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E853: Results of Bent Crystal Extraction at 900 GeV in the Tevatron

Motivation: $10^7$/sec extracted from SSC/LHC halo

1) Overview of crystal channeling and E853 goals

2) E853 apparatus

3) Results

4) Conclusions and future plans
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Goals of E853
(extraction with bent crystal already done at Dubna, Serpukov, CERN SPS)

1. Extract \(10^{-6}\) x Circulating protons/sec from the halo in a superconducting ring (e.g., if \(10^{12}\) protons circulating, extract \(10^6/sec\))

2. Show that luminosity lifetime not seriously shortened

3. Show that no intolerable backgrounds created at collider experiments

4. Explore methods of creating additional halo with RF noise
Crystal : Bent up $\uparrow 640 \mu \text{rad}$

Crystal cut along $\{111\}$ plane

Critical angle $\sim 1/\sqrt{P}$

Channeling losses $\sim P/R$

$\theta_{\text{critical}} = 8 \mu \text{radians}$

cf. beam $0 \sim 11 \mu \text{rad}$

$0.04 \text{ m crystal bend} = 8 \text{ m of kicker magnet!}$
Modes of operation

"Kick" mode - proton-only stores
- E853 sole user, ~ 2-4 hrs
- intensity ~ 10^11 circulating protons
- kick one bunch 1/2 mm closer to crystal
- establish vertical alignment of crystal angle
- study multiple-pass extraction
- study noise-induced halo

"Diffusion" mode - parasitic to end-of-store energy requirement that we be "unnoticed"
- DA protons-lost not exceed limit
- extraction rates achieved
- extraction efficiencies measured

Limitations:
- DA loss already too close to limit
- only 6 bunches:
  - 287 KHz extracted = 1 proton/bunch
    counters saturate

"Luminosity-driven diffusion"
**Extraction Rates achieved**

<table>
<thead>
<tr>
<th>store mode</th>
<th>circ. protons</th>
<th>extraction rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>proton-only, 3 bunched</td>
<td>~10^n</td>
<td>60-200 kHz</td>
</tr>
<tr>
<td>6 on 6 colliding, DQ loss &lt; limit</td>
<td>~10^{12}</td>
<td>30-150</td>
</tr>
<tr>
<td>36 on 3, DQ loss = 2 x limit</td>
<td>3 x 10^{12}</td>
<td>500-900</td>
</tr>
</tbody>
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- DQ loss was 1.6 x limit before crystal went in
- Colliding proton bunches had 6 times the extraction rate of non-colliding bunches

| proton-only, 84 bunches | 1 x 10^n | 95 |
| RF damper noise on | >450 |
Efficiency Measurements

Define efficiency as:

\[
\text{efficiency} = \frac{\text{extraction rate}}{\text{increase in total proton loss rate due to crystal}}
\]

- in collider mode need to measure a small change in \( \frac{d}{dt} \) (circulating protons)
- unknown other changes in the machine can simultaneously change loss rate

CERN effy at 120 GeV

\( \sim 10\% \)

Biryukov simulation of E853

\( \sim 40\% \)
\[ \text{ave} = 0.19 - 0.21 \]

Run number

Efficiency

\( \sigma \) from ave

6 on 6 bunches colliding

Proton-only stores

E853 Extraction Efficiency - Preliminary
RUN22 data

\[ \text{count rate extracted per 5 sec} \]

\[ \text{interaction counter rate per 5 sec} \]

\[ \text{channeling effy} = \frac{U_{\text{max}} - U_{\text{min}}}{U_{\text{max}}} \]

\[ \text{AG1\text{*CAL(therv)}} \]

\[ \text{Crystal vertical angle theta v} \]

\[ U_{\text{max}} \]

\[ U_{\text{min}} \]

\[ U_{2(\text{therv})} \]
Efficiency from $\Theta$, scan and ON/OFF data

\[ \text{ave} = 0.28 - 0.32 \]
Possible uses of crystal extraction:
* Active scraper
* Bunch eliminator
* 900-1000 TeV test beam at FNAL
* $10^{**7}$ proton/s heavy quark fixed target
* Extraction at LHC
* Extraction for long baseline neutrino beam