LHC IR UPGRADE - PHASE I
CORRECTOR STATUS UPDATE

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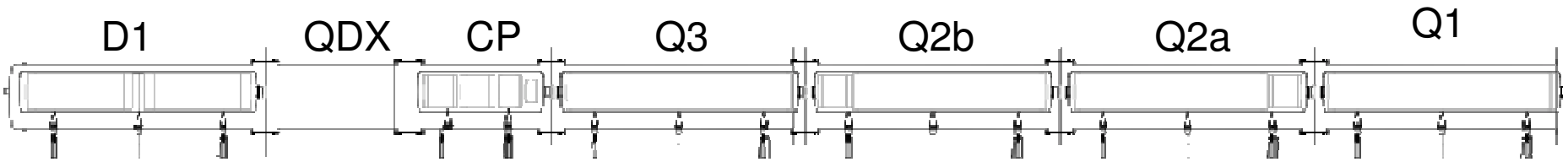
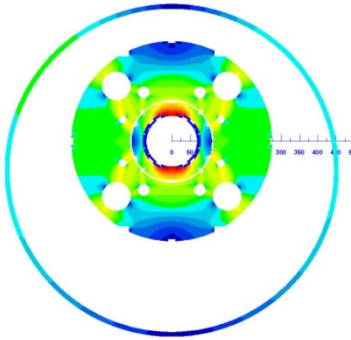
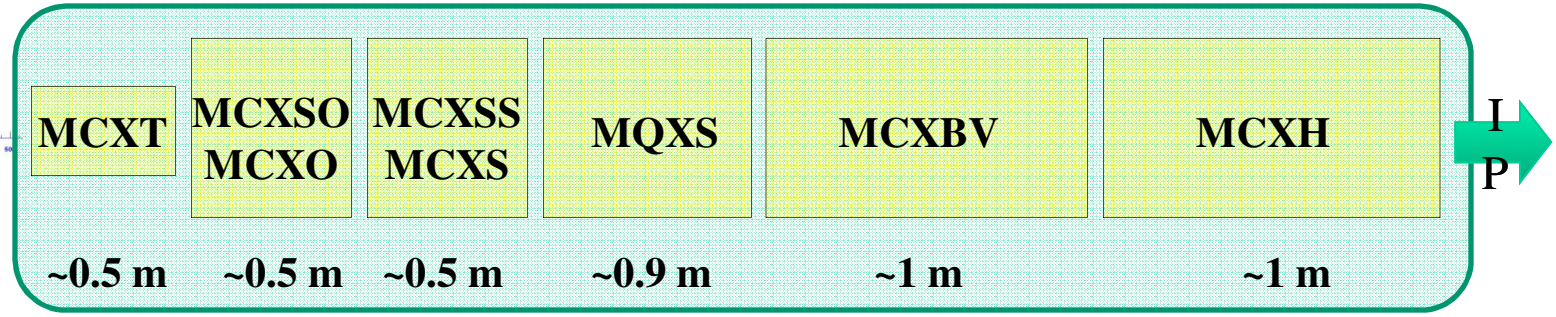
D. Smekens, G. Trachez



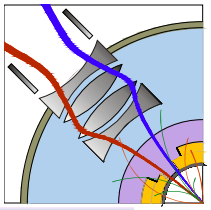
Corrector Package (CP)

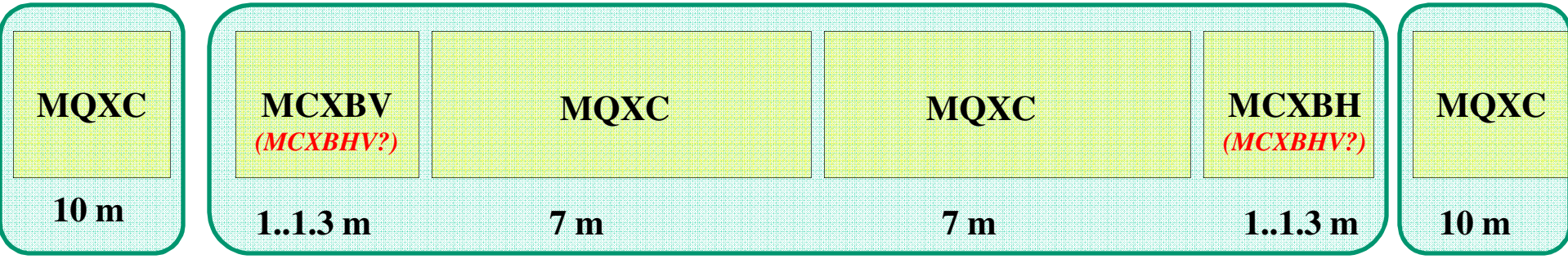




	Current	Integrated strength (field)	Aperture
MCXB (B_1/A_1)	**+/- 2.4 kA**	**1.5 Tm**	**140 mm**
MQXS (A_2)	**+/- 2.4 kA**	**0.65 Tm @40 mm**	**140 mm**
MCXT (B_6)	**+/- 120A**	***0.075 Tm @ 40 mm***	***140 mm***
MCXO (B_4)	**+/- 120A**	***0.035 Tm @ 40 mm***	***140 mm***
MCXSO (A_4)	**+/- 120A**	***0.035 Tm @ 40 mm***	***140 mm***
MCXSS (A_3)	**+/- 120A**	***0.055 Tm @ 40 mm***	***140 mm***
MCXS (B_3)	**+/- 120A**	***0.055 Tm @ 40 mm***	***140 mm***

Correctors in Q2

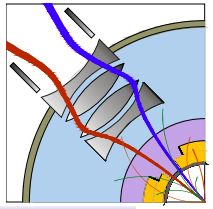


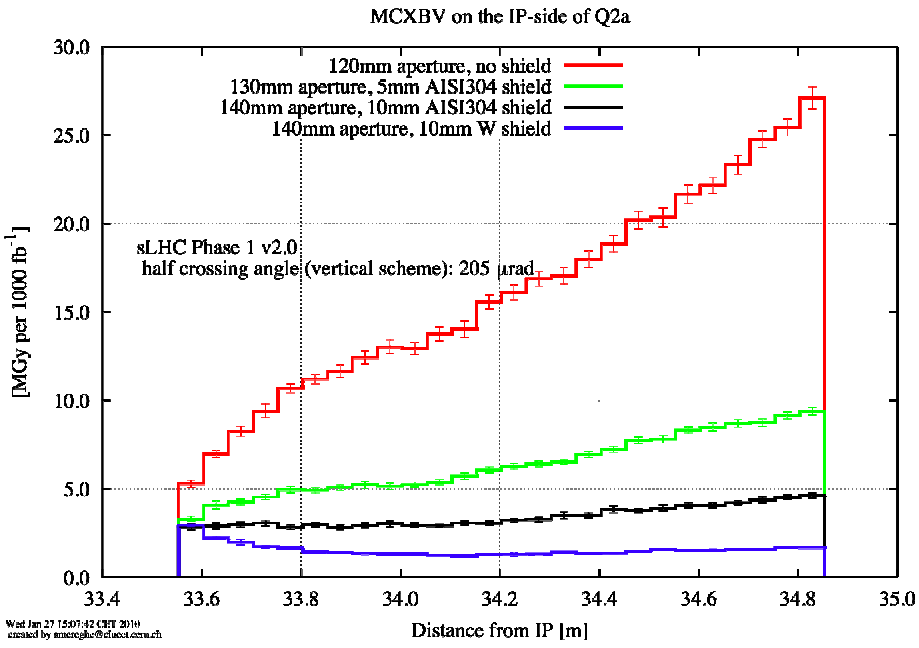


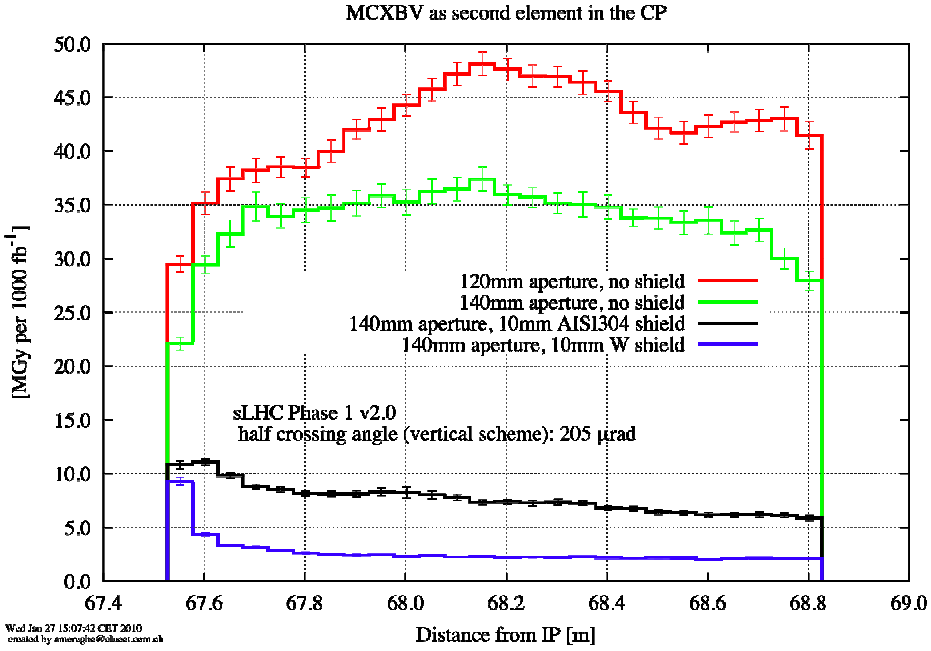
- Base-line (HV and VH) orbit corrector scheme allows controlling the orbit to a level 3 times larger that then BPM resolution.
- To reach the same level as the effective BPM resolution :
  - Provide 1.5 Tm (1.8 Tm) in H&V-plane in BOTH locations.
  - Feasibility study underway on combined H/V-corrector that meets the reliability requirements (Report by Mid-2010 + Model work..)
- An extra H/V pair means:
  - Magnet R&D, material R&D, design, component & tooling procurement
  - Additional powering and protections circuits

REF: S. Fartoukh, R. Tomas, J. Miles: "Specification of the Closed Orbit Corrector magnets for the NEW Inner Triplets", sLHC Project Report 030

Radiation Environment (Q2a & CP)

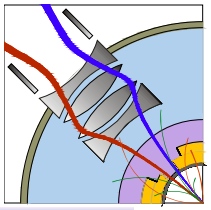






Courtesy of F. Cerrutti & A. Mereghetti
EN-STI-EET, FLUKA-team

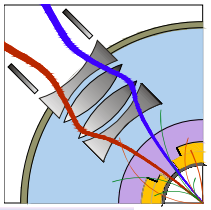
Radiation Environment (sLHC v2.0)



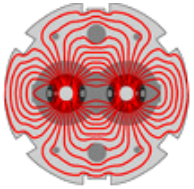
- Luminosity: $2\ L_0 = 2 \times 10^{34} cm^{-2}\ s^{-1}$ & $1000\ fb^{-1}$
- Peak dose CP:
  - ~50..65 MGy ø120 mm aperture, no shielding
  - ~30..35 MGy ø140 mm aperture, no shielding
  - ~10 MGy ø140 mm aperture, 10 mm SS
- Peak dose in Q2 (with 13 mm liner in Q1):
  - ~28 MGy, ø120 mm aperture, no shielding
  - ~ 8 MGy ø140 mm aperture, 10 mm SS

Courtesy of F. Cerrutti & A. Mereghetti
EN-STI-EET, FLUKA-team

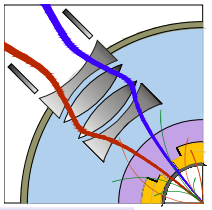
Organization



- MCXB
  - Design — CERN
  - Model — CERN
  - Series (20 off) — Special French Contribution/CERN?
- MQXS
  - Design — CERN
  - Model & R&D — CERN & STFC
  - Series (5 off) — Special French Contribution/CERN?
- MCXS and other Higher Order Correctors (TBC)
  - Design — CIEMAT
  - Model — CIEMAT
  - Series (5 off) — Special French Contribution/CERN?
- Testing (cold)
  - at CERN
  - Plan B for Models: RAL, CEA (TBC)
- Cold mass integration and cryostat assembly at CERN



