Study for an alternative design of ILC QD0

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Acknowledgments:
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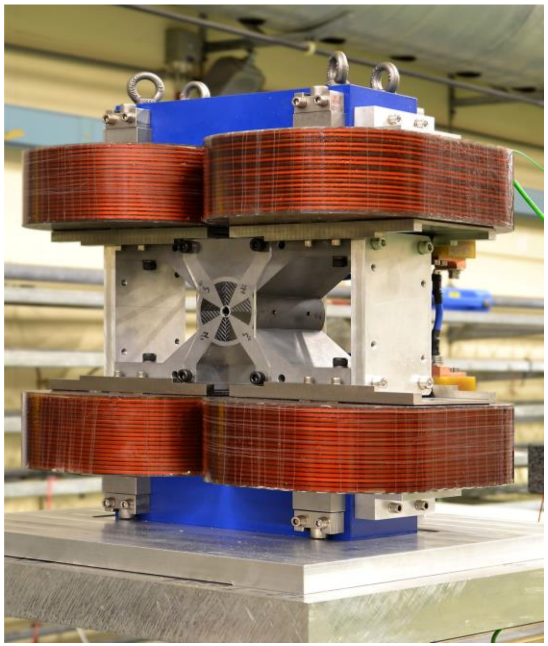
Outline:

1) Previous talk; i.e. the CLIC QD0 baseline …

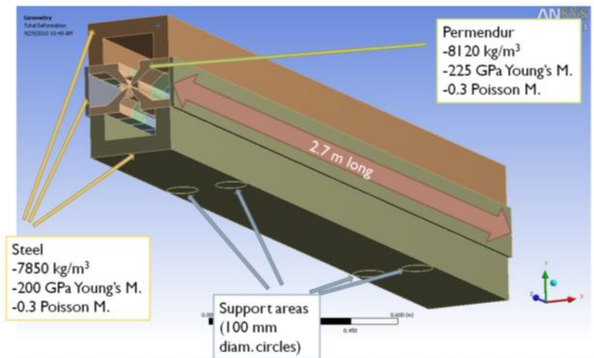
1) A hybrid QD0 for ILC ? (basic conceptual design)

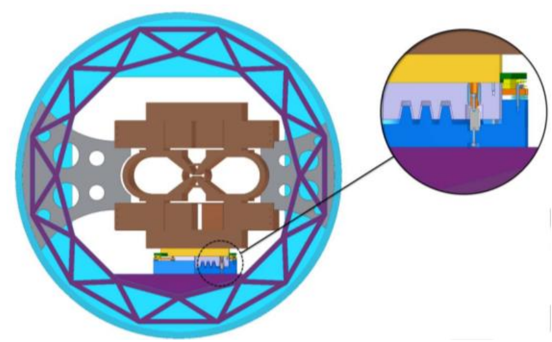
2) Some further considerations

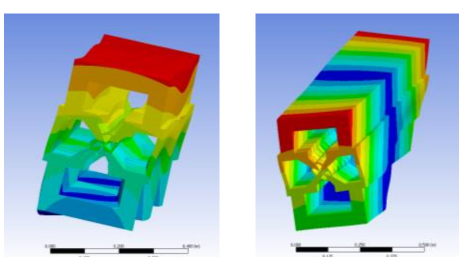
- A **short QD0 prototype** (for CLiC 3TeV layout) **was built** at CERN in 2010-2011.
- **Objective**: validate the Hybrid Magnet design proposed:
  PM blocks - Permendur core structure - coils for tunability (low current density).



CLIC QD0 Main Parameters		*Prototype (Iron yoke length of 100 mm)*	*Nominal magnet (Iron yoke length of ~ 2500 mm)*
Max. Gradient (computed)	[T/m]	552	615
Magnet aperture	[mm]	8.25	8.25
Tunability		32÷100%	32÷100%
GEOMETRY			
Total length	[mm]	273	2600
Width	[mm]	468	518
Height	[mm]	424	424
Total mass	kg	~ 200	~2700
COILS			
Conductor size	[mm]	4x4	4x4
N. of turns		324 (18x18)	324 (18x18)
Average turn length	[m]	0.586	5.786
Total coils (4) mass	[kg]	107.2	1060.8
ELECT.PARAMETERS			
Ampereturns per pole	[A]	5000	5000
Current	[A]	15.4	15.4
Current density	[A/mm²]	1	1
Total resistance	[mOhm]	896	8838
Total voltage	[V]	13.8	136.4
Total power	[W]	213	2150







