



# WHAT ABOUT THE FRONT END?

**30 October 2010, Osaka**  
**Ciprian Plostinar**

# WIKI WARS

## ISIS neutron source

From Wikipedia, the free encyclopedia

This is an old revision of this page, as edited by [Islander](#) (talk | contribs) at 18:18, 21 July 2007. It may differ significantly from the current revision.

[\(diff\)](#) — [Previous revision](#) | [Current revision](#) ([diff](#)) | [Newer revision](#) → ([diff](#))

The **ISIS neutron source** is currently (2007) the most powerful spallation neutron source in the world. Situated at the Rutherford Appleton Laboratory in Oxfordshire, United Kingdom, it is used to enable muon and neutron scattering science to probe the structure and properties of matter, from the atomic to the biological scales. It



## ISIS neutron source

From Wikipedia, the free encyclopedia

This is an old revision of this page, as edited by [160.91.232.143](#) (talk) at 03:02, 12 August 2007. It may differ significantly from the current revision.

[\(diff\)](#) — [Previous revision](#) | [Current revision](#) ([diff](#)) | [Newer revision](#) → ([diff](#))

The **ISIS neutron source** is the second most powerful spallation neutron source in the world. Situated at the Rutherford Appleton Laboratory in Oxfordshire, United Kingdom, it is used to enable muon and neutron scattering science to probe the structure and properties of matter, from the atomic to the biological scales. It



## ISIS neutron source

From Wikipedia, the free encyclopedia

This is an old revision of this page, as edited by [Tikiwont](#) (talk | contribs) at 09:52, 18 September 2007. It may differ significantly from the current revision.

[\(diff\)](#) — [Previous revision](#) | [Current revision](#) ([diff](#)) | [Newer revision](#) → ([diff](#))

The **ISIS neutron source** is one of the most powerful spallation neutron sources in the world. Situated at the Rutherford Appleton Laboratory in Oxfordshire, United Kingdom, it is used to enable muon and neutron scattering science to probe the structure and properties of matter, from the atomic to the biological scales. It



## ISIS neutron source

From Wikipedia, the free encyclopedia

This is an old revision of this page, as edited by [J bellingham](#) (talk | contribs) at 17:09, 3 October 2007. It may differ significantly from the current revision.

[\(diff\)](#) — [Previous revision](#) | [Current revision](#) ([diff](#)) | [Newer revision](#) → ([diff](#))

**ISIS** is a World leading neutron and muon source situated at the Rutherford Appleton Laboratory in Oxfordshire, United Kingdom. It uses the techniques muon spectroscopy and neutron scattering to probe the structure and properties of matter, from the atomic to the biological scales. It provides a powerful research tool for



## Spallation Neutron Source

From Wikipedia, the free encyclopedia

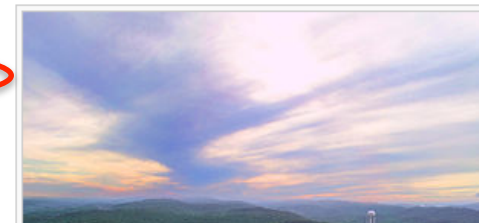
Coordinates: 35.951°



This article **needs additional citations for verification**.

Please help improve this article by adding reliable references. Unsourced material may be challenged and removed. (April 2009)

The **Spallation Neutron Source** (SNS) is an accelerator-based neutron source in Oak Ridge, Tennessee, USA, at the site of Oak Ridge National Laboratory by the U.S. Department of Energy (DOE). SNS was designed and constructed by a unique partnership of six DOE national laboratories: Argonne, Lawrence Berkeley, Brookhaven, Jefferson, Los Alamos, and Oak Ridge. As of September 1, 2007 it is the most powerful pulsed spallation neutron source in the world. At the end of 2007 SNS was recorded in the Guinness book of records.



**Contents** [\[hide\]](#)

- 1 Facility
- 2 Spallation

# HIGH INTENSITY, HIGH POWER

- Growing interest for high power proton accelerators (MW range beams)
  - Drivers for spallation neutron sources
  - Production of radioactive beams for nuclear physics
  - Nuclear Reactors
  - Transmutation of Nuclear Waste
  - Neutrino Factories for Nuclear Physics
  - Etc...



# ISIS



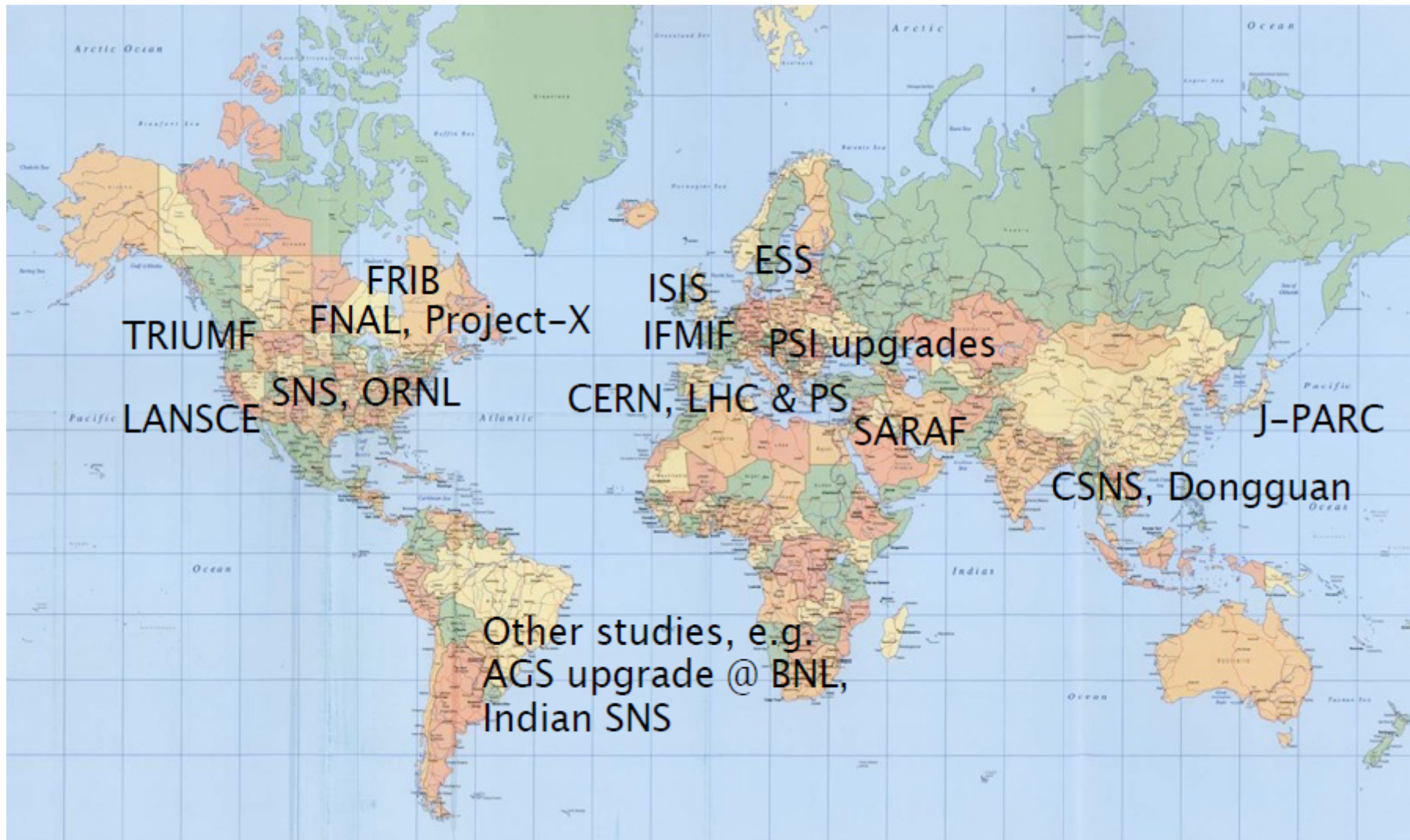
SNS



# J-PARC



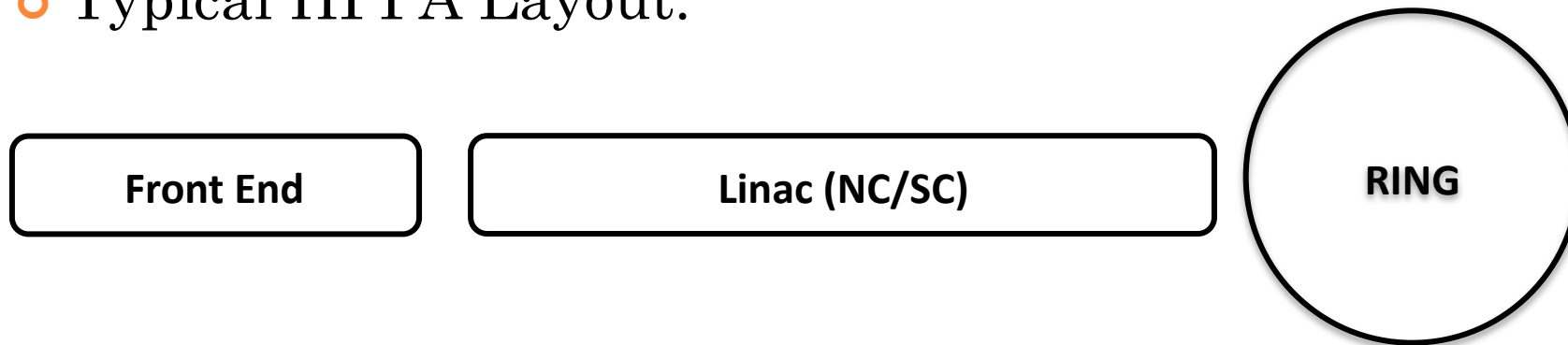
# PROJECTS WORLDWIDE



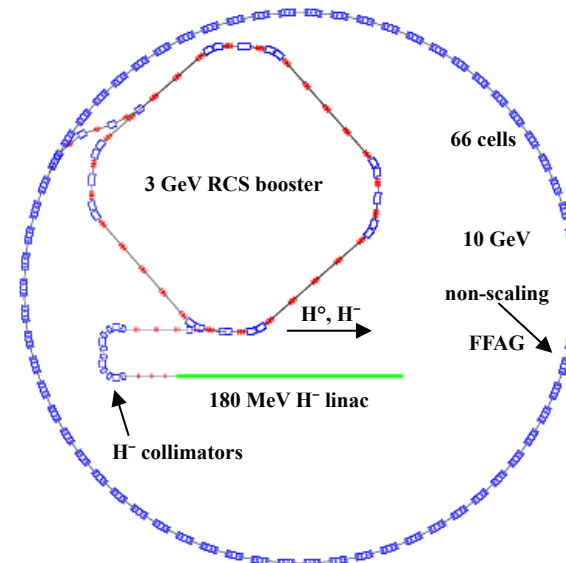
by courtesy of C. Prior

# HIGH INTENSITY, HIGH POWER

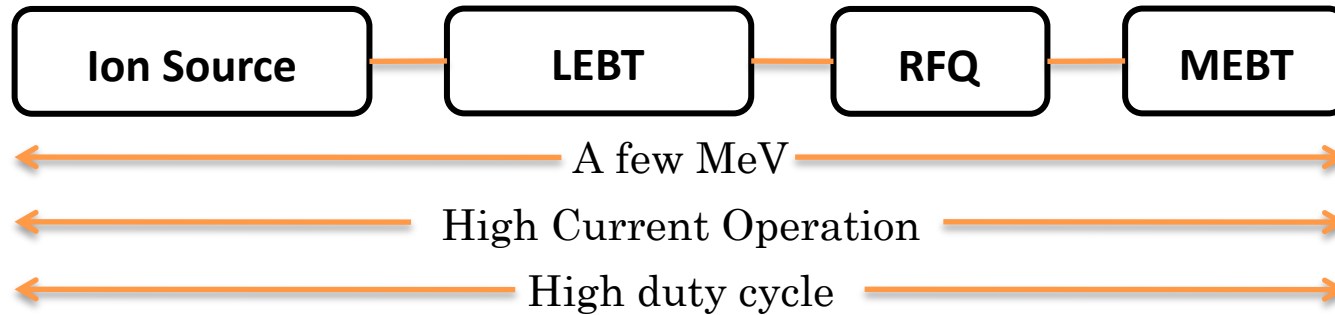
- Typical HPPA Layout:



- A proposed 50 Hz, 4 MW, 10 GeV proton driver for the Neutrino Factory based on a non-scaling FFAG

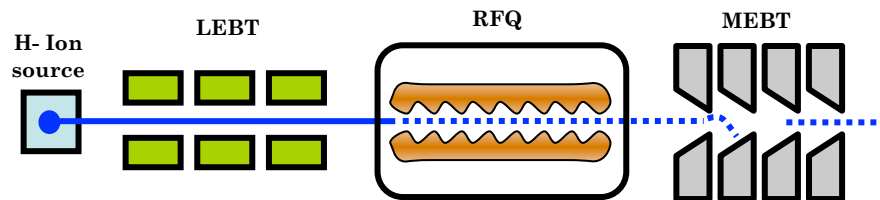


# THE FRONT END

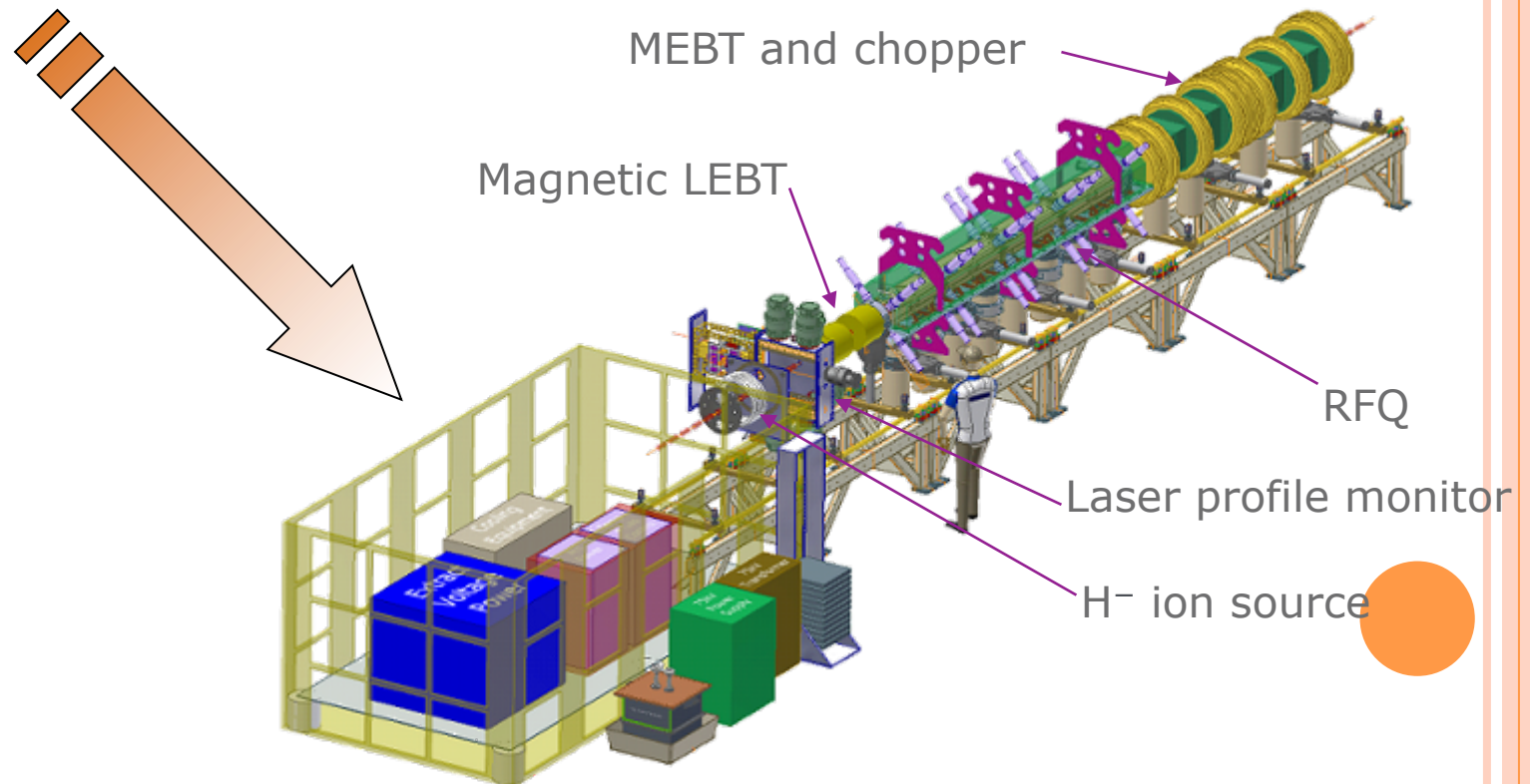
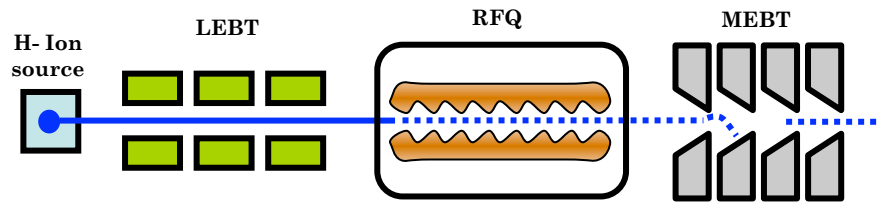


- For MW operation significant technical development is necessary.
- The Front End could be one of the bottlenecks in the acceleration chain.

