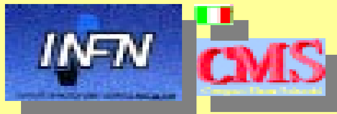
CMS Barrel Drift Tubes

Neutron Irradiation Tests of Chamber Electronics

Experimental setup and test results

S. Agosteo, L.Castellani, I. Lippi, R. Martinelli, P. Zotto



CMS Neutron Environment

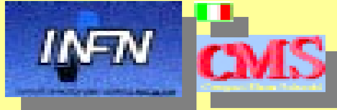
Neutron fluxes in the CMS area

1200
1000
800
600
400
200
0

0 500 1000 1500 2000 2500

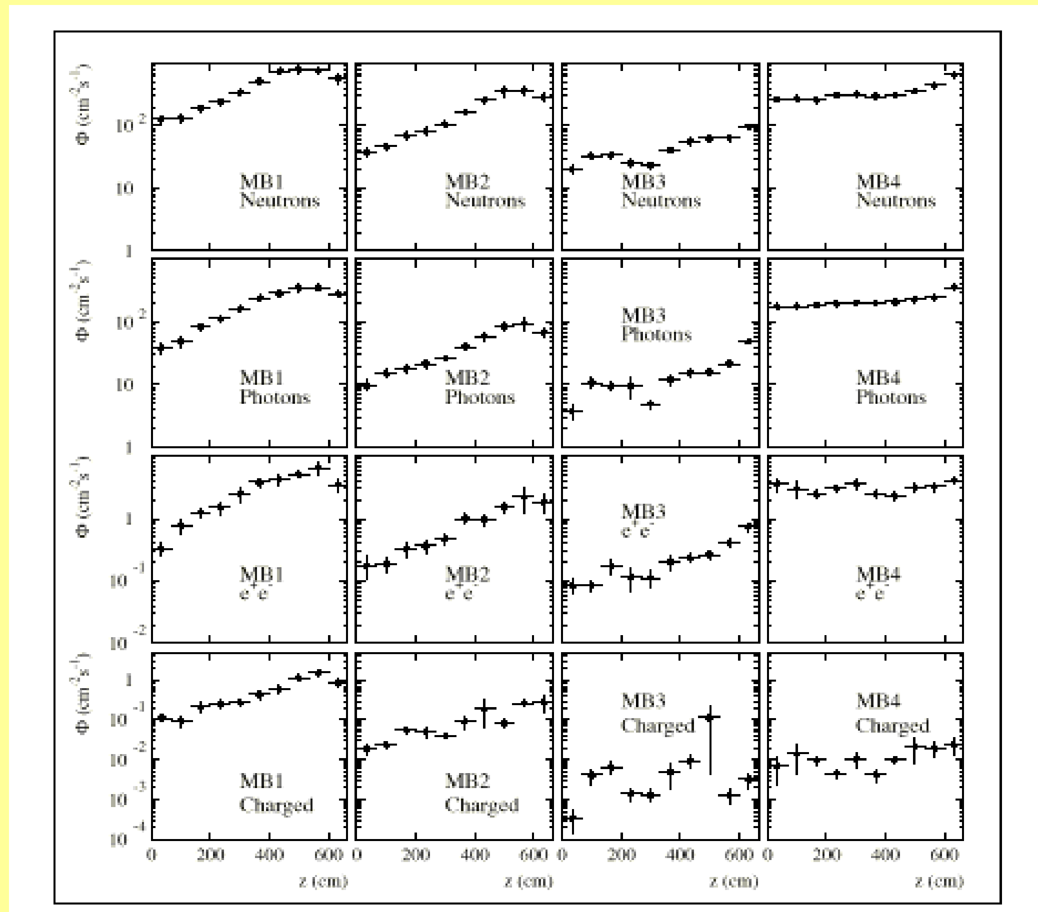
7.4E+09 1.0E+07 1.0E+06 1.0E+05 1.0E+04 1.0E+03 1.0E+02 1.0E+01 n/cm^2/s

