Adding electronic noise and pedestals to the CALICE simulation

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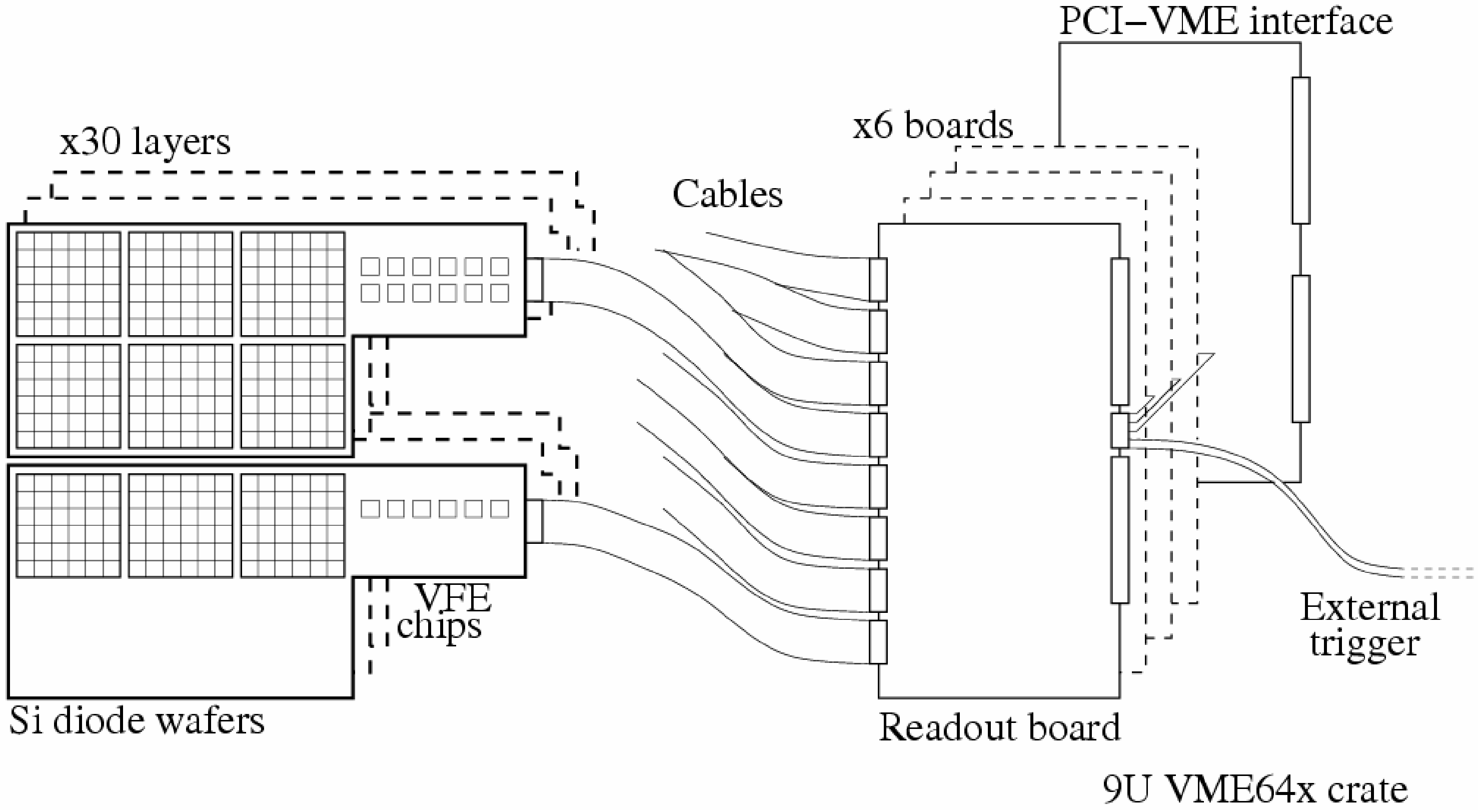
CALICE ECAL electronics readout setup



