Collector Ring Project at FAIR: Present Status

Dr. Petr Shatunov

Budker Institute of Nuclear Physics, Novosibirsk, Russia

Peterhof
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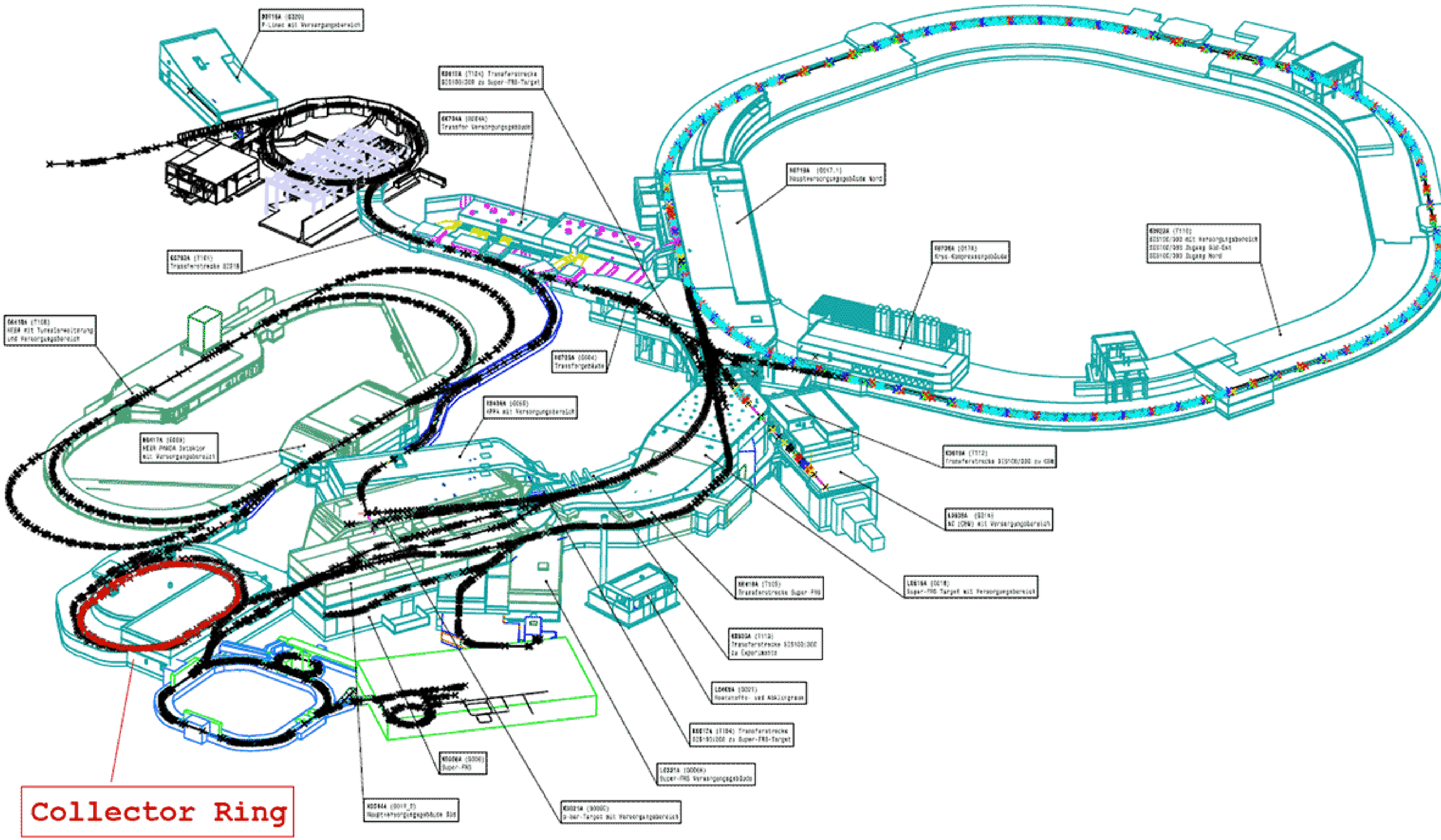
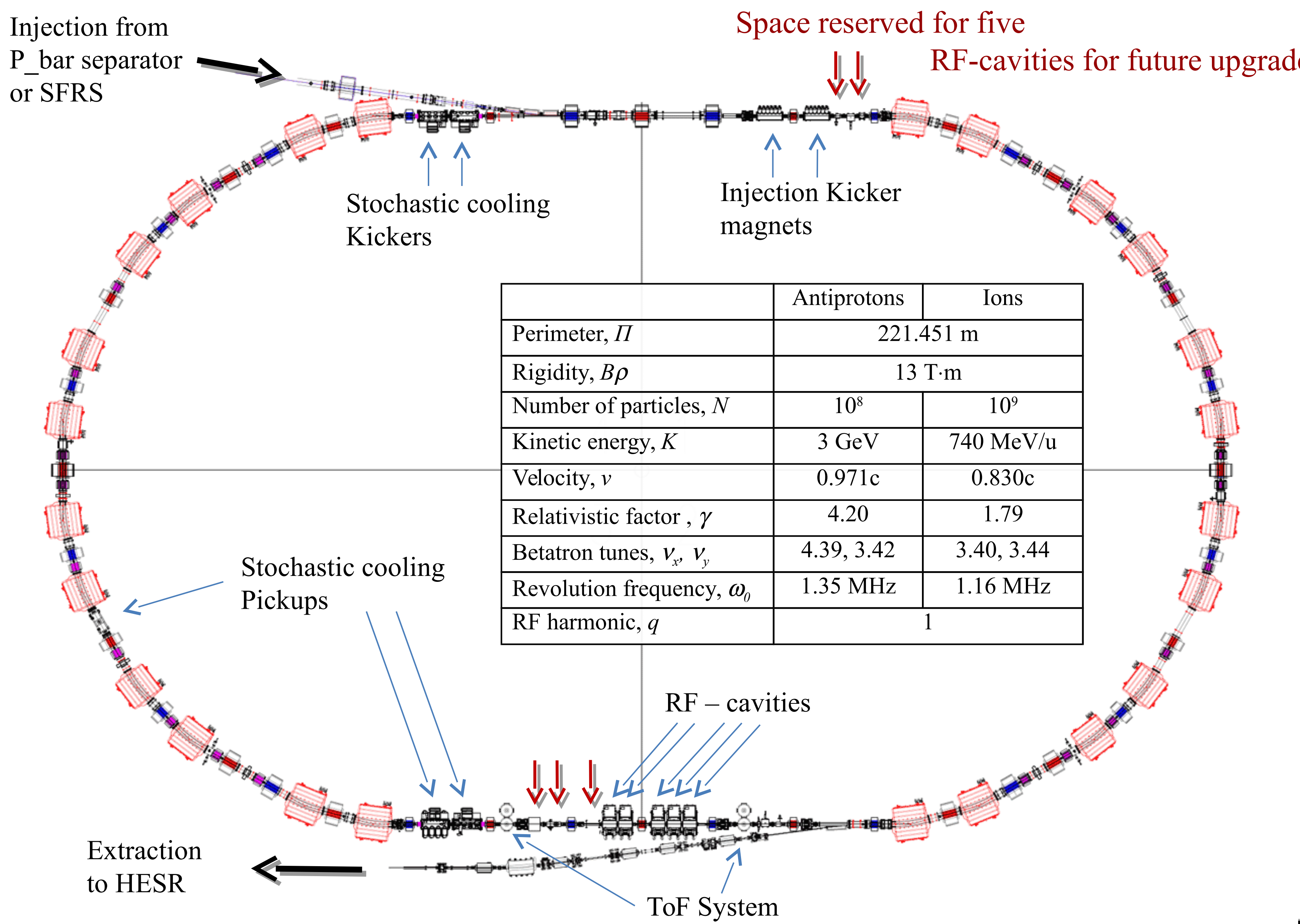
Project Timeline

- November, 2013: Memorandum of understanding — BINP, FAIR, GSI.
- February, 2014: the last version of TDR by the GSI team is published.
- August, 2014: The contract for the technical design, construction, installation, and commissioning of the whole CR and its components between BINP and FAIR.
- 2014-2015: 6 working meetings at GSI and BINP.
- November, 2015: International Workshop on Antiproton Physics and Technology at FAIR.
- May, 2016: Annex to TDR is published by BINP team.
- 2017-2020: Production, FAT, SAT, Installation.
- 2021+: Commissioning

FAIR Project



Present CR Layout



	Antiprotons	Ions
Perimeter, Π	221.451 m	
Rigidity, $B\rho$	13 T·m	
Number of particles, N	10^8	10^9
Kinetic energy, K	3 GeV	740 MeV/u
Velocity, v	0.971c	0.830c
Relativistic factor , γ	4.20	1.79
Betatron tunes, ν_x, ν_y	4.39, 3.42	3.40, 3.44
Revolution frequency, ω_0	1.35 MHz	1.16 MHz
RF harmonic, q	1	

Lattice

Pbar mode

$\nu_x = 4.39$

$\nu_y = 3.42$

$\gamma = 4.2$

RIB mode

$\nu_x = 3.40$

$\nu_y = 3.44$

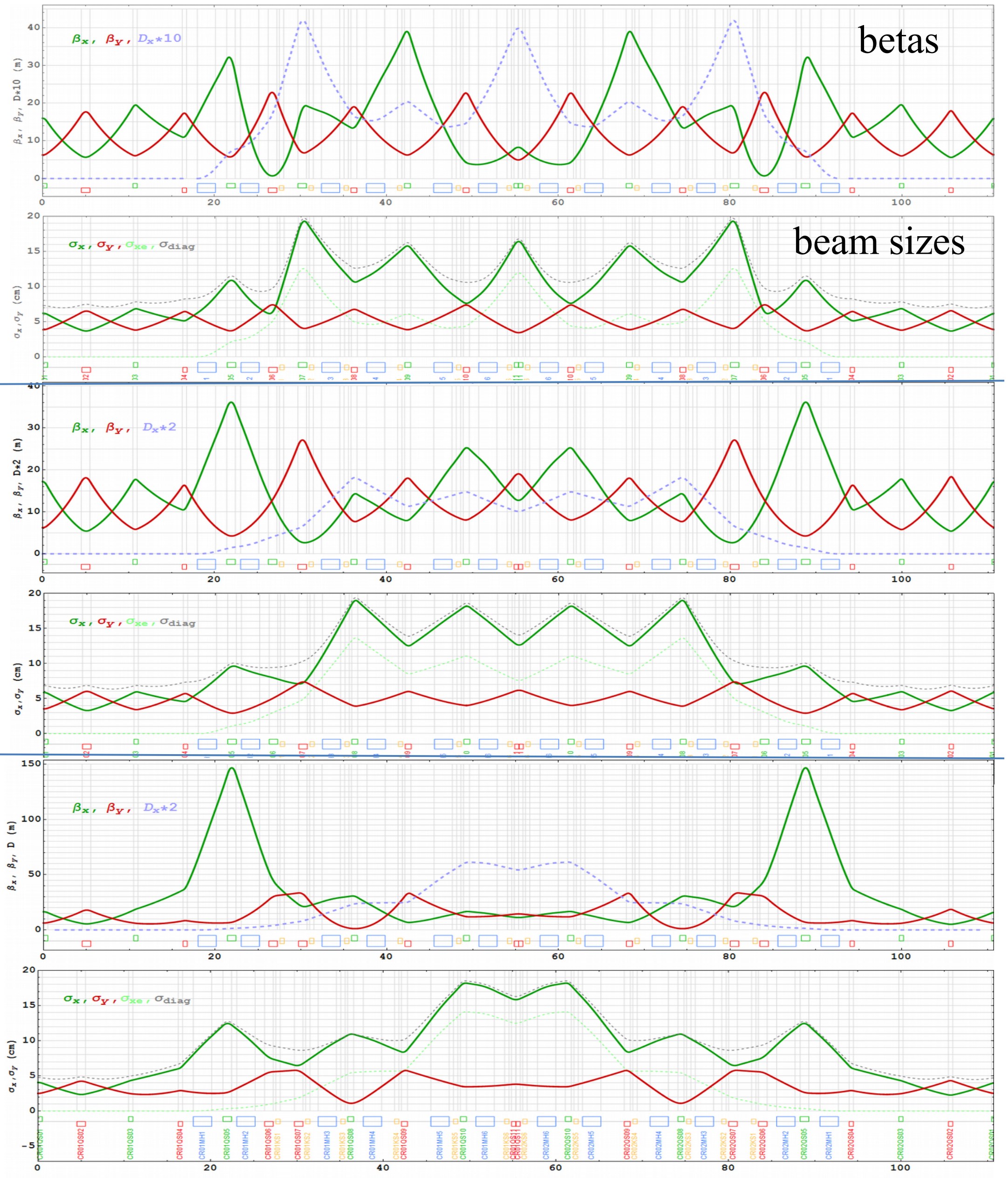
$\gamma = 1.79$

Isochronous mode

$\nu_x = 2.21$

$\nu_y = 4.27$

$\gamma = 1.43$



SC limitations:

$$\Delta \Psi_{pk\,x,y} \approx (2n+1)\cdot \pi/2.$$

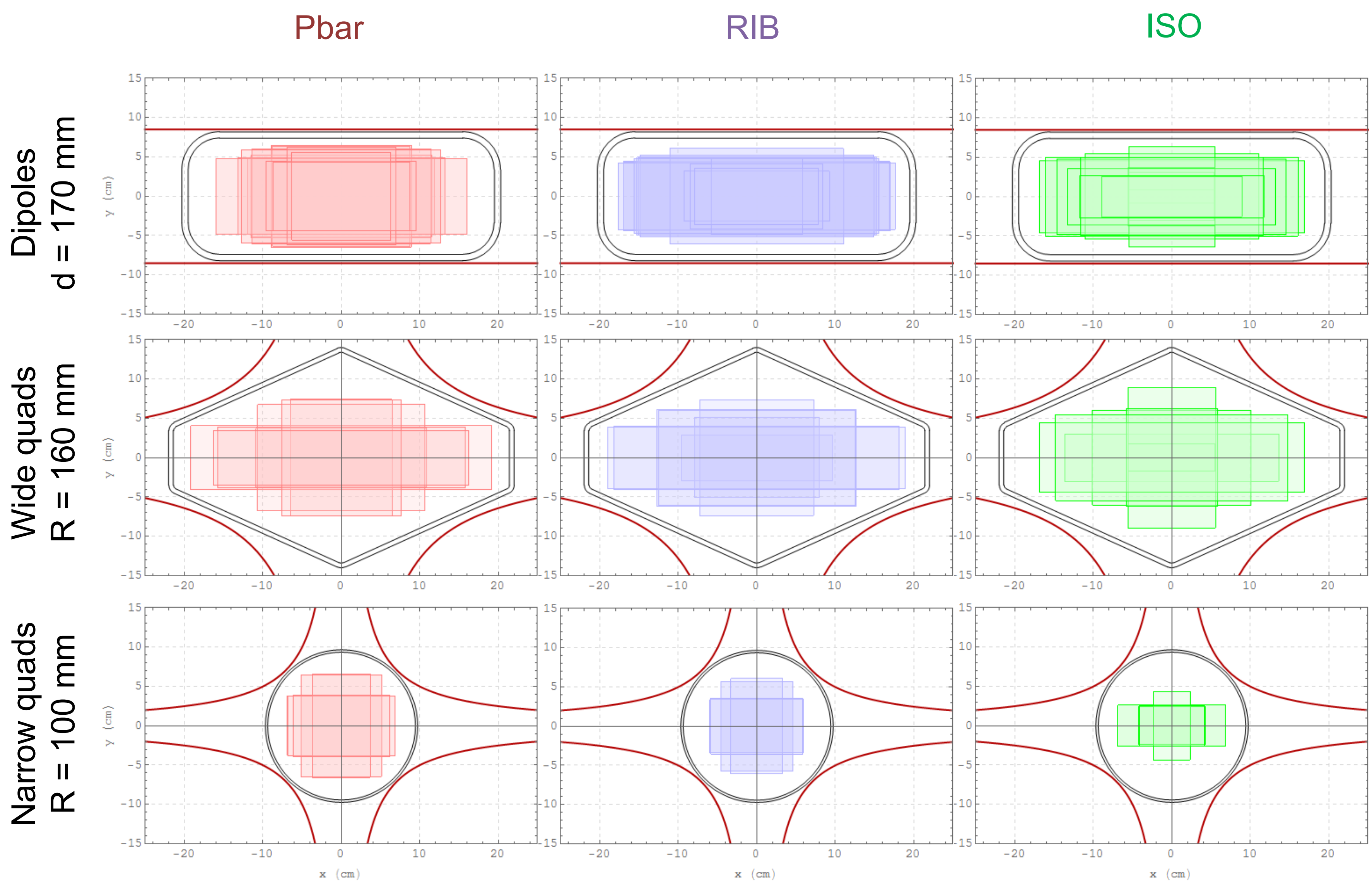
$$\eta_{pk} = \frac{1}{\gamma^2} - \frac{1}{s_k - s_p}\int_{s_p}^{s_k} \frac{D(s)}{\rho(s)}\,ds = 0$$

$$|\eta| = 0.014.$$

Aperture limitations:

1. Dipoles: $A_x = \pm 195$ mm, $A_y = \pm 75$ mm.
2. Arc "wide" quads: $A_x = \pm 214$ mm, $A_y = \pm 100$ mm (hexagonal shape).
3. RF-resonators: $(A_x^2 + A_y^2)^{0.5} = 75$ mm (round shape).
4. SC pickups and kickers: $A_{x,y} = \pm 70$ mm.
5. SC Palmer pickup: $A_y = \pm 66$ mm, $A_x = \pm 200$ mm.

