BNL HEP Accelerator R&D and Technology Development

Superconducting Magnet Division (SMD) (Peter Wanderer)

Advanced Accelerator R&D (Richard Fernow)

LHC Accelerator R&D Project (LARP) (Steven Peggs)

Accelerator Test Facility (ATF) (Vitaly Yakimenko)

(More details in plenary talks)

ILC Beam Delivery System R&D

LARP - Magnets

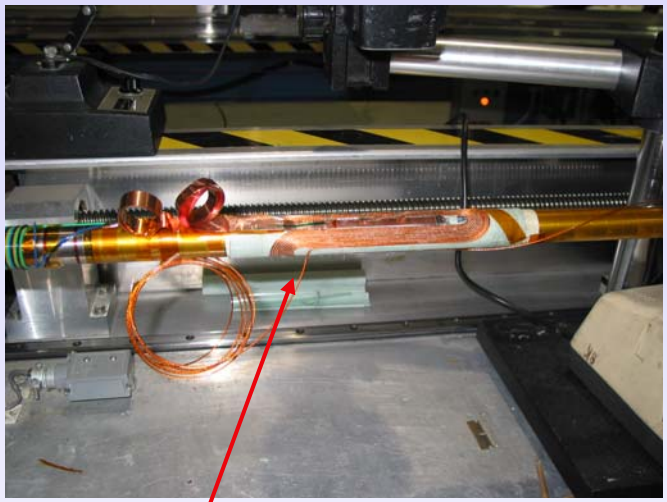
Superconducting Materials R&D

Accelerator Magnet R&D

ILC Beam Delivery System (BDS)

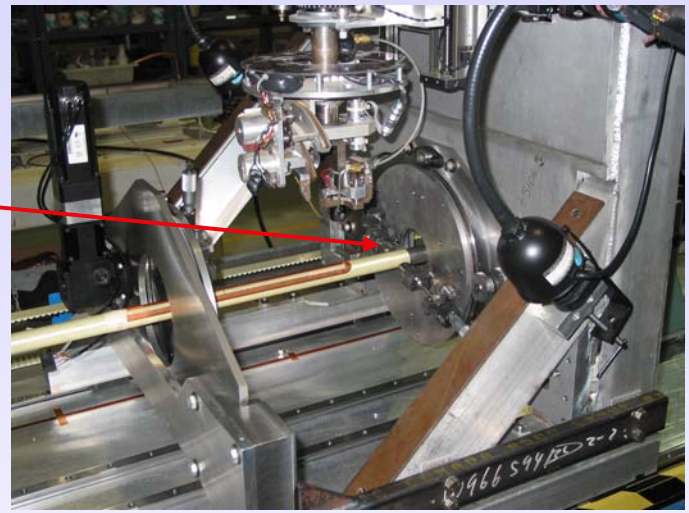
- TASK: Superconducting magnet system for 14 mrad IR, including magnet position stabilization, beam optics, interface with experiments, accelerator physics.
- ILC decision: only 1 IR, 14 mrad, two experiments ("push-pull")
- FY07 accomplishments:
  - Adapt design to push-pull, add force neutral anti-solenoid
  - Modify CAD/CAM coil winder to make 2.2 m final focus quad
  - Build model quad to measure sensitivity to simulated beam heating
- Significant reduction of magnet vibration using stabilization tables
- Measure motion of magnetic field with ~ 1 nm resolution
- FY07 budget reduced from planned $1.5 M to $975k.
- FY08 plans:
  - Wind coil for 2.2 m final focus quad
  - Continue measurement, control of magnet vibrations
  - Continue BDS design, including interface with experiments

ILC BDS Magnet Progress in FY07

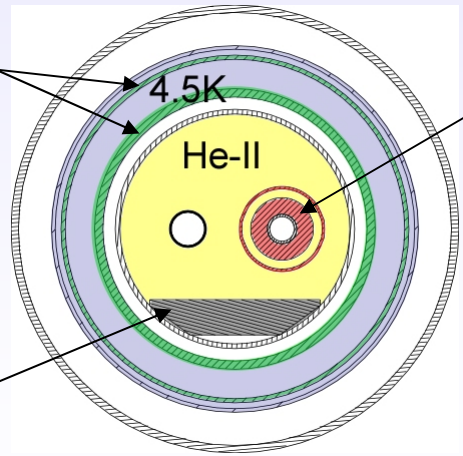


Test coil for beam heating study

Winding machine upgrade for long coils



Force Neutral Anti-Solenoid Coils



Actively Shielded QD0 Coil

Internal Coil Support & Alignment Structure

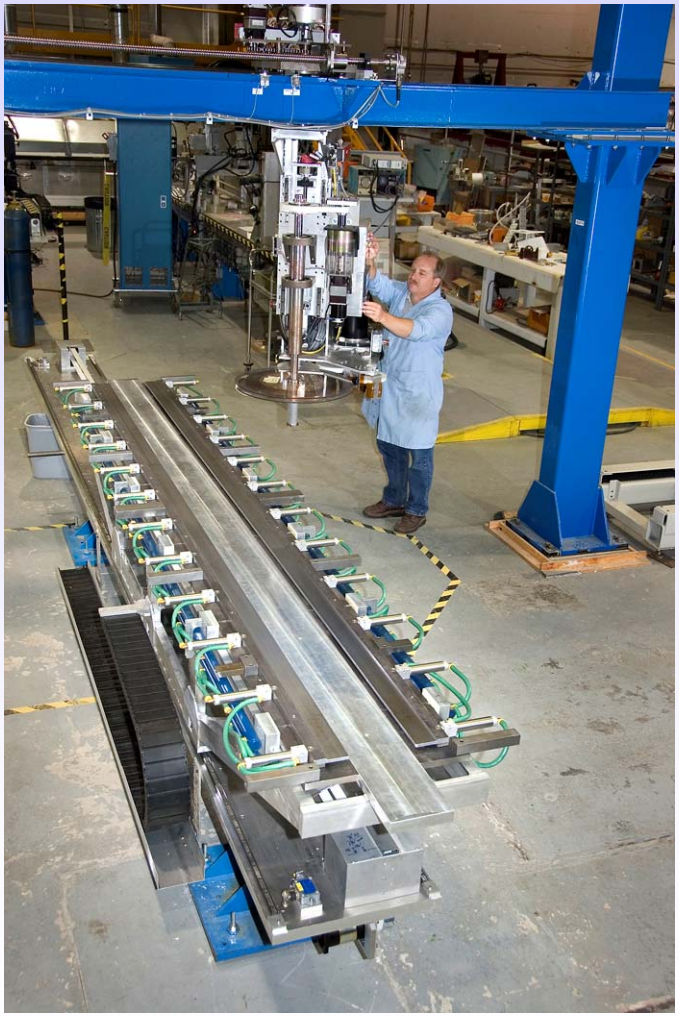
LARP Magnet and Material Program

- TASK: Make, test Nb3Sn 4 m racetrack coils in support structure ⇒ input to LARP 4 m quadrupole design
  - Collaboration: FNAL (manager) + LBNL (support structure) + BNL (coils)
- TASK: Develop, procure, test superconductor

- FY07 accomplishments: support structure tested ok with dummy coils
  - successful test of 30 cm "tech transfer" model
  - 4 m magnet nearly complete, test in June

