Crystal Collimation at Tevatron

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Fermilab

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OUTLINE

- Introduction
- Crystal Collimation: a Little History
- Towards Crystal Collimation at Tevatron
- Implementation and Commissioning at Tevatron
- 980-GeV Beam Channeling
- Encouraging Results, Problems and Future Plans
- Summary

INRODUCTION

Bent-crystal technique is well established for extracting high energy beams from accelerators. It was successfully applied at up to 900 GeV in E-853 at Fermilab, and simulations were able to predict the results correctly. Experiments at IHEP Protvino have demonstrated that 50-70% of the beam can be extracted using a thin (3-5 mm) *Si* channeling crystal with bending of 0.5-1.5 mrad.

It was shown (SSC, 1991) that it is promising to apply this technique to a beam halo scraping at high energy colliders. A bent crystal, serving as a primary element, should coherently bend halo particles onto a secondary collimator. Based on realistic modeling (1999, 2003), it was proposed to implement a bent crystal into the Tevatron collimation system. It was done, and first results are presented here.

A LITTLE HISTORY: SSC

Fraction of outscattered protons (%) per one 20 TeV proton:

Case	Elastic	$\Delta p/p < 0.001$	$\Delta p/p < 0.01$	$\Delta p/p < 0.3$
No target $\Delta \sim 1$ μm	4.460	0.026	0.053	2.520
1-mm W $\Delta \sim 100$ μm	0.240	0.020	0.031	0.175
5-mm bent Si $\Delta \sim 400$ μm	0.005	0	0	0.007

Calculated beam losses in SSC lattice were drastically down with W target and especially with bent crystal.

TEVATRON COLLIMATION SYSTEM EVOLUTION

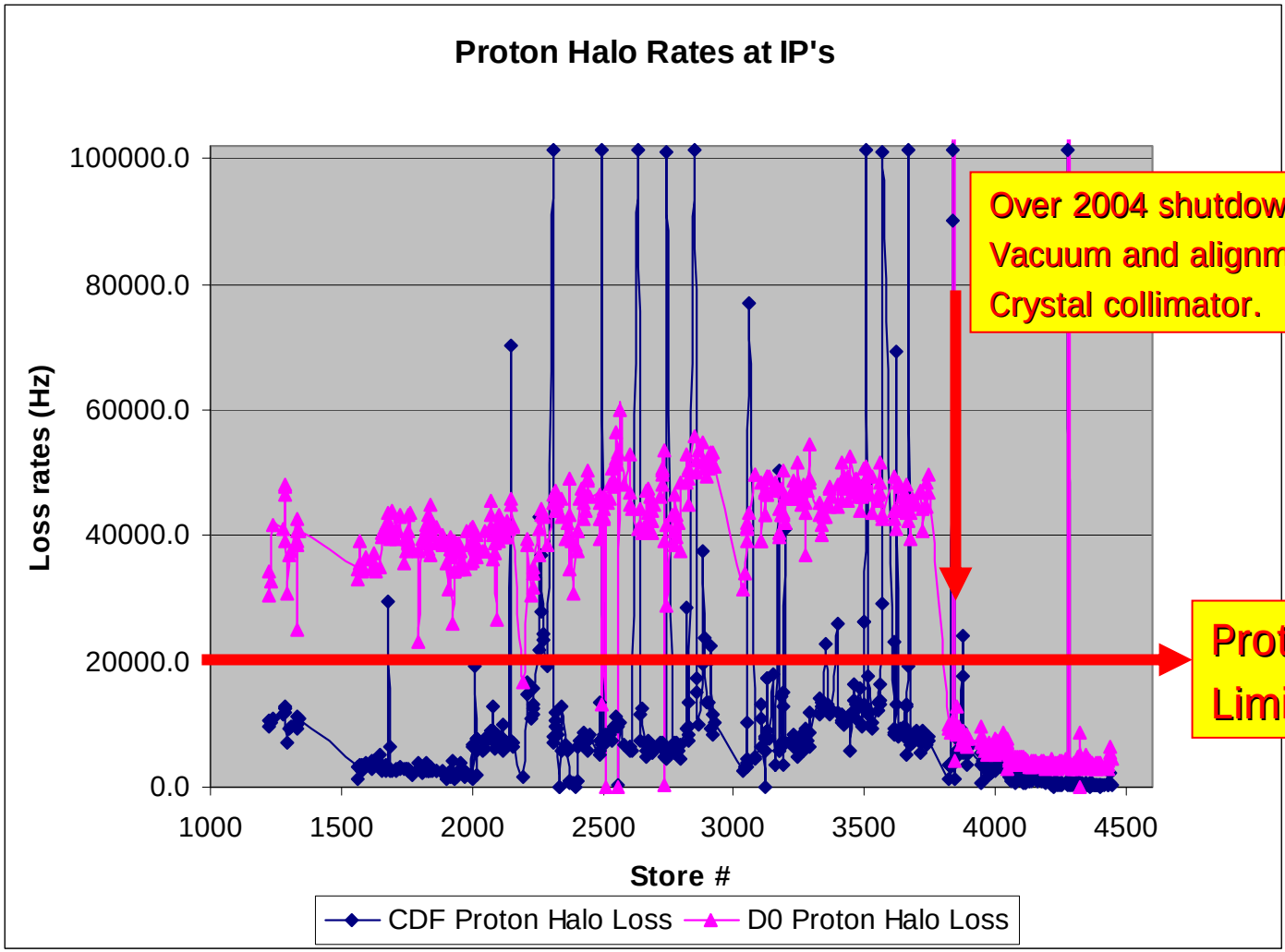
- Design report, commissioning, initial operation: a few single 0.9 to 1.8-m long SS collimators in front of SC magnets (Edwards, Pruss, Van Ginneken, 1979-1984).
- A set of two-unit collimators at optimal locations based on STRUCT/MARS modeling: 5-fold increase of 800-GeV proton beam intensity at fast resonant extraction (Drozhdin, Harrison, Mokhov, 1985).
- First two-stage system, two 2.5-mm thick L-shape tungsten targets with 0.3-mm offset relative to A0 scrapers: 5-fold reduction of beam loss rates upstream D0 and CDF detectors (Drozhdin, Mokhov et al., 1995).
- Genuine two-stage system proposed for Run-II with primary and secondary collimators at optimal locations optimized in STRUCT/MARS runs (Church, Drozhdin, Mokhov, 1999).
- Current system with tertiary collimators (Drozhdin, Mokhov,Still).
- Crystal collimation (RAC, AID, NVM, DAS).