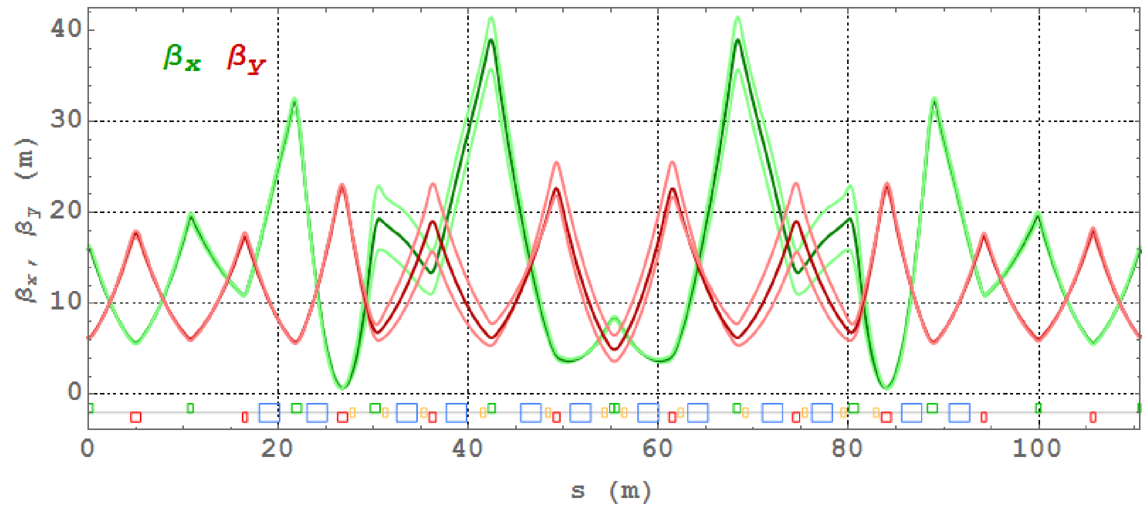
Aperture limitations



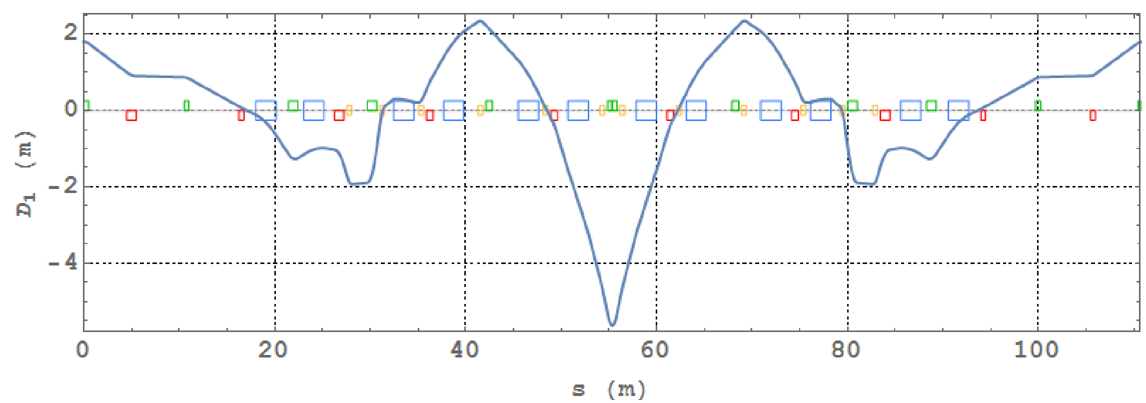
Injected beam cross-sections @ different types of magnets

Chromatic effects

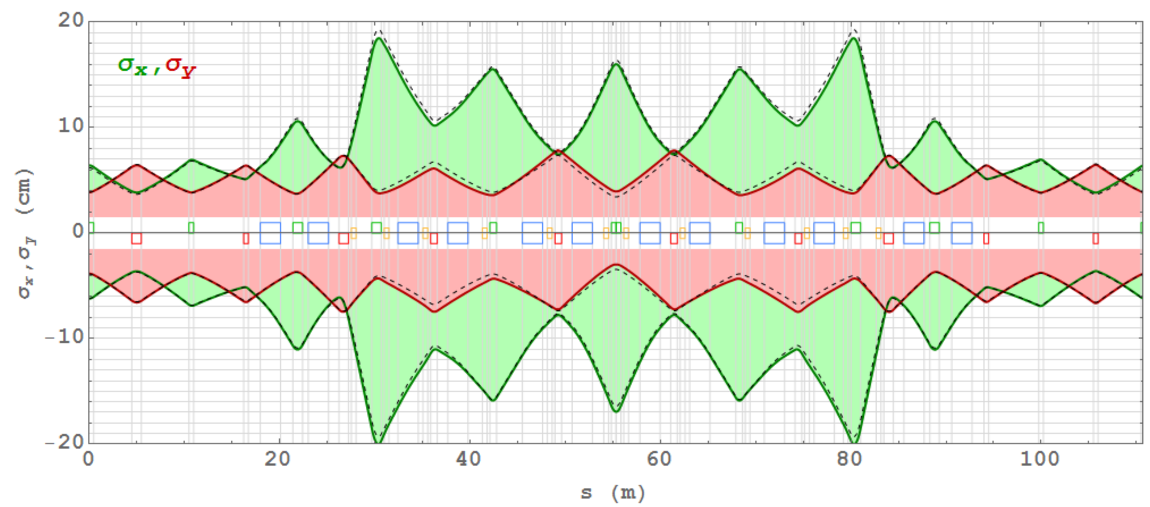
Lattice functions variation within $\Delta p/p = \pm 3$ %



Second-order dispersion function



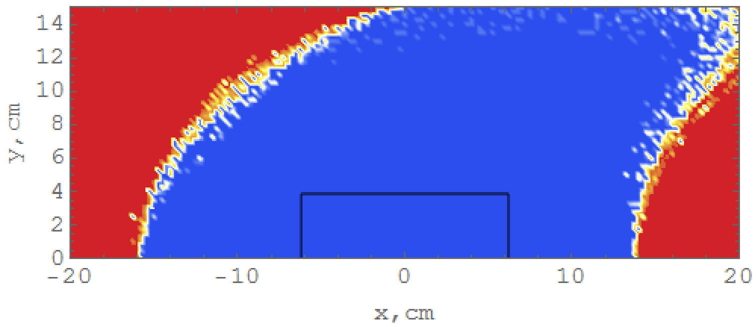
Beam size with chromatic aberrations



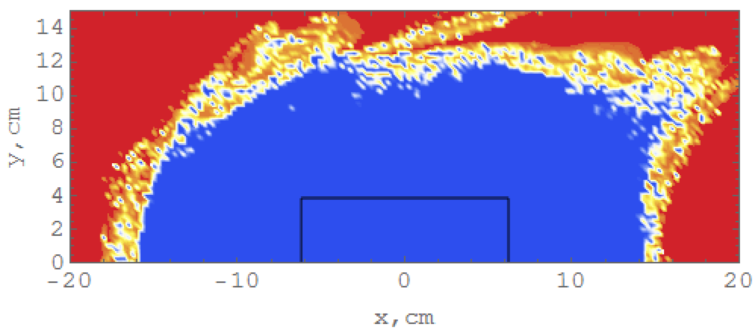
Dynamic Aperture

Simulation parameters: sextupoles + quad+/-1%err + quad 5mrad_rotat + sext10%err + sext10mrad_rot + quads_mult + dip_mult, 1000turns

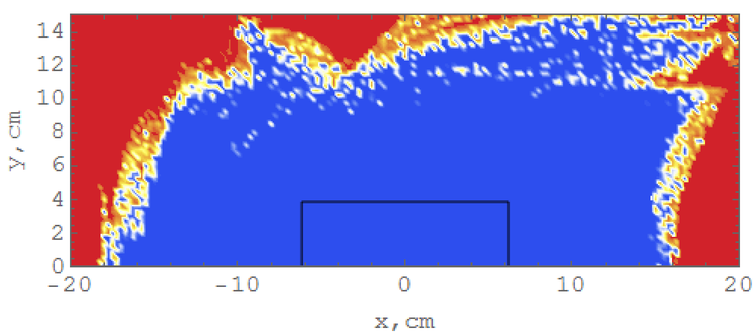
Δp/p = +3 %

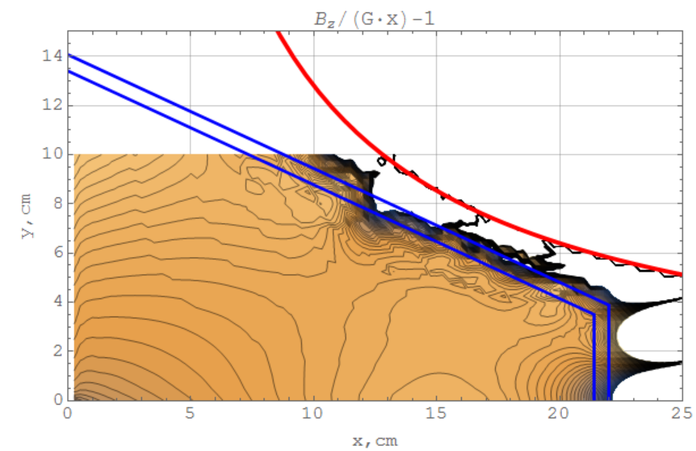


Δp/p = 0 %

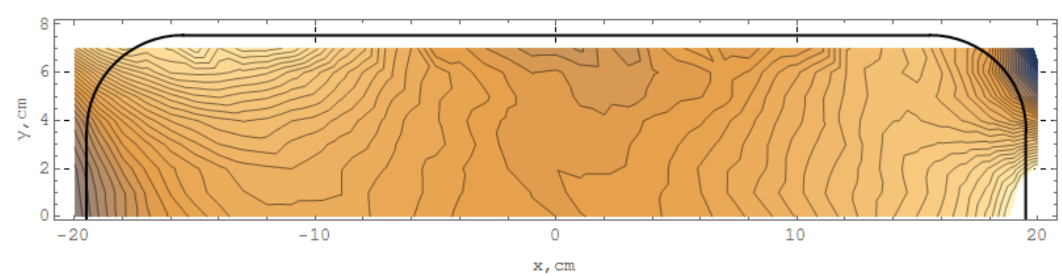


Δp/p = -3 %

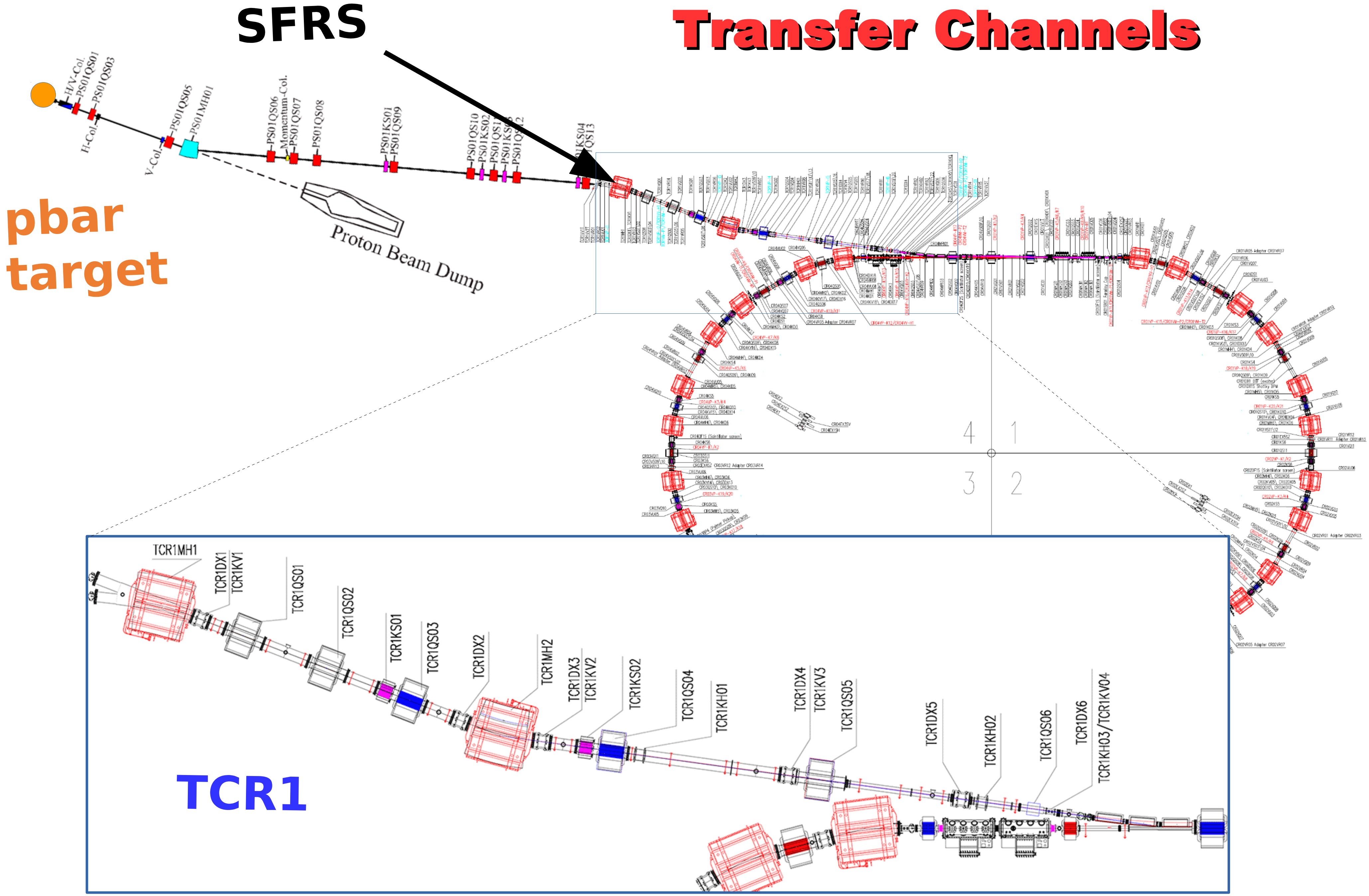




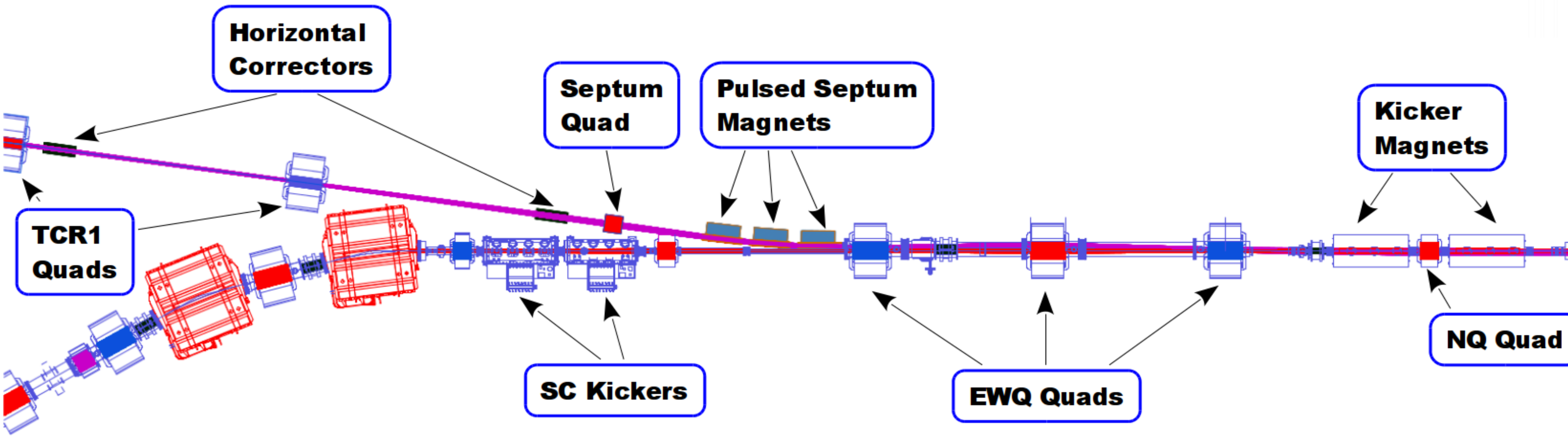
Field imperfections in dipoles and wide quads, in scale $\Delta B/B = \pm 5 \cdot 10^{-4}$