# THE FRONT END TEST STAND @ RAL



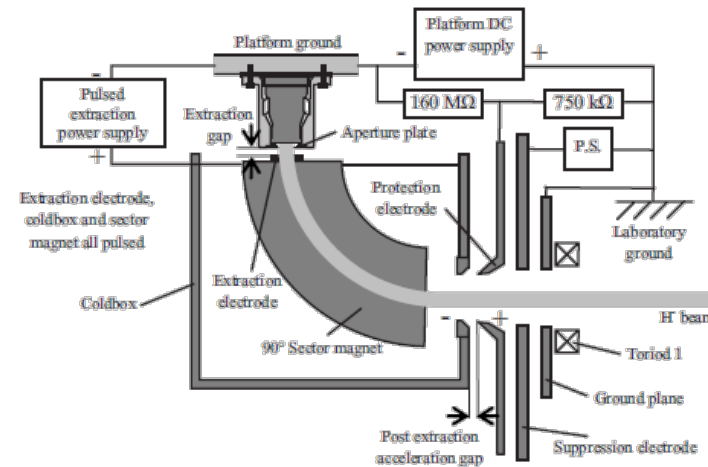
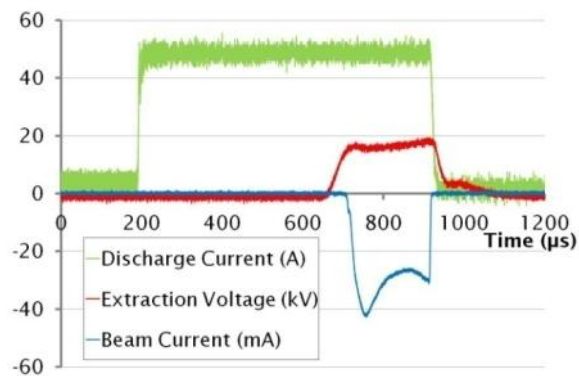
# The Front End Test Stand @ RAL



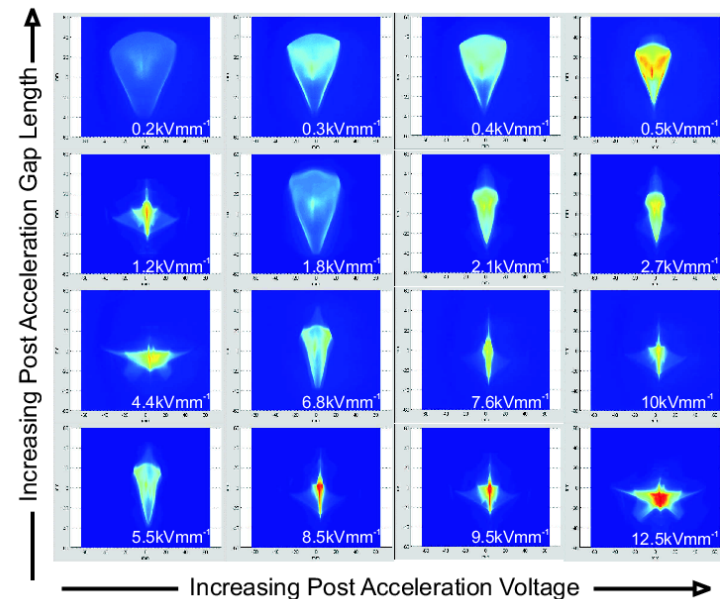
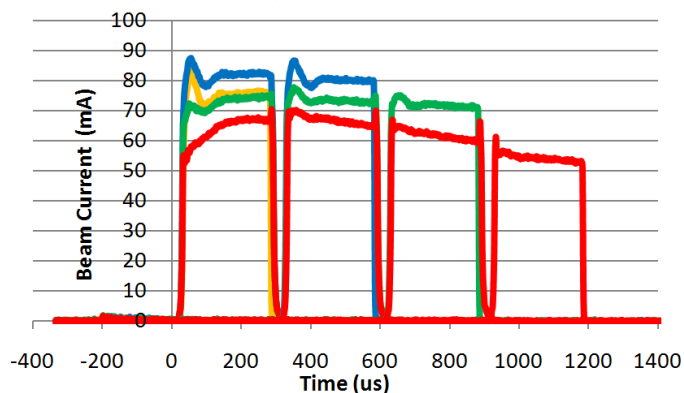
# THE FRONT END TEST STAND @ RAL

## - THE ION SOURCE -

FIRST FETS BEAM, APRIL 2009  
 35 mA H<sup>-</sup>, 200 μs, 50 Hz



LATEST BEAM CURRENT MEASUREMENTS  
 70 mA H<sup>-</sup>, 1 ms, 50 Hz



# THE FRONT END TEST STAND @ RAL

## - THE ION SOURCE -

Beam Parameter	ISIS Ion Source (presently)	FETS Ion Source
Total Energy	35 keV	65 keV
Current	55 mA (but only 35 mA to LEBT!)	60 – 70 mA
Rep. Rate	50 Hz	50 Hz
Pulse Length	200 $\mu$ s	2 ms
Normalised x emittance	0.9 $\pi$ mm mRad	0.3 $\pi$ mm mRad
Normalised y emittance	0.8 $\pi$ mm mRad	0.3 $\pi$ mm mRad

### Summary of Main Design Improvements

Duty Cycle/Cooling

Extraction

Discharge Current

Sector Magnet Poles

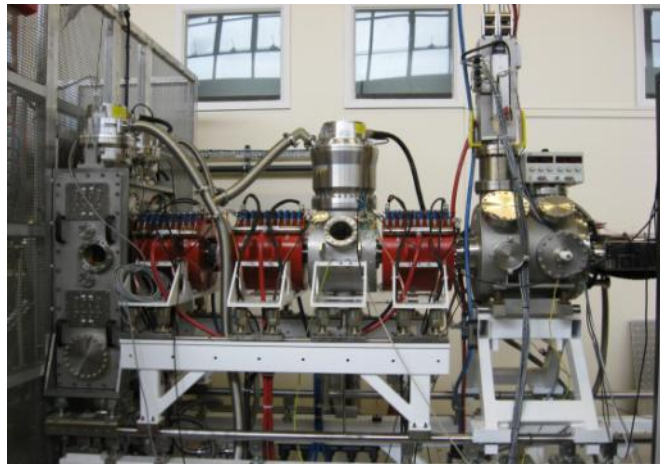
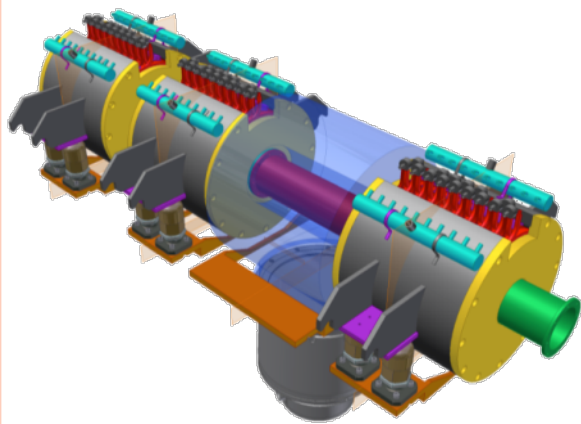
Permanent Magnet Penning Field

Postacceleration

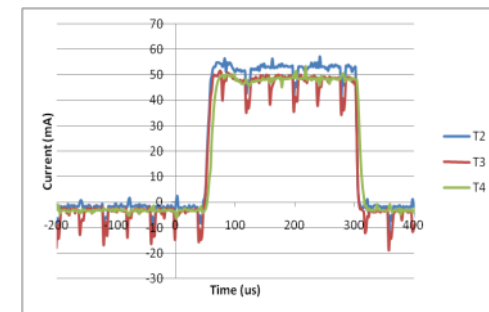
# THE FRONT END TEST STAND @ RAL

## - THE LOW ENERGY BEAM TRANSPORT LINE -

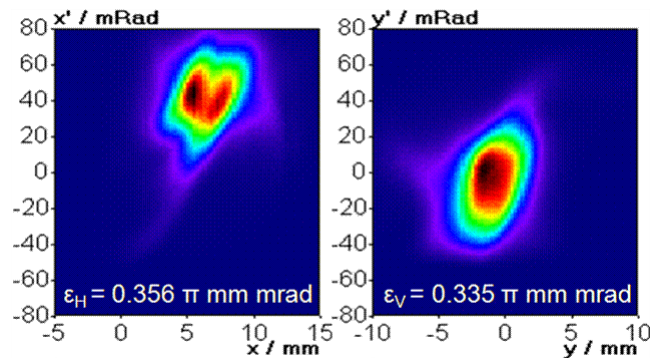
- Beam must be focussed from  $>20\text{mm}$  at Ion Source to  $2\text{-}3\text{mm}$  at RFQ.
- Large dynamic range required to handle beam size and space charge.
- 3 solenoid design provides effective focussing with minimal emittance growth.



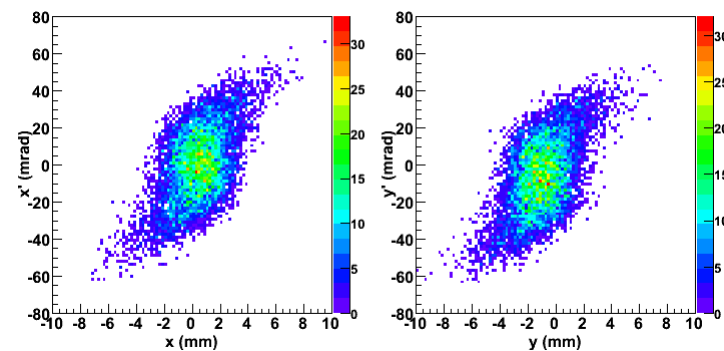
### Transmission



### Measurement

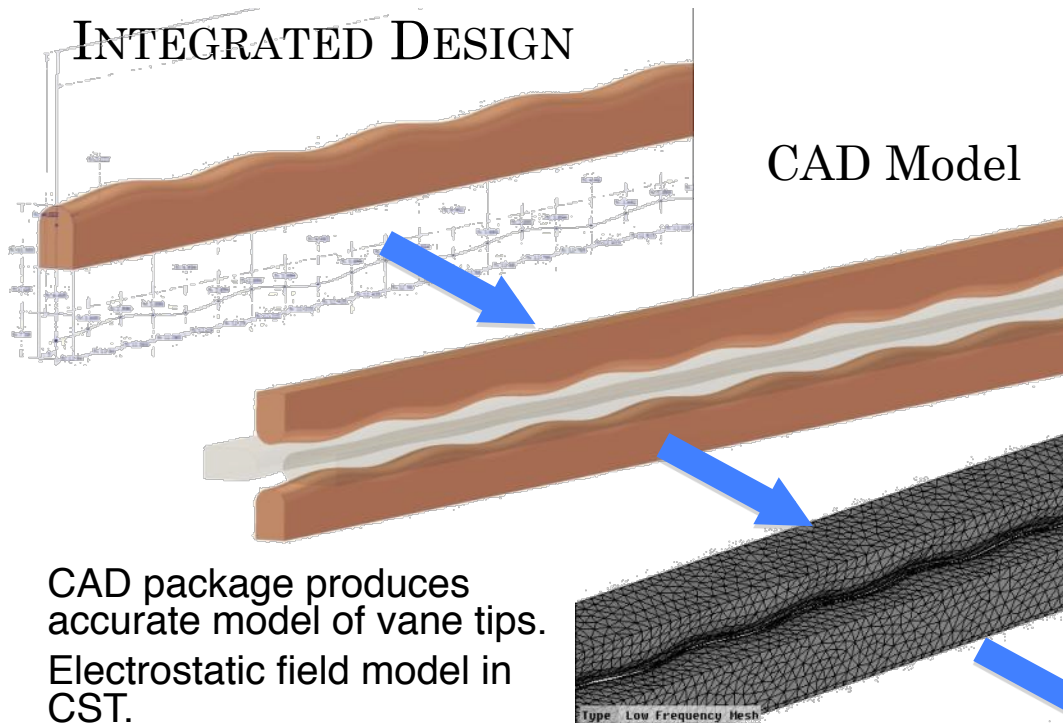


### Simulation



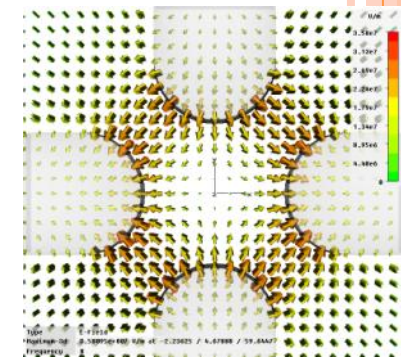
# THE FRONT END TEST STAND @ RAL - THE RFQ -

