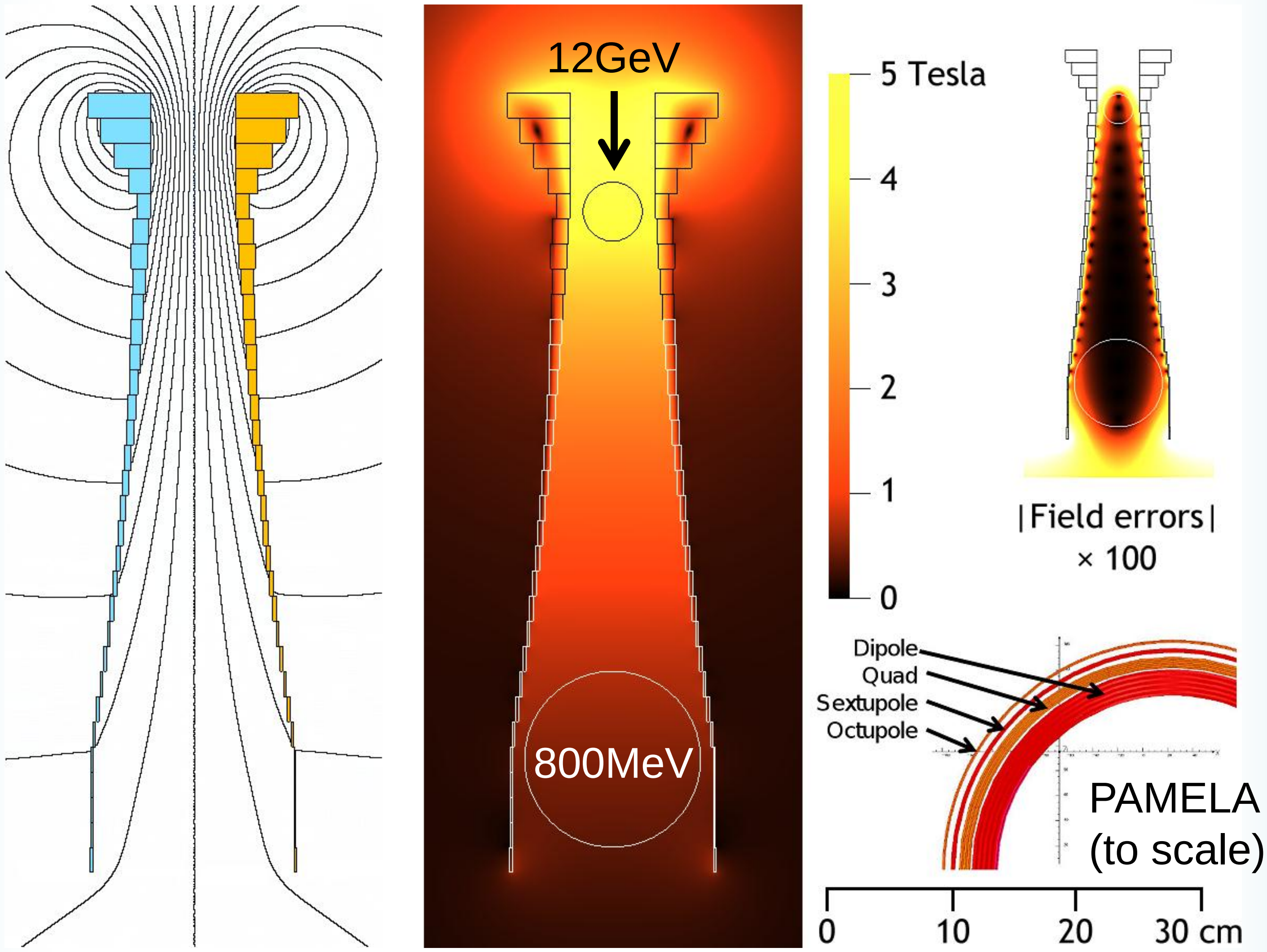
# Blue Skies Magnets

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

# 1. Vertical Orbit Excursion FFAG

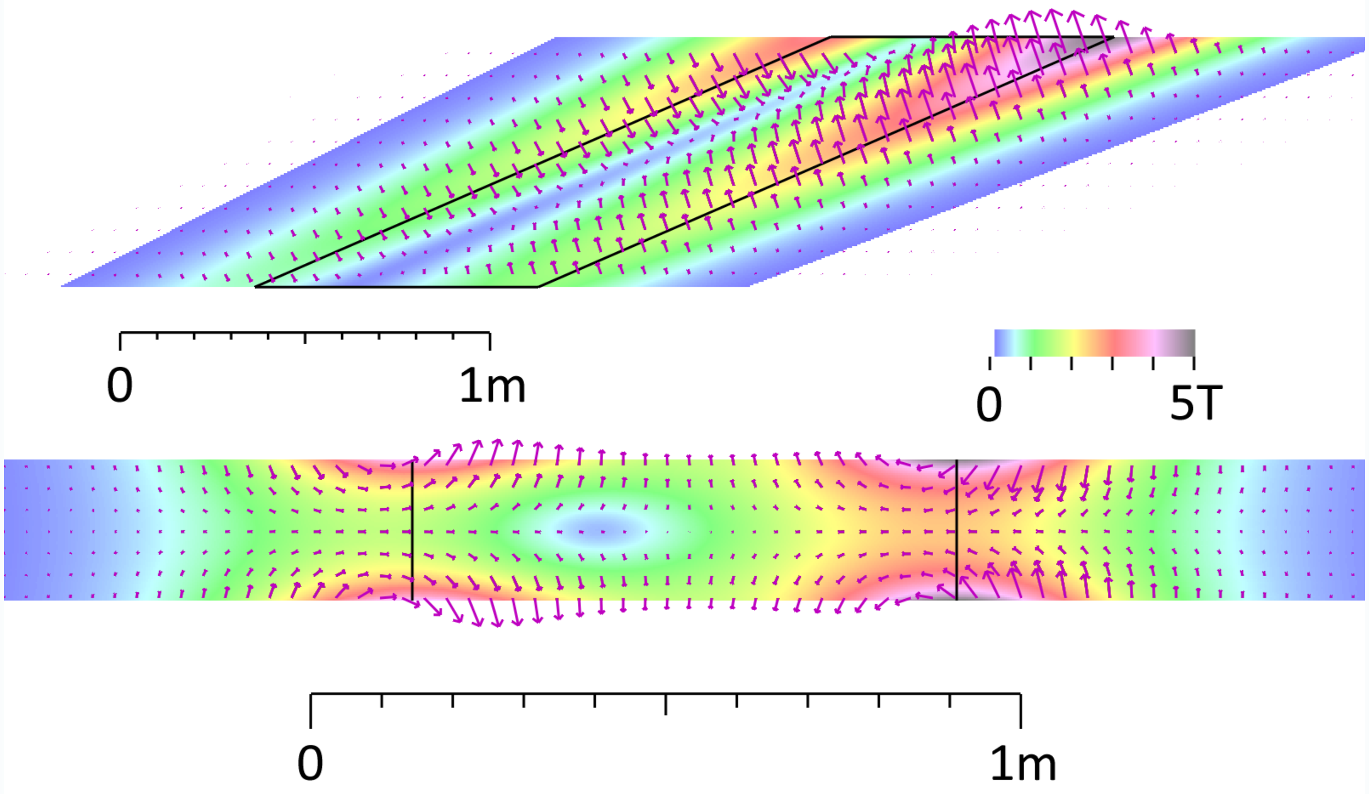
- Possible one-ring upgrade for ISIS to 2MW
  - 800MeV to 12GeV ring at 50Hz
- Has scaling optics (entirely fixed tunes)
  - Exponential field $B_y \sim e^{ky}$
    - Like horizontal field line tested in Kyoto/KURRI
  - Further applications in medical FFAGs and CW
- Field parallel to aperture allows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