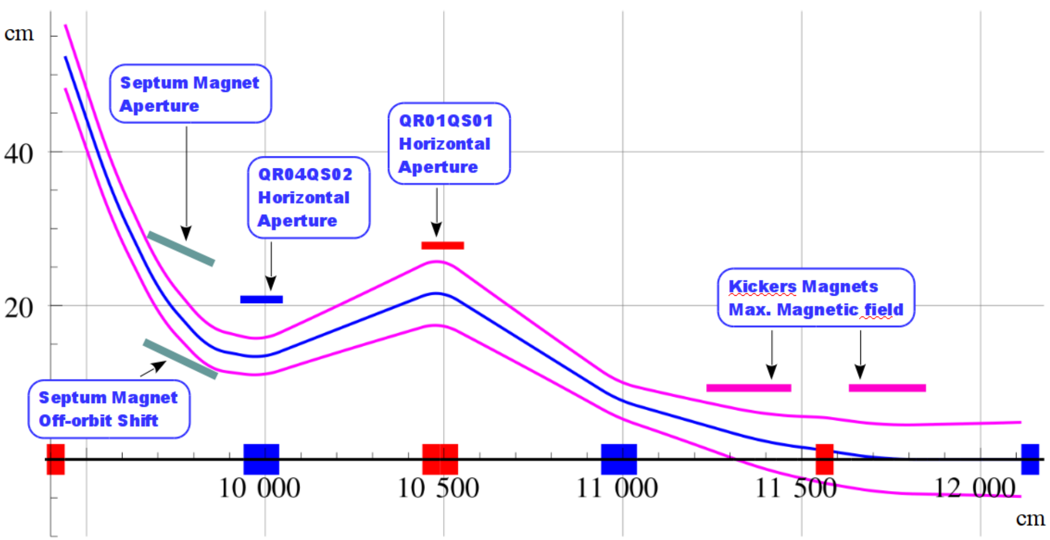
Transfer Channels



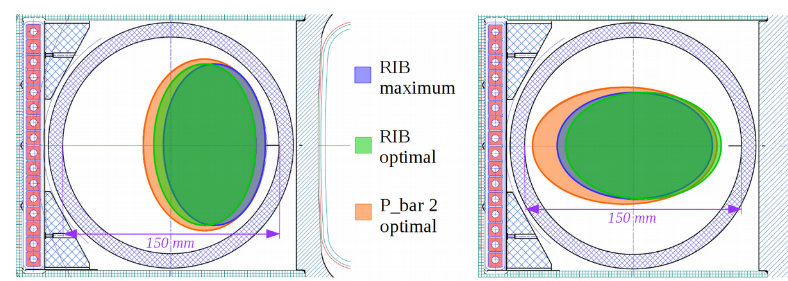
Beams Injection



Aperture limitations for injected beam

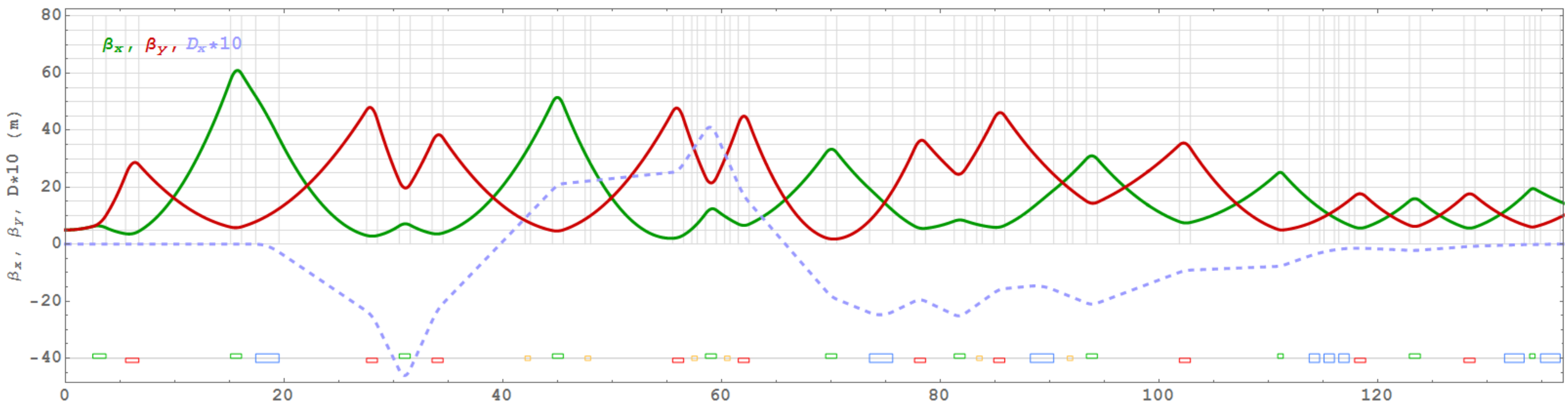


Beam cross-sections @ septa

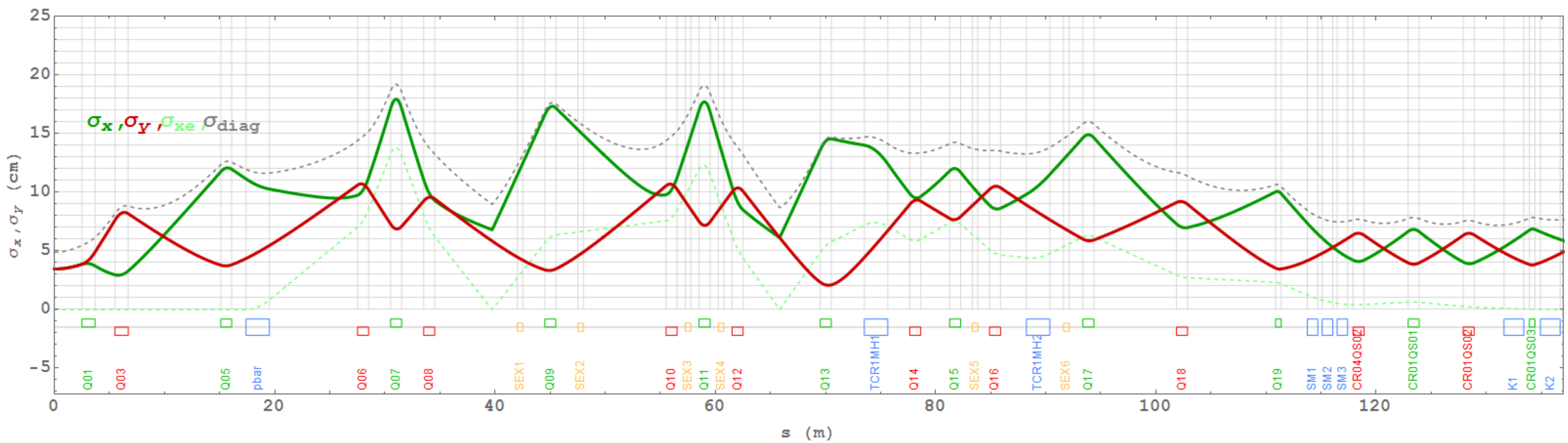


Pbar Channel Lattice

← pbar-separator →← TCR1 →← CR

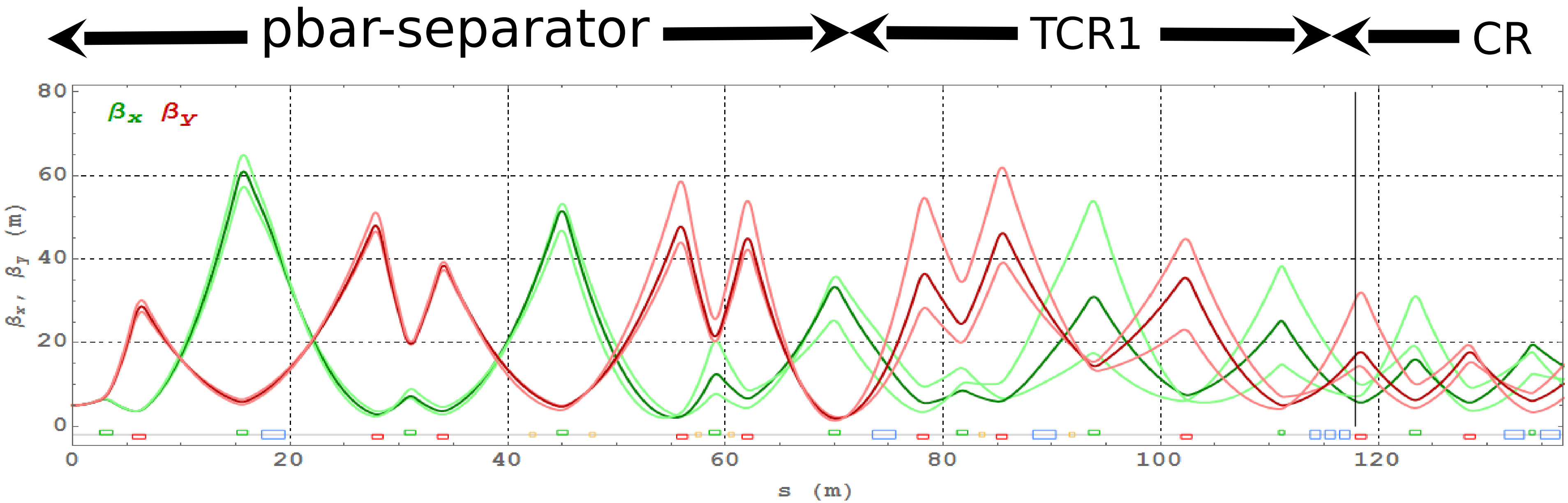


Lattice functions

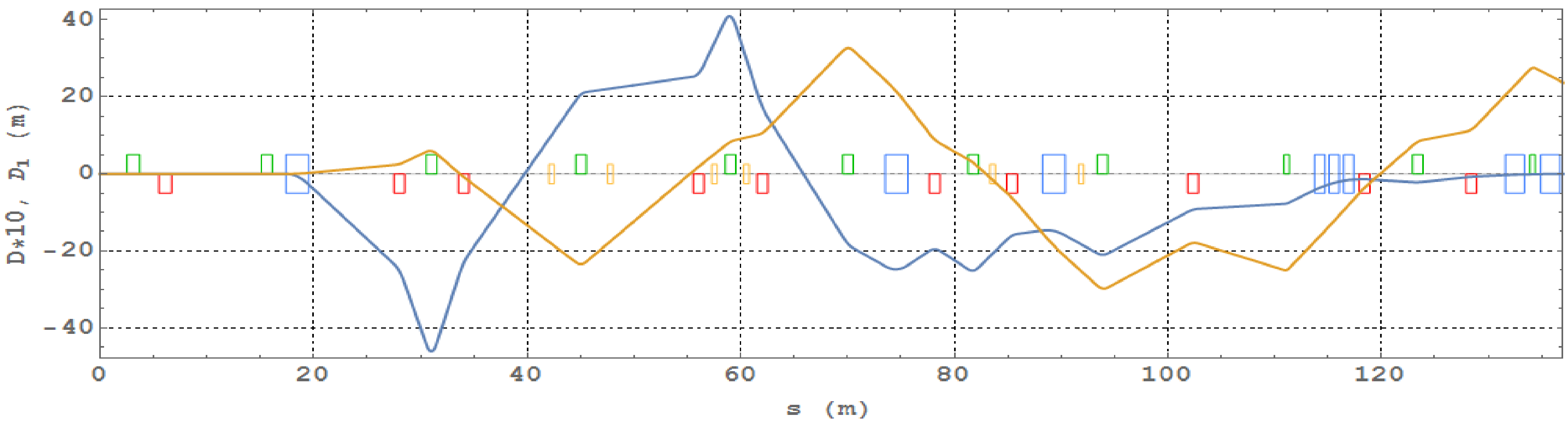


Beam sizes

Chromatic Effects in TC

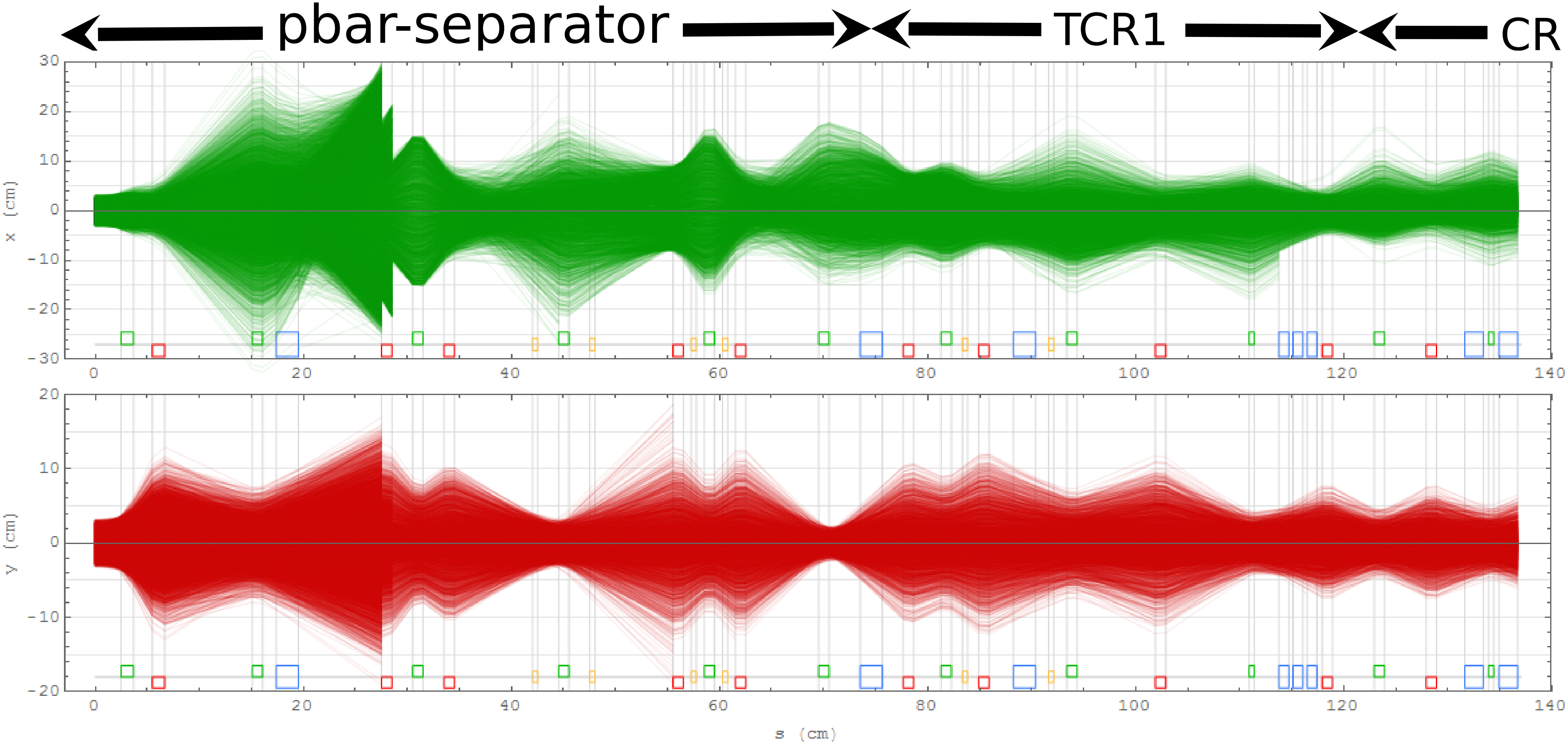


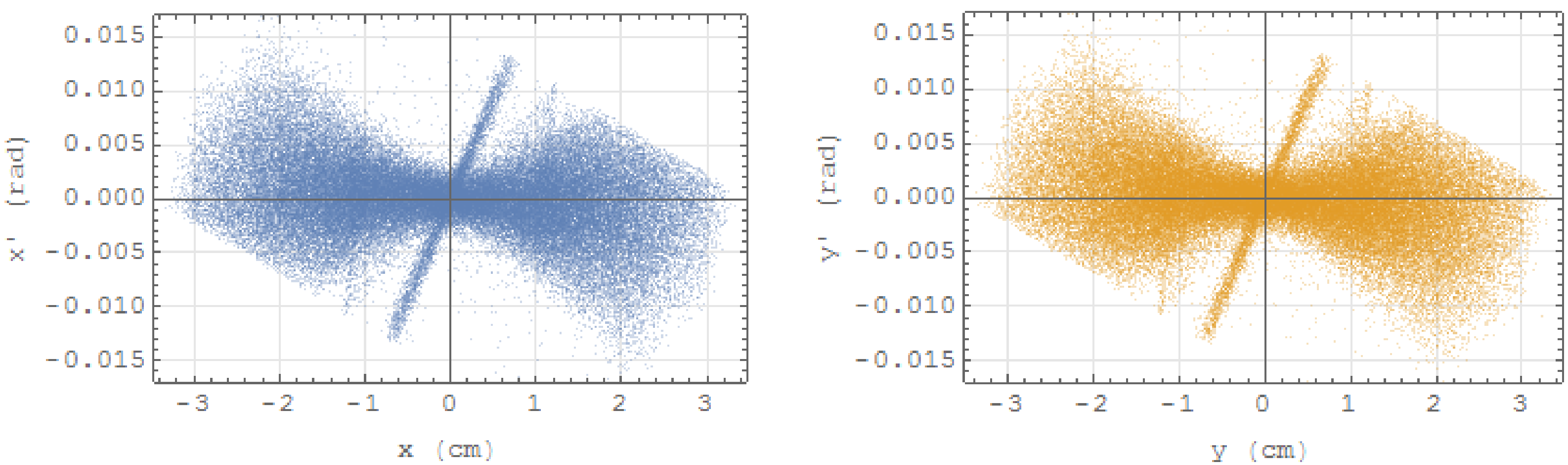
Lattice functions chromaticity



Dispersion

Particles Trackings in TC

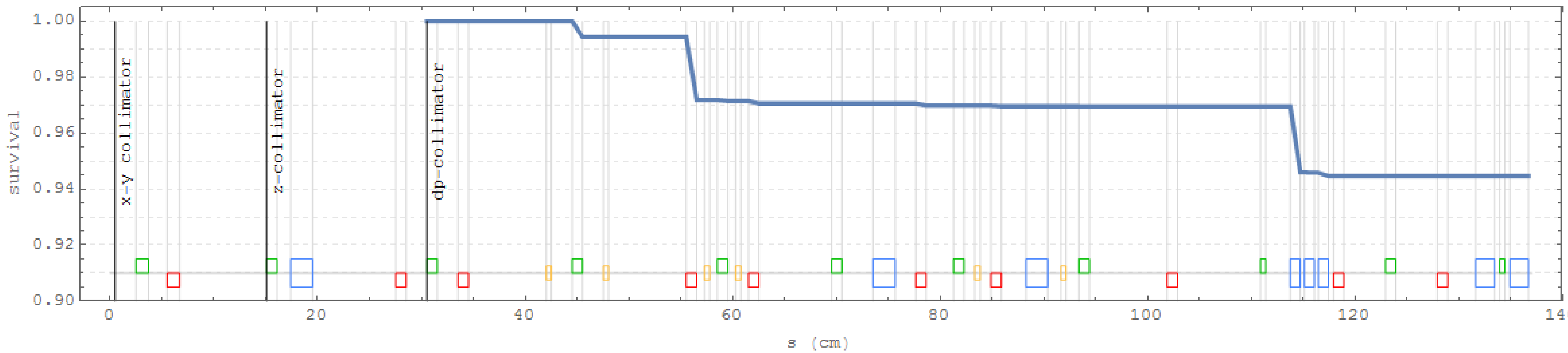




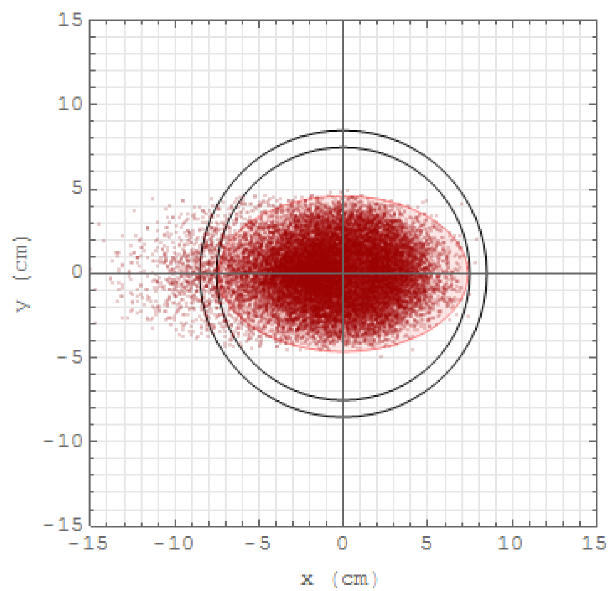
Phase space distribution (beginning)

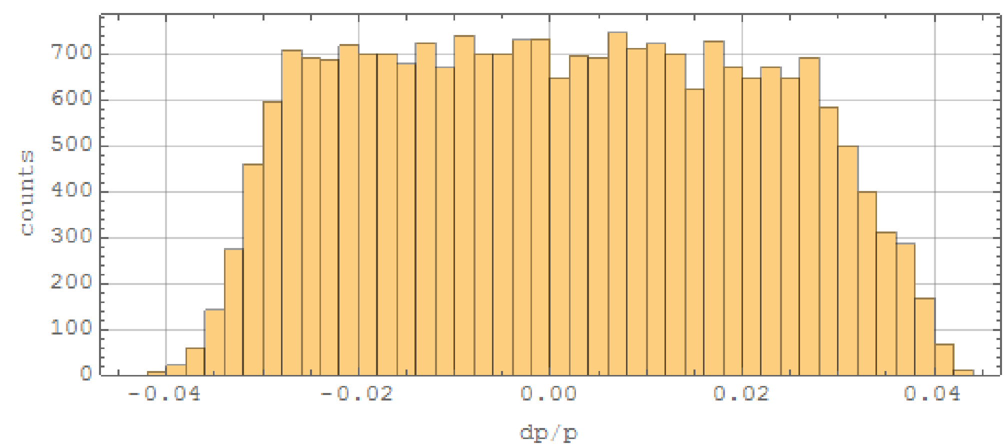
Particles Traching in TC

← pbar-separator →← TCR1 →← CR



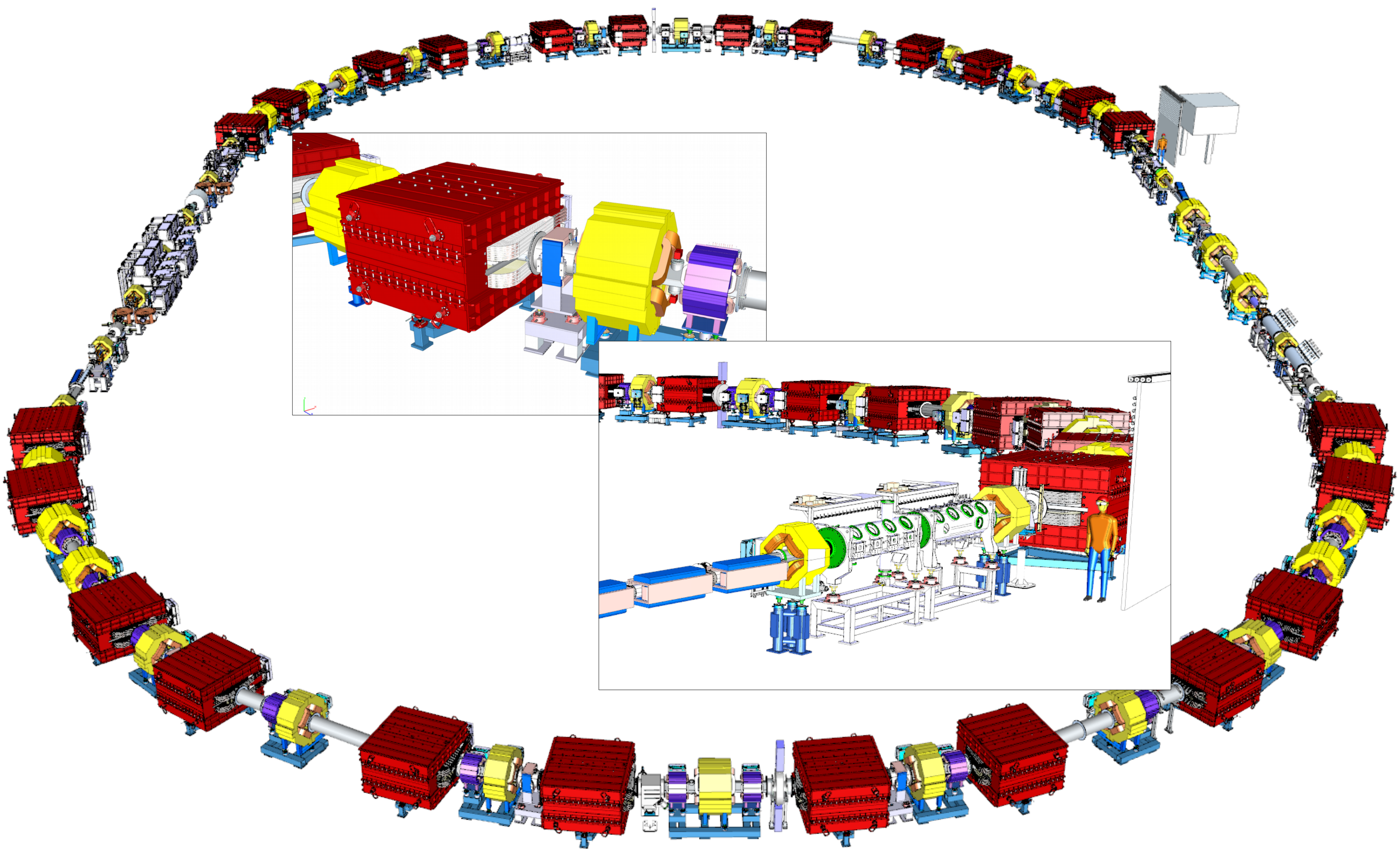
Particle losses estimations





Beam transverse and momentum distribution
