BNL's role in a national program of R&D aimed at future high energy physics facilities

LHC Accelerator Research Program (LARP)*

Future facilities

- Neutrino super-beams*
- Muon Collider/ Neutrino Factory*
- ILC R&D

Technology R&D

Accelerator Test Facility*

Non-HEP funded R&D

* Breakout session

Accelerator R&D: future facilities - LHC Accelerator Research Program

This is part of a national (Fermilab, LBL, BNL, SLAC) program with the goal of looking at LHC Upgrade scenarios, next generation instrumentation, and US hardware/beam commissioning. The main areas of BNL involvement are:

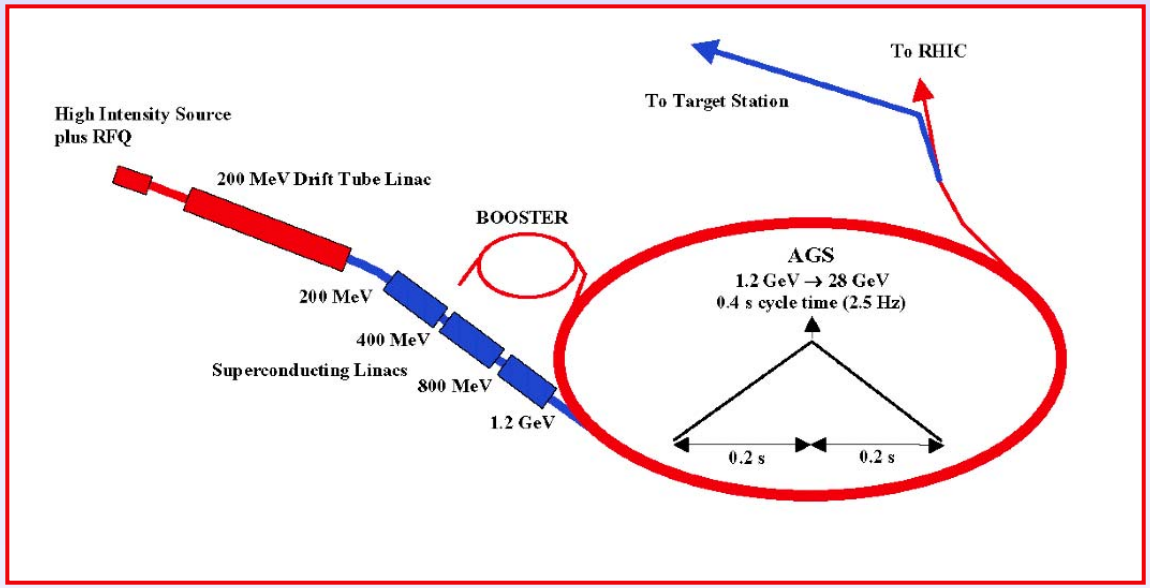
- Project Management
  - Steve Peggs, Project Director
  - Arup Ghosh, SC materials development
- Magnet R&D
  - Dipole first IR design study - concluding
  - Currently moving to Nb3Sn quadrupole demonstration with LBL & Fermilab
- Instrumentation
  - Phase lock loop, tune and chromaticity feedback
- Accelerator Physics
  - RHIC as the analogue computer: e-cloud monitor, long-range beam-beam wires, luminosity monitors ……
  - Collimation studies

Accelerator R&D: future facilities - LHC Accelerator Research Program

Issues:

- Manpower ramp up in FY06
- Optimal commissioning strategy
- Junior workforce pipeline
- RHIC-NP v's LARP HEP

Accelerator R&D: future facilities - AGS based Neutrino Superbeam



1 MW at 28 Gev beam energy

The use of much of the existing complex gives a cost effective Project.
New features required are:

1. 1 Gev SC Linac
2. Faster AGS cycling
3. Beamline & target station

Synergy with RHIC operations results in cost effective operation.

Accelerator R&D:future facilities - AGS based Neutrino Superbeam

Issues:

- Even though the proposal is cost effective (~$400M fully loaded) we feel it might be possible to reduce costs in some areas; SC linac based on the SNS design and costed on actuals.
- Does 1 MW represent the ultimate facility performance ?
- R&D plan to look at both these issues to OHEP in the next several months

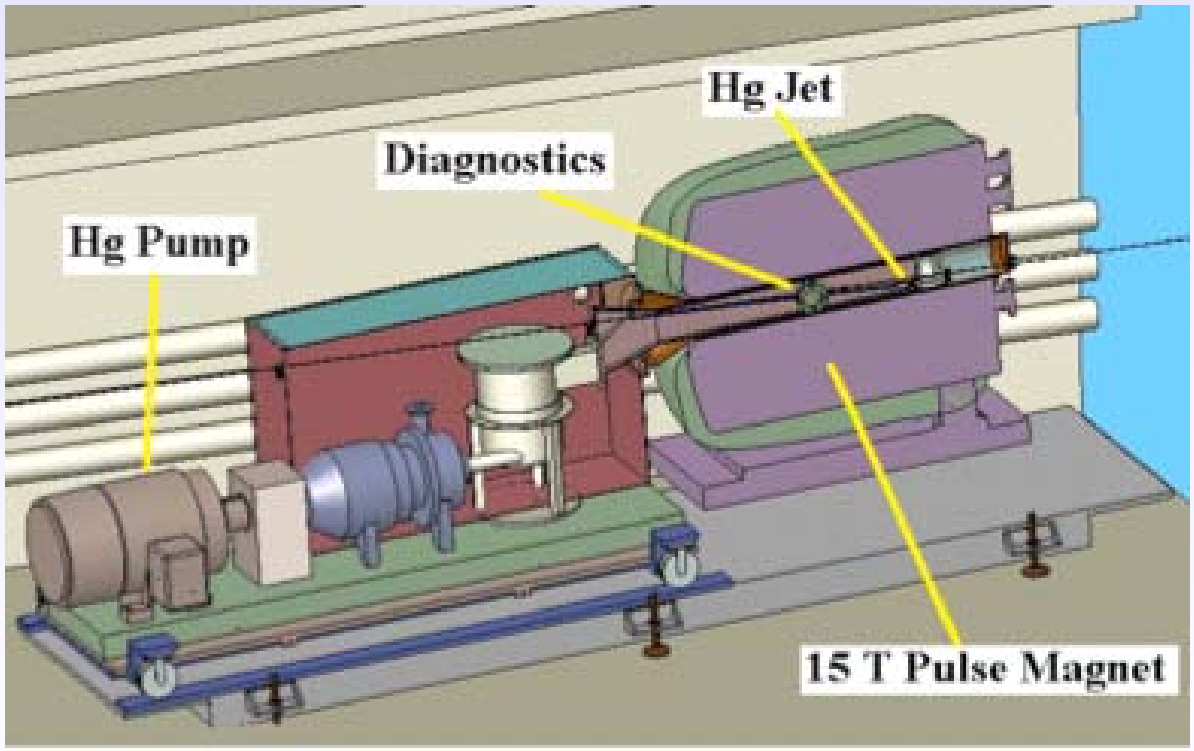
Accelerator R&D:future facilities - Neutrino Factory

