US-CERN Cooperation From the Main Ring to Hi-Lumi

Bruce Strauss

Fermilab

October 15, 2019

Cooperation in the Bob Wilson era

- Main Ring Magnet Lamination Stacking and Compression fixture to CERN for SPS Magnets.
- Roy Billinge and Bob Sheldon go to CERN to head up magnet fabrication group for SPS
  - On the average Fermilab livers see improvement
  - Wilson wants CERN head chef in return
  - Frogs legs on Fermilab lunch menu
  - American Comfort Food prevails

Tevatron contributions

- Design of cos θ
- Scale
  - 90% of world wide superconductor to date.
  - Paul J. Reardon: “We’ll buy four.”
  - Industrial development and procurement
- Production
  - Production travelers
  - In process testing
- Installation

Lessons from the SSC

- 10 pounds of budget in a 5 pound sack.
- Cost estimating assumptions and execution.
- Technology transfer.
  - Technology not resolved in transfer from LBNL to Texas
- Micro management imposed by Federal Agencies
- Carlo Rubbia
  - ‘It’s cheaper at CERN’


WE HAVE MET THE ENEMY AND HE IS US.

Lehman review at CERN circa 1996

- Hero with the Swiss plug adapter
- Bob Diebold—Micro Fireball
- High committee approval
  - Set design
  - Industrial Technology Transfer for Magnets
    - Multiple companies
      - Electrical Machinery Industry
    - Quotes
  - “It’s CERN”

Joined DOE in April 1997

- Signing of US-CERN Agreement
  - “We don’t understand American Lawyers.”
    - Christopher Llewelllyn-Smith
  - “We don’t understand American Lawyers either.”
    - Federico Peňa
- Signing of the USDOE/USNSF Agreement
  - Much harder!

US Contributions to the LHC

- Separation Dipoles
- Quadrupoles
- Collimators/Absorbers
- Instrumentation
- Feed boxes

Quadrupoles


Batavia to Geneva
ILLINOIS
SWITZERLAND
7105 km / 4415 mi


Batavia to Geneva

Challenges with the quads

- Humped!
- “Come up to my office now!”

Feedboxes


MEYER
MEYER TOOL & MANUFACTURING, INC
OAK LAWN, IL USA
LAWRENCE BERKELEY NATIONAL LAB
BERKELEY, CA USA
DFBX DISTRIBUTION BOX


SURVEY
MEYER
LAWRENCE BERKELEY NATIONAL LAB
BERKELEY, CA USA
DFBX DISTRIBUTION BOX

Commissioning the LLHC

- Jim Strait
- Jim Kerby
- Peter Limon
- Sandor Feher

Personal Remembrances

- “Vendors Lie”
- “Lucio’s Driving”
- “Valentine’s Day”
- “Yogi Berra”—“It ain’t over till its over.”
- “Angels and Demons Plane”
- “Come to my office now”
- The automatic welding machine—Lyn Evans

Angels and Demons?

