HL-LHC: UPDATE ON MAGNETS

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With relevant inputs from colleagues
M. Bajko, A. Ballarino, O. Bruning, R. De Maria, F. Cerutti, L. Rossi, …

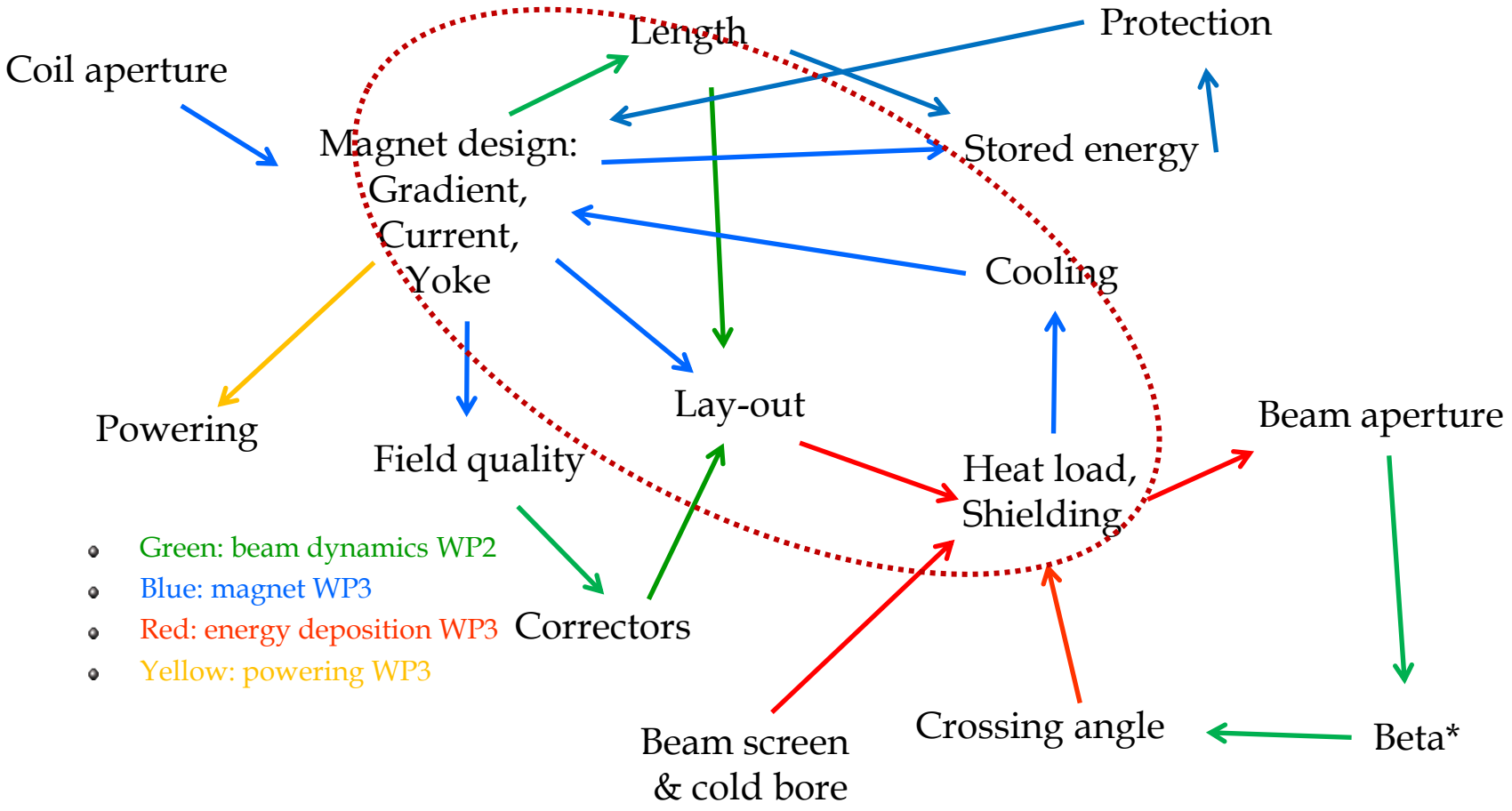
MAIN UPDATES

- The starting point: two technologies, two apertures
  - We focused on the 140 mm Nb_3Sn that provides more performance

