Preliminary results of the *Trento Proton Therapy facility* test for microstrip silicon sensor

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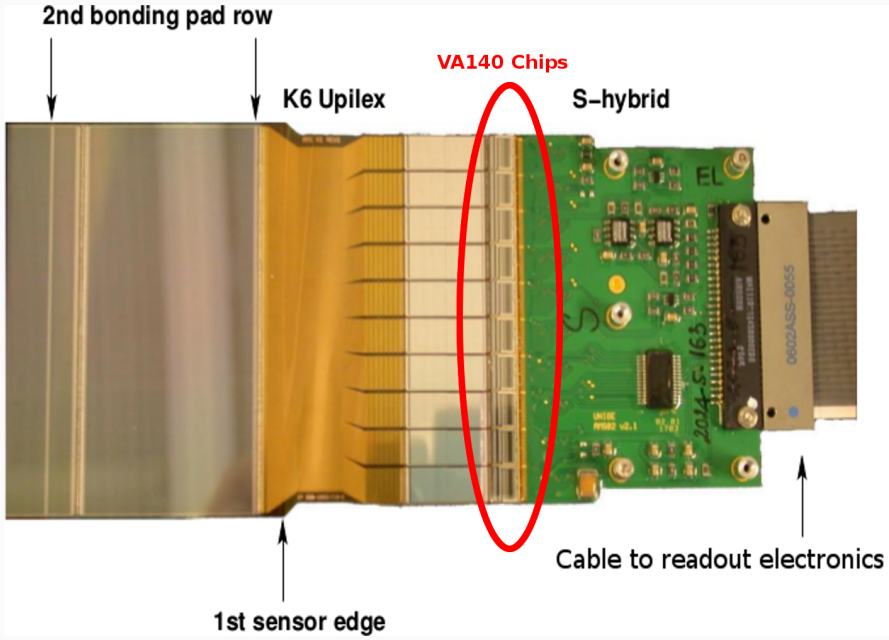
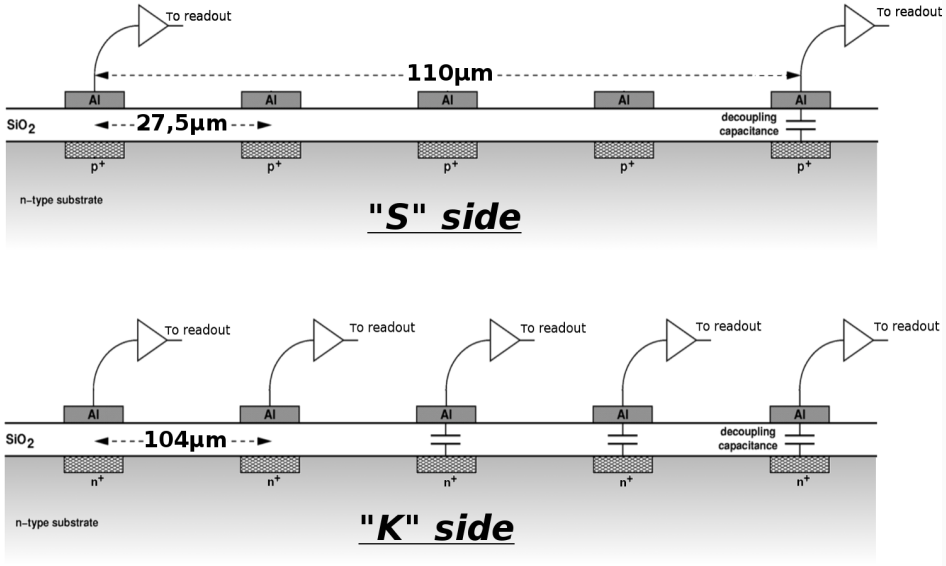
Sensor used





- Silicon sensor dimensions: approx. 4x7 cm^2
- Thickness: approx. 300 μm
- Number of strips on "S" side: 2568, of which 640 are read-out (1 in 4)
- Implantation pitch on "S" side: 27.5 μm, readout pitch of 110μm
- Number of strips on "K" side: 384, all read-out
- Implantation pitch on "K" side: 104μm

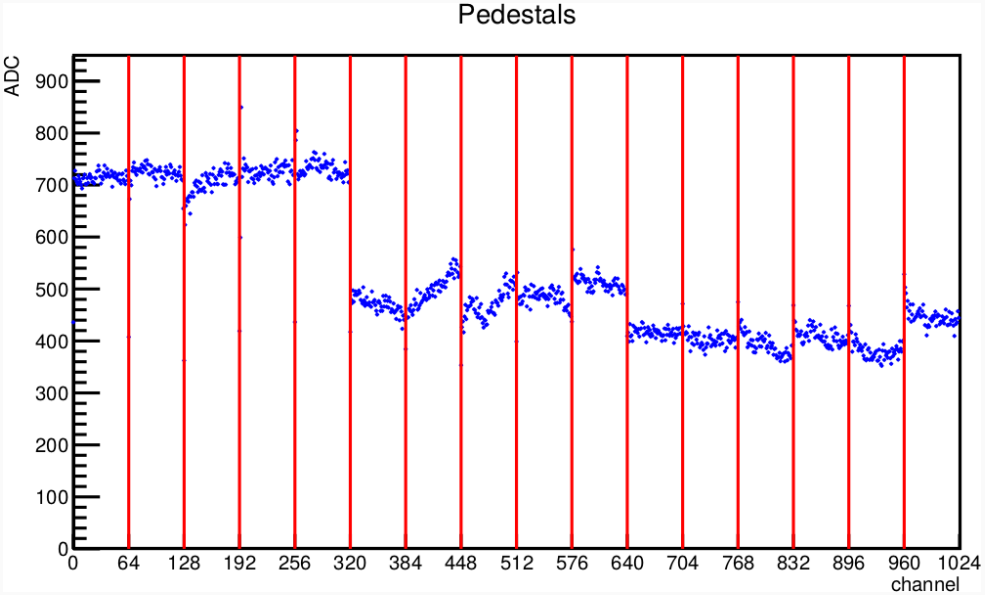
Sensor electronics

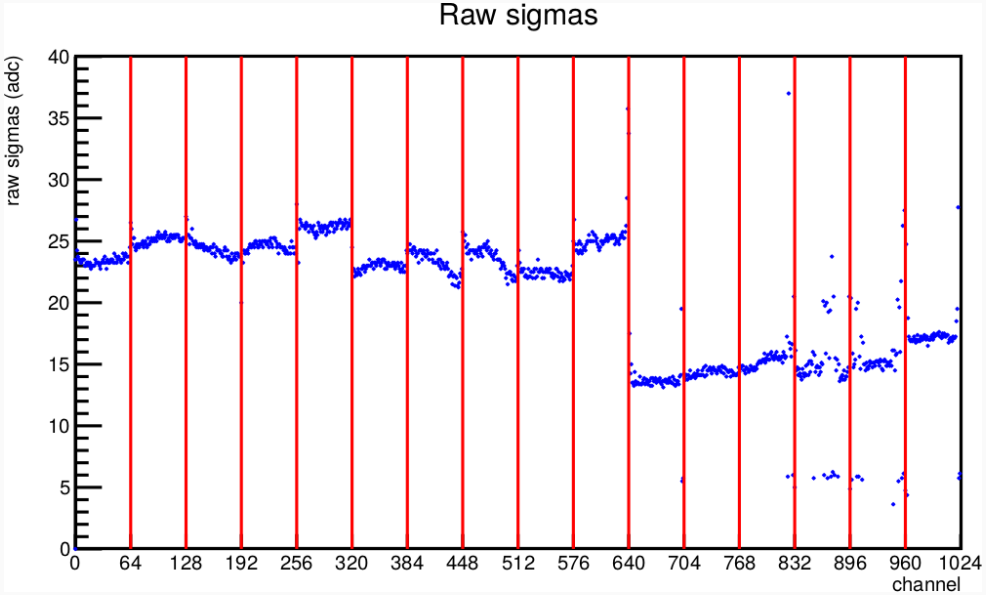
Tabella 1: Main features of readout chip VA140 as specified by IDEAS

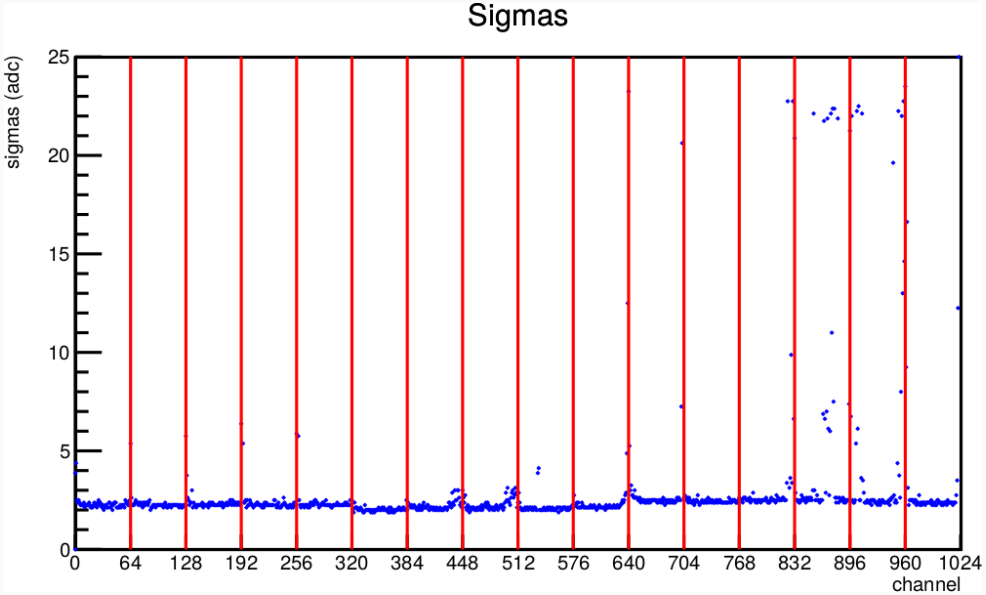
Detectors	Silicon (Si)
Application	Imaging, Spectroscopy, Calorimetry
Number of inputs	64
Input charge range	$\pm$200 fC
Shaping time	5 μs to 8 μs
Nominal capacitive load	50 pF
Equivalent Noise Charge (ENC)	98e + 6.5e/pF
Outputs	Multiplexed pulse height
Test and calibration	Internal calibration circuit
Power consumption	0.29 mW / channel

