bPOL12V
Status report @ information meeting 9 October 25

9/10/2025

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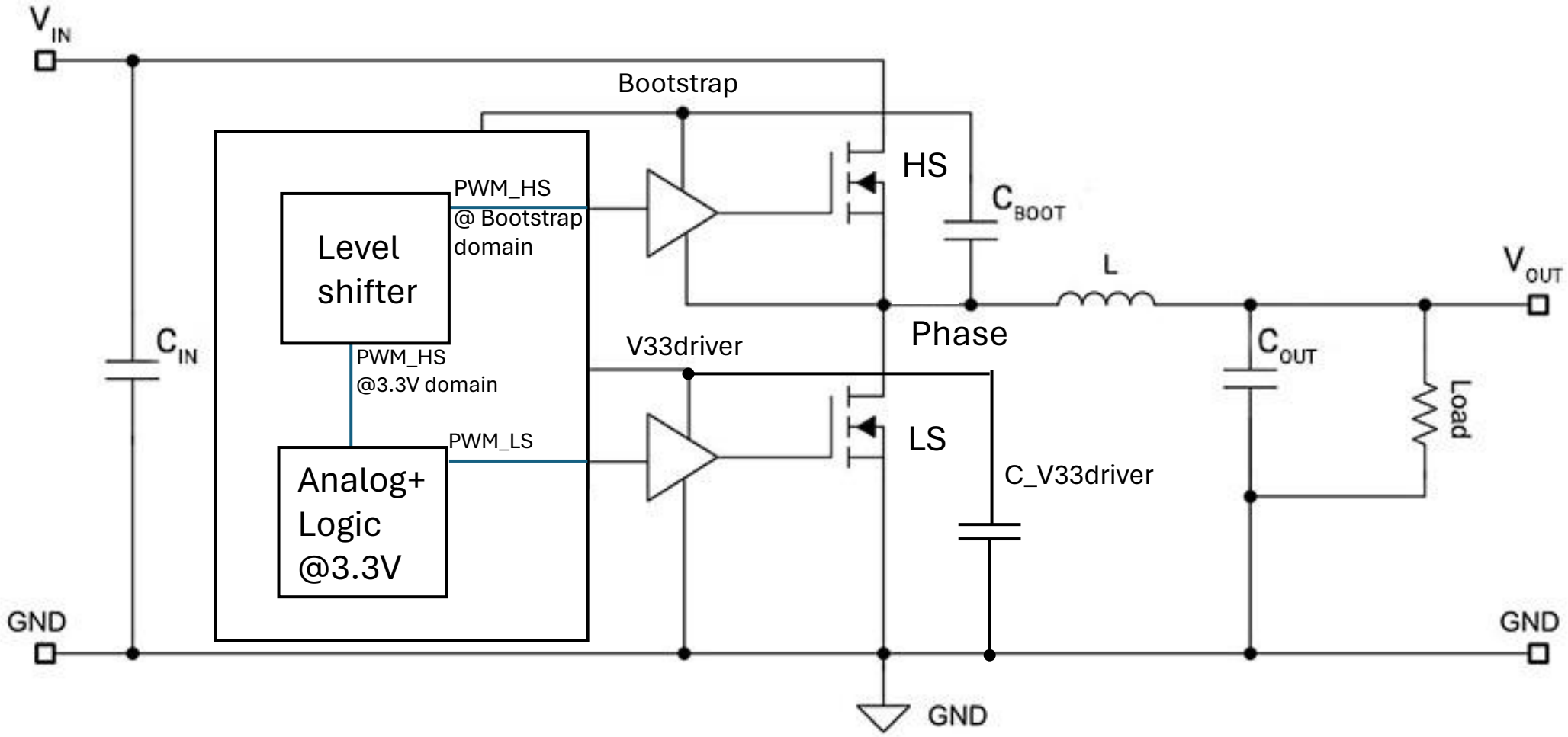
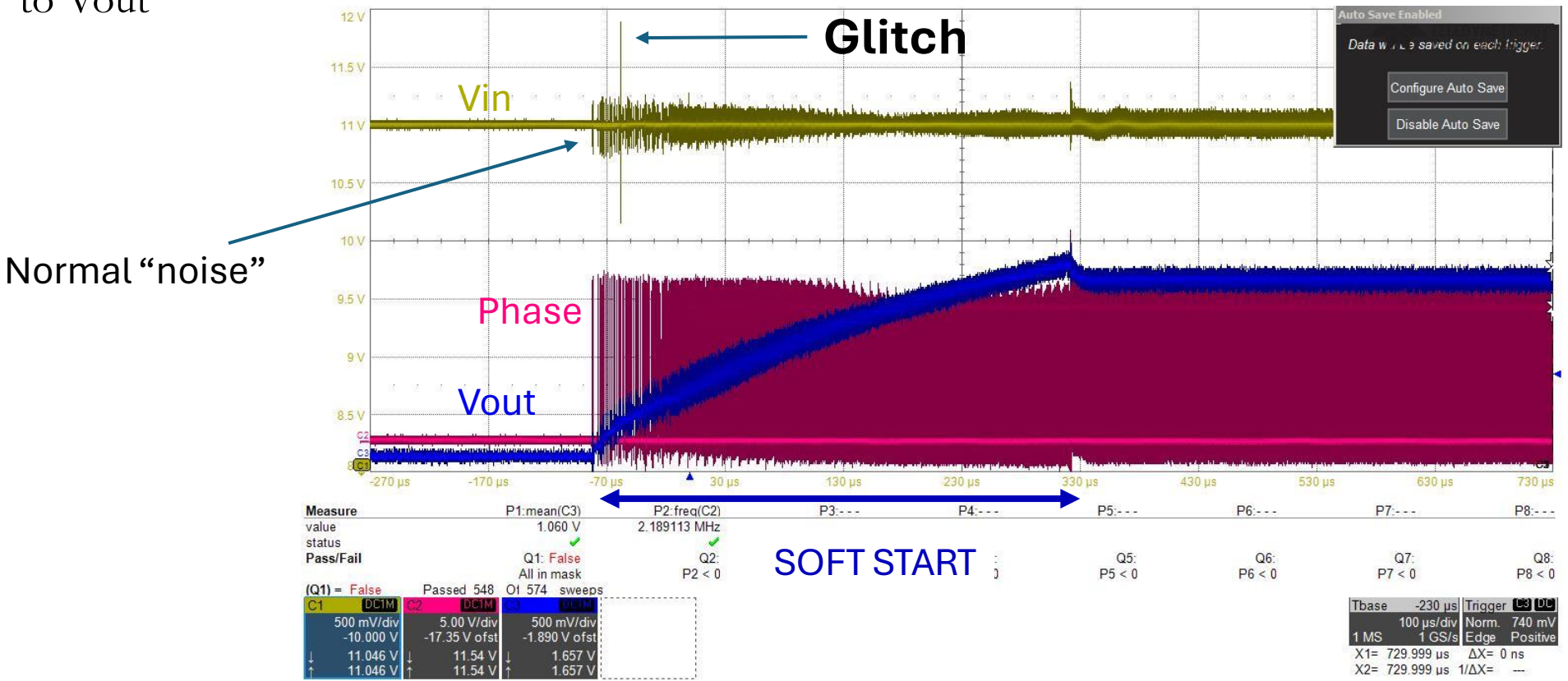
Schematic view of bPOL12V



The problem: observations

Power boards failing after TID irradiation follow a repetitive pattern:

