Update of Power Deposition Studies in the LHC Upgrade Phase I Insertion Regions

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October 16^{th}, 2008

Outline

1. the new layout
   - a general overview
   - the triplet: 120 mm aperture
   - the corrector package: 140 mm aperture - possible shielding?
   - the new definition of cable materials

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2. power deposition results
   - the triplet
   - the corrector package
   - the aperture effect
   - the D1

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   - the corrector package
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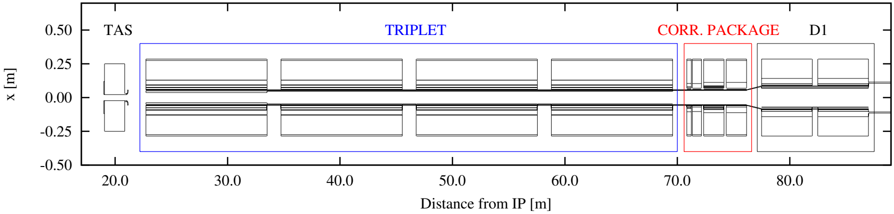
3. Conclusions



TAS, TAN and D2: *actual* positions i.e. as they are now in the LHC tunnel.

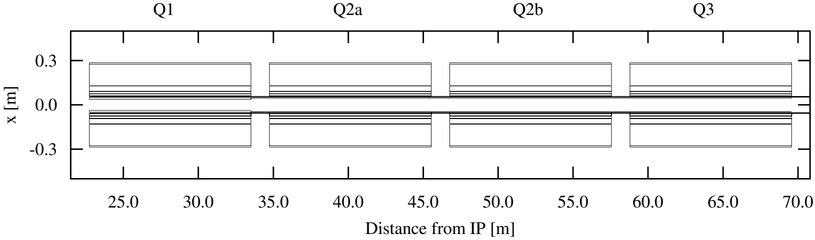
element	*distance from IP* [m]
TAS	19.503
TAN	140.45
D2	153.18

TAS aperture: **45** mm

a **2-modules** RHIC-style D1:

coil aperture [mm]	180
field [T]	4.04
mechanical/magnetic length [m]	4.5/**3.7**
Cold Bore Tube thickness [mm]	5.6
Warm Bore Tube thickness [mm]	1.7
distance corr. pack. - D1 [m]	1.335
inter-module distance [m]	0.5

The TRIPLET - layout



coil aperture	120	mm
field (Q1-Q3)/(Q2a-Q2b)	120/102	$T\ m^{-1}$
mechanical/magnetic length	10.784/**10.324**	m
Cold Bore Tube thickness - AISI304	3.17[1]	mm
Beam Screen Extra Shielding thickness (Q1) - AISI304	10.15[2]	mm
inter-module distance	1.235	m

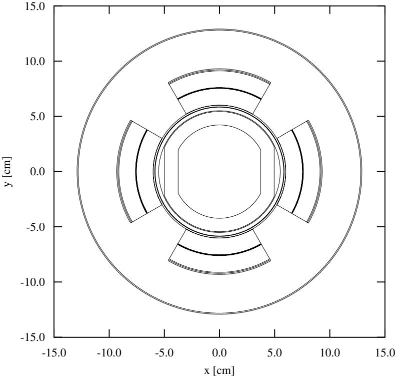
FDDF wrt **horizontal** plane.

[1] according to: $CBT_{th} = 0.0272 \cdot D_{out}$

[2] as for the 110 mm case.

