Time Resolution of a Few Nanoseconds in Silicon Strip Detectors Using the APV25 Chip

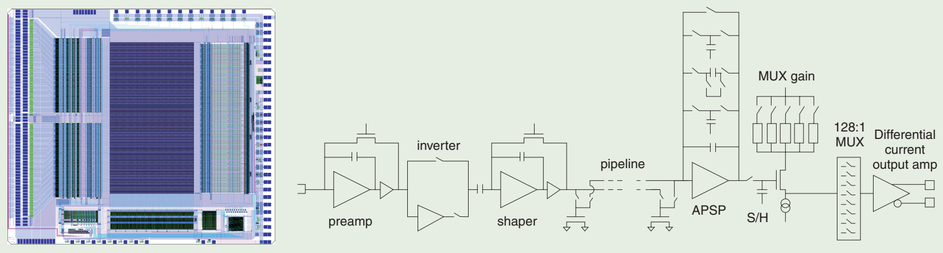
Presented at the 12th Workshop on Electronics for LHC and future Experiments, Valencia, 25-29 September 2006

M. Friedl*, C. Irmler, M. Pernicka Institute of High Energy Physics (HEPHY), Austrian Academy of Sciences, Vienna (Austria)

ABSTRACT

The APV25 front-end chip for the CMS Silicon Tracker has a peaking time of 50ns, but confines the signal to a single clock period (=bunch crossing) with its internal deconvolution filter.
This method requires a beam-synchronous clock and thus cannot be applied to a (quasi-) continuous beam. Nevertheless, using the multi-peak mode of the APV25, where 3 (or 6,9,12,...) consecutive shaper output samples are read out, the peak time can be reconstructed externally with high precision.
Thus, off-time hits can be discarded which results in significant occupancy reduction.
We will describe this method, results from beam tests and the intended implementation in an upgrade of the BELLE Silicon Vertex Detector.

APV25



APV25 Front-End Chip Features

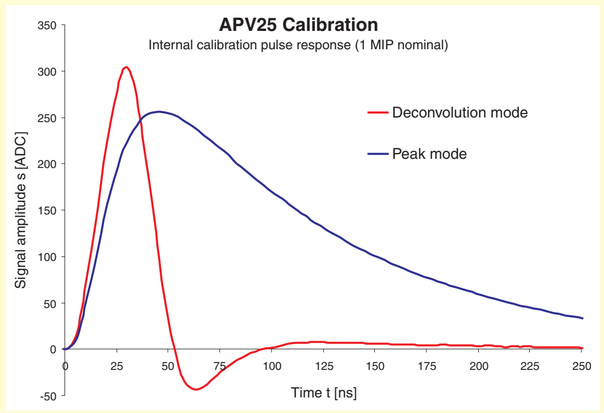
- 40MHz operation
- 128 channels
- 192 cell deep analog pipeline
- 50ns shaping time (adjustable between 30 and 400ns)
- Modes: Peak / Deconvolution / Multi-peak
- 0.25μm CMOS process
- Radiation tolerance >100MRad
- Low noise: 250e+36e/pF (peak), 400e+60e/pF (deconvolution)

DECONVOLUTION

Weighted sum of 3 consecutive samples

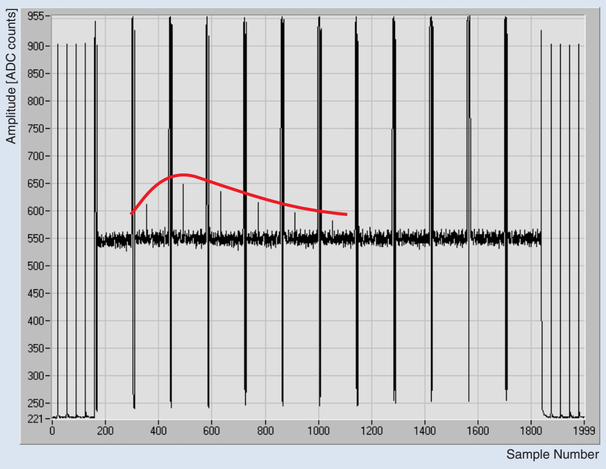
$d_i = 0.4463\ p_{i-2} - 1.4715\ p_{i-1} + 1.2131\ p_i$

The curve shows the normal shaper output (**peak mode**) obtained by a progressive scan.
The same procedure can be applied in **deconvolution mode**, resulting in a narrowed curve which is virtual because the deconvolution is a time-discrete procedure performed on samples spaced by the clock period (25ns).



