Final Focus Magnet Shielding Update

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ARIES Meeting

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Outline

- Review/update of point design results from last meeting
- Analysis for “off-center” target implosions
- Issues/comments for case without beamline cross jets & plans for FY03

General requirements for the final focusing magnet shielding design

- Shielding design consistent with target beam requirements (e.g., half-angle of array <24º)
- Magnets don't quench on a per-shot basis (limits energy deposition to ~100 mJ/cc/shot)
- Recirculating power for magnet cooling doesn't cause unacceptably large economic hit
- Magnets have reasonable radiation damage lifetime
- Avoid generation of above Class C waste, if possible

What limits the radiation lifetime of the final focusing magnets?

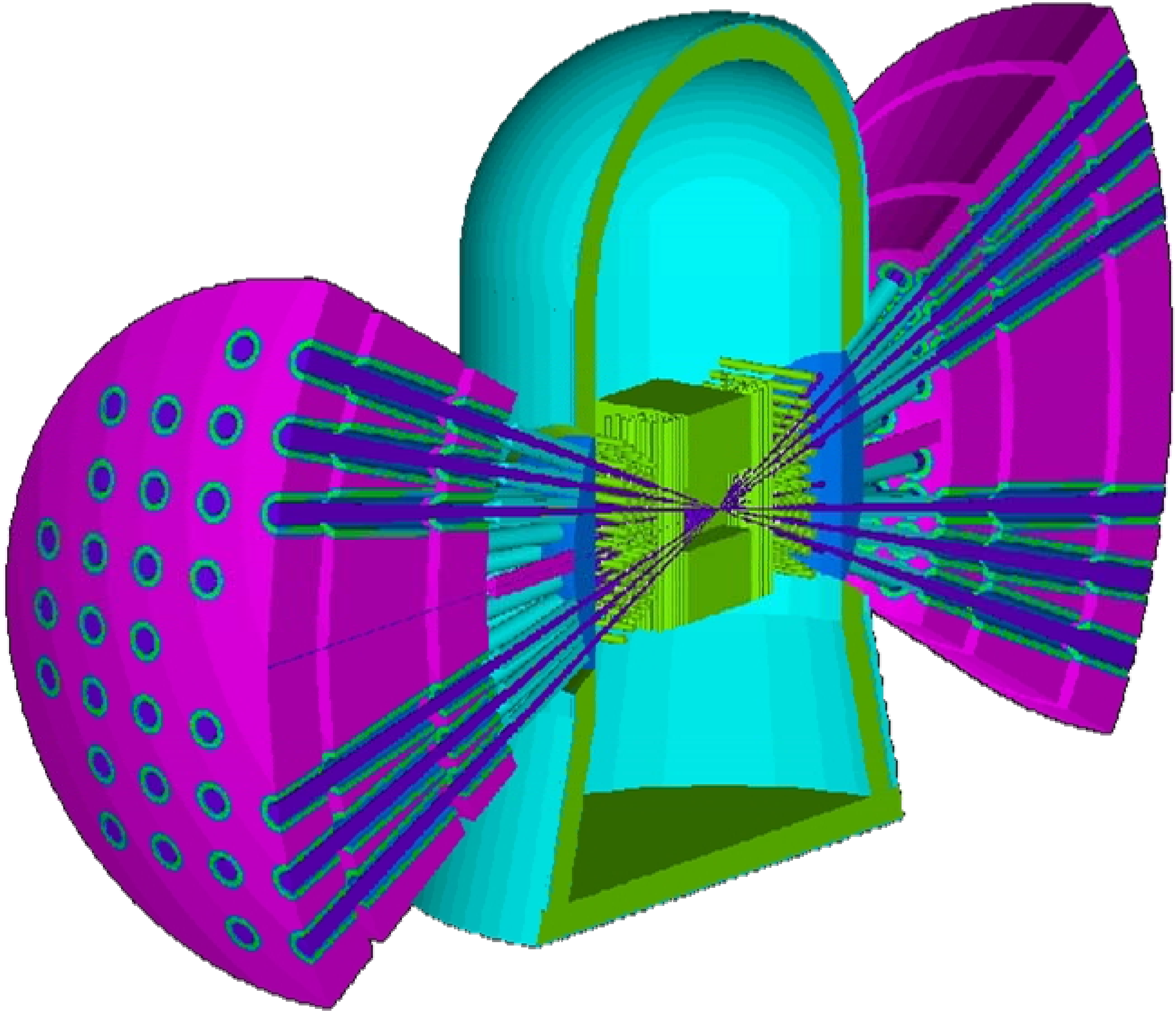
- Total dose to the insulators is limited to 100 MGy (ref. 1); tends to be dominated (90-95%) by contribution from gamma-rays

