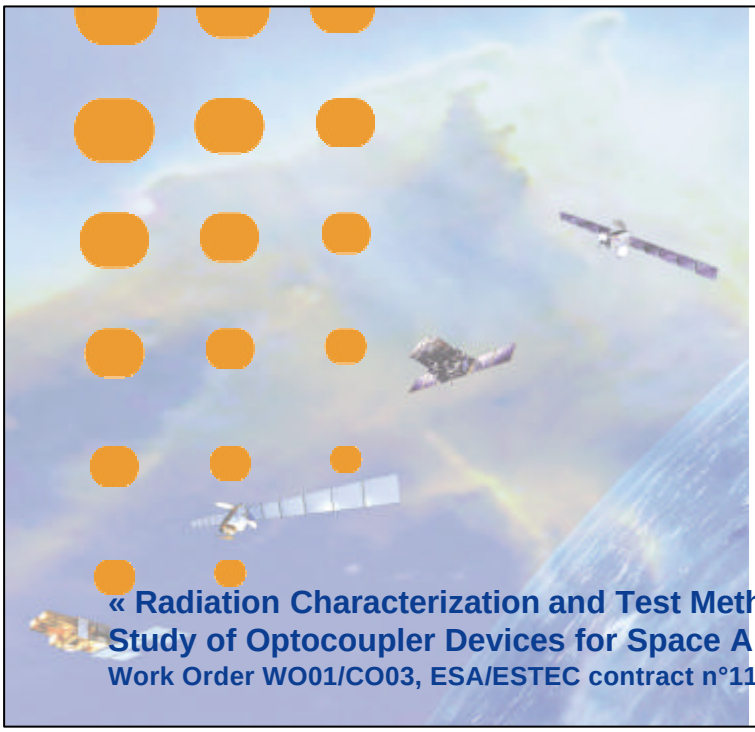


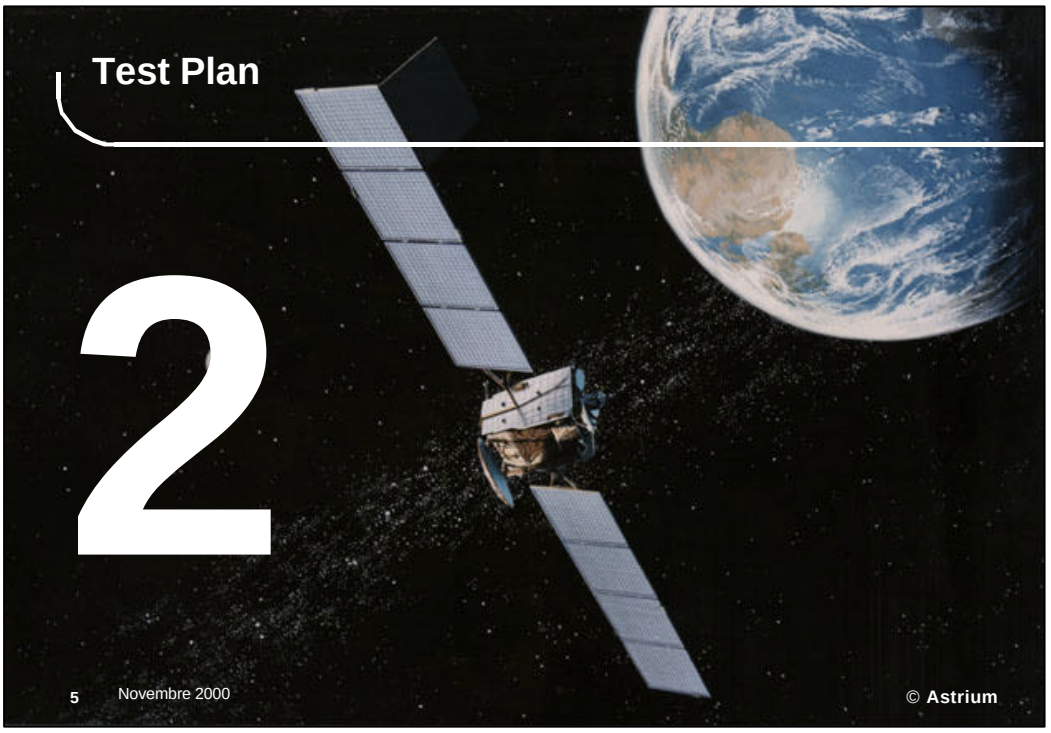
« Radiation Characterization and Test Methodology Study of Optocoupler Devices for Space Applications »

Work Order WO01/CO03, ESA/ESTEC contract n°11755/NL/PB

Contents

Study objectives

- **Establish an industrial methodology for optocoupler radiation testing**
  - validate the calculation of equivalent monoenergetic proton fluence with help of NIEL, whatever proton energy is concerned
  - quantify the additional degradation due to ionizing dose when proton testing does not allow to reach expected in flight dose level (electron rich orbits)
  - validate the possibility to perform a combination of [neutron + ionizing dose] testing instead of proton testing