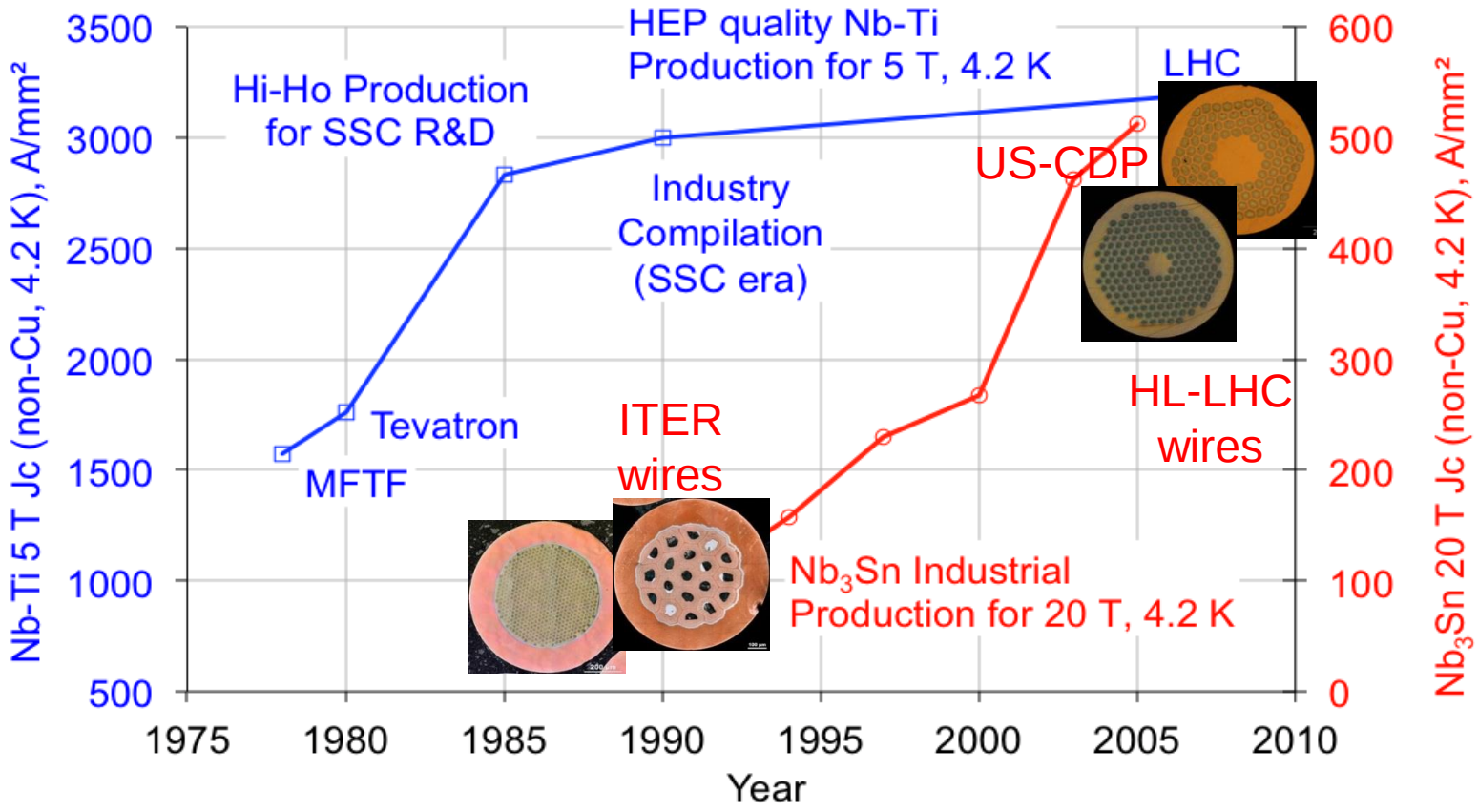
- CERN's very own X-33 space plane!