Technology		Nb-Ti	Nb-Ti	Nb3Sn	Nb3Sn
Aperture	(mm)	140	120	140	120
Name		MQXD	MQXC	MQXF	MQXE
Gradient	(T/m)	100	118	150	170
Q1-Q3 length	(m)	10.6	9.5	7.7	7.2
Q2 length	(m)	8.7	8.0	6.6	6.2
Total length	(m)	38.6	34.9	28.5	26.8
Current	(kA)	12.5	12.9	15.4	14.7
Triplet differential inductance	(H)	225	167	251	190
Triplet stored energy	(MJ)	19.4	14.4	34.8	26.4

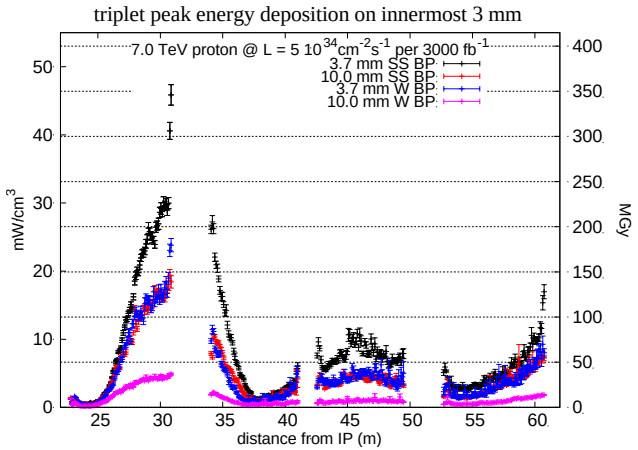
LAY-OUT FOR THE LUMINOSITY UPGRADE

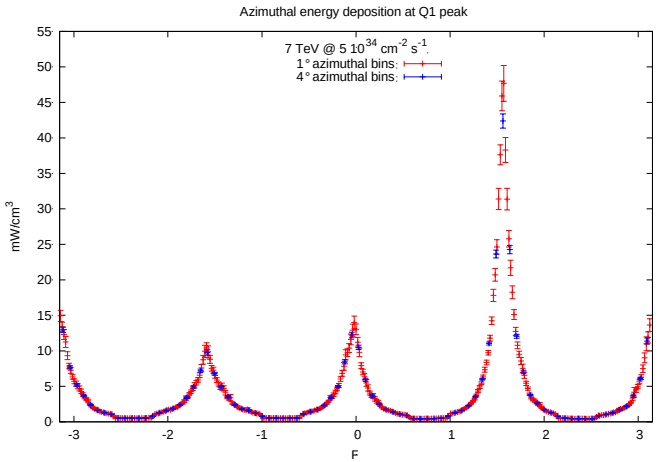
- First iteration for energy deposition, shielding, and cooling



