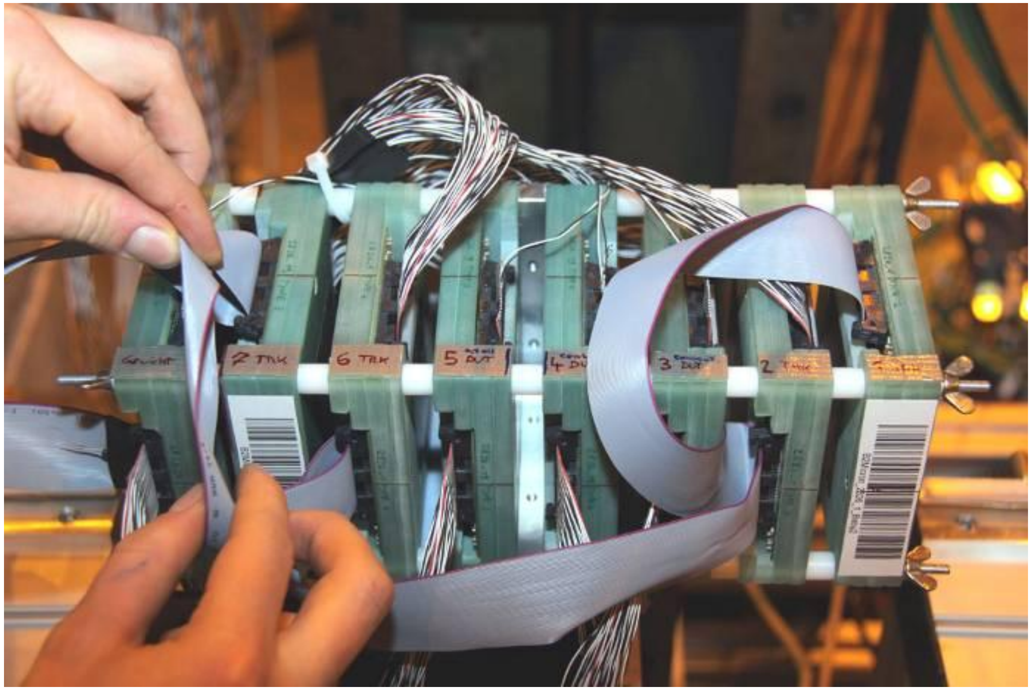

Optimization of strip isolation for silicon sensors

SVD-PXD meeting, Vienna

M. Valentan, T. Bergauer, M. Dragicevic
M. Friedl, C. Irmler, E. Huemer

Outline

- The sensors under test
- The experimental setup
- Comparison of p-stop patterns
- Summary and plans

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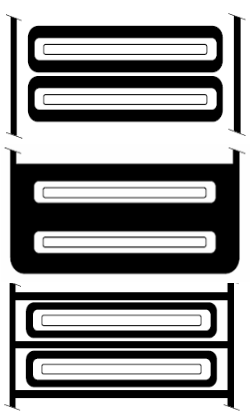
Sensor purchase for Belle II (Japan)

MICRON SEMICONDUCTOR ltd

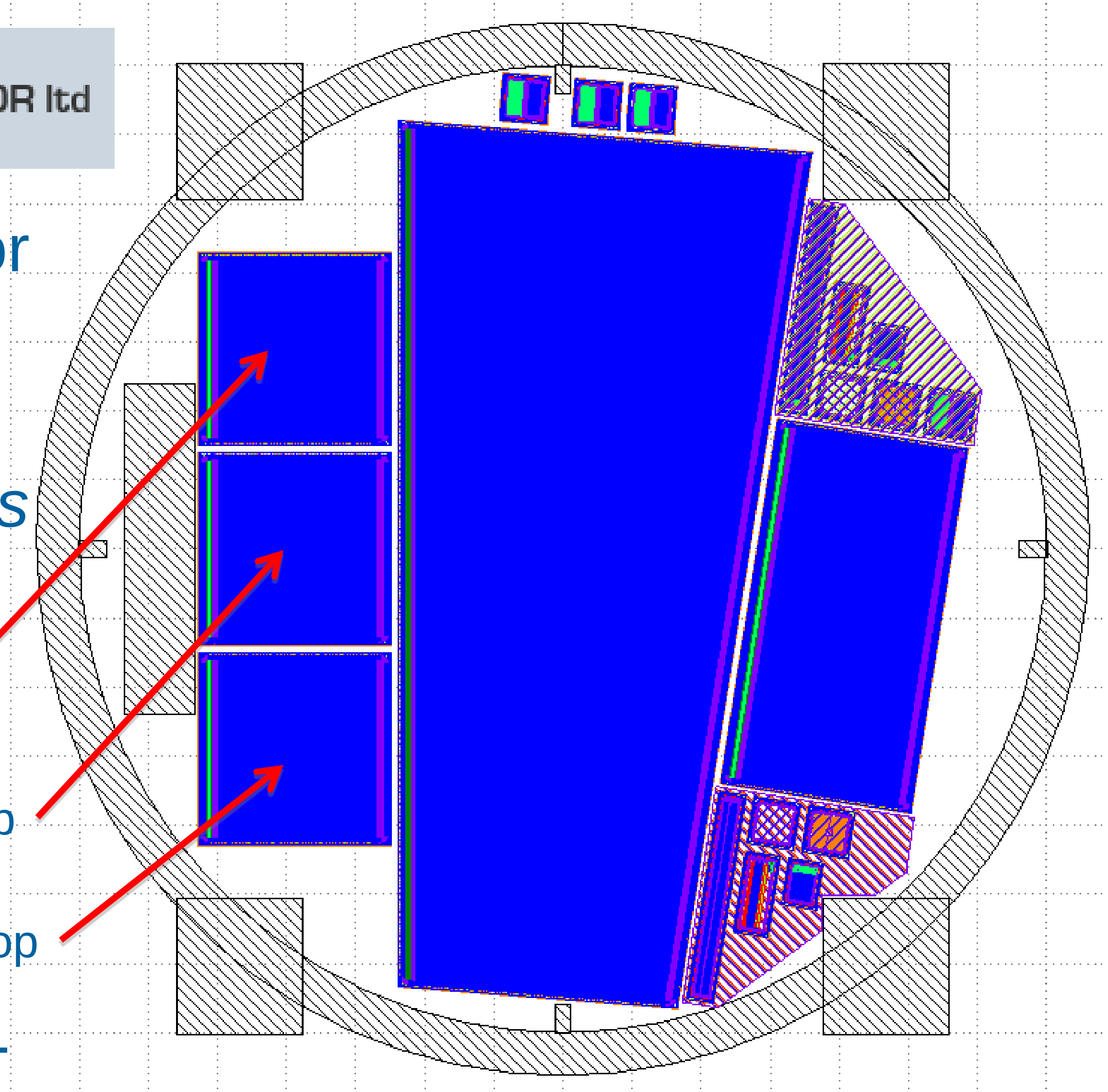
- Trapezoidal sensor for forward region
- *This talk focuses on the test sensors*