After the LHC / LARP to Present

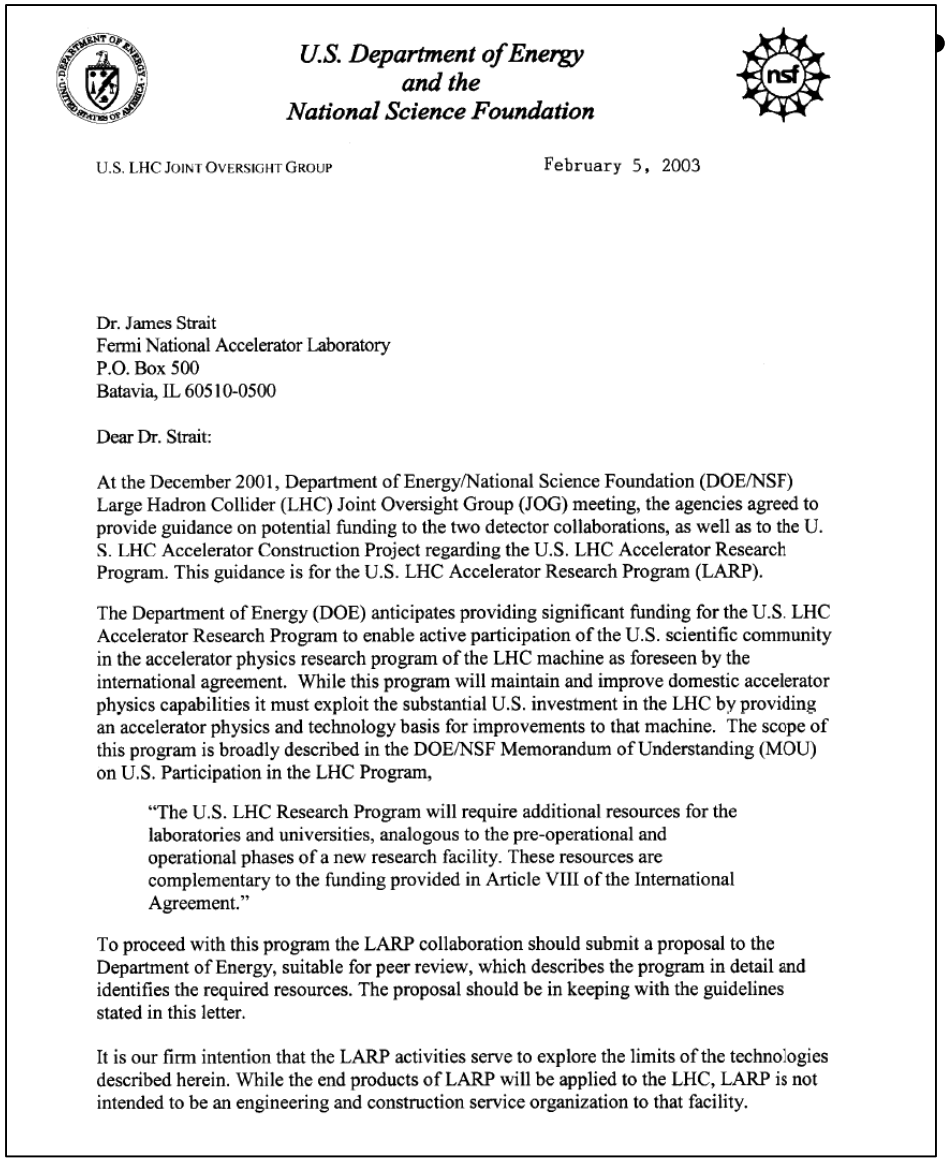
- Nb_3SnConductor development
- Magnet development
- Crab Cavities
- Instrumentation

CDP (Conductor Development Program) NbTi vs Nb_3Sn

- A Magnet can never perform better than the conductor it's made of



Origins of LARP (I): a "First" in HEP Accelerators



U.S. Department of Energy and the National Science Foundation

U.S. LHC JOINT OVERSIGHT GROUP

February 5, 2003

Dr. James Strait
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, IL 60510-0500

Dear Dr. Strait:

At the December 2001, Department of Energy/National Science Foundation (DOE/NSF) Large Hadron Collider (LHC) Joint Oversight Group (JOG) meeting, the agencies agreed to provide guidance on potential funding to the two detector collaborations, as well as to the U. S. LHC Accelerator Construction Project regarding the U.S. LHC Accelerator Research Program. This guidance is for the U.S. LHC Accelerator Research Program (LARP).

The Department of Energy (DOE) anticipates providing significant funding for the U.S. LHC Accelerator Research Program to enable active participation of the U.S. scientific community in the accelerator physics research program of the LHC machine as foreseen by the international agreement. While this program will maintain and improve domestic accelerator physics capabilities it must exploit the substantial U.S. investment in the LHC by providing an accelerator physics and technology basis for improvements to that machine. The scope of this program is broadly described in the DOE/NSF Memorandum of Understanding (MOU) on U.S. Participation in the LHC Program,

> "The U.S. LHC Research Program will require additional resources for the laboratories and universities, analogous to the pre-operational and operational phases of a new research facility. These resources are complementary to the funding provided in Article VIII of the International Agreement."

To proceed with this program the LARP collaboration should submit a proposal to the Department of Energy, suitable for peer review, which describes the program in detail and identifies the required resources. The proposal should be in keeping with the guidelines stated in this letter.

