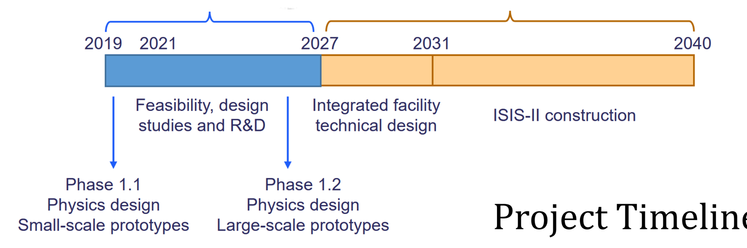
# RCS and Accumulator Ring Designs for ISIS II

D. J. Adams, H. V. Cavanagh, B. Kyle, H. Rafique, C. M. Warsop, R. E. Williamson, I. S. K. Gardner,
ISIS Facility, STFC, Rutherford Appleton Laboratory, Oxfordshire, UK

*Abstract*
ISIS is the spallation neutron source at the Rutherford Appleton Laboratory in the UK, which provides 0.2 MW of beam power via a 50 Hz, 800 MeV proton RCS. Detailed studies are now underway to find the optimal configuration for a next generation, short-pulsed neutron source that will define a major ISIS upgrade, with construction beginning ~2031. Determining the optimal specification for such a facility is the subject of an ongoing study involving neutron users, target and instrument experts. The accelerator designs being considered for the MW beam powers required, include proposals exploiting FFA rings as well as conventional accumulator and RCS rings. This paper summarises work on physics designs for the conventional rings. Details of lattice designs, injection and extraction systems, correction systems as well as detailed 3D PIC simulations used to ensure 0.1% losses and low foil hits are presented. Designs for a 0.4 to 1.2 GeV RCS and 1.2 GeV AR are outlined. Work on the next stages of the study are also summarised to benchmark and minimise predicted losses, and thus maximise the high intensity limit of designs.