## INTEGRATED DESIGN

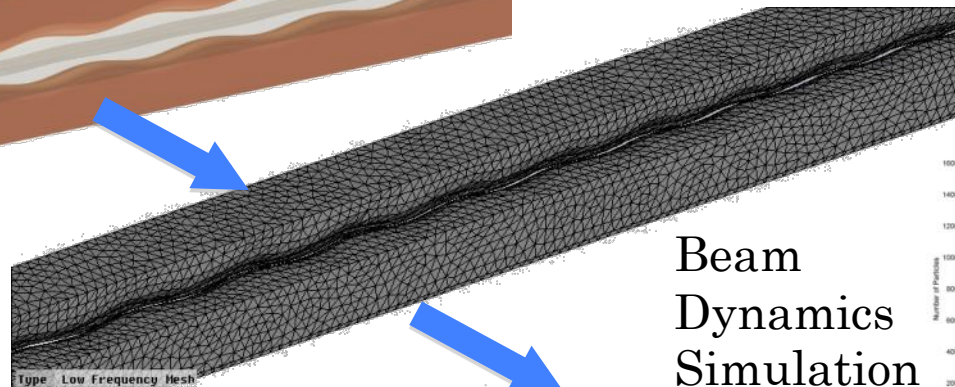


CAD Model

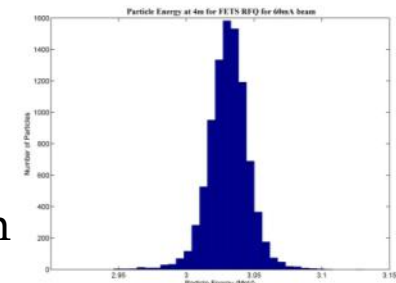
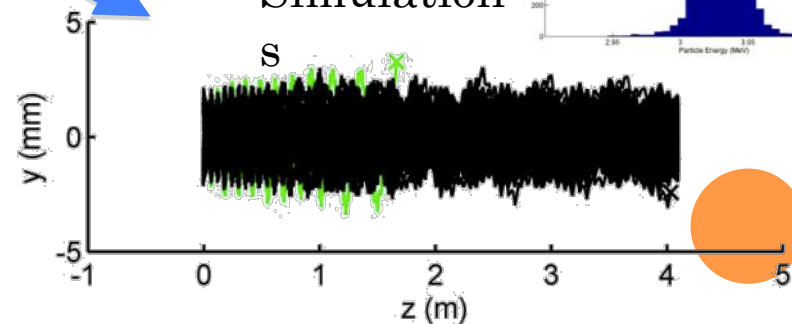
CST Field Model



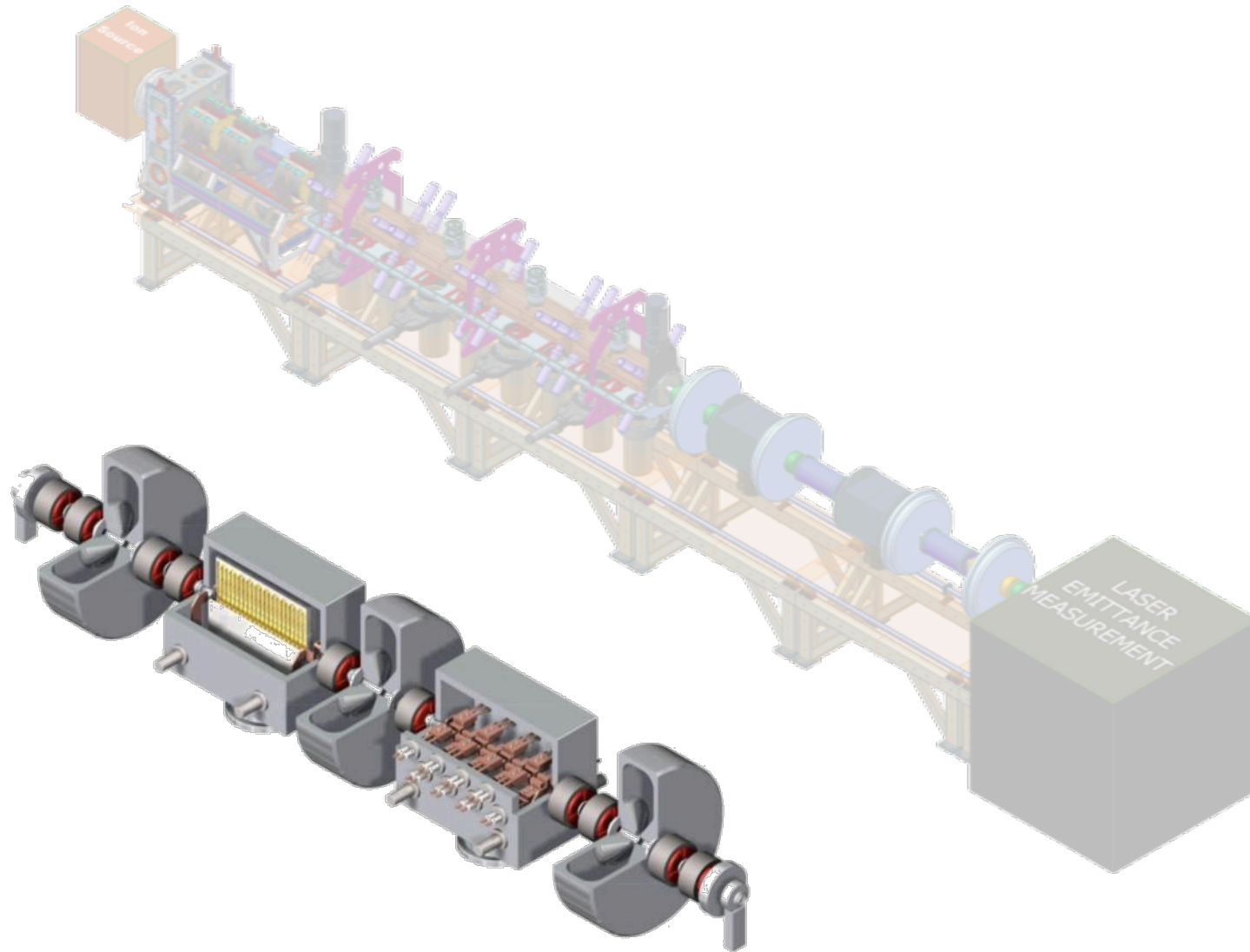
- CAD package produces accurate model of vane tips.
- Electrostatic field model in CST.
- Beam dynamics simulations in GPT.
- Good agreement between this method and RFQSIM model for 4-rod and 4-vane.
- Need to optimise RFQ design to increase acceptance.



Beam Dynamics Simulation



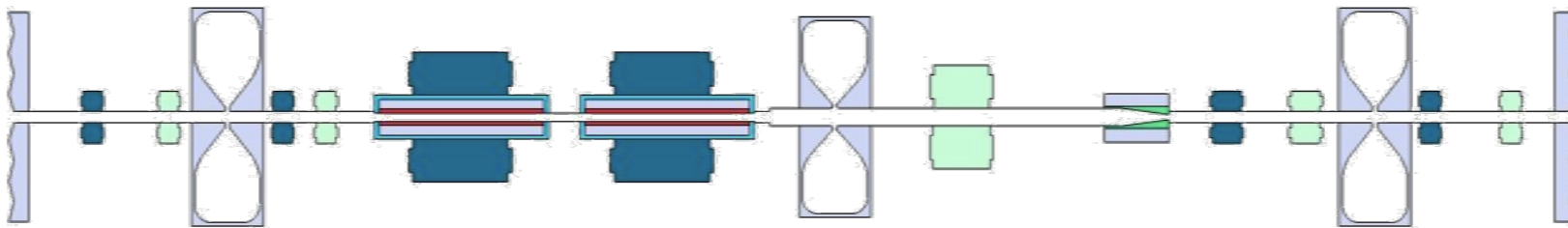
# THE FRONT END TEST STAND @ RAL - THE MEBT CHOPPER LINE -



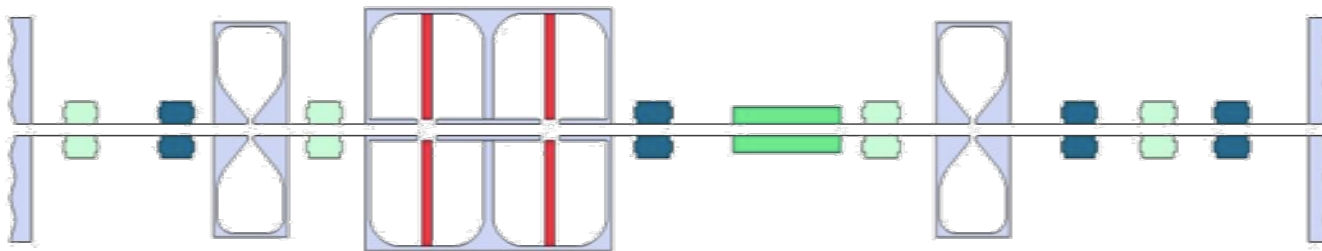
# THE FRONT END TEST STAND @ RAL

## - THE MEBT CHOPPER LINE -

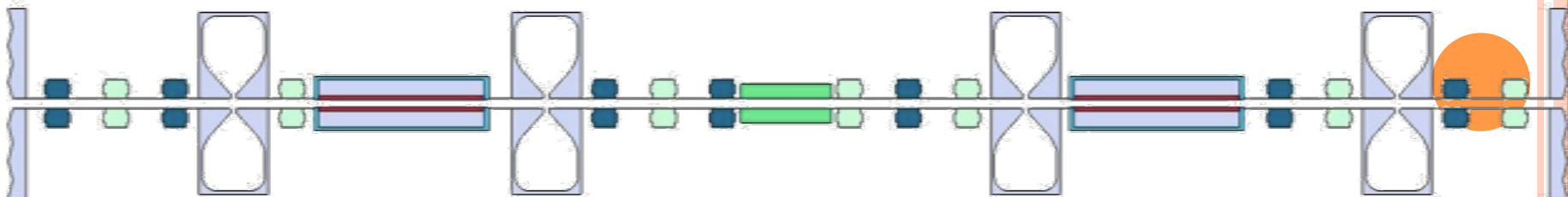
- CERN Linac4 MEBT



- J-PARC MEBT



- SNS MEBT

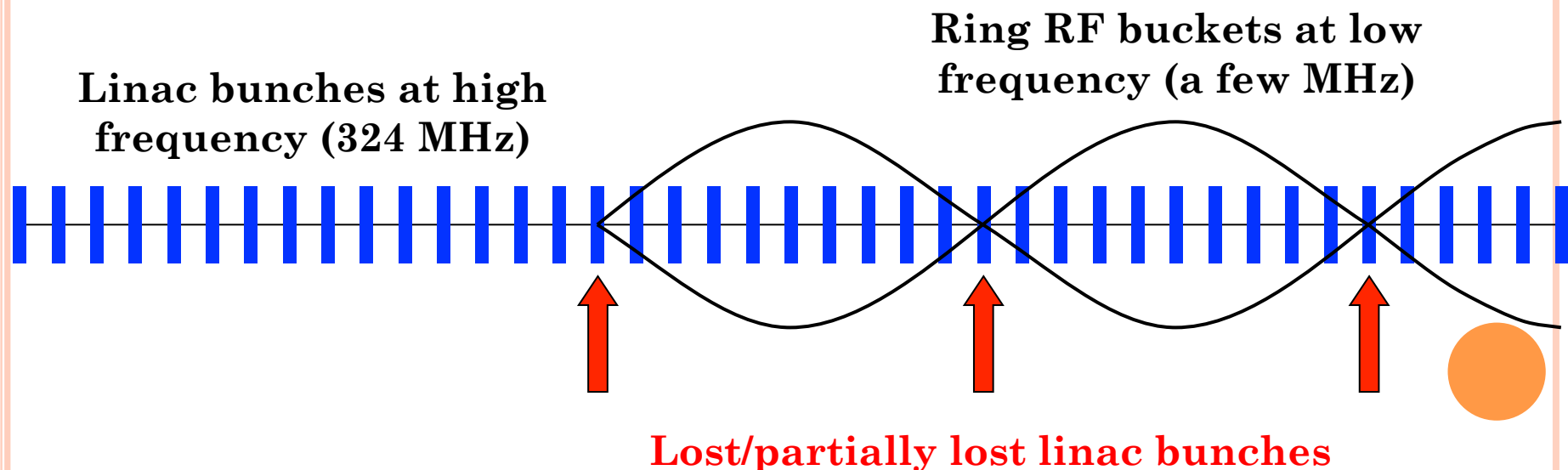


# THE FRONT END TEST STAND @ RAL

## - THE CHOPPING PRINCIPLE?

### ○ The Beam Chopper

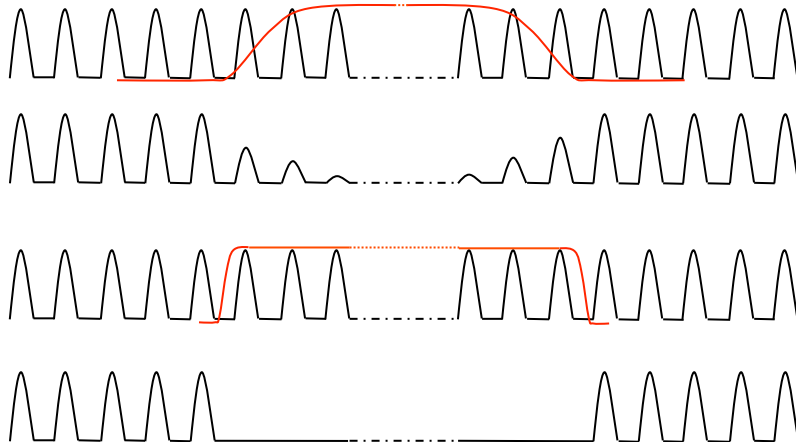
- Produces gaps in the bunched beam
- Enables low beam loss operation during injection in accumulator rings
- Low energy (2.5 – 3 MeV ), high duty cycle (~1-10%)  
beam chopping has not been demonstrated yet.



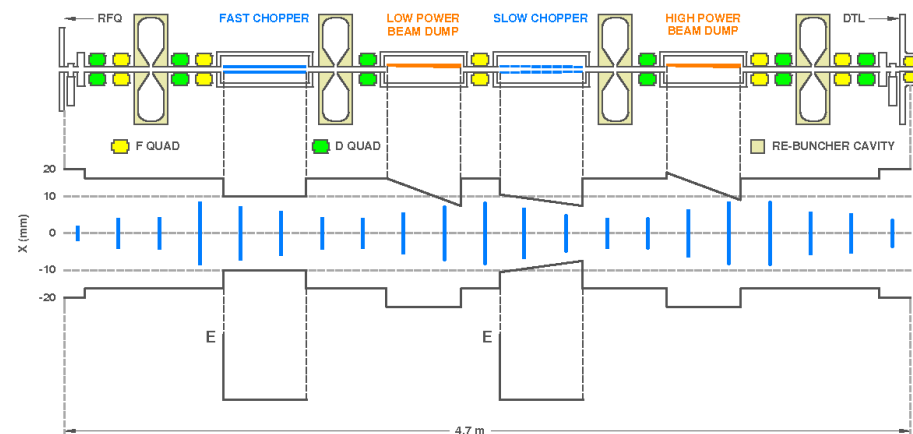
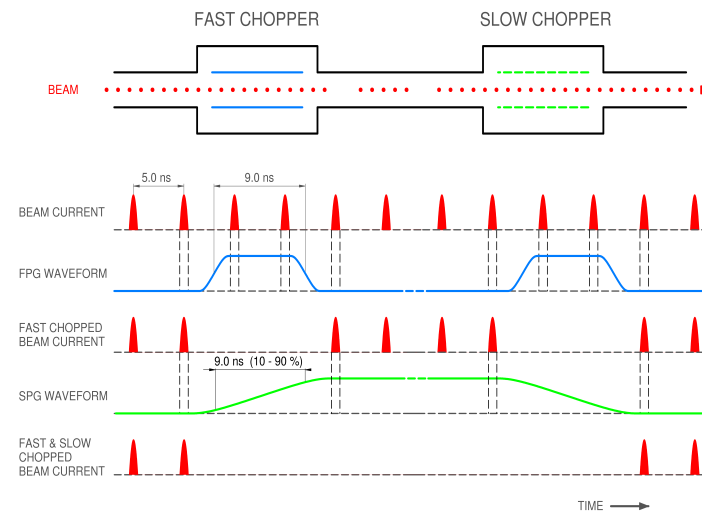
# THE FRONT END TEST STAND @ RAL