- OPTIONS FOR FY08: additional 4 m racetrack magnets
  - cable test fixture
  - work on design, construction of 4 m quads

LARP FY07: New Magnet Production Equipment



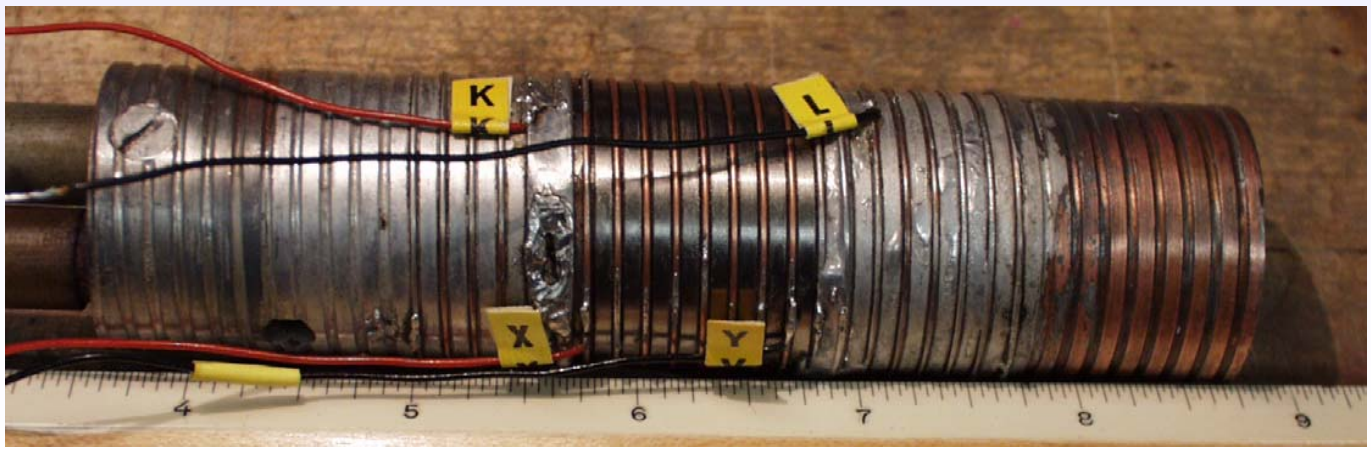
Putting coil into reaction oven.

Automatic winder for 4 m racetrack coils

Superconducting Materials Development

- Goal: optimized superconductors for HEP use ⇒
  - Encourage industrial development of material made to HEP specs
  - Advise HEP users re: industrial R&D progress, limits
  - Characterize R&D materials (Nb_3Sn, High Temp materials)
- Current work primarily in support of LARP
  - Manager of LARP conductor procurement, test program
  - Tested 130 strands in the last year

Holder for Nb_3Sn strand during testing



Accelerator Magnet R&D

- FY06: Successful test of 10 T superconducting dipole.
  - Coils wound using reacted Nb_3Sn – alternate construction method for handling material which is brittle after reaction.
- FY07: Proposed upgrade of cable test facility not approved ⇒ no funding
- FY08: FY08P budget has funds ⇒ study two options:
  - Less expensive upgrade to cable test facility
  - Use of high temperature superconductor for HEP application

Superconducting Magnet Program Summary

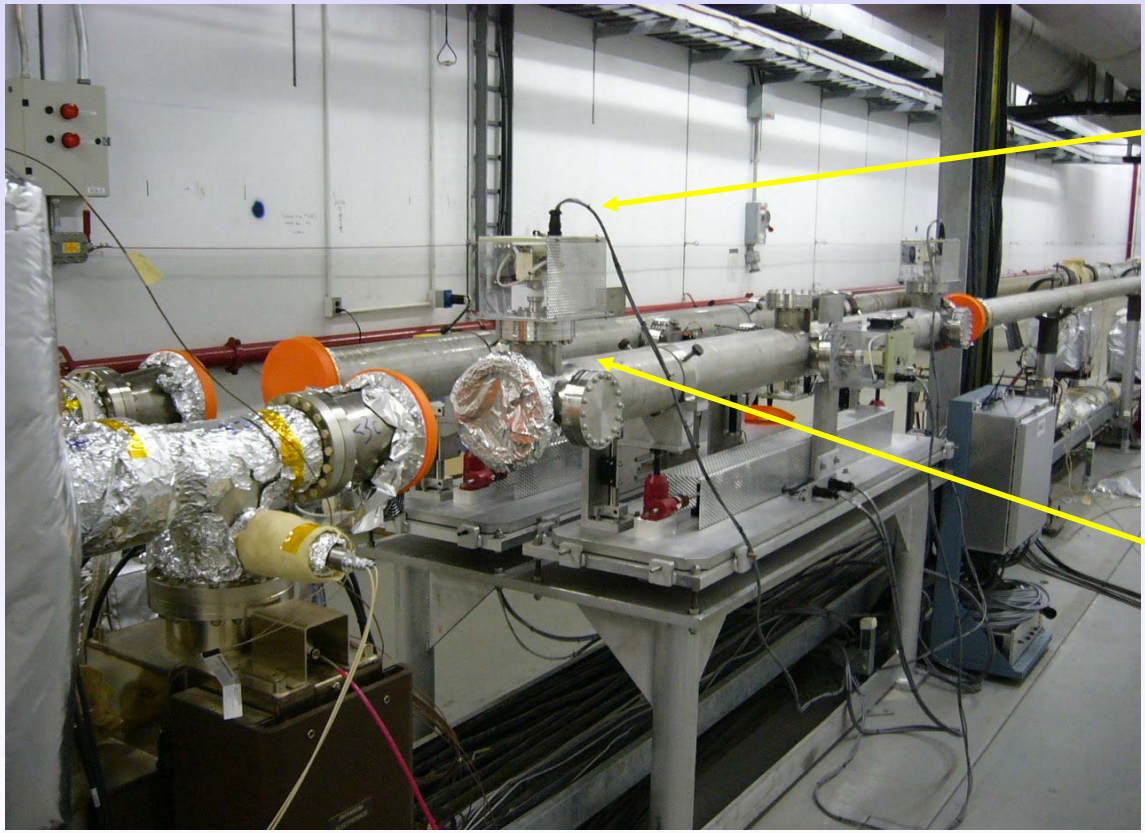
- Magnet program well aligned with the National goals : ILC, LARP. These elements receive direct programmatic funding.

