Testing electronics @ Trento 13-14 December

P. Antonioli, D. Falchieri, S. Geminiani, L. Rignanese

Working/Planning document

Introduction/disclaimer

- Still gathering information
- Not yet a plan → collect input → second round in one or two weeks (one month before)
- Many different devices → review & agree on tests to be done

What to irradiate / when

- ALCOR
- LDO LTM4709
- AtTiny417
- SiLab Si3526
- AMD AUX15P

(12)-13-14 December

- @Trento we managed for ALCOR easily fluxes of 5 10^8 p/cm^{2}s (I=50 nA E=100 MeV per 600 ns)
- @100 MeV: TID ≅10 rad / 10^8 p/cm^2
- For some irradiation better to stay at lower fluxes (see later in this presentation)

How much radiation? (1)

Levels expected at dRICH (new estimates, after some fixes)

Slide from RDO PDR (June)

other requirements: radiation, power

radiation tolerance:

The dRICH-PDU position is a moderately radiation hostile environment

(ref data: https://wiki.bnl.gov/EPIC/index.php?title=Radiation_Doses data at 1st March)

Key values (see backup: hadrons , TID + E. Aschenauer presentation today) extracted from 3D maps at dRICH-PDU positions

Φ (p+n > 20 MeV) = 200 Hz/cm^2

TID $\cong$ 650 rad (for 1000 fb^{-1}) < 1 krad

note these values include a safety factor 5

Now we need to add a **3.65 factor** or keep them as they are without safety factors

- mechanisms of protection against SEU in particular must be in place in addition to TMR in key firmware registers etc.
- radiation dose is not very high, basic protection against SEL must be however in plac

power management:

- robust on board prevention of SEL (and in general overcurrent) must be implemented: current monitor / etc.
- possibility to act as power manager (via additional pins on ALCORbus) also on FEB cards
- PDU will require cooling, choice of components to curb power consumption is an obvious requirement

How much radiation? (2)

650 rad * 3.65 = 2.3 krad it is still a factor 5 —> 25 krad is a factor 50 safety

200 Hz/cm^2 *3.65 = 700 Hz/cm^2 → 700 Hz/cm^2 has still a factor 5

$$\text{Rate of SEU} = \Phi\, \sigma\, B\, N$$

Φ = flux (E_h>20 MeV) [$cm^{-2}s^{-1}$]
σ = cross section [cm^2/bit]
B = exposed bits in the DUT
N = total # of devices in the dRICH

Device	Bits	N	R(10-15)	MTBF [10-15]	R(10-16)	MTBF (s) [10-16]
AtTiny417	2.80E+04	1242	2.43E-05	4.11E+04	2.43E-06	4.11E+05
SiLab	1.02E+03	1242	8.90E-07	1.12E+06	8.90E-08	1.12E+07
CRAM AUX15P	4.00E+07	1242	3.48E-02	2.88E+01	3.48E-03	2.88E+02
RAM AUX15P	2.00E+06	1242	1.74E-03	5.75E+02	1.74E-04	5.75E+03

MTBF is just the inverse of the Rate
If we can, set limits 95% C.L. at 10^{-16} for SiLab
For AtTiny also likely (using less than 4kB for the actual program)

How much radiation? (3)

- For SEU we have cross section $O(10^{15}\text{-}10^{16}\ cm^2/bit)$ for RAM o CRAM
- So in principle DUT should get integrated fluxes $O(10^{15}\text{-}10^{16})/cm^2$ / [monitored bits] to see something
- With protons @100 MeV TID is 9.38 rad every $10^8\ p/cm^2$ on the DUT

So 25 krad are reached with 2.6 $10^{11} p/cm^2$ integrated over DUT

Dobbiamo evitare di integrare troppo in fretta una TID troppo grande che puo' uccidere il device o la sua riprogrammabilita'. Ci interessano soprattutto SEU (e SEL) dato che la TID attesa al dRICH invece e' bassa e facilmente la superiamo

We can however set 95% C.L. in case of zero events

σ (95% c.l.) = 2.99 / (Φirr * B)

Device	Bits	Firr	C.L (95%)
AtTiny417	2.80E+04	1.00E+12	1.07E-16
SiLab	1.02E+03	5.00E+12	5.84E-16

