Science & Technology Facilities Council
ISIS

Status of the ISIS Upgrade: ISIS II

Chris Warsop

on behalf of the *ISIS II R&D and Design Teams*

4th ICFA Mini-Workshop on Space Charge 2019, CERN

4th November 2019

Contents

AR - *Accumulator Ring*
RCS - *Rapid Cycling Synchrotron*
FFA - *Fixed Field AG Synchrotron*

1. Background – the need for neutrons

ESFRI "Neutron Scattering Facilities in Europe" p.75
European Strategy Forum on Research Infrastructures

- What is the demand for neutrons in Europe?

- ESFRI report – studied outlook
  - Reduction in reactor based sources
  - Longevity of ILL …
  - … Commissioning of ESS
  - Manage "gap" – avoid "neutron drought"
  - A need to develop long term plans …

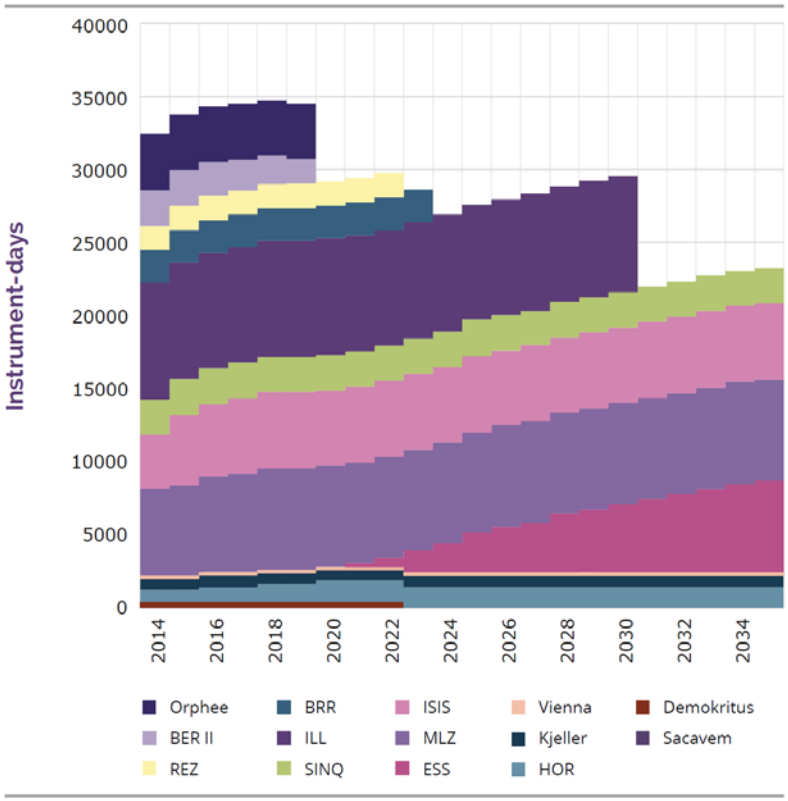


Figure 11. Enhanced Baseline Scenario

The predicted delivery of instrument beam-days in the Enhanced Baseline Scenario: ILL operates until 2030, ESS with 35 instruments beyond 2035.

- UK Plans: STFC Advisory Panel, Strategic Reviews
  - Need to "maintain UK's internationally competitive ISIS facility"
  - Need a detailed evaluation of UK's neutron needs – a plan ⇒ ISIS II Working Group

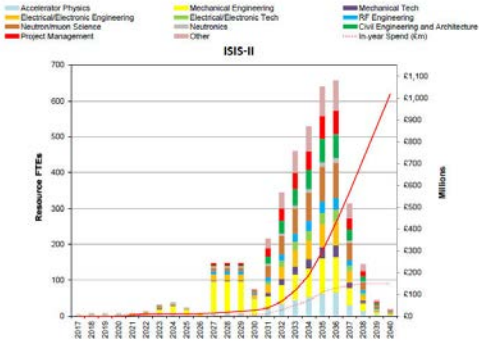
2. ISIS Road Map – ISIS II

- ISIS II Working Group: look at options and establish a Road Map
  - Experts on Instruments, Neutronics, Target, Accelerator, Engineering
  - User driven: work back from "ideal instrument suite" – optimised for neutrons
  - *Outline the studies to find the best facility upgrade options*

ISIS II Working Group

- Need to evaluate options for
  - Short-pulse sources (proton pulse ~1 μs)
  - A new stand-alone facility – "green field"
  - A facility upgrade, reusing existing ISIS infrastructure
  - *Study includes: Neutronics, Targets, Linacs, Rings, …*

Resources Required



- Time outline:

  2017-2027 ~ Feasibility, design and R&D
  2027-2031 ~ Integrated facility technical design
  2031-2040 ~ ISIS II construction

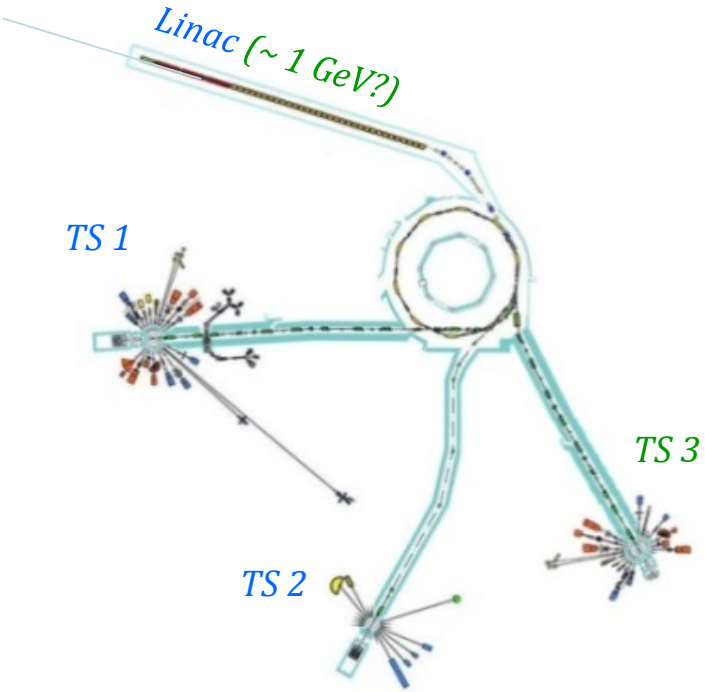
- Here we concentrate on *Rings* part of *Accelerator Study*
  - Present emphasis is on reuse of infrastructure – more difficult (constrained)
  - Later studies address stand-alone – less demanding

2. ISIS II Accelerator Studies

The Recommended Route for ISIS II

- Re-use of infrastructure
  - Upgrade 10 Hz TS2 for 0.25 MW
  - Build a new 40 Hz TS 3 for 1 MW
  - Phase out existing 40 Hz TS 1
  - Options for further upgrades

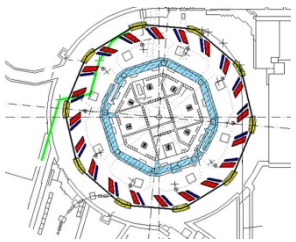
Reuse of Existing ISIS



- New accelerator in existing synchrotron hall
  - 1.25 MW, 1.2 GeV Ring, ~ 50 Hz, R ~ 26 m
  - Consider conventional AR, RCS and FFA
  - New linac

- Accelerator options: optimal 1.2 GeV ring
  - FFA – exciting but unproven – R&D and prototype ring
  - AR/RCS – established solution – R&D for best design

FFA



AR/RCS

- Optimise
  - Construction, operation costs
  - Performance, upgradability
  - ISIS impact, risks; environmental impact

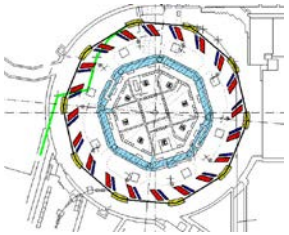
2. ISIS II Accelerator Studies

Conventional or FFA Rings?

- Why study both?
  - Find optimal accelerator for the next generation ISIS II
  - Compare best new vs established technology

Ring	***FFA***	***RCS***	***AR***
Magnet	DC large, complex	AC – fast ramp conventional	DC conventional
Rep rate	Flexible, high	Fixed <= 50 Hz	Flexible, high
Linac costs	Lower (~0.4 GeV)	Lower (~0.4 GeV)	High (1.2 GeV)
Features	Large RF, Stacking	Large RF	Small RF, few turns
Will it work?	Need a test ring	Established	Established, simple

- FFA Study
  - Build an R~4 m demonstrator ring, use FETS as injector (3 MeV)
  - Verify key aspects of operation for high intensity



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2. ISIS II Accelerator Studies
Outline Ring R&D

Dates		AR/RCS Ring Study	FFA Ring Study
2019 2020 2021	ISIS-II R&D Phase 1	Ref 1 designs: RCS & AR for ISIS Hall RCS & AR Green Field Working designs done	Prototype ring design Beam dynamics studies Prototype hardware: magnets, … Decide to build
2022 2023 2024	ISIS-II R&D Phase 2	Ref 2 designs: R&D, Optimise, HI limits Finalise designs ISIS Hall, Green Field	Construct test ring Experimental program: verify Finalize designs ISIS Hall, Green Field
2025		Designs Complete -> Design Costings Decide AR/RCS or FFA	
2026		Finalise chosen physics designs for accelerator type	
2026-2027		Design Costings Decide ISIS Hall or Stand Alone	
2027-2031		Facility technical design	
2031-2040		ISIS II construction	

