HEPHY

Institut für Hochenergiephysik

Resolution studies on silicon strip sensors with fine pitch

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This work is performed within the SiLC R&D collaboration.

Purpose of the Study

Evaluate the best strip geometry of silicon strip sensors with 50 micron pitch to achieve the highest possible spatial resolution.

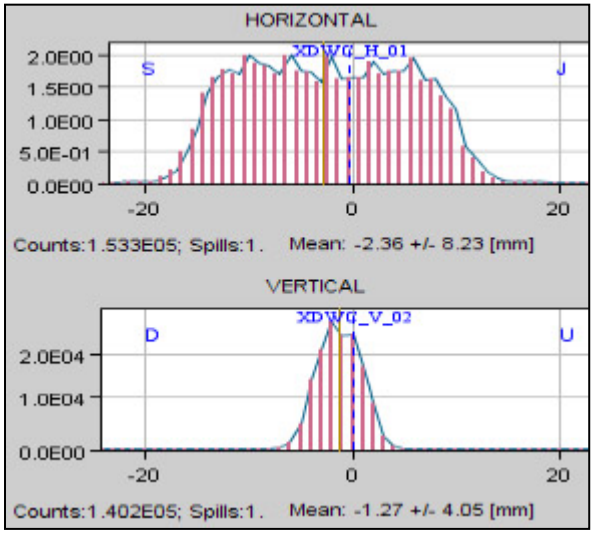
what we need:

- dedicated multi geometry silicon strip sensor developed by SiLC collaboration
  - sensor comprises different zones with different strip geometries
- EUDET pixel telescope
  - to get high precision tracks to determine the residuals for our Device Under Test (DUT)
- 120 GeV Pions from CERN SPS

Test Beam

test beam took place in H6B area (SPS NA hall) between 30th May and 5th June 2008

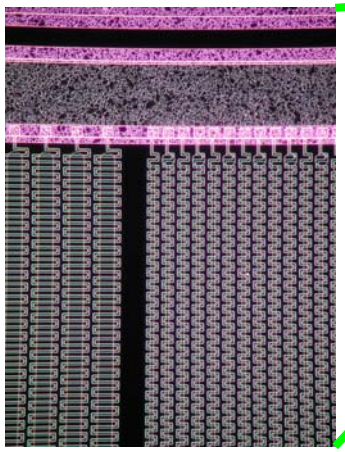
- 120 GeV Pions from CERN SPS
- SPS performed “reasonable” (few breakdowns)
- structure of the Beam:
  - 5.7×10^5 particles per spill (~5 sec) then pause of 20 - 40 sec
  - intensity has been reduced by closing collimators in the beam line (to minimize multiplicity for pixel telescope)



Beam profile

Mini Sensor Layout

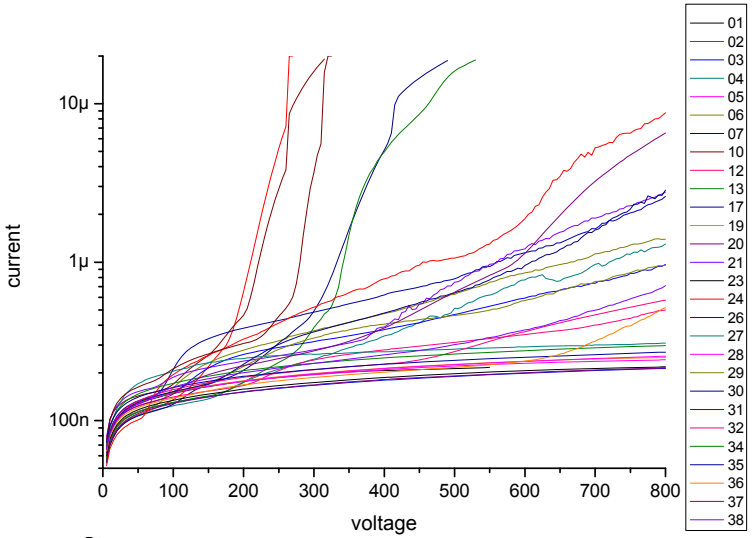
- produced by HPK Japan
- single-sided AC coupled strips
- thickness: ~ 320 µm
- active area: ~ 15 x 64 mm²
- depletion voltage around 65 V
- number of strips: 256
- biasing scheme: poly-Si resistor (20MOhm)
- readout pitch: 50 µm
  - 3 different regions with no, one or two intermediate strips
  - In total 16 zones **(separated by missing strip):**
    - **consisting of 16 strips each**
    - **different strip widths in each zone**

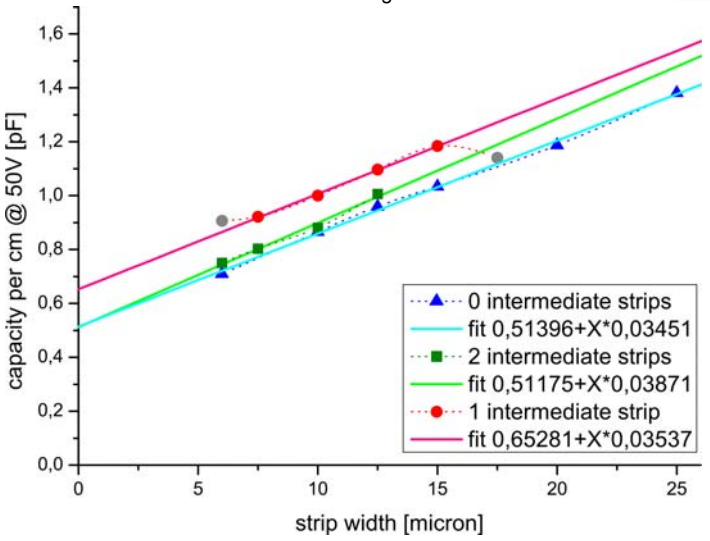


zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
strip width [µm]	6	10	12,5	15	20	25	6	7,5	10	12,5	15	17,5	6	7,5	10	12,5
# int. strips	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2

Electrical Sensors Characterization

- sensors have been intensively tested in Vienna
  - IV curves on all sensors
  - CV curves to determine full depletion voltages (approx 50-65V)
- measurement of the inter-strip capacitance reveal different values for each zone:
  - capacitance scales linearly with strip width
  - different offset for region with one or two intermediate strips