TRIPLET APERTURE

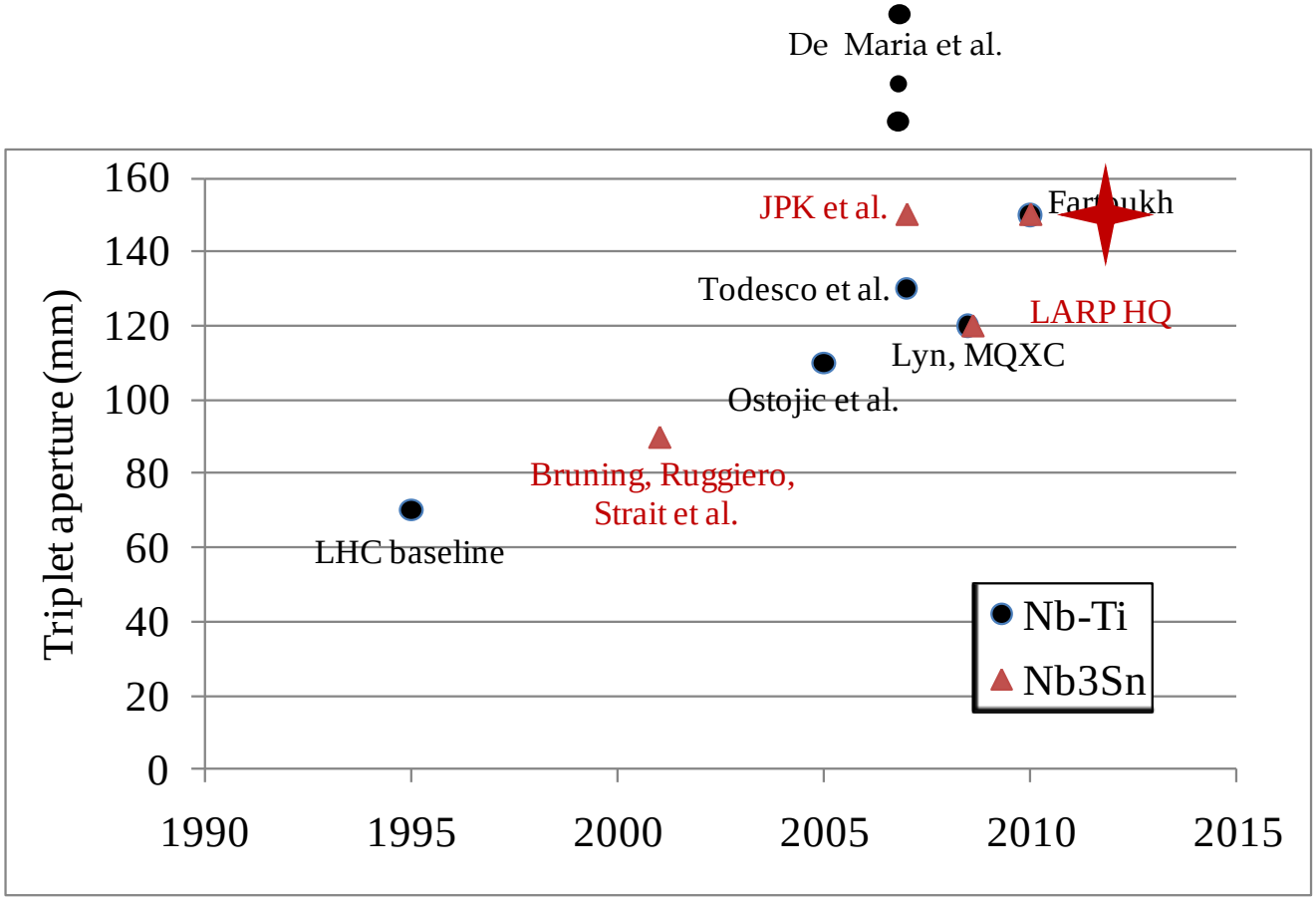
- First loop between energy deposition, shielding and heat loads has been done for the 140 mm Nb3Sn lay out
- Outcome: limiting factor is the radiation damage and not heat load
  - Tentative value of 40 MGy assumed
    - Studies on limits on present technology, and considering other ones
    - Weak point is impregnation of the magnet
  - One can gain a further factor two in Q1





Energy deposition for the 140 mm case [F. Cerutti, L. Esposito]

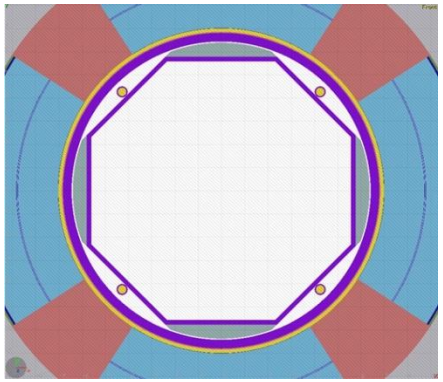
APERTURE CHOICE FOR THE TRIPLET



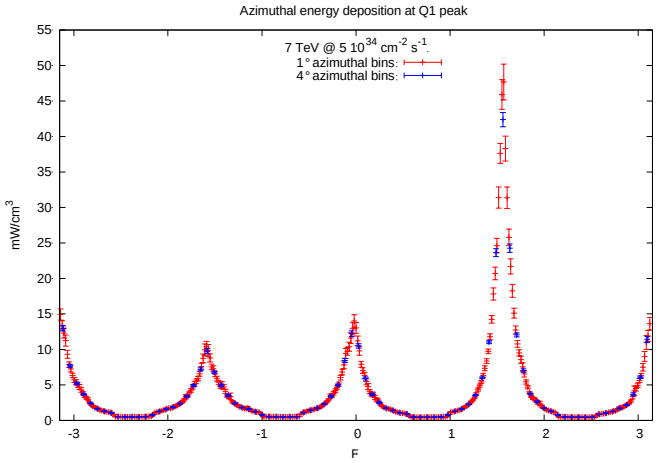
Aperture versus time, and decision for HL LHC

TRIPLET APERTURE AND SHIELDING

- Tungsten shielding of about 6 mm thickness
  - Similar shape as for phase I
- Beam screen: better to keep
  - Allow to intercept 500 out of 1000 before than in reaches the coil, at higher temperature
- All together the shielding will take at least 30 mm in aperture (plus non negligible tolerances)
  - Main reason to go from 140 to 150 mm to keep performance target

