STATUS OF DCDC DEVELOPMENT

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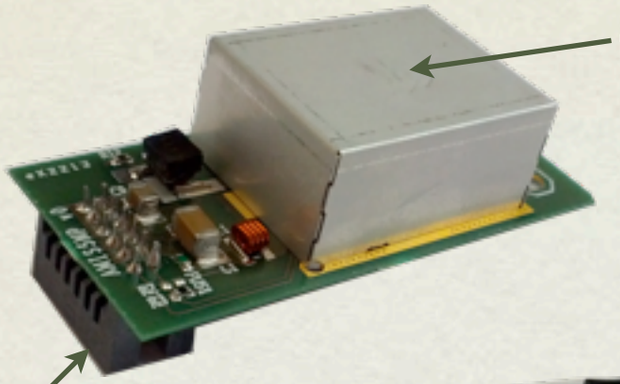
http://project-dcdc.web.cern.ch

GOAL

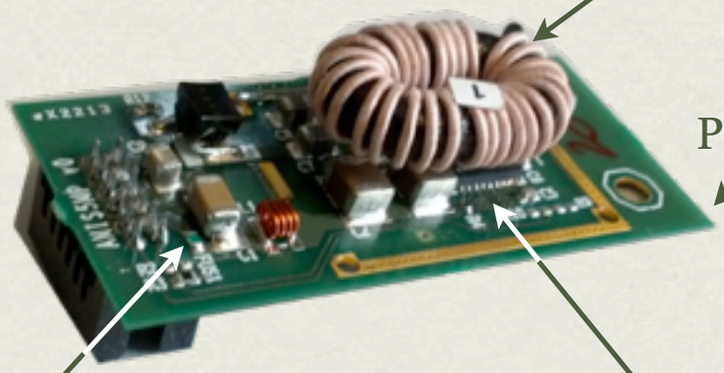
	positive	negative
V_{in}	6 to 12V	positive, $6V<V_{in}-V_{out}<12V$
V_{out}	0.9 to 5V	-0.9 to -5V
I_{out}	≤4A (but $P_{out}≤10W$)	as positive
protection features	OCP, OTP, UVLO	as positive
radiation hardness	>10Mrad, >5E14 n/cm2, SEE tolerance	as positive
magnetic field	4T	as positive
conducted noise	class B (CISPR11)	as positive

COMPONENTS



shield (for noise compatibility, radiated and conducted)

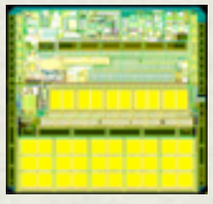
custom air-core inductor



PCB (layout and components optimized for low noise)

connector

passive components (R, C, L)



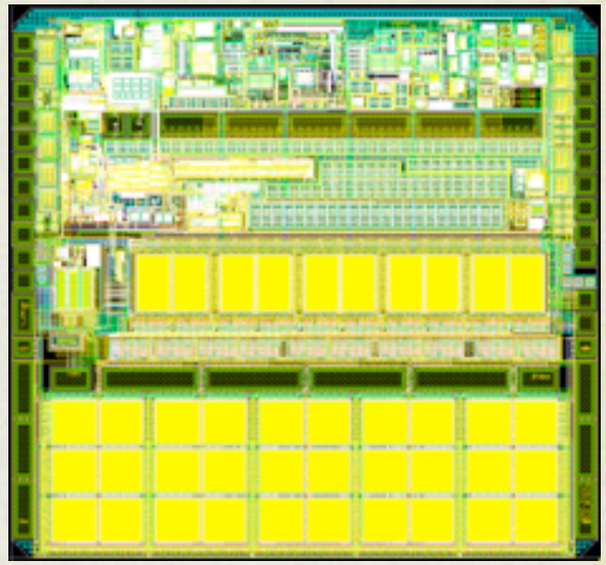
radiation-tolerant ASIC in qfn32 package

