Radiation tolerance studies of BTeV pixel readout chip prototypes

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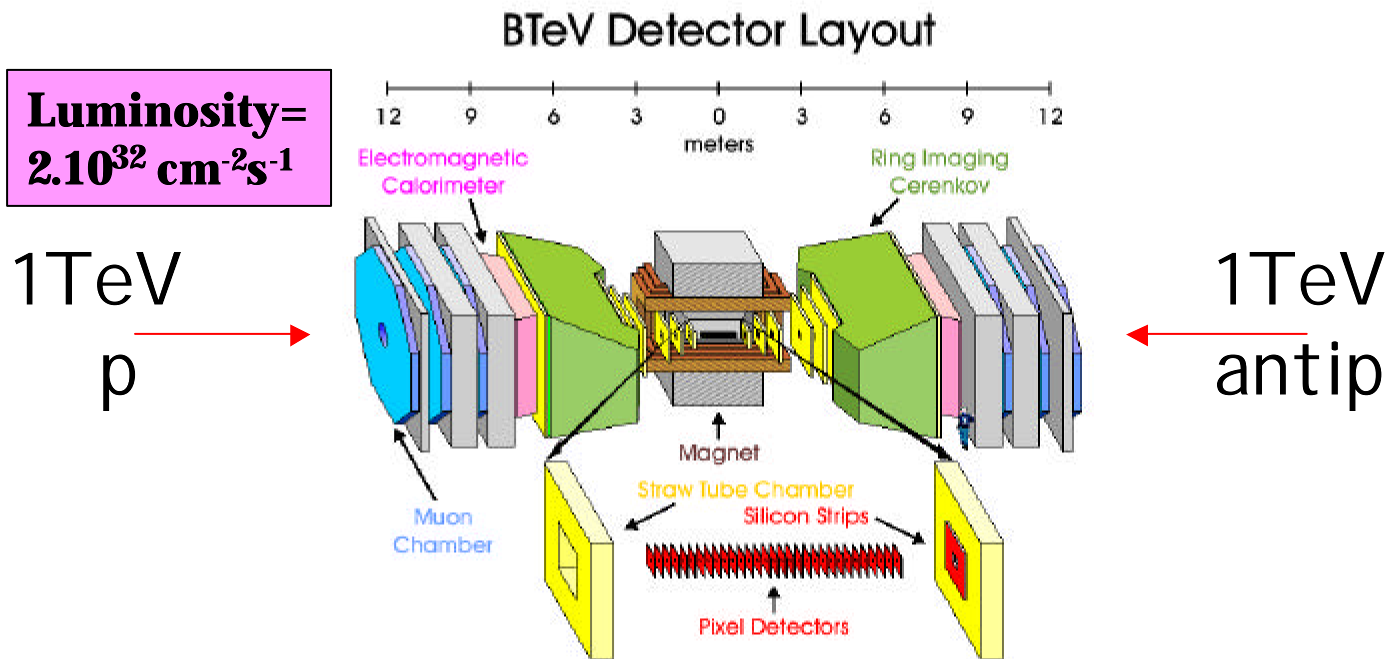
Outline of the talk

- Introduction
- FPIX readout chip prototypes
- 200 MeV proton irradiation:
  - » Total Dose Effects
  - » Single Events Effects
- Conclusions and next

Introduction:

The BTeV pixel vertex detector



• BTeV is a double arms spectrometer optimized to do b physic at the Tevatron hadron collider.

• The "hottest" pixel readout chips are located 6 mm from the beam (fluence about $10^{14} cm^{-2} y^{-1}$).

• FPIX readout chips is the only active device in the high radiation environment.

• Copper point-to-point links will connect the FPIX chips to FPGA's located behind the magnet.

➢ The pixel readout chip is implemented in deep submicron CMOS technology with rad-tolerant design rules.

FPIX readout chip prototypes :

Chip prototypes in 0.25 um CMOS technology

DSM preFPIX2 prototypes

- PreFPIX2_T, 2x160 array, TSMC 0.25 um CMOS
  - New leakage compensation strategy implemented in radiation tolerant techniques.
  - 3 bit FADC/cell
  - γ irradiation to a total dose of 33 Mrad.
- PreFPIX2_I , 18x32 array, CERN 0.25 um CMOS
  - Complete fast non-triggered RO.
  - p irradiation test in this talk.
- PreFPIX2_Tb 18x32 array, TSMC 0.25 um CMOS
  - Programmable 14 x 8 bit DAC's.
  - p irradiation test in this talk.