BENT CRYSTAL FOR TEVATRON COLLIMATION

Biryukov, Drozhdin, Mokhov (PAC99) have shown – and later calculations (2003) confirmed - that implementation of a silicon bent crystal instead of amorphous primary collimators, can improve the Tevatron collimation system efficiency by a factor of:

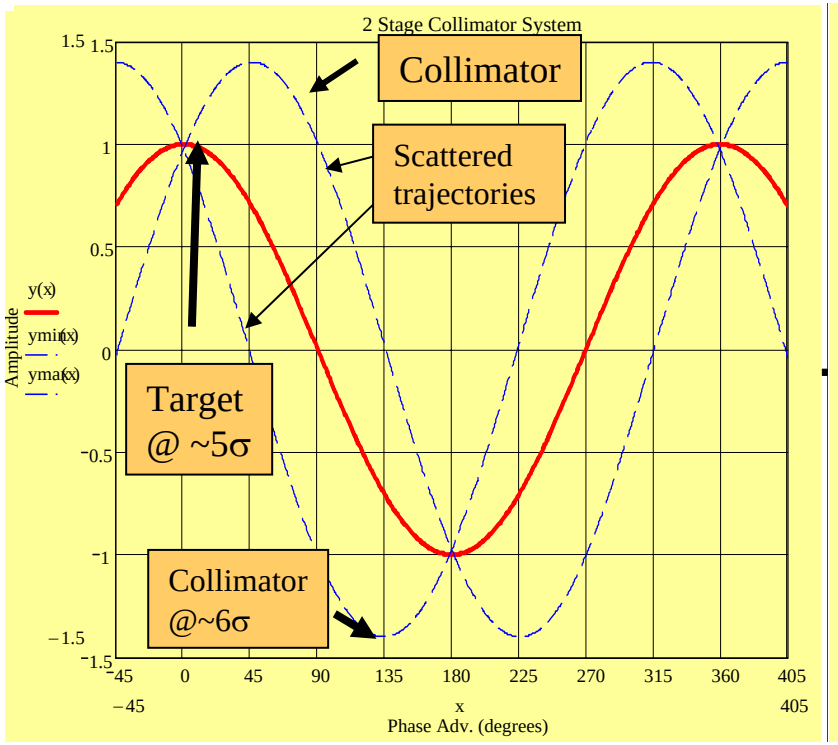
- 2 with only one (horizontal) collimator replaced, and with contribution from beam-gas scattering unsuppressed
- 3 with only one (horizontal) collimator replaced, and with contribution from beam-gas scattering suppressed
- 10 with three primary collimators replaced, and with contribution from beam-gas scattering suppressed