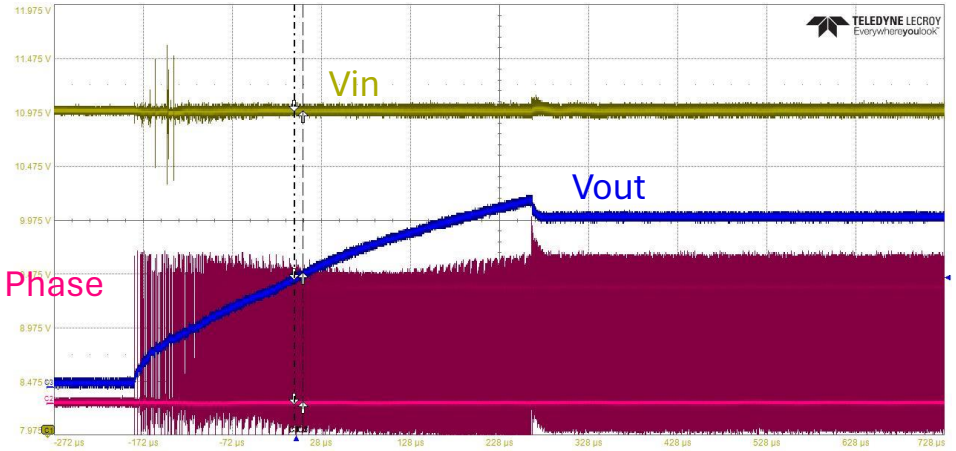
- Apparition of a first V glitch on Vin, in the early phases of the soft-start
- Evolution to an increasing number of glitches with repetitive number of soft-start cycles (several hundreds or thousands)
- Failure of the soft-start procedure with wrong turn-on of the HS transistor, effectively shorting Vin to Vout



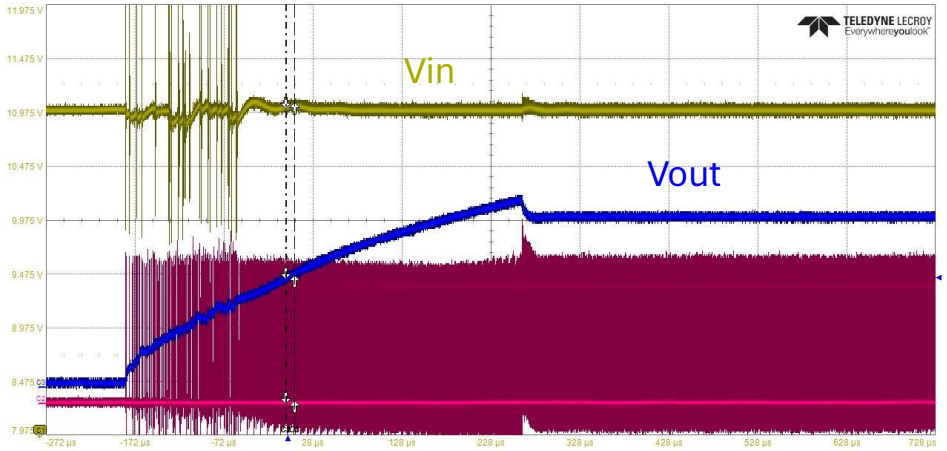
The problem: example of evolution

Example of a 70Mrad Xray irradiated bPOL12V, then Enable cycled at -30C at CERN

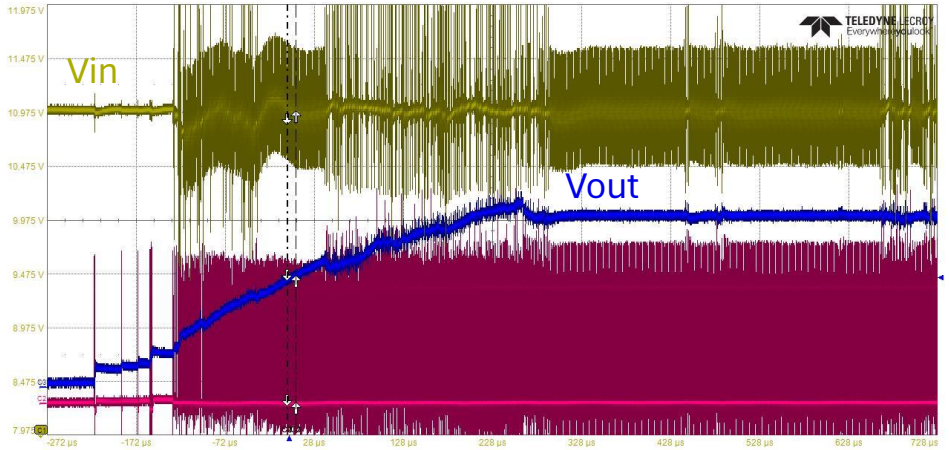
First cycle



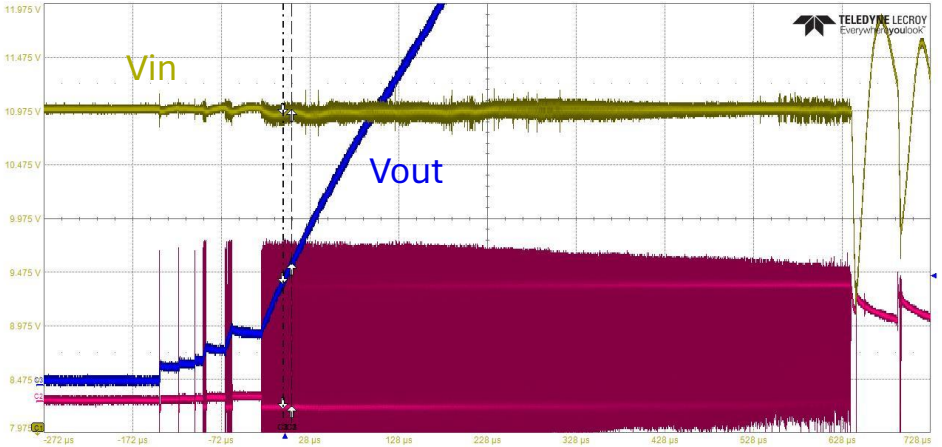
Cycle 1488



Cycle 1564



Cycle 1565 - failure



Why it hasn't been seen before

In tests carried out on bPOL12V we looked always at the Vout (value and startup shape), steady state input current (enabled and disabled), efficiency, frequency, different thresholds (Enable, UVLO, OCP, OTP).

Without knowing the presence of the glitch all characteristics of the bPOL12V remain the same until few cycles before the failure. In out tests in our lab it is necessary to do more that 1500 cycles (for high doses >70Mrad and -30C) to see a macroscopic effect.

Tests done on bPOL12V:

- Reliability of non irradiated samples

  150 bPOL12V have been kept under steady operation, with periodic soft-starts:

  - 120 boards at 12V Vin, large output current, and elevated T, for 3.5 years without any failure (~31000 cycles per board).
  - 30 boards at 13V Vin, large output current, and elevated T, for 3 years without any failure (~27000 cycles per board)
  - 14 of these bPOL12V have been measured in the last week for the presence of glitches on Vin at 25C and -30C, doing 1800 cycles each: no glitches have been detected

- Radiation characterization has been done with Xray (25C and -30C), protons (different energy), neutrons, heavy ions (more info on the datasheet https://power-distribution.web.cern.ch/assets/datasheets/bPOL12V_V6%20datasheet%20V1.9.pdf).

