Tracker Powering Points

Satish Dhawan, Yale University
Richard Sumner , CMCAMAC LLC

ATLAS ITK week September 14-18, 2015 @ CERN, Geneva, Switzerland.

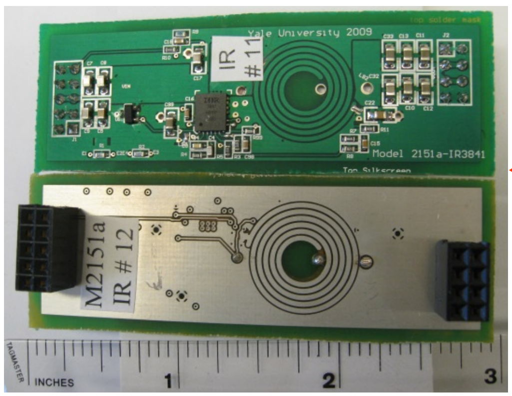
System Testing

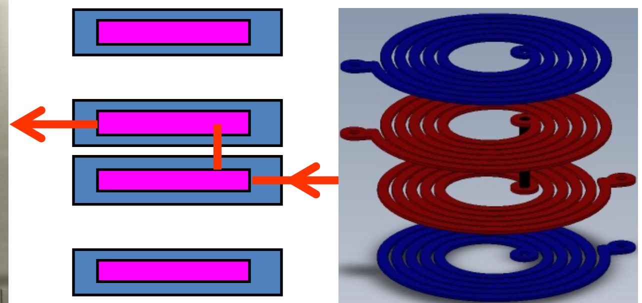
- DcDc Converter @ Yale . Tracker work stopped in 2009
- Thickness of Converters – Shield thickness!
- Tests @ Yale with FEAST 2 Chip mini-Module
- ATLYS readout
- Reduce mass/noise by using Fiber Carbon composite
  (it works at higher frequencies but may be marginally useful at 2 MHz)

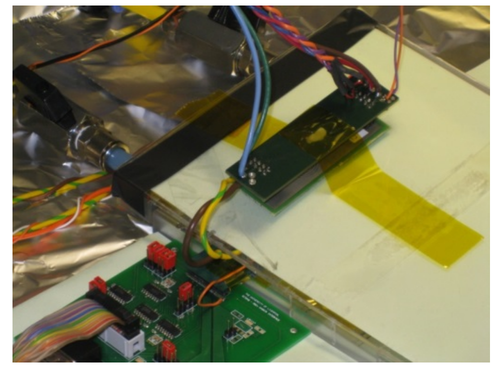
Prospects for Future

- Lower Mass @ 5 MHZ
- Topology Change Charge pump, Buck or something else?
- GaN

Old Cards
Liverpool Test
Paris Tweep 2009 –







- US Atlas Decided in favor of Serial Power. Funding > zero
- CERN Developed Toroid Inductors & FEAST Chip
- UK Groups (Liverpool & RAL).
  Requested a design with the YALE Planar Inductor.
- Compare using the same commercial Chip as Toroid Design

stackup, 2156, 2156a, 2156b, 2156c
thick, 487, 792, 486, 811 nanohenries
thin, 481, 796, 492, 816

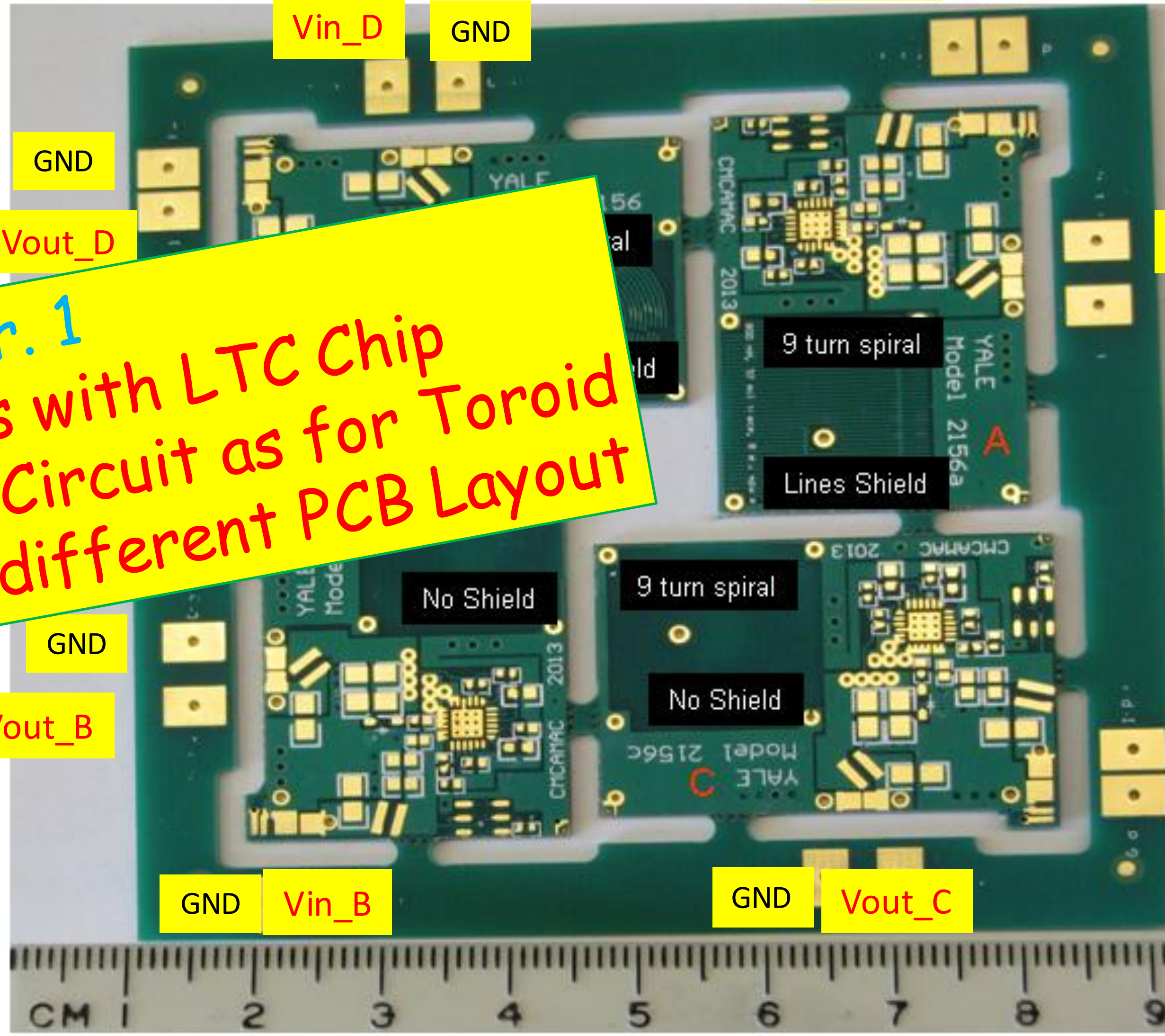
2156 and 2156b 7 turns, b has spiral shield 2156a and 2156c 9 turns, c has straight lines shield
Inductance lower with Shield

Q- Meter
C= 470 pF
F = 8 MHz / 10 MHz

Thick 59 mils
Thin 34 mils

Ver. 1

- Spirals with LTC Chip
- Same Circuit as for Toroid but different PCB Layout



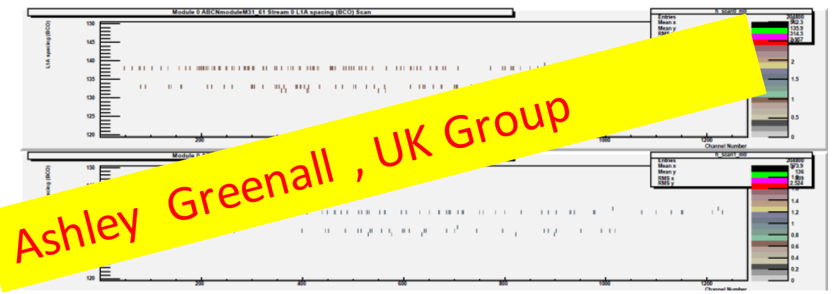
Satish Dhawan
Yale University
May 18, 2013

Planar Coil – "Up Close and Personal"

Double Trigger Noise (DTN)

With Toroid Converter

Reference measurement (CERN STV10 converter) @ 0.5fC



Ashley Greenall , UK Group

- CERN converter registers zero occupancy until 0.5fC, then registers 528/244 hits

Above picture is Double trigger noise
i.e. after a hit ; spurious counts are registered

With Planar Converter

Approx <3mm from wire bonds with improved reference @ 0.5fC

US ATLAS Moved towards Dc-Dc.

- For conducted noise configuration, Planar coil registers zero occupancy(even at 0.5fC)
- Only when close to asics are hits registered, 3/2 counts at 0.5fC, see above