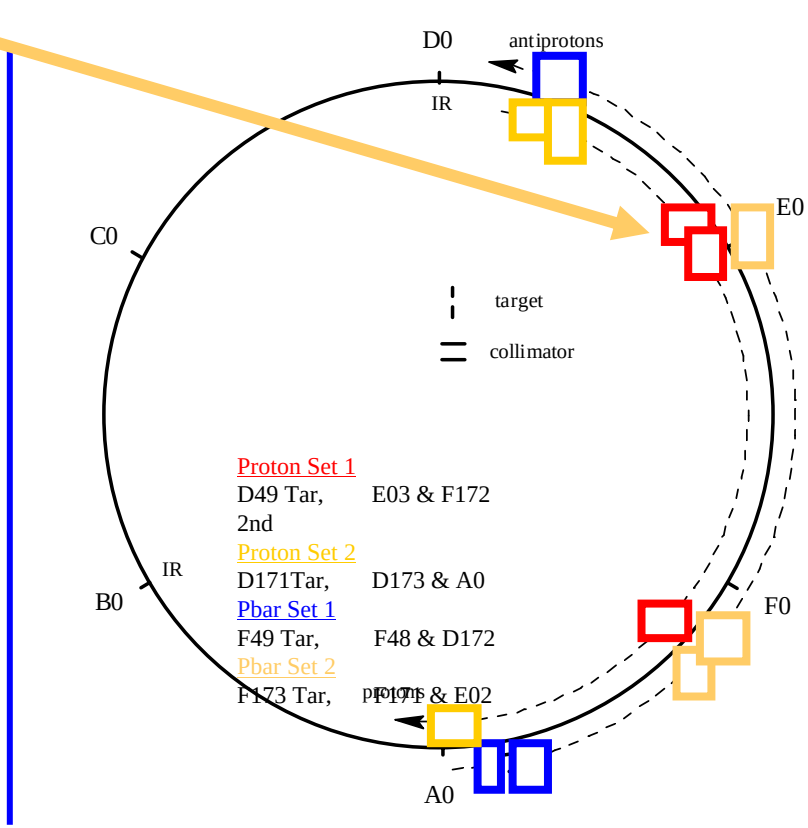
MOTIVATION FOR CRYSTAL COLLIMATION



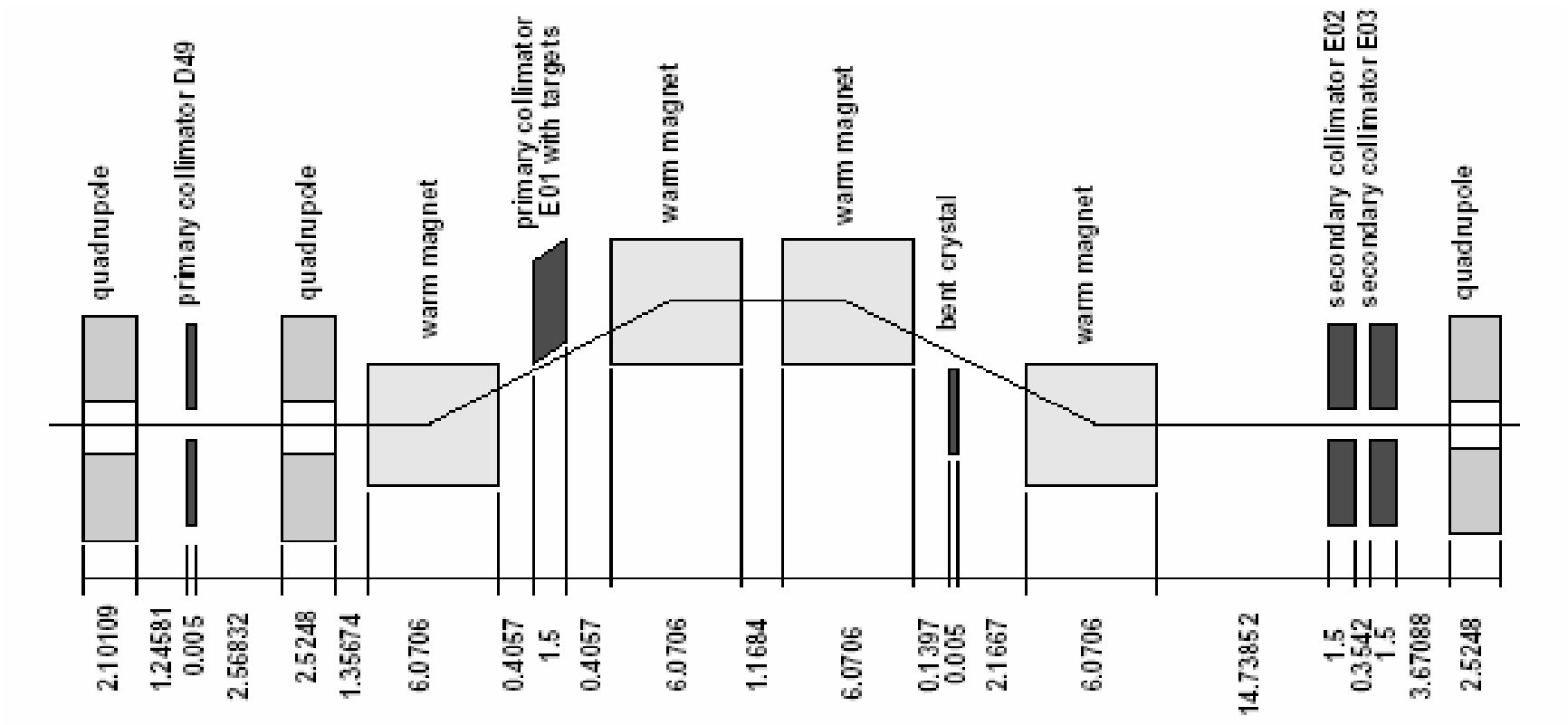
WHERE TO INSTALL CRYSTAL

Install Crystal Collimator at E0 to replace a Tungsten Target and utilize the rest of the collimator 2 stage System.





