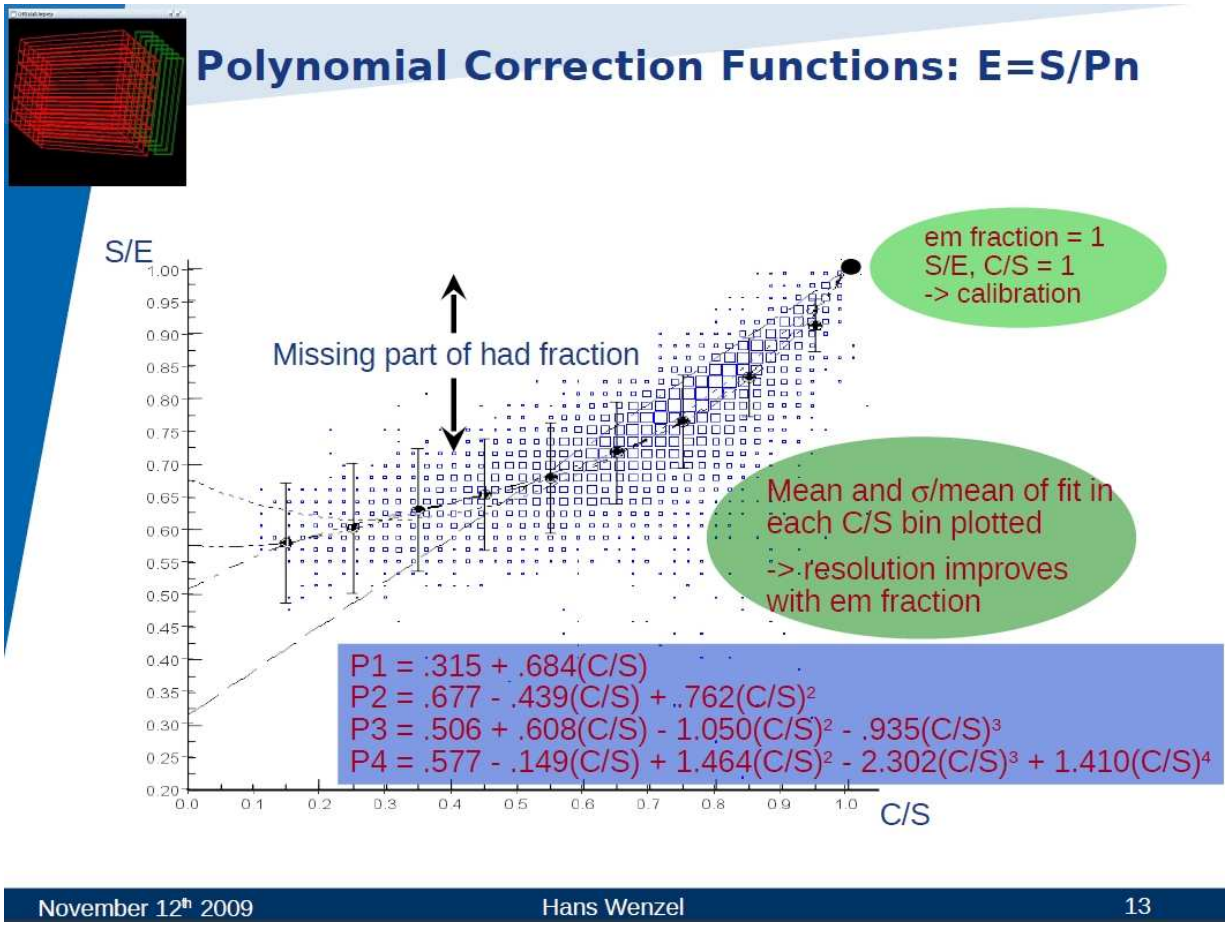


FIG. 2: Leakage also observed by Hans Wenzel

.

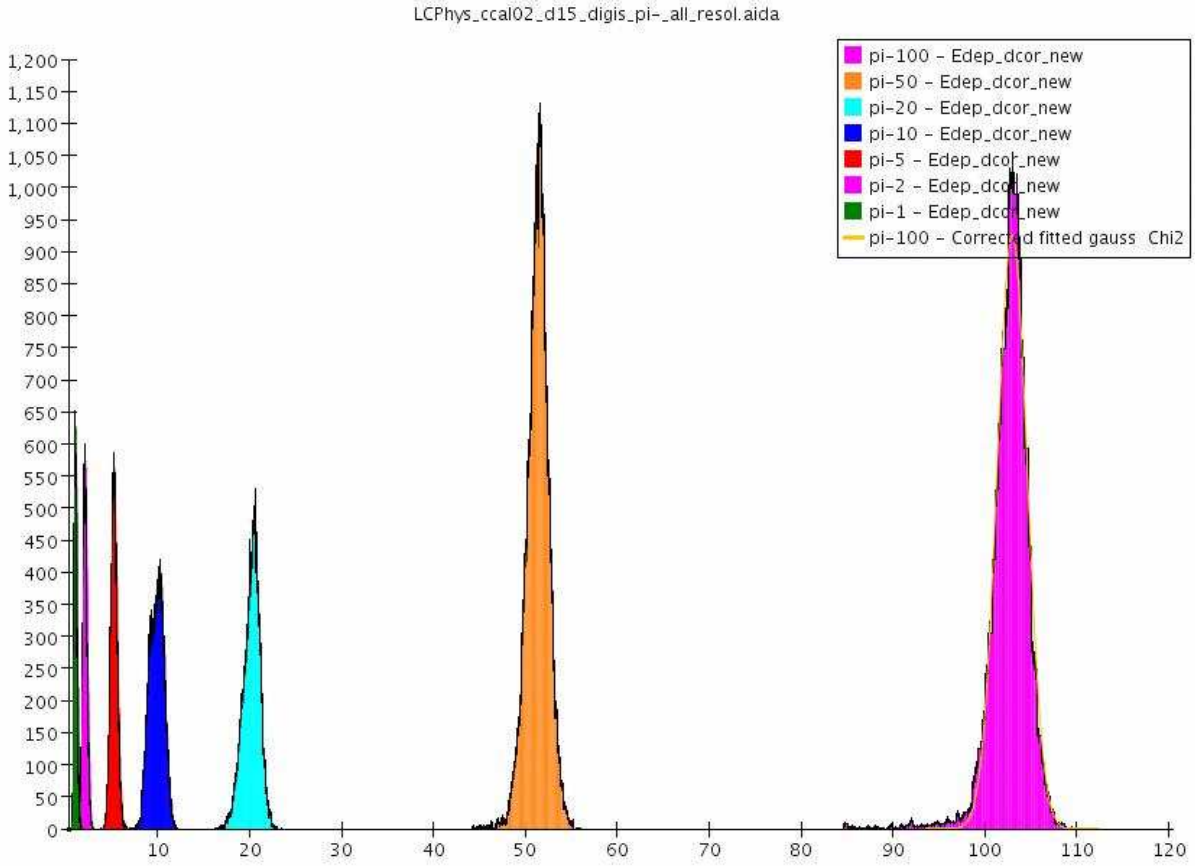


FIG. 3: D15 Dual Readout corrected $\pi^-$ energy, from Hans Wenzel

.

.

.