# VFFAG Magnet (for ISIS upgrade)



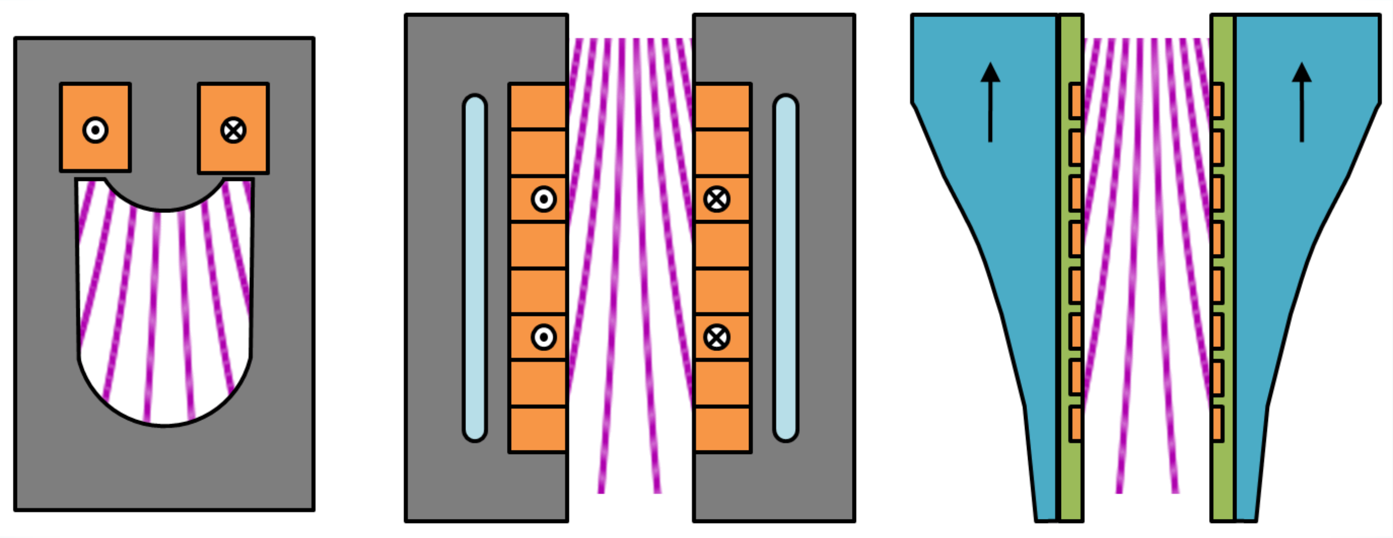
# VFFAG Magnet with Edge Angles

- 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- Ideas above originally in EMMA upgrade proposal, superseded by… [next section]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

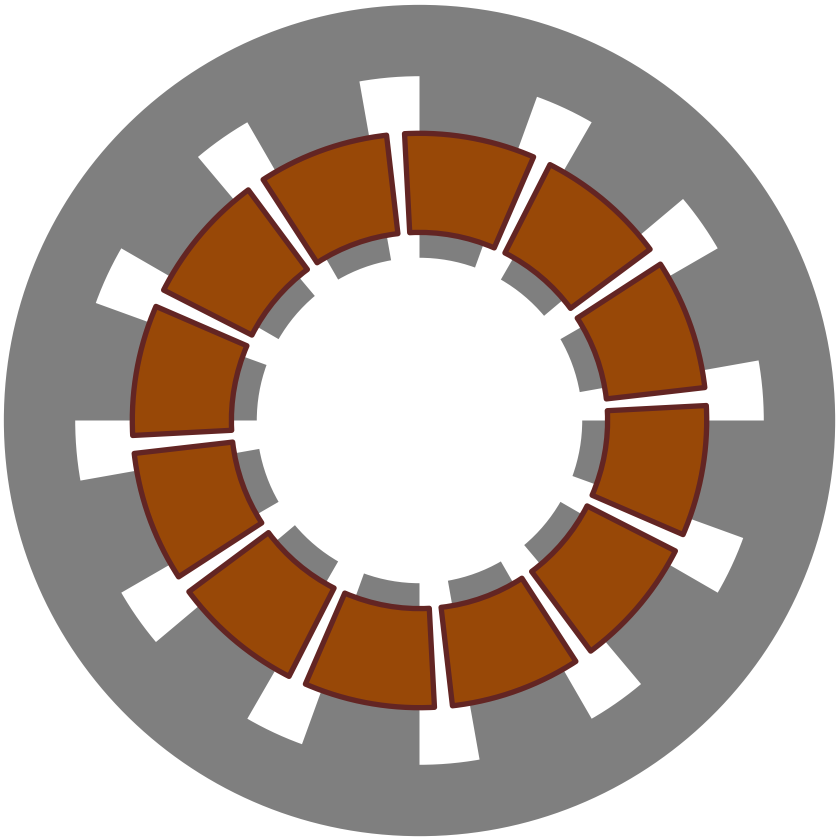
# 2. Proton "Omni-Ring"