Modal analysis of the central part (full size, weight: ~ 1600 kg)

Mode	1st	2nd	3rd	4th
Freq [Hz]	190	260	310	366

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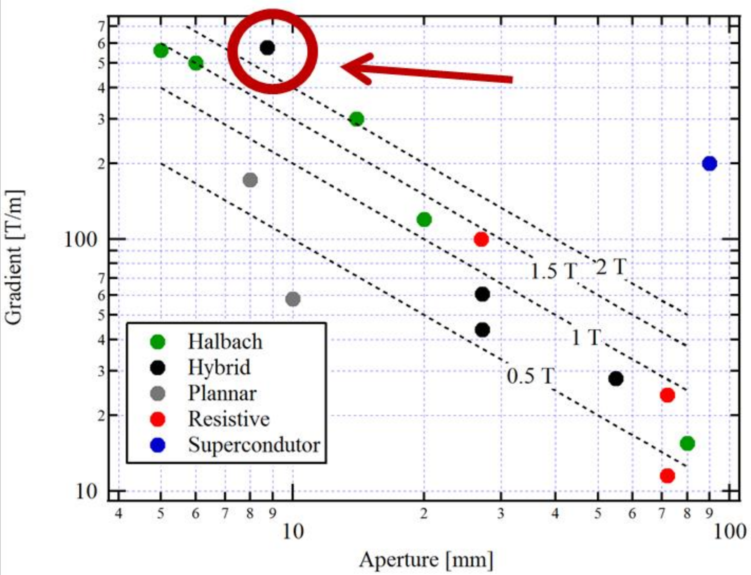
State of the art

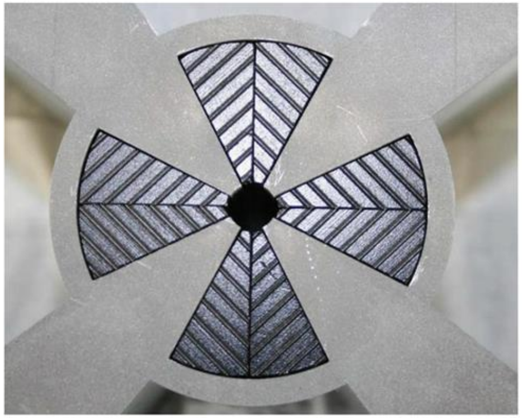
A Light for Science

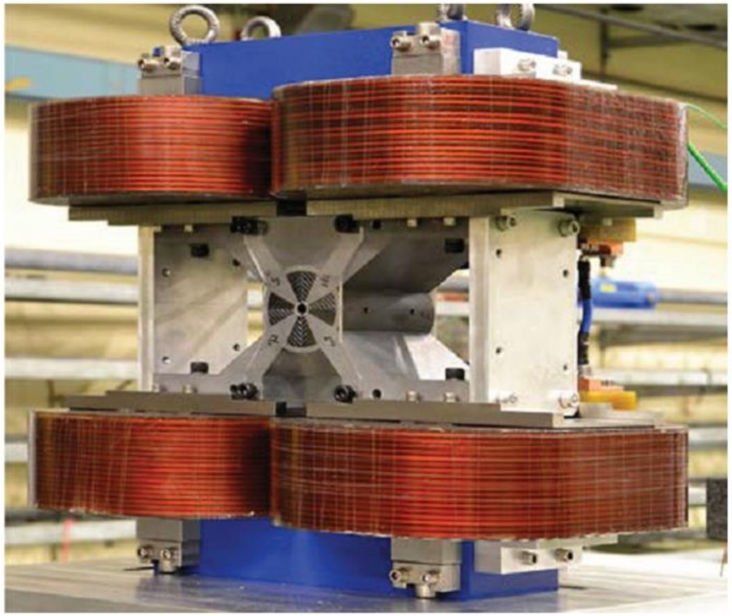
CLIC final focusing

- Iron dominated, Coils + PM
- Gradient 525 T/m
- Aperture 8.25 mm
- Tuning range 80 %



