Summary of Alignment & Metrology Activities at Fermilab

Bocean, Ford, Greenwood, Kyle,
Oshinowo

Fermilab

Summary Of A&M Activities At Fermilab

IWAA08
February 11-15, 2008
KEK
Rick Ford

- Its been a very challenging time for our group since the last IWAA.
- We have lost three members of our group since we met last including George Wojcik (may he rest in peace) and our former group leader Terry Sager (retired).
- More recently our lab has suffered a huge loss in funding and we are struggling to survive.

Fermilab

Summary Of A&M Activities At Fermilab

IWAA08
February 11-15, 2008
KEK
Rick Ford

- With all our challenges, we have succeeded in supporting a large shutdown last fall and simultaneously supporting ILC cryomodule construction.
- We are expecting the Tevatron to shutdown in 2010. This has always been a large support function for our group.
- However, we expect that effort will be supplanted by new efforts in support of interesting projects such as Project X, Nova, Minerva, Dark Energy Survey, Mucool, and our robust test beam program.
- Future work on the ILC is dependent on funding.

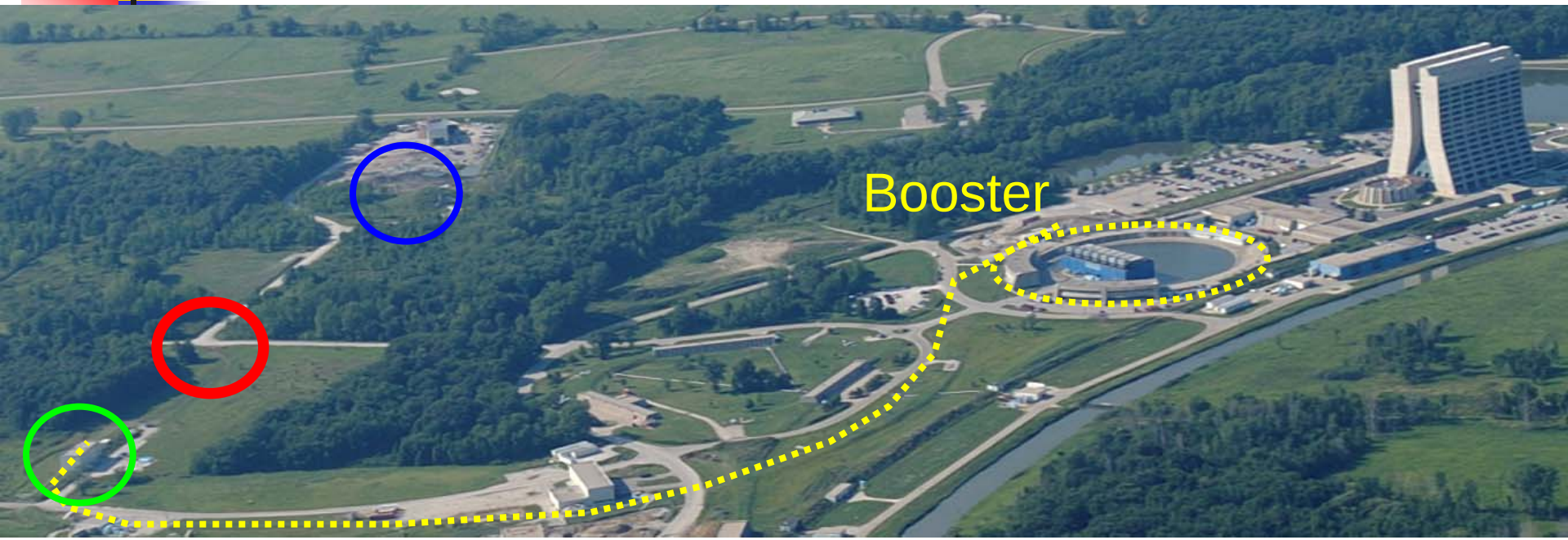
Fermilab

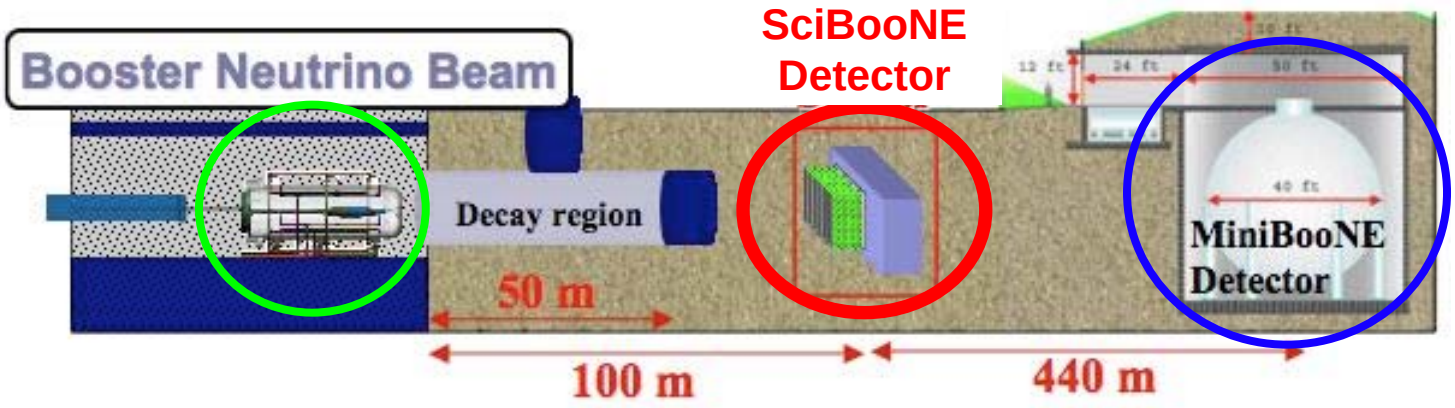
SciBooNE

- New *precision neutrino interaction experiment* at Fermilab
- SciBooNE = *Sci*Bar *Boo*ster *N*eutrino *E*xperiment
- K2K SciBar Neutrino Detector (KEK)
  - Finely segmented tracking detector
  - Fully active – used in K2K
- Booster Neutrino Beam (FNAL)
  - An intense and low energy beam (~1GeV)
  - Both neutrinos and anti-neutrinos
- The experiment *successfully started* in June 2007 and it is currently taking data

SciBooNE Site orientation

IWAA08
February 11-15, 2008
KEK
Rick Ford



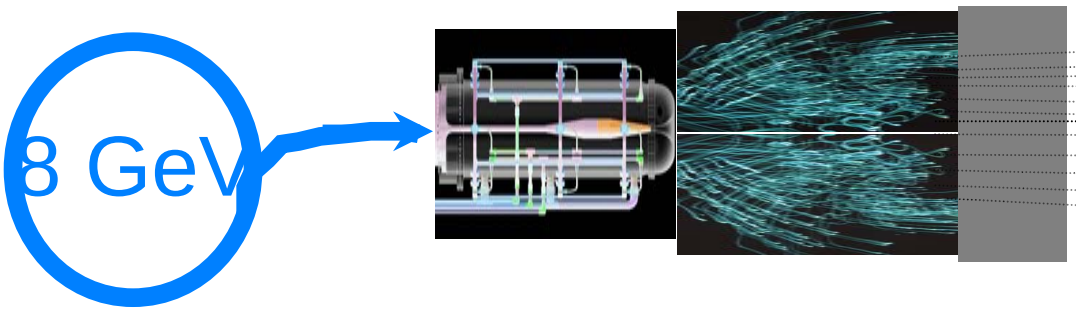


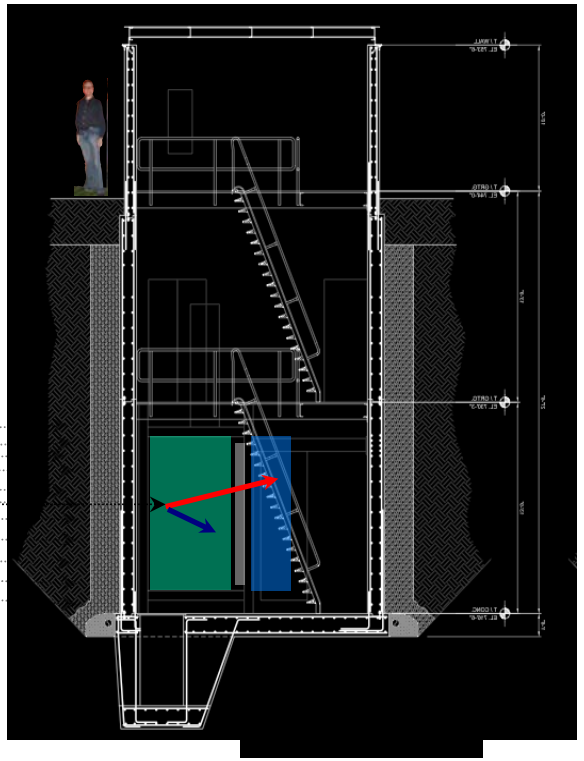
Fermilab

SciBooNE Overview

IWAA08
February 11-15, 2008
KEK
Rick Ford

- Physics Goals:
  - Precision study of neutrino cross sections for T2K
  - Anti-neutrinos
    - unexplored physics territory
    - important for CP study in T2K-II
  - MiniBooNE near detector
    - improve analysis

