Irradiation of the Optical Transmitters Test Results

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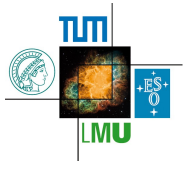
19th International Workshop on
DEPFET Detectors and Applications
10-13 May, 2015. Kloster Seeon

supported by:
Heinz Maier-Leibnitz Zentrum
Cluster of Excellence: Origin and Structure of the Universe,
BMBF



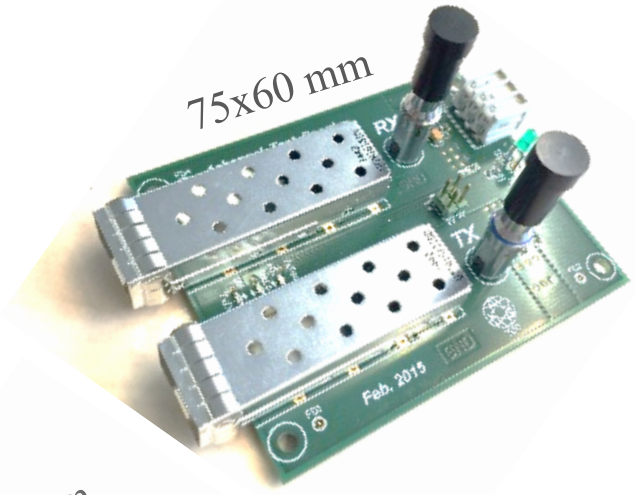
Bundesministerium
für Bildung
und Forschung