The TRIPLET - cross section

New cross-section layout
thanks to Paolo Fessia (AT/MCS/MDE)

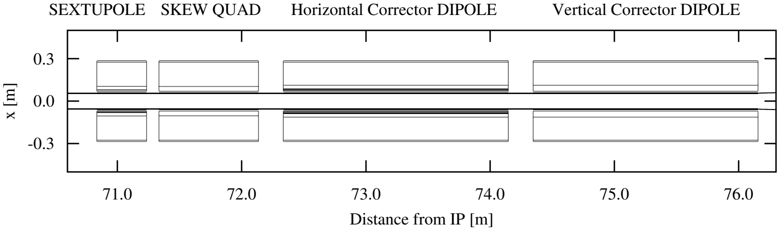


layer	*material*	*thickness* [mm]
insulation	**Kapton**	0.16
cable	**SC mat. 1**	15.1
insulation	**Kapton**	0.16
spacer	G11	0.5
insulation	**Kapton**	0.16
cable	**SC mat. 2**	15.1
insulation	**Kapton**	0.16
quench heater	Kapton	0.25
ground ins.	Kapton	0.5
coil prot. sheet	AISI316L	1.0
collar	AISI304	35.0
empty space	Vacuum	1.0
yoke	Iron[a]	145.91
steel shell	AISI316L	10.0

[a]Composition (mass fraction [%]):

98.2	Fe	1.0	C	0.4	Mn
0.2	Cu	0.1	Ni	0.1	Si

The CORRECTOR PACKAGE - layout

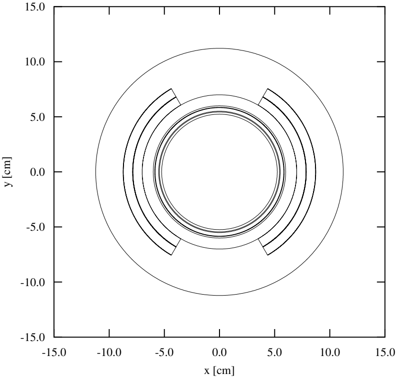


	Sextupole	*Skew Quad.*	*Hor. Dip.*	*Vert. Dip.*	
coil aperture	140.0	140.0	140.0	140.0	mm
field (IP1/IP5)	-/-	-/-	-/0.33 T	0.33 T/-	-
mechanical length	40.0	80.0	181.0	181.0	cm
magnetic length	**25.0**	**50.0**	**142.0**	**142.0**	cm
inter module distance	126.0	10.0	20.0	20.0	cm

the CBT and Beam Screen thicknesses are identical to those of the Triplet;
-> 10 mm gap between CBT and aperture !

The CORRECTOR PACKAGE - cross sections (I)

New cross-section layout
of the dipole corrector

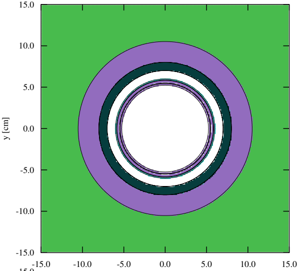


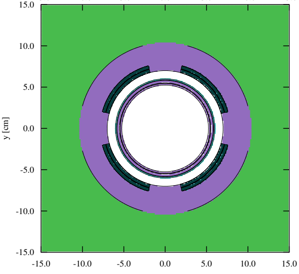
layer	*material*	*thickness* [mm]
insulation	**Kapton**	0.08
cable	**Dipole SC**	8.3
insulation	**Kapton**	0.08
spacer	G11	0.24
insulation	**Kapton**	0.08
cable	**Dipole SC**	8.3
insulation	**Kapton**	0.08
	G11	0.24
collar	AISI304	24.76
yoke	Iron[a]	162.84
steel shell	AISI316L	10.0

[a]Same as for Triplet Quad.

The CORRECTOR PACKAGE - cross sections (II)

cross-section layout of the sextupole and skew quadrupole correctors
thanks to Mikko Karppinen (AB/MCS/ML)





layer	*material*	Sextupole *thickness* [mm]	Sqew Quad. *thickness* [mm]
insulation	**Kapton**	0.08	0.08
cable	**SC mat. 1**	10.0	4.0
insulation	**Kapton**	0.08	0.08
spacer	G11	-.	0.24
insulation	**Kapton**	-.	0.08
cable	**SC mat. 1**	-.	4.0
insulation	**Kapton**	-.	0.08
collar	AISI304	25.0	25.0
yoke	Iron[a]	169.84	171.44
steel shell	AISI316L	10.0	10.0

[a]Same as for Triplet Quad.