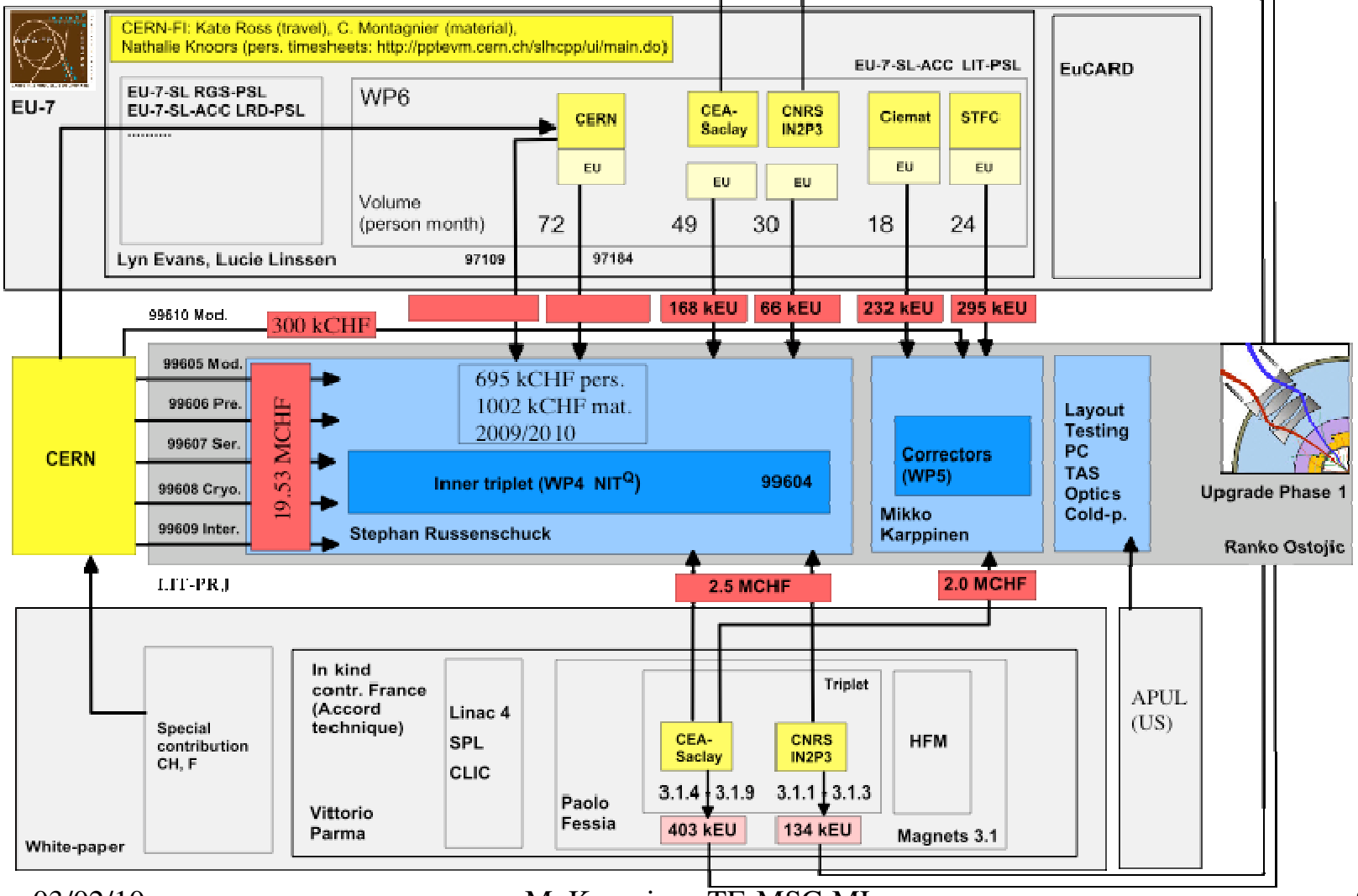
Organization: STFC Involvement



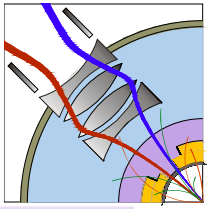
- R&D on coated metallic end spacers for cosϴ coils (rad resistance, alternatively usable for thermal reaction of Nb3Sn Coils)
- Validation of porous all polyimide insulation for the 18 strand Rutherford cable
- Study of E-modulus of the insulated cable / dielectric properties
- Assembly of the models at CERN (short mech. model & model)

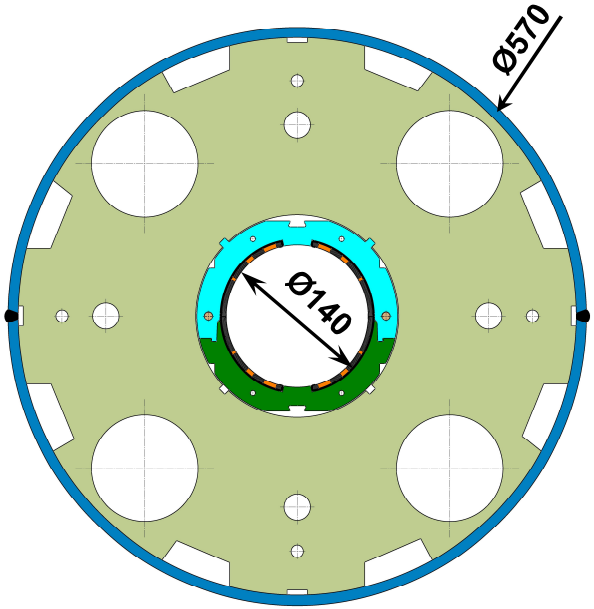
NIT Funding

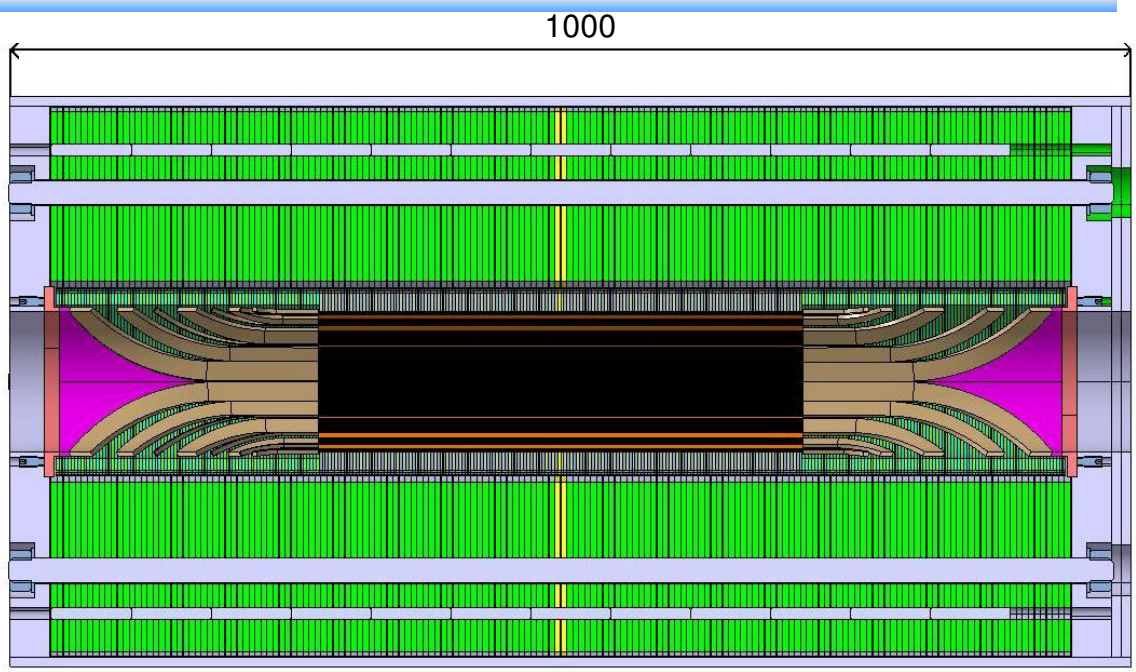
Courtesy of S. Russenschuck



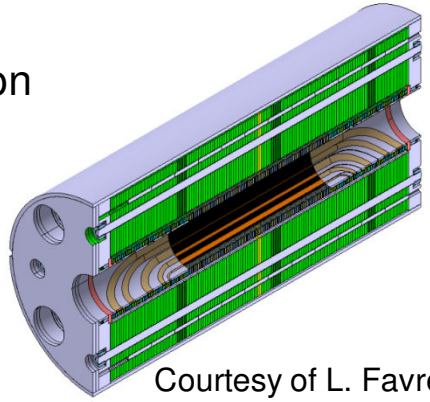
MCXB 4-Block Design







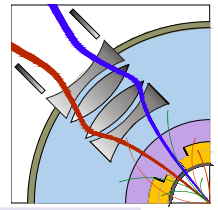
New 4.37 mm cable & Polyimide insulation
Self-supporting collars
Single piece yoke

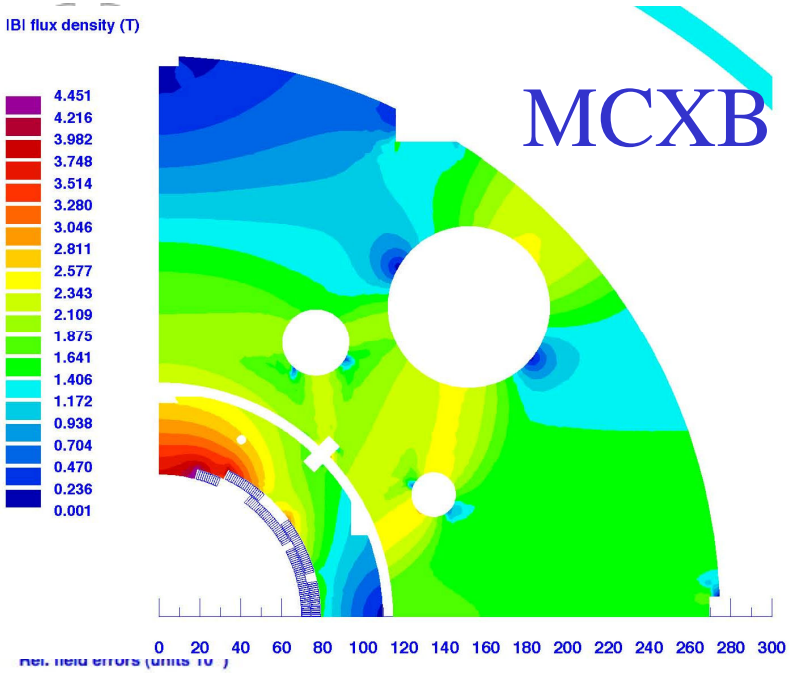


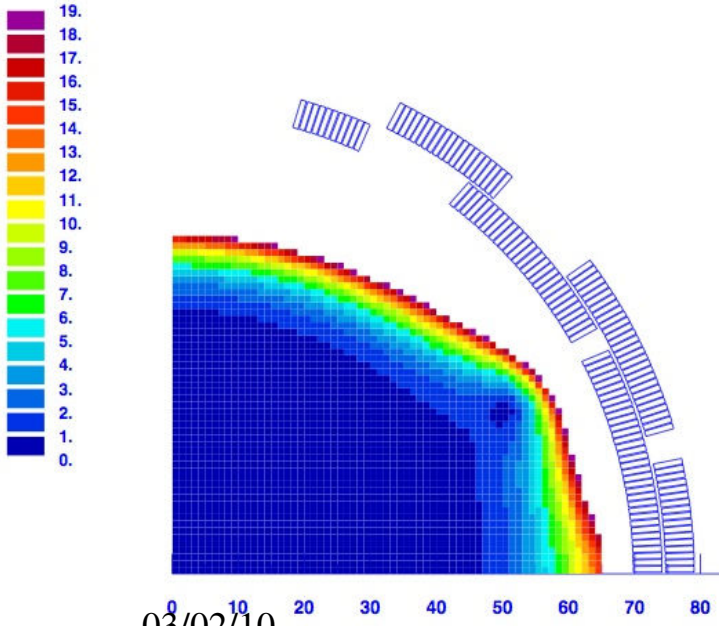
Courtesy of L. Favre

Field strength	**1.5 Tm**
Operating temp	**1.9 K**
Current	**2.4 kA**
Inductance	**10 mH**