- In general, each converter has been cycled 200-300 times during Xray irradiations and 100-200 times during annealing, without any noticeable change of the parameters.

The problem: difference from ITK

In ITK tests on barrel staves and endcap petals after 70Mrad irradiation, it is sufficient a few thermal cycles 25C ->-35C and <10 cycles Enable/Disable to make bPOL12V fail (FAILURE=wrong output voltage and in most of the case, higher than the nominal 1.5V, in same case Vout=0)

CMS OT tests on 3 bPOL12V irradiated with protons (equivalent TID>100Mrad) shows that are necessary ~100 Enable cycles to have a failure of the device at -40C

This rapid failure has not yet been reproduced in labs, at CERN and Freiburg where single modules are tested.

In Freiburg, single power modules irradiated at 70Mrad needs several hundreds Enable/Disable to see an evolution and close to a thousand to get to a failure at -30C (small statistic for the moment)

At CERN, bPOL12V modules exposed to 70Mrad, show evolution of the glitches and misbehaviour only after several thousands of cycles at 25C (small statistic also here). At -30C we have only one failure after 1565 cycles.

The problem: our current understanding

- The initial glitch on Vin is interpreted as a cross-conduction: there is insufficient dead time between the turn-off of the HS and the turn-on of the LS
- This happens for very short PWM (Pulse width modulation) pulses (35-40ns)=> only during the soft-start procedure

Before irradiation there is probably already a little [illegible] between HS and LS in this particular PWM configuration, since it is possible to find few (one at CERN and one in Freiburg) non-irradiated chips that produce a short glitch very occasionally during soft-start (in below 1% of the cycles – see next slide.

TID shifts the transistors' parameters and makes the glitch probability much larger and the cross-conduction wider.

Each glitch is a cross-conduction event where a large energy is dissipated in the chip, introducing damage that worsens the situation until failure.

Hypothesis to be confirmed

Further observations

- Until now we found only one new sample that is showing occasional glitches before TID irradiation. One other sample has been found in Freiburg. It doesn't appear to evolve to a worse condition
  - 1800 cycles at 25C and 1800 cycles at -30C leads to few tens of glitches without evolution
- The bias condition and dose rate might influence the process, but bPOL12V chips irradiated both floating or under bias are affected (albeit we still cannot say if there is a measurable difference).

Parallel paths ahead

1. Radiation levels reliably reachable
   - Environment (X-rays, gammas, protons)
   - Temperature (-40C, 25C, ?)
   - Under representative bias
2. Full understanding of the problem
   - Confirmation of the origin
   - Understanding of the evolution (mechanism?)
3. Formulation/qualification of corrective solutions

1. Radiation levels reliably reachable

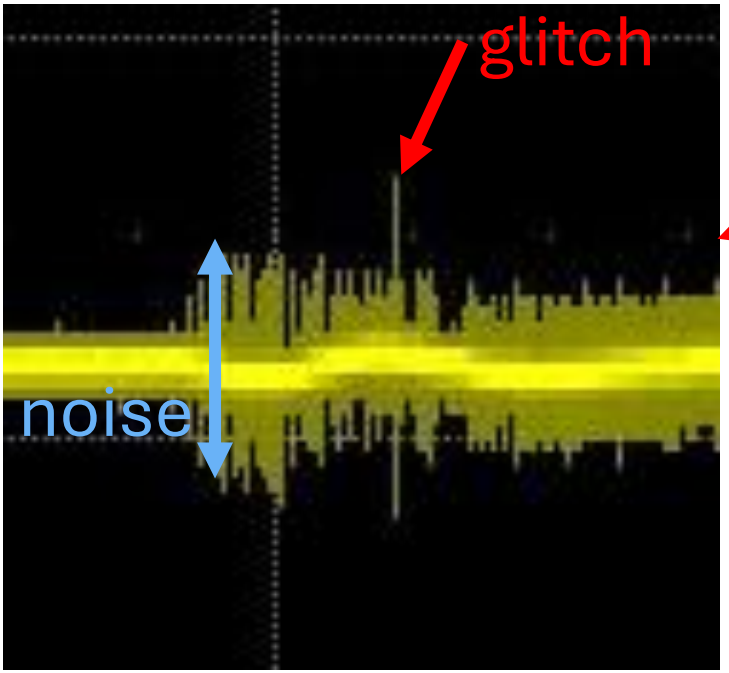
bPOL12V chips are used in a wide variety of radiation environments in HL-LHC (100krad to >70Mrad): where can they be used safely?

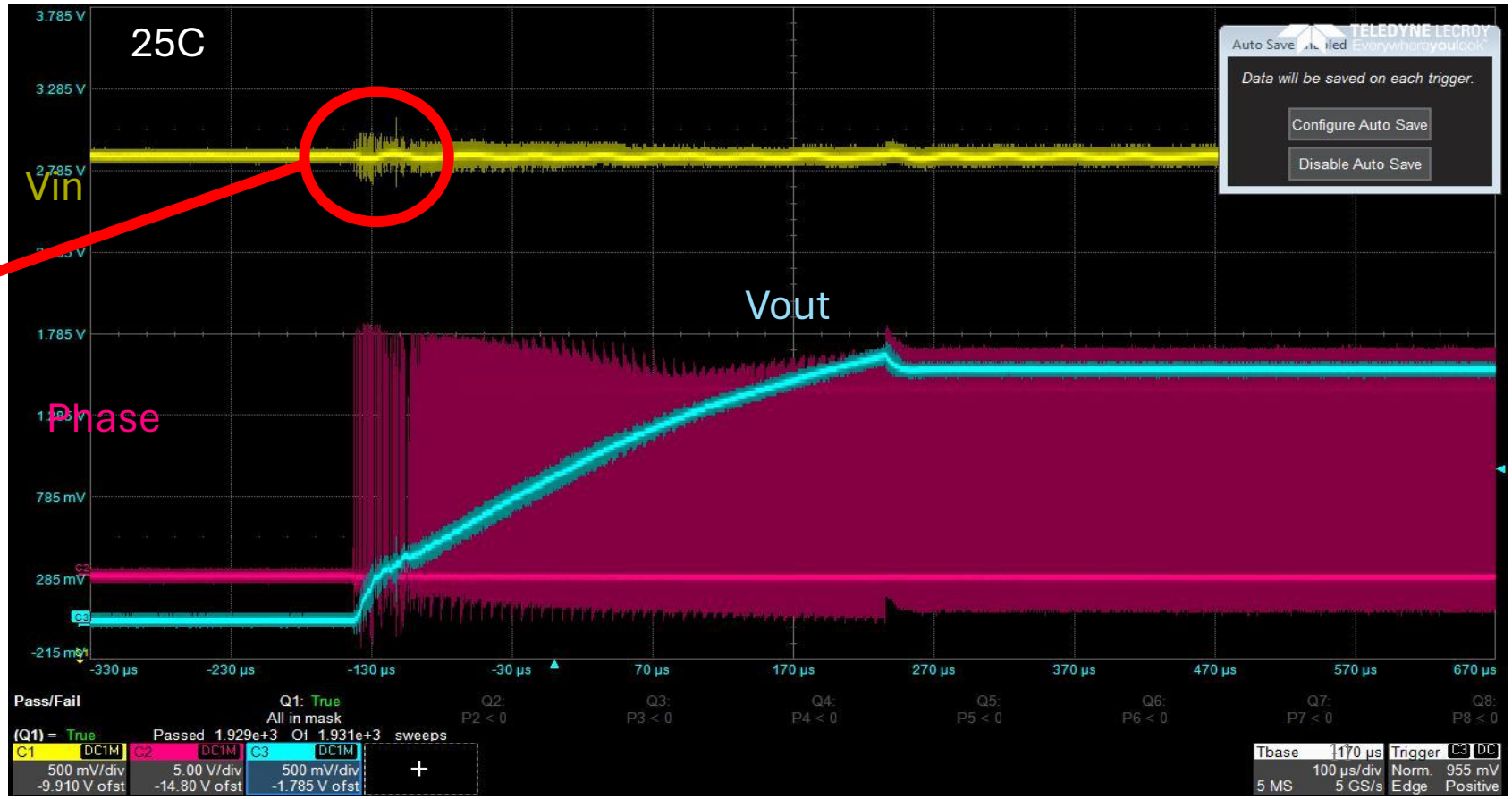
- Tests already done: Irradiation@25C, bias, X-ray machine, 2Mrad/h, cycles of 1800 Enable/Disable. Statistic is very low due to limited irradiation surface