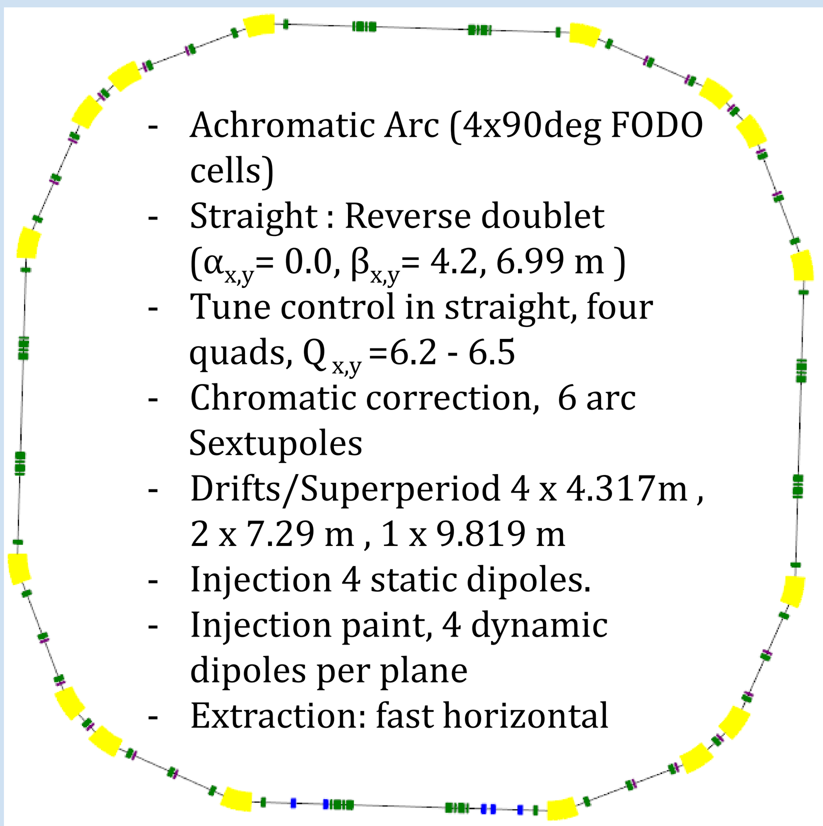
Main Parameters

| | RCS | AR |
|---|---|---|
| Energy Range | 0.4 -1.2 GeV | 1.2 GeV |
| Intensity | $1.3\times10^{14}$ ppp | $1.3\times10^{14}$ ppp |
| Repetition Rate | 50 Hz | 50 Hz |
| Mean Power | 1.25 MW | 1.25 MW |
| Circumference (mean R) | 282 m (45 m) | 282 m (45 m) |
| No Super Periods | 4 | 4 |
| Magnet Excitation | Sinusoidal | DC |
| Dipole Fields | 0.42-0.84 T | 0.84 T |
| Betatron Tunes ($Q_x$, $Q_y$) | (6.40, 6.32) (±~0.2) | (6.40, 6.32) (±~0.2) |
| Gamma Transition | 5.2 | 5.2 |
| Peak RF h=(2,4) | (300, 150) kV/turn | (50, 28) kV/turn |
| RF Frequency (h=2) | 1.52-1.91 MHz | 1.91 MHz |
| Number of Bunches | 2 | 2 |
| Acceptances: painted, collimation, aperture | 400, 600, 750 $\pi$ mm mr ($\Delta p/p$ ±0.01) | 300, 350, 500 $\pi$ mm mr ($\Delta p/p$ ±0.01) |



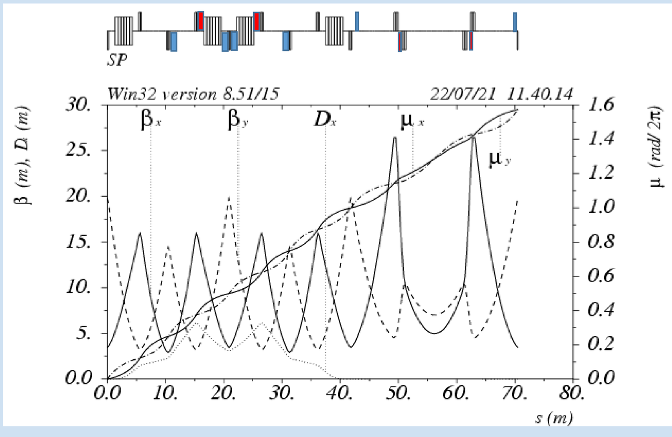

Project Timeline

## Ring Design for RCS and AR

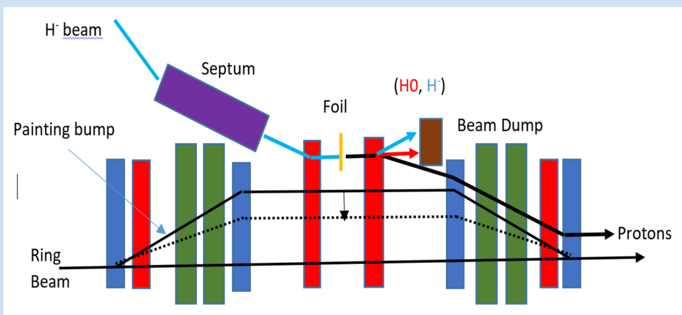


- Achromatic Arc (4x90deg FODO cells)
- Straight : Reverse doublet ($\alpha_{x,y}$= 0.0, $\beta_{x,y}$= 4.2, 6.99 m )
- Tune control in straight, four quads, $Q_{x,y}$ =6.2 - 6.5
- Chromatic correction, 6 arc Sextupoles
- Drifts/Superperiod 4 x 4.317m , 2 x 7.29 m , 1 x 9.819 m
- Injection 4 static dipoles.
- Injection paint, 4 dynamic dipoles per plane
- Extraction: fast horizontal

