Twenty five years of bent crystal channeling applications for beam splitting, extraction and collimation in the U70 accelerator of IHEP

Yu.Chesnokov, Protvino

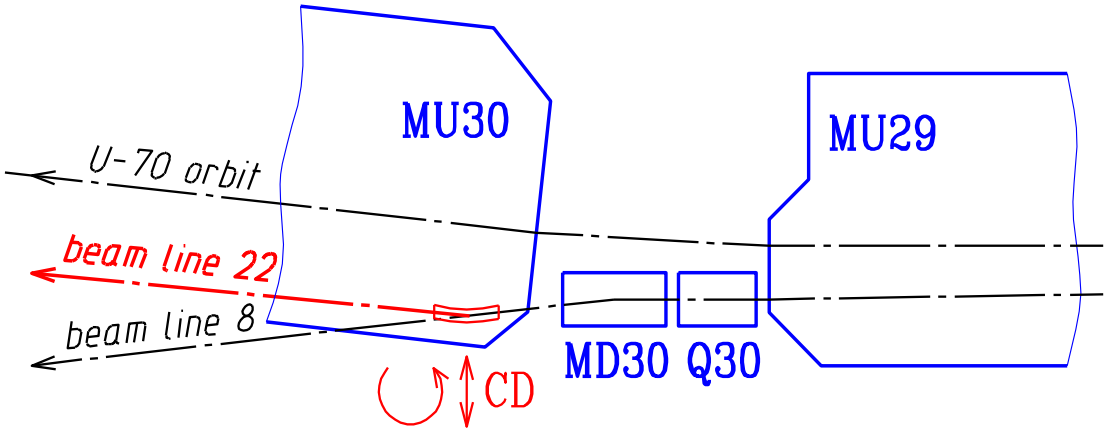
Ideas of use the particle channeling in bent crystals for steer the beams have been checked up and advanced in many experiments. This method has found the widest practical application on U-70 accelerator of SRC IHEP, where crystals are used in regular runs for beam extraction and forming.

Beam splitting(started since 1988)

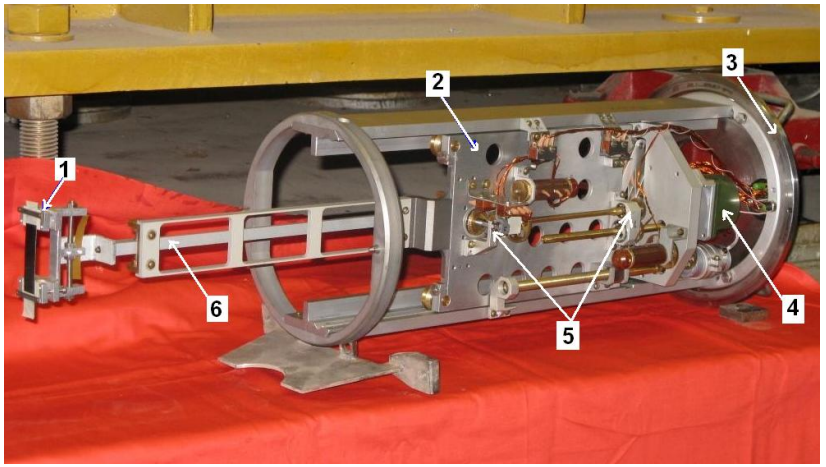
Usually a beam is split by an electrostatic or a magnetic splitter. This is a technically fairly complex approach requiring considerable space, since the angles of deflection of a beam by a conventional splitter are very limited. The use of crystals provides a simple means for beam splitting, which is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

IHEP new splitting station

Crystal location

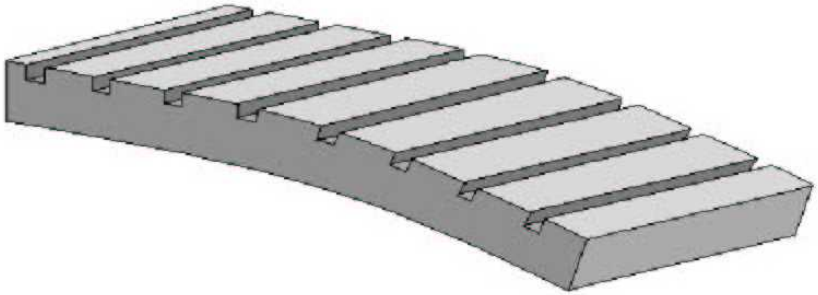


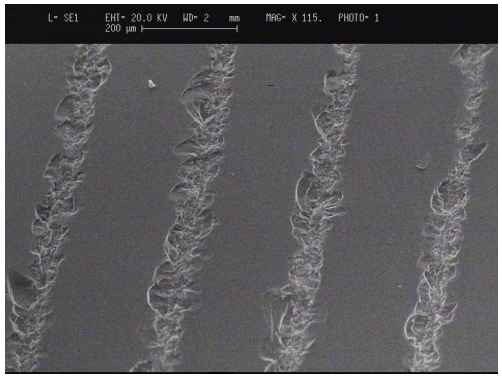
Construction of goniometer

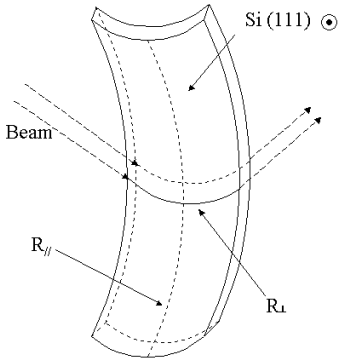


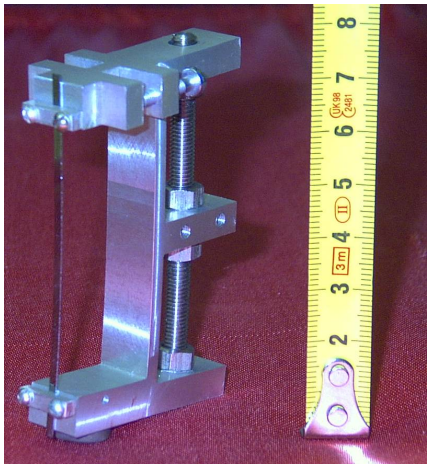
Preparation of the bent crystal with use of two original methods has allowed to lower losses of particles

at splitting up to 0.01 %

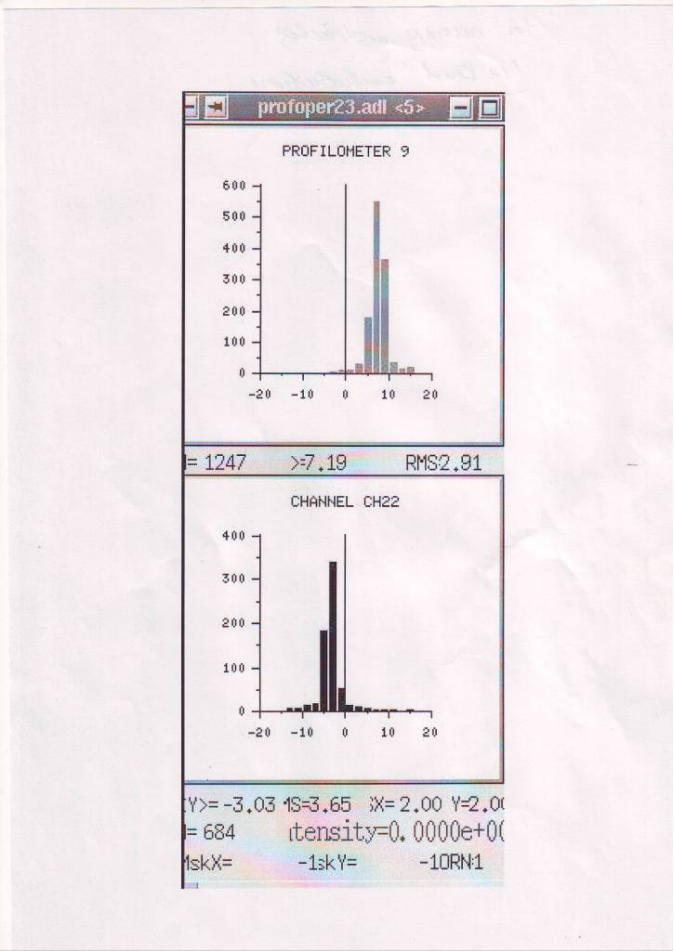








Deflected by crystal beam near the target



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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