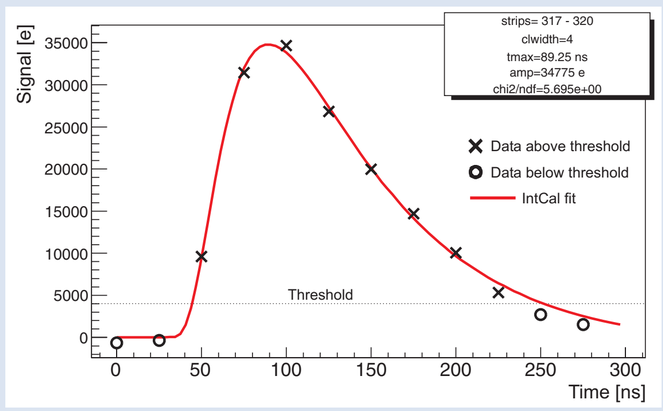
The deconvolution method requires clock synchronous particle signals (i.e. beam)! Thus, it cannot be applied with a quasi-continuos beam such as in BELLE.

MULTI-PEAK MODE



Multi-peak mode output

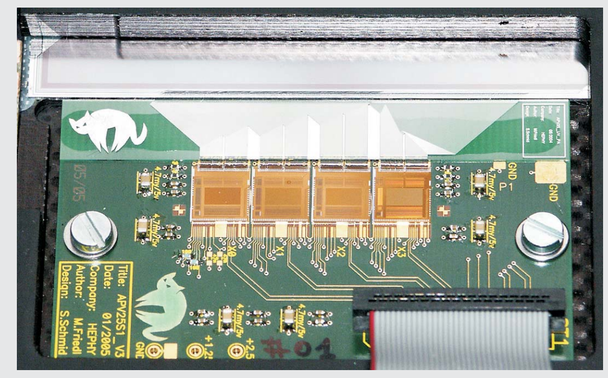
Scope picture of sequential sampling points.
Shaped waveform of a hit channel clearly visible



Waveform analysis by fitting

Peak amplitude and time determined by a fit applying the waveform obtained by internal calibration

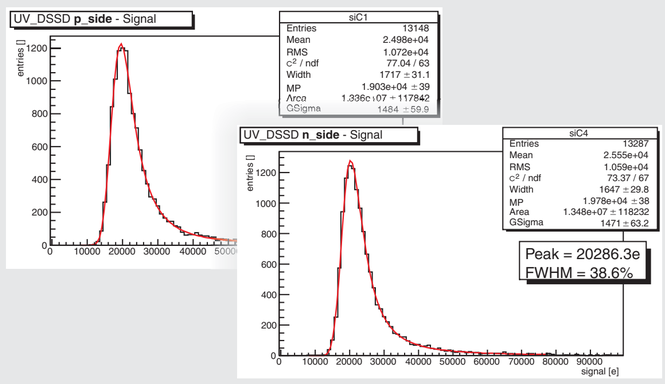
BEAM TEST RESULTS



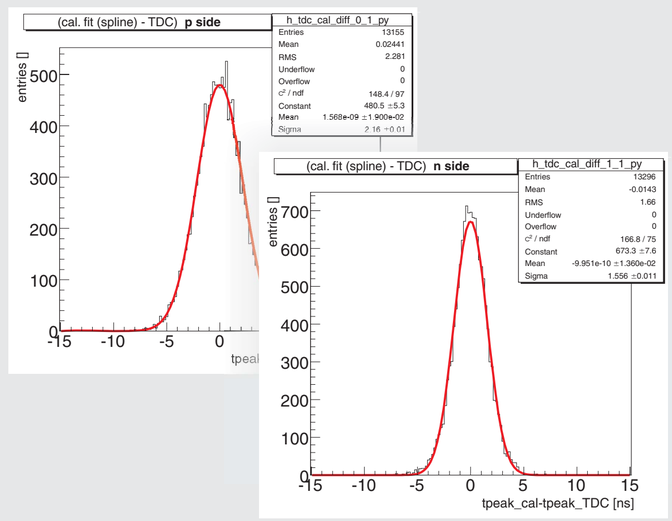
Double-sided sensor with APV25

UV-striplet sensor read out by 4 APV25 chips on each side (only p-side is shown here); used in beam tests

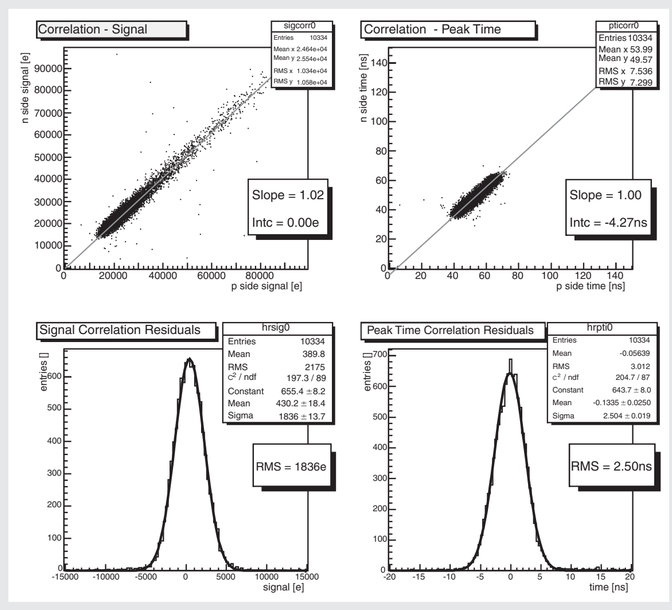
Selected Results



Landau (*Gauss) distributed amplitudes on both sides as a result of waveform fitting for each event.
Cluster S/N=25



