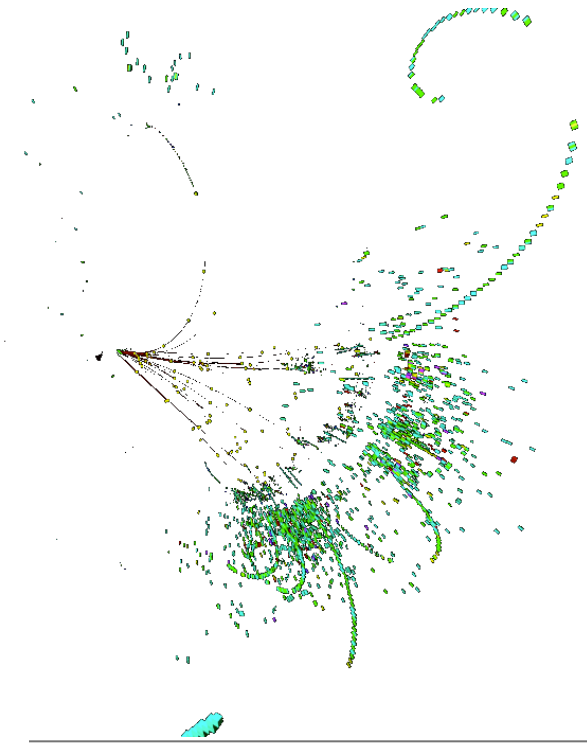
Detector R&D Workshop

Report and Plans



March 17, 2011

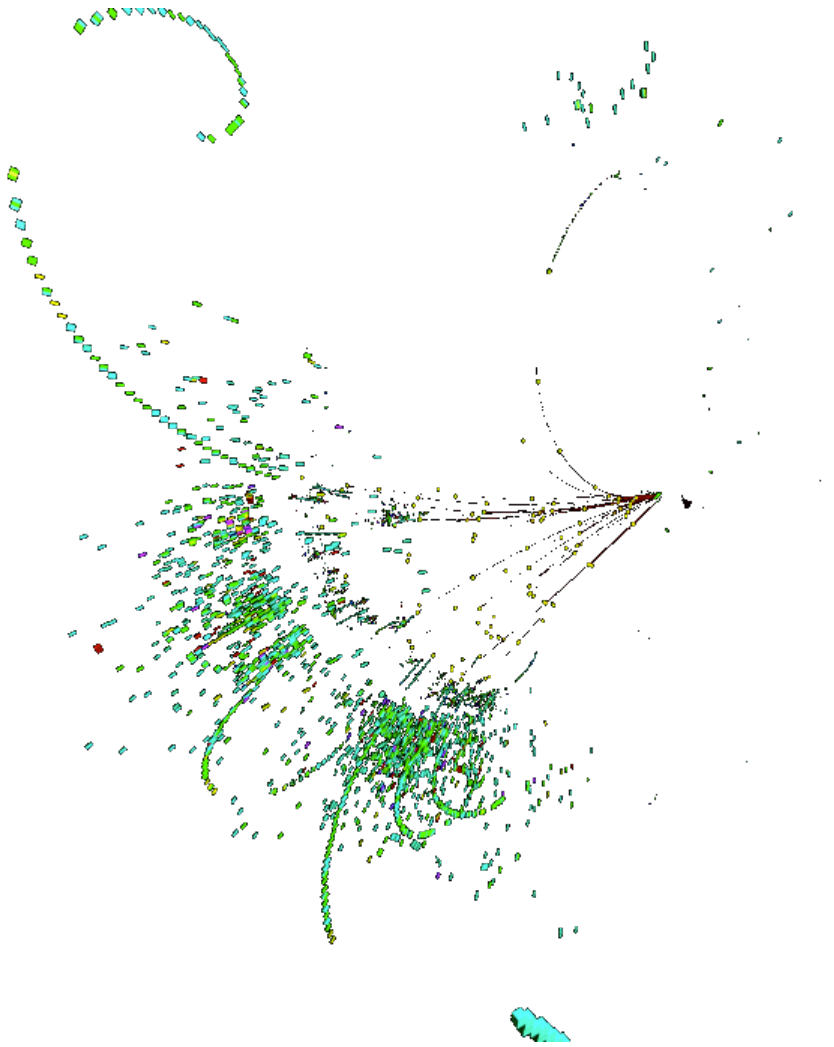
Chip Brock
Michigan State University

Marcel Demarteau
Argonne National Laboratory

HEPAP Meeting
Washington DC, March 17-18, 2011

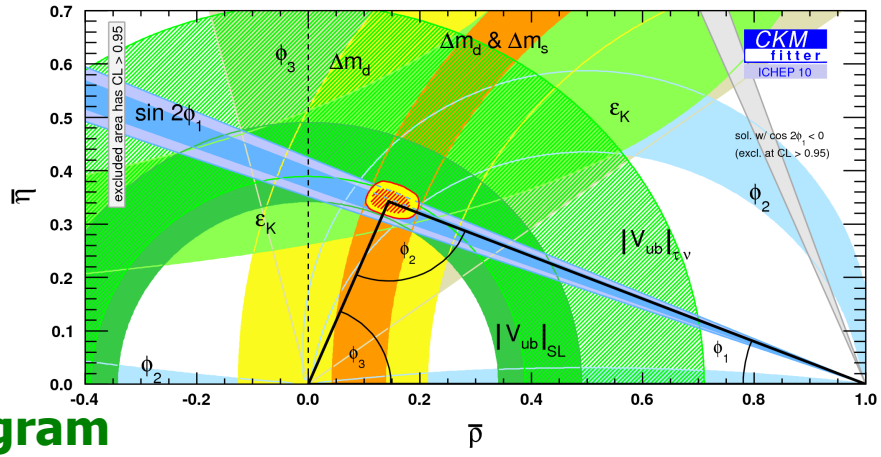
Outline

- Science Enablers
- Experimental Challenges
- History of Workshop
- Detector R&D Workshop
  - Four types of presentations
- Next steps: DPF Task Force



