Performance of the ATLAS Liquid Argon Endcap Calorimeter in Beam Tests

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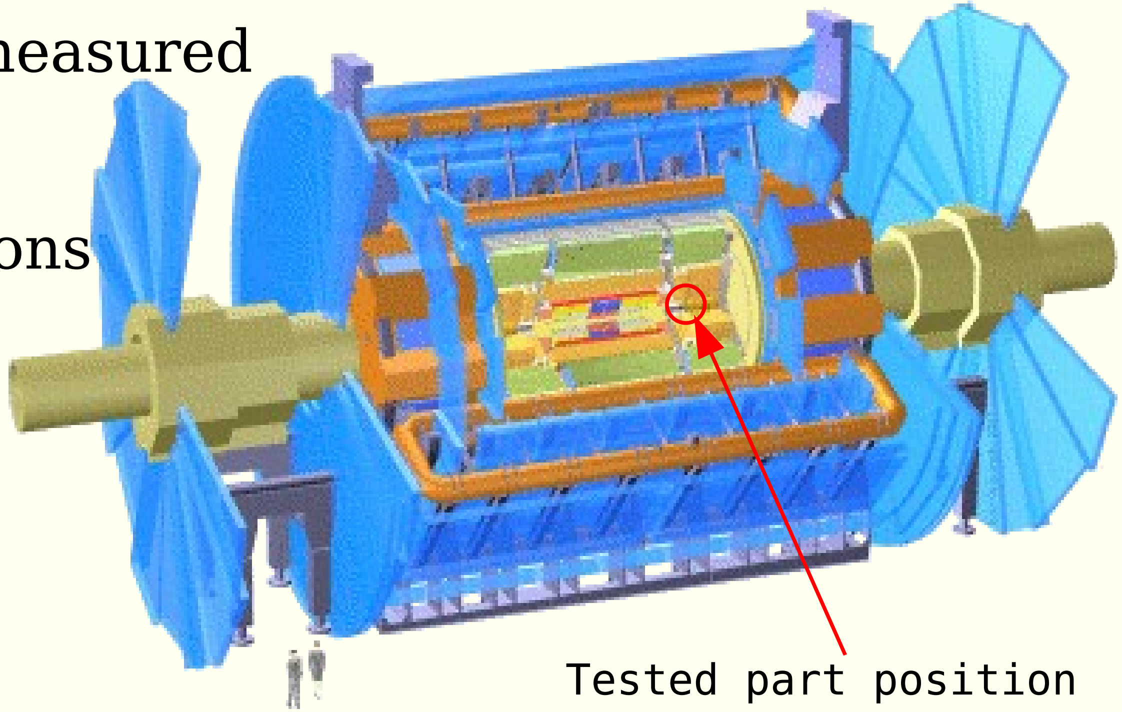
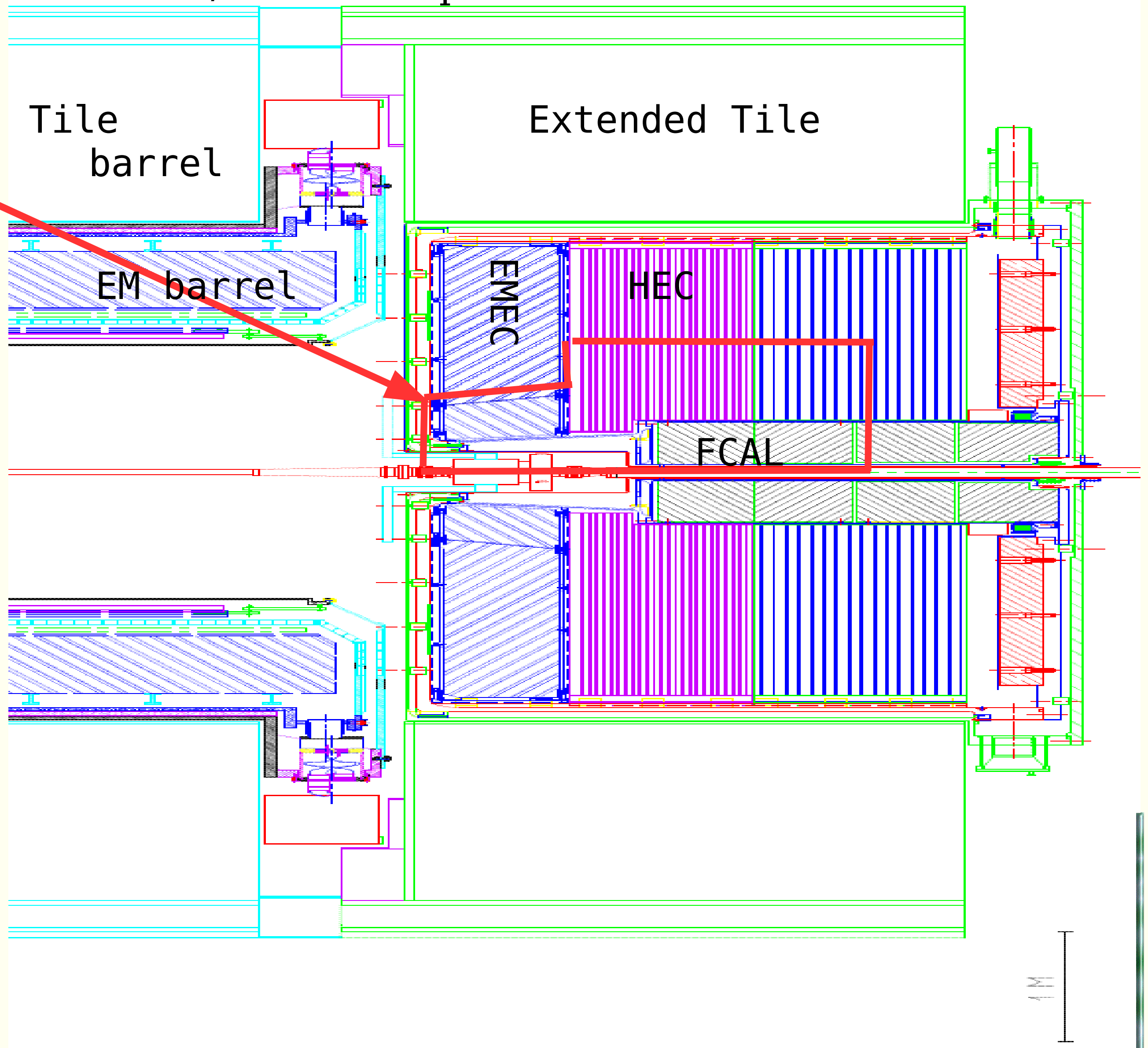
on behalf of ATLAS LAr Endcap Group

- Outline:
  - Setup description and data measured
  - MC description
  - Basic performance for electrons
  - Basic performance for pions
  - Noise cuts study
  - Conclusions



Setup:

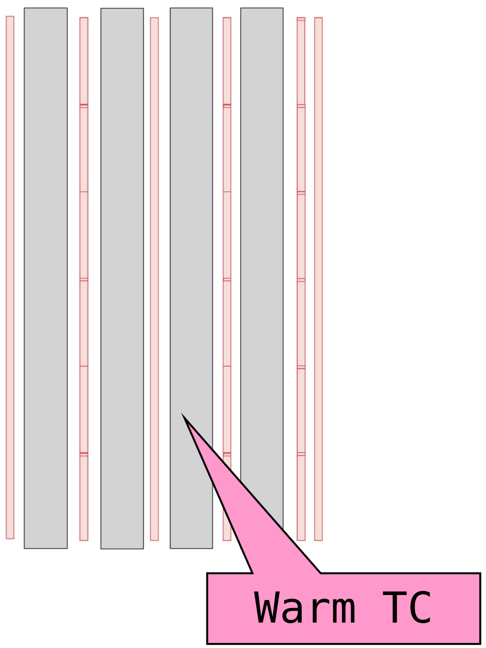
- Combined test of three LAr detectors in ATLAS forward region
- Quite complicated area – crack between EM/HAD endcap and forward detector

