Argonne NATIONAL LABORATORY

... for a brighter future

Argonne High Energy Physics: Plans and Views

Jimmy Proudfoot

March 7th, 2008

ANL HEP Programs

- Current energy frontier:- (CDF, ZEUS) ATLAS, Theory/Phenomenology
- Advanced Accelerator R&D
- ILC – the next energy frontier
- Neutrino Physics – (Soudan 2) MINOS, NOvA, Double Chooz
- Emerging program at Argonne: Particle and Nuclear Astrophysics & Cosmology
- **Electronics and Mechanical Groups Critical to Our Success**
  - Detector R&D

Our History

HEP at a multi-disciplinary laboratory

Part of fundamental science @ Argonne

Enabling technologies & connections → science

Accelerators

Strong accelerator groups at ANL

Connections

- Advanced Photon Source
- ATLAS (A Tandem Linear Accelerator)
- Intense Pulsed Neutron Source
- Advanced Wakefield Accelerator
- Advanced Accelerator Institute
- Material Science Division

Detector technologies

Sensor development (tools,TES)

Material Science Division

Center for Nanoscale Materials--

- CDF/ZEUS--
- MINOS/NOvA--
- LHC --
- ILC --

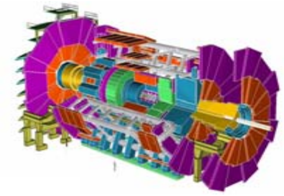
HEP Detector R&D & construction

Good connections within lab & collaboration with Fermilab contributes access to and from other science disciplines & expertise

HEP Division has the breadth of capabilities to do R&D, design, construction; from conception to operation (lab infrastructure)

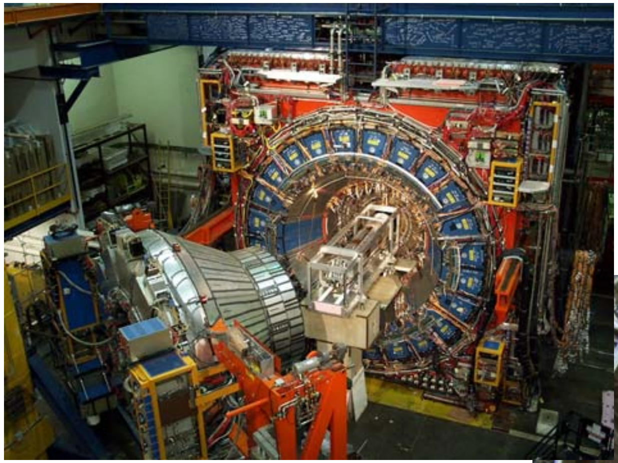
Historically have had, and continue to have strong ties with university groups

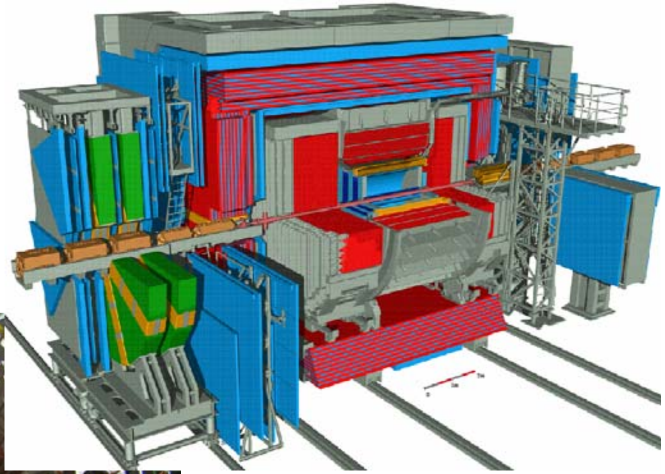
(A few of the) Current ANL Leadership Roles