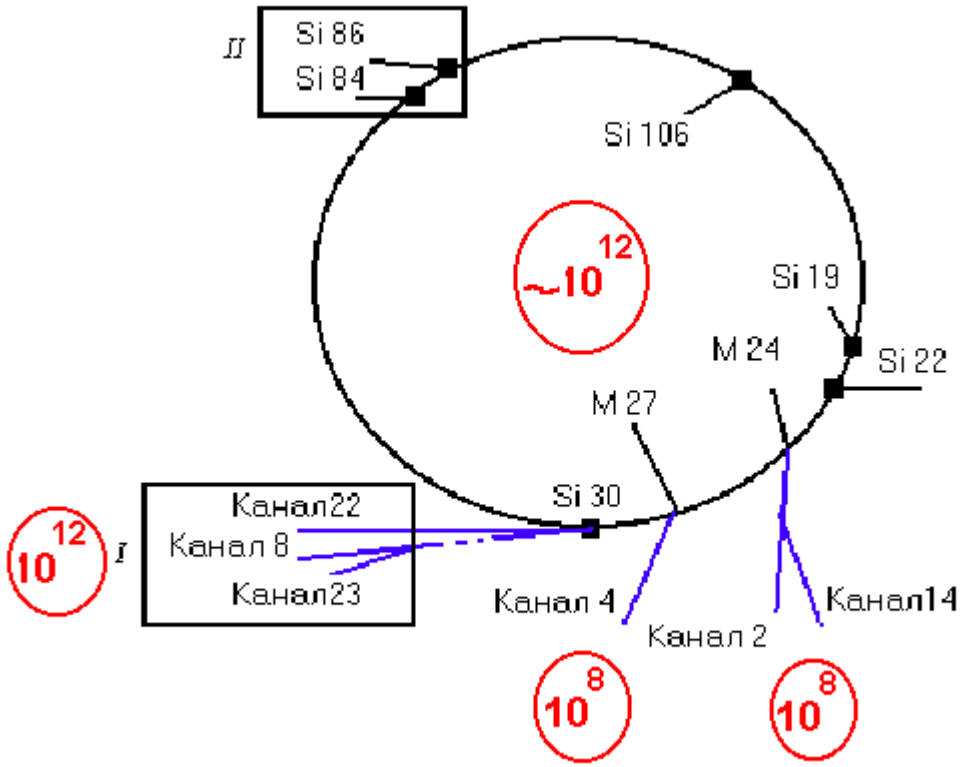
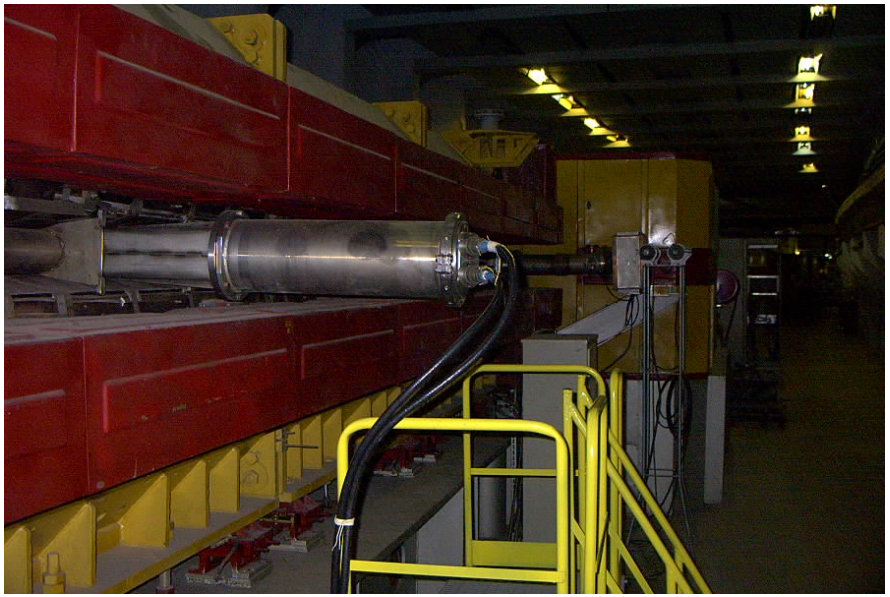


Схема вывода пучков из У-70: Si 19, Si 22, Si 30, Si 84, Si 106 – изогнутые кристаллы;
M 24, M 27 – внутренние мишени; *I* – зона экспериментальных установок;
II – *зона исследований кристаллов.*

Table1: The use of slow extraction by bend crystal on U-70 during 2010-2012.

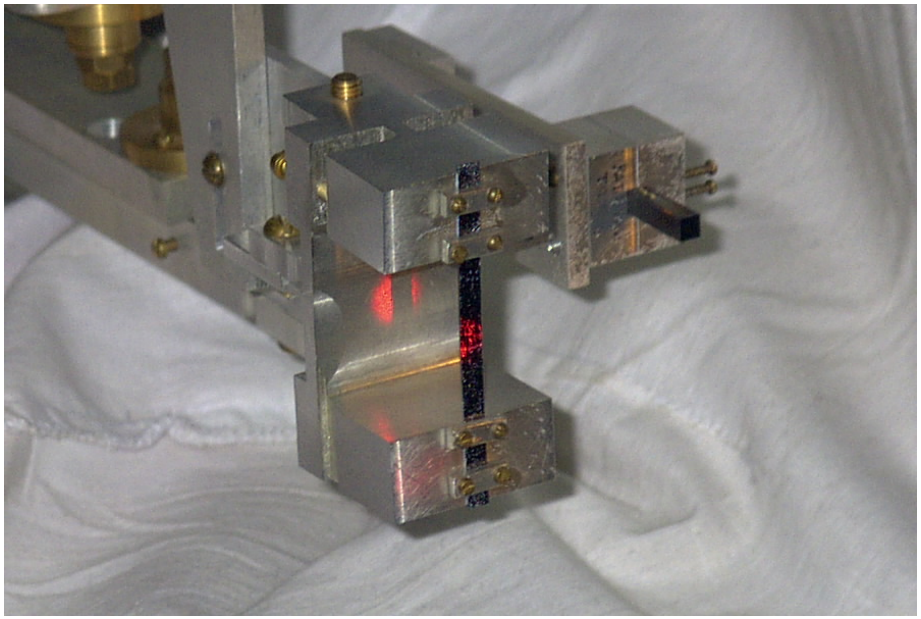
Run **U-70**	**Duriation, hours**	**KMN**		**SVD**		**FODS**		**SPIN**		**ISTRA- crystal**	
		Time, **hours**	Station	Time, **hours**	**Station**	Time, **hours**	**Station**	Time, **hours**	**Station**	Time, **hours**	**Station**
2-2010	744			744	Si30					120	Si27
1-2011	240			144	Si19	96	Si19	96	Si19		
2-2011	744			576	Si30	48 48	Si19 Si30				
1-2012	288	168	Si19							72	Si27

Different types of short crystals were installed in ring



. Станция кристаллических дефлекторов,
смонтированная на ускорителе У-70.

. Изогнутые кристаллы, установленные на станции.