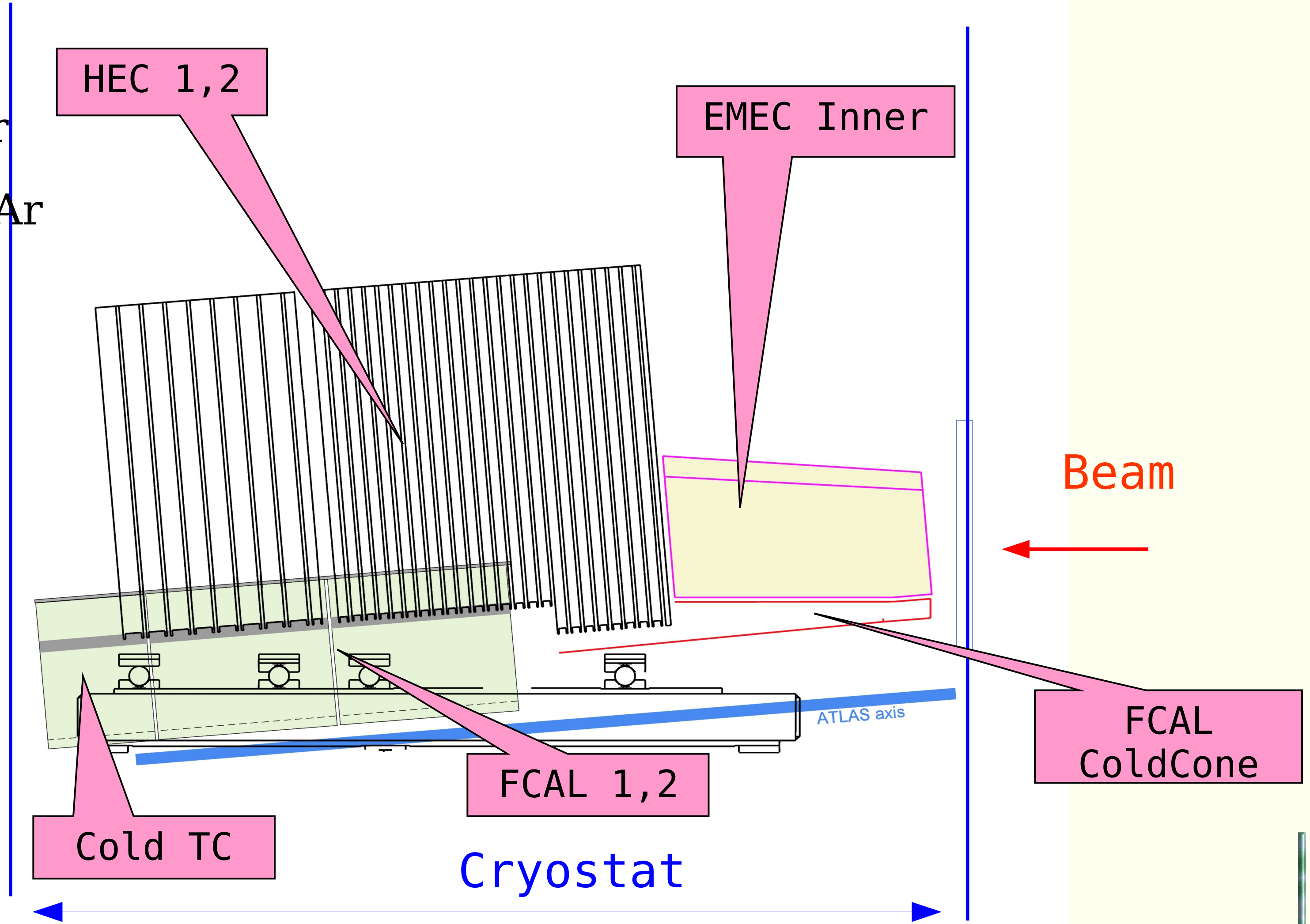


- on 2D view of calorimeters the tested region is marked by red line
- one Module0 of EMEC Inner Wheel (lead, accordion shape), readout segmentation 0.1 x 0.1 (η x ϕ)
- one quadrant in phi of HEC (parallel flat copper plates), readout segmentation 0.1 x 0.1 in outer and 0.2 x 0.2 in inner wheel
- one quadrant in phi of FCAL (EM part copper, HAD part tungsten alloy with cylindrical electrodes, parallel to beam), readout segmentation not projective, ~ 0.2 x 0.2
- dead materials between calorimeters and in front of FCAL close to the ATLAS case (no beam pipe...), trying to be as close as possible to "nominal" situation
- setup placed in H1 cryostat in CERN North Hall, using the H6 beam line
- slanting a setup to be "projective" at η ~ 2.8

- Limited acceptance, because of space constraint in H1 cryostat
- Warm and Cold Tail Catchers are TB specific devices to help identify a longitudinal leakage

- Warm TC: Iron+Scintillator
- Cold TC: Copper plates+ LAr





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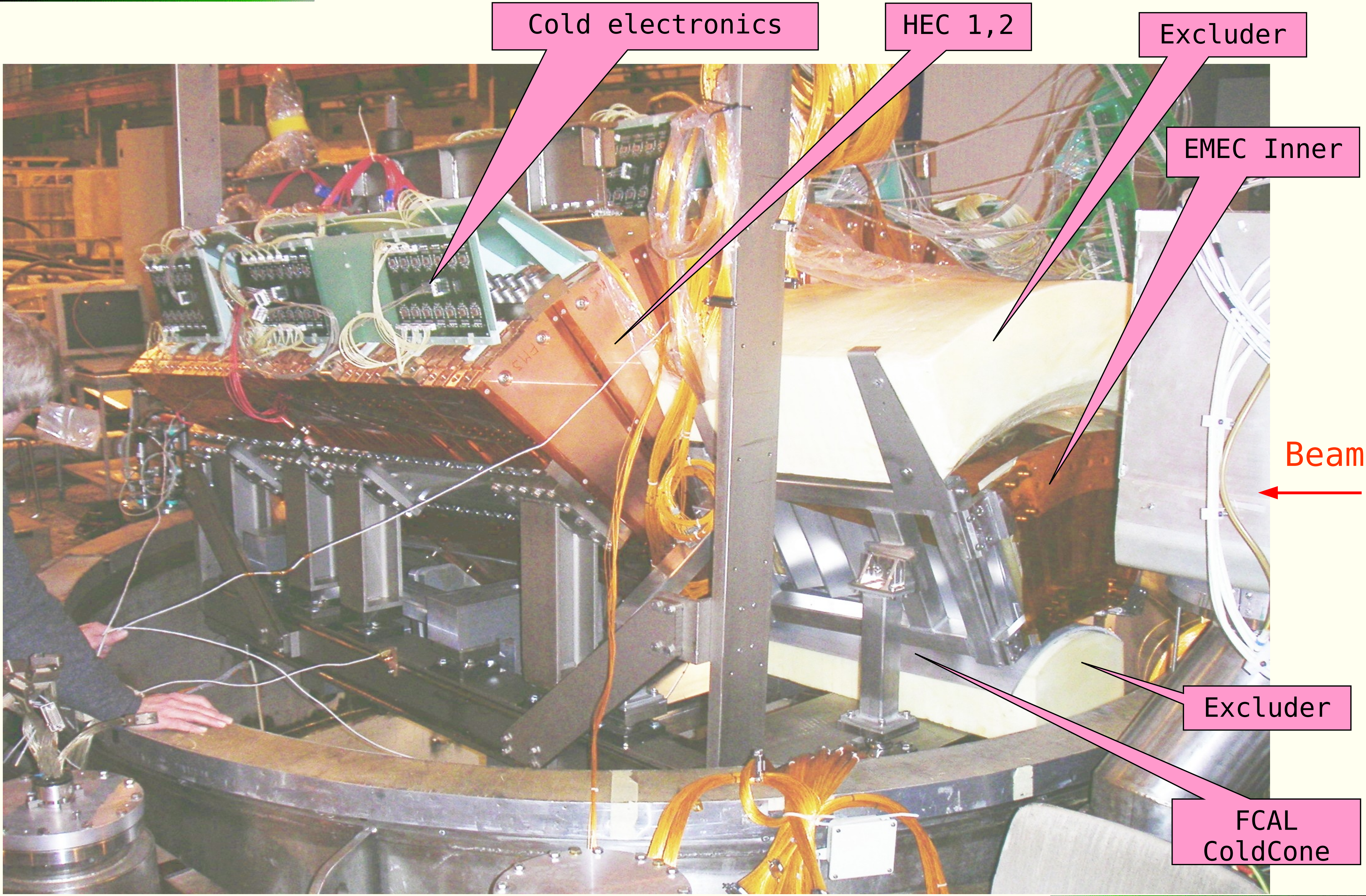
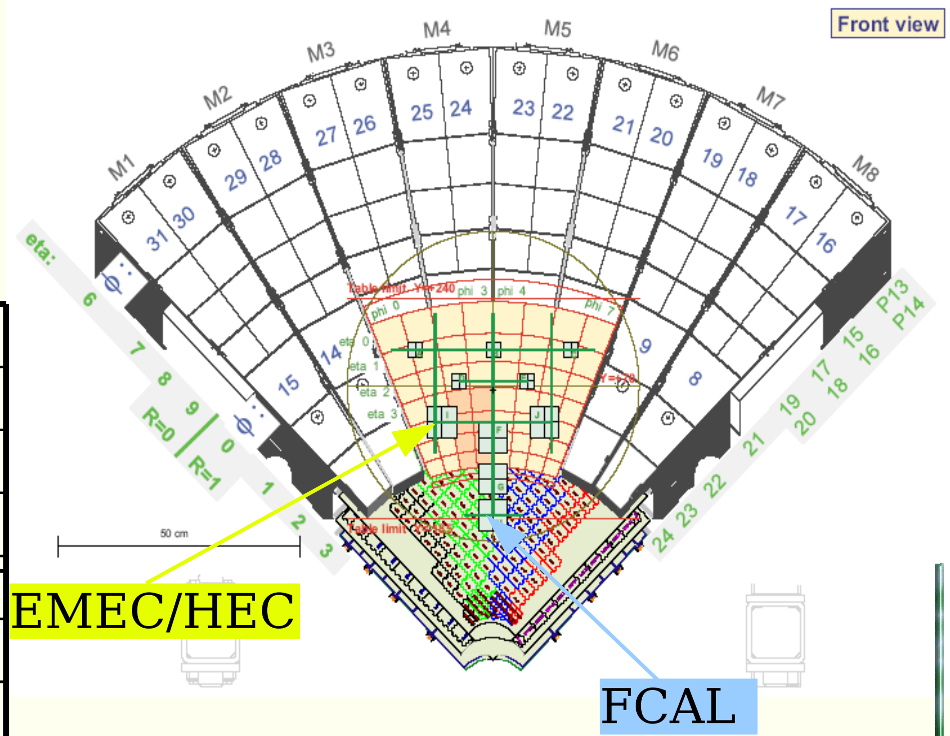


- Data:
  - Readout was done with various prototypes and versions -1 of final ATLAS electronics, therefore parameters not directly transferable to a data taking
  - Various scans were performed (e-, pi, position (x- and y-), energies 6-200GeV in fixed points)
  - Electronics calibration in a similar way as envisaged for ATLAS
- Noise:
  - Some problem with prototype of HEC Power supply found, source of coherent noise, but it was possible partially to correct it
  - noise is measured from *empty calo cells*, or using estimate from *first reading sample x suppression factor* (taking into account suppression done by filtering used for signal amplitude reconstruction)
  - also typical cluster noise shown for EM and had. clusters

	Cell noise [MeV]	Estimate [MeV]
EMEC2	80	80
EMEC3	60	60
HEC0	200	190
HEC1	280	250
HEC2	460	420
FCAL1	240	180
FCAL2	370	315

