D/TOS-QCA Final Presentation Day, ESA/ESTEC, Noordwijk, The Netherlands –
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# 60 MeV Proton Testing of 3C91C Optocouplers for ENVISAT-1, Summary Results.

by

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## Abstract

Mitel 3C91C Optocoupler devices from ENVISAT-1 lots were 60 MeV proton irradiated at the Centre de Protontherapie d'Orsay, Orsay, France, February 16th, 2001. Radiation summary results covering the Current Transfer Ratio (CTR) degradation will be presented for different date codes and biasing irradiation conditions.

## Objective:

# To Radiation Evaluate 3C91C Optocouplers from ENVISAT-1 lots:

- Using 60 MeV Protons
- Using representative ENVISAT-1 Operating conditions (3C91C)

# To Have Radiation Data before March 2001.

- HIREX Engineering, Toulouse – contacted week 3, 2001
- SOW Issued 18th January 200 Radiation Evaluation
- All parts forwarded to HIREX week 5, 2001
- Test facility booked for 16th February 2001, (Centre de Protontherapie d'Orsay, France)
- Acceptance of test set-up, biasing boards and electrical measurements (Ref.; ESA/SCC Spec. 5401/001) – 8th February 2001
- CPO testing 16th February 2001
- Final report to be delivered in week 09, 2001

# Why Proton Testing ?

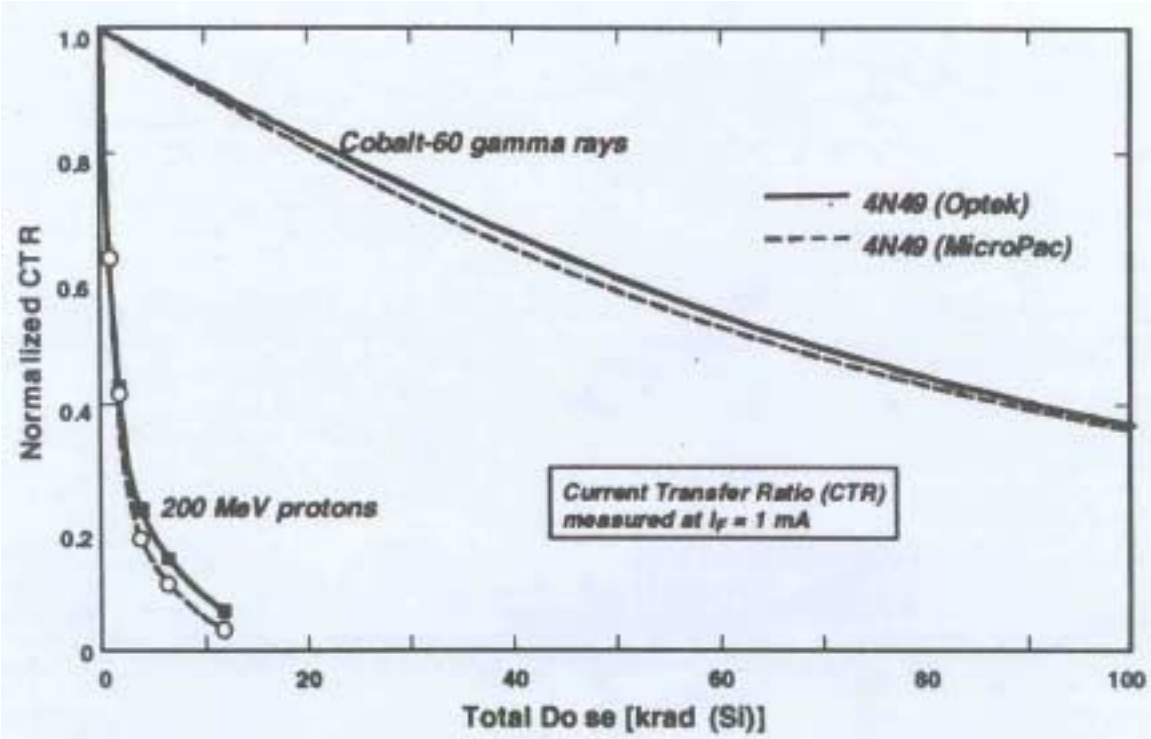



Figure 1. An optocoupler's response to Co-60 compared to proton irradiations.

**Ref.: K. A. LaBe et al, IEEE Trans. On Nucl. Sci. vol 46, No. 6, Dec. 1998.**

# Optocoupler Types Tested:

| CPO – 60 MeV Proton Test | Reference Devices | Bias Conditions During Test | | |
|---|---|---|---|---|
| | | 10 mA/5 V | 2 mA/ 5 V | Unbiased |
| 3C91C d/c 9508 | 1 | 2 | 1 | 1 |
| 3C91C d/c 9601 | 1 | 2 | 1 | 1 |
| 3C91C d/c 9519 | 1 | 2 | 1 | 1 |
| 3C91C d/c 9344 | 1 | 2 | 1 | 1 |
| 3C91C d/c 9426 | | 3 | 3 | 3 |
| 3C91C d/c 9309 | | 1 | | |
| ENVISAT-1 30 pc | 4 | 12 | 7 | 7 |
| 3C91C L234 | 1 | 2 | 2 | 2 |
| 3C91C d/c 9806 | 1 | 1 | 1 | 1 |
| CNES 11 pc | 2 | 3 | 3 | 3 |
| 4N49 Isolink | 1 | 2 | 2 | 2 |
| 4N49 Micropac | 1 | 2 | 2 | 2 |
| 4N49 Optek | 1 | 2 | 2 | 2 |
| 21 Devices | 3 | 6 | 6 | 6 |

# Test Conditions/Set-Up:

## # Electrical Testing – Ref.: ESA/SCC Spec. 5401/001

- Table 2 for DC Measurements – first 7 parameters
- With additional Output Current Test at If = 1, 2 & 5 mA
- Rise/Fall Time Test – Ref. Figure 4a

## # Parametric Testing

- DC - HP4142B connected to shielded DUT box
- AC - Pulse Generator/Oscilloscope

## # 2 Biasing Boards prepared for parts to be irradiated:

- Unbiased
- If = 2 mA - Ref. Figure 5b
- If = 10 mA - Ref. Figure 5b

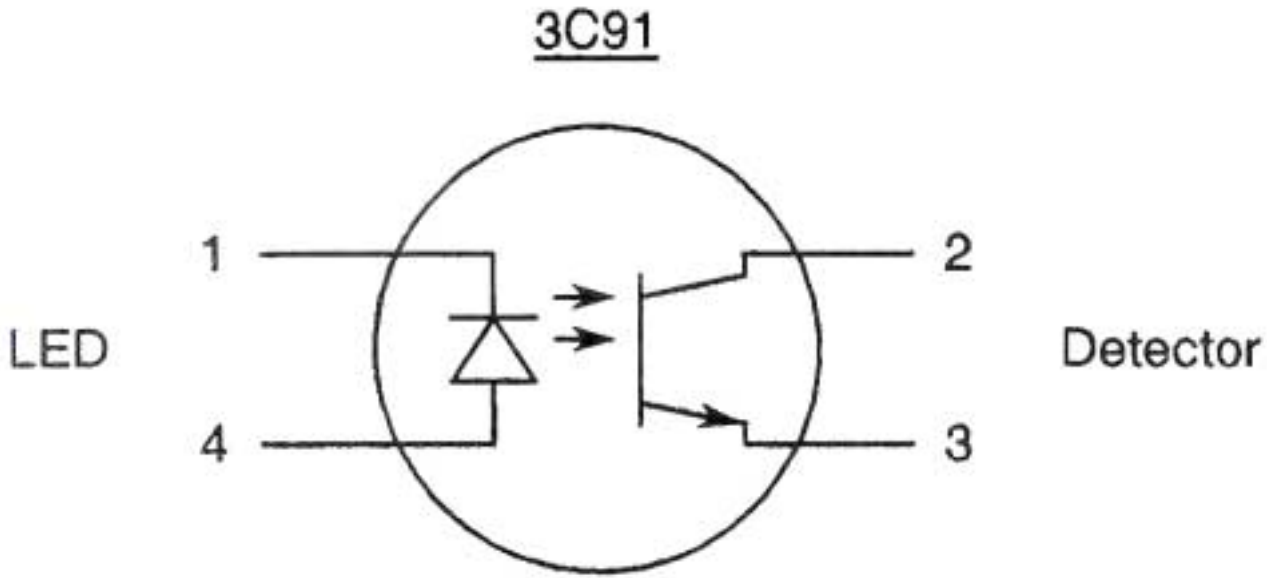
# Electrical Measurements: DC/AC Parameters

| Symbol | Description | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| VF1 | Forward Voltage 1 | IF=2.0mA | | 1.3 | V |
| VF2 | Forward Voltage 2 | IF=50mA | | 1.8 | V |
| VBR | Breakdown Voltage | IR=0.1mA | 7 | | V |
| VBRCE0 | Collector-Emitter Breakdown Voltage | IC=10mA | 50 | | V |
| ICE0 | Dark Current | VCE=5.0V. IF=0mA | | 5.0E-08 | A |
| IC1 | Output Current1 | VCE=5.0V. IF=1mA | | | A |
| IC2 | Output Current2 | VCE=5.0V. IF=2mA | | | A |
| IC5 | Output Current5 | VCE=5.0V. IF=5mA | | | A |
| IC10 | Output Current10 | VCE=5.0V. IF=10mA | 0.004 | | A |
| VCESAT | Collector Emitter Saturation Voltage | IC=2mA. IF=50mA | | 0.4 | V |
| trise | Rise Time | RL=100 Ohms. IC=2.0mA. VCE=5.0V | | 5.0E-06 | s |
| tfall | Fall Time | RL=100 Ohms. IC=2.0mA. VCE=5.0V | | 5.0E-06 | s |
| CTR1 | | | | | % |
| CTR2 | | | | | % |
| CTR5 | | | | | % |
| CTR10 | | | | | % |