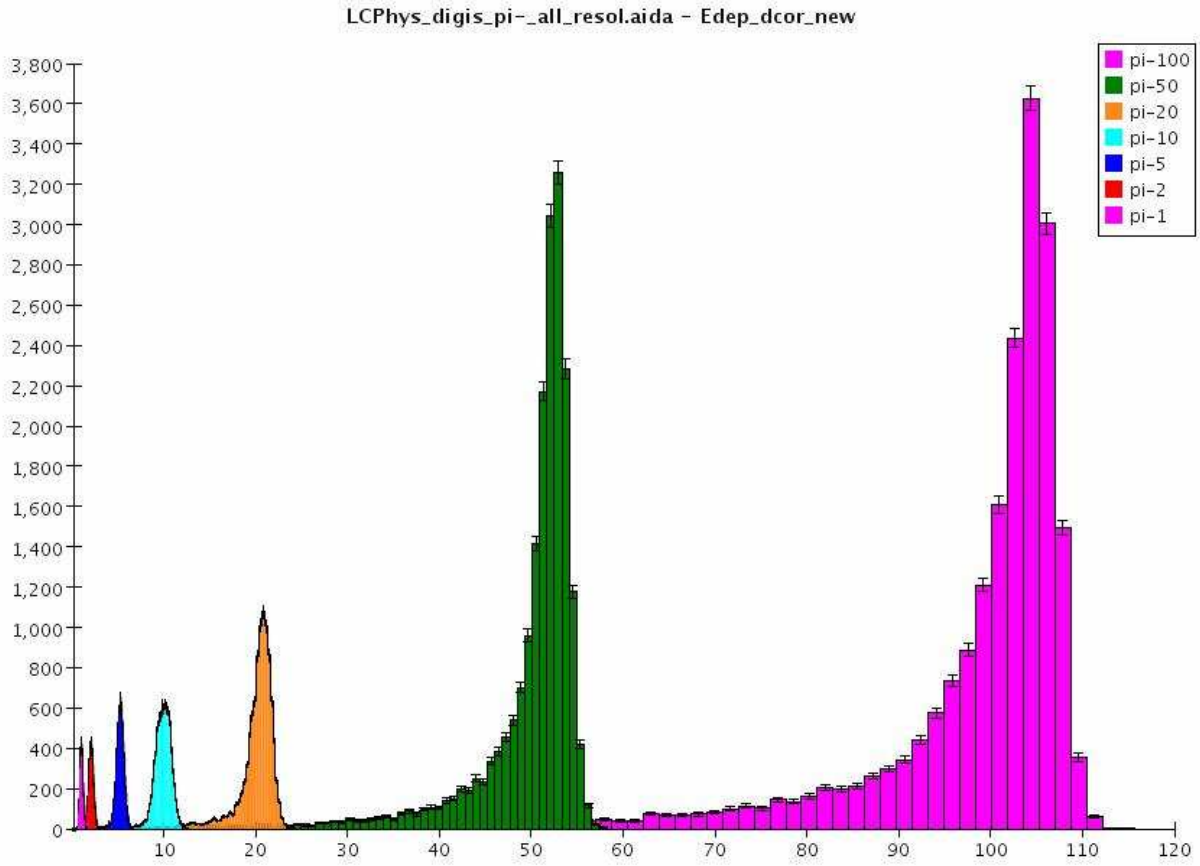


FIG. 4: BGO Dual Readout corrected $\pi^-$ energy, from Hans Wenzel

.

.

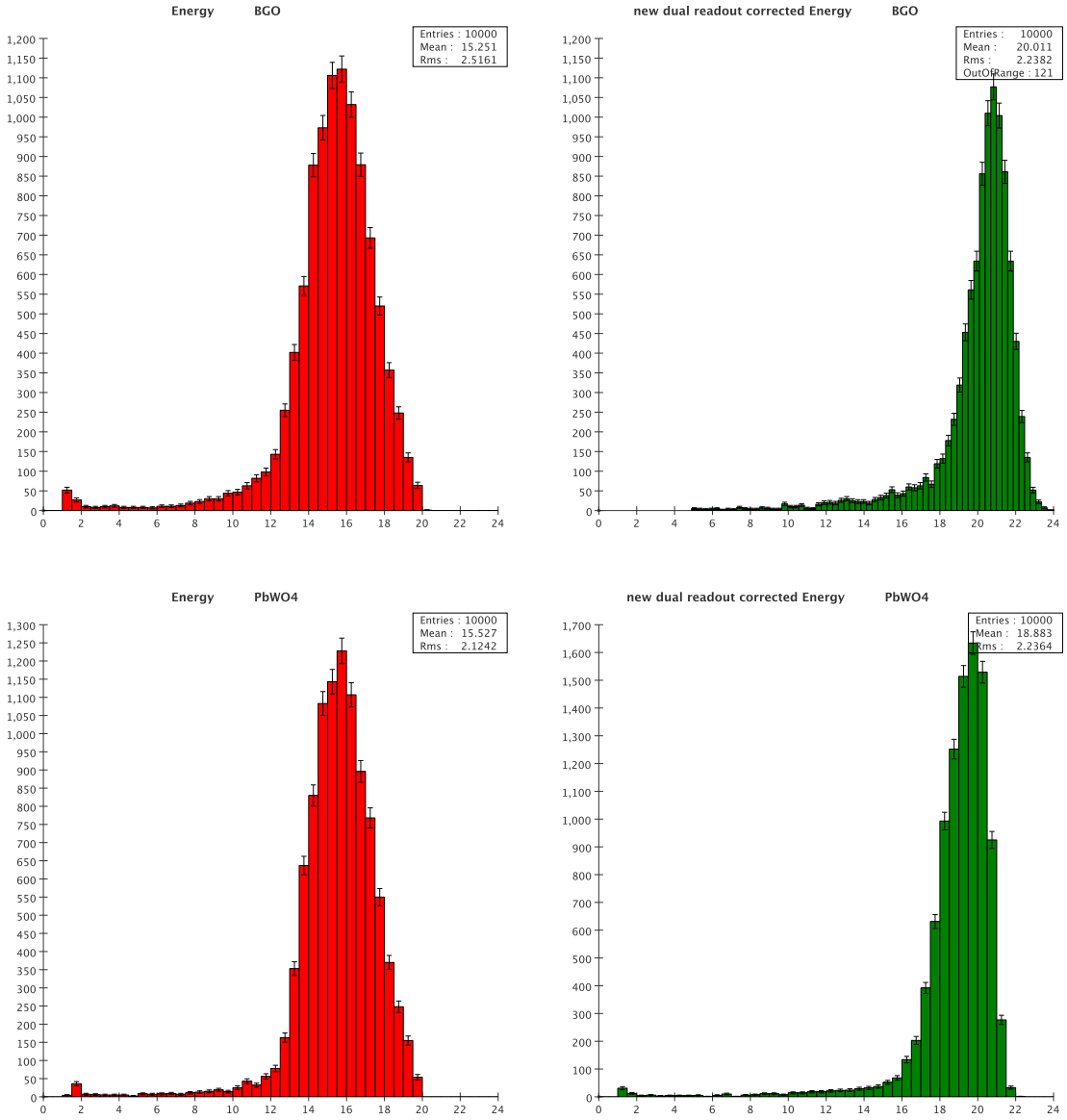


FIG. 5: Energy deposition and dual readout corrected energy for 20 GeV $\pi^-$ in BGO, PbWO4, D15