- 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

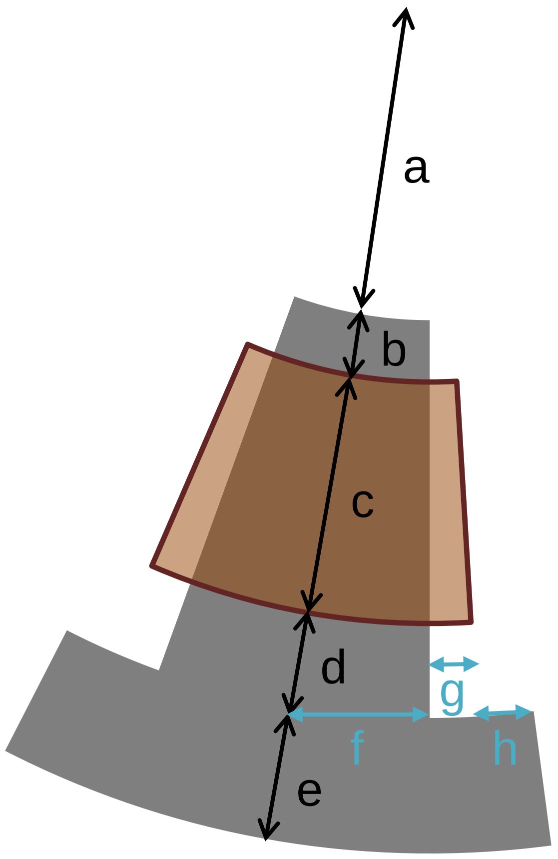
- Note: 3MeV = 75.1 MeV/c for protons/$H^-$
  - 4x as hard to bend as EMMA electrons already
- 0.2T dipole at 40% packing → 6.3m diameter
  - Compare EMMA at 5.3m
  - 24 magnets → 33cm magnet, 49cm drift per cell
  - Fits in R9, can branch off from >3MeV linac test stand (CH structure tanks etc.)
- Test: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

# Omni-Ring Magnet



- Dodecapole with separately-powered coils
- Calibrated to produce multipole fields

