RCS status

(Summary of the work done on the the RCS)

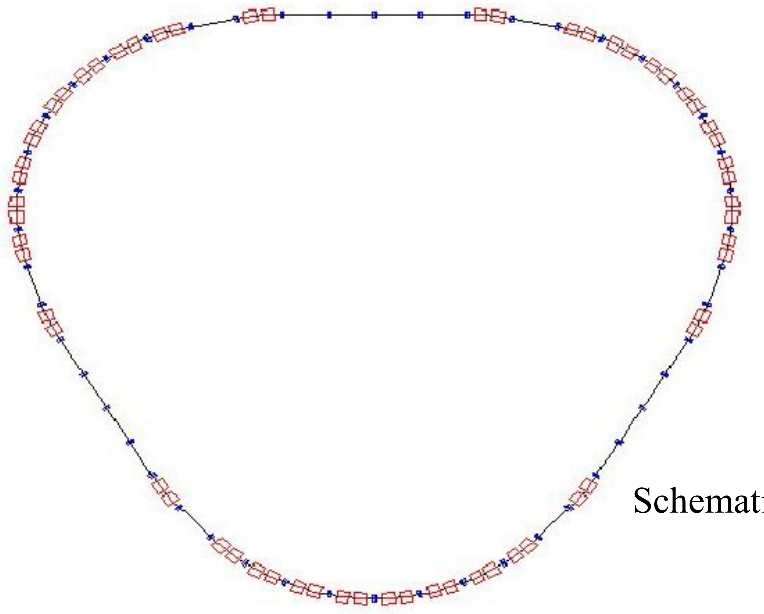
Programme

- Work done at IPNO
- Other contributions and further work to be done
- Conclusion

Work done at IPNO : general parameters and optical design

After several upgrades of the initial parameters, the RCS specifications have stabilized and have been fixed in november 2006 : E_{max} = 3.5 GeV (protons), R = 40m , Repetition rate of 10 Hz

A threefold symmetric lattice based on FODO cells has been defined. Working point, beam envelopes, vacuum chamber aperture and main magnets parameters have been specified.
Short dipoles (1.4 m) have been selected in order to limit the decay product losses in the yoke. The maximum magnetic field has been fixed to 1.08 T in order to avoid a large ramping rate for the 10 Hz operation.

