T-980

T-980: Studies in Tevatron

2008 Fermilab Crystal Collimation Workshop

Dean Still

October 27, 2008

T-980

Status of T-980

- History of Tevatron Crystal Collimation 2004 -2008
- 2008 Improvements & Beam Study Goals
- 2008 Beam Study Results
- Summary

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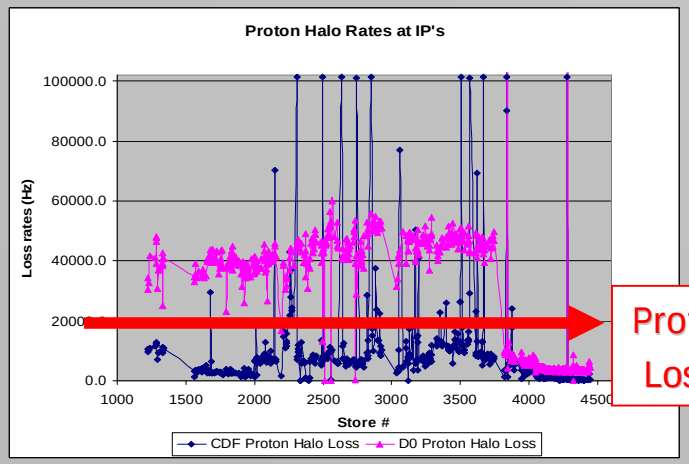
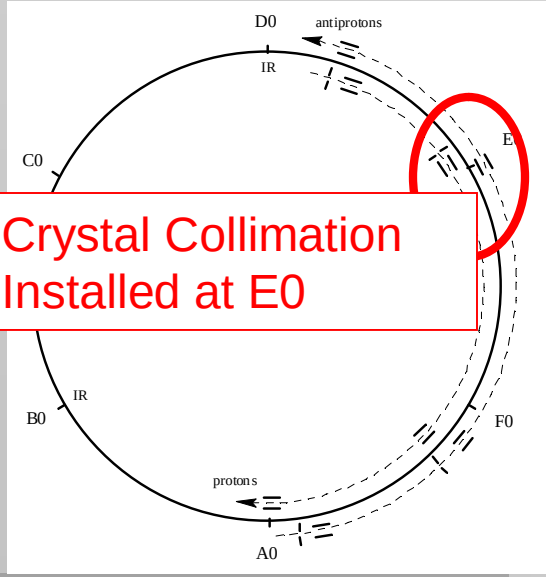
History of Tevatron Crystal Collimation

2004:

- Bent Crystal Collimation was used in the Tevatron for the first time.
- It was attempt to reduce halo losses at the IP's with growing Luminosity.
- Crystal Collimation system was installed at E0.
- Simulations predicted that a factor of 2 in proton halo reduction could be achieved compared to a tungsten target.



Proton Halo Loss Limit

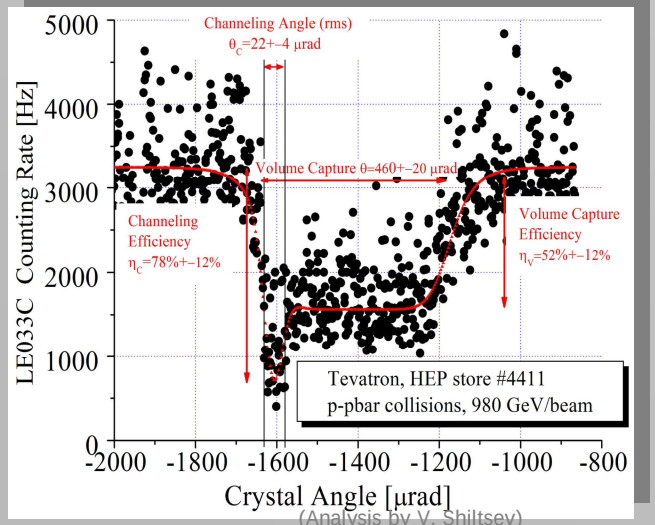


History of Tevatron Crystal Collimation(2)

2005:

Conducted ~ 13 hours of end of store studies which results included

- Demonstration of channeling protons in an “O” shaped crystal at 980gev.
- Demonstrating a factor of 2 difference in proton halo using crystal collimator over collimation with a tungsten target.



(Analysis by V. Shiltsev)

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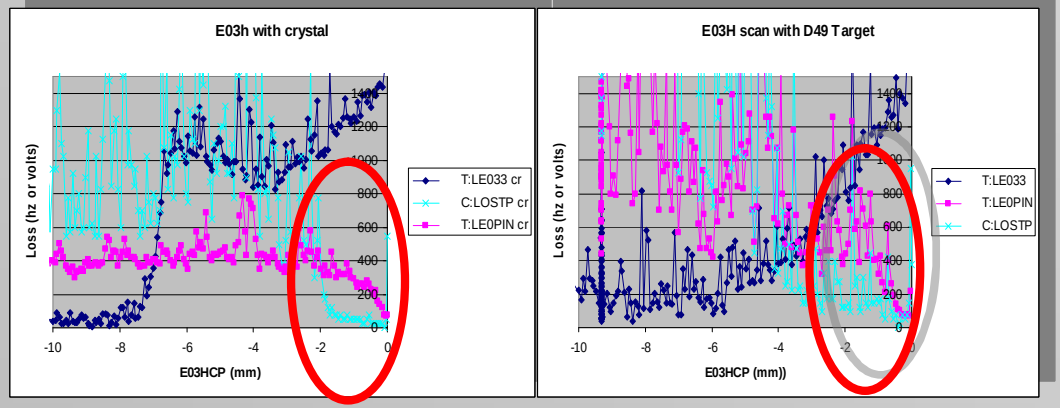

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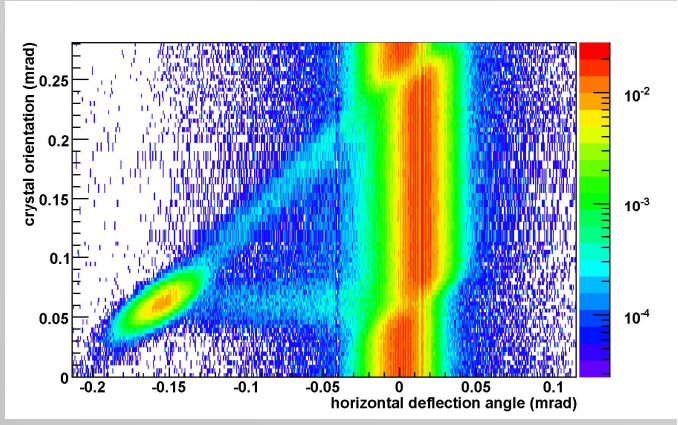
History of Tevatron Crystal Collimation(3)

2006:

•A year intertwined with collider shutdowns & transition of the assembly to change crystal styles from “O” shaped to strip & assemble repair.

•Also the 2005 Tevatron results produced questions about the details of the channeling profile of which the CERN H8 RD22 experiment demonstrated Volume Reflection.

•Therefore future Tevatron studies could also attempt to collimate the volume reflected beam as well as the channeled beam.



(Cern RD22 – Volume Reflection)

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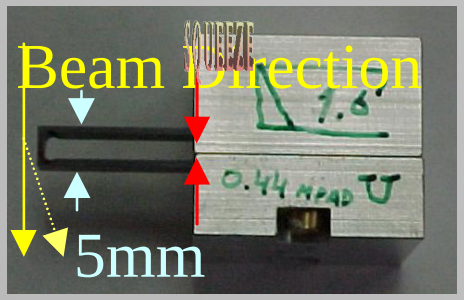
History of Tevatron Crystal Collimation(4)

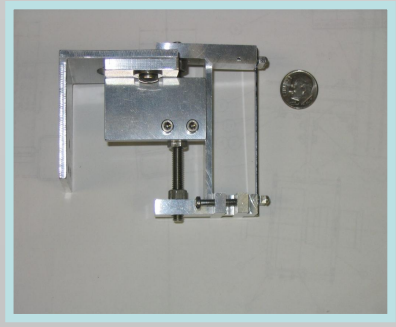
2007:

- *Use End of Store study to demonstrate difference in halo loss for strip crystal and tungsten target.*

- *Demonstrate this difference for channeled and volume reflected (VR) beam. (Single Plane only)*



"O" Shaped crystal
440 urad bend angle
Crystal Courtesy IHEP, Protvino



Strip type crystal
1mm wide X 3mm long
150 urad bend angle (INFN, IHEP)

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History of Tevatron Crystal Collimation(5)

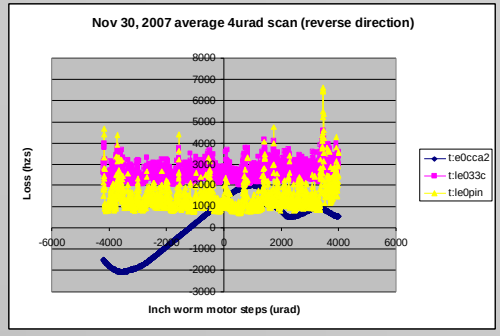
2007:

•Conducted ~ 28 hours of End of Store study in 2007 dedicated to demonstrating channeling with the strip crystal.

•Unfortunately channeling was **never** demonstrated in this strip crystal. There is much speculation about the crystal itself and this crystal on Oct 23, 2008 was returned to V. Guidi (INFN) for characterization and analysis.

•There were many lessons learned in 2007:

- •For part of the studies, crystal had gross alignment error.
- •Many problems with the goniometer- coupled angular/hor motion, vibration, dragging motion, ect.
- •Learned the instrumentation was inadequate.
- •Needed well characterized crystals.
- •Needed more and better simulations.
- •Needed a more formal status/collaboration to conduct beam studies under.



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2008 Improvements & Beam Study Goals

- Jan 2008 - Crystal assembly removed from Tevatron tunnel & work immediately begins on mechanical modifications.
- Jan 2008 – Sent the original “O” shaped crystal to CERN, INFN and PNPI for characterization & test if needed chemical etching to remove surface roughness.
- Spring 2008 – Instrumentation meetings proceed to discuss new instrumentation options for crystal collimation.
- Spring 2008 – Crystal Collimation with Collaborating Institutes receive formal test beam number - T980.
- Aug 8, 2008 – T-980 Installation Review
- Aug 28, 2008 – Crystal assembly installed in the Tevatron tunnel.
- Sep 14, 2008 – First 980gev end of store beam study to center crystal
- Oct 3, 2008 - 2nd 980gev end of store to characterize channel.