at the entrance of injection septum magnet.

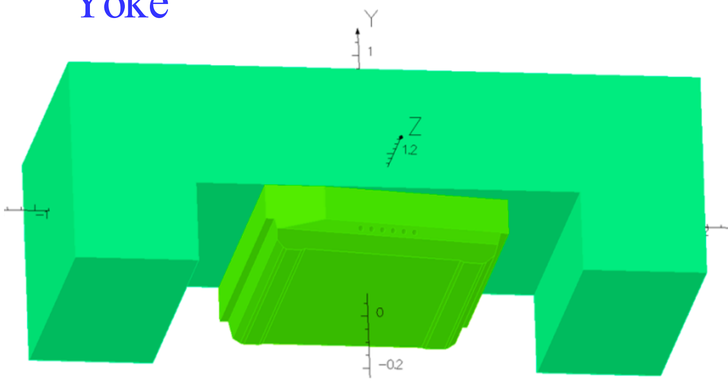
3D integration of the CR in DMU



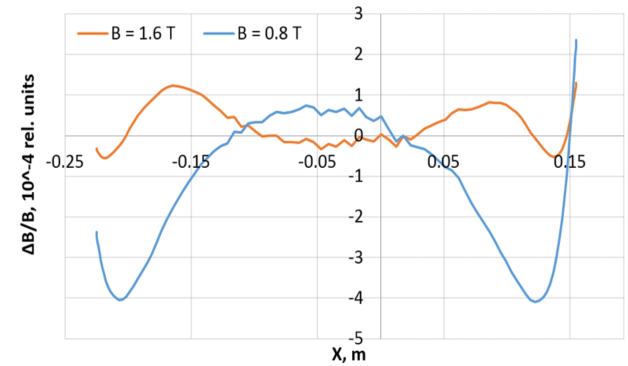
3D-models of CR components are prepared and uploaded to EDMS.

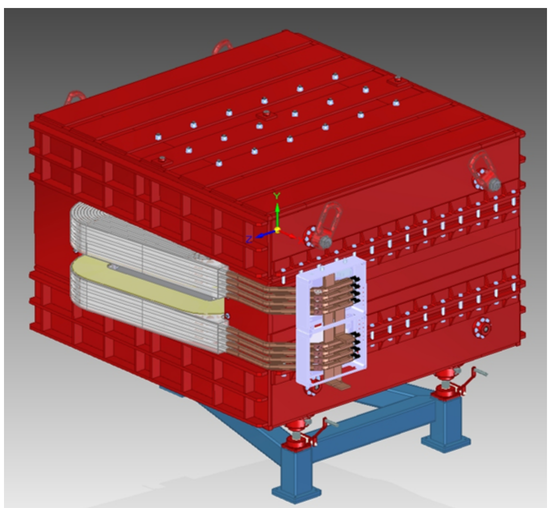
Bending magnet

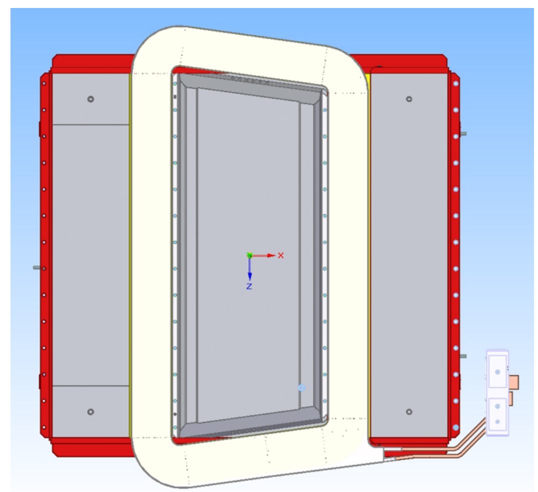
Yoke

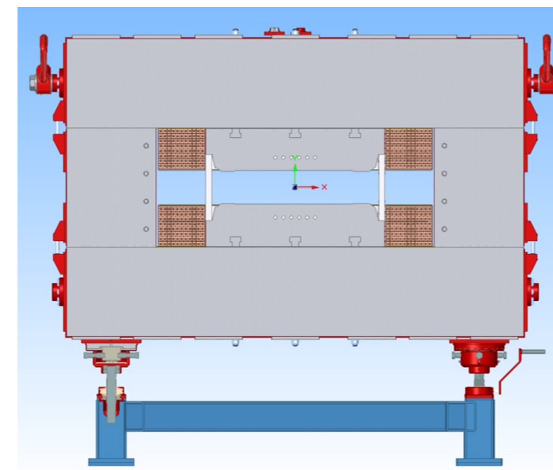


H	1.6 T
Bending radius	8.125 m
Homogeneity width	455 mm
ΔB/B	10^{-4}
Weight	59.8 to





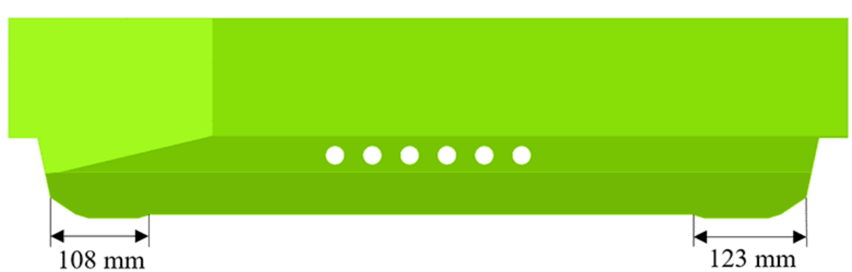




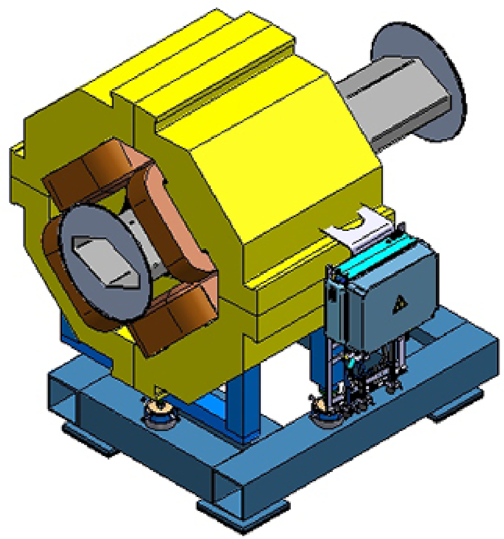
3D-model

Pole and coil shape

Cross-section

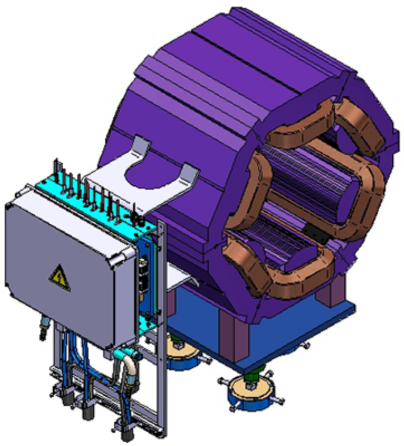


Other Magnets



Wide quadrupole

G	4.5 T/m
L_{eff}	1000 mm
R_{in}	160 mm
Weight	10.8 to

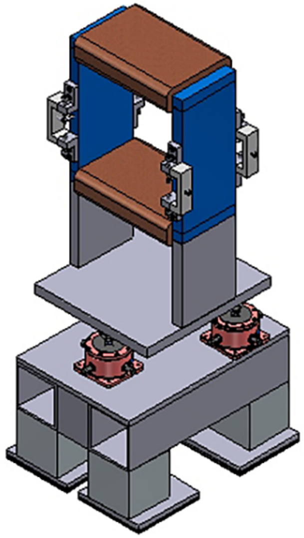


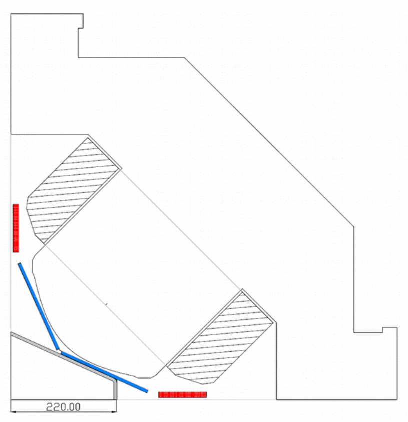
Sextupole

H’’	10 T/m^2
L_{eff}	600 mm
R_{in}	201 mm
Weight	1.4 to

Vertical steerer

Maximum field	0.045 T
Field homogeneity	±1.5 %
Effective length	0.740 m
Power loss	725 W
Maximum current	13.5 A