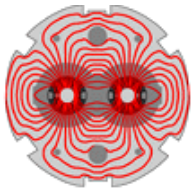
MCXB Initial 6-Block Design



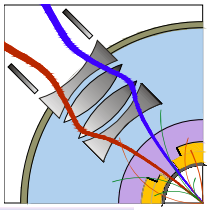


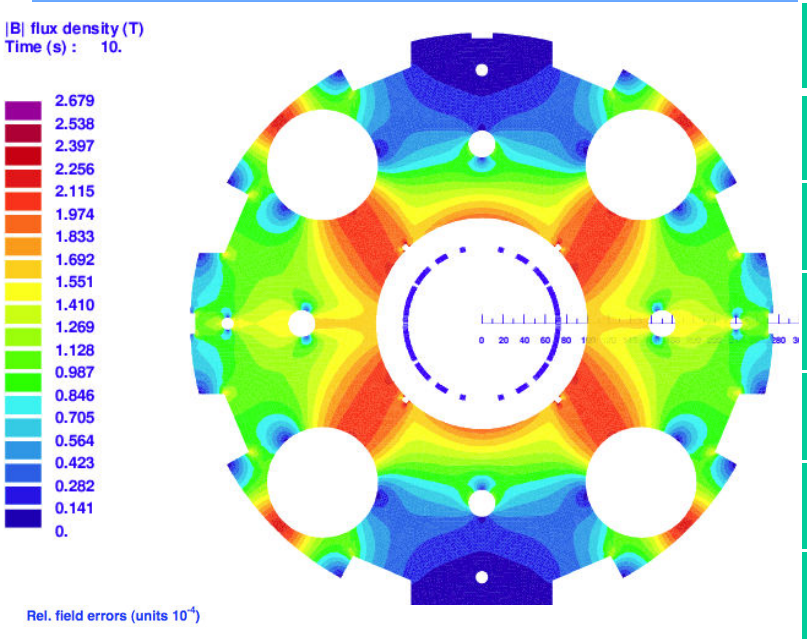


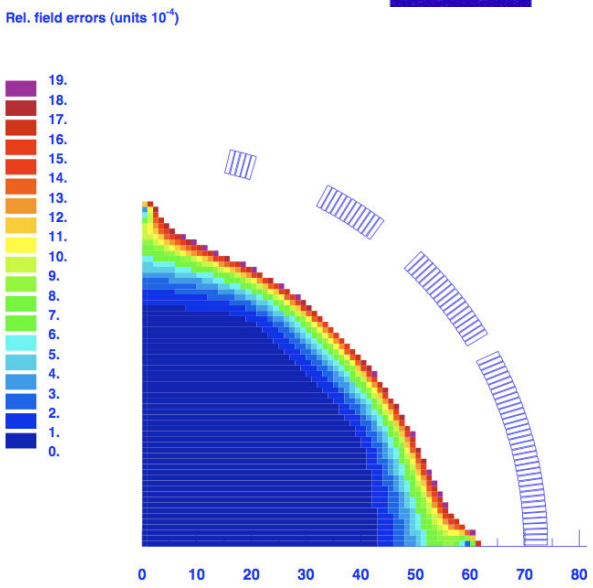
	Unit	
Integrated field	Tm	6
Nominal field	T	4.0
Mag. length	m	1.50
Nominal current	A	2438
Stored energy	kJ	233
Self inductance	mH	78
Working point		60%
Cable width/mid-height	mm	4.37 / 0.845
Total length	m	1.8..2
Aperture	mm	Ø140
Total mass	kg	~2700



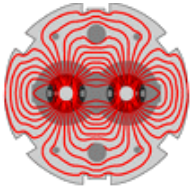
MCXB Single-Layer Design



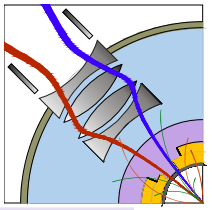




	Unit	
Integrated field	Tm	1.5
Nominal field	T	2.3
Mag. length	m	0.65
Nominal current	A	2400
Stored energy	kJ	28
Self inductance	mH	10
Working point		50%
Cable width/mid-height	mm	4.37 / 0.845
Total length	m	~1
Aperture	mm	Ø140
Total mass	kg	~2000



18-Strand Cable



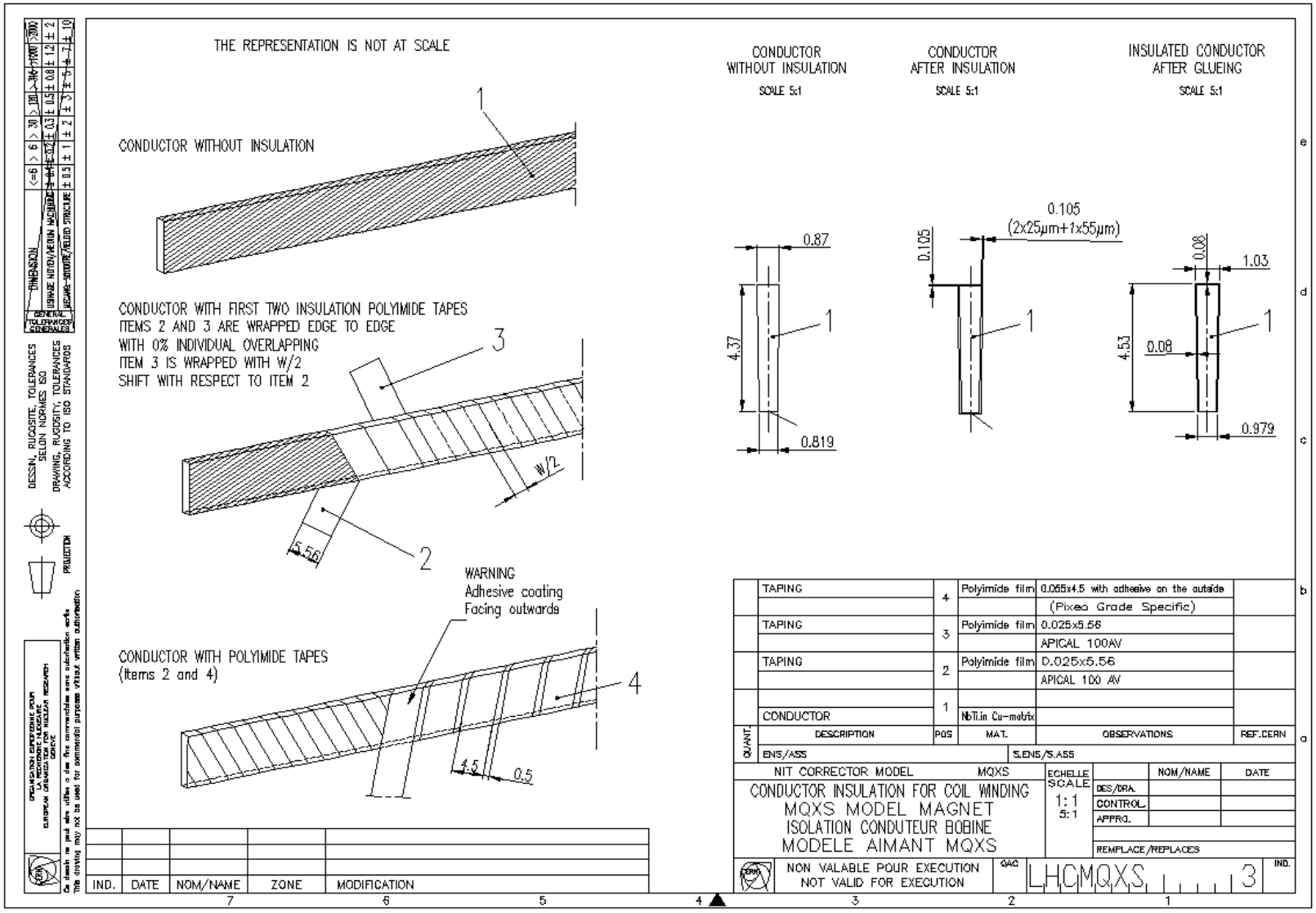
Strand parameters		
Cu:Sc	1.75	
Strand diameter	0.48	mm
Metal section	0.181	mm^2
No of filaments	2300	
Filament diam.	6.0	µm
I(5T,4.2K)	203*	A
jc	3085*	A/mm^2

*) extracted strand March -09

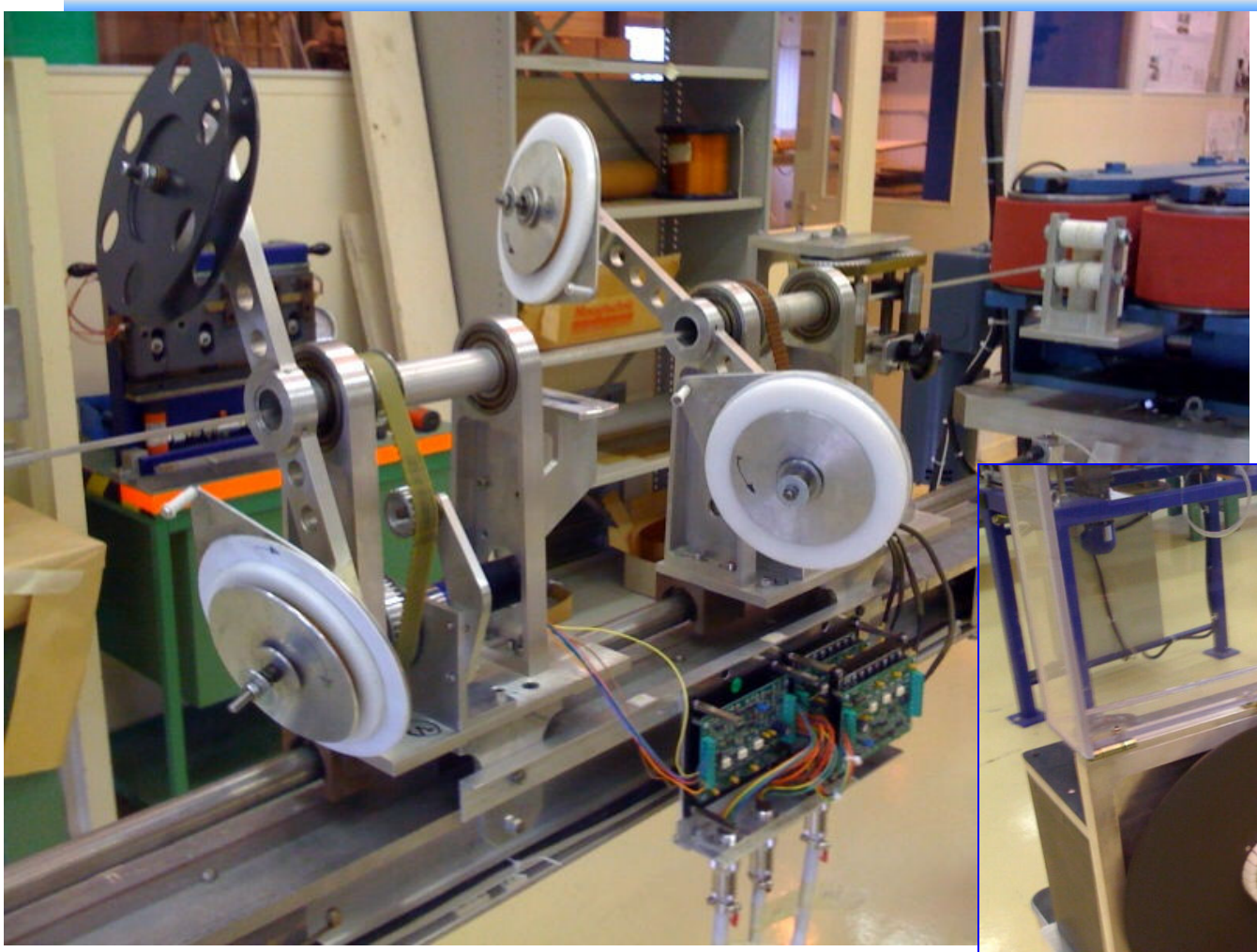
Cable Parameters		
No of strands	18	
Metal area	3.257	mm^2
Cable thickness	0.845	mm
Cable width	4.370	mm
Cable area	3.692	mm^2
Metal fraction	0.882	
Key-stone angle	0.67	degrees
Inner Thickness	0.819	mm
Outer Thickness	0.870	mm

