T980 STATUS

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Fermilab

LARP CM12 Collaboration Meeting
Napa Valley
April 8-10, 2009

OUTLINE

- Overview
- Crystals, Goniometer and Beam Diagnostics
- End-of-Store Beam Studies
- First Full Collider Store with Crystal (!)
- Simulations
- New Two-Crystal Goniometer
- Plans

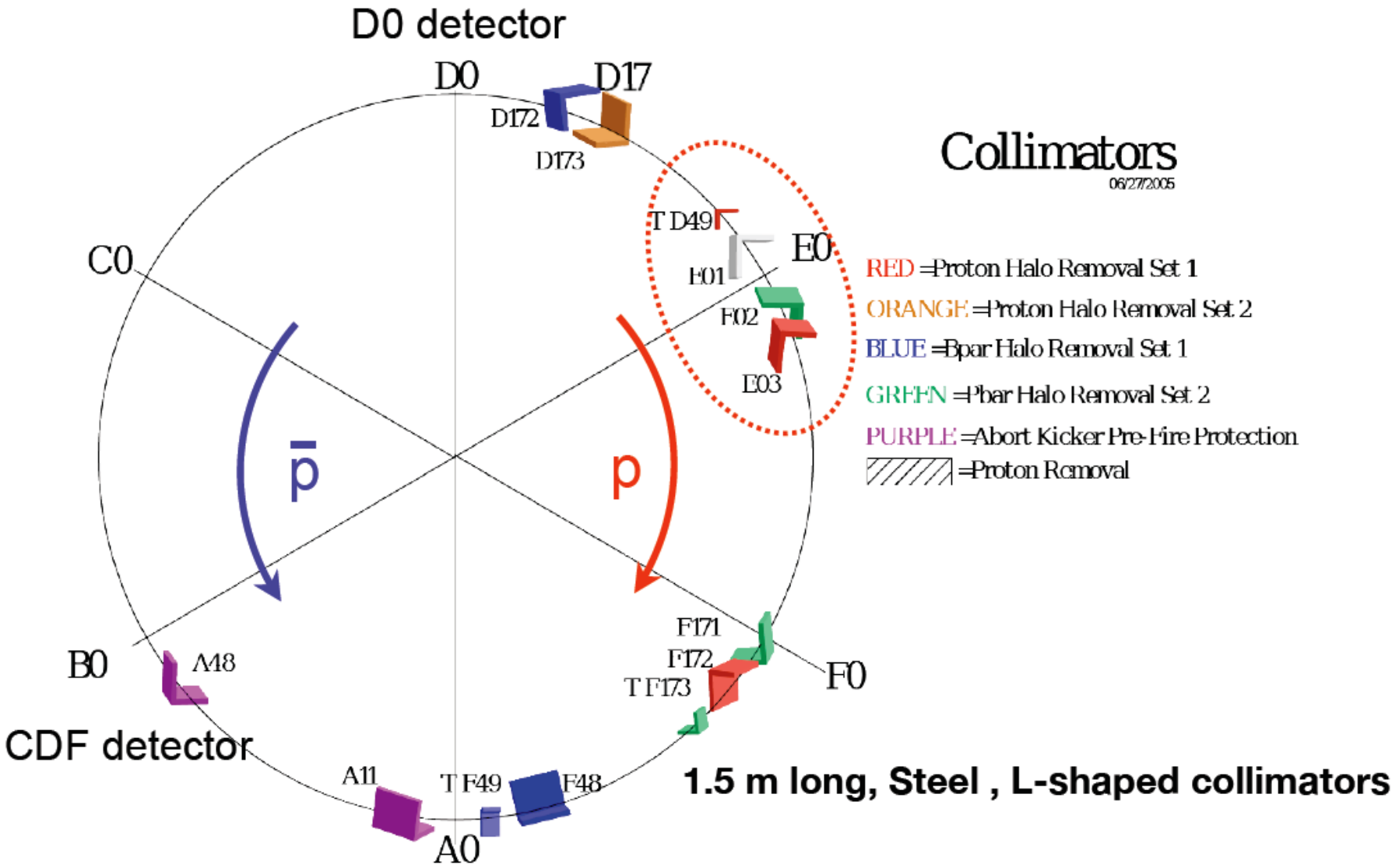
T980 MISSION

- Develop a collimation system for hadron colliders based on channeling crystal techniques, which has a promise to reduce machine impedance, beam losses in superconducting magnets, improve background conditions in the collider detectors and be compatible with heavy-ion operation.

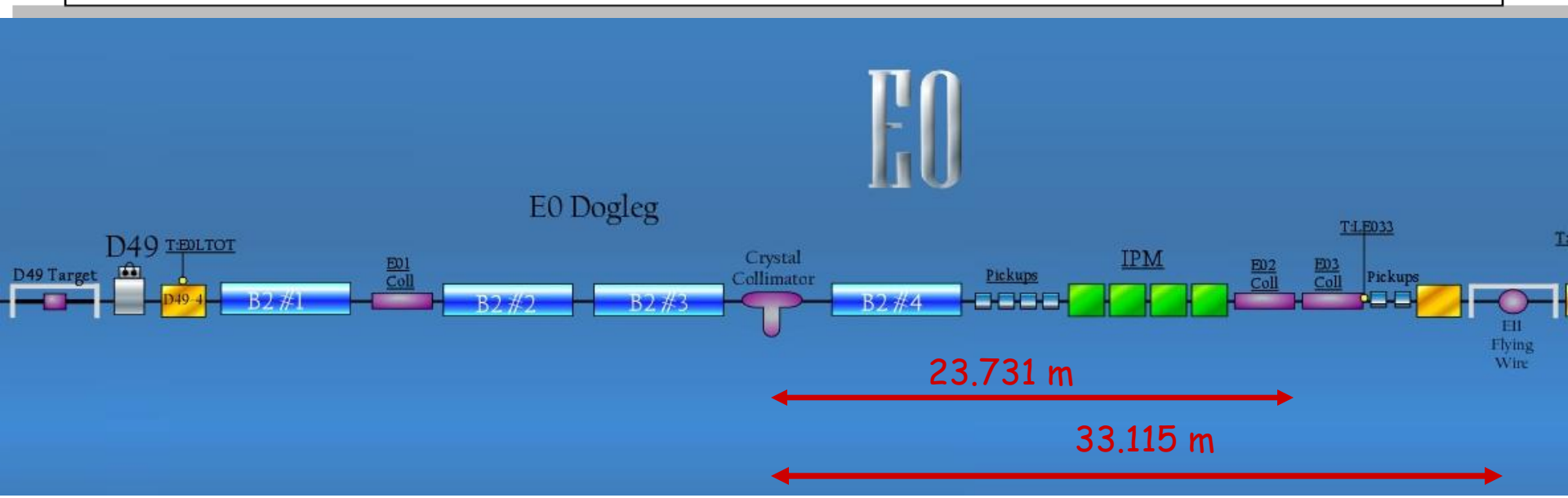
- Start routine use of crystal collimation in the entire Tevatron collider store.

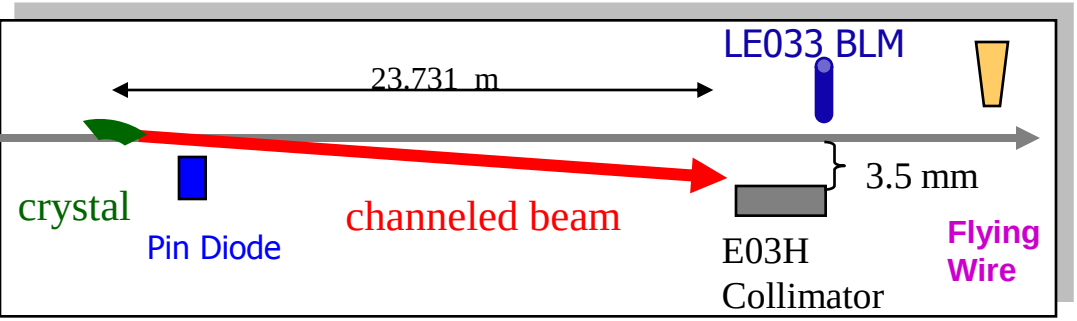
- Study the system's performance and underlying beam dynamics exploiting the unique possibility provided by the Tevatron collider to evaluate an engineering implementation of this technique in the LHC.

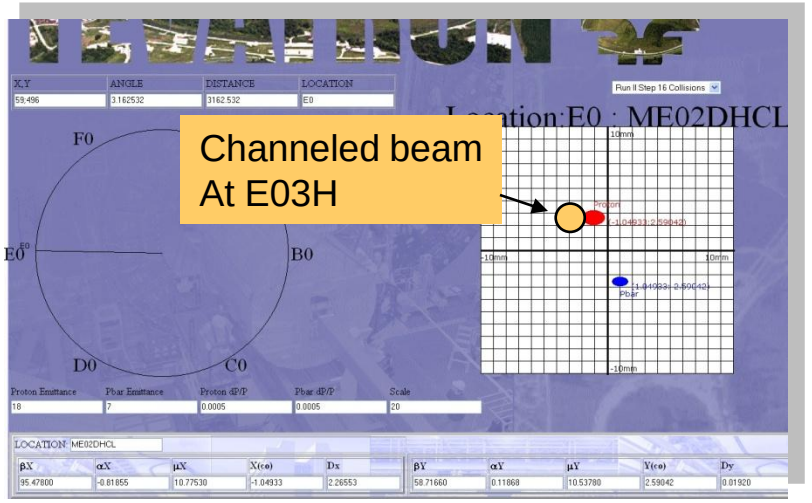
TEVATRON COLLIMATION SYSTEM



E0 Crystal Collimation Layout







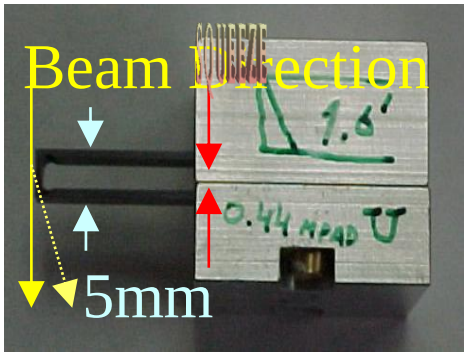
RETROSPECTIVE

Last months have been full of significant events for T980:

- Installation of substantially improved goniometer, proven/characterized crystal and enhanced beam diagnostics
- Interesting End-of-Store studies **culminating in the first use of the crystal collimation system through the entire Collider store on March 17-18, 2009 !**
- Simulation tool developments which allowed to get valuable predictions on the system performance
- Launch of a new push-pull goniometer project

CRYSTALS

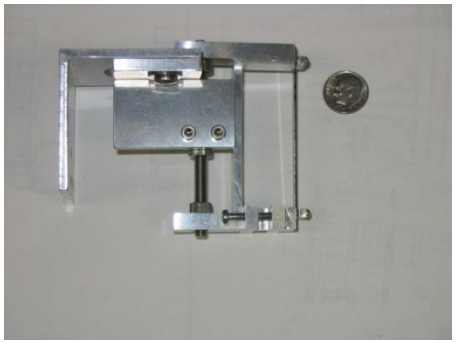
0.44mrad O-shaped crystal



The strip crystal was removed from the tunnel and replaced with the characterized O-shaped one (Ferrara and PNPI).

