RR + LR MAGNETS

Davide Tommasini

- RR: 10 GeV Linac + 10-60 GeV Ring magnets
- LR: 10 GeV Linac + 10-60 GeV Arc magnets
- Present experimental work
- Conclusion

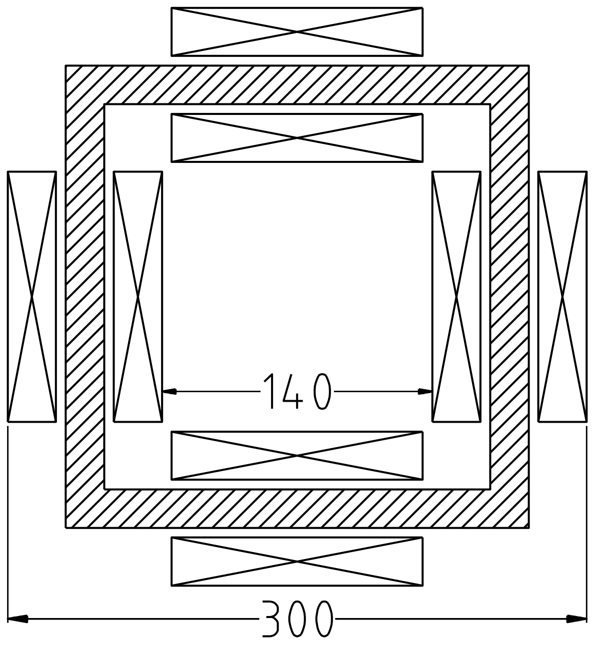
RR: 10 GeV Linac

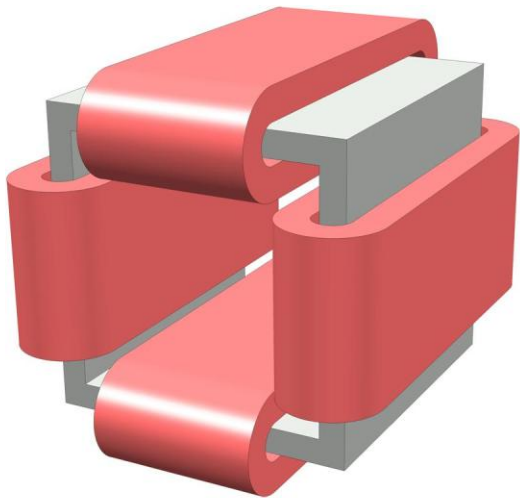
Requirements for Quadrupoles		
Number of magnets	37	
Aperture radius	70	mm
Field gradient	10	T/m
Magnetic Length	250	mm
Operation	D.C.	

Requirements for Correctors		
Number of magnets	37	
Free aperture	140x140	mm x mm
Field induction	40	mT
Magnetic Length	250	mm
Operation	pulsed up to 10 ms	

RR: Linac Correctors

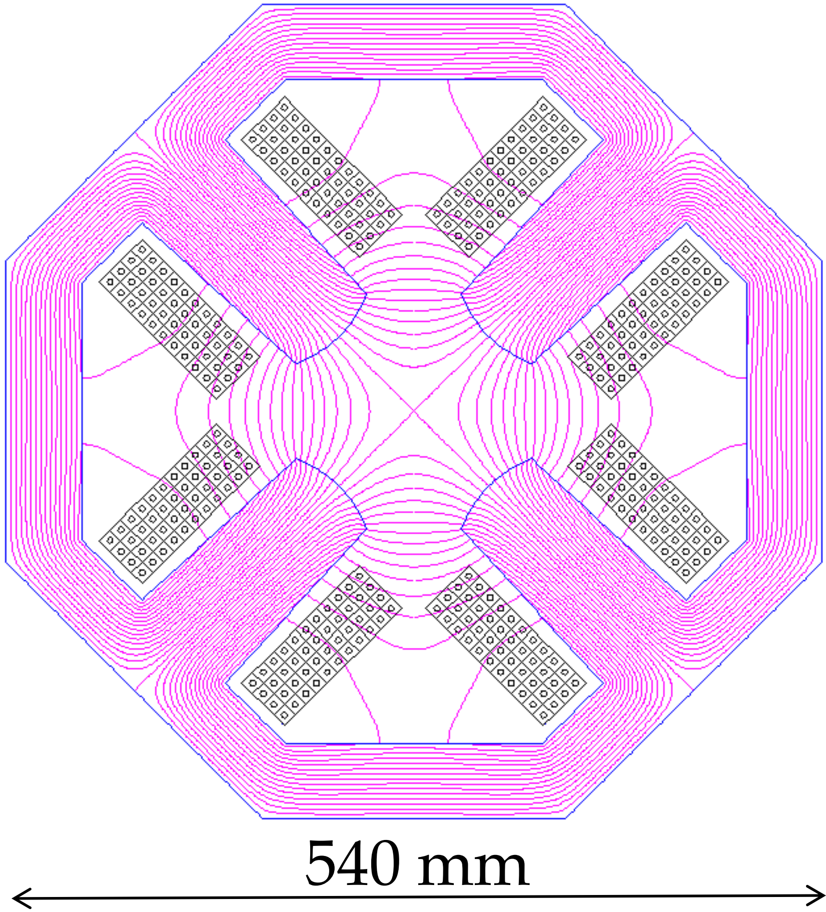
Parameters for Correctors		
Number of magnets	37	
Free aperture	140x140	mm x mm
Field induction	25	mT
Magnetic Length	400	mm
Yoke aperture	200x200	mm x mm
Yoke length	250	mm
Total length	350	mm
Weight	100	kg
Number of turns	2*100	per circuit
Current	40	A
Current density	1.5	A/mm^2
Resistance/circuit	0.1	mΩ
Power/circuit	160	W
Inductance/circuit	10	mH
Max Voltage @ 2.5 T/s	44	V

