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MW Upgrades for the ISIS Facility

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Upgrade Options

Option		Comments	Beam Power (MW)	Neutron Yield
1(a)	Add 180 MeV Linac	Technical Issues	~ 0.4	1.7
1(b)	Add 800 MeV RCS	Operational Issues	~ 0.5	2.0
1(c)	Upgrades 1(a) + 1(b)	Technical/Operational Issues	~ 0.9	3.8
2	Add ~ 3 GeV RCS	Recommended 1st Upgrade	1	3.2
3	Add ~ 6 GeV RCS	Technical/Cost Issues	2	5.6
4	Upgrades 1+2 or 1+3	Technical/Operational Issues	~ 2 – 6	~ 6.4 – 16.8
5	400 – 800 MeV Linac + 3 GeV RCS	Recommended 2nd Upgrade	2 – 5	6.4 – 16.0
6	1.334 GeV Linac + Accumulator Ring	Good "Green Field" Option	5	18.8

- Upgrade routes for ISIS are summarised in the table above. All designs are to be developed primarily for an optimised neutron facility, and should provide provision of an appropriate proton beam to the newly built TS-2. The list here is not exhaustive, but presents the main, reasonable routes that would provide a major boost in beam power. Primary considerations are the cost relative to a new facility and the impact on ISIS operations.

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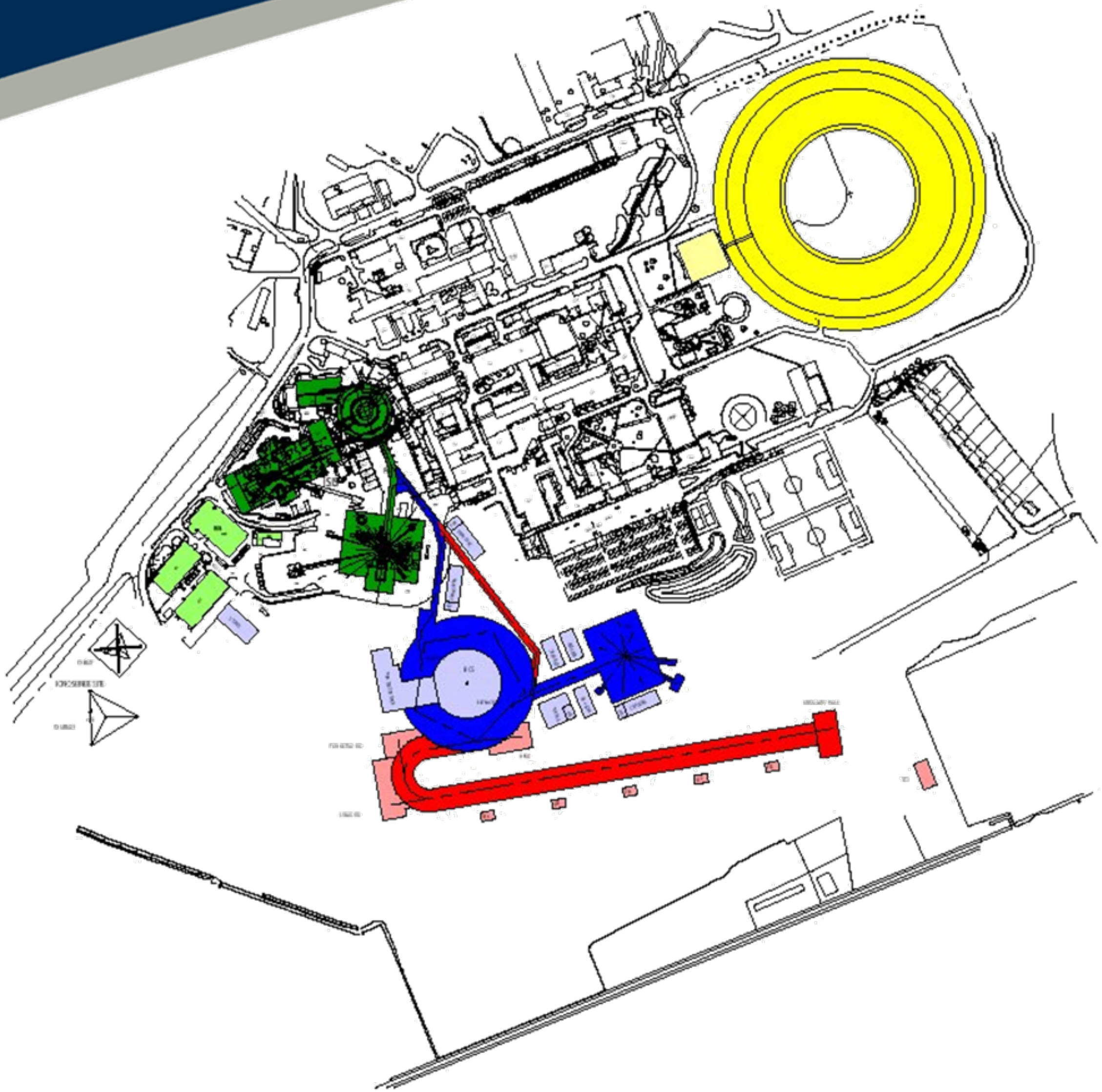
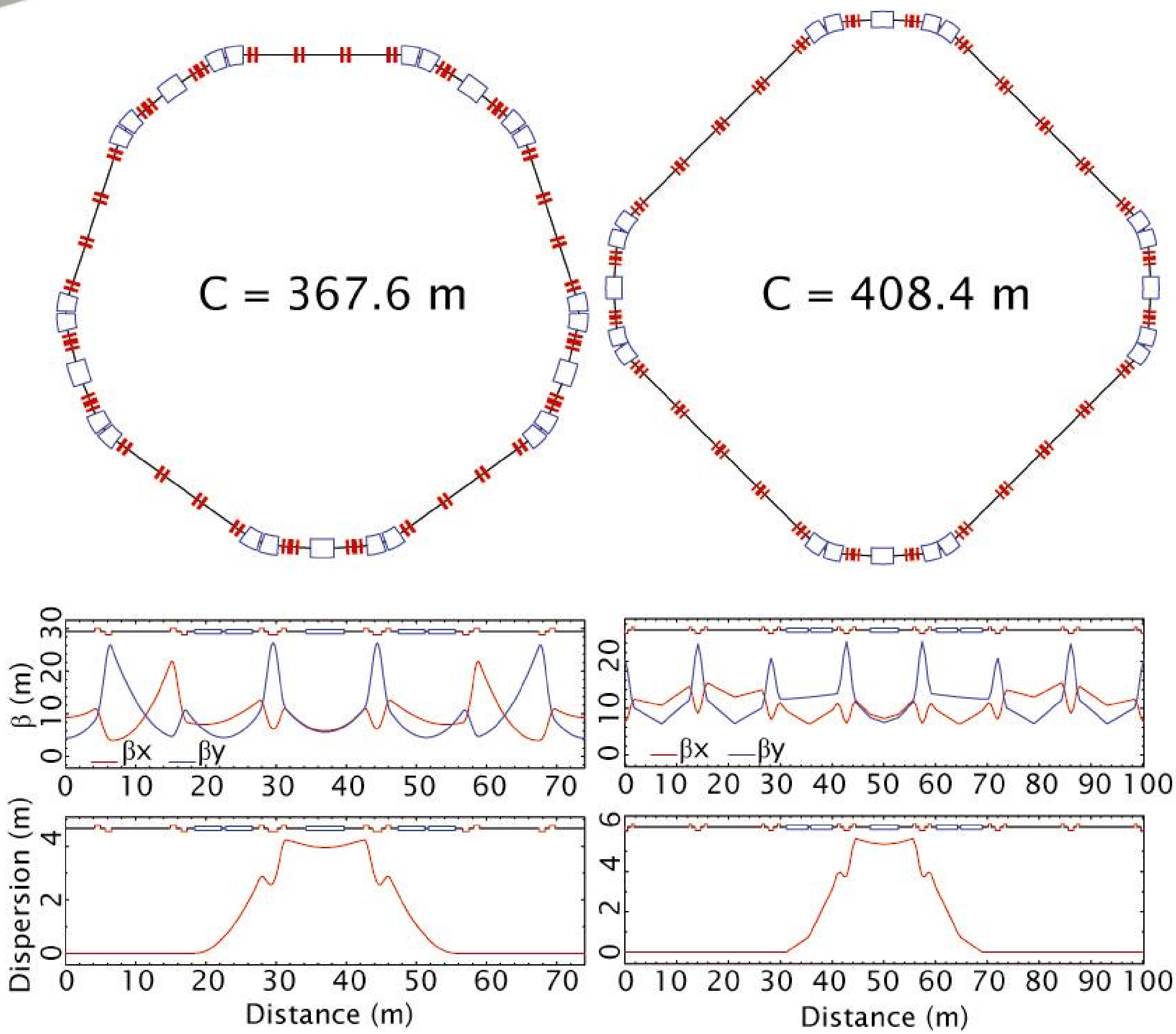
Recommended Upgrades



