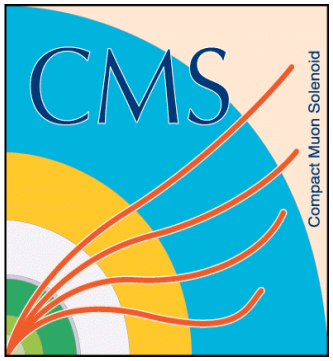


Performance Study of the CMS Ecal Electronics using electrons from 15 GeV to 250 GeV

Stefano Argirò
University of Torino and INFN

On behalf of the CMS ECAL group

TWEPP - Prague - 3,7 September 2007

Test Beam Scope

8 (of 36) Ecal Barrel Supermodules exposed to the H4 beam in 2006 in their final configuration

Electron Energy range : 15 - 250 GeV

Goals : Performance studies
Intercalibration

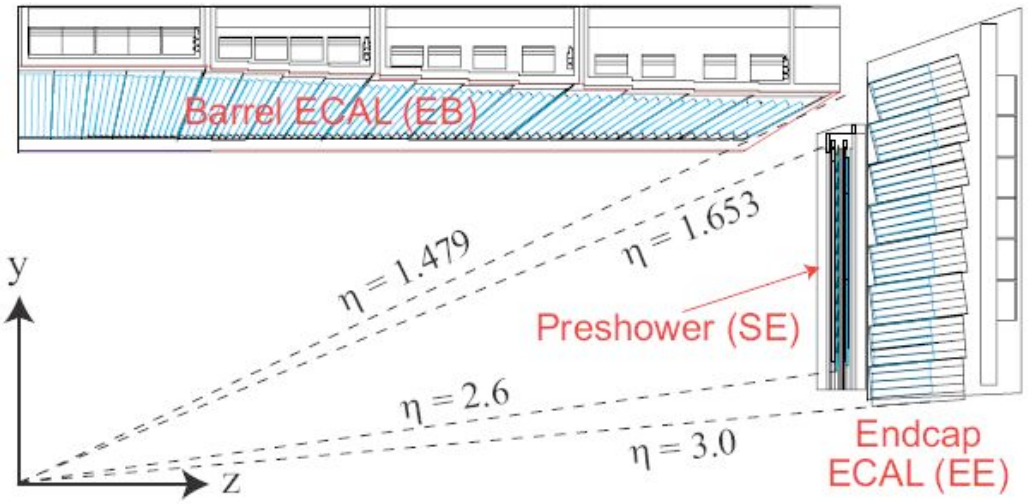
Performance studies:

- Shower containment
- Position Resolution
- **Response Linearity**
- **Energy Resolution**
- **Noise**

Other tests:

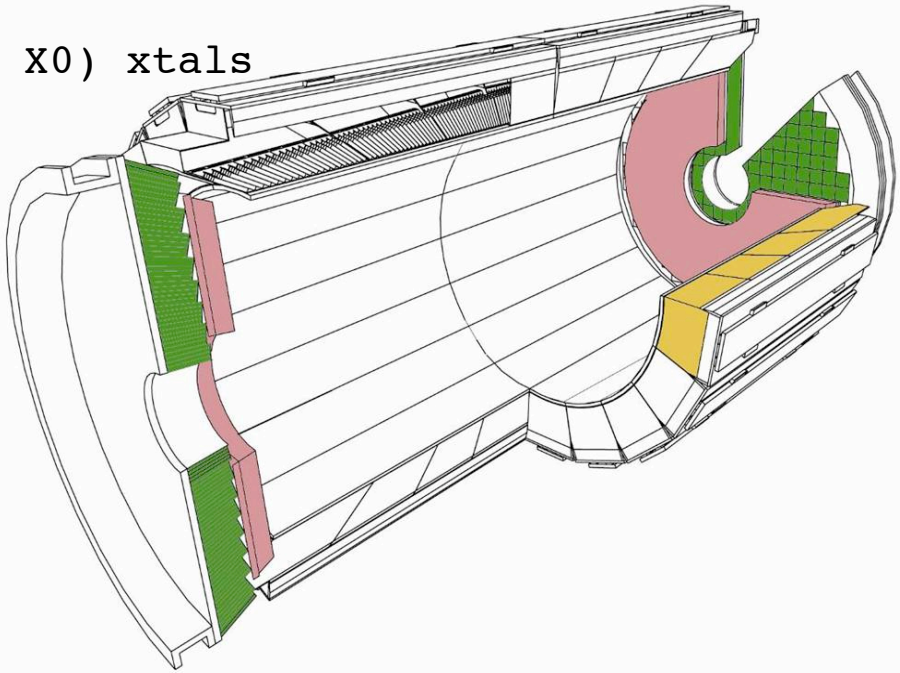
H2 testbeam:
e^{+-} 1-10 GeV
Pions
Cosmic testbed

Ecal Description



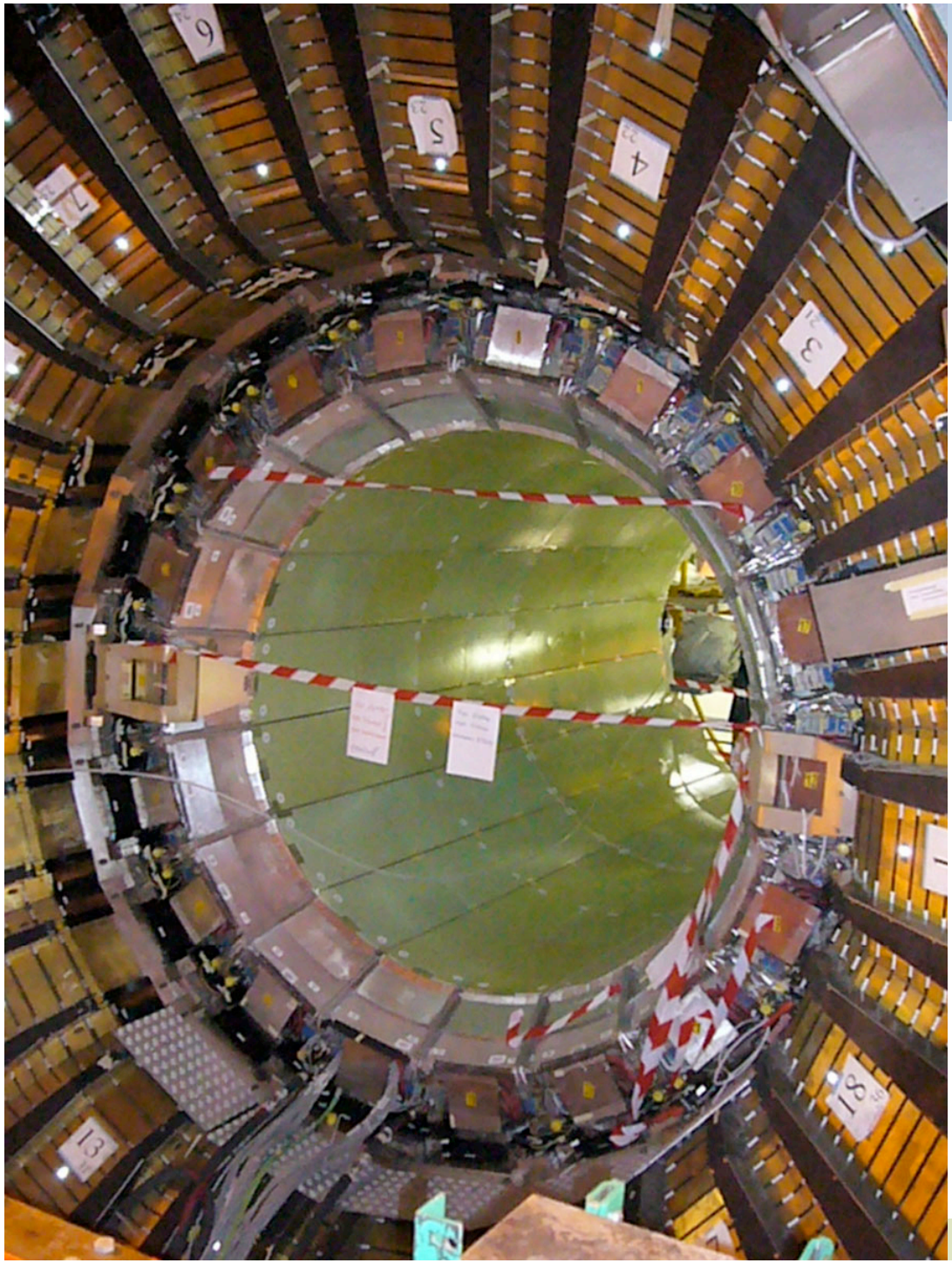
EB

61200 PbWO4 (fast, rad tolerant, low X0) xtals
36 super-modules (1700 xtals each).
25 X0 depth
Quasi projective geometry
(tilt = 3°)
APD photoconverters



