# HTS Dipole Discussion

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# HTS Magnets for NSLS : Challenges

## There are two challenges:

- Will HTS magnets satisfy NSLS technical requirements?
  - We need to prove it technically (HTS is brittle and a new technology)
  - We need to make larger community feel comfortable with this option
- Can HTS magnet technology be developed such that it can compete with the conventional room temperature magnet technology in terms cost of ownership (capital + operational)
  - Since there is a proven alternate to HTS, one needs to be very much cost conscious right from the beginning.
  - New technology means new issues and new opportunities. Apart from adapting the old designs, also take a fundamental bottom up approach and see if alternate designs offer a cheaper solution.

# HTS Magnets for NSLS

- The longer term goal is to determine if HTS technology can be made attractive for NSLS2 magnets.
- However, the near term goal is to put HTS magnet design and technology for evaluation in VUV ring magnets.

**But remember important caveats:**

- It is not necessary that a design developed for VUV ring magnets will be the best and the most cost-effective for NSLS2 magnets.
- Therefore, it is not necessary that actual cost comparisons for VUV ring will be fully applicable to NSLS2.
- However, still the exercise should give a good sense of general direction and should force us to address longer term issues like reliability, etc.
- BNL folks should worry about the details of NSLS2 magnets. At this stage, this joint collaboration, would focus on VUV ring magnets.

# VUV Ring Magnets

**As such magnets exists, but machine needs to be moved.**

**And BNL is very conscious about the impact of rising cost of electricity in operating its facilities.**

- This offers an opportunity to evaluate if there is a technology that may be more attractive for the next generation machines.
- But remember, VUV ring is a "*real machine*" with "*real users*", and not just a test-bed for fancy magnets.
- This unique situation offers both opportunities and challenges.
- There is nothing more convincing for future accelerators then a proof-of-principle of HTS magnet technology in a "*real machine*".

# VUV HTS Magnet Options

**There are two major options for new HTS magnets:**

## Retrofit coil option

- Advantage : Use existing yoke
- Disadvantage : Limits coil and cryostat design to fit within the existing slot (shape and size)

## Retrofit magnet option

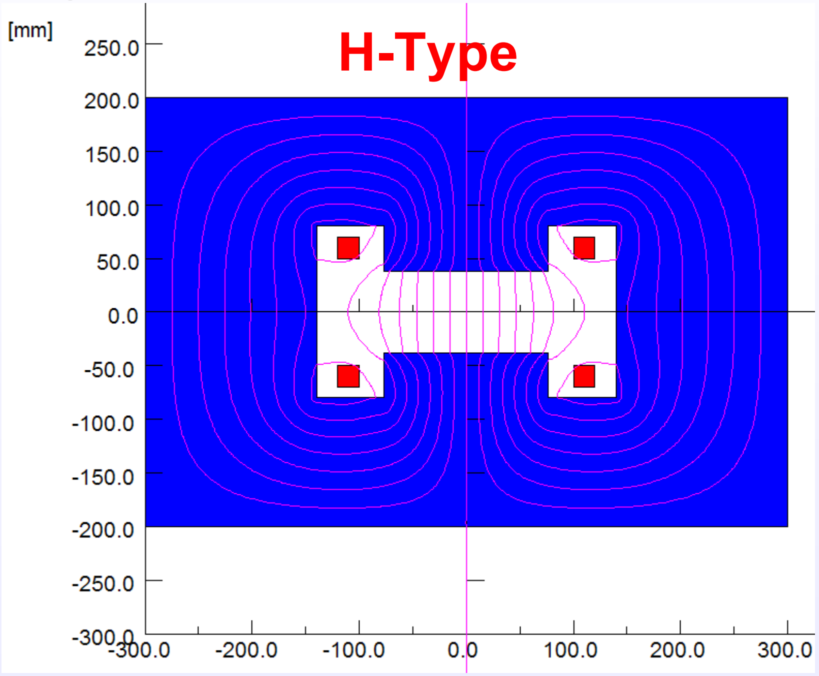
- Advantage : Gives a clean sheet of paper to develop new designs that will roughly fit within the existing envelop of the magnet
- Disadvantage : Need to make new yoke, etc.