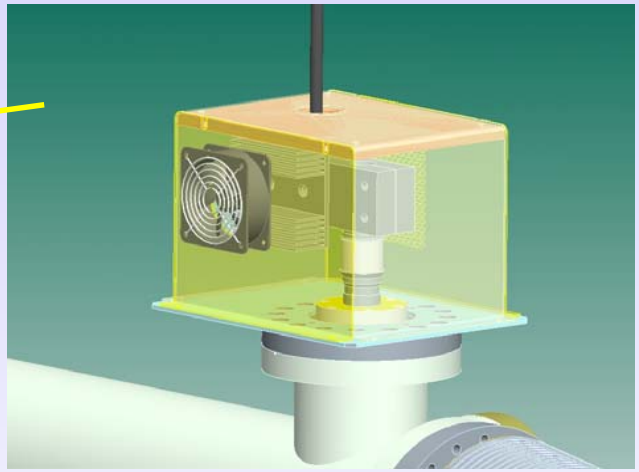
- Distinguishing features of the program are:
  - Direct wind (CAD/CAM) technique – e.g., ILC
  - Full length fabrication and testing – e.g., ILC, LARP
  - Materials expertise – e.g., LARP
  - HTS development (mostly outside HEP in BES/NP)

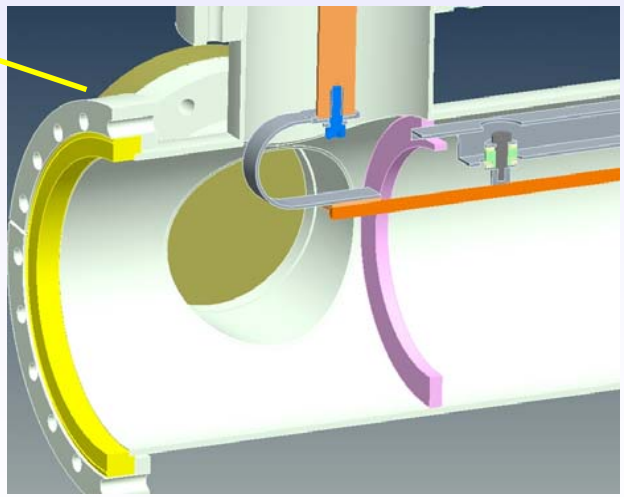
LARP: BNL resources & contributions

- Triplet Quads
  - Infrastructure: physicists, engineers, coil-winding, ovens, ...
  - Collaboration: load balancing, optimized skill sets
- Slim Magnets
  - Design and construction resources in place
  - BNL direct wind slim magnets at CESR, HERA & BEPC
- Electron lenses
  - Must validate & test in RHIC – soon the only U.S. hadron collider
  - RHIC contemplates funding its own lens – collaborate with LARP
- Crab cavities
  - Synergy with ILC, KEK, Daresbury, ERLs (eg eCOOL)
  - R. Calaga (Toohig Fellow) plays a central role

Beam-beam (long range) wire compensators





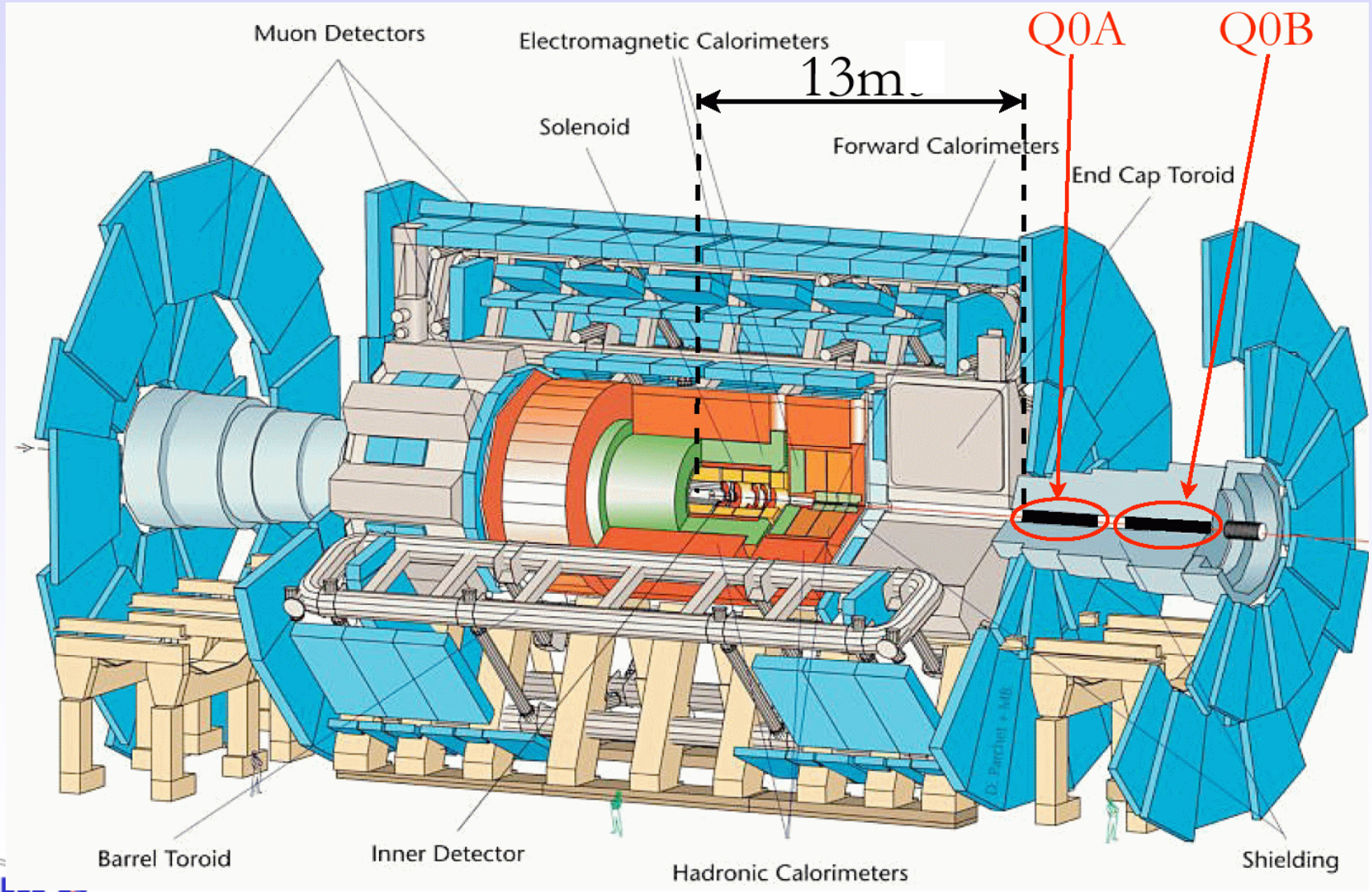


2006 RHIC studies without BBLR

2007 With 2 DC BBLR wires

2008 With AC (pulsed) wires

"Slim" magnets in ATLAS



LARP Summary

- RHIC will soon be the only U.S. hadron collider – BNL "stewardship role" for beam test & development capabilities.
- BNL has world class resources:
  - Nb3Sn R&D tooling & oven,
  - slim magnet experience,
  - crab cavity leadership,
  - superconductor materials testing capabilities.
- IRUP (a construction project) and LARP (an R&D Program) would proceed in parallel.
- Multiple "full upgrade" scenarios are being discussed – 4 in "slim magnets" alone. Need experience with beam.
- Junior workforce pipeline needs explicit support from DOE & NSF for BNL & University involvement in LARP.