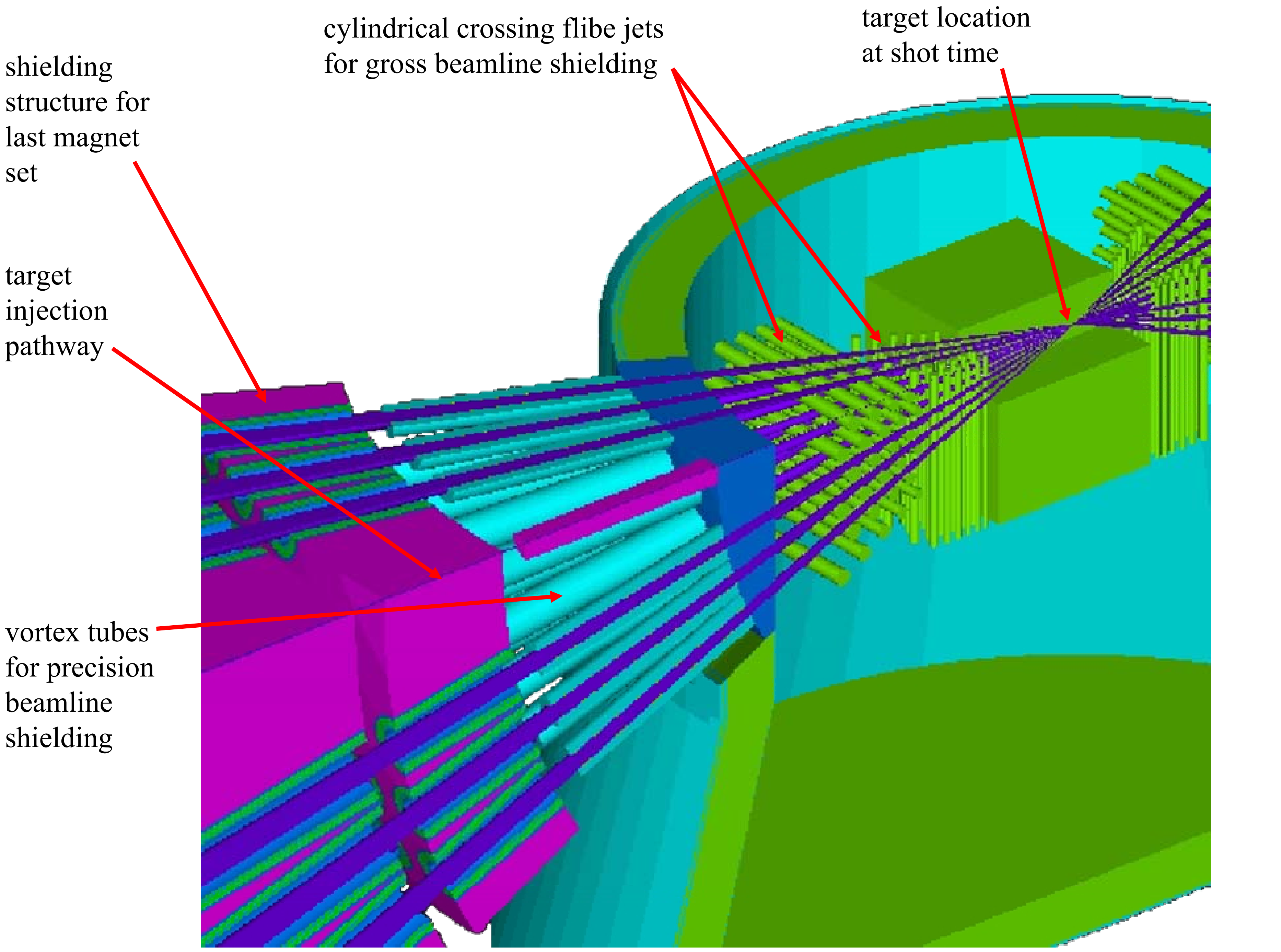
Inorganic insulators that may be usable with high-temperature superconductors (HTS) offer significantly (~$10^3\times$) greater limits (ref. 2)