- Based on a ~ 3 GeV RCS fed by bucket-to-bucket transfer from ISIS 800 MeV synchrotron (1MW)

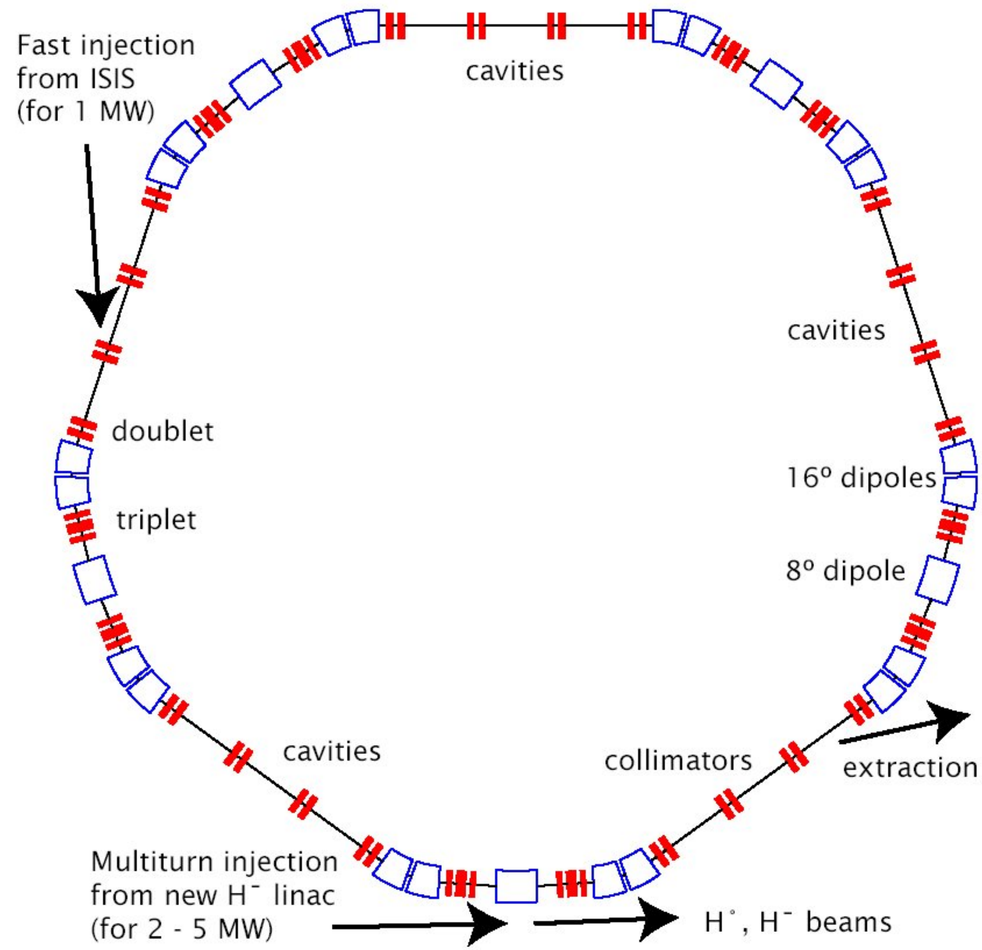
- RCS design also accommodates multi-turn charge exchange injection to facilitate a further upgrade path where the RCS is fed directly from a 800 MeV linac (2 – 5 MW)

