Characterization of strip detector parameters for the SuperB Silicon Vertex Tracker

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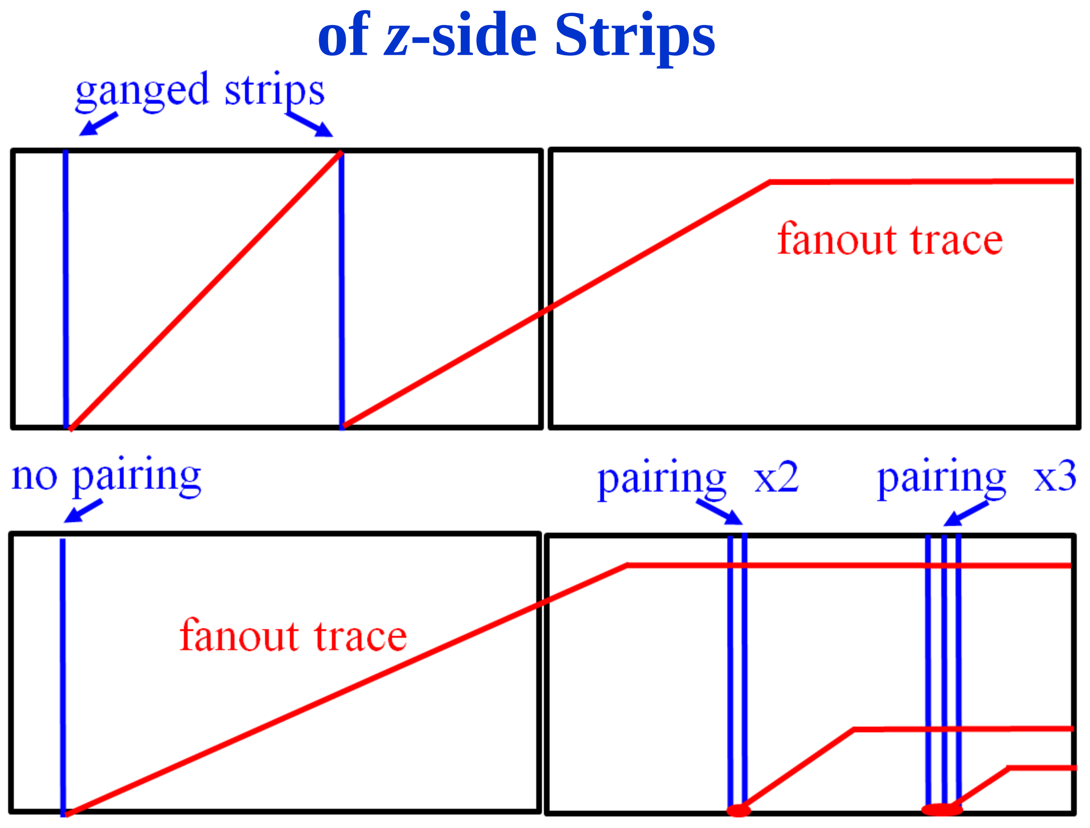
Abstract The Silicon Vertex Tracker for the SuperB detector will be an evolution of the BaBar SVT, based on double-sided strip detectors. The wider acceptance in polar angle (down to 300 milliradians) will imply larger incidence angles (up to 73 degrees) on the sensors. On the *z*-side (reading out the *z* coordinate, along the beam direction) this results in large clusters with small signal values on individual channels. For optimum performance it would be desirable to continuously vary the sensor pitch on *z*-side versus position. An easy and convenient way to approximate this configuration is to bond two or three adjacent strips to a single trace of the fanout circuit that connects the strips to the front-end electronics (the so-called 'pairing' option). In order to accurately measure the total capacitance of strips in various pairing configurations (x2, x3, x4) two test detectors have been assembled on PCBs, and various strip connection schemes have been implemented by wire bonding, on *p* and on *n*-side, respectively. Capacitance and dissipation factor have been measured versus bias voltage and frequency. These data are being used to estimate the noise contribution of the detector and to choose the best *z*-side connection scheme in the SVT.

Strip Connection Options

'Ganging' versus 'Pairing' connection of *z*-side Strips



The *z*-side strips will be connected to the front-end electronics (placed outside of the active area) by a thin flexible 'fanout' circuit. The readout pitch is set at 100 µm in layers 1 to 3, and 210 µm in layers 4 and 5, with a 'floating' strip in between, to improve spatial resolution. Since the number of readout strips exceeds the number of available electronic channels, it is necessary to 'gang' together up to three (depending on the SVT layer) strips. This 'ganging' scheme connects two or three far-apart strips to the same readout channel (see figure), thus preserving the strip pitch at the expense of a higher capacitance (and series resistance) and of ambiguities in the hit position.