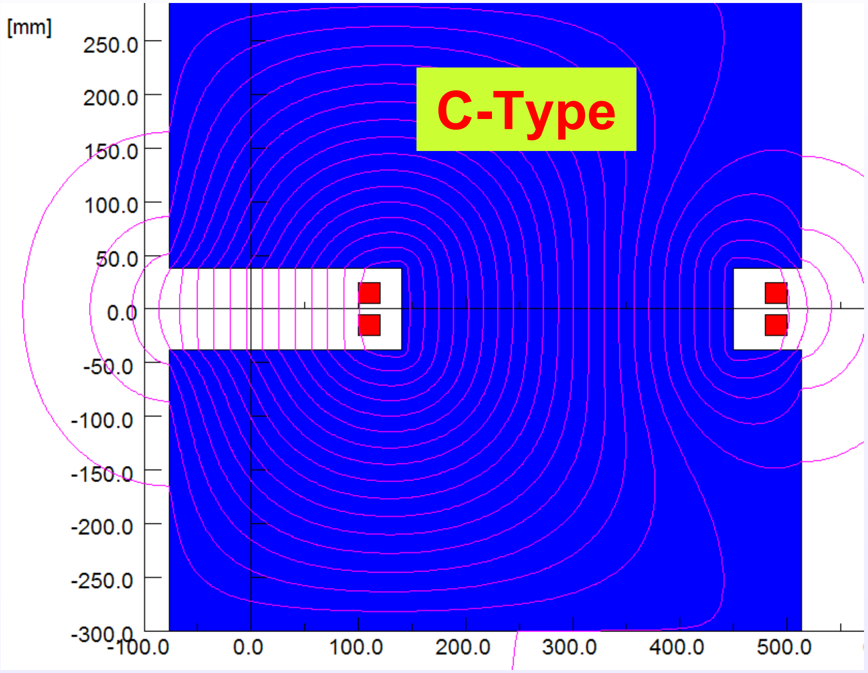
# Retrofit Magnet Option

At the initial stage of the design work, we will follow the general concepts developed for a Neutrino facility dipole

- Those magnets had similar design parameters as VUV dipole.
- Therefore, that exercise of developing a bottom up design for cost minimization (where we looked in to old designs and tried new concepts) should provide a good start in this case as well.
- The design concepts can be adapted to accommodate the required sagitta in magnet and coils.
- This provides a variation to what we believe HTS-110 has started looking in to, i.e., retrofit coil market.

# Two Types of Basic Designs




We prefer C-type over H-type. It should produce lower cost HTS magnets

(a) Needs one cryostat instead of two

(b) Simpler and cheaper support structure because no need to deal with vertical forces

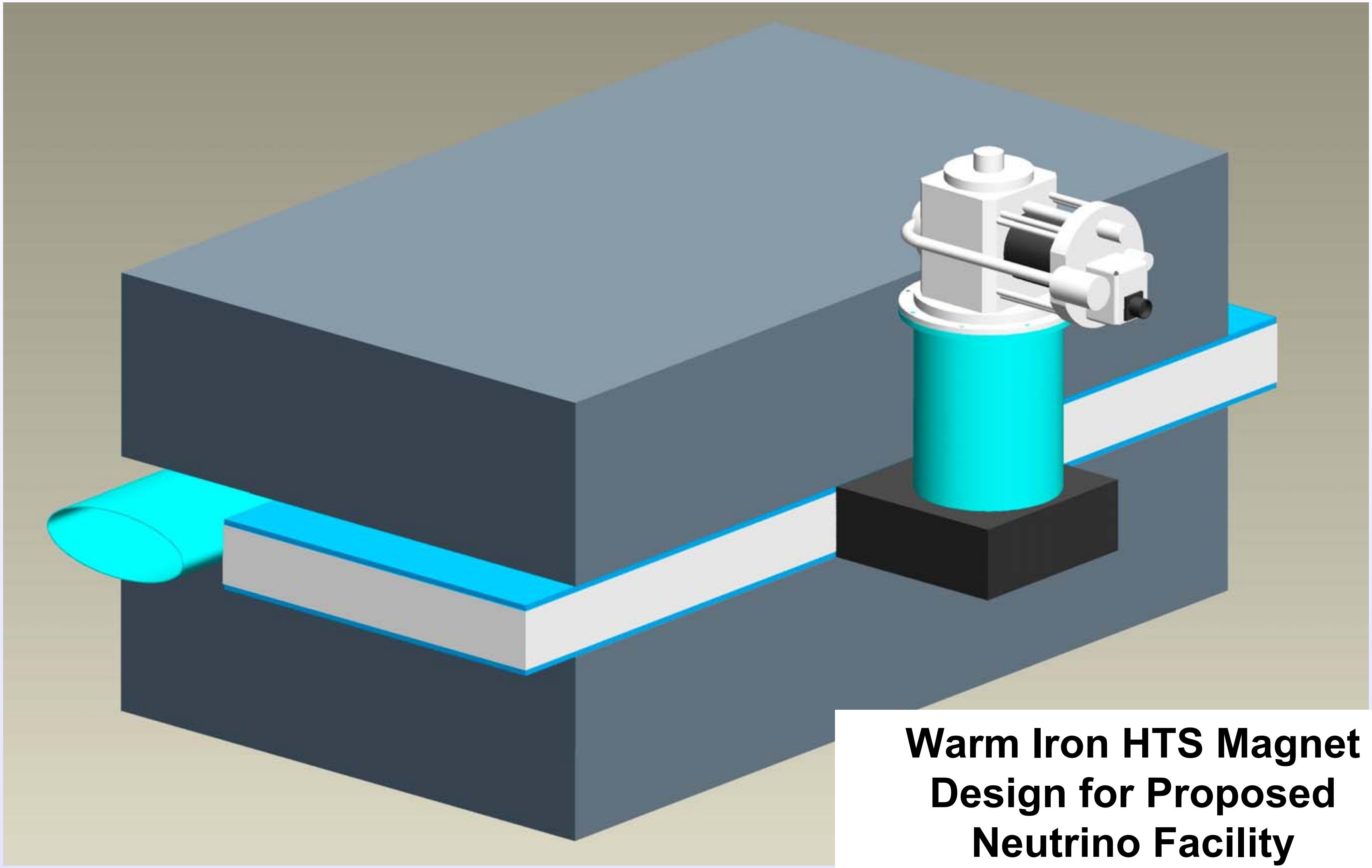
(c) Heat leaks will be lower

(d) Need much less superconductor because field is parallel to superconductor surface

