

# Proton irradiation at The Svedberg Laboratory

*Setup and results*

*DCS card*

*Xilinx Virtex-II Pro*

Kjetil Ullaland, Ketil Røed, Dieter Röhrich, Gerd Tröger, Matthias Richter

# Beam line configuration and monitoring at TSL

## I. GENERAL INFORMATION

**Date(s):** 07.10.04 -09.10.04

**Beam line:** B

**Project:** FA163

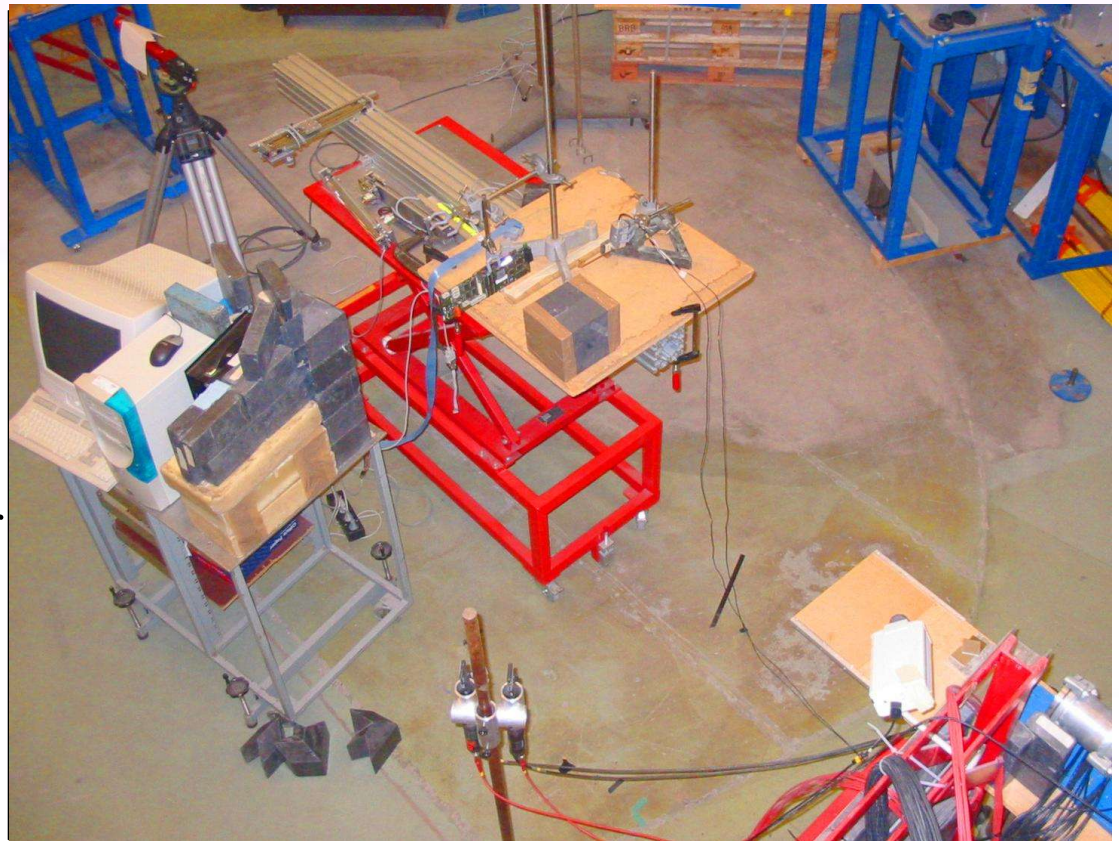
**User:** D. Röhrich, K. Røed, G. Tröger