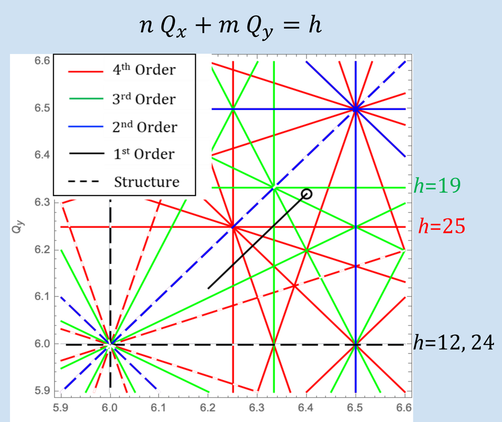
Lattice



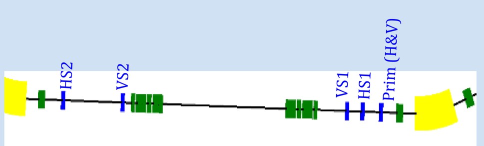
Injection Layout



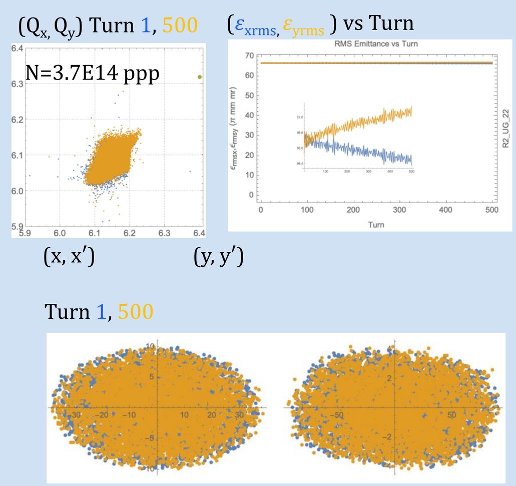

Tune Diagram



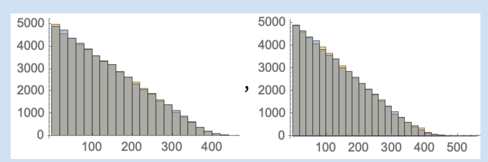

Collimation Layout



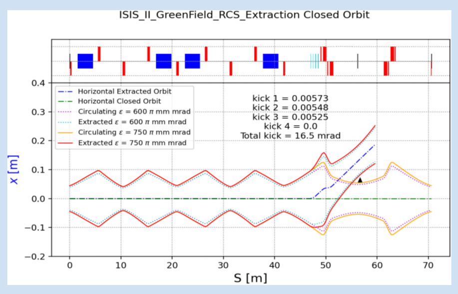
Gradient and Non-linear Errors



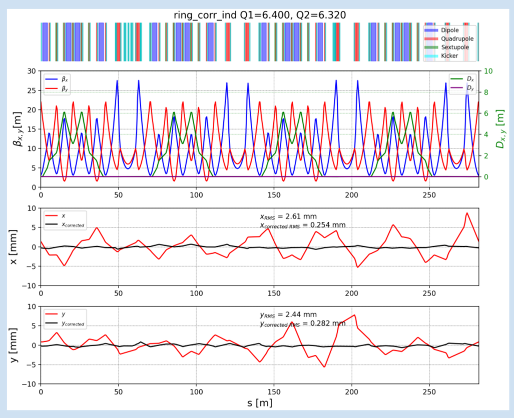

Histogram Single Particle emittances, Turn 1 and 500
$n(\varepsilon_x)$ vs $\varepsilon_x$ $n(\varepsilon_y)$ vs $\varepsilon_y$