- Low noise chip with high dynamic range
- Typical noise of VA chip alone: $\approx$ 1 ADC
- Typical total noise of the whole sensor: $\approx$ 3 ADC

Sensor calibrations







For every channel we can define:

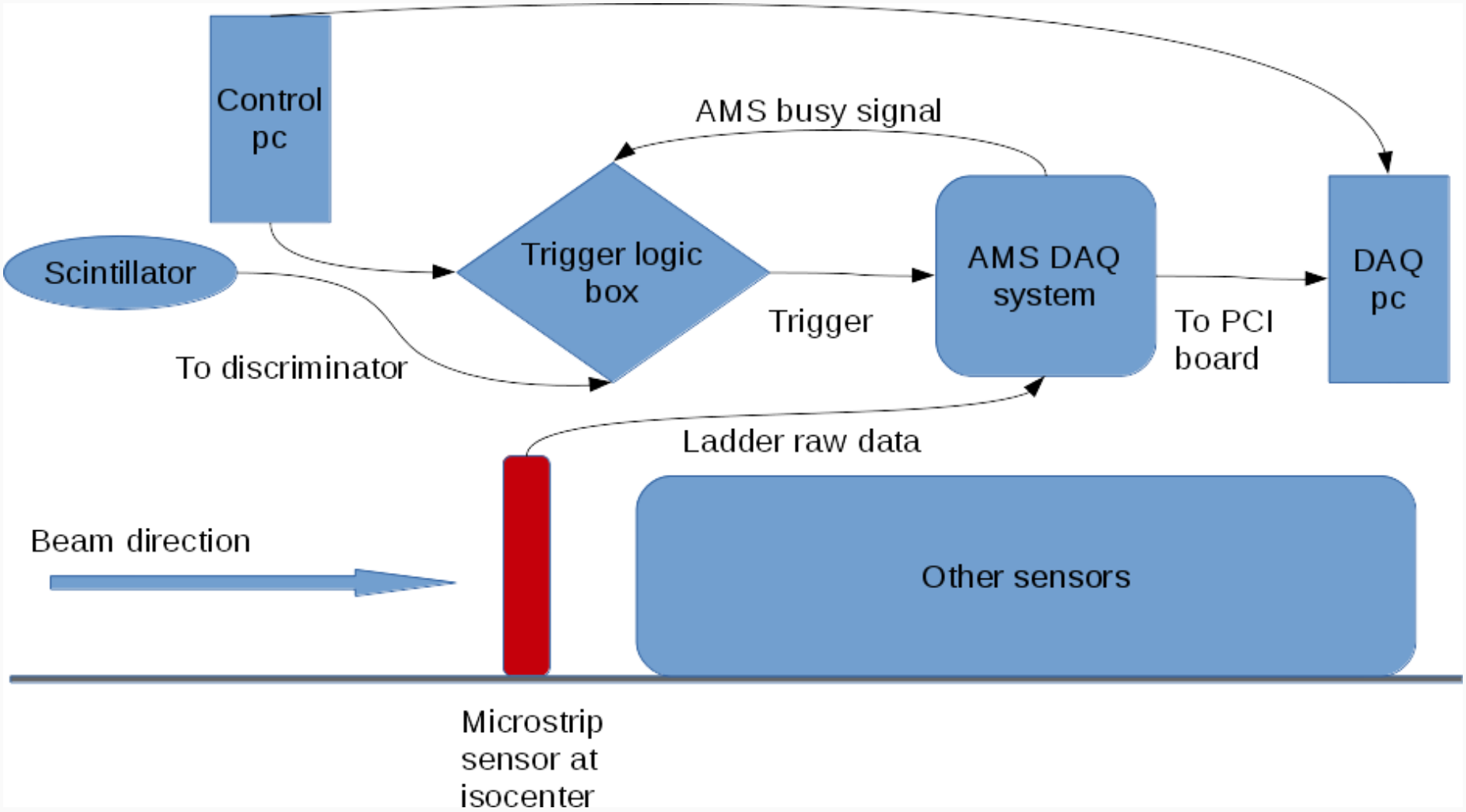
- Pedestals: ADC value with no real signal
- Sigma raw: pedestals variance

$$\sigma_j = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(ADC_{ij} - ped_j)^2}$$

- Sigma: pedestals variation taking into account *Common Noise* mode of the whole chip

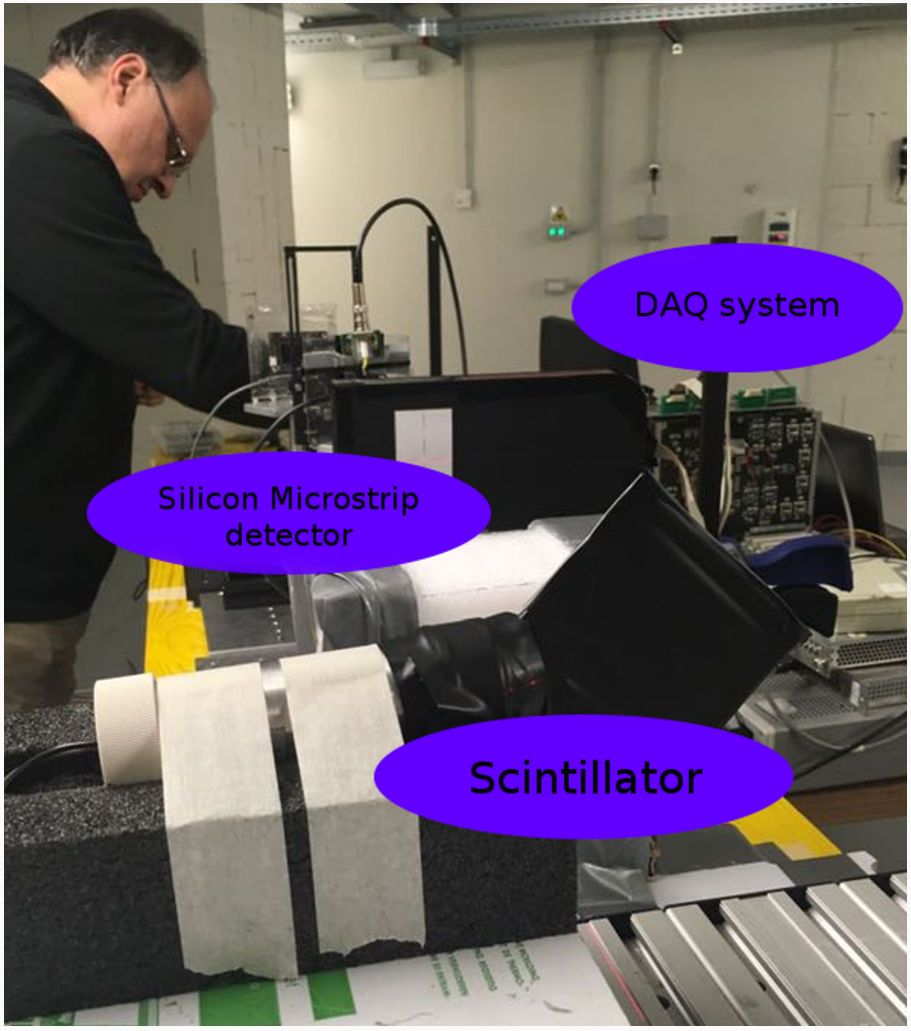
$$\sigma_j = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(ADC_{ij} - ped_j - CN_j)^2}$$