## THE FAST-SLOW CHOPPING SCHEME

To achieve perfect chopping a very high speed (<2 ns) chopper is required



### Fast-Slow Chopping Scheme



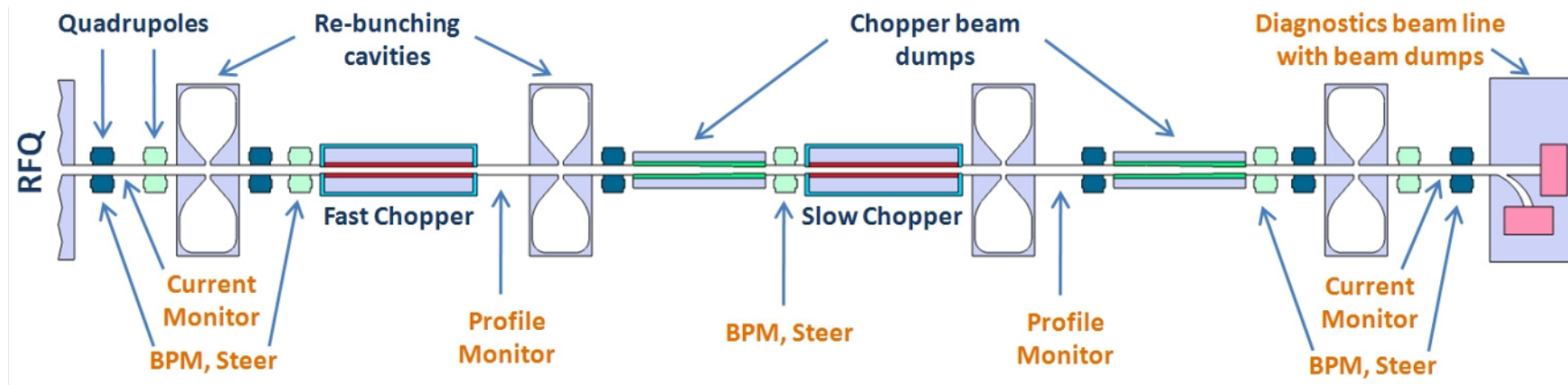
KEY PARAMETERS	SCHEME A
ION SPECIES	H-
ENERGY (MeV)	3.0
RF FREQUENCY (MHz)	324
BEAM CURRENT (mA)	40 - 60
NORMALISED RMS INPUT EMITTANCE IN X / Y / Z PLANES ( $\pi$ .mm.mr & $\pi$ .deg.MeV)	0.25 / 0.25 / 0.18
RMS EMITTANCE GROWTH IN X / Y / Z PLANES (%)	6 / 13 / 2
CHOPPING FACTOR (%)	30 - 100
CHOPPING EFFICIENCY (%)	99.9
FAST CHOPPER PULSE: TRANSITION TIME / DURATION / PRF / BURST DURATION / BRP	2 ns / 12 ns / 2.6 MHz / 0.3 - 2 ms / 50 Hz
FAST CHOPPER ELECTRODE EFFECTIVE LENGTH / GAPS (mm)	450 x 0.82 = 369 / 20
FAST CHOPPER POTENTIAL(kV)	$\pm 1.3$
SLOW CHOPPER PULSE: TRANSITION TIME / DURATION / PRF / BURST DURATION / BRP	12 ns / 250 ns - 0.1 ms / 1.3 MHz / 0.3 - 2 ms / 50 Hz
SLOW CHOPPER EFFECTIVE LENGTH / GAPS (mm)	450 x 0.85 / 18
SLOW CHOPPER POTENTIAL (kV)	$\pm 1.5$
POWER ON FAST / SLOW BEAM DUMPS (W)	150 / 850
OPTICAL DESIGN CODE(S)	IMPACT / TRACEWIN / GPT

# THE FRONT END TEST STAND @ RAL

## - THE CURRENT MEBT SCHEME -

- Two opposing requirements:
  1. Provide strong transverse focusing
  2. Provide sufficiently long empty drifts for the choppers

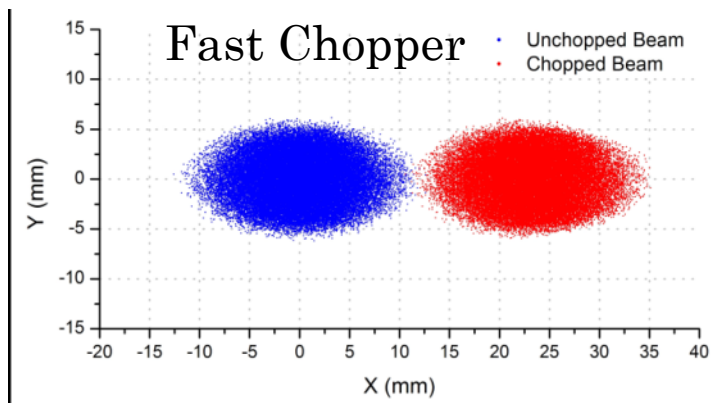
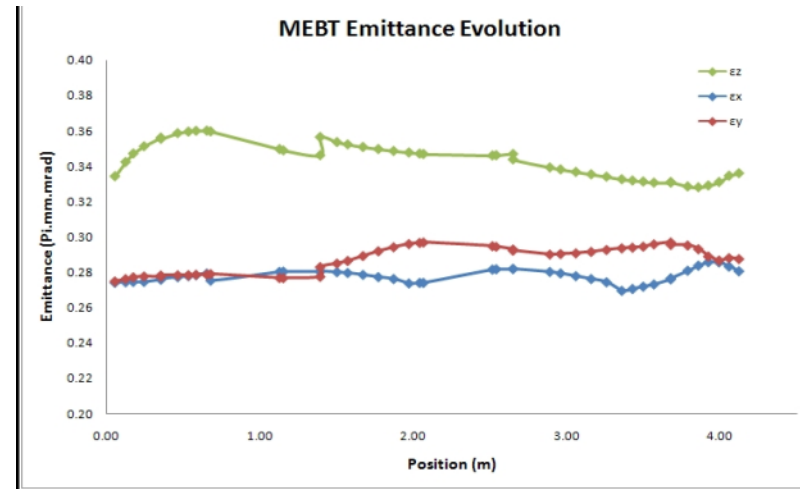
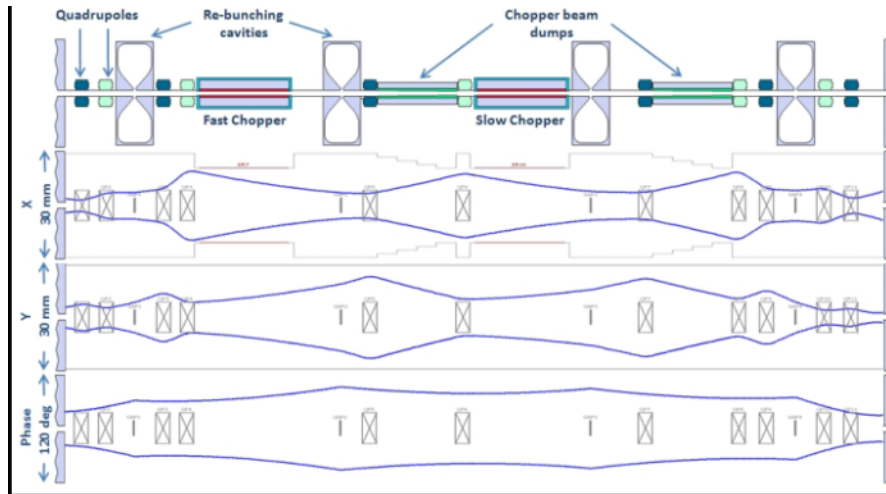
Elem. Type	No	Length	Prop.
Quadrupoles	11	70 mm	$G = 9 - 33 \text{ T/m}$
Buncher Cavities	4	200 mm	$V = 75 - 100 \text{ kV}$
Fast Chopper	1	450 mm	$V = \pm 1.3 \text{ kV}$
Slow Chopper	1	450 mm	$V = \pm 1.5 \text{ kV}$
Beam Dumps	2	400 mm	-



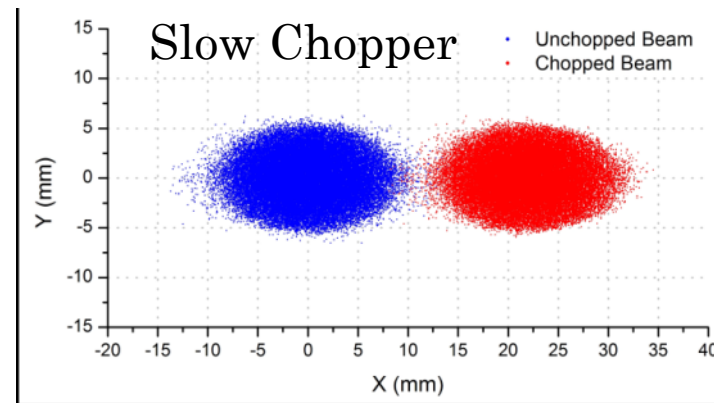
# THE FRONT END TEST STAND @ RAL

## - THE CURRENT MEBT SCHEME -

### Beam Envelopes



23.2 mm centre separation  
4.5 mm gap between the 99% emit ellipses.



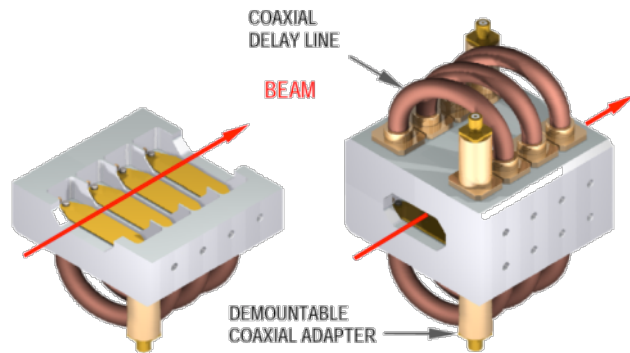
21.8 mm centre separation  
2.6 mm gap between the 99% emit ellipses.



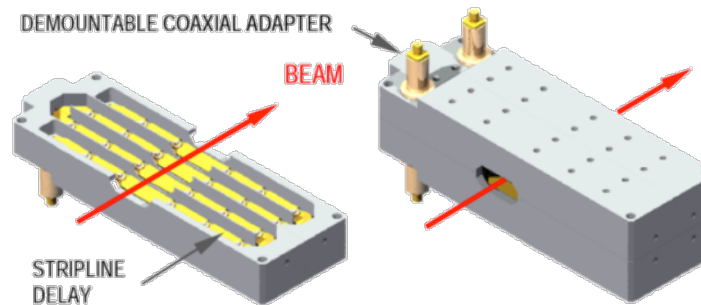
# THE FRONT END TEST STAND @ RAL - THE CURRENT MEBT SCHEME -

## Chopper Electrode Design

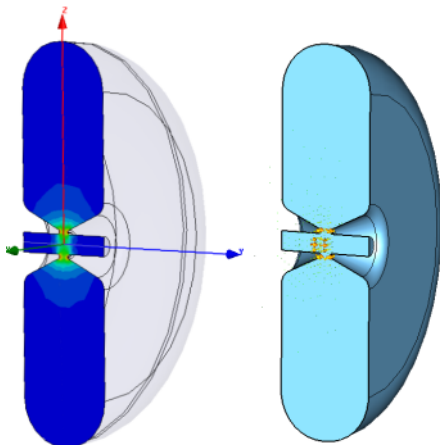
Short length helical prototype



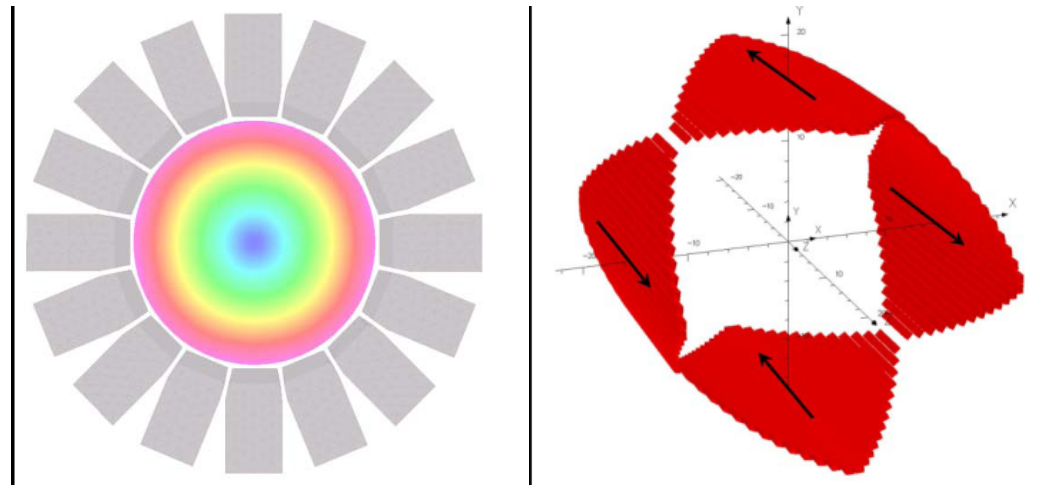
Short length planar prototype



Re-bunching cavities

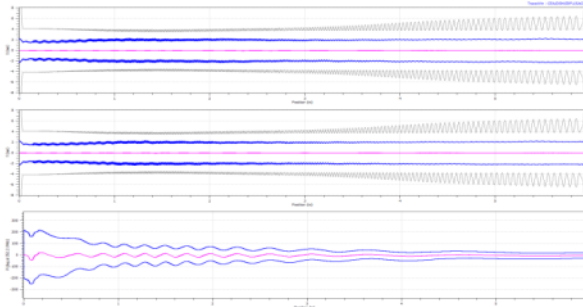


Hybrid Quadrupoles



# ALTERNATIVE MEBT DESIGN

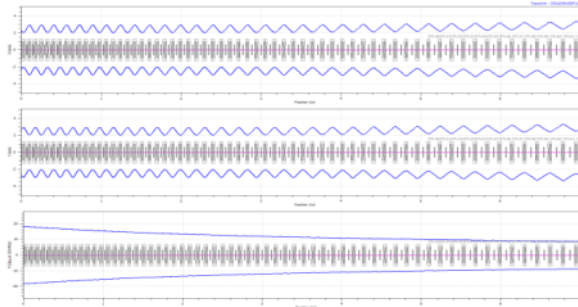
RFQ



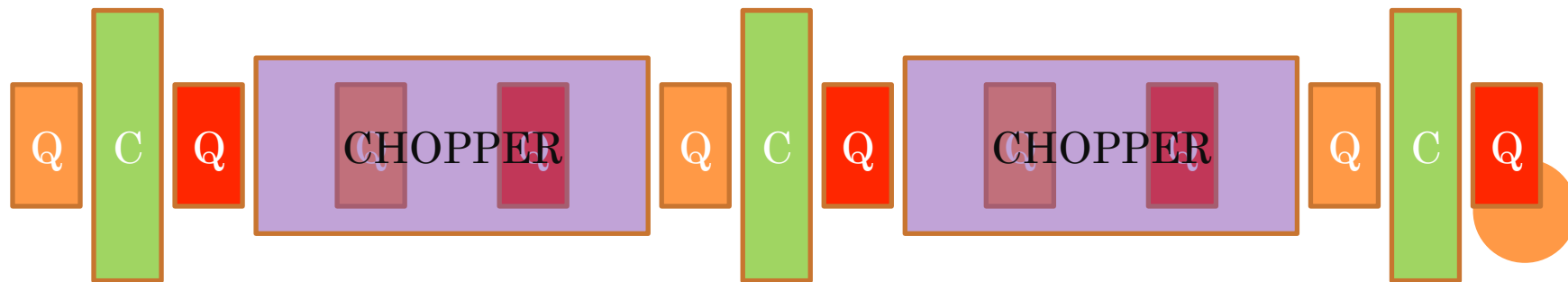
MEBT



DTL



- RFQ, DTL – focusing elements adjusted -> smooth beam phase advances
- FODO structure – high quality beam transport if the zero current phase advance/period  $< 90^\circ$  (envelope stability criteria)



