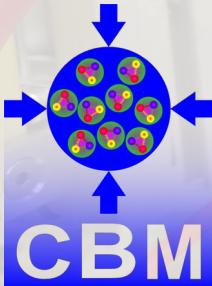
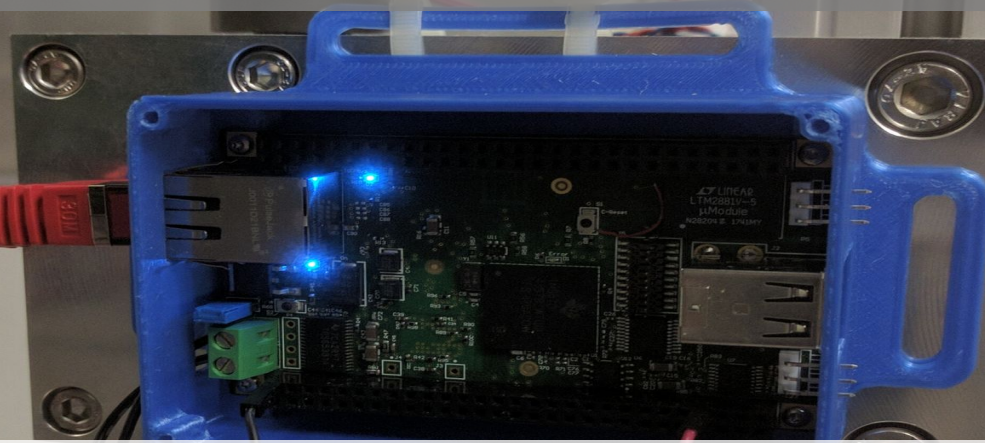


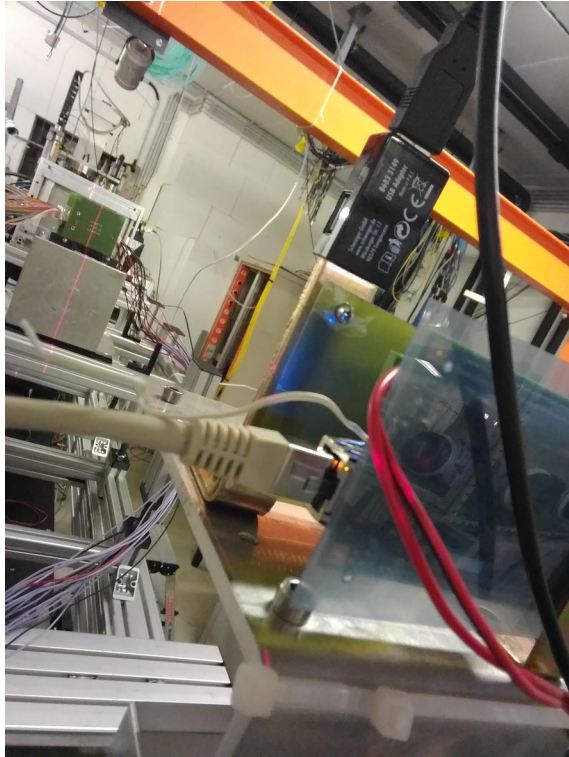
Fault Tolerant Local and Monitoring Control Board



Research group Prof. Udo Kebschull
José Antonio Lucio Martínez

Infrastructure and Computer Systems in Data Processing
Goethe Universität Frankfurt

