CRYSTAL COLLIMATION STUDIES AT THE TEVATRON ~ T980 ~

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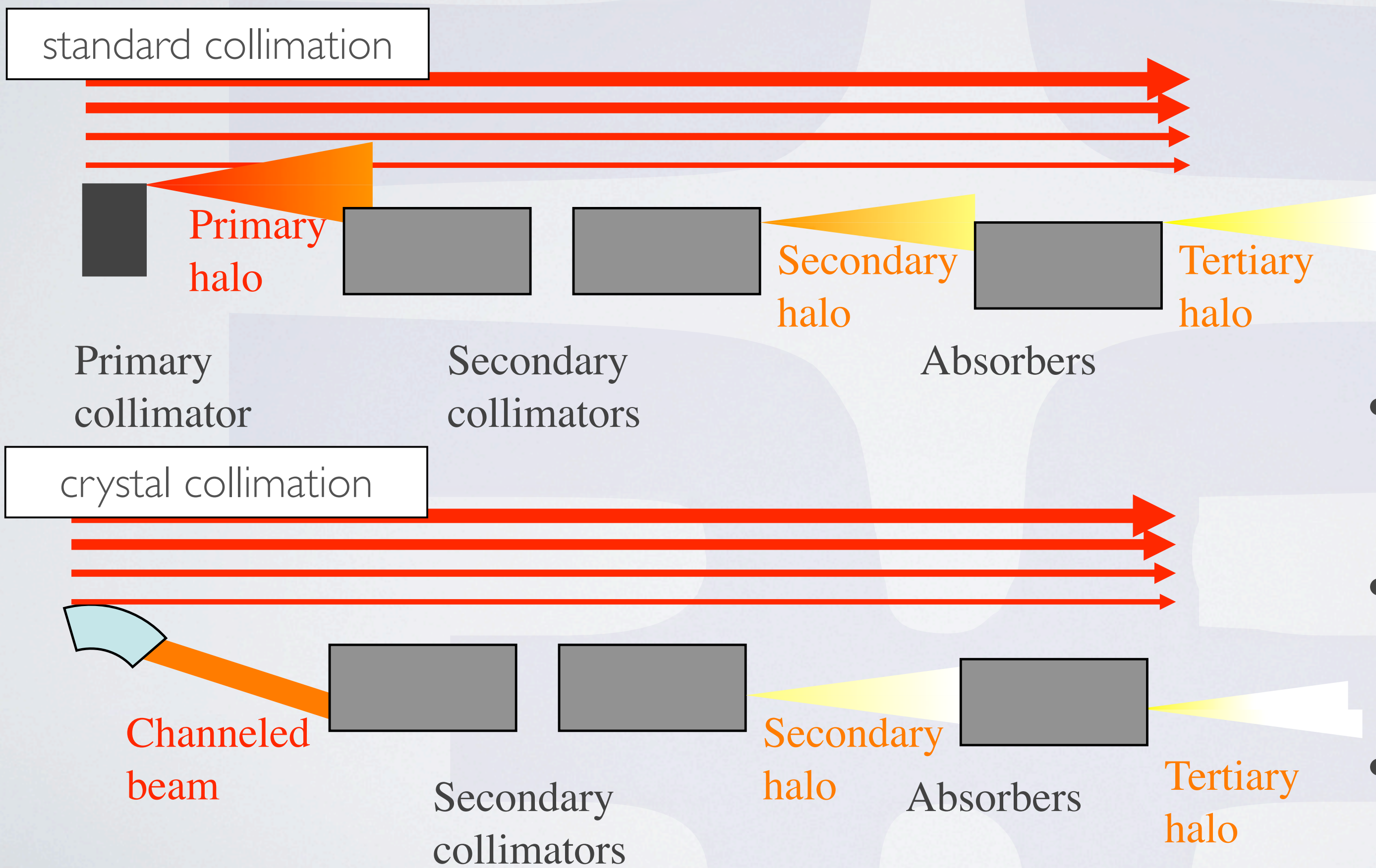
OUTLINE

- Introduction
  - The crystal collimation concept
  - The past experiences
- T980
  - The experimental layout
  - The crystal
  - End Of Store (EOS) studies
    - Angular and collimator scans
    - Experimental and simulation results
  - Crystal collimation for Collider Stores Results
- Conclusions

INTRODUCTION

- Bent-crystal channeling is a technique with a potential to increase the beam-halo collimation efficiency at high-energy colliders.



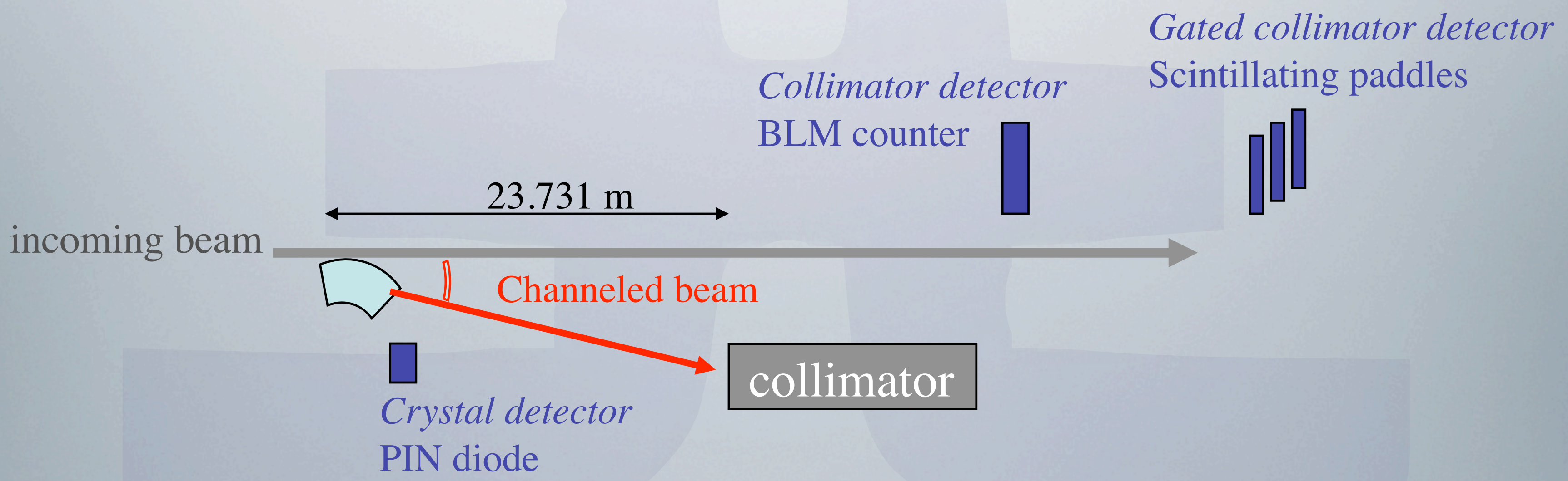
Use the crystal to drive the beam halo deep into a secondary collimator/absorber