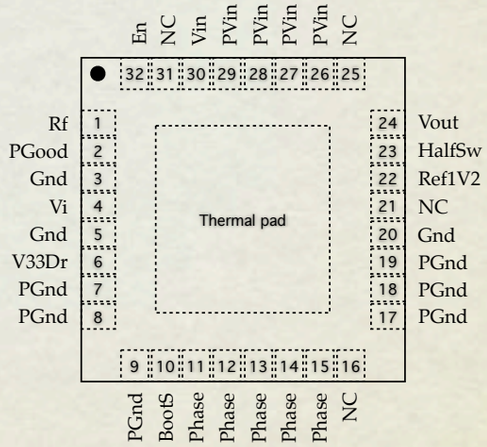
COMPONENTS

	production-ready
ASIC	
Custom inductor	
Shield	
Connector	
PCB design	

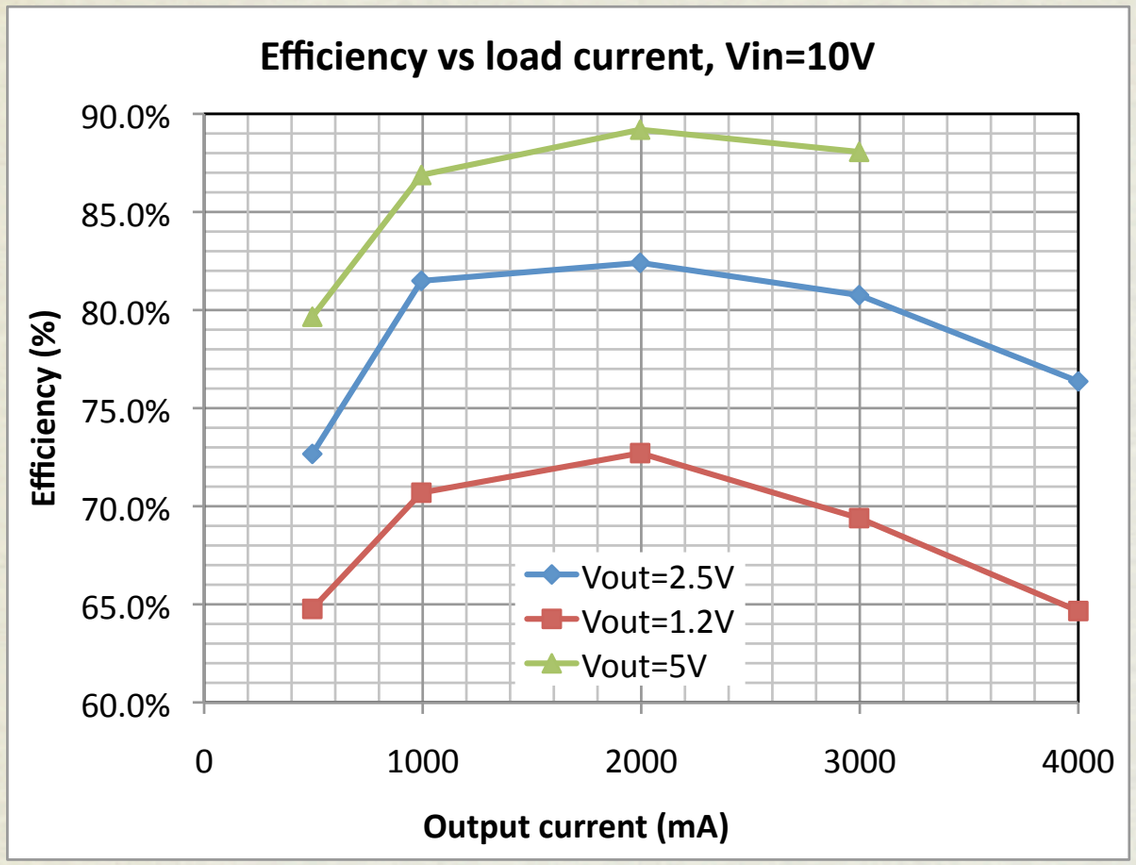
ASIC: FEAST

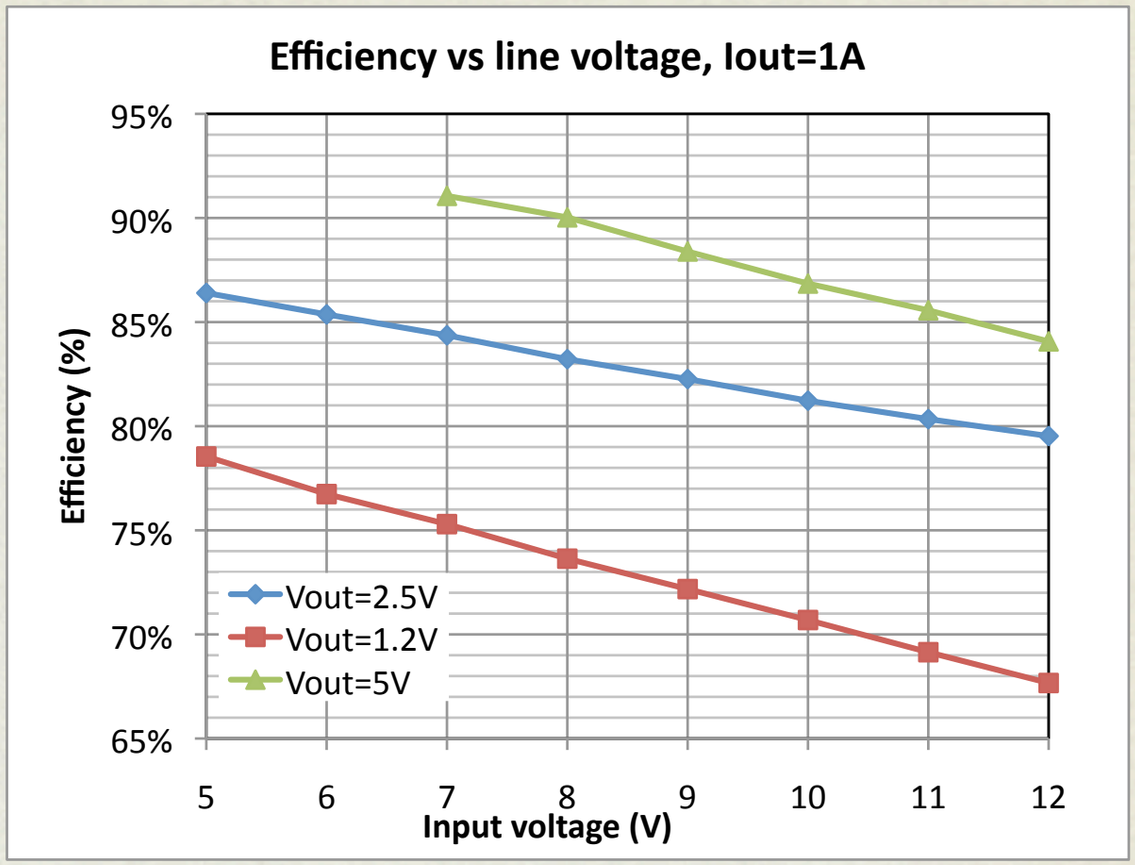
- Some features:
  - ✓ 2.8x2.88mm size, packaged in plastic qfn32 (5x5mm)
  - ✓ Switching frequency selectable 1-3MHz (selected to 1.8MHz in modules)
  - ✓ Protection features:
    - Over-Current (OCP), Over-Temperature (OTP), Input Under-Voltage Lock-Out (UVLO)
  - ✓ Accessible configuration pins:
    - Enable (threshold ≈ 0.8V)
    - Power Good (open-drain, asserted if V_{out} ≈ nominal)
    - Half_Switch (to increase efficiency for small load currents ≤700mA)