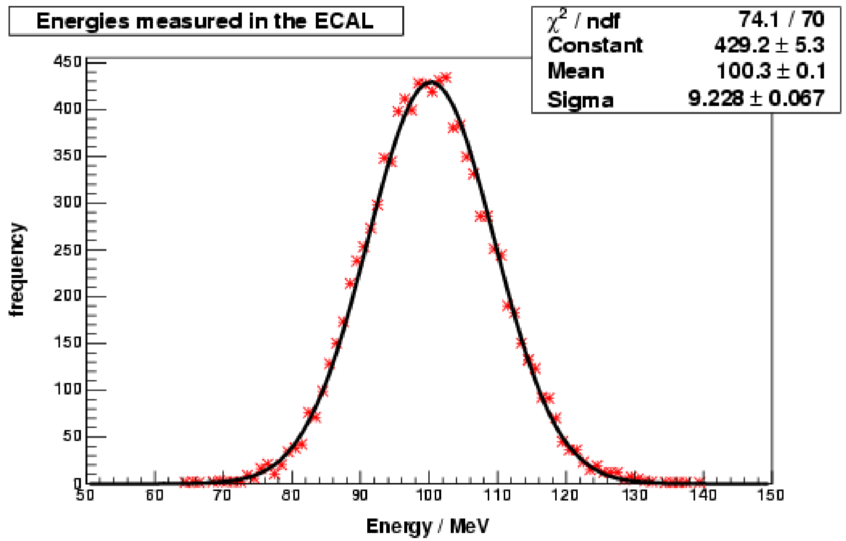
- Each pad on the silicon wafers is read out by a separate channel, 9720 in total, and the signal is digitised
- Will apply a threshold cut per channel to reduce data volume
- Aim to check the effects of analogue noise, digitisation noise and threshold cut on energy resolution

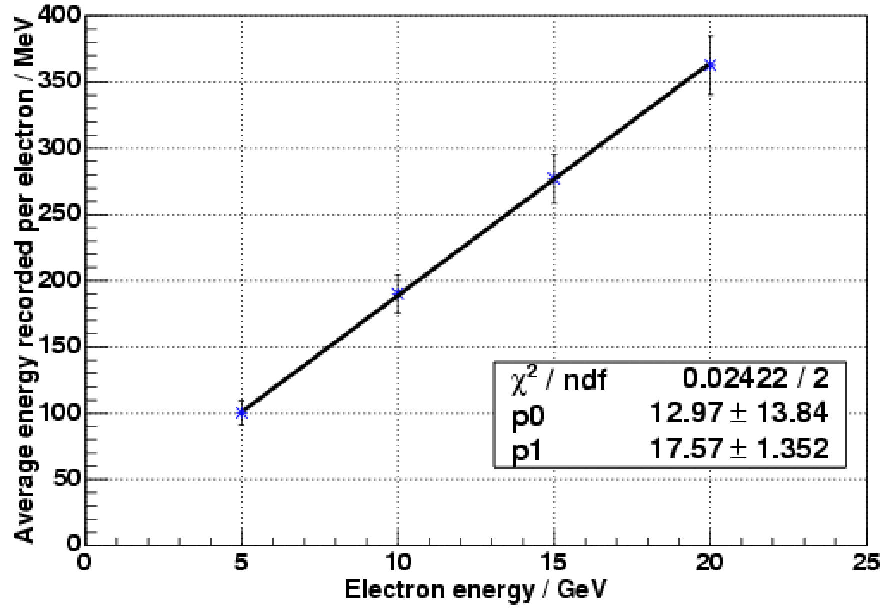
The model for adding the noise

- ADC range: 0 - 65535, 16 bits
- Dynamic range: 200 MeV or 1000 m.i.p.s
- Generate pedestals and noise
- Account for saturation effects
- Digitise the energy in each pad