	500Krad	1Mrad	5Mrad	10Mrad	70Mrad
25C	1 irradiated chip **Very rare small single glitches (2 over 1800 cycles)** no evolution	1 irradiated chip **Rare single glitches (few tens)** no evolution	2 irradiated chips, **occasional single glitches**, no evolution	2 irradiated chips, **frequent multiple glitches in each startup**, no evolution	1 irradiated chip **frequent multiple glitches**, 4000 cycles no failure, but evolution with increasing number of glitches
-30C	ongoing	1 irradiated chip **no events recorded** no evolution	Higher amplitude glitches (higher rate) No evolution Same behavior at -40C	Higher amplitude glitches (higher rate) No evolution	1 irradiated chip **Failed after 1565 cyles**

500KRad

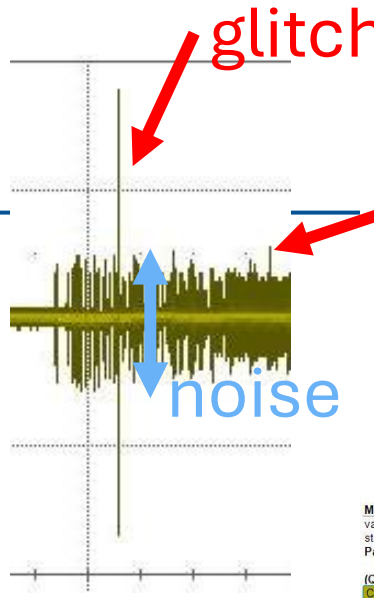
- **b114**: 1800 cycles at 25C, -30C(TBD, ongoing). Conductions observed in 2/1800 cycles, very small, difficult to see in the noise of Vin.
  NO FAILURE and NO EVOLUTION