EFFICIENCY

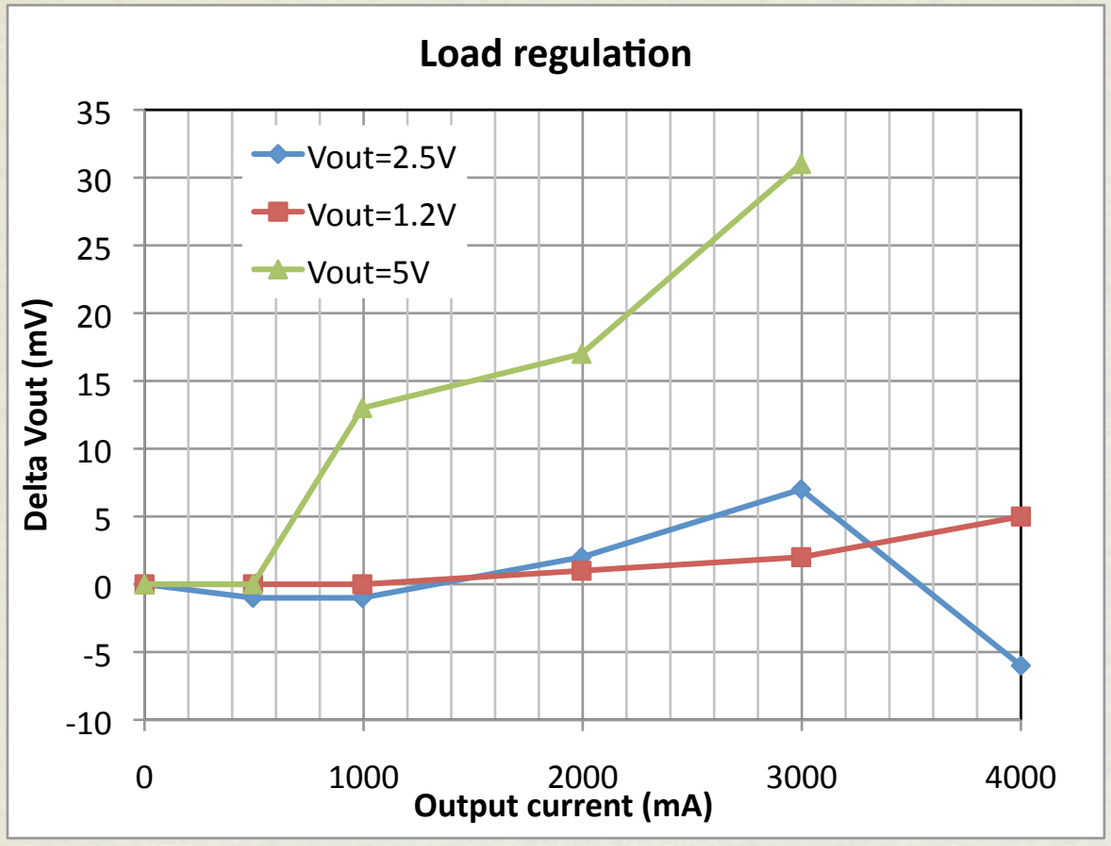




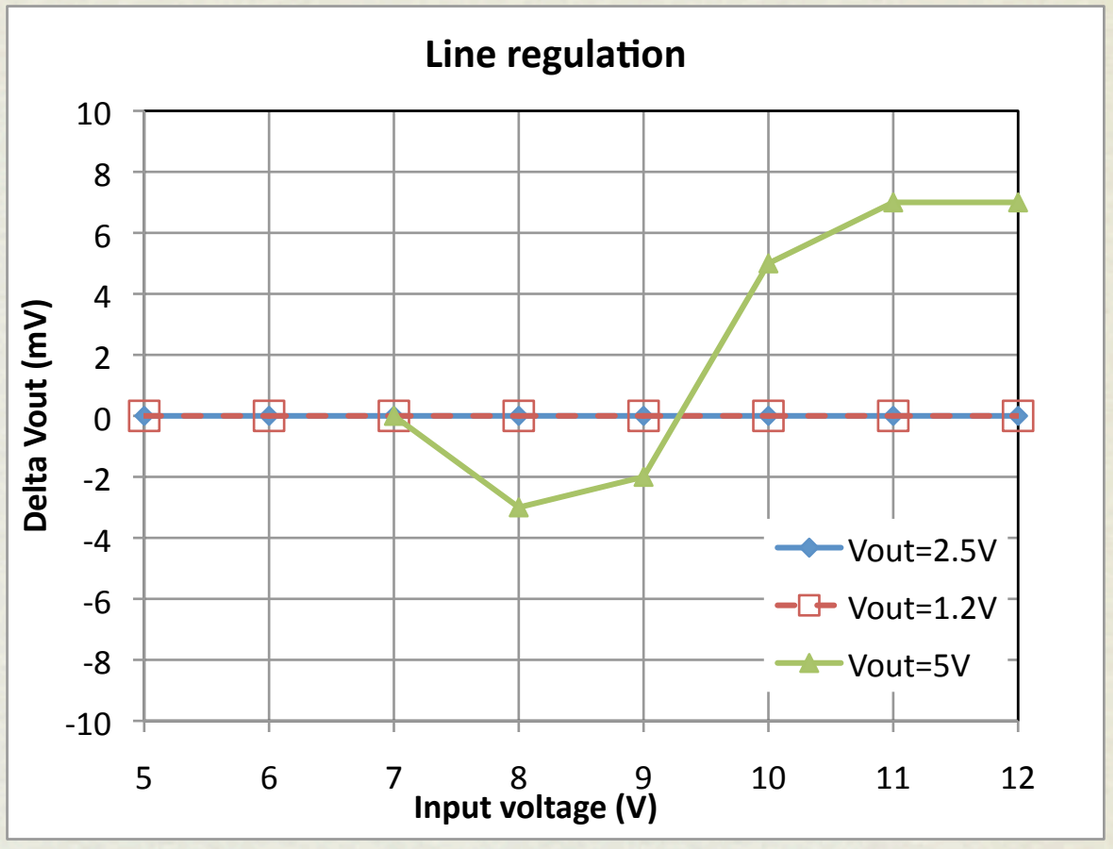
Conditions: cooling plate at about 18C, L=430nH oval toroidal (bulk Cu wire), f=1.8MHz

REGULATION

Load regulation is the capability to maintain a constant output voltage level despite changes to the output current.



Line regulation is the capability to maintain a constant output voltage level despite changes to the input voltage level.

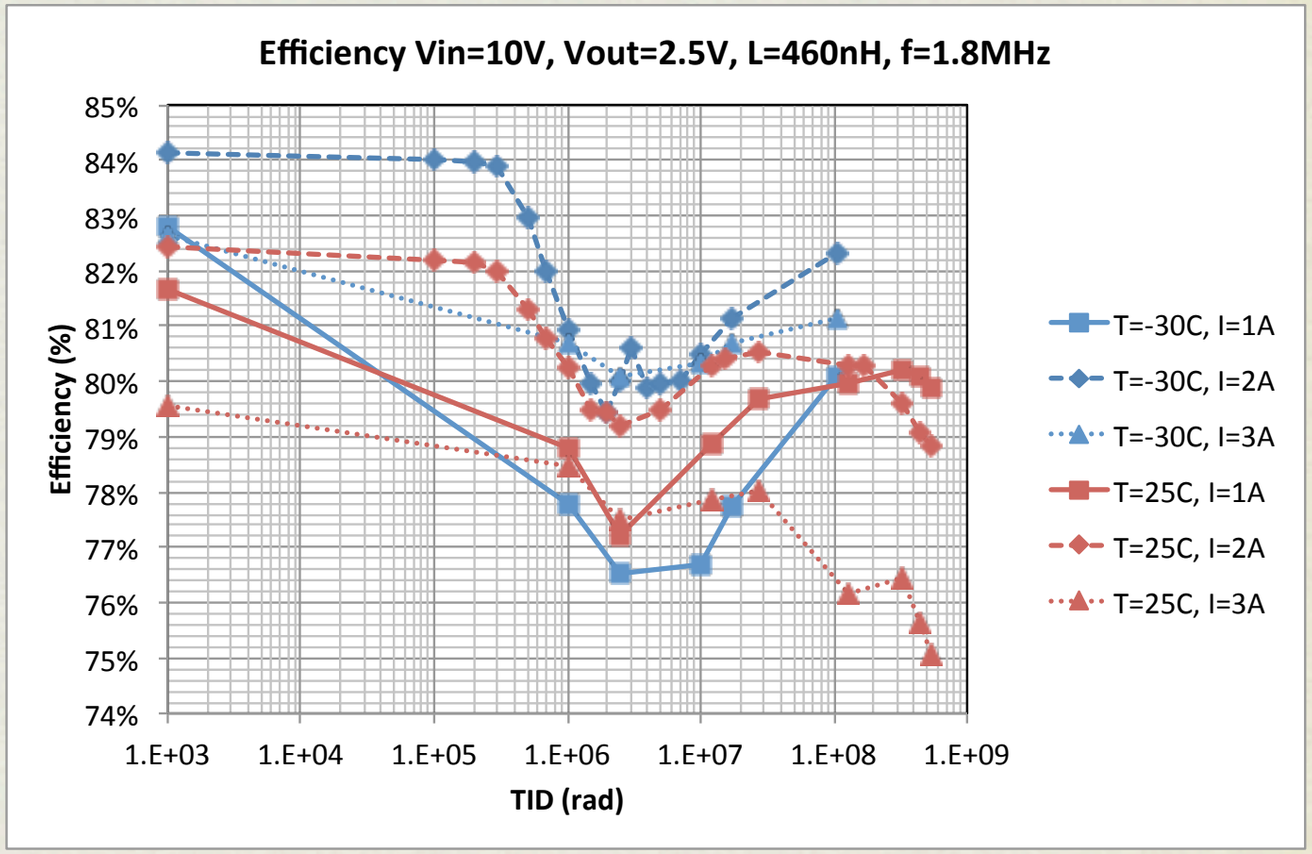


Conditions: cooling plate at about 18C, L=430nH oval toroidal (bulk Cu wire), f=1.8MHz