The BNL group under Bob Palmer is a significant contributor to the US effort. The National program comprises of:

- Design studies of Neutrino Factories
  - Since the initial study the performance has been improved by a factor of 12 and the cost reduced by a factor of 40%.
  - Negociations are in process for the World Design Study (start in June 05)
  - All members of the BNL group participate in these activities, the main simulation tool (ICOOL) written and maintained at BNL
- Develop And Demonstrate Ionisation Cooling
  - Prototype hardware production
  - MICE experiment at the Rutherford lab, 4 members of the group are in the MICE collaboration.

Accelerator R&D:future facilities - Neutrino Factory

- Liquid Mercury Target Experiment at CERN
  - Demonstrate jet in a magnetic field and high intensity targeting
  - Experiment approved by CERN
  - Spokesman & 4 collaborators from BNL.

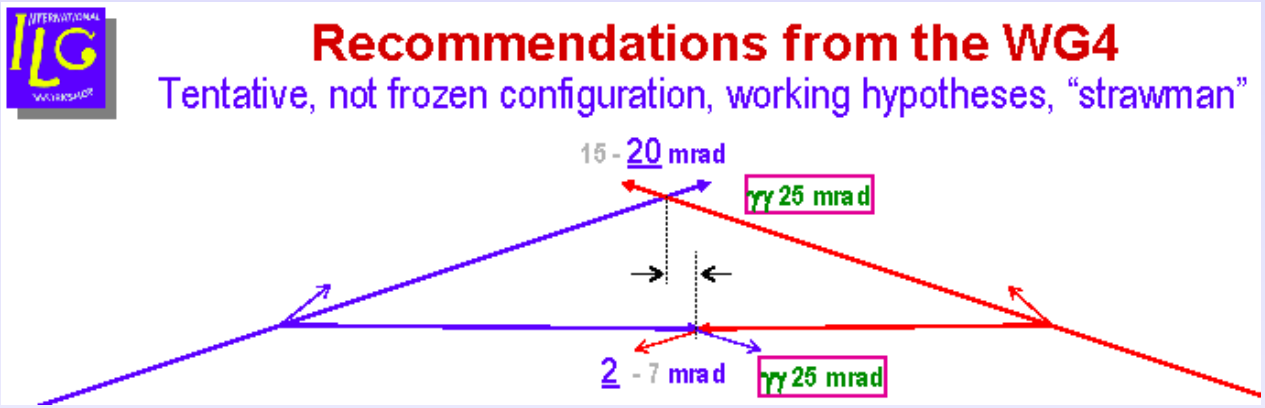


Accelerator R&D:future facilities - Neutrino Factory

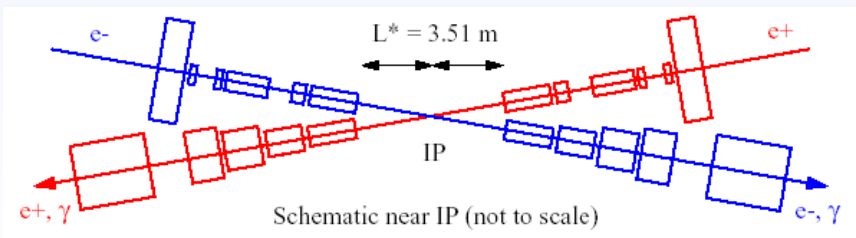
Issues: In addition to the BNL specific problems as discussed by Sam Aronson, there is a steady erosion of resources at the national level. At some point the rate of progress becomes imperceptible.

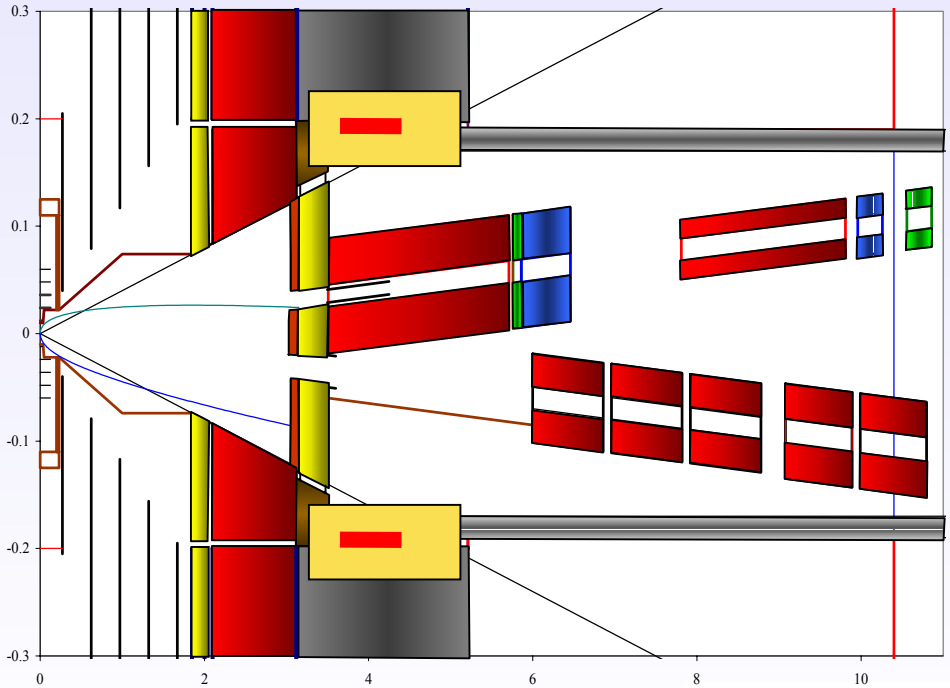
Are we close to this point ?