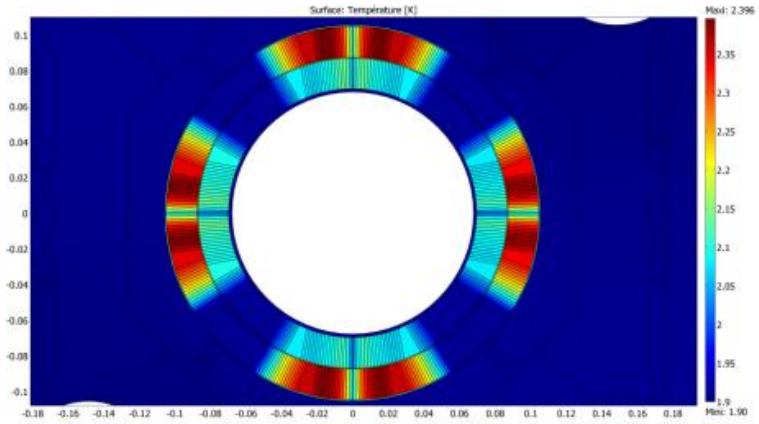


Sketch of beam screen and cold bore [R. Kersevan]

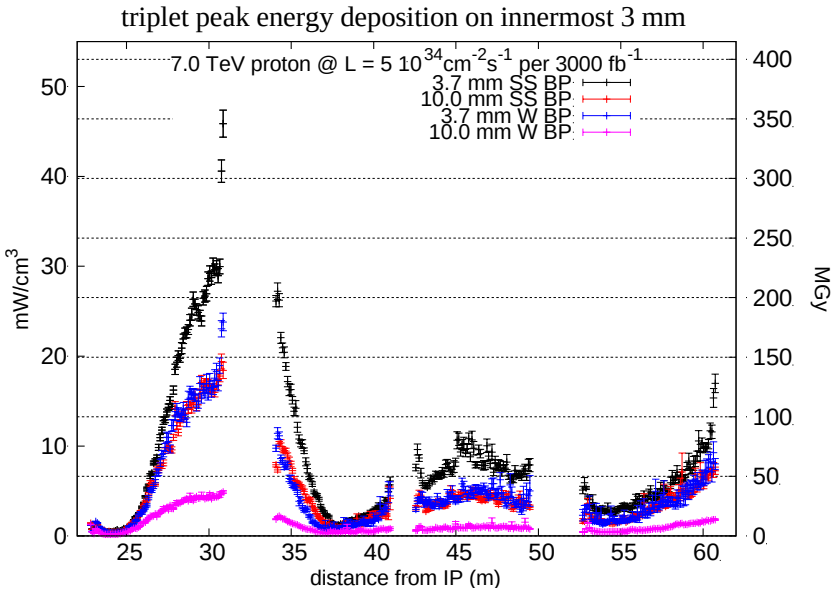


HEAT LOADS

- With 40 MGy, one has about 5 mW/cm^3 peak heat load
  - Typical limit assumed in literature was 12 mW/cm^3