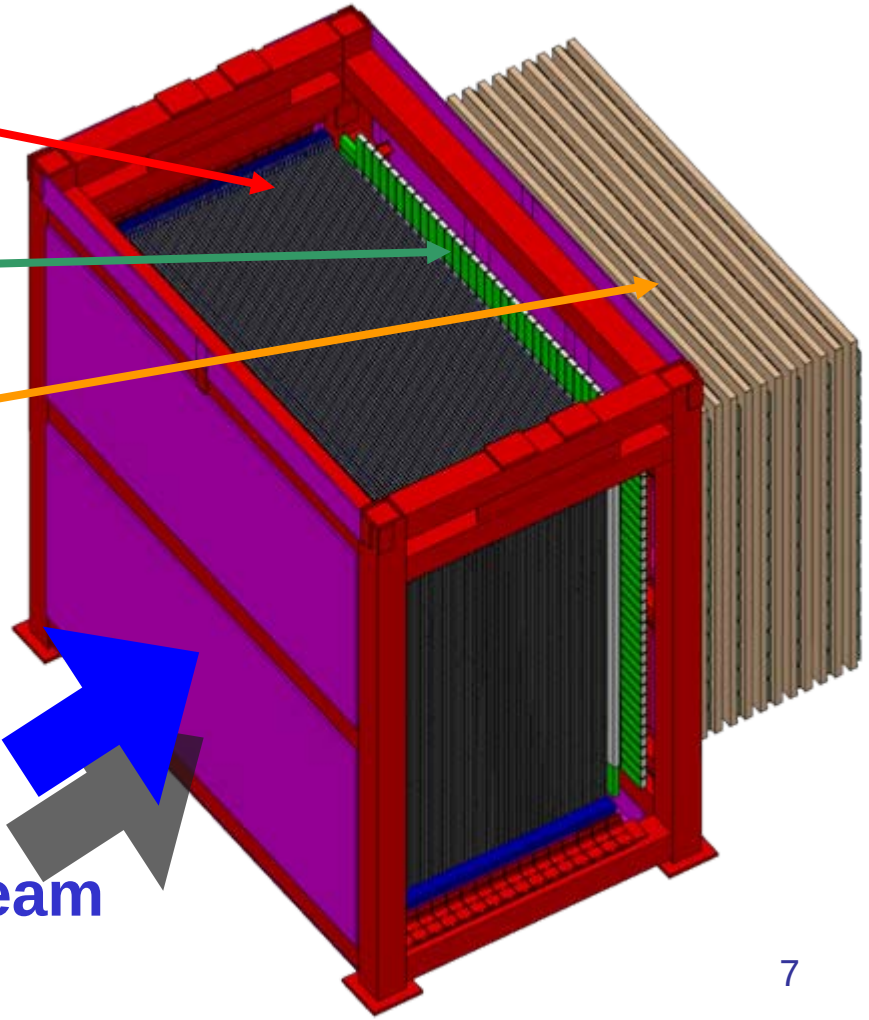




SciBooNE Detectors

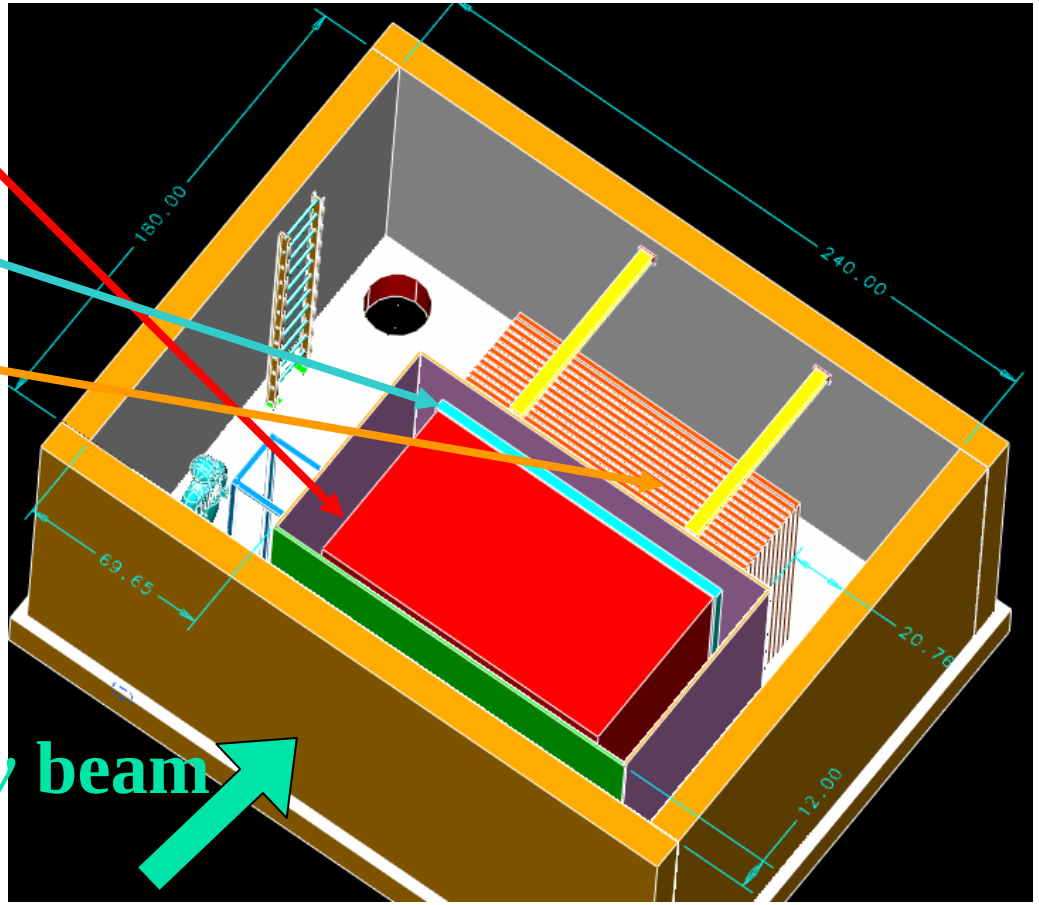
- Scintillator Bar (SciBar) Detector
  - From KEK, Japan
- Electron Calorimeter (EC)
  - From KEK, Japan
- Muon Range Detector (MRD)
  - Built at Fermilab

- detectors assembled in CDF Hall



SciBooNE Detectors

- Scintillator Bar (SciBar) Detector
  - From KEK, Japan
- Electron Calorimeter (EC)
  - From KEK, Japan
- Muon Range Detector (MRD)
  - Built at Fermilab
- detectors installed in new SciBooNE Detector Hall
  - very tight space



Fermilab

SciBooNE
AMG Support

- Tolerance: relative positions of detectors components with respect to each other and to the beam known to 1 mm (1σ)
- Established survey network in the new SciBooNE Detector Hall (including ties to Fermilab Primary network): $\pm$ 0.5 mm at 95% confidence
- Reference of the SciBar and MRD detectors during assembly phase: 0.1-0.2 mm
- Precision surveys to support the installation and positioning of the detectors in the Detector Hall to better than 0.5 mm
- Various monitoring deformations surveys of the detector components and experimental hall

Fermilab

MINERvA

- New *neutrino scattering experiment* at Fermilab
- MINERνA = *M*ain *I*njector *N*eutrino *E*xpe*R*iment for *ν-A*
- The MINERνA detector - placed in the NuMI beamline:
  - high intensity beam
  - provides a wide range of neutrino energies

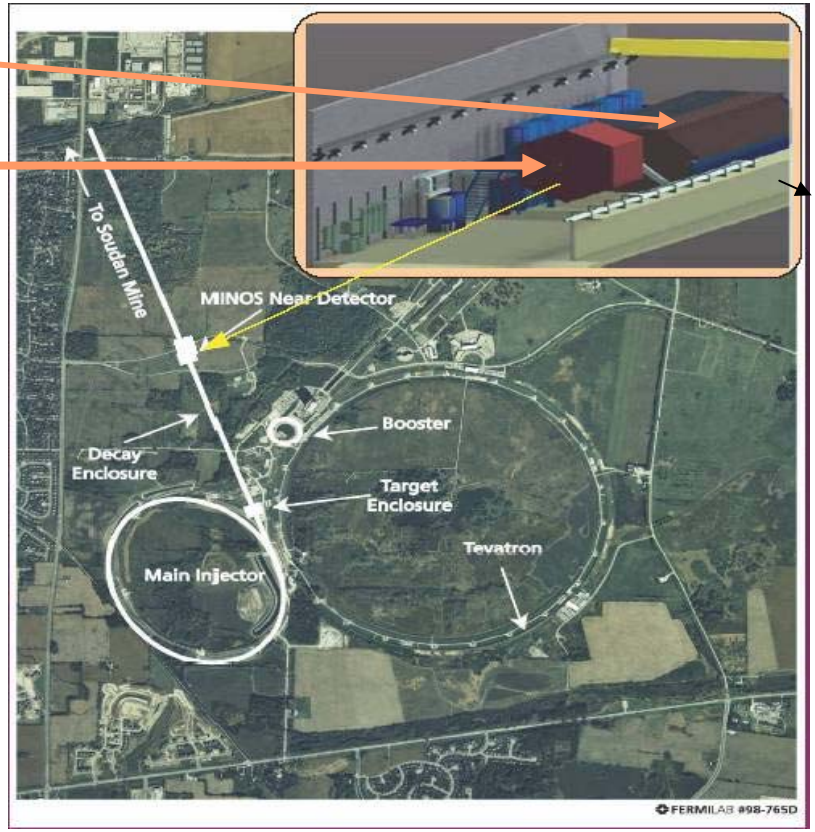
➢ *Physics Goals*:
  - precision measurements low energy neutrino interactions
  - first study of neutrino induced nuclear effects

