DCDC converters in high magnetic field

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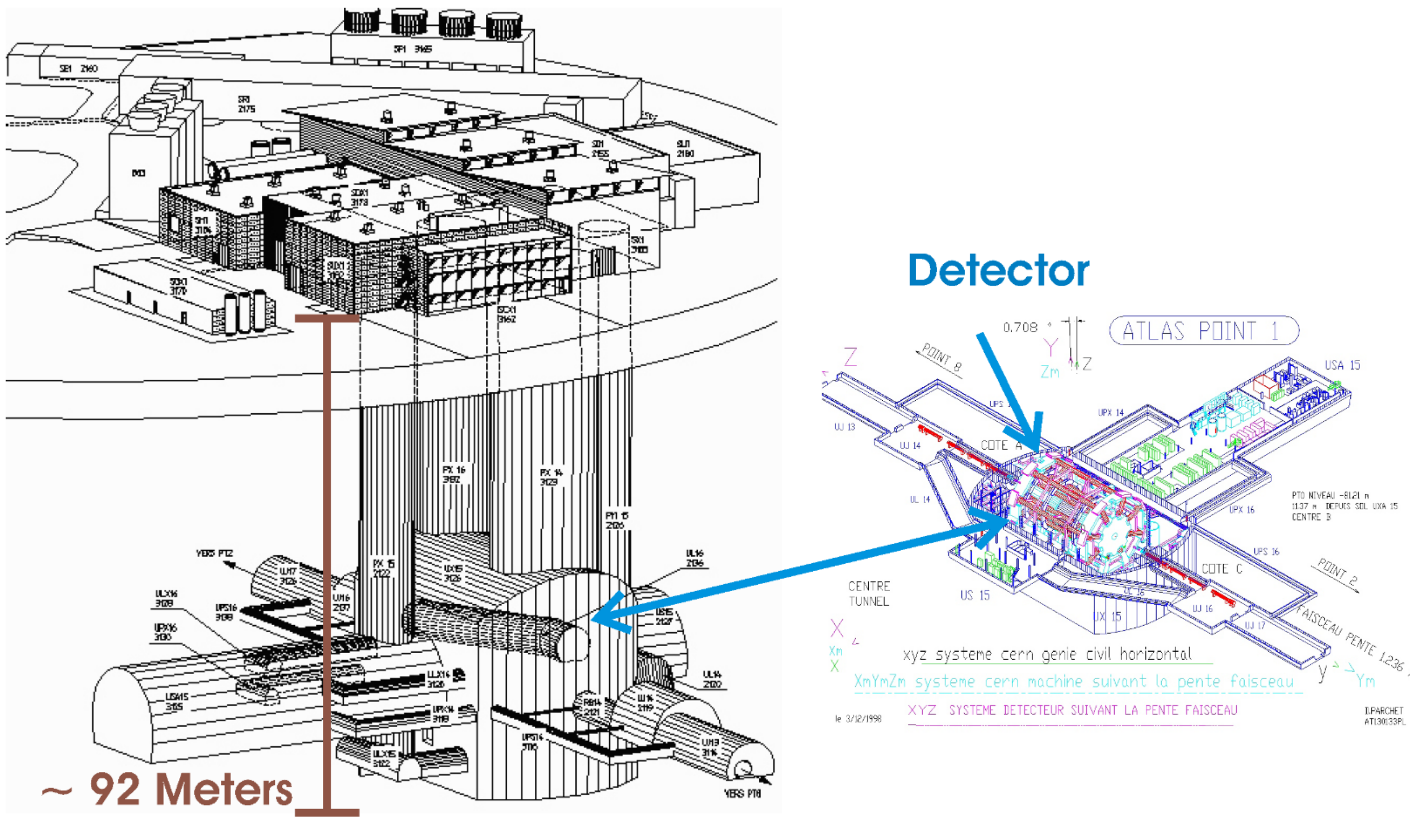
Atlas Detector is underground



Application:

Point of load DC-DC converters for a particle tracking detector system at the Large Hadron Collider. The detector consists of narrow silicon strips connected by bond wires to readout chips.