Sensor Modules

9 modules have been built in Vienna using self-developed hybrid based on APV25 readout chip (same chip as used in CMS Tracker)

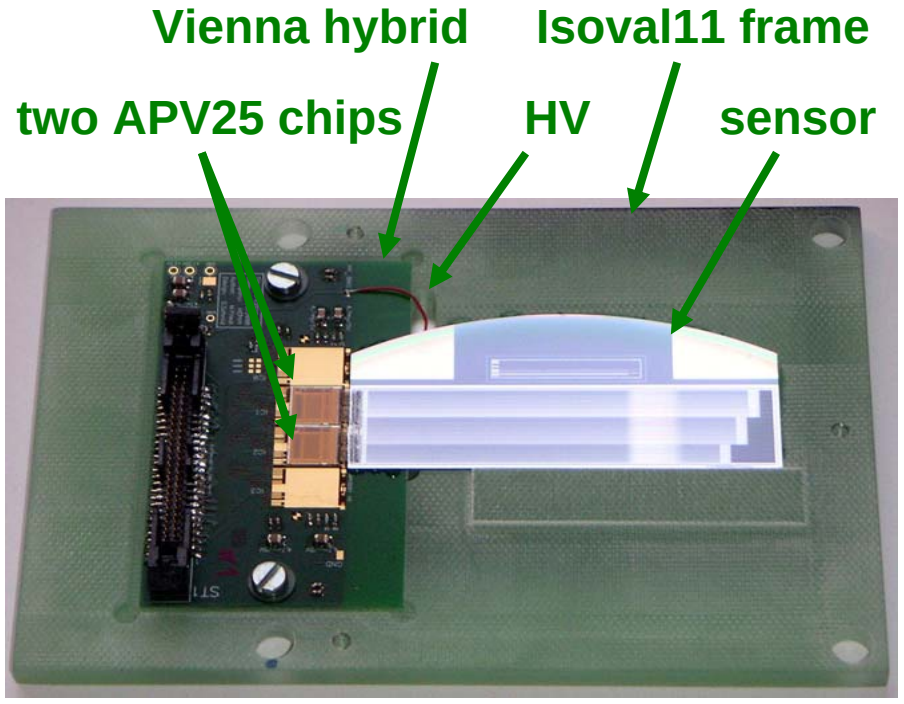
front side

back side

- **holes in front and back side to minimize multiple scattering**
- **measurements were done under a light-tight cloth**

without top cover

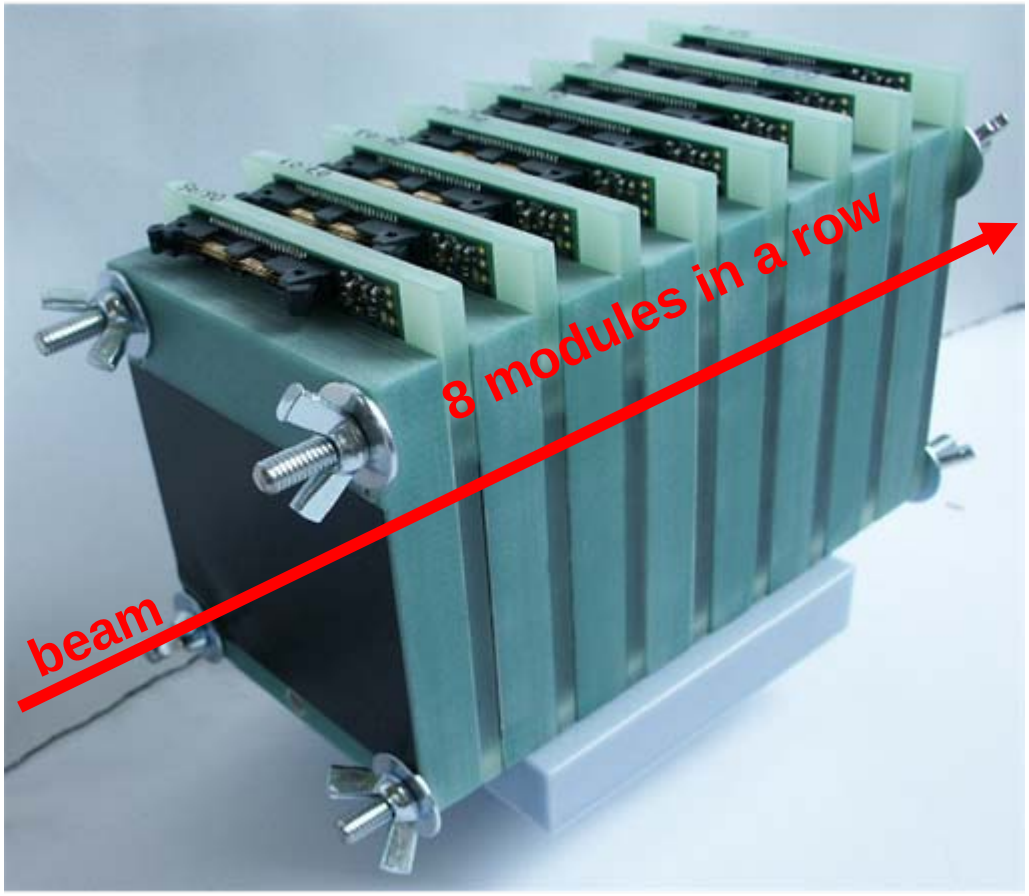
microbonds are used to connect hybrid, APVs and sensor