RCS Rings



5SP RCS Ring

Energy	0.8 – 3.2 GeV
Rep Rate	50 Hz
C, R/R_0	367.6 m, 9/4
Gamma-T	7.2
h	9
f_{rf} sweep	6.1-7.1 MHz
Peak V_{rf}	~ 750 kV
Peak K_{sc}	~ 0.1
ε_l per bunch	~ 1.5 eV s
$B[t]$	sinusoidal



Current Work: Initial Topics

Starting Points

- 1D Calculation and Simulation of Longitudinal Dynamics - ORBIT

  - FI into 5SP and 4SP Lattices

  [Rob Williamson, Chris Warsop]

- 2D Transverse Space Charge Studies - Set

  - for 5SP lattice at intensities for FI and MTI

  [Ben Pine, Chris Warsop]

- 2D Simulation of Injection - ORBIT

  - MTI into 5SP lattice, presently 2D at intensities up to 5 MW

  [Bryan Jones, Dean Adams]

Plus

- Lattice Error Analysis and Modifications

  [Dean Adams]

Longitudinal Dynamics

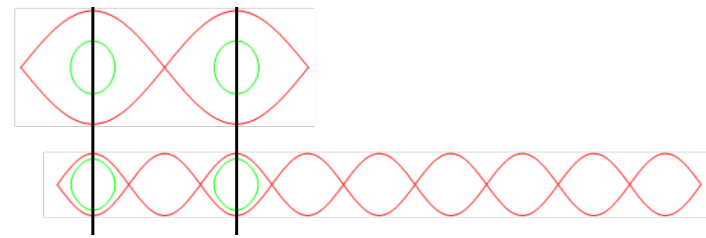
Look at Fast injection from ISIS into the two selected rings (0.8-3.2 GeV, 50 Hz)

367.6 m Circumference Ring
$R=58.5$, $h=9$, $R/R_0=9/4$, 5 SP

- Buckets halve in size – harder

ISIS1 h=2

ISIS2 h=9

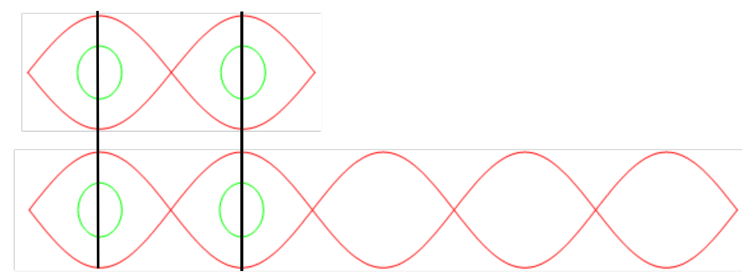


408.4 m Circumference Ring
$R=65.0$, $h=5$, $R/R_0=5/2$, 4 SP

- Buckets same size – easier
- More space

ISIS1 h=2

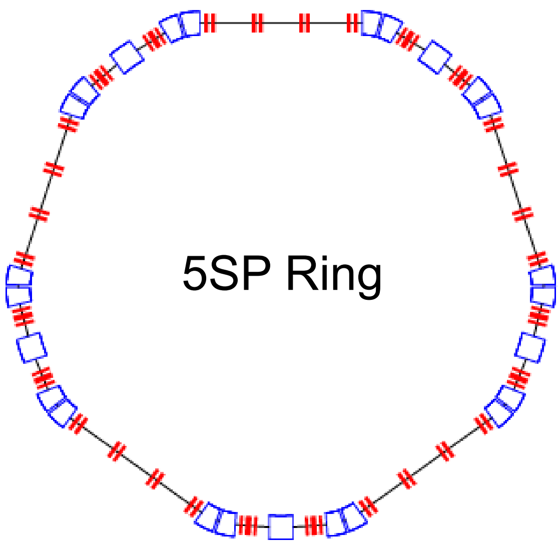
ISIS2 h=5



Longitudinal Dynamics

RF System Requirements

- Acceleration, bucket acceptance
- Momentum spread control
- Matching: minimise halo with space charge
- Longitudinal stability: k_{sc}<0.4
- Minimise peak volts (enough space?)
- Ensure losses ≤ 0.01%
- MTI painting requirements

