Design study of in-flight fragment separator for rare isotope science project in Korea

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Science Business Belt and Institute for Basic Science in Korea

Science Business Belt

Layout of Institute for Basic Science (IBS)

Bird’s-eye View of the Accelerator Facility Design in Korea

June 2012

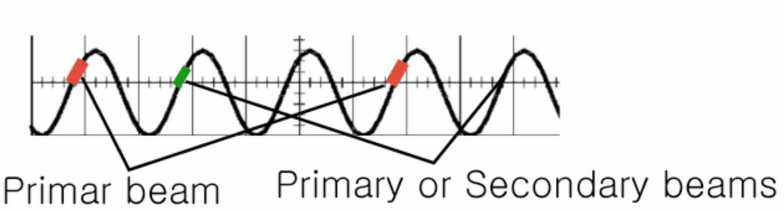
Advanced heavy ion accelerator facility for nuclear science and applications

Three accelerators

- **SC Linac1** 200 MeV/u for ^{238}U, 600 MeV for p: IF and ISOL driver
- **Cyclotron** 70 MeV for p: ISOL driver
- **SC Linac2** ~18 MeV/u for A/q ≤ 4 (?): ISOL post accelerator

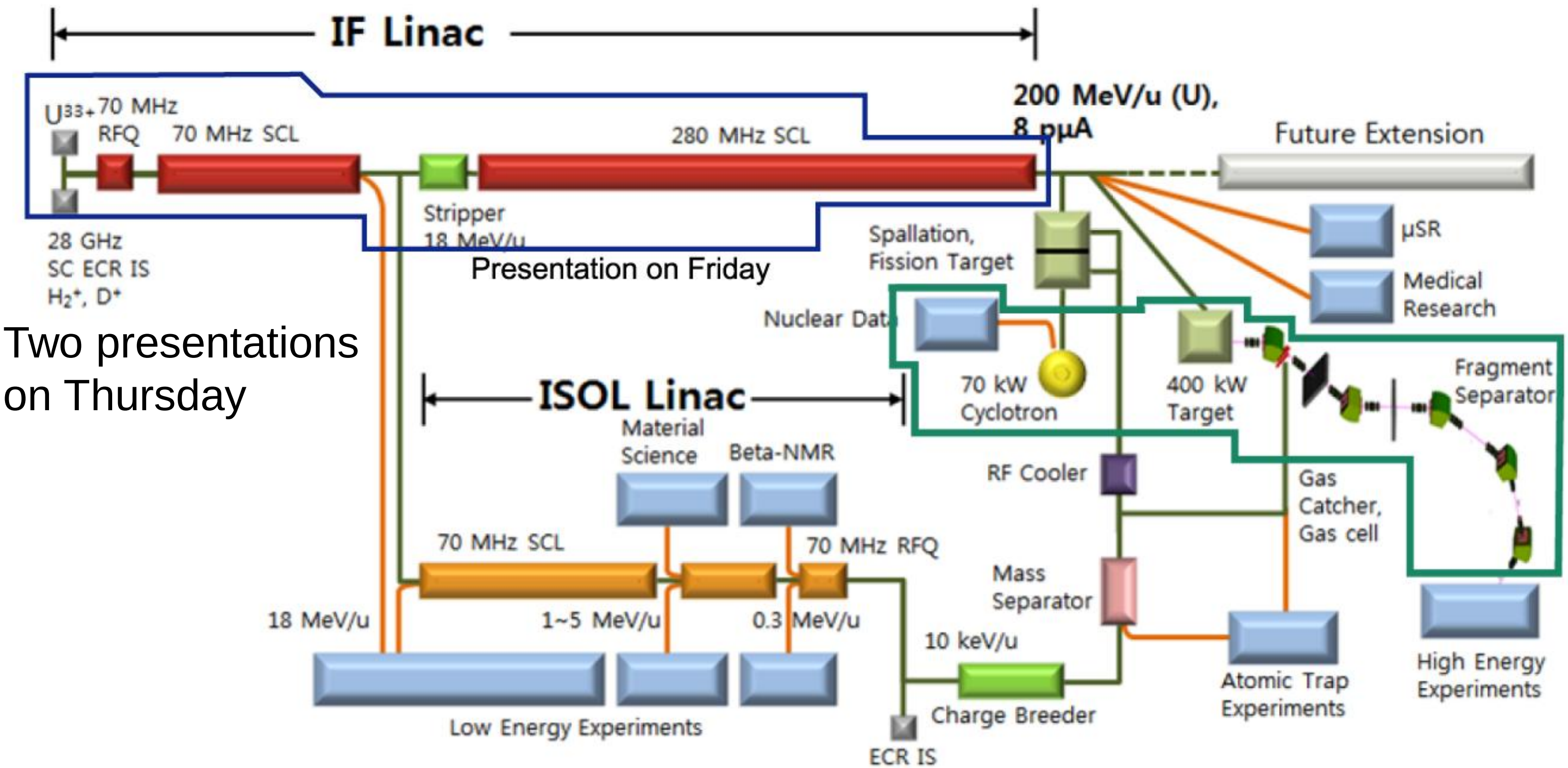
Multi-user capability

- Independent operation of three accelerators
- Multiple operation modes: e.g. SC Linac1, Cyclotron + SC Linac2
- Utilization of empty rf buckets for different beams



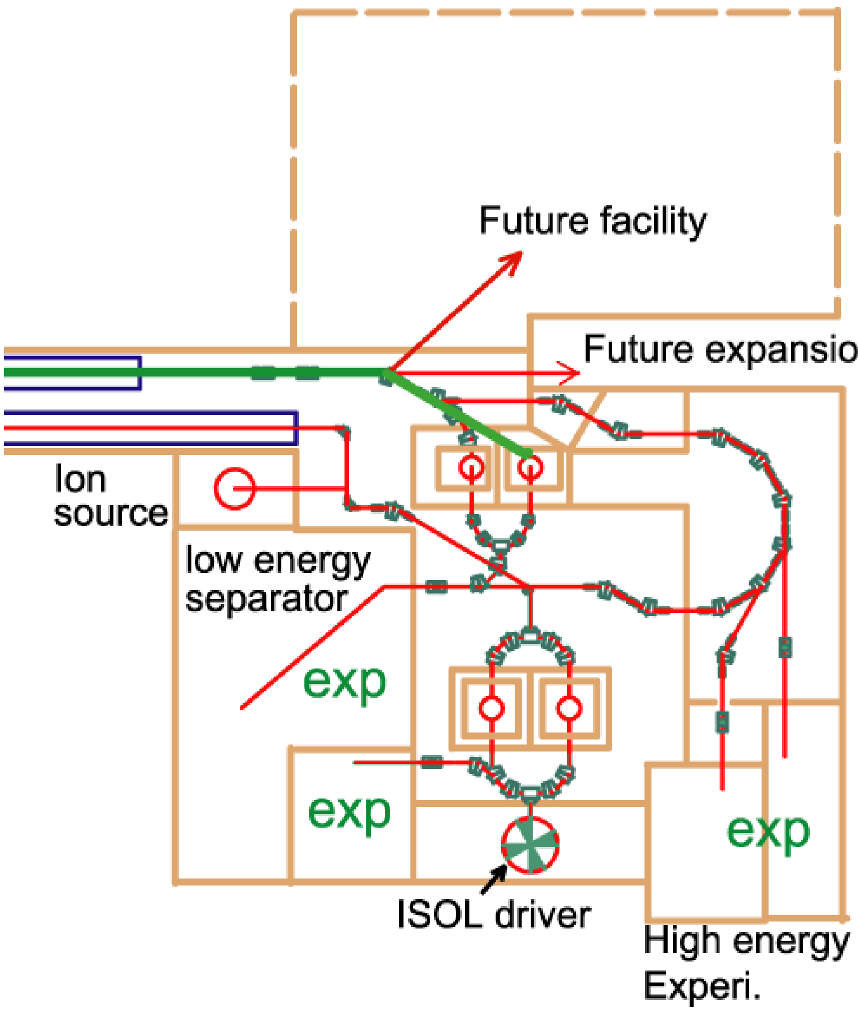
81.25 MHz (QWR), 162.5 MHz (HWR), **325 MHz** (Spoke)