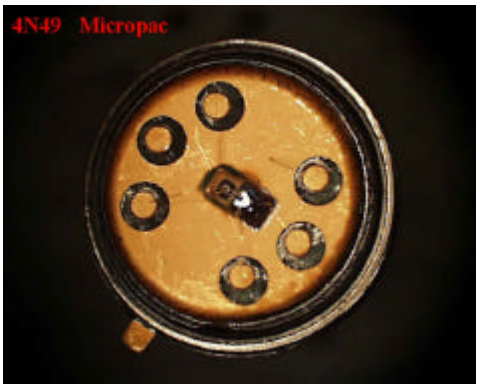
Test Plan 1/

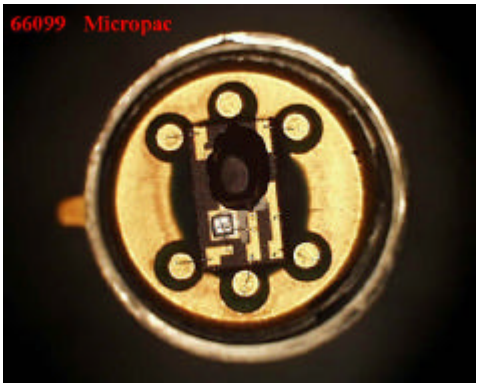
- **Devices tested**

Device type	Manuf.	Version	Proton sample size	Neutron / TID sample size	TID sample size
4N49	Optek	Standard	15 x 3 Ep	18	18(HDR)+18(LDR)
4N49	Isolink	standard	15 x 3 Ep	18	18(HDR)+18(LDR)
4N49	Micropac	standard	15 x 3 Ep	18	18(HDR)+18(LDR)
66099	Micropac	Hardened to displac' damage and TID	12 x 3 Ep	12	9(HDR)+9(LDR)
66168	Micropac	Hardened to displac' damage	15 x 3 Ep	18	18(HDR)+18(LDR)
66163	Micropac	standard	15 x 3 Ep	18	18(HDR)+18(LDR)
OLH249	Isolink	Hardened to displac' damage	12@Ep=60 MeV 9@Ep=200 MeV	9	9(HDR)+9(LDR)