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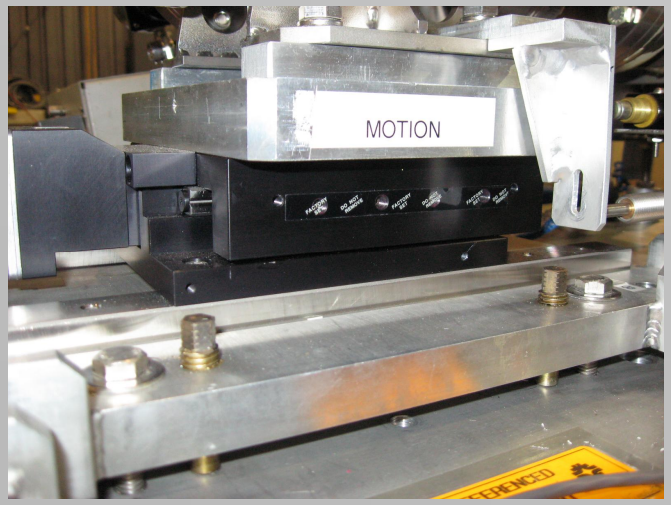
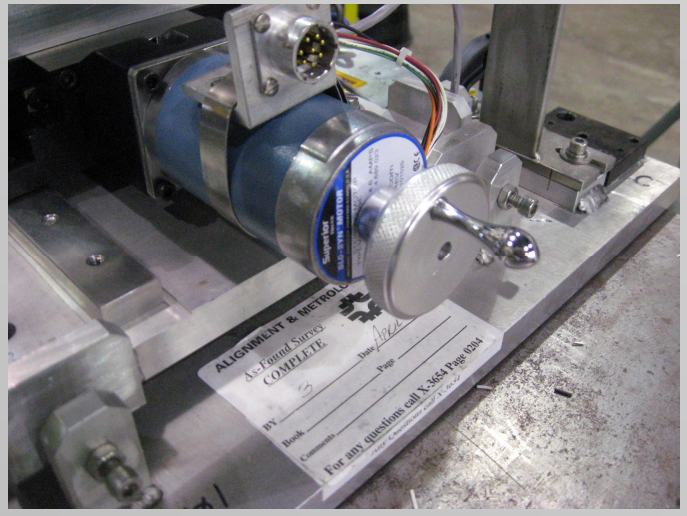
Crystal Collimator Modifications

Major modifications in 2008

- New horizontal insertion drive slide is self-locking lead-screw type, not affected by vacuum load
- New horizontal insertion drive stepper motor with hand crank, in case of motor or controls failure the crystal can be extracted out of the beamline by hand cranking
- Linear motion .00005” per step





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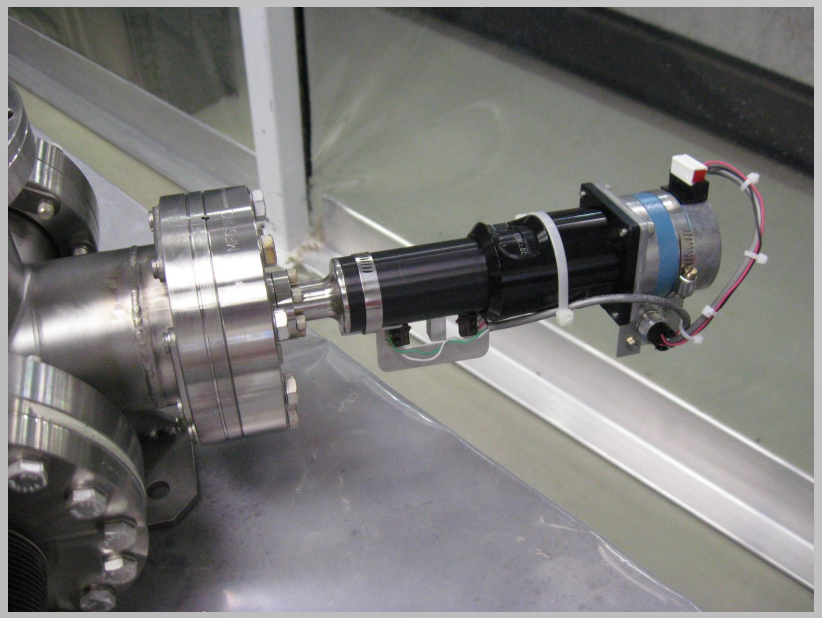
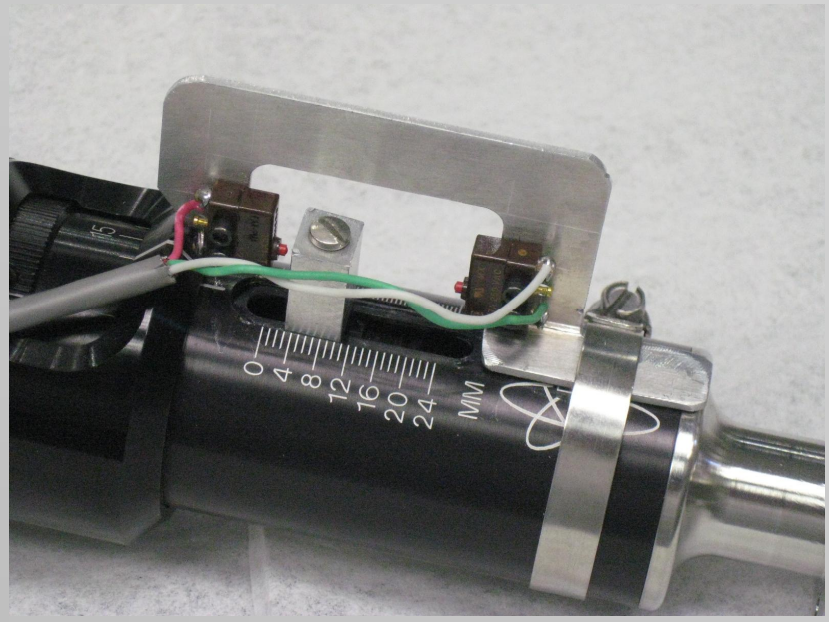
Crystal Collimator Modifications

Major modifications in 2008

- New angular swing motion linear actuator vacuum feedthru with external stepper motor and limit switches
- Angular positioning of the crystal in steps of 1.36 microradians
- Max angular angle = 70mrad instead of 8mrad.





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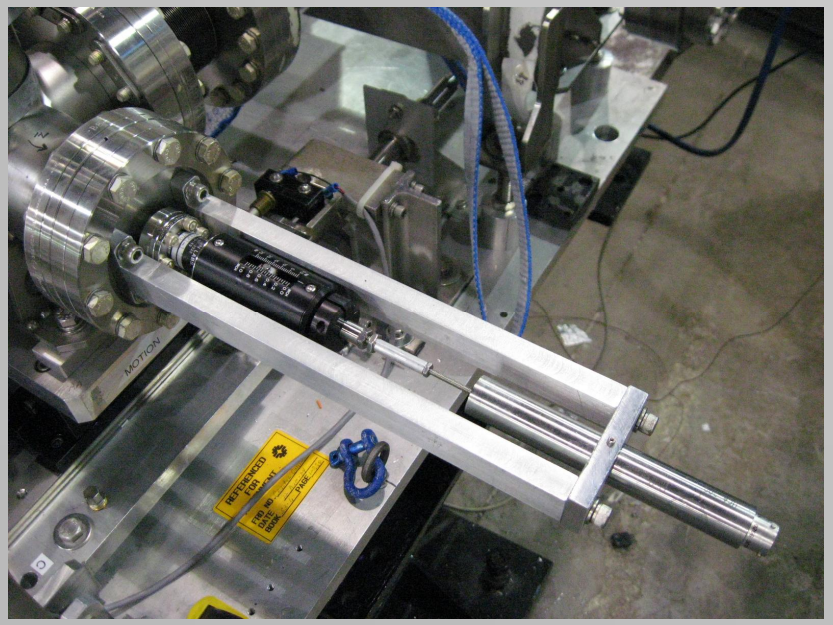
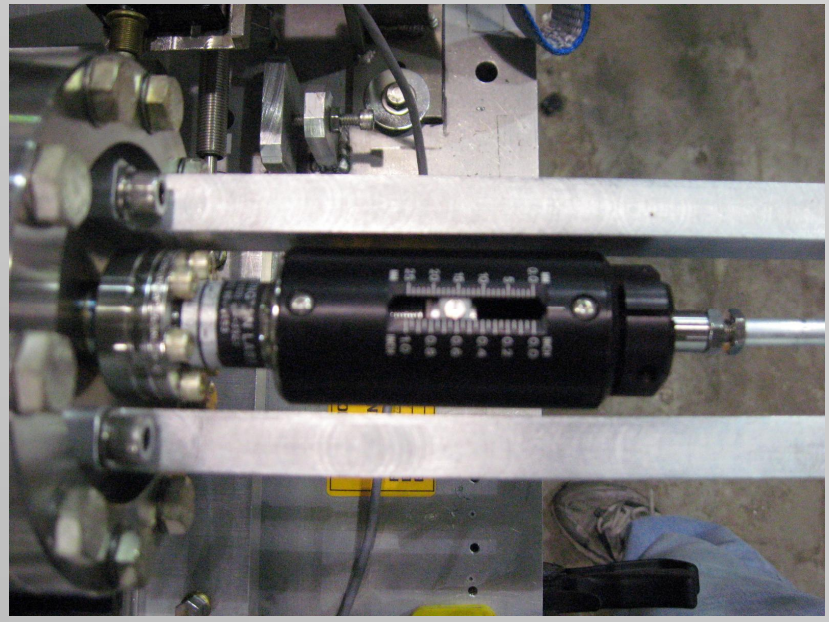
Crystal Collimator Modifications

Major modifications in 2008

- New linear feed thru with external LVDT and visual position indicator for angular swing motion
- Angular measurement 2.1 microradians