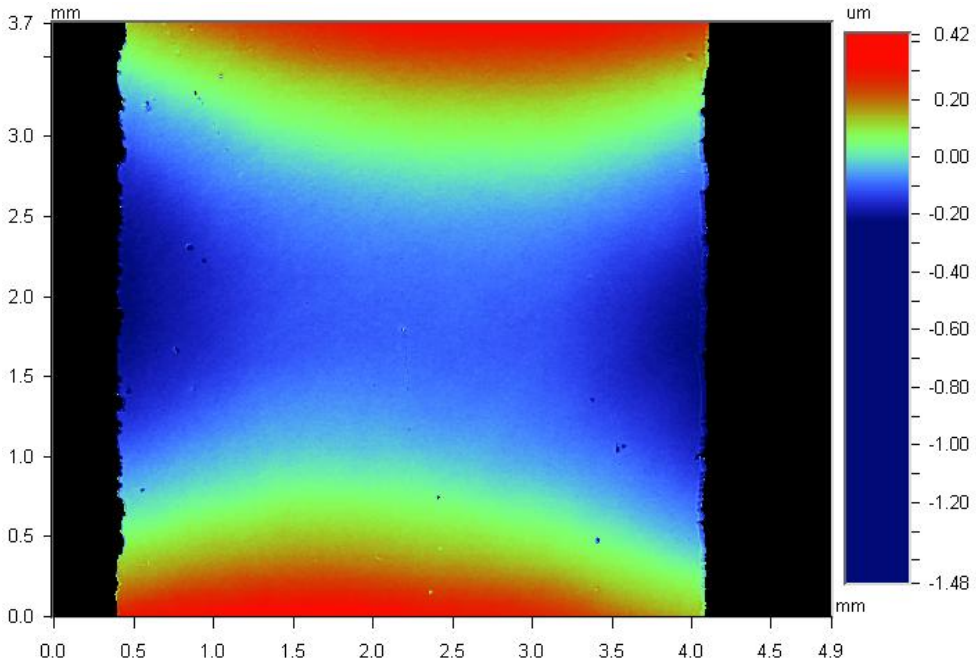
The characterized O-shaped is again used in T980 since September 2008.

0.15mrad strip crystal



The strip crystal has recently been characterized at Ferrara.

Characterization of the Strip Crystal at Ferrara

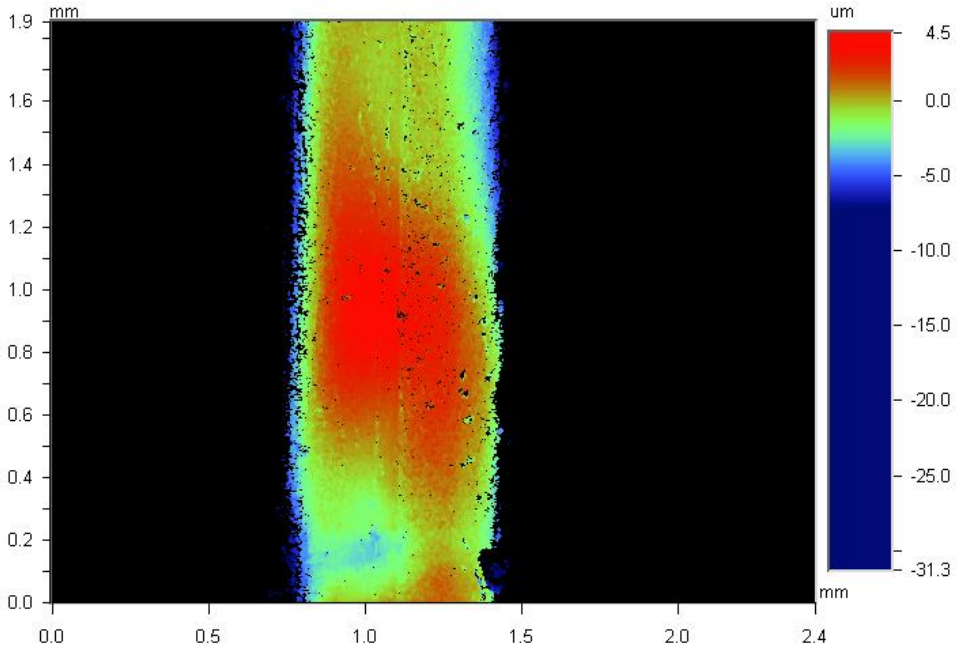


No channeling was observed with this crystal in numerous attempts in 2007

Morphology of the lateral face:

1. No chemical etching was applied at side surfaces
2. Bending radius R=15.7 m
3. Torsion = 20 μrad/mm

Characterization of the Strip Crystal at Ferrara



Morphology of the entry face:

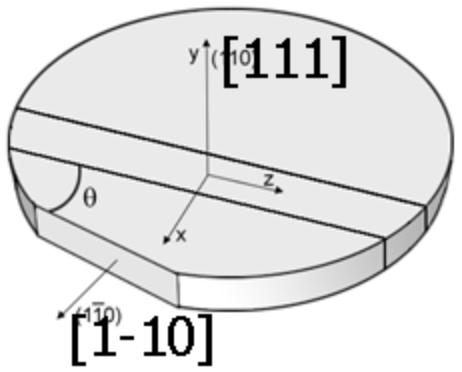
Presence of large "chipping" at the edges, an indication of rough cut of the sample

Characterization of the Strip Crystal at Ferrara

RBS-channeling characterization				
Axis	Beam	Face	Measured χ (%)	Reference χ (%)
[111]	2 MeV He+	Lateral	4.3 ± 0.2	2.5
[1-10]	2 MeV He+	Entry	4.6 ± 0.2	2.0

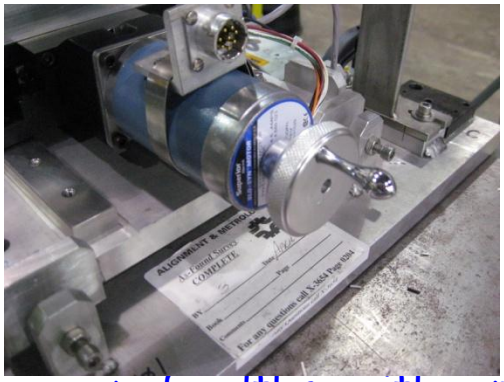
The quality of the surface is modest, probably not adequate for the energy at FNAL

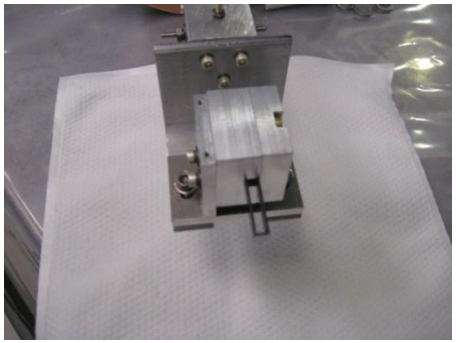
RBS measurements highlighted that the [1-10] axis is 7° out of axis, i.e., rather an unusual value



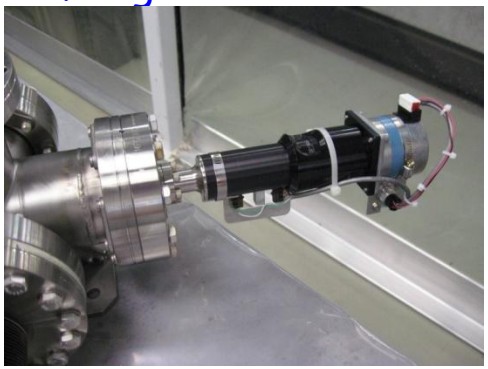
Numerous Goniometer Modifications

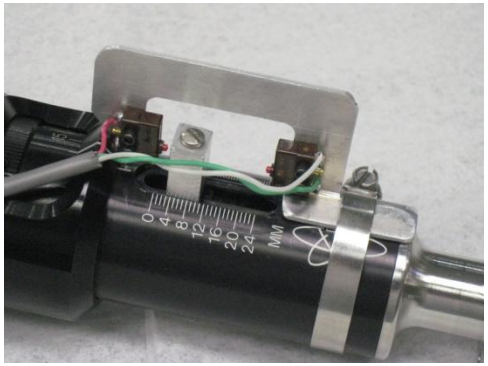
- New horizontal insertion drive slide is self-locking lead-screw type, not affected by vacuum load.
- New horizontal insertion drive stepper motor with hand crank, in case of motor or controls failure the crystal can be cranked out of the beamline by hand; linear motion .00005" per step.

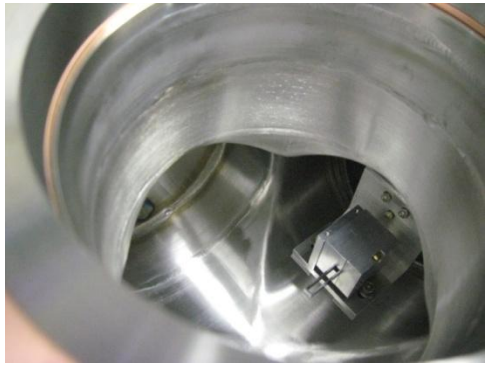




- New angular swing motion linear actuator vacuum feedthru with external stepper motor and limit switches, thumbwheel for hand operation; angular positioning of the crystal in steps of 1.36 urad; angular measurements 2.1 urad.



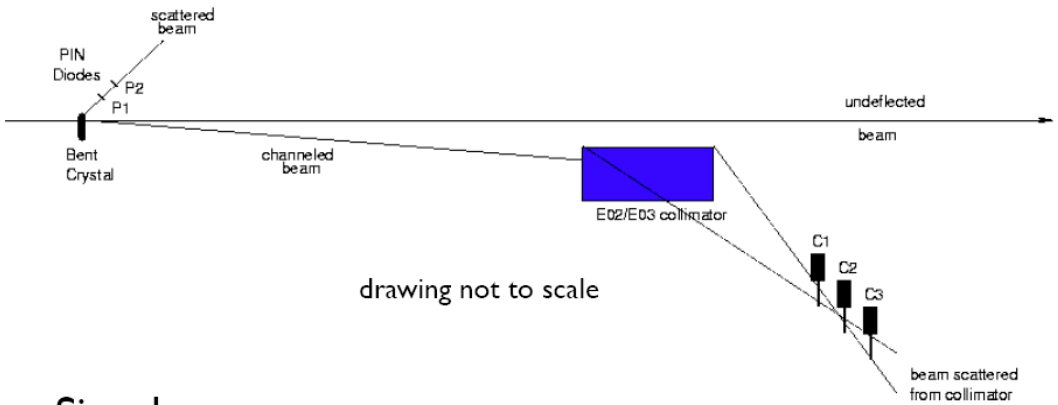




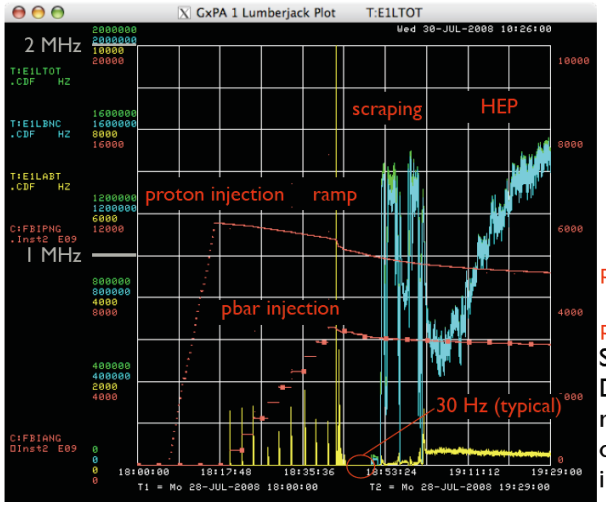
BEAM DIAGNOSTICS

- 1-cm^2 PIN diodes immediately downstream xtal arranged in telescope
- LE033 beam loss monitor (~24 m downstream)
- EOCH (EI) scintillation counter telescope
- E11 flying wires (~33 m downstream)
- CDF beam loss monitors (~3 km downstream)

E0CH COUNTERS



Injection



proton current

pbar current

Study rates w/ D49 (target) retracted, all other collimators in nominal pos.