Advanced Accelerator R&D

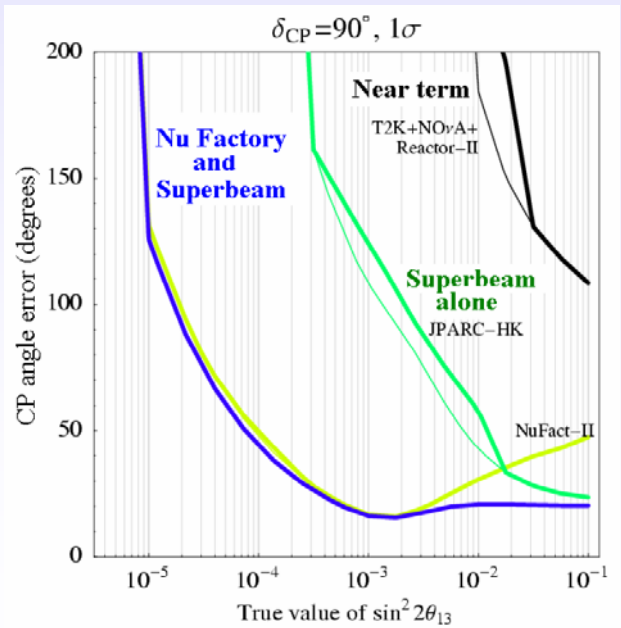
- Machine design and simulation of future μ-based facilities
  - neutrino factory
  - muon collider
- MERIT experiment
  - test of liquid jet targetry at CERN
- Fixed field alternating gradient (FFAG) acceleration theory and simulations
- EMMA experiment
  - demonstration of non-scaling FFAG acceleration at Daresbury

- Most of group's work is done as part of U.S. NFMCC
- Collider work also done in collaboration with Fermilab MCTF and Muons Inc

Advanced Accelerator R&D (AARD)

Neutrino Factories

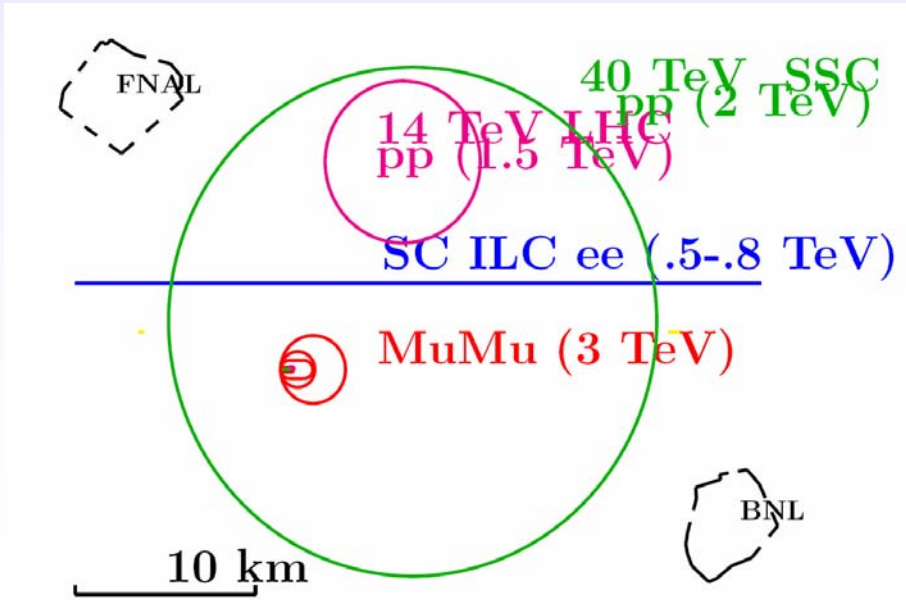
- Lower backgrounds than conventional beams
- Only way to study CP violation if θ_{13} small
- Lower systematic with 4GeV beam if θ_{13} large



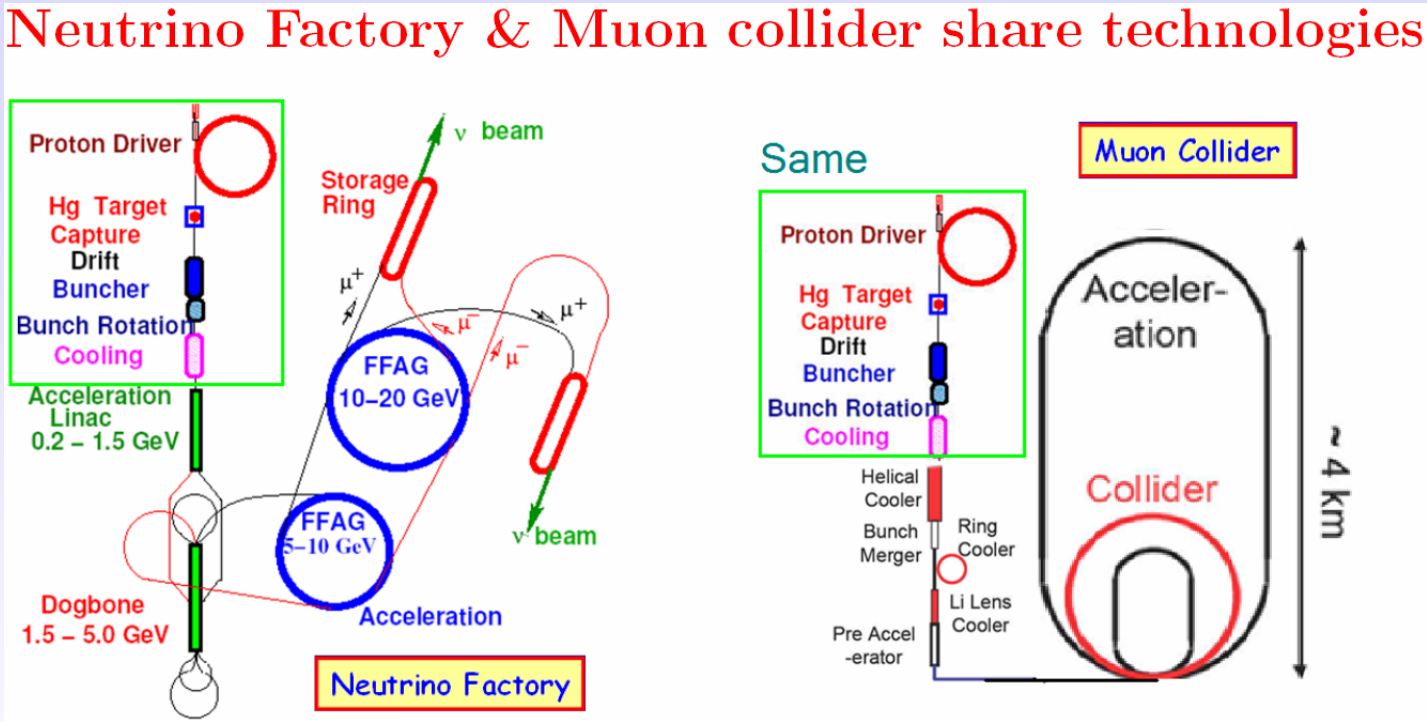
Errors in CP angle δ

Muon Colliders

- Muons are point like
- Same physics as $e^+ e^-$, plus some …
- But 40,000 less radiation
- So Muon Collider circular and much smaller than linear
- First Complete Collider cooling scenario