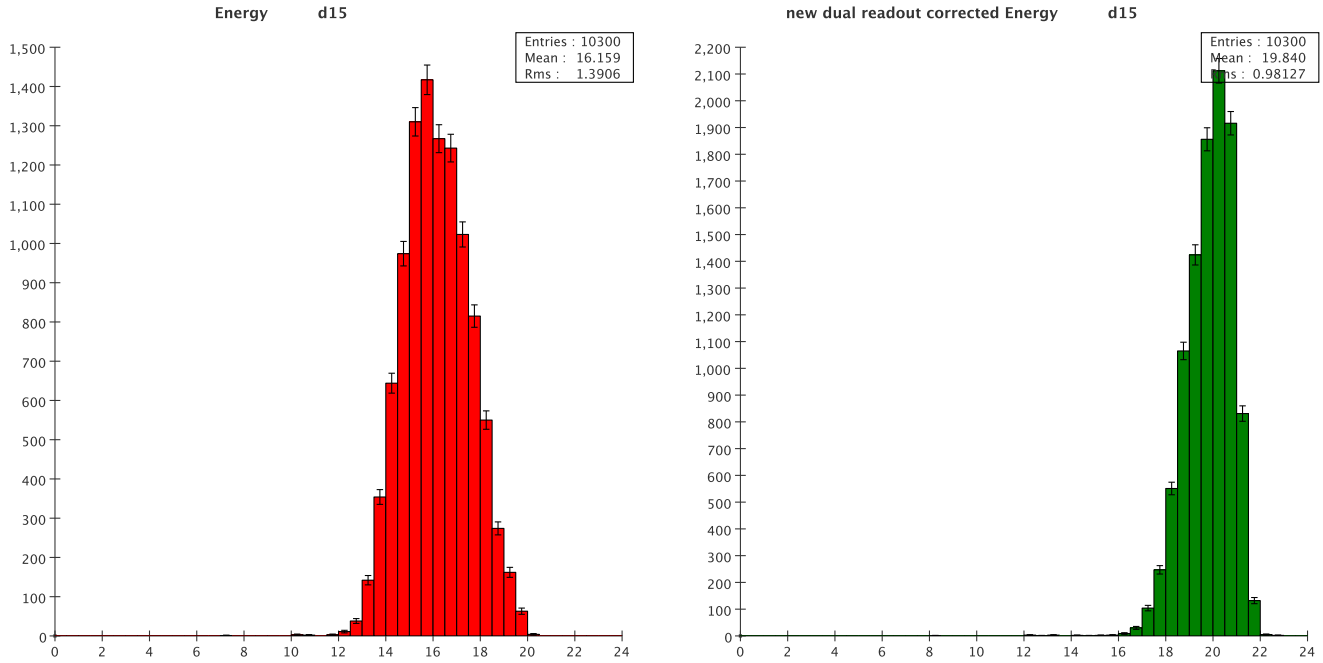


FIG. 6: Energy deposition and dual readout corrected energy for 20 GeV $\pi^-$ in BGO, PbWO4, D15

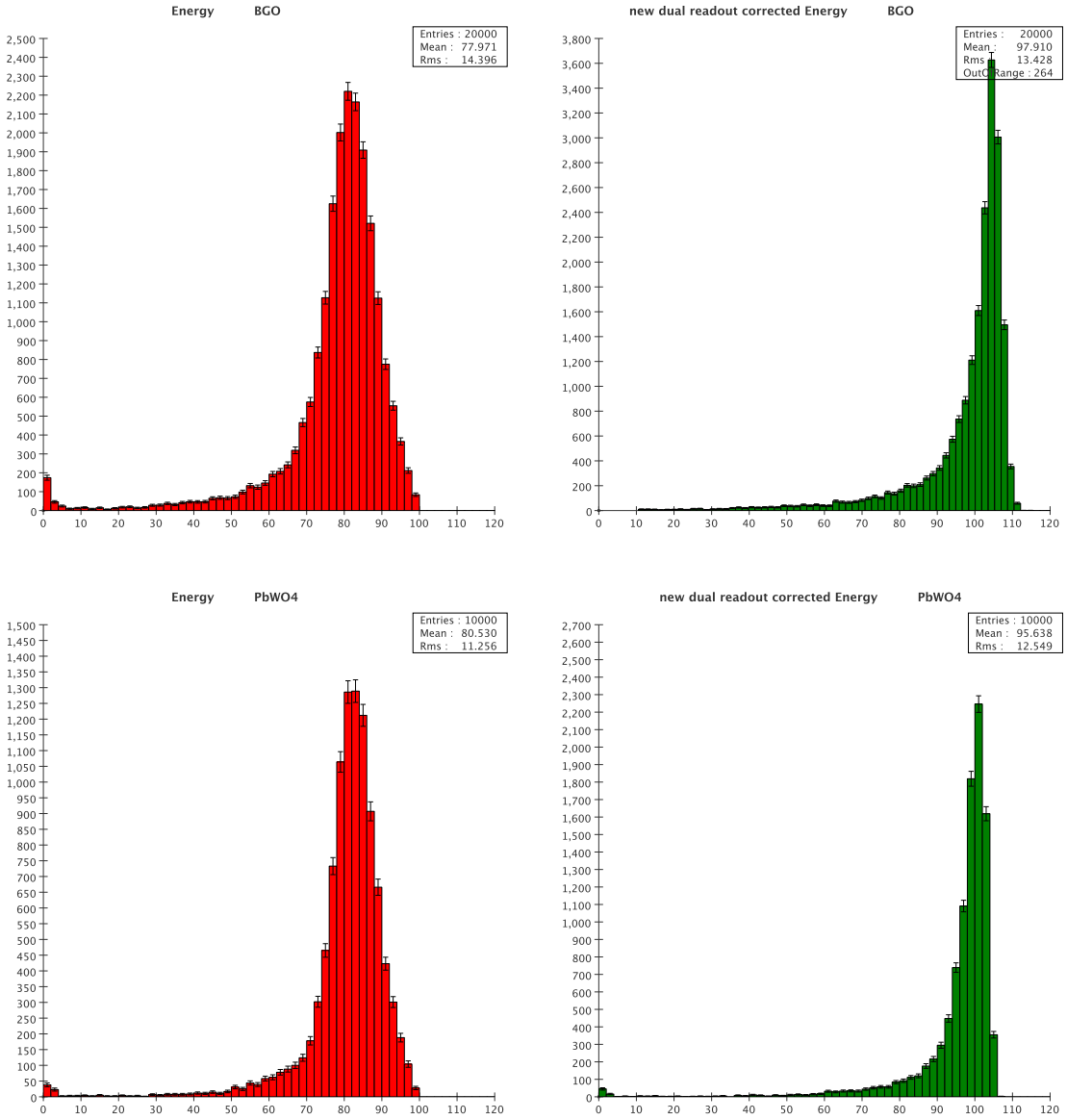


FIG. 7: Energy deposition and dual readout corrected energy for 100 GeV $\pi^-$ in BGO, PbWO4, d15