Extraction Layout



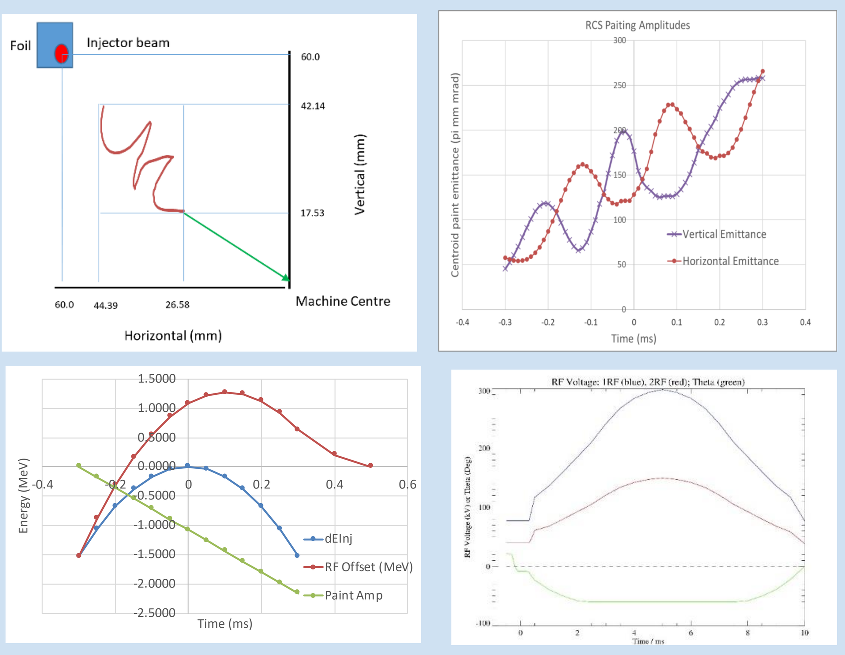
Closed Orbit Correction



## RCS Option

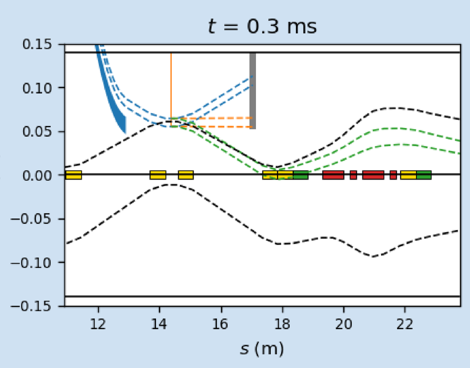
| | |
|---|---|
| **Linac** | |
| Beam Current (mA) | 57.86 |
| Energy (MeV), dE/E | 400 , 0.75e-3 |
| Pulse length (µs), chopped duty factor | 600 , 60 % |
| 100 % Emittance (un normalised) π mm mrad | 3.65 |
| Inj Line Twiss on foil ($\alpha_x$, $\beta_x$ (m),$\alpha_y$,$\beta_y$ (m)) | 0.0, 6.0, 0.0, 6.0 |
| | |
| **Ring** | |
| Inj Turns | 455 |
| Ring Twiss at foil ($\alpha_x$, $\beta_x$ (m),$\alpha_y$,$\beta_y$ (m)) | 0.0, 4.2, 0, 6.99 |
| Injection Point x,y (mm) | 60 , 60 |

Injection Paint and RF Volts

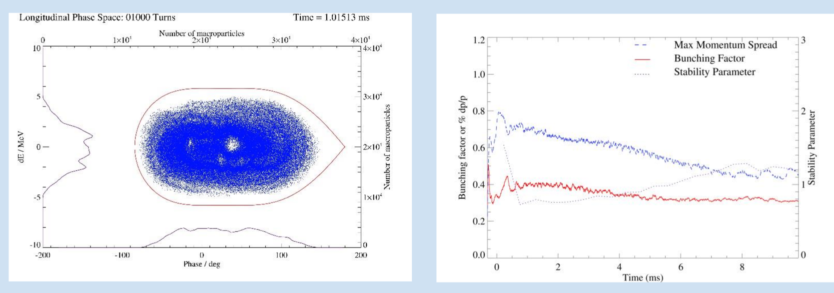


RCS: Injection Straight Design

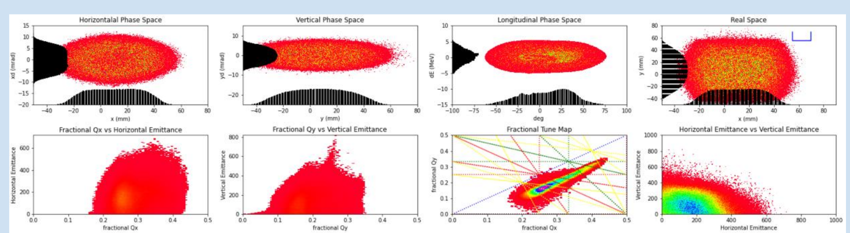
- 20 cm thick tungsten beam dump (50% safety margin)[2]
- 2.6 m long septum magnet, θ = 17.8°, B = 0.493 T




1D Beam Simulations (in house code)

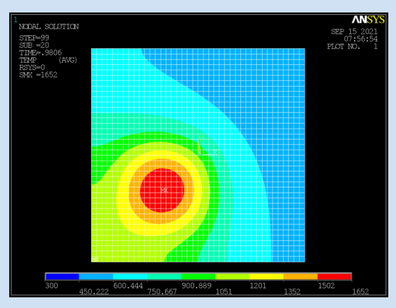


3D Beam Simulations (PyORBIT) @ Injection End



$\varepsilon_x$ , $\varepsilon_{y\ rms}$ = 84.5, 71.2 π mm mr,
$\varepsilon_x$ , $\varepsilon_{y,99\%}$=410.2 ,376.6 π mm mr.