(e) Need for reverse bend in coil winding because of sagitta, can be eliminated

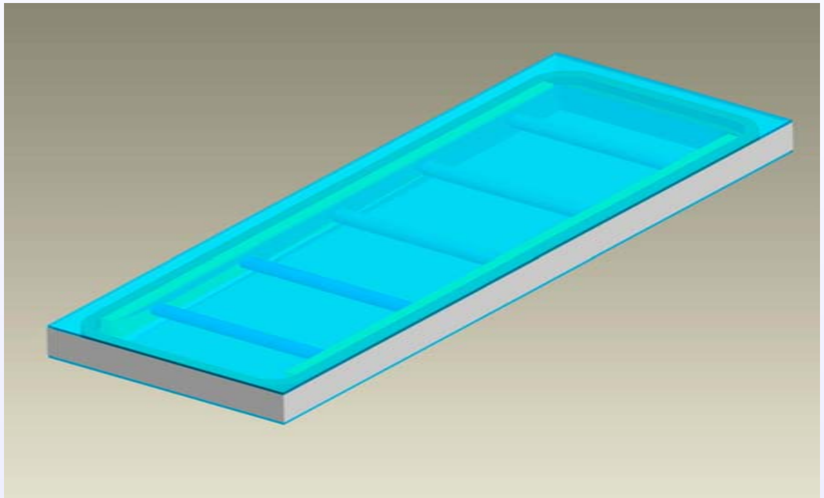
(f) Should facilitate a simpler and cheaper cryostat design