Constraints:

Very high Magnetic field (2 Tesla)
Must be as small as possible
Must be low mass and low radiation length (minimal interaction with particles)
No magnetic materials allowed (distorts the magnetic field)
Must be radiation resistant.

Solution:

High frequency DC-DC Buck converter with an air core coil.

Proiblem:

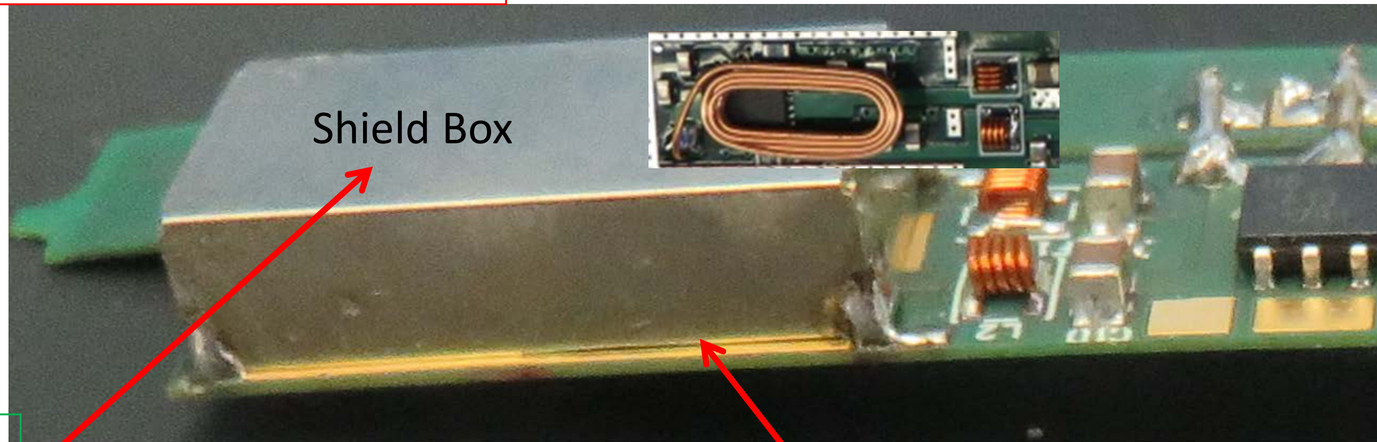
The ripple current in the inductor produces an AC magnetic field. This can couple to the bond wires in the detector system, inducing currents that appear as noise.

Shielding:

The AC magnetic field from the coil induces eddy currents in a conductive box surrounding the coil. These eddy currents cancel the field outside the box (and reduce the inductance of the coil). The sheet resistance of the box material must be as low as possible to maximize shielding effectiveness and minimize power loss. If the box is more than 2 mm away from the coil, the power loss in the shield can be very small, 10-30 mW.

ATLAS upgrade Silicon Strip Detector

2 MHz 2 Amps
Buck converter

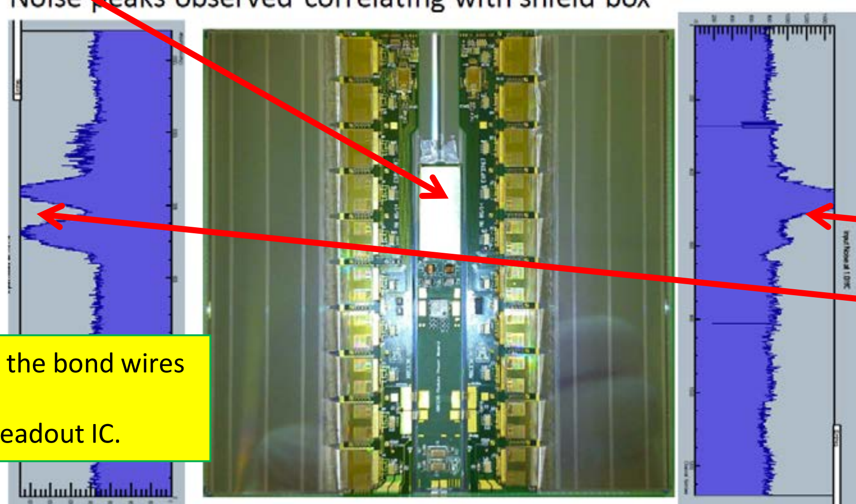


Shield Box
Size 9x18x 5 mm

Need Gasket to fill this cracks around
Soldering works but….