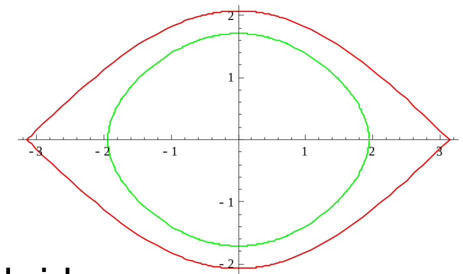


Work in progress …

still working through this list

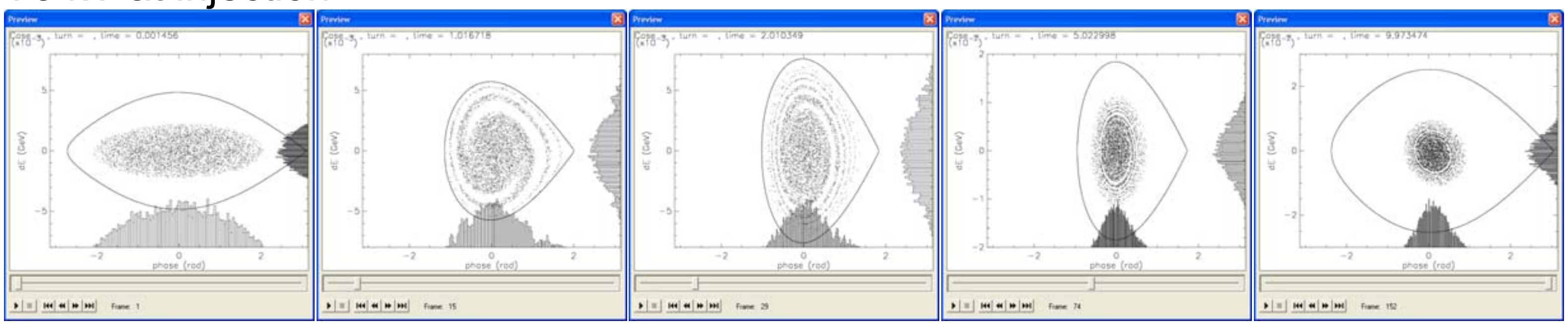
Longitudinal Dynamics

“Match” ISIS extracted beam into bucket
Pulse length of ± 50 ns → ± 110 degrees
in h=9 ring, dp/p ~ ± 0.3%

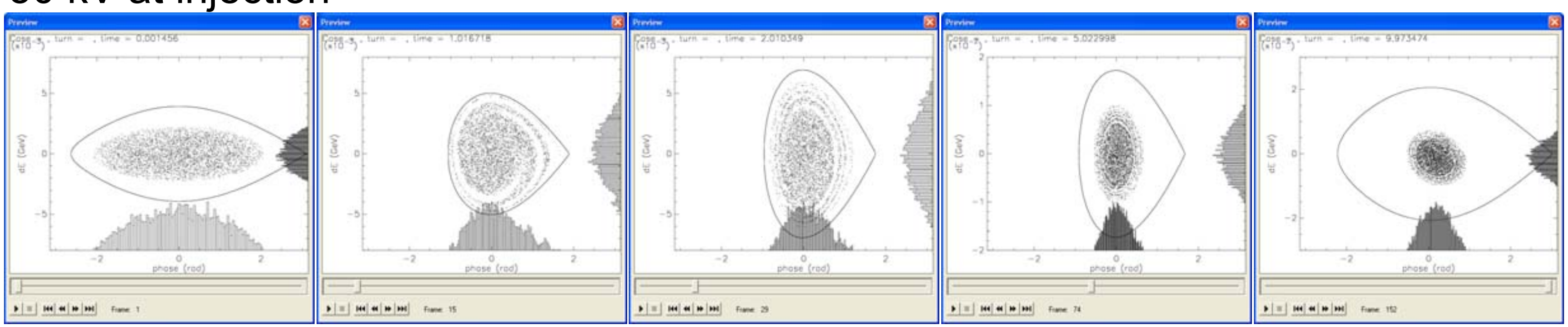


First ORBIT 1D runs - no space charge - still working through ideas …

75 kV at injection



50 kV at injection



Early days, but looks OK!

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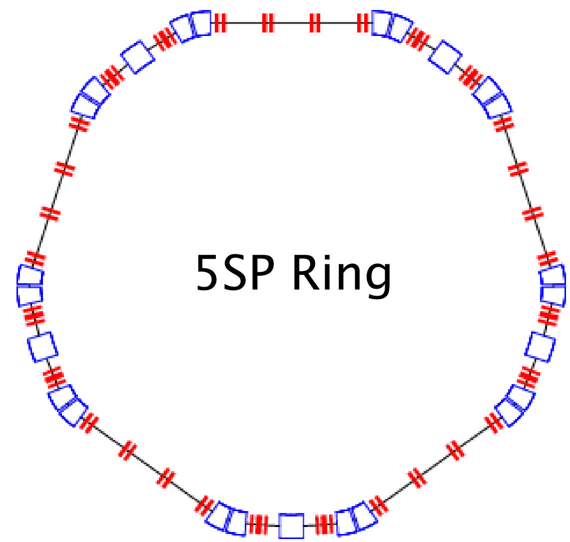
Transverse Space Charge

A *first look* at intensity limits – with Ben Pine's "Set" code

2D Space Charge Studies of 5SP ring

- Coasting 0.8 GeV beam
- Waterbag distribution: ε_{rms}= 27 pi mm mr
  (Design acceptance 400 pi mm mr)
- Parabolic real space
- RMS matched
- 100000 Macro Particles
- No Driving Terms (just space charge)
- ±200 mm Vacuum Vessel (rectangular)

