CMS/SLHC irradiation tests of current optical link components in March 06

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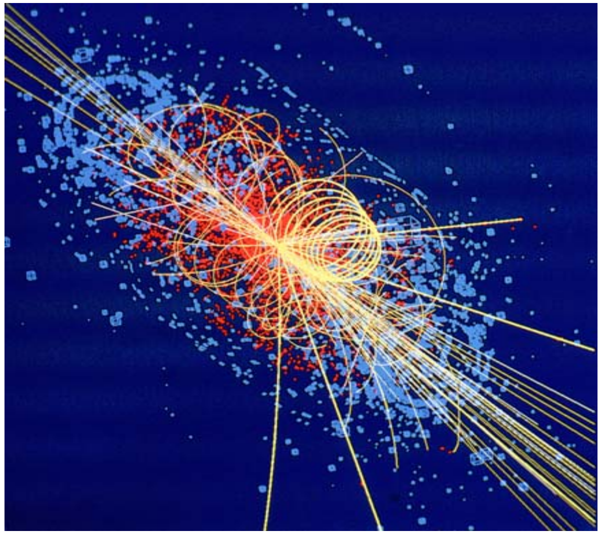
23-6-06

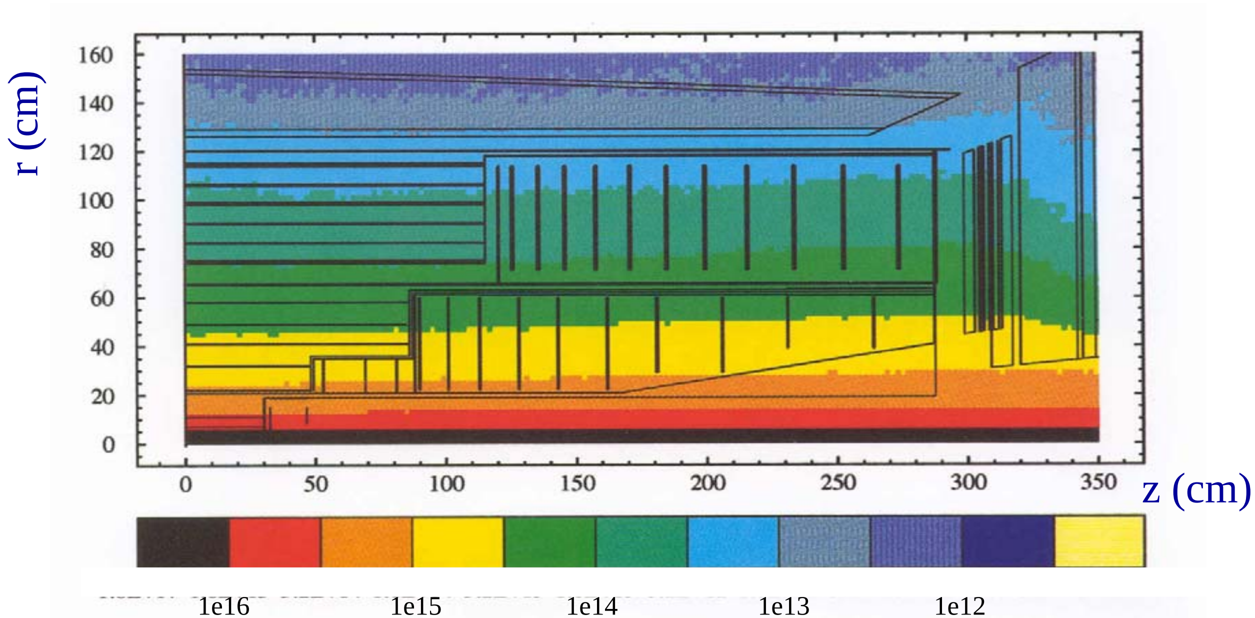
Objectives

- CMS
  - Measure the ‘ultimate limit’ for current components
- General
  - Get more experience of SLHC testing
  - Use a new gamma source (CMF at SCK-CEN)
  - Improve upon last test to high neutron fluences (12/04)
    - L-I measurements over wider range
    - Spectrum measurements on all lasers
  - First collaboration with ATLAS (Oxford, Taiwan)

Guess/Assumption - SLHC Operating environment



- Temperature: Tracker -10°C (TBD)
- Magnetic field 4T
- Radiation environment
  - $2\times10^{15}\pi/cm^2$ ($E_\pi \sim 200MeV$)
  - 1MGy

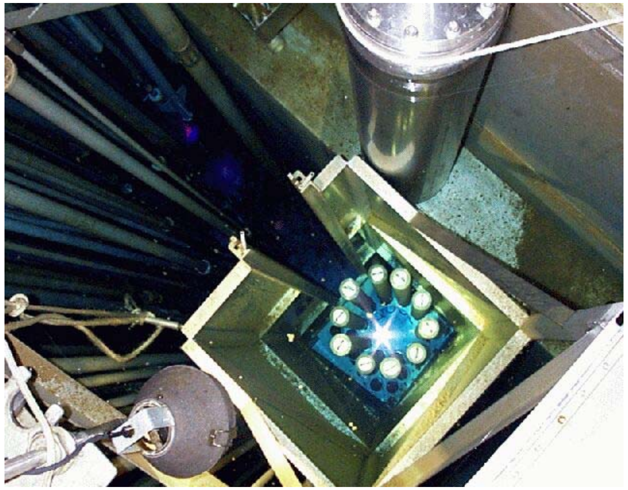


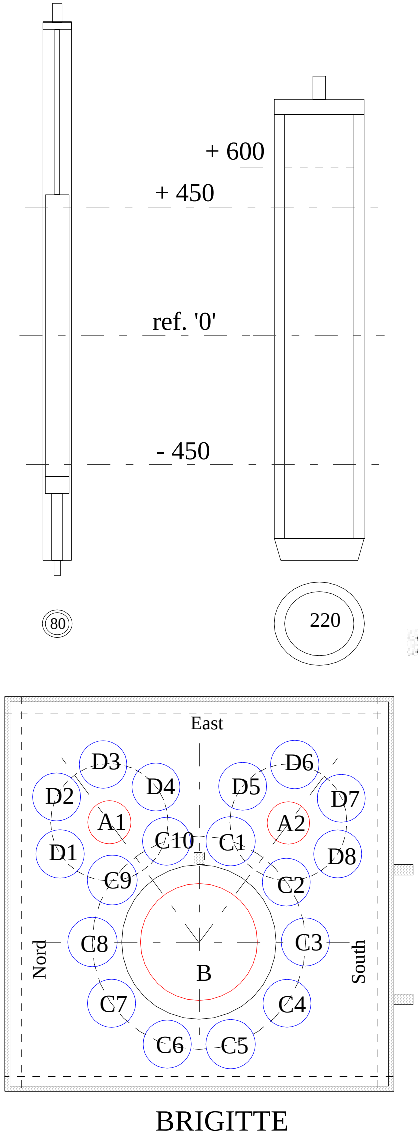
Charged hadron fluence (/cm^2) over (10^6pb^{-1})
(10x LHC over first 10 years)

