Collimation in CEPC collider ring

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1. Goals of the collimation

1. Ability for the passive machine protection, mainly considering fast beam loss
2. Equipment protection
   - clearance in IP region
   - clearance in RF region
   - superconducting magnets protection
   - vacuum chamber protection
   - detector protection
3. Background reduction, caused by SR…(MDI)
4. Beam quality during the beam injection
5. Optimization of the beam parameters

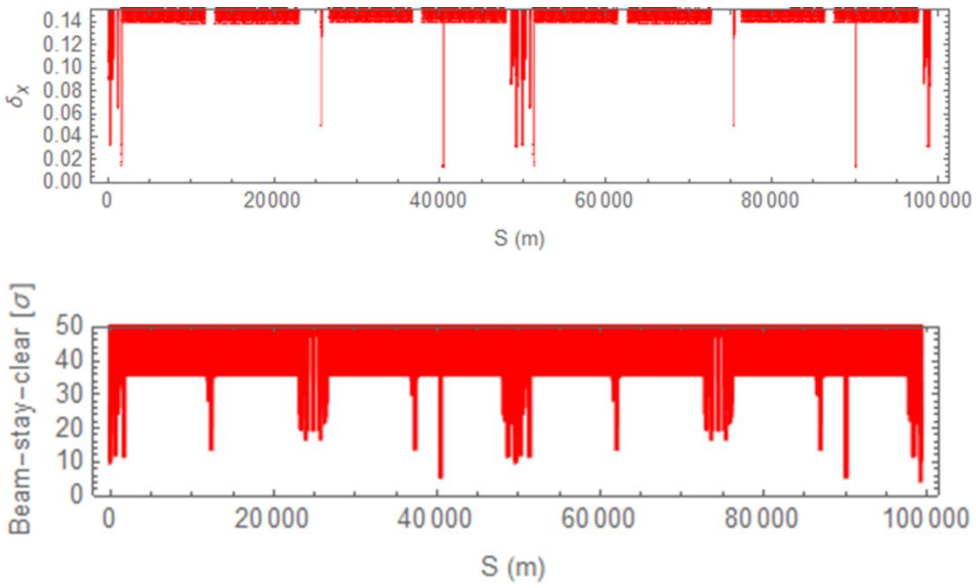
2. Scenarios of the beam loss

- Critical RF failure (Taking ~773 μs for the voltage to decrease to 0) *JY Zhai*
- Powering failure of the normal bending magnets (~10 ms) *B Chen*
- Powering failure of the normal quadrupole magnets (~10 ms) *B Chen*
- Powering failure of the normal sextupole magnets(~10 ms) *B Chen*
- Failure of the superconducting quadrupole magnets(~10 ms) *ZS Zhou*

3. Aperture model

Finding the momentum acceptance and beam stay clear region will allow us to identify the loss locations and the bottlenecks.

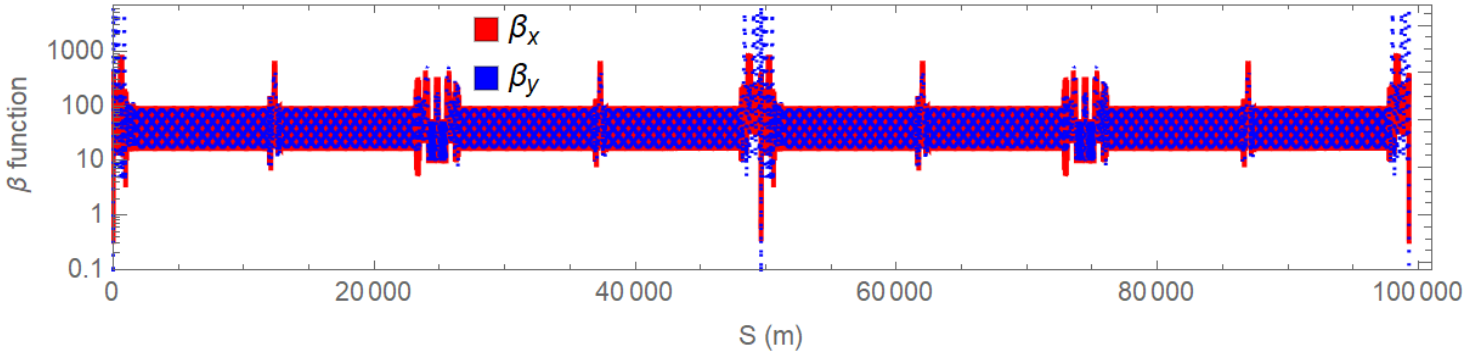
$$\delta_{max,\,x} = \frac{A_x - n\,\sigma_x}{D_x}, \qquad n_x = \frac{A_x - z_{cod} - z_D - z_{others}}{\sqrt{\beta_x \varepsilon_x}}$$

