Status Report on the Survey and Alignment Activities at Fermilab

Virgil Bocean
Gary Coppola
Rick Ford
John Kyle

Major Alignment Activities

- TeVnet - George Wojcik
- Ecool - O'Sheg Oshinowo
- NuMI - Virgil Bocean
- Alignment Data Management System
- MIPP (Main Injector Particle Production)
- Sitewide Vertical Network Upgrade
- ILC Related Activities Including Test Beams

Alignment Data Management System

- Gary Coppola- Project mgr
- May Chau - Oracle programming
- John Greenwood - Coord conversion program
- John Kyle - Merging of elevation database
- Bocean, Oshinowo, Sager, Wojcik - Individual machine data conversion
- Numerous contributions from survey techs and consultations from others outside AMG

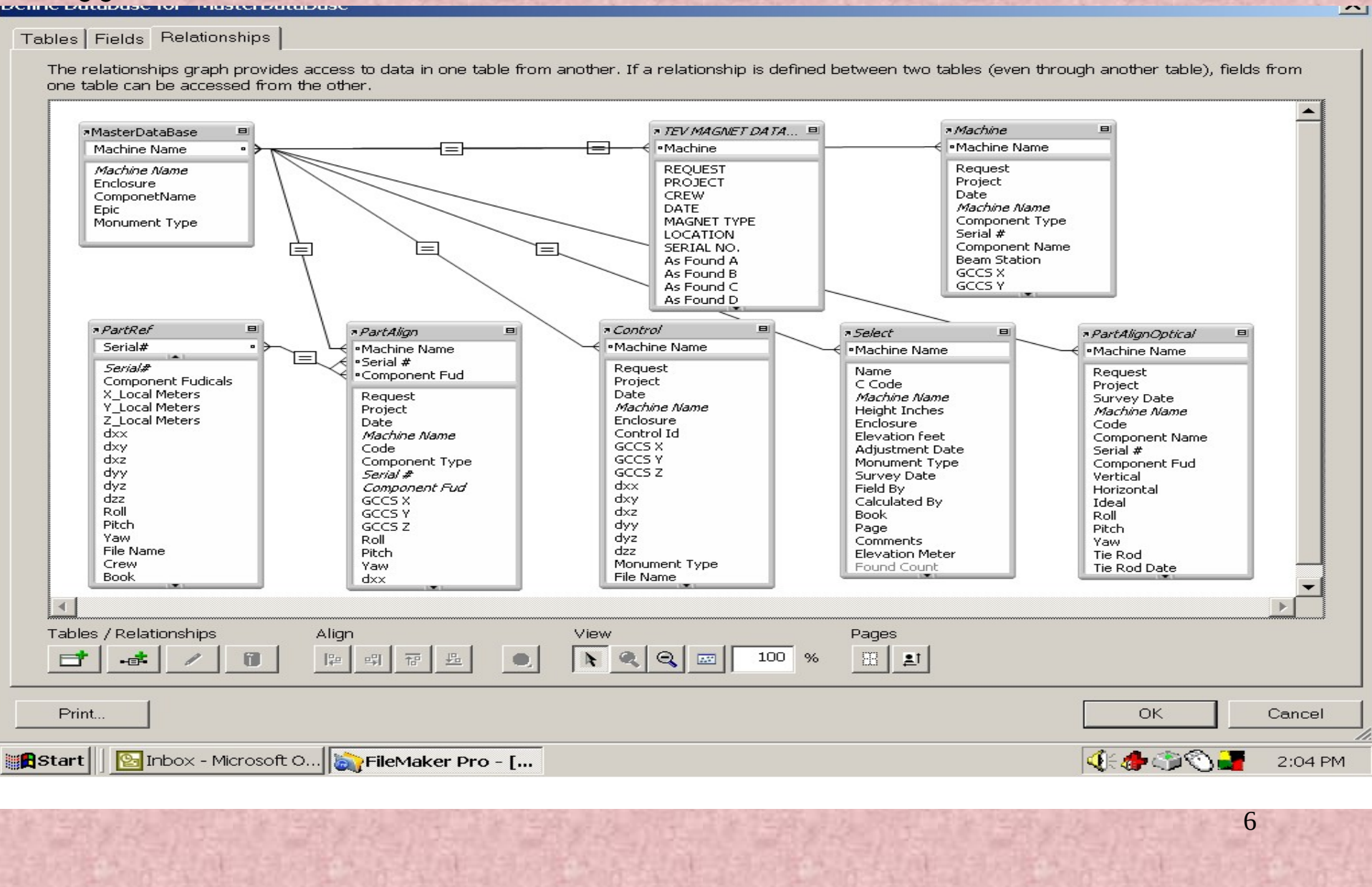
Alignment Data Management System

- Issues
  - Organization of Data
    - Multiple projects simultaneously
    - Multiple storage locations & formats
  - Non-Uniform Data Collection
    - Much data still handwritten in logbooks
    - Quality control difficult
  - Access to Data
    - Long turnaround time before client receives data
    - Changes difficult to track
    - Accelerator Div. wants to include data in device database

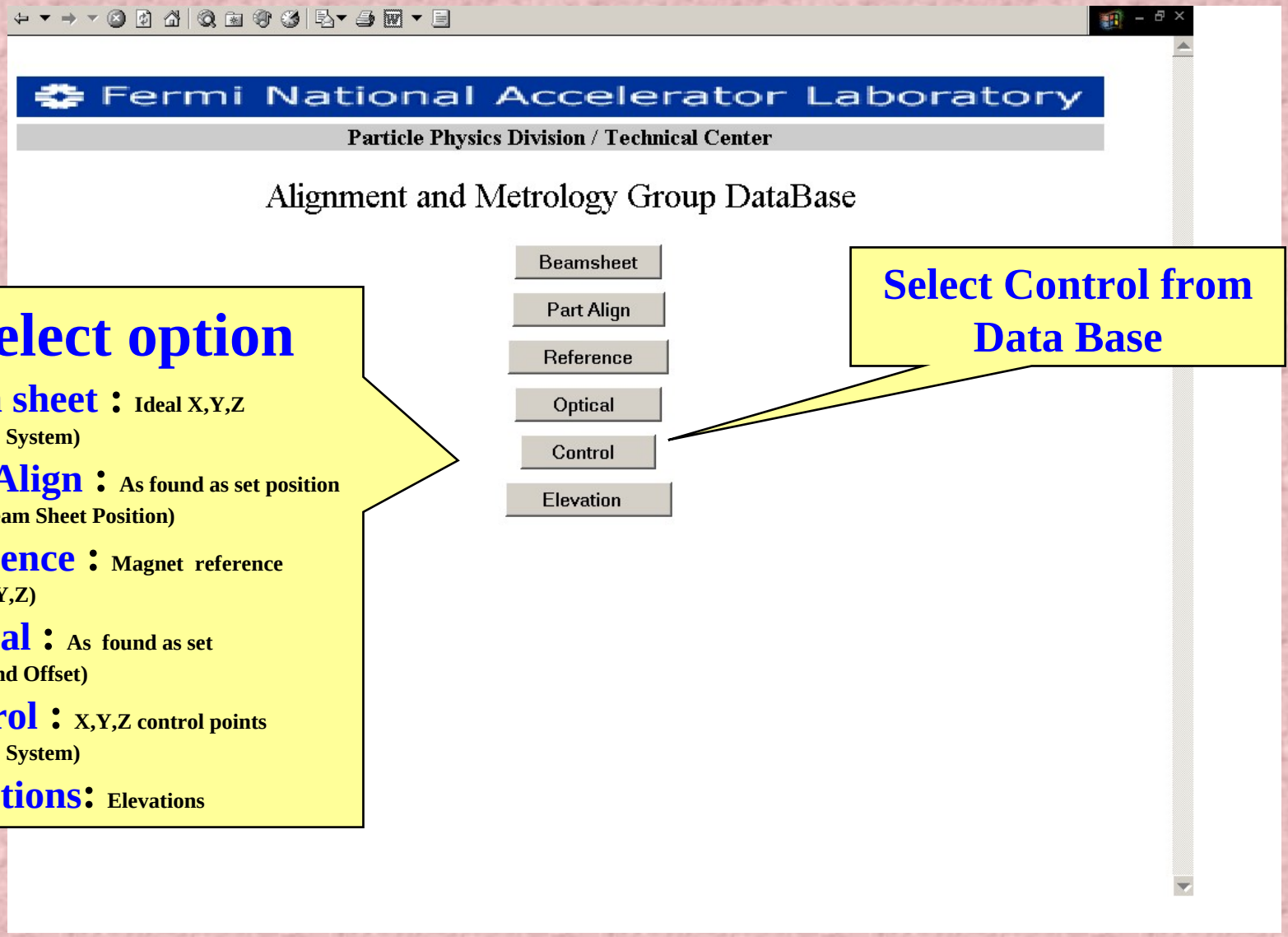
Alignment Data Management System

- Solution - New relational database with improved data collection techniques
  - Organization of Data
    - Regardless of data collection technology, data entered, checked, analyzed, & transported to client electronically.
    - Single storage location & format
  - Uniform Data Collection
    - No more handwritten data
    - Quality control much easier
  - Access to Data
    - Much shorter turnaround time to access data
    - All changes recorded and easily retrieved
    - Data accessible by other databases and web