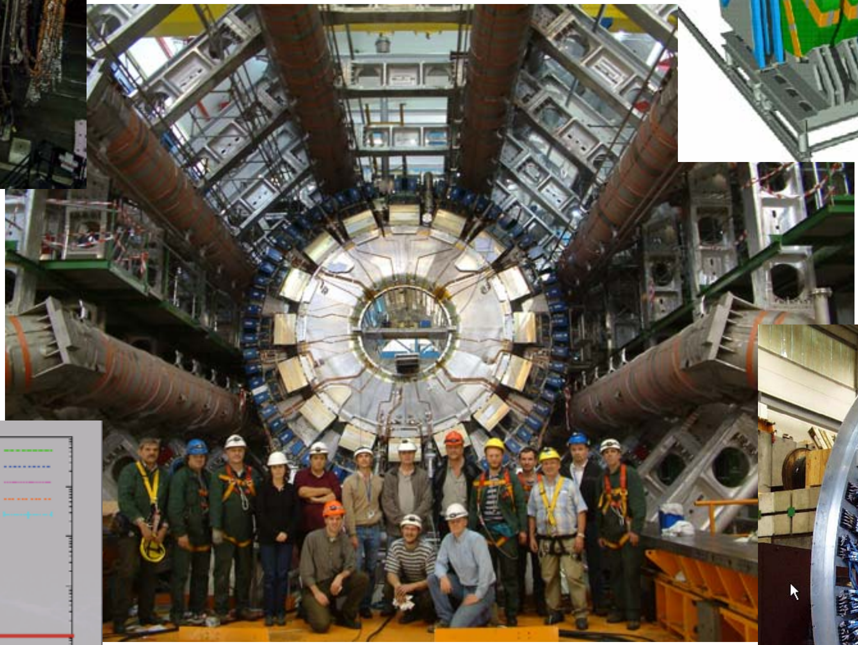


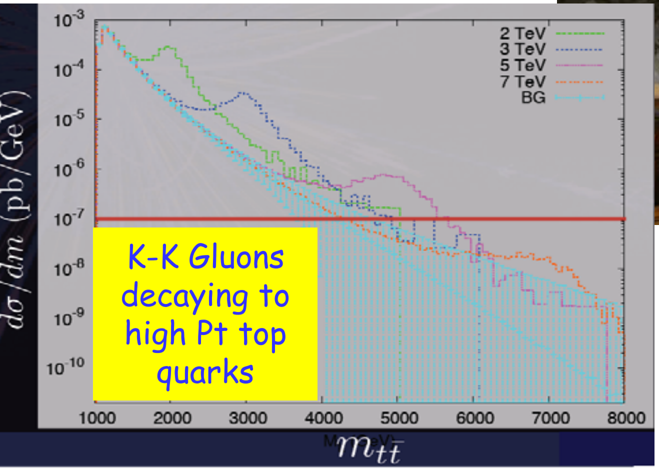
- **CDF:**
  - *Incoming Co-Convener Electroweak Physics Group (L. Nodulman)*
- **ATLAS:** Tile Calorimeter Project Leader: R. Stanek
  - Physics Coordination:
    Co-convener Standard Model (T. LeCompte); JetEtMiss (J. Proudfoot)
  - Computing Management Board
    Distributed Database Operations Coordinator (S. Vaniachine)
- **SiD:** Co-Coordinator (H. Weerts)
- **CALICE:** Steering Board Chair (J. Repond)
- **MINOS:** Deputy Spokesperson (D. Ayres)
  - Institutional Board Chair (M. Goodman)
  - *Co-Convener, ν_e appearance analysis group (M. Sanchez); (Past Convener) far detector non-oscillation physics analysis (M. Goodman)*
- **NOvA:** Executive Committee, (D. Ayres)
  - Level 2 Manager, PVC & Extrusions (R. Talaga); Detector Assembly (D. Ayres)
- **Double Chooz:** Executive Committee (M. Goodman)
  - US-DChooz Co-Spokesperson (M. Goodman)
- **VERITAS**
  - *Deputy Leader, Dark Matter Science Group (K. Byrum)*
- **AGIS**
  - Co-Project Manager, R&D Program (K. Byrum)

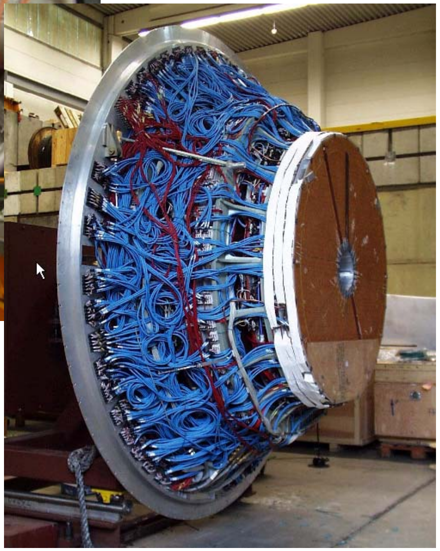
Our Main Science Focus: "The Energy Frontier"