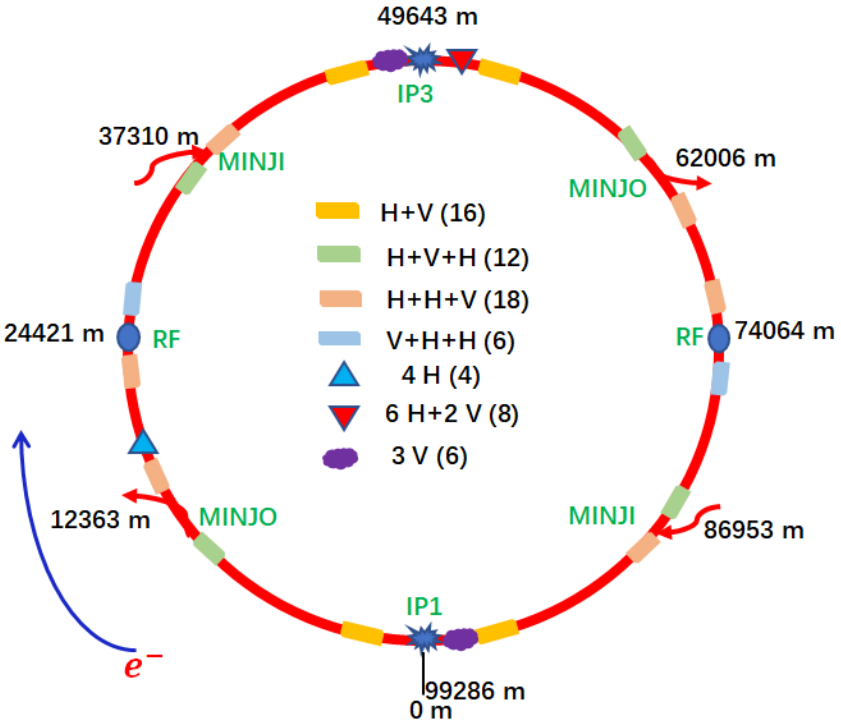


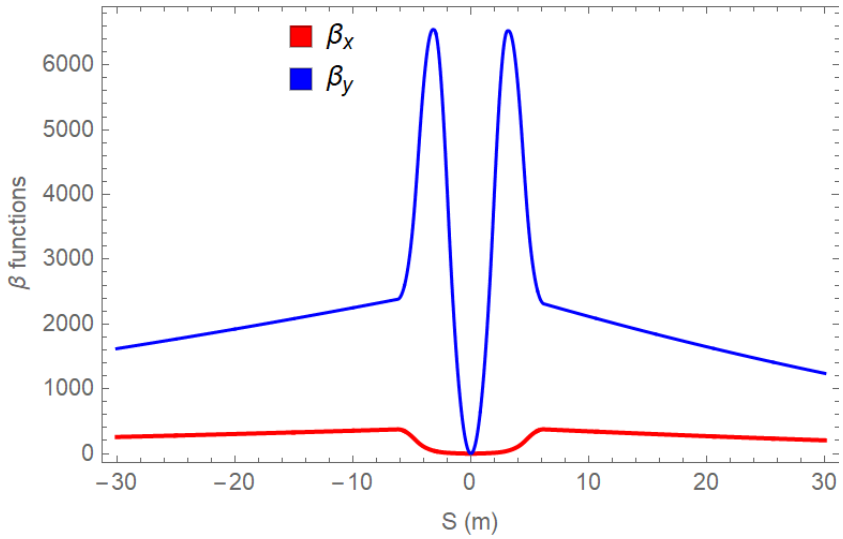
Strategy of installing the collimators:

- Large beta function: beam losses easily, reduce the effective impedance
- Phase advance of π: the special equipment protection
- In drift: easy to build the model for further simulation, easy for installation…

4. Layout of the collimators



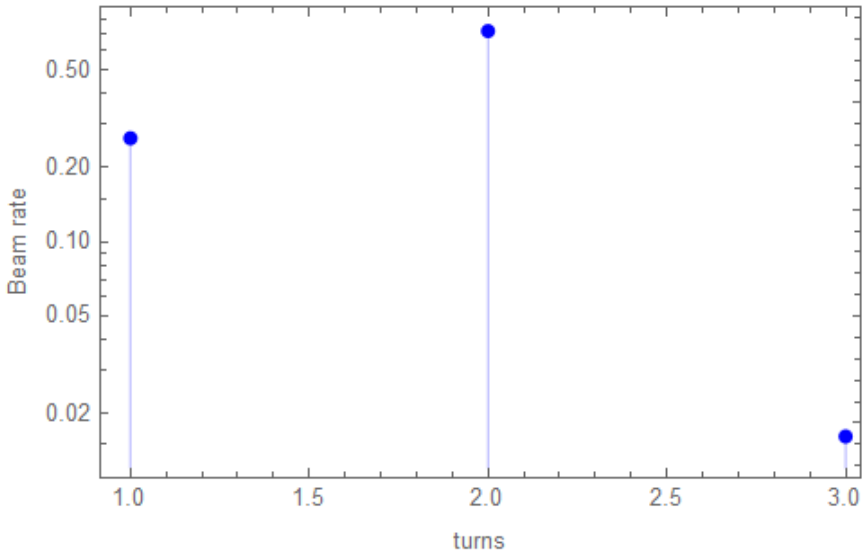


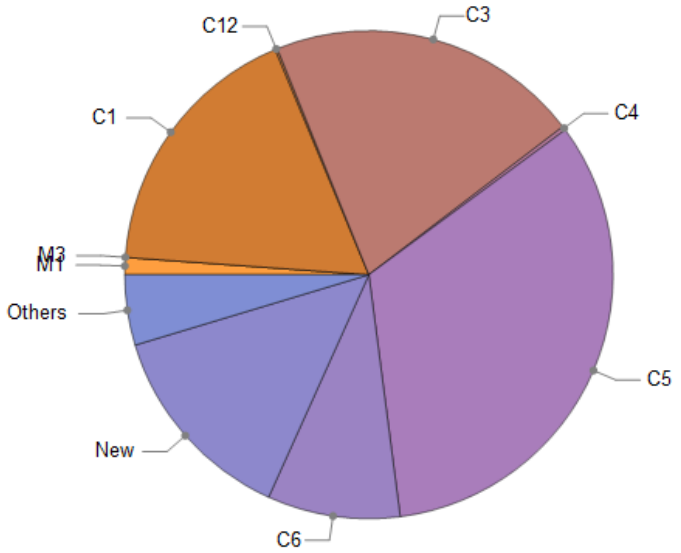


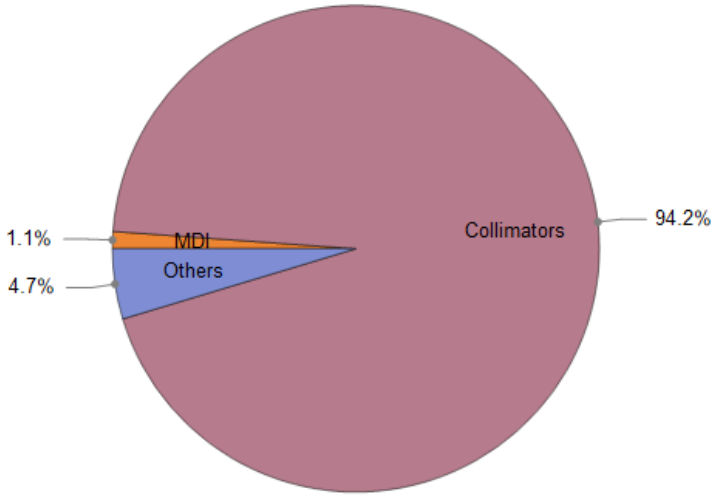
70 collimators are inserted into the collider ring for the passive machine protection.