PROPOSAL FOR CRYSTAL COLLIMATION (2003)

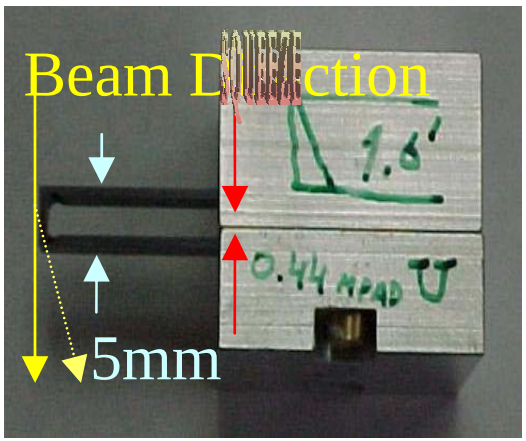


Current collimation system in Tevatron is somewhat different compared to the one planned before Run-II. Based on detailed modeling, Carrigan, Drozhdin, Mokhov and Still, proposed to implement a bent crystal in the EØ straight section.

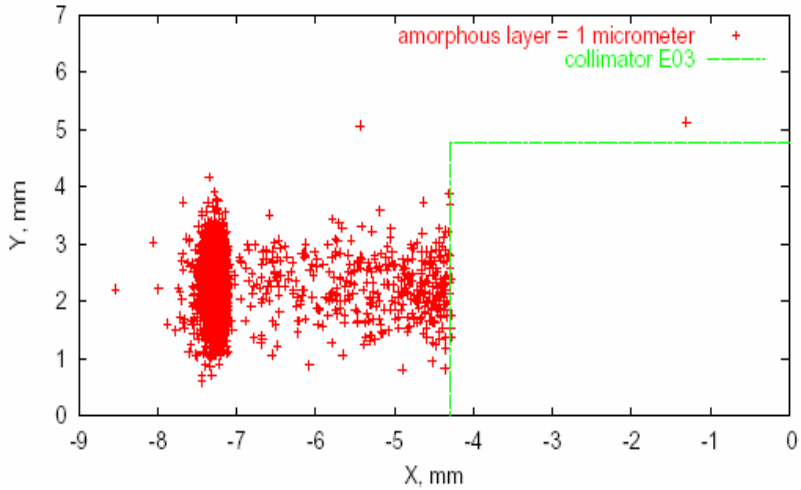
REPLACING PRIMARY COLLIMATOR WITH CRYSTAL

Current primary H-collimator (D49 tungsten L-shaped target) is before the dog-leg at β_H=96 m, D=2.3 m. The crystal is in the dog-leg at β_H=73 m, D=2.5 m, about the same phase advance wrt secondary collimators.

1. Installed modified BNL assembly and crystal during Fall 2004 shutdown
2. Vertical assembly was found to have "fallen" during exercising horizontal motion: repaired in place in February 2005
3. Beam studies at 150 and 980 GeV in summer and fall of 2005

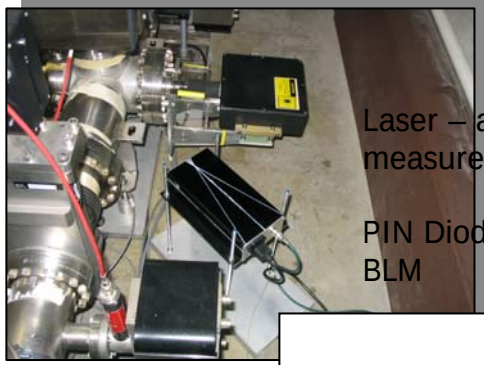


Channeled and scattered protons on E0 secondary collimator



O-shaped 110 Si-crystal
5-mm long, 5 mm H, 1mm V
bending angle 0.439 mrad
miscut angle 0.465 mrad

