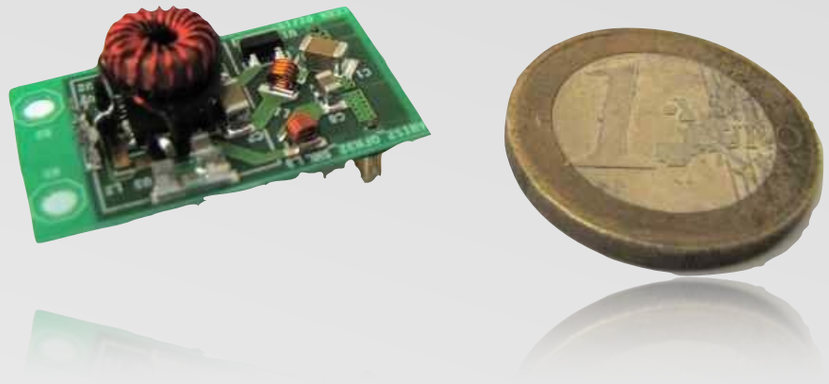
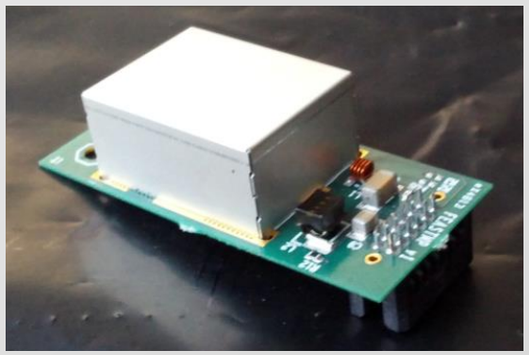


POL DC-DC for LHC upgrades

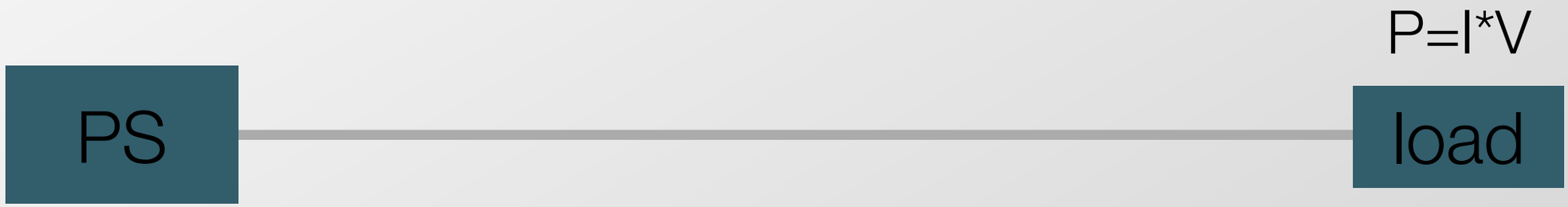
F.Faccio, S.Michelis, G.Blanchot, I.Troyano
CERN - PH/ESE

Outline

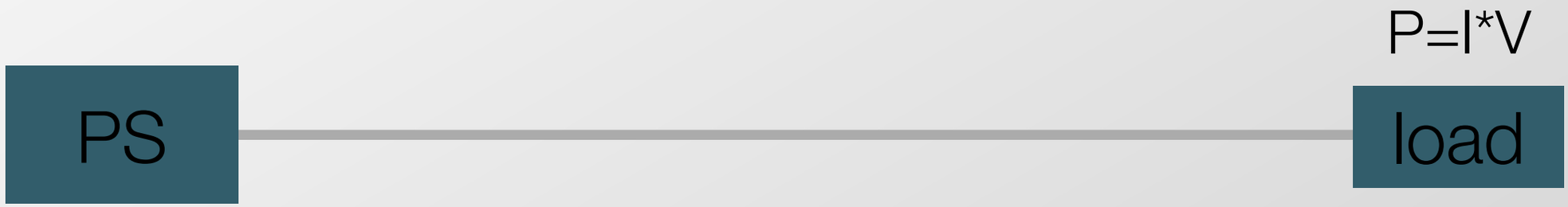


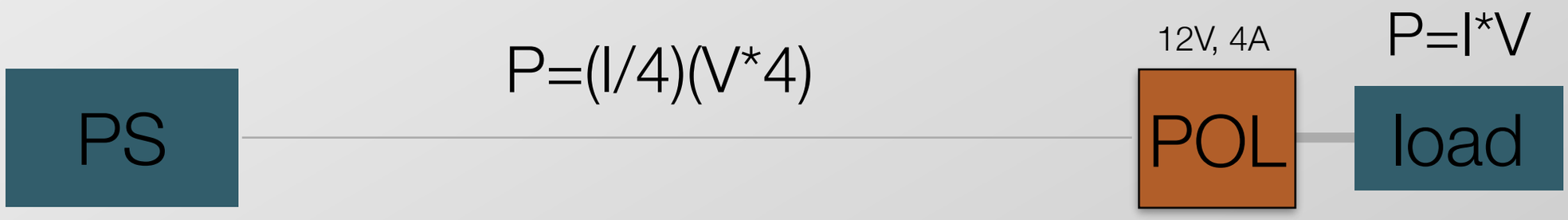
ATLAS-CMS
phase2 trackers

Point Of Load (POL) DCDC

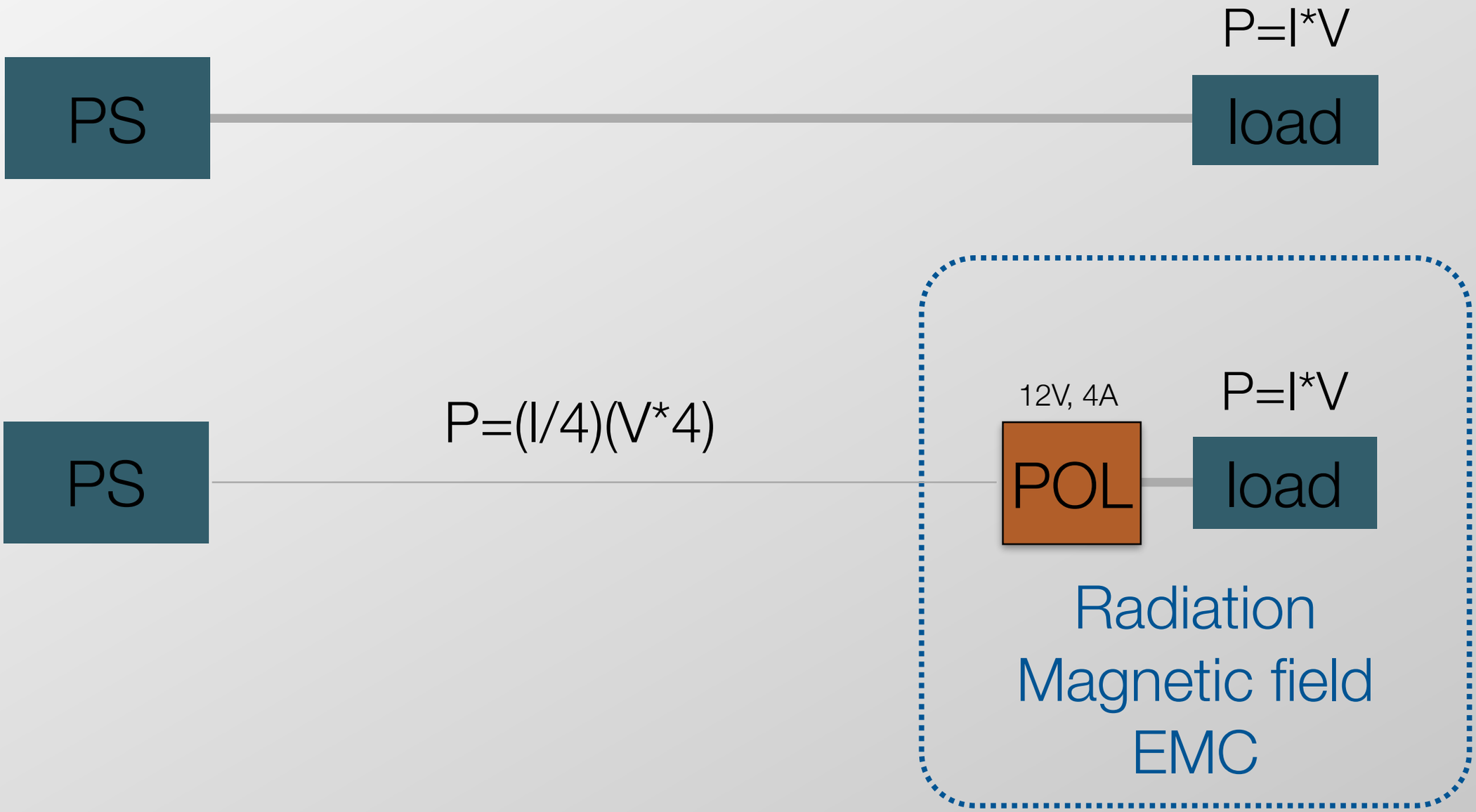


Point Of Load (POL) DCDC





Point Of Load (POL) DCDC



2007-2008

Rad-tol ASIC

which architecture?

2007-2008

2007-2008

Rad-tol ASIC

which architecture?

anything else?

inductor, shield, PCB

2007-2008

Rad-tol ASIC

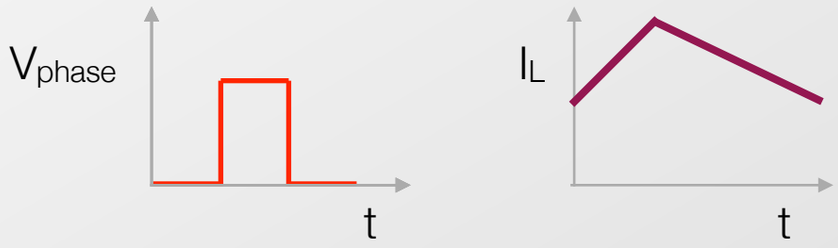
which architecture?