Database Outline



Database Example



Select option

Beam sheet : Ideal X,Y,Z
(In GCCS System)

Part Align : As found as set position
(X,Y,Z Beam Sheet Position)

Reference : Magnet reference
(Local X,Y,Z)

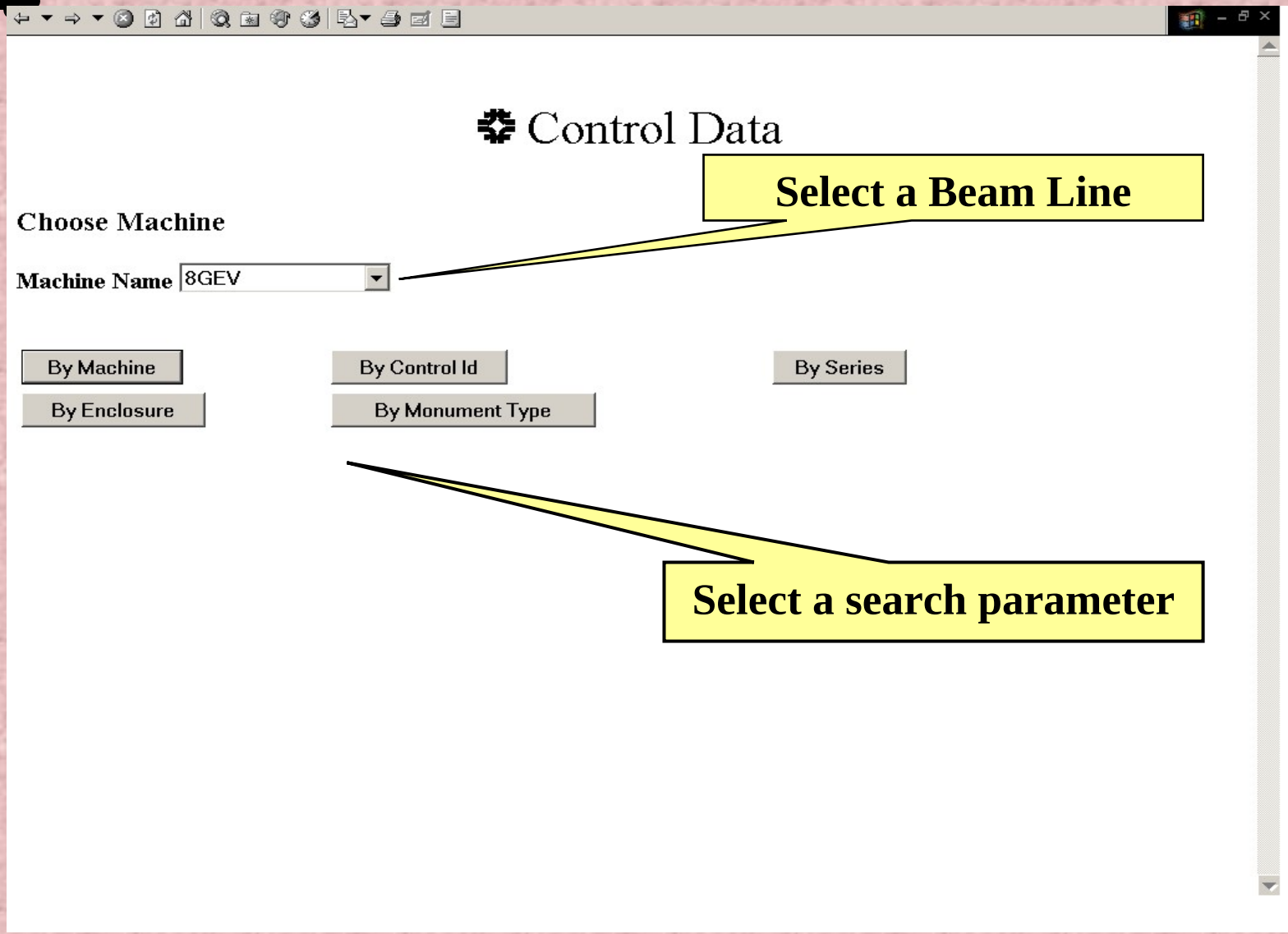
Optical : As found as set
(Height and Offset)

Control : X,Y,Z control points
(In GCCS System)