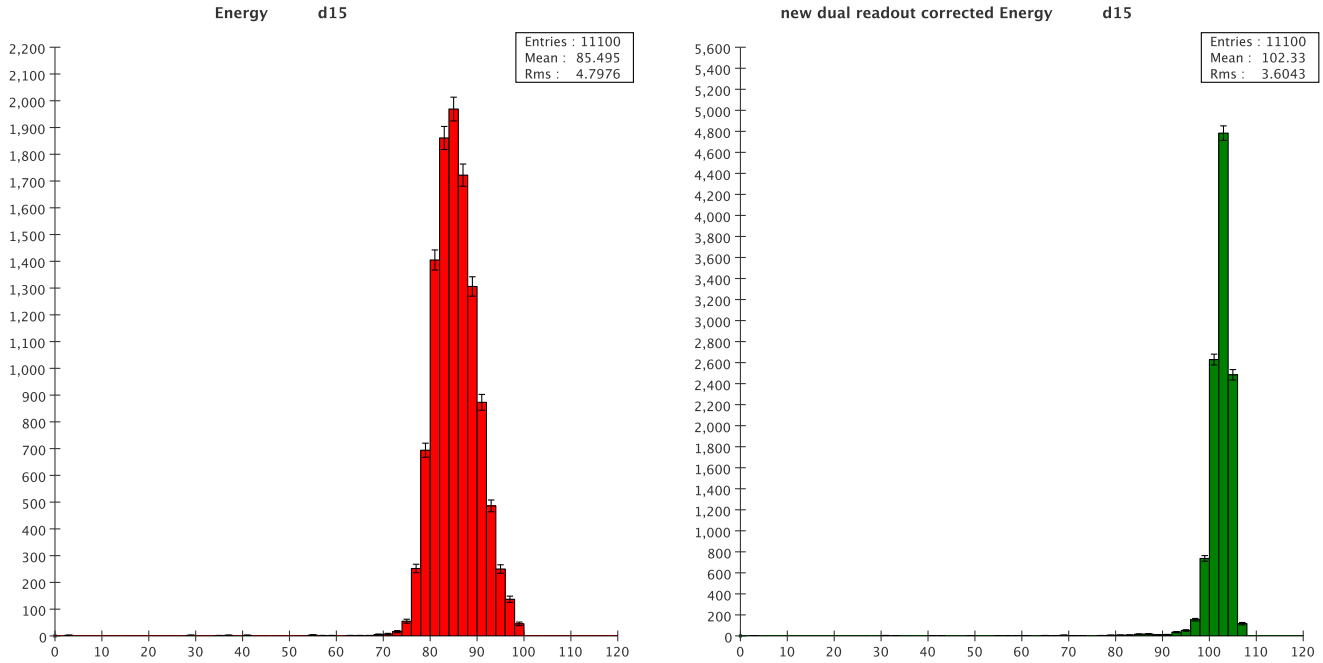


FIG. 8: Energy deposition and dual readout corrected energy for 100 GeV $\pi^-$ in BGO, PbWO4, d15