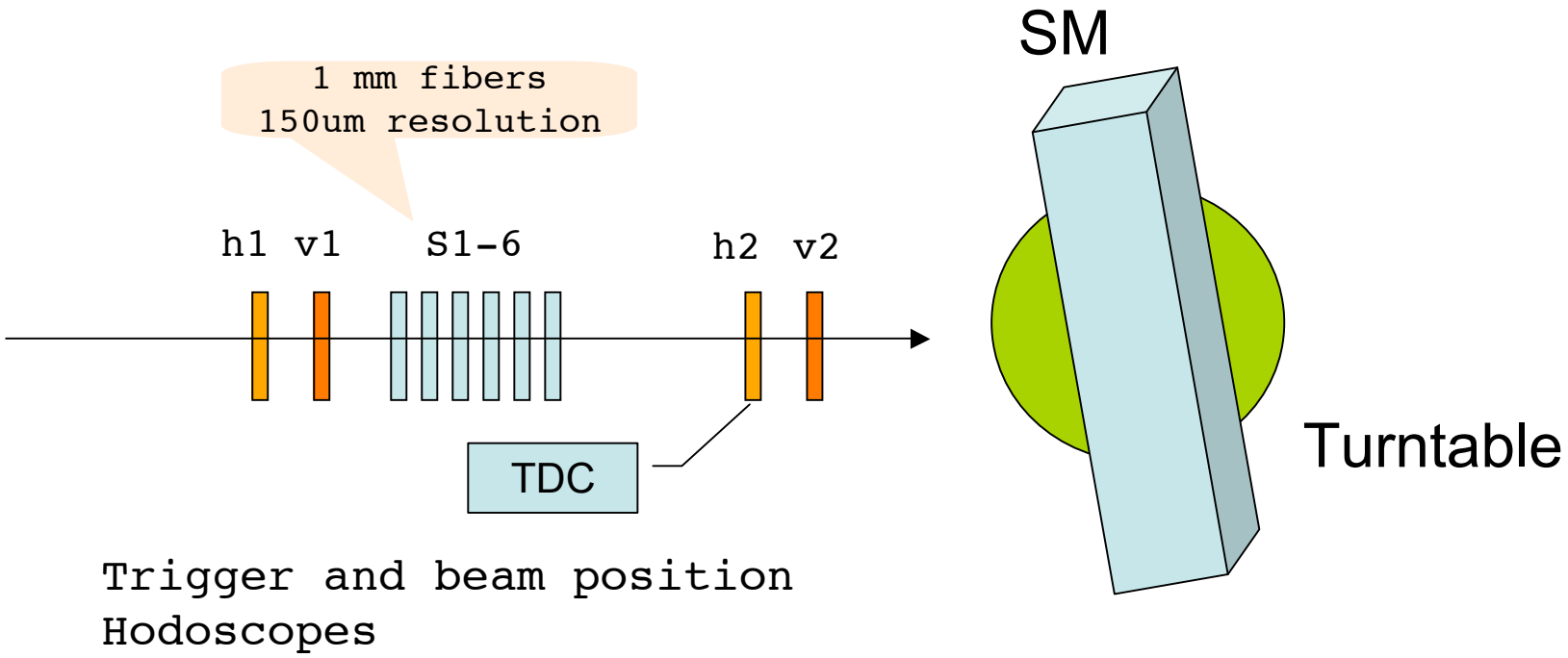
EE

2x 7324 PbWO4 xtals in 4 "dees"
VPT photoconverters



The ECAL barrel installed
Inside the HCAL on
July 27th, 2007

Test Beam Setup



H4 extracted SPS beam line (secondary/tertiary electrons)

8 supermodules exposed for intercalibration

On **2** supermodules additional studies performed

~70 days, ~6300 runs, ~ 2 billions electrons

Design Performance

Excellent energy resolution needed to discover a potentially narrow Higgs

Barrel design energy resolution (low luminosity)
In 5x5

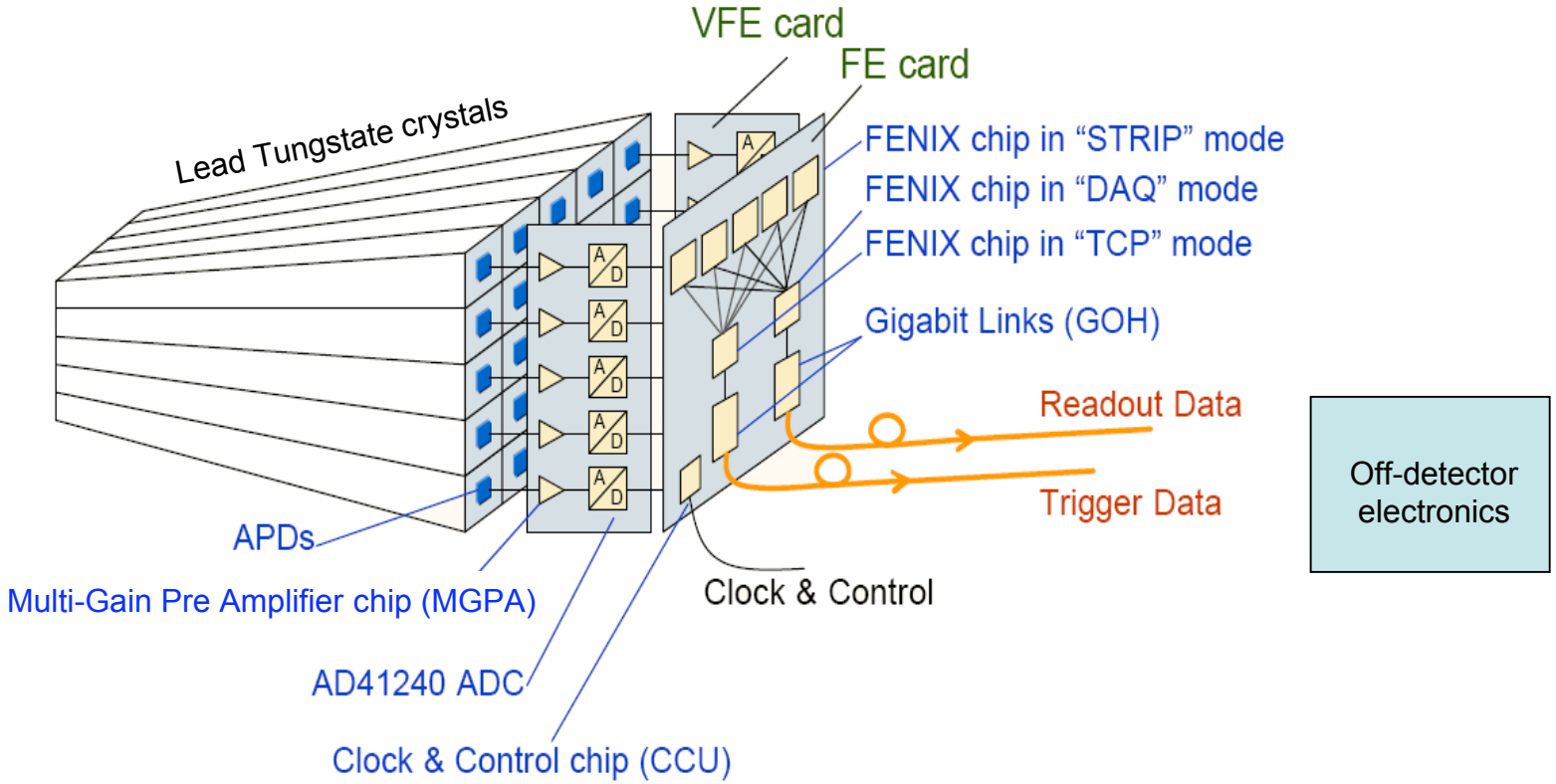
$$\frac{\sigma}{E} = \frac{2.7\%}{\sqrt{E}} \oplus 0.5\% \oplus \frac{150\,MeV}{E}$$

Stochastic
photostatistics
shower containment

Constant
Intercalibration
Non uniformity

Electronics (noise)

Electronics (short) Description



25 xtals form the "***trigger tower***"