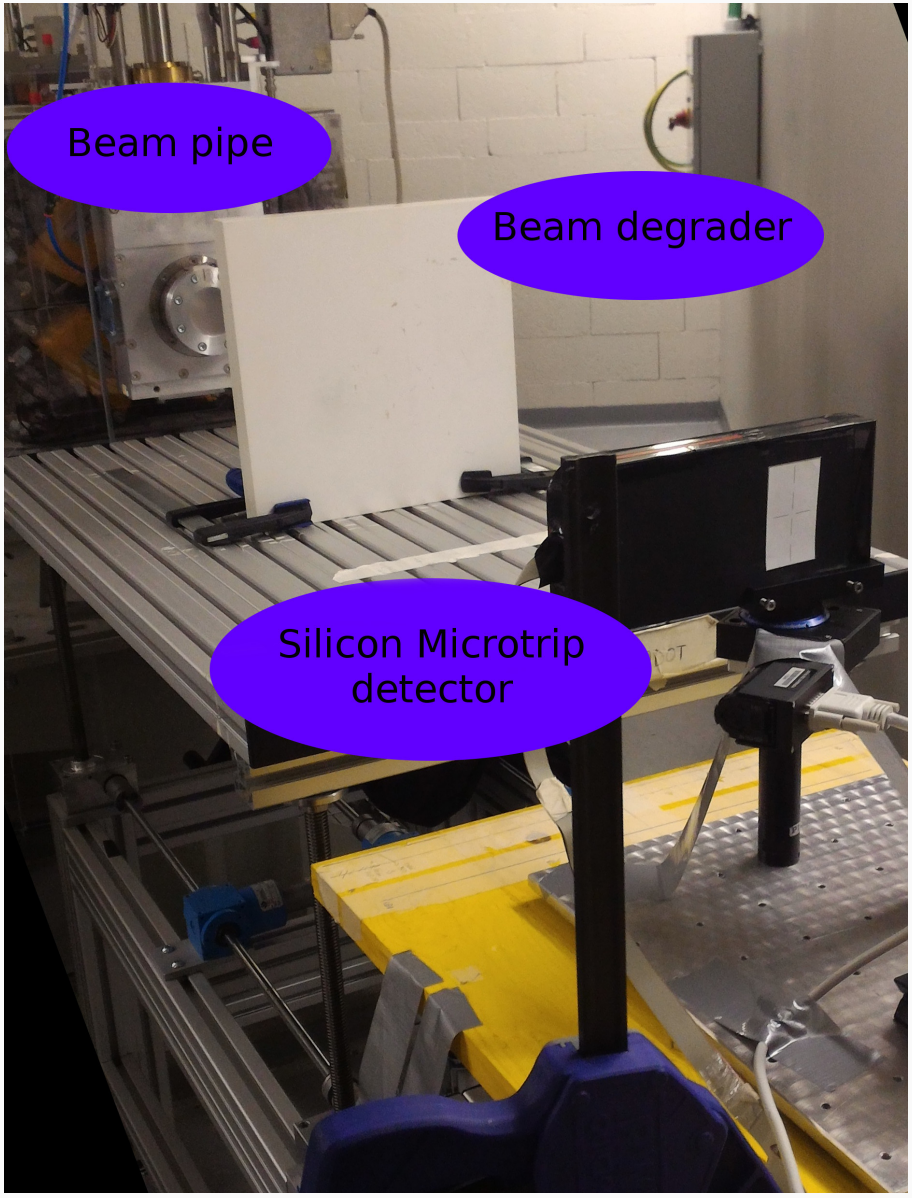
Setup used in Trento



- Test at the *Trento Proton Therapy facility* in December 2017
- Silicon microstrip sensor derived from the ones used in *AMS* experiment
- Sensor positioned at the isocenter
- Proton beams at 7 different energies: 50MeV, 70MeV, 80MeV, 112MeV, 159MeV, 200MeV, 228MeV

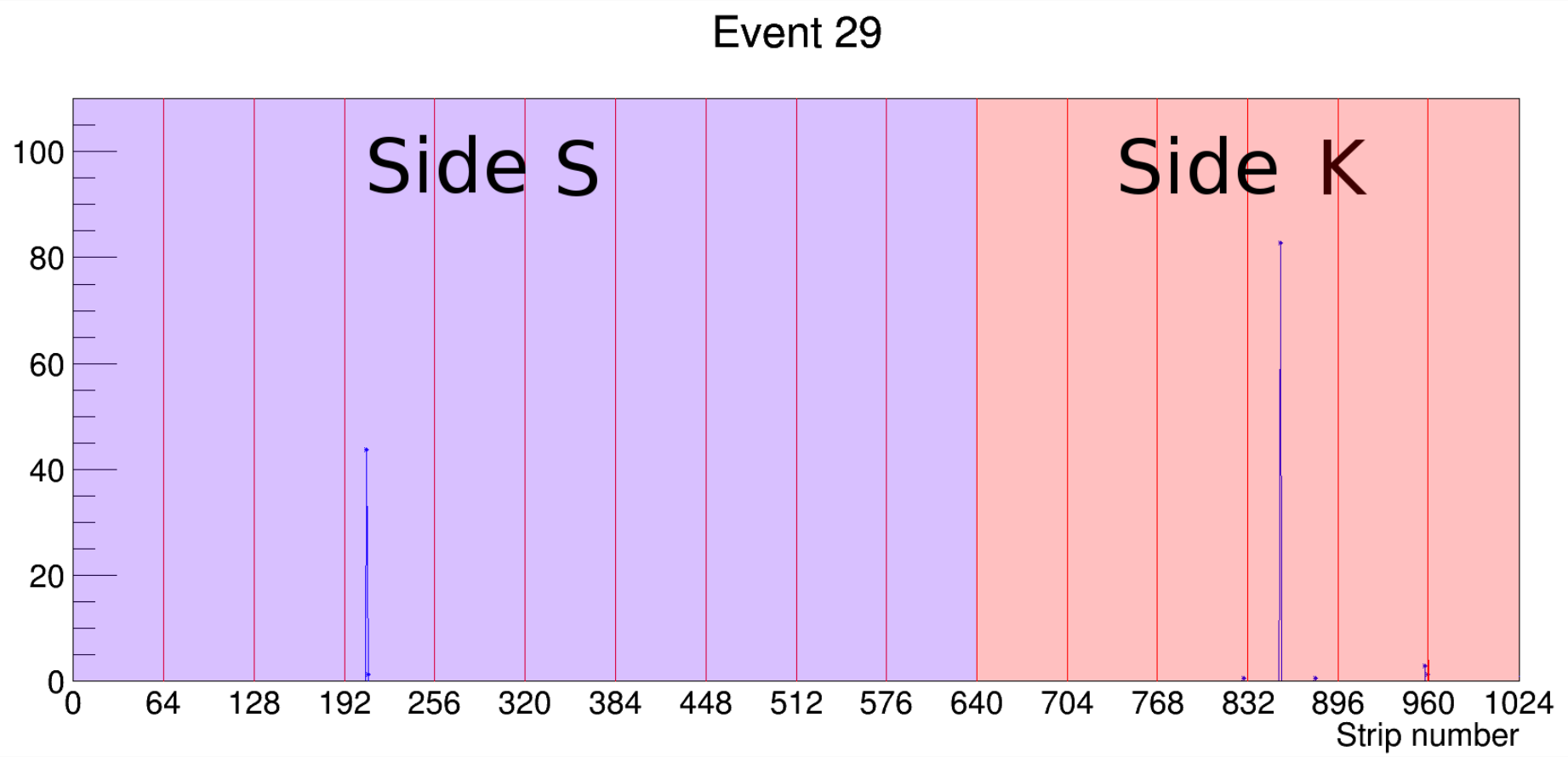
Setup used in Trento





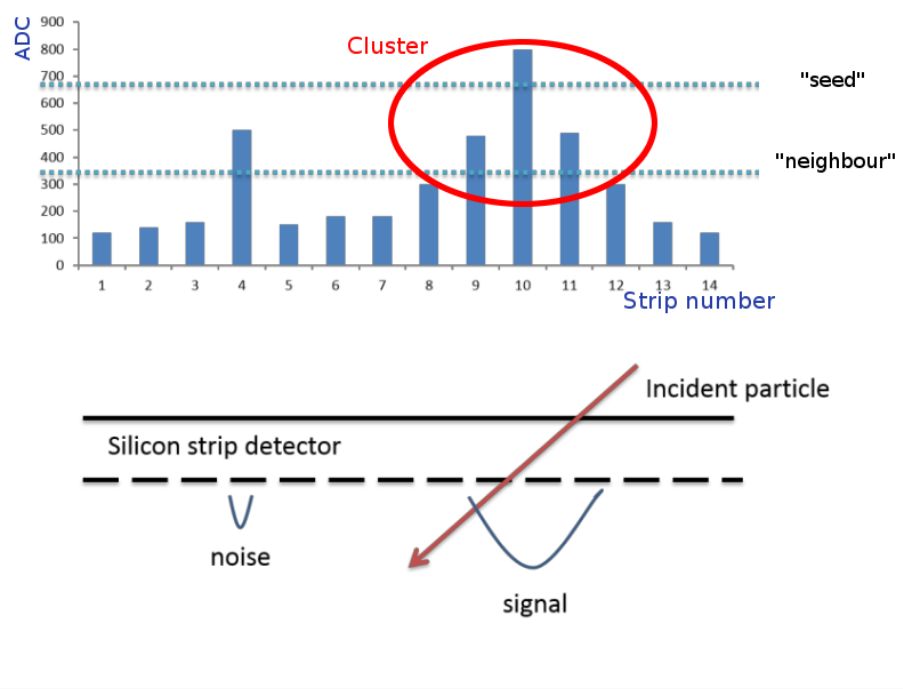
Goal of the test: *use low energy beam data to investigate possible saturation effects of the electronics*

