

Update on the Analog Section of the FE chip for the Silicon Strip Detectors of the Super B SVT Inner Layers

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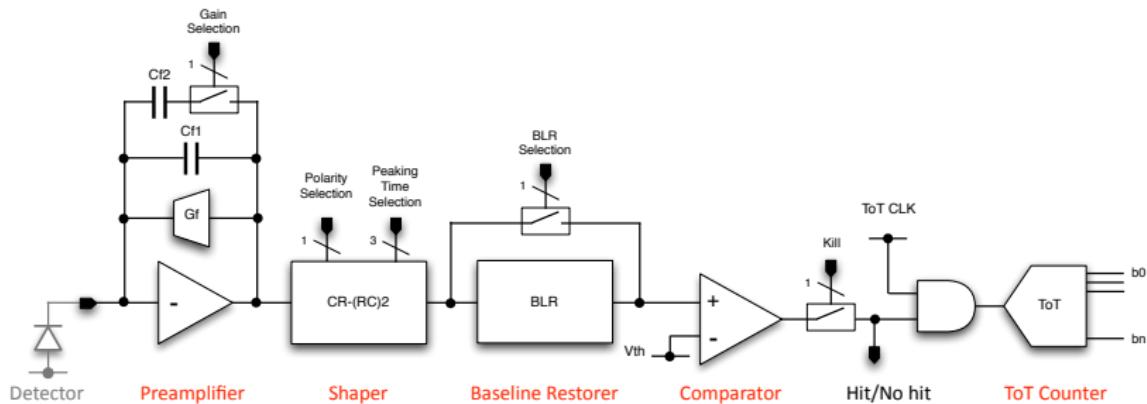


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La Biodola, Isola d'Elba

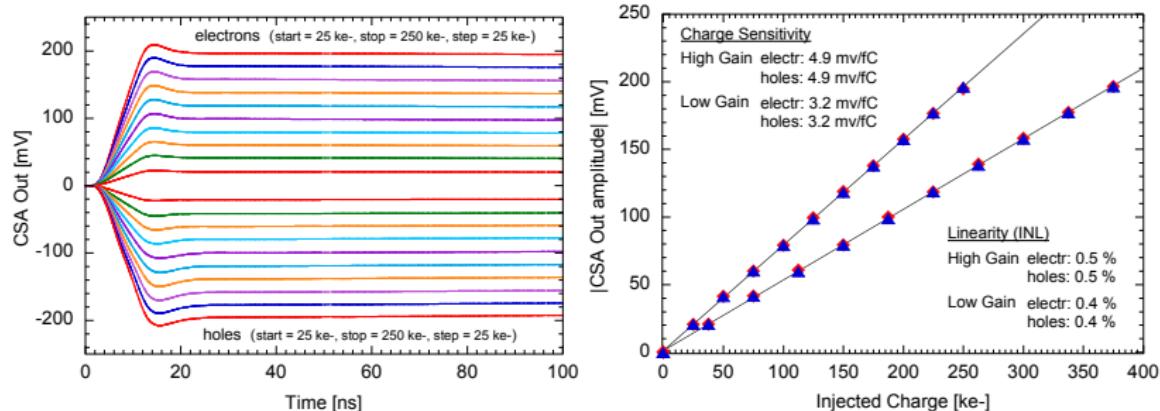
Analog channel block diagram



- Charge-sensitive preamplifier with gain selection (1 bit)
- Unipolar semi-Gaussian shaper with polarity (1 bit) and peaking time (3 bit) selection options
- Symmetric baseline restorer to achieve baseline shift suppression, may be included or not (1 bit)
- Hit discriminator (comparator)
- 3-4 bit analog-to-digital conversion will be performed by a Time-Over-Threshold (TOT) detection

CSA response and dynamic range

Sensitivity increased by about a factor of 2 wrt to the previous version of the CSA¹