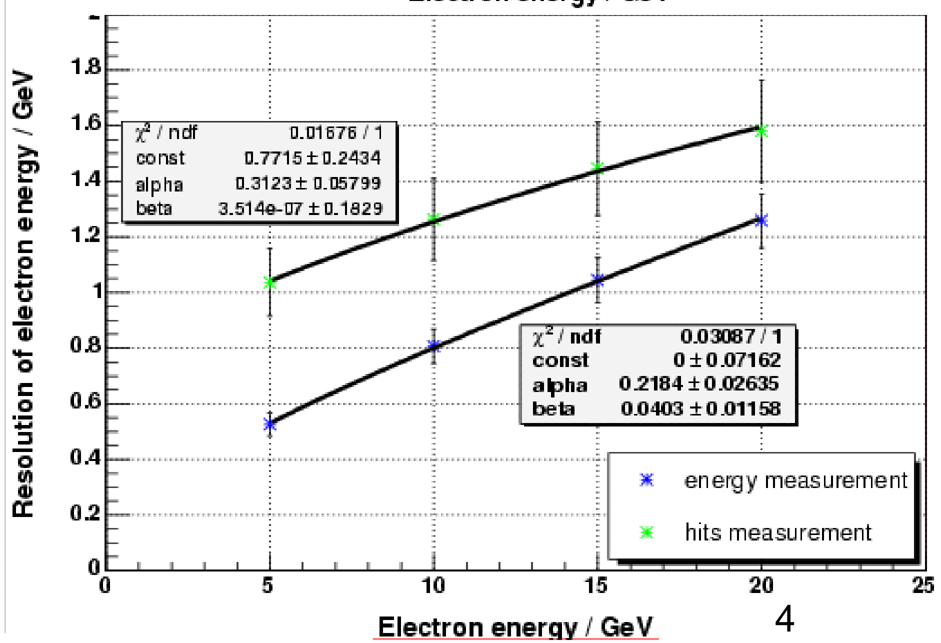
- Generate Monte Carlo from Mokka - without noise
- Set values for average noise and pedestals and their widths (ADC counts)
- Add noise and pedestals to each pad and digitise, retain truth information
- Can choose to apply a threshold to the energy read out from each pad
- Output in same ASCII format as original Mokka files
- Not yet added in other electronics effects e.g. crosstalk, common mode, unique pedestal and noise for each channel…

Energy resolution without noise





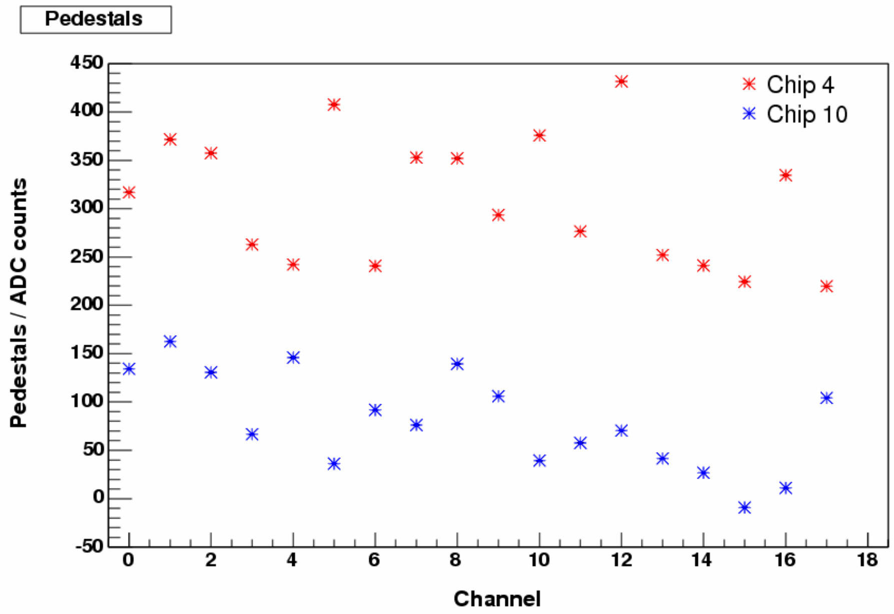
- 10,000 electrons at 5, 10, 15 and 20GeV were generated with Mokka
- Plot distribution of energy measured
- Make calibration curve
- Calculate resolution of electron energy
- For 6GeV electrons: energy resolution = 8.9±1.0 %

