Collimation System Design and Dynamic Vacuum Simulation for the BRing

Reporter: Peng Li

Email: lipeng@impcas.ac.cn

Institute of Modern Physics, Chinese Academy of Science

61 th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High Brightness Hadron Beams, Daejeon, Korea

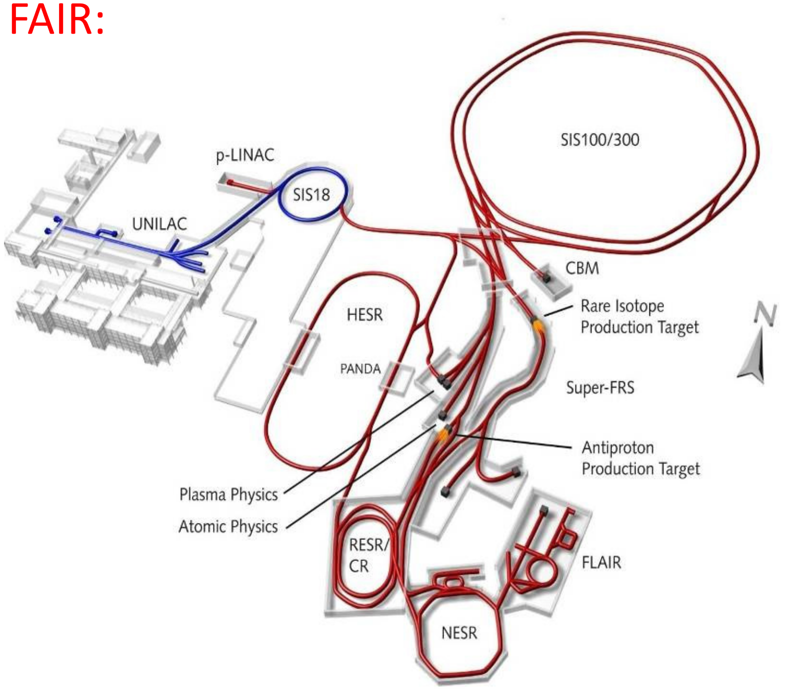
Outline

1. Introduction
2. Collimation system design
3. Dynamic vacuum simulation
4. Desorption measurement experiment
5. Challenge, future studies, Conclusion

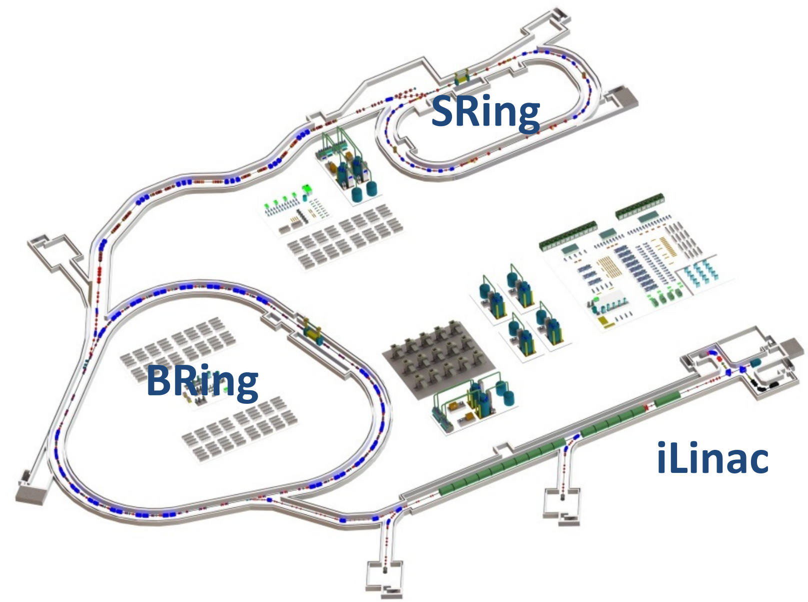
1. Introduction

Accelerator development goal: High Energy and High Intensity

FAIR:



HIAF:



■**Radioactive beam program:**

Intensity: 5*10^11 uranium ions per second.

Energy: 400 to 2700 MeV/u

■**Plasma physics**

Intensity: 1*10^11~5*10^11 uranium ions in a short bunch (50~100 ns).

Energy: 400 to 1000 MeV/u

■**Nuclear Physics, High energy and density physics, Nuclear astrophysics, Atomic physics**

Provide:

Ion	Energy (GeV/u)	Intensity (ppp)
18O6+	2.6	6*10^11
78Kr19+	1.7	7.5*10^10
238U35+	0.8	2*10^11

1. Introduction

Beam Intensity limited by space charge (apart from other instabilities)

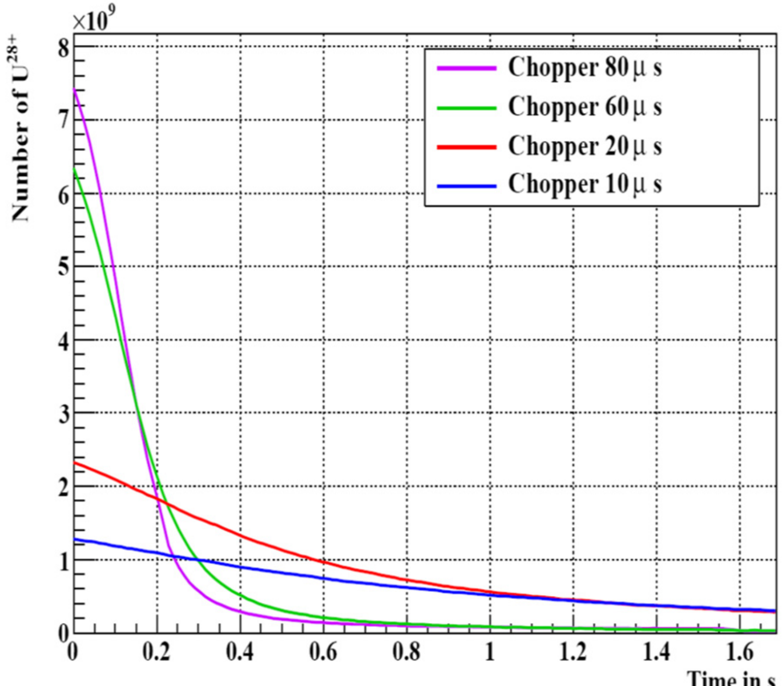
Maximum beam intensity:

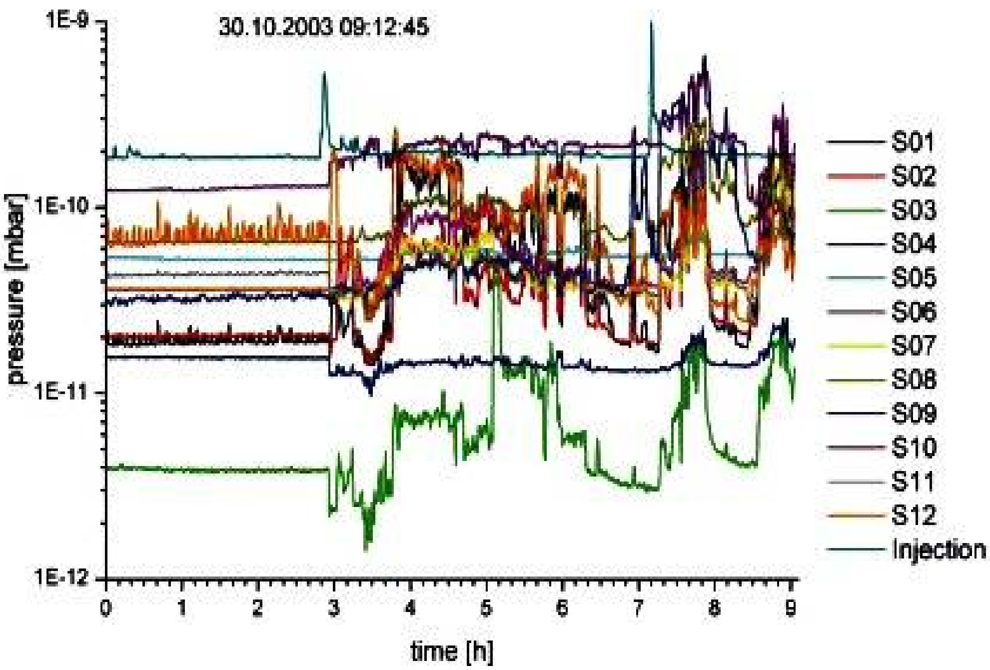
$$I_{max} \propto \frac{A}{q^2}$$

Adopt **intermediate charge states** can increase beam intensity.

In SIS18, only 3~4*10^9 U28+ ions can be accelerated to the final energy.

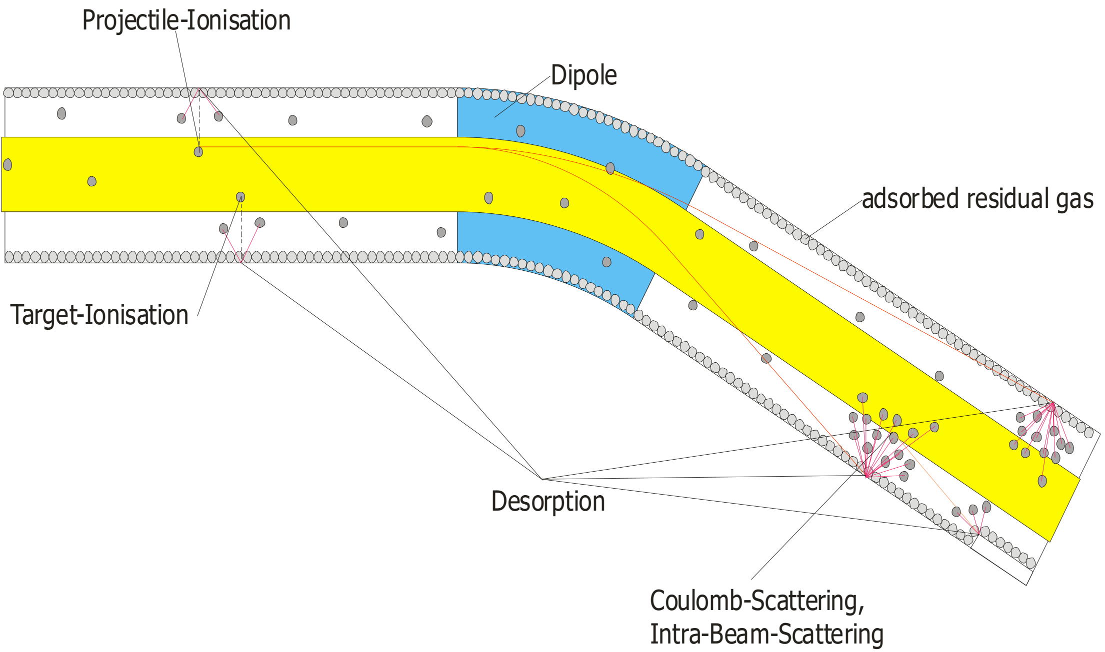
The beam was lost quickly.





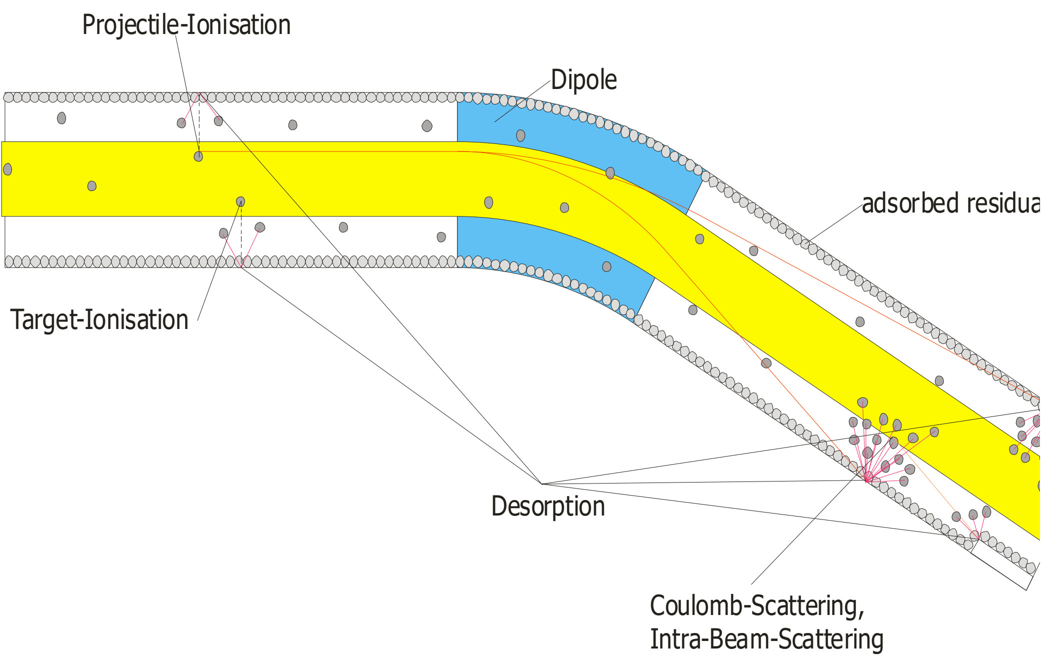
1. Introduction

Beam Loss Mechanism:

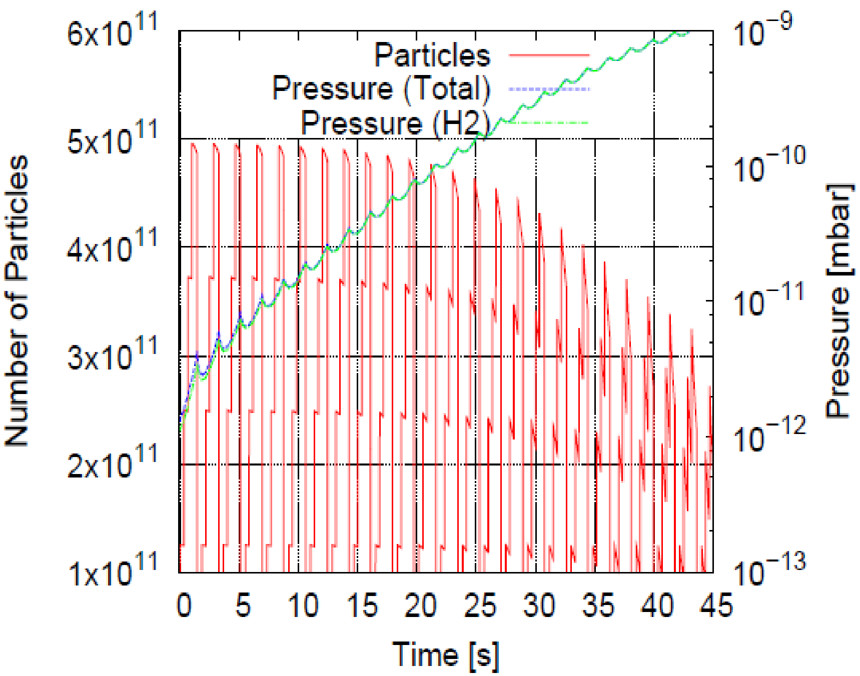


1. Introduction

Beam Loss Mechanism:

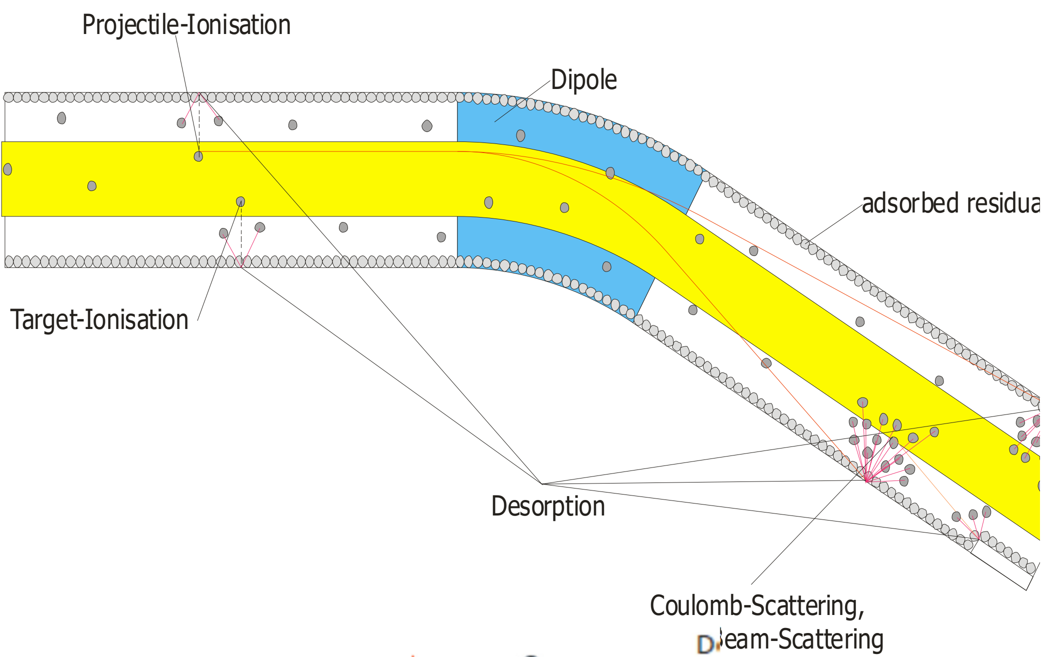


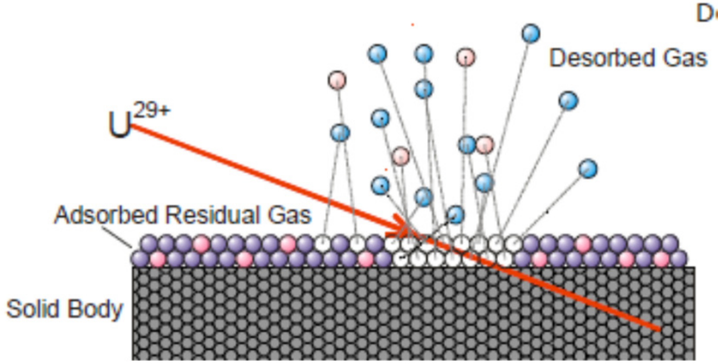
SIS100



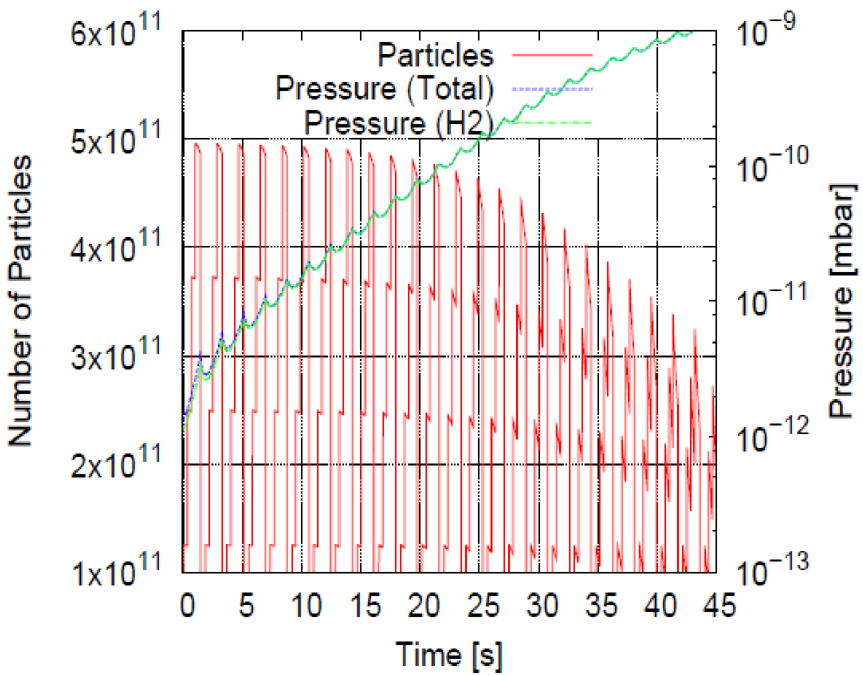
1. Introduction

Beam Loss Mechanism:





SIS100



Main Issue: Vacuum Stabilization

1. Introduction

1. Short cycle time and short sequences

   SIS18: 10 T/s - SIS100: 4 T/s

   (high pulse power > new network connection)

2. Localization of losses and control of

   desorption gases Collimator

   SIS18/SIS100: Desorption Scrapers

   SIS100: Optimized lattice structure

3. Low-desorption rate materials

   Desorption rate and ERDA measurements

   Minimization of systematic (initial) losses

4. High pumping power, optimized XHV spectrum

   SIS18: NEG coating (local and distributed)

   SIS100: Actively cooled magnet chambers 4.5 K

1. Introduction

1.Short cycle time and short sequences

SIS18: 10 T/s - SIS100: 4 T/s

(high pulse power > new network connection)

2. Localization of losses and control of desorption gases Collimator

SIS18/SIS100: Desorption Scrapers

SIS100: Optimized lattice structure

3. Low-desorption rate materials

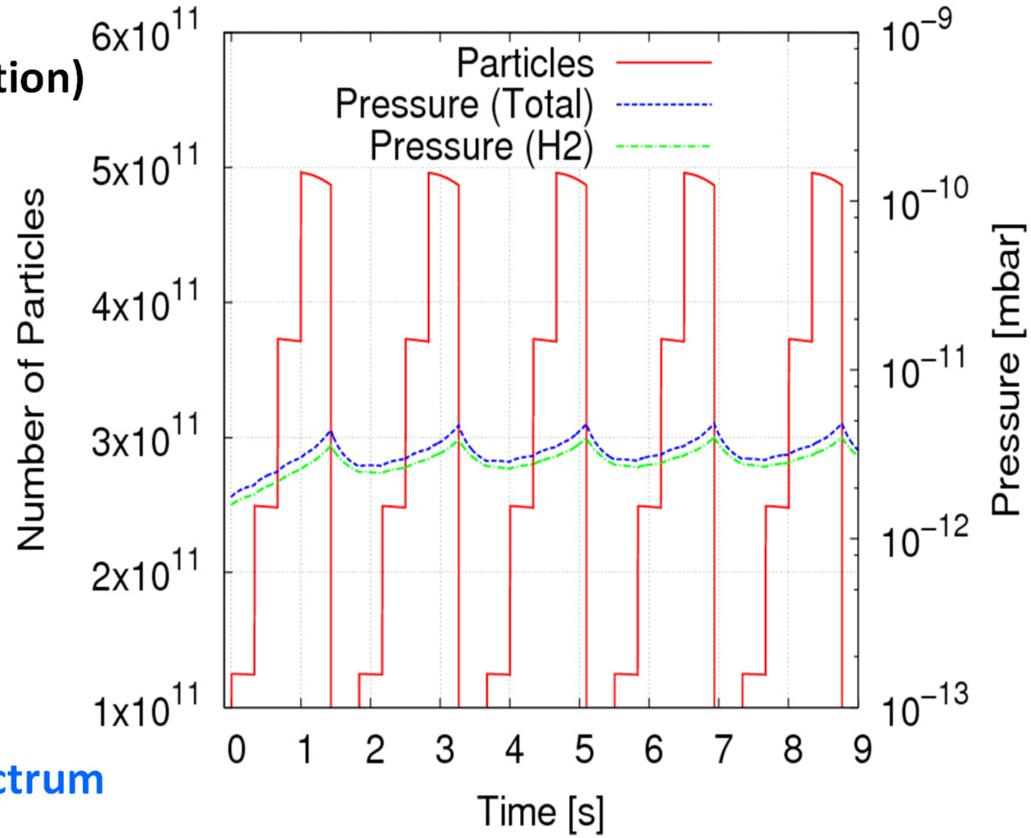
Desorption rate and ERDA measurements

Minimization of systematic (initial) losses

4. High pumping power, optimized XHV spectrum

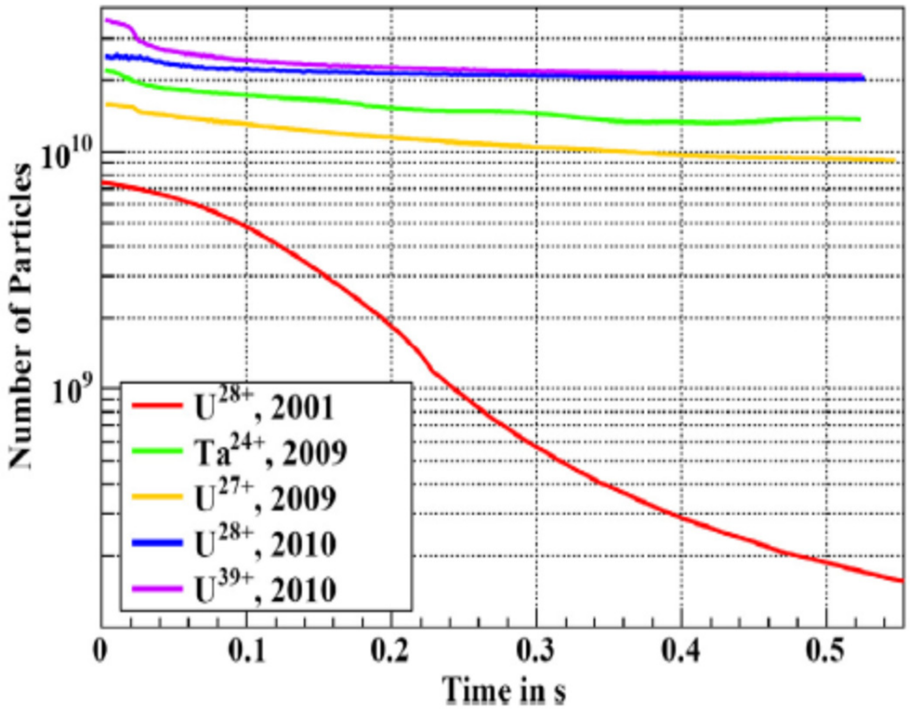
SIS18: NEG coating (local and distributed)

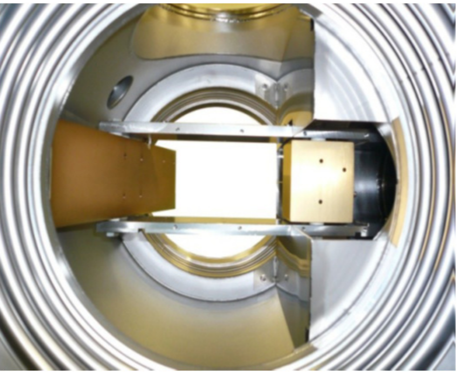
SIS100: Actively cooled magnet chambers 4.5 K

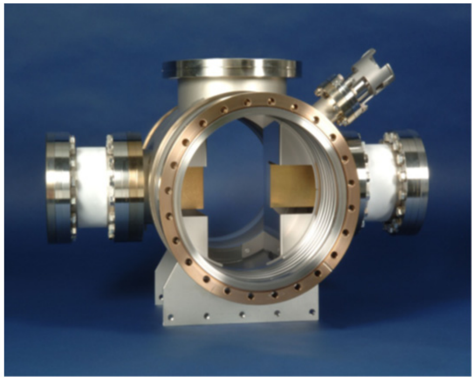


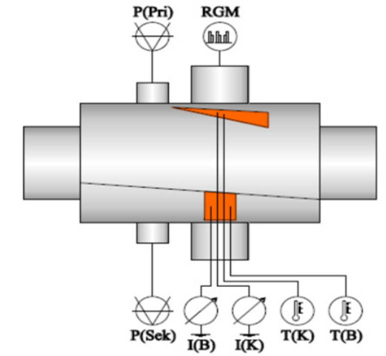
1. Introduction

SIS18 Collimators with UHV upgrade









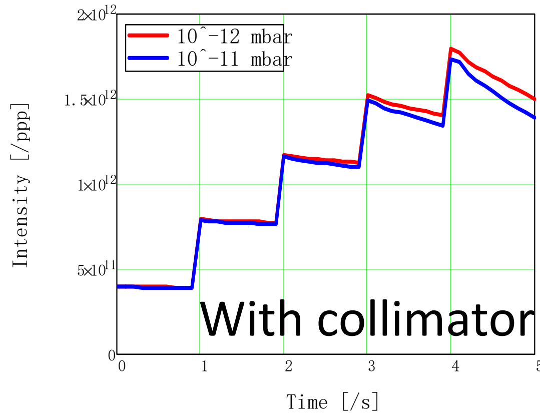
1. Introduction

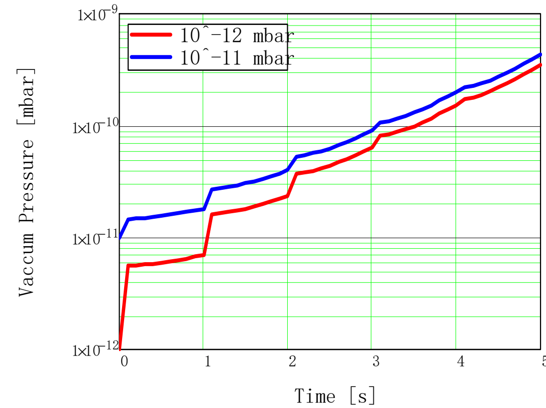
HIAF Project:

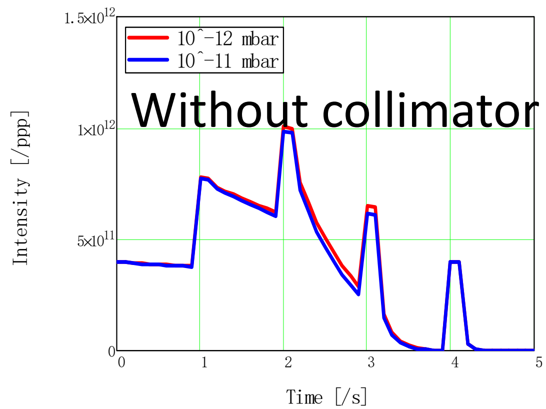
Ion	Energy (GeV/u)	Intensity (ppp)
18O6+	2.6	6*10^11
78Kr19+	1.7	7.5*10^10
238U35+	0.8	2*10^11

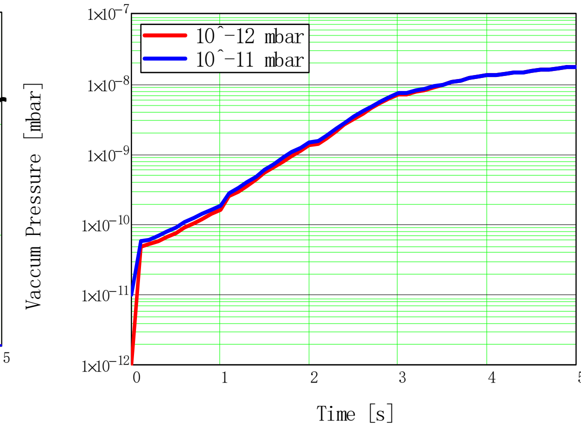
BRing:

Static pressure: <10^-11 mbar





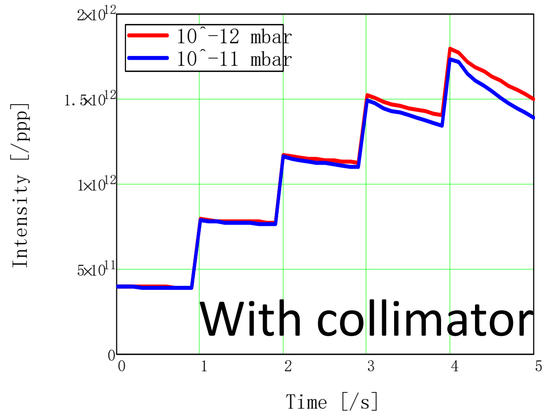


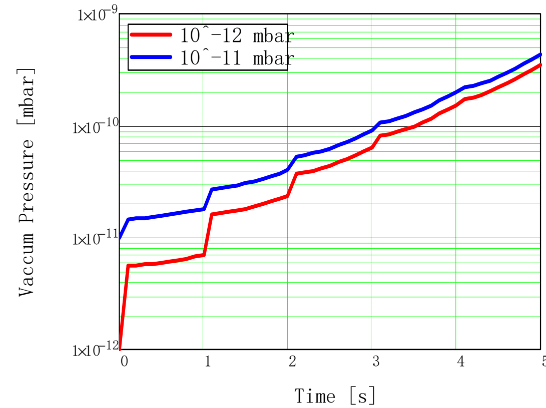


1. Introduction

HIAF Project:

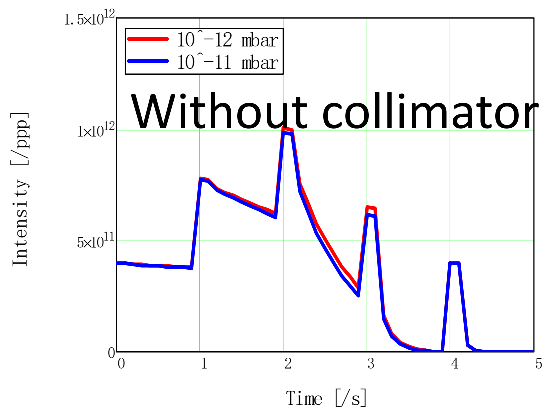
Ion	Energy (GeV/u)	Intensity (ppp)
18O6+	2.6	6*10^11
78Kr19+	1.7	7.5*10^10
238U35+	0.8	2*10^11

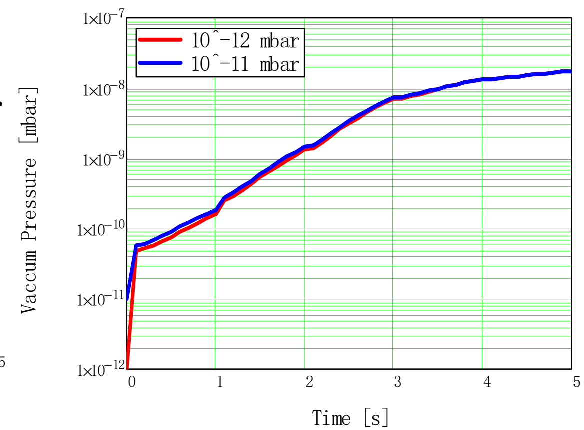




BRing:

Static pressure: <10^-11 mbar





We need collimation system to stabilize the vacuum pressure to get high intensity beam

1. Introduction

Steps:

1. Calculate the beam loss distribution in the ring. -Position

2. Put a device at the beam loss position to decrease the desorption rate. – Collimator.

3. We can't put the collimator at every beam loss position– Collimation efficiency.

4. In order to get a high efficiency, Lattice design is important. -Optimize Lattice.

5. Simulate the vacuum pressure evolution with the desorption rate -Dynamic vacuum simulation

6. Design the collimator chamber: material, length, geometry, coating. -Prototype.

7. Measure the prototype: pumping speed, temperature, pressure evolution. –Test

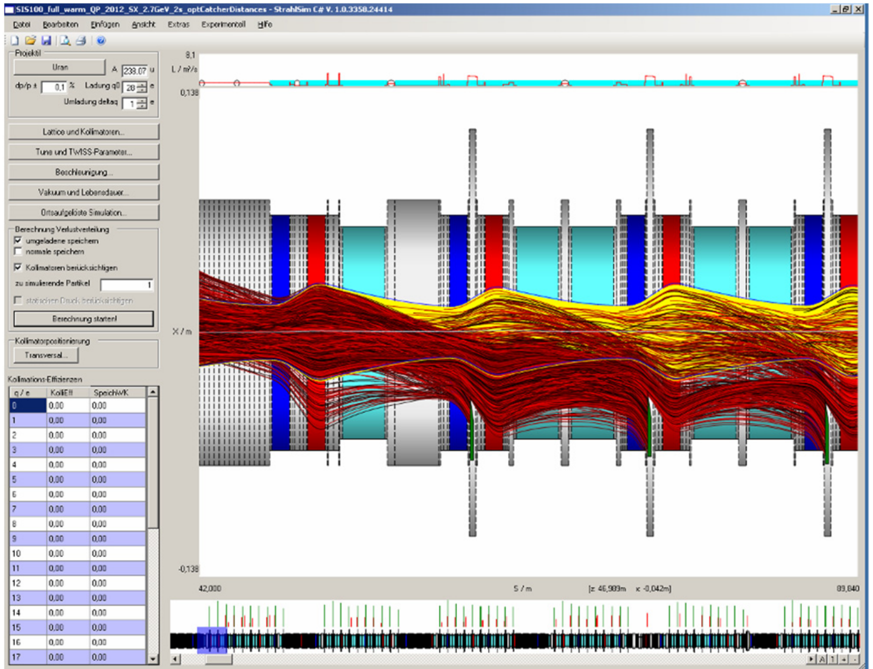
8. Install the collimator into the ring to stabilize the vacuum system -Finish

Simulation Code + **Mechanical Design** + **Team**

1. Introduction

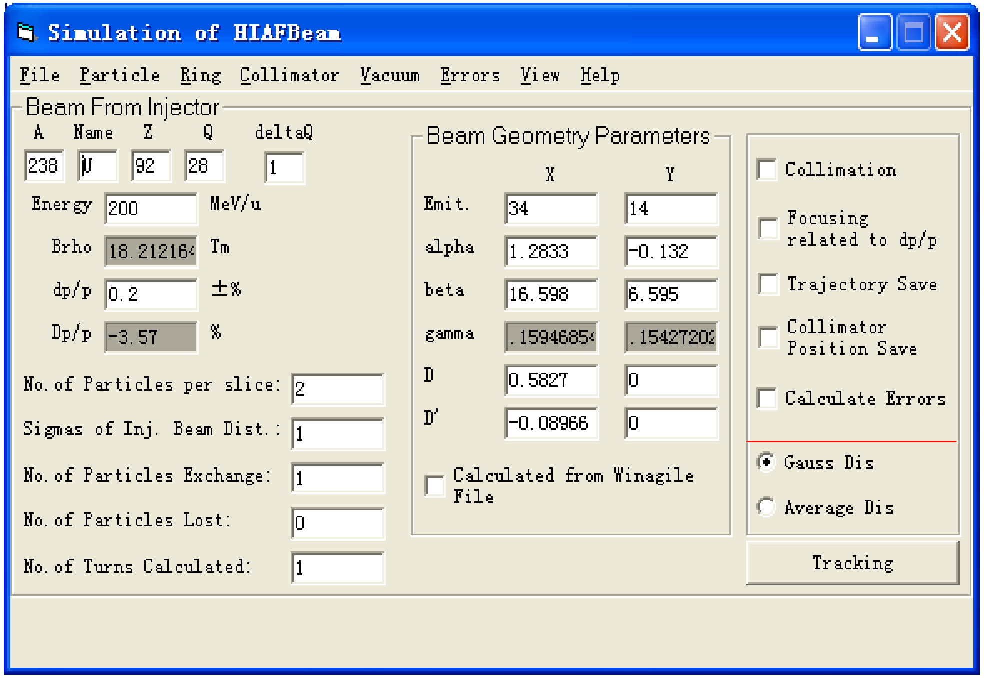
Simulation Code:

GSI --StrahSim



- beam loss distribution calculation
- collimation efficiency calculation
- dynamic vacuum profile simulation
- Long term vacuum pressure evolution calculation

IMP --ColBeam

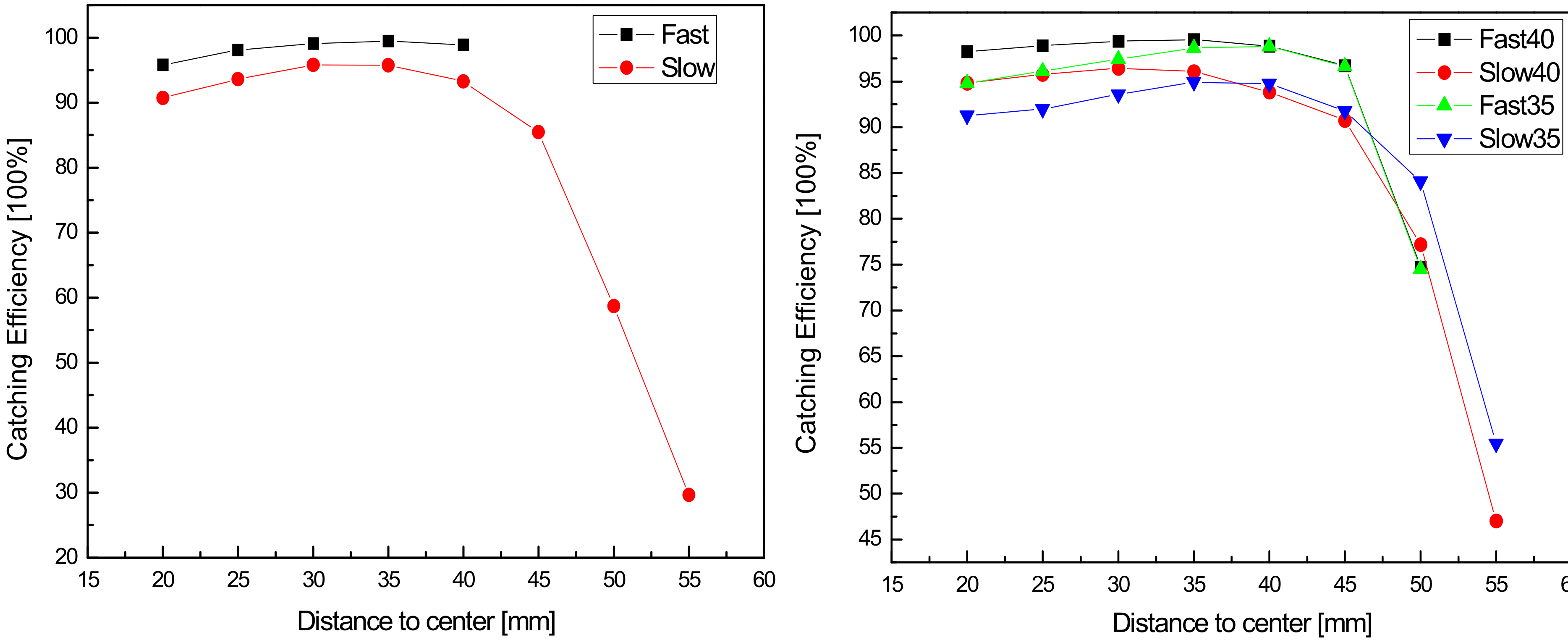


- beam loss distribution calculation
- collimation efficiency calculation
- collimation efficiency calculation under different types of errors.

1. Introduction

HIAF

Comparison between StrahlSim and My code.

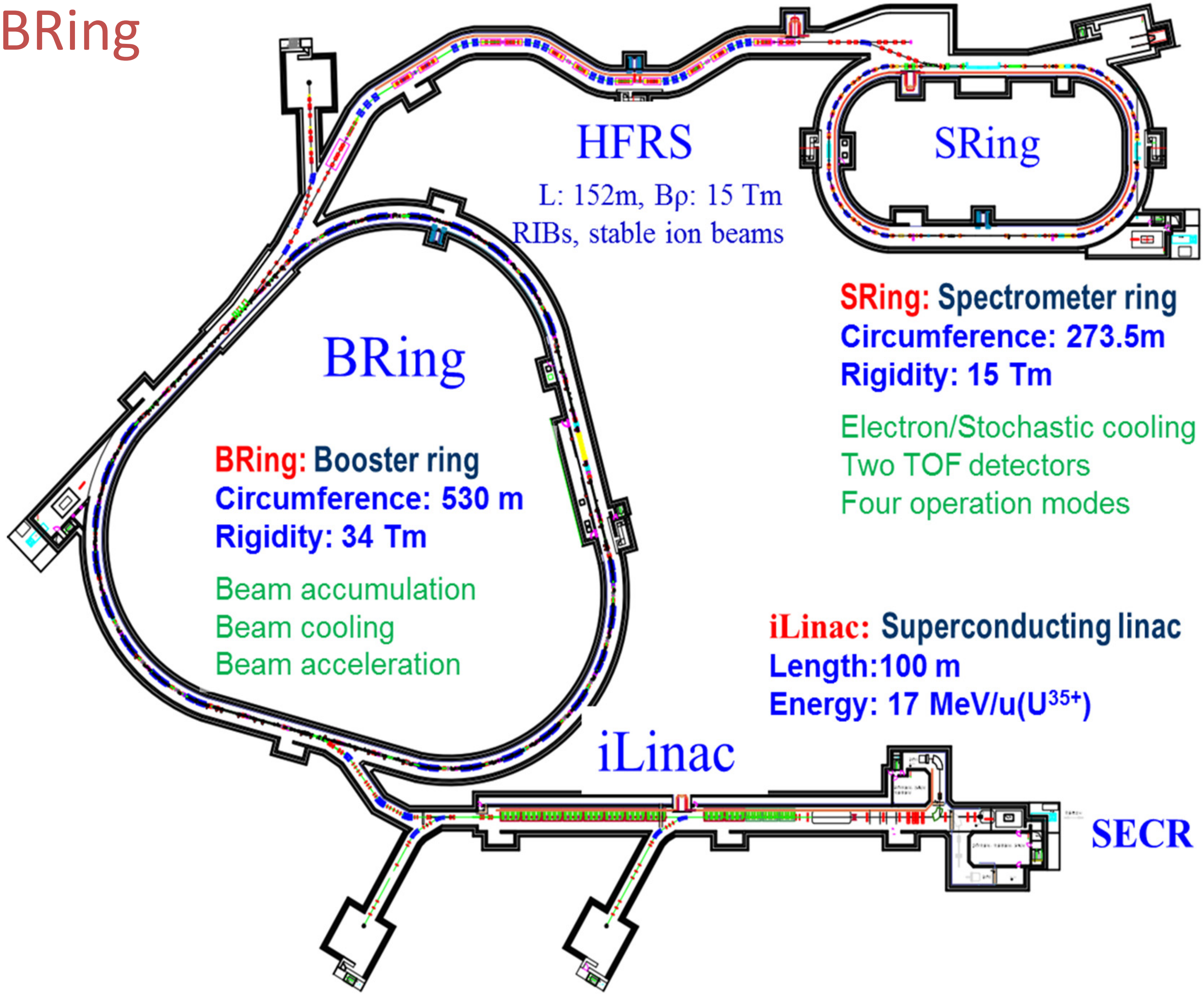


Results:

HIAF-DYSD can be used to simulate the collimation efficiency for BRing

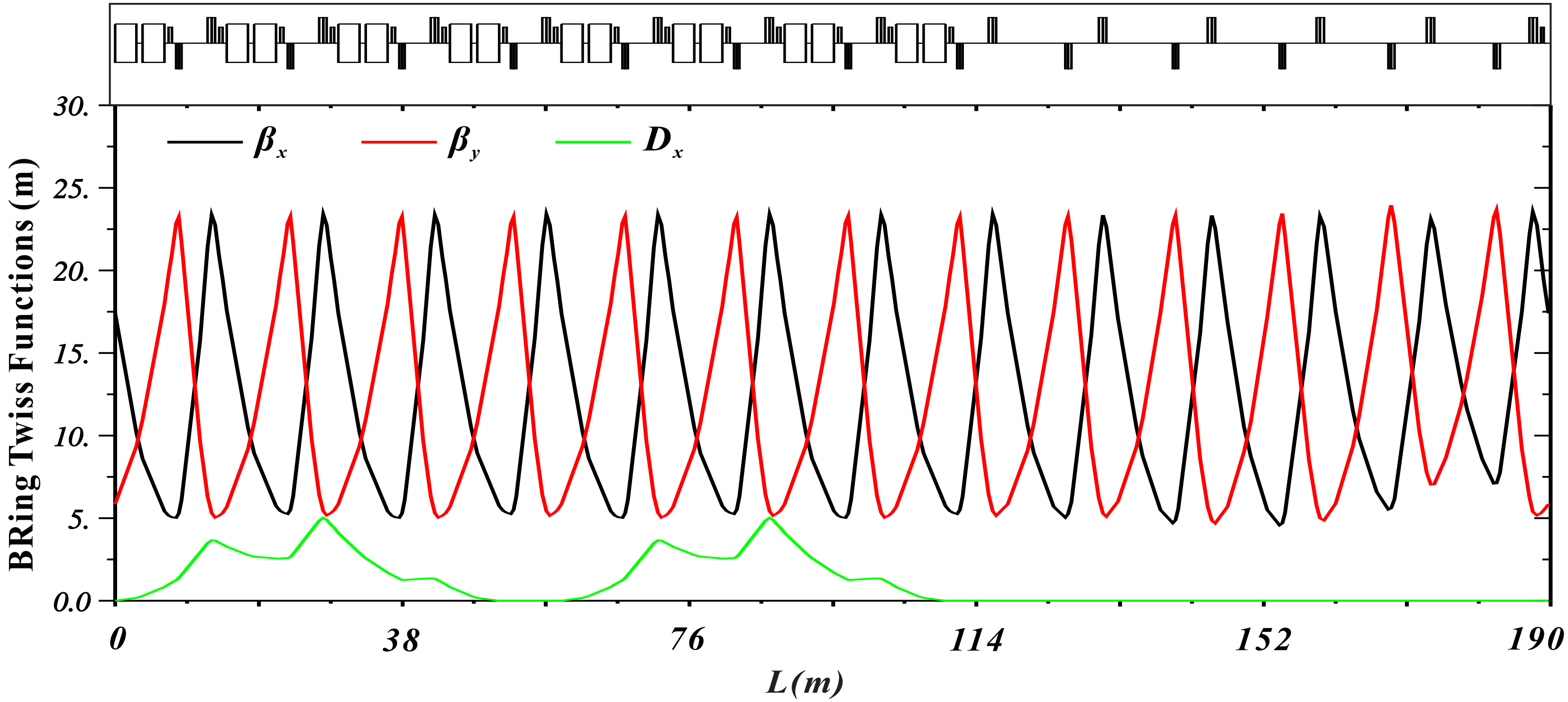
1. Introduction

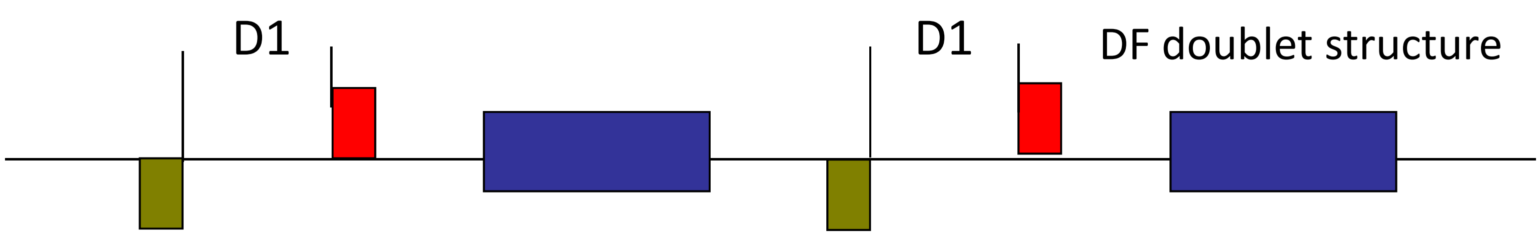
HIAF: BRing



1. Introduction

HIAF: BRing



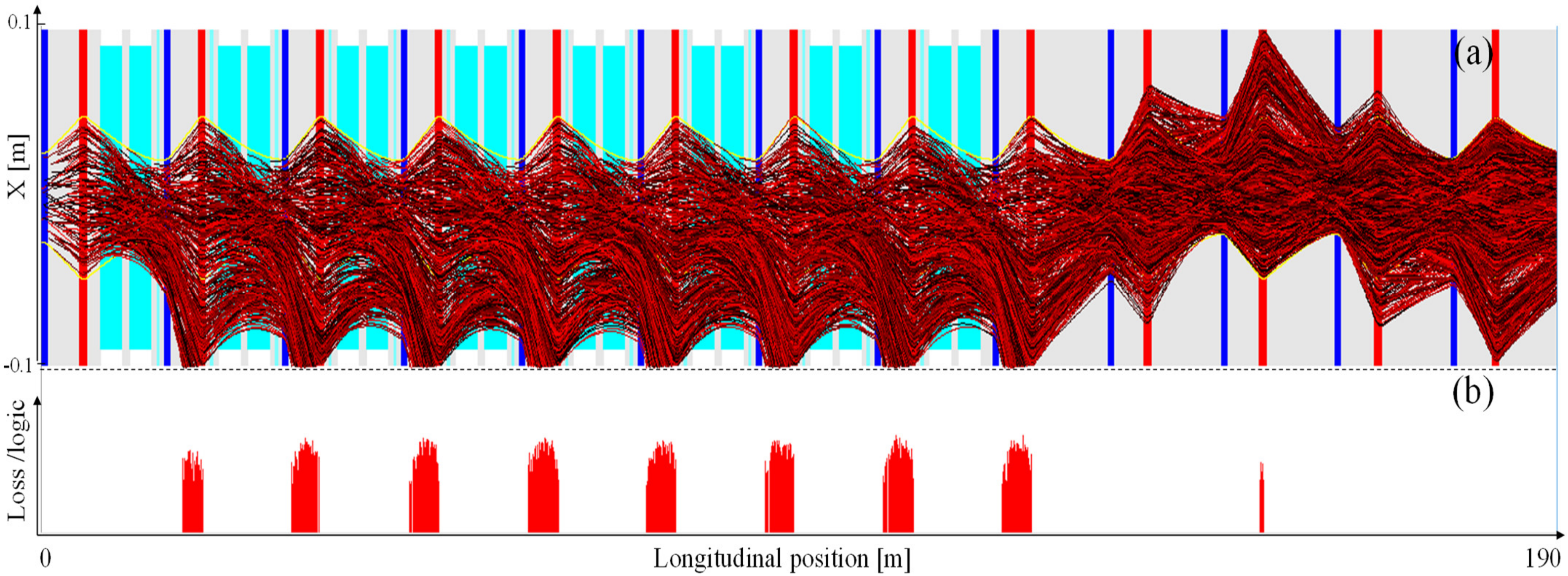


2. Collimation system design

Reference ion	$^{238}U^{35+}$
Energy (MeV)	17
Transverse Tune (Qx/Qy)	9.47/9.43
Horizontal emittance (pi mm.mrad) 5-sigma	100
Vertical emittance (pi mm.mrad) 5-sigma	60
Momentum deviation for $^{238}U^{32+}$	$\sim10^{-4}$
Charge exchanged ion (Coasting beam)	$^{238}U^{34+}$ and $^{238}U^{36+}$