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 ± 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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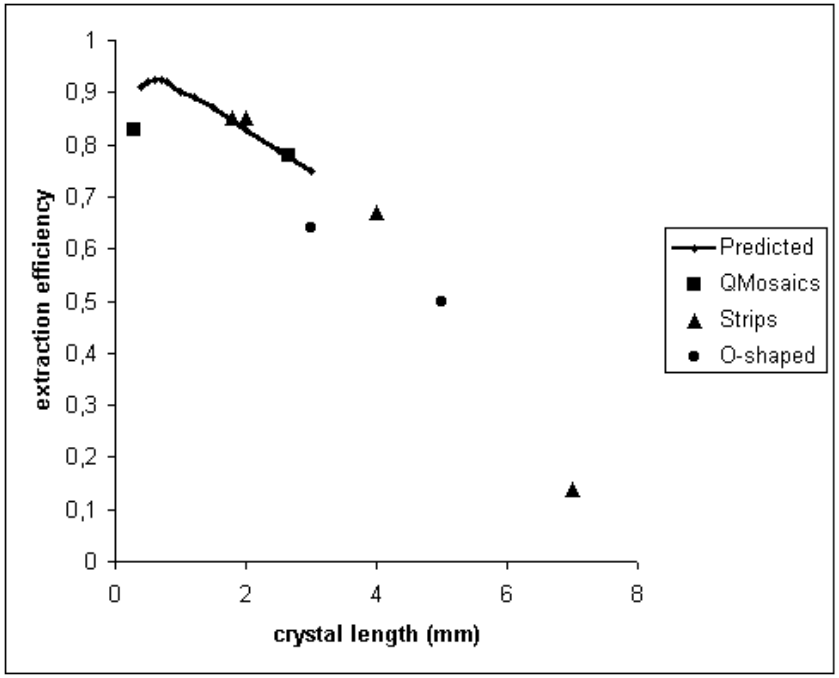
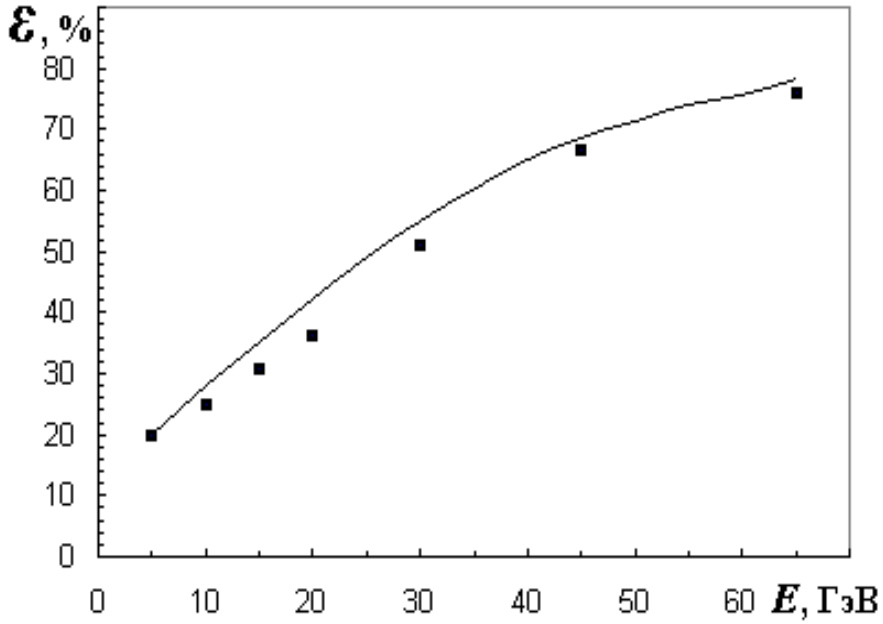
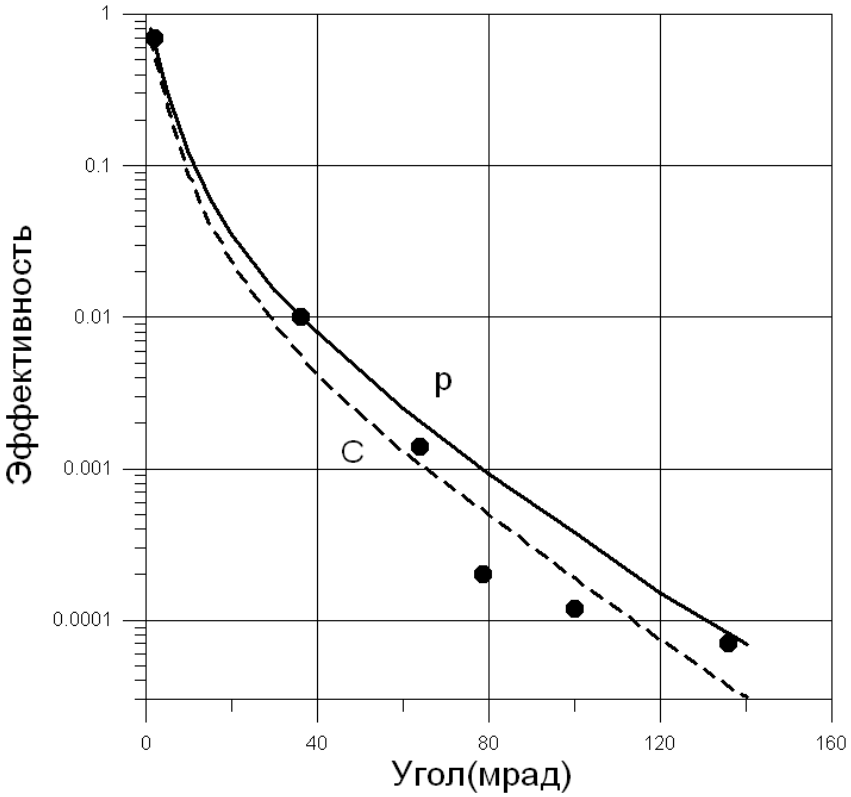
Parameters of crystal extraction



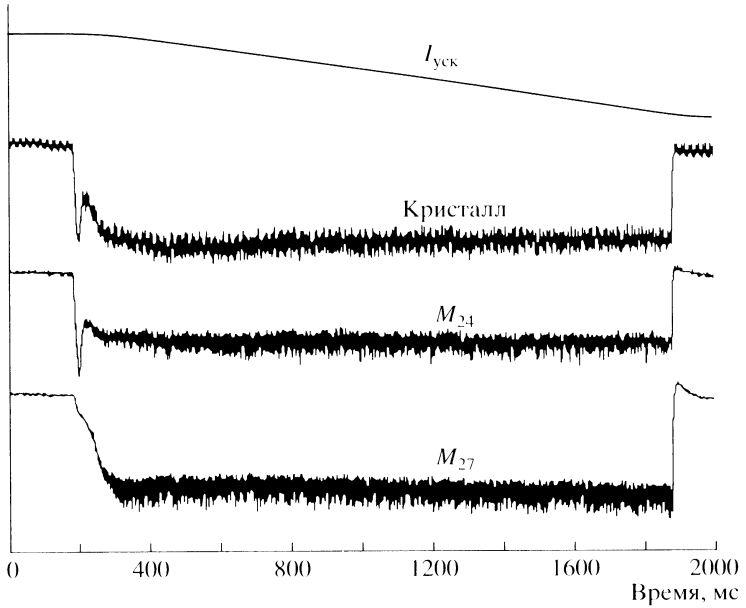
Efficiency dependence versus crystal length



Crystal efficiency versus proton energy



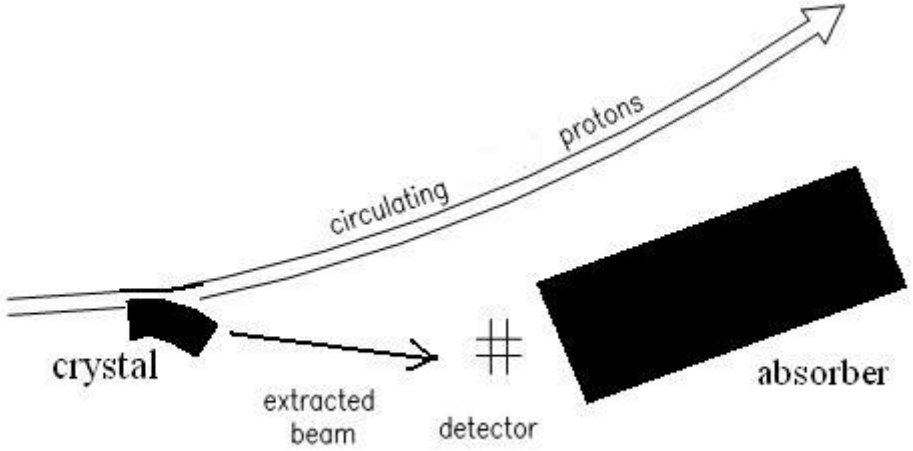
Efficiency dependence versus crystal bend angle

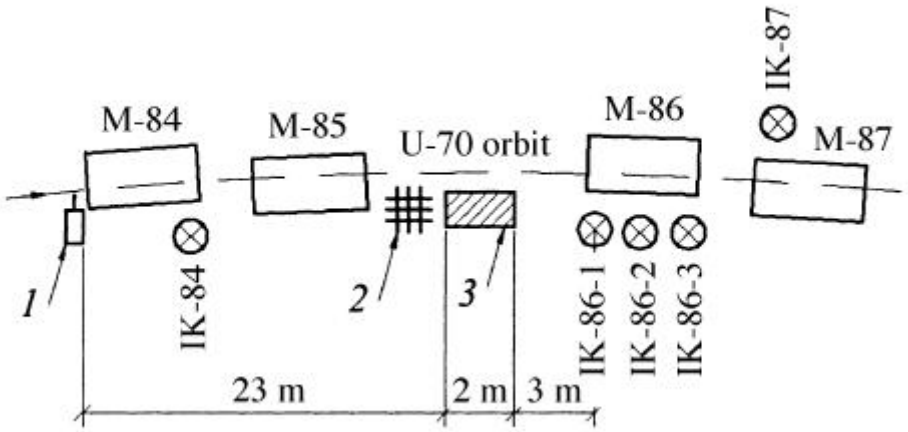


Time structure at Simultaneously operation

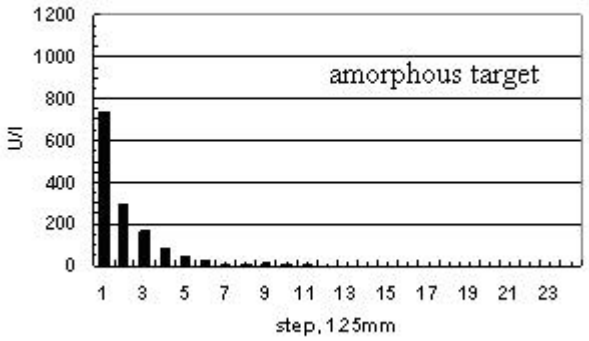
Extraction with large bending

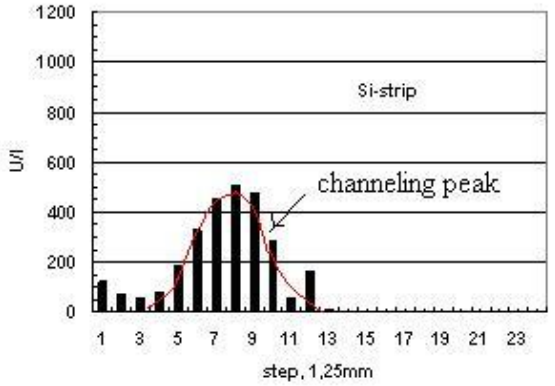
Use of crystals to improve beam collimation in U-70.

