ISRS Project
Beam dynamics

Progress Report WP1

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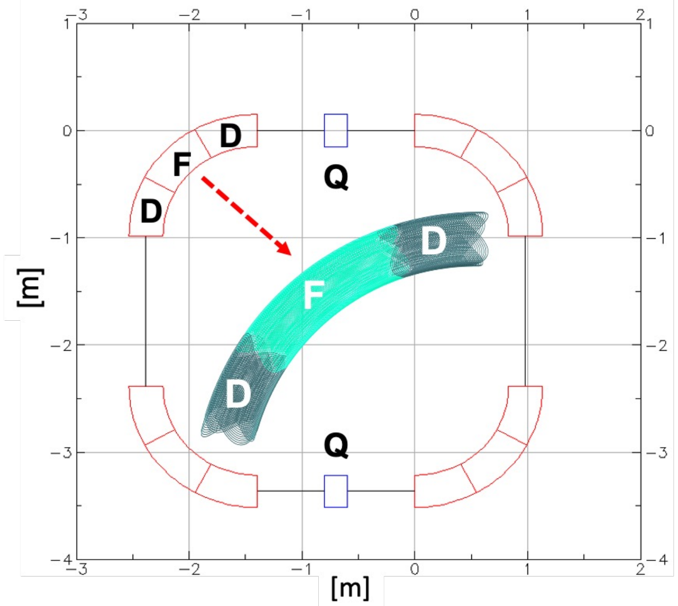
Introduction

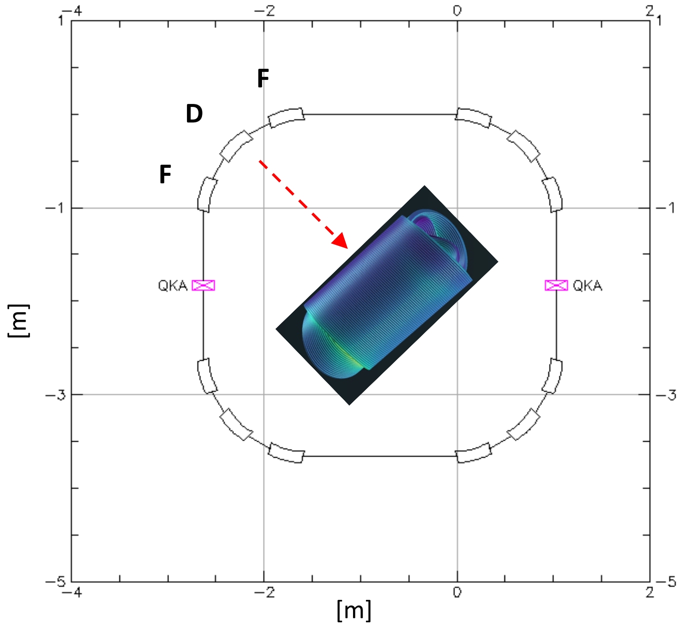
Selection of machine layouts and lattices

ISRS ring design. Different candidates

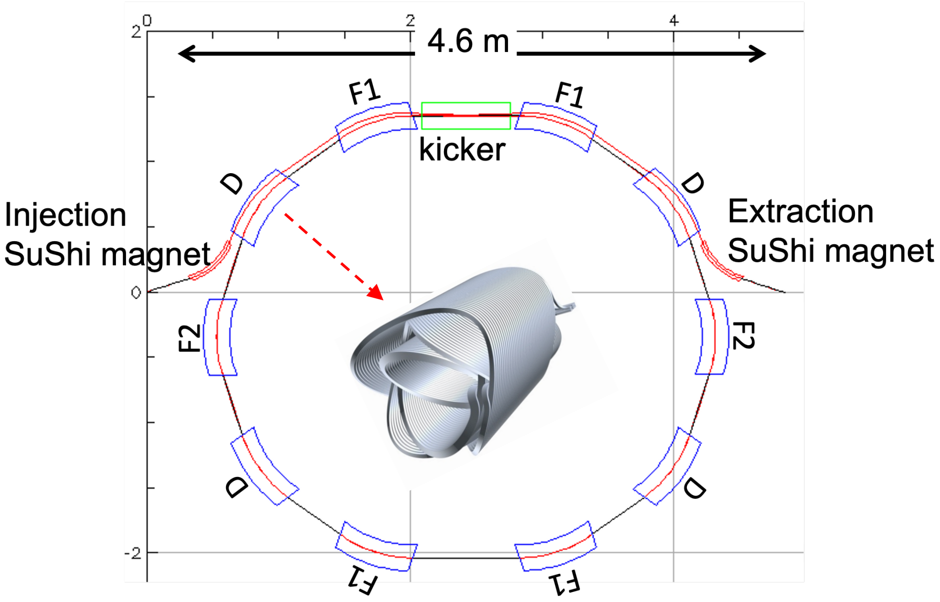
4 curved CCT magnets (90 deg. bend)



