Blue Skies Magnets

1. Vertical orbit-excursion FFAG
2. Omni-Magnet for FETS 3MeV ring
1. Vertical Orbit Excursion FFAG

- Possible one-ring upgrade for ISIS to 2MW
  - 800MeV to 12GeV ring at 50Hz
- Has scaling optics (entirely fixed tunes)
  - Exponential field $B_y \sim e^{k_y}$
    - Like horizontal field line tested in Kyoto/KURRI
  - Further applications in medical FFAGs and CW
- Field parallel to aperture allows constructive interference between SC coils
  - Also forces repel rather than attract coils
VFFAG Magnet (for ISIS upgrade)

800MeV

12GeV

5 Tesla

Field errors × 100

Dipole Quad Sextupole Octupole

PAMELA (to scale)
VFFAG Magnet with Edge Angles

• Improves focussing, allows practical ring size
VFFAG Test Magnet?

- Difficult to do, tends to prefer bare coils

- Ideas above originally in EMMA upgrade proposal, superseded by... [next section]
Questions for Daresbury (1/2)

• Interesting winding patterns for VFFAG magnet with edges
• Is it worth prototyping a low-field one with bare copper coils and measuring field in body and edges?
• The high field SC magnets required for high-energy ISIS upgrades will be challenging
  – Paper study?
VFFAG Bibliography

• ISIS upgrade VFFAG
  – Stephen Brooks HB2012 paper
  – HB2010 paper introduces VFFAG principle
• EMMA VFFAG upgrade document
• Note on calculating VFFAG fringe fields
• All available from
  http://stephenbrooks.org/ral/report
2. Proton “Omni-Ring”

- Magnets with independently-powered coils can provide nearly arbitrary combinations of multipoles up to a certain order
- May be used to make a general-purpose FFAG and synchrotron test ring for beam dynamics studies, if apertures reasonably large
  - Good fit for FETS, 3MeV, H\(^{-}\), space in R9
- Normal-conducting, simulated with Poisson
Possible Parameters

• Note: 3MeV = 75.1 MeV/c for protons/H⁻
  – 4x as hard to bend as EMMA electrons already
• 0.2T dipole at 40% packing → 6.3m diameter
  – Compare EMMA at 5.3m
  – 24 magnets → 33cm magnet, 49cm drift per cell
  – Fits in R9, can branch off from >3MeV linac test stand (CH structure tanks etc.)
• Test: space charge, injection, FFAGs, halo…
Omni-Ring Magnet

- Dodecapole with separately-powered coils
- Calibrated to produce multipole fields
Geometry Parameters (1/12 magnet)

- Aperture = 2a, coil thickness = c, yoke = e, etc.
- $f=pole\ fraction, \ g=coil\ fraction, \ f+g+h=1$
Compare ISIS EPB2 magnet “Q11”

- 235A in 10x10mm coils
  - $2.35A/mm^2$ in coil+water+insulator overall
- 5.4kW total power (water-cooled copper)
- 105mm radius physical aperture
  - 80mm radius good field ±0.5%
- $3.76T/m \times 105mm = 0.395T$ pole tip field
  - Spec says up to 1.4T flux in return arms
Before Optimisation (0.0158 T)
After Optimisation (0.1141 T)
Field Quality (Dipole case)

10cm aperture

$10^{-3}$

<1%

Currents just from $\cos(\theta)$ rule
Questions for Daresbury (2/2)

• Seems an obvious idea, has it been done?
• Can it be done cheaply/practically?
  – Needs many-channel power supply
  – Fair amount of iron around the outside
  – Maybe current density can go higher?
• Calibration is an interesting problem
  – Use standardised test rig for all magnets
  – Integrate magnet field sensors into poles?