Adding the DCDC

- After DCDC was added module draws 0.42 A at 9.7 V
  - 74.3 % efficiency
- Noise peaks observed correlating with shield box



H field leakage
From sides of the
shield box

Leakage ac H field induces emf into the bond wires
(Secondary of the transformer)
connecting Silicon sensor strips to readout IC.

Science & Technology Facilities Council
Rutherford Appleton Laboratory

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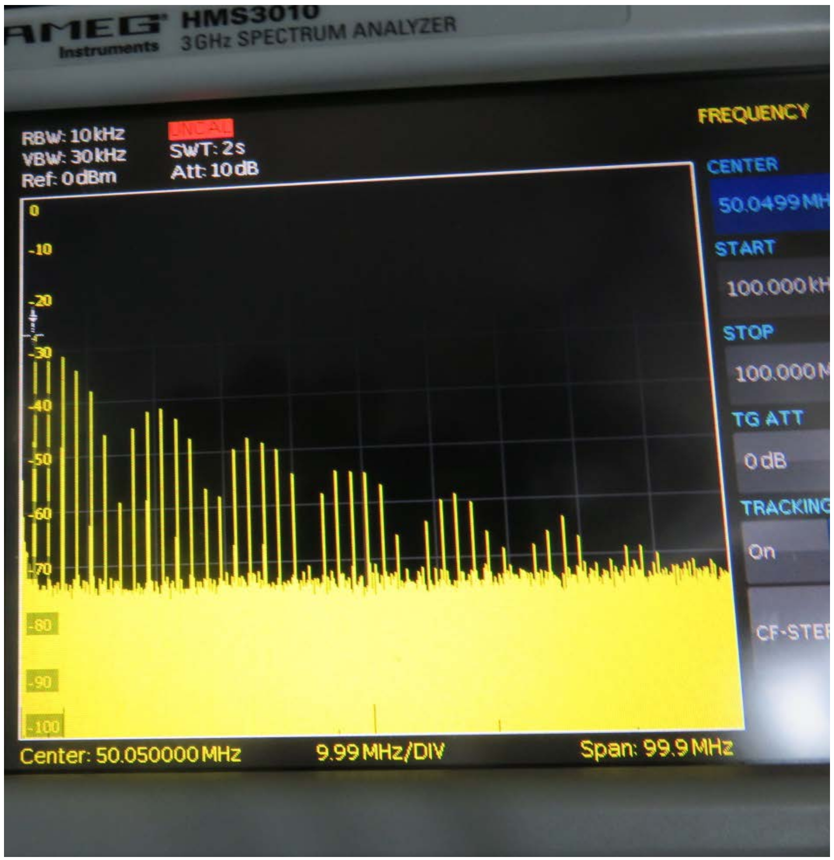
ATLAS EXPERIMENT