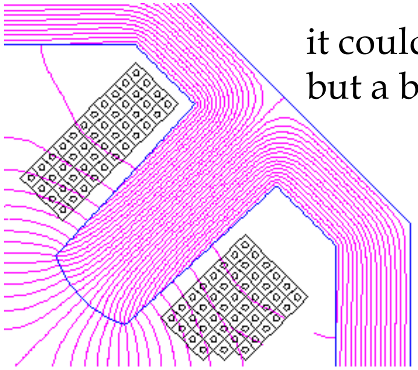




RR: Linac Quadrupoles

Parameters for Quadrupoles		
Number of magnets	37	
Aperture radius	70	mm
Field gradient	10	T/m
Magnetic Length	250	mm
Yoke length	200	mm
Total length	350	mm
Weight	300	kg
Number of turns/pole	44	
Current	500	A
Current density	5	A/mm^2
Resistance	24	mΩ
Power	6	kW
Inductance	12	mH
Field error	$<\pm 5 \cdot 10^{-4}$	@ r=10 mm





it could be more compact, but a bit longer

RR: 10-60 GeV Ring Magnets

Requirements for Bending		
Number of magnets	3080	
Free aperture	90x40	mm x mm
Field induction	127-763	Gauss
Magnetic Length	5350	mm
Field quality	$\pm 2 \cdot 10^{-4}$ in GFR ±10Hx6V	mm x mm
Field reproducibility @ inj	better than ±0.1	Gauss

Requirements for Arc QF		
Number of magnets	368	
Aperture radius	>20	mm
Field gradient	10.28	T/m
Magnetic Length	1000	m

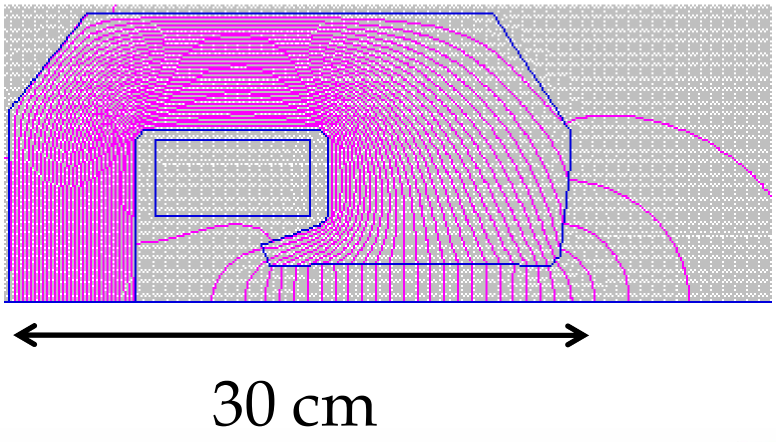
Requirements for Arc QD		
Number of magnets	368	
Aperture radius	>20	mm
Field gradient	8.40	T/m
Magnetic Length	1000	mm

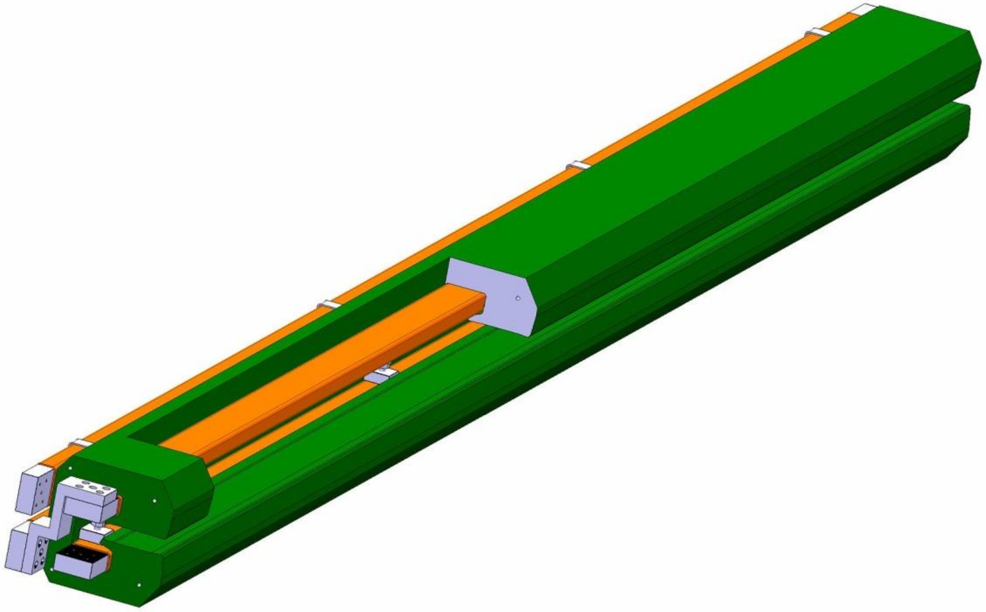
Requirements for I-BP QF		
Number of magnets	97	
Aperture radius	>20	mm
Field gradient	18	T/m
Magnetic Length	1000	m