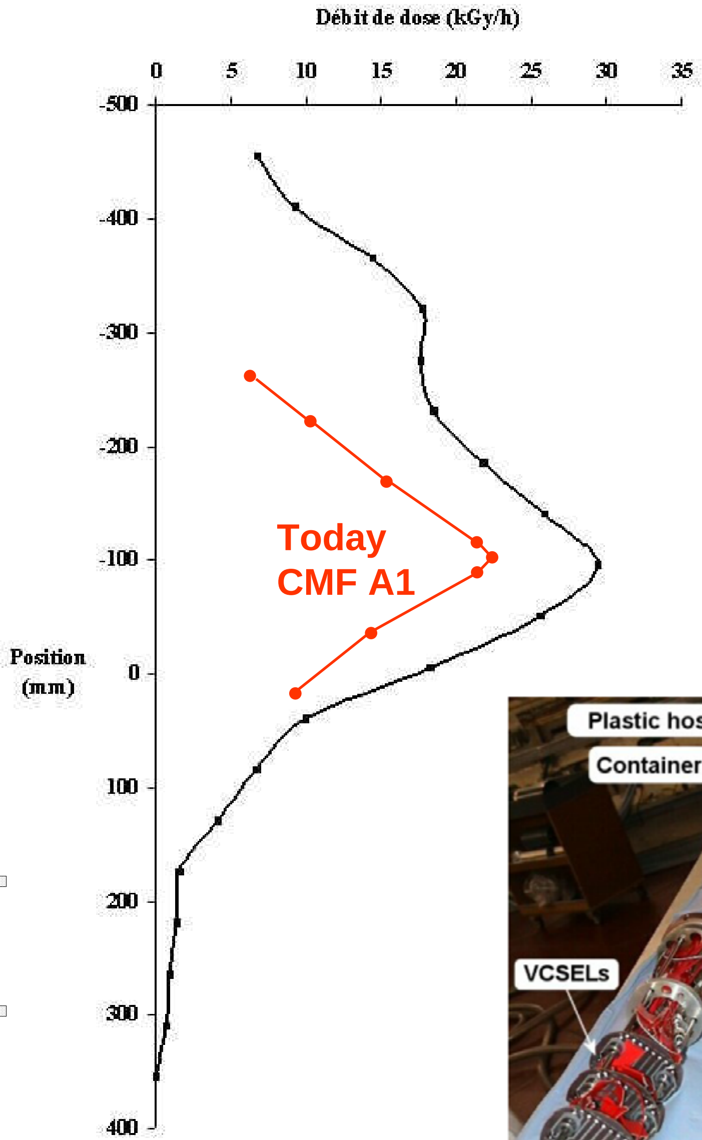
Test facilities

- High dose
  - SCK-CEN (Belgian Nuclear Research Institute in Mol)
    - Brigitte/CMF facility, high dose rate ^{60}Co gamma
    - Irradiation 15-18/3/06
- High fluence
  - CRC at Univ.Louvain-la-Neuve
    - T2 source – high flux neutrons, mean energy 18MeV
    - Irradiation 20/3/06

Brigitte/CMF gamma facility at SCK-CEN







	BRIGITTE		
	Pos. A	Pos. B	
Gamma source	Spent fuel or ^{60}Co		
Dose rate	10 -50 kGy/h	5 - 40 kGy/h	0.1
Instrumentation			
On-line biasing capabilities	yes		
Microelectronic test capabilities	yes		
Photonic test capabilities	-	yes	
Environmental control			
Standard temperature control	50 - 200 °C		3
Pressure control	2 bar		
Atmosphere	Air, inert gas		A
Gas analysis	Available		
Dosimetry	yes		
Available volume			
diameter	80 mm	220 mm	
height	900 mm	900 mm	
Useful volume			
diameter	80 mm	220 mm	
height	600 mm	600 mm	

TABLE
General overview of the SCK-CEN irradiation facilities. The useful volume indicates the

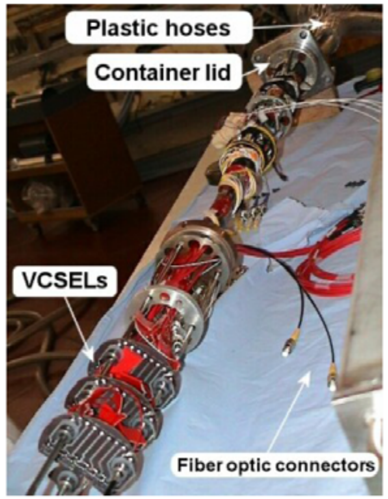
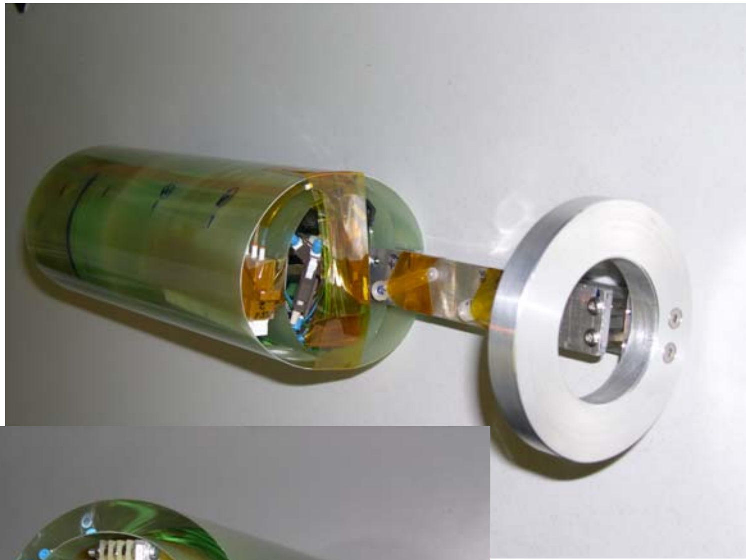
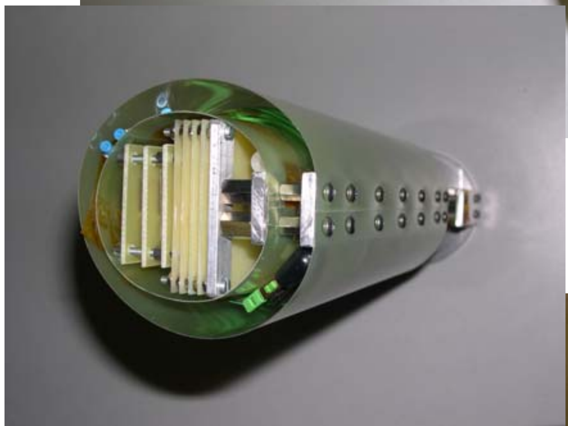


Fig. 5. Typical irradiation set-up for the position A of the BRIGITTE facility. Vertical-Cavity Surface Emitting Lasers (VCSELS) were biased and measured during the irradiation at constant temperature.

Gamma irradiation samples and details





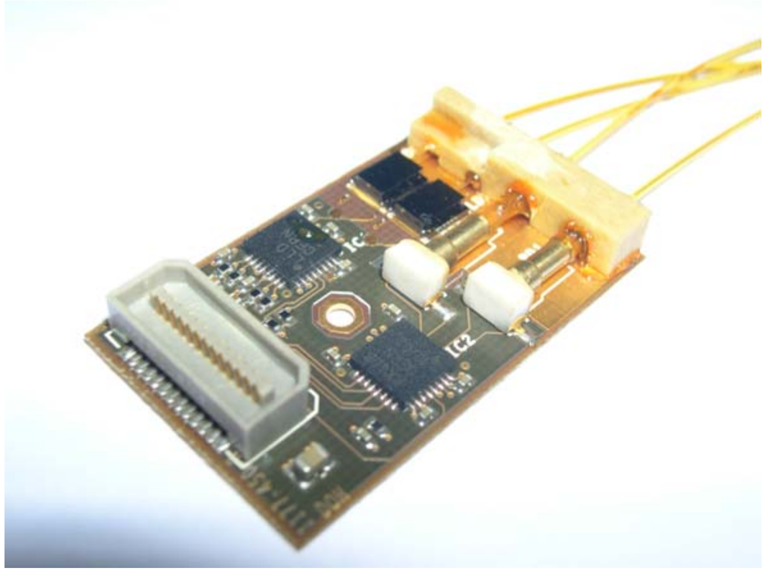
- Max dose 1.5MGy
  - Max rate was 21.7kGy/hr (70hrs)
  - 40C
  - in air

- Variety of parts included
  - 2x Digital optohybrids (DOHs)
  - 4x lasers
  - 5x MU-terminated SM patch-cords
  - 1x MFS-sMU terminated single mode 12-way fanout

- "Quick and dirty" passive test
  - No on-line measurement
    - only before and after tests
  - Identify weak and strong parts