FRM II
Forschungs-Neutronenquelle
Heinz Maier-Leibnitz

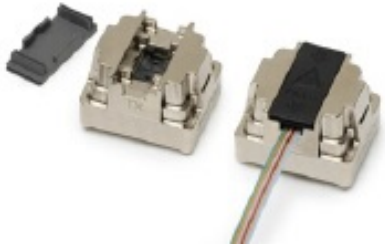
Outline

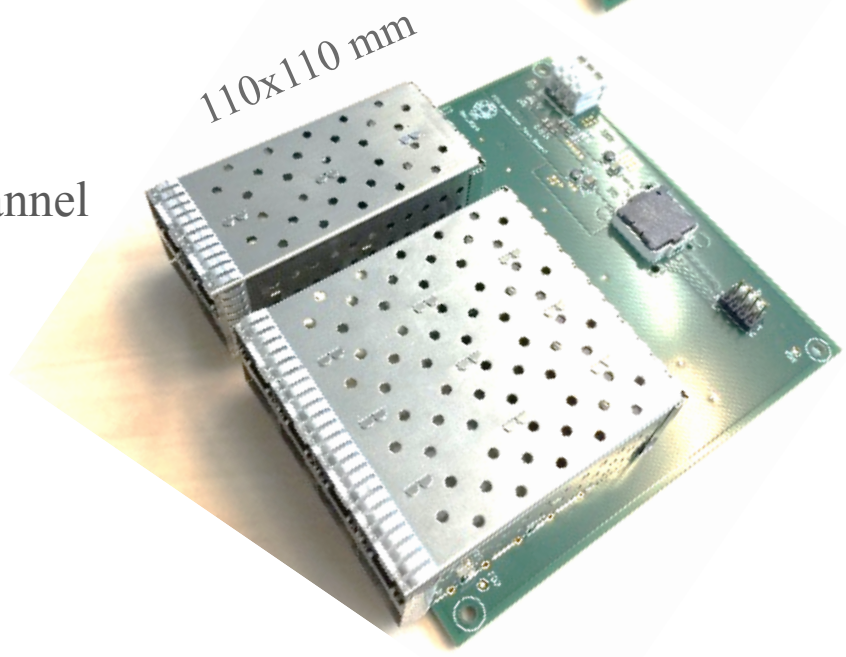
Devices and test boards

1. Glenair 050-301
   - 850nm, 1.25Gbps
   - 3.3V, 300mW Power consumption
   - Size 24x8x8 (mm)



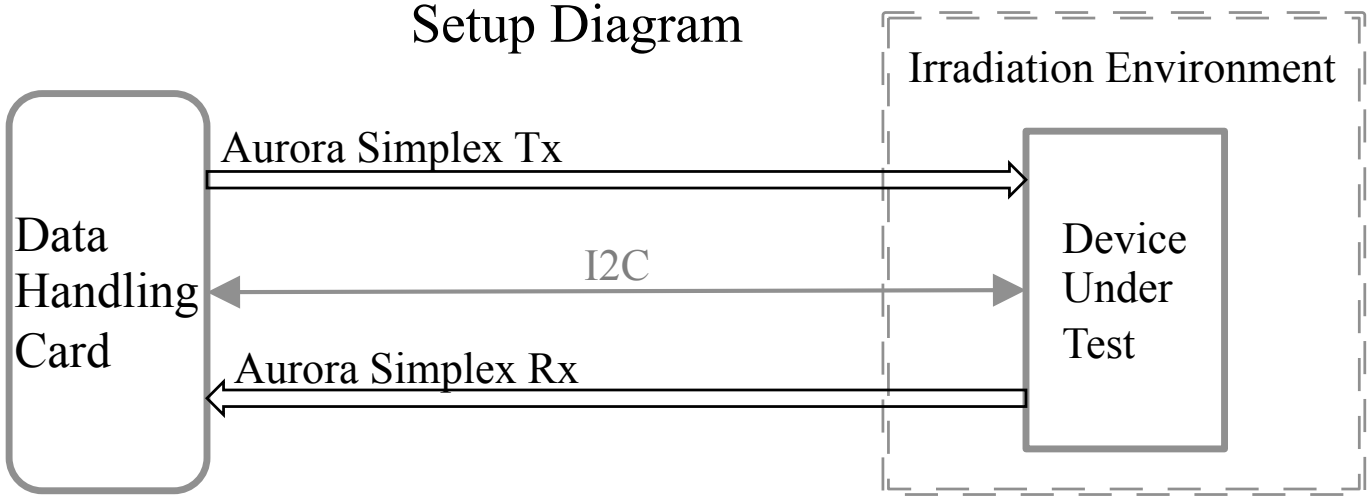
2. Avago AFBR-811FN1Z
   - 12 channels, 850nm, 10Gbps per channel
   - 3.3V, 2.5V; 100mW per channel
   - Size 22x19x15 (mm)





Setup

Setup Diagram



1. Data Handling Card

- AMC form factor with Xilinx Virtex 6
- Installed on the 6U standard carrier card

2. Cables between DHC and DUT

- Data transmitted using the SFP passive copper cable to DUT
- Data received via optical cable from DUT
- I2C lines for the device control

3. Irradiation Environment

- Neutron at NECTAR in FRM II, TUM Garching: **$2.3 \cdot 10^{8}$ cm^{-2} s^{-1}**
- Gamma ray from Co^{60} at Helmholtz Centre Munich,
  I: **1.33 Gy min^{-1}**
  II: **9 Gy min^{-1}**

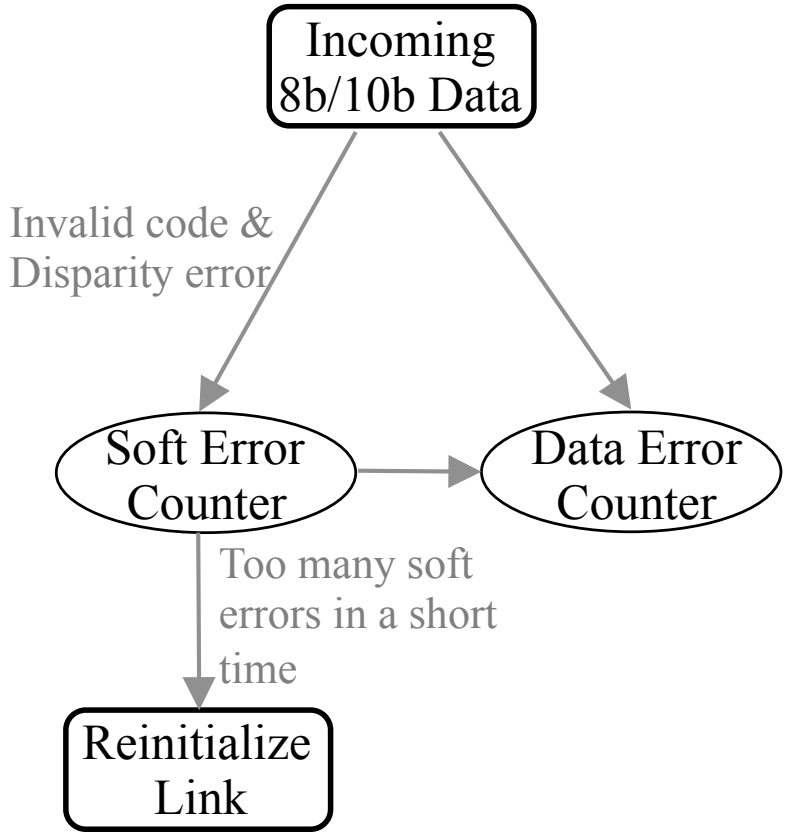
Firmware

1. Aurora Simplex Protocol

- 125Mhz reference clock
- 2 Gbps with 8b10b coding
- Back channel with sideband signal

2. Error counter at the receiving side

- Link down counter
- Soft error counter
  1) Corrupted data is not valid in 8b/10b table
  2) Corrupted data is in the table but has the disparity error
- Data error counter