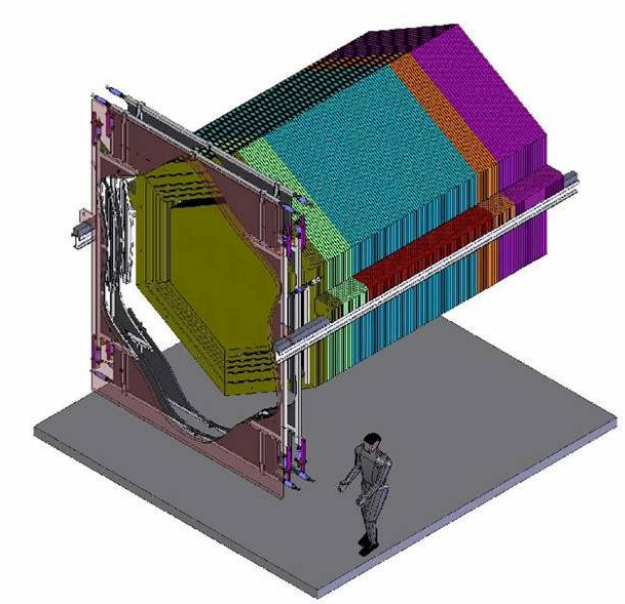
- MINERvA will provide crucial input to current and future oscillation measurements

MINERvA Site orientation

MINOS ND

MINERνA



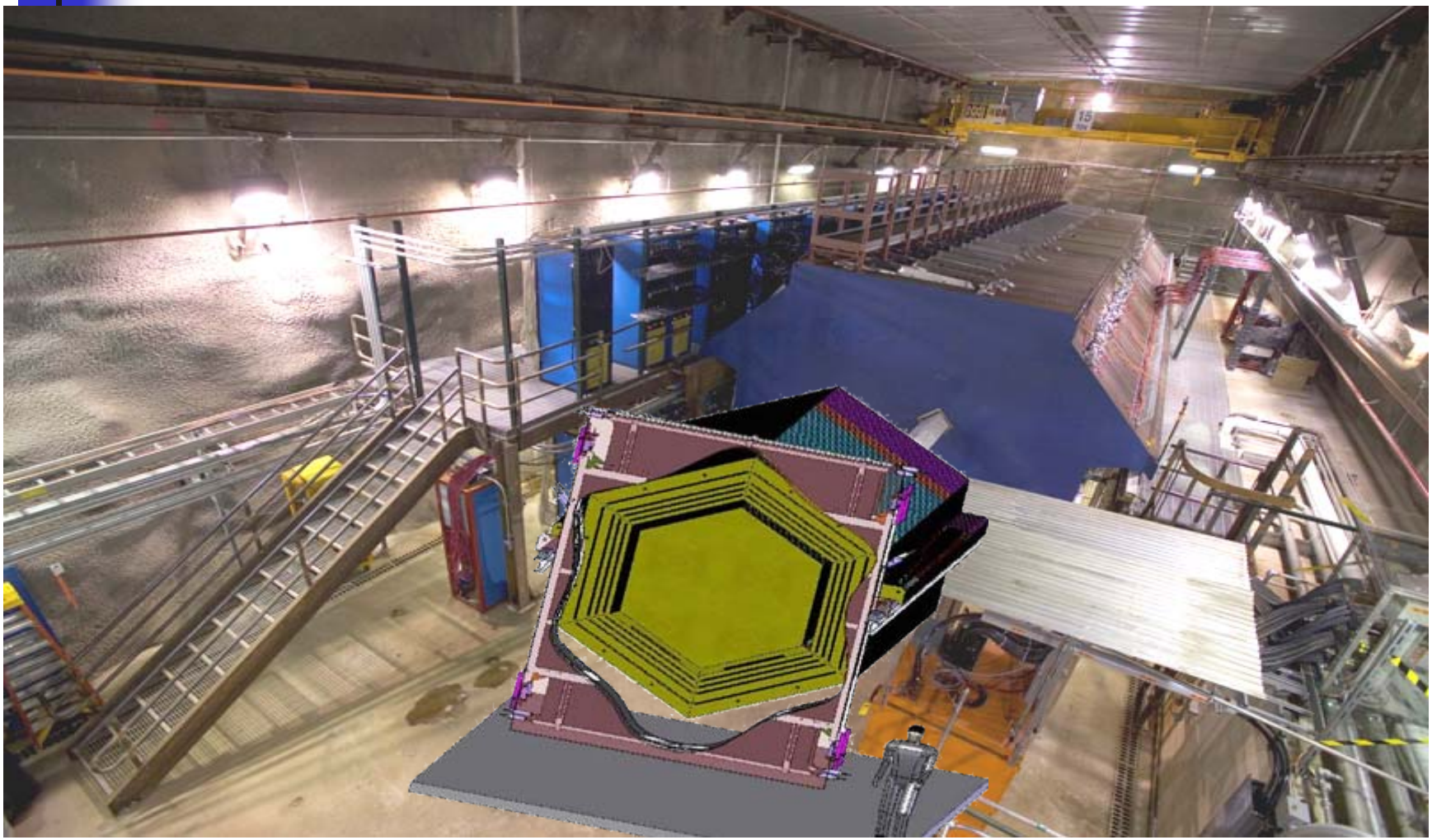


- in the NuMI beam
- upstream of MINOS near detector

Fermilab

MINERvA Detector
and the MINOS Hall

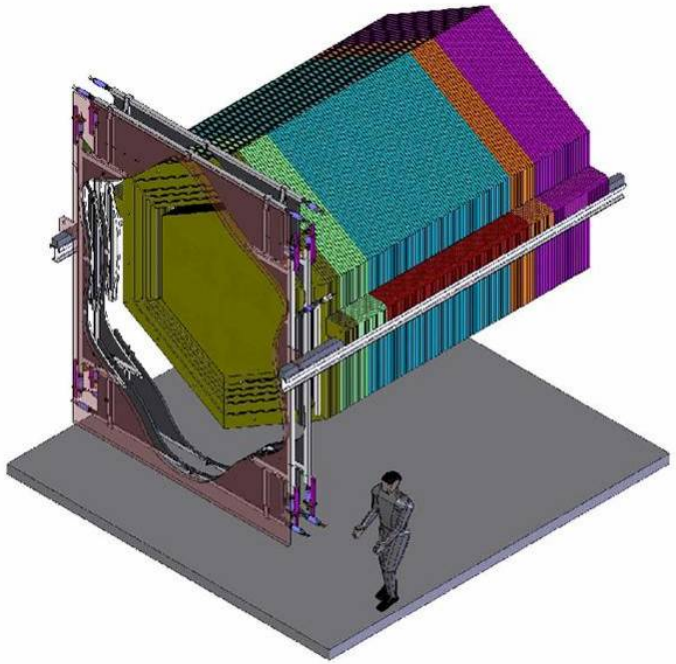
IWAA08
February 11-15, 2008
KEK
Rick Ford



Fermilab

MINERνA Detector

- Detector constructed from ~100 modules
  - Inner Detector - layers of scintillator
  - Outer Detector - steel frame – calorimeters
- Need to know:
  - Position of detector with respect to beamline
  - Relative position of inner detector scintillator after hanging
  - Stability over time
- Required Accuracy = 1-2 mm

