Сессия Ученого Совета ОФВЭ

Эксперимент UA9 (CERN)

Ю.М.Иванов

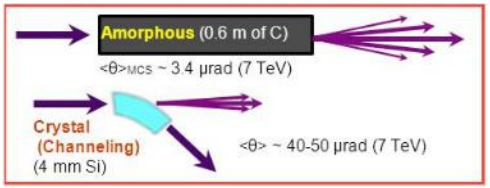
25 декабря 2018

Opportunities for in-kind contributions

OPTIONS

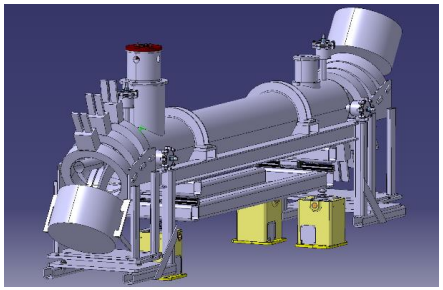
Becoming baseline

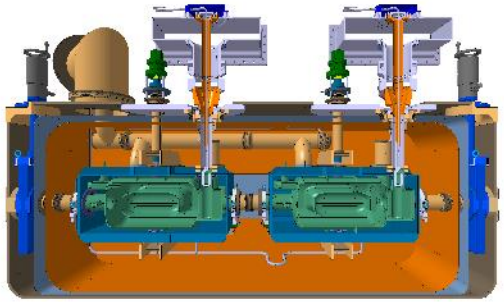
Additional low impedance collimators	4.5 MCHF	2023; in time for installation in LS3	Russia
Additional tertiary collimators	4.5 MCHF	2023; in time for installation in LS3	Russia
Crystal collimation for protons	6 MCHF	2029; in time for installation in LS4	IHEP-PNPI?
Crystal collimation for ions	1.5 MCHF	2023; in time for installation in LS3	IHEP-PNPI?
Hollow electron lens for beam halo removal	7-20 MCHF	2023; in time for installation in LS3 (2024-2025)	BINP
Second half of Crab Cavities	24 MCHF	2029; in time for installation in LS4	BINP?
Inclinometer for vibration measurements	0.5 MCHF	2019; in time for installation in LS2	JINR



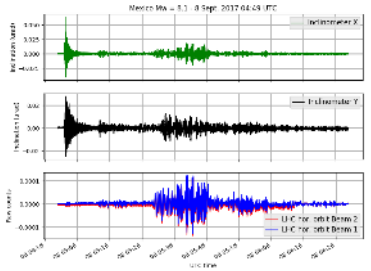
Crystal collimators

Hollow electron lens





Crab cavities



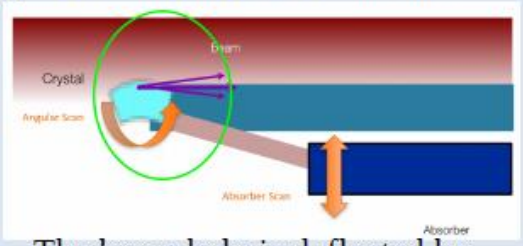
Precision Laser Inclinometer

23.04.2018, CERN. Заседание Комитета по сотрудничеству Россия-ЦЕРН (5+5): "Status of the HL-LHC accelerator project and provisional Russian in-kind contributions".

«… переслал все материалы Г.В. Трубникову и уверен, что он в своём вводном слове отметит основные предложения российских организаций, а потом мы их оформим в виде общего документа и направим Ф. Бордри для рассмотрения…»

Crystal collimation at LHC

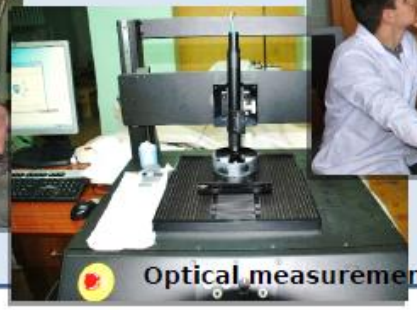
Crystal collimation scheme

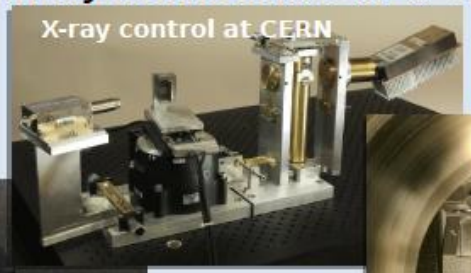


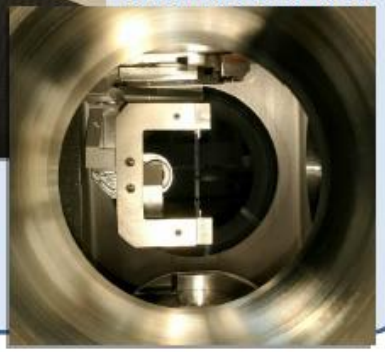
The beam halo is deflected by primary crystal collimator towards secondary amorphous absorber