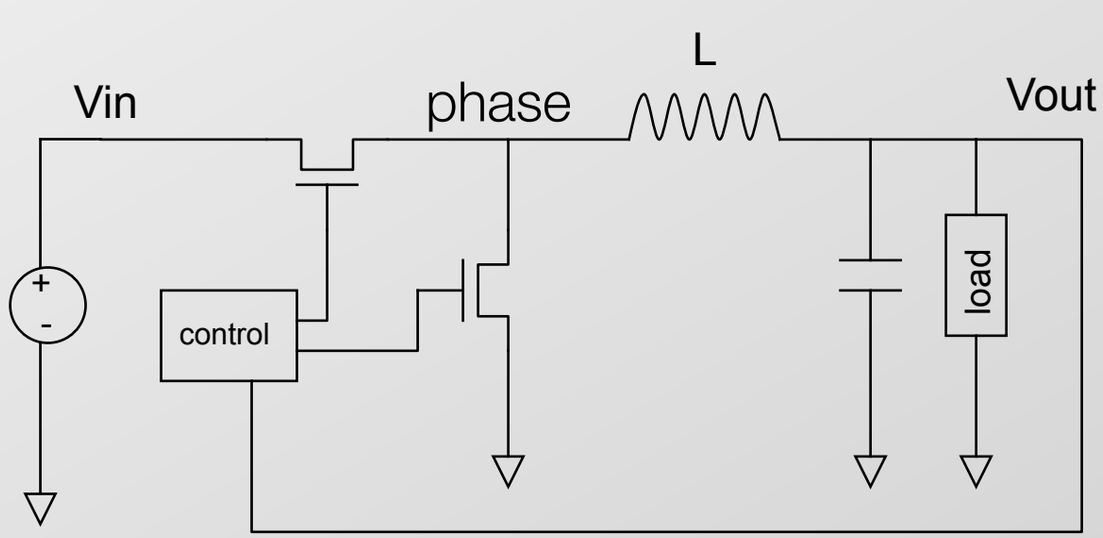
integration

anything else?

inductor, shield, PCB

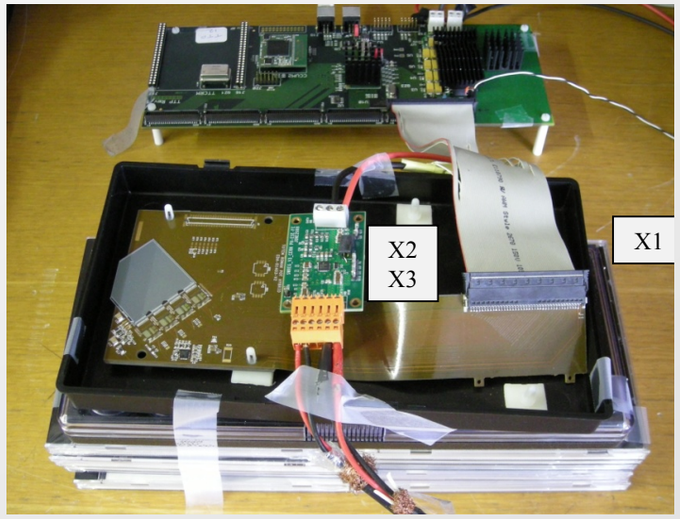
Buck DCDC converter

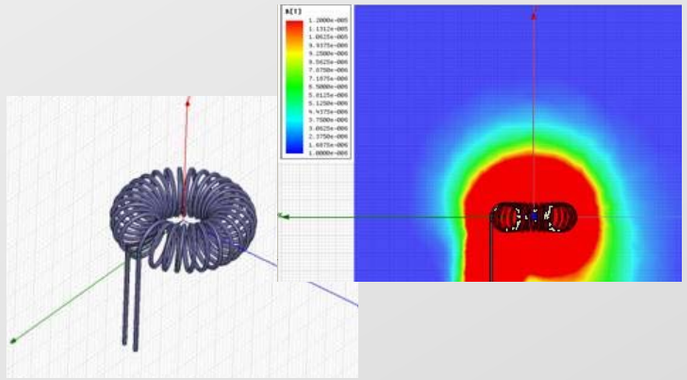


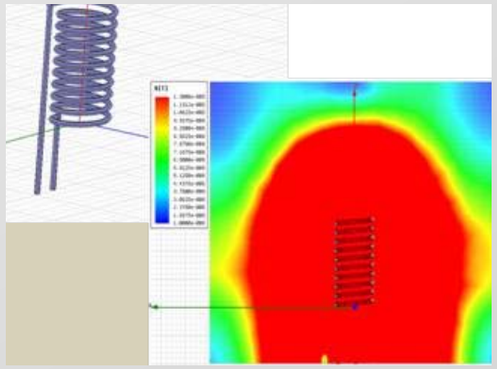


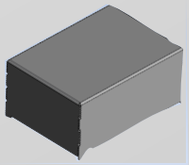
diffidence towards the possibility to use it in the sensitive HEP detector environment

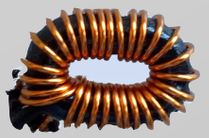
EMC, Integration, Custom components

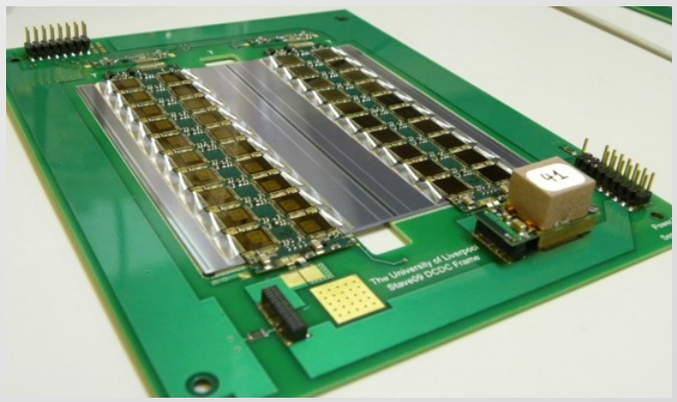


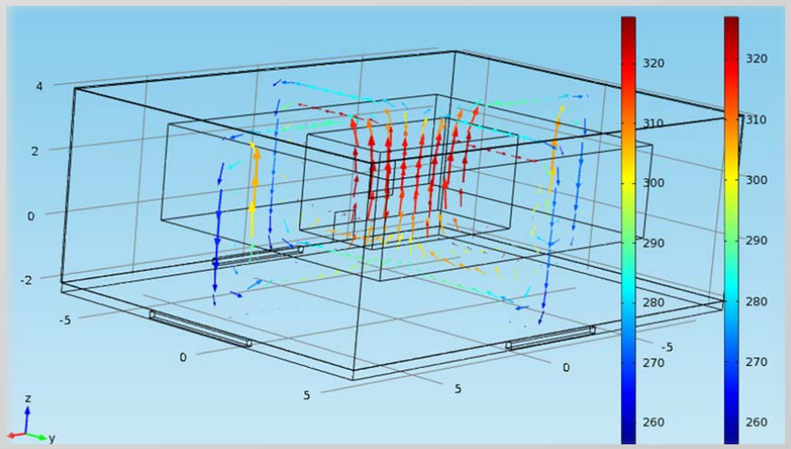






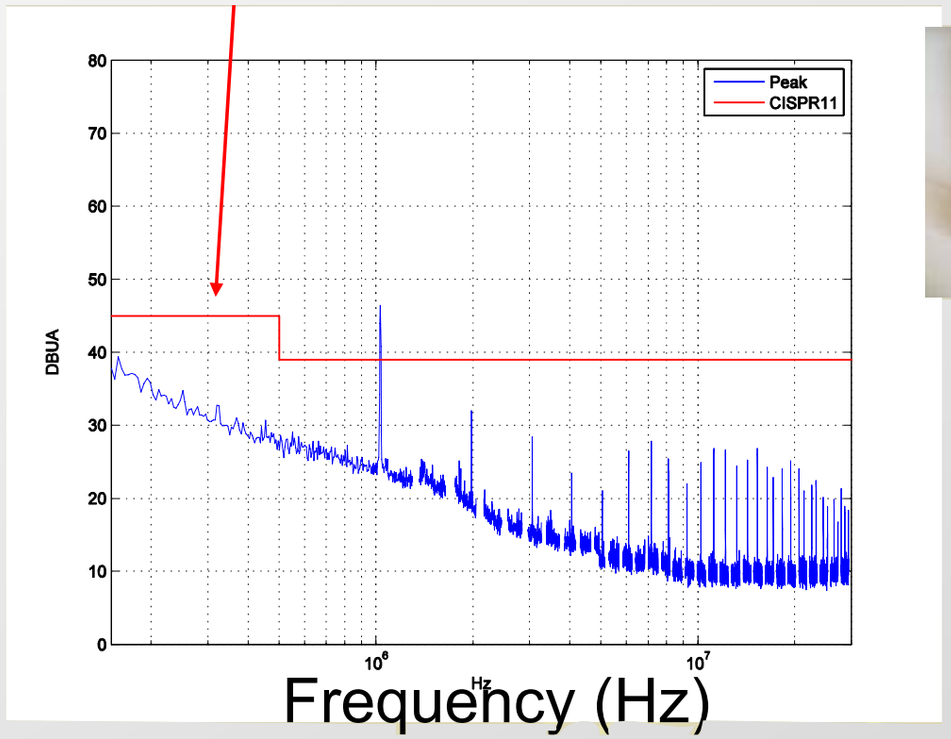






EMC, Integration, Custom components

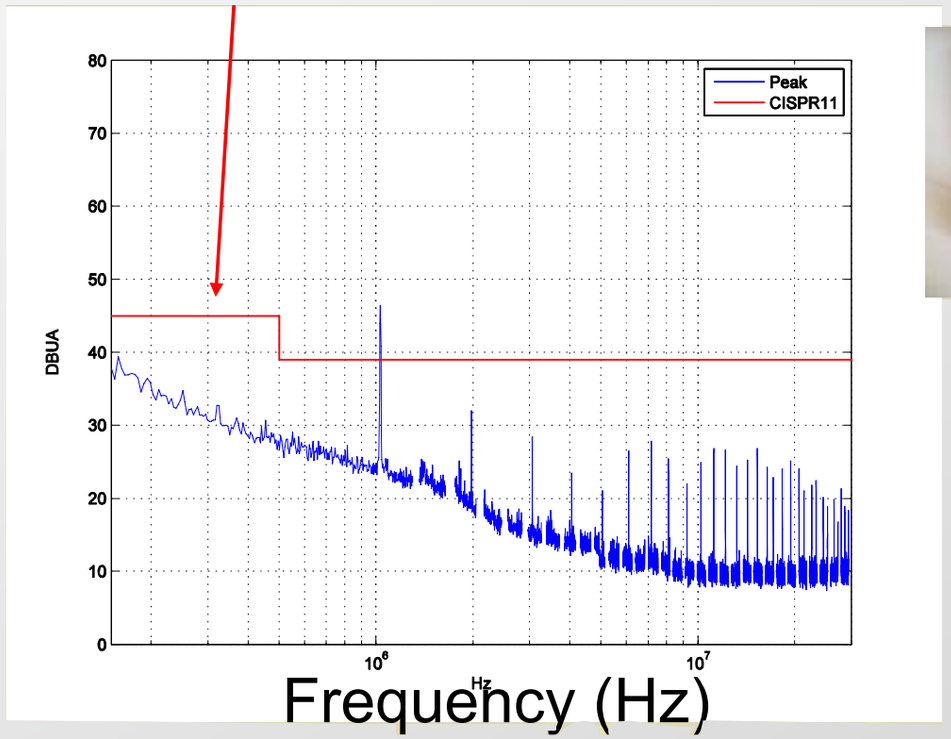
Class A (Average)



From this early prototype…..

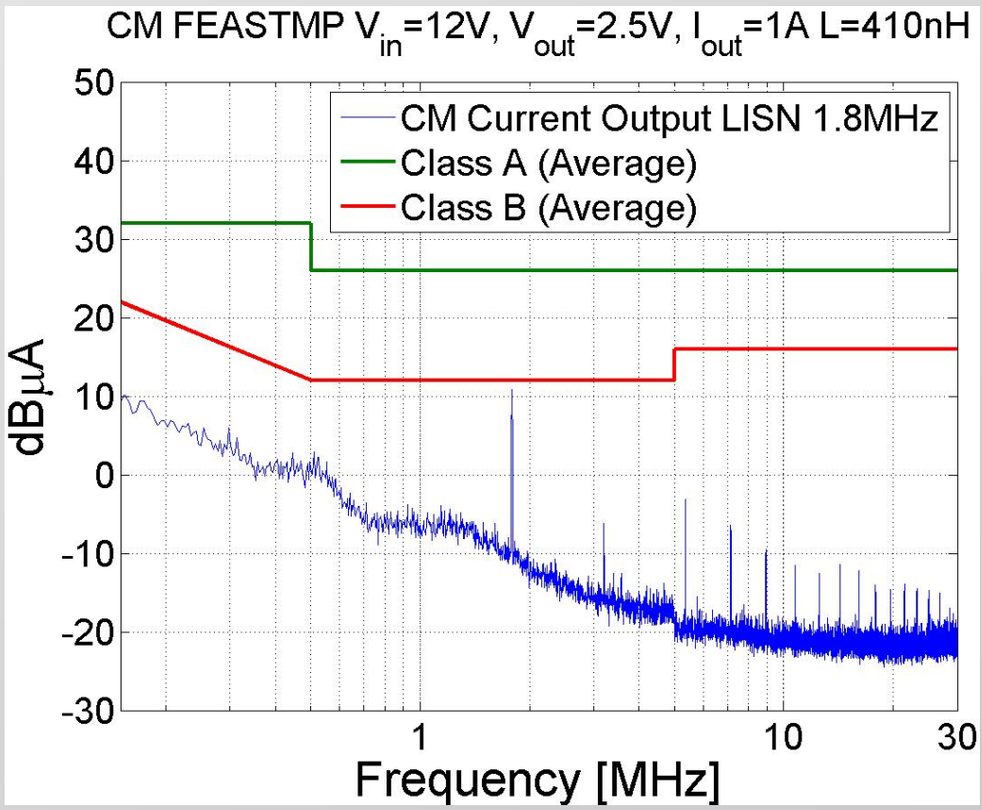
EMC, Integration, Custom components

Class A (Average)

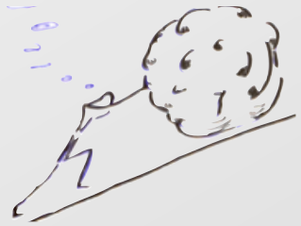


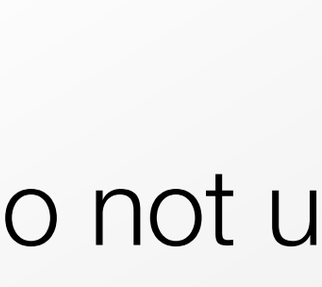
From this early prototype…..