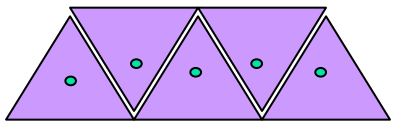


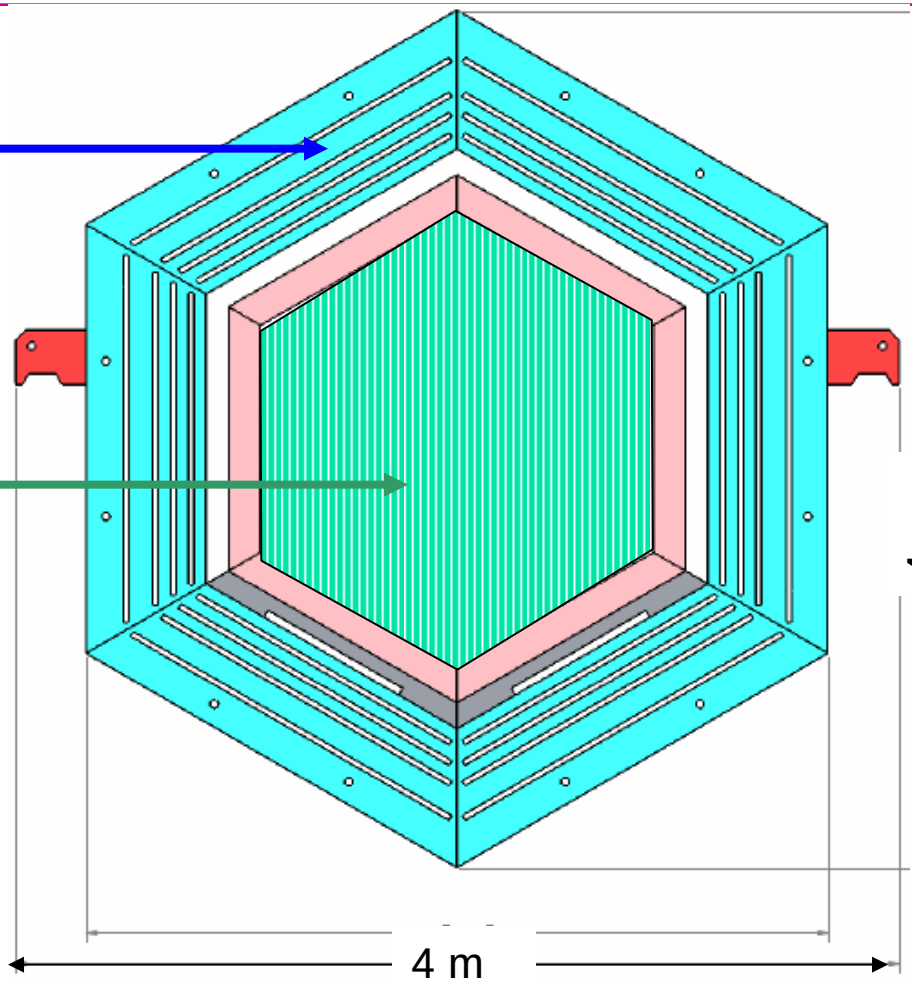
MINERvA Detector Module

Outer Detector (OD)
Layers of iron/scintillator for hadron calorimetry.

Inner Detector (ID)

Scintillator planes made of triangular extrusions laid out into planes





Weighs 2.5 ton

Fermilab

MINERvA
AMG Support

- During module prototype assembly and installation:
  - Quality control of various components during assembly
  - Monitored module components deformation during installation
  - Analysis of the spatial geometry of all module prototype components before/after hanging
  - Monitor stability over time
- Results: relative positions of the scintillator planes remain within tolerance (to each other and to outer supporting frame)
- Installation procedure, instrumentation and accuracy (0.5 mm) same as for the MINOS Near Detector

Fermilab

MINERvA
Current Status and Schedule

- Construction of the MINERvA experiment has been approved in November 2007
- Construction begun: 20 modules will be built in first half of 2008
- Detector installation and ***commissioning in 2009***

Upgrade of MTest Beam line from M03 thru MT6

- Redesign of the MTest beamline to accommodate for ILC needs
- Design was to provide secondary beam at ultra-low to high energies, from approx 1 GeV to 90 GeV in addition to a primary, 120 GeV proton mode of operation
- New design allowed for improved beamline monitoring and particle ID, which included
  - reduction of material in the beam,
  - addition of differential Cherenkov counter,
  - additional instrumentation (TOF, Fiber Profile Monitors, movable target)

MTest Beamline
(M02 thru MT6)

MTest Control Networks

- MTest upgrade was from M03 thru MT6 (~215 metres)
- Installation and densification of new monumentation for Horizontal and Vertical Control Networks from M02 thru MT6 (~425 metres)
- Vertical Network tied to Site Coordinate Coordinate System (FSCSH)
- Horizontal Network measured with Laser Tracker and processed as a trilateration network
- Incorporated historical data from previous campaigns into overall adjustment to study control network behaviour which included: Mekometer distances, E2 angles, and Gyro azimuths

Alignment Support

- Referenced beam line components and instrumentation (Fiber Profile Monitors, PWC's, Target)
- Established horizontal and vertical network throughout the beam line and enclosures from M02 thru MT6
- Laser Tracker As-found+referencing of primary components from M02 thru MT6 prior to upgrade
- Provided initial layout of beam line components prior to and during installation of components
- Final alignment of components
- Data reduction/analysis of each component in various coordinate systems (Reference/Local/Global)

Fermilab

Reference of Scintillating Fiber Profile Monitor

IWAA08
February 11-15, 2008
KEK
Rick Ford

Multi-anode phototube scintillating-fiber profile monitor:

- designed to sample the position and size of the beam via scintillating fibers in a vacuum
- minimizing the material interacting with the beam (especially crucial with low-energy beams)

Referencing:

- traditional optical tooling methodology – non contact survey
- Instrumentation required: Tooling Bars/Brunson's/N3's
- Incorporated fiducials to accommodate either optical tooling or Laser Tracker alignment
- Fibers Referenced both horizontally and vertically to external fiducials
- Coordinates generated with optical tooling accuracies
- Data input and reduction completed in Excel template

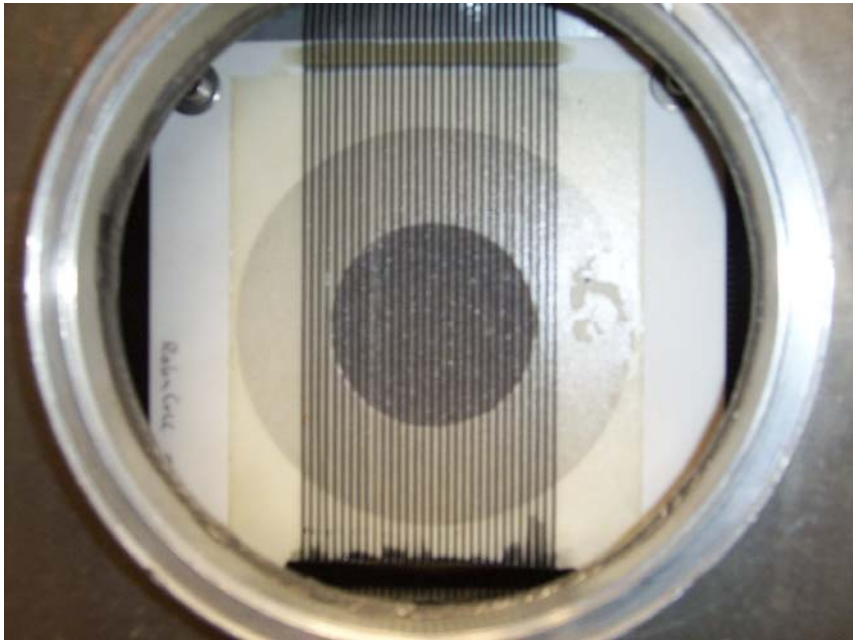
Fermilab

Reference of Scintillating Fiber Profile Monitor

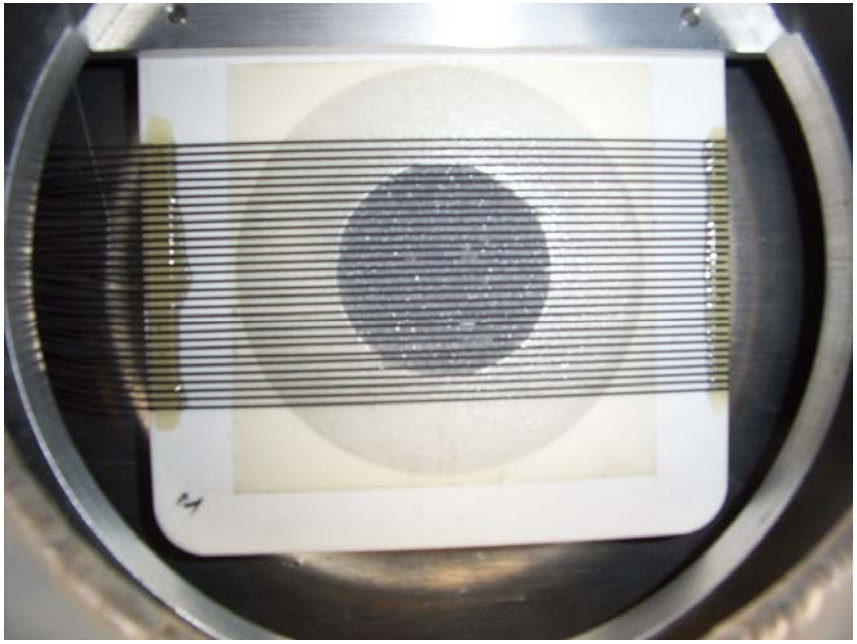
IWAA08
February 11-15, 2008
KEK
Rick Ford

- Fiber plane assembly constructed from a set of 32 scintillating fibers mounted on two orthogonal ceramic boards
- Unique identifier/serial number for each profile monitor
- Disassembly of Profile Monitor Housing or installation of new plane(s) requires new reference

