Consideration on LHC upgrade from A US perspective

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Disclaimers and Acknowledgments

- I am not currently directly involved in this program
  => I am not up to date on all topics
- I have no current official role in this area
  => I do not speak for LARP, US-CMS or US-ATLAS, DOE, …
  This is a personal view
- Nonetheless, I have discussed this topic with, and obtained material presented here from:
  Steve Peggs (US LARP Leader),
  Jim Kerby (LARP Magnet R&D Leader),
  Jim Freeman (US CMS),
  Abe Seiden (US ATLAS),
  Bruce Strauss (US DOE),
  Tom Ferbel (US DOE)
  => I believe the views presented here are reasonably well aligned with reality.

The LHC and the US HEP Program

The LHC is a central part of the US HEP Program:

- Major US collaboration on CMS and ATLAS and smaller collaborations on ALICE and LHC-b.
- Small but important US contribution to construction of the accelerator, mainly in the IRs.
- Developing US effort in support of machine commissioning.
- We expect to be strong collaborators with CERN and the world HEP community in the research program of the LHC and in its future upgrades that will expand that program.
- EPP-2010 recommended that LHC be the top priority of US HEP

=> We expect the US to play an important role in the R&D and eventual implementation of upgrades to the LHC and its experiments.

EPP 2010

Ordered Priorities

1. Exploit the opportunities offered by the LHC
2. Plan and initiate a comprehensive program to participate in the global effort to complete the necessary R&D to design and plan an international linear collider
3. Do what is necessary to mount an internationally compelling bid to build the international linear collider on U.S. soil
4. Seize the opportunities at the intersection of particle physics, astrophysics, and cosmology by coordinating and expanding domestic efforts
5. Pursue an internationally coordinated, staged program in the physics of neutrinos and proton decay
6. Pursue precision probes of physics beyond the Standard Model using available resources as a guide to overall level of effort while maintaining diversity

Upgrades to CMS and ATLAS

- We have just heard about the upgrade plans for ATLAS and CMS, so that they can deal with $\mathscr{L}$ -> 1×10^{35}.
- US groups are actively engaged in planning for these upgrades, starting with areas in which they have strength and where they have contributed to the initial construction.

US ATLAS R&D

- Rad-hard pixels using "3-D" detectors
- Short Si strips for inner tracker replacement using n-on-p technology
- New LAr front end electronics

USCMS R&D Activities

- Optical Links: Study next generation optical links. Important for new tracker. Joint project with CMS/ATLAS
- HCAL: Replacements for high eta HE region. Collaboration with RDMS
- EMU: Studies of EMU Trigger functionality at SLHC lumi.
- Pixel: Starting to think through Pixel Replacement, Pixel Trigger. First Workshop Oct 10-12, 2006 at FNAL.
- SiTrk: New materials for tracker (RD50). Power and cooling budgets. Connectivity.
- Trigger/DAQ: Upgrade studies for higher frequency operation

US Strategy for Detector Upgrades

- R&D for upgrades is an approved part of the US LHC M&O programs for each experiment.
- Current R&D funding ~$2-3M/year per experiment, growing with time.
- Construction of upgrades would be a separate project, with separate budget, which would be considered and approved at the appropriate time.
- Anticipate that the US contributions to the upgrades would be commensurate with the US role in each experiment, but the actual level awaits a detailed plan, and is several years off.

LHC Machine Upgrades

- US interest has focused mainly on the LHC itself, and mainly on the IRs. See talks by:

G.Sabbi	Development of Nb3Sn model quadrupoles
T.Sen	Nb3Sn large aperture large gradient
	US dipole first optics
R.Gupta	Open midplane dipoles & crab cavity quadrupoles
N.Mokhov	Handling collision debris in quad. & dipole first options
P.Limon	Integrability of Q0 in experiments
W.Fischer	Long-range beam-beam compensation test at RHIC
R.Calaga	Crab cavities
V.Shiltsev	Head-on compensation with e-lenses

- Also paying attention to other aspects, e.g. intensity limitations and injector upgrade, offering ideas and expertise, but no significant R&D at the moment. See talks by:

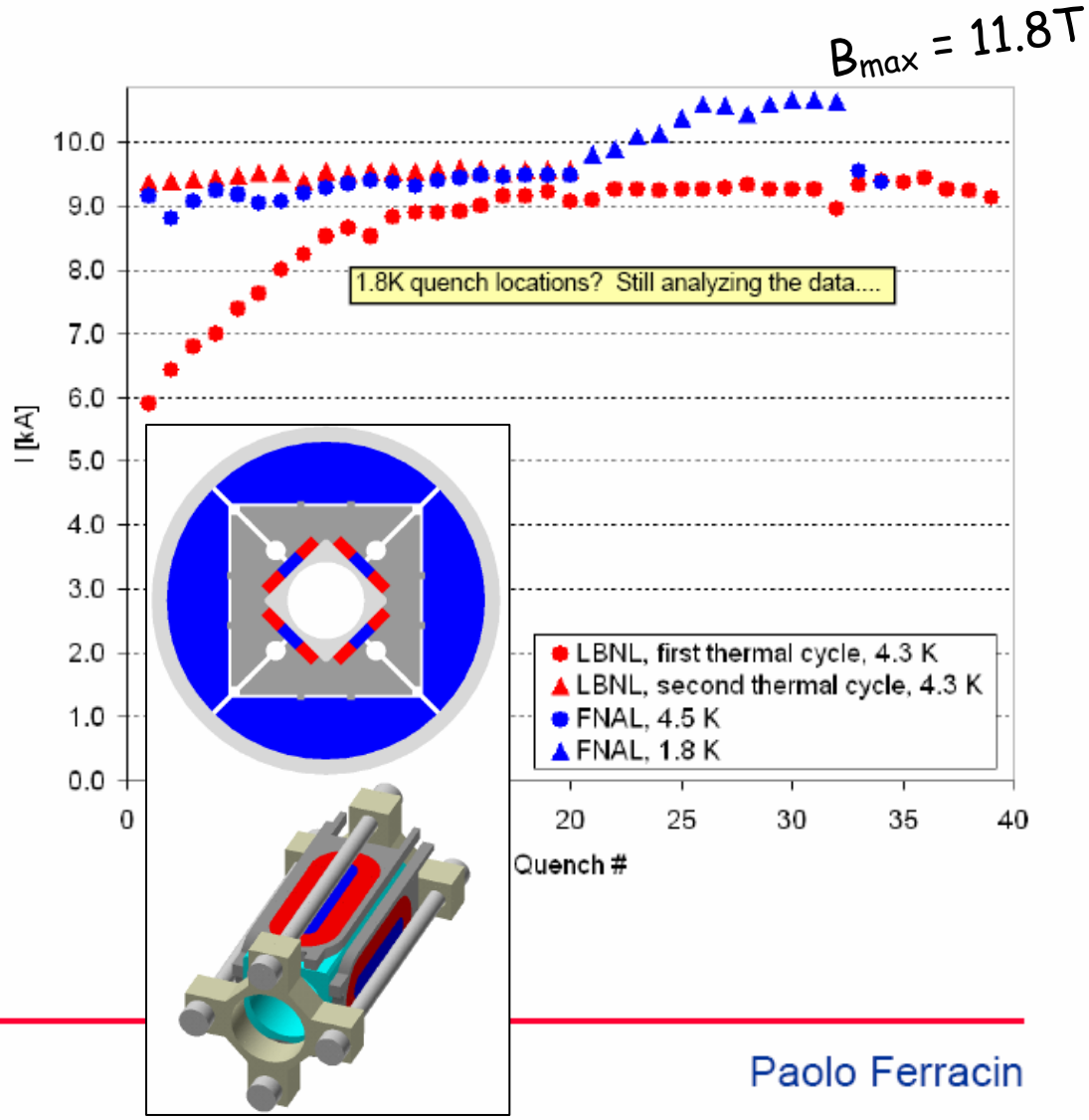
V.Shiltsev	Experience with Tevatron feedback in coast
M.Furman	e-cloud in PS2, PS+, SPS+
V. Shiltsev	Summary of LER injector workshop