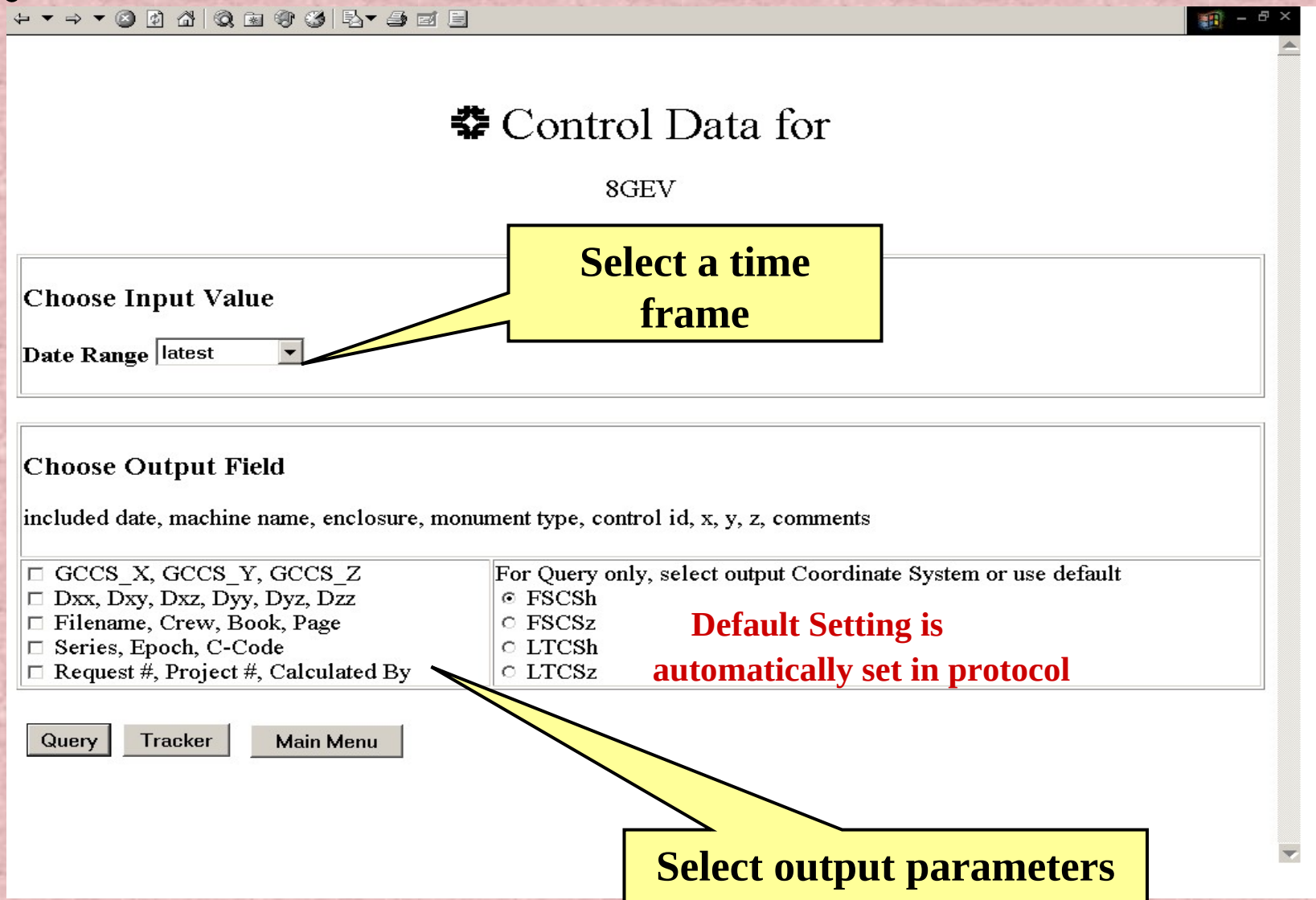
Elevations: Elevations

Select Control from Data Base

Database Example



Database Example



Database Example

Fermilab

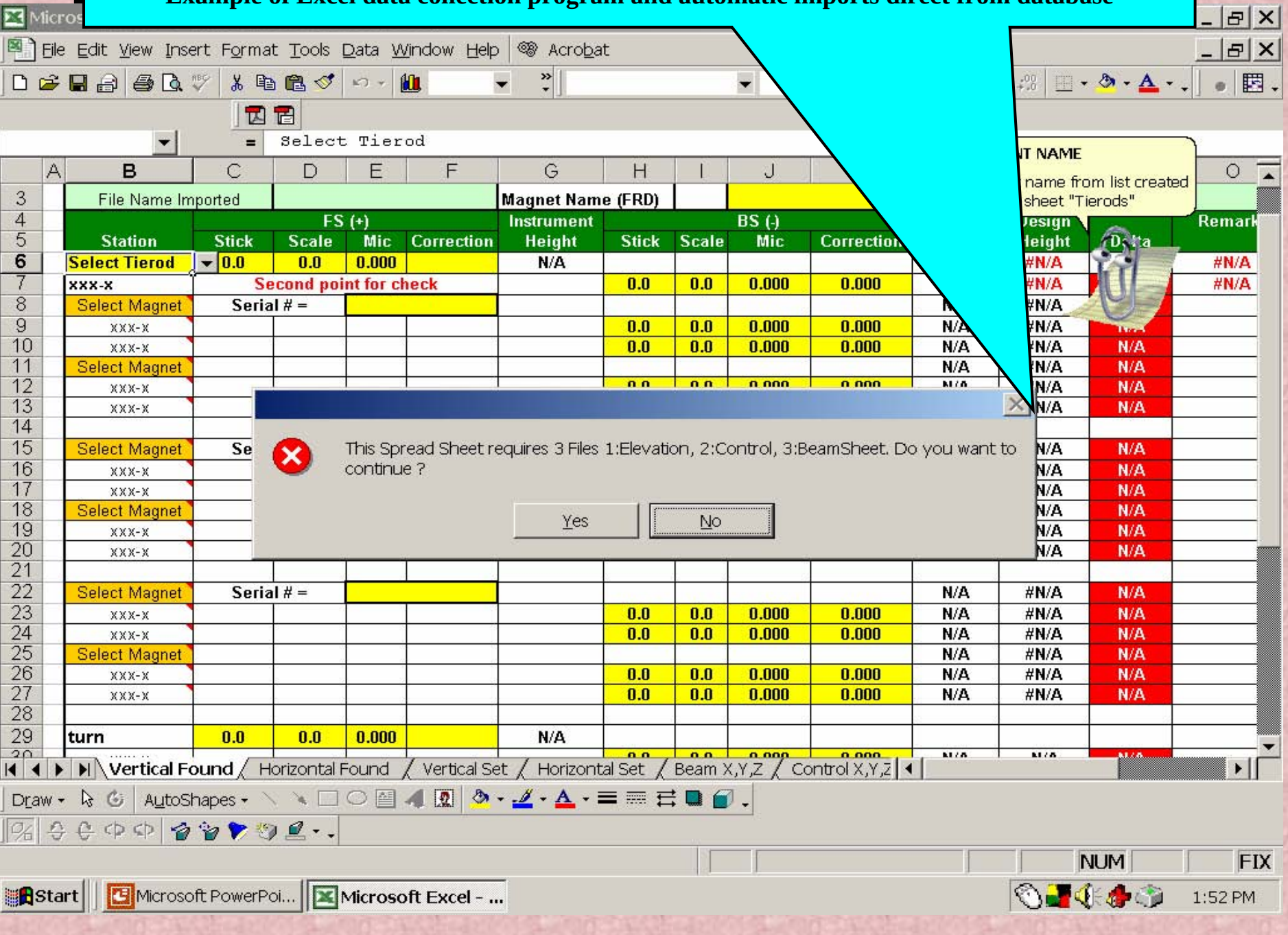
Output file can be exported into Excel and other data collection software.

C7

	A	B	C	D	E	F		H	I
1	Date	Machine Name	Enclosure	Monument Type	Control ID	X		H	N
2	28-Jul-98	8GEV	8GEV	TIE ROD BOTTOM	207001L	30420.76234	30161.33551	219.3072928	-32.78118515
3	28-Jul-98	8GEV	8GEV	TIE ROD N	207001N	30420.76234	30161.33551	219.2723628	-32.78118515
4	28-Jul-98	8GEV	8GEV	TIE ROD TOP	207001U	30420.76234	30161.33551	219.3294428	-32.78118515
5	28-Jul-98	8GEV	8GEV	TIE ROD Z	207001Z	30420.76234	30161.33551	219.3643629	-32.78118515
6	28-Jul-98	8GEV	8GEV	TIE ROD BOTTOM	207002L	30466.3686	30122.44124	219.3084844	-32.78076553
7	28-Jul-98	8GEV	8GEV	TIE ROD N	207002N	30466.3686	30122.44124	219.2735644	-32.78076553
8	28-Jul-98	8GEV	8GEV	TIE ROD TOP	207002U	30466.3686	30122.44124	219.3306345	-32.78076553
9	28-Jul-98	8GEV	8GEV	TIE ROD Z	207002Z	30466.3686	30122.44124	219.3655644	-32.78076553
10	28-Jul-98	8GEV	8GEV	TIE ROD BOTTOM	207800L	30345.54125	30247.33531	222.087349	-32.78210831
11	28-Jul-98	8GEV	8GEV	TIE ROD N	207800N	30345.54125	30247.33531	222.0524289	-32.78210831
12	28-Jul-98	8GEV	8GEV	TIE ROD TOP	207800U	30345.54125	30247.33531	222.109499	-32.78210831
13	28-Jul-98	8GEV	8GEV	TIE ROD Z	207800Z	30345.54125	30247.33531	222.1444189	-32.78210831
14	28-Jul-98	8GEV	8GEV	TIE ROD BOTTOM	207801L	30349.37794	30242.94961	221.921109	-32.78205872
15	28-Jul-98	8GEV	8GEV	TIE ROD N	207801N	30349.37794	30242.94961	221.886179	-32.78205872
16	28-Jul-98	8GEV	8GEV	TIE ROD TOP	207801U	30349.37794	30242.94961	221.9432591	-32.78205872
17	28-Jul-98	8GEV	8GEV	TIE ROD Z	207801Z	30349.37794	30242.94961	221.978179	-32.78205872
18	28-Jul-98	8GEV	8GEV	TIE ROD BOTTOM	207802L	30352.96544	30231.81883	222.105873	-32.78194427
19	28-Jul-98	8GEV	8GEV	TIE ROD N	207802N	30352.96544	30231.81883	222.070943	-32.78194427
20	28-Jul-98	8GEV	8GEV	TIE ROD TOP	207802U	30352.96544	30231.81883	222.128023	-32.78194427
21	28-Jul-98	8GEV	8GEV	TIE ROD Z	207802Z	30352.96544	30231.81883	222.162943	-32.78194427
22	28-Jul-98	8GEV	8GEV	TIE ROD BOTTOM	207803L	30358.42179	30226.03801	221.4870551	-32.78188324
23	28-Jul-98	8GEV	8GEV	TIE ROD N	207803N	30358.42179	30226.03801	221.4521251	-32.78188324
24	28-Jul-98	8GEV	8GEV	TIE ROD TOP	207803U	30358.42179	30226.03801	221.509195	-32.78188324
25	28-Jul-98	8GEV	8GEV	TIE ROD Z	207803Z	30358.42179	30226.03801	221.5441251	-32.78188324
26	28-Jul-98	8GEV	8GEV	TIE ROD BOTTOM	207804L	30360.51517	30224.92951	218.8767305	-32.78186798
27	28-Jul-98	8GEV	8GEV	TIE ROD N	207804N	30360.51517	30224.92951	218.8418005	-32.78186798
28	28-Jul-98	8GEV	8GEV	TIE ROD TOP	207804U	30360.51517	30224.92951	218.8988706	-32.78186798
29	28-Jul-98	8GEV	8GEV	TIE ROD Z	207804Z	30360.51517	30224.92951	218.9338005	-32.78186798
30	28-Jul-98	8GEV	8GEV	TIE ROD BOTTOM	207805L	30364.23398	30219.81606	219.3476305	-32.78181458
31	28-Jul-98	8GEV	8GEV	TIE ROD N	207805N	30364.23398	30219.81606	219.3127005	-32.78181458
32	28-Jul-98	8GEV	8GEV	TIE ROD TOP	207805U	30364.23398	30219.81606	219.3697705	-32.78181458

testdb.ctrlMachine

Example of Excel data collection program and automatic imports direct from database



Query Survey Database ?