Requirements for I-BP QD		
Number of magnets	97	
Aperture radius	>20	mm
Field gradient	18	T/m
Magnetic Length	700	mm

RR: Ring Bending

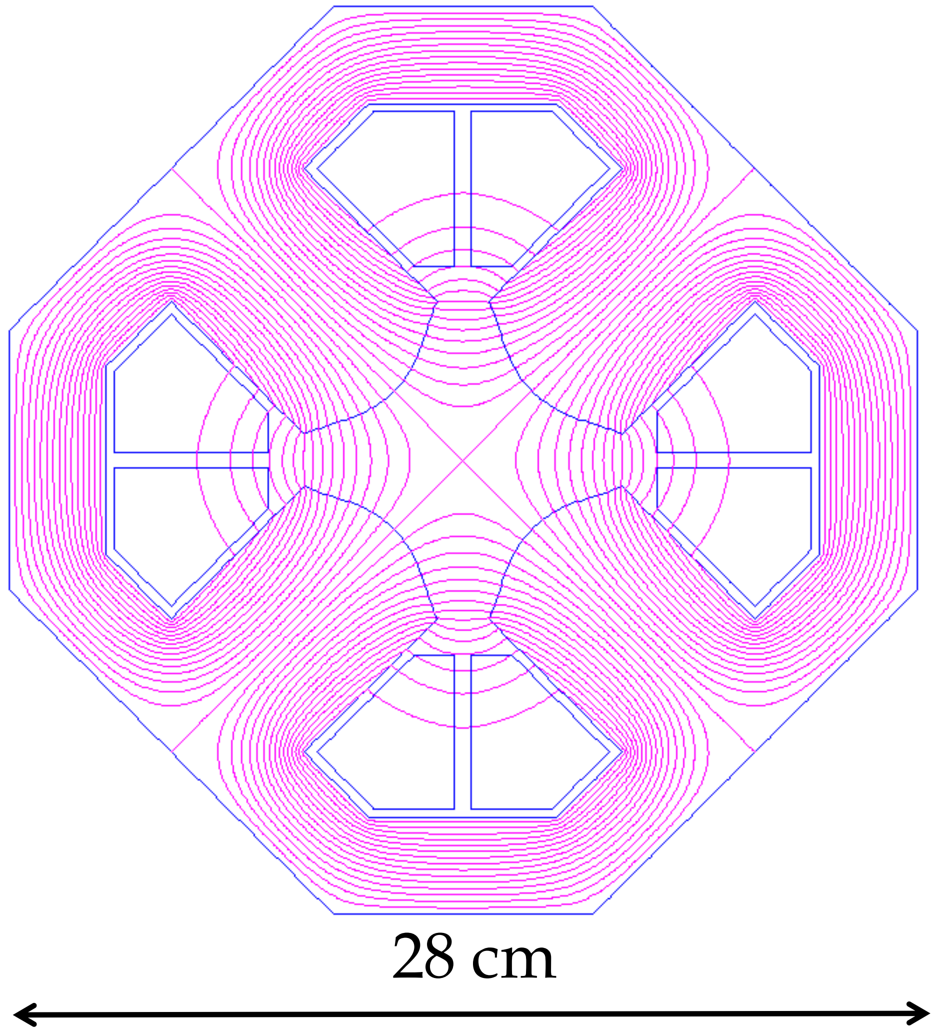
Parameters for Bending	
Beam Energy [GeV]	60
Magnetic Length [m]	5.35
Magnetic field [Gauss]	763
Number of magnets	3080
Weight [kg]	
Vertical aperture [mm]	40
Pole width [mm]	150
Number of coils	2
Number of turns/coil	1
Current [A]	1300
Conductor material	aluminum
Magnet Inductance [mH]	0.15
Magnet Resistance [mΩ]	0.20
Power per magnet [W]	340
Cooling	air





