Radiation hardness studies of a 130 nm Silicon Germanium BiCMOS technology with a dedicated ASIC

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MOTIVATION

- S-LHC increased luminosity implies replacement full Inner Detector and LAr readout electronics
- Candidate technologies for analog part:
  - Main option: Deep-Sub-Micron CMOS
  - **Alternative: SiGe BiCMOS technologies**

SiGe working group goals

- Radiation hardness studies of several SiGe BiCMOS technologies (IBM, IHP)
- Find a technology that meets ATLAS Upgrade requirements
  - → Main SiGe option: 130 nm **IBM 8WL technology**
- Design and test FE analogue TC for Si Tracker and LAr calorimeter that meets the specs with reduced power consumption

130 nm IBM 8WL TEST PROGRAM

- Silicon Tracker readout test chip (SGST)
- 4-channel prototype LAr readout chip (LAPAS)
  - Designed and fabricated: testing in progress (to be presented on *TWEPP09*[1])
  - ASICs simulations already reported on *TWEPP08*[2]
- **Dedicated TC for technology radiation hardness studies (SiGBiT)**
  - Radiation hardness assurance:
    - Gamma irradiations (in test)
    - Proton irradiations (in progress)
    - ELDRS studies (in progress)
    - **NEUTRON IRRADIATIONS**

The SiGBiT 8WL ASIC

- 40 SiGe bipolar transistors (18 differential pairs):

8wl Test Structure NPN and Resistor Inventory

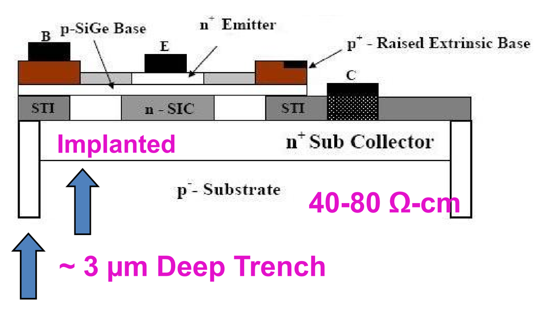
NPN SiGe bipolar transisotrs (120um emitter width)

Count	Pair	Single	Type	Emitter(um	Nstripe
4	X		HP	20	2
2	X		HB	20	2
3	X		HP	8	1
3	X		HB	8	1
6	X		HP	1	1
4		X	HP	4	2

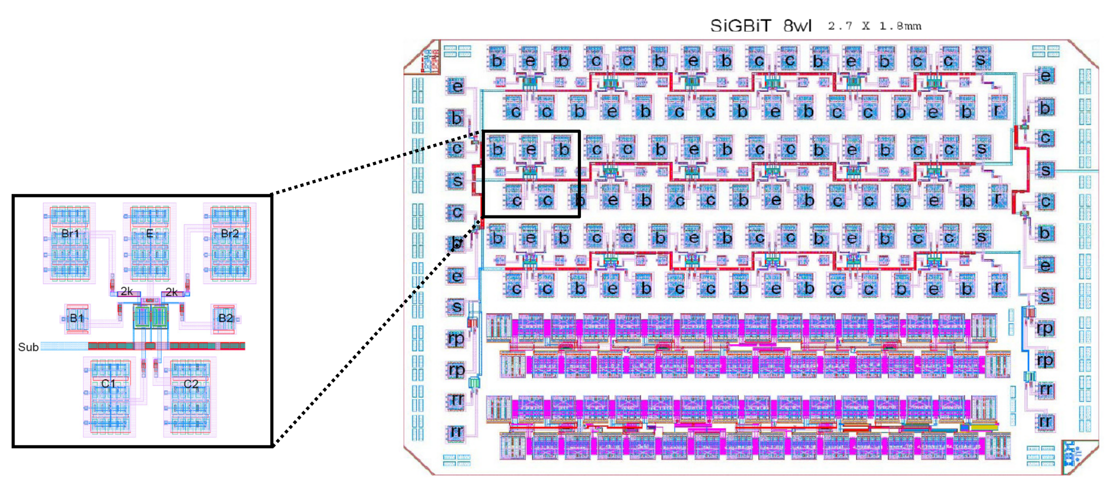
RESISTORS

COUNT	PAIR	SINGLE	TYPE	L (um)	W (um)	RES
3		X	PP	35	6	2k
2	X		RP	30	3	2.3k
2	X		RR	30	3	17k

8WL SiGe HBT



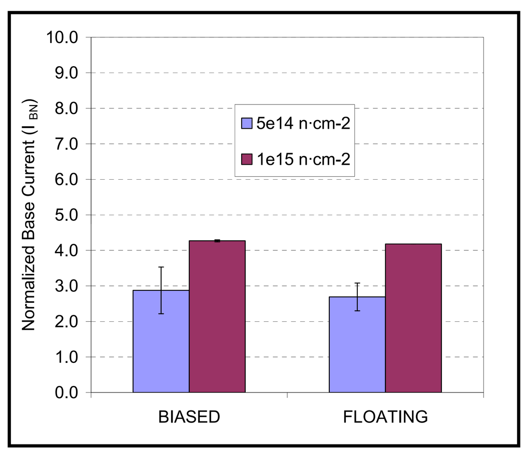
- Good synergy with **8RF** 130nm CMOS technology
- **8RF** CMOS test structure included (CERN)