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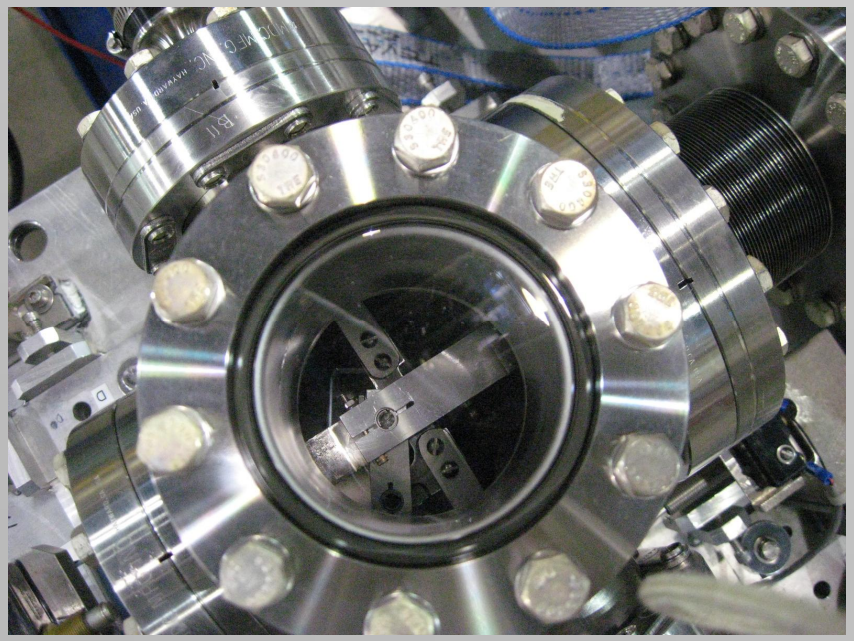
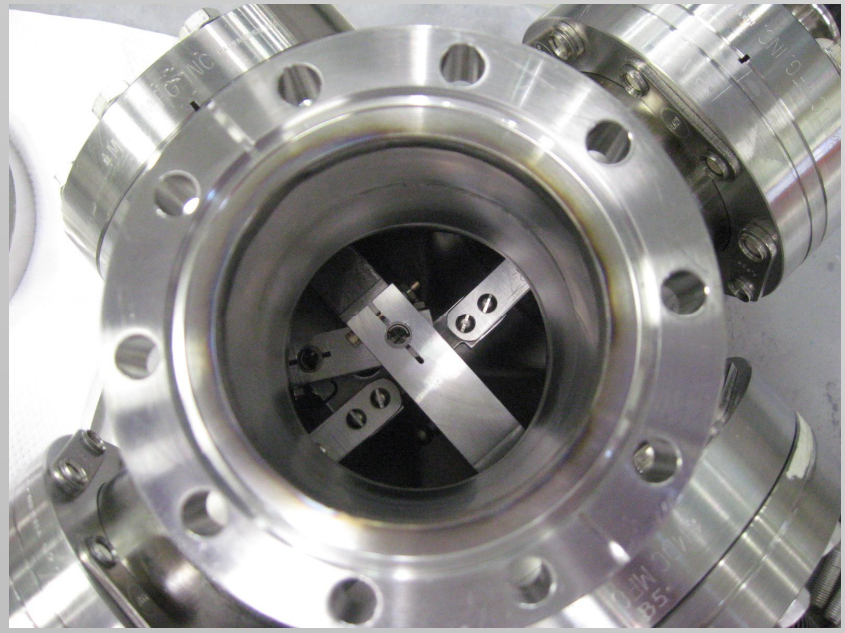
Crystal Collimator Modifications

Major modifications in 2008

- Glass viewport to observe angular swing motion





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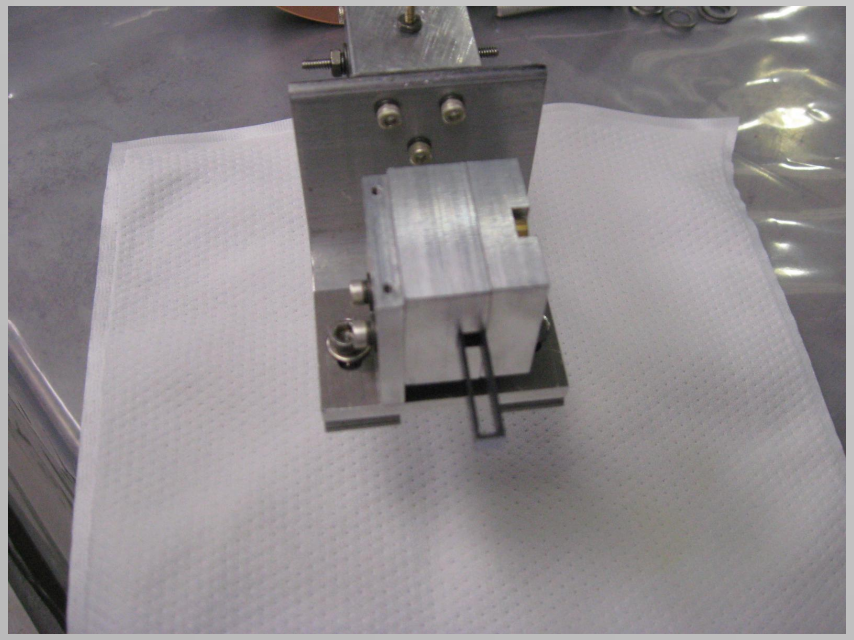
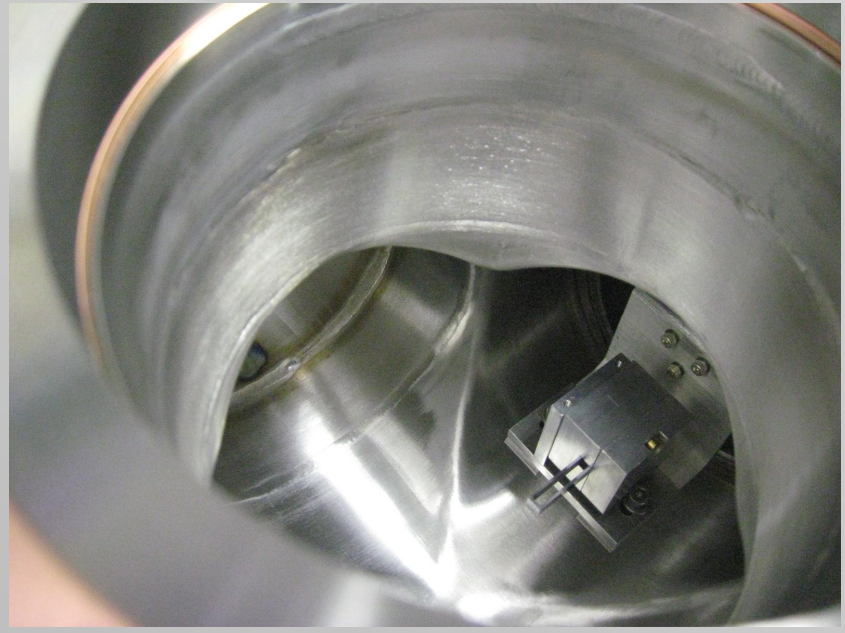
Crystal Collimator Modifications

Major modifications in 2008

- Repaired vibration problem with crystal mounting bracket
- Repaired dragging arm problem with angular swing motion
- Original o-shaped RHIC crystal installed again





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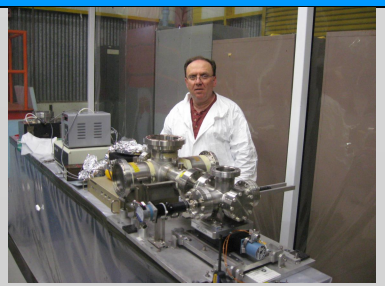
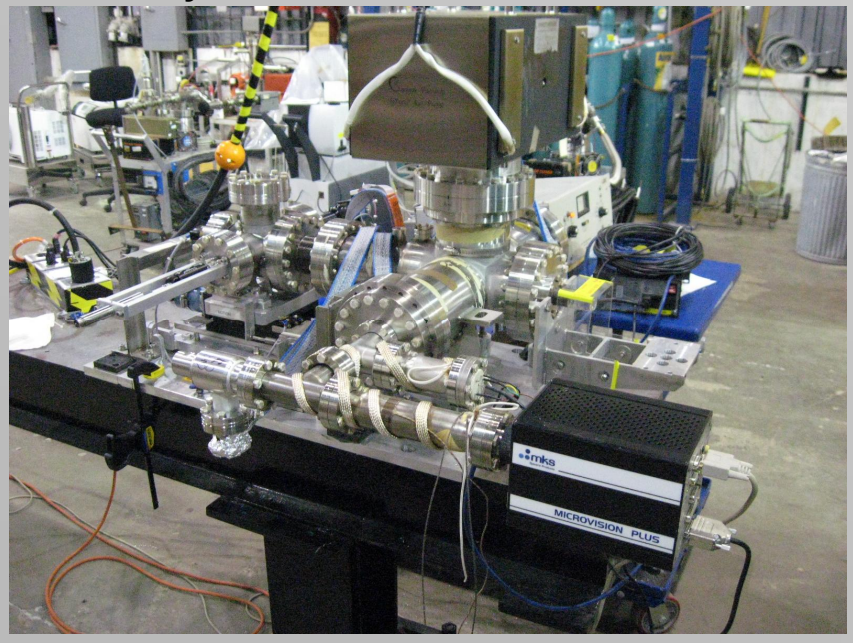
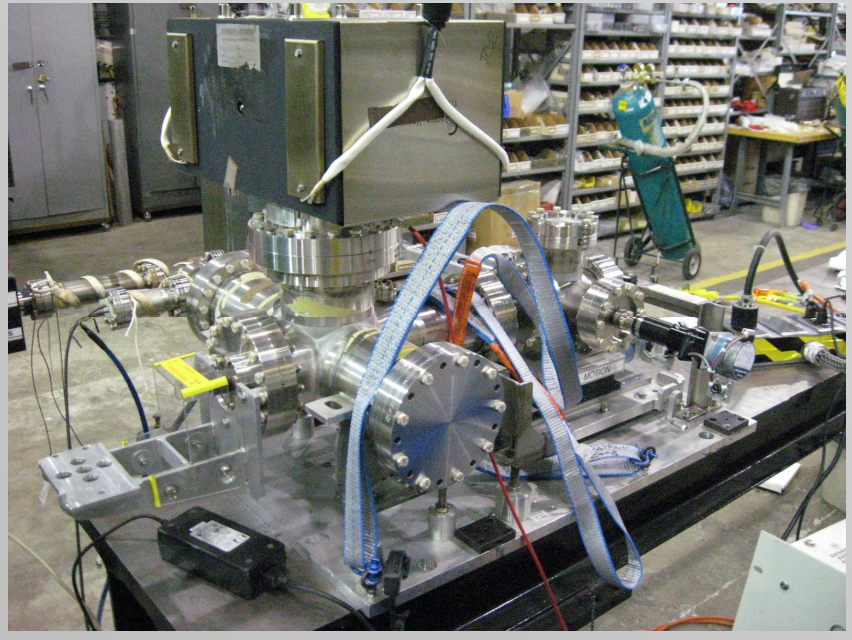
Crystal Collimator Modifications

Major modifications in 2008

- Operated under vacuum
- Vacuum chamber baked
- Vacuum certified
- Ready to install on 12 hr access