Atoll p-stop

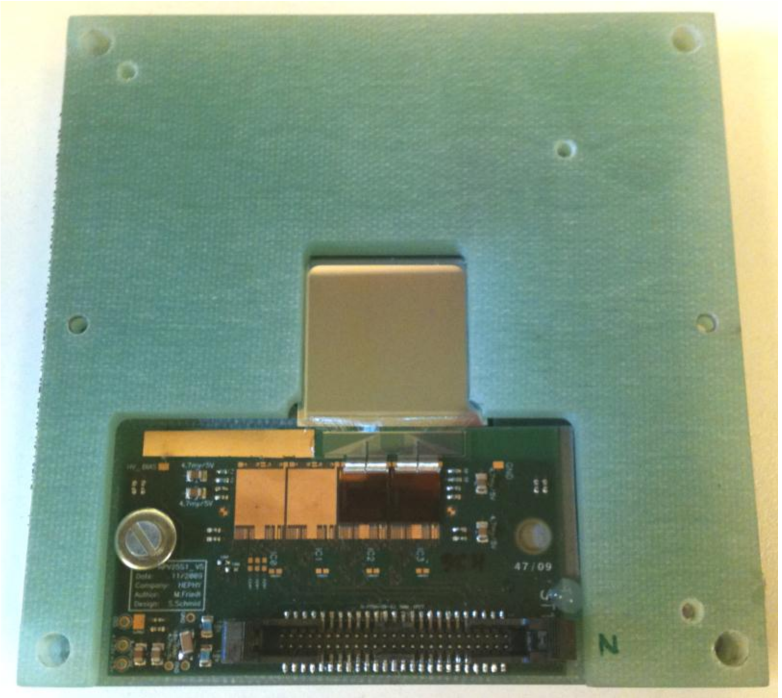
Common p-stop

Combined p-stop



The devices under test

- Double sided silicon detector (DSSD)
- n-type substrate
- $V_{depl} = 60V$
- Focus on n-side
  - 256 n-doped strips
  - 100 µm pitch, no interm.
  - Strip isolation by p-stop blocking method



- Readout by APV25 chip (CMS)
  - Analogue readout of pulse height

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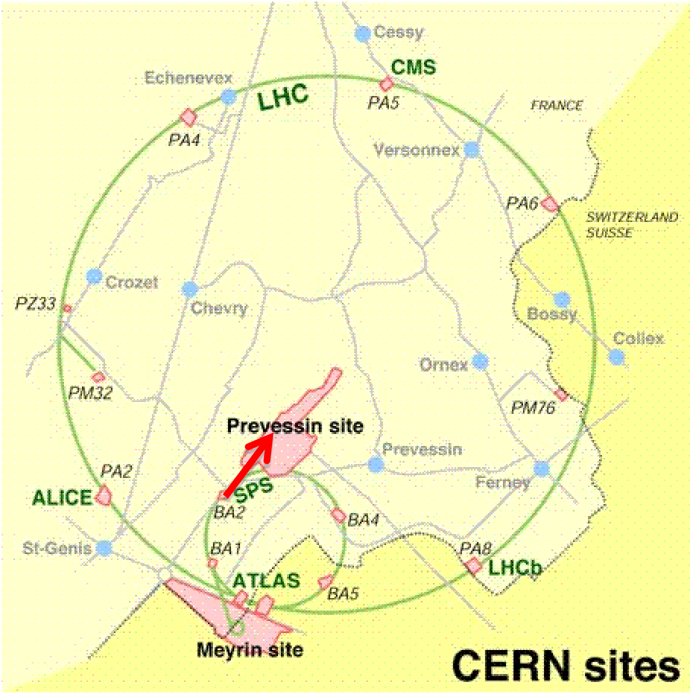
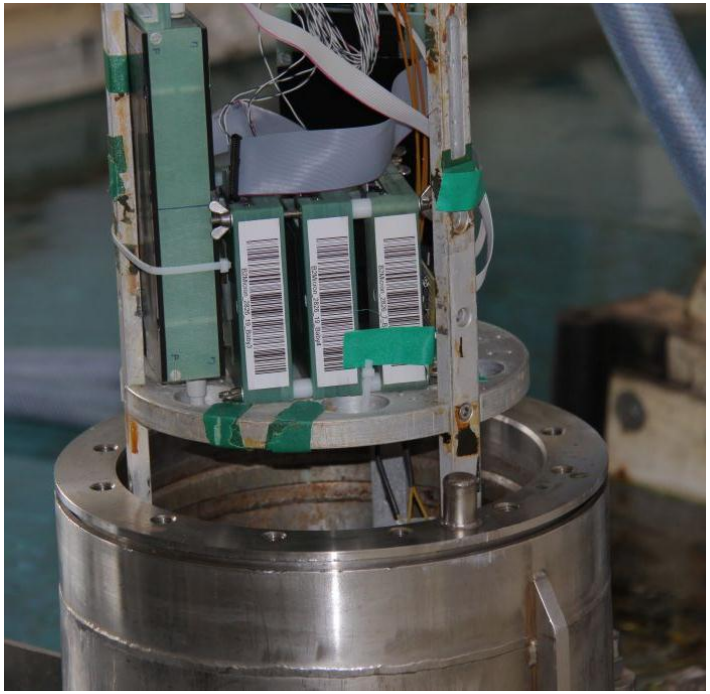
The locations





- CERN, beam line H6 of SPS
- September 27 – October 11, 2010
- 120 GeV hadrons, mostly pions
- 100k events
- EUDET telescope

