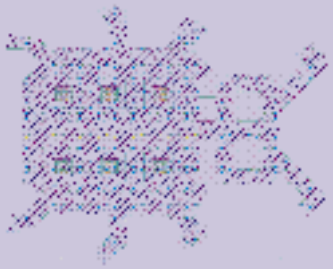
SEU Robustness, Total Dose Radiation Hardness and Analogue Performance of the



BEETLE Chip

Niels van Bakel[1], Jo van den Brand, Hans Verkooijen
(NIKHEF / Free University, Amsterdam)
Michaela Agari, Christian Bauer, Johan Blow, Daniel Baumeister[2], Werner Hofmann,
Karl-Tasso Knöpfle, Sven Löchner, Michael Schmelling, Edgar Sexauer[3]
(Max-Planck-Institute for Nuclear Physics, Heidelberg)
Martin Feuerstack-Raible[4], Ulrich Trunk
(University of Heidelberg and Max-Planck-Institute for Nuclear Physics, Heidelberg)
Neville Harnew, Nigel Smale
(University of Oxford)

[1] now at Stanford Linear Accelerator Center, Menlo Park CA , USA
[2] now at Continental Teves AG, Frankfurt a.M., Germany
[3] now at Dialog Semiconductors GmbH, Kirchheim-Nabern, Germany
[4] now at Fujitsu Mikroelektronik GmbH, Dreieich-Buchschlag, Germany

Ulrich Trunk
The Beetle Group at MPI for Nuclear Physics, Heidelberg

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Outline

- LHC*b*:
  Requirements on the Beetle
- Beetle:
  Architecture and Performance
- Radiation Hardness:
  Total Ionizing Dose Irradiation
  SEU Robustness Test at PSI
- The Beetle_ER Engineering Run:
  Beetle 1.3
  Beetle 1.4
  Beetle 1.5
- Chip/Wafer Test
- The Future

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The Beetle Group at MPI for Nuclear Physics, Heidelberg

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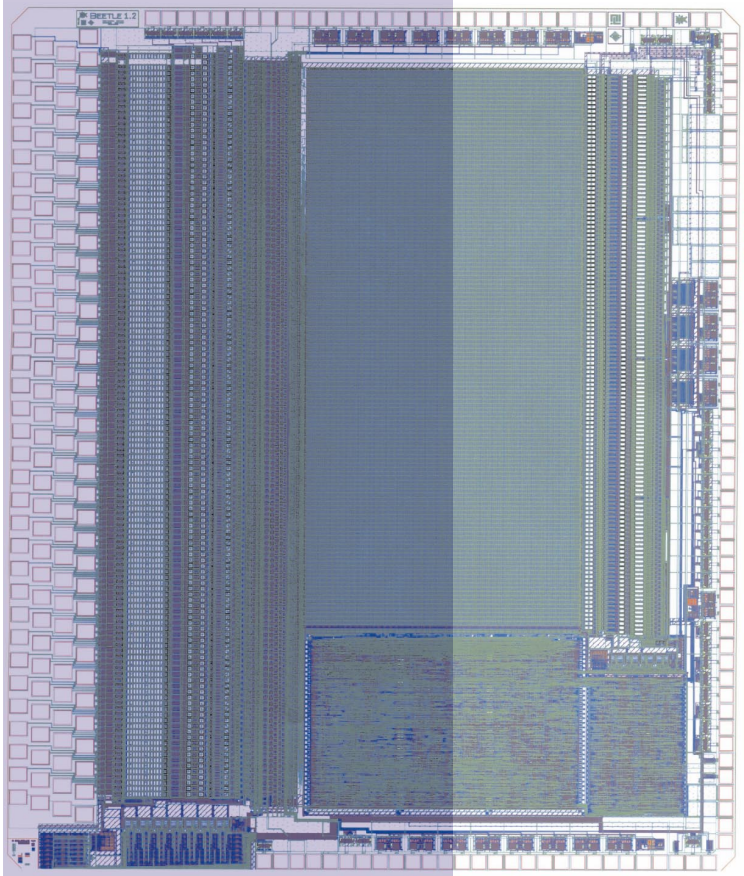
LHC*b* Requirements



environment			
1.1	total radiation dose	10 Mrad	✓
1.2	average dose rate	0.2 rad/s	✓
1.3	capacitive load	≤50pF	✓
1.4	load variation/chip	≤10pF	✓
1.5	occupancy	≤5%	✓
1.6	temperature range	-30 … +50 °C	✓

DAQ requirements			
2.1	sampling frequency	40 MHz	✓
2.2	max. L0 latency	4 μs	✓
2.3	L0 accept rate	1.1 MHz	✓
2.4	consecutive triggers	yes	✓
2.5	trigger buffer	16 triggers	✓
2.6	readout time	900 ns	✓
2.7	read-back of registers to ECS	yes	✓
2.8	fast reset of pipeline and FIFO	yes	✓
2.9	differential inputs for trigger and clock	yes	✓

basic VELO requirements			
3.1	power dissipation/channel	≤6 mW	✓
3.2	peaking time	25 ns	✓
3.3	signal remainder 25 ns after peak	≤30%	✓
3.4	non-linearity over ±110,000e^-	≤5%	✓
3.5	crostalk between channels	≤5%	✓
3.6	ENC at 10 pF input capacitance	1500 e^-	✓
3.7	input charge-rate	≥20 nA	✓
3.8	output driver strength at 100Ω TP	≥ 1m	✓
3.9	synchronisation check with PCN	yes	✓

No Specification Document for VETO counters yet, but local threshold linearity and switching crosstalk on Beetle 1.3 need further improvement

