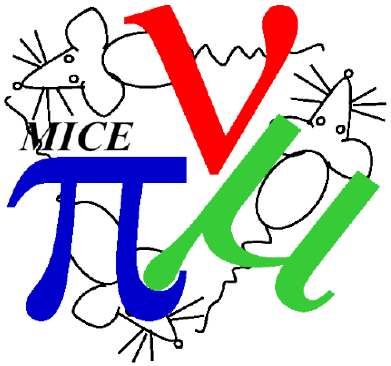
Characterisation of the KURRI FFAG main ring



C. T. Rogers, on behalf of the KURRI-FFAG collaboration
ASTeC Intense Beams Group
Rutherford Appleton Laboratory

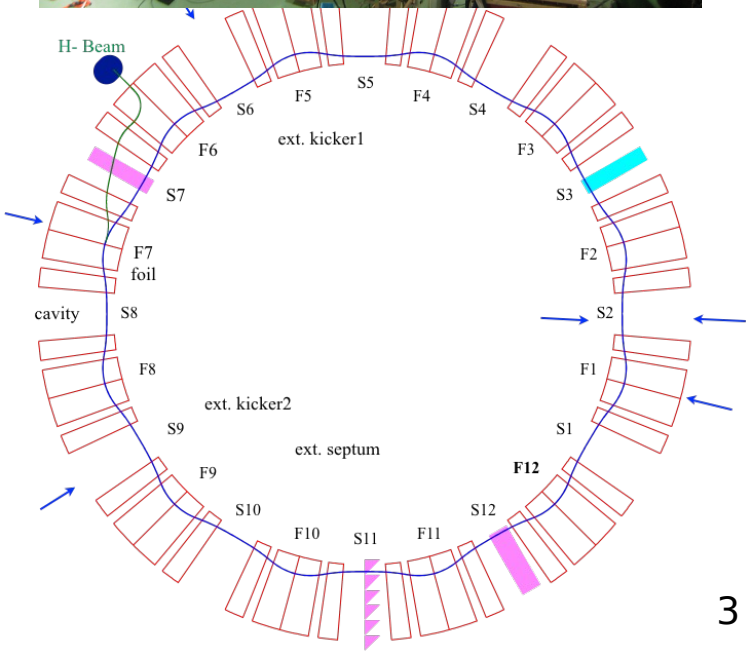
ASTeC

FFAG accelerators for muons

- Need to accelerate muons quickly – they decay!
- Rapid Cycling Synchrotron
- Recirculating Linear Accelerator
- Fixed-Field Alternating Gradient Accelerator (FFAGs)
  - Higher bending field at large radii
  - Scale the optics with radius – keeps constant tune

KURRI FFAG accelerators

- 11 MeV linac for injection
- Three FFAG accelerators at KURRI
  - Old injector ring 3 – 11 MeV
  - ERIT ring 11 MeV internal target machine
  - **Main ring 11 - 150 MeV; test ring for test ADS Reactor**



Design features

- Yoke-free combined function scaling magnets
- Tight bend at injection
- Variable frequency RF (not a cyclotron)
  - Magnetic material in RF cavity
- Diagnostics
  - Radial probe
  - Beam monitors
  - Horizontal and vertical perturbators