# DC: Electrical Parameters (example after 3.63E10 p/cm$^2$)

| Bias | VF1 | VF2 | VBR | VBRCE0 | ICE0 | IC_1mA | IC_2mA | IC_5mA | IC_10mA | VCESAT | date code | # |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ref | 1.077 | 1.314 | 26.884 | 57.376 | 350.34E-12 | 593.14E-6 | 1.7432E-3 | 6.061E-3 | 13.918E-3 | 32.40E-3 | DC9344 | 029 |
| Ref | 1.073 | 1.246 | 25.146 | 59.718 | 173.16E-12 | 467.96E-6 | 1.413E-3 | 5.0416E-3 | 11.782E-3 | 32.68E-3 | DC9508 | 179 |
| Ref | 1.069 | 1.229 | 26.076 | 76.136 | 551.86E-12 | 321.28E-6 | 951.04E-6 | 3.4134E-3 | 8.1248E-3 | 81.00E-3 | L234 | 1 |
| Unbiased | 1.061 | 1.251 | 31.338 | 58.764 | 251.02E-12 | 211.06E-6 | 668.92E-6 | 2.6726E-3 | 6.9226E-3 | 51.48E-3 | DC9344 | 046 |
| Unbiased | 1.063 | 1.308 | 30.178 | 59.800 | 178.96E-12 | 155.62E-6 | 509.92E-6 | 2.1106E-3 | 5.5892E-3 | 55.52E-3 | DC9426 | 29 |
| Unbiased | 1.061 | 1.262 | 23.302 | 60.312 | 226.72E-12 | 163.58E-6 | 545.50E-6 | 2.2992E-3 | 6.1612E-3 | 54.28E-3 | DC9426 | 38 |
| Unbiased | 1.057 | 1.266 | 29.922 | 56.572 | 72.56E-12 | 115.68E-6 | 369.20E-6 | 1.4908E-3 | **3.9046E-3** | 51.52E-3 | DC9806 | 627 |
| Unbiased | 1.054 | 1.243 | 31.998 | 76.302 | 510.18E-12 | 125.90E-6 | 403.18E-6 | 1.6532E-3 | 4.4106E-3 | 96.48E-3 | L234 | 2 |
| Unbiased | 1.053 | 1.247 | 41.428 | 68.102 | 550.38E-12 | 157.74E-6 | 511.24E-6 | 2.103E-3 | 5.5616E-3 | 87.40E-3 | L234 | 3 |
| 2 mA | 1.060 | 1.272 | 22.170 | 60.100 | 149.76E-12 | 178.92E-6 | 580.18E-6 | 2.3744E-3 | 6.2398E-3 | 52.64E-3 | DC9508 | 280 |
| 2 mA | 1.059 | 1.246 | 30.160 | 60.136 | 531.62E-12 | 146.60E-6 | 462.30E-6 | 1.833E-3 | 4.7242E-3 | 61.20E-3 | DC9519 | 167 |
| 2 mA | 1.058 | 1.262 | 26.668 | 56.584 | 269.98E-12 | 229.30E-6 | 730.60E-6 | 2.925E-3 | 7.559E-3 | 41.92E-3 | DC9601 | 282 |
| 2 mA | 1.060 | 1.247 | 29.306 | 53.690 | 121.98E-12 | 183.98E-6 | 562.56E-6 | 2.1572E-3 | 5.458E-3 | 40.32E-3 | DC9806 | 739 |
| 2 mA | 1.056 | 1.221 | 30.894 | 75.876 | 462.52E-12 | 185.00E-6 | 584.92E-6 | 2.3458E-3 | 6.1002E-3 | 86.04E-3 | L234 | 4 |
| 2 mA | 1.060 | 1.242 | 42.666 | 69.070 | 616.52E-12 | 155.34E-6 | 495.78E-6 | 2.0122E-3 | 5.2646E-3 | 98.24E-3 | L234 | 5 |
| 10 mA | 1.059 | 1.277 | 31.376 | 58.586 | 222.60E-12 | 228.02E-6 | 745.94E-6 | 3.046E-3 | 7.9332E-3 | 47.12E-3 | DC9309 | 097 |
| 10 mA | 1.057 | 1.253 | 24.834 | 61.206 | 310.96E-12 | 103.64E-6 | 341.92E-6 | 1.4236E-3 | **3.7734E-3** | 65.48E-3 | DC9519 | 107 |
| 10 mA | 1.060 | 1.269 | 34.120 | 60.564 | 166.16E-12 | 162.16E-6 | 533.82E-6 | 2.1522E-3 | 5.534E-3 | 54.80E-3 | DC9519 | 241 |
| 10 mA | 1.053 | 1.240 | 27.590 | 55.142 | 446.24E-12 | 294.34E-6 | 939.88E-6 | 3.7066E-3 | 9.4174E-3 | 38.92E-3 | DC9601 | 73 |
| 10 mA | 1.059 | 1.246 | 27.148 | 57.616 | 186.74E-12 | 245.48E-6 | 774.88E-6 | 3.0268E-3 | 7.6408E-3 | 37.80E-3 | DC9601 | 232 |
| 10 mA | 1.057 | 1.238 | 19.552 | 53.984 | 150.84E-12 | 120.98E-6 | 396.98E-6 | 1.629E-3 | 4.281E-3 | 51.12E-3 | DC9806 | 694 |
| 10 mA | 1.050 | 1.222 | 34.064 | 70.260 | 480.18E-12 | 197.40E-6 | 634.60E-6 | 2.6104E-3 | 6.9122E-3 | 78.04E-3 | L234 | 6 |
| 10 mA | 1.059 | 1.226 | 30.648 | 74.780 | 363.34E-12 | 132.24E-6 | 414.98E-6 | 1.6352E-3 | 4.1826E-3 | 95.12E-3 | L234 | 7 |

# Current Transfer Ratio (CTR)




**CTR is defined as the Collector Current ($I_C$) in the Detector Divided by the LED Forward Current ($I_F$).**

# Centre de Protontherapie d'Orsay: 200 MeV proton beam

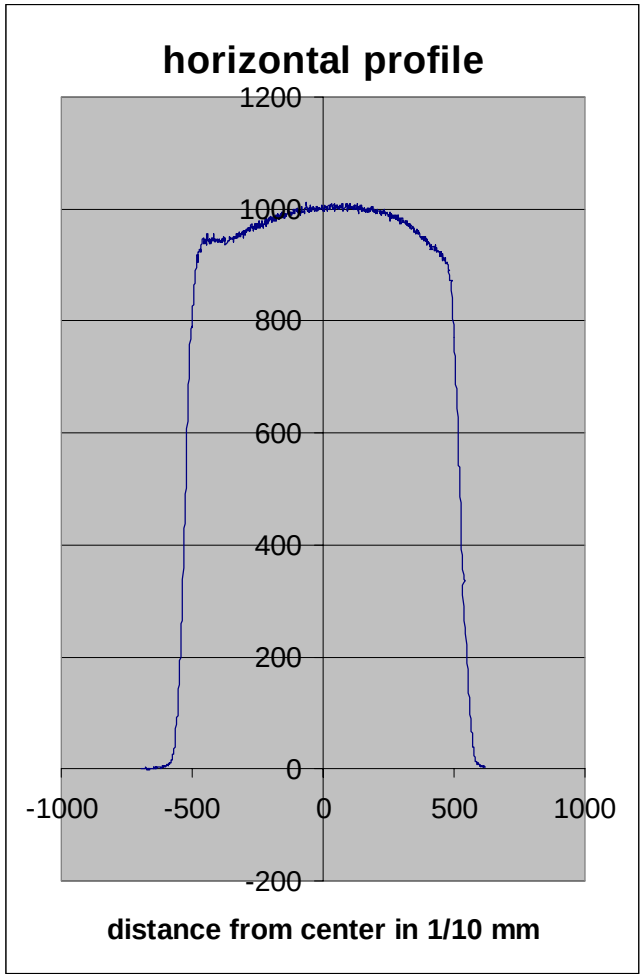
# Synchro- cyclotron SC200 installed in Orsay in 1957