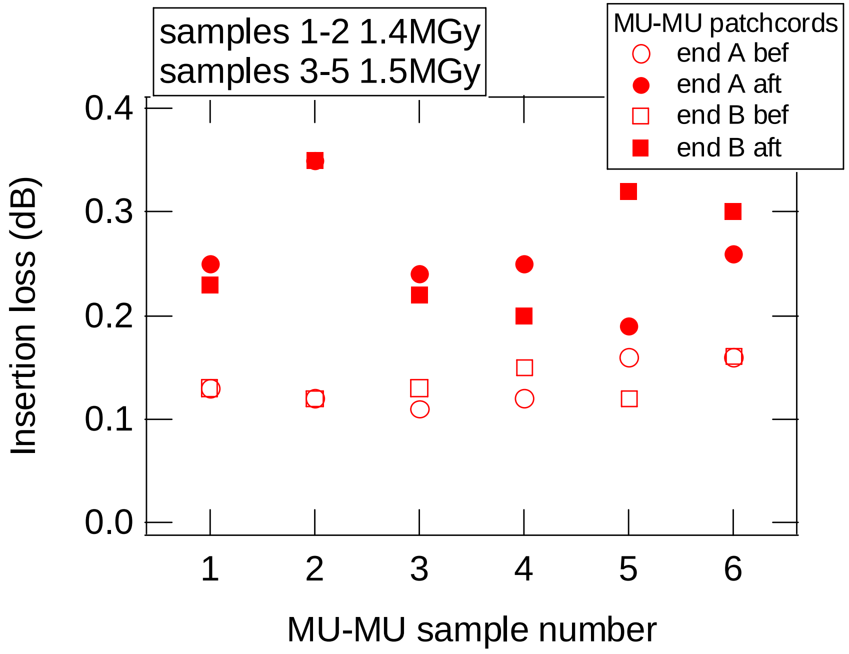
- Dose rate measured by SCK-CEN
- Include also CERN RPL dosimeters
  - Not relying on these since calibrated only to <1MGy

Basic results from gamma irradiation



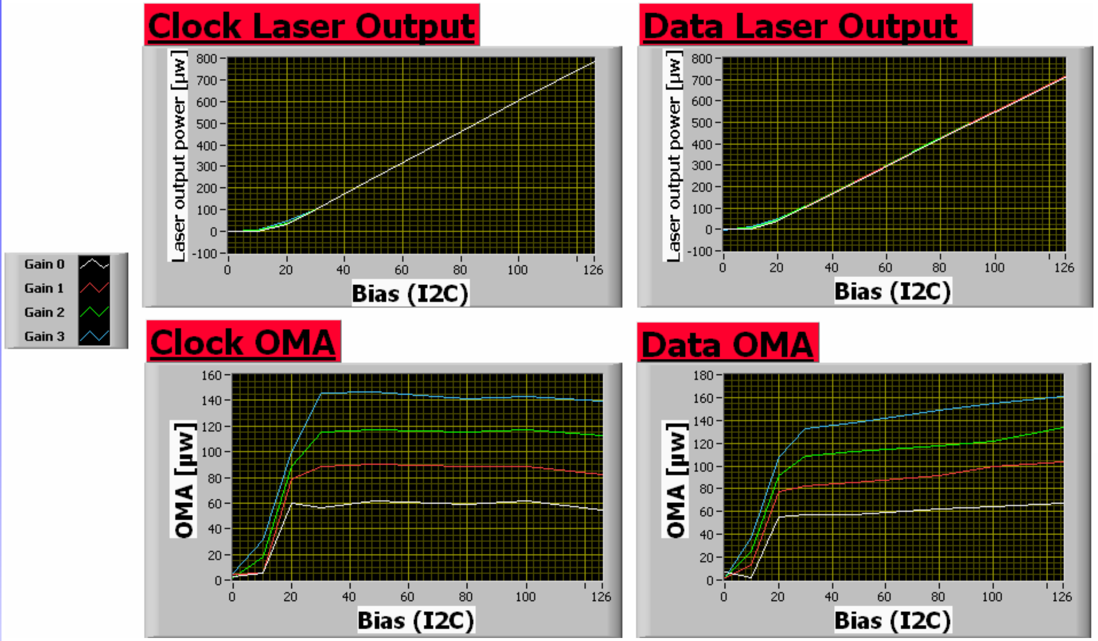
- Basic observations of digital optohybrids after 1.5MGy
  - Parts darkened - fibres, glue, PCB
  - Very smelly! Outgassing a problem?
- Seems mechanically weaker (embrittlement)
- QR codes OK
- No new fibre buffer ruptures

MU-MU SM-fibre patchcords after gamma irradiation



- 6 MU-MU samples
  - 4.5m long single mode
  - ‘Standard’ Ge-doped fibre
  - 1-2 acrylate coated
  - 3-6 PE-coated
- Dose 1.5MGy
  - Additional loss
    - 0.1 to 0.2 dB

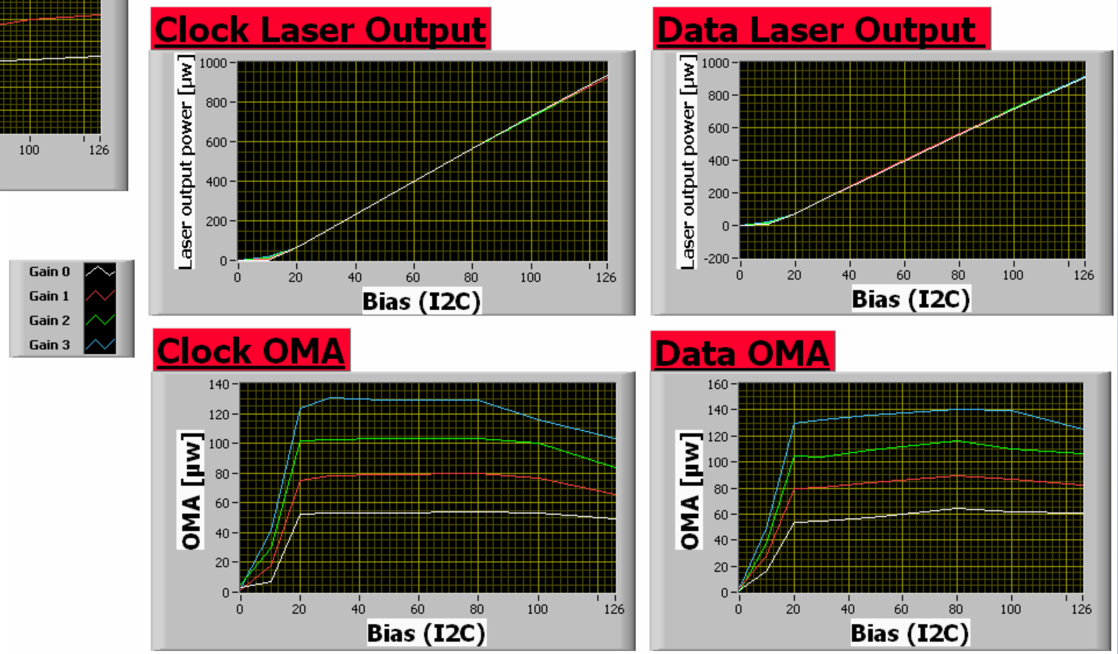
DOH Results (Tx side) gamma irradiation

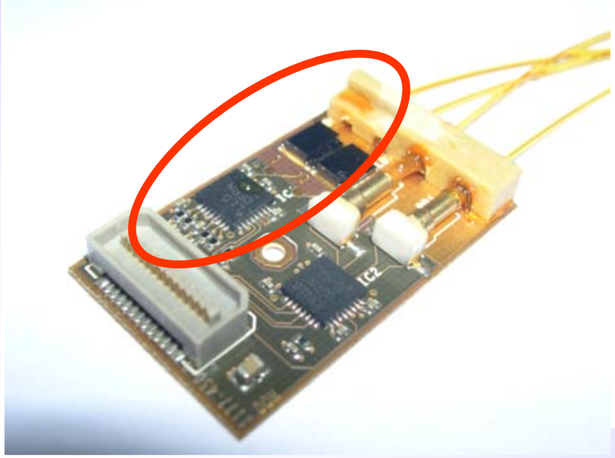


Changes small…..

