

Radiation tolerance studies of BTeV pixel readout chip prototypes

G. Chiodini, J.A. Appel, G. Cardoso, D.C. Christian,
M.R.Coluccia, J. Hoff, S.W. Kwan, A. Mekkaoui, R.
Yarema, and S. Zimmermann
FNAL (USA)

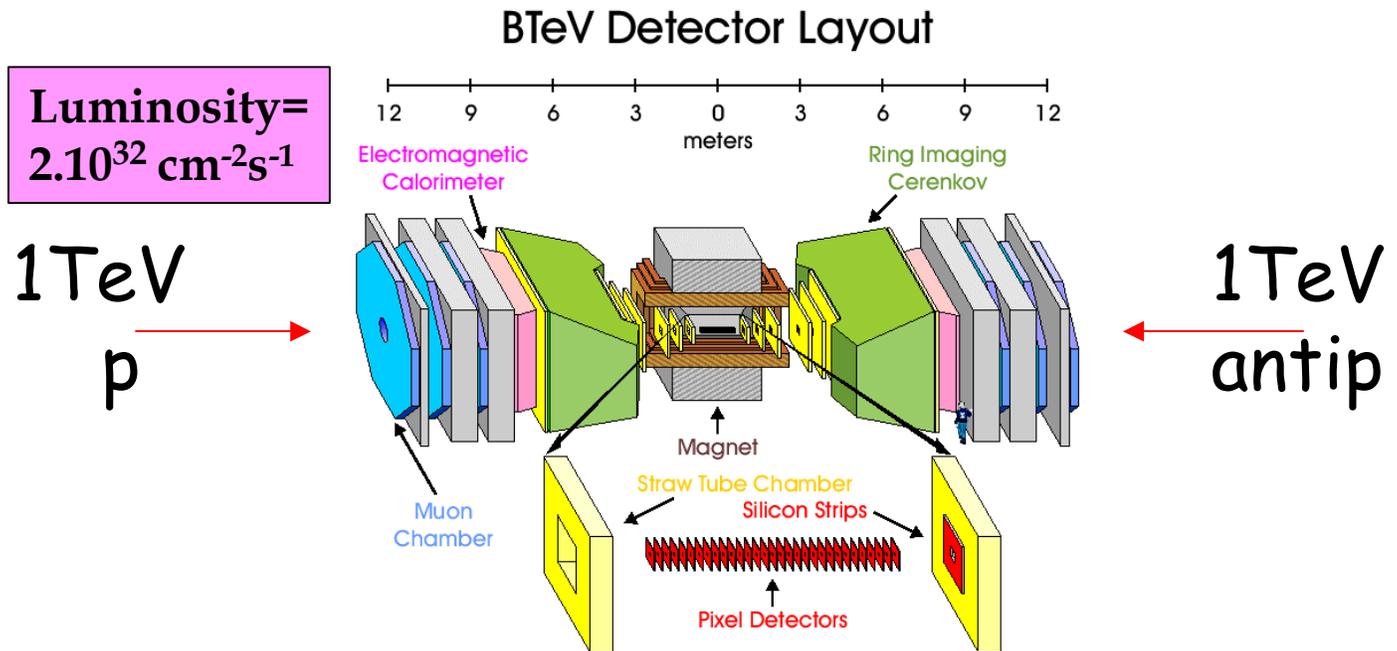
**7th Workshop on Electronics
for LHC Experiments
Stockholm, Sweden, 10-14 September 2001**

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 $10^{14} \text{ cm}^{-2} \text{ y}^{-1}$).
 - 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:

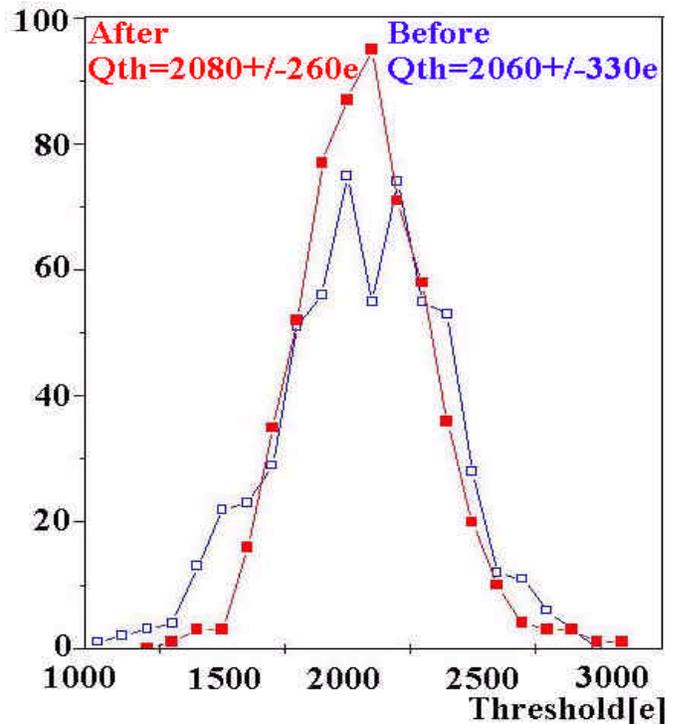
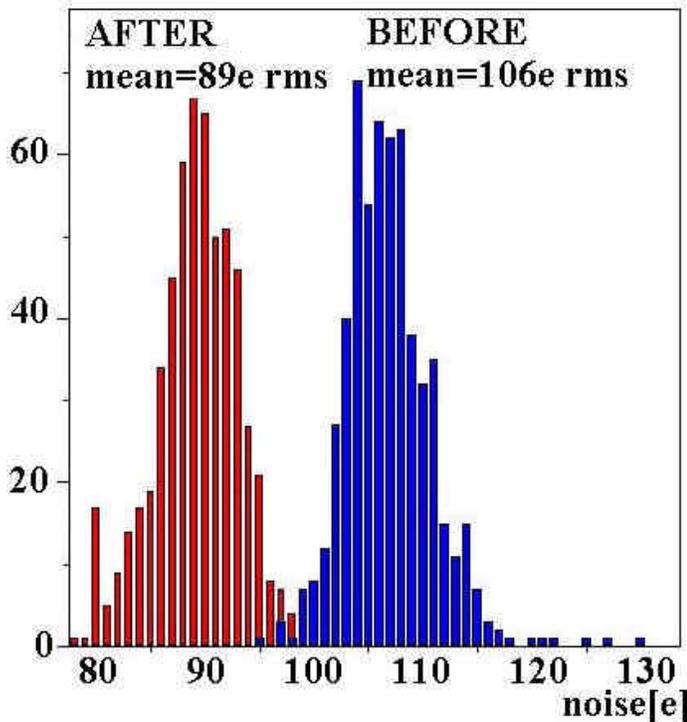
- I_{analog} decreased slightly during irradiation.
- I_{digital} increased slightly during irradiation.
- No evidence of Single Event Latch-up.

200 MeV proton irradiation :

Results: Total dose and SEGR

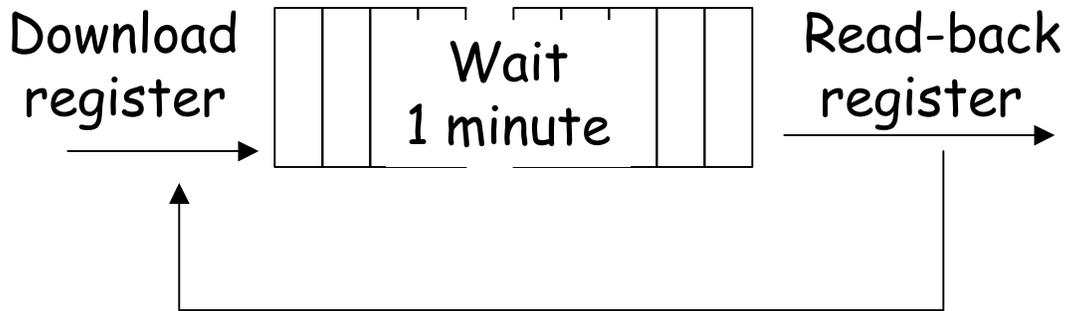
- Noise and discriminator threshold of each individual cell was measured before and after irradiation.
- For the four preFPIX2I chips (Dec. 00) all the 32rows x 18cols x 4chips = 2304 cells work after 26 Mrad proton irradiation:
 - The noise is decreased by about 10%.
 - The threshold dispersions is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

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



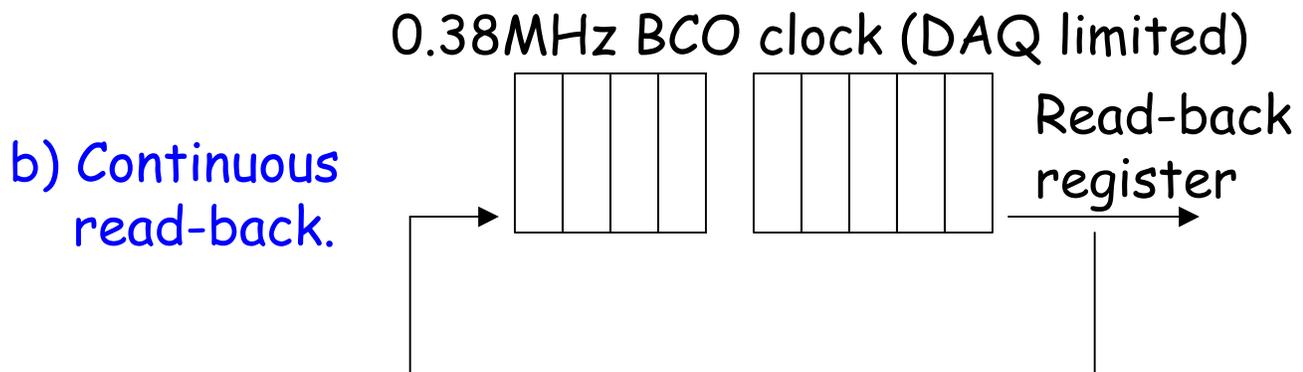
200 MeV proton irradiation : SEU testing procedure