- *"Conservative limit"* for the fast neutron fluence ($E_n \geq 0.1$ MeV) in Nb_3Sn superconductor is 10^{19} n/cm^2 (ref. 1):
  - Room-temperature anneal required after 3×10^{18} n/cm^2
  - 70% recovery assumed

HTS appear to have fast neutron fluence limits that are *at least* as good as that for Nb_3Sn (ref. 2)

References:
(1) Sawan and Walstrom
(2) Bromberg, ARIES meeting (Jan. 2002)





shielding structure for last magnet set
cylindrical crossing flibe jets for gross beamline shielding
target location at shot time
target injection pathway
vortex tubes for precision beamline shielding

1 cm of structure, insulation, and H_2O cooling

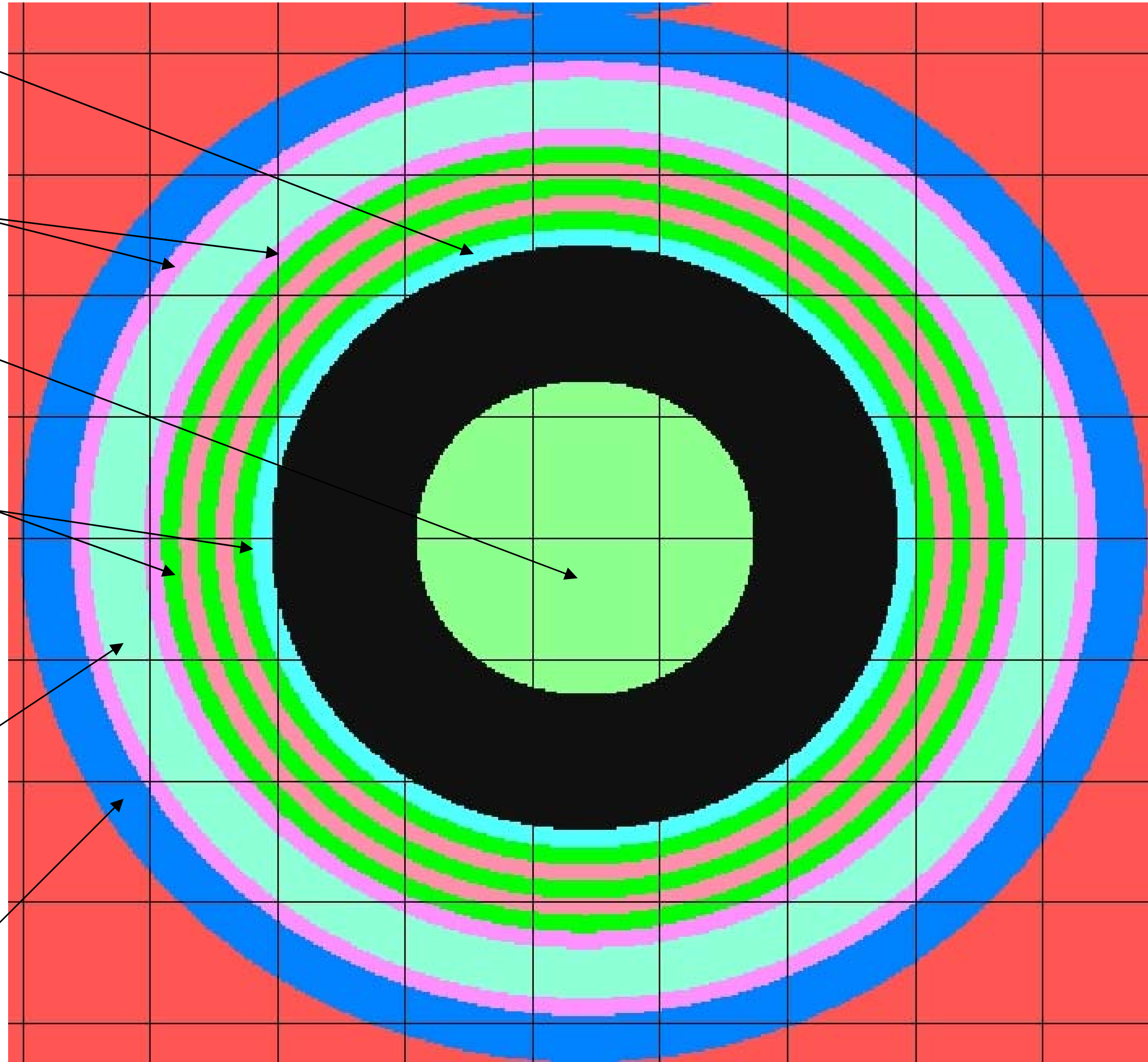
1 cm of structure, insulation, and LN_2 cooling (inside and outside coil)

