PROPOSAL OF APERTURE FOR THE INNER TRIPLET

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With relevant inputs from colleagues
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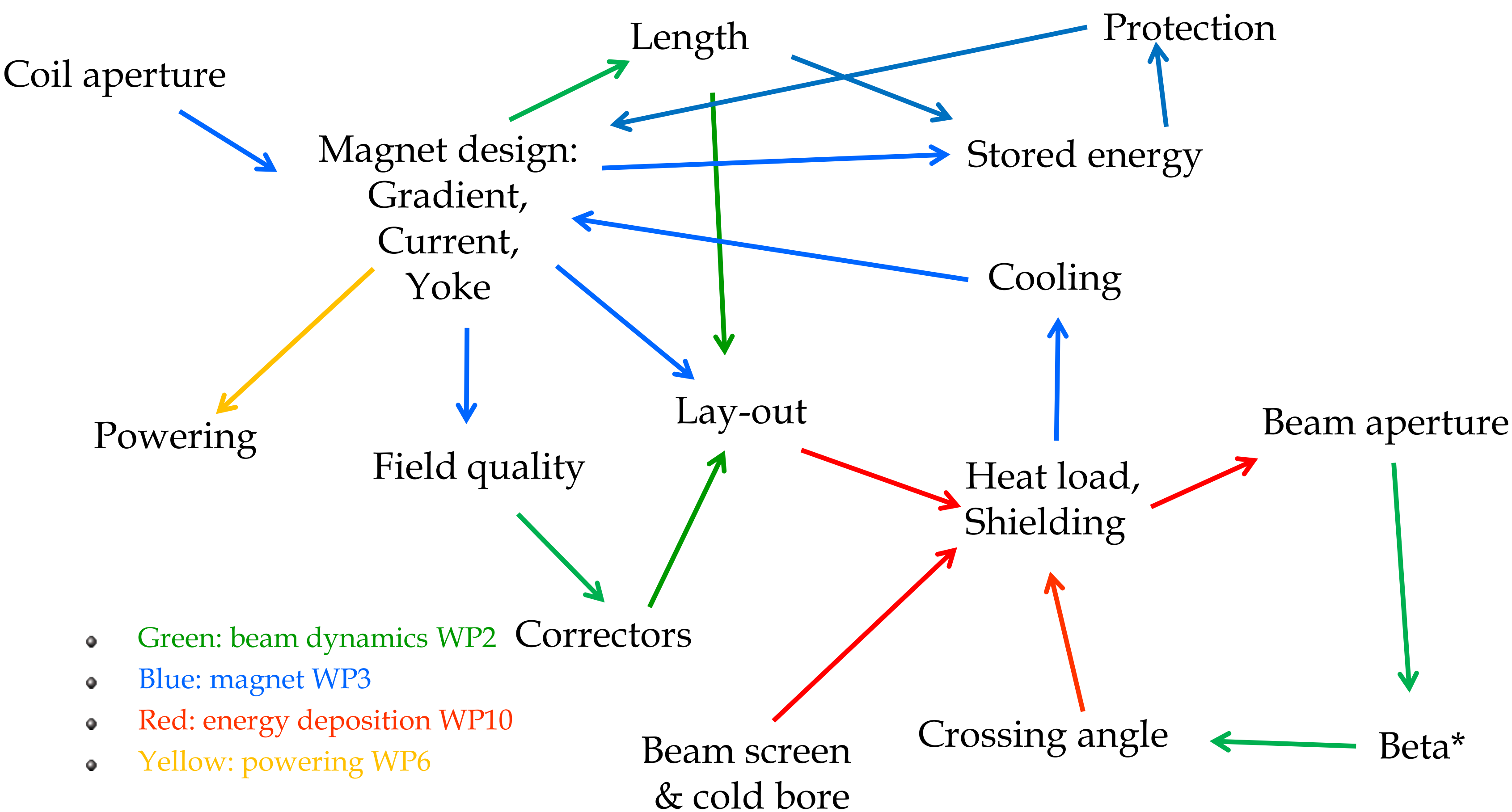
THE FRAMEWORK