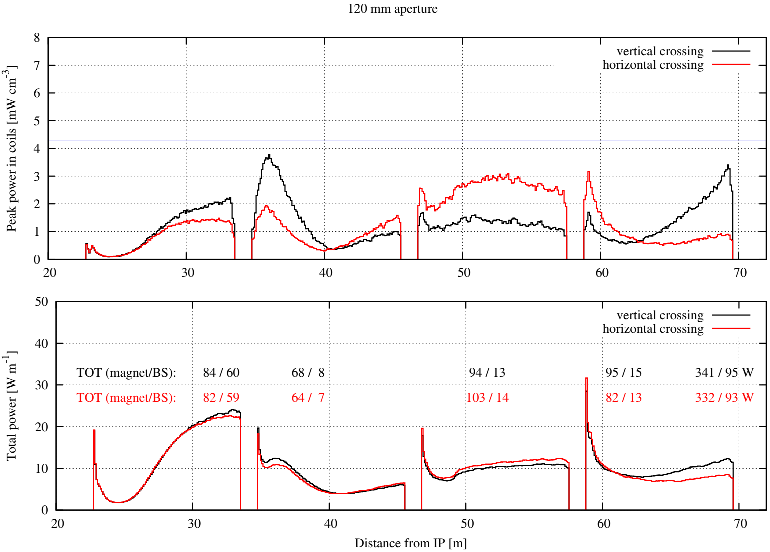
The new definition of coil materials

The material in the cable regions has been re-defined:
the **Cu wedges** in-between cables were **not** considered

		Cable 1	*Cable 2*	*Dipole*	
Cu to SC ratio		1.65	1.95	1.75	(volume)
void fraction		13 %	14 %	12.26 %	(volume)
mean cable thickness		1.9	1.48	0.85	mm
Material	*density* [g cm^{-3}]	*fraction by volume* [%]			
Cu	8.96	47.16	47.47	55.83	
Nb	8.57	10.69	9.09	11.93	
Ti	4.54	17.83	15.26	19.97	
Liquid He	0.122	11.37	11.58	12.26	
Kapton	1.42	12.94	16.60	-	
density		**6.15**	**5.97**	**6.95**	g cm^{-3}

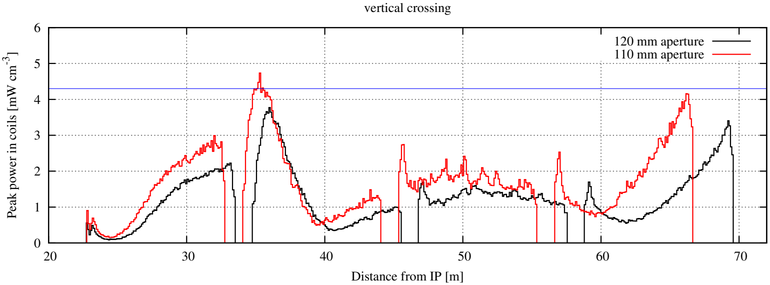
thanks to John Miles (AB/ABP/LCU)

The TRIPLET - crossing schemes



. . . the horizontal crossing scheme seems to be preferable

The TRIPLET - in the past?