TID EFFECTS

- Irradiation performed at our X-ray irradiation system at controlled T (-30C, 25C) at a dose rate of 100krad/min
- Maximum TID reached: 547Mrad(SiO_2)

- Efficiency drop limited to a few % in quick irradiation (but with annealing it is expected to be practically negligible)
- Line and load regulation properties practically unaffected up to 100Mrad
- All safety features unaffected



DISPLACEMENT DAMAGE

- Displacement damage tests have been done on several previous prototypes in the same technology. The last one, AMIS5, is very similar to FEAST (the changes do not determine different radiation responses for displacement)
- AMIS5 is qualified up to 7e14 n/cm2 (1MeV-n equivalent)
  - After this fluence the HV PMOS pass-transistors of the linear regulators are excessively damaged
  - The linear regulators present in FEAST are exactly the same of AMIS5, therefore the performances of FEAST should be comparable
- Displacement damage test on FEAST is foreseen end 2013 - beginning 2014

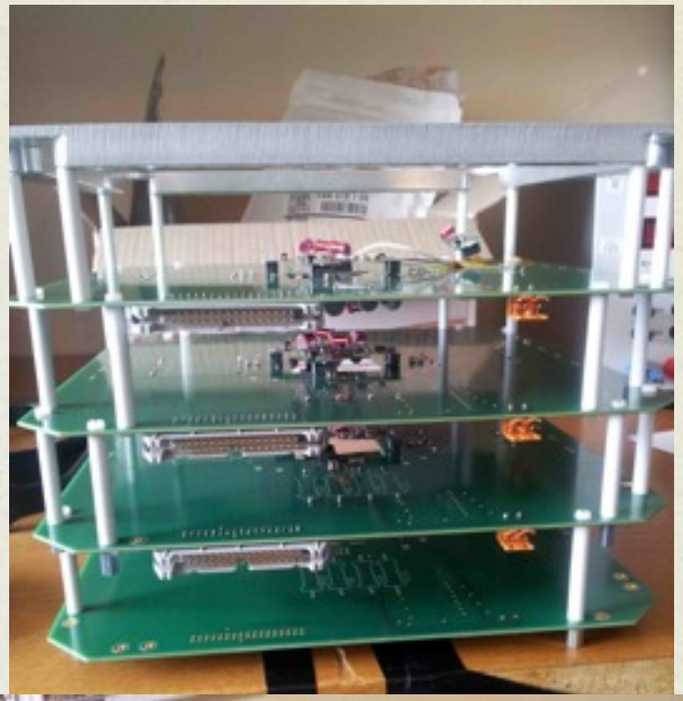
SEE

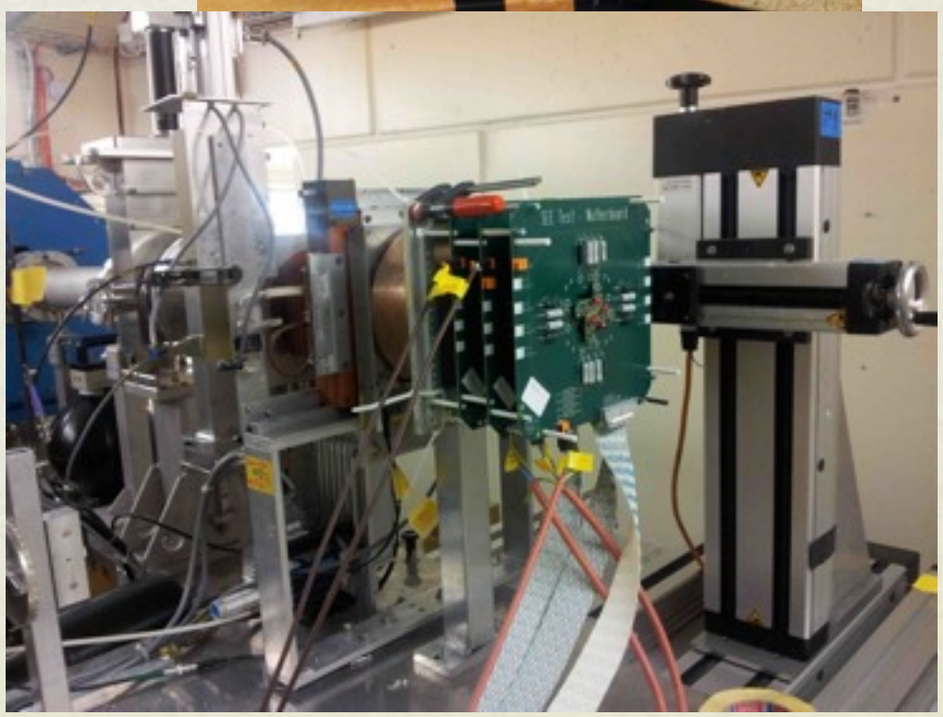
Measurements performed with different particle beams:

- Heavy Ions (CRC, Louvain-la-Neuve)
  - ✓ Results have been found NOT to be representative of our hadron-dominated radiation environment
  - ✓ However, they exclude the possibility of destructive SEEs (SEB) up to an LET of 30MeV·cm^{2}mg^{-1} (even at 45degrees incidence)
- 230MeV protons (Paul Scherrer Institute, Villigen)
  - ✓ very representative of our environment