5. Simulation results

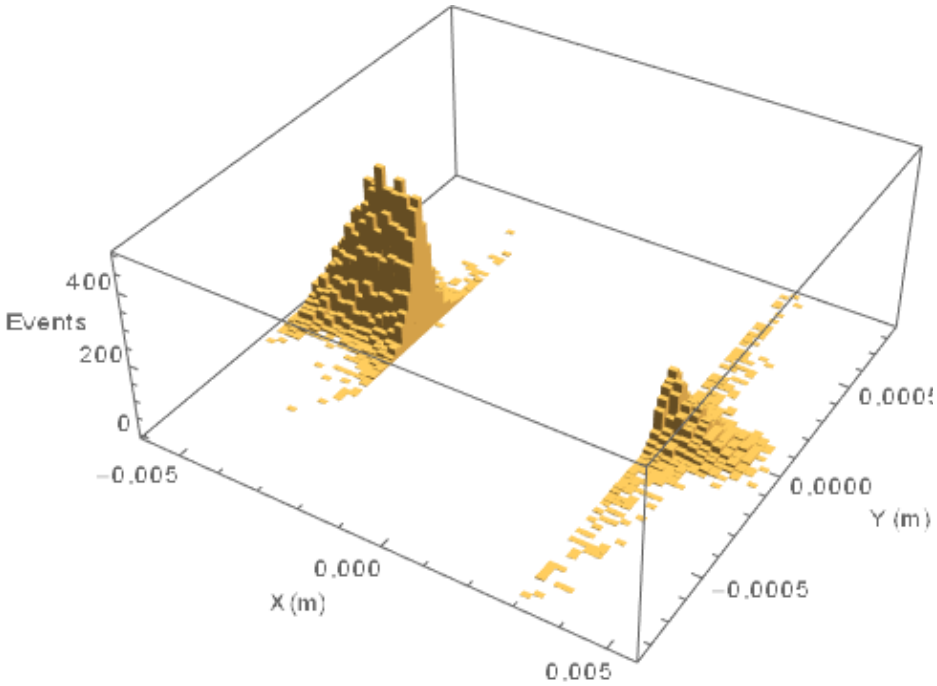
RF failure with collimators

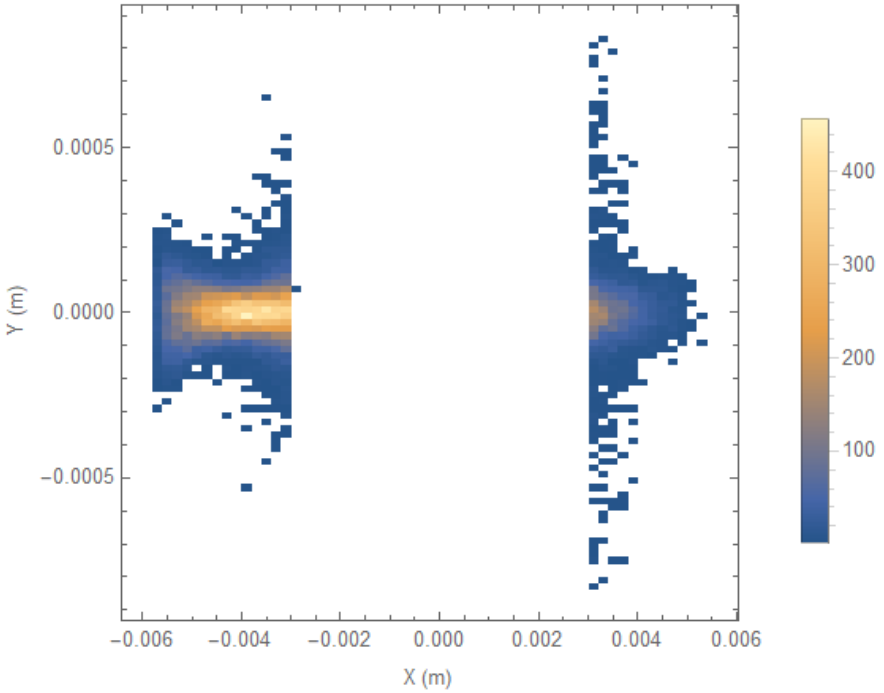




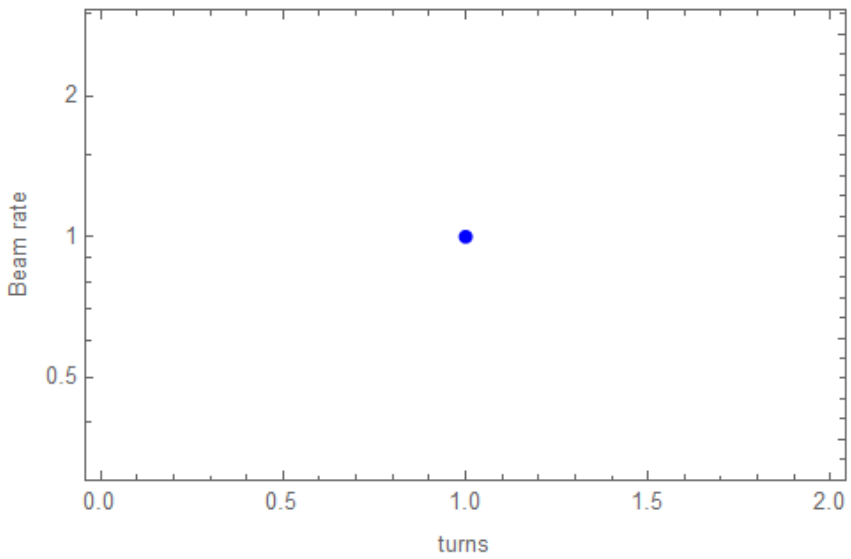


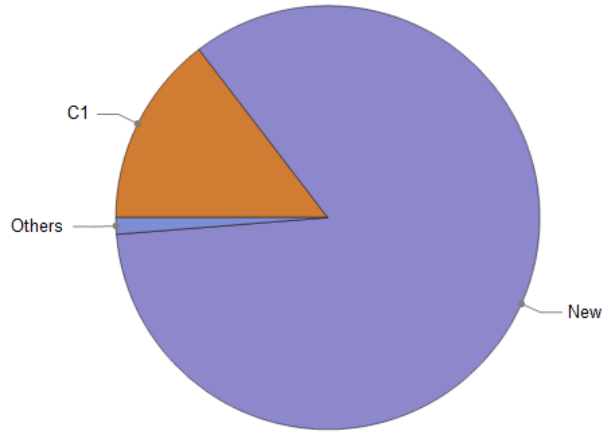
32% beam loss

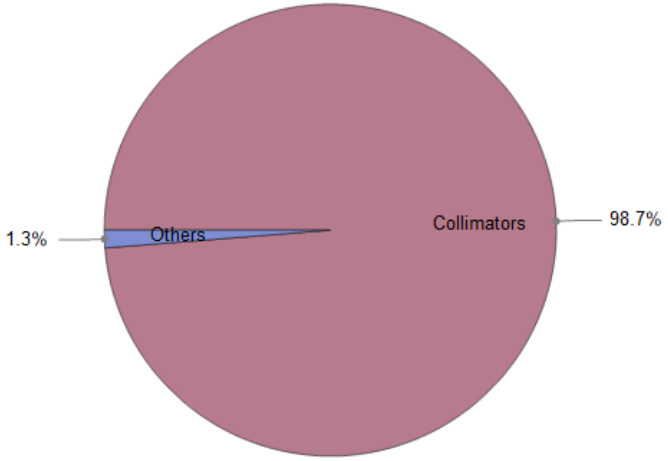

400
Events
200
0
−0.005
0.000
X (m)
0.005
0.0005
0.0000
Y (m)
−0.0005


0.0005
0.0000
−0.0005
Y (m)
−0.006
−0.004
−0.002
0.000
0.002
0.004
0.006
X (m)
400
300
200
100

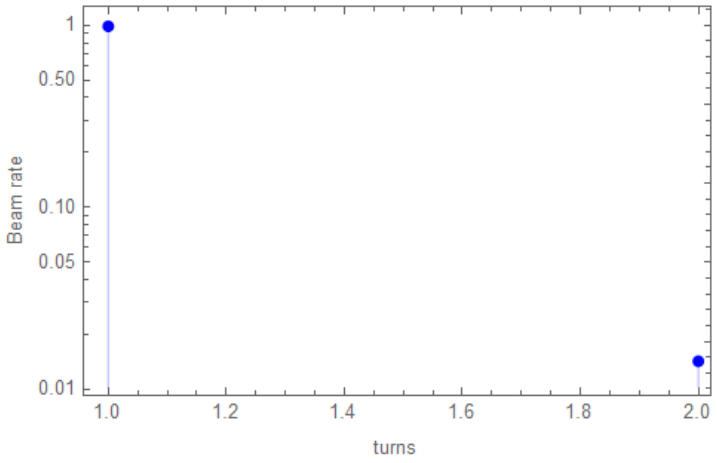
Normal Q magnet failure with collimators