IR Upgrades – Main US Focus

- Main effort is development of Nb_3Sn quadrupoles to permit:
  - Larger aperture at same or larger distance from IP
  - Higher gradient if quads are pushed closer to IP.
- Objective: Demonstrate by 2009 that Nb_3Sn magnets are a viable choice for an LHC IR upgrade.
- Success is not guaranteed, but Nb_3Sn offers promise of substantially higher performance than NbTi, and it is therefore worth investing in the R&D.
- Vigorous program in US on several fronts:
  - Conductor R&D
  - "Sub-scale" quadrupole models
  - 2-layer, 90 mm aperture cos2θ models
  - Long coil tests, up to 4 m
  - Design studies for 90 mm quads with G > 300 T/m (or 250 T/m with aperture $\geq$ 100 mm)
- Recent results are encouraging.

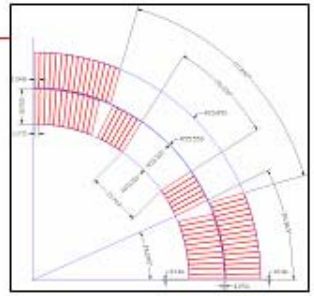
SQ02b test results
Conductor and magnet performance

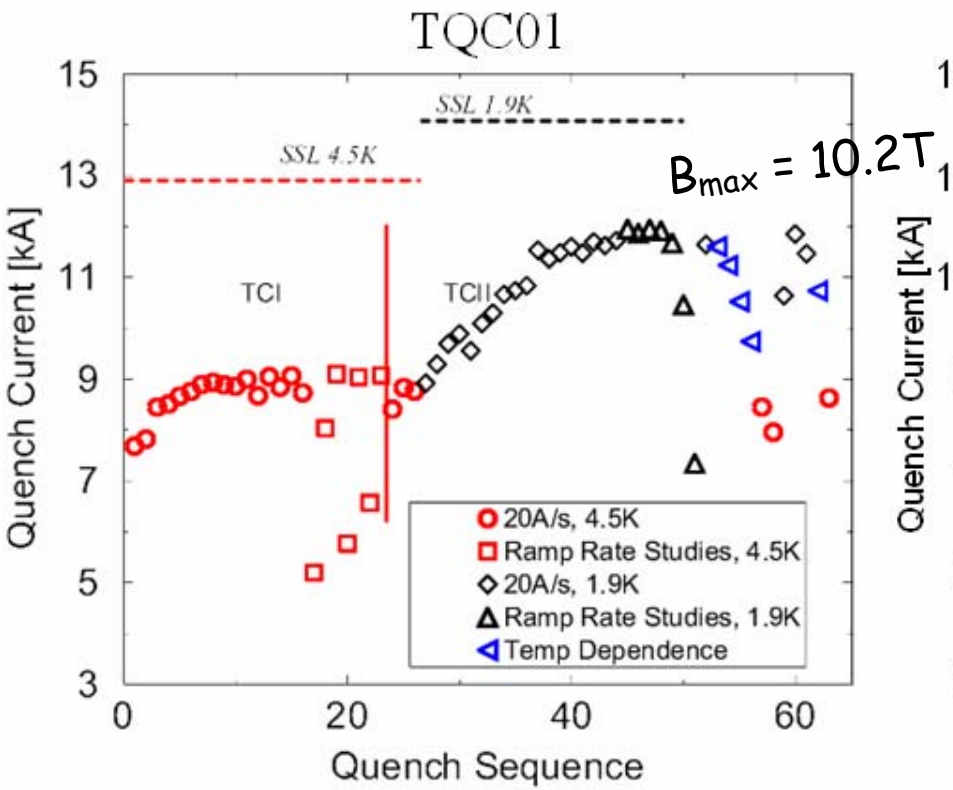
- 4.5 K
  - 1st quench
    - 9.1 kA (93 % I_{ss})
  - Highest quench
    - 9.5 kA (97 % I_{ss})
  - Similar as second thermal cycle at LBNL
- 1.8 K
  - 1st quench
    - 9.8 kA (90 % I_{ss})
  - Highest quench
    - 10.6 kA (98 % I_{ss})

