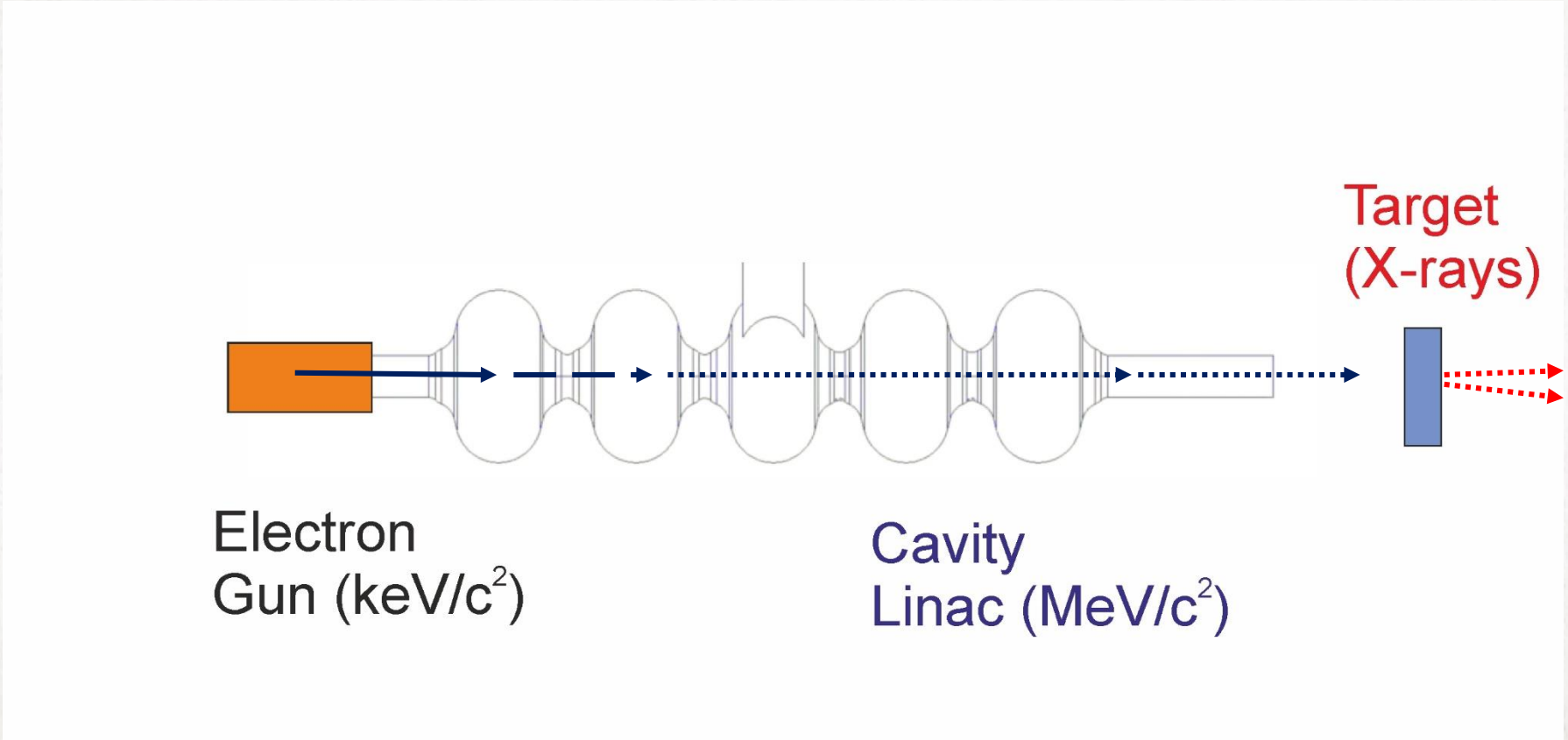
ELECTRON BEAM FOCUSING

USING PERMANENT MAGNETS TO FOCUS ELECTRON BEAM FOR X-RAYS

X-RAY SOURCE: LIFE CYCLE FOR ELECTRONS

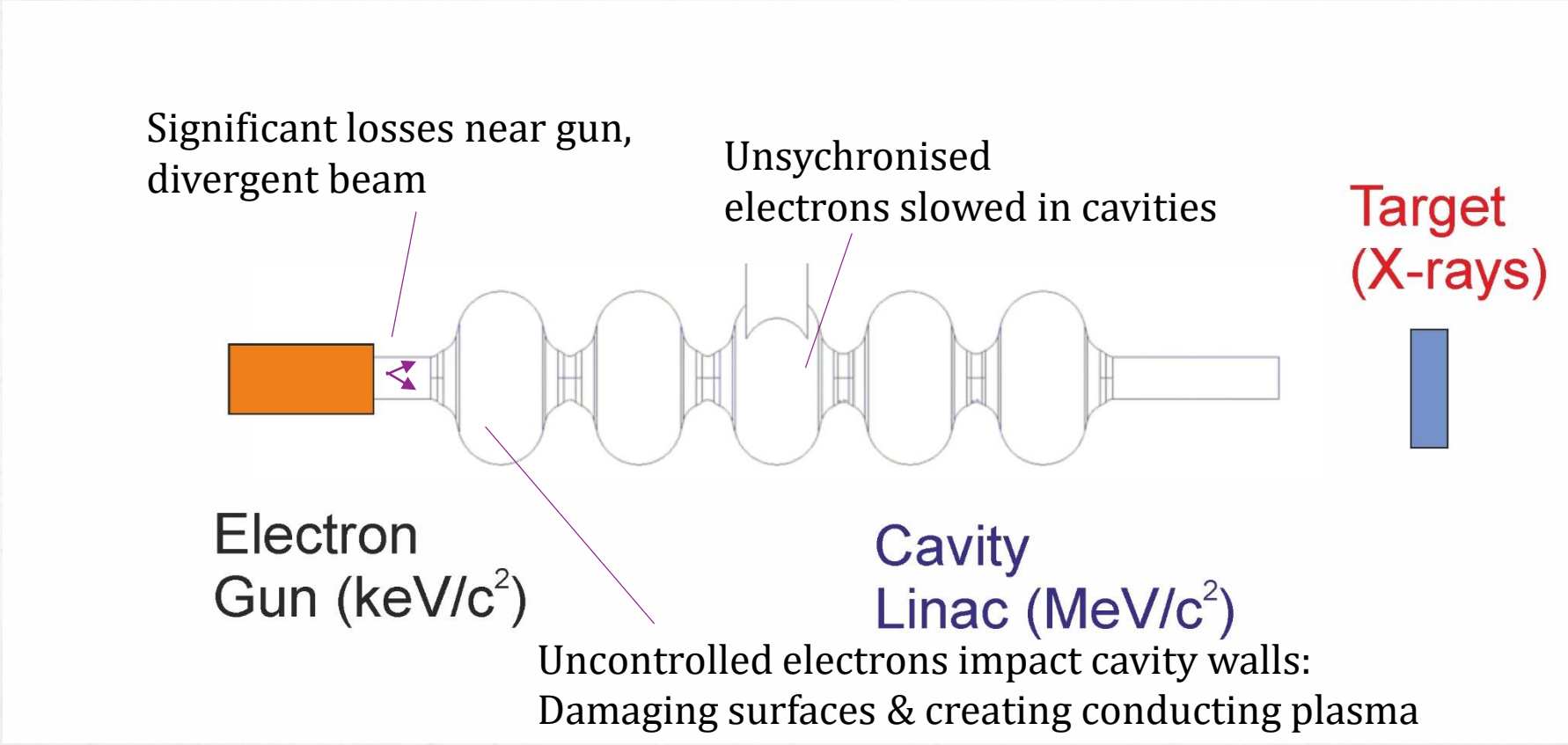


ALAS! NOT ALL ELECTRONS REACH TARGET

For the effort needed to ensure a required current reaches the x-ray target:

- Disadvantages of unfocused / lost electrons
  - Wasting energy accelerating unused electrons
    --> Higher energy bills
  - Greater cooling load
    --> Consumed but wasted electricity still needs removing as heat
  - Stray electron current causes
    - cavity surface damage
    - excess radiation
    - potential for RF breakdown / avalanche
      - releasing more stray electrons