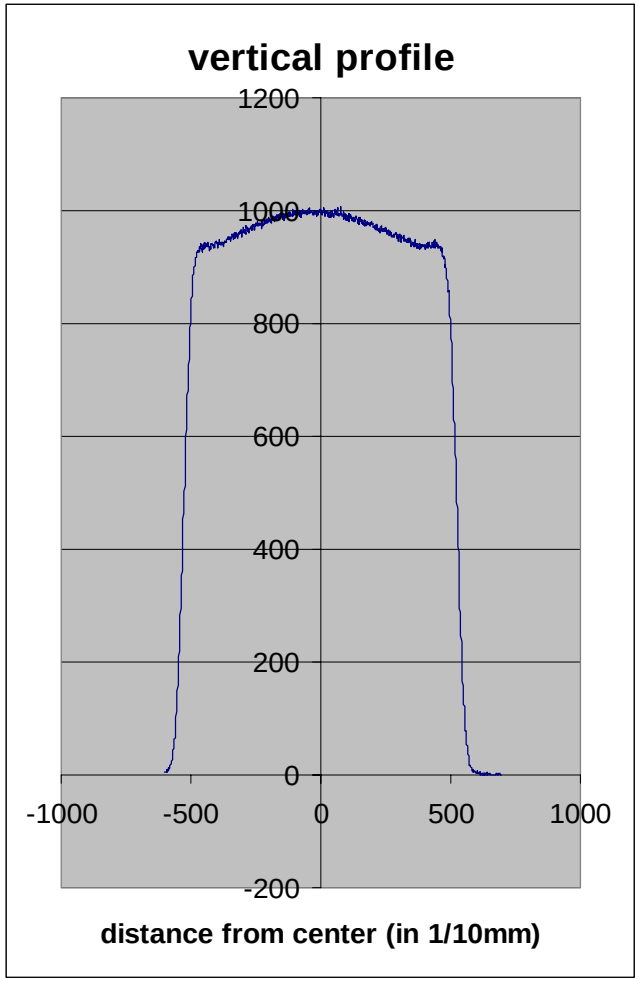
- Used for physics research until 1990
- Devoted to Medical Treatment since 1991
- However, open for other applications during night and weekend hours.

# Used Test Conditions

- Energy: 60 MeV
- Beam size Ø: 10 cm
- Flux: 2.7E07 p/cm$^2$/sec.
- Calibration: On-line ionization chambers
- Beam Profile: horizontal/vertical

# CPO: Beam Profile

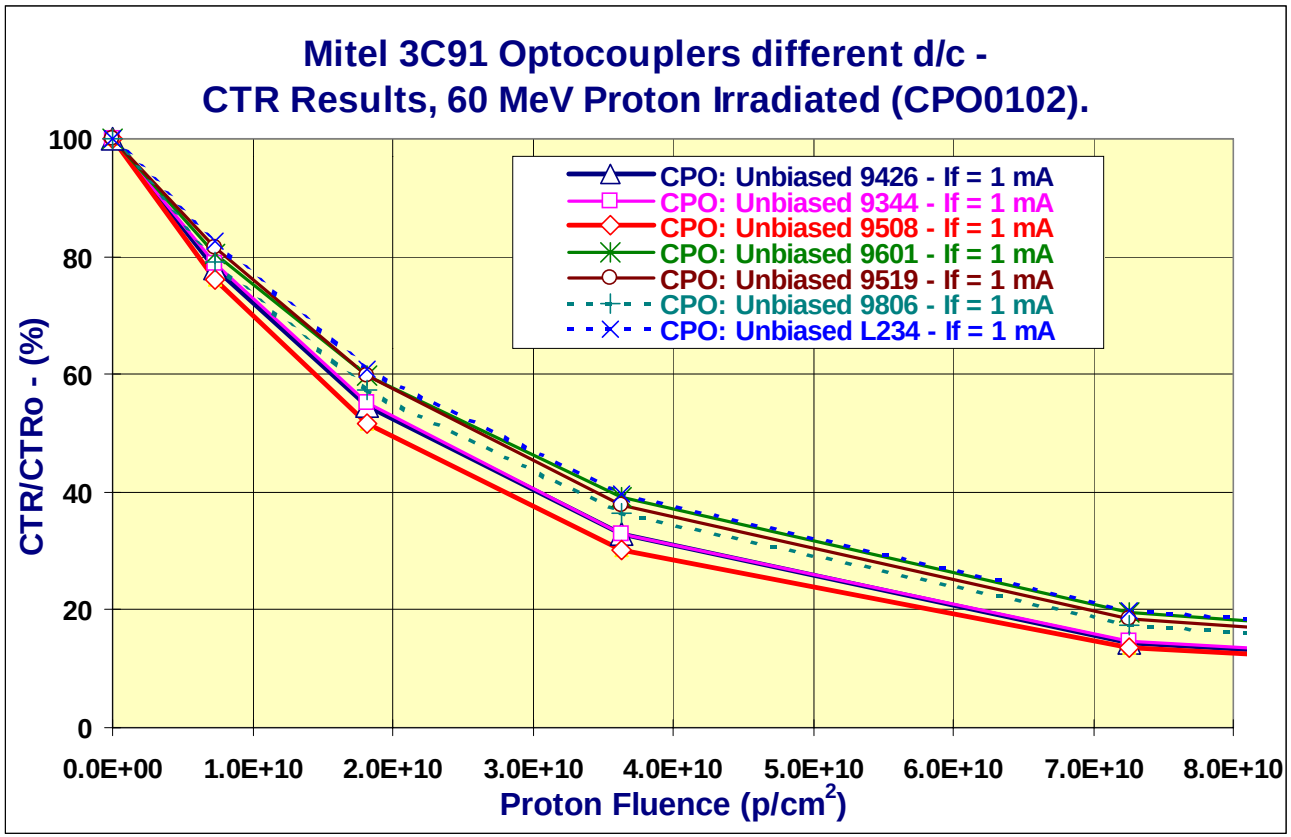


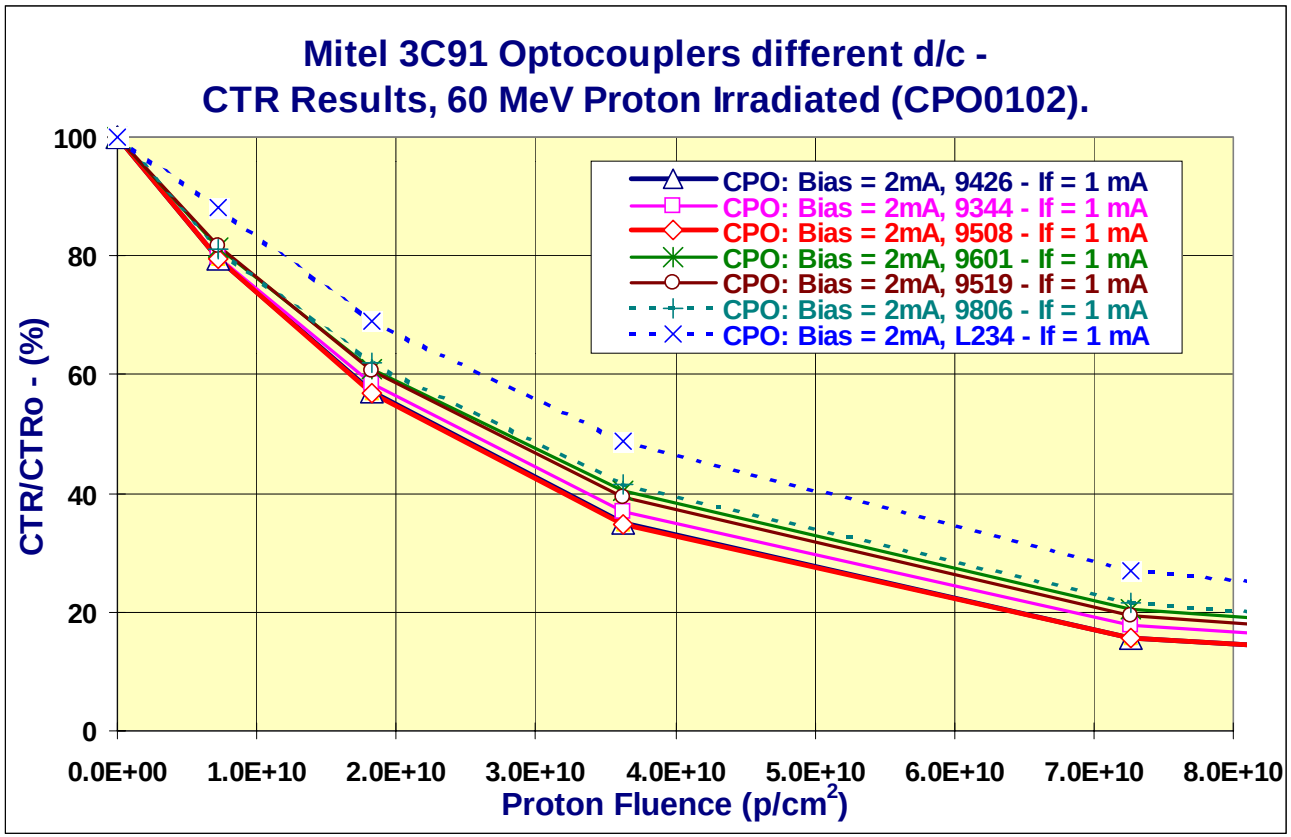
# CPO: 60 MeV Proton - Irradiation Steps