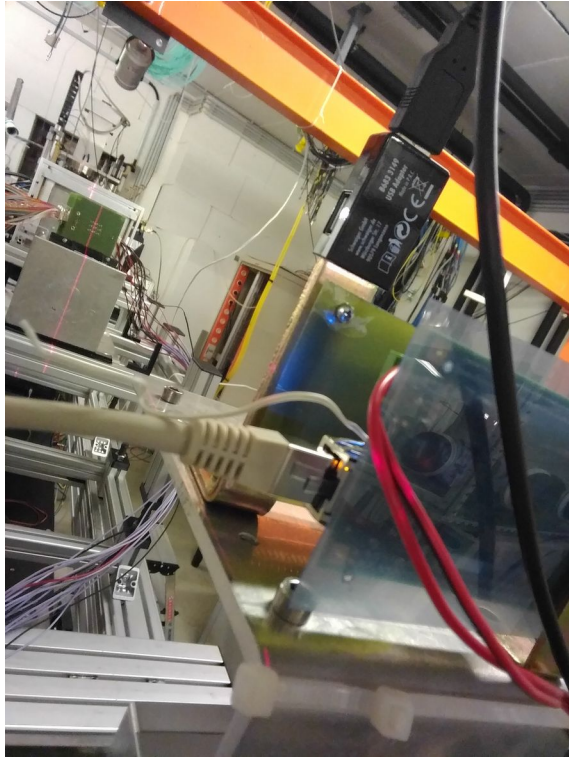
Beamtime conditions



- Beam
 - Cycle duration: 26s
 - Beam on: 2s
 - Intensity: $3 \cdot 10^9$
 - Energy: 2740 MeV/c

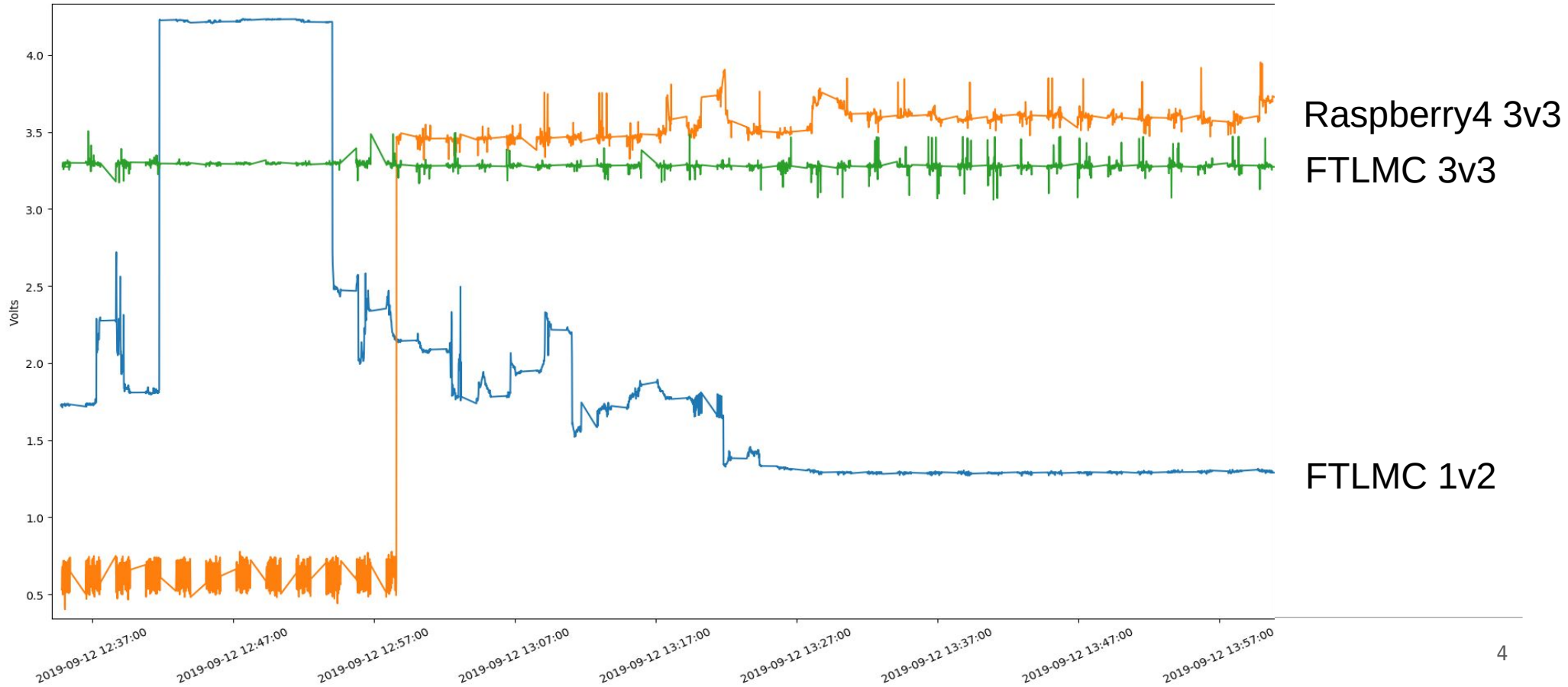
EXPERIMENT: 4					
Momentum: 2740 MeV/c					
Cycle Duration: 26 s					
Name	Time/ms	Timer1	Timer2	Status	Activ
Pulsgenerator	0	600	600	---	1
diagnose	1	302	---	840	1
Libera aus	2	---	711	---	1
Bumper laden	120	610	---	---	1
Tims-warte1_01	129	601	---	---	1
Bumper starten	130	---	611	---	1
dipolstart	150	101	---	---	1
poco-start	153	100	100	---	1
fastTune_rauschen	751	901	---	---	1
BPM	6000	301	---	---	0
bb_an	6001	---	---	851	1
Libera an	6500	710	---	---	1
use1_on	6501	---	---	811	1
HF_kurz	6900	---	---	831	0
hf_kurz_bb_off	7500	---	---	831	0
TuneStripLine_an	7999	---	---	785	0
use1_off	8499	---	---	810	0
use2_on	8500	---	---	812	1
use12_on	8502	---	---	813	0
Timswarte2_1	10000	---	602	---	1
Timswarte2_2	12000	---	602	---	1

