Local energy correction in the CMS ECAL

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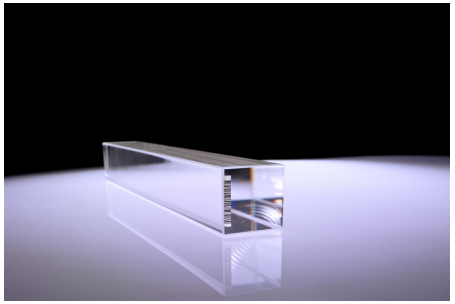
Introduction

The CMS electromagnetic calorimeter (ECAL) consists of approx. 75 000 scintillating crystals

The energy response is dependent on the position of impact on the crystal face. Effect quantified by looking at ratio of measured energy to momentum for electrons

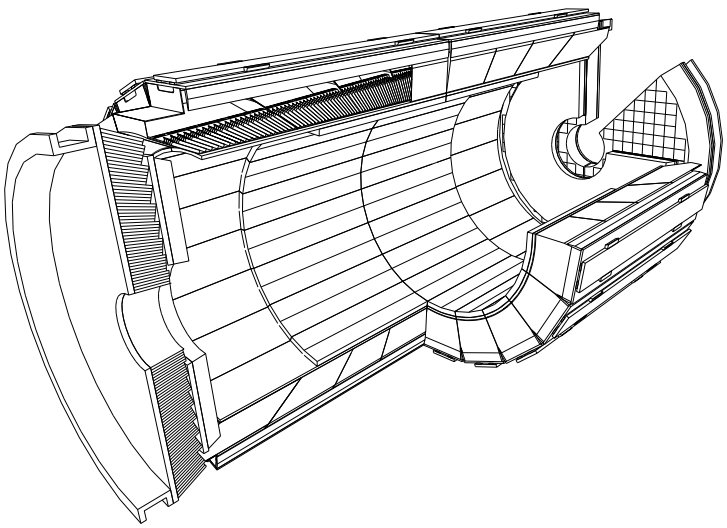


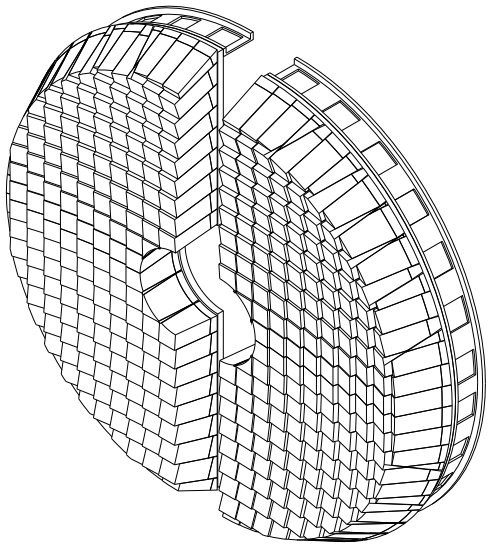
$PbWO_4$ crystal

Local E/p dependence studied using $W \to e\nu$ and $Z \to e^+e^-$ events from first half of 2012 (corresp. to 5 fb^{-1})

- Wish to make a data-driven correction algorithm to compensate for local crystal effects
- Test the effect of the correction on the resolution of Z peak

ECAL geometry





Local position of incident e/γ defined as the difference between the calculated EM shower position, and the crystal center position

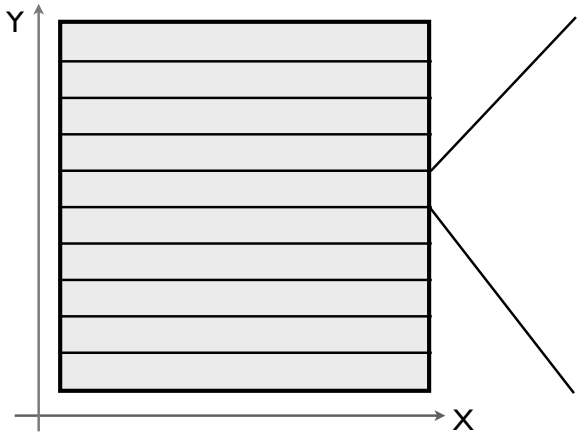
$(\mathrm{X_{local}}, \mathrm{Y_{local}}) = (0, 0)$ corresponds to a hit in the center of the crystal,
$(\mathrm{X_{local}}, \mathrm{Y_{local}}) = (\pm 0.5, \pm 0.5)$ corresponds to the corners