200 MeV Proton irradiation tests at the Indiana University Cyclotron Facility

Dec. 2000:
- 4 preFPIXI irradiated to a total dose of 26 Mrad.

Apr. 2001:
- 1 preFPIXTb irradiated to a total dose of 14 Mrad.

Aug. 2001:
- 4 preFPIXTb irradiated to a total dose of 29 Mrad.
- One of the boards was used in Apr. 2001 test collected a total dose of 43 Mrad.
- One of the boards was placed at 45 degrees.

200 MeV proton irradiation :

Results: Total dose and SEL

Analog and digital currents were constantly monitored during irradiation separately for each board:

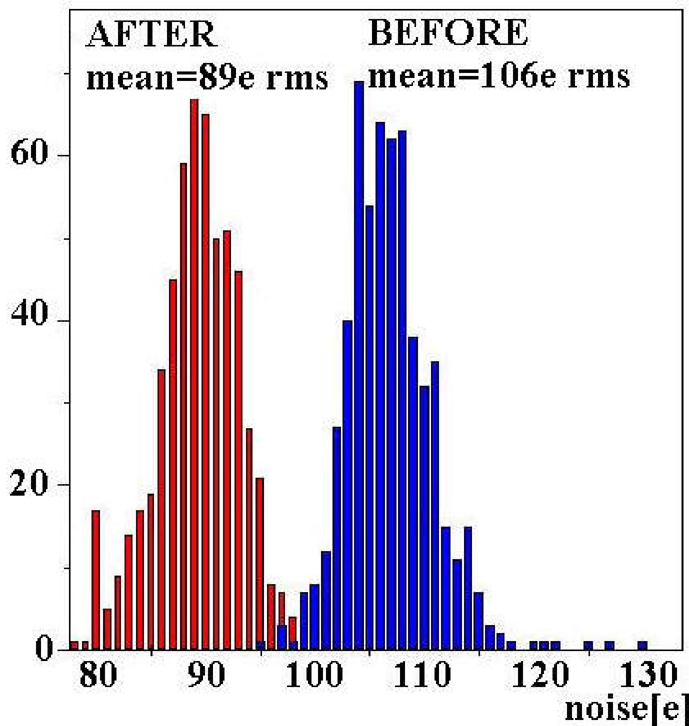
- I_{analog} decreased slightly during irradiation.
- $I_{digital}$ increased slightly during irradiation.
- No evidence of Single Event Latch-up.

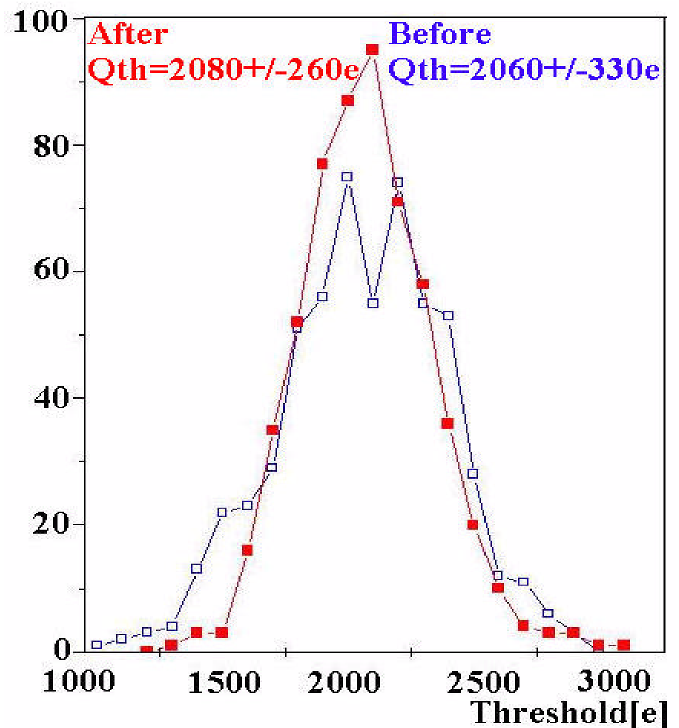
200 MeV proton irradiation :

Results: Total dose and SEGR

- Noise and discriminator threshold of each individual cell was measured before and after irradiation.
- For the four preFPIX2I chips (Dec. 00) all the 32rows x 18cols x 4chips = 2304 cells work after 26 Mrad proton irradiation:
  - The noise is decreased by about 10%.
  - The threshold dispersions is decreased by about 20%.

