EMMA PROJECT STATUS

Neil Bliss, STFC Technology, Daresbury Laboratory

FFAG09 International Workshop Fermilab

21st September 2009

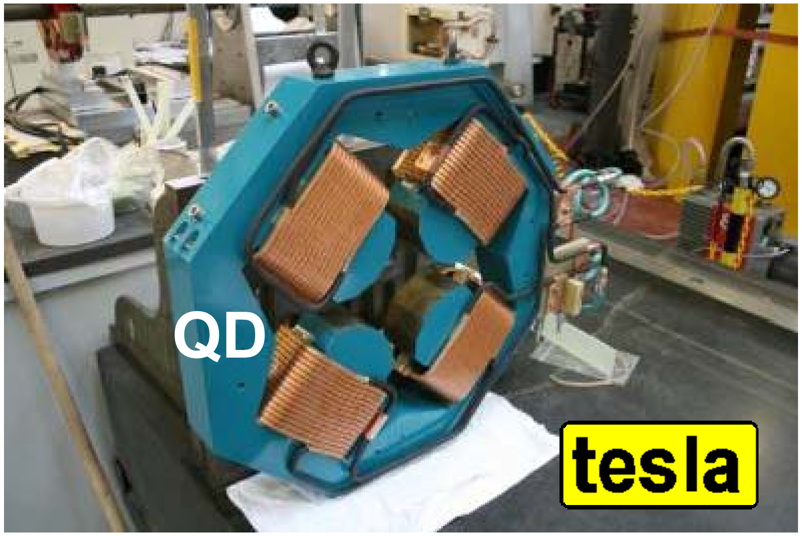
Content

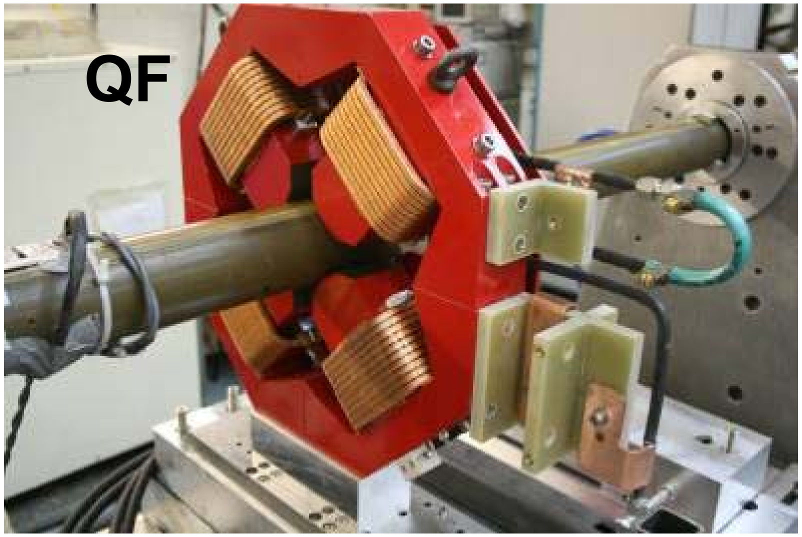
- Technology developments, status and testing
  - Magnets
  - Diagnostics
  - Radio Frequency
- Off line assembly
- Installation in ALICE
- Summary - Schedule Update

MAGNETS

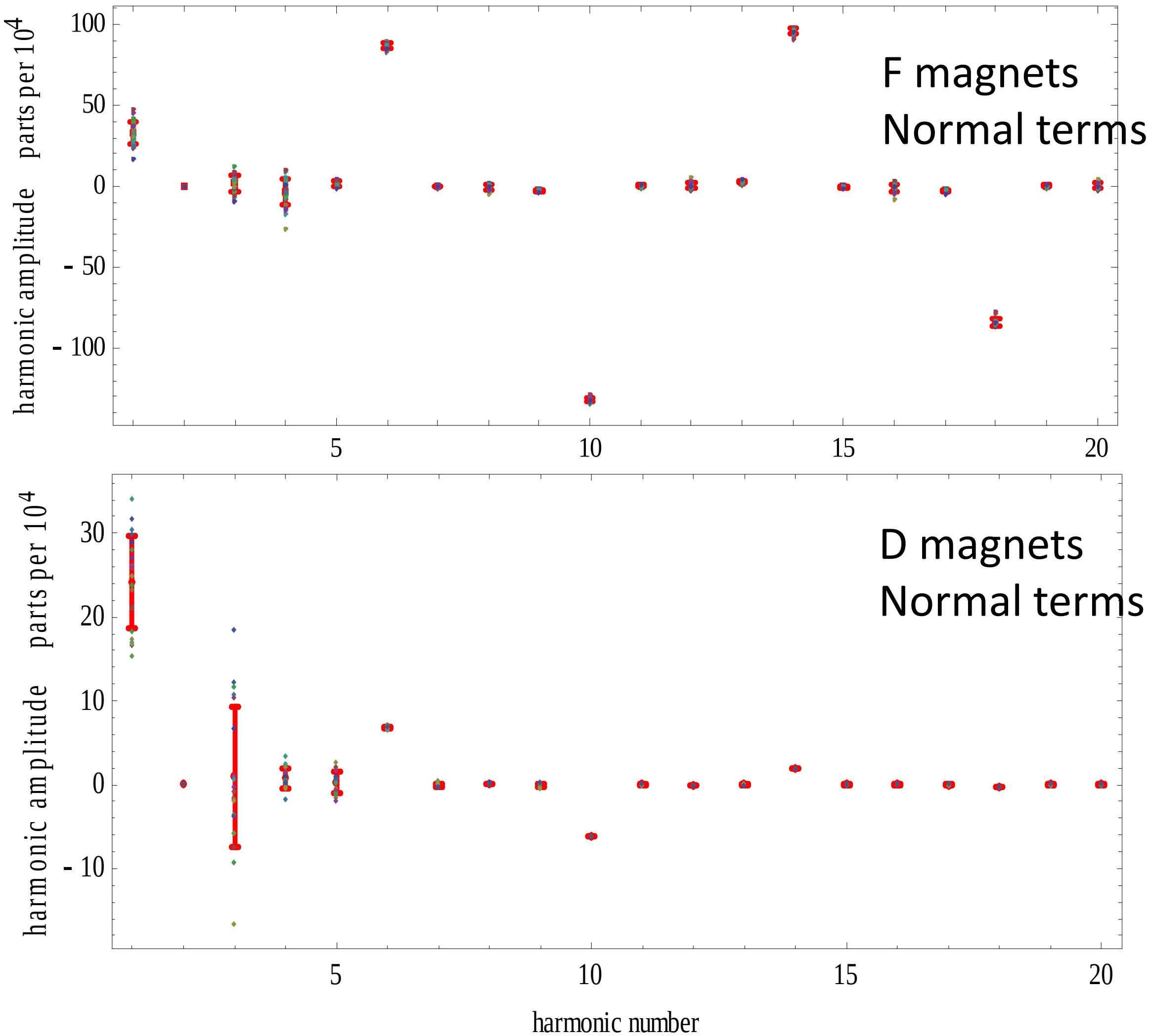
Production Quadrupoles

- Magnet construction & measurement s are complete for all 42 D-type and 42 F-type quadrupoles
- Assembly on to girder modules in progress at Daresbury





Measured Harmonics – F & D magnets



Graphs showing spread of harmonics – i.e. variation across magnet family

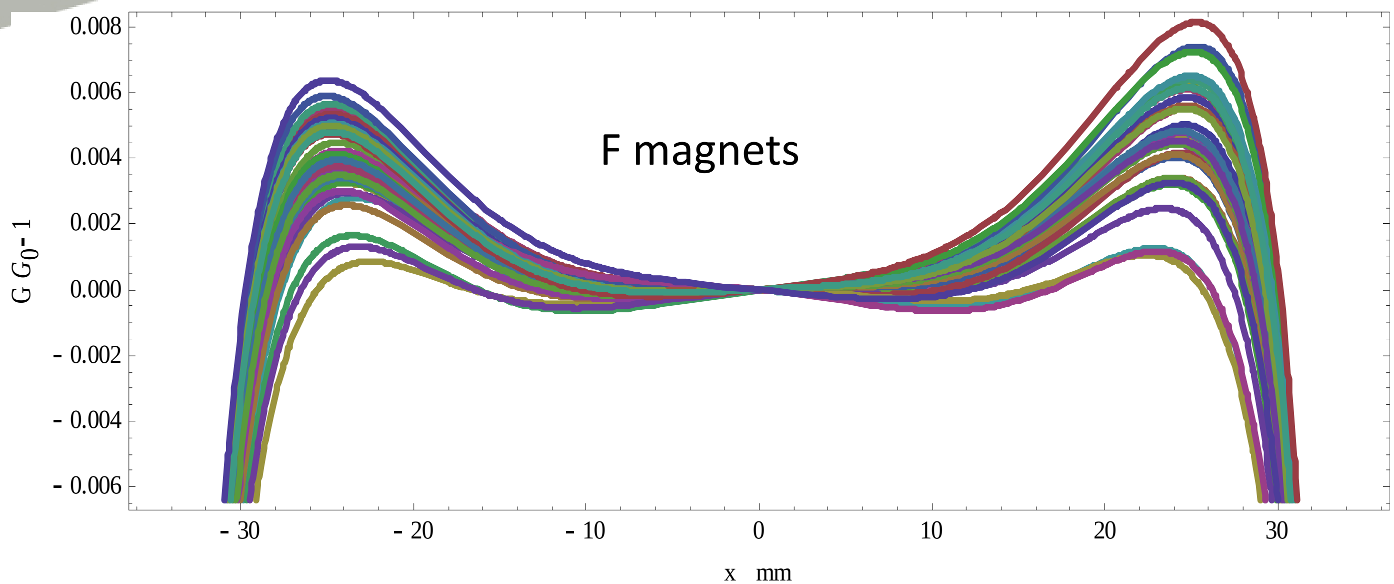
D magnets seem to show a lot of **variation, especially in the n=3 (sextupole)** component

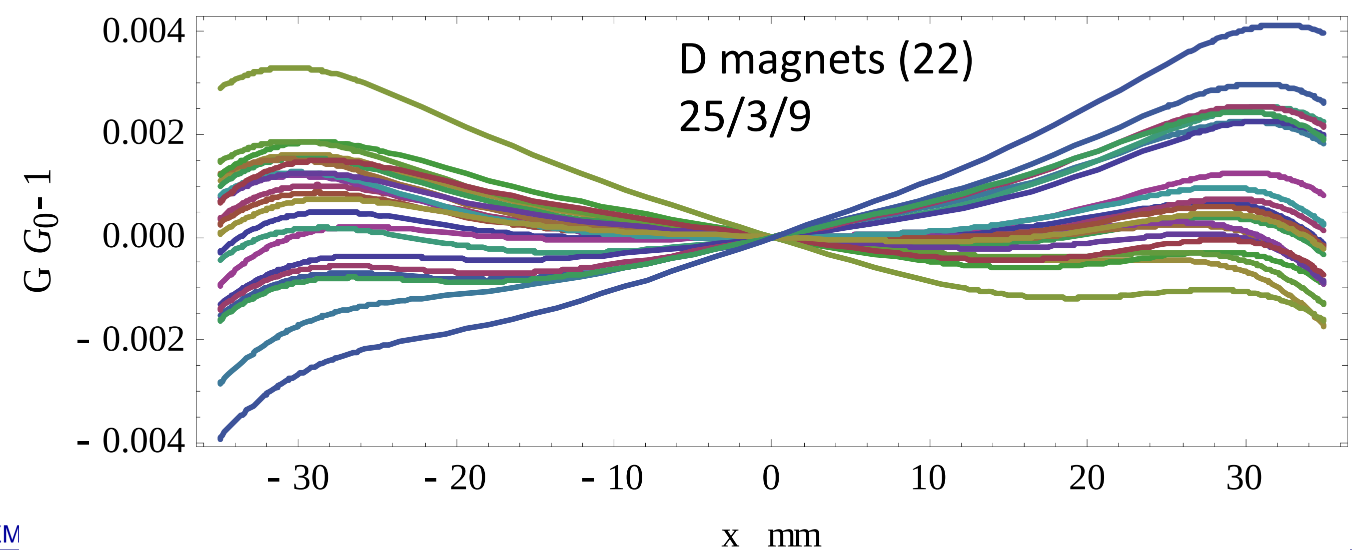
Cause unknown

Acc. Phy. group currently looking into effect of this on beam dynamics

Ben Shepherd

Field quality plots





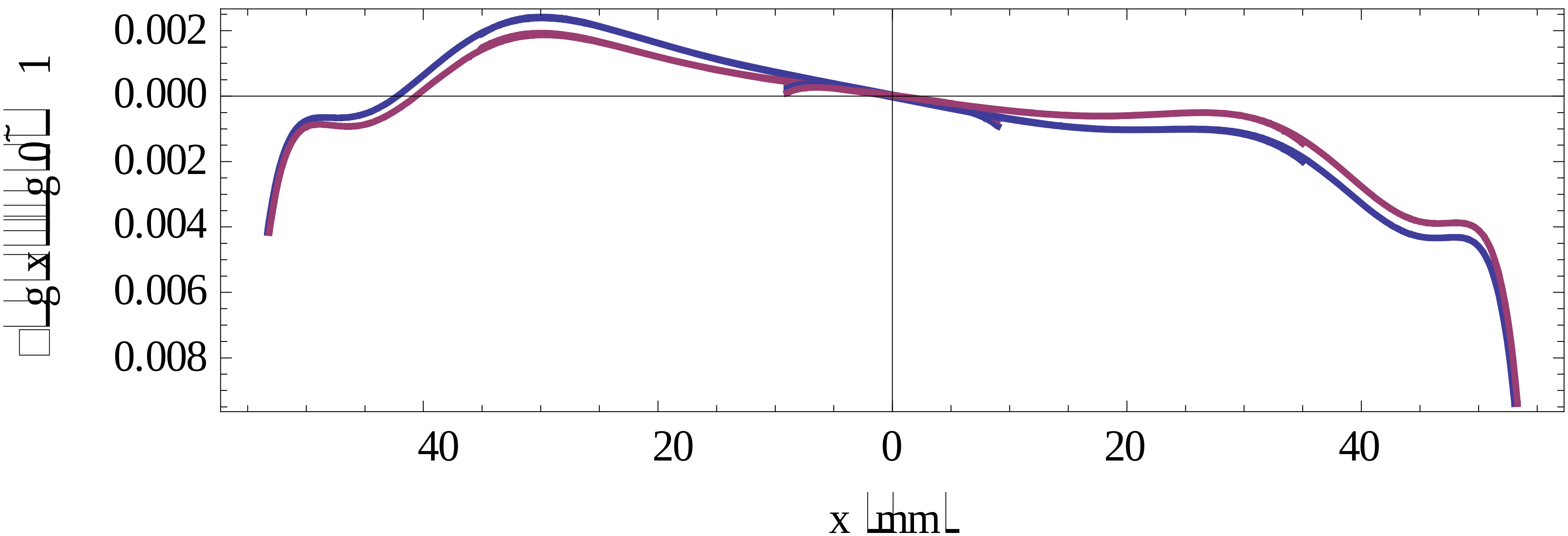
Integrated gradient quality shown

F magnets all within **0.8%** for a good field region of **±32mm**

D magnets within 0.3% inside rotating coil radius – but good field region is much larger

Ben Shepherd

Measurements with positive and negative offsets



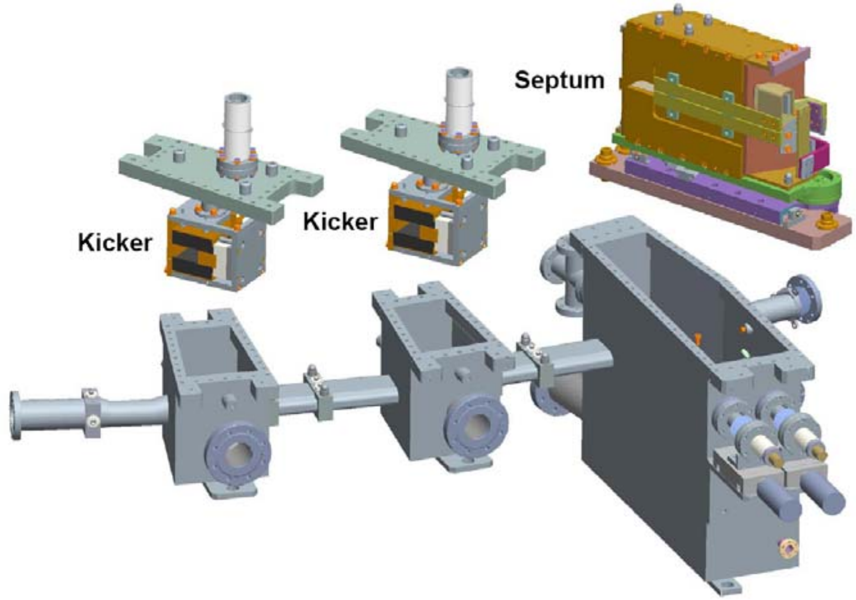
Measurements of two D magnets were taken with the coil offset by +20mm, and again by -20mm to show how the gradient varied across the entire aperture of the magnet.

