SEU beam test
FIB patch

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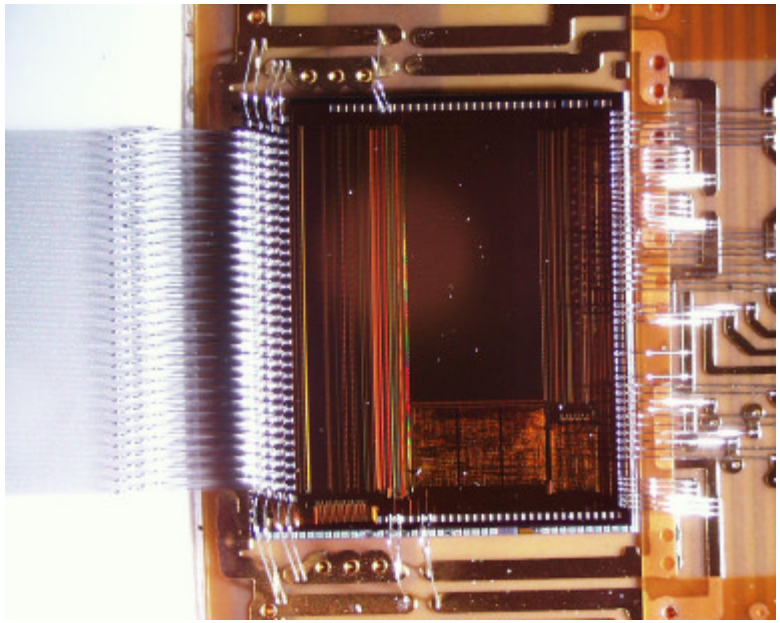
Outline

- **SEU beam test**
  - **setup**
  - **results**
- **FIB patch**
  - **problem**
  - **patch solution**
  - **FIB**
  - **lab-tests**



Beetle 1.3 on a IT hybrid

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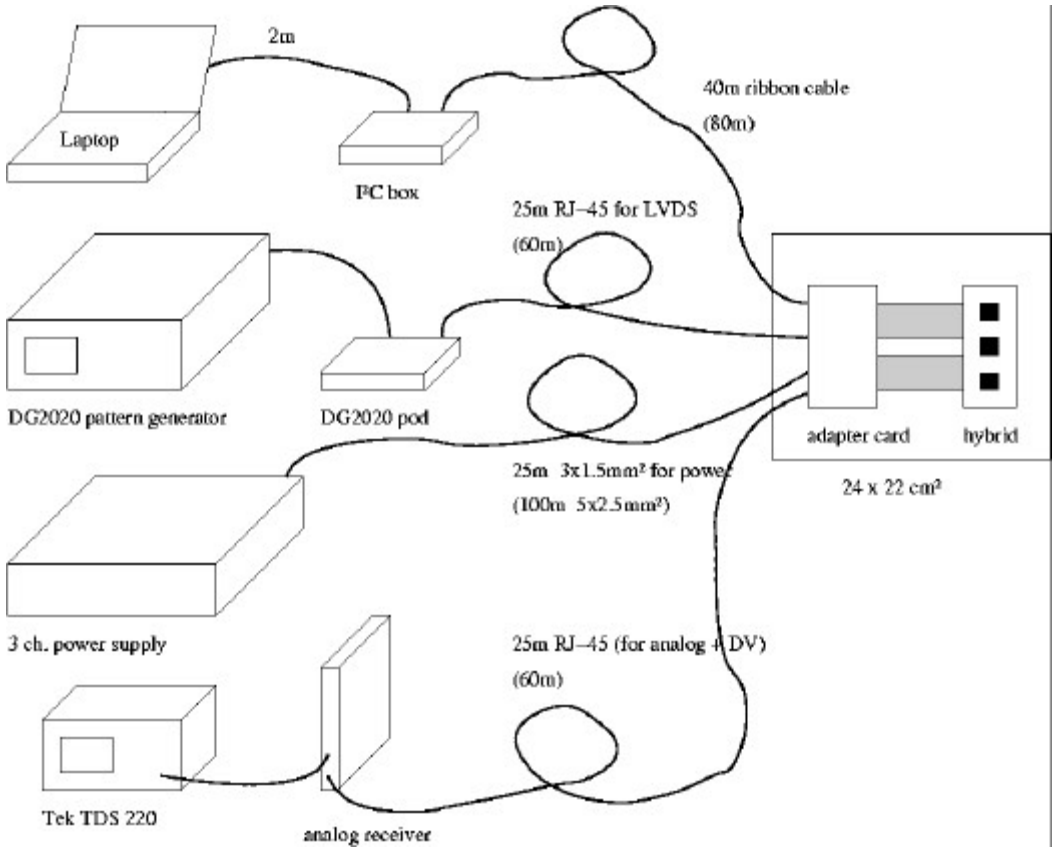
SEU beam test

- SEU beam test at
  Proton **I**rradiation **F**acility **(PIF)**
  Paul-Scherrer Institute, CH

- Irradiation of 3 Beetle chips:
  - 65 MeV protons

- Check for bit-flips in Beetle registers
  - SEU cross section for a std. flip-flop