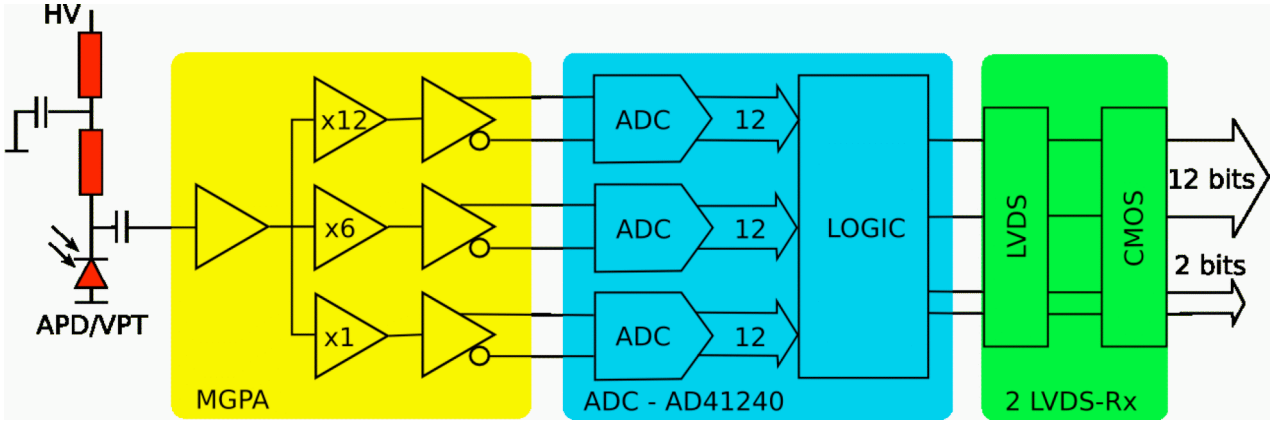
VFE: amplification, shaping, digitization

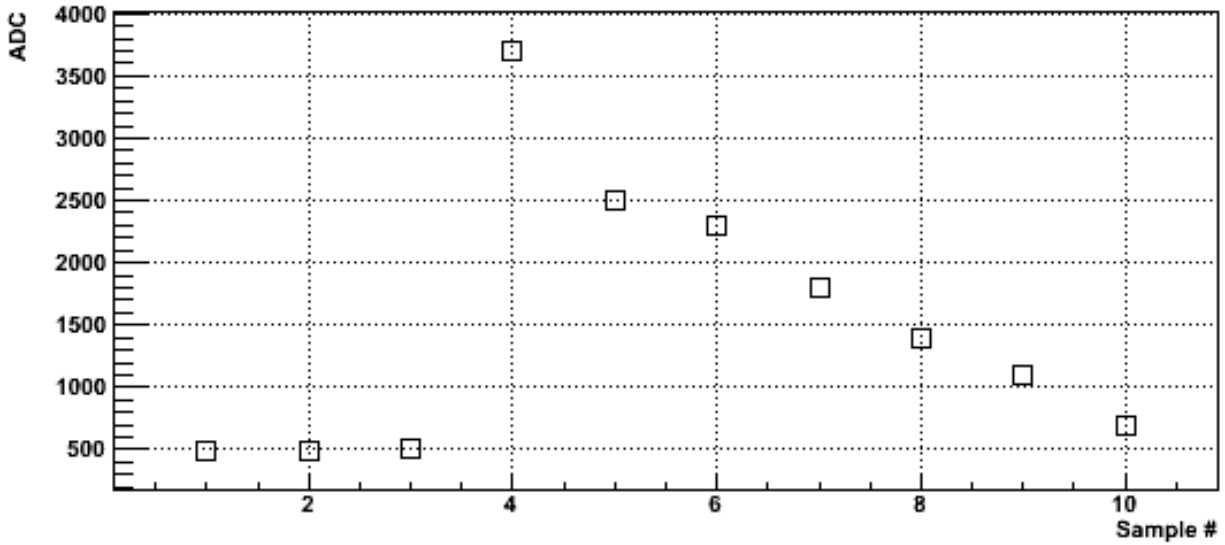
FE: trigger and readout

The Very Front End

40 ns shaping
3 gains
Int. test pulse

12 bit ADC
15 bit dynamic range
40 Mhz clock





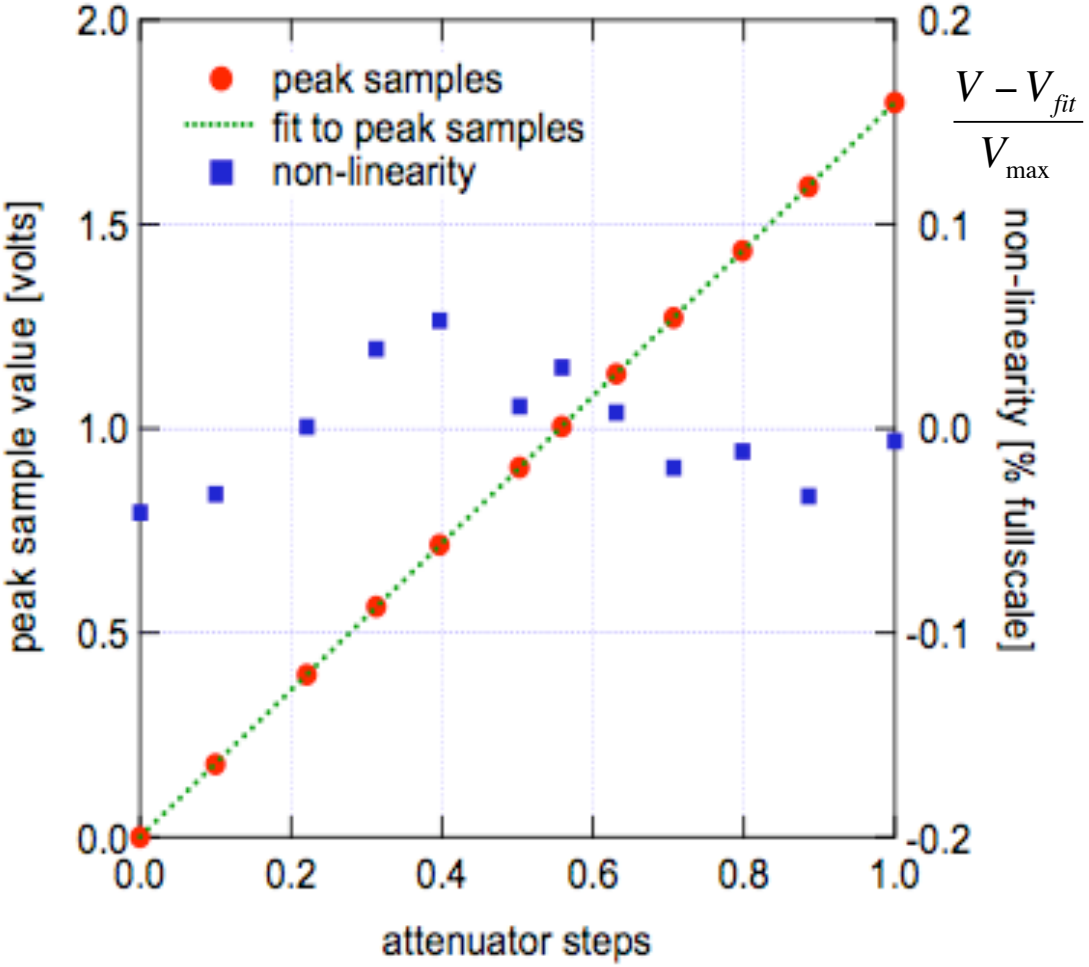
Readout highest non saturated sample with no turning back for 5 samples

VFE specifications

Parameter	Barrel (APD)	End-Cap (VPT)
fullscale signal	60 pC	16 pC
noise level (ENC)	10000e (1.6 fC)	3500e (0.56 fC)
input capacitance	~ 200 pF	~ 50 pF
output signals (to match ADC)	differential 1.8 V, ± 0.45 V around Vcm = Vdd/2 = 1.25 V	
gain ranges	1, 6, 12 ± 10 %	
pulse shaping	40 ns CR-RC	
nonlinearity (each range)	< ± 0.1 % fullscale	

VFE bench tests results

Linearity



Noise

Measured Noise (ENC) on single ch (G12):

~8000 e /1.28 fC

Beam Energy Determination

Ad hoc system to measure bending magnets current.
Current read out 3 times per spill.