Ulrich Trunk
The Beetle Group at MPI for Nuclear Physics, Heidelberg

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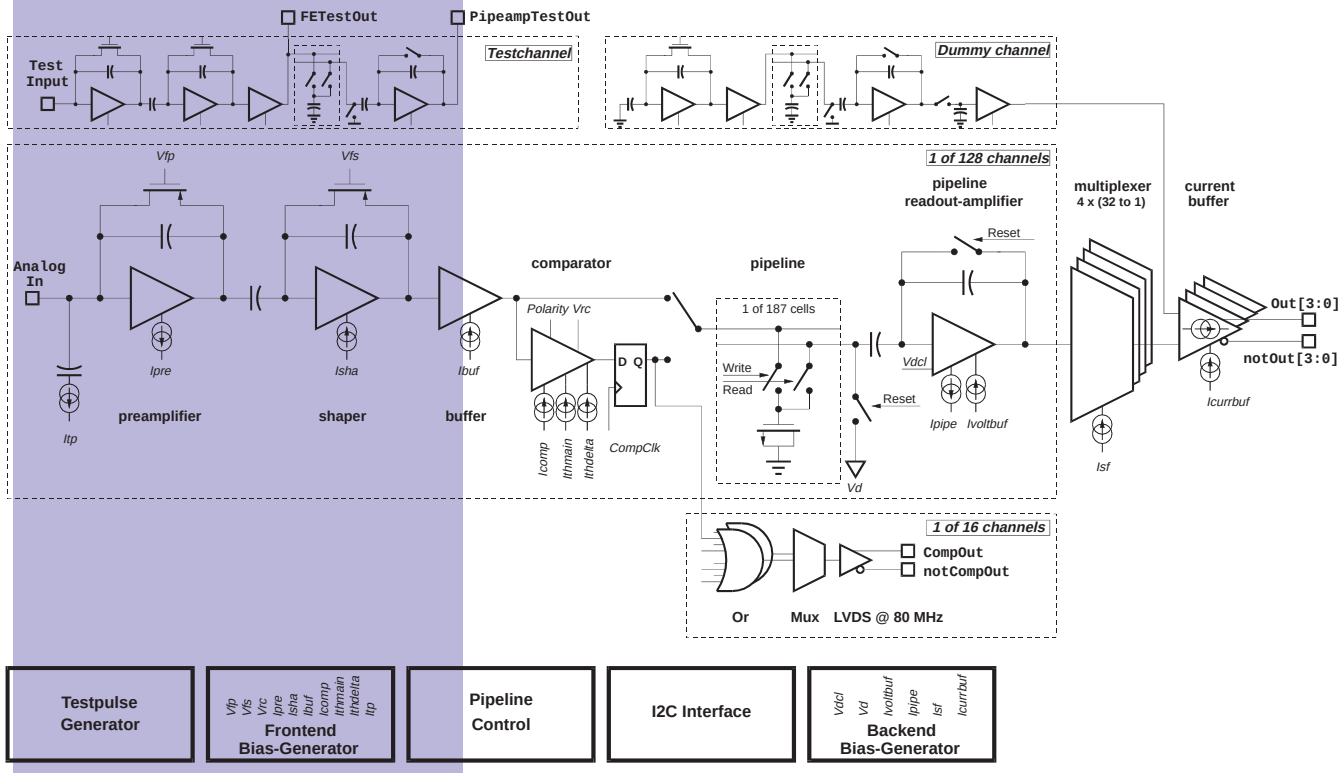
Beetle Architecture & Performance



Features:

- 128 input channels
- CSA/Shaper with 25ns peaking time
- 40 MHz sampling (LHC clock)
- 128 discriminators with switchable polarity
- analogue memory for 160 sampling steps
- buffer for 16 triggered events
- 4 µs max. latency
- 900ns/event readout speed
- internal DACs for bias settings
- test pulse injector with adjustable amplitude
- setup/slow control via I^2C interface

Employment in LHC*b*:

- VELO
- Pile-up veto counters
- Silicon Tracker
- MAPMT readout (RICH backup)

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The Beetle Group at MPI for Nuclear Physics, Heidelberg