Signal:

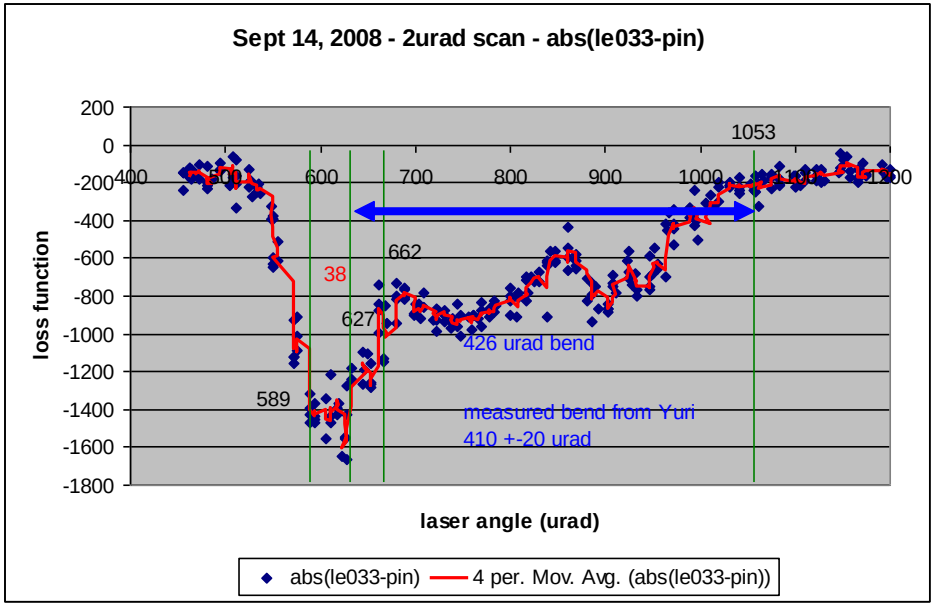
- increased rates in counters
- decreased rates in PIN diodes

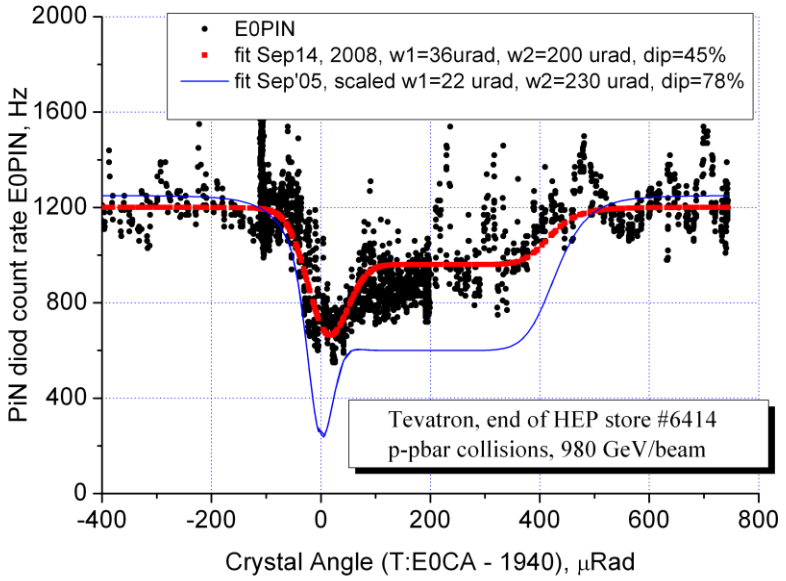
S. Shiraishi, R. Tesarek

FIRST T980 BEAM TESTS

Sept. 14, 2008: First End-of-Store (EOS) study (3 hours) with the new setup:

- aligning crystal
- first angle scan produced channeling results!





EOS Measurements Sept. 2008 – March 2009

Thus far, T980 has conducted 7 EOS studies since Sept 14, 2008 to provide data and understanding on how to utilize crystal collimation.

These can be broken down into 2 categories:

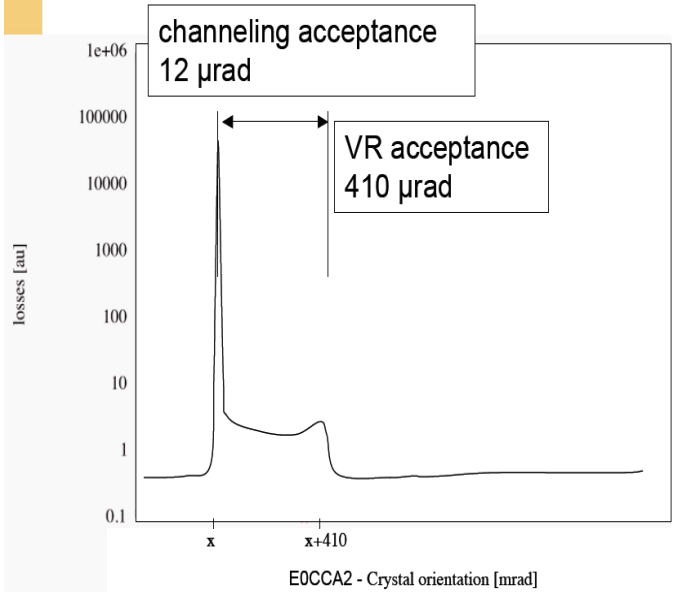
1) 1-5 EOS: establish channeling with reinstalled O-shaped crystal, goniometer and beam diagnostics.
2) 6-7 EOS: tests for incorporating the crystal into the Tevatron automated halo removal system.

Excellent analyses by Valentina Previtali during her two-month visit at Fermilab.

Beam Loss Localization vs Crystal Angle Scan

The outcome of EOS) since is quite positive: channeled beam can be collimated improving localization efficiency; results are reproducible, although not so clean signal as in 2005.

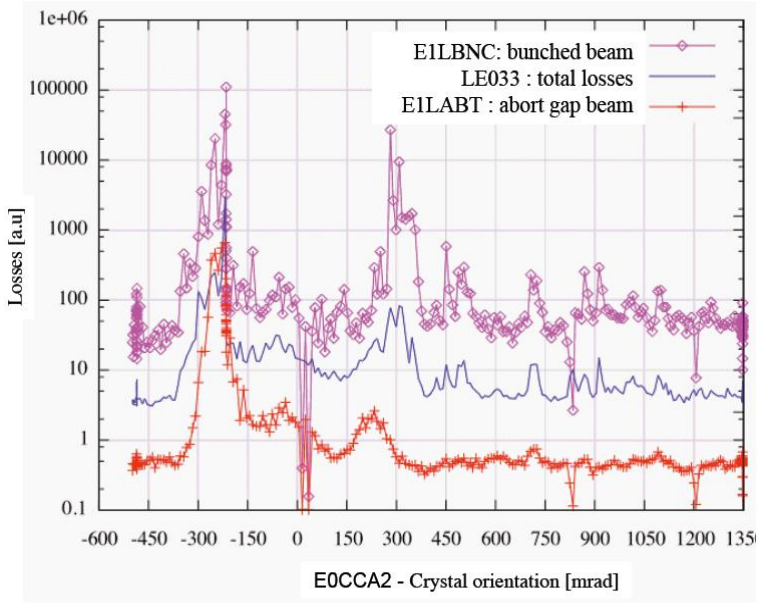
Theory



The ideal behaviour:

- clear channeling region, width of 2*critical angle (12 μrad)
- clear volume reflection region, acceptance = channeling angle (410 μrad)
- maybe a bump at the end of the VR region (as foreseen by simulations)

Data



ISSUES

Angular scan:

- Channeling peak width is larger than expected
- Volume reflection plateau is noisy
- Secondary peaks

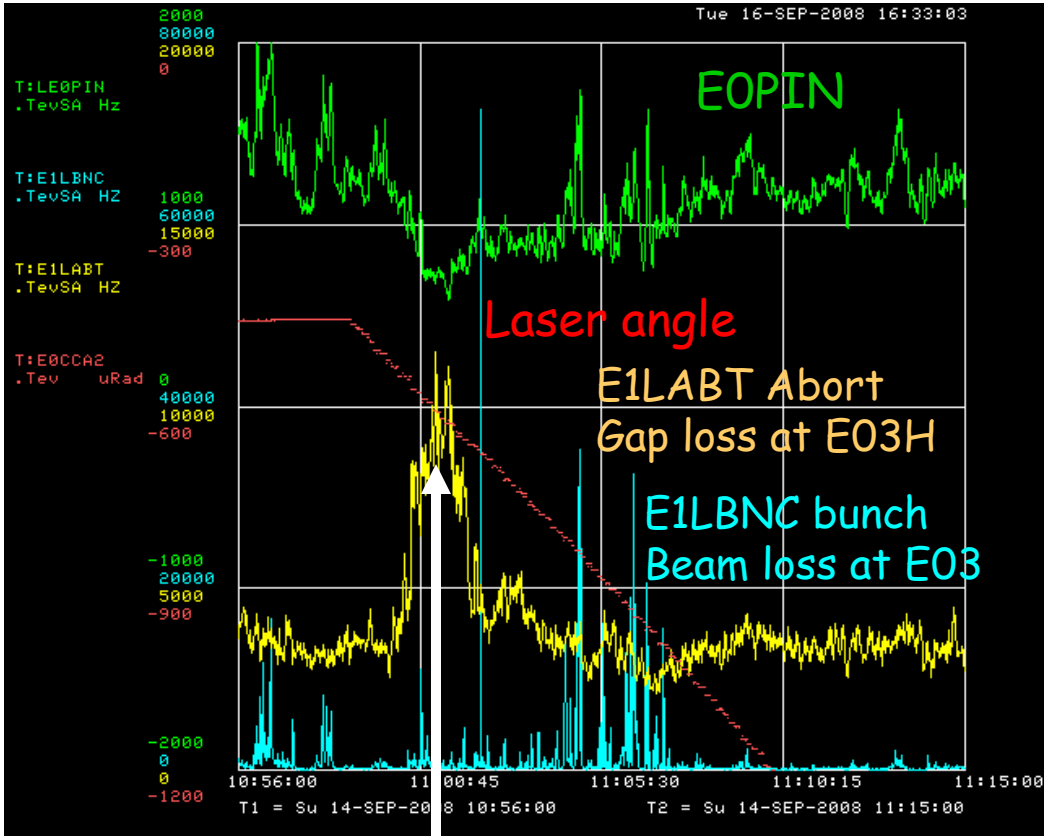
Collimator scan:

- Measured displacement (~7mm) for the channeling peak is lower than expected (9.6mm)

Valentina performed comprehensive analyses of these issues. Based on thorough simulations by A. Drozhdin et al, these effects are now thought to be due to a very large miscut angle (1.6mrad) of wrong orientation.