LHC luminosity = 10^{34} cm^{-2} s^{-1}

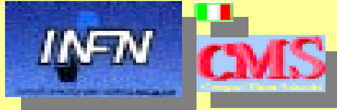


CMS Neutron Environment

Neutron fluxes in the barrel muon chambers

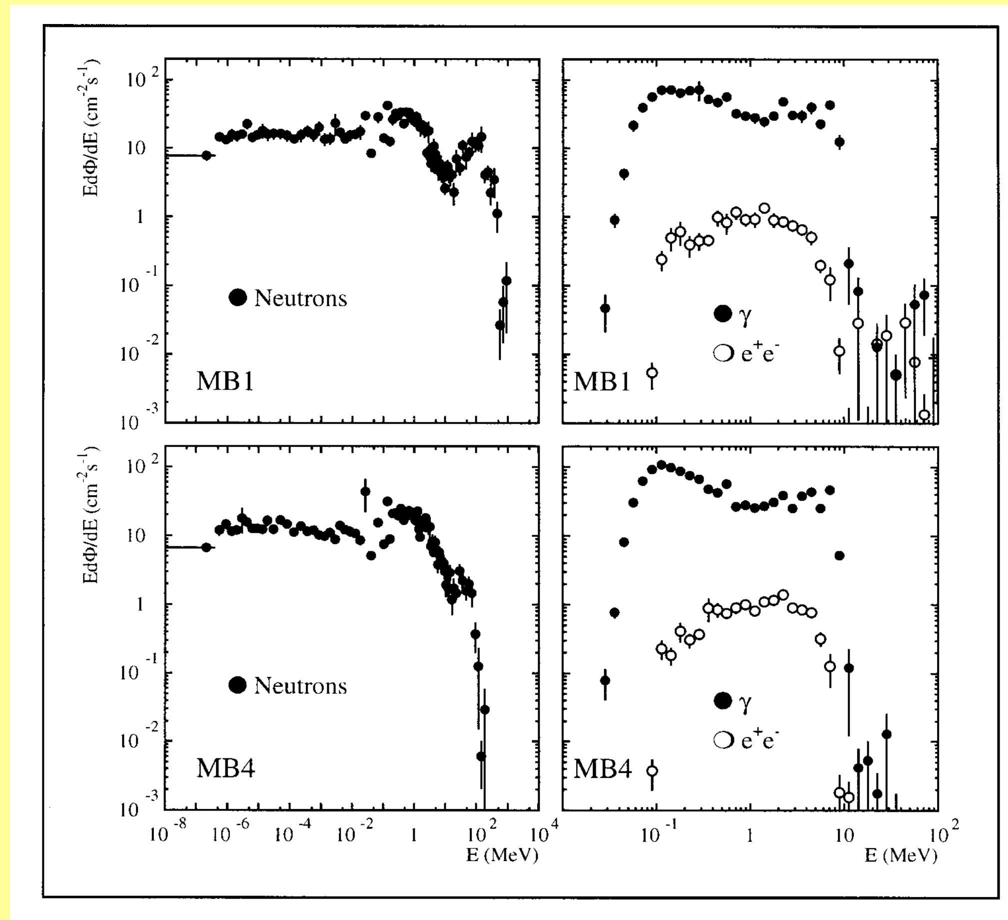


LHC luminosity = 10^{34} cm^{-2} s^{-1}

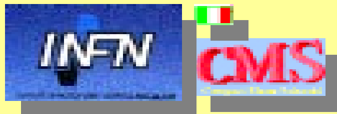


CMS Neutron Environment

Particle spectra in the barrel muon chambers

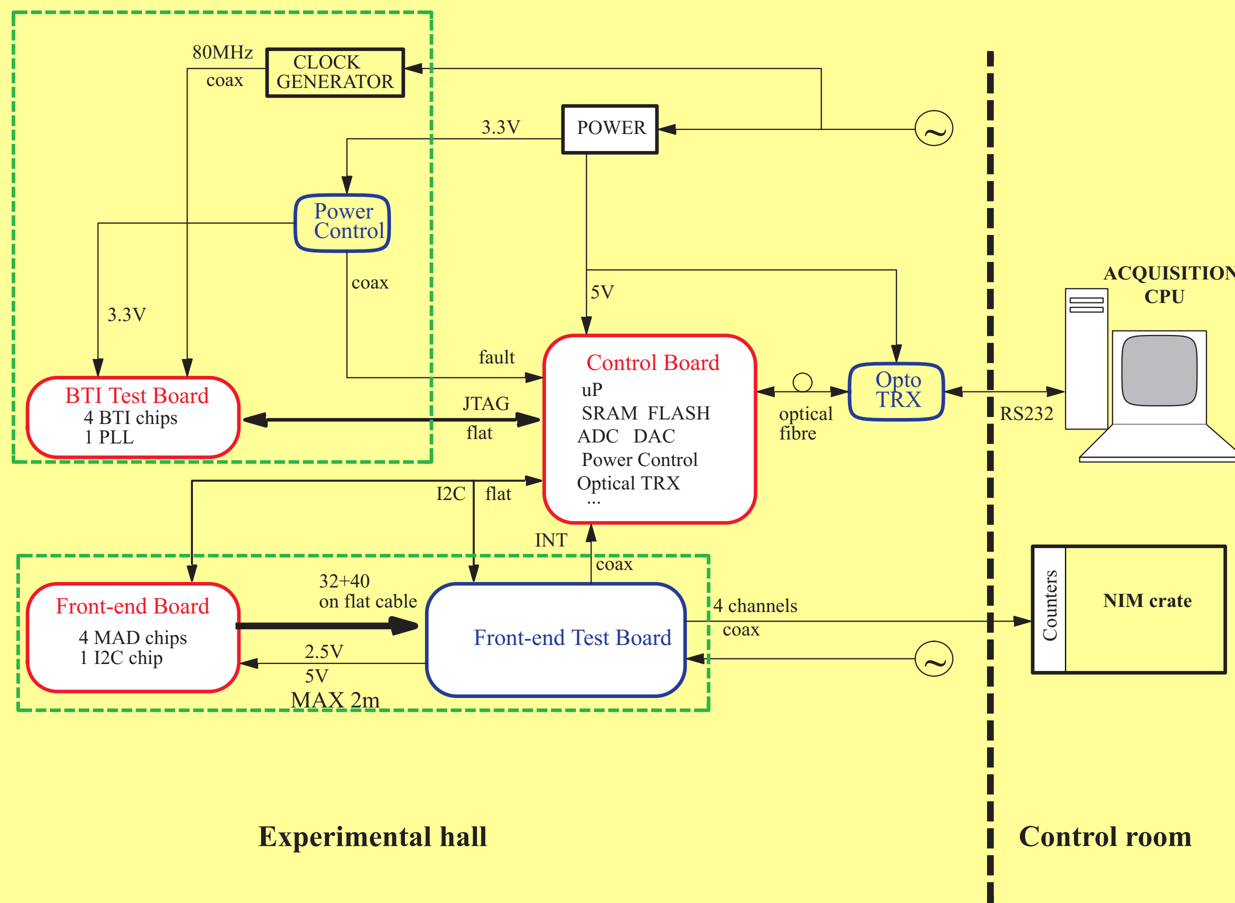


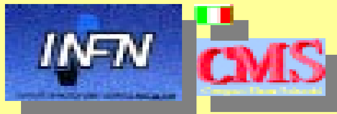
LHC luminosity = 10^{34} cm^{-2} s^{-1}



Neutron Irradiation Test 1999

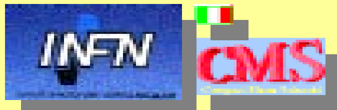
Acquisition setup for SEE characterization