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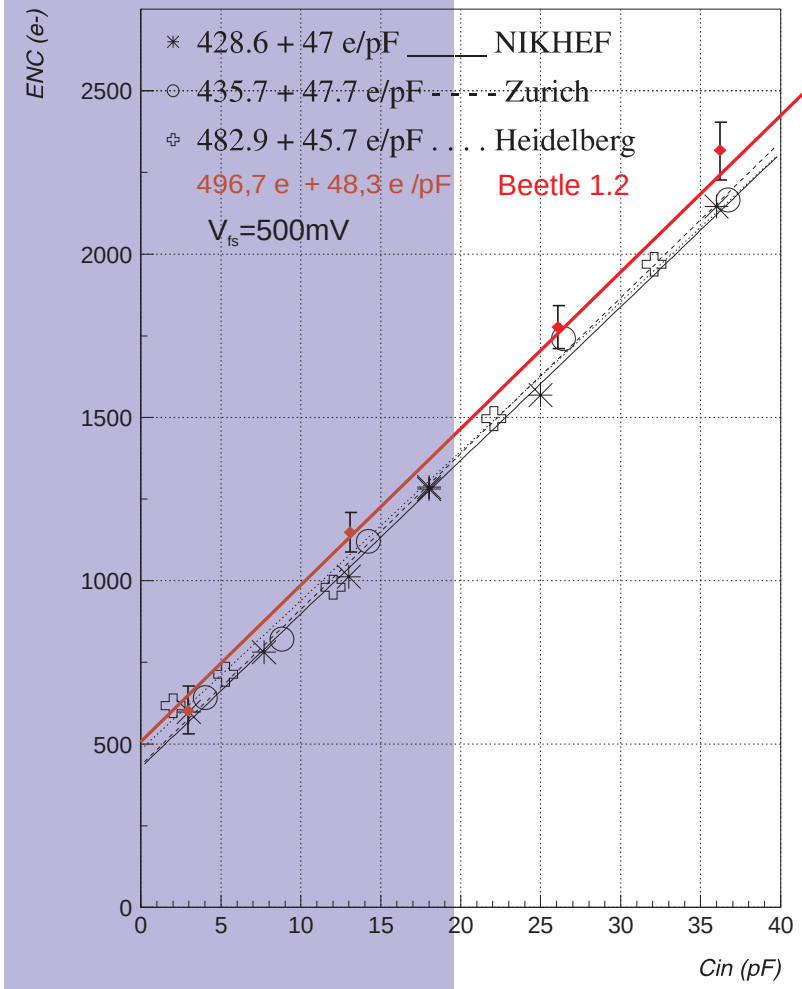
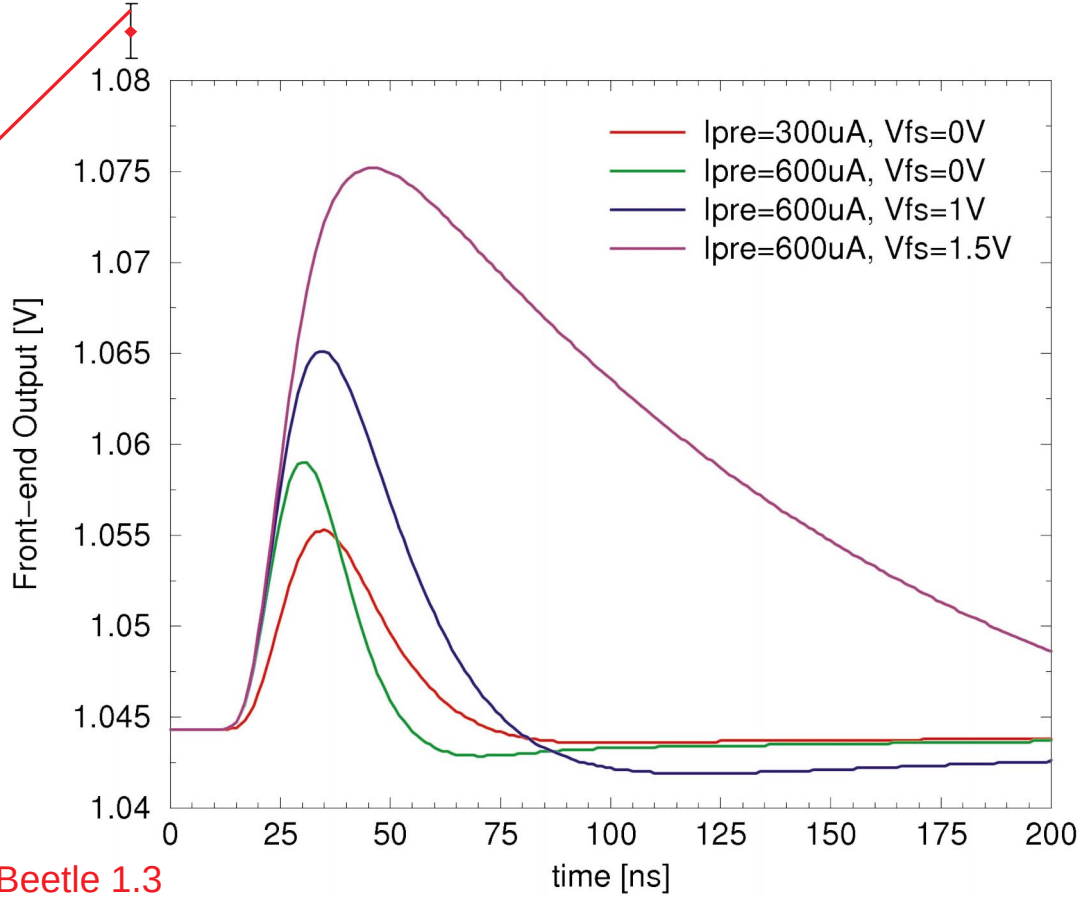
Beetle Architecture & Performance





Beetle 1.3

Vfs [mV]	*Equivalent Noise Charge*
0	547.7e- + 52.64e-/pF
100	539.1e- + 51.89e-/pF
400	542.8e- + 49.38e-/pF
1000	465.1e- + 45.22e-/pF

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The Beetle Group at MPI for Nuclear Physics, Heidelberg