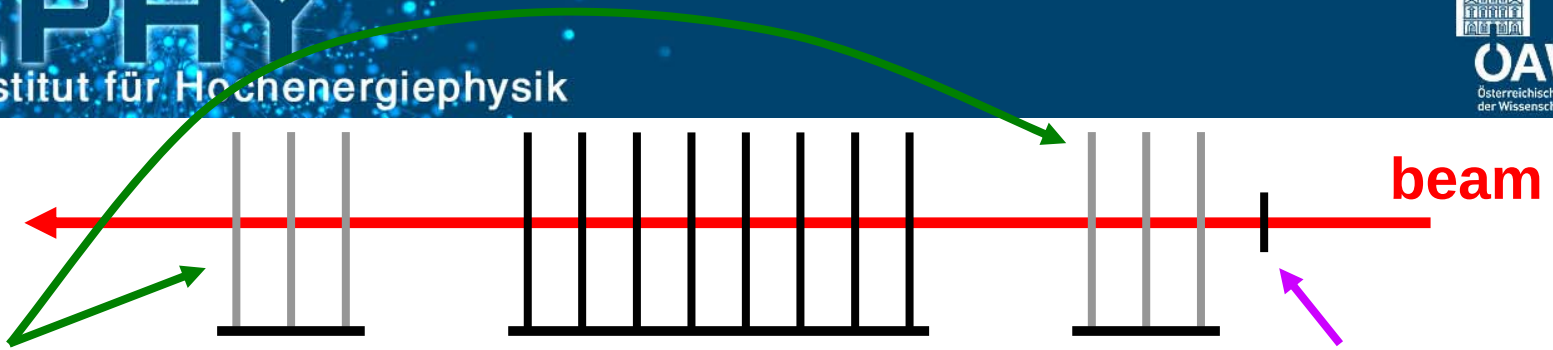
Module Stack

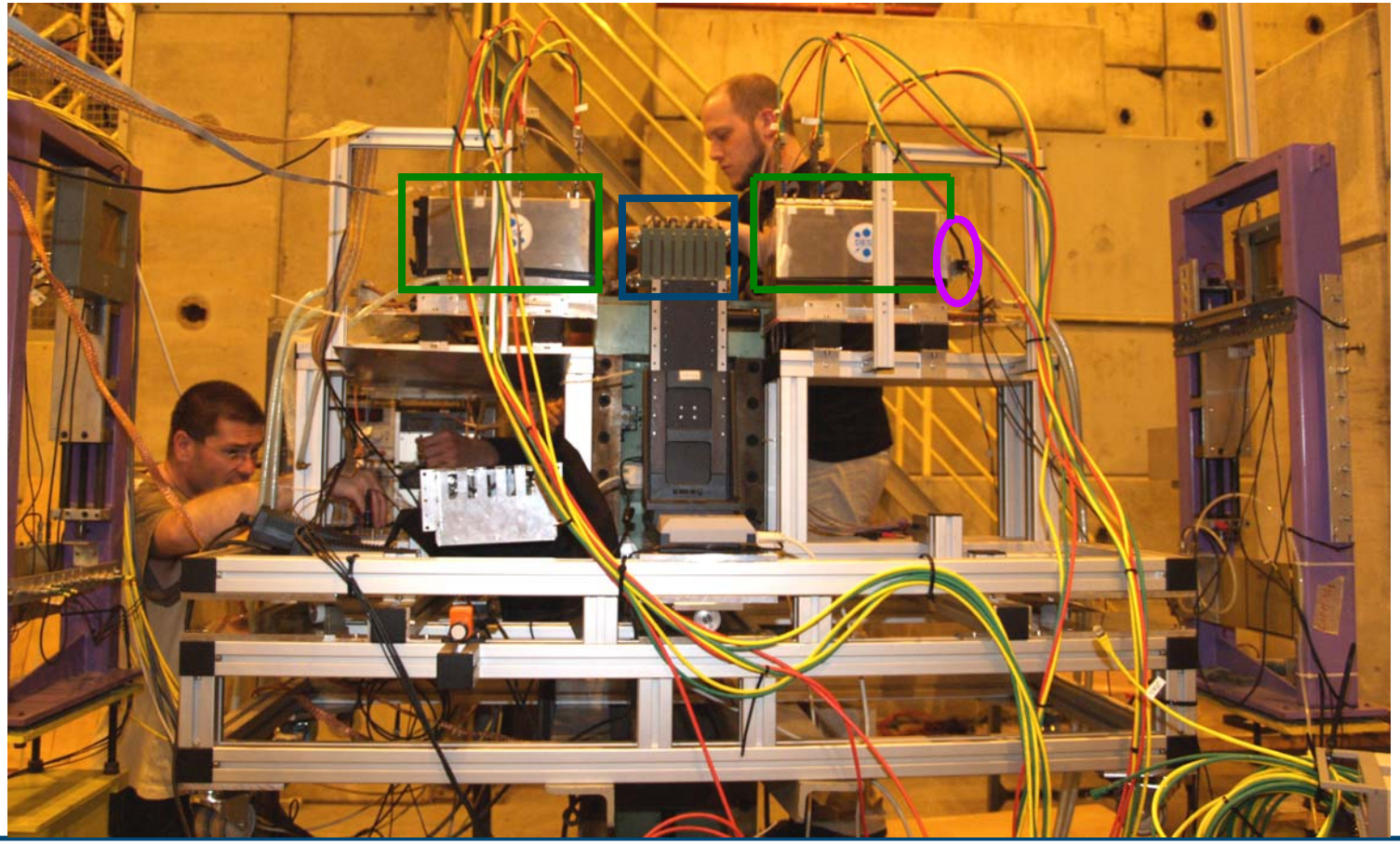
- the DUT is composed of 8 Modules screwed together and mounted on an adapter table
- gets mounted in between EUDET telescope planes

- stack of 8 modules allows us:
  - autonomous tracking (using 7 sensors as telescope for the 8th sensor)
  - and to increase the statistics
  - small drawback: increasing multiple scattering - but not that problem with 120 GeV Pions



