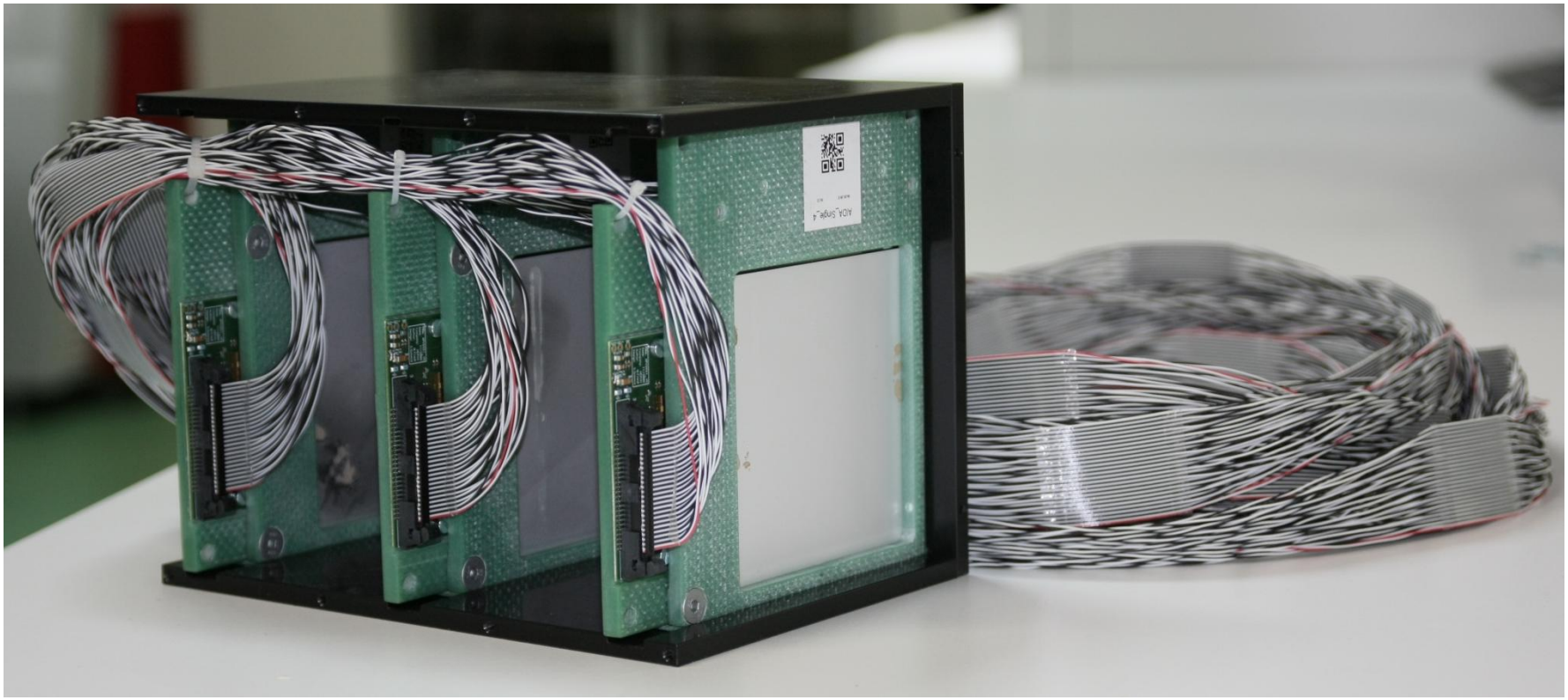
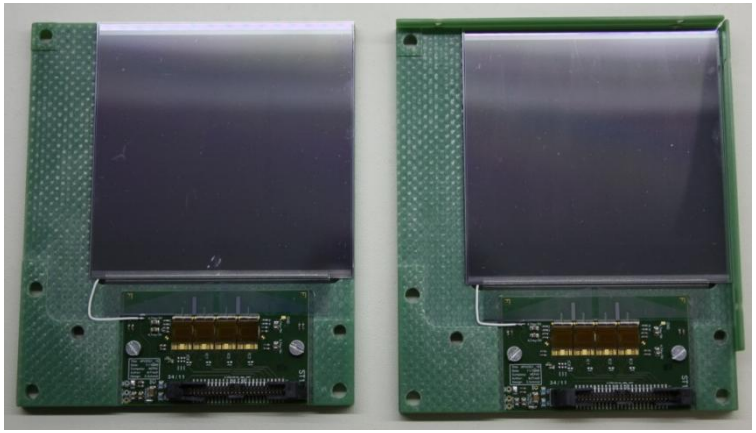
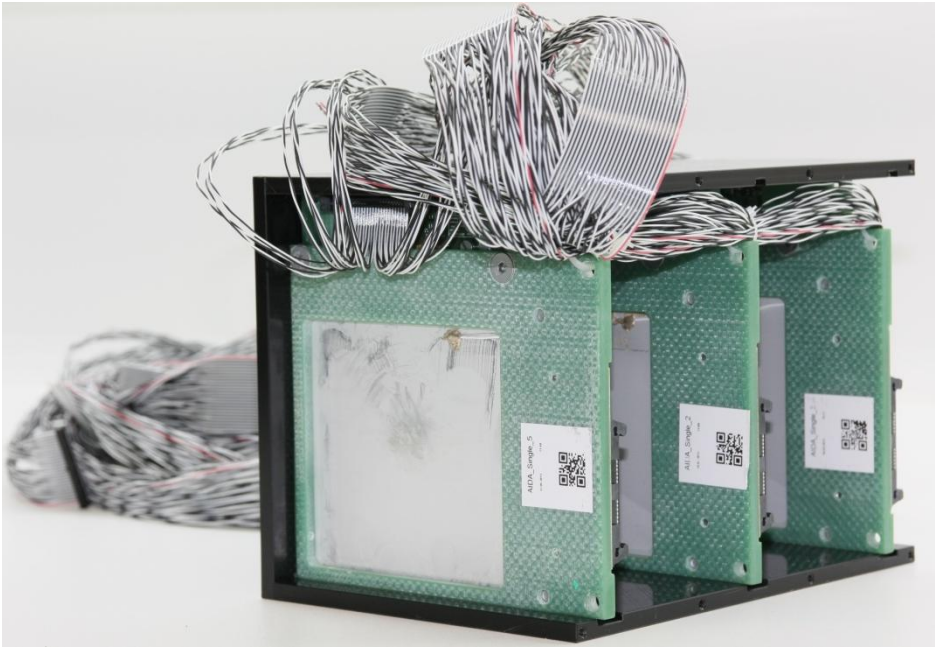
The performance of the silicon telescope



Outline

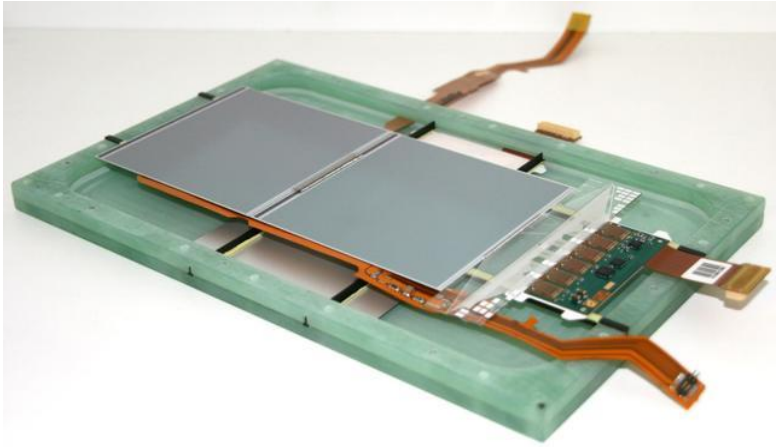
- **Hardware:**
  - The Sensors
  - The Modules
  - The Telescope
- **Test beam:**
  - Setup and read out
  - Results