- Coherent deviation of the primary halo
- Larger collimation efficiency
- Reduced tertiary halo

PAST EXPERIENCE

- A bent crystal for beam halo collimation was first suggested for the ***SSC***.
- Beam studies of crystal collimation were conducted at ***IHEP and RHIC*** ....
- .... followed by beam studies at the ***Fermilab Tevatron***...

...which ultimately became the ***T-980 experiment*** -
the first crystal collimation experiment in realistic conditions of a TeV hadron collider.



THE EXPERIMENTAL SETUP

In 2008, the T-980 hardware was substantially improved

goniometer:

upgraded to fix angular motion, vibration and dragging problems.

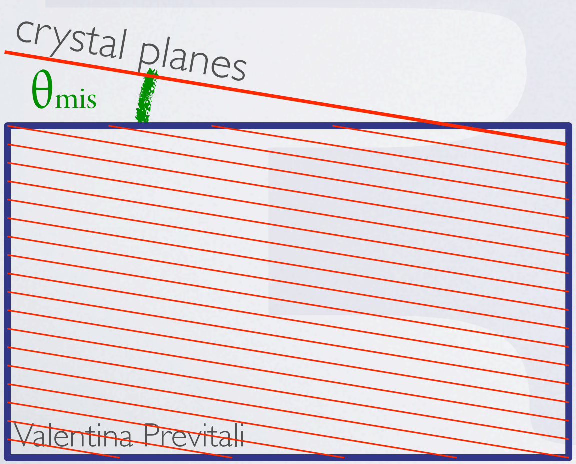
Angular resolution ~ 2 μrad

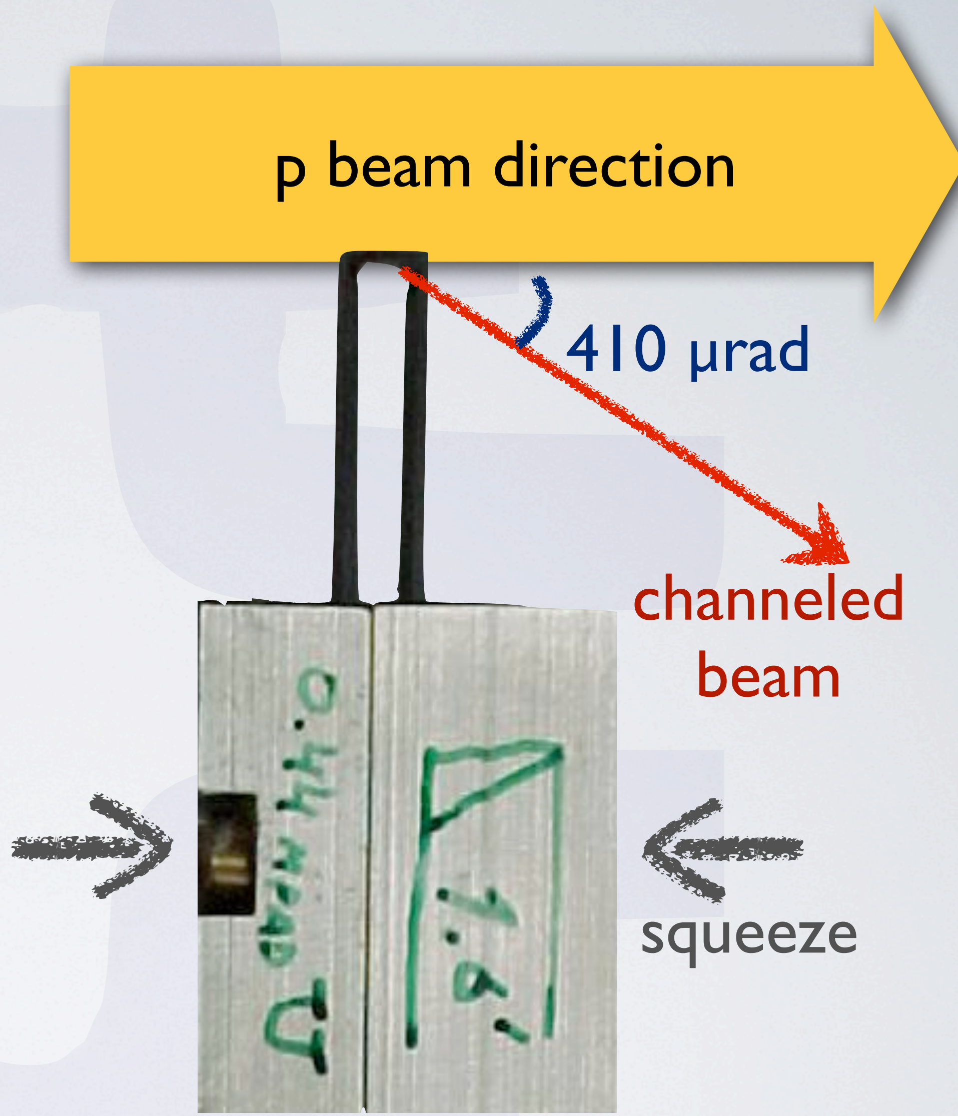
beam diagnostics:

Pin diode: measures the total inelastic interactions at the crystal
BLM: it measures the total losses at the collimator
Scintillating paddles: gated counters for losses at the collimator - discriminate between bunched and abort gap beam.