Before irradiation

After 1.5MGy irradiation

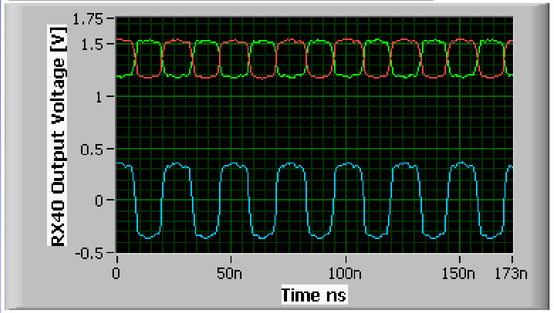


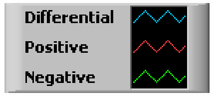


DOH Results (Rx-side) gamma irradiation

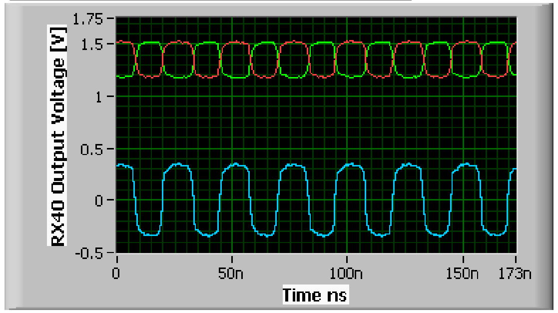
Before irradiation

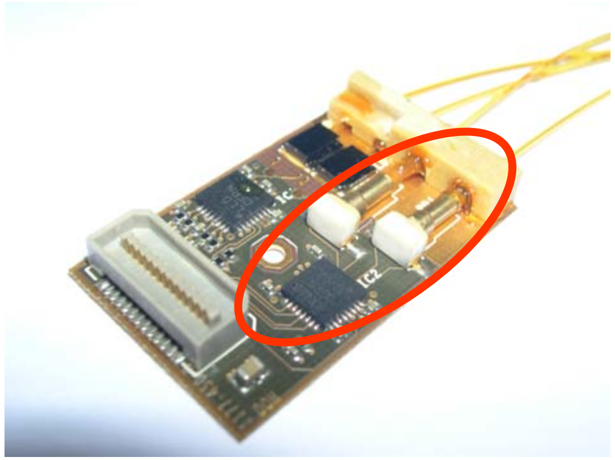
Clock Output Graph





Data Output Graph

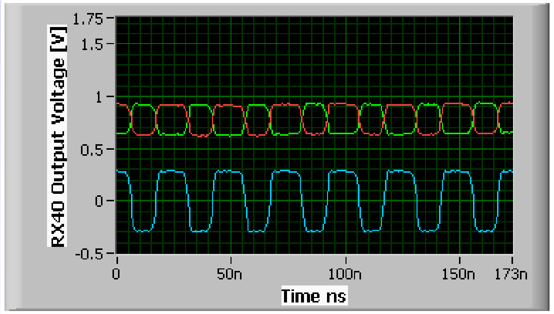


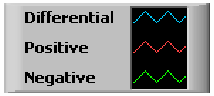


RX output before irradiation, nominal operating conditions

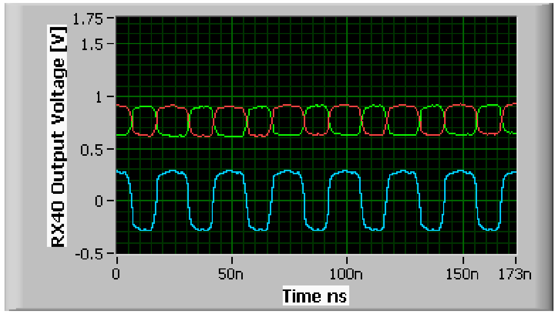
After 1.5MGy irradiation

Clock Output Graph





Data Output Graph



RX output after irradiation, nominal conditions

Problems with output levels and duty cycle

Results interesting but conclusions uncertain since irradiated unbiased (shorted)

Summary gamma tests

- Tried new gamma source
  - Successful (mainly thanks to lot of help from SCK-CEN)
    - CERN dosimetry inadequate
      - Needs some more work there…
- Quick and dirty test (no connections, or bias)
  - Interesting results
    - Positive
      - loss in fibres small
      - TX (LLD ASIC + laser diodes) OK
      - Optical cables ok
      - Optical connectors appear ok
      - QR codes ok
    - Not sure/negative
      - RX (RX40 + photodiodes) affected, but not conclusive since not under bias
      - PCB and connector material strength/reliability

Test facilities

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- High fluence
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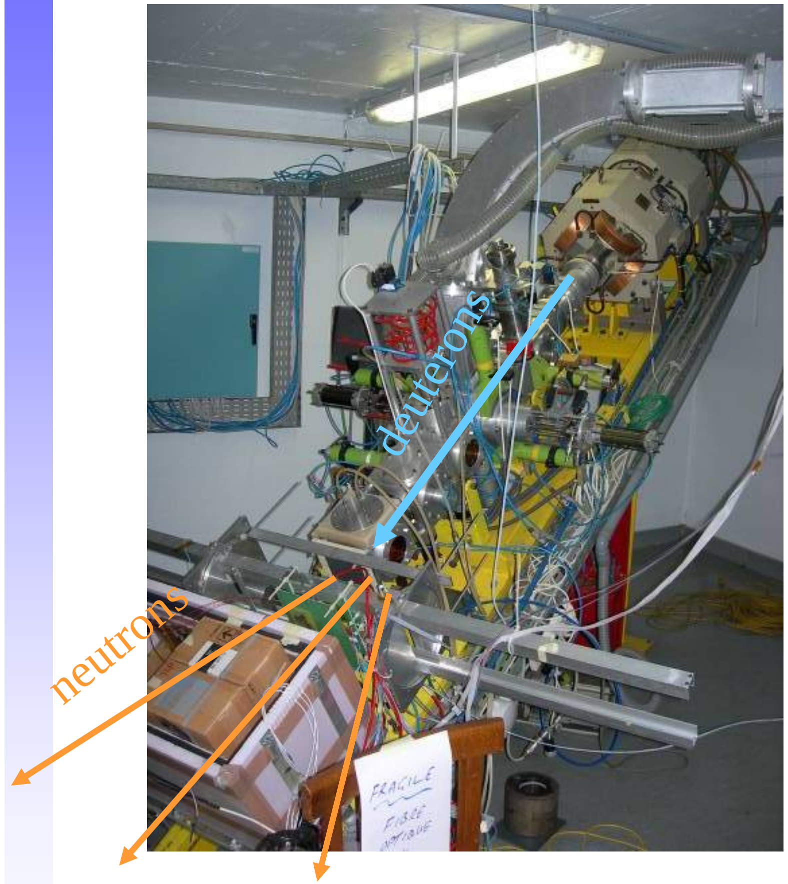
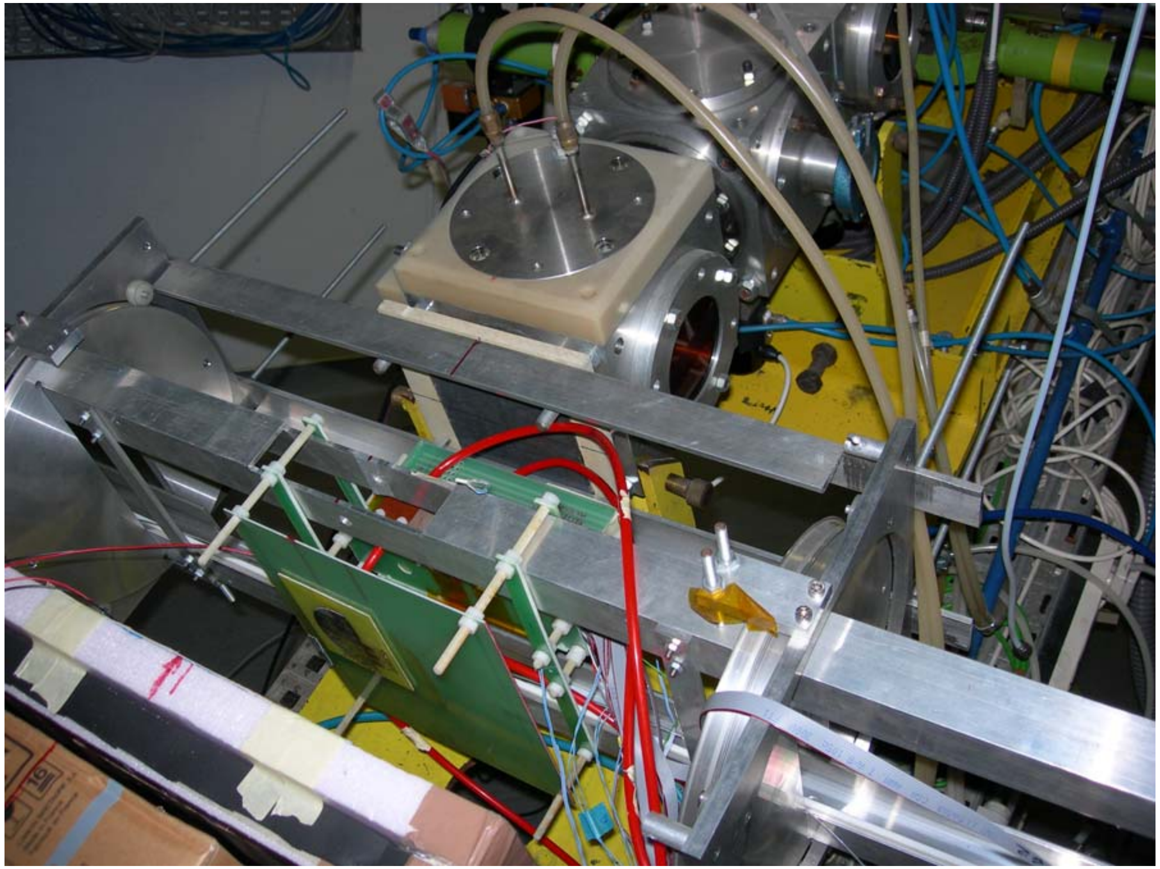
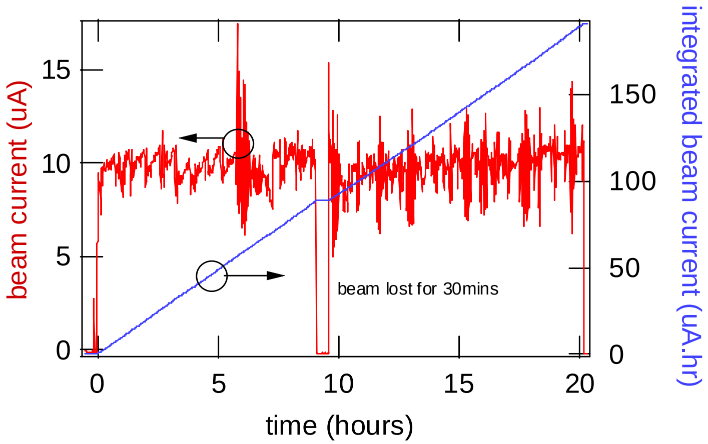
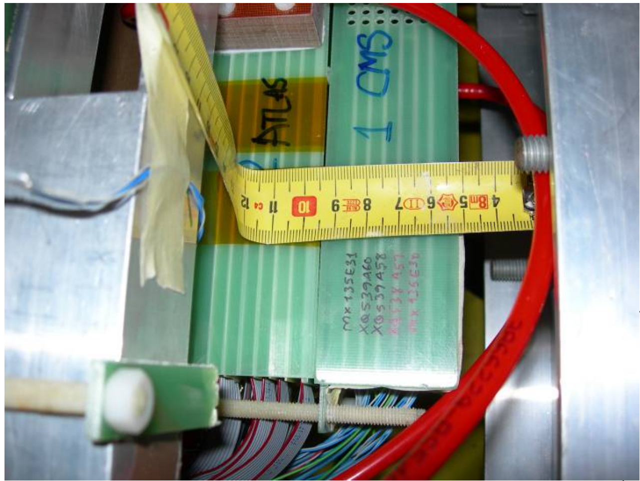
Neutron irradiation at CRC/UCL