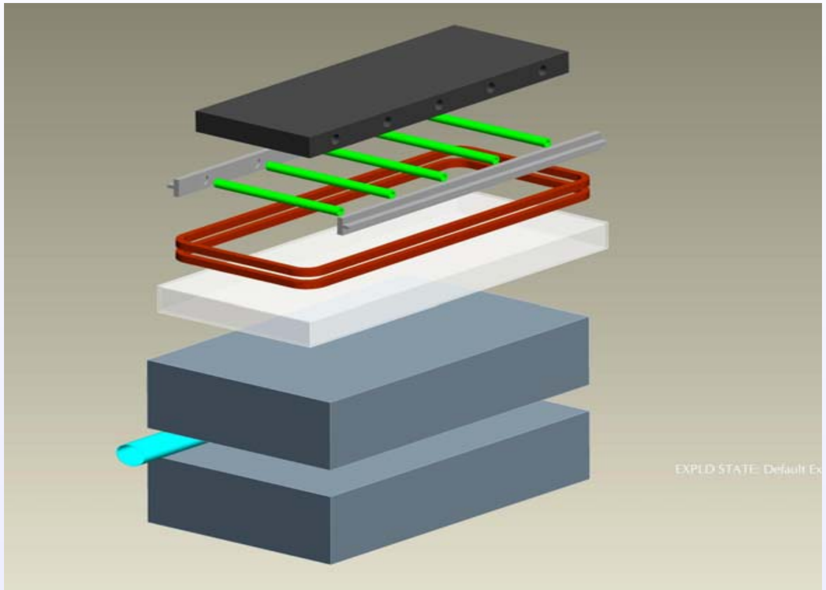
# Magnet Concept with Cryo-cooler

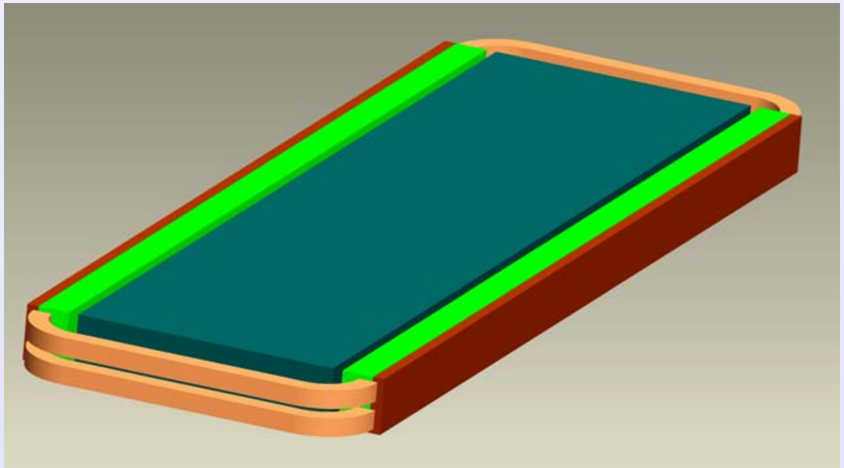


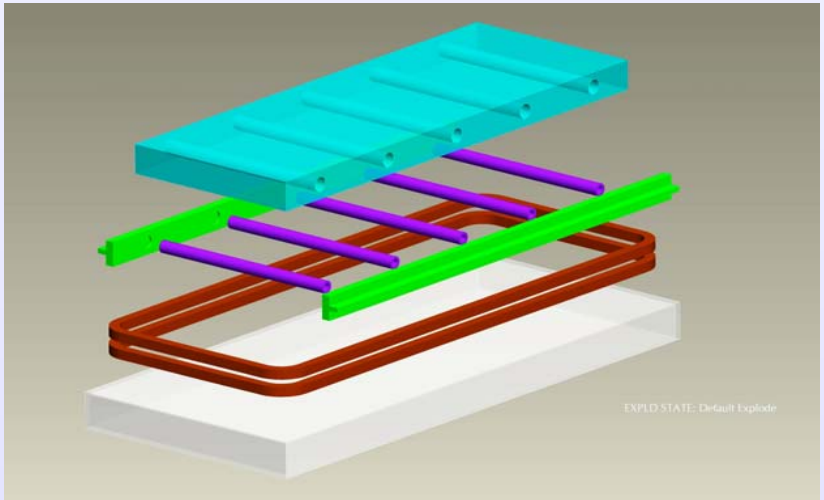
**Warm Iron HTS Magnet Design for Proposed Neutrino Facility**

# Details of Cryo-vessel









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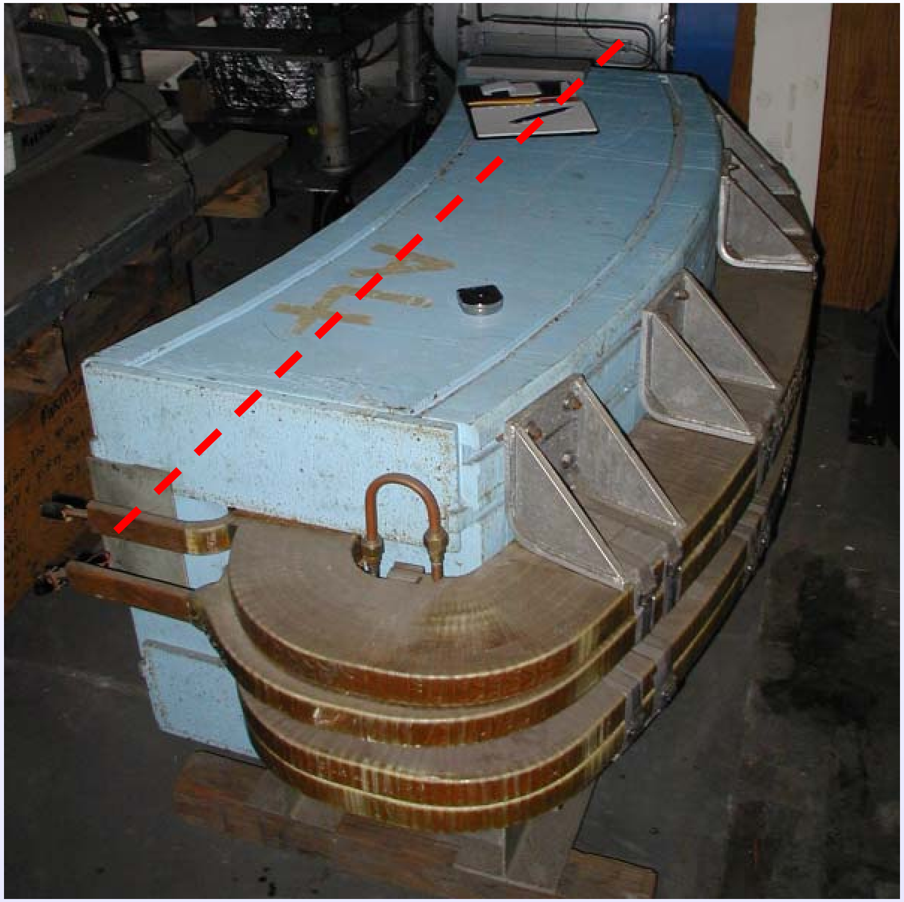
# Pictures of VUV Ring Magnet with Sagitta (Note: Coil has a reverse bend on one side)



In the proposed design the HTS coil will go on the outer lag (return yoke).

One side of the coil will be curved and other side will be straight and thus the problem of negative curvature (sagitta) will be avoided.