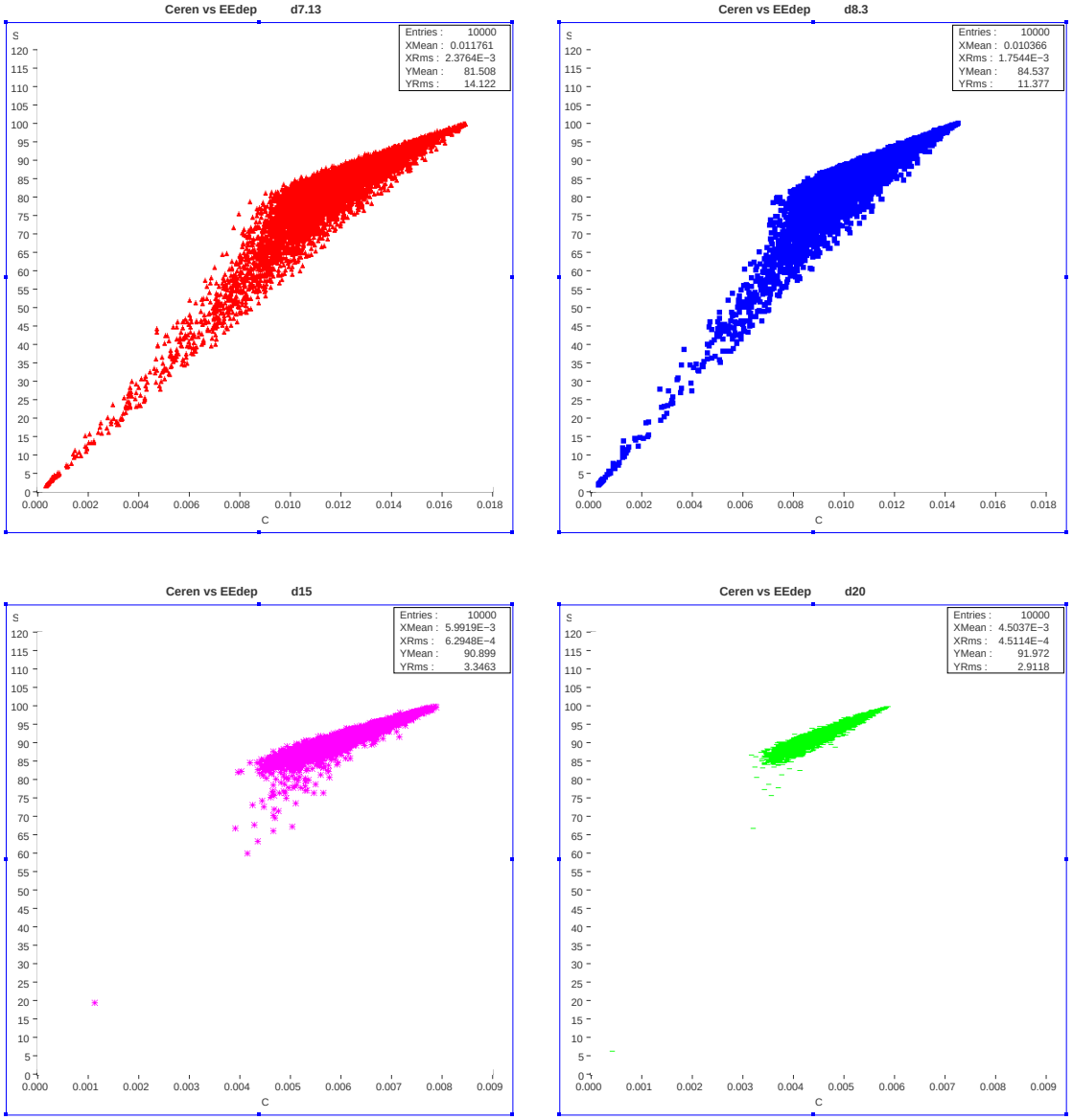


FIG. 9: S vs. C for 100 GeV $\pi^-$ in BGO, PbWO4, d15, d20

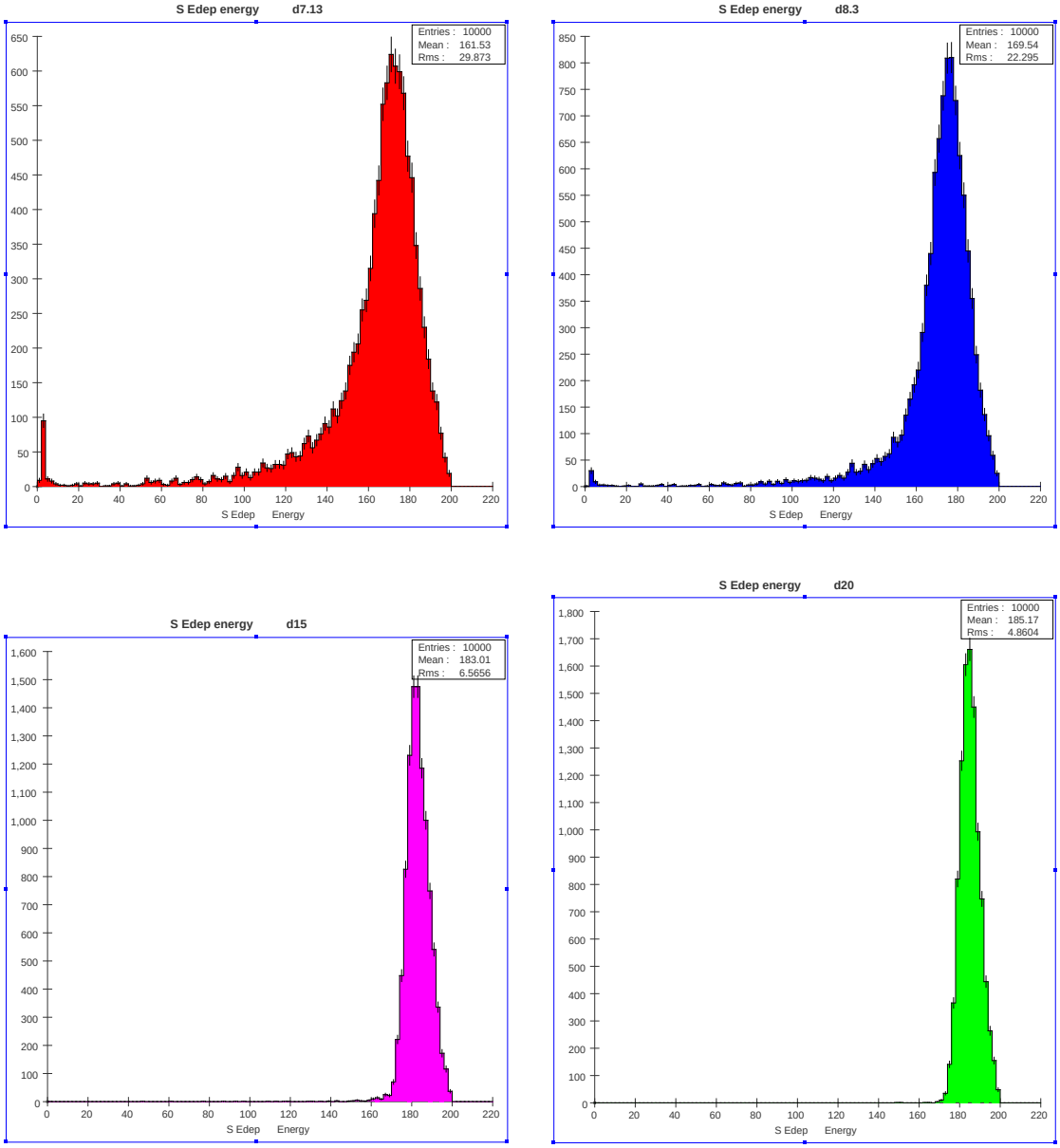


FIG. 10: 200 GeV $\pi^-$ energy deposition, Edep, in BGO, PbWO4, d15, d20

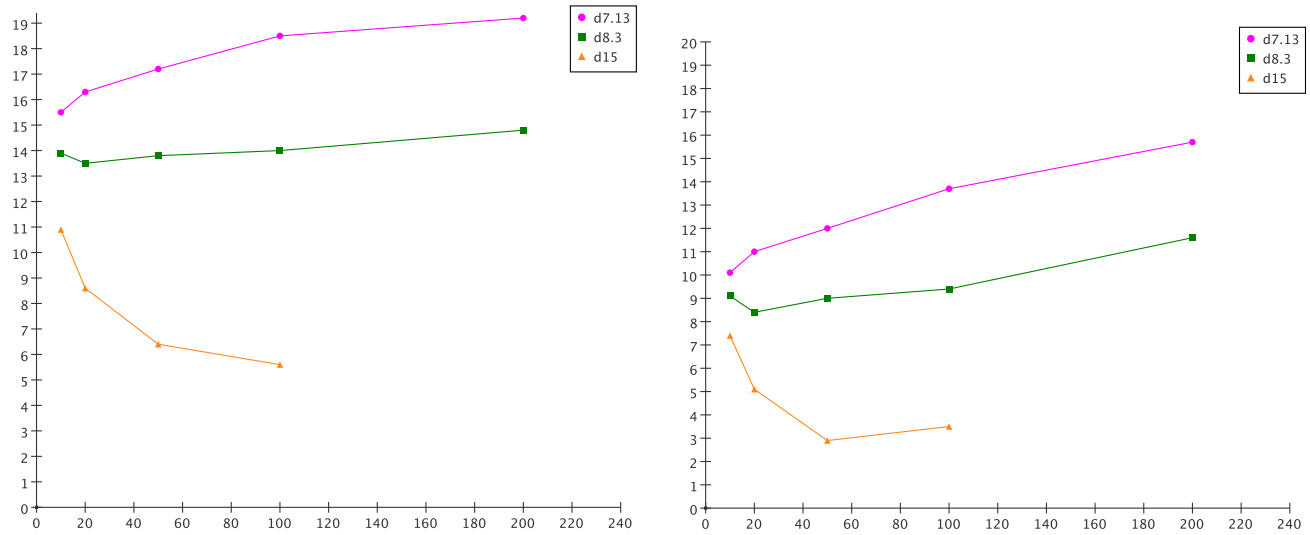


FIG. 11: rms/mean vs E (left) before and (right) after Dual Readout C/S Correction for crystal density = 7.13 BGO, 8.3 PbWO4, d15. (Table **??**)

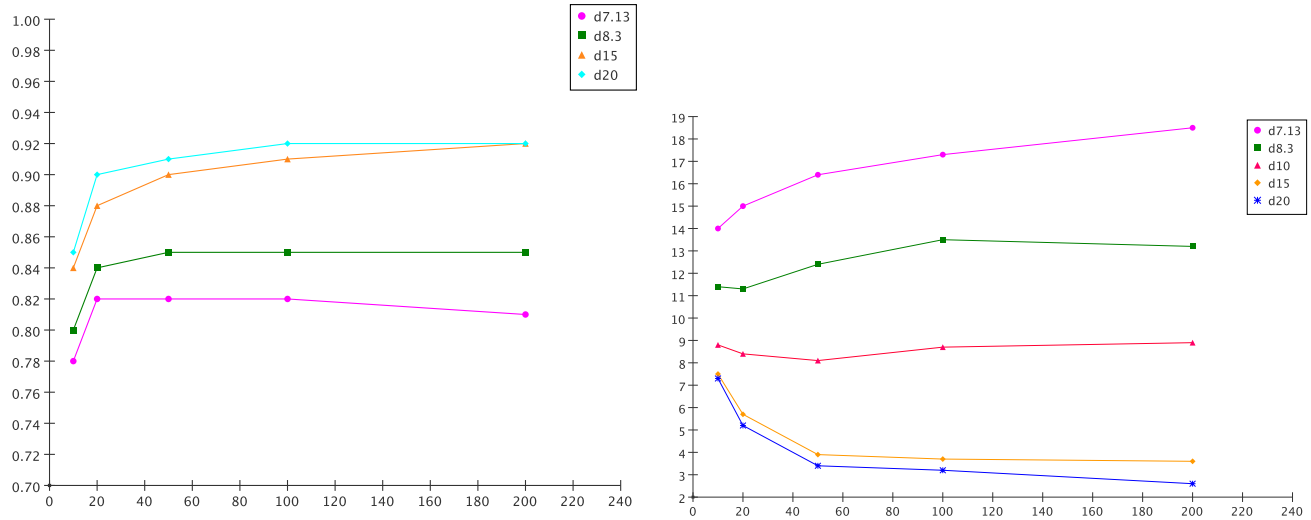


FIG. 12: S_Edep/E vs E, and rms/mean vs E for crystal density = 7.13, 8.3, 15, 20 for $\pi^-$ with 10, 20, 50, 100, 200 GeV. (Table **??**)