M. Modena, CERN, IPAC 2012



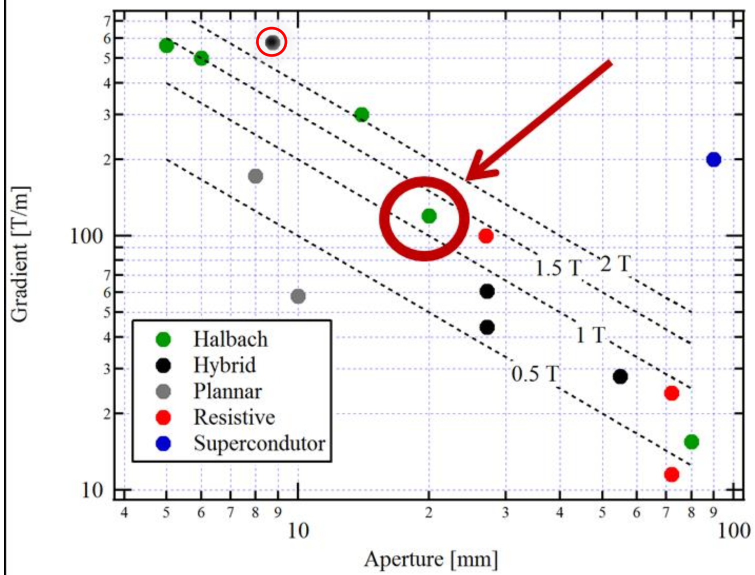


State of the art

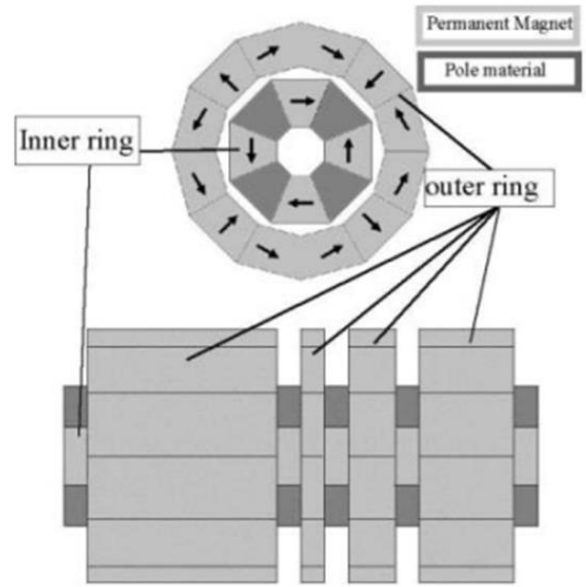
A Light for Science

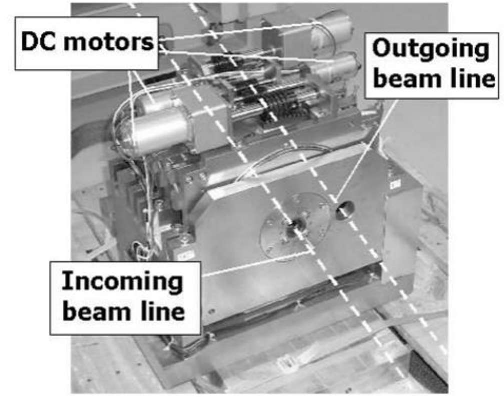
ILC final focusing

- PM
- Gradient 120 T/m
- Aperture 20 mm
- Tuning by 7 T/m steps



Y. Iwashita, Kyoto U., EPAC 2006

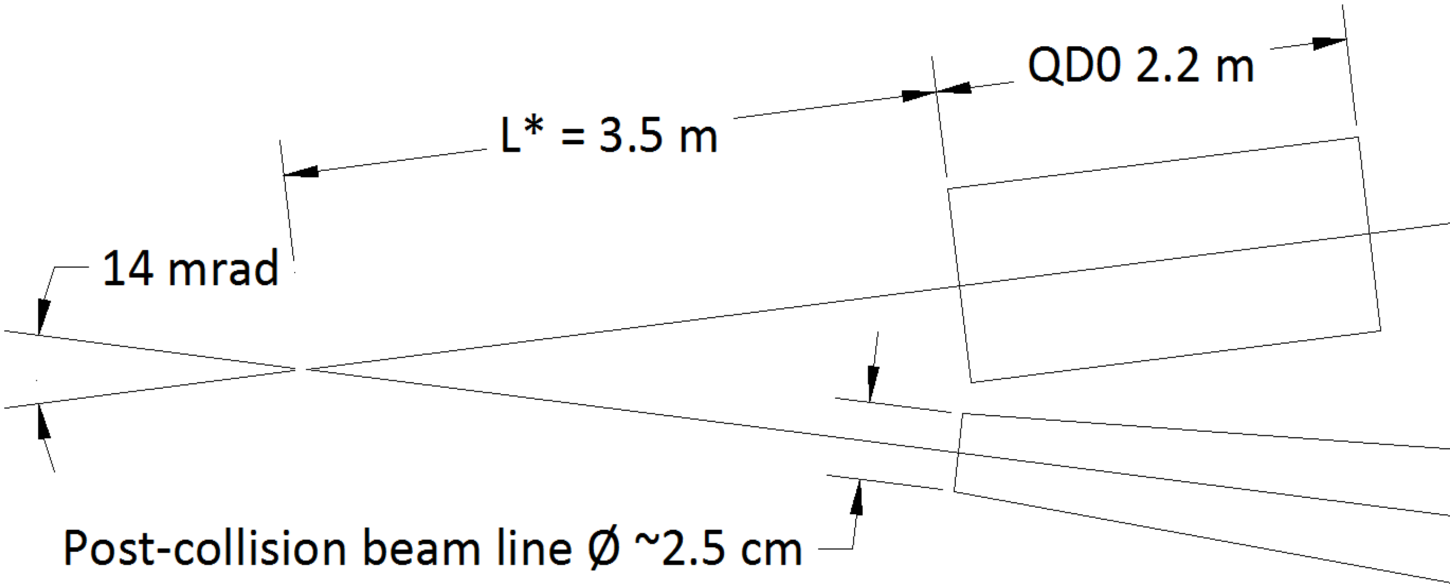