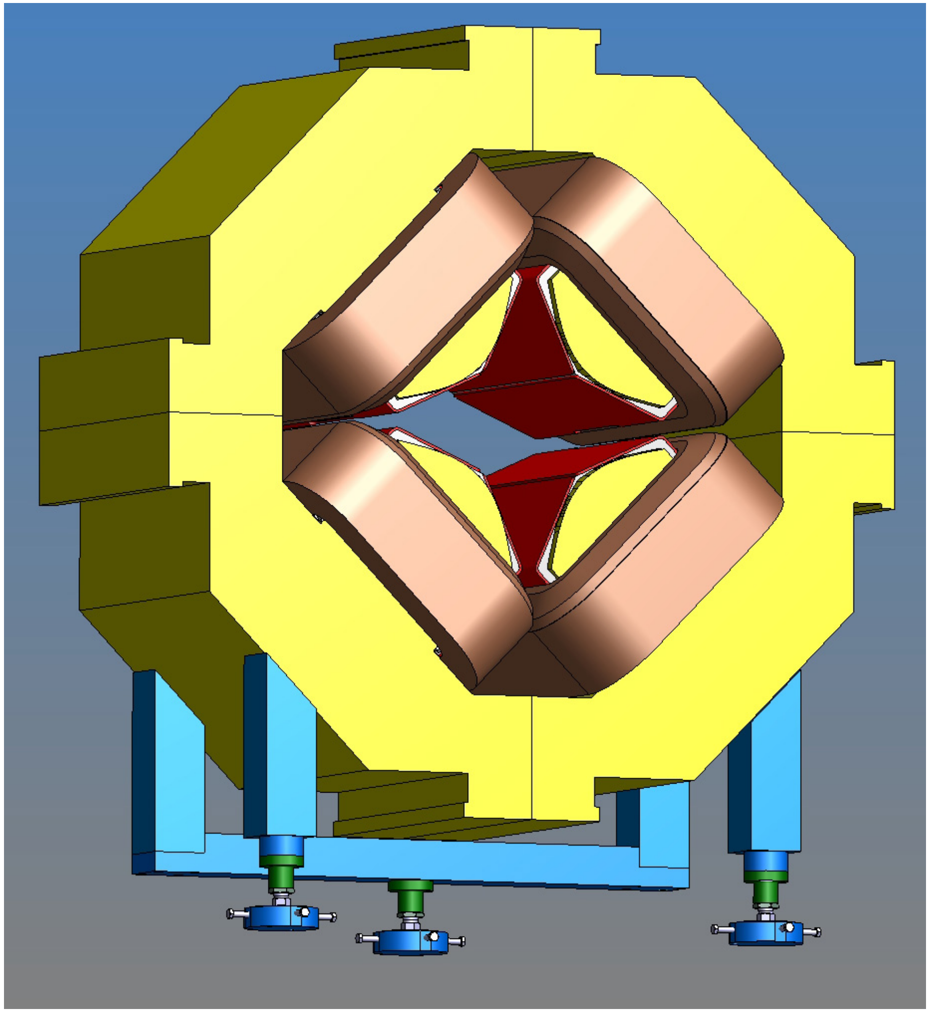


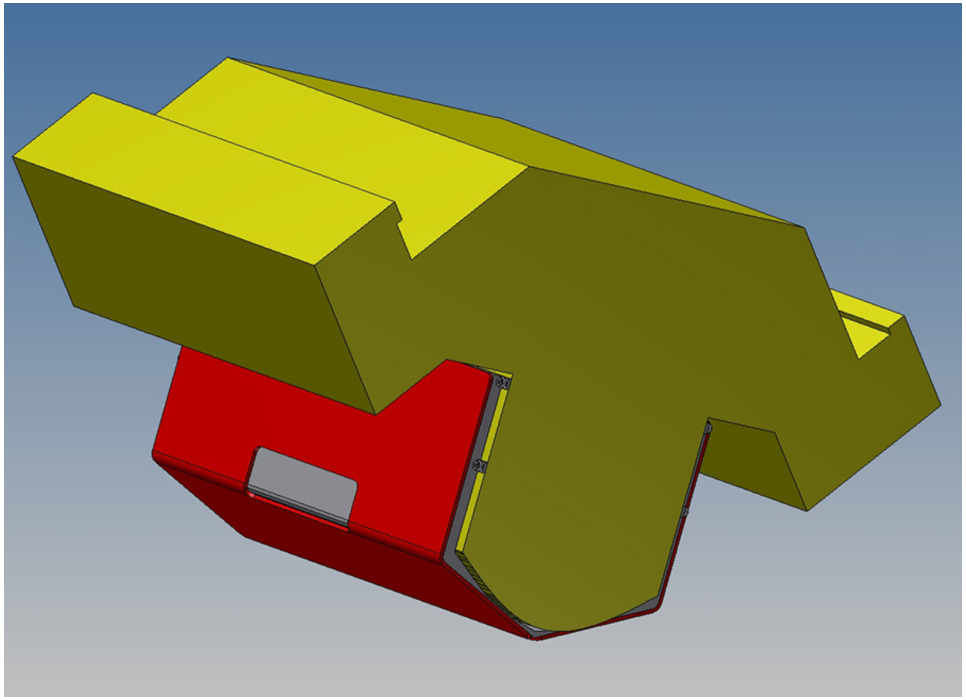
Octupole coils

H’’’	13 T/m^3
$\Delta B/B$	15 %
Current	6 A
Power consumption	500 W

Octupoles

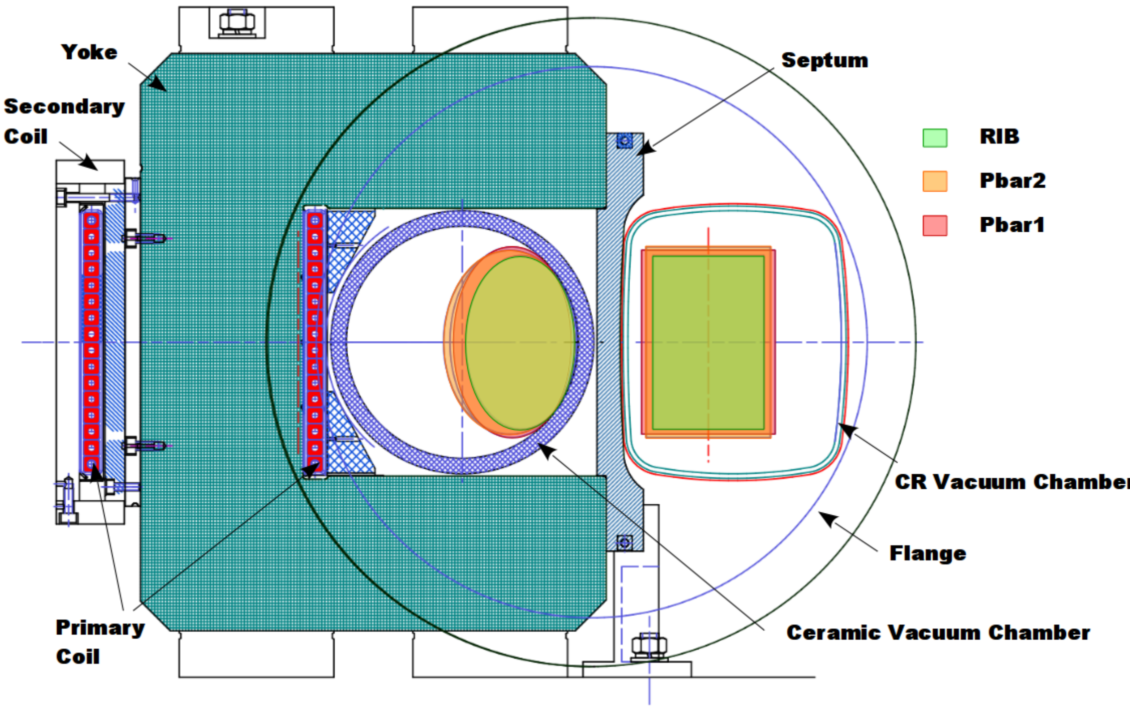
The technical solution for last magnetic element, octupole correction coil inside SWQ quadrupole, was finally found without disturbing other elements.

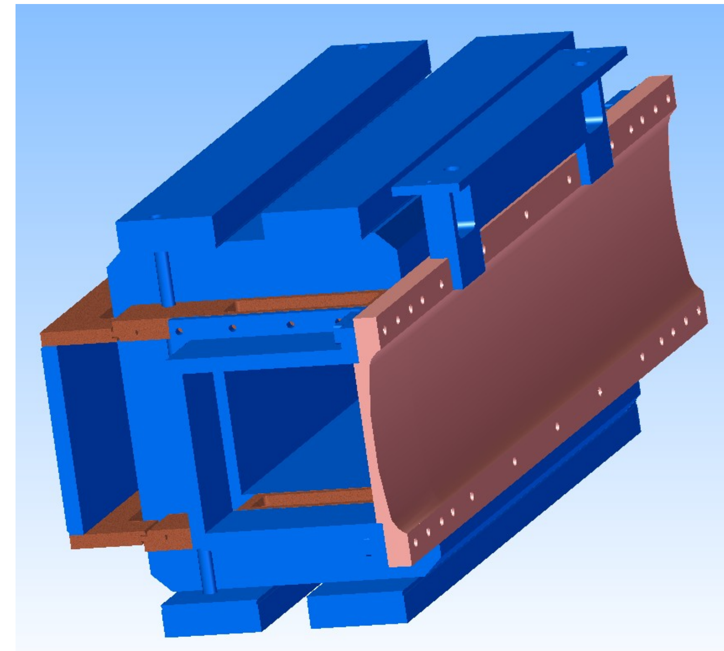


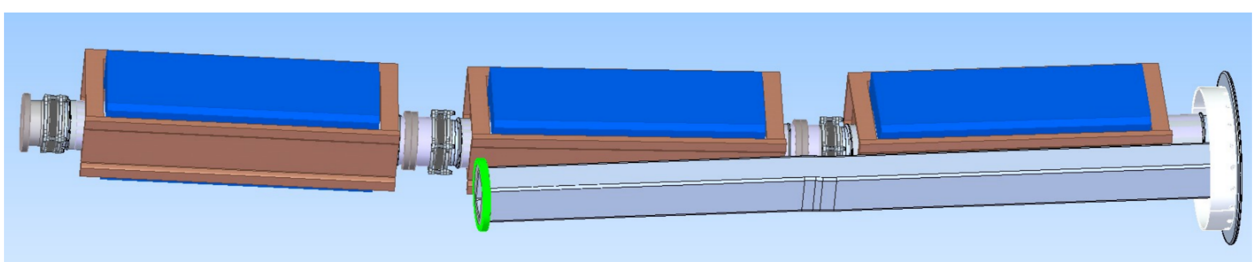


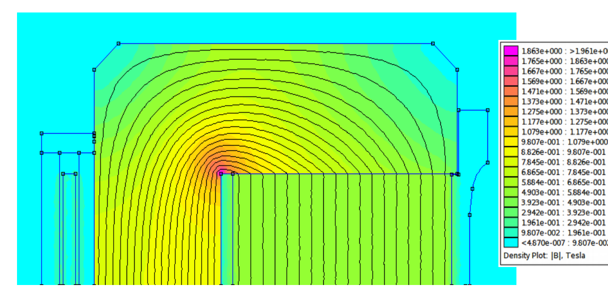
The thin octupole windings are wound in a gap between iron pole and main coil. The quad’s pole serves as a support for the octupole winding.

Injection Septum Magnet





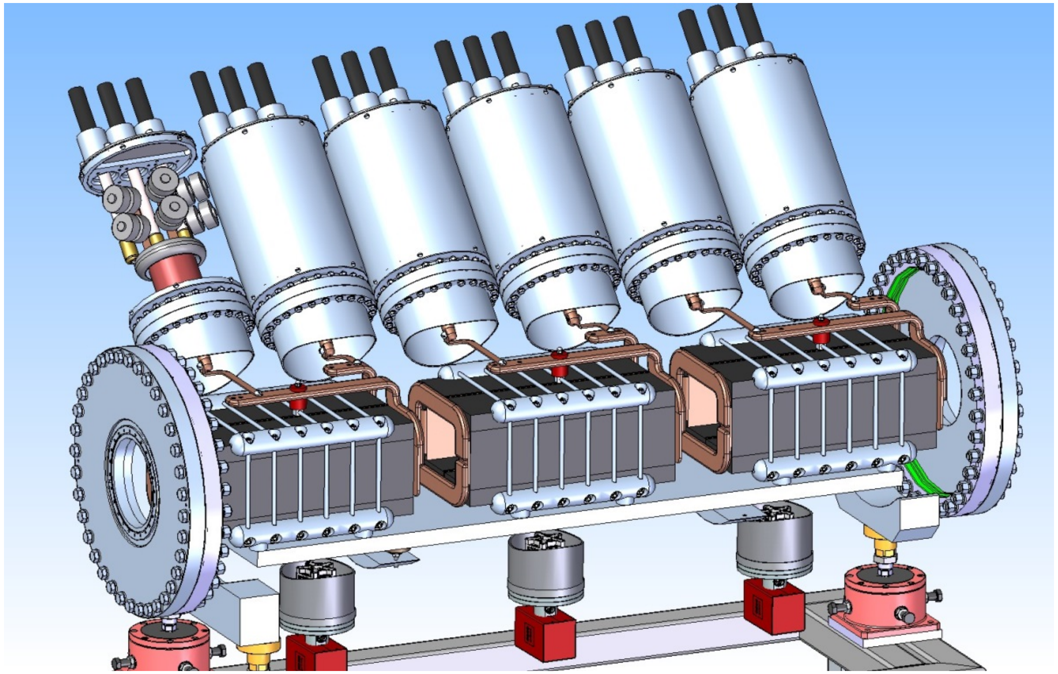


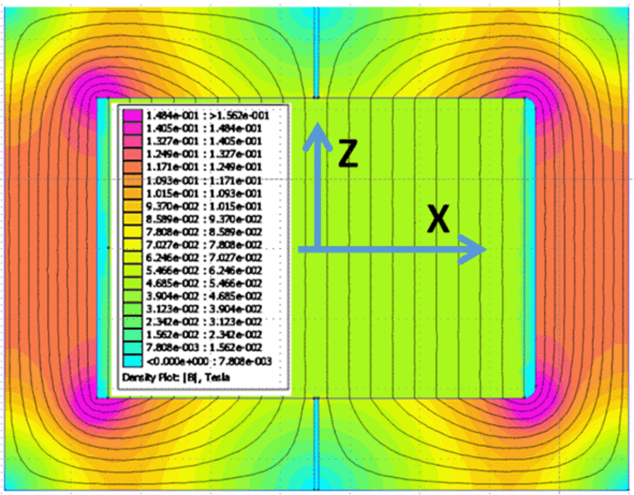


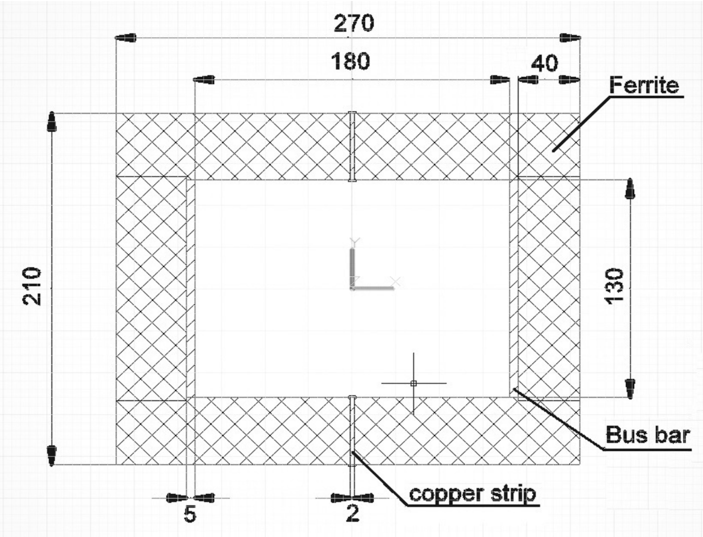
The set of three septa together

Injection/Extraction kickers

Number of kicker units	6
Deflection angle	15 mrad
Length of vacuum tank	1.9 m
Maximum B-field	54 mT
Unit length on ferrite	470 mm
Horizontal aperture	180 mm
Vertical aperture	130 mm
Current	5.6 kA
Loading voltage	64 kV
Ferrite mass per module	74 kg
Rise/fall time response of magnet to real current pulse	< 318 ns
Flat top length	(0.05–1.5) µs