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2. ISIS II Accelerator Studies

Outline Ring R&D

Dates		AR/RCS Rin
2019	ISIS-II R&D Phase 1	Ref 1 design
2020		RCS & AR fo
		RCS & AR Gr
2021		Working des
2022	ISIS-II R&D Phase 2	Ref 2 design
2023		R&D, Optim
2024		Finalise des ISIS Hall, Gr
2025		
2026		Finali
2026-2027		
2027-2031		
2031-2040		ISIS II construct

n
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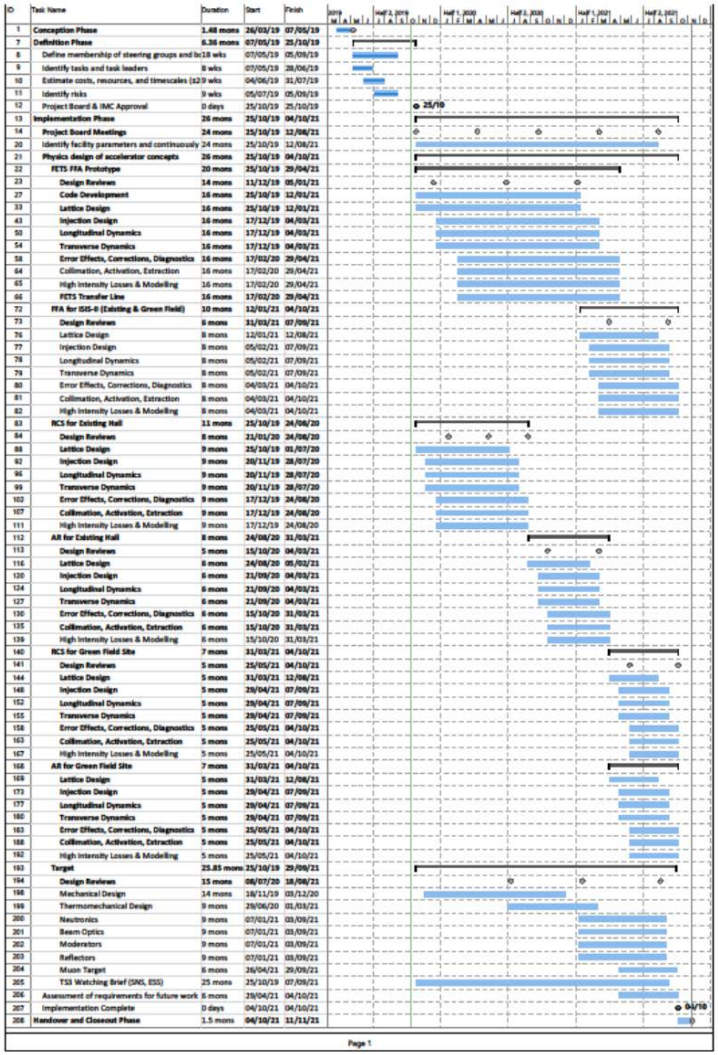
magnets, …
m: verify
r type

Project Plan



ID	Task Name	Duration	Start	Finish
1	Conception Phase	1.48 mons	26/03/19	07/05/19
7	Definition Phase	6.36 mons	07/05/19	25/10/19
8	Define membership of steering groups and bo	18 wks	07/05/19	05/09/19
9	Identify tasks and task leaders	8 wks	07/05/19	28/06/19
10	Estimate costs, resources, and timescales (12	9 wks	04/06/19	31/07/19
11	Identify risks	9 wks	05/07/19	05/09/19
12	Project Board & IMC Approval	0 days	25/10/19	25/10/19
13	Implementation Phase	26 mons	25/10/19	04/10/21
14	Project Board Meetings	24 mons	25/10/19	12/08/21
20	Identify facility parameters and continuously	24 mons	25/10/19	12/08/21
21	Physics design of accelerator concepts	26 mons	25/10/19	04/10/21
22	FETS FFA Prototype	20 mons	25/10/19	29/04/21
23	Design Reviews	14 mons	11/12/19	05/01/21
27	Code Development	16 mons	25/10/19	12/01/21
33	Lattice Design	16 mons	25/10/19	12/01/21
43	Injection Design	16 mons	17/12/19	04/03/21
50	Longitudinal Dynamics	16 mons	17/12/19	04/03/21
54	Transverse Dynamics	16 mons	17/12/19	04/03/21
58	Error Effects, Corrections, Diagnostics	16 mons	17/02/20	29/04/21
64	Collimation, Activation, Extraction	16 mons	17/02/20	29/04/21
65	High Intensity Losses & Modelling	16 mons	17/02/20	29/04/21
66	FETS Transfer Line	16 mons	17/02/20	29/04/21
72	FFA for ISIS-II (Existing & Green Field)	10 mons	12/01/21	04/10/21
73	Design Reviews	6 mons	31/03/21	07/09/21
76	Lattice Design	8 mons	12/01/21	12/08/21
77	Injection Design	8 mons	05/02/21	07/09/21
78	Longitudinal Dynamics	8 mons	05/02/21	07/09/21
79	Transverse Dynamics	8 mons	05/02/21	07/09/21
80	Error Effects, Corrections, Diagnostics	8 mons	04/03/21	04/10/21
81	Collimation, Activation, Extraction	8 mons	04/03/21	04/10/21
82	High Intensity Losses & Modelling	8 mons	04/03/21	04/10/21
83	RCS for Existing Hall	11 mons	25/10/19	24/08/20
84	Design Reviews	8 mons	21/01/20	24/08/20
88	Lattice Design	9 mons	25/10/19	01/07/20
92	Injection Design	9 mons	20/11/19	28/07/20
96	Longitudinal Dynamics	9 mons	20/11/19	28/07/20
99	Transverse Dynamics	9 mons	20/11/19	28/07/20
102	Error Effects, Corrections, Diagnostics	9 mons	17/12/19	24/08/20
107	Collimation, Activation, Extraction	9 mons	17/12/19	24/08/20
111	High Intensity Losses & Modelling	9 mons	17/12/19	24/08/20
112	AR for Existing Hall	8 mons	24/08/20	31/03/21
113	Design Reviews	5 mons	15/10/20	04/03/21
116	Lattice Design	6 mons	24/08/20	05/02/21
120	Injection Design	6 mons	21/09/20	04/03/21
124	Longitudinal Dynamics	6 mons	21/09/20	04/03/21
127	Transverse Dynamics	6 mons	21/09/20	04/03/21
130	Error Effects, Corrections, Diagnostics	6 mons	15/10/20	31/03/21
135	Collimation, Activation, Extraction	6 mons	15/10/20	31/03/21
139	High Intensity Losses & Modelling	6 mons	15/10/20	31/03/21
140	RCS for Green Field Site	7 mons	31/03/21	04/10/21
141	Design Reviews	5 mons	25/05/21	04/10/21
144	Lattice Design	5 mons	31/03/21	12/08/21
148	Injection Design	5 mons	29/04/21	07/09/21
152	Longitudinal Dynamics	5 mons	29/04/21	07/09/21
155	Transverse Dynamics	5 mons	29/04/21	07/09/21
158	Error Effects, Corrections, Diagnostics	5 mons	25/05/21	04/10/21
163	Collimation, Activation, Extraction	5 mons	25/05/21	04/10/21
167	High Intensity Losses & Modelling	5 mons	25/05/21	04/10/21
168	AR for Green Field Site	7 mons	31/03/21	04/10/21
169	Lattice Design	5 mons	31/03/21	12/08/21
173	Injection Design	5 mons	29/04/21	07/09/21
177	Longitudinal Dynamics	5 mons	29/04/21	07/09/21
180	Transverse Dynamics	5 mons	29/04/21	07/09/21
183	Error Effects, Corrections, Diagnostics	5 mons	25/05/21	04/10/21
188	Collimation, Activation, Extraction	5 mons	25/05/21	04/10/21
192	High Intensity Losses & Modelling	5 mons	25/05/21	04/10/21
193	Target	25.85 mons	25/10/19	29/09/21
194	Design Reviews	15 mons	08/07/20	18/08/21
198	Mechanical Design	14 mons	18/11/19	03/12/20
199	Thermomechanical Design	9 mons	29/06/20	01/03/21
200	Neutronics	9 mons	07/01/21	03/09/21
201	Beam Optics	9 mons	07/01/21	03/09/21
202	Moderators	9 mons	07/01/21	03/09/21
203	Reflectors	9 mons	07/01/21	03/09/21
204	Muon Target	6 mons	26/04/21	29/09/21
205	TSI Watching Brief (SNS, ESS)	25 mons	25/10/19	07/09/21
206	Assessment of requirements for future work	6 mons	29/04/21	04/10/21
207	Implementation Complete	0 days	04/10/21	04/10/21
208	Handover and Closeout Phase	1.5 mons	04/10/21	11/11/21

G Aymar, J W G Thomason et al

2. ISIS II Accelerator Studies
Design Specification

- Basic Requirements for Upgrade Rings

Power	TS1	TS2	Machine
Power (MW)	1.0	0.25	**1.25**
Frequency (Hz)	40	10	**50**
Energy (GeV)	1.2	1.2	**1.2**