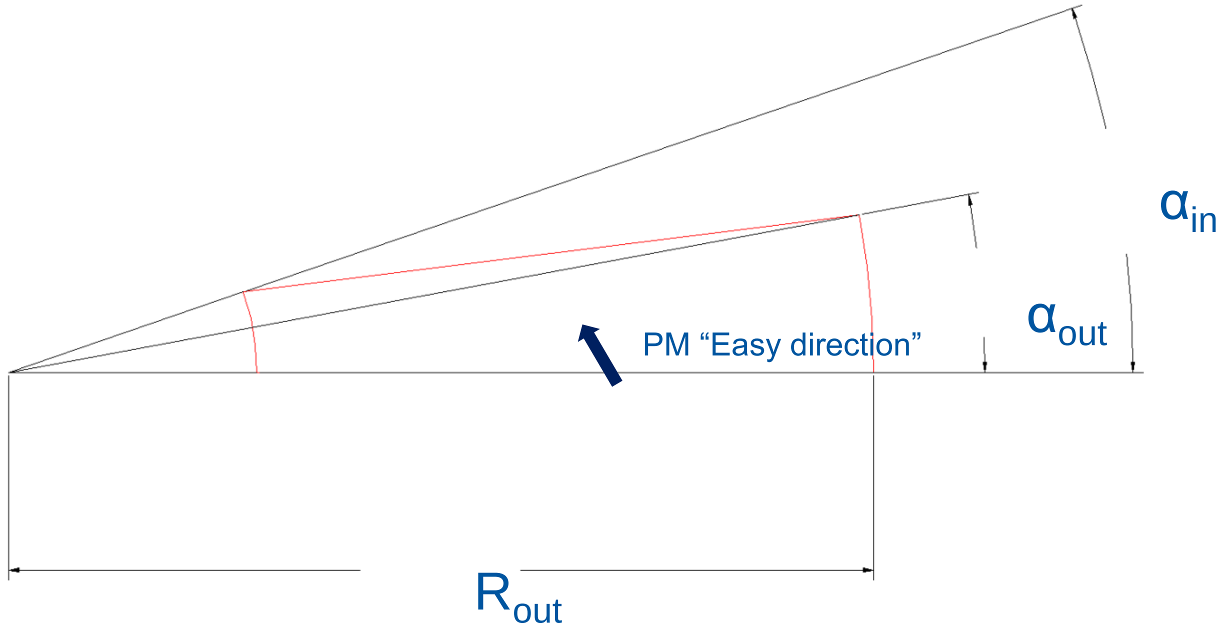
The ILC baseline solution for QD0

Basic ILC QD0 parameters *(R. Tomas: private communication, May 2013):*

- Crossing angle: 14 mrad
- L* = 3.5 m
- QD0 full aperture: 2 cm
- QD0 total length: 2.2 m
- QD0 gradient: 124 T/m
- Post Collision Line vacuum pipe radius at 3.5 m: ~ 12.5 mm