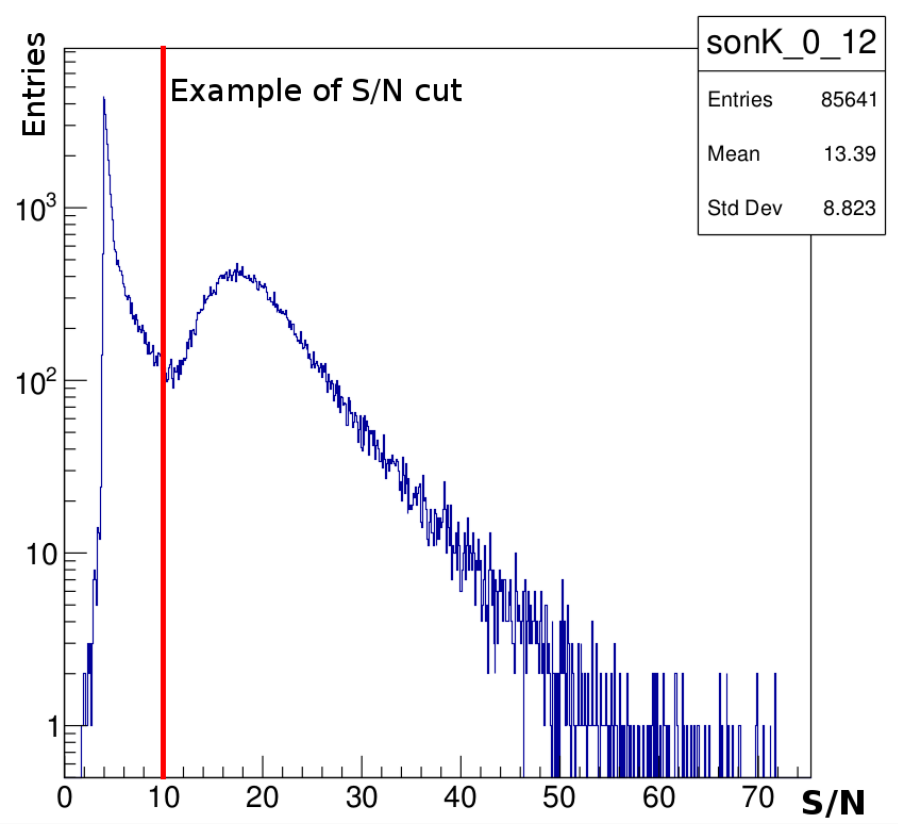
Example of a raw event



- Raw data of each strip is acquired during each event
- Clusters recontructed from raw data of all strips each event
- We search for a cluster seed strip seed and all *"neighbour"* strips

Signal reconstruction



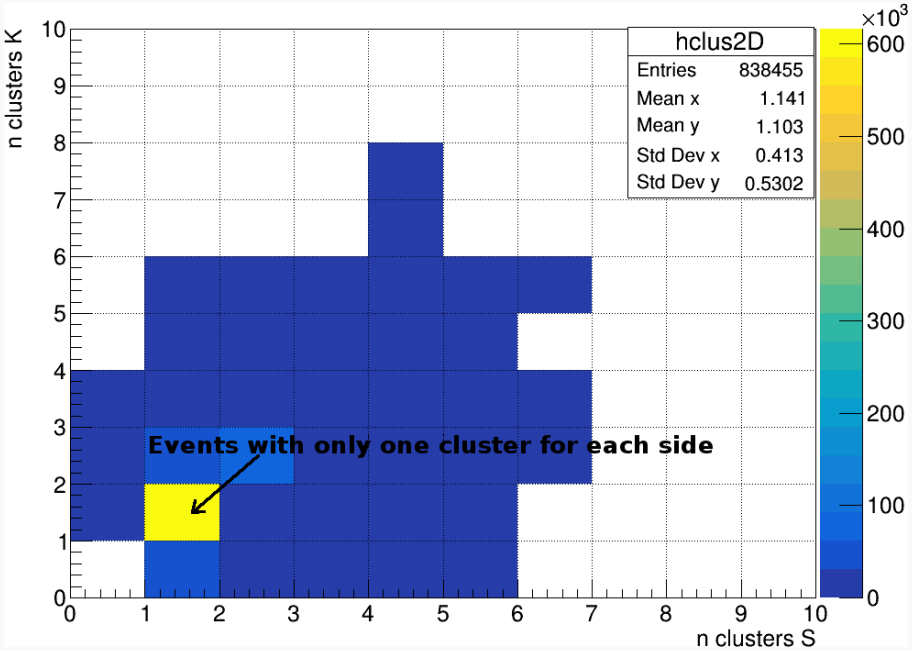


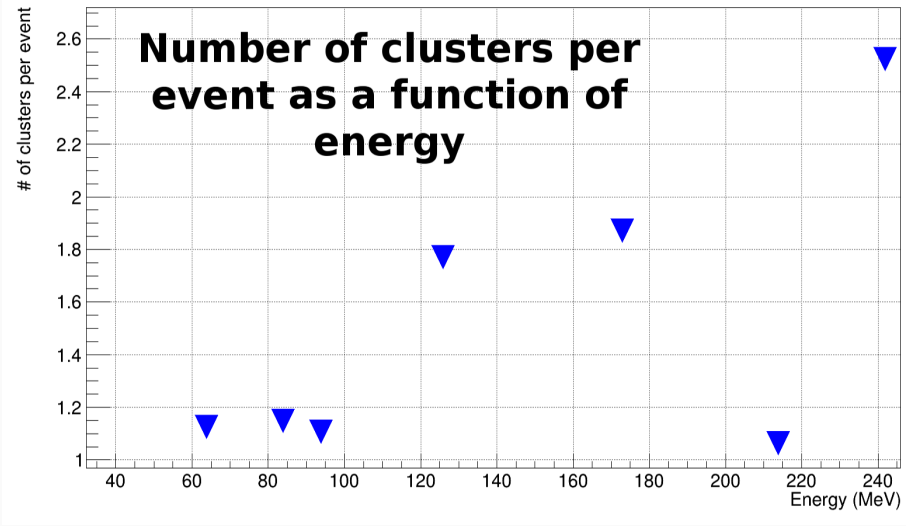
- Thresholds depends on S/N (ADC of strip / fluctuation of the strip value with no signal)
- Particles that are not at minimum of ionization require different threshold than the ones of a MIP

Analysis parameters

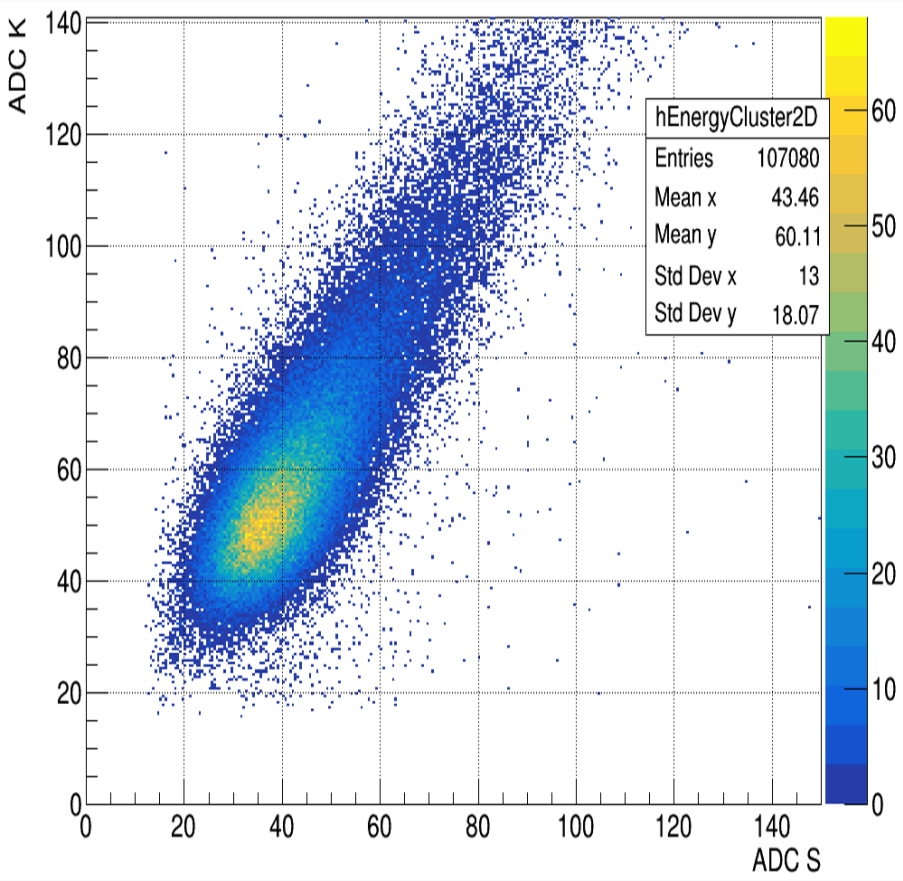
Constraints used for data analysis:

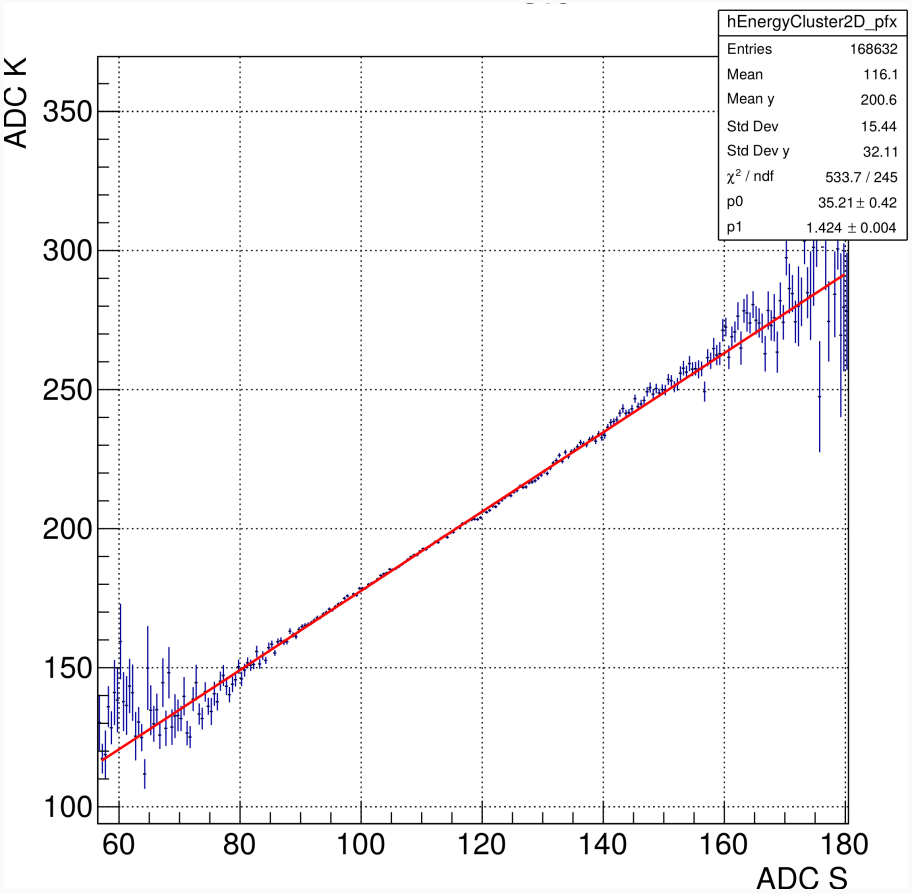
- Events with a single particle: only one cluster for each side
- Analysis restricted only to "K" side: better charge collection given readout scheme used
- "S" side used as a check on the event selection
- Analysis restricted to each VA





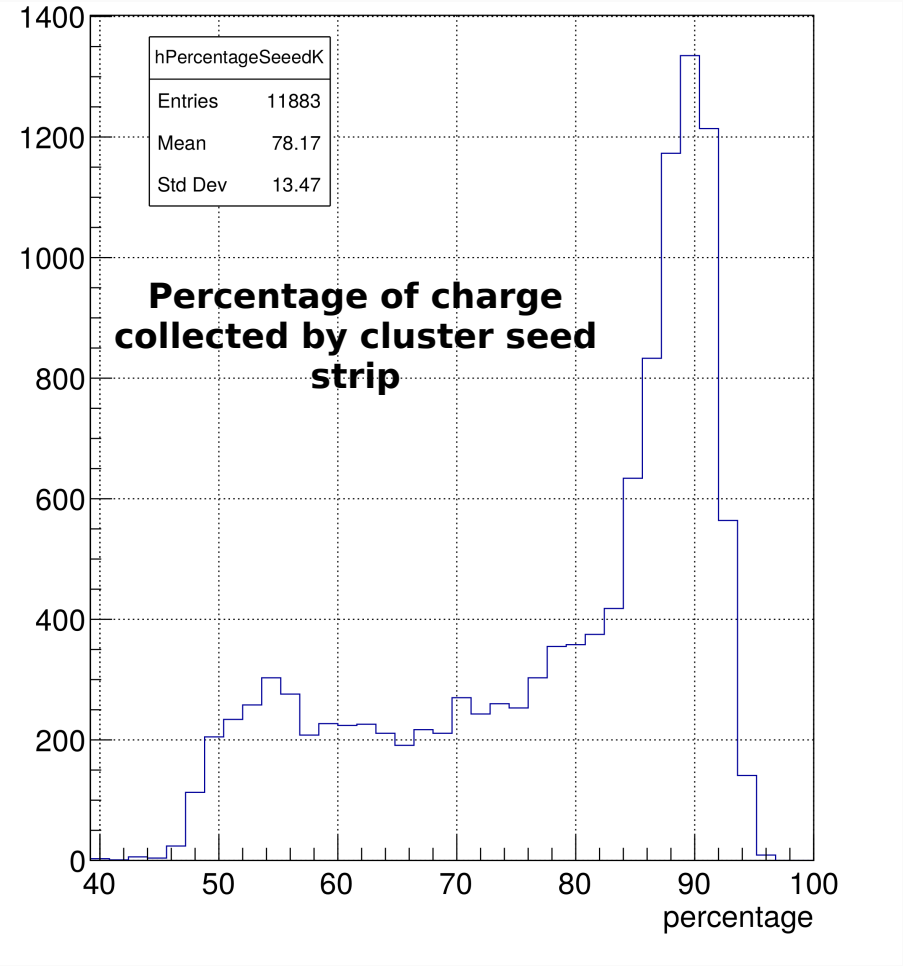
Charge correlation

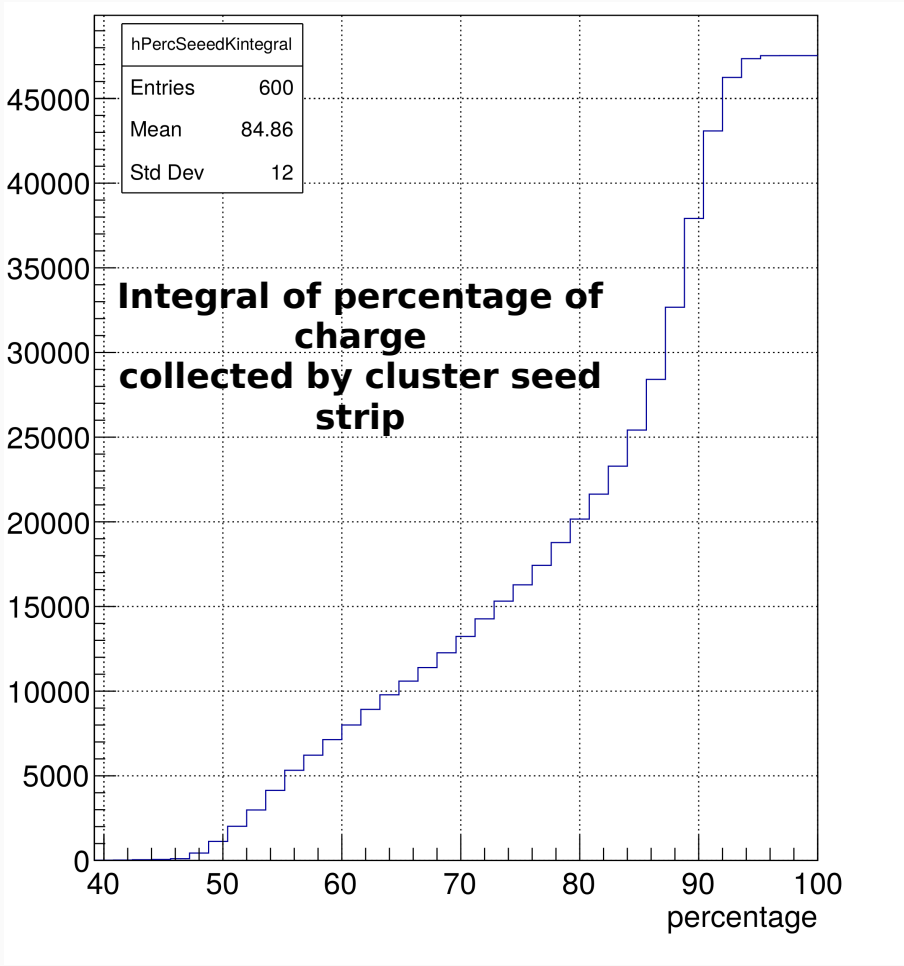




- Good charge correlation for the two sides
- Quantitative differences due to different readout scheme used on "S" side