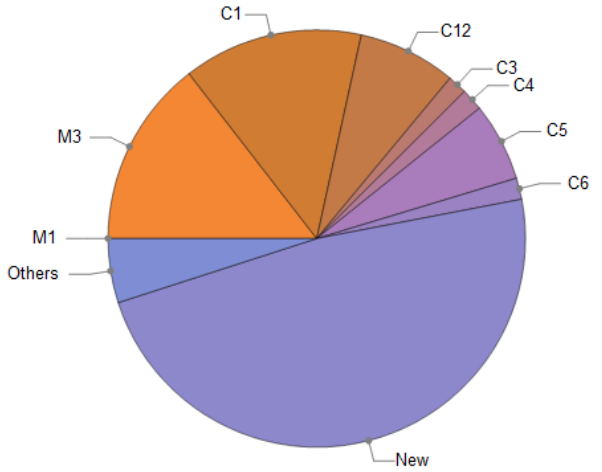


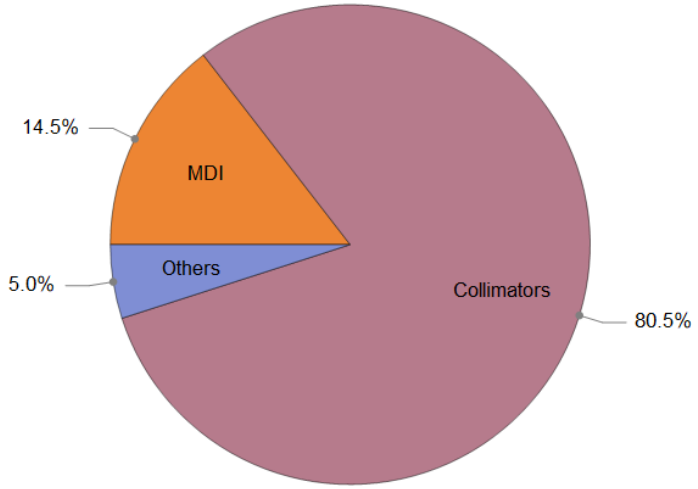




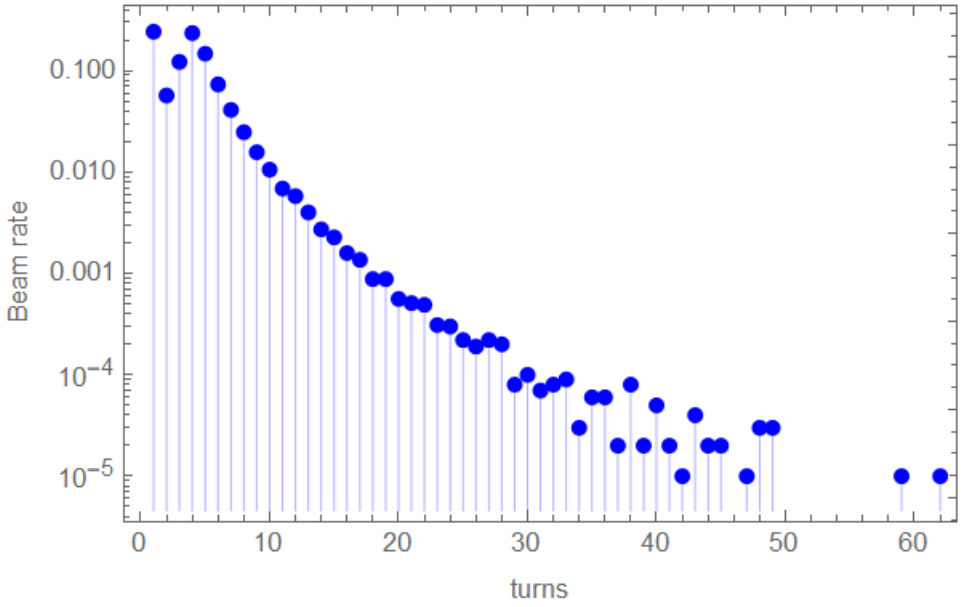
Superconducting Q magnet failure with collimators

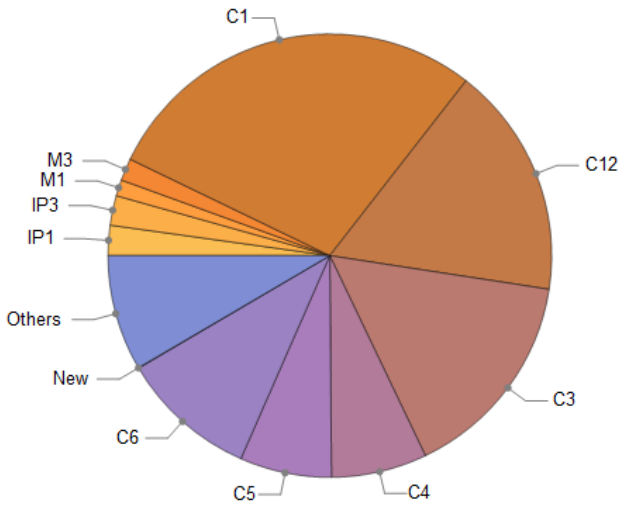




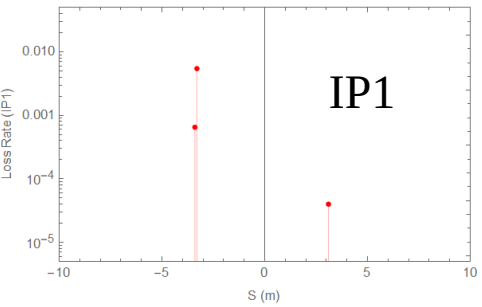


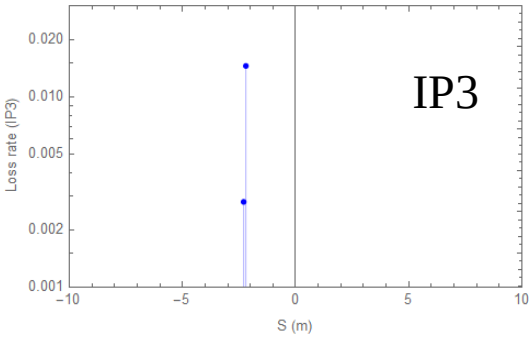
Bending magnet failure with collimators

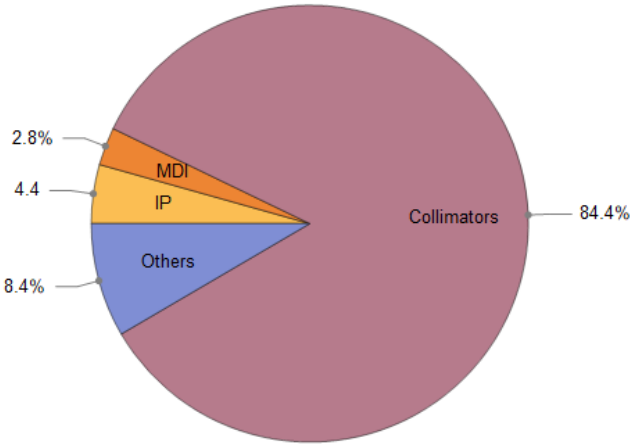




Q1CIRUSL (upstream IP3)
Q1CIRU.2SL (upstream IP1)