Track over 100 turns



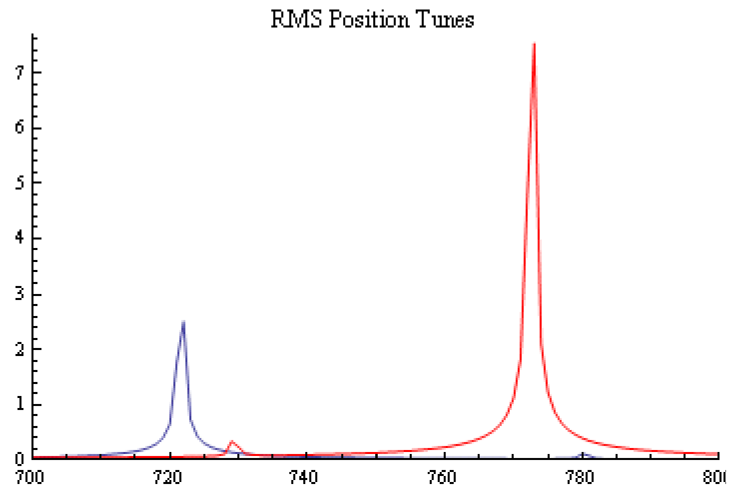
Nominal Tunes
$(Q_x\ Q_y)$=(7.21, 7.73)

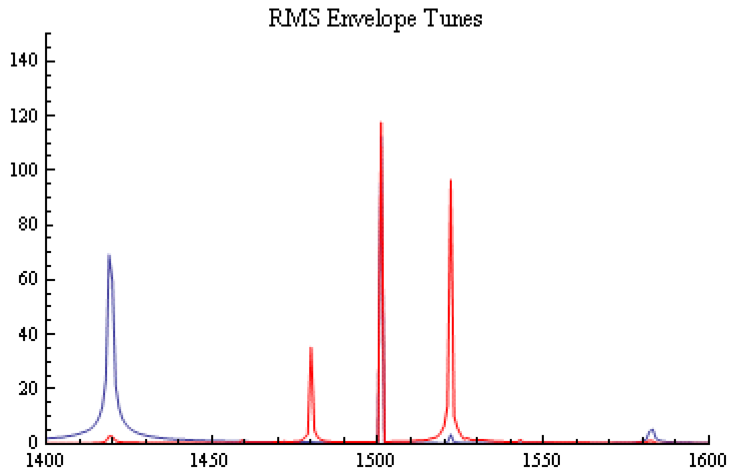
Coasting Beam Equivalent (CBE) intensities (Assume BF=0.4)
1 MW → 3.8E13 in 2/9 bunches → CBE 1.7E14 ppp
2 MW → 1.3E14 in 4/4 bunches → CBE 3.3E14 ppp
5 MW → 2.0E14 in 4/4 bunches → CBE 5.0E14 ppp

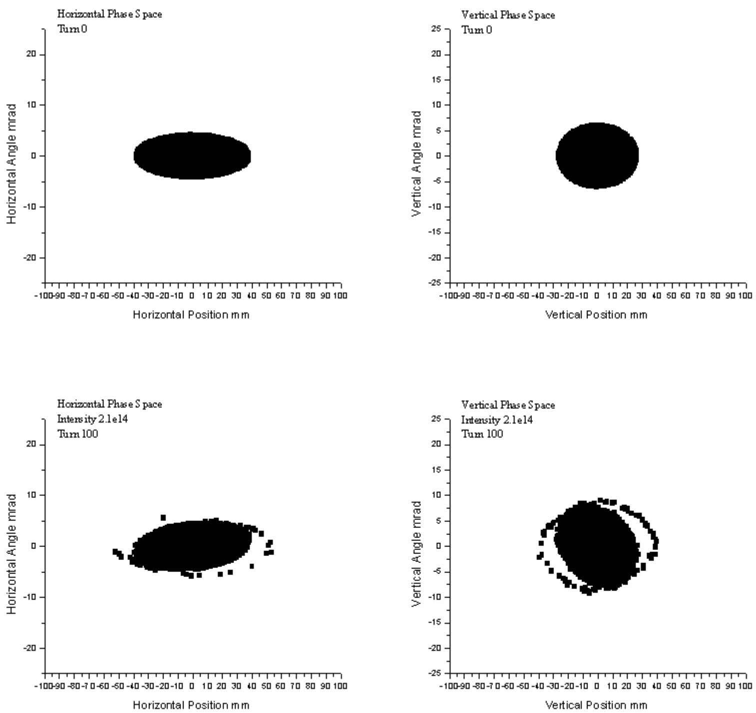
Provisional Results!