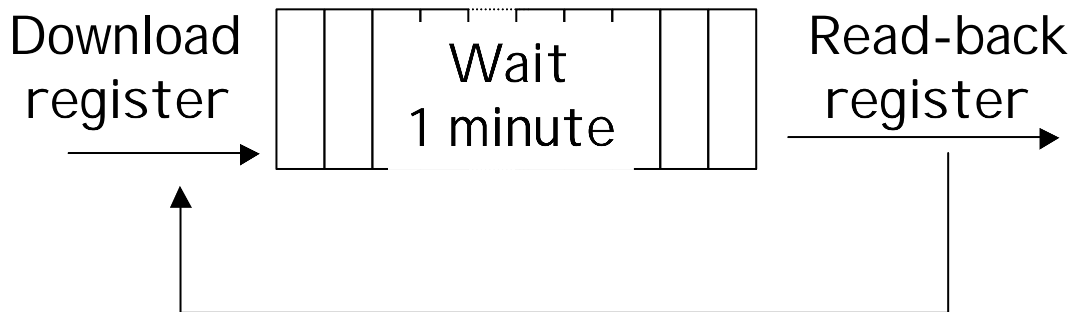
Noise and thresholds distribution before and after 26 Mrad proton irradiation for one preFPIX2I chip.





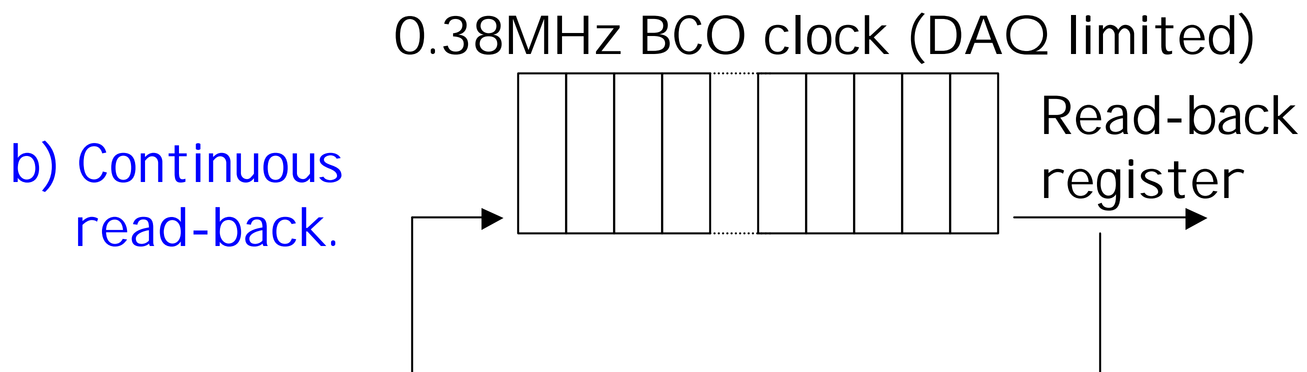
200 MeV proton irradiation :
SEU testing procedure

Test 1: un-clocked registers



Test 2: clocked shift-register

a) Download pattern.



b) Continuous read-back.

c) Stop when an error is detected.

200 MeV proton irradiation :

SEU error table

N.B. In Apr.01 the DAC registers were downloaded with 82 0's and 30 1's.

Time	Board	Fluence $[cm^{-2}]$	Bit errors in S-R [2x576 bits]	Bit errors in DAC [8x14 bits]
Apr.01	1	2.33E14	53=18↑+35↓	10=8↑+2↓
Aug.01	2	3.65E14	74=22↑+52↓	19=9↑+10↓
Aug.01	3	3.65E14	86=27↑+59↓	19=8↑+11↓
Aug.01	1	3.65E14	80=23↑+57↓	20=8↑+12↓
Aug.01	4 (45^0)	3.65E14	77=14↑+63↓	31=19↑+12↓

No statistical significant beam angle dependence.