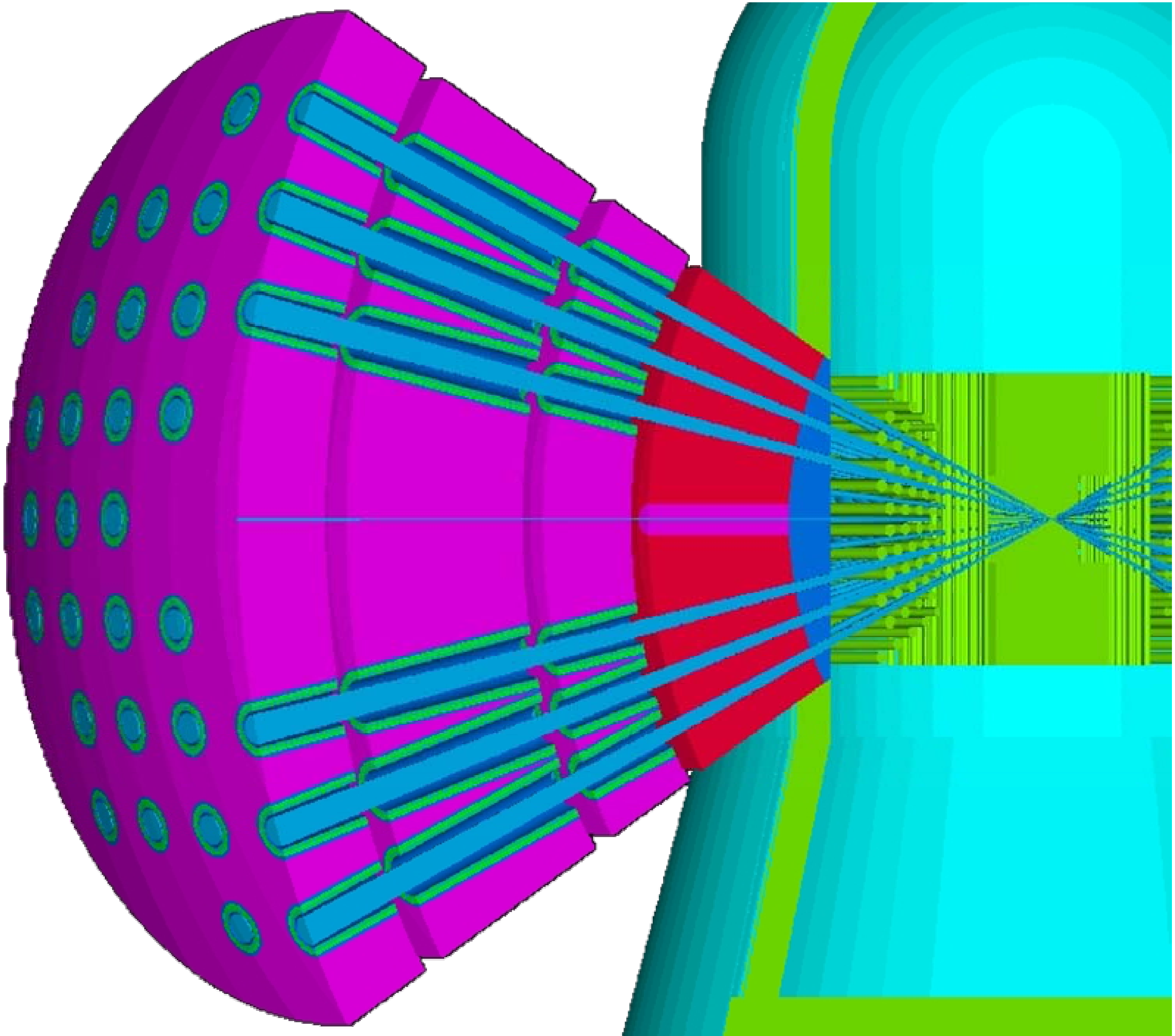
size of beam at front of last magnet

alternating layers (1 cm each/5 cm total) of W and a proprietary material (good for neutrons)