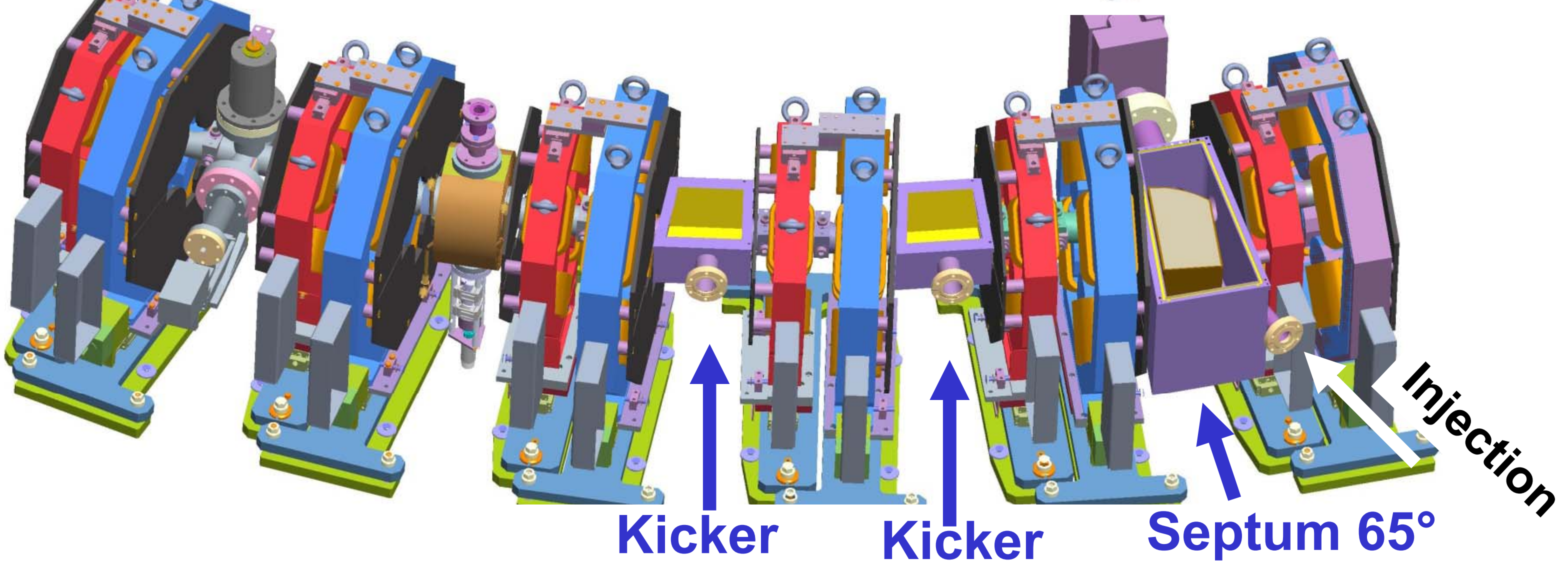
Data sent 5 May for D #29 and #35

Ben Shepherd

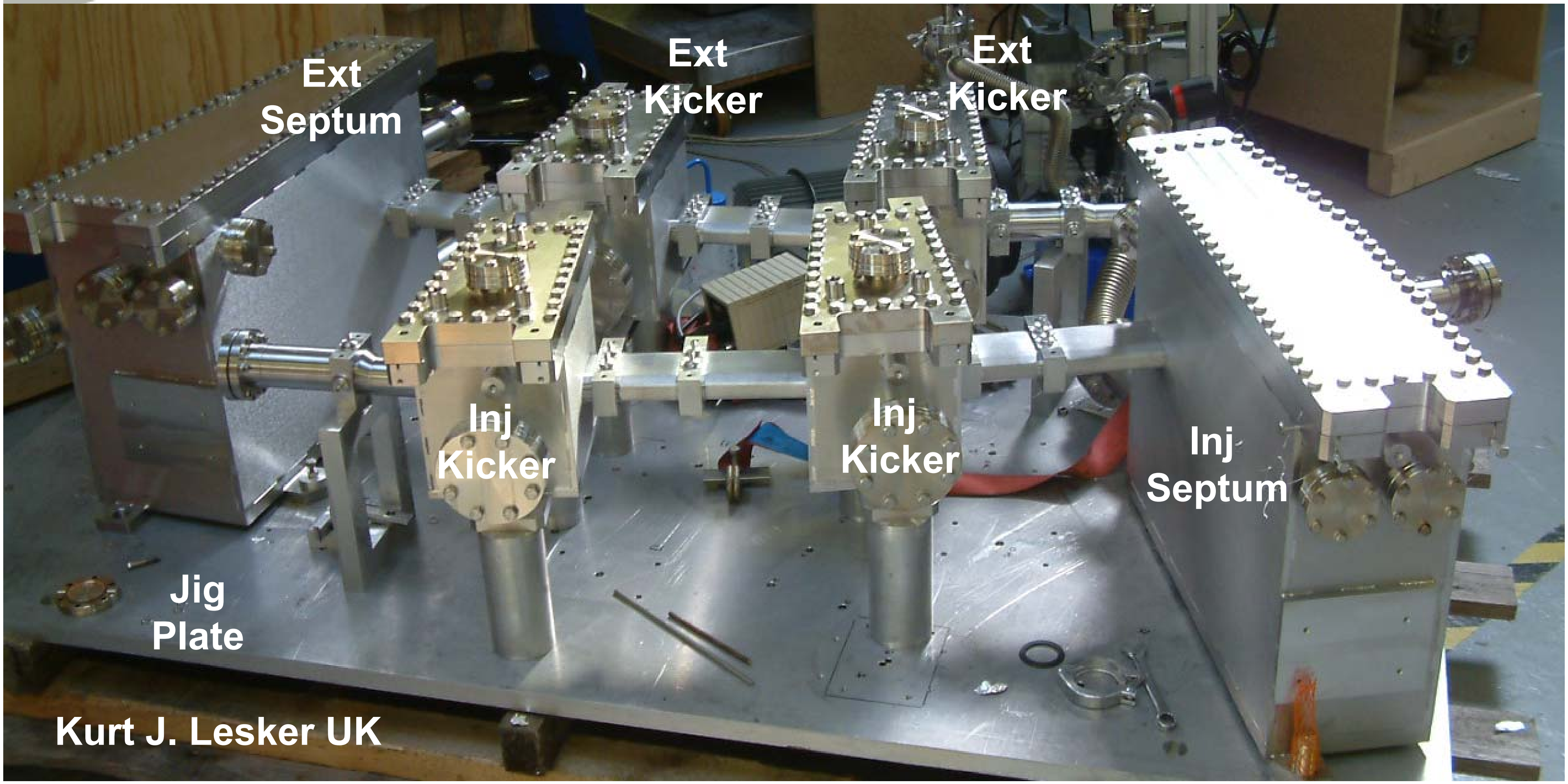
Field quality (for these two) is within **0.8%** inside the good field region (**56mm**)

Injection Region





Pulsed Magnet Vacuum Chambers



- Chambers manufactured and cleaned, ready for vacuum bake.
- Delivery end of September

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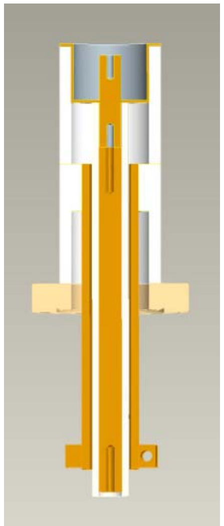
Kicker Parameters

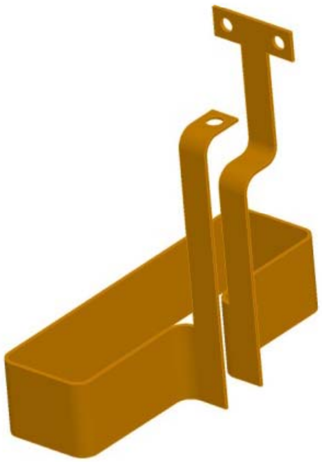
Max. beam deflection	105 mR
Hor. good field region	46 mm
Min vertical gap	25 mm
Hor. deflection quality	± 1 %
Min. flat top (+0 -1%)	≥5 nS
Field rise/fall time	**< 50 nS**
Repetition rate	20 Hz
Physical length available	100 mm
Field strength	0.007 Tm
Peak voltage	30 kV
Peak current	1.3kA

Kicker

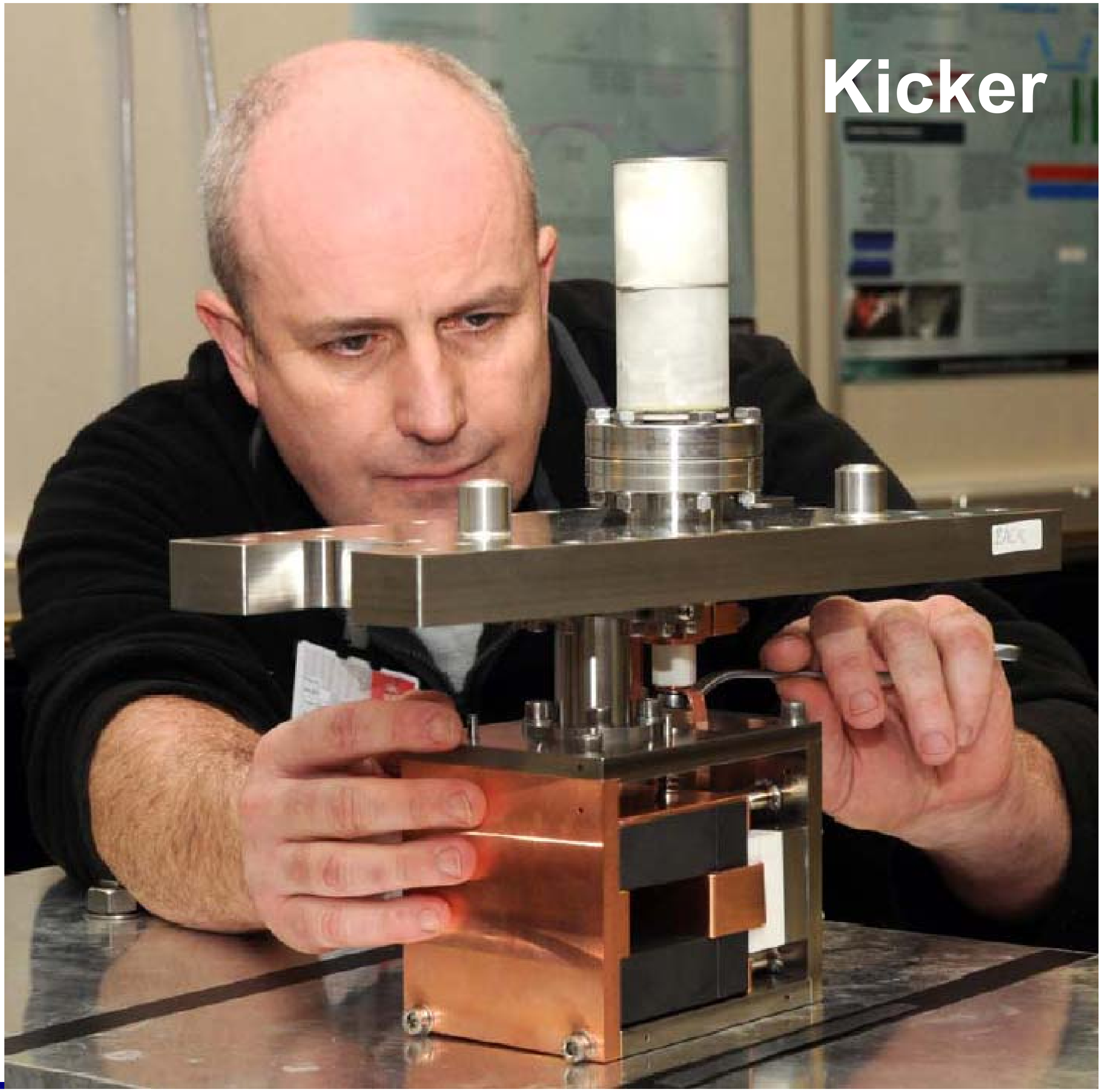
- Single turn conductor
- Coaxial feedthrough
- C shape ferrite construction
- Ceramic Magnetics CMD5005
- Air bake at 600ºC
- Designed to test at 30kV in air
- Spring loaded box assembly



Feedthrough



Conductor



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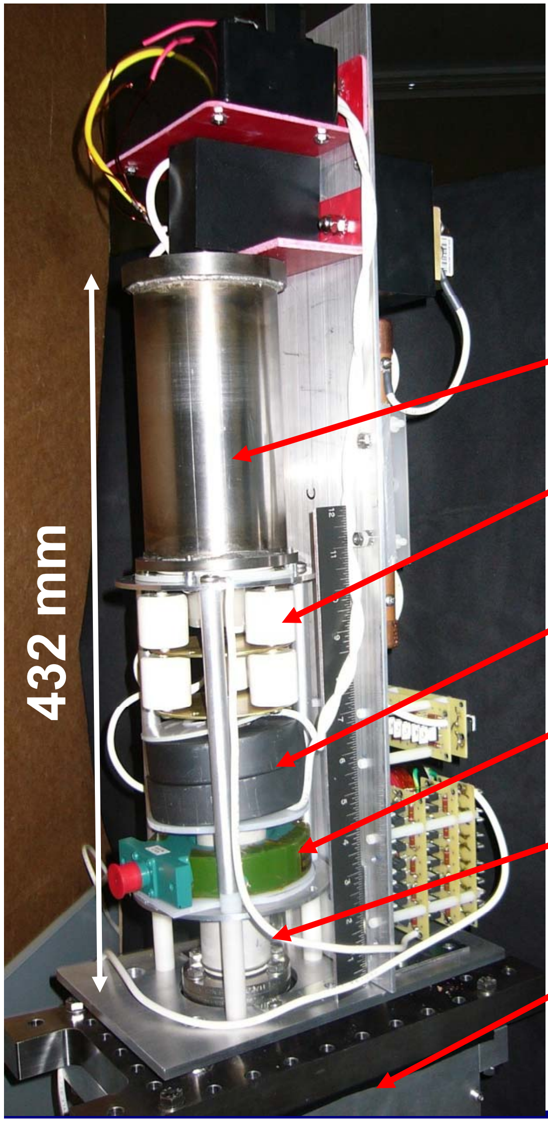
Prototype Kicker power supply

Thyristor units using magnetic switching and Pulse Forming Network techniques

Applied Pulse Power Inc.



Magnetic switch

Pulse forming network (PFN)

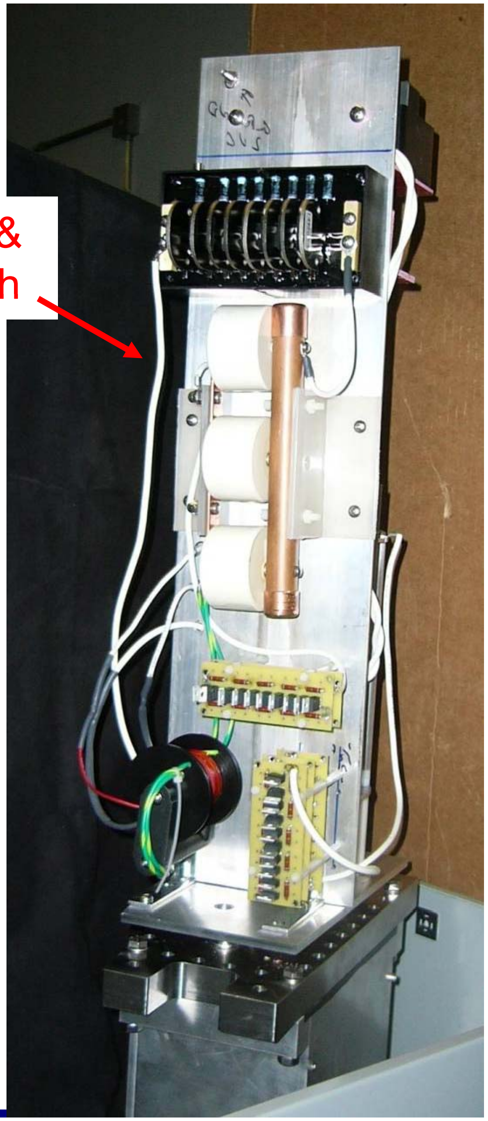
Ferrite rings

Current monitor

Coaxial feedthrough

Kicker magnet

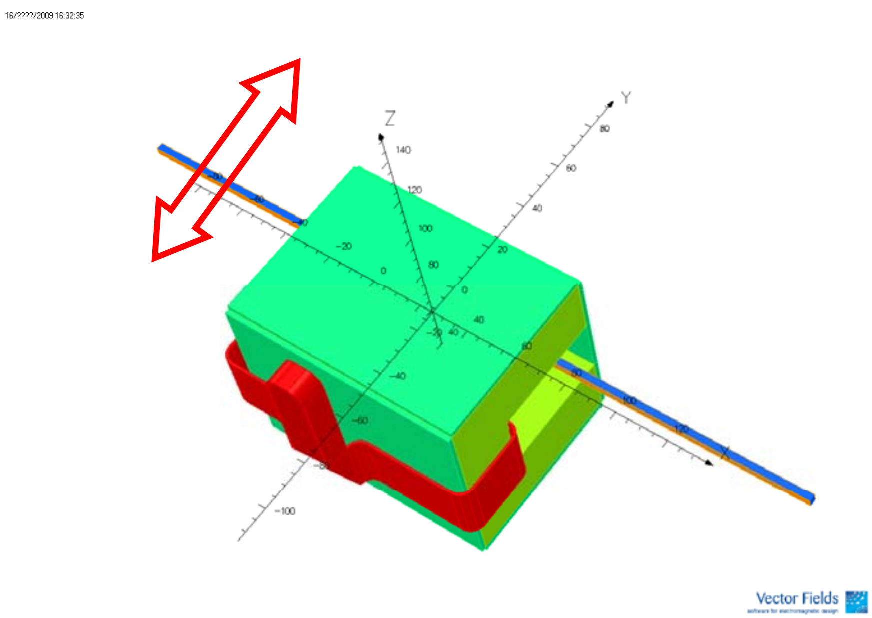
Charging Circuit & Solid State Switch

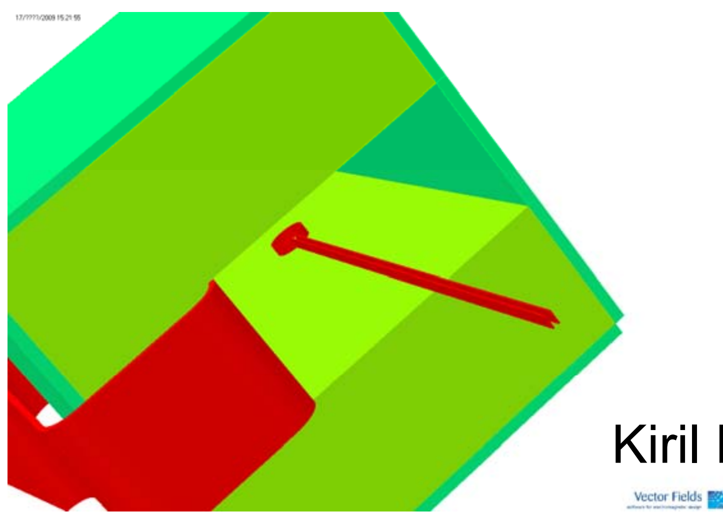


Outer enclosure removed for clarity

Kicker Measurement Method

- Rectangular coil, 300 mm long, 3mm thick; metallic layer (100 μm) on the appropriate sides
- Gives the integrated field strength
- Coil positioning with the Hall-probe bench
- Plans to make a detailed field map with a 6 mm diameter small coil didn’t quite work out: stray capacitance in the coil creates a resonance