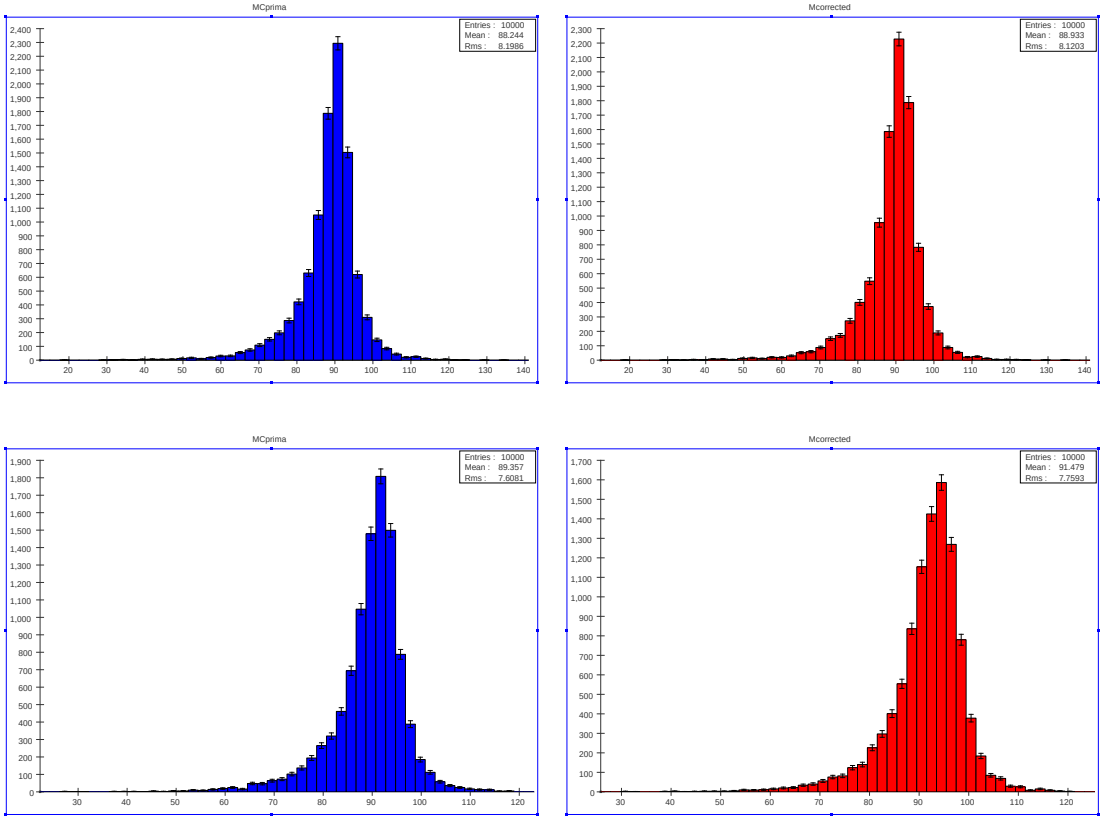


FIG. 13: Top: BGO Z 50 MCprima & Mcorrected; Bottom: BGO Z 100 MCprima & Mcorrected