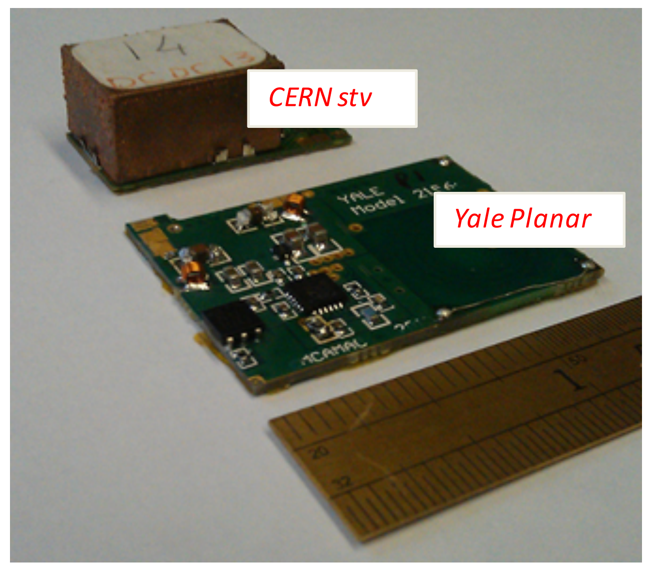
Comments inserted by Yale University

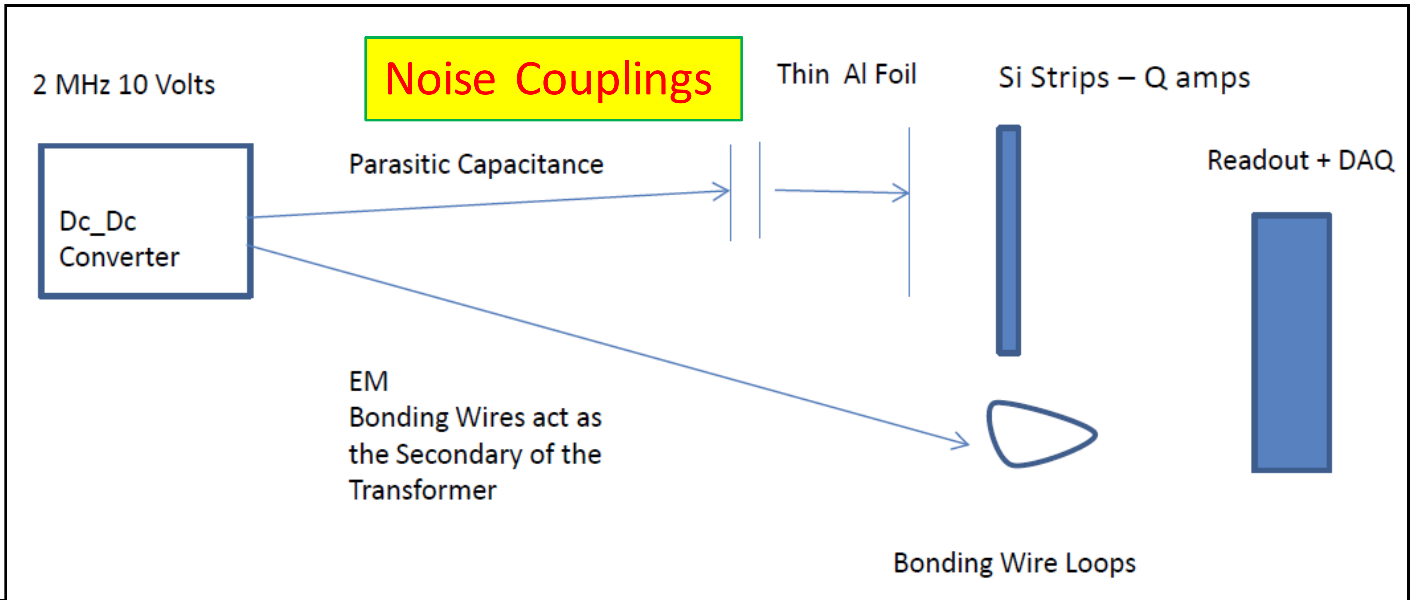
Noise in Electrons Measured @ Liverpool

cern stv10 noise 589, 604 average = 601
yale planar noise 587, 589 average = 588
noise with dc supplies (no dcdc) = 580
assuming the noise adds in quadrature, extract noise due to dcdc converter:
cern stv10 Additional noise = 157
yale planar Additional noise = 96
Planar Converter uses the same components except Inductor coil

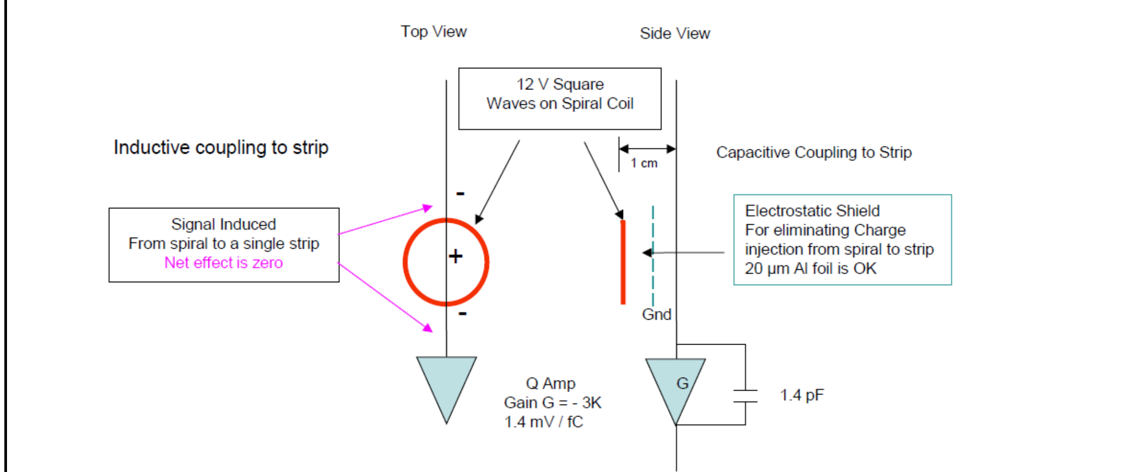
Thickness of stv = 8 mm vs 3mm for Planar

Shield to Silicon strips are Electrostatics & Eddy current
Bottom side shield 2 mm from Planar coil traces
Can be mounted on the sensor with 50 µm Kapton
Cooling via sensor





Electrostatic & H field Coupling/Shields



Why do we need electrostatic Shield ?

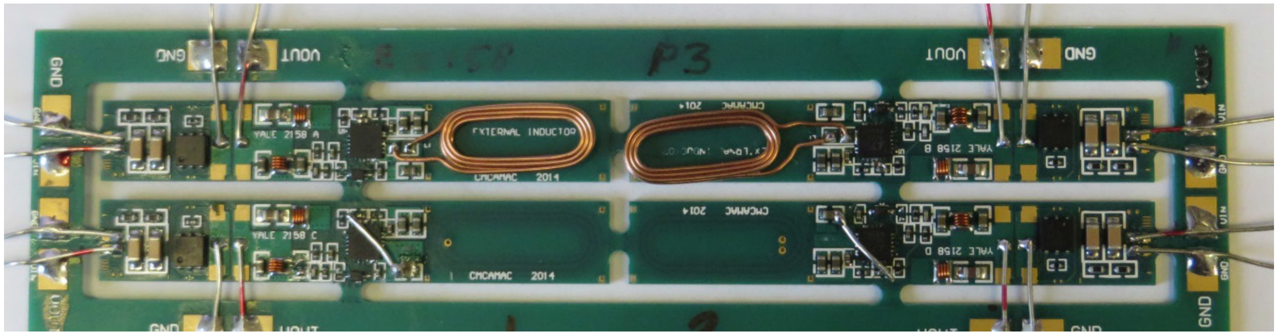
Parallel Plate Capacitance in pF = 0.225 x A x K / Distance

	Inches	C in femto farads
Area =	1	
Distance =	0.4	500
GLAST = .5 x 1.3	0.6	
per strip= 0.6 /48	0.0125	6.25

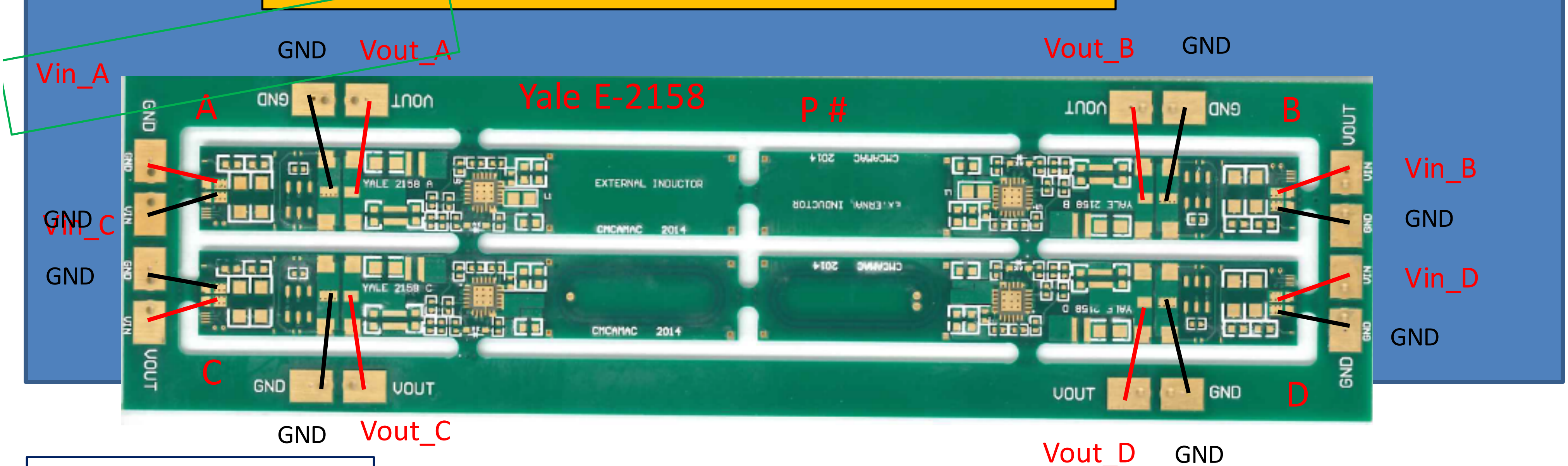
1 volt swing on spiral coil will inject Q= 6 femto Coulombs

Charge from one minimum ionizing particle (1 mip) = 7 femto Coulombs

Ver. 2 OVAL / Spirals with LTC Chip

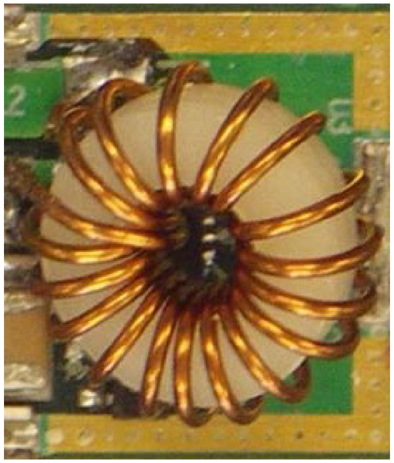


Each Converter PCB 10 mm x 63 mm. Different Coil Configuration
Channel D: Embedded Coil with 2 via: 687 nH, 83 mΩ
Channel C: Embedded Coil with 1 via: 703 nH, 83 mΩ
Channel B: External Coil: Wurth 540 nH* with short Leads
Channel A: External Coil: Wurth 540 nH* with short Leads
* With BK Precision LCR Meter



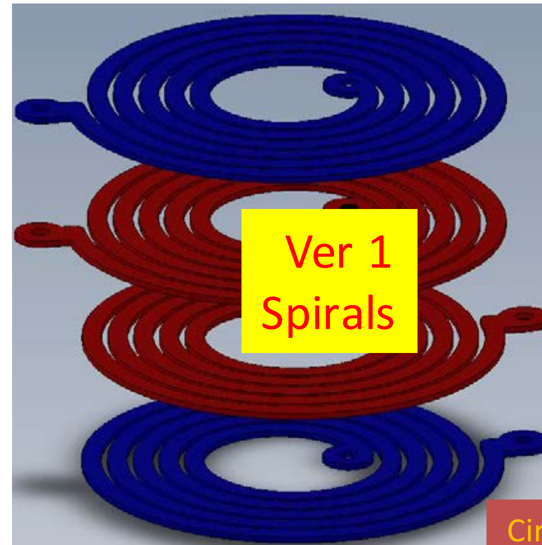
DC-DC Converter Model E-2158
Yale University
October 19, 2014