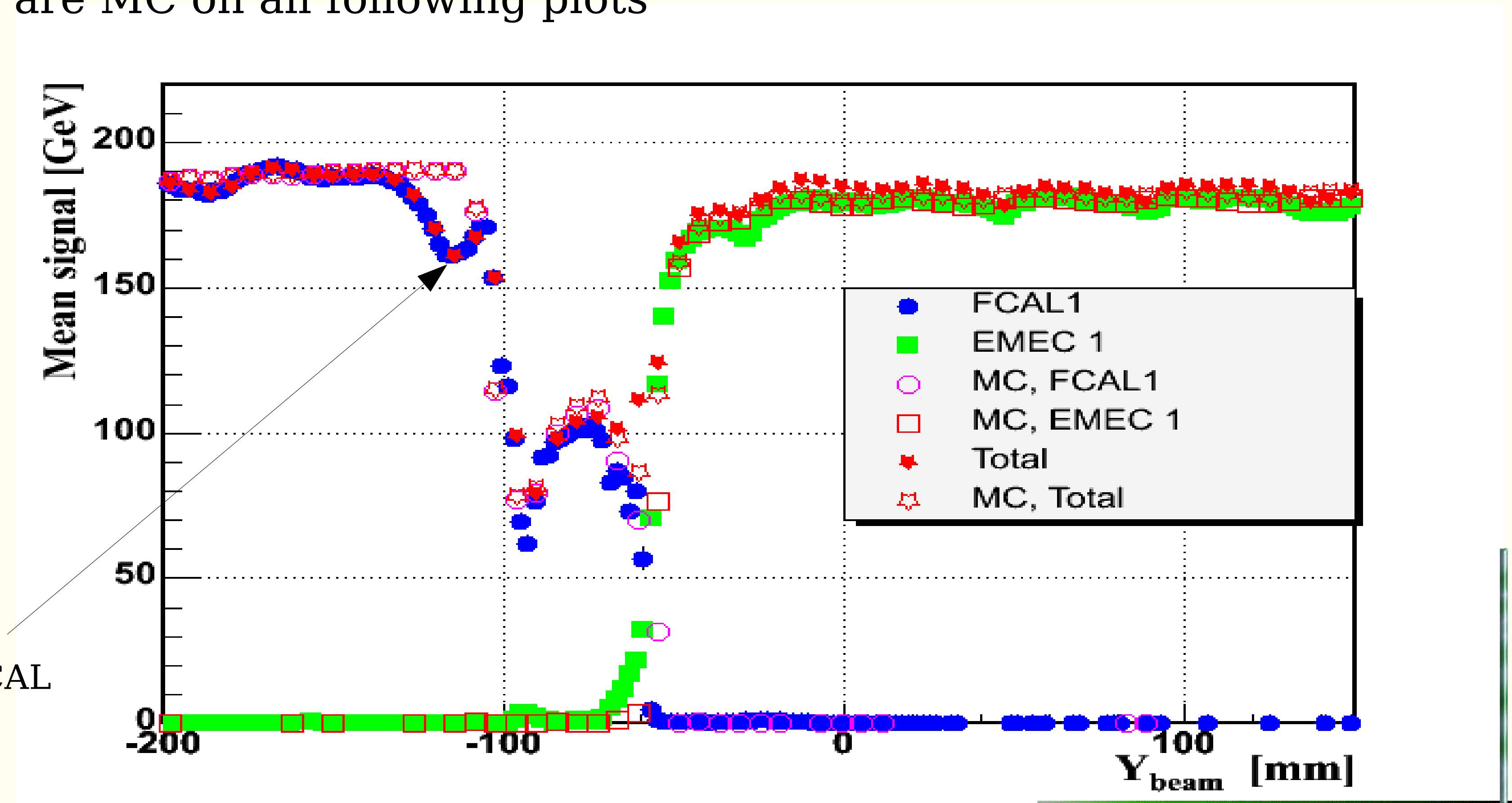
Cluster EM	Noise [MeV]
EMEC, 0.15	550
EMEC, 0.25	1300
FCAL, 0.25	1100

Cluster HAD	Noise [MeV]
EM/HEC, 0.3	4200
EM/HEC, 0.5	7100
FCAL, 0.3	3100
FCAL, 0.5	6700



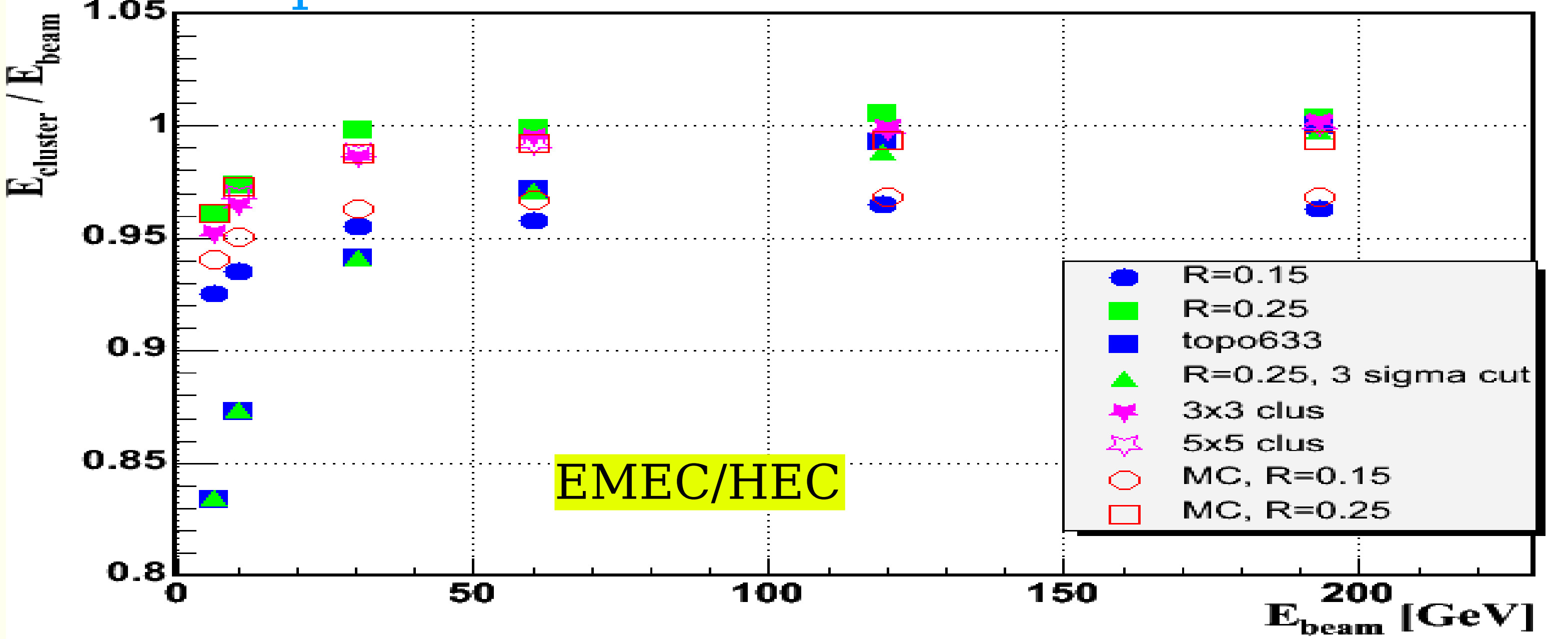
MC:

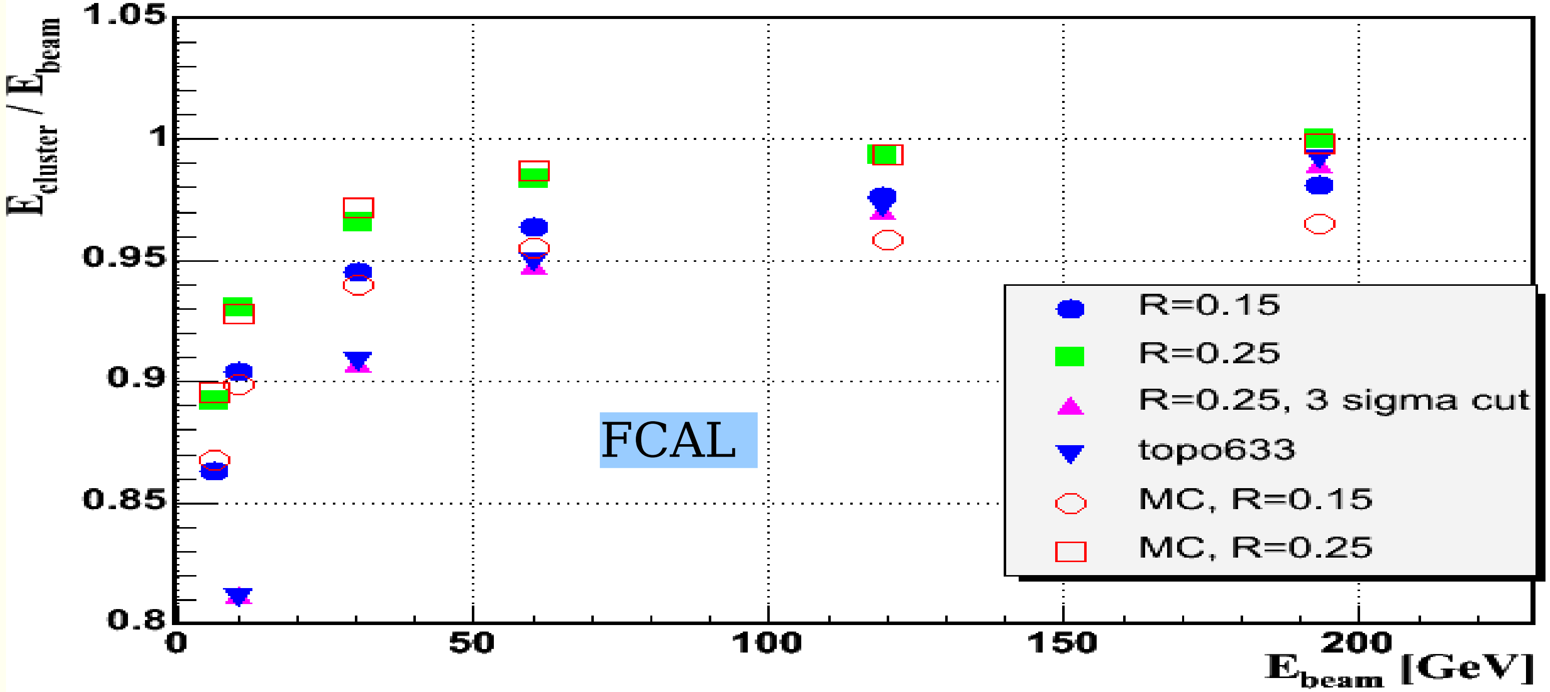
- Most simulation done so far with G4 7.1p01, only recently switched to a newer versions (coupled to a ATLAS releases used for analysis), not final results yet
- Physics list used QGSP_GN and QGSP_BERT, the second one used for comparison with data – better description, specially of shower shape
- to check the MC geometry – vertical scan with electrons
- open symbols are MC on all following plots



known weak channel in FCAL readout

Basic performance for electrons:

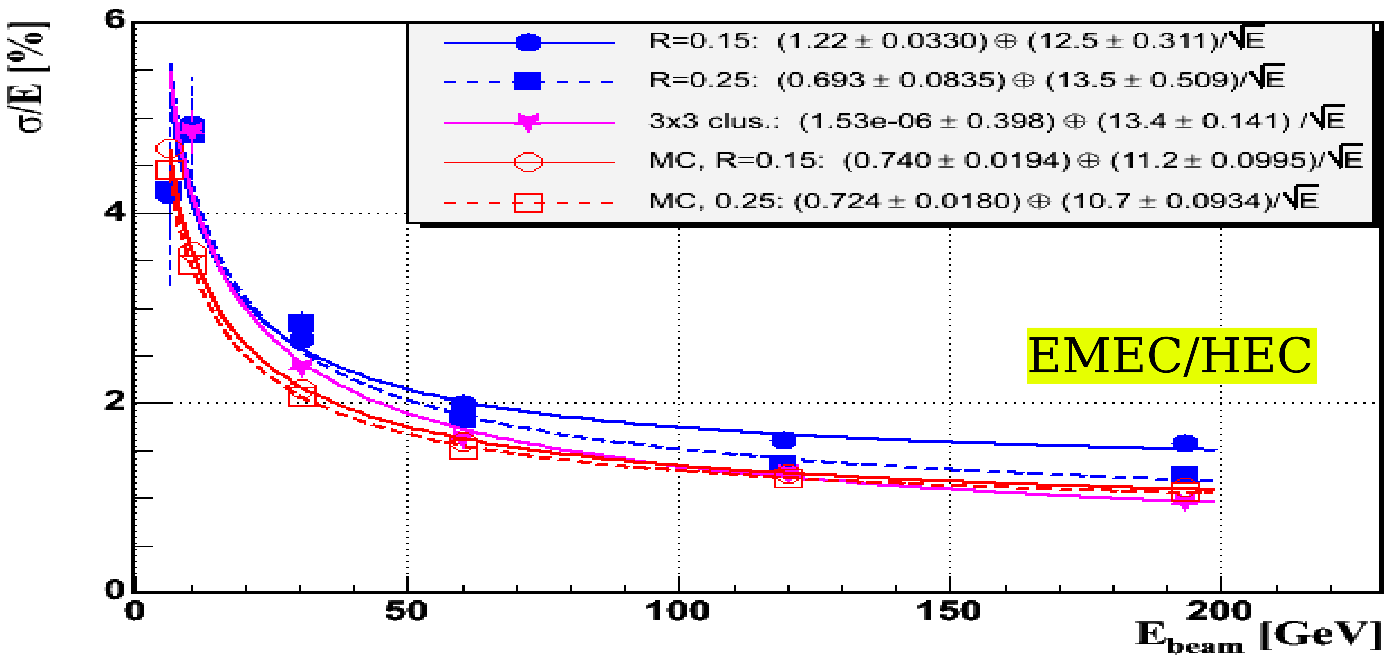


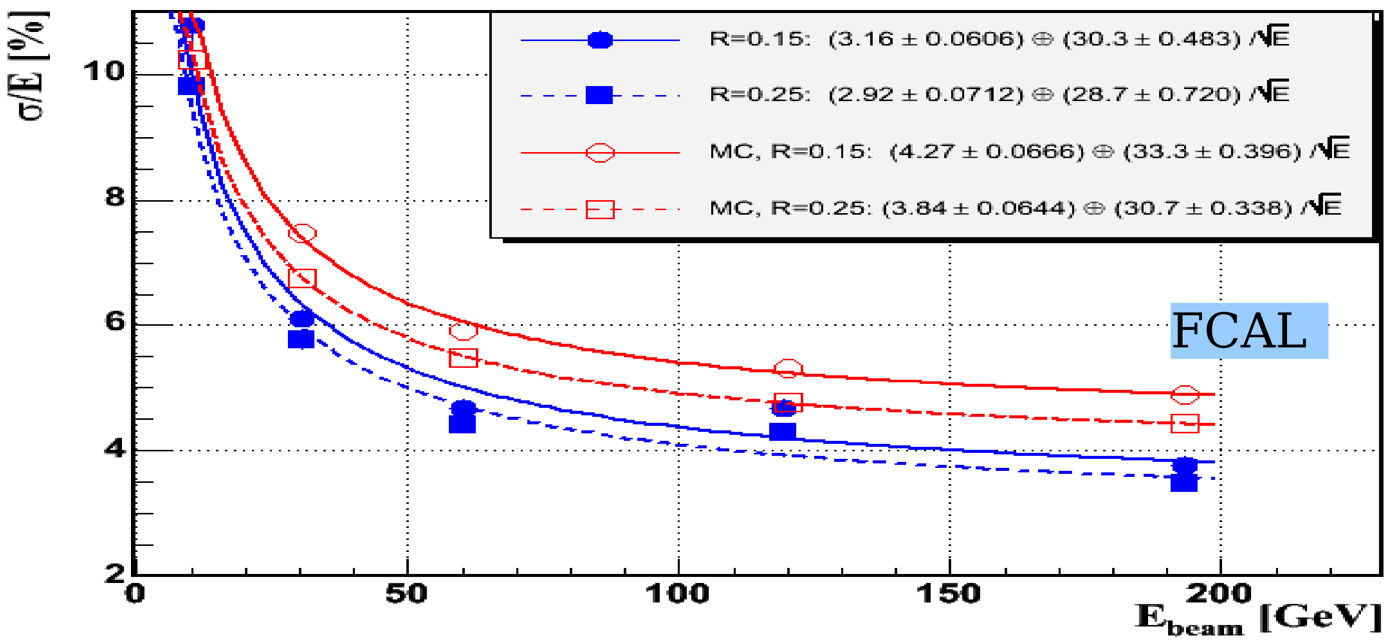


Electron linearity in standard impact points

- cone clusters - clear visible that R<0.15 does not collect enough signal
- cone 0.25 cluster very close to MC expectation, 0.15 shows difference at low energies
- "topo 633" topological cluster *(more about topological clustering in a talk of G. Pospelov)* expected behaviour – comparable with cone+3σ cut
- 3x3 and 5x5 are standard towers used in EM calo for e/γ reconstruction

Basic performance for electrons:





Electron resolution for standard points

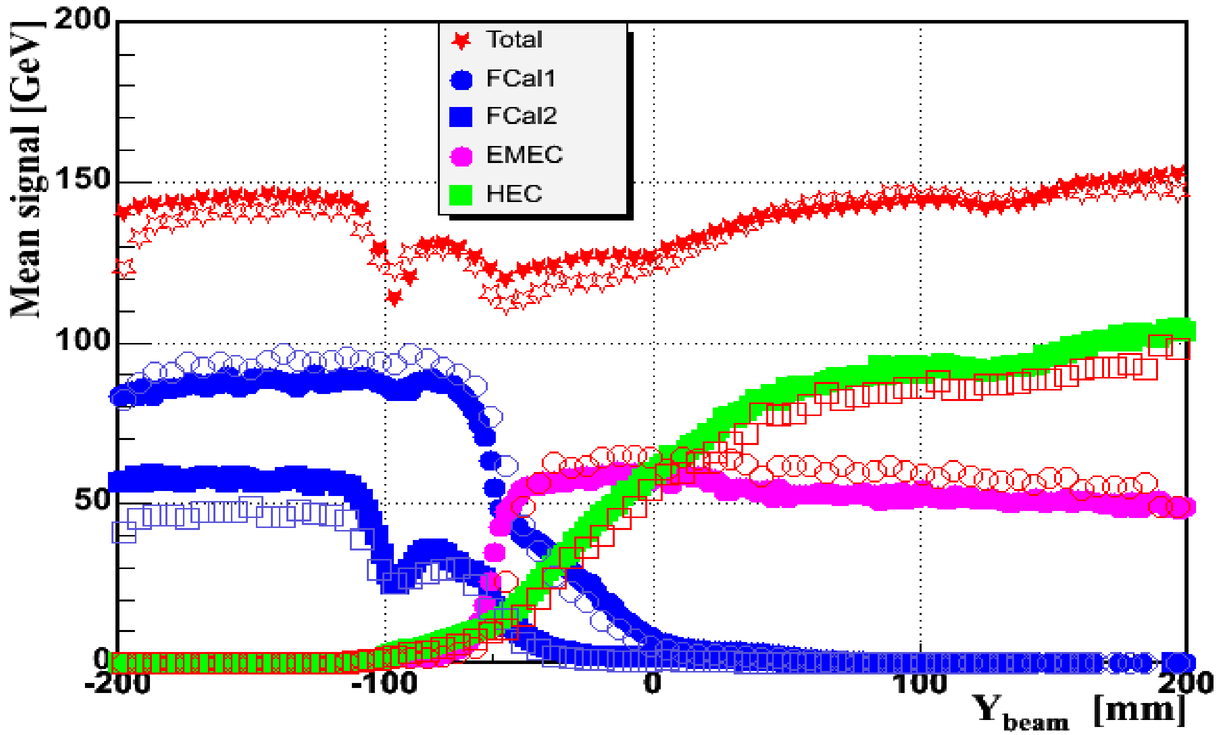
- cone and 3x3 clusters - easy to subtract noise
- topo 633 cluster - average noise subtracted
- EM 3x3 cluster with a "standard" EM corrections – gives the best result
- FCAL MC is worse than data – but it's much closer to data with newer G4 (new multiple scattering ?) and ATLAS sw. release

Basic performance for pions:

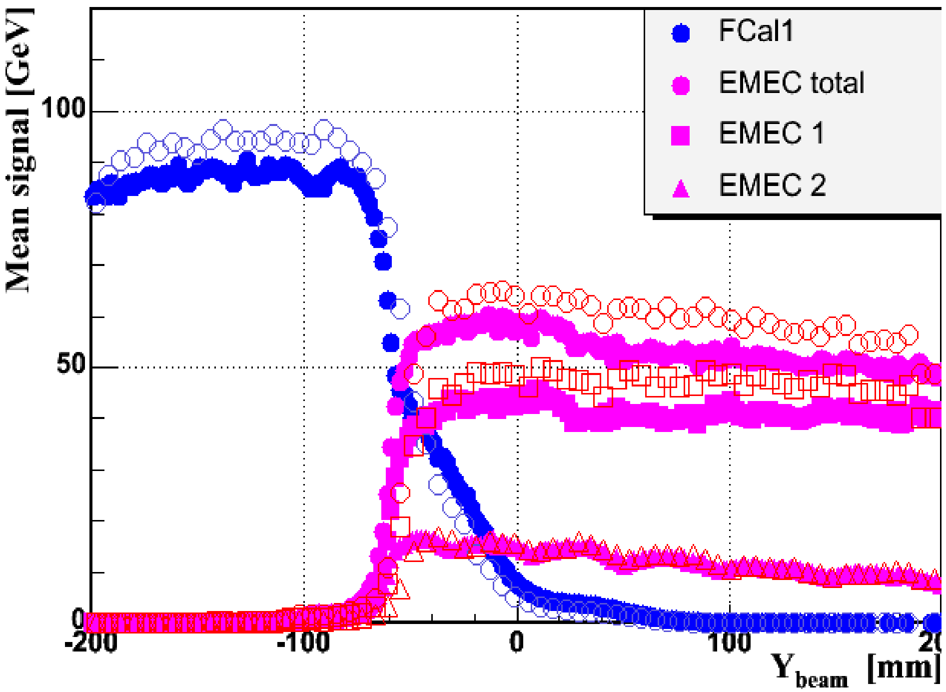
Y-scan of 200 GeV pions over a crack

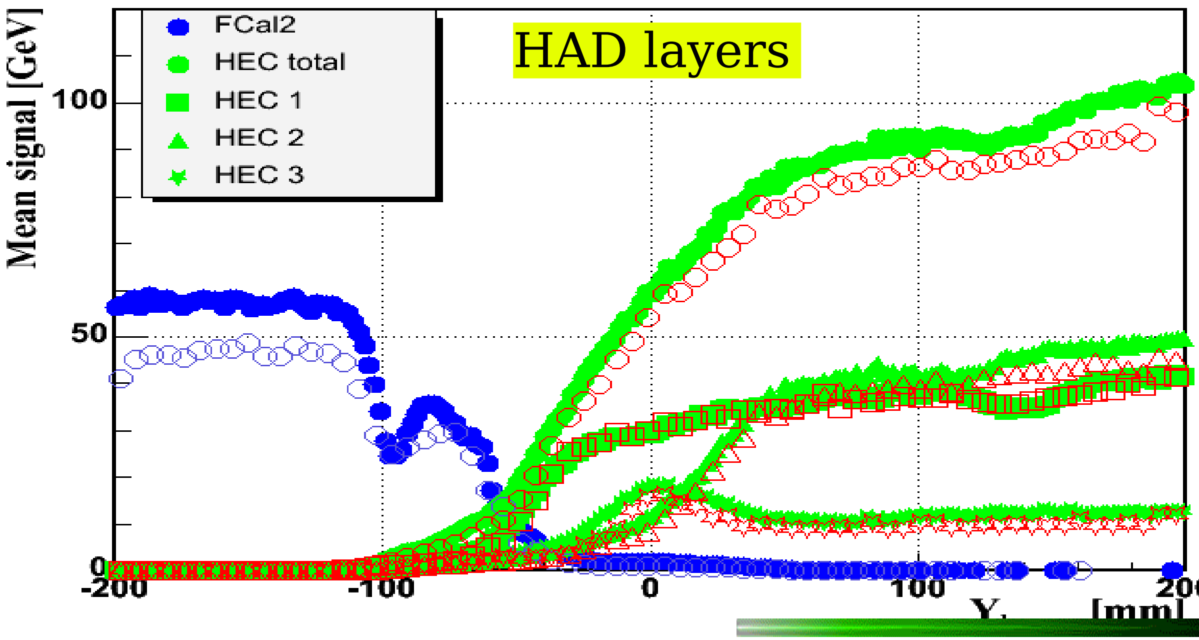
- reasonably well described
- position of standard impact points showed
- MC is QGSP_GN, e.m. scale is fixed with electrons
- hint, that early showering in MC is present here

Total



EM layers

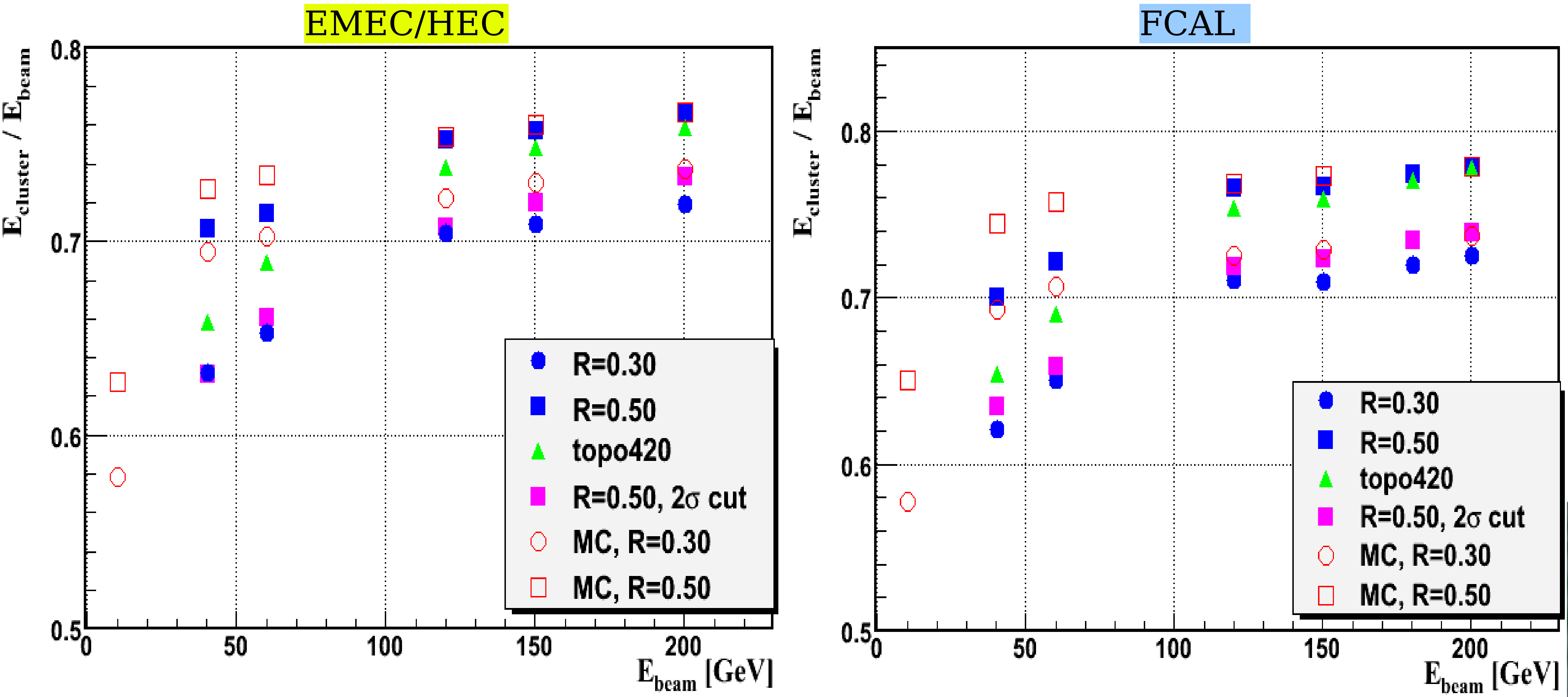




Basic performance for pions:

Linearity of pions in two standard impact points (e.m. scale, MC is QGSP_BERT)

- cone clusters R<0.4, 0.5
- topo cluster 420 and R=0.5 with 2σ cell cut
- reasonably well described for higher energies and larger cluster
- discrepancy seen for lower energies

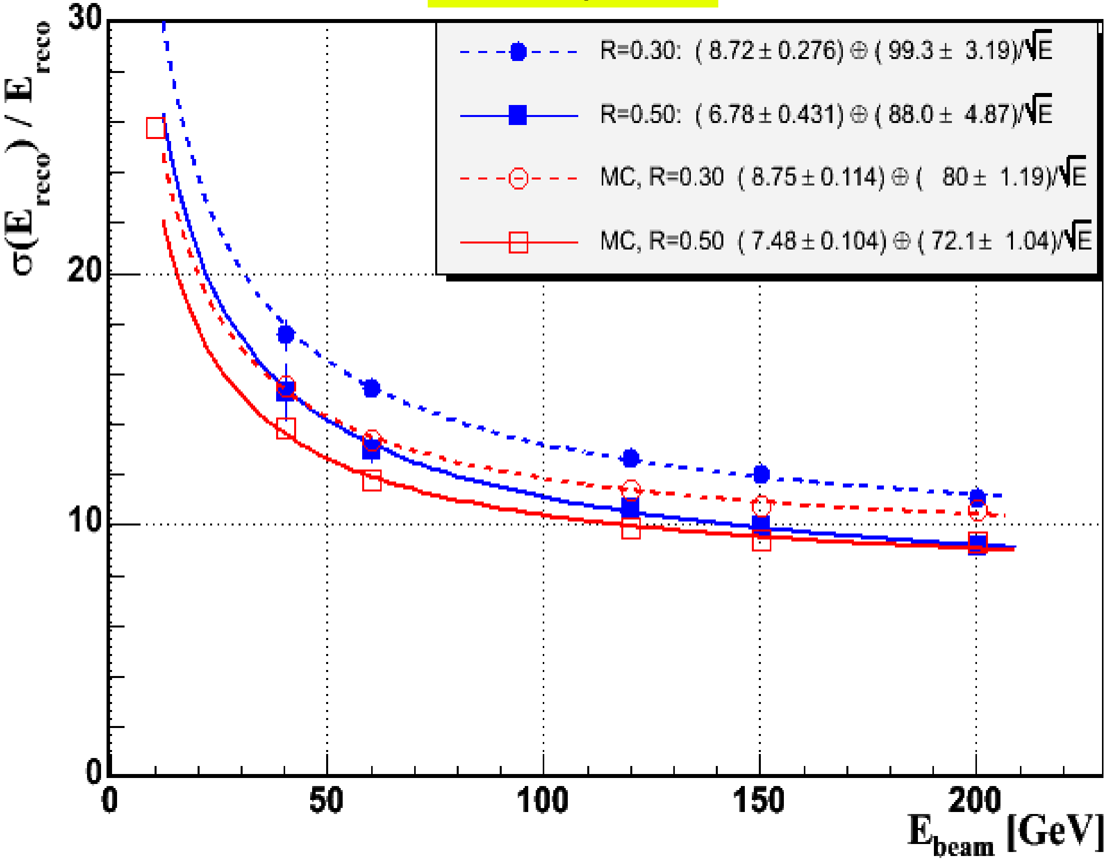


Basic performance for pions:

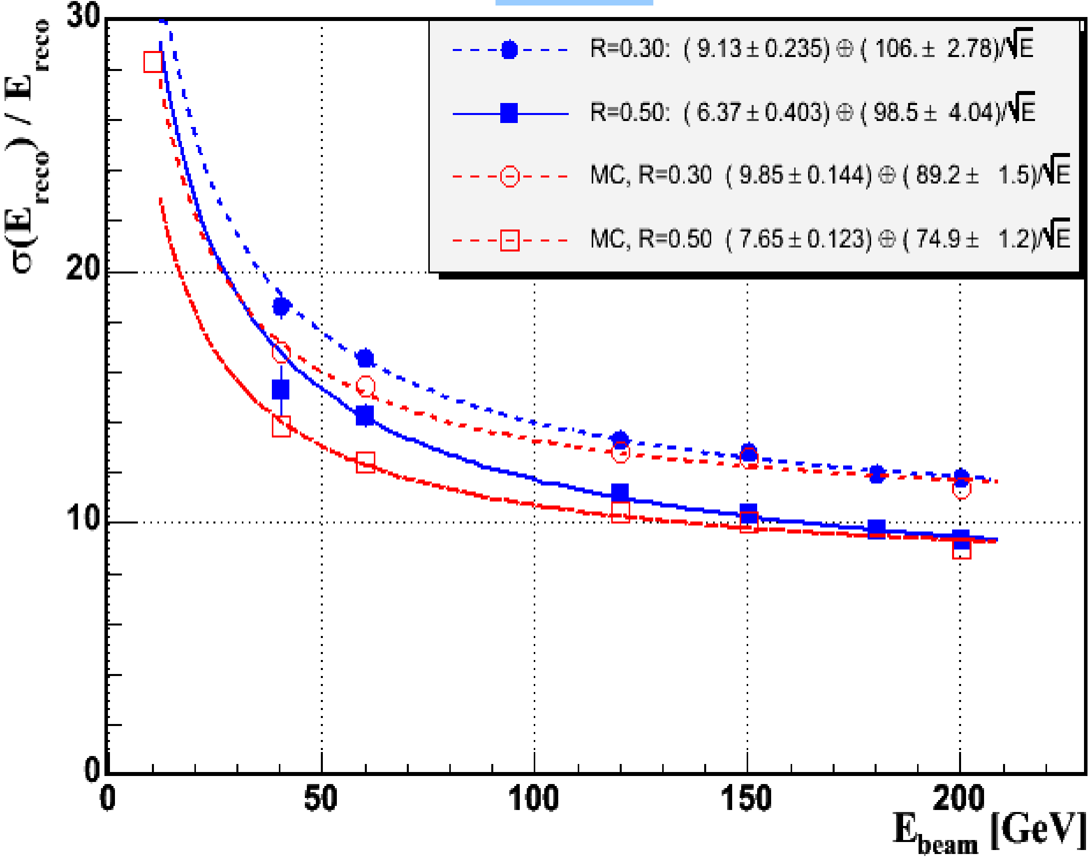
Energy resolution of pions in two standard impact points (MC is QGSP_BERT)

- cone clusters R<0.3, 0.5
- noise subtracted in data - event-by-event estimated for cone, no noise in MC
- one calibration constant per layer in cone
- MC is close for constant term and too optimistic for sampling term - different to HEC TB, there were a good description with G4. (Both QGSP_GN and QGSP_BERT physics lists shows this difference.)

EMEC/HEC



FCAL

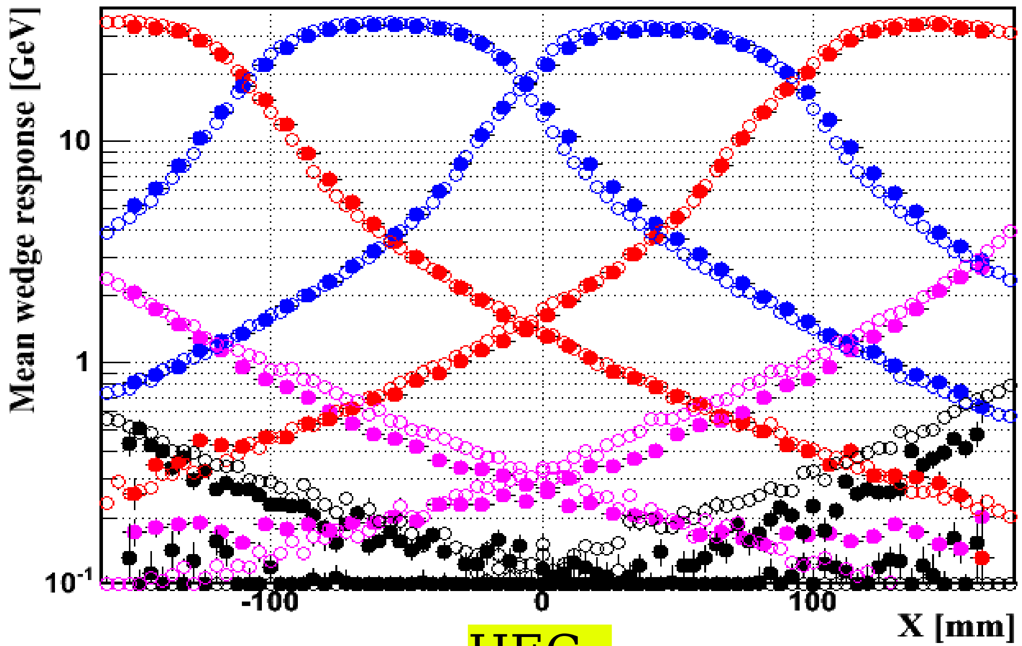


Lateral shower profile:

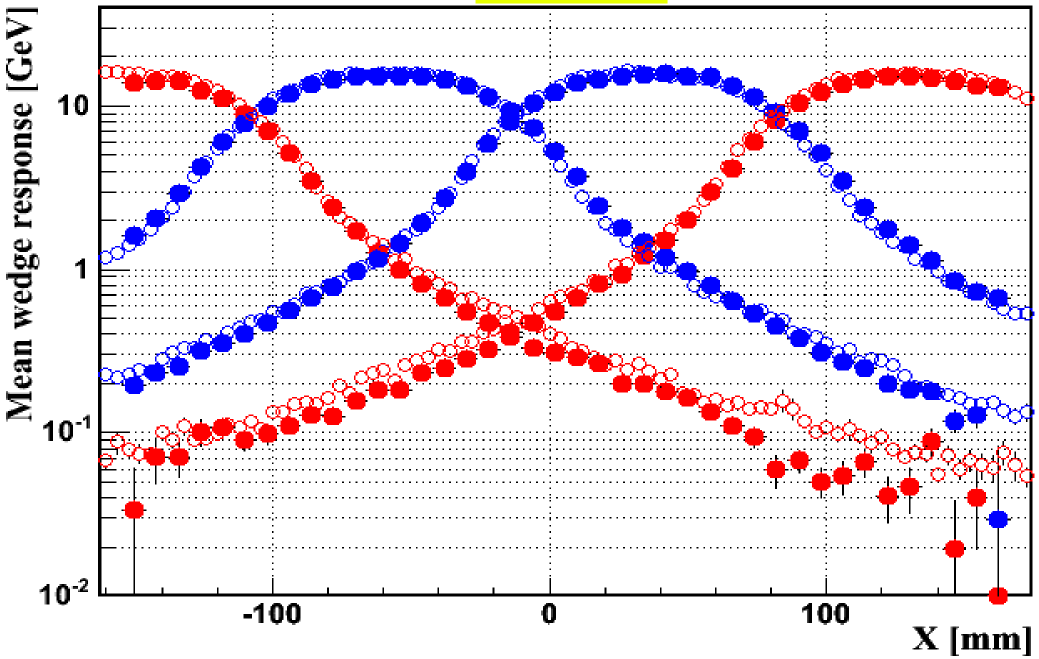
X-scan of 60 GeV pions over a EMEC/HEC region (data are full, MC open symbols)

- each profile is energy summed in one phi-bin
- reasonably well described, small difference on far tails
- MC is QGSP_BERT, still some hint on early showering (EM part slightly more energy on tails, HAD slightly less)