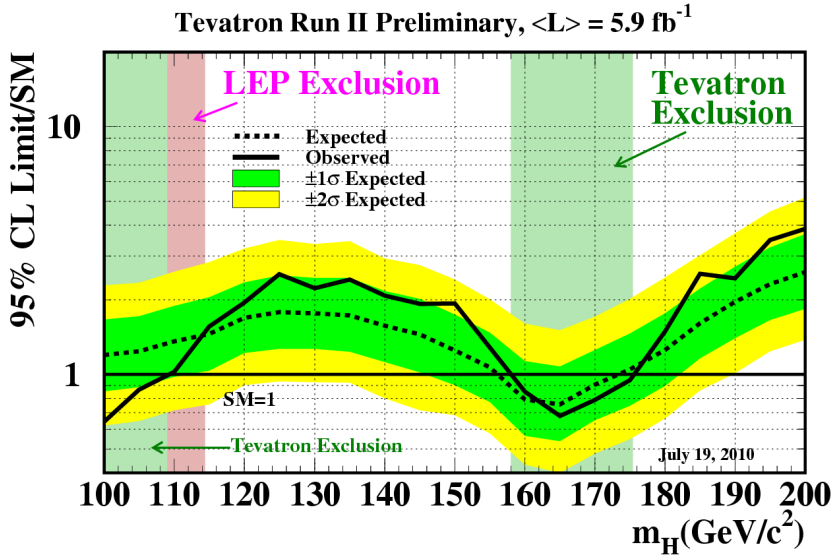
Science Enablers

- **New technologies are science enablers; example silicon detectors**
  - **Charm physics 80-90's**
  - **R_b at LEP / SLC**
  - **Top Quark discovery: 1995**
  - **B_s Oscillations: 2006**
  - **Σ_b and Ω_b discoveries**
  - **Single Top discovery: 2009**
  - **BaBar and BELLE b-physics program**
  - **Higgs (if found)**



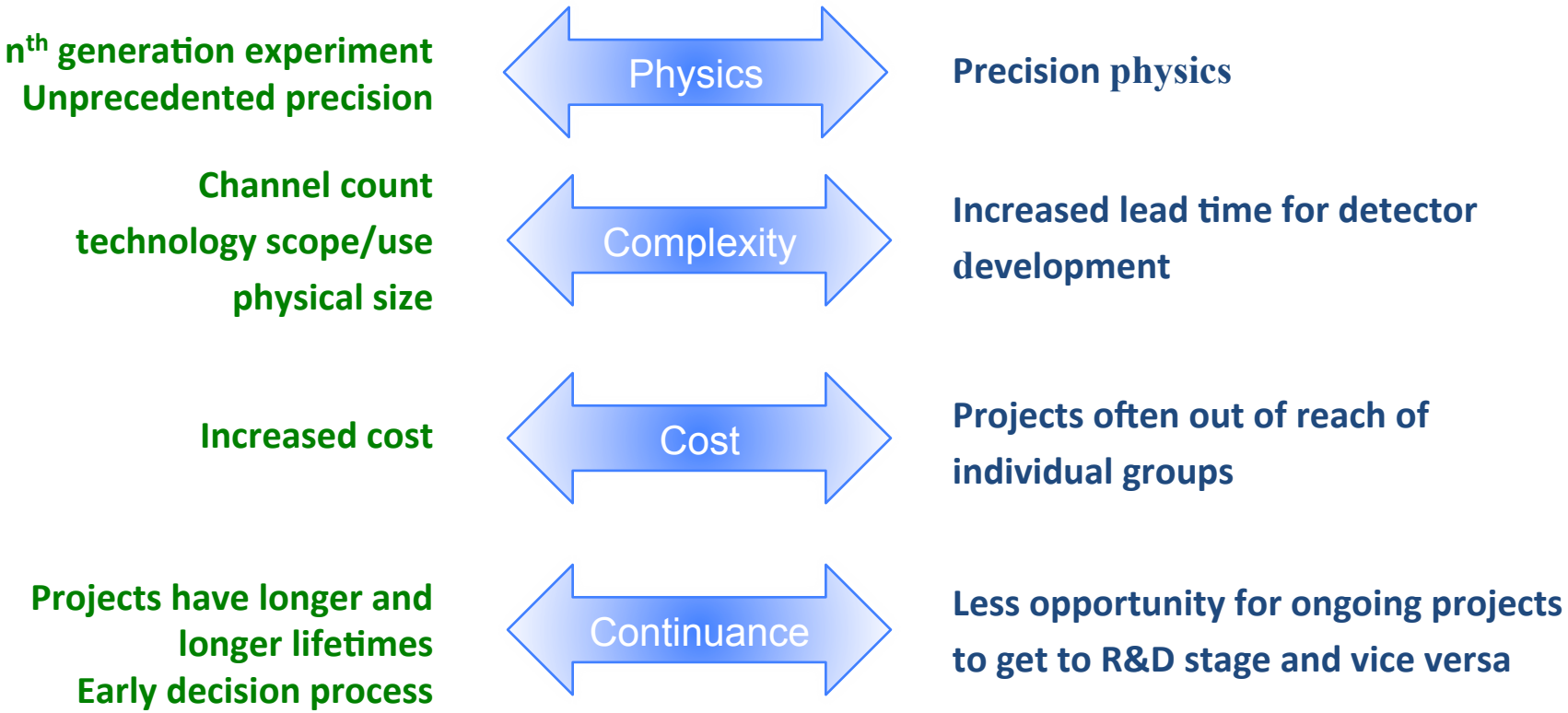
- **Many measurements would not have been possible without silicon detectors**

- **There was – and there is – no alternative**



Experimental Challenges

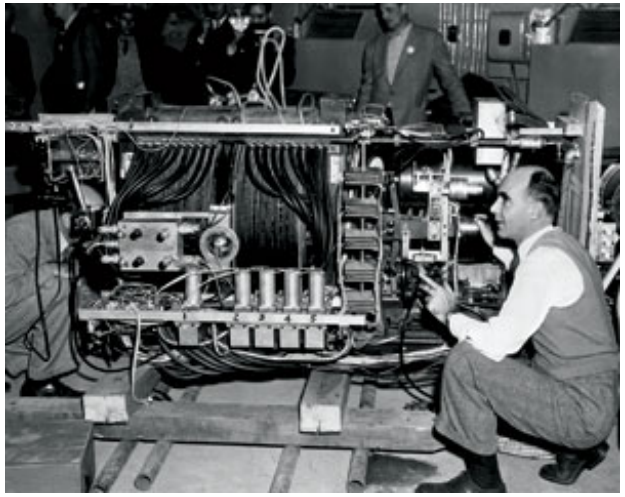
- **The next generation of detectors are extremely challenging**



- **Often, a scaling of existing technologies is difficult to justify for future experiments**