Devices and TIFPA beam

DUT	Area (cm^2)
ALCOR	0.187
LDO LTM4709 (6x12 mm)	0.72 → 0.36 (50%)
Si3526 (6x6 mm)	0.36 → ?
AtTiny417 (4x4 mm)	0.16 → ?
AUX15P (19x19 mm)	3.61 → 2.2 (62%)

- Difficult to find die dimension information, still chasing…
- **Which die/package factor should we use?**
- With a 1 nA (recommended min.) intensity at TIFPA is 1.2 10^7 p/s. Fluence and flux depends on device area if the die dimension exceeds the beam spot
- We normally use 100 MeV with $\sigma_{x/y}$ = 5 mm, it is it a problem for AUX15P? Use of 70 MeV would enlarge beam and reduce intensity by a factor 3.
- Another possibility is to move farer from the isocenter

TIFPA beam

https://www.sciencedirect.com/science/article/pii/S0168900217306654

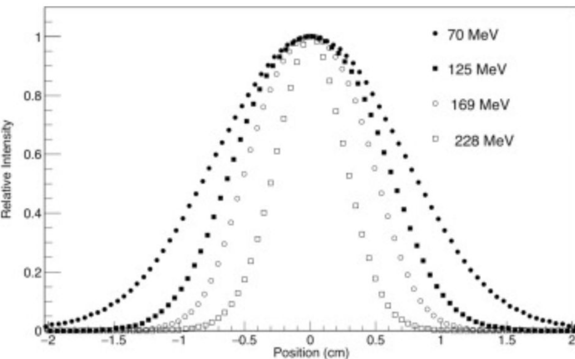


Table 3. Beam spot size estimated from a Gaussian fit on the profiles measured in the X–Y plane perpendicular to the beam direction. The spot asymmetry is calculated according to Eq. (1).

E (MeV)	σ_x (mm)	σ_y (mm)	Asymmetry (%)
70.2	**6.93**	**6.91**	**0.1**
73.9	6.63	6.74	0.8
82.7	6.28	6.41	1.0
90.8	6.04	6.15	0.9
100.0	5.63	5.73	0.8
105.6	5.42	5.63	1.8

Energy [MeV]	Range [g cm^2]	FWHM [mm]	Intensity [p/s]
100	7.72	13.7	1.19E+07
91	6.5	14.6	9.94E+06
83	5.5	15.2	7.50E+06
74	4.5	15.9	-
70	4.1	16.2	3.83E+06

ALCOR

- Schedina ALCOR
- Cavo FireFly
- Breakout board
- KC705
- Aim TTI power supply

- PC (epiclab02) connesso in rete a Aim TTI e KC705
- Threshold scan a alto TID?
- Programma che monitora SEU su BCR, PCR, ECCR + monitor correnti
- Autoreset in caso SEU su ECCR
- No lettura SPI by block

	PCR	BCR	ECCR
Bits	2048	128	128
σ (cm^2/bit) 2023	(2.5 +/- 0.5) 10^{15}	(7.6 +/- 1.1) 10^{14}	(9.4 +/- 1.8) 10^{14}

We measured 28 (ECCR) e 24 (BCR) upsets with integrated fluence of 4.6 10^{12}.
We probably need a similar number of SEU. In 2023 one evening: approx 15 shots of 600 s
Main idea: repeat test but with greater intensity to speed up things

Irradiation 2023

Parameters	Flux (p/s/cm2/n					TID/10^8 (rad)
1nA->Flux	2.34E+07	da verificare con misura			E=100 MeV	9.38
Bits ECCR+BCR	192				E=140 MeV	7.38
Bits PCR	2048				E=228 MeV	5.37
Frazione su ALC	8.36E-02					
Area ALCOR	0.187					
Run	Current (nA)	Duration (s)	P/Misurati	Fluence on ALCOR	Integrated Fluence (p/cm2)	TID (krad)
1	10	427	1.00E+11	4.47E+10	4.47E+10	4.19E+00
2	50	427	5.00E+11	2.23E+11	2.68E+11	2.51E+01
3	50	427	5.34E+11	2.39E+11	5.07E+11	4.75E+01
4	50	600	7.19E+11	3.21E+11	8.28E+11	7.77E+01
5	50	600	6.78E+11	3.03E+11	1.13E+12	1.06E+02
6	50	600	6.71E+11	3.00E+11	1.43E+12	1.34E+02
7	50	600	6.74E+11	3.01E+11	1.73E+12	1.63E+02
8	50	600	6.82E+11	3.05E+11	2.04E+12	1.91E+02
9	50	600	6.72E+11	3.00E+11	2.34E+12	2.19E+02
10	100	600	1.28E+12	5.72E+11	2.91E+12	2.73E+02
11	100	600	1.31E+12	5.86E+11	3.50E+12	3.28E+02
12	100	600	1.26E+12	5.63E+11	4.06E+12	3.81E+02
13	100	600	1.31E+12	5.86E+11	4.64E+12	4.36E+02

threshold scan performed by Fabio to check TID damage (+ 1 Saturday morning)