It is our firm intention that the LARP activities serve to explore the limits of the technologies described herein. While the end products of LARP will be applied to the LHC, LARP is not intended to be an engineering and construction service organization to that facility.

- DOE guidance for LARP received on February, 2003
  - NSF/DOE supported
  - Follow in the foot-prints of HEP Experimental Physics endeavors:
    - Enable US scientists to maintain and expand world-wide technological leadership in accelerator physics and superconducting magnets
  - LARP goal to increase physics productivity by:
    - Commissioning of Triplets
    - Advanced beam Diagnostic
    - Simulation Studies

Origins of LARP(III): the Proposal

The U.S. LHC Accelerator Research Program:

A Proposal

R. Kephart, M.J. Lamm, P. Limon, J. Marriner, T. Sen, J. Strait, A.V. Zlobin
Fermi National Accelerator Laboratory
Batavia, IL 60510

P. Cameron, A. Drees, W. Fischer, R. Gupta, M. Harrison, F. Pilat, S. Peggs
Brookhaven National Laboratory
Upton, NY 11973

W. Barletta, J. Byrd, P. Denes, M. Furman, S. Gourlay, A. Ratti, W. Turner
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

J. Strait
Interim Director

S. Peggs
Director 2004-2008

E. Prebys
Director 2008-2013

- LARP Will Advance High-Energy Physics
  - LHC Commissioning
  - LHC performance improvement through novel instrumentation
  - Extend LHC as a frontier high-energy physics instrument with a timely luminosity upgrade.
- LARP Will Advance U.S. Accelerator Science & Technology
  - Conduct forefront accelerator physics research and development.
  - Advance US national capabilities
- LARP Will Advance International Cooperation

Operative Concepts: *Funding Agency Mandate* hinged on *National Leadership R&D*

CERN-LARP Interactions

- Very tight and frequent interactions between CERN and LARP to define viable and important R&D venues for LHC.
- Continued acknowledgments by CERN Management on value of LARP activities

Letter to Dennis Kovar, Head Office of DOE
Office of High Energy Physics, 17-August-2010

Dear Dennis,

We are writing to express our support for the US LHC Accelerator Research Program (LARP) and to clarify the relevance and priority of some of the activities within this program with respect to the current CERN upgrade plans.

First and foremost, we are relying primarily on LARP to establish Nb_3Sn as a viable technology for use in the high luminosity upgrade of the LHC (HL-LHC), currently scheduled to be implemented in 2020 or 2021. LARP's Nb_3Sn program has had some impressive achievements over the last few years, but there are still several key demonstrations which are needed to provide the confidence necessary to proceed with the design and production of the focusing quadrupoles to be used in the LHC. LARP is working closely with CERN to establish a set of milestones which must be met, and it is vital that LARP have sufficient resources to meet these milestones.

In addition to the magnet program, two LARP activities which are closely linked to the CERN schedule are the crab cavity effort and the rotatable collimator development. Following the 9th crab cavity workshop in the fall

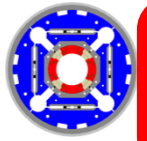
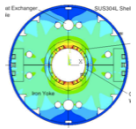
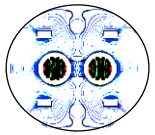
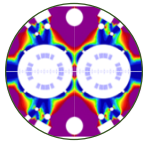
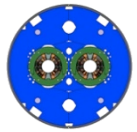
(...)

Prof. Rolf Heuer
Director-General

Dr. Steve Myers
Director for Accelerators

Magnet System Development

- HL-LHC Main Magnet Needs

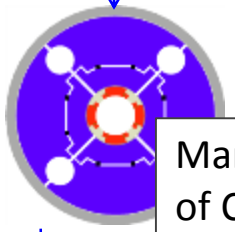






	Type	Material	Field/Gradient (T)/(T/m)	Aperture (mm)	Length (m)
Q1,Q3 Q2	Single aperture	Nb_3Sn	(11.4) 133	150	8.4 7.3
D1	Single aperture	Nb-Ti	5.2	150	6.7
D2	Twin aperture	Nb-Ti	3.5…5.0	95…105	7…10
Q4	Twin aperture	Nb-Ti	(5.9) 90	120	4.2
DS 11T	Twin aperture	Nb_3Sn	10.8	60	11