Experiments Then

- **Discovery of antimatter (1932)**

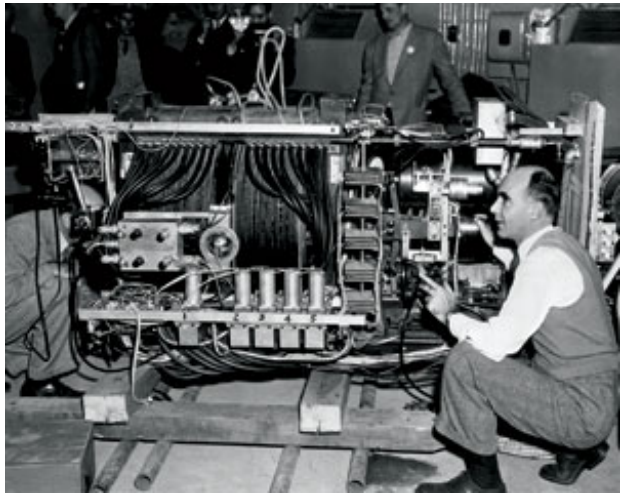


Experiment

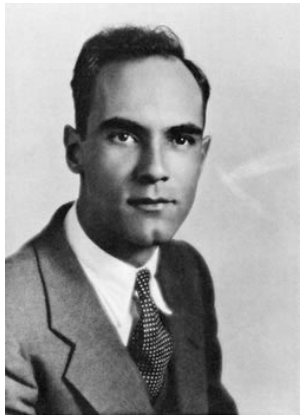
Experimental Group

Experiments Then and Now

- **Discovery of antimatter (1932)**

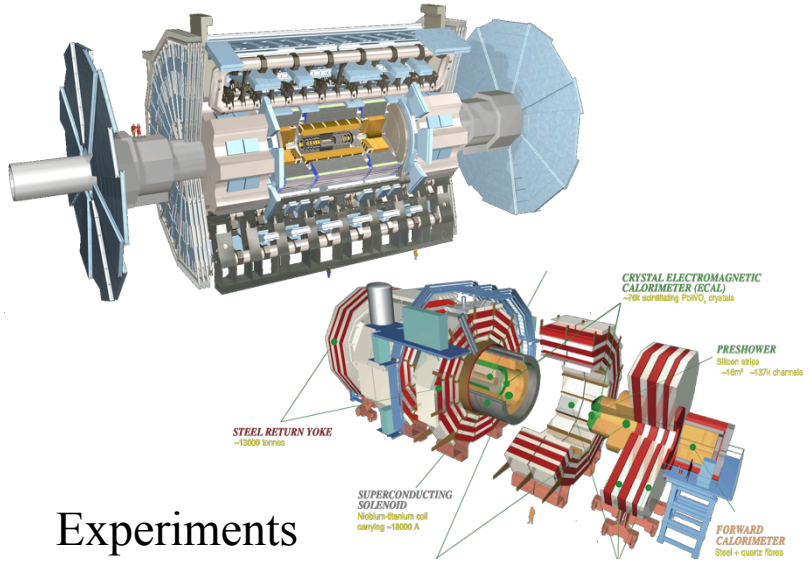


Experiment

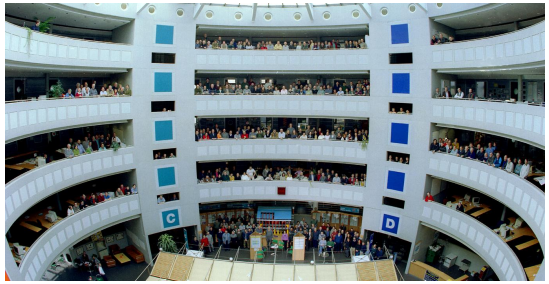


Experimental Group

- **Discovery of the Higgs (20??)**



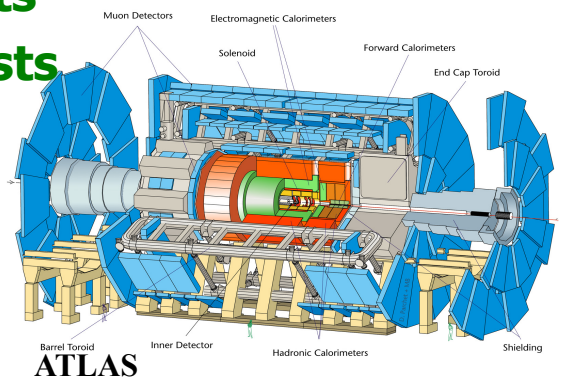
Experiments



1/4th of Experimental Groups

Status Quo

- The complexity, cost, construction and running time of current generation of experiments has evolved significantly over the last two decades
- This evolution of the field is believed to possibly have led to:
  - Too small an investment in the development of new instrumentation to adequately address the future scientific questions
  - Insulation from new developments in other fields such as materials science
  - Insulation from instrumentation advances and innovations in industry
  - Difficulties in retaining and training of experienced technical personnel
  - Descoping of scientific reach of future projects
  - Erosion of hardware skills of younger physicists
  - Erosion of infrastructure at universities and laboratories
  - ...



History of the Workshop

- **Future research in High Energy Physics requires an enabling instrumentation program to pursue research at the energy, intensity, and cosmic frontiers**

- **The DOE program officer for detector R&D at that time, Dr. Howard Nicholson, initiated a review of the detector R&D programs at the national laboratories on July 8-10, 2009**
  - **Argonne, Brookhaven, Fermilab, LBL, SLAC**

Committee members:

- **National**
  - **Steve Ahlen (BU)**
  - **Katsushi Arisaka (UCLA)**
  - **Joe Incandela (UCSB)**
  - **Roger Rusack (Minn.)**
  - **Ian Shipsey Purdue**
  - **Bob Svoboda UC Davis**
  - **Rick Van Berg (Penn)**
  - **Andy White (UTA)**
- **International**
  - **Marcello Giorgi (Pisa)**
  - **Yannis Karyotakis (LAPP Annecy)**

Charge of the Review

- **The reviewers were asked to assess:**
  - **The quality of the recent scientific performance of the lab groups**
  - **The merit and feasibility of their proposed activities for achieving the scientific goals and milestones of the field**
  - **The relevance of their detector R&D efforts to the overall HEP mission**

- **An evaluation was asked for along the following programmatic thrust lines:**
  - **Sensor Development**
  - **Detector System Development**
  - **Data acquisition system development, including triggering, front-end electronics and online computing**

- **In addition, the reviewers were asked to comment on:**
  - **The size and scope of the current core detector R&D efforts at each lab**
  - **The breadth of support for detector development that the laboratories provide to the entire HEP community**

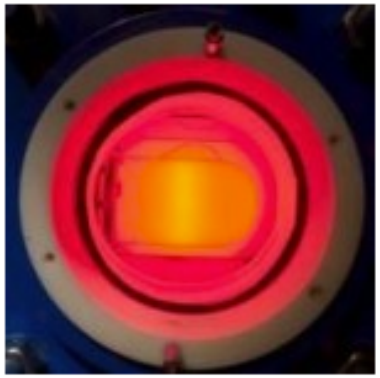
Review Briefing

- **Each lab was individually briefed during the fall of 2009 on the committee's evaluation of the detector R&D program of each lab**

- **The report of the committee was not available but the following observations across the labs were made:**
  - **R&D program at the labs is more or less following P5 recommendation**
  - **Some duplication of effort between the labs was observed**
  - **Significant leveraging observed at multi-disciplinary labs**
  - **More coherence and collaboration between the labs is encouraged**
  - **More collaboration between universities and labs encouraged**
  - **Community needs an organized set of visible goals, endorsed by the field, that can be judged by the community**
  - **Explore possibility of annual workshop on detector development**

Response

- **In response to the review of the labs, Fermilab initiated the organization of a Detector R&D Workshop together with DPF**