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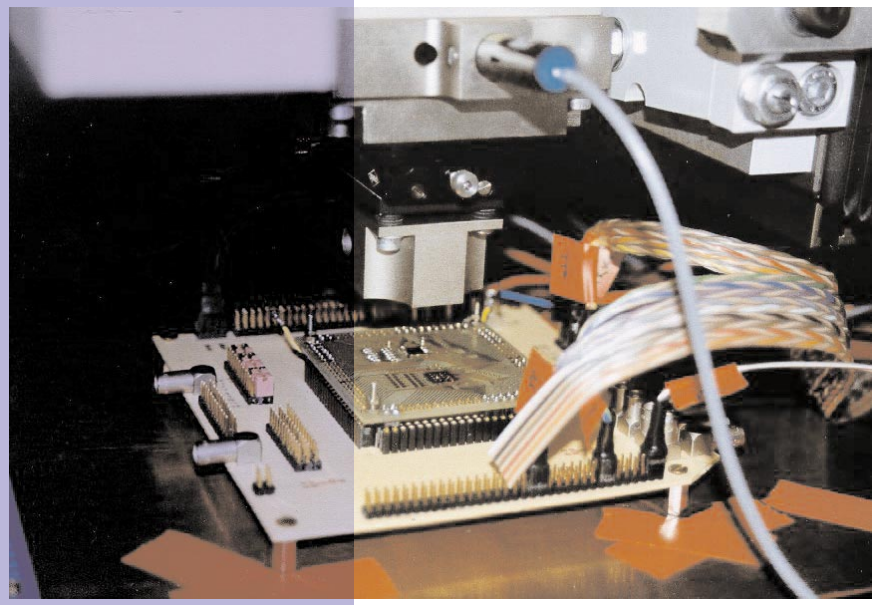
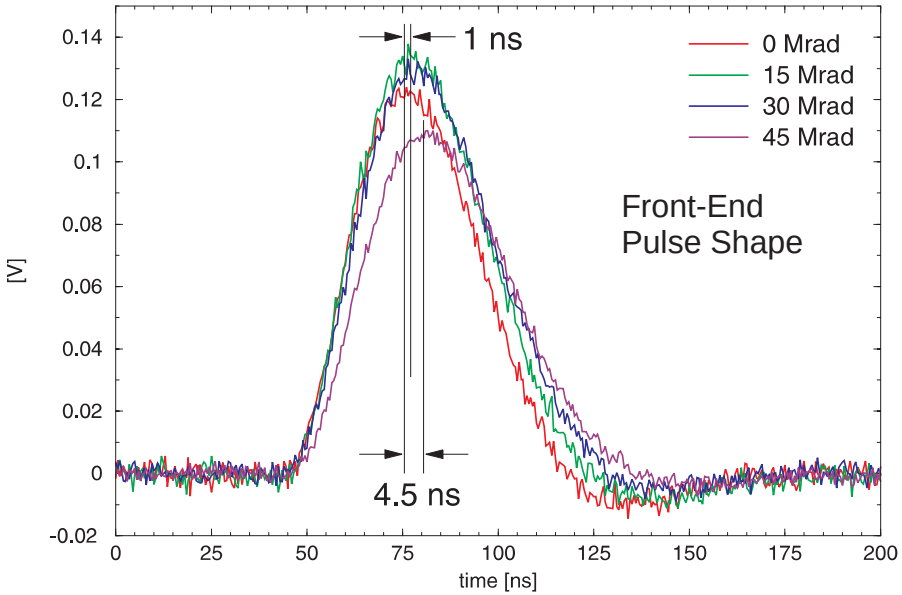
TID Radiation Hardness

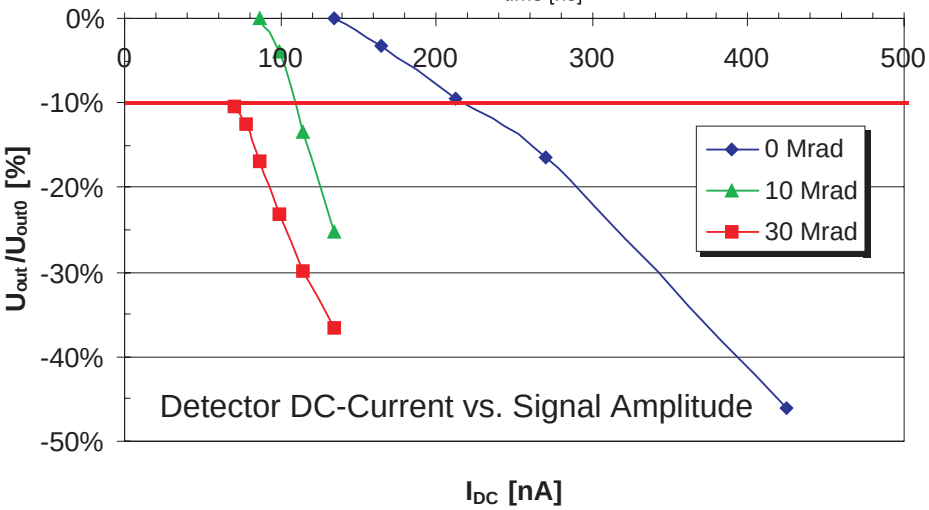
TID Effects

- A sample of 3 Beetle 1.2 Chips were irradiated
- the CERN MIC X-ray facility was used
- 45Mrad were reached in the allocated time window

- only subtle effects were observed







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The Beetle Group at MPI for Nuclear Physics, Heidelberg

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SEU Robustness Test

- 2 Irradiation runs with 65MeV protons
- @ PIF (PSI, Villigen, Switzerland)
- 24-25 and 26-27 Feb 2004

- Number of chips: 3
- Number of SEUs: 4
- **on-chip SEU detection and correction works as designed**