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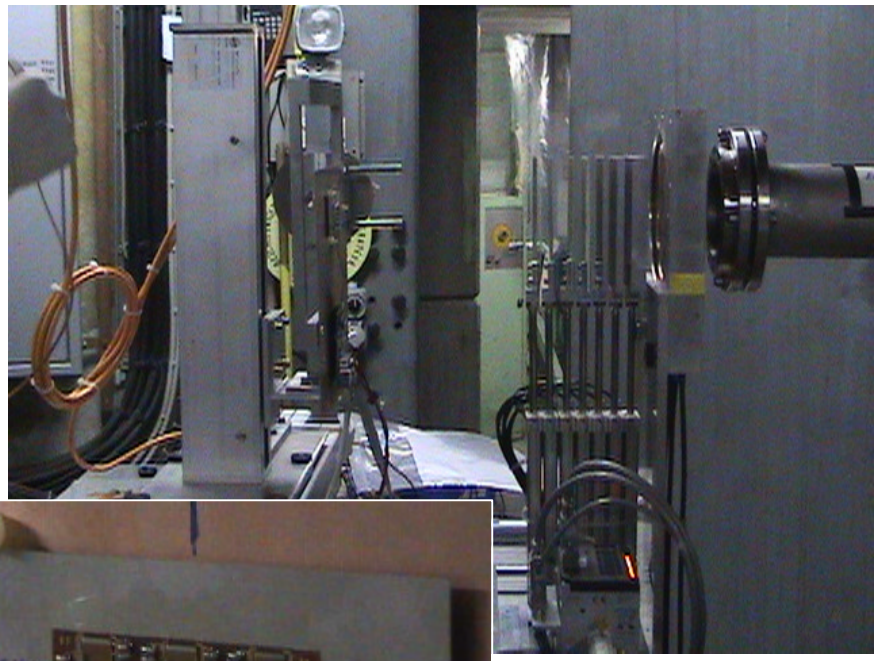
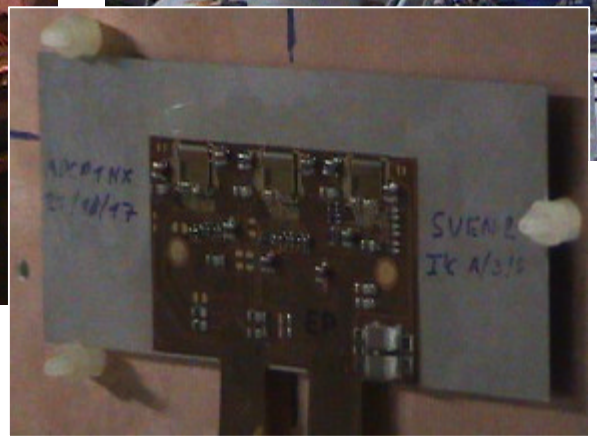
SEU test - setup





setup on top of the irradiation facility

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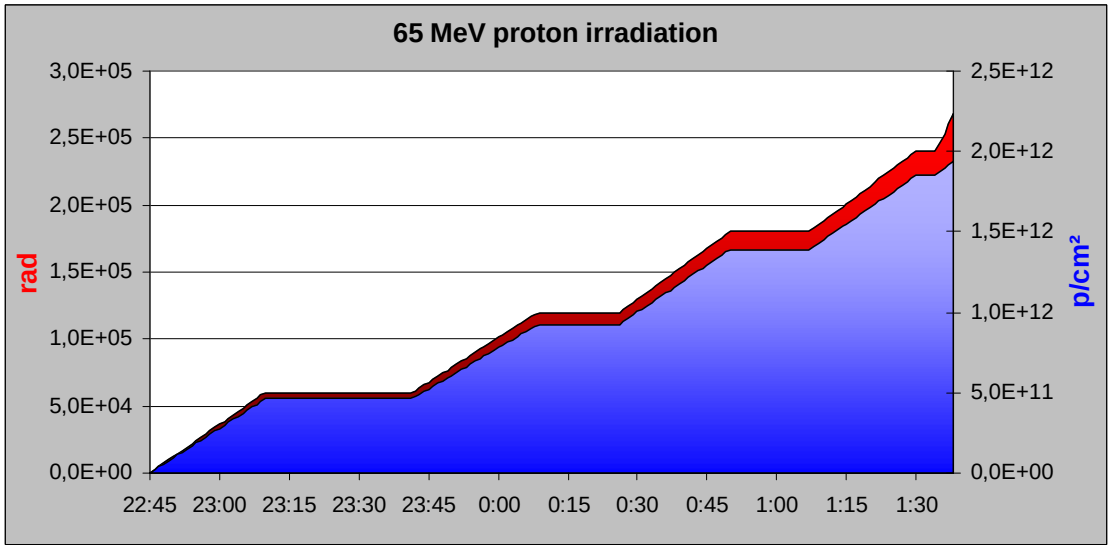
SEU test - irradiation (1)

