Modern Success in Channeling Study and Applications at IHEP Protvino Accelerator

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Ideas of use the particle channeling in bent crystals for steer the beams have been checked up and advanced in many experiments. This method has found the widest practical application on U-70 accelerator of SRC IHEP, where crystals are used in regular runs for beam extraction and forming.

1. Beam splitting (started since 1988)

Usually a beam is split by an electrostatic or a magnetic splitter. This is a technically fairly complex approach requiring considerable space, since the angles of deflection of a beam by a conventional splitter are very limited. The use of crystals provides a simple means for beam splitting, which is unattainable by conventional techniques. The first crystal beam-splitting station began to operate since 1988.

IHEP new splitting station



Construction of goniometer



Preparation of the bent crystal with use of two original methods has allowed to lower losses of particles

at splitting up to 0.01 %









Deflected by crystal beam near the target



2.Beam extraction from U-70 ring by means of bent crystals

Different types of extraction schemes were realized by bent crystal. In first case high efficiency of extraction up to 85% is reached applying short silicon crystals Si 19,22,106 (Fig.3)

Schemes of crystal channeling extraction



Different types of short crystals were installed in ring



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High-Efficiency Beam Extraction and Collimation Using Channeling in Very Short Bent Crystals

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A silicon crystal was used to channel and extract 70 GeV protons from the U-70 accelerator with an efficiency of $85.3 \pm 2.8\%$, as measured for a beam of $\sim 10^{12}$ protons directed towards crystals of ~ 2 mm length in spills of ~ 2 s duration. The experimental data follow very well the prediction of Monte Carlo simulations. This demonstration is important in devising a more efficient use of the U-70 accelerator in Protvino and provides crucial support for implementing crystal-assisted slow extraction and collimation in other machines, such as the Tevatron, RHIC, the AGS, the SNS, COSY, and the LHC.

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Parameters of crystal extraction



Efficiency dependence versus crystal length

Crystal efficiency versus proton energy





Time structure at Simultaneously operation

Efficiency dependence versus cl bend angle

Extraction with large bending



3.Use of crystals to improve beam collimation in U-70.



Beam profiles at collimator entry: channeling in 3 different crystals compared to amorphous target (50 GeV protons).



Collimation efficiency measurement by comparison with kicker effect.



Reduction of losses, factor 2-3.



4. Low energy crystal extraction (about 1 GeV)



Results of different-type crystal testing at 50 GeV and 1.3GeV

| Crystal type | Length along the beam, mm | Transversal Dimension, mm | Deflection angle, mrad | Collimation Efficiency, % | | Channeling peak Efficiency, % | |
|------------------|------------------------------------|---------------------------------|------------------------------|------------------------------|---------|----------------------------------|---------|
| | | | | 50 GeV, | 1.3 GeV | 50 GeV | 1.3 Gev |
| Simple strip | 1 | 0.3 | 1.0 | 91±2.5 | 30±2.5 | 86±2.5 | ~ 0 |
| Crystal array | 0.9 | 7×0.2 | 1.1 | 77±2.5 | 40±2.5 | 72±2.5 | ~ 20 |
| Veer (Fan) | 7×0.25 | 3 | ~7×0.05 | 82±2.5 | 35±2.5 | 70±2.5 | ~ 5 |

5.Reflections offer new way to steer the particle trajectories.

The phenomenon of reflection occurs in wide area of angles and is more effective, than usual channeling



Enhancement of reflection angle in multi-crystals





Installation in U-70 goniometer.



Measured beam profiles at absorber entry run april-2008.



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Over 80 % of particles were reflected in a crystal and were deserted in absorber on distance over 1 mm from the edge. It is expected, that over 90 % of circulated particles can be reflected by crystal in thin-walled electrostatic deflection for extraction from the U-70 ring.

Further reading:

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conclusion

Bent crystals are very promising for application at accelerators for beam extraction/collimation and generation of powerful photon radiation.

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