Test 1: un-clocked registers



Test 2: clocked shift-register

a) Download pattern.



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°)	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:

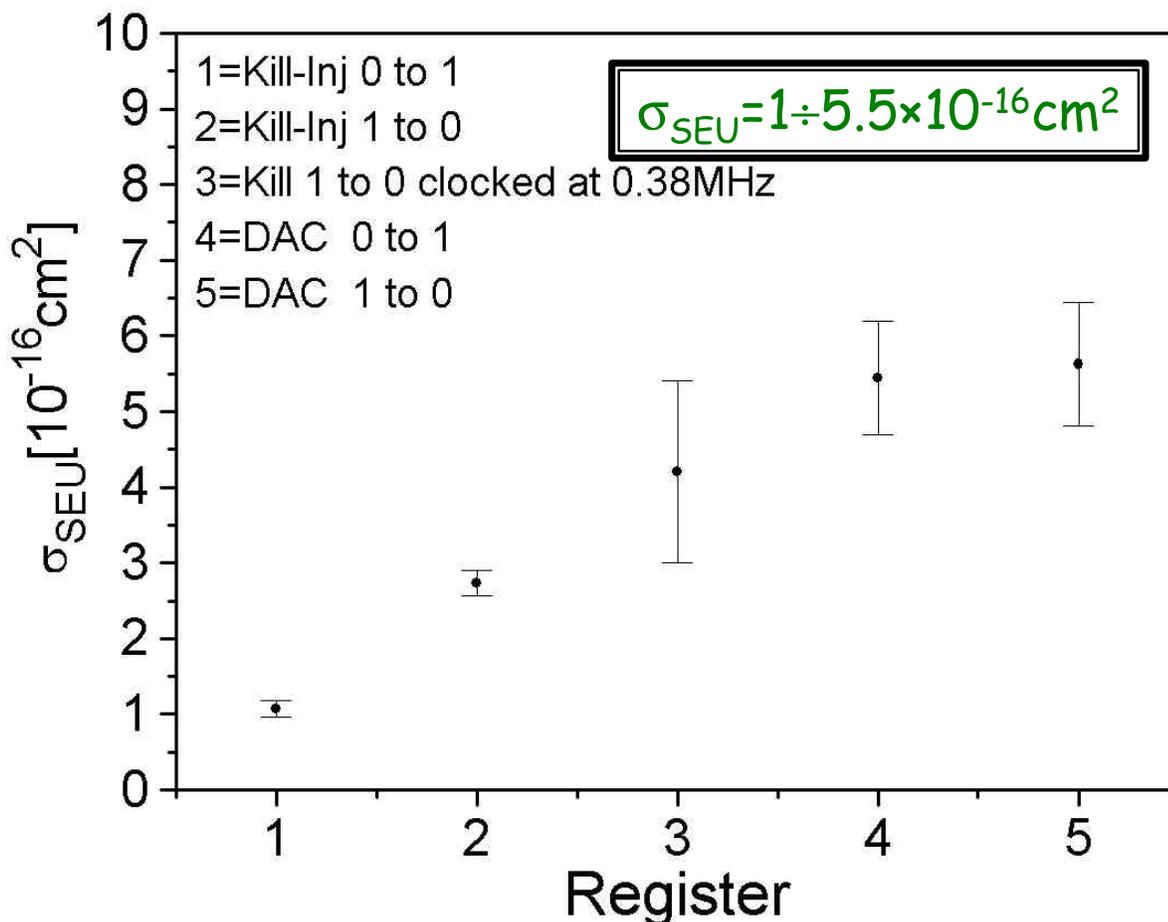
- DFF with Nor-Nor cross-coupled gates
 (expected symmetry in 0→1 and 1→0 upset rate).
- Constant pattern with equal number of 0's and 1's.

200 MeV proton irradiation : SEU cross sections

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

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

Single-bit SEU cross section in preFPIX2Tb



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:
 - » $\sigma_{SEU} = 1 \div 5.5 \times 10^{-16} \text{cm}^2$
- 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).