Workshop on Detector R&D

Marcel Demarteau and Chip Brock

Last spring we announced a unique workshop, jointly sponsored by the five DOE labs and the DPF focused on detector R&D in the U.S. This reminder is to bring you up to date and to **bring to your attention a solicitation of posters for an extended poster session during the workshop.**

- **From DPF**
  - **Chip Brock*, MSU**
  - **James Brau, Univ. of Oregon**
  - **Andy White, UT Arlington**
  - **Sarah Eno, Univ. of Maryland**
  - **Kara Hoffman, Univ. of Maryland**
  - **Kevin McFarland, Rochester**
- **From Laboratories**
  - **Marcel Demarteau*, Fermilab**
  - **Laurence Littenberg, Brookhaven**
  - **David MacFarlane, SLAC**
  - **Erik Ramberg, Fermilab**
  - **Jim Siegrist, LBNL**
  - **Harry Weerts, Argonne**

*** = Co-chair**

Workshop Goals

- **Workshop Goals:**

  1. **To survey the detector research and development currently being carried out at national laboratories and universities**

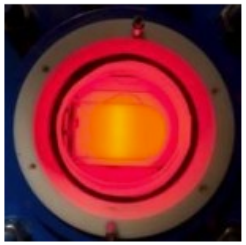
  2. **To identify the areas of detector R&D that hold greatest promise**

  3. **To identify current challenges and future needs of all stakeholders and discuss the future of detector R&D in the U.S**

- **Program followed closely the three main frontiers: Cosmic, Energy and Intensity**

Workshop

- **Workshop held at Fermilab, 7-9 October 2010**
  - **~130 participants**



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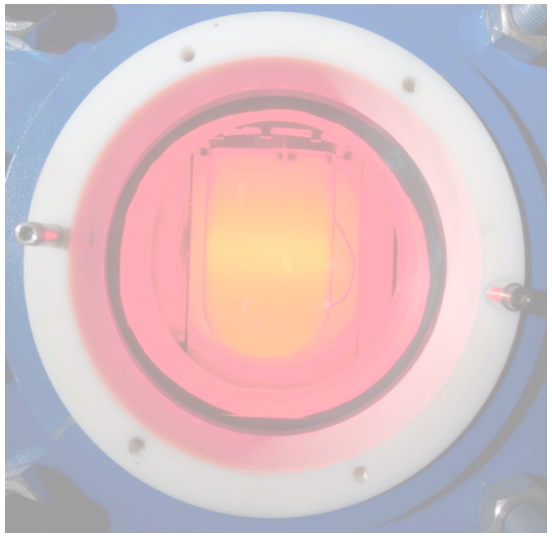
- **Program Format:**
  - **"Lab talks" (5 talks)**
    - Overviews of each lab's program; collaborative efforts and plans
  - **"Physics and Technology talks" (20 talks)**
    - Physics and technology challenges and drivers, near and far term
  - **"Survey talks" (4 talks)**
    - Specific research, educational programs, the process of collaboration
  - **Poster session (33 posters)**
    - Provide opportunity to younger physicists to present their results
  - **"Special Topic Talks" (4 talks)**
    - European Perspective, Personal "DOE" perspectives

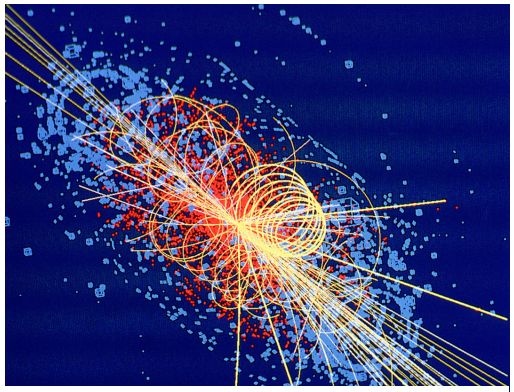
All talks at: https://indico.fnal.gov/conferenceDisplay.py?confId=3356



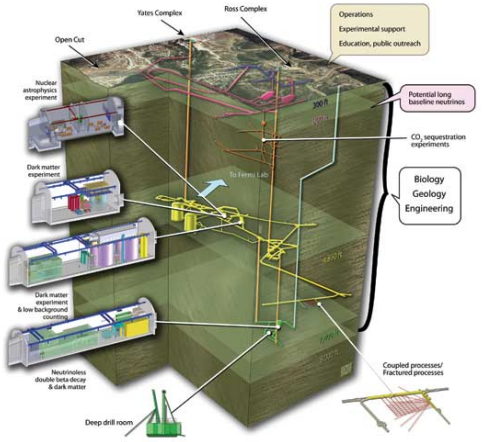
Laboratory Programs

Frontier Challenges

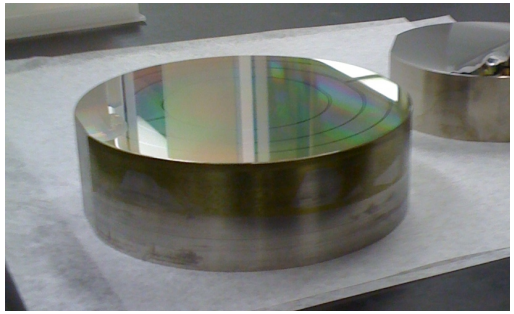
- **The Energy Frontier**
  - Rad hard, low mass vertex sensors
  - Triggering at luminosities > $10^{35}/cm^2/s$
  - 4 μm point tracking resolution
  - Hadronic jet energy resolutions of 30%/sqrt(E)
  - …



- **The Intensity Frontier**
  - Low-cost efficient photo-detectors
  - Large volume, long drift LAr TPC with maintained purity and robust readout
  - Psec level time-of-flight for rare decays
  - …



- **The Cosmic Frontier**
  - Background rates in dark matter detectors down to a level of 1 nuclear recoil per ton per year
  - Depth of observation of galaxy clusters
  - Probe the Planck scale of space-time
  - …

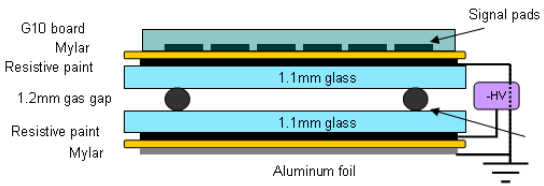


Laboratory Programs

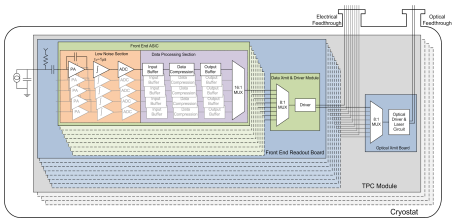
- **National labs have unique strengths and programs, which continue to have major impact on the field**

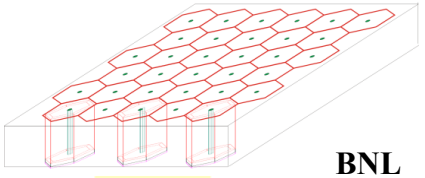
Examples:

- **Argonne:**
  - **Digital Hadron Calorimetry**
  - **Large Area Photodetectors**
- **Brookhaven:**
  - **Cold readout electronics**
  - **Rad hard Si trench detectors**
- **Fermilab:**
  - **LAr TPC**
  - **Tiered, 3D silicon**
- **Berkeley:**
  - **CCD**
  - **High pressure Xe TPC**
- **SLAC:**
  - **Low background FE electronics**
  - **High rate, high volume DAQ**



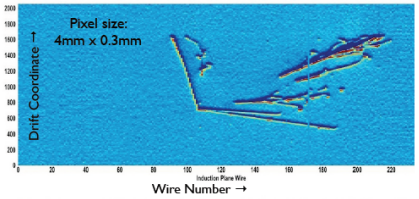
ANL

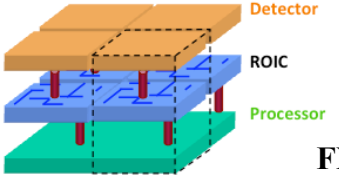




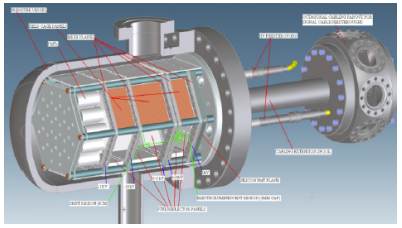
BNL

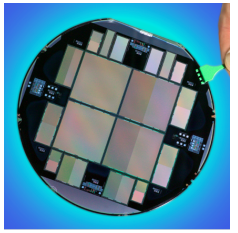
3-D Pixel



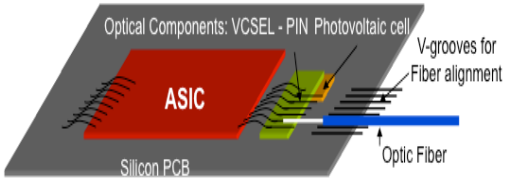


FNAL





LBNL



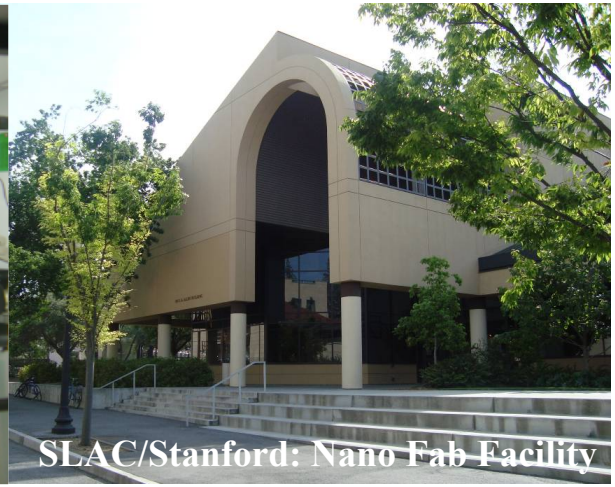
SLAC

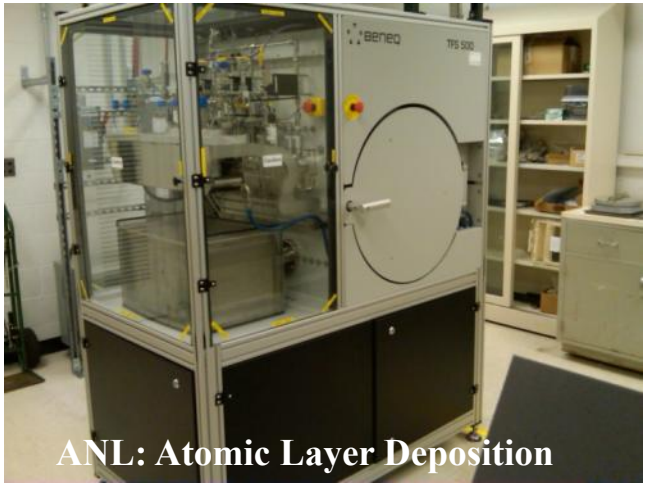
Laboratory Facilities

- **Workshop gave an overview of the significant facilities at the laboratories**


LBNL: MicroSystems Laboratory

BNL: Silicon Fabrication Lab


SLAC/Stanford: Nano Fab Facility


ANL: Atomic Layer Deposition


FNAL: Liquid Argon Test Facility

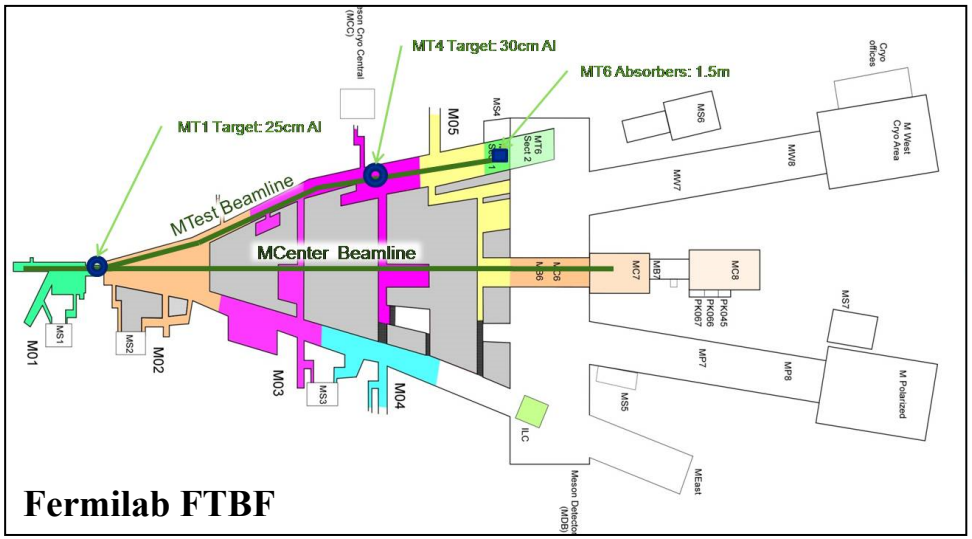
- **A wealth of facilities available to the user community**