- **Irradiation (Tuesday to Wednesday):**
  - **65 MeV protons**
  - **mean flux: 3.13 x 10^8 p/cm²/s**
  - **fluence: 1.95 x 10^{12} p/cm²**
  - **accumulated dose: 273 krad**
- **estimated cross section per FF: 10^{-13} to 10^{-15} cm²**
  - **1 SEU every 300 s (at 10^8 p/cm²/s)**
  - **+/- 1 magnitude**



but no SEU bit flips found

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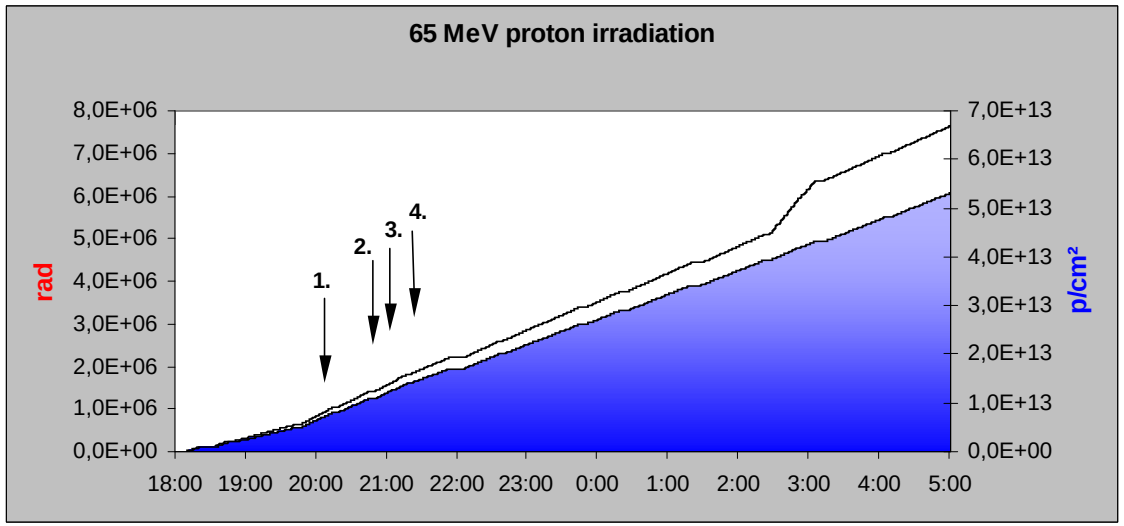
SEU test - irradiation (2)

- **Second irradiation (Thursday to Friday):**
  - **65 MeV protons**
  - **mean flux: 1.56 x 10^9 p/cm²/s**
  - **fluence: 5.31 x 10^{13} p/cm²**
  - **accumulated dose: 7.66 Mrad**



- **4 SEU flips found**
- **time distribution not yet understood**

- **Pulse shape scan:**
  - **no variation of pulse before / after irradiation**

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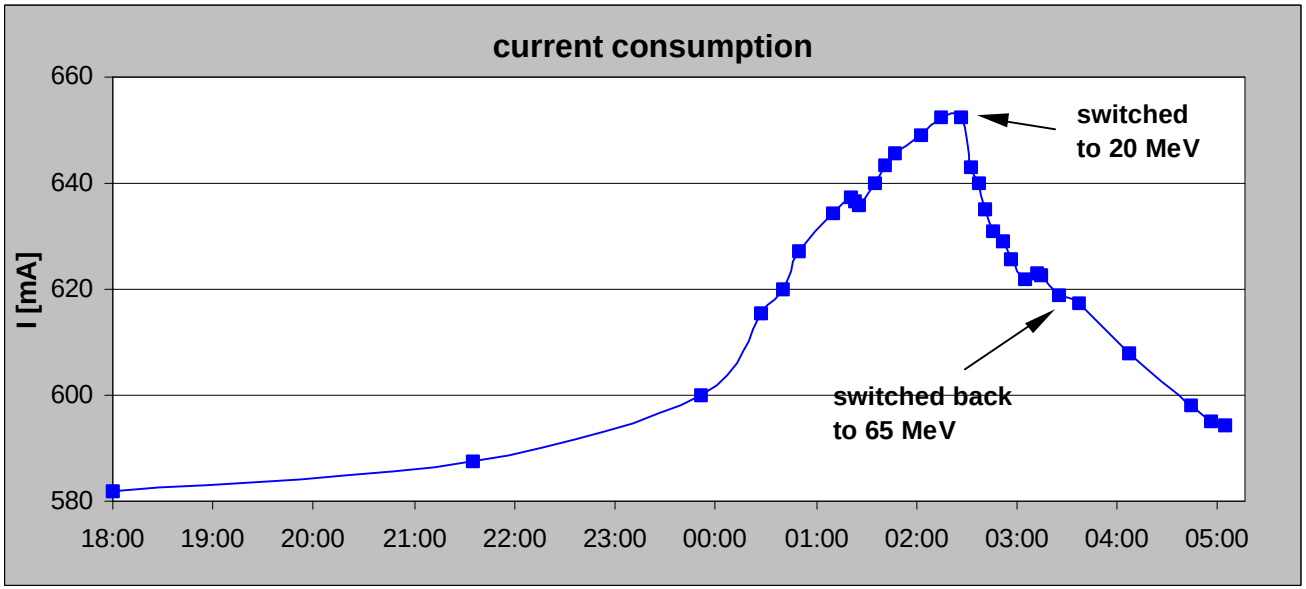
SEU test - power consumption