….. to the production-ready FEASTMP

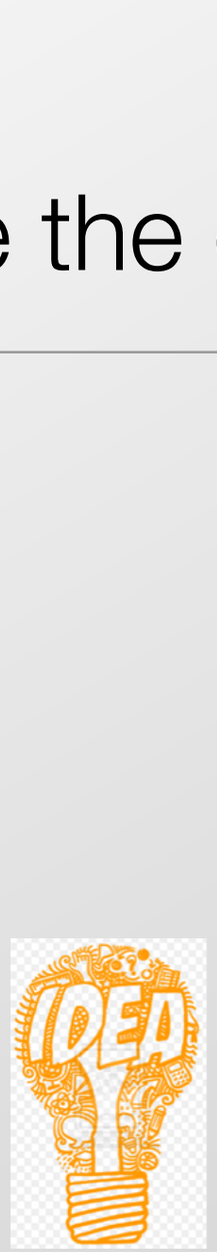


Do not underestimate the efforts!

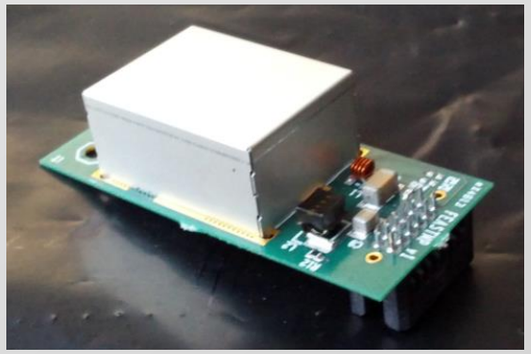


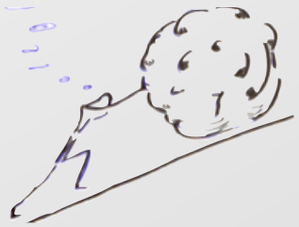


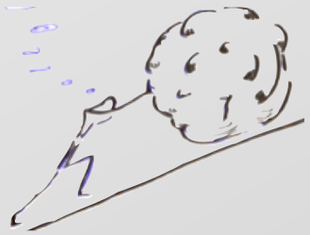
rad-tol

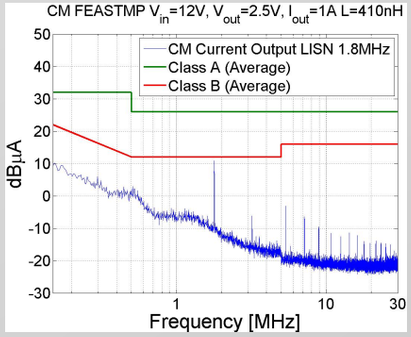


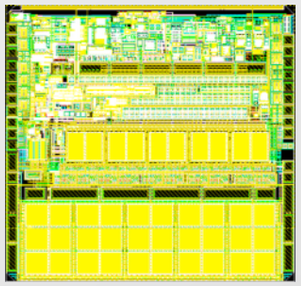
Do not underestimate the efforts!



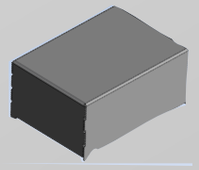






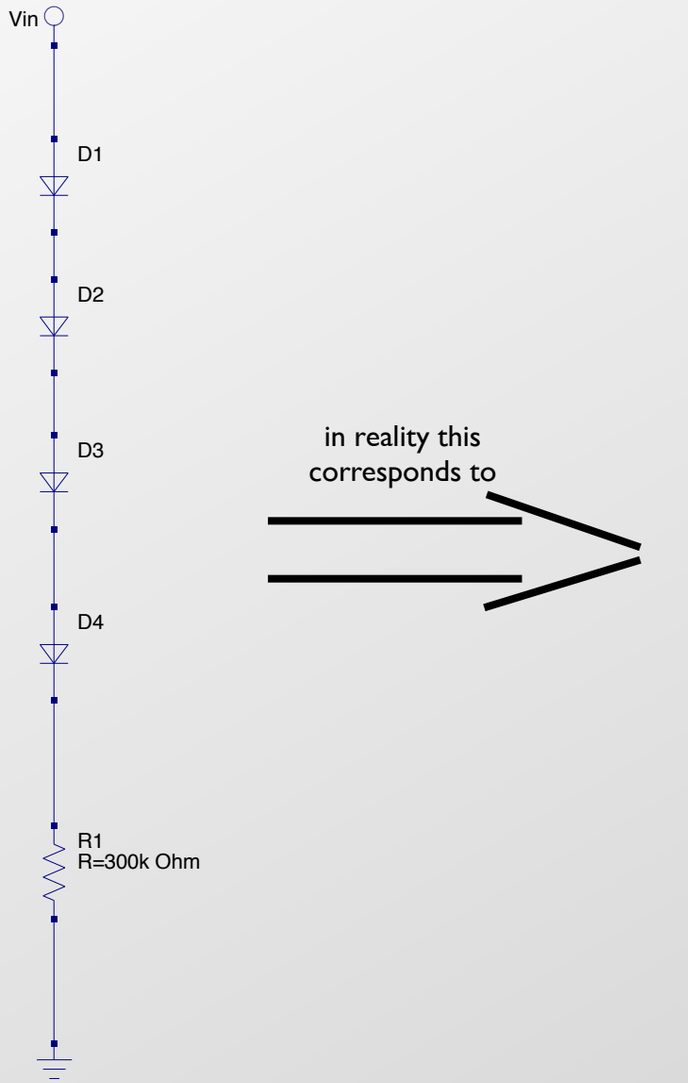


rad-tol

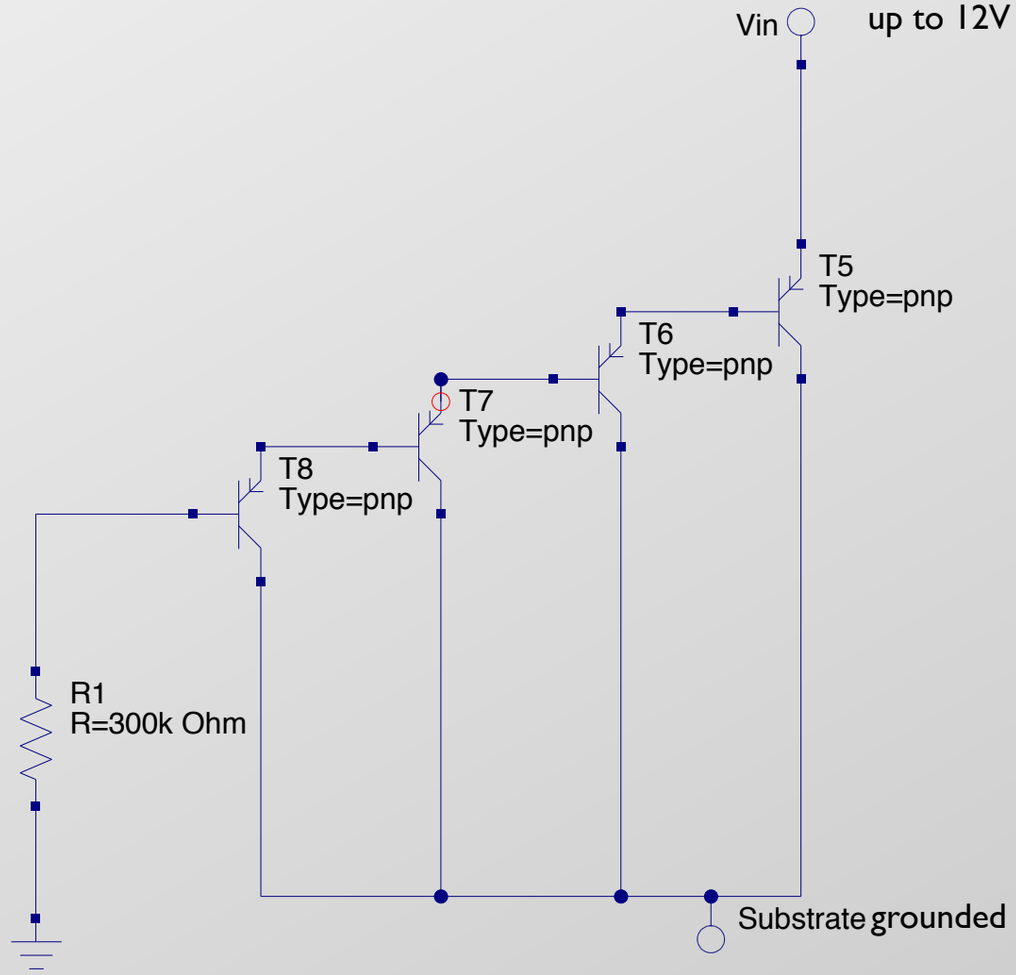


The ASIC: a hindsight on the main difficulties

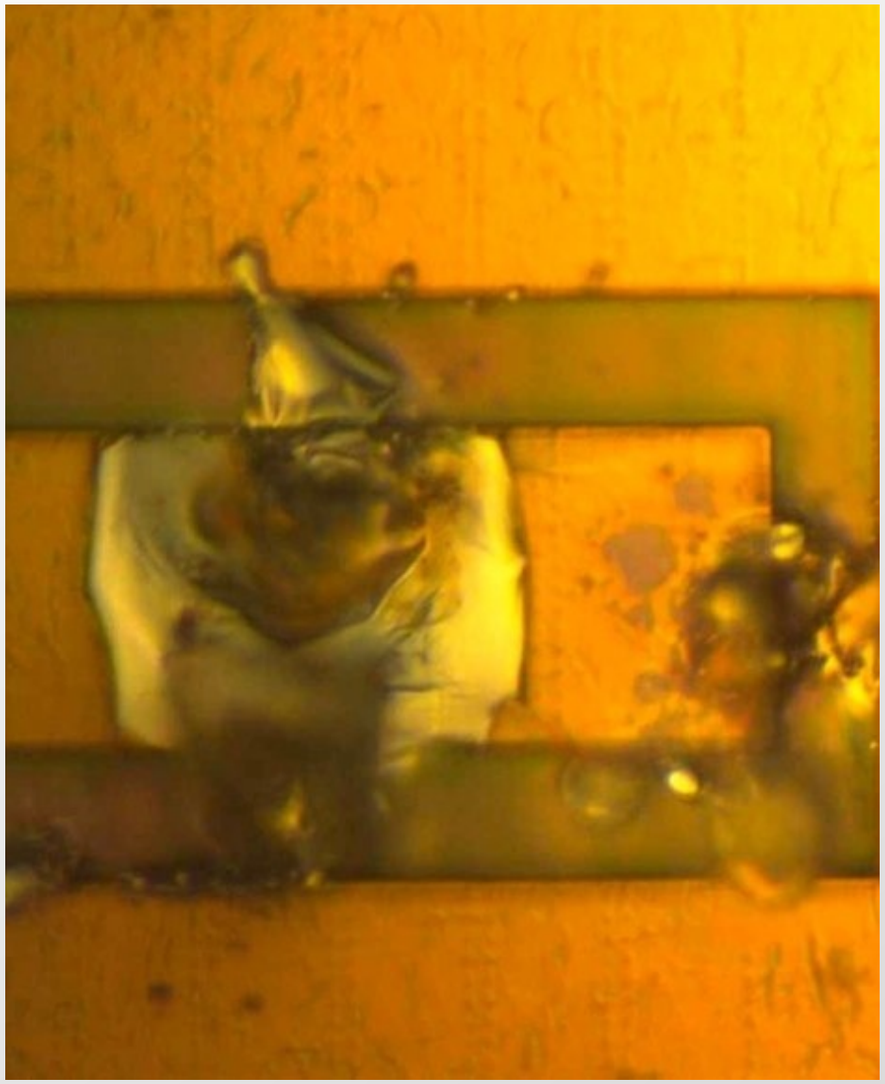
Parasitics…..