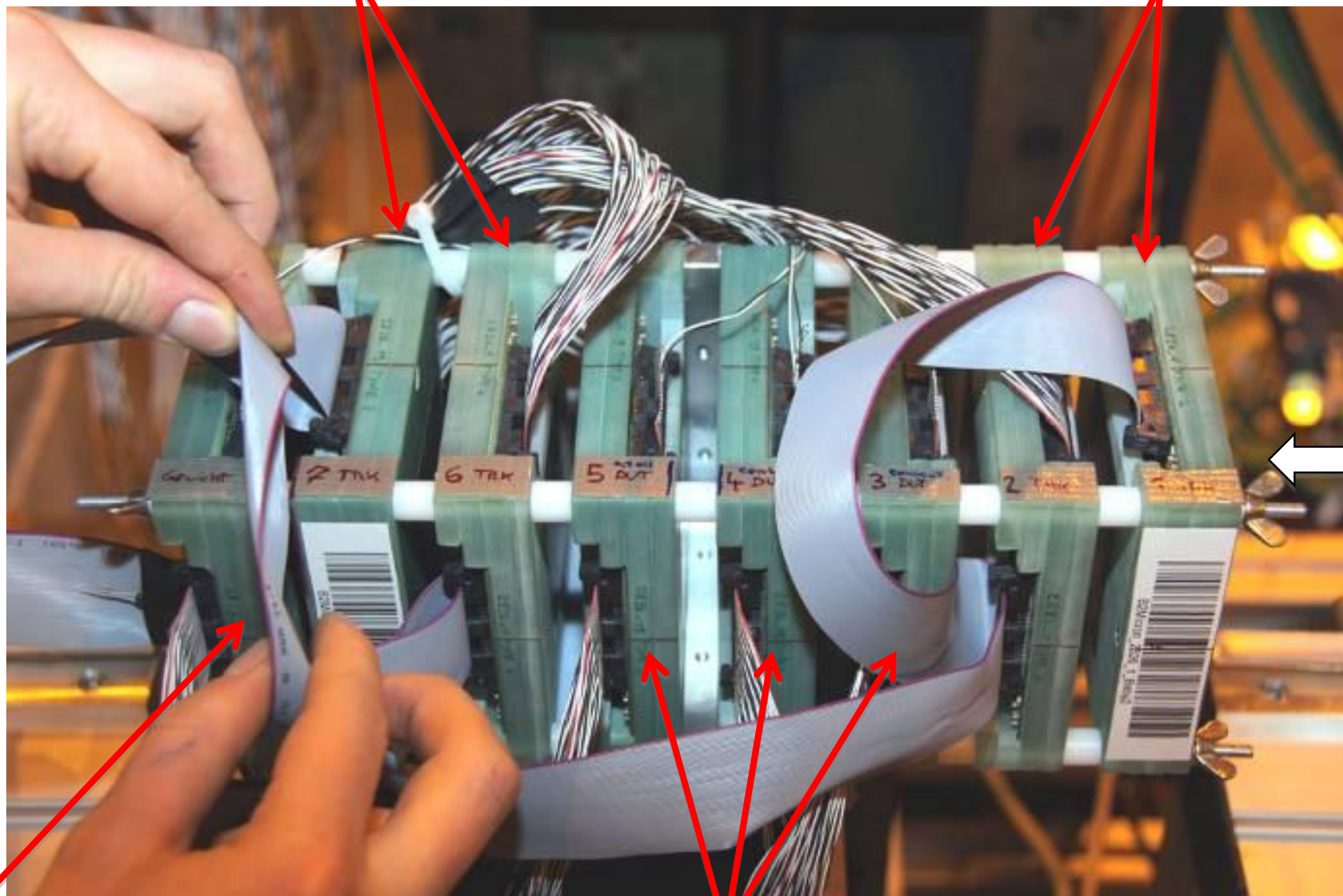
- SCK-CEN, Mol, Belgium
- October 3 – 5, 2010
- ^{60}Co gamma source
- 25 kGy per hour
- Irradiation to 700 kGy

SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Stack setup

Two sensors for tracking (p-side)

Two sensors for tracking (p-side)



120 GeV hadrons (mostly π)

One module just for balance

Three DUTs, one of each p-stop pattern (n-side)

Outline

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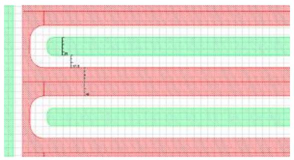
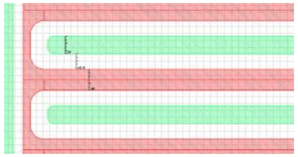
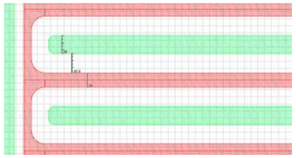
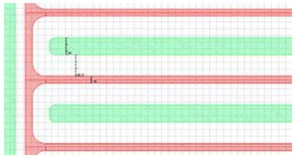
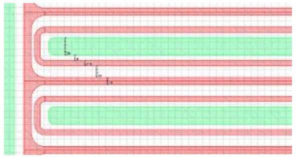
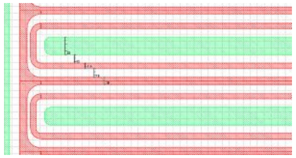
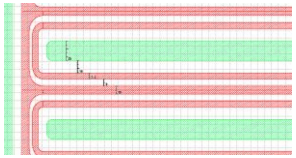
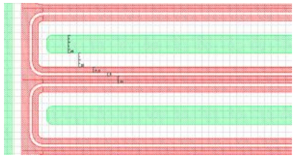
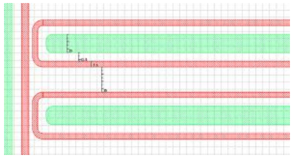
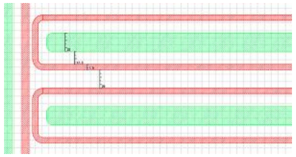
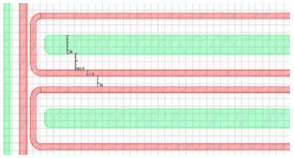
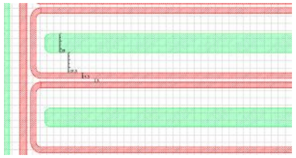
p-stop layouts of the test sensors

- Three different p-stop patterns
- Per pattern, four zones with different geometry
- Green: strip implant (n), Red: p-stop

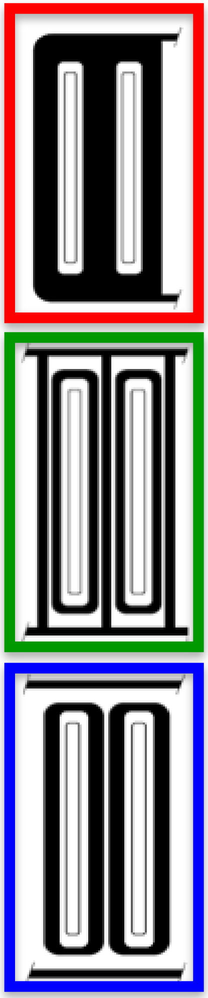
	narrow	half-narrow	half-wide	wide
Common				
Combined				
Atoll				