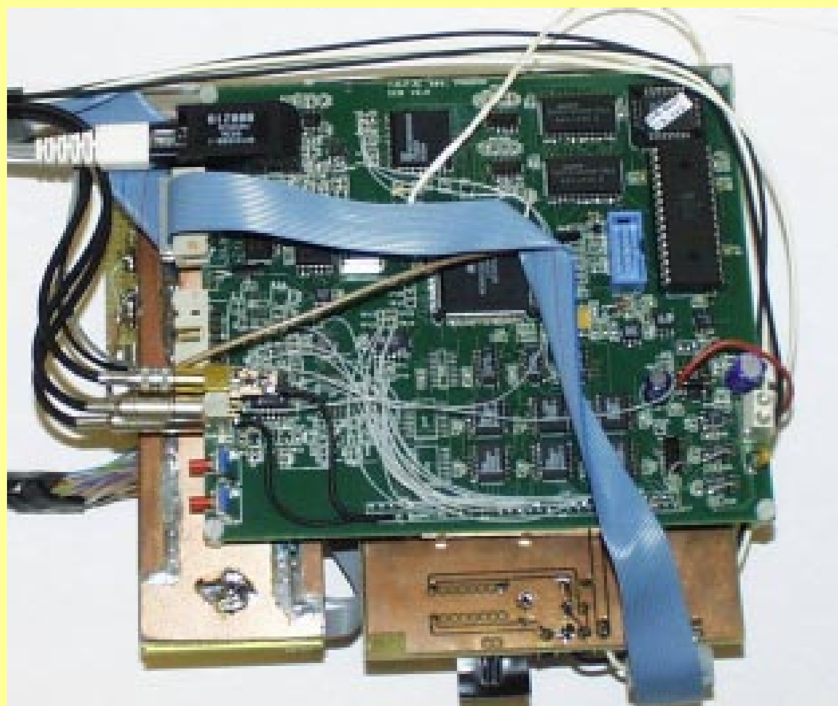
Neutron Irradiation Test 06/99

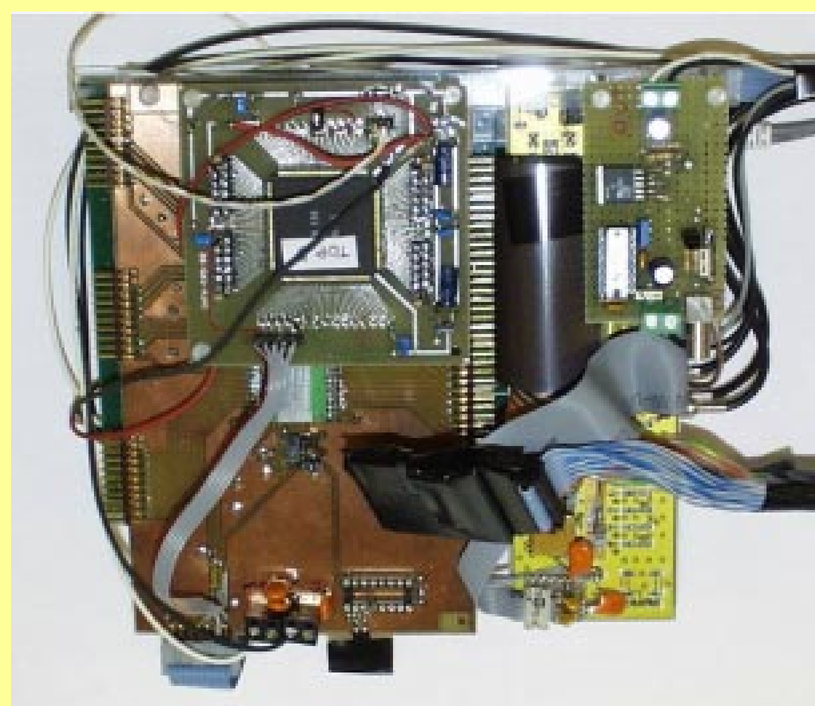
DAQ Setup

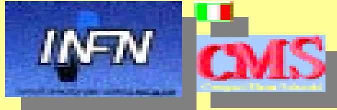


Neutron Irradiation Test 06/99

Thermal neutron irradiation DUT



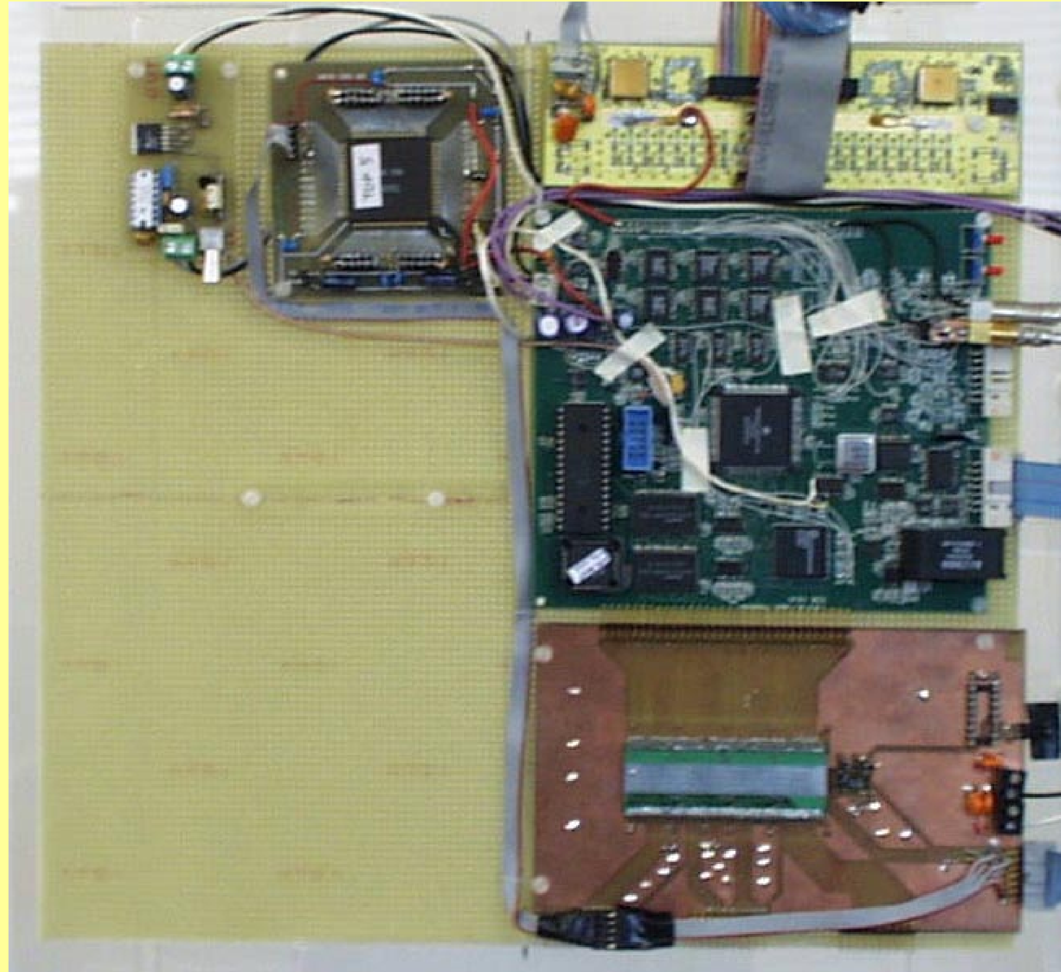




CMS

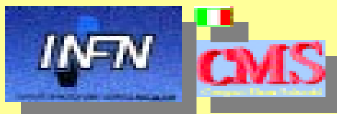
Neutron Irradiation Test 06/99

Fast neutron irradiation DUT



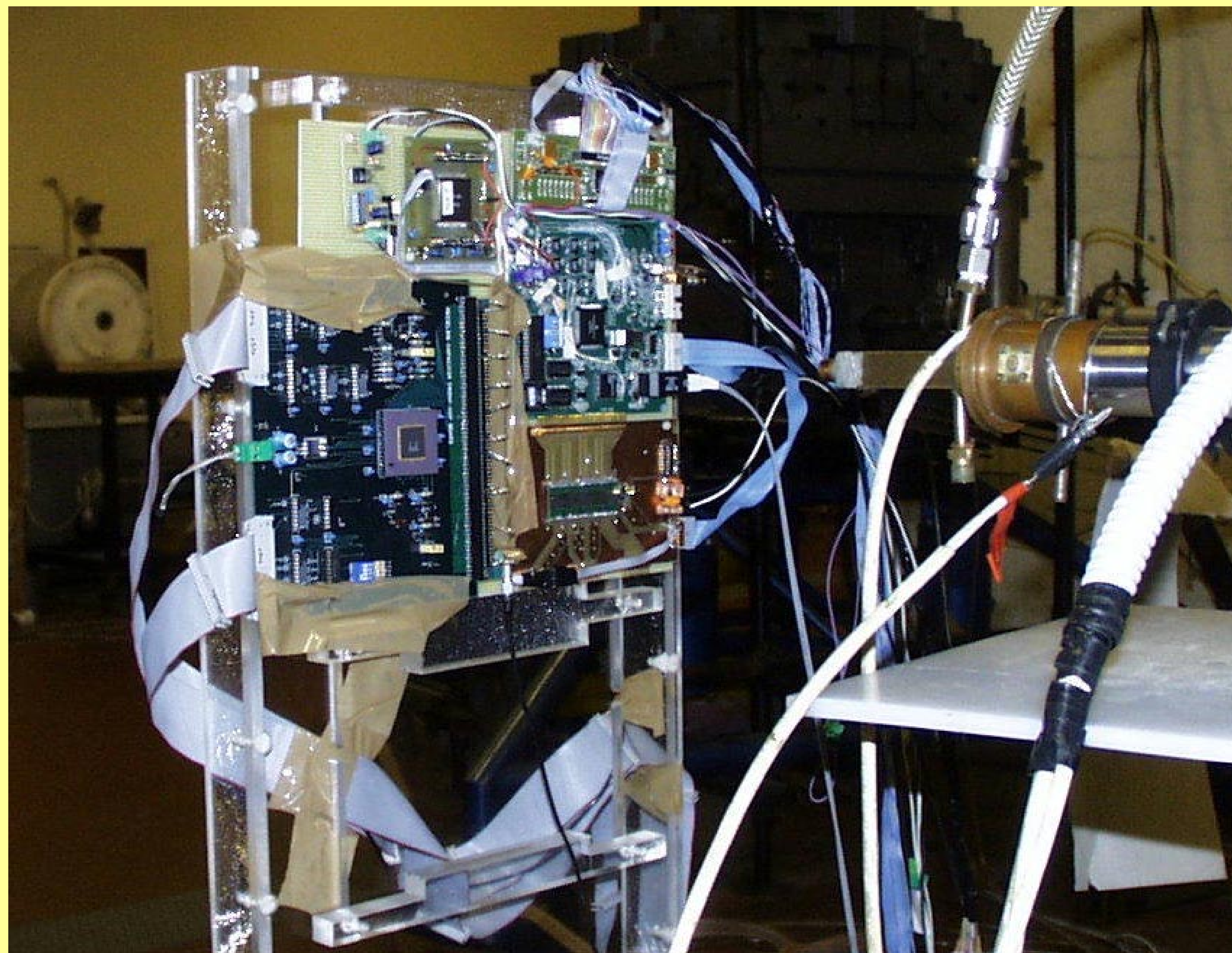
Neutron Irradiation Test 06/99

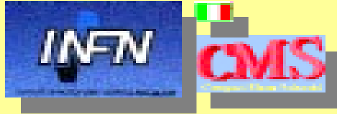
Thermal neutrons experimental setup



Neutron Irradiation Test 06/99

Fast neutrons experimental setup





Neutron Irradiation Test 06/99

Thermal neutron spectrum

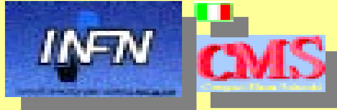
Neutron fluence per deuteron current unit (cm^{-2} s^{-1} MeV^{-1} μA^{-1})