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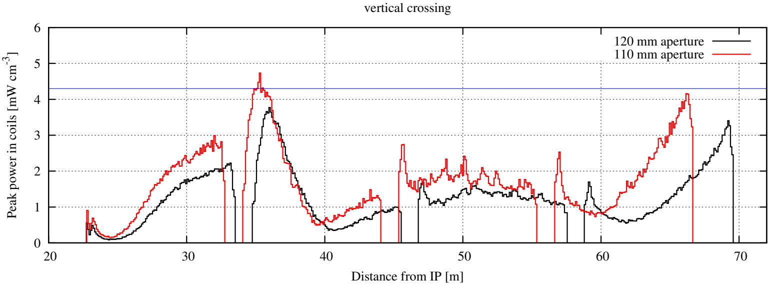
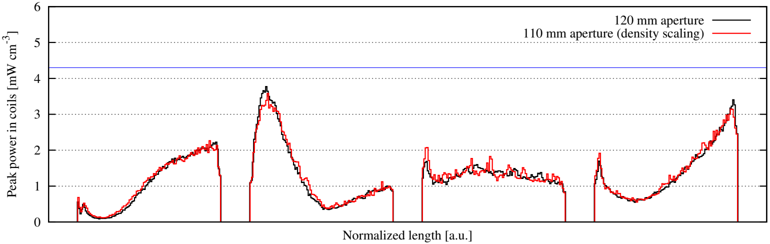
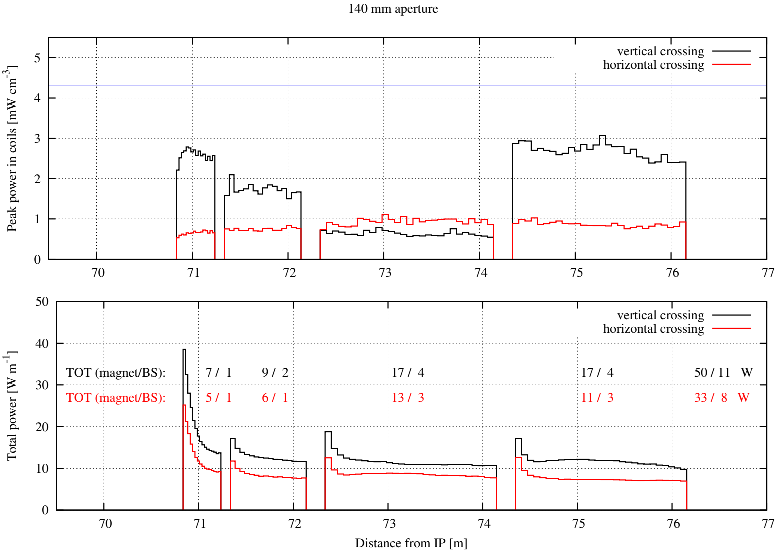




-> the aperture plays a **minor** role !

The CORRECTOR package - crossing schemes



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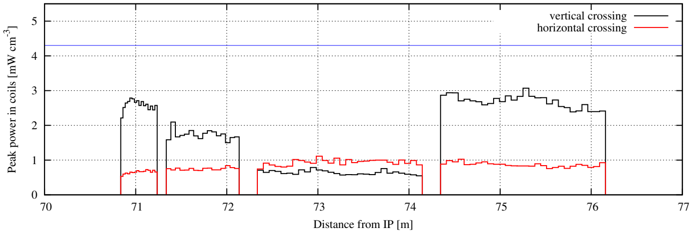