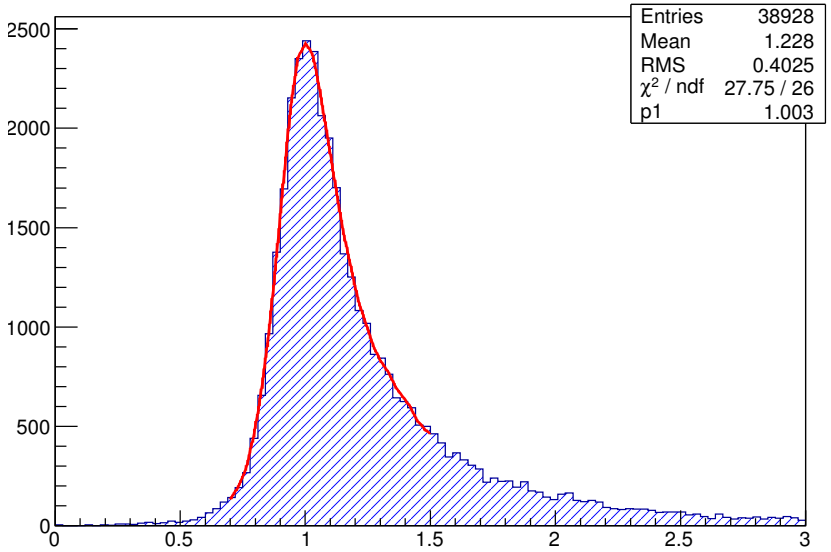
E/p distribution

Template method

Divide crystal in bins along local coordinate, fit E/p distribution
Compare each bin to template distribution for entire crystal, to extract relative energy scale factor

For the endcaps:
Template distributions built using electrons in $1.56 < |\eta| < 2.50$, use 4 templates to account for E/p shape changes vs η

