Hollow e-lens powering scheme

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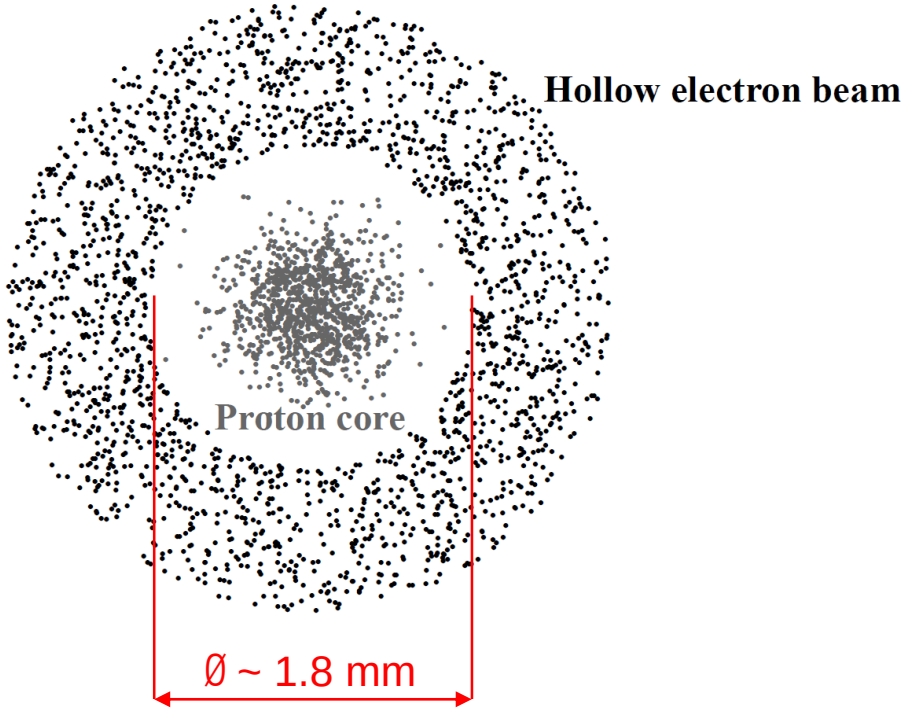
Outline

- HEL configuration. Design choices.
- Number of circuits.
- Conclusions.

Work carried out under the WP5 HL study.
Acknowledgments to G. Kirby, G. Gobbi.

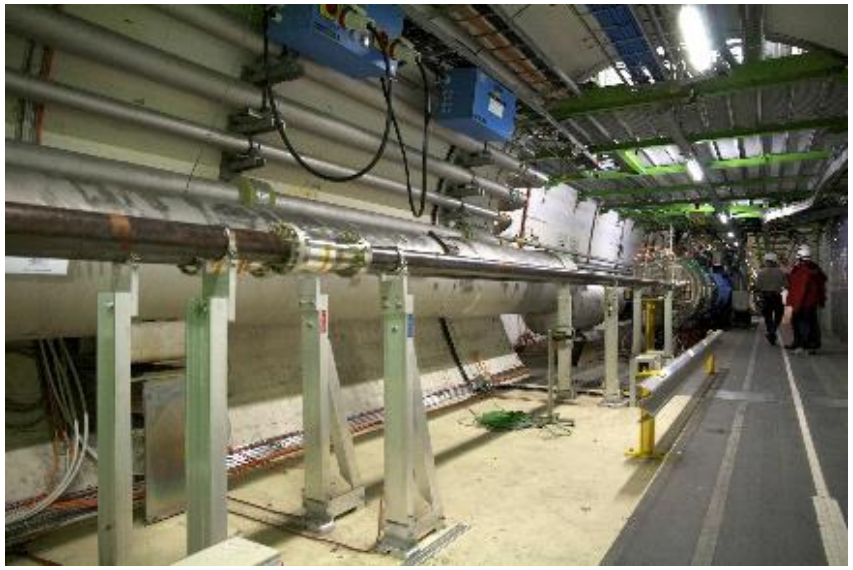
Functional specifications 1



Off-centre of the ring ± 0.15 mm

Beam-beam overlapping: ~3m , e current intensity: up to 5 A.
Use at injection and at collision level => different ring size

Functional specifications 2



Candidate locations for the electron lenses are RB-44 and RB-46 at Point 4, on each side of the interaction region IR4.