Residual distributions of the fitted peak time against a TDC reference measurement: **~2ns RMS!**

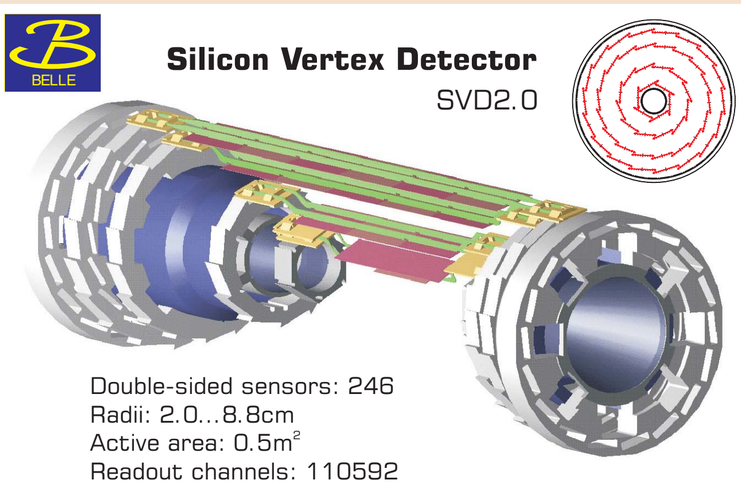


Excellent correlations between p and n sides for both amplitudes and fitted peak times

BELLE SILICON VERTEX DETECTOR

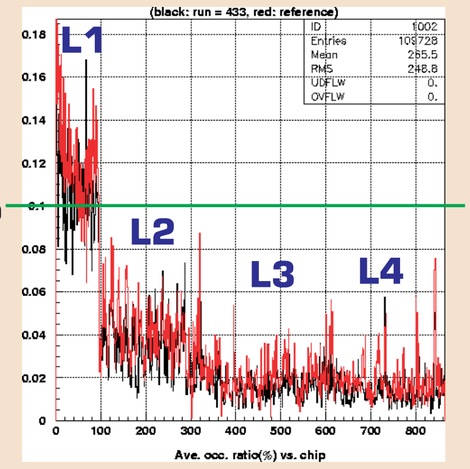
Silicon Vertex Detector

SVD2.0



Double-sided sensors: 246
Radii: 2.0...8.8cm
Active area: 0.5m^2
Readout channels: 110592
Front-end chip: VA1TA (~800ns shaping time)

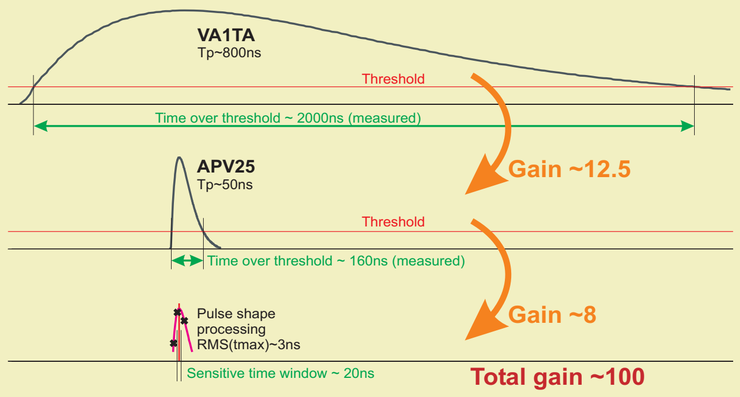
Occupancy Limit in innermost layer



The innermost layer is very close to the interaction point (r=2.0cm) and thus is mainly hit by off-time background particles.

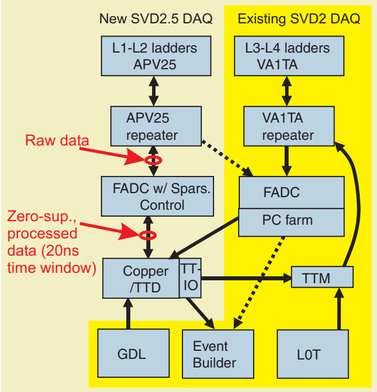
Due to the long shaping time of the VA1TA chip, only few of the many measured hits are actually of physical interest, and tracking efficiency suffers from high occupancy.