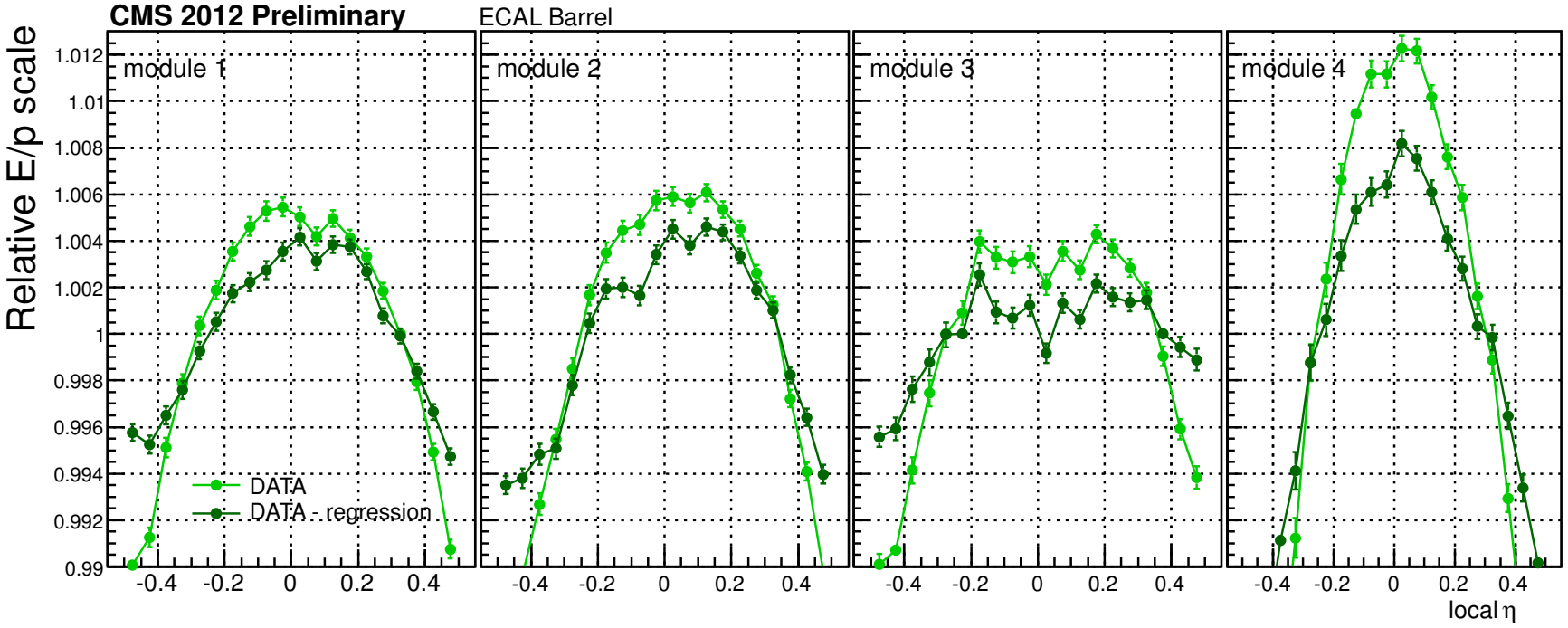




E/p distribution

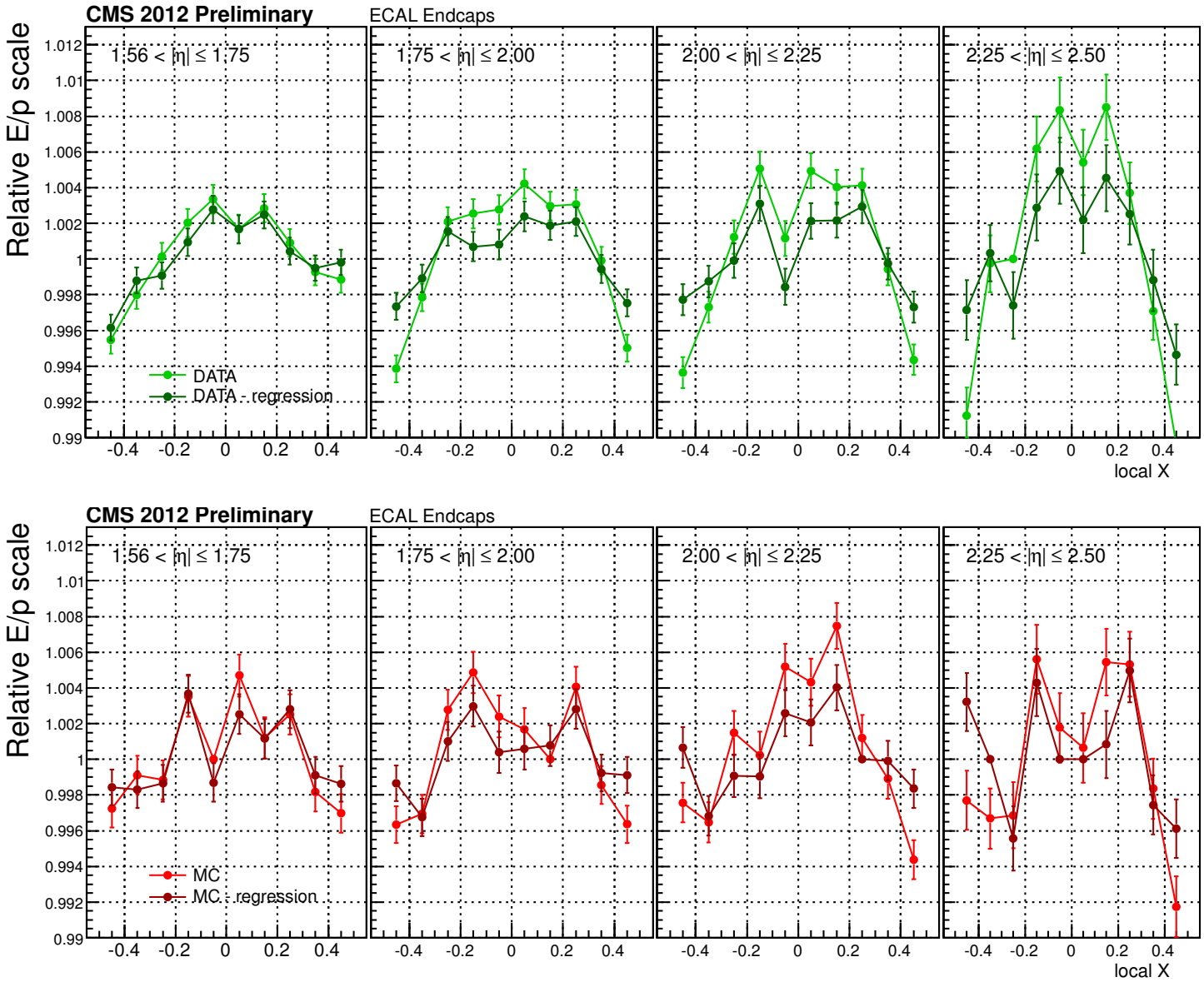
Barrel - local η

How things look in the barrel...
Dark colors are after regression corrections



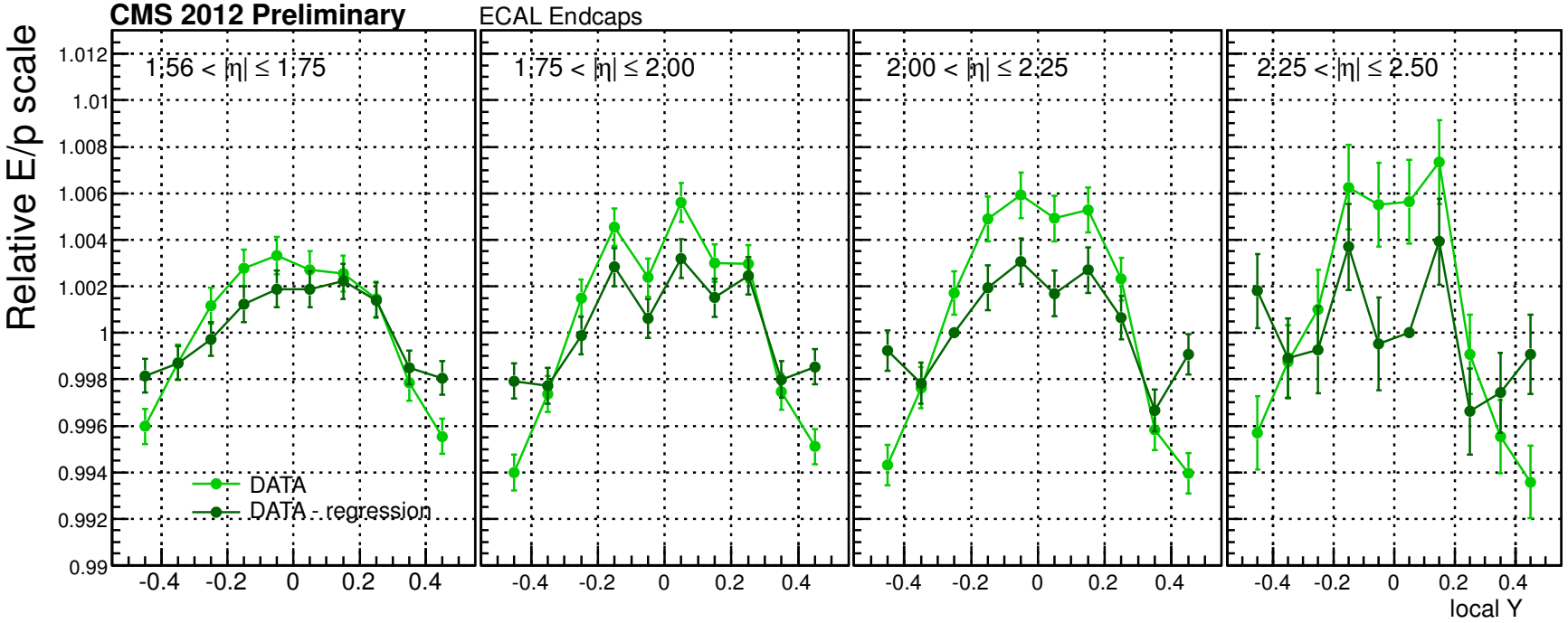