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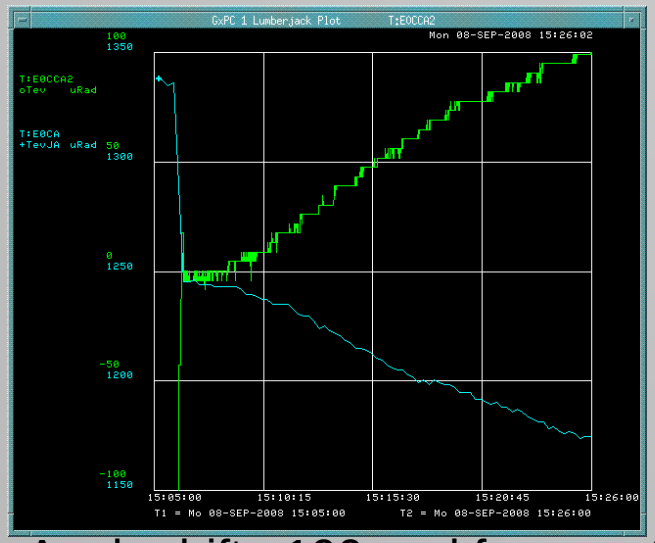
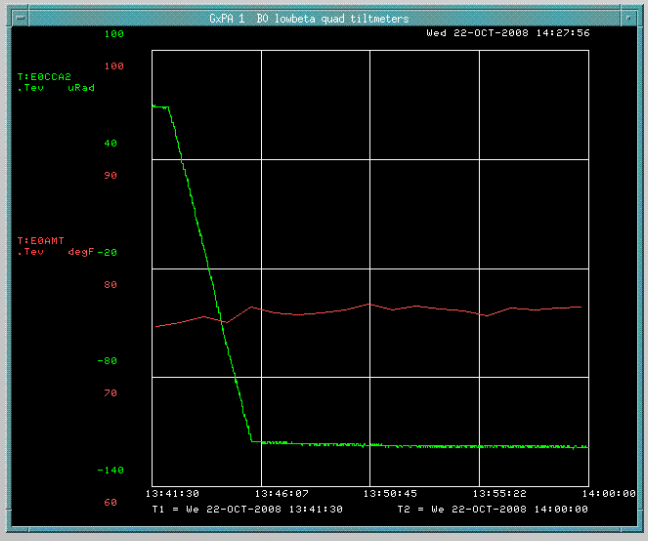
Current Problem after Installation

- **There was an drift of the angular motion after it has been moved and left at a fixed angle due to heating in a miswired motor.**
- **This limited the minumum step size to ~ 8 urad/step**
- **This was fixed last week!**



Angle drift ~100urad from motor Heating.



After motor was rewired- drift is fixed

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Check out of O-shaped Crystal

Results O-shaped crystal - Y. Ivanov PNPI April 2008:

1. Bending angle was found to be (410+-20) microradians.
2. miscut angle was found to be (1.6+-0.1) milliradians.
3. sign of miscut angle is the same as shown in BNL photo.
4. Crystal block was not disassembled for measurements. data and procedures were checked in view of large value of miscut angle - no mistake was found.

Results O-shaped crystal - V. Guidi INFN-LNL Padova groups

– Quality of surface is very good with depth explored – No etching is necessary.

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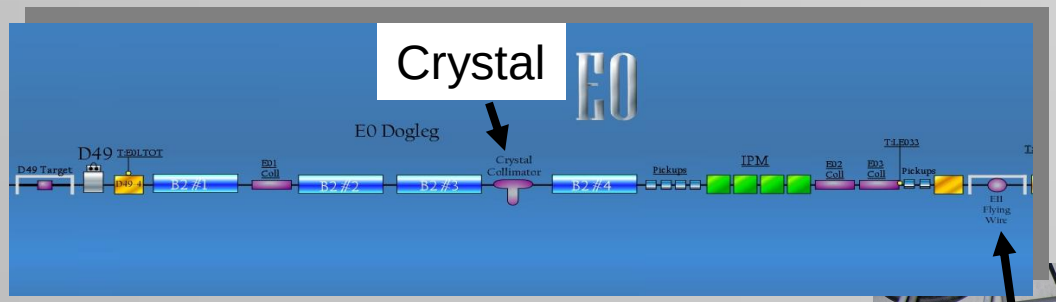
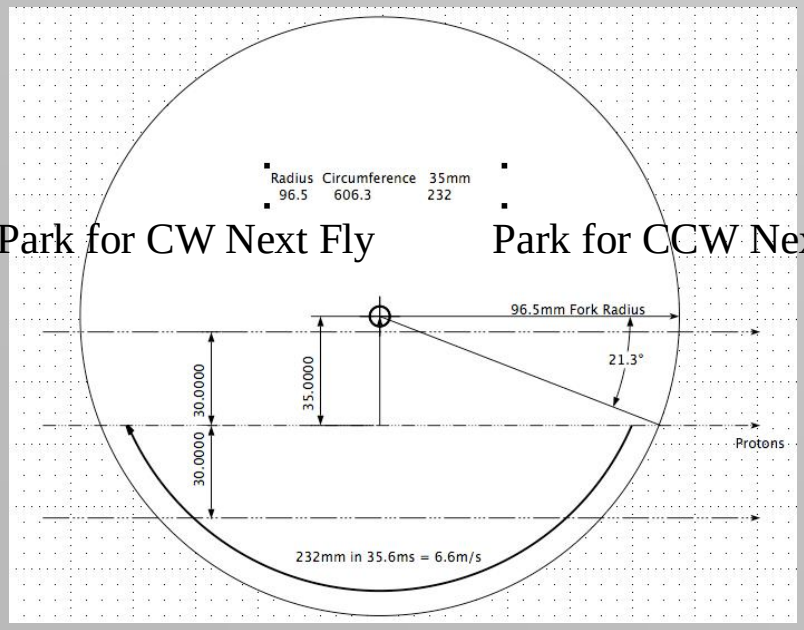
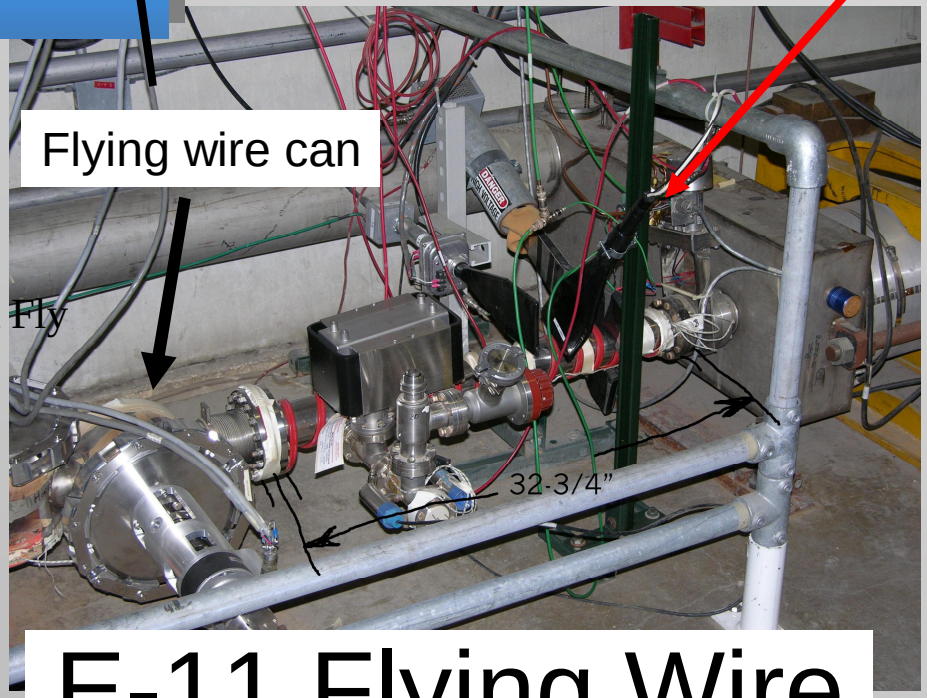
Additional Instrumentation – E11 Flying Wire



New High Gain Paddle



(From J. Zagel – T980 Installation review)



E-11 Flying Wire

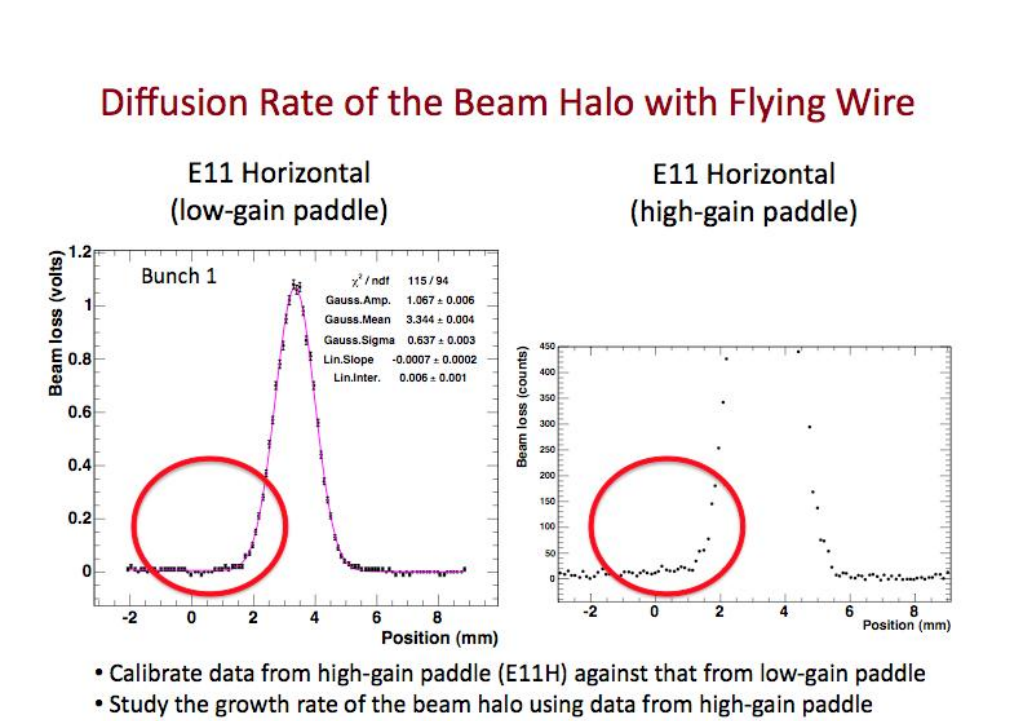
T-980

Analyzing Flying Wire Profiles

•TEV Flying Wires will be used in the normal mode!

•Losses Monitored with HG Paddle

•D0 Crawling Wire will NOT be installed.