Beamtime conditions

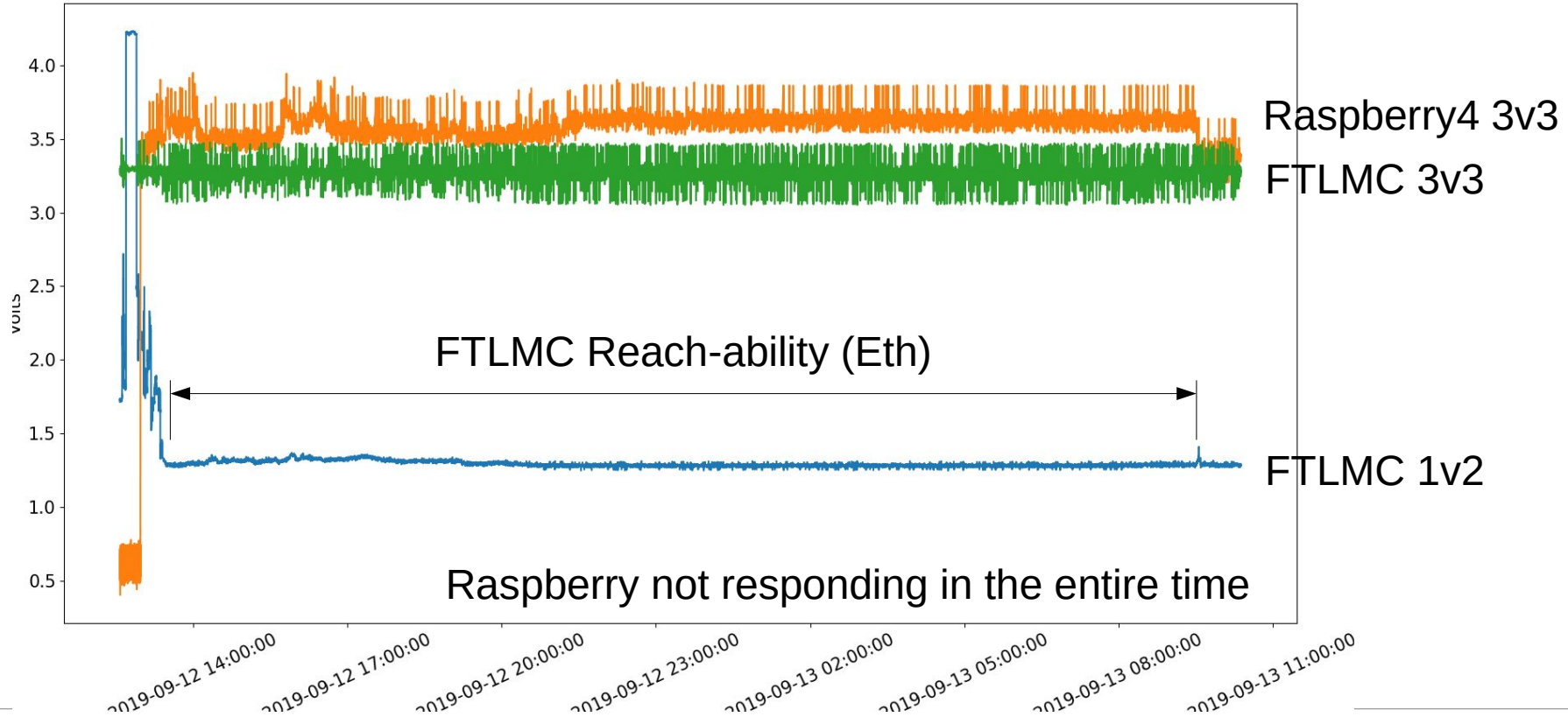


- Test covered |
 - Raspberry and FTLMC
 - DC-DC converter
 - μC
 - EBT3 Dosimetry
 - Screws to locate components in film
 - Measure dcdc voltage
 - Binary server to check μC