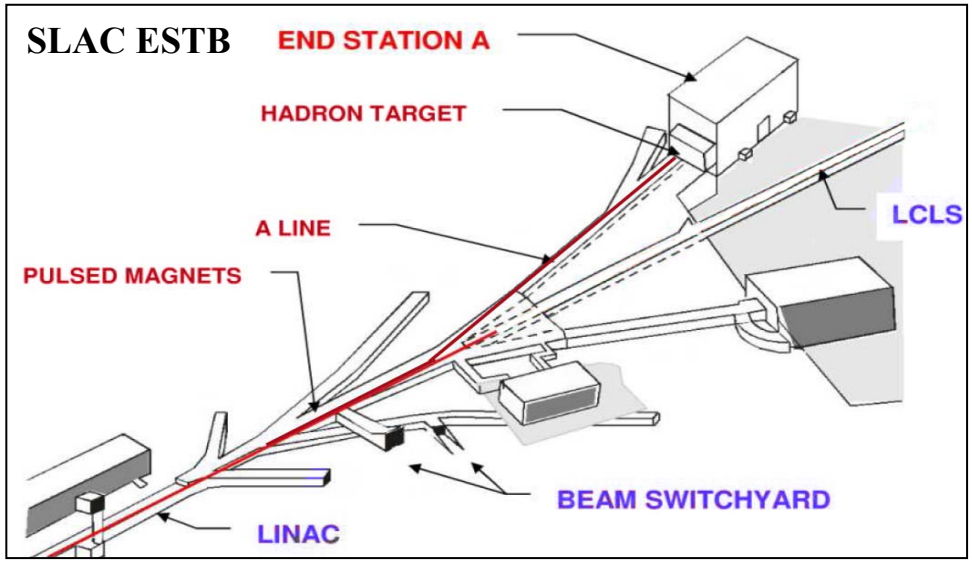
Laboratory Test Beam Facilities

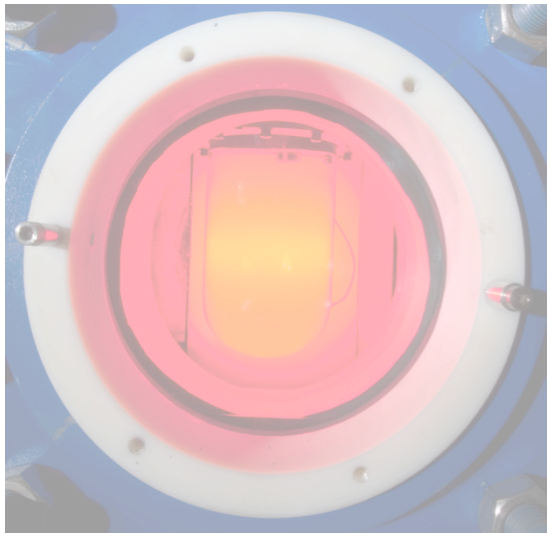
- **Fermilab Test Beam Facility**
  - **120 GeV primary protons**
  - **Pions, Electrons, Muons up to 70 GeV**
  - **Tertiary target down to 300 MeV**

- **End Station Test Beam at SLAC being built; first beam this year**
  - **3.5 – 13.6 GeV primary electrons at 120 Hz**
  - **Secondary hadrons ~1 π / pulse < 12 GeV/c**

- **Incredible resource to the community**







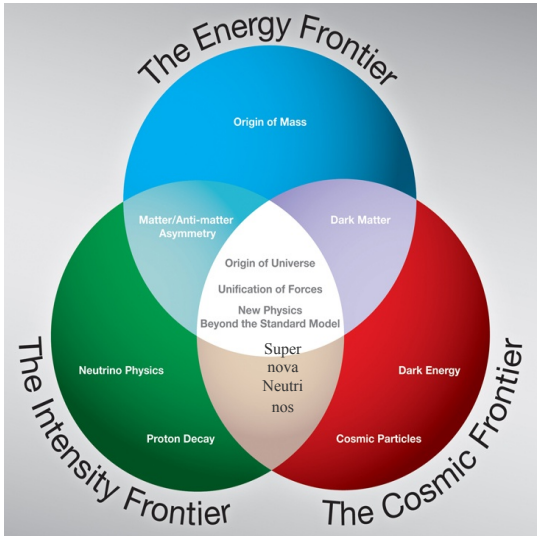
Science and Technology Drivers

Physics and Technology Presentations

- **Approach from a science driver point of view:**
  - **What breakthrough, fundamental science is severely limited by current technology?**
- **Approach from a technology driver point of view:**
  - **What technologies would leverage qualitatively new physics and what are the limitations?**

Tevatron / LHC / Lepton Colliders
John Jaros
Maurice Garcia-Sciveres
Abe Seiden
Wesley Smith

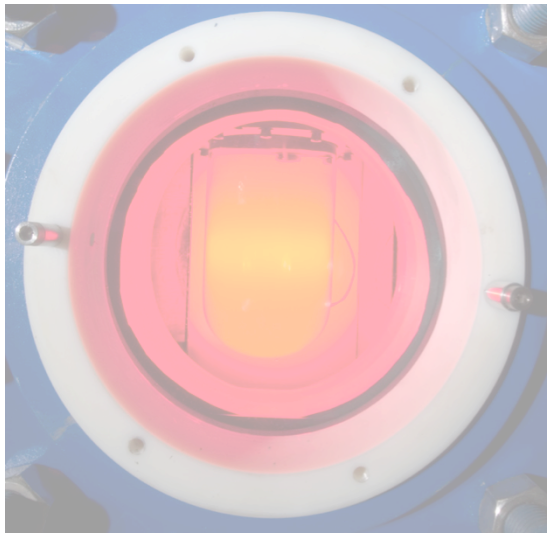
Neutrinos / Fixed Target
Regina Rameika
Bill Molzon



Dark Matter, Energy, UHE Cosmic Rays
Carter Hall
Spencer Klein
Juan Collar

- **Technology driven talks**

Carsten Hast: Test Beam Facilities
Joey Houston: Jet Energy Measurements
Zheng Li: Radiation Hard Detectors
Ron Lipton: Semiconductor Detectors
Hong Ma: Electromagnetic Calorimetry
Gary Varner: Radio Detection
Jerry Va'vra: PID detectors
Bob Wagner: Photo-detectors
Minfang Ye: Scintillators
Bo Yu: MPGD



Surveys

University – Fermilab Collaboration

- ArgoNeuT is small successful university – Fermilab collaboration that built a LAr TPC. What made it successful?

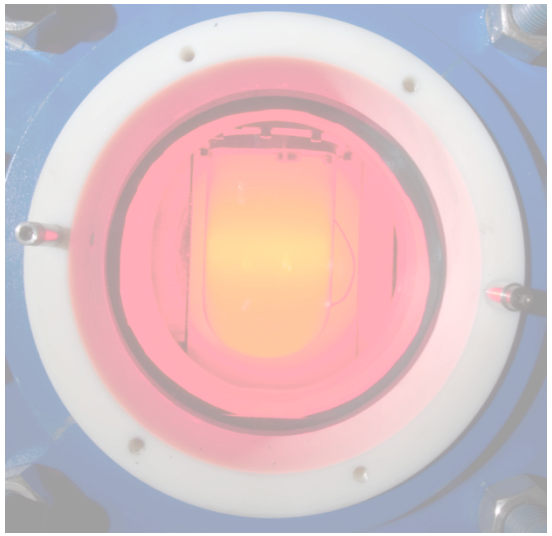
- Funding from NSF/DOE made this project possible
- Infrastructure at the lab, most universities would never have
  - TPC fabrication
  - Cryogenic design/fabrication
  - Process controls design/fabrication
  - Safety analysis
  - Installation/logistics
  - Computing
- Another reason for success would be the combination of R&D with neutrino data that will lead to real physics results.
  - Opportunities for publications (PRL, PRD, NIM, etc…) obviously very important for young collaborators…enables them to participate.