**DUT:** Xilinx Virtex II, DCS card

**Particles delivered:** protons

**Particle energy:**

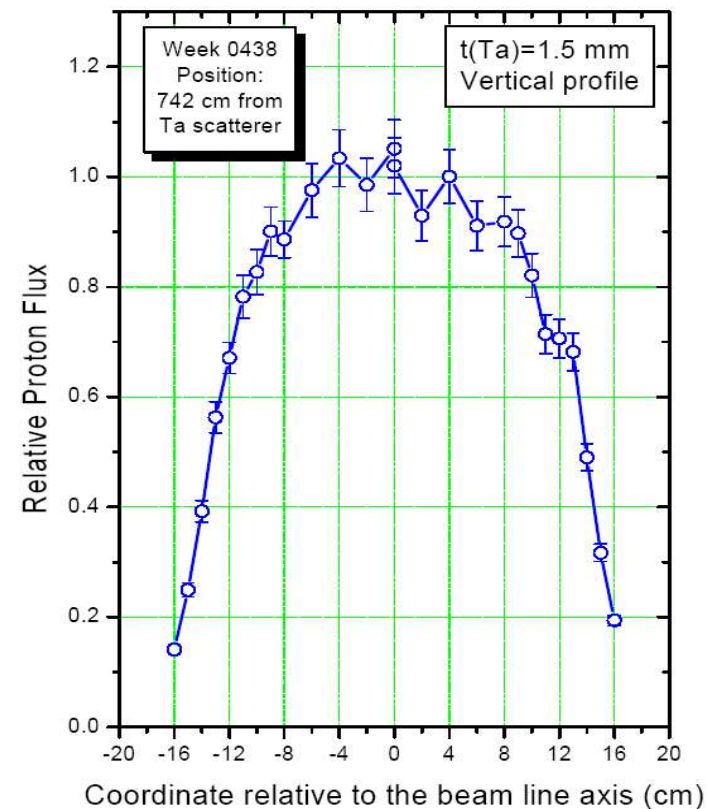
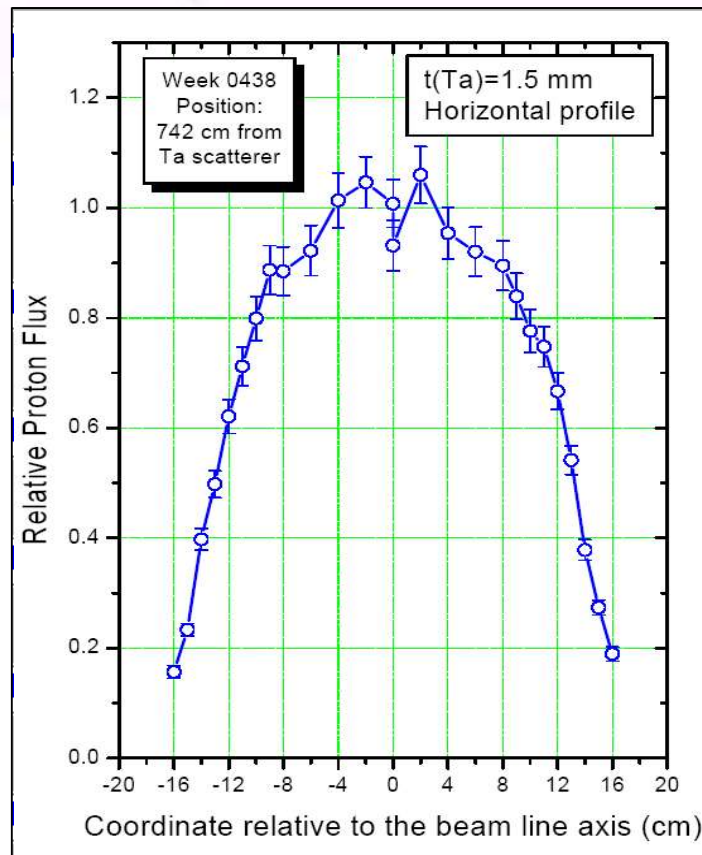
- Nominal: 180 MeV
- Measured, delivered by the cyclotron: 177.3 MeV