10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}

■ Neutron fluence in the irradiation cavity
(calculated @ 7 MeV deuteron energy)

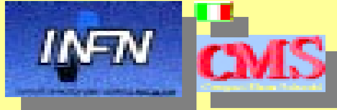
1E-7 1E-6 1E-5 1E-4 1E-3 0,01 0,1 1 10

Energy (MeV)



Neutron Irradiation Test 06/99

Thermal neutron fluence in irradiation cavity



Neutron Irradiation Test 06/99

Epithermal neutron fluence in irradiation cavity

□ TOPx10^2 <φ>=1.96×10^5

■ CENTREx10 <φ>=2.24×10^5

○ BOTTOM <φ>=2.62×10^5

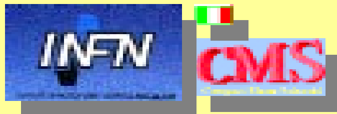
Deuteron energy=6.5 MeV

(0.4 eV - 10 keV) fluence rate per deuteron current unit (cm^{-2} s^{-1} μA^{-1})

10^8 10^7 10^6 10^5

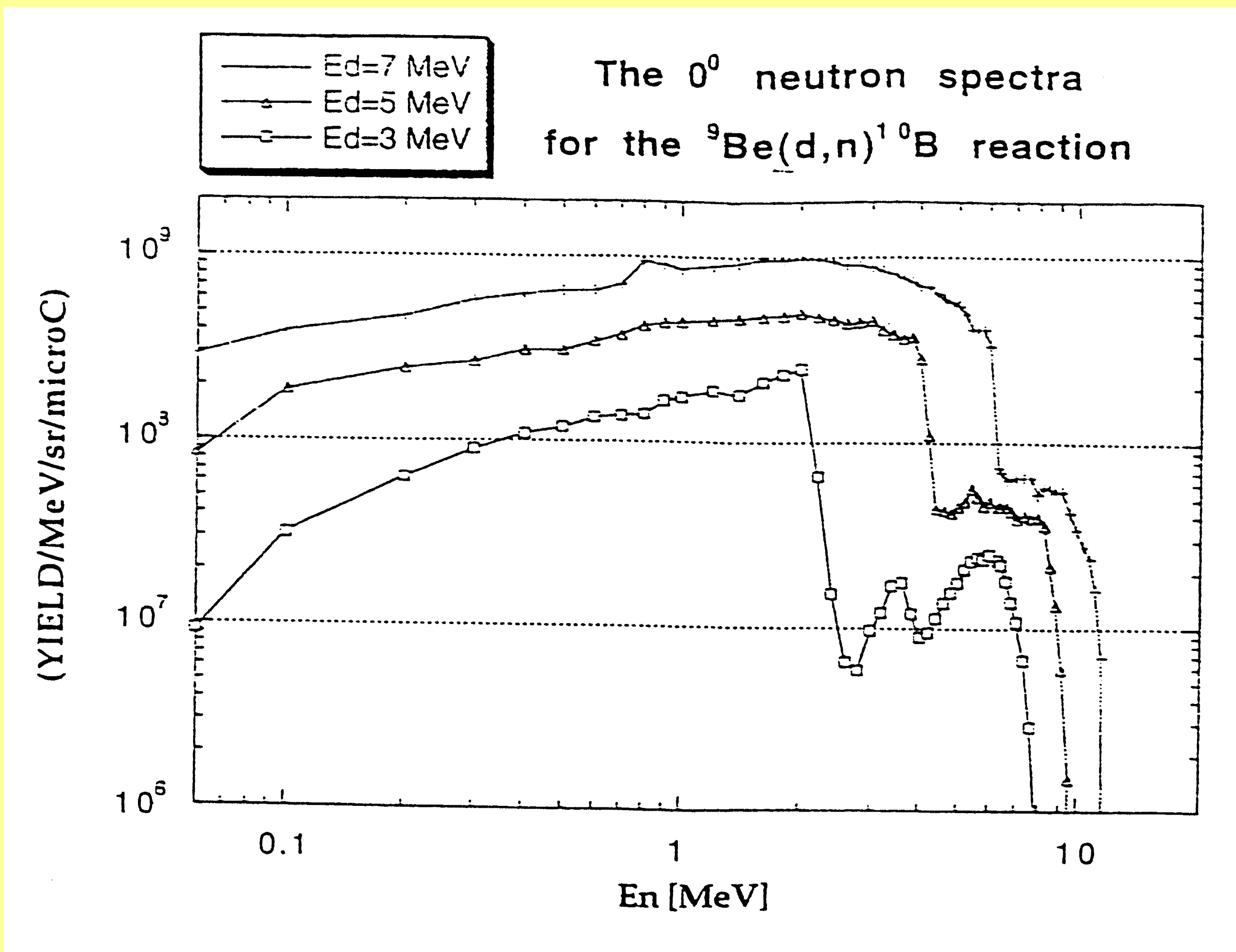
0 2 4 6 8 10 12 14 16

Position number



Neutron Irradiation Test 06/99

Fast neutrons spectra



Neutron Irradiation Tests

L. Castellani, I.Lippi, R.Martinelli, P.Zotto

INFN Padova

Reaction $^{9}Be + d \rightarrow {}^{10}B + n$ (d @ 6.5MeV)

Thermal neutrons obtained using a heavy water moderator and a graphite reflector.

Expected neutron rate at CMS is 1000 ($n/cm^2 s^{-1}$) of which 50% is thermal and 50% is fast neutrons.

Tested components

Component	**Productor / Type / Year**
LD Regulator	MICREL / 29501-3.3BU / 1997
µP	MOTOROLA / MC68HC16 / 1994
FLASH	ATMEL / AT29C101A-12PC / 1996
SRAM#1	SONY / CXK581000AM-70LL / 1993
SRAM#2	SONY / CXK581000AM-70LL / 1993
EPROM	ATMEL / AT27C512R-15JC / 1995
Optical transceiver	HONEYWELL/ HFM2600-1 / 1998
ASIC TSS	ES2 0.7 µm / TOP5 ceramic package / 1997
BTI	ATMEL 0.5 µm / LTCC substrate & in dies /1997
MAD	AMS 0.8 µm / BCMOS / 1997

Results with thermal neutrons

Component	Total rate n/cm^2	Device SEU probability SEU/(n*cm^2)	**Mean time between failures in the full detector** hh:mm
LD Regulator	$3.54*10^{10}$	< $2.68*10^{-10}$	> 33:09
µP	$3.54*10^{10}$	< $2.68*10^{-10}$	> 198:51
FLASH	$3.54*10^{10}$	< $2.68*10^{-10}$	> 198:51
SRAM#1	$3.54*10^{10}$	$1.35*10^{-9}$	19:49
SRAM#2	$3.54*10^{10}$	< $2.68*10^{-10}$	> 99:25
EPROM	$3.54*10^{10}$	< $2.68*10^{-10}$	> 198:51
Optical transceiver	$3.54*10^{10}$	< $2.68*10^{-10}$	> 198:51
ASIC TSS	$2.36*10^{10}$	< $2.68*10^{-10}$	> 16:42
BTI	$2.36*10^{10}$	< $2.68*10^{-10}$	> 00:59
MAD	$9.10*10^{9}$	See dedicated slides	