Should Translation be applied ?

The Global Cartesian Coordinates will be selected. Which coordinate system should they be translated to:

- ○ Fermi Site Planar (FSCSz)
- ◉ Fermi Site Projection (FSCSh)
- ○ Main Injector Planar (LTCSz)
- ○ Main Injector Projection (LTCSh)
- ○ Latitude/Longitude/Ellipsoidal Hgt/Geoid Hgt/Orthometric Hgt (GCS)

Pick additional fields to be queried ?

The Fiducial name is also included in the query by default. Pick additional fields to see:

☑ Create date ☑ Machine name ☑ Part type ☑ Part serial no
☑ Roll ☑ Pitch ☑ Yaw ☑ Comments
☐ Covariance Matrix ?

Alignment Specific fields

☑ Name code ☑ Survey date ☑ Calc by ☑ Calculate length

Beamsheet Specific fields

☑ Beam station

Where ?

[ ] Specific Machine?
[ ] Specific Code?
☐ Show only the center point

Put Constraints on the date

◉ Return All Dates
○ Return Most Recent Entries
○ Return Entries as of [ ] (Format - YYYY-MM-DD)
○ Pick a range
From: [ ] (Format - YYYY-MM-DD) To: [ ] (Format - YYYY-MM-DD)
○ Show Entries on a date: [ ] (Format - YYYY-MM-DD)

☐ Also get date most recent previous to this date

View Data | Export Data

Contact webmaster-ad@fnal.gov

Sitewide Vertical Network Upgrade

John Kyle
George Wojcik

Sitewide Vertical Network Upgrade

- Several machines at Fermilab had very old elevation data
- Desired a homogeneous Vertical Control Network which incorporates surface and subsurface networks derived from ‘current’ observations during a common epoch
- During last shutdown performed large campaign to update datums and tie them together
- Contributions from entire group

Surface/Tunnel Networks Observed

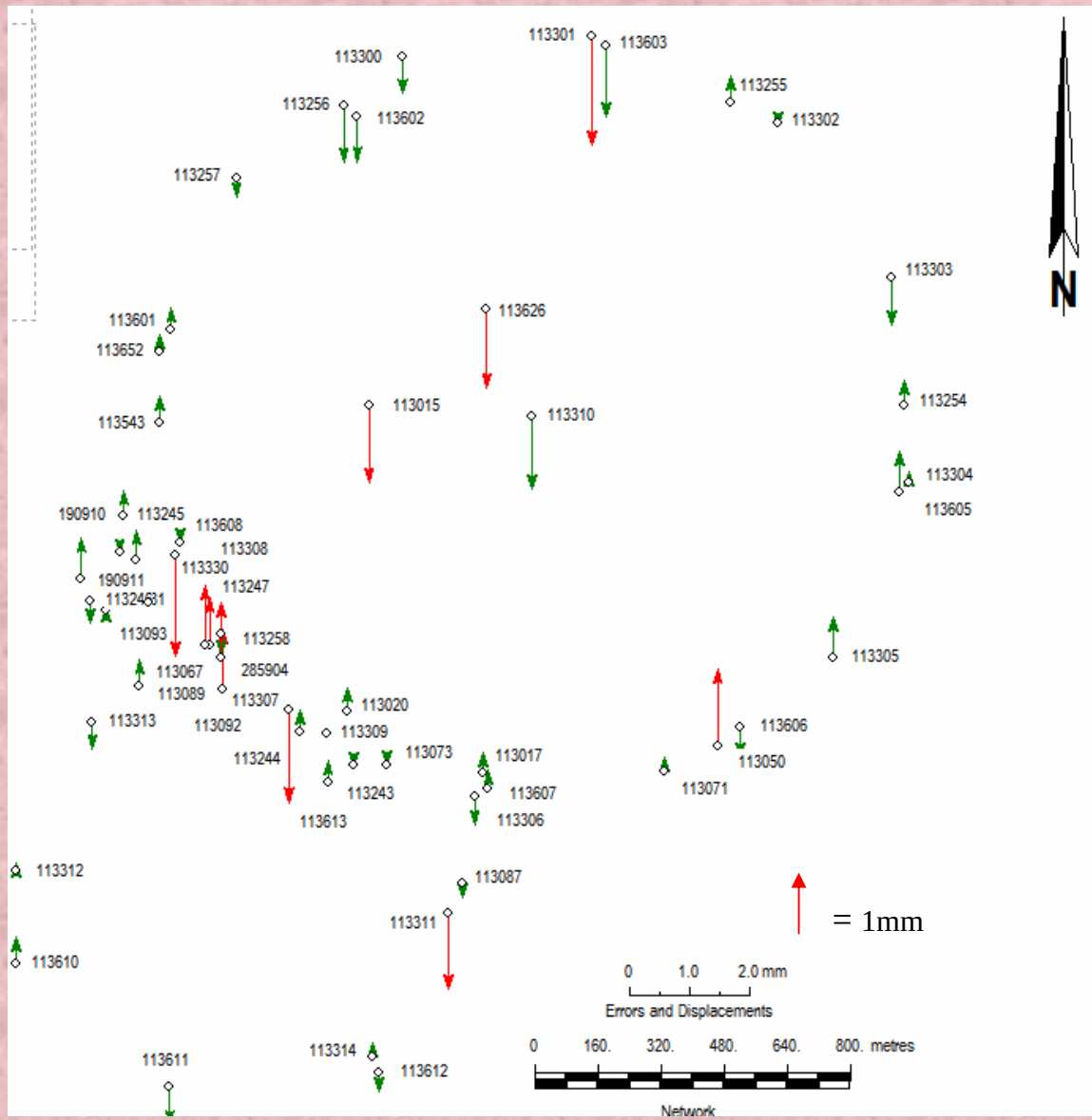
- Main Injector (FMI)
- Numi
- MiniBoone
- 8 GeV Line
- Antiproton Source
- Tevatron
- Meson Beamline
- Remainder of Site (Deep Rod Monuments)

Relative Adjustments Completed (Includes Stable Point Analyses of Tunnels)

- FMI/8 GeV
- Tevatron
- MiniBoone
- Surface (Based on data reduced to date)

Stable Point Analyses performed using software (UNB DEFNAN Version 2.05) developed at the University of New Brunswick.

Surface Displacements



LEGEND

Fails Stability Test
Statistically Stable

Vertical Displacements and Errors

WEIGHTED VARIANCE FACTOR : 1.084120131334

DEGREES OF FREEDOM : 25

VERTICAL DISPLACEMENTS AND ERROR BARS (AT 95.%)

STATION	DZ (mm)	ERROR BAR (mm)	
+ 113310	-1.22	1.38	*
+ 113311	-1.28	1.03	**
+ 113312	0.12	1.11	
+ 113313	-0.46	0.91	
+ 113314	0.24	1.18	
+ 113330	0.51	0.83	*