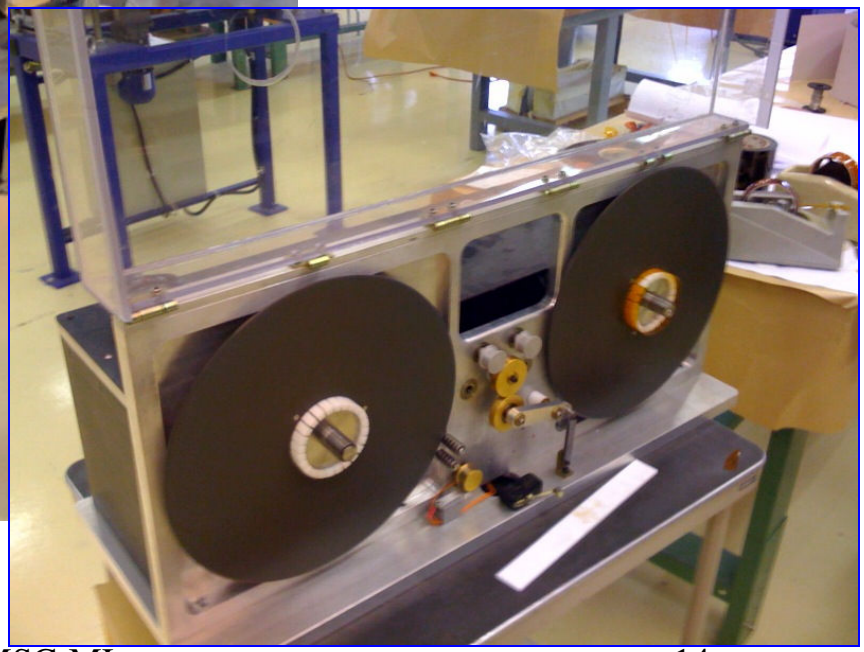
Polyimide Insulation: 2 x 25µm + 55 µm
Trial cabling length (~100 m) done!
Insulation trials & characterization in progress..

Cable Insulation

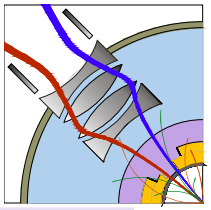


Cable insulation





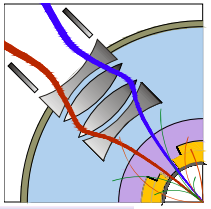
Conductor and Insulation Needs

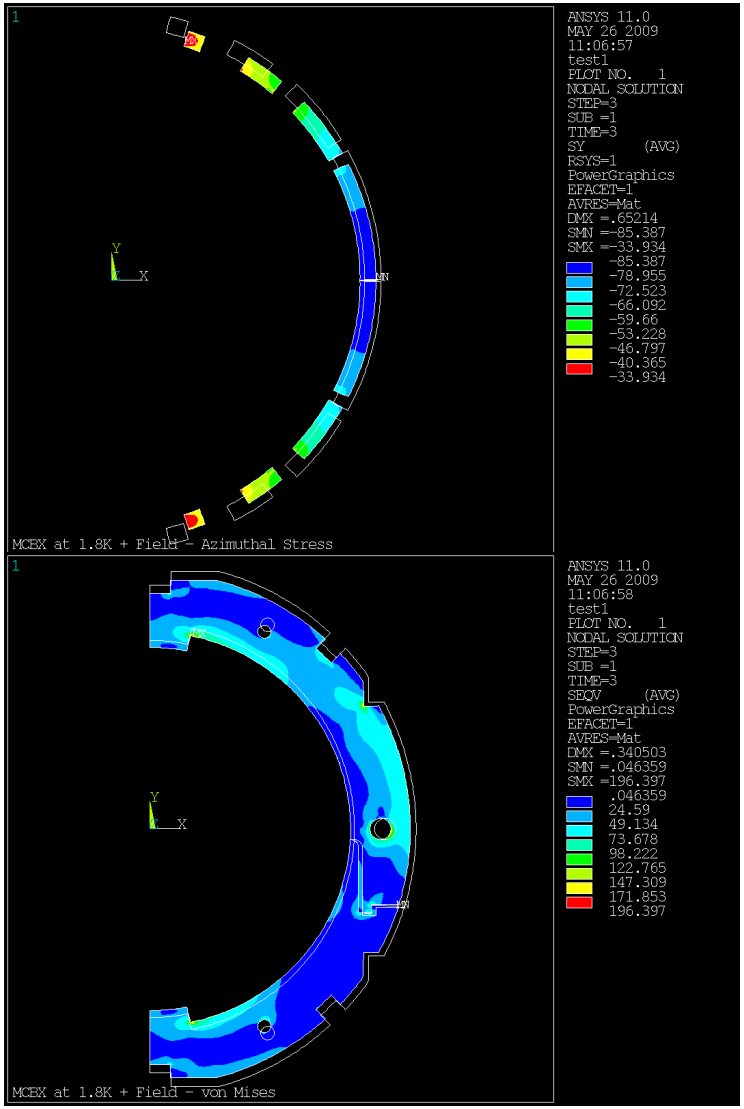


18-strand Cable	MCXB	MQSX	
Unit Cable Length	320	30	m
Total Cable Length	7.2	1.2	km
Total Strand (+5%)	136	22.7	km
Polyimide 25 µm	6	1.2	kg
Polyimide 55 µm	7	1.3	kg

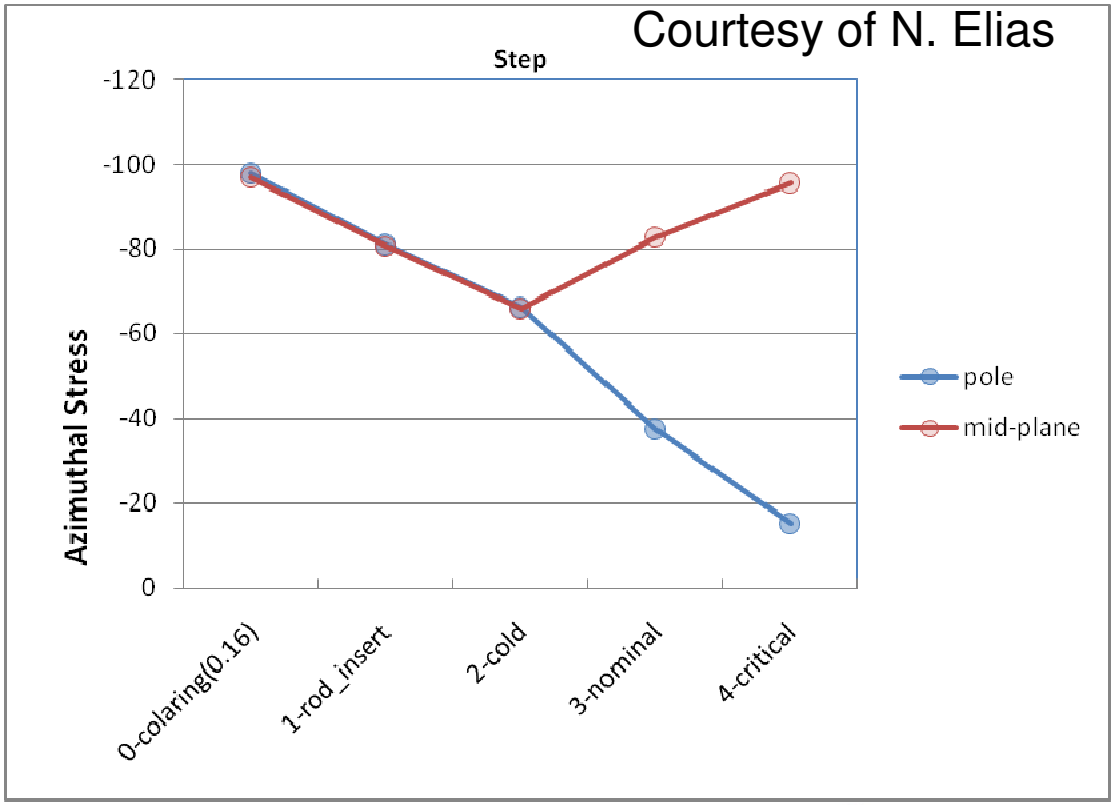
~250 km of strand in stock @CERN

MCXB 4-Block Design: FEA

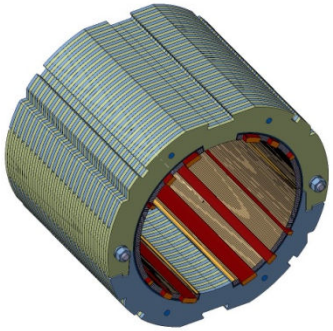


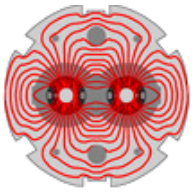


Courtesy of N. Elias

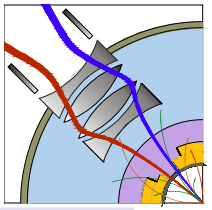


150 mm model to verify material properties and assembly parameters





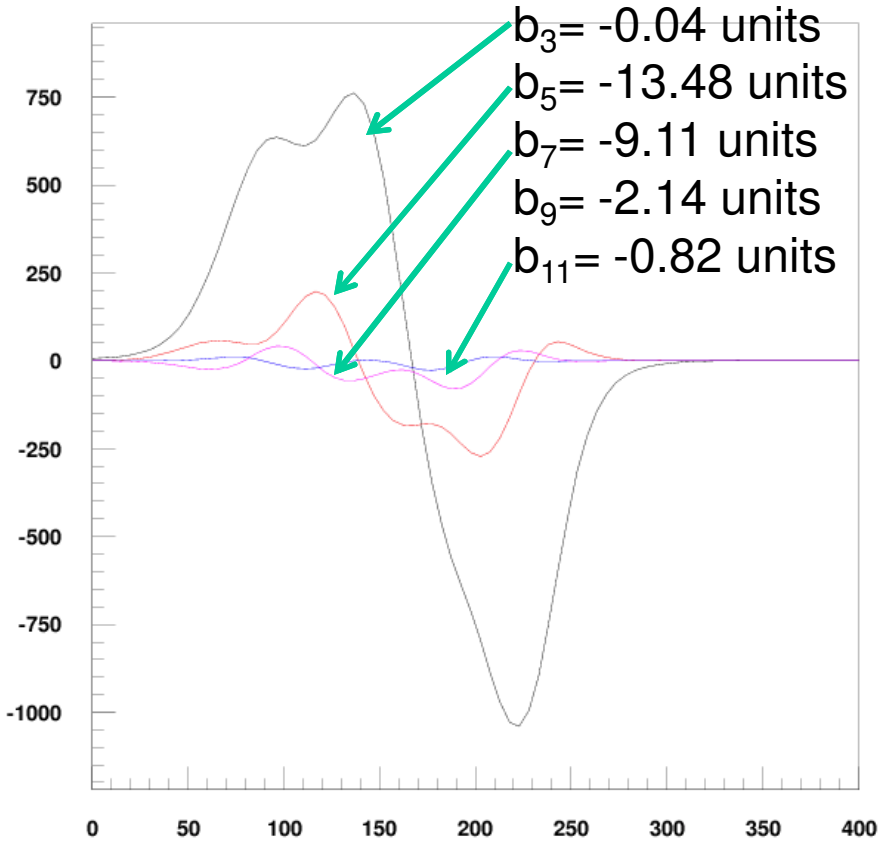
MCXB 3D (return end)