AARD: Neutrino Factory & Muon collider share technologies

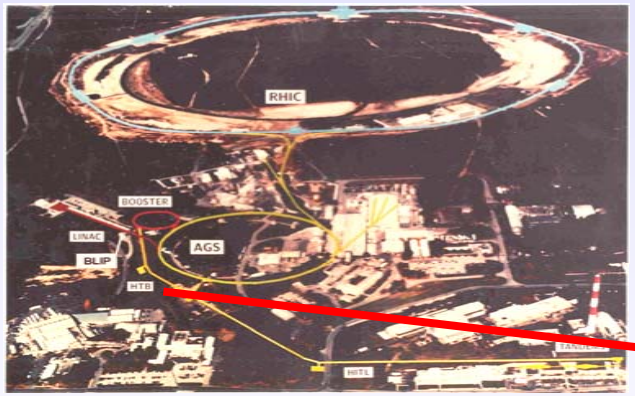


BNL Involvement

- High power solid targets (Radiation damage studies at BLIP)
- High power liquid targets (MERIT HG target experiment at CERN)
- Capture, bunchier, phase rotation (Simulations with Intern. Design Study)
- Cooling (Simulation and MICE cooling demonstration at RAL)
- Acceleration (Beam dynamics &EMMA electron FFAG model)

AARD: Target program

- **Vision—Convert intense Proton Beams into intense secondary beams**
- **Solid Target Studies** – Potential for service in proton beams up to 1 MW
- Material Irradiation Studies

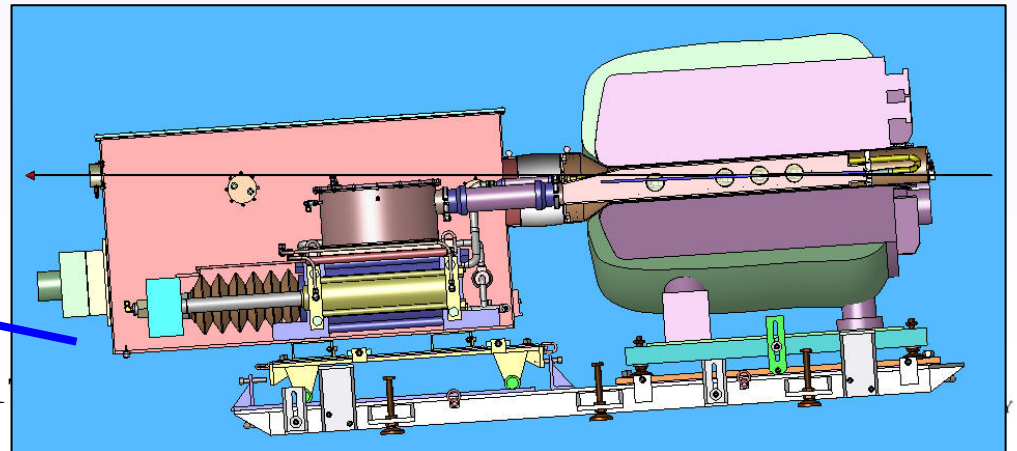


Irradiation takes place at BLIP using 200 MeV protons

Post irradiation analysis at BNL Hot Labs

- **Liquid Target Studies**– Potential for service with proton beams 4 MW and beyond

The MERIT target experiment at CERN



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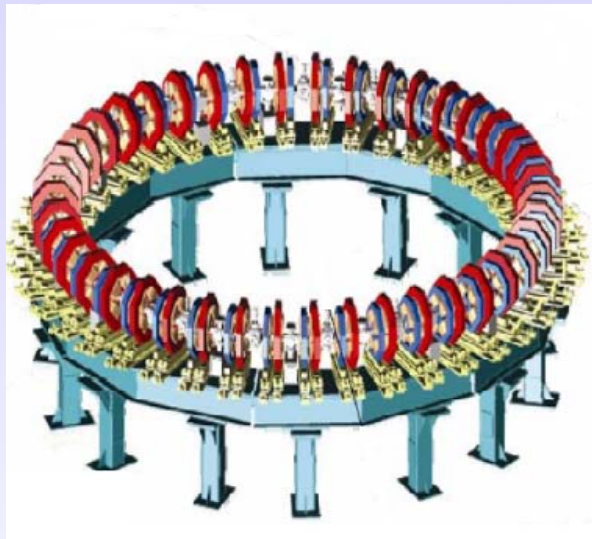
Fixed Field alternating Gradient Accelerators (FFAG)



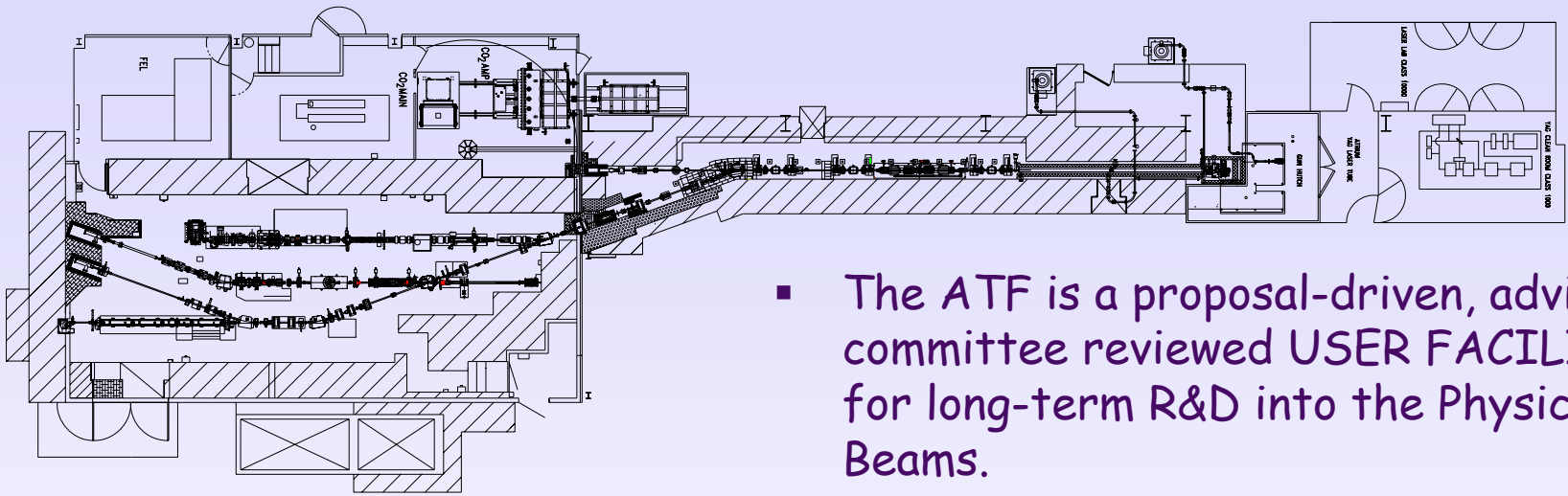
Accept momenta over factor of 2-3

- **Scaling Designs (MURA)**
  - Tune independent of momentum
  - But large magnet apertures
  - Several operating examples in Japan
- **Non-Scaling (Carol Johnstone)**
  - Orbits are not similar, but closer together than in scaling
  - Smaller apertures But tunes not constant
  - Suitable for very fast muon acceleration
  - Electron Model (EMMA) funded in Daresbury, UK
  - BNL heavily involved in Design

Advanced Accelerator R&D Conclusion

- Neutrino Factory International Scoping Study (ISS) complete
  - Convergence to one concept
  - International Design Study (IDS) being organized
- Progress on Muon Collider Design
  - First complete scenario Space charge ok Progress on lattices
  - Collaboration with new Fermilab Muon Collider Task Force (MCTF)
- Progress on MERIT Target Experiment
  - 15 T magnet tested Optics and Hg system tested
  - Run this summer
- New Results on Solid Targets for Super-Beams
  - Radiation disintegrates Carbon-Carbon; GUM metal loses ductility
  - Funded under Neutrino Initiative; Needs funding to continue
- Progress on FFAG Studies
  - EMMA approved and funded in UK Lattice nearly finalized