DCDC Converter irradiation



DCDC Converter irradiation- Reachability



μ C irradiation

- After DCDC irradiation, FTLMC DUT 1 was replaced by FTLMC DUT 2
- Raspberry 4 was replaced by raspberry3b
- No DCDC voltage measure was obtained in the μ C irradiation
- Devices were probed through Ethernet traffic
- There are EBT3 films for both DCDC and μ C irradiation, but only took cellphone pic from the second
- EBT3 DCDC film will be picked together with the DUTs on friday

μC irradiation-Initial Ethernet traffic

No.	Time	Source	Destination	Protocol	Length	Info
1565...	67650.449959	10.0.0.1	10.0.0.16	TCP	74	51779 → 80 [SYN] Seq=0 Win=14600 Len=0 MSS=1460 SACK_PERM=1 TSval=360172920 TSecr=0 WS=128
1565...	67650.450358	de:ad:be:ef:c0:1a	Broadcast	ARP	60	Who has 10.0.0.1? Tell 10.0.0.16
1565...	67650.450393	AsustekC 09:e0:24	de:ad:be:ef:c0:1a	ARP	42	10.0.0.1 is at 14:da:e9:09:e0:24
1565...	67650.450802	10.0.0.16	10.0.0.1	TCP	60	80 → 51779 [SYN, ACK] Seq=0 Ack=1 Win=4096 Len=0 MSS=1474
1565...	67650.450902	10.0.0.1	10.0.0.16	TCP	54	51779 → 80 [ACK] Seq=1 Ack=1 Win=14600 Len=0
1565...	67650.591988	10.0.0.1	10.0.0.89	ICMP	98	Echo (ping) request id=0x6f18, seq=1376/24581, ttl=64 (reply in 156576)
1565...	67650.592564	10.0.0.89	10.0.0.1	ICMP	98	Echo (ping) reply id=0x6f18, seq=1376/24581, ttl=64 (request in 156575)
1565...	67650.953271	10.0.0.1	10.255.255.255	UDP	58	39400 → 5065 Len=16
1565...	67650.973540	10.0.0.1	10.255.255.255	UDP	58	39400 → 5065 Len=16
1565...	67651.013812	10.0.0.1	10.255.255.255	UDP	58	39400 → 5065 Len=16
1565...	67651.094083	10.0.0.1	10.255.255.255	UDP	58	39400 → 5065 Len=16
1565...	67651.254409	10.0.0.1	10.255.255.255	UDP	58	39400 → 5065 Len=16
1565...	67651.453870	10.0.0.1	10.0.0.16	TCP	62	51779 → 80 [PSH, ACK] Seq=1 Ack=1 Win=14600 Len=8
1565...	67651.454254	10.0.0.16	10.0.0.1	TCP	60	80 → 51779 [PSH, ACK] Seq=1 Ack=9 Win=4088 Len=4
1565...	67651.454321	10.0.0.1	10.0.0.16	TCP	54	51779 → 80 [ACK] Seq=9 Ack=5 Win=14600 Len=0
1565...	67651.574666	10.0.0.1	10.255.255.255	UDP	58	39400 → 5065 Len=16
1565...	67651.591989	10.0.0.1	10.0.0.89	ICMP	98	Echo (ping) request id=0x6f18, seq=1377/24837, ttl=64 (reply in 156587)
1565...	67651.592525	10.0.0.89	10.0.0.1	ICMP	98	Echo (ping) reply id=0x6f18, seq=1377/24837, ttl=64 (request in 156586)
1565...	67652.070863	10.0.0.1	10.255.255.255	NTP	90	NTP Version 4, broadcast
1565...	67652.214926	10.0.0.1	10.255.255.255	UDP	58	39400 → 5065 Len=16
1565...	67652.453824	10.0.0.1	10.0.0.16	TCP	62	51779 → 80 [PSH, ACK] Seq=9 Ack=5 Win=14600 Len=8
1565...	67652.454175	10.0.0.16	10.0.0.1	TCP	60	80 → 51779 [PSH, ACK] Seq=5 Ack=17 Win=4080 Len=4
1565...	67652.454220	10.0.0.1	10.0.0.16	TCP	54	51779 → 80 [ACK] Seq=17 Ack=9 Win=14600 Len=0
1565...	67652.592000	10.0.0.1	10.0.0.89	ICMP	98	Echo (ping) request id=0x6f18, seq=1378/25093, ttl=64 (reply in 156594)
1565...	67652.592576	10.0.0.89	10.0.0.1	ICMP	98	Echo (ping) reply id=0x6f18, seq=1378/25093, ttl=64 (request in 156593)