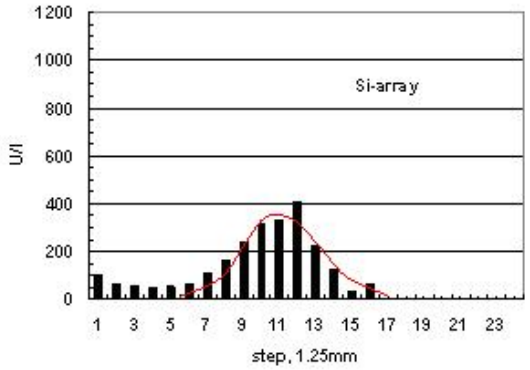


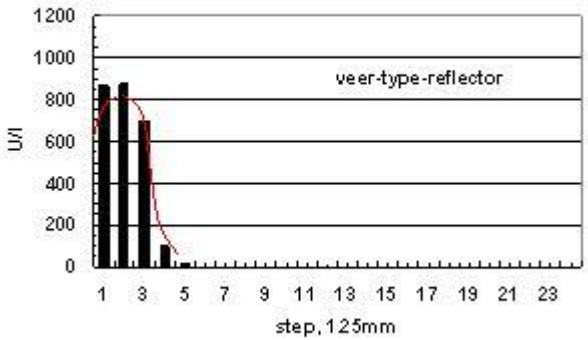


Collimation by channeling mode

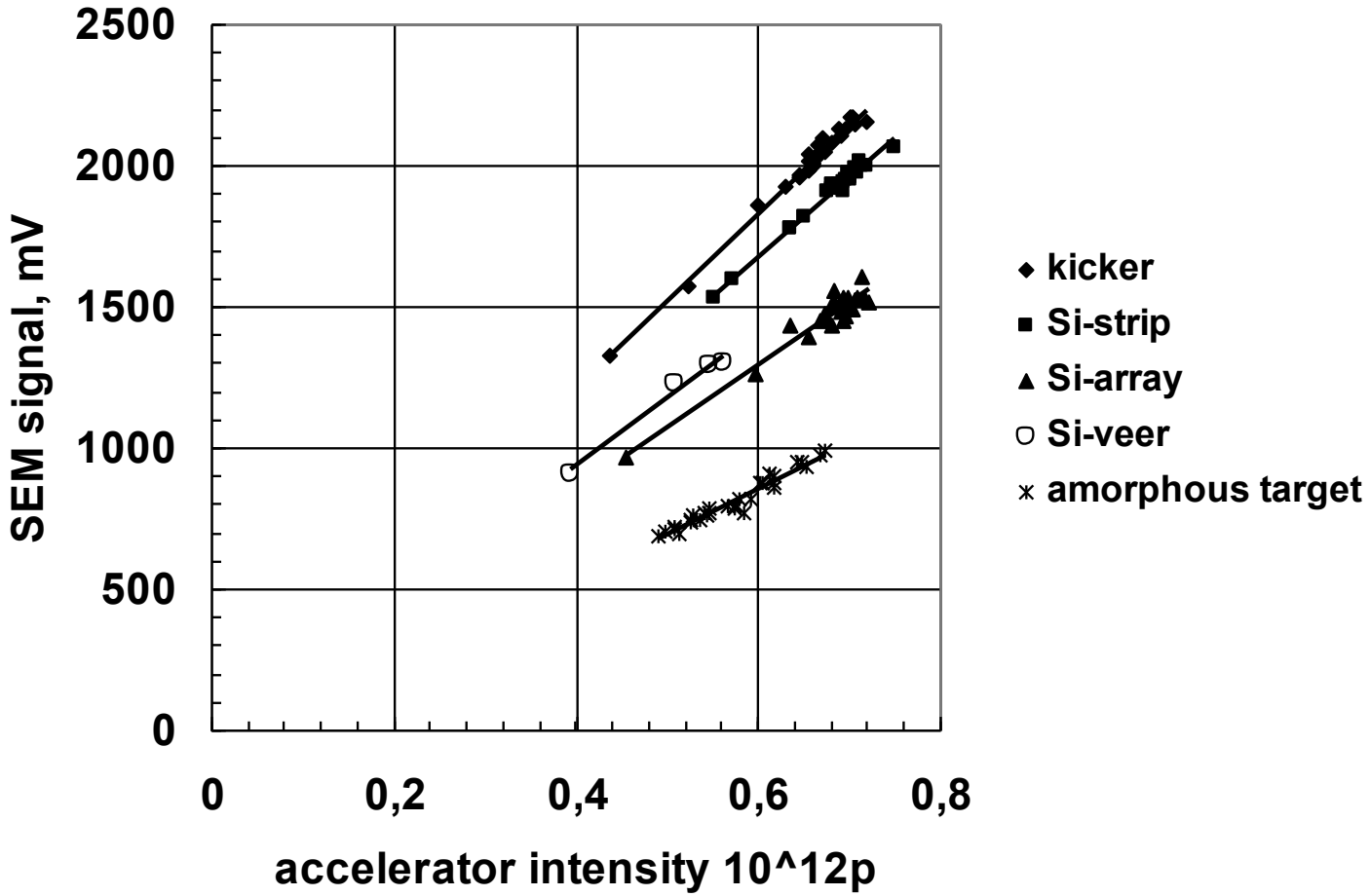




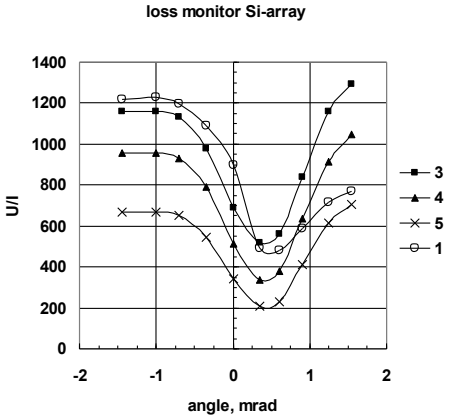


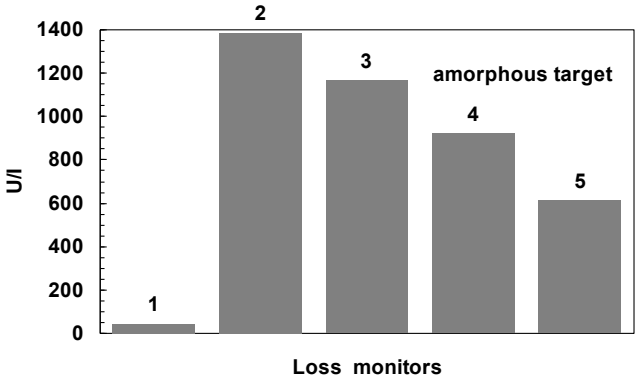


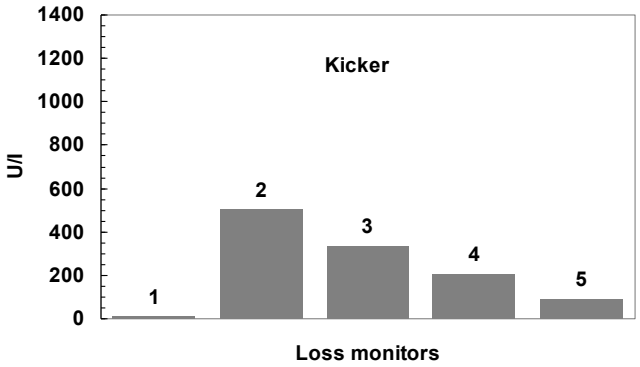
Efficiency measurements

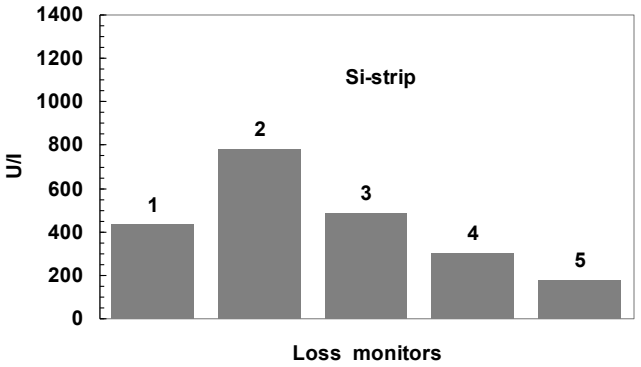


Reduction of losses, factor 2-3.