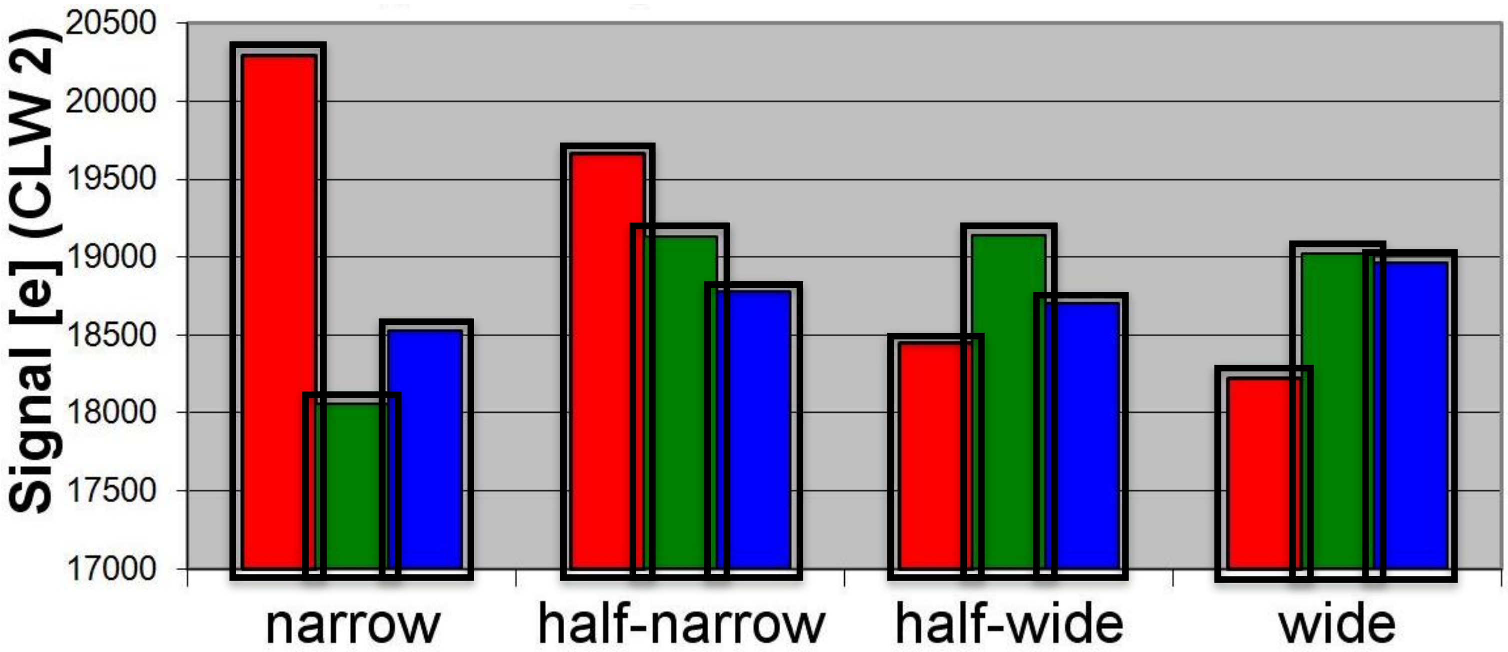
Comparison of p-stop patterns

- Quantities to compare:
  - Signal levels, noise levels
    - Subject to calibration – compare with caution!
  - Signal-to-noise ratio (SNR)
    - Calibration cancels out → can be directly compared, even before and after irradiation
- Clusters of exactly 2 strips
  - To see effects of charge sharing and be sensitive to the region between the strips i.e. the p-stops
- Combined p-stop favored by
  –

[1] IEEE Transactions On Nuclear Science 45 (1998) 303-309 - Iwata et.al
[2] IEEE Transactions On Nuclear Science 45 (1998) 401-405 - Unno et.al

Cluster signal before irradiation



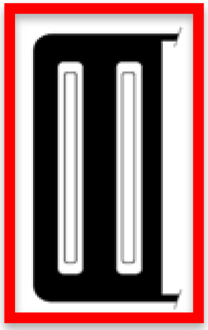


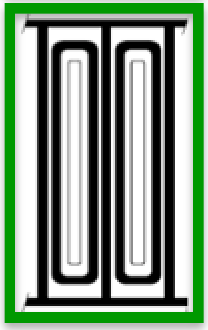
Common p-stop: signal yield sensitive to implanted area

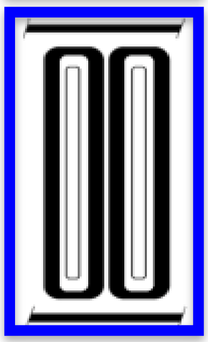
Combined p-stop: high signal, fairly constant

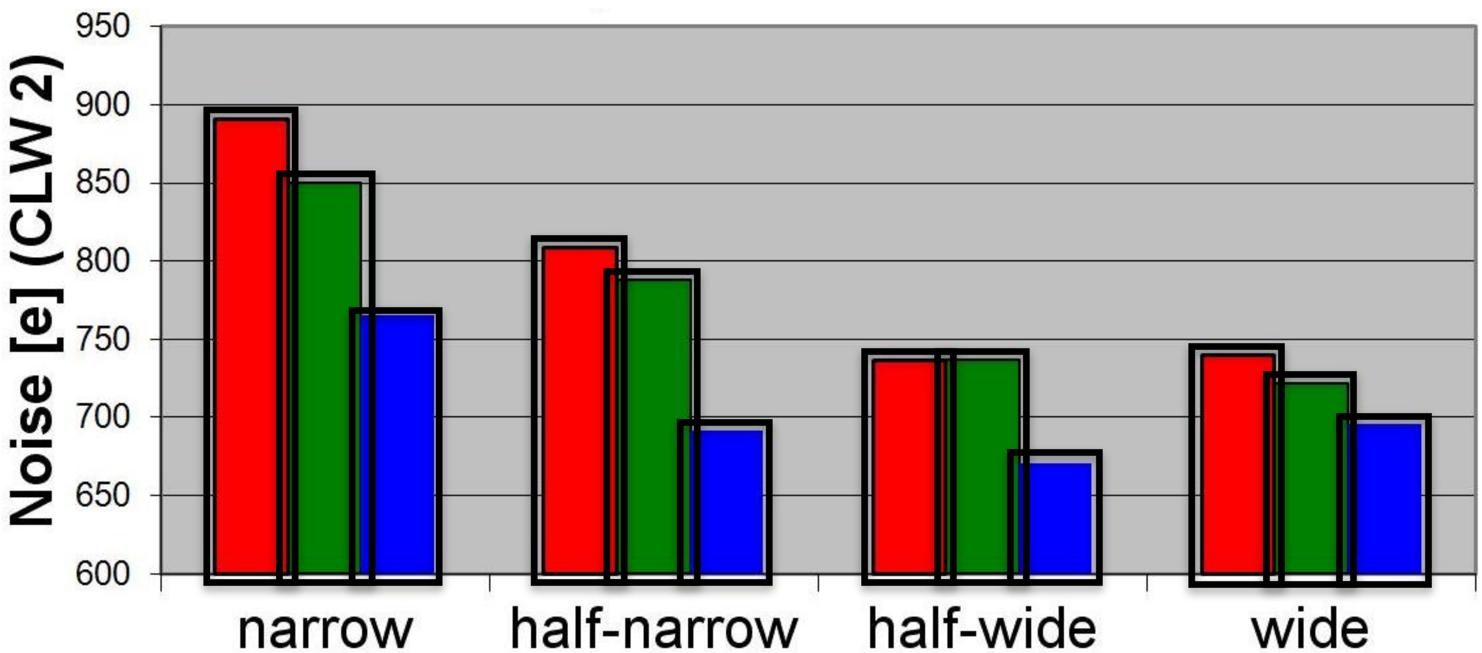
Atoll p-stop: fairly constant, lower than combined p-stop