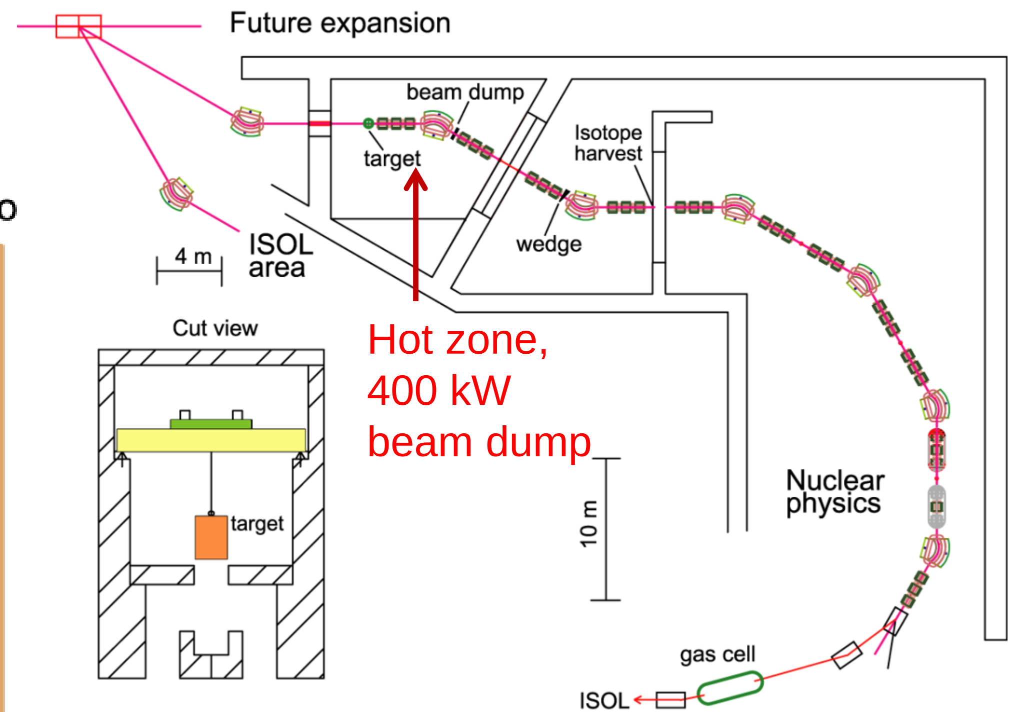
Scope of Presentation in the RI Science Project