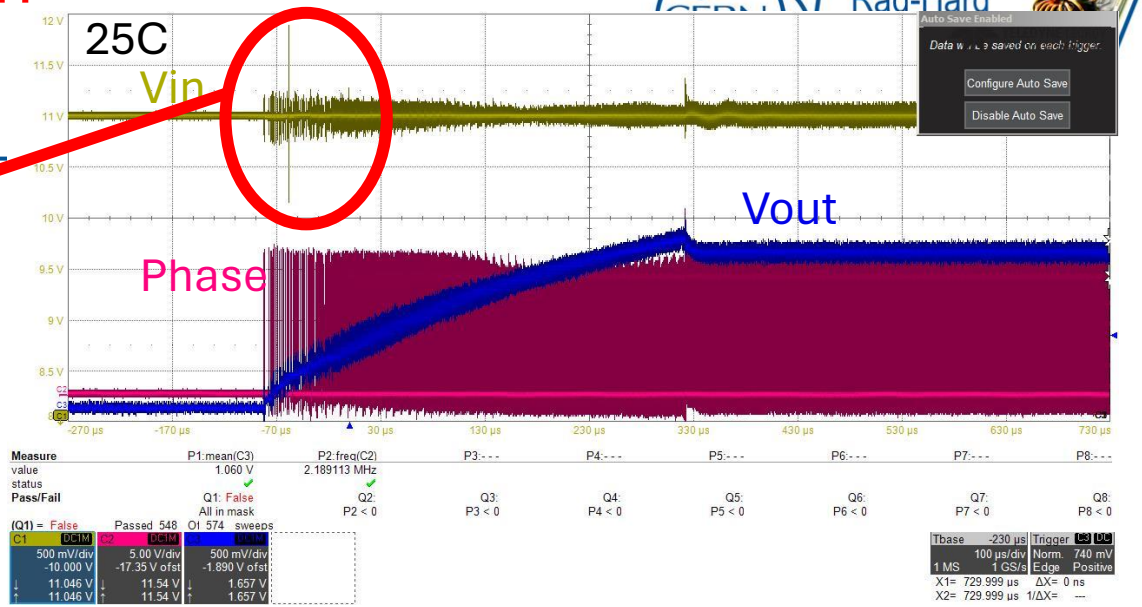


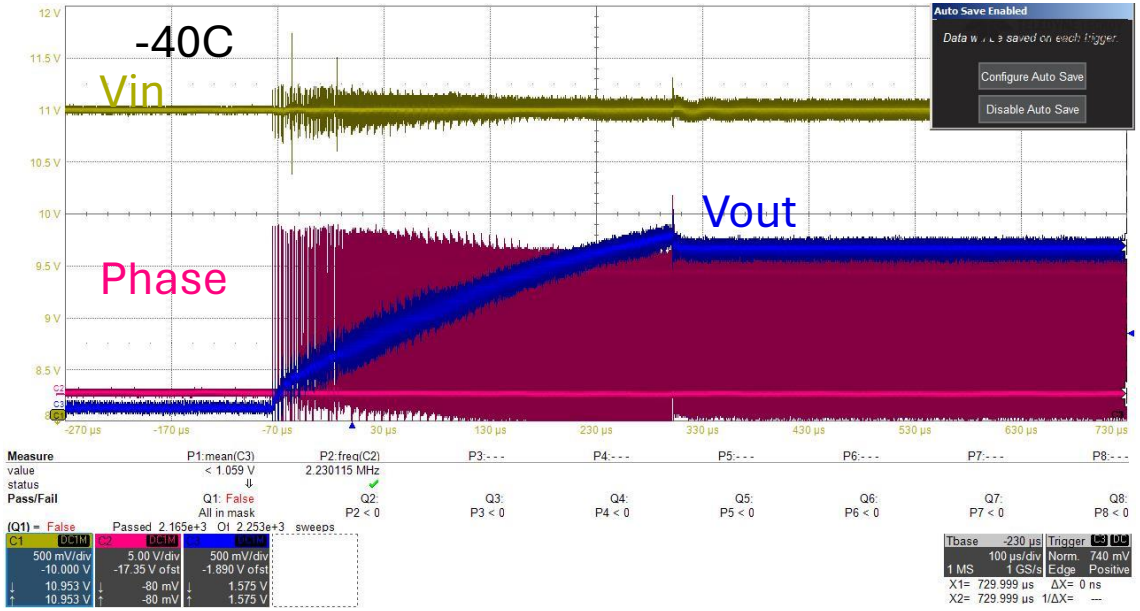


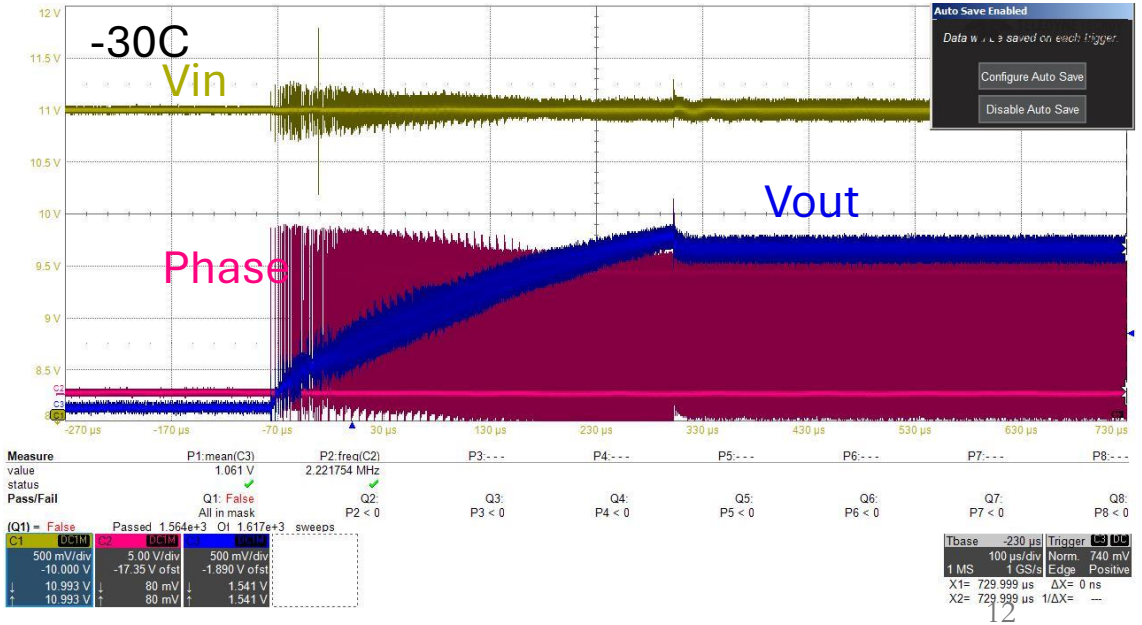
5MRad

- **b148**: 1800 cycles at 25C, -30C, -40C. Few cross-conductions observed, increasing rate of occurrence only at low temperature.
NO FAILURE and NO EVOLUTION over the 1800 cycles