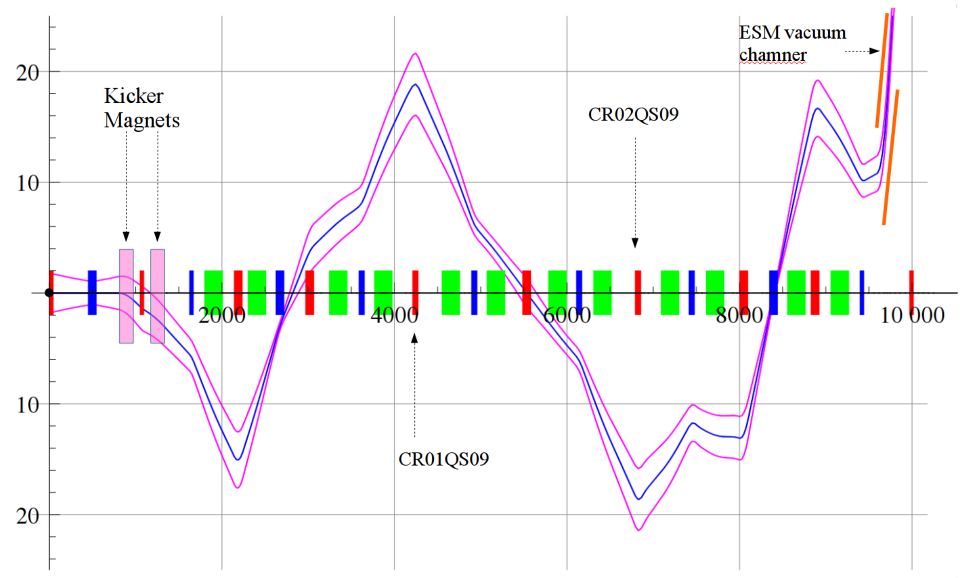




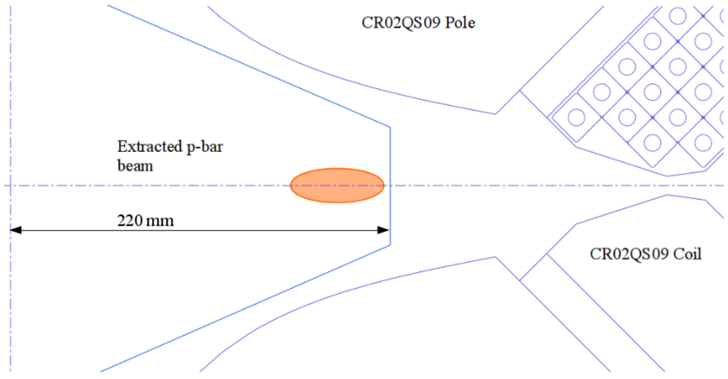


Beams Extraction

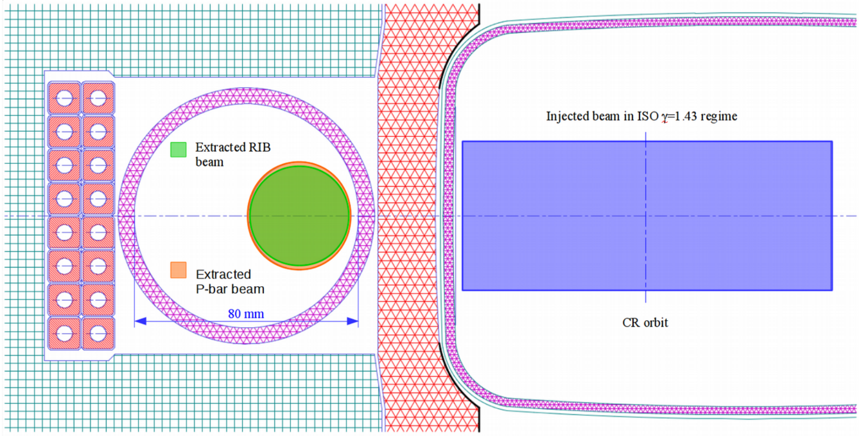
Beam extraction



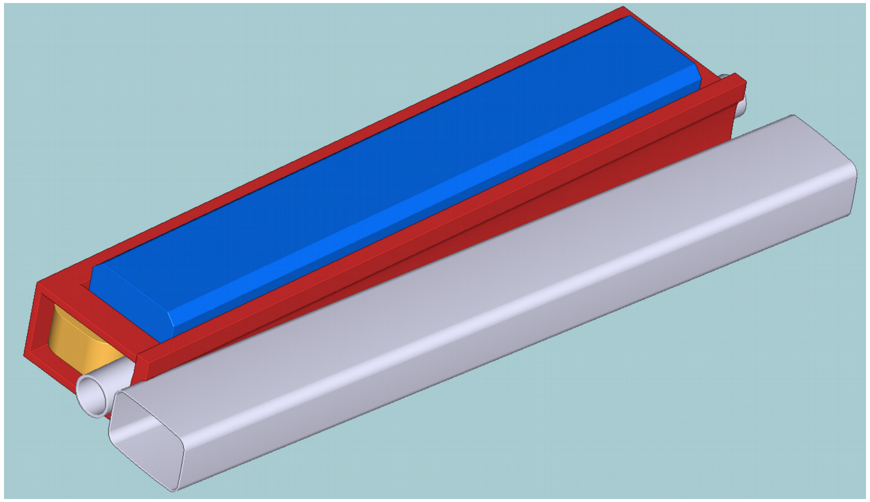
Propagating in arc with large amplitudes



Extracted and injected beams cross-sections @ extraction septum

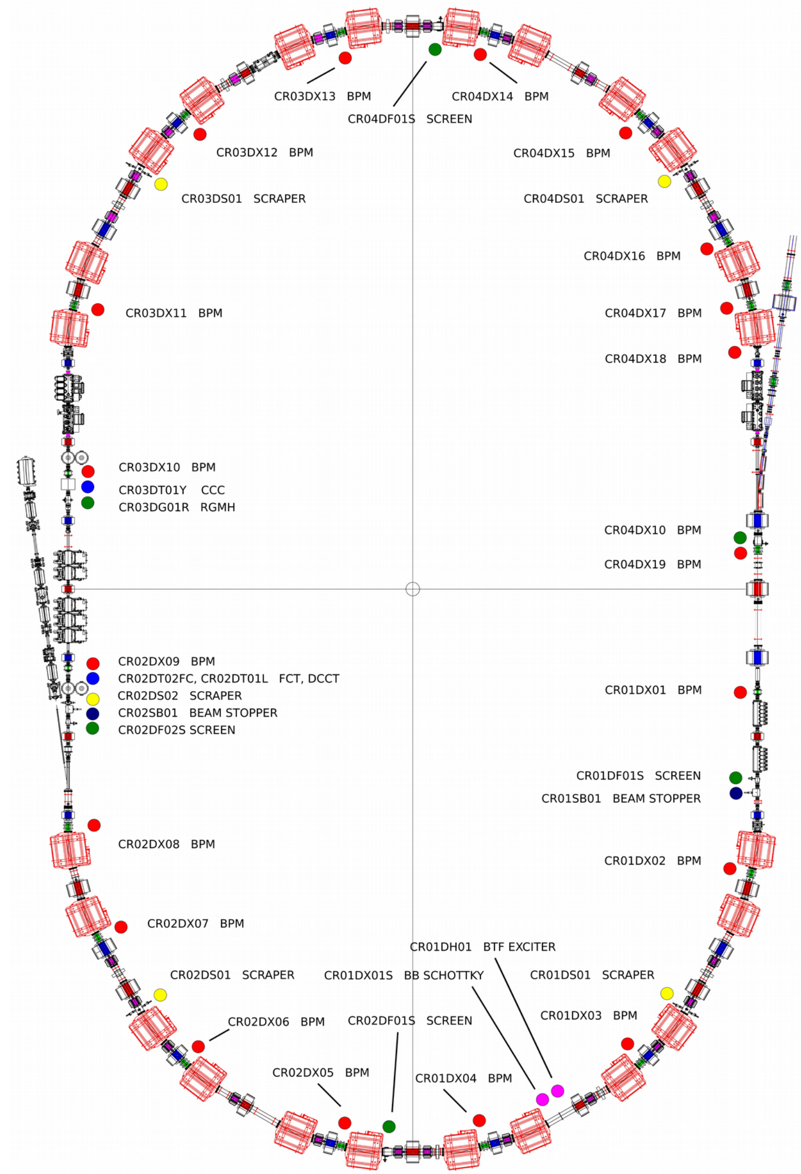


3D model



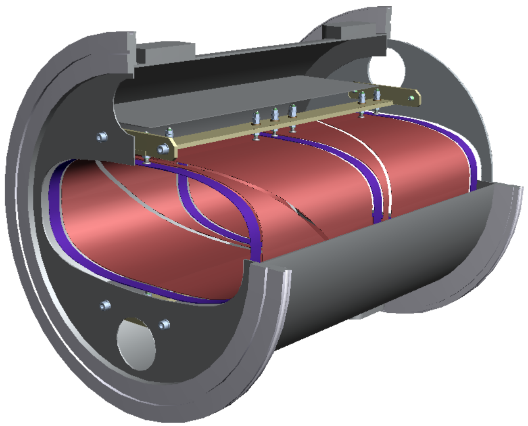
Beam Diagnostics

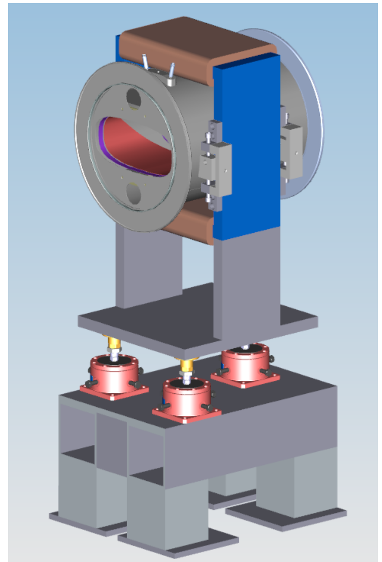
Device	Qty	Parameter	Application
DC Transformer	1	DC current	Stored current, beam lifetime
Cryogenic Current Comparator	1	DC current	Stored current, beam lifetime
BPM	19	Beam center-of-mass	Closed orbit, turn-by-turn, K-modulation, lattice functions
BTF Exciter	1	Frequency of Schottky sidebands	Tune by BTF, tune by noise excitation, tune by Q-kick
Schottky pickup	1	Momentum distribution	Δp/p, tune, chromaticity
Fast Current Transformer	1	Broadband bunch structure	Longitudinal emittance, bunch gymnastics
Residual Gas Profile Monitor	2	Beam profile	Transverse emittance, injection matching
Beam Loss Monitor	Distri-buted	Beam loss	Mis-steering of magnets, halo detection at scrapers
Scintillating Screen	5	Beam profile	First turn diagnostics
Beam-Stopper	2	Stop the beam	First turn diagnostics
Scrapers	2×4 2×4	Beam size	Transverse beam size and beam alignment