E/p distribution

Endcap - local X coordinate



E/p distribution

Endcap - local Y coordinate



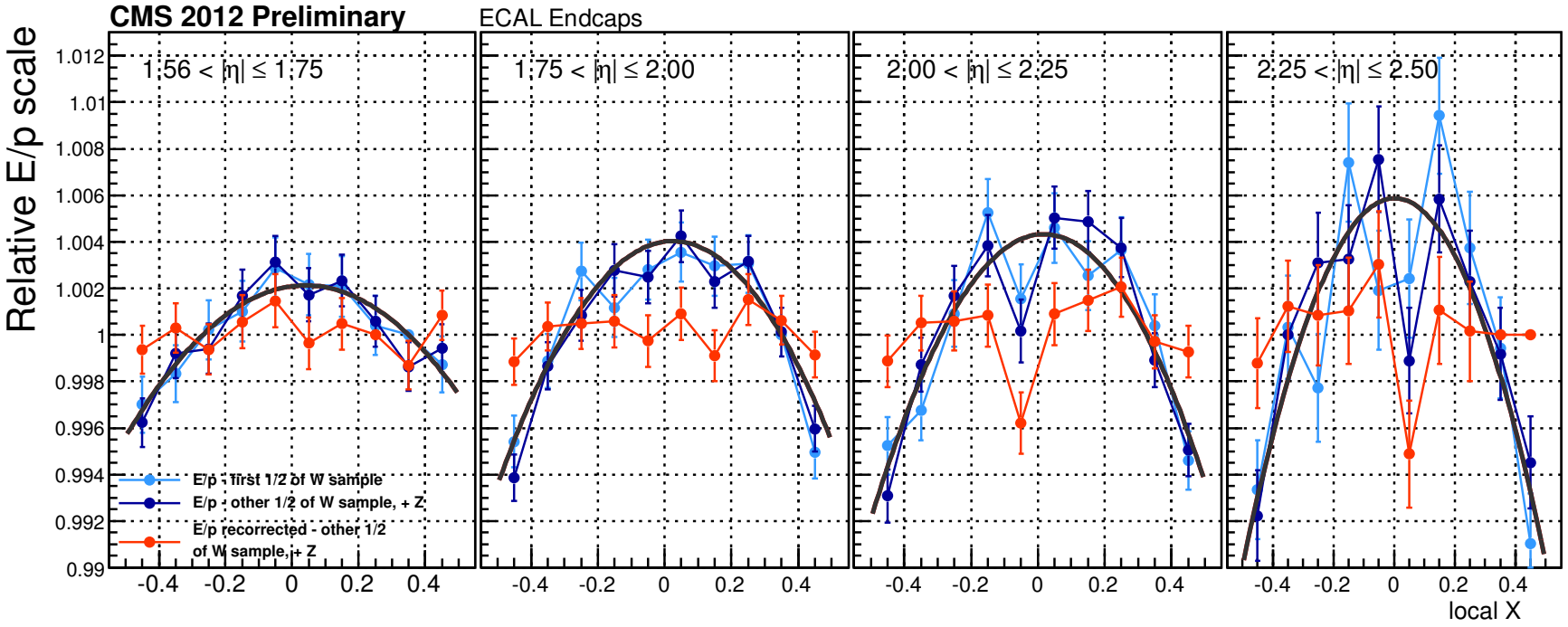
Have $\sim 1\%$ dependence on the local coordinate in EE, compared to $1-3\%$ in EB