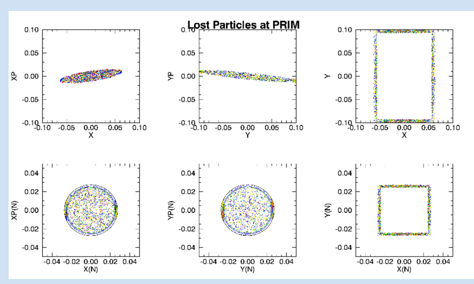
0.1 % Halo Loss
$\varepsilon_x$ , $\varepsilon_y$ = 585,585 π mm mr.



Foil

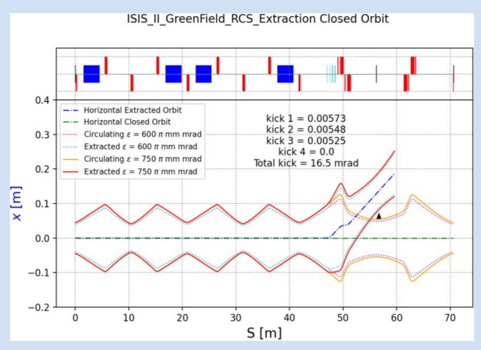
- 300 µg/cm²
- 99.4% stripping efficiency
- Peak T = 1652 K
- #recirculations = 1.3

Collimation



- $\varepsilon_P$ = 600 π mm mrad
- $\varepsilon_S$ = 650 π mm mrad
- 20 cm Tungsten jaws, Long straight
- 750 π mm mrad beam (10,000 particles) tracked from injection point in MADX

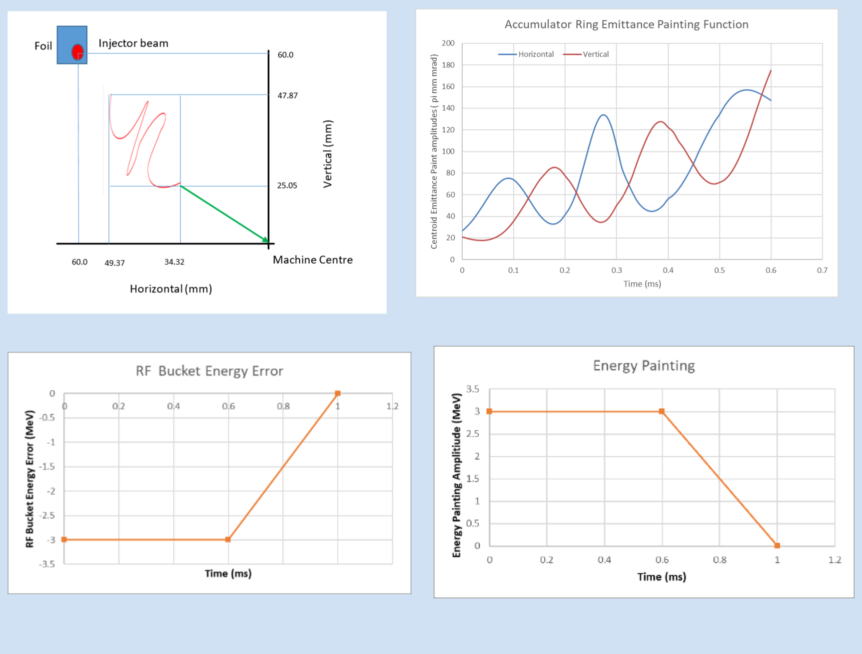
Extraction



## Accumulator Ring

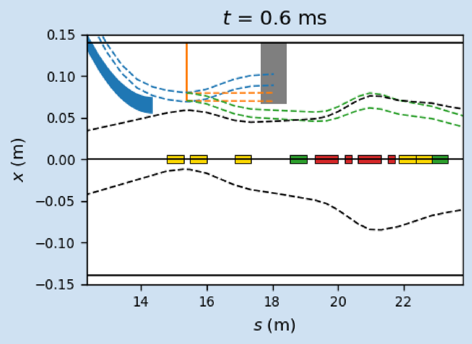
| | |
|---|---|
| **Linac** | |
| Beam Current (mA) | 57.86 |
| Energy (MeV), dE/E | 1200 , 1.6e-3 |
| Pulse length (µs), chopped duty factor | 600 , 60 % |
| 100 % Emittance (un normalised) π mm mrad | 3.65 |
| Inj Line Twiss on foil ($\alpha_x$, $\beta_x$ (m),$\alpha_y$,$\beta_y$ (m)) | 0.0, 6.0, 0.0, 6.0 |
| | |
| **Ring** | |
| Inj Turns | 573 |
| Ring Twiss at foil ($\alpha_x$, $\beta_x$ (m),$\alpha_y$,$\beta_y$ (m)) | 0.0, 4.2, 0, 6.99 |
| Injection Point x,y (mm) | 60 , 60 |