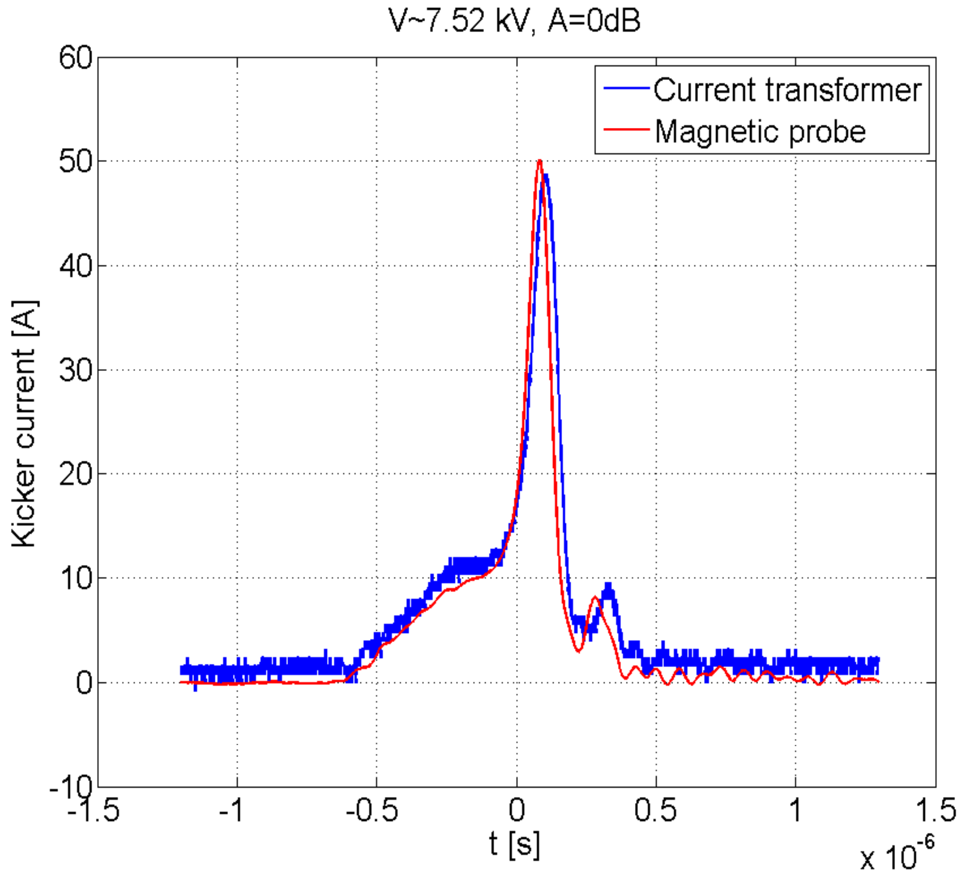




Kiril Marinov

Kicker: calibration

$$I(t) = \frac{h}{\mu_0 l_{eff} d} \int V dt.$$



The current can be measured independently with a CT installed on the kicker PSU and thus l_{eff} can be obtained.

l_{eff} =130 mm.

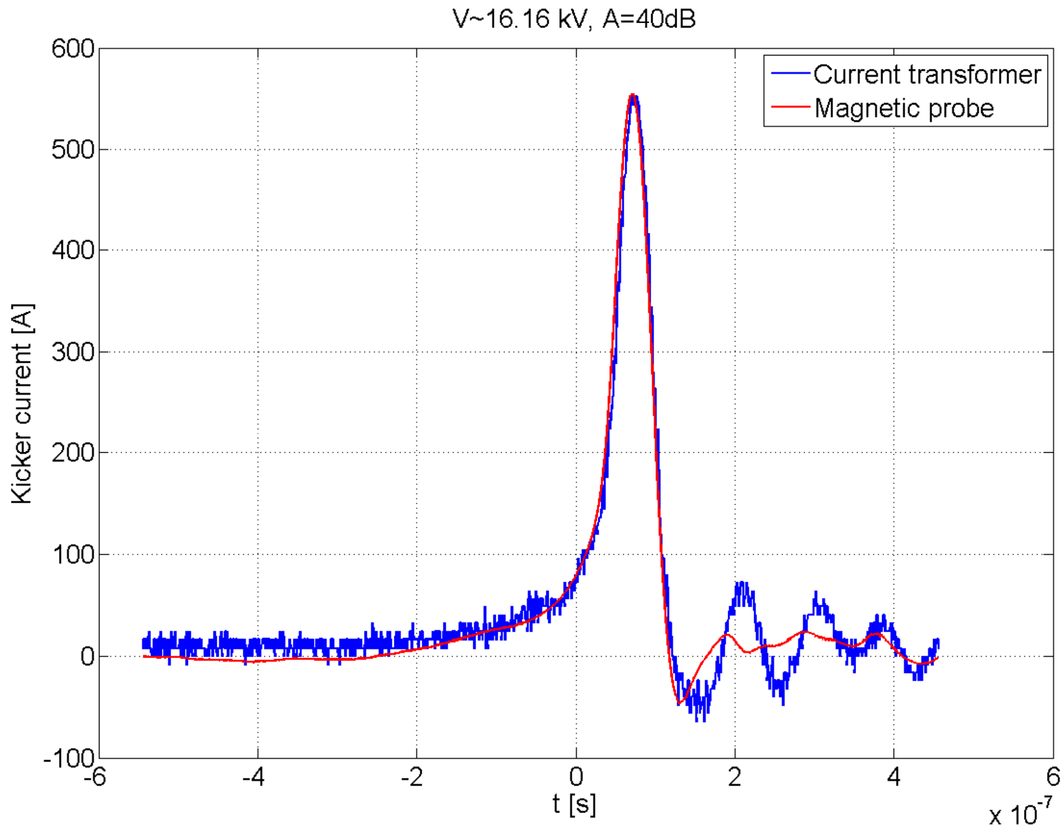
ELEKTRA simulations give the **same** value.

At full kicker strength the long coil generates voltages of the order of 1kV.

Attenuators are necessary

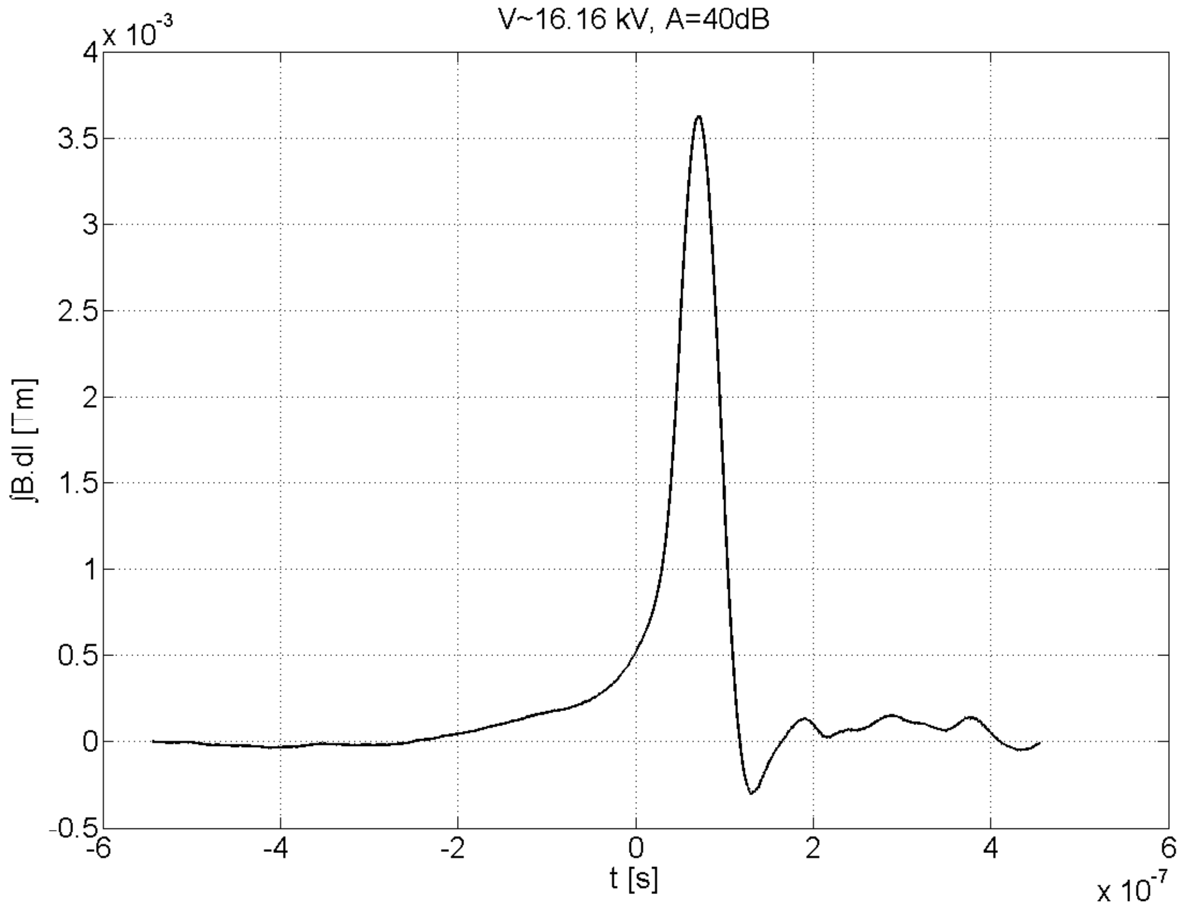
Repeated the measurements using attenuators & determined the attenuation coefficient

Kicker @ ½ of the max. specified kicker strength



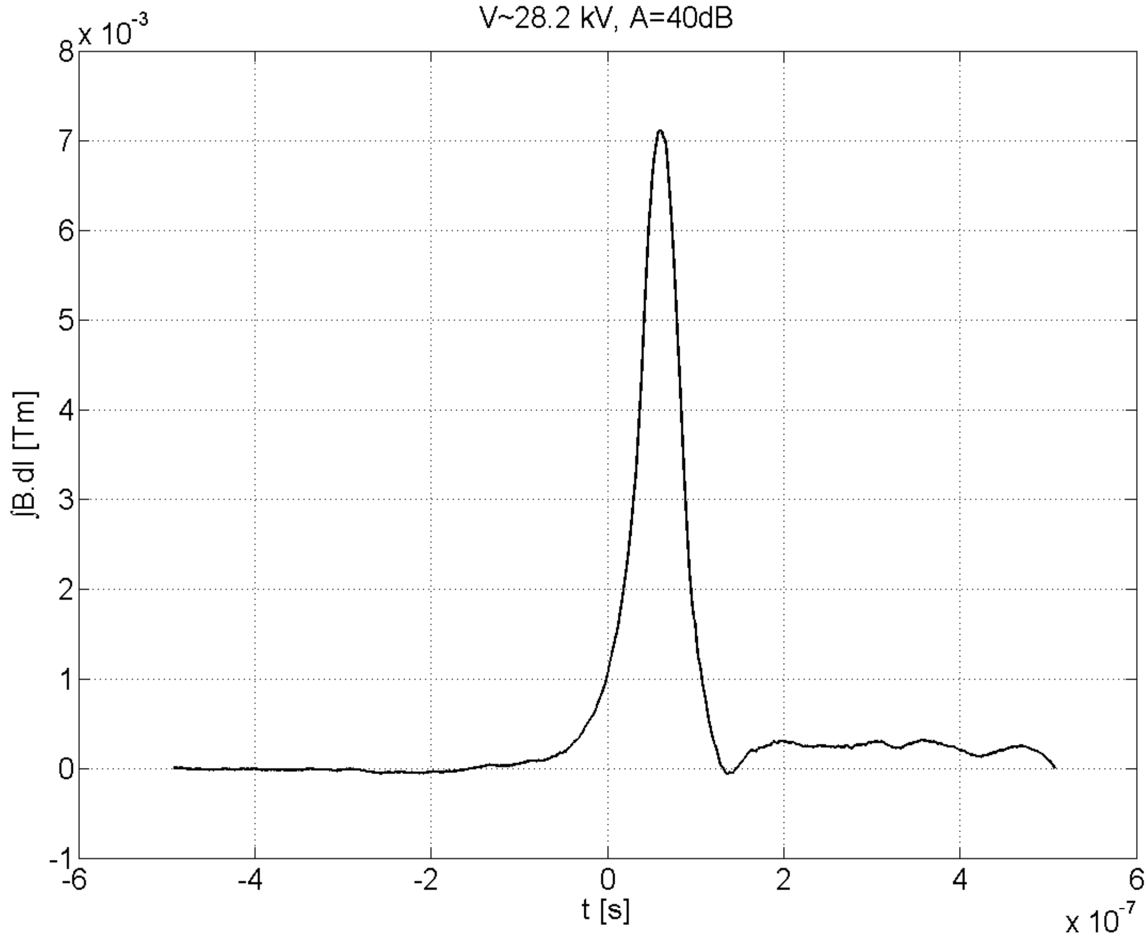
Ringing in the pulse tail is not as bad as the CT signal suggests!

Kicker: ½ of the max. specified kicker strength



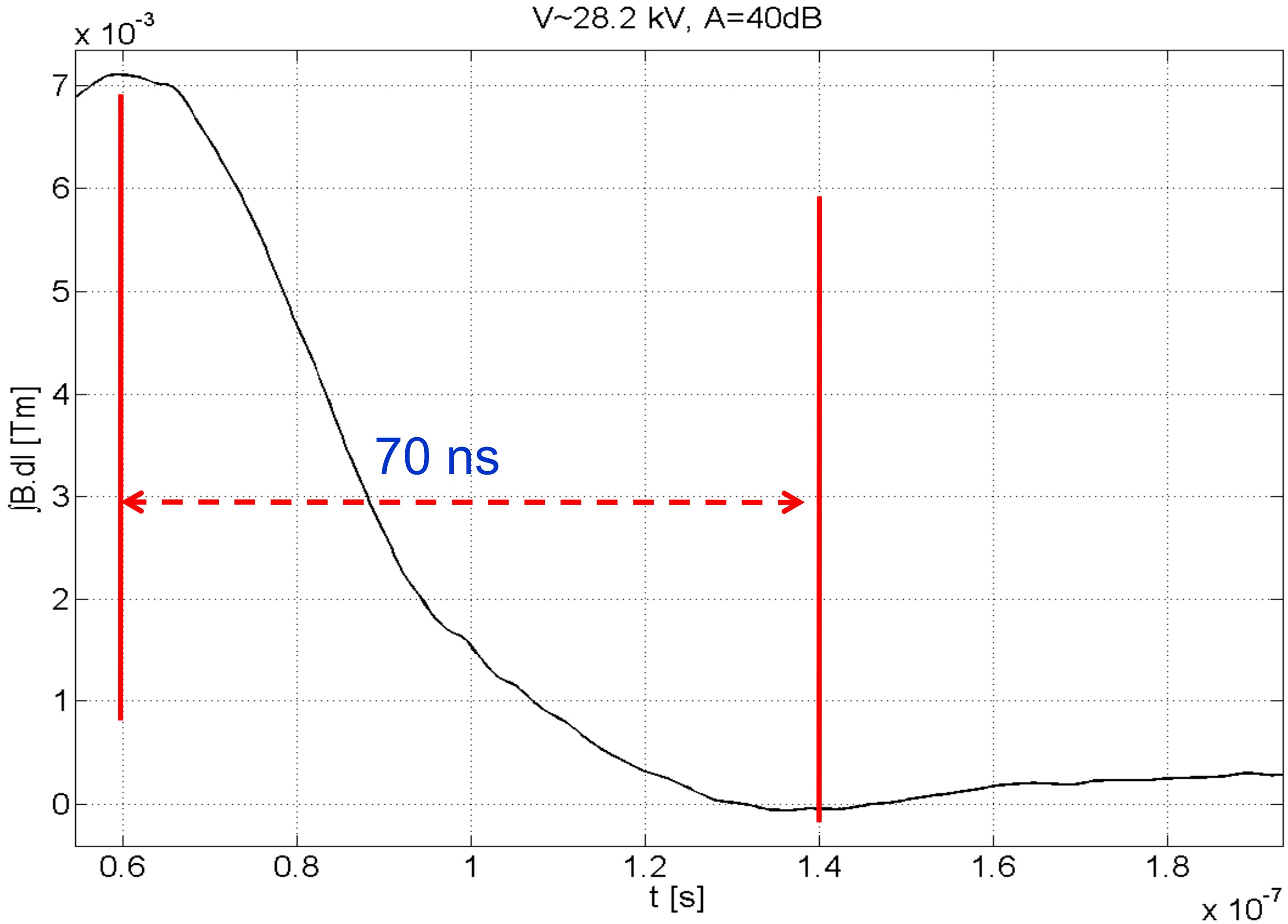
Magnetic field pulse. Integration suppresses the high-frequency noise.