RR: Ring Quadrupoles

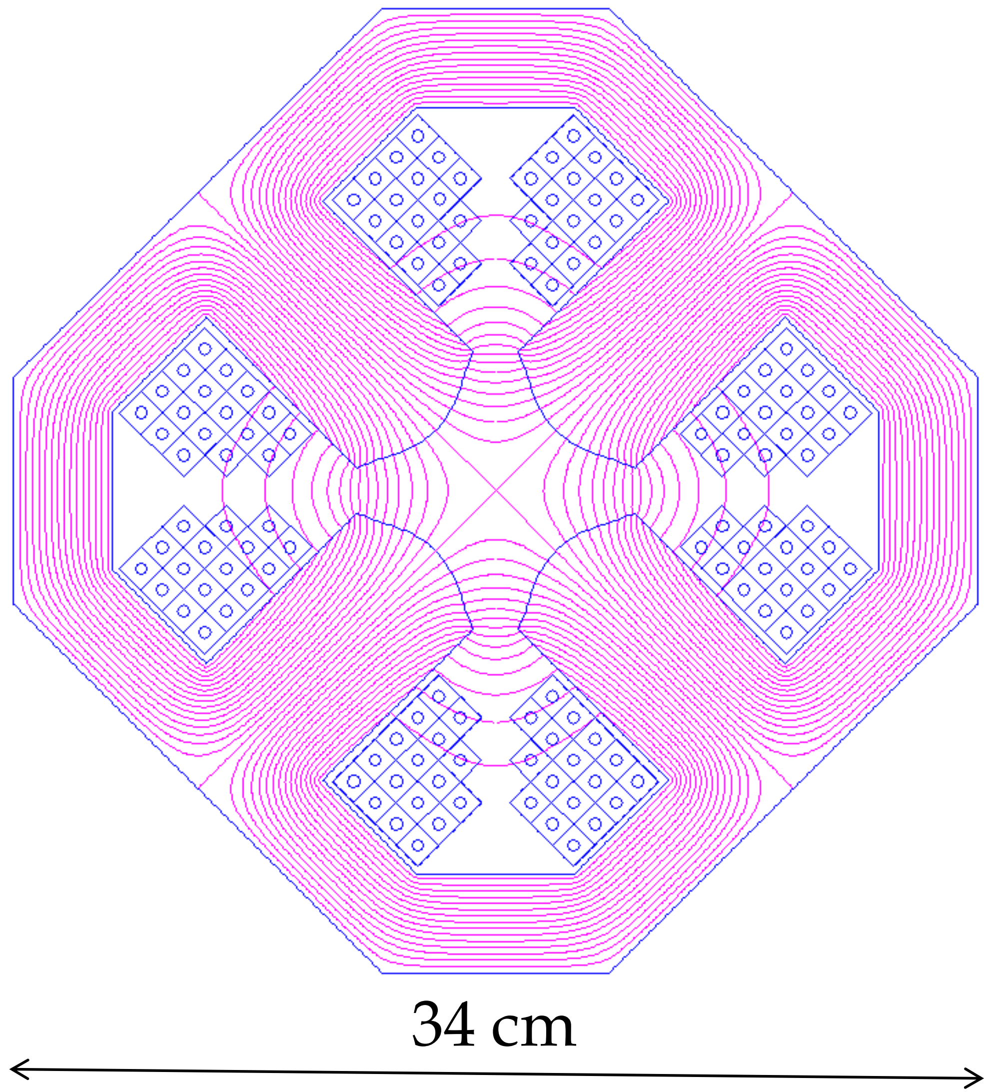
Parameters for Quadrupoles	
Number of magnets	736
Aperture radius [mm]	30
Field gradient [T/m]	10.5
Magnetic Length [mm]	1000
Yoke length [mm]	980
Total length [mm]	1200
Weight [kg]	500
Number of turns/pole	1
Current [A]	3850
Conductor material	copper
Current density [A/mm^2]	2.5
Resistance [mΩ]	0.12
Power [kW]	1.8
Inductance [mH]	0.05
Cooling	water/air



made with one-piece laminations

RR: Insertion+BP Quadrupoles

Parameters for Quadrupoles	
Number of magnets	194
Aperture radius [mm]	30
Field gradient [T/m]	18
Magnetic Length [mm]	1000
Yoke length [mm]	980
Total length [mm]	1200
Weight [kg]	500
Number of turns/pole	17
Current [A]	385
Conductor material	Copper
Current density [A/mm^2]	5
Resistance [mΩ]	40
Power [kW]	6
Inductance [mH]	12
Cooling	water



60.5 GeV Recirculator

Parameters from Alex Bogacz

60.5 GeV LHeC Recirculator: Linac FODO, Arcs FMC optics

	Dipoles (R=764 m)			Q0			Q1			Q2			Q3		
	#	*Field*	*M.Length*	*#*	*Gradient*	*M.Length*	*#*	*Gradient*	*M.Length*	*#*	*Gradient*	*M.Length*	*#*	*Gradient*	*M.Length*
LINAC 1				18	2.200	1.000				18	-2.200	1.000			
LINAC 2				18	2.200	1.000				18	2.200	1.000			
Arc 1	600	0.046	4.000	60	-3.179	1.000	60	10.515	1.000	60	-11.053	1.000	60	10.535	1.000
Arc 2	600	0.089	4.000	60	-6.206	1.000	60	20.529	1.000	60	-21.579	1.000	60	20.568	1.000
Arc 3	600	0.133	4.000	60	12.397	1.000	60	17.493	1.000	60	-24.576	1.000	60	17.918	1.000
Arc 4	600	0.177	4.000	60	16.462	1.000	60	23.228	1.000	60	-32.633	1.000	60	23.792	1.000
Arc 5	600	0.221	4.000	60	29.227	1.000	60	28.904	1.000	60	-40.791	1.000	60	29.667	1.000
Arc 6	600	0.264	4.000	60	35.014	1.000	60	34.627	1.000	60	-48.868	1.000	60	35.541	1.000