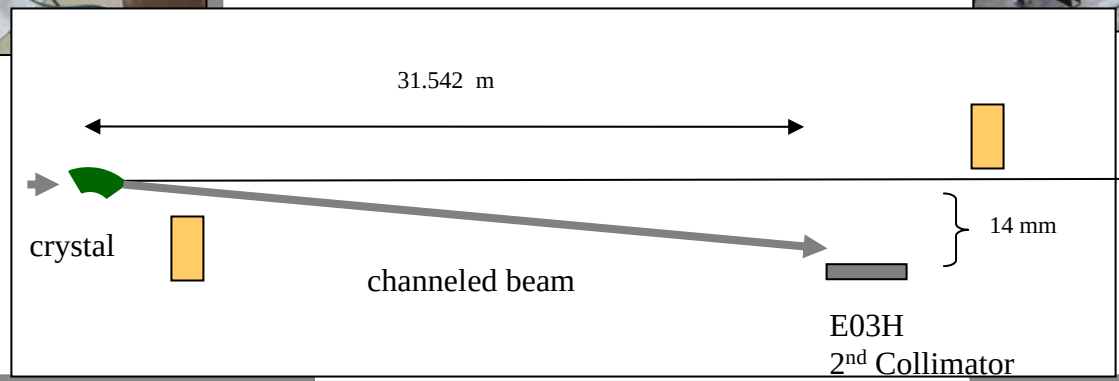
CRYSTAL COLLIMATOR SYSTEM



Laser – angular measurement

PIN Diode BLM

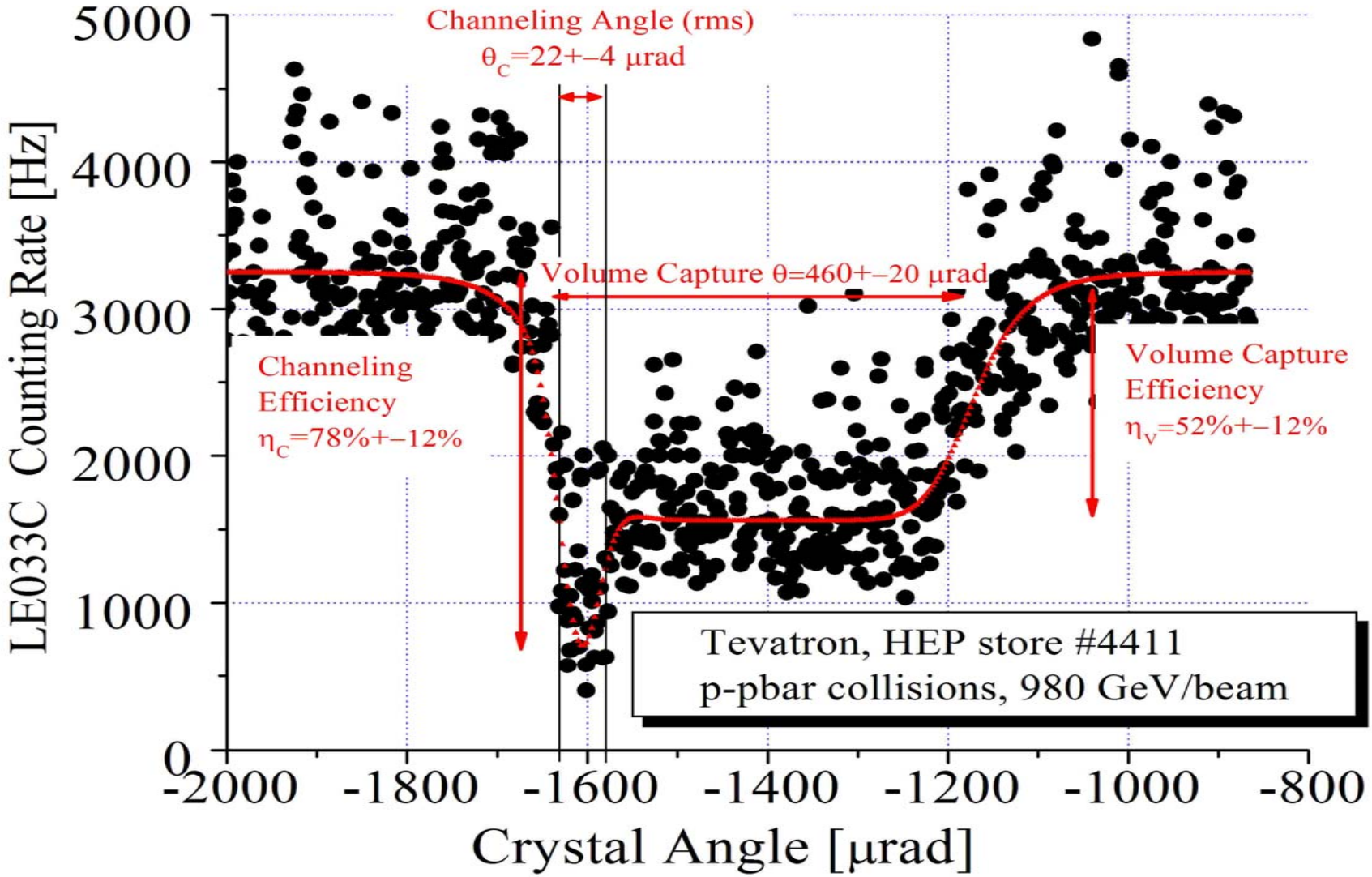
E0 Scintillator Paddles



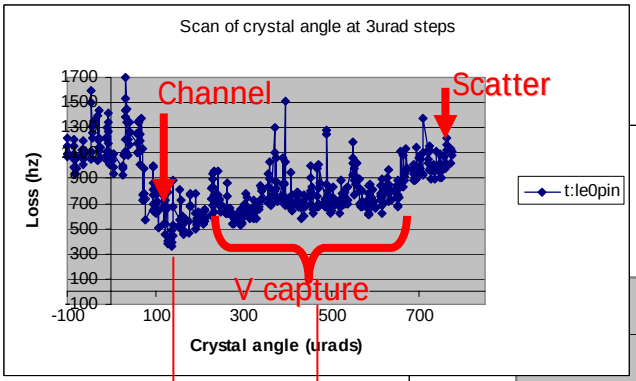