ALAS! NOT ALL ELECTRONS REACH TARGET

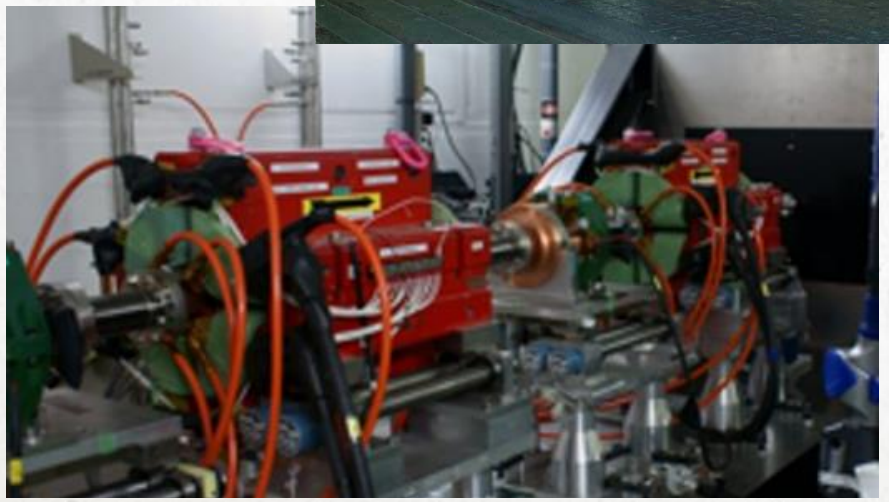


FOCUSING MAGNETS CONTROL ELECTRON FLOW

- Several magnet options (photos from high energy physics - not for x-ray machines)
  - Solenoid

Large Hadron Collider
ATLAS detector solenoid
Electromagnet
for ~100 GeV charged particles
(produced in collisions)