Development History (LARP)

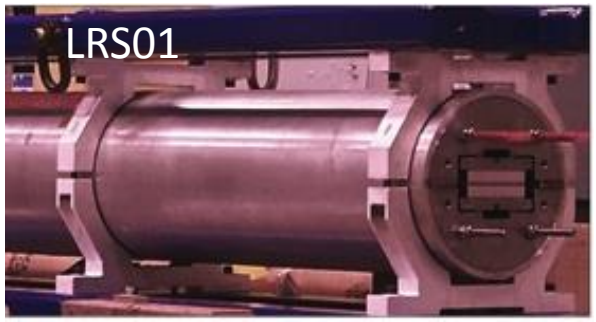
Subscale Quad. SQ
0.3 m long
110 mm bore
2004-2006

Technology Quadrupole TQS - TQC
1 m long
90 mm bore
2006-2010

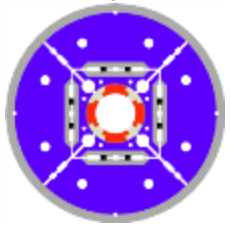


Manufacturing & Reproducibility of Cos2θ Coils, Mech. Structure

Long Racetrack LRS
3.6 m long
No bore
2006-2008

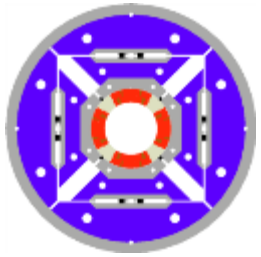


Long Quadrupole LQS
3.7 m long
90 mm bore
2007-2012



First (and only) length scale up

High Field Quadrupole HQ
1 m long
120 mm bore
2008-2014



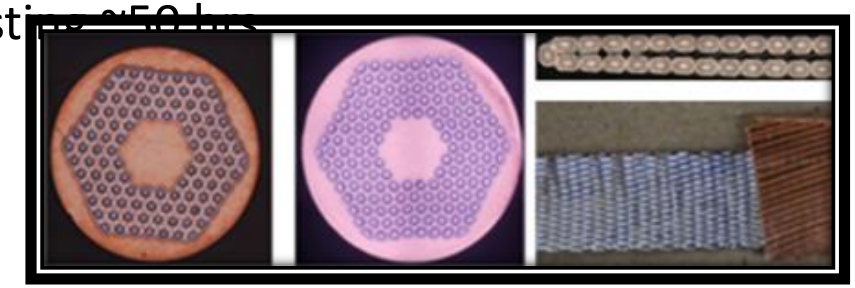
Aperture increase, Acc. Quality

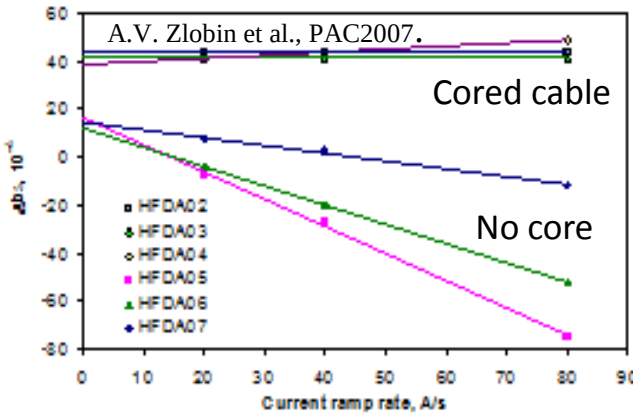
It Takes a Village !