- Potential for further upgrades, higher performance (~2.5 MW)
  - FFA (AR)
    ~ Higher rep rates; stacking for flexible pulse structure
  - RCS (AR)
    ~ Stack two rings

- Possible update of facility design parameters: not "set in stone"
  - "Watching brief" on science performance of SNS, JPARC, ESS, etc.
  - "Facility Parameters Review Group" (users) to monitor, update spec. if required

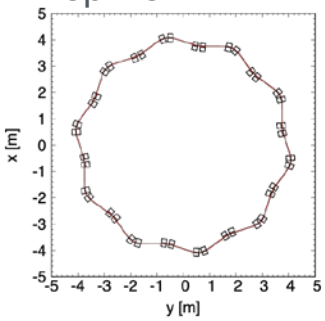
Contents

AR - *Accumulator Ring*
RCS - *Rapid Cycling Synchrotron*
FFA - *Fixed Field AG Synchrotron*

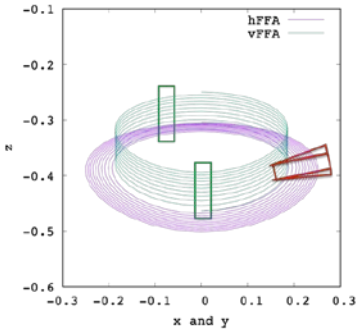
3.1 Accelerator work: FFA Rings
3.1.1 Vertical Excursion FFA: Prototype

- Vertical FFA selected, *not* Horizontal
  - Smaller, simpler magnets
  - Flexible scaling law
  - Suitable for SC magnets
- vFFA ~ would be a world first
  - Orbit moves vertically with acceleration
  - Coupled focusing fields
  - Intrinsic non-linearity

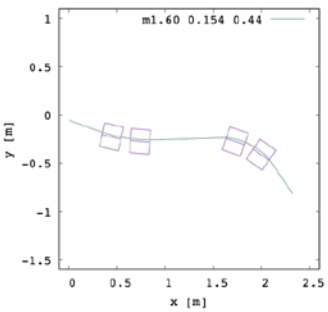
Top view



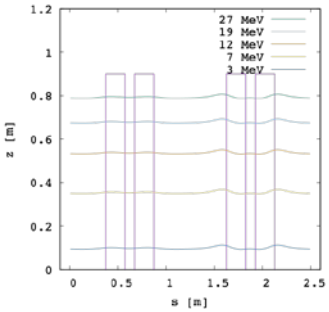
Bird's-eye view



Top view - cell



Side view - cell



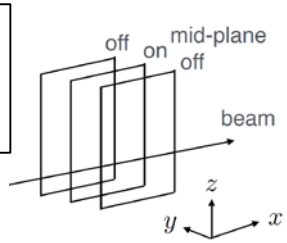
Baseline design

FETS-FFA parameters

Kinetic energy	**3 - 12 (17) MeV**
Number of cell	**10**
Cell length	**2.5 m** (=1.25 m + 1.25 m)
Num er of Bd segment	2
Length of Bd segment	0.2 m
Space between Bd segment	0.1 m
Angle between Bd segment	-8 deg
Number of Bf segment	2
Length of Bf segment	0.2 m
Space between Bf segment	0.1 m
Angle between Bf segment	+16 deg
Relative displacement btw Bd and Bf	+/- 0.154 m
Length of straight section	**0.75 m**
Fringe length L (Tanh x/L)	0.125 m
-Bd/Bf	0.44
Field index m	1.58 m^-1

Magnet
- *Upright rectangular or sector*
- *Aperture ~ 60 × 700 mm*
- *Length ~ 200 mm*

Magnet field required



x Longitudinal

y Horizontal

z Vertical

$$B_z(z,x,y) = B_0 \exp(mz) \sum_{i=0}^{\infty} b_{zi}(x)\, y^i$$

$$B_x(z,x,y) = B_0 \exp(mz) \sum_{i=0}^{\infty} b_{xi}(x)\, y^i$$

$$B_y(z,x,y) = B_0 \exp(mz) \sum_{i=0}^{\infty} b_{yi}(x)\, y^i$$

$$b_{z0}(x) = g(x)$$

$$b_{x0}(x) = \frac{1}{m}\frac{\partial g}{\partial x} \qquad b_{y0}(x) = 0$$

field expanded as polynomial in y about mid plane

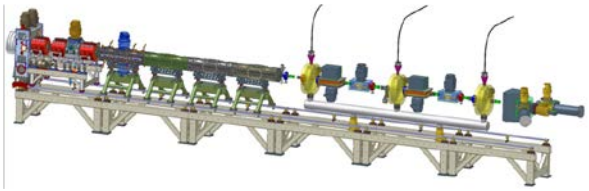
S Machida, D Kelliher, J-B Lagrange, C R Prior, C Rogers

3.1 Accelerator work: FFA Rings
3.1.2 Prototype Ring on FETS

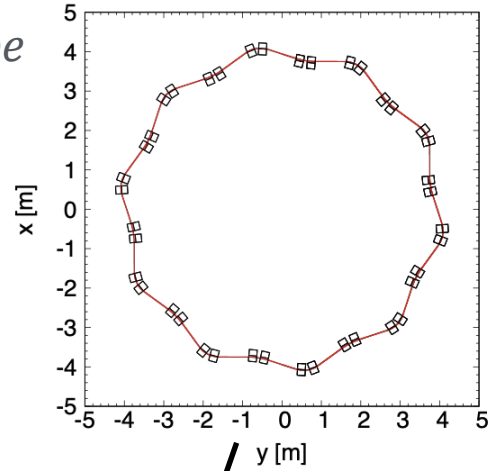
Designing prototype ring to demonstrate the technology

- Vertical FFA with FETS injector
  - H^- (proton) beam
  - Inject, Extract, RF, Diagnostics
  - High intensity, space charge
- Physics design objectives
  - Show vFFA design works
  - Benchmark simulation
  - Beam dynamics study
  - High intensity effects
- Hardware R&D objectives
  - Wide aperture components
  - Optimise designs
  - Develop in-house skills

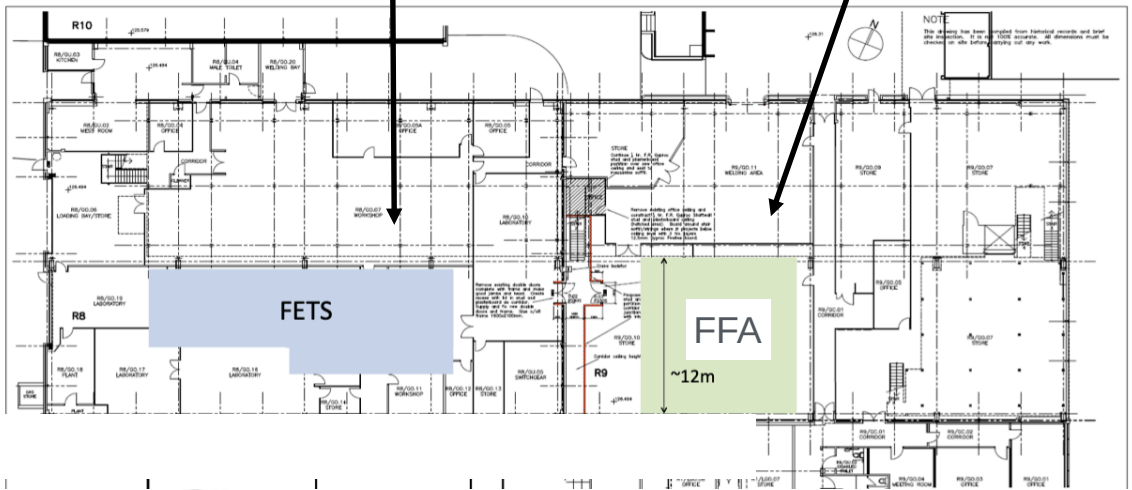
3 MeV H^- (proton) beams will be available from FETS