Accelerator R&D:future facilities - ILC R&D beam delivery system



Direct wind technology capable of providing compact medium field magnets suitable for the 20 mr IP final focus elements and extraction line I.e. those elements before the separation gets large enough for a more conventional approach

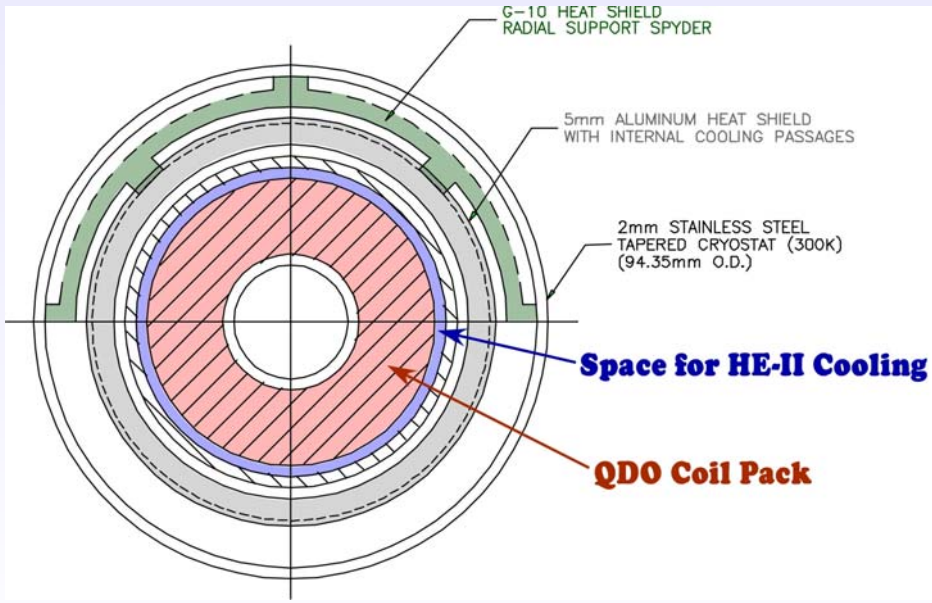


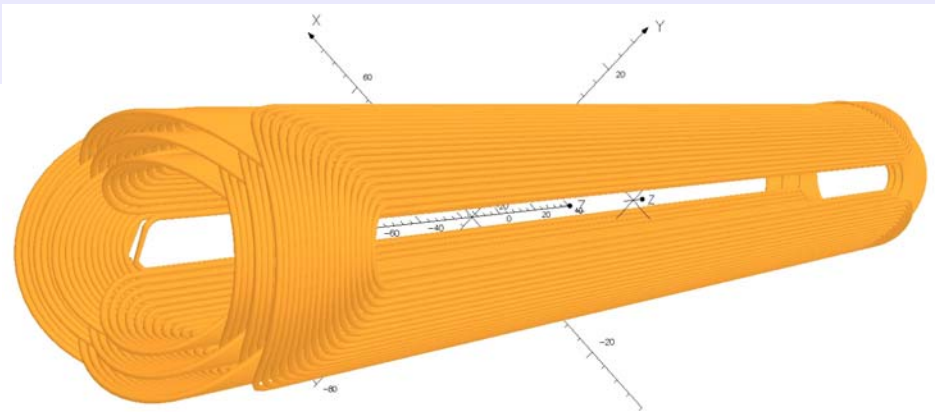


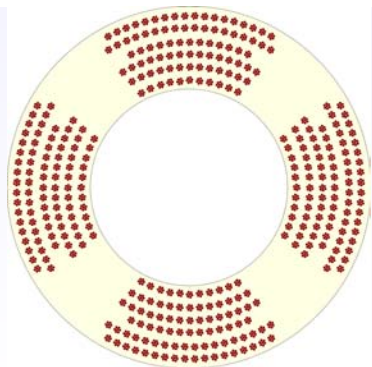
Accelerator R&D:future facilities - ILC R&D beam delivery

Significant 'real' design work is taking place for the machine-detector interface, extraction line, and the beam delivery system. This in turn implies 'detailed conceptual' knowledge of the components i.e. we're starting to fight like dogs for 'prime real estate'.

Supplemental 05 HEP funds (thanks !) have enabled us to start working seriously along these lines. Design has morphed into 1.8K, cable, side-by-side