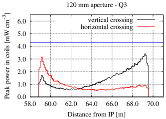

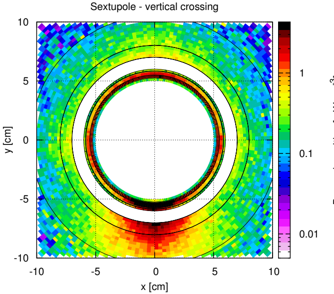

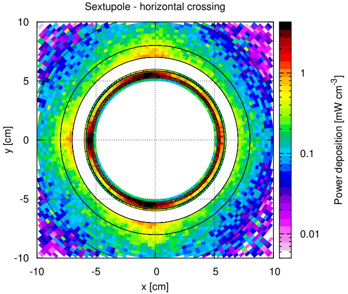

for the horizontal crossing: the TRIPLET is **FDDF**

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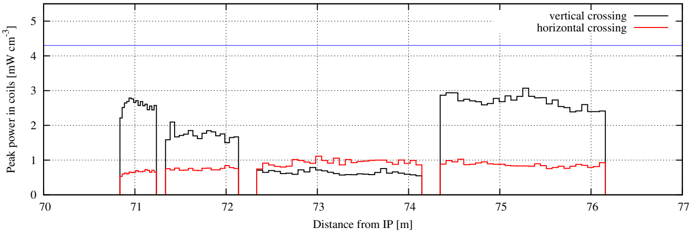
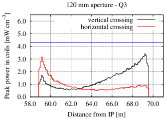
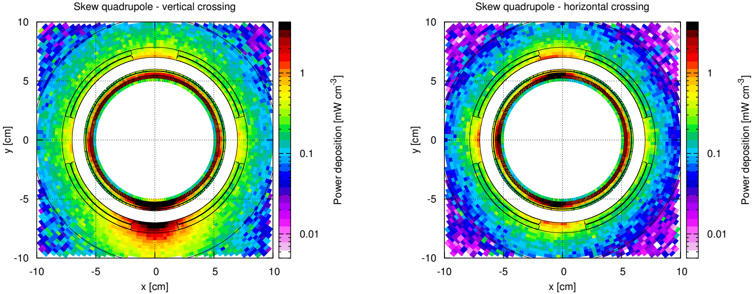
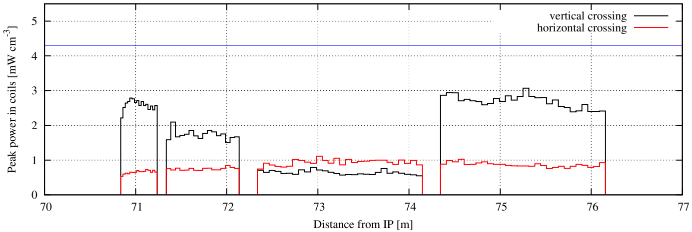


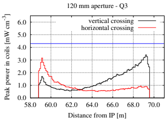


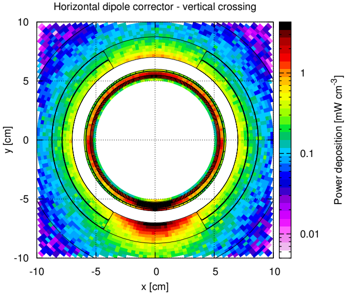


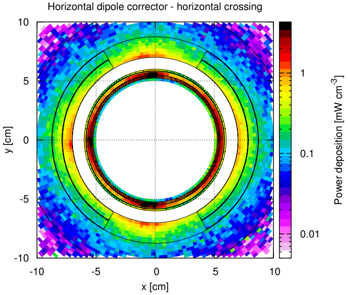
coils in good position!

The CORRECTOR package - crossing schemes









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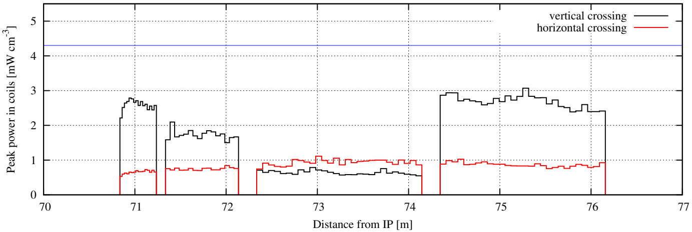

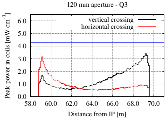

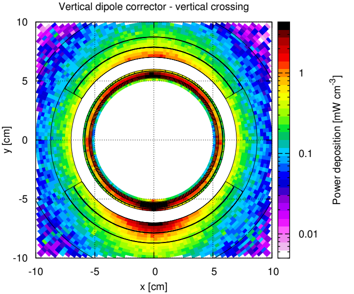

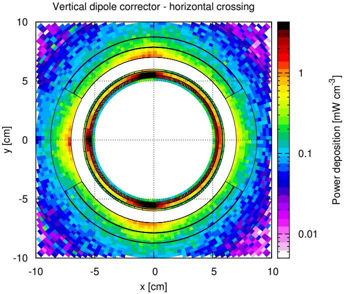

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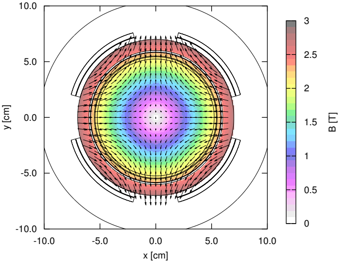
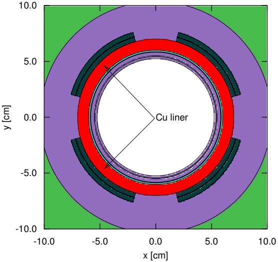
The CORRECTOR package - theme and variations...