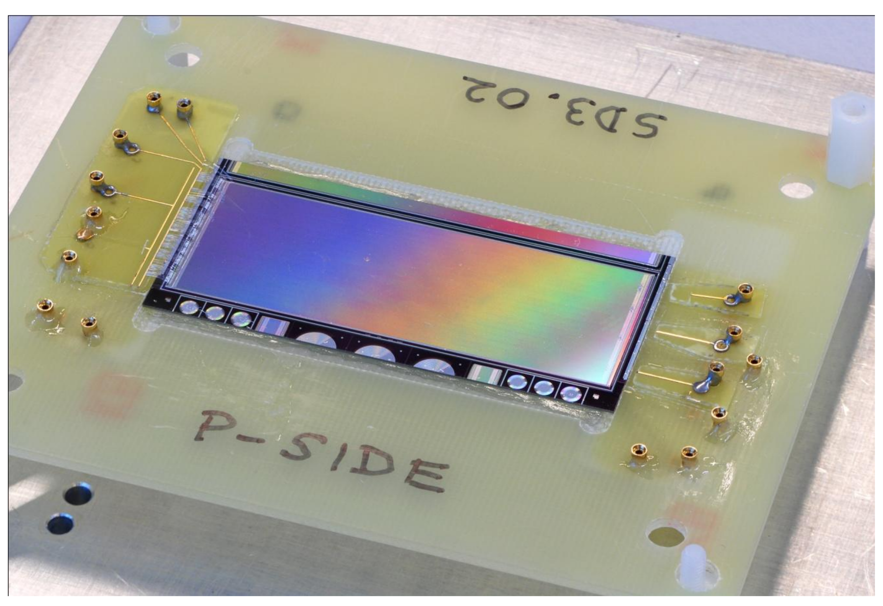
At small θ angles (large incidence angles), the signal-to-noise ratio is further degraded by the fact that a track traverses several *z*-strips (up to 9 in the inner layers!) and the signal becomes ~ proportional to the strip readout pitch (only 1/3 the wafer thickness). This suggest an alternative connection scheme, in which two (or more, at large incidence angles) *adjacent* strips are bonded to a single fanout trace, effectively increasing the strip pitch and the signal into a readout channel, with a less than proportional increase in capacitance, and no increase in series resistance. We call this connection scheme 'pairing'.

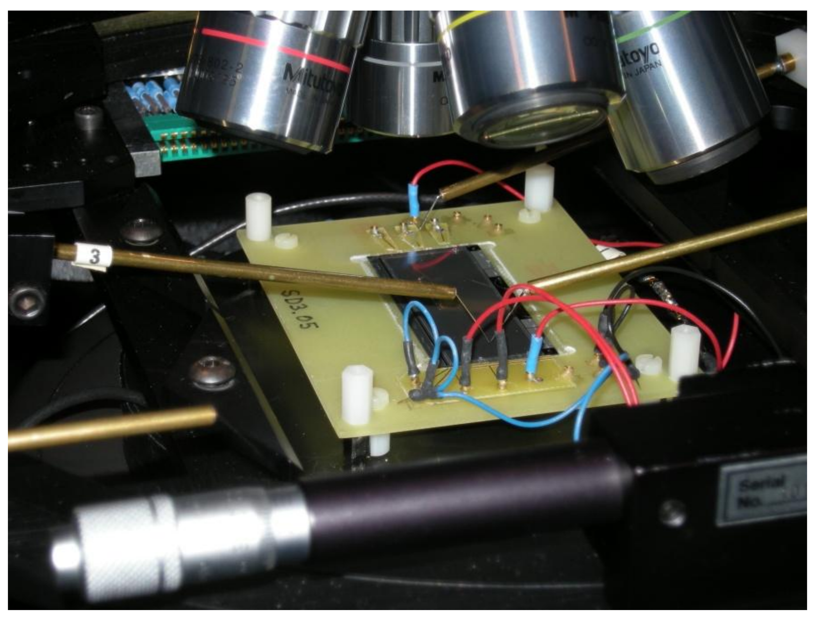
This gives better S/N and efficiency at small theta angles even compared to individually connected strips. The improvement is more important in comparison to the 'ganging' scheme, where the strip capacitance is proportional to the number of strips ganged together, but the signal remains that of a single strip. Moreover, for paired strips also the fanout capacitance and resistance can be made lower, because of the larger trace pitch.

Due to the lower noise, at small theta angles pairing is also expected to give better spatial resolution with respect to ganging.