Toroid vs Planar Coil



Toroid Inductors Designs- Round & Elliptical

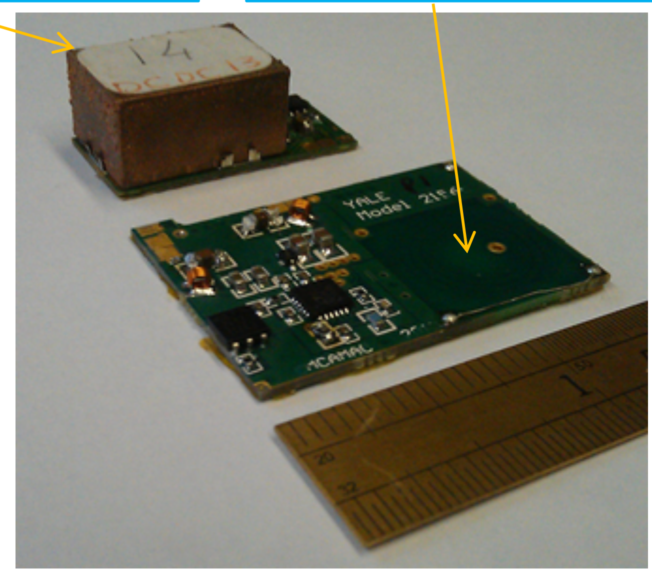
Lower Mutual Coupling if turns are further apart but adds to DC Resistance

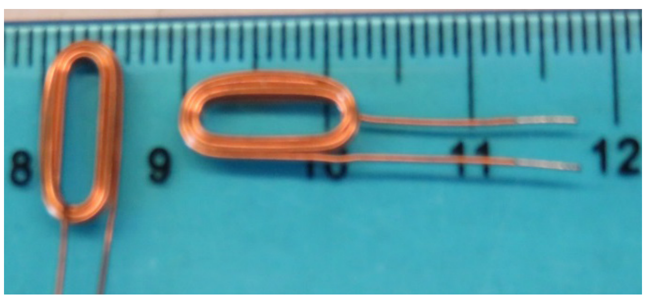


Circa 2008

Toroid Inductor with Shield on toroid height = 8 mm

Embedded Spirals
Disabled for the hand wound coil
Height = 2 mm plus shield



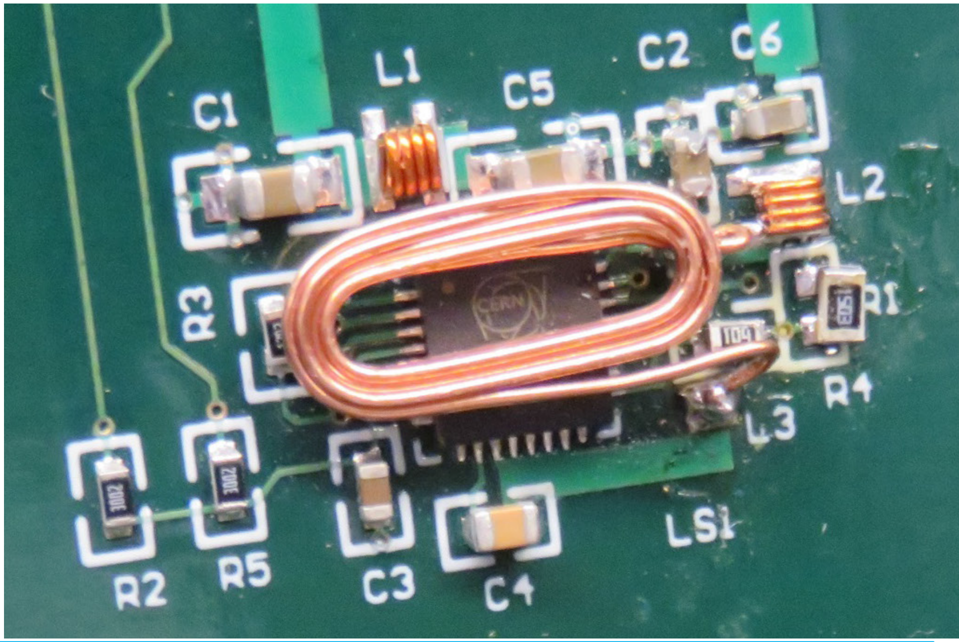


Wurth Coil 5 mm x 8 mm
9 turns (3 layers with 3 turs)
750 nH
July 2015

Coils squeezed in one direction for Mechanical

Comparison of toroidal inductor and planar inductor

toroid coil	toroid radius mm	coil radius mm	turns	L	wire length mm	R mOhms	wire dia mm	volume cubic mm	mass grams
	4.5	1.7	32	413	342	32.5	0.48	129	1.1
planar coil	coil length								
same L, same Ohms	1.0	5.4	6	415	203	34.4	0.36	58	0.5
Same L, same mass of Copper	1.0	5.4	6	415	203	8.5	0.72	115	1.0
same mass, same Ohms	1.0	5.5	9	967	311	33.0	0.46	111	1.0



Yale RLS 1

Using Bigger components for hand soldering

Wurth Elektronik

Custom Wound

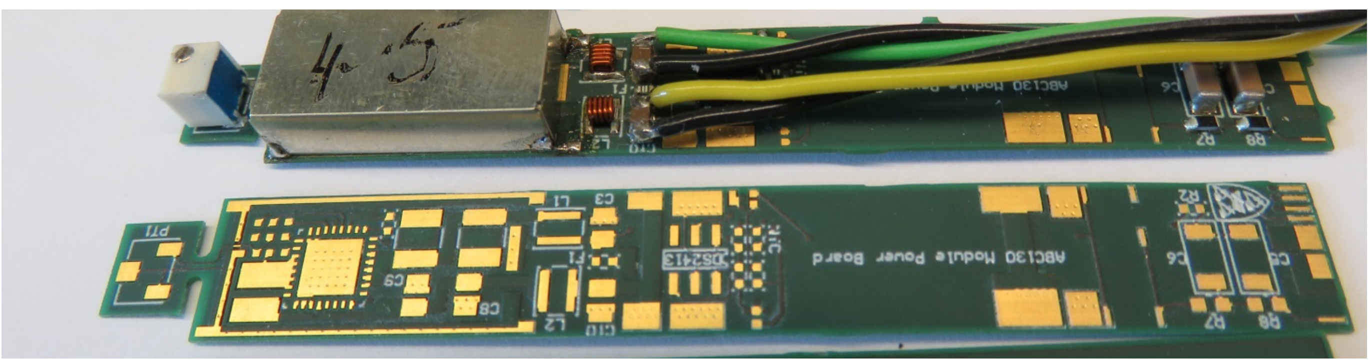
3 turns x 3 layers = 9 turns

Produced > 100 pieces

Inductor / coil

740 nH / 38.5 mΩ

Ver 3 Squeezed Oval shape for 130 nm Stave design

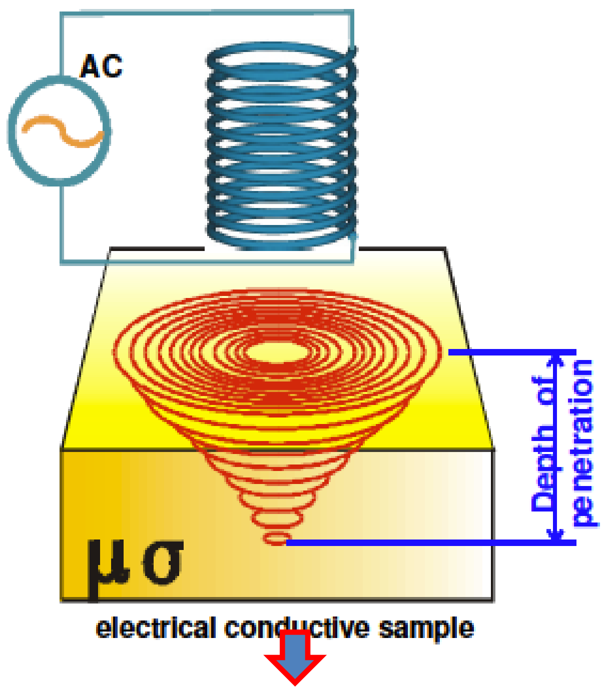


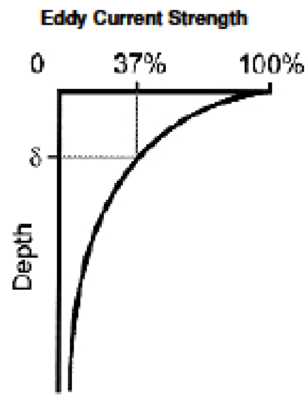
ABC130 Pwr Bd Plus MUX Liverpool

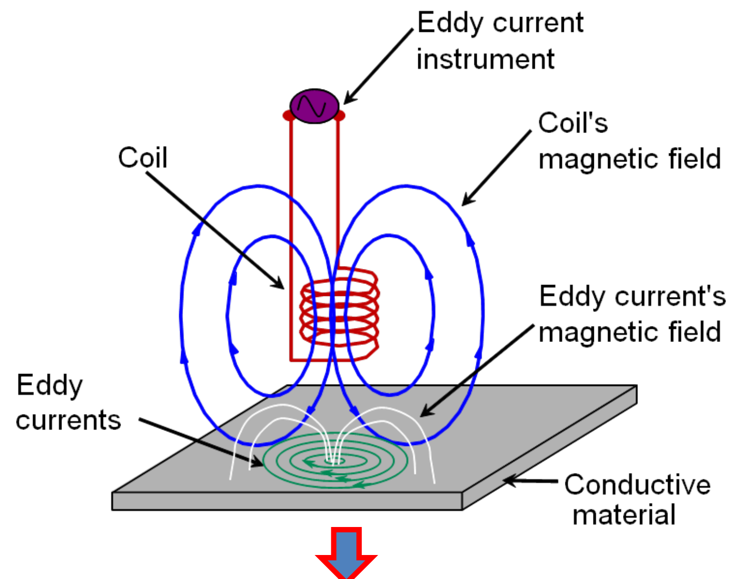
Using smallest components

Eddy Current Shield

Diagram 1: Eddy Current Field Depth of Penetration & Density







Skin effect arises when the Eddy Currents flowing in the test object at any depth produce magnetic fields which oppose the primary field, thus reducing the net magnetic flux and causing a decrease in current flow as the depth increases.

Alternatively, Eddy Currents near the surface can be viewed as shielding the coil's magnetic field, thereby weakening the magnetic field at greater depths and reducing induced currents.

Eddy Current is used in the inspection of ferromagnetic and non-ferromagnetic materials. The principle of Eddy Current based inspection is explained below.