- =transition from 0 to 1
‾=transition from 1 to 0

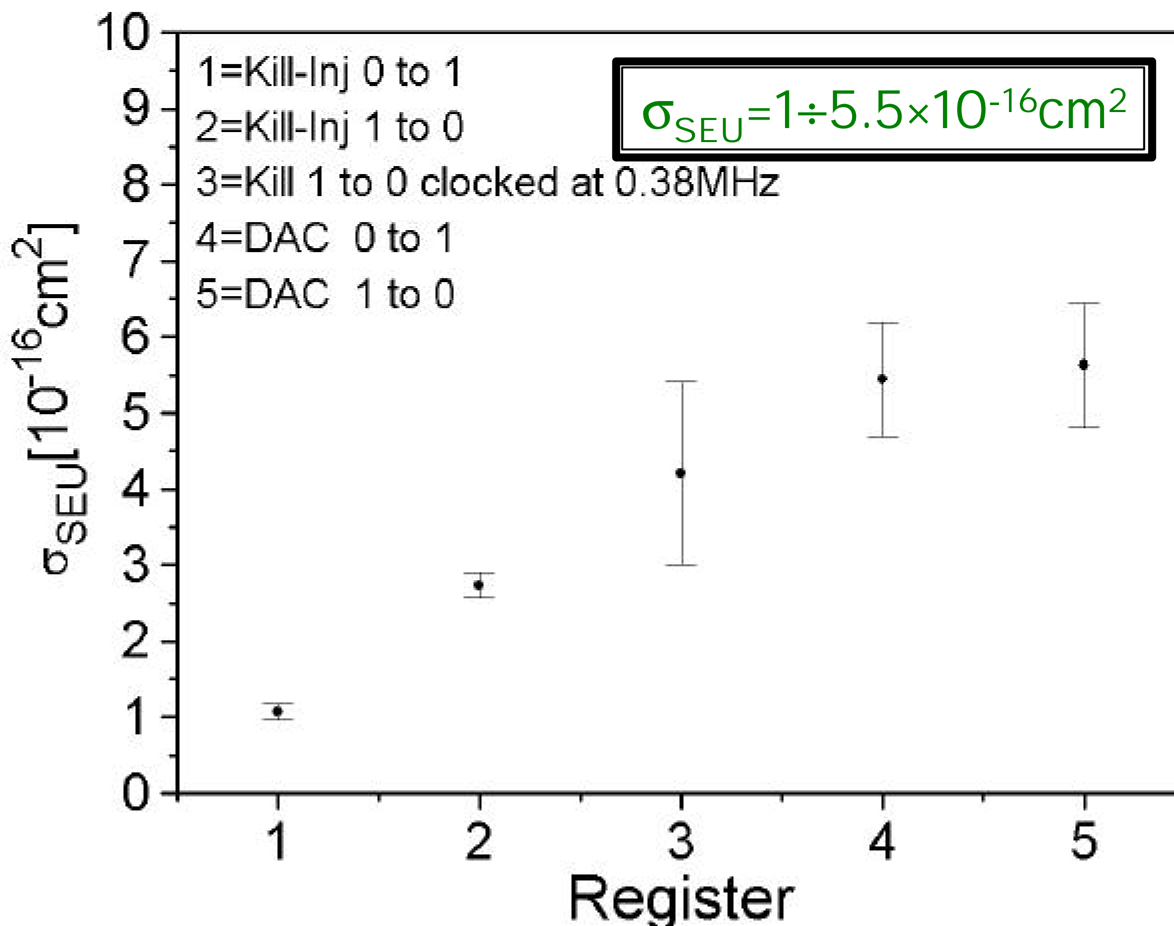
Kill and Charge-Injection shift-registers:
- DFF with Nor-not cross-coupled gates
  (expected asymmetry in 0->1 and 1->0 upset rate).
- Random pattern with equal number of 0's and 1's.

DAC registers:
- DFF with Nor-Nor cross-coupled gates
  (expected symmetry in 0->1 and 1->0 upset rate).
- Constant pattern with equal number of 0's and 1's.

200 MeV proton irradiation :
SEU cross sections

$$N_{error} = F \cdot N_{bits} \sigma_{one\ bit}$$

- N_{error} = total bit errors
- F = I *time = integrated fluence
- N_{bits} = number of bits exposed
- σ_{bit} = one bit SEU cross section



N.B. the uncertainty in the integrated fluence is less than 10%

Conclusions and Next

- Small change of the bias currents.
- No evidence of Latch-Up (43Mrad).
- No evidence of Gate Rupture in the 5 chips tested so far (26 Mrad).
- We measured SEU's in 0.25um preFPIX2Tb in two different Registers:
  - » $\sigma_{SEU} = 1 \div 5.5 \times 10^{-16} cm^2$
- No incident beam angle dependency has been found in the upset rate.

- Irradiation of sensors bump-bonded to readout chip (Sept. 01).
- Submission of full-size FPIX readout chip for BTeV (before the end of the year).
- Test beam with irradiated sensors bump-bonded to readout chip (next year).