Current consumption of all 3 Beetle chips



behaviour not yet understood

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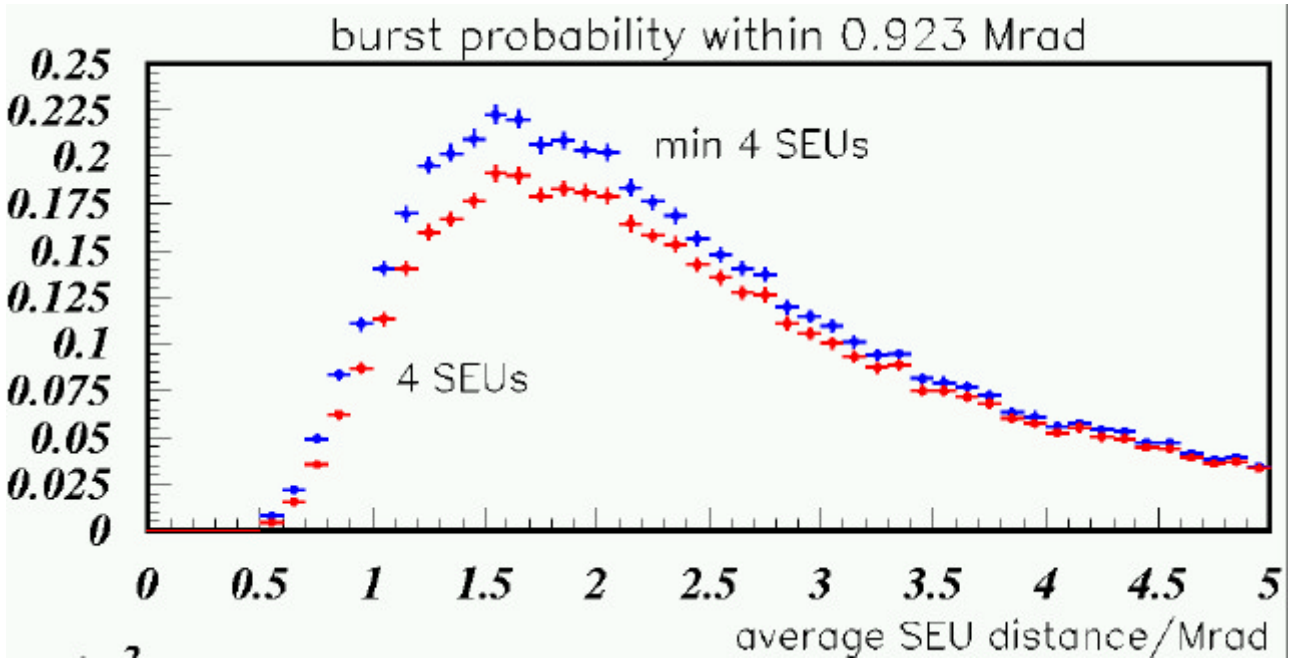
SEU test - probability

- **probability of a burst of 4 SEUs (or more) within a window of 0.923 Mrad (total 6.647 Mrad):**
  - **4 SEU: 0,2 % probability... (unlikely...)**



SEU test - cross section

- **Analysis is restricted to the 0.923 Mrad window with SEUs under worst condition:**
  - **1 monitored SEU per chip per 0.69 Mrad or**
  - **1 SEU per chip per 0.21 Mrad**
- **VELO:**
  - **1344 chips (21 stations x 64 chips per station)**
  - **10 Mrad in 3 years**