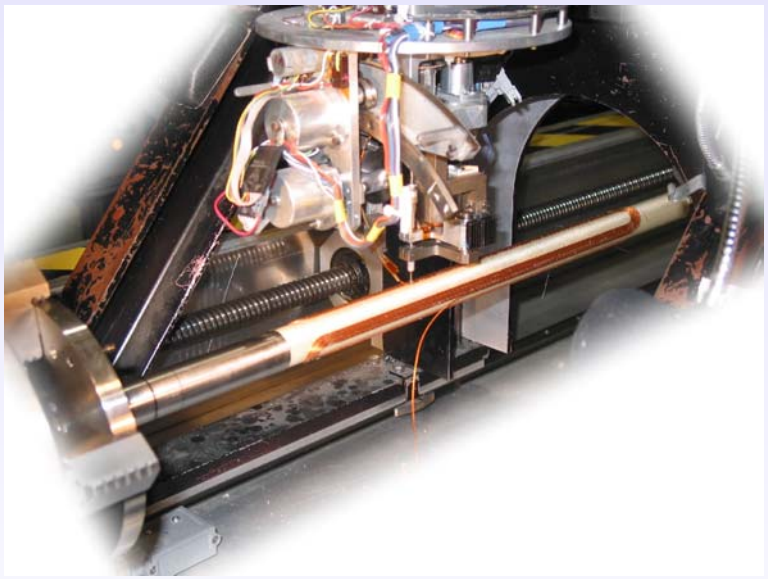




Accelerator R&D:future facilities - ILC R&D beam delivery

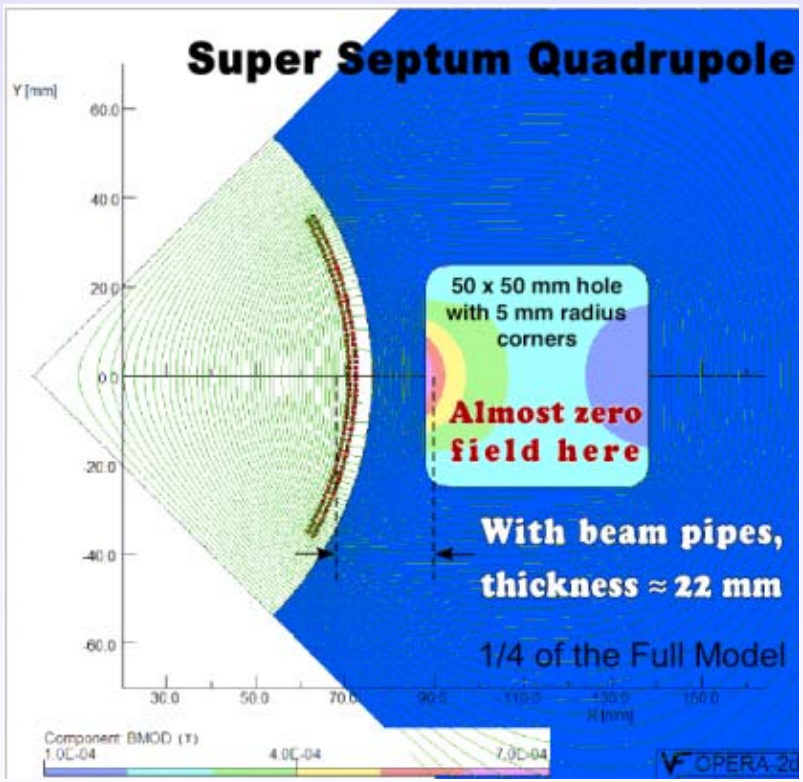
Coil winding R&D has recommenced to investigate compact cable (6 around 1) magnets

FY05 R&D goal is to wind and test a short 6 layer cable coil



Also working on vibration issues and larger aspects of the beam delivery system design

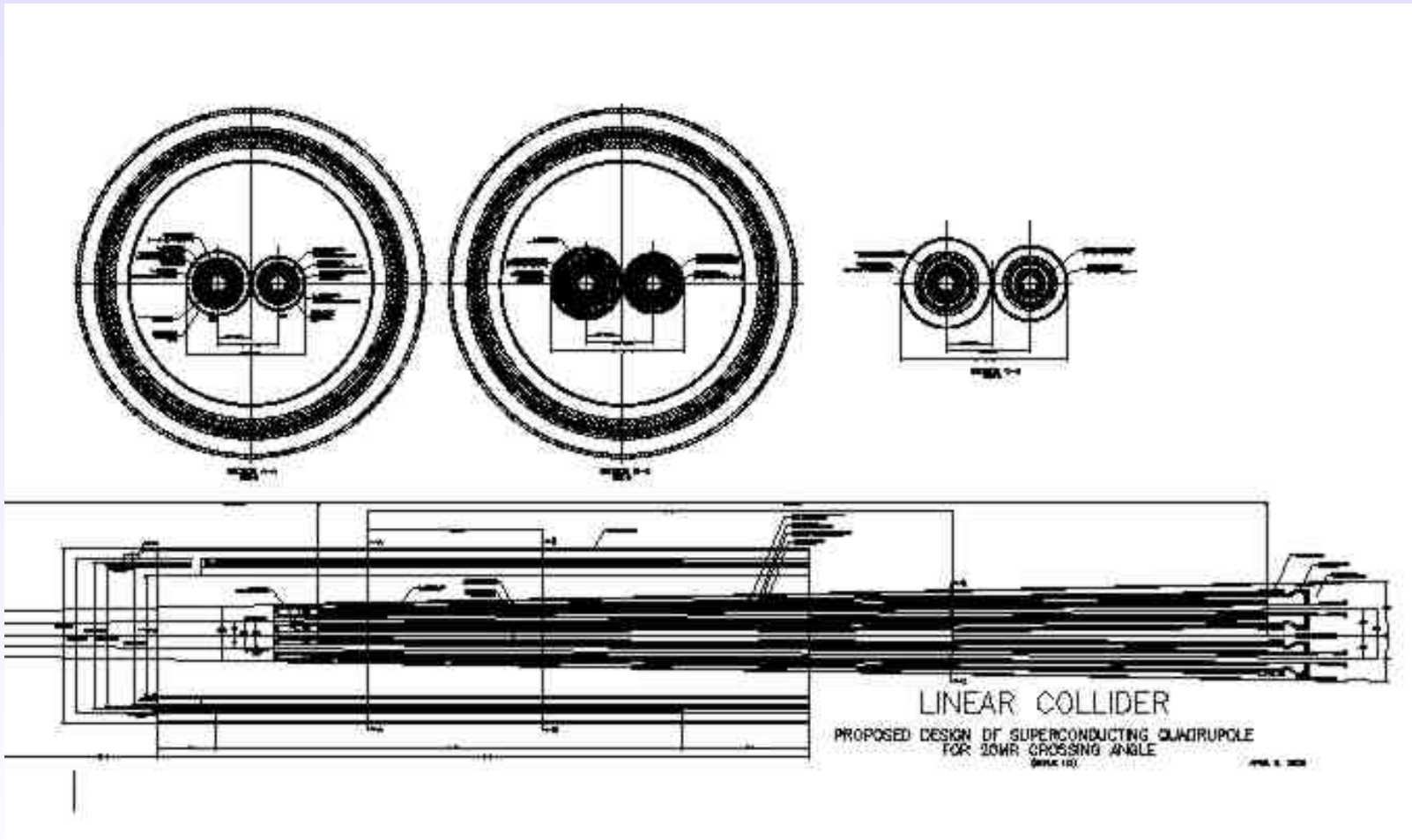
Accelerator R&D:future facilities - ILC R&D beam delivery



The 2 mrad X-ing angle design is much less developed at the moment. It does appear however that there are other classes of magnets that also lend themselves to the technique. The potential BNL scope could be significant

Accelerator R&D:future facilities - ILC R&D beam delivery

Real Engineering !