Cluster noise before irradiation







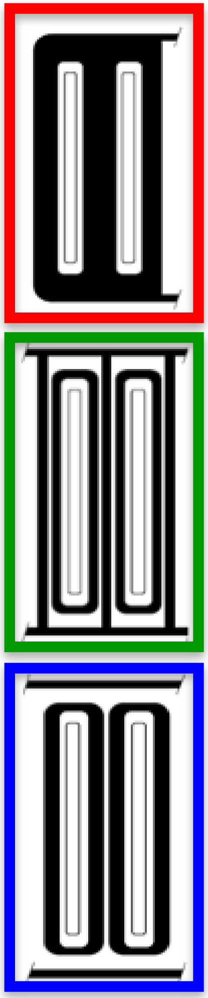


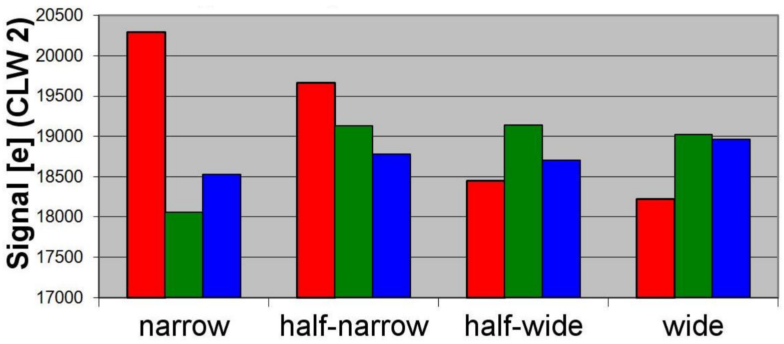
Common p-stop: highest noise, best for half-wide geometry

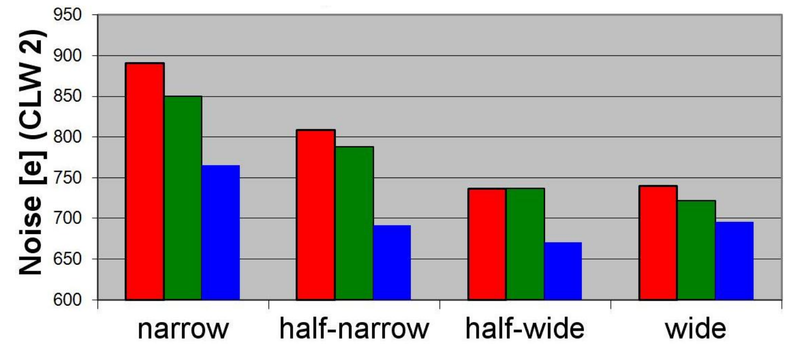
Combined p-stop: close second, best for wide geometry

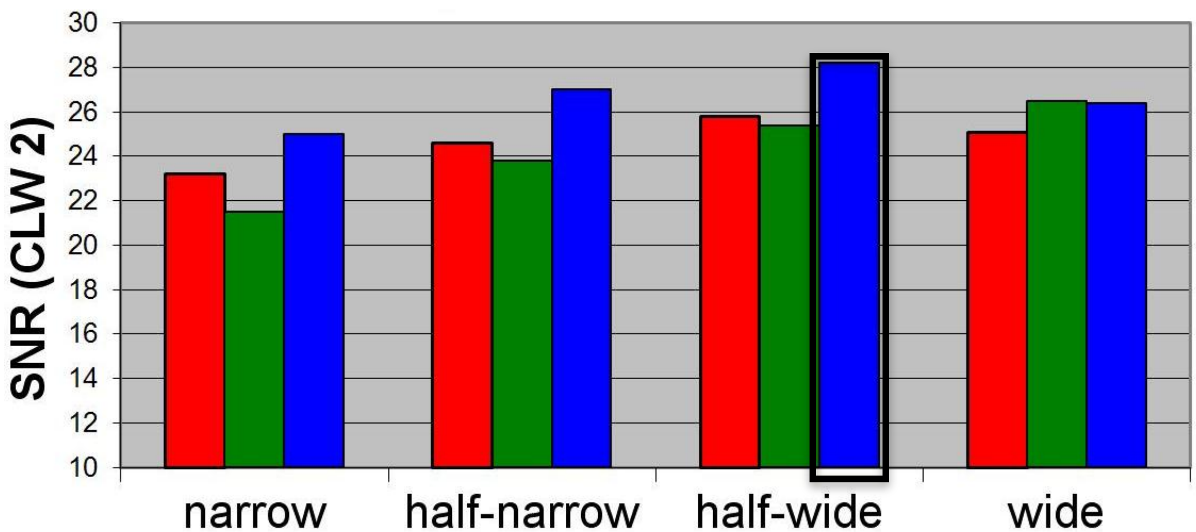
Atoll p-stop: lowest noise, best for half-wide geometry