# Beam line configuration and monitoring

## II. Broad irradiation field

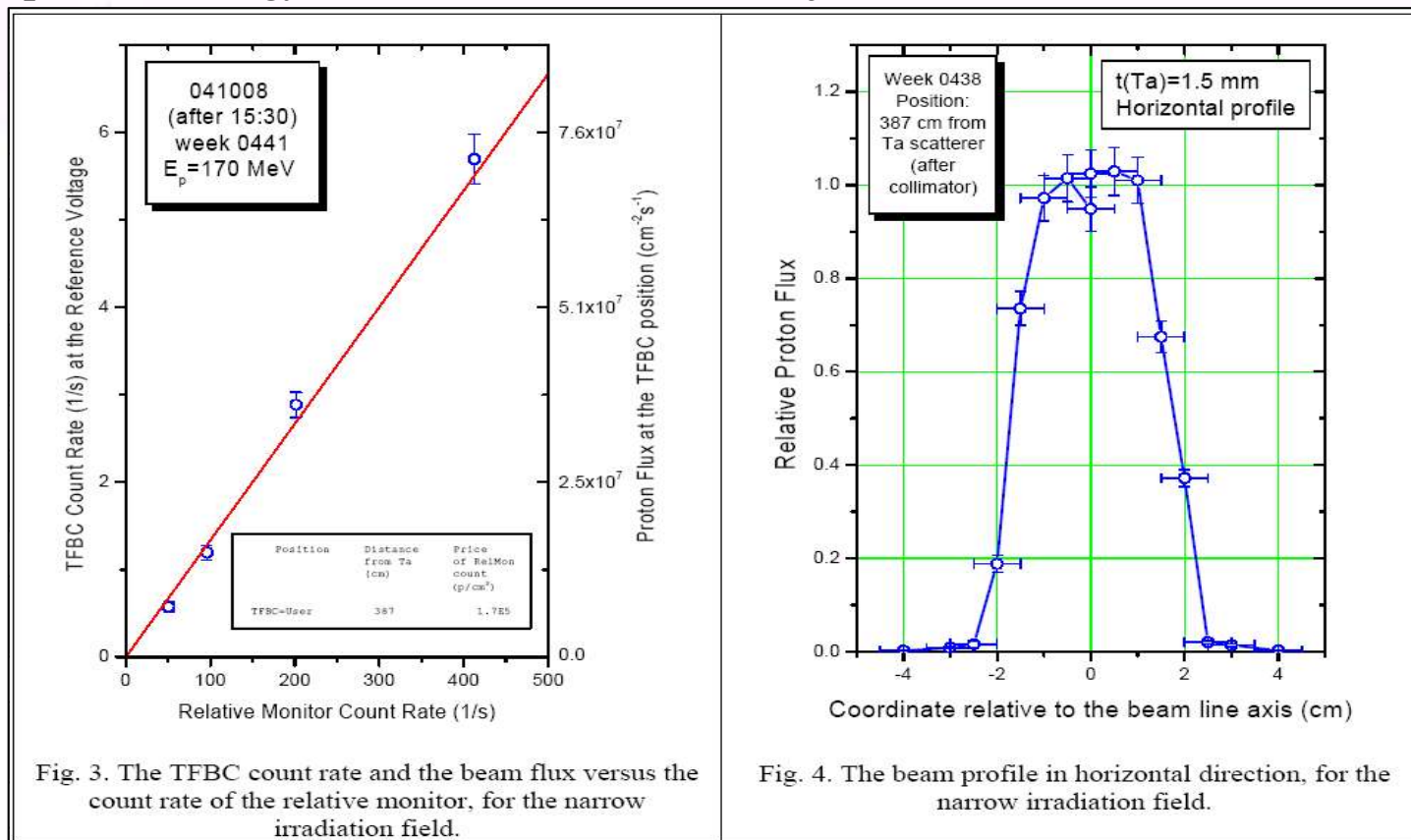
- DCS card
- Deduced particle energy on the user's irradiated object: **167.6 MeV**.



# Beam line configuration and monitoring

## III. Narrow irradiation field

- Xilinx FPGA
- Deduced particle energy on the user's irradiated object: **169.7 MeV**.