$$\frac{\Delta p}{p} = \frac{q_0}{q} - 1$$

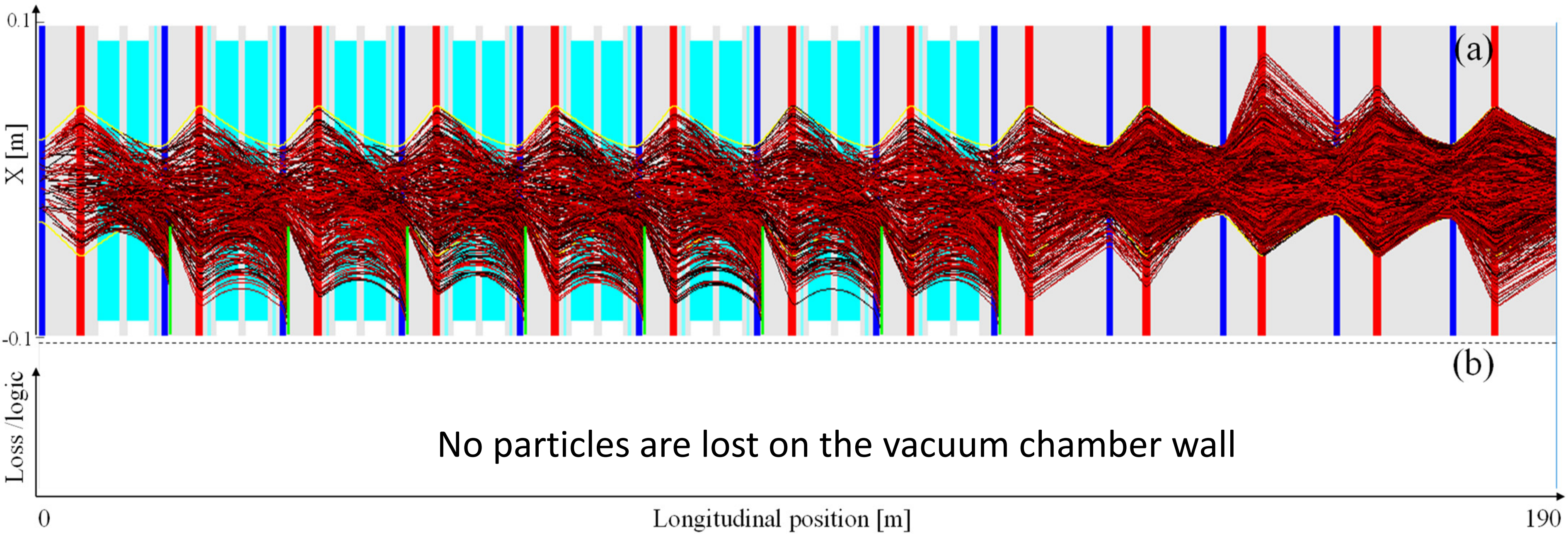
Trajectory of charge exchanged beam —U35+->U36+



2. Collimation system design

Trajectory of charge exchanged beam —U35+->U36+

With collimators



One section of threefold: 8 collimators are installed in the arc.

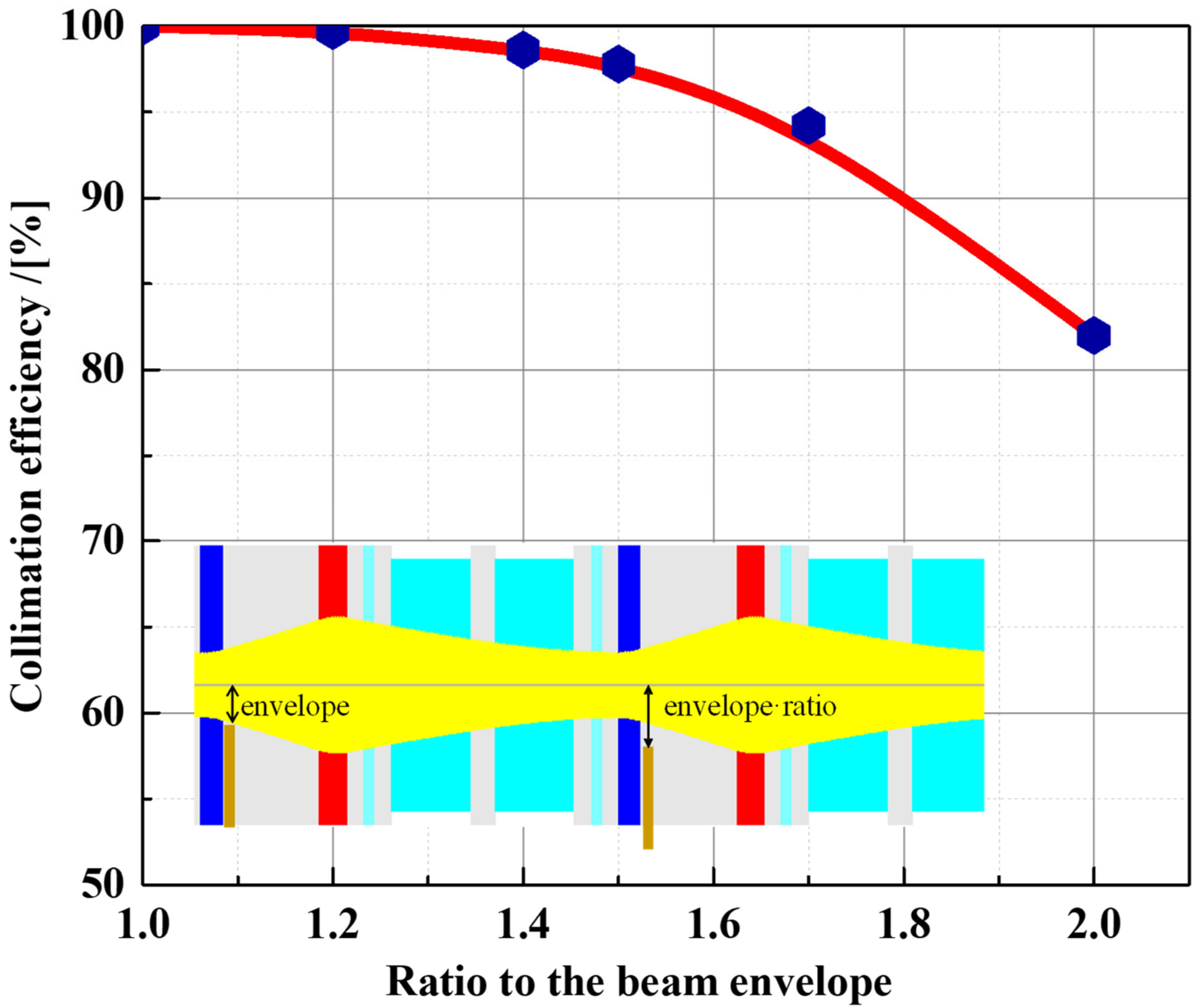
All the charge exchanged particles are lost on the collimators.

2. Collimation system design

Collimation efficiency:

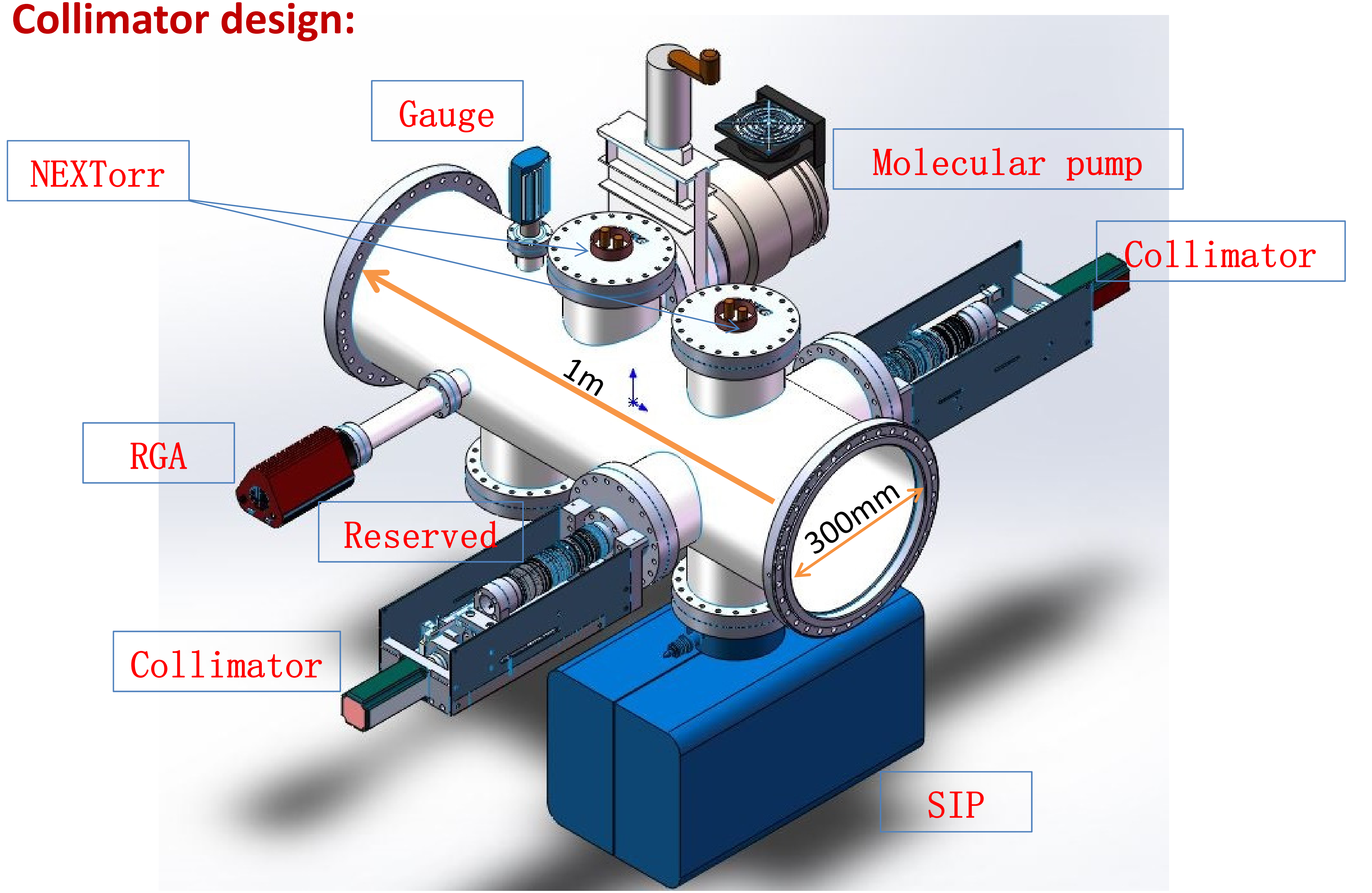
Considering the closed orbit.

$$\theta = \frac{N_c}{N_w + N_c}$$



2. Collimation system design

Collimator design:



3. Dynamic Vacuum Simulation

HIAF

Steps:

1. Calculate the beam loss distribution in the ring. -Position

2. Put a device at the beam loss position to decrease the desorption rate. – Collimator.

3. We can't put the collimator at every beam loss position– Collimation efficiency.

4. In order to get a high efficiency, Lattice design is important. -Optimize Lattice.

5. Simulate the vacuum pressure evolution with the desorption rate -Dynamic vacuum simulation

6. Design the collimator chamber: material, length, geometry, coating. -Prototype.

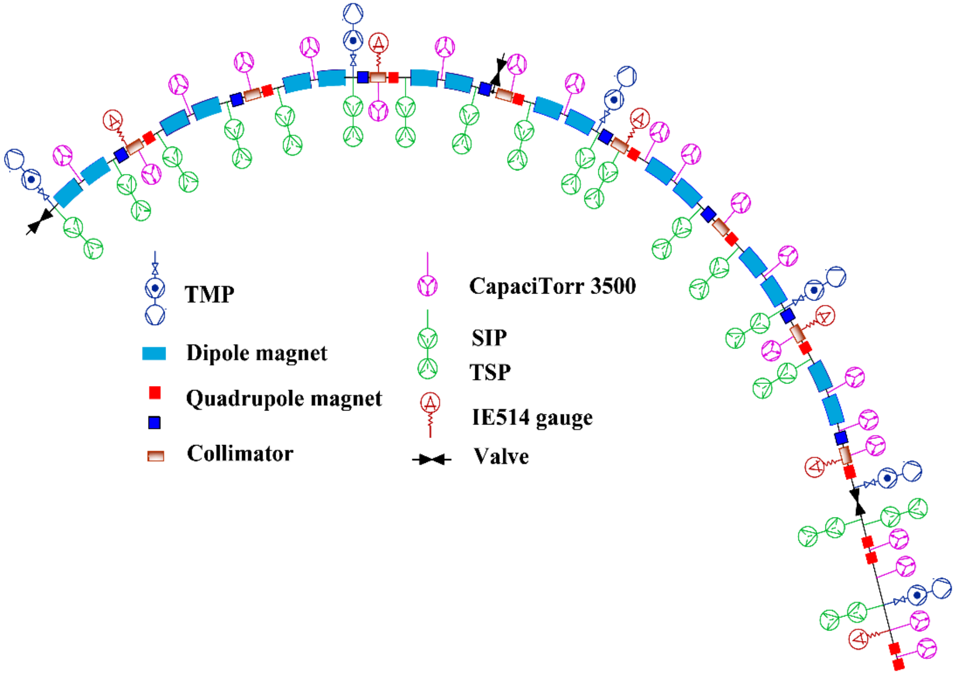
7. Measure the prototype: pumping speed, temperature, pressure evolution. –Test

8. Install the collimator into the ring to stabilize the vacuum system -Finish

Simulation Code + Mechanical Design + Team

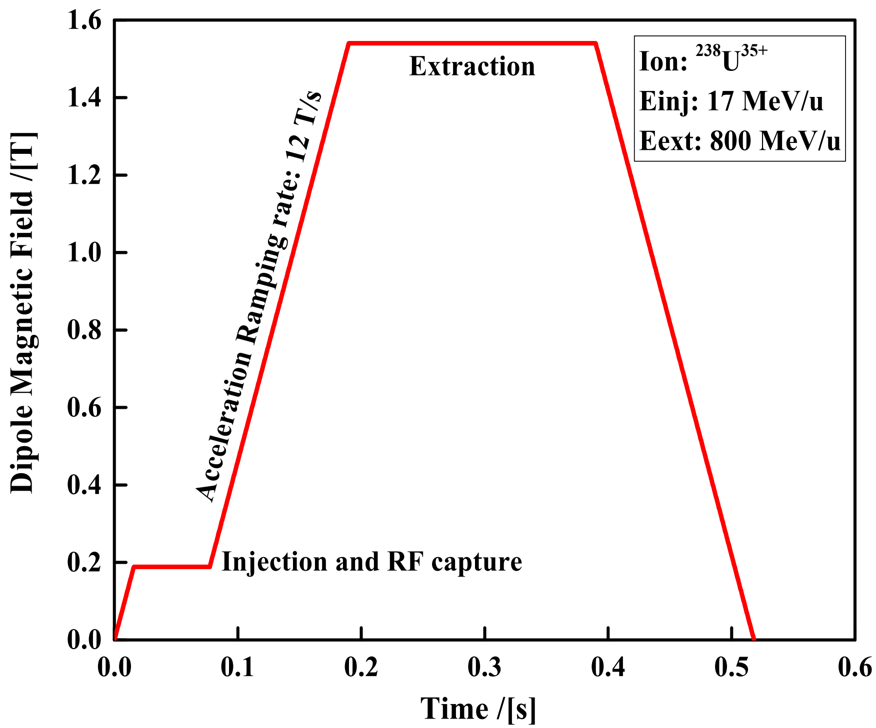
3. Dynamic Vacuum Simulation

BRing Vacuum System:



Pump Speed of NEXTorr:	3500 L/s
Pump Speed of TSP:	5000 L/s
Pump Speed of SIP:	400 L/s
Out gassing rate: 7*10^-13 mbar*l/(cm^2*s)	

BRing Operation Cycle:



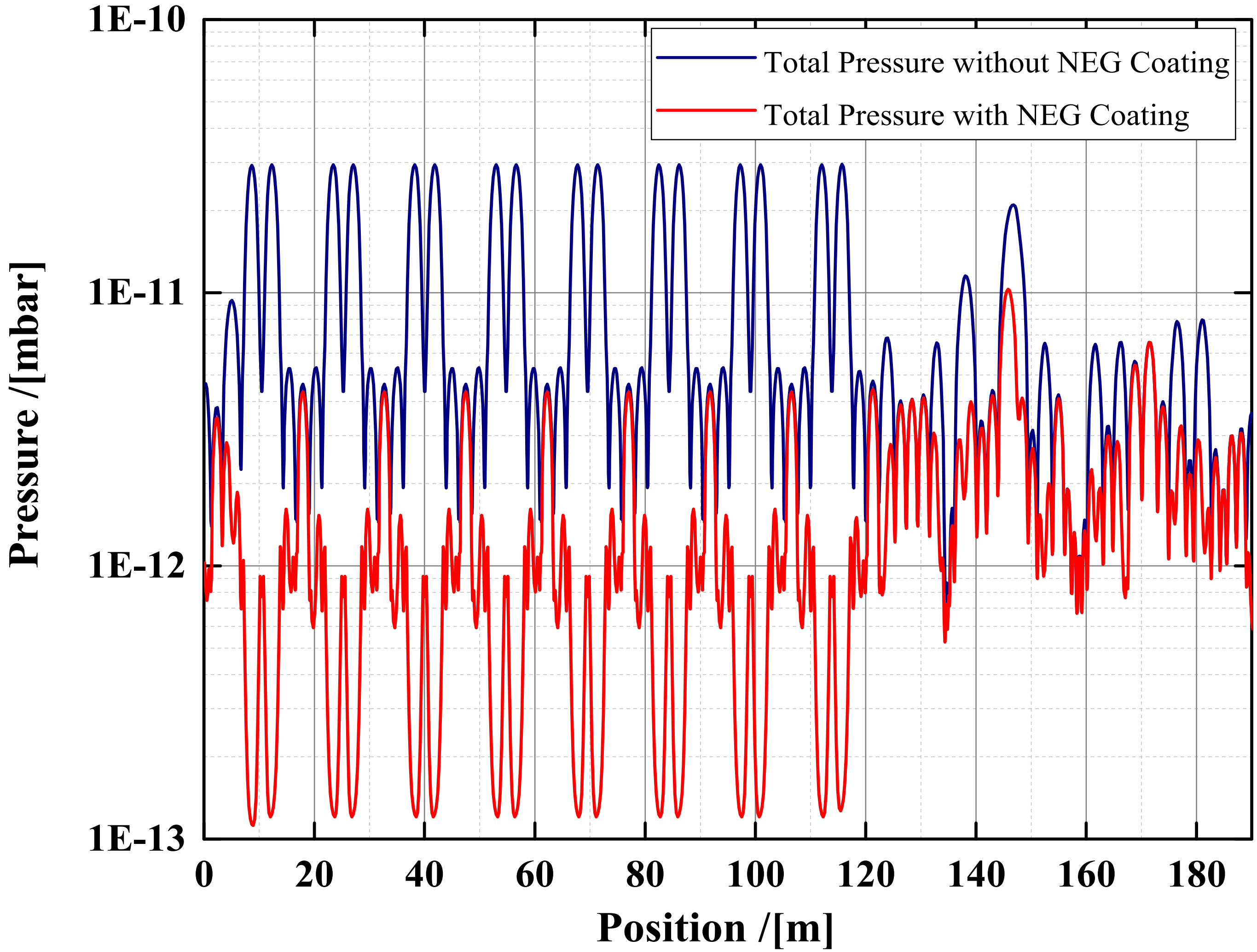
Injection: 150 Turns
Capture : 60 ms
Acceleration: Based on the Energy
Debunch: 150 ms

3. Dynamic Vacuum Simulation

GSI's simulation code: StrahlSim

The average pressure can be reached to the 9×10^{-12} mbar without NEG coating

The average pressure will be 2.1×10^{-12} mbar when the NEG coating.

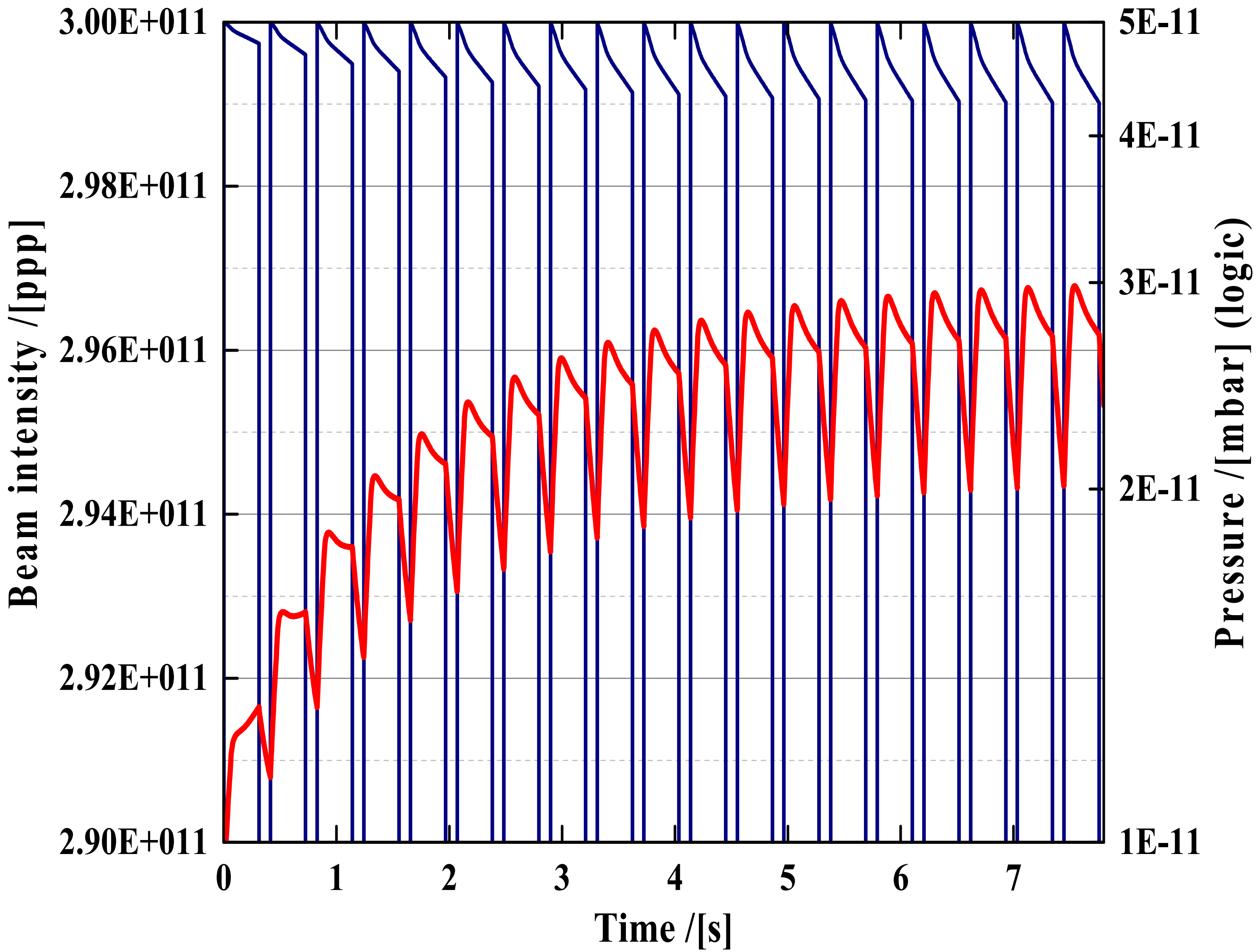


3. Dynamic Vacuum Simulation

HIAF

Injection beam intensity: 3*10E11

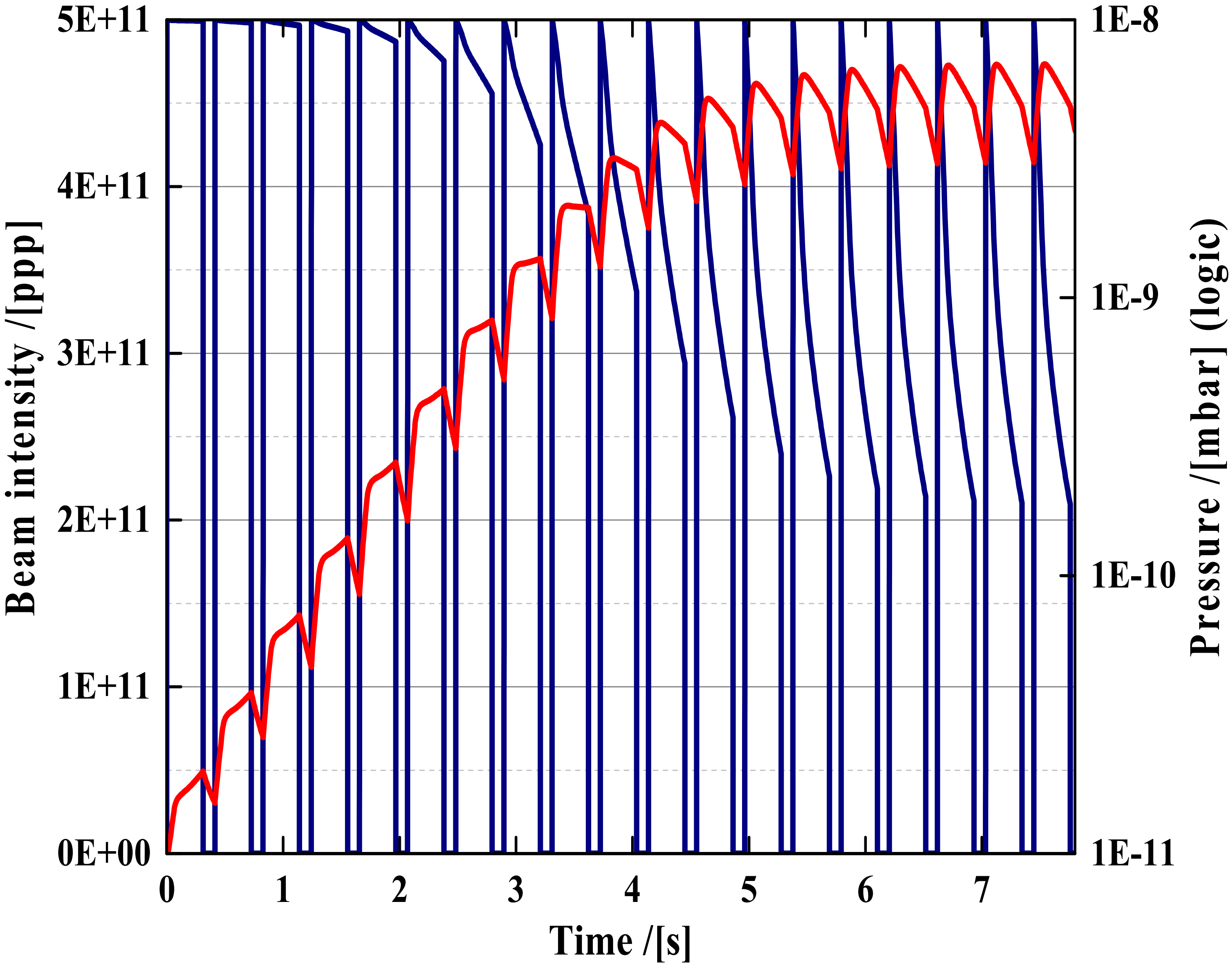
Desorption rate: 25500 Molecules/ion



3. Dynamic Vacuum Simulation

Injection beam intensity: 5*10E11

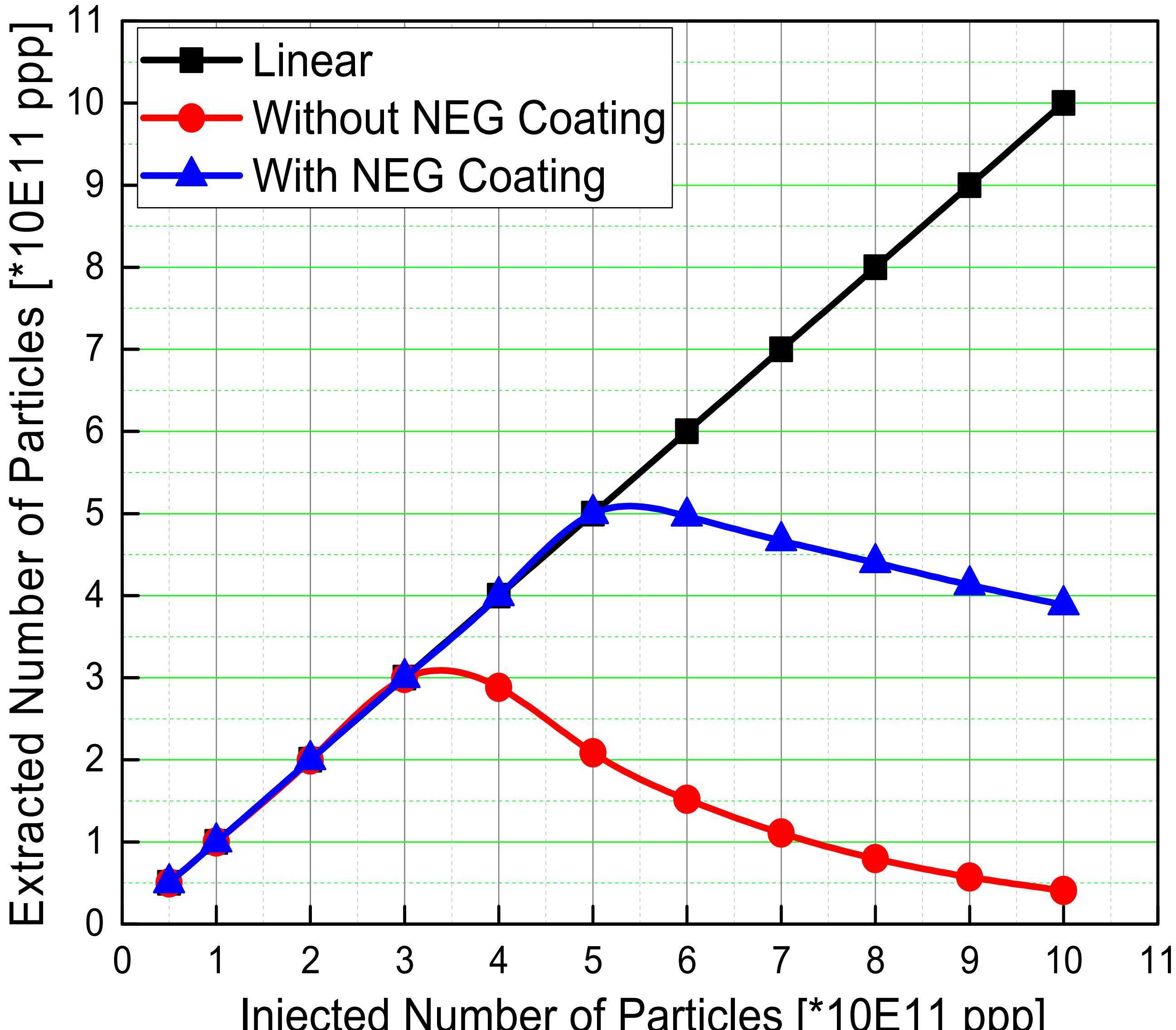
Desorption rate: 25500 Molecules/ion



3. Dynamic Vacuum Simulation

Injection beam intensity

Desorption rate: 25500 Molecules/ion



3. Dynamic Vacuum Simulation

Two issues:

1. The benchmark of the dynamic vacuum simulation code.
   - The pump speed is changing with vacuum pressure.
   - long-time simulation

2. The desorption of the collimator material.

   GSI's value: 25500 (SS).