Average Error: +/- 0.94 mm

\+ STATION USED IN DATUM DEFINITION

* DISP. IS BEYOND BOUNDS OF STANDARD ERROR BAR

** DISP. IS BEYOND BOUNDS OF 95.% ERROR BAR

Displacements Around FMI Tunnel

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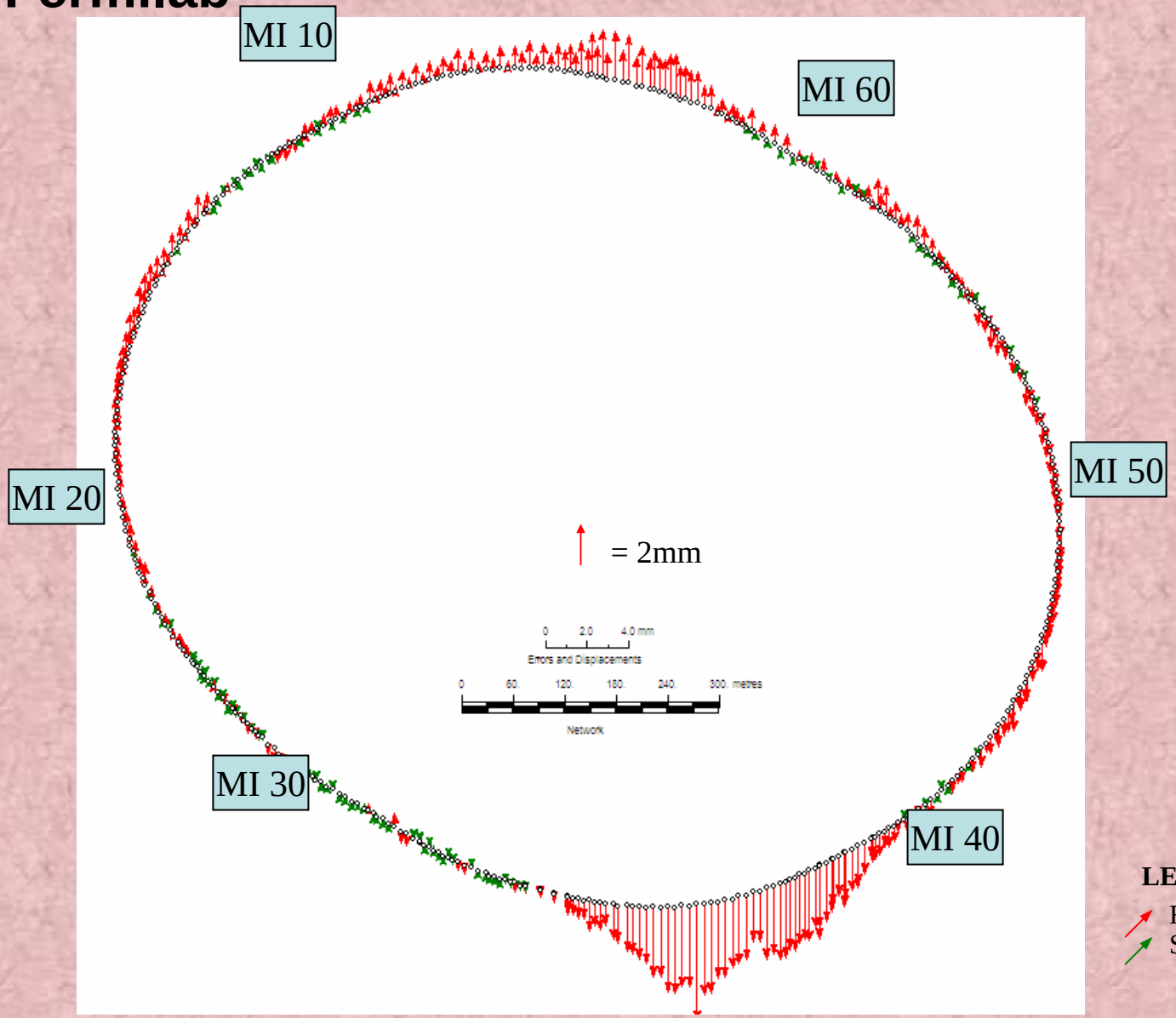

LEGEND

Fails Stability Test
Statistically Stable

Current Survey vs. Jan 2001

Vertical Displacements and Errors

WEIGHTED VARIANCE FACTOR : 0.339734490786

DEGREES OF FREEDOM : 89

VERTICAL DISPLACEMENTS AND ERROR BARS (AT 95.%)

STATION	DZ (mm)	ERROR BAR (mm)	
+ 207230	-0.42	0.28	**
+ 207231	-0.40	0.28	**
+ 207232	-0.28	0.28	*
+ 286020	0.21	0.29	*
+ 286021	0.14	0.29	
+ 286022	0.00	0.29	
+ 286023	-0.15	0.29	*

Average Error: +/- 0.28 mm

\+ STATION USED IN DATUM DEFINITION

* DISP. IS BEYOND BOUNDS OF STANDARD ERROR BAR

** DISP. IS BEYOND BOUNDS OF 95.% ERROR BAR

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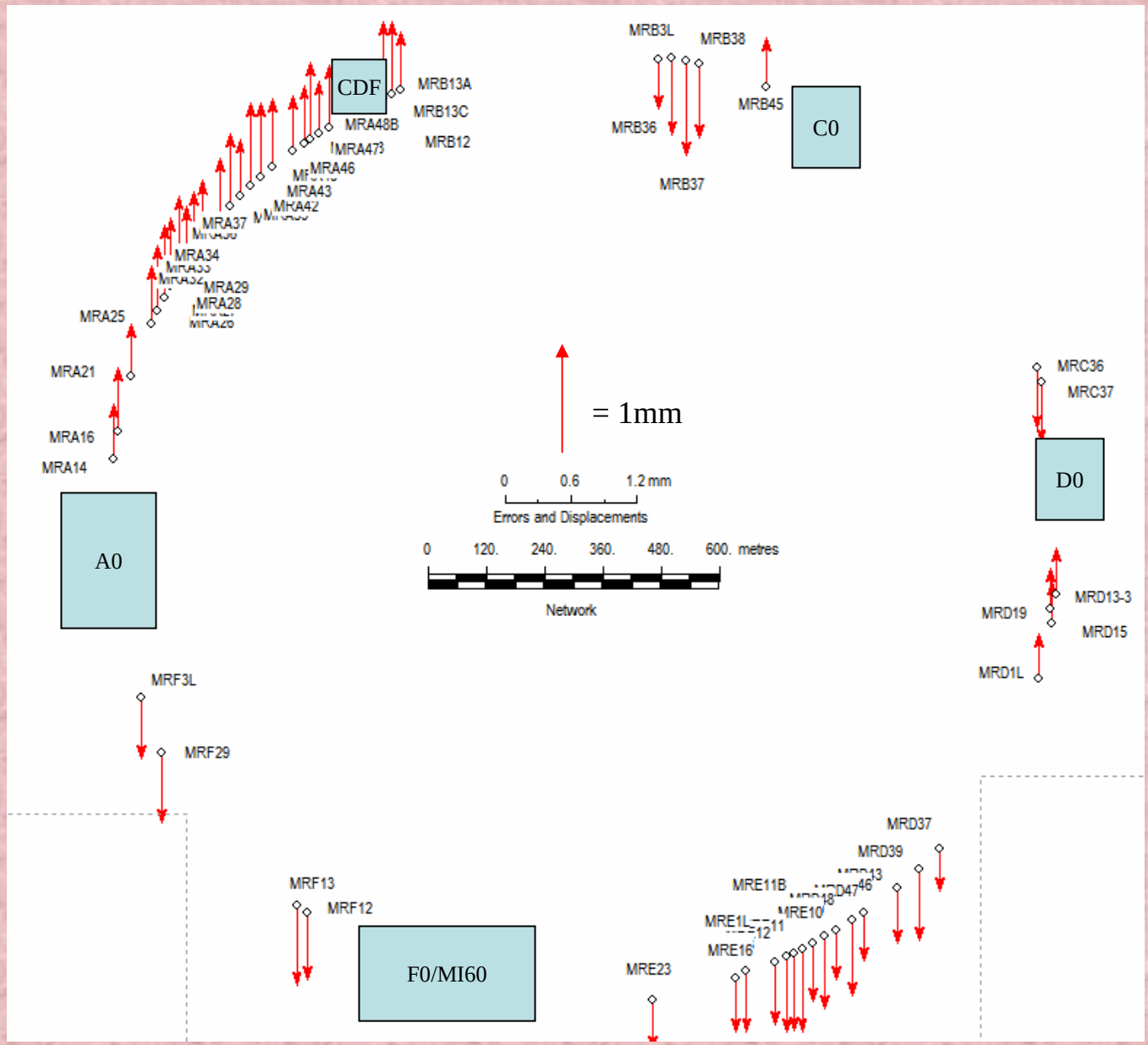
Tevatron Displacements



LEGEND

Fails Stability Test

Statistically Stable

Current Survey vs. Oct 2004

Vertical Displacements and Errors

WEIGHTED VARIANCE FACTOR : 0.692031228021

DEGREES OF FREEDOM : 296

VERTICAL DISPLACEMENTS AND ERROR BARS (AT 95.%)