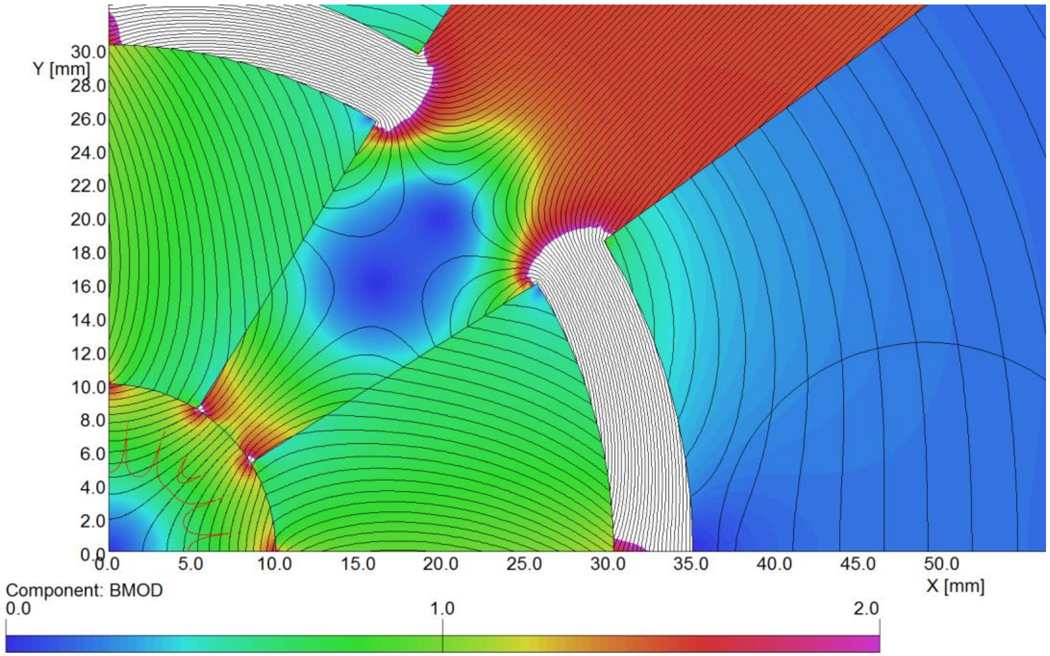
Examples of an optimization done on 3 parameters (α_{in}, α_{out}, ↑$_{easy\ dir}$) (R_{out} =30 mm):
-The field quality is optimized by: 32° for both α_{in}, α_{out}, and 55° for the easy dir. (1st table)
-The gradient is maximized with: α_{in}=32°, α_{out}=13° and 32° for the easy dir. (2nd table)

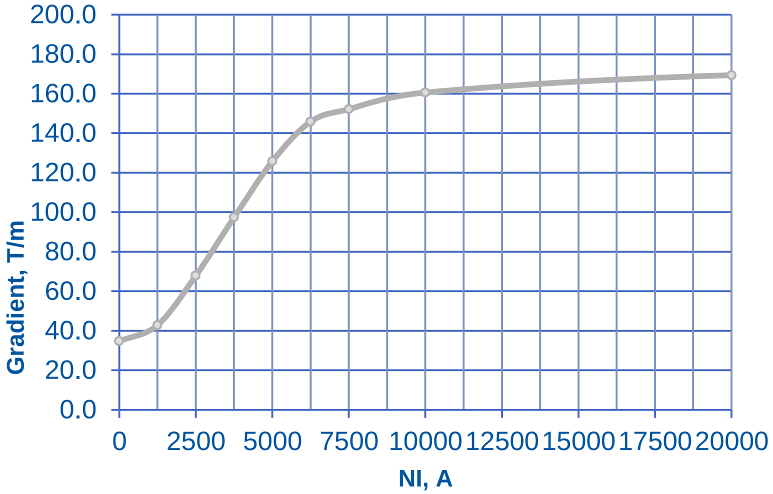


outer angle	inner angle	easy direction	Gradient, T/m	b6, units	b10, units	b14, units	b18, units	abs(b6)
32	32	55	-125.6883919	-0.018011928	0.021495857	0.001156133	-5.42639E-06	0.018011928
14	33	37	-109.7656866	0.035278019	0.020945055	0.000970438	-1.71047E-06	0.035278019
28	28	32	-128.8464878	-0.069765144	-0.102218168	0.001223987	7.28026E-06	0.069765144