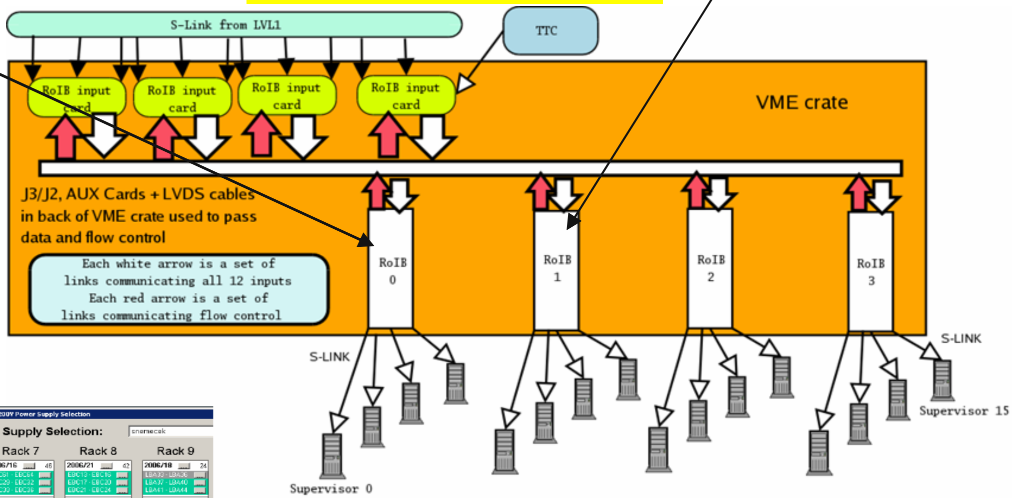


ANL and ATLAS
Our Highest Priority Accelerator-Based Program

Building on >2 decades of Experience at CDF

RoIB: CENTRAL to the ATLAS L1 Trigger

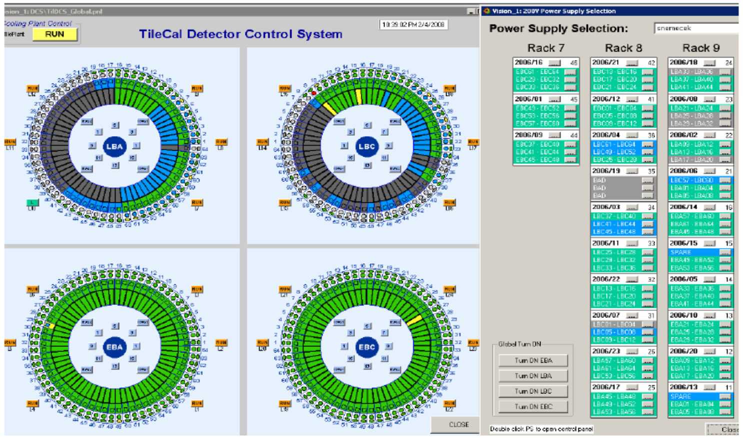
TDAQ: Region of Interest Builder



Tile Calorimeter: Design Construction, Commissioning and Operations

LVPS "Brick" for debugging and repair

This Problem now Behind Us



Exploring Ways to perform Remote Monitoring of Detector Operation & Performance

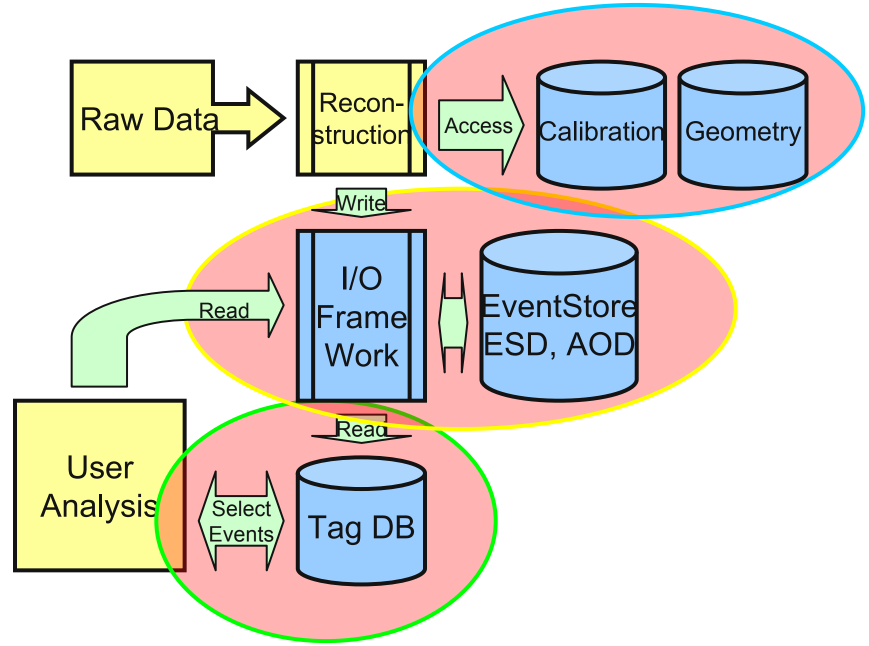
ATLAS Software and Computing & Analysis Support Center

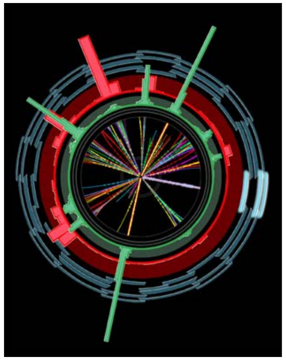
- unifying thread is infrastructure for flexible and efficient access to ATLAS data
- With petabytes of data accumulated annually, efficient data discovery, identification, location, delivery, and access is crucial to the success of ATLAS physics

Event store design and optimization

Event selection services

Distributed database services





Our Physics Interests:
Standard Model Jets and Photons, Higgs, Exotics

Analysis Support Center

ENABLING Physics Analysis for local university groups

Tutorials, Workshops, Experts, Development of "helpers" etc.

Theory and Phenomenology

Working on forefront research relevant to the LHC (and earlier collider programs)

Improved computation of the gamma-gamma background for Higgs searches at the LHC

Analysis of the production of excited gluons and quark states in warped extra dimensions at the LHC

Analysis of the search for a Higgs boson decaying into two lighter scalars at the Tevatron and the LHC

Demonstration of the consistency of four generation models and study of their collider implications

Improved determination of high energy neutrino cross sections

Improved analysis of flavor constraints on MSSM Higgs searches at hadron colliders

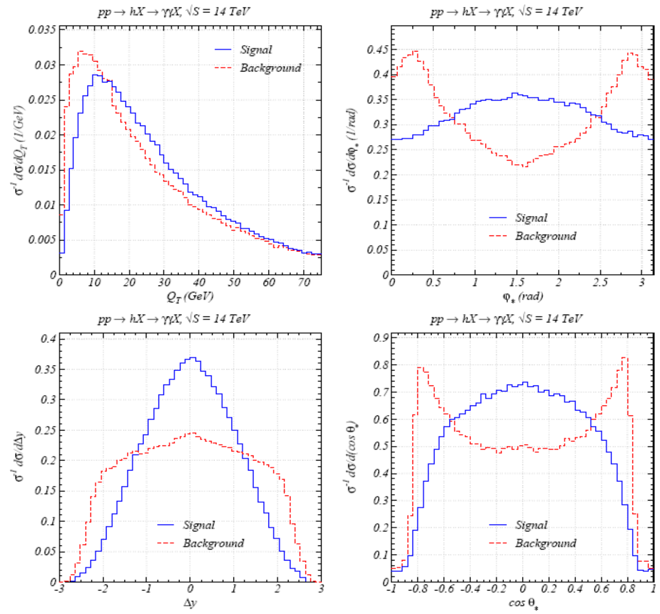


Figure 1: Comparison of the normalized Higgs boson signal and diphoton background distributions

One Example: The Background to H->γγ

Joint appointments:

Two with Northwestern University

One with the University of Chicago

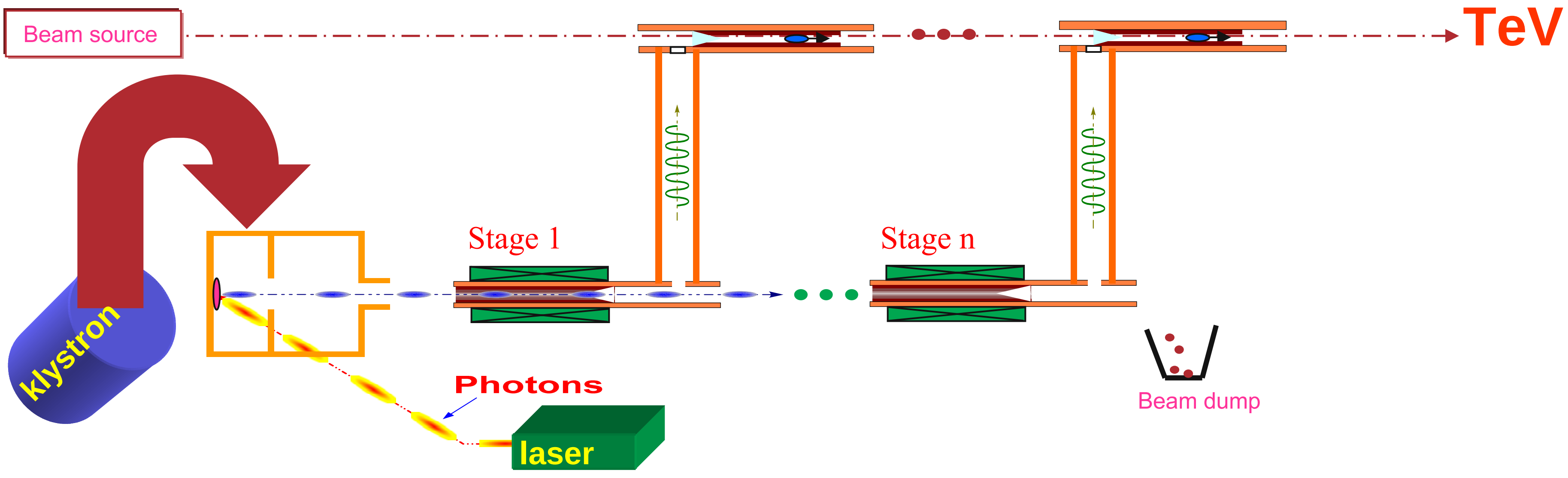
AWA: Wakefield Acceleration at Argonne

A Pathway to TeV Class Linear Colliders

The Scheme Under Study:

- **Novel Power Source**: high-current drive-beam to generate high-power RF (GW level)
- ***Advanced structures*:** dielectric-loaded (and other novel) structures to reach high-gradient (hundreds of MV/m)

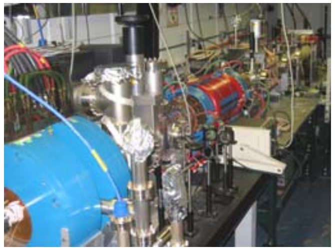
- GeV acceleration module to demonstrate the wakefield scheme



Advanced Accelerator R&D Activities at the Argonne Wakefield Accelerator (AWA)

The AWA Facility

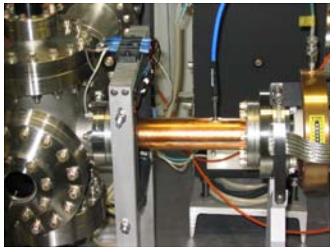
- Operating an RF Photoinjector based facility that produces the world's highest photoelectron charge
- Providing a unique facility for the HEP community



AWA Facility

Wakefield Acceleration Milestones

- Pioneered many wakefield acceleration schemes
- Demonstrated the dielectric-based two beam acceleration scheme



Dielectric: Structure Under Test

Recent highlights

- Achieved 100 MV/m wakefield gradient (at $\Delta\tau \sim$ a few nanoseconds).
- Demonstrated enhanced transformer ratio with a ramped bunch train.

Future Plans

- Generate high-power RF (GW class, ~ 10 ns) and test advanced accelerating structures.
- Demonstrate GeV concept module based on the two-beam wakefield scheme
- Upgrade to double the drive beam energy underway

Dielectric Loaded Accelerator

ILC: Accelerator R&D
A Lab Wide Effort

- SuperConducting RF Cavity Processing

  Nuclear Physics Division (with >20yr experience in SCRF cavities) in collaboration with Fermilab

- Positron source simulation (end-to-end from production to damping ring)

  High Energy Physics Division

- Damping ring design/lattice

  Advanced Photon Source

- Control System (EPICS)

  APS/GDE

Work started in 2006, ramped up in 2007 and is stopped now in FY08

Future is unclear and depends on national priorities

ILC: Calorimetry R&D

Development of calorimetry optimized for the application of Particle Flow Algorithms

Performance Driven by Physics Goal

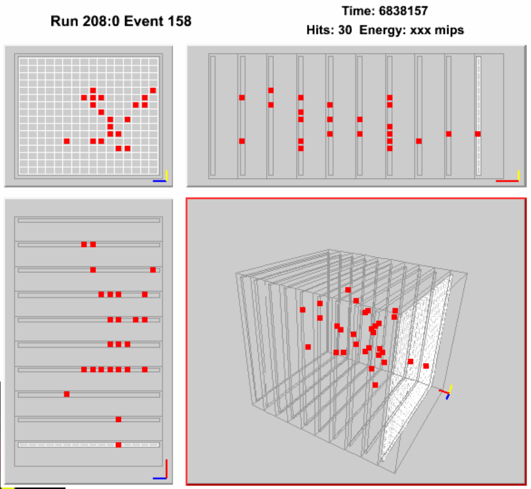
Particle Flow Algorithms

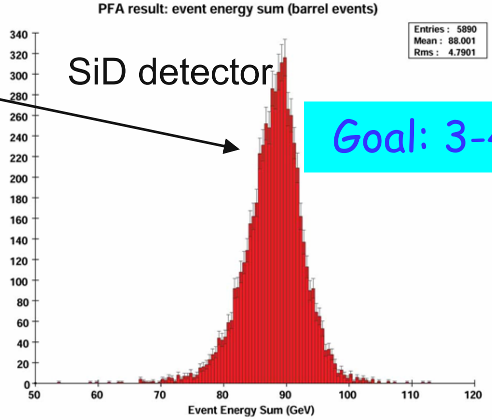
Utilize tracking and calorimetry

Major challenge → associating energy deposits to charged and neutral particles in jets

Require very finely segmented calorimeters

Testbeam Event Display

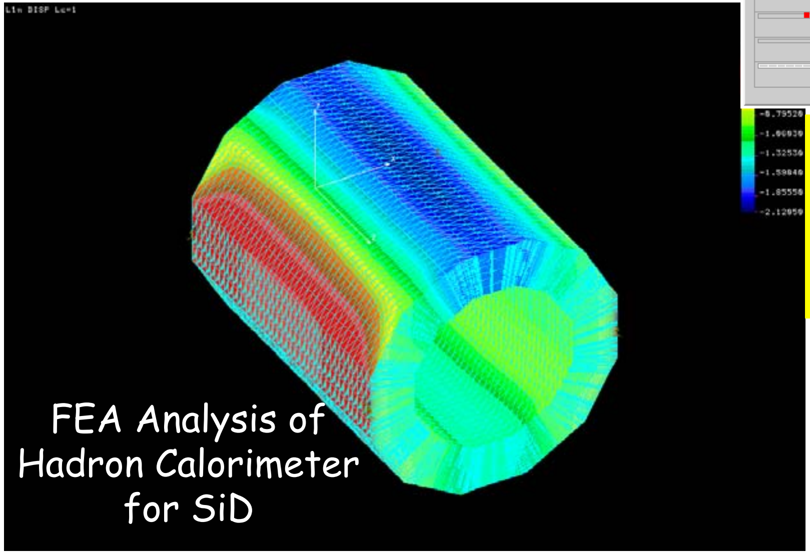




Goal: 3-4%

Barrel event (cos(theta[Q]) < 1/sqrt(2))

Mean 88.0 GeV
RMS 4.79 GeV
RMS90 3.37 GeV
[35.9%/sqrt(E)]