STATION	DZ (mm)	ERROR BAR (mm)	
+ MRA0U	-0.05	0.47	
+ MRA10	0.23	0.46	
+ MRA11	0.05	0.47	
+ MRA12	0.10	0.46	
+ MRA13	0.36	0.46	*
+ MRA14	0.51	0.47	**
+ MRA15	0.41	0.46	*
+ MRA16	0.58	0.47	**

Average Error: +/- 0.42 mm

\+ STATION USED IN DATUM DEFINITION

* DISP. IS BEYOND BOUNDS OF STANDARD ERROR BAR

** DISP. IS BEYOND BOUNDS OF 95.% ERROR BAR

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Surface Drop Elevations vs FMI Tunnel Elevations

SURFACE ADJUSTMENT			TUNNEL ADJUSTMENT			SURFACE - TUNNEL	
Holding 113302			17-APR-2006 13:34				
Point Name	(m)	(mm)	Point Name	(m)	(mm)	Point Name	(mm)
207116	219.333160	0.79	207116	219.333214	0.22	207116	-0.054
207117	219.332010	0.79	207117	219.332035	0.22	207117	-0.025
207232	219.394286	0.86	207232	219.394162	0.14	207232	0.124
207301	219.348876	0.86	207301	219.348683	0.15	207301	0.193
207308	219.387336	0.89	207308	219.387025	0.18	207308	0.311
207309	219.353396	0.89	207309	219.353346	0.18	207309	0.050
207416	219.316264	0.85	207416	219.316956	0.28	207416	-0.692
207417	219.306464	0.85	207417	219.307127	0.28	207417	-0.663
207532	219.382751	0.31	207532	219.382922	0.29	207532	-0.171
207601	219.402601	0.31	207601	219.402753	0.29	207601	-0.152
207609	219.312556	0.38	207609	219.312545	0.29	207609	0.011
207610	219.295996	0.38	207610	219.295916	0.29	207610	0.080
Holding 113613			17-APR-2006 13:34				
	(m)	(mm)		(m)	(mm)		(mm)
207116	219.333013	0.79	207116	219.333214	0.22	207116	-0.201
207117	219.331863	0.79	207117	219.332035	0.22	207117	-0.172
207232	219.394139	0.86	207232	219.394162	0.14	207232	-0.023
207301	219.348729	0.86	207301	219.348683	0.15	207301	0.046
207308	219.387189	0.89	207308	219.387025	0.18	207308	0.164
207309	219.353249	0.89	207309	219.353346	0.18	207309	-0.097
207416	219.316117	0.85	207416	219.316956	0.28	207416	-0.839
207417	219.306317	0.85	207417	219.307127	0.28	207417	-0.810
207532	219.382605	0.31	207532	219.382922	0.29	207532	-0.317
207601	219.402455	0.31	207601	219.402753	0.29	207601	-0.298
207609	219.312409	0.38	207609	219.312545	0.29	207609	-0.136
207610	219.295849	0.38	207610	219.295916	0.29	207610	-0.067

NEGATIVE INDICATES SURFACE DROP
ELEVATION IS LOWER

MIPP

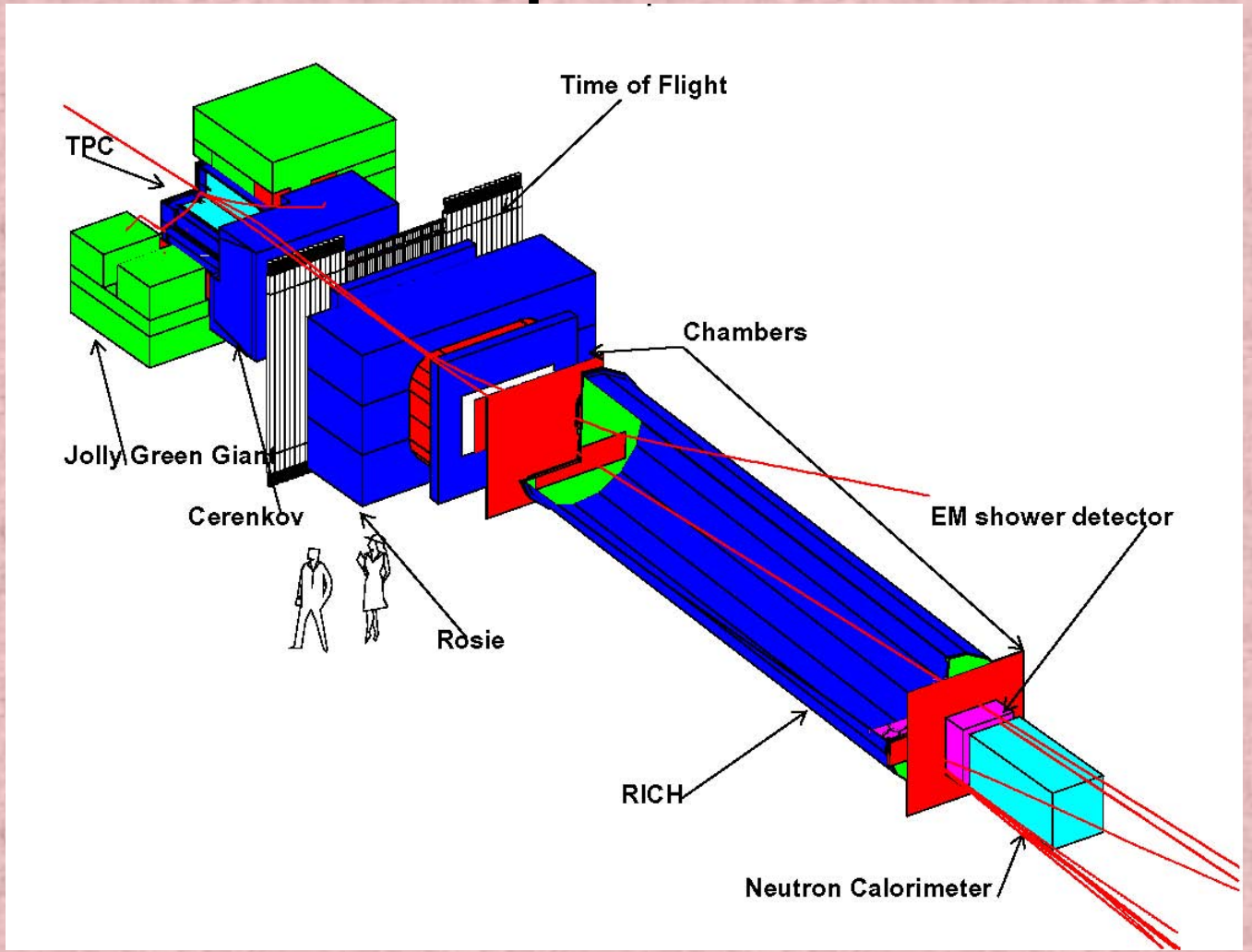
(Main Injector Particle Production)

Virgil Bocean

MIPP

- **Measures hadronic particle production using primary and secondary beams from the Main Injector.**
- **Location: Fixed Target area - Meson Center**
- **Experiment goals:**
  - **to verify a general scaling law of hadronic fragmentation;**
  - **to measure particle production off NuMi targets (using 120 GeV/c protons to predict the NuMI neutrino spectrum);**
  - **to collect a comprehensive dataset: with profound impact on related physics issues (atmospheric neutrino flux estimates, neutrino factory design, and simulations of hadronic showers for high energy colliders).**

MIPP Experiment 3D View



MIPP

- **The experiment ran for 14 months (finished taking data in February 2006)**
- **Three alternate target configurations used:**
  - **nuclear targets (installed on remotely controlled target wheel)**
  - **cryogenic target**
  - **NuMI (spare) target**
- **(Different) target aligned prior to each run**
- **Different beam energy used for different runs**
- **Primary beam configuration changes for different runs (pinhole collimator in/out, primary target in/out)**

MIPP: Alignment Support

- Referenced beamline and experiment components with the Laser Tracker (2003-2004)
- Established high-accuracy network throughout the beam enclosures and Experimental Hall (2003)
- Provided precise initial alignment of beamline and experiment (2003-2004)