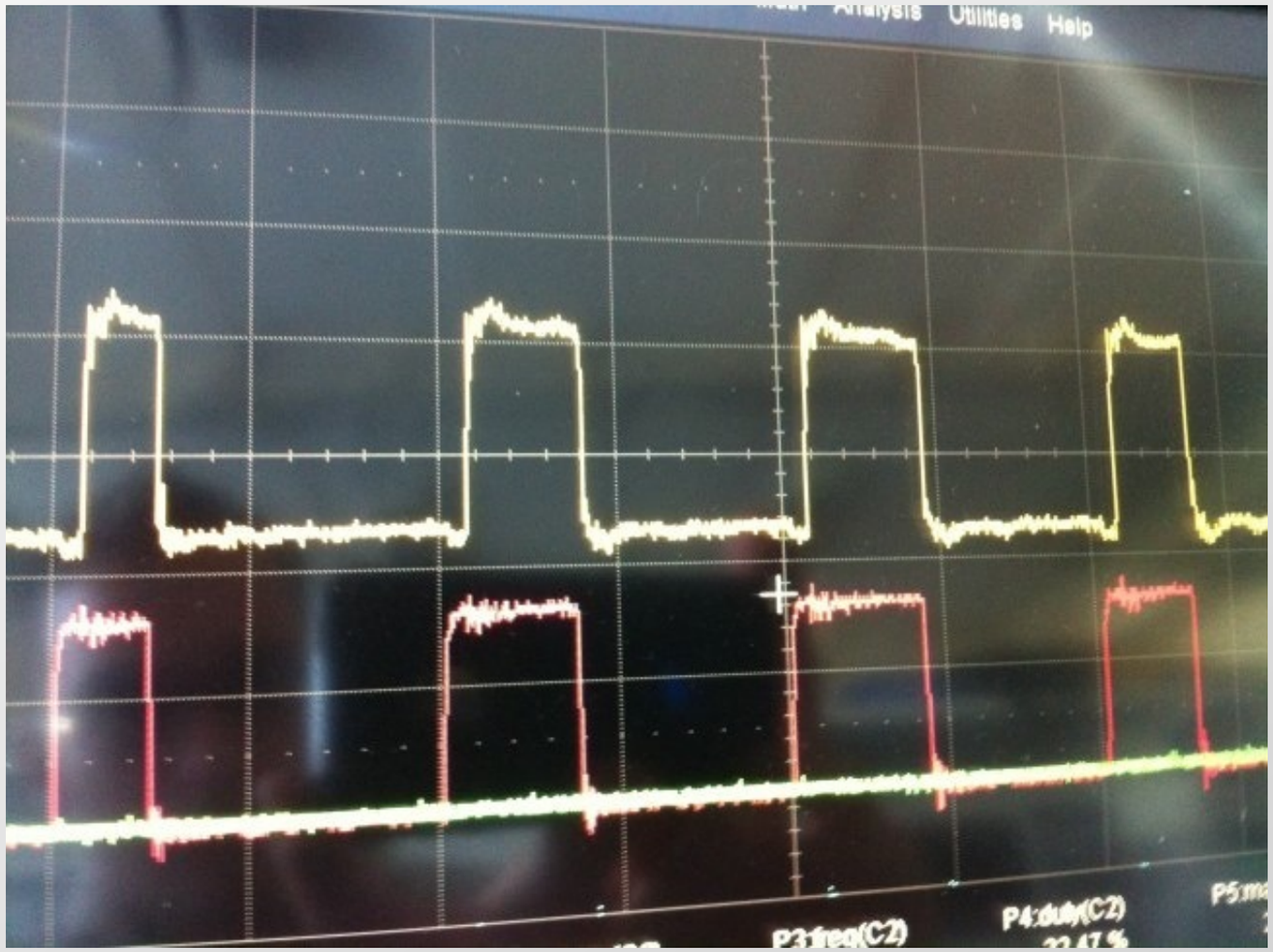
in reality this corresponds to



… more parasitics…..

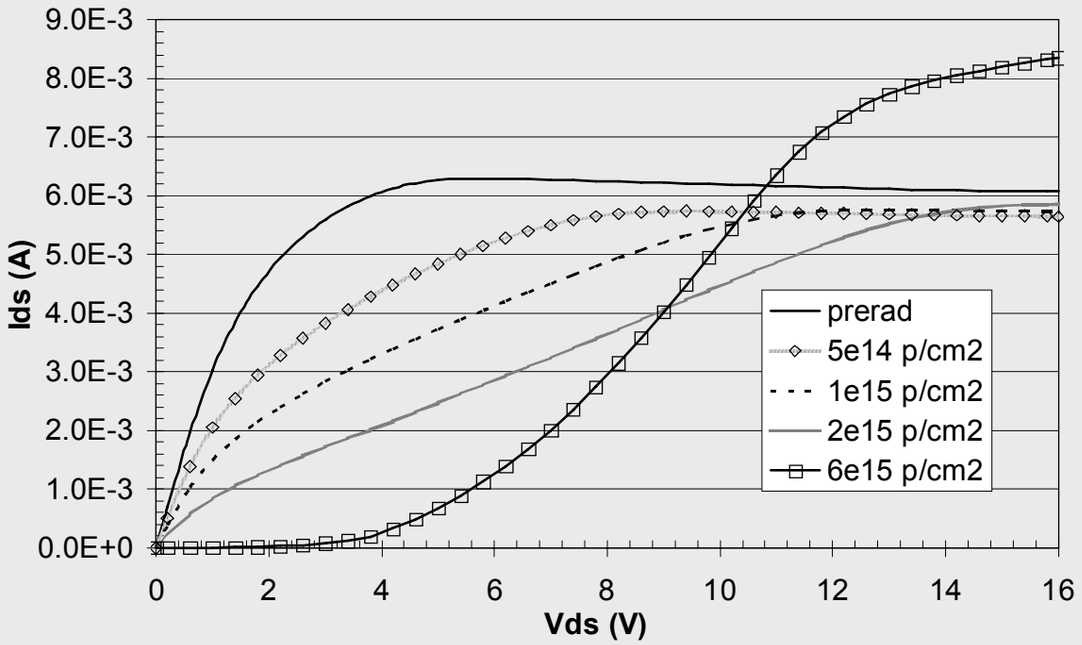


… and more parasitics…..

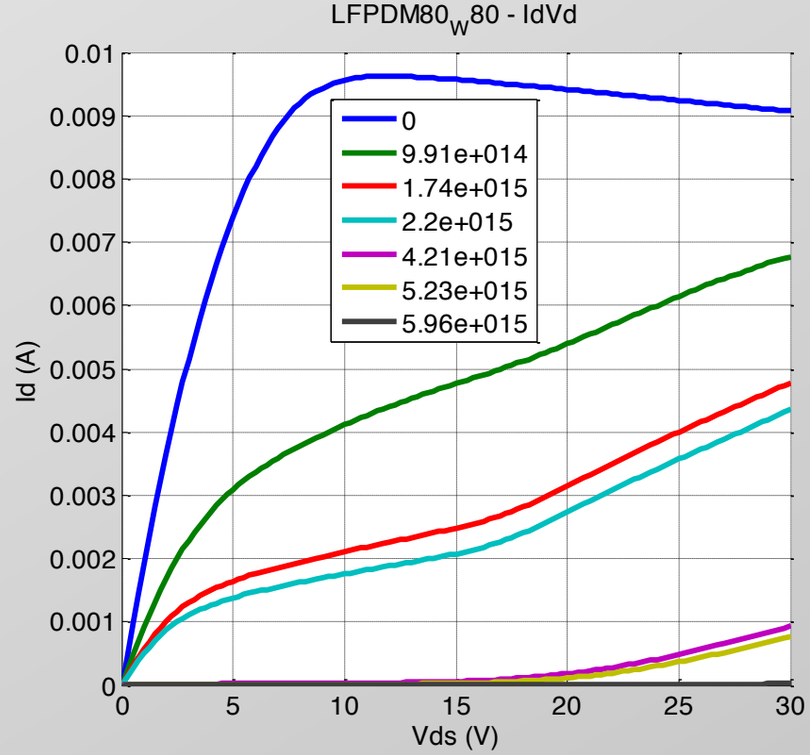


PWM duty cycle should be constant!

Radiation effects…..