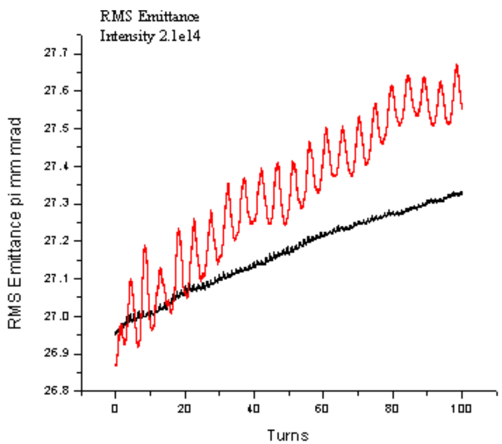
Transverse Space Charge

2.1×10^{14} ppp coasting

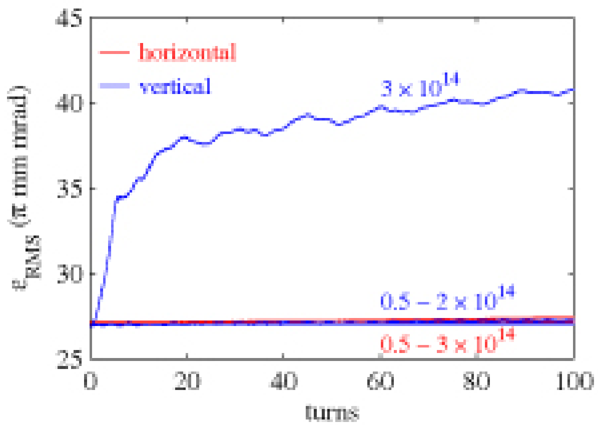


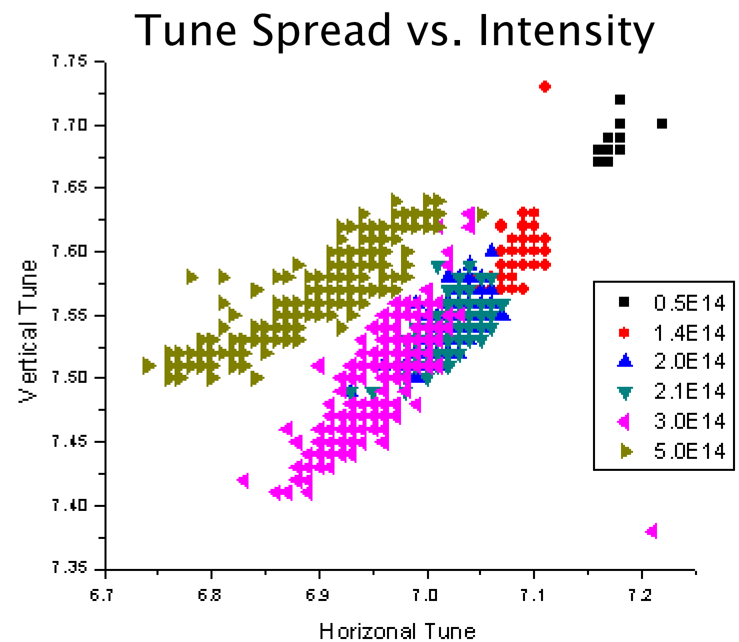






Transverse Space Charge





Next

- Assessment and inclusion of important driving terms
- Exploration of working point, Correction schemes

Set code is being developed further

- plan to extend for longitudinal and injection simulations
- complementary use of ORBIT, Set, SIMBAD, etc

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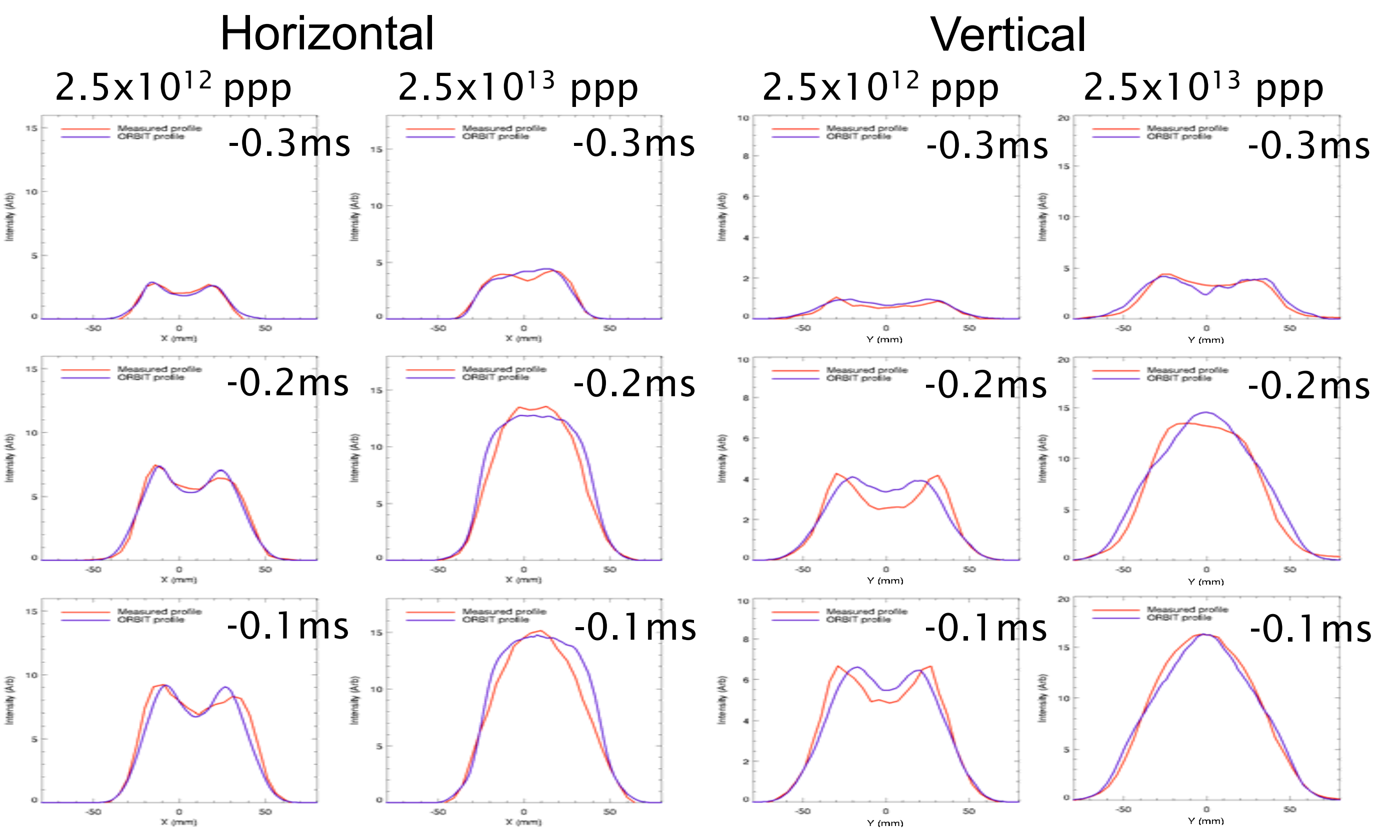
Current Work: Related HIR&D Study