3 to 12 MeV FFA ring proof of principle



Front End Test Stand at RAL

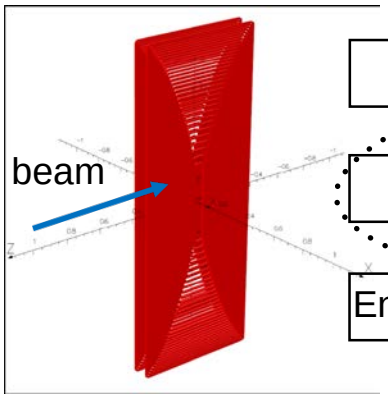


S Machida, et al, A Letchford, et al

3.1 Accelerator work: FFA Rings
3.1.3 vFFA Hardware

Magnet design loop

Initial proposal

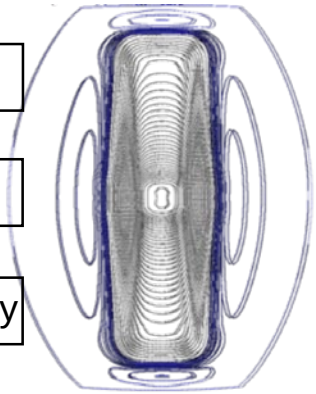


Analytical model

Coil configuration

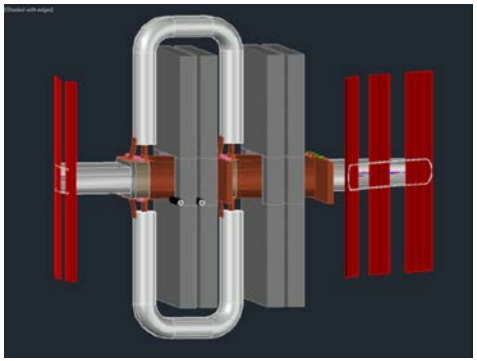
Engineering feasibility

After refinement

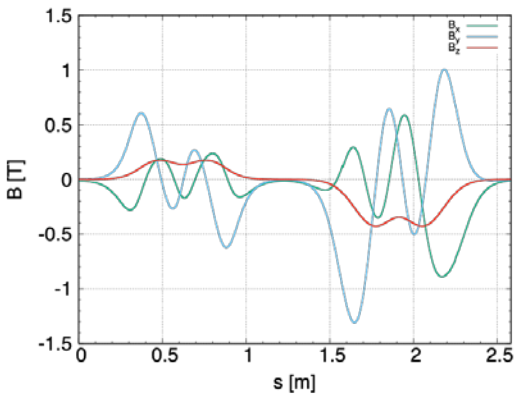


Solve Biot-Savart law inversely to find coil shape

Initial RF cavity design



Magnet field required



$$B_z(z,x,y) = B_0 \exp(mz) \sum_{i=0}^{\infty} b_{zi}(x)\, y^i$$

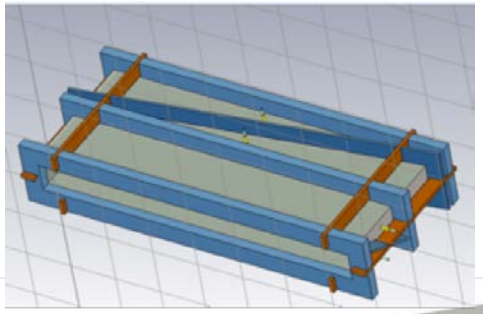
$$B_x(z,x,y) = B_0 \exp(mz) \sum_{i=0}^{\infty} b_{xi}(x)\, y^i$$

$$B_y(z,x,y) = B_0 \exp(mz) \sum_{i=0}^{\infty} b_{yi}(x)\, y^i$$

$$b_{z0}(x) = g(x)$$

$$b_{x0}(x) = \frac{1}{m}\frac{\partial g}{\partial x} \qquad b_{y0}(x) = 0$$

Initial BPM design

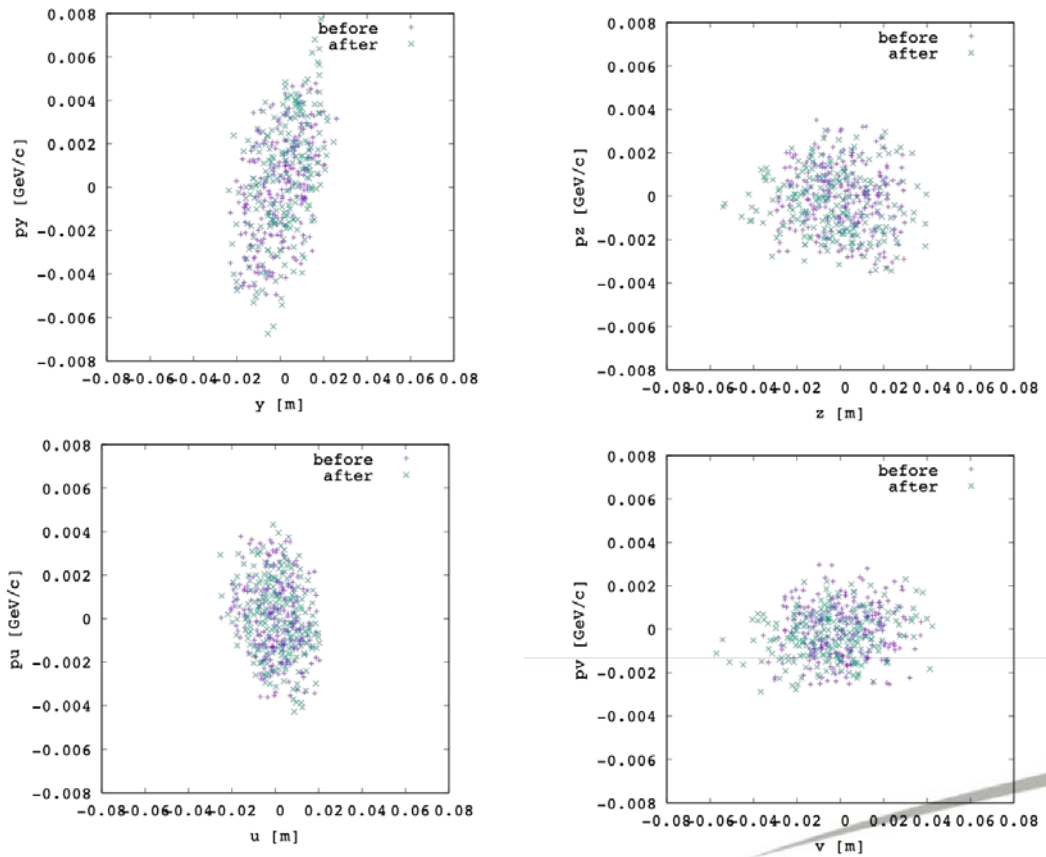


Preliminary design of the FFA BPM, modelled in CST

S Machida, et al, I Rodriguez, S Brooks, I S K Gardner, R Mathieson, C Wilcox, E Yamakawa, et al

3.1 Accelerator work: FFA Rings
3.1.4 vFFA Beam Dynamics

- Dynamic aperture verification for baseline design
  - Strongly coupled traverse motion
  - Non-linearity of all orders
  - DA for 1000 turns: >30 π mm mr (nor.)



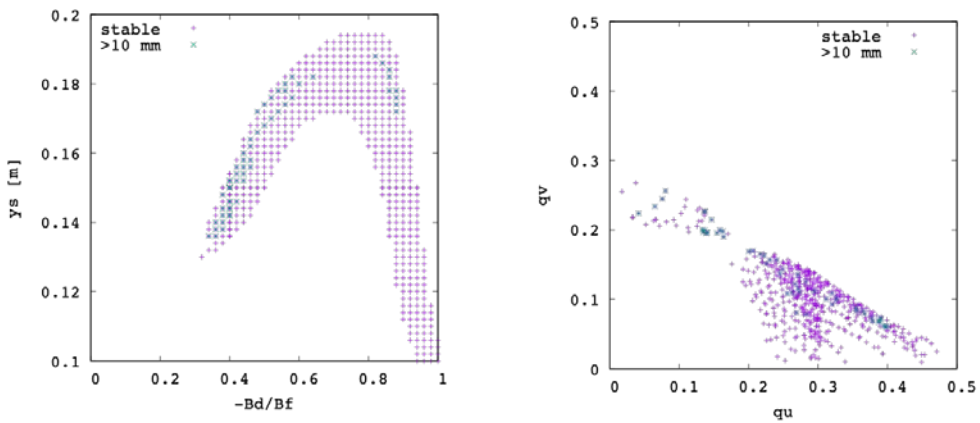
Coupled space (y - z)

Decoupled space (u -v)

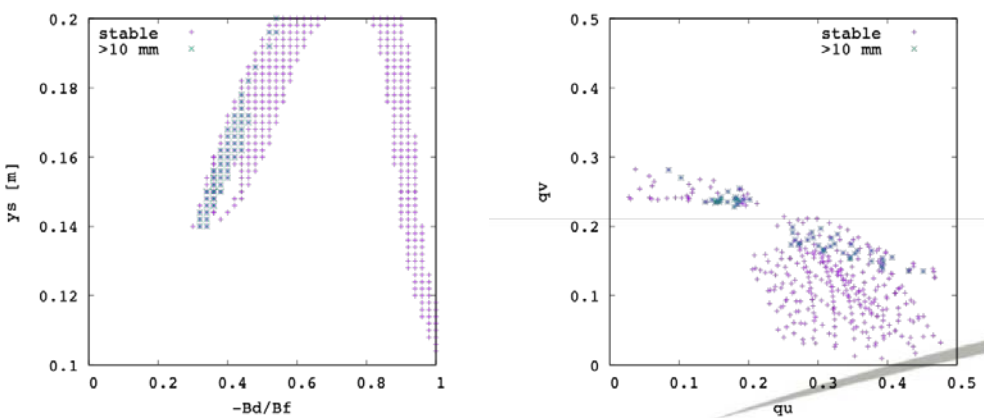
S Machida, D Kelliher, J-B Lagrange, C R Prior, C Rogers

3.1 Accelerator work: FFA Rings
3.1.5 vFFA Beam Dynamics

- Adjustability for baseline design: tuning knobs
  1. Field index (gradient) m
  2. Ratio of Bd/Bf
  3. Radial distance between Bd and Bf



m=1.60



m=2.00

S Machida, D Kelliher, J-B Lagrange, C R Prior, C Rogers

Contents

AR - *Accumulator Ring*
RCS - *Rapid Cycling Synchrotron*
FFA - *Fixed Field AG Synchrotron*