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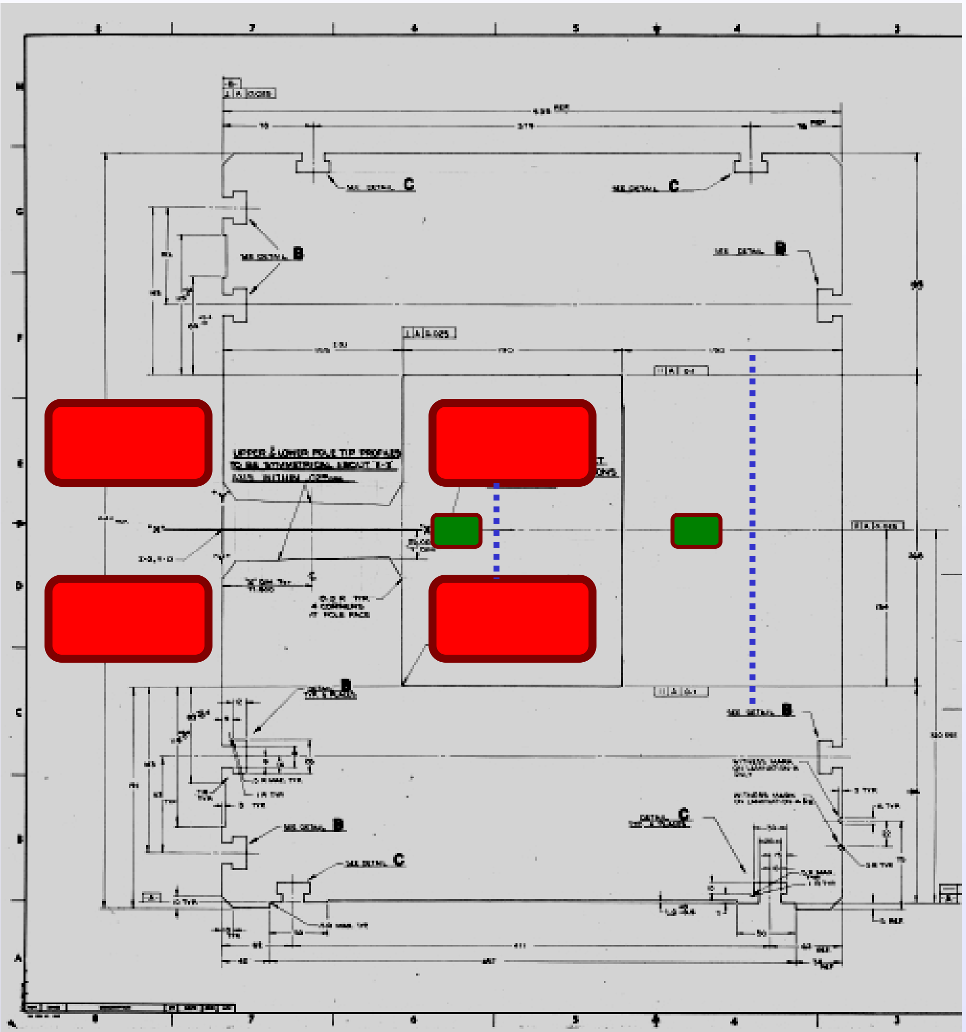
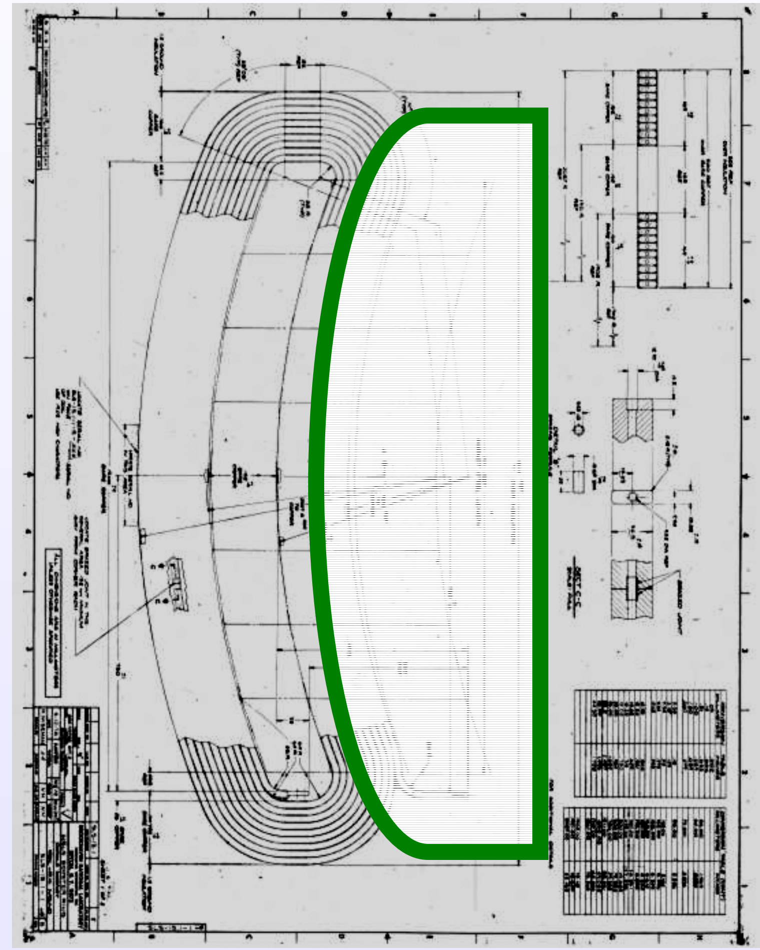
# VUV Ring Magnet with Copper Coils and with Proposed HTS Coils