Test Plan 1/

- **Optocoupler description**

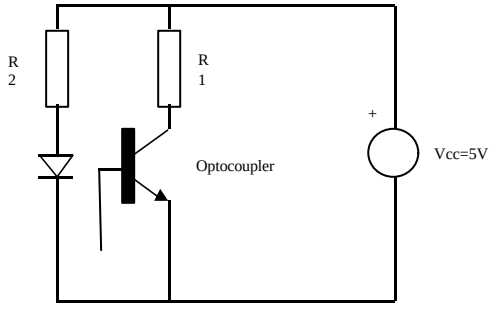




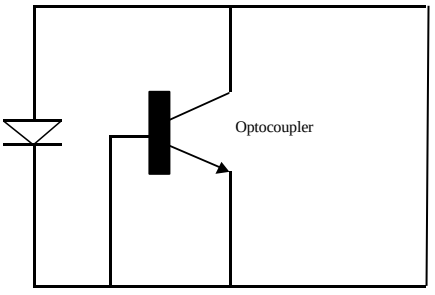
Test Plan 2/

- **Electrical testing conditions for proton, neutron and ^{60}Co experiment**

4 3 biasing mode during irradiation : Static ON : If = 1 mA, 10 mA or static OFF



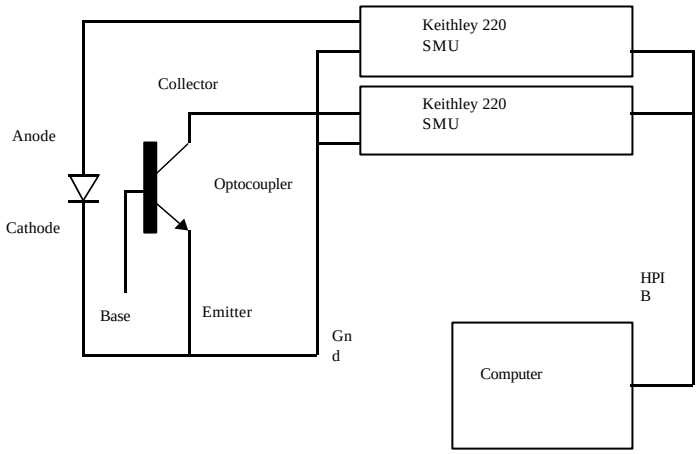
Static ON mode



Static OFF mode

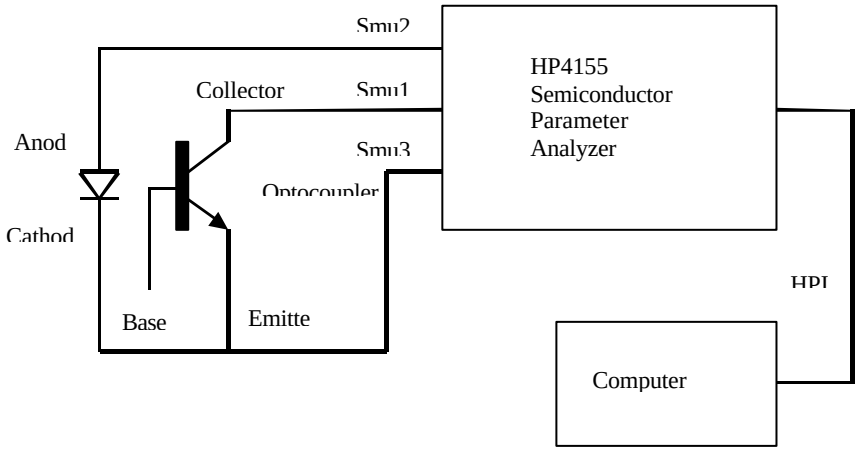
Test Plan 3/

4 Electrical measurement test set-up for proton and neutron experiment



Test Plan 3/

4 Electrical measurement test set-up for TID experiment



Test Plan 4/

- **Proton irradiation : at PSI, Villingen**
  - 3 proton energies : 15, 60 and 200 MeV

	STEP0		STEP1	STEP2	STEP3	STEP4	STEP5	STEP6	STEP7
15 MeV	0	(0k)	(1k)	1.24e+10 (5k)	2.48e+10 (10k)	4.9e+10 (20k)	1.2e+11 (50k)	1.8e+11 (75k)	2.42e+11 (100k)