outer angle	inner angle	easy direction	Gradient, T/m	b6, units	b10, units	b14, units	b18, units
33	13	32	-142.2927103	40.41430891	0.020803327	0.001981567	-0.000987569
33	13	34	-142.2817507	40.80280099	0.024709188	0.002024723	-0.000996354
33	12	30	-142.2787609	41.64605989	0.039128861	-0.002075543	0.000436098

We have tried to "scale" our QD0 design taking into account the geometric condition but also starting an optimization of the main parameter toward a wider field quality range for the asked tunability.



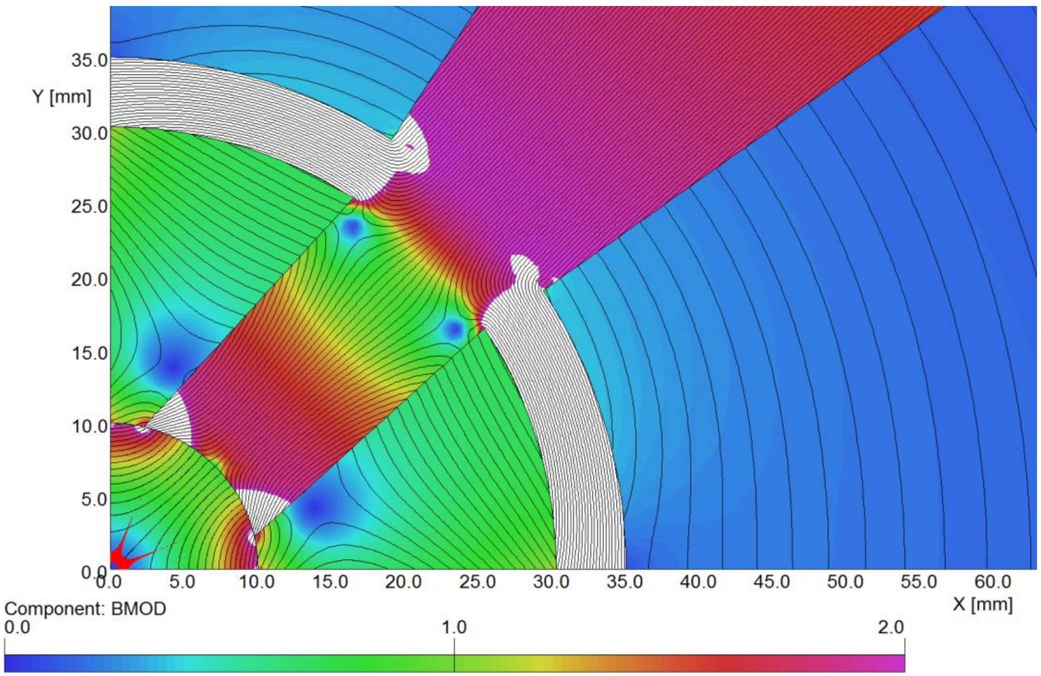


"red line" inside the aperture: area where ΔG/G ≤1 unit (good field region)

Main multipoles estimation at r = 3 mm; 5000 NI is the nominal working point (G:125 T/m)