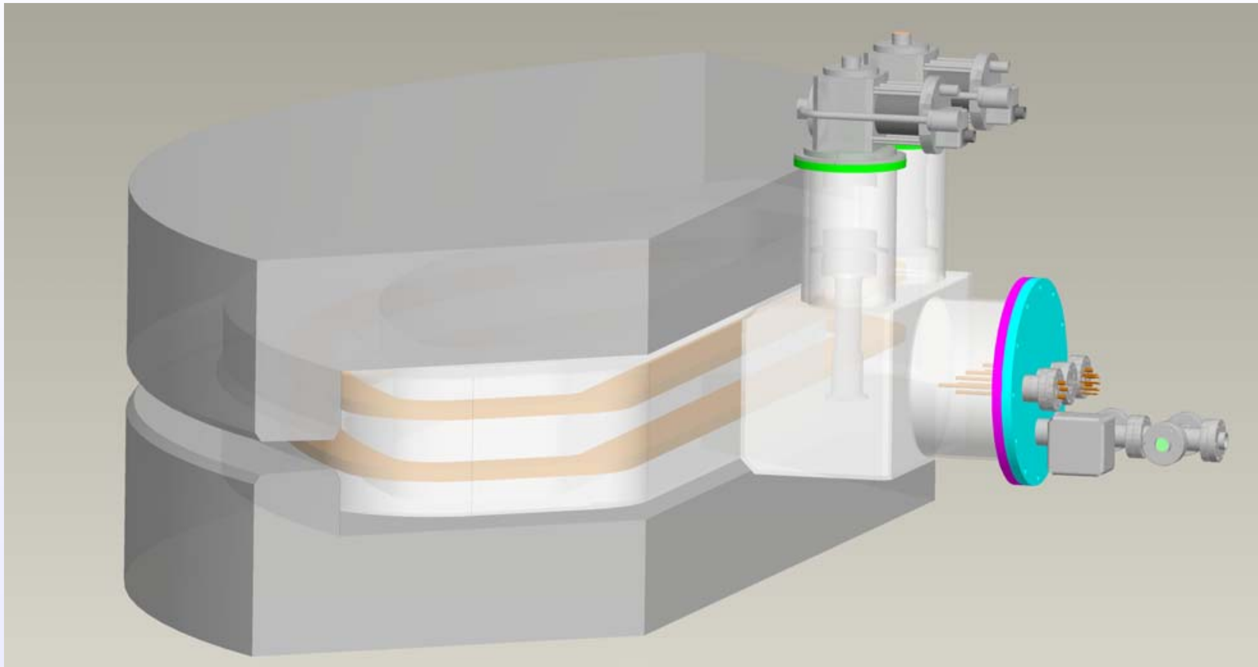


Proposed HTS Coils

Return yoke with HTS coils

Existing Copper Coils

# A Proposed Way to Build Dipoles Having Large Sagitta With Brittle Superconductors

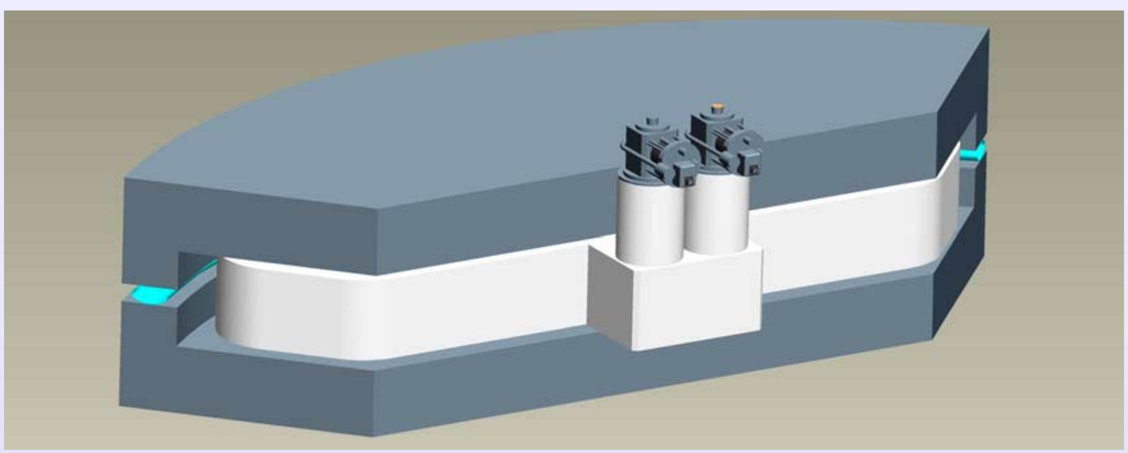


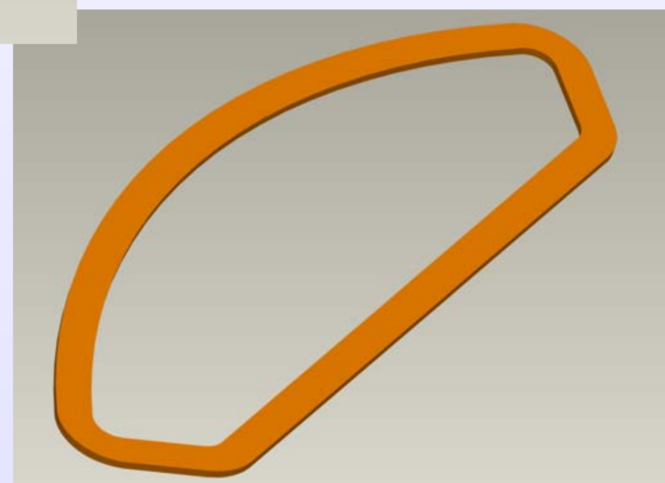