Outline

Requirement

- Neutron fluence in Belle II from the simulation

$$\text{Rate1} = 1.25 \cdot 10^{11}\ \text{cm}^{-2}\ \text{year}^{-1}$$

So, the 10 years' dose is

$$\text{Dose} = 12.5 \cdot 10^{11}\ \text{cm}^{-2}$$

⇩

- Neutron rate at NECTAR in FRM II

$$\text{Rate2} = 2.3 \cdot 10^{8}\ \text{cm}^{-2}\ \text{s}^{-1}$$

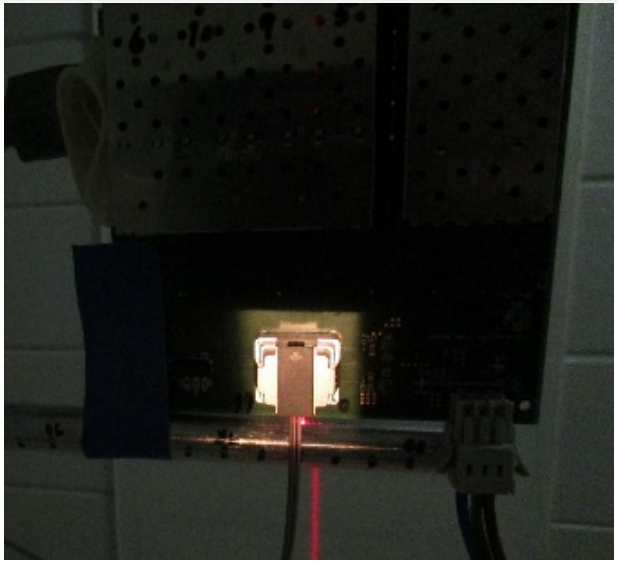
So, the equivalent irradiation time of the 10 years' dose is

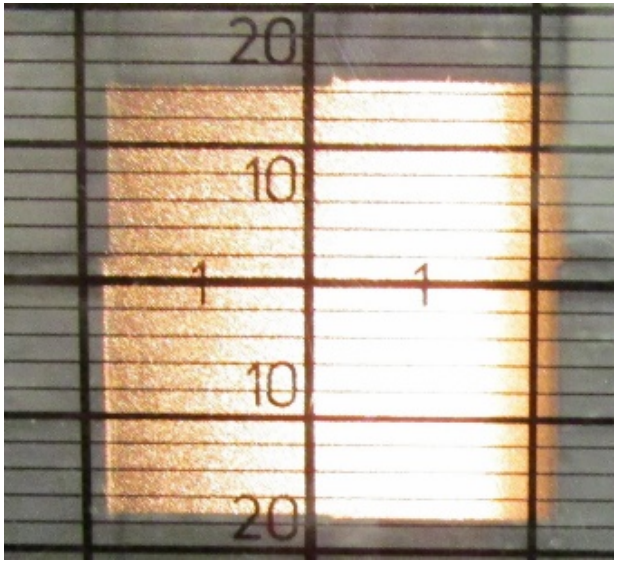
$$\text{Exposure time} = \text{Dose}/\text{Rate2}$$

$$= 5435\ \text{s}$$

Avago AFBR-811FN1Z

- Device is 40cm away from the neutron output
- The neutron source slot variable up to 30x20 cm





Results Avago AFBR 811FN1Z

- Irradiating results

  Increasing the dose step by step

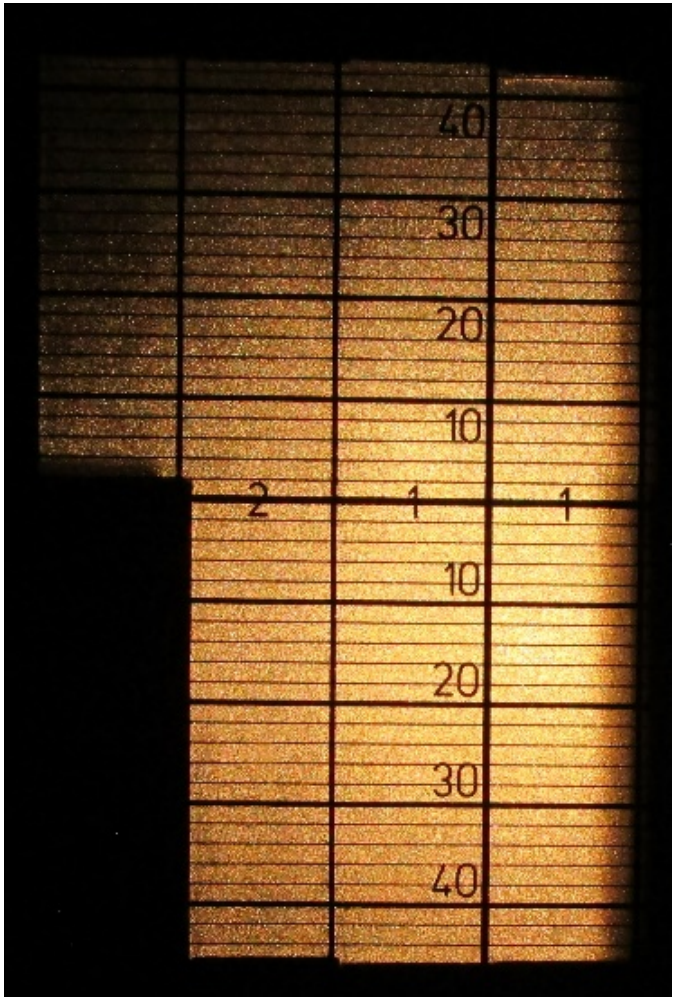
1. 13 seconds are the system time for neutron to reach the slot

