

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006

## Survey and Alignment of the Fermilab Electron Cooling System

### Babatunde O'Sheg Oshinowo Jerry Leibfritz

Fermi National Accelerator Laboratory Batavia, Illinois



## Electron Cooling System

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006

The goal of Electron Cooling (E-Cool) in the Recycler Ring is to effectively cool 8.9-GeV/c antiprotons by mixing them in a 20-m long cooling section with a cold beam of 4.3-MeV electrons

The implementation of Electron Cooling should significantly increase the number of antiprotons stored in the Recycler and improve the antiproton production rate in the Accumulator In turn, it will increase the luminosity of the Tevatron collider



Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006

3



Cold electrons flow through a hot antiproton beam and cool it, so it is natural to call it Electron Cooling

Antiproton beam is hot when the initial temperature of the antiproton gas, in the beam rest frame, is much higher than the corresponding electron temperature Antiproton beam needs to be cooled:

- To increase life time
- To put more and more particles into the given accelerator
- To deliver more intense and denser beams to the Tevatron, which presently is the main source for increasing the luminosity



## **Electron Cooling Location**

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006



Electron Cooling is located in the MI-31 service building and in the Recycler Ring in the Main Injector tunnel at MI-30



Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006

# **Electron Cooling Enclosures**



5



## Fermilab Electron Cooling System

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006





## **Pelletron Accelerator**



7





Fully Assembled Pelletron Accelerator at MI-31 (Left)

The Pelletron weighs 45 metric tonne

Accelerator Cross-Section (Right)



## Electron Cooling System





Cooling Section Line is 20 m long in the Recycler in MI-30

Return Line is 20-m long and 1 m below the Recycler in MI-30

Supply Line is 19 m long in MI-31
 Transfer Line is 19 m long and 1 m below the Supply Line in MI-31

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006



### **Electron Cooling Components**



Electron Cooling System consists of 105 components, which include: 10 Cooling Solenoids (with fiducials) 4 90° Bend Magnets (with fiducials) 2 180° Bend Magnets (with fiducials) 25 Focusing Solenoids 26 Beam Position Monitors (BPMs) **1** Flying Wire 12 Beam Scrapers Vacuum chambers, Toroids Pelletron Lenses Components with Fiducials were

Referenced with Laser Tracker





Survey and Alignment of Electron Cooling System Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006

Establish a precision control network for positioning Electron Cooling Beamline components in the Fermilab Local Tunnel Coordinate System (LTCS)

October 2004 Upgrade of the October 1998 MI-30 Horizontal network due to construction using the Laser Tracker for deformation analysis

October 2004 Upgrade of the January 2001 MI-30 Vertical network for deformation analysis due to construction

Tie the new MI-31 Horizontal and Vertical networks to the upgraded MI-30 network



11

□ All Survey and Alignment were done with:

- Laser Tracker
- Total Station
- Optical and Electronic Levels used for Elevations
- Gyro-Theodolite for Azimuths
- Optical Tooling Instruments
- Optical Zenith and Nadir Plummets

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006



### MI-30 Control Network



MI-30 Network consisted of:

- 15 Floor Monuments
- 31 Pass Points
- > 13 Tie-Rods on the Wall

Deformation Analysis performed after Network Adjustment revealed deformations due to construction



Horizontal Deformation - MI-30 Oct2004 - Oct1998



Larger deviations around construction area between Cell bodies 304 and 308

13



Horizontal Deformation - MI-30 Oct2004 - Oct1998



14



Vertical Deformation - MI-30 Oct2004 - Jan2001



Larger deviations around construction area between Cell bodies 304 and 308



Vertical Deformation - MI-30 Oct2004 - Jan2001



Larger deviations around construction area between Cell bodies 304 and 308



### MI-31 Control Network



### MI-31 Network consisted of:

- 24 Floor Monuments
  27 Wall Monuments
- > 8 Tie-Rods on the Wall
- 7 Pass Points
- 3 Brass Points

September 25-29, 2006

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006



## MI-31 Control Network



19



### MI-31 Network Results





20

### **MI-31 Network Results**

Error Ellipses (95% Confidence Level)





# **Component Alignment**

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006





 Tracker Measurements to referenced Fiducials
 Cooling Solenoid
 90° Bend Magnets
 180° Bend Magnets

 Measured as Cylinders/Planes and Circles:
 Focusing Solenoids, (BPMs),
 Beam Scrapers, Flying Wire,
 Vacuum chambers, Toroids

Lenses in Pelletron aligned with Optical Zenith and Nadir Plummets 21



# **Component Alignment**

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006



Cylinders Fits
Circle Fits
Line Fits
Plane Fits
Plane-Line
Intersections

22

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006



### Beam Alignment Results

**Cooling Solenoids: Deviations from Beamline** 



Cooling Solenoids Fiducials



# Status of Electron Cooling System



The Electron Cooling system was fully commissioned in May 2005

The first cooling of antiprotons was achieved in July 2005

Electron Cooling is currently operational at a beam current of 0.5 amps DC

Fermilab has a unique electron cooling system routinely used for cooling 8.9 GeV/c antiprotons in the Recycler Ring

> The Recycler anti-proton stack size has been increased to over 200 x  $10^{10}$  pbars

Fermilab now has a world record Electron Cooling system, which is a major contributor to the record luminosity for the Tevatron

Dr. O'Sheg Oshinowo IWAA2006 Conference SLAC, California, USA September 25-29, 2006



## Conclusion



The Electron Cooling system has been surveyed and aligned and the results have been presented

The alignment methodology used has also been presented





## Acknowledgment



□ The co-author Jerry Leibfritz (middle) of the Accelerator Division was the Project Engineer for the Electron Cooling project

- We would like to thank
   Alignment and Metrology Group members who participated in the Electron Cooling project
- Tom Kroc for the alignment schematic
- Steve Wesseln for supplying drawings
- Sasha Shemyakin E-Cool Group Leader

### The E-COOL System is really COOL!!!