Channeling Beam in the Abort Gap

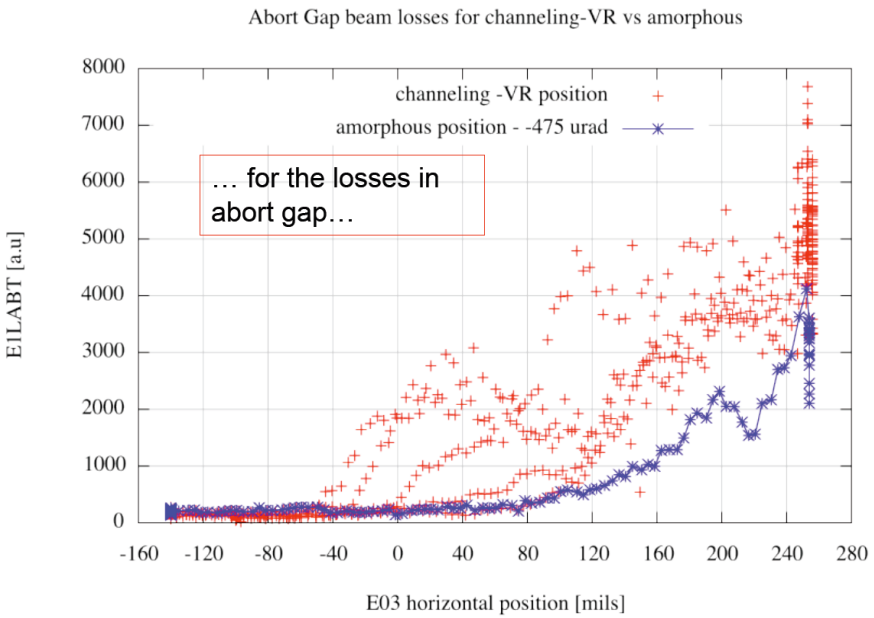
The main contribution of beam that is channeled and hitting the E03H collimator is from the abort gap

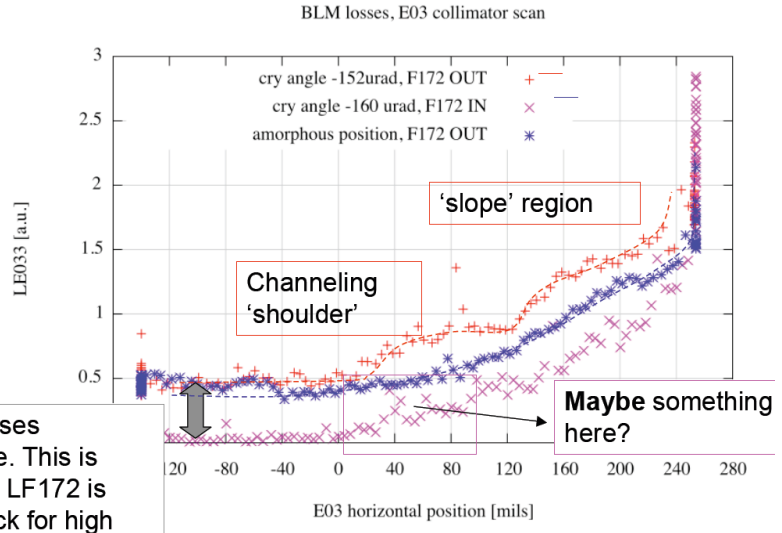


Channeling

Beam Loss Localization vs E03 Position

Channeling improves localization!





Total losses decrease. This is because LF172 is bottleneck for high off-momentum beam!

Other collimator positions need to be tuned for the crystal collimation!

Practical aspects of crystal collimation are much more delicate than those in conventional two-stage collimation system!

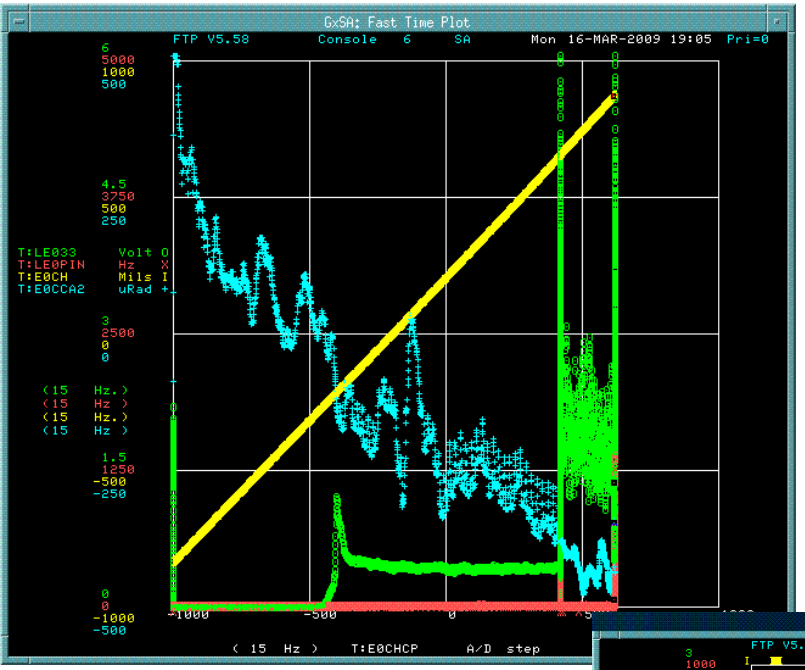
BOS Crystal Collimator Review, Feb. 4, 2009

Chaired by Roger Dixon with AD, CDF and D0 representatives on the Committee: review the progress of T980 and determine whether the experimenters should be allowed to insert the crystal into the Tevatron beam at the beginning of the collider stores.

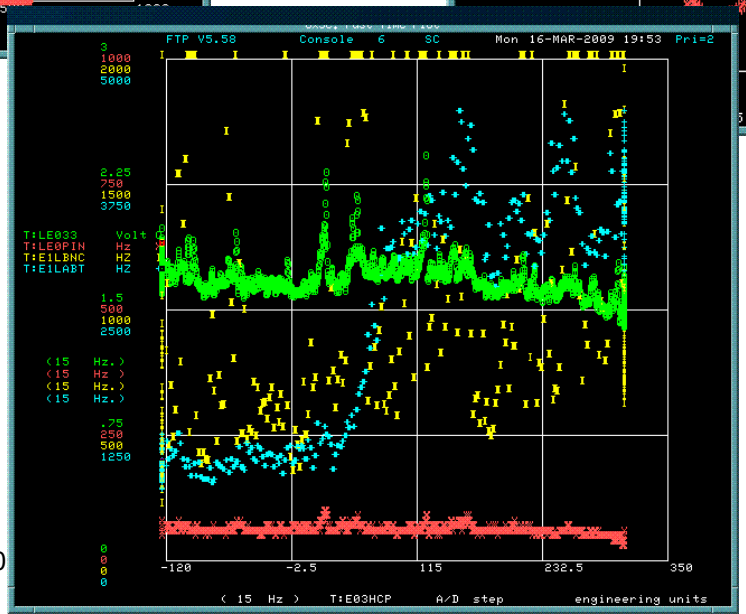
The studies since September 2008 have demonstrated that the crystal can be moved into the beam without causing undo losses. In addition, there is some evidence that the crystal could lower losses at CDF and D0. To make further progress the group has asked to put the crystal in at the beginning of a store.

It was agreed that the beginning of store studies should be initiated at the discretion of the Run Coordinator. The goal of these studies should be to establish normal operating parameters and to more effectively determine the performance of the crystal.