12 straight 350 mm
effective magnetic length
CCT magnets (30 deg. bend)



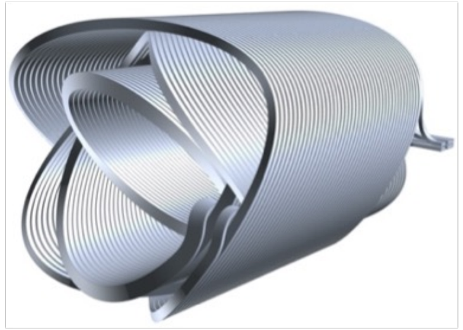
10 straight 580 mm
effective magnetic length
CCT magnets (36 deg. bend)

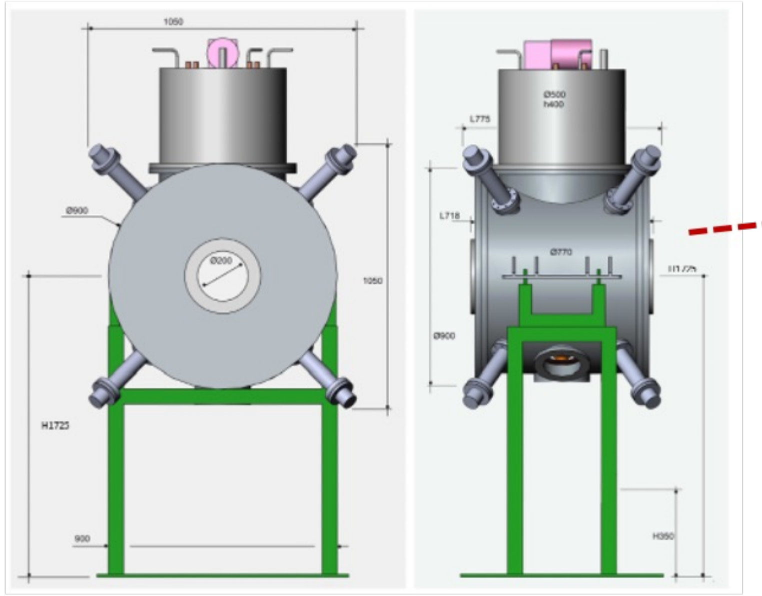


Magnet models (based on the software Rat GUI) revealed that the effective CCT magnetic length must be higher than 500 mm to safety operate the magnet in terms of thermo-mechanical parameters obtaining the required dipolar and quadrupolar strengths