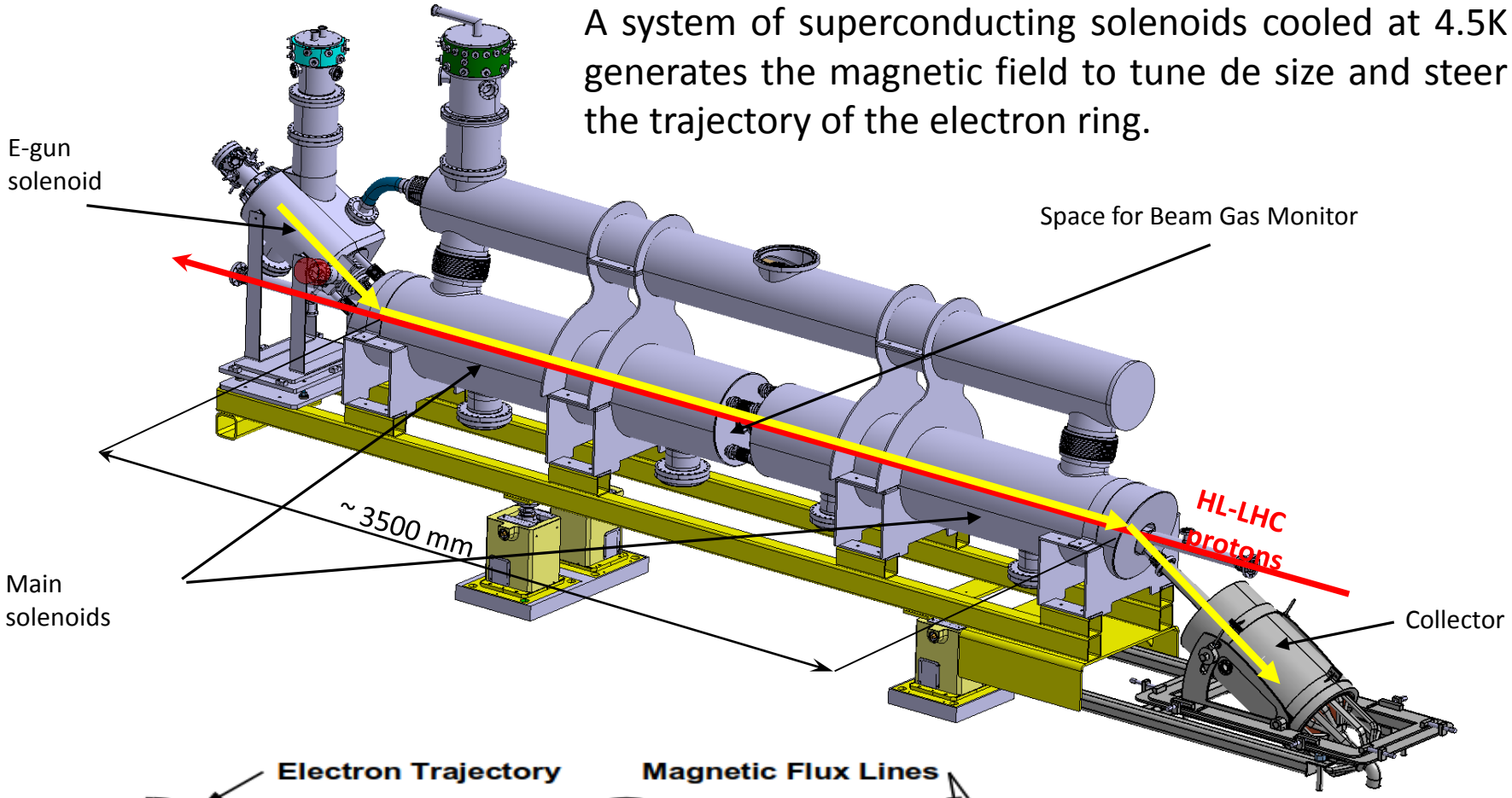
The beam to beam distance is 420 mm.
The longitudinal available space is limited.