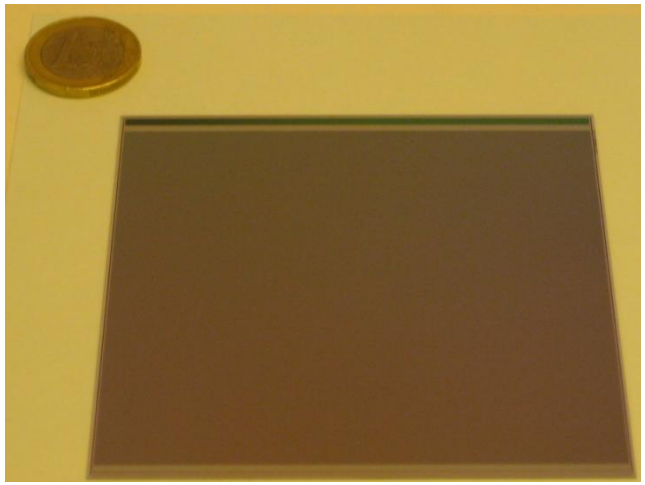
General:

- HPK sensors procured by the SiLC collaboration are used:
  - 6 Sensors available from Vienna Modules (LP-TPC)
  - Another 10 from LPNHE Paris
- Requirements:
  - Resolution: For most drift chambers studies a sub-millimeter accuracy would sufficient, but for detailed uniformity checks 0.1 mm would be desirable (statement of calorimeter group)

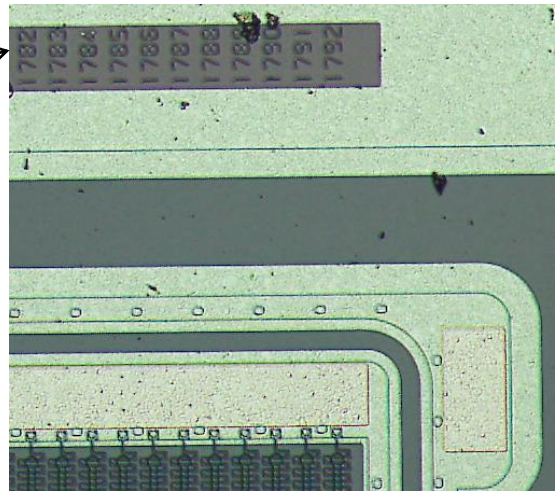


1.1. The Sensors

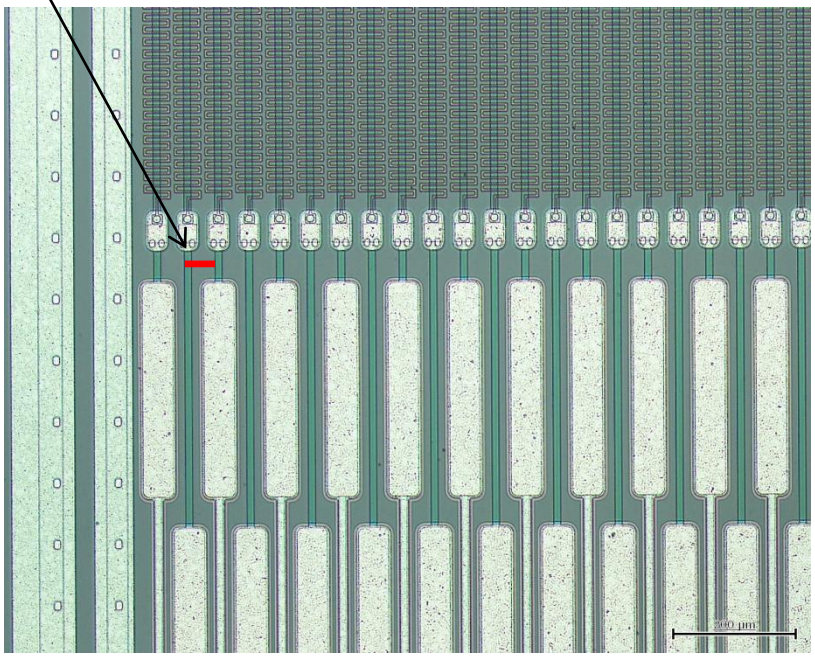
- Design Parameter:
  - Strip width: 12.5 µm
  - Pitch: 50 µm
  - Area: 95 x 95 mm^2
  - Strip length: ~95 mm
  - Thickness: 320 µm



1792 Strips on each sensor



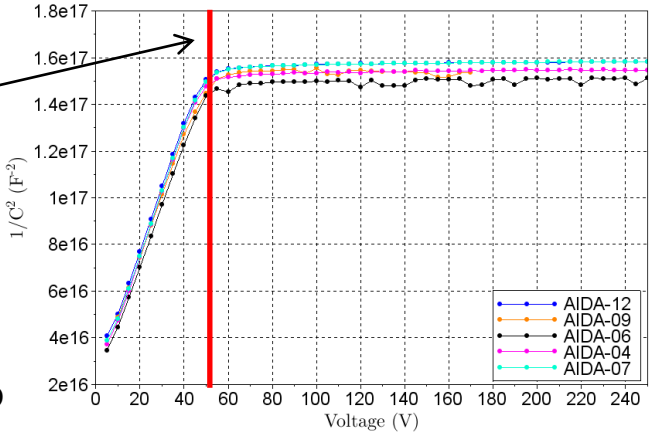
Small pitch of 50 µm



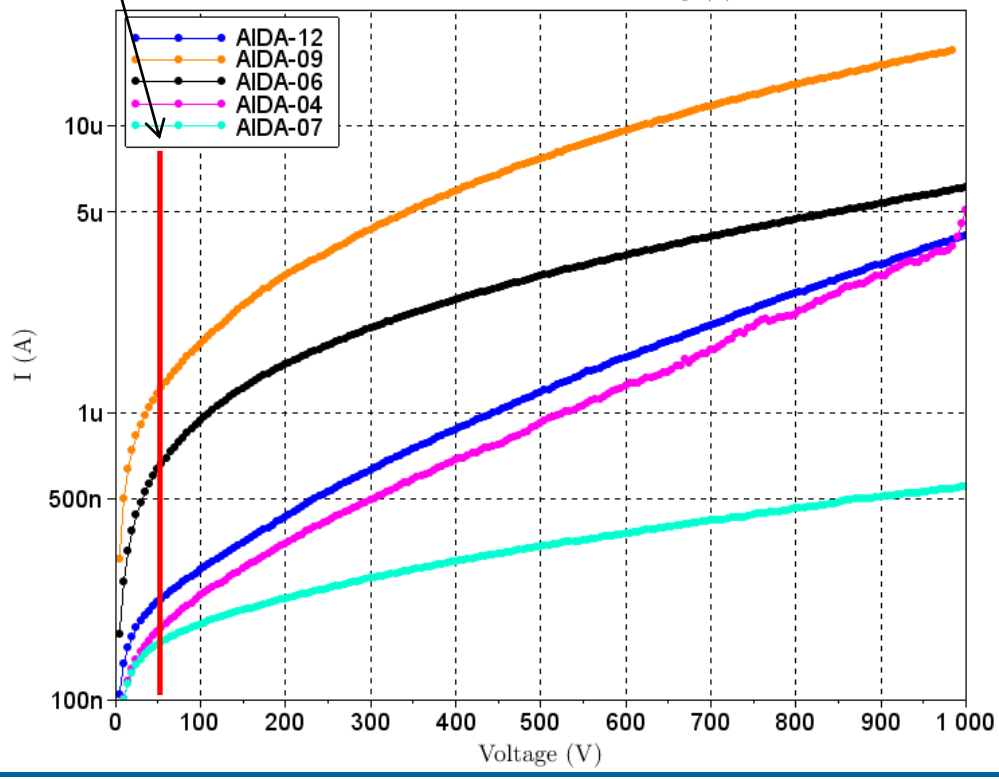
1.1. The Sensors

- Electrical characterization
  - Full depletion Voltage reached between 50 and 60 V
  - Leakage current: No break though until 1 kV although there are differences between the sensors the leakage currents is fine
  - Operation Voltage:100 V