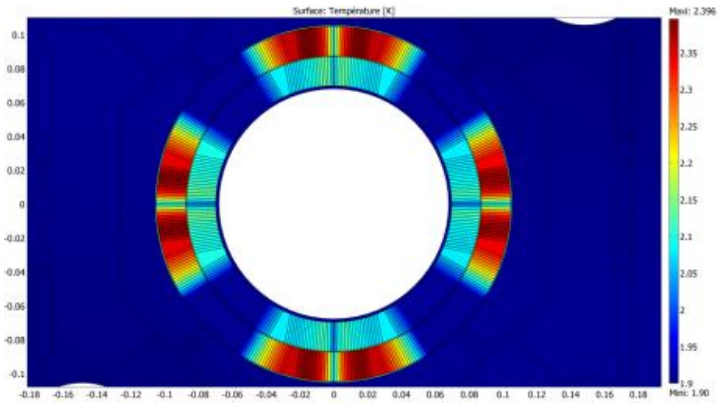


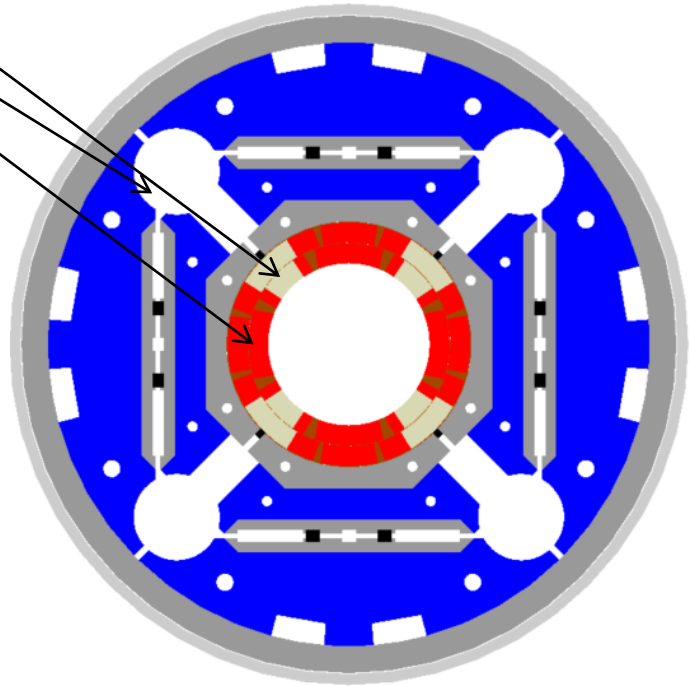
Heat temperature in the coil [R. Van Weelderen, A. Herve]



HEAT LOADS

- First indications of features to be included in the cold mass design
  - Opening of the coil pole
  - Size of the heat exchangers
  - Possible openings in the midplane
- Aim at having a $\Delta t \sim 0.5$ K
  - With a min temp margin of 5 K

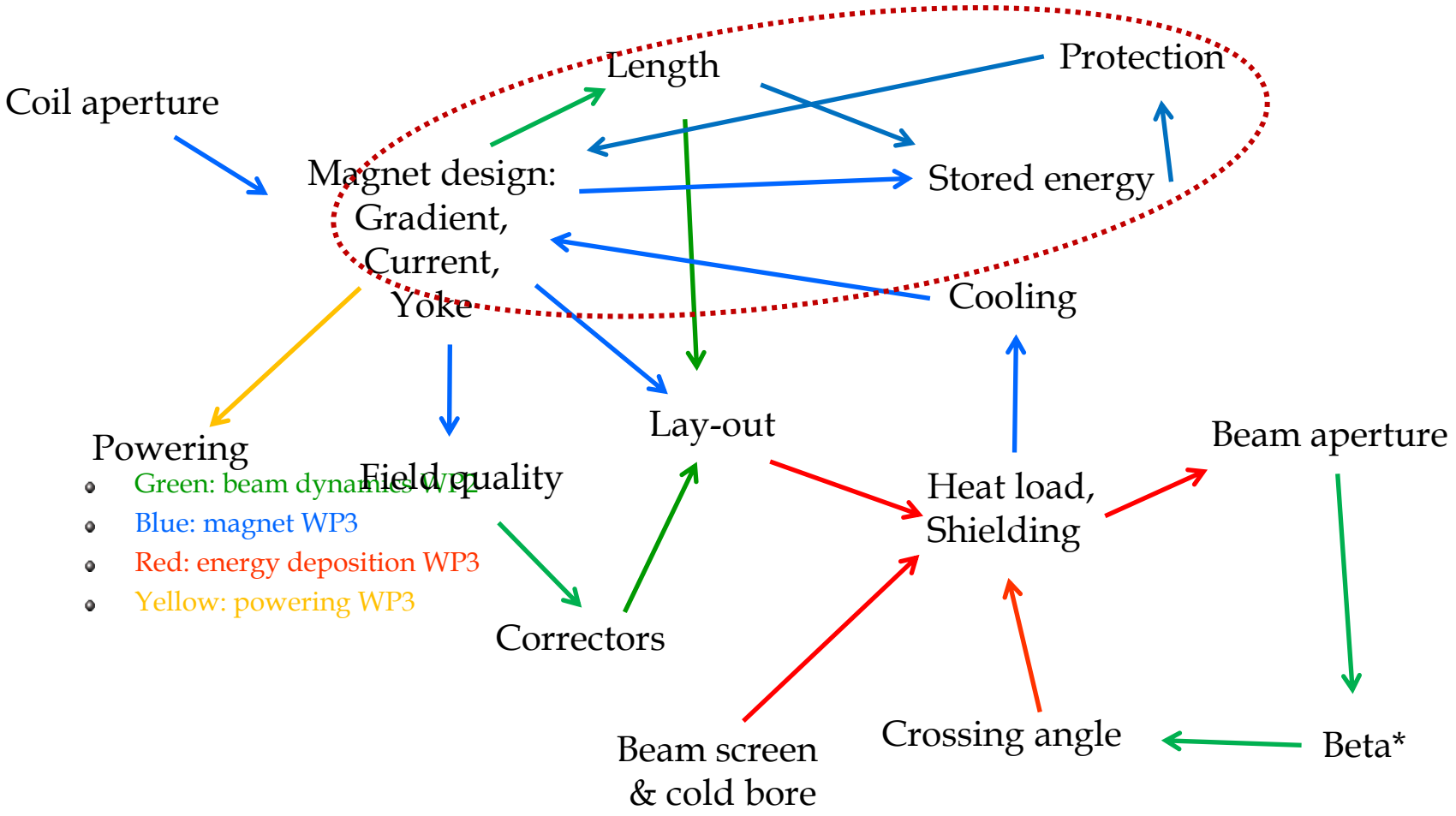




Tentative cold mass design [P. Ferracin]