BNL Accelerator Test Facility - ATF



- The ATF features:
  - **High brightness electron gun**
  - **75 Mev Linac**
  - High power lasers beam-synchronized at the picosec level (**TW level CO2 laser**)
  - 4 beam lines + controls

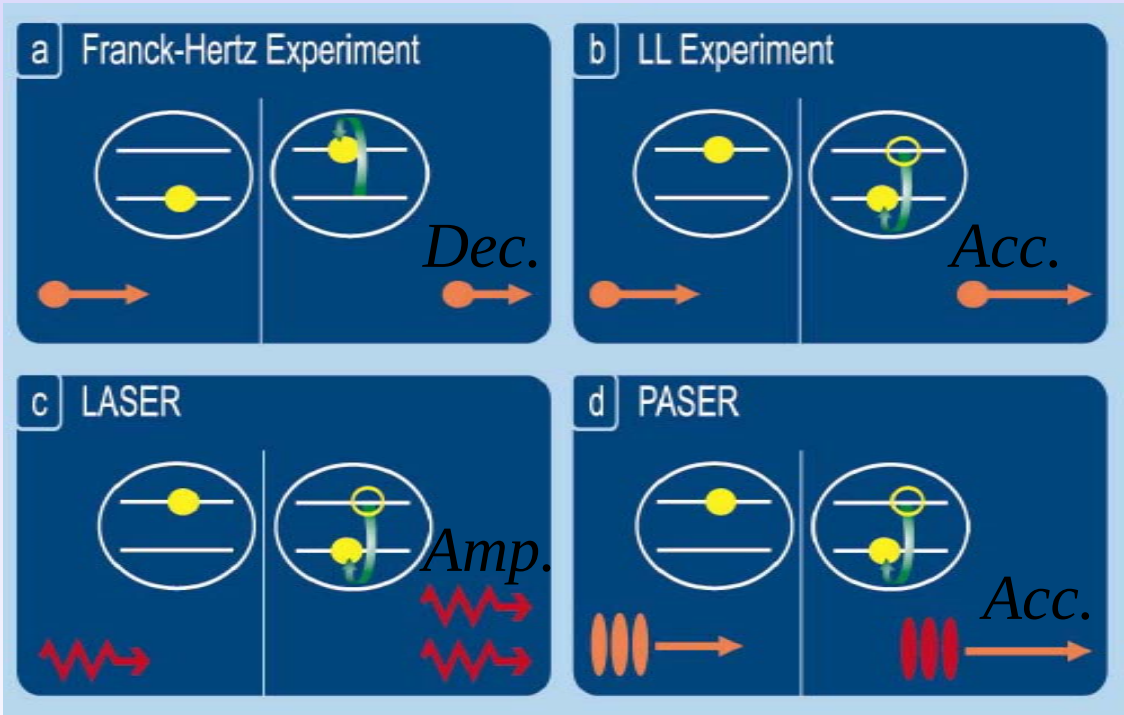
- The ATF is a proposal-driven, advisory committee reviewed USER FACILITY for long-term R&D into the Physics of Beams.
- The ATF serves the whole community: National Labs, universities, industry and international collaborations.
- ATF contributes to Education in Beam Physics. **(~2 PhD / year)**
- In-house R&D on photo injectors, lasers, diagnostics, computer control and more **(~3 Phys. Rev. X / year)**
- Support from HEP and BES.

April 2007, User meeting

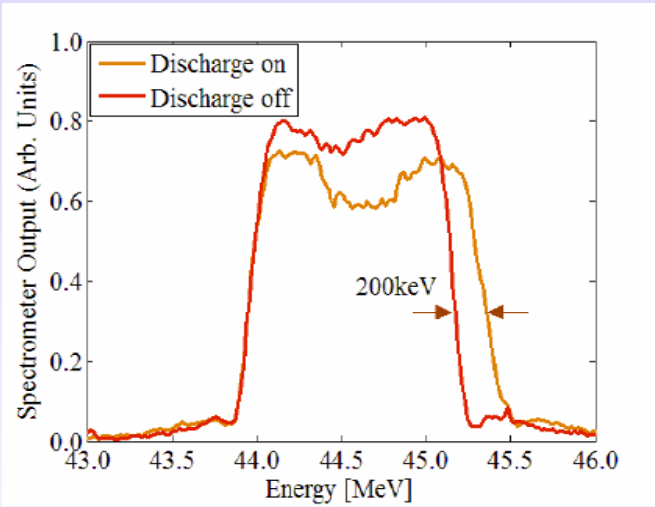
- ATF distinctions:
  - High brightness electron beam, its manipulation and advanced diagnostics
  - Picoseconds terawatt CO2 laser and its diagnostics
  - Set of plasma sources and its diagnostics
- Large number of attendees
- 5 New proposals
- 3 PRL and 5 PRST published in 2006
- Requests from users for:
  - X band technology at ATF
  - Multiterawatt CO2 power
  - Better longitudinal beam diagnostic

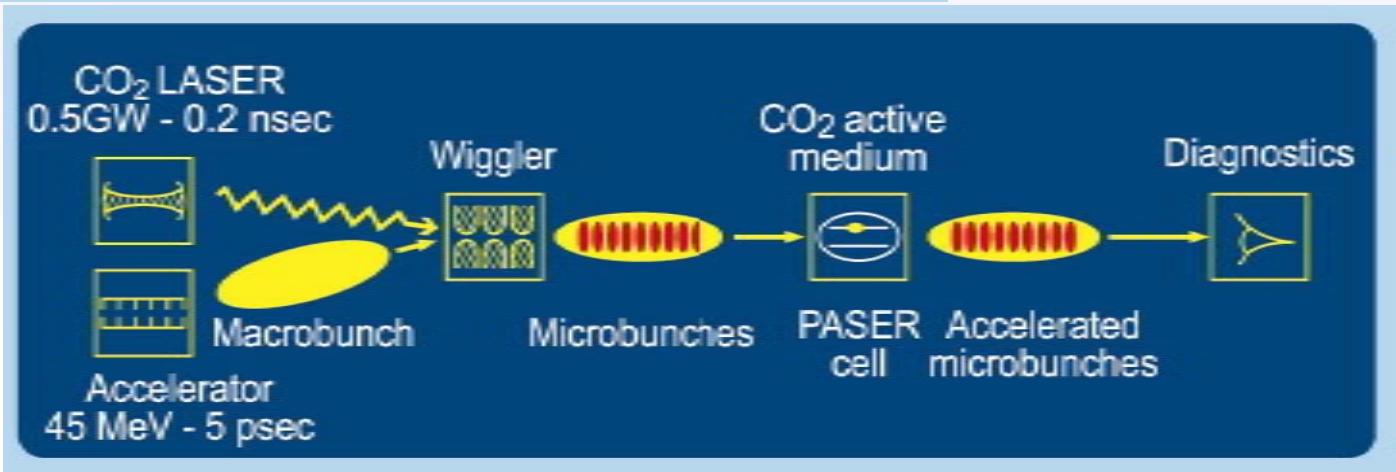
PASER, Phys. Rev. Lett. 97, (2006) (S. Banna et al.)