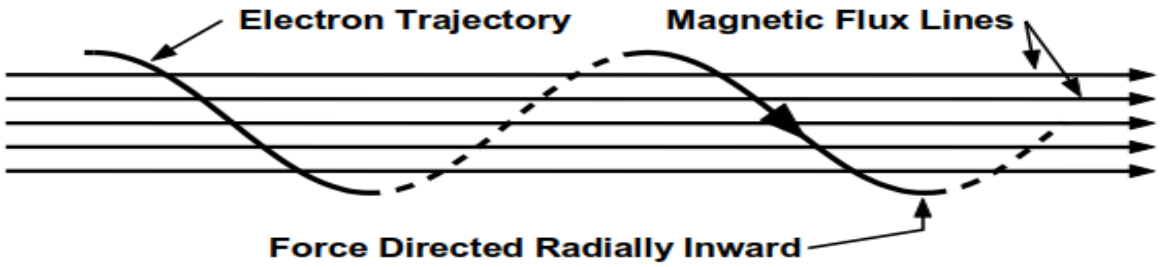
➡ Compact design.

Construction of two elements plus a spare.

The system configuration

Electrons are produced by the cathode of an e-gun.
A system of superconducting solenoids cooled at 4.5K generates the magnetic field to tune de size and steer the trajectory of the electron ring.





HL-LHC hollow electron lenses.

Comparison with existing electron lenses

	RHIC EL	Tevatron EL	HL-LHC HEL
Effective length [m]	2.1	2	3
Current from cathode [A]	1	0.6-1	Up to 5
Main solenoid field [T]	6	3	5
Solenoid inner bore [mm]	200	160	180
E-gun field [T]	0.2-0.8	0.3	0.2-4
Cathode radius [mm]	4.1 @250GeV 7.5 @100GeV	7.5	4 – 8.05 Hollow
Cathode surface [cm^2]	0.53 @250GeV 1.77 @100GeV	1.77	1.53
Current density [A/cm^2]	1.89 @250GeV 0.53 @100GeV	0.6	3.27
E-beam compression	1.6-5.5	3.26	1.41-4.47