Accelerator R&D:future facilities - ILC R&D beam delivery

Issues:

The technical progress in WG4 has been remarkably good in spite of (because of ?) the lack of a global team for the past 9 months. We have found no drop dead issues yet. The major unknown at this point is probably energy deposition from the IP debris.

The biggest issue involves defining the FY06 program in the absence of the US Regional Director. The old model of SLAC telling us what to do, doesn't work anymore. Getting the new structure in place in time for FY06 will be a challenge.

Accelerator R&D:technology R&D - High Temperature Superconductors

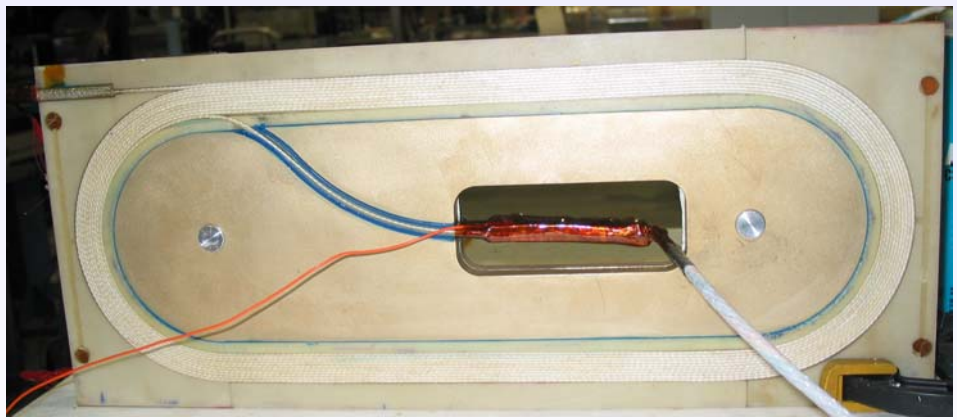
HTS in accelerator magnets offer two unique opportunities:

- Very high field magnets operating at low temperature (~4 K)
  - as critical current density (Jc) falls slowly as a function of field
- Medium field magnets operating at higher temperature (20-60 K, => 77 K)
  - as critical current density falls slowly as a function of temperature

Additional advantages in both cases are that (a) they can tolerate large heat loads and (b) temperature control can be relaxed (simple cryogenic system)

This coil carried a record 4+ kA.

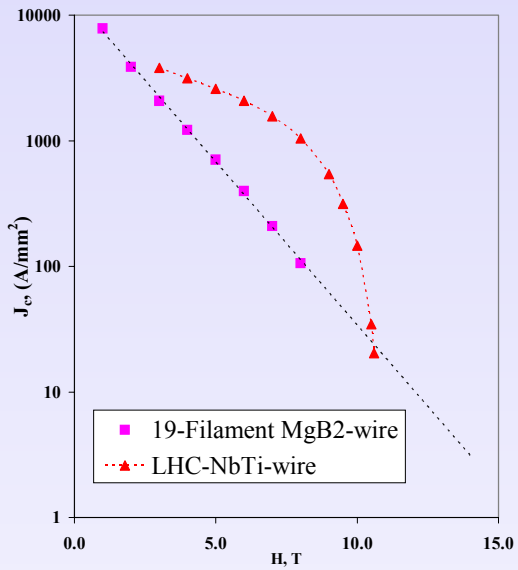
At present no superconductor can carry such engineering current density at ~25 T or more. (need a factor of 2-4 improvement in Jc for 12-20 T range)

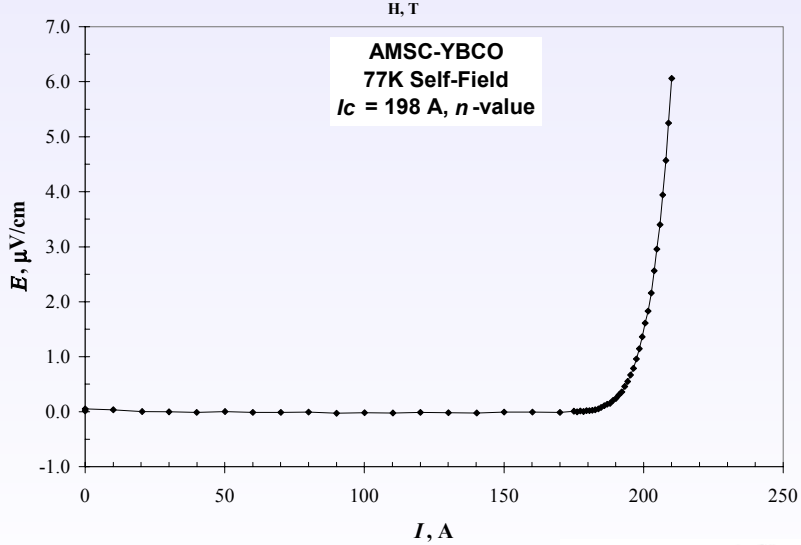


Accelerator R&D:technology R&D - Superconductor Development

SC Program funded thru HEP Accelerator Technology program also supports the Test Facility

- Nb_3Sn
  - J_c ~ 3000 A/mm² at 12T, 4.2K
  - J_c > 1500 A/mm² at 15T, 4.2K
  - Good Transverse strain tolerance
  - Filament Diameter < 40 μm (being developed)
- Bi-2212 Wire
  - J_c (16T) ~ 2000 A/mm², J_e ~ 600 A/mm²
  - Exceeds J_e of Nb_3Sn at 16T, 4.2K
  - Higher temperature margin
- Next Generation
  - MgB_2
    - now capable of 40 T if doped (Carbon) to add electron scattering
    - Steady development of wire technology
    - Improving Jc
  - YBCO
    - 20K application
    - Only in tape form
    - Highly anisotropic