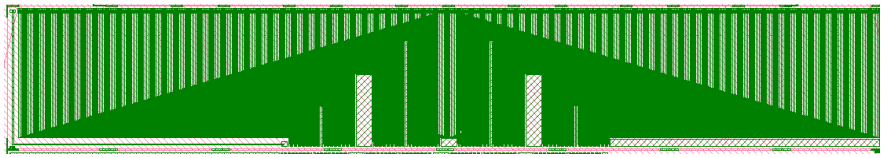
V_{FD} around 50 V



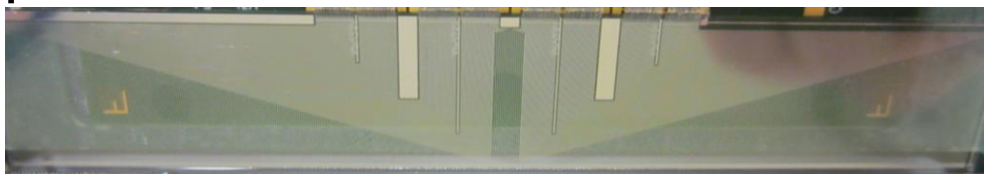
Leakage currents at V_{FD}



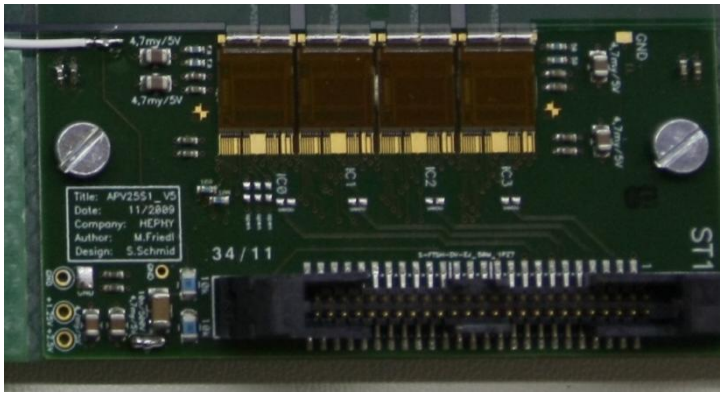
1.2. The Modules



- Pitch Adapter:
  - 512 channels with 150 µm pitch for 4 APVs
  - Designed at HEPHY Vienna, produced by CMN Barcelona



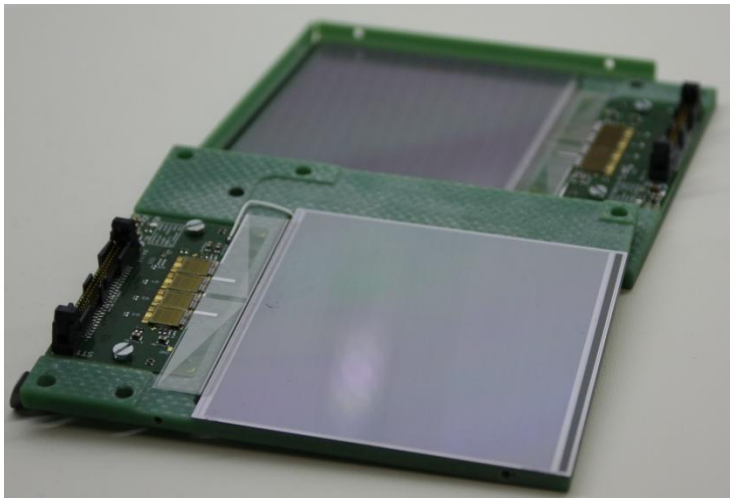
- Hybrid:
  - Prototype hybrids of the Belle II project; are able to read out 4 APV chips

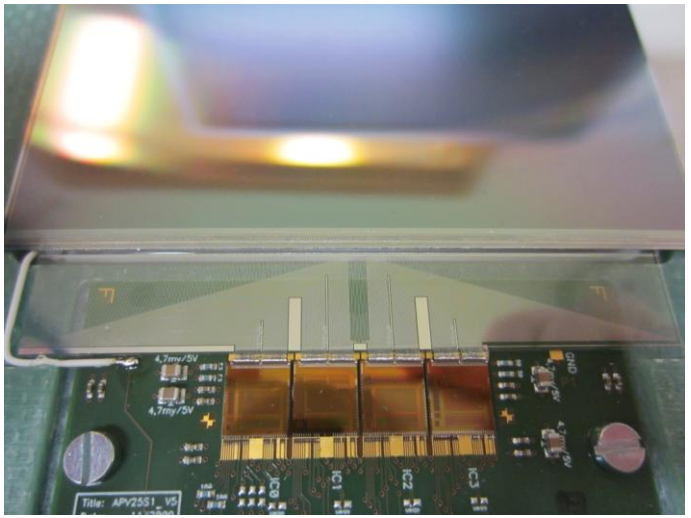


- APV 25 analog read out chip

1.2. The Modules

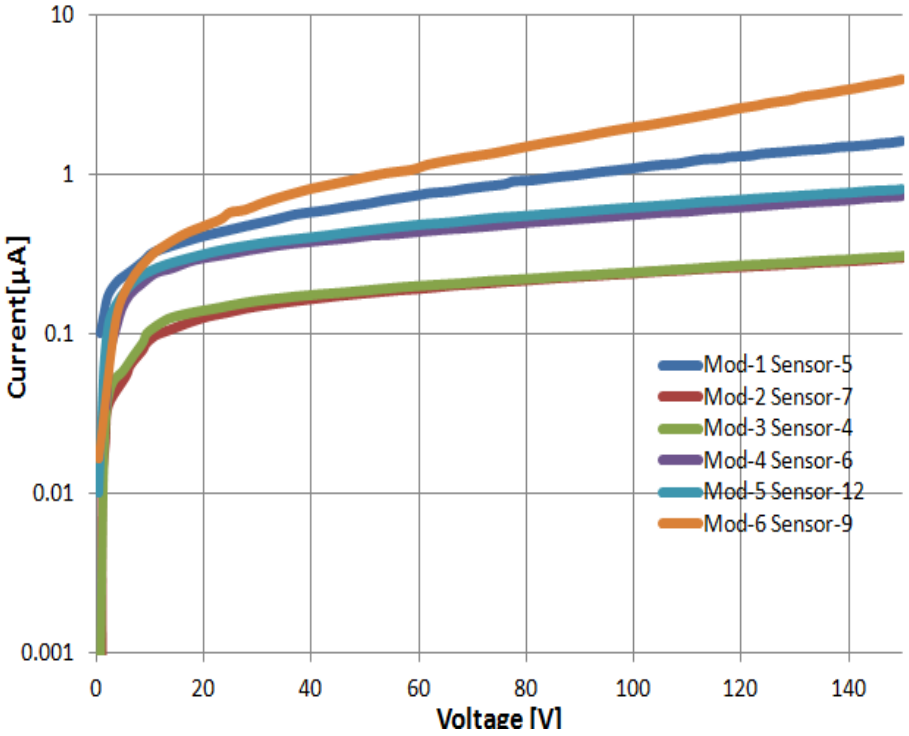
- Readout:
  - 512 strips are read out
  - Two intermediate strips are not read out (150 µm pitch)
- Design:
  - The support frame of all six modules is identical designed
  - Sensors are mounted perpendicular to each other
  - Two single modules are arranged to one double module; fixed by distance holder





1.2. The Modules

- Leakage currents:
  - The current of the single modules
  - Operated over depleted (100 V)
- Overall Arrangement: Sensor – Single Modules – Double Modules - Telescope