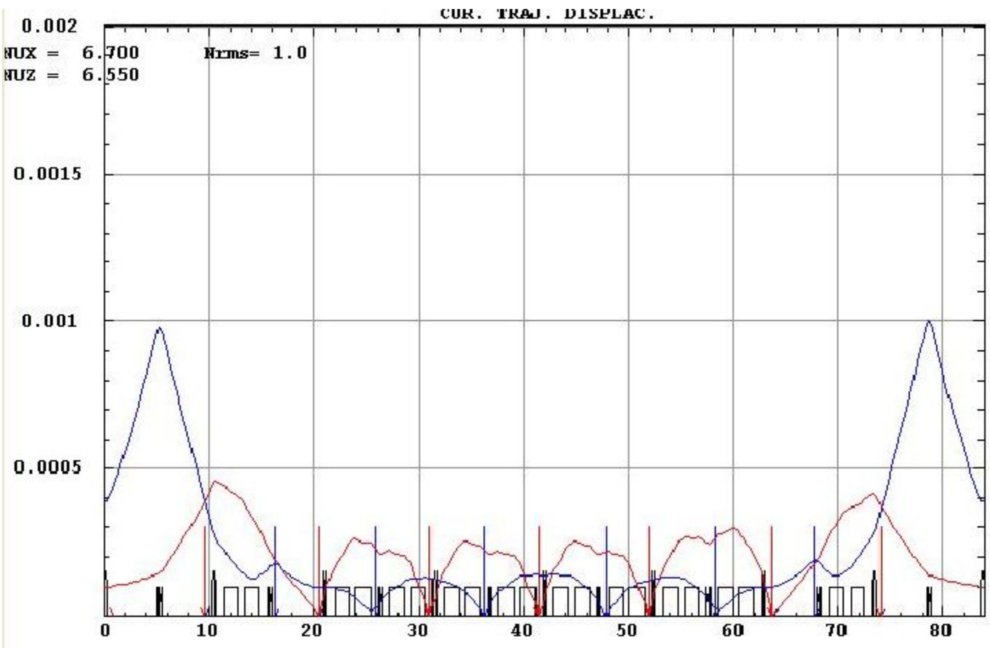


Schematic layout of the RCS

Work done at IPNO : Closed orbit prognosis and correction system

Assuming standard field and alignement errors, distortions of the closed orbit have been evaluated (5 mm rms in QF) with the code BETA.

A correction system based on 7H + 6V dipole steerers coupled to 14 BPM per period has been defined and correctors parameters have been specified.



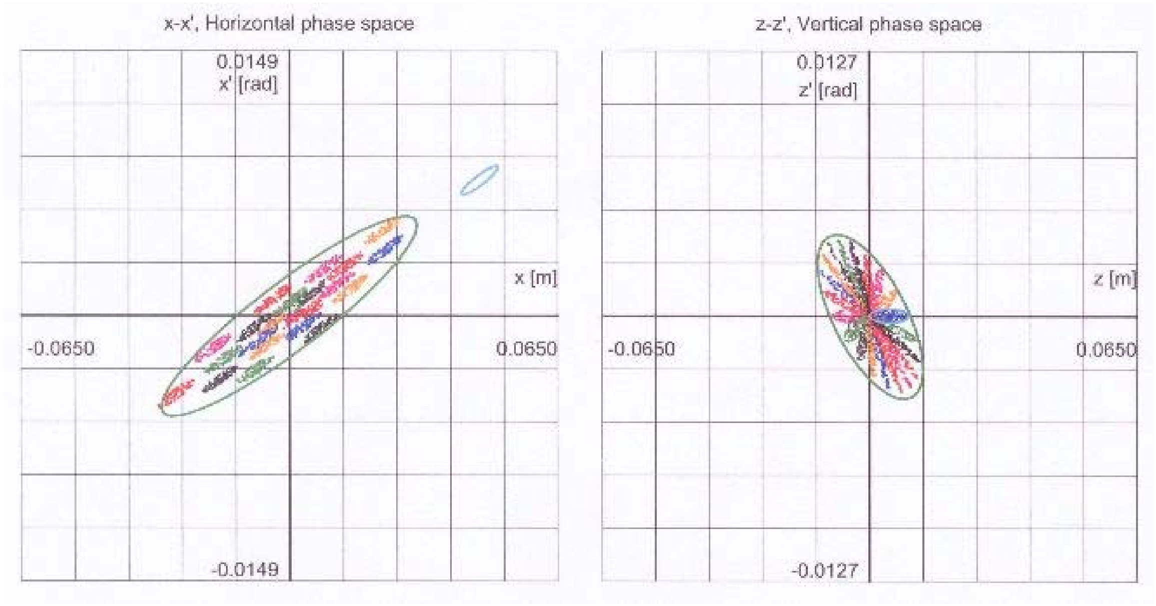
Closed-orbit after correction

Work done at IPNO : Injection process

A multiturn injection scheme has been calculated with the code WinAgile to inject the 50µs pulse delivered by EURISOL.

The position and the slope of the incoming beam have been optimized in order to maximize the number of ions in the specified transverse emittances (79% efficiency).

Septum wall position and pulsed kicker parameters have been specified and a preliminary sketch of the injection line has been studied.