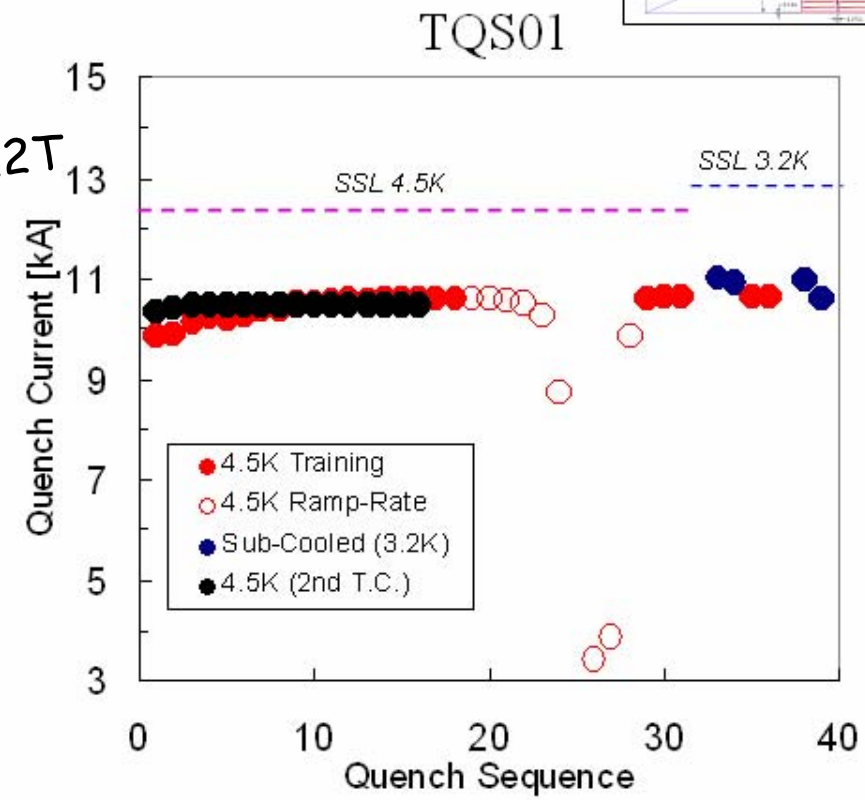


TQS01 and TQC01 Quench Performance

"Conventional" design 90 mm quad.







- Both magnets achieved gradients close to 200 T/m (TQ objective)

Ref: G.Sabbi via J.Kerby

Nb_3Sn R&D

- Main R&D is done as part of US LARP, but with support from the US "core" program"
  - FNAL dipole R&D focused on coil length studies
  - DOE-funded conductor R&D program

- Nb_3Sn technology is not yet proven for LHC upgrades, and its demonstration by 2009 is not guaranteed.
  => Alternatives using NbTi must also be explored. See talks by:

T. Taylor	NbTi pushed
O. Brüning & R.De Maria	Low-gradient triplet magnets

- However, potential advantages of Nb_3Sn are sufficiently great and progress is sufficiently good that we are convinced it needs to be pursued, and we are committed to its development.

Future Plans

- LARP funding expected to continue at ~$12M/year through 2012, with about half devoted to LHC upgrades.
- LARP supports only the R&D towards upgrades, but not construction.
- Construction of equipment for LHC upgrades would be a separate project.
- Anticipate that the US will play an important role in implementing LHC luminosity upgrades, but decisions about the scope of US involvement will be made only when the overall upgrade plans are fully developed.

Conclusions

- The LHC program, including its future upgrades, is a high-priority component of the US HEP program.
- We are committed to participation in the R&D towards upgrades of the experiments (ATLAS and CMS) and of the LHC accelerator.
- Decisions regarding the scope of US participation in the upgrade projects will be made later, when the scope and plans of the upgrades are established, but we anticipate being significant partners in these projects.