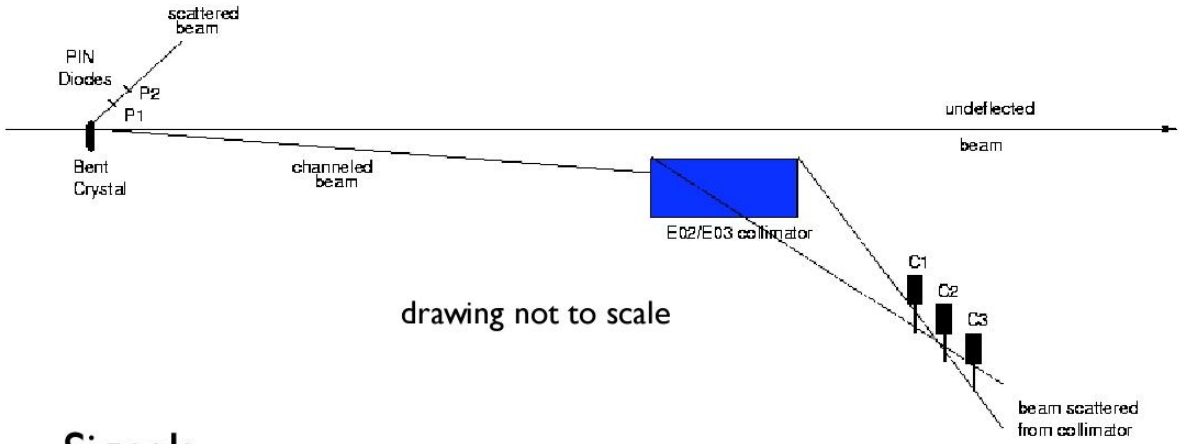


(From J. Zagel, S. Shiraishi – T980 Installation review)

T-980

E1 Counters

Detecting Crystal Collimation



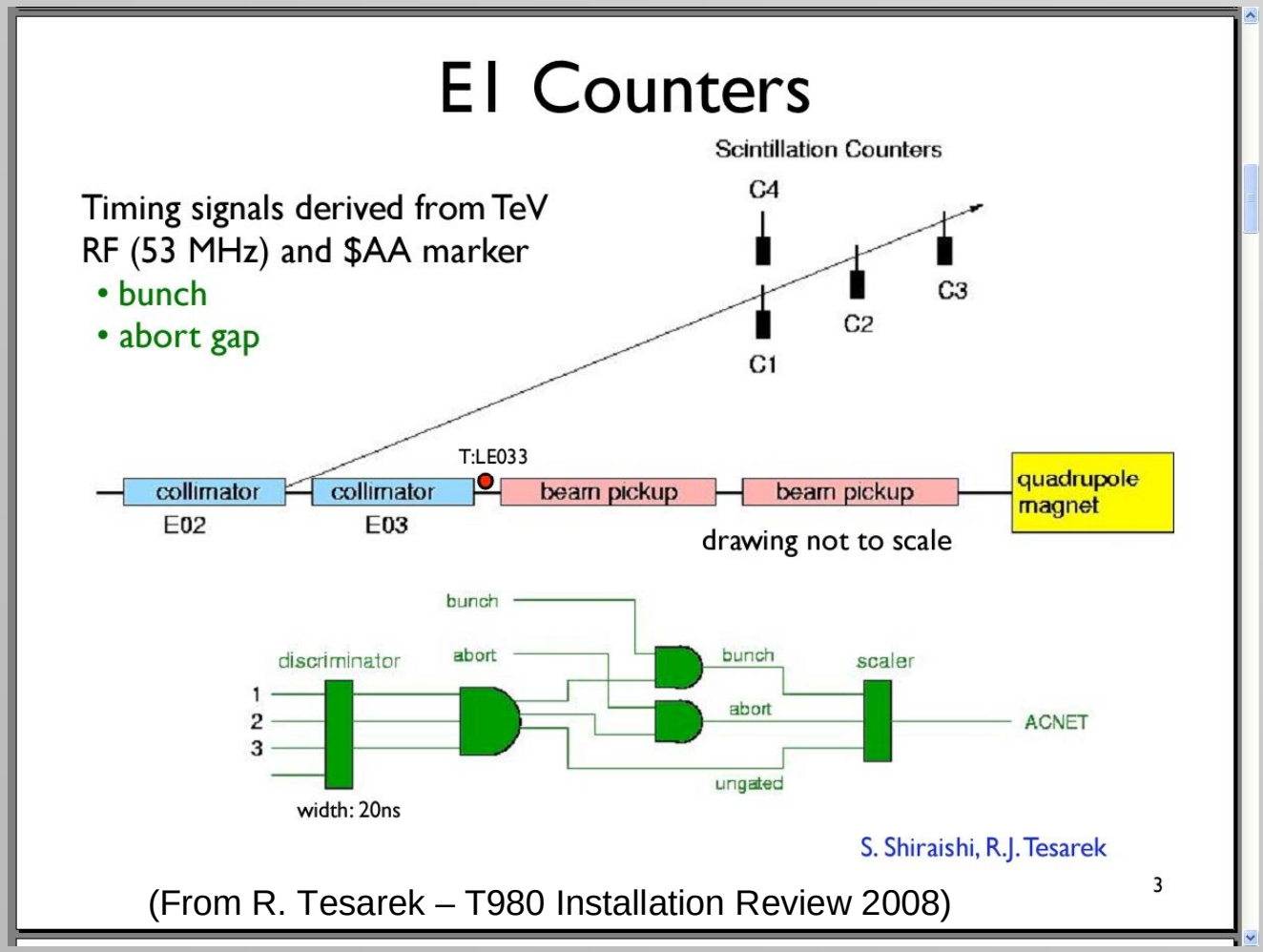
Signal:

- increased rates in counters
- decreased rates in PIN diodes

(From R. Tesarek – T980 Installation Review 2008)

2

E1 Counters



(From R. Tesarek – T980 Installation Review 2008)

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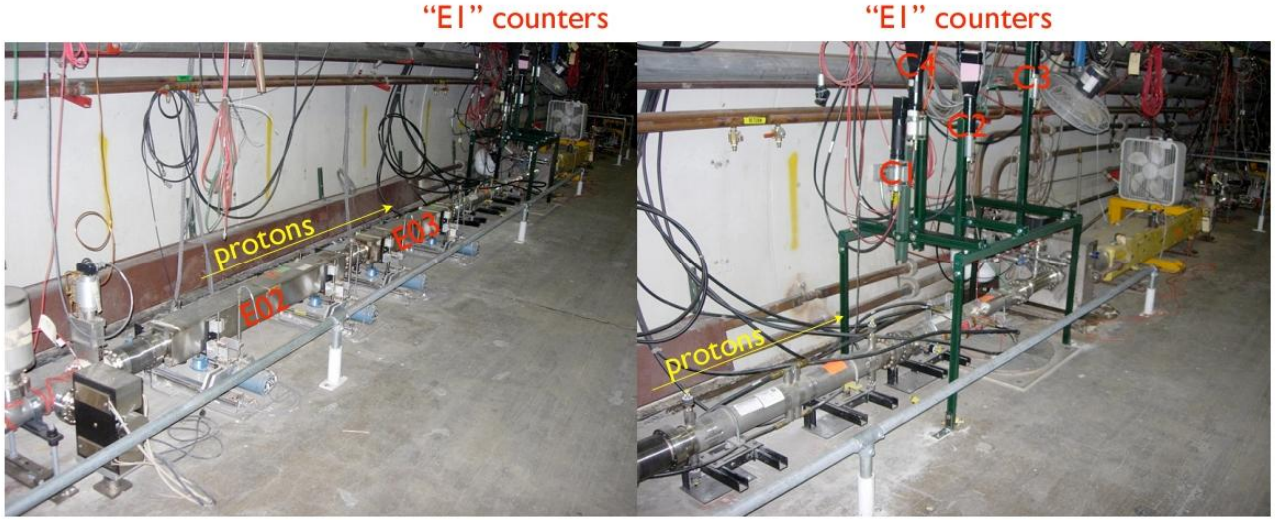
E1 Counters

E1 Counters



(From R. Tesarek – T980 Installation Review 2008)

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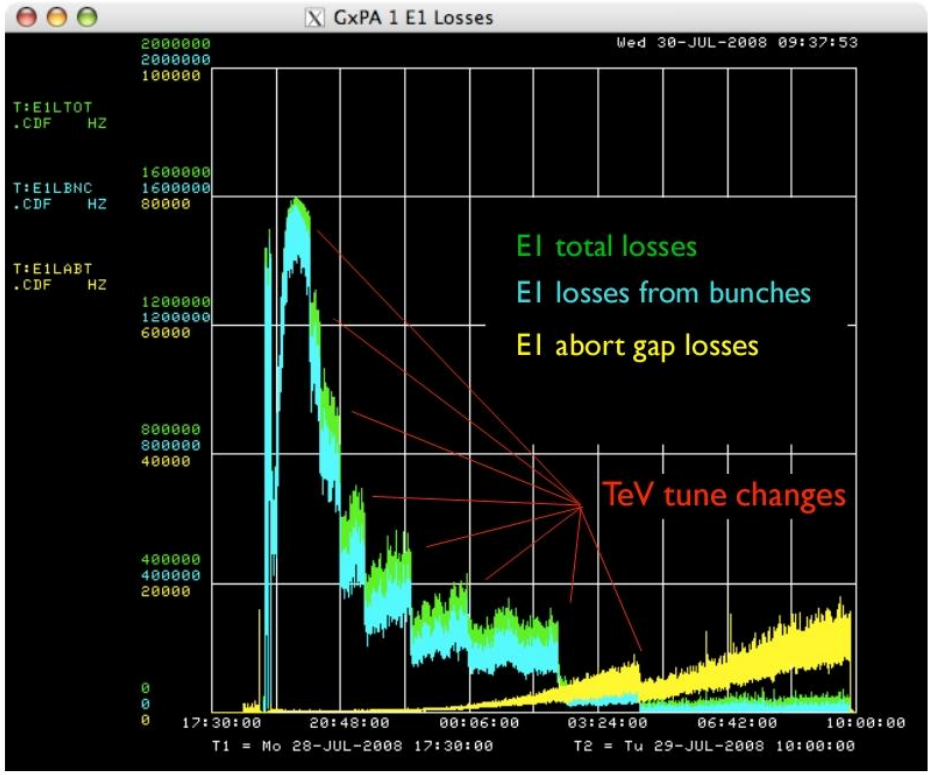
Beam on counters from Store 6323

E1 Counter Performance

typical store 6323



Regions of Interest

- no beam
- collimator out

(From R. Tesarek – T980 Installation Review 2008)

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Crystal 2008 Study Plans

T-980 has requested 12-20 hours of EOS to reach the following goals:

- **Measure channeled, volume-reflected and scattered beams** as well as beam losses (radiation levels) downstream of the crystal setup in comparison with simulations.
- Demonstrate reproducible beam loss reduction in the B0 and D0 in comparison with simulations, aiming at a **routine** use of the crystal based collimation in the Tevatron stores.
- Develop optimal crystal/goniometer/instrumentation system for one- and two-plane collimation exploring and exploiting novel crystal technologies and newly understood phenomenon, volume reflection.
- All of the above in conjunction with the CRYSTAL experiment at CERN SPS, aiming at a Phase II crystal-based collimation system for the LHC (performance, reduced impedance and heavy-ion option)

To date: crystal EOS have conducted ~ 40+ hours of successful studies.