  in total 64230 SEUs or 1 SEU per 25 minutes

- **SEU cross section for a single flip flop for 60 MeV protons:**

  $s = (1.12 \pm 0.56) \cdot 10^{-16}\ cm^2$

F. Facio: $\sigma = 2 \cdot 10^{-16}\ cm^2$

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Readout header: parity bit

1 port mode

AO[0]	I0	I1	I2	I3	I4	I5	I6	I7	P7	P6	P5	P4	P3	P2	P1	P0

4 port mode

AO[0]	I0	I4	P1	P0
AO[1]	I1	I5	P3	P2
AO[2]	I2	I6	P5	P4
AO[3]	I3	I7	P7	P6

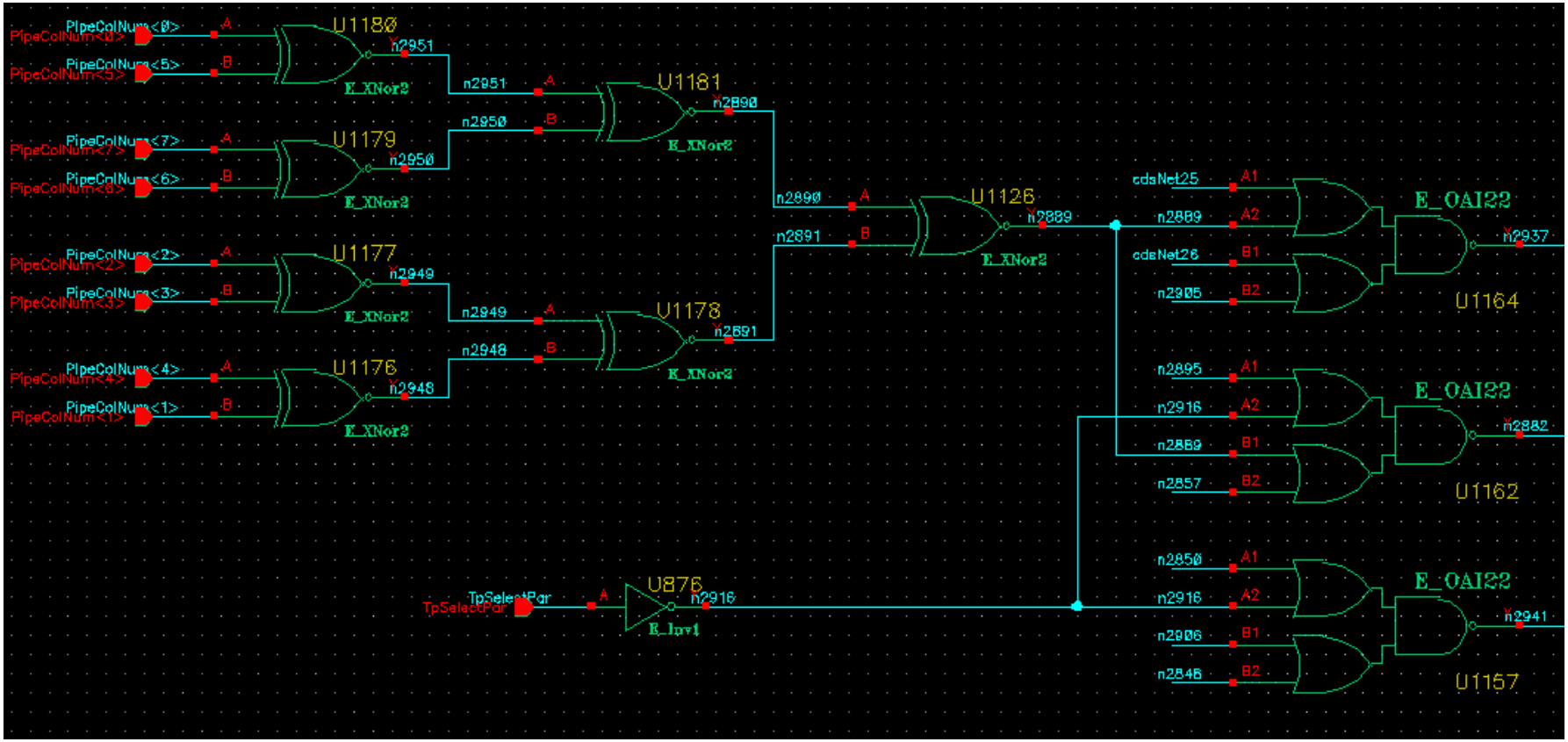
I0	leading bit (always 0)
I1	parity of PCN (even)
I2	Active EDC
I3	parity of reg. CompChTh
I4	parity of reg. CompMask
I5	parity of reg. TpSelect
I6	SEU counter <1>
I7	SEU counter <0>

- **Parity bit (I1) is wrong encoded in 4 port mode and Rclk divider = 0 (LHCb mode)**

  all other modes or Rclk divider settings
  ➔ Parity bit is OK

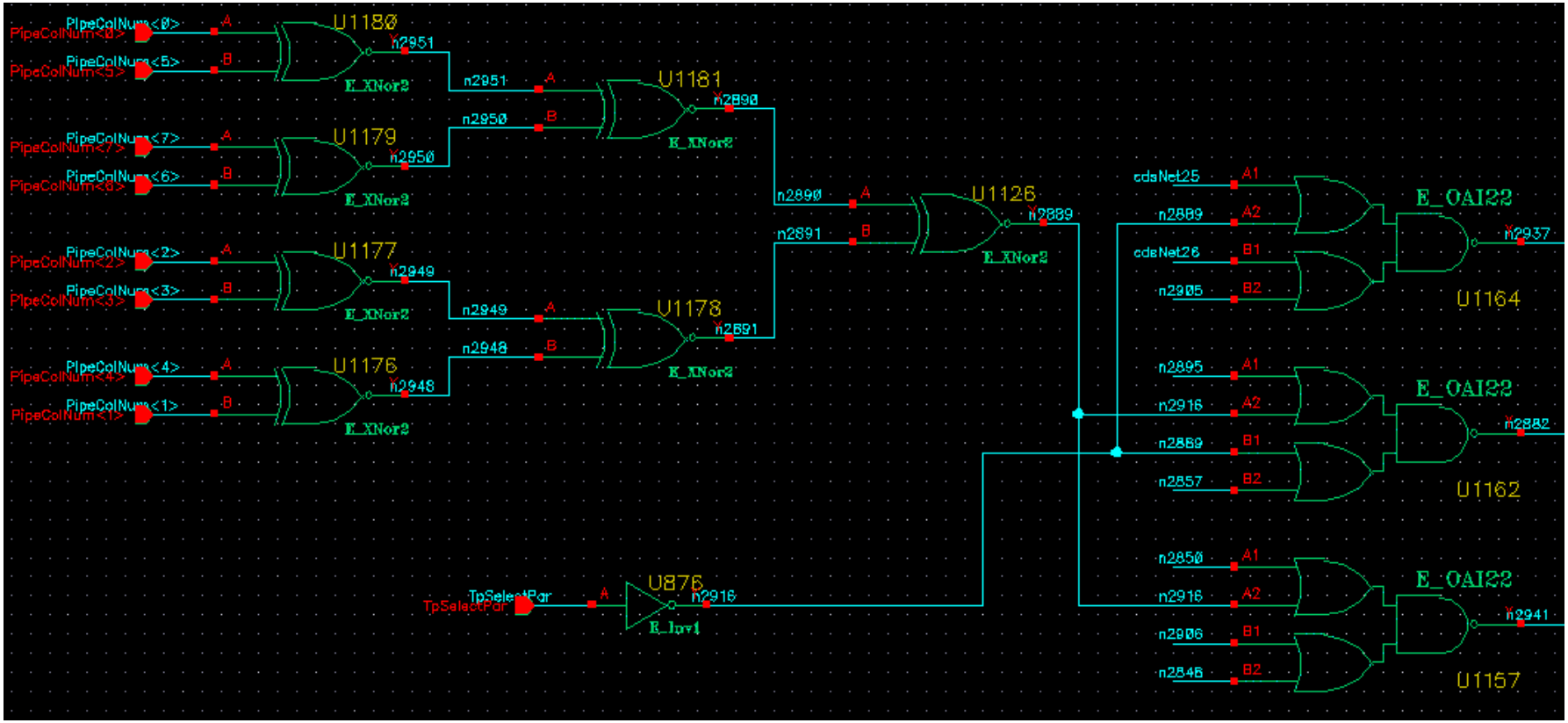
- **problem is understood in verilog**
  - **not so easy to fix**
  - **simple workaround: swap position I1 with I5 could be tested on a 1.3 with a FIB patch**