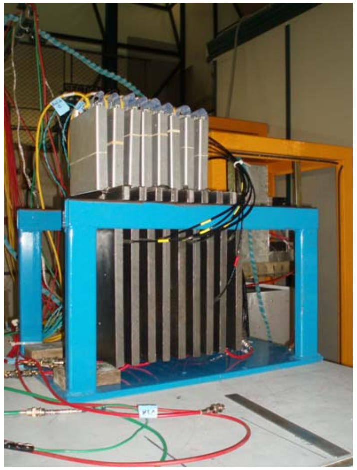


FEA Analysis of Hadron Calorimeter for SiD

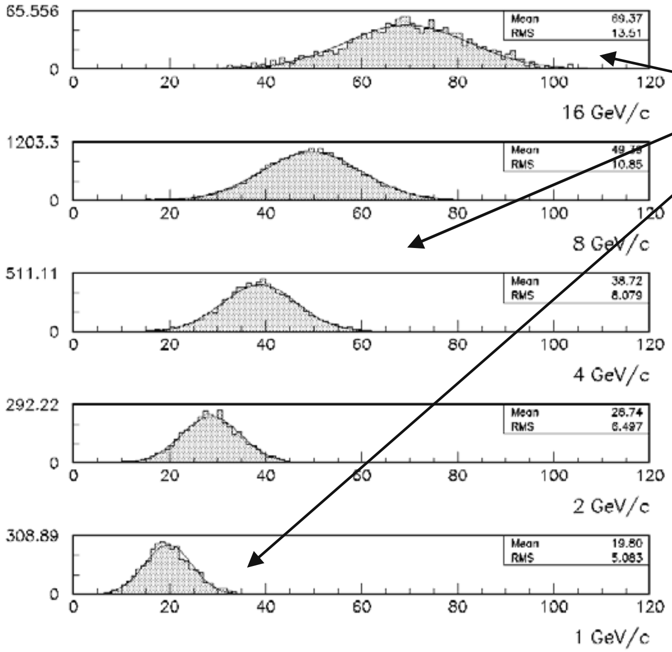
- Key role in the U.S to develop PFA's
- Contributing to the design of SiD and of the hadron calorimeter

Future: Follow the national priorities but if at all possible complete the R&D for the digital hadron calorimeter

ILC: DHCAL Prototype Test



- **Sample EVERY layer EVERY cm²**
  - Using Resistive Plate Chambers (RPCs) as active elements
  - Developed complete electronic readout system
  - Assembled small stack with up to 9 layers (with 2,300 channels)
  - Extensive tests in Fermilab test beam and with cosmic rays



- Response to electrons (for example)

Proves stack behaves as a real calorimeter
(Response highly non-linear due to leakage (only 6 layers) and saturation (digital readout)

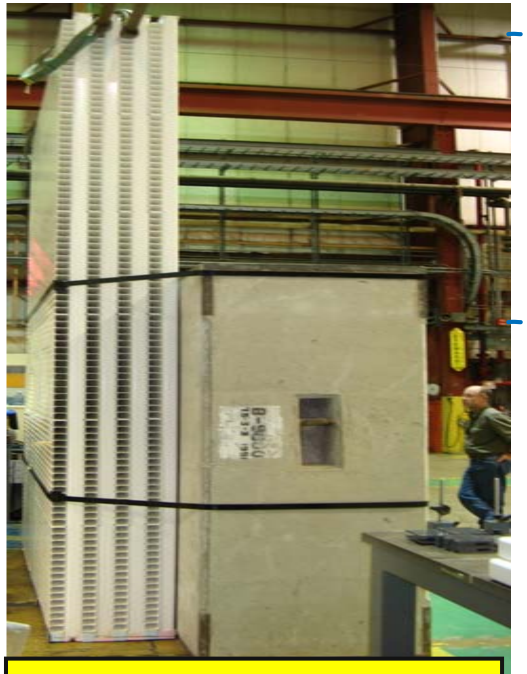
Next step: construction of 1 m^3 prototype section with 400,000 channels

Neutrino Program: Some Highlights

MINOS Near Detector at Fermilab: ANL built all Near Detector scintillator modules, and all its readout electronics

MINOS has the world's most precise measurement of Δm^2_{32}

- **Double Chooz**
  - Engineering support for calibration systems (with Drexel, Alabama, Davis)
  - Next leap in world's θ_{13} sensitivity from (×6 in 3 years)



NOνA Prototype Module

- **NOνA**
  - Argonne mechanical engineering and prototype studies have been crucial in demonstrating NOνA feasibility
  - *The loss of FY08 funding could delay NOνA construction by 1 year but signing of CD2 and CD3 before funding resumes in FY09 could shorten this delay*

Future for the ANL Neutrino Group

building on >3 decades of neutrino expertise at ANL

- Neutrino physics at Fermilab will proceed with NOνA & SNuMI, or with Project X to Soudan, or with Project X to DUSEL

We have the technical skills to contribute and believe this presents a unique and exciting physics opportunity

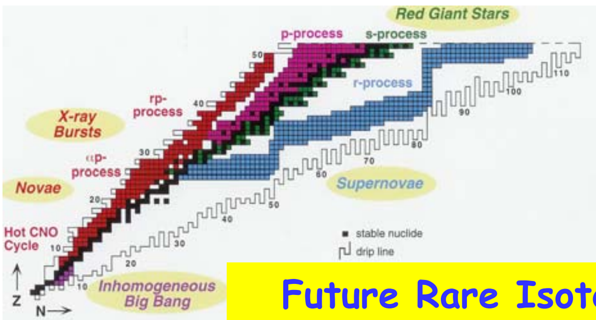
→The future depends not only on good ideas but also the value of θ_{13} & decisions in other countries←

Exploring long-term directions for the ANL neutrino group which include: Project X, DUSEL, NOνA II, UNO, INO, supernova detectors, small ν detectors, next generation reactor neutrino experiments

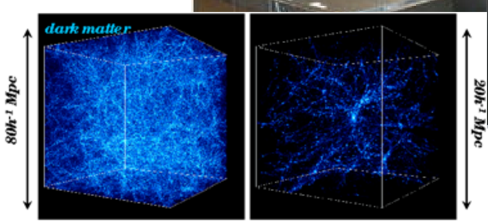
Laboratory Strategic Initiative FY08- $2M

Particle and Nuclear Astrophysics & Cosmology – Emerging Program

- Establish a world-class astrophysics program at Argonne
- Form strong connections to Fermilab, the University of Chicago and other local universities.
- Build on strengths and unique capabilities at Argonne.
- Attract a scientific leader who can establish and shape this initiative



Future Rare Isotope Beam (FRIB)