3. The desorption rate of different material.

   different surface treatments

1. CSRm: benchmark of the dynamic vacuum simulation code.

2. Platform: gas desorption measurement and test dynamic vacuum effect

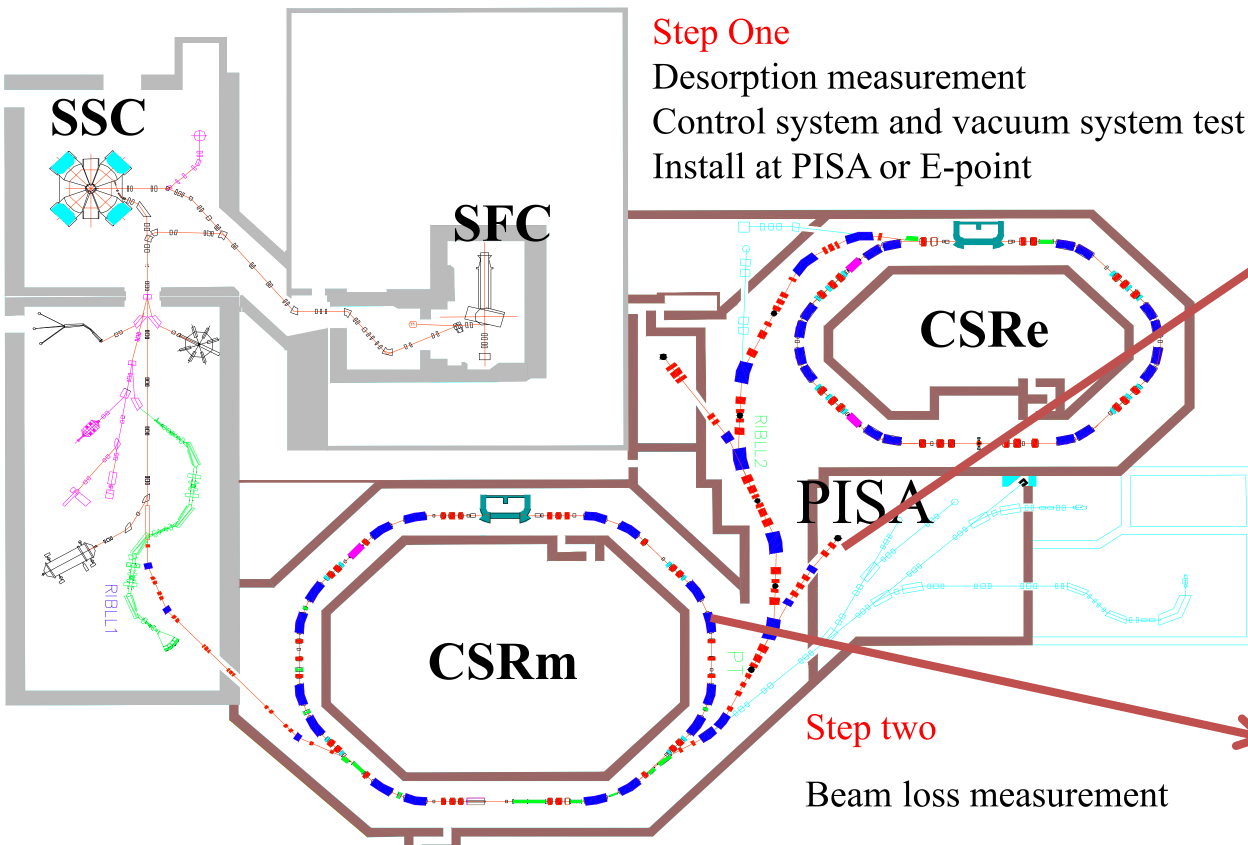
4. Desorption measurement experiment

Motivation:

Measure the desorption rate of different material.

Measure the pumping speed of NEG.

Measure the beam loss on the catch block.



Step One

Desorption measurement

Control system and vacuum system test

Install at PISA or E-point

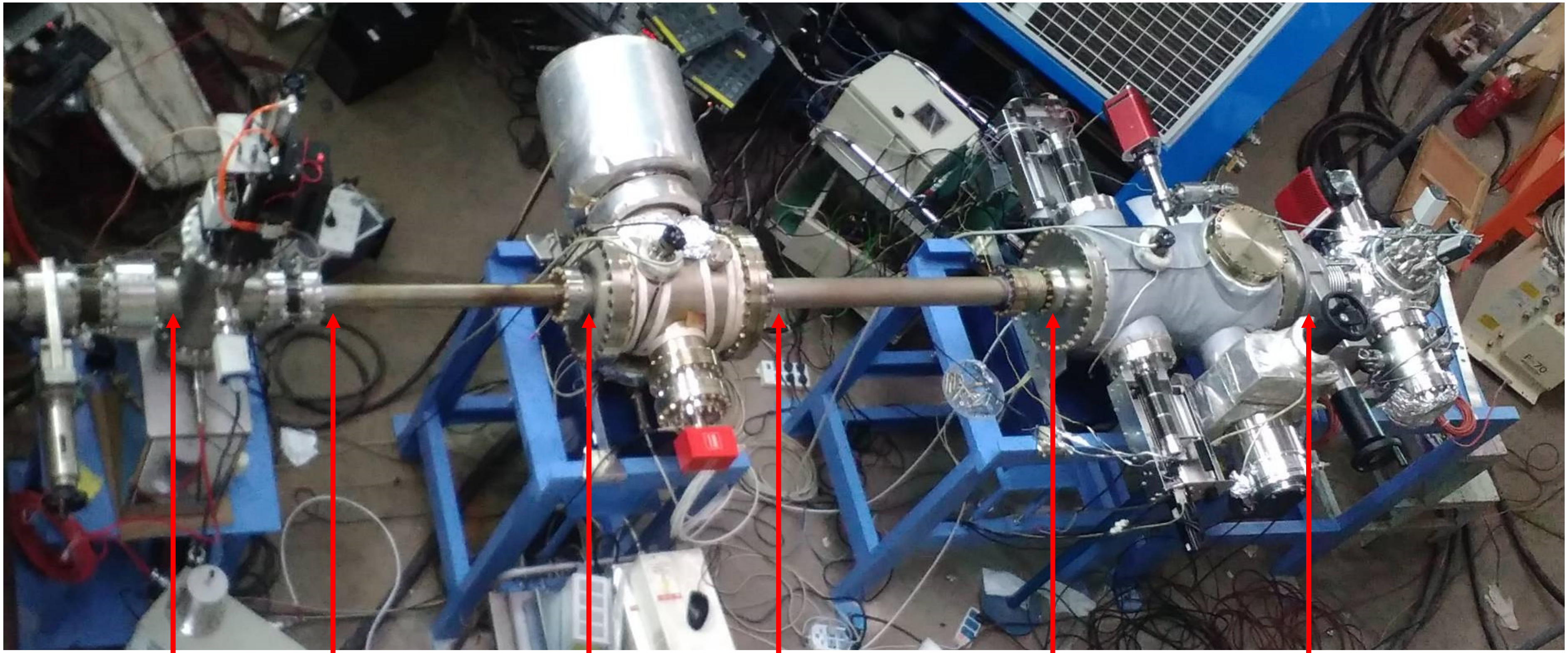
Step two

Beam loss measurement

Install at the CSRm

4. Desorption measurement experiment

Setup I: Install at PISA of the HIRFL-CSR, high energy



Beam Parameters Measurement

Pumps Chamber

Desorption Measurement

1：Stepper Motor（Copper block）2：Stepper Motor（Copper coated with gold）

3：Gauge 4：Turbo Molecular Pump 5：RGA（Residual gas analyzer）

6：ICT and VS 7：SIP and TSP 8：NEXTorr Pump 9: Sensors

4. Desorption measurement experiment

First beam test:

2015. 11.25

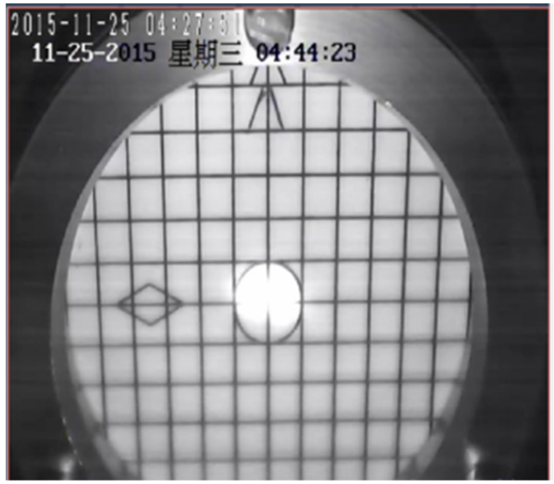
Beam: Sn26+,

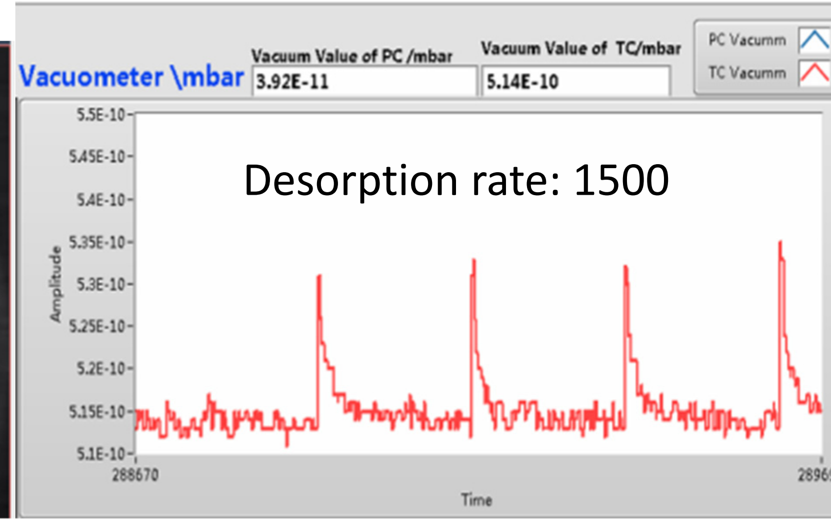
Injection Energy=3.7 MeV/u

Extraction Energy=150 MeV/u.

Beam Intensity: 80 uA (2*10E7)

dP=1.5*10^-11 mbar





Second beam test:

2015. 12.05

Beam: C6+,

Injection Energy=7MeV/u

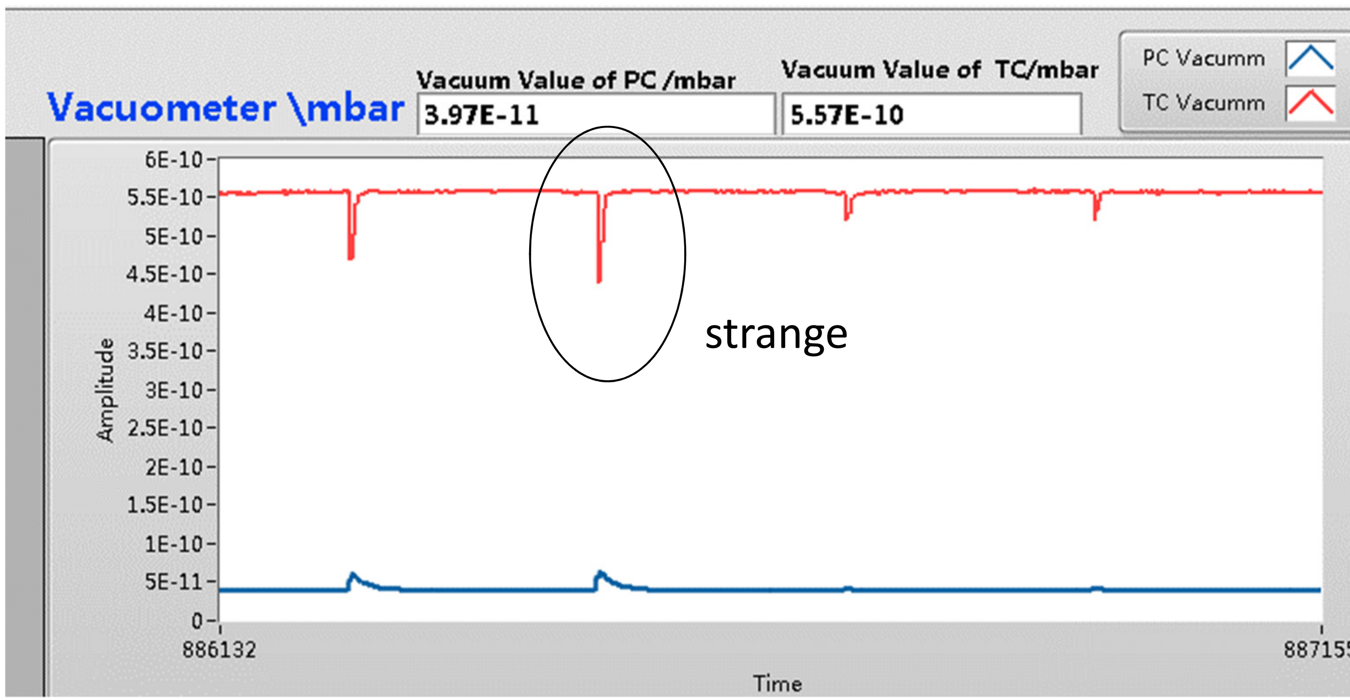
Extraction Energy=380 MeV/u.

Beam Intensity: (2*10E9)