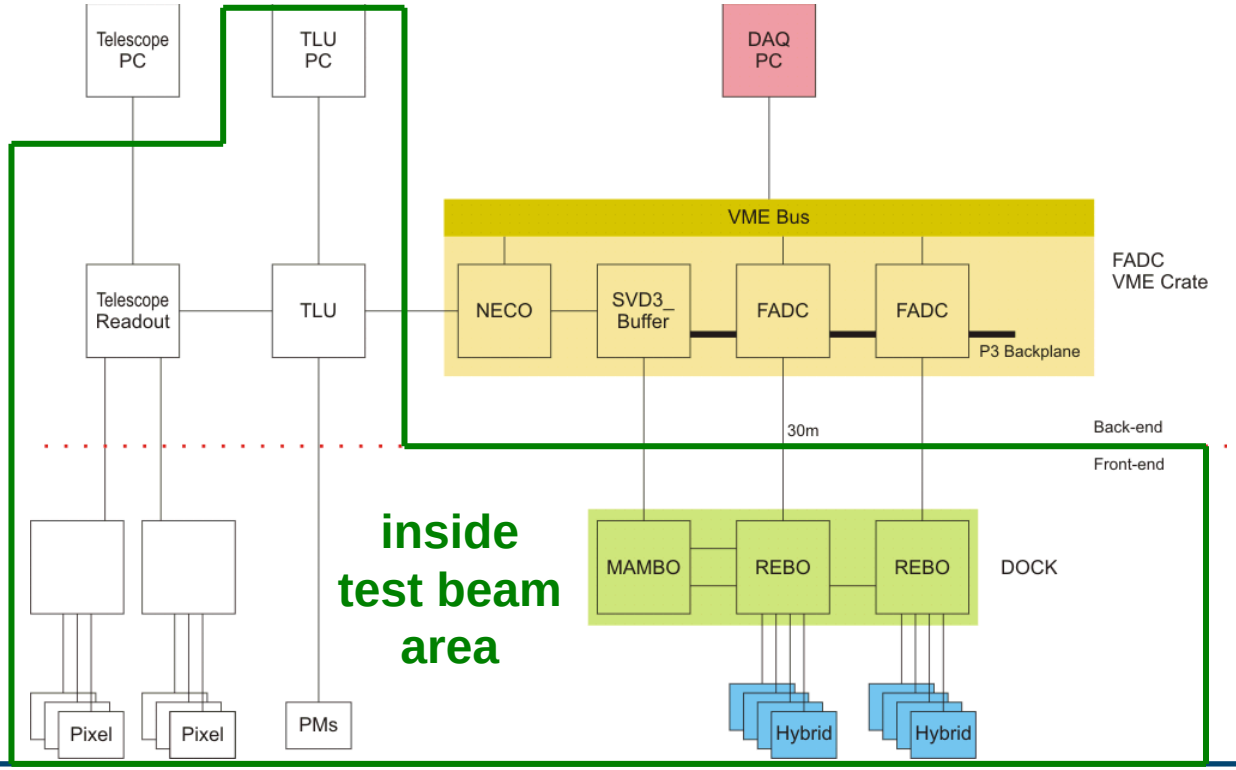
Setup:





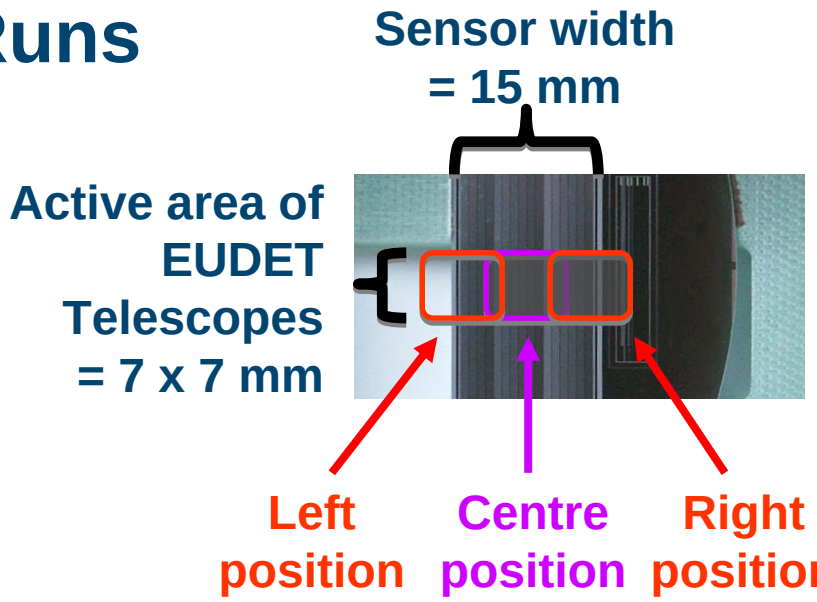
DAQ for the APV25 chip

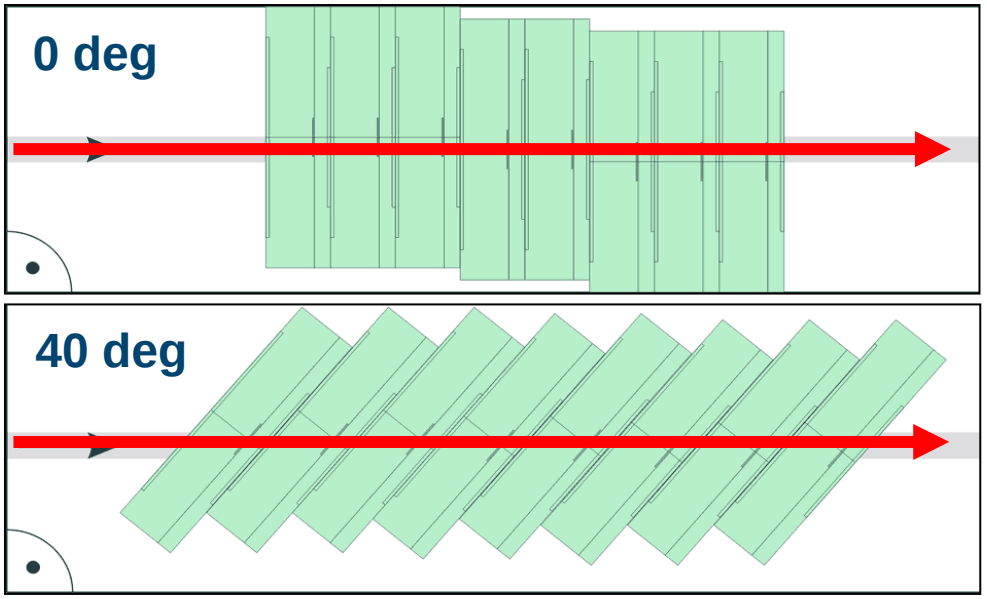
- Vienna hybrids of the modules are connected to Repeater Boards (REBO) located in DOCK box
- two 9U VME Boards with FADCs are reading data and digitalize them
- NECO Board gets clock and trigger from EUDET TLU and distributes them via the SVD3_Buffer board
- PC running CVI (LabWindows) is used for online monitoring and to store data - it is located just outside the beam area and controlled via an Ethernet connection
- TLU delivers trigger and timestamp to APV DAQ and EUTEL DAQ
- trigger rates during spills: 50 Hz
  - APVDAQ: raw
  - Telescope: zero-suppressed