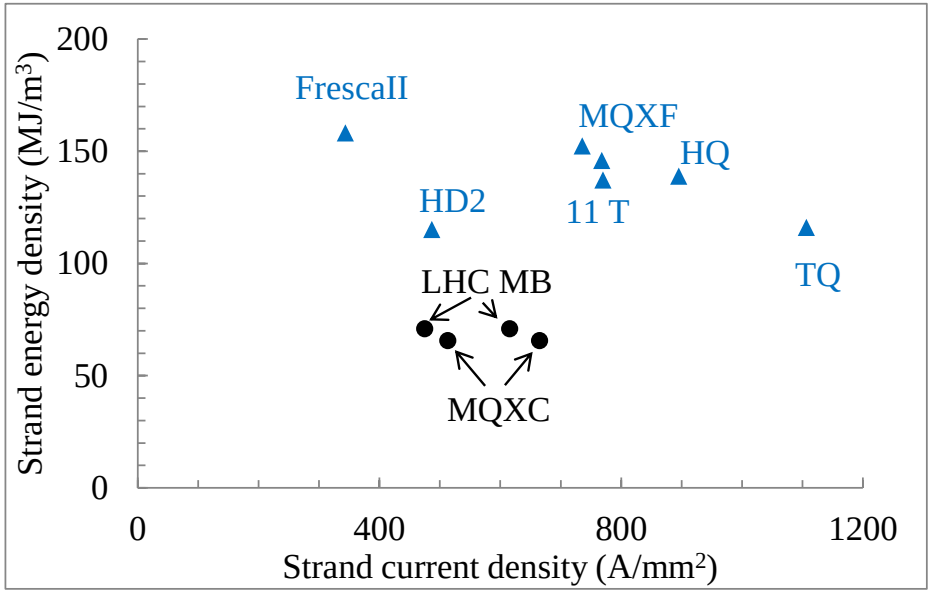
LAY-OUT FOR THE LUMINOSITY UPGRADE

- With larger and larger apertures, what about protection ?



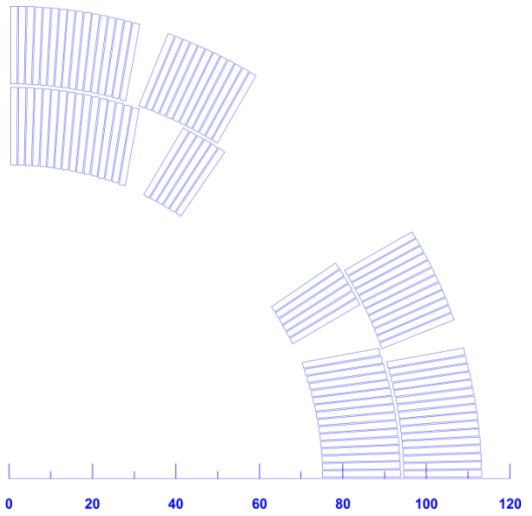
PROTECTION

- Main issue: balance between stored energy and quantity of cable
  - Try to keep the same energy density around 0.15 J/mm^3
  - Larger aperture → larger coil → lower current density
    - Current density was very high for TQ (90 mm)
  - So with larger aperture if we put enough coil we will have more margin



CABLE CHOICE

- Cable choice is on the critical path
  - Strand: from 0.8 to 0.85 mm
  - Number of strands: from 35 to 40
  - We will have a 18.5 mm width cable, two layers
  - Ratio cable width / aperture radius = 75/37 ~ 2



Tentative cross-section [P. Ferracin, F. Borgnolutti, H. Felice]