SEE: PROTONS AT PSI

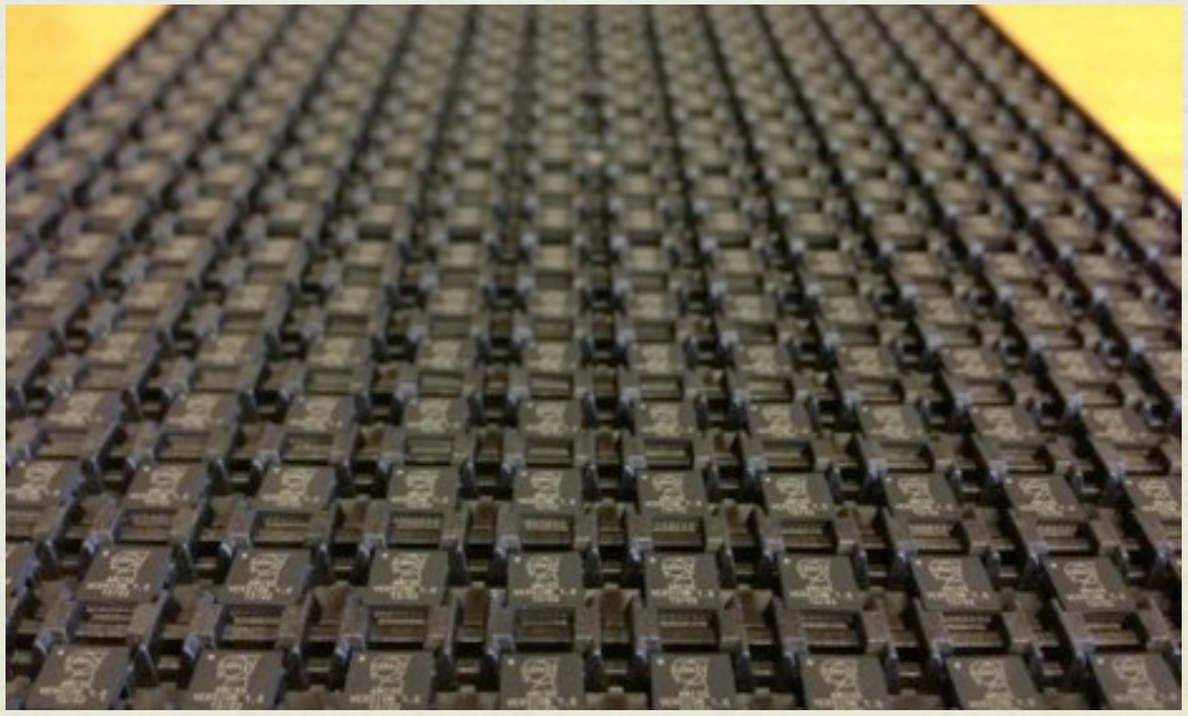
- ✓ 23 DCDC on-beam for 36hours at a flux ~ 5E8p·cm^{2}s^{-1}
- ✓ Integrated fluence ~ 5E13 p·cm^2 per DCDC
- ✓ 2 type of events happen in our environment:
  - short transients of Vout (<2us, <200mV)
  - resets of the DCDC, where the converter goes into soft-start. Vout drops to gnd and gently rises to the nominal in 4-500us. The measured cross-section is 2-3E-13cm^2
    - In an environment with an integrated flux of hadrons (10 years) above 20MeV of 1E12cm^{-2}, the expected rate of reset is 2-3 every 10 DCDC over the full lifetime of the experiment





ASIC STATUS

- FEAST ASIC fully tested, including radiation effects. It is qualified for production
- 6 wafers have been produced (about 1300 chips/wafer)
- Packaging in qfn32 of 3 wafers is ongoing, parts expected at CERN in about 6 weeks

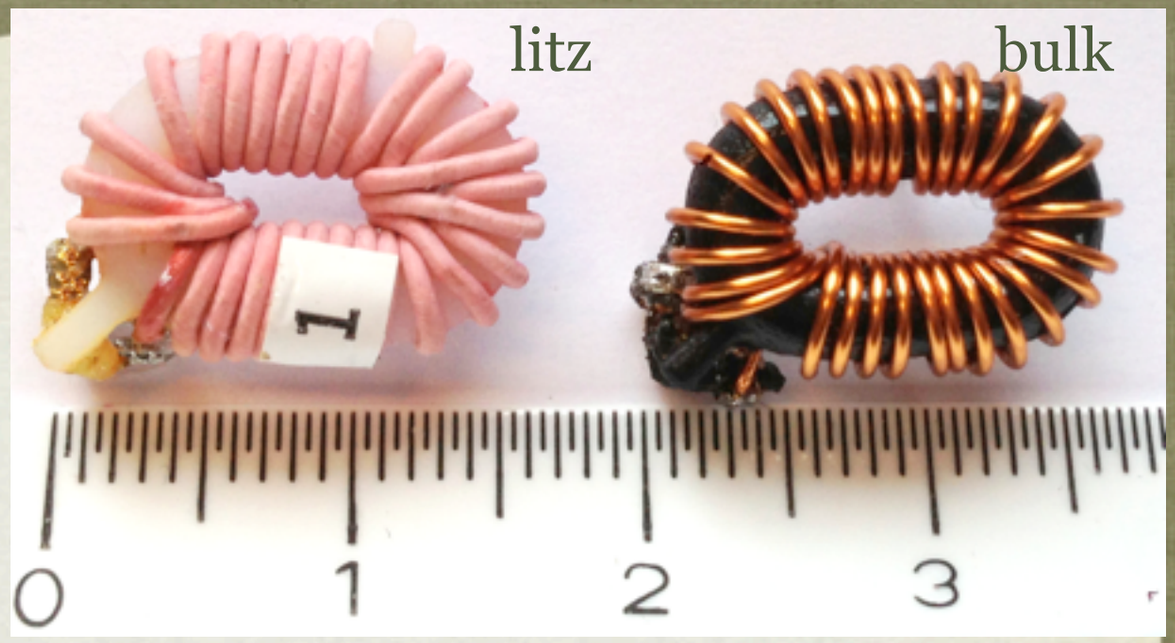


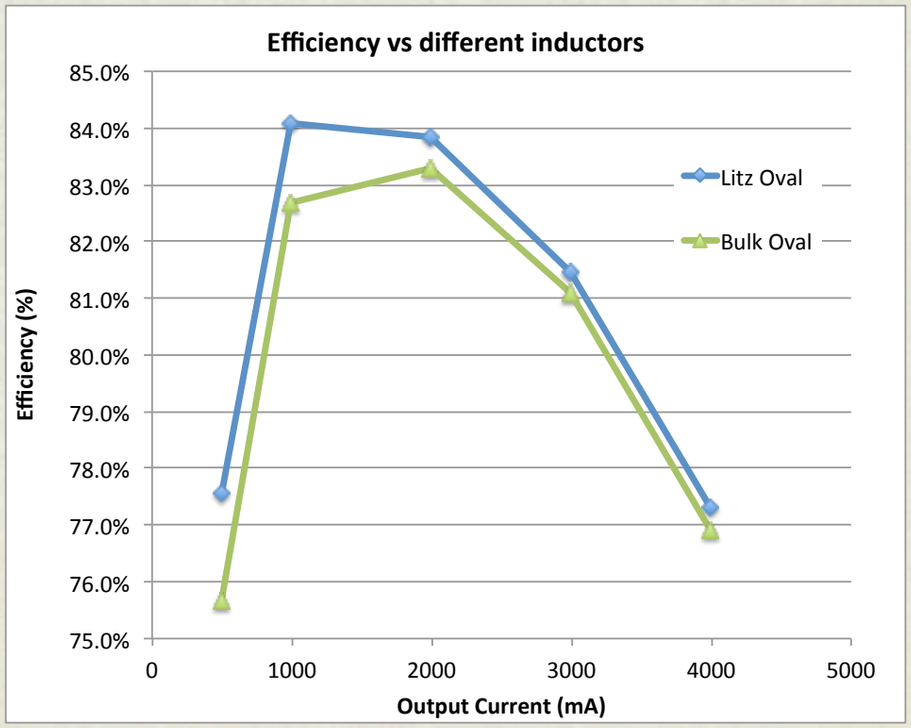
COMPONENTS

	production-ready
ASIC	✓
Custom inductor	
Shield	
Connector	
PCB design	

CUSTOM INDUCTOR

- Best shape determined with 3-D simulations and trials. It minimizes radiated fields and optimizes efficiency
- Custom development made with Coilcraft
- L=430nH as benchmark
- 2 different wires explored with Coilcraft:
  - ✓ bulk=copper wire with diameter 480um
  - ✓ litz=146 copper wires with diameter ~40um
  - ✓ comparable DC resistance, but much lower AC resistance for the litz wire due to skin effect
  - ✓ However, cost considerably larger for the litz wire solution (due to much more complex construction of the terminals)
- Choice made: bulk Cu wire. Large production order about to be launched