Crystal collimator prototypes developed by Russian Institutes for LHC

Crystal manufacturing, Optical, X-ray, Particle beam Quality control Russia & CERN







ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE (CERN)
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

Addendum No. P109/AXY

to

THE 2013 PROTOCOL CONCERNING SCIENTIFIC COLLABORATION

between

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

and

THE NATIONAL RESEARCH CENTRE KURCHATOV INSTITUTE (NRC-KI)

to

THE 1993 CO-OPERATION AGREEMENT BETWEEN THE GOVERNMENT OF THE RUSSIAN FEDERATION AND CERN

concerning

Collaboration in the Research and Development of Crystal Devices for the High Luminosity LHC Project

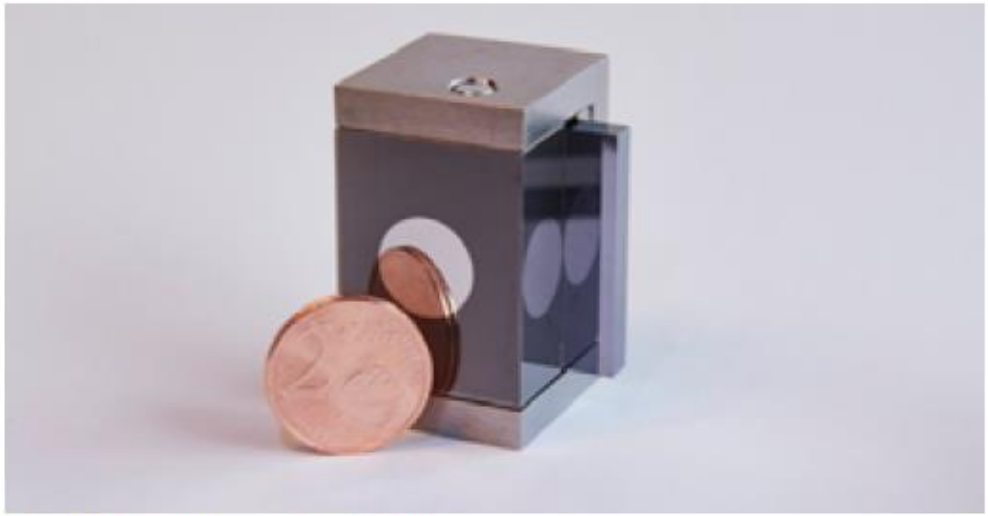
2018

CERN Bulletin

Issue No. 49-50/2015 - Monday 30 November 2015
More articles at: http://bulletin.cern.ch

CRYSTALS CHANNEL HIGH-ENERGY BEAMS IN THE LHC

Bent crystals can be used to deflect particle beams, as suggested by E. Tsyganov in 1976. Experimental demonstrations have been carried out for four decades in various laboratories worldwide. In recent tests, a bent crystal inserted into the LHC beam halo successfully channelled and deflected 6.5 TeV protons into an absorber, with reduced secondary irradiation.



Quasimosaic crystal for the LHC (developed by PNPI).

Strip crystal for the LHC (developed by INFN).

LHC-type Quasimosaic crystals tested in 2015 - 2017

QMP52 – installed into LHC in February, 2017
changed for ACP76 in February, 2018

QMP53 – installed into LHC in February, 2017

	Crystal	Runs	Deflection angle, urad ± 1 urad	Efficiency, % ±3 mm Y pos. cut ±8 urad X ang. cut		Torsion urad/mm ± 1 urad/mm	Stability at 250 °C
				Protons 400 GeV/c	Pions 180 GeV/c		
QM QuasiMosaic	QMP46	2018-2017	56	71	68	0	OK
	QMP54	2015-2017	56	70	68	0	OK
	QMP52	2015-2016	55	70	65	0	OK
	QMP53	2015-2016	55	69	66	0	OK