# DCS system test

## Main device: Altera Excalibur EPXA1

- ARM922T hardwired processor
- APEX 20K100E PLD
- Running linux stored in flash memory

## Test scheme:

- DCS card placed in beam line
- JTAG connection to experiment pc
- remote connection through local ethernet to control room (SSH)
- c-program running under linux (M.Richter, UiB)
- writing random data to *message buffer* and reading back for comparison

## Experienced failures

- data errors in readback of *message buffer* ~10%
- Communication loss (ethernet failure) ~70%
- Kernel related failures (linux) ~20%
- Ethernet largest design on chip

## DCS irradiation results

*Total fluence =  $2.09 \cdot 10^{10}$  protons / cm<sup>2</sup>*

*Dose = 15 Gy (for 168 MeV protons) = (1.2 – 2.6) \* 10 ALICE years*

Dcs board fully functional, LINUX + memory test ran stable for 3 hours after the end of the irradiation.

### SEFI rate

MTBF (mean time until first error) : 316 sec at a flux =  $1.5 \cdot 10^6$  protons / cm<sup>2</sup> s

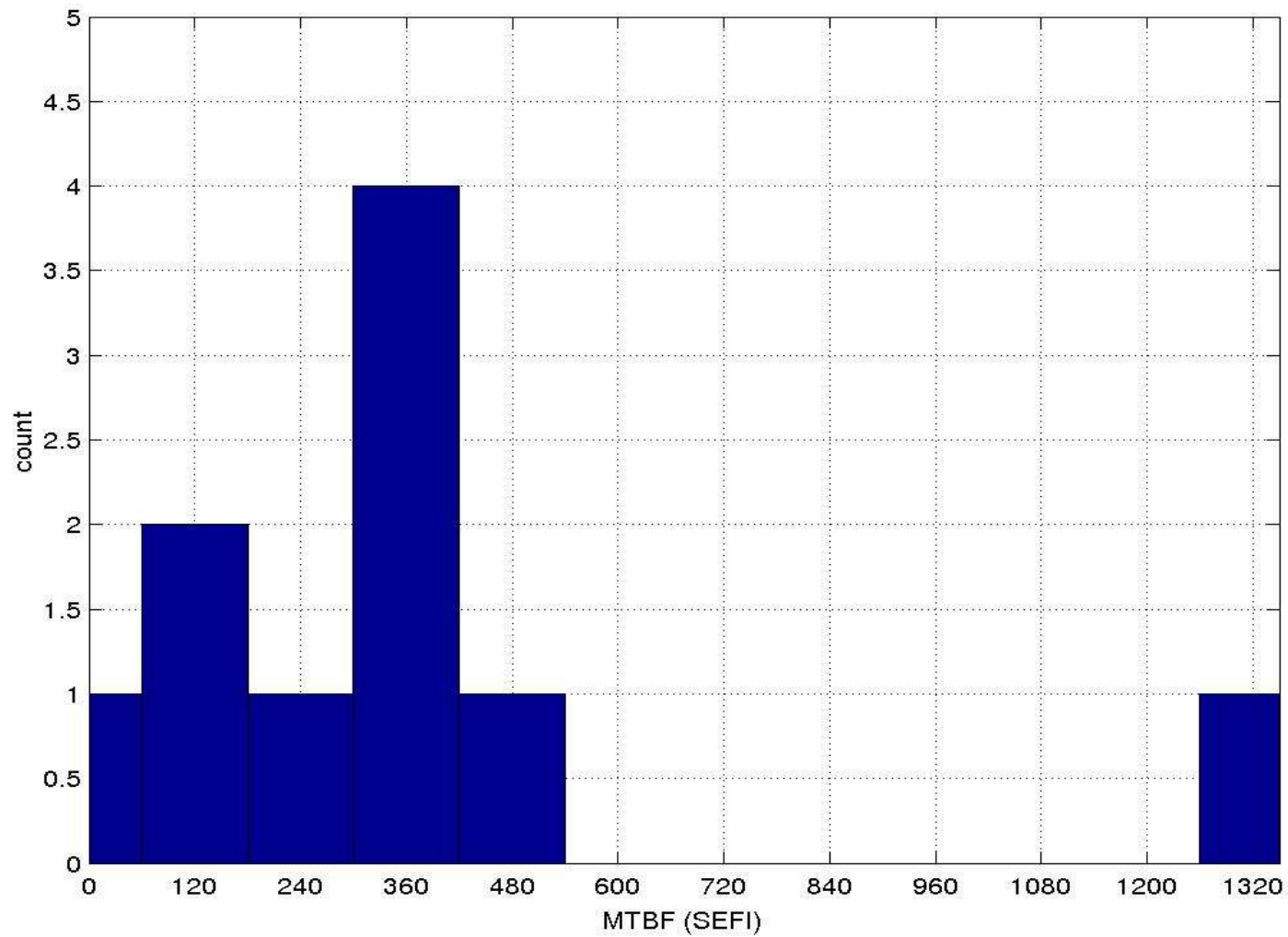
MTBF per board (inner TPC sector) = 167 – 343 hours ([x1-x2] uncertainty in simulation)