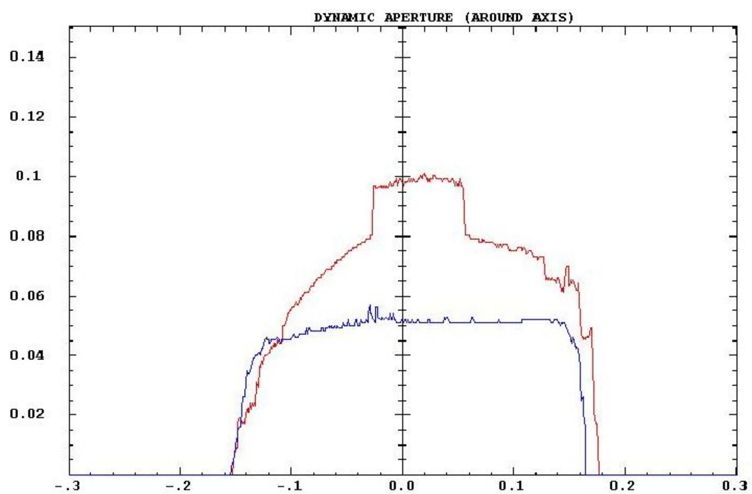


Phase space distribution of the beam

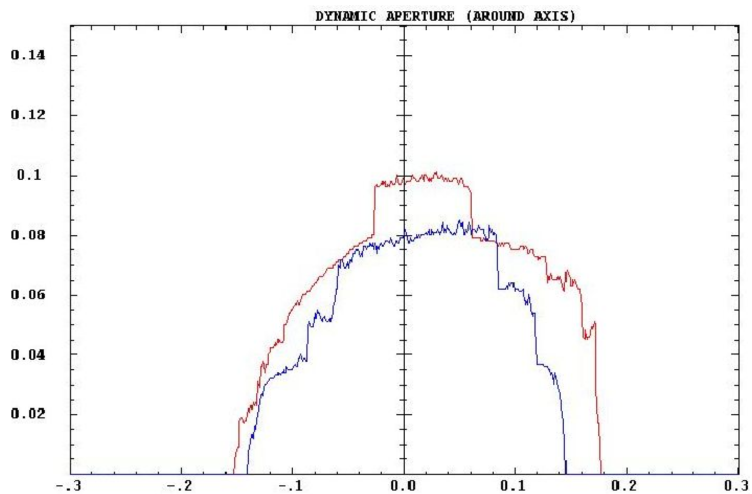
Work done at IPNO : Main magnet cycle, eddy currents, chromaticity correction and dynamic aperture calculation

Assuming a biased sinusoidal ramp the time variation of the magnetic field in main magnets has been calculated

Induced eddy currents effects in the vacuum chambers have been evaluated using analytical expressions. Their contribution to the ring chromaticity has been calculated and a chromaticity correction scheme providing a large dynamic aperture has been defined.



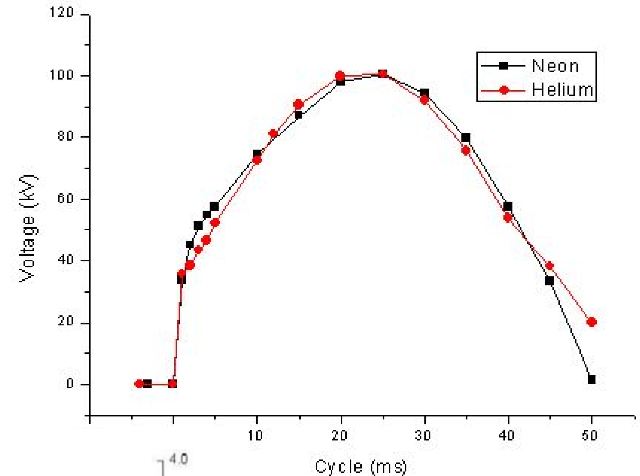
Dynamic aperture for He at 10 Hz



Dynamic aperture for Ne at 10 Hz

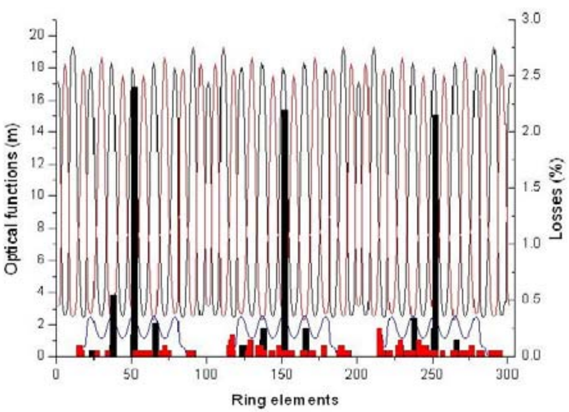
Work done at IPNO : RF acceleration cycle, RF cavities parameters and beam losses

The RF cycle has been simulated and optimized with the code ACCSIM and another code developed at IPNO for this purpose.