| Irr. Steps $p/cm^2$ | Fluence $p/cm^2$ | Irr. Time Seconds | Temp. °C |
|---|---|---|---|
| 0 | | | 22 |
| 7.26E09 | 7.26E09 | 269 | 22 |
| 1.10E10 | 1.82E10 | 407 | 22 |
| 1.82E10 | 3.63E10 | 674 | 22 |
| 3.63E10 | 7.26E10 | 1344 | 22 |
| 7.26E10 | 1.50E11 | 2688 | 22 |
| per board – 2 boards Irradiated | | | |
| Flux : 2.70E07 $p/cm^2$/sec. | | | |

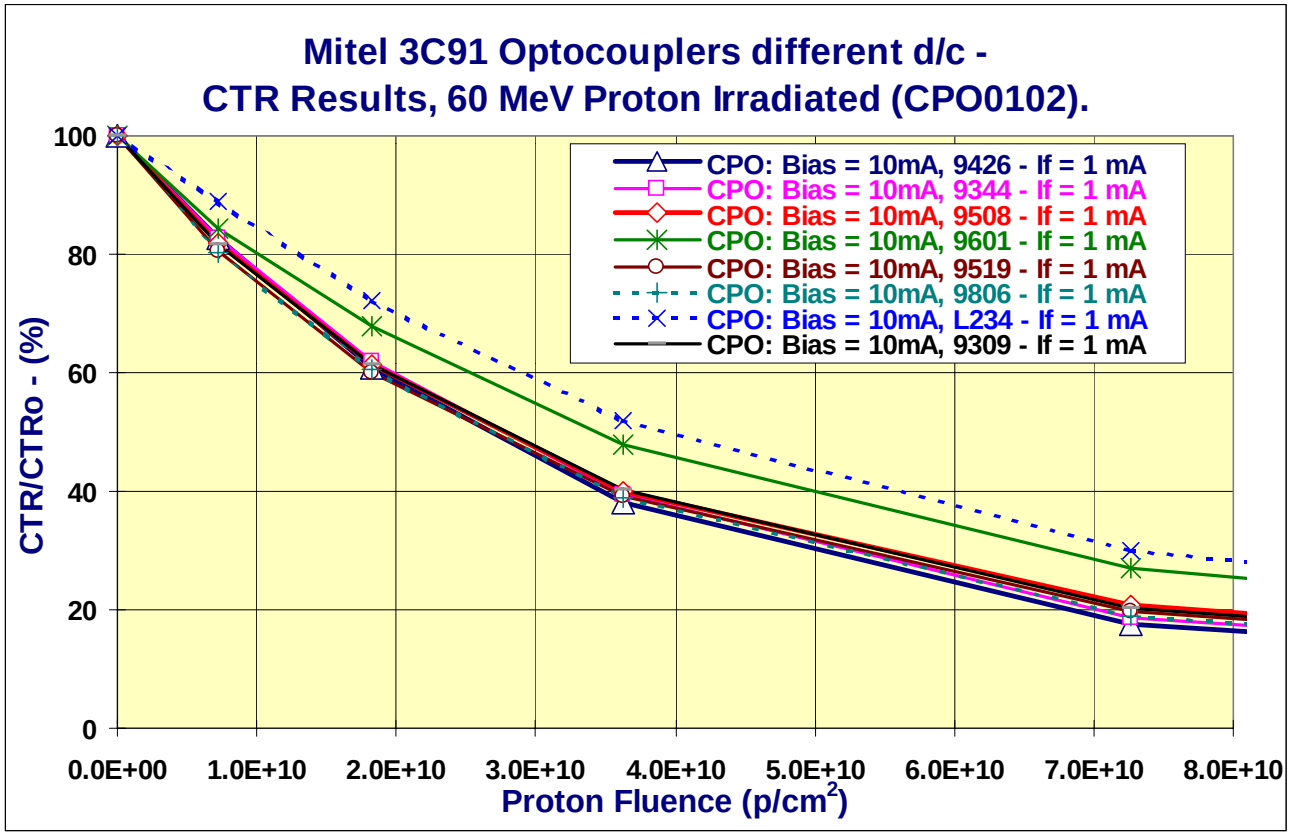