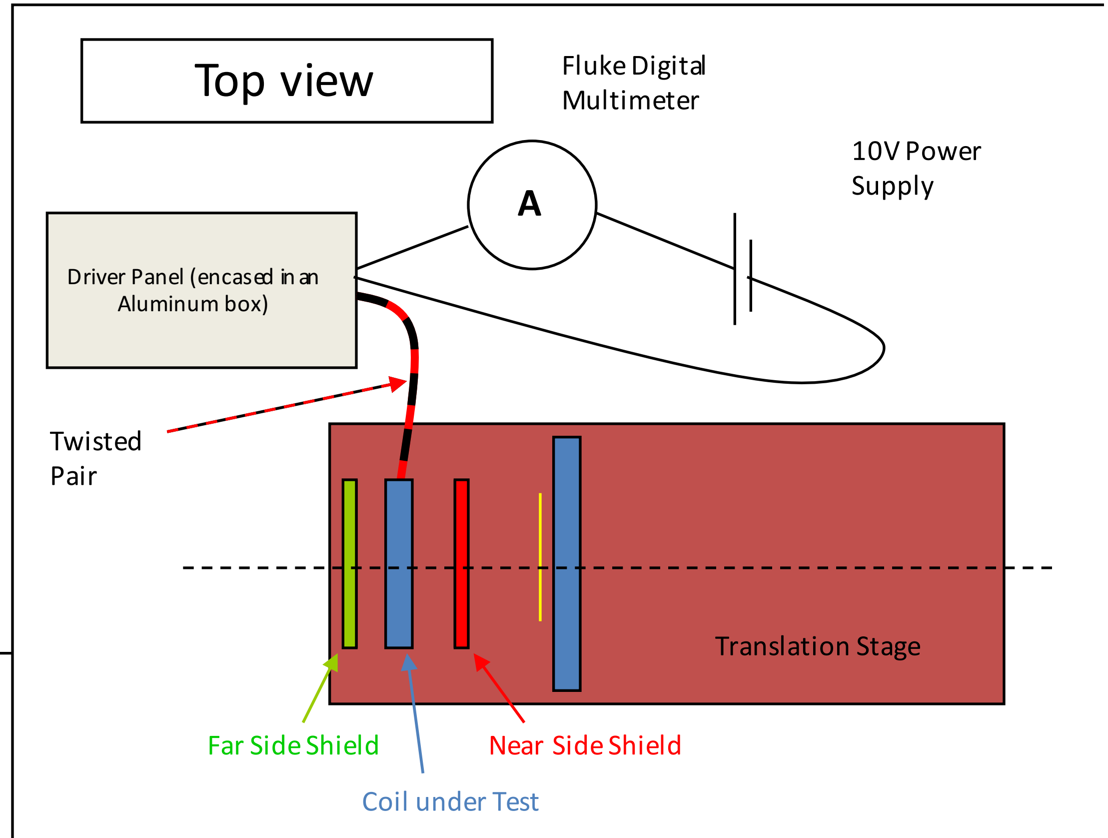
Field Leakage ???
Close to the Cu Surface

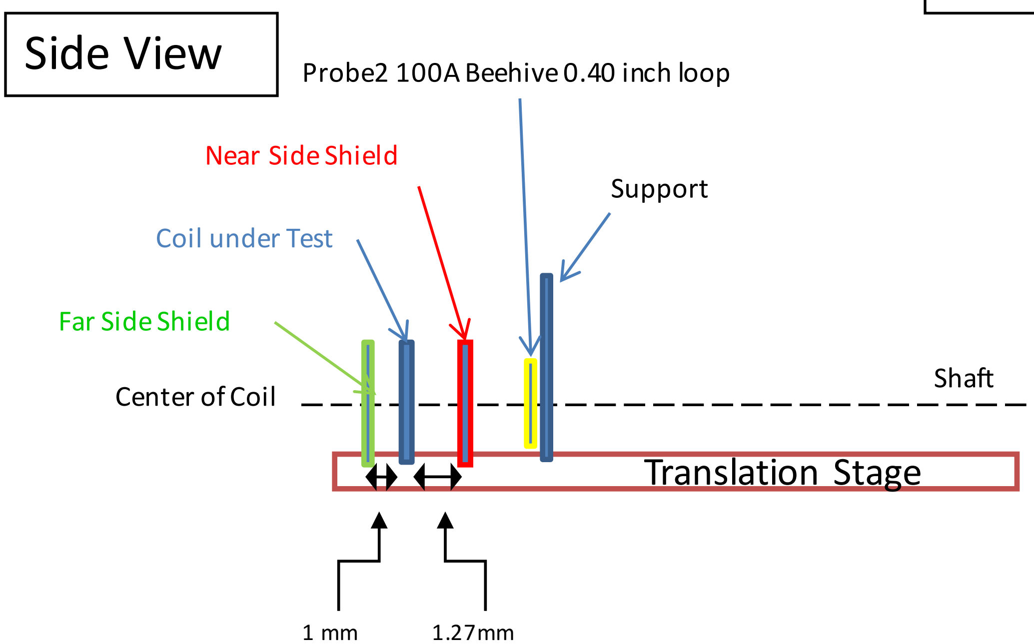
From WWW

Shield Thiness ≈ Conductivity of Shield
Power Loss ≈ Resistivity of Shield Material

Eddy Current Shield Measurements

Idc Change ≈ Eddy Losses





The Shields

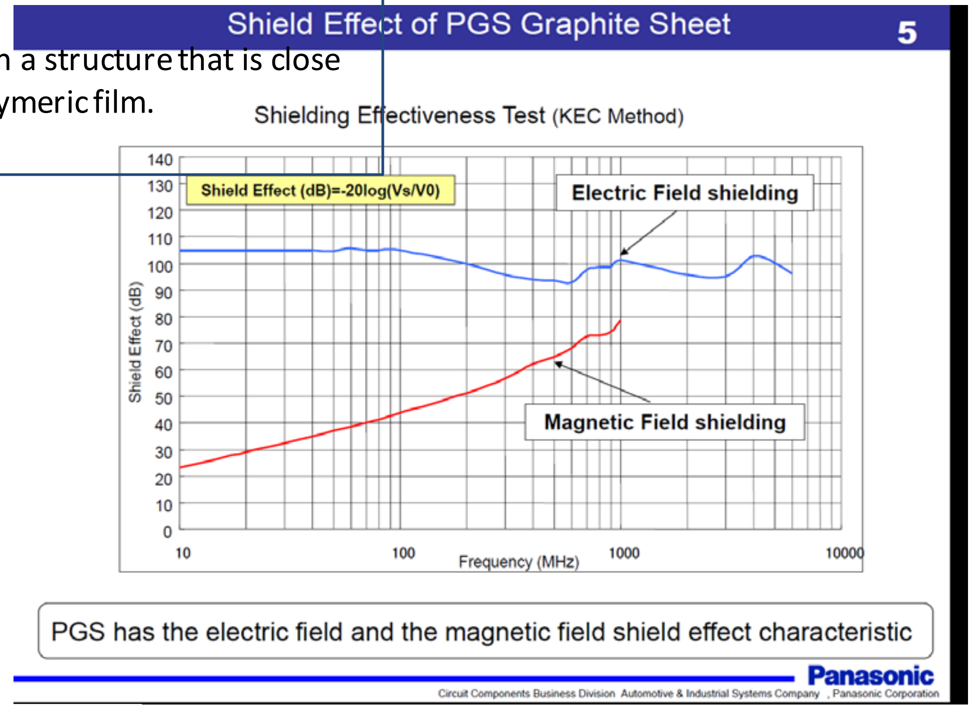
Far side Shield H3H: Half Oz/ 3 mil thick/ Half Oz

4 Types of Near Side Shield

1. Half Oz/ 3 mil thick/ Half Oz
2. One Oz/ 3 mil thick/ One Oz
3. One Oz/ 5 mil Thick/ Zero Oz
4. One Oz/ 10µm/ One Oz

PGS (Pyrolytic Highly Oriented Graphite Sheet) is made of graphite with a structure that is close to a single crystal, which is achieved by the heat decomposition of polymeric film.
PGS is a competitive conductive sheet with high thermal conductivity.

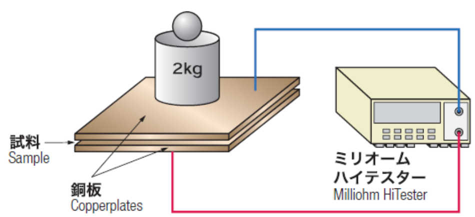
Intrigued by this Chart
Attenuates High Frequencies



抵抗(厚み方向)の測定方法 Method of measuring resistance (in the vertical direction)

金めっきした銅板に試料を挟み込み、2kgの荷重をかけ銅板間の抵抗を測定します。
試料の大きさ(貼付面積)は25mm×25mm。
(試料の貼付部以外は、絶縁する)

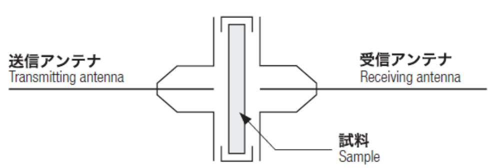
A weight (2kg) is placed on a sample put between gold plated copper plates and the resistance between the plates is measured. The sample size (contact area) is 25mm by 25mm (the sample's non-contact area is insulated).



シールド効果(電界):KEC法について Shielding effectiveness (electric field): KEC Method

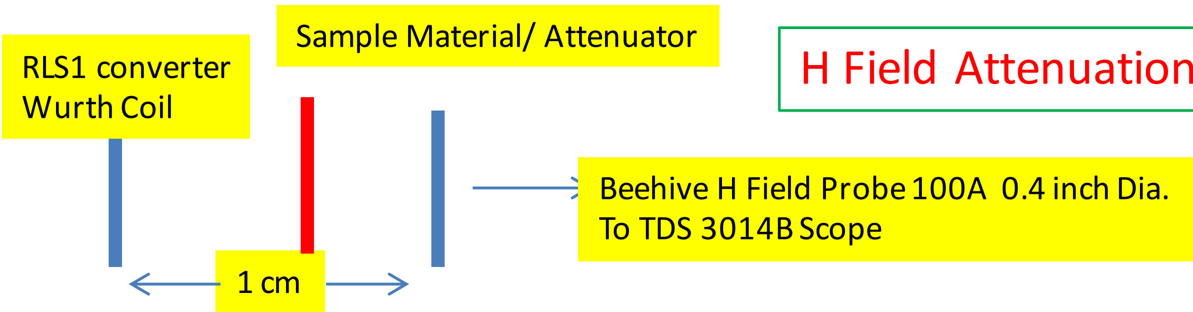
KEC法によって定められた評価方法です。
電界シールド効果評価装置はTEMセルの寸法配分を取り入れ、その伝送軸方向に対して垂直な面内で左右対称に分割した構造になっており、測定試料の両面から挟み込んで測定します。送信アンテナから電磁界を発生させ、受信アンテナで伝送レベルを測定し、電界の減衰量を比較する事によってシールド効果を評価します。

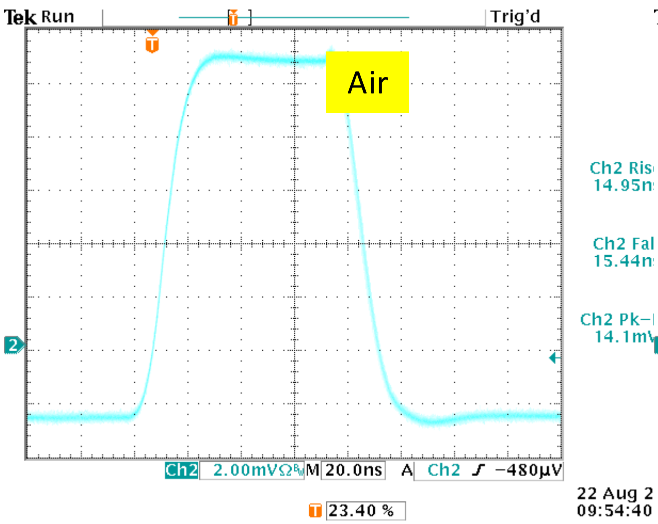
The KEC method is a shielding effectiveness measuring method developed by Kansai Electronic Industry Development Center.
Based on electric field distribution in a TEM cell, EMI shielding effectiveness testing equipment has a testing space which symmetrically holds a sample between two opposite surfaces on a plane perpendicular to a signal transmission axis. A transmitting antenna is set in a way to generate an electromagnetic field and the signal level at a receiving antenna is measured. A field intensity attenuation is calculated by comparison of the signal levels at the transmitting and receiving antennas and this attenuation is a measure of shielding effectiveness.