dP=-5*10^-11 mbar

Leybold CM52

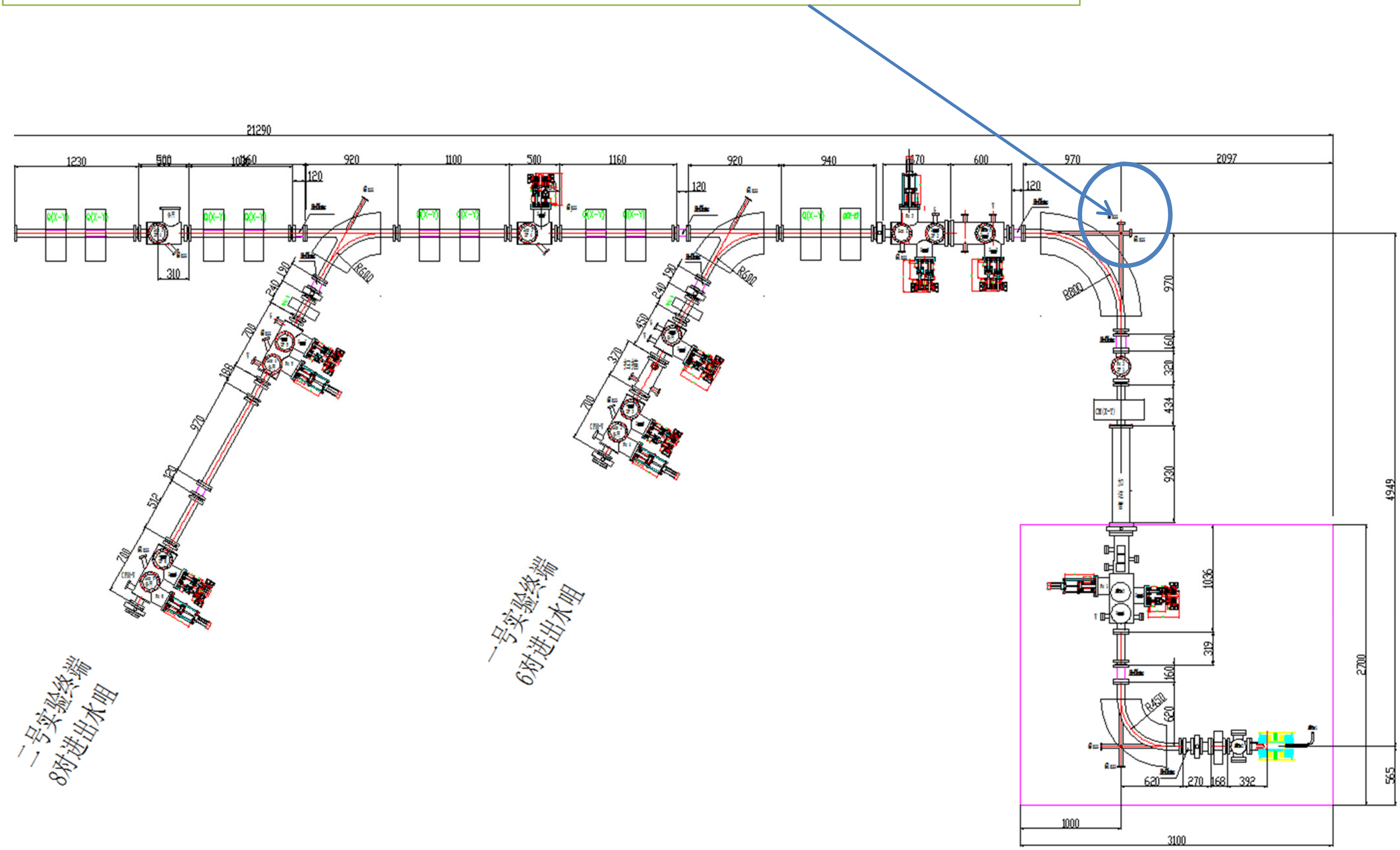
IE514 Gauge



4. Desorption measurement experiment

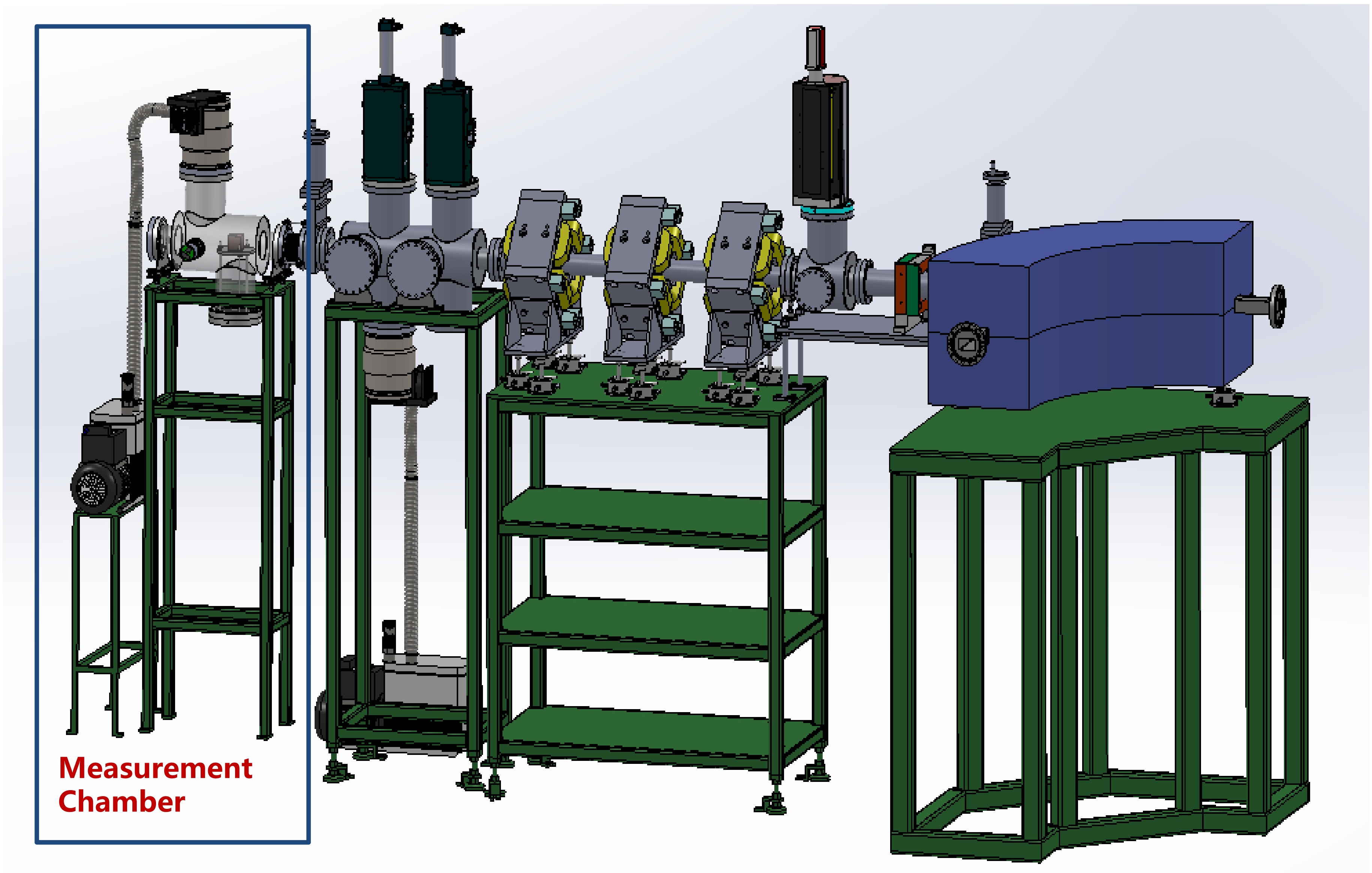
Setup II: Install 320kV high voltage platform T6#, Low energy

2016.11.26



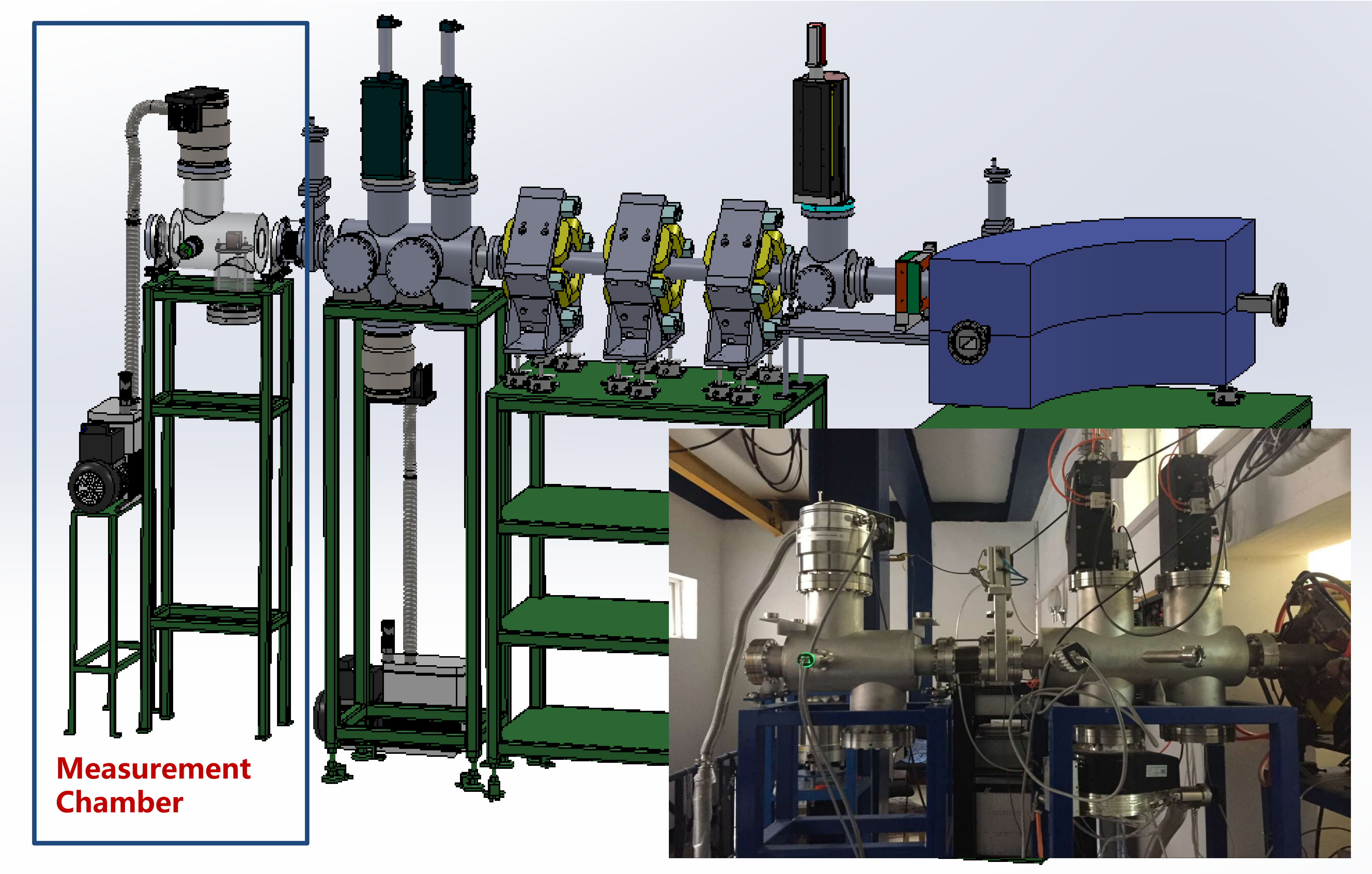
4. Desorption measurement experiment

Setup II: Install 320kV high voltage platform T6#，Low energy



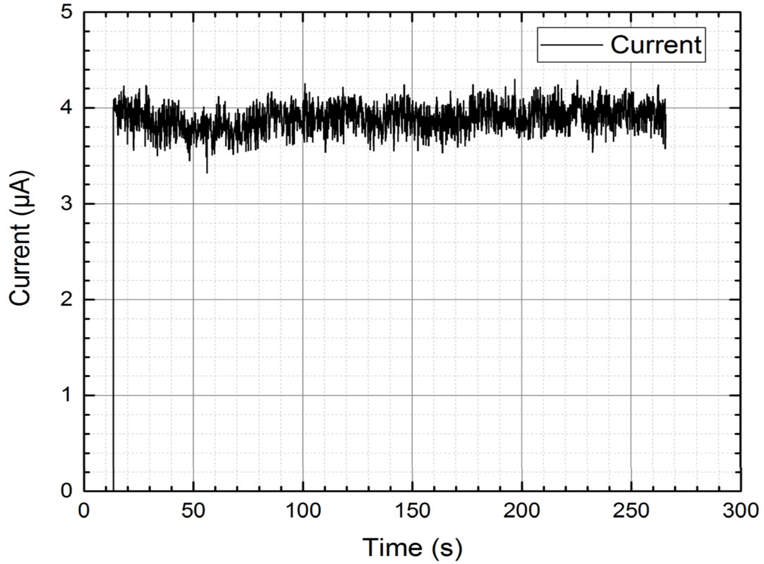
4. Desorption measurement experiment

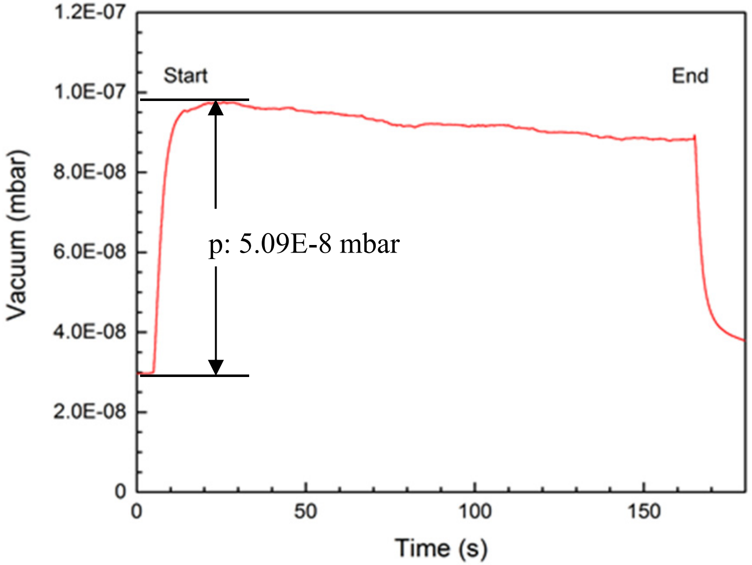
Setup II: Install 320kV high voltage platform T6#，Low energy



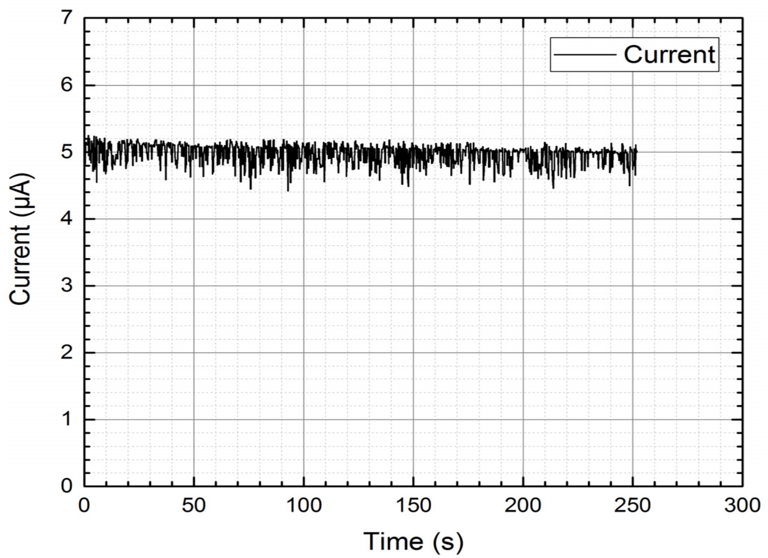
4. Desorption measurement experiment

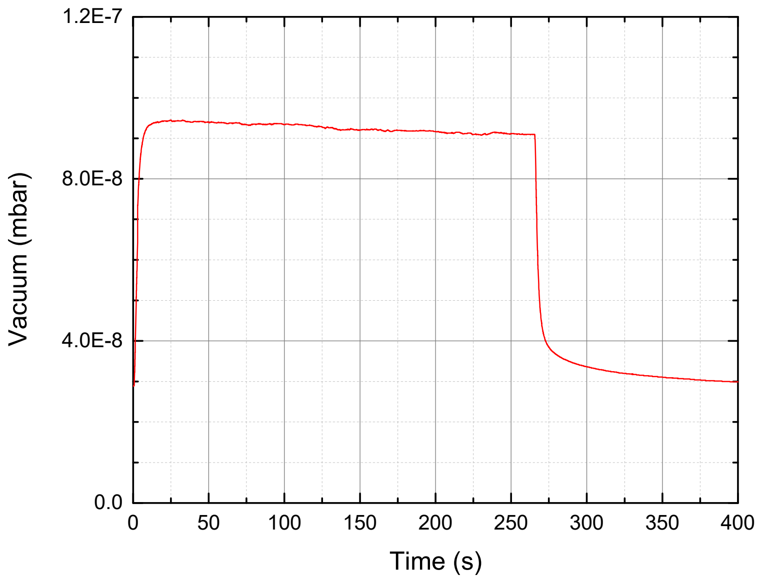
1. 129Xe10+, Current=4 euA, Energy=2.5 MeV:





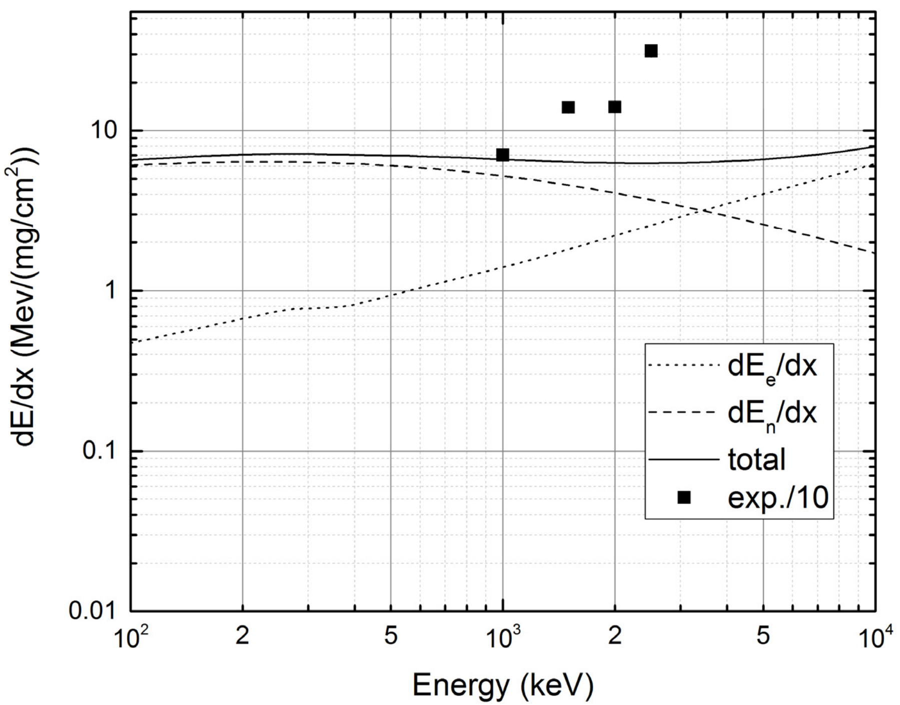
2. 16O1+, Current=5 euA, Energy=0.25 MeV:

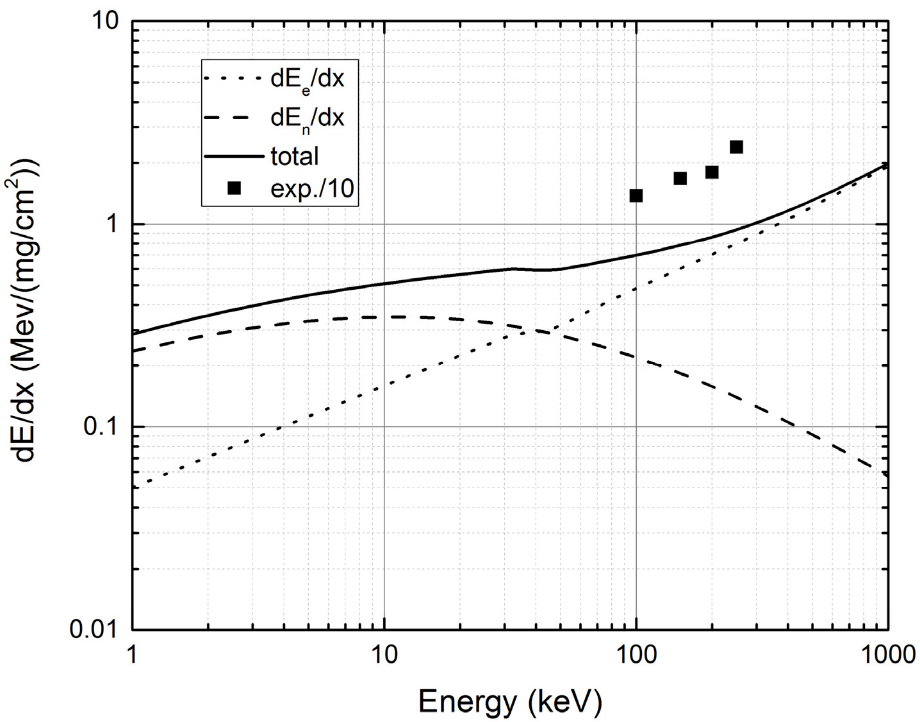




4. Desorption measurement experiment

- *CERN GIS Measurement results*: $\eta_{eff} \propto \left(\frac{dE_e}{dx}\right)^2$
- Xe : $\eta_{eff} = 41.174\left(\frac{dE_e}{dx}\right)^2$;O： $= 39.732\left(\frac{dE_e}{dx}\right)^2$