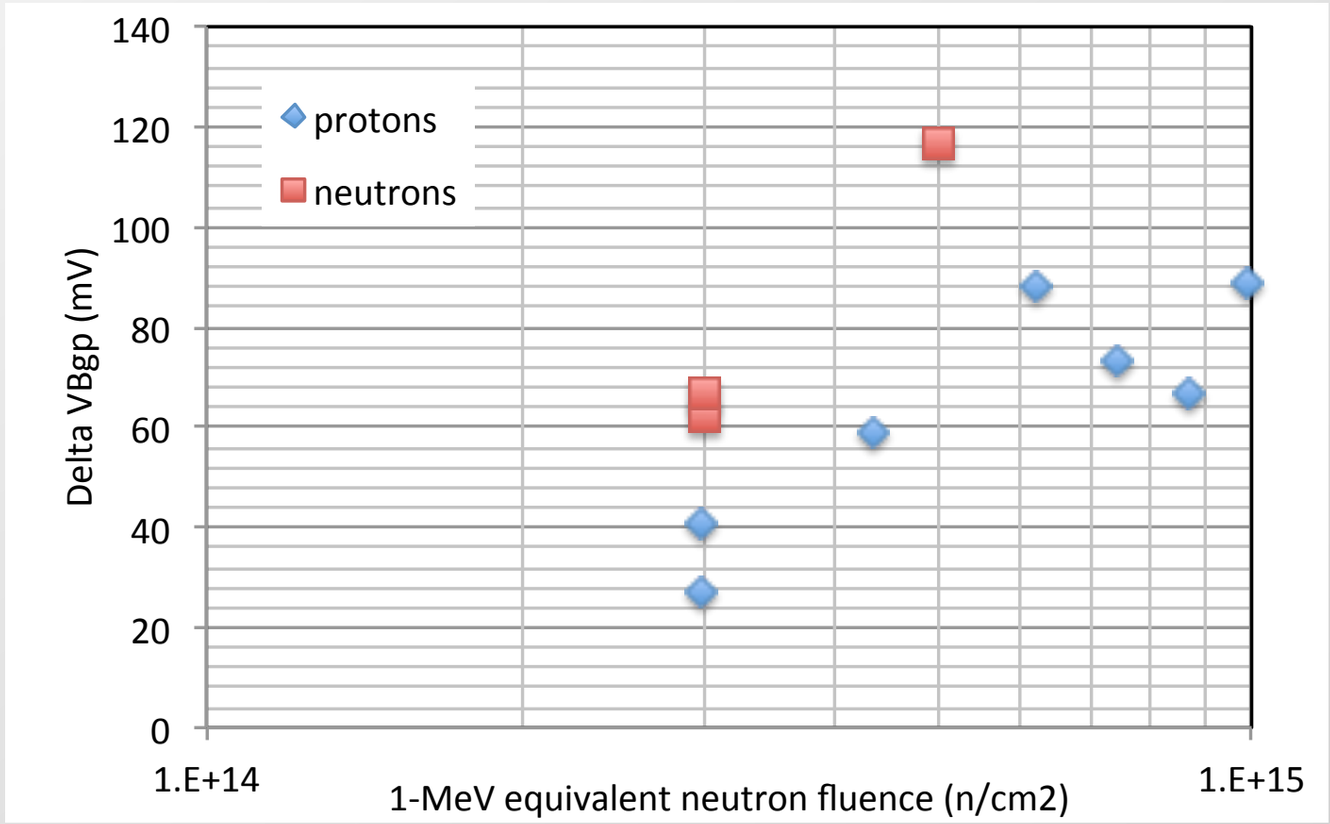


The Ids=f(Vds) curves of high voltage transistors are distorted as a consequence of displacement damage

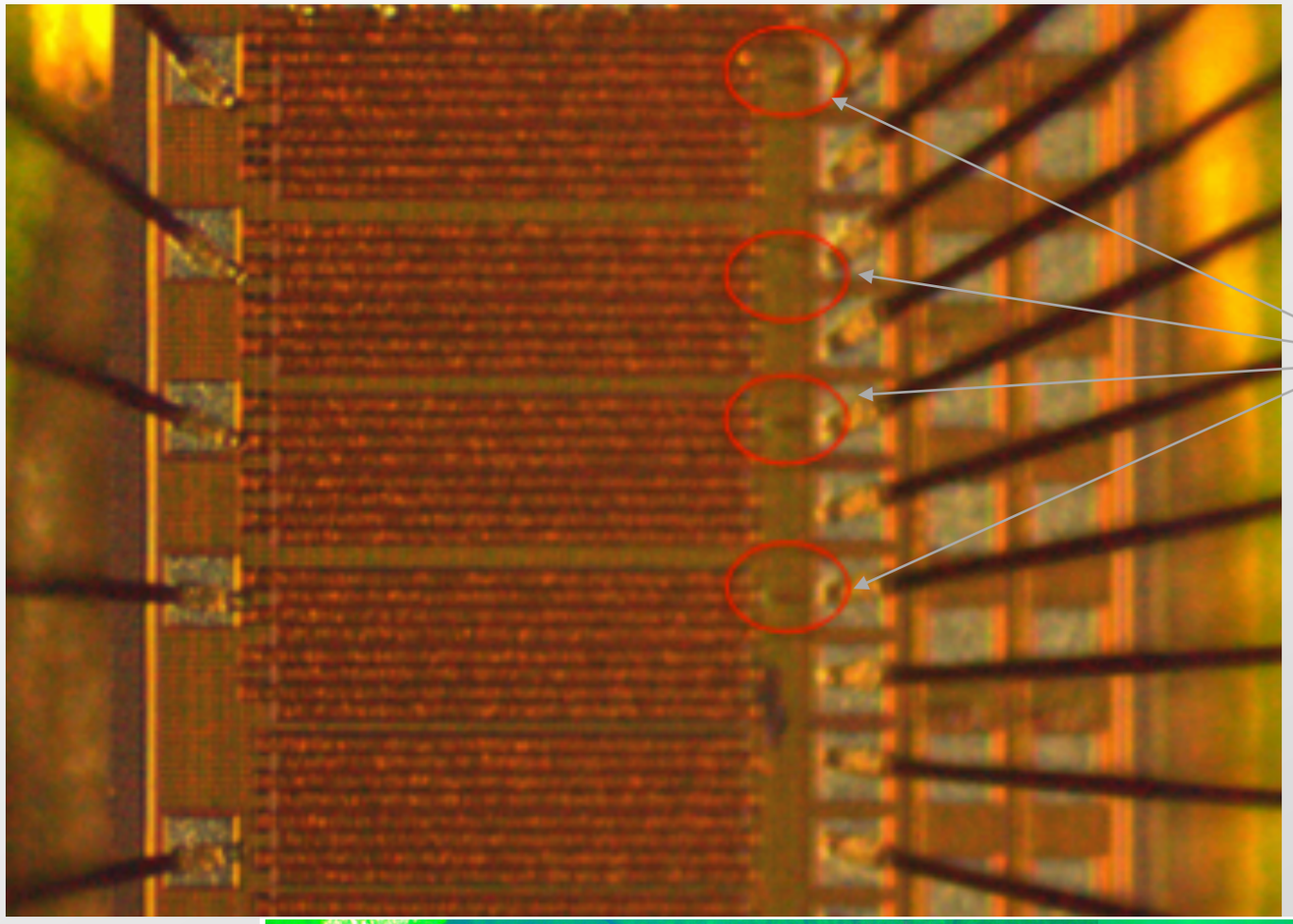


… and radiation effects…..

The bandgap voltage shifts considerably with displacement damage



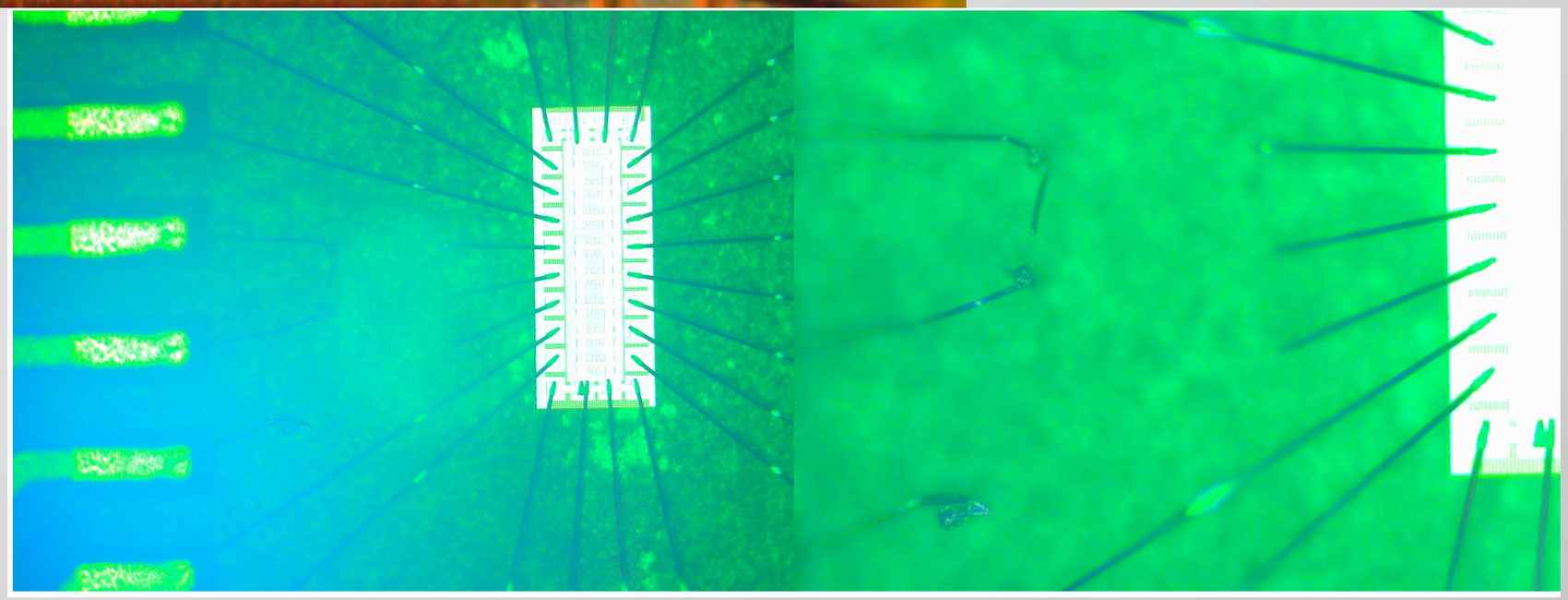
… and more radiation effects…..



Evidence of SEB on test chips with LDMOS

On-chip metal line burnt (encircled dark shadows)

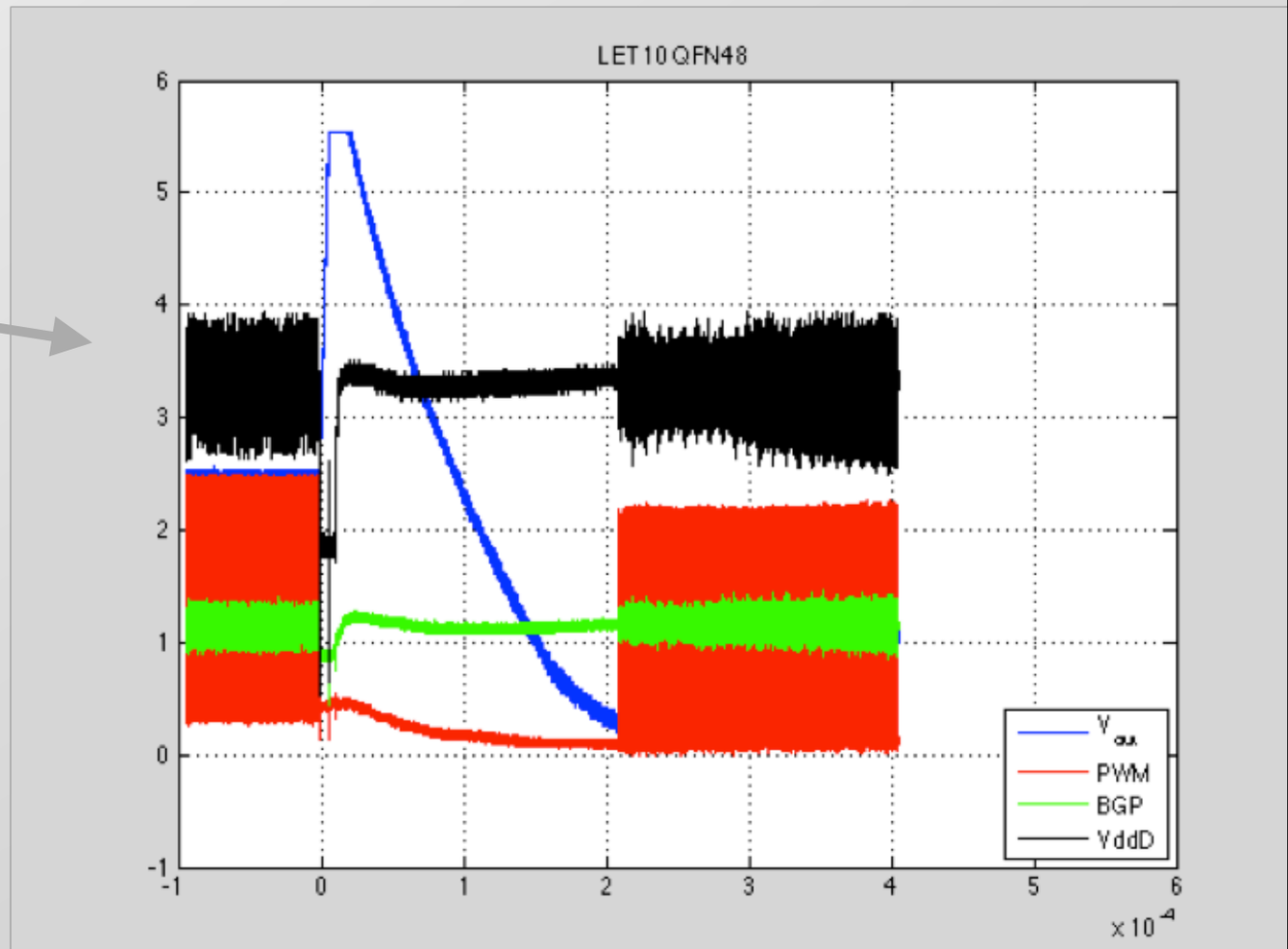
Molten wirebonds



… and even more radiation effects…..