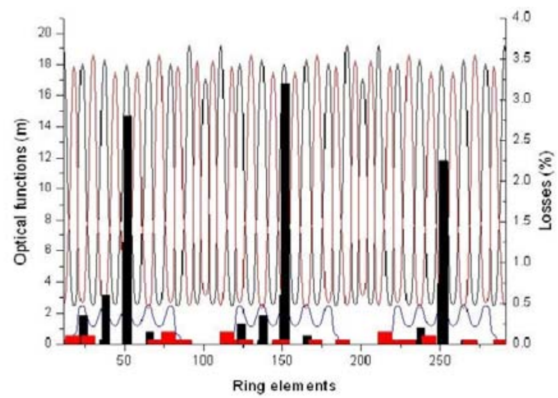


RF voltage and synchronous phase variation during capture and acceleration have been optimized to minimize losses and to match the bunch to the PS buckets at extraction.
Realistic characteristics of RF cavities have been proposed.

Finally, beam losses occuring during injection, trapping and acceleration have been investigated with ACCSIM.
Beam losses location and intensity have been determined.



Helium



Neon

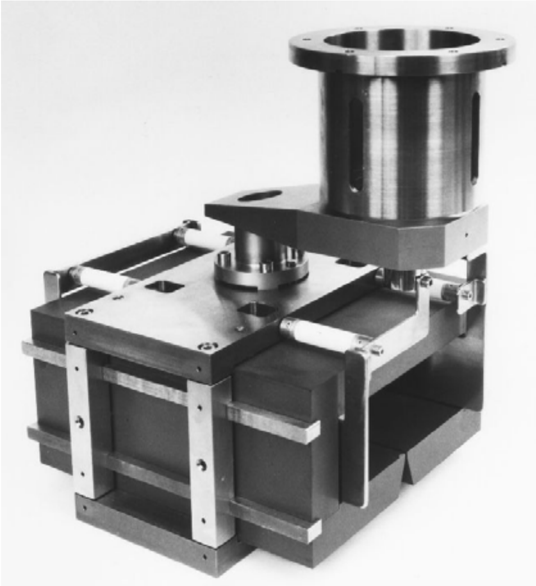
If necessary, further simulations could be done assuming the use of a chopper in order to reduce losses during the cycle.

Work done at IPNO : Fast extraction system

After acceleration to the top energy, ion beams are extracted in a single turn using 2 fast kickers and 3 septum magnets.

The extraction magnet layout in one of the 3 straight sections has been defined.

Realistic kicker and septum magnet parameters have been proposed. Their technology is based on existing designs made at GSI for SIS18 and for the J-parc project in Japan.