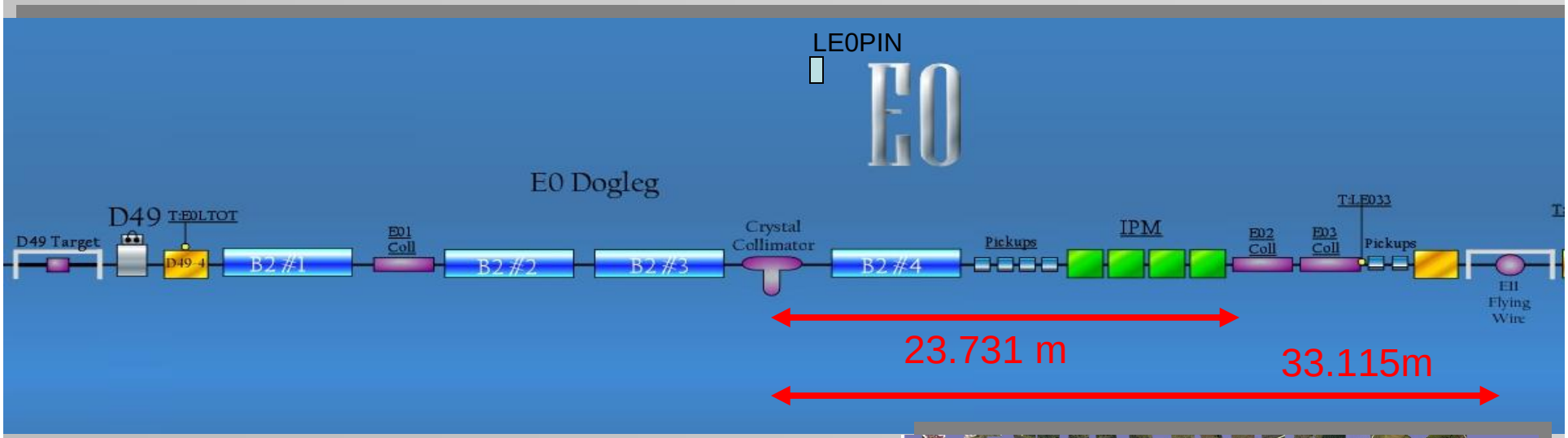
T-980

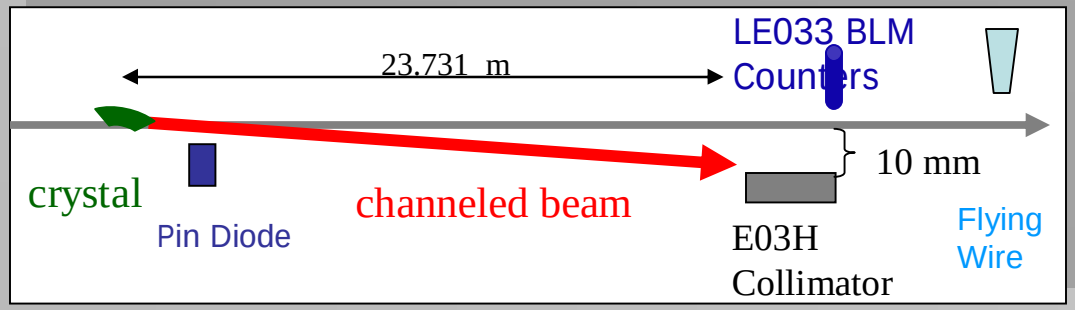
Crystal Commissioning

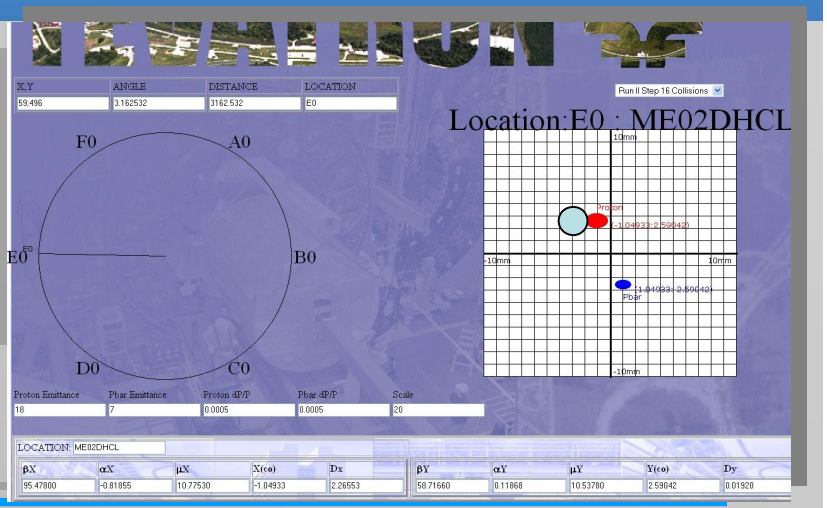
Crystal Collimator Commissioning Estimate 2008		
Commission Task	**Shifts**	**Personnel**
Prebeam Testing:		
Crystall Tunnel installation		Tev mech group
Laser installed and controls tested to MCR (start w/ wide detector)		T. Johnson
All beam intrumentation installed and controls tested to MCR		Johnson,Tesarek,Zagel
Hor. & Ang. motion control installed and tested to MCR		Legan
Final alignment confirmed (provide lbseq25 helix values)		Survey, Still
Add new feedback devices to application C10 and rebuild		Still
Scintilator detectors and flying wire currently working and taking data		Tesarek, Zagel
150gev Beam Tests: (Conducted in Downtime and Shot Setup)		
Scan crystal Hor and Ver with beam to find center. Record	0.125	Still
Test angular motion control using feedback	0.125	Still
Test horizontal motion control using BLM/PIN feedback to stop motion	0.125	Still
980gev Beam Test : (EOS or proton only)		
On Proton helix & lbseq25 - Find center of crystal hor and ver with beam !!	0.25	
Angluar scans to determine channel. (EOS)	0.5	Still
Verify baseline for Instrumentation FW,SD,BLM,PIN in channel	0.25	Johson,Tesarek,Zagel, Shiraishi
With crystal channeling - intercept wit E03 collimator. Record effiency	0.25	Still
Test channel setup for future automated use at beginning of store	0.125	Still
980gev Lowbeta- Proton/Pbar EOS Study Program:		
Ready to demonstrate beam goals for T-980		
	Total shifts	
	1.75	

T-980

E0 Crystal Layout







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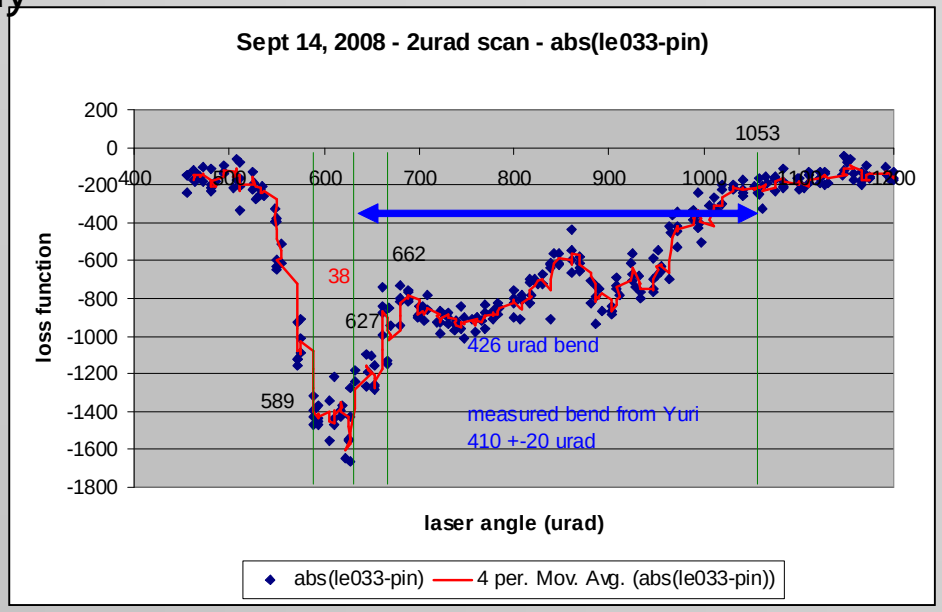
2008 Beam Study Results

There have been 2 EOS (5 hours) beam study periods:



Sept 14, 2008

- Crystal was vertically aligned
- Preliminary angle scans were made.
- Channeling was seen.

Oct 3, 2008

- Look at reproducibility of channel.
- Get a fine 1urad scan over bend angle.
- Measure the displaced channel beam w/ E03H
- Get flying wire data in the channel.