Confidence level is 90%

Particular events

One LD regulator SEU happened after $7*10^9$ n/cm^2 integrated flux

Assuming they were due to a true LD regulator fault we should have

SEU probability $2.82*10^{-11}$ SEU/(n*cm^2)

Mean Time Between Failures 314:40 hh:mm

Results with fast neutrons

Component	Total rate n/cm^2	Device SEU probability SEU/(n*cm^2)	**Mean time between failures in the full detector** hh:mm
LD Regulator	$1.27*10^{12}$	$< 7.50*10^{-12}$	$>$ 1185:34
µP	$1.27*10^{12}$	$< 7.48*10^{-12}$	$>$ 7128:16
FLASH	$1.21*10^{12}$	$< 7.83*10^{-12}$	$>$ 6811:20
SRAM#1	$7.49*10^{11}$	$2.82*10^{-10}$	94:29
SRAM#2	$1.52*10^{12}$	$1.75*10^{-12}$	19019:27
EPROM	$1.10*10^{12}$	$< 8.59*10^{-12}$	$>$ 6206:52
Optical transceiver	$1.24*10^{12}$	$< 7.65*10^{-12}$	$>$ 6970:36
ASIC TSS	$1.87*10^{12}$	$< 5.06*10^{-12}$	$>$ 866:42
BTI	$1.35*10^{12}$	$< 7.03*10^{-12}$	$>$ 37:56
MAD	$6.30*10^{10}$	see dedicated slides	