Two presentations on Thursday

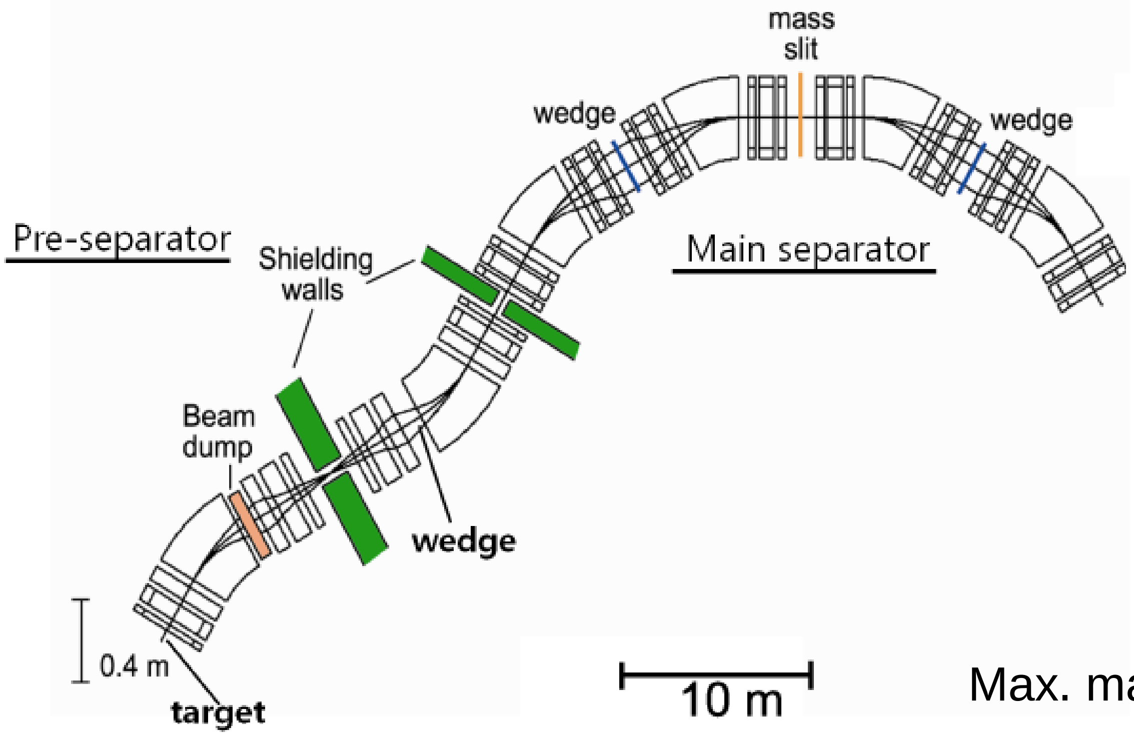
Layout of the fragment separator area





Design of In-flight Fragment Separator

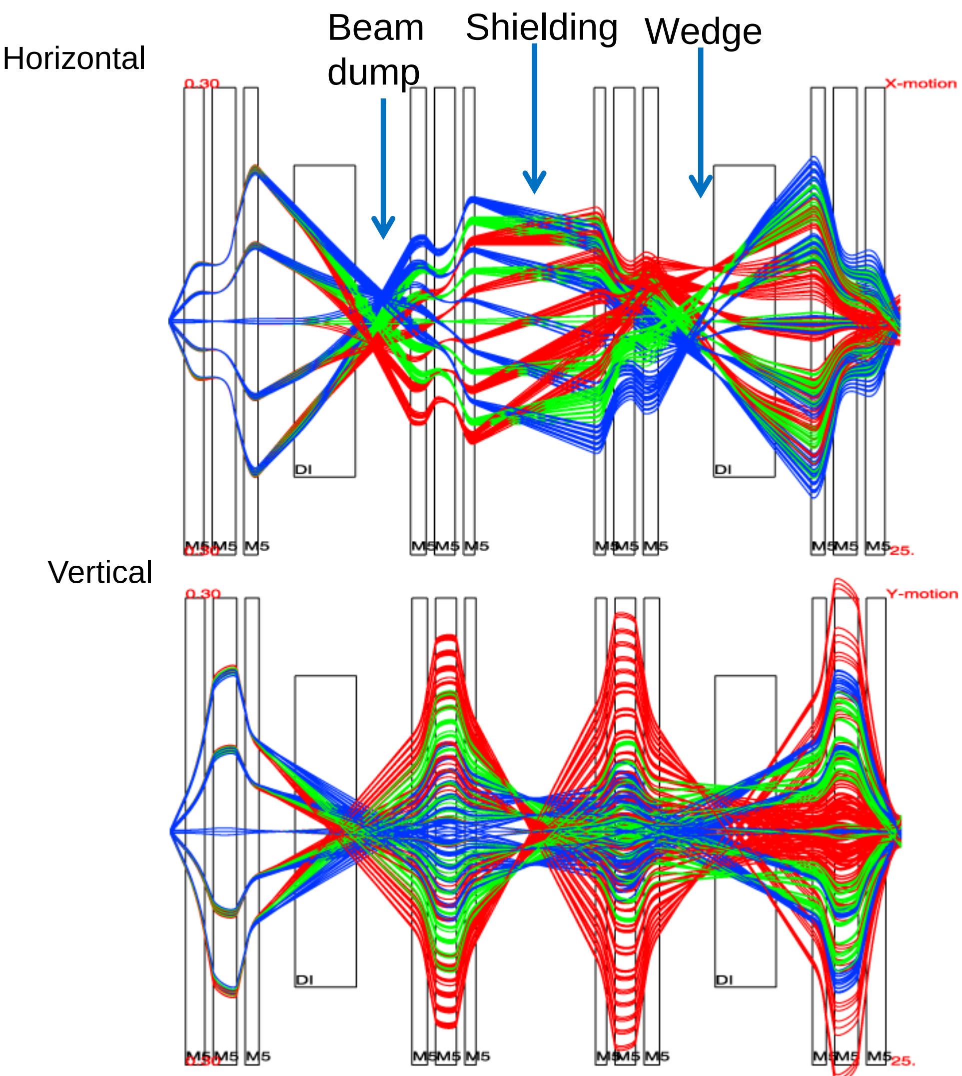
Pre-separator: S-shape
Main separator: C-shape