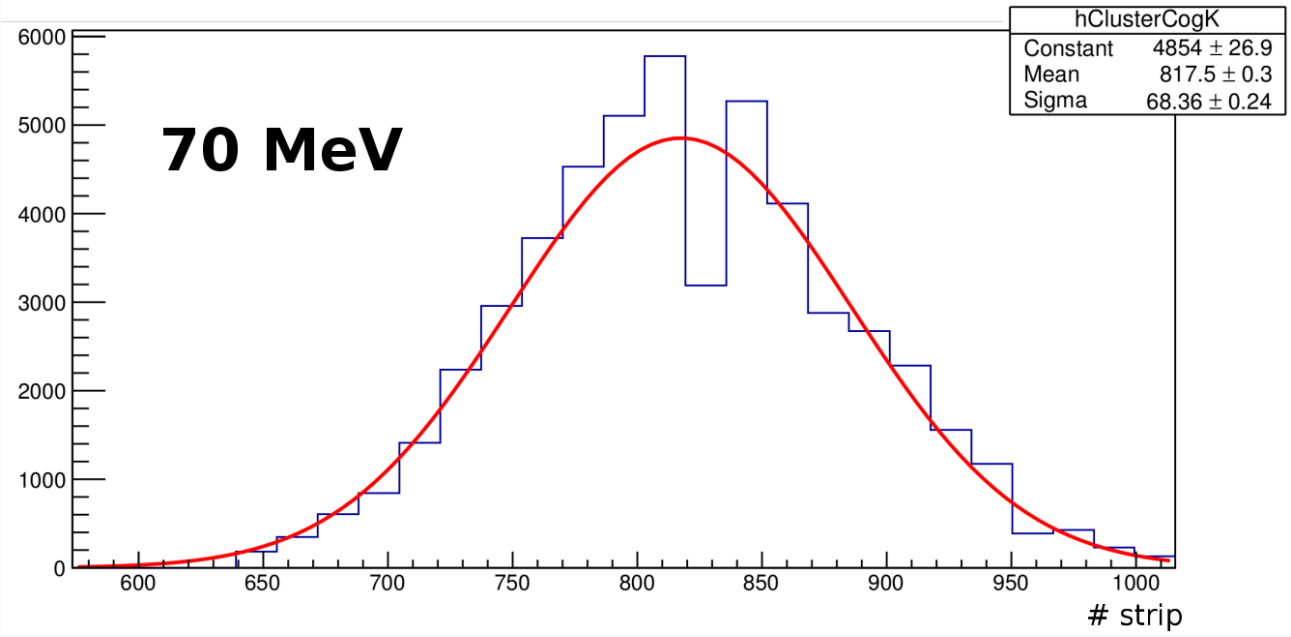
Charge division in a cluster

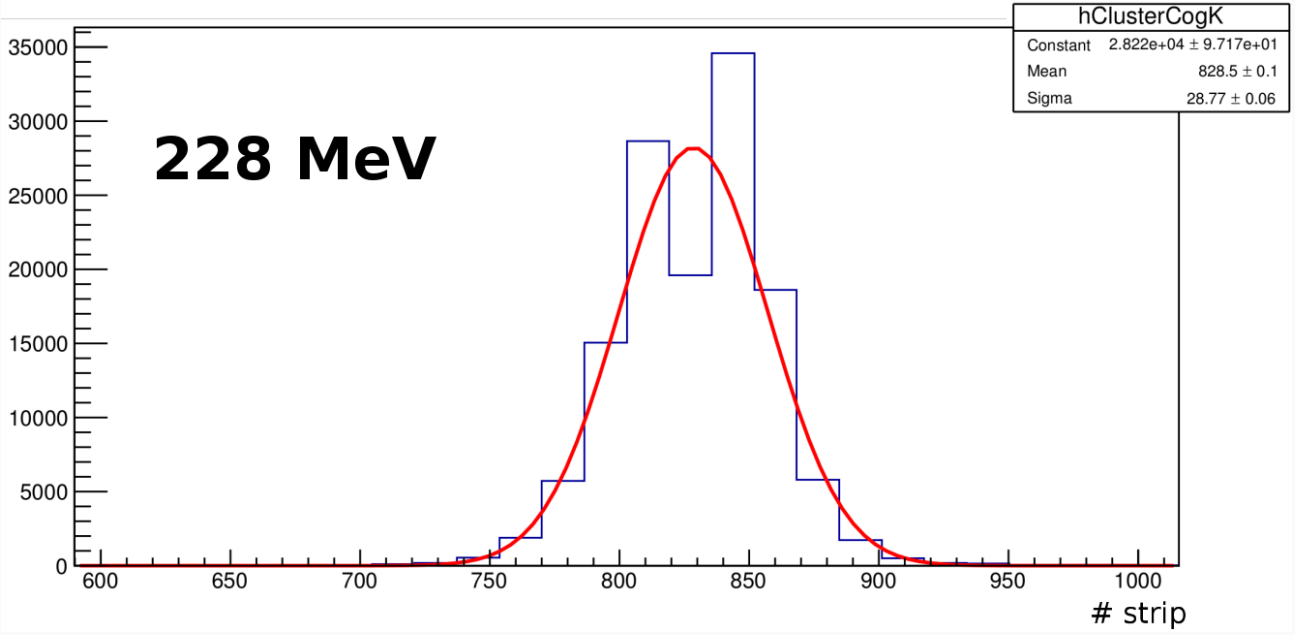




- Clear peak on the distribution of the percentage of charge collected by seed strip
- Cluster are usually composed of an high signal seed strip and few low signal "neighbouring" strips

Beam profiles

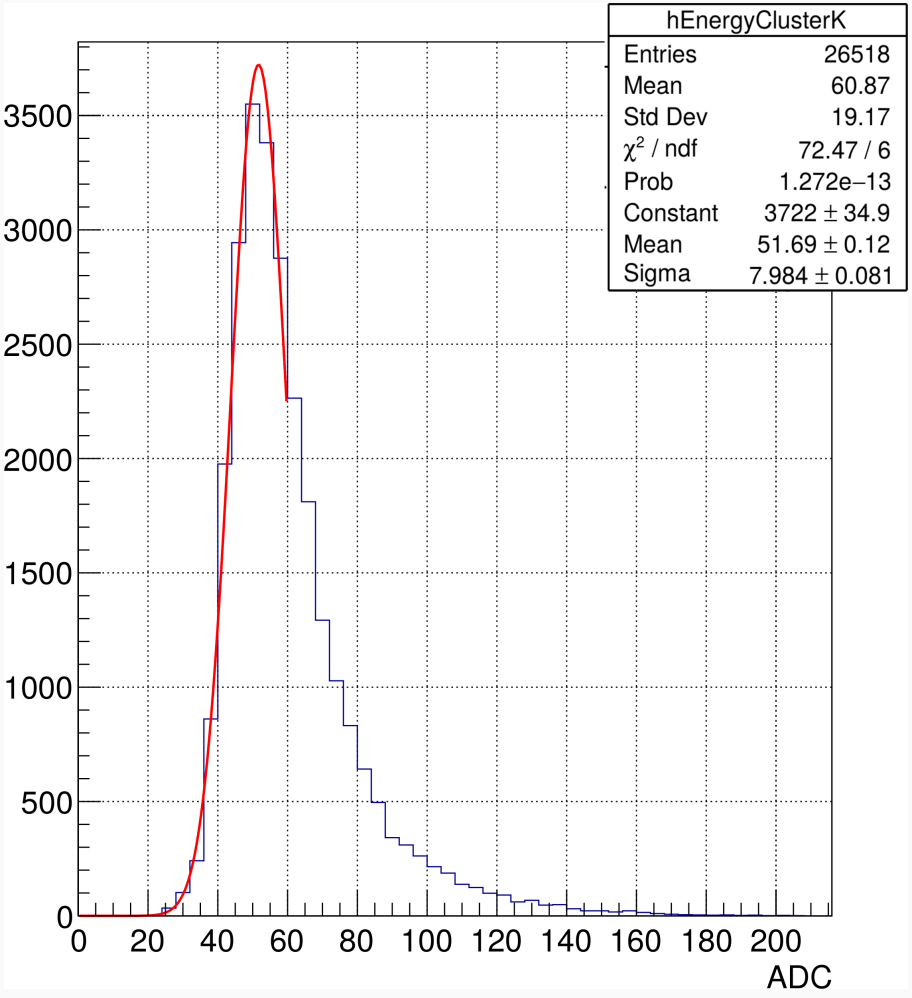




- Measured beam profiles agree with beam size provided by the facility
- Gaussian-profile beam
- **70 MeV**: sensor at the isocenter, **FWHM≈16.7 mm**
- **228 MeV**: sensor at the isocenter **FWHM≈7.1 mm**

Results

- Analysis of VA13 and VA14: good enough statistics at all the energies
- Preliminary analysis: gaussian fit on the peak of the cluster ADC distribution
- Analysis of the distribution of cluster width



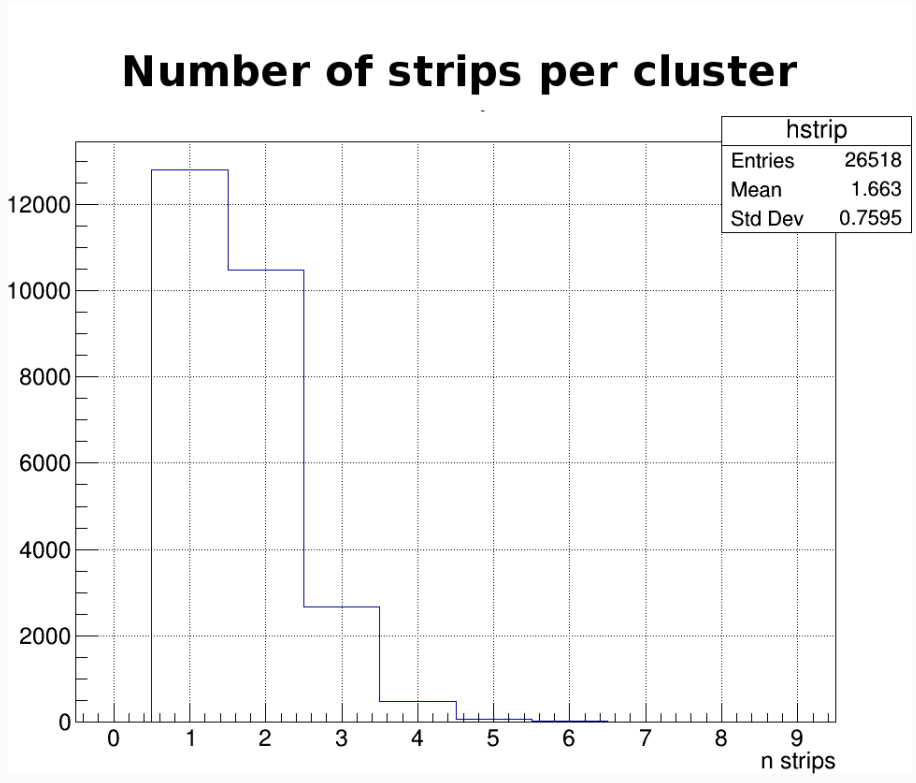
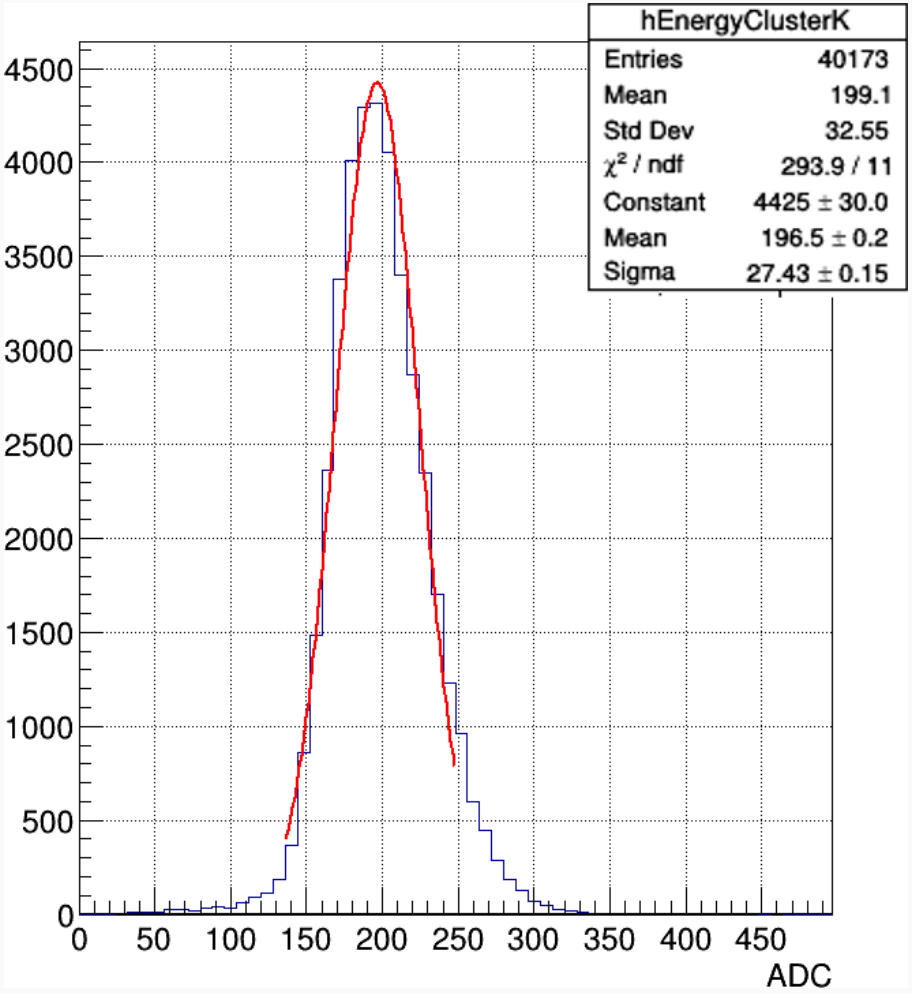