**Note: The coils do not need a reverse bend.**

Clear pole gap is where the electromagnetic radiation come out.

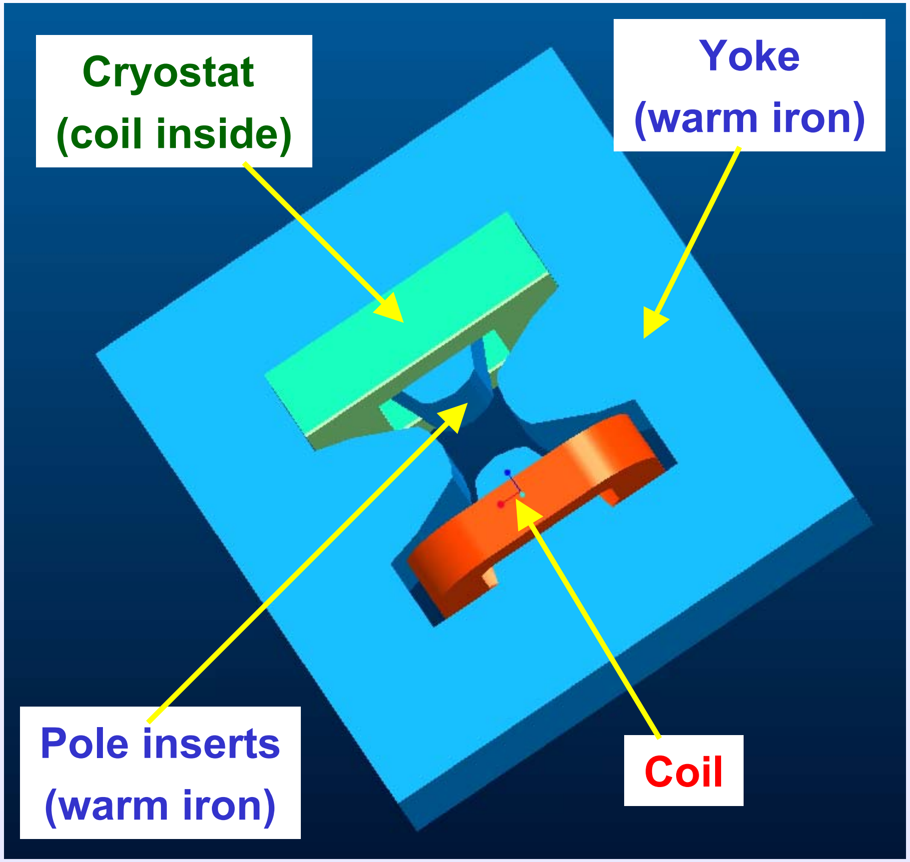
**Concept simulated for VUV dipole geometry**

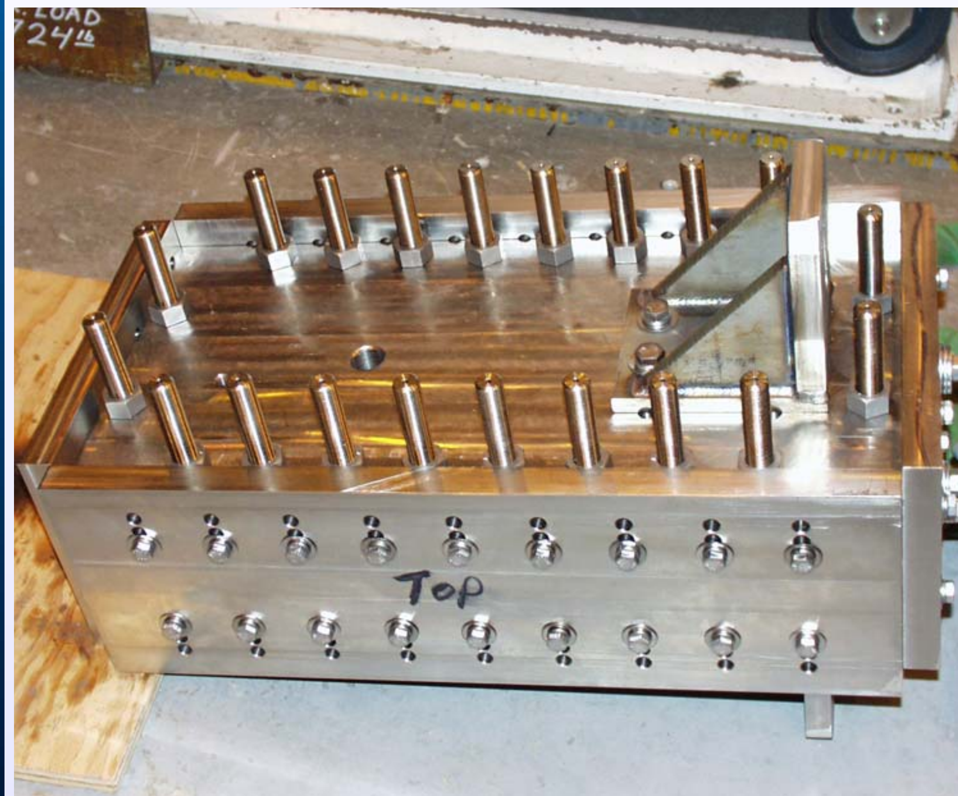
(Paul Kovach)