SEFI with collapse of on-chip supply rails and increase of Vout
(only observed with Heavy Ion irradiation)

Reset pulses - Vout goes to GND and the ASIC restarts (380us)
(with Heavy Ion and 230MeV proton irradiation)



All issues solved in **FEAST2** ASIC (March 2014)

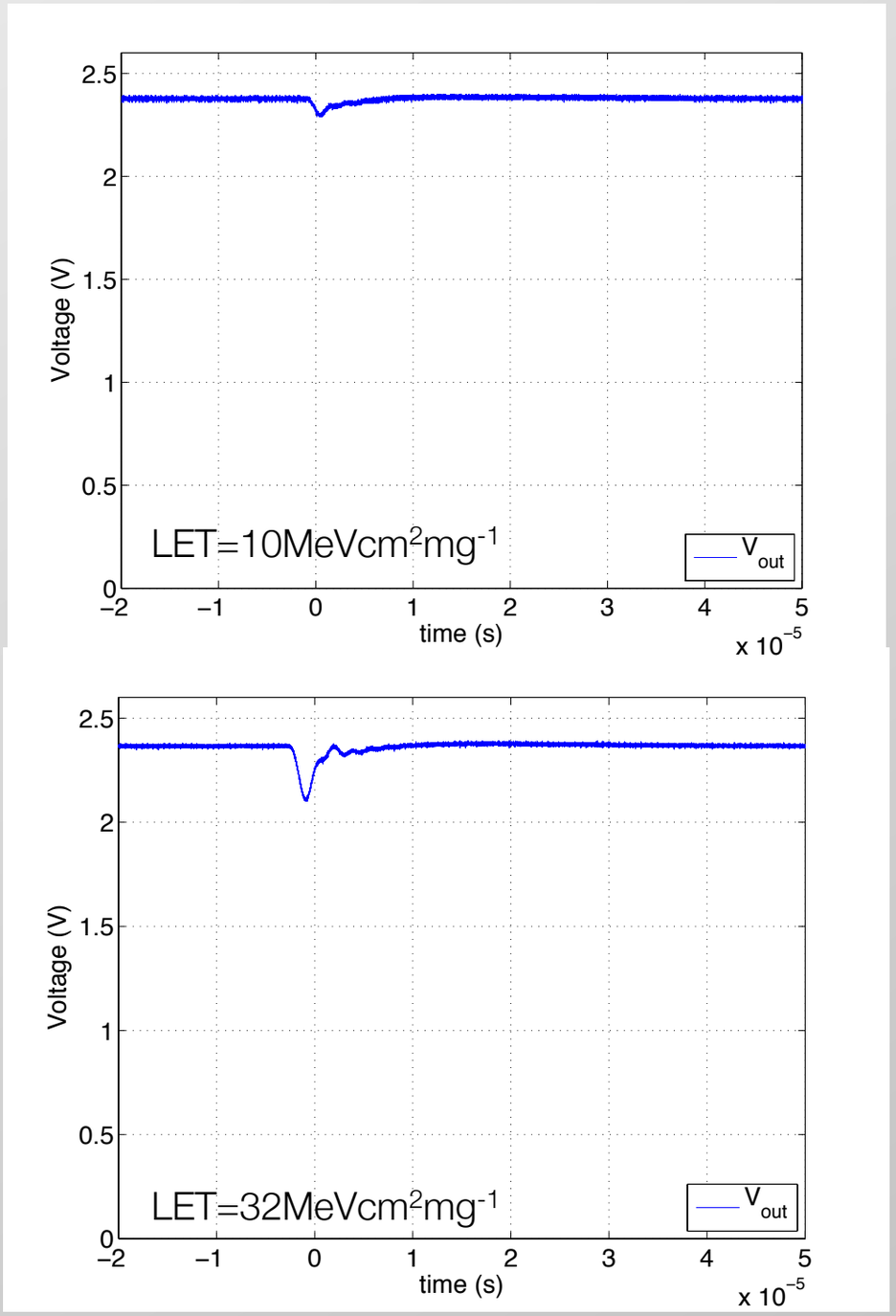
Heavy Ions

(LET up to 65 Mev cm^2 mg^{-1})

No SEFI with collapse of on-chip supply rails and increase of Vout

No Reset pulses

SETs on Vout observed (< 20% Vout, duration ≲ 2us)



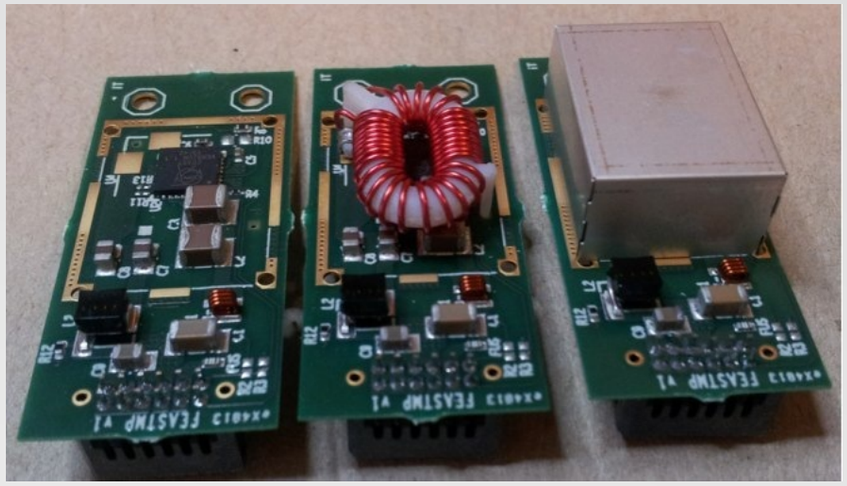
Production-ready DCDC modules

FEASTMP: production-ready module

Specifications		
	Min	Max
Vin (V)	5	12
Vout (V)	0.9	5
Iout (A)		4
Pout (W)		10

Safety features
Under-Voltage Lock-Out
Over-current
Over-Temperature
Line-protecting fuse in case of failure

Communication
Enable in (any CMOS up to 3.3V)
Power Good (open drain)



Radiation tolerance		
TID	>200	Mrad
DD	5-8E14	n/cm2 (1MeV eq.)
SEEs (reset)	2.8E-13	cm2

FEASTMP: production-ready module

Specifications		
	Min	Max
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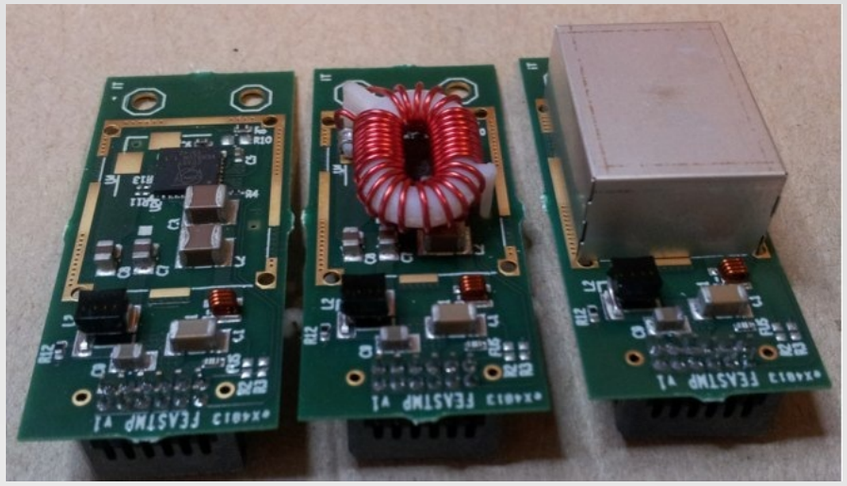
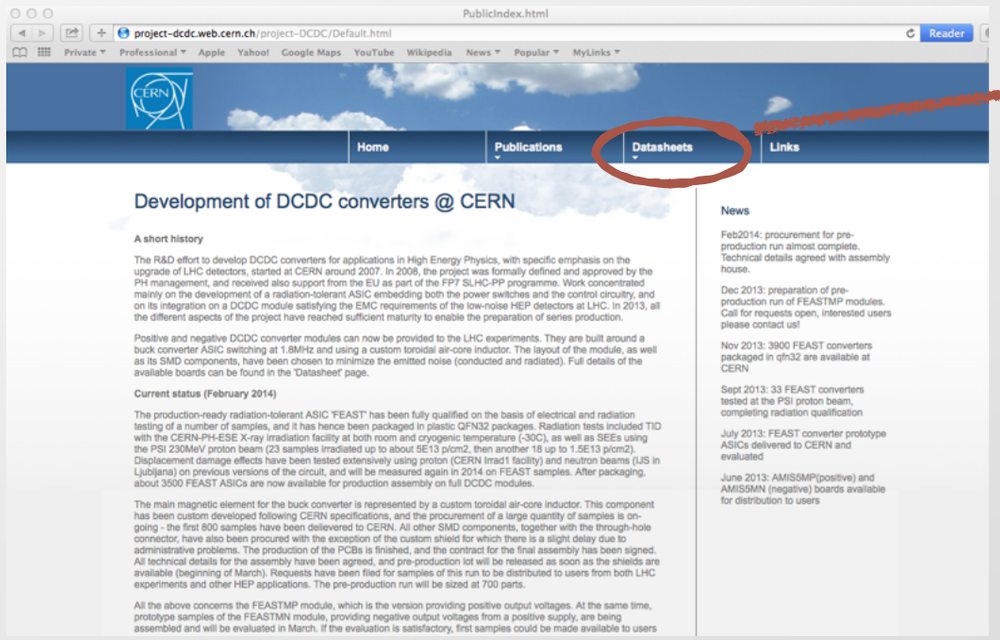


Radiation tolerance		
TID	>200	Mrad
DD	5-8E14	n/cm2 (1MeV eq.)
SEEs (reset)	2.8E-13	cm2