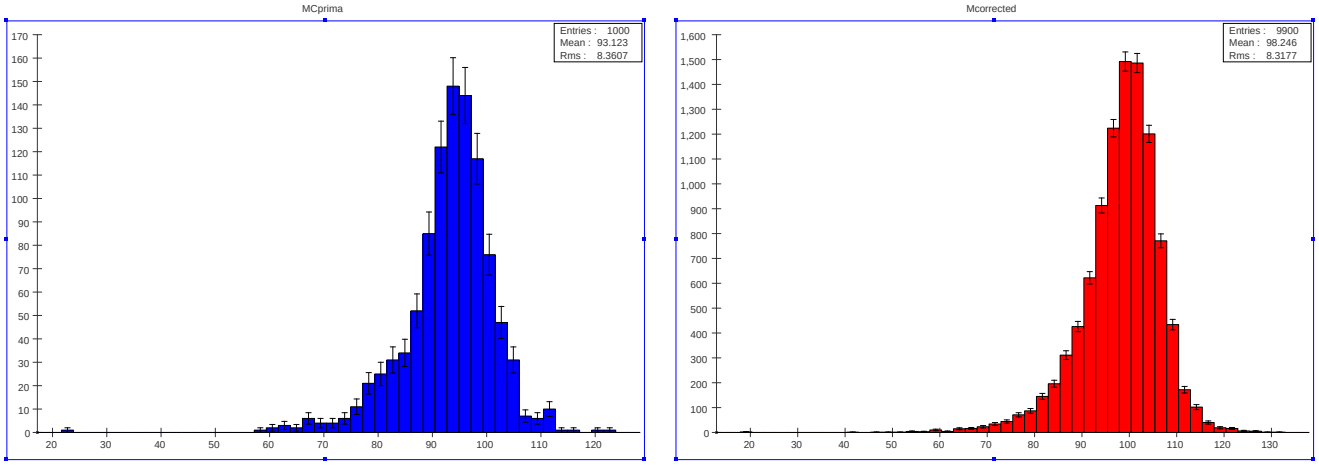


FIG. 14: BGO Z 200 MCprima & Mcorrected

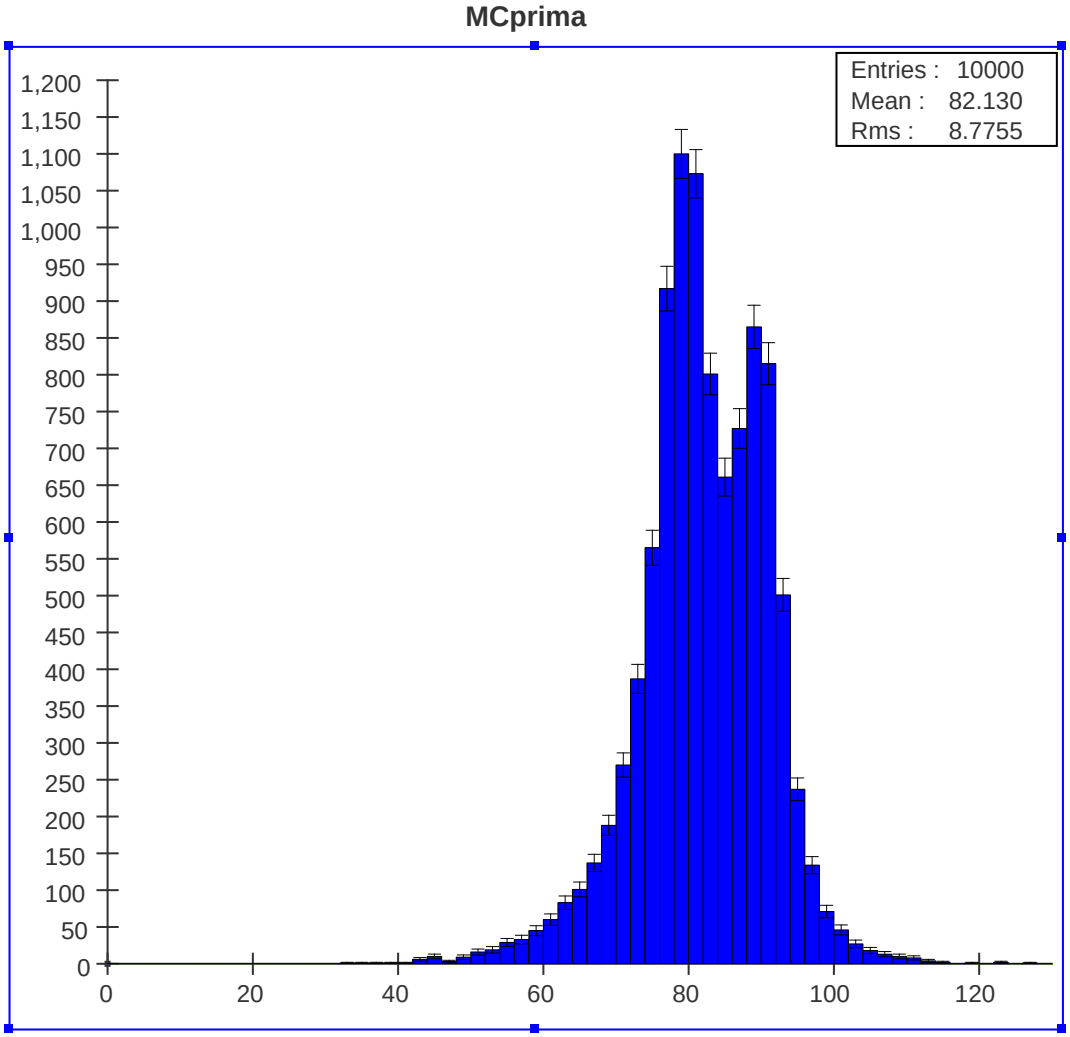


FIG. 15: Dual Readout reconstructed W and Z mass (without jet clustering), for 5,000 $W \rightarrow jets$ and 5,000 $Z \rightarrow jets$.

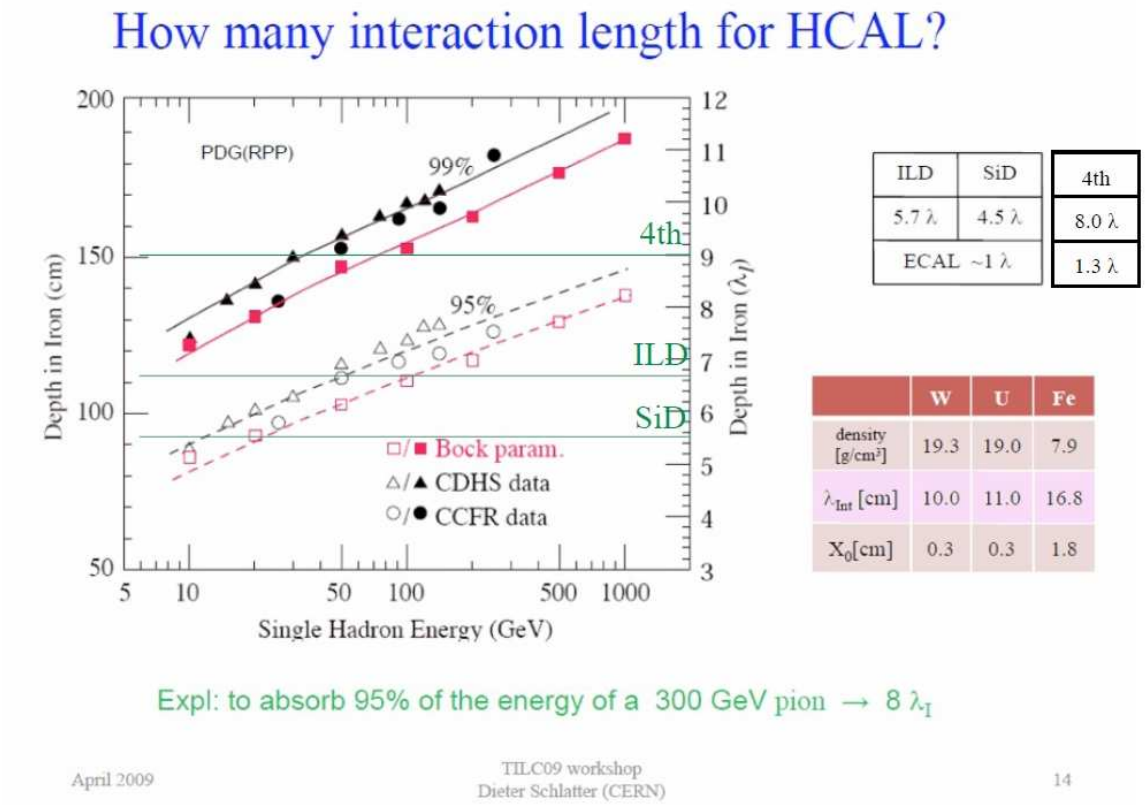


FIG. 16: Interaction Lengths for Hadron calorimeter[? ]

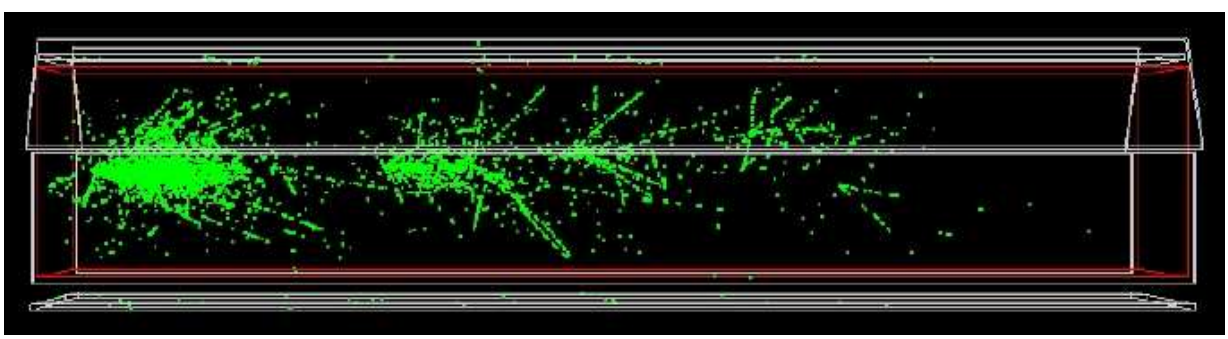

FIG. 17: Simulation of 100 GeV $\pi^-$ shower in the DREAM daul readout Calorimeter, which has 10 interaction lengths[? ]

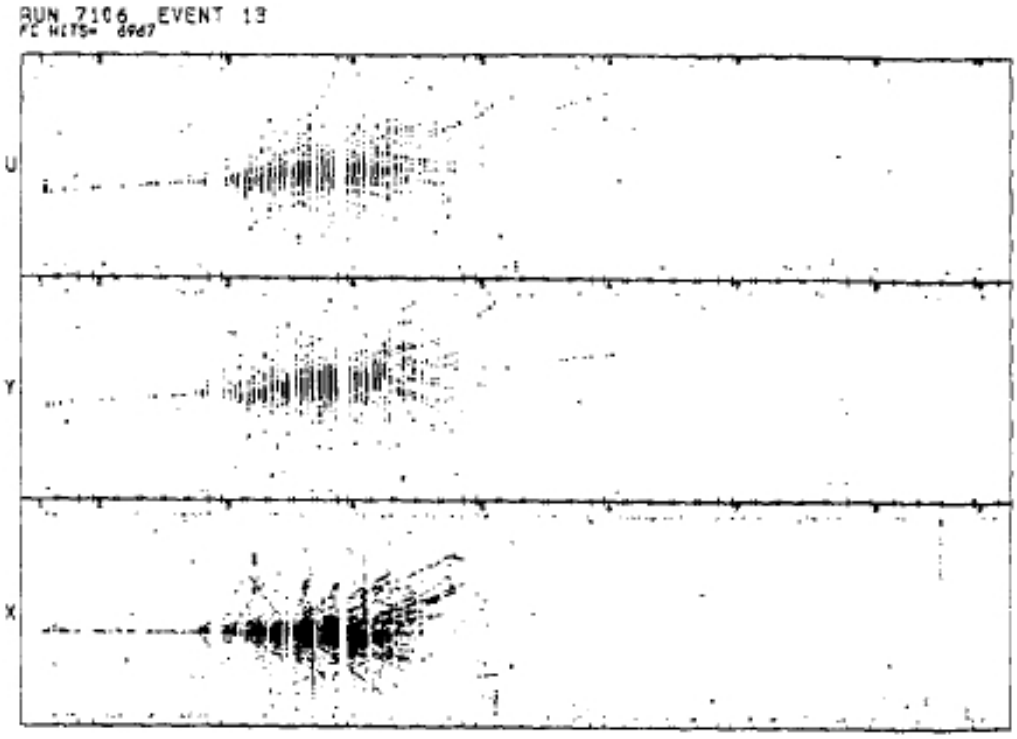


FIG. 18: 315 GeV Hadron shower in E594 calorimeter with 22 interaction lengths [? ]