# MEBT DESIGN CONSIDERATIONS

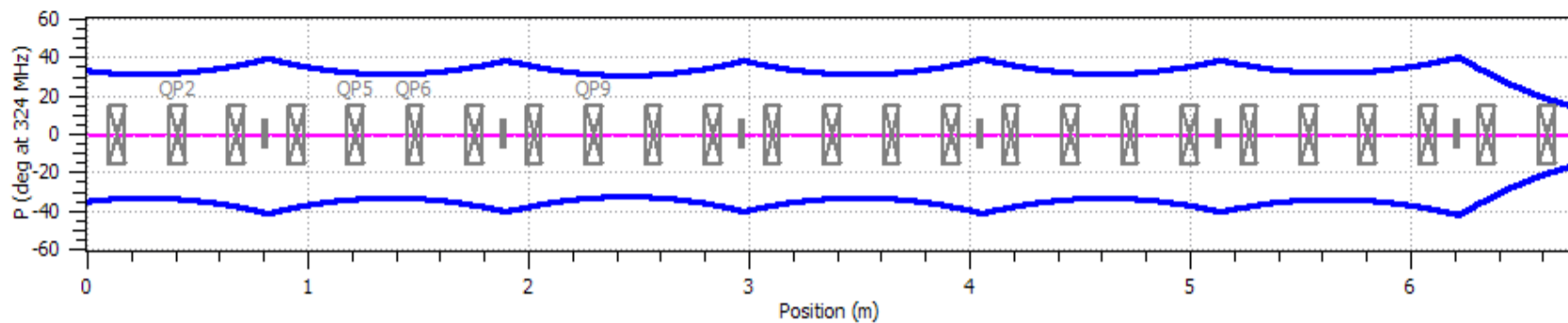
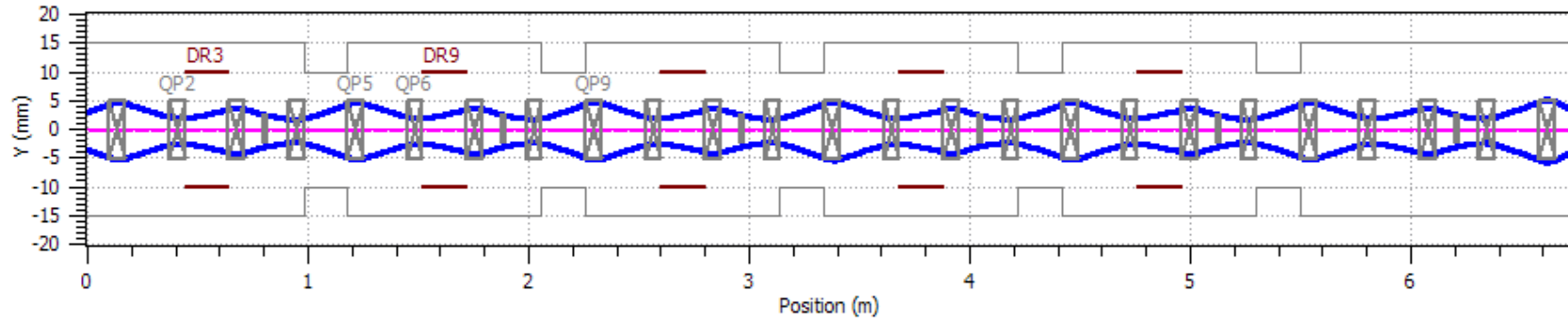
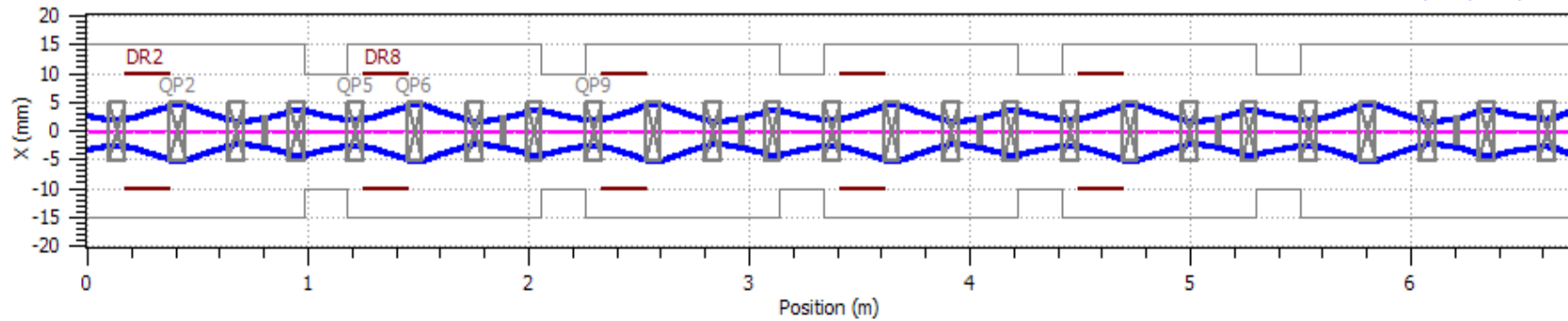
## ○ New MEBT Optics

- Regular lattice between the RFQ and the DTL (strong focusing, smooth phase advance variation - FODO).
- Multiple short beam choppers.
- The choppers can't be placed anywhere, but at positions where the kicks will add up.
- For a  $90^\circ$  phase adv/cell (FODO) the kickers should be placed in every other cell.
- Chopping in both planes (vertical & horizontal).
- Deflecting alternatively up and down (left - right).
- One can make the MEBT as long as necessary to get the required deflection.



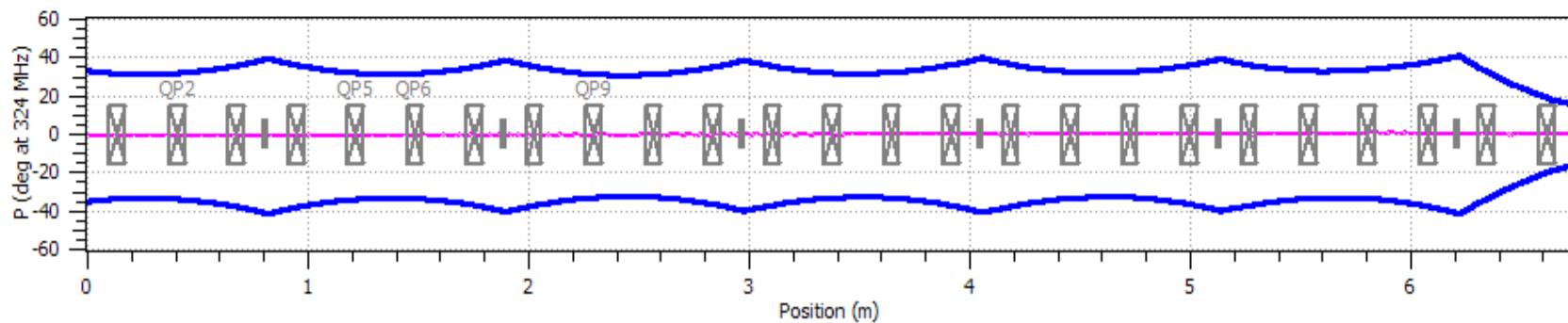
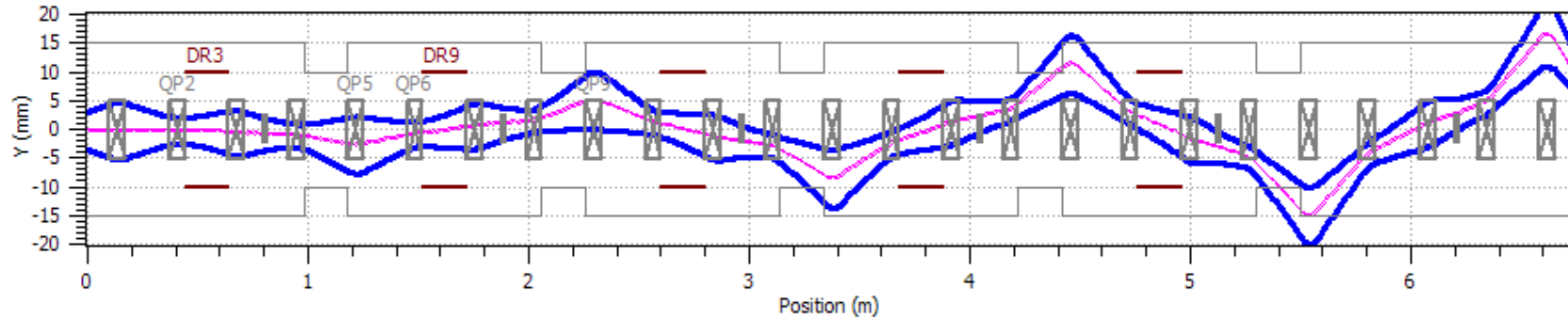
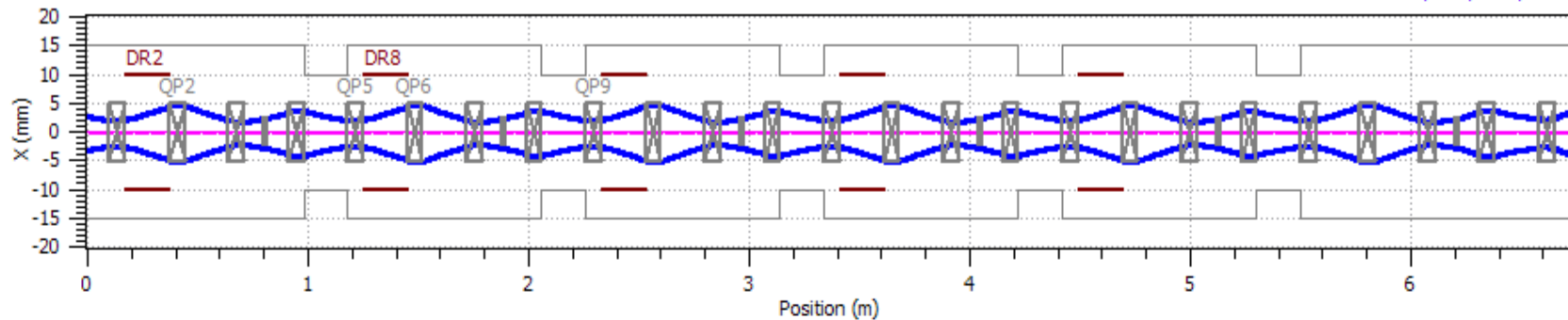
# FODO LATTICE (PRELIMINARY) – CHOPPERS OFF

TraceWin - CEA/DSM/IRFU/SACM



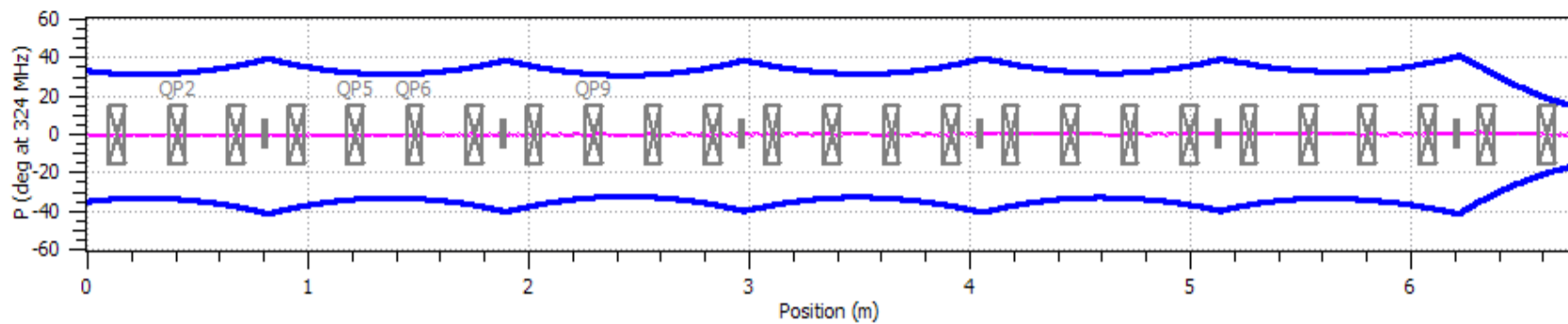
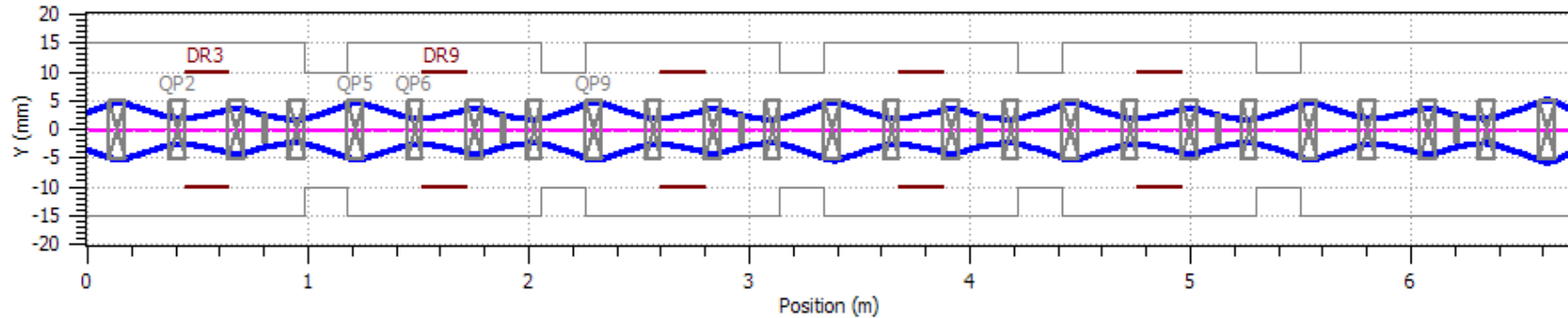
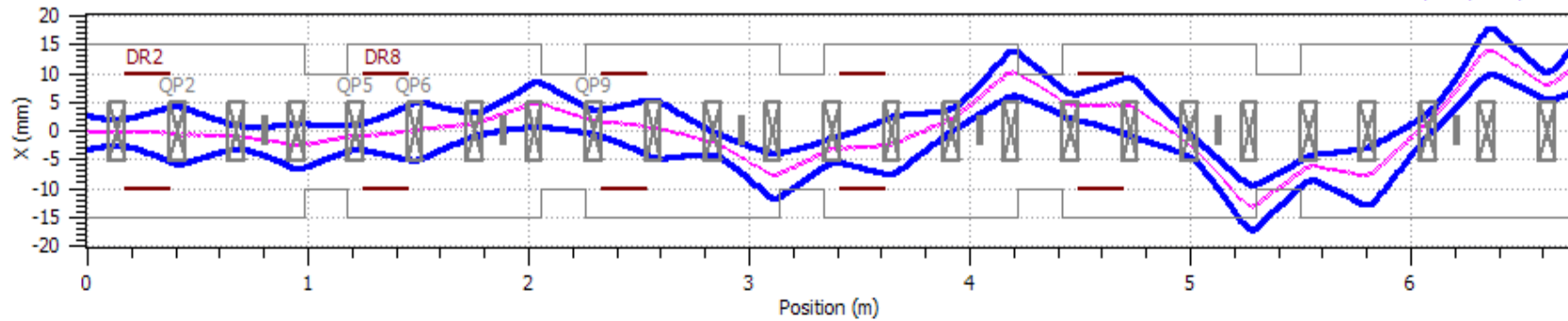
# FODO LATTICE – FAST CHOPPER ON