ISIS Comparisons of Injection Profiles with ORBIT Simulation

[Bryan Jones *et al.*]



Red=Meas
Blue=Sim
(ORBIT)

Makes use of profile monitor corrections

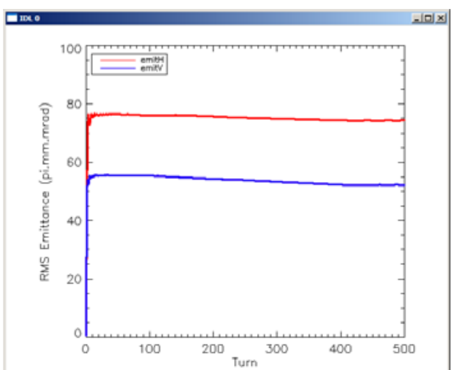
(Rob Williamson, Ben Pine)

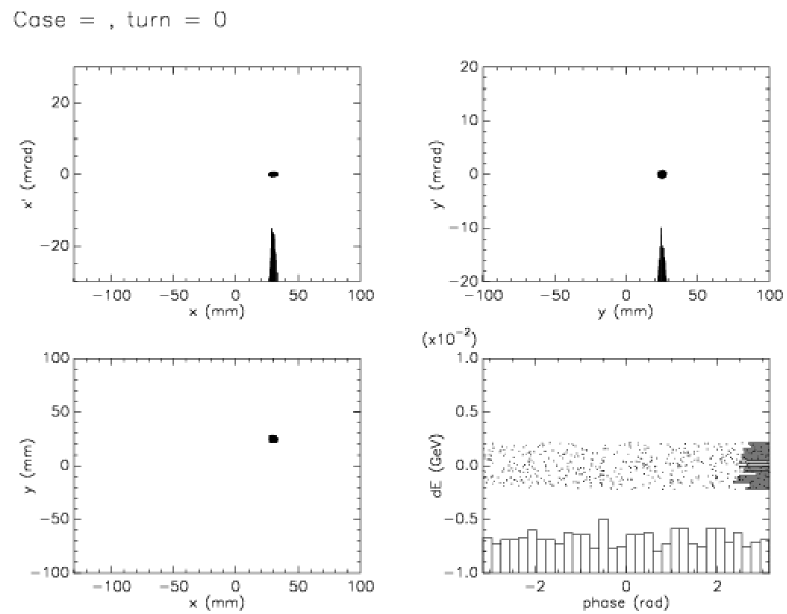
See EPAC'08 papers

Injection Studies

A *first look* at Multi-Turn Injection into 5SP R=58.5 ring – with ORBIT

Simple Fixed Large Amplitude Injection, 2D
3.25×10^{14} ppp over 400 turns (600us), tracking 500 turns total. (~2 MW case)
Giving centroid emittance of ~ 135 pi mm.mrad in both planes
dp/p = 0.27%





Now working towards 3D painting …

Outline Work Plan

Main topics to cover

- Longitudinal Calculations/Simulations for candidate FI Rings, then MTI
- Build up MTI simulation 2D to 3D, then acceleration
- Model Injection Magnet and Region (CST based, as profile monitors)
- Transverse Space Charge and Working Point, Correction Schemes
- Lattice Optimisation, Analysis, Correction
- Instabilities: standard checks, e-p work
- Collimation: outline designs, full simulations with activation
- Review all main systems

Pull work together: comparisons

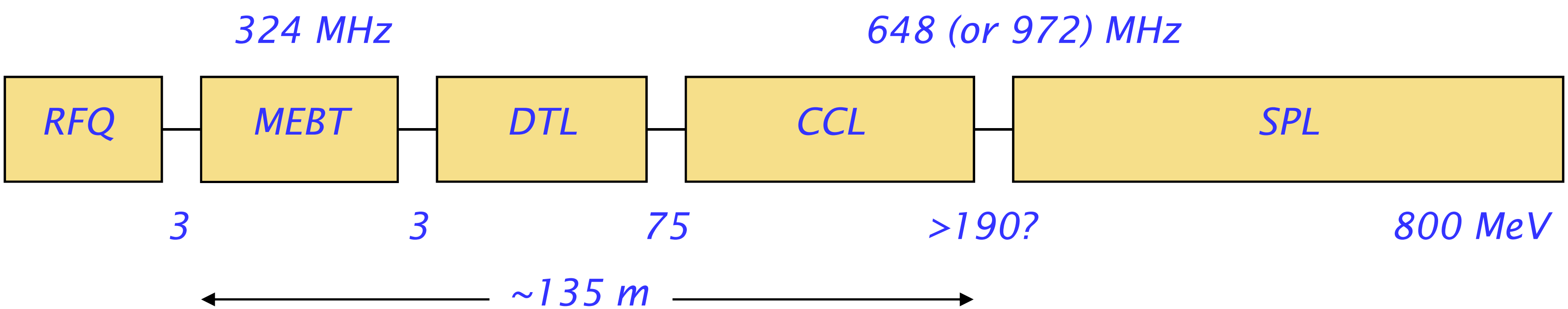
- Best lattice and ring size; RF and MMPS combinations
- Estimated losses and activation