THE CRYSTAL

- Si crystal, 111 orientation
- O-shaped technology
- Full channeling angle **410 μrad**
- Miscut angle θ_{mis}= 1.6 mrad "positive" orientation:



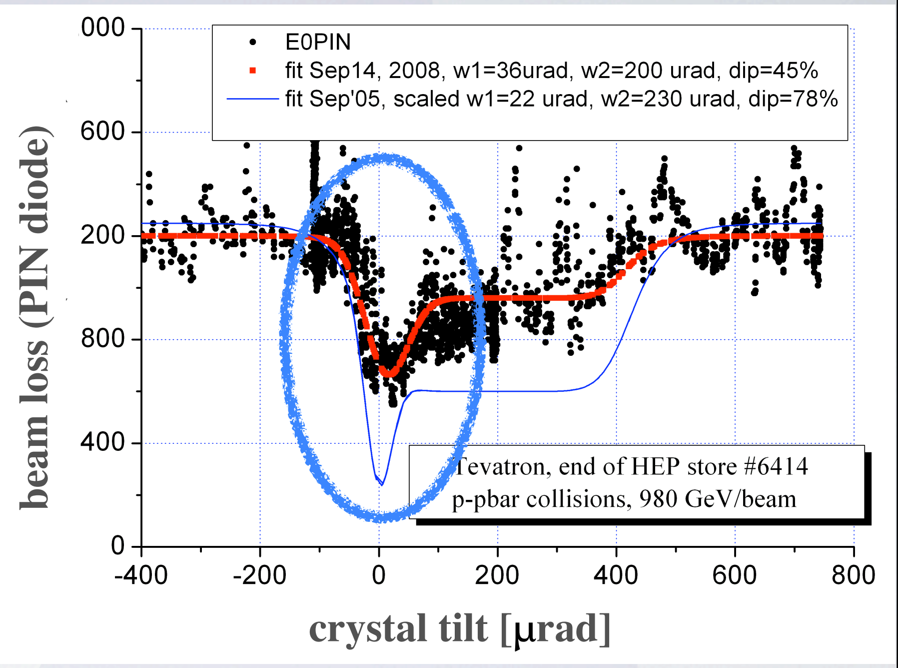


Crystal Courtesy of IHEP, Protvino

TWO MAIN RESULTS

Crystal angular scan:

Particle response depends on the angle between the incident particles and the crystal planes.



Purpose: ***find the crystal channeling angle.***

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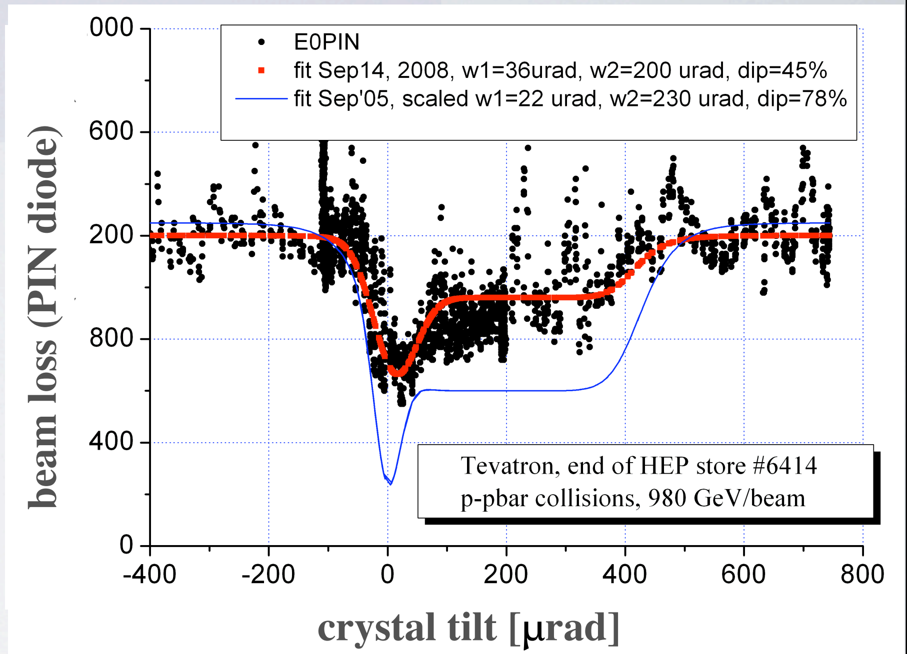
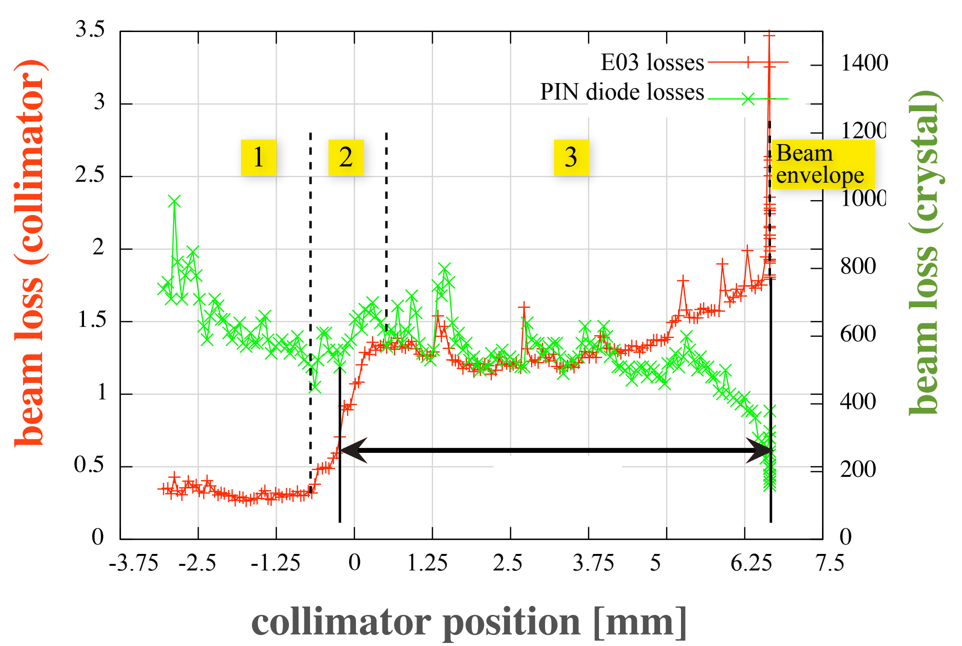