Accelerator R&D:technology R&D - Superconductor Development

- Nb_3Sn Conductor development
  - Strand Testing
    - New testing barrel design and power supply modifications allows critical current testing to 1500 A, in background fields up to 11.5T
    - Ic testing extended to temperature range of 4.2 K to 1.9 K
  - Heat treatment optimization
    - By changing the intermediate heat-treatment temperature and duration, the total time for reaction has been reduced from 328 h to 144 h without any loss of Jc at 12T.
  - Stability Studies
    - Modern strands maximize J_c at the expense of *d* (filament dia.) which leads to flux-jump instability at low fields
    - Comprehensive study of flux-jump instability of high Jc strands show that magnets can operate with *adiabatically unstable* strands when *dynamic stability* is provided by high RRR
    - *What's new and surprising*: 90% of the Jc performance can be retained if the final reaction is as short as 24 hours
    - RRR > 50 seems to be the threshold for dynamic stability

Accelerator R&D:technology R&D - Superconductor Development

Future plans for the SC Test Facility

- In collaboration with industry and HEP Conductor Development program, continue the development of high-Jc Nb_3Sn
  - HT optimization
  - Measurement and control of low-field magnetization
  - Measurement of strand I_c to 16T, in the temperature range of 4.2-1.9K
- Engage in the development of Bi-2212 wires (collaborate with OST)
  - Improve Jc by a factor of two.
  - Examine bending strain limits
  - Effect of radiation on J_c and T_c
- MgB_2 wire development (collaborate with Material Science Dept. and industry)

Issue: Develop a dedicated facility for testing Nb_3Sn cable samples

- Build a high-field dipole magnet of reasonable bore (40-50mm) to provide a background field in the range of 10-12T

Advanced Accelerator R&D - Accelerator Test Facility

- The ATF is a proposal-driven, advisory committee reviewed, USER FACILITY for long-term R&D into the Physics of Beams.
- The ATF features:
  - High brightness electron gun **(World record in beam brightness)**
  - 75 Mev Linac
  - High power lasers beam-synchronized at the picosec level
  - 4 beam lines + controls
- The ATF serves the whole community: National Labs, universities, industry and international collaborations.
  - ATF contributes to Education in Beam Physics. (~2 PhD / year)
- In-house R&D on photoinjectors, lasers, diagnostics, computer control and more (~3 Phys. Rev. X / year)
- Support from HEP and BES.

ATF: A Unique resource world-wide in the comprehensive nature of the facilities. Supported by both HEP and BES

Advanced Accelerator R&D - Accelerator Test Facility

During the past year Vitaly Yakimenko has taken over from Ilan Ben Zvi

The facility performance continues to be enhanced:

- New RF Photo injector, bunch compressor and control system (Summer 2004). New record in the beam brightness achieved due to novel cavity tuning.
- Multiyear CO_2 laser upgrade to the Terawatt level (nearly completed; first experiment produced excellent data and confirmed laser performance).
- Radiation and laser interlock systems upgrade (this and next years).
- Photo injector laser upgrade: shorter pulse for CO_2 laser, better pulse for RF GUN (next 3-4 years, post-doc ?)
- X-bend section after the bunch compressor (establishing collaboration with SLAC who will supply cavity, waveguide, and modulator [~$1M]. Unique position to investigate high brightness beam in warm X-band structure - ILC nonlinear bunch rotator ?)
- Energy upgrade to ~ 1GeV and new experimental hall. Discussions with users to determine the correct energy range. Will require a recirculator and could give Orion type performance level. (~$3M)

Advanced Accelerator R&D - Accelerator Test Facility

5 active experiments in 2004

- A SASE-Free Electron Laser Experiment, VISA, at the ATF Linac, UCLA
- Structure-based Laser Driven Acceleration in a Vacuum, National Tsinghua Univ., BNL
- Photocathode R&D, BNL
- Electron Beam Pulse Compression Based Physics at the ATF, UCLA
- Study of Compton Scattering of Picosecond Electron and CO2 Beams Tokyo Metropolitan U, Waseda U, KEK, Princeton U

Feasibility studies and LDRD

- Stony Brook Univ. : X-ray generation from target
- Kyushu Univ.: CO2 Laser induced EUV
- Univ. of Texas: Application of thin SiC films to sub-wavelength lithography and compact particle acceleration
- RHIC/BNL: Magnetized beam transport
- LDRD: Optical stochastic cooling of the Gold ion beams in RHIC

6 experiments scheduled to start in 2005

- Ultra-fast Detection of Relativistic Charged particles by Optical Techniques, BNL, Montclair State University, Univ. of Pittsburgh
- Laser Driven Cyclotron Autoresonance Accelerator, Omega-P/Yale
- Particle Acceleration by Stimulated Emission of Radiation (PASER), Technion, Israel.
- Multi-bunch Plasma Wakefield Acceleration at ATF, Univ. Southern California
- Laser Wakefield Acceleration Driven by a CO2 Laser, STI Optronics
- Emittance optimization using active transverse laser shaping, Duke Univ.

Advanced Accelerator R&D - Accelerator Test Facility

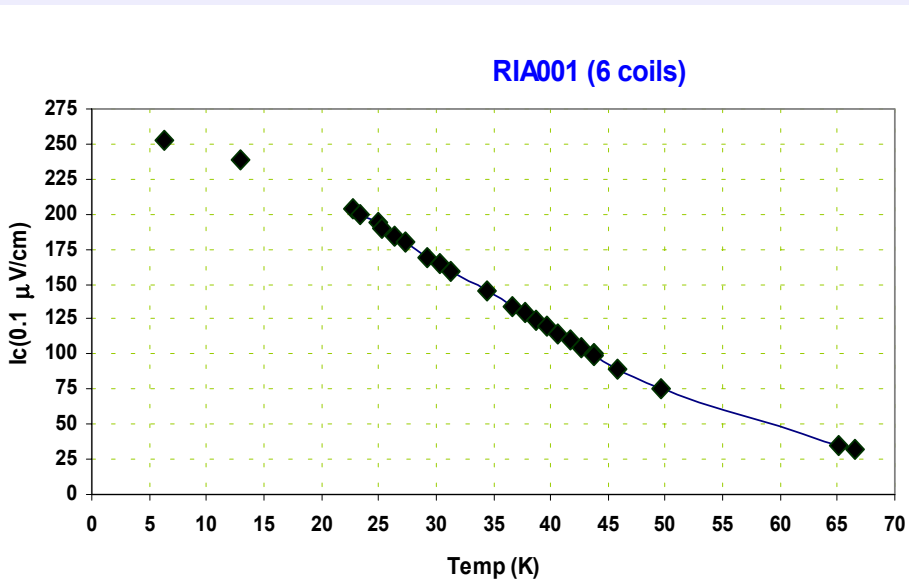
Issues:

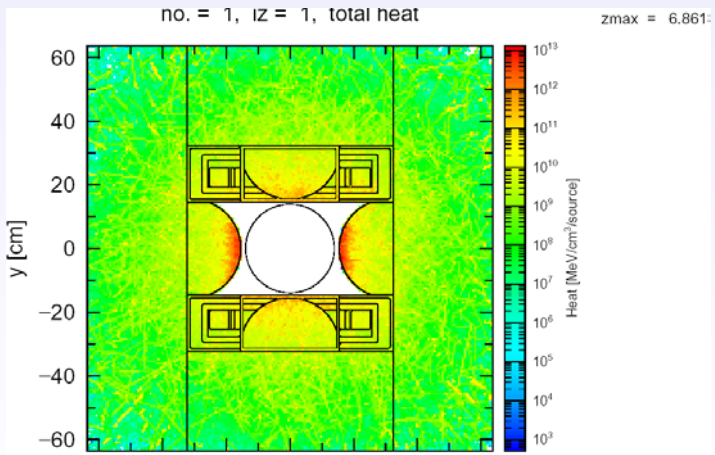
- The science program is in good shape and the goal is to maintain quasi-steady state in the near term. Some items in the long term would lead to facility enhancement.

- The biggest issue involves resources. Safety related changes to operating procedures involving lasers will require additional manpower

Accelerator R&D:Non HEP funded R&D - HTS Magnets for RIA

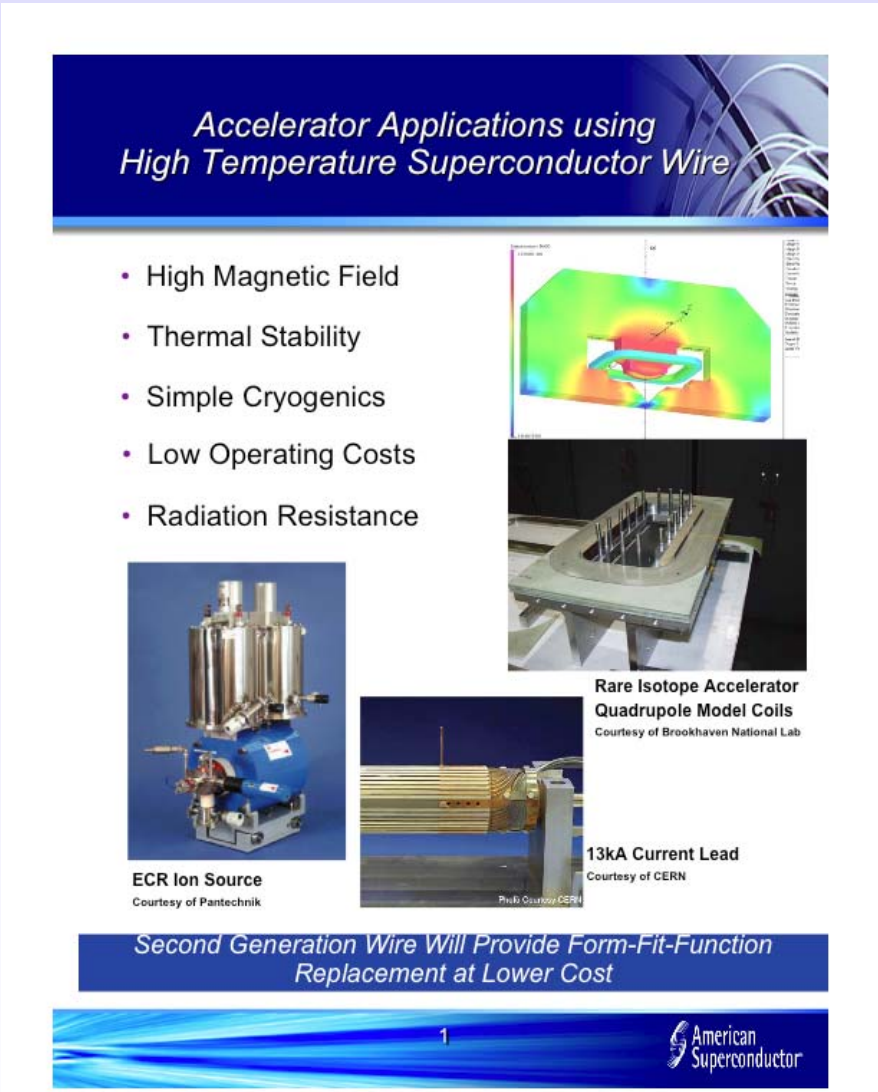
- Rare Isotope Accelerator magnets are based on commercially available high temperature superconductors.
- They will reside in an environment (the fragment separator immediately down stream of the production target) where a large amount of heat and radiation will be deposited.
- We have designed, built and tested a magnetic mirror model of this design.
- The magnet performance has been very impressive. It speaks well for the future of HTS magnets in accelerators.





Accelerator R&D:Non HEP funded R&D - HTS Magnets

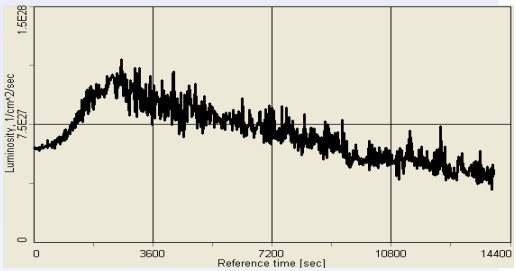
Good communications with industry

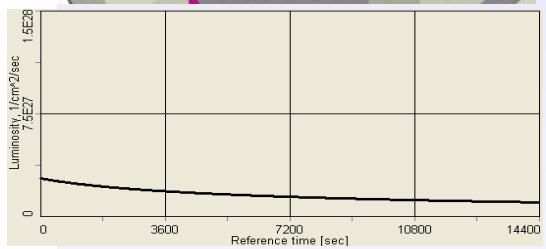


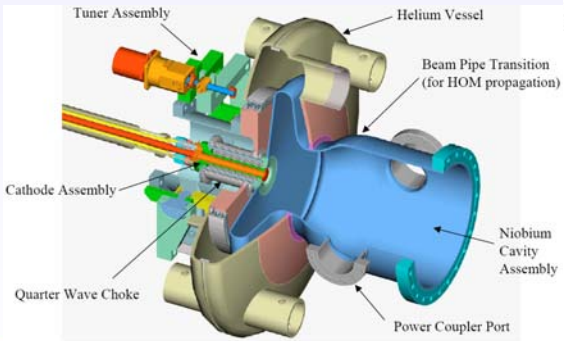
Accelerator R&D:Non HEP funded R&D - High Energy e-Cooling