MTBF per TPC (worst case) = 0.8 – 1.6 hours

MTBF per board (TRD) = 1200 hours

Results are consistent with our error rate estimates based on the irradiation results of the components

# Time between SEFIs for the DCS board



# Xilinx FPGA

## **DUT: Xilinx Virtex II Pro XC2VP7**

- Main controlling device on the RCU card (XC2VP4)
- Contains a Power PC: hardwired processor – not in use

## **Test scheme (G. Tröger, KIP):**

- Xilinx FPGA test card placed in beam line
- remote connection through local ethernet (telnet)
- Pushing a know bit pattern of data through a shiftregister design
- Serial communication (VHDL)

## **Experienced failures**

- Data pattern error
- Communication loss (seldom, small design)



# Xilinx FPGA irradiation results

**DUT: Xilinx Virtex II Pro XC2VP4**

**UPPSALA @ 180 MeV**

## Design

shiftreg, no scrub, no ecc

$$2.8 \cdot 10^{-9} \text{ cm}^2$$

## SEU CS

$$4.5 \cdot 10^{-8} \text{ cm}^2$$

shiftreg, with scrub, no ecc

$$3.4 \cdot 10^{-9} \text{ cm}^2$$

$$6.3 \cdot 10^{-8} \text{ cm}^2$$

shiftreg, with scrub, bch38

$$5.1 \cdot 10^{-10} \text{ cm}^2$$

$$6.6 \cdot 10^{-8} \text{ cm}^2$$