Collimator position scan:
fix the crystal angle and change the horizontal position of the collimator.

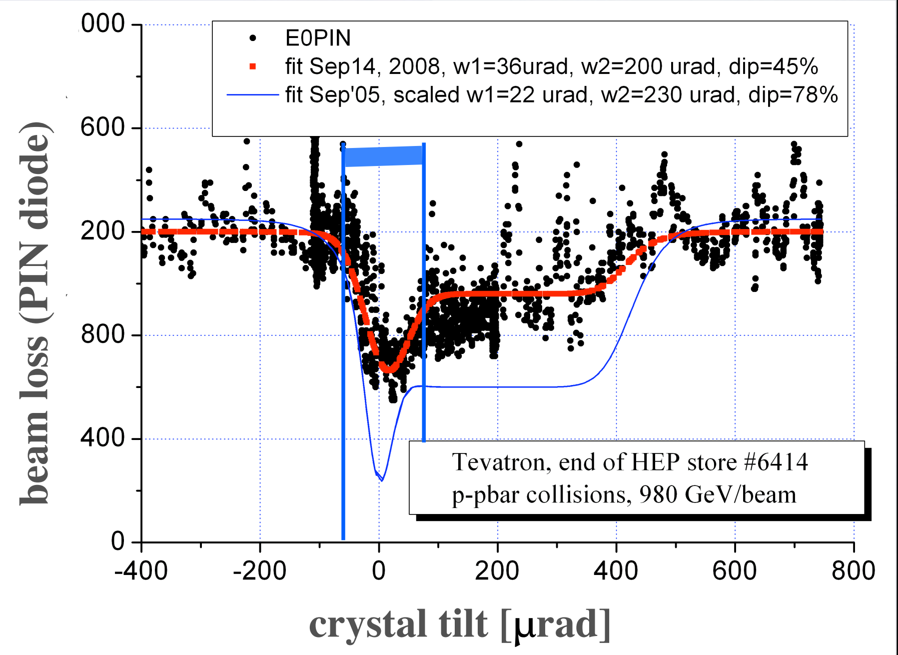
Purpose: ***measure the displacement of the channeled beam from the beam envelope.***

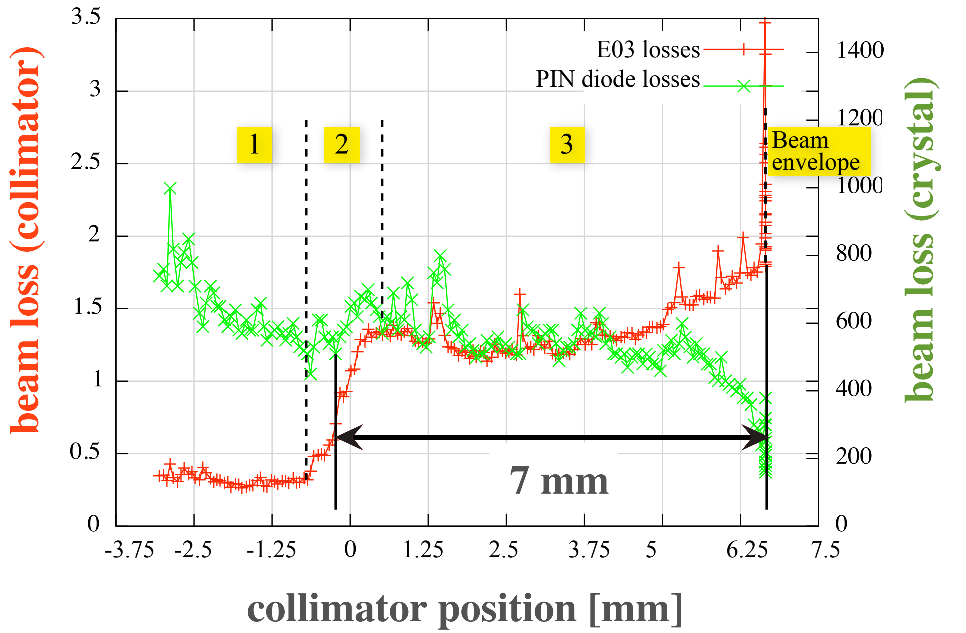
TWO BASIC QUESTIONS

Crystal angular scan: →

Why is the channeling width larger than expected?

10 urad (predicted) ⟶ 100 urad (measured)





← *Collimator position scan:*

Why is the observed displacement of the channeled beam at the collimator less than expected?