60 MeV		0	7.26e+9	3.63e+10	7.26e+10	1.5e+11	3;63e+11	5.45e+11	7.27e+10
200 MeV		0	1.74e+10	8.59e+10	1.72e+11	3.44e+11	8.6e+11	1.27e12	1.72e+12

  - OPTIS line for 15 and 60 MeV protons, PIF line for 200 MeV

Test Plan 5/

- **Neutron irradiation :** Prospero neutron accelerator from CEA Valduc

Prot. Eq. Dose (krad)	**0**	**10 kRad**	**20 kRad**	**50 kRad**	**75 kRad**	**100 kRad**
Prot. 15 MeV (p/cm²)	0	2.4e+10	4.8e+10	1.2e+11	1.8e+11	2.4e+11
Neut. 1 MeV(n/cm²)	0	1.84e+11	3.7e+11	9.24e+11	1.38e+12	1.84e+12

  - flux from 2.05 to 6.2 10E8 n/cm²/s
  - neutron energies from 100 keV to 6 MeV spectrum, assimilated to 1 MeV neutron based on displacement damage in Silicon

Test Plan 6/

- **Cobalt 60 irradiation**

  4 low dose rate (<140 rad/h) : Shepherd 484, ASTRIUM, Velizy

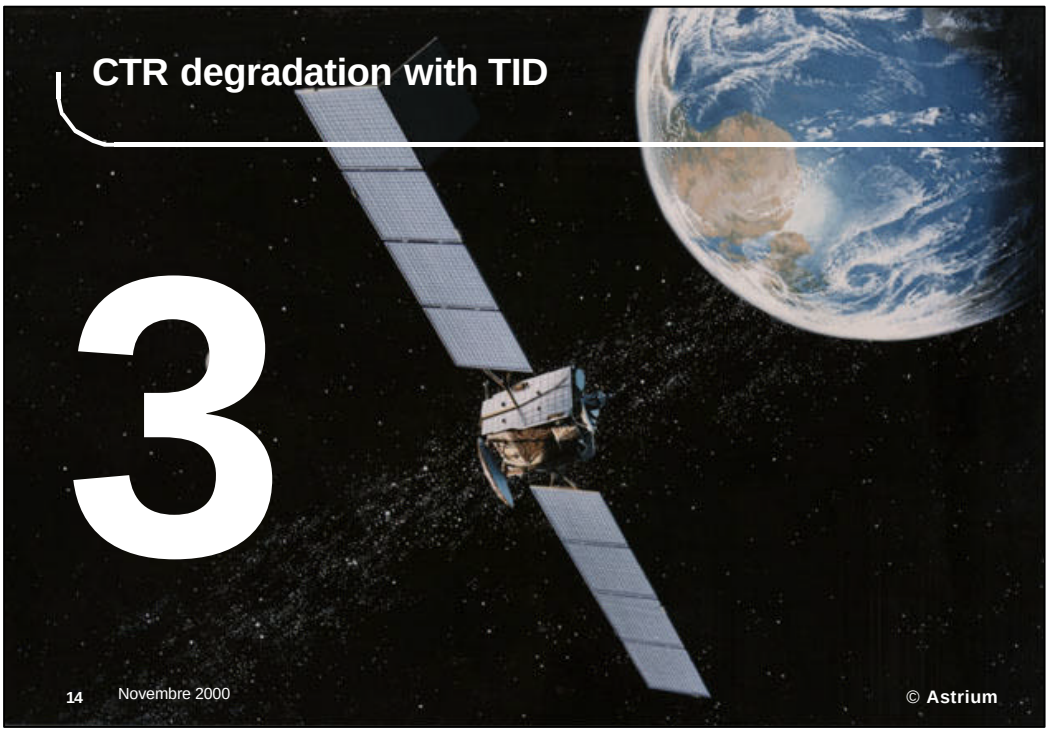
0 kRad	10 kRad	22 kRad	39 kRad	56 kRad	66 kRad	75 kRad	102 kRad