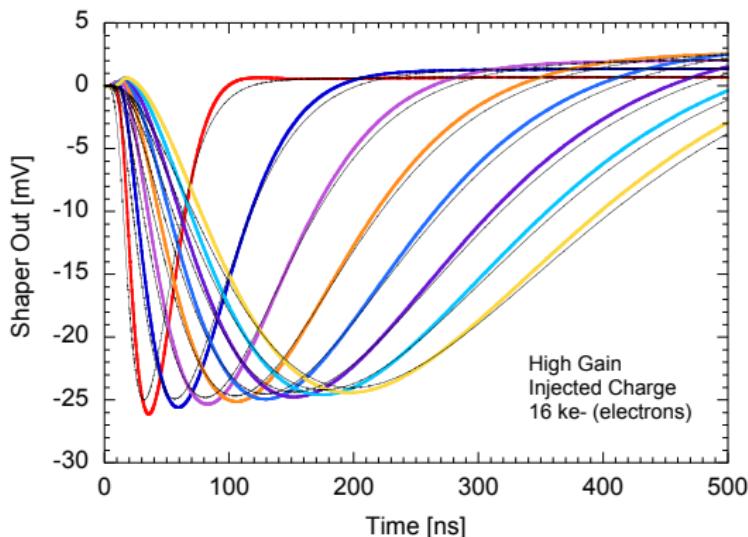


- **Rise time:** $t_r \approx 7$ ns for both holes and electrons
- **Charge sensitivity:** low gain 3.2 mV/fC (electrons and holes), high gain 4.9 mV/fC (electrons and holes)
- **Dynamic range:** the CSA covers the full dynamic range of 15 MIP (240 ke- in L0 and 360 ke- in L1-3) for both the input signal polarities
- **Linearity:** $\approx 0.5\%$ in high gain and $\approx 0.4\%$ in low gain

¹M. Manghisoni, "Analog Section for the Silicon Strip Detectors of the Super B SVT Inner Layers", 2nd SuperB Collaboration Meeting, 13-16 December 2011

Peaking Time Selection

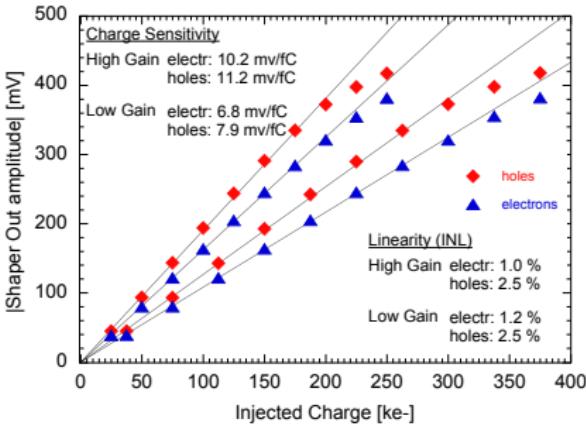
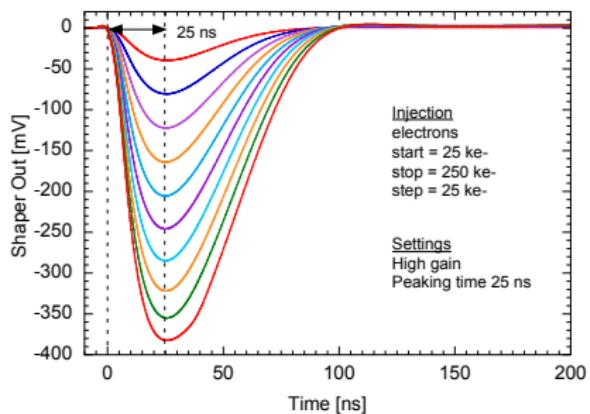
An additional bit for peaking time selection has been included wrt to the previous version of the shaping stage \Rightarrow 8 selectable peaking times



n	Peaking Time [ns]	
	Nominal	Simulated
1	25	28
2	50	53
3	75	77
4	100	101
5	125	125
6	150	148
7	175	171
8	200	194

- Good agreement between ideal (black lines) and simulated (colored lines) shaping functions and peaking times
- A better matching can be obtained with a fine tuning of the shaping circuit capacitances (to be done)