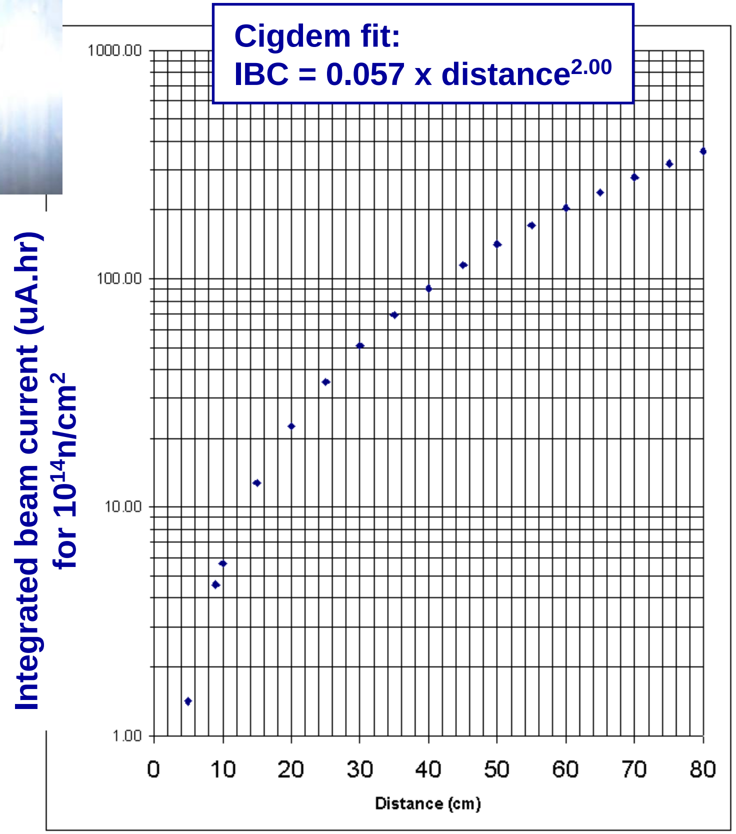
Neutron irradiation details





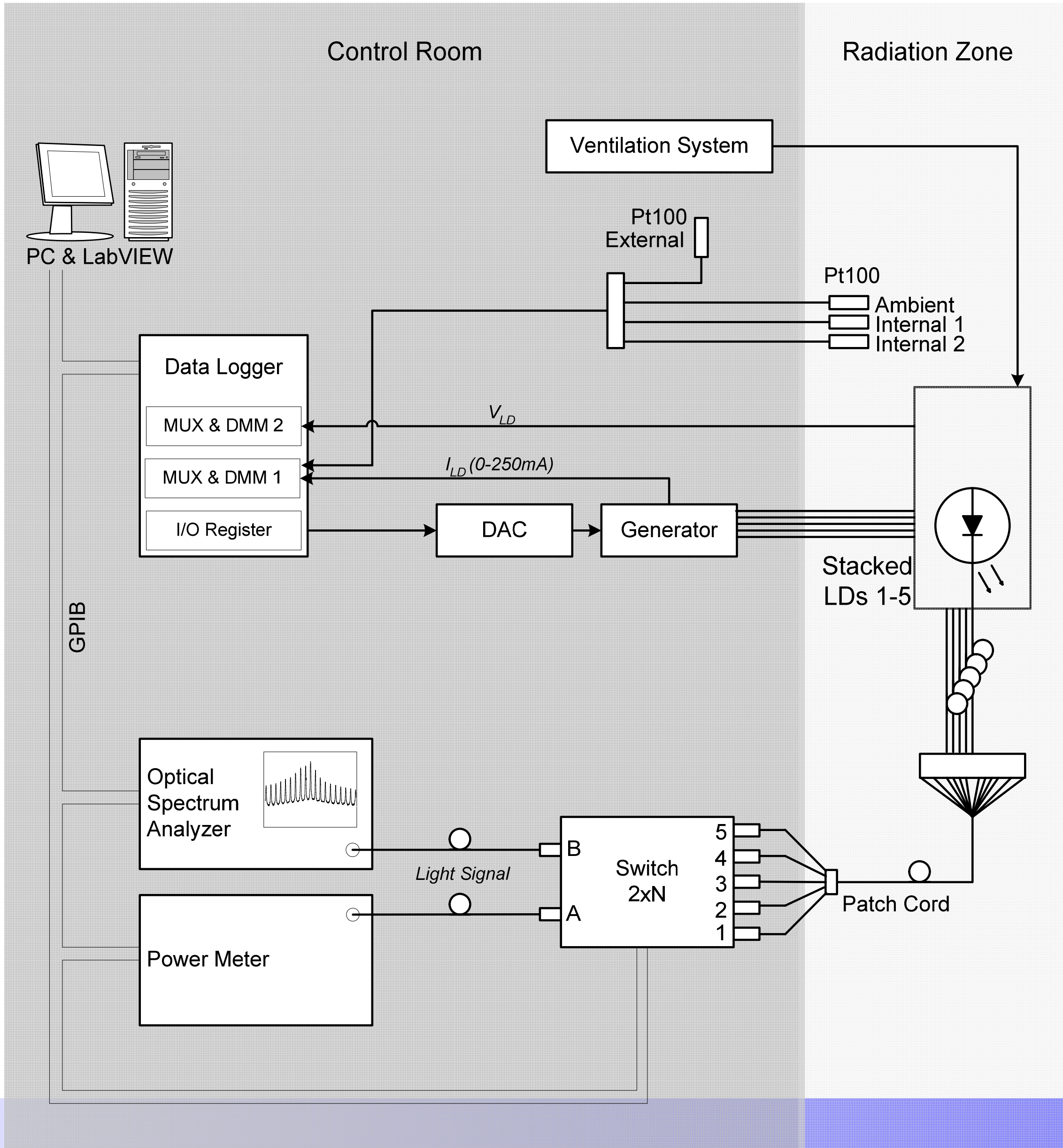
- Nominal beam current 10uA
  - Monitored at target
- Stability not too bad
  - One period with lost beam
  - Learned how to restart cyclotron!
- Integrated beam current 192uA.hr