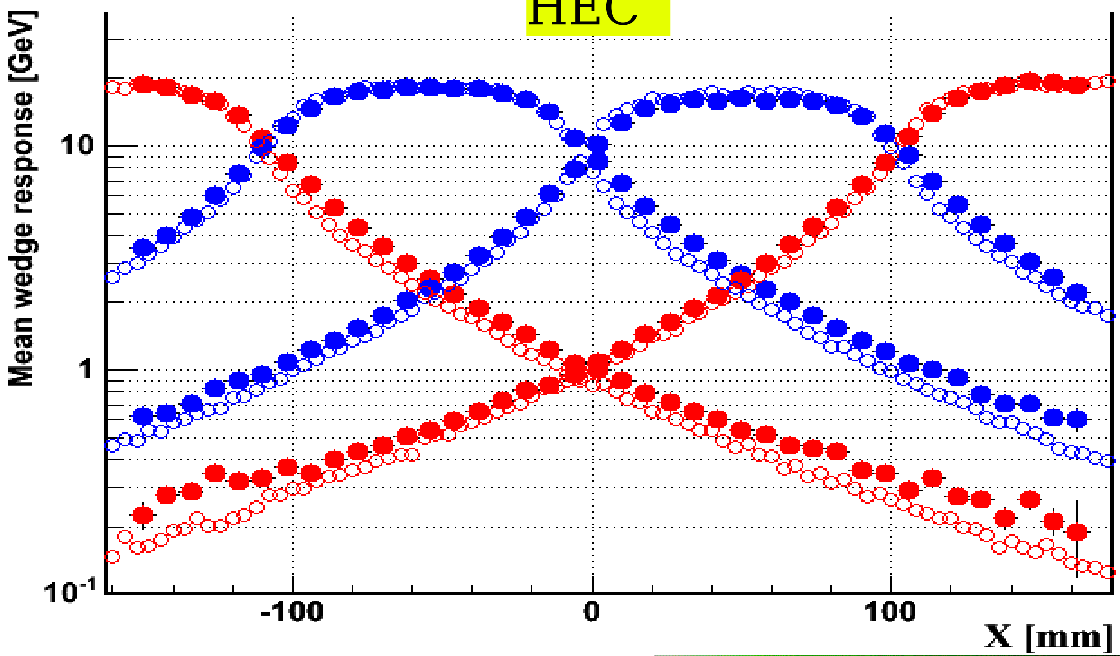
Total



EMEC

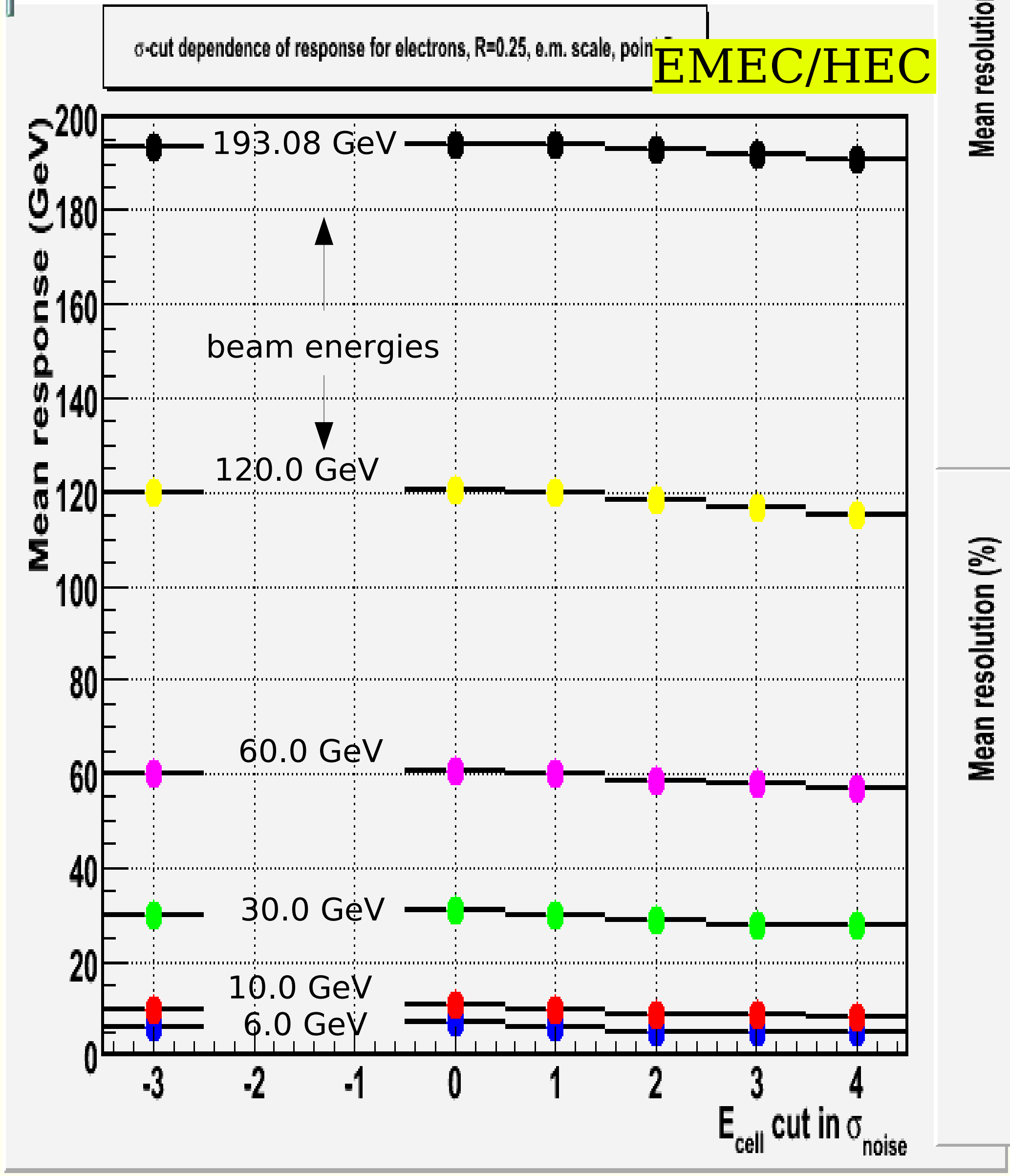


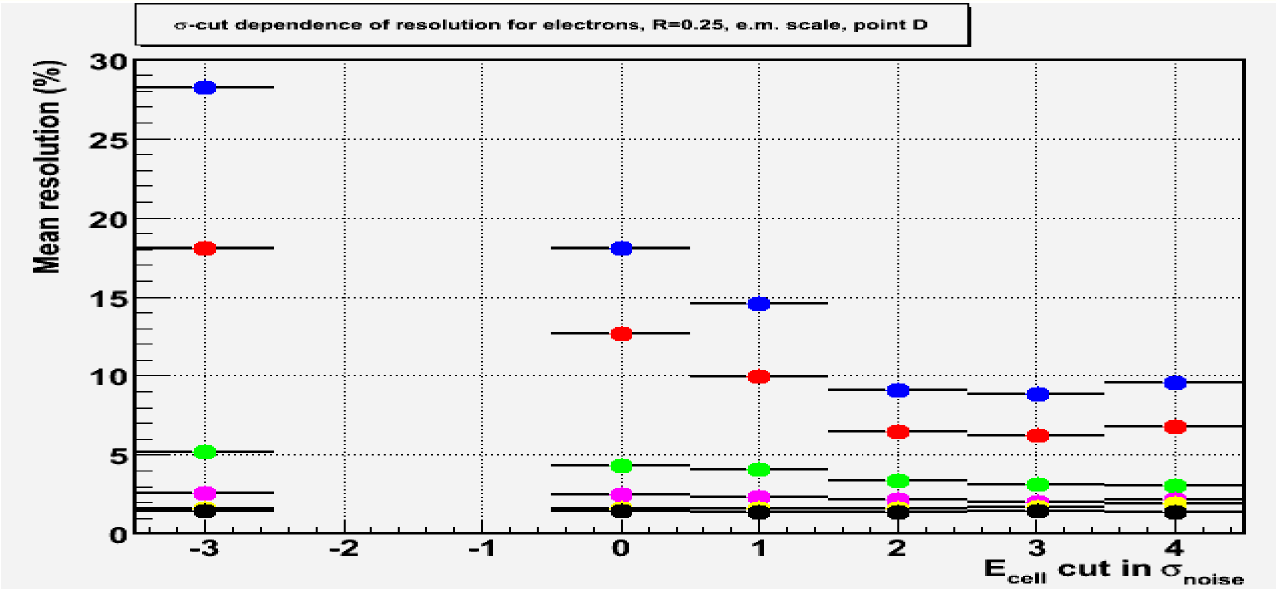
HEC

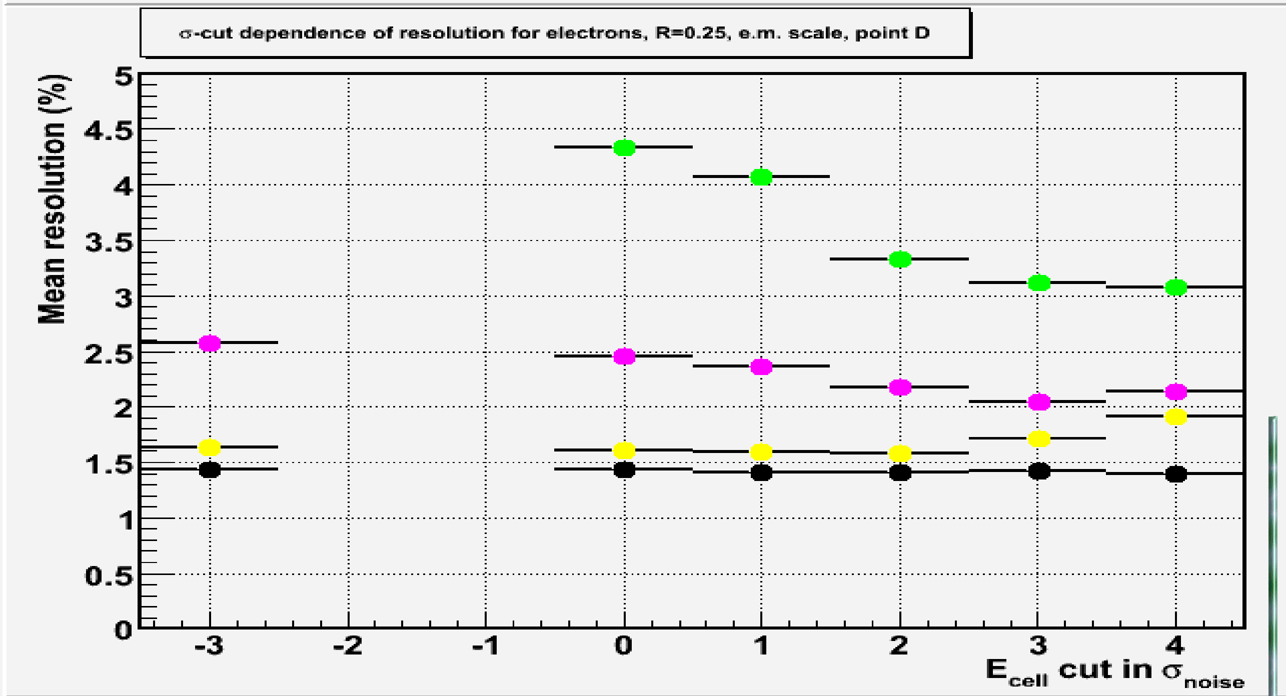


Noise cuts analysis

- scale and resolution for electrons, , -3 means no cut at all:
- resolution optimal ~ 3 σ cell cut