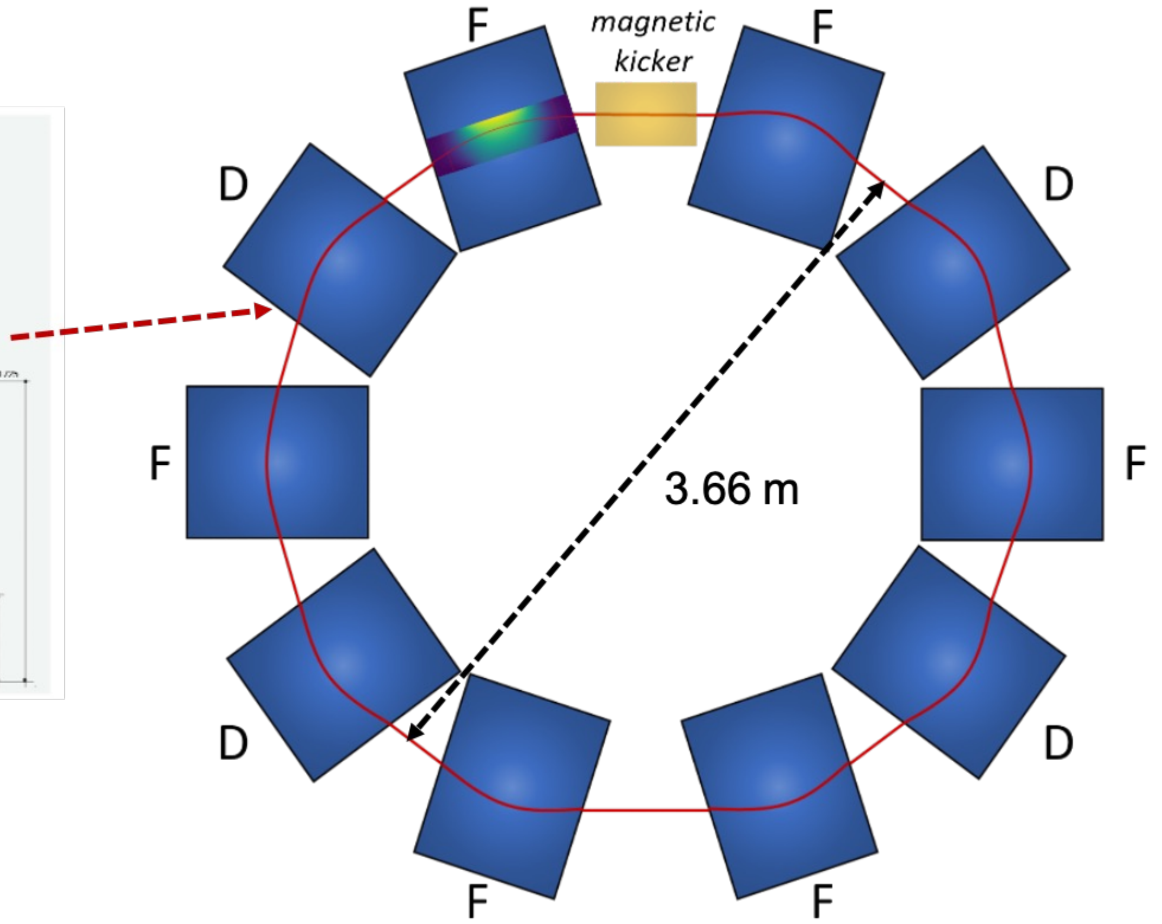
Latest ISRS layout

Based on 580 mm effective magnetic length CCT magnets





MAGDEM
(See progress report of WP2)