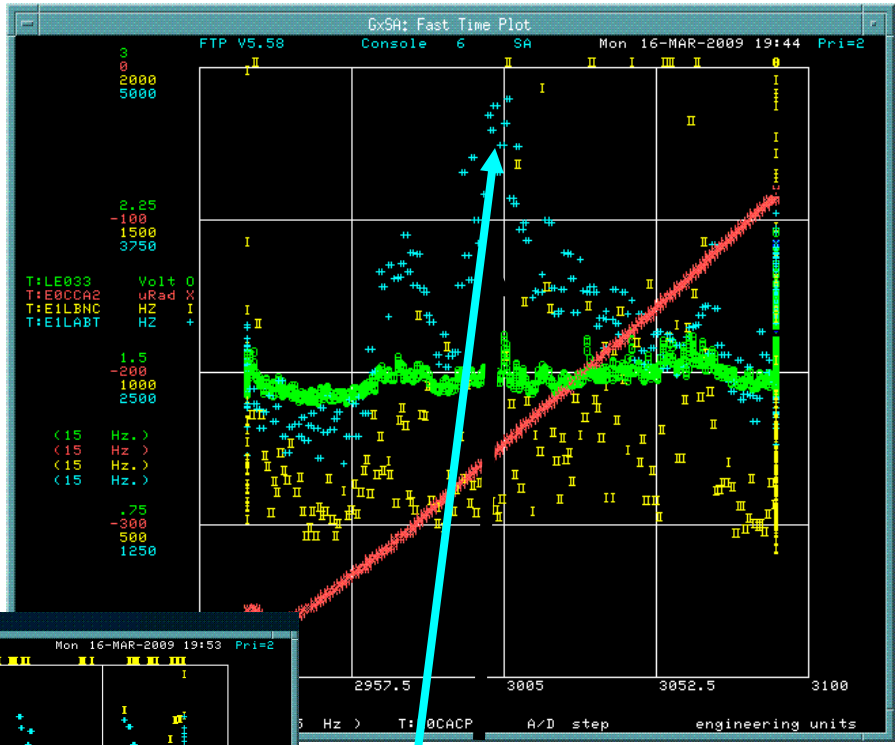
March 16, 2009, End-of-Store Study



Auto insertion of crystal horizontal, worked well



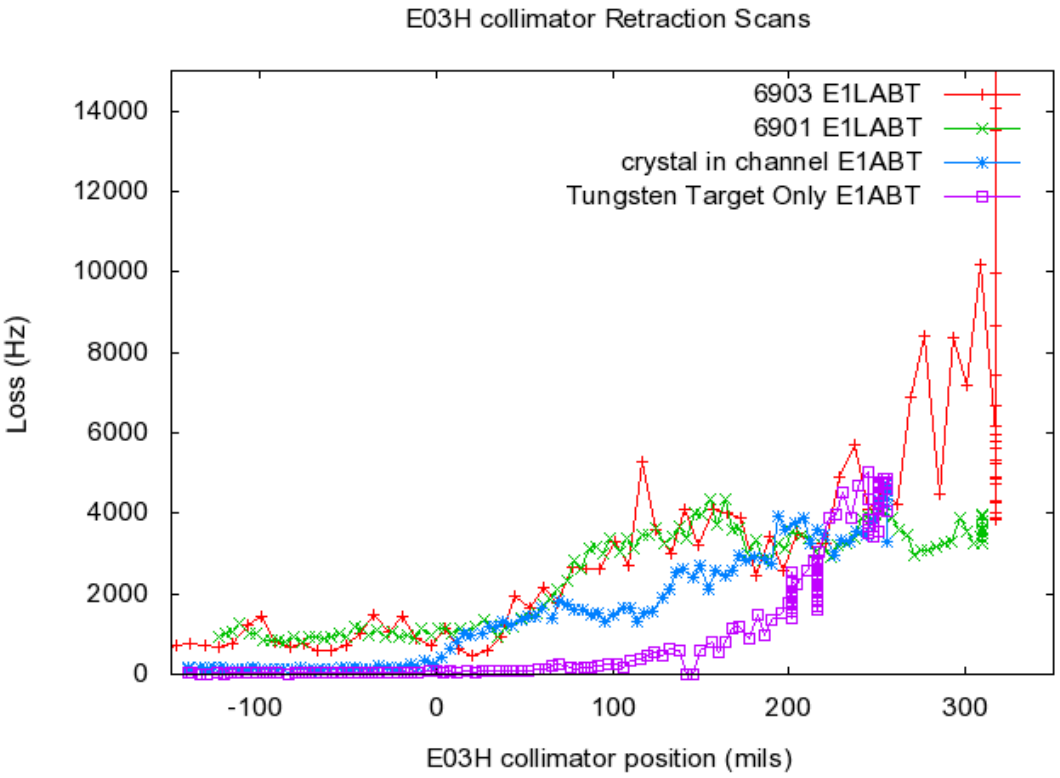
After angle set to channeling, completed E03H scan to verify



Setting the crystal angle to channeling

D. Still

First Use of Crystal for the Entire Collider Store



March 17-18, 2009

1. Successful test of crystal automatic insertion with no impact on the store.
2. Evidence of better cleaning.
3. Found angular drift over the entire store (heating?)

Flying Wire Sensitivity to Channeled Beam (1)

HG/LG Counter Sensitivity

$$s \geq 10\sigma_{pedestal}\sqrt{\delta x_{meas} L \theta_c}$$

Quantity	value	units
θ_c	10×10^{-6}	radians
L	33115	mm
δx_{meas}	0.083	mm
$\sigma_{pedestal(LG)}$	0.925	10^9 protons/mm
$\sigma_{pedestal(HG)}$	0.261	10^9 protons/mm

$s_{LG} > 1.53 \times 10^9$ protons
$s_{HG} > 0.43 \times 10^9$ protons

How does the sensitivity compare with expected signal size?

R. Tesarek

Flying Wire Sensitivity to Channeled Beam (2)

Expected lost signal size:

- Particles loss rate: ~ 1×10^{6}/sec (N. Mokhov)
- Bunch integration time: ~60×10^{-9}sec
- # bunches: 36
- # samples in deflected beam: ~ 20
- # particles in sample: ~ $1 \times 10^{6} * 60 \times 10^{-9} * 36 * 20$ = 42 protons

High Gain Counter Sensitivity = 0.4×10^{9}

Need increase signal by ~10^{8}

Typical "high gain" PMT has gain of ~10^{6}

Unlikely we can use flying wires to "see" channeled beam.

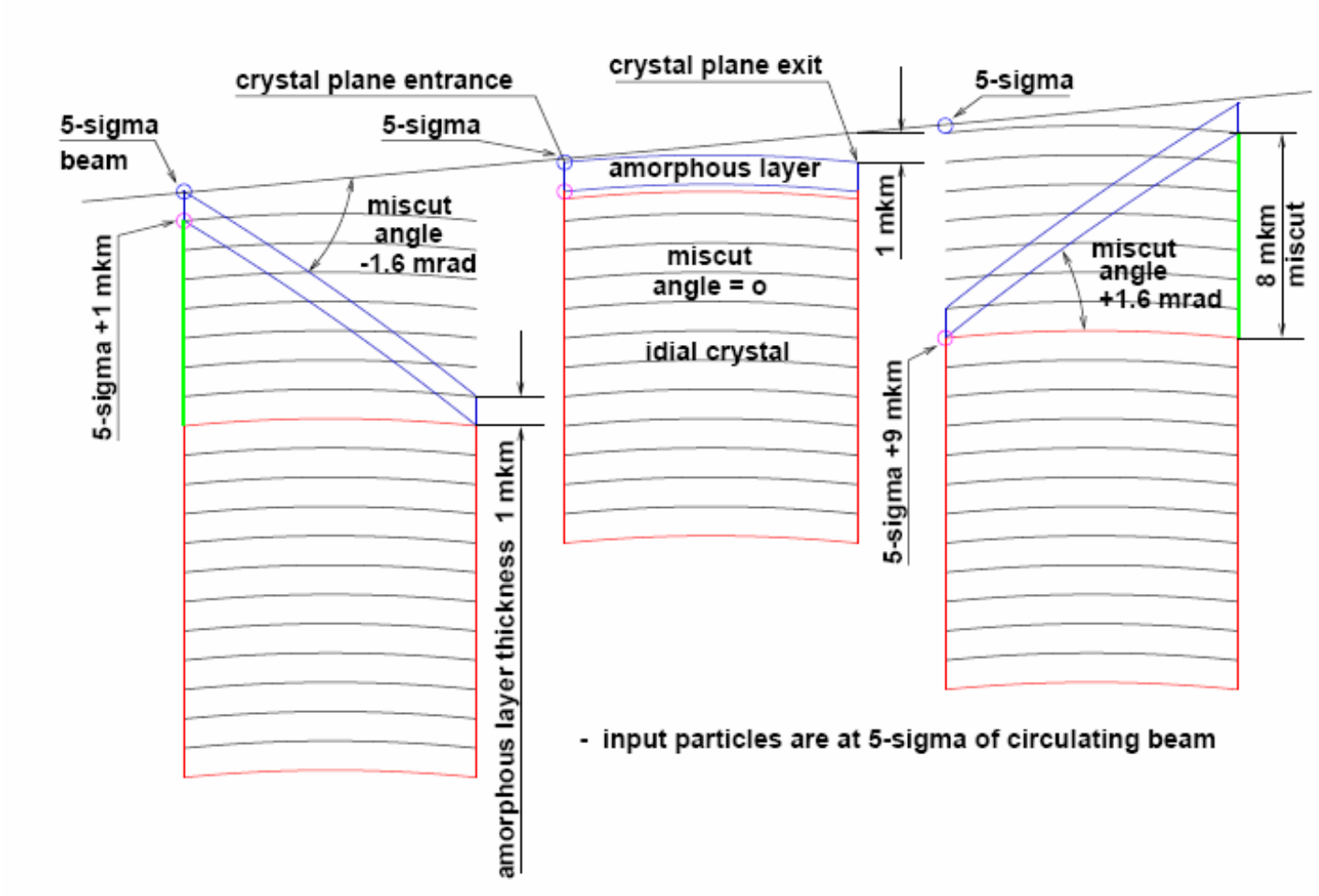
R. Tesarek

Computer Modeling for T980

- About a year ago, the Collaboration switched from CATCH to Igor Yazynin's CRYAPR code.
- Since then, numerous improvements, extensions and tests by Igor, Sasha Drozhdin, Armen Apyan and Bob Noble.
- Converging to a stable documented version.

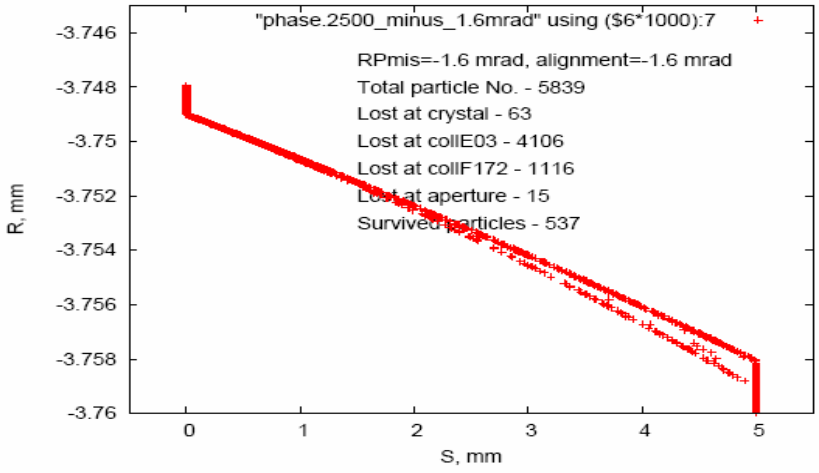
- Studies at FNAL with STRUCT/CRYAPR package: detailed simulations in the real Tevatron lattice with all the apertures included, focusing on the effect of miscut angle, beam profiles at critical locations, and optimizing new goniometer configuration.
- Studies at IHEP: modeling to make a crystal choice for new goniometer.
- Studies at SLAC: electron beams.
- Studies at BNL by G. Robert-Demolaize.

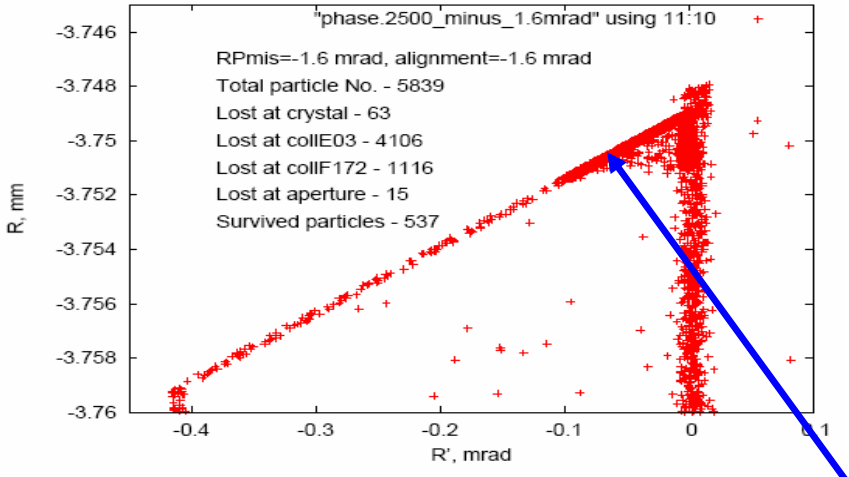
Computer Modeling for T980: Miscut Angle