- November 2011:
  - Two technologies: Nb_3Sn is the baseline, Nb-Ti is the back-up
  - Apertures: hardware available at 120 mm: MQXC and HQ
  - Larger apertures considered to have more performance
    - We started considering 140 mm Nb-Ti and Nb_3Sn
  - Main questions:
    - Is there a showstopper to larger apertures ? [this talk]
    - In the Nb_3Sn case we need to build a short model, clone of HQ, with plan, time and cost estimate to check compatibility with project schedule and resources [talk by G. Sabbi]
  - Decision was to be taken in June 2012 (we are two days late…)
  - Nb_3Sn technology will be proved on HQ and LHQ by LARP
- Definition: aperture is coil aperture, not the aperture available for the beam

THE FLOWCHART FOR THE DESIGN

- Complex iteration between different aspects



- Green: beam dynamics WP2
- Blue: magnet WP3
- Red: energy deposition WP10
- Yellow: powering WP6

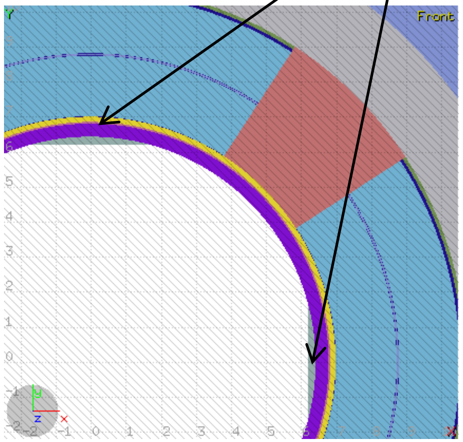
CONTENTS

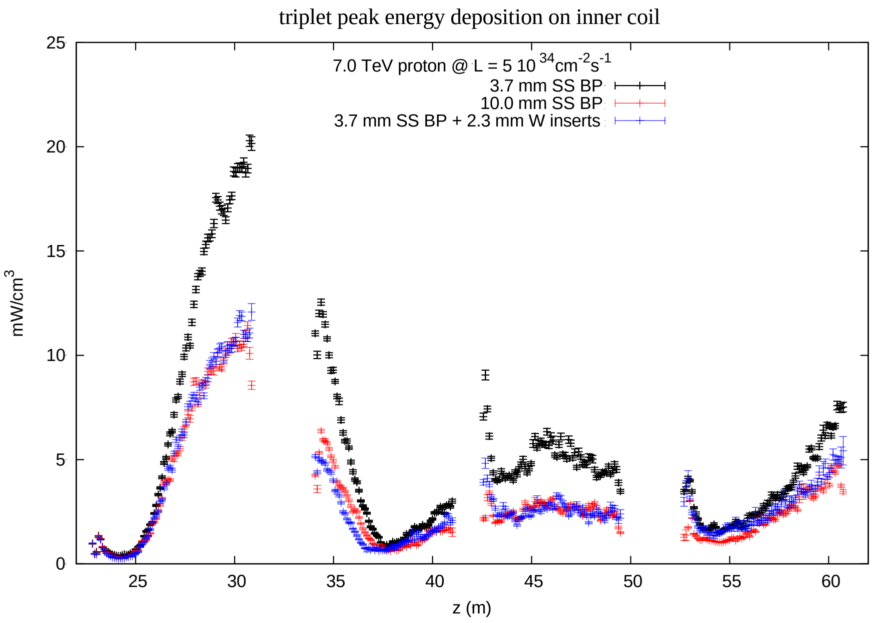
- Heat loads
- Radiation damage
- Stored energy
- Stress
- Protection

Disclaimer: 150 mm analysis based on scaling to have trends, a real case has to be fully analysed (within July)

HEAT LOADS

- Nominal luminosity of 5×10^{34} cm^{-2} s^{-1}
- To stay below a heat load of 12 mW/cm^3 [talks by F. Cerutti, L. Esposito]
  - (this is limit for Nb_3Sn with factor 3 margin)
  - 1.5 mm thickness of He ring
  - 3.7 mm cold bore thickness
  - 2.3 mm thick W inserts





RADIATION DAMAGE

- Integrated lumi of 3000 fb^{-1}
- With previous solution, doses of 180 MGy on the coil [talks by F. Cerutti, L. Esposito]
  - Not acceptable!
- The main news: the MGy dominate over the mW/cm^3
- Rough scaling to go below 50 MGy
  - 1.5 mm thickness of He ring
  - 3.7 mm cold bore thickness
  - 2 mm beam screen
  - 6 mm thick W inserts
- Analysis in progress by WP10
  - 50 MGy is a first (nonconservative) guess, estimates needed
  - We are also considering 20 MGy (data within July)

Other side effects

- Positive side effects
  - This also brings the dT on the coil from 2 K (probably too much) to acceptable values [talk by H. Allain, R. Van Weelderen]
    - Analysis of the case with 6 mm W is being done
  - Beam screen will allow to considerably reduce heat load on the magnet (now 800 W)

- Negative side effects
  - Less performance
  - About 30 mm coil aperture go with shielding and cold bore etc.