E0 Crystal Collimator Assembly

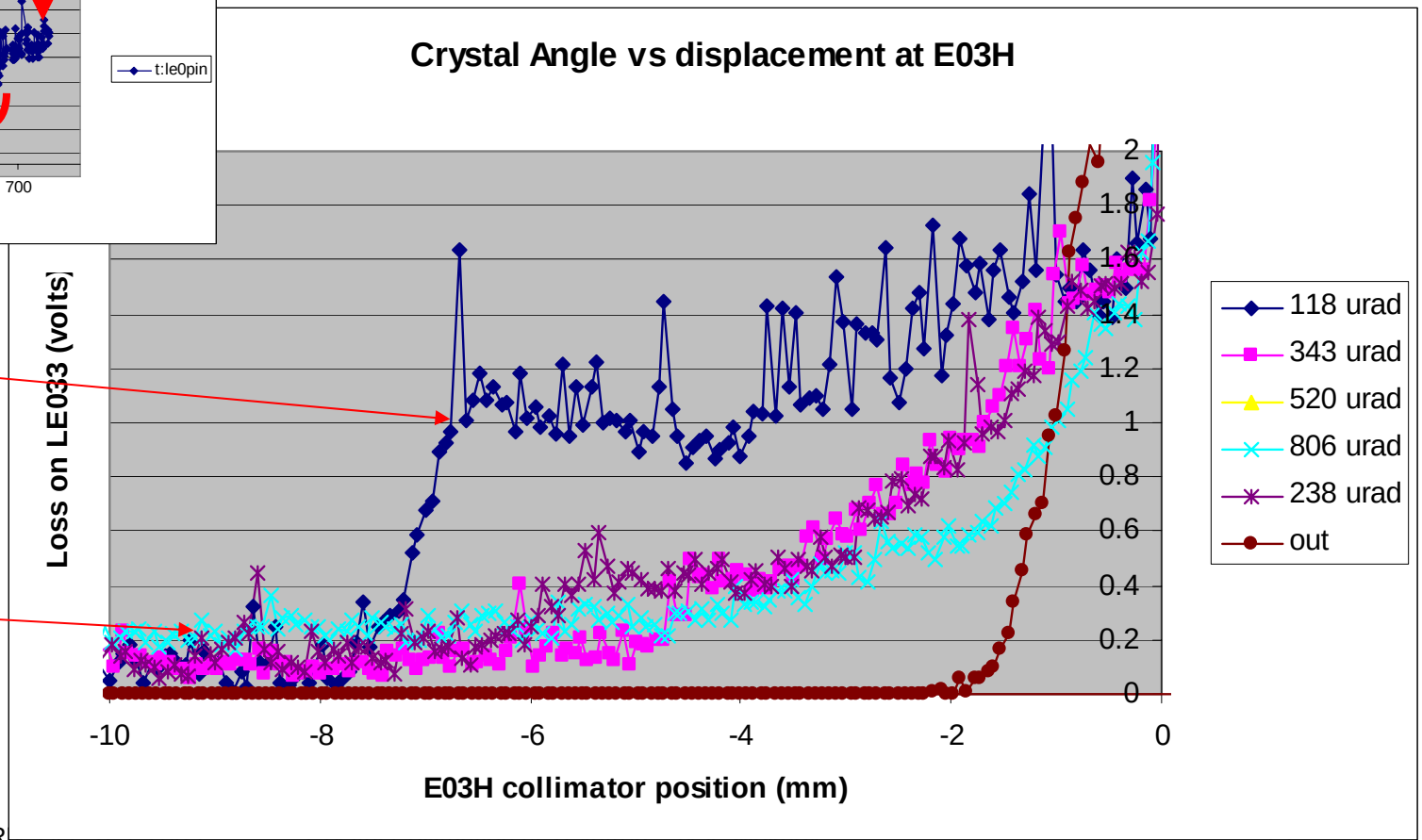
E03 Secondary Collimator

980-GEV BEAM CHANNELING

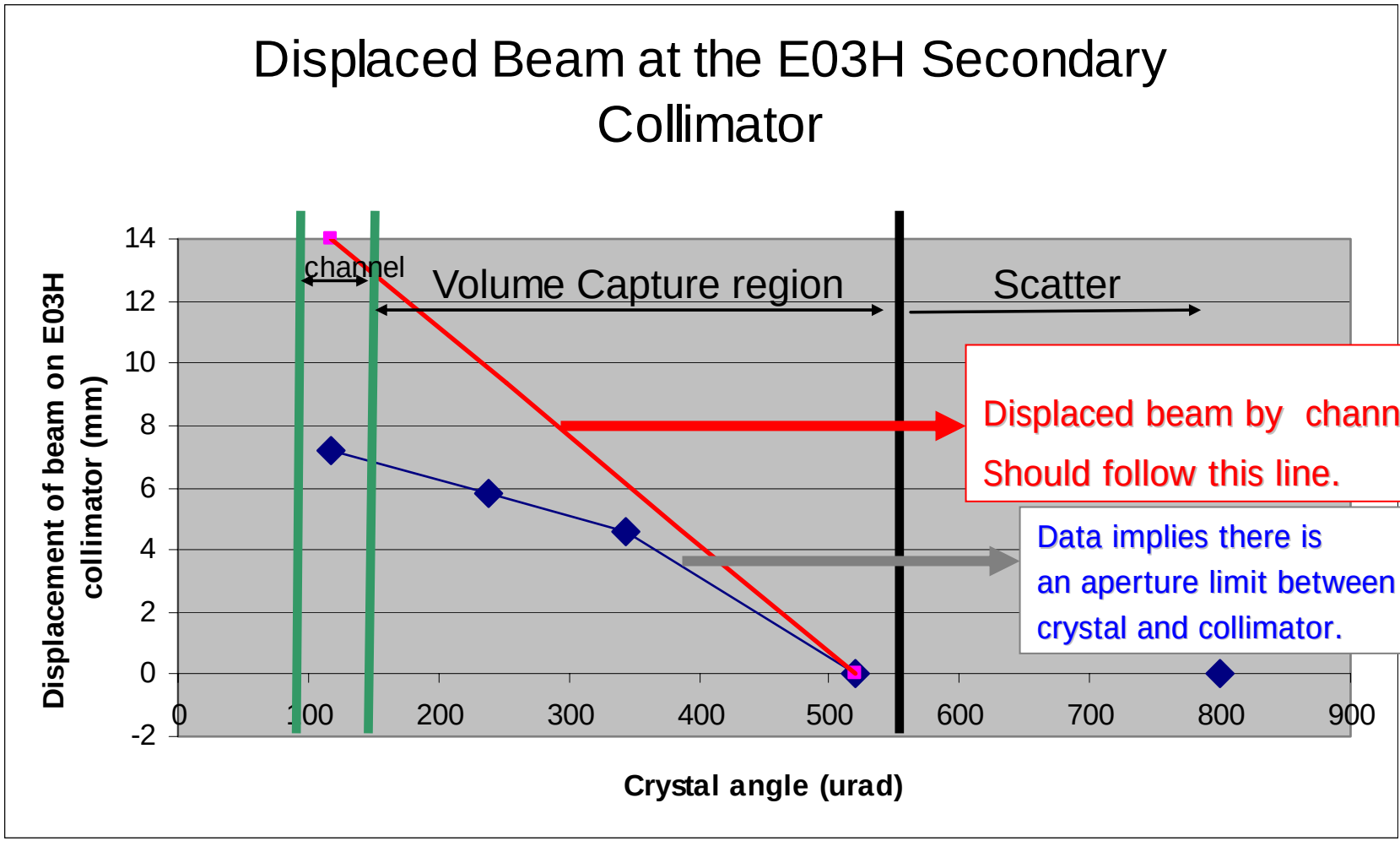


RESULTS OF E03 COLLIMATOR SCAN FOR DIFFERENT CRYSTAL ANGLES