9.5 mm(predicted) ⟶ 7 mm (measured)

TWO HYPOTHESES

1.Off momentum particles:

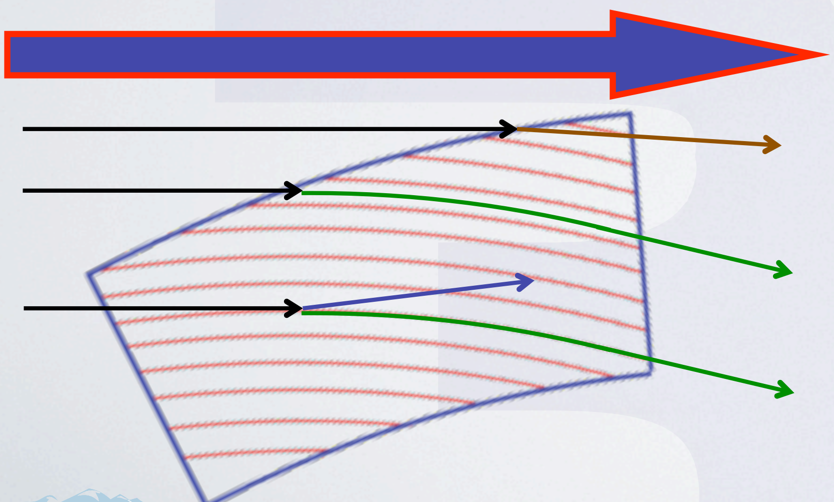
Particles with different energies have different impact angles

$$x' = -\frac{\alpha}{\beta} \cdot x_c + \left(\frac{\alpha}{\beta}\eta + \eta'\right) \cdot \frac{\Delta p}{p}$$

nominal angle

linear dependency on momentum offset

The angular spread is only 1.2 μrad (vs. 100 μrad observed)



2.Miscut angle:

In the crystal angular scan over the bending angle region of 410 μrad, **there is always an impact parameter region where the particles are channeled with a reduced deflection angle**.

ONE SOLUTION!

1.Off momentum particles:

Particles with different energies have different impact angles

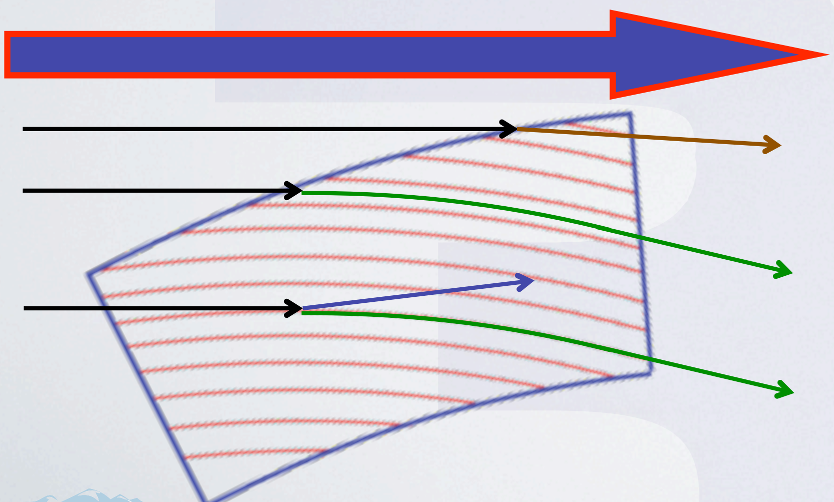
$$x' = -\frac{\alpha}{\beta} \cdot x_c + \left(\frac{\alpha}{\beta}\eta + \eta' \right) \cdot \frac{\Delta p}{p}$$

nominal angle

linear dependency from momentum offset

Th .2 µrad (vs. 100 µrad observed)

partial channeling: different kicks for different orientations!



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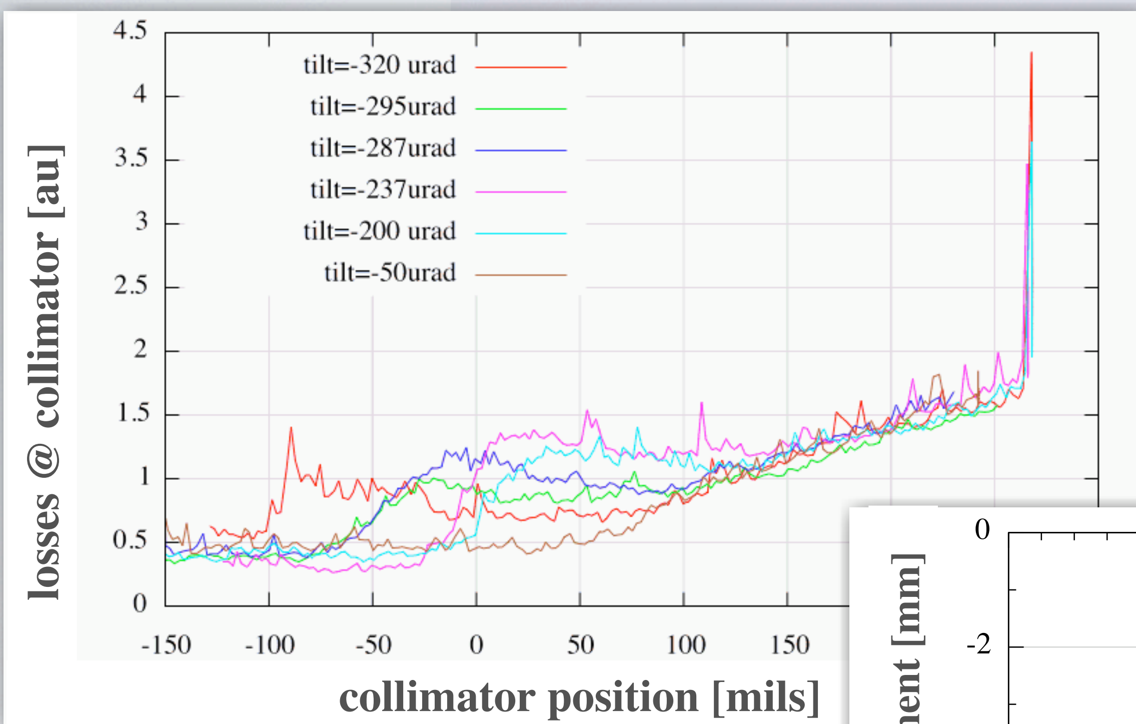
In the crystal angular scan over the bending angle region of 410 µrad, **there is always an impact parameter region where the particles are channeled with a reduced deflection angle**.