Horizontal Fiber Plane

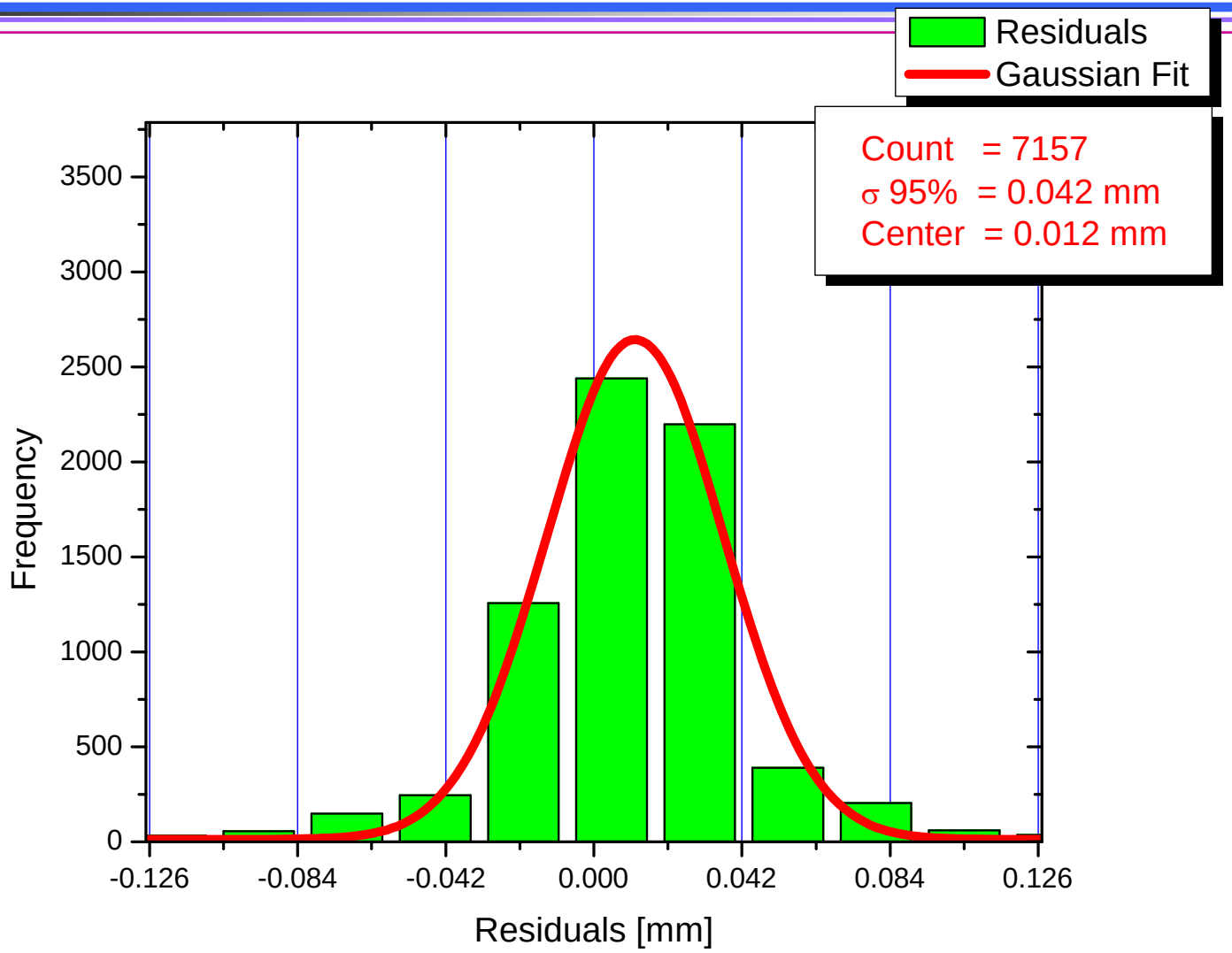


Vertical Fiber Plane



MTest Tunnel Network

Histogram of standardized residuals (bar scale tick = 1 σ)

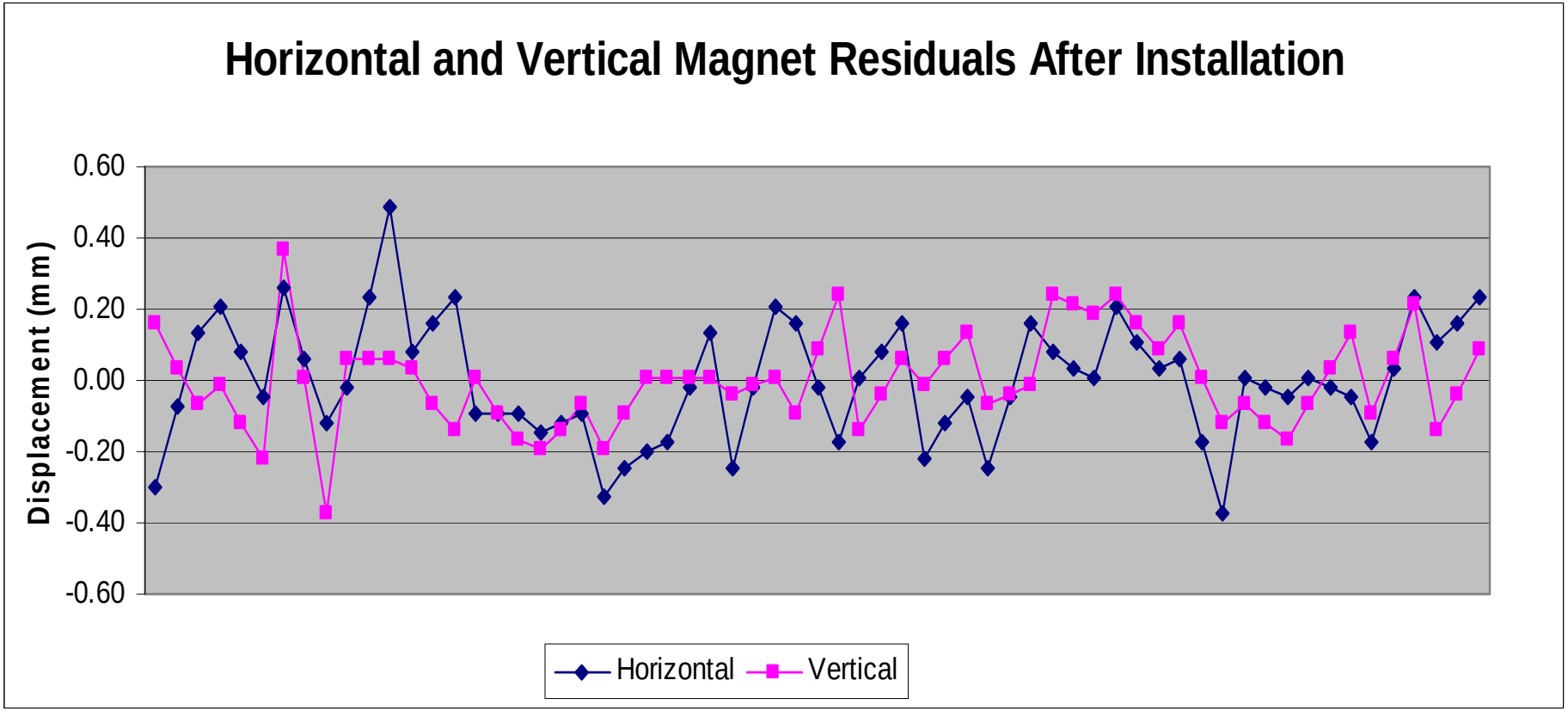


Fermilab

MTest Primary beamline
Magnets alignment results

IWAA08
February 11-15, 2008
KEK
Rick Ford

- Alignment **tolerance**: Horizontal ±1 mm at 95% confidence level
- Alignment **results**: Horizontal/Vertical residuals ±0.33/0.26 mm 95% confidence level



Booster Upgrade

- A major project to build a new corrector system for the Booster to replace old ones
- System to increase Booster efficiency required to meet the needs of the neutrino program over the next several years
- Schedule to install 48 correctors by 2008 shutdown. 12 installed during 2007 shutdown.

Fermilab

2 MW upgrade of the Main Injector

IWAA08
February 11-15, 2008
KEK
Rick Ford

- Fermilab working on a roadmap towards the goal of a 2 MW upgrade of the Main Injector (MI)
- Each step will help improve the MI performance in its present (Run 2) and near future (NuMI) operations
- A critical step to achieving this goal are the collimators used to localize beam loss in MI.
- 4 Collimators installed during 2007 shutdown

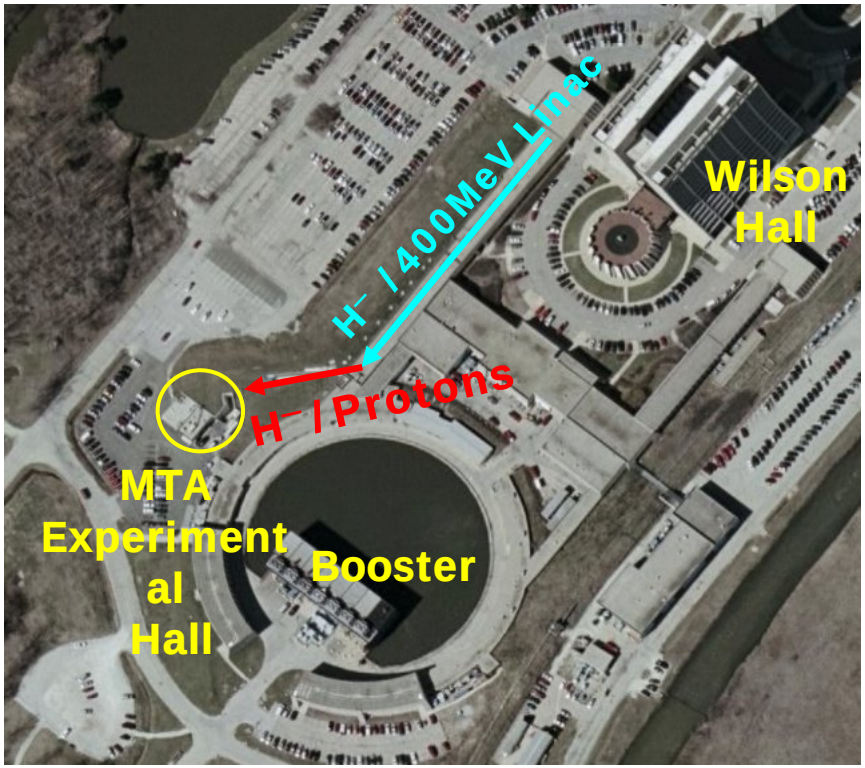
MuCool Test Area (MTA) Beam Line

IWAA08
February 11-15, 2008
KEK
Rick Ford

- MuCool Test Area (MTA) is designed to develop and test muon ionization cooling components using the intense Fermilab Linac beam