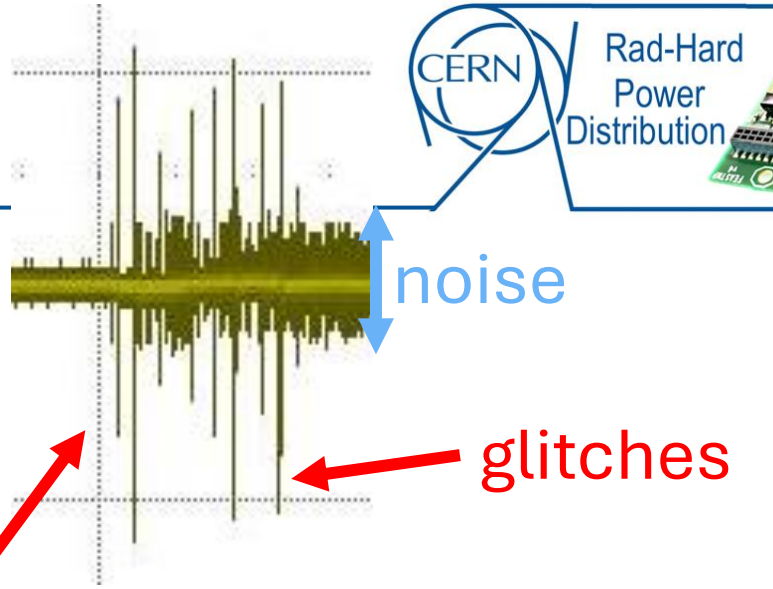


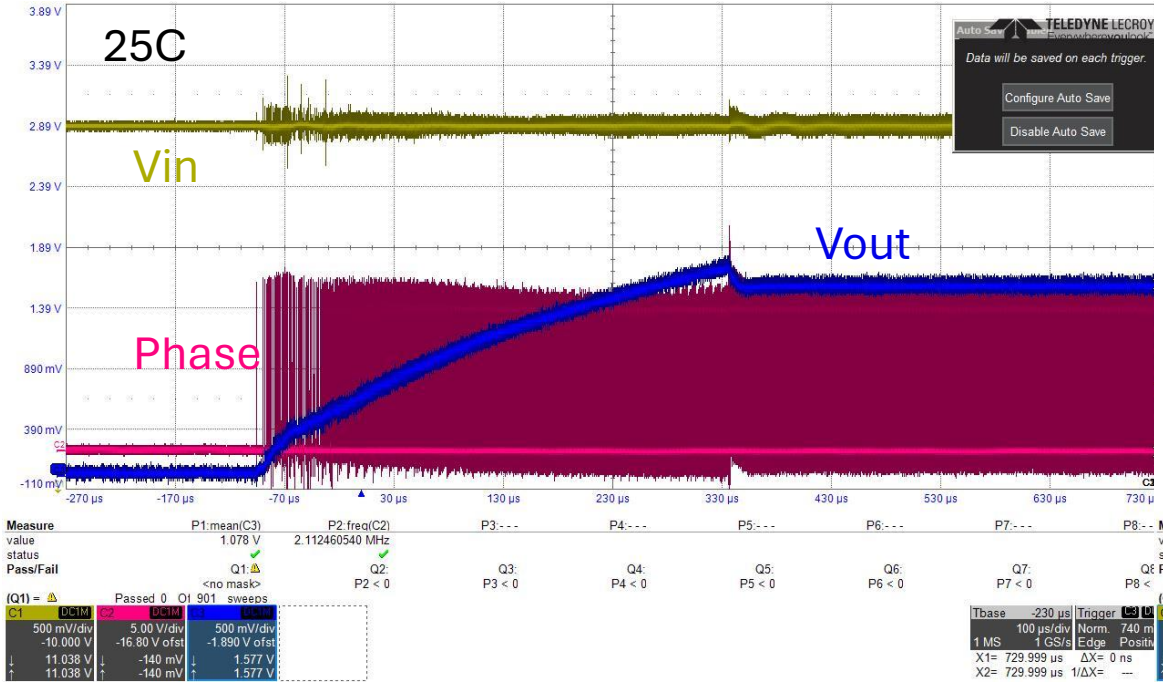


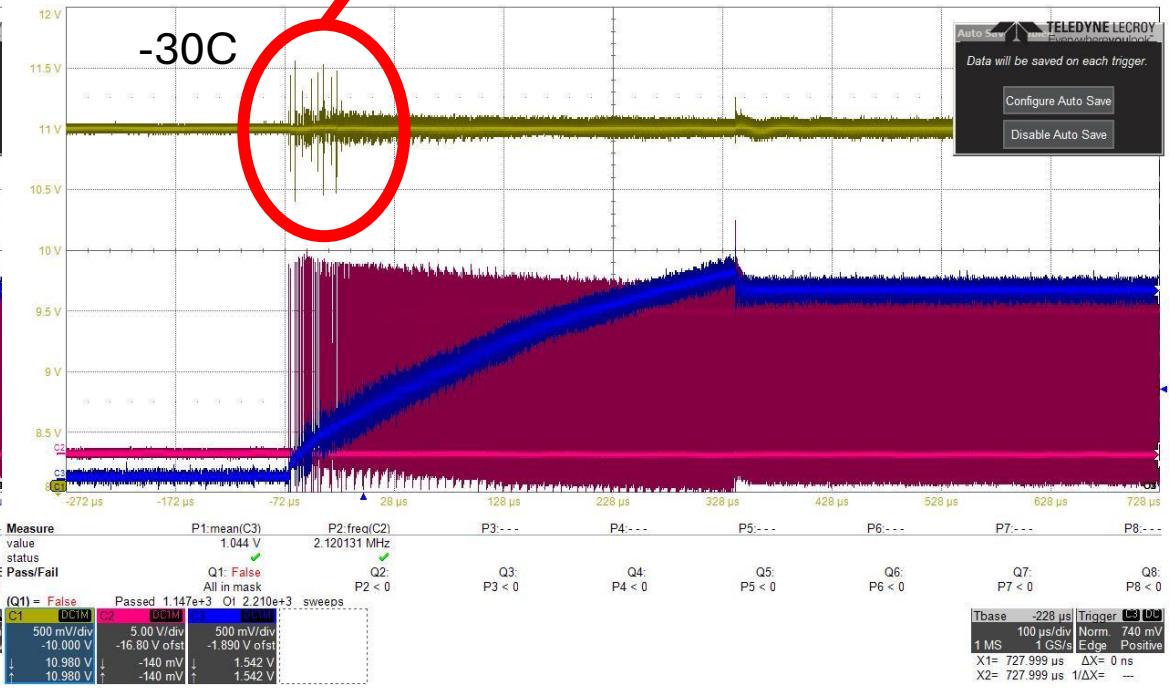


10MRad

- **b101:** 1800 cycles at 25C, -30C. Many cross-conductions observed, increasing rate of occurrence and amplitude at low temperature.
  NO FAILURE and NO EVOLUTION over the 1800 cycles



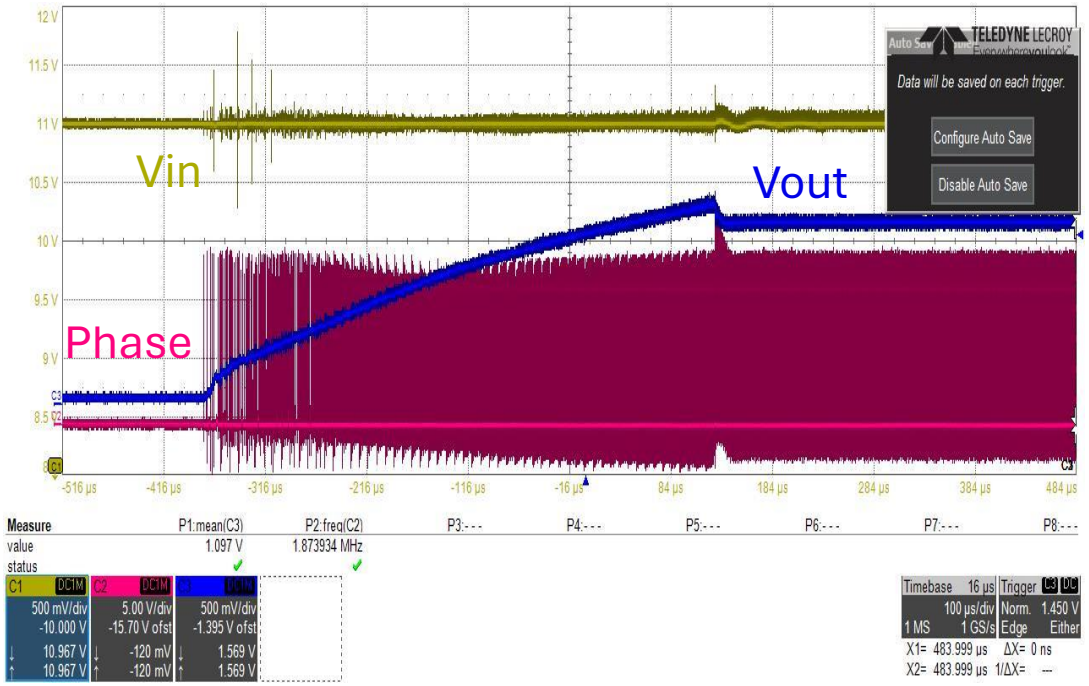




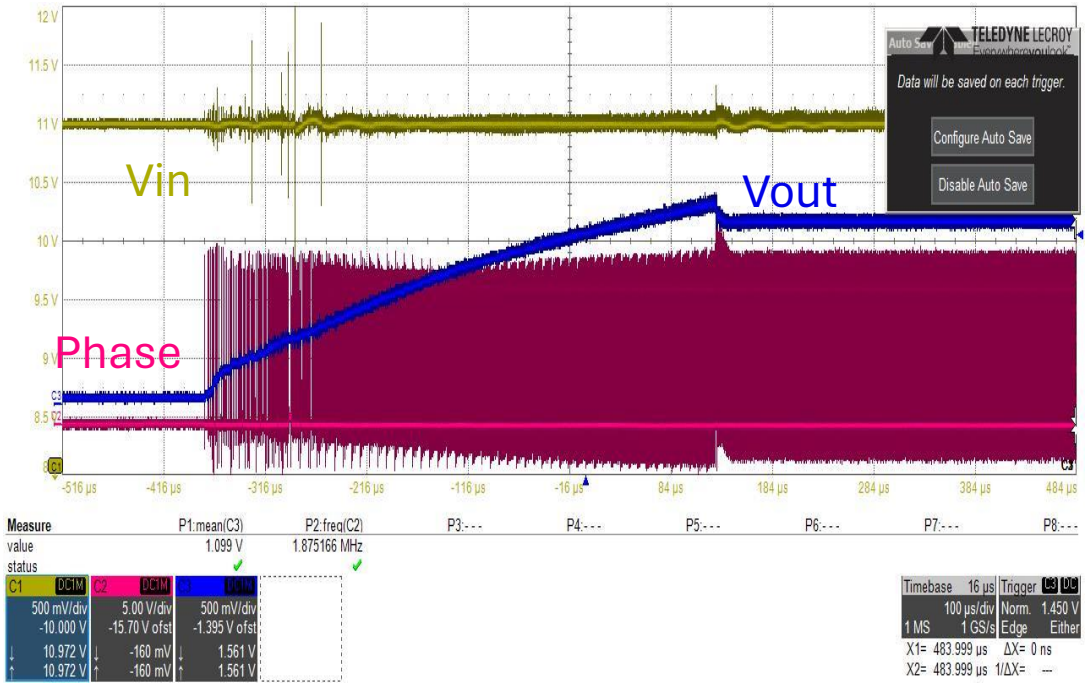
70Mrad 25C

4000 cycles at 25C. Many cross-conductions observed, increasing rate of occurrence and amplitude when increasing the number of cycles
NO FAILURE after 4000 cycles