Frame 156569: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
+ Interface id: 0 (p5p1)
Encapsulation type: Ethernet (1)
Arrival Time: Sep 14, 2019 11:24:23.172808000 CEST

FTLMC

Raspberry

Raspberry stops responding

Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1593...	68188.599990	10.0.0.1	10.0.0.89	ICMP	98	Echo (ping) request id=0x6f18, seq=1914/31239, ttl=64 (no response found!)
1593...	68188.611894	AsustekC_09:e0:24	Raspberr_ed:9d:88	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1593...	68189.453913	10.0.0.1	10.0.0.16	TCP	62	51779 → 80 [PSH, ACK] Seq=4305 Ack=2153 Win=14600 Len=8
1593...	68189.454308	10.0.0.16	10.0.0.1	TCP	60	80 → 51779 [PSH, ACK] Seq=2153 Ack=4313 Win=2712 Len=4
1593...	68189.454371	10.0.0.1	10.0.0.16	TCP	54	51779 → 80 [ACK] Seq=4313 Ack=2157 Win=14600 Len=0
1593...	68189.599973	10.0.0.1	10.0.0.89	ICMP	98	Echo (ping) request id=0x6f18, seq=1915/31495, ttl=64 (no response found!)
1593...	68189.613908	AsustekC_09:e0:24	Raspberr_ed:9d:88	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1593...	68189.702744	10.0.0.80	10.255.255.255	UDP	60	1026 → 5065 Len=16
1593...	68190.453854	10.0.0.1	10.0.0.16	TCP	62	51779 → 80 [PSH, ACK] Seq=4313 Ack=2157 Win=14600 Len=8
1593...	68190.454211	10.0.0.16	10.0.0.1	TCP	60	80 → 51779 [PSH, ACK] Seq=2157 Ack=4321 Win=2704 Len=4
1593...	68190.454267	10.0.0.1	10.0.0.16	TCP	54	51779 → 80 [ACK] Seq=4321 Ack=2161 Win=14600 Len=0
1593...	68190.599968	10.0.0.1	10.0.0.89	ICMP	98	Echo (ping) request id=0x6f18, seq=1916/31751, ttl=64 (no response found!)
1593...	68191.453949	10.0.0.1	10.0.0.16	TCP	62	51779 → 80 [PSH, ACK] Seq=4321 Ack=2161 Win=14600 Len=8
1593...	68191.454321	10.0.0.16	10.0.0.1	TCP	60	80 → 51779 [PSH, ACK] Seq=2161 Ack=4329 Win=2696 Len=4
1593...	68191.454370	10.0.0.1	10.0.0.16	TCP	54	51779 → 80 [ACK] Seq=4329 Ack=2165 Win=14600 Len=0
1593...	68191.599938	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1593...	68192.453882	10.0.0.1	10.0.0.16	TCP	62	51779 → 80 [PSH, ACK] Seq=4329 Ack=2165 Win=14600 Len=8
1593...	68192.454243	10.0.0.16	10.0.0.1	TCP	60	80 → 51779 [PSH, ACK] Seq=2165 Ack=4337 Win=2688 Len=4
1593...	68192.454293	10.0.0.1	10.0.0.16	TCP	54	51779 → 80 [ACK] Seq=4337 Ack=2169 Win=14600 Len=0
1593...	68192.601859	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1593...	68193.453928	10.0.0.1	10.0.0.16	TCP	62	51779 → 80 [PSH, ACK] Seq=4337 Ack=2169 Win=14600 Len=8
1593...	68193.454306	10.0.0.16	10.0.0.1	TCP	60	80 → 51779 [PSH, ACK] Seq=2169 Ack=4345 Win=2680 Len=4
1594...	68193.454376	10.0.0.1	10.0.0.16	TCP	54	51779 → 80 [ACK] Seq=4345 Ack=2173 Win=14600 Len=0
1594...	68193.603911	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1594...	68194.453896	10.0.0.1	10.0.0.16	TCP	62	51779 → 80 [PSH, ACK] Seq=4345 Ack=2173 Win=14600 Len=8