Ref: Peter Phillips etal. UK ATLAS Group

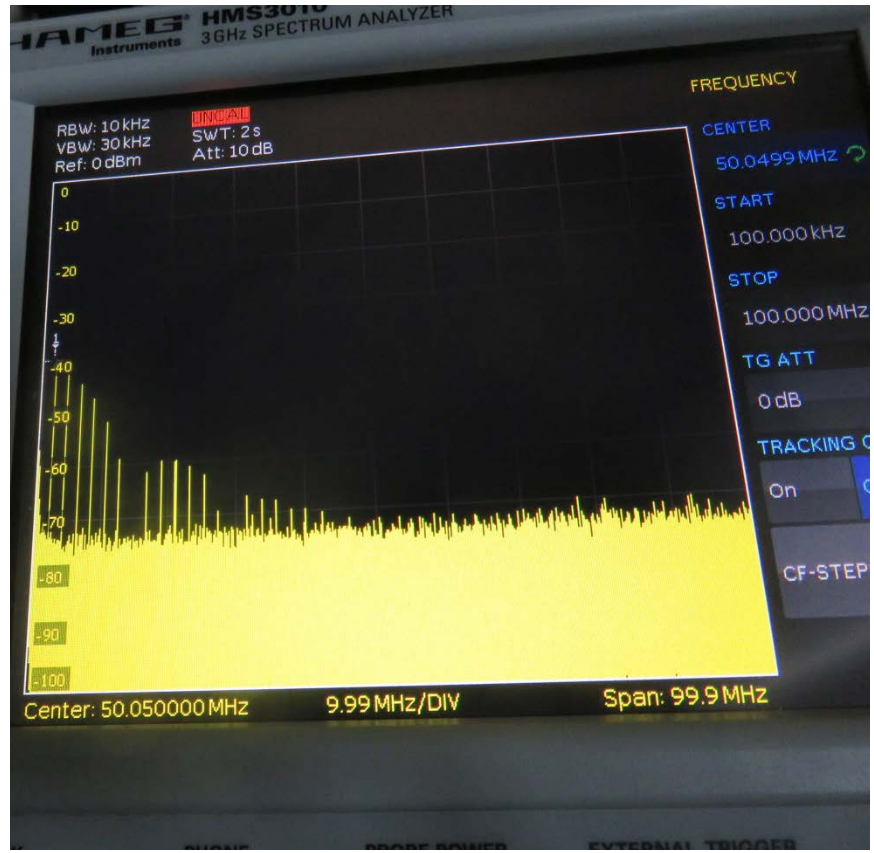
Pick up thru the PCB of PowerBD#1 (From Liverpool)

Probe H- field E401. OD= 0.125 inches http://www.bcarsten.com/?page=probes
Spectrum Analyzer Hambeg HMS3010

Without Carbon Fiber



Wit Carbon Fiber



Leakage ac H field thru PCB. 2 MHz Ripple field.
Hard switching produces high frequency noise to ~ 1Ghz. Here low mass Carbon fiber is effective in attenuating it.

Excess noise with various shiel **(noise with an unpowered DCDC subtracted)**

Rms = Rms of distribution of input noise across all channels

Run 467 with no +10 V on power card

		Converter on this chip	unbonded (no Si strips)	Far Chip
Chip # from Results Data .txt file		s261	s262	s263
Innse = mean input noise in mv				
Note	All Shields are soldered on all sides - as much as possible			
Liverpool shield		528	-4	90
		547	-5	93
2 mil Cu		61	-2	2
3 mil Cu		24	0	-1
5 mil Cu		18	-2	1
		9	-5	-1
4 mil Al		10	-2	8
5 mil Al		21	-1	1
		17	-3	2
6 mil Al		6	2	-1
		6	-4	2
		12	-1	0
	5 ohm load	8	-2	4