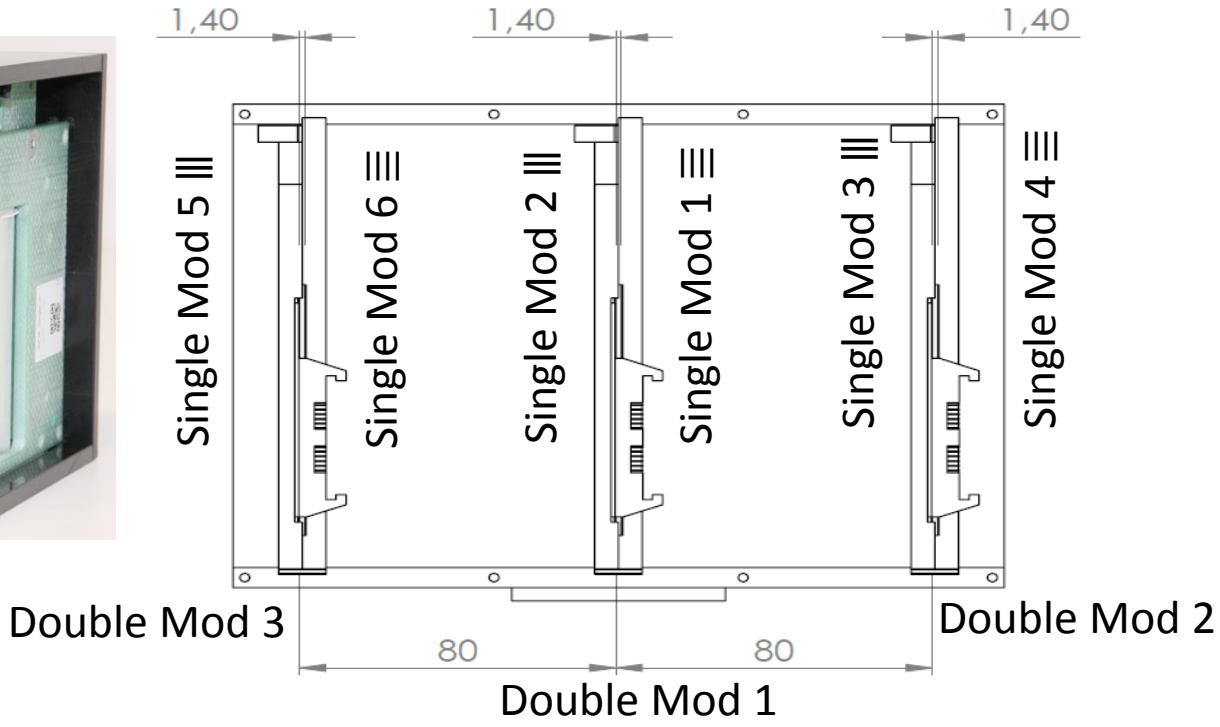


Sensor 12	Sensor 9	Sensor 5	Sensor 7	Sensor 4	Sensor 6
Single Mod 5 |||	Single Mod 6 ≡	Single Mod 2 |||	Single Mod 1 ≡	Single Mod 3 |||	Single Mod 4 ≡
Double Mod 3		Double Mod 1		Double Mod 2	

Telescope

1.3. The Telescope

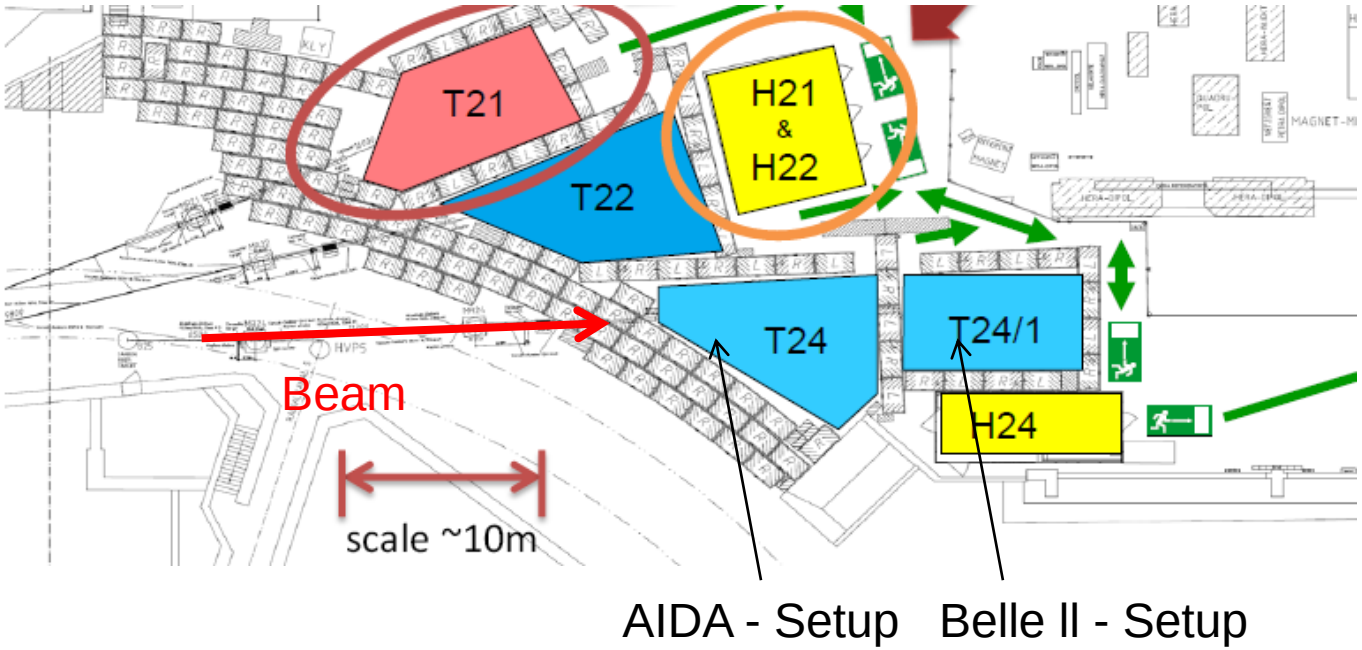
- Design Parameter:
  - Double module: 1.4 mm between two single modules, arranged with strips perpendicular to each other
  - Telescope: 80 mm between the different double modules



TB at DESY January 2014

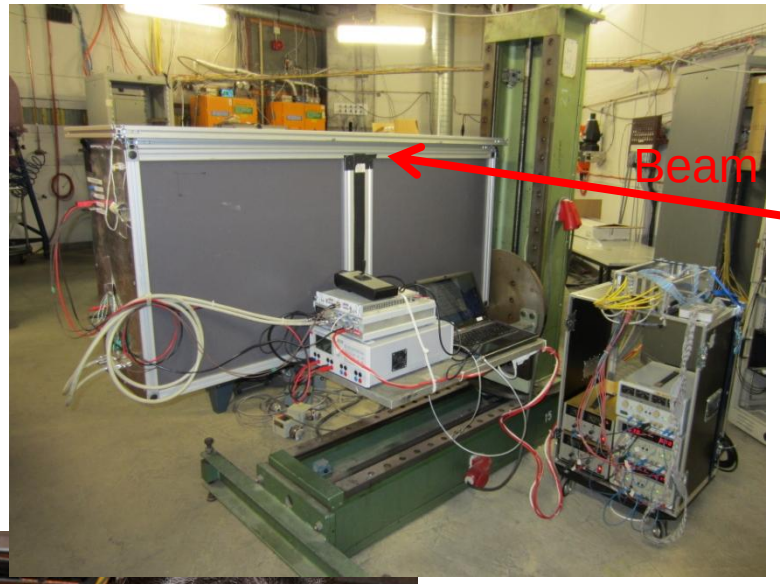
General:

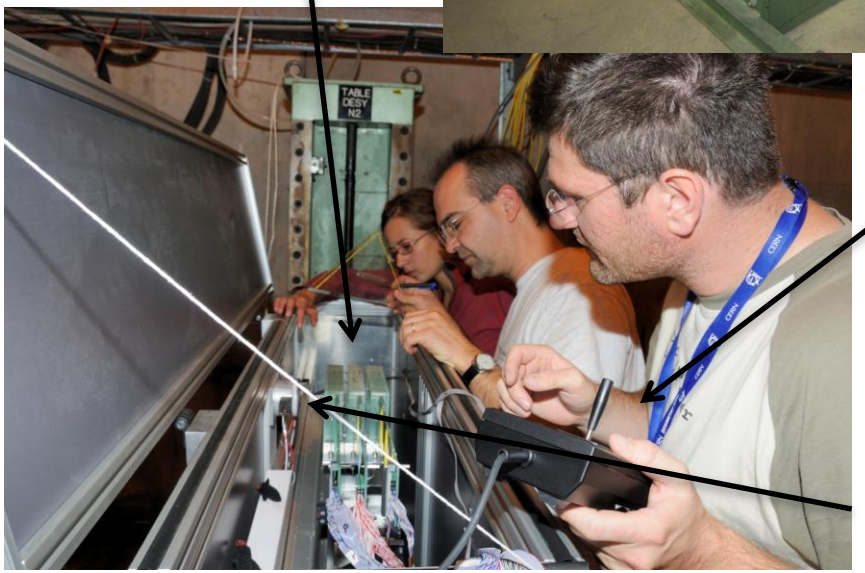
- Dates: 03.01.2014 - 31.01.2014
- Electron beam with energy between 3 and 6 GeV
- The setup has been placed upstream parasitic during the Belle II test beam



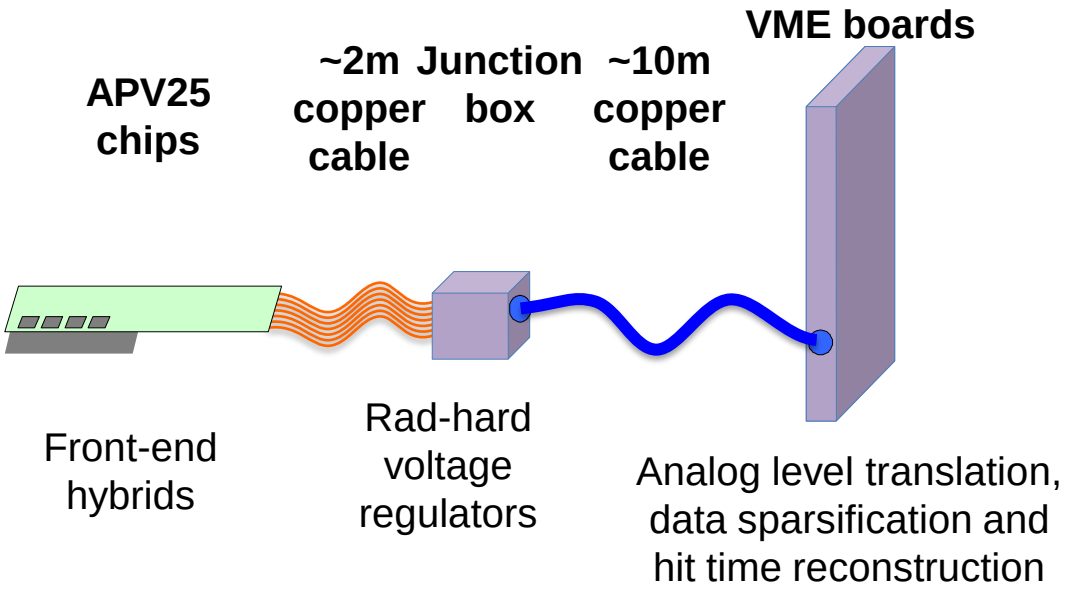
2.1. The Setup

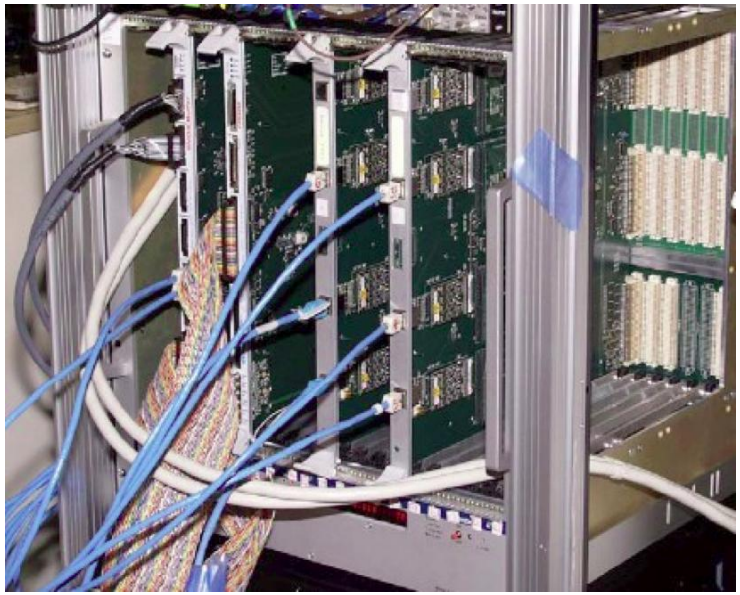
- Hardware
  - Box: The DUT has been mounted on an moveable x-z table
  - Triggering with scintillator and photomultiplier
- Readout
  - Presented data have been taken with an self developed DAQ system using LabWindows/CVI (NI)





2.1. The Setup





Readout APVDAQ:

- Self-developed DAQ system, based on APV 25 readout chip (CMS development)
- Experience verified that the system is working very stable
- Actual Software is running LabWindows/CVI (NI)
- An LINUX based DAQ is also available (next talk)

2.2. Results

- Run Overview:
  - Different beam energies (blue)
  - General purpose (black)
  - Bias scan (green)
  - Position scan (orange)
- Event rate depends on beam energy
- Most analysis done on representative run 36