# CTR Results: Unbiased/CTR = 1 mA



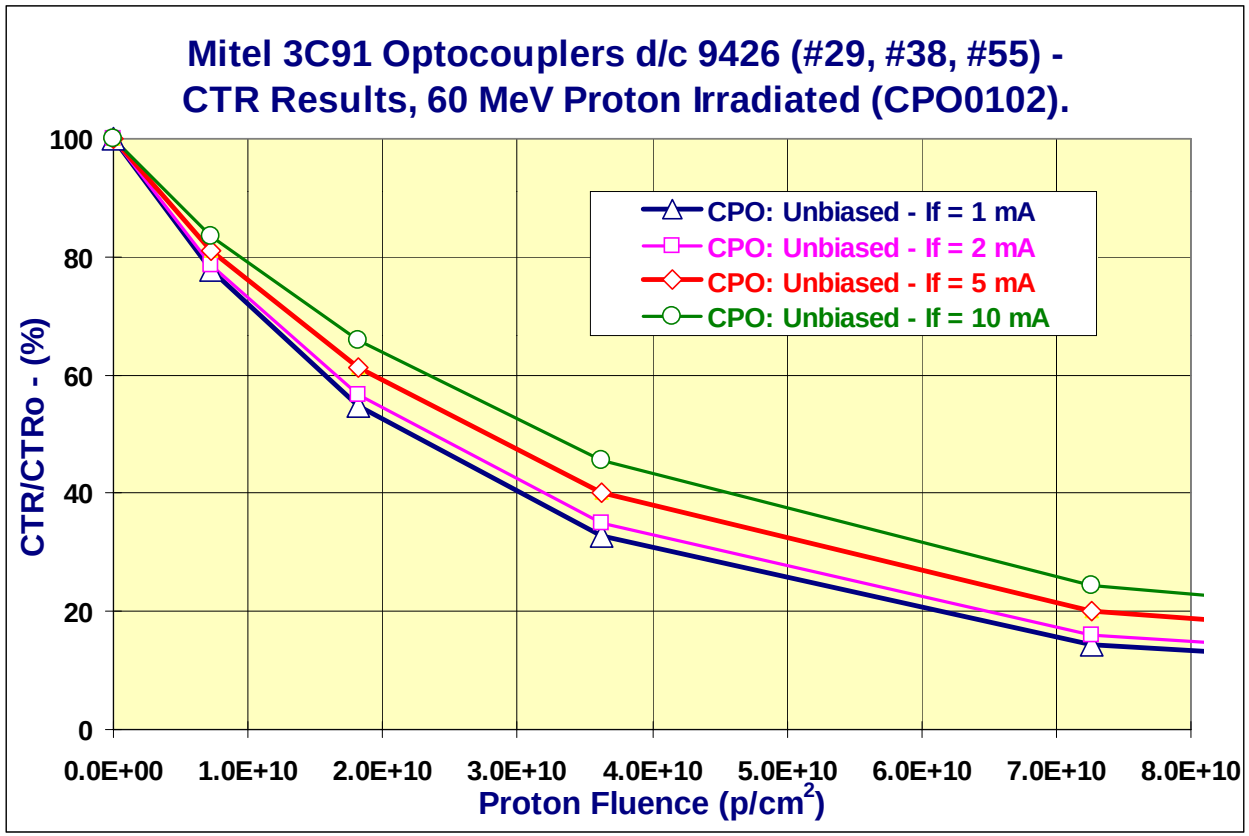
# CTR Results: Bias = 2 mA/CTR = 1 mA



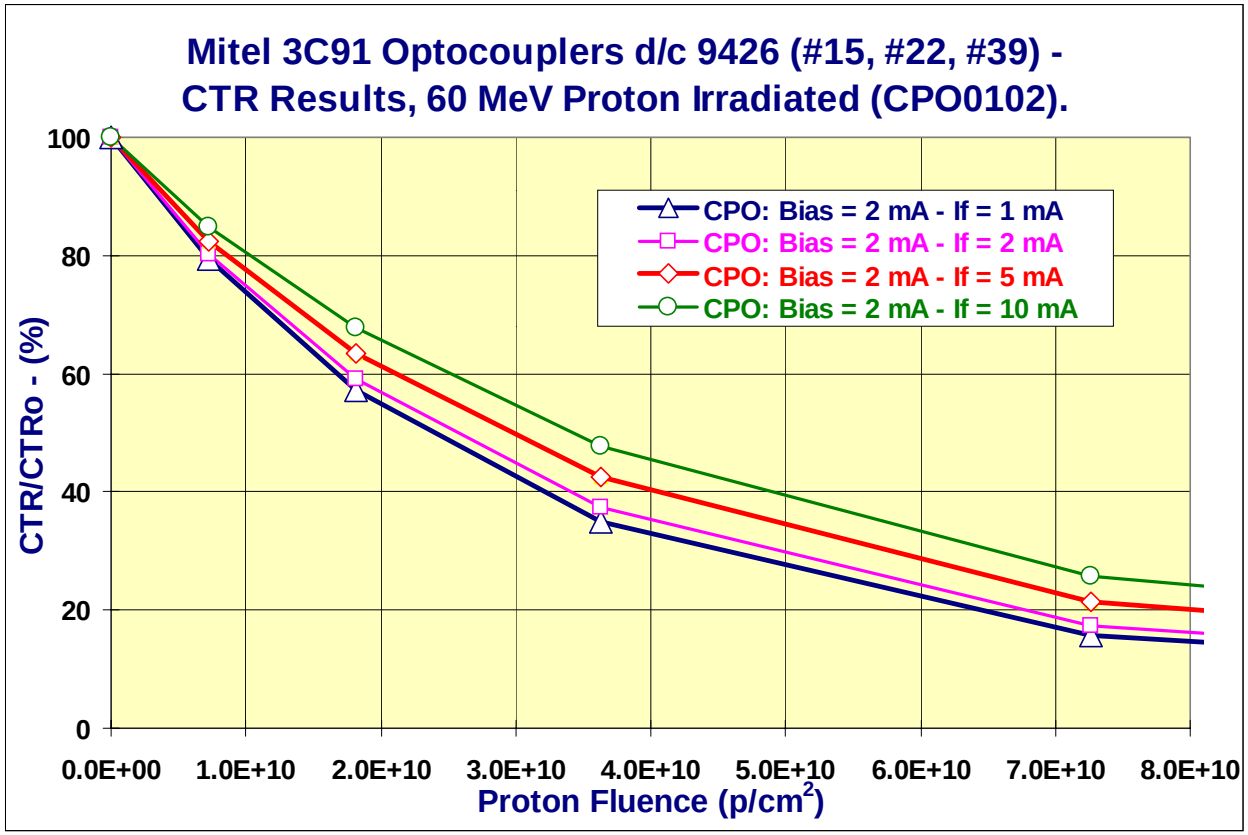
# CTR Results: Bias = 10 mA/CTR = 1 mA



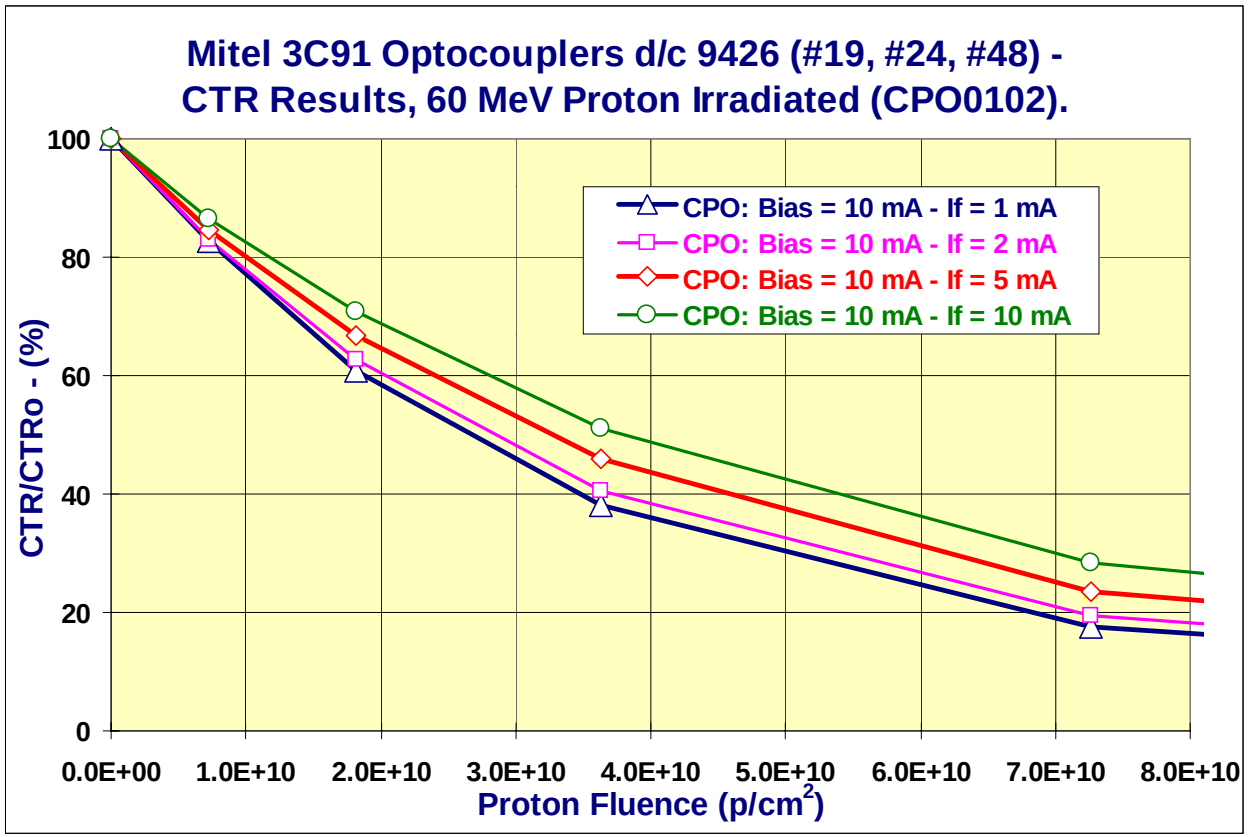
# CTR Results: Unbiased/CTR = 1, 2, 5 & 10 mA



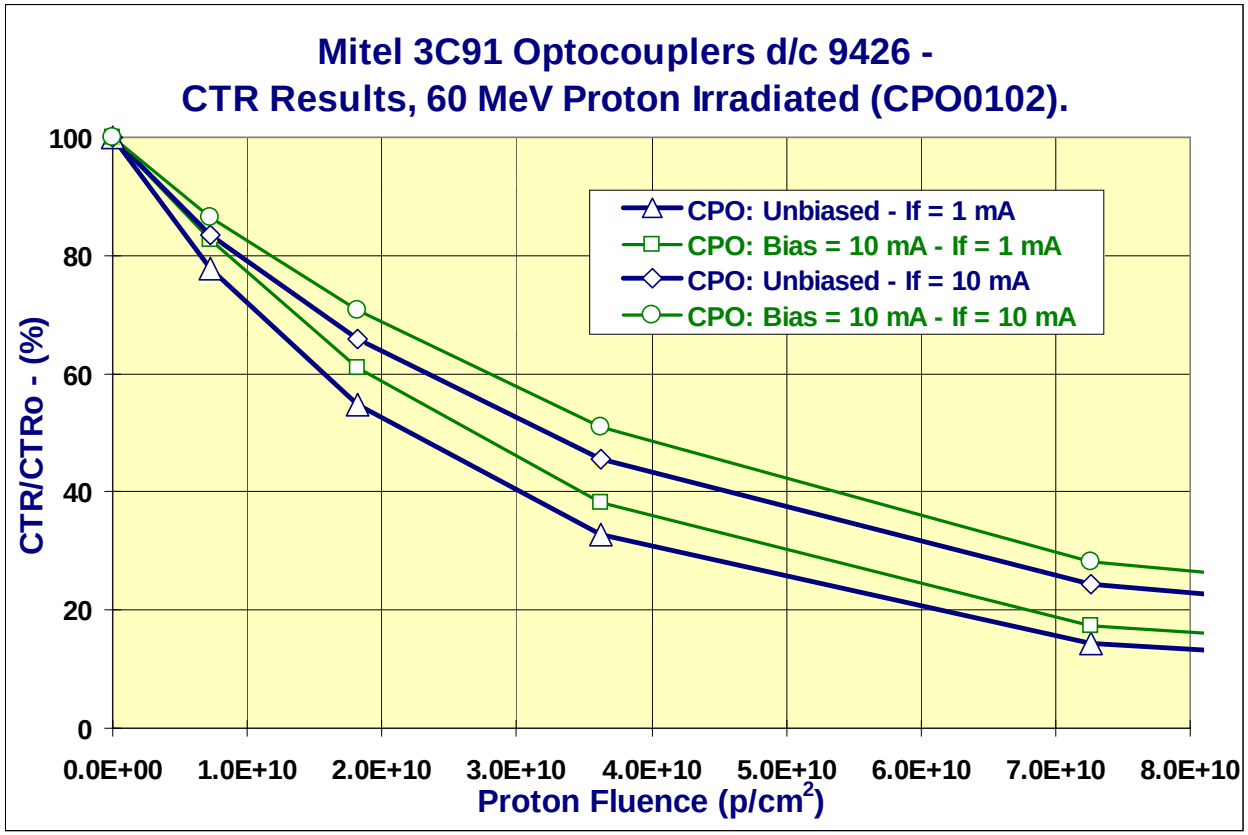
# CTR Results: Bias = 2 mA/CTR = 1, 2, 5 & 10 mA