Frame 159384: 42 bytes on wire (336 bits), 42 bytes captured (336 bits) on interface 0

- Interface id: 0 (p5p1)
- Encapsulation type: Ethernet (1)
- Arrival Time: Sep 14, 2019 11:33:23.026227000 CEST

FTLMC binary server stops

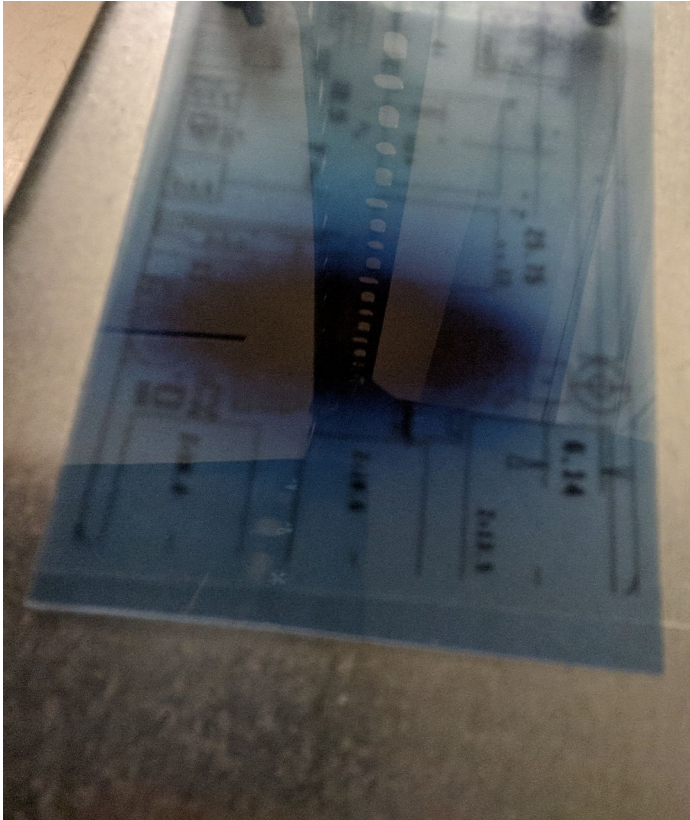
Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1657...	69791.453980	10.0.0.16	10.0.0.1	TCP	60	80 → 51779 [PSH, ACK] Seq=8561 Ack=17129 Win=3072 Len=4
1657...	69791.454011	10.0.0.1	10.0.0.16	TCP	54	51779 → 80 [ACK] Seq=17129 Ack=8565 Win=14600 Len=0
1657...	69791.989275	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69792.453904	10.0.0.1	10.0.0.16	TCP	62	51779 → 80 [PSH, ACK] Seq=17129 Ack=8565 Win=14600 Len=8
1657...	69792.454172	10.0.0.16	10.0.0.1	TCP	60	80 → 51779 [PSH, ACK] Seq=8565 Ack=17137 Win=3064 Len=4
1657...	69792.454250	10.0.0.1	10.0.0.16	TCP	54	51779 → 80 [ACK] Seq=17137 Ack=8569 Win=14600 Len=0
1657...	69792.989829	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69793.453949	10.0.0.1	10.0.0.16	TCP	62	51779 → 80 [PSH, ACK] Seq=17137 Ack=8569 Win=14600 Len=8
1657...	69793.654895	10.0.0.1	10.0.0.16	TCP	62	[TCP Retransmission] 51779 → 80 [PSH, ACK] Seq=17137 Ack=8569 Win=14600 Len=8
1657...	69793.991830	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69794.057886	10.0.0.1	10.0.0.16	TCP	62	[TCP Retransmission] 51779 → 80 [PSH, ACK] Seq=17137 Ack=8569 Win=14600 Len=8
1657...	69794.863838	10.0.0.1	10.0.0.16	TCP	62	[TCP Retransmission] 51779 → 80 [PSH, ACK] Seq=17137 Ack=8569 Win=14600 Len=8
1657...	69795.990170	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69796.085859	10.0.0.1	10.255.255.255	NTP	90	NTP Version 4, broadcast
1657...	69796.473841	10.0.0.1	10.0.0.16	TCP	62	[TCP Retransmission] 51779 → 80 [PSH, ACK] Seq=17137 Ack=8569 Win=14600 Len=8
1657...	69796.991895	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69797.993825	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69799.697851	10.0.0.1	10.0.0.16	TCP	62	[TCP Retransmission] 51779 → 80 [PSH, ACK] Seq=17137 Ack=8569 Win=14600 Len=8
1657...	69799.991032	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69800.993888	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69801.455535	10.0.0.1	10.255.255.255	UDP	58	39400 → 5065 Len=16
1657...	69801.995828	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69803.992080	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69804.993864	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1
1657...	69805.995853	AsustekC_09:e0:24	Broadcast	ARP	42	Who has 10.0.0.89? Tell 10.0.0.1