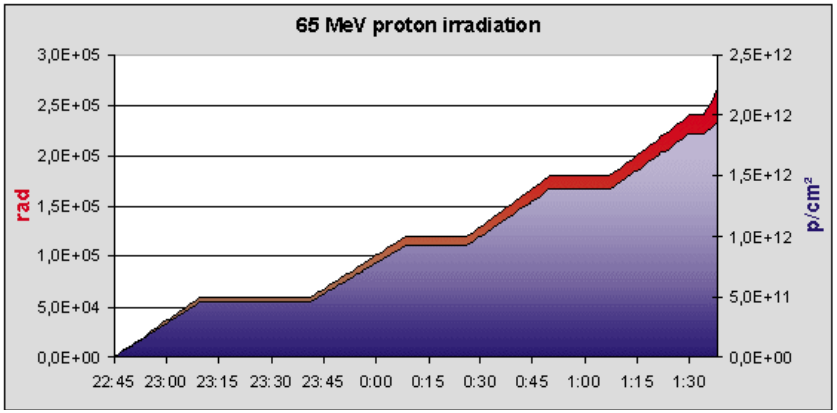
- Strange distribution pattern:
- Only 4 SEUs in a 923 krad window
- For constant SEU X-section it is P=0.2%

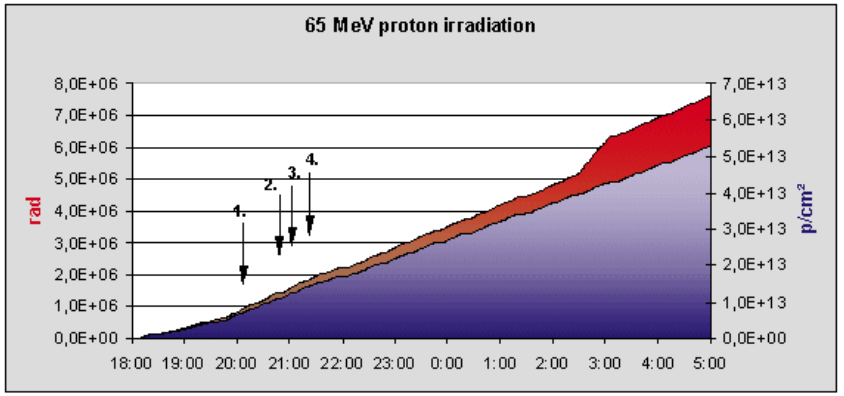
- Worst-case analysis based on the 923krad window yields:
  - 1 SEU per 0.23 Mrad (3 Chips)
  - 1 SEU per 0.69 Mrad (1 Chip)

  - All SEUs were flagged and cannot affect the ST and VELO data

  - Which means for the LHC*b* VELO:
  - 1344 Chips (21 Stations 64 Chips)
  - 10 Mrad in 3 Years

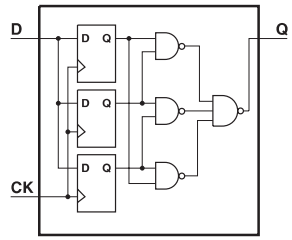
  - 64230 SEUs in Total
  - 1SEU every 25min