steps for low dose rate experiment

4 high dose rate (50 krad/h) : PAGURE line, CISbio Int., Saclay

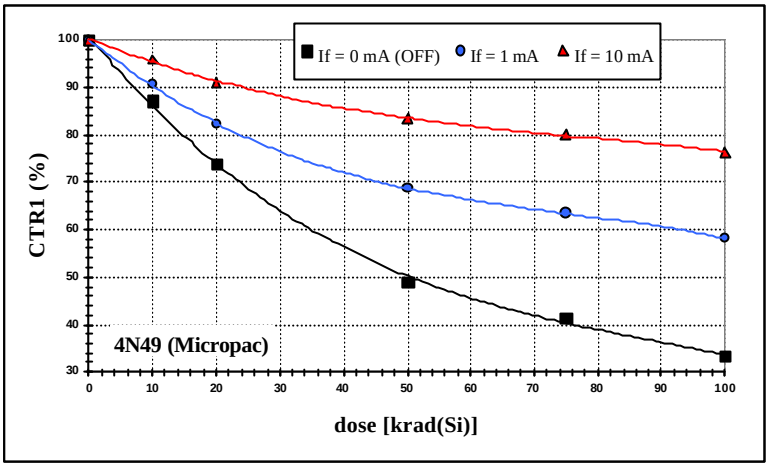
0 kRad	20 kRad	50 kRad	100 kRad

steps for high dose rate experiment



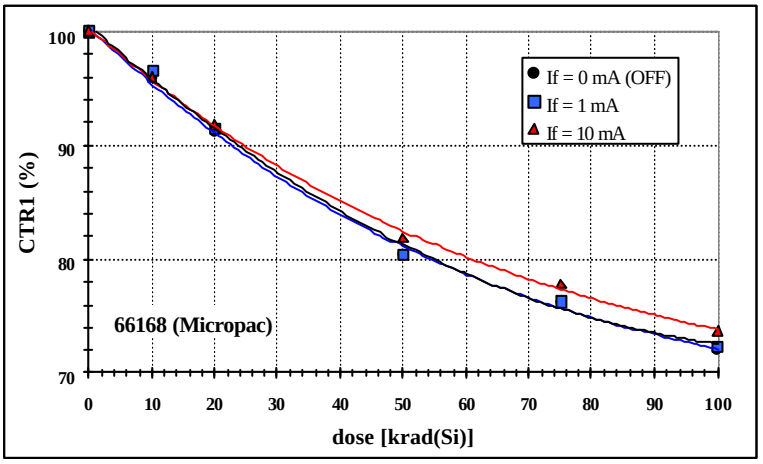
CTR degradation with TID 1/

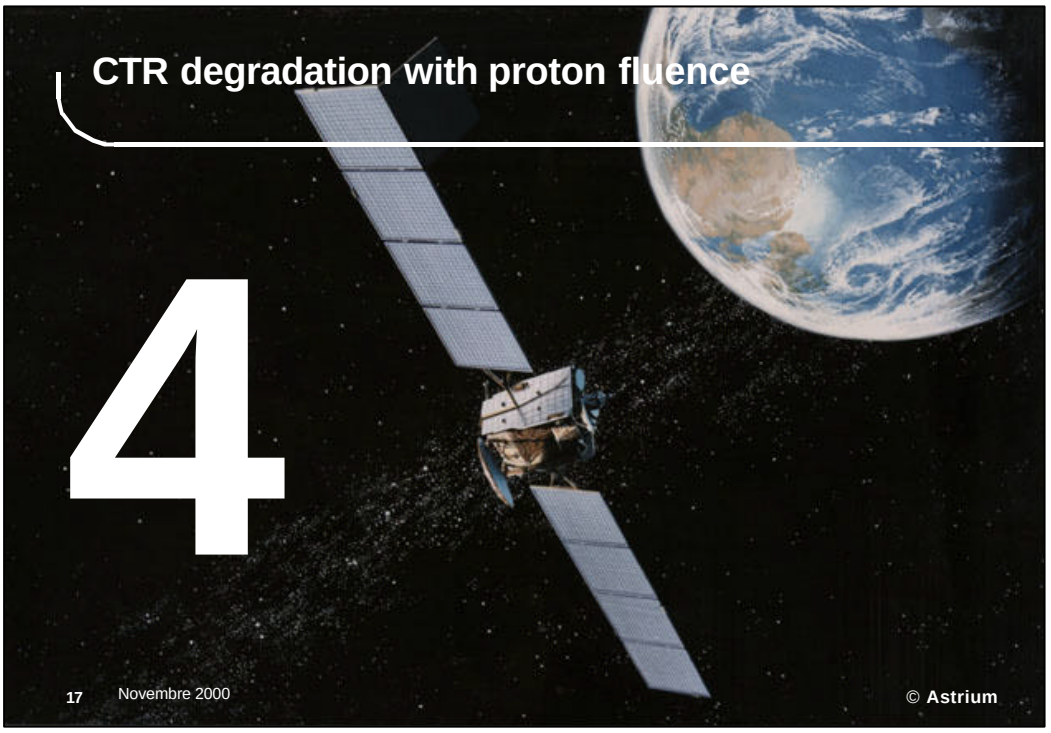
- Example of CTR degradation with TID : standard device



CTR degradation with TID 2/

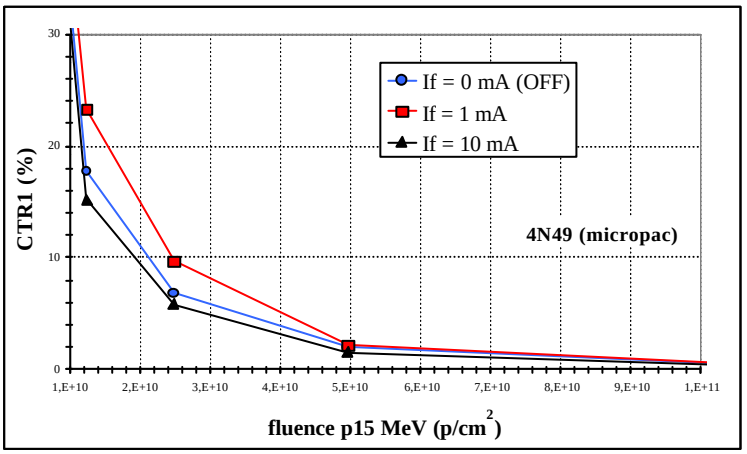
- Example of CTR degradation with TID : hardened device