University – Argonne Collaboration

- **The Development of commercializable Large-Area Thin Planar Psec Photodetectors (LAPPD) within 3-5 years**
  - **Collaboration of 3 National Labs, 6 Divisions at Argonne, 3 small US companies, 3 US universities**

- **Unique combination of**
  - **Different areas of expertise: materials science, solid state physics, …**
  - **Understanding of the fundamentals**
  - **Industrial partners**

- **Ingredients for an effective lab – university collaboration:**
  - **A clear goal with near-term applications**
  - **Encouragement and seed funds at the university**
  - **Competitive opportunities for next level seeding**
  - **Risk portfolio management at the agencies for the step after ADR, LDRD**
  - **Support from enlightened the Lab management**
  - **Access to talent and facilities at the Labs**
  - **Local infrastructure at the universities**



Special Topic Talks

View From Europe

- **Prof. Tatsuya Nakada, Chair of ECFA, presented the status of Coordination of Detector R&D in Europe**

- **Europeans share concerns on detector R&D:**
  - **Emergence of "global" projects without a central host laboratory**
  - **Scale of those projects**
  - **Scale of the detector R&D is becoming large**
    - Example: CALICE: Calorimeter R&D for Lepton Colliders
      - 336 physicists/engineers from 57 institutes and 17 countries from the 4 regions (Africa, America, Asia and Europe)

- **Funding starts to become an issue**

- **Concerns by some national funding authorities on the review processes**

View From Europe

- **Funding issue is addressed by obtaining EU funding for the detector R&D**
  - **Funding meant for infrastructure and not for the actual R&D**
  - **EU review process, decoupled from the rest of the HEP community**
  - **EUDET Program within Framework 6**
    - Infrastructure for Detector R&D Towards the ILC
    - €21.5 M, of which €7M from EU for 30 institutes
    - Funding period: 2006-2009
  - **AIDA "Advanced European Infrastructures for Detectors at Accelerators" Program within Framework 7**
    - Funding for development of detectors
    - Wide area: i.e. CLIC, ILC, neutrinos, SLHC, flavor factories
    - €27 M, of which €8M from EU for 70 institutes
    - Funding period: 2011-2014

- **Review of some detector R&D groups carried out by the DESY PRC, even though not projects at DESY**
  - **Not a global solution and true "European" flavor is missing**

- **ECFA is in the process of setting up a panel for European detector R&D to review some European detector R&D efforts**

DOE Emeritus Perspective

- **Dr. Howard Nicholson was IPA from 2006 – 2010, and managed the DOE detector R&D program and gave a personal perspective**

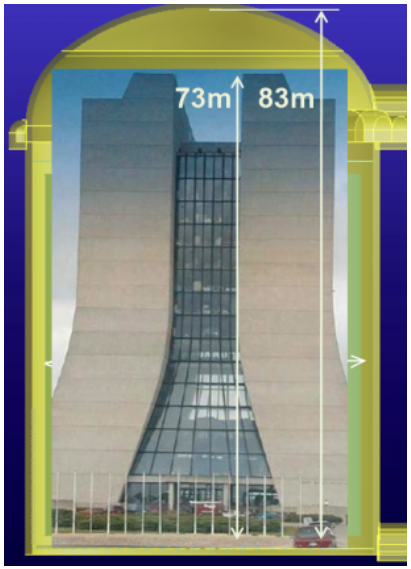
- **Observed that future research in High Energy Physics requires an enabling Detector R&D program to pursue that research at the three frontiers**

- **This program should:**
  - **Develop novel new detector technologies and methods**
  - **Improve the characteristics of existing detectors commonly used in High Energy Physics**
    - Increase speed, improve radiation hardness, improve energy resolution, improve precision, improve mechanical robustness, reduce intrinsic radioactivity backgrounds, …
  - **Develop cheaper technologies for large detector systems**

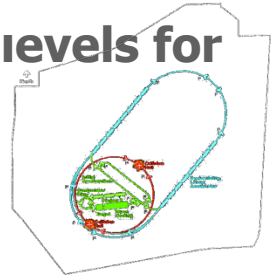
- **The program would:**
  - **Enhance the leadership ability of the US HEP community**
  - **Enable the US HEP community to mount world class experiments**
  - **Help optimize the use of limited funding**

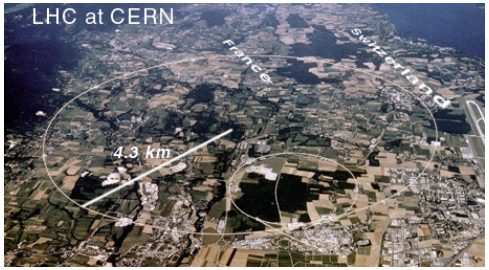
Tensions

The workshop revealed obvious tensions:



- Enormous experimental challenges for the next generation of projects
- Approved projects, such LHC upgrades, versus new projects such as lepton colliders
- Erosion of university infrastructure & opportunities
- Pressures on and within the laboratory system
- Graduate student training separating from hardware
- National priorities and overall funding levels for inquiry-driven R&D
- Industry moving beyond us

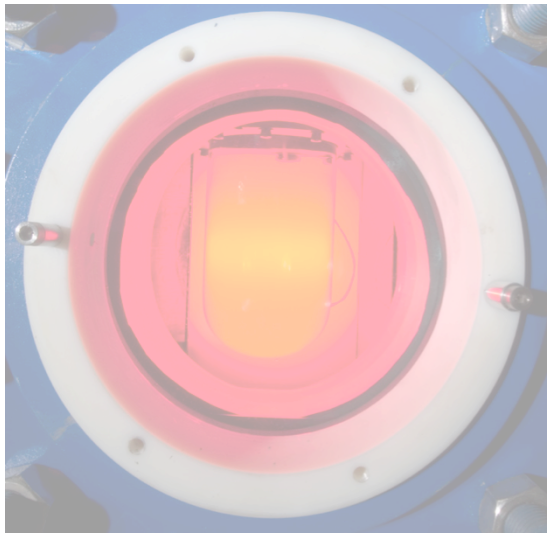




DPF

- **The workshop was co-organized, and sponsored, by DPF and the national laboratories**
- **Although there is fascinating instrumentation research in our community, there are indications – both from the agencies and the community – that this effort would benefit from coherent, national attention**
- **The question: "Should the community attempt to craft a national program of Detector R&D?" was discussed during the workshop.**
- **The answer was "yes" and, that the DPF is the appropriate organization to envision such a national approach**
- **DPF took a pro-active role in establishing a DPF task force on instrumentation in High Energy Physics to address these issues**