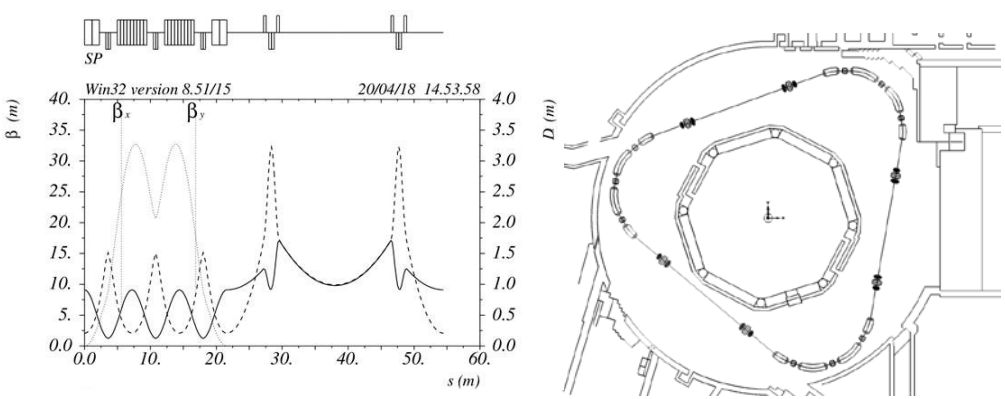
3.2 Accelerator work: Conventional Rings
3.2.1 Lattice Designs

- Lattice and optics requirements for RCS
  - Circumference, apertures, long straights, magnets
  - Injection, extraction, collimation, RF, correction
  - Beam dynamics, stability, foil, loss ~0.2%
- A number of "working designs" for RCS
  - Optics: BF-D & triplet; FODO & doublet
  - Long achromatic straights
  - Satisfy essential "first order" requirements …

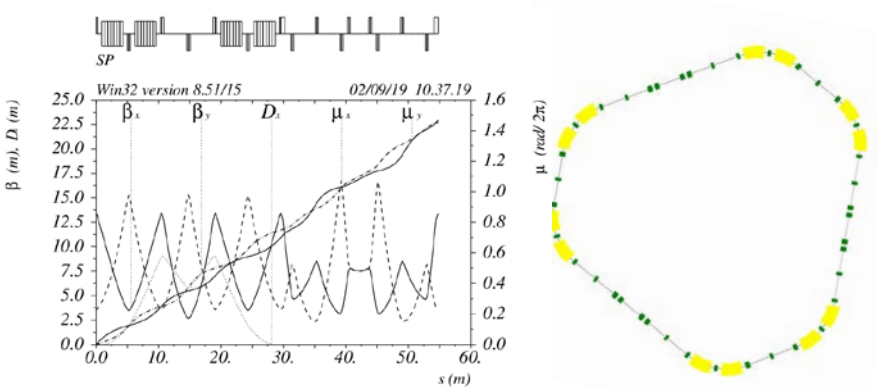
Nominal RCS Parameters

Energy Range	0.4 – 1.2 GeV
Intensity	1.3×10^{14} ppp
Repetition Rate	50 Hz
Mean Power	1.25 MW
Circumference (mean R)	163 m (26 m)
No. Super-periods	3
Nominal Tunes	(Q_x, Q_y)=(4.40, 4.36)
Magnet Excitation	Sinusoidal
Dipole Fields	0.49 – 0.99 T
Gamma Transition	3.78
Peak RF h = (2, 4)	(240, 120) kV/turn
RF Frequency (h = 2)	2.62 – 3.30 MHz
Number of Bunches	2

REF 1 Study Ring (EPAC 18)



REF 2 Study Ring



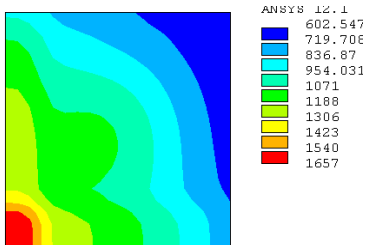
D J Adams, C M Warsop, R E Williamson et al

3.2 Accelerator work: Conventional Rings
3.2.2 Injection Designs

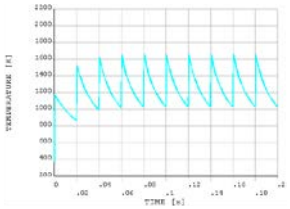
Examples from 180 MeV Injection Upgrade

- Injection straight requirements
  - Foil, geometry and mounting
  - Stripping product control: H*, e-
  - Painting and bump magnets
  - Physical space and optics
- Beam dynamics requirements
  - Paint stable beam distributions
  - Minimise foil re-circulations: temperature, loss
  - Optimise at high intensity: simulations – see later
- Working design parameters
  - Solutions for 400 MeV injection into RCS
  - Foil: 300 μg/cm^2 carbon
  - Foil re-circulations ~2 (simulation)
  - Foil temps ~1700 K

Foil Temperatures Spatial

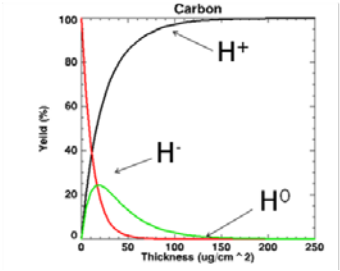


Foil Temperatures Time

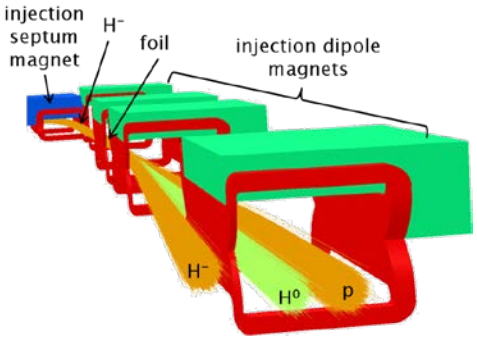


ORBIT and ANSYS

Foil Stripping



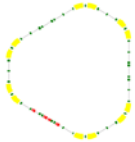
Injection Straight



D J Adams, H V Cavanagh, B Jones, et al

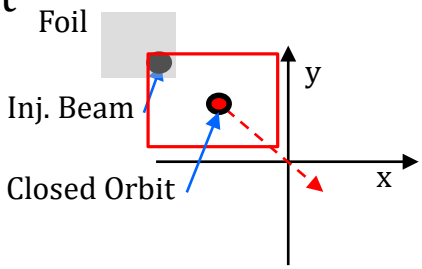
3.2 Accelerator work: Conventional Rings
3.2.3 Injection Designs

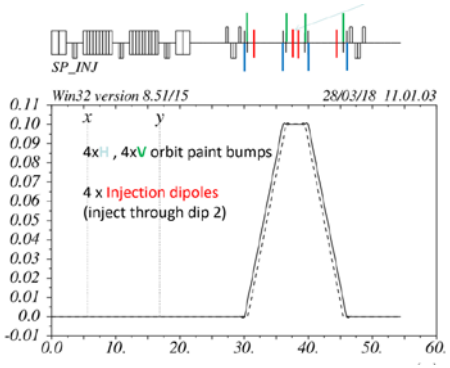
Outline of RCS injection



- RCS Injection system designs under study
  - Lattice optics: zero dispersion, dual waist
  - Horizontal injection bump (chicane)
  - Horizontal and vertical painting bumps
  - Flexible, independent painting vs time

Real space at Foil

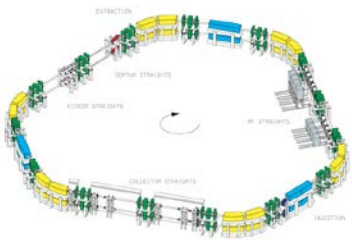




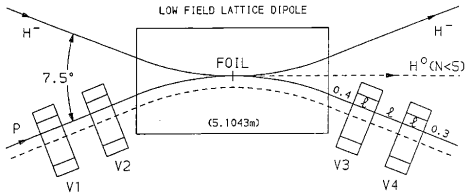
Injection painting, bumps

- Key optimisation: bump program
  - Collapse bump, move away from foil
  - Key challenge ⇒ low foil re-circulations
  - Minimise emittance growth …

ESS Accumulator Ring (1996)



- ESS AR Study, R=26 m at 1.25 MW
  - Unusual dispersive injection system
  - Reworked dynamics: detailed simulation
  - Foil temperatures OK, losses ~0.1%



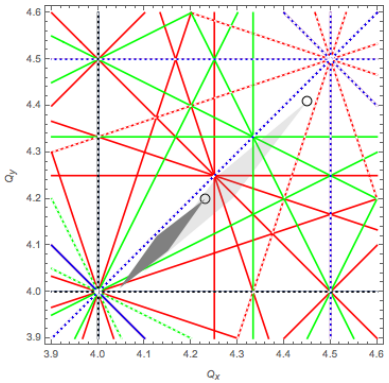
ESS Injection

D J Adams, H V Cavanagh, B Jones, C R Prior, G H Rees, C M Warsop et al

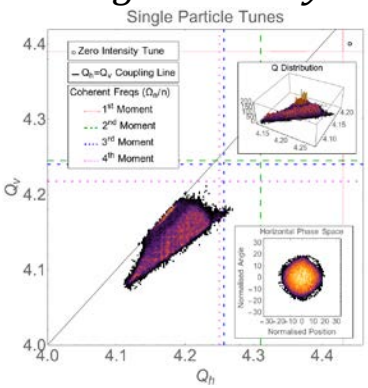
3.2 Accelerator work: Conventional Rings
3.2.4 Transverse 2D Dynamics and Errors