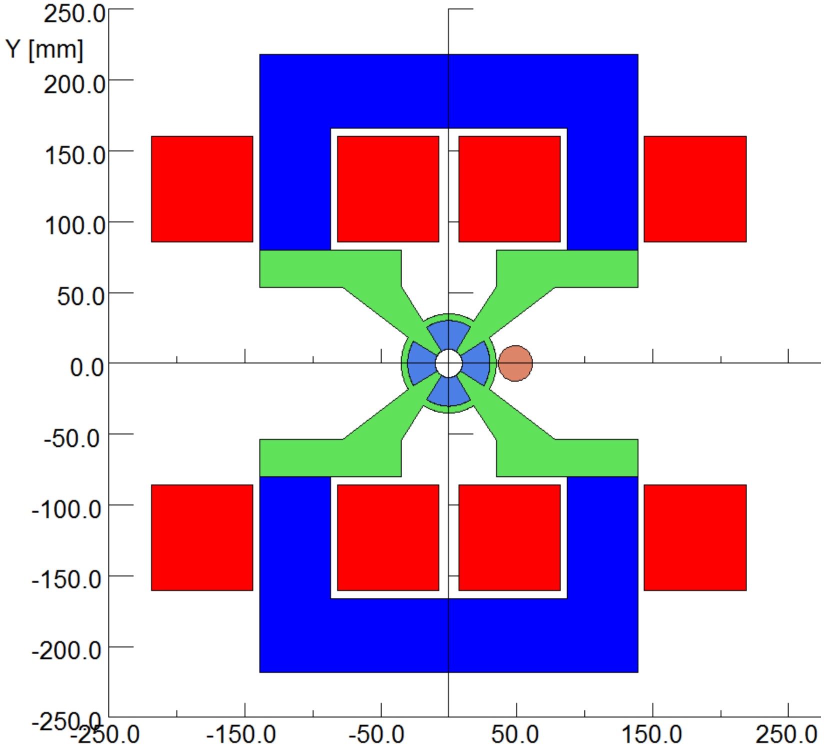
NI	A	0	1250	2500	3750	5000	6250	7500	10000	20000	40000
Gradient	**T/m**	**34.7**	**42.8**	**67.8**	**97.3**	**125.7**	**145.8**	**152.2**	**160.6**	**169.4**	**174.9**
b6	units	61.2472	45.2059	19.9428	6.8605	-0.0183	-3.3895	-4.2944	-5.3982	-6.4427	-7.0075
b10	units	0.1978	0.1510	0.0769	0.0386	0.0215	0.0173	0.0173	0.0182	0.0201	0.0217
b14	units	0.000192	4.51E-04	8.62E-04	1.07E-03	1.16E-03	1.16E-03	0.001148	0.001123	0.001086	0.001056
b18	units	0.003501	2.58E-03	1.14E-03	3.89E-04	-4.59E-06	-1.98E-04	-0.00025	-0.00031	-0.00037	-0.0004

In this slide a MAXIMUM gradient configuration (~ 142 T/m) is shown:
Poles are wider, saturation appear in some areas, field quality is affected (even in this IDEAL calculation)



"red line" inside the aperture: area where ΔG/G ≤1 unit (good field region)

NI	A	1250	2500	3750	5000	6250	40000
Gradient	**T/m**	**44.14719**	**75.58737**	**111.0874**	**142.2917**	**155.2365**	**171.4439**
b6	**units**	58.93988	54.76554	48.30059	40.41387	36.75506	32.13193
b10		0.216246	0.14742	0.072838	0.023252	0.013356	0.011051
b14		0.001752	1.04E-03	0.000633	6.08E-04	6.24E-04	5.96E-04
b18		0.000583	5.37E-04	0.000473	3.95E-04	3.59E-04	3.13E-04



On the left, a basic sketch for the hybrid CLIC QD0 adapted to the ILC parameters:

- As for CLIC case, this solution minimises vibrations;
coils are sized for a current density J ~ 0.9 A/mm (→ no water cooling).

- Overall dimension are in the range of 500 x 500 mm.

Other solutions to minimise the cross-section, could be studied:

- *A coils cooling system could be added if not detrimental to magnet stability (vibrations)*
- *Even more interesting…: a "super-ferric" solution could be envisaged. (I had very interesting discussions with Akira Yamamoto on this two weeks ago, and this could become an interesting subject to be developed…)*

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ANTI-SOLENOID:

An anti-solenoid should be considered in case of a hybrid solution for QD0. It is in fact necessary to protect the PM blocks of the QD0 from the external magnetic field generated by the detector solenoid.

(NOTE: This is not required in case of a SC QD0 solution, but would be anyway an anti-solenoid needed in ILC for beam optic reasons ?)

The work done for the CLIC MDI anti-solenoid design (see previous presentation on CLIC BDS status) could be taken as a starting point to study a similar solution for ILC detectors.

OTHER MAGNETS OF THE FINAL FOCUS SYSTEM:

In CLIC MDI upstream of QD0 (at the end of the accelerator tunnel), an adequate space is allocated to the other optic elements of the FF system (SD0, multipole correctors, etc.).

The situation in ILC could be different (in the SC baseline solution correctors coils are added to the QD0 main coils). This aspect must be also revised.

Thanks