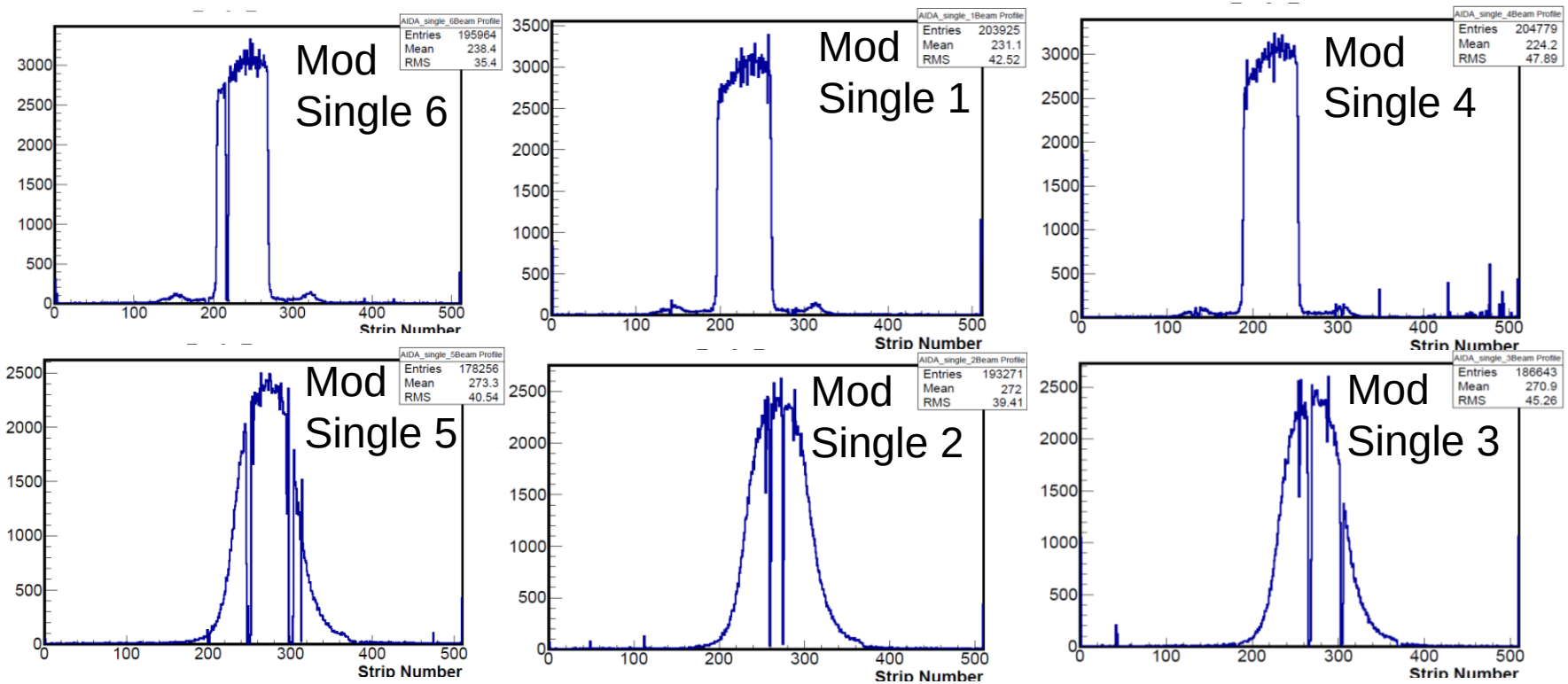
Run #	Voltage [V]	Event	Energy [GeV]
5	100	200k	3
36	100	320k	5
39	10	100k	5
40	20	100k	5
41	30	100k	5
42	40	100k	5
44	50	100k	5
45	60	100k	5
46	70	100k	5
47	80	100k	5
48	90	500k	5
49	100	100k	5
50	110	100k	5
51	120	100k	5
52	130	100k	5
53	140	100k	5
54	150	100k	5
55	100	311k	5
56	100	510k	5

2.2. Results

Beam Profiles (run 36): Different shape due to different orientation

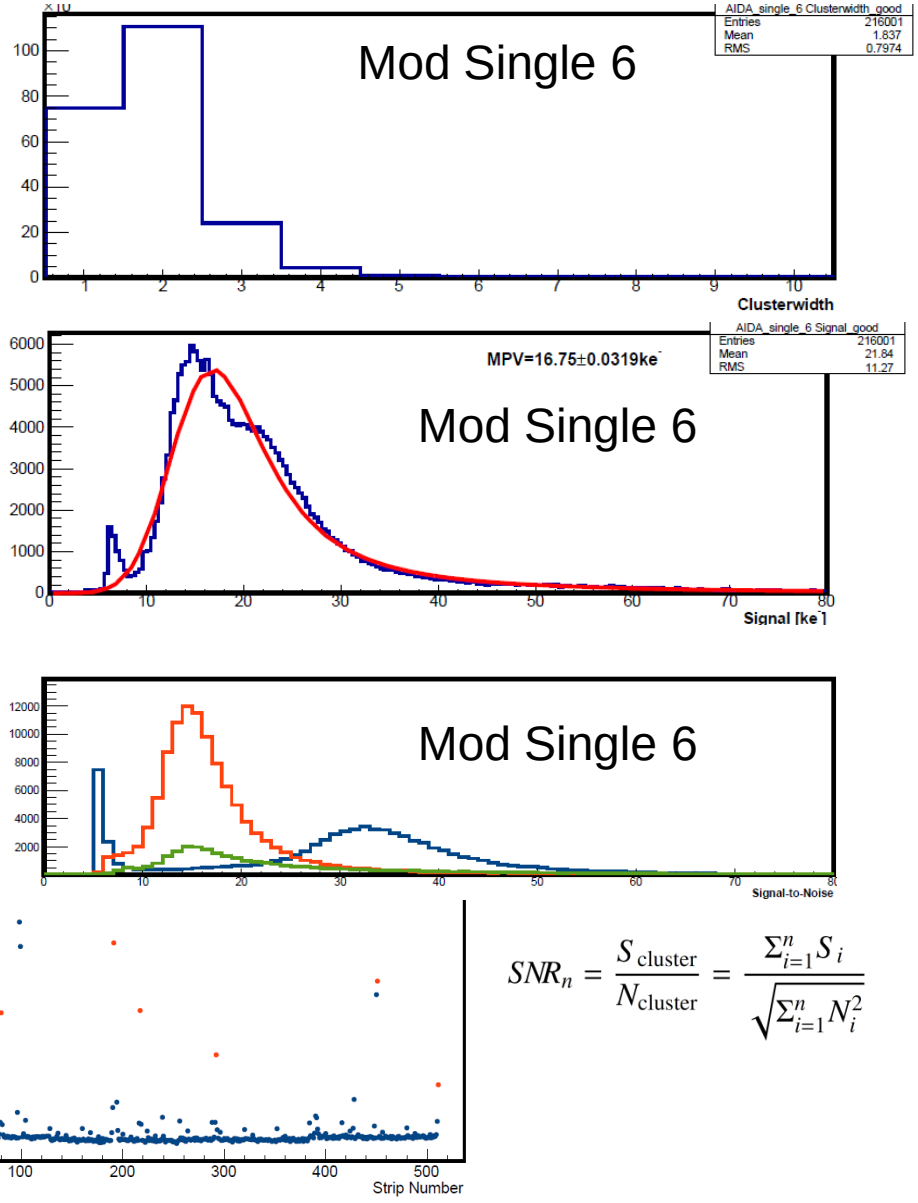
Single Mod 5 |||	Single Mod 6 ≣	Single Mod 2 |||	Single Mod 1 ≣	Single Mod 3 |||	Single Mod 4 ≣
Double Mod 3					Double Mod 1				
Double Mod 2									

Telescope



2.2. Results

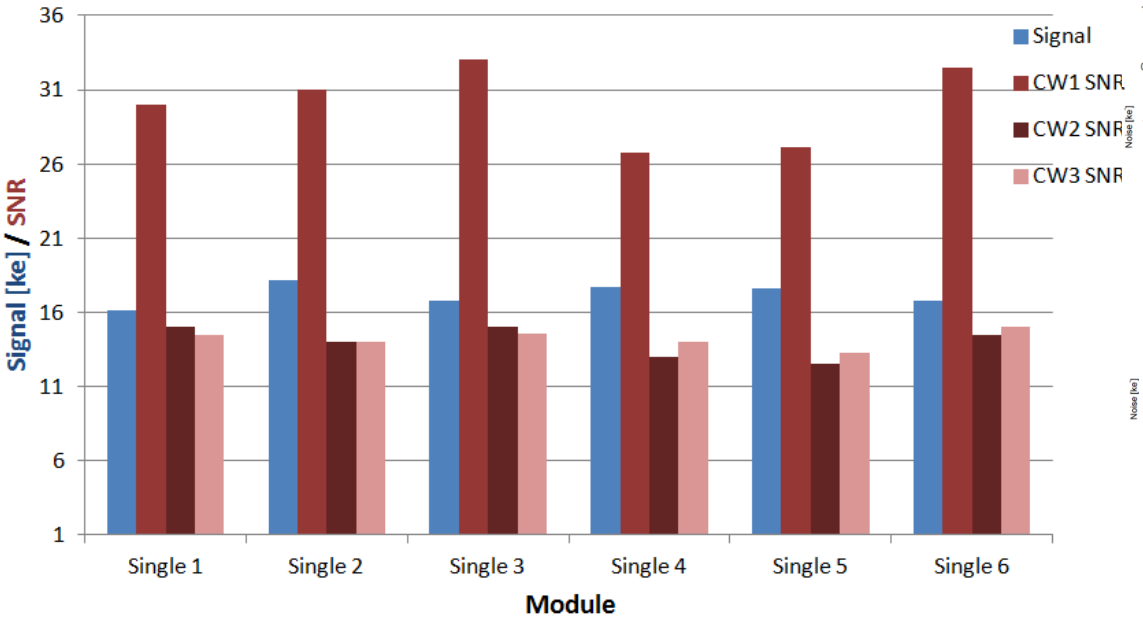
- General properties (run 36):
  - Cluster width: Due to intermediate strips mainly cluster with width two
  - Signal: around 16 ke; cluster of all widths are considered
  - SNR: for different cluster widths (1, 2, 3)
  - Noise: Very low (mainly smaller than 1 ke)