Distance (mm)	Laser S/N	Fluence (10^{15}n/cm^2)
76	MX135A30	5.8
81	XQ538A57	5.1
86	XQ539A58	4.6
92	XQ539A60	4.1
96	MX135A31	3.7



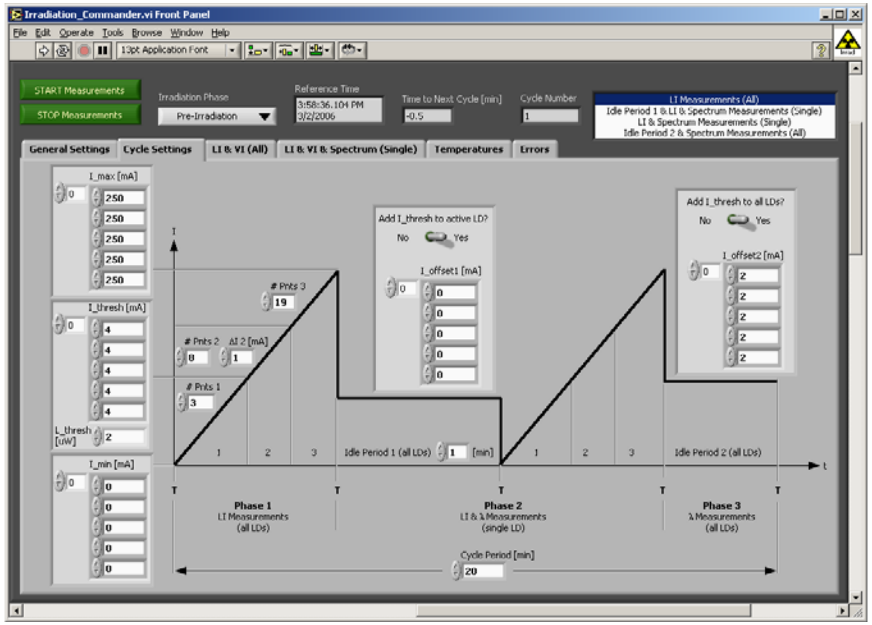
Setup

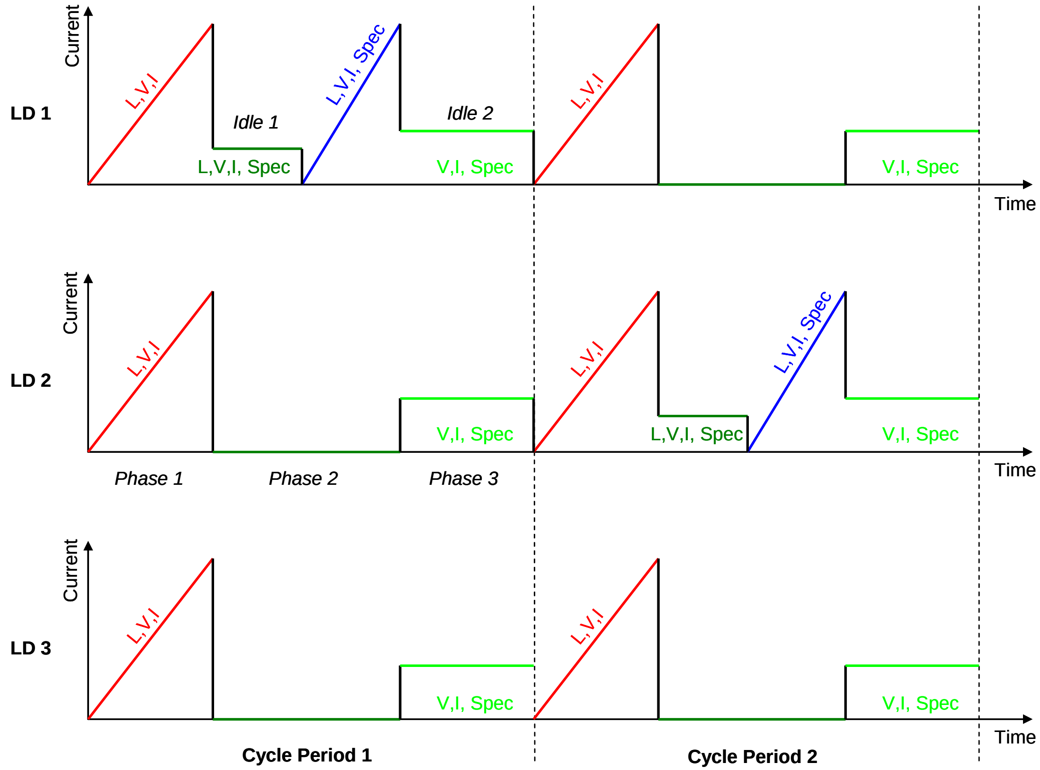
- Similar to previous test
- Some improvements:
  - 2xN Optical switch
  - High current L-I foreseen from start
  - New software
    - based on thermal resistance test-bed
  - Ventilation not modulated



Laser measurements during neutron test

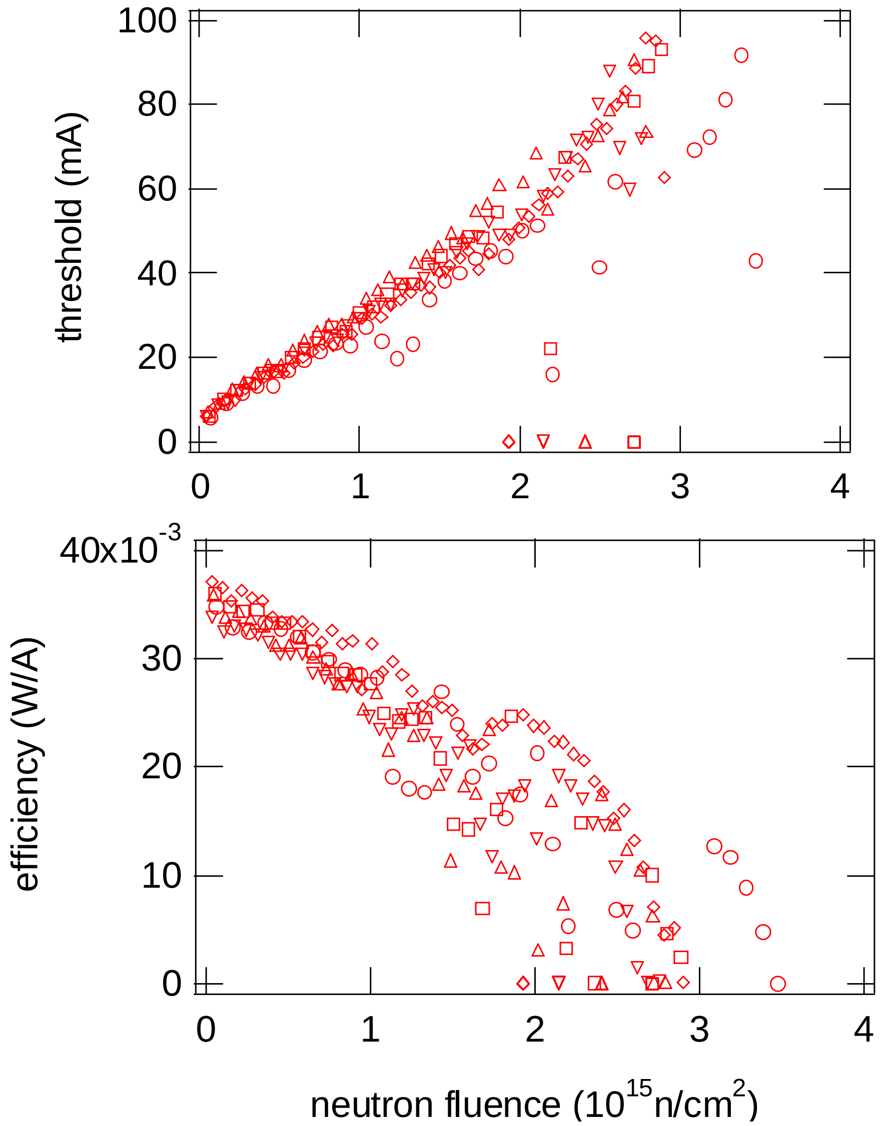
- Varied set of measurements
  - Phase 1 L-I & V-I,
  - Phase 2 L-I & V-I + spectrum
  - Phase 3 dc + spectrum
- Very ambitious
  - No time yet to complete analysis….