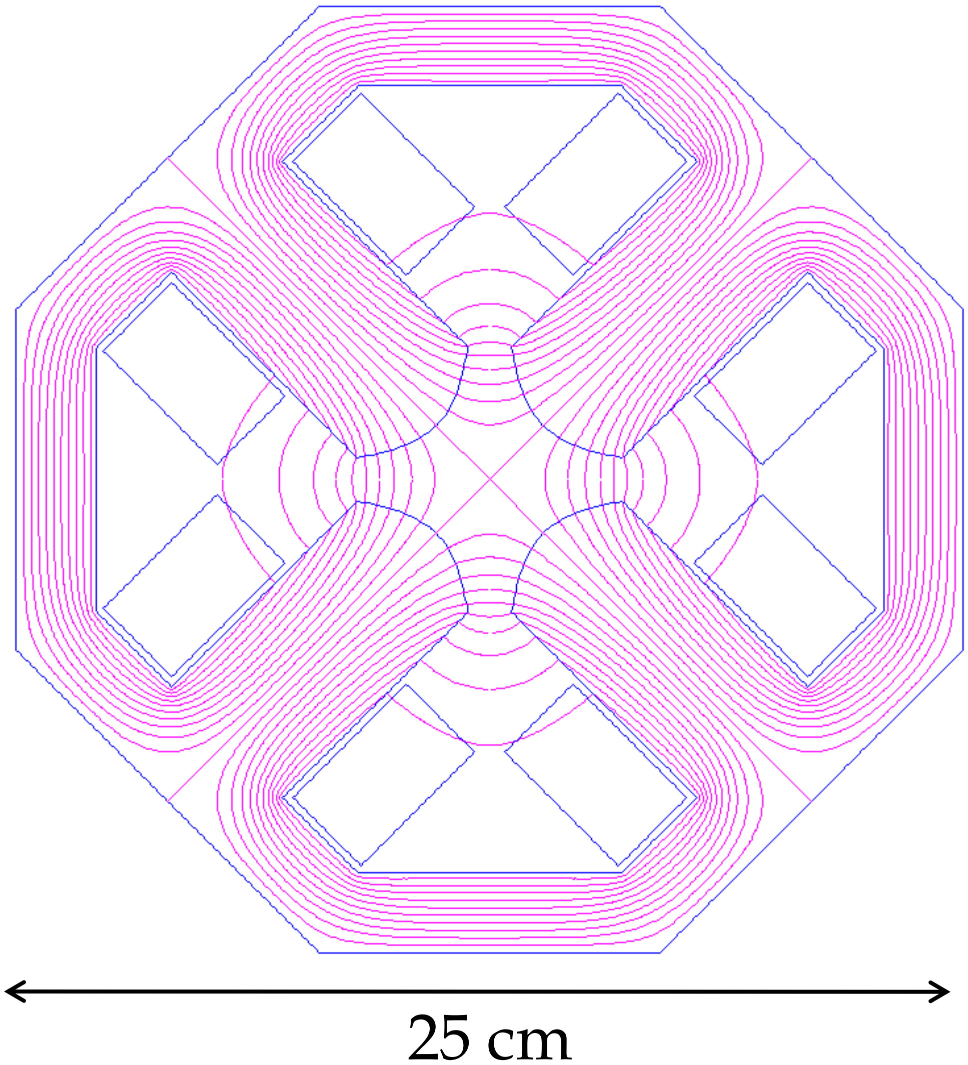
Units: meter (m), Tesla (T), T/m

Proposed solution:

- one type of bending magnets, possibly with different conductors
- one type of quadrupoles for the Linacs
- one type of quadrupoles for the arcs in two different length: Q2 1200 mm, Q0-Q1-Q3 900 mm; possibly with different conductors, radius 20 mm

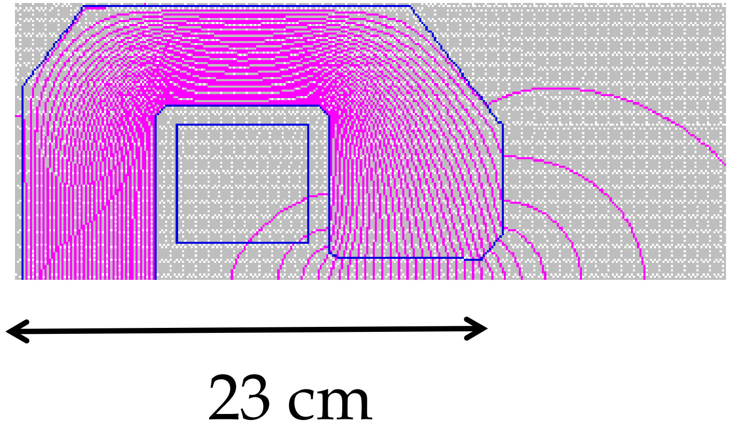
Quadrupoles for 10 GeV Recirculator Linacs