# Support Structure and Cryostat



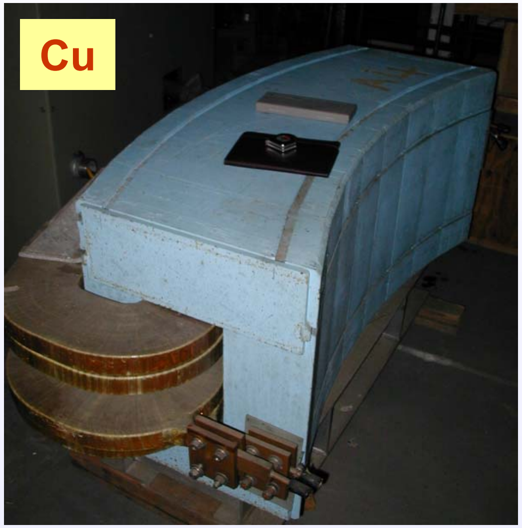



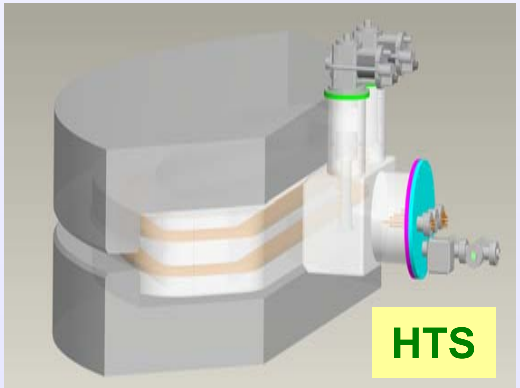

Support structure and cryostat adds significantly to the cost of magnets, specially when these are compared to the cost of room temperature magnets.

# A Case Study for Cost Comparison Copper and HTS Dipole for Neutrino Facility

**Design Parameters:**

- B = 1.55 T
- L = 3.73 m
- Pole width = 153 mm
- Pole gap = 76 mm




**Copper Magnets:**

- Better known costs (estimated : ~150k$ each for this magnet)
- Cost of individual components like coil, yoke, etc., is well understood
- High operating costs (estimated ~3 MW total)
- Low thermal conductivity water cooling plan
- Higher current (a few kA) power supply (higher cost)
- Maintenance issues (cost, downtime): water leak etc.

Desired cost of support structure and cryostat in this HTS magnet: < 20 K$

**HTS Magnets:**

- Develop designs to reduce cost (goal : ~150k$/magnet for equivalent integral field)
- Cost of HTS. present price : ~50 k$ (only 1/3, expected to go down)
- Need to include cost of other components like iron (low and well understood), support structure, cryostat (major driver unless better designs developed)
- Lower operating costs (wall power of cryo-cooler?)
- Cost of cryo-coolers (compare with infrastructure cost of Low Thermal Conductivity Power Plant)
- Lower current (a few hundred Amp) power supply (cheaper)
- Maintenance issues (cost, downtime): cryo-coolers

# Joint Work/Collaboration Between BNL and HTS-110

There are several specific applications where HTS magnets are attractive.

These applications have been important in helping the development of HTS magnet technology. However, they don't bring a large scale application.

Both BNL and HTS-110 have a common interest in making HTS magnets become competitive with room temperature magnets in wider application. That will create a much bigger market.

**One Example Each:**

BNL: Development of overall accelerator magnet concept and engineering

HTS-110: Cryo-cool system (all aspects: design, analysis, construction)

**Specific Application : Replacement VUV ring coil/magnet**

# Discussion Topics

## Technical

- What are the major challenging technical challenges in this particular (first VUV and later NSLS2) application?
- What are the technical strengths and experience of individual group?
- Where can we benefit with the help from the other group?

## Cost

- Should we set a target cost goal? If yes, how? What?
- How does it compare with the equivalent room temperature magnet?
- Beside conductor, what are the other cost drivers of HTS magnets? Can they be reduced by smart designs and by smart manufacturing?
- What are the operating costs (maintenance of cryo-cooler or cryo plant)?
- How do they compare with water cooled copper magnets?
- Determine and compare cost of ownership for 5 or 10 years!