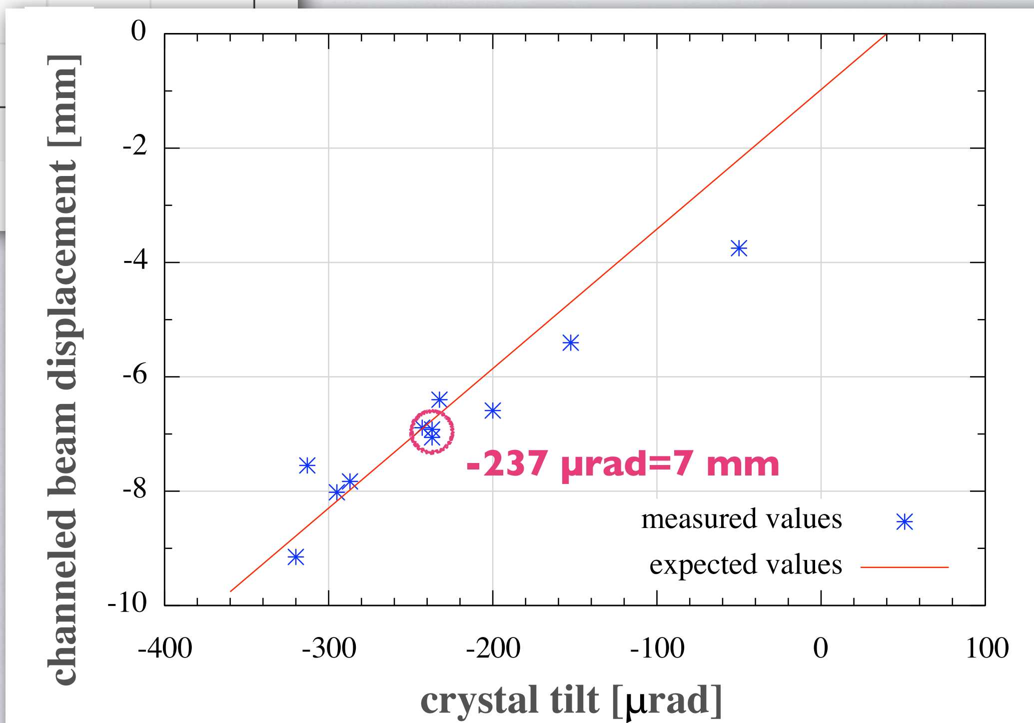
TWO VALIDATIONS



1. Experimental

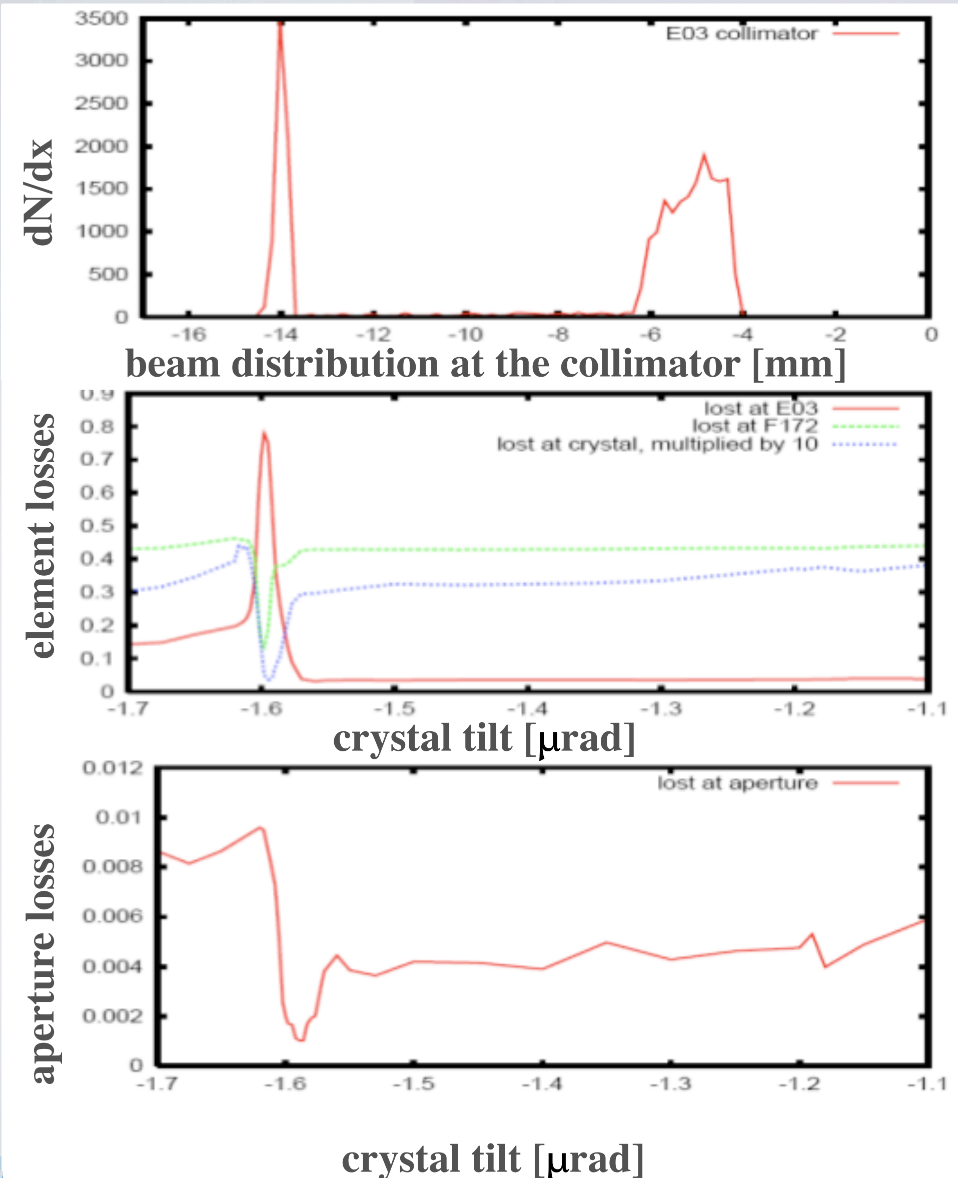
- ☑ collimator scans at different crystal angles reveal different channeling kicks.