Started
Next
Uncertain Cover

"Robust Physics Design by [December 31] 2010"

Outline Linac Design

ASTeC Intense Beams Group
[Grahame Rees, Ciprian Plostinar]



MEBT:	2 options (an MCG type and a solenoid-triplet type)
DTL:	4 tanks at 19.40, 37.68, 56.43 & 74.8 MeV, 6 βλ cells
CCL:	At 972 MHz: > 60, 14 cell cavities, 3.5 βλ separations,
SPL:	~ 70, 4 /6 cell cavities, doublet focusing, ~ 23 βλ cells

Outline Linac Design

H^- linac design parameters

Beam power for 2 MW, 30 Hz, 3.2 GeV RCS:	0.5 MW
Beam pulse current before MEBT chopping:	43.0 mA
Beam pulse current after MEBT chopping:	30.0 mA
Number of injected turns for a 370 m RCS:	~500 turns
Beam pulse duration at the 30 Hz rep rate:	~700.0 μs
Duty cycle for the extent of the beam pulse:	~2.1 %
MEBT(in) normalised rms emittances (π mm mr):	0.25, 0.375
MEBT(out) normalised rms emittances (π mm mr):	0.292, 0.41
Cell equipartition trans/long phase shift ratios:	1.40

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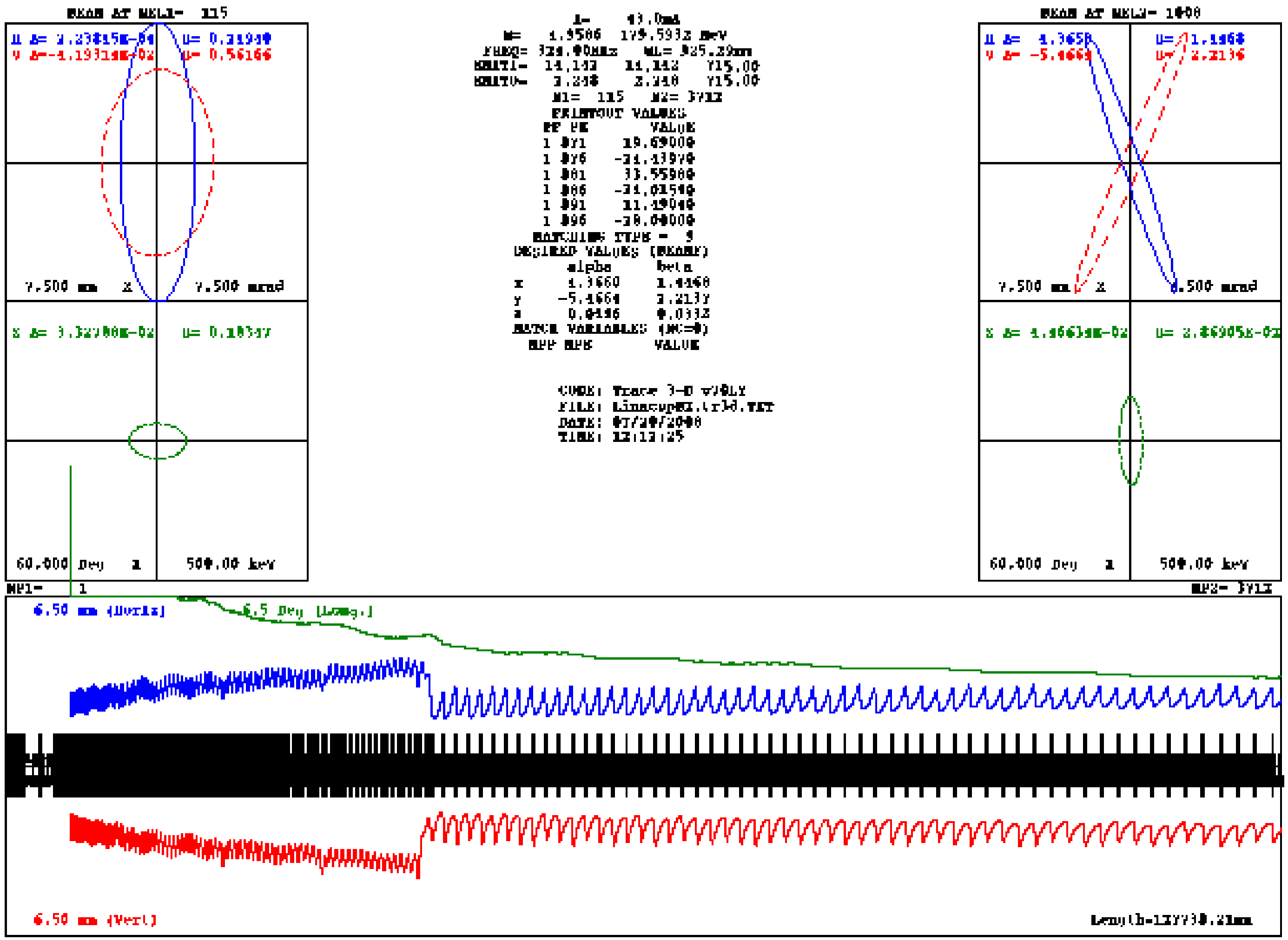
Outline Linac Design

Beam envelopes in DTL & 972 MHz CCL



Outline Linac Design

Studies now required:

- MEBT optics and chopper re-evaluation
- DTL inter-tank separations and matchings
- CCL cavity optimisation with Superfish
- Alternatives to CCL (e.g. Spoke resonators)
- Design of SPL and the CCL-SPL matching
- CCL & SPL 648 & 972 MHz comparisons
- Refine design of the various linac stages
- Error effect evaluation for the full linac