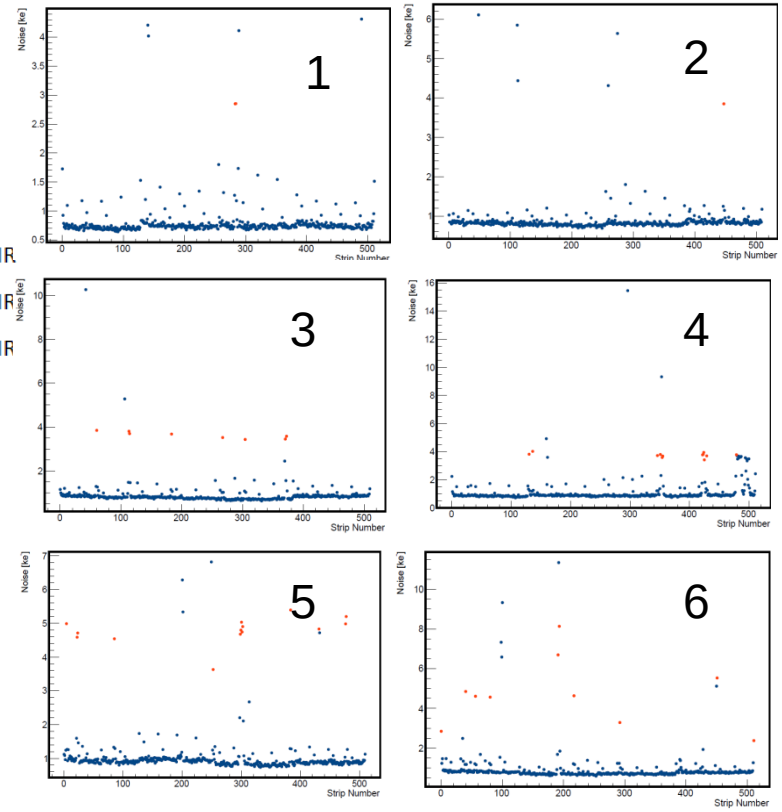


$$SNR_n = \frac{S_{\text{cluster}}}{N_{\text{cluster}}} = \frac{\Sigma_{i=1}^{n} S_i}{\sqrt{\Sigma_{i=1}^{n} N_i^2}}$$

2.2. Results

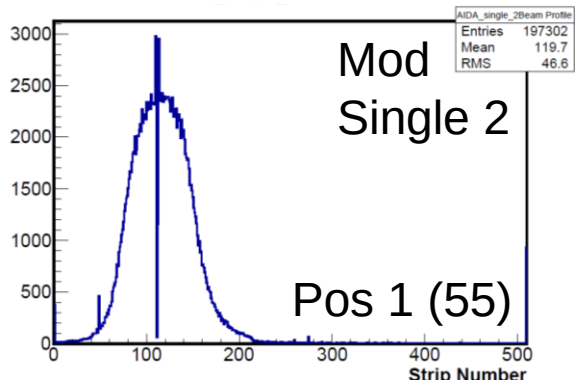
- The different single modules behave very similar (run 36)
- Only single module 4 features a small accumulation of noisy strips at the right edge

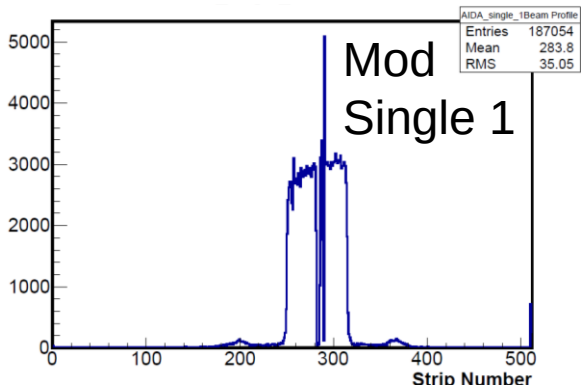


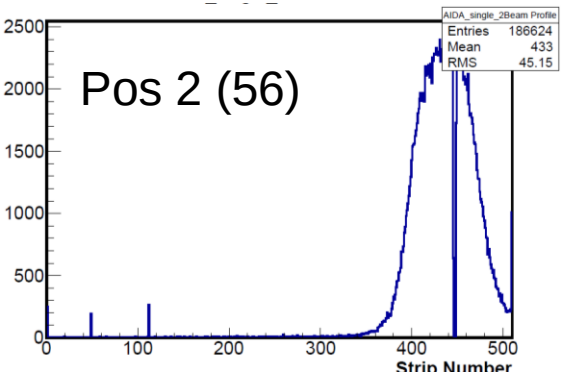


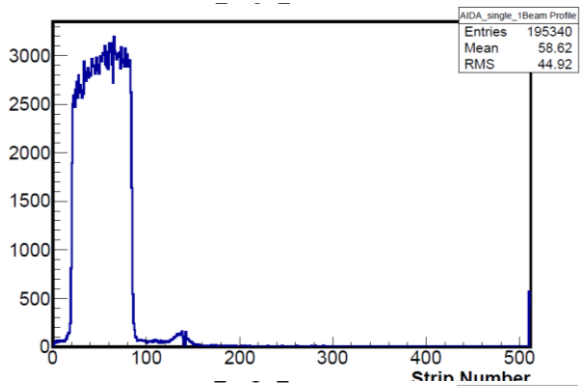
2.2. Results

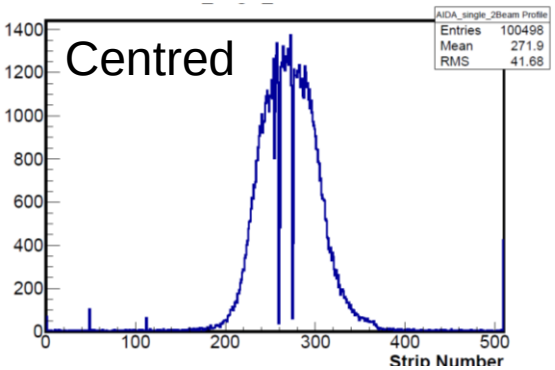
- Position Scan:
  - Different Positions tested before centering the telescope
  - Good quality in all tested areas of the modules