Cluster SNR before irradiation



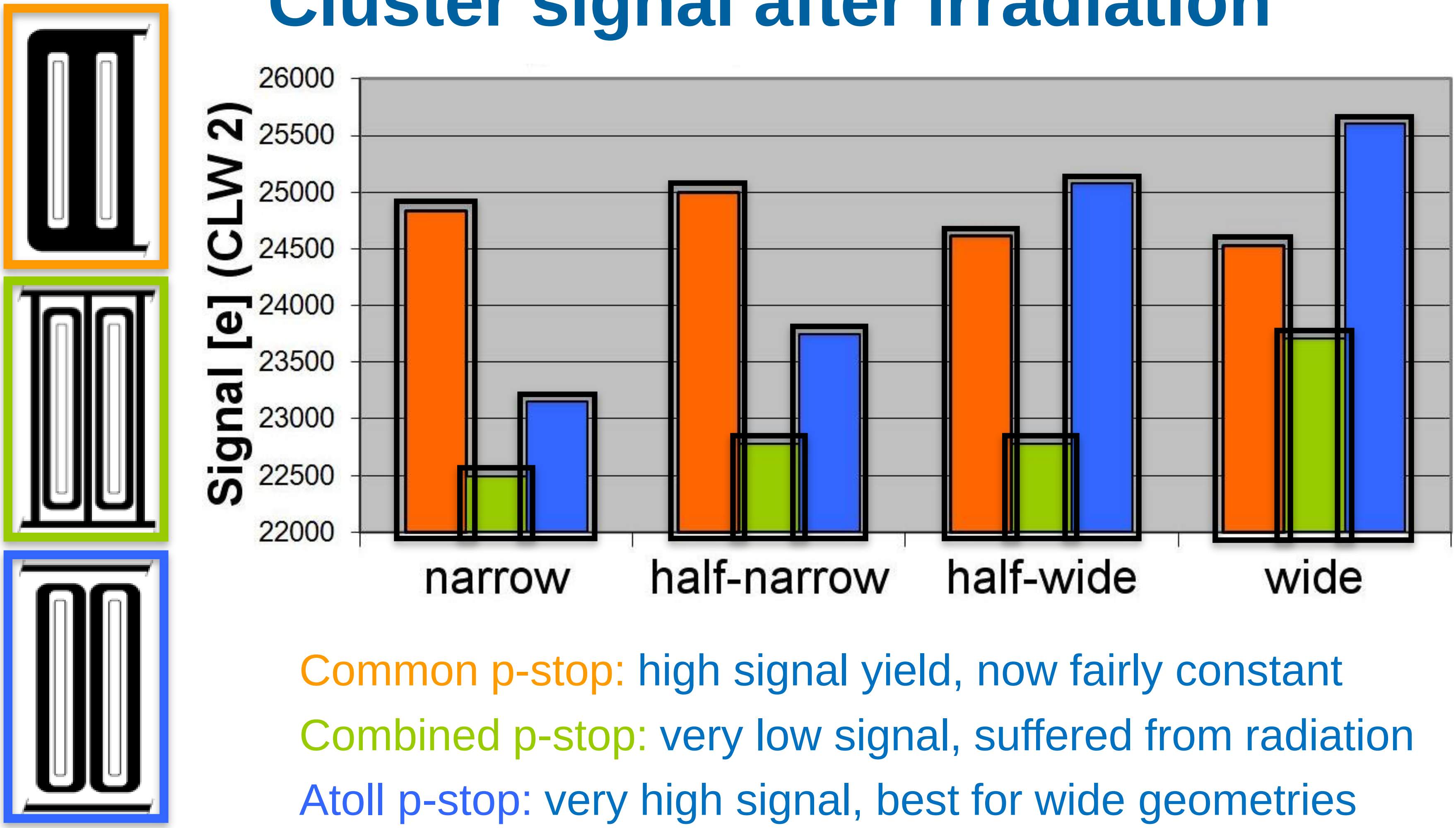






- Half-wide atoll best of all variants

Cluster signal after irradiation

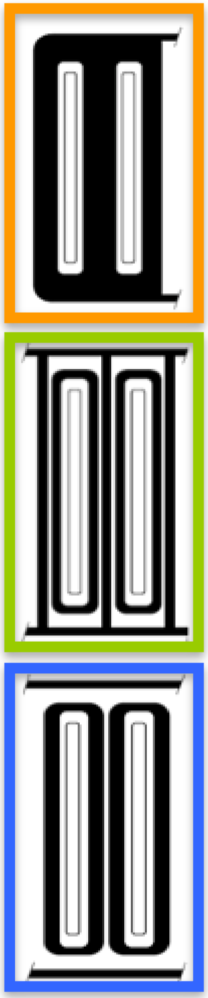


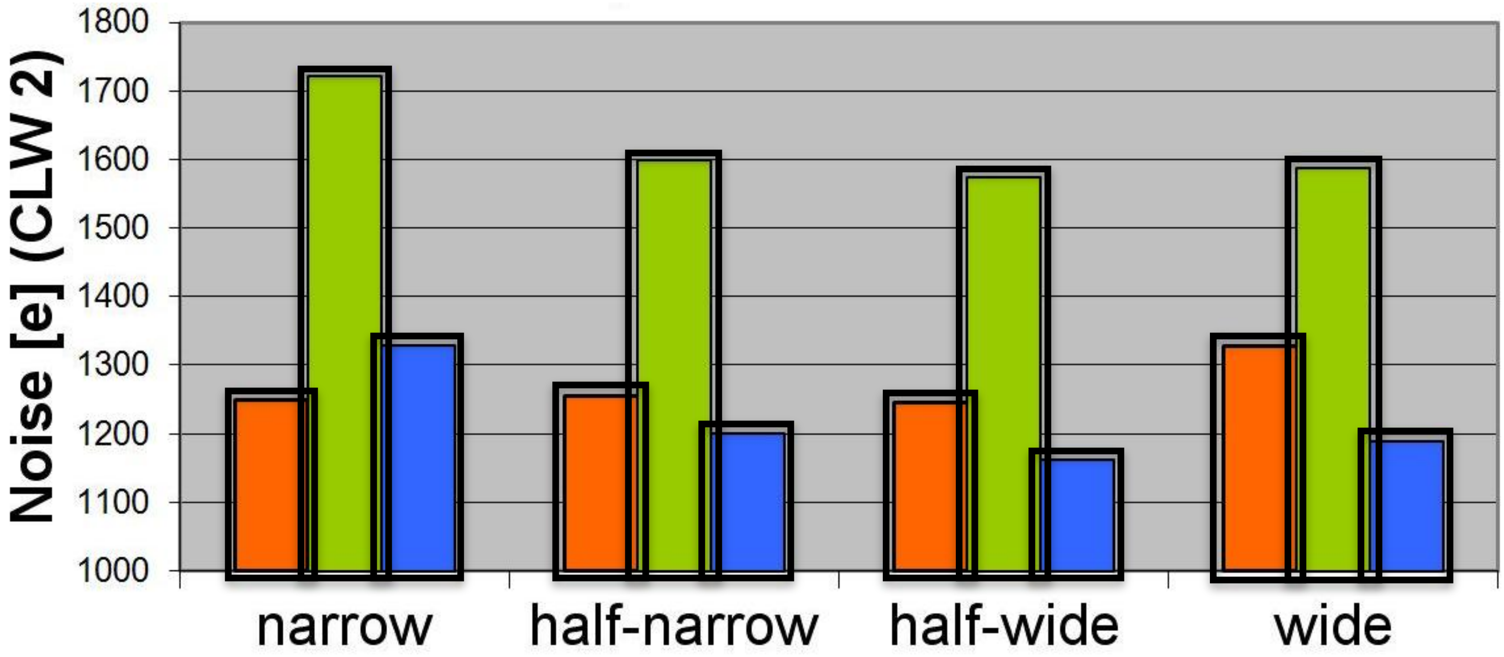
Common p-stop: high signal yield, now fairly constant