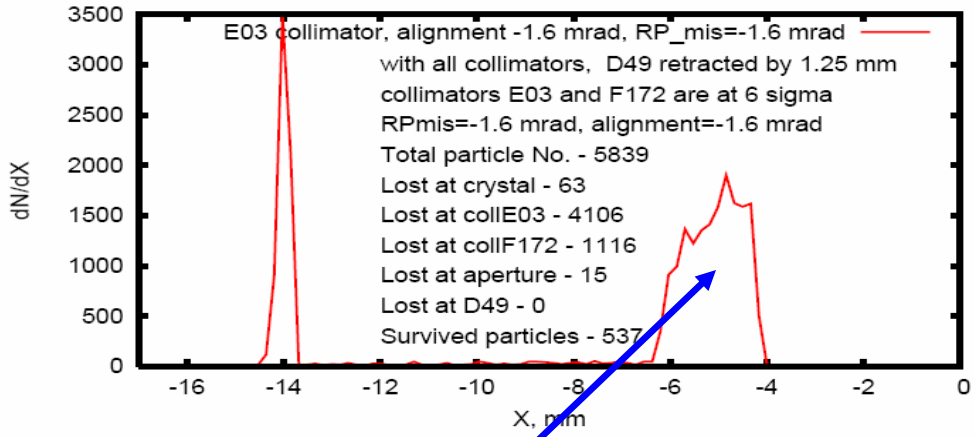


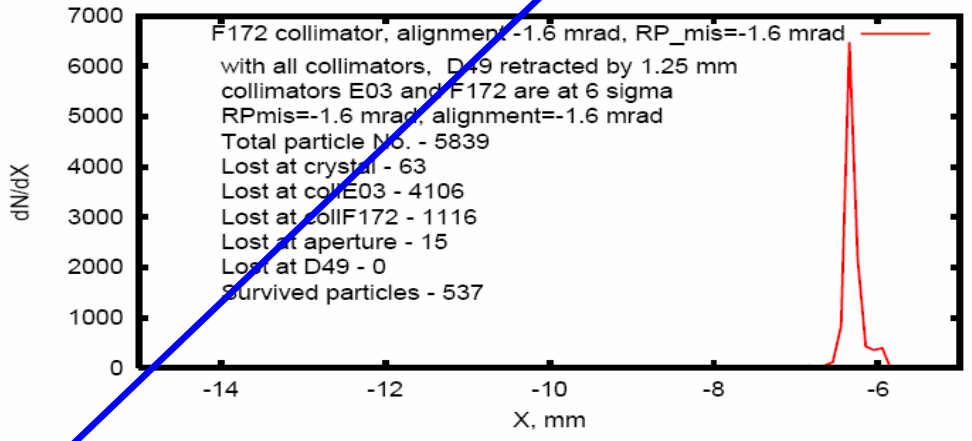
Modeling for T980: Studying Miscut Angle ±1.6 mrad