SOME NEWS FROM LARP

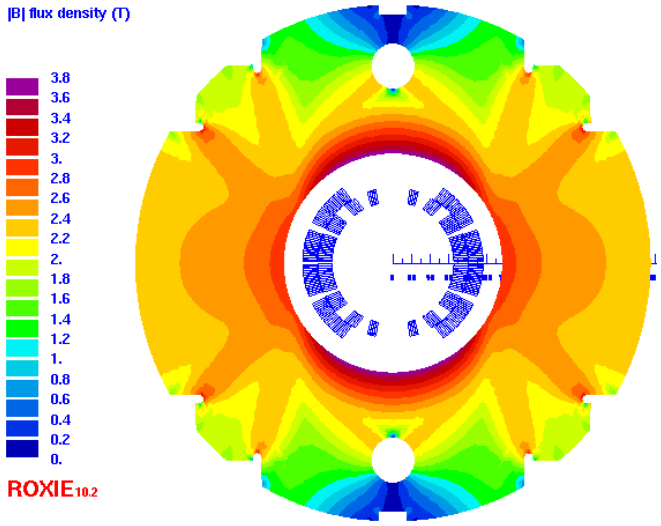
- Test of HQ completed at CERN
  - Able to stay at operational value of 15 kA with limited training
  - Special test on protection – seems able to resist without energy extraction (no dump) and inner layer heaters
- Test of LHQ ongoing
  - Reached operational value at 1.9 K
  - In both cases, not able to reach 90% of short sample at 1.9 K

SEPARATION DIPOLES D1

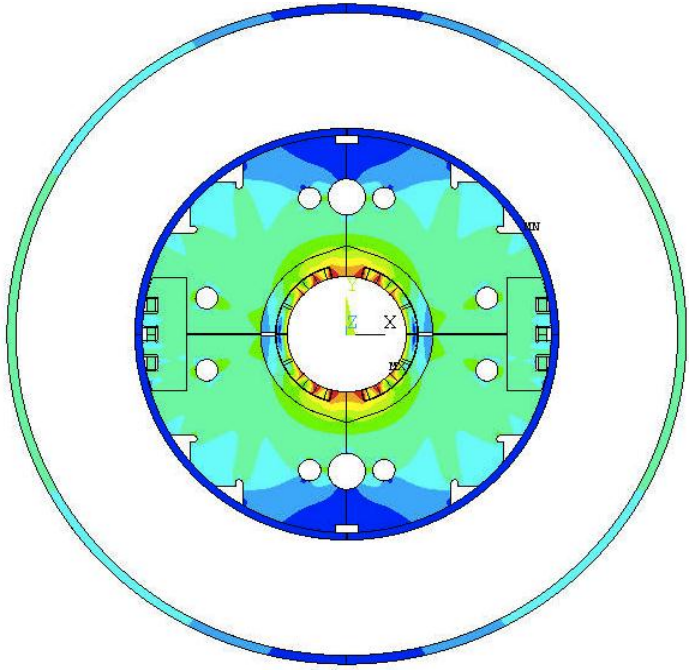
Nb-Ti separation dipole – decision to go from two to one layer

[Q. Xu, T. Nakamoto]

- Small reduction of operation field (from 6 to 5 T) – around 8 m length
- Higher current density but still OK with forces
- More possibility of shielding



Previous two-layers version[Q. Xu, T. Nakamoto]



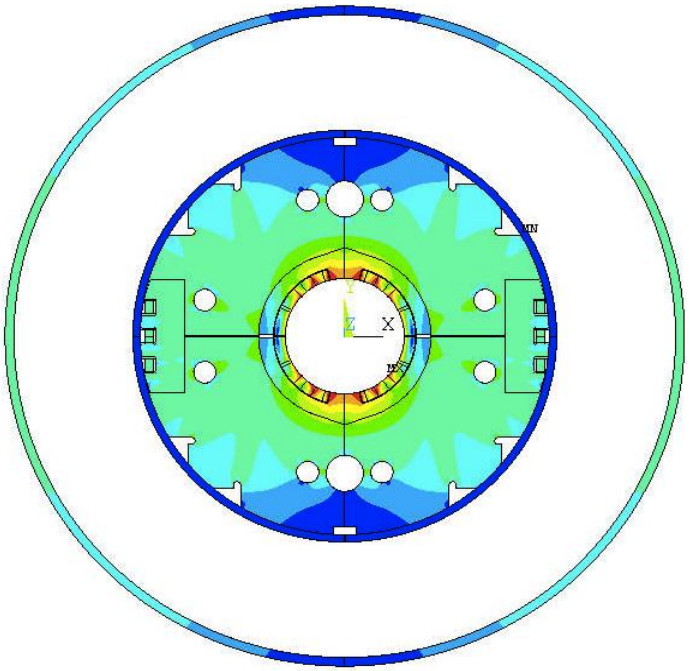
One layer version [Q. Xu, T. Nakamoto]

SEPARATION DIPOLES D1

Nb-Ti separation dipole – decision to go from two to one layer

[Q. Xu, T. Nakamoto]