- Assessment of working points
  - Study near equal tunes (Q_x, Q_y)~(4.40,4.36)
  - Basic resonances, systematics …
- Simple 2D PIC study* with Space Charge
  - Checks of high intensity behaviour
- Error studies: correction; tune-ability
  - Closed orbit prediction, corrections
  - Tune range and options in lattice
- Non-linear correction and optimisation
  - Non-linear errors (non-space charge)
  - Sextupole, octupole families, dynamic aperture

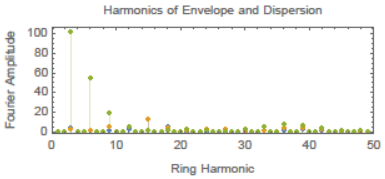
Q Plane for RCS



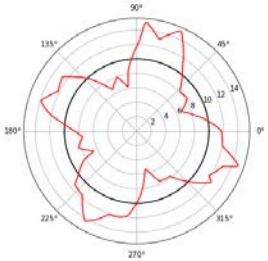
High Intensity



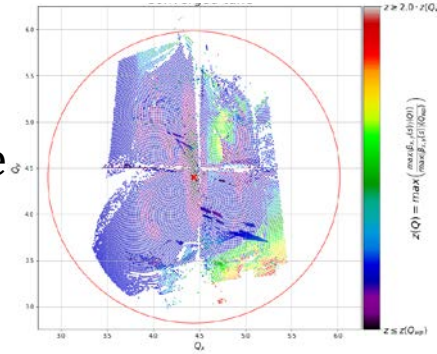
Envelope Harmonics



COD Model

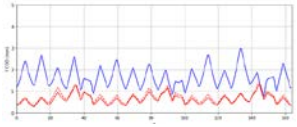


Exploring Tune Range



COD (RMS)

Uncorrected Corrected



** Using in-house PIC code*

D J Adams, P T Hicks, B G Pine, C M Warsop, et al

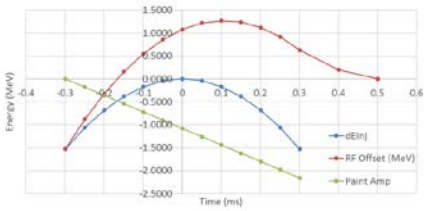
3.2 Accelerator work: Conventional Rings
3.2.5 Longitudinal and 3D Dynamics

- Longitudinal dynamics design* (1D)
  - Optimised bunch capture, control
  - Lattice space for h=2, 4 RF systems
  - Volts/turn for 0.4-1.2 GeV in 10 ms
  - Chop at revolution frequency
  - 58 mA injector beam, 60%, 780 turns
  - Optimise painting for distribution
  - Capture, stability, halo, bunching factor
  - Free gap for extraction

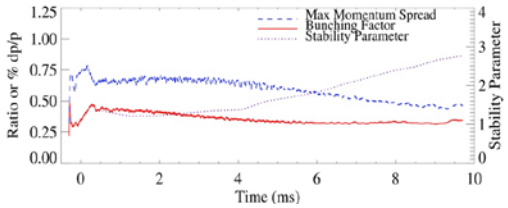
- 3D Design and Simulation Model
  - Longitudinal and transverse dynamics
  - ORBIT 3D PIC, AG lattice, …
  - Injection painting, foil, collimation, …
  - 1.5E6 macro particles 128x128x64 bins
  - Linear and TEAPOT lattices

- Extraction, Collimation
  - Designs include suitable optics and space

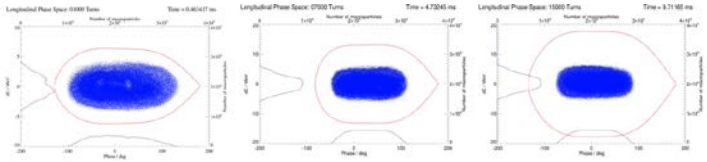
Painting Functions



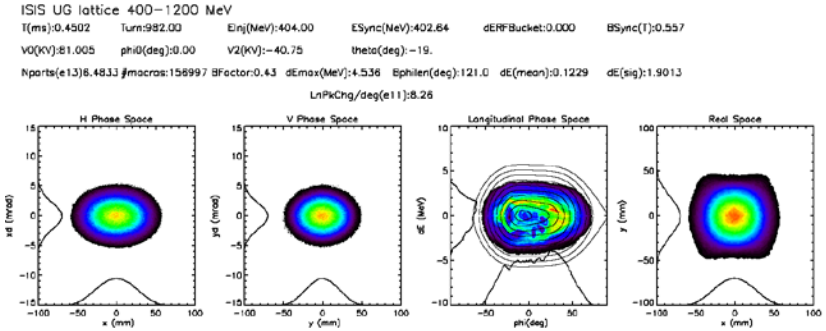
Parameters vs Time



Longitudinal Distributions 0.5, 5.0, 10 ms



ORBIT Results for 1.25 MW RCS



** Using in-house PIC code*

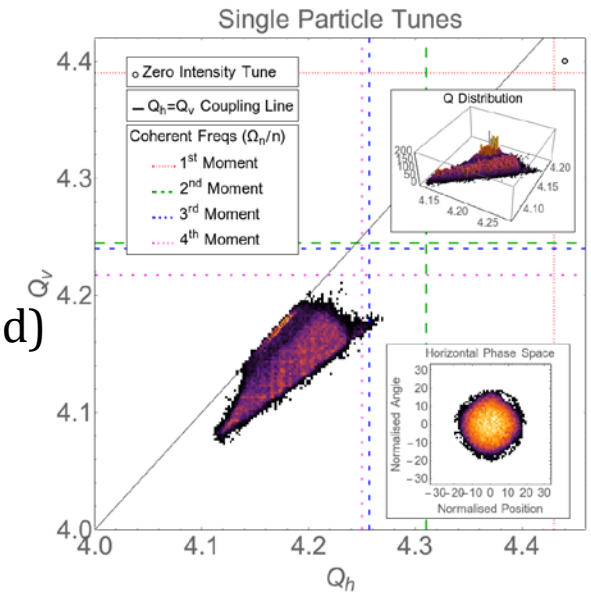
R E Williamson, D J Adams, et al

Contents

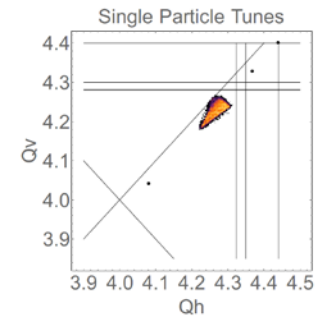
AR - *Accumulator Ring*
RCS - *Rapid Cycling Synchrotron*
FFA - *Fixed Field AG Synchrotron*

4 Space Charge on Conventional Rings
4.1 Transverse 2D Behaviour: Working Point

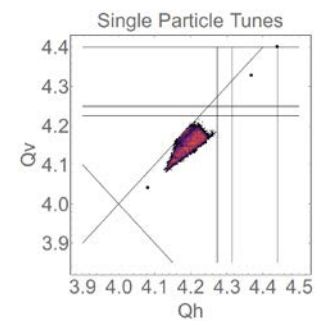
- High intensity check on RCS lattice
- 2D simulation study: Set* PIC code
  - RCS AG lattice, quadrupole errors
  - 4D Waterbag distribution (~matched)
  - $\varepsilon_{xrms}=\varepsilon_{yrms}=50\ \pi$ mm mr
  - Q=(4.44, 4.40), 100 turn track
- Analyse with increasing intensity
  - Check for loss, emittance growth
  - Coherent and incoherent frequencies
- Result: OK at RCS design intensity
  - Beam OK at equiv. ~1.3E14 ppp
- Much to understand in detail
  - Coupling $Q_x \approx Q_y$; $2Q_x$-$2Q_y$=0
  - $4Q_x$=17 driven by coherent moment
  - Next level: painted distributions, 6D, …



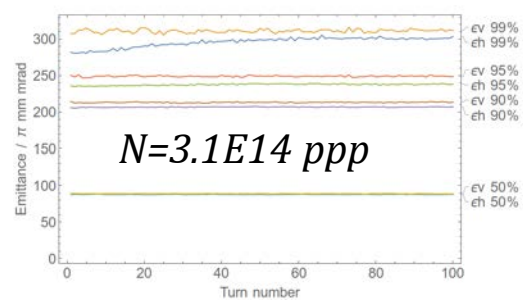
N=2.4E14 ppp



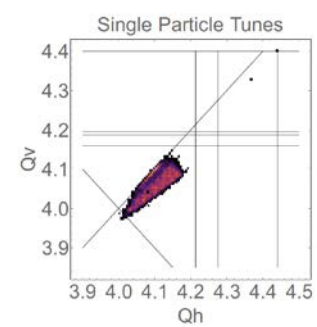
N=3.1E14 ppp



Emittance Growth



N=4.4E14 ppp

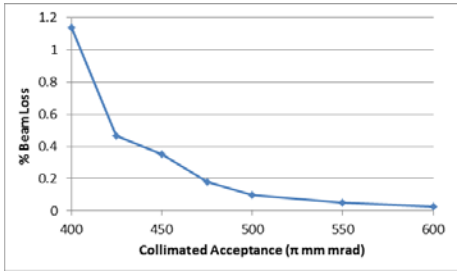


** in-house PIC code*

B G Pine, C M Warsop, et al

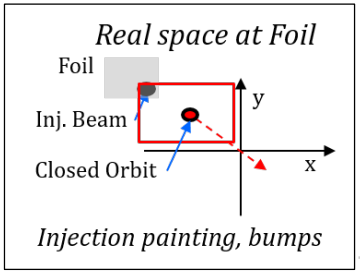
4. Space Charge on Conventional Rings
4.2 Injection Optimisation: Search Codes