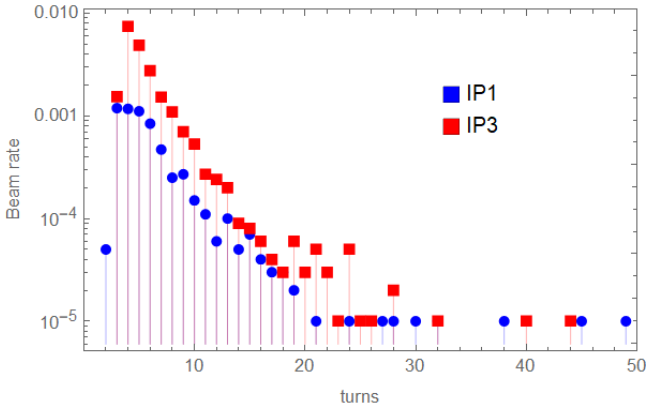


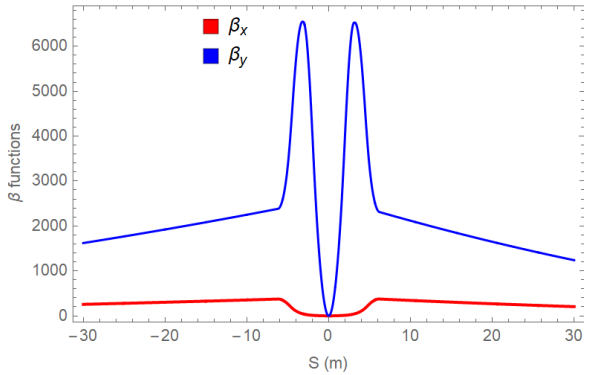


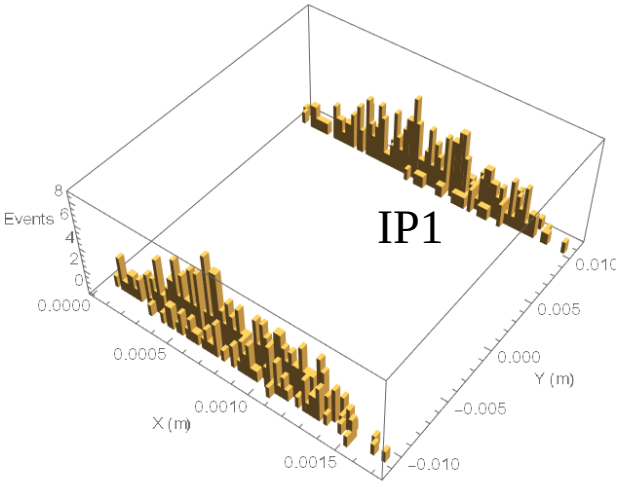


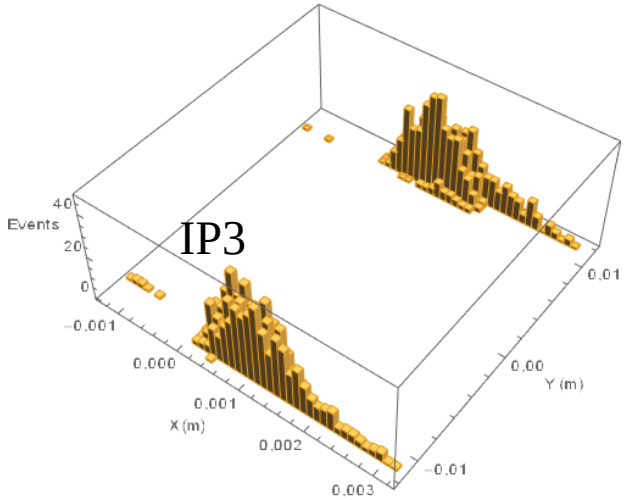
0.61%

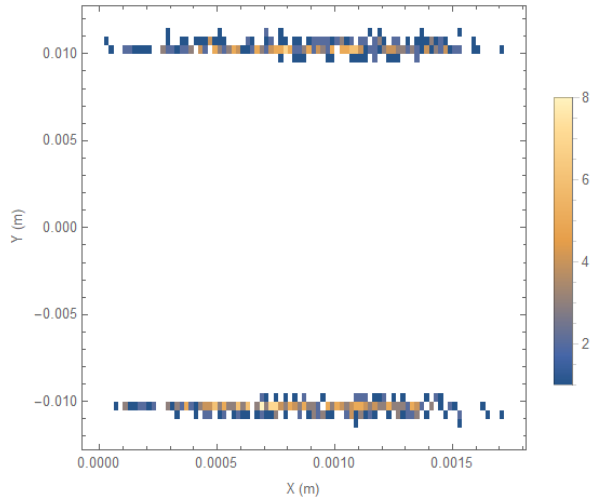
2.17%

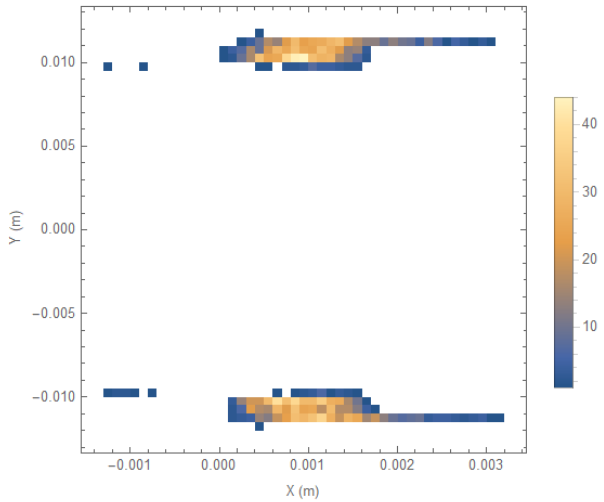

Beam rate
turns
IP1
IP3


β functions
S (m)
β_x
β_y

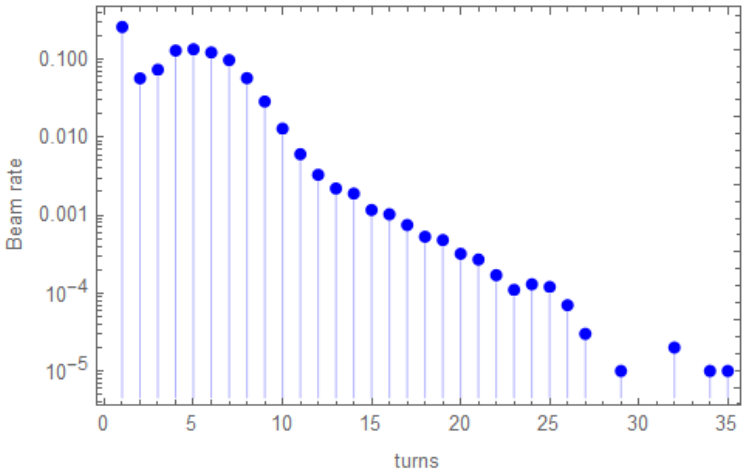

IP1
Events
X (m)
Y (m)

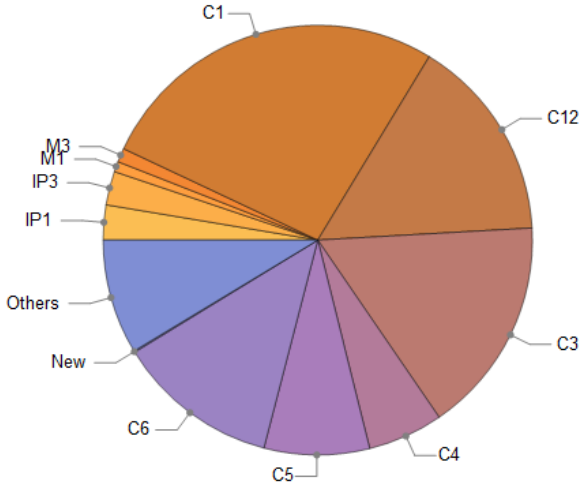

IP3
Events
X (m)
Y (m)


Y (m)
X (m)