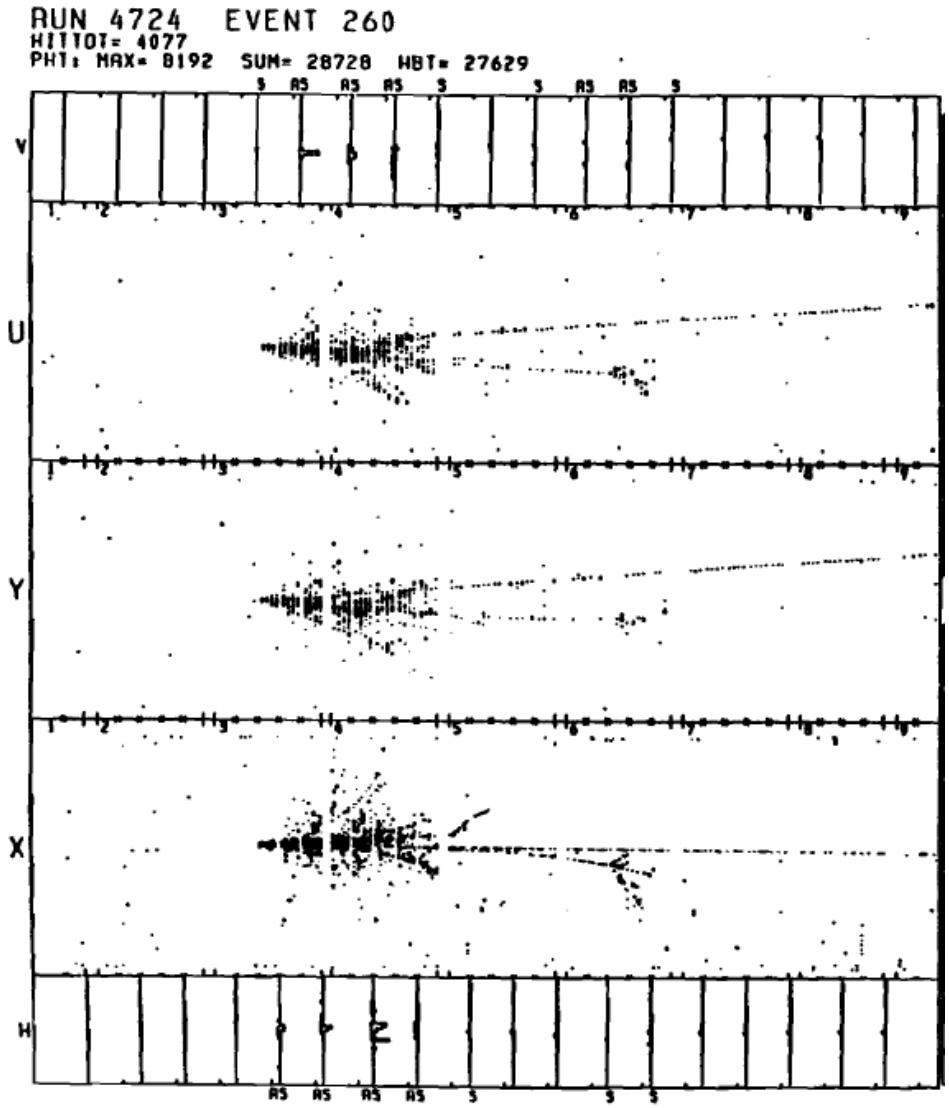


FIG. 19: Typical Hadron shower in E594 neutrino interaction.[? ] The calorimeter had 22 interaction lengths.

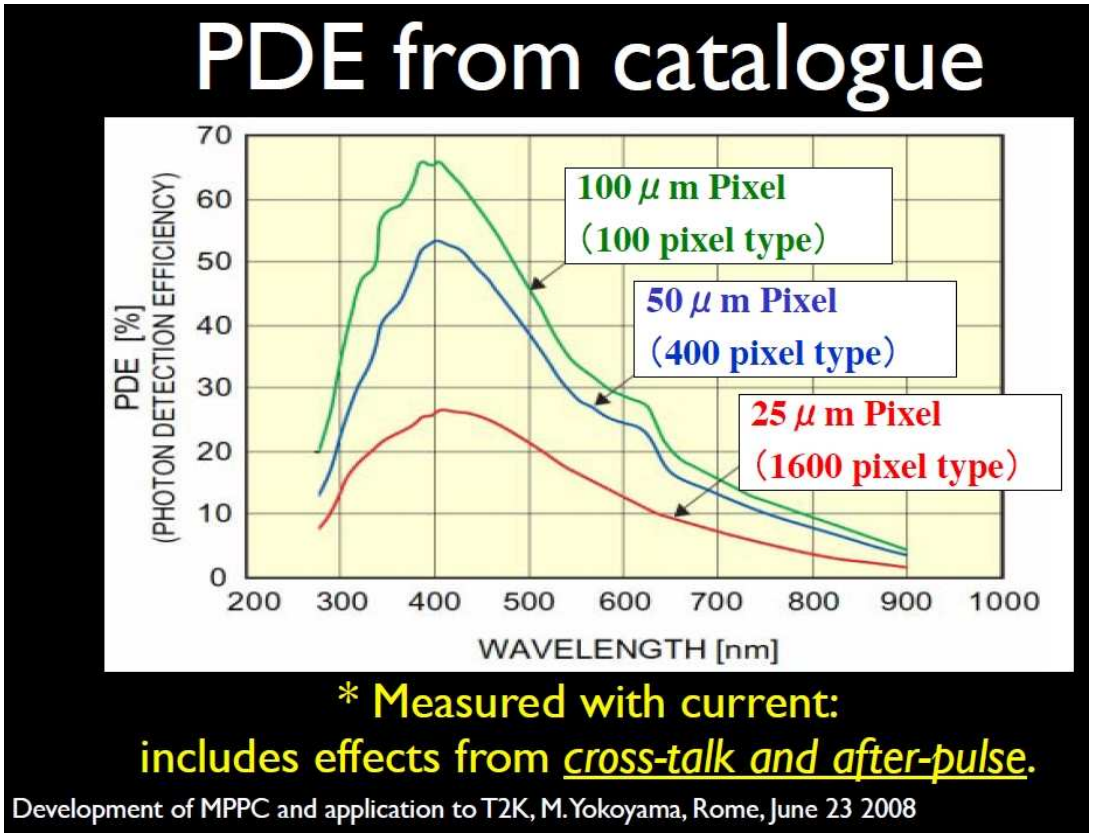


FIG. 20: Photon detection efficiency of MPPC/SiPM, including cross-talk and after-pulse (20-30% over-estimate).[**?** ]
Light yields of crystals, Photon detection efficiency, longitudinal segmentation, crystal support structure, and more realistic geometry should be implemented in the simulation.