Tolerances 95 % Confidence Level

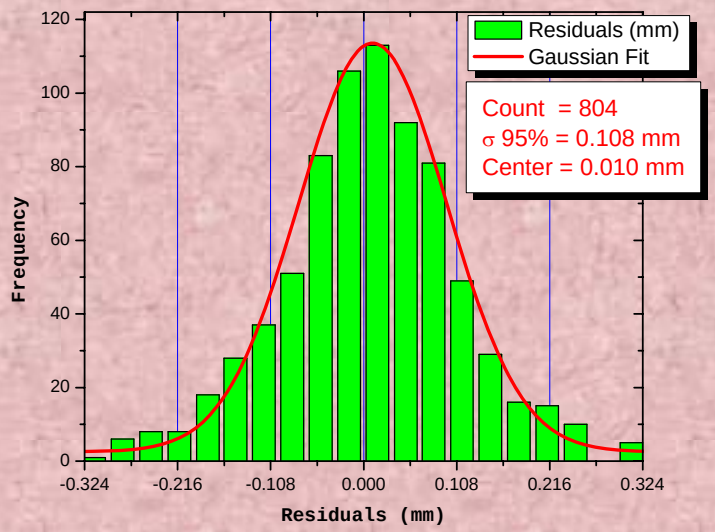
Beam components/instrumentation	± 0.50 mm
Beam position at Targets	± 0.50 mm
Time Projection Camber (TPC)	± 0.50 mm
Analysis Magnets (JGG and Rosie)	± 5 mm
Time of Flight counters (TOF)	± 1 mm
Drift Chambers (DC1-DC6)	± 1 mrad
RICH Counter	± 0.5 mm
EM Shower Detector	± 0.5 mm
Neutron Calorimeter	± 1 mm

MIPP Tunnel Control

- Measured with the Laser Tracker and processed as trilateration
- Additional measurements to study/control network behaviour and for confirmation: Mekometer distances, angles, and gyro-azimuths
- Network results: relative errors below ±0.150 mm at 95% confidence level

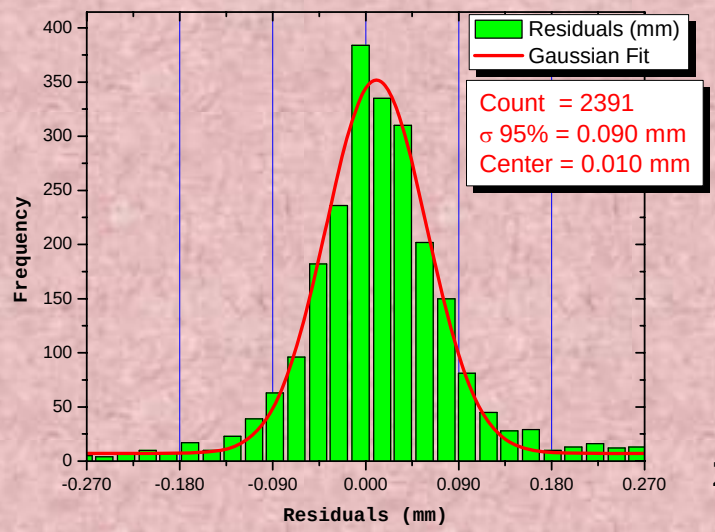
Primary Beamline Tunnel Network

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



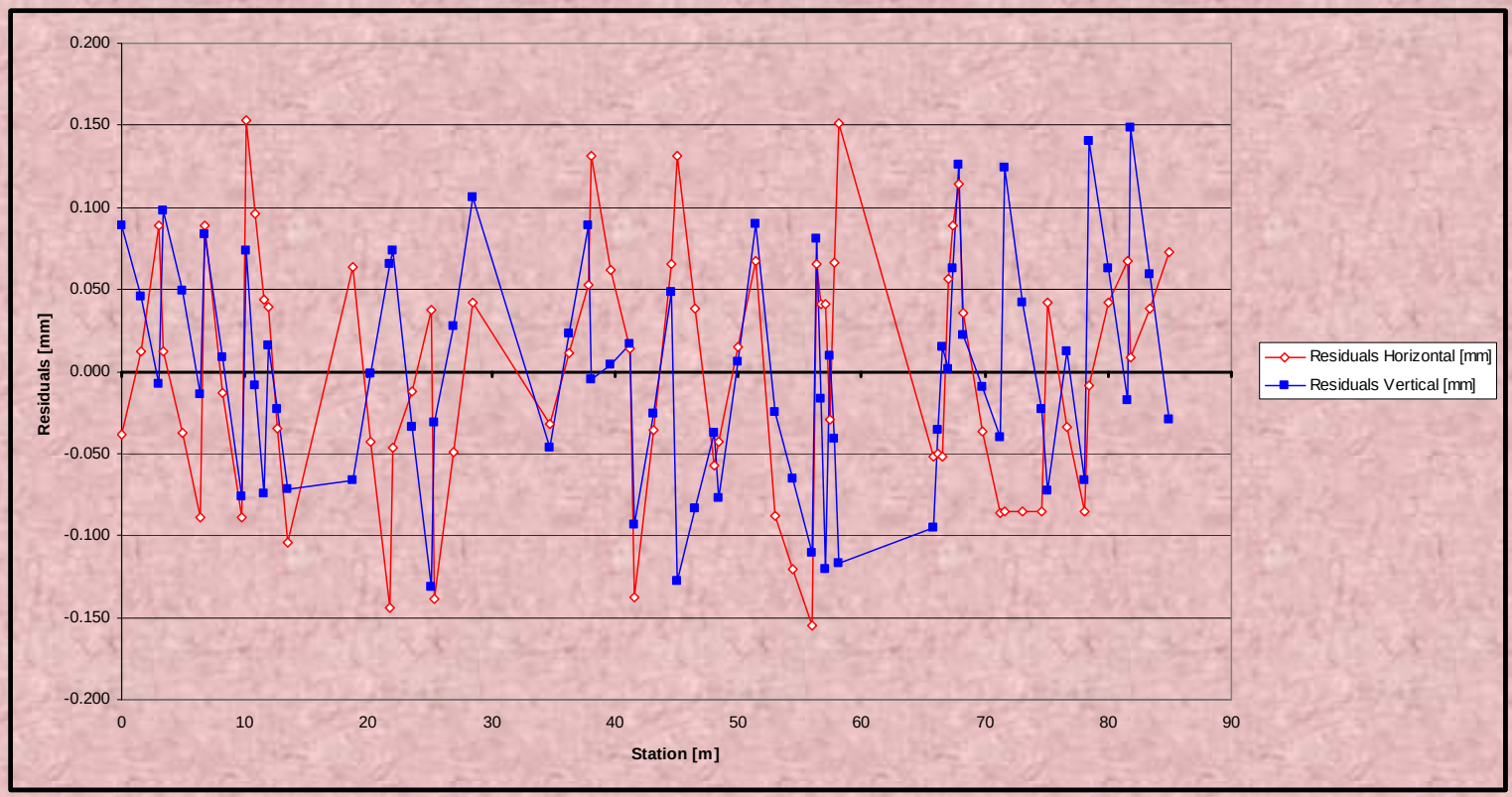
Experimental Hall Network

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



MIPP: Primary Beam Alignment

- Components referenced and aligned with the Laser Tracker
- Alignment tolerance: Horizontal/Vertical ±0.500 mm at 95% confidence
- Alignment results: Horizontal/Vertical residuals ±0.150 mm at 95% confidence