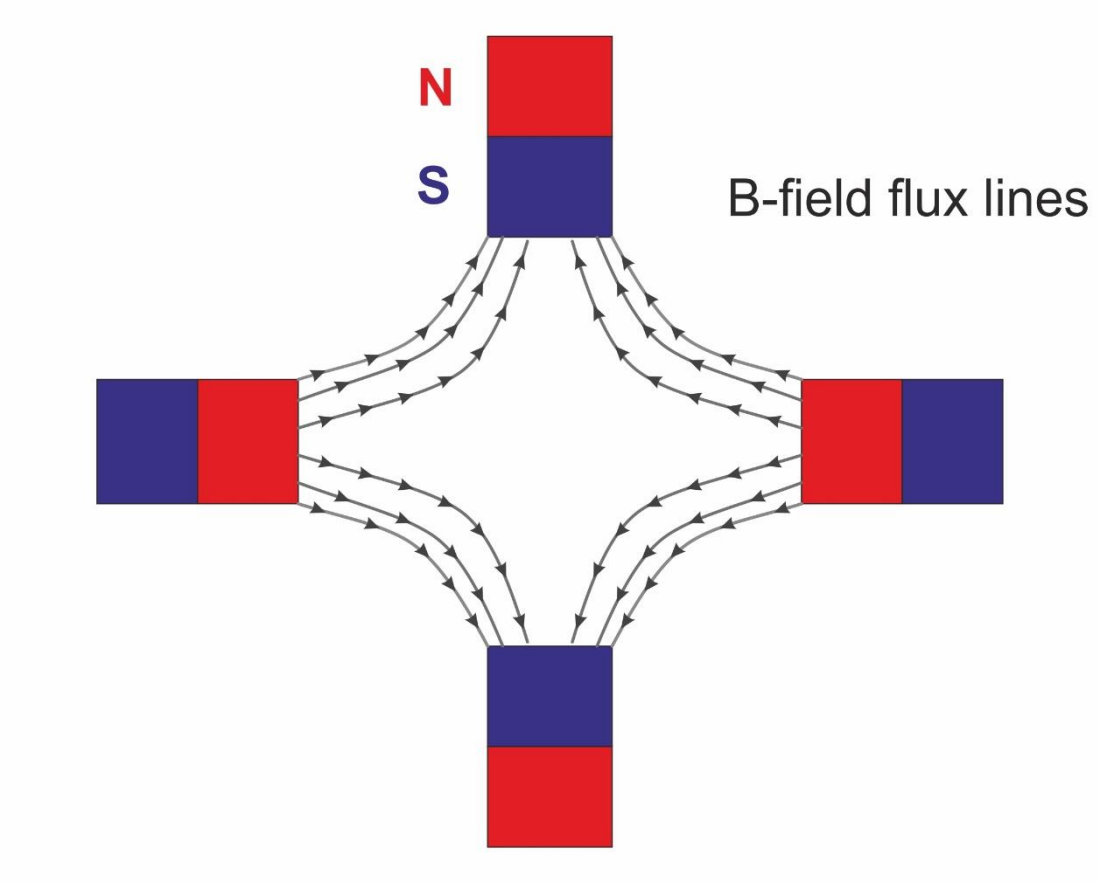
  - Quadrupole

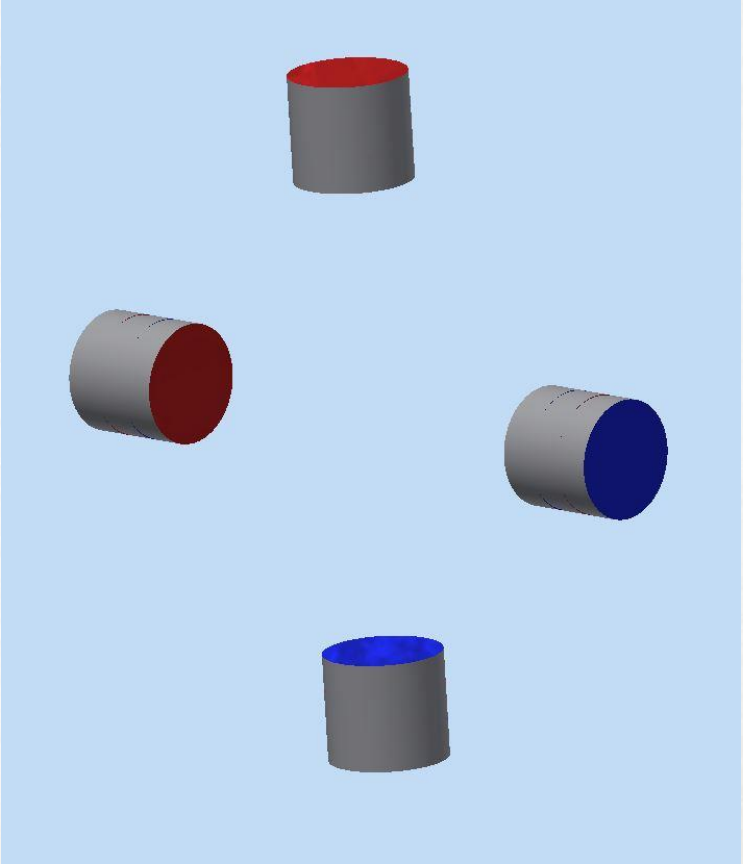


Final Focus Quadrupole
Electromagnet
for 30 GeV electron beam

ATF-2 @ KEK, Japan

SIMPLEST QUADRUPOLE - 4 PERMANENT MAGNETS





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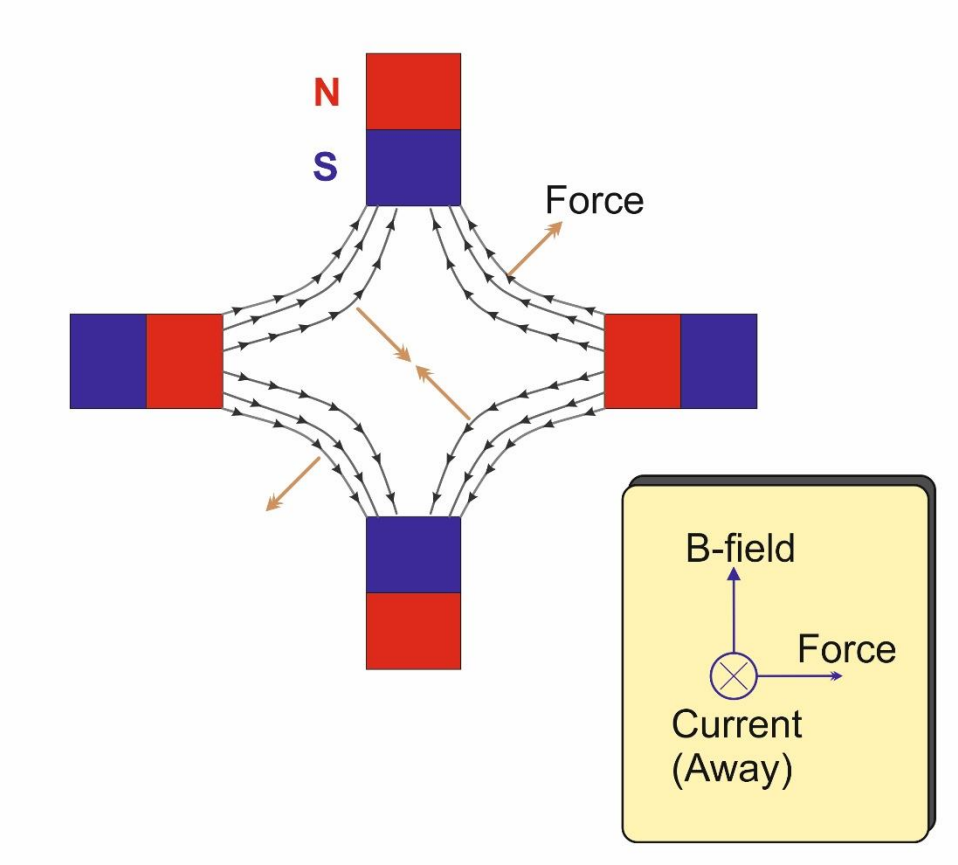


- "Analogous" to optical lens
  BUT
  - Focusing in one tranverse plane
  - Defocusing in the orthogonal plane

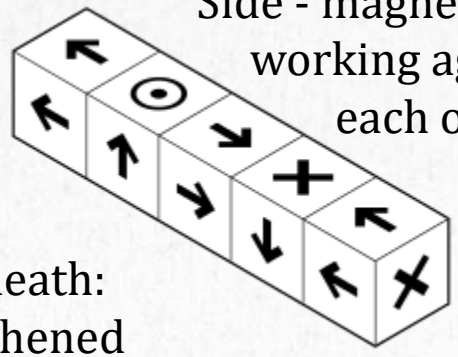
- Need to remember
  - Electrons, being negative
  - flow against the (conventional) current

EXAMPLE PERMANENT MAGNETS - DISC

- Neodymium examples shown
  - Curie temperature ~300 C
- Samarium Cobalt preferred
  - Curie temperature ~ 800 C
  - Operational up to ~300 C
- Magnets strength quoted in kg "pull"
- Need care converting to Tesla/Gauss