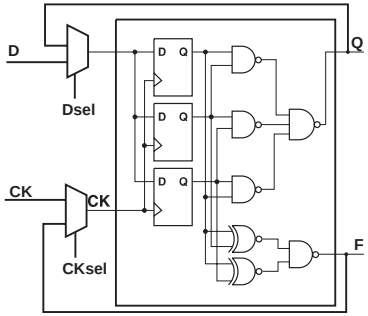


SEU Protection

State machines



Static registers

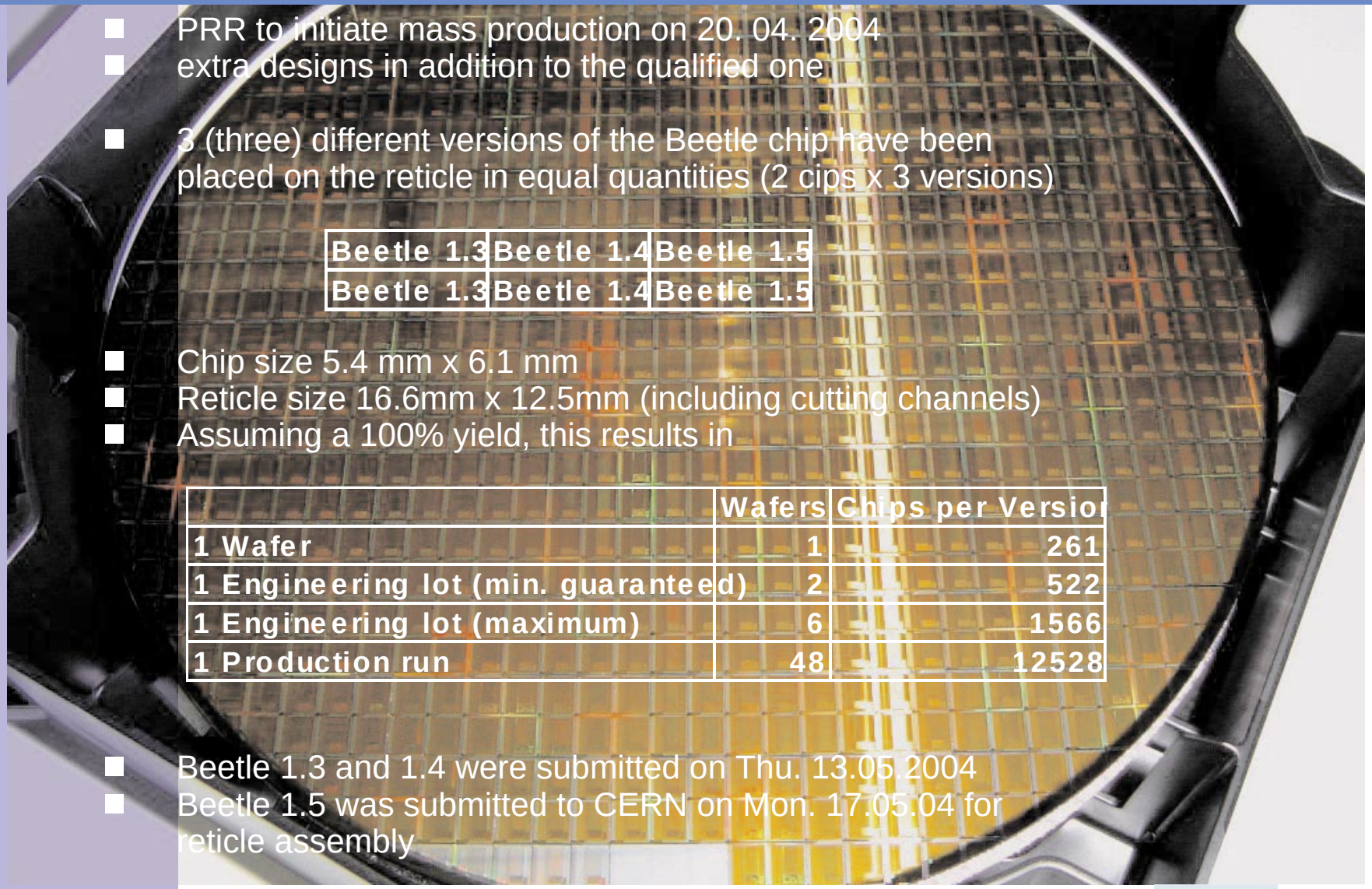


Irradiation Time	1	2
Flux	3.13×10^{8} p s^{-1} cm^{-2}	1.56×10^{9} p s^{-1} cm^{-2}
Integ. Flux	1.95×10^{12} p cm^{-2}	5.31×10^{13} p cm^{-2}
Dose	273 krad	7.66 Mrad
SEUs	0	4
Analogue Performance	no Change	no Change

Ulrich Trunk
The Beetle Group at MPI for Nuclear Physics, Heidelberg

ASIC Labor Heidelberg

Beetle_ER Engineering Run



- PRR to initiate mass production on 20. 04. 2004
- extra designs in addition to the qualified one

- 3 (three) different versions of the Beetle chip have been placed on the reticle in equal quantities (2 cips x 3 versions)

Beetle 1.3	Beetle 1.4	Beetle 1.5
Beetle 1.3	Beetle 1.4	Beetle 1.5

- Chip size 5.4 mm x 6.1 mm
- Reticle size 16.6mm x 12.5mm (including cutting channels)
- Assuming a 100% yield, this results in

	Wafers	Chips per Version
1 Wafer	1	261
1 Engineering lot (min. guaranteed)	2	522
1 Engineering lot (maximum)	6	1566
1 Production run	48	12528

- Beetle 1.3 and 1.4 were submitted on Thu. 13.05.2004
- Beetle 1.5 was submitted to CERN on Mon. 17.05.04 for reticle assembly

Ulrich Trunk
The Beetle Group at MPI for Nuclear Physics, Heidelberg

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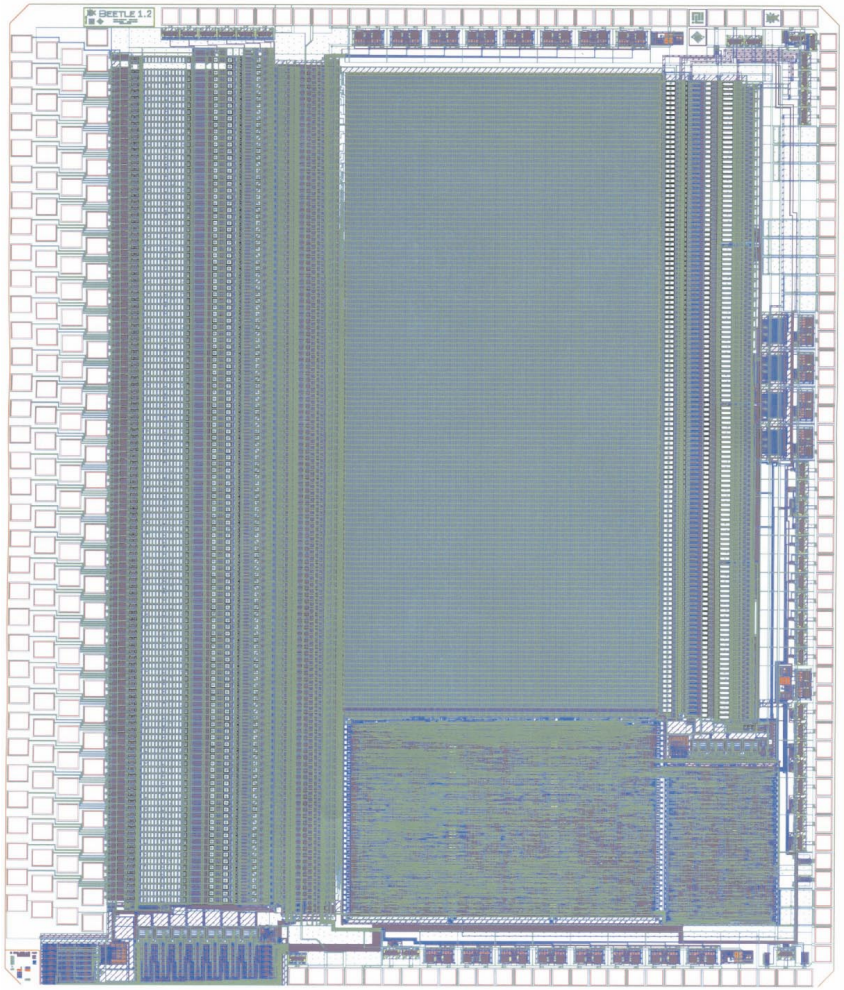
Beetle 1.3