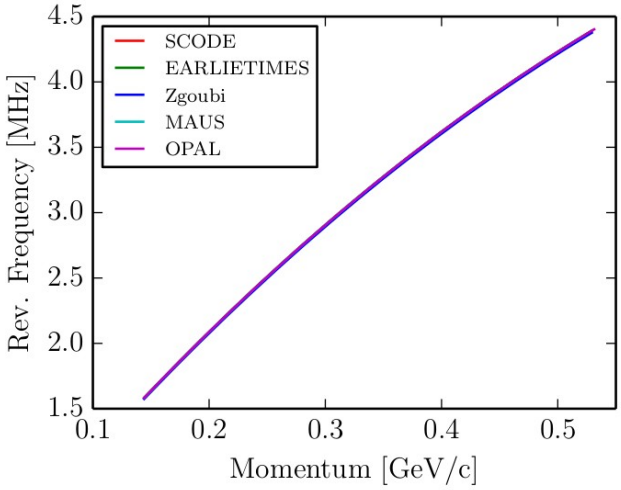
Table 1: Parameters of the 150 MeV FFAG

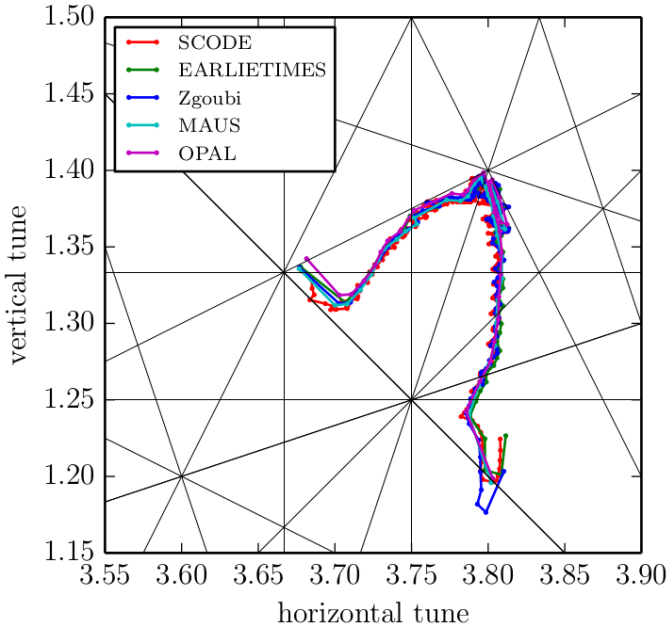
Parameter	**Value**	
r_0	4.54	m
Cell structure	DFD	
N_{cells}	12	
k, field index	7.6	
Injection Energy	11	MeV
Extraction Energy	100 or 150	MeV
f_{rf}	1.6-5.2	MHz
B_{max}	1.6	T

Experimental Programme

- Experimental programme aims to:
  - Validate simulation of the FFAG
    - Kinematics
    - Foil/stochastics
  - (Later) Examine space-charge dominated regime
    - Effect of foil
    - Effect of high radius/not symmetric beam-pipe
- Measure
  - Closed orbit distortion
  - Energy-dependent tune
  - Field index
  - Foil characteristics

Transverse Simulation

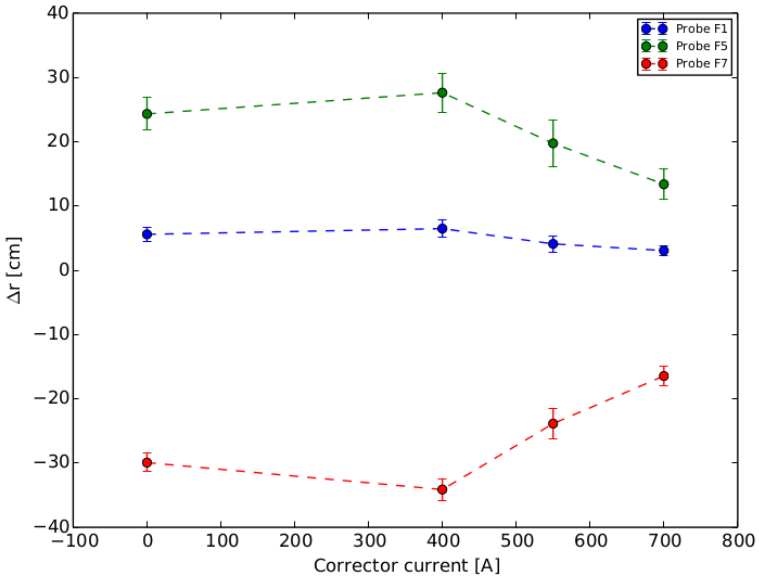


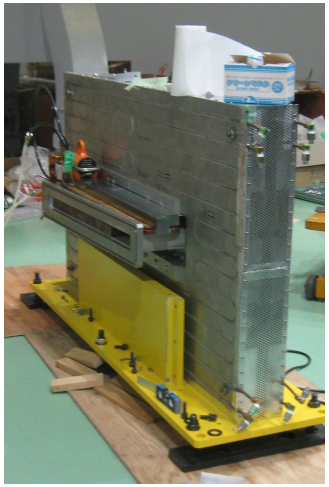


- Excellent agreement between many codes
- SCODE: FFAGs and synchrotron code with space charge
- OPAL: Cyclotron modelling code with space charge
- MAUS: Geant4 based code (yes the MICE code) with good material physics models
- Zgoubi: standard FFAG code
- EARLIETIMES: KURRI home-brew code

Closed orbit distortion

- Closed orbit distortion (COD)
  - Magnetic alloy in RF cavity
  - Yoke-free scaling magnets
- Measure using radial probe
  - Place probe (collimator) at a given radius
  - Inject beam at 11 MeV
  - Look at time-to-loss
  - Move probe
  - Repeat...
- Allows to study radial position of beam
- Make a coil to correct COD