Compare 2008 to 2005 Data

Fit=1200*(1-0.20/(1+(abs(X-220))/200)^8)-0.36*exp(-(X-10)^2/36^2/2))

Channel:

50% wider (22 urad → 36 urad)

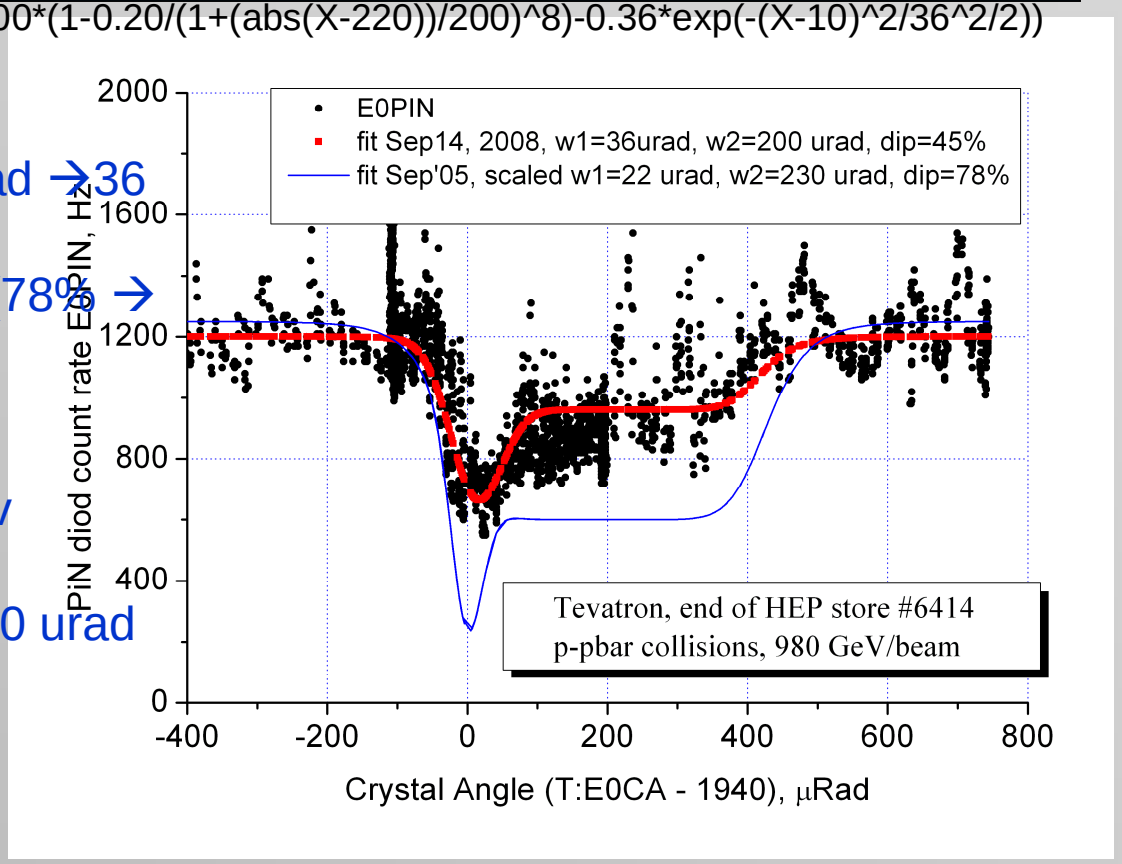
Not as deep (78% → 45%)

Bend:

426 urad

Y. Chesnokov measured

410 urad +/-20 urad

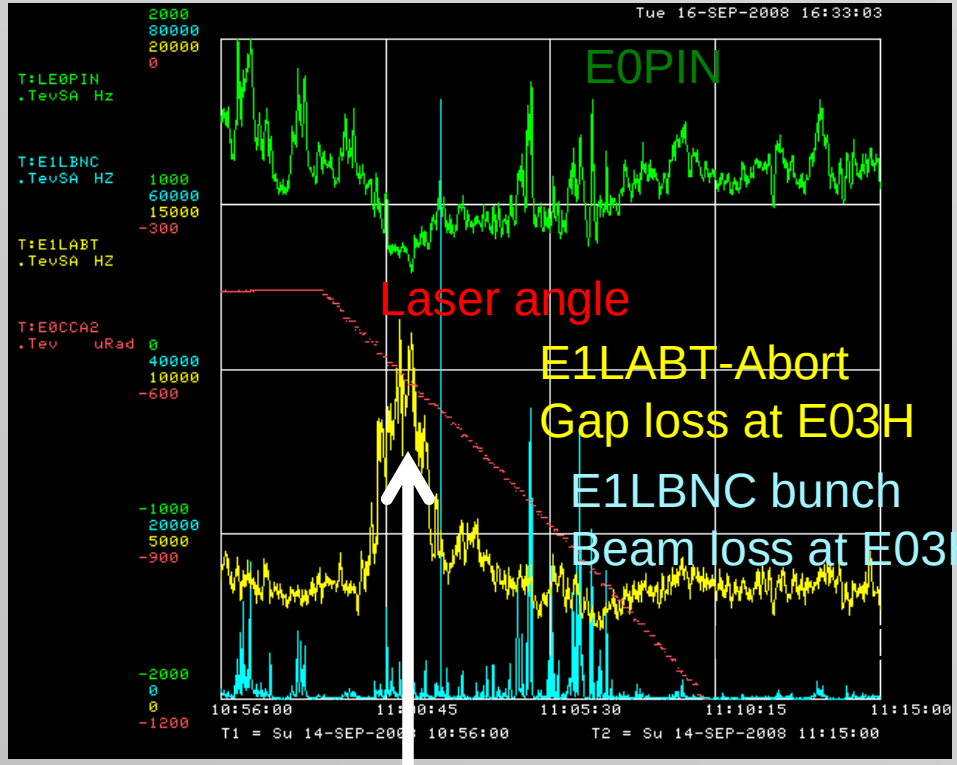


(Analysis by Vladimir Shiltsev)

T-980

Channeling Beam in the Abort Gap

- The main contribution of beam that is channeled and hitting the E03H collimator is from the abort gap.



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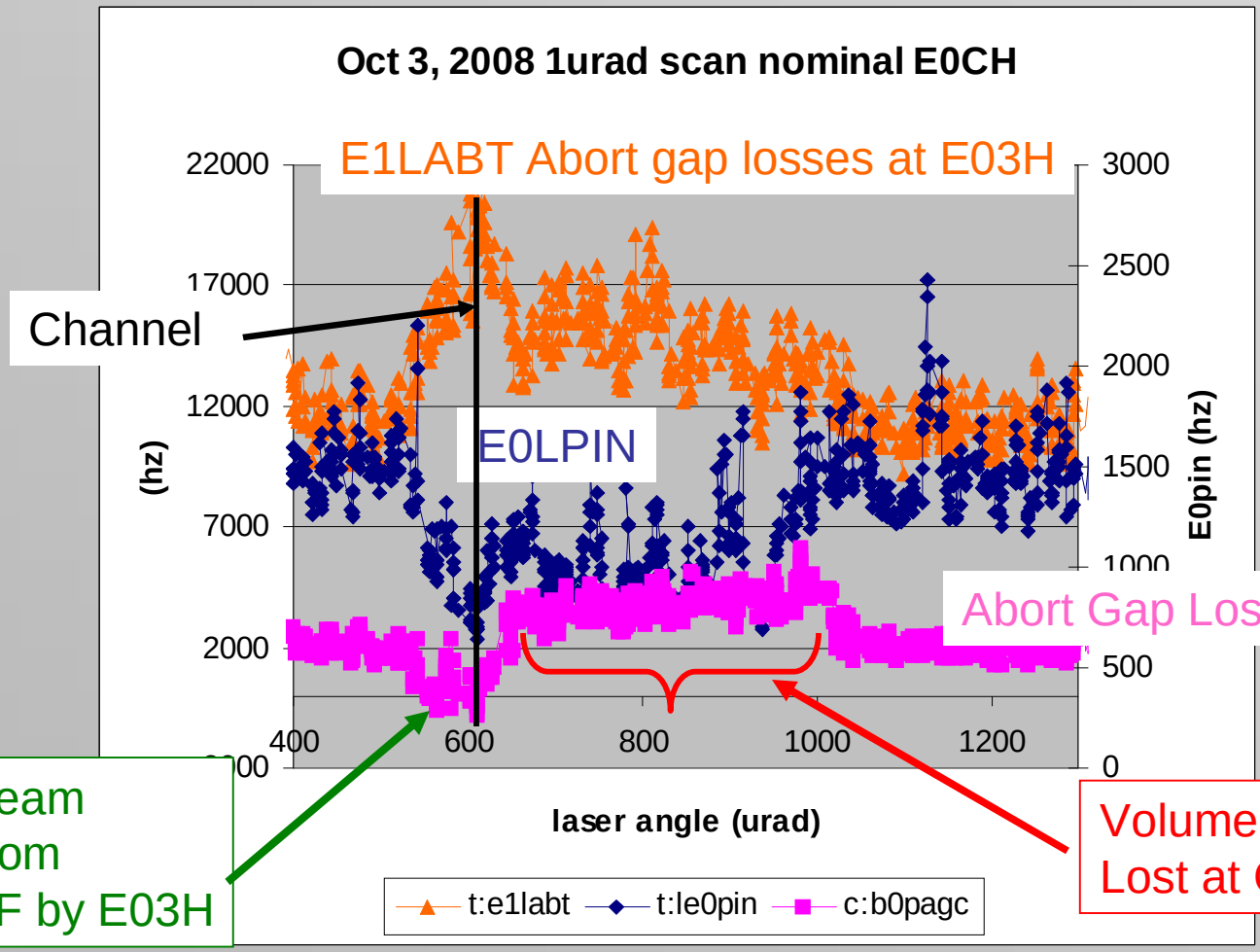
Channeling Abort Gap Beam

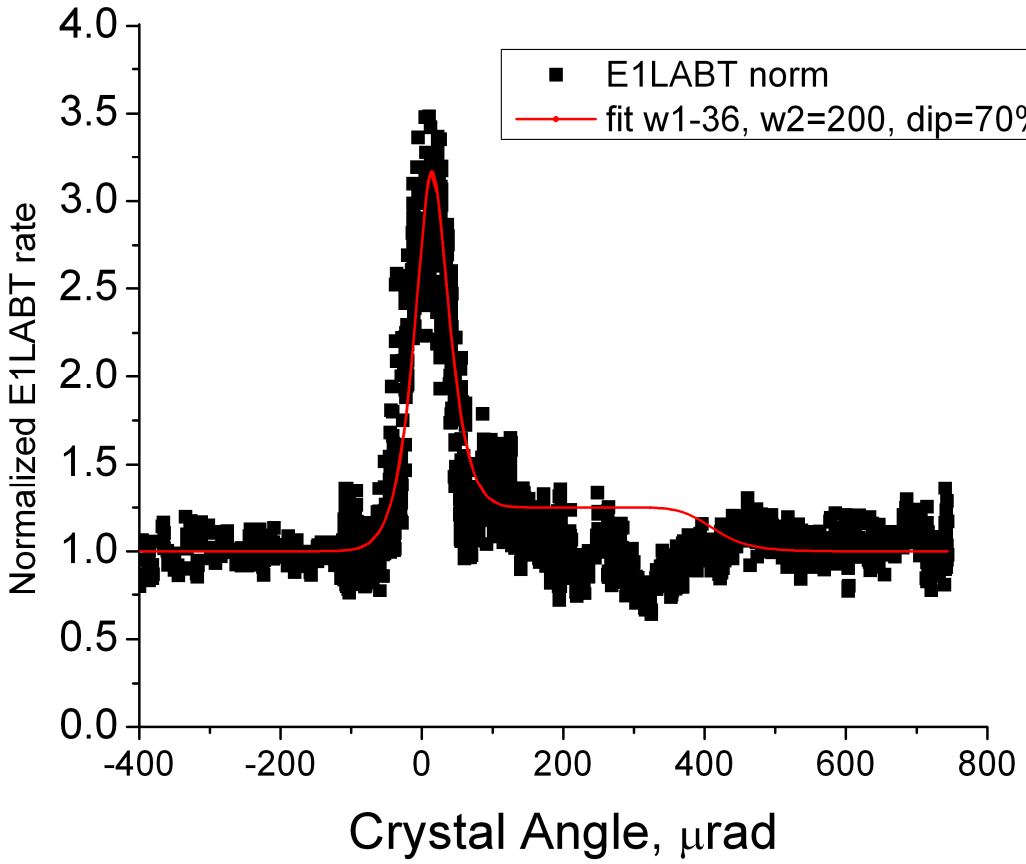


Channel beam Stopped from Hitting CDF by E03H

Volume reflected beam Lost at CDF

Fitting E1ALABT for the channel

Fitting to the width of the abort gap beam that hits the E03H collimator again the Channel width is ~ 36 urad.