- Beetle 1.3 was submitted without any changes
- The original gdsII-file of the MPW-run was used



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The Beetle Group at MPI for Nuclear Physics, Heidelberg

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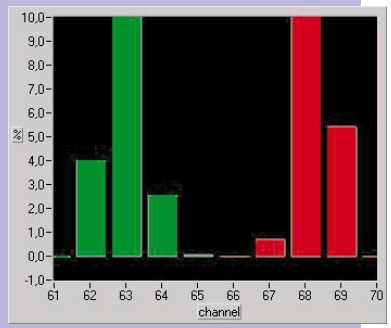
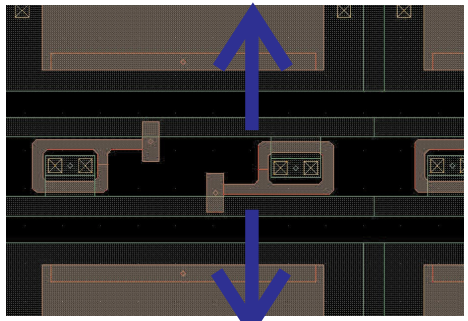
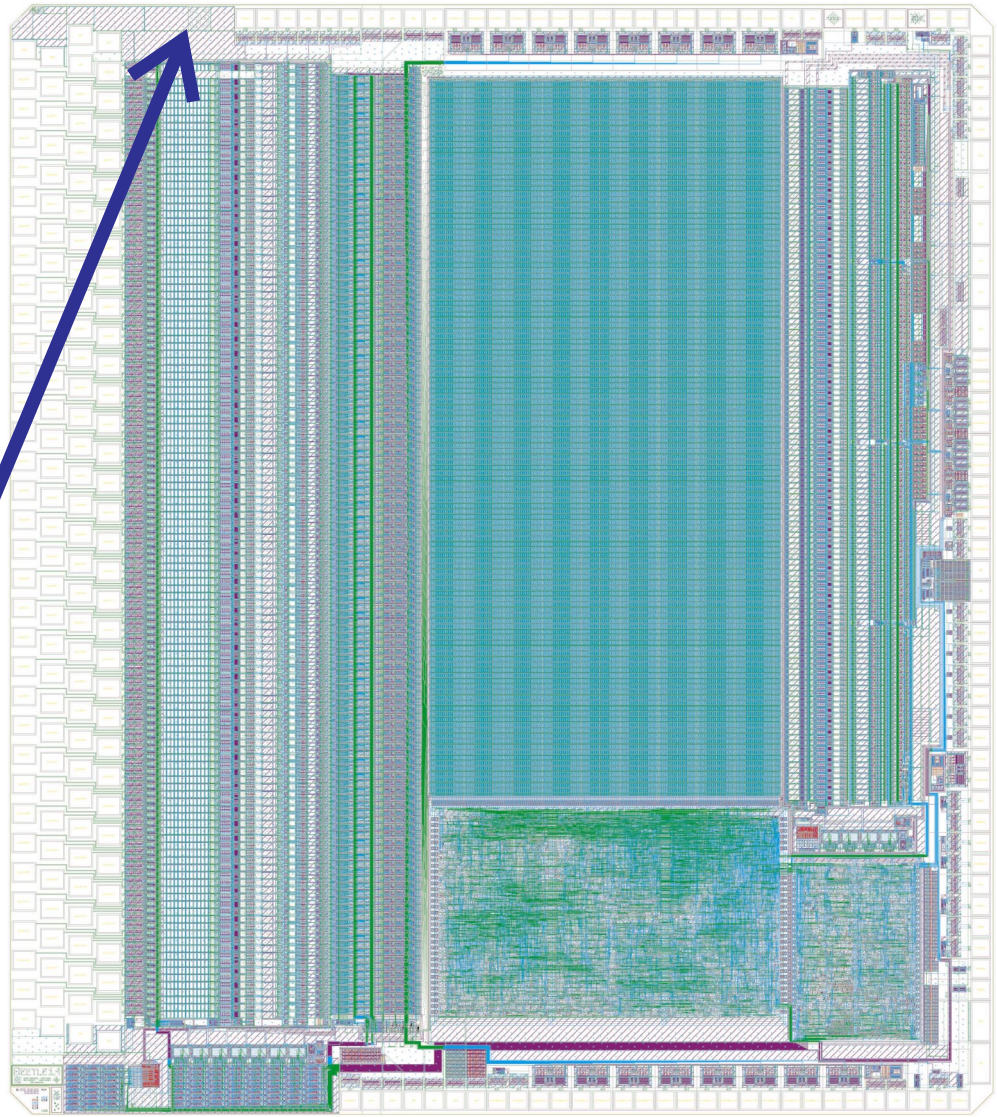
Beetle 1.4

On Beetle 1.4 the changes approved by the Beetle Production Readiness Review (20.04.04) were included:

- Comparator:
  - improved linearity of local threshold DAC
  - reduced crosstalk/feedback due to the removal of an (analogue powered) inverter stage
- Fixed Pipeline Column Number (PCN) parity bit
- Beetle Version ID in CompThreshold register
- visual identification/alignment marks
- increased spacing of pipeline readout lines for reduced even/odd crosstalk







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The Beetle Group at MPI for Nuclear Physics, Heidelberg