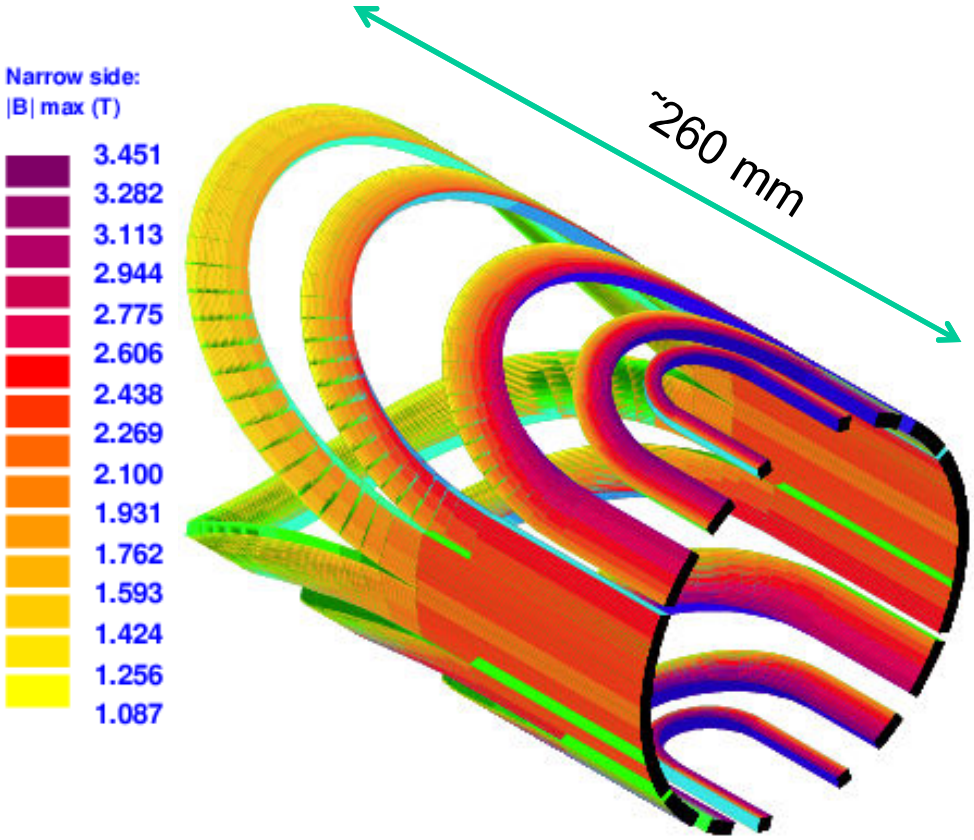


Design current = 2.4 kA
Coil length = ~0.84 m
Total length = ~1 m

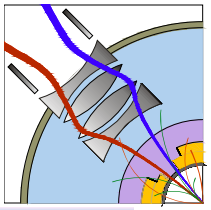
B1= 0.37 Tm x 2 + 2.28T x 0.34 m = 1.5 Tm

ENDS STRAIGHT



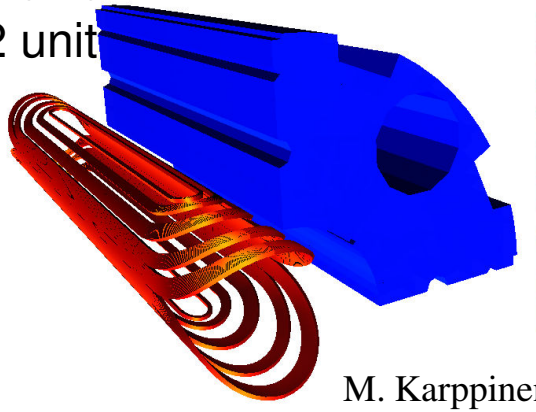


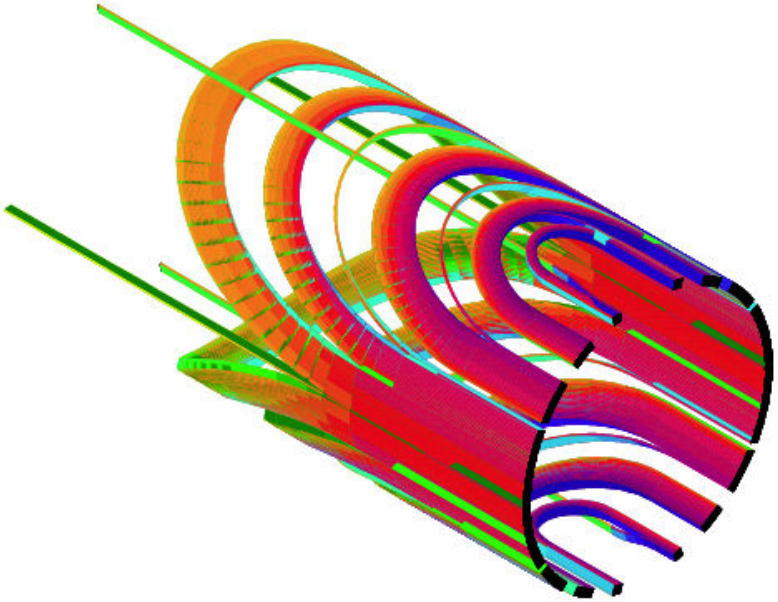
MCXB 3D Harmonics



Integrated Field (2.4 kA)

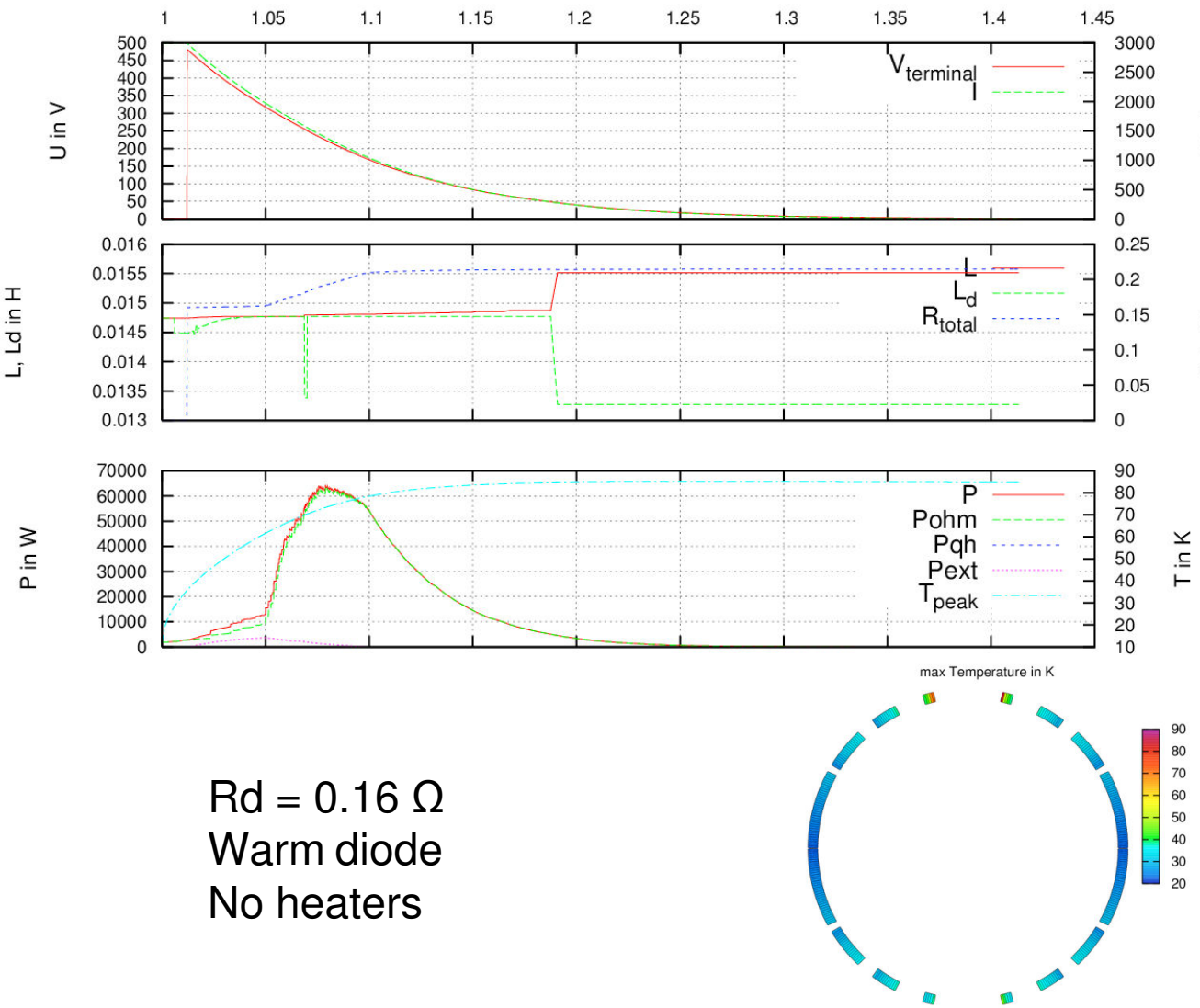
B1	1.5 Tm
b3	0.20 unit
b5	-3.59 unit
b7	-4.46 unit
b9	-0.84 unit
b11	-0.41 unit
a1	-22.71 unit
a3	6.32 unit
a5	-0.52 unit
a7	-0.07 unit
a9	0.03 unit
a11	-0.02 unit

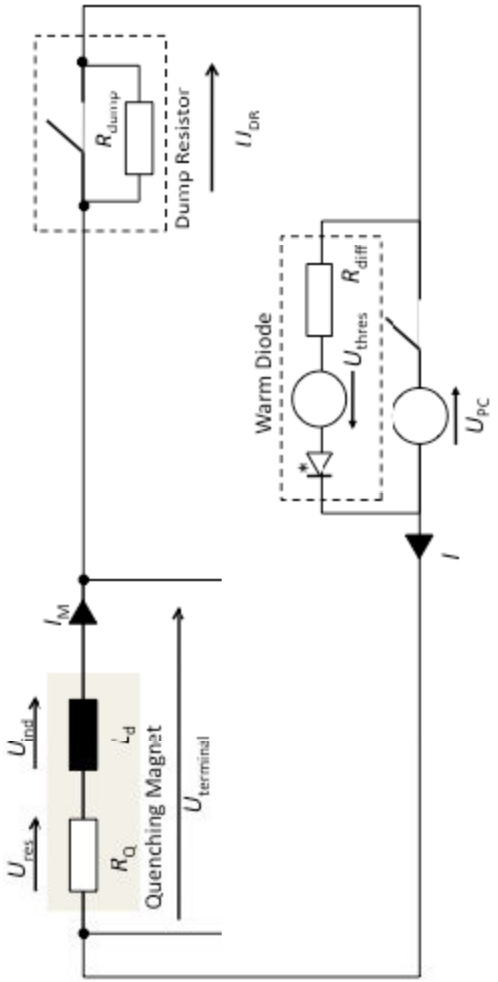




ROXIE 10.1

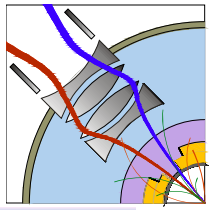
MCXB 4-Block Design Quench (3kA)