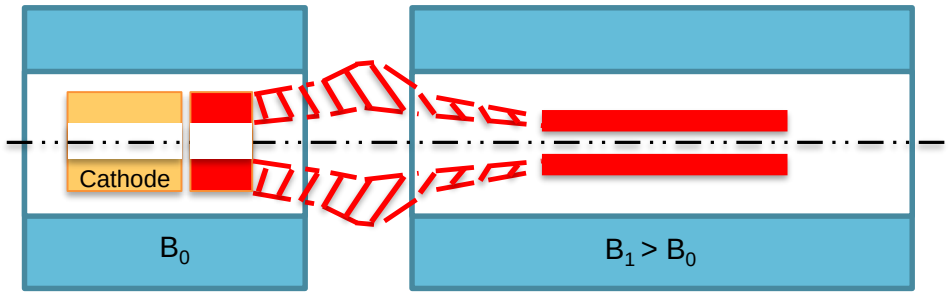
Cathode size and magnetic fields

Use at injection and at collision level => different electron ring size

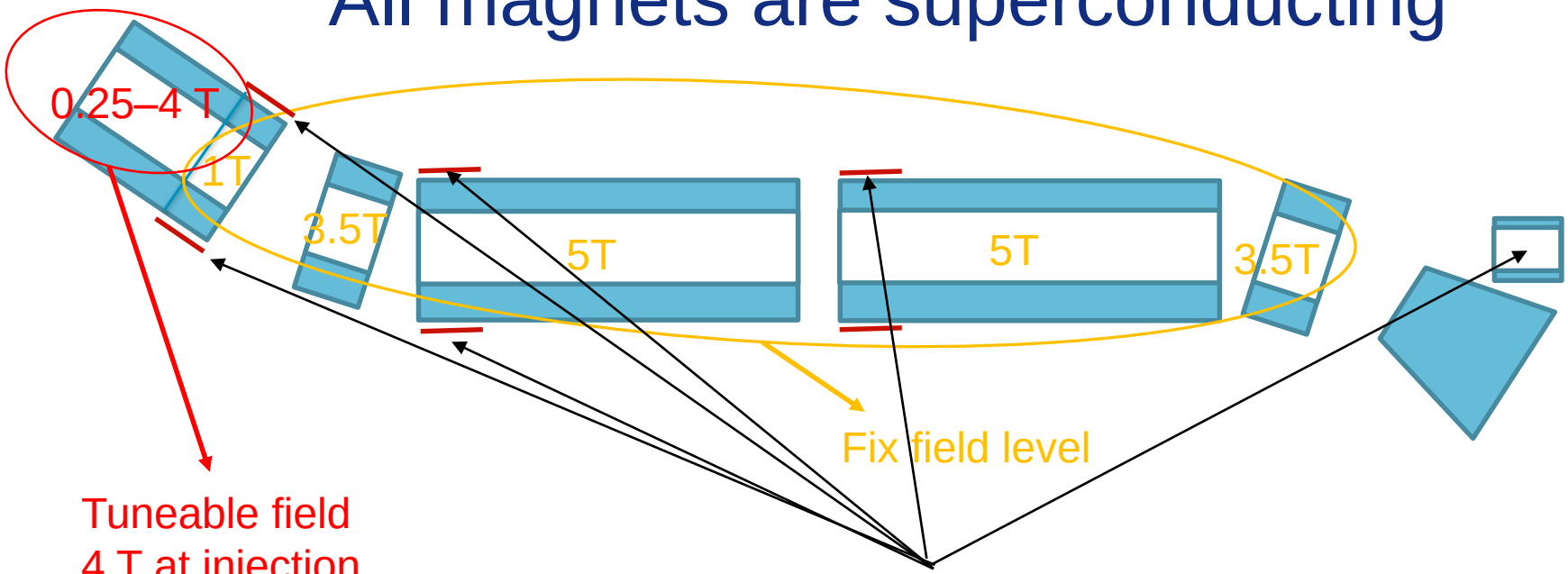
Nominal magnetic field of the main solenoid	5T
Nominal magnetic field in the e-gun cathode	0.25 T – 4 T
Inner radius of the hollow electron beam @ operation fields (5T, 0.25T)	0.9 mm
Outer radius of the hollow electron beam @ operation fields (5T, 0,25T)	1.8 mm
Inner diameter of the cathode	8.05 mm
Outer diameter of the cathode	16.10 mm
Inner radius of the hollow electron beam @ 5 T with 4 T @ cathode	3.6 mm
Outer radius of the hollow electron beam @ 5 T with 4 T @ cathode	7.2 mm
Nominal current at the cathode	Up to 5 A

$$\frac{r_0}{r_1} = \sqrt{\frac{B_1}{B_0}}$$

Where r_0 and r_1 are the radii of the electron beam in point 0 (cathode) and 1 (main solenoid) and B_0 and B_1 are the magnetic field in points 0 and 1 respectively.