Figura 1: Example: data for 200MeV beam

Results

- Fit model to be improved
- Clear widening and deviation from the Landau distribution expected for a MIP
- Physics phenomena for a non MIP is much more complex



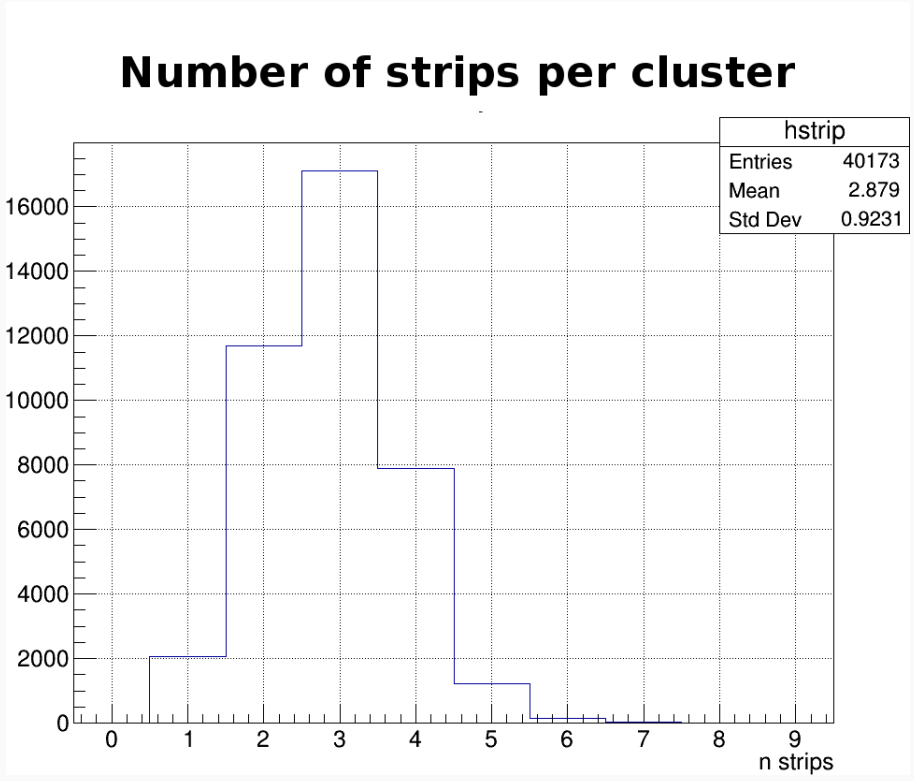


Figura 2: Example: data for 50MeV beam

Dependence on energy

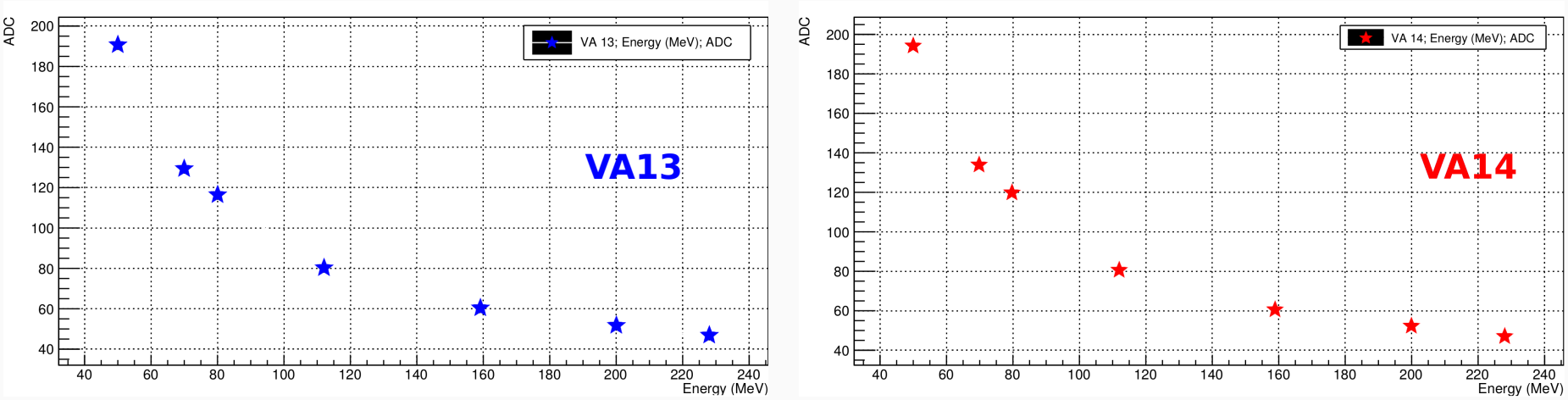


Figura 3: ADC of cluster as a function of energy for the two VAs

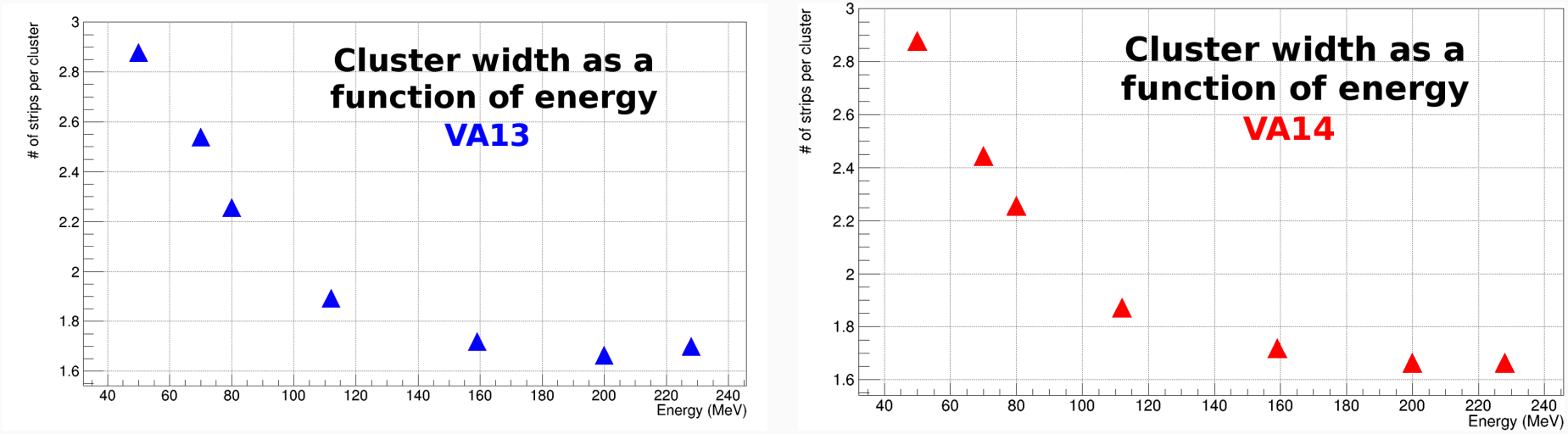
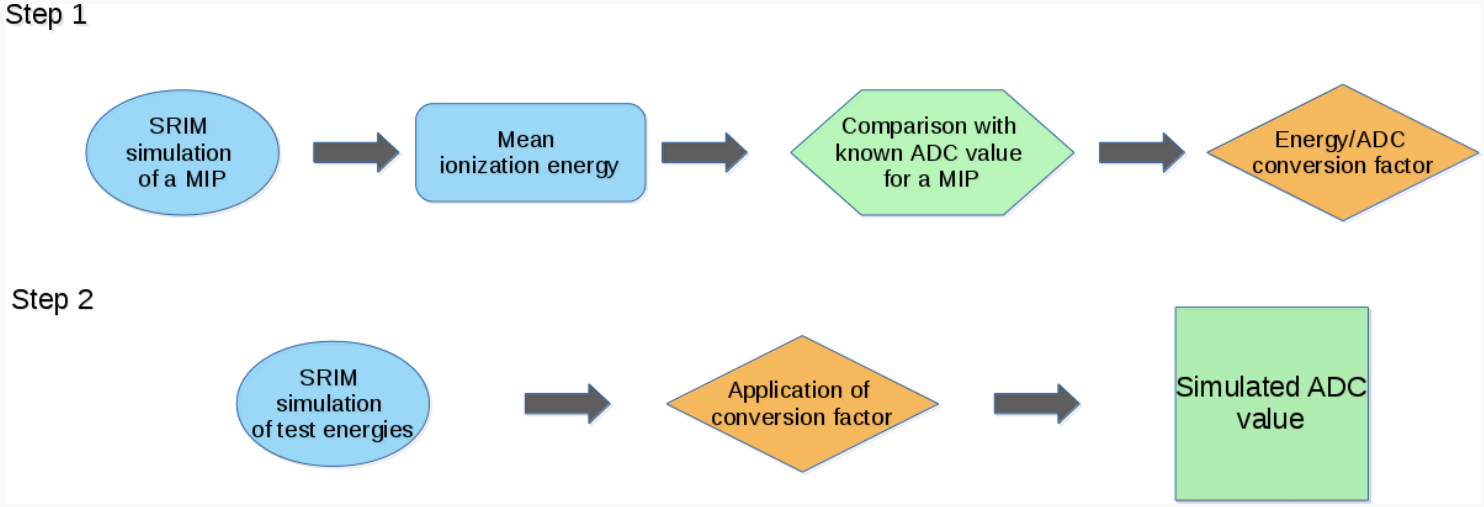