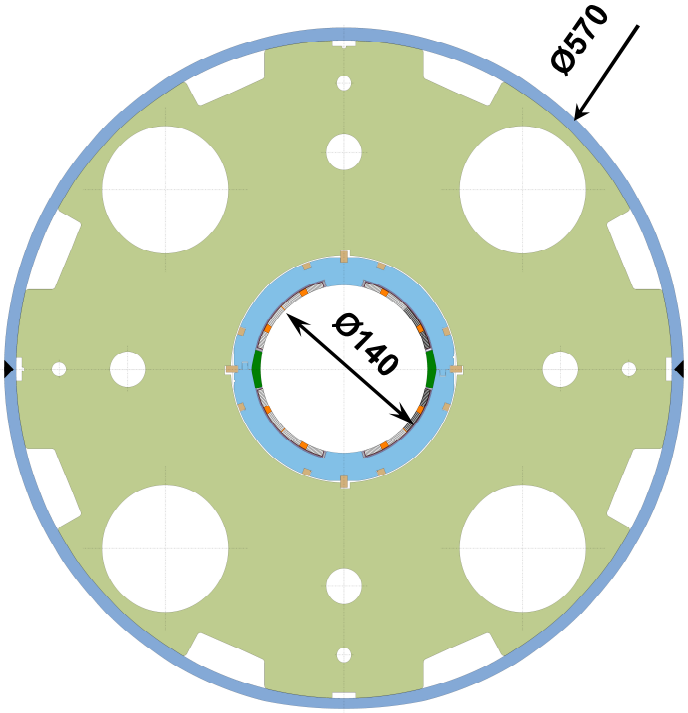


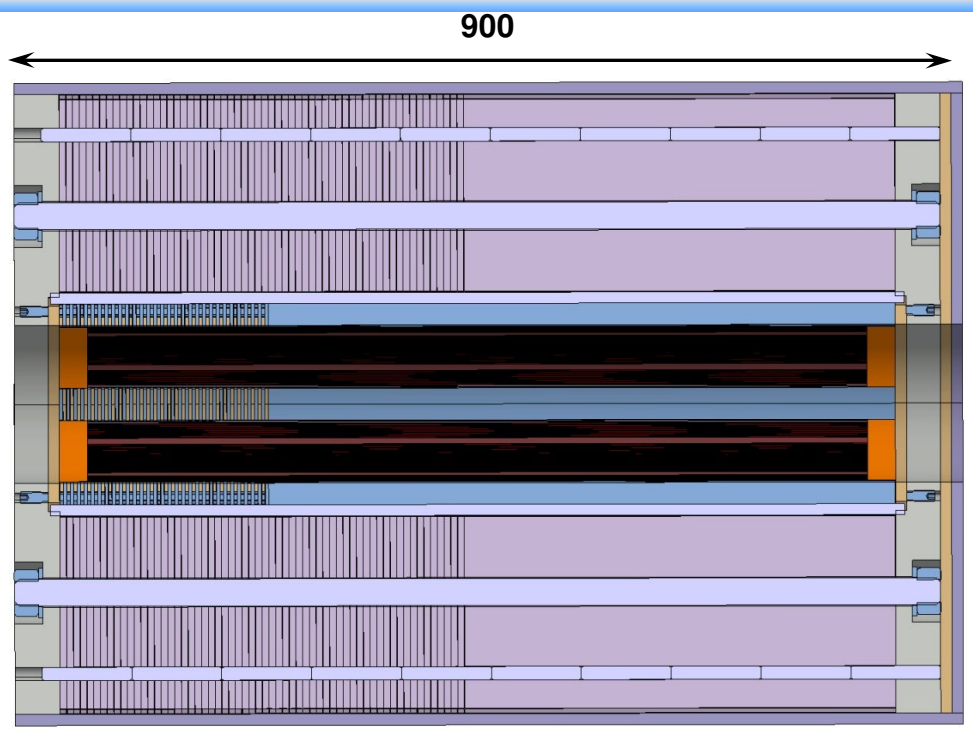


Rd = 0.16 Ω
Warm diode
No heaters

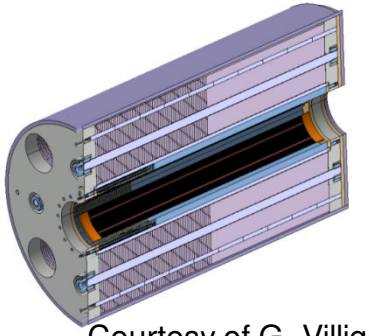
MQXS Assembly







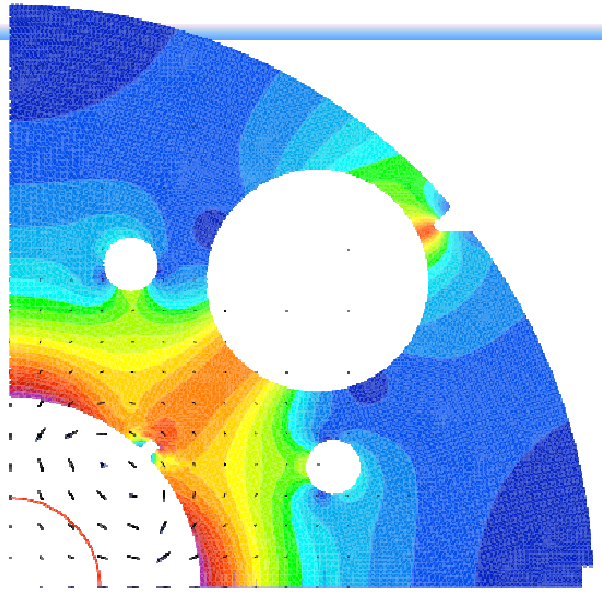
New 4.37 mm cable & Polyimide insulation
Single layer coils
Self-supporting collars
Single piece yoke



Courtesy of G. Villiger

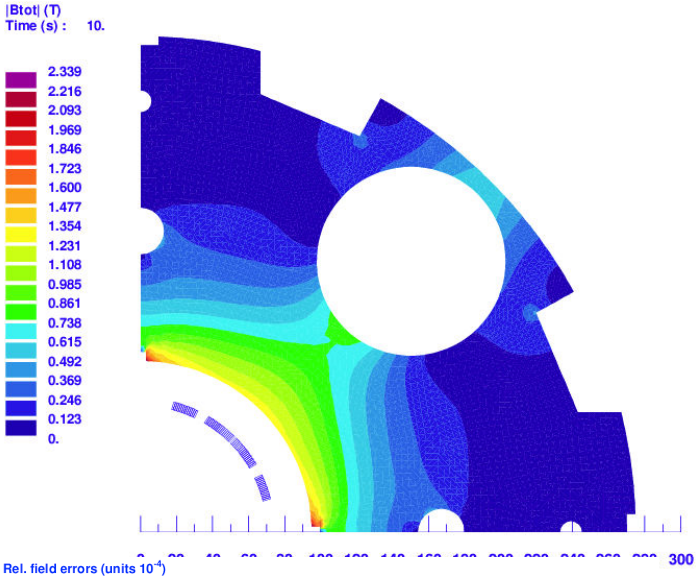
Field strength	**0.65 Tm**
Gradient	**25.5 T/m**
Operating temp	**1.9 K**
Current	**2.4 kA**
Inductance	**3.3 mH**

MQSX Initial 2-Layer Design



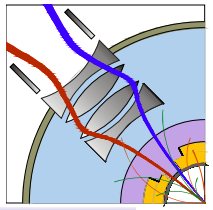
	Unit	
Nominal gradient	T/m	40
Mag. length	m	0.5
Nominal current	A	1602
Stored energy	kJ	19.1
Self inductance	mH	15
Working point		<55%
Cable width/mid-height	mm	3.40 / 0.845
Cu/Sc		1.2
Total length	m	~0.8
Aperture	mm	ø140
Total mass	kg	~500

MQSX Single-Layer Base-Line Design



	Unit	
Nominal gradient	T/m	21
Mag. length	m	0.64
Nominal current	A	2400
Stored energy	kJ	8.8
Self inductance	mH	3.0
Working point		44 %
Cable width/mid-height	mm	4.37 / 0.845
Cu/Sc		1.2
Total length	m	~0.9
Aperture	mm	ø140
Total mass	kg	~500

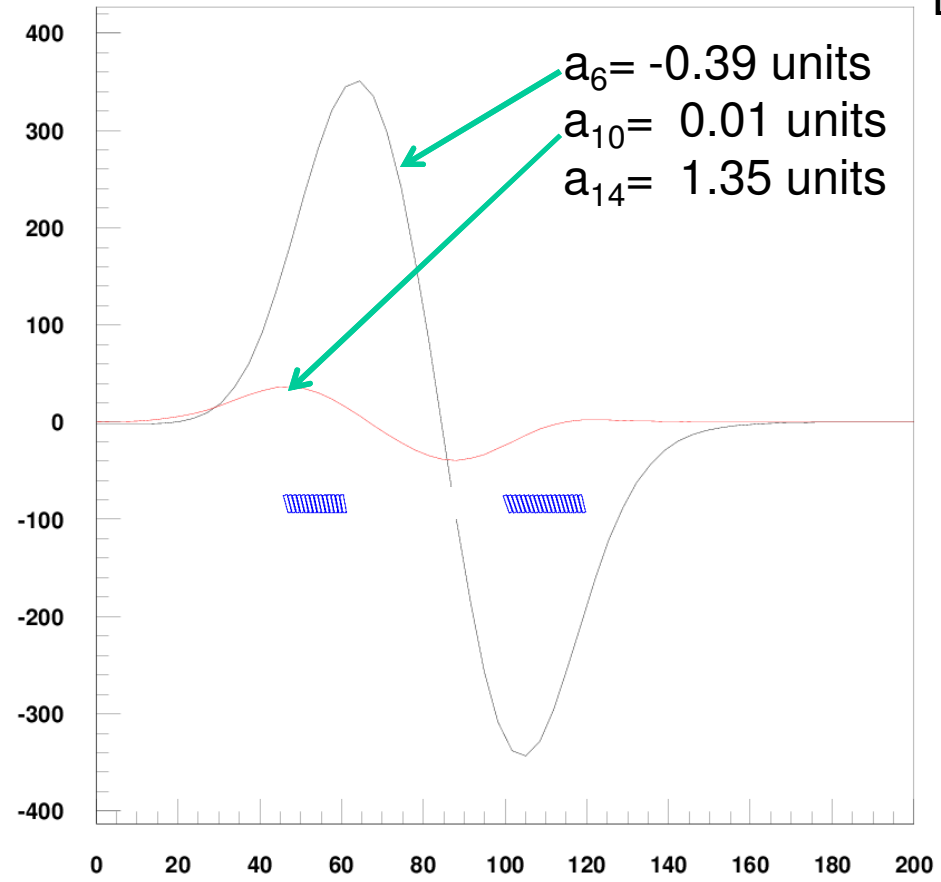
MQSX 3D (return end)

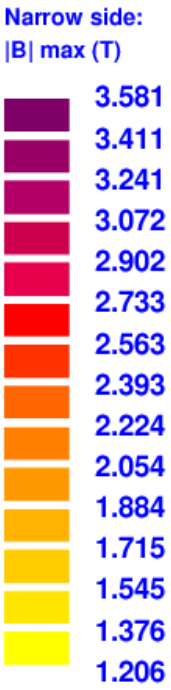


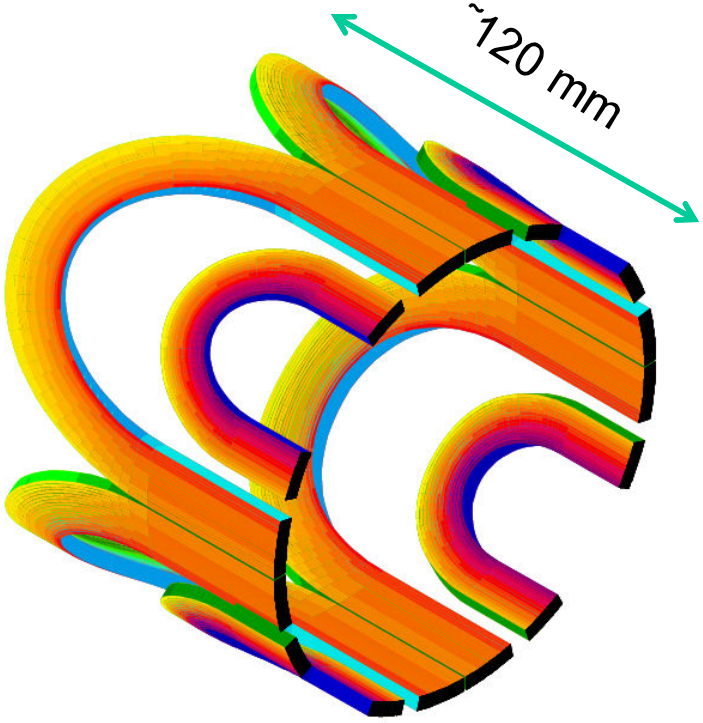
Design current = 2.4 kA
Coil length = 0.7 m
Total length = ~0.9 m