Frame 165722: 62 bytes on wire (496 bits), 62 bytes captured (496 bits) on interface 0

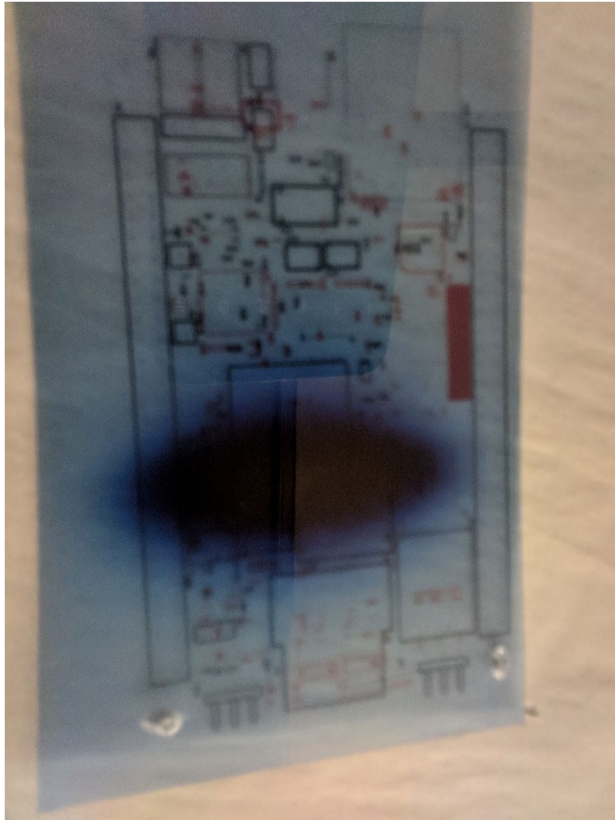
- Interface id: 0 (p5p1)
- Encapsulation type: Ethernet (1)
- Arrival Time: Sep 14, 2019 12:00:07.067214000 CEST

Raspberry 3b μ C irradiation



- Failed to establish ethernet connection 9 minutes after cave closed (probably when beam turned on)
- Ping used for probing
- Still to be picked up (cooling down)
- Unknown if is still operational after irradiation

FTLMC μ C Irradiation



- FTLMC Ethernet binary server stopped responding after 30 minutes
- After 3 hours FTLMC binary server is again online for 3 minutes (ray on, high intensity)
- Same happens after 1 hr 45 minutes, this time for 8 minutes
- Unknown if DUT is operative after beamtime
- To be picked up in Jülich

Notes

- No picture of Beam in DCDC EBT3, film still to be picked up in Jülich
- XY frame fixed for the part from where the results were taken
- Two different FTLMC DUT used for DCDC converter irradiation and μC
- Raspberry4 used for DCDC converter irradiation
- Raspberry3b used for μC irradiation

Conclusion

- FTLMC DCDC converter is not radiation tolerant, but FTLMC kept working for more than 18 hours with DCDC in the high intensity beam after got stabilized from wide voltage variations.
- μC irradiation showed that TMS570 is not radiation tolerant, but it kept working for 30 minutes within the high intensity beam
- In former beam exposure it was demonstrated that as long as TMS570 is working, it scrubs its RAM memory in search for single and multiple event upsets, and corrects the SEUs
- Raspberry is not able to withstand radiation and did not seem to work at all in the high intensity beam