3 cm thick coil region (40 vol% each of Cu and Nb_3Sn + 20 vol% LHe)

2.3 cm of SS304 for banding/shielding





Review of point design results from last meeting

- Results for the final magnet:
  - Average insulator lifetime (total dose limited): 26 years (18-42)
  - Average superconductor lifetime (ϕ_n,fast limited): 33 years
  - WDR_{coil} = 14

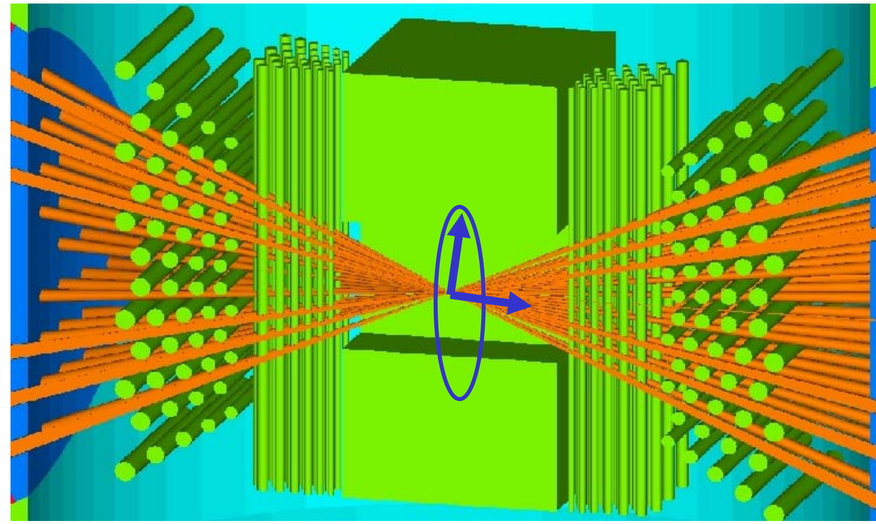
1st room-temp anneal needed at ~10 years

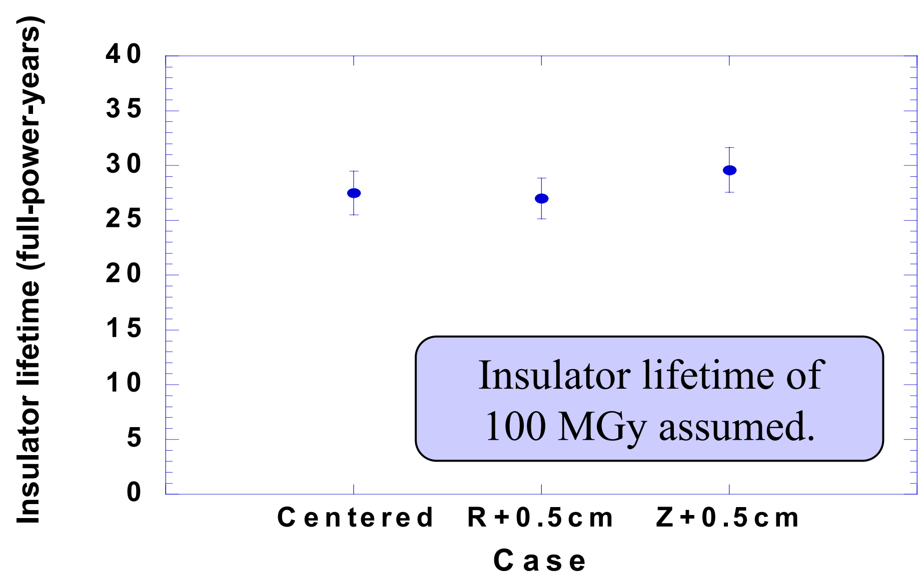
- Second-to-last magnet:
  - Insulator lifetime: 300 years
  - Superconductor lifetime (ϕ_n,fast limited): 33 years
  - WDR_{coil} = 5.6