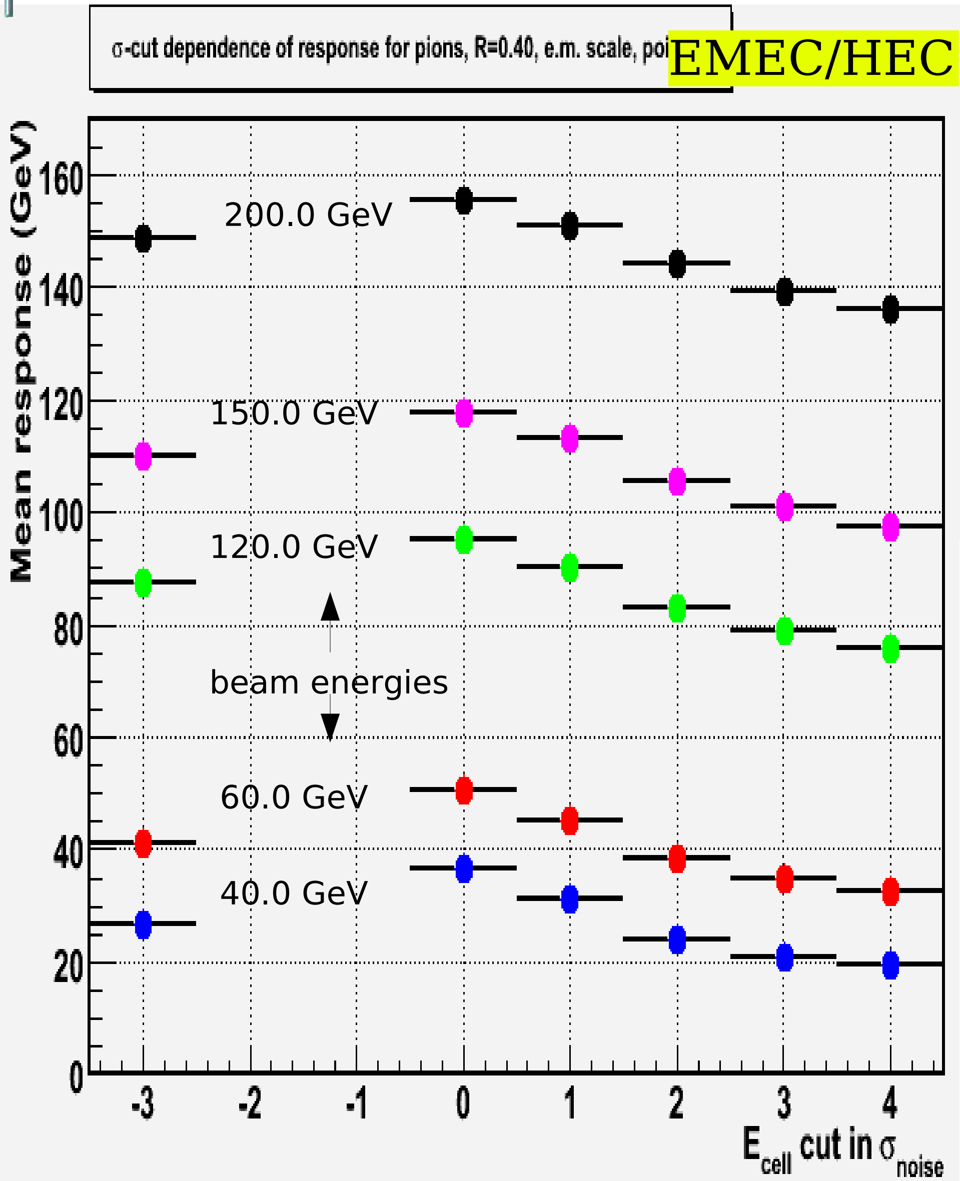


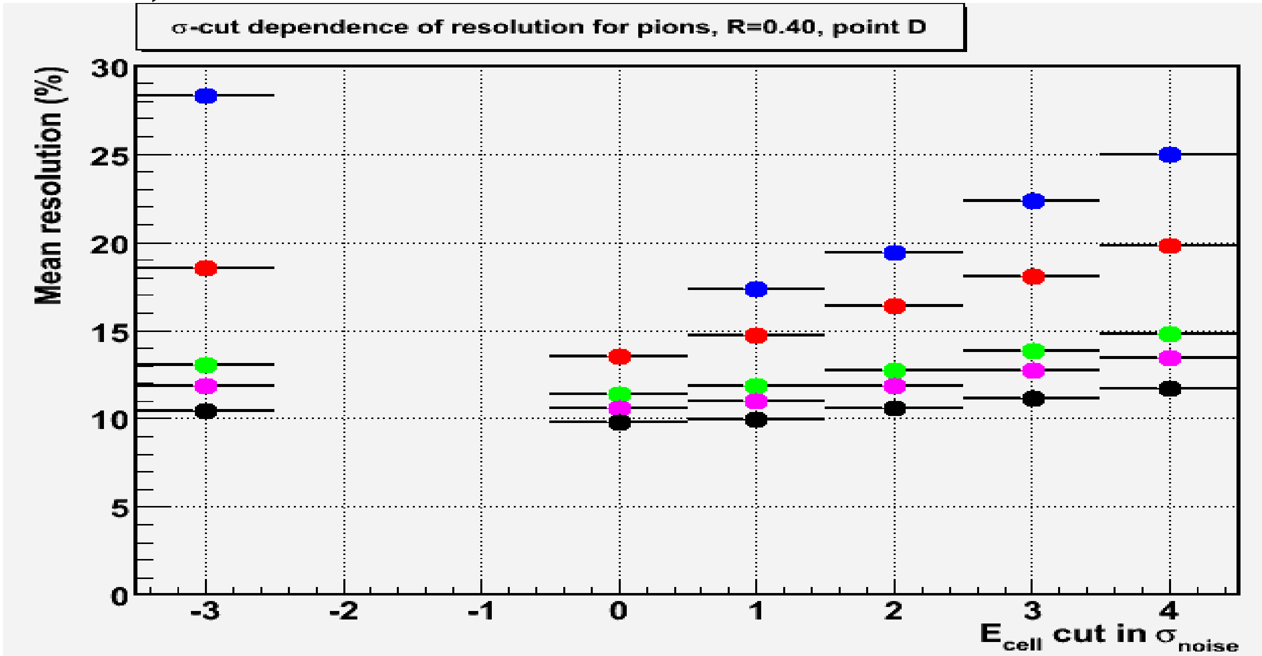


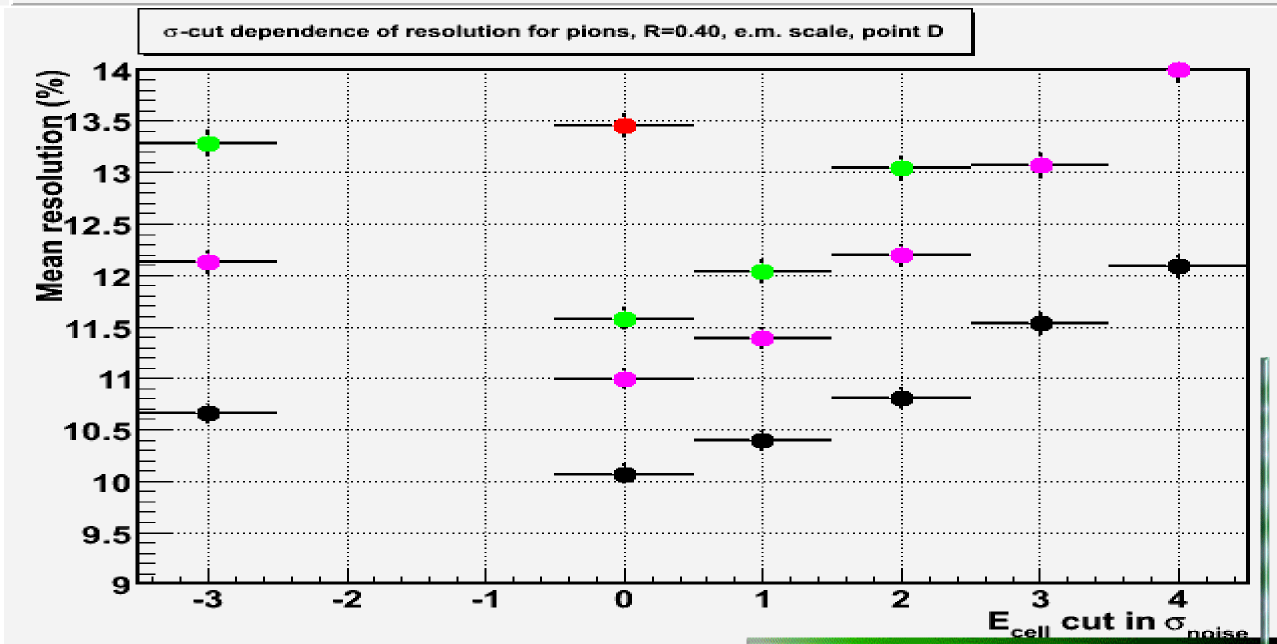


Noise cuts analysis

- scale and resolution for pions (e.m. scale):
- above 0 σ resolution only worser







- Conclusions:
  - Performance of ATLAS LAr Endcap calorimeters in the crack region (2.5 < | η | < 4.0 was studied in beam test, and is basically understood
  - This test closes the extensive program of beam-testing the ATLAS LAr endcap calorimeters modules, started already at 1996
  - Standard parameters of noise, response and resolution extracted
  - Expected parameters for electrons seen, well compared with MC
  - For pions MC does not describe data perfectly (larger response and better resolution) at low energies, quite good description at higher energy
  - Limited acceptance makes results very sensitive to a proper shower description in MC, here QGSP_BERTINI physics list gives better results (not all possible physics list tested yet)
  - First paper accepted for publication in NIM A (describing in more details what was presented here)
  - Next paper will follow, containing the results presented by next speakers