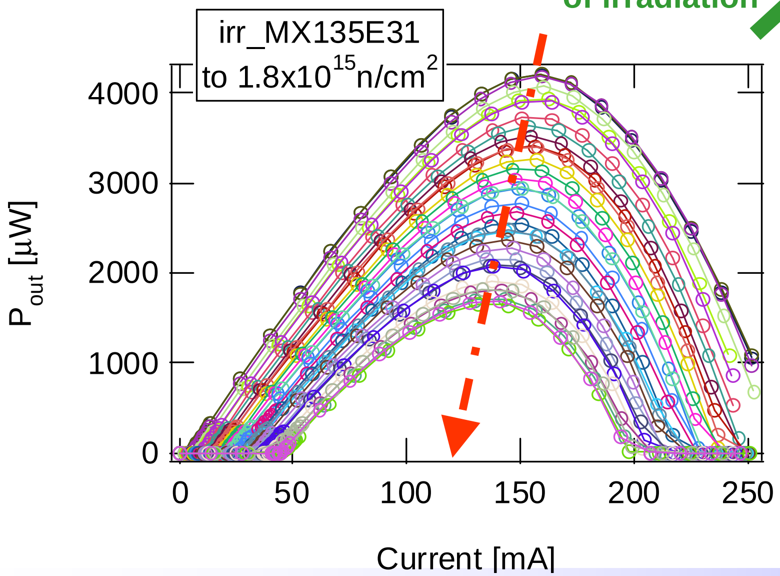
New results: Laser threshold and efficiency

- Threshold and efficiency
  - Similar effect in all lasers
    - Similar to last test
    - ‘Death’ 2-3x10^{15}n/cm^2
    - Should anneal over time

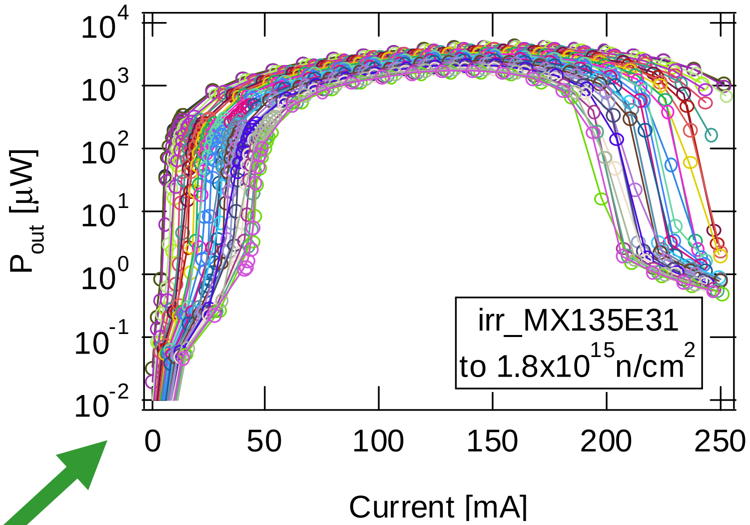


Laser L-I

- Some very nice results
  - until S/W had problems…!

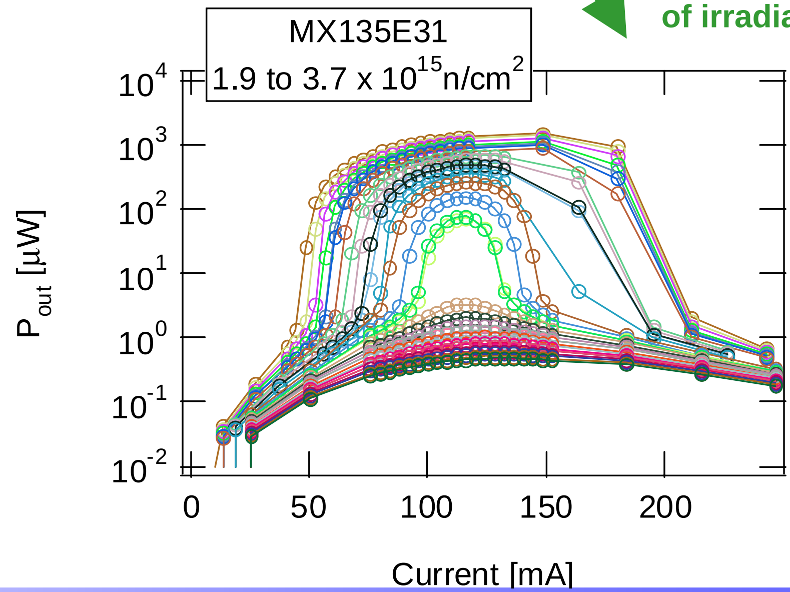


Same plot
On log scale



First half
of irradiation

Second half
of irradiation



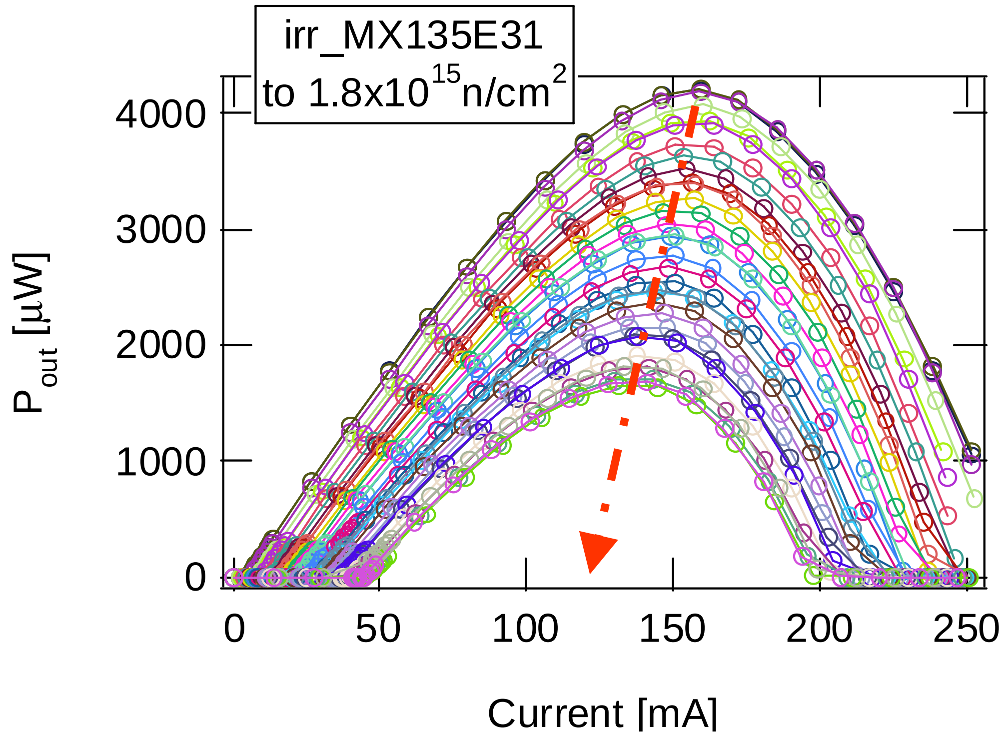
Next steps...