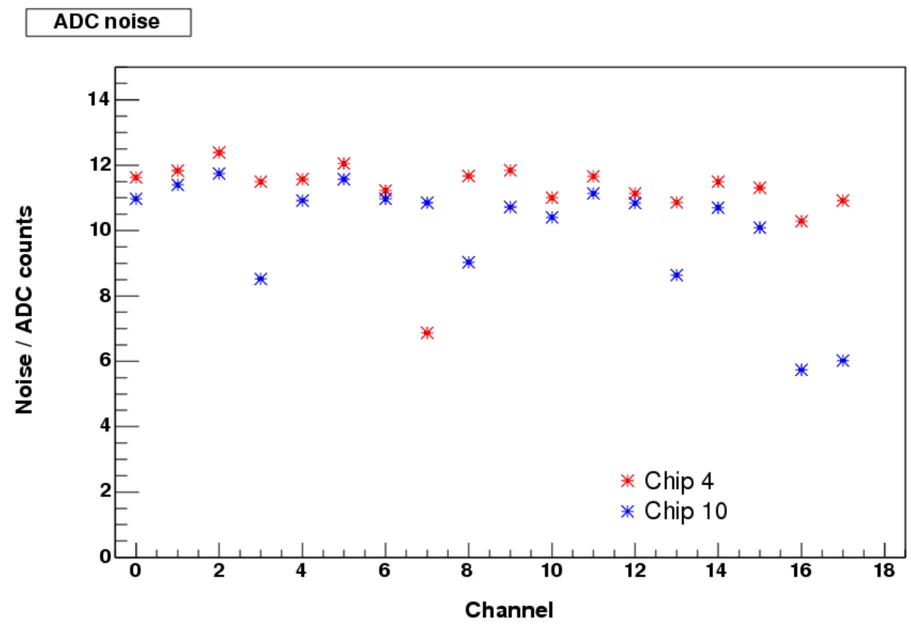


Noise studies performed

- Measure the actual electronic noise and pedestals of the prototype detector
- Using Mokka version 01-05 and the "ProtoEcalHcalScintillator" option, generate 1000 6GeV electrons (DESY test-beam)
- To this sample, the following noise scenarios were applied (ADC range 0 – 65535):
  - DESIGN: ped = 500 ADC noise = 16 ADC (48 keV)
  - PRESENT: ped = 32750 ADC noise = 10 ADC (60 keV)
  - HOPEFUL: ped = 500 ADC noise = 10 ADC (30 keV)
  - WORST: ped = 32750 ADC noise = 25 ADC (150 keV)
- The pad readout threshold was varied from 0.0 – 0.4 MeV
- Plot energy resolution as a function of the threshold
- Plot energy resolution as a function of average ADC noise