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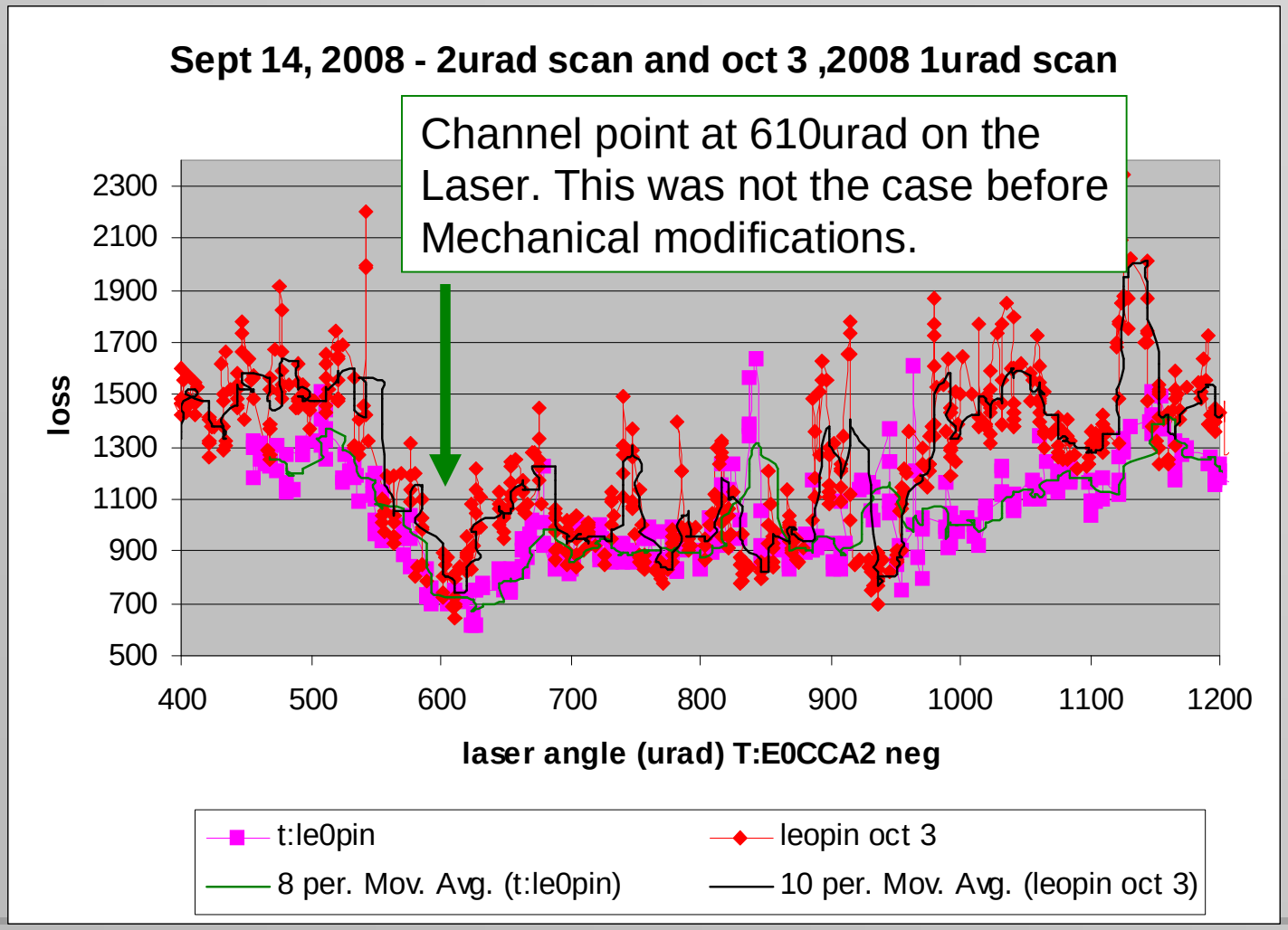
Reproducablity of channel



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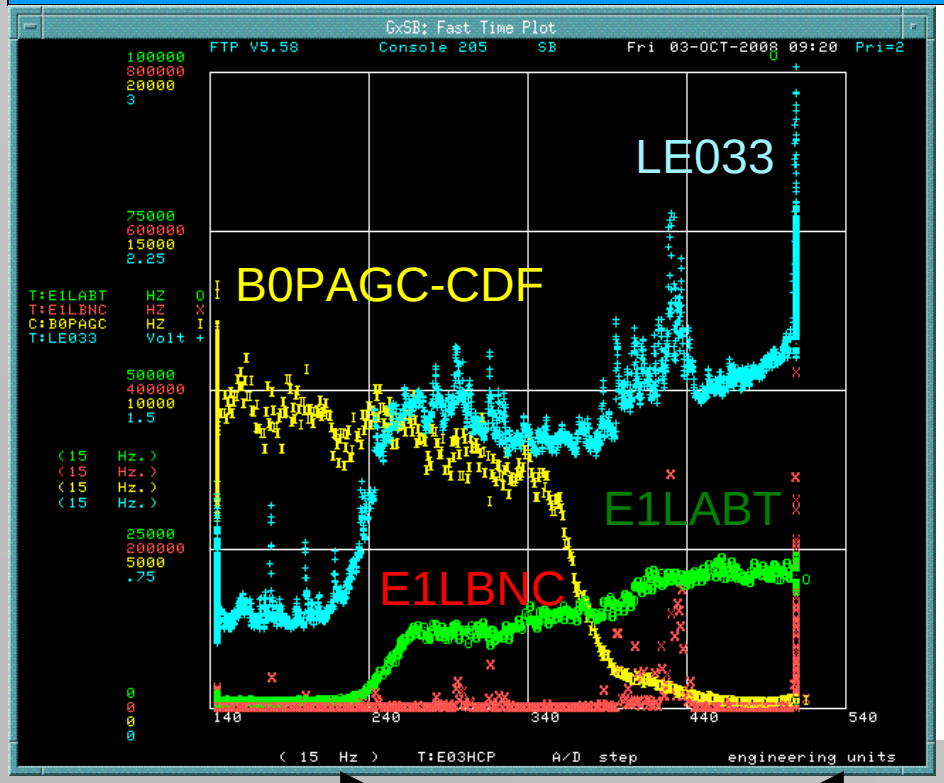
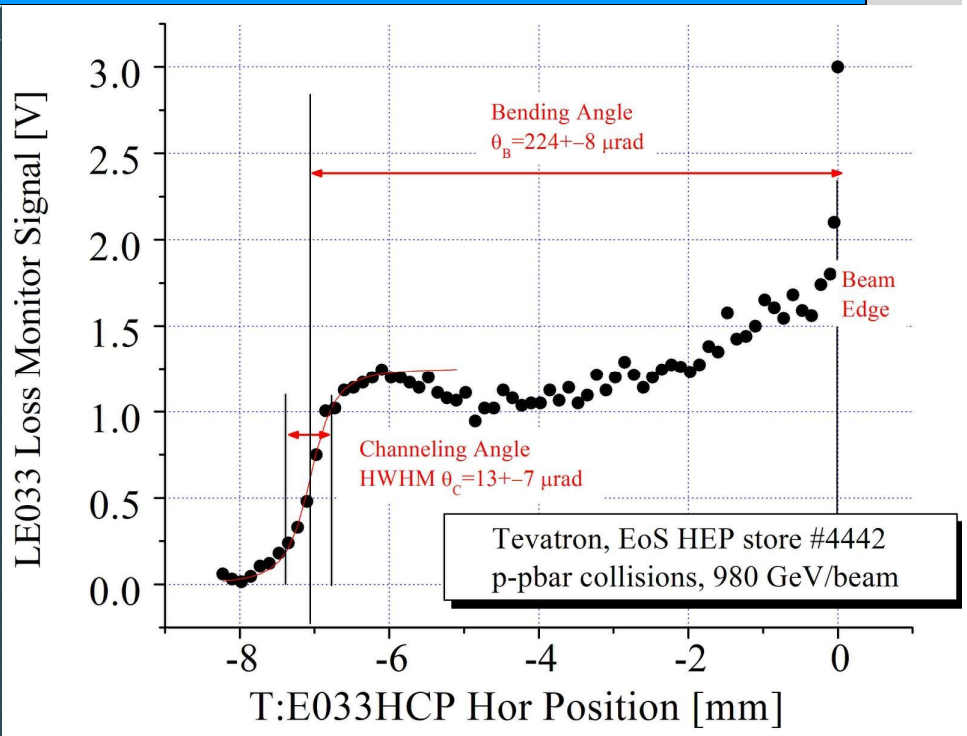
Measure Displaced Channeled Beam



269 mil or 6.72mm

NOT 10.31mm for 410urad bend – Same result as 2005????



(2005 E03H retraction scan)

This has to be understood – It is believed that the large miscut angle may explain this. Attempting to simulate this effect.

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Summary

- Channeling in the O-shaped crystal has been established w/ differences in channel width and efficiency. These may be explained by angular motor problems and need to rescan now it is fixed.
- Displaced channel beam on E03H is similar to results of 2005. ~ 7mm instead of 10mm displacement. Possible that the miscut angle is effect. Simulations are being run to confirm effect.
- Have seen major portion of channeled particles are in the abort gap.
- New E1 counters are working well to provide helpful data.
- Have seen volume reflected beam in the abort gap at CDF.
- Reproducibility of finding the channel is better that 2005.
- Had an angular motor drift problem that is now fixed.
- Flying wire data is still be analyzed to see if channeled beam profile can be seen.
- Not far from attempting using the crystal for a Beginning of Store.