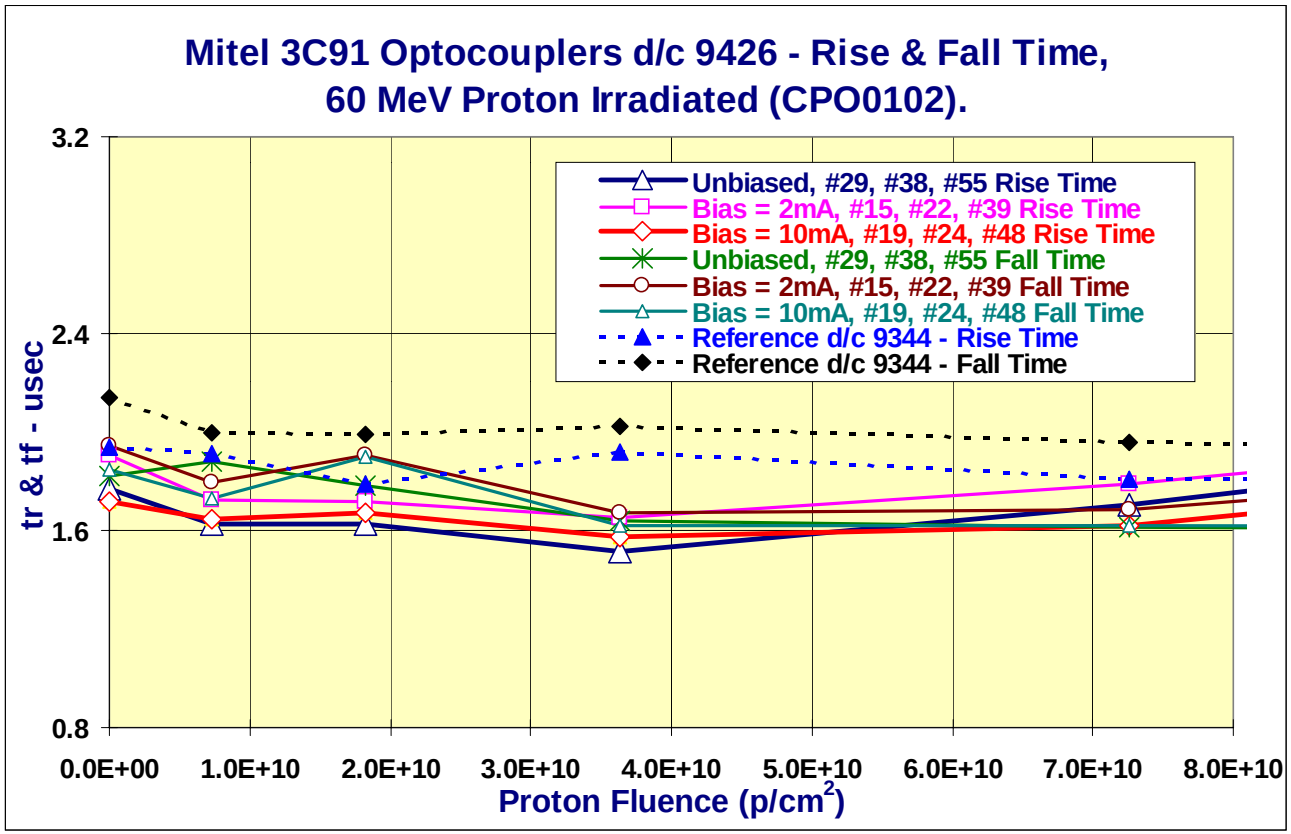
# CTR Results: Bias = 10 mA/CTR = 1, 2, 5 & 10 mA



# CTR Results: Unbiased/Bias = 10 mA - CTR = 1 & 10 mA



# Rise & Fall Time Results: d/c 9426



# ENVISAT-1 3C91C Optocoupler Testing: Conclusion

**# Within a 12 hours test slot at CPO, various Optocoupler parts were fully radiation characterized using a 60 MeV proton beam – addressing both bias and CTR conditions.**

**# Characterized parts covered:**

- **30 Mitel 3C91C parts from ENVISAT-1 (6 different date codes)**
- **7 Mitel 3C91C parts from SPOT-1**
- **4 Mitel 3C91C parts from SPOT-5**
- **7 Isolink 4N49 parts for radiation evaluation**
- **7 Micropac 4N49 parts for radiation evaluation**
- **7 Optek 4N49 parts for radiation evaluation**

**# Radiation data presented here were used for the final 3C91C Optocoupler Radiation Degradation Analysis for ENVISAT-1**

**# Final test report available – https://escies.org/public/radiation/**

D/TOS-QCA Final Presentation Day, ESA/ESTEC, Noordwijk, The Netherlands –
April 09, 2002.