Injection Paint and RF Volts

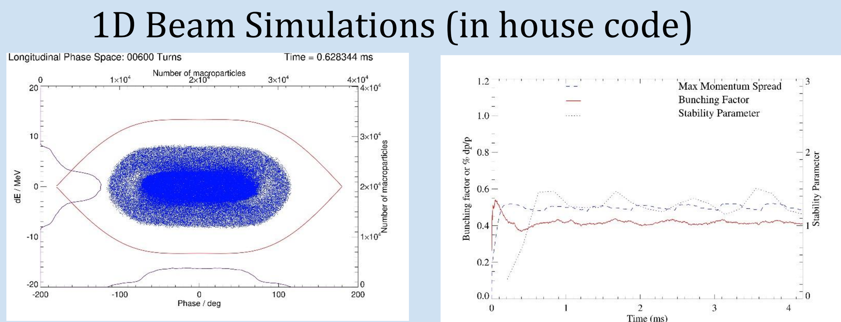


RCS: Injection Straight Design

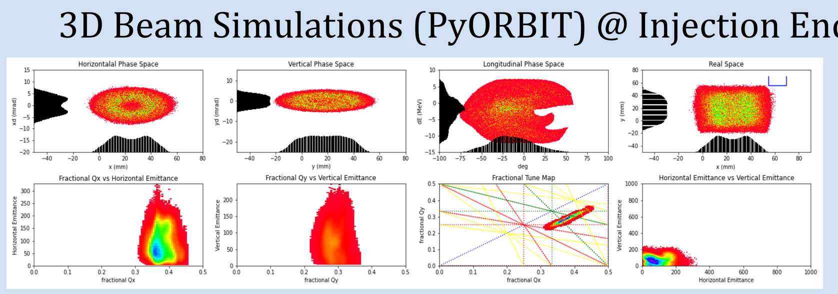
- 79 cm thick tungsten beam dump (50% safety margin)[2]
- 4.7 m long septum magnet, θ = 10.3°, B = 0.245 T




1D Beam Simulations (in house code)

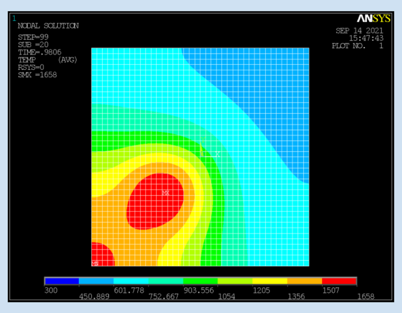


3D Beam Simulations (PyORBIT) @ Injection End



$\varepsilon_x$ , $\varepsilon_{y\ rms}$ = 44.9, 36.3 π mm mr,
$\varepsilon_x$ , $\varepsilon_{y,99\%}$=206.9 ,180.4 π mm mr.

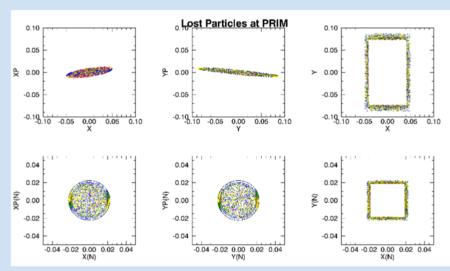
0.1 % Halo Loss
$\varepsilon_x$ , $\varepsilon_y$ = 250,250 π mm mr.



Foil

- 500 µg/cm²
- 99.4% stripping efficiency
- Peak T = 1658 K
- #recirculations = 2.5

Collimation



- $\varepsilon_P$ = 350 π mm mrad
- $\varepsilon_S$ = 400 π mm mrad
- 50 cm Tungsten jaws, Long straight
- 750 π mm mrad beam (10,000 particles) tracked from injection point in MADX

Extraction