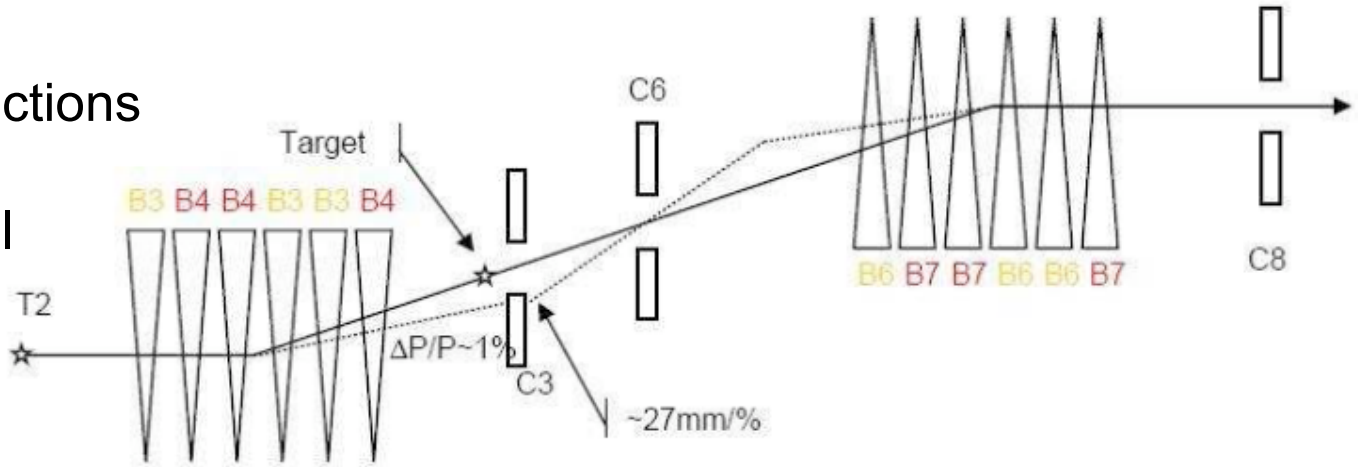
Absolute momentum uncertainty: $\frac{25\%}{p} + 0.5\%$

Momentum spread: 0.15 ->0.3%

Remnant B

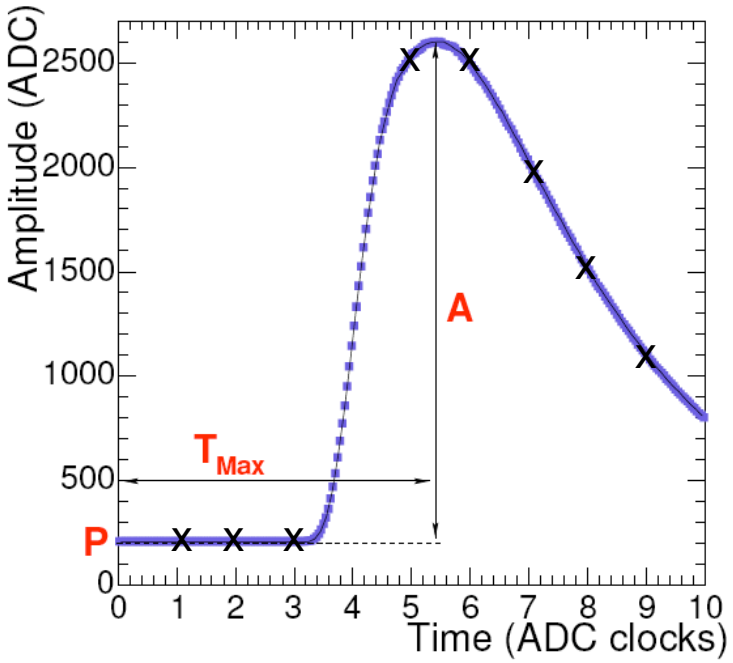
geometry

Systematics :
Synchrotron corrections
Earth MF
Upstream material



Signal Reconstruction in TestBeam

Signal reconstruction performed by digital filtering.
Asynchronous running in test beam complicates amplitude estimation (each ADC clock tick divided in 25 1ns bin)



$$\hat{A} = \sum_{i=1}^{N} w_i \cdot S_i \qquad w_i = f_i / \sum_{j=1}^{N} f_j^2$$

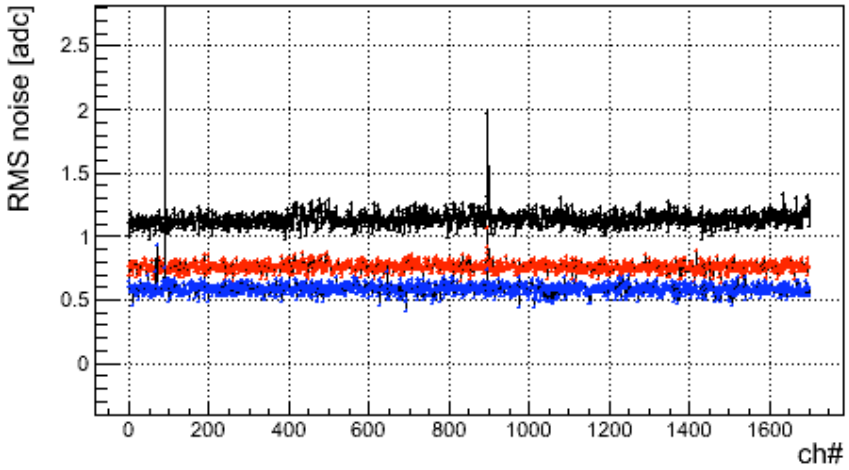
3+5 weights method @ G12

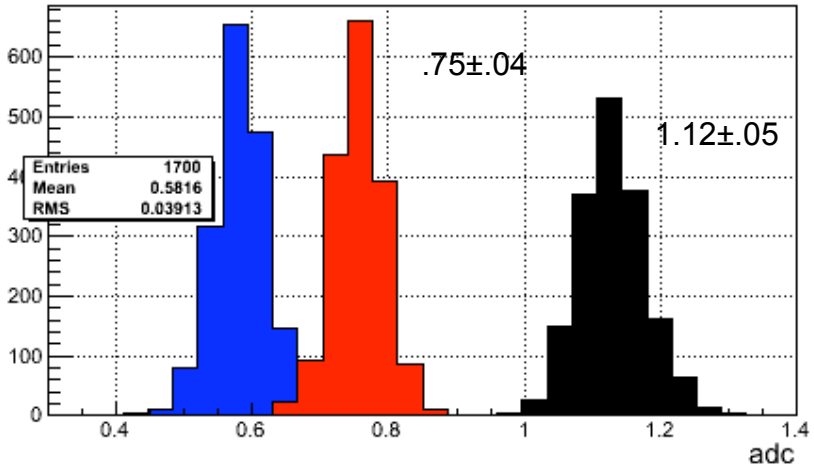
0+4 weights method @ G6,G1 (need to use pre-measured pedestals)

Noise (individual channel)

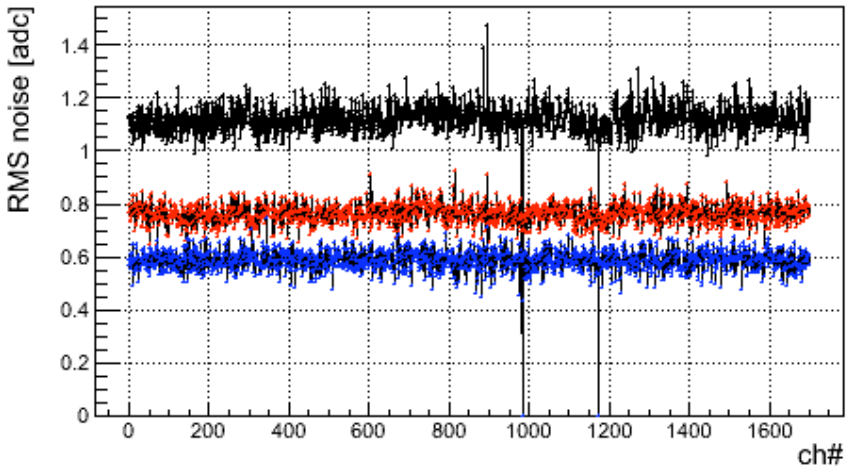
SM06

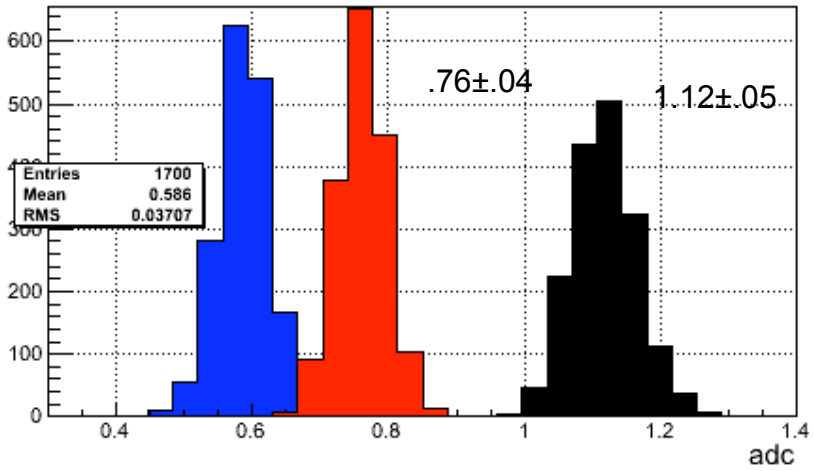
G1 G6 G12





SM16





RMS calculated over 450 pedestal events

Noise (sum)