Regression does not fully compensate for the local coordinate dependence seen in data

E/p distribution

Data-driven correction

- Parametrize E/p distribution with a 2nd order polynomial
- Apply energy correction to a separate dataset



Half of W $\rightarrow$ eν sample used to parametrize local dependence, parametrization then used to correct energy response of other half, plus Z $\rightarrow$ e^+e^- events

Z peak

$Z \to e^+e^-$ inv. mass fitted with Breit-Wigner $\otimes$ Crystal Ball lineshape

- Parameters of BW lineshape fixed to PDG values
- α, n of CB lineshape constrained from fitting to MC

FWHM of the instrumental contribution to the visible lineshape calculated using the Oliviero-Longbothan[1] approach:

$$\mathrm{FWHM_{visible}} = \mathrm{A} \times \mathrm{FWHM_{BW}} + (\mathrm{B} \times \mathrm{FWHM_{BW}^2} + \mathrm{FWHM_{instr}^2})^{1/2}$$

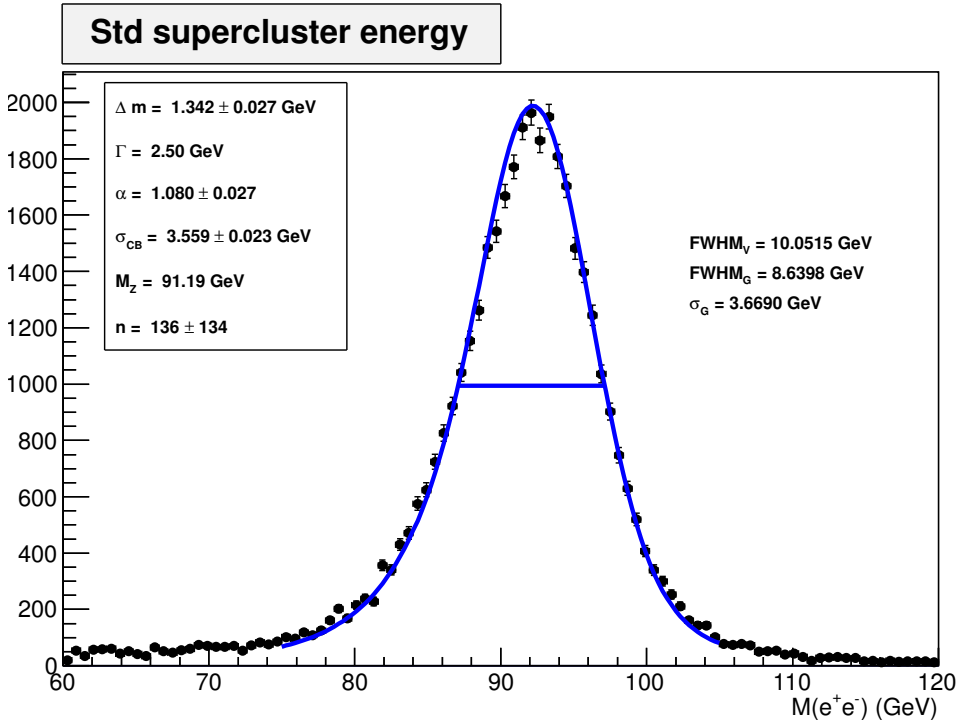
with A = 0.5346, B = 0.2166

[1] J.J. Olivero, R.L. Longbothan, "Empirical Fits to Voigt line width: a brief review", Jour. Quantitative Spectroscopy and Radiative Transfer, 17 (2) 233, 1977