(New acceleration concepts)



2,000,000 collisions !!





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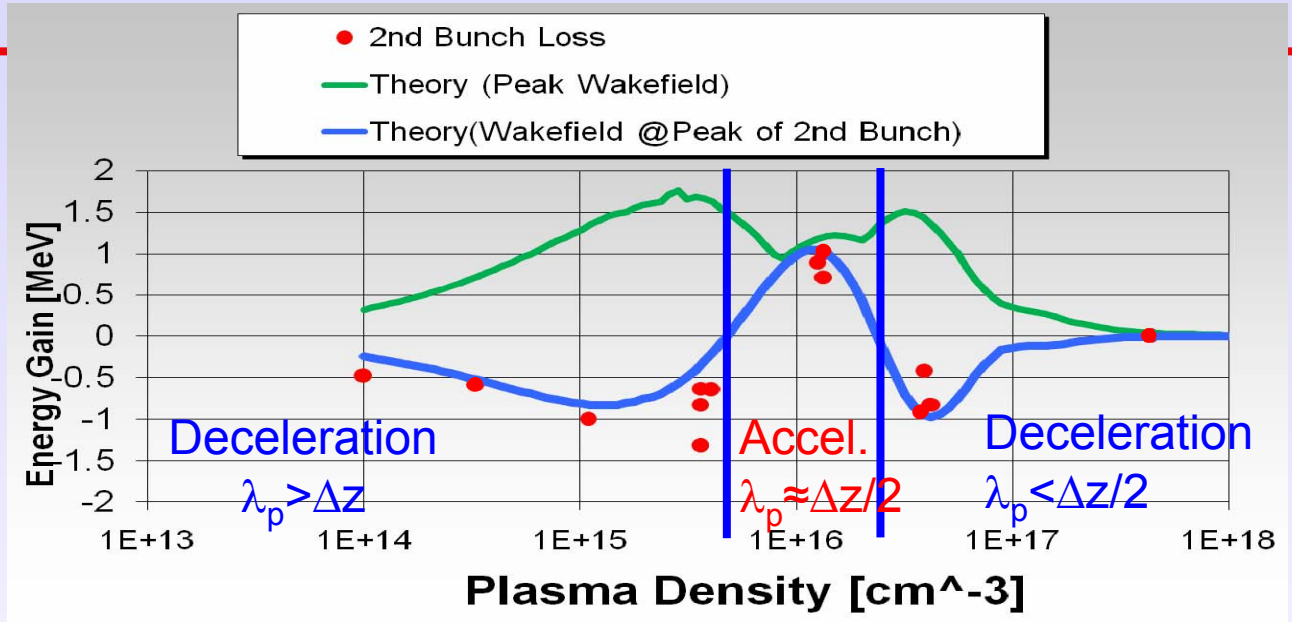
Two bunch Plasma Wake Field Acceleration (T. Kallos, et al.), *(New acceleration concepts)*



- Agreement with 2D model
- Maximum accelerating gradient (0.9+1.0)MeV/6mm=316MeV/m

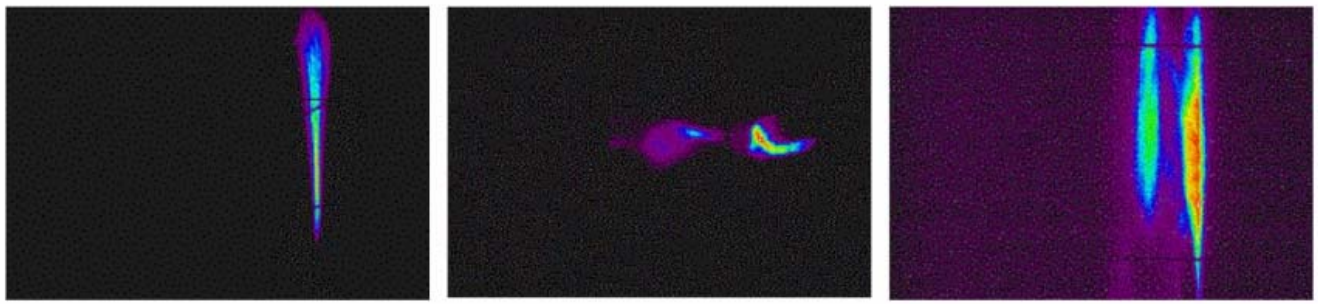
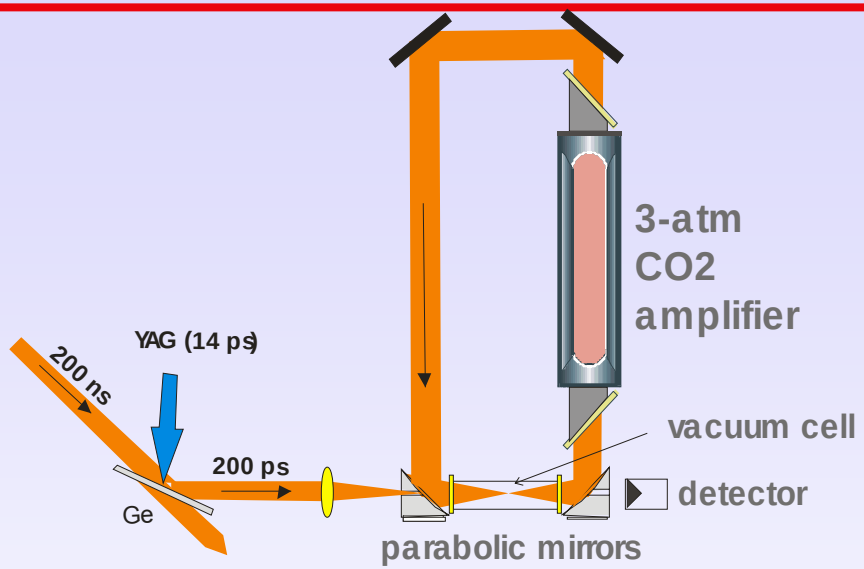
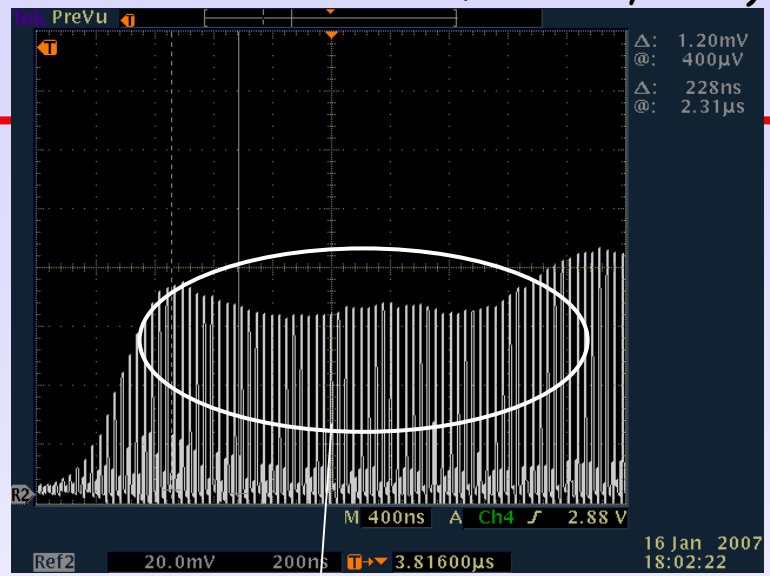