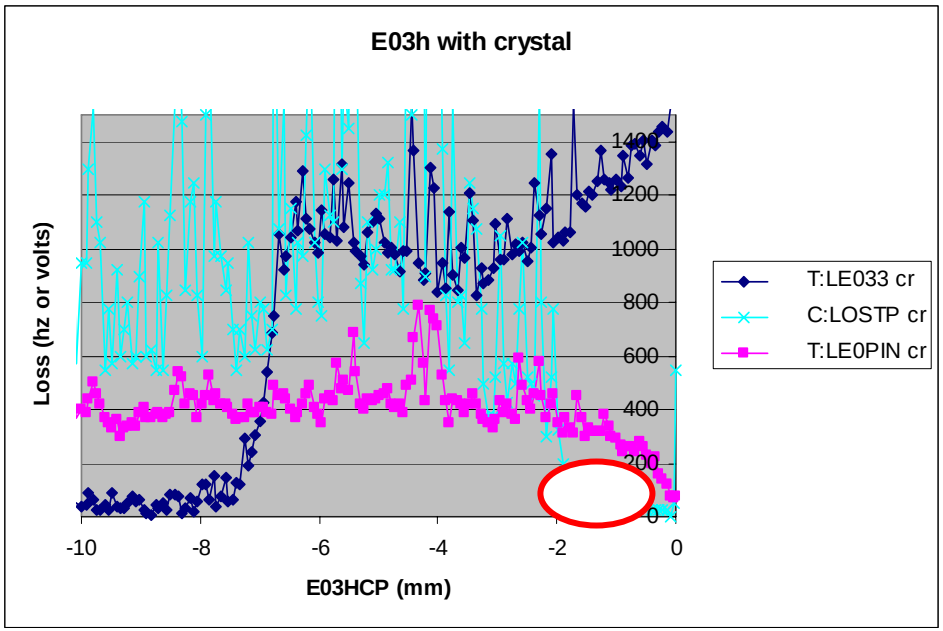


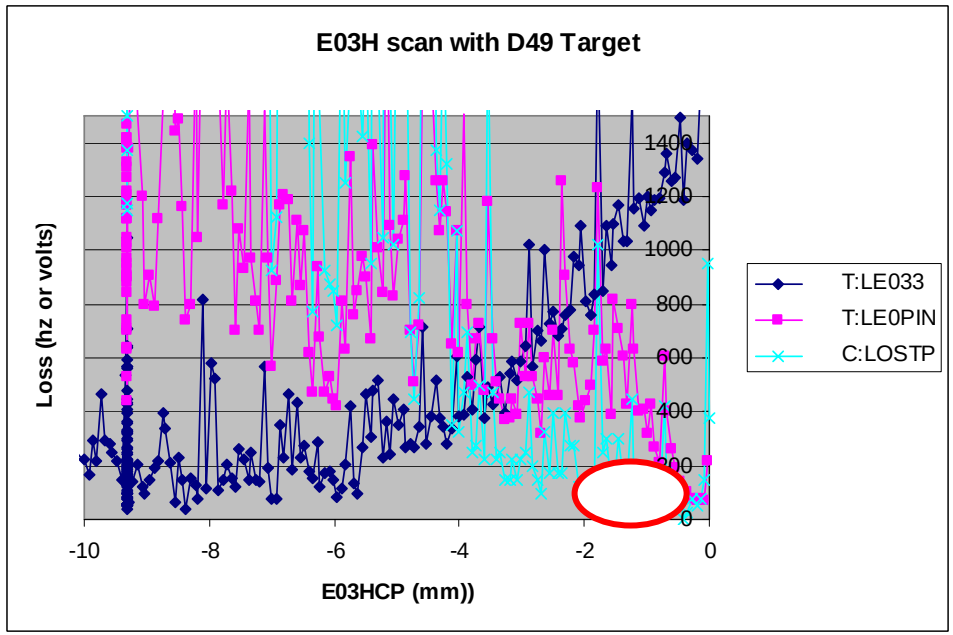
CHANNELED BEAM IS APERTURE-LIMITED



Therefore, hard to conclude about effects on halo reduction, but...