Kicker: Full strength



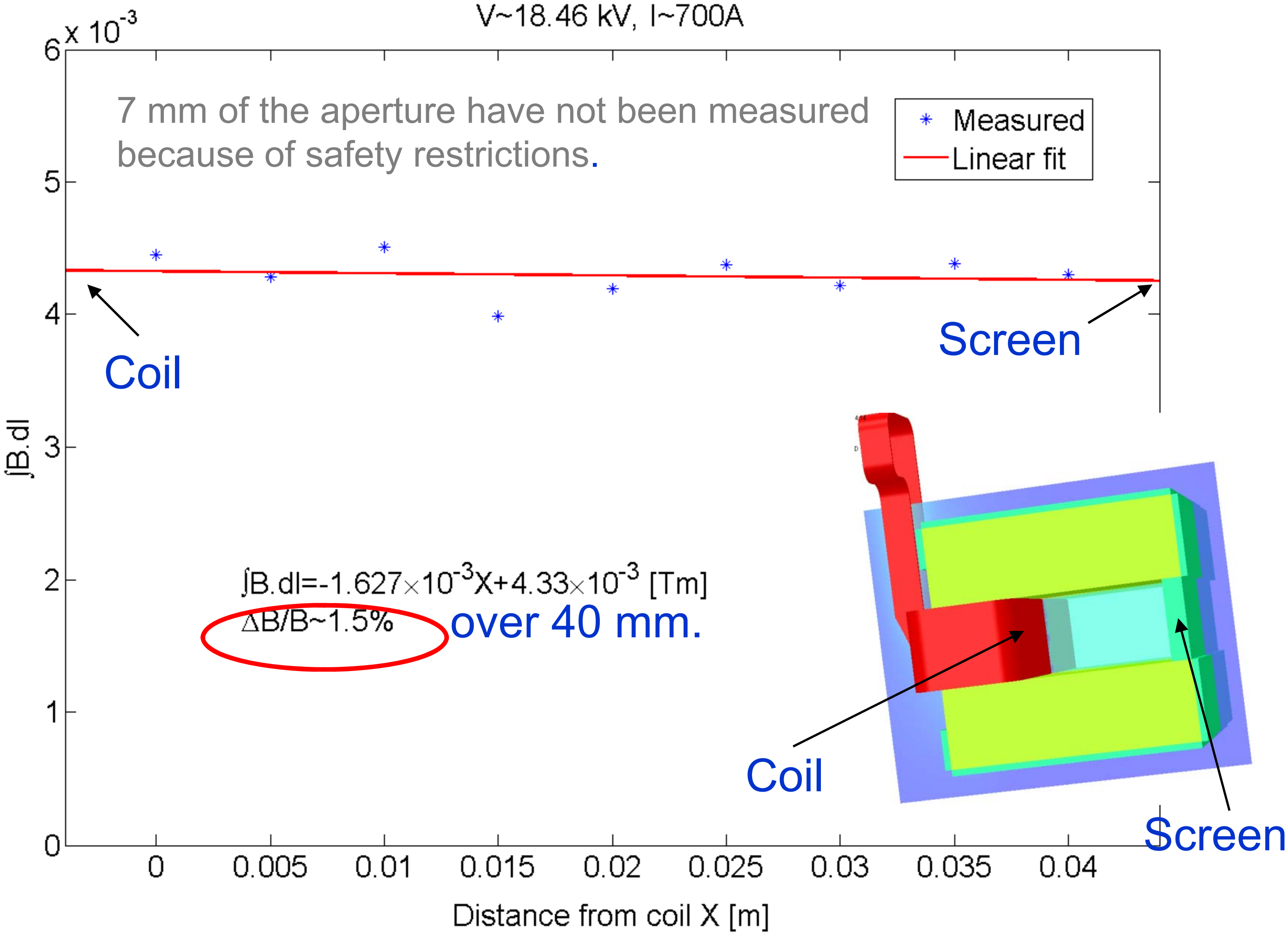
0.007 Tm reached at about 28 kV

Kicker: Full strength



Fall-time is longer than what is needed.

Kicker: Field homogenity



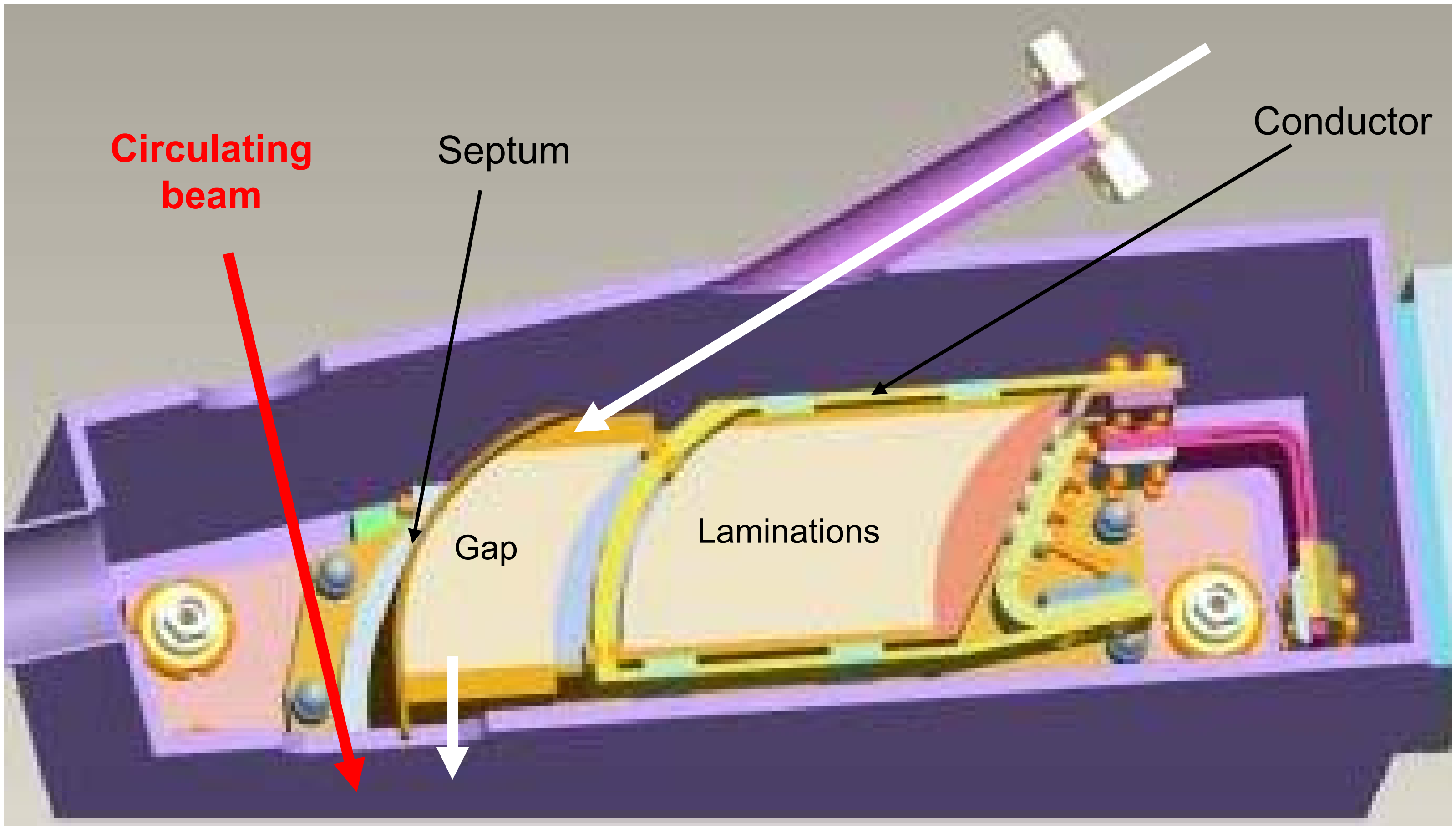
Kicker Measurement Summary

- Full kicker strength 0.007 Tm reached at 28 kV.
- Ringing in the pulse tail does not seem to be as bad as the CT signal suggests.
- Work to do to optimise pulse fall-time to less than 50 ns

Septum Parameters

Max. beam deflection (injection)	65°
Max. beam deflection (extraction)	70°
Max. flux density in the gap	0.83 T
Excitation pulse (half-sine-wave)	25 µS
Peak excitation voltage	2 kV
Peak excitation current	9 kA
Repetition rate	20 Hz

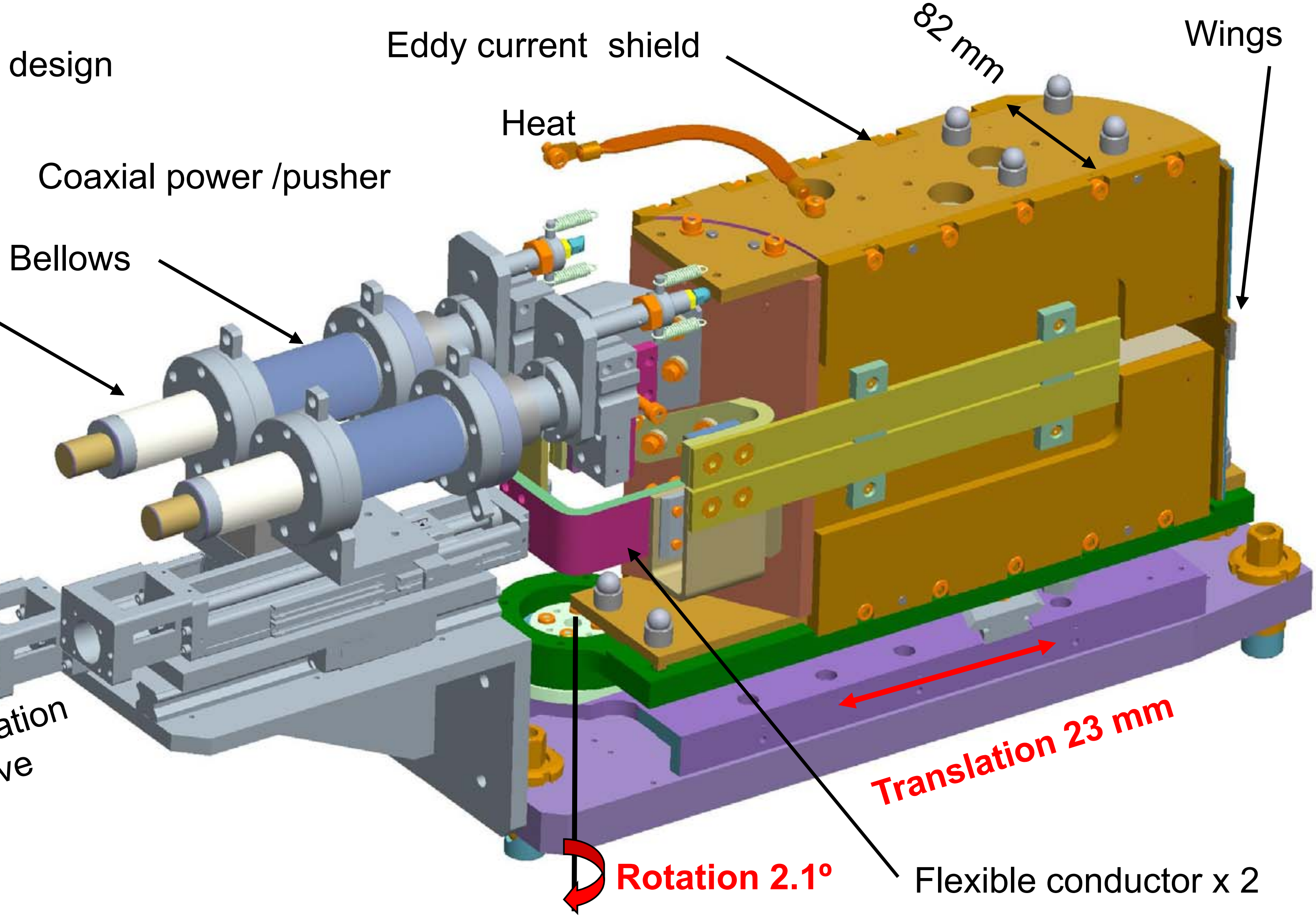
Injection Septum Design



Horizontal plane section view of septum in vacuum chamber

Extraction Septum Design

Passive septum design
2 turns



Septum laminations

0.1 mm Silicon Steel laminations with 0.7µm insulation
Pole profile wire eroded to 20µm
760 x 2 laminations required for the 2 septums
Clean & bake @ 250ºC for 24 hours in the fixture shown
7 bakes required
Injection septum is ready for clean assembly

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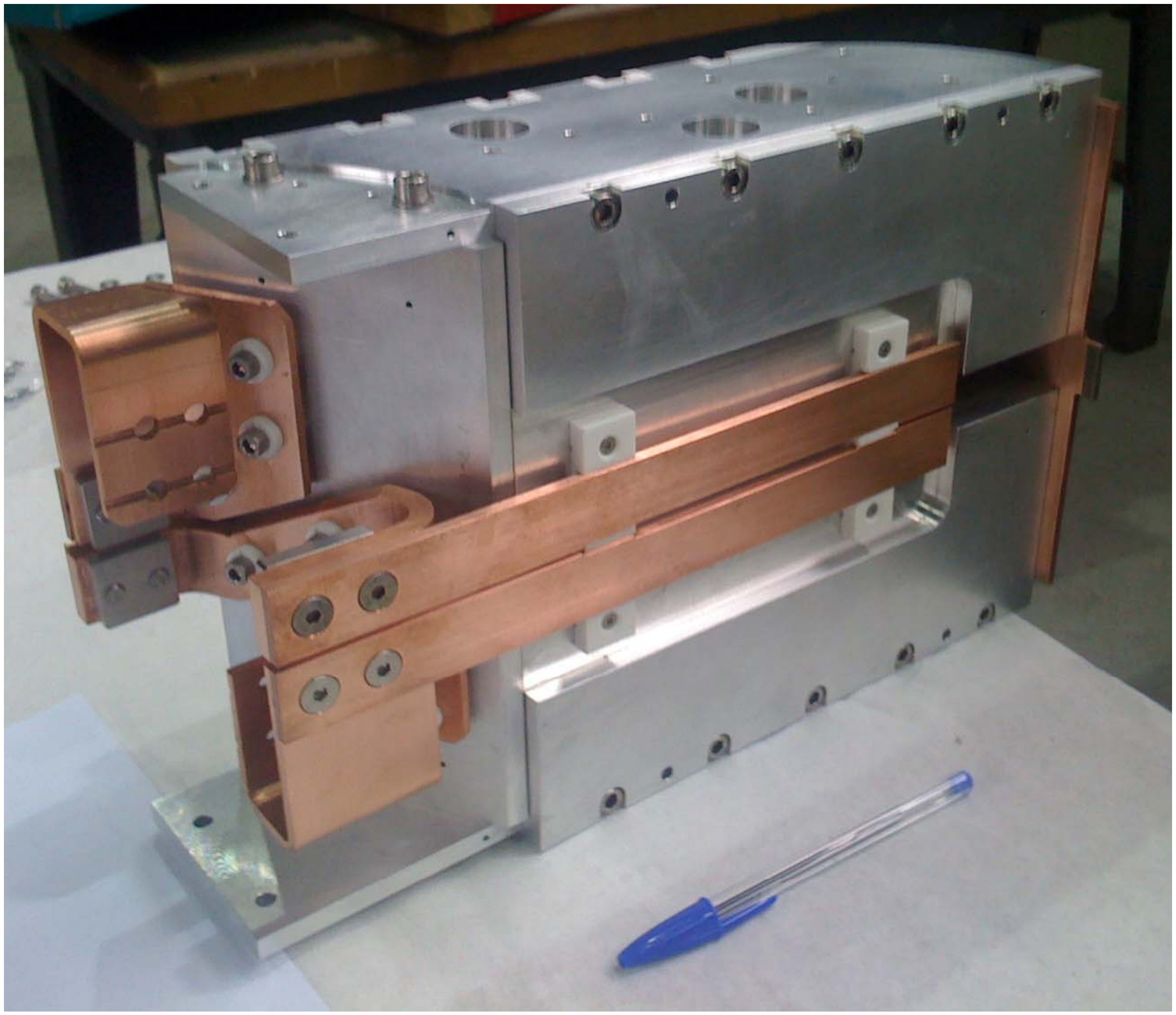
Extraction Septum



- In parallel we have been building and testing a dirty (not UHV clean) assembly
- Eddy current shield box also serves as compression feature to compact the laminations
- 97% packing factor achieved
- Good packing factor required to meet the flux specification

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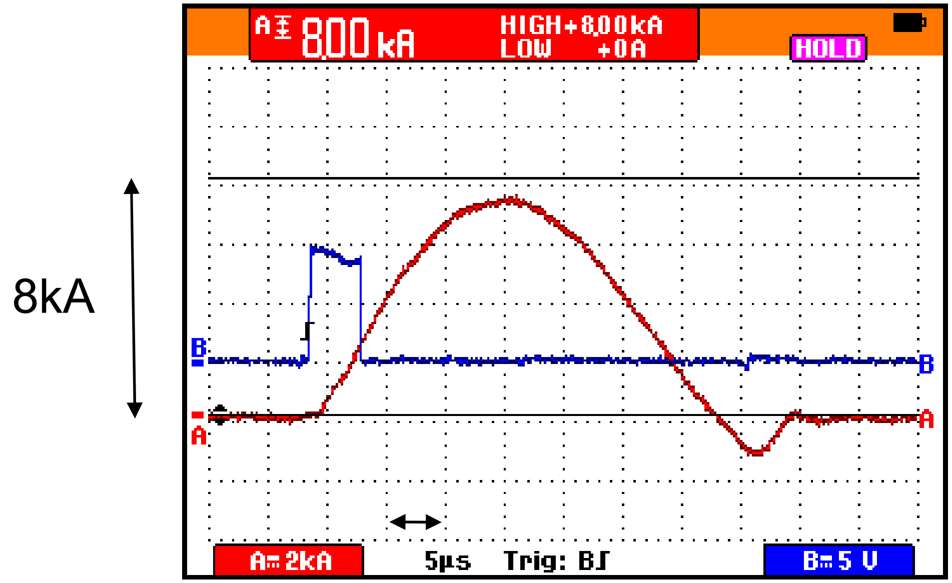
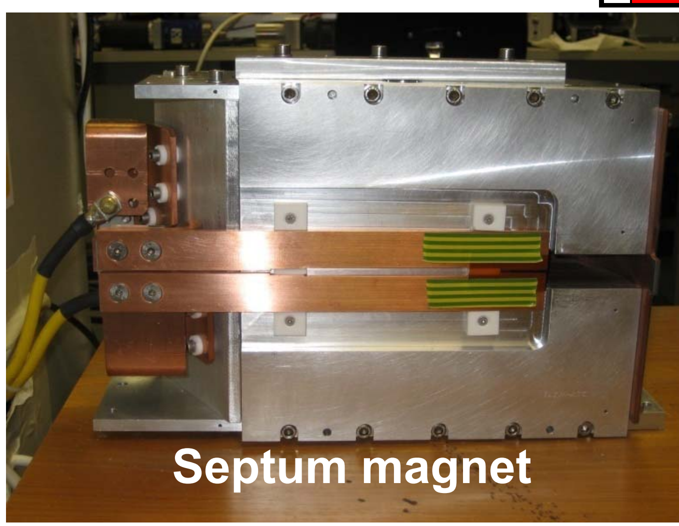
Septum pulse power supply