# Geometry Parameters (1/12 magnet)

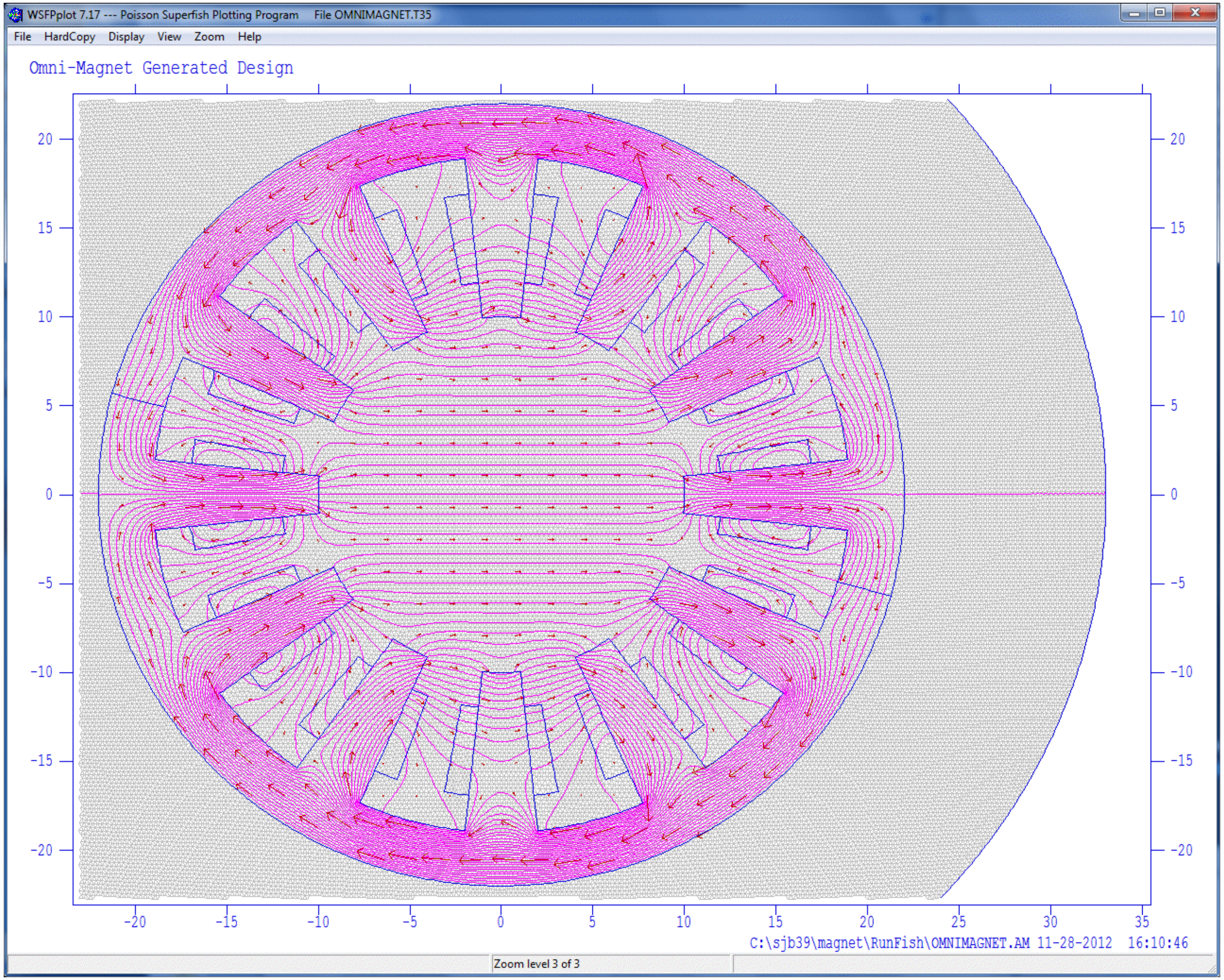



- Aperture = 2a, coil thickness = c, yoke = e, etc.