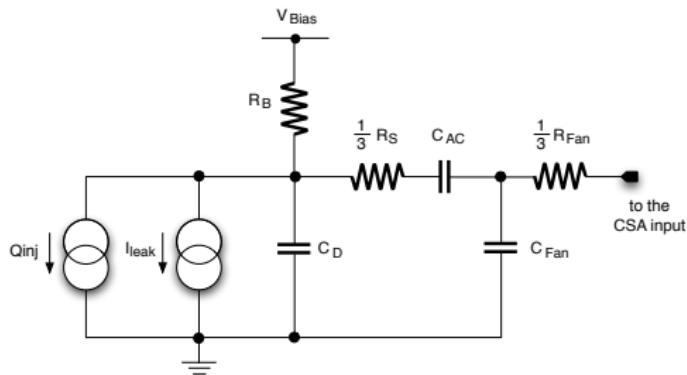
Channel Output response and dynamic range



- **Charge sensitivity:**
 - high gain $\approx 10 \text{ mV/fC}$ (electrons) and $\approx 11 \text{ mV/fC}$ (holes)
 - low gain $\approx 7 \text{ mV/fC}$ (electrons) and $\approx 8 \text{ mV/fC}$ (holes)
- **Dynamic range:** the channel covers the full dynamic range of 15 MIP (240 ke- in L0 and 360 ke- in L1-3) for both the input signal polarities
- **Linearity:**
 - high gain $\approx 1.0 \%$ (e) and $\approx 2.5 \%$ (h) in the 200 ke- injected charge range
 - low gain $\approx 1.2 \%$ (e) and $\approx 2.5 \%$ (h) in the 300 ke- injected charge range
- **TOT:** the effect of channel non-linearity on TOT must be evaluated (to be done)

Detector Model and Parameters

Detector model used for the ENC evaluation²



- Total Capacitance: $C_T = C_D + C_{Fan}$
- Total Resistance: $R_T = R_S + R_{Fan}$
- Decoupling Capacitance: $C_{AC} = 20 \cdot C_D$
- Leakage Current
 - accounts for 7.5 years of operation and safety factor of 5
 - Shot Noise: $S_{leak}(f) = 2qI_{leak}$
- 1/3 coefficient for the distributed resistances
- Pairing $\times 2$ only in z side Layers 1, 2 and 3
- Option A only for Layer 3

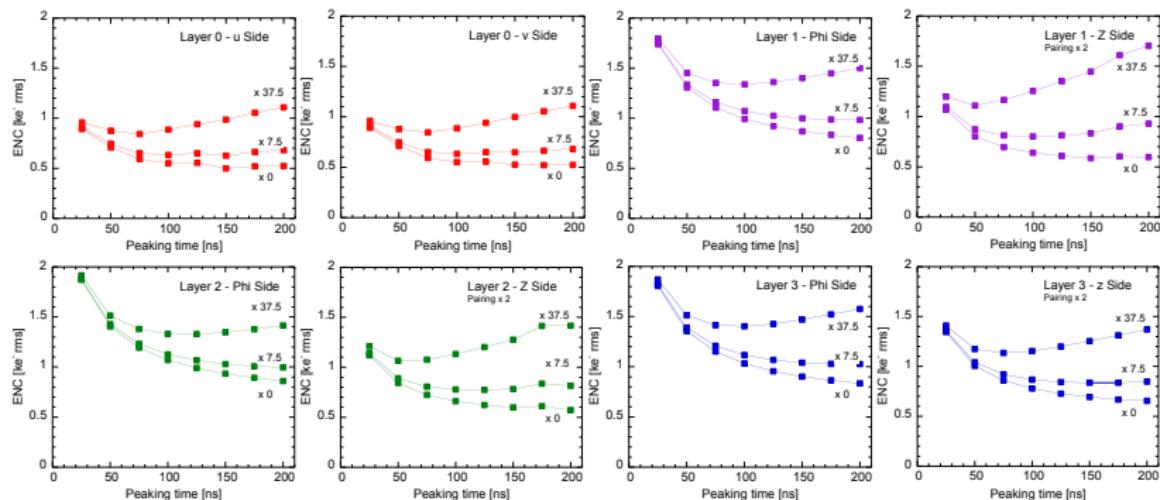
Layer	Sensor Side	Fanout		Total Capacitance C_T [pF]	Total Resistance R_T [\Omega]	R bias R_B [\Omega]	Total leakage I_{leak} [nA]
		Capacitance C_{Fan} [pF]	Resistance R_{Fan} [\Omega]				
0-u	p	10	18	14.9	44	1	708
0-v	n	10	18	14.9	59	1	708
1 phi	n	5.8	12	33.4	107	4	1184
1 z	p	7	14	16.2	22	2	1711
2 phi	n	4.7	7	37.2	94	4	926
2 z	p	7	14	18.0	24	4	1242
3 phi	p	3.4	7.5	35.7	84	4	1321
3 z	n	8.5	16	24.6	39	4	1072

