Questions session

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CSNS Collaboration meeting

21-25 July 2025

UKRI Science and Technology Facilities Council

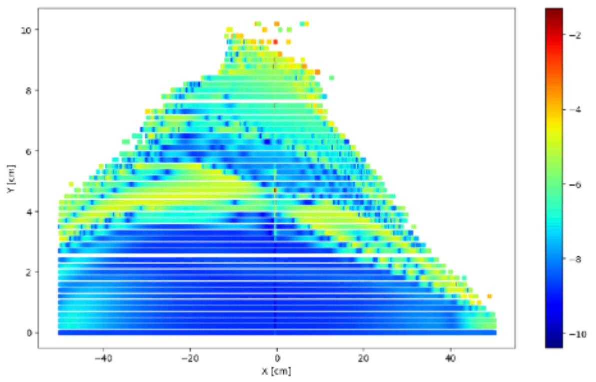
ISIS Neutron and Muon Source

Lattice Structure Design Considerations

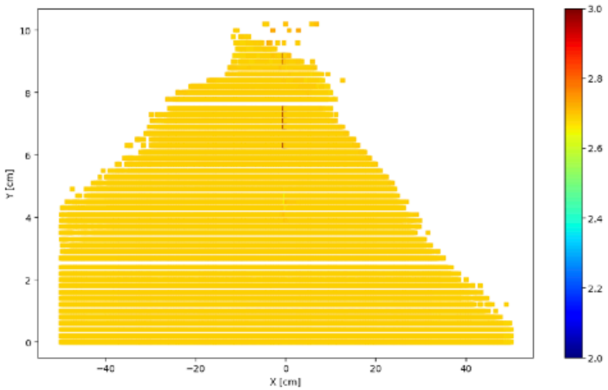
- Q1. You have presented a 16-period FD structure. What are the specific advantages of this configuration compared to 12 or 14-period alternatives? Could you elaborate on the optimisation criteria that led to the selection of 16 periods for your design?
- Q3. For identical spiral angles, why does the FD lattice structure exhibit larger vertical tune spread compared to the FDF configuration? Our preliminary analysis suggests that a 12-period FDF structure may demonstrate superior stability compared to the 16-period FD design. What is your assessment of this comparison?
- Q10. About the Lattice design, there are two schemes: FDF and FD. Based on your research experience, could you discuss the advantages and disadvantages of both schemes.

Spiral Angle Effects on Beam Dynamics

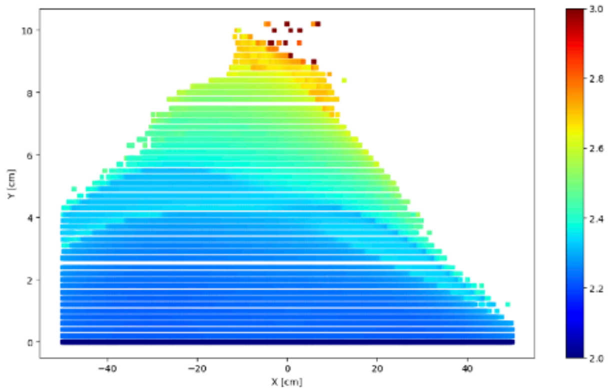
- Q2. Regarding vertical tune stability and spiral magnet edge structure: You mentioned that larger spiral angles at magnet entrance and exit regions increase the octupole field component amplitude, leading to increased βz and consequently larger vertical tune shifts.
    - What is the fundamental physical mechanism by which increased spiral angles generate enhanced octupole components?
    - Can you clarify the relationship between nonlinear particle amplitude and frequency shift in this context?
    - Are there analytical expressions or scaling laws that describe this relationship?
- Q9. We attempted to track the dynamic aperture by Zgoubi. We found that the transverse tune shifts of particles with vertical position offset are much greater than those in the horizontal direction. Have you encountered this problem before. Or is this due to Zgoubi's incorrect handling of particles with significant vertical offsets?



Diffusion rate



ν_x



ν_y

Q6. Stripping Foil

- If the main stripping foil is placed between the F and D magnets, aside from the mechanical and space constraints, do you think there are any other issues? For example, the magnets or vacuum chamber.

Q7. Injection

- Why did you select to inject the beam from inside? What are the advantages?

Magnet Design

- Q4. For our 300-600 MeV energy range, feasible FD solutions require spiral angles around 40 degrees, which unfortunately increases vertical tune spread. If we pursue optimisation of octupole edge field components through magnet boundary shaping:
  - What are the primary design and manufacturing challenges for such magnets?
  - Does reducing fringe field width (i.e., creating steeper field gradients) effectively minimise octupole field components?
  - What are the practical limits and trade-offs in fringe field optimisation for FFAG applications?
- Q5. In our variable gap magnet scheme, what are the specific operational advantages of the FDF configuration compared to the FD scheme during actual accelerator operation?
  - Does the FDF structure provide enhanced design tolerance margins for field errors and manufacturing imperfections?
  - What are the comparative capabilities for tune adjustment range and flexibility between FDF and FD configurations?
  - How do the error correction mechanisms and compensation strategies differ between the two lattice types?

Magnet Design (2)

- Q8. When simulating FFAG, we found that the optical functions of the lattice is very sensitive to the fringe field parameters of the bending magnets. The change in the operating point can be as high as several tenths. How do you handle fringe fields?
- Q11. How to coordinate the vacuum chamber thickness, magnet aperture, and physics requirements in FFAG?
- Q12: For FFAG accelerators, adjustable K-values are certainly advantageous. However, variations in K-values achieved by discrete current distributions should cause small-scale oscillations in K-values, particularly in magnetic fields away from the central plane. How do you take this issue into account?
  - Regarding the need for adjustable K-values to shift operational points, do you think all magnets should be adjustable K-values, or partial adjustment (at specific locations/quantities) is enough?

Collimation system

- (HC): Regarding withdrawing primary collimators during operations at CSNS now, and running only with secondaries, what power is measured on the secondaries and were they designed to intercept that much beam? Secondaries at ISIS are not designed to withstand intercepting this much.

Simulation code

- Based on the valuable suggestions received, the following improvements of the PyFFAG code are planned:
- 1. Adjust the orientation of the 2D slices in the 2.5D space charge calculation to ensure they are perpendicular to the direction of momentum.
- 2. Extend the off-midplane expansion to 6th or higher order to evaluate higher-order nonlinear effects.
- 3. Construct the fringe field using a sum of two sigmoid functions and compare the results with the current multiplication-based method.
- 4. Increase the number of macro-particles used during the injection process to improve statistical accuracy.

Thanks to Machida, JB, and all colleagues at ISIS for their helpful advice and guidance.
We want to know if there are any other areas that deserve attention or should be improved for the simulation, we are happy to take them into account in the next work.