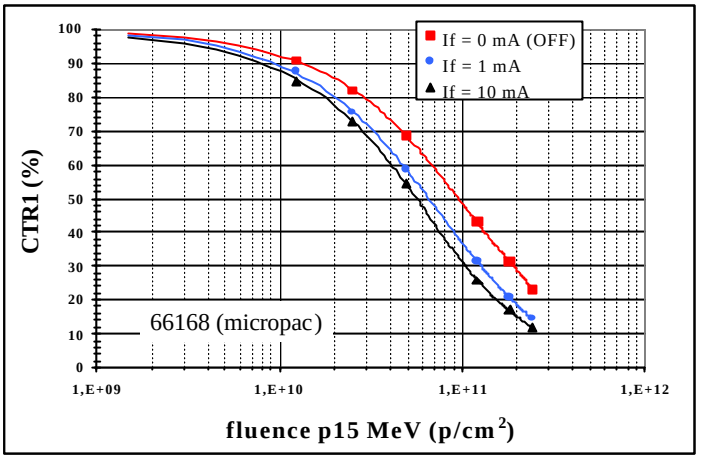
CTR degradation with proton fluence 1/

- Example of CTR degradation with proton fluence : standard device



CTR degradation with proton fluence 2/

- Example of CTR degradation with proton fluence : hardened device

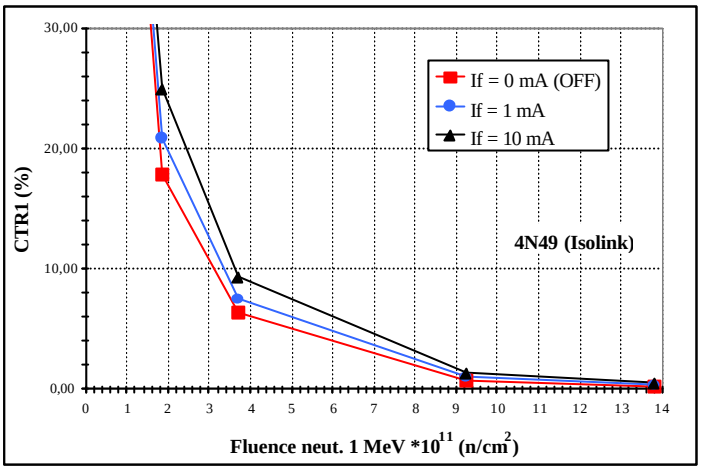


CTR degradation with neutron fluence

5

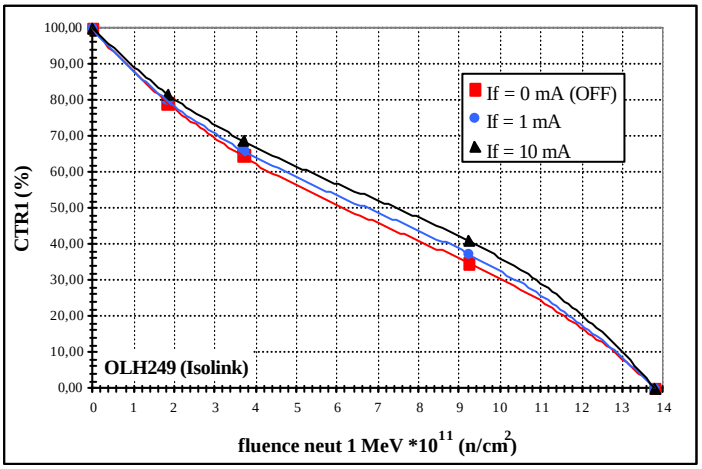
CTR degradation with neutron fluence 1/2

- Example of CTR degradation with neutron fluence : standard device



CTR degradation with neutron fluence 2/2

- Example of CTR degradation with neutron fluence : hardened device

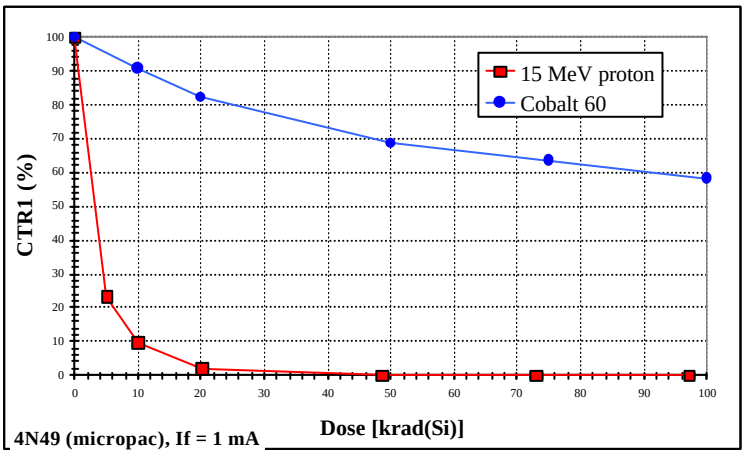


Comparison between ionization and displacement damage

6

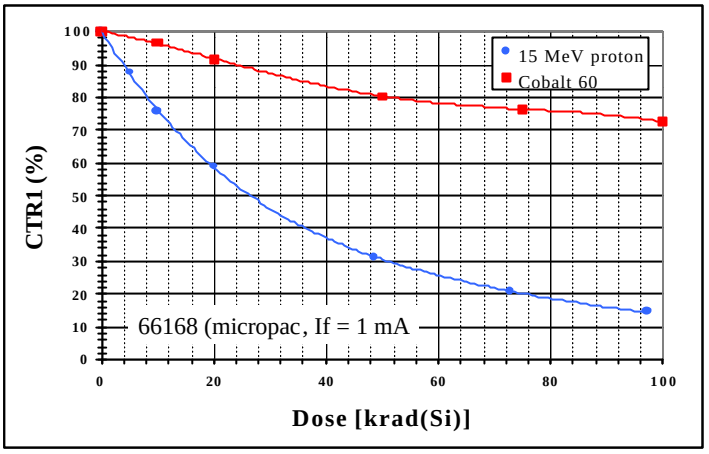
Comparison between ionization and displacement damage