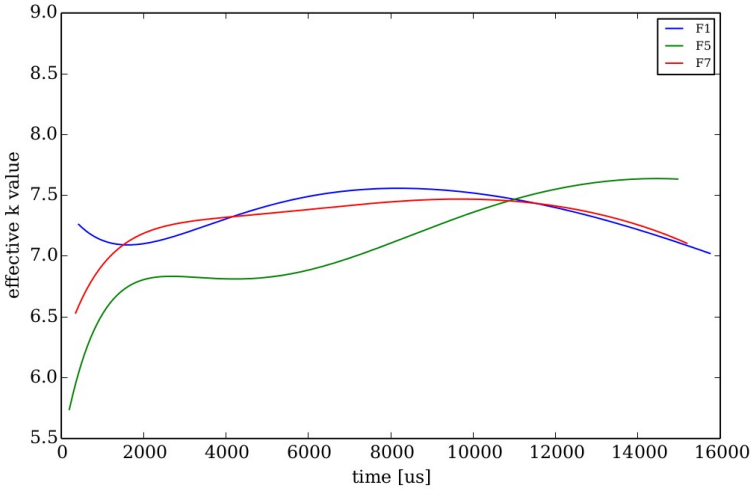




Measure field index

- Measure closed orbit in the acceleration cycle
  - Move radial probe;
  - Accelerate beam and look at RF frequency when the beam scrapes on the probe
  - Apply:

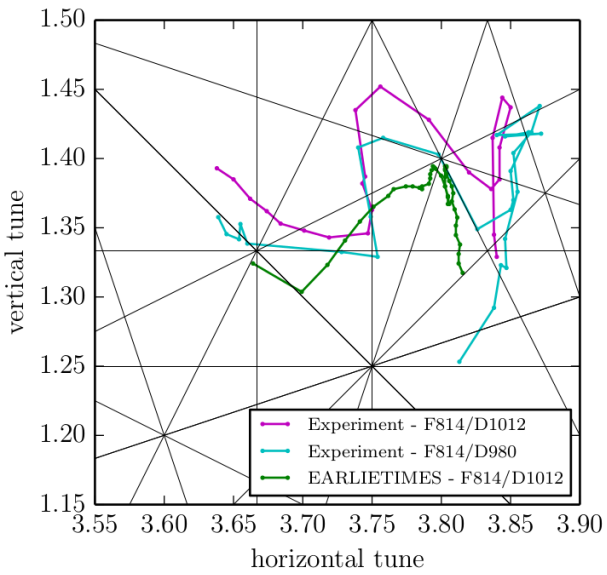
$$k = \gamma^2 \frac{df/f}{dr/r} - (1 - \gamma^2).$$



- Note influence of closed orbit distortion

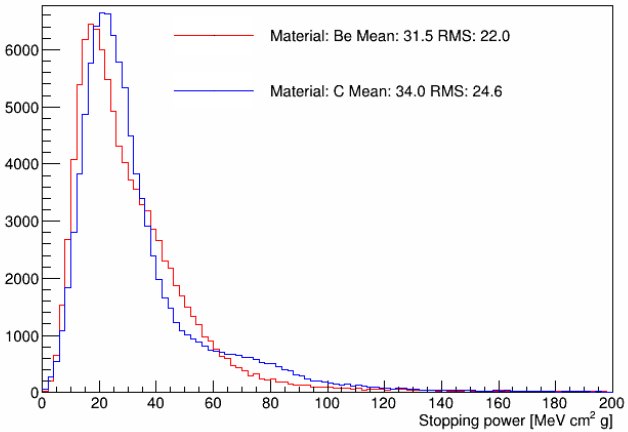
Measured Tune

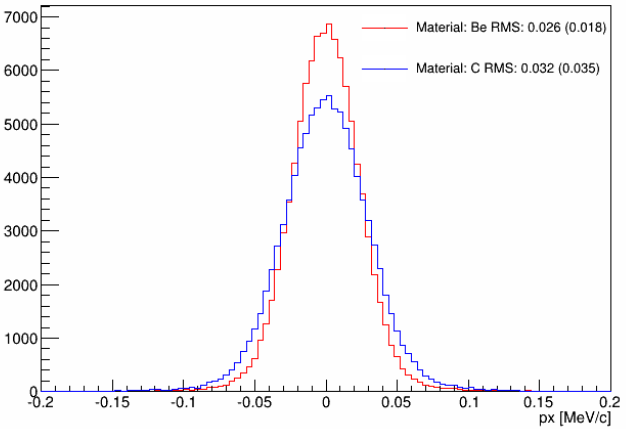
- Use vertical perturbator to excite vertical coherent oscillations
- For horizontal tune
  - Use horizontal perturbator
  - In low energy region use RF cavity
  - In high energy region use extraction kicker
- Look for coherent oscillations in bunch monitors