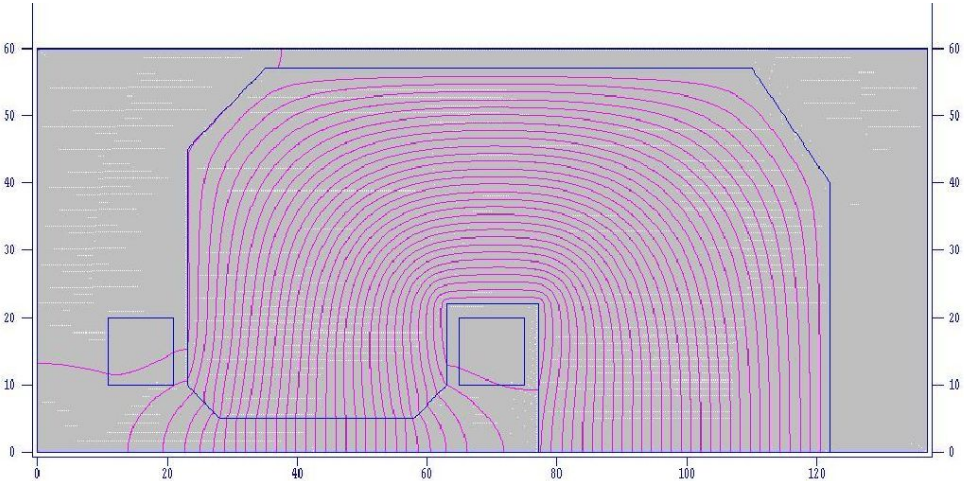


Extraction kicker proposed by GSI

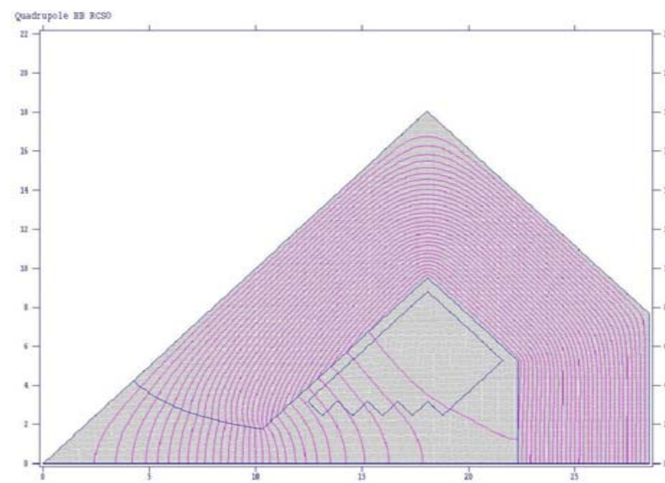
Work done at IPNO : Main magnet design

A preliminary design of main dipoles and quadrupoles has been studied and proposed.

2D calculation of the transverse cross section have been made with the code POISSON.



Dipole cross-section


Quadrupole cross-section

C-type magnets have been selected for dipoles in order to afford easy extraction of Ne decay products.
Coil configuration and technology together with water cooling and power supply parameters have to be defined more precisely.

Some modifications of the dipole extremities have been suggested by Thomas Zickler, from CERN

RCS parameter list

General parameters

Injection energy	100 MeV/u
Extraction energy	3.5 GeV eq. Proton
Maximum rigidity	14.47 T.m
Ring circumference	251.33 m
Number of FODO cells	24
Superperiodicity	3
Repetition rate	10 Hz
Momentum compaction	0.00349
Transition gamma	5.35
Tunes (H, V)	6.7 6.55
Revolution time at injection	1.95 µs
Injection time	50 µs
RMS emittances at injection (H, V)	18.11 pi.mm.mrad 9.69 pi.mm.mrad

RF system

Bunching time	4 ms for He 3ms for Ne
Acceleration time	50 ms
Maximum peak voltage	100kV
Harmonic number	h=1
Frequency swing	0.51 to 1.12 MHz
Maximum synchronous phase	60° for He 72° for Ne
Longitudinal emittance at injection	0.22 eV.s for He 0.66 eV.s for Ne
Longitudinal emittance at extraction	0.61 eV.s for He 1.45 eV.s for Ne

Injection parameters

Optical parameters of the incoming beam

Horizontal plane (matched to ring)	Vertical plane (mismatched to ring)
β_x= 13.273 m	β_z= 14.7894 m
α_x= -2.1918	α_z= 0

Beam position and slope at the septum

Horizontal plane	Vertical plane
x_{inj} = 4.6 cm	z_{inj} = 0.471 cm
x'_{inj} = 7.6 mrad	z'_{inj} = 0

Injection components

Element	Septum 1	Septum 2	Electrostatic deflector
Deflection angle	100 mrad	230 mrad	17. mrad
Field	0.75 T	1.27 T	60 kV/cm
Length	0.6 m	0.8 m	1.6 m
Horizontal aperture	4. cm	4. cm	2. cm
Vertical aperture	4. cm	4.cm	3. cm

Injection bumpers

Number	2 (3)
Maximum deflection angle	4.15 mrad
Number of turns for bump collapse	40
Horizontal aperture - Gap	8.0 cm
Vertical aperture - Gap	7.0 cm

