

RCS pulsed magnets chambers

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What has been discussed

- A first chamber layout has been discussed for the RCS pulsed magnets
 - Horizontal aperture constrained by RCS 2 optics design (beam size and beam excursion)
 - Vertical aperture constrained by magnet design (field reach)
 - Materials constrained by vacuum requirements, eddy currents and power loss, impedance and beam stability
- See RCS normal conducting magnets vacuum chambers: <https://indico.cern.ch/event/1423057/>

Greenfield RCS chain parameters

- Current baseline is a chain of four RCS to reach 5 TeV
- Large magnet ramping rate are needed in all RCS
- RCS 4 ramping rate is 565 T/s → possible candidate for HTS pulsed dipoles

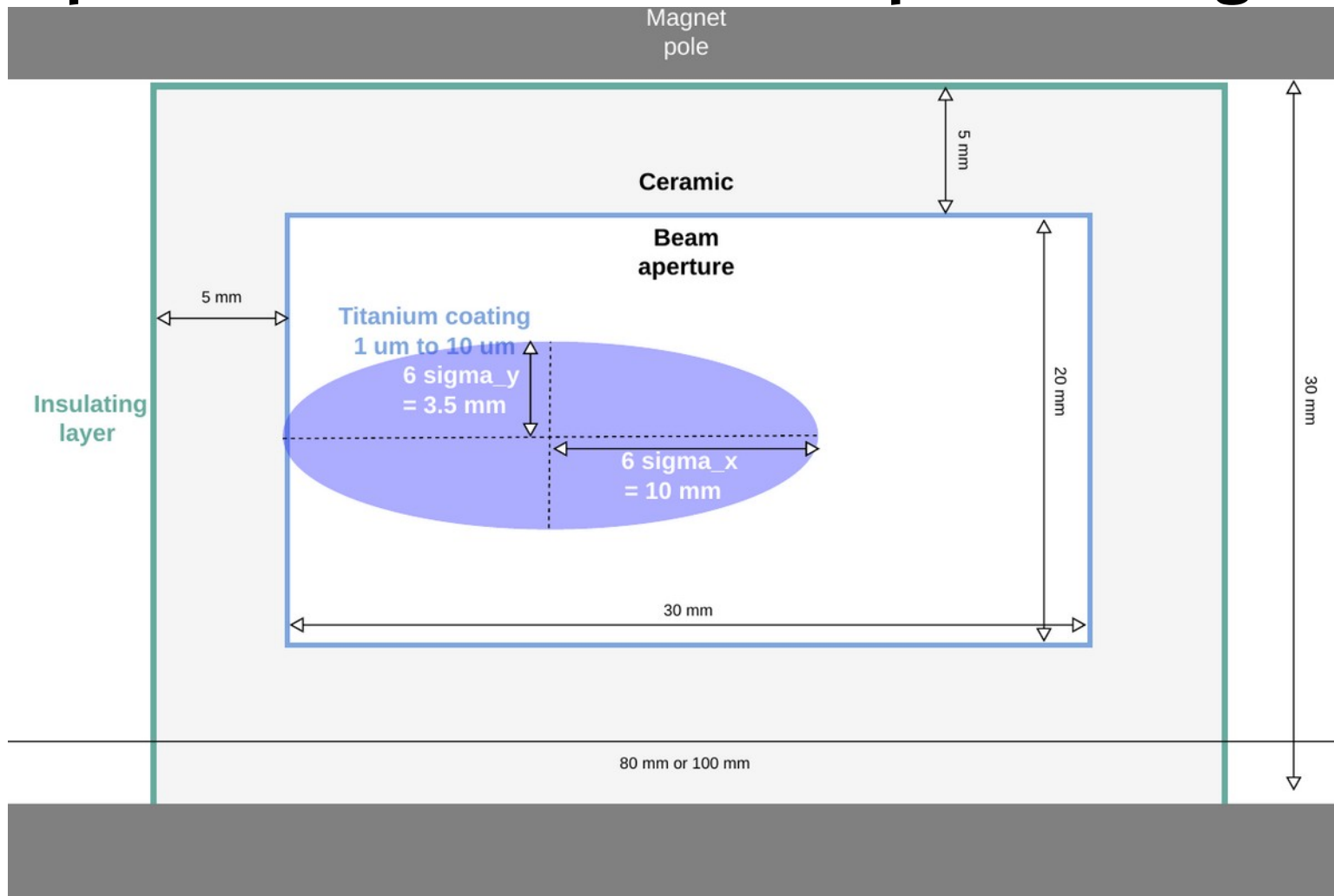
Parameter	Unit	RCS1	RCS2	RCS3	RCS4
Hybrid RCS	-	no	yes	yes	yes
Repetition rate	Hz	5	5	5	5
Circumference	m	5990	5990	10700	35000
Injection energy	GeV	63	314	750	1500
Extraction energy	GeV	314	750	1500	5000
Energy ratio	-	5.0	2.4	2.0	3.3
Assumed survival rate	-	0.9	0.9	0.9	0.9
Total survival rate	-	0.9	0.81	0.729	0.6561
Acceleration time	ms	0.34	1.10	2.37	6.37
Revolution period	μs	20	20	36	117
Number of turns	-	17	55	66	55
Required energy gain per turn	GeV	14.8	7.9	11.4	63.6
Average accel. gradient	MV/m	2.44	1.33	1.06	1.83
Straight section length	m	2335	2335	3977	10367
Length with NC magnets	m	3655	2539	4366	20376
Length with SC magnets	m	-	1115	2358	4257
Max. NC dipole field	T	1.8	1.8	1.8	1.8
Max. SC dipole field	T	-	10	10	16
Ramp rate	T/s	4200	3282	1519	565
Main RF frequency	GHz	1.3	1.3	1.3	1.3
Harmonic number	-	25900	25900	46300	151400