LHC-type Anticlastic crystals tested in October 2017 – September 2018

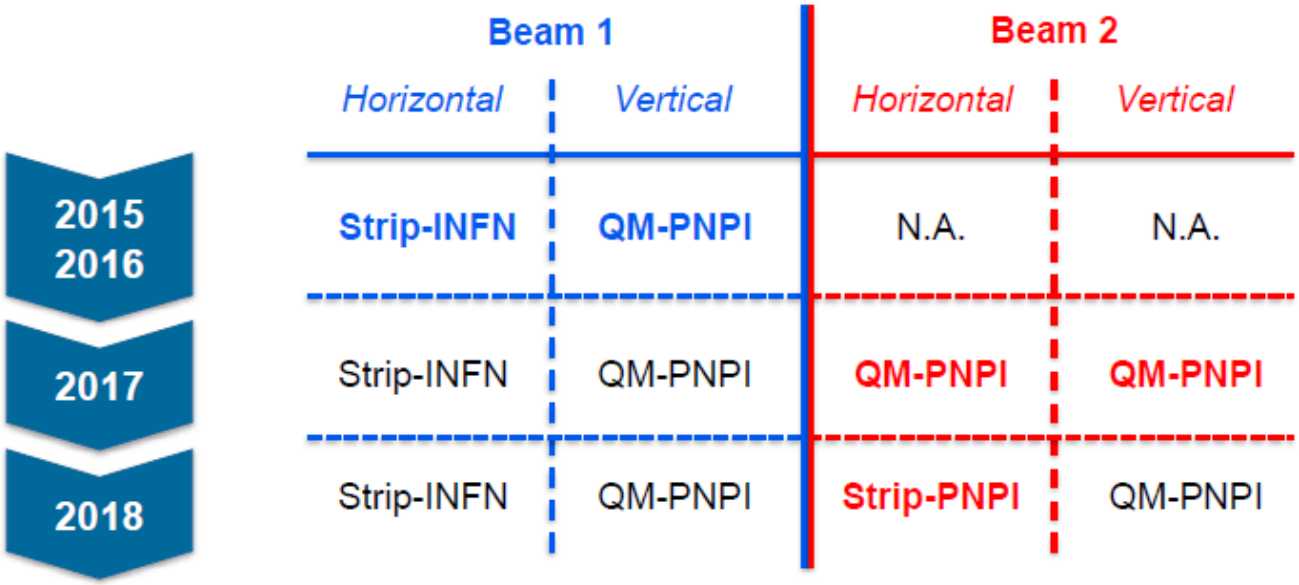
- **TCP76 – installed into LHC in February, 2018**

	Crystal	Runs	Deflection angle, urad ± 1 urad	Efficiency, % ±3 mm Y pos. cut ±8 urad X ang. cut Pions 180 GeV/c	Torsion urad/mm ± 1 urad/mm	Stability at 250 °C
ACP AntiClastic PNPI crystal	TCP76	Oct.-Dec. 2017	50 ±2	70	0	OK
	TCP77	Oct.2017-May 2018	50	70	5	OK
	ACP79	April-May 2018	49	69	0	OK
	ACP80	Sept. 2018	57	67	0	OK
	ACP84	Aug.-Sept. 2018	52	68	0	OK
	ACP85	Aug.-Sept. 2018	49	68	0	OK
	ACP86	Aug.-Sept. 2018	56	66	0	OK

Present layout

Four crystals installed in the LHC: two per beam, one per plane

Same design specifications for all crystals, two different producers and technologies