List of Runs

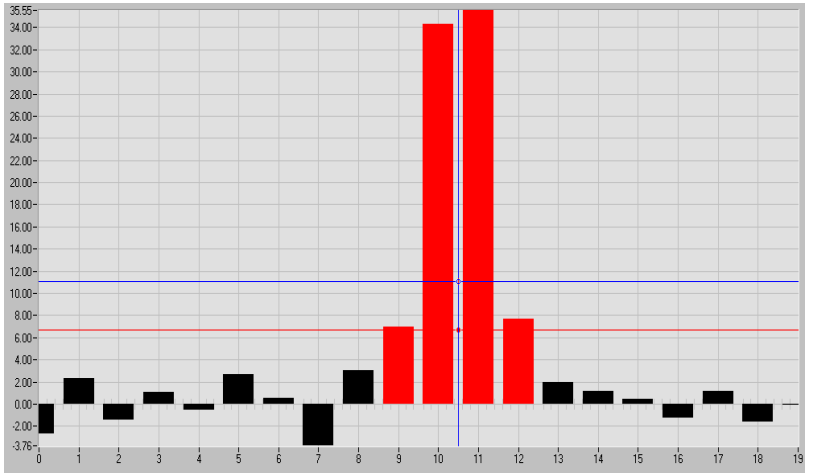
- Resolution runs
  - were repeated 3 times to cover full area
  - run numbers 2718, 2719, 2720 (each 100k events)
- HV Voltage scan
  - between 10 and 100V
  - run 2787 to 2828 (10k events each)
- Angle scan
  - between 0 and 60 deg (in steps of 10deg)
  - had to be performed manually since rotational stage of EUDET was not working (3-2-3 configuration)
  - run 2831-2837 (10k each)



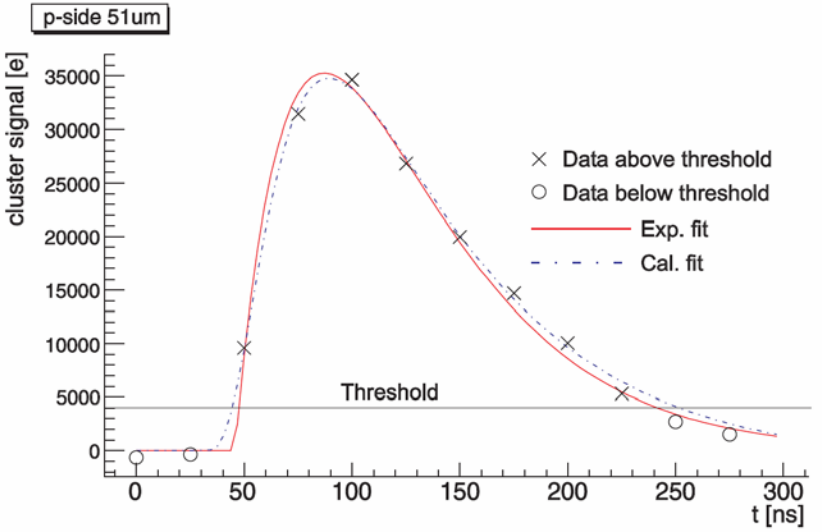


Offline Data Analysis: split in two parts

1. "low-level" Data analysis of APV DAQ data using Vienna code:
   - Pedestal subtraction
   - Common mode correction
   - Hit finding, Clustering by center-of-gravity (top pic.)
   - Peak time reconstruction (bottom pic.)

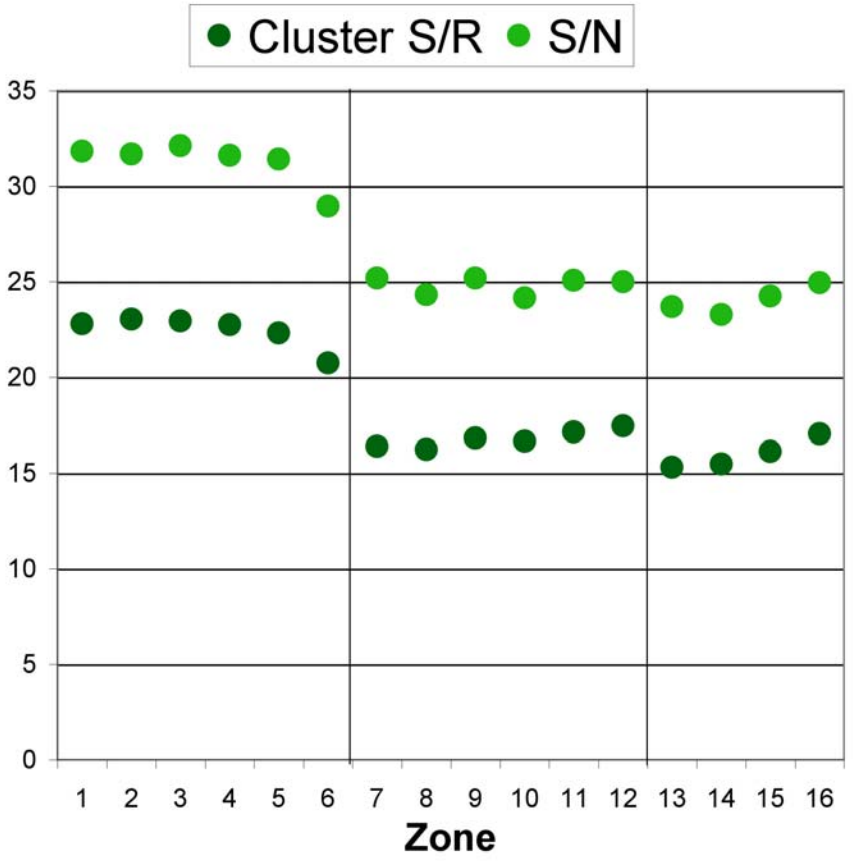


2. "high level" Tracking and residual calculation
   - determine resolutions in individual zones of the sensor to find optimum strip configuration
   - two independent tracking schemes:
     a) only strips (w/o telescope)
     b) including telescope