Measurement setup

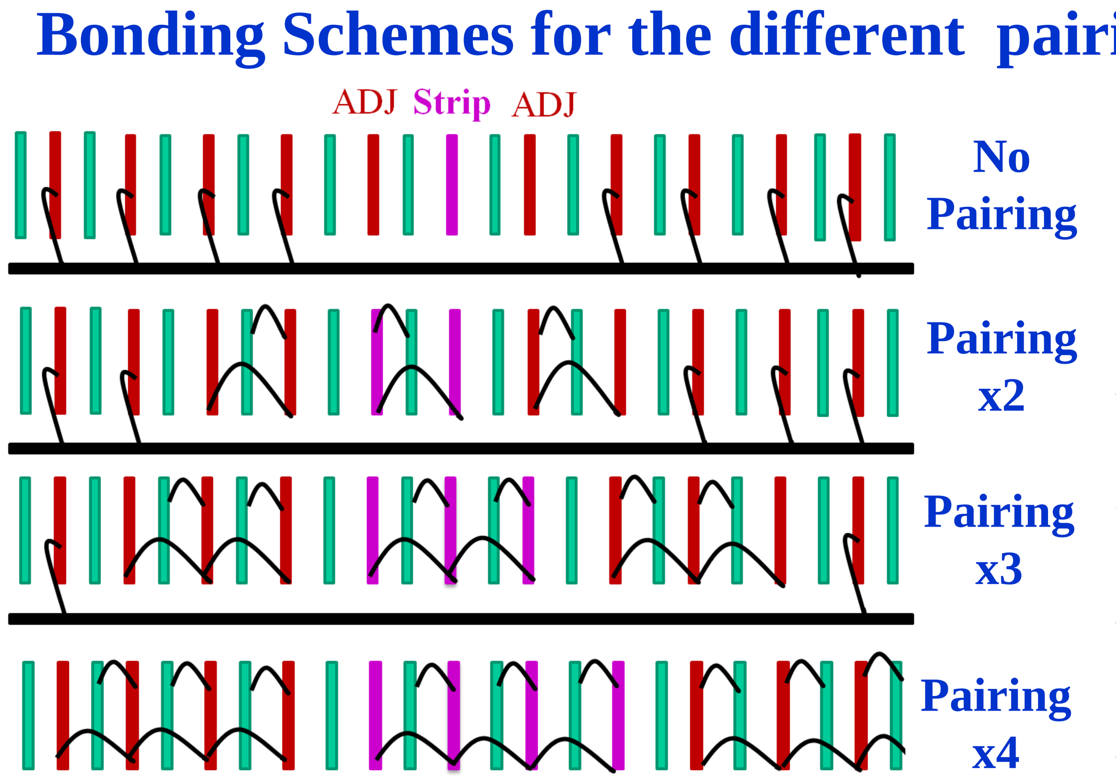
Setup for Strip Capacitance Measurements

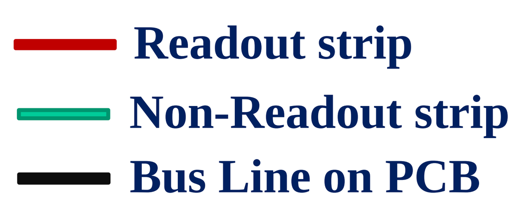




The strip capacitance in different pairing configurations has been measured on FBK-irst double-sided test sensors of BaBar-like design, but with parallel strips on *p* and *n* sides, 5.3 cm long, at 50 um pitch.
Two sensors have been glued to fiberglass boards, for measurements on *p*-side and *n*-side, respectively. Strips and Guard Rings have been bonded to suitably arranged terminals.
On front side four groups of strips have been bonded in such a way to facilitate capacitance measurements on four pairing configurations (x1, x2, x3, x4).
On opposite (back) side all strips have been bonded to a common terminal, to allow for a proper measurement of the backside capacitance.

Bonding Schemes for the different pairing configurations





'Paired' strips are connected together by short bonds on the sensor. The strip (or paired group) under test and its first neighbors are contacted by probe needles: this allows minimizing stray capacitance.
A further 10 readout strips on the left and right sides are bonded to a bus line on the PCB. This allows to measure with good approximation to the capacitance toward all other strips.
Pairing has been made between the 'readout' strips, at 100 µm pitch, so that a floating strip is always present *between* two adjacent groups of paired strips. However, we implemented also the option of connecting also the intermediate strips *within* a group of paired strips.

For every configuration three C-V measurements have been performed at two frequencies (100 kHz and 1MHz):
- capacitance to first-neighboring strips (or paired groups)
- capacitance to all strips on the same side of sensor
- total strip capacitance to front and back sides of sensor

The same measurement have been made in two configurations: with intermediate 'non readout' strips left floating or connected to the paired 'readout' strips (as shown in the figure).