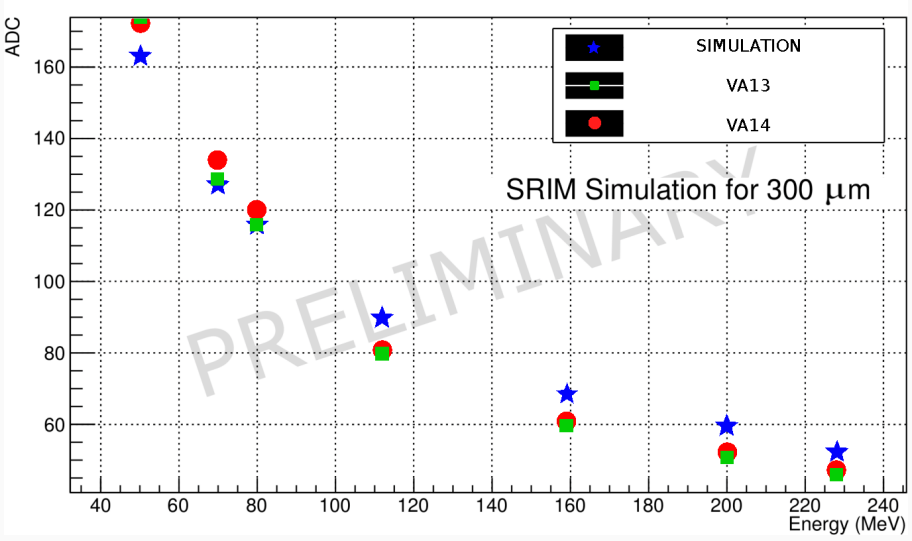
Figura 4: Cluster width as a function of energy for the two VAs

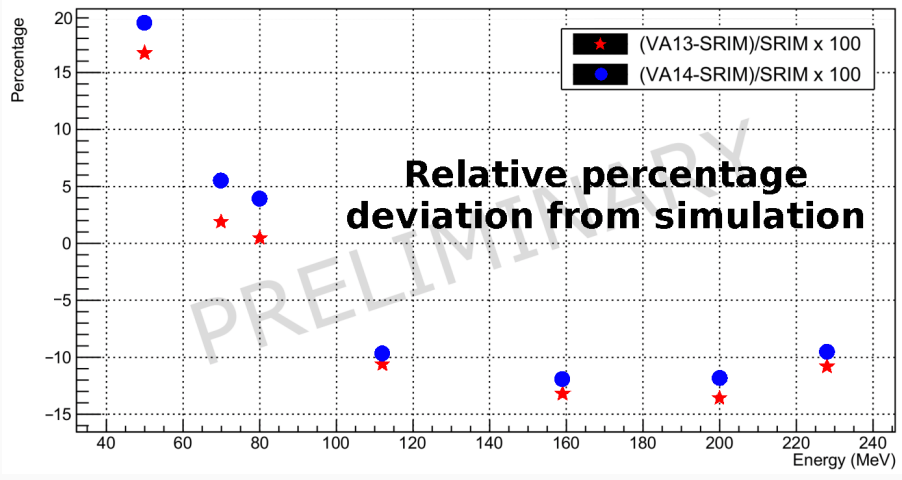
The two chips show similar behavior

Simulation for 300μm of silicon

Simulation of the proton beam on 300μ of silicon in SRIM



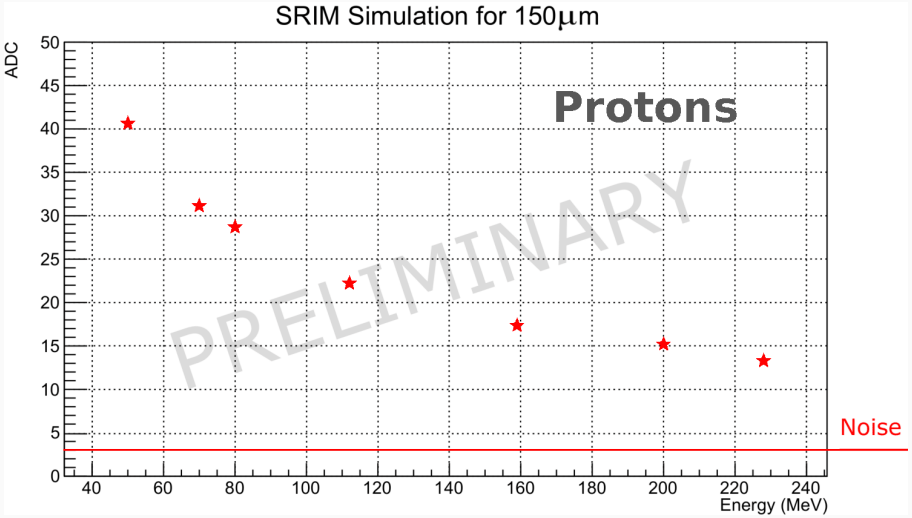


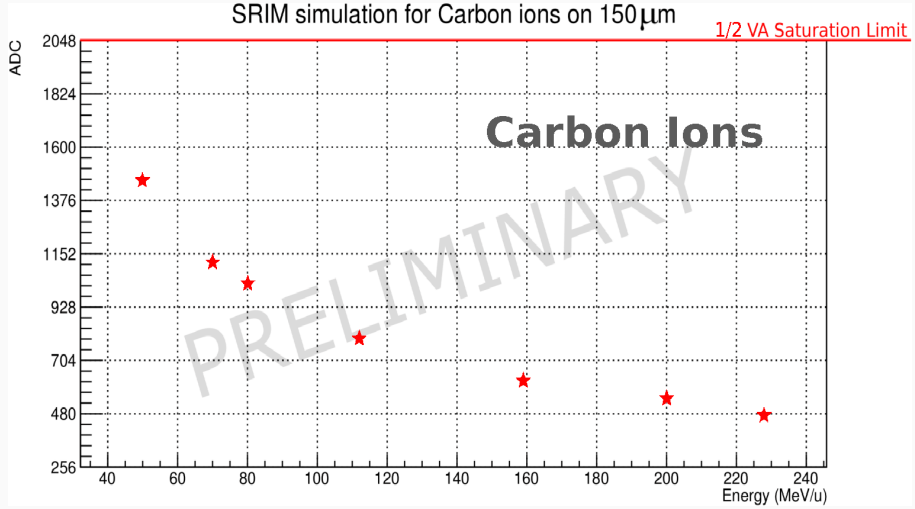


- Good qualitative agreement with the simulations
- Quantitative differences with simulations need to be analyzed

Simulation for 150μm of silicon

- Simulation of a proton beam on 150μm of silicon in SRIM
- Comparison with the typical noise value of the electronics
- Simulation of a carbon beam on 150μm silicon in SRIM
- Comparison with the saturation values of the electronics





- Simulations for carbon ions at 150μ do not predict saturation
- Given the typical pedestal value of $\approx$ 600ADC we predict an effective dynamic range of about 160 pC for the VA140 chip

Conclusions

- Observed beam profiles compatible with expected values
- Good qualitative agreement with the simulations
- Similar behavior for the analyzed VAs
- Quantitative difference from the simulation within $\pm$ 20%
- Carbon ions simulations at 150μm do not predict saturation