- MTA Beam Line is a simple beam line to transport **H^-** or proton beam from the end of the Fermilab 400 MeV Linac to the MTA

- MTA Beam Line installed and aligned during Shutdown 2007

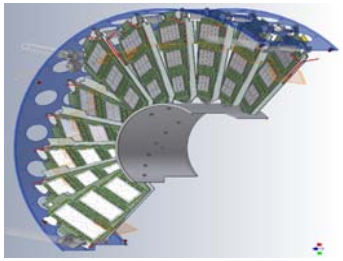


CMS Forward-pixel Detector As-built Survey

IWAA08
February 11-15, 2008
KEK
Rick Ford

AMG Support:

- Measure the installed locations of the half-disk in the canoe, a 2.5m long, carbon fiber half-cylinder
- Do this for each of four cylinders
- Use only non-contacting methods
- Precision: < 10 μm – 1μm
- Develop compatible photogrammetric targeting for use with optical and touch-probe CMM systems



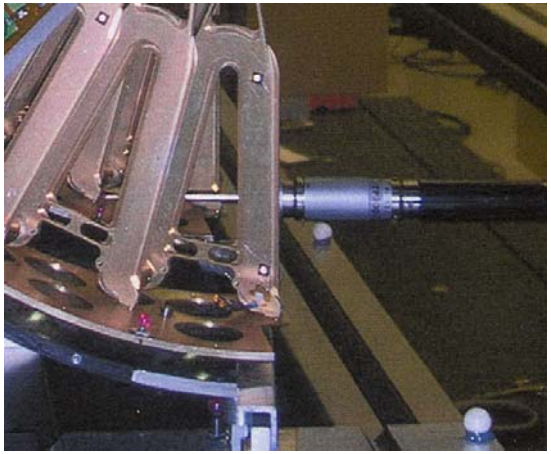
Fermilab

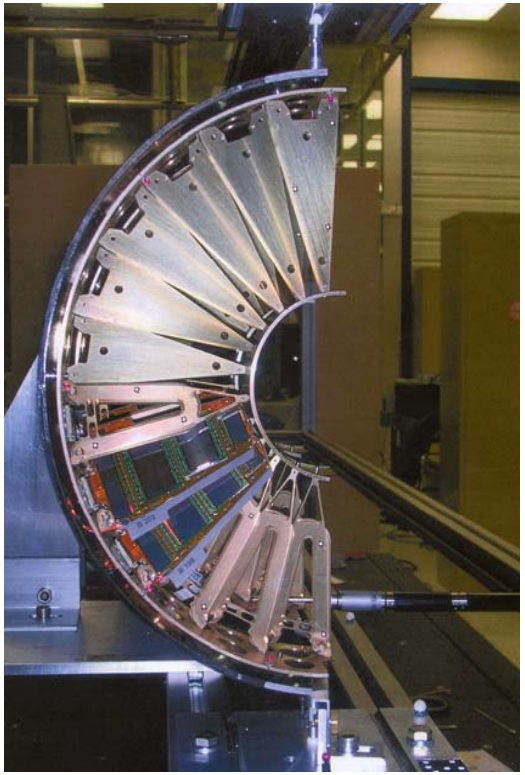
Renishaw probe in no-man's land

CMM nightmare:

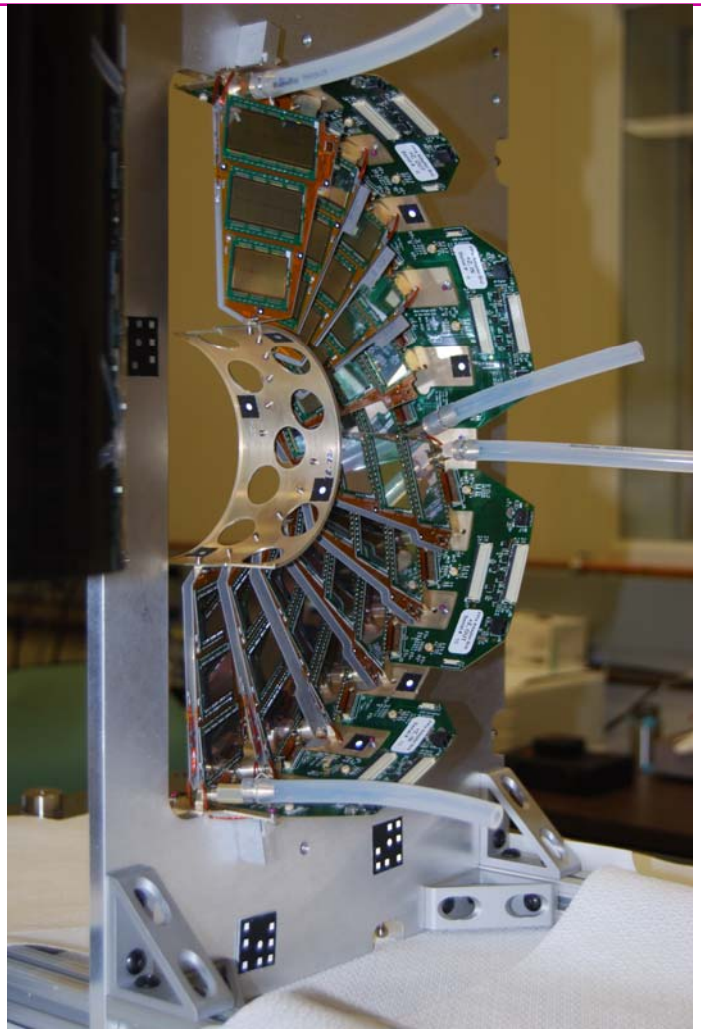
Problem: Using a touch-probe on 3 mm balls from 3m away, around a corner, in a forest of custom silicon.

Solution: Photogrammetry to the rescue.





Photogrammetry
Survey setup for completed half-disk



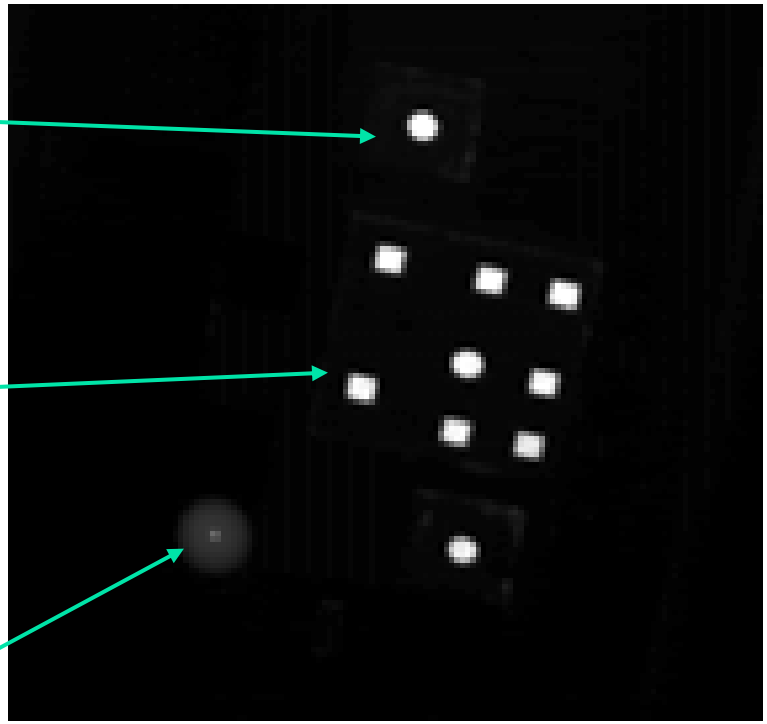
CMM touch-probe to photogrammetry connection