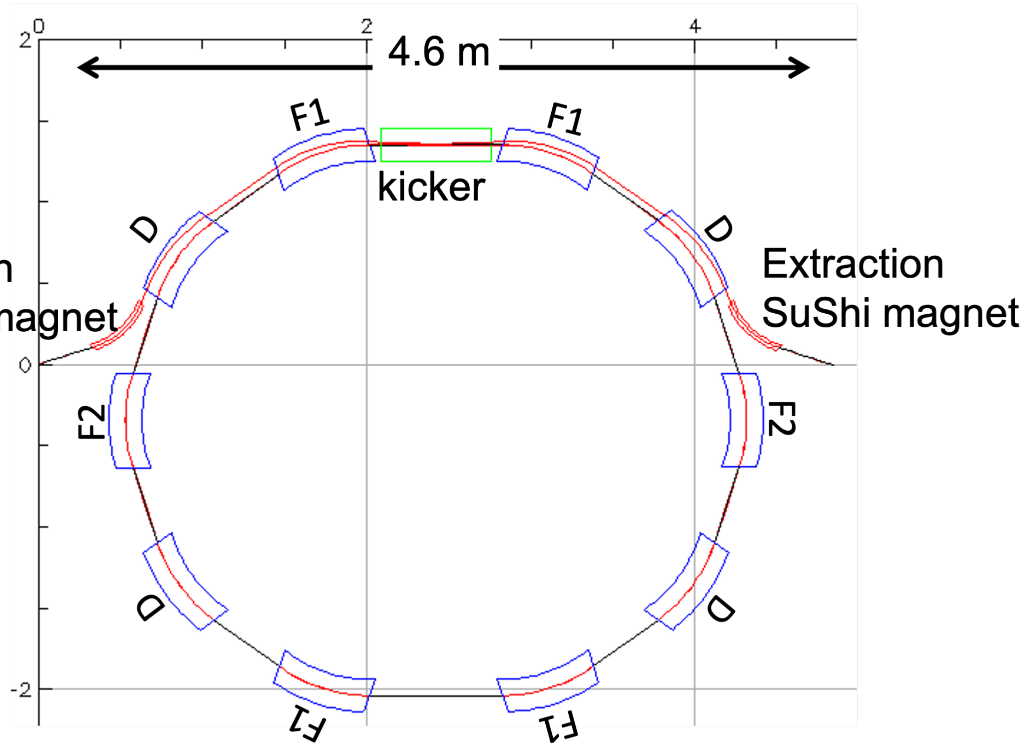


ISRS optics layout

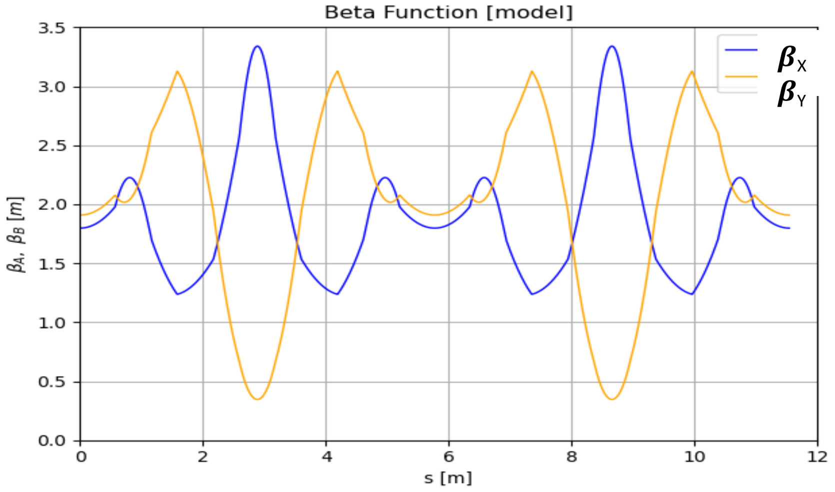
Isochronous configuration

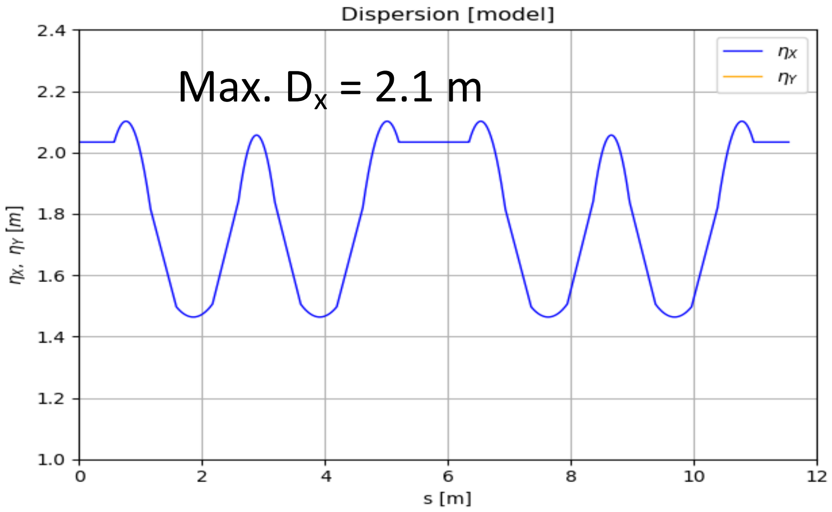
Matched for a reference ion 234Ra at 10 MeV kinetic energy

$$\text{Rigidity } B\rho = 2\ \mathrm{T}\cdot\mathrm{m}$$



CCT magnet	Dipole B [T]	Quad. gradient [T/m]
D	2.12	-2.007
F1	2.12	2.270
F2	2.12	3.692