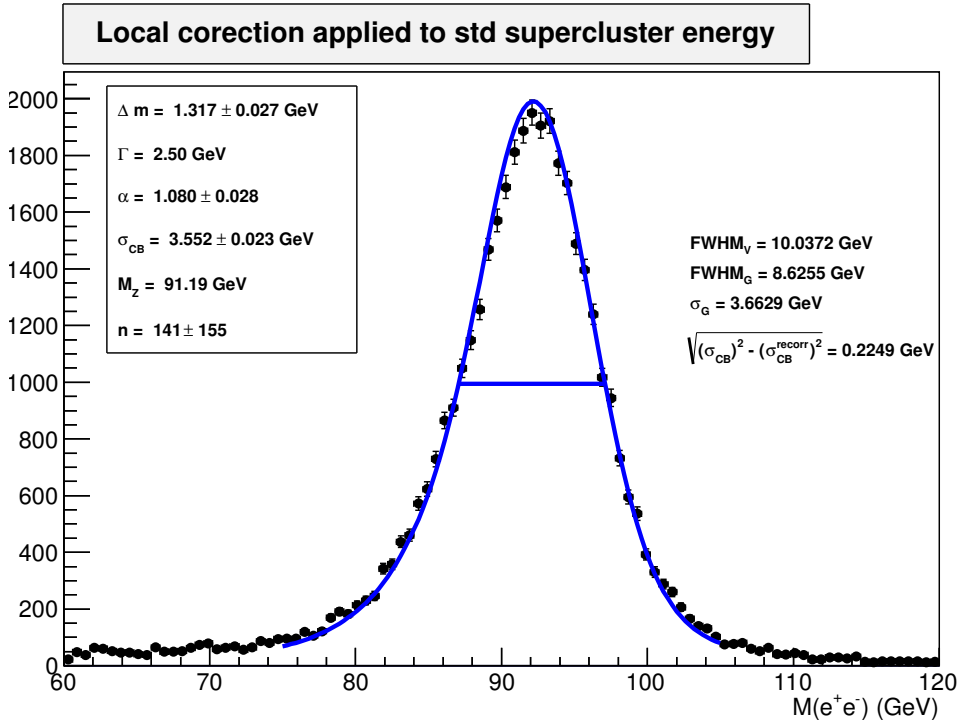
Z peak

Resolution improvement

Correction applied to supercluster energy, in this case corrected in local X only