Parity bit - workaround (1)



schematic of parity-bit generation (part of MuxScheduler)

Parity bit - workaround (2)



new schematic of parity-bit patch

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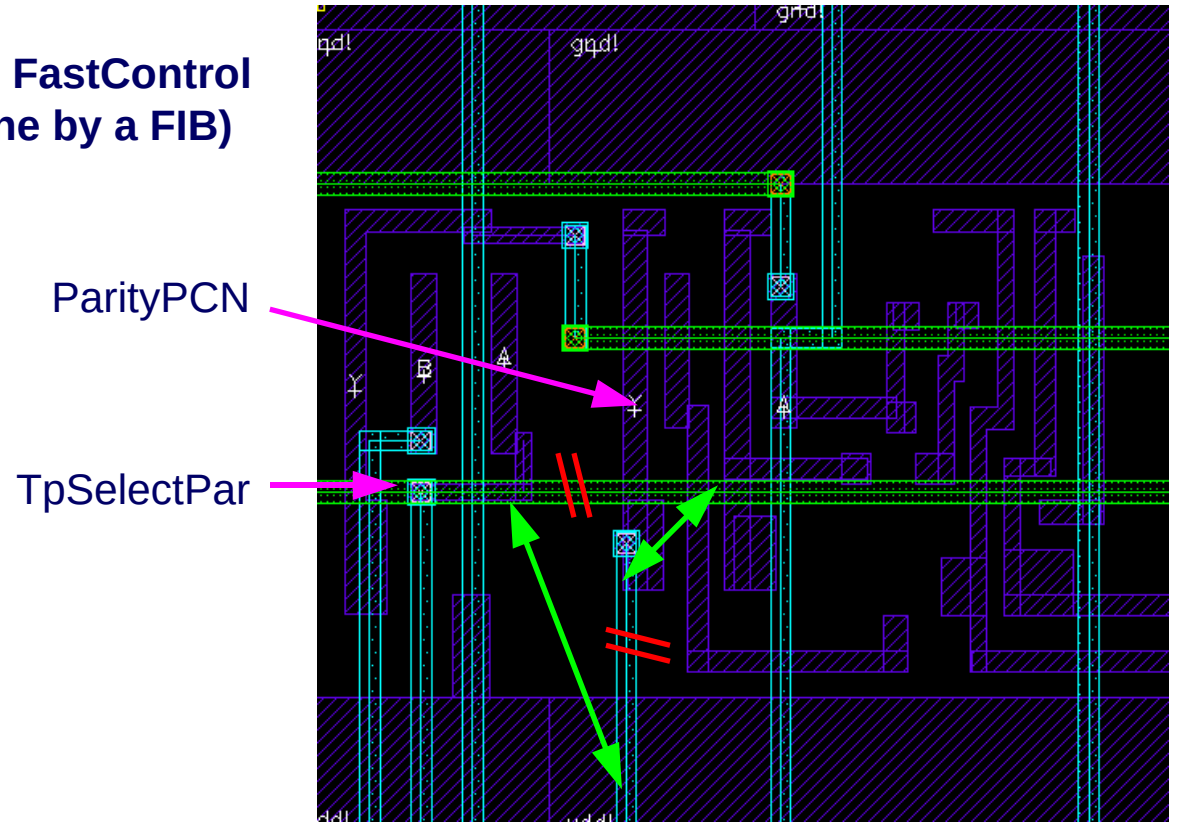
Parity bit - workaround (3)

- **Layout modification in FastControl of Beetle (could be done by a FIB)**
  - **2 cuts**
  - **2 connections**



Output device of ParityPCN generation - E_XNor2 (U1126)