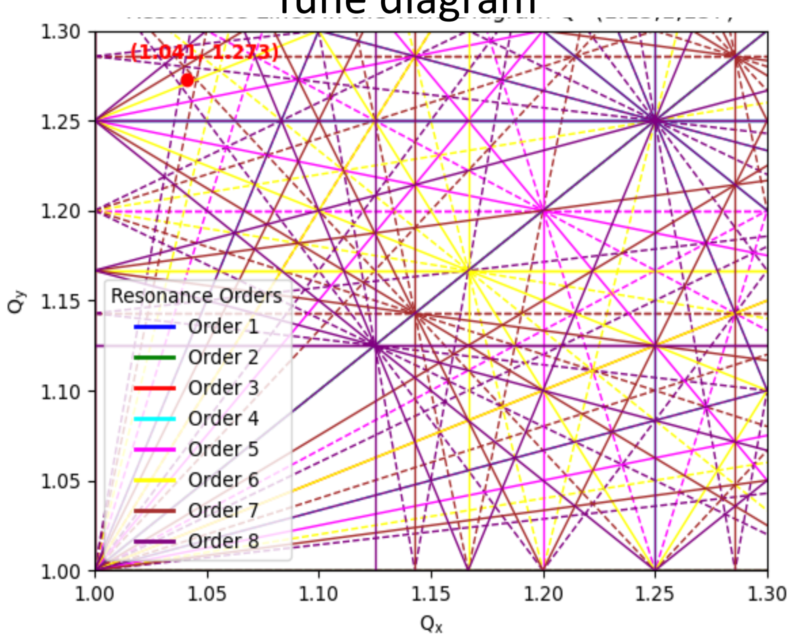


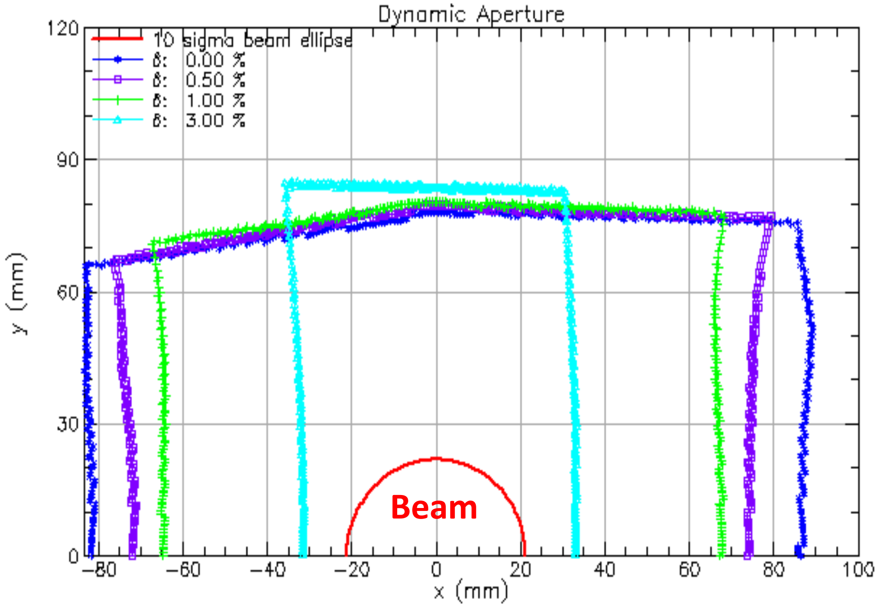
Momentum acceptance 4.8 %

ISRS optics characterisation

Isochronous configuration

Tune diagram





Momentum Compaction	0.979244
Slip factor	0.0000321828
Gamma at transition	1.01054
(Qx,Qy)(1 turn)	1.040567 ,1.272772
Chrom_x ,Chrom_y (dQ/dE/E)	-3.848913, -0.699243

Next step: characterisation of nonlinear optics, including higher order terms and corrections (T1.7): see talk by T. Kurtukian-Nieto

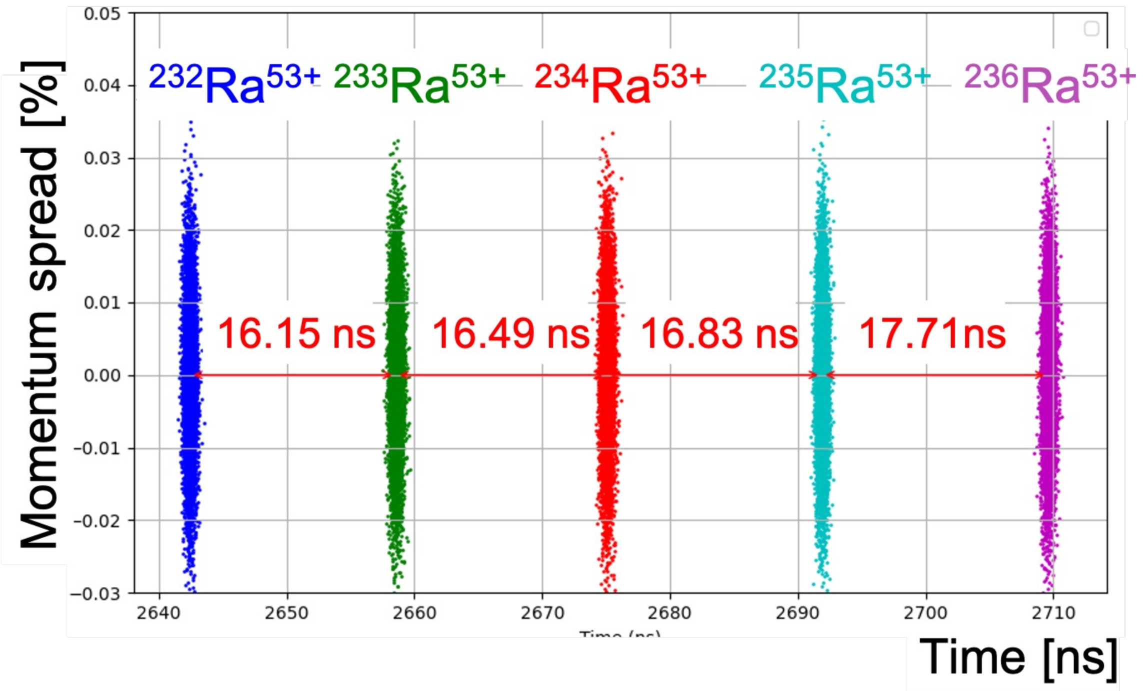
Tracking simulations

Isochronous configuration

Input particle distribution:

Gaussian distribution
5 isotopes of radium: $^{232\text{-}236}Ra$
5000 macroparticles per isotope
^{234}Ra in reference orbit
Kinetic energy = 10 MeV/u
Transverse emittance (x,y) = 5 mm-mrad
RMS longitudinal size σ_z = 0.01 m
RMS Momentum spread $\sigma_{\Delta p/p}$ = 0.01%

Isotopes separation by ToF after 10 turns (2670 ns)



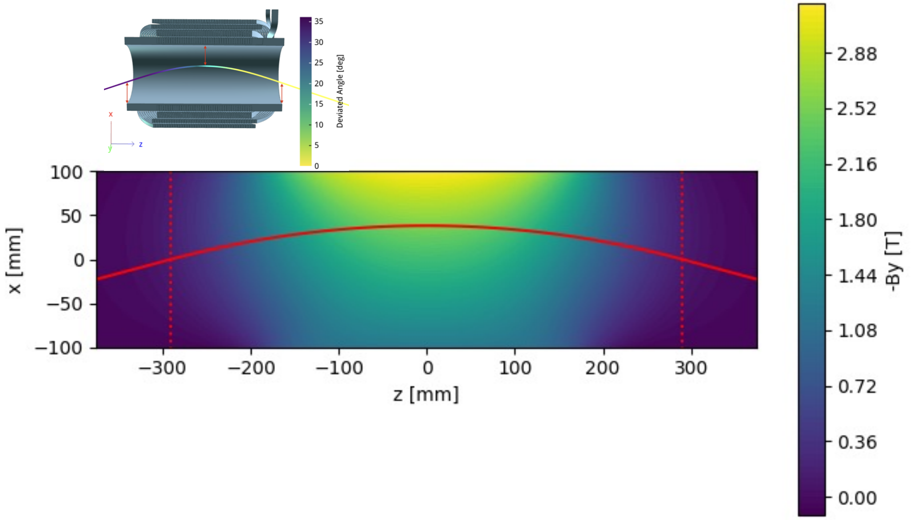
Tracking simulations

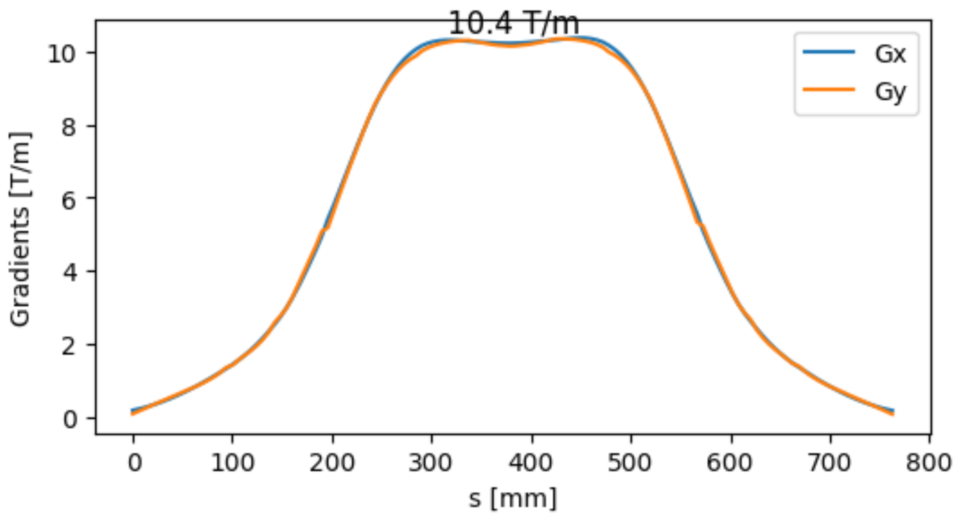
Towards more realistic simulations

Considering the **3D magnetic field map of the CCT element**. Generated using the software Rat GUI
Example provided by Nikkie Deelen (Little Beast engineering) and Glyn Kirby (CERN)

We are able to import this 3D magnetic field map into different accelerator codes: BMAD, RF-Track and COSY Infinity.