http://www.dpfnewsletter.org/



Next Steps

DPF Taskforce

- **Task force launched with explicit membership:**
  - **From Universities**
    - **Ian Shipsey*, Purdue**
    - **Marina Artuso, Syracuse**
    - **Ed Blucher, Chicago**
    - **Bill Molzen, Irvine**
    - **Gabriella Sciolla, MIT**
    - **Andy White, UT Arlington**
  - **From Laboratories**
    - **Marcel Demarteau*, Argonne**
    - **David Lissauer, Brookhaven**
    - **David MacFarlane, SLAC**
    - **Greg Bock, Fermilab**
    - **Gil Gilchriese, LBNL**
    - **Harry Weerts, Argonne**
  - **Ex-officio**
    - **Chip Brock, DPF (MSU)**
    - **Patty McBride, DPF (Fermilab)**
    - **Howard Nicholson, Mount Holyoke**

* = Co-chair

- **Expert members will be consulted by virtue of their particular expertise or responsibilities.**
- **The taskforce will consult the European and Asian particle physics communities**
- **The taskforce will also consult experts in other disciplines, in particular nuclear physics, materials science, condensed matter physics and electrical and computer engineering**

Taskforce Charge

Charge organized along three broad categories

I. Structure for a National Instrumentation R&D Strategy

i. Need, merit and process for evaluating and promoting the national R&D program through a National Instrumentation Advisory Panel

ii. Appropriate role for a standing panel on instrumentation vis-à-vis existing and new projects

iii. Models for universities-laboratory collaborative projects

iv. Strategic links to other scientific disciplines

v. Strategic links to industry

II. Models for Entrepreneurial Instrumentation Science Strategy

i. Availability of targeted resources at each of the five national laboratories to specifically support particular needs of individual researchers at the universities and the laboratories?

Taskforce Charge

III. Graduate Student and Post Doctoral Training

i. Role of experience in instrumentation R&D in the life of U.S. graduate students

ii. Academic, intensive, US-based instrumentation experience for graduate students with academic credits, within the context of a global program of coordinated instrumentation schools

iii. National instrumentation fellowship program for Ph.D. students and postdoctoral scholars to encourage and support research in instrumentation

- **Taskforce is in the process of forming working groups**
  - **Will meet at APS meeting and TIPP conference**

- **Taskforce is asked to deliver a preliminary report by the DPF meeting in August at Brown University**

Charge can be found at http://www.dpfnewsletter.org/?p=425

NSF

- **NSF has always been very supportive of new instrumentation development**
- **Detector development for DUSEL strongly supported**
- **But, to the best of our knowledge, no structured program within NSF currently exists for HEP**

- **The task force would very much welcome active NSF participation**
- **We are exploring how to involve the NSF at this early stage of the process to provide input**
- **Especially the academic training of new generations of physicists would benefit greatly from NSF involvement**

Summary

- **A review of the detector R&D programs at the five national laboratories led to a self-organization of the community**
- **A workshop dedicated to an overview of Detector R&D in the country was organized. This was the first time that a workshop dedicated to this topic was organized**
- **The workshop was very informative and positively received by the community. A lot of high quality R&D is being carried out**
- **There seems to be an acute awareness that for a sustained viability of the field a renewed investment in sensor and detector development with the appropriate organization is needed**
- **A DPF taskforce has been established to address the organization of HEP instrumentation**

Poster Session

- **33 posters**

Title	Primary Authors
Fermilab Detector R&D Programs and Facilities	Prof. RAMBERG, Erik
Development of a tracking system for the new (g-2)_mu experiment	CASEY, Brendan et al.
LArTPC R&D with ArgoNeuT and MicroBooNE	Mr. SPITZ, Joshua
Pixel Detector Research with Undergraduate Students	BEAN, Alice
Reliability Study of DC-DC Conversion Powering Scheme for the CMS Pixel Detector at the SLHC	Dr. TODRI, Aida
Free-Space Optical Interconnects for Cableless Readout in Particle Physics Detectors	Dr. KWAN, Simon; Mr. PROSSER, Alan
Fermilab Test Beam Facility	SOHA, Aria
Parallel Optics Technology Assessment for the Versatile Link Project	Dr. KWAN, Simon et al.
ADRIANO - A Dual-Readout Integrally Active and Non-homogeneos Option for future colliders.	Dr. DI BENEDETTO, Vito et al.
Low Mass Optical Readout for Tracking	Dr. UNDERWOOD, David
Multi -Anode Wire Straw Tube Tracker	Prof. OH, Seog
Fast timing detector for ATLAS Forward Proton Upgrade	Prof. BRANDT, Andrew
Results from a Telescope of CMS PSI46 Pixels and the CAPTAN Data Acquisition System	Mr. RIVERA, Ryan
A new method for detecting and reconstructing high-energy photons from GRBs	Prof. MCINTYRE, Peter
Streaming Data Acquisition System Design for High Energy Physics Applications	Mr. BOWDEN, Mark
Uniform Gas distribution inside the gas chamber detector and position of inlet and outlet	Dr. SINGH, Venktesh
FE-I4 : The Next-Level Hybrid Pixel Readout	DUBE, Sourabh et al.
A Promising Technology for ASIC Developments in Detector Front-end Electronics	Prof. YE, Jingbo
VIP 3D Pixel Detector Technology	Dr. HOFF, Jim
Using SiPM sensors in the CMS hadron-outer calorimeter and its effect on MIP identification	ANDERSON, Jake
LENS High-Concentration Indium Loaded Liquid Scintillator	HU, Liangming
Development of a low-material TPC endplate for the ILD experiment at the ILC	Dr. PETERSON, Daniel
Development of DHCAL Using Gas Electron Multiplier (GEM) Technology	Prof. YU, Jaehoon et al.
Liquid Argon Purity Demonstrator (poster)	YANG, Tingjun
Progress towards a large-scale high-pressure xenon gas TPC for 0-nu double beta decay search	NYGREN, David
Dual-Readout Calorimetry: DREAM Results	HAUPTMAN, John; FRANCHINO, Silvia
Construction of a Large Scale Prototype for a SiW Electromagnetic Calorimeter for the ILC - EUDET Module	Mr. POESCHL, Roman
Pixel Sensor/ROIC Integration Using Oxide Bonding	ZHENYU, Ye
Low noise readout and applications with High resistivity CCDs	Dr. CANCELO, Gustavo
Depleted Argon From Underground Sources	Dr. BACK, Henning
Test Beam Analysis of Directly Coupled Scintillator Tiles	COLE, Stephen
Secondary Emission Sensor Ionization Calorimetry	Prof. WINN, David
Monte Carlo Simulations Of Detector Backgrounds At A Muon Collider	Mr. MORRIS, Aaron