Magnetic field configuration. All magnets are superconducting



Minimum number of circuits

2 solenoids e-gun
1 bending solenoids
2 main solenoids

1 Dipole V e-gun
1 Dipole H e-gun
2 Dipole V main
2 Dipole H main
1 Dipole V at the exit (in series with the bending)

Tot: 5 circuits with current < 450 A, 6 circuits with current < 50 A

	BlueWhale Inner	BlueWhale Outer	Dump Solenoid	Bend Solenoid 2	Gun 3	Gun 2	dipole y3 B	dipole y3 A	dipole x3 B	dipole x1 B	dipole x3 1	dipole x1 A	Gun Dipole y B	Gun Dipole y A	Gun Dipole x B	Gun Dipole x A	dipole y1 B	dipole y1 A	tube	Solenoid - 1	Solenoid - 2
BlueWhale Inner	558.8468	-101.762	7.673725	0.015978	0.004349	0.007945	0.028076	0.018593	-0.00493	-0.00034	0.004898	0.000341	0.000219	5.07E-05	-0.00014	-8.1E-07	0.003571	0.002913	0	0.214137	4.092367
BlueWhale Outer	-101.762	451.7353	-4.84342	-0.01058	-0.00218	-0.00425	0.014927	0.022468	0.003925	0.000273	-0.0039	-0.00027	0.001613	0.001587	-1.7E-05	-0.00012	0.002333	0.002857	0	-0.17046	-3.24785
Dump Solenoid	7.673725	-4.84342	845.8878	0.030507	0.006876	0.012828	0.003425	-0.0506	-0.02804	-0.00092	0.028035	0.000918	-0.00236	-0.00246	-0.00015	0.00015	-0.001	-0.00277	0	0.552208	99.79656
Bend Solenoid 2	0.015978	-0.01058	0.030507	849.8073	5.425018	4.155577	-0.00735	8.22E-05	0.003863	5.352241	-0.00386	-5.36512	0.617751	-0.3819	-0.48895	0.488952	-5.91016	4.694945	0	99.79211	0.562848
Gun 3	0.004349	-0.00218	0.006876	5.425018	328.5775	82.95297	-0.00196	-0.00071	0.000635	0.070812	-0.00063	-0.07097	12.73542	-12.7384	-12.7366	12.73686	-0.04156	0.091766	0	2.920631	0.114847
Gun 2	0.007945	-0.00425	0.012828	4.155577	82.95297	851.289	-0.00266	-0.00063	0.001029	0.063187	-0.00103	-0.06333	-12.8412	12.84148	12.84116	-12.8415	-0.00548	0.108935	0	3.390528	0.202196
dipole y3 B	0.028076	0.014927	0.003425	-0.00735	-0.00196	-0.00266	56.46795	9.303792	2.376862	0.00044	-2.37666	-0.00044	-0.00237	-0.00201	1.61E-05	-1.6E-05	-0.01317	-0.01215	0	-0.99367	12.25227
dipole y3 A	0.018593	0.022468	-0.0506	8.22E-05	-0.00071	-0.00063	9.303792	56.46794	-2.37725	-0.00044	2.377011	0.000441	-0.00252	-0.00224	-2.3E-05	2.26E-05	-0.01215	-0.01317	0	1.000495	-12.2534
dipole x3 B	-0.00493	0.003925	-0.02804	0.003863	0.000635	0.001029	2.376862	-2.37725	56.73225	-0.01354	8.364307	-0.01245	-0.00012	-0.00014	-0.00238	-0.00233	0.000441	-0.00044	0	1.031887	-12.0818
dipole x1 B	-0.00034	0.000273	-0.00092	5.352241	0.070812	0.063187	0.00044	-0.00044	-0.01354	56.67521	-0.01243	8.340357	0.002611	-0.00656	-0.06198	-0.04799	2.419985	-2.42031	0	-12.0525	-0.03522
dipole x3 1	0.004898	-0.0039	0.028035	-0.00386	-0.00063	-0.00103	-2.37666	2.377011	8.364307	-0.01243	56.73223	-0.01356	0.000116	0.000139	-0.00233	-0.00238	-0.00044	0.000441	0	-1.02533	12.07913
dipole x1 A	0.000341	-0.00027	0.000918	-5.36512	-0.07097	-0.06333	-0.00044	0.000441	-0.01245	8.340357	-0.01356	56.73223	-0.00264	0.006569	-0.04808	-0.06208	-2.37598	2.376316	0	12.07913	0.0353
Gun Dipole y B	0.000219	0.001613	-0.00236	0.617751	12.73542	-12.8412	-0.00237	-0.00252	-0.00012	0.002611	0.000116	-0.00264	109.0884	5.399662	13.22303	-13.2227	-0.07355	-0.0509	0	0.027867	-0.02369
Gun Dipole y A	5.07E-05	0.001587	-0.00246	-0.3819	-12.7384	12.84148	-0.00201	-0.00224	-0.00014	-0.00656	0.000139	0.006569	5.399662	109.0887	-13.223	13.22275	-0.05213	-0.05711	0	-0.33003	-0.02751
Gun Dipole x B	-0.00014	-1.7E-05	-0.00015	-0.48895	-12.7366	12.84116	1.61E-05	-2.3E-05	-0.00238	-0.06198	-0.00233	-0.04808	13.22303	-13.223	109.0888	5.399629	0.000436	-0.00819	0	-0.19171	-0.00318
Gun Dipole x A	-8.1E-07	-0.00012	0.00015	0.488952	12.73686	-12.8415	-1.6E-05	2.26E-05	-0.00233	-0.04799	-0.00238	-0.06208	-13.2227	13.22275	5.399629	109.0892	-0.00042	0.008194	0	0.189776	0.003176
dipole y1 B	0.003571	0.002333	-0.001	-5.91016	-0.04156	-0.00548	-0.01317	-0.01215	0.000441	2.419985	-0.00044	-2.37598	-0.07355	-0.05213	0.000436	-0.00042	56.46795	9.303792	0	12.25227	0.033974
dipole y1 A	0.002913	0.002857	-0.00277	4.694945	0.091766	0.108935	-0.01215	-0.01317	-0.00044	-2.42031	0.000441	2.376316	-0.0509	-0.05711	-0.00819	0.008194	9.303792	56.46794	0	-12.2534	-0.03397
tube	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solenoid - 1	0.214137	-0.17046	0.552208	99.79211	2.920631	3.390528	-0.99367	1.000495	1.031887	-12.0525	-1.02533	12.07913	0.027867	-0.33003	-0.19171	0.189776	12.25227	-12.2534	0	9313.454	36.03791
Solenoid - 2	4.092367	-3.24785	99.79656	0.562848	0.114847	0.202196	12.25227	-12.2534	-12.0818	-0.03522	12.07913	0.0353	-0.02369	-0.02751	-0.00318	0.003176	0.033974	-0.03397	0	36.03791	9313.454