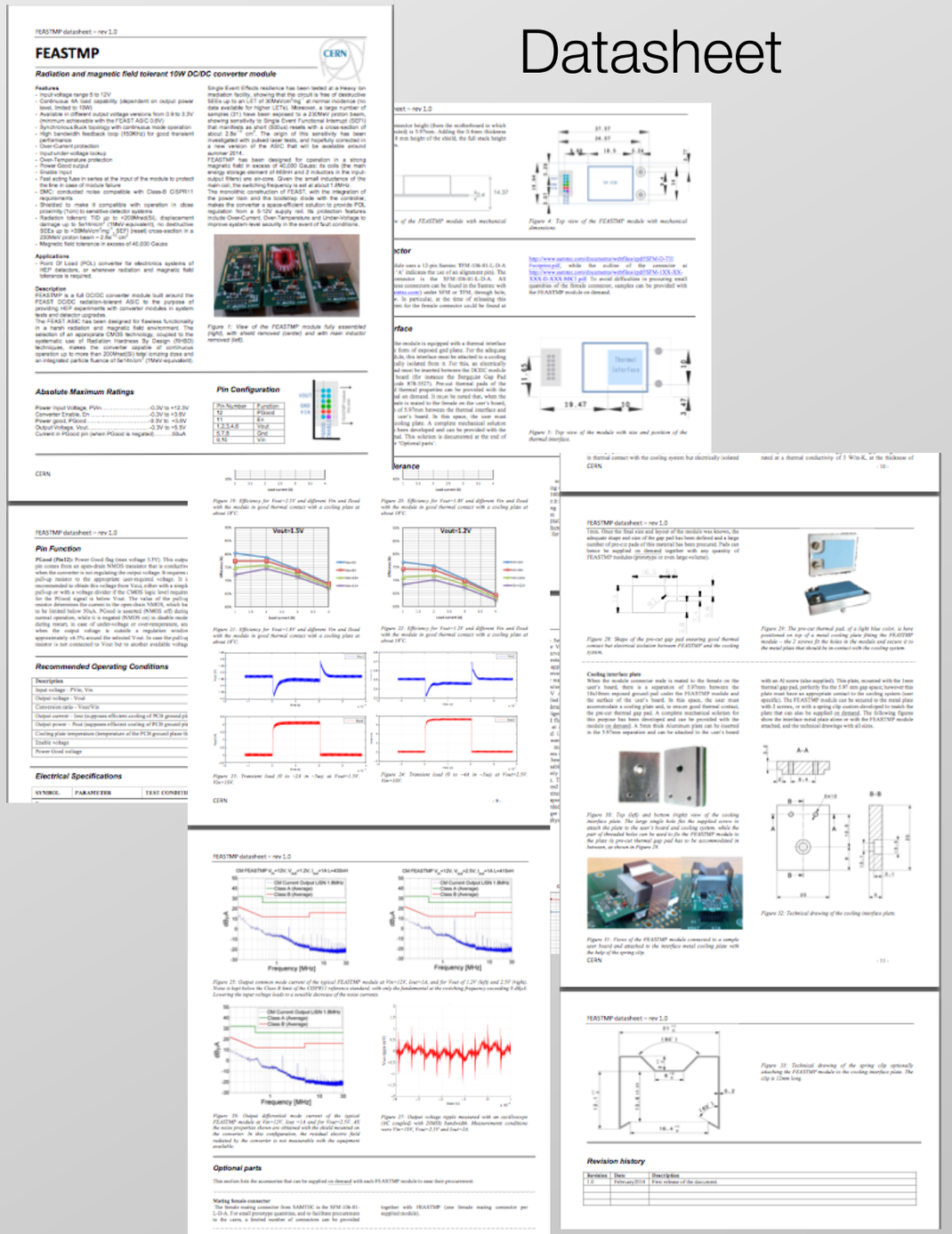
FEAST2 is immune

FEASTMP: production-ready module

http://project-dcdc.web.cern.ch



Datasheet



e-group: DCDC-users

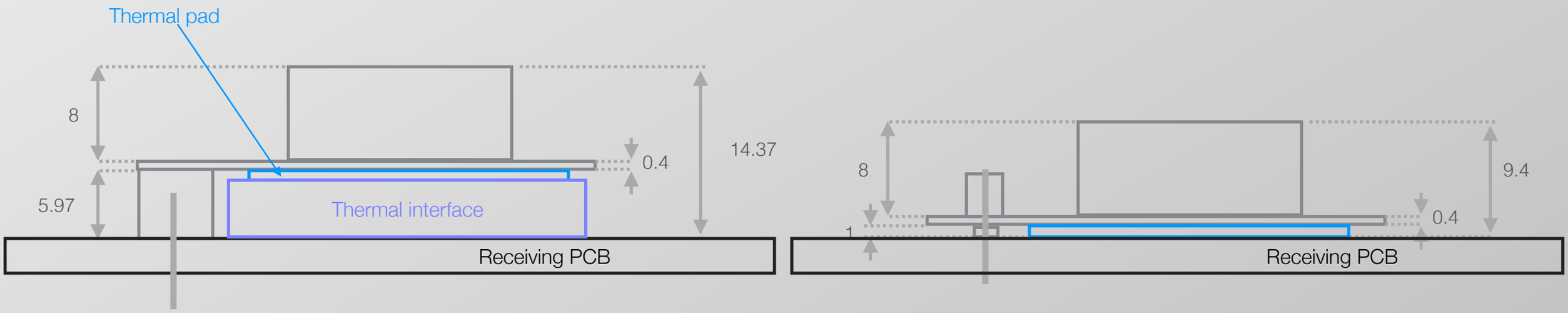
all announcements concerning the production of modules

First assembly run soon launched

1000 modules @ 9 Vout

Other DCDC modules in preparation

- FEASTMN
  - Negative output voltage from a positive supply
  - Built around the FEAST ASIC, but different module configuration
  - First prototypes of the projected production-ready module just received. Testing is just started
- Alternative mounting system on the receiving motherboard is studied. This should decrease the stack height to below 1cm. FEASTMP and MN will both be made available with this option

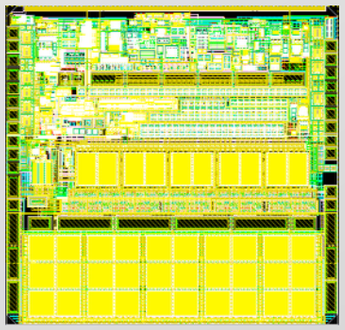


Possible users of DCDC modules

- For radiation tolerance and size/mass, the module satisfies the requirements of almost every LHC detector system
  - It is also interesting for other HEP applications. For example, sample requests have been filed by Belle @ KEKB, Panda @ FAIR (GSI)
- For ATLAS and CMS phase2 trackers, there are fundamental limitations on the use of the present modules:

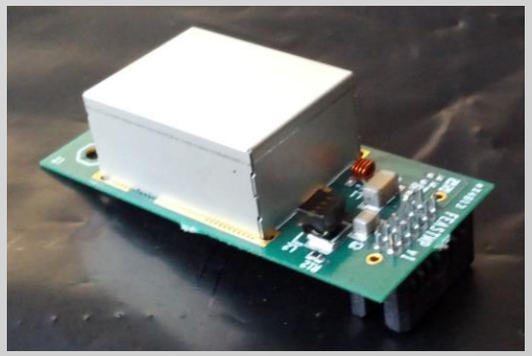
ASIC

insufficient radiation tolerance (displacement damage, limit at 5-8e14 n/cm^2)

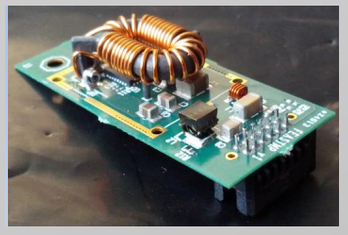


module

size (footprint, stack height)



contribution to material budget

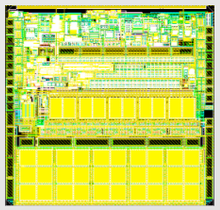


Projection to phase2 ATLAS/CMS trackers

Upgraded trackers (HL-LHC)

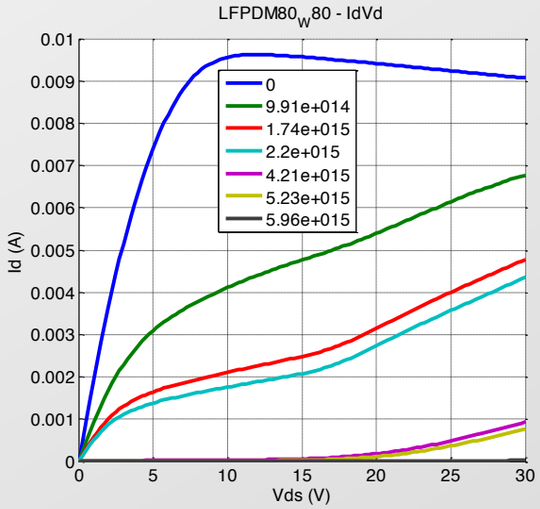
ASIC

insufficient radiation tolerance (displacement damage)

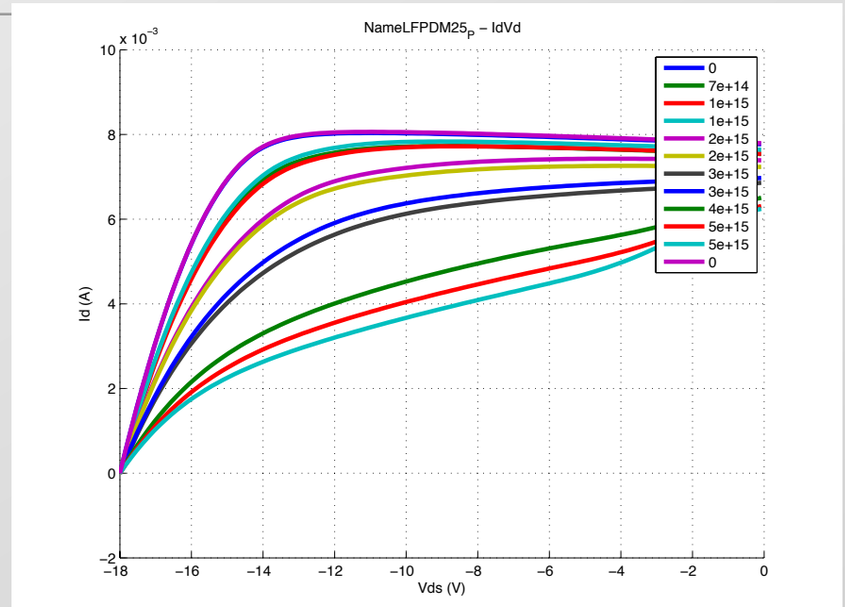


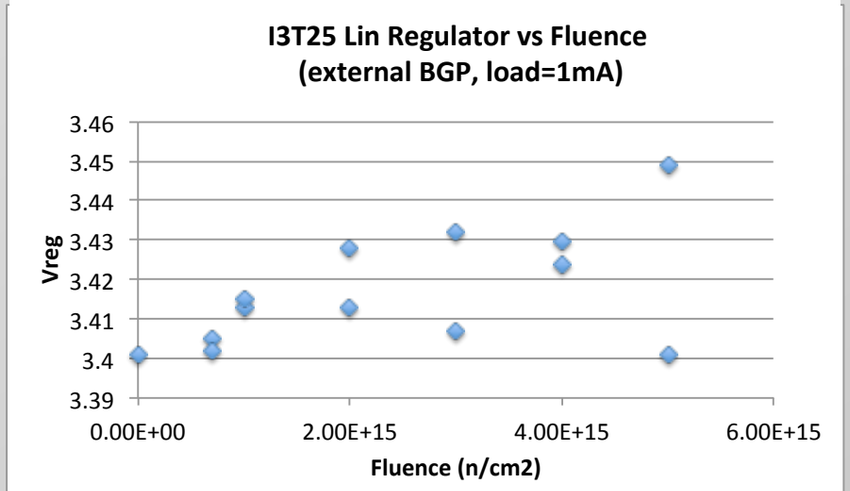
P-channel LDMOS

(on-chip regulators, protection elements)



Tests in twin technology with 25V LDMOS shows that tolerance can be extended to at least 5e15 n/cm^2