Signal to Noise

Zone	Int. Strips	Width [um]	MP Signal [e]	Avg Noise [e]	Avg ClWid	Cluster SNR
1	0	6,0	22035,5	692,1	1,95	22,8
2	0	10,0	22183,3	700,2	1,89	23,0
3	0	12,5	23159,2	720,8	1,96	22,9
4	0	15,0	22459,1	710,3	1,93	22,8
5	0	20,0	23270,8	740,7	1,98	22,3
6	0	25,0	22850,2	788,7	1,95	20,7
7	1	6,0	19286,1	765,6	2,36	16,4
8	1	7,5	19035,8	782,3	2,25	16,2
9	1	10,0	20159,2	800,4	2,24	16,8
10	1	12,5	20050,4	830,0	2,10	16,7
11	1	15,0	21211,7	846,0	2,14	17,1
12	1	17,5	20738,4	829,7	2,05	17,5
13	2	6,0	18398,3	776,8	2,39	15,3
14	2	7,5	18351,1	788,2	2,26	15,5
15	2	10,0	19490,5	803,3	2,26	16,1
16	2	12,5	19449,9	779,3	2,14	17,1



Cluster S/R = MP_signal / (AVG_noise * sqrt(AVG_clwid))

Prague Tracking Package

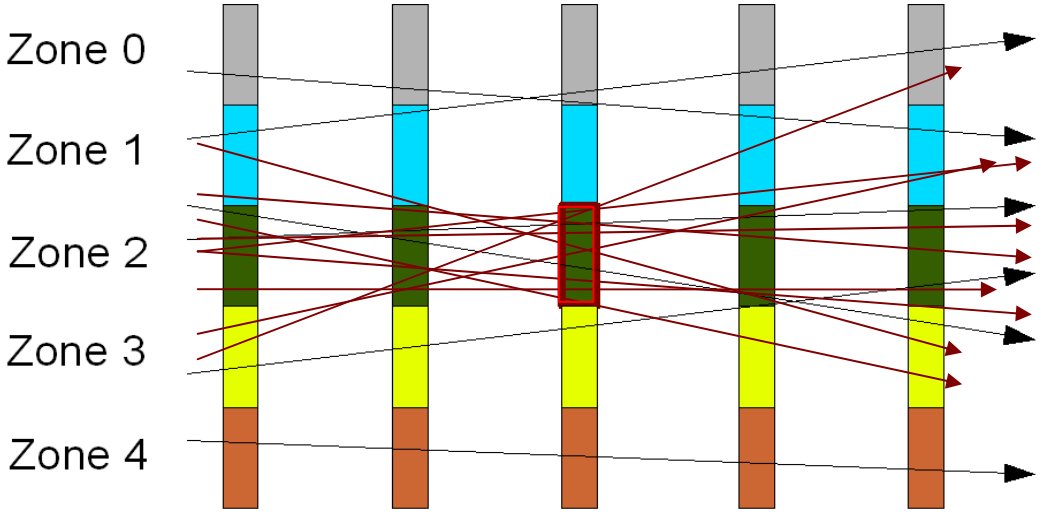
- **Package developed for tracking of DEPFET pixels**
- **A standard analysis chain, comprising**
  - hit reconstruction
  - track identification
  - detector alignment and track fitting
  - calculation of detector resolutions
  - sensibility/reliability study on simulated data

- **Features:**
  - hit alignment based on the Scott and Longuet-Higgins algorithm
  - track filter based PCA
  - robust linearized alignment
  - direct computation of detector resolutions using a track model that explicitly takes into account multiple scattering
  - calculation of alignment and resolution errors using bootstrap resampling

Zone Resolutions – only strips (I)

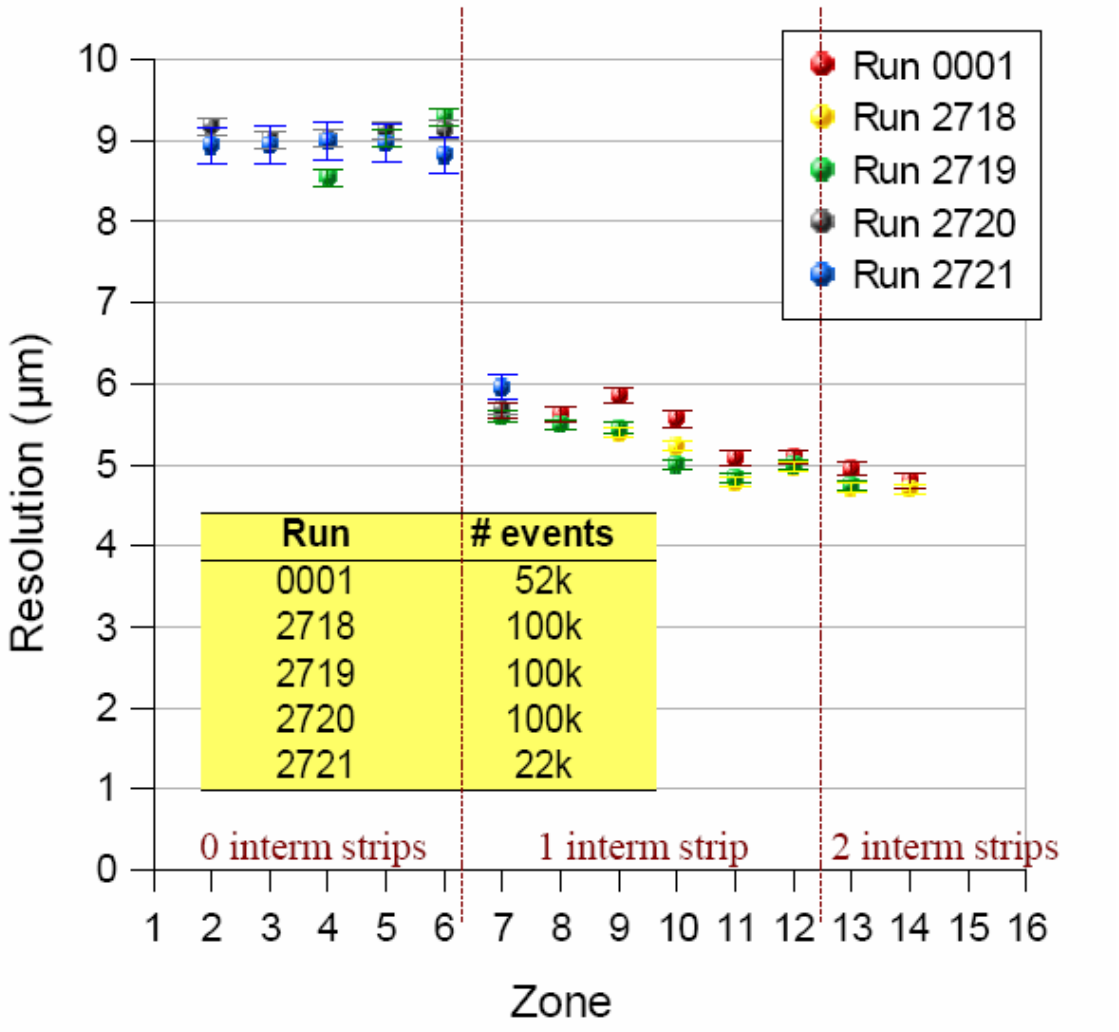
first approximation:

- **calculate resolutions for zones on detector 3, using only tracks going through the respective zone**
- **each time, resolutions are calculated for all detectors, but we have a "clean" resolution only on detector 3.**
- **resolutions on other detectors are "mixed", arising from tracks passing different zones**
- **the resolutions obtained this way were used on other detectors as appropriate for individual tracks**



- **no special treatment for edge zones was used**
- **Iteration - use zone resolutions from previous step brought very small improvement**

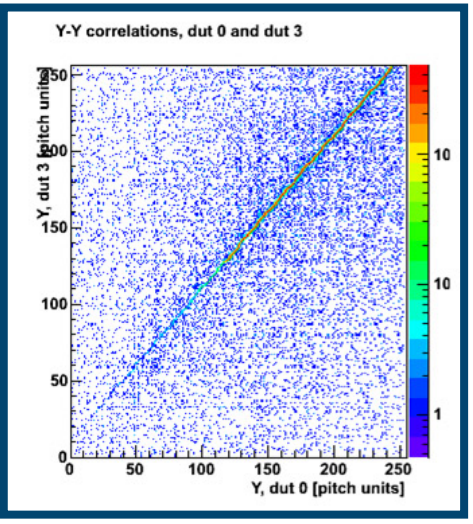
Zone Resolutions – only strips (II)

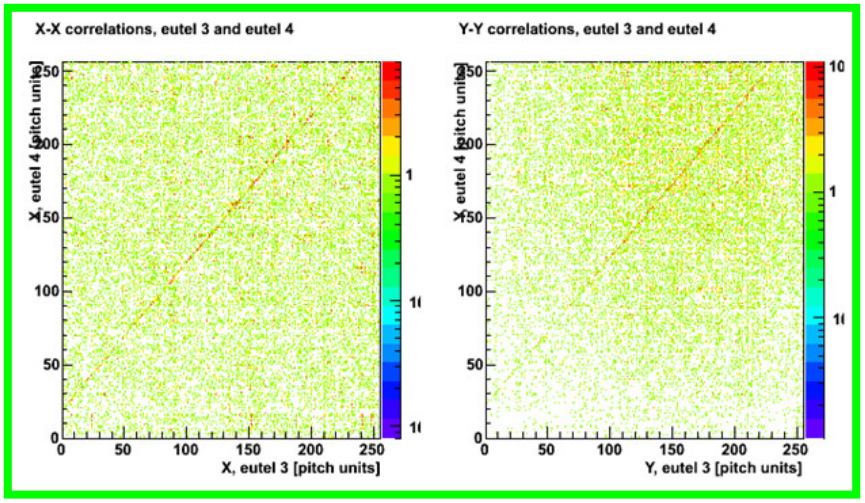


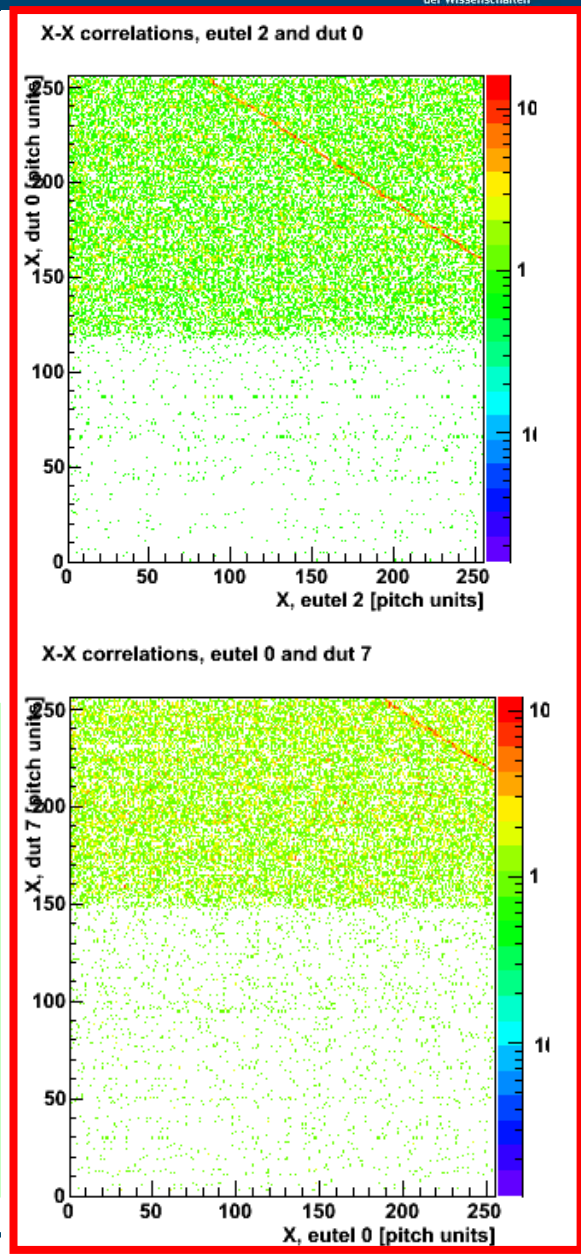
- we have to combine results of several runs with a different position of the setup relative to the beam to reach sufficient occupancy over the whole area of the detector
- even so, we don't have enough data for edge zones
- overlap regions allow to assess the precision of calculated resolutions