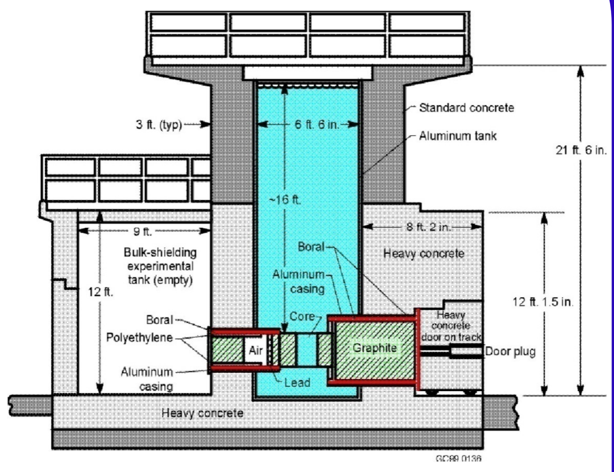


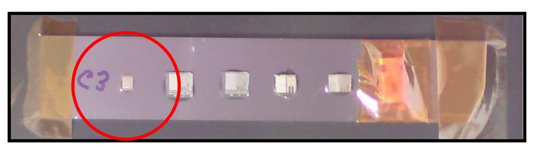
NEUTRON IRRADIATIONS

- TRIGA reactor (JSI, Ljubljana)
- Fluences: $2x10^{13}$, $2x10^{14}$, $6x10^{14}$, $1x10^{15}$ and $5x10^{15}$ n_{eq}/cm^{-2}
- Devices mounted on bare Si boards to minimize samples activation
- Transistors with floating terminals during irradiation
- Cd shielding to reduce effect of thermal neutrons

Other SiGe HBTs





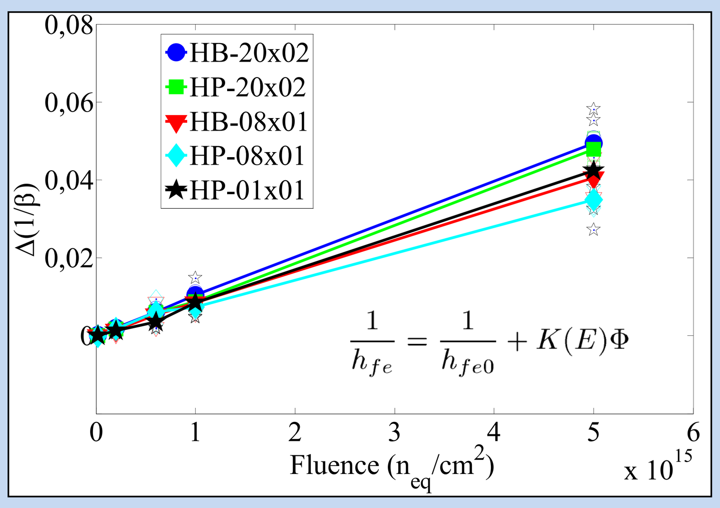


RESULTS

Total fluence

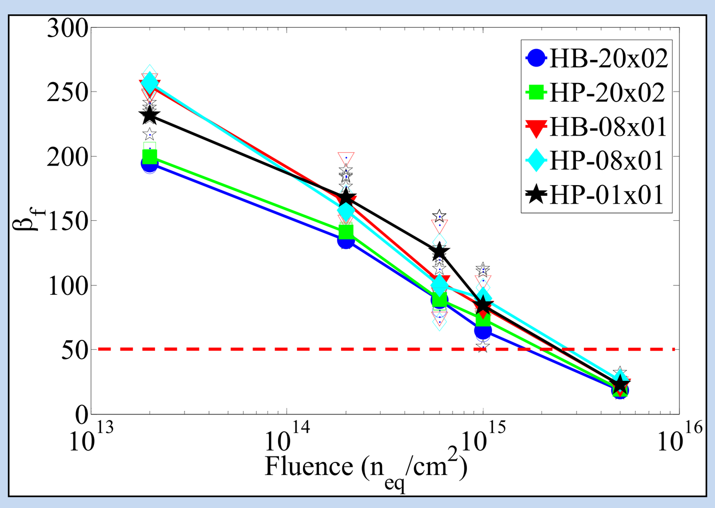
Reciprocal gain

$\Delta(1/\beta) = 1/\beta_F - 1/\beta_0$ (@V_{BE} = 0.75 V)