Parameters for Quadrupoles	
Number of magnets	72
Aperture radius [mm]	20
Field gradient [T/m]	4.4
Magnetic Length [mm]	500
Weight [kg]	150
Number of turns/pole	18
Current [A]	40
Conductor material	Copper
Current density [A/mm^2]	1.5
Resistance [mΩ]	60
Power [kW]	0.1
Inductance [mH]	9
Cooling	air



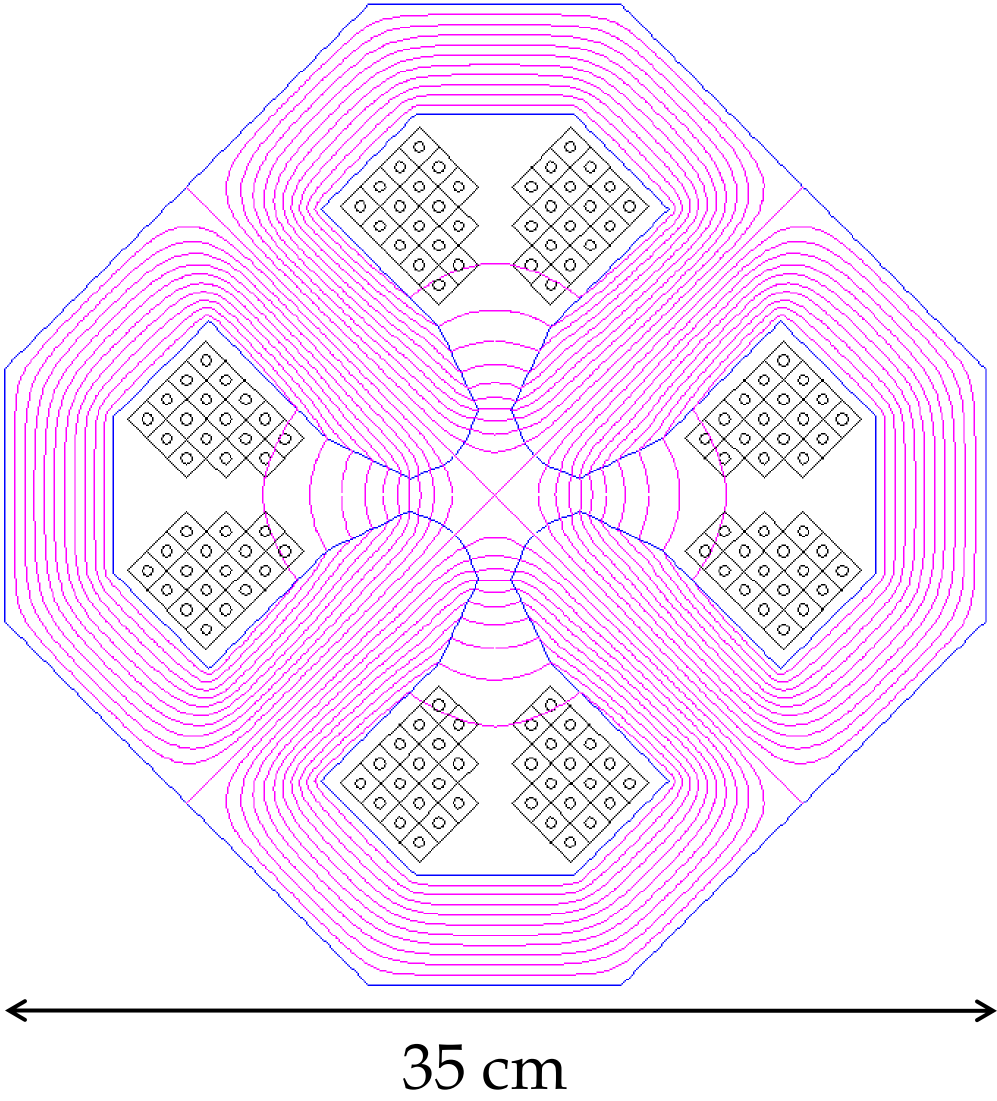
Bending for 60 GeV Recirculator

Magnet Parameters L-R	
Beam Energy [GeV]	70
Magnetic Length [m]	5.0
Magnetic field [Gauss]	3300
Number of magnets	6*600
Vertical aperture [mm]	25
Pole width [mm]	80
Number of coils	2
Number of turns/coil	1
Current [A]	2750
Conductor material	copper
Magnet Inductance [mH]	0.12
Magnet Resistance [mΩ]	0.13
Power per magnet [kW]	1
Cooling	Air or water