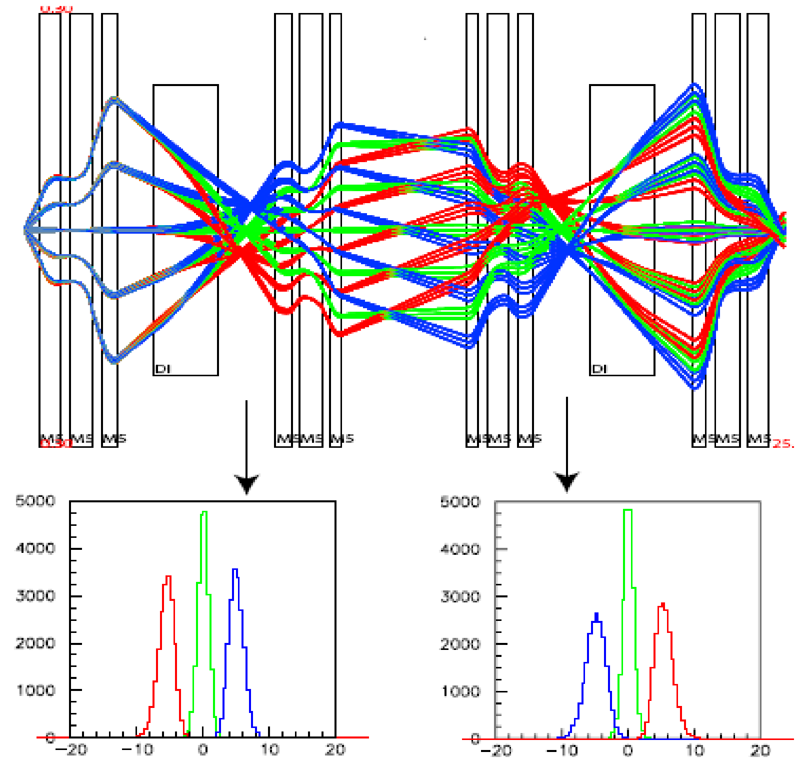


Max. magnetic rigidity= 8 T·m

W. Wan, J. Kim, Cyclotron Conf. 2010

Beam optics calculation of s-shape pre-separator





$\Delta p/p$= 1.5%

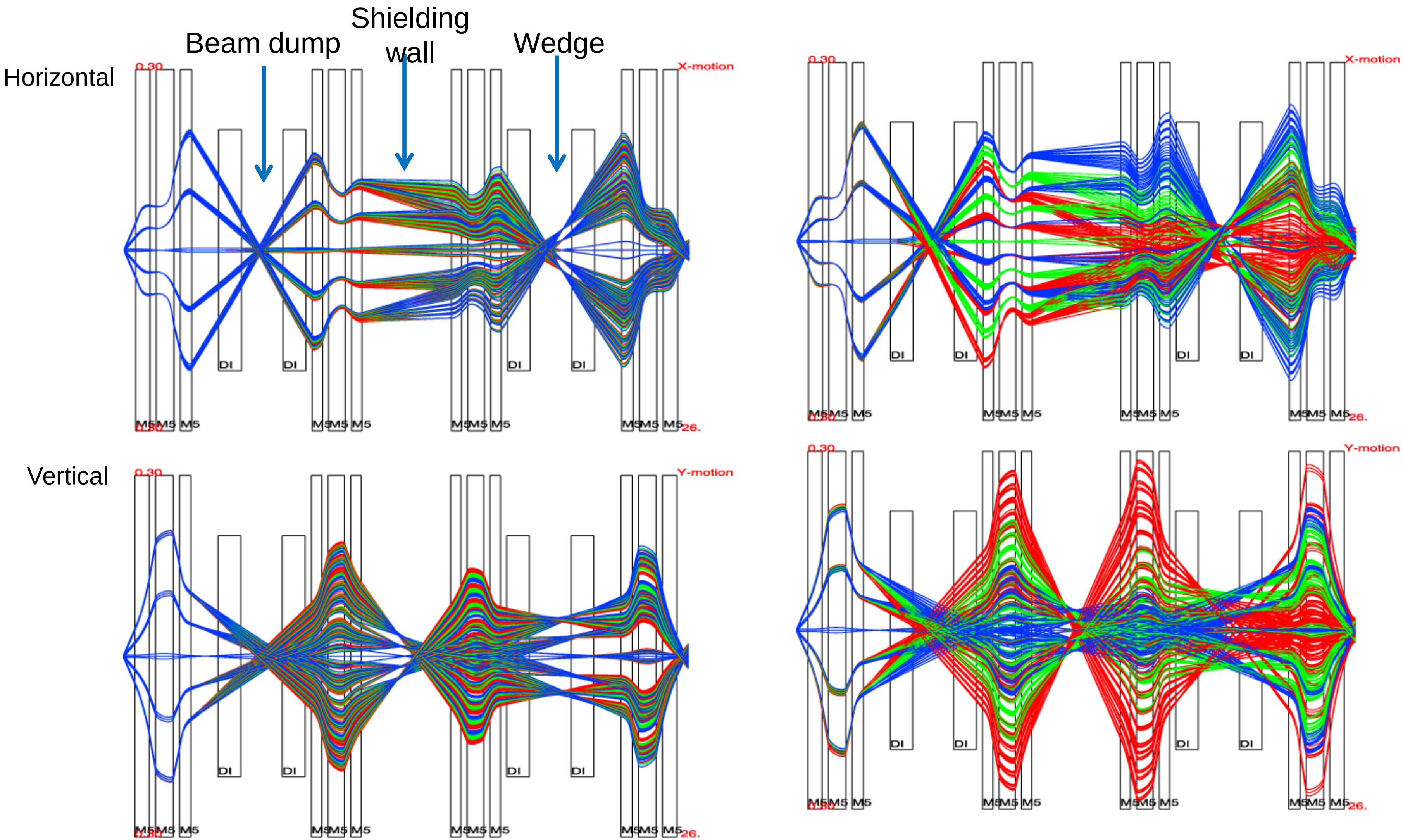
Aberrations up to 7th order

Calculated with TURTLE

ε= 4 π mm· mrad

$\Delta p/p$ = $\pm$ 5 %

Optics of the 4-dipole C-shape pre-separator

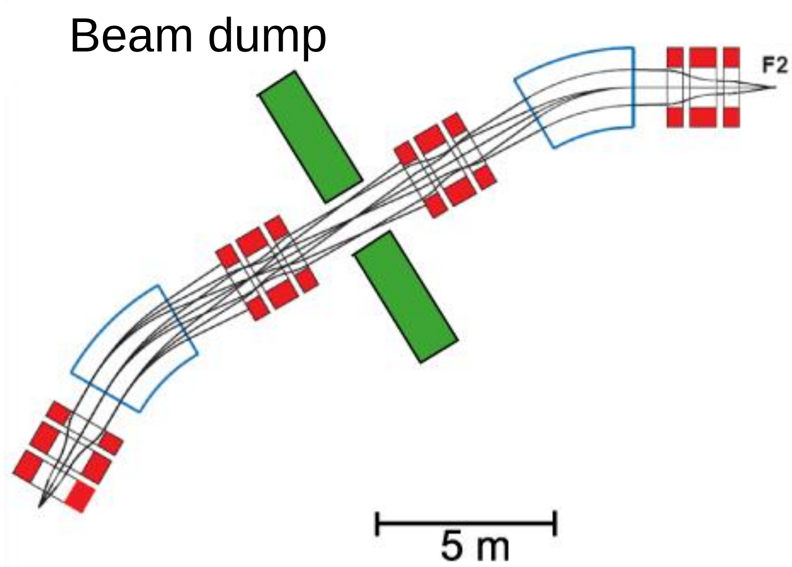


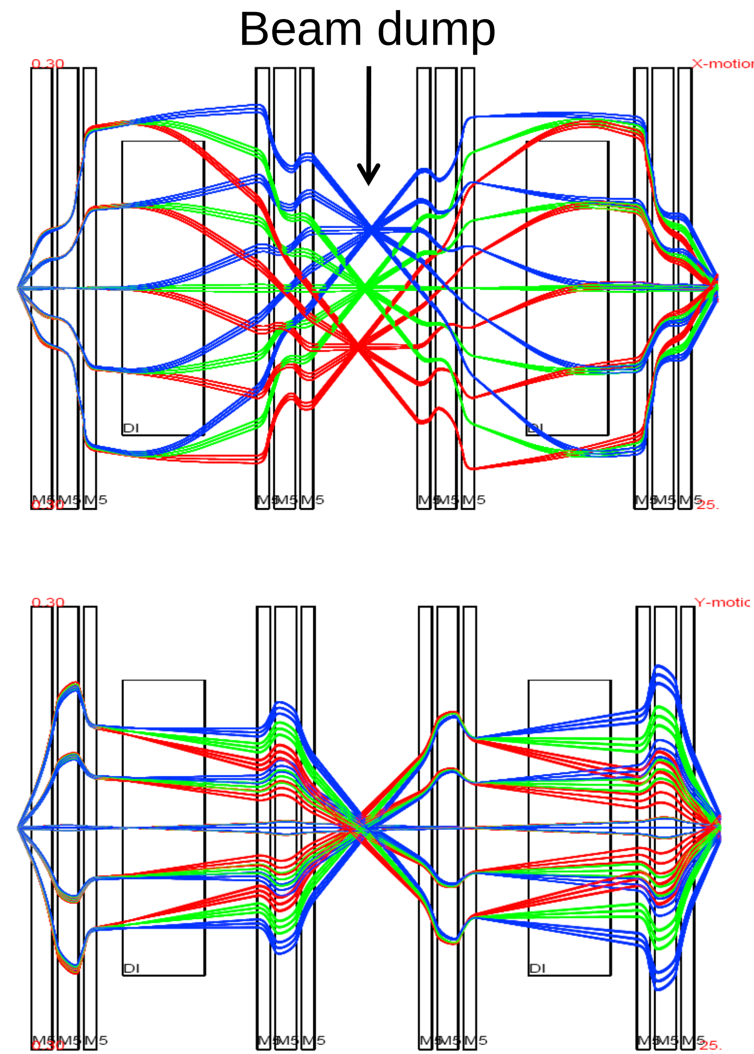
Δp/p= 0.1%

Δp/p= 1.5%

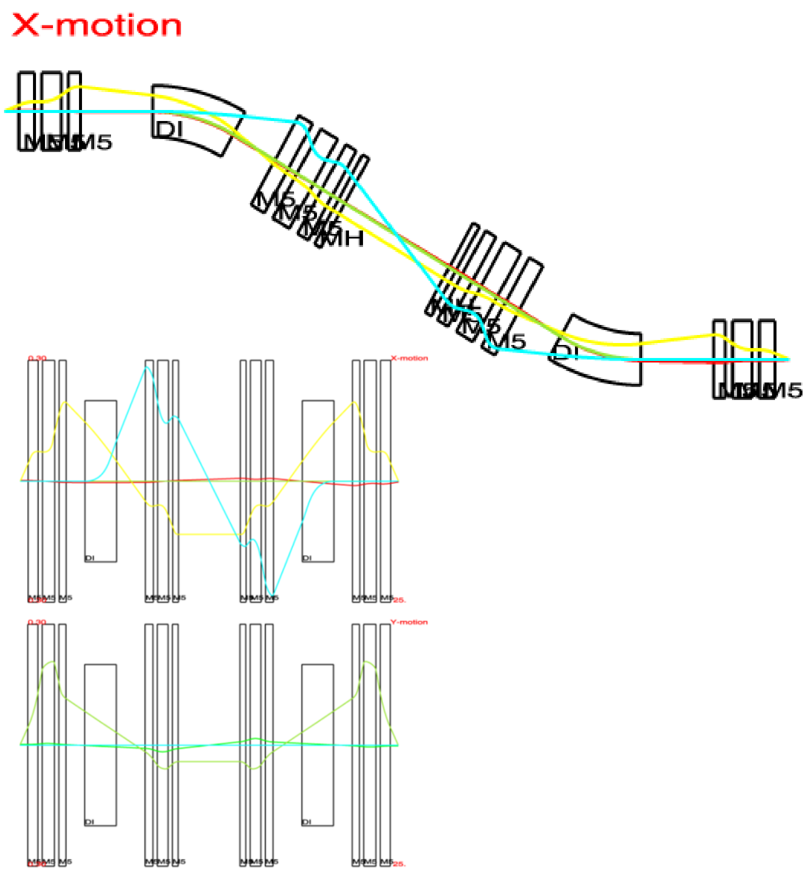
A 4-dipole C-shape with more elements

A half of the pre-separator





Magnet parameters for the S-shape pre-separator



Type	Length (m)	Pole tip radius (m)	Field at pole tip (T)
Quad	0.65	0.15	2.25
Quad	0.8	0.15	-2.33
Quad	0.5	0.15	2.16
Dipole	30 degrees	0.1	1.20
Quad	0.65	0.2	1.96
Quad	0.8	0.2	-2.28
Quad	0.5	0.2	1.99
Sextupole	0.3	0.2	1.26
Sextupole	0.3	0.2	-1.26
Quad	0.5	0.2	1.99
Quad	0.8	0.2	-2.28
Quad	0.65	0.2	1.96
Dipole	30 degrees	0.1	1.20
Quad	0.5	0.15	2.16
Quad	0.8	0.15	-2.33
Quad	0.65	0.15	2.25