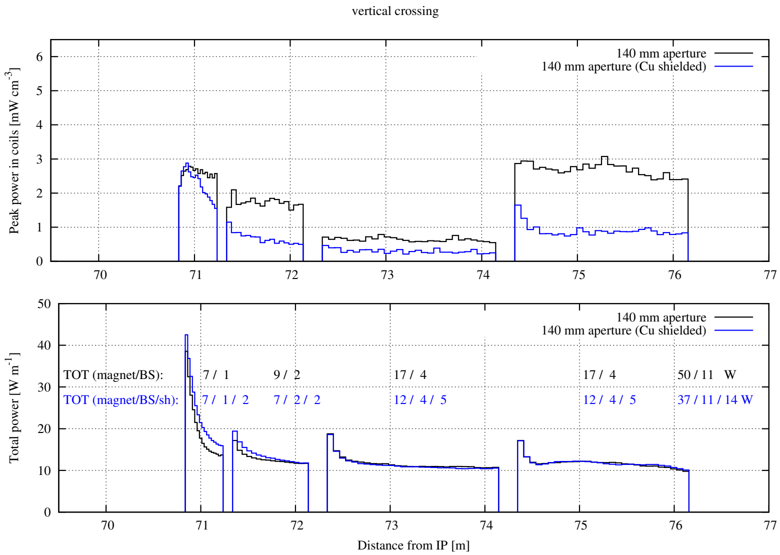
Two more independent cases were studied:

1. the magnetic field of the skew quadrupole was turned on, with a gradient of 40 T m^{-1};

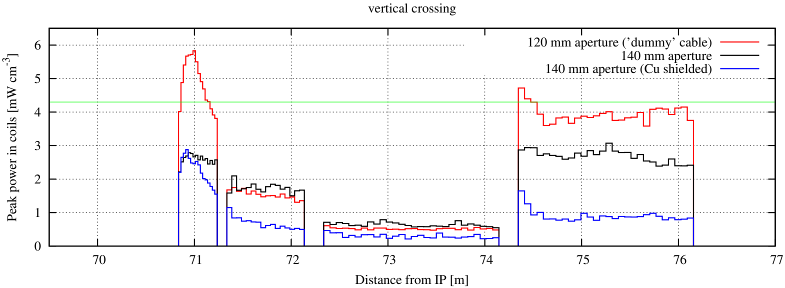


2. a Cu liner was inserted inside each element in the 1 cm wide gap between coils and Cold Bore Tube;

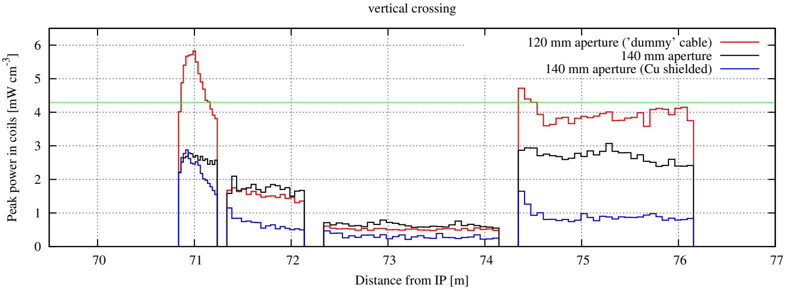




vertical crossing
Peak power in coils [mW cm-3]
140 mm aperture
140 mm aperture (Cu shielded)
0
1
2
3
4
5
6
70
71
72
73
74
75
76
77
Total power [W m-1]
TOT (magnet/BS): 7 / 1 9 / 2 17 / 4 17 / 4 50 / 11 W
TOT (magnet/BS/sh): 7 / 1 / 2 7 / 2 / 2 12 / 4 / 5 12 / 4 / 5 37 / 11 / 14 W
0
10
20
30
40
50
Distance from IP [m]