Foil Model

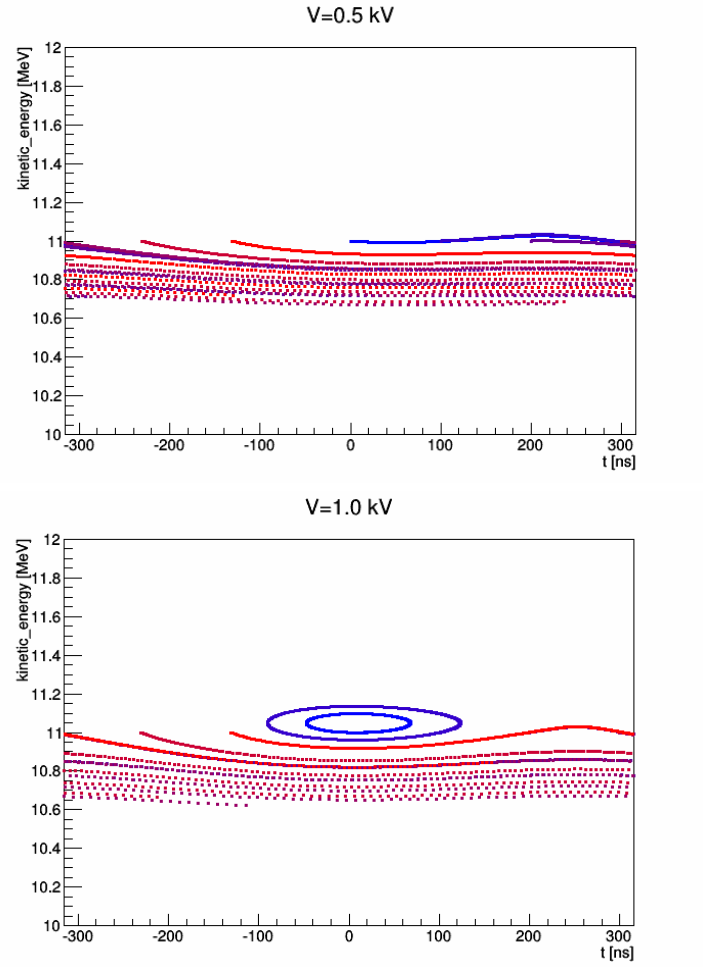
- Use GEANT4 to model foil
  - Energy loss and MCS is consistent with PDG numbers
  - Note slight over estimate of the tail of the stopping power distribution for C