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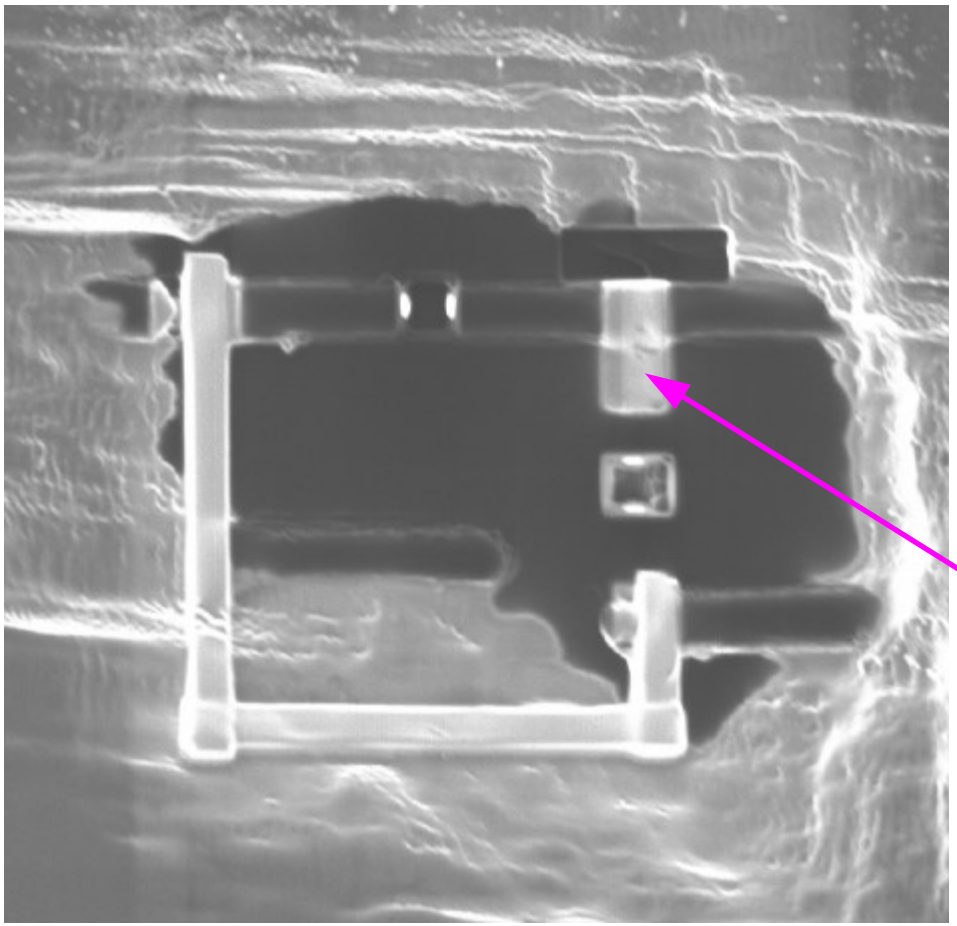
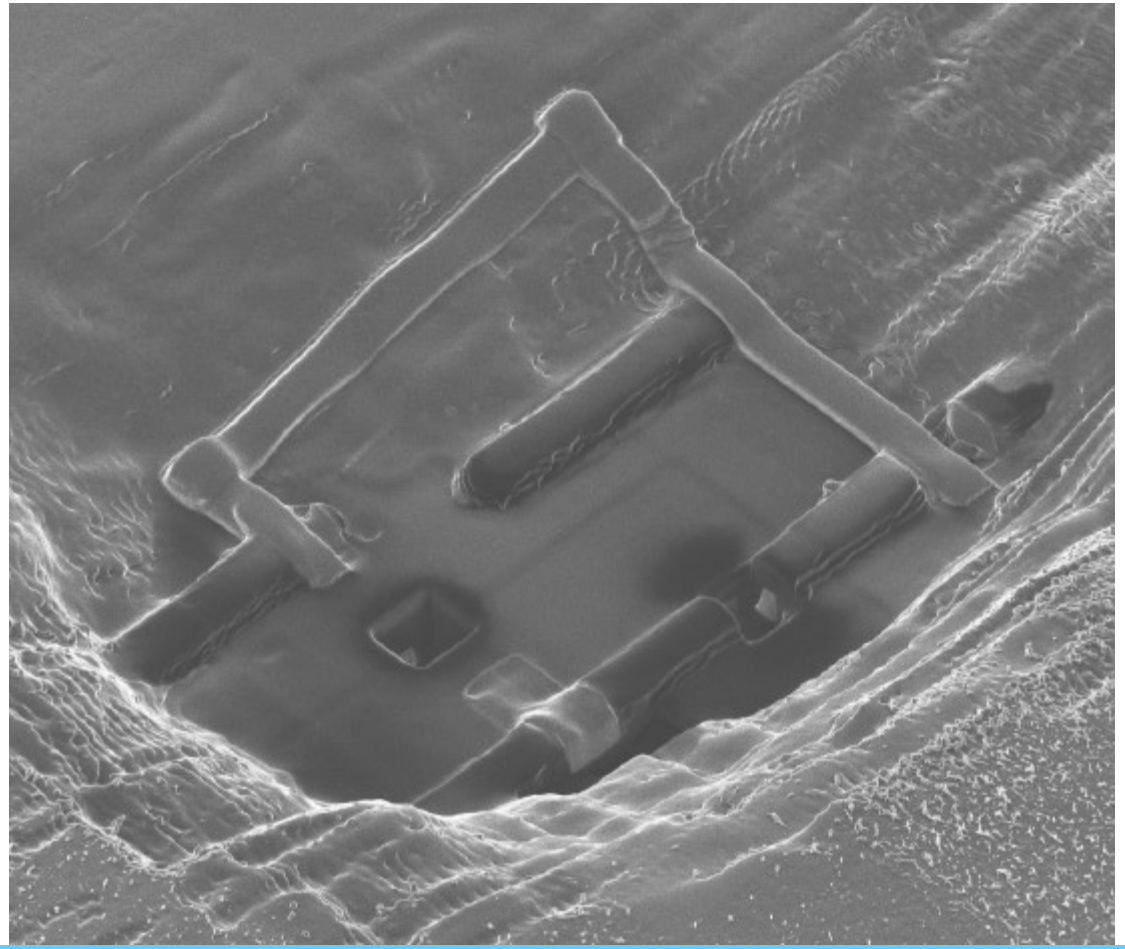
FIB patch (1)