²L. Bosisio - 20/05/2012

Equivalent Noise Charge

For each Layer the total ENC has been evaluated

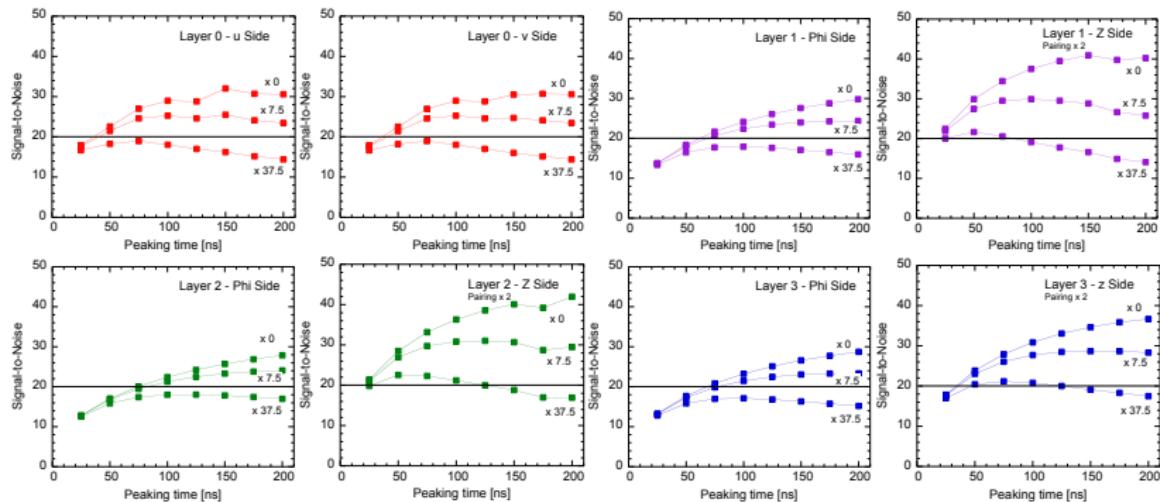
- for fresh detectors with \approx no leakage ($\times 0$)
- after 7.5 years of operation ($\times 7.5$)
- after 7.5 years of operation with a safety factor of 5 ($\times 37.5$)



A detailed evaluation of ENC contributions can be found in backup slides:

S/N ratio vs t_P at 1 MIP

S/N evaluated at 1 MIP (16 ke- in L0 and 24 ke- in L1 to L3)



- With fresh detectors ($\times 0$) and after 7.5 years of operation ($\times 7.5$)
S/N is < 20 in
 - L0 (u and v) and L3 (z) at $t_p=25$ ns
 - L1, 2 and 3 (phi) at $t_p < 75$ ns
- After 7.5 years of operation and considering the safety factor of 5 ($\times 37.5$)
S/N is always < 20 with few exceptions for L1, 2 and 3 (z)