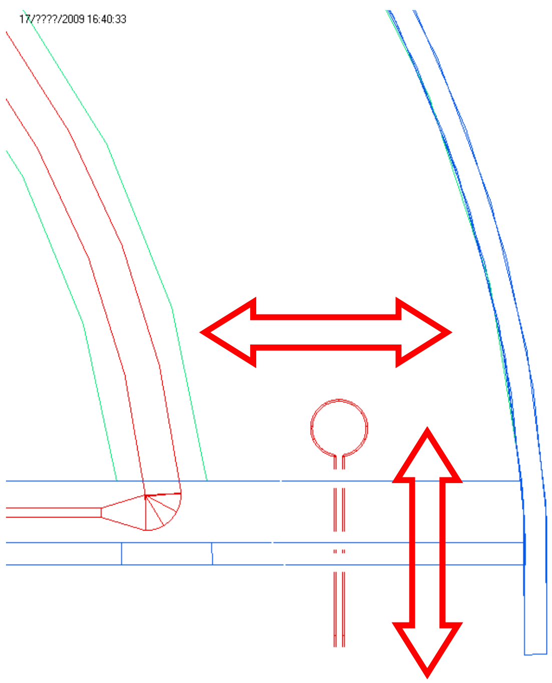


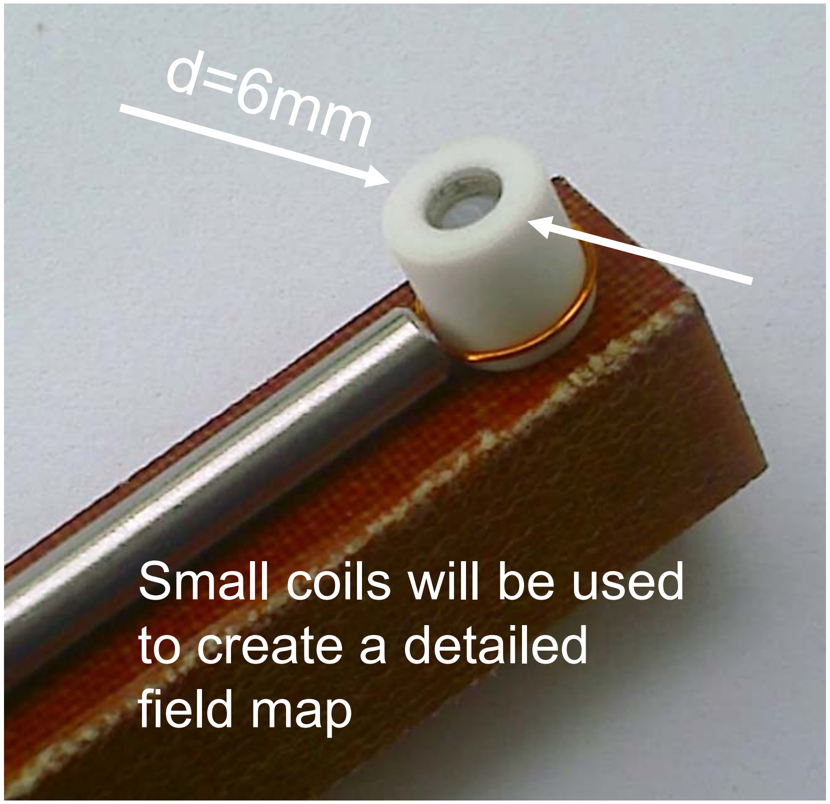
First test result 7300A pulse

Septum Measurements

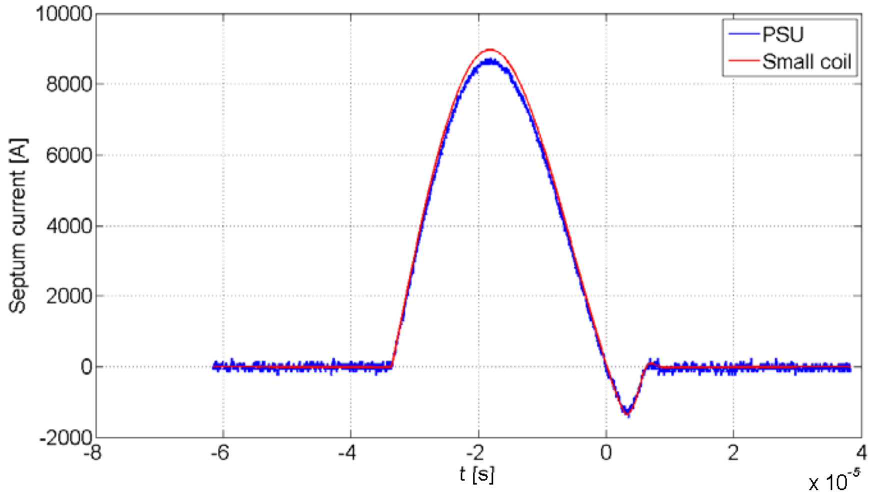
Same technique as kicker measurements: calibration followed by actual measurement

Much lower frequency; no problems with stray capacitances;





Septum Measurements

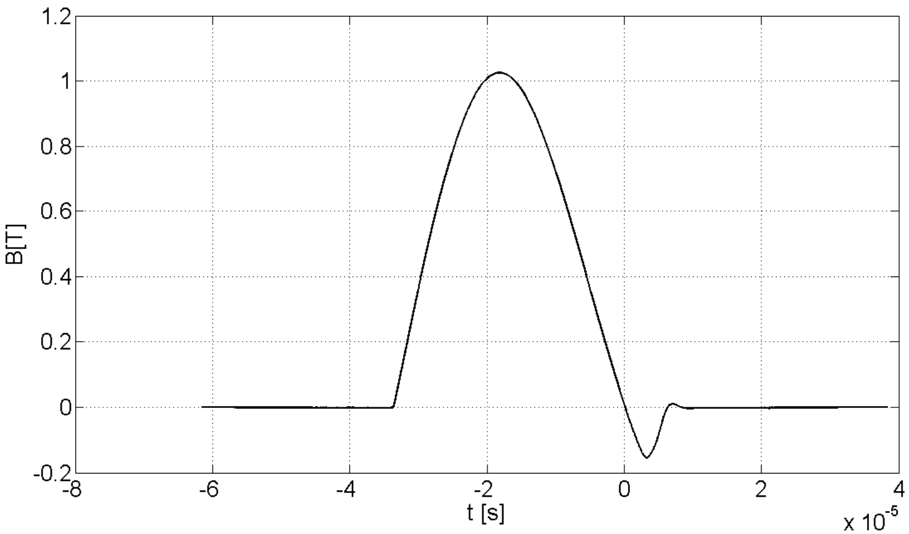


B=1T reached

with a 35 μs half-sine-wave pulse

The pulse may need shortening to 25 μs

No sign of saturation at 125% strength.



Septum Measurement Summary

Septum magnet flux reached B=1T (125%)

Detailed field mapping measurements in progress, some hardware required to conduct the measurements

Stray field measurements also in progress – adding some additional material most likely required – but where ? 1 – 2 mT could be more realistic than 0.1 mT

More work to do !!

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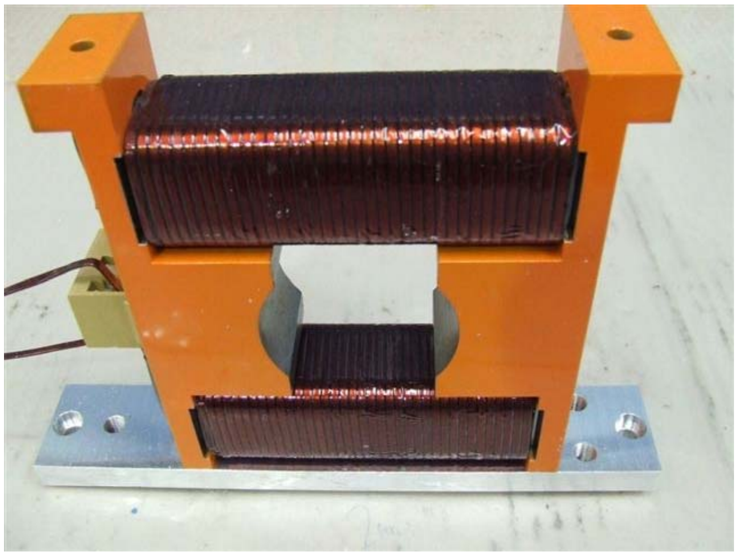
Corrector Magnet Design

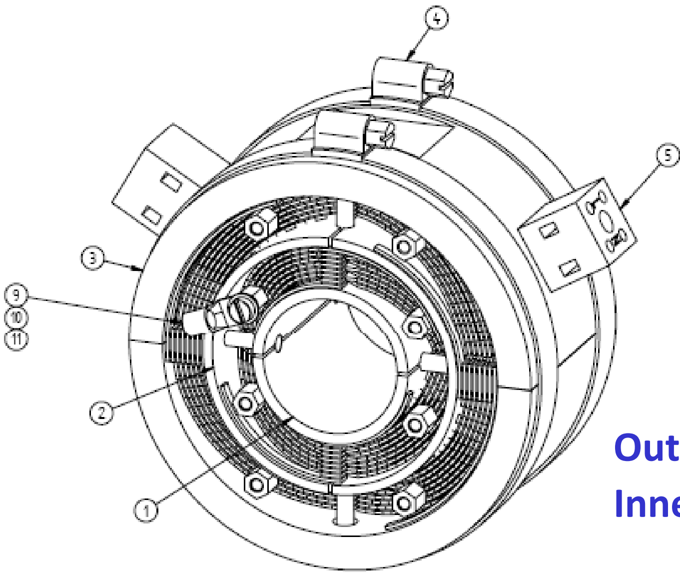
- Contract placed with Tesla Engineering - scheduled delivery October 09
- 20 vertical correctors (Ring x 16, Injection line x 2, Diagnostics beamline x 2)
- 8 combined vertical/horizontal correctors (Injection line x 4, Diagnostics beamline x 4)

Strength: 1.609T.mm
Good field region (1%): ±16mm (H)
±11mm (V)



Vertical corrector magnets

Strength: 0.436T.mm (H); 0.403T.mm (V)
Good field region (1%): >± 20mm



Outer coils (V)
Inner coils (H)

Combined vertical/horizontal corrector magnets

DIAGNOSTICS

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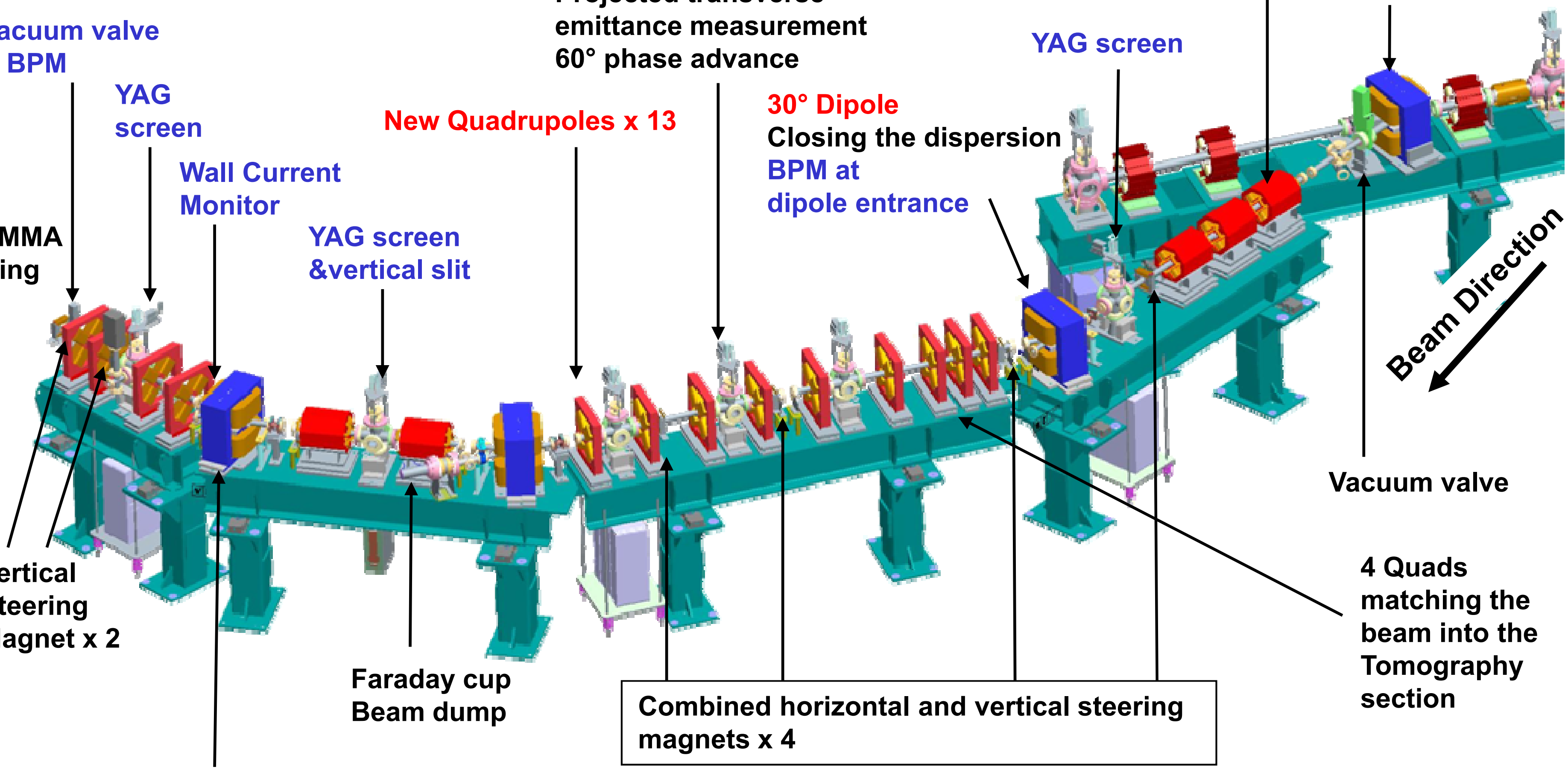
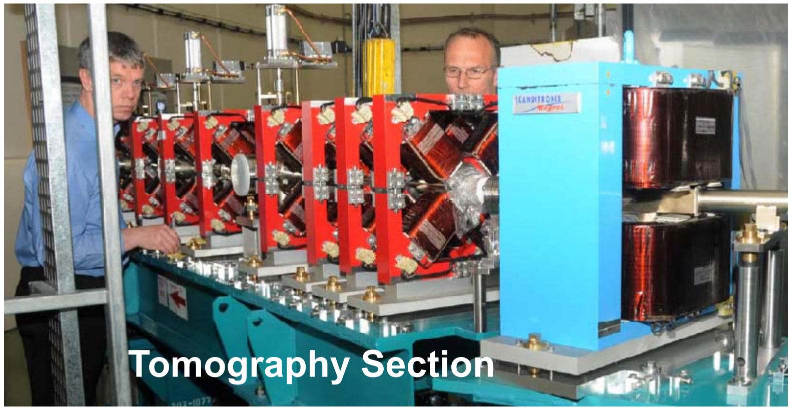
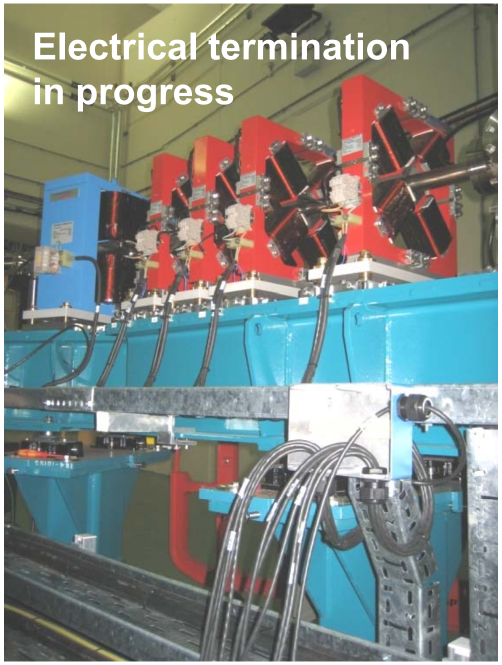
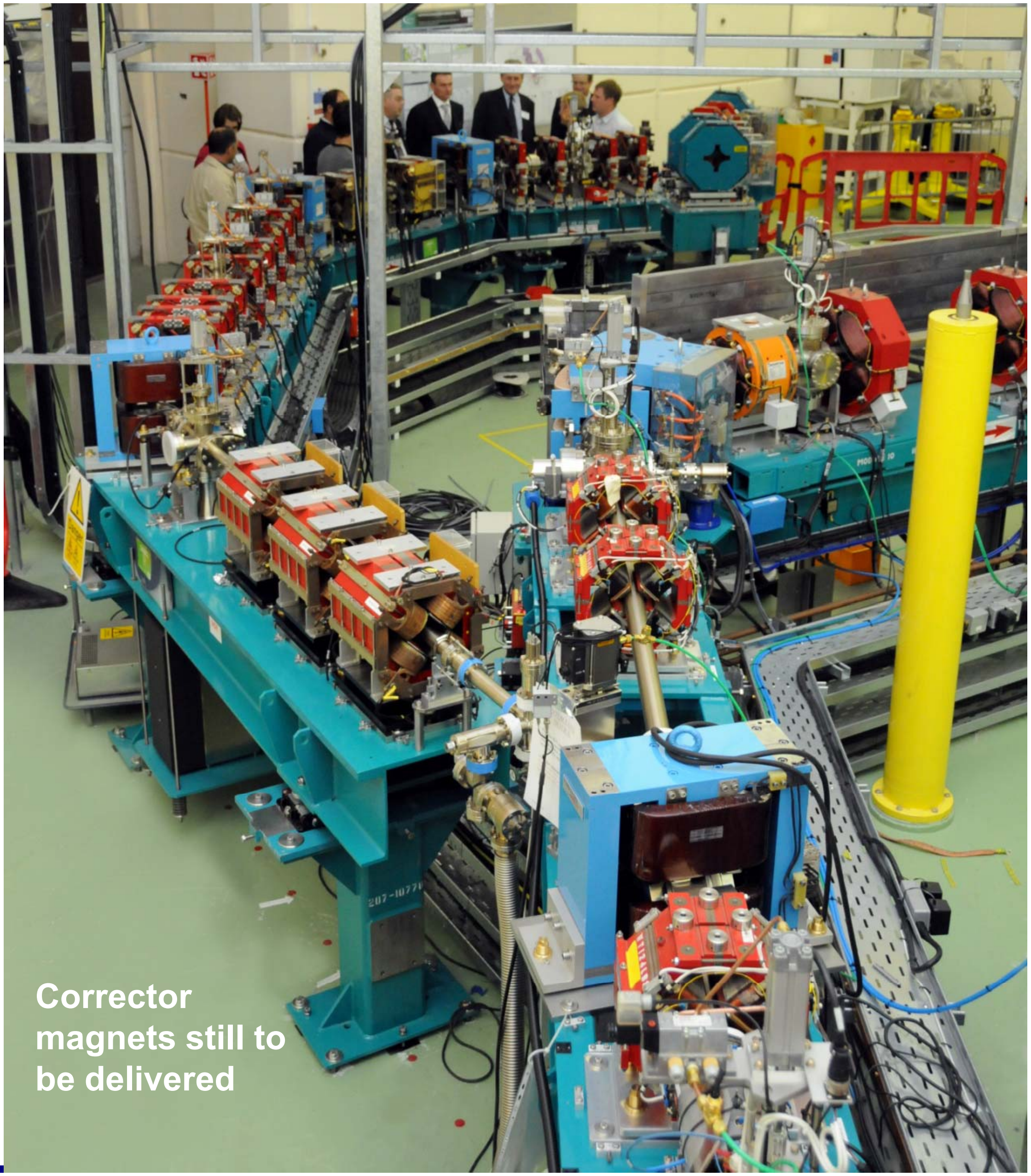
INJECTION LINE