Multipolar optimisation for 36-degree curve trajectory





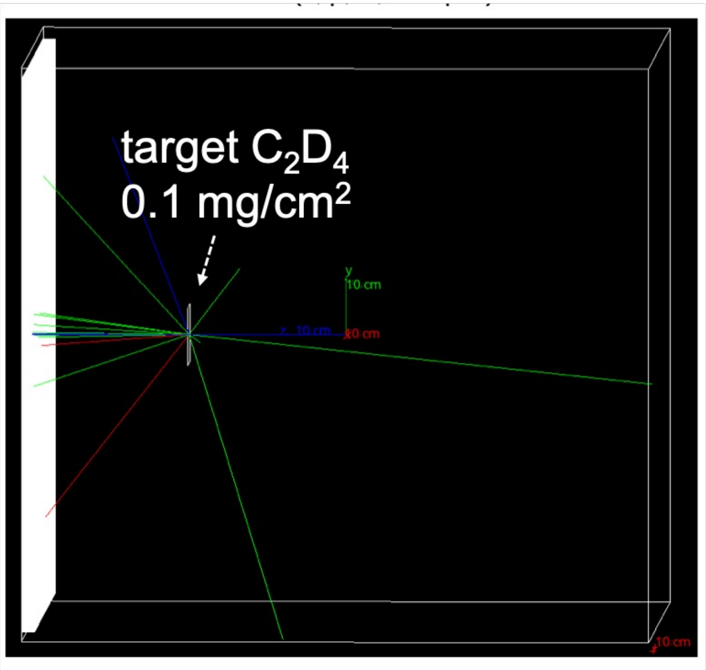
Ongoing study: benchmarking between the usual transfer matrix approximation and a more realistic 3D field map.
Somehow this is also relevant for T1.7 (High order corrections to beam dynamics)

Tracking simulations

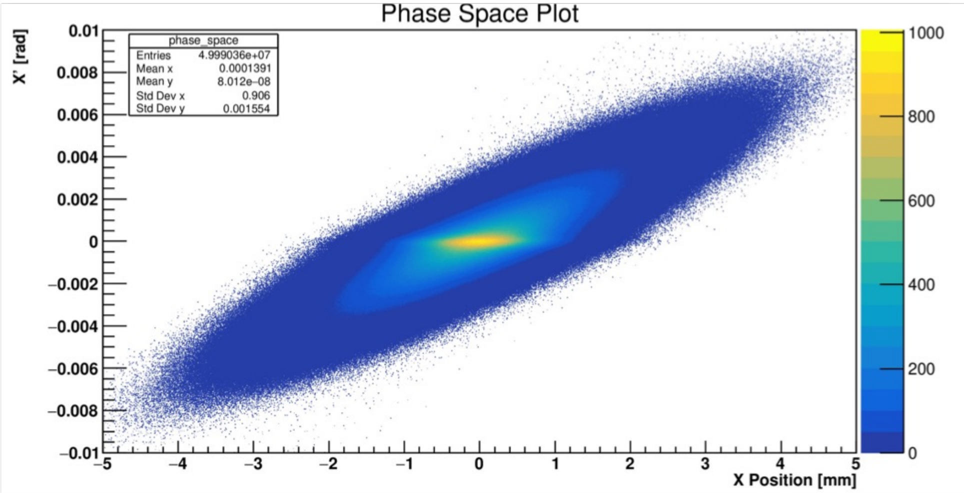
Towards more realistic simulations

Tracking model starting from the Scattering Experiments Chamber (SEC)
Monte Carlo simulations of the beam-target interaction using the GEANT4.
The primary objective is to generate realistic beam and reaction product distributions for injection into the ring

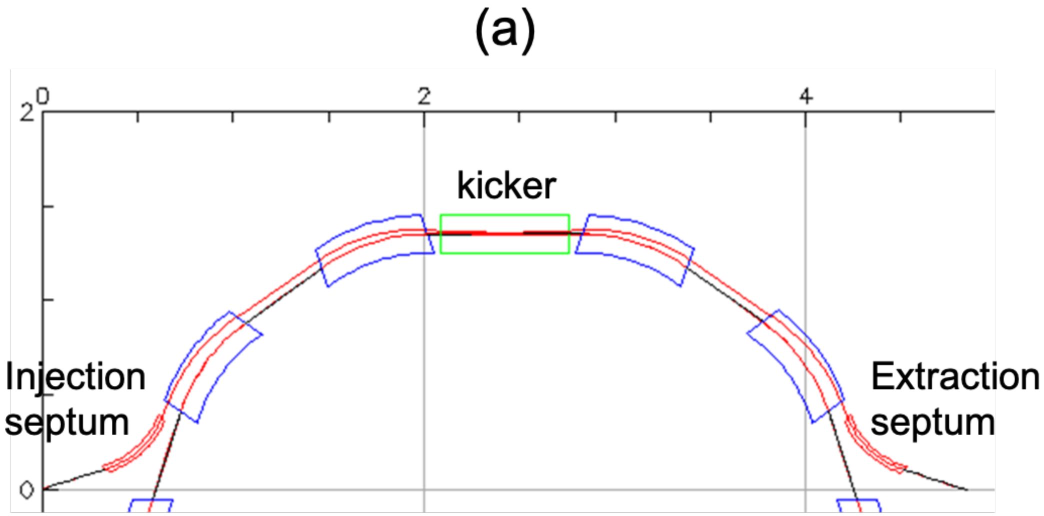
232Ra beam impinging a C2D4 target. 10k event.