**OSLO @ 29 MeV**

## Design

shiftreg, no scrub, no ecc

$$9.4 \cdot 10^{-9} \text{ cm}^2$$

$$2.4 \cdot 10^{-7} \text{ cm}^2$$

shiftreg, with scrub, no ecc

$$1.0 \cdot 10^{-8} \text{ cm}^2$$

$$1.5 \cdot 10^{-7} \text{ cm}^2$$

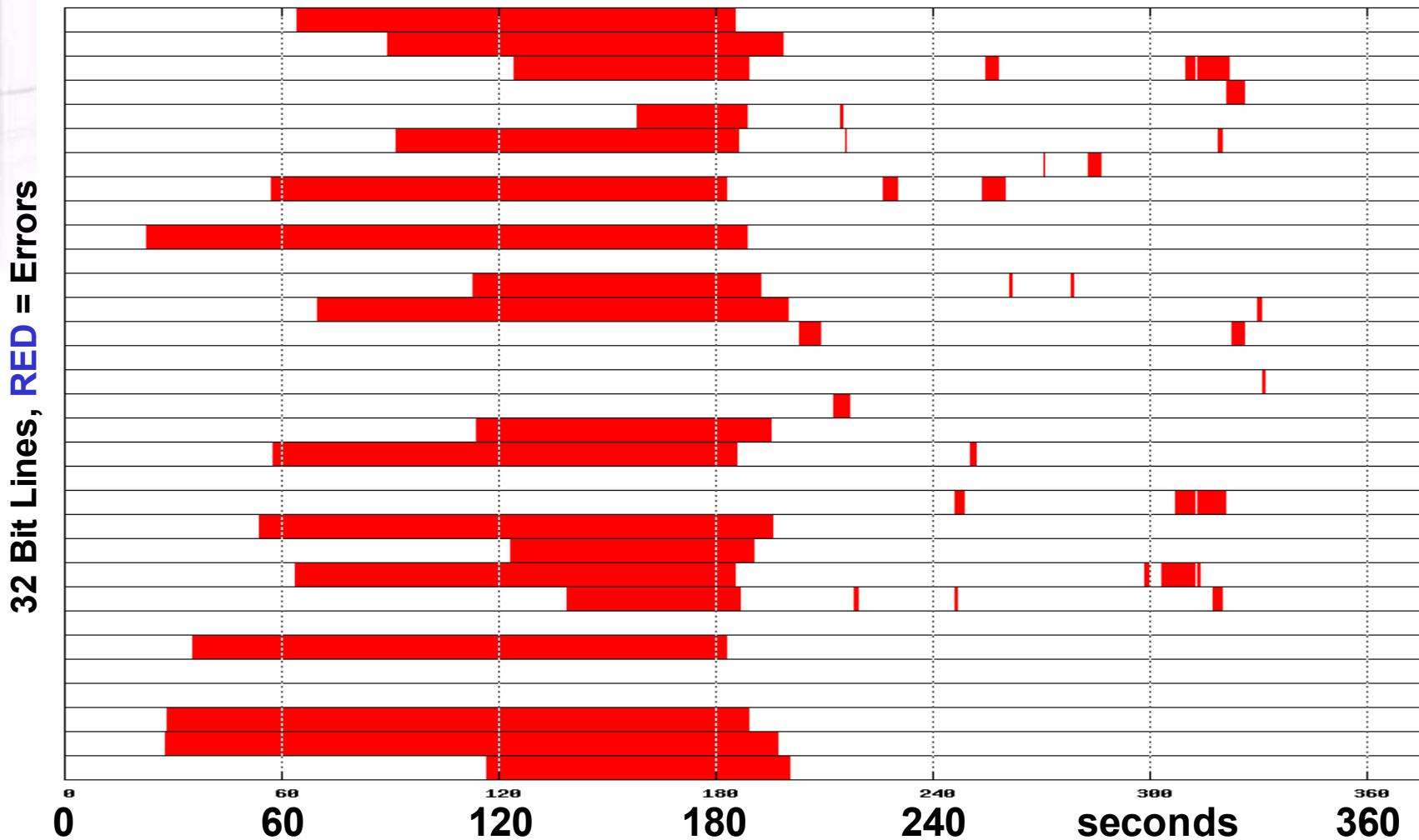
shiftreg, with scrub, bch38

$$1.1 \cdot 10^{-9} \text{ cm}^2$$

$$1.8 \cdot 10^{-7} \text{ cm}^2$$

**Altera APEX 20K400E SEFI @ 180 MeV:  $6.0 \cdot 10^{-9} \text{ cm}^2$**

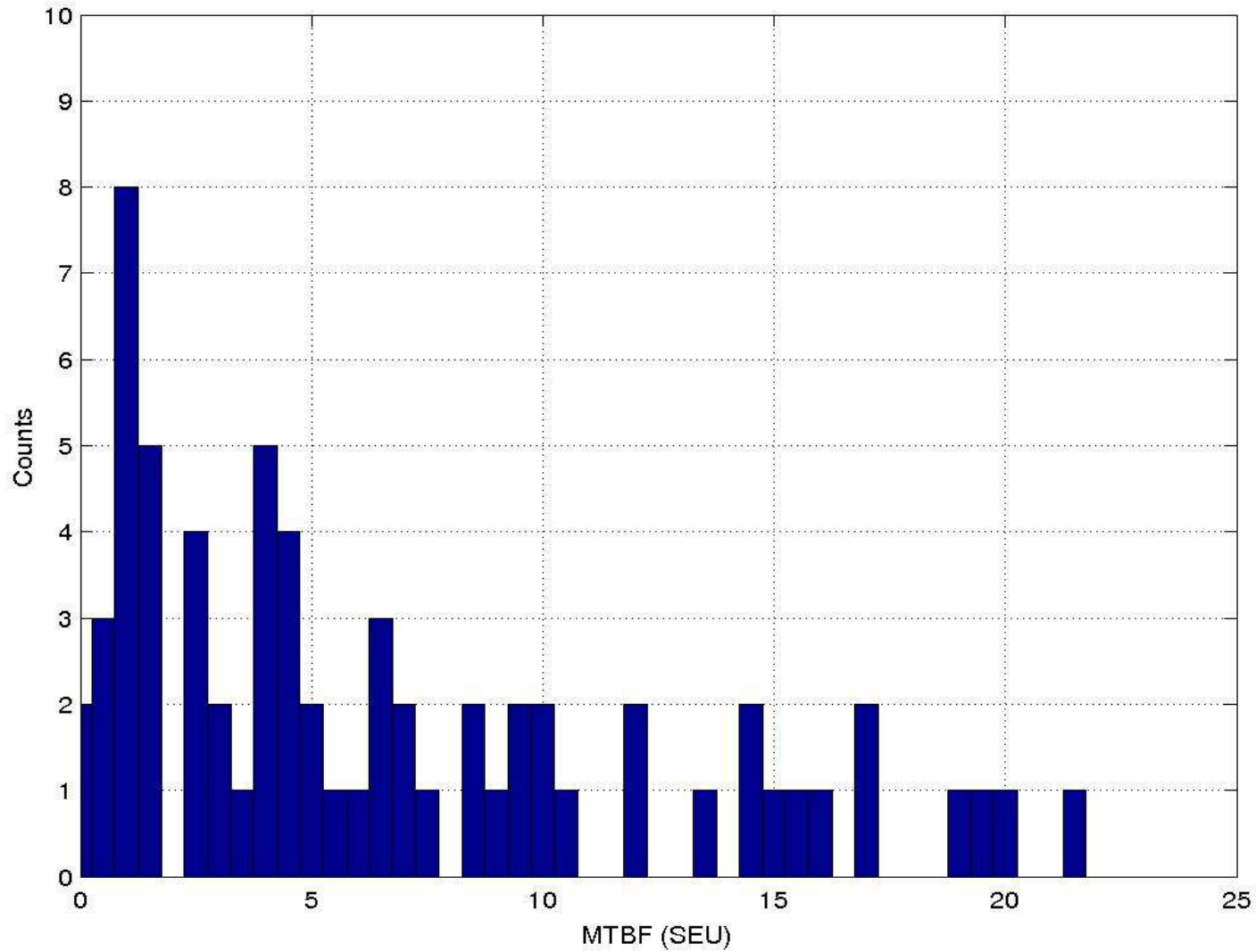
Plain Shift Register (flux  $\sim 1.5 \cdot 10^7$  protons/cm<sup>2</sup>s)  
 scrubbing started after ca. 180 sec.