COMPONENTS

	production-ready
ASIC	✓
Custom inductor	✓
Shield	
Connector	
PCB design	

SHIELD

- Totally commercial shield from Orbel company

  ✓ 127µm thick bulk copper

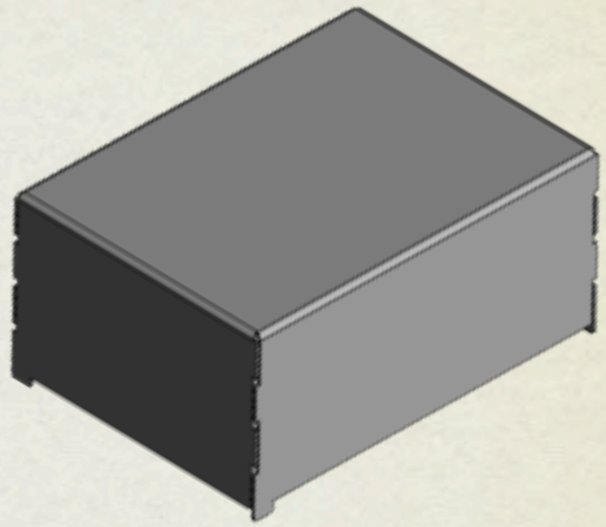
  ✓ Matte tin plating to avoid oxidation/ corrosion

  ✓ SMD component

  ✓ Use of multi-louvered corners

  ✓ Alignment pin to improve assembly

  ✓ Small slots to deal with thermal expansion of the air inside the shield volume

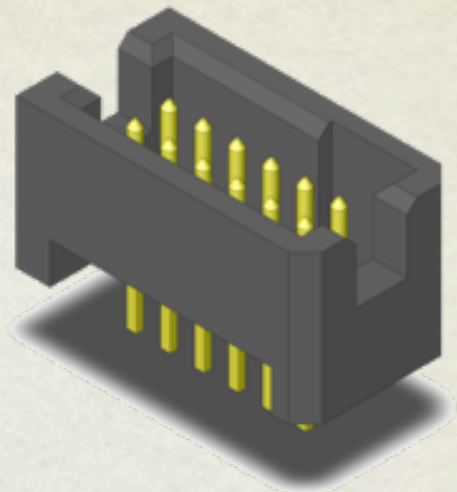


COMPONENTS

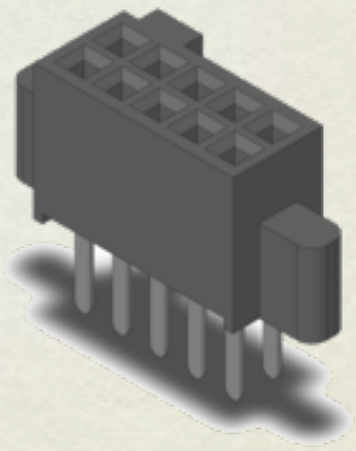
	production-ready
ASIC	✓
Custom inductor	✓
Shield	✓
Connector	
PCB design	

CONNECTOR

- The connector chosen for our module is SAMTEC TFM-106-01-L-D:
  - ✓ Through-hole male connector
  - ✓ 12 pins
  - ✓ High current rating per contact (5A@20°C)
  - ✓ Shrouded body for blind mating
  - ✓ Classified as a ruggedized product by the manufacturer
  - ✓ Good quality/price compromise