TraceWin - CEA/DSM/IRFU/SACM



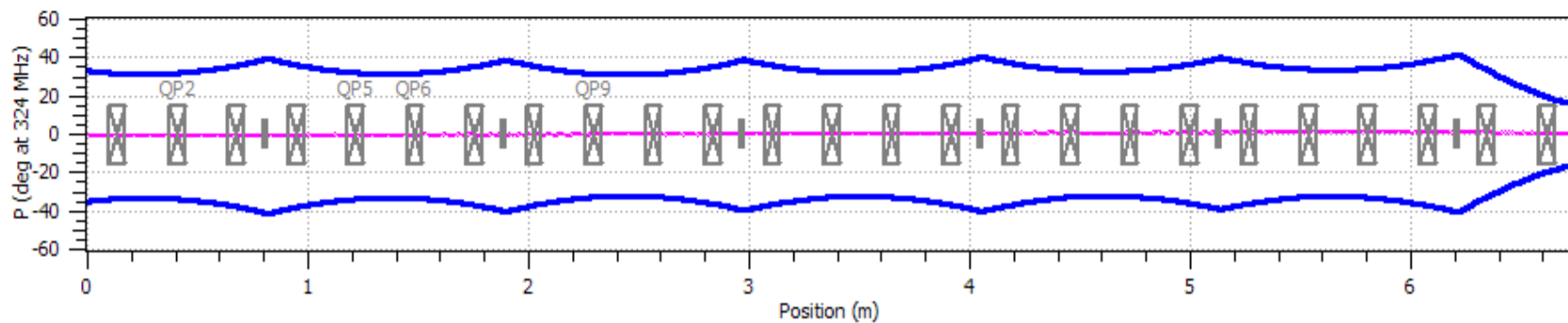
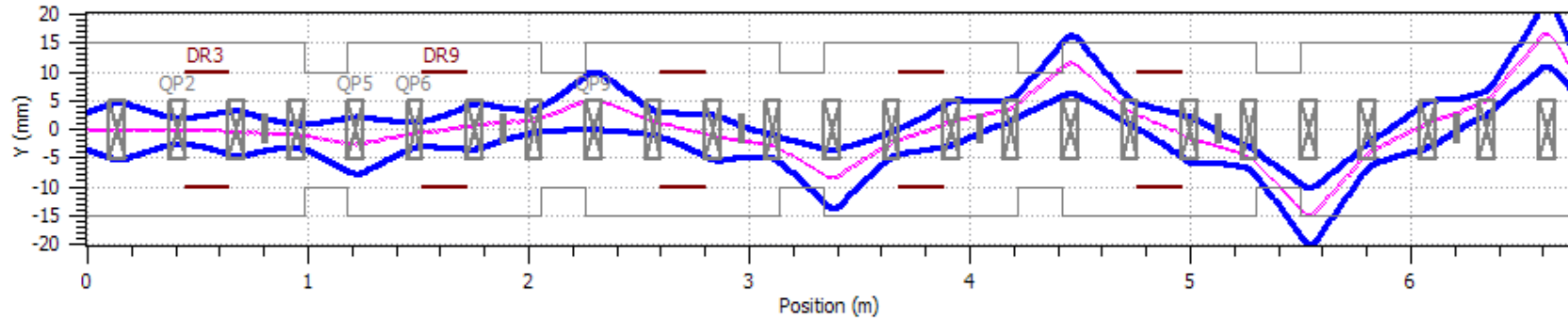
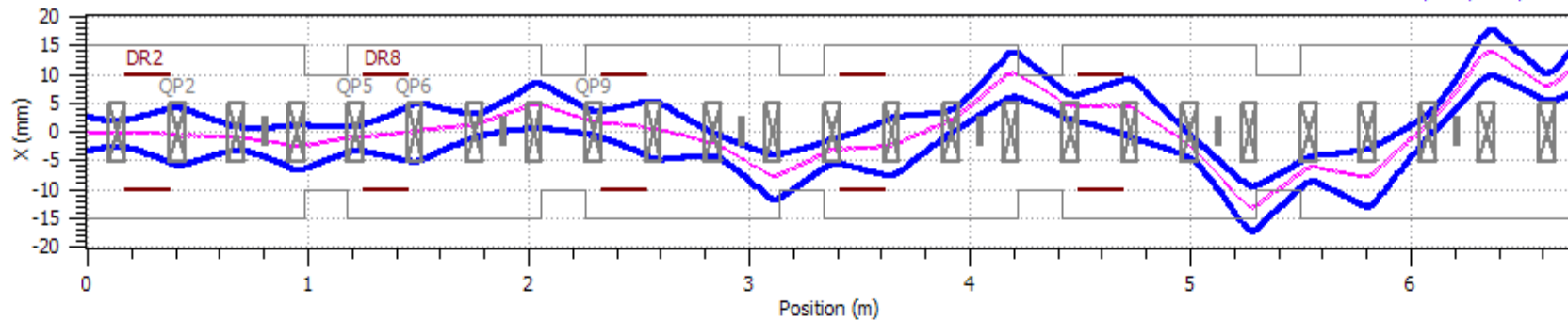
# FODO LATTICE – SLOW CHOPPER ON

TraceWin - CEA/DSM/IRFU/SACM

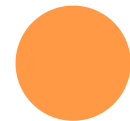
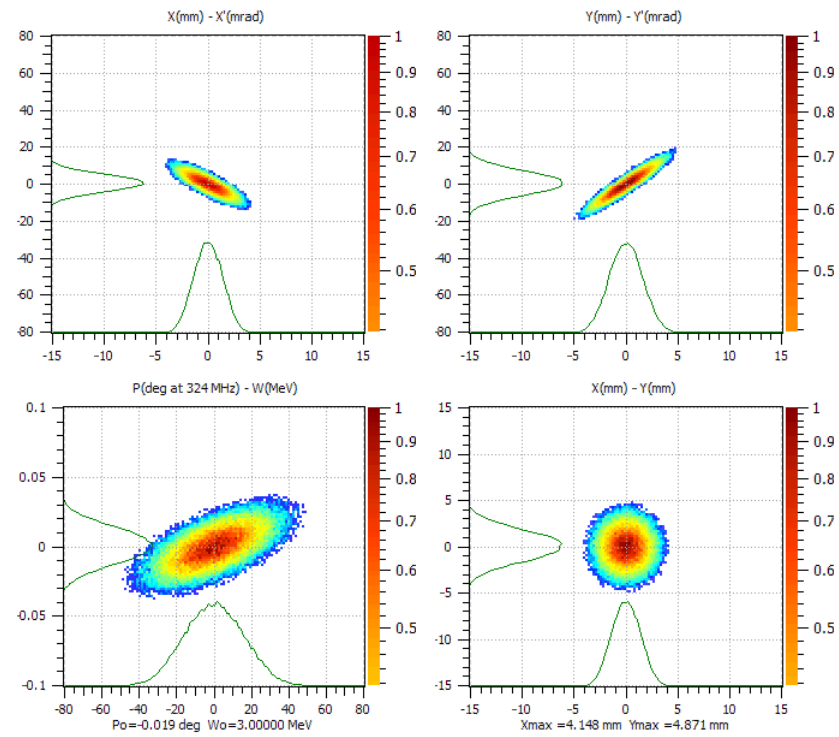
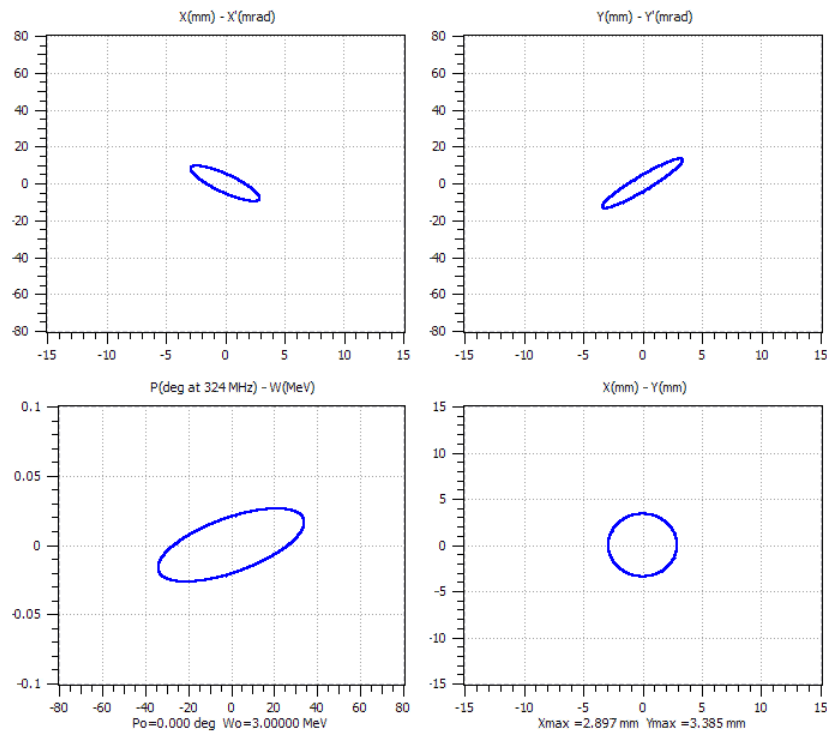


# FODO LATTICE – BOTH CHOPPERS ON

TraceWin - CEA/DSM/IRFU/SACM

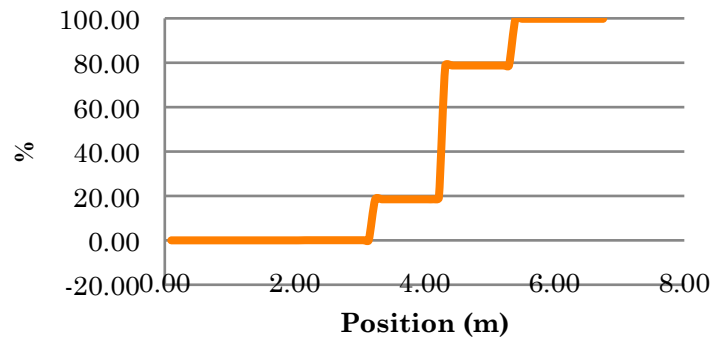


# FODO LATTICE – BOTH CHOPPERS ON

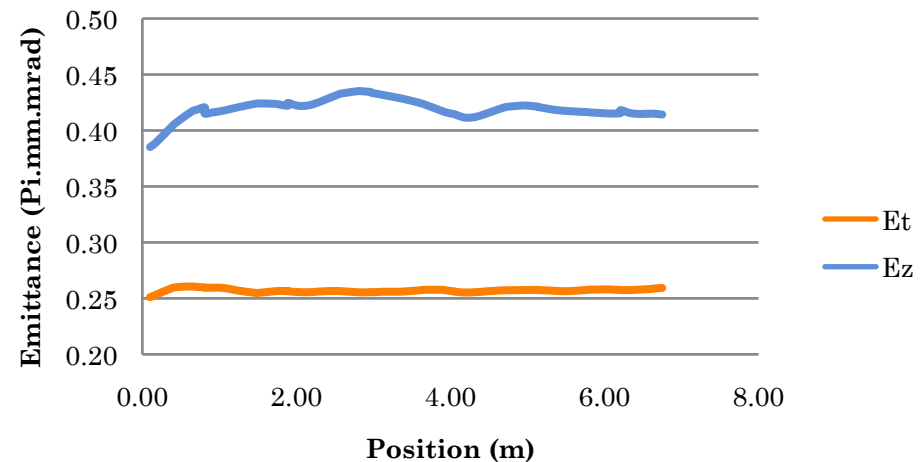


# FODO LATTICE

**FODO: Chopped beam by the slow chopper(%)**



**FODO MEBT - Emittance Evolution**

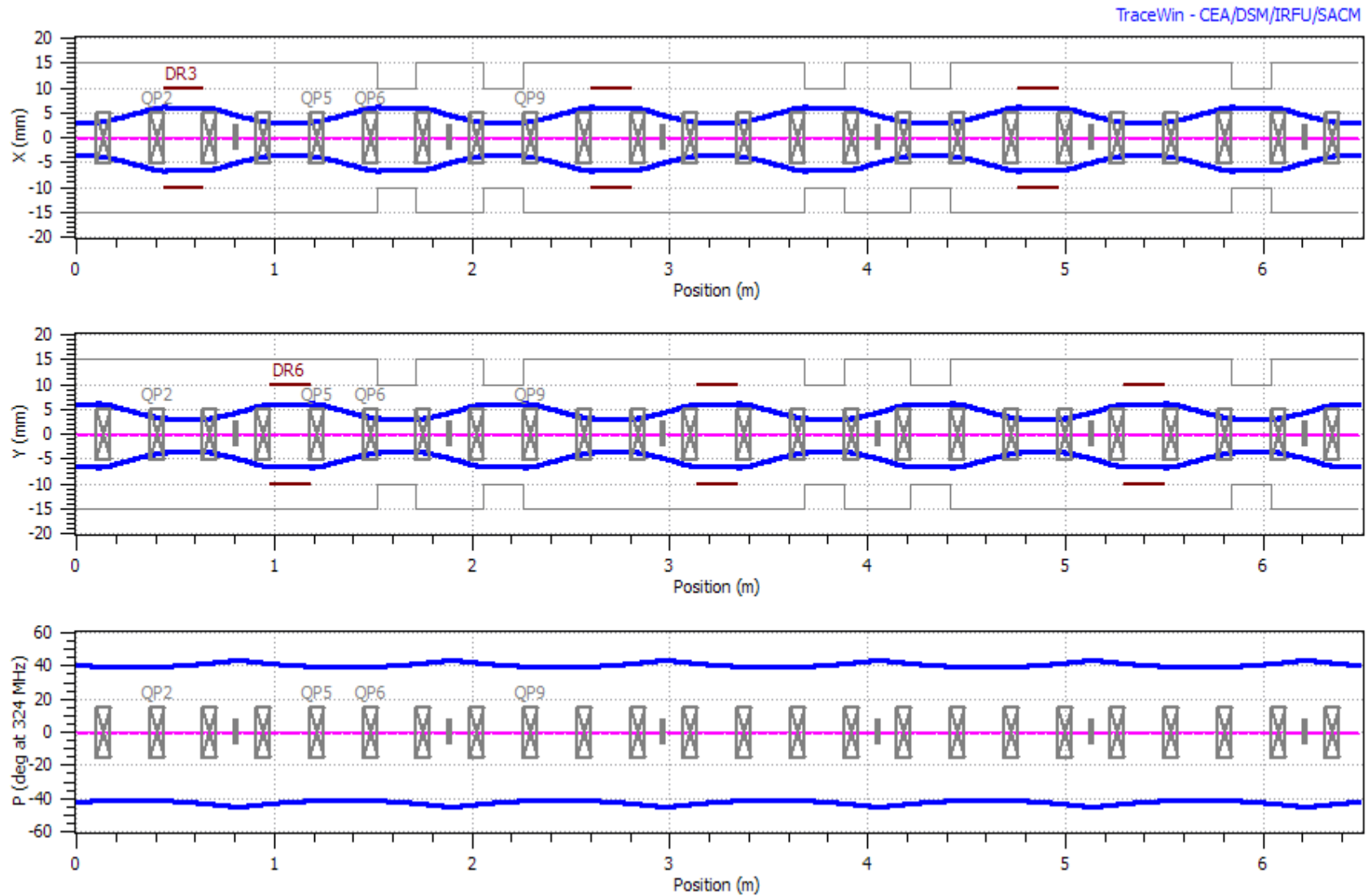


## Advantages

- Small emittance growth
- Zero Losses
- No partially chopped beam
- ~20% less voltage required on the chopper plates in current configuration (coverage factor not taken into account)
- Chopped beam distributed on several beam dumps
- Easier DTL matching
- Can add more cells if required, to reduce the voltage