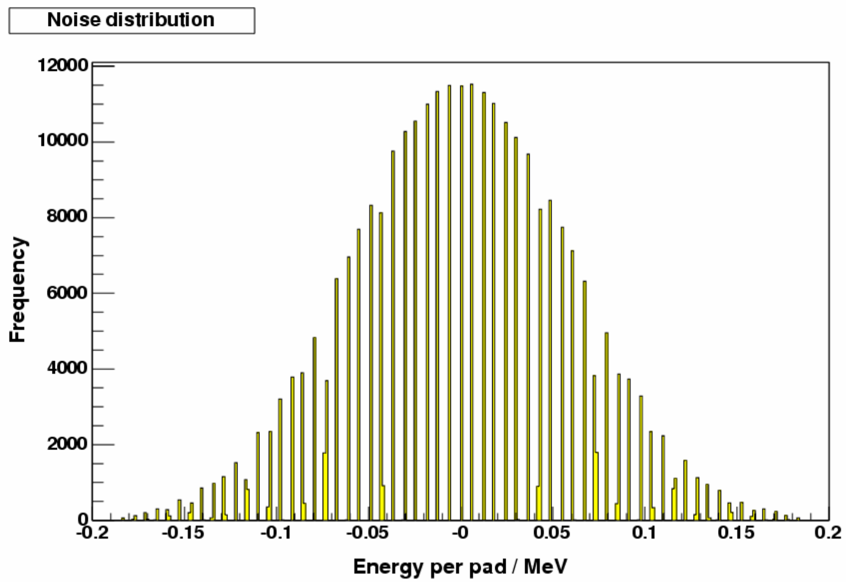
Measurement of the actual noise

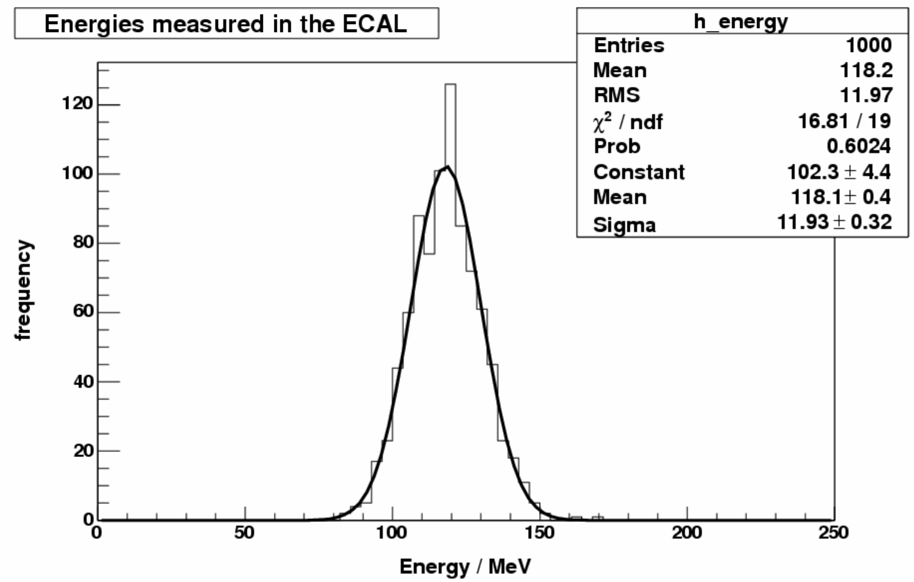




- Two chips, each reading out 18 channels (pads), were connected to a silicon wafer
- Pedestals ~ few hundred ADC counts
  - range: –32768 to +32767 ADC counts → only upper half usable
- Noise ~ 10 – 12 ADC counts (60 – 72 keV)
  - The low noise channels are dead and so were not included in this study

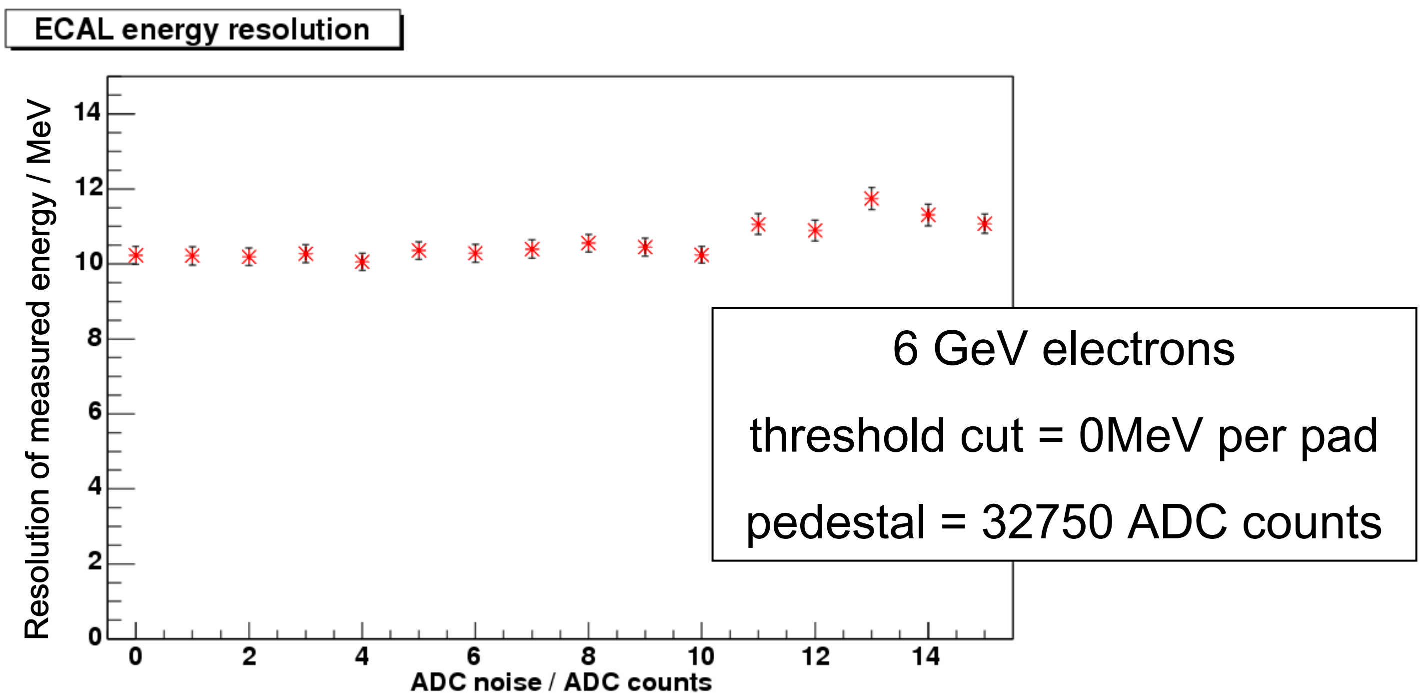
Noise distribution and energy measured in ECAL