Synergies between Core HFM program (GARD) and LARP

- Hard to give enough credit to the constructive “antagonism” that brought to the solution and control of accelerator-quality magnet problems such as SC instabilities, mechanical structure, coil fabrication techniques, etc. …. contributed by GARD to LARP

- Magnet Technology
  - W&R approach with reaction at ~650C lasting ~50 hrs
  - SC Strand Development – RRP108/127 and RRP150/169
  - Cable – 0.025 mm stainless steel core
  - cable insulation – ceramic, S2 or E-glass
  - coil end parts – water-jet/laser-sintering
  - coil curing – ceramic binder at ~150C
  - coil radial and azimuthal expansion gaps
  - coil impregnation – CTD101K
  - coil size control – CMM



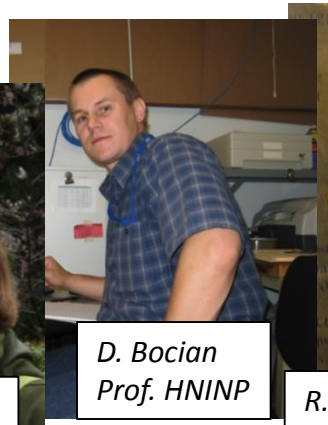


CERN Visitor Program and Toohig Fellowships

- Several Long Term Visito
  contributed to LHC
  Commissioning activities
  early LARP period
  - Among others:
    - Uli Wienands (SLAC)
    - Chandra Bhatt(FNAL)
    - Rama Calaga (former To
    - Eliana Gianfelice-Wendt
  - Program reduced in rec
    under budget constraints
- Extremely successful Fello
  program – Toohig Fellowsh
  with several young Accele
  Scientist providing vital
  contributions to the LHC and field
  in general


R. Calaga – CERN


H. Felice – Saclay


D. Bocian
Prof. HNINP


R. DeMaria –CERN

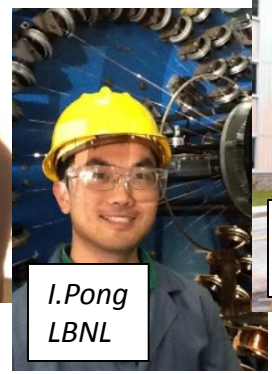

R. Miyamoto – ESS


T. Mastoridis
Prof. CPU


V. Previtali
Teacher, Geneve


S. White – ESRF


J.Cesaratto
Phillips


I.Pong
LBNL


S. Verdu
BNL

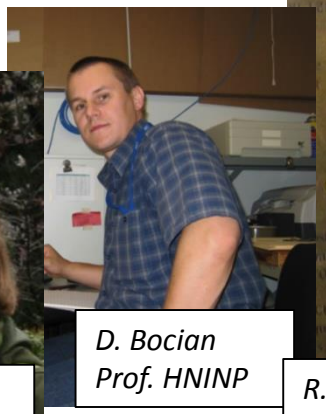

T. Helik
U. Texas

CERN Visitor Program and Toohig Fellowships

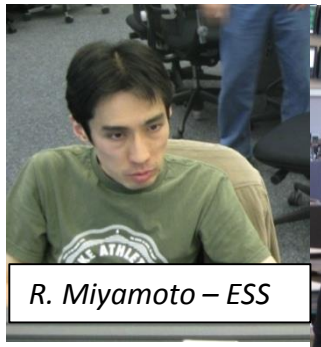
- Several Long Term Visitors contributed to LHC Commissioning activities in early early LARP period
  - Among others:
    - Uli Wienands (SLAC)
    - Chandra Bhatt(FNAL)
    - Rama Calaga (former Toohig Fellow)
    - Eliana Gianfelice-Wendt
  - Program reduced in recent years under budget constraints
- Extremely successful Fellowship program – Toohig Fellowship - with several young Accelerator Scientist providing vital contributions to the LHC and field in general


R. Calaga – CERN

H. Felice – Saclay


D. Bocian
Prof. HNINP


R. DeMaria –CERN


R. Miyamoto – ESS


T. Mastoridis
Prof. CPU

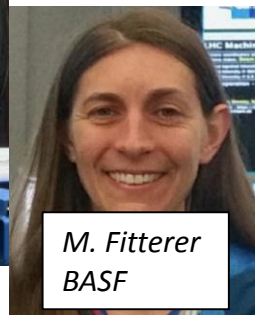

V. Previtali
Teacher, Geneve


S. White – ESRF


J.Cesaratto
Phillips


I.Pong
LBNL


S. Verdu
BNL


M. Fitterer
BASF


T. Helik
U. Texas


E. Ravaioli
CERN


V. Marinozzi
FNAL