Combined p-stop: very low signal, suffered from radiation

Atoll p-stop: very high signal, best for wide geometries

Cluster noise after irradiation



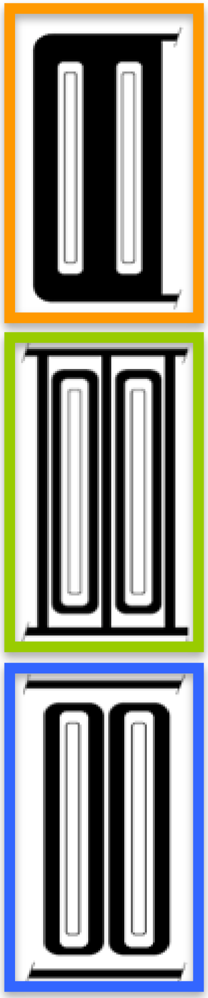


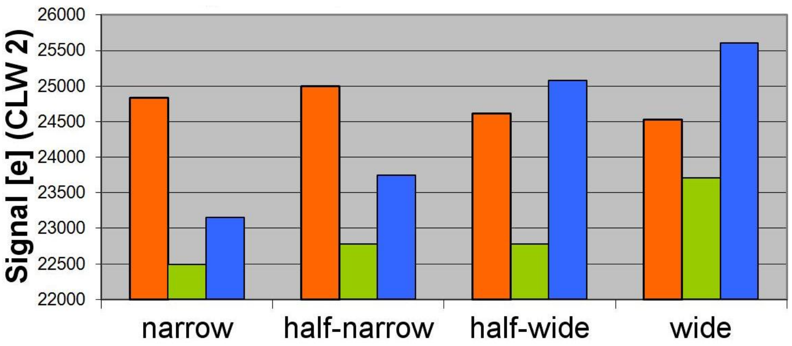
Common p-stop: low noise, fairly constant except for wide g.

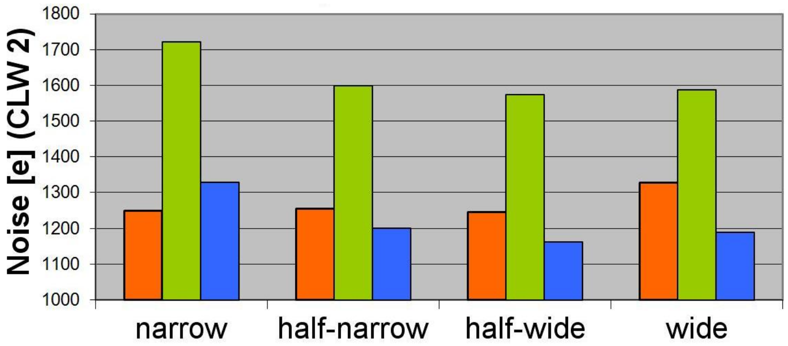
Combined p-stop: very high noise, suffered from radiation

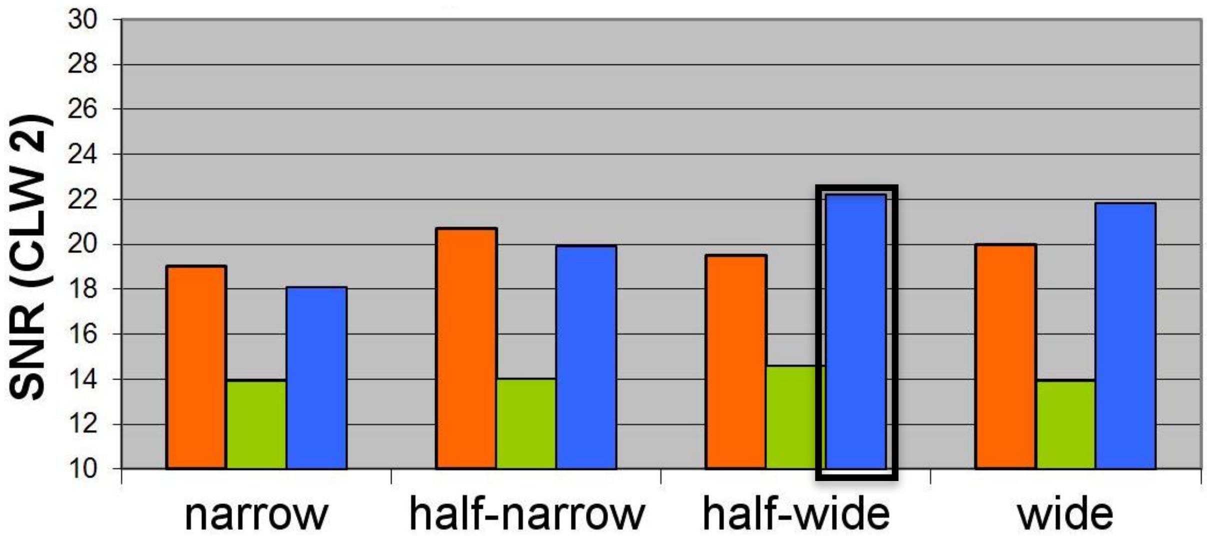
Atoll p-stop: lowest noise, best for wide geometries

Cluster SNR after irradiation









- Again, half-wide atoll best of all variants

Outline

- The sensors under test
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Summary

- We developed test sensors featuring three different p-stop patterns, with four different geometries per pattern
- The half wide atoll pattern was found to perform best in terms of signal-to-noise-ratio, both unirradiated and irradiated

Plans

- Belle II uses sensors with intermediate strips which are not read out.
  ➔ Remove every second bond to mimic the behavior of a sensor with intermediate strips
  – Beam test done, data awaiting analysis → B2GM
- Purchase new batch of sensors with finer variation between wide and half-wide geometry
  – Production in progress

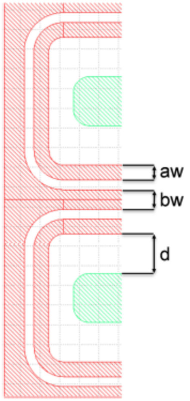

That's all Folks!