	Dose(neutron/cm^{-2})	Time(s) + 13s[1]	Accumulated Dose	Errors
Step 1	$5 \cdot 10^{10}$	217 + 13	$5 \cdot 10^{10}$	No
Step 2	$5 \cdot 10^{10}$	217 + 13	$10 \cdot 10^{10}$	No
Step 3	$10 \cdot 10^{10}$	434 + 13	$20 \cdot 10^{10}$	No
Step 4	$10 \cdot 10^{10}$	434 + 13	$30 \cdot 10^{10}$	No
Step 5	$20 \cdot 10^{10}$	868 + 13	$50 \cdot 10^{10}$	No
Step 6	$75 \cdot 10^{10}$	3265 + 13	$125 \cdot 10^{10}$	No
Step 7	$125 \cdot 10^{10}$	5435 + 13	$250 \cdot 10^{10}$	No

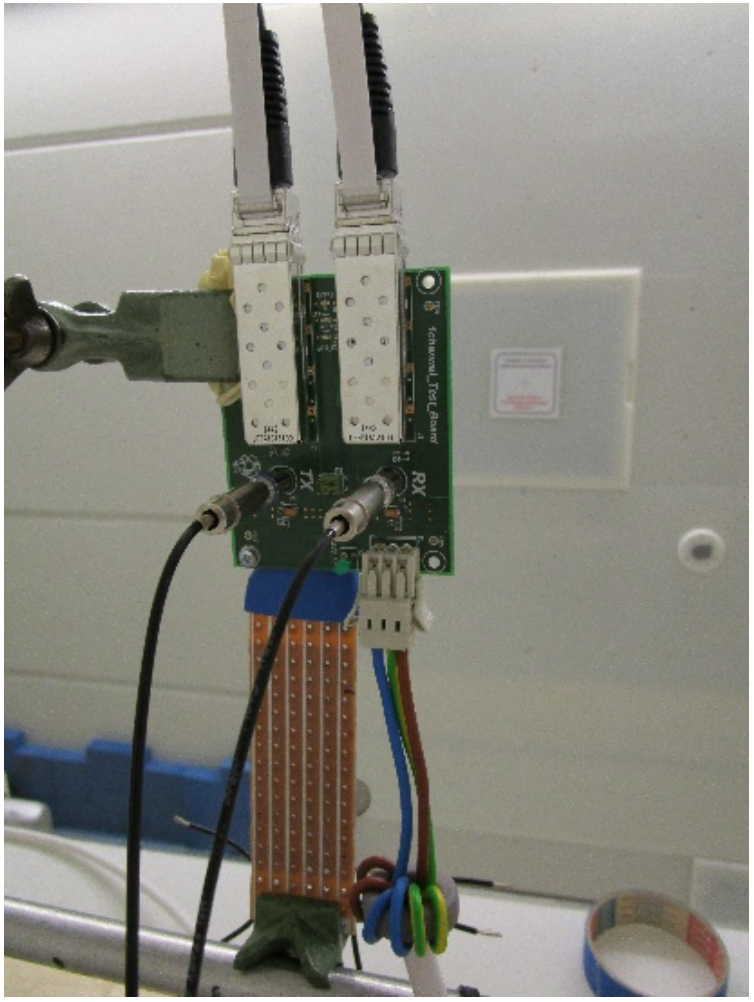
- Step 7 is the 10 years' equivalent dose of neutrons
- Total dose is equivalent to 20 years

Glenair 050-301

- The neutron source slot



- Connections



Results Glenair 050-301

- Irradiating results

  Increasing the dose step by step

	Dose(neutron/cm^{-2})	Time(s) + 13s[1]	Accumulated Dose	Errors
Step 1	$62.5 \cdot 10^{10}$	2718 + 13	$62.5 \cdot 10^{10}$	No
Step 2	$62.5 \cdot 10^{10}$	2718 + 13	$125 \cdot 10^{10}$	No
Step 3	$125 \cdot 10^{10}$	5435 + 13	$250 \cdot 10^{10}$	No