First cycles



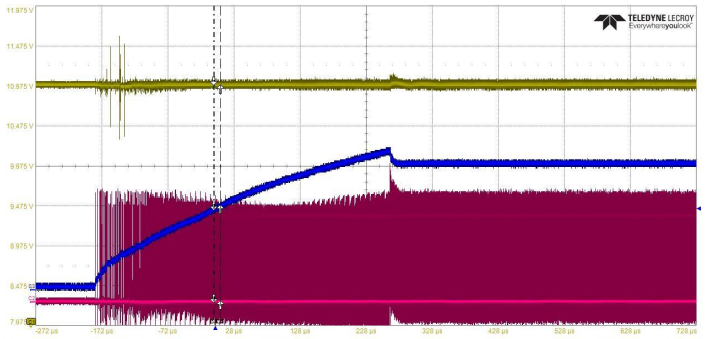
After 3900 cycles



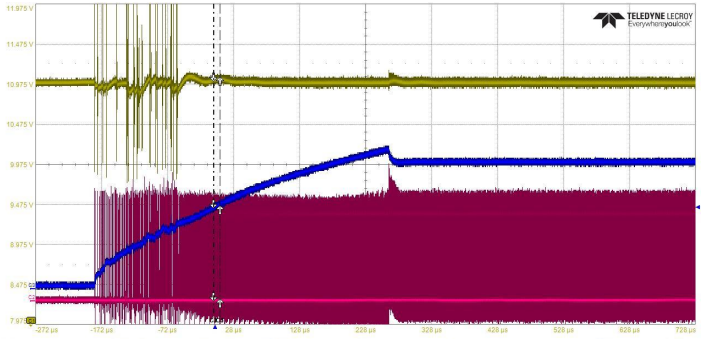
70Mrad -30C

B120, cycling at -30C. Many cross-conductions observed, increasing rate of occurrence and amplitude when increasing the number of cycles, exceeding after ~1500 cycles the softstart and failure at 1565 cycles.

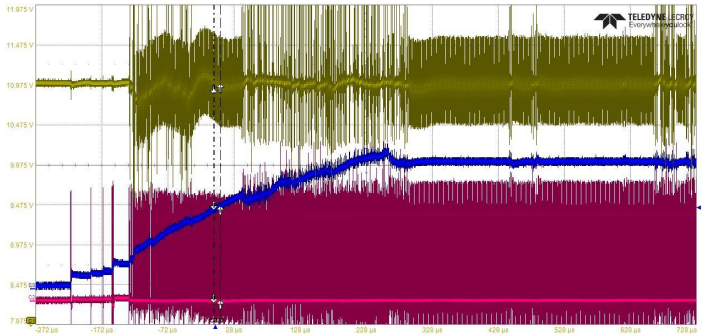
First cycle



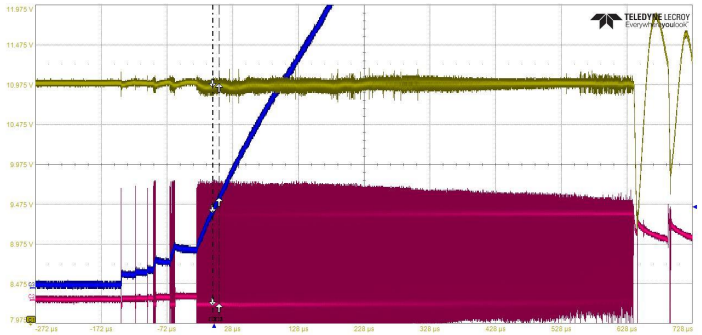
Cycle 1488



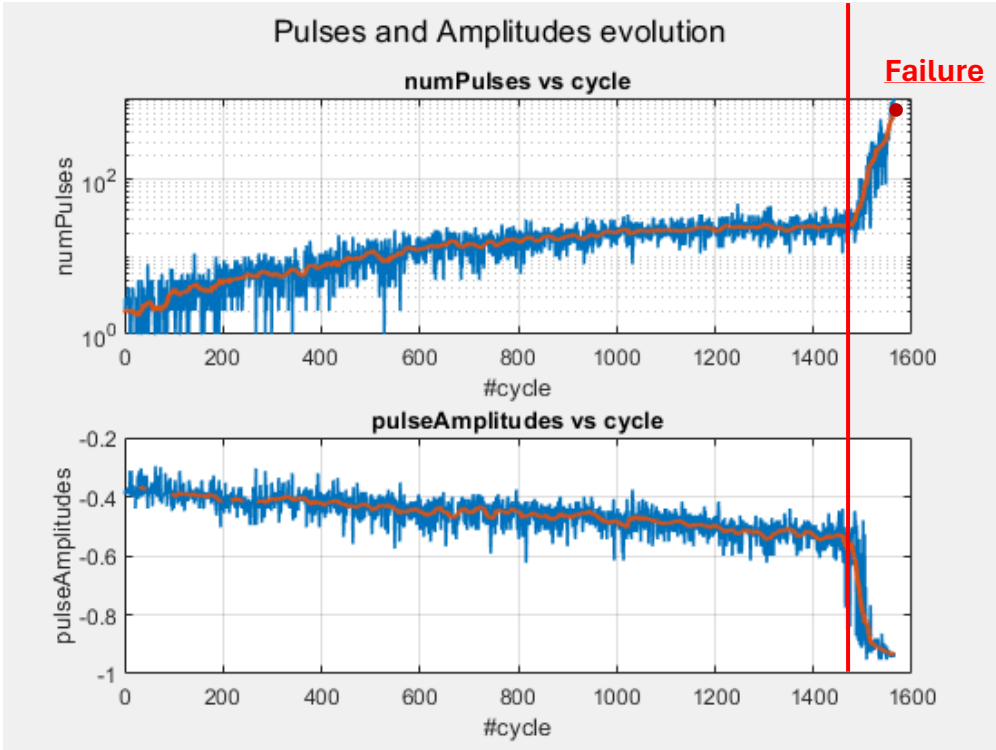
Cycle 1564



Cycle 1565 - failure



Rapid worsening of cross-conductions



1. Radiation levels reliably reachable

bPOL12V chips are used in a wide variety of radiation environments in HL-LHC (100krad to >70Mrad): where can they be used safely?

A lot of efforts are done to assess the levels:

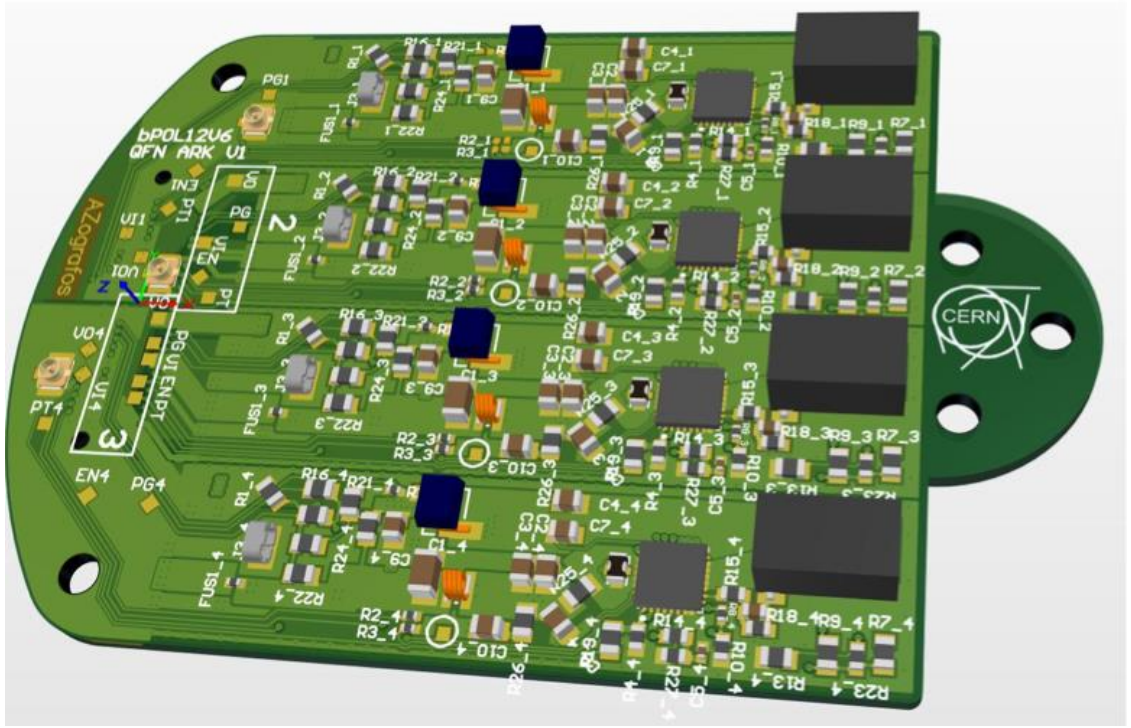
- Cern is preparing modules hosting 4 bPOL12V to be irradiated at the same time with Xrays (and ^{60}Co) for increasing the statistic