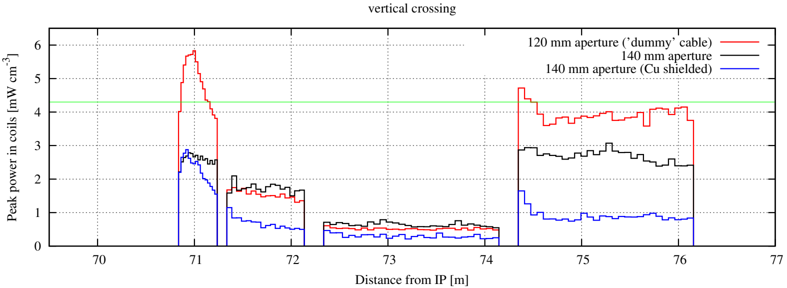
Some remarks:



Some remarks:

- with **vertical** crossing, the corrector package is below the design limit, and a Cu liner in-between the coils and the Cold Bore Tube is helpful downstream, especially on the **vertical** dipole corrector;

The CORRECTOR package - more…



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- with **vertical** crossing, the corrector package is below the design limit, and a Cu liner in-between the coils and the Cold Bore Tube is helpful downstream, especially on the **vertical** dipole corrector;
- there is a **net gain** in having the Corrector aperture **larger** then the Triplet aperture, namely by a factor of **2**: **6** mW cm^{-3} for the *110* mm case versus **3** mW cm^{-3} for the *140* mm;

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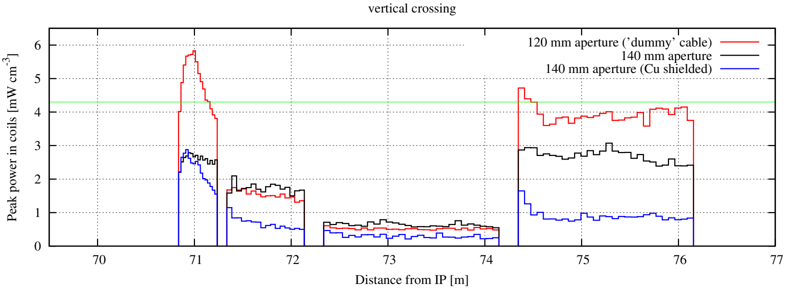

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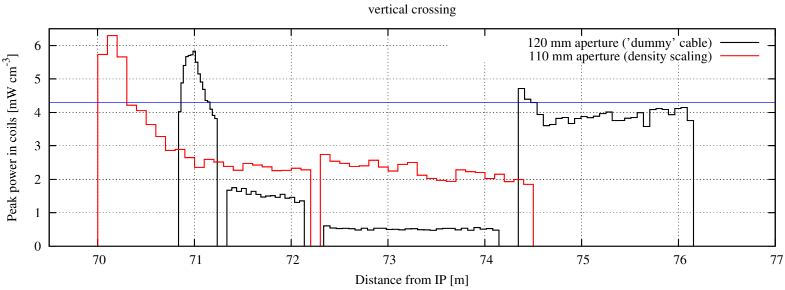
- bringing the aperture of only the dipole correctors to 120 mm represents a problem for the for the **vertical** dipole corrector, in case of **vertical** crossing;

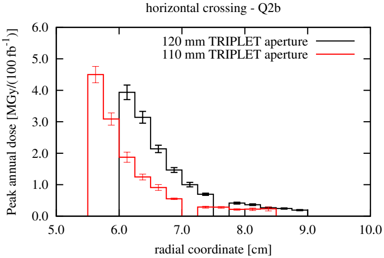
The CORRECTOR package - in the past?