Fermilab

3-mm retro target

3-mm coded target

8-mm ceramic sphere



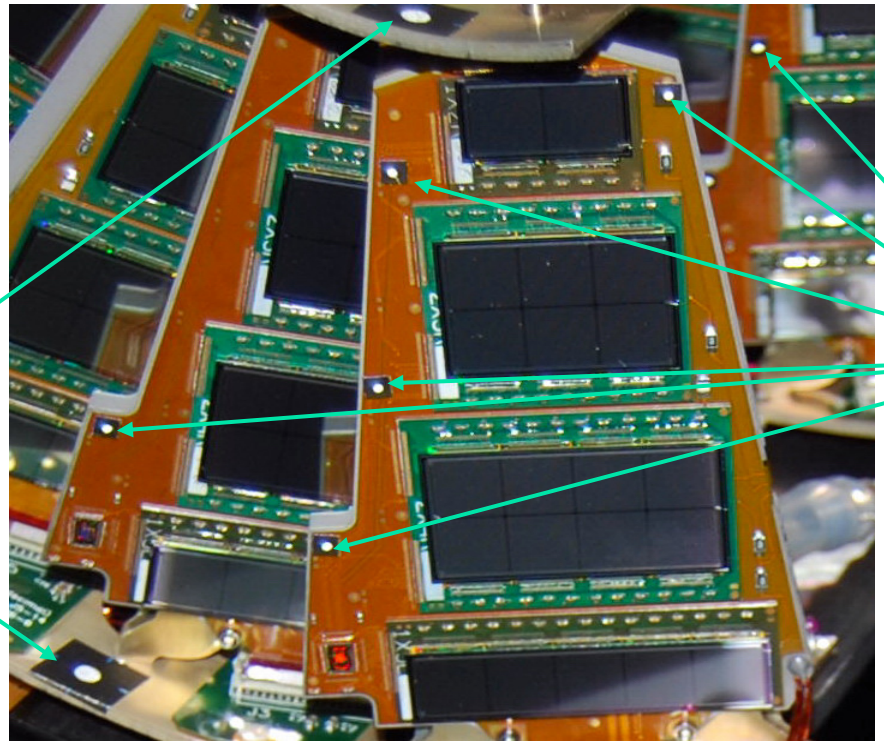
Photogrammetry '**sees**' all features; CMM '**touches**' ceramic ball

Fermilab

Introduction of 1mm retro-targets

Silicon has fiducials. OGP* can 'see' both 1mm retros and fiducials. Provides link and scale

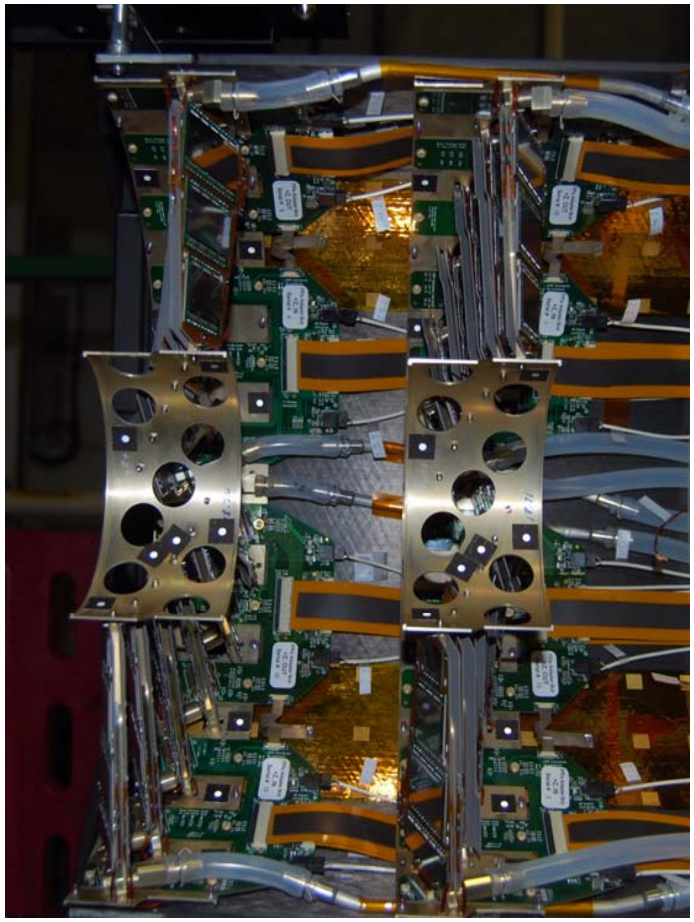
3mm retros; too big for OGP FOV

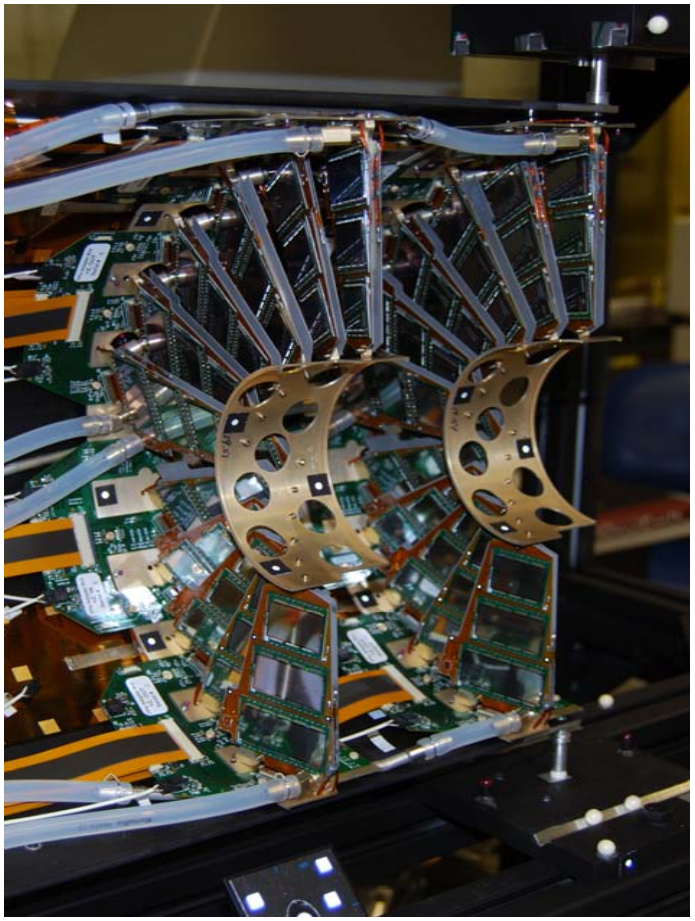


1mm retros on silicon carriers

* Optical Gaging Products CMM

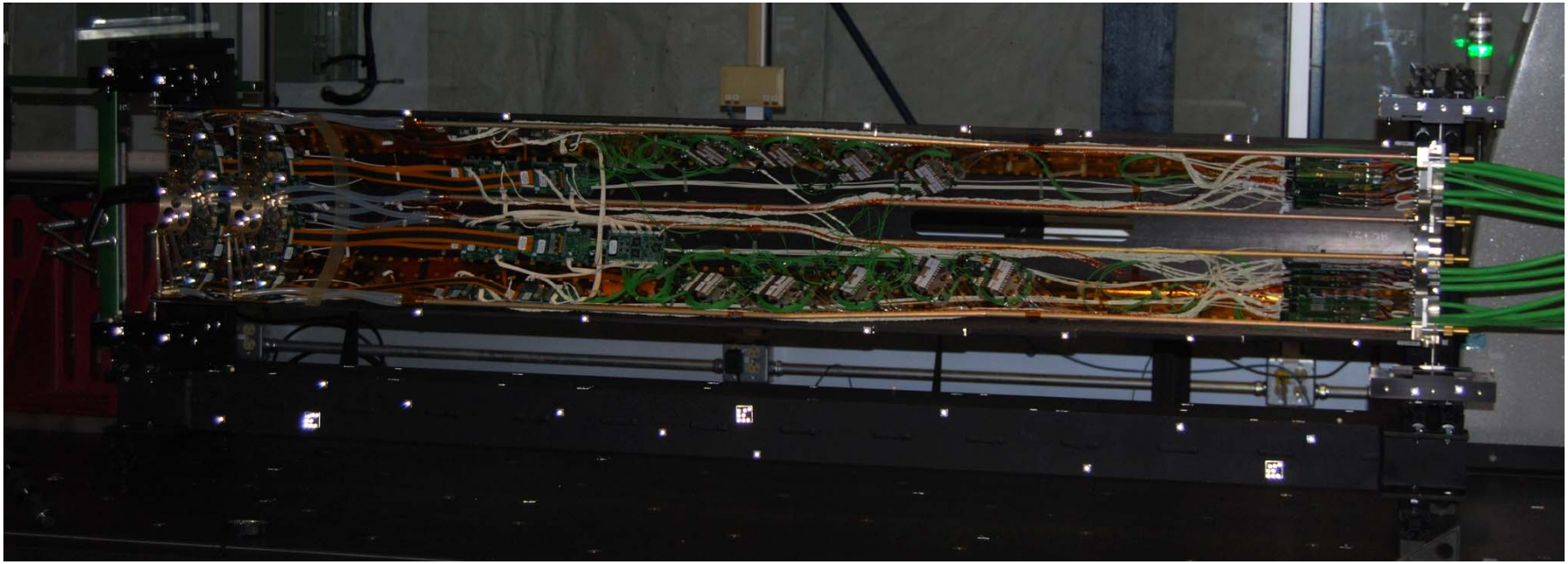
Installed half-disks





Fermilab

Completed ‘canoe’ (1 of 4)



Dark Energy Survey
Cooperative venture with FNAL and CTIO*

IWAA08
February 11-15, 2008
KEK
Rick Ford

Fermilab

AMG Support:

- DECam – Measure the focal plane flatness < 5 μm, while under vacuum at –100° C
- Support the mirror mount remediation
- Participate in the design of a real-time camera positioning system
- Support the camera + hexapod positioning system simulation and testing