Total dose is equivalent to 20 years’

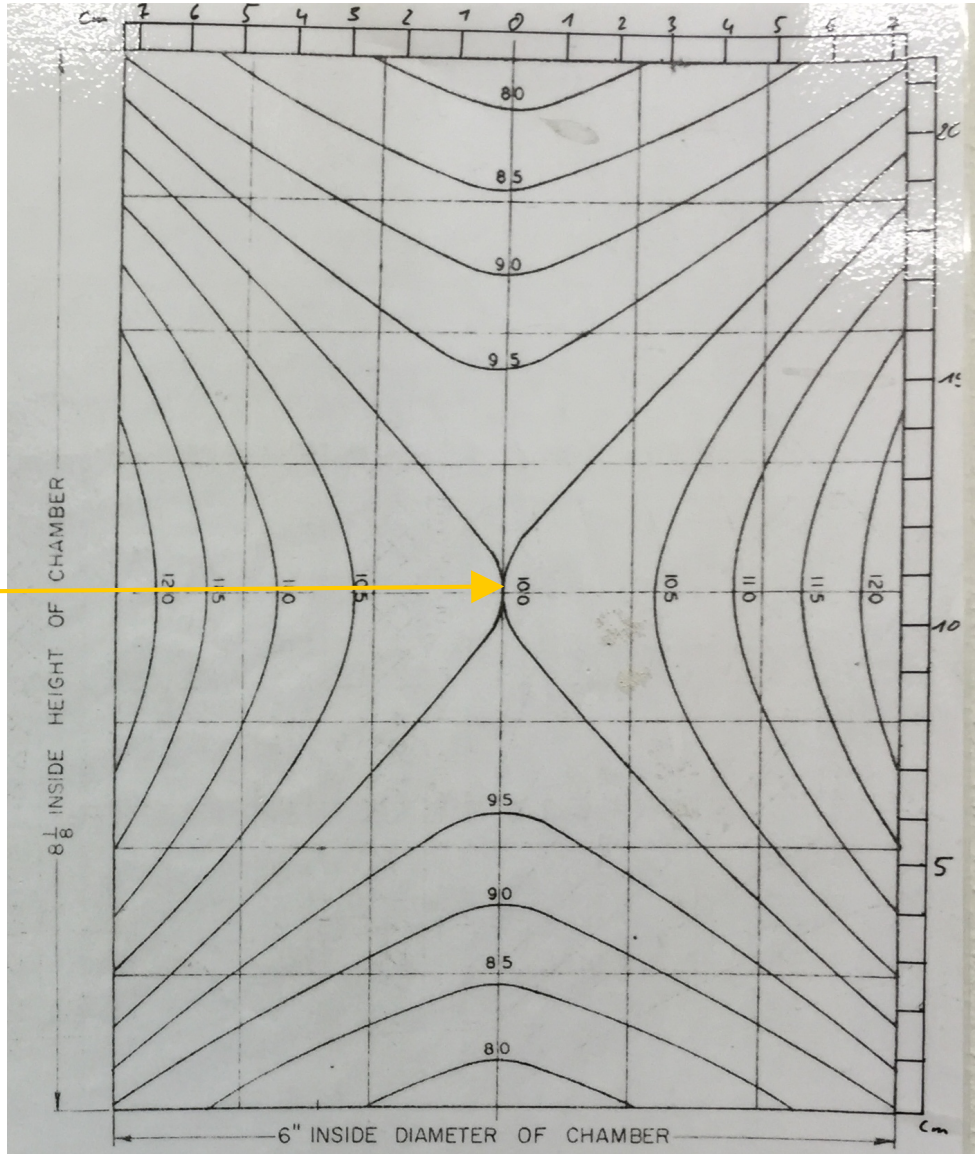
Outline

Setup at Helmholtz Centre Munich

Technische Universität München

Gammacell 220 I / II

- Nuclide: Cobalt-60
- Closed unit irradiation chamber
- Size: height 20,6cm; ø 15,2 cm
- Homogeneous value in the centre 4x5 cm



Avago AFBR-811FN1Z

Setup

- Align the test device in the centre of the chamber
- All the cables are guided outside through the hollow cylinder

Gammacell I strength

- In April: **1,33 Gy min^{-1}**

Deutsches Forschungszentrum für Gesundheit und Umwelt

DL - Werte an der ***Gammacell I*** im Jahr 2015

Co^{60} ; $T_{1/2}$ = 5.27 a

(Bei Verwendung des Ausgleichsfilters gelten die ***halben*** Werte)