A2(40 mm)= 0.087 Tm x 2 + 1.02 T/m x 0.47 m = 0.65Tm

ENDS STRAIGHT



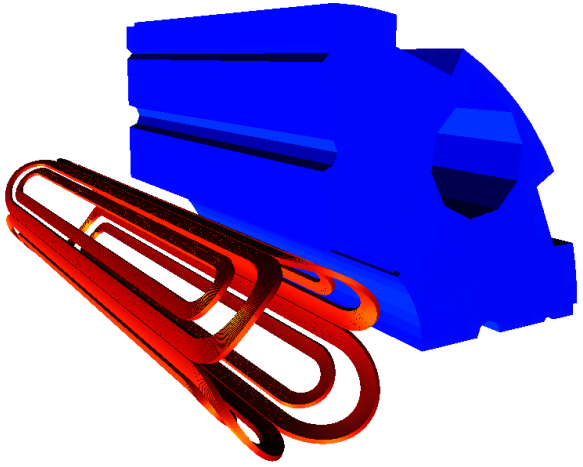


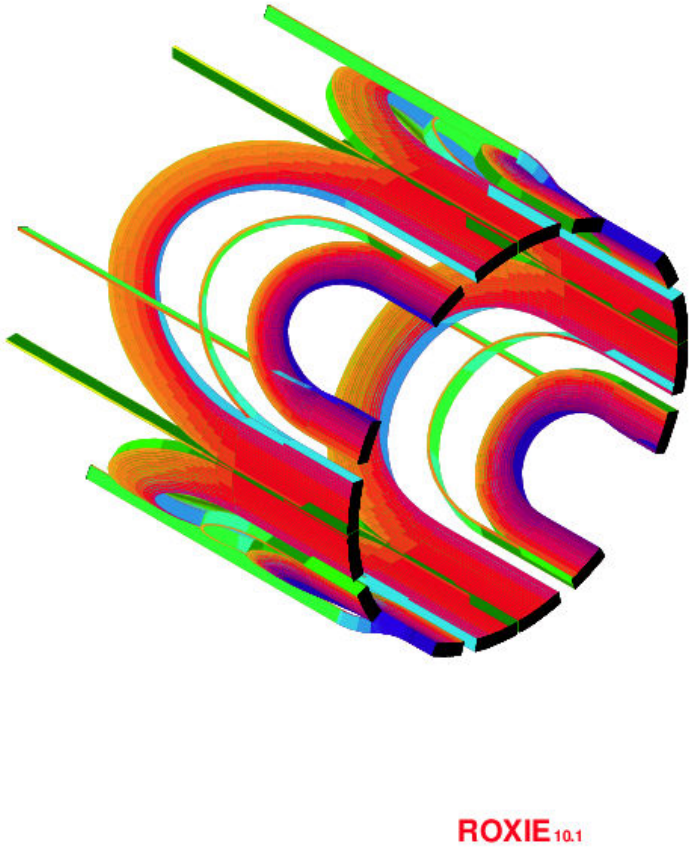


MQSX 3D harmonics

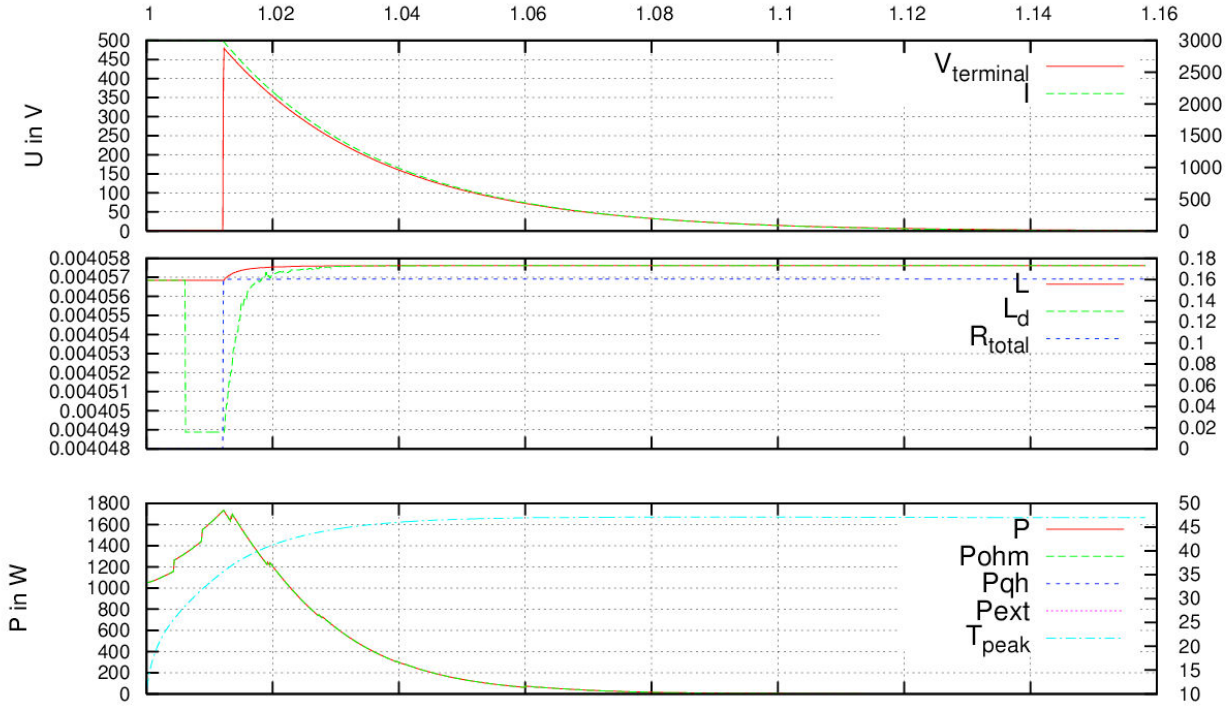
Integrated Field (2.4 kA)

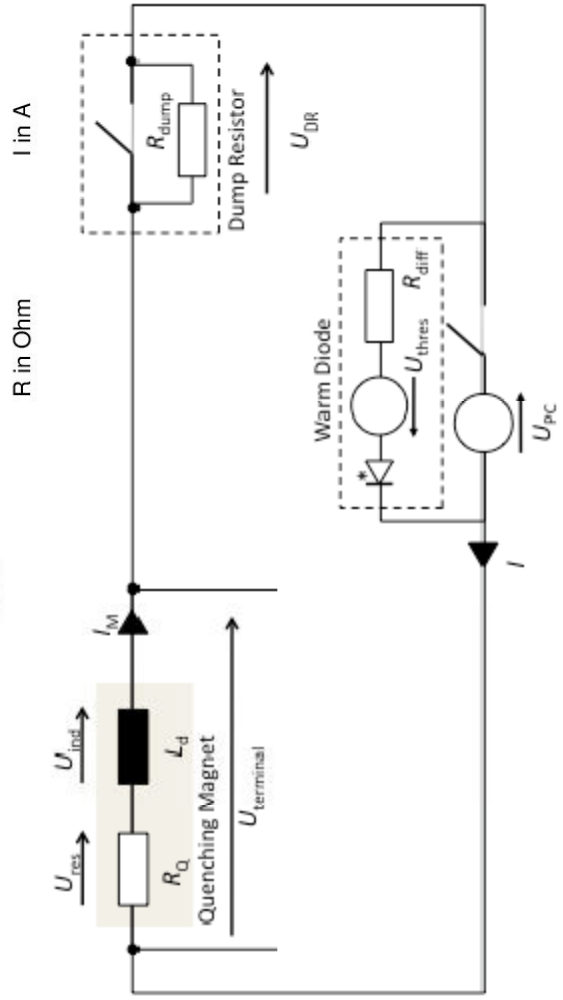
A2	0.65 Tm
a6	0.04 unit
a10	0.25 unit
a14	-1.37 unit
b2	19.59 unit
b6	0.49 unit
b10	-0.08 unit
b14	-0.01 unit

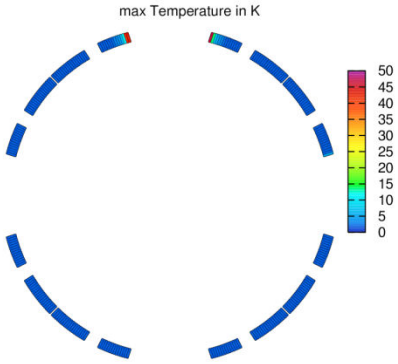




MQSX Single Layer Design Quench (3kA)