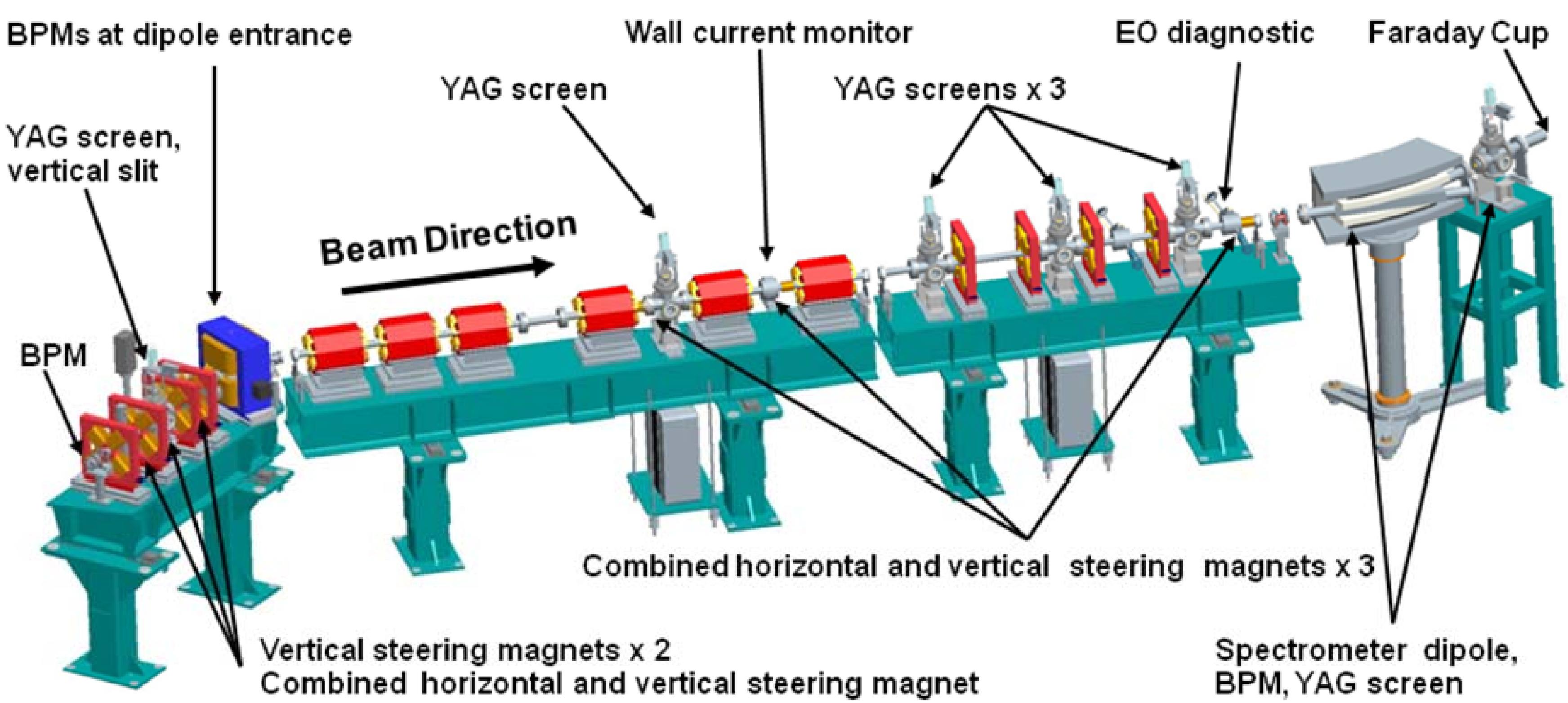
INJECTION LINE







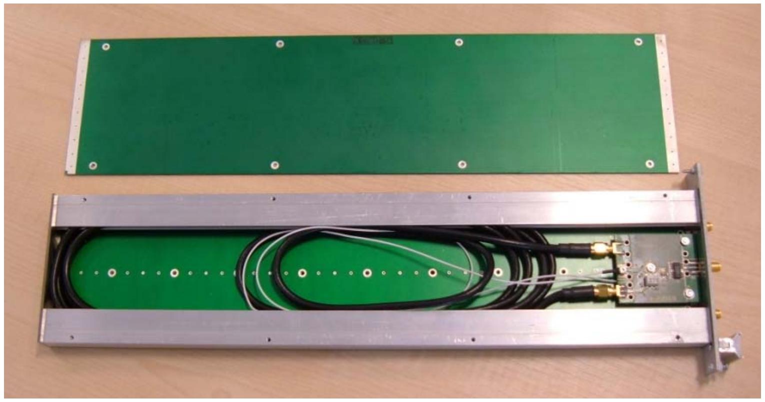
DIAGNOSTICS BEAMLINE



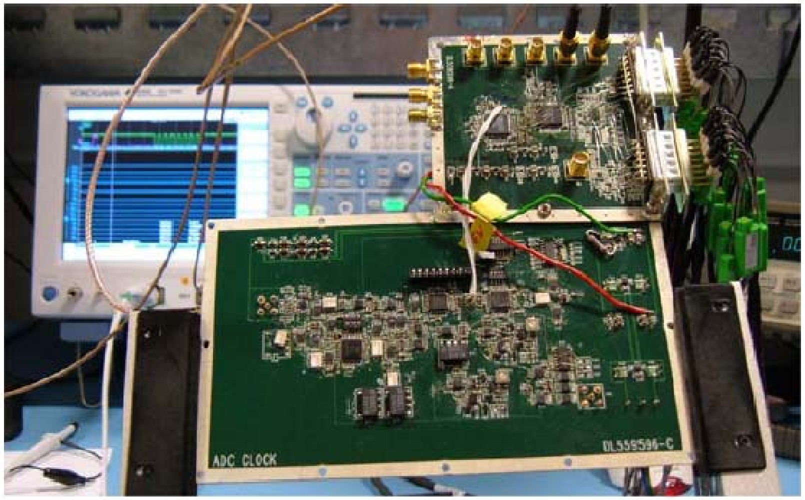
- All dipole and quadrupole magnets on site
- Correctors due end of October
- BPMs delivered from VG Scienta
- YAG screens due end of September from Kurt J Lesker UK
- Girder order placed on ESE UK, delivery end of October

Electron Beam Position Monitors

- The BPM electronics system has to deliver 50 μm resolution over a large aperture
- Locally mounted coupler card amplifies and separates signals from opposite buttons in time, to give a 12nS delay between each. Signals combined and transmitted via a single high quality coax cable to….
- ……VME based detector cards located in rack room outside of shielded area.
- Status:- All elements of the detector and digitisation stages are designed. Contract has been placed to design the VME interface. A production prototype card will be available by mid Nov. Test on ALICE by end of Nov, followed by production run of 50 cards by end of Jan 2010.



Production Coupler **due the end of Oct**



RF Detector, Clock, Control & ADC

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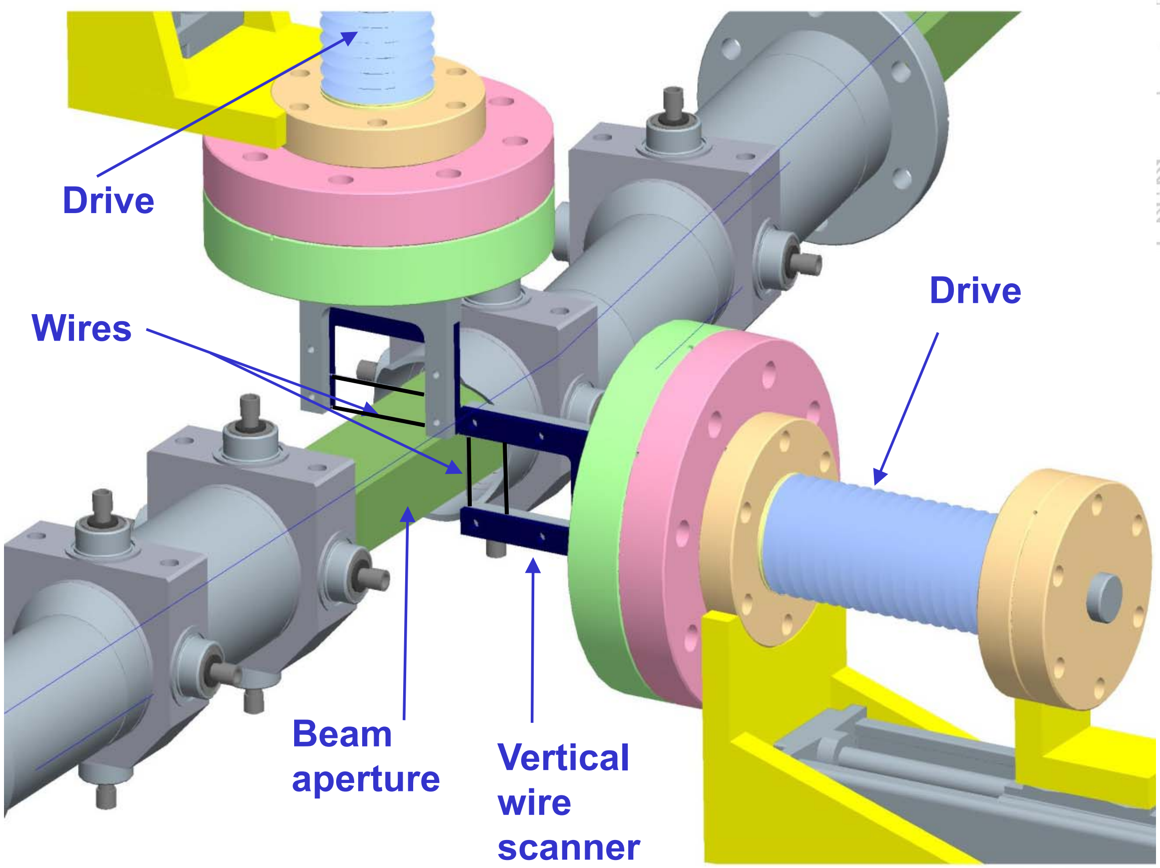
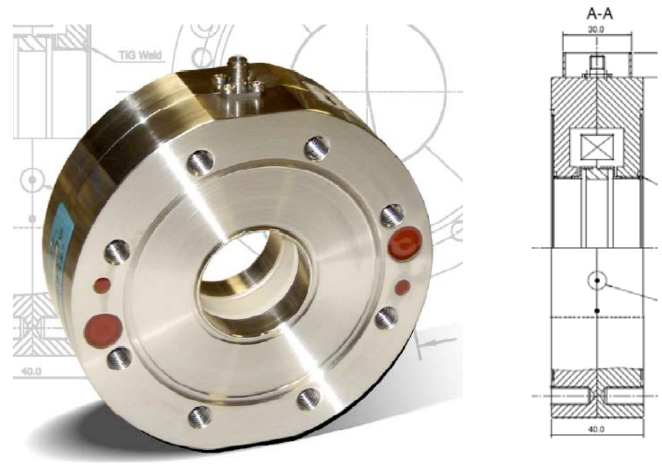
Other Diagnostics





- FNAL Collaboration design of Wall Current Monitor based on commercially available ‘in flange’ current transformer.

- In house design of wire scanners and YAG screen systems based on designs already manufactured for ALICE.

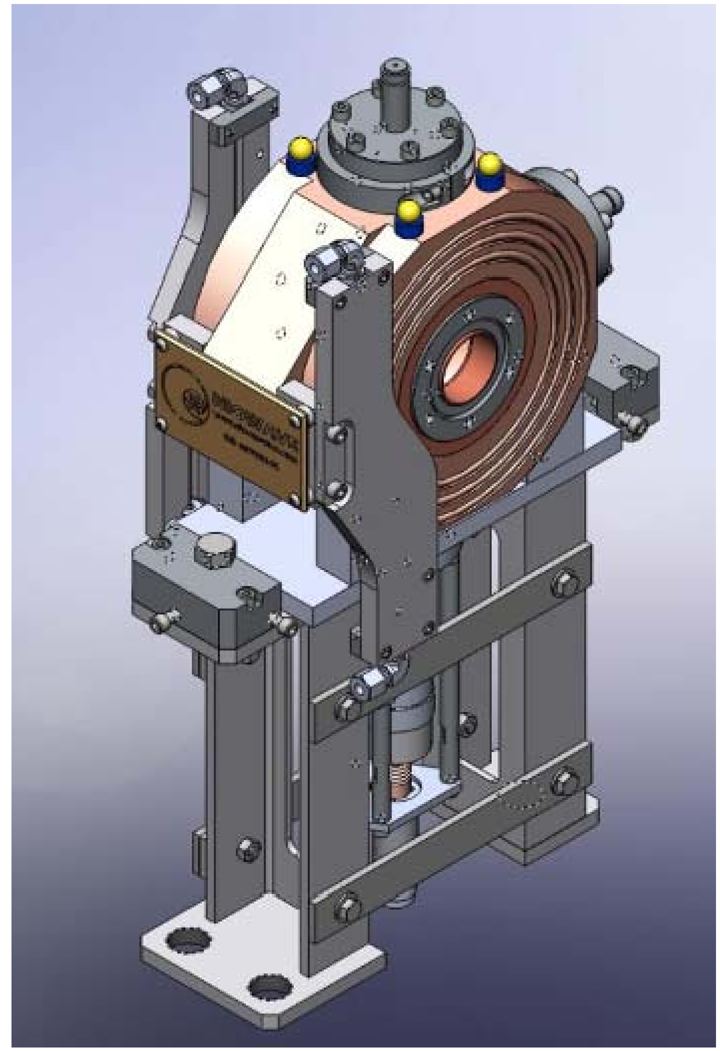
RADIO FREQUENCY

Cavity Construction

- Manufacture of prototype cavities and 20 production cavities completed by **Niowave**
- 16 delivered**,** 2 ready for waiting for input couplers and 2 ready for delivery
- High quality manufacture including electron beam welding of body to reduce distortion
- Chemical etching adopted to improve Q (Qo 18,500 to 20,400)