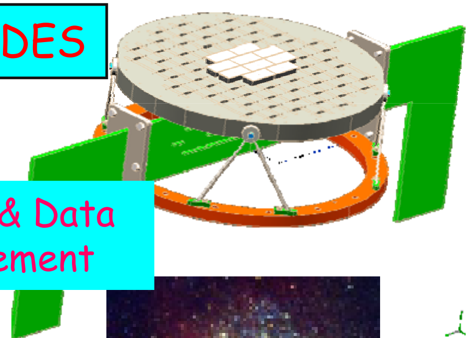


Petascale computing using BlueGene/P

N-body Dark Matter Hydrodynamic FLASH

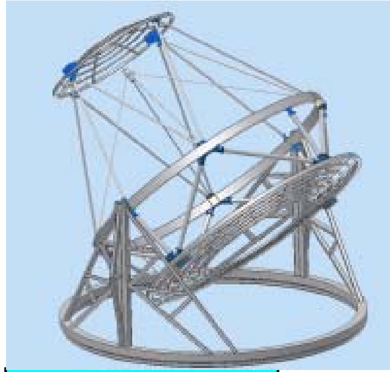
HEP: Dark Matter & Dark Energy

DES



Camera & Data Management

Dwarf Satellites



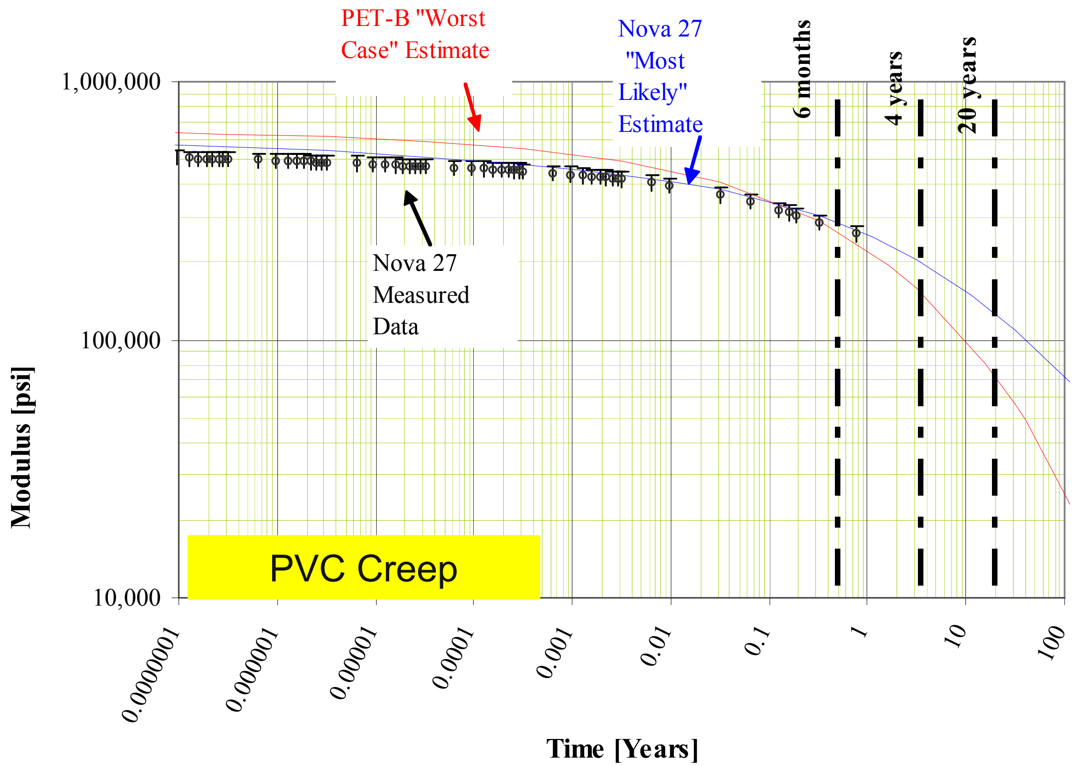
VERITAS
AGIS

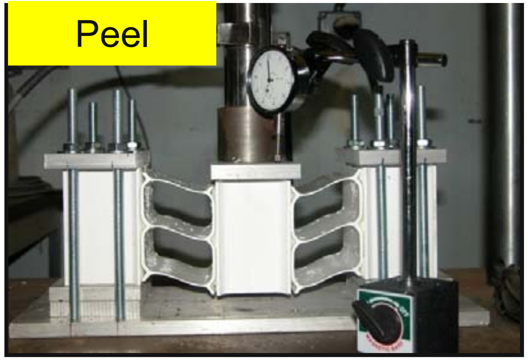
$\chi\chi \rightarrow q\bar{q}, \gamma\gamma, \nu\nu, z\gamma$

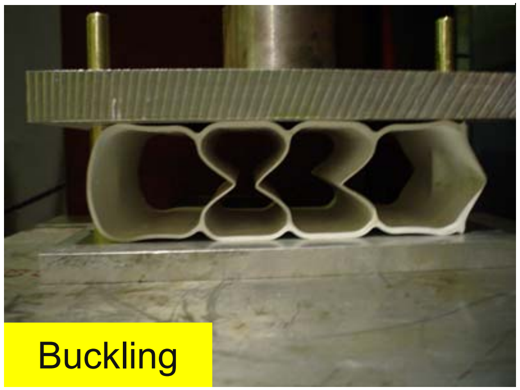
Indirect DM search

Mechanical Support Group

- Project Management
- Structural analysis
- Thermal analysis
- Finite Element modeling
- 3D solid modeling and 2D drafting
- Mechanical construction
- Machine design
- Civil Construction
- Fiber optics
- Material testing
- Automatic control systems
- Safety Analysis
- Hydraulics
- Ultra-High Vacuum
- Machine Shop Services







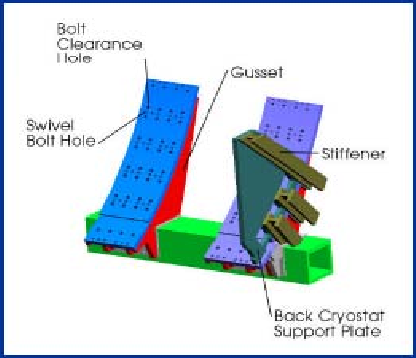
Mechanical Support Group: Past Achievements

ATLAS Tile Calorimeter Support Structure

High Energy Physics Division, Argonne National Laboratory

Pioneering Science and Technology

Argonne's High Energy Physics Division is collaborating on the LHC ATLAS experiment and was responsible for construction of a large fraction of the Extended Barrel Tile Hadron Calorimeter. HEPD is making a unique contribution to the experiment in terms of providing engineering design and analysis of much of the support structure of the calorimeter; the "saddles" on which the cylinders rest and the link plates which connect modules together. The resulting structure is entirely self-supporting .