Irradiation 2024/ALCOR

It could be:

1 run 600 s 50 nA → approx 25 krad - check operations

8 run 600 s 100 nA → approx 400 krad in total

Interleaved by 4 (or 3) threshold checks: at 0, 100, 300, 425 krad

We might stay in two hours, if lucky.

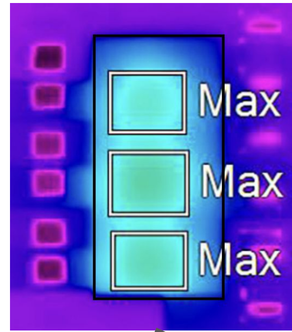
One possibility is to consider refresh PCR registers every “n” seconds, given the TMR mechanism is not fully enabled (voting enabled, not self-correction)

LDO: LTM4709

- Ev. board LTM4709
- Schedina con ATtiny + PC connesso a seriale ATtiny
- TTCmi: fornisce VDH/VDL
- Scheda settata per fornire 1.2/1.8/2.5 V oppure 0.85/0.9/1.0 V e ≈ 2 A (0.47-1 Ω)

- PC (epiclab02) connesso in rete a TTCmi e seriale ATtiny via PC dentro
- Programma che monitor correnti input
- Seriale ATtiny monitora segnali power good e correnti
-

Evb board: DC3211A User Guide



6 x 12 mm
Active area ≈ 50%

Test:
- Irraggiamento fino a TID

Suggested irradiation:
- 1 run 10 nA 300 s
- 1 run 100 nA 600 s

AtTiny417

ATTINY817 XPLAINED MINI

- Ev. board ATtiny
- PC connesso a seriale ATtiny
- TTCmi: fornisce VDH

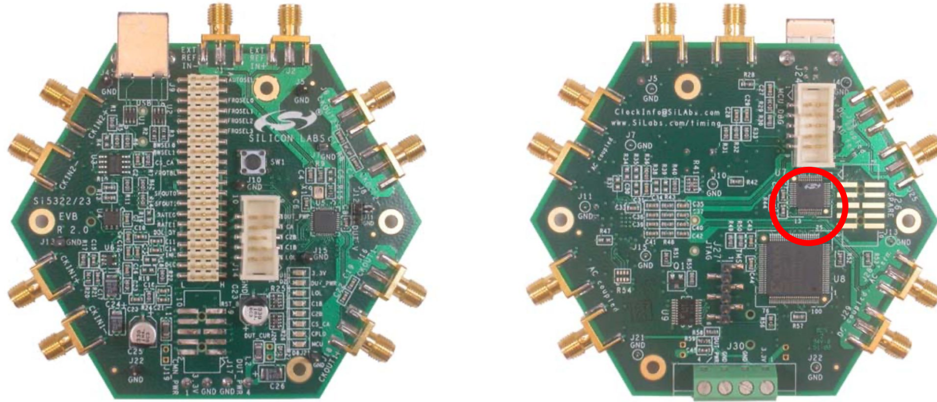
- PC (epiclab02) connesso in rete a TTCmi e seriale ATtiny via PC dentro
- Programma che monitor correnti input
- Seriale ATtiny riporta upset di memoria registrati
- We test reprogrammability at the end

4 kB memoria (programma + memoria) Il programma caricato occupa circa 500 byte, monitora pattern bit nei restanti 3500 byte → $2.8\ 10^{4}$ bit

Suggested irradiation: up to 10^{12}p/cm^{2} → in case of 0 SEU this gives us a limit at 95% C.L. of O(10^{-16} cm^{2}/bit) for the cross section

WIth =10^{-16} cm^{2}/bit for the AtTiny417 we expect 1 SEU every 5 days in the whole dRICH (and we will not occupy all 4 the kB of memory)