TFM-106-01-L-D



SFM-106-01-L-D

- The female connector is the model SFM-106-01-L-D from the same manufacturer

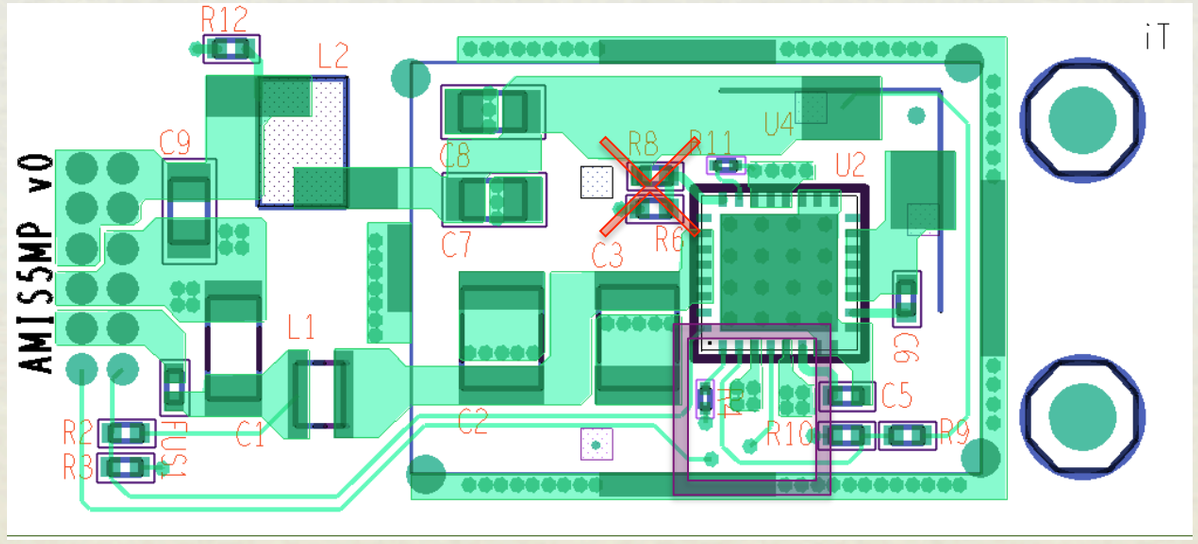
COMPONENTS

	production-ready
ASIC	✓
Custom inductor	✓
Shield	✓
Connector	✓
PCB design	

PCB AND PASSIVES

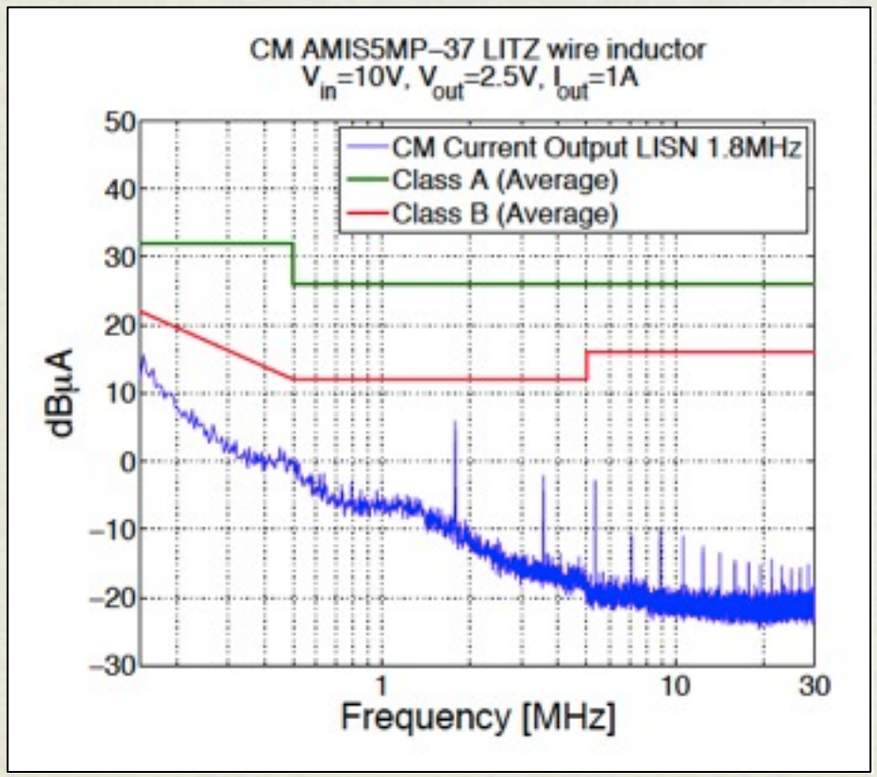
- The design of the PCB and the choice of the passives is the fruit of a long and systematic study within the R&D project (C.Fuentes, G.Blanchot, I.Troyano)

- The final design guarantees excellent noise performance and good streamline of the assembly steps - boards are fully assembled in Industry. Quality assurance can be improved that way.