Quadrupoles for 60 GeV Recirculator

Parameters for Quadrupoles	
Number of magnets	1440
Aperture radius [mm]	20
Field gradient [T/m]	41
Magnetic Length [mm]	900-1200
Weight [kg]	550-750
Number of turns/pole	17
Current [A]	410
Conductor material	Copper
Current density [A/mm^2]	5
Resistance [mΩ]	30-40
Power [kW]	5-7
Inductance [mH]	15-20
Cooling	water



Experimental work for RR: why

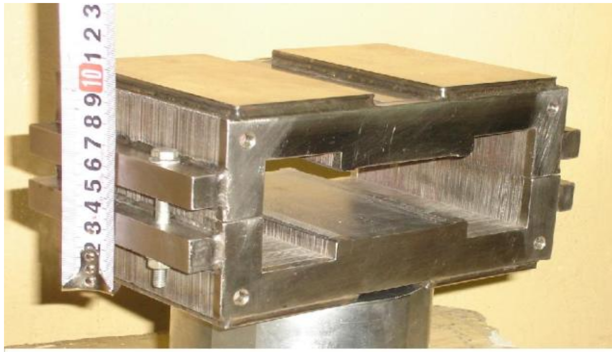
ISSUES

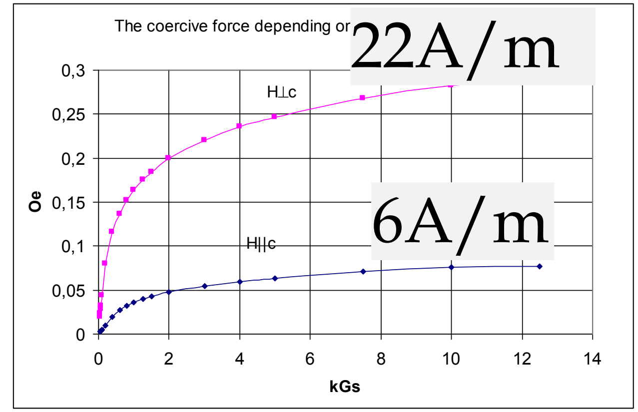
- field reproducibility & homogeneity at injection
- synchrotron radiation power
- compact & easy magnets to fit in the present LHC

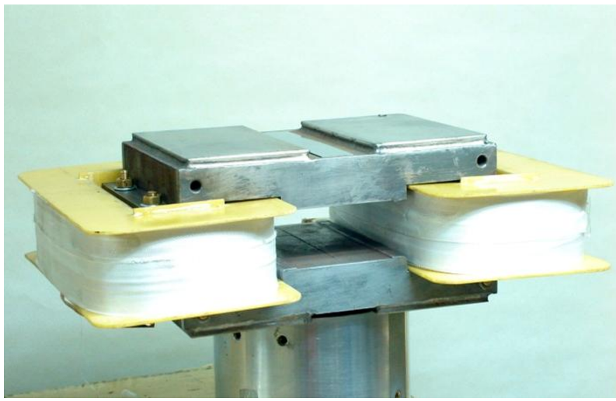
STRATEGY

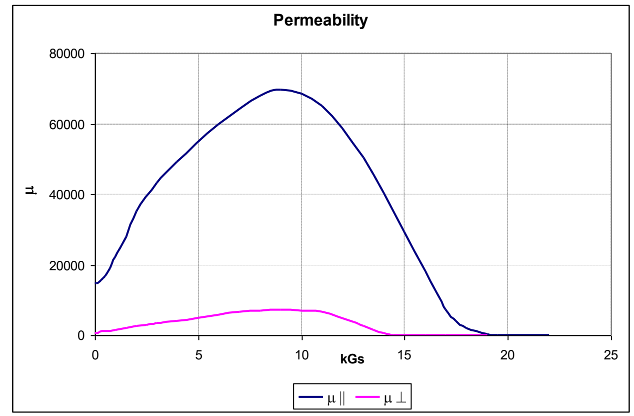
- low coercivity concepts: two alternatives are being explored
  - all-iron (BINP)
  - interleaved laminations (CERN)
- C-Type, open towards the outside