- Atlas ITK is organizing:
  - Irradiations of ~200 bPOL12V at different fluen… …+GeV protons @ IRRAD (CERN)
  - Irradiations with X-rays & ^{60}Co @ low T (du… …diation and soft-start cycles)
- CMS is organizing
  - testing old boards irradiated with pr… …Strasburg
  - preparing tracker 2S modules to… …posed to Xray
  - Testing of 40 already irradi… …OL12V modules for GEM at 5Mrad

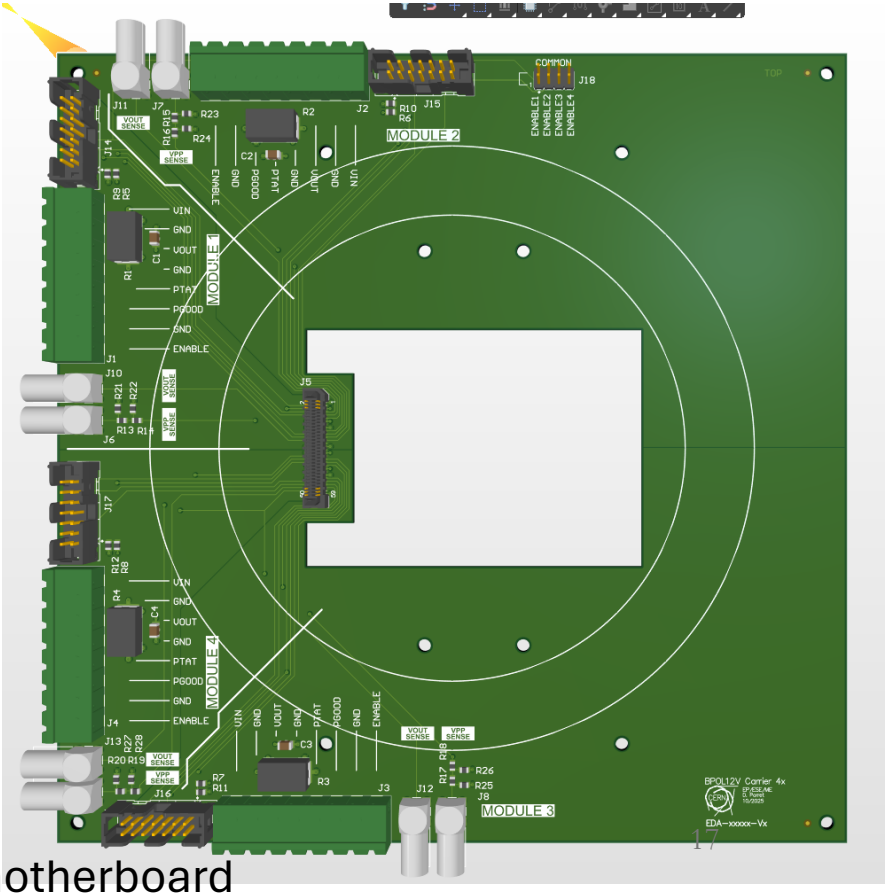
Covered by following presentations

1. Radiation levels reliably reachable

EP-ESE is developing a board for hosting 4 bPOL12V, to be irradiated with Obelix Xray machine @10cm distance. The beam is sufficiently large to cover the 4 bPOL12V at the same time. This board can be used also for larger scale irradiations (^{60}Co for example).



Board with 4 bPOL12V



motherboard

1. Larger scale irradiation

EP-ESE is also developing a test system for monitoring many converters (at least 12) for large scale irradiation tests at ^{60}Co, when the TID limit is found, in order to increase the statistic.

The work is divided between

1) software developments:
   - control of all the bPOL12Vs
   - monitoring of all the Vin and Vout
   - Automatic counting of the Vin peaks
   - Read-out and plotting of the data
2) Hardware developments:
   - Large card hosting several of the 4bPOL12V modules (previous slide)
   - Rack for hosting several of long boards with multiple 4bPOL12V modules

Parallel paths ahead

1. Radiation levels reliably reachable
   - Environment (X-rays, gammas, protons)
   - Temperature (-40C, 25C, ?)
   - Under representative bias
2. Full understanding of the problem
   - Confirmation of the origin
   - Understanding of the evolution (mechanism?)
3. Formulation/qualification of corrective solutions

2. Full understanding of the problem

On-going priority effort of core DCDC designers in the ESE team, based on simulation and observation of the bPOL12V chips (particular attention to the soft-start procedure)

- Use of simulation to guide experiment
- So far based on electrical measurements of bPOL12V chips
- Possible use of failure analysis techniques in the near future, to collect additional evidence pointing at the resulting damage at the microscopic level

Parallel paths ahead

1. Radiation levels reliably reachable
   - Environment (X-rays, gammas, protons)
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Based on the progress in understanding, possible corrective solutions are being explored in ESE

- A modification of the existing design seems excluded: the I3T25 technology used for the design and manufacture has been discontinued
- Modifications of the DCDC power board are considered, with addition of components in the surrounding of bPOL12V to modify some details of its electrical functionality: resistors, diodes, power transistors, capacitors
  - If a satisfactory solution is found, it will be qualified on a large number of samples

Conclusions

Facts:

- There is a first understanding that the glitches on Vin could be due to unwanted cross-conductions between Vin and GND, due to insufficient dead time between the turn-off of the HS and the turn-on of the LS
- The cross-conduction appears at the beginning only in startup
- On high TID boards and -30C, if a lot (hundreds) of Enable/Disable cycles are done, there is an evolution, with increased number of cross-conductions and their amplitude. Similar behavior has been tested on single power modules in Freiburg.
- HOWEVER it is still not clear why in ITK staves and petals is sufficient to do <10 Enable cycles to have failures of the bPOL12V

Ongoing activities:

- Find radiation levels that are reliably reachable (matrix of radiation levels, radiation source, bias, temperature). Some statistic is necessary, therefore large irradiation campaigns are in preparation.
- Try to fully understand the problem with simulations and tests
- Try to find a solution for the detectors with high TID levels (modification of the boards with some passive/active elements)

Final words:

- EP-ESE deeply regrets this situation and is making all efforts to investigate, understand and characterize the issue as quickly as possible.
- Input from the user community is desirable, necessary and welcome. These information meetings are the ideal place to exchange information and collectively progress towards a solution.