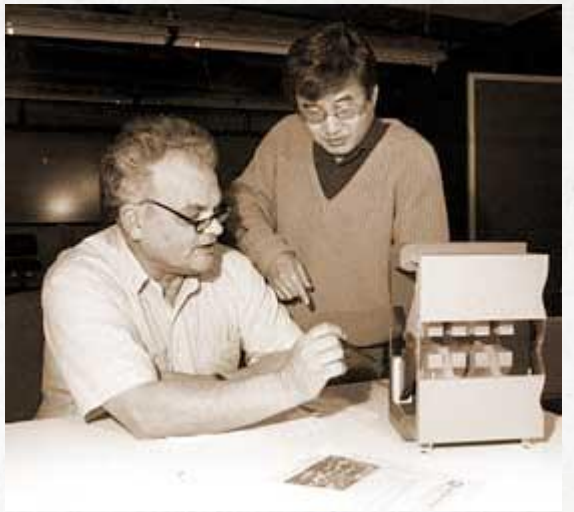
HALBACH MAGNETS

Upper: Weakened Side - magnets working against each other



Underneath: Strengthened side - cooperation

Halbach Array



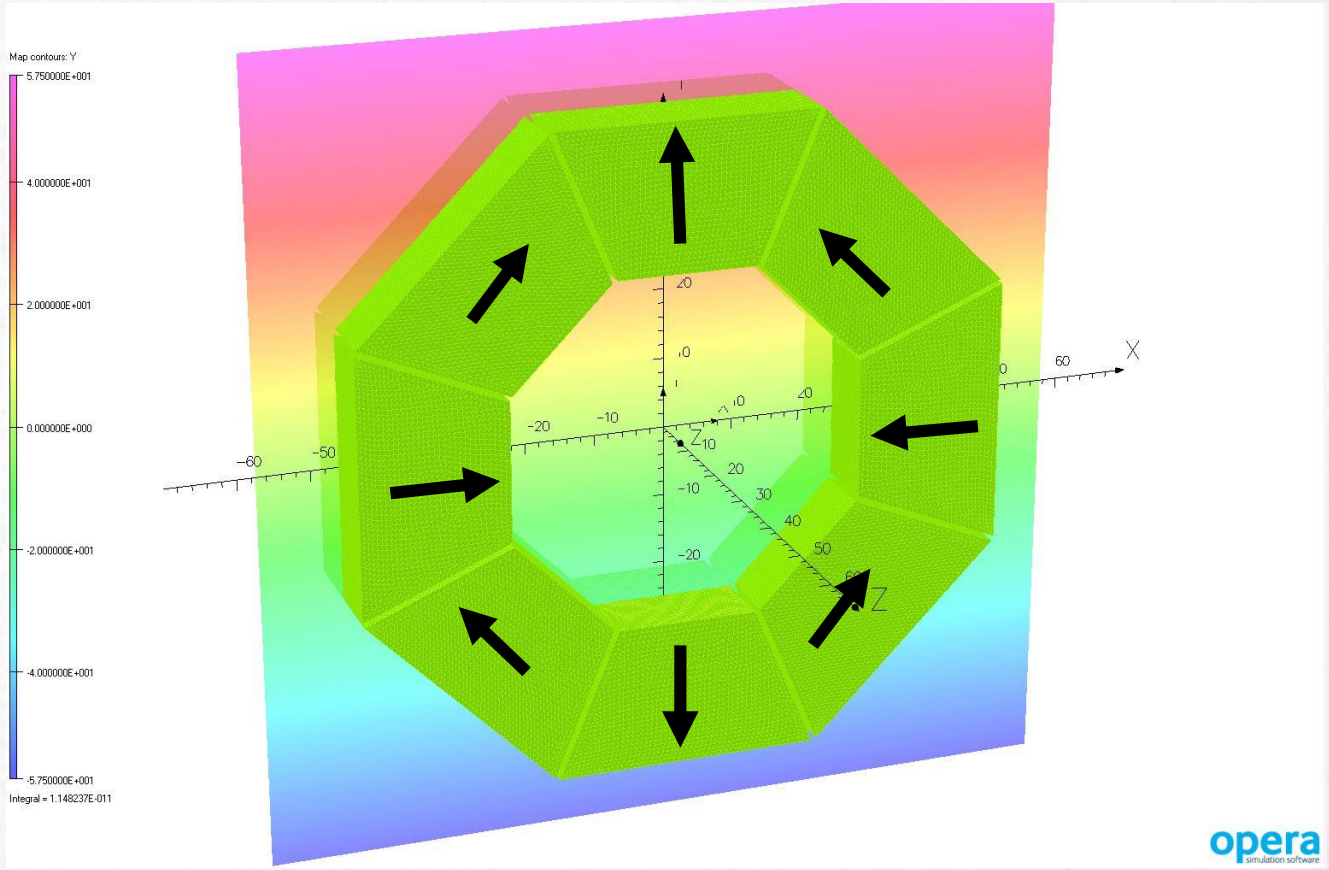
Klaus Halbach

- Arrangement of magnets to cooperate
- Field strength increased on 1 side
- Side effect is a decrease of field strength on opposite side
- Our interest is in the stronger side

OCTAGONAL - HALBACH ARRANGEMENT

- Just getting started with Opera
  - simulation package
- Example arrangement
  - may not be appropriate
- Illustrative example
  - colours show Y (vertical) B-field component

Green = zero
Red = Positive
Blue = Negative



FORTHCOMING WORK

- Study Halbach arrangements
  - Initial study using notional octagon elements
  - Later study equivalent arrangement with stacks of disc magnets
    - Readily available from commercial suppliers
    - Easy to assemble and measure to compare with simulation
- Feed flux profiles from Opera simulations
  - into electron flow simulations (Adam's talk)