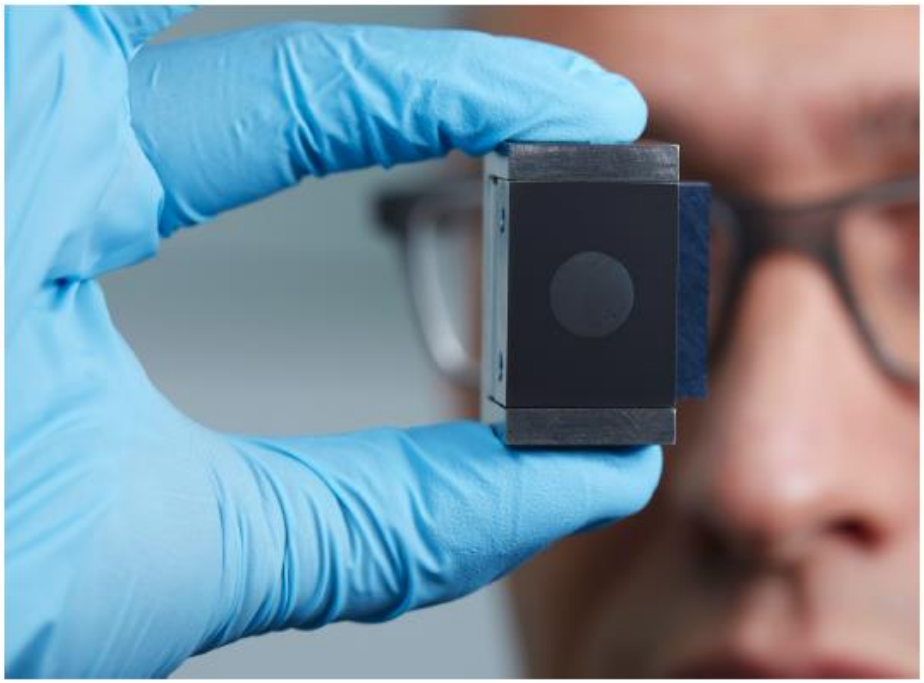


Complete layout to allow thorough investigations and operational tests

CERN Bulletin
Issue No. 48-49/2018-Wednesday 28 November 2018
More articles at http://home.cern/cern-people

CRYSTAL CLEANING THE LHC BEAM

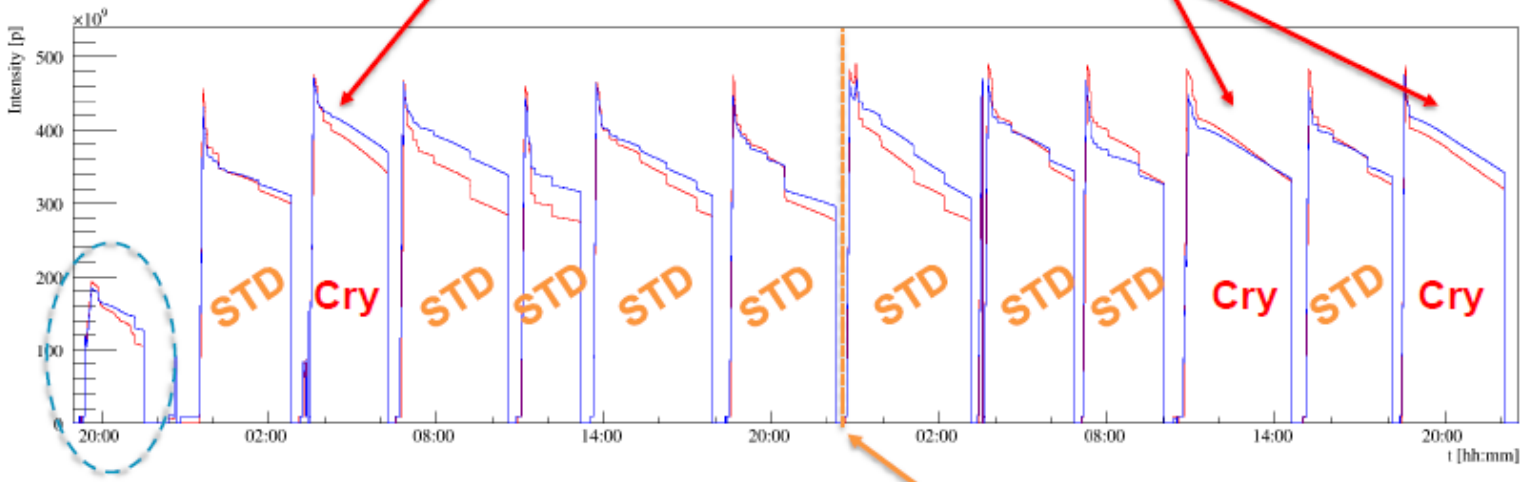
In October, for the first time, crystal collimators were used to improve the performance of the beam cleaning process at the LHC during a physics run



High-beta physics run at 450 GeV

- **Promising results obtained during initial tests** (crystal setup in about 15 min!)
  - Decided to have the **crystals as a viable option** for the real physics run
- Operational **sequences** and **beam process** prepared for **both collimation scheme**
  - **Easy handling by OP**