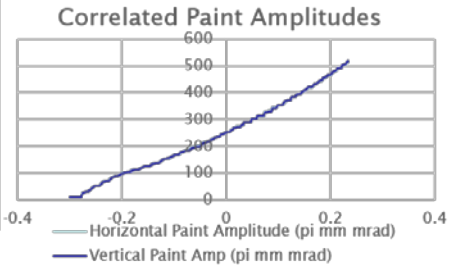
Total Loss vs Collimation Limit (ORBIT)

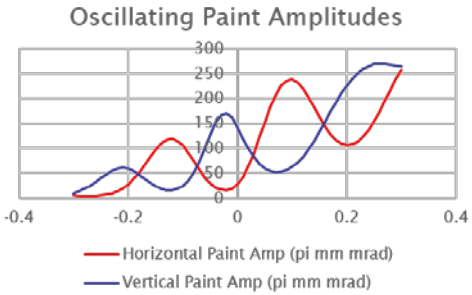


- Key challenge: control distributions
  - Foil hits ⇒ temperature, loss (small R ring)
  - Emittance growth ⇒ aperture occupied
- Working on numerical optimisation codes
  - "Brute force hill search" on foil hits, with time
  - $(\varepsilon_h, \varepsilon_v)$ vs time (i.e. bumps); also (Q_h, Q_v), (β_h, β_v)
- Levels of approximation and speed
  - Analytical, no space charge
  - Smooth Focusing, 2D PIC space charge*
  - AG 3D PIC in ORBIT
- Typical search: optimise 2D paint bump
  - Step through injection process
  - Test foil hits/loss for surrounding points
  - Adjust to minimise: generate time dependent bumps
- Challenges
  - Select constraints: optimisation metrics (loss, ΔQ, …)
  - Confidence in results?

Example: correlated bump search







** Using in-house PIC code*

D J Adams, B G Pine, C M Warsop, et al

4. Space Charge on Conventional Rings
4.3 Injection Optimisation: Simulation Results

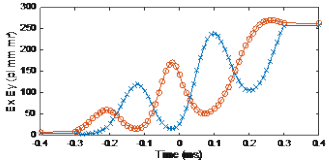
- Study of "optimised" injection
  - RCS ORBIT injection, 750 turns
  - Linear lattice, no errors
  - N=1.3E14 ppp, Q=(4.36,4.40)

1. *Oscillating paint*

ε 10-270 π mm mr

foil hit 2

ε99% ~600

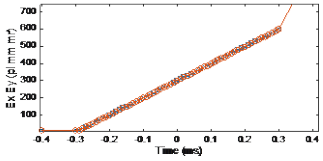


2. *Simple paint:* limited ΔQ_{sc}~ -0.2

ε 10-600 π mm mr

foil hit 7

ε99% ~1000

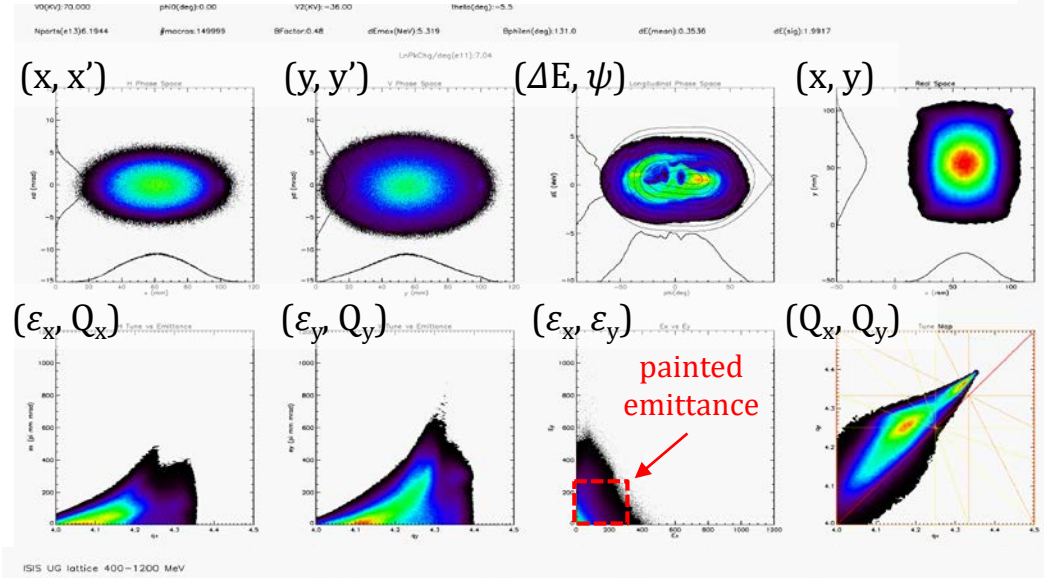


- Work in progress …

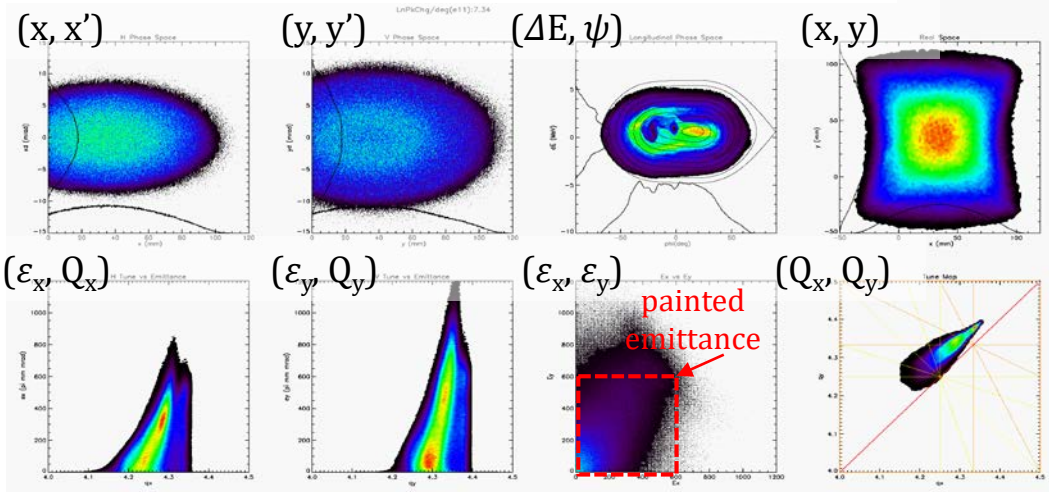
  How far can we optimise painting?

  Can we trust, understand codes?

1. Oscillating paint: distributions end of injection



2. Simple paint: distributions end of injection



4. Space Charge on Conventional Rings
4.4 Injection Optimisation: What Next?

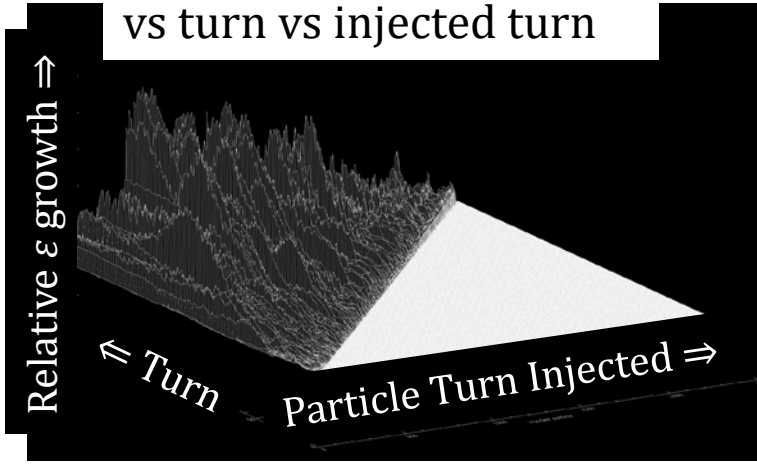
- Critical task: understand & optimise injection:⇒ true for AR/RCS/FFA
  - Can we achieve better distribution control? Detailed, fast paint variation?
  - If paint smaller, stable beam ⇒ get cheaper ring (beam power)

- Key factors
  - Geometric effects: optimise bumps, Q to miss foil, paint over halo
  - High intensity beam dynamics effects: evolution of distributions
    - Coherent, incoherent; magnet errors, space charge; 4D-6D

- What are the best <u>*code beam diagnostics*</u>?
  - Coherent: moments, spectra, …
  - Semi-coherent: moments of sub sets
  - Incoherent: particle ε, Q, trajectories, growth, …
  - As function of $(\varepsilon_h,\varepsilon_v,\varepsilon_l)$; injection time;

- Next …
  - Continue to study, identify key physics
  - Cross check with different codes
  - Include non-linear lattice effects