Negative miscut angle of -1.6 mrad





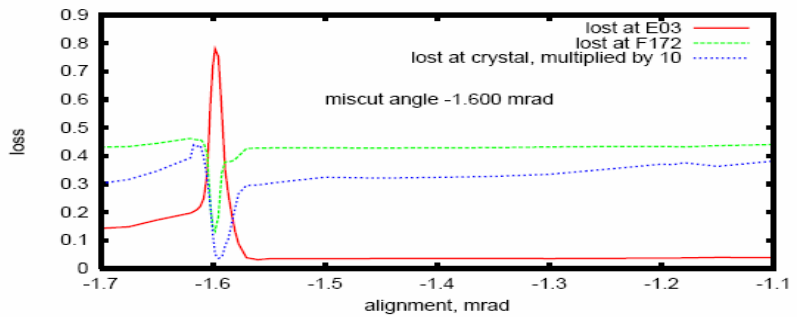


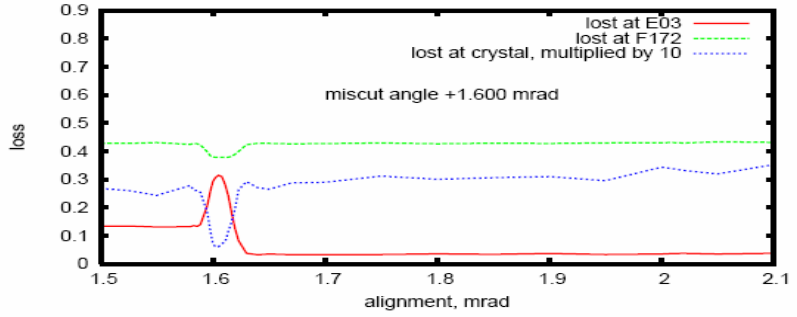


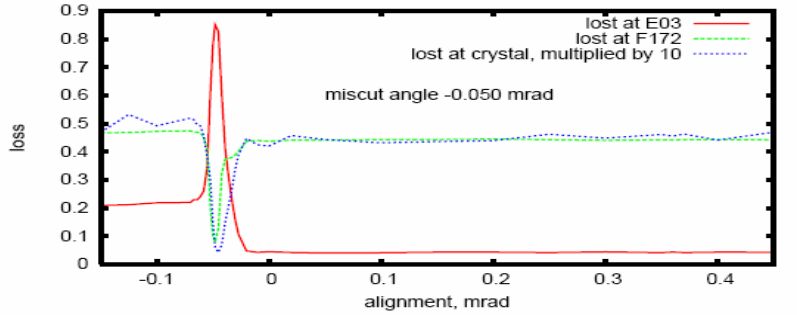
Partial channeling

STRUCT/CRYAPR Beam Loss Calculations

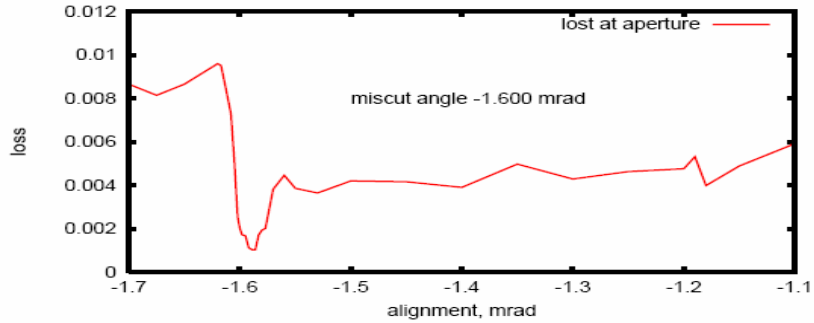
E03 and F172 collimators and xtal

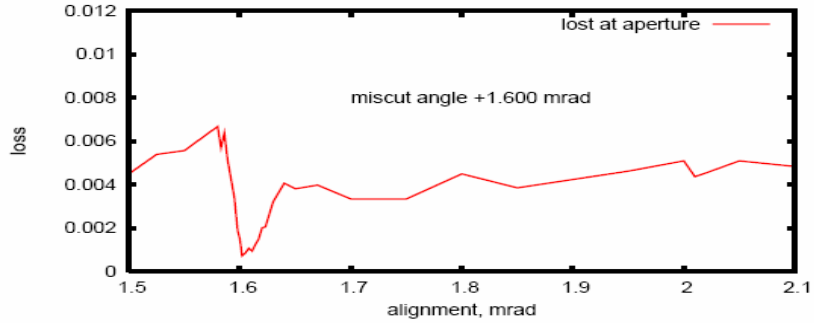


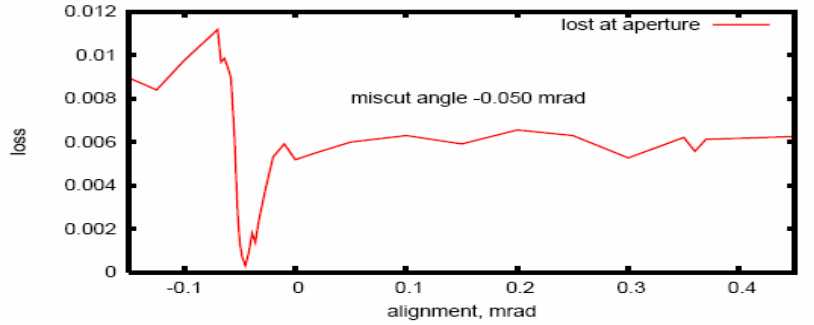




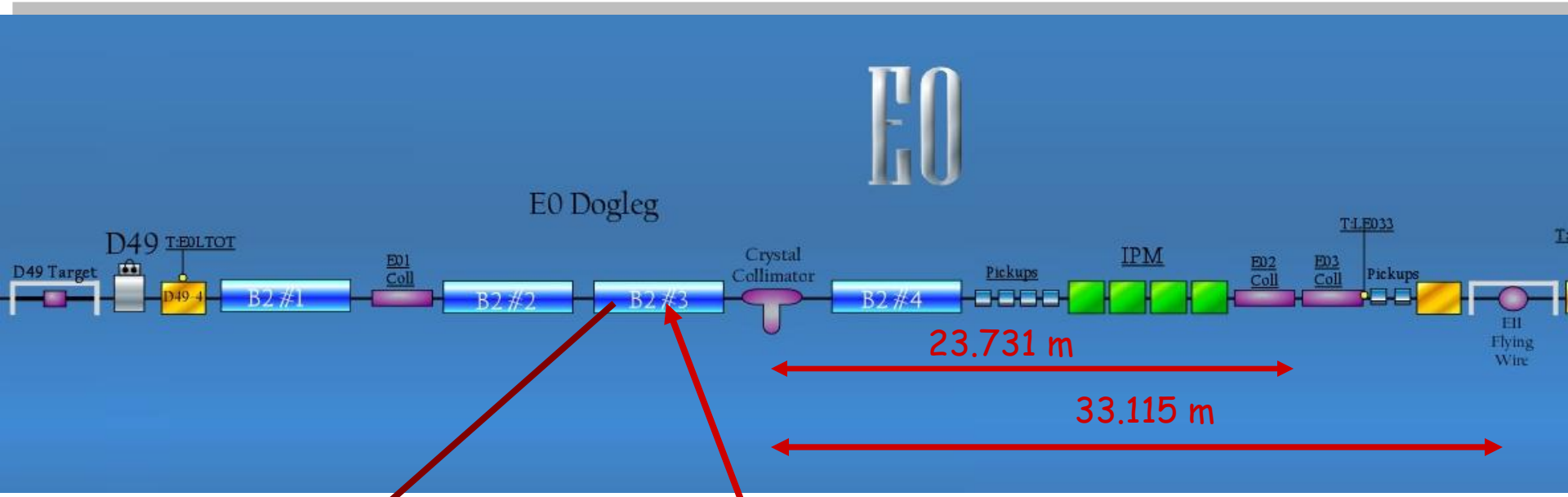
Rest of the Tevatron







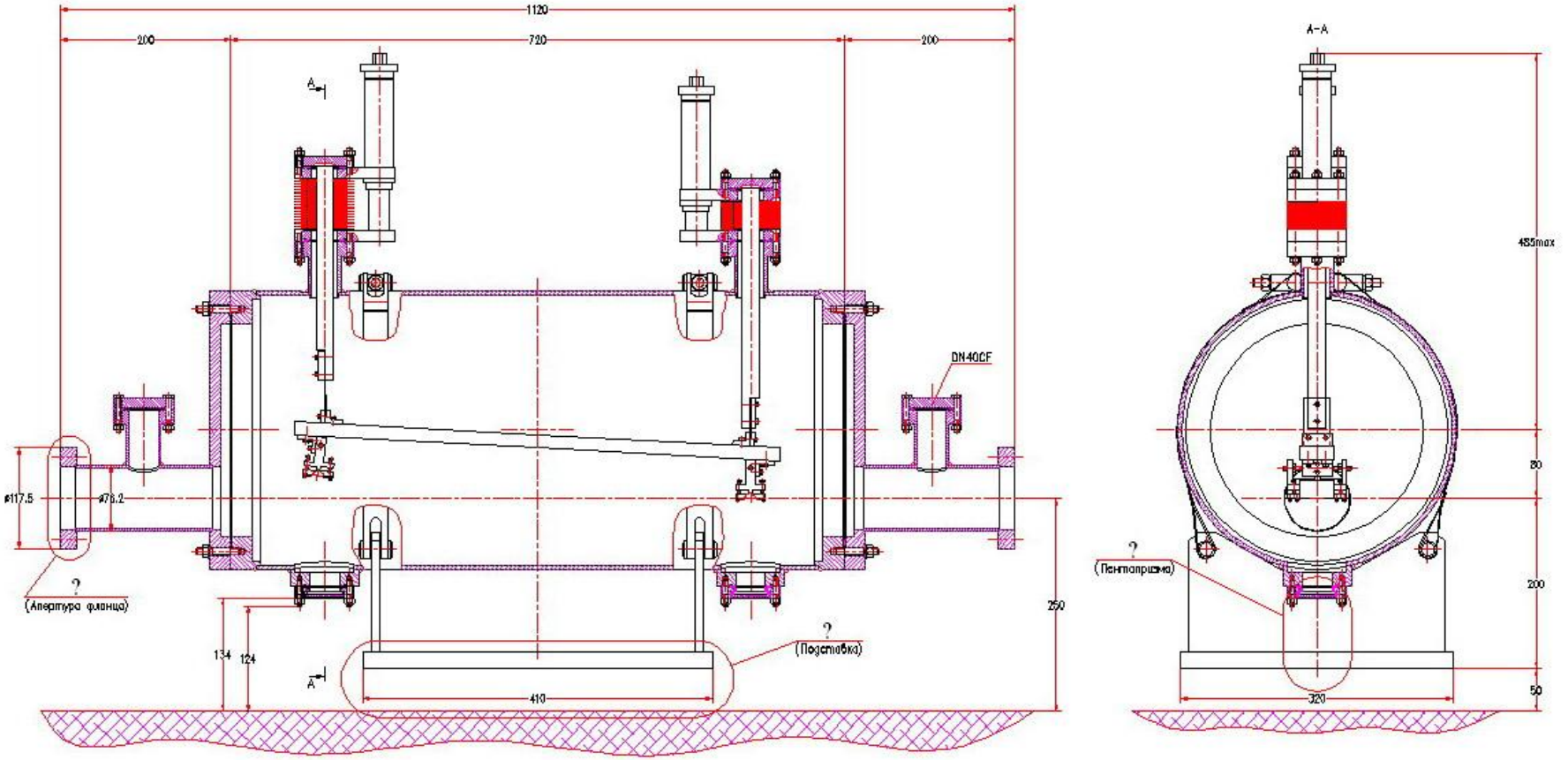
New Vertical Goniometer Location



Remove B2-3 dipole

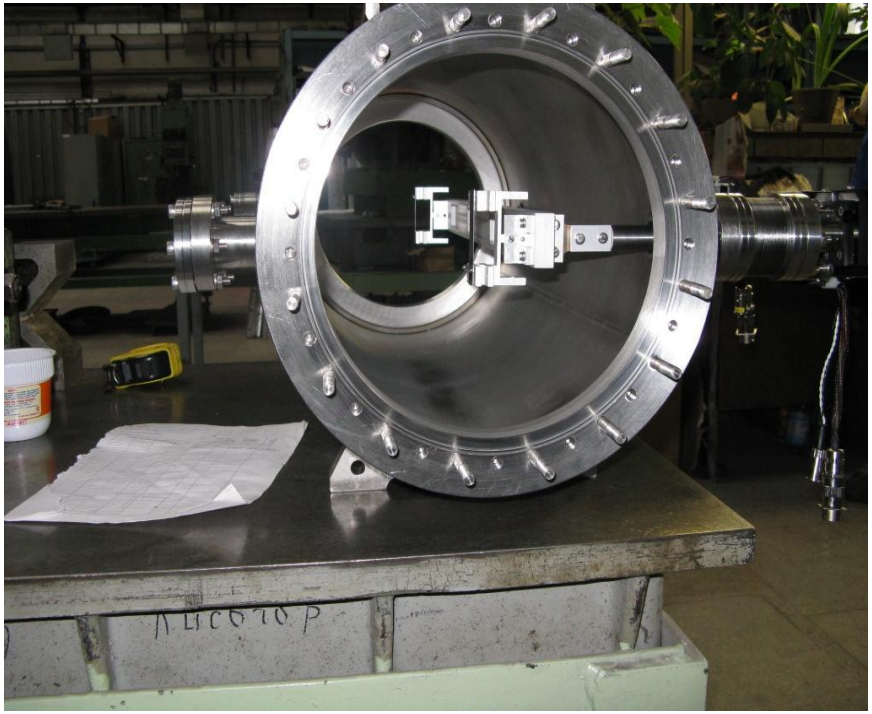
Install new goniometer here
Alternate crystals without breaking vacuum !

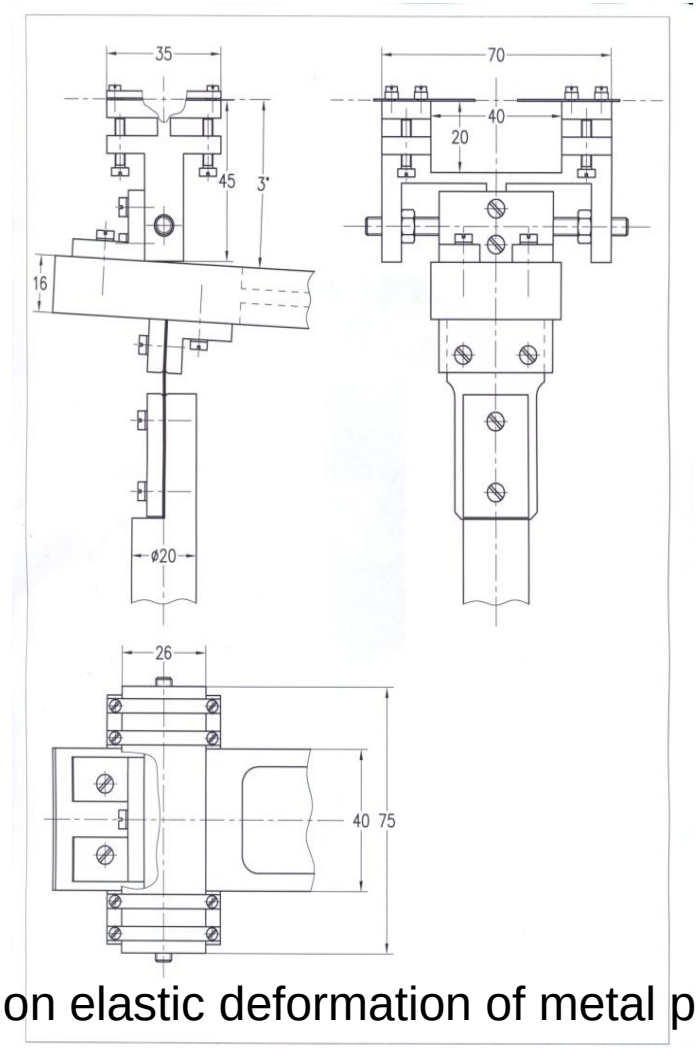
New Two-Crystal Vertical Goniometer by IHEP



IHEP Two-Crystal Goniometer

Linear step – 0.1 micron,
angular step 0.2 microrad

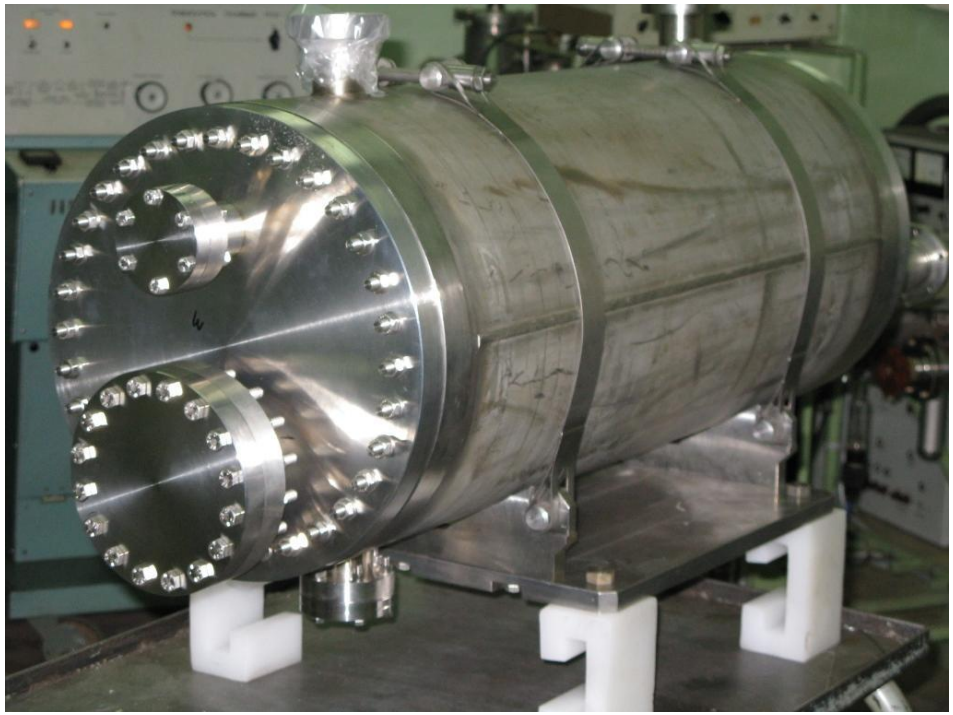


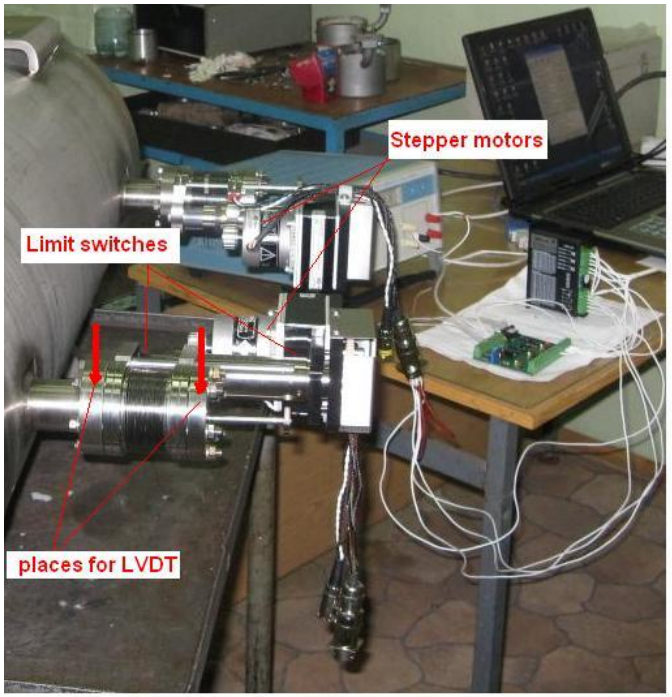


No friction details inside –rotation is based on elastic deformation of metal plate