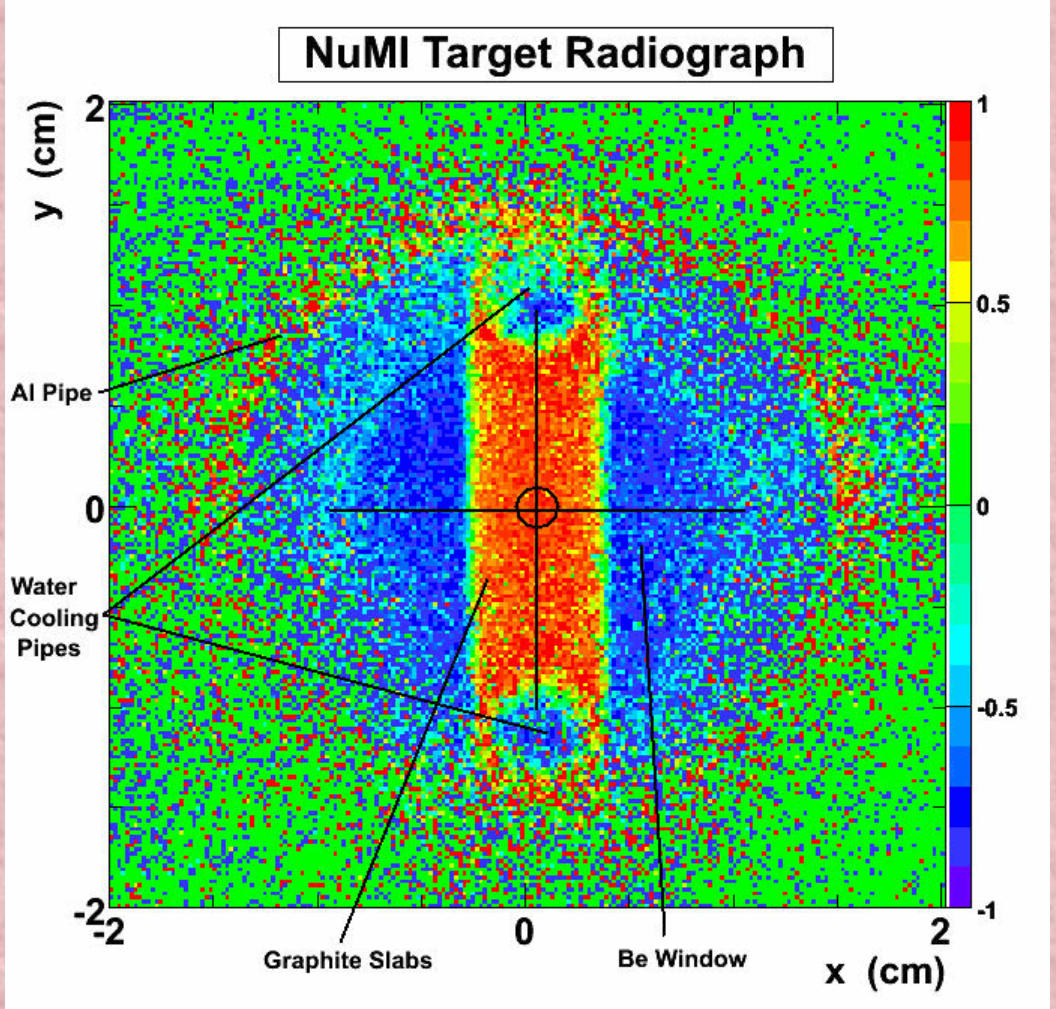


MIPP: NuMI Target Alignment

Beam alignment to target center

x = 0.020 mm, y = 0.510 mm

The cross hairs represent the center of the target and the circle represents the beam profile (determined using reconstructed beam chamber tracks for "on-target" data).



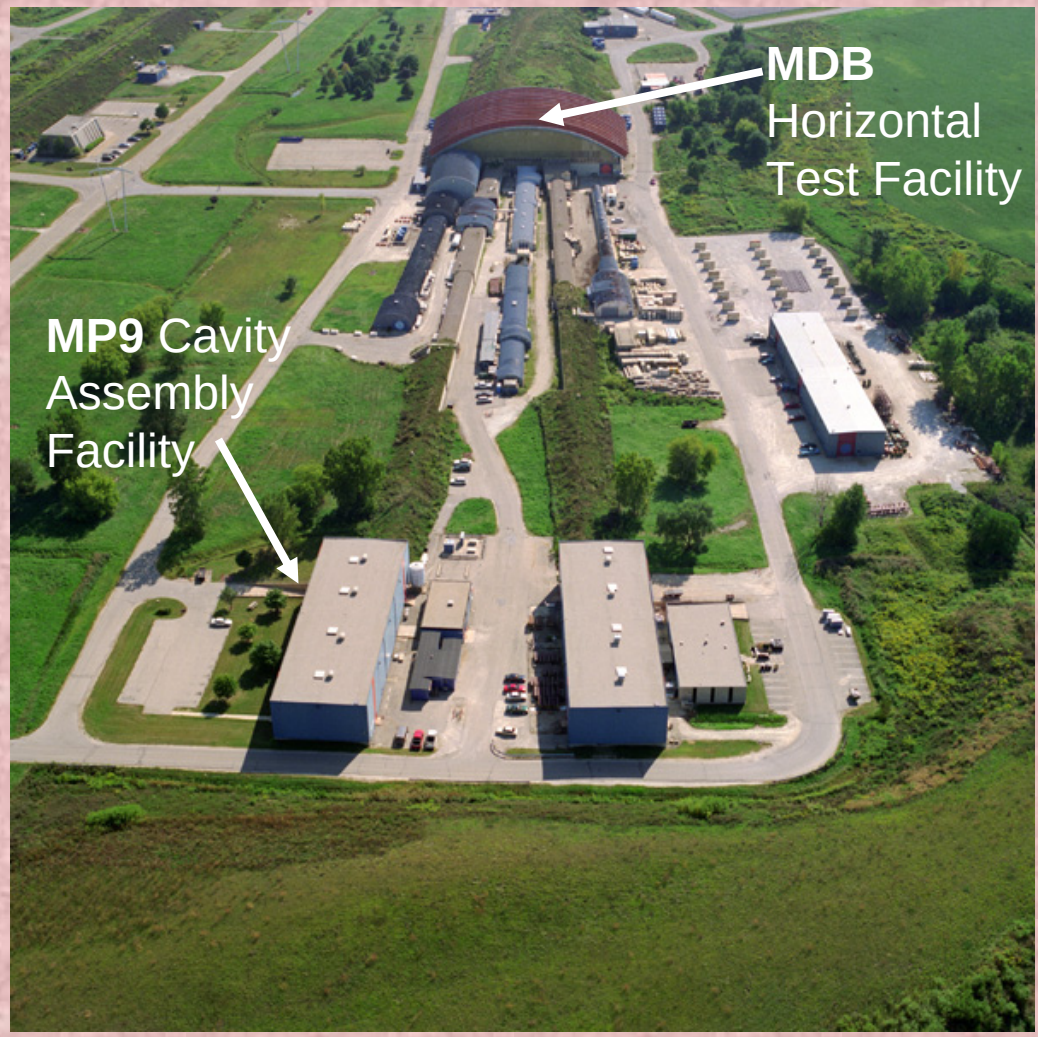
ILC Activities

Virgil Bocean
John Kyle
George Wojcik

ILC Test Areas

- **ILCTA - part of Fermilab's R&D program for the ILC**
- **Focus: on the design, manufacturing and testing of cavities and cryomodules**
- **Priorities:**
  - **To determine cavity processing parameters for a reproducible cavity gradient of 35 MV/m;**
  - **Test one ILC RF unit at ILC beam parameters, high gradient, and full pulse rep rate;**
  - **Design, produce and test an ILC-specific cryomodule.**
- **Currently Fermilab is developing infrastructure for cavity processing and testing and fabrication of cryomodules.**

ILCTA-MDB
(Meson Detector Building)



ILC -MDB

- MDB is the 3.9 GHz/1.3 GHz Cavity Horizontal Test Facility
- The only U.S. facility capable of performing this test
- The infrastructure for testing has been completed
- The first TESLA 9-cell 1.3 GHz “ILC-like” cryostat (Capture Cavity II) is undergoing testing

ILC-MDB
AMG Support

- Reference cavities after arrival from DESY
- Established high-accuracy network throughout MDB (including ties to Fermilab Primary network)
- Monitoring deformations surveys
- Establish beamline and support installation
- Provide alignment of cavity inside testing cage

ILC-NML
(New Muon Lab)

ILC-NML
Inside New Muon Lab

ILCTA-NML

- NML is the ILC Cryomodule Beam Test Facility
- The only U.S. facility capable of testing completed cryomodules at high accelerating gradients
- Goal: to (produce and) test a single RF unit (two Type-III+ and one Type-IV cryomodules) by end of 2009
- The infrastructure for testing is under development:
  - Building is cleaned out (including CCM removal)
  - Started to install cryogenic system (complete 2007)
  - Move FNPL Photo-injector to provide electron beam (2007)
  - Upgraded FNPL will provide beam tests of ILC cryomodules (2008)

ILC-MDB
AMG Support

- Established survey network throughout NML (including ties to Fermilab Primary network)
- Various surveys to support the design of test facility beamline and components
- Monitoring deformations surveys
- Surveys to support installation of various components
- High-accuracy as found of all Photo-injector components at A0 in preparation for the new installation and alignment at NML

Photo-injector

Conclusion

- We've had a busy few years since the last IWAA
- Continuously improving our methods and technology
- A major part of our future is working on the ILC
- We look forward to collaborating with all of you on the ILC!