Confidence level is 90%

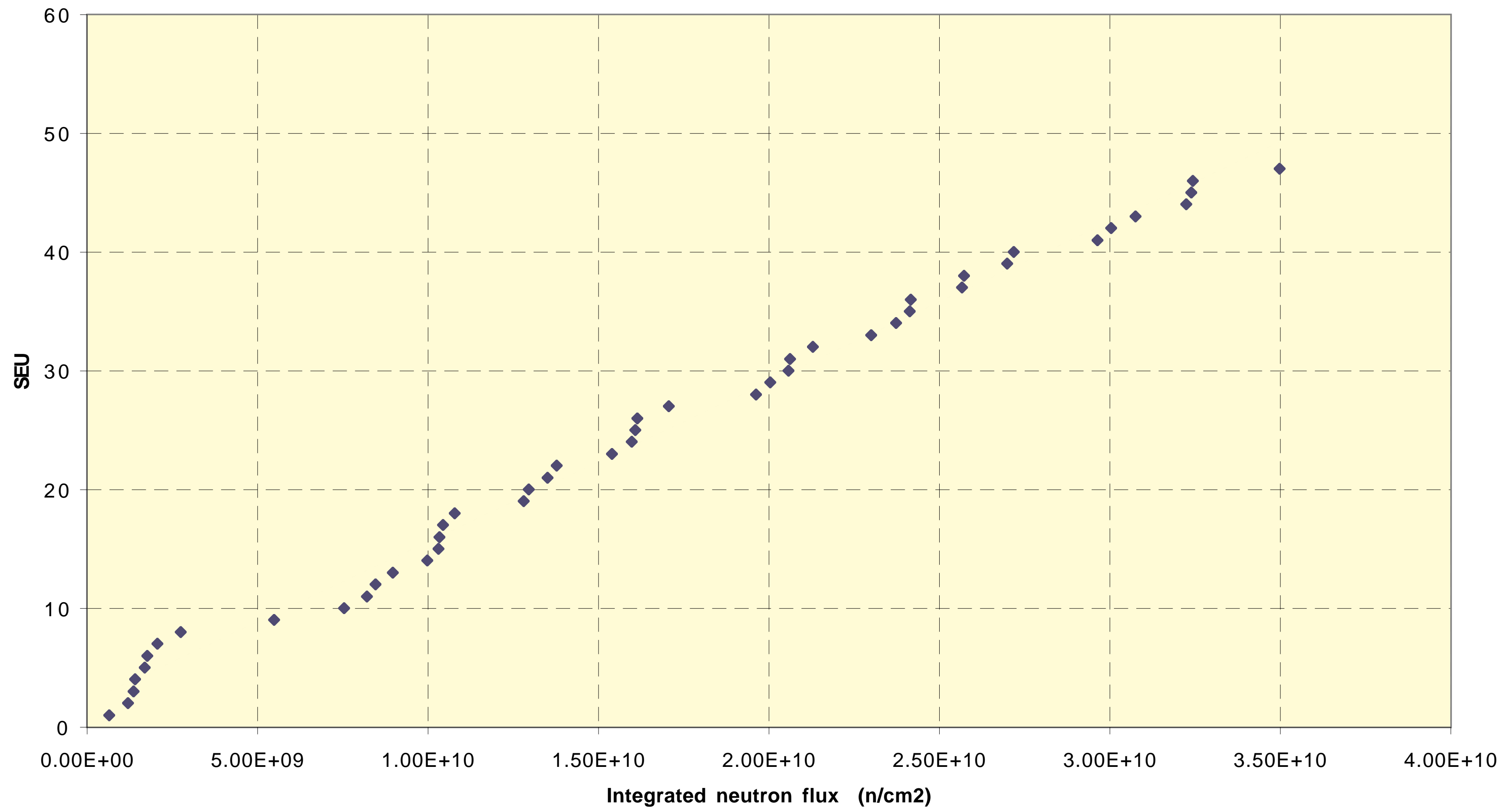
Particular events

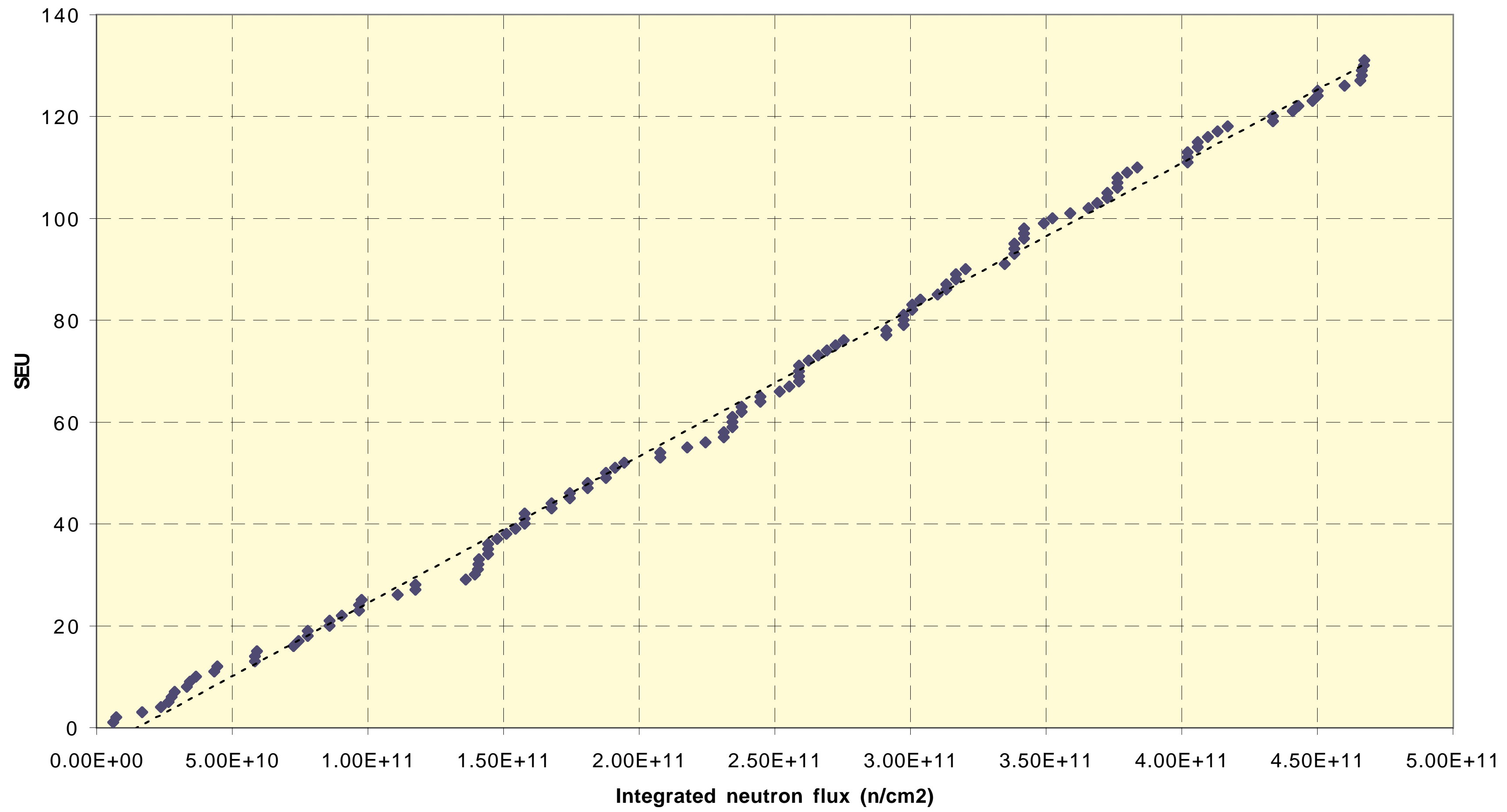
Two microprocessor reboot happened

We could not uniquely identify the problem (program corrupted in RAM, I/O lines upset,…). Assuming they were due to a true microprocessor fault we should have

SEU probability	$1.07*10^{-12}$ SEU/(n*cm^2)
Mean Time Between Failures	12498:30 hh:mm