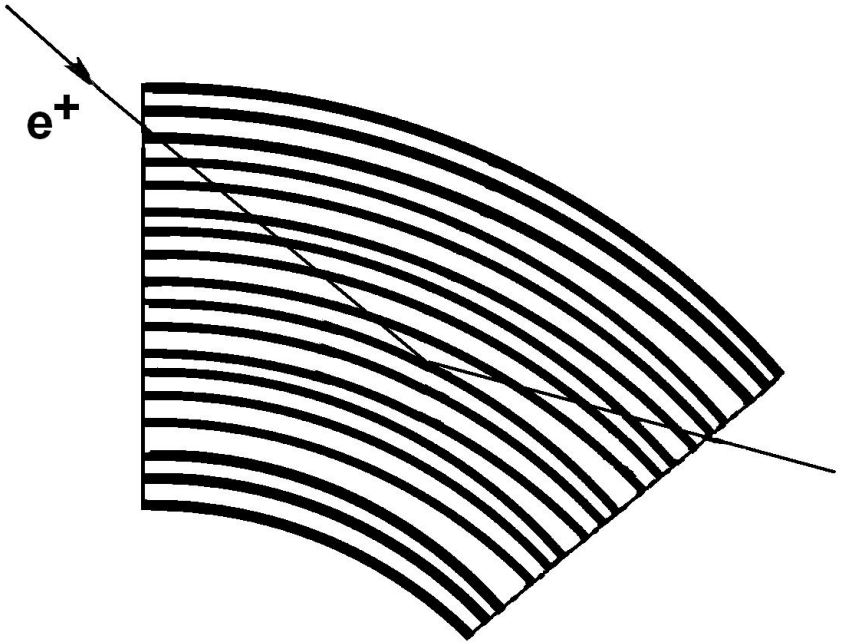




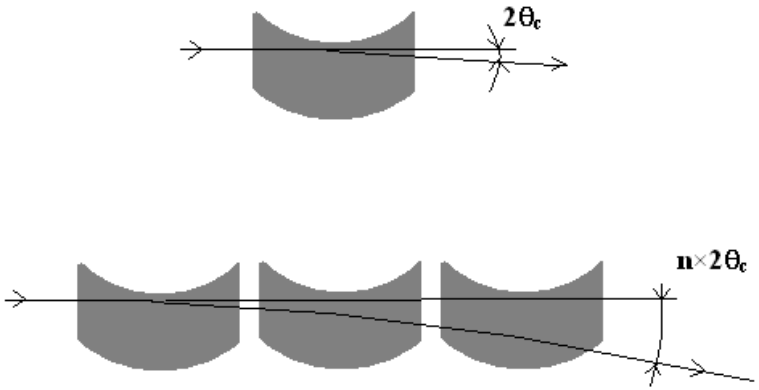


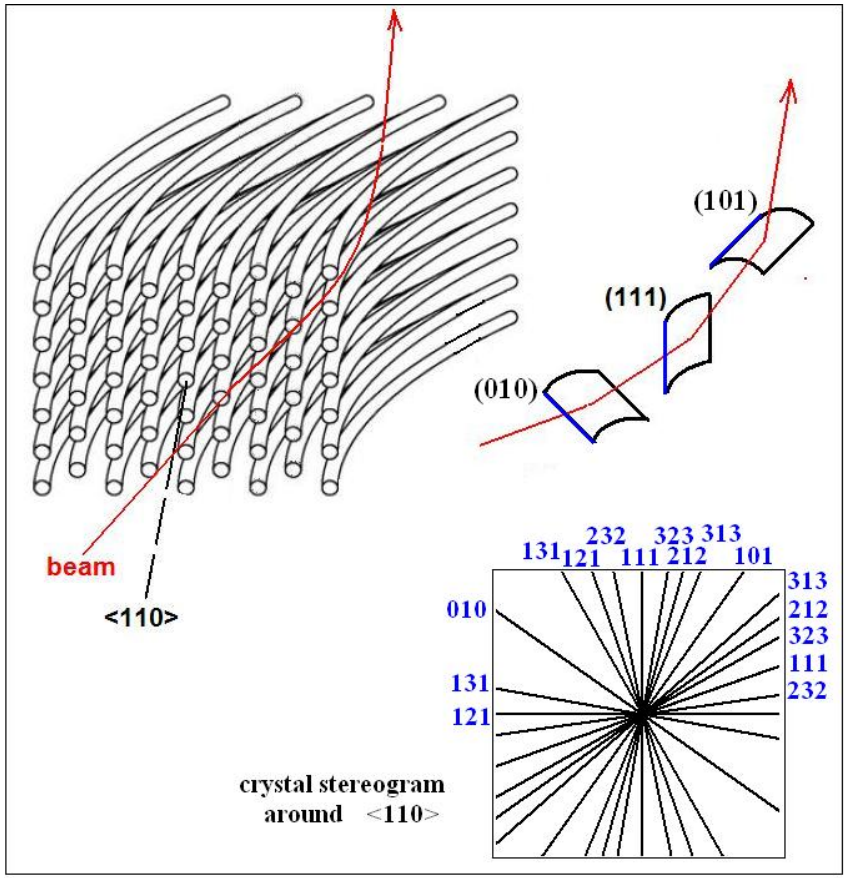
Reflections offer new way to steer the particle trajectories.