In real life xtals are analyzed in clusters: a more interesting parameter is the noise of 3x3, 5x5

	Noise SM 16 [MeV]	Noise SM 6 [MeV]
G12 1x1	36.5	36.5
G6 1x1	28.19	28.56
G12 3x3	107.5	104.9
G6 3x3	72.9	71.7
G12 5x5	179.9	174.0
G6 5x5	121.7	119.5

Absence of correlation between channels

Gain ratio determination

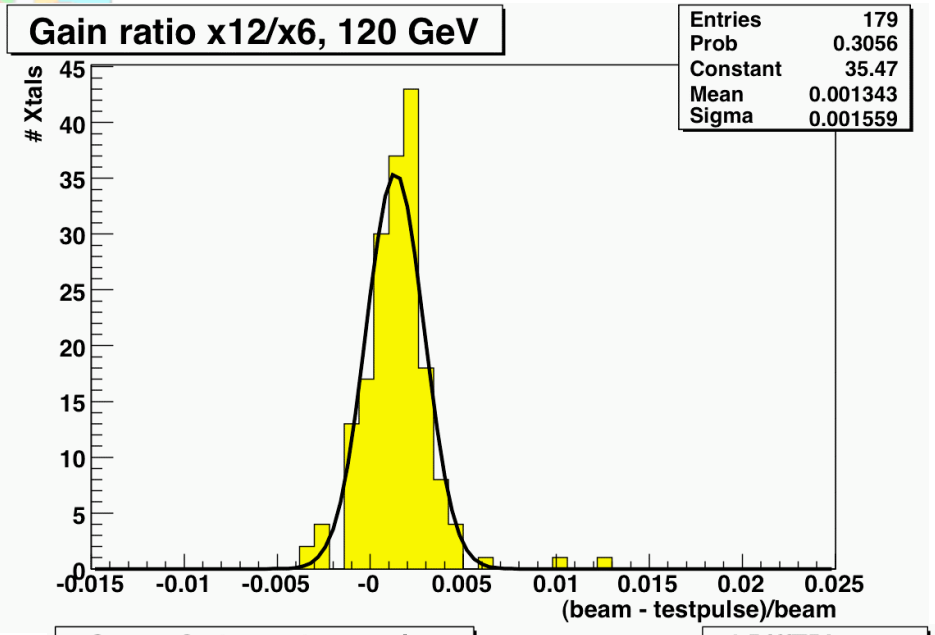
Gain ratios for each MPGA channel can be determined in several ways:

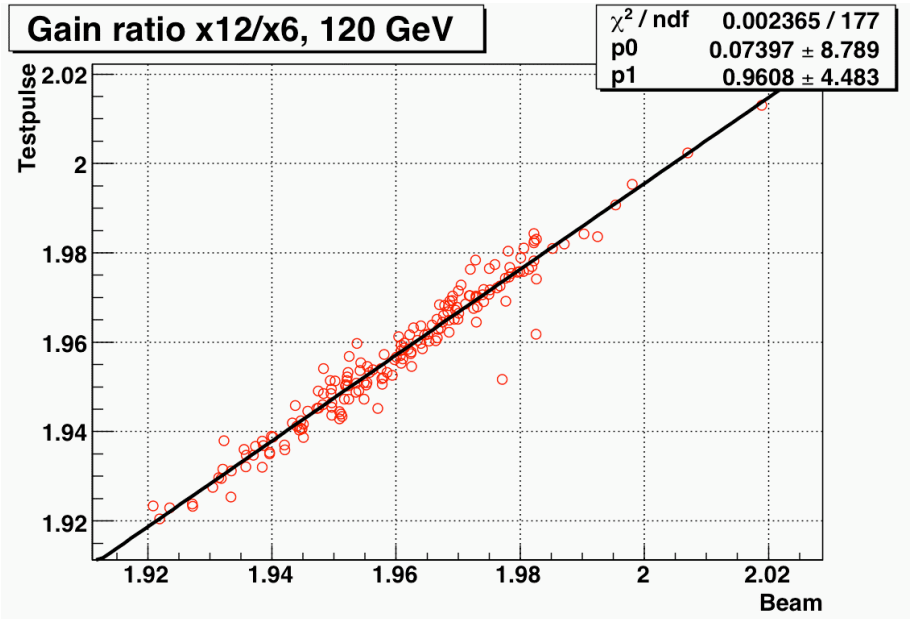
1. On board **Test pulse**
   Built-in charge injection system
2. **Laser** system
   APD-independent method
3. **Test Beam**
   Forcing gain range at same beam energy

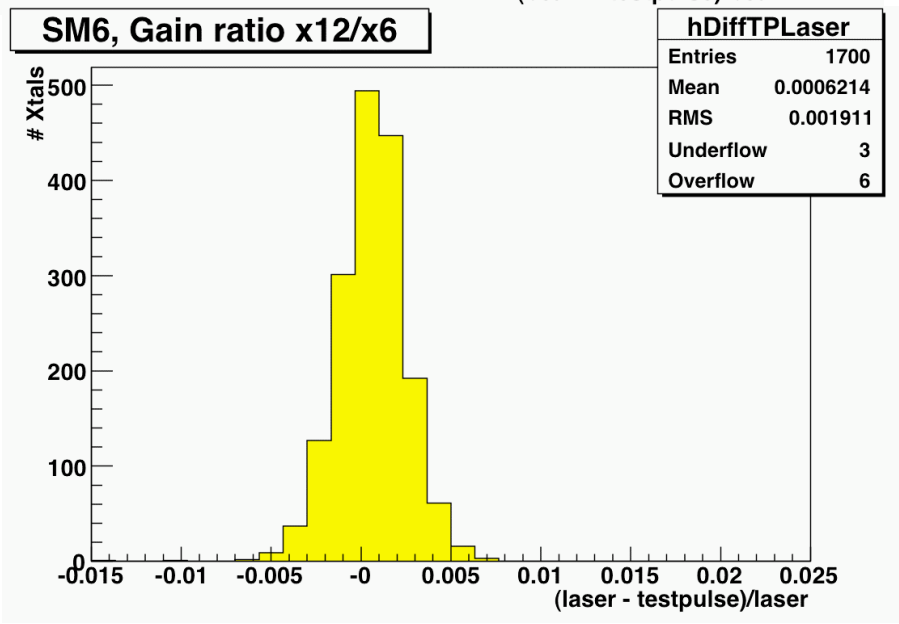
The three methods have been compared and proven to give consistent well correlated results.