- Third-to-last magnet:
  - Insulator lifetime: 120 years
  - Superconductor lifetime (ϕ_n,fast limited): 33 years
  - WDR_{coil} = 15

Analysis performed for "off-center" targets

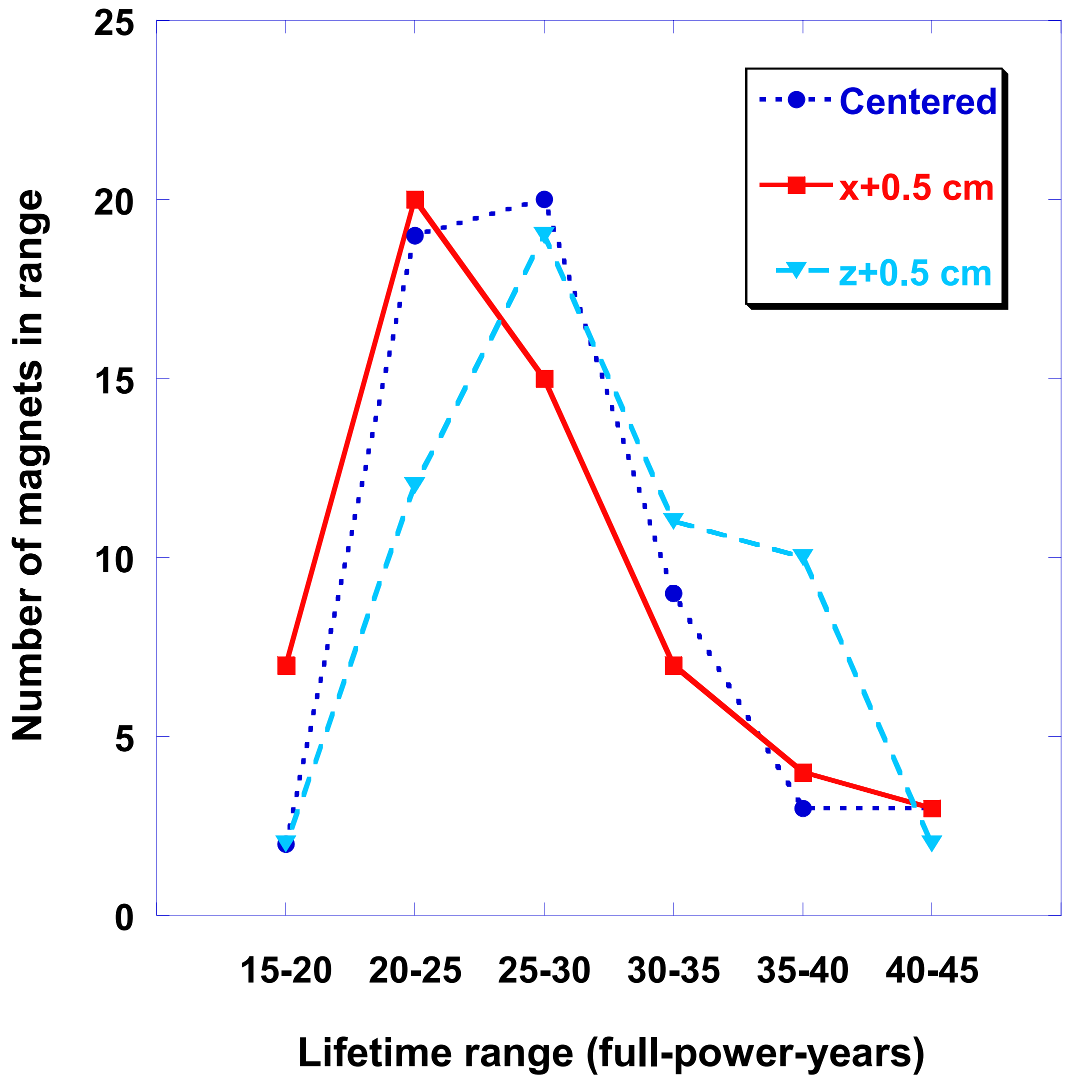
- Target position was varied by 0.5 cm in two directions:
  - Along the axis of symmetry
  - Perpendicular to the axis of symmetry
- The average insulator lifetime is insensitive to the target position at "bang time."