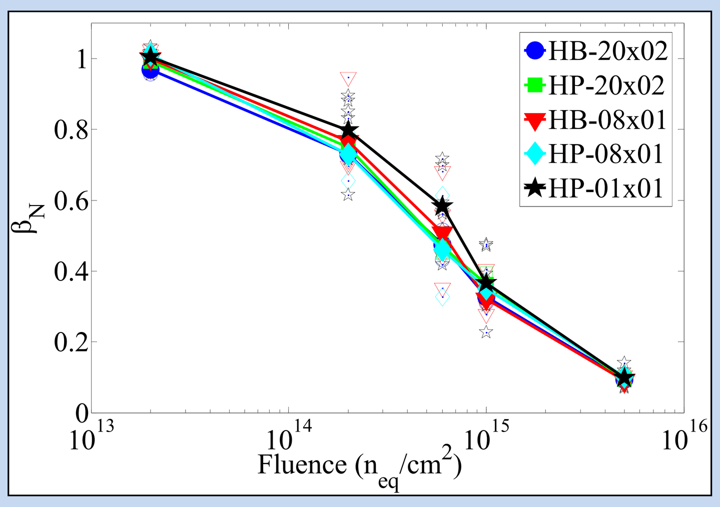
Final current gain

$\beta_f = I_{Cf}/I_{Bf}$ (@V_{BE} = 0.75 V)



Normalized gain

$\beta_N = \beta_F/\beta_0$ (@V_{BE} = 0.75 V)

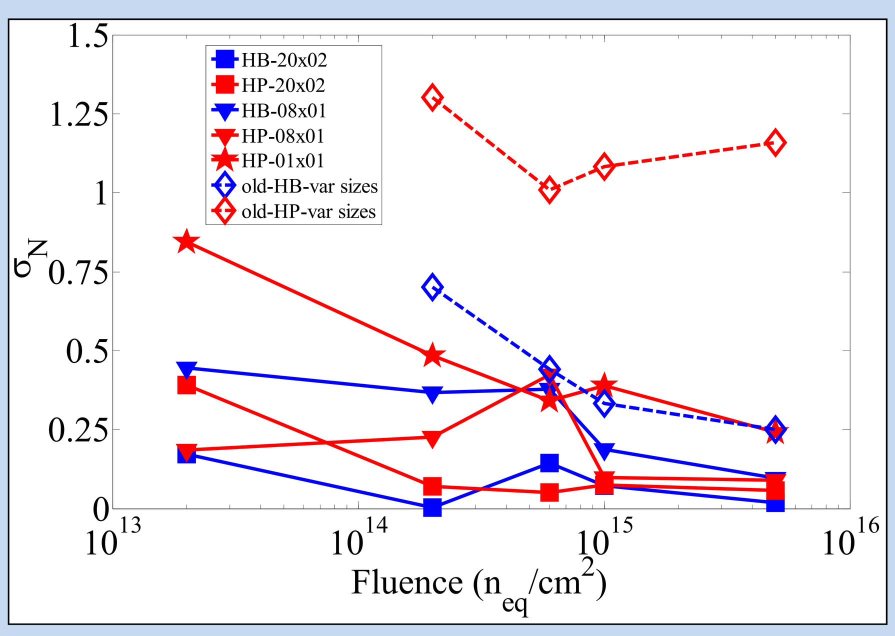


- Damage on devices linear with neutron fluence as expected (G.C. Messenger et al)[3]
- Final gains above 50 at target values
- High damage at the highest fluence, but far beyond maximum fluence expected in Si Tracker and LAr (~7x10[14] cm[-2])
- Similar degradation for all geometries and transistor types

Transistor damage variability

Normalized standard deviation

$\sigma_N = \sigma(\Delta J_B) / \overline{\Delta J_B}$ (@V_{BE} = 0.75 V)



- Observed in previous neutron irrads with "spare" test chips
- Smaller variability than obtained in previous experiments
- Increased variability for smaller emitter geometries
- Possible fluence dependence
- Influence of low probable nuclear interactions under study
- Worst-case transistor final gain still above 50 at target fluence

Conclusions:

Devices remain at reasonable performances at the maximum radiation levels expected in the Si tracker and the LAr calorimeter

Variability on results still to be understood (dependence with area), although transistors' gain still above 50 at the target fluences

References:

[1] Ma et al. "*A SiGe ASIC Prototype for the ATLAS LAr Calorimeter Front-End Upgrade*", TWEPP09, talk ID:121, 2009

[2] Ullán et al. "*Evaluation of Silicon-Germanium (SiGe) Bipolar Technologies for Use in an Upgraded ATLAS Detector*", NIM-A, vol. 604, Issue 3, pp. 668-674, 2009

[3] Messenger et al. "*The Effects of Neutron Irradiation on Germanium and Silicon*" Proc. of the IRE, vol 46, Issue 6, pp. 1038-1044, 1958

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