Calculated using COSY Infinity (W. Wan)

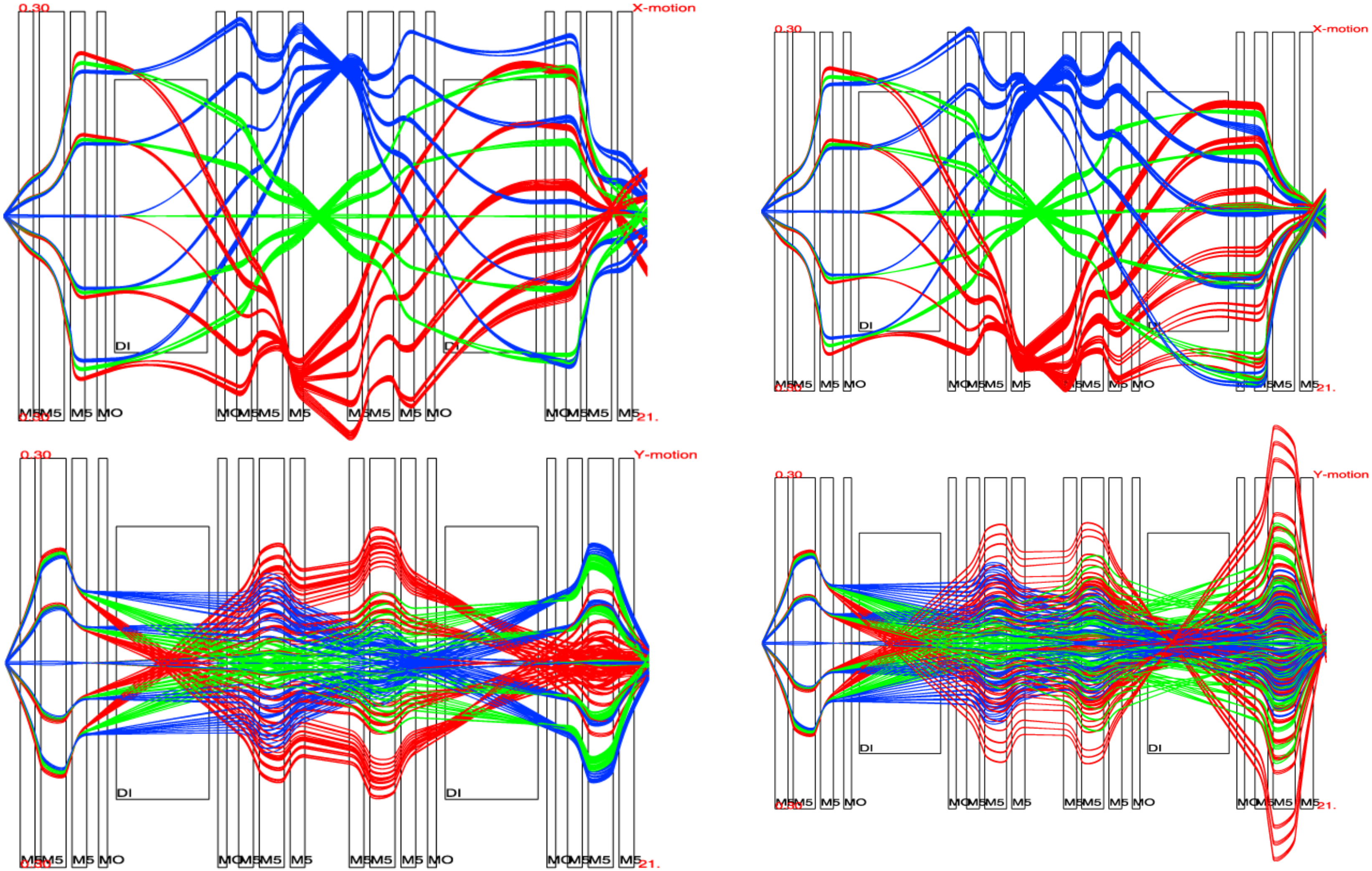
→**Further calculation underway to increase momentum dispersion at beam dump**

→ **Multipole coils at the locations of quadrupole**

- angular acceptances: 80 mrad, 100 mrad
- momentum acceptance : 18 % for r=20 cm, 9 % for r= 15 cm
- length: 24.8 m

Beam optics of the main separator

$\Delta p/p = \pm 5$ %



Without correction

With sextupole+octupole correction

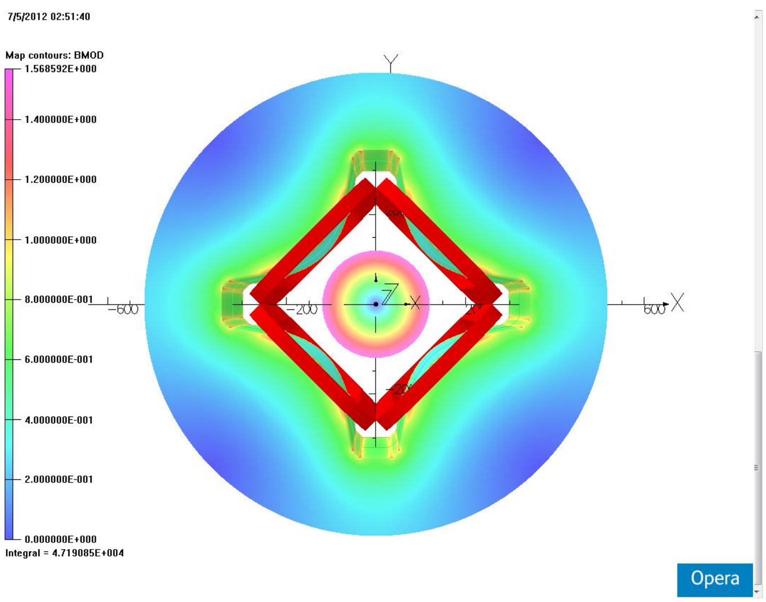
Plans for the next fiscal year (July ’12 – April ‘13)

- Finalizing the IF separator configuration with more optics calculations (a design review planned in the end of the year)
- Start prototyping of superferric and high-Tc SC magnet.
  → collaboration with BNL
- Design and test on a single layer and multi-layer graphite targets
- Radiation transport and shielding calculations especially in the pre-separator area (MCNPX, PHITS,…)
- Study on the remote handling system.
- RF deflector design study for beam purification.