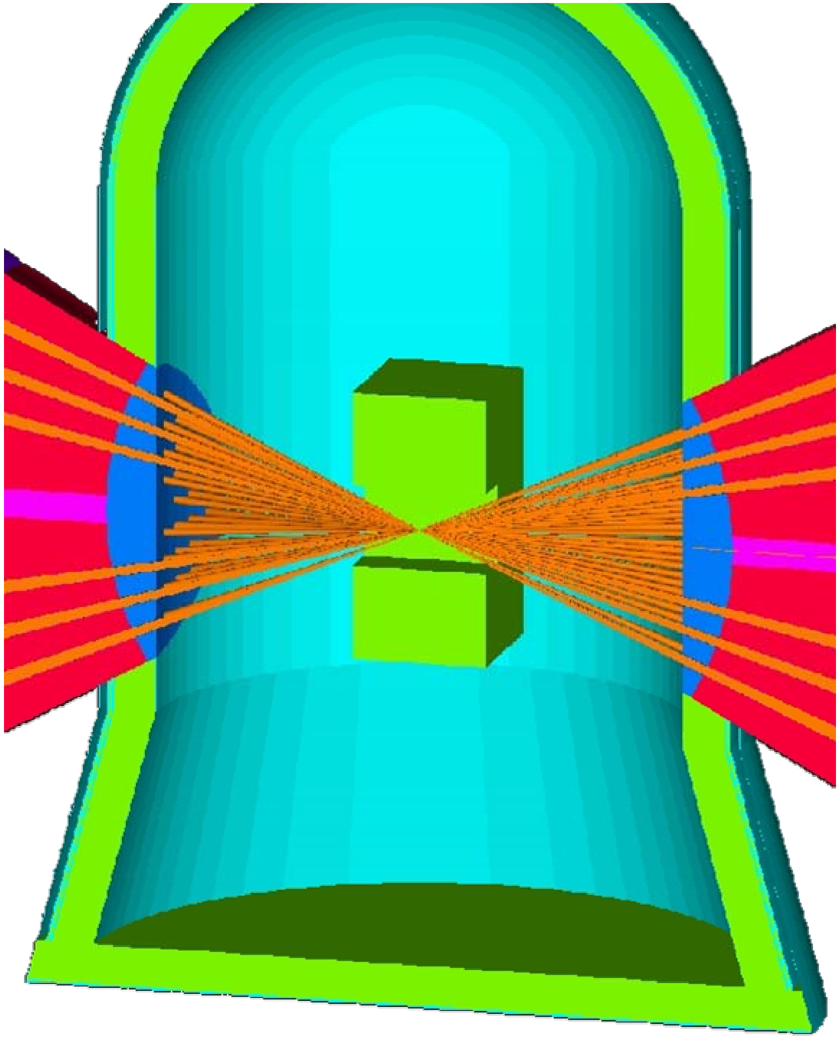
The distribution of magnet lifetimes (not all are equal) is essentially unchanged

- We observe a slight shift in the magnet lifetime distribution
- Effect is probably not real, but statistical
- Error bars are 15-20% (2-4 years at the low end and 5-9 years at the high end)
- Waste disposal results are unaffected



Issues/comments for case without beamline cross jets

- Assume that wetted wall protects structural material from x-ray and ion threats
- Removing liquid cross jets increases neutron damage to port plug structure by nearly 5x
- Expect magnet dose to increase by similar factor; Compensate by thickening port plug?
- Port plug is difficult location to tolerate damage given desire for precision shielding; need swelling-tolerant design → variable thickness liquid vortices?



Additional work is needed for the final focus shielding issues

- Examine damage to vortex structures and flow nozzles
- Address port plug issues in more detail
- Waste disposal needs considerable improvement: WDR_{coil} = 14 (^{94}Nb) for last magnet; consider high-temperature (low-activation, in some cases) superconductors?
- Look at life-cycle waste volume vs. shielding design (ironically, long life magnets may actually increase overall waste volume and lead to production of high-level waste)
- Work is planned for FY03