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

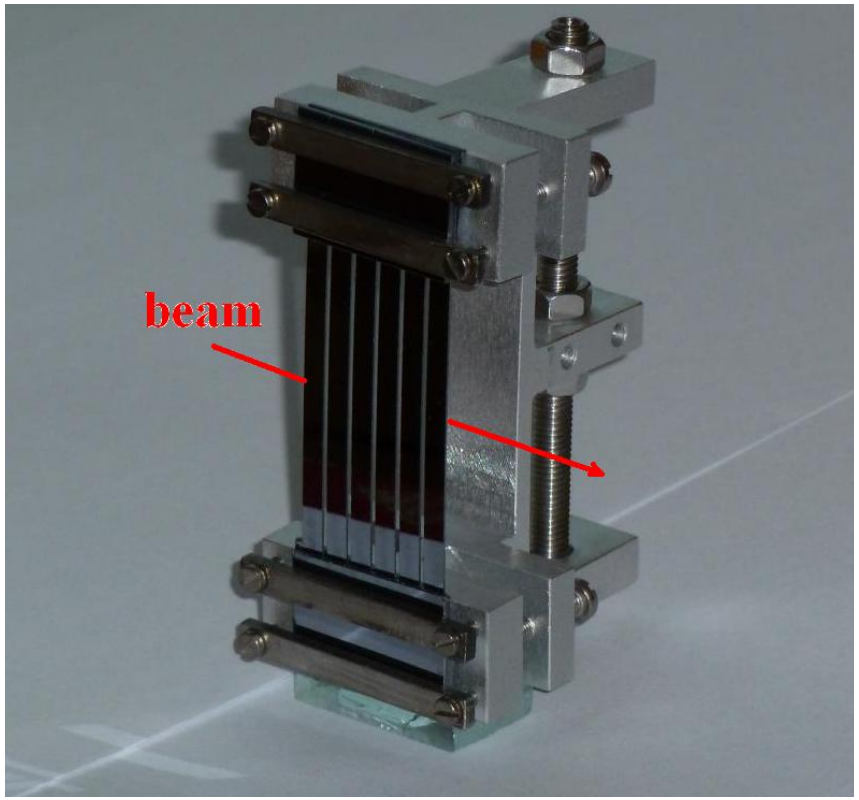


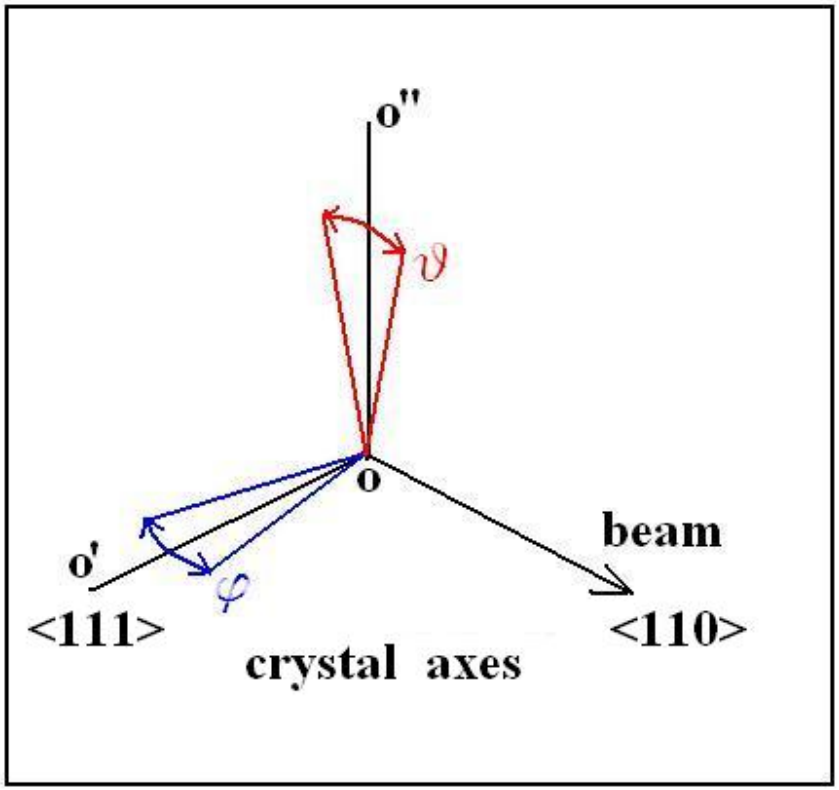
Two ways of enhancement of reflection angle: use of multi-crystals and axial potential



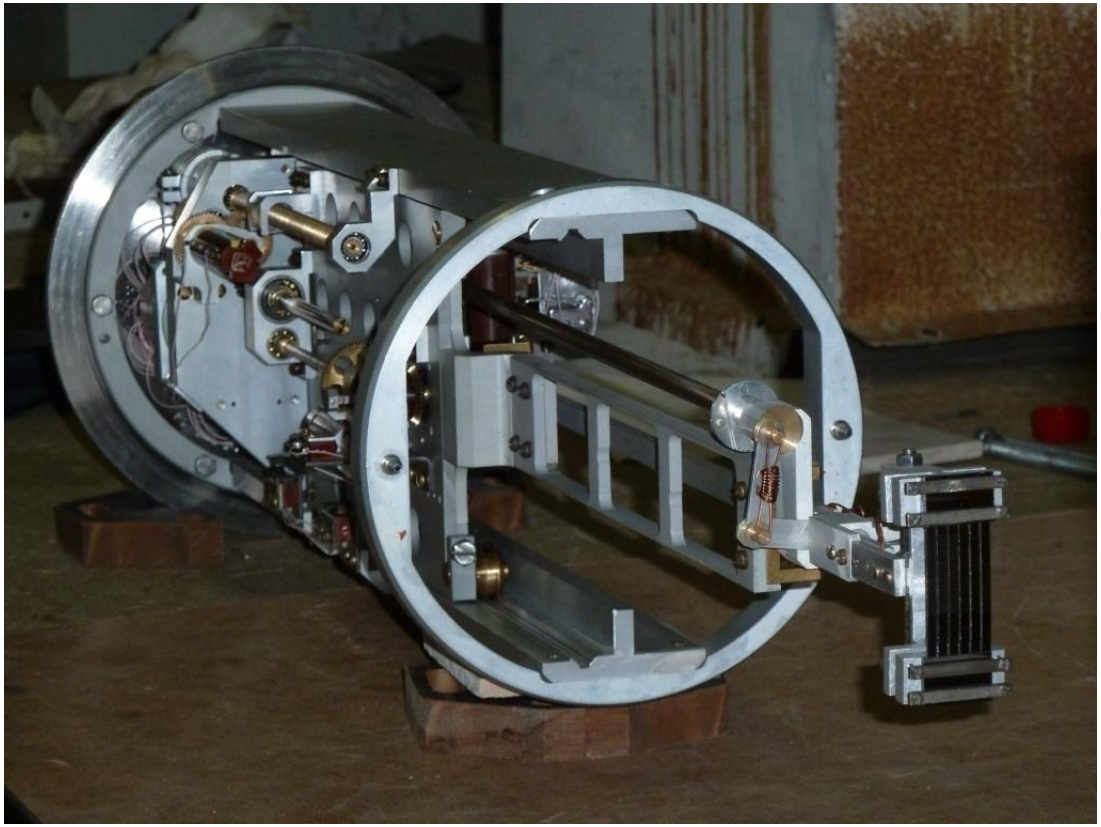


6-strip crystal was installed in biaxial goniometer placed in U-70 ring

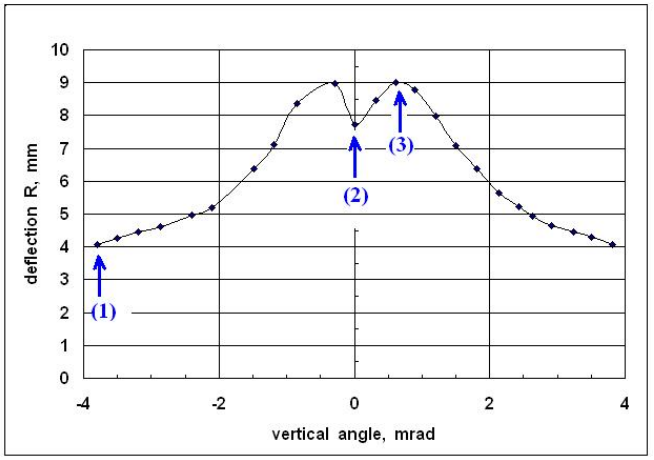


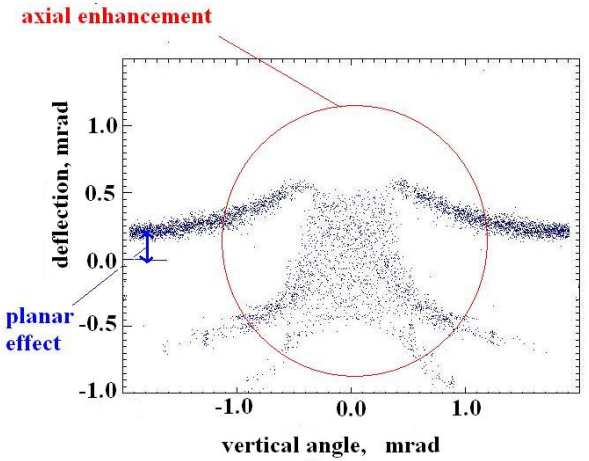


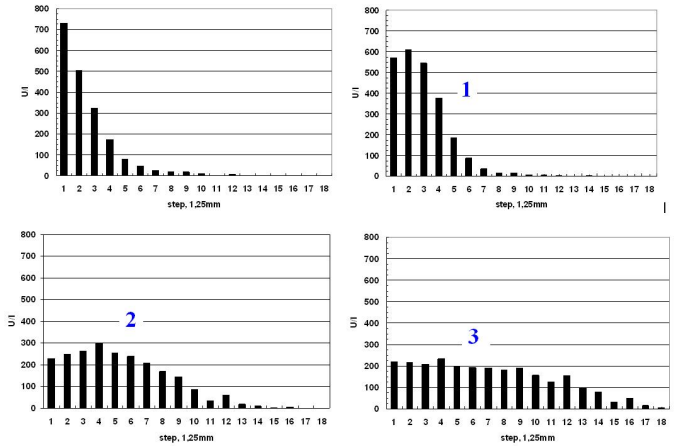
Biaxial goniometer before installation in U-70

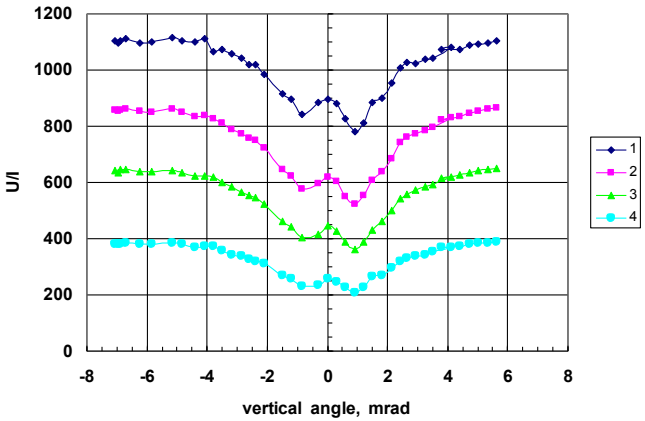


Deflection effect and reduction of particle losses due to axial reflection in multicrystal.