Equivalent Noise Charge and S/N

Layer	t_p [ns]	Total ENC [e rms]	Total ENC [e rms]	Total ENC [e rms]	S/N	S/N	S/N
Selected			after	after	after	after	
			7.5 years	7.5 years	7.5 years	7.5 years	
				with $\times 5$			
				safety factor			safety factor
0 u	25	892	905	958	18	18	17
0 v	25	893	907	959	18	18	17
1 phi	75	1106	1160	1352	22	21	18
1 z	75	697	812	1165	34	30	21
2 phi	100	1070	1127	1332	22	21	18
2 z	100	660	778	1132	36	31	21
3 phi	150	864	1040	1470	28	23	16
3 z	150	669	836	1254	36	29	19

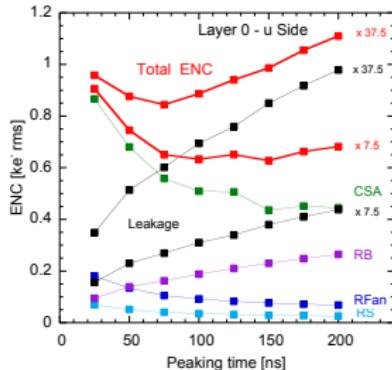
- Layer 0: S/N is always < 20
- Layer 1, 2 (phi): S/N close to 20 before and after 7.5 years of operation
- Layer 3 (phi): S/N close to 20 after 7.5 years of operation
- Layer 1, 2 and 3: S/N < 20 after 7.5 years of operation with the safety factor of 5 (with exception for L1 and L2 z-side)

- An improved version of the readout channel has been simulated with:
 - Charge sensitivity increased by a factor of 2
 - 8 selectable peaking times
- Noise simulation performed with a complete model of the detector show:
 - Layer 0: S/N always < 20 at $t_p=25$ ns
 - Layer 1, 2 and 3 (z): S/N acceptable after 7.5 years of operations
 - Layer 1, 2 and 3 (phi): S/N close to 20 before and after 7.5 years of operations
- New solutions in the FE are under study to reduce (slightly) the noise of the CSA
- Are the current numbers acceptable for the TDR?

Backup Slides

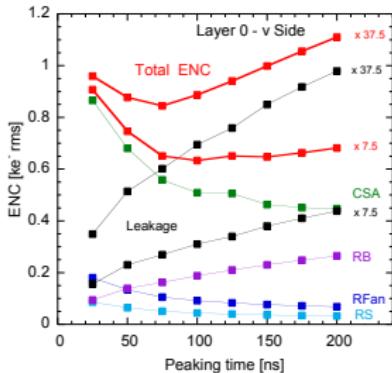
ENC in Layer 0

u Side



t_p [ns]	ENC [e rms]						Total $\times 37.5$
	CSA	R_{Fan}	R_S	R_B	I_{leak}	Total $\times 37.5$	
25	866	180	68	94	156	348	905
50	679	134	51	139	229	514	745
75	558	105	40	162	268	601	650
100	509	91	35	187	310	694	633
125	506	83	31	209	339	759	650
150	435	76	28	229	380	849	627
175	451	71	27	248	410	917	662
200	445	67	25	264	437	978	681
							1109

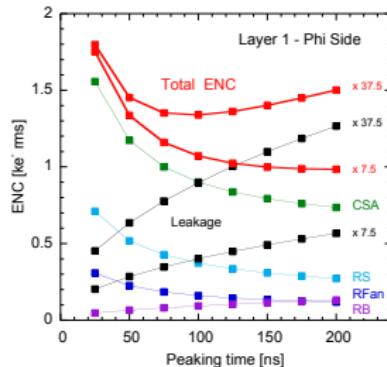
v Side



t_p [ns]	ENC [e rms]						Total $\times 37.5$
	CSA	R_{Fan}	R_S	R_B	I_{leak}	Total $\times 37.5$	
25	865	180	86	94	156	348	907
50	680	134	64	139	229	514	746
75	558	105	50	162	268	601	651
100	508	91	43	187	310	694	633
125	505	83	39	209	339	759	650
150	463	76	36	229	380	849	647
175	451	71	34	248	410	917	663
200	444	67	33	264	437	978	681
							1109