Injected particle* growth vs turn vs injected turn



**Injected centroid particle*

5. ISIS II Upgrade Project Summary

- A substantially upgraded ISIS will be required to supply the neutrons Europe needs
- A roadmap for determining the best upgrade route for ISIS has been established
- An extensive and ambitious program of accelerator physics R&D and design work is underway to determine the best accelerator solution for the optimal next generation source
- We need to study many interesting accelerator physics challenges to find the best solutions

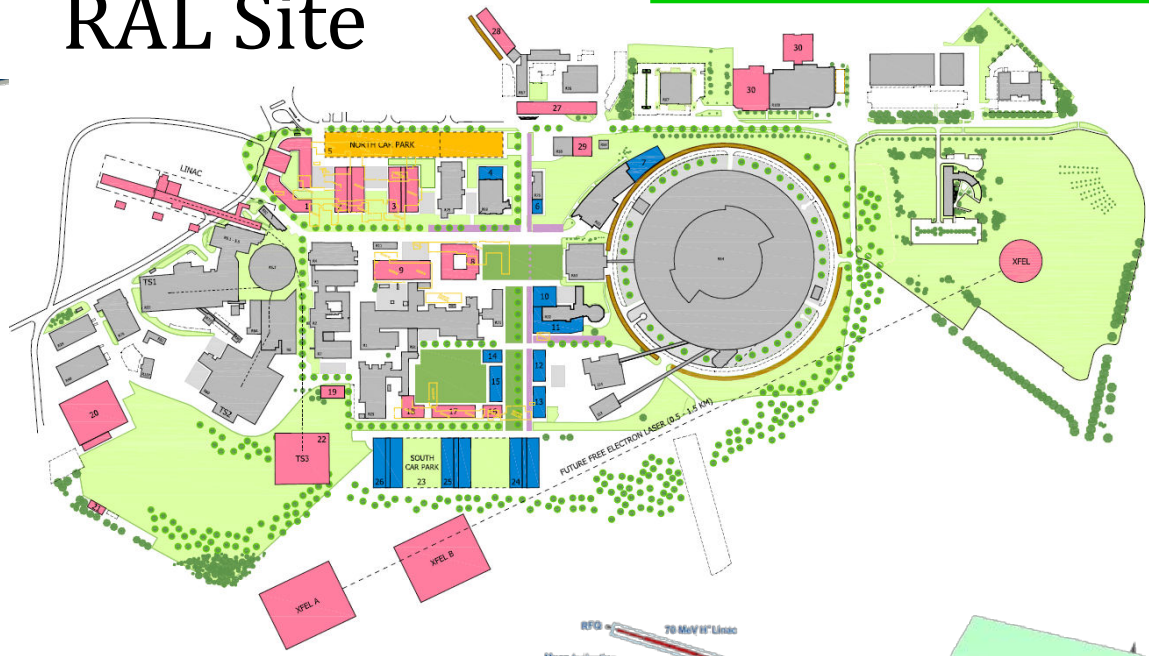
Additional Slides

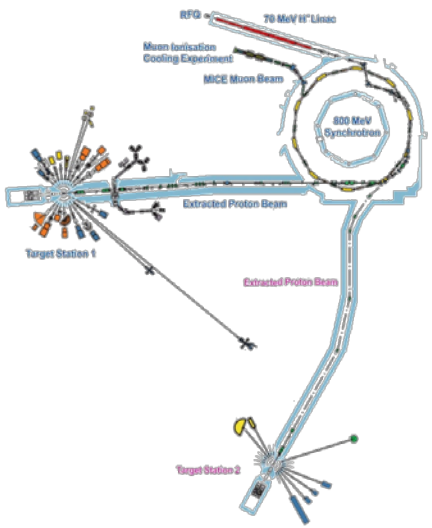
Science & Technology Facilities Council
ISIS

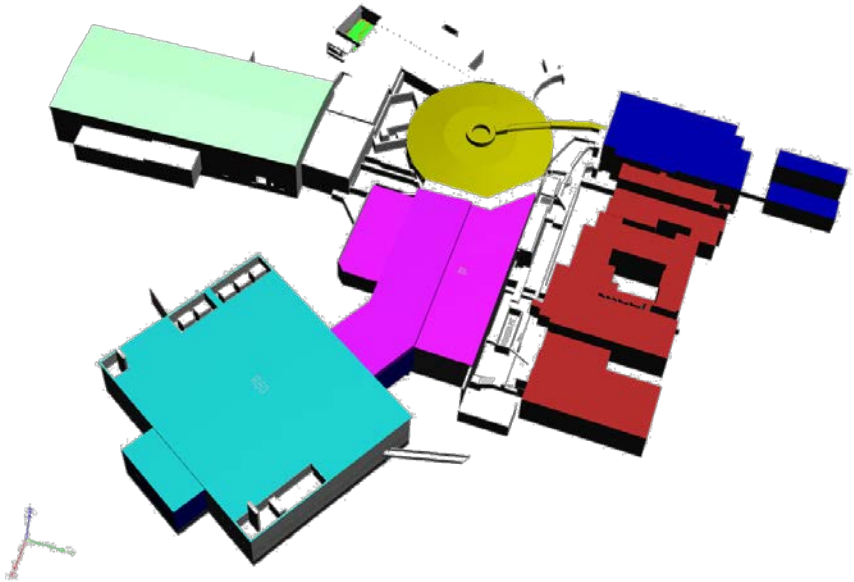
A1. ISIS II Accelerator Studies

Reuse of ISIS Infrastructure

RAL Site







A.2 Accelerator work: General R&D
Relevant work on and around ISIS

- Space charge studies on ISIS Ring
  - Transverse loss and resonances
  - Profile evolution on resonance
  - Profile monitor errors: performance

LF Z_T Measurements

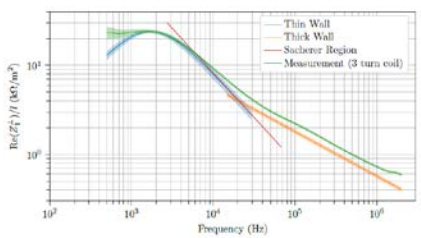
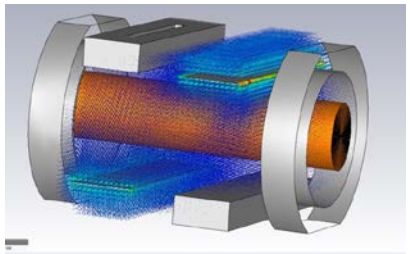
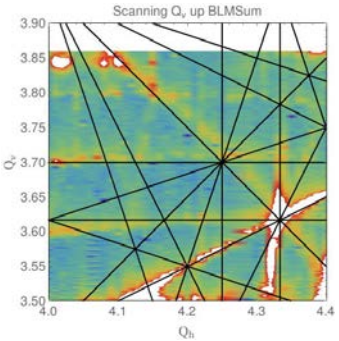


Figure 13: Real part of the transverse dipolar impedance per unit length of the 3 mm thick pipe with theoretical lines for the thin, Sacherer and thick-wall regions; shaded areas represent uncertainties.

Residual Gas Profiles



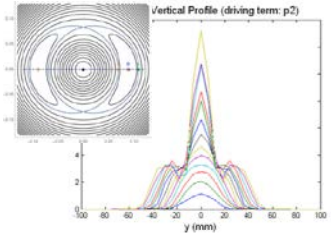
ISIS Loss vs Q Measurements



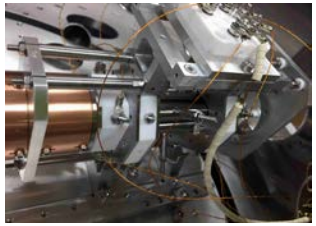
Order	Resonance
Sextupole	$3Q_h = 13$
Sextupole	$3Q_v = 11$
Octupole	$4Q_v = 15$
2nd order	$Q_h + Q_v = 8$
3rd order	$Q_h - 2Q_v = -3$
3rd order	$2Q_h - Q_v = 5$

Resonances found during investigations.

Resonance Studies



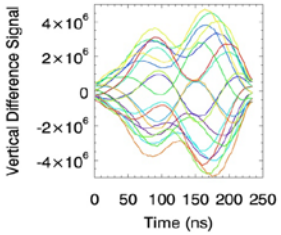
IBEX Paul Trap



- Impedance, instabilities on ISIS
  - Head-tail study (space charge)
  - Impedance measurements
  - Damper system

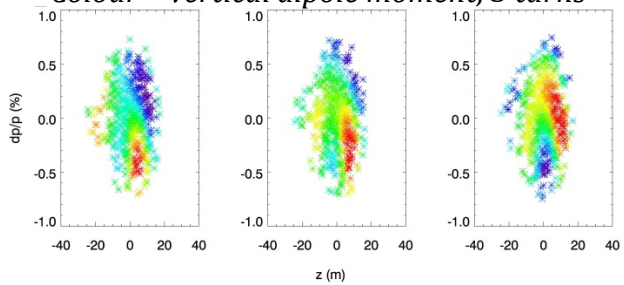
Head-tail instability with space charge

Mode Structure



Y Dipole Motion in Longitudinal Plane

Colour = vertical dipole moment, 3 turns



- Also:
  - Codes, diagnostics, …
  - Magnets, power supplies, …
  - Ion Sources, MEBT, FETS, …

P T Hicks, B Jones, B G Pine, A Pertica, D Posthuma de Boer, C M Warsop, C C Wilcox, R E Williamson, L K Martin, D J Kelliher, S L Sheehy, et al