- **Standard device**



Comparison between ionization and displacement damage

- Hardened device

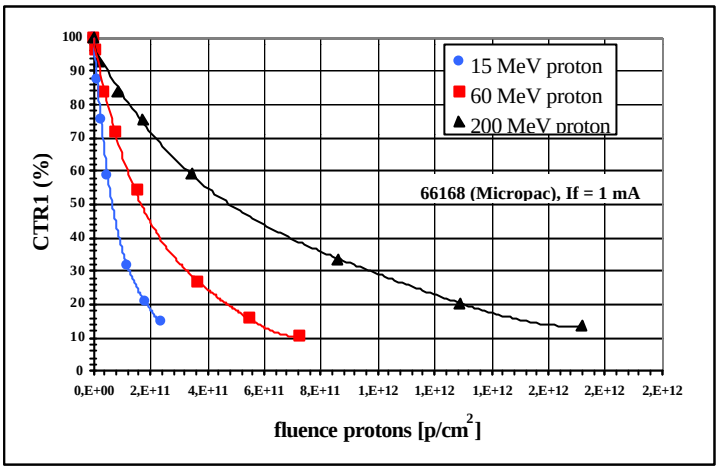


Comparison of CTR degradation with proton energy

7

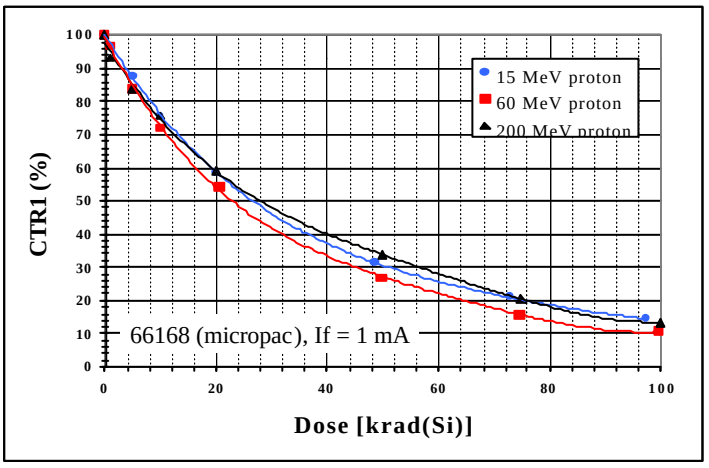
Comparison of CTR degradation with proton energy

- Comparison based on real protons fluences, hardened device



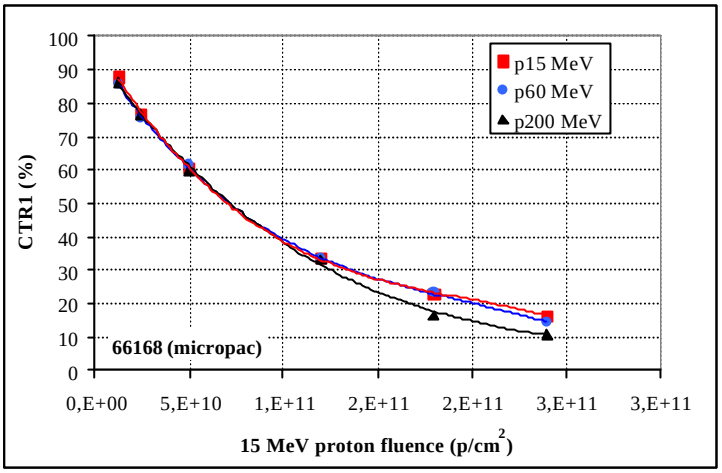
Comparison of CTR degradation with proton energy

- Comparison based on dose deposited by protons, hardened device



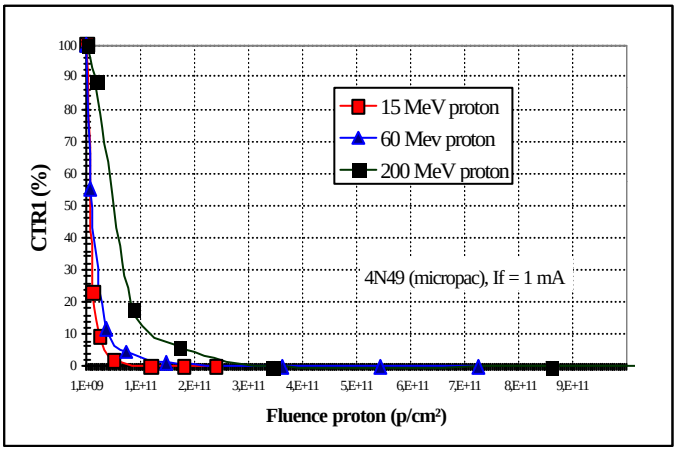
Comparison of CTR degradation with proton energy

- Comparison based on equivalent fluence, hardened device



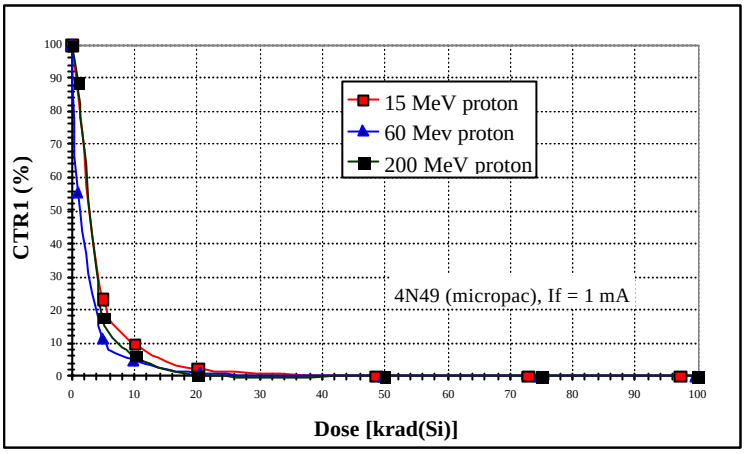
Comparison of CTR degradation with proton energy