Table 7.1: RCS acceleration chain key parameters

RCS 4 ramp rate < 600 T/s

RCS chain parameters from 2024
parameter report, F. Batsch, L. Thiele

Proposed radial build for the pulsed magnets



New developments: lattices for the Greenfield study

- New lattice design by L. Soubirou for the 4 RCS chain of the Greenfield study: [HEMAC discussion on 24/09/2024](#), and the update in her presentation today



	RCS 1	RCS 2	RCS 3	RCS 4
Type	Normal	Hybrid	Hybrid	Hybrid
Circumference	5990	5990	10700	35000
Number of arc	34	26	26	26
Number of cells per arc	4	4	6	9
Filling ratio arc	0.85	0.92	0.94	0.89
Filling ratio dipole	0.37	0.61	0.63	0.70
Pattern	NC, NC	SC, NC, SC	SC, NC, SC	2 bloc: SC, NC, SC
Length NC [m]	4.06	12.21	13.99	21.77
NC traj excursion [mm]	0	71.0	44.0	43.0
NC hor. aperture [mm]	174.3	142.1	93.1	83.2
Length SC [m]	-	2.68	3.78	2.27
SC traj excursion [mm]	-	26.0	24.0	8.0
SC hor. aperture [mm]	-	98.1	67.9	61.6
Vertical aperture [mm]	42.1	33.0	28.2	29.6
Length QP [m]	1.89	3.49	4.98	9.16
Aperture min. QP [m]	177.3	79.6	64.7	63.1
Length SXT [m]	0.5	0.5	1.0	1.0
QP B_{pole} (ϕ 50 mm)	1.31	1.25	1.35	1.18
SXT B_{pole} (ϕ 50 mm)	0.17	0.2	0.12	0.13
Max path length diff. [mm]	0	49.6	21.0	10.0
Relative path length diff. [1e-6]	0	0.2	0.1	0.1
MCF				0.0002
Qs			0.285	0.297
Qx	31.558	33.291	41.780	65.624
Qy	31.563	23.069	35.694	58.604
Qx	5.0	5.0	5.0	5.0
dQy	5.0	5.0	5.0	5.0

Larger chamber aperture are needed

NC too long, to be separated later

Beam excursion and beam size (from tracking) + 20 mm of margin (vacuum pipes..)

1 T recommended + large QP apertures for RCS 1&2

See L. Soubirou presentation for more details



New developments: high-level parameters for a RCS chain at CERN

- Several scenarios studied by F.Batsch and L.Thiele for a CERN based chain of RCS, using SPS and LHC tunnels
- Example here shows a chain of three RCS, reaching 3.8 TeV
 - Normal RCS in SPS (6.9 km)
 - Normal RCS in LHC (26.7 km)
 - Hybrid RCS in LHC
- Ramp rate of RCS LHC 2 is ~810 T/s

Parameter	Unit	RCS SPS	RCS LHC1	RCS LHC2
Hybrid RCS	-	No	No	Yes
Repetition rate	Hz	5	5	5
Circumference	m	6912	26659	26659
Injection energy	GeV	63	350	1600
Extraction energy	GeV	350	1600	3800
Energy ratio	-	5.6	4.6	2.4
Assumed survival rate	-	0.88	0.86	0.92
Total survival rate	-	0.88	0.76	0.70
Acceleration time	ms	0.45	2.60	4.42
Revolution period	μ s	23.0	88.9	88.9
Number of turns	-	19	29	50
Required energy gain per turn	GeV	15.1	43.1	44.4
Average accel. gradient	MV/m	2.15	1.62	1.68
Straight section length	m	2809	8000	8000
Length with NC magnets	m	4103	18650	12940
Length with SC magnets	m	-	-	5680
Max NC dipole field	T	1.8	1.8	1.8
Max SC dipole field	T	-	-	10
Ramp rate	T/s	3320	1400	810
Main RF frequency	GHz	1.3	1.3	1.3

RCS chain parameters from 2024 parameter report, F. Batsch, L. Thiele

References for RCS vacuum chambers

- 15/05/2024: MuCol Mini_workshop on RCS, pulsed magnets and powering
 - <https://indico.cern.ch/event/1388830/timetable/#20240515>
- 03/06/2024: RCS normal conducting magnets vacuum chambers
 - <https://indico.cern.ch/event/1423057/>
- 10/06/2024: short summary at Accelerator Design meeting
 - <https://indico.cern.ch/event/1408565/>
- 24/09/2024: 27th meeting on HEMAC discussions
 - <https://indico.cern.ch/event/1459125/>