- Based on first few L-I to high current should be able to predict end-of-life with only short irradiation to low fluence
  - (e.g. few 10^{14}n/cm^2)
  - Needs a little more analysis to demonstrate power of the method

- Lower cost
  - Maybe - this usually depends on time more than fluence…

- Less activation
  - 3 months since last test and devices still quarantined

- Other work remaining (large amount!)
  - Analysis of thermal (spectrum) measurements
  - Build model of threshold and efficiency change (and internal temperature) versus current and fluence.



Experience with ATLAS

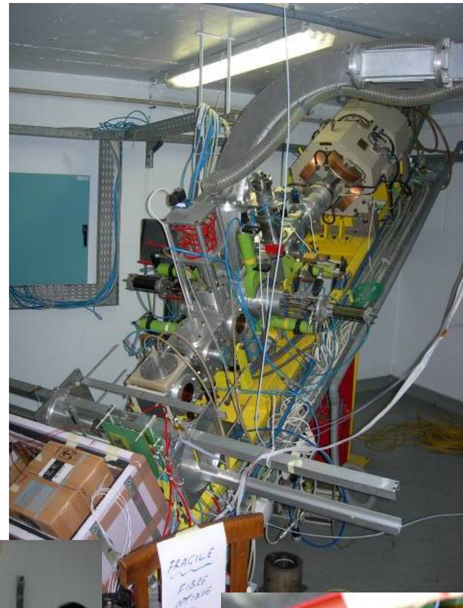
- Was relatively easy to work together
  - at level of integrating testing at same facility
    - Minor problems overcome
      - better preparation on both sides would help
        - Hardware (mechanical support)
        - Cables etc – should use rugged cables for testing if possible
        - Requirements for dose/fluence

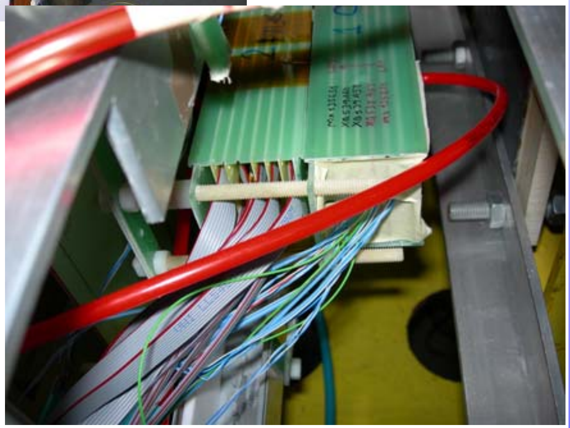
- Next steps for collaborative work of this kind?
  - ‘Academic’: NIEL and bulk damage
  - ‘Experimental’: More irradiation tests (ionization, displacement, SEE)
      - Ideally, need to go more frequently than 1/year to have momentum
      - Can propose a project at UCL if we want to seek EU ‘access funds’
  - ‘QA’: Common test procedures and comparable reporting

Summary and Conclusions

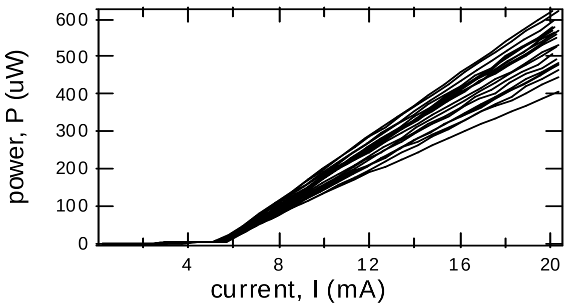
- Both tests interesting and informative
  - Gamma
    - Most components seem to survive quite well to high doses
      - except DOH Rx (but unbiased is not appropriate mode to test with)
    - Material outgassing and embrittlement a problem?
    - Need to see if new gamma source ok to use with on-line measurements?
      - much more complicated setup!
  - Neutrons
    - Max. fluence for current lasers confirmed
    - Rollover versus fluence measured quite nicely
    - Thermal analysis still to do
  - ‘Usual’ problems related to requiring more preparation
- Very nice experience with ATLAS and CRC
  - Can think about future
    - Follow-up tests, academic work, standard procedures

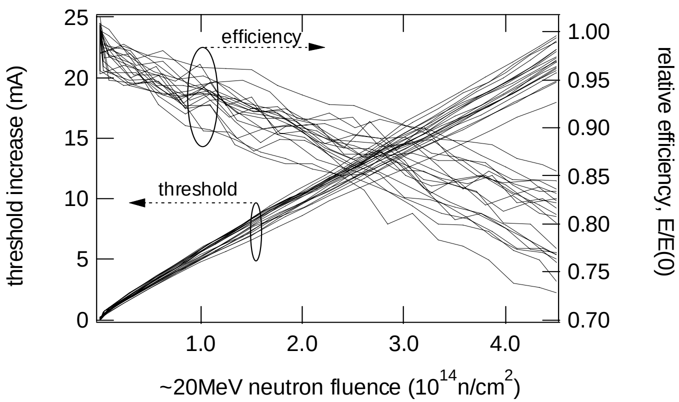
Many hands make light work

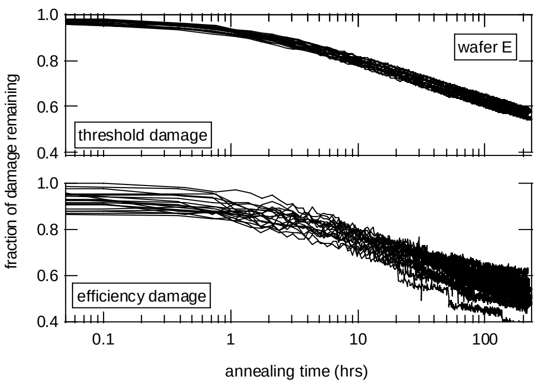




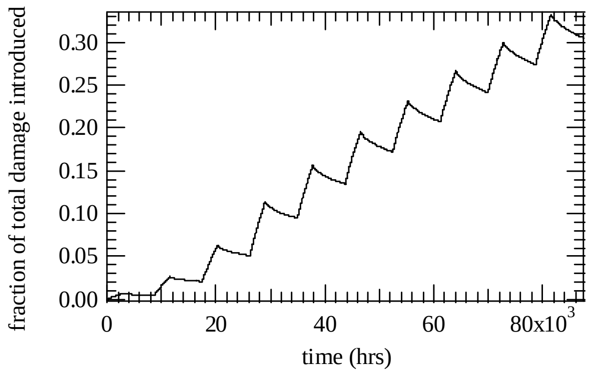
Reminder - Current ST/Mitsubishi lasers AVT data

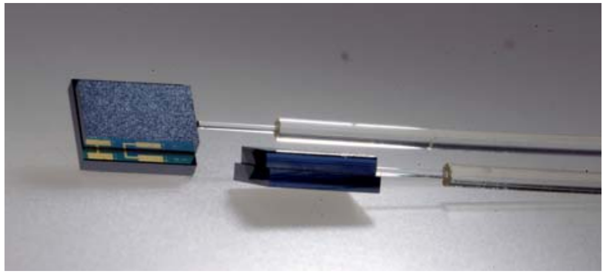






- The current lasers perform well for our intended application
- Damage proportional to fluence
  - After 4.5×10^{14}n/cm^2
    - (equivalent to $1\times10^{14}\pi$/cm^2 at 200MeV)
    - threshold increase ~20mA
    - efficiency loss ~20%
- Significant annealing
  - Expect only 6mA and 6% efficiency loss in worst case in CMS





- Ultimately, how much radiation can they resist?
  - Lasers woked up to 3×10^{15}n/cm^2 at UCL (12/04)
  - But could be 3x higher fluence over 10years if annealing included
    - Still to be checked…..