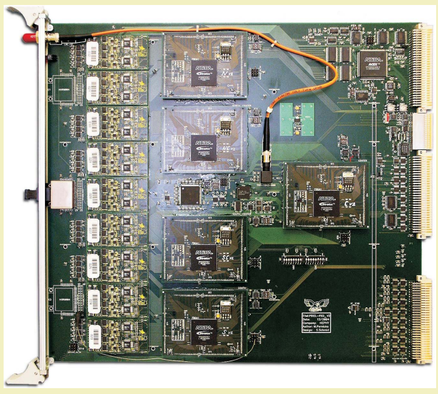
BELLE SVD2.5 UPGRADE



Occupancy reduction using the APV25

A factor of 12.5 is already gained by the shorter shaping time of the APV25, which can be further reduced by waveform analysis.
Depending on the S/N, the overall gain is up to 100.



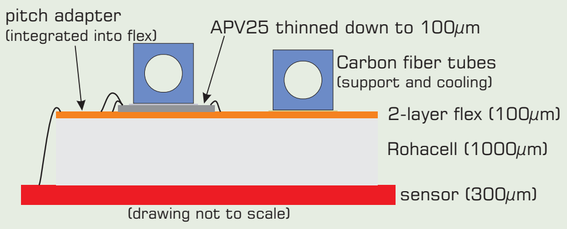


DAQ for BELLE SVD2.5

The inner layers 1 and 2 will be replaced with APV25 readout, hence two different DAQ paths will coexist. The CMS Pixel FED is modified for use as FADC with pulse shape processing (using Altera FPGAs) in BELLE.

BELLE SVD2.5 PROTOTYPE

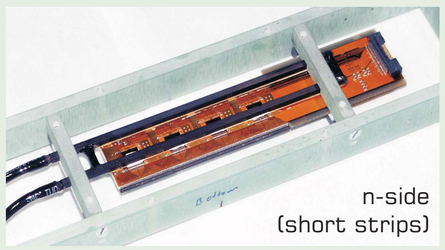
Thinned APV25s on top of sensor



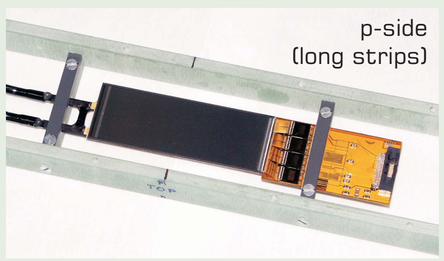
In order to achieve good S/N (i.e. low capacitance) we mounted APV25 chips directly on the detector using a 2-layer flex "hybrid" circuit and Rohacell for insulation.

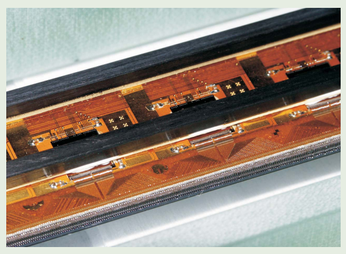
The APV25 chips are thinned to 100μm to minimize the radiation length budget.

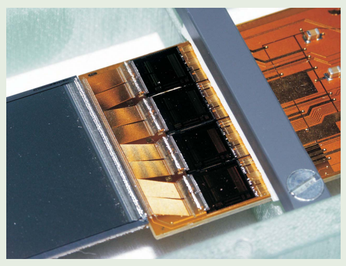
Carbon fiber tubes are used for support of hybrid and sensor and cooling of the APV25s.



Sensor size: 80x28mm^2





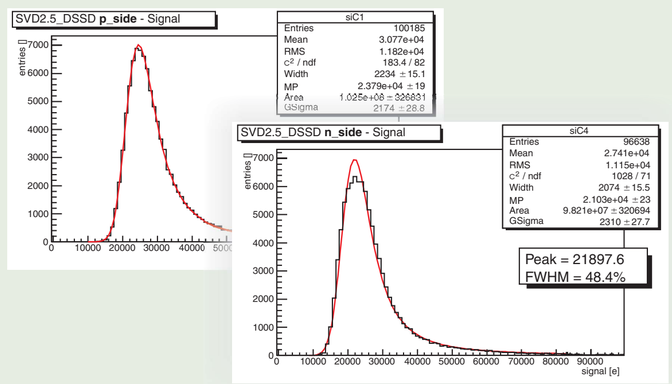


Beam Test Results (preliminary)

This module was successfully tested in a beam recently; analysis is in progress.

Lower S/N was found due to higher capacitance as expected.

The preliminary time resolution, measured against a reference TDC, is 3.9 (p-side) and 2.3 (n-side) ns RMS.



Landau (*Gauss) distributed amplitudes
Cluster S/N=13.5 (p-side), 18.9 (n-side)

* Email friedl@hephy.at

http://belle.hephy.at