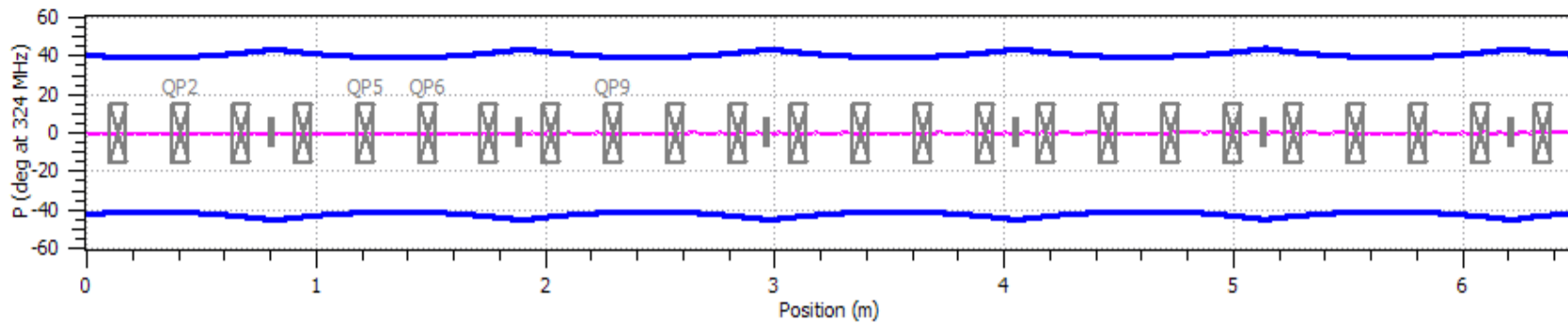
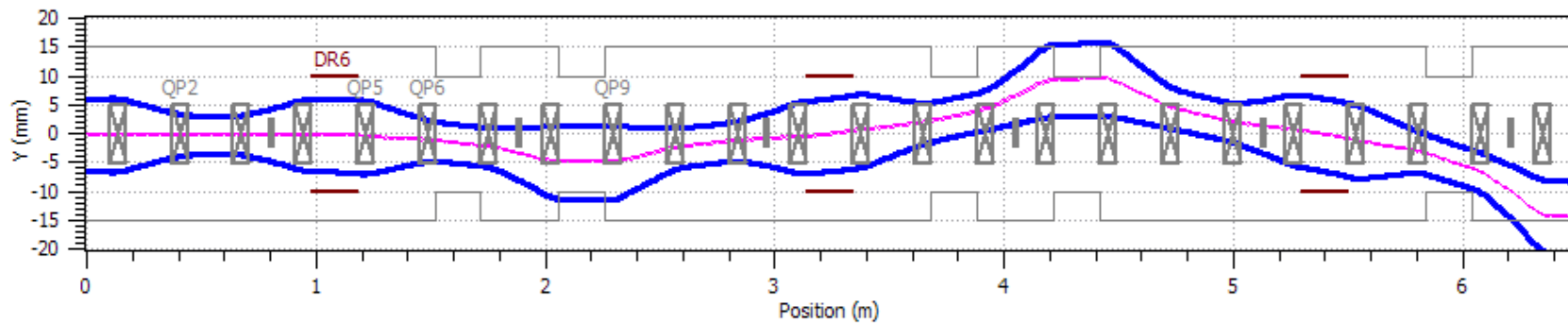
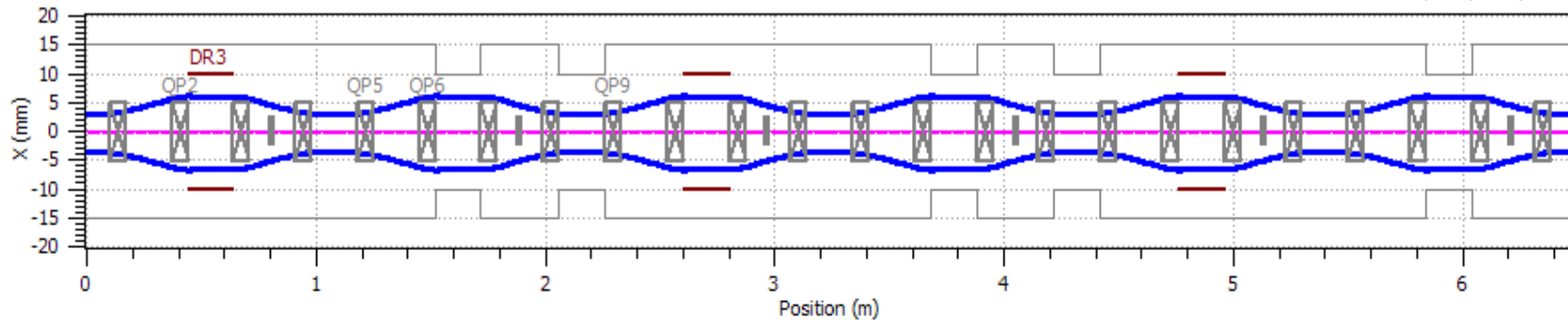


# FFDD LATTICE (PRELIMINARY) – CHOPPERS OFF

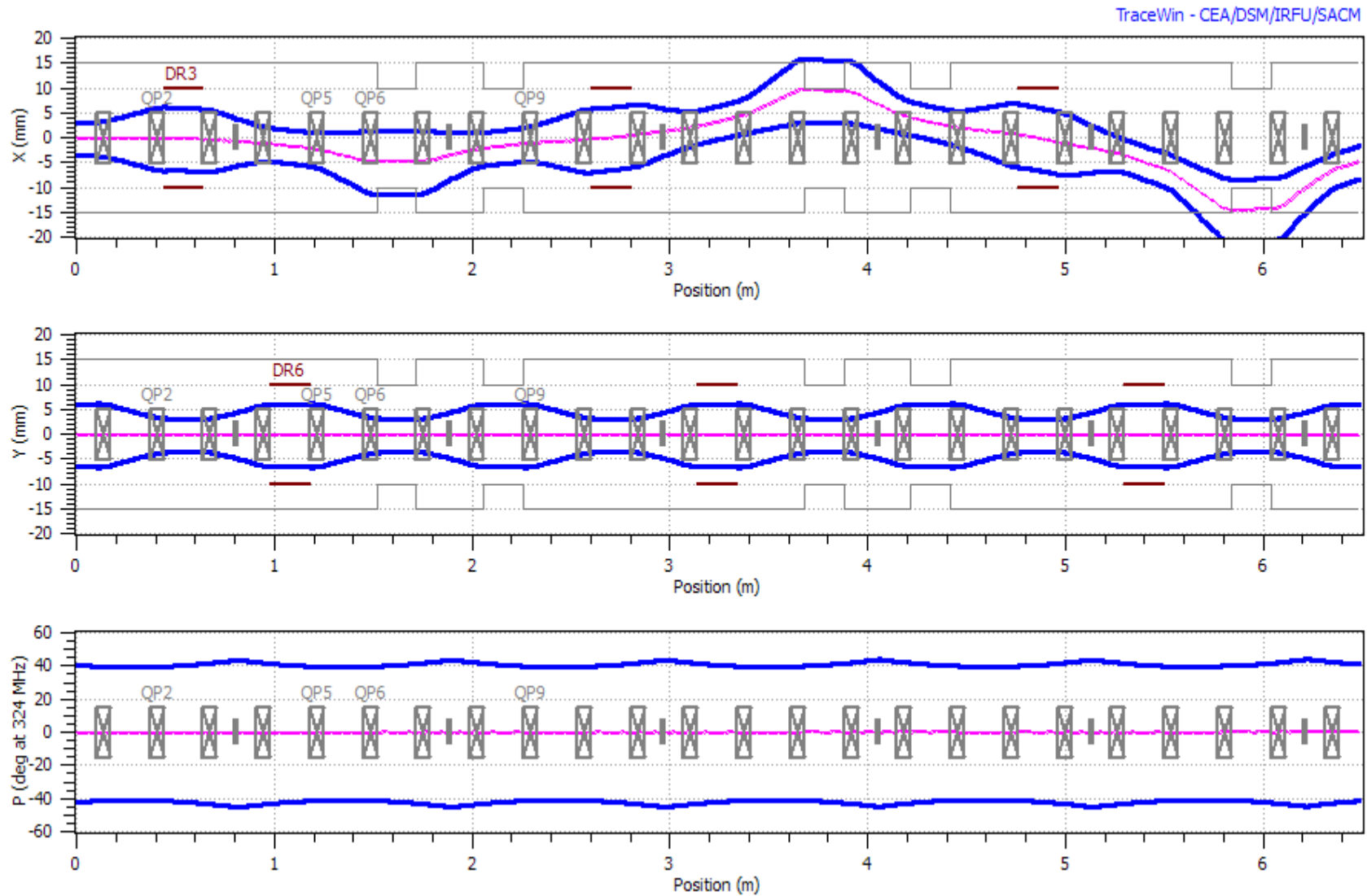


# FFDD LATTICE – FAST CHOPPER ON

TraceWin - CEA/DSM/IRFU/SACM

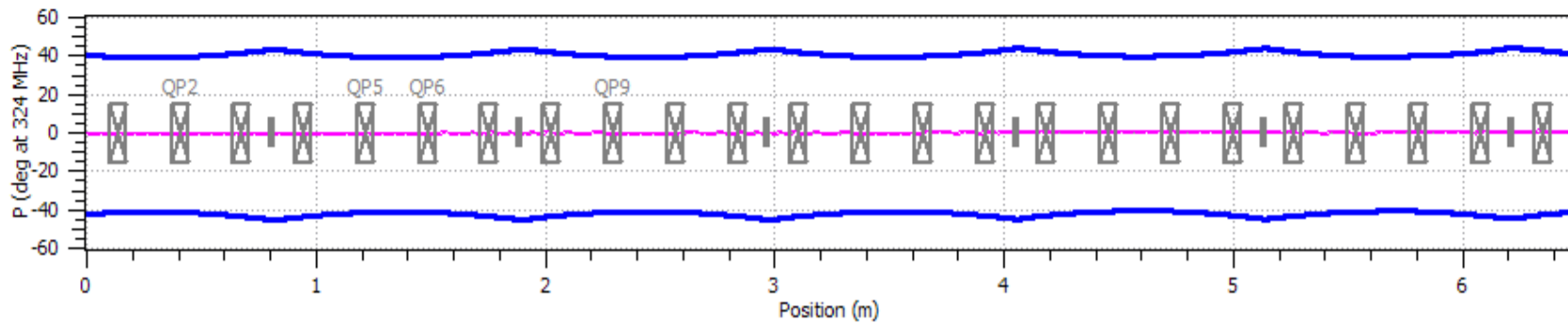
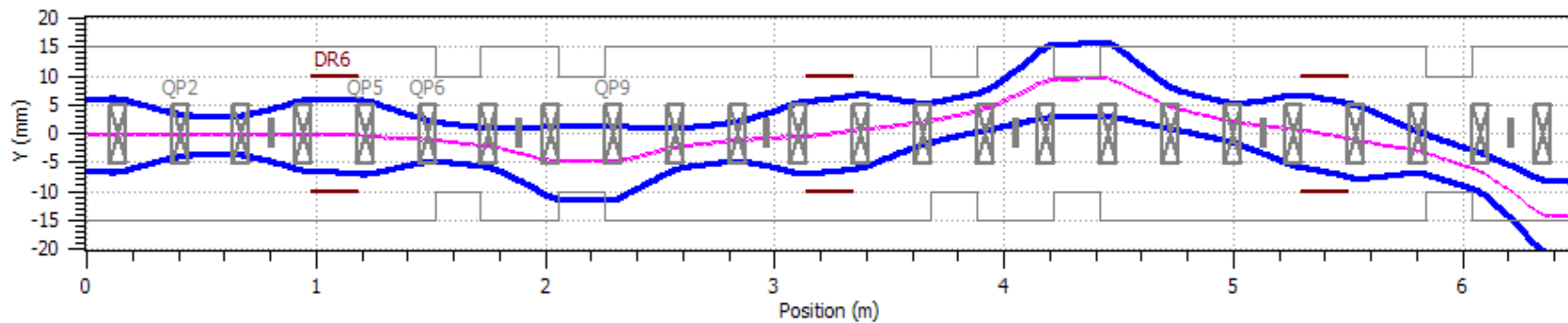
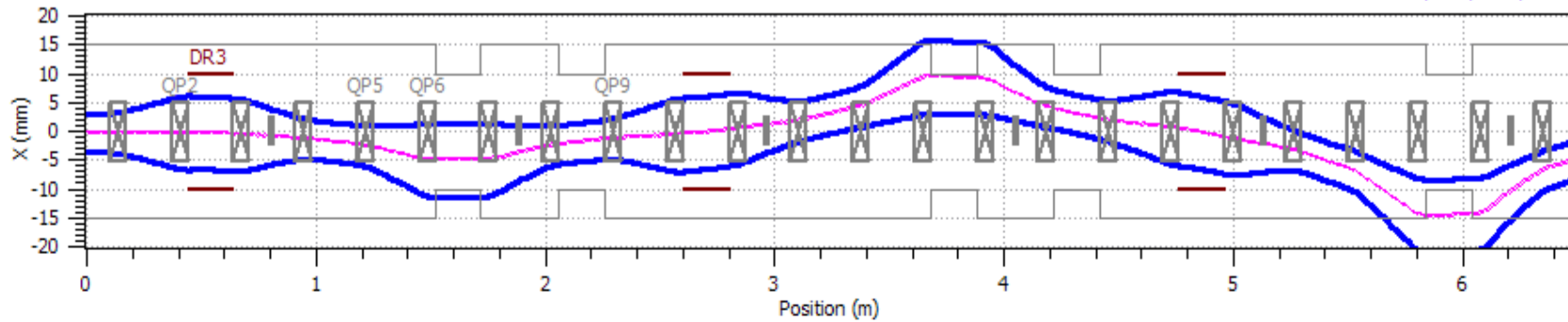