- f=pole fraction, g=coil fraction, f+g+h=1

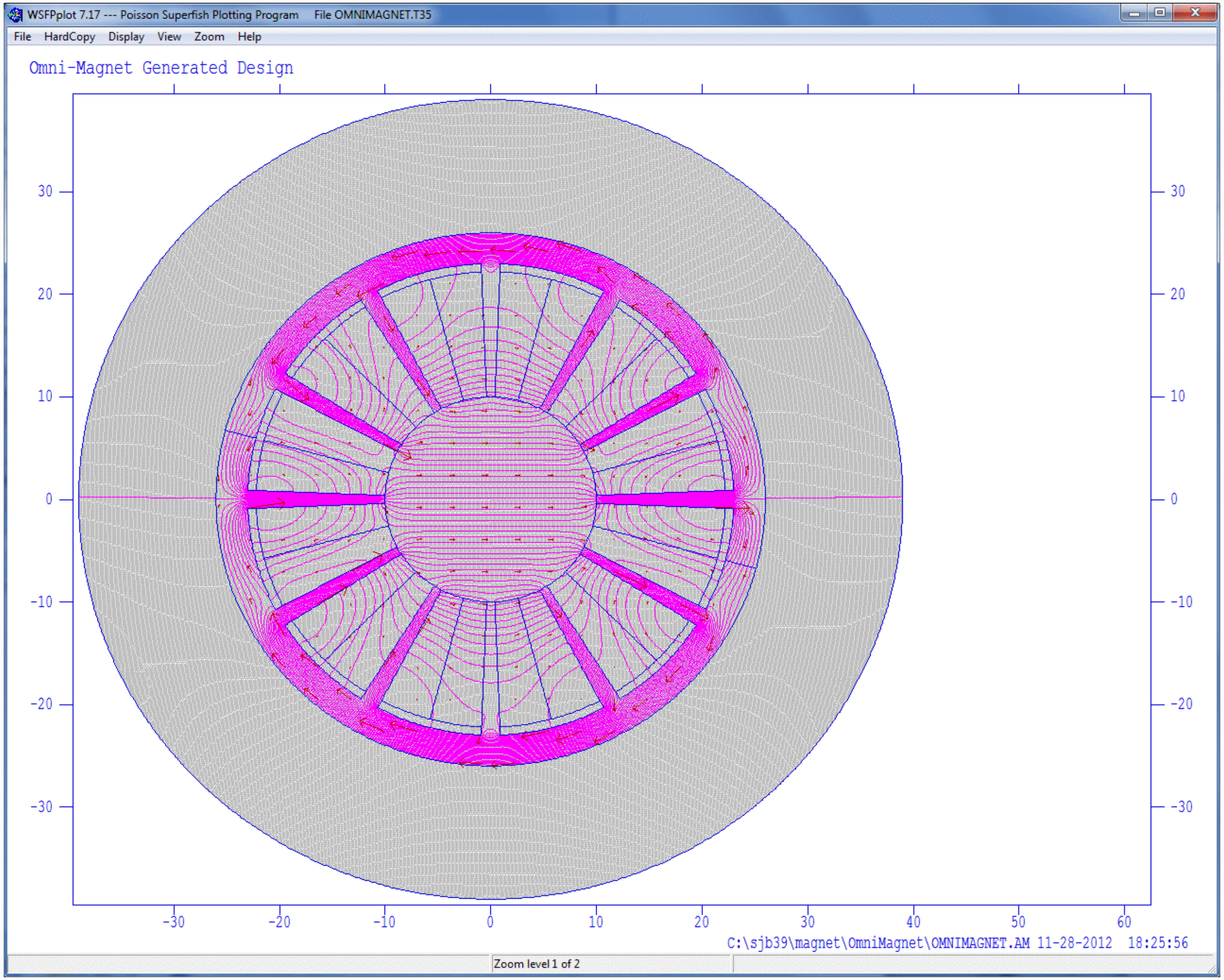
# Compare ISIS EPB2 magnet "Q11"