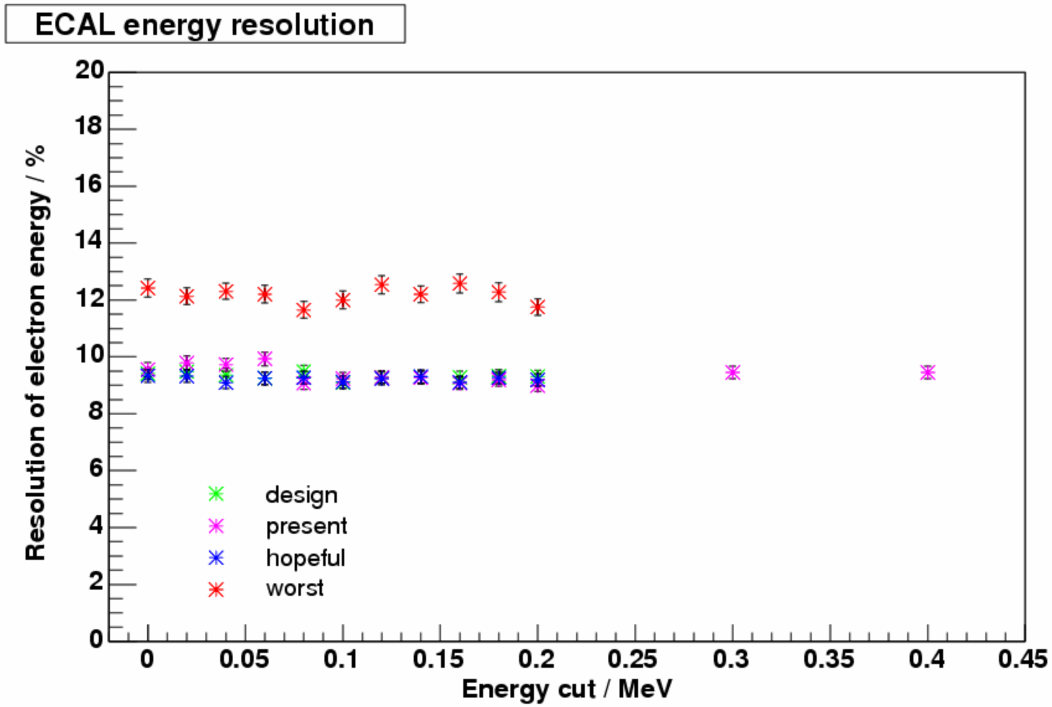
- Digitized noise distribution ('present' scenario shown above) is Gaussian
- Measured energy distribution with average noise = 10 ADC counts (60 keV) and average pedestal = 32750 ADC counts is also a Gaussian distribution, width = 11.9 ± 0.3 MeV (energy resolution ~ 11%)

Resolution as a function of noise



- The above plot shows the width of the total energy distribution measured
- Adding more noise only makes the resolution slightly worse
- Combining ~10,000 channels gives a noise about 100 times the individual noise, which for 10 ADC counts or 30keV is around 3MeV and significantly less than the energy width from the electromagnetic shower process of around 10MeV

Resolution as a function of threshold



- Resolution hardly affected by threshold on energy read out per pad
  - Only around 2% of the energy is in pads whose energy recorded is less than 0.2MeV, so cutting these out hardly affects the total energy measured
- Resolution ~ 9-10% - very close to that with no noise (8.9%)!

Summary of results

- Worst case (ped = 32750, noise = 25 ADC counts or 75 keV):
  - Energy resolution around 12%
  - Hardly changes as pad threshold is increased
- Present day (ped = 32750, noise = 10 ADC counts or 30 keV):
  - Energy resolution around 9-10%
  - Hardly changes as pad threshold is increased
- As noise is increased from 0 to 15 ADC counts, the resolution only worsens slightly

Next steps

- Accurate measurements of noise and pedestals for each channel
- Additional features:
  - Crosstalk between readout channels
  - Common noise
  - Unique noise and pedestals for each pad of real silicon wafers