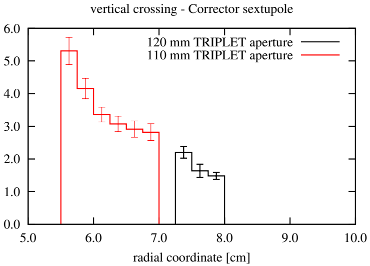


if the CORRECTOR and the TRIPLET aperture were the same, there would be the same situation found for the 110 mm TRIPLET aperture case.

-> only 1 effect is playing:
the different **aperture** between the TRIPLET and the CORRECTOR package;

The aperture effect - Dose





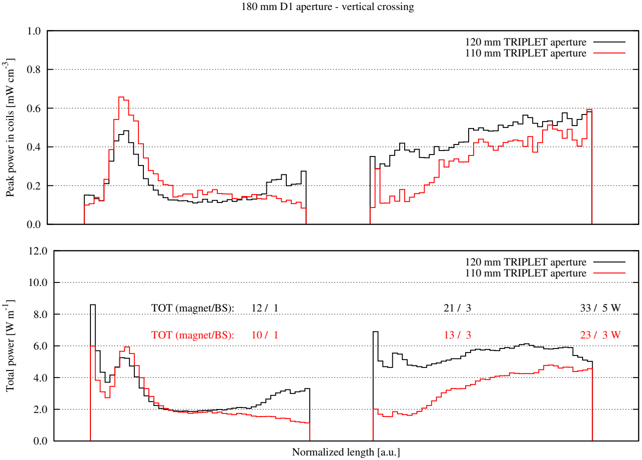
Triplet having increased the aperture from 110 mm to 120 mm plays a very minor role;

Corrector having increased the aperture not only to 120 mm but to the larger value of 140 mm plays the major role;

binning:

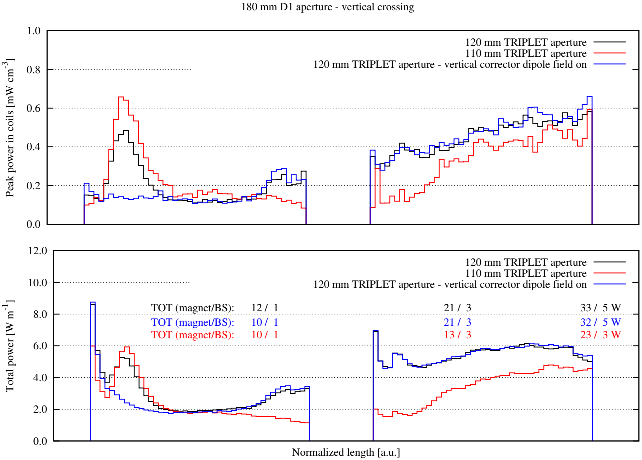
$\Delta\phi$=2 deg;
Δr=2.5 mm;
Δz=10/2.5 cm;

The D1



- the heat load onto the 2^{nd} module of the D1 is increased with the 120 mm TRIPLET aperture option;
- the horizontal scheme is safer for both peak and totals, as already seen for the 110 mm TRIPLET aperture case;

The D1



the power deposition in the D1 is sensitive to the corrector magnetic configuration;

Conclusions

general horizontal crossing scheme: safer (wrt the power deposition in the Triplet, the Corrector package and the D1);

triplet no substantial gain in changing the aperture from 110 mm to 120 mm;

corrector

1. **vertical** crossing: the sextupole and the vertical corrector dipole are quite loaded (due to TRIPLET optics), even if within the design limit;
2. a 1 cm Cu liner: helpful in the **vertical** crossing scheme, especially in protecting the vertical corrector dipole;
3. the **different** aperture of the corrector package wrt the triplet's one is the **key-factor** in protecting the corrector package itself, decreasing the peak at the beginning of the sextupole by a factor of **2**;
4. a reduction of the dipole corrector aperture implies a shielding liner upstream; nevertheless, in case of **vertical** crossing tha last dipole corrector is significantly impacted;

D1

1. the peak pattern is sensitive to the corrector magnetic configuration;
2. higher total load (21 W vs 13 W) on the second element of D1 wrt to the previous case (110 mm triplet aperture);