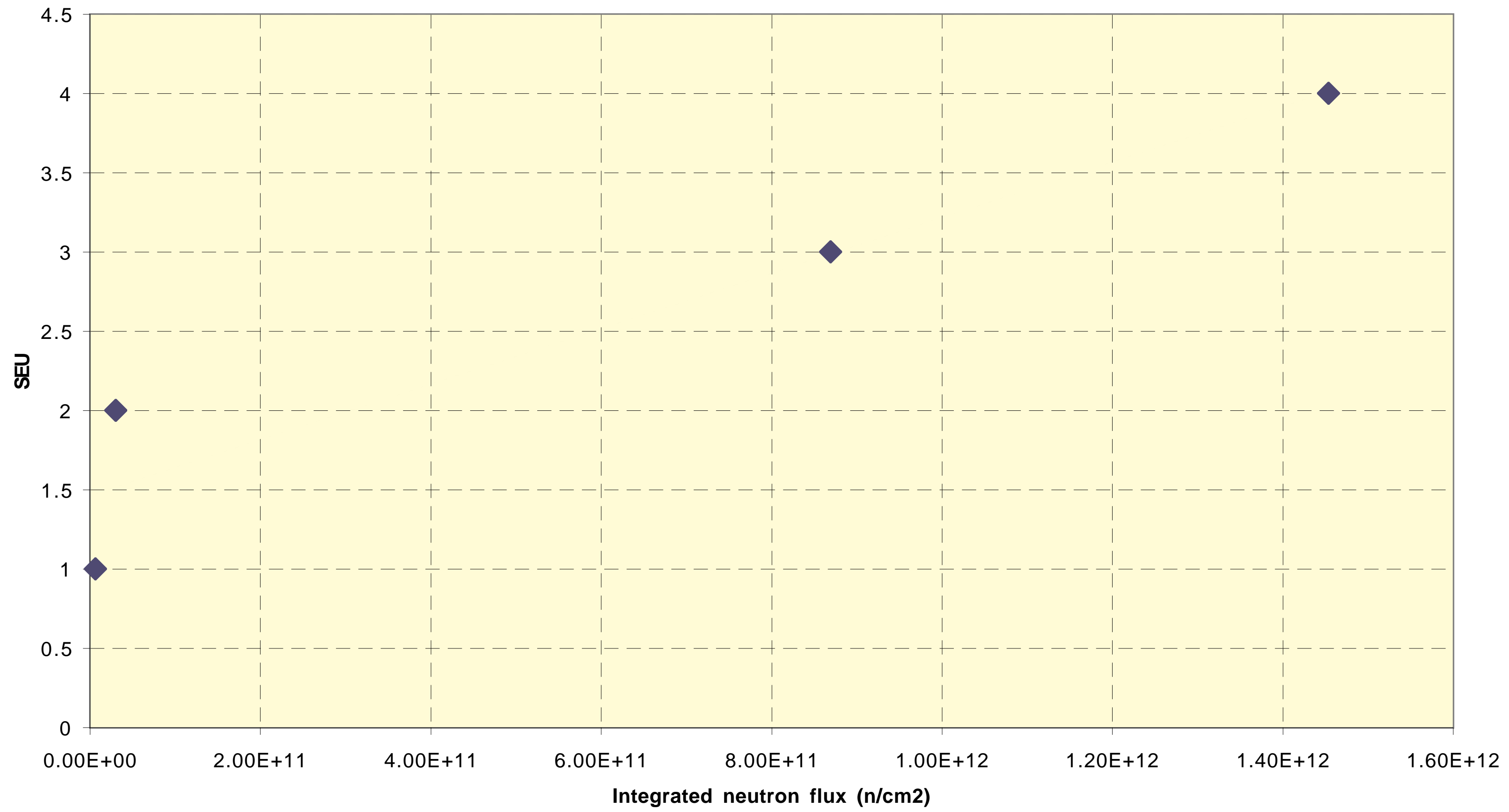
Thermal neutrons induced SEU on SRAM #1

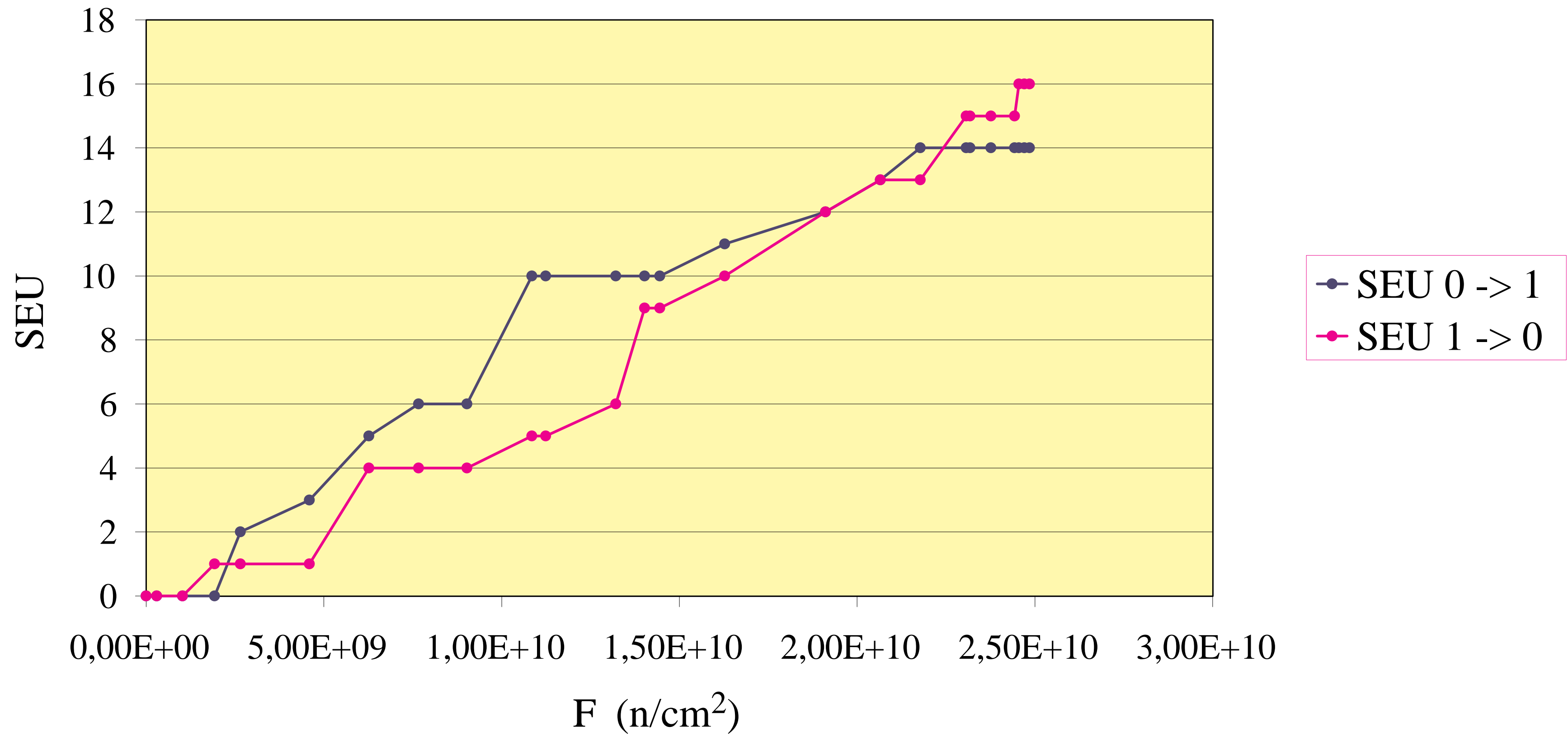




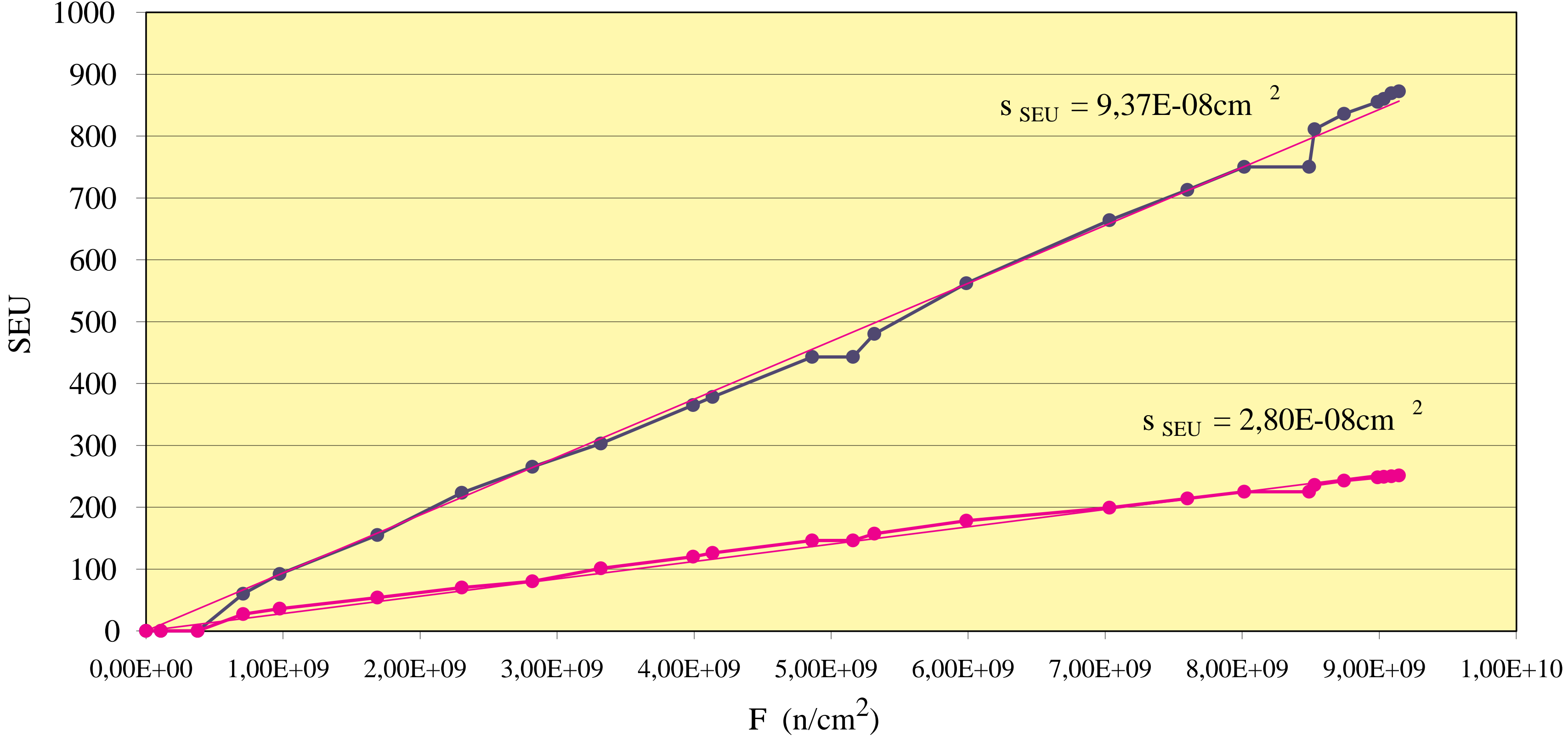
Fast neutrons induced SEU on SRAM#1
SEU
Integrated neutron flux (n/cm2)
0
20
40
60
80
100
120
140
0.00E+00
5.00E+10
1.00E+11
1.50E+11
2.00E+11
2.50E+11
3.00E+11
3.50E+11
4.00E+11
4.50E+11
5.00E+11