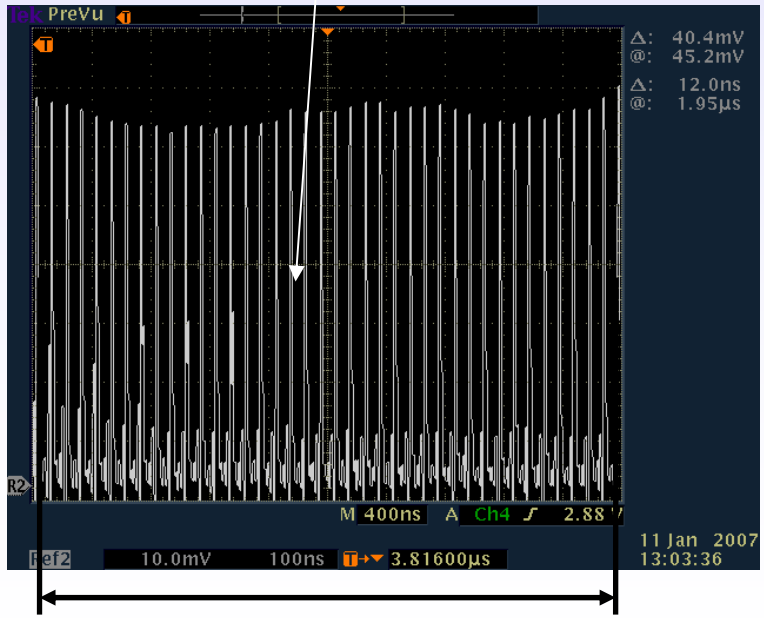
FIGURE 3. Raw energy spectrums of double-bunch *e*-beam. Energy dispersion increases to the left. (a) Before the chicane and without compression. Energy spread is ~4% FWHM. (b) At the high-energy slit located downstream of the chicane. (c) At the spectrometer at the end of the beamline.

Simplified CO2 cavity test (Polarized Positron Source for ILC, RIA)

(Sources and instrumentation)





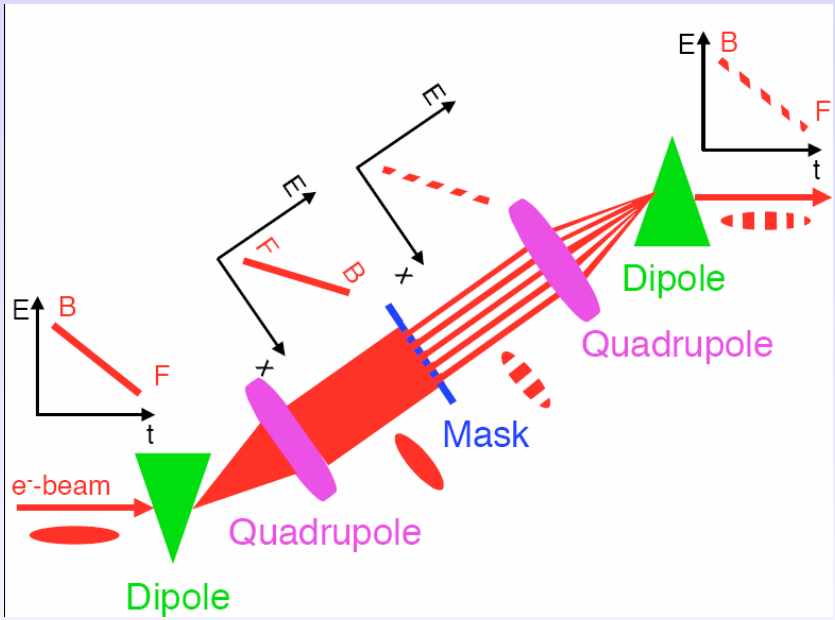


3% over 1 µs

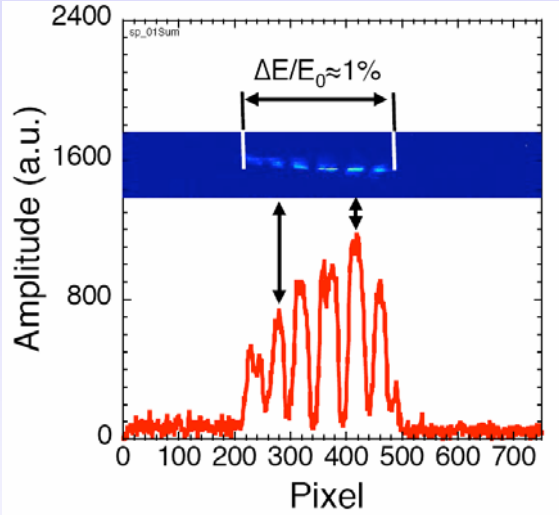
First observations:

- Optical gain over 4 µs
- Very encouraging results obtained with simplified cavity test setup: ~200 ps pulse of the order of 100 mJ circulated for >1 µs.
- Further test would require pulse length monitoring and high pressure or isotope mixture based amplifier (to sustain 5 ps beams).

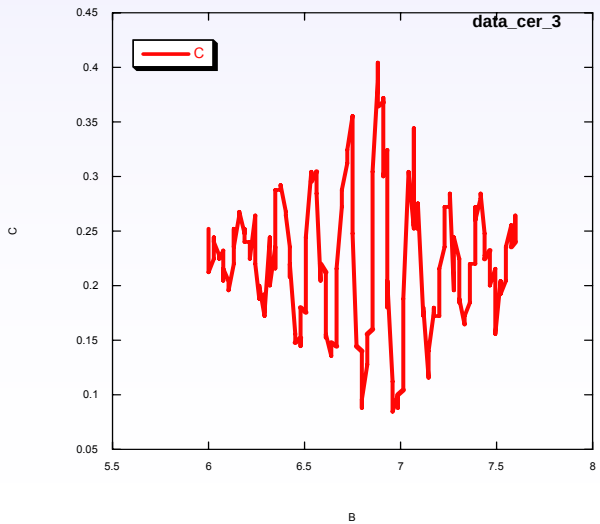
Micro bunch formation with wire mesh (P. Muggli et al.), *(Sources and instrumentation)*



End of the line energy spectrometer:



Interferometer data:



Wire mesh:

X-band installation timeline
(High gradient structures)

- Modulator construction (03/2007)
- Low level RF (4/2007)
- Klystron repair and delivery (4/2007)
- Klystron test (5/2007)
- Linac section installation (8/2007)

- Part of the US high gradient collaboration to test new structures with high brightness beam
- Plasma Wakefield Acceleration experiments and VISA would be the first experiments to benefit from this upgrade

ATF Conclusion

- Demand from user community is very strong
- This was a very productive year but difficult
- Multiple hardware upgrades were done to
  - improve reliability
  - simplify operations and protect components against operator error
  - allow for future upgrades
- 1 micron laser is being upgraded to new technology with new possibilities
- CO2 laser is on its way to multi terawatt level with reliable operations and adequate diagnostics
- Additional funding from HEP in FY07- FY08 allowed us to address the main issue: to improve support of linac operations