(a) Before correction

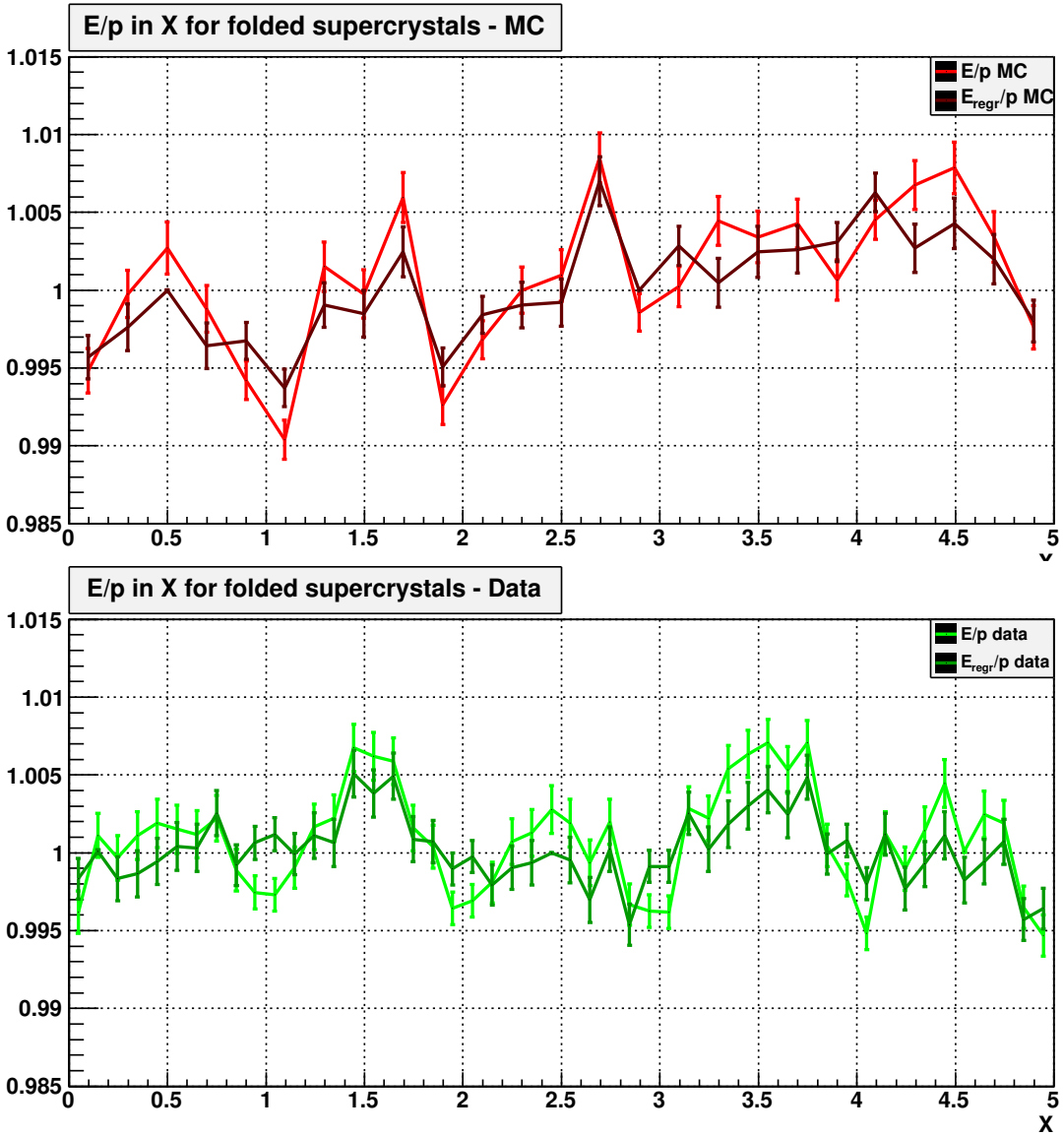


(b) After correction

Small improvement in resolution: $\sim$ 0.2 GeV in quadrature

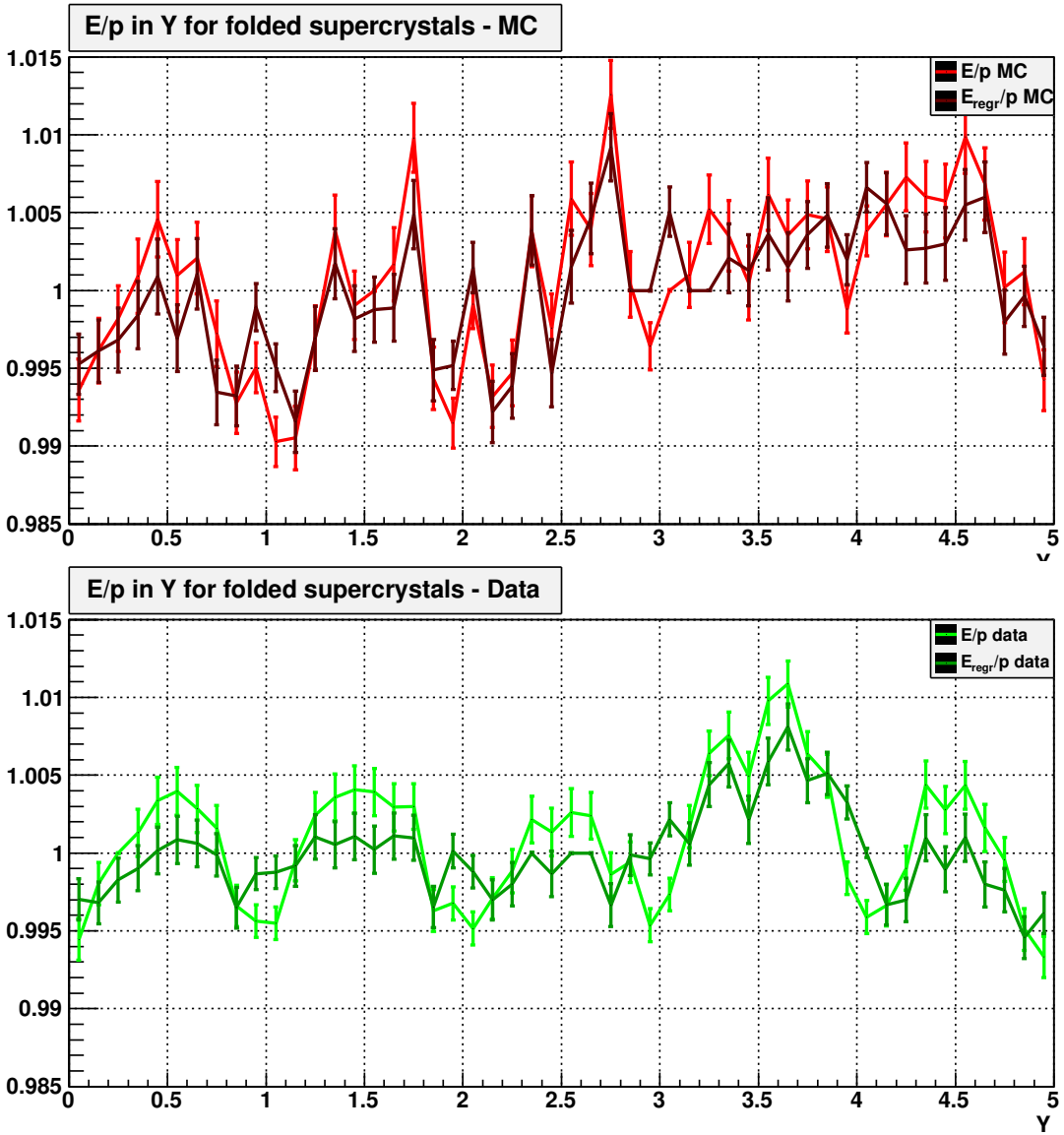
E/p distribution in supercrystals

Do same study, but for 5×5 matrix of crystals (supercrystal)