Results

Measured Capacitances on P-side

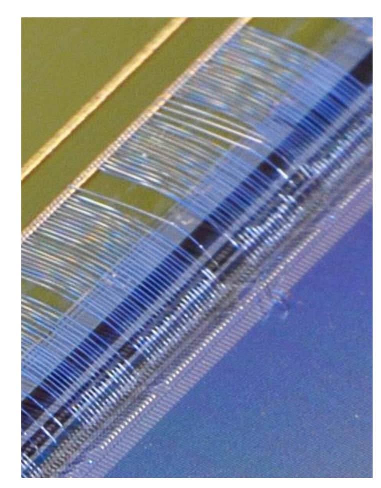
PAIRING MULTIPLICITY		x 1	x 2		x 3		x 4	
C versus First Neighbors	pF/cm	0.99	1.40	41%	1.51	52%	1.58	59%
	pF/cm		1.48	5.4%	1.60	6.0%	1.66	5.2%
C versus all strips on the same side	pF/cm	1.28	1.59	24%	1.67	30%	1.76	37%
	pF/cm		1.66	4.1%	1.78	6.3%	1.84	4.8%
Total C versus both sides of sensor	pF/cm	**1.62**	**2.25**	**39%**	**2.70**	**66%**	**3.11**	**92%**
	pF/cm		**2.36**	**4.9%**	**2.84**	**5.3%**	**3.24**	**4.1%**

BLACK figures: Values with intermediate strips floating

RED figures: Values with intermediate strips connected

Measured Capacitances on N-side

PAIRING MULTIPLICITY		x 1	x 2		x 3		x 4	
C versus First Neighbors	pF/cm	0.89	1.24	40%	1.38	55%	1.42	59%
	pF/cm		1.35	9.0%	1.50	8.7%	1.53	8.2%
C versus all strips on the same side	pF/cm	1.24	1.58	27%	1.78	43%	1.90	53%
	pF/cm		1.69	6.7%	1.90	7.1%	2.02	6.3%
Total C versus both sides of sensor	pF/cm	**1.56**	**2.24**	**43%**	**2.76**	**77%**	**3.21**	**105%**
	pF/cm		**2.37**	**6.1%**	**2.94**	**6.2%**	**3.41**	**6.3%**



black % = Capacitance increase for "*pairing*" vs. "*non pairing*"
red % = Capacitance increase for *intermediate strips connected* vs. *floating*

- Pairing gives significantly lower capacitance with respect to ganging the same number of strips.
- The advantage in capacitance of pairing with respect to ganging increases for higher pairing/ganging multiplicity.
- The additional increase in total capacitance when connecting also the intermediate strips is ~ 4 – 5 % for *p*-side, ~ 6 % for *n*-side. In front of this, a better signal collection is expected.

Comparison of the different *z*-side connection schemes

- The table refers to Layer 3 of the SVT, and reports the parameters relevant for estimating the noise contribution from the sensors and fanout: total capacitance, series resistance, bias resistance and leakage current expected after 7.5 years of operation at nominal luminosity.
- We see that pairing gives both lower capacitance and lower noise contribution from resistance and leakage current, even when comparing pairing x3 with ganging x2.

Ganging/ Pairing multiplicity	Total strip volume	Sensor C/L	Sensor Rs/L	Max Fanout C	Max Fanout Rs	Total C	Total Rs	Total R_bias	Total leakage current	ENC from Rs	ENC from Rbias	ENC from I_leak	ENC from Rs + Rbis + I_leak
Ganging	(cm^3)	(pF/cm)	(ohm/cm)	(pF)	(ohm)	(pF)	(ohm)	(Mohm)	(nA)	(e)	(e)	(e)	(e)
x2	**4.2E-03**	**1.7**	**4**	**17**	**32**	**40.8**	**88**	**4.0**	**128**	**661**	**173**	**662**	**952**
Pairing													
x1	**2.1E-03**	**1.7**	**4**	**16**	**30**	**27.9**	**58**	**8.0**	**64**	**367**	**122**	**468**	**607**
x2	**4.2E-03**	**2.3**	**4**	**8.5**	**16**	**24.6**	**30**	**4.0**	**128**	**233**	**173**	**662**	**723**
x3	**6.9E-03**	**2.8**	**4**	**5.8**	**11**	**25.4**	**20**	**2.7**	**210**	**198**	**211**	**850**	**898**

Related Contributions at the 2012 Pisa Meeting

Front End, Trigger, DAQ and Data Management - Poster Session

Luca BOMBELLI

[177] Analog Front-end Electronics for the Outer Layers of the SuperB SVT: Design and Expected Performances

Luigi GAIONI

[157] The design of fast analog channels for the readout of strip detectors in the inner layers of the SuperB SVT