# 60 MeV Proton Testing of 4N49 Optocouplers from Isolink, Micropac and Optek, Summary Results.

by

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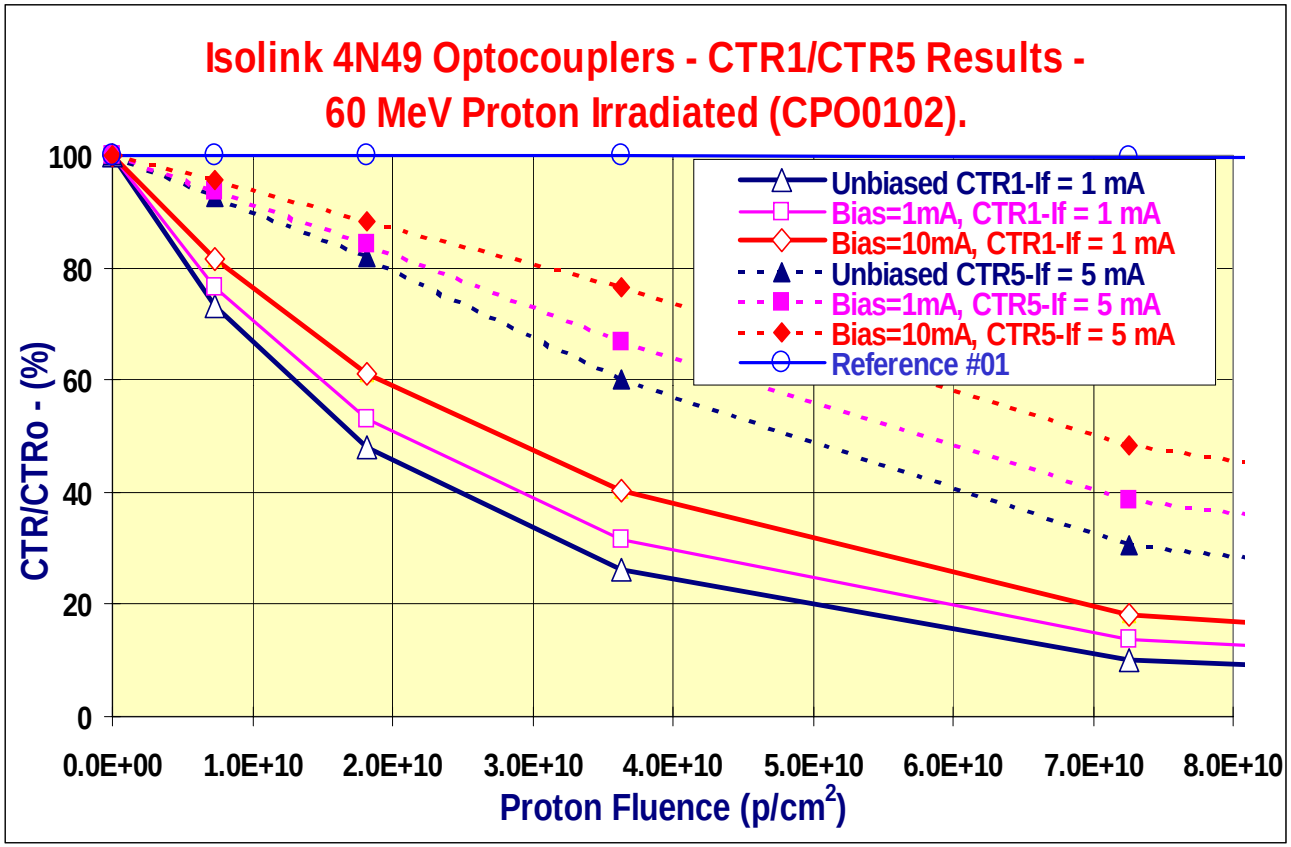
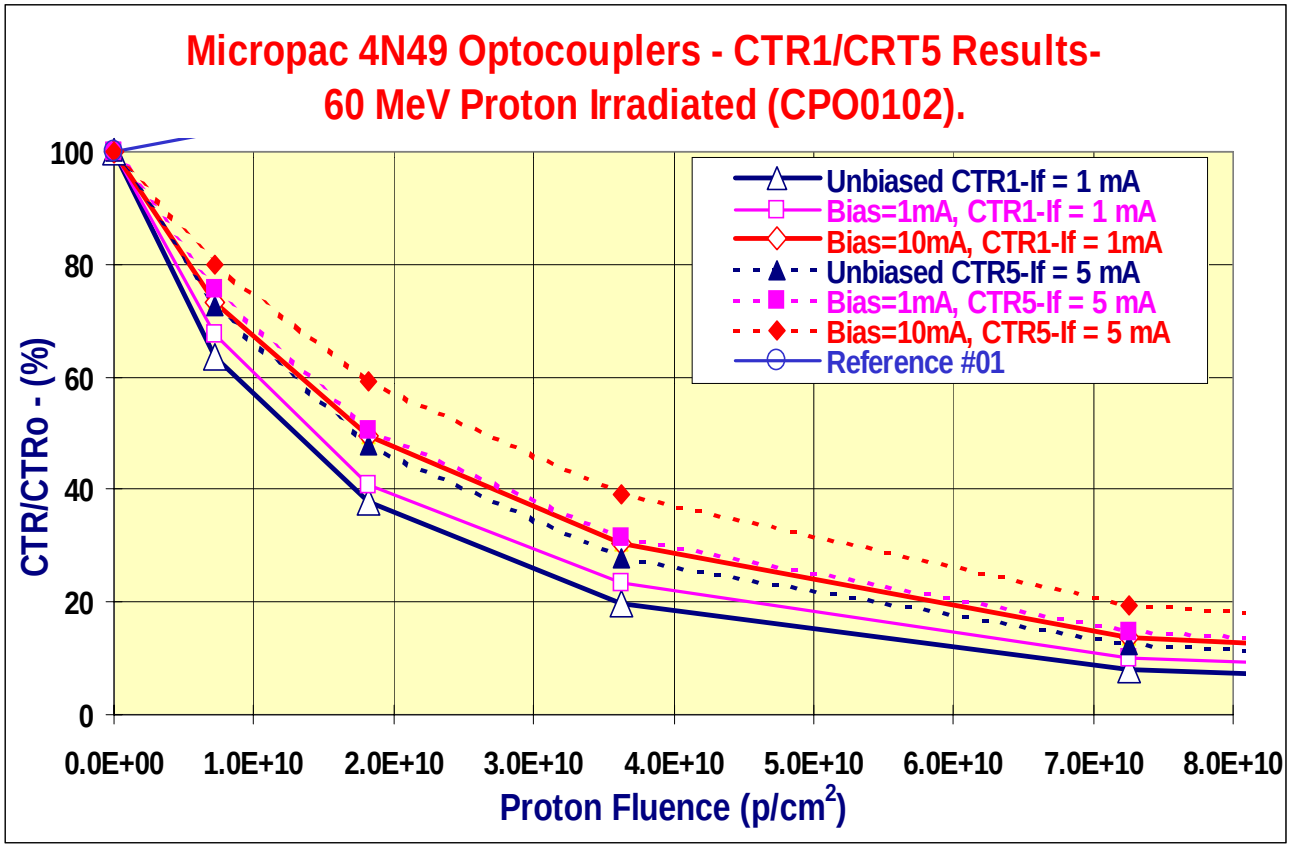
## Abstract

At the same time as the 3C91C proton testing was carried out for ENVISAT-1, a few 4N49 Optocoupler parts from Isolink, Micropac and Optek were also irradiated. Summary results covering the same biasing conditions and addressing the Current Transfer Ratio (CTR) degradation will be presented and compared with results obtained on the 3C91C.

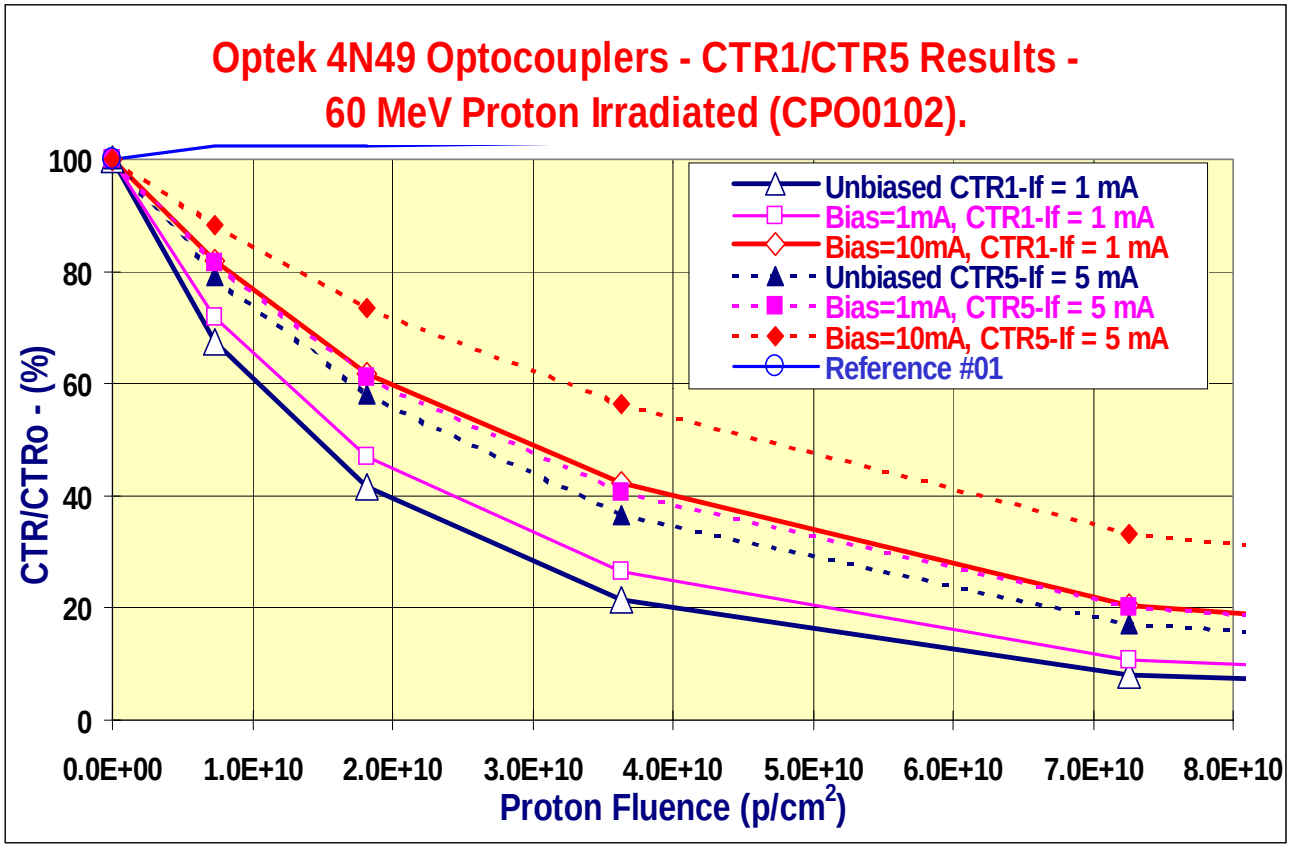
# Isolink 4N49 CTR Results:
# Unbiased, Biased 1 mA and 10 mA - CTR = 1 mA and 5 mA