- 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 * 105mm = 0.395T pole tip field
  - Spec says up to 1.4T flux in return arms

# Before Optimisation (0.0158 T)

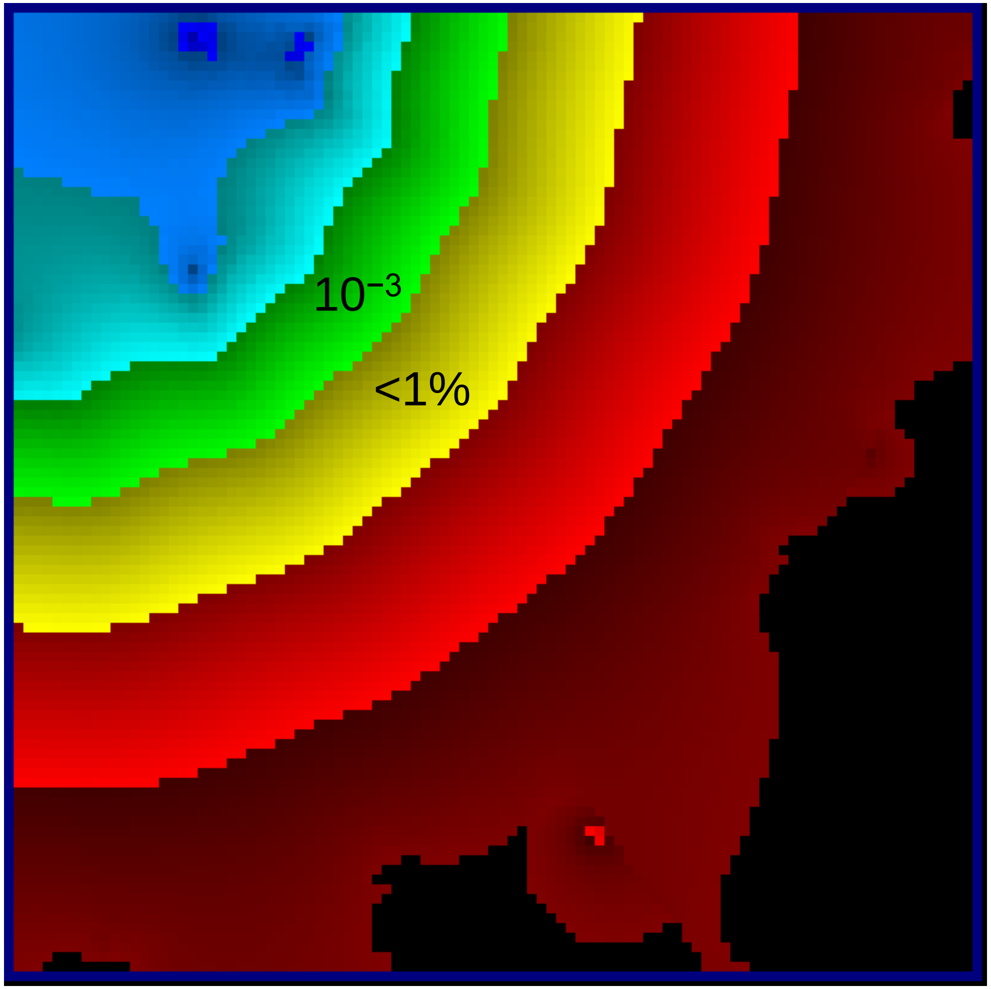


# After Optimisation (0.1141 T)



# Field Quality (Dipole case)

10cm aperture




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?