SiLab (SkyWorks Si5326)



Purpose of the test:

- Monitor current to check against SEL
- Verify device maintains programmability after a certain TID
- Monitor SEL inside configuration bits (likely we will get an upper limit)
- Monitor stability of the output clocks pre/during(?)/after irradiation

SiLab (SkyWorks Si5326)

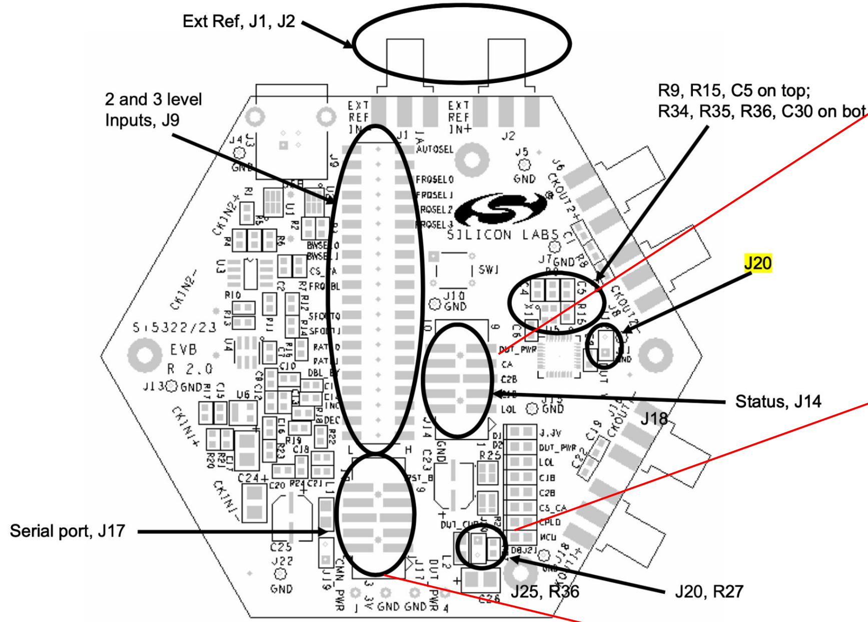
- SiLab 5236-EVB
- ALINX (implementing IPBUS)
- Aim TTI (3.3 V)
- PC Windows connesso USB a SiLab
- Ext. clock gen. 98.5 MHz (SRS)
- Scope externally controlled

- PC (epiclab02) → Alimentatore + ALINX
- Monitor registers via ALINX
- Monitor clock via ALINX
- Monitor currents

A. Maximum ambition: program and monitor via ALINX (IPBUS): registers + LOL signal + current of the device
B. Minimal ambition: program via USB, just monitor current + clocks + latchup + check configuration pre/after

Note: SkyWorks 5326 has 128 x 8 bit registers (1 kb) (only 66 user accessible)
With a $\boldsymbol{\sigma} \cong 10^{-16}$ cm^2/bit we expect a SEU every 4 months in all dRICH

SiLab (SkyWorks Si5326)



J14 is a 10 pin ribbon header that provides an external path to monitor the status pins.

Table 4. Status Header, J14

J14	Pin	Comment
J14.1	LOL	
J14.3	C1B	
J14.5	C2B	
J14.7	CS_CA	clock active
J14.9	DUT_PWR	

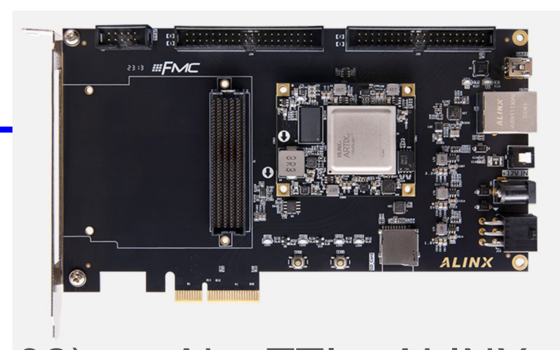
J20 assists in measuring the Any-Frequency Precision Clock current draw. If J20 is to be used, R27 should be removed.

Table 5. External Serial Port Connector, J17

J17	Pin	Comment
J17.1	SDA_SDO	
J17.3	SCL_SCLK	
J17.5	SDI	
J17.7	A2_SS	
J17.9	DUT_RST_B	not reset

Big effort but all gained for RDO!