- This pushes to 150 mm aperture to recover performance
  - For 150 mm one has ~120 mm for the beam to stay below 50 MGy

Large apertures: length, energies

- First estimate of the gradient
  - We assumed 170 T/m for 120 mm, and 150 T/m for 140 mm at ~80% of short sample
  - We rescale the 140 mm values (150 mm T/m) → 140 T/m operational gradient as a target
  - The increase in length is small (50 cm)
- But the total stored energy 80% larger than HQ ☹
  - More than 60% comes from the aperture increase

		HQ	MQXF 140		MQXF 150	
Aperture	(mm)	120	140	17%	150	25%
Gradient	(T/m)	170	150	-12%	140	-18%
Energy/m	(MJ/m)	0.85	1.20	41%	1.41	65%
Length	(m)	7.2	7.7	7%	8.1	12%
Energy	(MJ)	6.2	9.2	49%	11.3	82%

Large apertures: current

- Gradient: -18% → Current density: -18%
  - This is probably the key point
- Cable surface:+36%
- Moderate increase of current: 12% (0.82*1.36=1.12)

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Energy	(MJ)	6.2	9.2	49%	11.3	82%
N. Strands	(adim)	35	40	14%	40	14%
Strand diam.	(mm)	0.778	0.778	0%	0.85	9%
Cable width	(mm)	15.2	17.3	14%	18.9	25%
Sc current density	**(A/mm^2)**	**1801**	**1613**	**-10%**	**1485**	**-18%**
Current	**(kA)**	**14.5**	**14.8**	**2%**	**16.3**	**12%**

Large apertures: stress

- To lower stress we have to lower current density
  - This is also good for protection (next slide)
- Therefore, we propose to keep the same ratio coil width/aperture, i.e. increase cable width of 25%
- This is done by putting more strands (40) and increasing strand diameter (0.85 mm)
- Marginal increase of stress (below 10 MPa)

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Strand diam.	**(mm)**	**0.778**	**0.778**	**0%**	**0.85**	**9%**
Cable width	**(mm)**	**15.2**	**17.3**	**14%**	**18.9**	**25%**
Stress	**(MPa)**	**128**	**137**	**7%**	**136**	**6%**

LARGE APERTURES: PROTECTION

- Larger cables surface (36%) → much larger available MIITS in the cable (+86%)
  - Dump resistors for these large inductances are not viable
- For HQ one had ~30 ms to quench all the magnet before reaching 300 K – very tight ☹
- For MQXF 150 we have ~45 ms ☺
  - Notwithstanding much larger energy, protection looks a bit more comfortable – to be checked on full model

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Cable width	(mm)	15.2	17.3	14%	18.9	25%
Γ=Available MIITS	**(MA^2s)**	**17**	**22**	**31%**	**32**	**86%**
Γ_q=MIITS of global quench	**(MA^2s)**	**11**	**14**	**33%**	**20**	**89%**
$(\Gamma-\Gamma_q)/I_o^2$	**(ms)**	**31**	**37**		**45**	

LARGE APERTURES: COLD MASS SIZE

- We need a larger cold mass size:
  - Space for helium container in SS
  - Larger aperture
  - Mechanical structure
  - Fringe fields
    - Larger holes in the iron for heat load (to be verified if still needed with new shielding)
- We propose to keep the ma e cryostat size, and to add 50 mm to the cold mass, going from 570 to 630 mm
  - 30 mm for the larger aperture, 20 mm for the SS shell, 10 mm for the iron
  - This can fit the same cryostat without going to non standard techniques [L. Williams]
  - ~20% increase in weigth

SUMMARY

- Proposals
  - Adopt 150 mm aperture with Nb_3Sn as baseline
  - Increase number of strands from 35 to 40
  - Increase strand diameter from 0.778 to 0.85 mm
  - Increase cold mass size from 570 to 630 mm
- A large shielding is needed to avoid radiation damage
  - Reducing available aperture for the beam to ~120 mm
  - Heat load should become a negligible aspect
  - Estimates of radiation damage on HQ materials needed, possible improvements to be considered
- Protection is a very important issue
  - 150 mm with this cable looks easier, results from LASA team on full model are needed