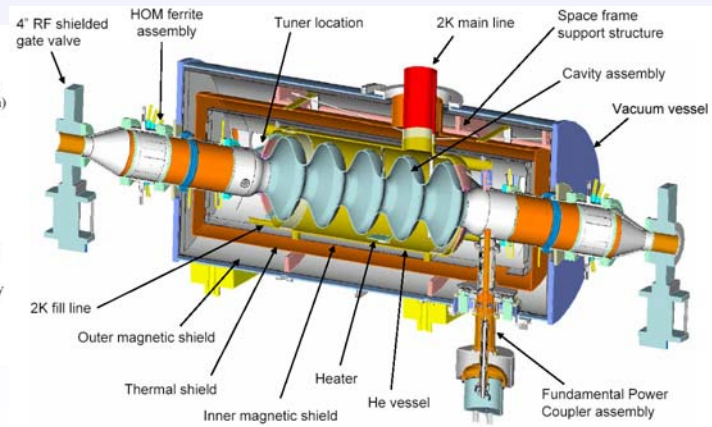
Electron cooling at $\gamma \geq 100$:

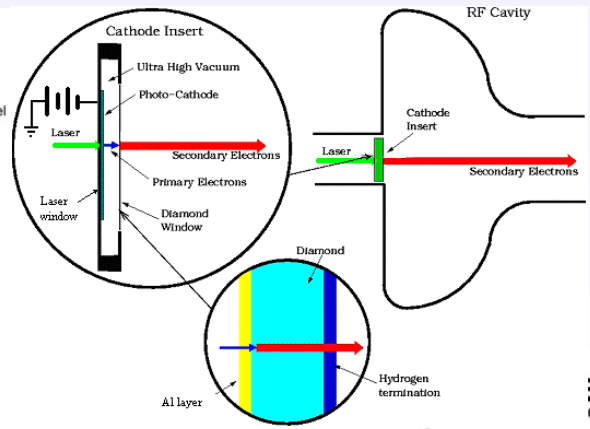
- Much more difficult than lower energies.
- Requires new technologies
  - Photo-cathodes
  - SRF photoinjector
  - Ampere ERL cavity
  - Ampere-class ERL
  - Precision solenoids











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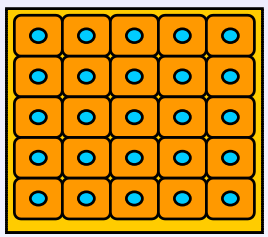
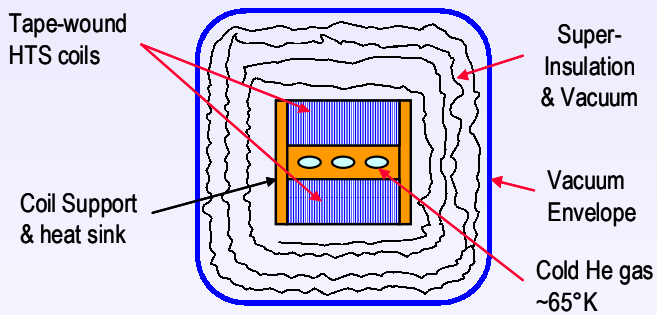
U.S. DEPARTMENT OF ENERGY

Accelerator R&D:Non HEP funded R&D - HTS Light Source Magnets

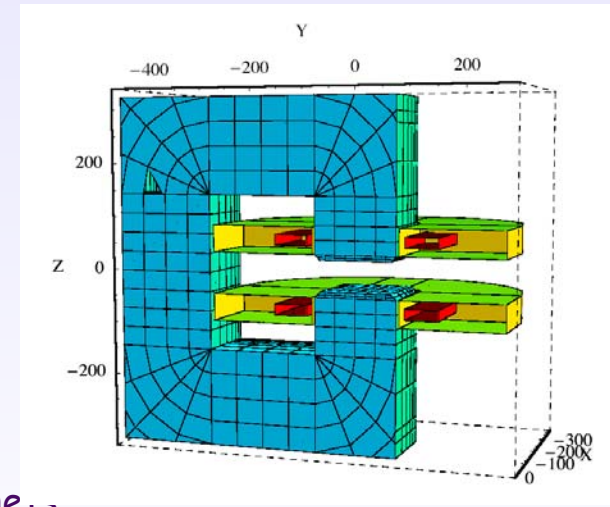
- Explore the possibility of savings in the ever rising cost of electricity while at the same time facilitating a machine upgrade because of higher field magnets
- A joint (NSLS and Magnet Division) LDRD proposal to develop and build form fit/ functional HTS replacements for water-cooled copper coils in Synchrotron Magnets and examine overall cost issues over a period of time
- Start with the commercially available 1st generation BSCCO wire/tape (30 K- 60 K) and then after a few years move to 2nd generation wider YBCO tape (77 K operation)
- This may have a similar and as far-reaching impact as the introduction of Low Temperature Superconducting (LTS) had on proton accelerators a few decades ago



Present Conventional water-cooled Copper Coil



Replacement HTS Cryo-Coilpack



Permits the use cryo-coolers in such magnets

Accelerator R&D:Conclusions

The BNL HEP Accelerator R&D program is well focused on the national goals in the context of future facilities

This R&D program benefits greatly from the synergy inherent in the more diverse environment of a multi-program national lab

The program plays to our strengths in terms of facilities and technologies and is complementary to other parts of the national program

The efforts are highly leveraged; thus cost effective for OHEP given the role of NP as landlord and a significant on-site presence of BES