- ☑ a linear dependence is verified



partial channeling: different kicks for different orientations!

TWO VALIDATIONS



2. Simulation

- ☑ Monte-Carlo simulations with CRYAPR and STRUCT reproduce the linear dependency
- ☑ Simulations show that θ_{mis}>100 μrad affects the distribution only if the orientation is “positive”

partial channeling: different kicks for different orientations!

CRYSTAL COLLIMATION IN COLLIDER STORES

Crystal collimation has been used during collider stores beginning in March 2009.

- ☑ A successful automatic insertion test of crystal has been achieved.
- ☑ A reduction of ring losses was reproducibly observed along with local loss effects on the collimator due to crystal channeling.
- ☑ No adverse effects were found.
- ☐ In the first store a problem appeared - the crystal angle drifted by approximately 90 μrad, due to heating from a nearby high-current bus ...
  - ☑ .... but was fixed with angular feedback software.

A more quantitative analysis will be conducted in the fall of 2009.

CONCLUSIONS

- ✓ Crystal channeling has been observed.
- ? Measurement results did not agree with expectations - the origin of discrepancies was investigated
  - ✓ both measurements and simulations confirm the significance of the ***large miscut angle*** (1600 μrad).
  - ✓ Simulations set a ***maximum acceptable miscut angle of (plus) 100 μrad***
- ✓ After reproducible end of store performance, crystal collimation was used ***during physics store*** with promising results.
- ✓ Preliminary results suggest that ***two-stage cleaning*** with the crystal as primary collimator is effective.

NEW HARDWARE AND FUTURE PLANS

- New hardware installation:
  In the summer 2009 the O-shaped ***crystal will be replaced with a new one*** with a much smaller miscut angle and a negative orientation.
  In addition, a ***second (vertical) goniometer with two alternating crystals*** will be installed: an O-shaped crystal (to exploit channeling) and a multi-strip array (to exploit volume reflection). Improved beam diagnostics will be installed.
- In the fall of 2009, Tevatron ***beam studies will start for two-plane beam cleaning*** aimed at observing convincing reproducible loss reduction in the superconducting ring and the CDF/D0 detectors

THANKS!