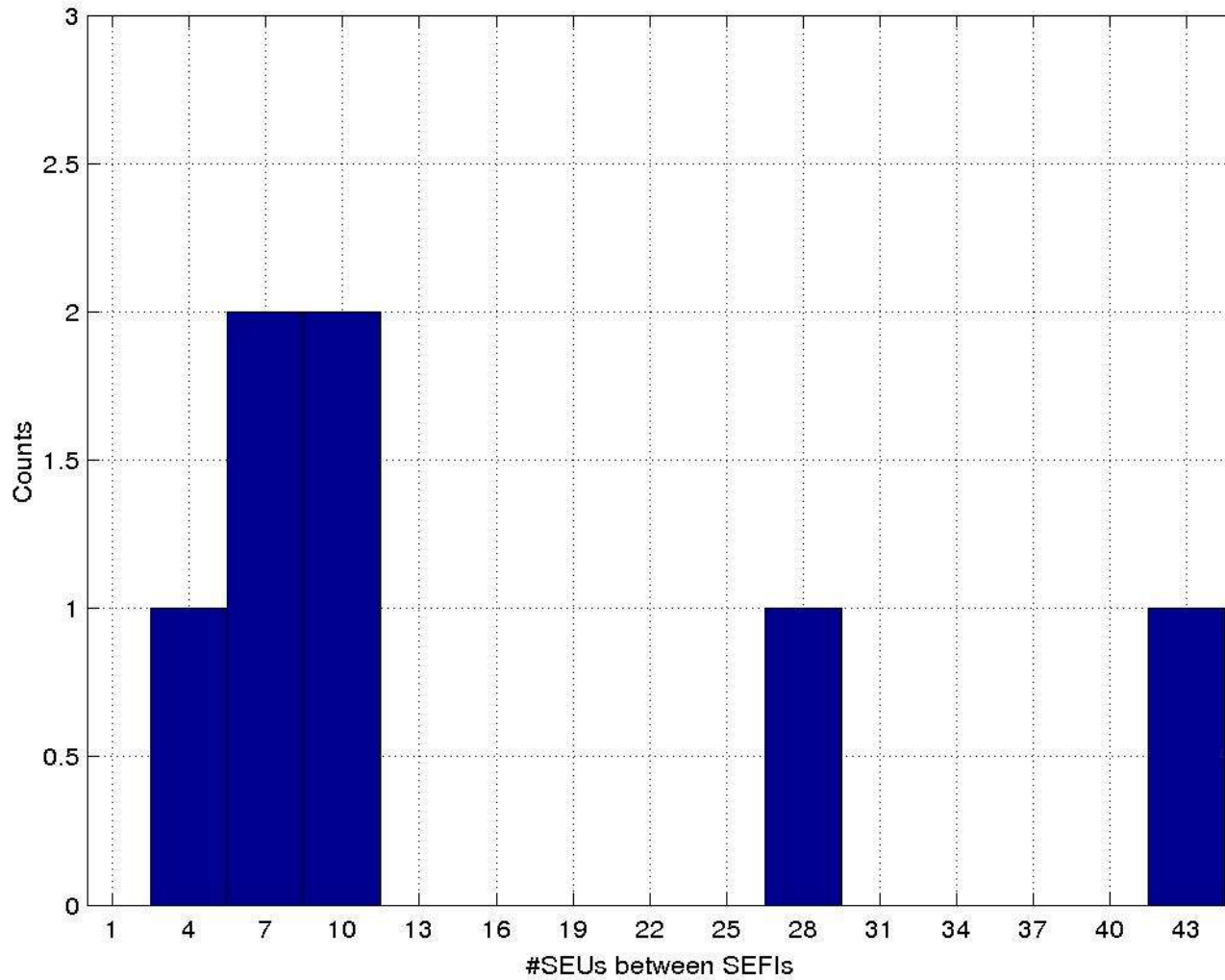
Gerd Tröger (www.ti.uni-hd.de, www.ti-leipzig.de) 14 Jan 2005



# Time between SEUs for the Xilinx FPGA



# Number of SEUs between SEFIs for the Xilinx FPGA



# Summary

- Xilinx FPGA cross-section in the order of the Altera APEX FPGA
- Xilinx offer active partial reconfiguration & configuration SRAM readback
- Thus able to repair SEU & SEFI failures
- Increasing scrubbing speed will reduce the no. of SEFI to an accepted level
- Possible cumulative effect (SEFIs)
- Final irradiation test of complete readout-chain under normal data taking conditions. Parasitic neutron beam at TSL (March 2005)