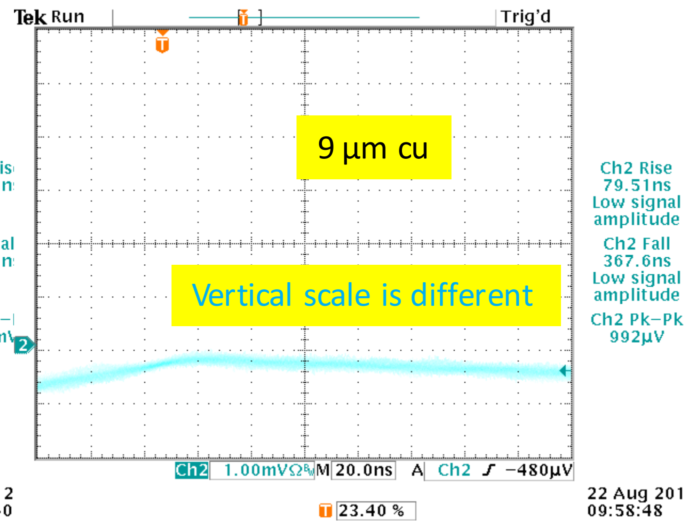


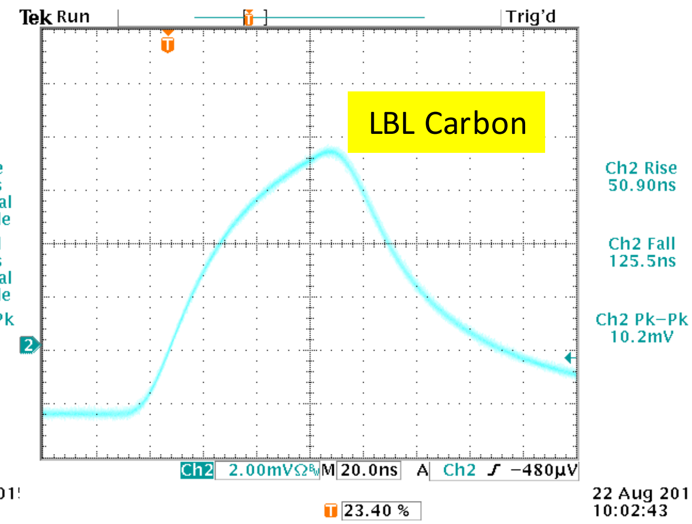
電磁波シールド効果評価装置
EMI shielding effectiveness testing equipment