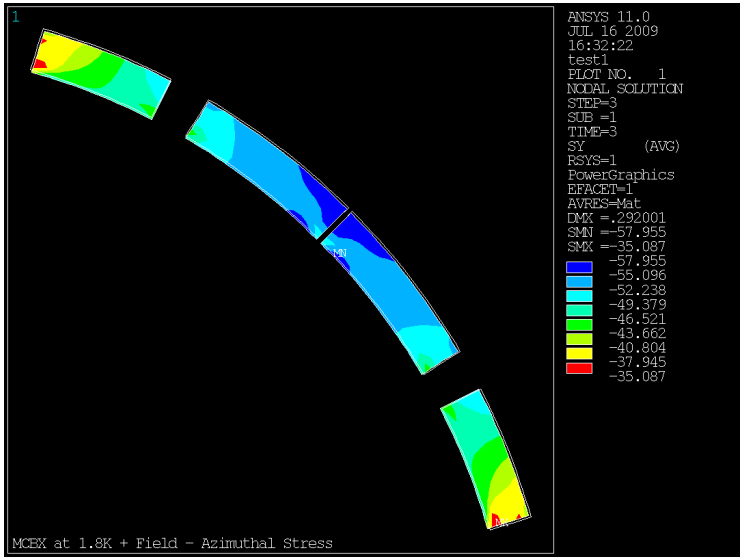


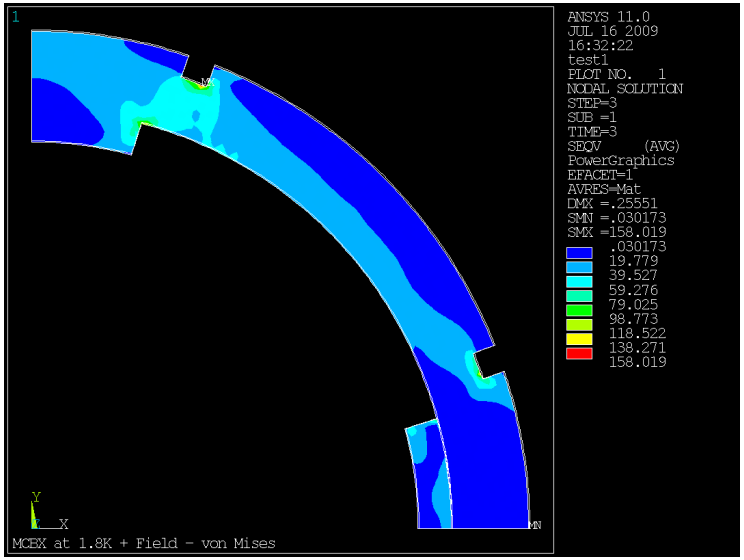


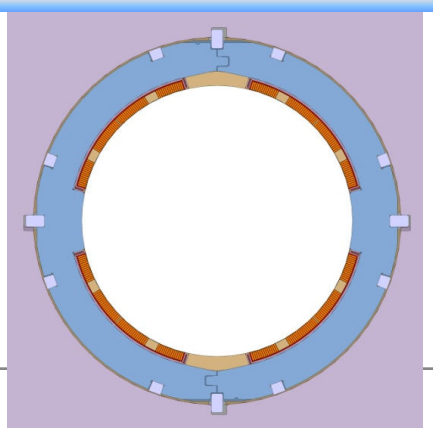


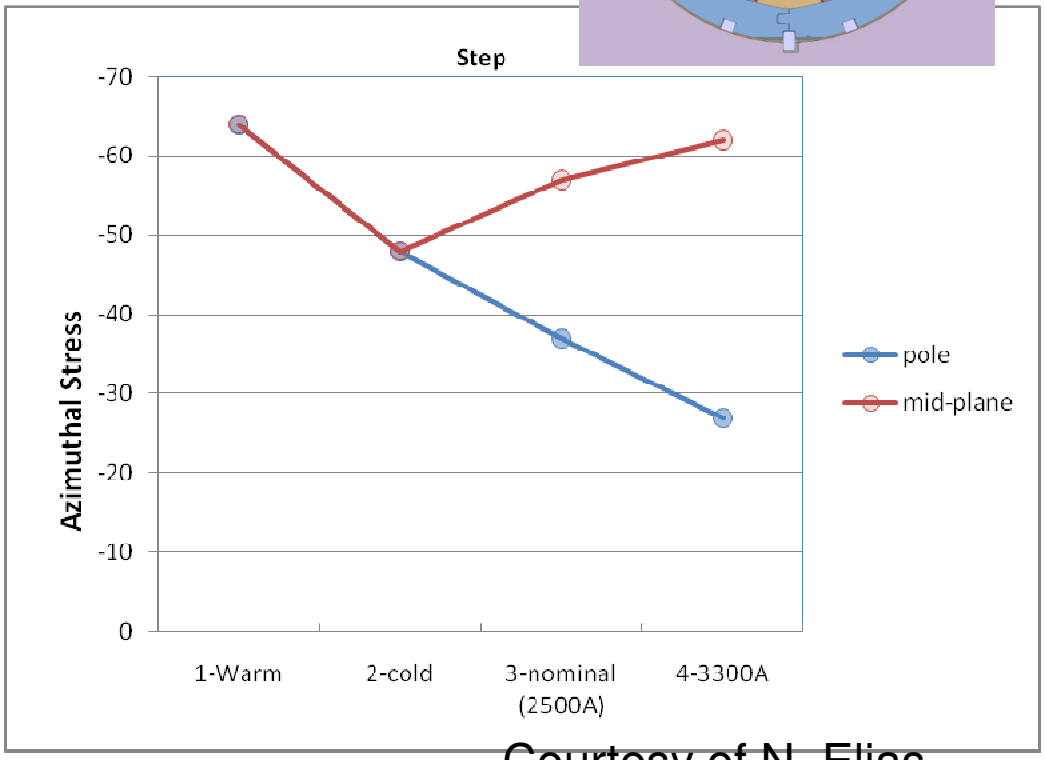
Rd = 0.16 Ω
Warm diode
No heaters

MQXS Single-Layer Design: FEA



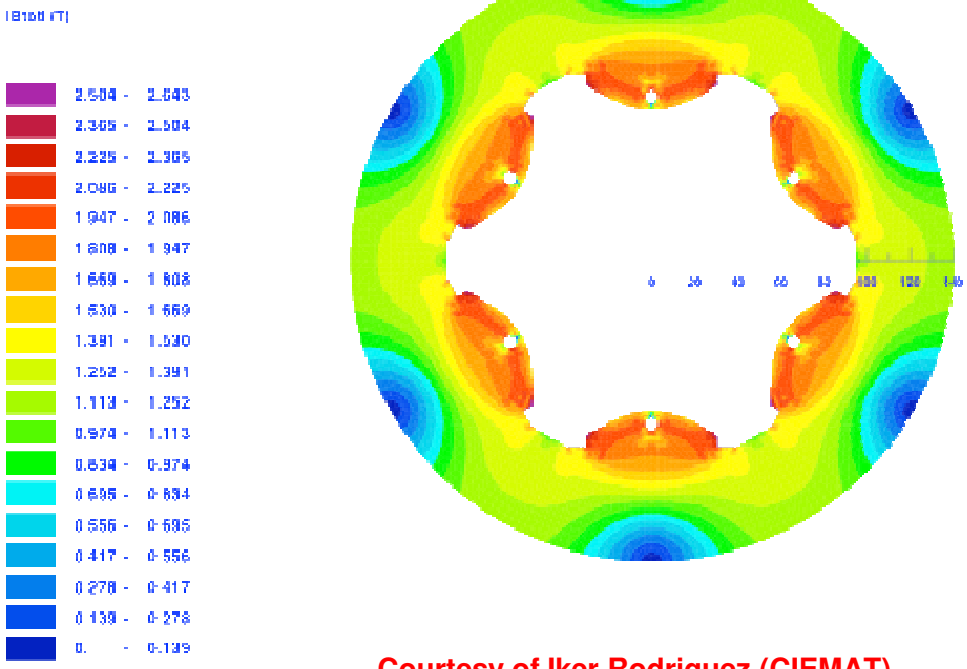






Courtesy of N. Elias

Super-ferric MCSX



Courtesy of Iker Rodriguez (CIEMAT)

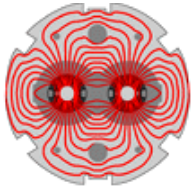
2D DESIGN

	Value	Units
Nominal current	**113.63**	A
Bare wire diameter	**0.65**	mm
Insulation thickness	**0.025**	mm
Cu/Sc	**1.3**	
Filament size	**8**	µm
Number of turns	**264**	
Aperture	**140**	mm
Reference radius	**40**	mm
Gradient	**313.75**	T/m^2
Nominal field	**0.502**	T
b9	**-0.201**	1E-4
b15	**-0.092**	1E-4
b21	**-0.003**	1E-4
Non-linearity in the load line	**5**	%
Coil peak field	**1.537**	T
Working point @ 4.2 K	**38.3**	%
Working point @ 2 K	**29.8**	%
Iron outer radius	**140**	mm
Self inductance	**1.65**	H/m
Stored magnetic energy	**10.65**	kJ/m
F∥ per half coil	**15455**	N/m
F⊥ per half coil	**28746**	N/m

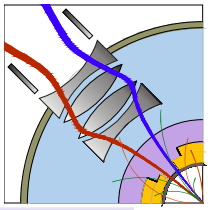
- Design report in progress
- This concept is no longer compatible with the requirements
- Updated scope of CIEMAT's involvement being discussed

3D DESIGN

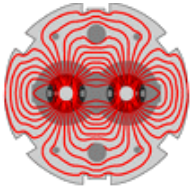
	Value	Units
Effective length	**0.275**	m
Integrated strength	**0.1377**	Tm
3D b9	**-0.212**	1E-4
3D b15	**-0.068**	1E-4
3D b21	**-0.001**	1E-4
Iron length	**260**	mm
Iron weight	**82**	kg



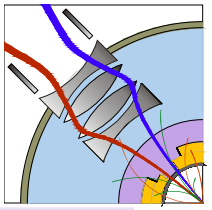
Next steps…



- Optics studies => Confirm parameters & Lay-out **(getting there..)**
- Cabling & insulation trials and characterization **(in progress..)**
- Detailed fabrication design (magnet & tooling) **(in progress..)**
- Model magnet construction (MCXB, MQXS)
- Feasibility study of combined H-V orbit corrector **(in progress..)**
  - Material R&D, Trials, Magnet model..?
- Higher order correctors
  - Magnetic and mechanical designs (Feb -10 .. Sep -10)
  - Material R&D (Mar -10 .. Nov -10)
  - Conductor procurement (Aug -10 .. Jul -11)
  - Model/prototype magnets construction (Jul -11..May -12)

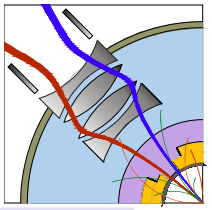


Milestones… (MCXB & MQXS)



• Parameter list	Oct-09..Jan-10
• Magnetic and mechanical design	Nov-09
• Fabrication drawings	May-10
• Trial coils	Jul-10
• Mechanical model	May-10 & Jul -10
• Model magnets completed	Dec-10
• Technical specifications	Mar-11
• Industrial contracts	Jul-11
• Pre-series magnets	Jul-12
• Series production	Sep-12 .. Dec-13

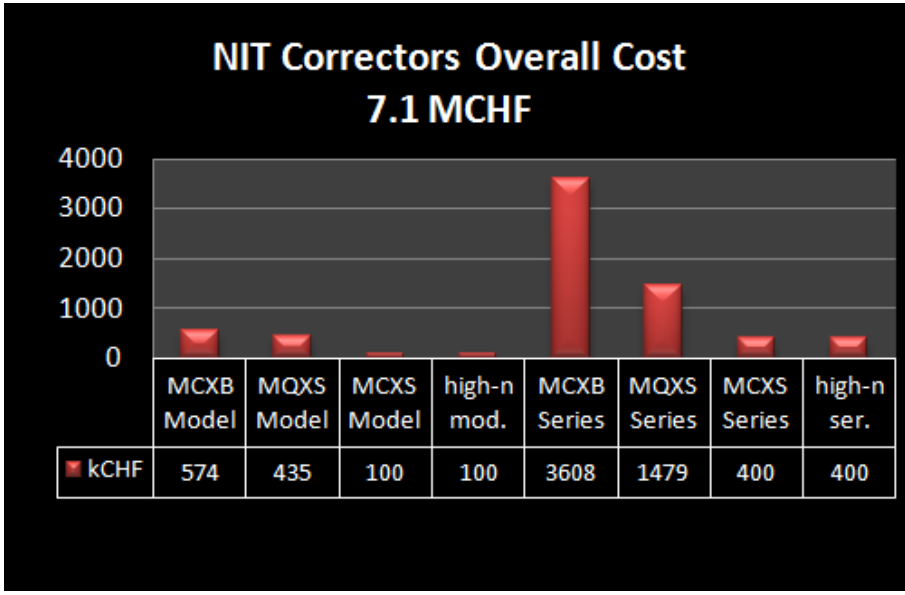
Preliminary Cost-estimate

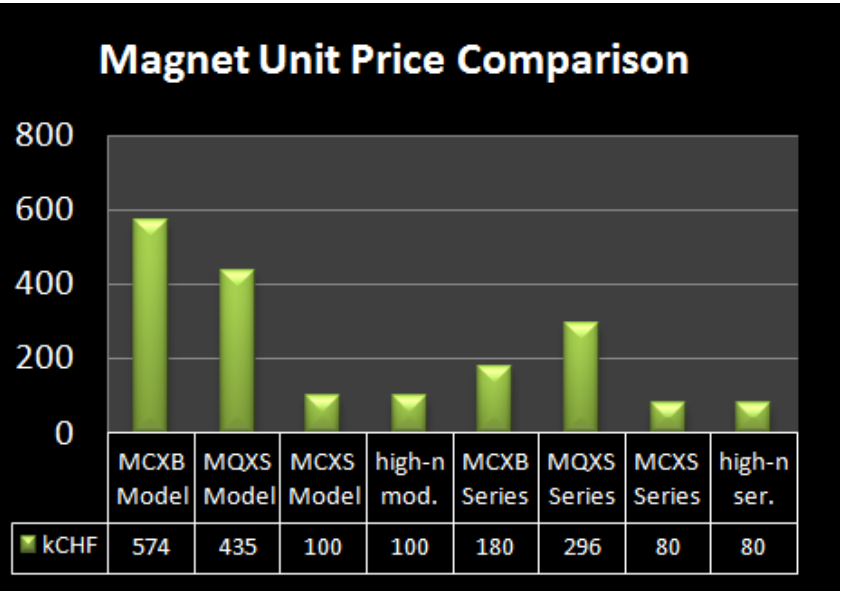


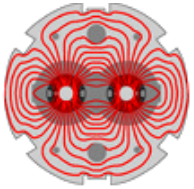
LHC IR Upgrade - NIT Corrector Magnets / Models & Series / Global Costing

Global Cost MCXB (1Model + 20 off series)	**MCHF**	**4.18**	***3.2***
Global Cost MQXS (1 Model + 5 off series)	**MCHF**	**1.91**	***1.3***
Estimate MCXS (Model: 0.1Mo + 5 off series: 0.4Mo)	*MCHF*	*0.50*	*0.50*
Estimate High Order Multipoles (1+1 models, 5+5 series)	*MCHF*	*0.50*	*0.50*
Total for NIT Correctors excl. High Order Multipoles	**MCHF**	**7.10**	**5.48**

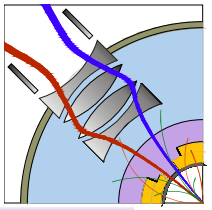
Low Profile Costing, considering free material (SC cable, steel for collars, iron for laminations), and Contractors already equipped with curing press and collaring press.







Yet To Define…



- Integration & Parameters
  - Final optics, Orbit correction scheme, error tables
  - Bus-bar routing and X-sections
  - Cold-mass & Cryo-magnet integration
  - QPS design and lay-out
- Contractual
  - Scope of Special French contribution
  - Industrial procurement and/or in-house production
  - Testing
- Funding..