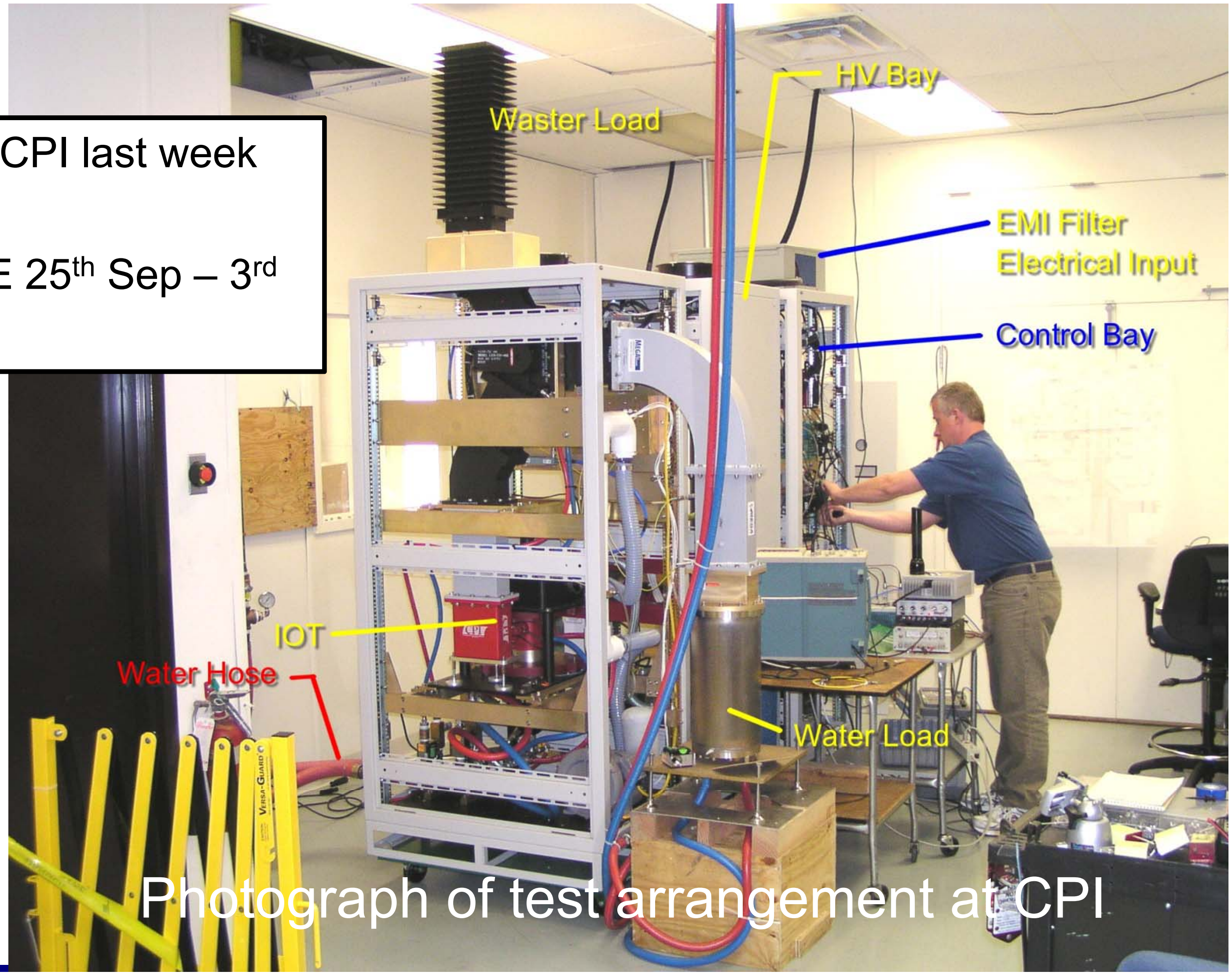
Cavities exceeds EMMA specification

Input Coupler
Times Microwave



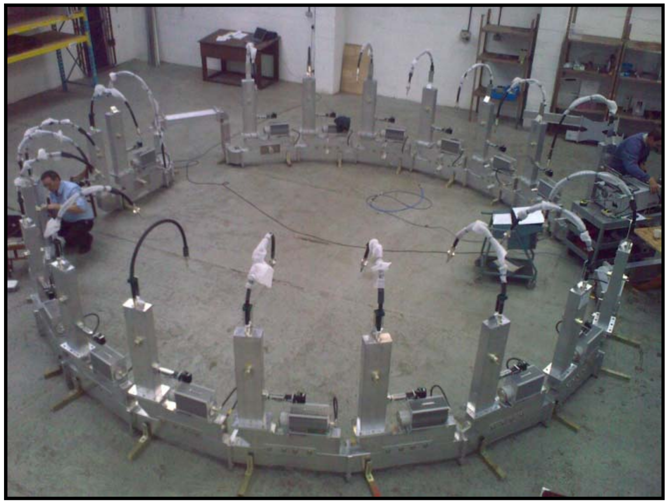
100KW (pulsed) IOT

- Acceptance tests at CPI last week
- Delivery in progress
- Installation on ALICE 25th Sep – 3rd Oct



Photograph of test arrangement at CPI

RF Distribution



Q-Par Angus

- Acceptance tests performed on the 27th May 2009
- System delivered 29th June 2009
- Installation in Jan 2010

Low Level RF

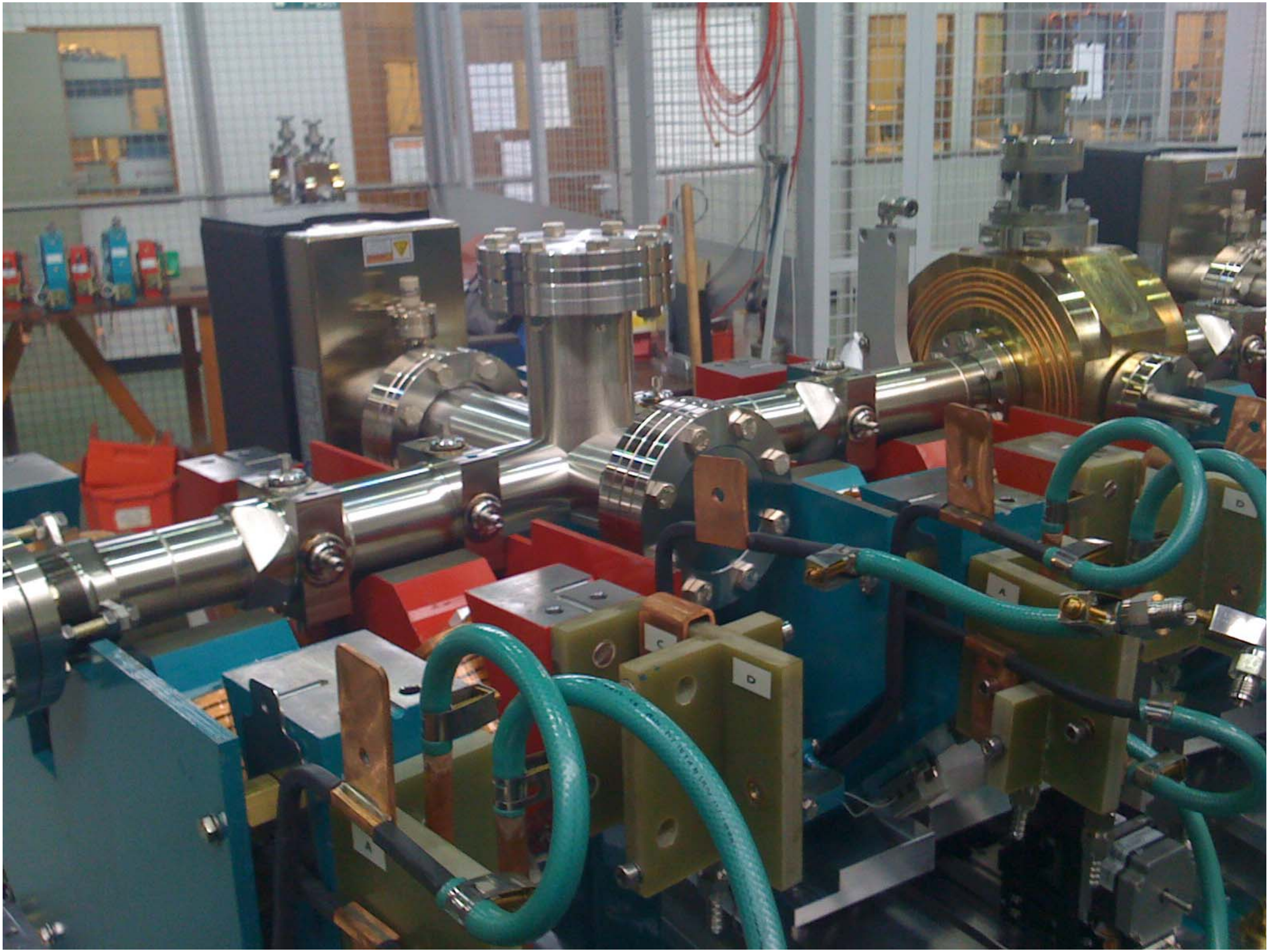
Instrumentation Technology
www.i-tech.si/
Libera

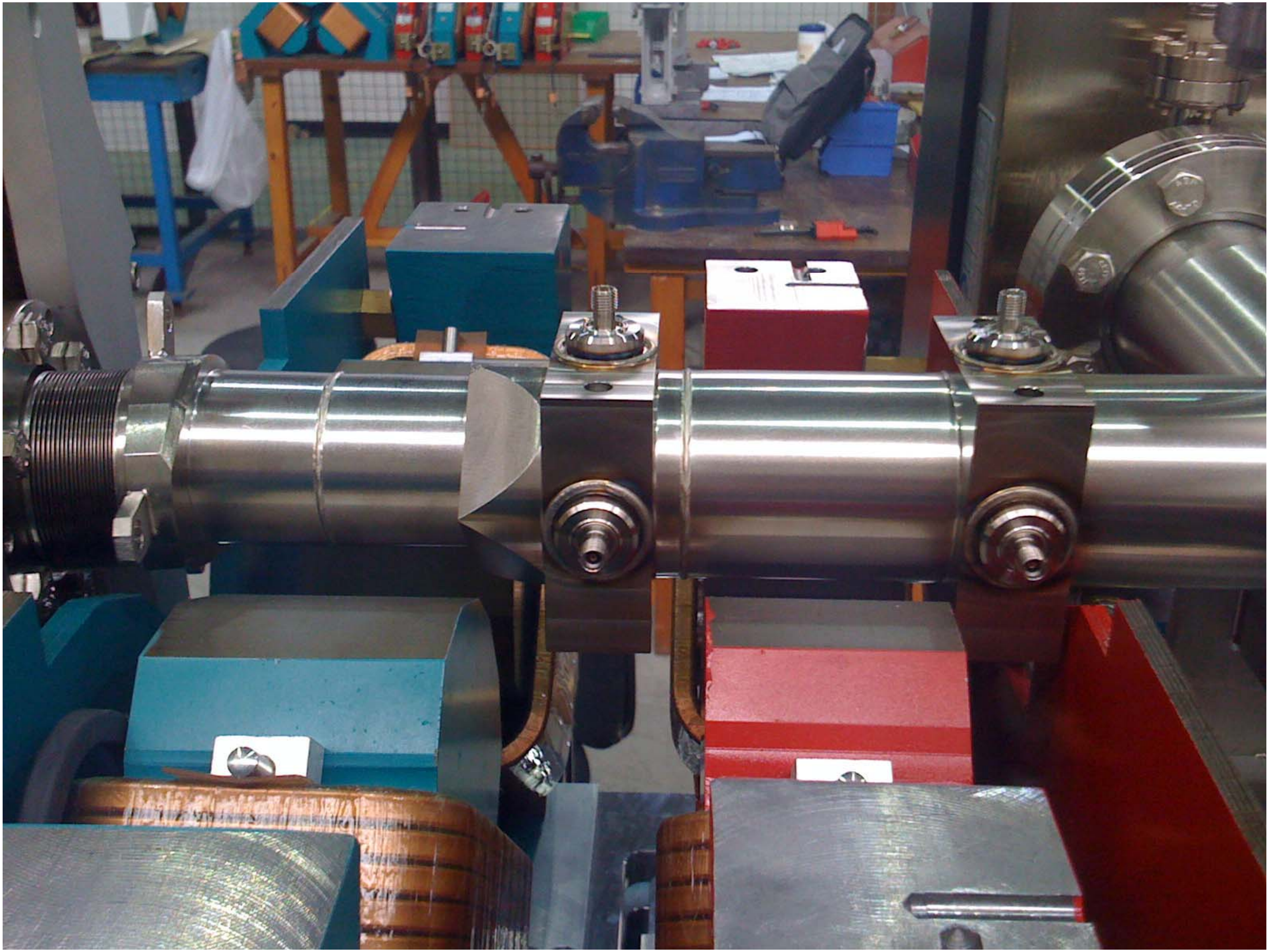
- Hardware delivered
- Software not delivered yet
- Critical issue to be resolved:
  - Synchronisation of the phase with the arrival of the beam

RING ASSEMBLY STATUS


Off Line Assembly

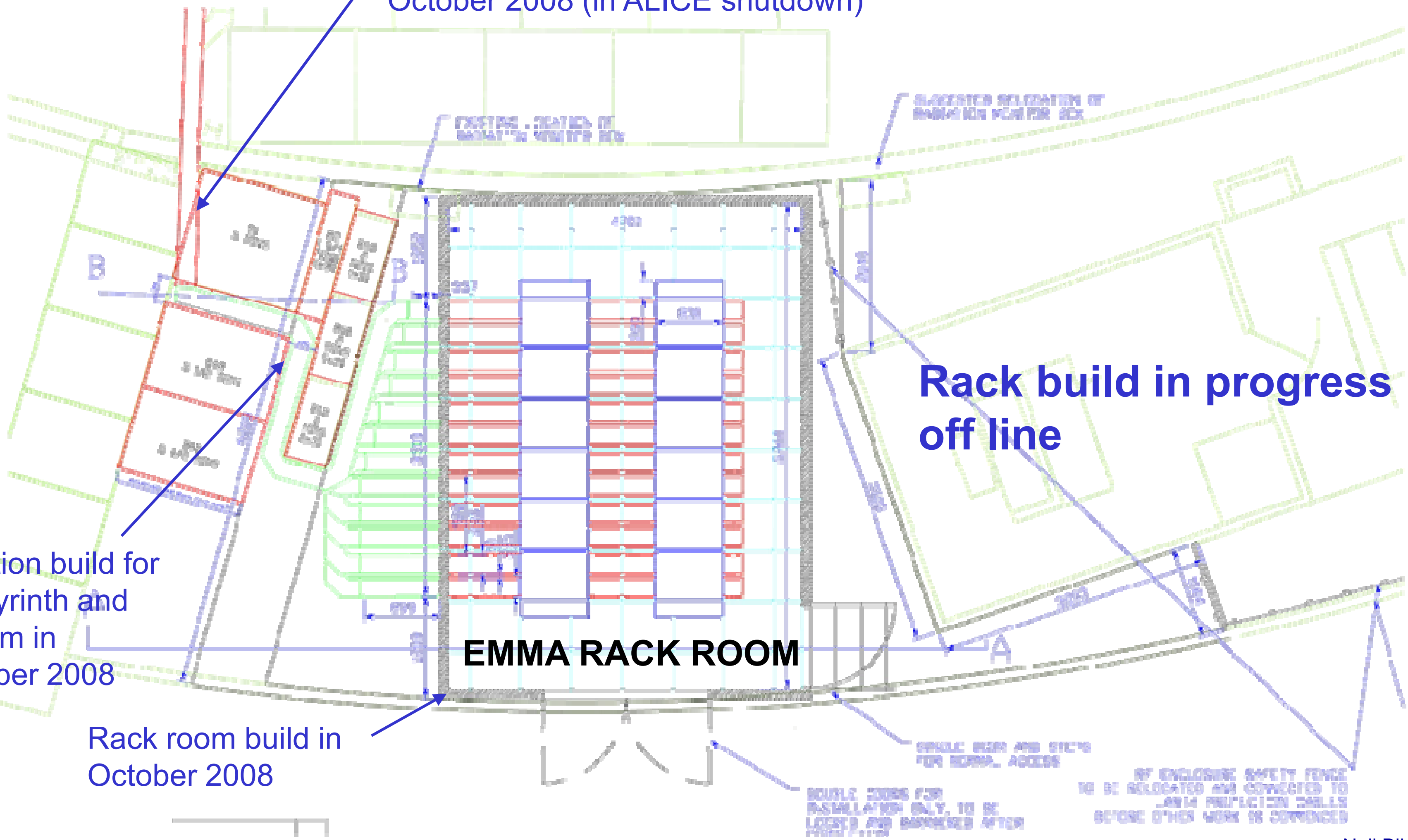

NIOWAVE





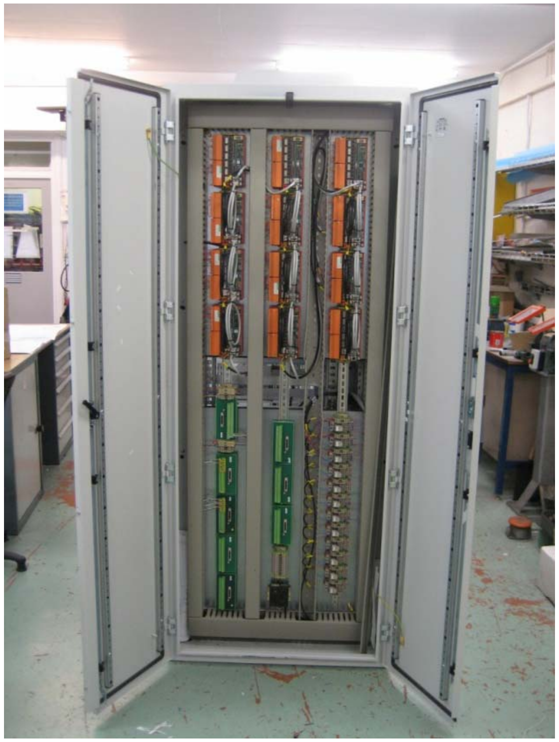

Cable tray fitted ready for installation of magnet and BPM cables

Rack Room


Diamond drilling of ALICE shield wall on 27 – 30 October 2008 (in ALICE shutdown)
Rack build in progress off line
Foundation build for new labyrinth and rack room in September 2008
EMMA RACK ROOM
Rack room build in October 2008
B
B
A

Rack Build





Power Converter Racks

Control Station & Vacuum Racks

Rack Room

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BASROC CONFORM

ALICE Accelerator Hall

Summary

Off line build in progress	Oct 2008 - Dec 2009
IOT Installation in ALICE Hall	25th Sep - 3rd Oct 2009
ALICE Shutdown	19th Oct - 15th Nov

Target is to have 4 of the 7 girder assemblies ready to be transported through the equipment door

Injection line ready for beam	7th December 2009
Further 3 girders to be installed	Jan 2010
Full ring assembled by	end of Jan 2010
Systems tests & commissioning	February - mid March 2010
EMMA ring ready for beam	mid March 2010
1st beams in to EMMA	Mar 2010