Extraction parameters

Fast kickers

Rigidity	14.5 T.m
Kick angle	4.5 mrad (first kick) 6 mrad (second kick)
Number of modules per kicker	2 (first kicker) 3 (second kicker)
Direction of kick angle	horizontal

Septum magnets

Deflection angle (mrad)	(20, 50, 80)
Length (m)	(0.6, 0.7, 0.9)
Magnetic field (T)	(0.482, 1.03, 1.29)
Horizontal aperture - Gap	5 cm
Vertical aperture - Gap	5 cm

Kicker modules

Rise time	700 ns
Pulse length	200 ns
Horizontal aperture– Gap	10.0 cm
Vertical aperture- Gap	8.0 cm
Length of ferrite of module	36 cm
Effective length of module	44 cm
Ferrite weight / module	70.5 kg
Field for deflecting the beam	104 mT

Main magnet parameters

Bending dipoles

Number of dipoles	60
Magnetic length	1.4 m
Good field region	± 5 cm (H) ± 5 cm (V)
Bending radius	13.369 m
Magnetic field (He)	0.199 – 1.08 T
Magnetic field (Ne)	0.332 – 1.08 T
Gap height	10 cm
Maximum Ampere-turn	85940 A.t
Magnet cycle	Biased sinusoidal ramp
Maximum current	1719 A
Minimum current	528.4 A for He 316.7 A for Ne
I_{DC} DC current	1123.7 A for He 1017.8 A for Ne
I_{AC} AC peak current	595.2 A for He 701.1 A for Ne
Number of turns (2 coils)	2*25
Size of the squared conductor	20*20 mm
Cooling hole diameter	8 mm
Number of cooling system	1 per coil
Resistance (2 coils)	10.9 mΩ
Yoke weight	11 t
Coil weight	0.36 t

Quadrupoles

Number of quadrupoles	48
Length	0.4 m
Bore radius	0.06 m
Maximum gradient	10.825 T/m
Maximum Ampere-turn/ coil	15545 A.t
Maximum current	517.8 A
Minimum current	159 A for He 95.25 A for Ne
I_{DC} DC current	338.4 A for He 306.52 A for Ne
I_{AC} AC peak current	179.4 for He 211.27 A for Ne
Number of turns (4 coils)	4*30
Size of the squared conductor	10*10 mm
Cooling hole diameter	5 mm
Number of cooling system	1 per coil
Resistance	34.04 mΩ per quad
Yoke weight	0.525 t
Coil weight	0.146 t per quad

Correction magnet parameters

Sextupoles

Number of sextupoles	27
Maximum strength	25 T/m²
Maximum Ampères-turn / coil	1432.4 A.t
Magnetic length	0.15 m
Bore radius	0.06 m

Correction dipoles

Number of correctors	39
Magnetic length	0.15 m
Maximum field	0.04 T
Horizontal aperture - Gap	8.0 cm
Vertical aperture - Gap	10.0 cm

Other contributions and further work to be done

Beam loss distribution and associated dynamic vacuum effects have been estimated by GSI. No problems to obtain a pressure of 10^{-7} mbar.
Intra-beam scattering has been studied at CERN, it is not an issue in the RCS.

Shielding design and calculations have been done at CERN, the RCS radiation protection system is under study (see talks of S.Trovati).

The cost estimate of a RCS similar to the Beta-Beam RCS has been made by CERN.

Parameters of the extraction kickers have been proposed by Udo Blell from GSI and improvements of our magnet design have been suggested by Thomas Zickler from CERN.

The accelerator hardware (magnets, septa, collimators, vacuum system and beam monitoring system) is not technically defined in details.

Conclusion

A complete design of the Beta-Beam RCS including a review of main dynamics issues has been done.

The Beta Beam RCS parameters are well inside typical RCS specifications and do not pose critical technical issues.

All studies are presented in a detailed draft report which is already available.

Further work is needed if we want to define the ring hardware in details.

Final remark : The design of the Beta-Beam RCS is the subject of my PhD thesis which will be submittet in the next months.