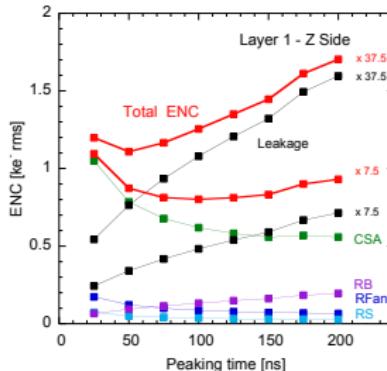
ENC in Layer 1

Phi Side



t_p [ns]	ENC [e rms]						Total
	CSA	R_{Fan}	R_S	R_B	I_{leak}	Total	
					$\times 7.5$	$\times 37.5$	$\times 7.5$
25	1557	308	710	47	202	452	1751
50	1174	225	517	66	284	636	1335
75	1000	185	427	81	347	777	1160
100	901	161	373	93	401	897	1071
125	837	145	336	104	449	1004	1023
150	793	134.	309	114	491	1099	999
175	761	125	288	124	530	1186	987
200	736	118	272	132	566	1267	984
							1501

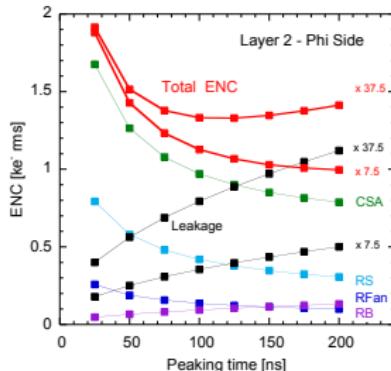
Z Side with Pairing $\times 2$ only



t_p [ns]	ENC [e rms]						Total
	CSA	R_{Fan}	R_S	R_B	I_{leak}	Total	
					$\times 7.5$	$\times 37.5$	$\times 7.5$
25	1049	173	72	66	243	544	1095
59	786	122	51	93	341	764	872
75	678	100	41	115	418	934	812
100	618	86	36	132	482	1079	801
125	582	78	32	148	539	1206	812
150	558	72	30	162	591	1322	832
175	569	70	29	183	668	1494	900
200	558	66	27	195	713	1596	930
							1704

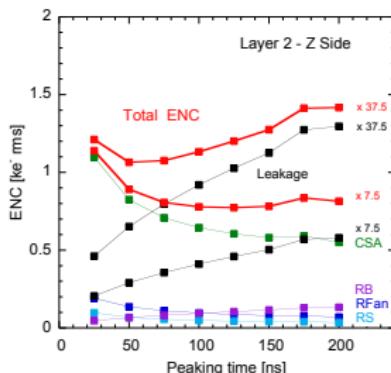
ENC in Layer 2

Phi Side



t_p [ns]	ENC [e rms]						Total
	CSA	R_{Fan}	R_S	R_B	I_{leak}		
					$\times 7.5$	$\times 37.5$	$\times 7.5$
25	1675	258	793	47	179	401	1881
50	1265	189	579	66	251	562	1428
75	1078	157	480	81	307	688	1233
100	970	136	419	93	355	794	1127
125	900	123	378	105	397	887	1067
150	850	113	348	114	434	971	1029
175	815	106	324	123	468	1048	1008
200	787	100	306	132	501	1120	996
							1413