Prototyping of a sc-quadrupole magnet

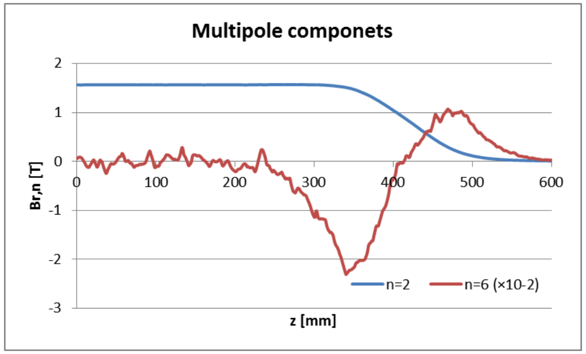
Design parameters

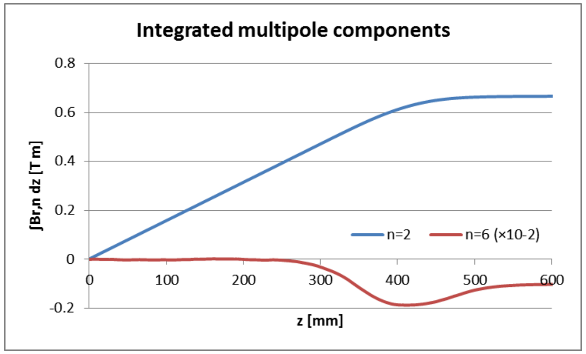
- Pole tip radius: 170 mm
- Length of iron: 740 mm
- Outer radius of yoke: 480 mm
- Field gradient: 14 T/m



Multipole components at r=12 cm

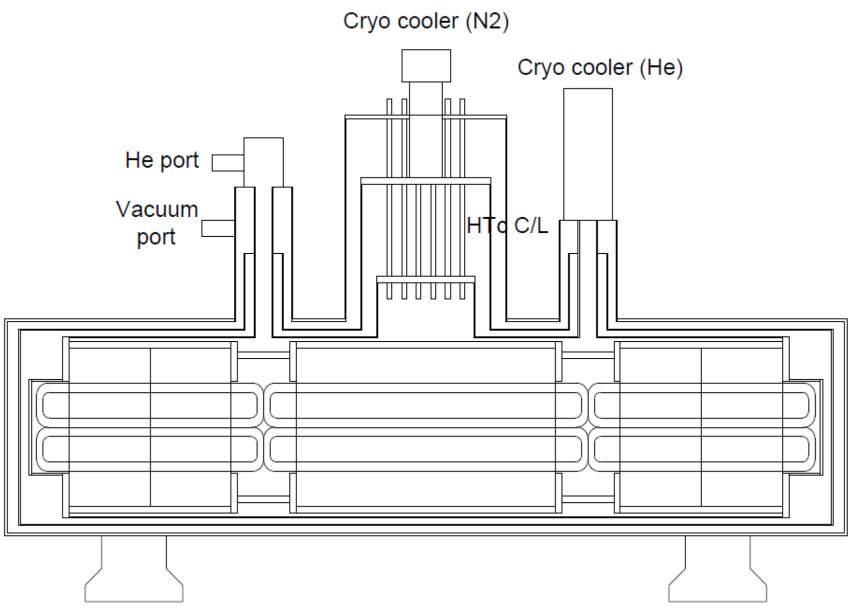
- $\int B_{hex}/B_{quad}$: ~1/1000





Test cryostat for prototype quadrupoles

- Two small cryo-coolers?
- Multipole coils placed on the cold bore tube
- High Tc SC-magnet test.

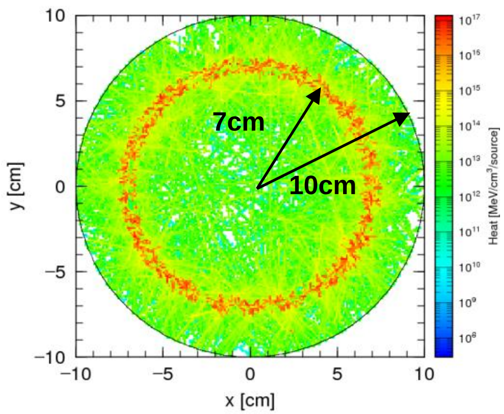


Schematic view of the cryostat with prototype quadrupole magnets inside

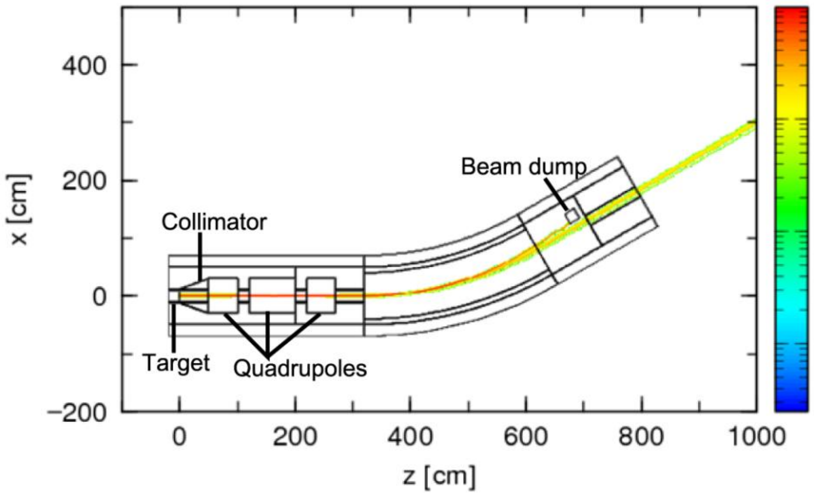
Estimation of heat loads on the cryostat

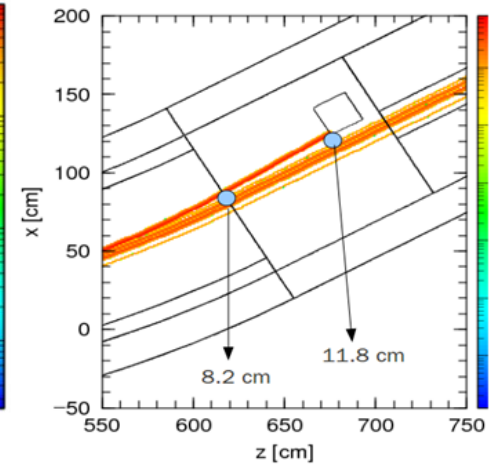
Part	Heat load (He, 4K)	Heat load (N2, 80K)
Shield radiation	0.30 W	9.4 W
Support link	0.64 W	16.0 W
He port (vent)	0.77 W	7.8 W
Current lead	0.75 W	45.0 W
Total	2.46 W	78.2 W

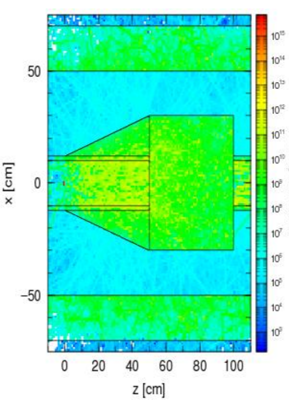
Preliminary heat deposit calculation using PHITS



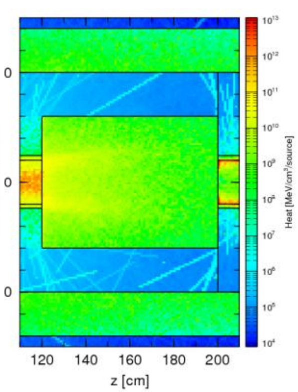
Heat at rotating target (^{12}C)