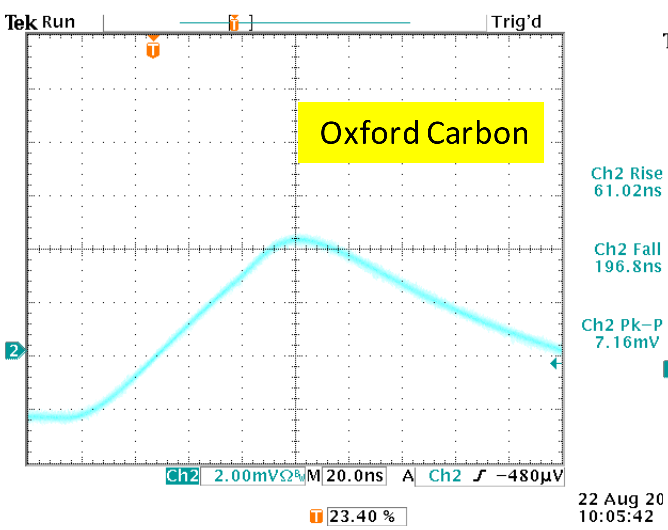
H Field Attenuation with Gap Material

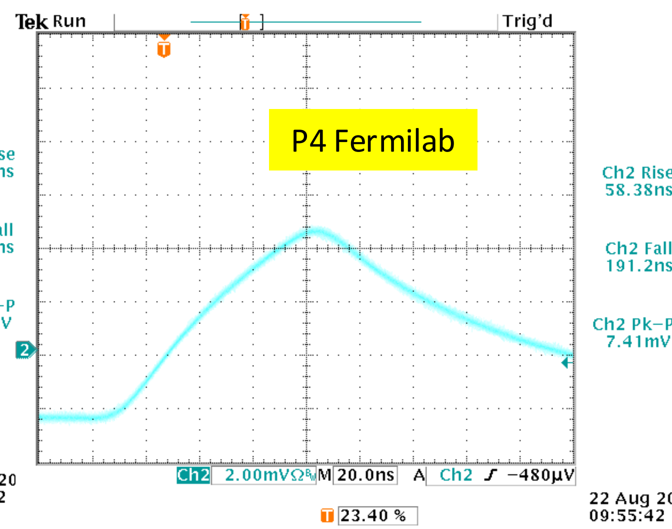


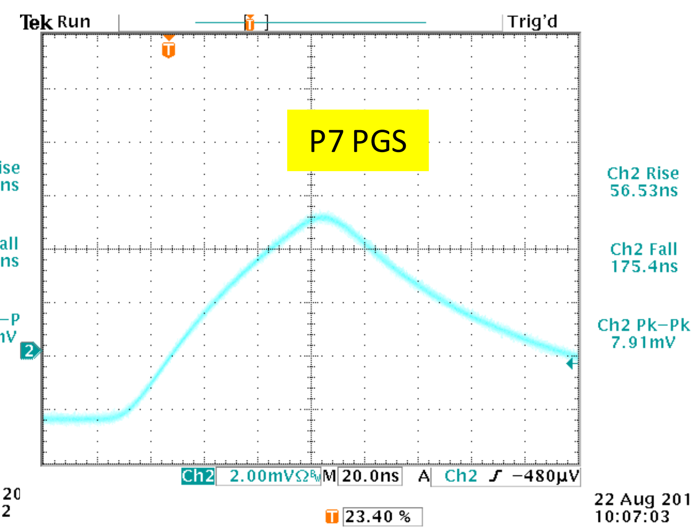




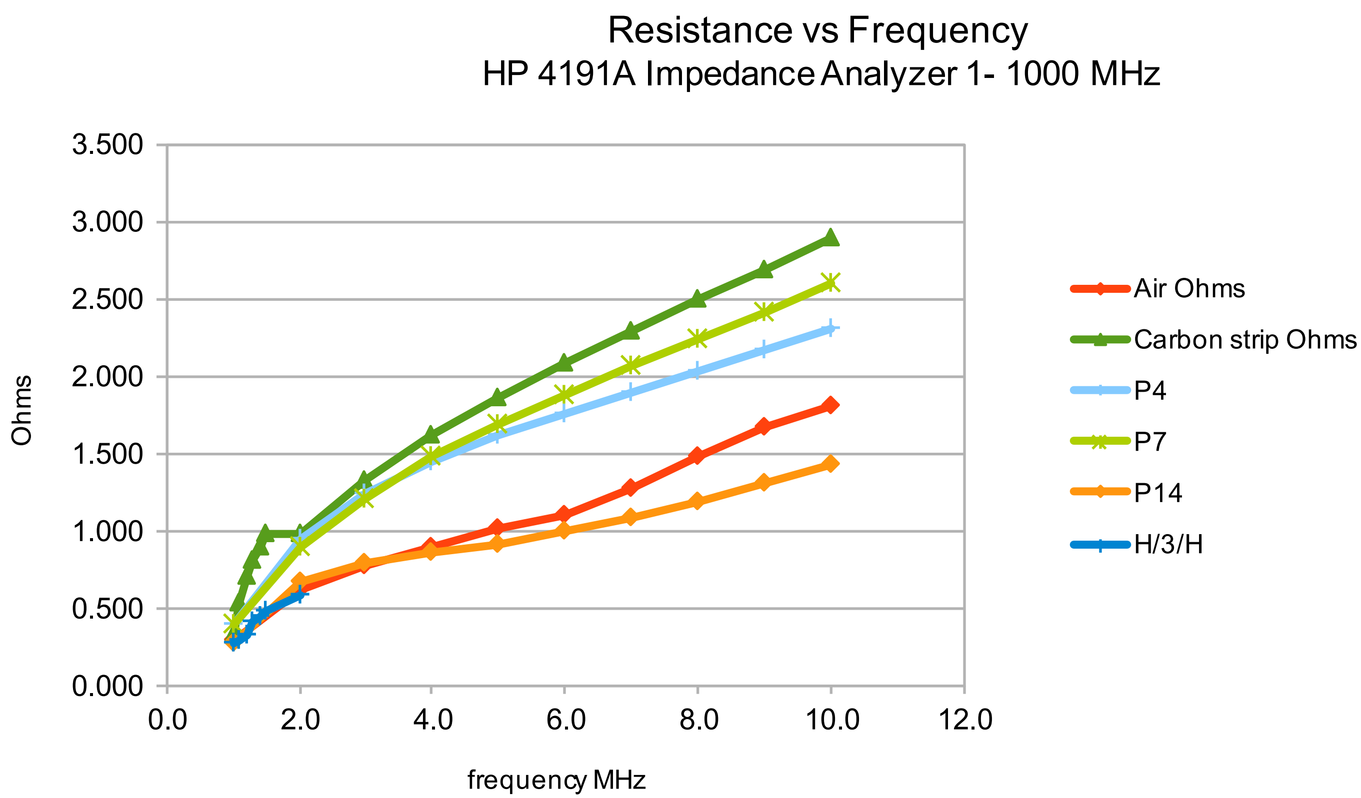






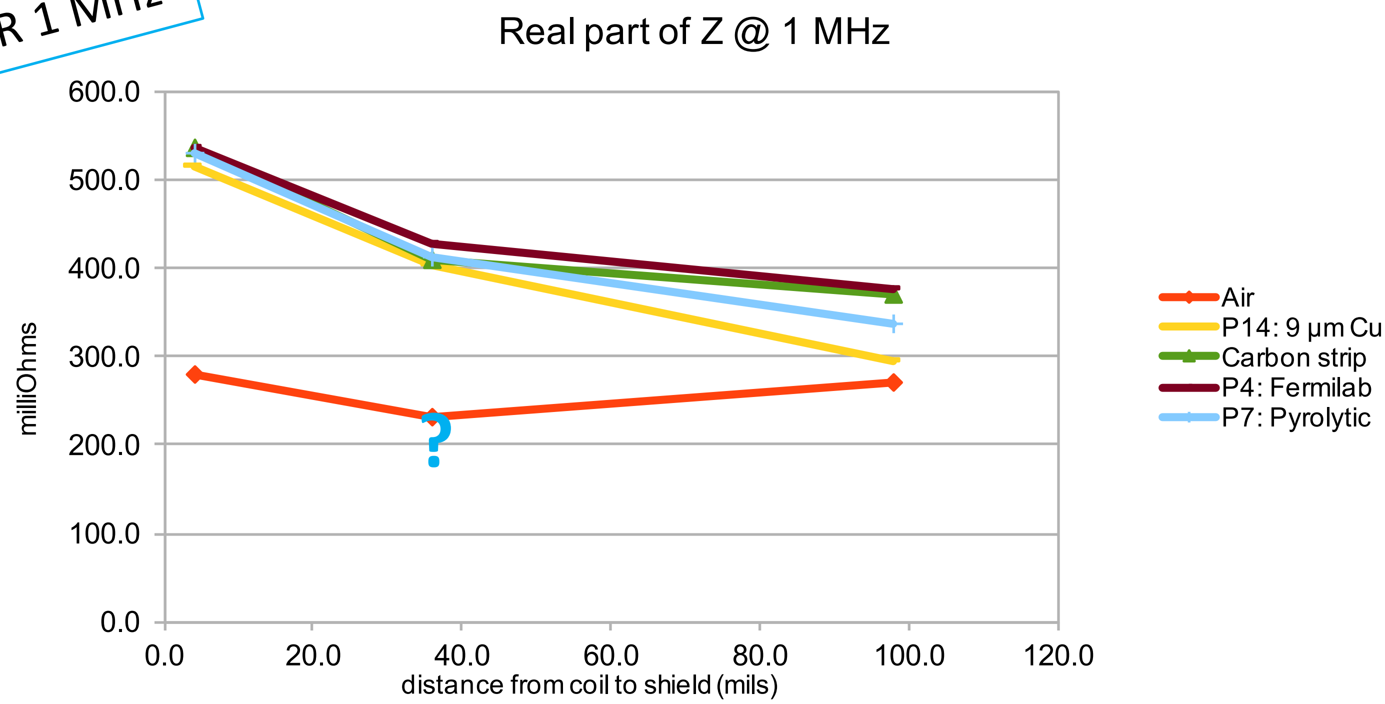


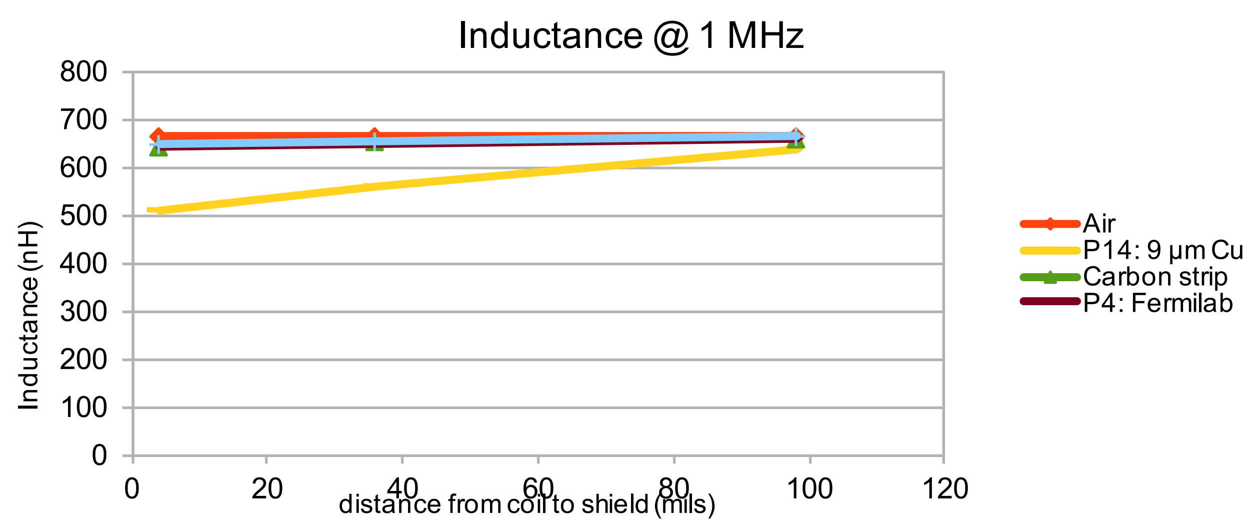
August 22, 2015



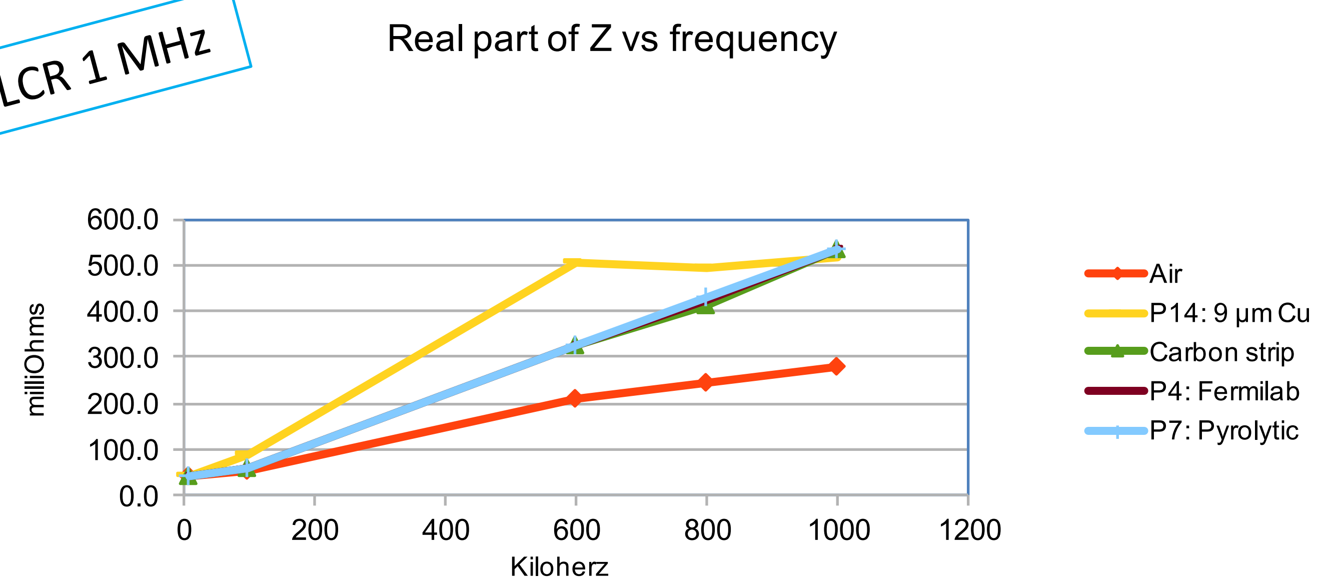
Coil Under Test
With SMA connector

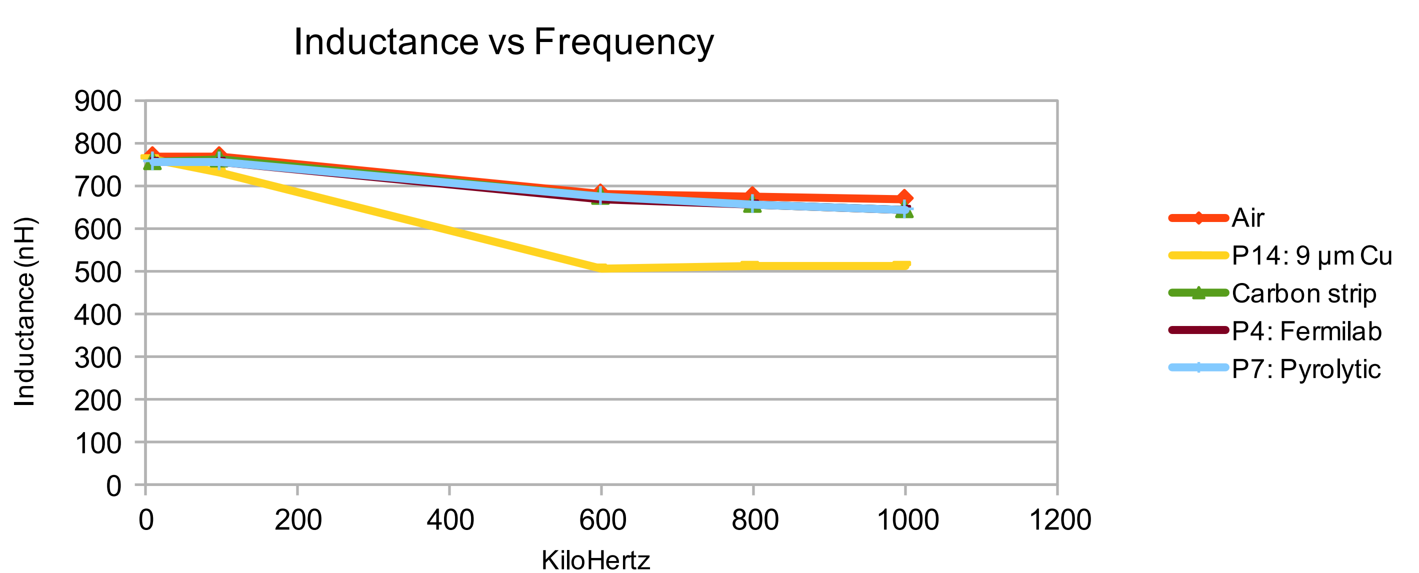
QuadTech LCR 1 MHz





QuadTech LCR 1 MHz

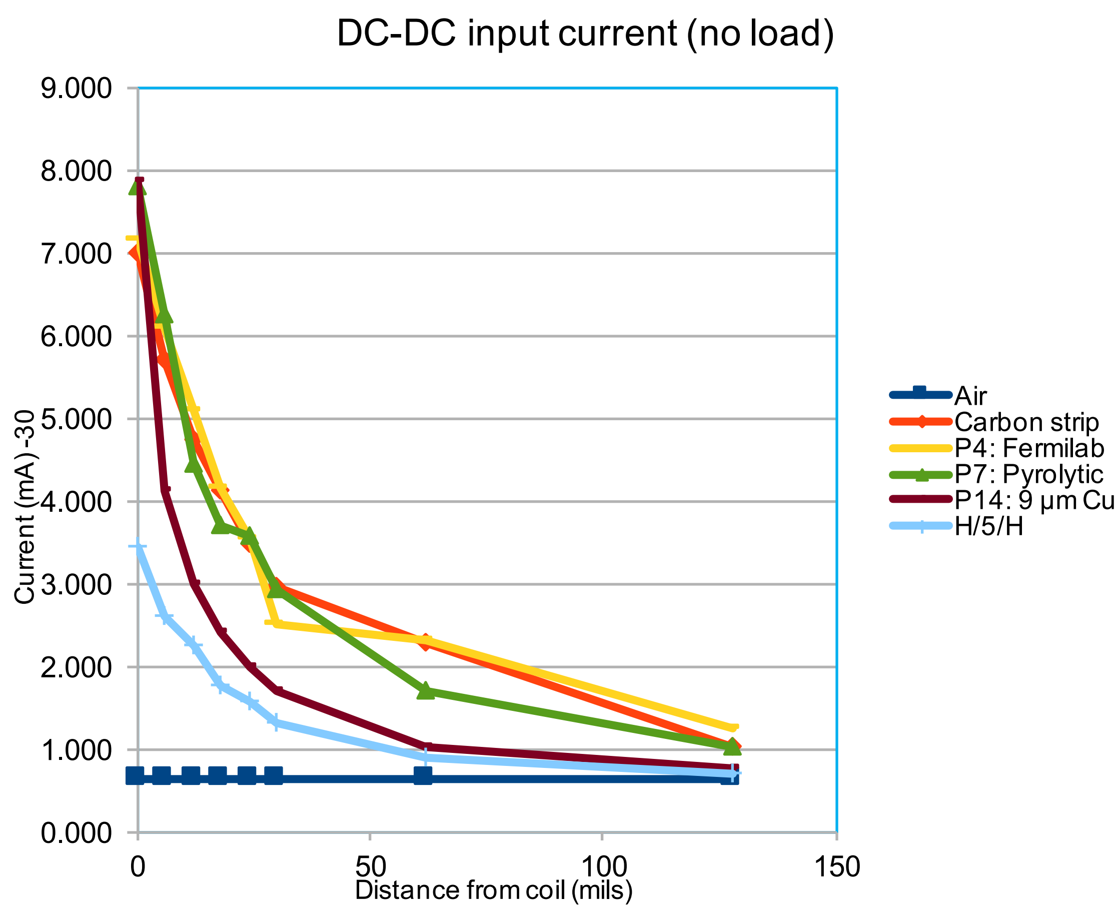


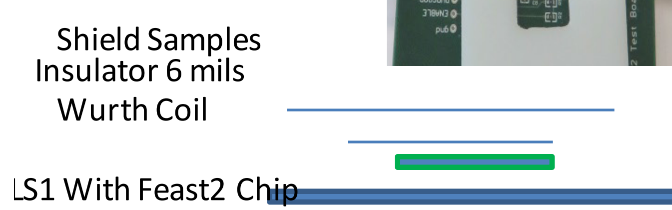


Yale Hand Held BK Precision LCR Meter Shows no effect Maximum Frequency 100 KHz