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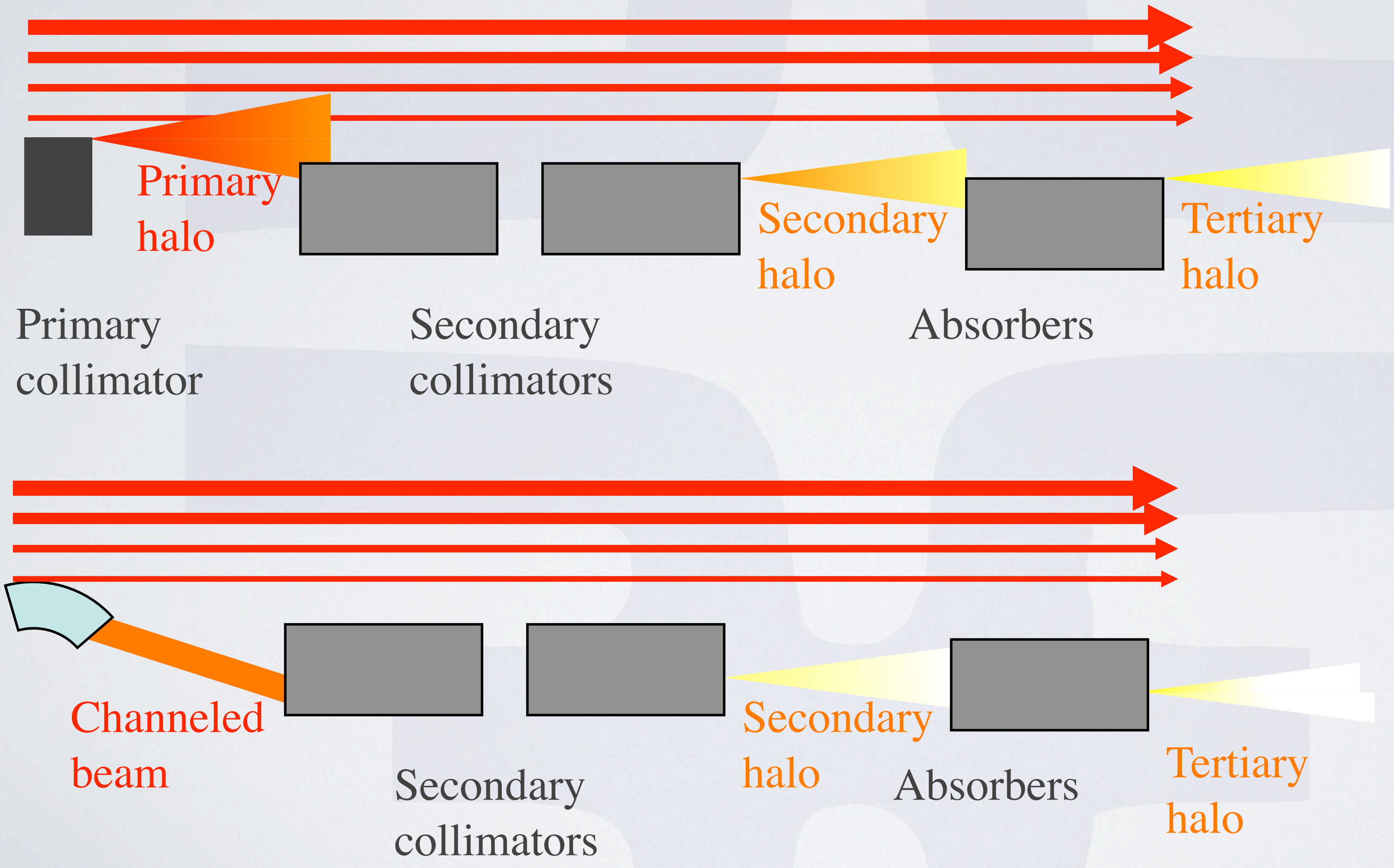
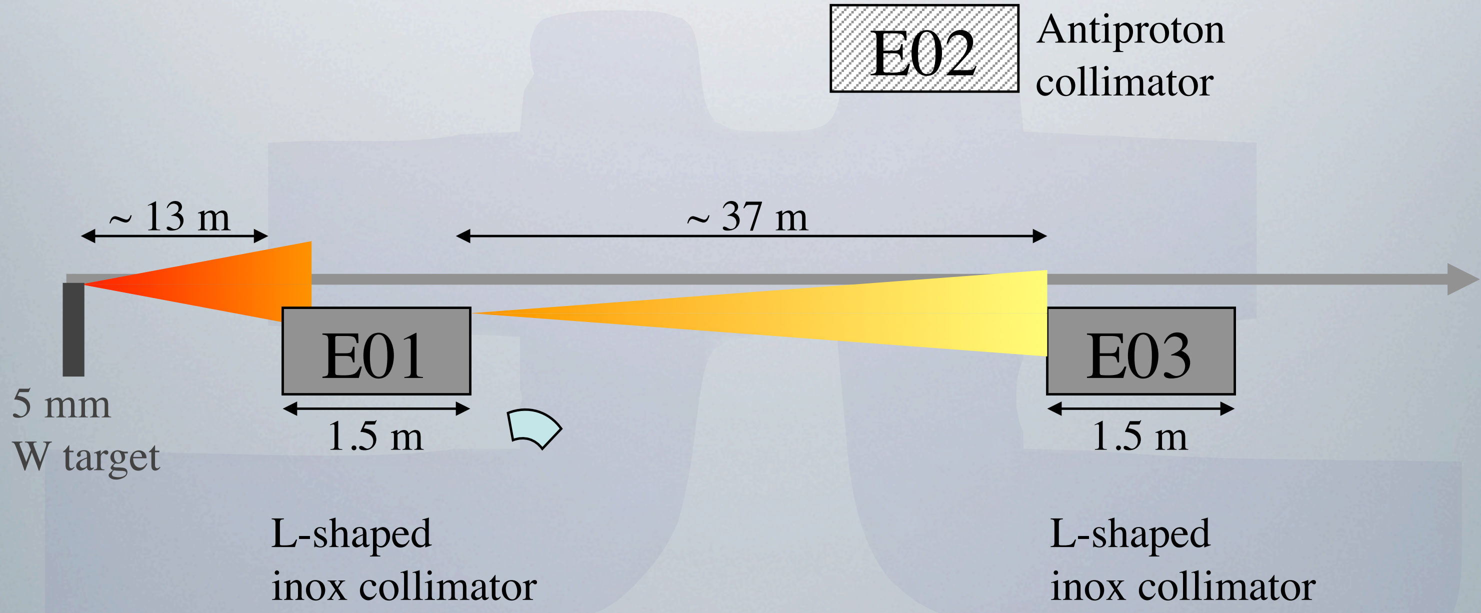
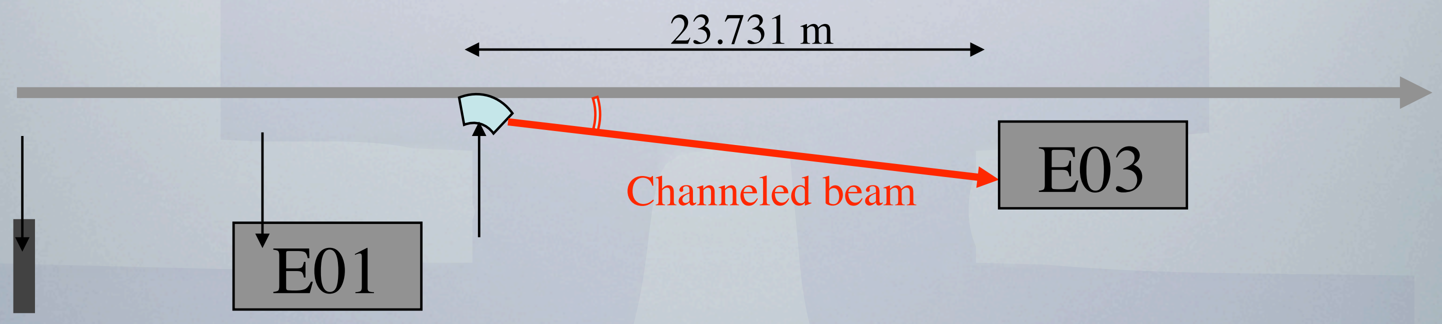
STANDARD VS CRYSTAL COLLIMATION





THE EXPERIMENTAL SETUP

standard collimation system



THE EXPERIMENTAL SETUP

crystal collimation system