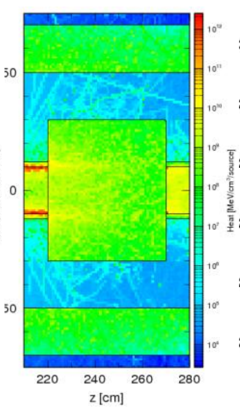




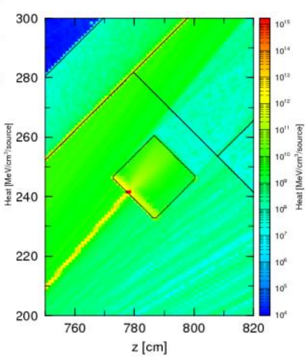
Colli. & Q1



Q2



Q3

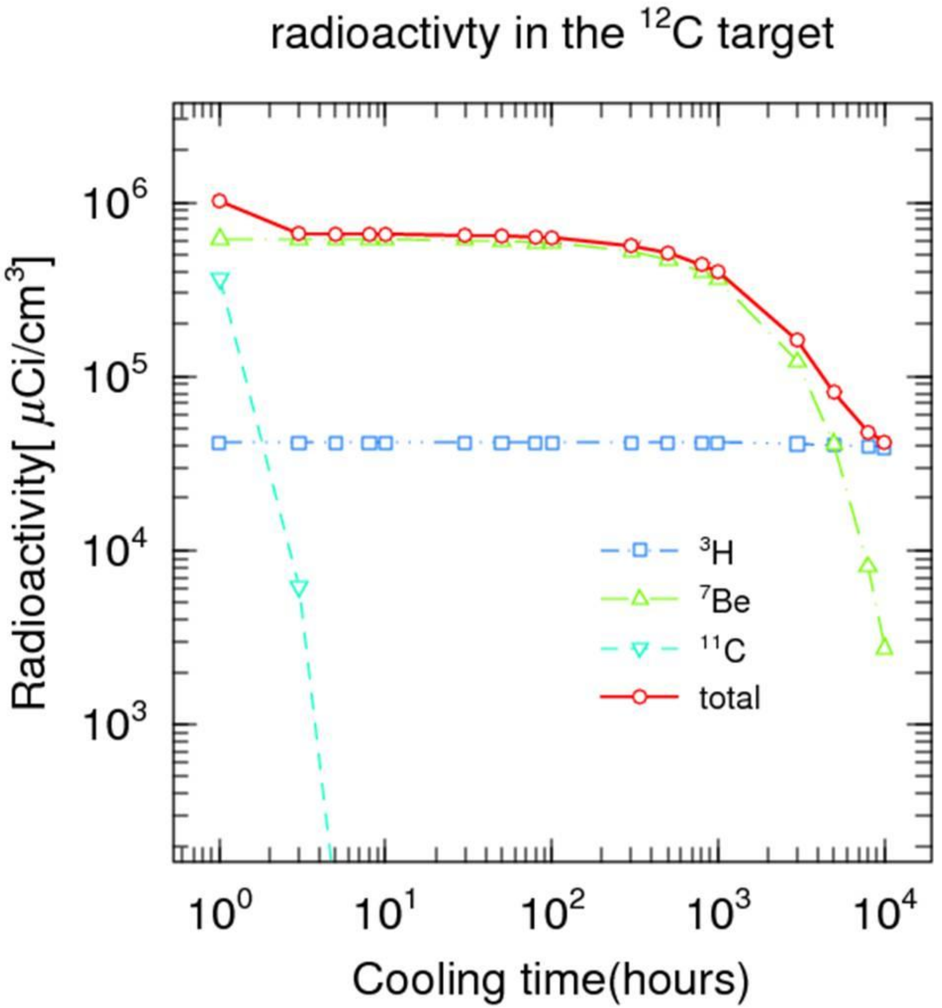


Beam dump

Elements	$Heat_{max}$ [J/cm^3]	Dose rate [Gy/yr]*
Coll. & Q1	0.37	$2.06*10^8$
Q2	0.05	$2.06*10^6$
Q3	0.02	$2.06*10^6$
Beam dump	277.15	$5.57*10^{12}$

dose rate calculated using 400MeV/u ^{238}U beam at 400 kW and ^9Be target

Calculation of radioactivity decay for ^{12}C target

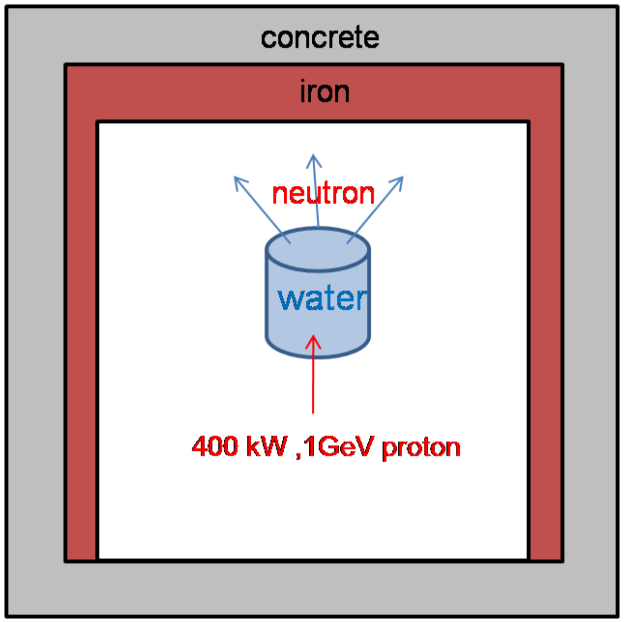


Used codes:
PHITS → DCHAIN-SP

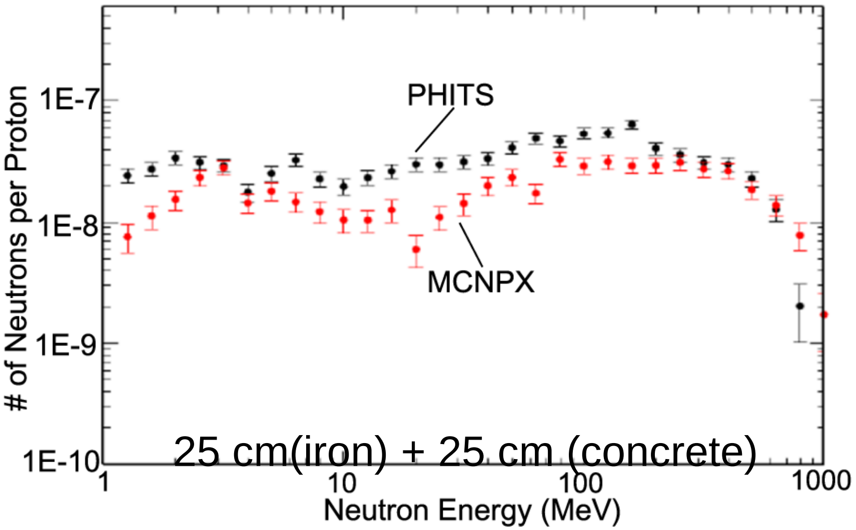
- Assuming 30 days of irradiation with U beam at 400 kW.
- Decay during the irradiation period of 30 days is not properly considered.