Fast neutrons induced SEU on SRAM#2

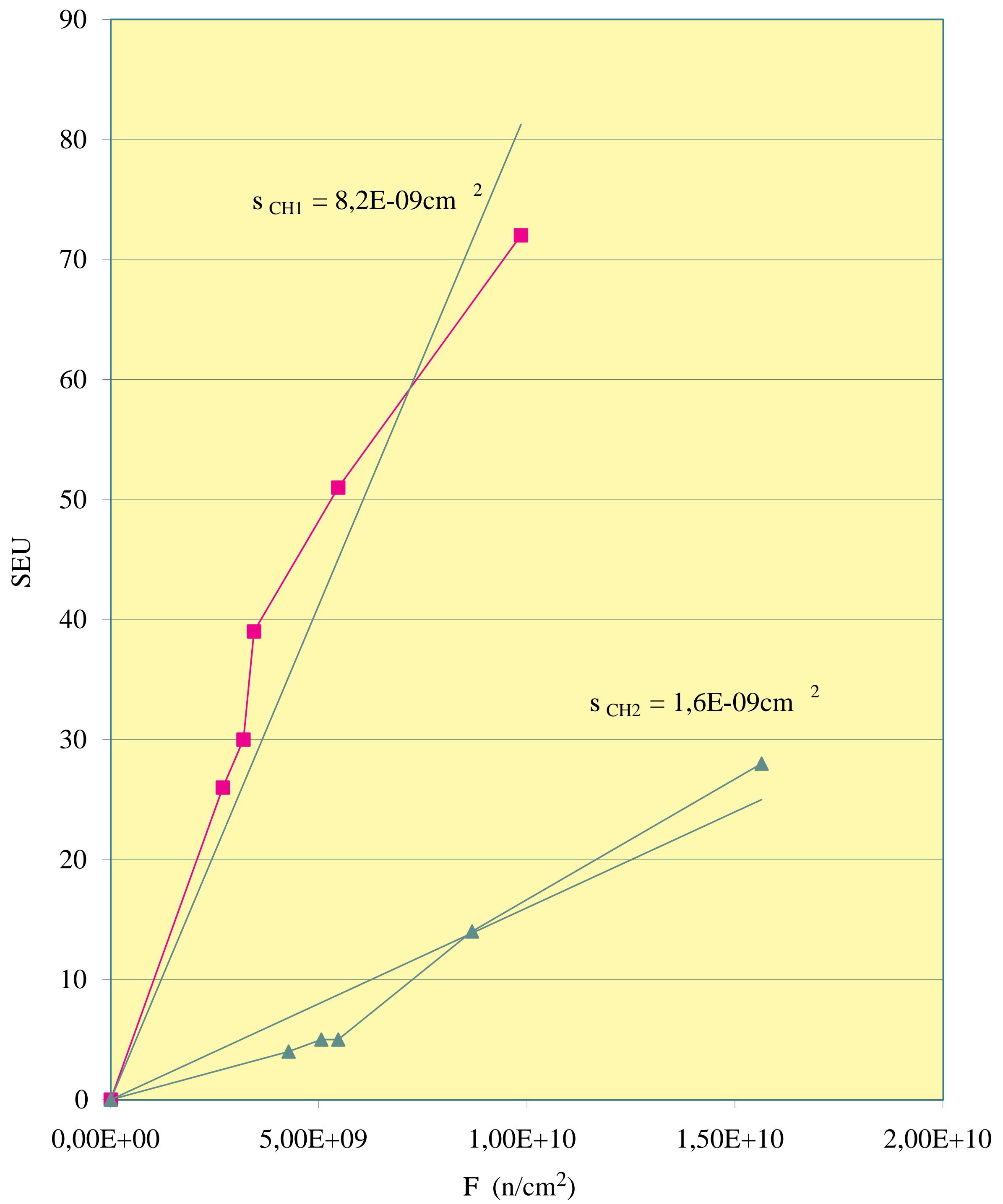


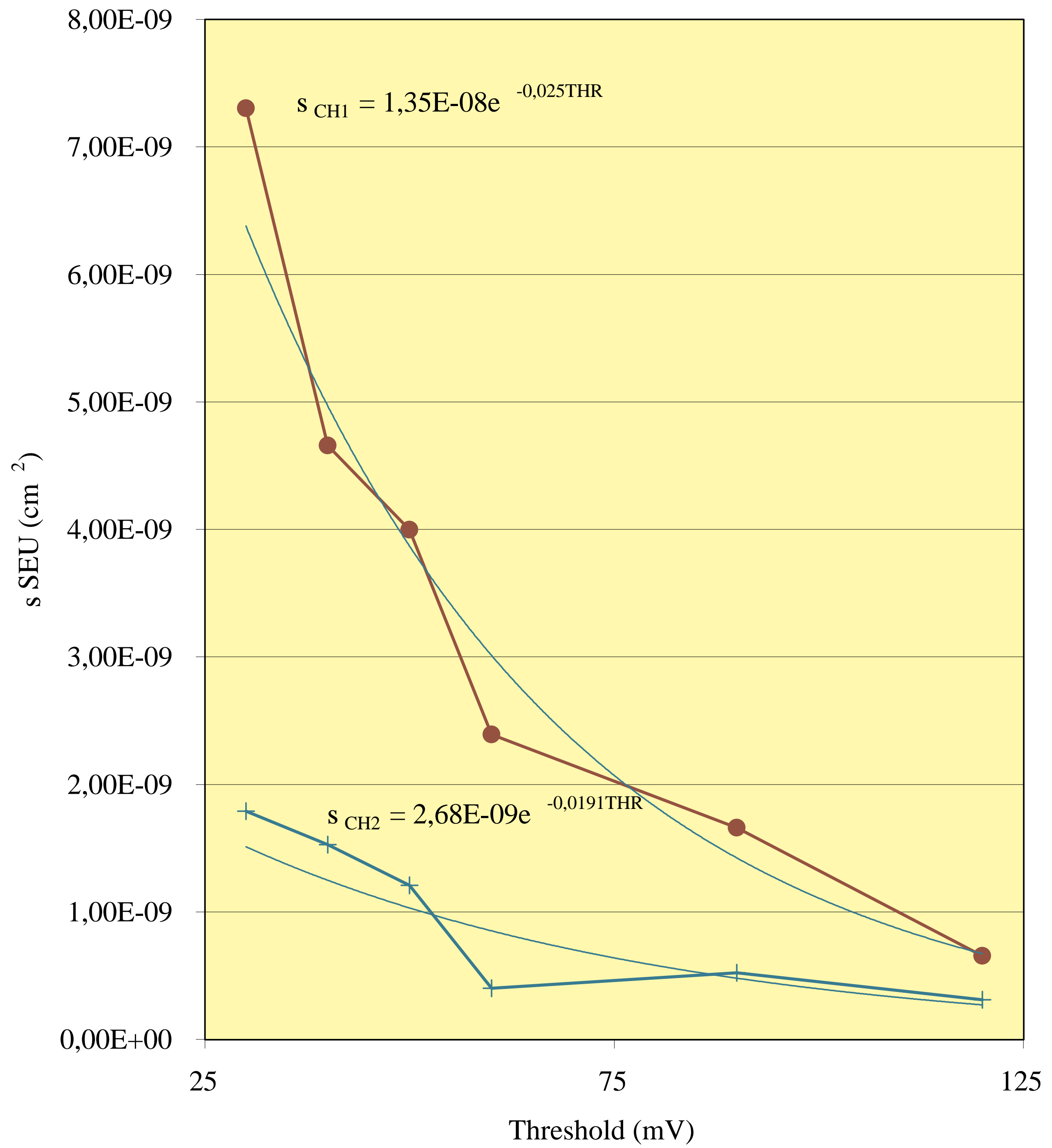


Thermal neutrons induced SEU on SRAM#1 06/99
SEU
18
16
14
12
10
8
6
4
2
0
0,00E+00
5,00E+09
1,00E+10
1,50E+10
2,00E+10
2,50E+10
3,00E+10
F (n/cm2)
SEU 0 -> 1
SEU 1 -> 0



Thermal neutrons induced SEU on MAD @ thr=60mV
SEU
F (n/cm2)
s SEU = 9,37E-08cm 2
s SEU = 2,80E-08cm 2
0
100
200
300
400
500
600
700
800
900
1000
0,00E+00
1,00E+09
2,00E+09
3,00E+09
4,00E+09
5,00E+09
6,00E+09
7,00E+09
8,00E+09
9,00E+09
1,00E+10


Fast Neutrons induced SEU on MAD @ thr=30mV
SEU
90
80
70
60
50
40
30
20
10
0
s CH1 = 8,2E-09cm 2
s CH2 = 1,6E-09cm 2
0,00E+00
5,00E+09
1,00E+10
1,50E+10
2,00E+10
F (n/cm2)



MAD SEU cross-section versus threshold
s CH1 = 1,35E-08e -0,025THR
s CH2 = 2,68E-09e -0,0191THR
8,00E-09
7,00E-09
6,00E-09
5,00E-09
4,00E-09
3,00E-09
2,00E-09
1,00E-09
0,00E+00
s SEU (cm 2)
25
75
125
Threshold (mV)

Radiation damage verification

As a test of the radiation damage caused by the neutron interactions with the devices we compared the standby current of the devices

Device	Current before irradiation	Current after irradiation
Control board	220 mA	222 mA
TSS	3.1 mA	3.4 mA
LD regulator	12.7 mA	12.7 mA
BTI	4.7 mA	4.7 mA

The Flash memory con still be reprogrammed
The EPROM is still working with Vcc = HIGH, LOW, STD
The levels of optical link are unchanged
The ADC channels are still working correctly

Only the TSS shows an indication of damage, but it will be remade using 0.5 µm technology