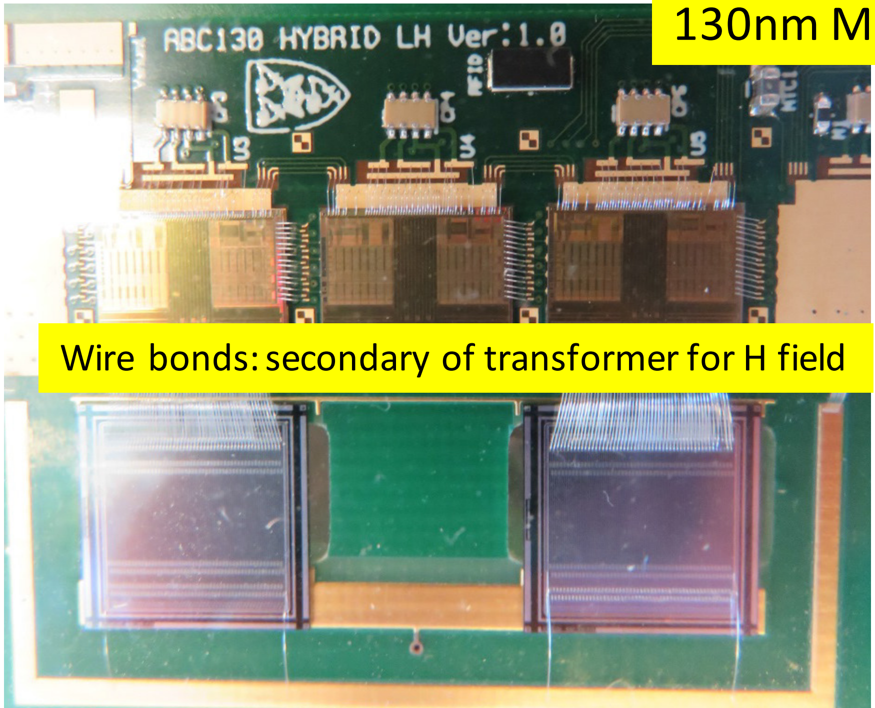
Measure DC Current drawn by Feast2 chip vs Shield material and distance/gap from top of coil

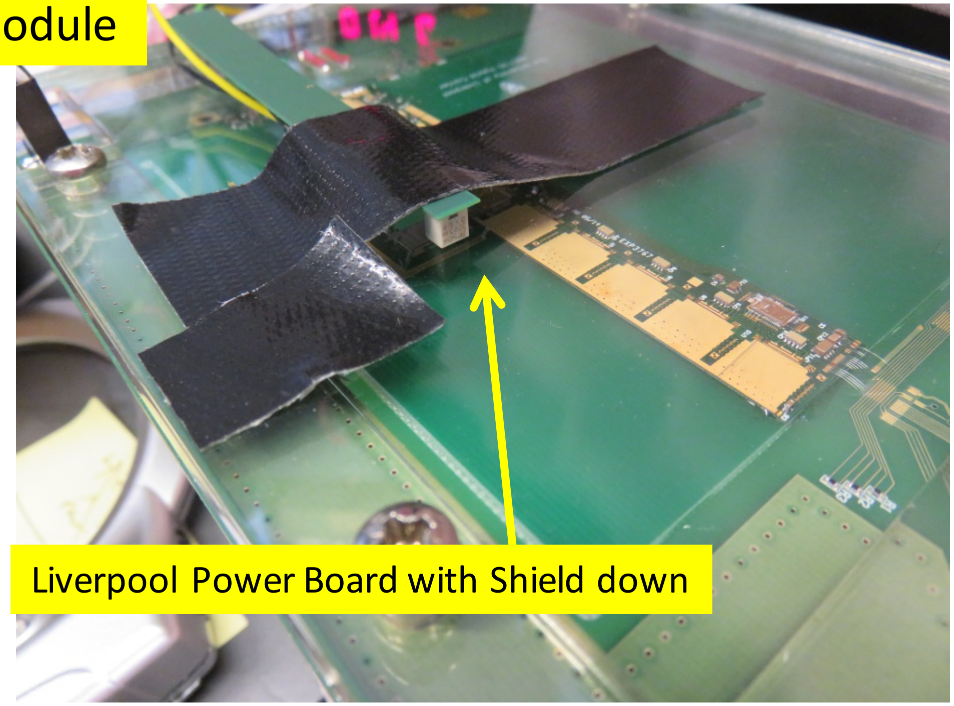
Wurth Coil Shield	Curremt mA	Spacers: Black Mylar = 6 mils each > total = ~30 mils					FR4 Spacers		
		1	2	3	4	5	32 mils	62 mils	2 x 62 mils
Air	30.650								
Carbon strip	37.010	35.72	34.75	34.12	33.49	32.96	33.53	32.29	31.04
P4: Fermilab	37.160	36.08	35.11	34.16	33.55	32.51	33.74	32.32	31.26
P7: Pyrolytic	37.810	36.25	34.46	33.7	33.58	32.93	33.37	31.7	31.02
P14: 9 µm Cu	37.860	34.12	33	32.41	32	31.72	31.93	31.04	30.78
H/5/H	33.440	32.62	32.26	31.78	31.58	31.32	31.54	30.9	30.72