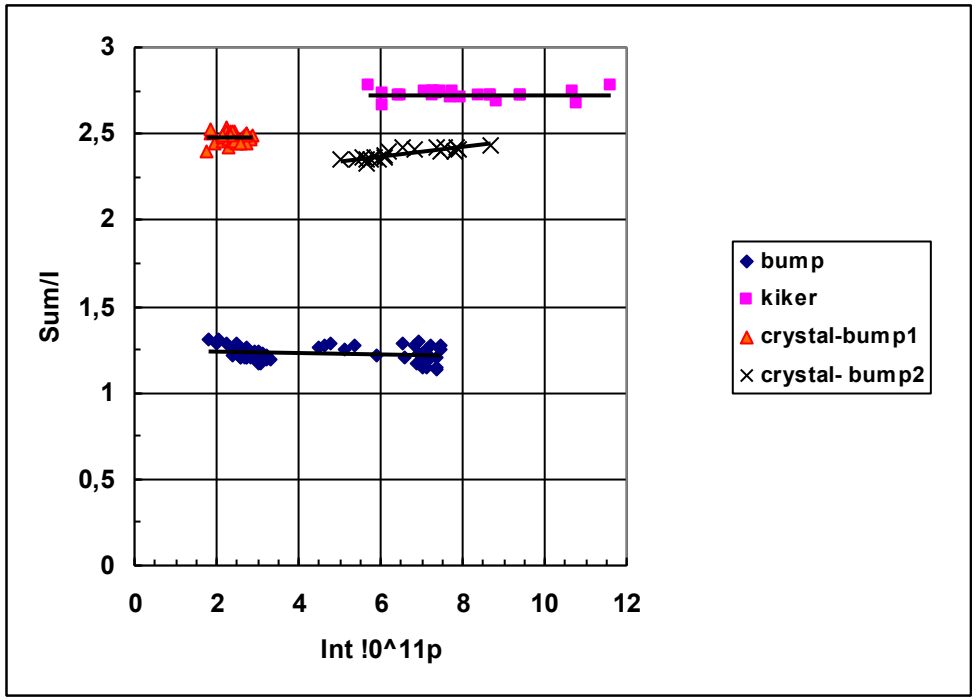




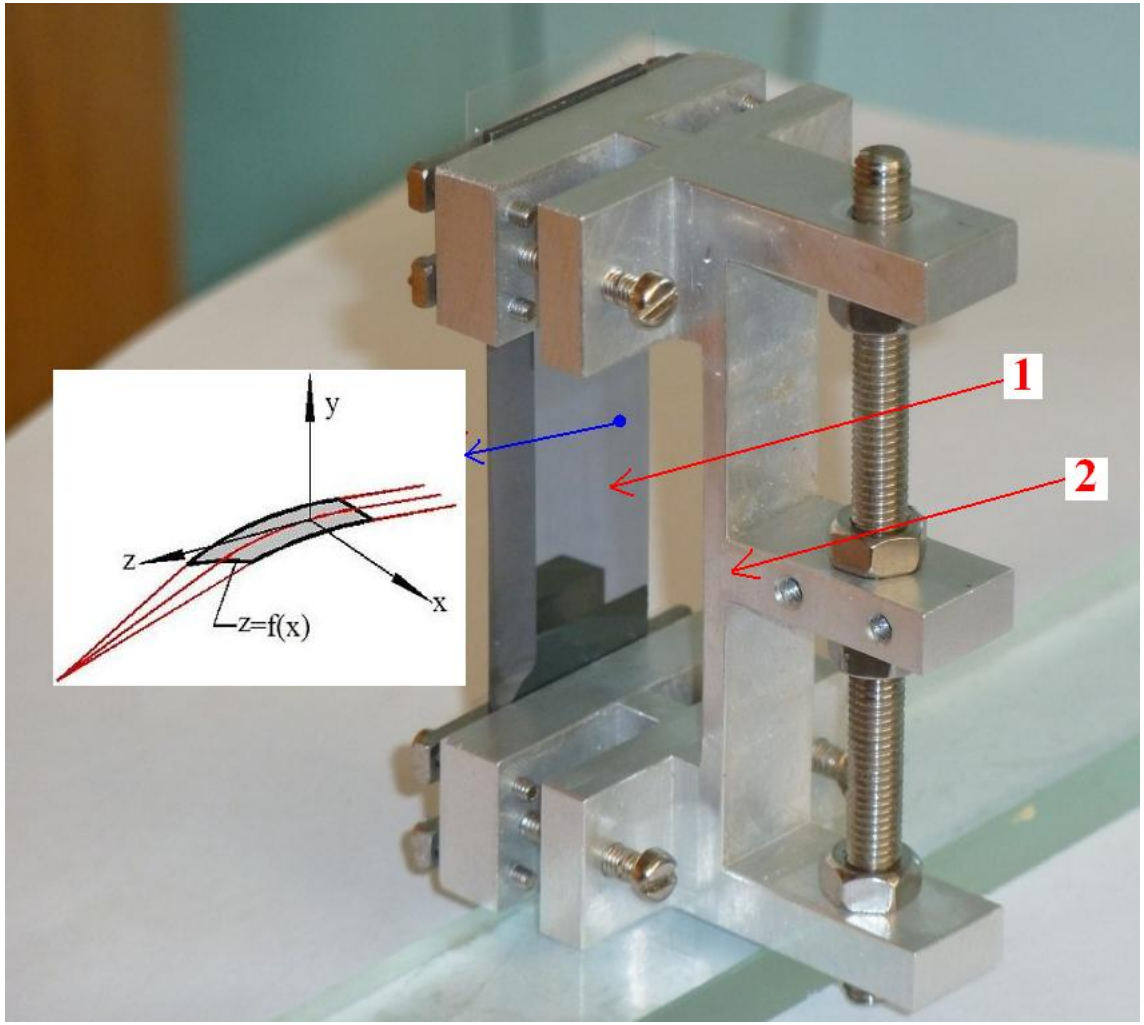




Over 90 % of particles were reflected in a crystal and were deserted in absorber on distance over 1 mm from the edge in axial case