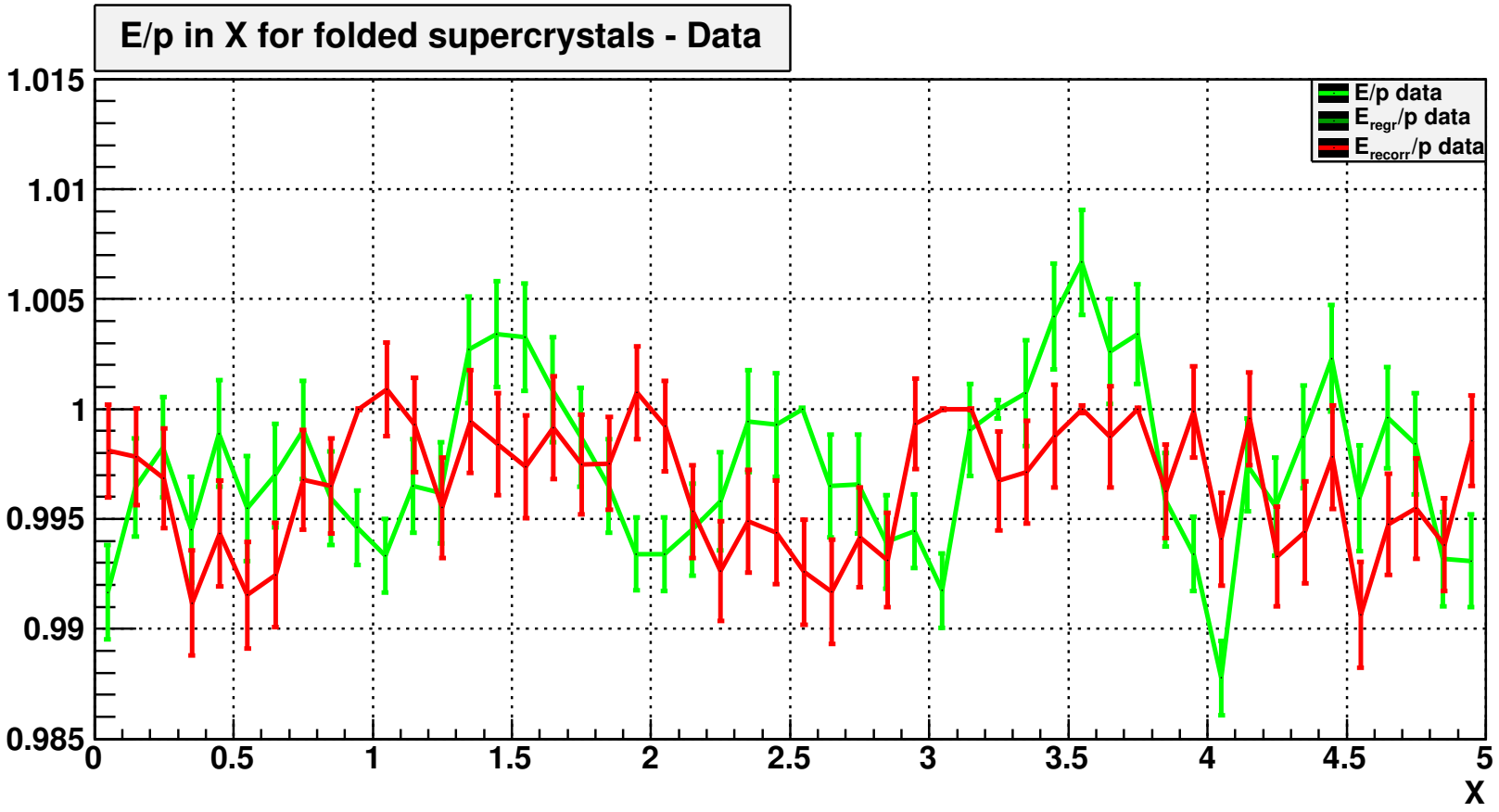
E/p distribution in supercrystals

In local Y coordinate:



E/p distribution in supercrystals

Apply local, single-crystal correction
Use half of W $\rightarrow$ eν sample to make parametrization, apply correction to other half of W events, plus Z $\rightarrow$ e^+e^- events



Conclusion

- Studied local containment in EE using $W \to e\nu$, $Z \to e^+e^-$ events
- Dependence on the local coordinates is at $\sim 1\%$ level. Correcting along one coordinate in EE yields a resolution improvement of 0.2 GeV