- Comparison based on real protons fluences, standard device



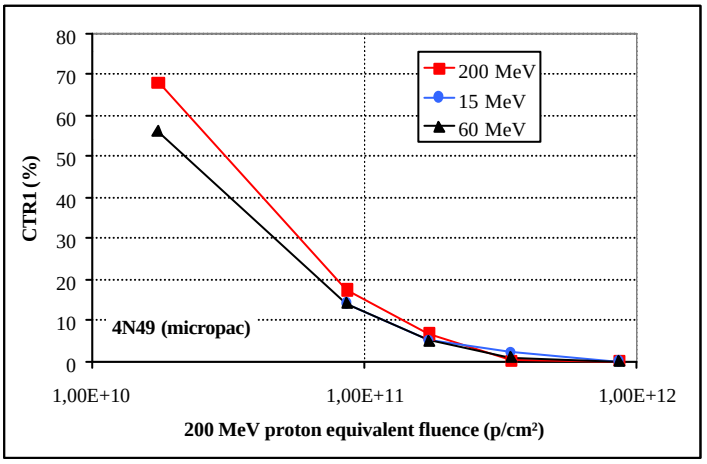
Comparison of CTR degradation with proton energy

- Comparison based on dose deposited by protons, standard device



Comparison of CTR degradation with proton energy

- Comparison based on equivalent fluence, standard device

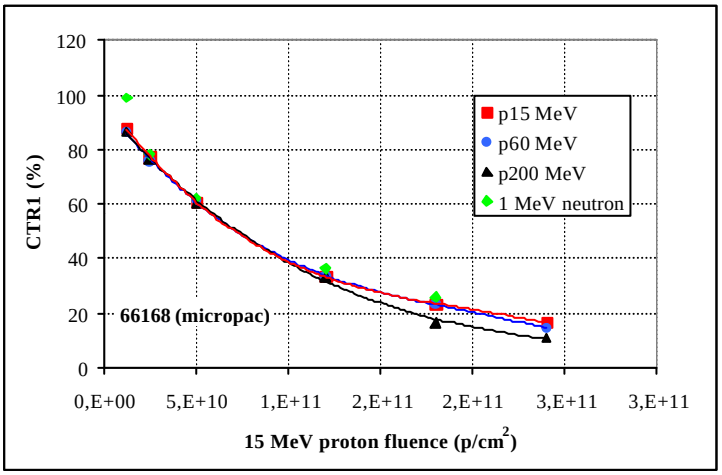


Comparison of CTR degradation with proton and neutron

8

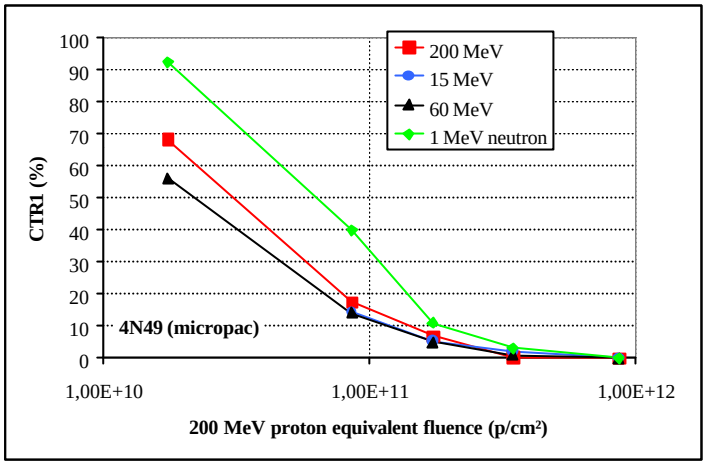
Comparison of CTR degradation with proton and neutron

- Comparison based on equivalent fluence, hardened device



Comparison of CTR degradation with proton and neutron

- Comparison based on equivalent fluence, standard device



Conclusion 1/2

- **A lot a data to analyse!**
- **Displacement damage is the main degradation mechanism**
- **biasing conditions during irradiation have an impact only for standard devices, for CTR values measured at low If**
- **NIEL concept works well, when using Barry 's table**
- **protons and neutrons results very well correlated for hardened devices, slight differences for unhardened devices**
- **Test methodology applicable for all optocoupler types**

Conclusion 2/2

- **Still to perform**
  - analysis of dose rate influence for Cobalt 60 results
  - complete tables for 3 remaining types
  - analysis of neutron spectrum in GaAs