Inductance Given in mH

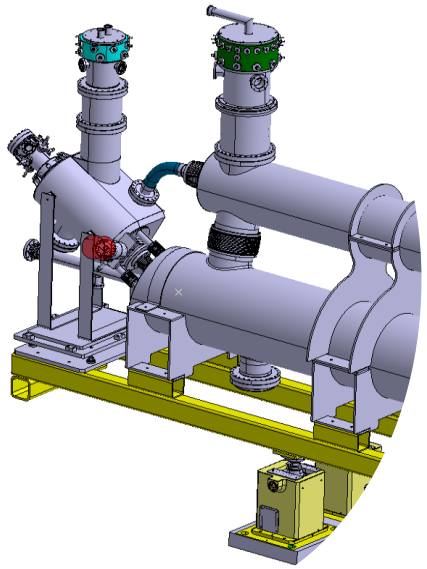
Stored Energy 1.182 MJ

Conclusions

Open points - How to continue quickly

Next steps

Open points:



- Quadrupole correctors.
  Proposed solution: Staging.

- Smaller diameter of vacuum chamber.
  Proposed solution: Continue with the 180 mm but compute as well the 160 mm. The CAD 3D model is parametric.

Next steps:

Fill the table of values needed for circuit computation. Correction quadrupoles in.

Work with 180-mm bore main solenoids. Consider the 160-mm bore option and implement it as soon as possible (if possible).

Thank you for your attention