NO NEED TO SCRAPING WITH CRYSTAL

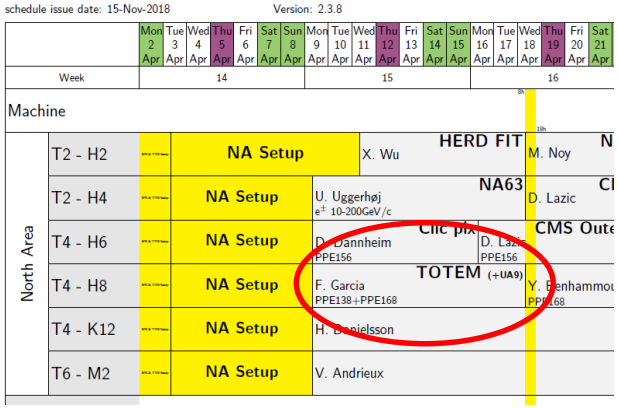


1 setup fill: confirmed alignment STD and Cry coll.

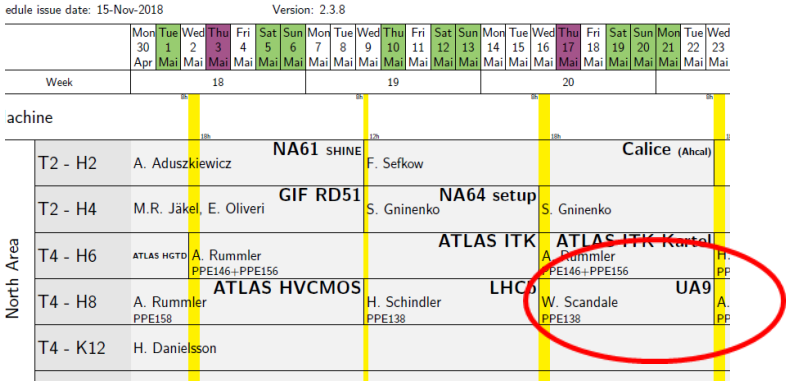
Re-align needed for STD

- **From a thinking aloud** in a Collimation Working Group **to operations in about 1 month**:
  - ✓ Intense simulation studies to optimize performance
  - ✓ Preparation of operational sequences and beam process for OP use
  - ✓ Setup of the system in 15 min thanks to the knowledge acquired in MDs
- **First time ever that crystal collimation has been used operationally in a physics run!**
  - ✓ Very efficient cleaning of halo (no need for re-scraping)
  - ✓ Excellent physics data taking during long periods
  - ✓ Stable performance (retracted and inserted directly in channeling)
  - ✓ Very important milestone!
- **Excellent results obtained with TOTEM** for both background rate and distribution
  - ✓ Crystals saved the day when increased background for totem without need of re-align
- **Similar background rate for ALFA but potentially problematic distribution**
  - ✓ Settings optimized for background rate
  - ✓ Confident that also better distribution could be achieved