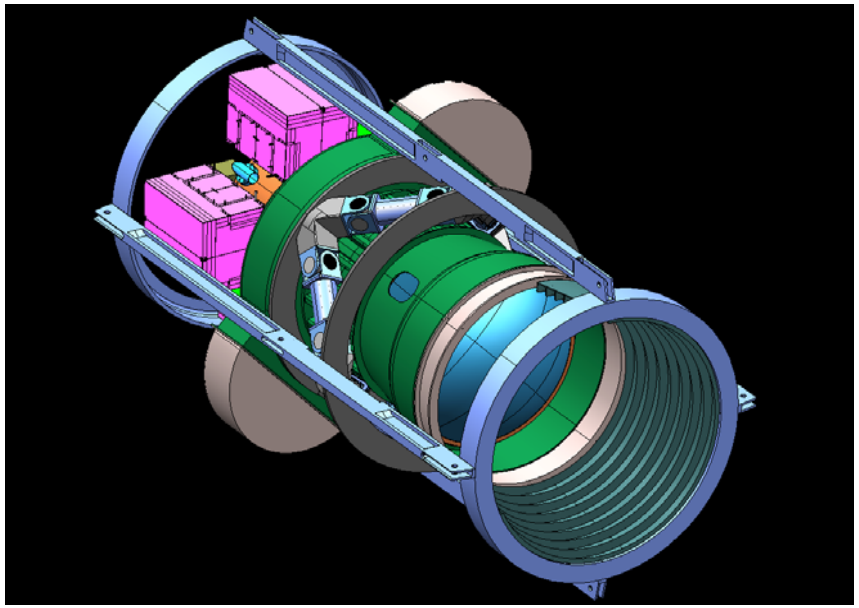
*Cerro Tololo Inter-American Observatory, Chile

DARK ENERGY SURVEY

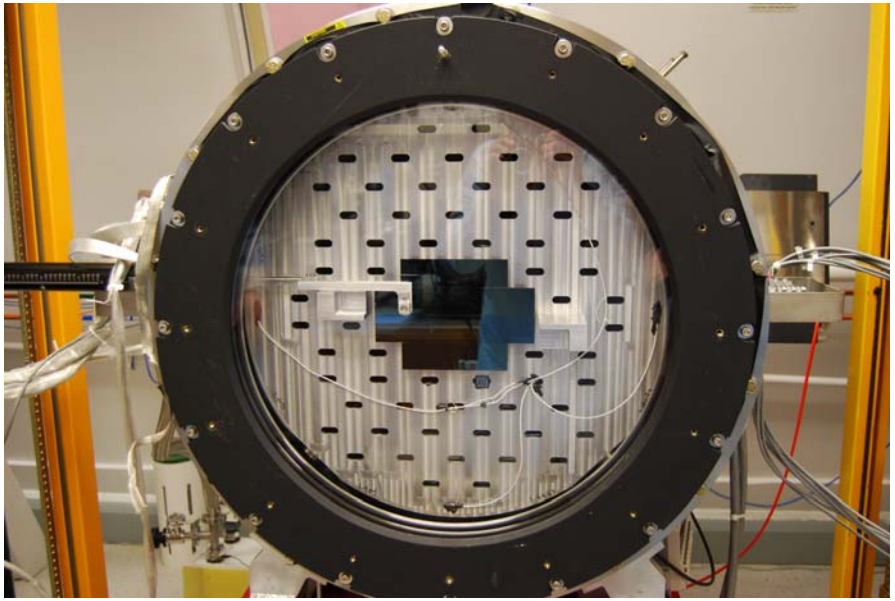
Fermilab

Measure DECam image plane flatness of 62 CCD cells

IWAA08
February 11-15, 2008
KEK
Rick Ford



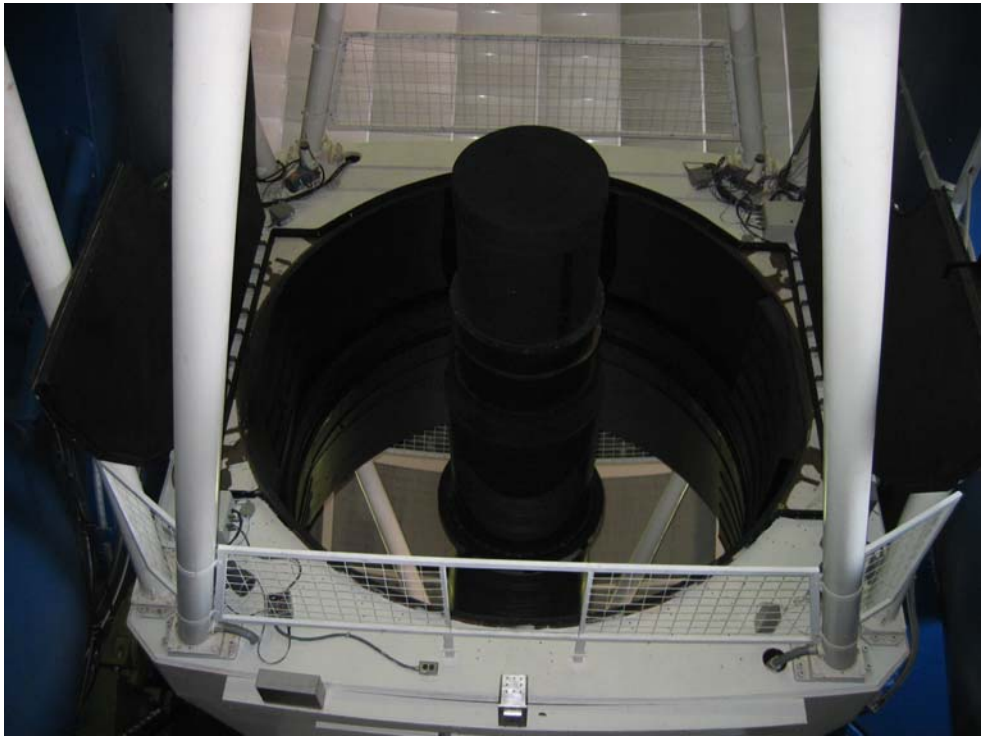
Schematic of 500 M-pixel camera



Focal plane of DECam showing
10 of 62 CCD, each 3x6 cm

ID = 48.62cm

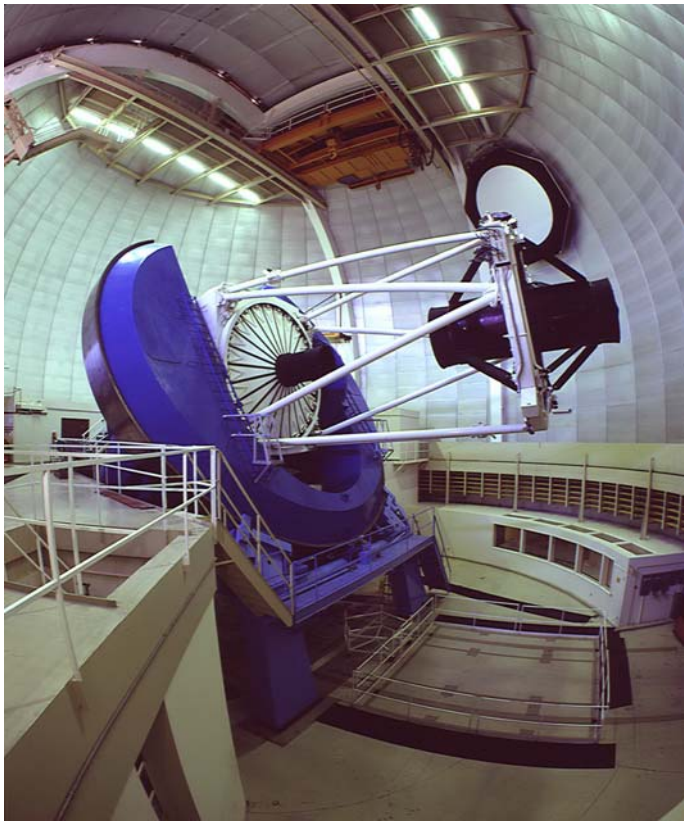
Support the mirror mount remediation



- 4 m parabolic mirror is held in place by 24 brackets
- Brackets have a history of breaking off
- Likely cause is imprecise positioning of brackets, thereby causing tension in the system
- Measure the location of the ring girder slots and position the H-beam brackets on the mirror using LaserTracker

Fermilab

Camera positioning system design requirements



- Camera is 10 m from 4 m mirror
- Camera is mounted on a hexapod positioning system. Feedback is required between images
- Accuracy required:
  - 1 arcsec tip and tilt
  - 25 μm x-y translation
  - 5 μm focus distance
- Use 1500 nm emitters – DECam is 'blind' at that wavelength

Fermilab

Support the DECam hexapod motion study

- Develop a measurement plan to support the testing of the camera positioning system on the telescope simulator system

Conclusion

- It has been a very busy and challenging few years since the last IWAA
- We have had successfully supported all the ongoing and new projects, including a large shutdown last fall.
- We are continuously improving our methods and technology.
- With the expecting shutdown of the Tevatron in 2010, we will put our efforts in the near future in supporting other new interesting projects such as Project X, Nova, Minerva, Dark Energy Survey.
- Work on the ILC is dependent on future funding.