Transverse phase space of the beam
and its reaction products at the exit of the target.

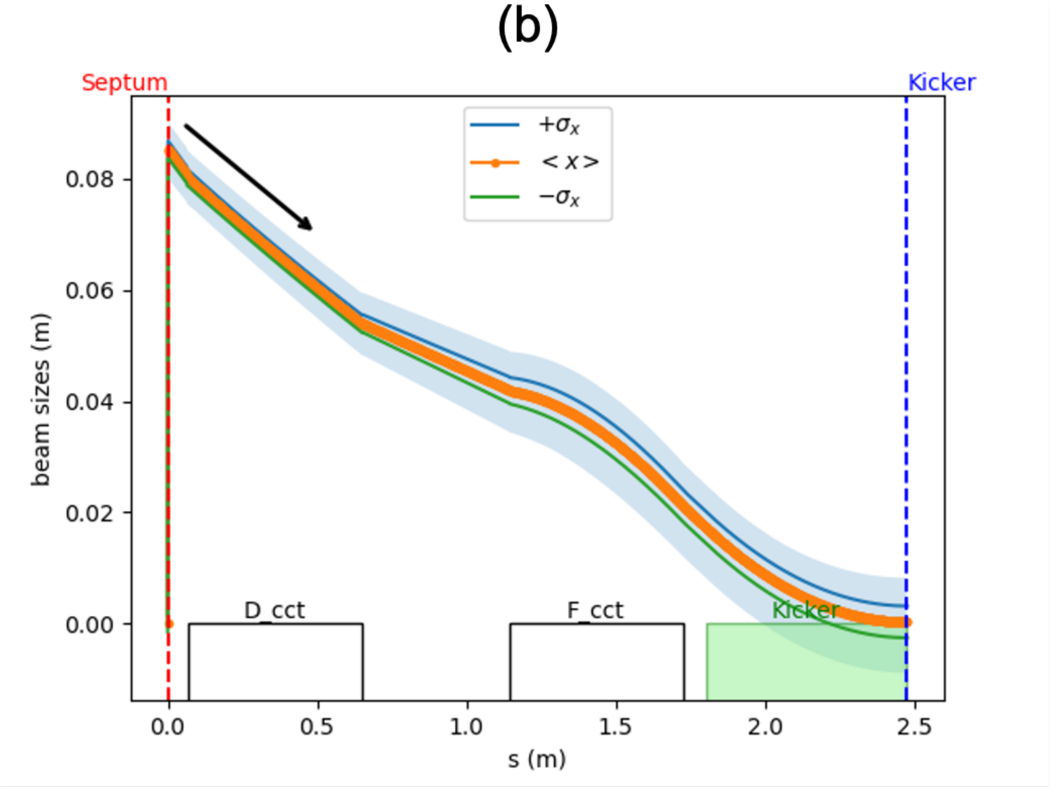


Injection/Extraction system



SuShi septum	
Bending angle	45 deg
Effective length	400 mm
Magnetic field	3.8 T

Magnetic kicker	
Kick angle	50 mrad
Length	600 mm
Magnetic field	0.16 T
Integrated field	0.1 T·m
Pulse rise/fall time	300 ns



The limited space requires the use of two CCT magnets to minimize the kick angle as much as possible with the action of the quadrupoles.

The challenge lies on integrating the septum between two magnets.

Summary

Since the last meeting in June 2024, significant progress has been made on WP1: 60% completed

- T1.3. Study of beam dynamics: characterisation of the ISRS linear optics, tracking simulations in isochronous operation mode

- T1.4. Selection of configurations: converging to a final and optimal ISRS design

- T1.5. Study of Injection/Extraction: preliminary design based on SuShi type septum and magnetic kicker. Simulations in progress. Monte Carlo simulations of the beam-target interaction

- T1.6. Beam diagnostics: task delayed. Action required

- T1.7. High order corrections to beam dynamics: We are able to import realistic 3D magnetic field maps of CCT magnets into different accelerator design codes. Next step: nonlinear optics characterisation

Thanks to all the contributors

Rafael Berjillos, Carlos García-Ramos, Domingo Gómez, Ismael Martel (University of Huelva, Spain)

Jorge Giner-Navarro, Yanis Fontenla, Fazel Taft (University of Valencia, Spain)

Teresa Kutukian-Nieto (Instituto de Estructura de la Materia, CSIC, Madrid, Spain)

Glyn Kirby, Volodymyr Rodin (CERN, Geneva, CH)

Thank you for your attention!