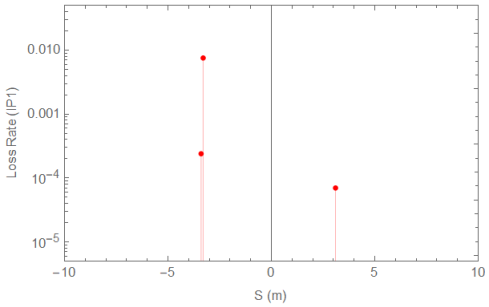

Y (m)
X (m)

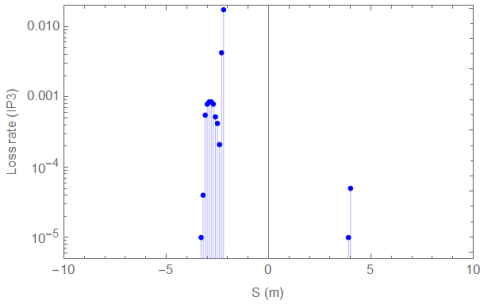
Sextupole magnet failure with collimators

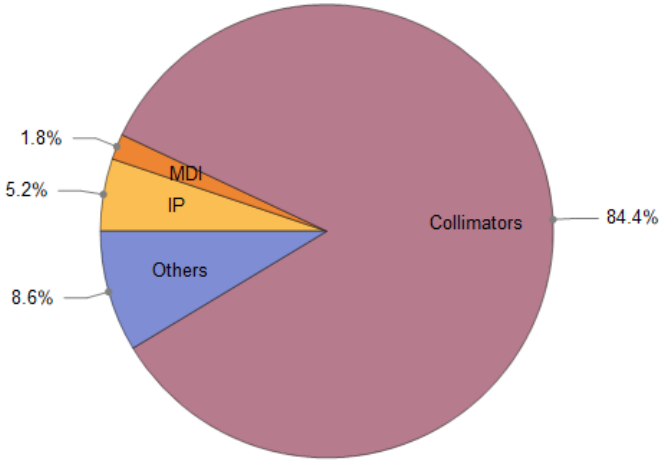




Q1CIRUSL (upstream IP3)
Q1CIRU.2SL (upstream IP1)