COMPARING EFFECTS OF PROTON HALO LOSSES FOR BENT CRYSTAL AND TUNGSTEN TARGET

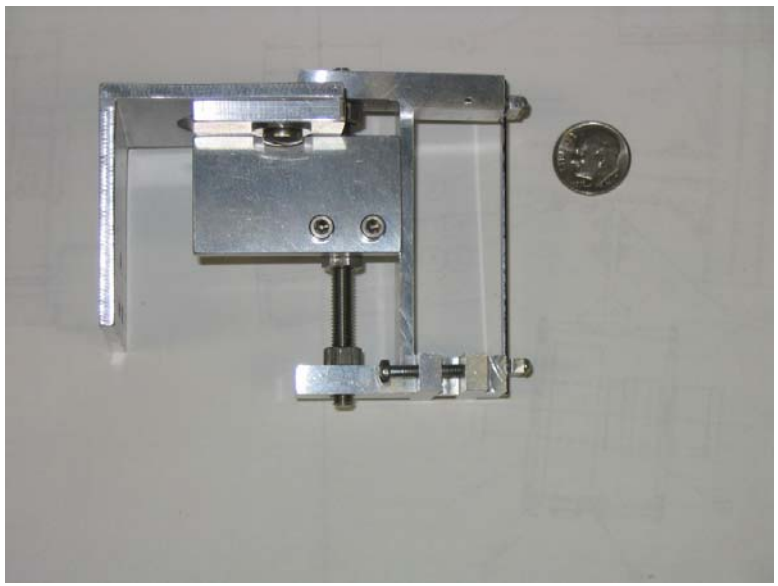


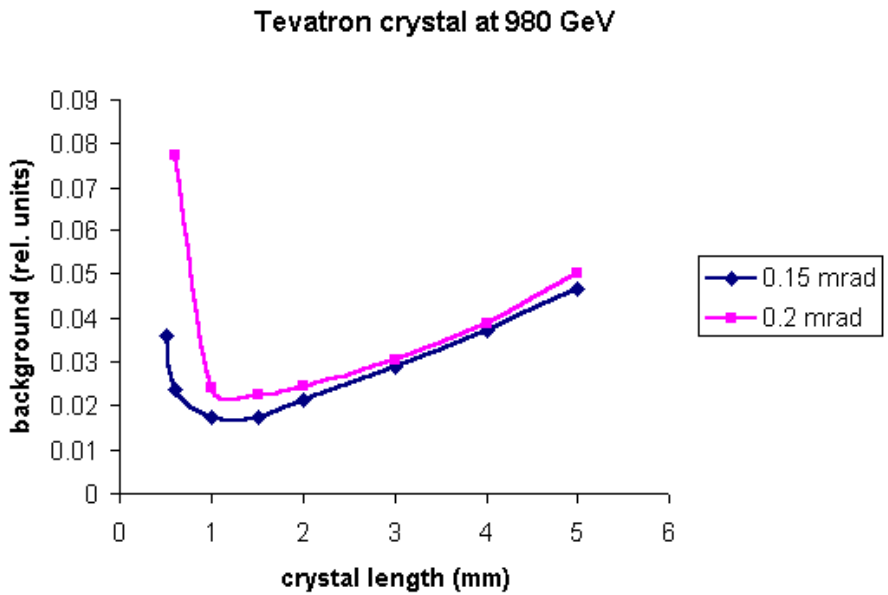


Using the crystal, the secondary collimator E03 can remain further (-1 mm or so) from the beam and achieve almost a factor of 2 better result!

FUTURE PLANS

- Finish data collection and analysis using current BNL crystal with purpose of answering "Does and how much CC reduce CDF and D0 proton halo losses?"
- Next long shutdown (> March 2006) - install 1-TeV custom crystal from Protvino/Ferrara (0.15-mrad bend, 3-mm length) and gather data, analyze and prepare conclusions.





SUMMARY

- Detailed simulations show that it is promising to use a bent crystal as a primary collimator (target) to increase efficiency of beam collimation at hadron colliders.
- We have demonstrated high-efficiency channeling for 1-TeV proton beam.
- It seems that there is a two-fold reduction in CDF loss rates, but we are careful with a final conclusion about reduction of beam losses at Tevatron critical locations due to limited aperture effects of current crystal setup.
- Hopeful with new crystal that we can come to a reliable conclusion about amount of a halo reduction.
- With optimized crystal-based collimation system at LHC, one can expect substantial reduction of beam loss rates and accelerator-related backgrounds in detectors.