Radiation shielding calculation in the beam dump area

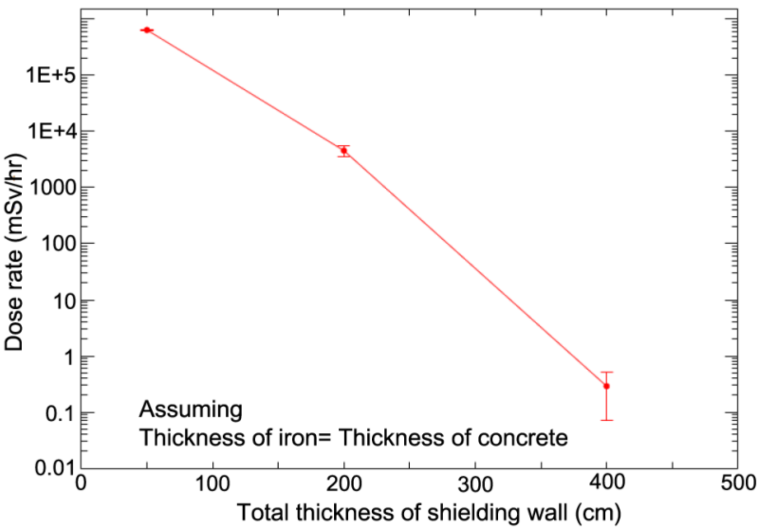
Simplified geometry for shielding calculation near beam dump



Comparison of neutron energy spectrum in forward direction

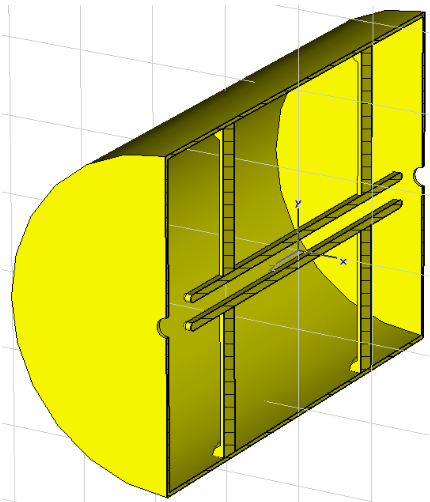


Dose rate versus shielding wall thickness

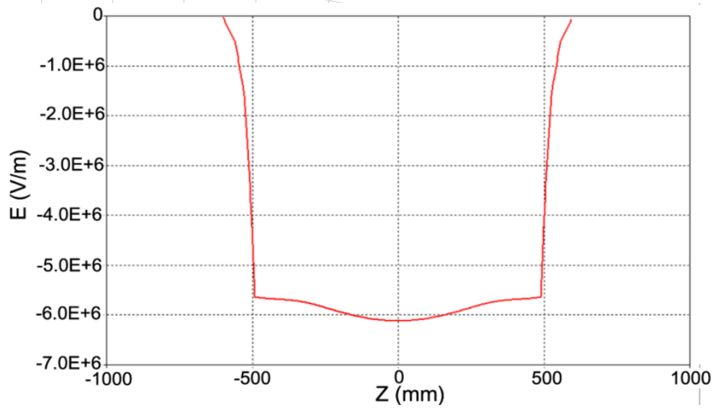


Design of an rf deflector to purify rare isotope beams

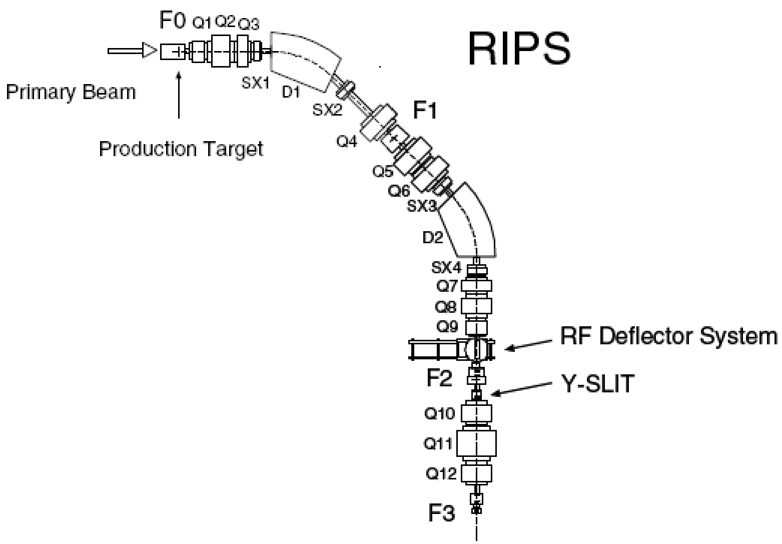
A filtering option to purify proton-rich rare isotope beams → rf deflector

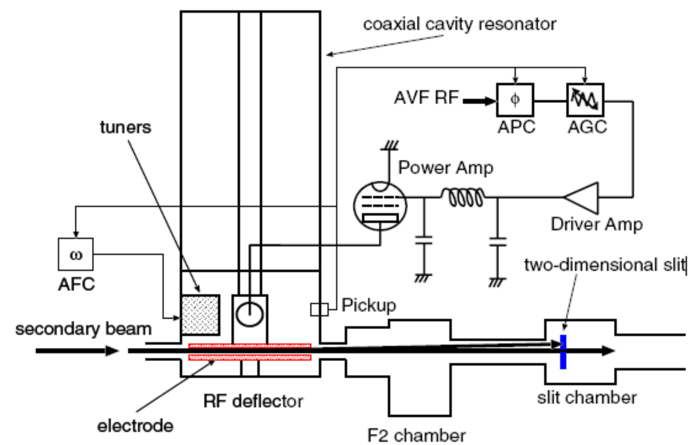


Q=11400
V=100 kV at 7.1 kW



3D modeling and E-field distribution calculated along the electrodes





Current Status

- **Beam optics design** will be performed with more manpower.

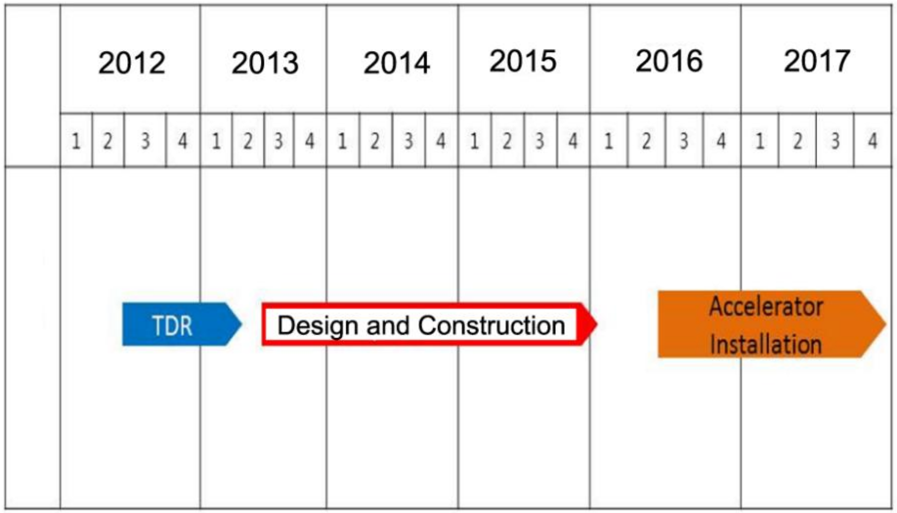
→ Possibility of a branched beam line in the pre-separator area is to be studied.

- **Pre-separator design including the target and beam dump** is the main focus.

- **Radiation shielding** and **radiation transport** calculations are carried out using different codes.

- **Preparations for prototyping** of superferric quadrupole magnet and high-Tc coil magnet are underway.

Schedule and Budget



Budget

~420 M$ (accelerator and experimental systems excluding staff salary and civil construction)