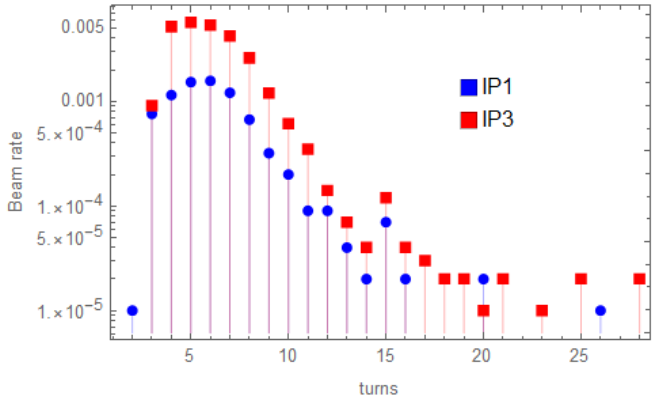


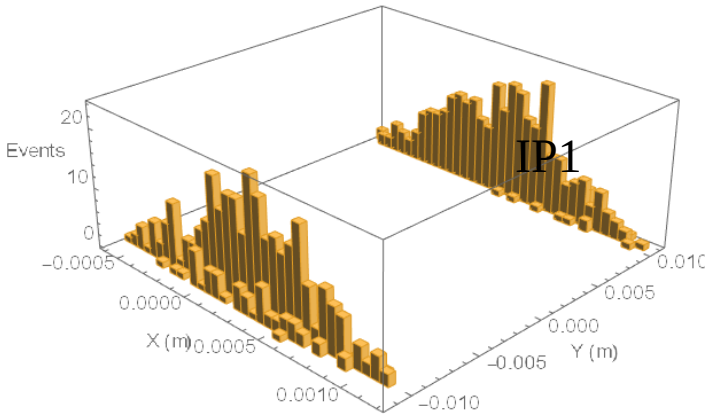


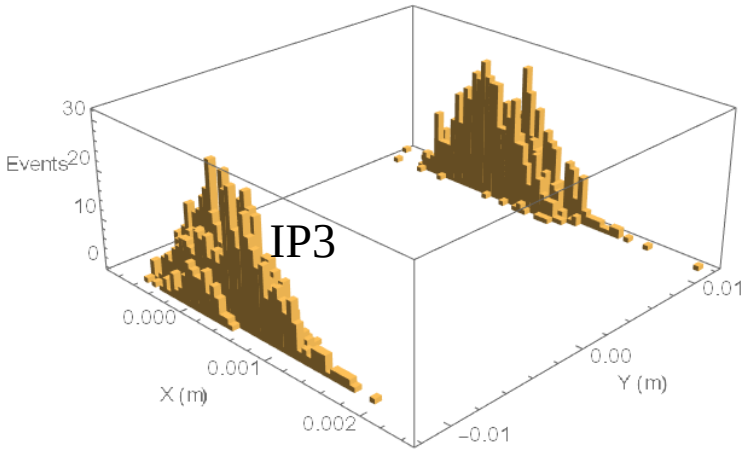


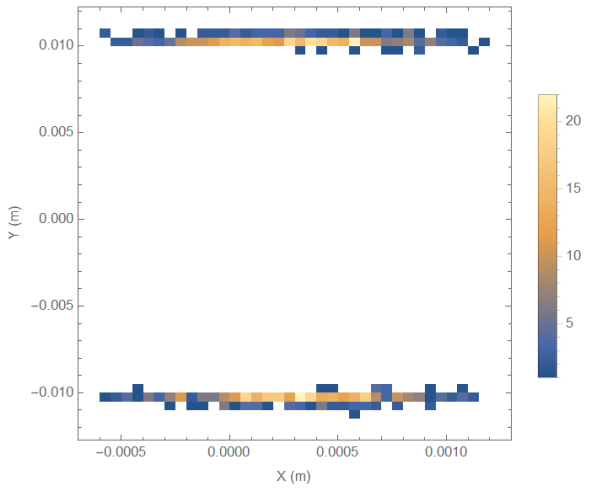
0.79%

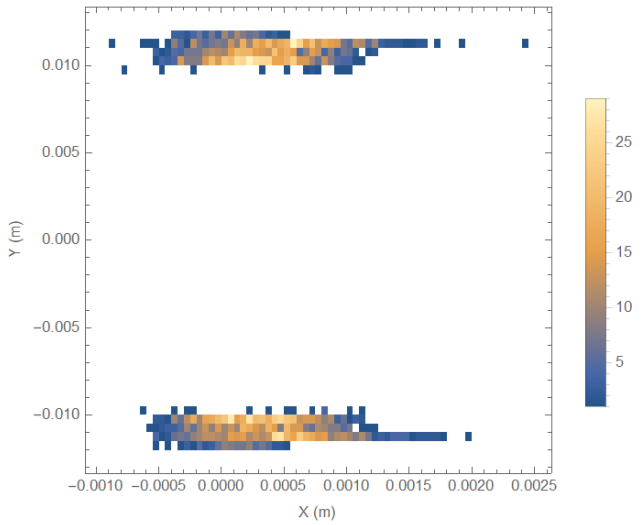
2.67%


IP1
IP3
Beam rate
turns


IP1
Events
X (m)
Y (m)


IP3
Events
X (m)
Y (m)


Y (m)
X (m)


Y (m)
X (m)

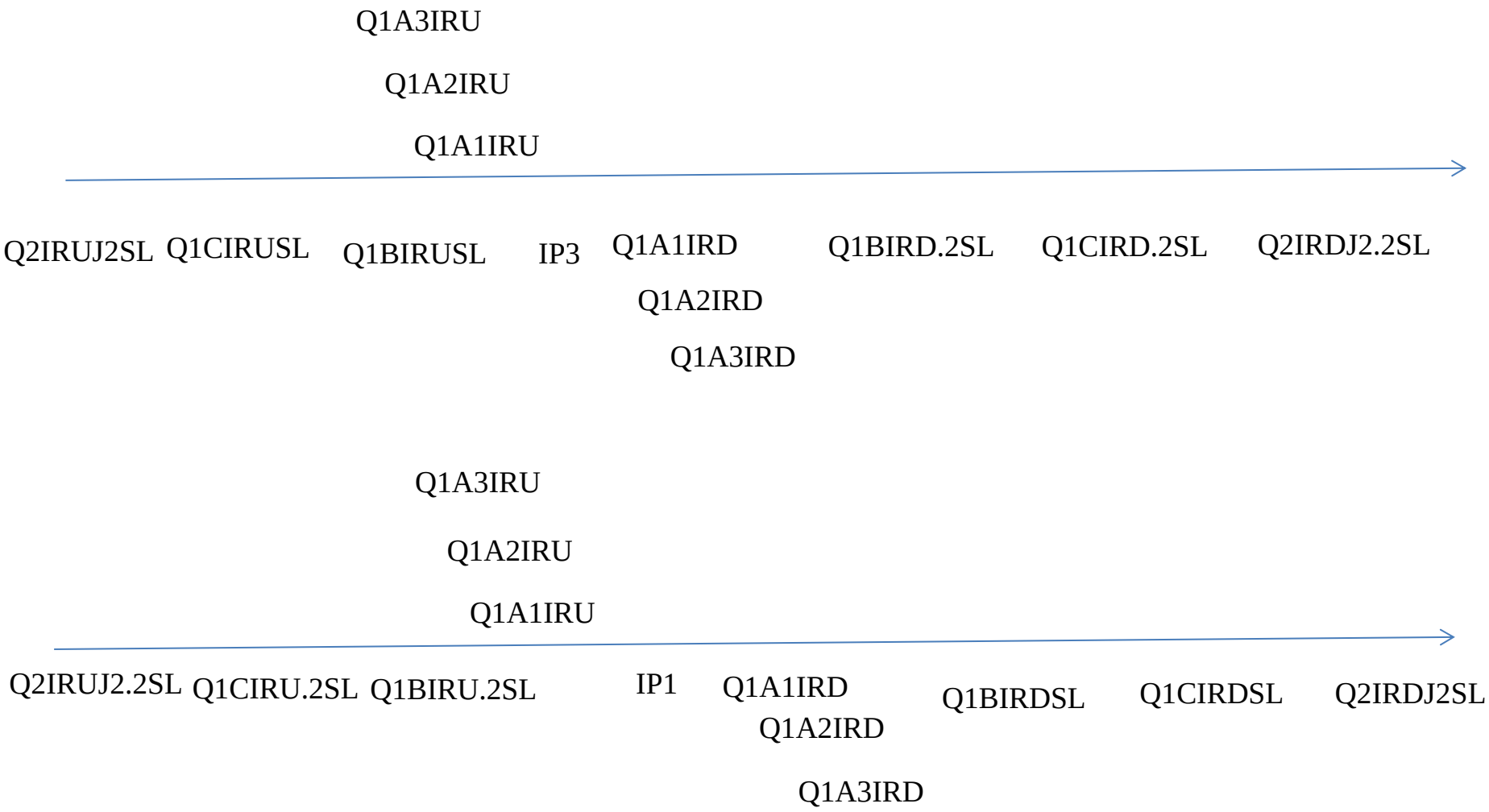
6. Urgent problem

Urgent problem:

- ✓ Optimize the number and location of the collimators
- ✓ Beam loss upstream IP (beam dump works?)
- ✓ Impedance budget
- ✓ More simulation to make sure if the multi-stage collimators is needed or not

Backup

SC magnet


Q1A3IRU
Q1A2IRU
Q1A1IRU
Q2IRUJ2SL
Q1CIRUSL
Q1BIRUSL
IP3
Q1A1IRD
Q1A2IRD
Q1A3IRD
Q1BIRD.2SL
Q1CIRD.2SL
Q2IRDJ2.2SL
Q1A3IRU
Q1A2IRU
Q1A1IRU
Q2IRUJ2.2SL
Q1CIRU.2SL
Q1BIRU.2SL
IP1
Q1A1IRD
Q1A2IRD
Q1A3IRD
Q1BIRDSL
Q1CIRDSL
Q2IRDJ2SL