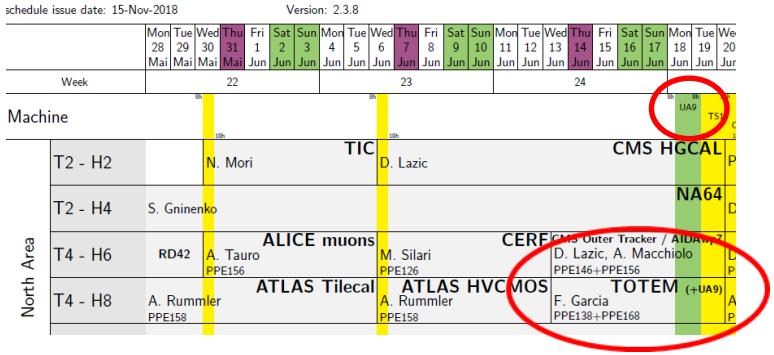
SPS: April 2018



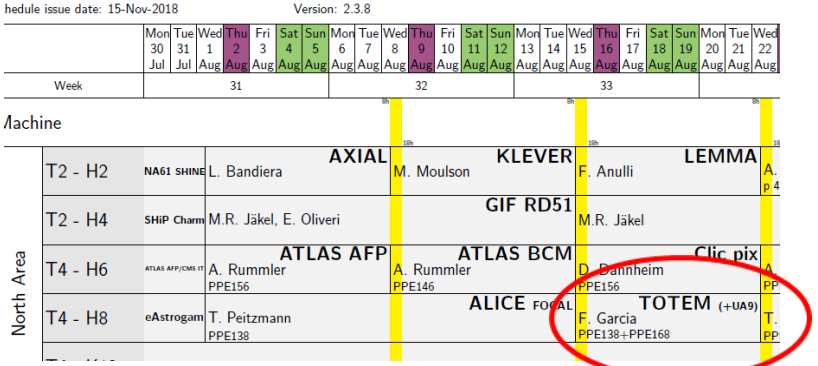
SPS: Mai 2018



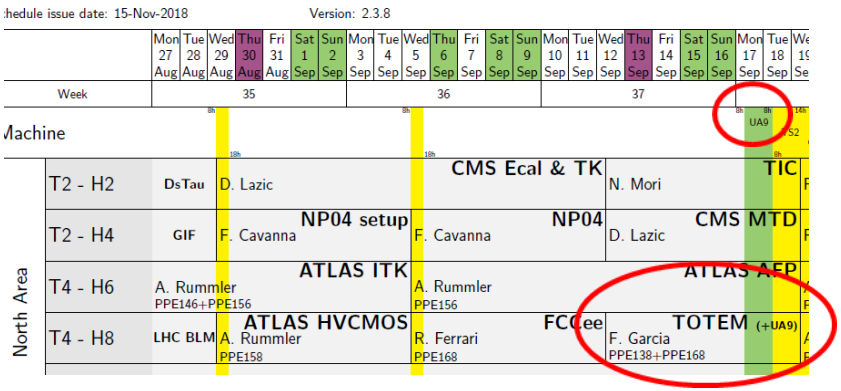
SPS: June 2018



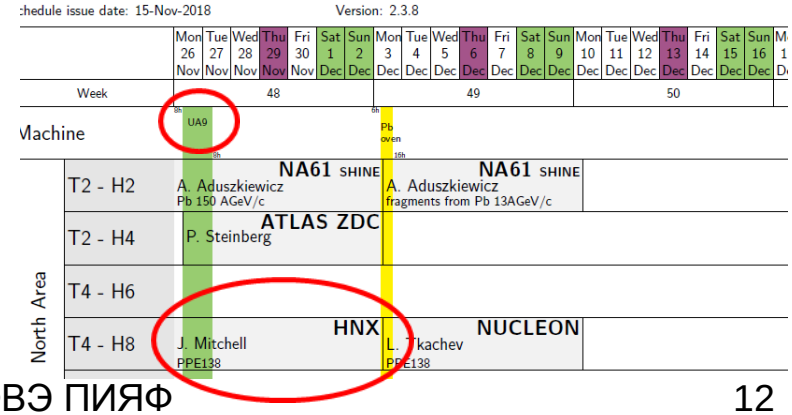
SPS: August 2018



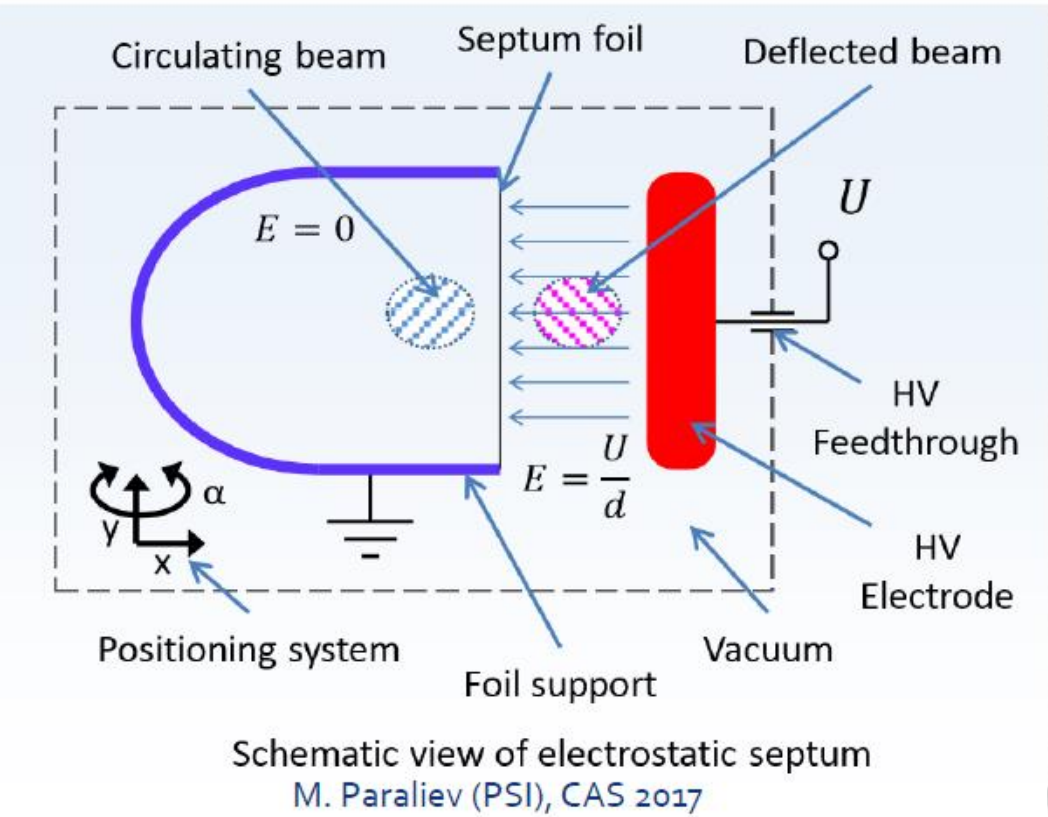
SPS: September 2018



SPS: December 2018