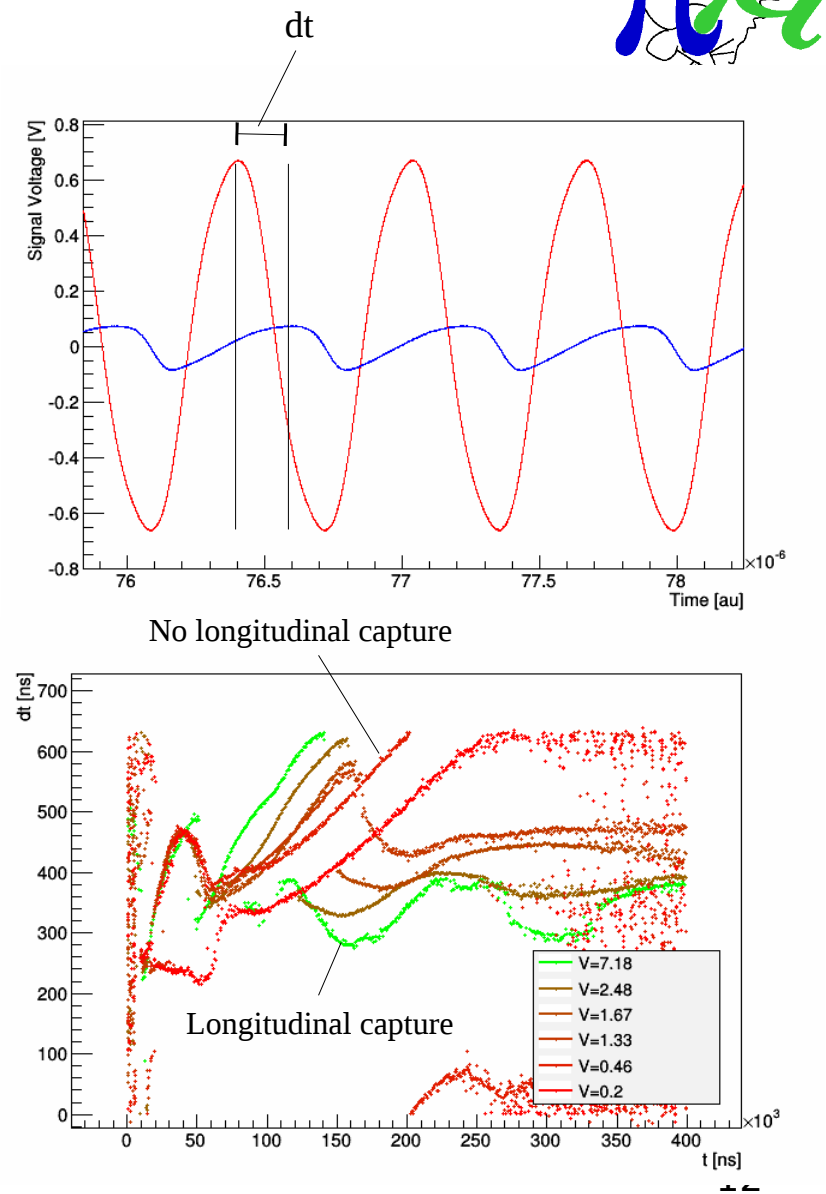
Simulation of Foil in Ring

- Combined ring simulation
  - Try simulating foil and RF in the ring
  - How can we study the foil effect on beam?
- Vary RF cavity voltage
  - When does the RF bucket form?



Measurement of foil energy loss

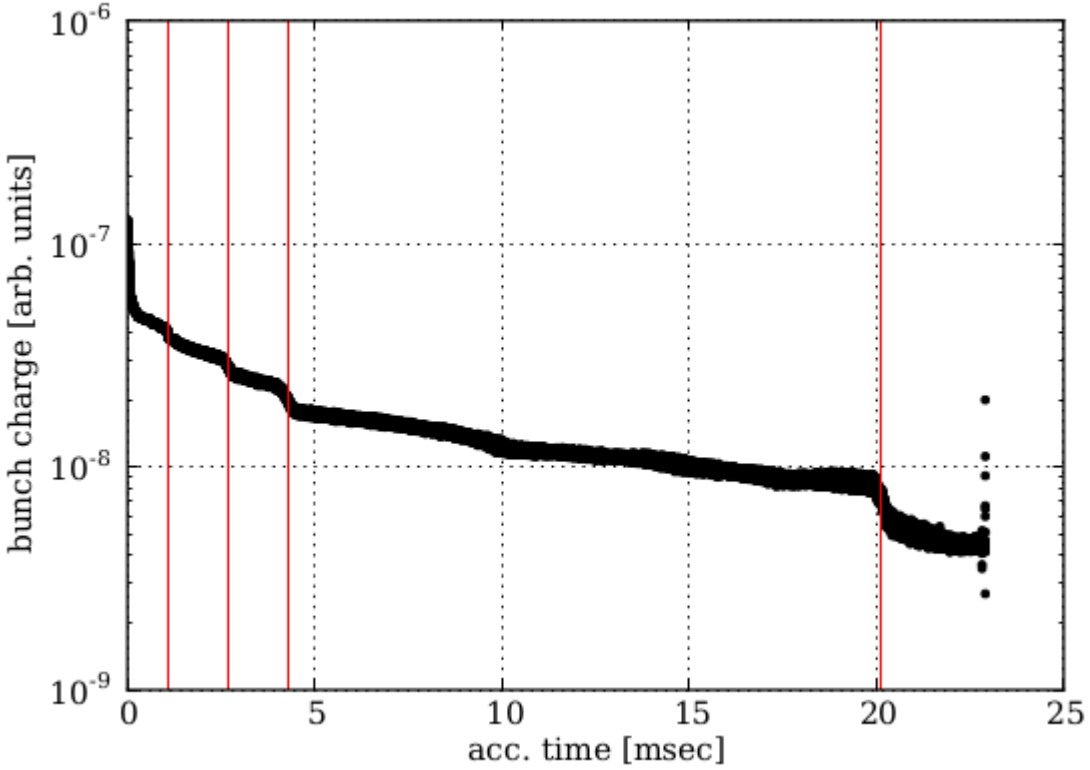
- Measure time of RF peak compared to bunch peak
- Validate longitudinal model
  - What voltage is required to get RF bucket formation?
- Get RF bucket formation between 0.46 V – 1.33 V
  - Consistent with MC
- Seek to quantify



Summary

- Characterisation of KURRI FFAG
  - Closed orbit
  - Tune
  - Field index
  - Foil model (energy loss)

Towards high intensity



- Looking to move to high intensity running
  - Correct COD
  - Correct tune shift
  - Improve transmission