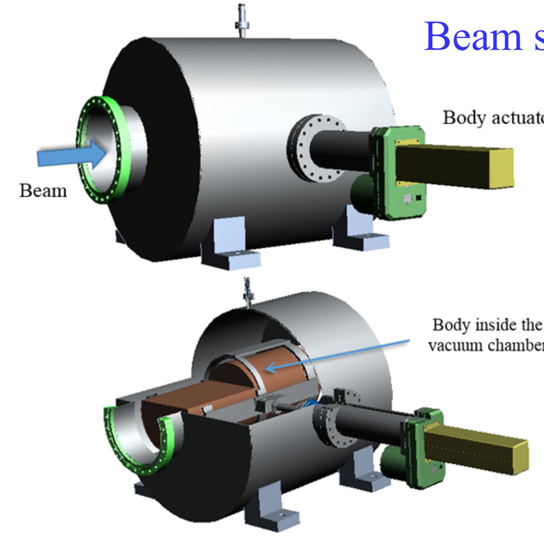
Beams Extraction

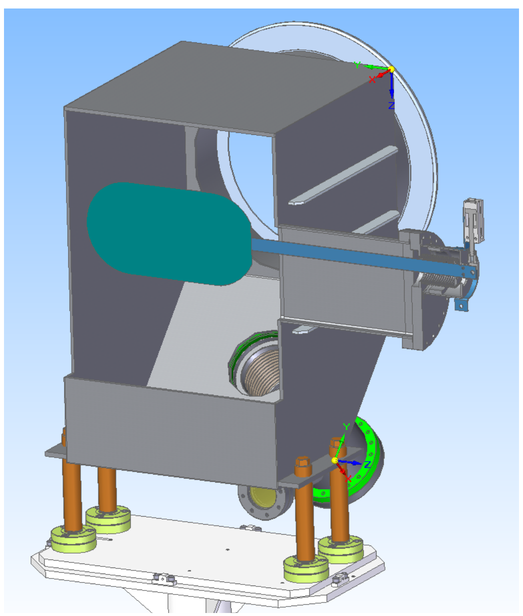
BPM @ arc



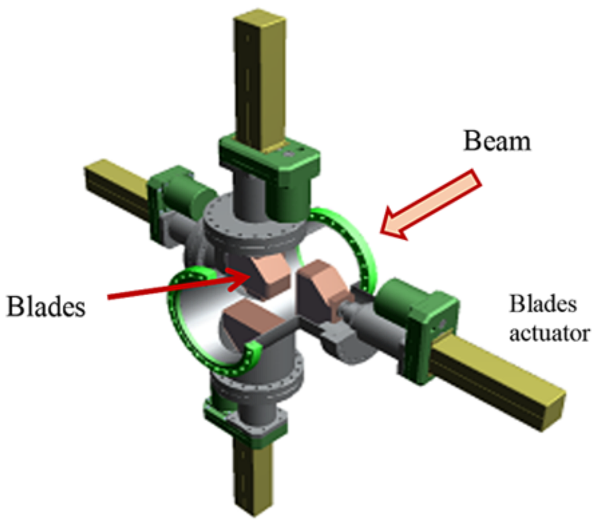


Beam stopper

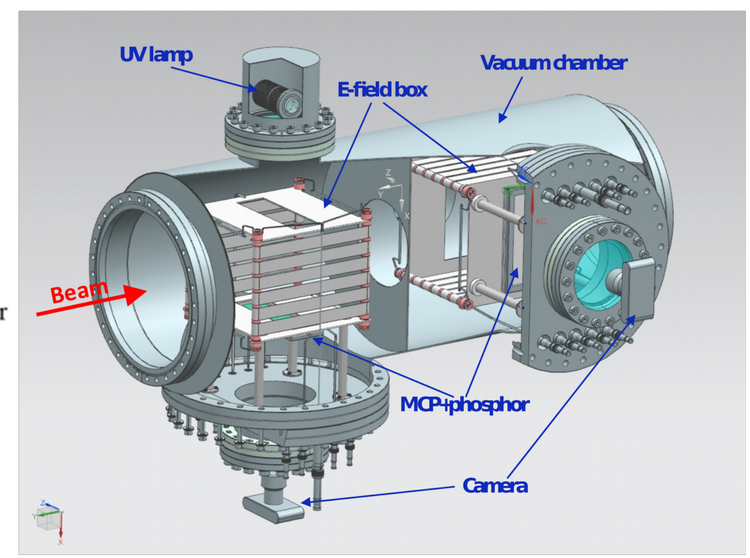




Scintillator screen

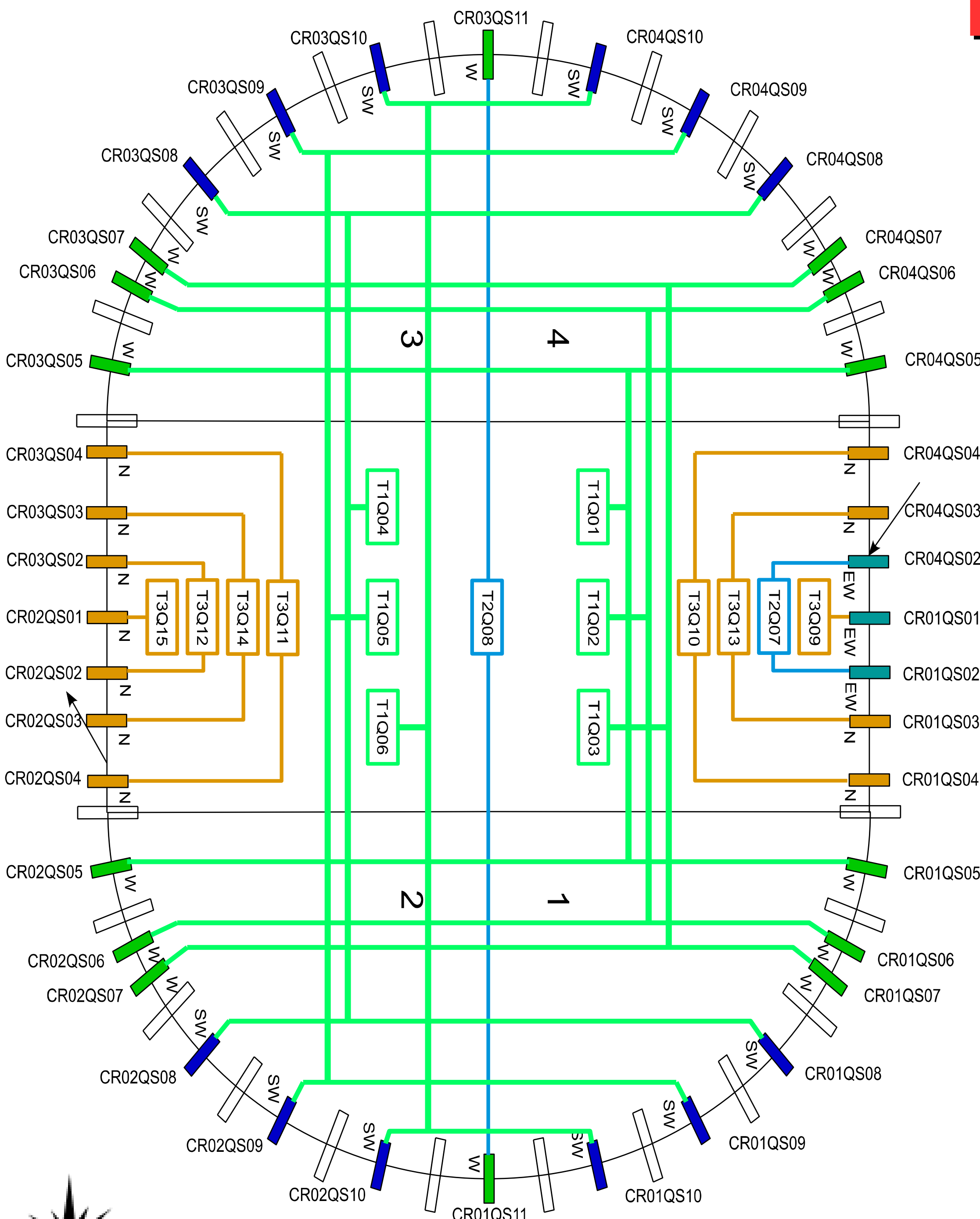


Scraper



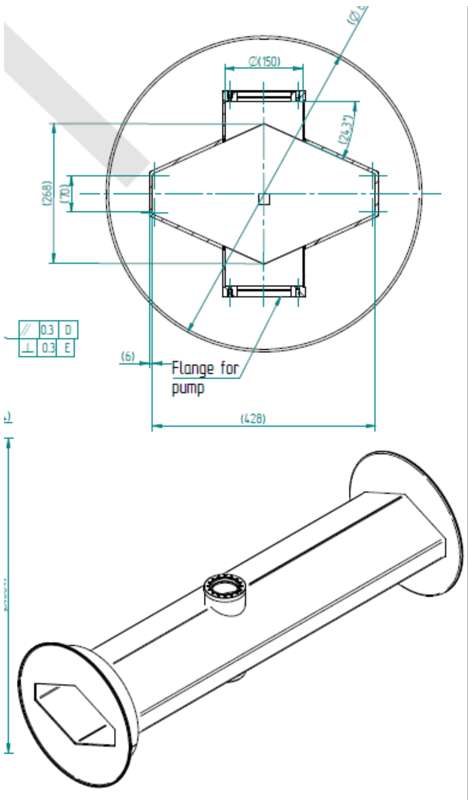
Residual gas monitor

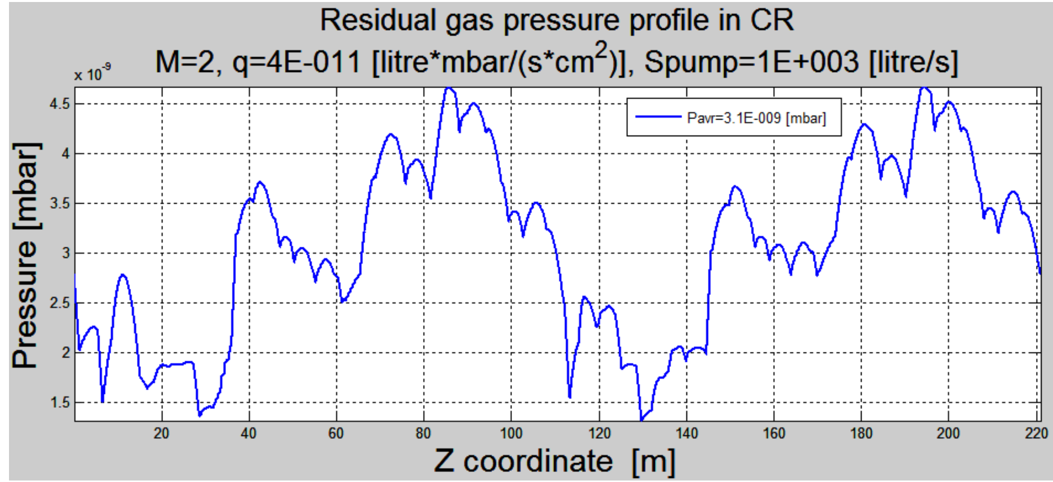
Power Converters

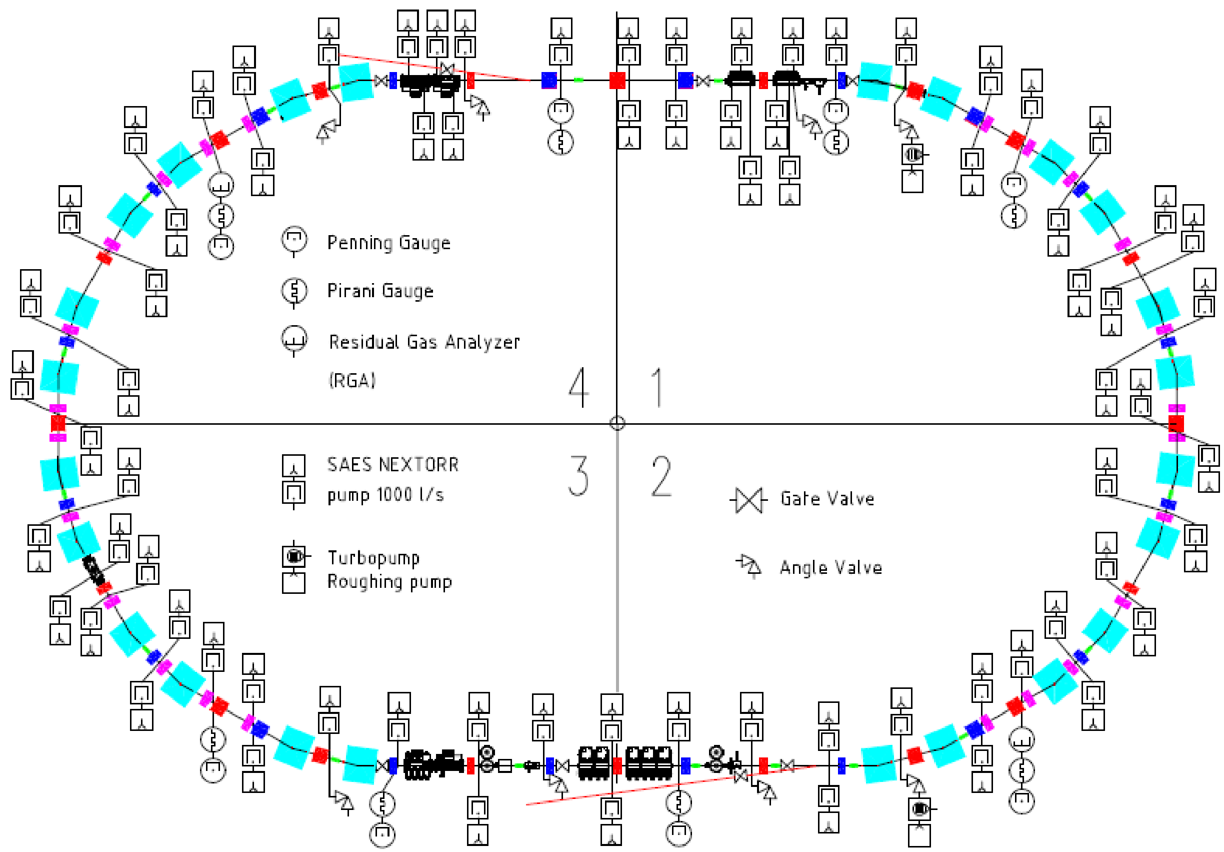


2.5.3	Power converters of CR	Num	Current [A]	Voltage [V]	Power [kW]
2.5.3.1	Dipole magnets PC	1	1450	2750	4000
2.5.3.2.1	Quad magnets PC Type1	6	1350	200	300
2.5.3.2.2	Quad magnets PC Type2	2	1100	100	150
2.5.3.2.3	Quad magnets PC Type3	7	1200	50	75
2.5.3.3.1	Sextupole magnets PC	6	500	100	50
2.5.3.4.1	Octupole magnets PC	12	6	50	0.5
2.5.3.2.1	Steering hor. PC	24	6	50	0.55
2.5.3.2.2	Steering vert. PC	16	20	100	2
2.5.3.2.3	Steering hor./vert. PC	8	12	100	1.2

Vacuum Systems







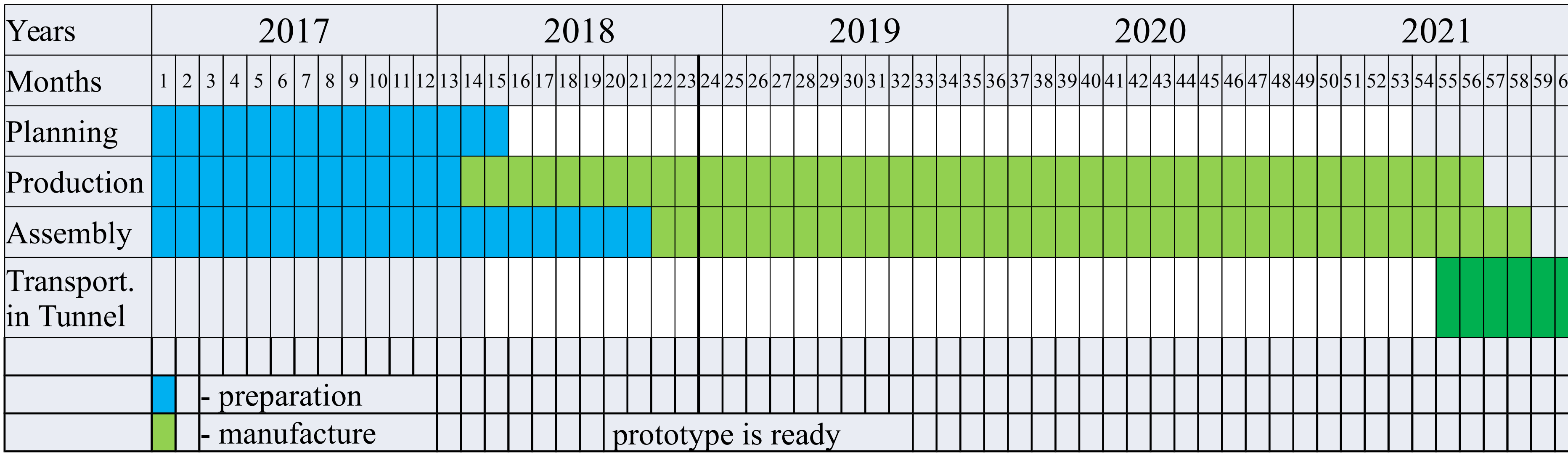
Specifications status

PSP	Description	Quant.	Status	EDMS Cont.	Resp.	CB-2005
2.5.2	**CR Magnets**	**7**				**53.0 %**
2.5.2.1	CR Dipole Magnet		Released	1174030	BINP	38.5 %
2.5.2.2.1	Wide Quadrupole Magnets		Released	1518619	BINP	8.8 %
2.5.2.2.2	Narrow Quadrupole Magnets		Released	1518618	BINP	0.5 %
2.5.2.3	Sextupole Magnets		Released	1516972	BINP	2.8 %
2.5.2.4	Octupole Magnets		Under preparation (Q4/2016)	--	BINP	--
2.5.2.5	CR Septum Magnets		Engineering check	1698195	BINP	1.1 %
2.5.2.6	Steering Magnets		Engineering check	1698837	BINP	1.3 %
2.5.3	**Power Converters**	**6**				**11.4 %**
2.5.3.1	Dipole Magnets PS		Engineering check	1533537	BINP	2.6 %
2.5.3.2	Quadrupole Magnets PS		Released	1518594	BINP	4.5 %
2.5.3.3	Sextupole Magnets PS		Released	1518595	BINP	1.0 %
2.5.3.4	Octupole coils PS		Engineering check	1719038	BINP	0.1 %
2.5.3.5	Injection/Extraction Septa		Engineering check	1698195	BINP	0.8 %
2.5.3.6	Steering Magnets		Released	1573731	BINP	1.8 %
2.5.5	**Injection /Extraction**	**1**				**15.6 %**
2.5.5.1,2	Kickers		Released	1580588	BINP	15.6 %
2.5.6	**Beam Diagnostics**	**10**				**8.2 %**
2.5.6.1.1	DC Transformer		Released	1563303	BINP	0.2 %
2.5.6.2	Beam Position Monitors		Engineering check	1562811	BINP	2.4 %
2.5.6.3.1	BTF Exciter		Engineering check	1609816	GSI	0.8 %
2.5.6.3.2	Schottky Pickup		Engineering check	1560768	GSI	0.6 %
2.5.6.3.4	Fast Current Transformer		Released	1557833	BINP	0.4 %
2.5.6.4	Residual Gas Profile Monitor		Released	1571623	BINP	1.2 %
2.5.6.6.1	Scintillation Screen		Engineering check	1566551	BINP	0.1 %
2.5.6.6.1.6	Data Acquisition for Sci. Scr.		Engineering check	1560764	GSI	0.1 %
2.5.6.6.3	Beam Stopper		Engineering check	1603677	BINP	0.1 %
2.5.6.7	Scraper		Engineering check	1577945	BINP	1.0 %
2.5.7	**Vacuum**	**11**	Under preparation (Q4/2016)			**11.9 %**
2.5.7.1.2.2	Dipole Chambers		Engineering check	1518019	BINP	1.4 %
2.5.7.1.3	Valves		Engineering check	1719672	BINP	0.6 %
2.5.7.1.5	Vacuum instrumentation		Engineering check	1719736	BINP	0.3 %
2.5.7.1.1.1	Rouging stations		Engineering check	1720669	BINP	0.2 %

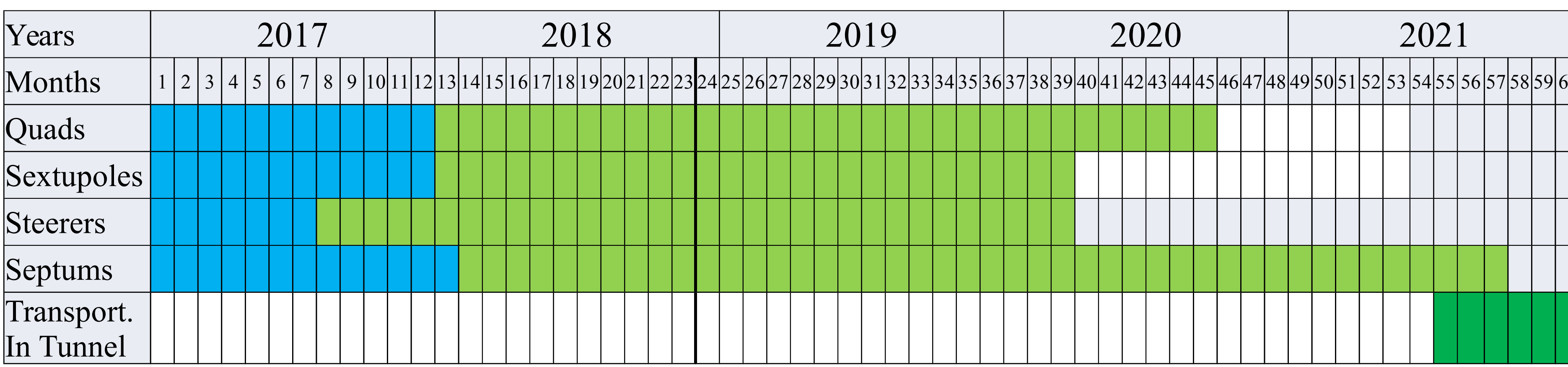
Released specs cover **75%** of the cost (BINP part)

Production Plans

Timeline for other CR Magnets

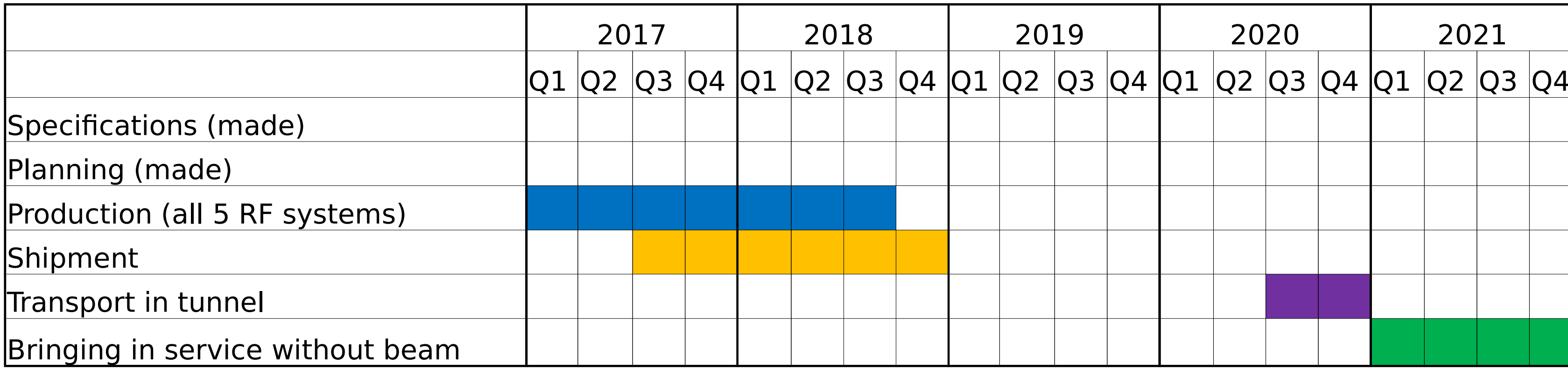


Timeline for other CR Magnets

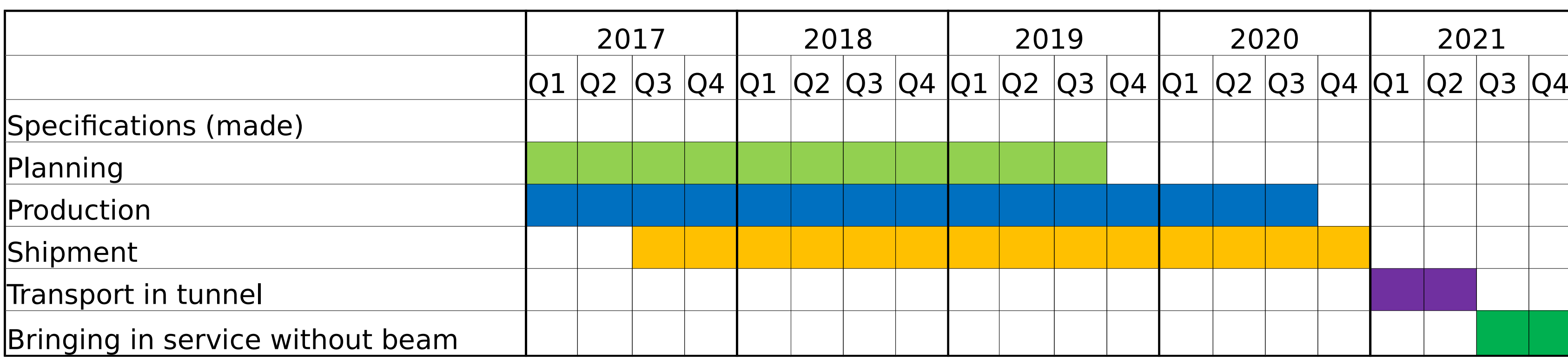


GSI Responsibility Part

Overall time schedule for CR debunchers



Overall time schedule for Stochastic Cooling System



Thank you!