Study of 50 GeV proton beam focusing by novel crystal device



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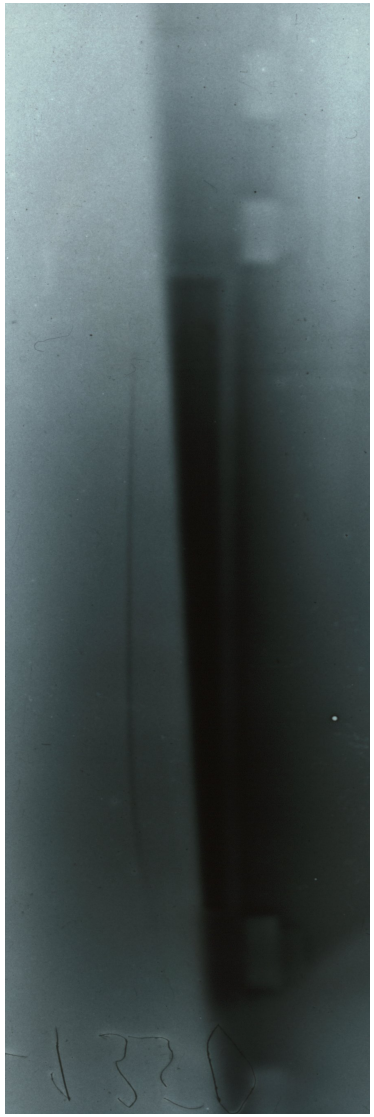
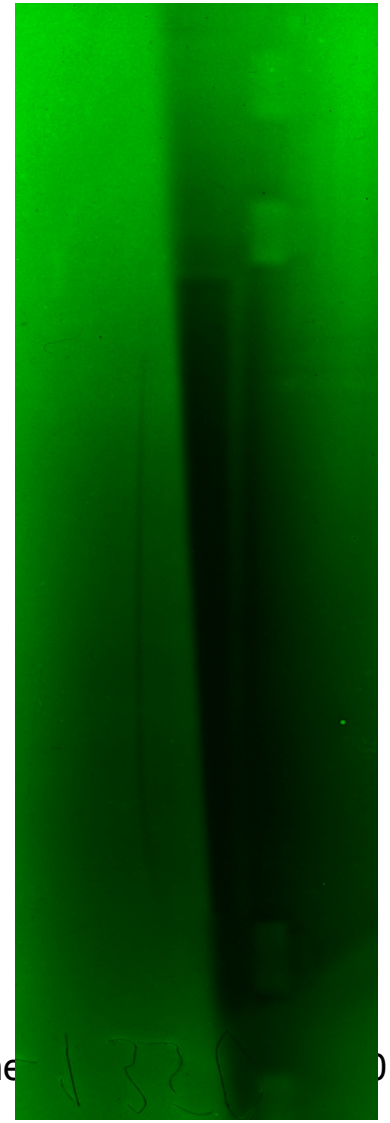
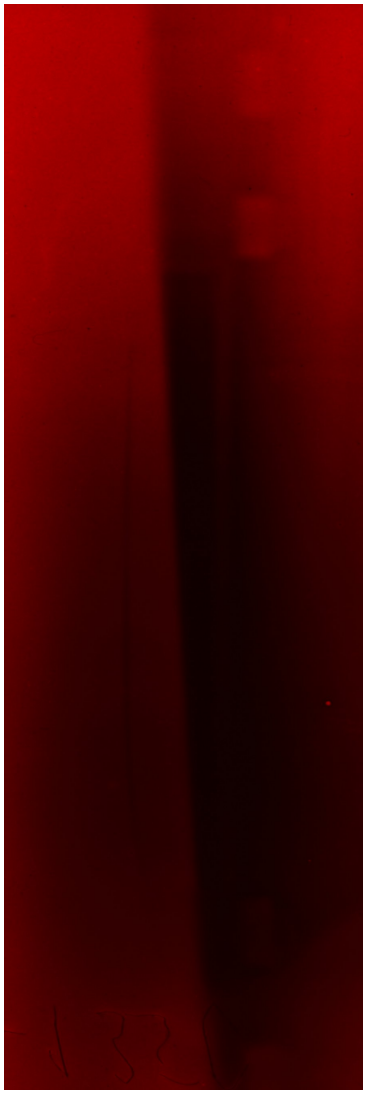
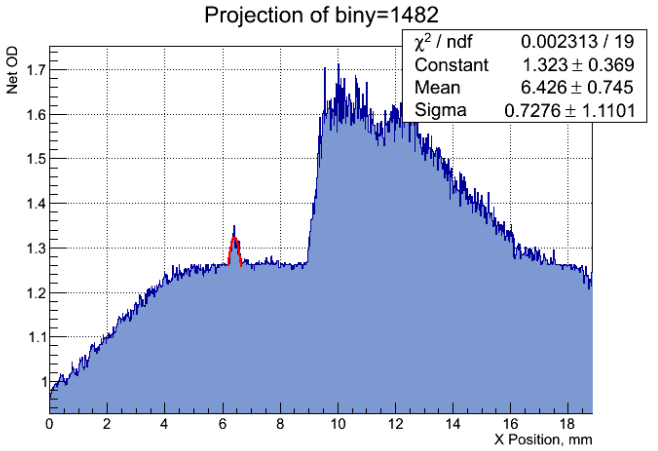
Effect of focusing of a beam on distance of 1.7 m from a crystal.

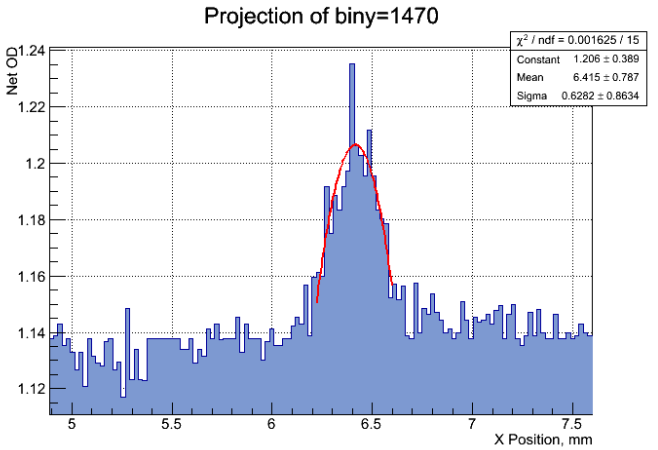




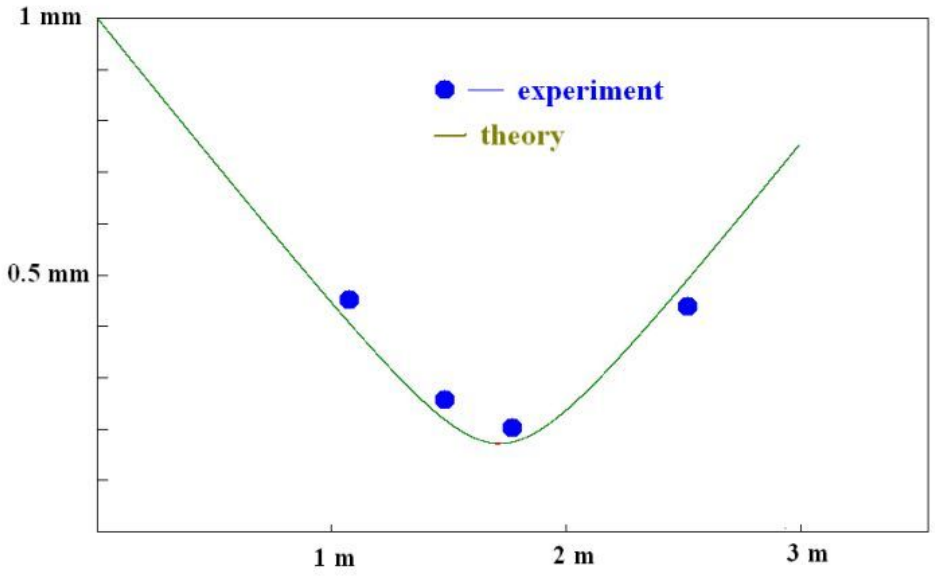


The focused beam profile received by digital scanning





The measured beam envelope as a result of focusing



measured:

L = 1.150 m FWHM = 0.46 mm

L = 1.450 m FWHM = 0.26 mm

L = 1.750 m FWHM = 0.22 mm

L = 2.650 m FWHM = 0.44 mm

Physics Opportunities of a Fixed-Target Experiment using the LHC Beams

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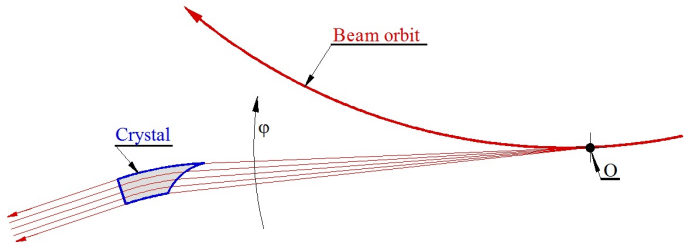
Abstract

We outline the many physics opportunities offered by a multi-purpose fixed-target experiment using the proton and lead-ion beams of the LHC extracted by a bent crystal. In a proton run with the LHC 7-TeV beam, one can analyze pp, pd and pA collisions at center-of-mass energy $\sqrt{s_{NN}} \simeq 115$ GeV and even higher using the Fermi motion of the nucleons in a nuclear target. In a lead run with a 2.76 TeV-per-nucleon beam, $\sqrt{s_{NN}}$ is as high as 72 GeV. Bent crystals can be used to extract about 5×10^8 protons/sec; the integrated luminosity over a year reaches 0.5 fb^{-1} on a typical 1 cm-long target without nuclear species limitation. We emphasize that such an extraction mode does not alter the performance of the collider experiments at the LHC. By instrumenting the target-rapidity region, gluon and heavy-quark distributions of the proton and the neutron can be accessed at large x and even at x larger than unity in the nuclear case. Single diffractive physics and, for the first time, the large negative-x_F domain can be accessed. The nuclear target-species versatility provides a unique opportunity to study nuclear matter versus the features of the hot and dense matter formed in heavy-ion collisions, including the formation of the quark-gluon plasma, which can be studied in PbA collisions over the full range of target-rapidity domain with a large variety of nuclei. The polarization of hydrogen and nuclear targets allows an ambitious spin program, including measurements of the QCD lensing effects which underlie the Sivers single-spin asymmetry, the study of transversity distributions and possibly of polarized parton distributions. We also emphasize the potential offered by pA ultra-peripheral collisions where the nucleus target A is used as a coherent photon source, mimicking photoproduction processes in ep collisions. Finally, we note that W and Z bosons can be produced and detected in a fixed-target experiment and in their threshold domain for the first time, providing new ways to probe the partonic content of the proton and the nucleus.



An example of application of a focusing crystal for research of low-angular processes. The same scheme can be a source of a parallel beam of secondary particles for the wide physical researches proposed by S.Brodsky et al

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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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