Acknowledgements

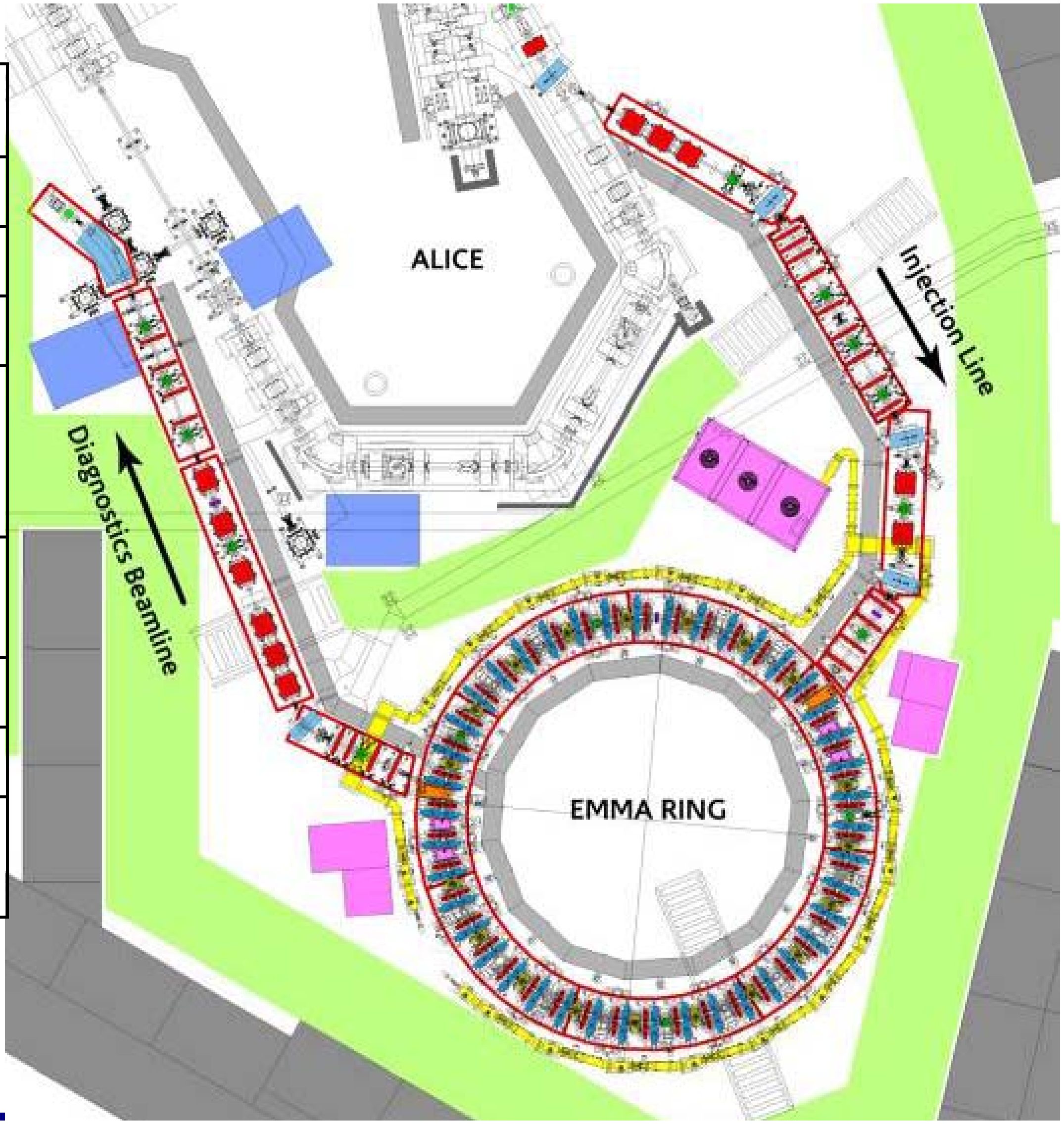
All the team

- STFC
- Cockcroft Institute
- John Adams Institute staff
- UK Universities
- International Collaborators
- Commercial suppliers

ADDITIONAL SLIDES

EMMA Parameters & Layout

Energy range	10 – 20 MeV
Lattice	F/D Doublet
Circumference	16.57 m
No of cells	42
Normalised transverse acceptance	3π mm-rad
Frequency (nominal)	1.3 GHz
No of RF cavities	19
Repetition rate	1 - 20 Hz
Bunch charge	16-32 pC single bunch



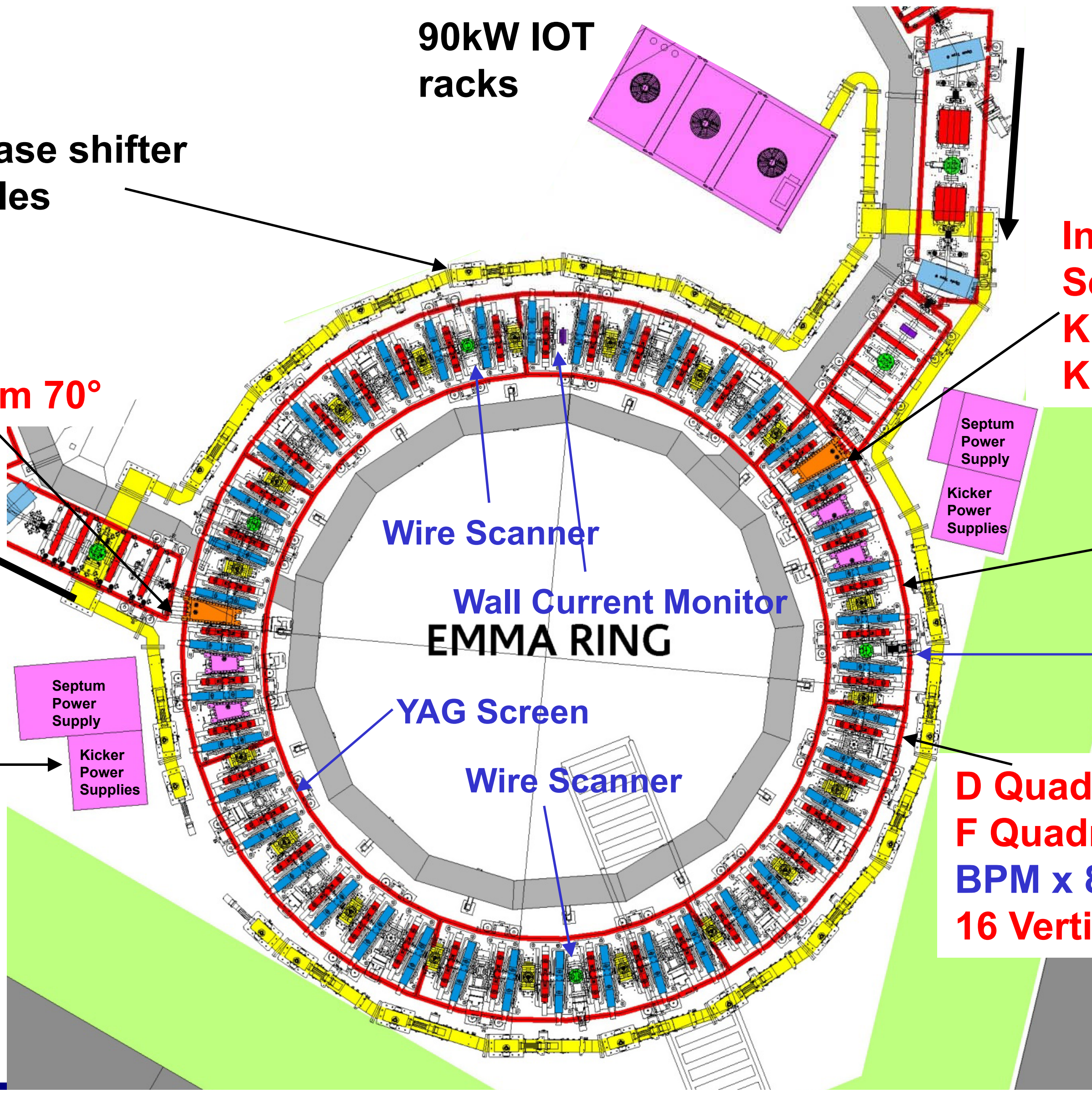
EMMA Ring

RF distribution
17 hybrid and phase shifter waveguide modules

90kW IOT racks

Kicker
Kicker
Extraction Septum 70°

Injection
Septum 65°
Kicker
Kicker



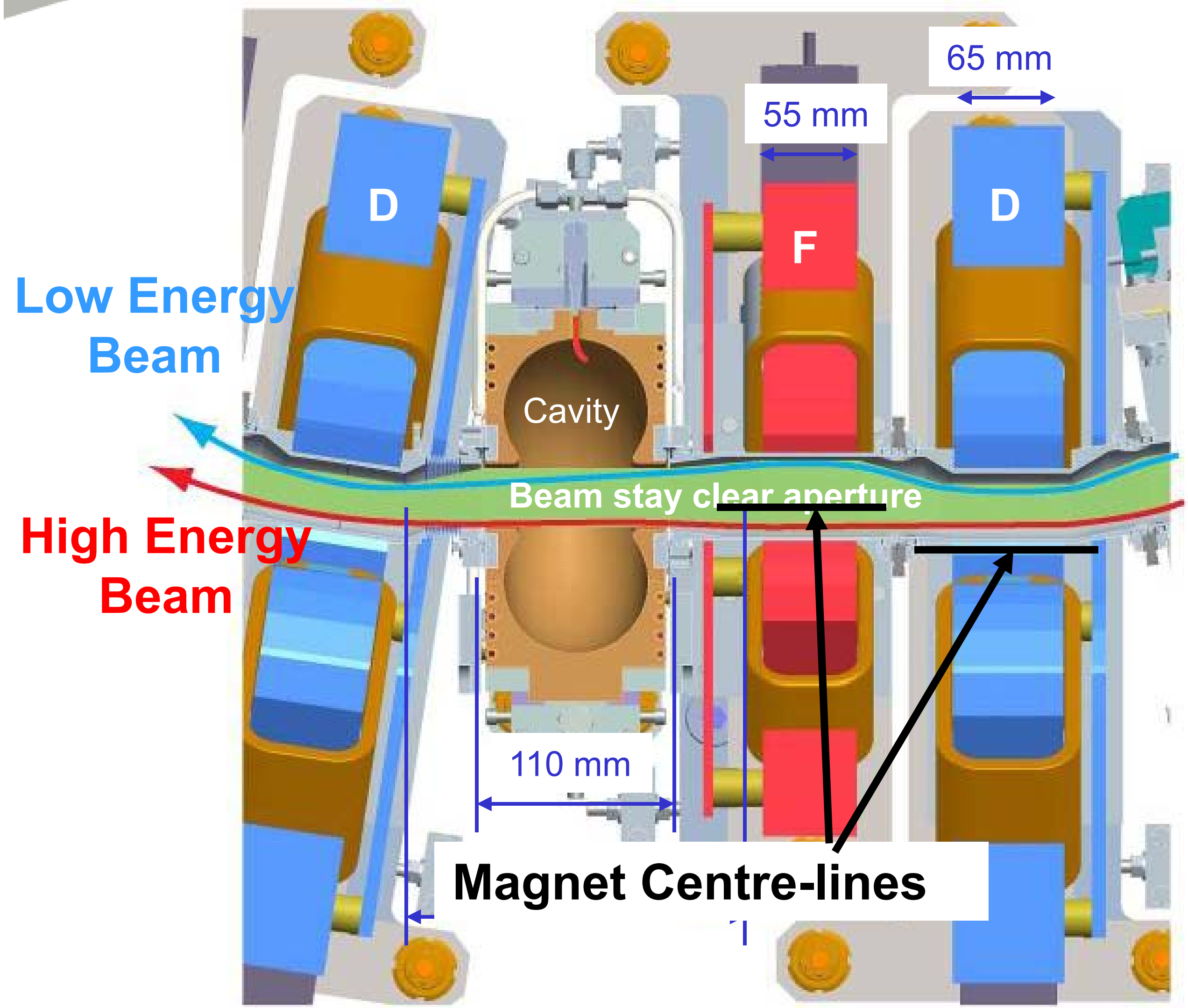
RF Cavities x 19

YAG Screen

Septum & kicker power supplies

D Quadrupole x 42
F Quadrupole x 42
BPM x 82
16 Vertical correctors

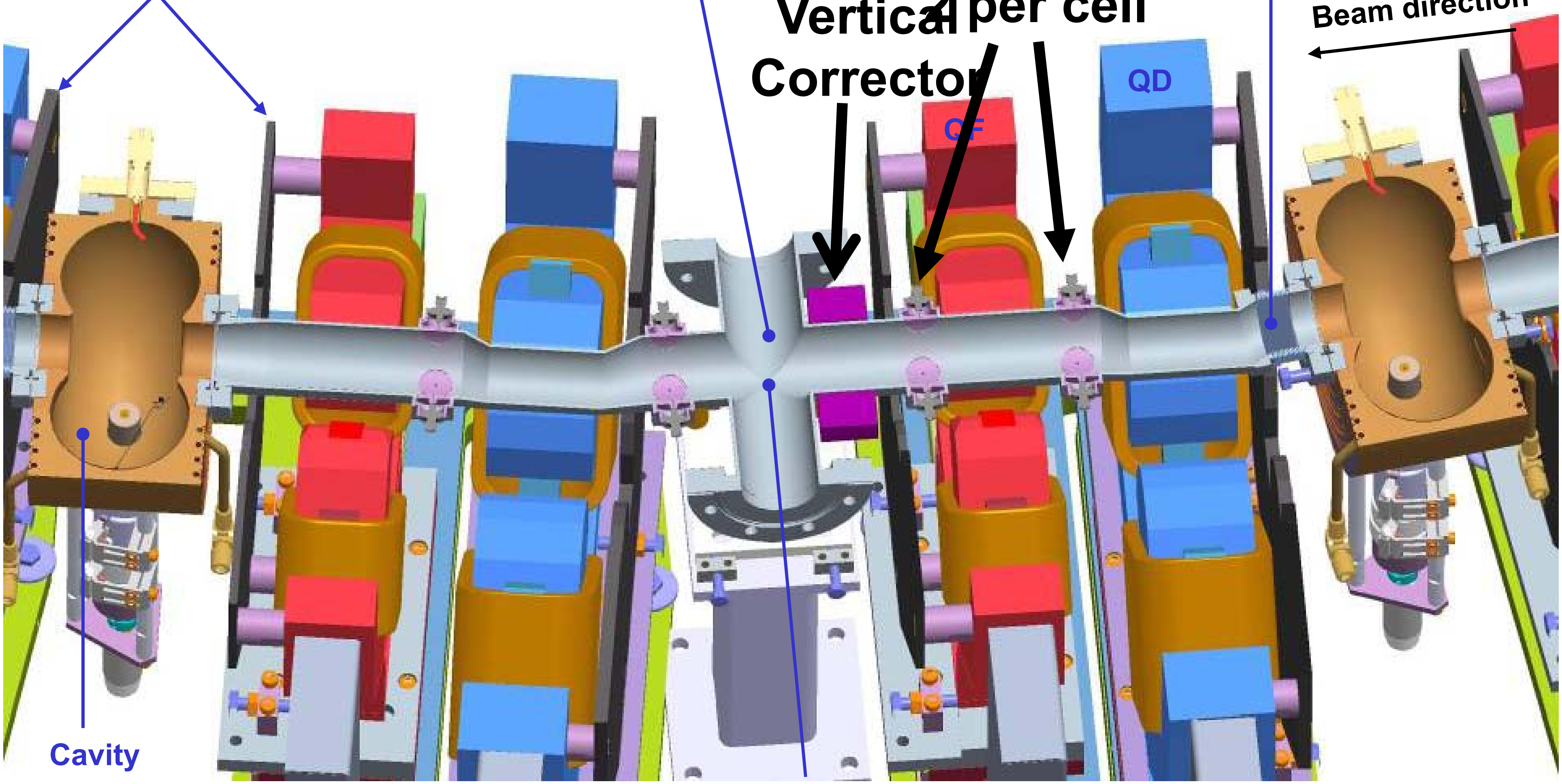
EMMA Ring Cell



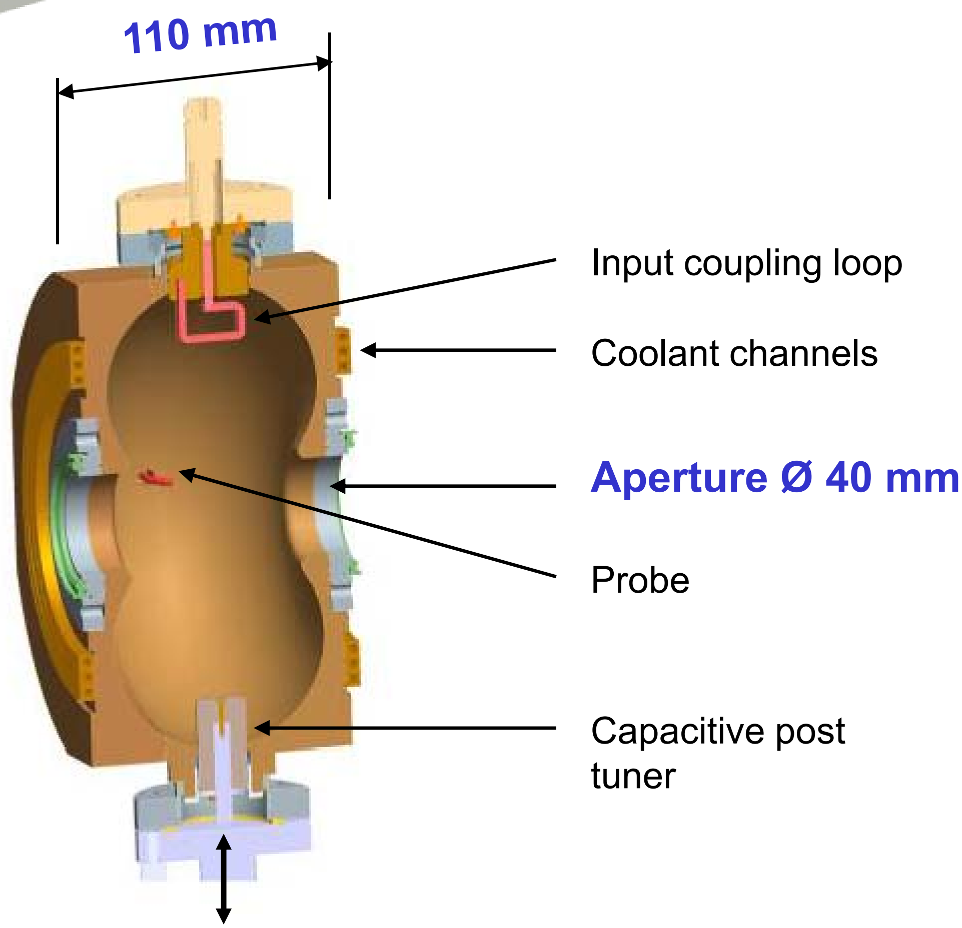
Long drift	210 mm
F Quad	58.8 mm
Short drift	50 mm
D Quad	75.7 mm

42 identical cells
Cell length 395 mm

EMMA Ring Section



Cavity Design



Normal conducting single cell re-entrant cavity design optimised for high shunt impedance

Parameter	**Value**
Frequency	1.3 GHz
Theoretical Shunt Impedance	2.3 MΩ
Realistic Shunt Impedance (80%)	**2 MΩ**
Qo (Theoretical)	23,000
R/Q	100 Ω
Tuning Range	-4 to +1.6 MHz
Accelerating Voltage	120 kV
Total Power Required (Assuming 30% losses in distribution	**90 kW**
Power required per cavity	3.6 kW