ALINX



Smontiano FAN o irraggiamo lato opposto?
12 V su tutta carrier difficile accorgersi latchup

- AXAU15 (implementing IPBUS)
- Aim TTi 12V

- PC (epiclab02) → Aim TTI + ALINX
- Monitor registers via ALINX
- Monitor currents

FW caricato su Flash prima di irraggiamento
Three type of registers monitored via IPBUS

- Shift registers to monitor flip-flop
- CRAM (via internal features):

  modalita' mitigation & testing (corregge se ci riesce oppure dice che non ci riesce) - come base
  modalita' detect & testing (non correggiamo e vediamo che succede…)

- RAM: 2 Mbit

AUX15P die size

Estimated by AMD documentation:

https://docs.amd.com/r/en-US/xapp1377-heatsinks-thermal/InFO?tocId=pFFU4iAl0CiiF~jDiWgt1w
https://www.amd.com/en/products/adaptive-socs-and-fpgas/fpga/artix-ultrascale-plus.html

For InFO packages, the contact area is the package body area. This is because the periphery of the package body is filled with a mold material that is planar to the die. This measurement is specified in the top view perspective of the mechanical drawings. The height is derived from the A parameter.

Figure: Example Top View of InFO Device

Figure: Example Diagram Denoting the A Parameter used for Clearance and Attachment Considerations

In this case/example:

Package/Die is: 3.29x7.04 / 16 × 9,5 = 0.6155

We estimate for AUX15P:
Package: 19x19 mm
DIE: 2.23 cm^2

ALINX

Xilinx declares 2.67 × 10^{-16} cm^2/bit cross-section for CRAM bits

AUP15 has 42.8 × 10^6 configuration bits

With a flux of 10^8 p/cm^2s we would have 1 SEU in CRAM ogni secondo!!!

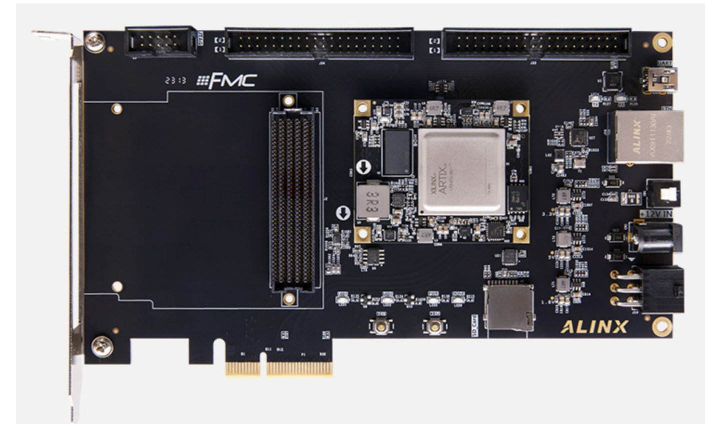
Flux needed: 10^6 - 10^7 , note the 10^7 is with 1 nA → need to discuss with TIFPA

Plan to start with low intensities → SEU

BEAM SPECIFICATIONS:

A list of all energies available at TIPFA is listed below together with the corresponding range. Intermediate energy values can be obtained on request. Energies lower than 70 MeV can be obtained with the use of degraders. FWHM refers to the beam Gaussian profile as measured in air at Isocenter position (i.e. 1.25 m from beam exit window). Beam intensity values reported in the table correspond to 1 nA beam current requested at beam extraction. Any beam extraction current can be requested in the range 1-300 nA. In case lower intensities are needed, beam rate at Isocenter position in the order of 10^2 Hz can be obtained.

Additional problem: the fan. Plan to remove and check temp



Sequence proposal (with some doubts)

- LDO LTM4709
- AtTiny417
- SiLab Si3526
- AMD AUX15P
- ALCOR

13 December evening

14 December morning

1) ALCOR is “easy”, we repeat the test. On the other end could be seen as second priority even at the end of everything → move to the end
2) AMD AUX15P more complicated, but is where we have existing measurements and we know it
3) LDO, AtTiny and SiLab could be potential show stoppers for RDO
4) We have to think if we can save time making something in parallel. SiLab and ALCOR might be two candidates, with one of them down on the beam line. They might reach similar fluence ($5\ 10^{12}$ p/cm^2). But for SiLab we need to grow intensity with a different curve.