Bestrahlungs-geometrie / Monat	sehr kleine H_2O - Menge Gy min^{-1}	kl. H_2O - Menge im Temp. Becher Gy min^{-1}	ca. 100 ml H_2O im Tem. Becher Gy min^{-1}	0.5 - 1.0 l H_2O Gy min^{-1}
Januar	1,37	1,30	1,24	1,17
Februar	1,36	1,28	1,22	1,16
März	1,35	1,27	1,21	1,14
April	1,33	1,26	1,20	1,13
Mai	1,32	1,24	1,18	1,12
Juni	1,30	1,23	1,17	1,11
Juli	1,29	1,22	1,16	1,09
August	1,27	1,20	1,15	1,08
September	1,26	1,19	1,13	1,07
Oktober	1,25	1,18	1,12	1,06
November	1,23	1,16	1,11	1,05
Dezember	1,22	1,15	1,10	1,04

Gammacell I, Avago AFBR 811FN1Z

- Belle II 20 years' equivalent dose
  Dose = **200 krad**
- Gammacell I rate
  Rate = **1,33 Gy/min = 133 Rad/min**

⇒ **So, the equivalent irradiation time is**
Exposure time = Dose/Rate = 1534 min

1. At beginning in Gammacell I
   - Two channels are working
   - 3.3V has 138mA current
   - 2.5V has 176mA current
   - I2C working
2. Power Cycle after step2 completed
   - Two channels are not working
   - 3.3V has 114mA current
   - 2.5V has 47mA current
   - I2C gets wrong value

	Dose(krad)	Time(min)	Accumulated Dose(krad)	Status
Step 1	9.3	70	9.3	✔
Step 2	125.6	944	134.9	
	67.3	506	76.6	No Data Err, but both link are down, I2C gets wrong value

Gammacell II

Setup is the same as that in Gammacell I

- A new Avago AFBR-811FN1Z into it
- Gammacell II rate in April:
  Rate = **9 Gy min^{-1}**

So, the equivalent irradiation time is

Exposure time = Dose/Rate

= **200krad/900rad min^{-1}**

= **222 min**

HelmholtzZentrum münchen
Deutsches Forschungszentrum für Gesundheit und Umwelt

DL - Werte an der ***Gammacell II*** im Jahr 2015

Co^{60} ; $T_{1/2}$ = 5.27 a

(Bei Verwendung des Ausgleichsfilters gelten die ***halben*** Werte)

Bestrahlungs-geometrie / Monat	sehr kleine H_2O - Menge Gy min-1	kl. H_2O - Menge im Temp. Becher Gy min-1	ca. 100 ml H_2O im Tem. Becher Gy min-1	0.5 - 1.0 l H_2O Gy min-1
Januar	9,30	8,78	8,37	7,90
Februar	9,19	8,68	8,27	7,82
März	9,10	8,59	8,19	7,74
April	9,00	8,50	8,10	7,65
Mai	8,90	8,41	8,01	7,57
Juni	8,81	8,31	7,92	7,48
Juli	8,71	8,22	7,84	7,40
August	8,61	8,13	7,75	7,32
September	8,52	8,04	7,67	7,24
Oktober	8,43	7,96	7,58	7,16
November	8,33	7,87	7,50	7,08
Dezember	8,24	7,78	7,42	7,01

Results Avago 811FN1Z in Gammacell II

	Dose(krad)	Time(min)	Accumulated Dose(krad)	Status
Step 1	108	120	108	
	98.1	109	98.1	No Data Err, but both link are down, I2C gets wrong value

1. At beginning in Gammacell II
- Two channels are working
- 3.3V has 129mA current
- 2.5V has 172mA current
- I2C works well

2. Before Power Cycle
- Two channels do not work anymore
- 3.3V has 145mA current
- 2.5V has 175mA current
- I2C gets wrong value

3. After Power Cycle
- Two channels still do not work
- 3.3V has 110mA current
- 2.5V has 51mA current
- I2C gets wrong value

Glenair 050-301

Setup

- The test device in the centre of the **Gammacell II** chamber
- All the cables are guided outside through the hollow cylinder

Gammacell II centre strength

- In April: **9 Gy min^{-1}**

Results Glenair 050-301 in Gammacell II

Experiment in Gammacell II

	Dose(krad)	Time(min)	Accumulated Dose(krad)	Status
Step 1	168.3	187	168.3	✔

- Two devices, one Tx, one Rx
- 3.3V has 153mA current at the beginning
- 3.3V has 155mA current in the end
- After power cycle 7, there is one single event upset in the transmitting channel

Power Cycle Steps

	Time	State
1	11:40	OK
2	11:55	OK
3	12:10	OK
4	12:25	OK
5	12:40	OK
6	12:55	OK
7	13:25	OK
8	13:55	OK
9	14:25	OK
10	14:45	OK

Outline

Summary

1. Device under neutron irradiation within the Belle II requirement

- Avago AFBR-811FN1Z: no error, working stably
- Glenair 050-301: no error , working stably

2. Device under Gamma irradiation within the Belle II requirement

- Avago AFBR-811FN1Z: stop working after the dose reach:

  76.6krad(I) ≈ 7.5 years

  91.1krad(II) ≈ 9 years
- Glenair 050-301:

  Only 1 SEU during the whole period

  Total dose 168.1krad

3. Reason for the damages of the Avago device under Gamma irradiation

- Corruption of the configuration memory
- We are contacting the company to check if we could program the device memory

Outlook

Outlook

- Avago AFBR-811FN1Z has a problem during the Gamma irradiation

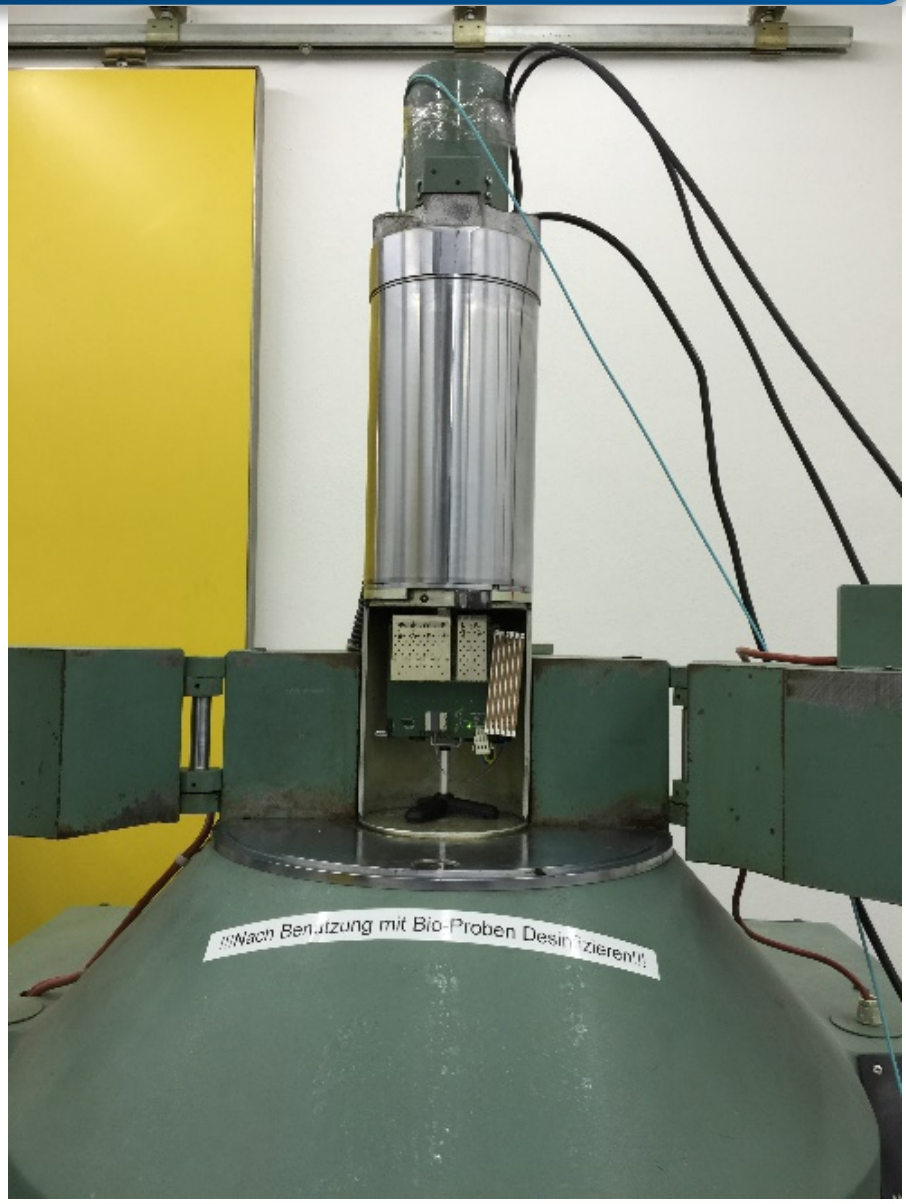
  → ASAP we get feedback from Avago, futher study on this device

- Glenair 050-301 has good performance during both tests

  → Increasing the dose upto Megarad

Thank You for Your Attention!