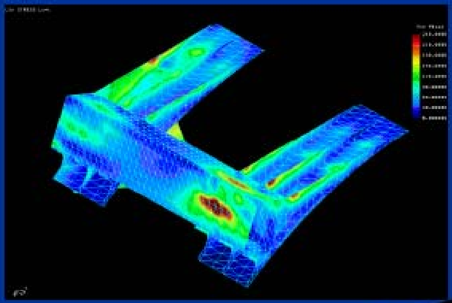


This schematic shows the main elements of the saddle. One pair of these is used to support each Extended Barrel cylinder, which is approximately 2.7m in length and 2 pairs of saddles are used to support the Barrel cylinder,which is 6m in length.

33mm diameter pins in the connecting plates between modules carry the tension load below the saddles which resists the moment from the modules above the saddles

A full pre-assembly of each cylinder will be carried out prior to final assembly in the ATLAS cavern.
The first of these is shown here. The assembled cylinder is itself over 8m high, weighs 640 tons and sits on 2 pairs of blocks below each of the saddle beams.

Modules in the region of the saddles simply rest on swivel bolts which are mounted in the holes shown.

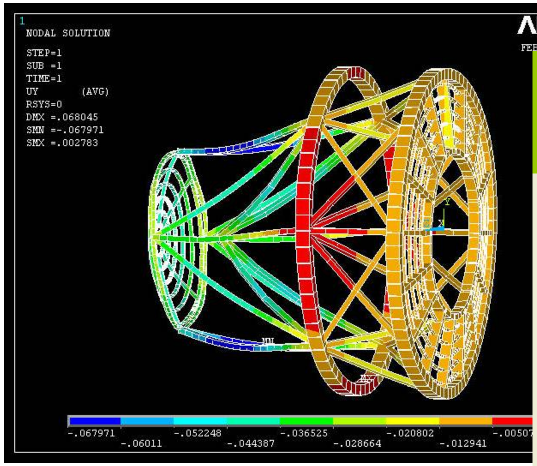


Finite element analysis calculations were made for all connections in the structure. This figure shows the stress concentration in the saddles themselves. The stress concentration seen at the bottom of the beam results from the local load of the endcap calorimeter, which is itself support ed from the tile calorimeter.

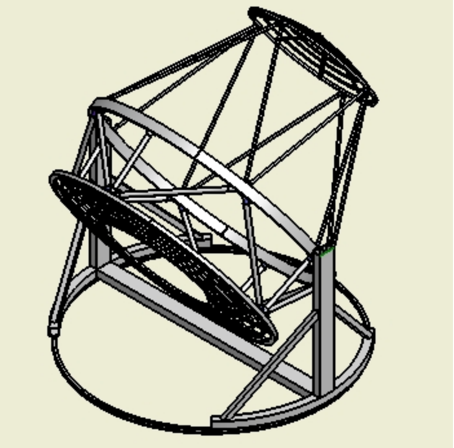
A special module for which the connecting plate is a single piece has a key which sits in the slots shown in the saddle. The key carries the vertical shear load in the cylinder which is transferred through the saddle to the ATLAS support rails..

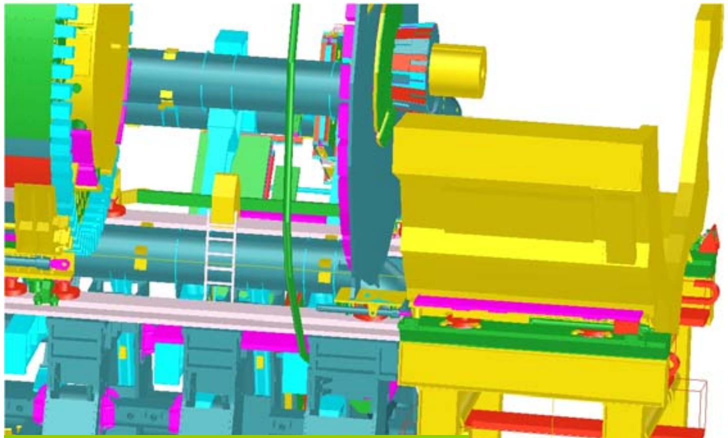
Mechanical Support Group: Some Current Activities

- Atlas: Leading the design, construction, and installation of the movement system
- NOvA:-Leading the structural analysis, material development and testing, and construction
- Chooz2-Leading the design of the calibration systems.
- Veritas/AGIS-Performing structural analysis and design of next generation telescope.
- DES-performing thermal/structural analysis of camera.

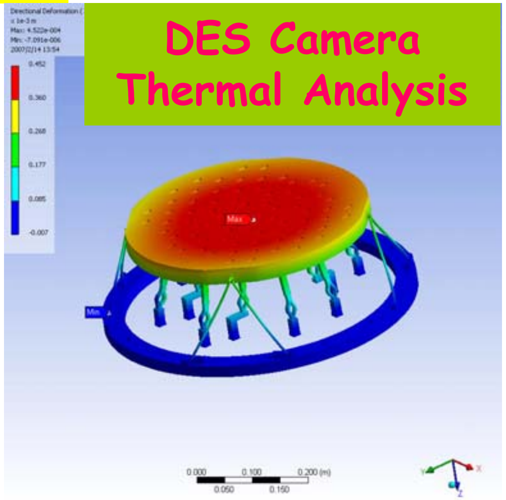


AGIS Design & Structural Analysis





ATLAS Detector Movement System



DES Camera Thermal Analysis

DES CCD Test Cell

ANL HEP Electronics Group

- Group Resources:
  - 4 Hardware Engineers
  - 2 Software/Computer Sci.
  - 3 Technical Assistants
  - 1 CAD Layout Person
  - 1 Instrument Repair
  - 1 Technician (Assembly)

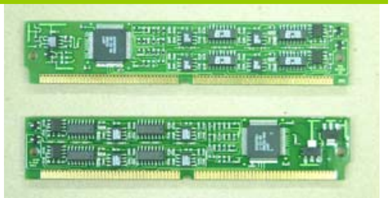
Supports both HEP and Other Basic Sciences (PHY, CHEM, Mat. Sci., BIO, IPNS, NE, APS (CAD))