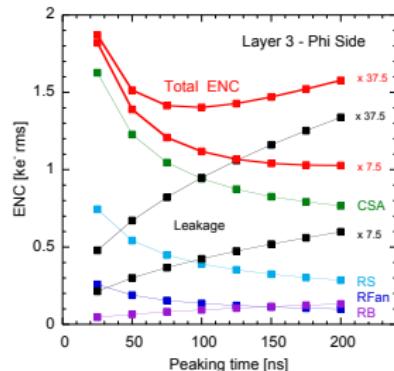
Z Side with Pairing $\times 2$ only



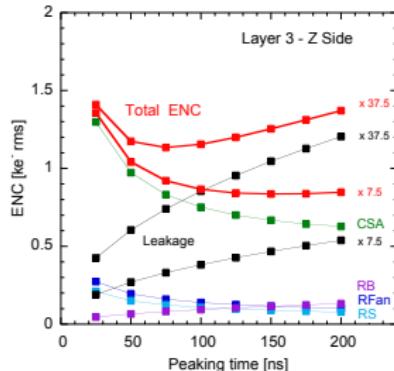
t_p [ns]	ENC [e rms]						Total	
	CSA	R_{Fan}	R_S	R_B	I_{leak}			
					$\times 7.5$	$\times 37.5$	$\times 7.5$	$\times 37.5$
25	1098	191	96	47	206	461	1139	1211
50	825	135	68	66	291	651	890	1064
75	708	110	56	81	356	796	806	1076
100	645	96	48	93	411	919	778	1132
125	605	86	44	104	459	1027	773	1201
150	580	79	40	114	503	1125	782	1275
175	591	78	39	130	569	1273	835	1413
200	550	70	35	132	579	1296	814	1417

ENC in Layer 3

Phi Side



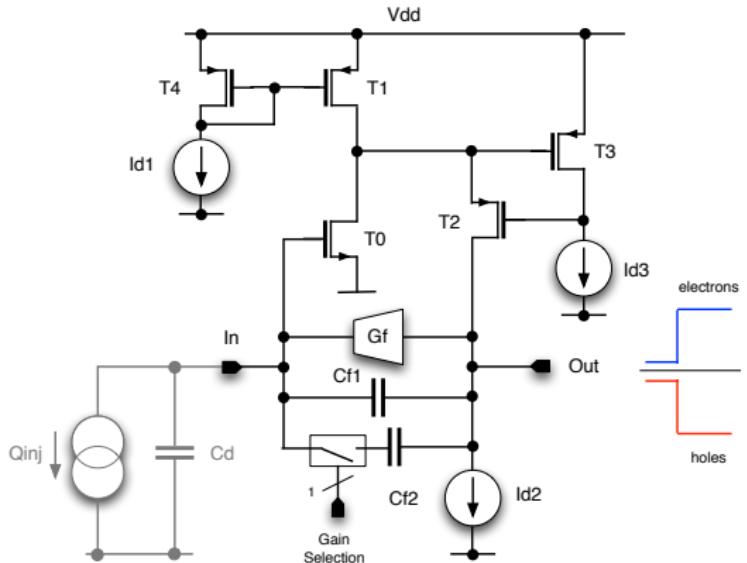
Z Side with Pairing $\times 2$ only



t_p [ns]	ENC [e rms]						Total $\times 37.5$
	CSA	R_{Fan}	R_S	R_B	I_{leak}	Total $\times 7.5$	
25	1627	258	743	47	214	478	1821
50	1227	188	542	65	300	671	1389
75	1045	155	448	81	367	821	1208
100	942	135	391	93	424	948	1117
125	873	122	353	104	474	1060	1067
150	826	112	324	114	519	1160	1040
175	792	105	302	123	560	1252	1029
200	766	99	285	132	598	1338	1027

t_p [ns]	ENC [e rms]						Total $\times 37.5$
	CSA	R_{Fan}	R_S	R_B	I_{leak}	Total $\times 7.5$	
25	1298	273	210	47	190	425	1357
50	973	196	150	66	270	604	1042
75	831	160	123	81	330	740	921
100	751	139	107	93	381	853	866
125	700	126	97	104	426	954	842
150	667	115	89	114	467	1046	836
175	642	108	83	123	504	1128	837
200	627	101	78	132	538	1204	847