- Based on Nb-Ti LHC dipole cable
- It could possibly use the «Tommasini» insulation scheme which is being tested in the MQXC
  - Promising results, analysis needed

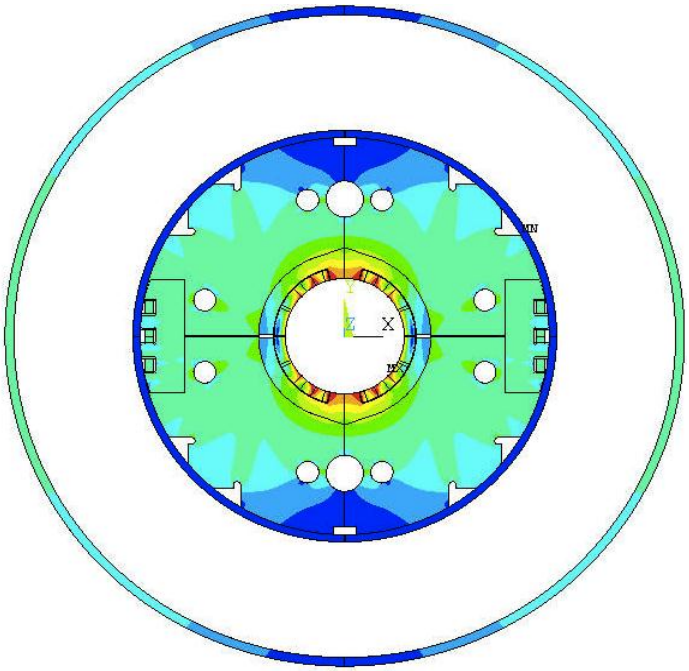


One layer version [Q. Xu, T. Nakamoto]

Q4

Aperture of 90 mm

- Based on Nb-Ti LHC dipole cable
- It could possibly use the «Tommasini» insulation scheme which is being tested in the MQXC
  - Promising results, analysis needed

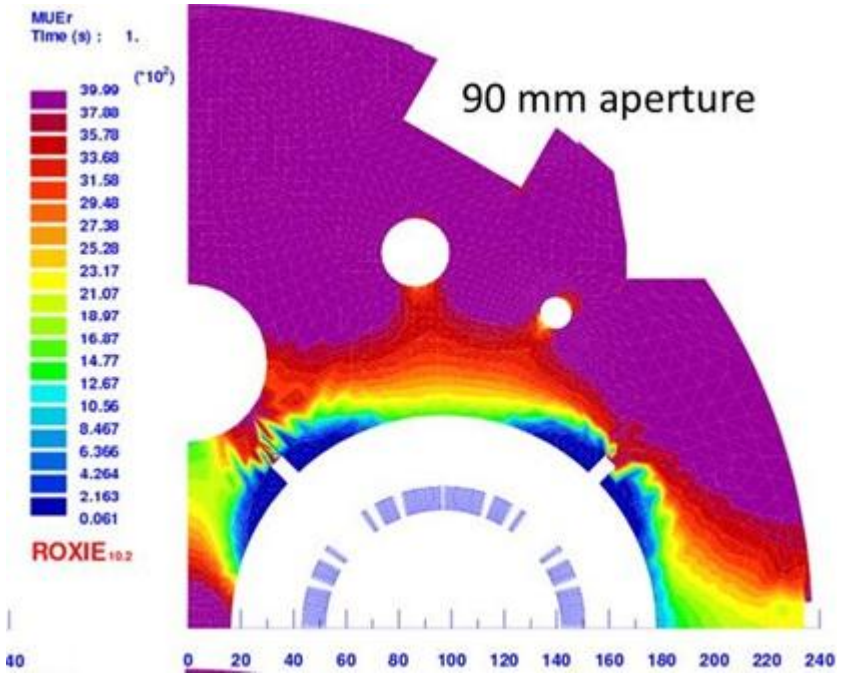


One layer version [Q. Xu, T. Nakamoto]

Q4

Aperture of 90 mm, two in one

- Based on Nb-Ti LHC dipole cable [M. Segreti, J. M. Rifflet]
- Field quality looks reasonable



Q4 tentative cross-section [M. Segreti, J. M. Rifflet]

NEXT STEPS

- Have a model with the 150 mm aperture and D1 to make again the loop with energy deposition cooling etc
  - With a first guess on the correctors
- Possibly extend to Q4
- Review field quality
  - And iterate on the correctors
- Define powering scheme
  - Individually powered or in series ?

www.cern.ch/hilumi/wp3