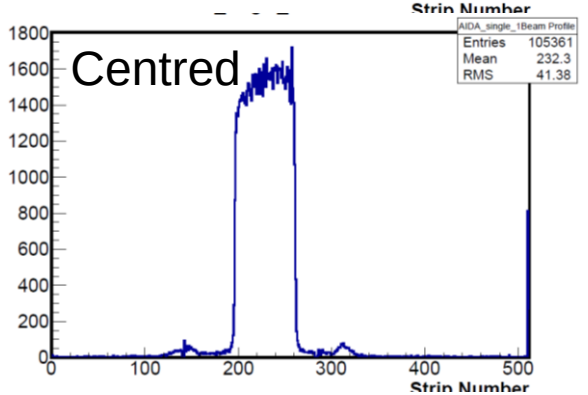






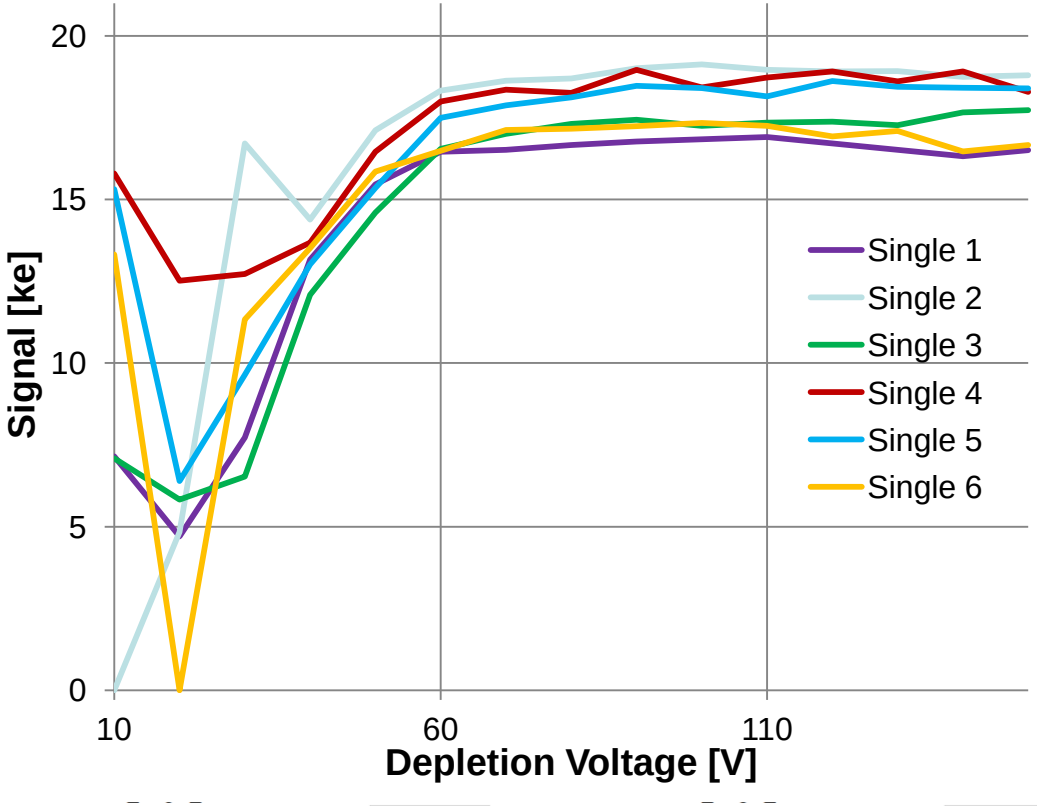


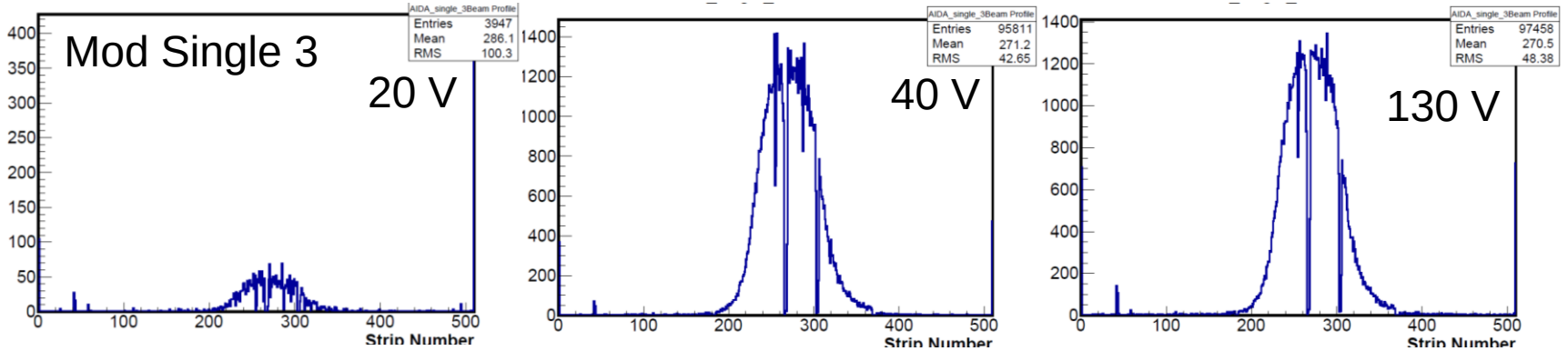




2.2. Results

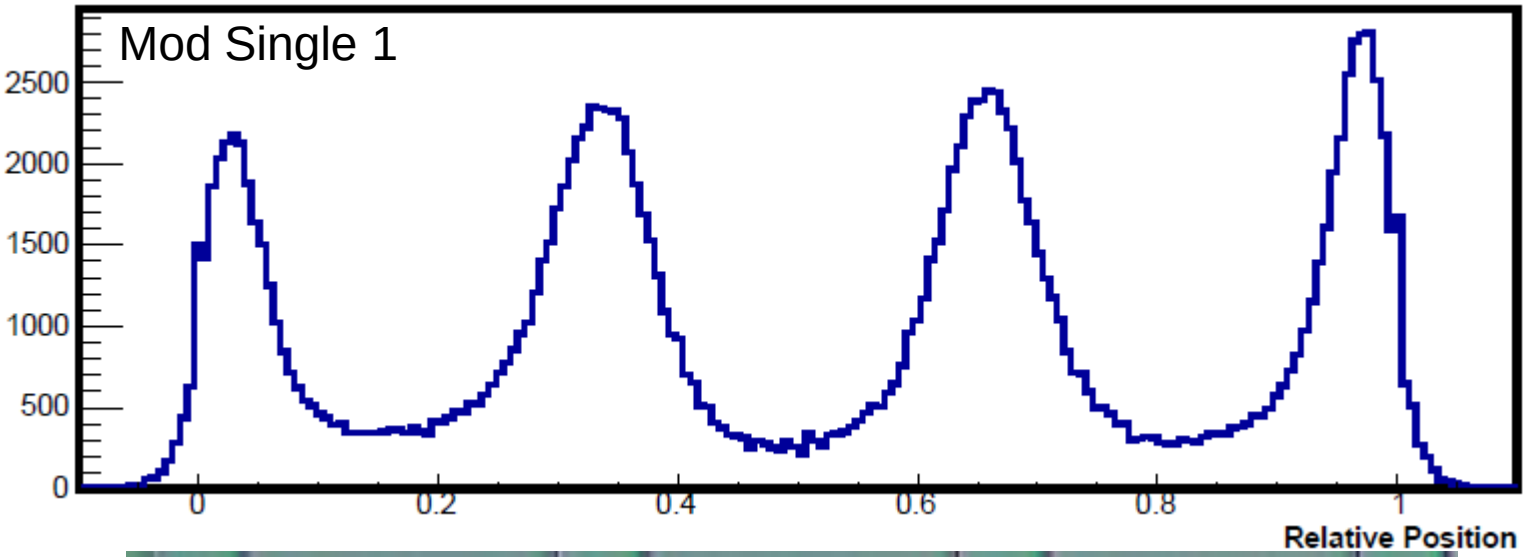
- High Voltage Scan:
  - 15 runs with different bias voltage (10-150 V)
  - Signal clearly stabilize between 50 and 60 volt
  - Bad fit at low voltages causes derivations





2.2. Results

- Eta Distribution (run 36): The effect of two intermediate strips is clearly seen (hits with cluster size one are also included)



Bonded strip read out (left)

Intermediate strip (left)

Intermediate strip (right)

Bonded strip read out (right)

Summary

- Baseline option:
  - The silicon telescope has been assembled, tested and is performing well
  - For building the telescope different sensors have been organized (SiLC) and electrically characterized for selection
  - The performance of the telescope has been investigated with an electron beam at DESY
- Remaining points:
  - There is still some DAQ development ongoing
  - Will be covered in the next talk