Charge Sensitive Amplifier

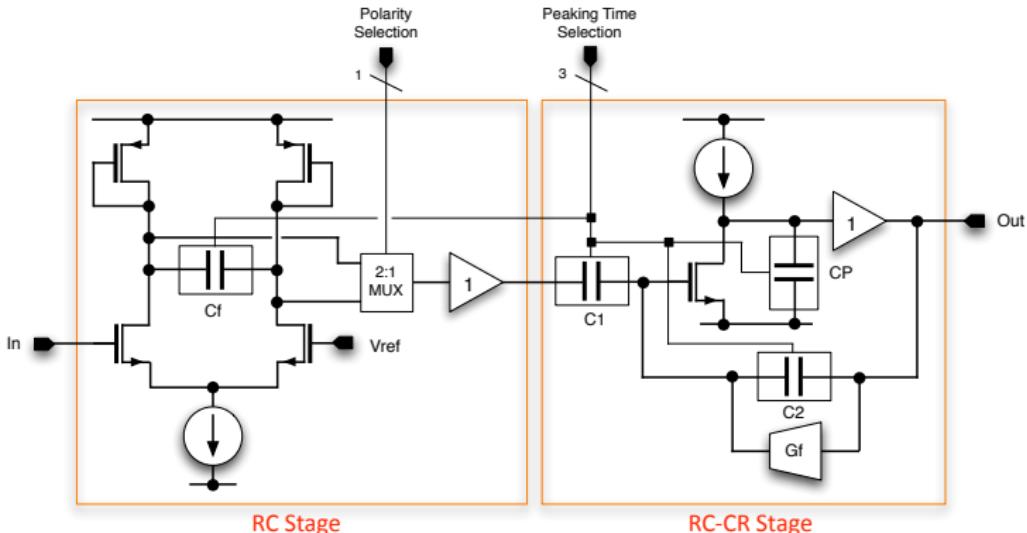


Main design features

Chip Bias	1.2 V
V_{DD}	
PA input	2000/0.2
W/L	
PA input	500 μ A
I_D	
Power consumption	1.1 mW
Feedback	200 fF
C_{f1}, C_{f2}	100 fF
Reset	100 nS
G_f	

- **Architecture:** active folded cascode (with local feedback) loaded by an active cascaded load
- **Sensitivity:** low gain 3.3 mV/fC ($C_f = C_{f1} + C_{f2}$), high gain 5.0 mV/fC ($C_f = C_{f1}$)
- **Reset:** performed by a time continuous feedback network implemented with a differential pair

Shaping circuit



- **Shaping function:** Unipolar semi-Gaussian ($RC^2\text{-CR}$)
- **Polarity selection** (1 bit): allows to operate with signals delivered both from n- and p- sides of double-sided strip detectors
- **Peaking time selection** (3 bit): obtained by setting the values of capacitances in the shaper according to the following relationships (with $t_{P0}=25$ ns, $C0=50$ fF and $n=1,2,3,4,5,6,7,8$):

$$t_P = n \cdot t_{P0}$$

$$C_P = n \cdot C_0$$

$$C_1 = n \cdot 4 \cdot C_0$$

$$C_2 = n \cdot 2 \cdot C_0$$

$$C_f = n \cdot 2.5 \cdot C_0$$

Electronic Readout for SVT Inner Layers (L0-L3)

- Microstrips and striplets detectors are the baseline option for the design of the SVT fast (Layers 0 to 3) front-end at SuperB
- ASIC: the signals from the silicon strip detectors will be processed by a custom-designed IC based on a 130 nm planar technology with 128 channels
- Analog Channel
 - amplification
 - filtering
 - threshold discrimination
 - 3-4 bit analog information about the signal amplitude
- Main requirements
 - Operating temperature: $<40\text{ }^{\circ}\text{C}$
 - Radiation tolerance: $>3\text{ Mrad/year}$ for 10 years
 - Power dissipation: $<4\text{ mW/channel}$
 - Signal polarity: readout channel should be capable of reading signals from both P and N-side of the strip detectors
 - Dynamic range: 10-15 MIP charge
 - Analog Resolution: 0.2 MIP minimum input charge
 - Hit efficiency: $>95\%$ at design luminosity
 - Peaking Time: $\leq 25\text{ ns}$ for Layer 0
 - Signal-to-Noise Ratio: >20
 - Threshold dispersion: $<300\text{ e- rms}$
- Simulation results for a preliminary version of the charge preamplifier and the shaping stage of the SVT inner layers will be shown