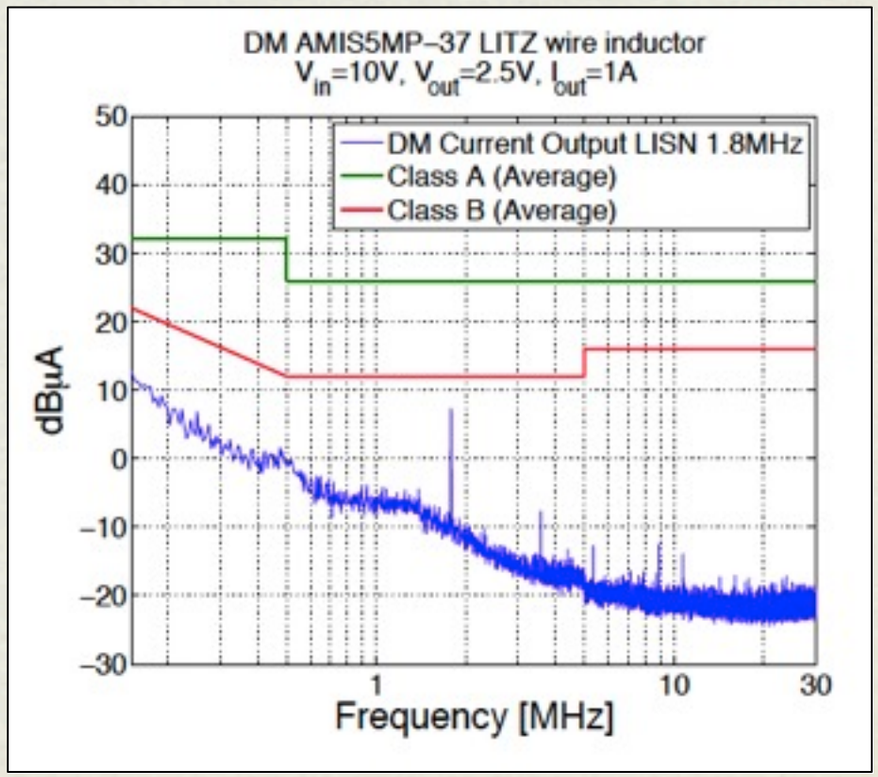


NOISE

Common mode output conducted noise



Differential mode output conducted noise

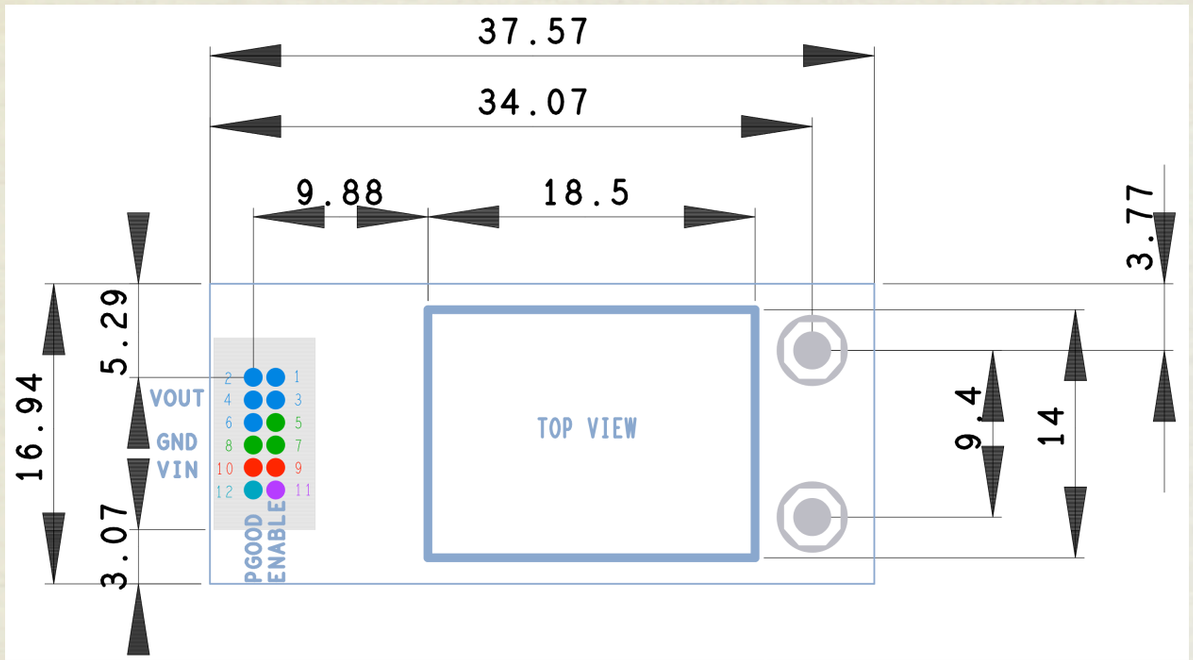


COMPONENTS

	production-ready
ASIC	✓
Custom inductor	✓
Shield	✓
Connector	✓
PCB design	✓

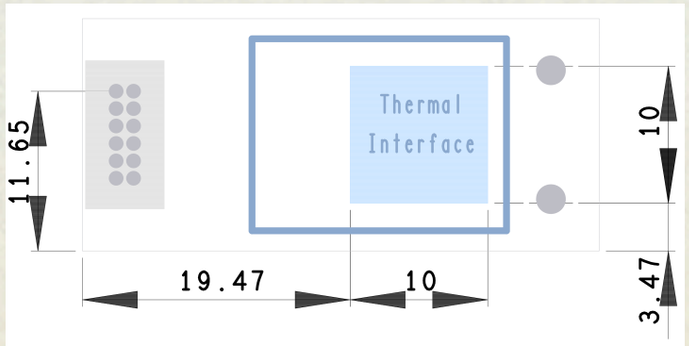
OVERALL DIMENSIONS

footprint



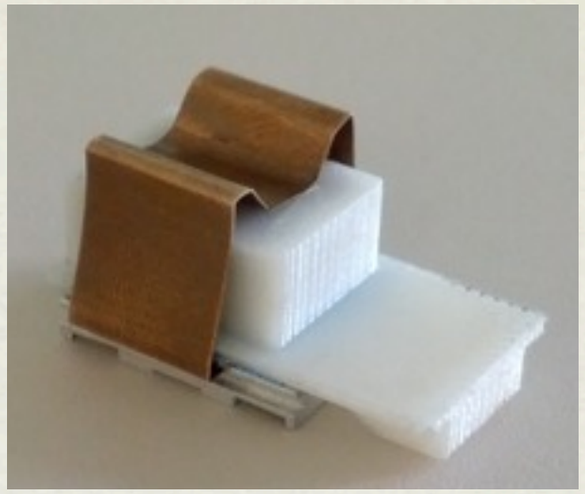
stack height:
mated connector ~6mm
pcb ~0.4mm
shield ~8.5
Total just short of 15mm

Thermal interface (required)



OPTIONAL MECHANICAL SUPPORT

- An optional mechanical support structure is being developed at CERN (PH-DT) to ensure easy and reliable attach of the converter module on a mother board

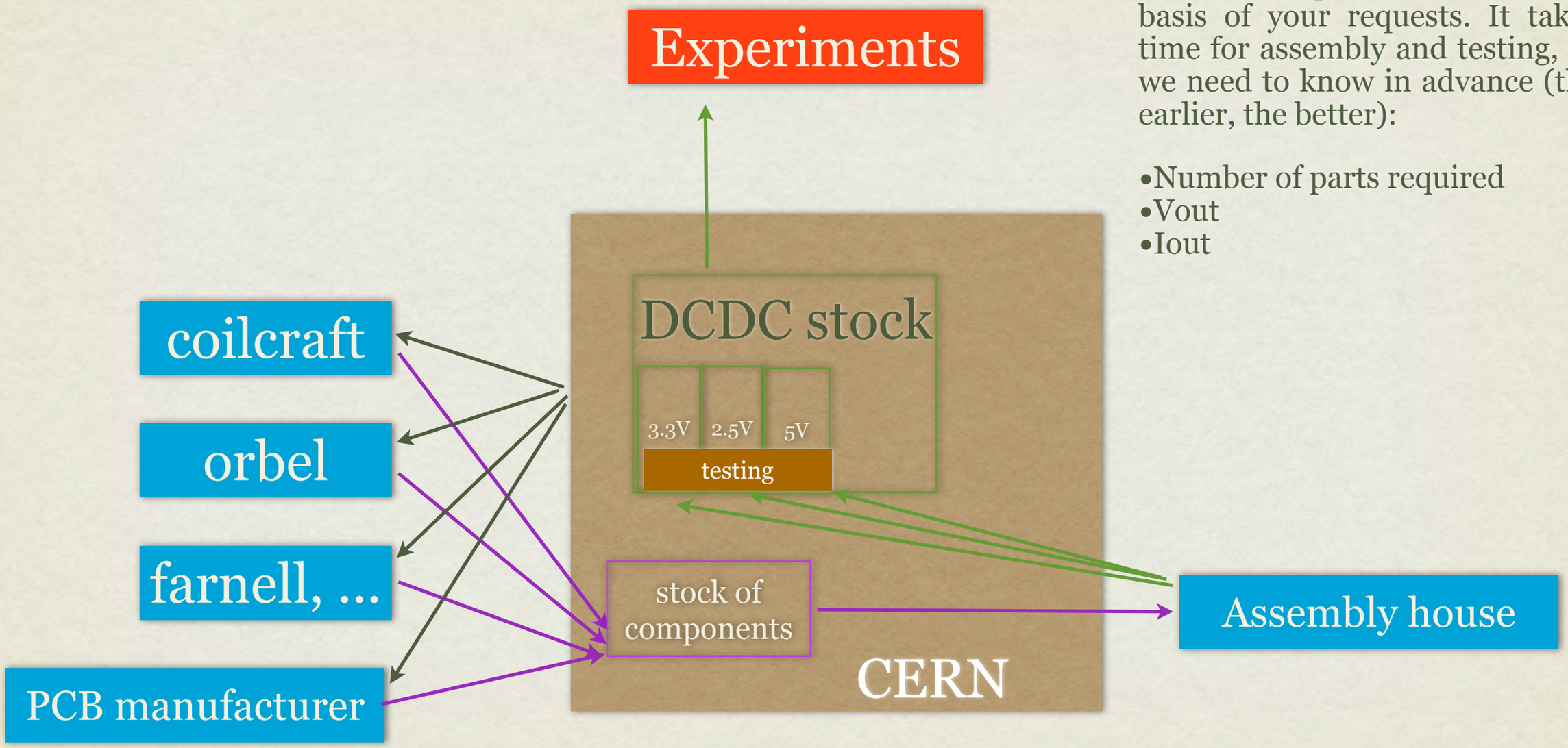


- Cooling should be ensured from the motherboard gnd plane or from the back of it (connection to the cooling system via a screw)

TIMELINE

- Today
  - ✓ We can distribute modules very representative of final ones, but still using the previous prototype ASIC (AMIS5) and hand-wrapped coils. These are available for ‘positive’ and ‘negative’ types (the negative has not been extensively tested so far)
- Procurement of all final components is on-going. We expect having all required parts before the end of 2013
  - ✓ A pre-production lot of about 200 parts will be launched at the beginning of 2014 (larger lot if requests are filed in advance)
- Reliability testing procedure has been developed and first measurements have been made (at the PH-DT QART Lab). A more complete qualification will be done on the pre-production lot (a full HAST is considered)

WHAT WE NEED FROM YOU



Stocks are provisioned on the basis of your requests. It takes time for assembly and testing, so we need to know in advance (the earlier, the better):

- Number of parts required
- Vout
- Iout