# FFDD LATTICE – SLOW CHOPPER ON

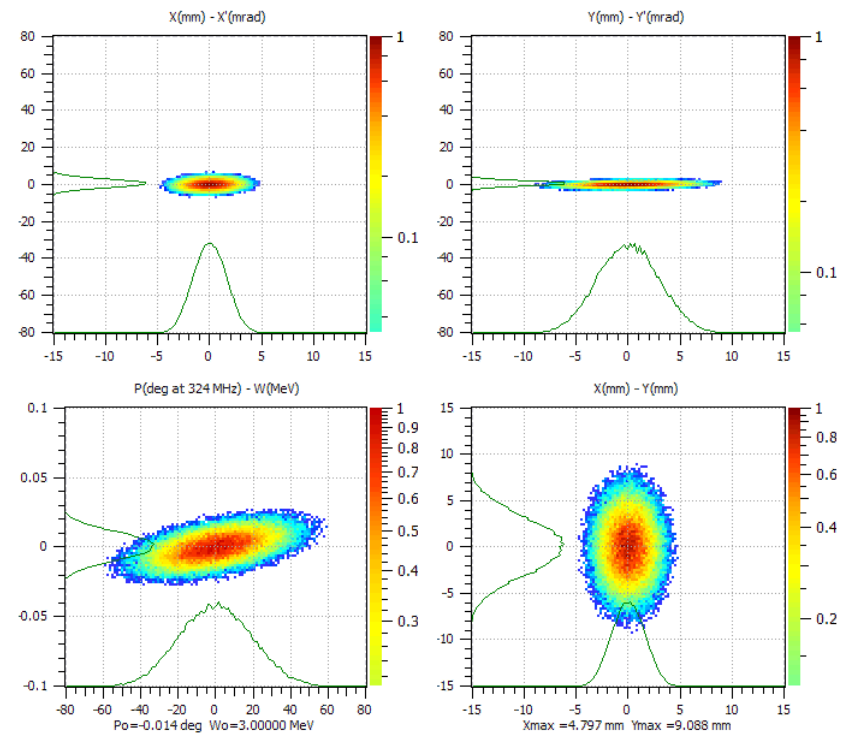
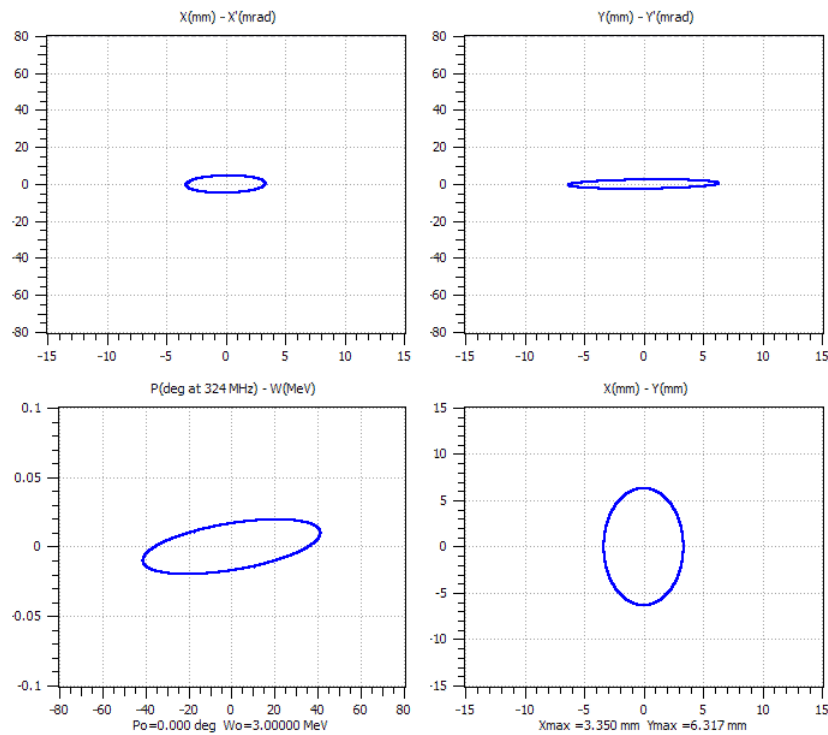


# FFDD LATTICE – BOTH CHOPPERS ON

TraceWin - CEA/DSM/IRFU/SACM

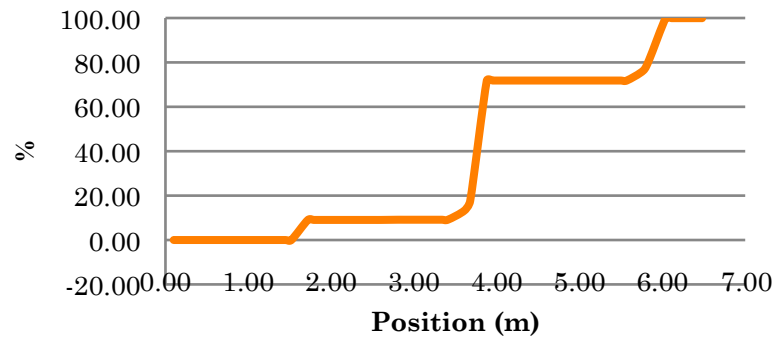


# FFDD LATTICE – BOTH CHOPPERS ON

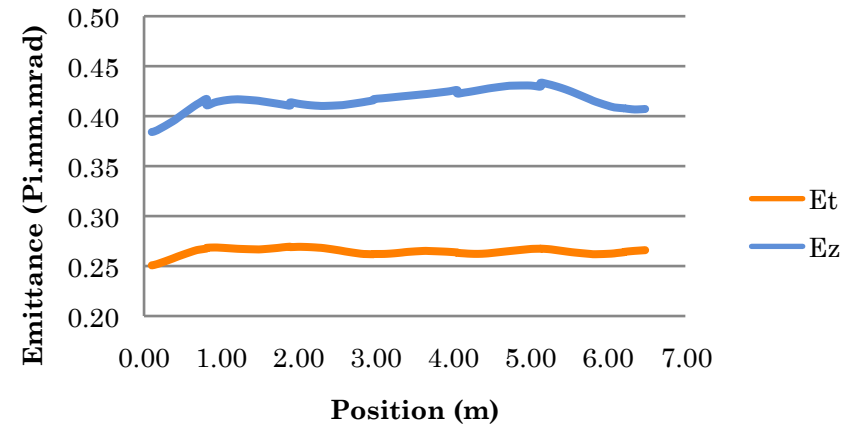


# FFDD LATTICE

### FFDD: Chopped beam by the slow chopper(%)



### FFDD MEBT - Emittance Evolution



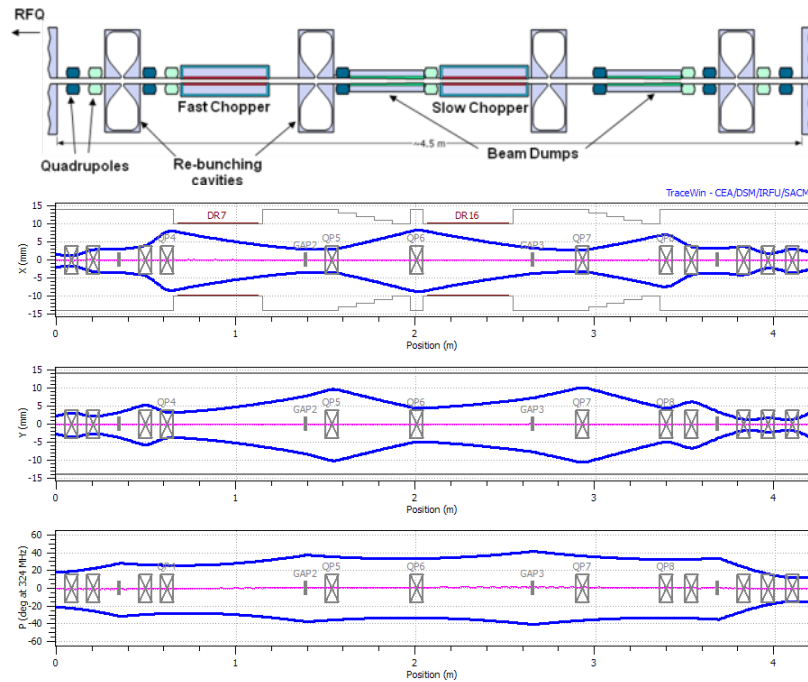
## ○ Advantages

- Similar to FODO +
- Fewer chopper plates than FODO
- Less voltages required

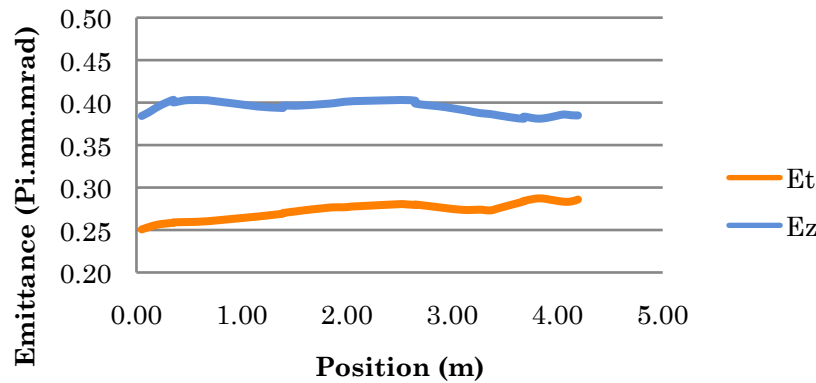


# COMPARISON WITH EXISTING DESIGNS

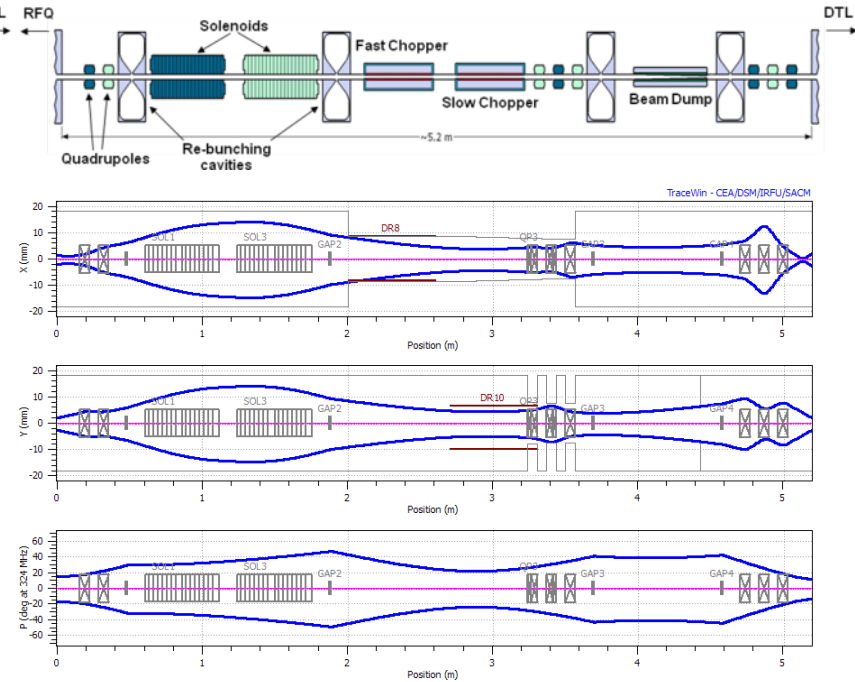
## FETS MEBT



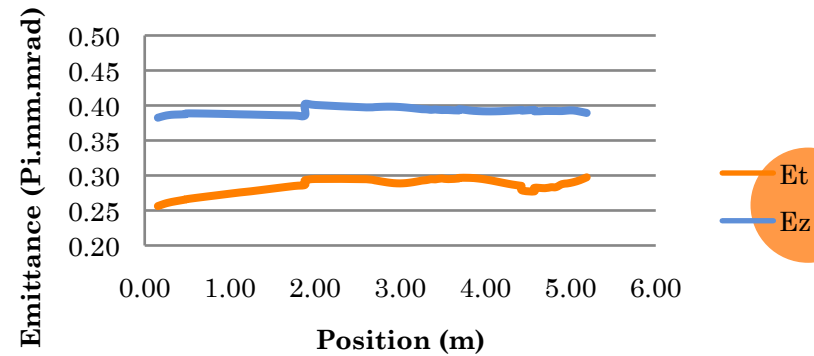
FETS MEBT - Emittance Evolution



## Solenoid MEBT

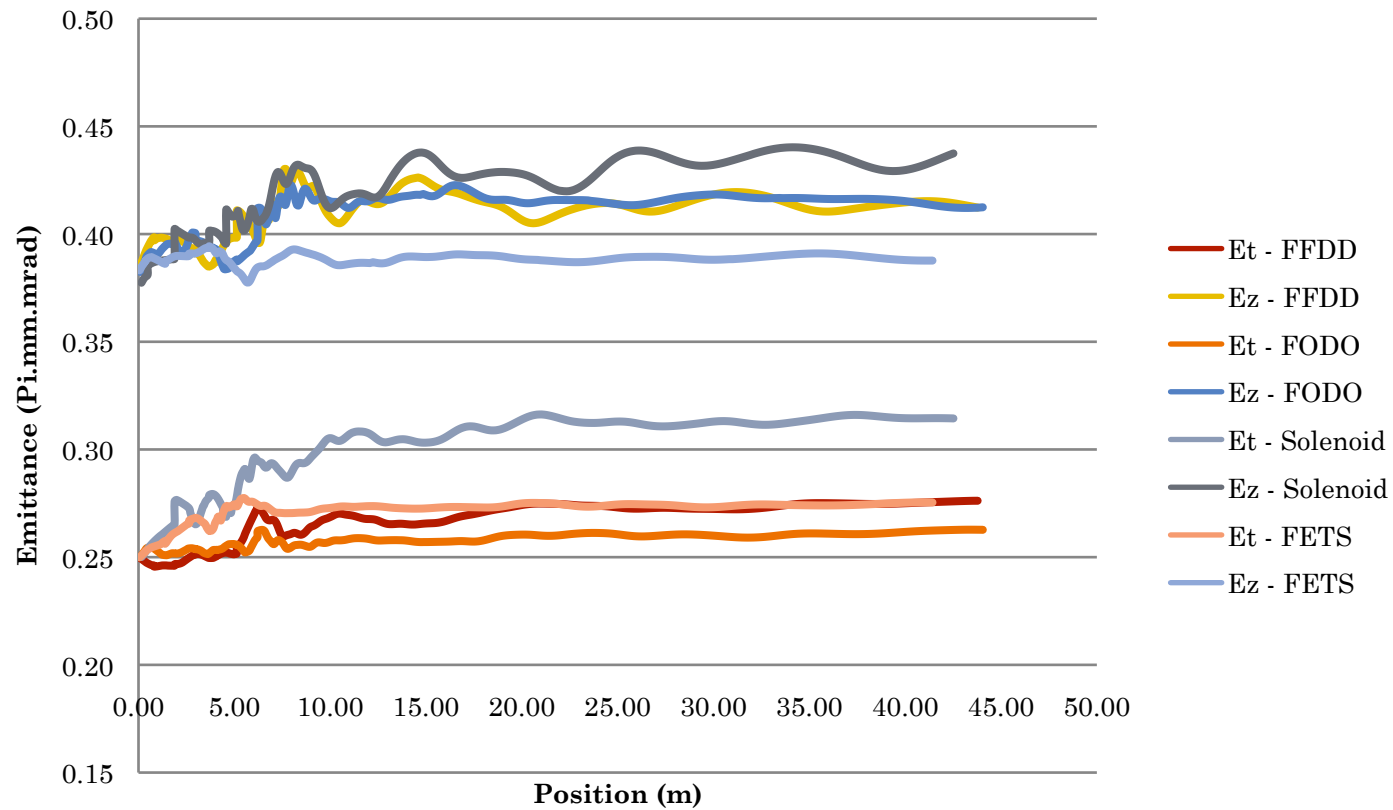


Solenoid MEBT - Emittance Evolution



# MEBT + DTL EMITTANCE EVOLUTION

## MEBT + DTL Emittance Evolution



# CONCLUSIONS

- Front End Test Stand at RAL is progressing well
  - Ion Source and LEBT installed
  - New RFQ design approach
  - Innovative MEBT optics under consideration
  - Comprehensive diagnostics currently being developed and tested