BINP:

V. Anashin, E. Bekhtenev, D. Berkaev, M. Bryzgunov, D. Gurov, A. Kasaev, M. Kholopov, V. Kolmogorov, I. Koop, A. Krasnov, O. Meshkov, N. Nefedov, Yu. Rogovsky, T. Rybitskaya, L. Schegolev, A. Semenov, D. Senkov, P. Shatunov, Yu. Shatunov, S.Shiyankov, D. Shwartz, A. Starostenko, A. Sukhanov, A.Tsyganov, A. Utkin

GSI:

O. Chorniy, C. Dimopoulou, A. Dolinskyy, O. Gorda, K.Knie, A. Kraemer, J. Kurdal, H.Leibrock, C. Muehle, U.Blell, M.Petryk, I. Petzenhauser, H. Schwarz, I. Baurer, I.Schurig, T. Ziglasch, S. Litvinov, S. Sanjari, M. Shwickert, P. Kovina, B. Hohne-Walasek, Y. Litvinov.

FAIR:

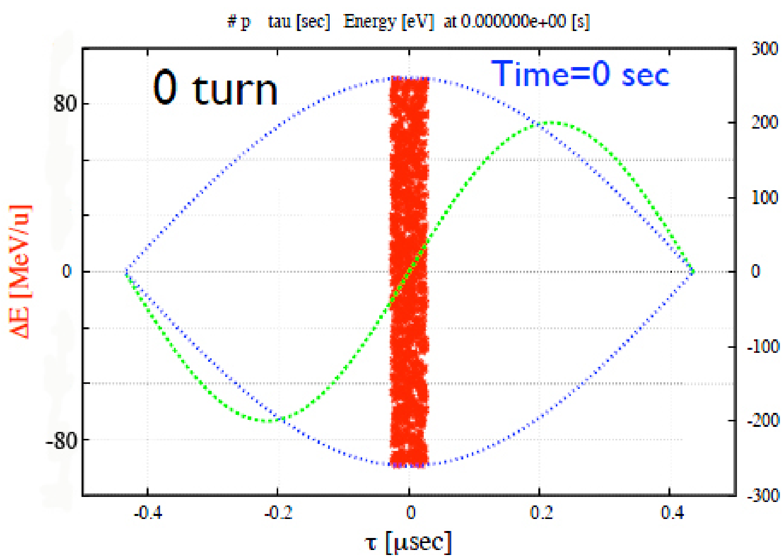
J.Henschel, J.Blaurock, D.Urner, R.Amirikas, N.Winters, K.Istomin, F.Becker.

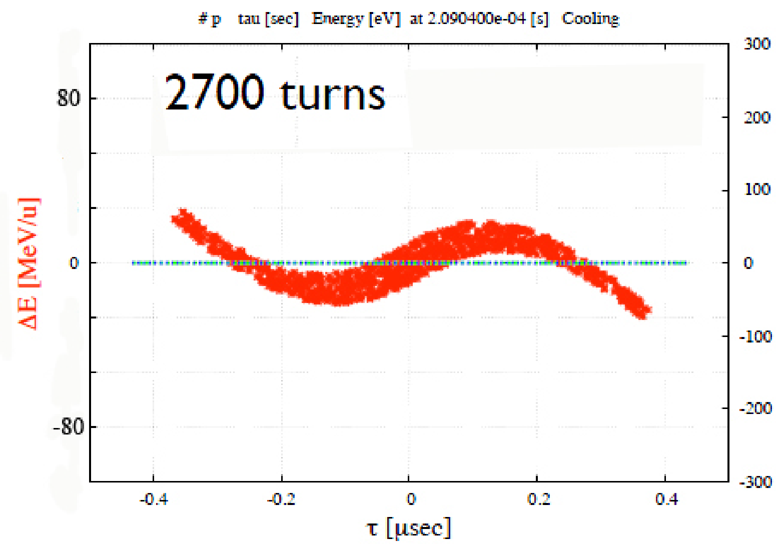
CERN: E.Mahner.

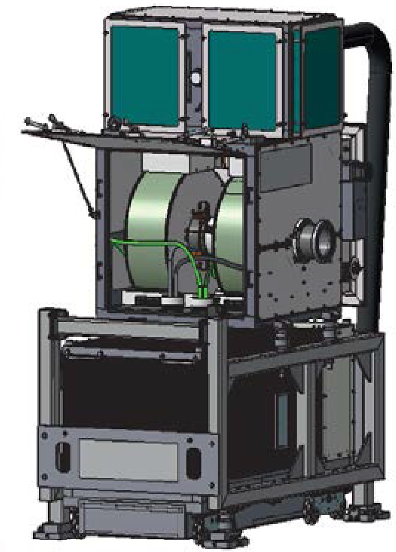
Jülich: D. Prasuhn.

Cosylab: R. Hrovatin.

2.5.4 RF System

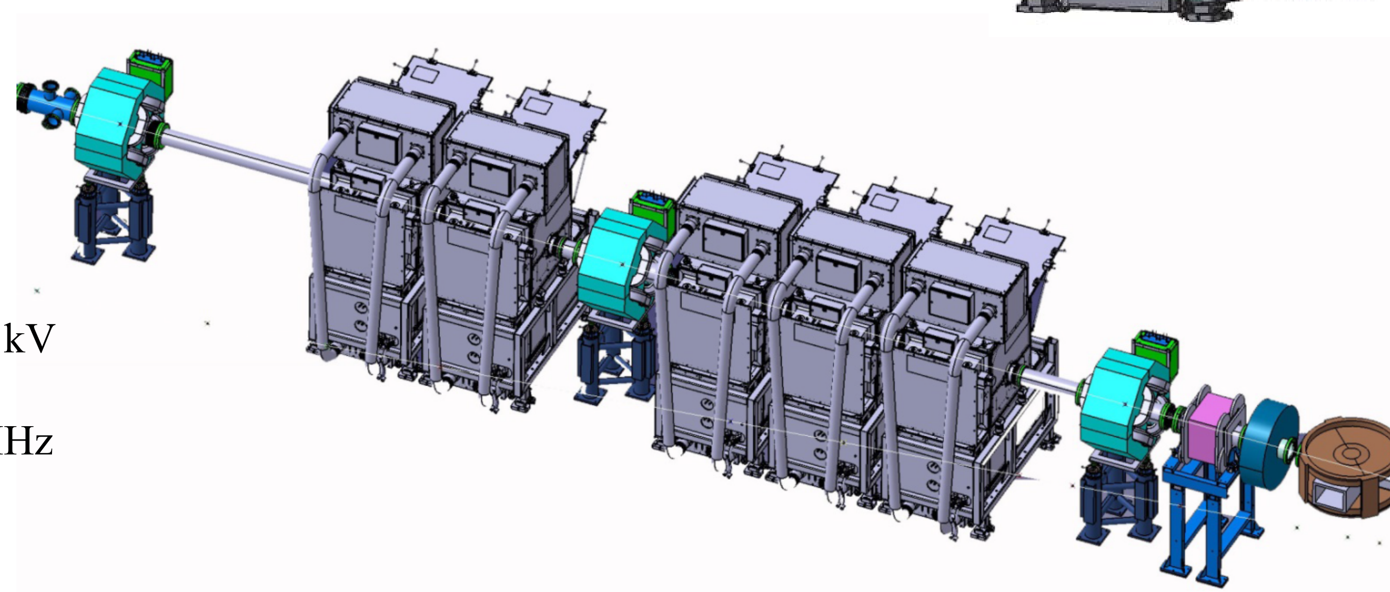






Bunch rotation of ions

U.Laier



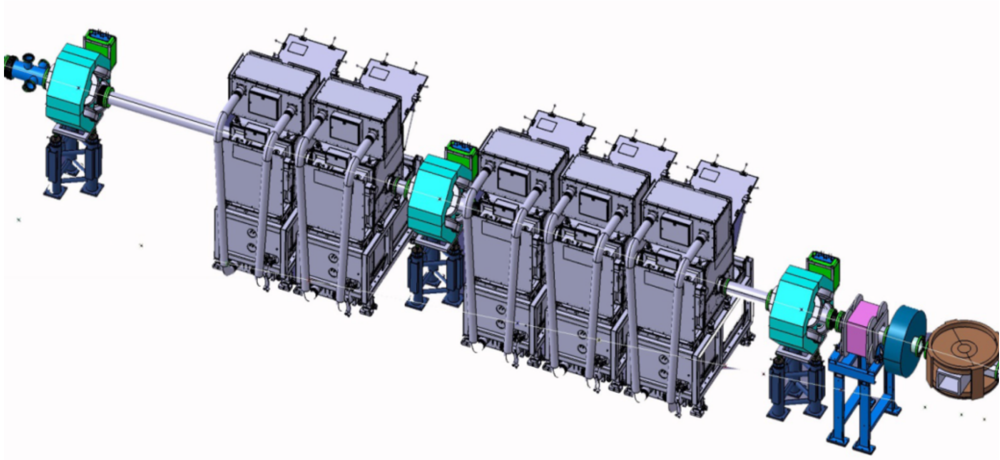
Total voltage (5 RF stations) 200 kV
Peak voltage per cavity 40 kV
Frequency range 1.1-1.5 MHz
Peak power per RF station 1 MW

The commissioning of the FoS module whole system is ongoing.

CR Debuncher Cavities at GSI

Status:
- Contracts with Research Instruments, PPT Ampegon (Germany), OCEM (Italy)
- All subcomponents of the FoS system are available at GSI
- System integration has started in 2015
- DC working points CW + Pulse established
- Gap voltage (30 v to 2 kV) in CW operation established
- Gap voltage in pulsed operation (1 Hz, 2 ms, 1 kV to 40 kV) established
- SAT of RF power supply unit : December 2016
- FAT/SAT of overall RF system: Q1/2017

First device for installation into tunnel



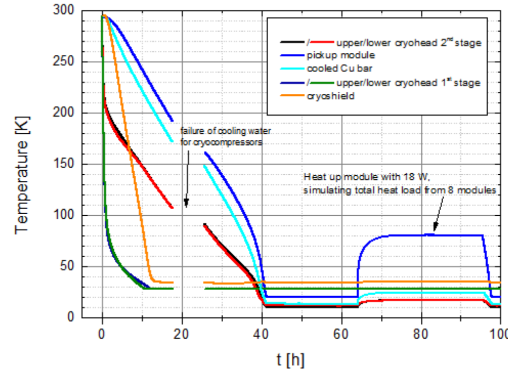
One needs 5 pieces

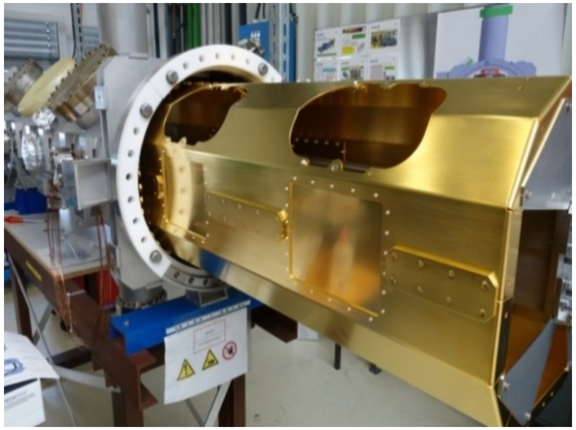
I.Koop, MAC16

Stochastic Cooling: Prototype PU tank at GSI

Prototype pickup tank with cryoheads, intermediate (Au on Cu) cryoshield, motor drive units for moving electrodes

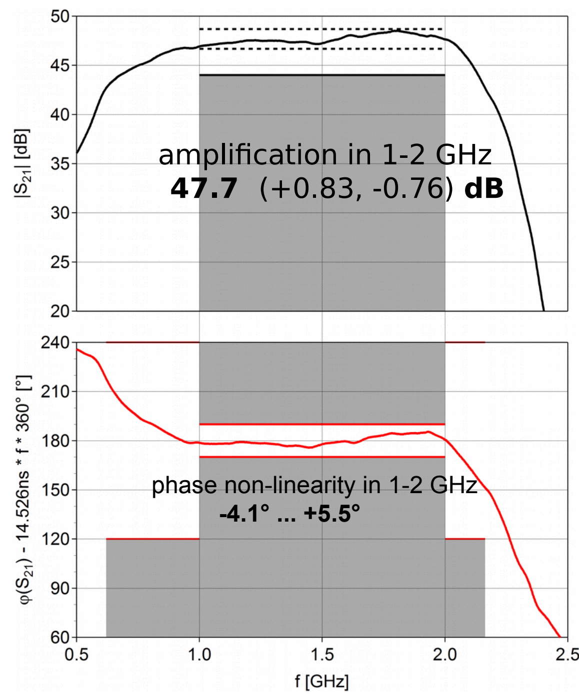
successful UHV cryotests down to 20 K with 2 electrode dummies and 2 He cryoheads (up/ down)
Heat up module with 18 W simulating heat load from 8 modules
→ thermal concept OK for full version (modules < 30 K)





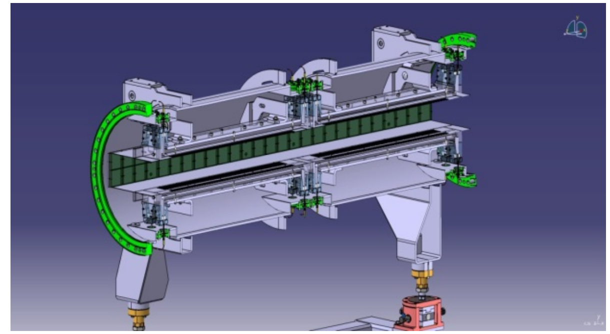
34 Power amplifiers is a large cost factor for the SC system. Contract with an external company has been signed. Production is ongoing.

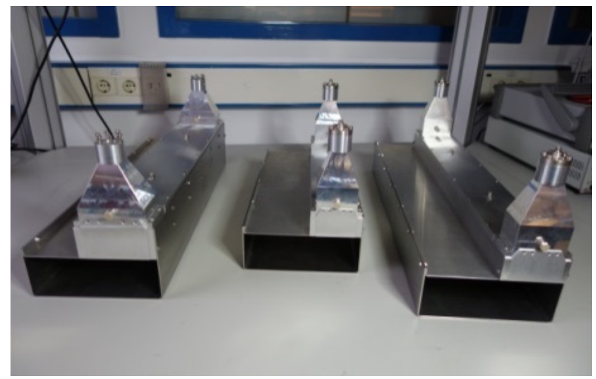
SAT FoS has been performed. The results of SAT: The amplifier are fully compliant with the RF specification! But needs amendments (power supply, controls) at the manufacturer before final acceptance



Stochastic Cooling: Prototype PU tank at GSI

- Palmer pickup (rail electrodes): RF concept finished in 2015, consolidation/ refinements engineering of tank underway in 2016; continuation (specs & tendering) subject to personnel recruitment





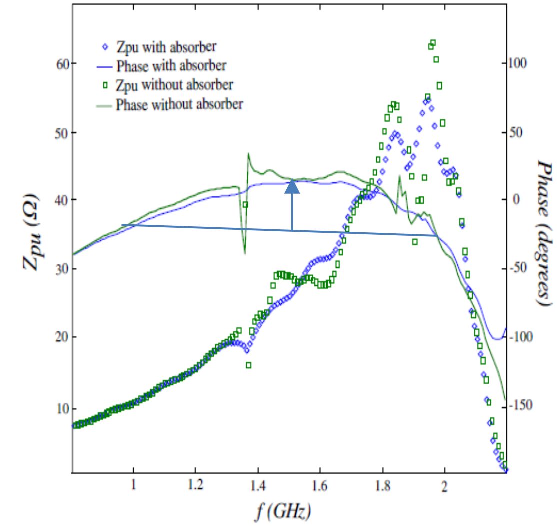


Figure 6: Pickup impedance and nonlinear phase deviation for Faltin rail structure B consisting of two rails of 49 slots each whose signals have been combined. The performance both with and without the presence of ferrite damping material is shown. Simulations are done with a beam centred vertically and with horizontal offset of 40 mm.

Overall time schedule for Stochastic Cooling System

	2017				2018				2019				2020				2021			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Specifications (made)																				
Planning	■	■	■	■	■	■	■	■	■	■	■									
Production	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
Shipment			■	■	■	■	■	■	■	■	■	■	■	■	■	■				
Transport in tunnel																	■	■		
Bringing in service without beam																			■	■