IHEP Two-Crystal Goniometer

Preliminary vacuum and mechanical testing finished



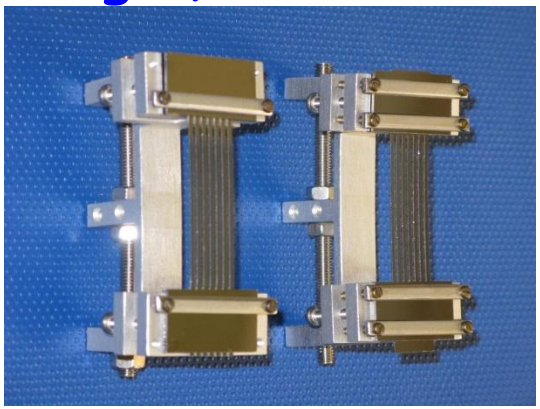


Flanges are manufactured for Tevatron beam-pipe

Goniometer and Crystal Installation

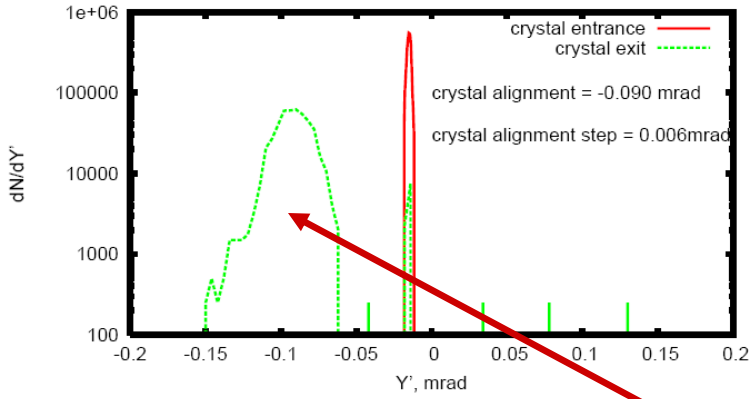
Goniometer to be delivered to Fermilab in early May 2009. Four new crystals – two O-shaped (IHEP) with minimal miscut angle, two multi-strip (IHEP and Ferrara) - to be delivered in mid-May to CERN for X-ray characterization, and then to Fermilab for installation in TeV tunnel in mid-June.

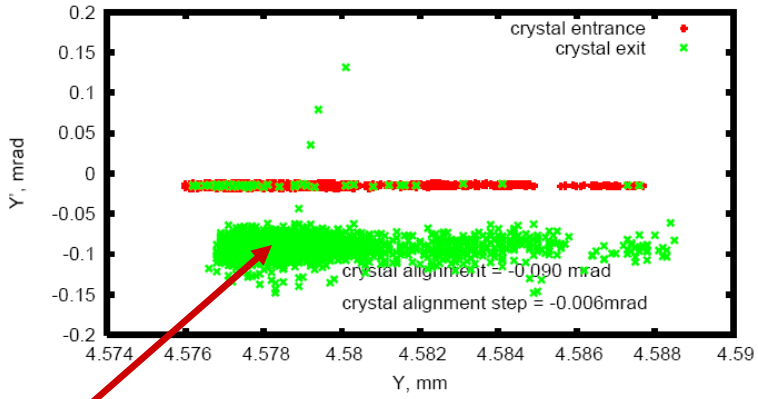
One O-shaped and one multi-strip to the new vertical goniometer, another O-shaped to replace the existing one (with a 1.6-mrad miscut angle) in the horizontal goniometer.



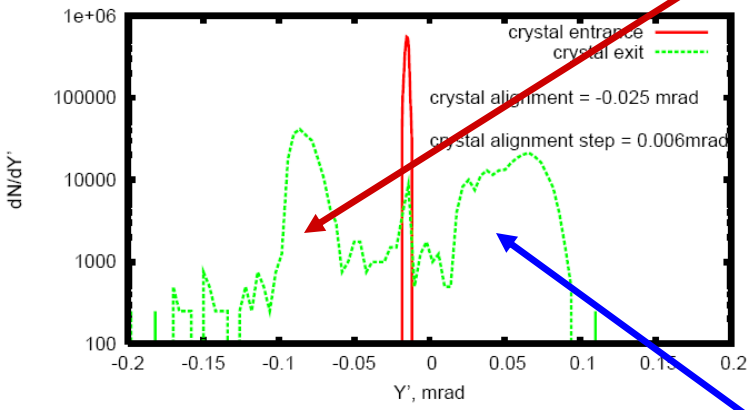
Vertical Multi-Strip Crystal (1)

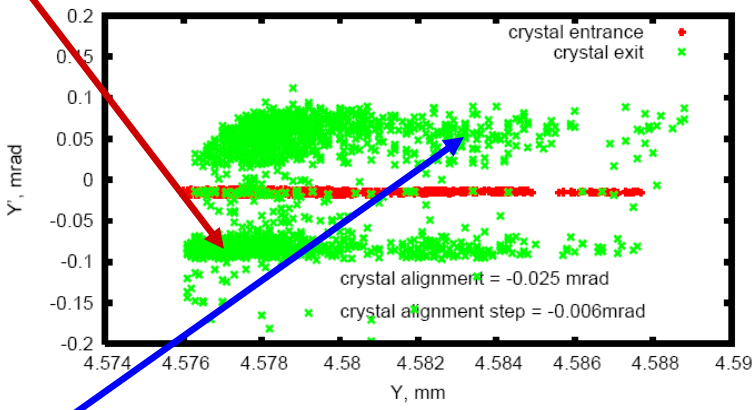
12 strips: 0.5-mm wide, 1-mm thick, R=9m, θ=5.5 μrad each





Volume reflection



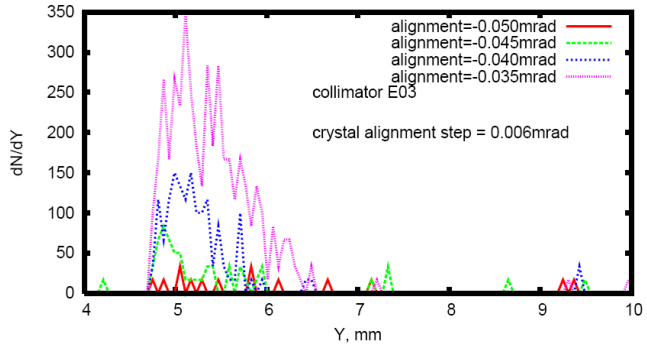


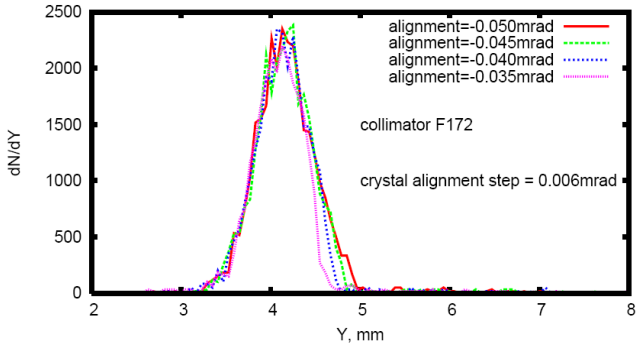
Channeling

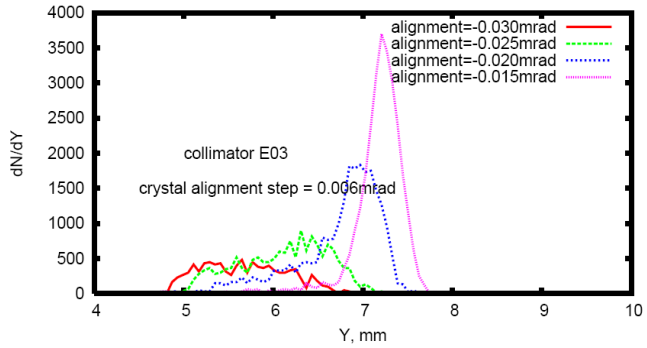
Vertical Multi-Strip Crystal (2)

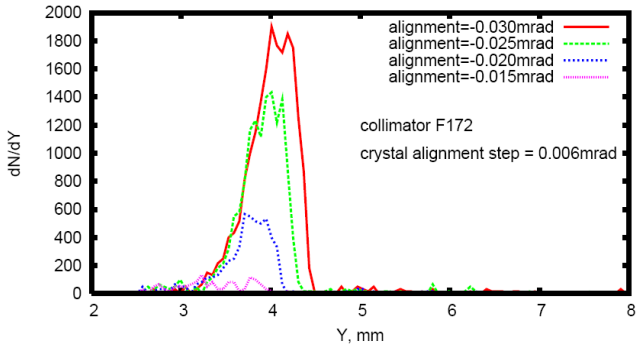
12 strips: 0.5-mm wide, 1-mm thick, R=9m, θ=5.5 μrad each

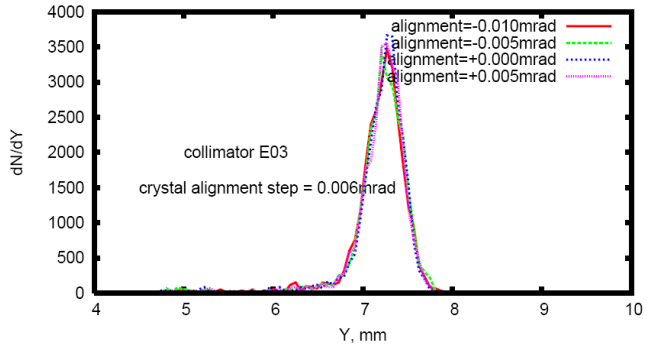
E03 Channeling

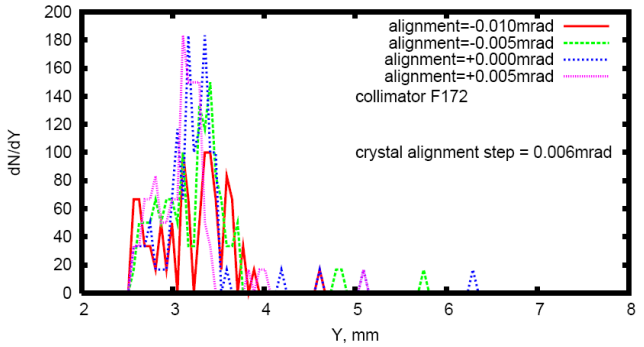












F172 VR

Plans for 2009 through Beginning of 2010

1. Continue BOS aiming at convincing reproducible loss reduction in the machine, CDF and D0; first, fix the angular drift problem for the entire store (15-20 hrs *vs* 2-hr EOS), insulate goniometer if heating is the problem.
2. Investigate alternatives to Flying Wire for beam profile measurements. Add beam diagnostics at E11.
3. Install the new vertical goniometer at E0 ~2 m upstream of the horizontal one; in September 2009 start beam tests with it; study performance of alternating crystals of two different technologies: O-shaped (channeling) and multi-strip (VR).
4. Start two-plane beam cleaning with horizontal and vertical crystal collimators simultaneously.