Appendix



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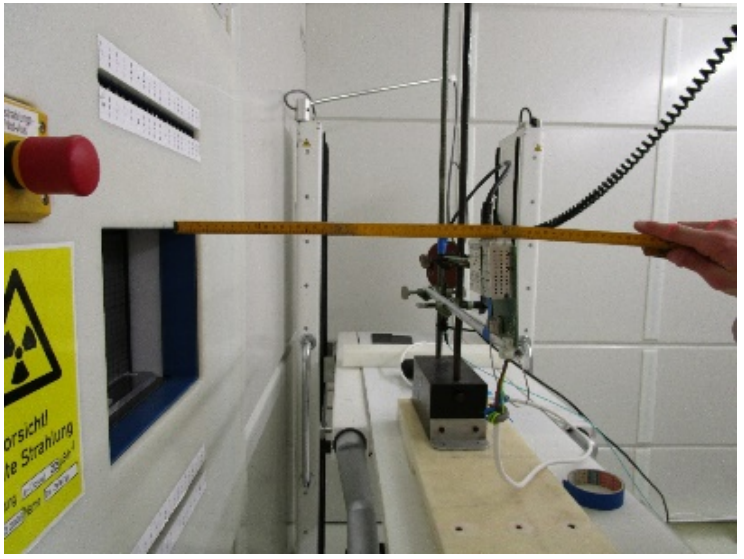
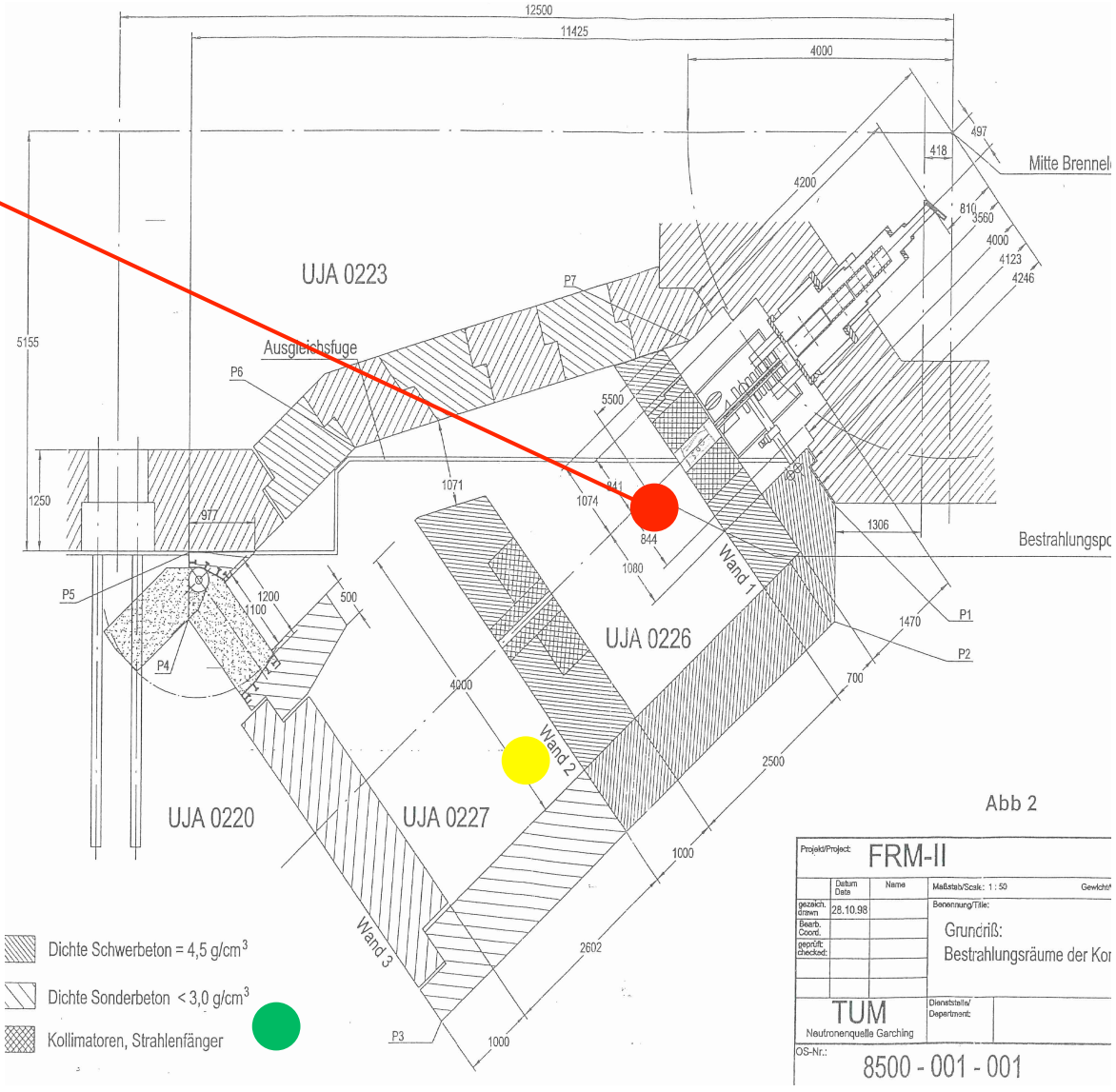


DUT is 40cm away from the neutron output slot



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Data handling card is in the second chamber behind the concrete wall