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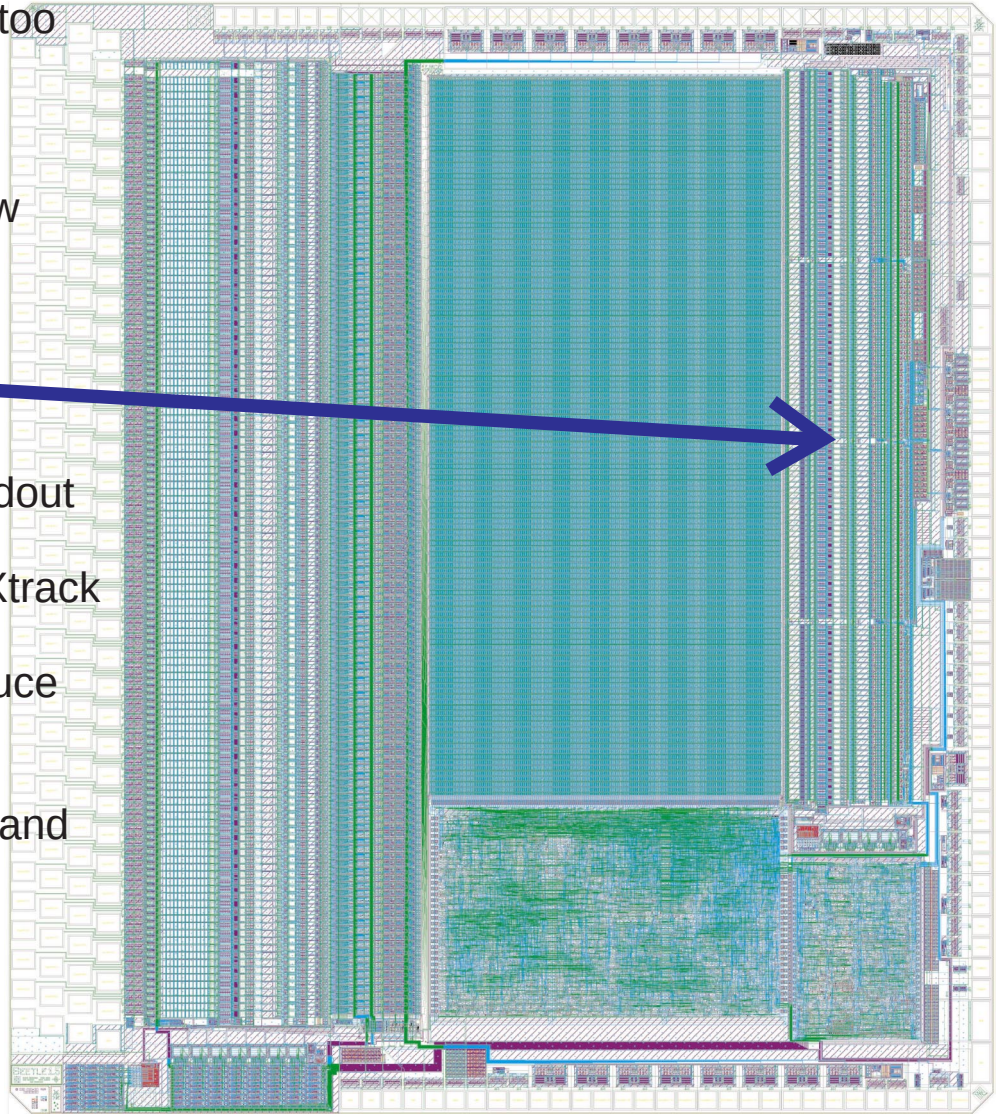
Beetle 1.5

Beetle 1.5 includes further changes considered “too risky” by the PRR for Beetle 1.4:

- All changes applied on Beetle 1.4
- Changed power routing and separation of comparator power from FE. Therefore 2 new power pads were introduced
- Pipeline cells with NFET over NWELL caps
- Pipeamp:
  - Pipeamp split into 4 blocks
  - Power bars to multiplexer
  - Improved flatness and stability of the readout baseline
  - Driver tree of RoAmpReset equal to MUXtrack (driver for each 32 channel MUX)
  - Synchronisation of PCN and MUX to reduce crosstalk
- Process parameter test structure
- Improved power routing for MUX, Pipeamp and top pads
- Different Beetle Version ID
- Other minor modifications



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The Beetle Group at MPI for Nuclear Physics, Heidelberg

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Chip & Wafer Test

Current setup:

- Suss PM4 manual probe station
- Needle card with active electronics as a mezzanine board (samtec connectors)
  - Allows quick and easy exchange or replacement of the needle card
- Tek DG2020 pattern generator
- Tek TDS744D DSO

- Visual inspection of digital signals (top scope) and readout figure (bottom scope):
  - Pseudo-random trigger pattern together with the
  - Beetle's internal test pulse and the
  - DPO mode of the scope enable the
  - detection of dead channels and pipeline cells

Test setup for mass testing:

- Suss semi-automatic prober (PM2000)
- Fast DAQ system (adopted from HERA-B)
- Detailed online analysis with Linux PC

Ulrich Trunk
The Beetle Group at MPI for Nuclear Physics, Heidelberg

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The Future.....

- The Beetle 1.3 fulfills all VELO and ST requirements
- Beetle 1.4 provides an improved discriminator for the VETO and reduced channel crosstalk
- Beetle 1.5 fixes some minor issues (e.g. the stability of the Readout Baseline)

- After the relevant Beetle versions have been qualified to the needs of the different detectors
- a production run (48 Wafers = 11000 Chips / Version) is planned for the end of this year

Ulrich Trunk
The Beetle Group at MPI for Nuclear Physics, Heidelberg