Nickel Silver
0.2mm NS106 HH
60% Cu.
Conductivity 8% of Cu

Liverpool Power Boards + BNL Shields

Eddy Current Shield needs high Electrical conductivity

Sheet Resistance Equivalence
4 mil copper == 6 mil Aluminum

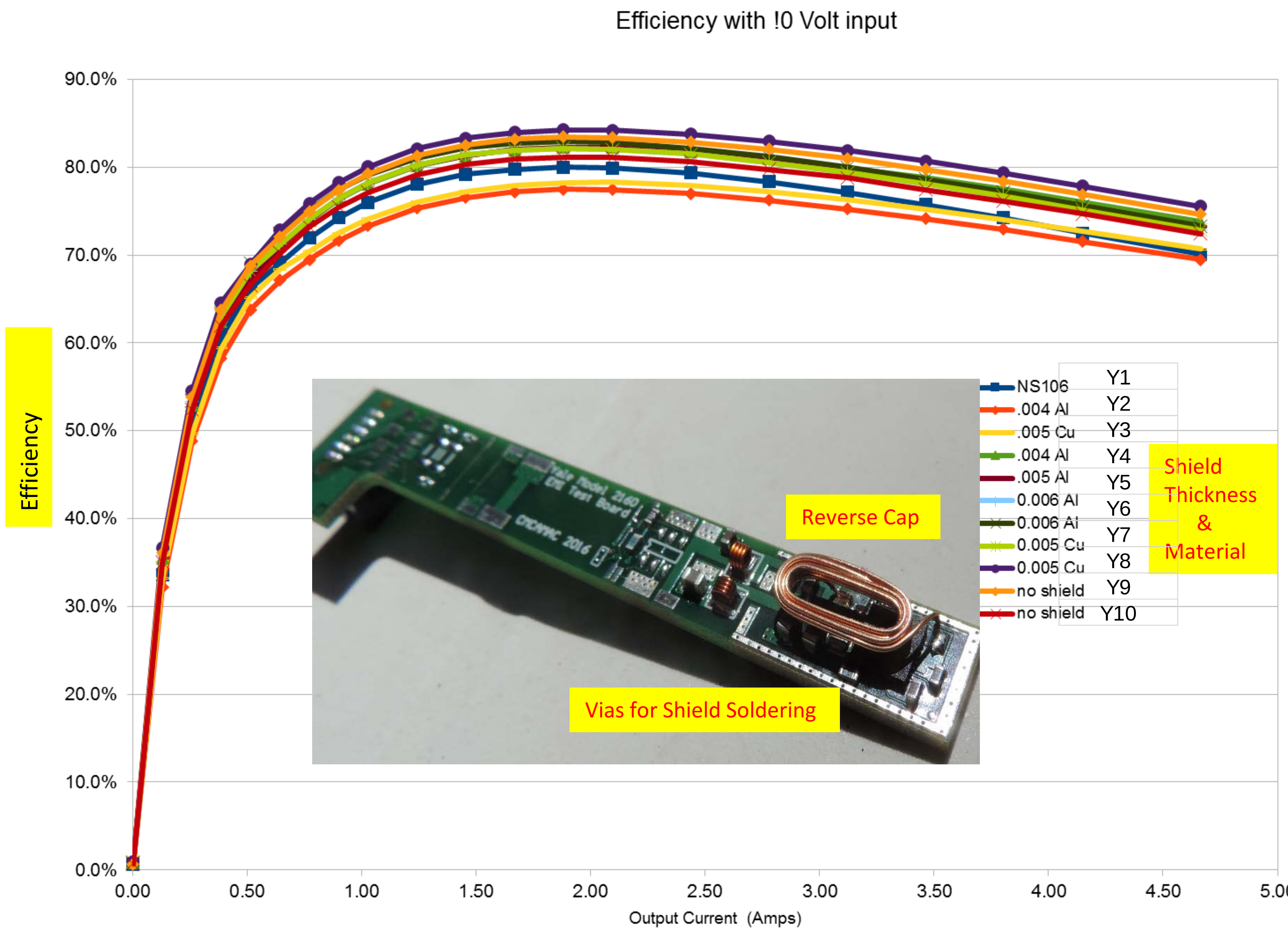
	Resistivity									
	microOhm*cm				thickness in mils					
				1	2	4	5	6	7	
Cu	1.68			0.66	0.33	0.17	0.13	0.11		
Al	2.62			1.03	0.52	0.26	0.21	0.17		
HH NS106	27	calculated							1.5	measured
(soft)	33.00	published		12.99	6.50	3.25	2.60	2.17	1.86	
	Radiation Length	density		thichness in Radiation lengths						
	gm/cm**2	gm/cm**3								
Cu	12.86	8.96		0.18%	0.35%	0.71%	0.88%	1.06%		
Al	24.01	2.699		0.03%	0.06%	0.11%	0.14%	0.17%		
NS106	12.74	8.73		0.17%	0.35%	0.70%	0.87%	1.04%	1.22%	

The thickness in radiation lengths is the proability that an incoming gamma ray will interact and produce an electron positron pair.

calculation of NS106 radiation length

	pct	rad len	total
Cu	0.63	12.86	8.102
ni	0.18	12.68	2.282
mn	0.003		
zn	0.19	12.43	2.362
			12.75

Radiation Length Equivalence
1 mil copper == 6 mil Aluminum



Efficiency with !0 Volt input
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Efficiency
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Output Current (Amps)
NS106 Y1
.004 Al Y2
.005 Cu Y3
.004 Al Y4
.005 Al Y5
0.006 Al Y6
0.006 Al Y7
0.005 Cu Y8
0.005 Cu Y9
no shield Y9
no shield Y10
Shield Thickness & Material
Reverse Cap
Vias for Shield Soldering

End