- **Swap header bit I1 with I5**
- **done with a FIB patch (FEICO Munich)**

Output device of ParityPCN generation - E_XNor2 (U1126)

FIB patch (2)



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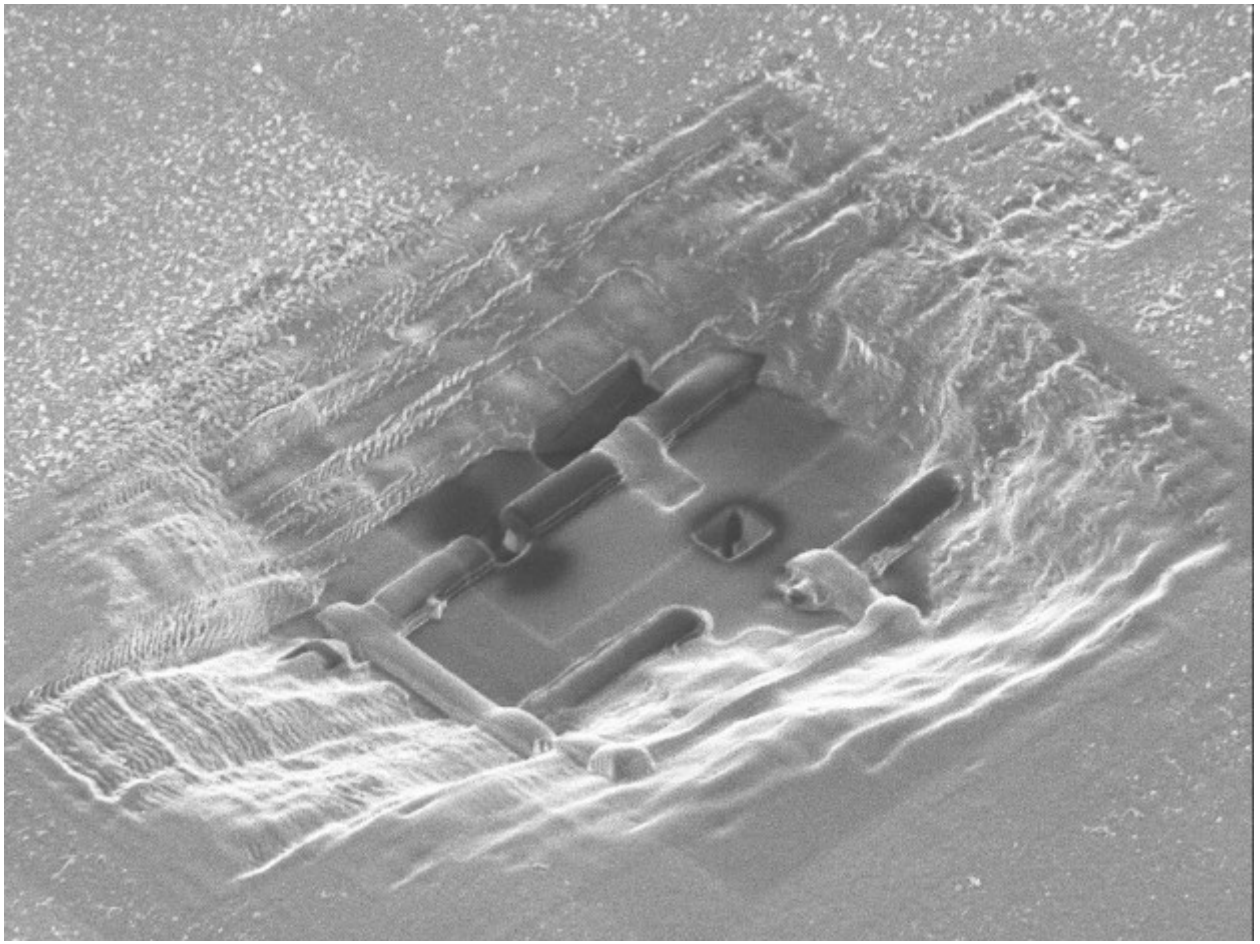
FIB patch (3)



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FIB: results:

- one patched Beetle 1.3 chip tested:
  - 1 x 10^6 readouts in 1 port mode (Testmode)
  - 3 x 10^6 readouts in 1 port mode (LHCb mode)
  - non-consecutive / consecutive readouts
  - different Rclk divider settings
- ➔ Parity bit is now right enconded

- asynchron trigger:
  - 3 x 10^6 readouts
- ➔ no hiccup of FastControl

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