Route B: EUDET Telescope

- including the EUDET telescope provides an independent path to the same results – cross checking
- still in progress – for now we see correlations between:
  - two SiLC detectors
  - two Telescope-planes
  - SiLC detectors and Telescope







Summary

- we have performed a test beam to determine the spatial resolution of a silicon strip sensor with different geometric zones using the EUDET telescope as reference

- test beam at CERN between 30th May and 5th June 2008
- SPS performed “reasonable” (some breakdowns)
- Trigger was working well thanks to TLU integration during preparation
- support by EUDET was excellent (even on weekends and during night)

- we see correlation between SiLC detectors and EUDET telescope

Preliminary Results (w/o using the telescope):

➢ Resolution: 9 μm with no intermediate strips, 5-6 μm with either one or two intermediate strips

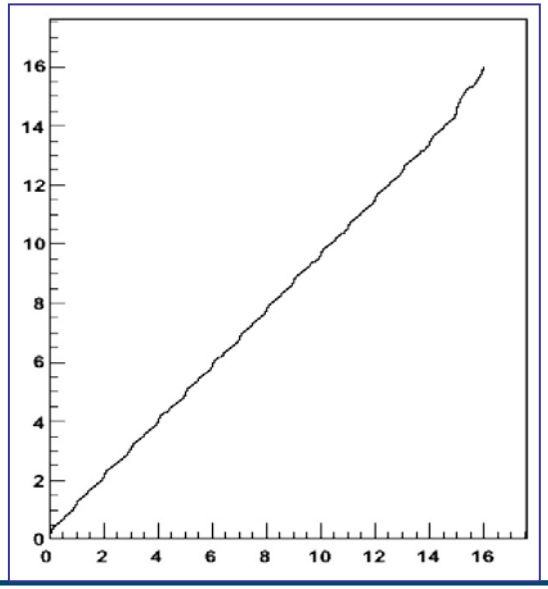
Thanks for your attention!

APV DAQ Online Monitoring

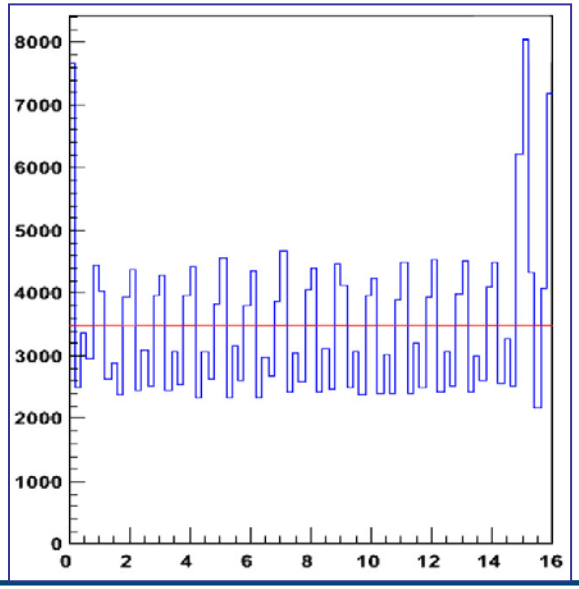
The Zone η Correction

- Zone η correction = η correction uniform for 16 strips (not for single strips): Calculate displacements so that the distribution of hits over the whole zone becomes uniform.
- Boundary effects between zones with different strips are handled by the zone η correction in a straightforward manner.
- A simple method relying on the large statistics that we have.

η correction map



hit distribution



The zone η correction:
left: the correction map
right: the original distribution of hits (blue) and distribution of η - corrected hits (red).
(in this way zone boundaries are handled automatically)

Resolution Calculations

for in detector resolution calculations we decompose track projection errors (fit residuals) into contributions of:

- measurement error (detector resolution)
- telescope error (error of track projection on the detector)
- contribution of multiple scattering to telescope error

$$diag^{-1} cov\left(u^{(c)}\right) = \mathbf{M_\Delta} \cdot \mathbf{\Delta^2} + \mathbf{M_\Sigma} \cdot \mathbf{\Sigma^2}$$

vector of diagonal elements of the matrix

covariance matrix of fit residuals (from tracking)

Vector of squared detector resolutions

vector of mean square angular deflections

Matrices depending on the method of calculation - whether fits are calculated using the given detector or not

- we need positive solution of the matrix equation, so we use quadratic programming or bootstrap resampling of the residual covariances to assure positivity

Zone resolutions - Results

Strip width [µm]	Intermediate strips	Run 0001	Run 2718	Run 2719	Run 2720	Run 2721
6	no					
10	no				9.17±0.11	8.93±0.21
12,5	no				9.01±0.10	8.94±0.23
15	no			8.54±0.11	9.02±0.10	8.99±0.21
20	no			9.03±0.10	9.12±0.10	8.97±0.21
25	no			9.29±0.11	9.13±0.10	8.81±0.21
6	single	5.66±0.10		5.60±0.07	5.69±0.07	5.95±0.14
7,5	single	5.61±0.09		5.49±0.06		
10	single	5.85±0.09	5.39±0.07	5.45±0.07		
12,5	single	5.56±0.09	5.23±0.06	5.00±0.06		
15	single	5.08±0.08	4.78±0.05	4.84±0.06		
17,5	single	5.09±0.08	4.97±0.06	5.00±0.06		
6	double	4.95±0.08	4.72±0.05	4.75±0.06		
7,5	double	4.80±0.08	4.70±0.05			
10	double					
12,5	double					

DAQ: APV25 Readout System

- DAQ Hardware was installed outside of testbeam zone to allow intervention without cutting the beam
  - We had 30m cables between crate and front-end
- Ethernet connection was used to communicate with DAQ from control room