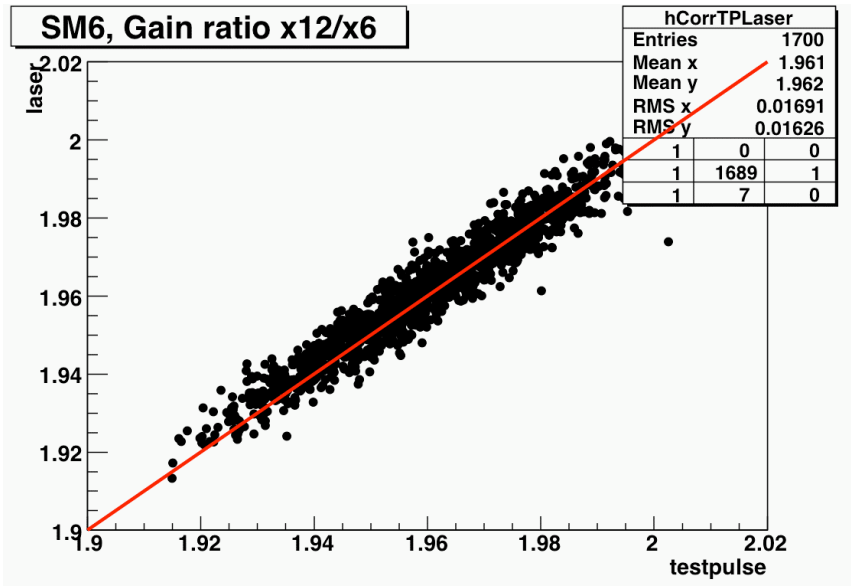
The Test pulse will be used to calibrate in-situ

Difference and correlation between Gain R measurements





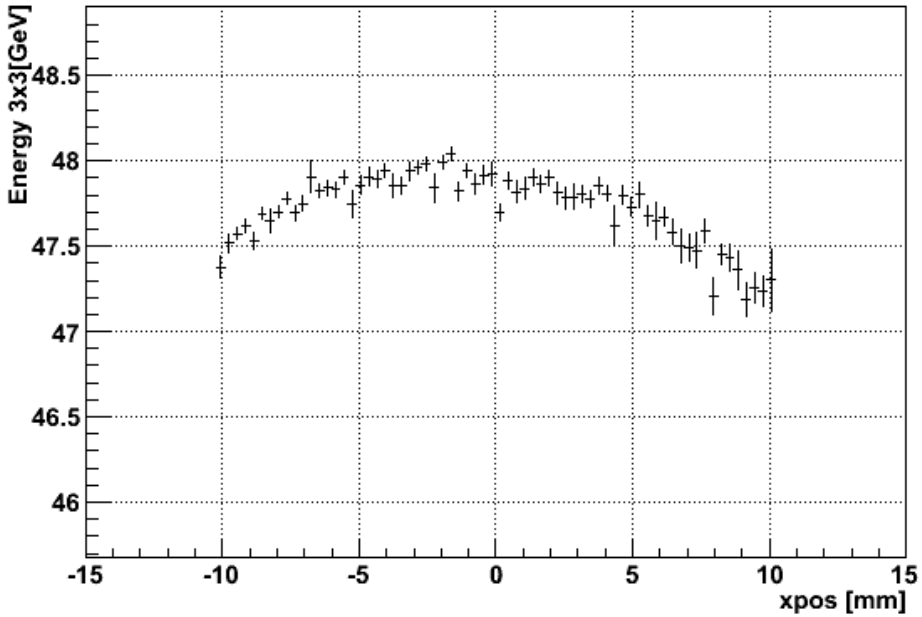


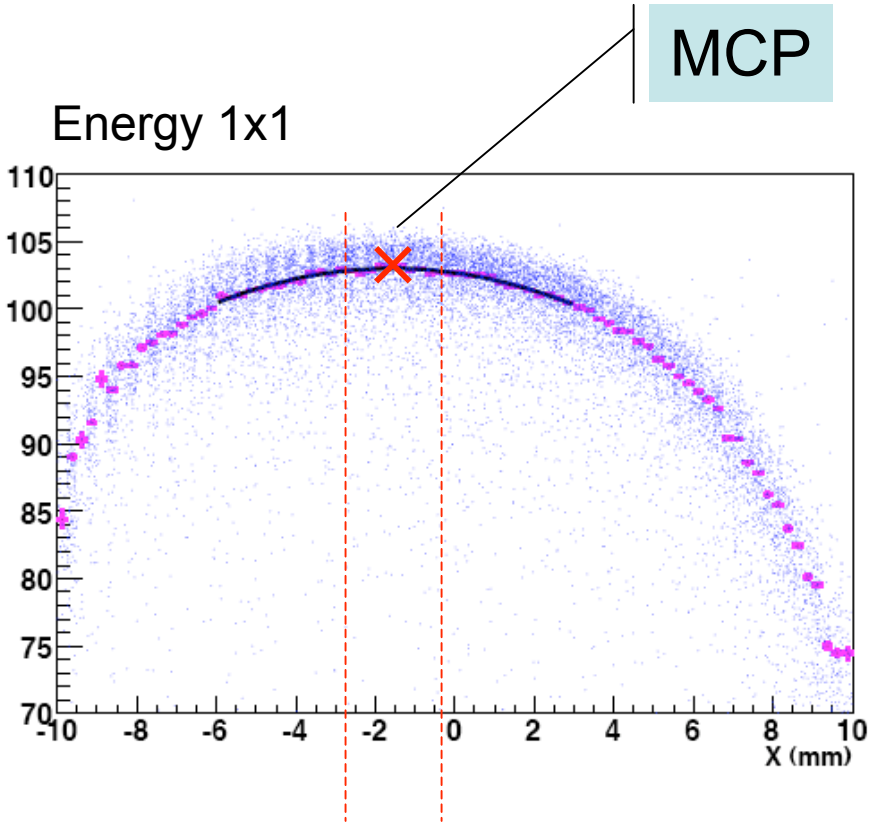


1. For each event, select hottest crystal and make sure it is the nominal crystal in beam
2. Use position cuts
3. sum 5x5
4. Histogram the energy
5. Fit with “xtal ball” function (gaussian with exponential tail at low energies)

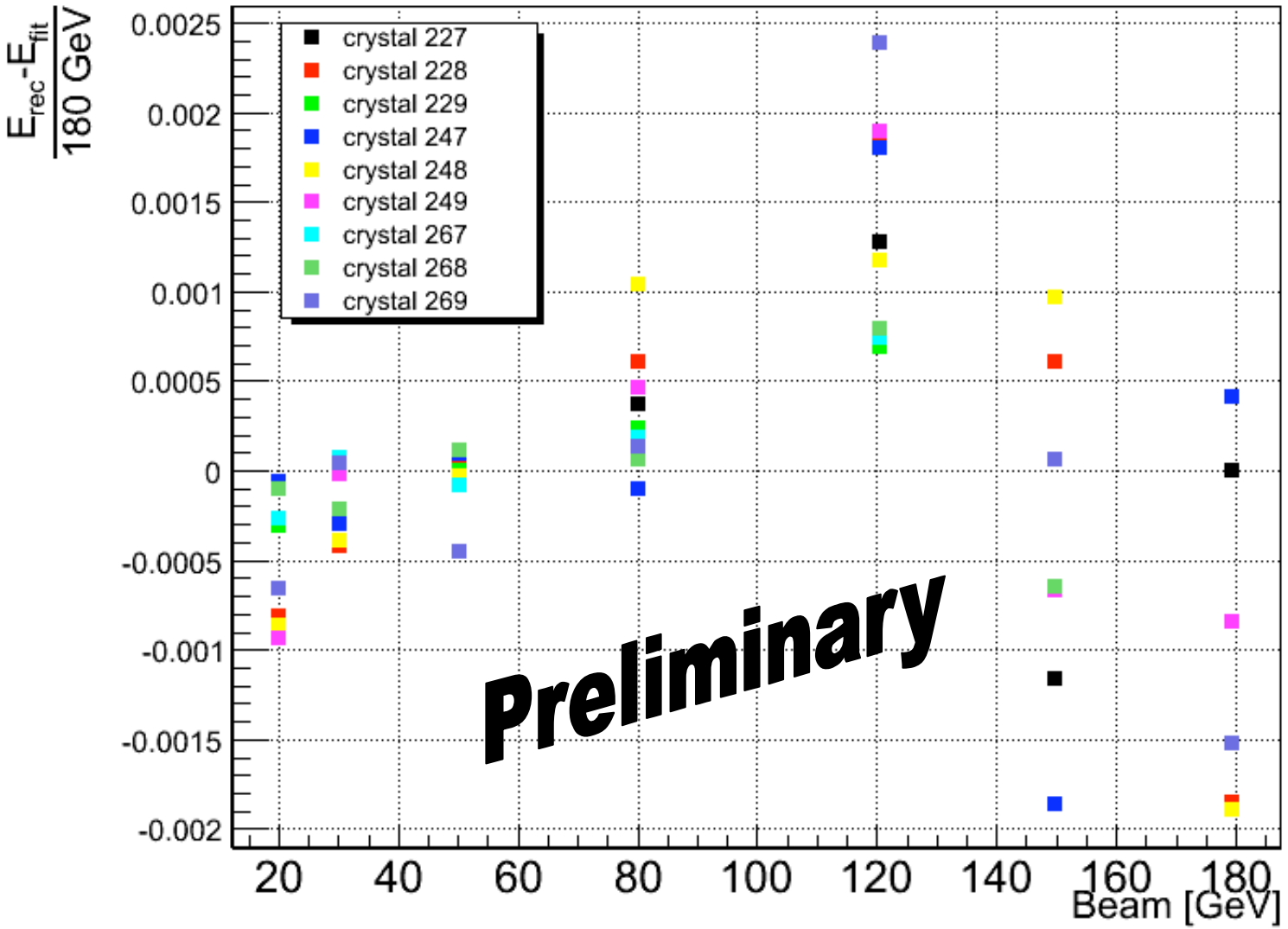
Position cuts:

Determination of the Maximum Containment Point by parabolic fit



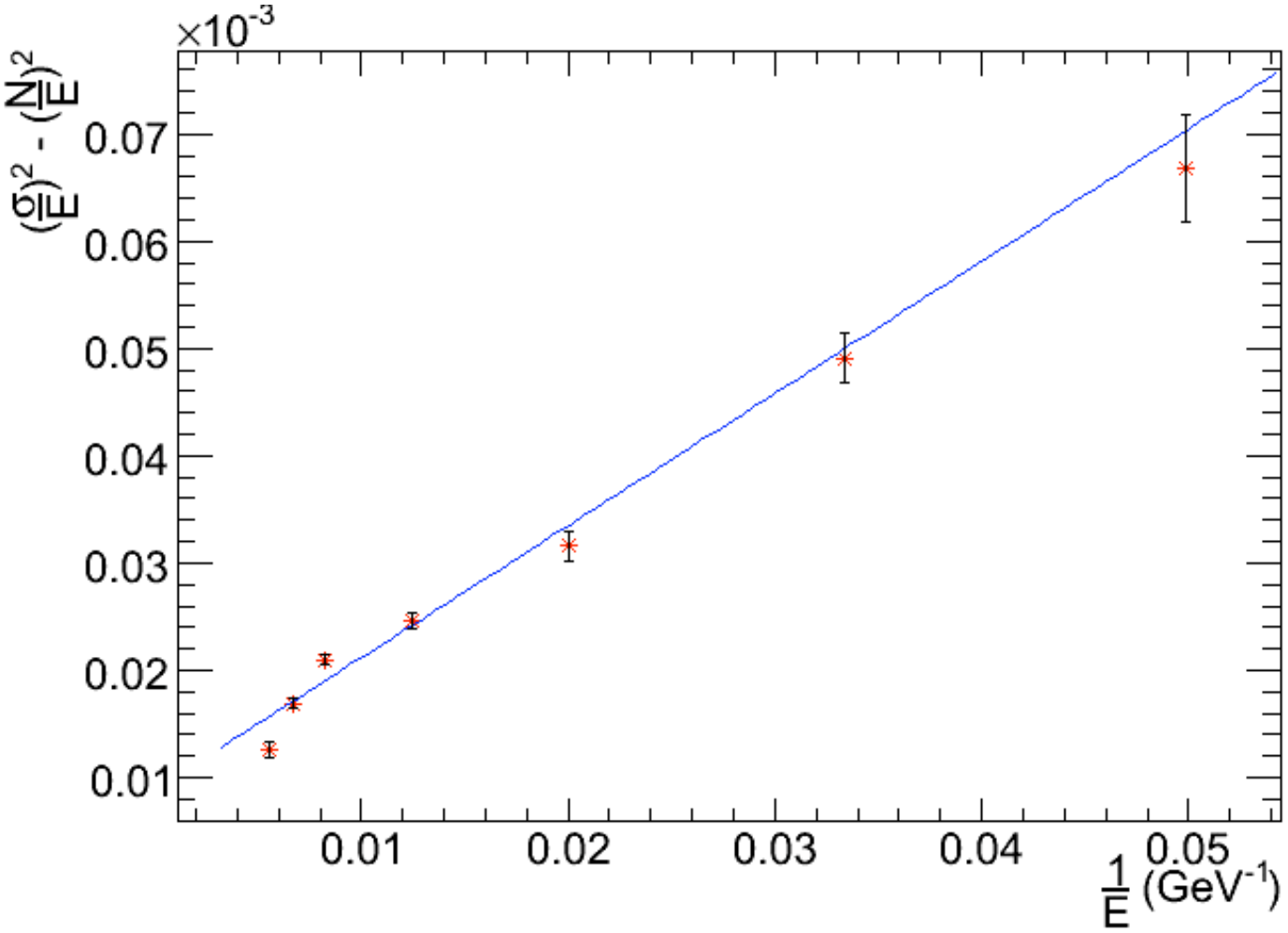


Differential non linearity



SM16

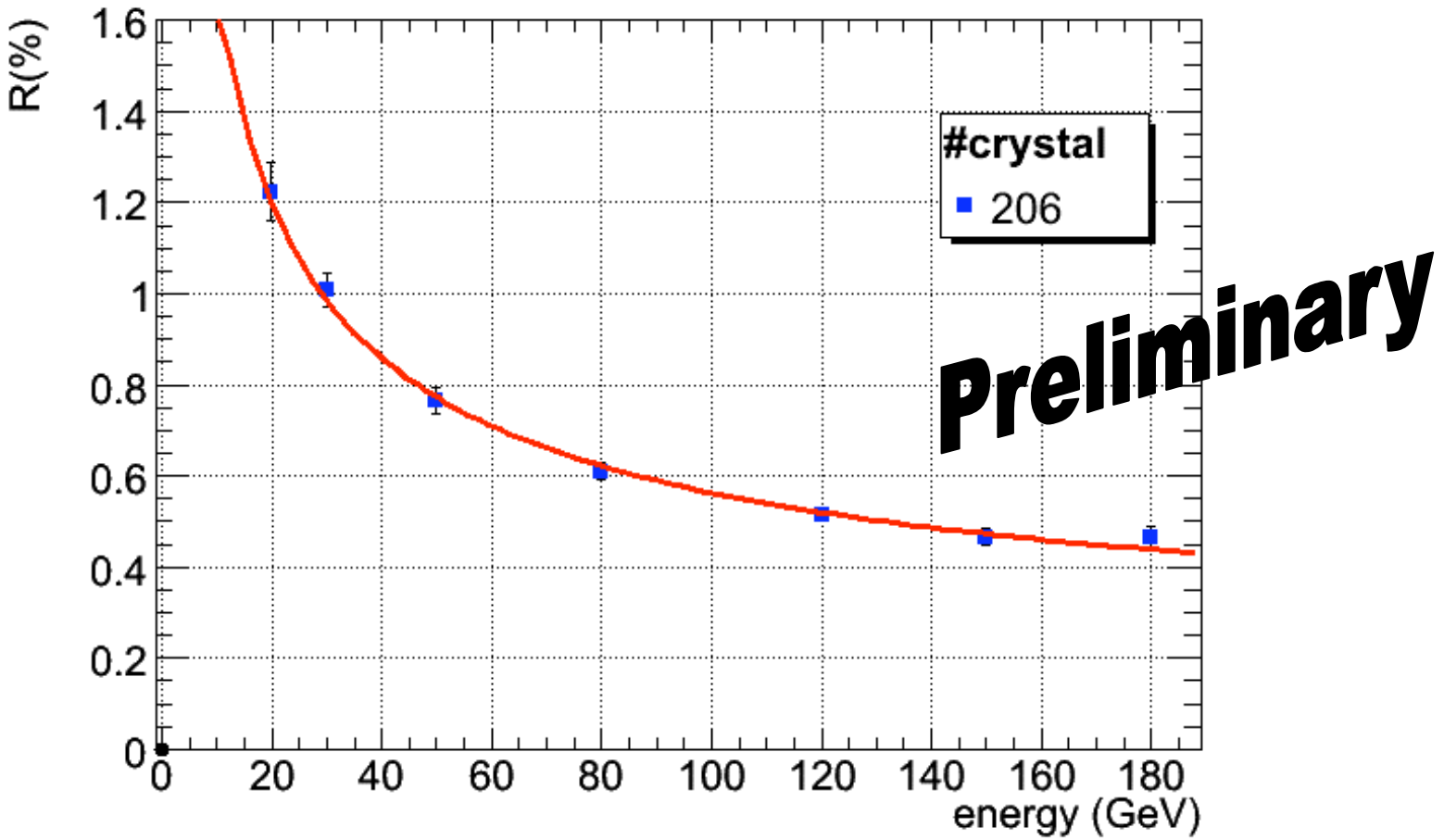
Resolution



Global fit (2x2mm cut): S[%]:3.5 ±.08 C[%]:0.33± 0.01

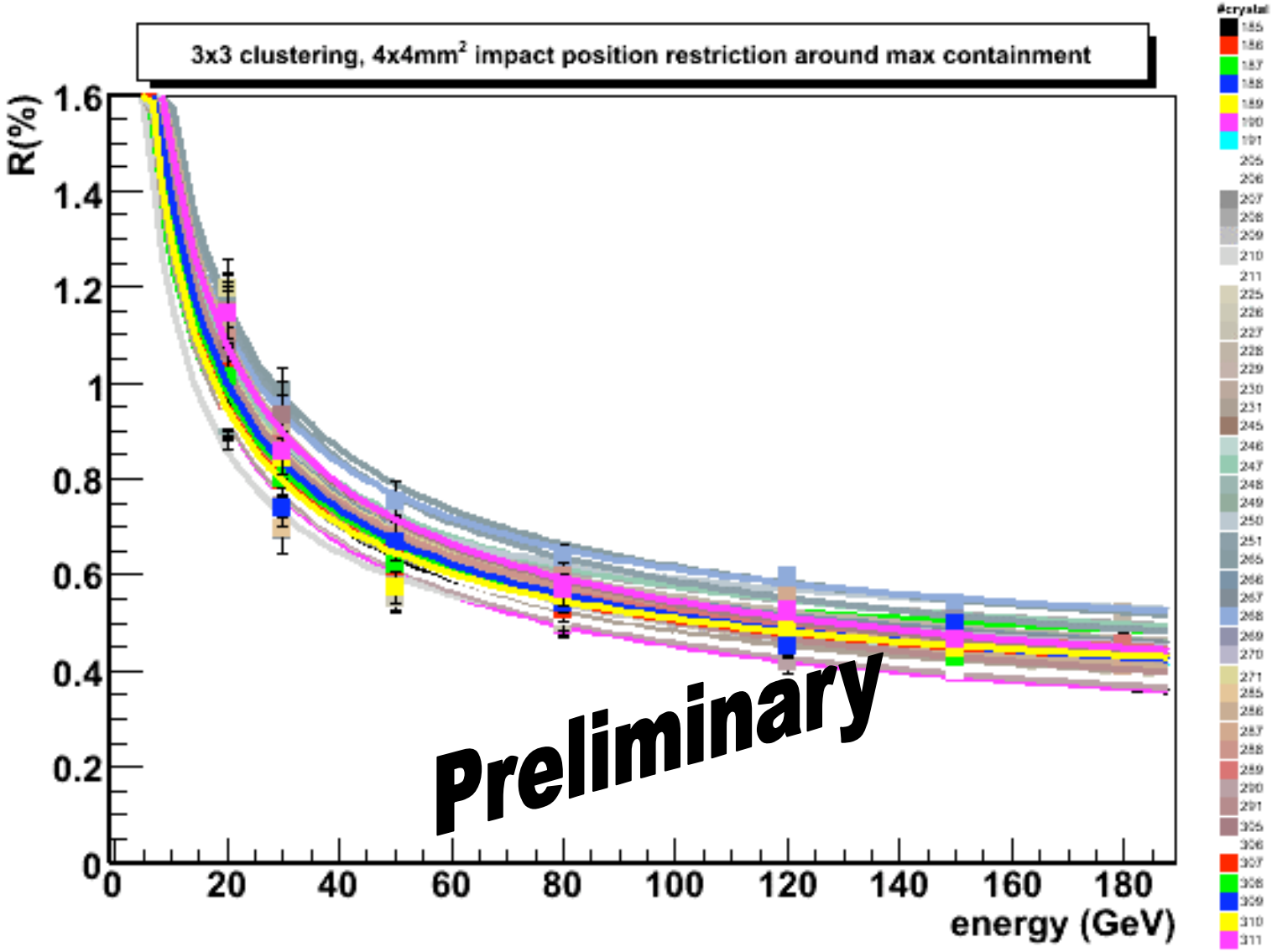
Compatible results on 3x3, 5x5

Resolution plot



Resolution plot for one channel, SM16, 5x5

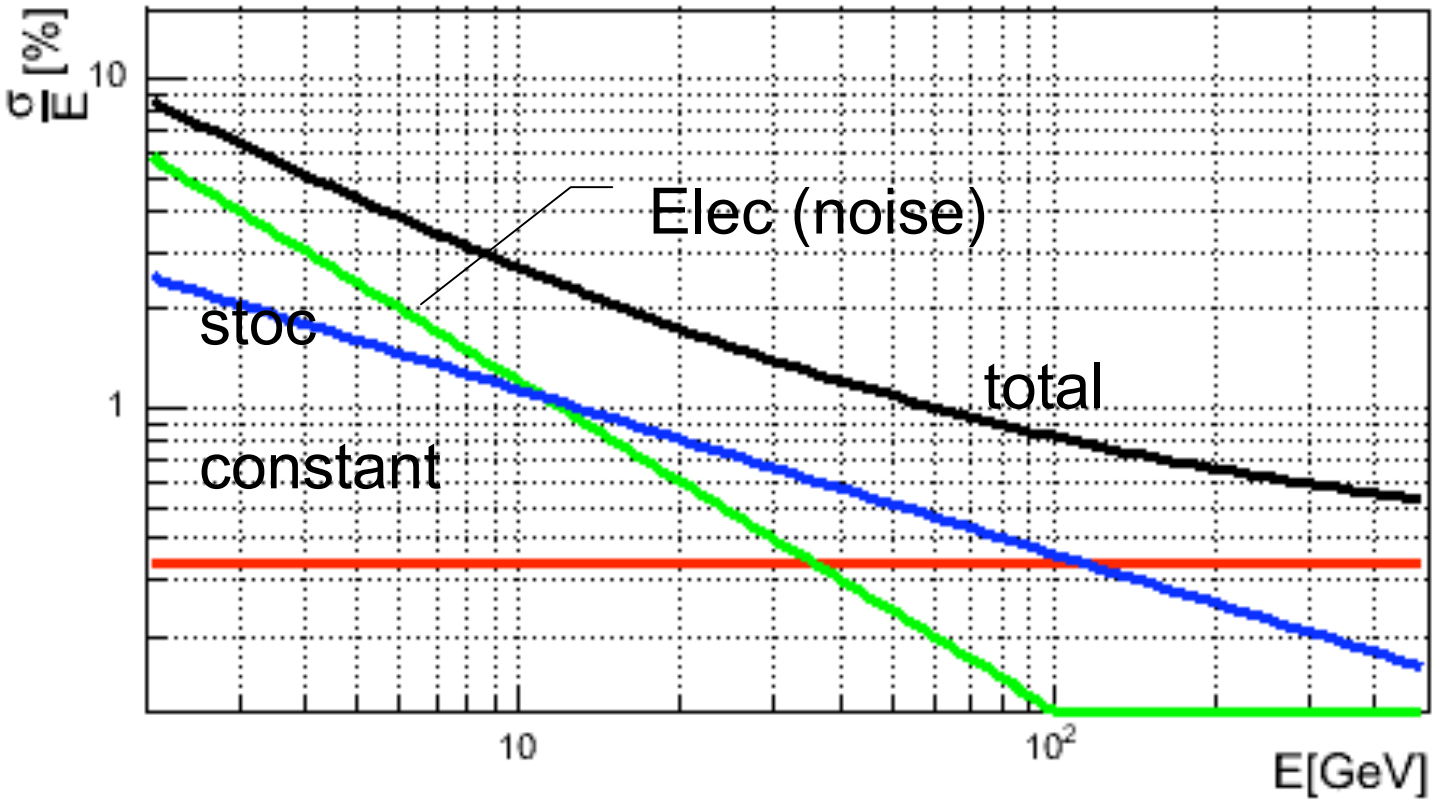
Resolution plots



SM 16

Contributions to Resolution

Testbeam measurements are used to plot the contribution to resolution



Above 10 GeV, resolution is dominated by statistics and the degradation due to electronics noise is negligible

Conclusions

The CMS Ecal has been extensively studied with electron beam
Supermodules were equipped with final electronics

Results meet or are close to design goals

Energy Resolution	3.5%/√E + 0.3% global fit SM16
Noise 3x3	~110 MeV
Noise 5x5	~170 MeV

Ecal electronics behaved as expected, its contribution to detector performance is within specs

The calorimeter is pre-calibrated and ready to be cabled and commissioned