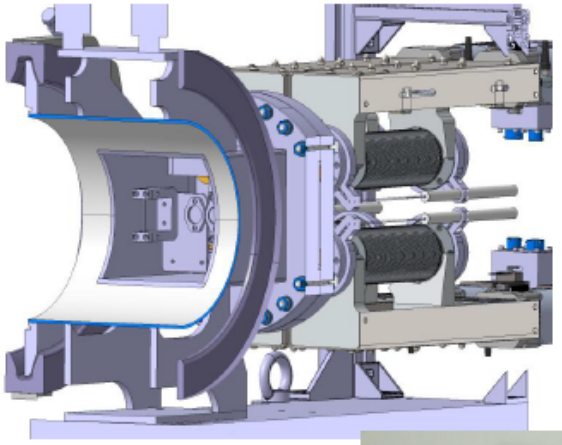


Crystals helping slow extraction



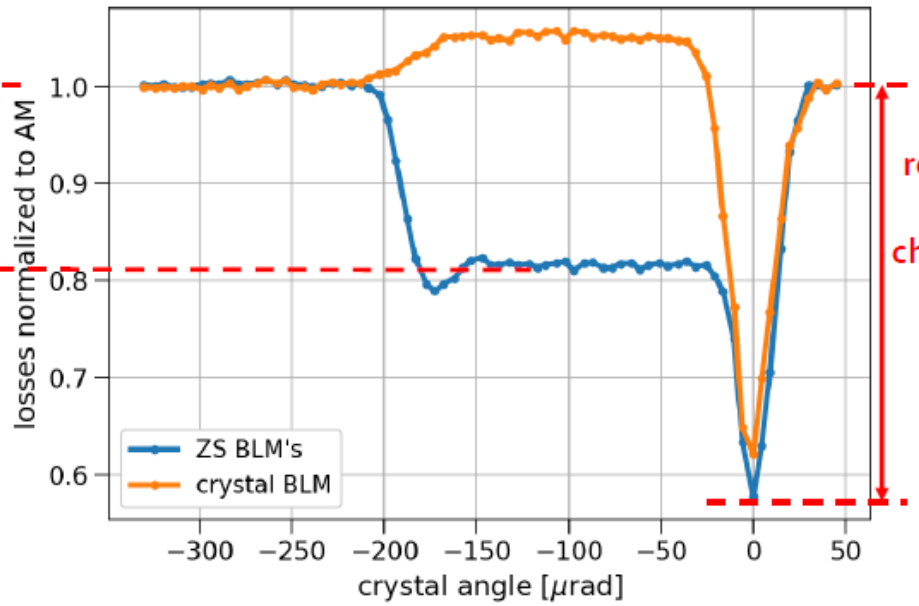
Schematic view of electrostatic septum
M. Paraliev (PSI), CAS 2017

Shadowing of the SPS electrostatic septum



Device built in few months and installed in ITS2 2018 by EN-SMM, EN-STI, TE-ABT and UA9