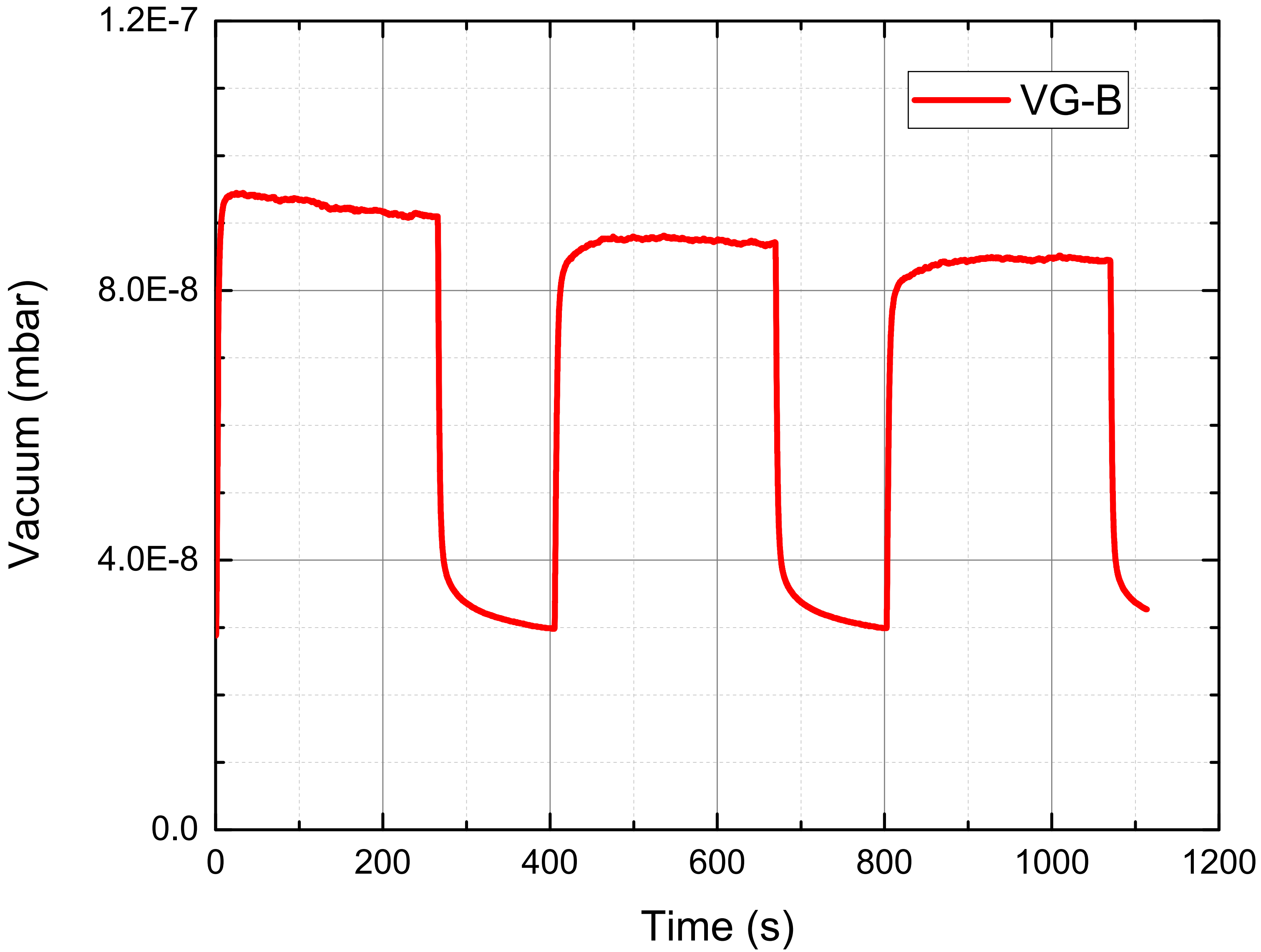
4. Desorption measurement experiment

Desorption rate:

Beam	Charge state	P_0 (mbar)	P_{max} (mbar)	Desorption η_{eff} (mol./ion)
Xe^{10+}	1000	2.91×10^{-8}	4.43×10^{-8}	52
	1500	3.04×10^{-8}	6.15×10^{-8}	104
	2000	3.05×10^{-8}	6.15×10^{-8}	105
	2500	2.97×10^{-8}	9.76×10^{-8}	104
O^{+}	100	2.82×10^{-8}	6.60×10^{-8}	10
	150	2.81×10^{-8}	7.64×10^{-8}	12
	200	2.85×10^{-8}	7.82×10^{-8}	13
	250	2.88×10^{-8}	9.45×10^{-8}	18

4. Desorption measurement experiment

Beam cleaning effect:



4. Desorption measurement experiment

Though this measurement:

1. We have checked our design of the gas desorption measurement setups.
2. We observed the beam scrubbing effects.
3. Dynamic vacuum effect has been experienced and recorded.
4. Desorption rate of Cu at this low energy regime is obtained.

More desorption measurement:

1. Check the dynamic vacuum simulation code.
2. Measure the gas desorption rate of different materials.

5. Challenge, future studies

Challenge:

- How to optimize the lattice for different type of particles?
- How to do the simulation code benchmarking?
- How to optimize the design of the collimator?

  The mechanical design, control system, vacuum system test.
- How to measure the desorption rate more accurately?
- We need a team to design and test the collimation system.

5. Conclusion

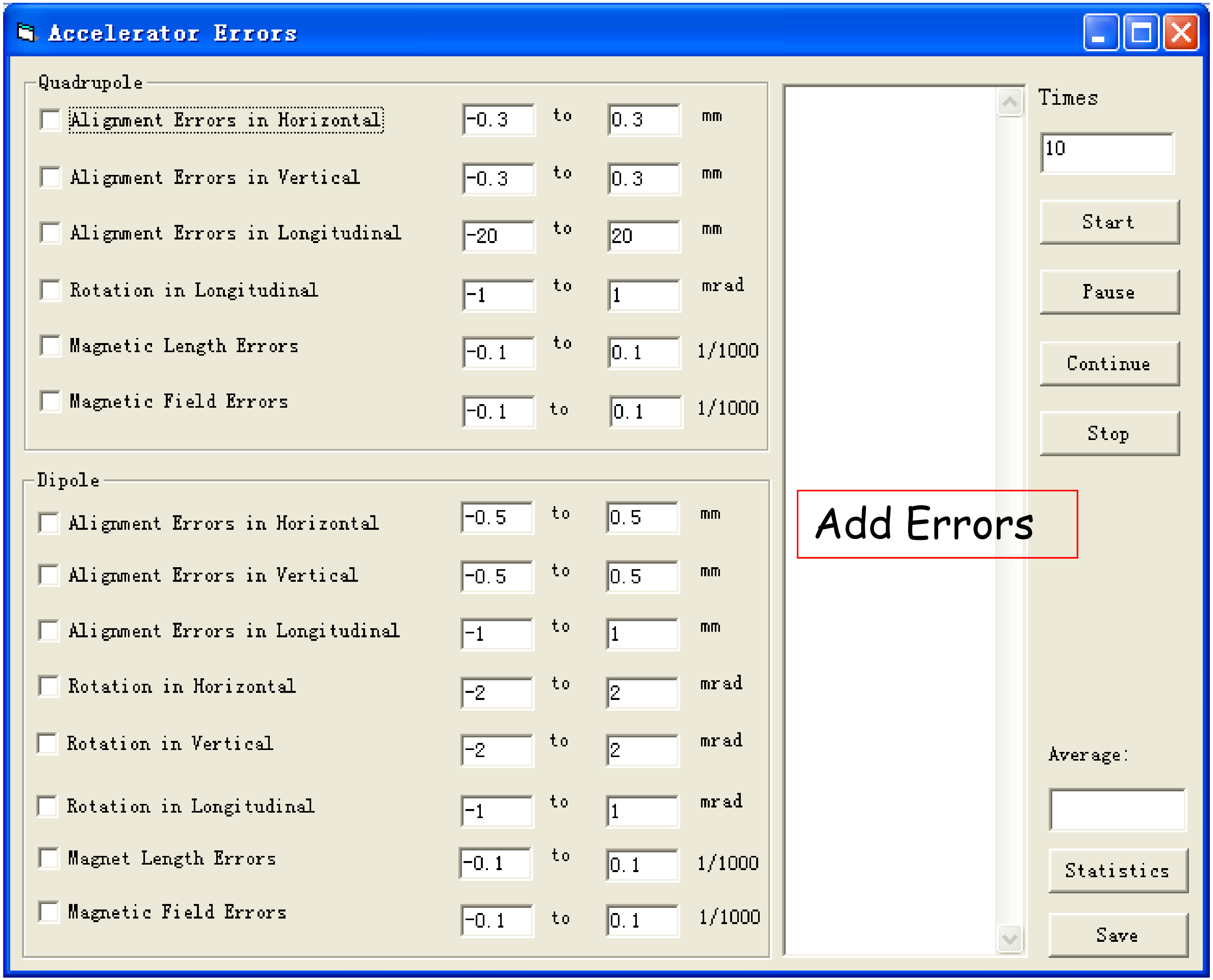
1. We have developed a code to simulate the beam loss distribution and collimation efficiency.
2. New Lattice has been optimized to get high collimation efficiency.
3. Dynamic vacuum pressure for the BRing has been simulated.
4. The current vacuum system design is feasible.
5. Collimator for the BRing has been designed.
6. Two setups to measure the desorption rate has been established at the IMP.

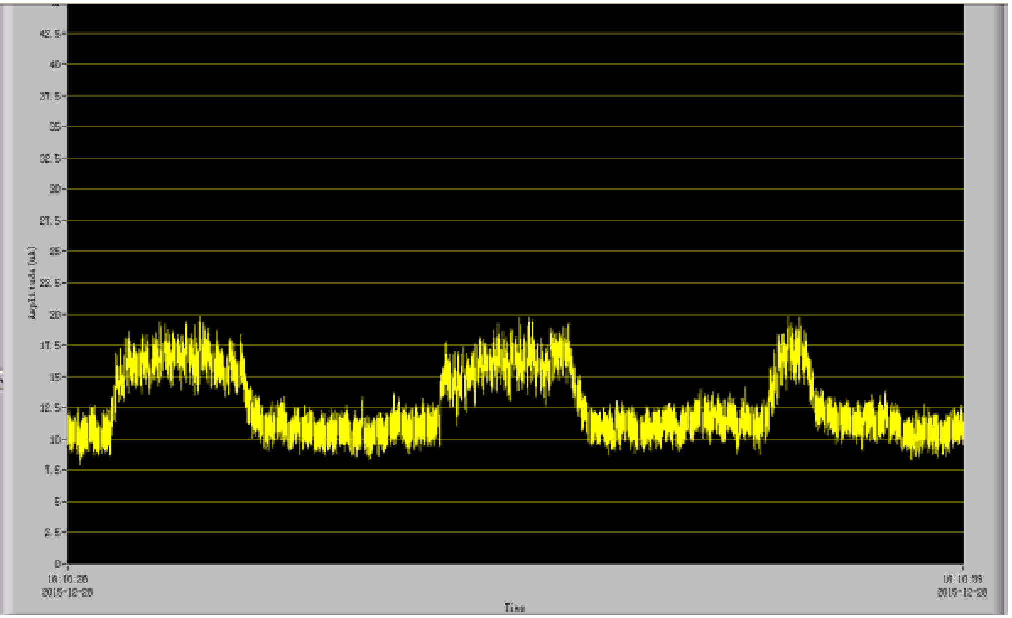
5. Conclusion

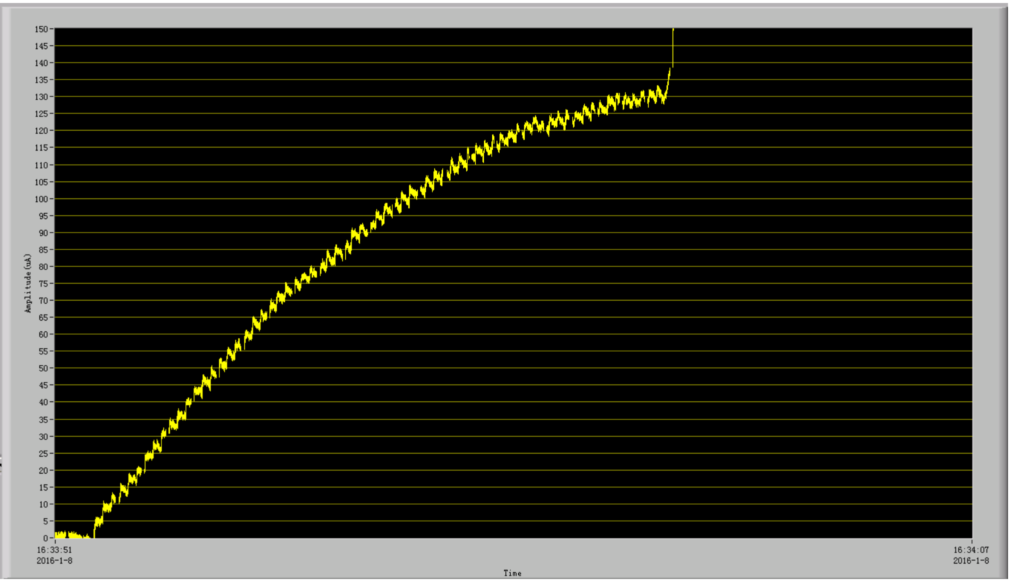
1. We have developed a code to simulate the beam loss distribution and collimation efficiency.
2. New Lattice has been optimized to get high collimation efficiency.
3. Dynamic vacuum pressure for the BRing has been simulated.
4. The current vacuum system design is feasible.
5. Collimator for the BRing has been designed.
6. Two setups to measure the desorption rate has been established at the IMP.

Thank you !

Collimation efficiency: Different types of errors.







First beam test:

2015. 11.25

Beam: Sn26+,

Injection Energy=3.7 MeV/u

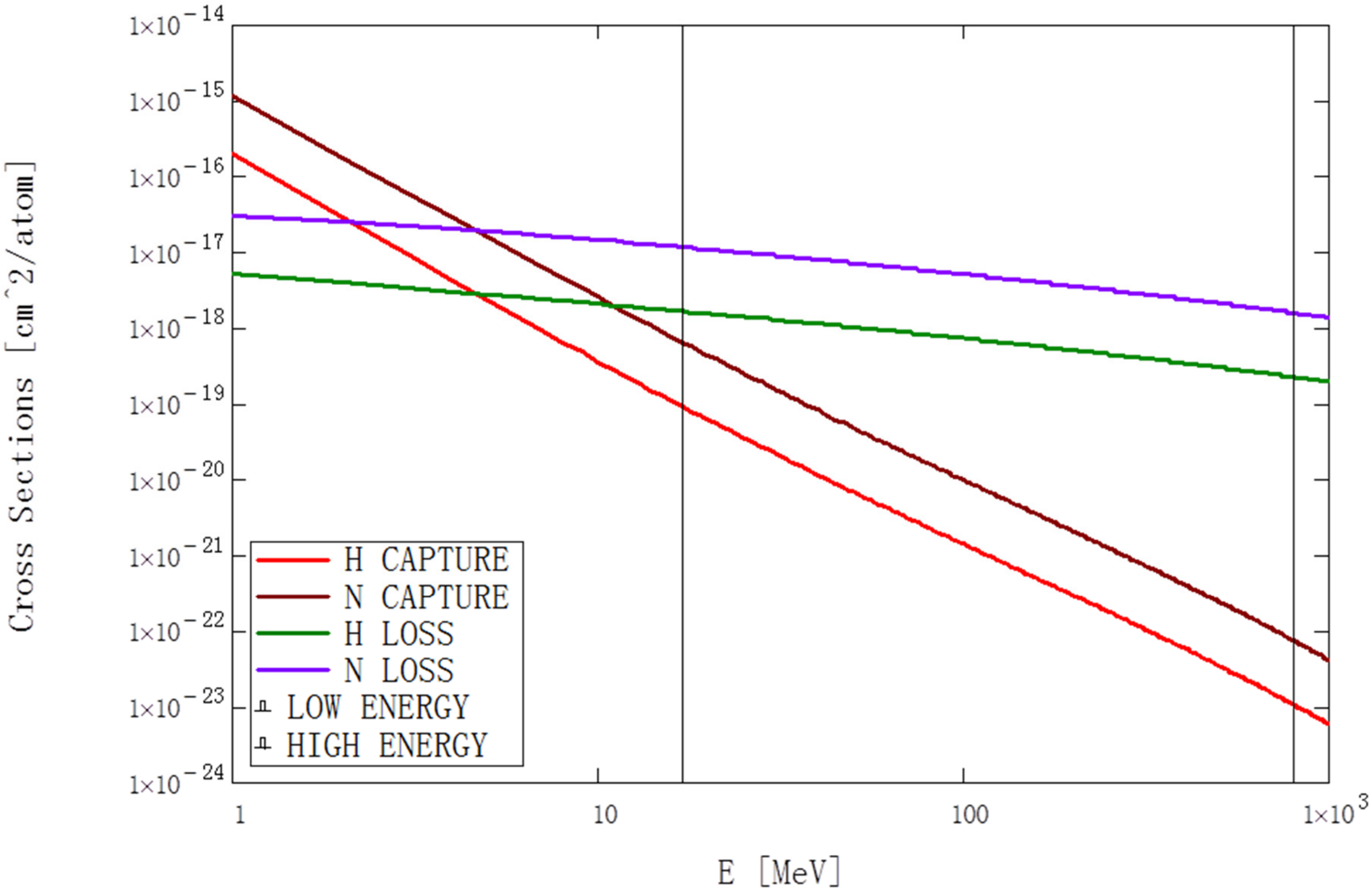
Extraction Energy=150 MeV/u.

Beam Intensity: 80 uA (2*10E7)

dP=1.5*10^-11 mbar

2. Collimation system design

Franzke's Formula：U35+ → U36+



Loss cross section ~ 2 magnitude of capture cross section