Backup slides

p-stop patterns - details

		narrow	half-narrow	half-wide	wide
Common	bar width (bw)	40	30	20	10
	distance (d)	17.5	22.5	27.5	32.5
Combined	bar width (bw)	10	10	10	10
	atoll width (aw)	7.5	7.5	7.5	7.5
	distance (d)	8	12	16	20
Atoll	atoll width (aw)	7.5	7.5	7.5	7.5
	distance (d)	12.5	17.5	22.5	27.5

The dimensions of the different p-stop geometries, values are given in [μm]



Geometry with dimensions

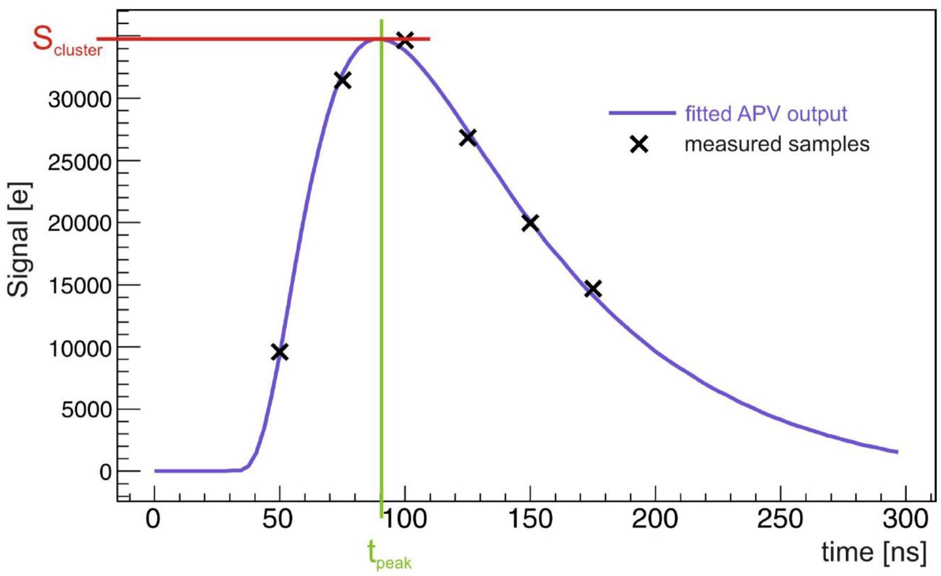
		narrow	half-narrow	half-wide	wide
Common	unirradiated	23.2 ± 0.08	24.6 ± 0.07	25.8 ± 0.07	25.1 ± 0.06
	irradiated	19.0 ± 0.06	20.7 ± 0.05	19.5 ± 0.05	20.0 ± 0.04
Combined	unirradiated	21.5 ± 0.06	23.8 ± 0.06	25.4 ± 0.07	26.5 ± 0.08
	irradiated	13.9 ± 0.02	14.0 ± 0.03	14.6 ± 0.03	13.9 ± 0.04
Atoll	unirradiated	25.0 ± 0.06	27.0 ± 0.07	28.2 ± 0.08	26.4 ± 0.06
	irradiated	18.1 ± 0.03	19.9 ± 0.04	22.2 ± 0.04	21.8 ± 0.04

Most probable SNR fit values of the p-stop patterns and geometries. Green: best value within one pattern; Red: overall best value.

Definition of cluster signal

The APV25 chip is capable of taking multiple samples of the shaped waveform when readout is triggered. For determining the peak signal and exact hit time, six samples around the signal peak are recorded. The cluster signal for each sample is calculated by summation of the respective samples of all adjacent strips above a certain threshold and therefore contributing to the cluster. Note that this procedure yields the cluster signal and not the single strip signal. Then these samples are fitted with a reference waveform to obtain amplitude and timing (see figure 6). The reference waveform is taken from an internal calibration scan of the APV25 chip.

The cluster signal values obtained by this procedure follow a Landau distribution with a small admixture of a normal distribution. The Landau distribution describes the physical sensor response, whereas the Gaussian part accounts for electronic noise and intrinsic detector fluctuations. We fit a convolution of a Landau probability density function (pdf) with a normal pdf to a histogram of the cluster signal values. The free parameters of the fit are the most probable value and the width of the Landau pdf, as well as the width of the Gaussian pdf and a normalization constant. For comparisons of signal yield we use the most probable value given by this fit.



Definition of cluster noise

At the begin of each data taking run, we take 600 readings with random triggers and no beam. This ensures that the sensor does not give a signal at the time of the trigger. The pedestal offset of the individual strips is calculated as the mean value of the first 200 readings of each strip, which is hereafter substracted from all following readings. From the next 200 readings the mean value of blocks of 32 strips is calculated, which gives the common mode noise, and for each strip a first approximate noise value is calculated by the root mean square (RMS). From now on, strips with high RMS are omitted when calculating common mode noise. After pedestal subtraction and common mode correction, the last 200 readings are histogrammed for each strip and the distribution is fitted with a Gaussian function. The standard deviation of this fit is the single strip noise, whereas the cluster noise is hereafter calculated according to

$$\sqrt{\Sigma_{i=1}^{n} N_i^2}$$

Definition of cluster SNR

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

Like the cluster signal values, also the SNR values follow a Landau distribution with a small admixture of a normal distribution. The Gaussian part accounts for electronic noise and intrinsic detector fluctuations, which are of no interest for the comparison between different sensor properties. The Landau part of the SNR distribution describes the sensor response and thus the performance of the different p-stop geometries. So, we fit a convolution of a Landau pdf with a normal pdf to a histogram of the SNR values. The fit parameters are again the most probable value and width of the Landau pdf, the width of the Gaussian pdf and the normalization. For comparing the detector performance we use the fit results of the most probable value (MPV) of the distribution's Landau part.