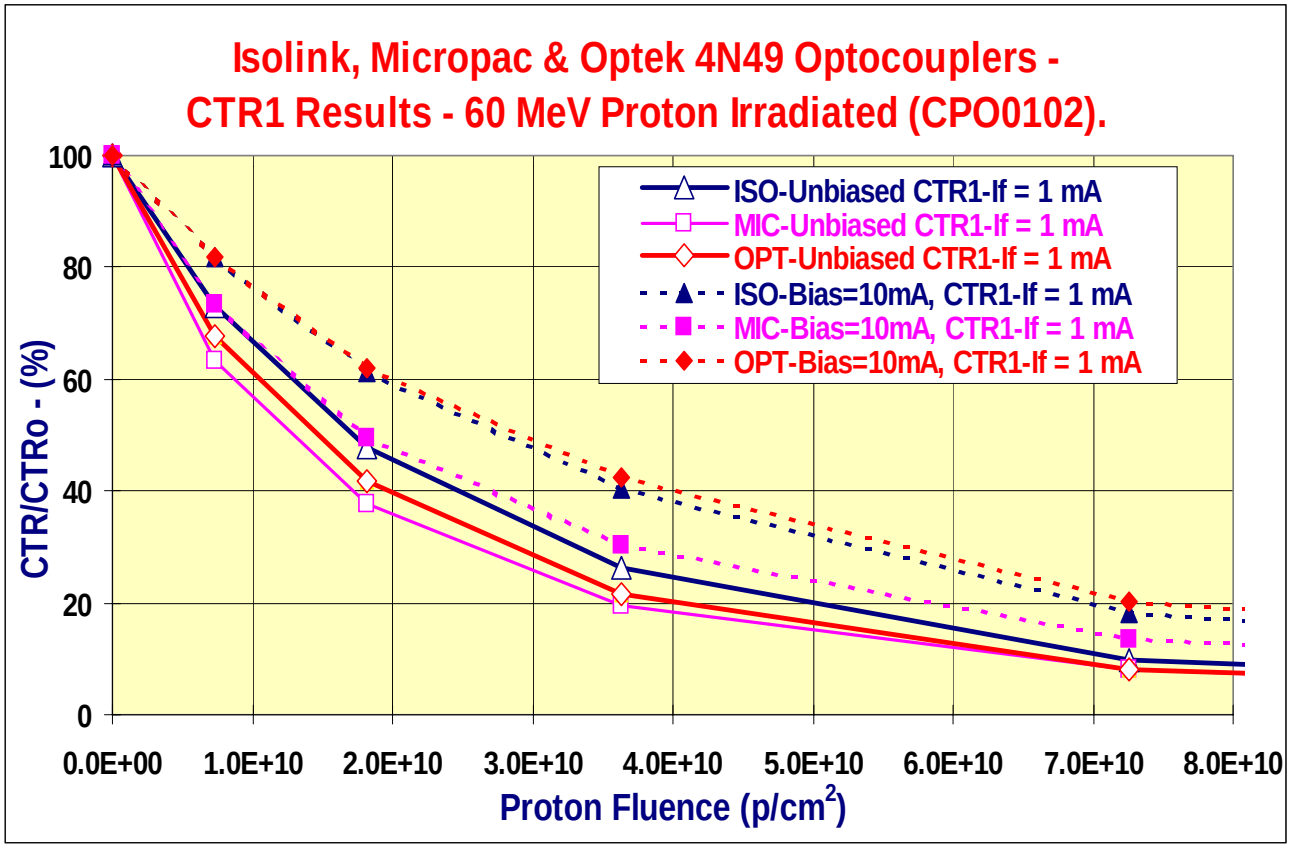
# Micropac 4N49 CTR Results:
# Unbiased, Biased 1 mA and 10 mA - CTR = 1 mA and 5 mA



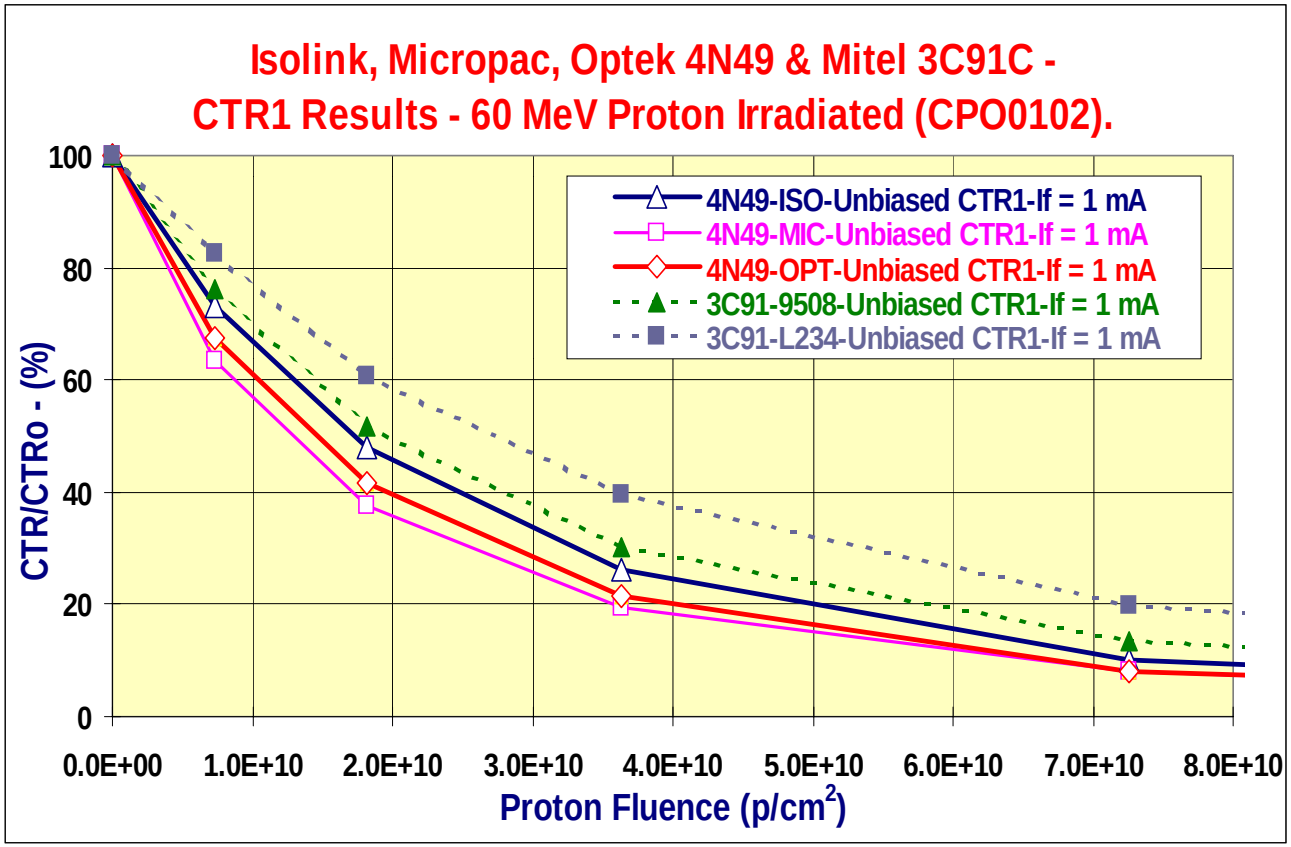
# Optek 4N49 CTR Results:
# Unbiased, Biased 1 mA and 10 mA - CTR = 1 mA and 5 mA



# Isolink, Micropac and Optek 4N49 CTR Results: Unbiased and Bias = 10 mA - CTR = 1 mA



# Isolink, Micropac, Optek 4N49 and Mitel 3C91 CTR Results: Unbiased - CTR = 1 mA



# Isolink, Micropac, Optek 4N49 Optocoupler Testing: Conclusion

**# 4N49 Preliminary radiation CTR data presented here**

**# Tested types show increased degradation of CTR when compared to the ENVISAT-1 3C91C lots.**

**# At a 60 MeV proton fluence of 3.63E10 p/cm$^2$ – 4N49 Unbiased and $I_F$ = 1 mA – the CTR was reduced to;**

- **Isolink : 26 %**
- **Micropac : 20 %**
- **Optek : 21 %**

**# Test report not available, however, presentation material to be found under –**

**5th QCA Presentation Day**
**https://escies.org/public/radiation/**