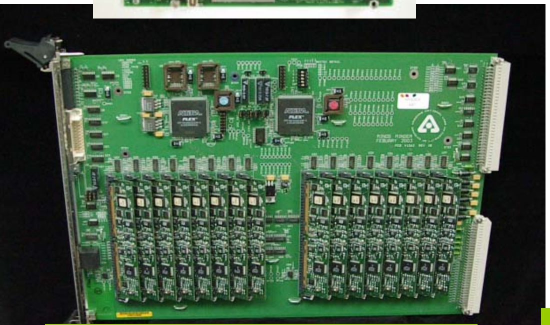
» **Strengthens HEP Program**

» **Provides Crucial Electronics Support for ANL Science & Research**

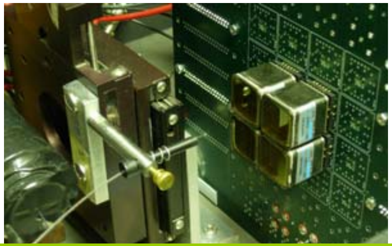
Gbit Ethernet LSC

CDF-SMX: SQUID





MINOS MINDER



TRICE 16ch MPMTs

TRSAX – for APS

MINOS MASTER

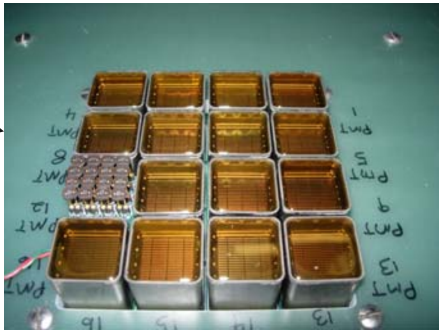
System Design – Lead Role in Sys. Design, Engineering & Management

ANL HEP Electronics Group

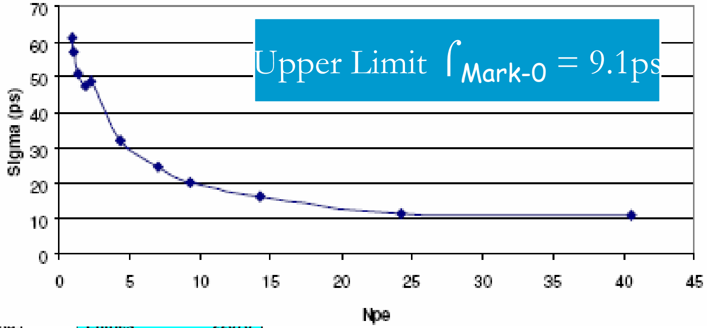
- Areas of Specialty
  - Design of High-Speed Data Processors
    - *Data Acquisition, Trigger Processors, Computer Interfaces*
    - *Recent Projects: ATLAS L2 Trigger, MINOS VME DAQ, CDF VME DAQ*
    - *Current Projects: ILC Had CAL - Data Concentrator, GRETINA Trigger,*
    - *VERITAS Topological Trigger: 500 Ch, 400 MHz Pattern Trigger*
  - Front End Design – Low-Noise, High Precision, Highly Integrated
    - *Low-Noise Charge Amplifiers, Preamplifiers, Digitizers, Discriminators, Implementation & Specification of Custom ASICs, Noise Abatement, Low-Voltage Power Supplies, High-Voltage Power Supplies*
    - *Recent Projects: MINOS Front-End, CDF Front-End, ZEUS HV PMT*
    - *Current Projects: ATLAS LV Power Supplies, Ethernet Electrometer, ILC Digital Had CAL – Front End: 64 CH Custom ASIC integral to detector - 400,000 CH "prototype"*

Other (forward-looking) R&D Programs and Activities

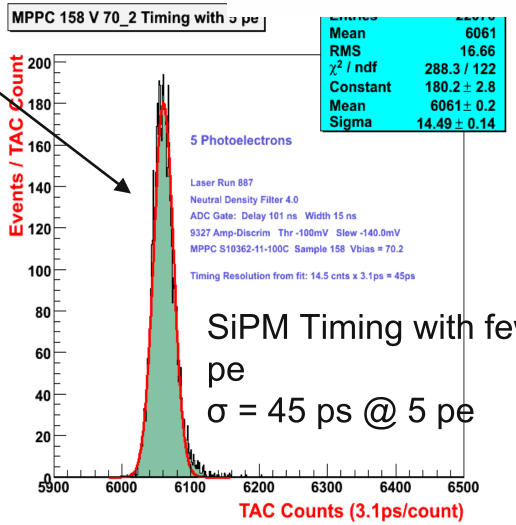
- Development of SiPM camera for AGIS
- MAPMTs for AGIS gamma-ray array; successor to VERITAS.
- Fast timing with resolution approaching 1 picosecond (with Frisch at Chicago)
- Development of fast, intelligent trigger processor for AGIS/VERITAS
- SiPM development for PET scanning (with Chen and Kao at Chicago Dept. of Radiology).
- CCD development & testing for DES
- Upgrades to ATLAS for sLHC
  - Silicon tracker, L1 Trigger, LVPS
  - Software and computing



4×4 SiPM array installed in TrICE camera where first Cherenkov images recorded using SiPM detection



Timing resolution vs # pe for MCP



SiPM Timing with few pe

σ = 45 ps @ 5 pe

Program Summary

- We have been a major force in CDF & ZEUS. Now ATLAS and Theory at the "energy frontier" is our main science focus.
- We were pioneers in the development of wakefield and two-beam acceleration and continue to pursue advanced accelerator R&D to establish this as a viable technology for both high frequency rf sources and for particle accelerators
- Neutrino physics has been of long-standing importance in the Division and this will continue. NOvA will provide a stepping stone towards Fermilab's future long-baseline neutrino program
- We have a strong detector R&D effort – both targeted and generic
- We have spearheaded a lab-wide initiative to establish a world-class program in nuclear and particle astrophysics & cosmology, where the understanding of dark matter and dark energy are considered to be amongst the most important physics questions to be addressed in the future

Views

- The strong support of the LHC program is essential to retaining US participation in physics at the energy frontier
- Strong support of advanced accelerator R&D is essential for the US to acquire the technology which will enable us to construct future particle accelerators at the energy frontier. Historically, advances in this type of technology have significant benefits in other basic sciences.
- Astrophysics and the quest for the understanding of dark matter and dark energy with its connection to accelerator-based particle physics will increase in importance – eventually we must be able to produce DM in a controlled environment
- Neutrino physics will continue as a strong element of the US High Energy Physics program
- Long-term:- discoveries at the LHC will compel us to look towards a multi-TeV linear collider