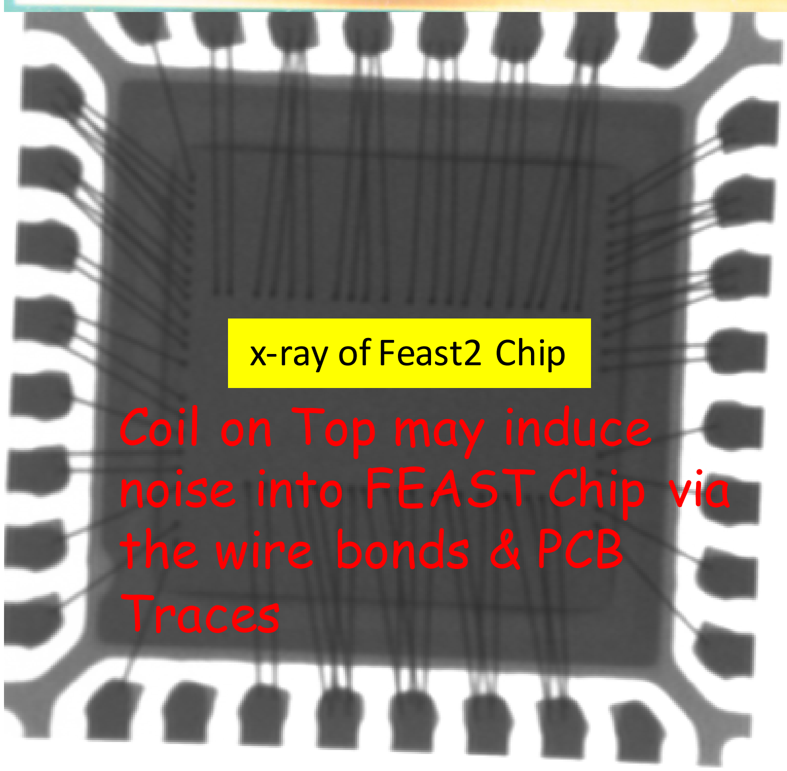


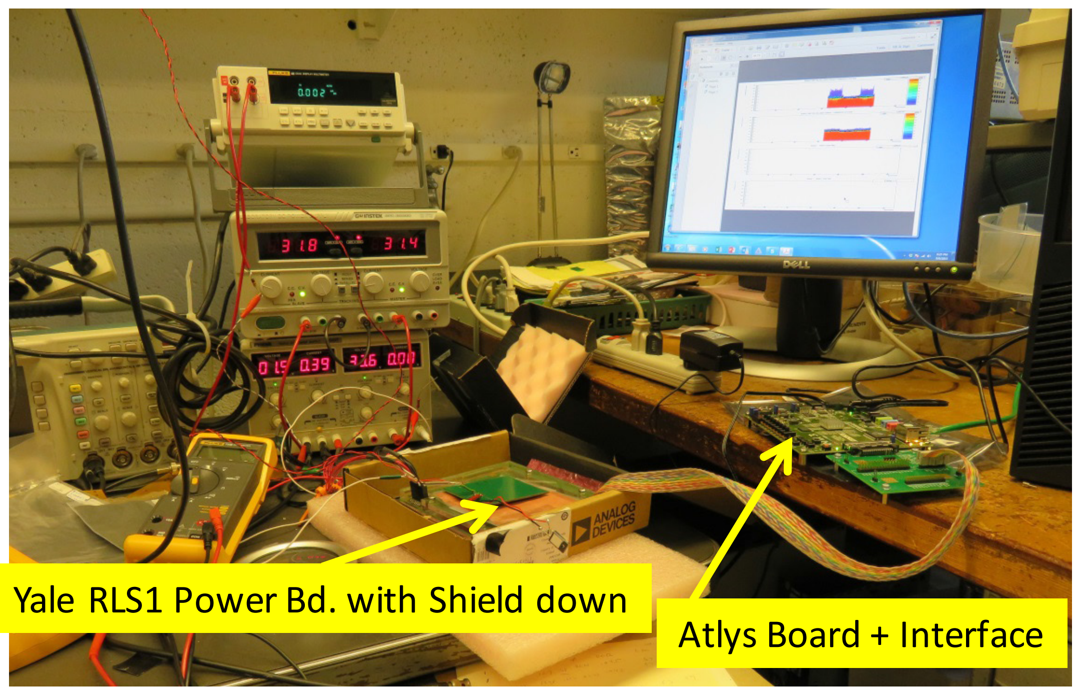


130nm Mini Module





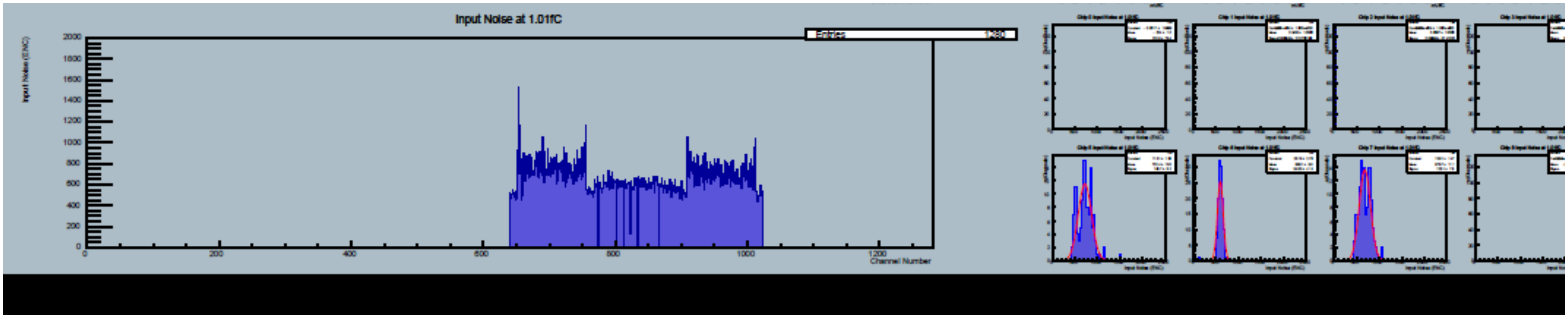




Seek Ashley & Peter's Help

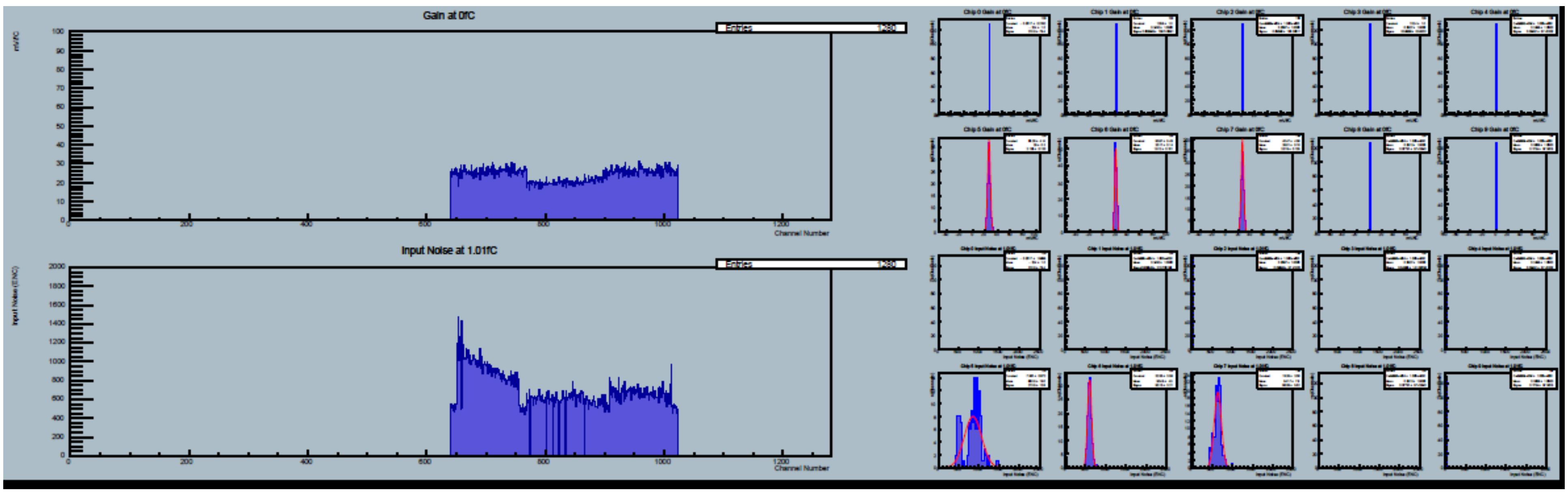
Yale Run 62 Test Results – August 07, 2015

RLS1 with P4(grounded) with 9 µm Cu Foil added & grounded



RLS1 with P4 (grounded)

Yale Run 61 Test Results – August 07, 2015



- With shielding we replicate noise numbers as quoted by Ashley
- Slope should be the other way around
- Understand pickup sensitivity of the sensors

Further Work
Investigate / Goals
Shield with Carbon+Copper
(Carbon closer to Inductor)

Acknowledgements

Adrian Au
Savannah Thais

DR. Eric Paulson
Prof. Keith Baker
Prof. Steven Lamoreaux

THE END

Questions Please?

Back up Slides

Seminar 9: Wireless charging of EV
Chris Mi . U of Michigan

http://www-personal.engin.umd.umich.edu/~chrismi/

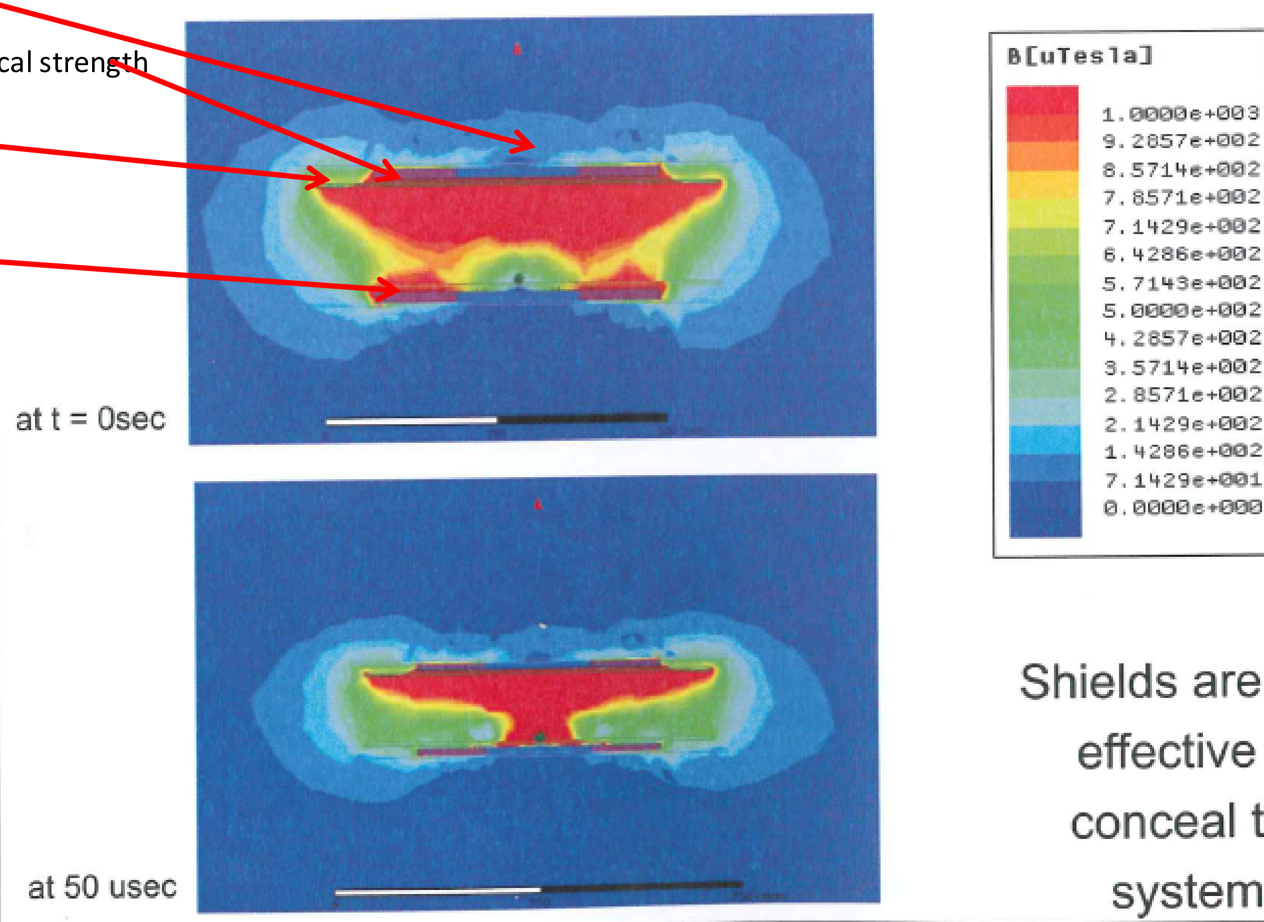
Effect of the shield in the systems

Car Metal

Al Plate 600 mm x 800mm 1 mm thick for mechanical strength

Coil - Top

Coil - Bottom



Shields are very effective to conceal the system.

Frequency = 85 KHz
Power transmitted = 10KW
Inefficiency without Al shield = 20 %
Inefficiency with Al shield = 1 %
Power loss in Car metal without Al shield = 2 KW > 15C rise in temperature
Power loss in Al shield = 0.1 KW

Yale University
March 21, 2014