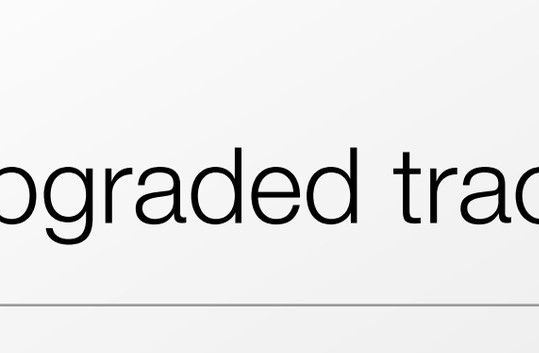
Bandgap voltage generator

Other architectures to be tried, based on transistors - plan to do this as from summer ‘14

Upgraded trackers (HL-LHC)

module

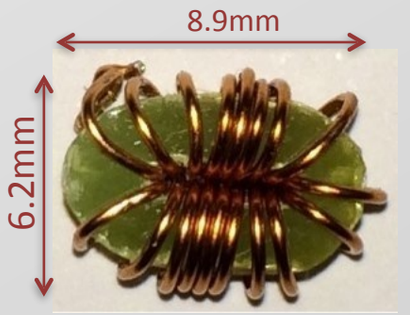
size
(footprint, stack height)

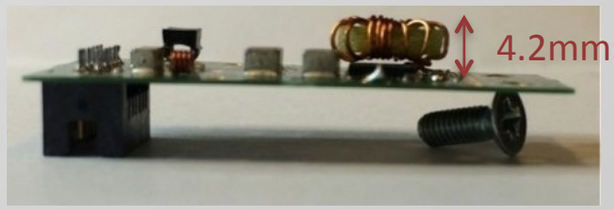


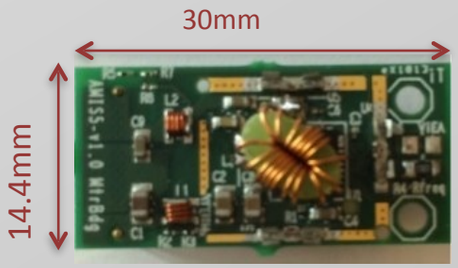
contribution to
material budget

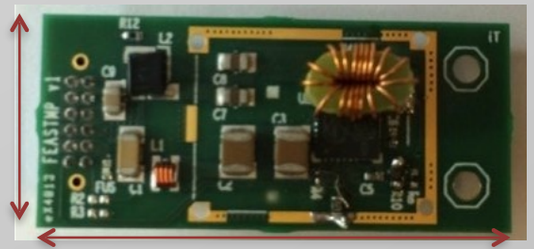
The inductor can be redesigned
compromising electrical performance
for size and mass

example: ECCA wire hand wound

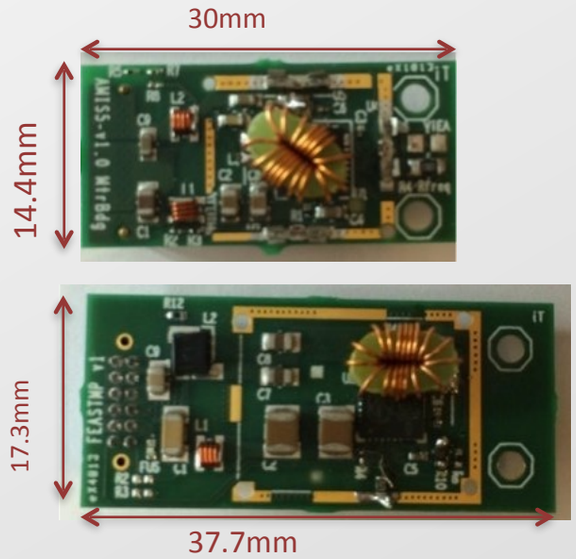




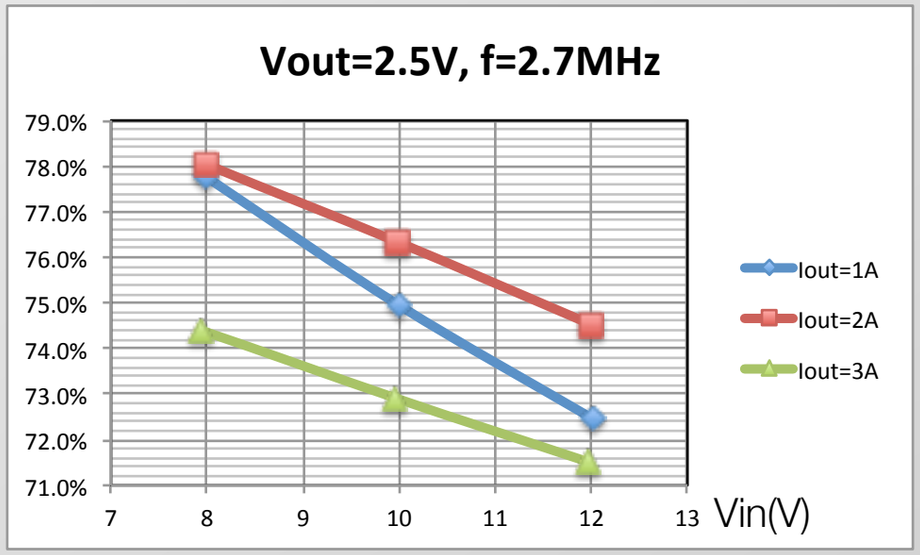


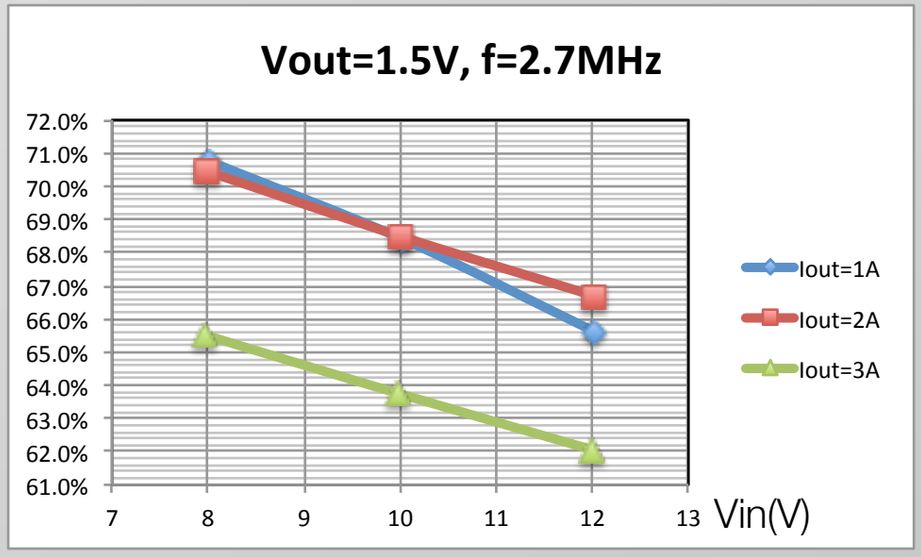


Upgraded trackers (HL-LHC)



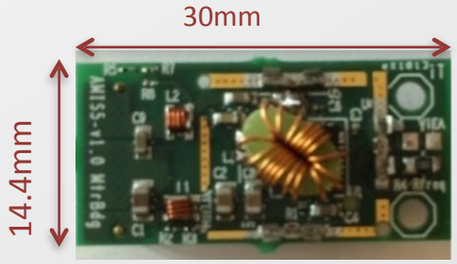
Efficiency vs input voltage for different output currents



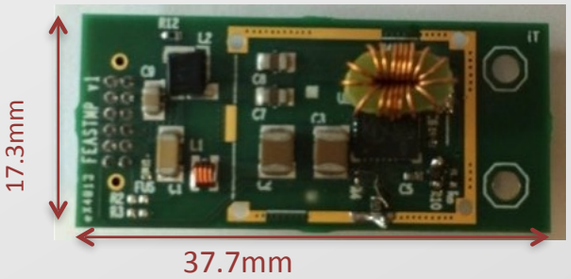


Upgraded trackers (HL-LHC)

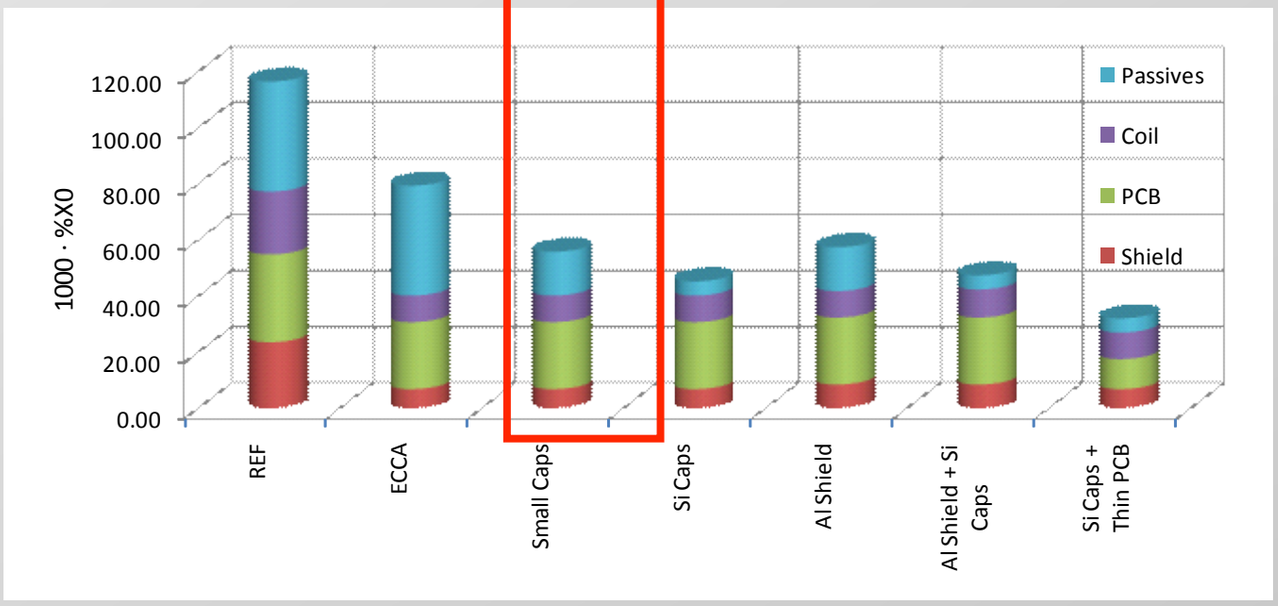
"DC-DC converters with reduced mass for trackers at the HL-LHC", G.Blanchot et al., 2011 JINST 6 C11035 (TWEPP 2011)



small caps



	REF	ECCA	Small Caps	Si Caps	Al Shield	Al Shield + Si Caps	Si Caps + Thin PCB
Reference	X	☐	☐	☐	☐	☐	☐
ECCA inductor	☐	X	X	X	X	X	X
10µm coated shield	☐	X	X	X	☐	☐	X
Al foil shield	☐	☐	☐	☐	X	X	☐
Small capacitors	☐	☐	X	☐	☐	☐	☐
Silicon capacitors	☐	☐	☐	X	☐	X	X
300um thin PCB	☐	X	X	X	X	X	☐
100um thin PCB	☐	☐	☐	☐	☐	☐	X



In the estimate, the inductor is larger than the sample used in these tests, so is the shield. Therefore the dominant contribution is from the PCB and the passives.

Conclusion

- DCDC modules are moving to production now
- They can be provided to all HEP detector systems (and they will be made available for several years)
  - Radiation tolerance limited **only** by displacement damage effects to 5-8e14 n/cm^2
- For CMS and ATLAS trackers:
  - an upgrade is possible making the DCDC tolerant to at least 5e15 n/cm^2
  - optimisation of the module can be made to considerably reduce contribution to material budget