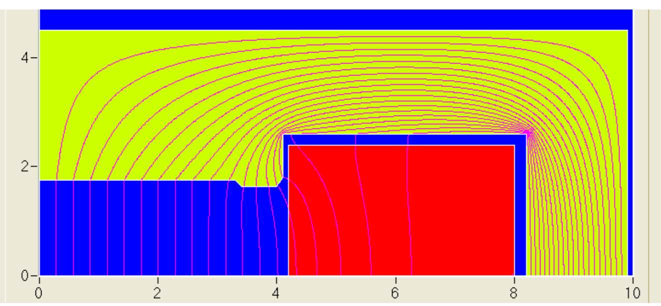
STATUS OF BINP WORK

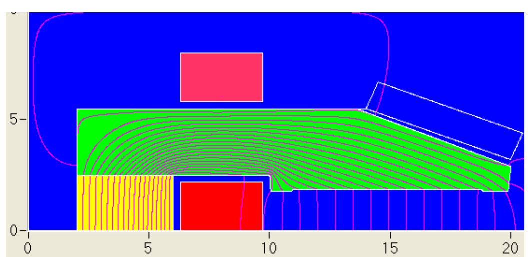










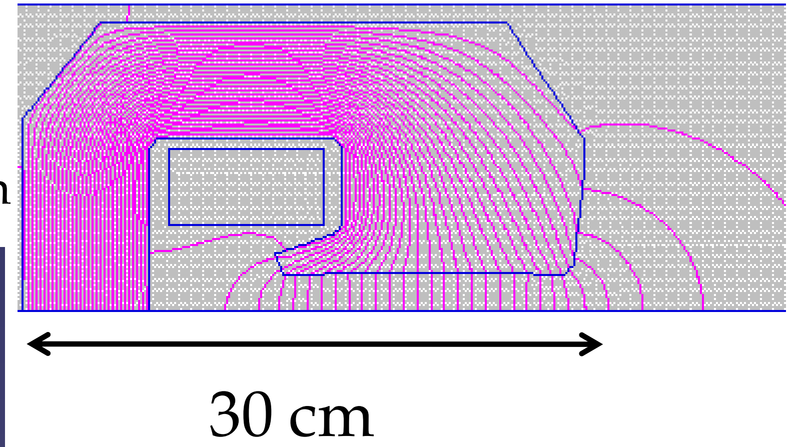


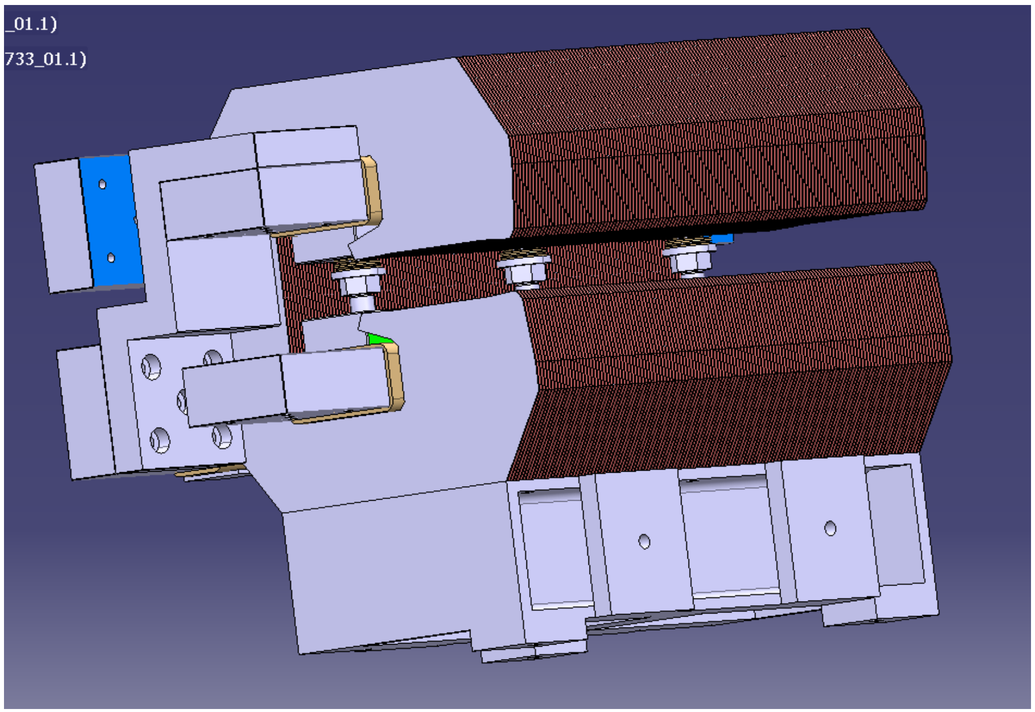
3408 grain oriented steel
0.35 mm thick laminations

- after cycles of different amplitude, the remanent field is of about 1 Gauss in all cases
- the reproducibility of the injection field is about ± 0.075 Gauss

STATUS OF CERN WORK

- interleaved, low-coercivity iron (H_c<25A/m)
- low resistance conductor, air cooled
- two turns only, bolted bars
- 400 mm long models with different types of iron





Magnet Parameters	
Beam Energy [GeV]	70
Magnetic Length [m]	5.45
Magnetic field [Gauss]	874
Number of magnets	3080
Vertical aperture [mm]	40
Pole width [mm]	150
Number of coils	2
Number of turns/coil	1
Current [A]	1500
Conductor section [mmxmm]	92x43
Conductor material	aluminum
Magnet Inductance [mH]	0.15
Magnet Resistance [mΩ]	0.2
Power per magnet [W]	450
Cooling	air

- design completed
- spacers under manufacture (phenolic)
- NiFe 50 steel (H_c = 3 A/m,) as reference
- low carbon iron (H_c=20 A/m) is available
- first model expected before Christmas

Conclusion

- magnets are certainly not the major issue of this Project
- they are small, light, relatively cheap though numerous
- the tight requirements of low field reproducibility in case of the RR option can be met by a proper use of materials and design
- magnets for the transfer lines were not considered here