~20% reduction in volume reflection



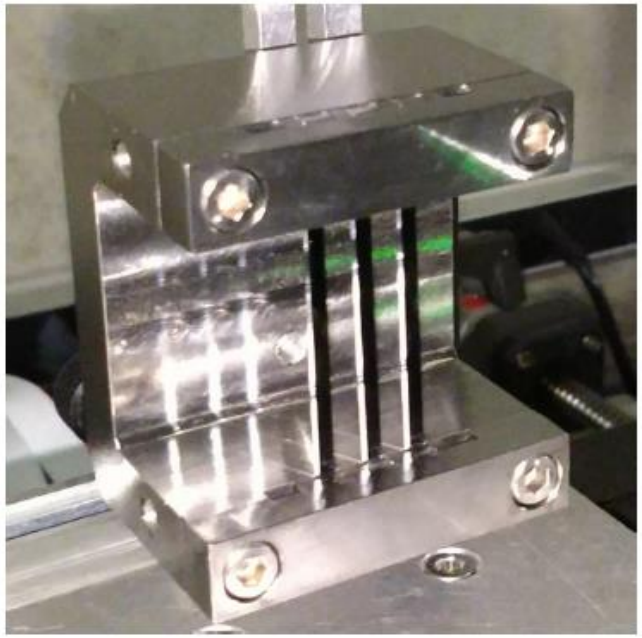
>40% reduction in channeling

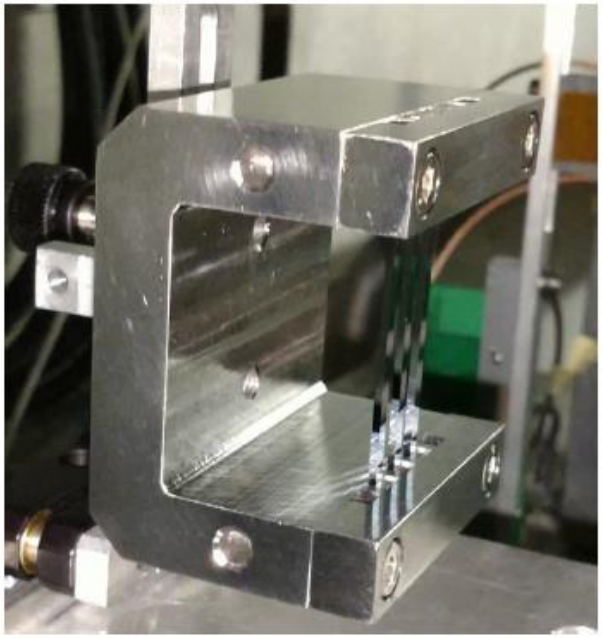
Demonstrated reduction of the losses in SPS of ~20% in VR and > 40% in CH
Successfully test in operation for 12 hours with constant loss reduction

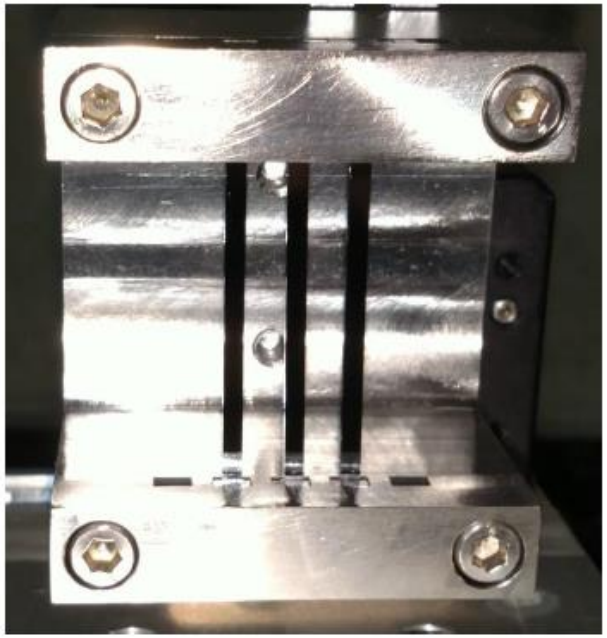
Мульти-кристаллическая сборка

Основные характеристики:

- Монолитный дизайн без регулирующих винтов
- Высокая стабильность изделия при нагреве до 250°C
- Идентичность изгиба отдельных кристаллов



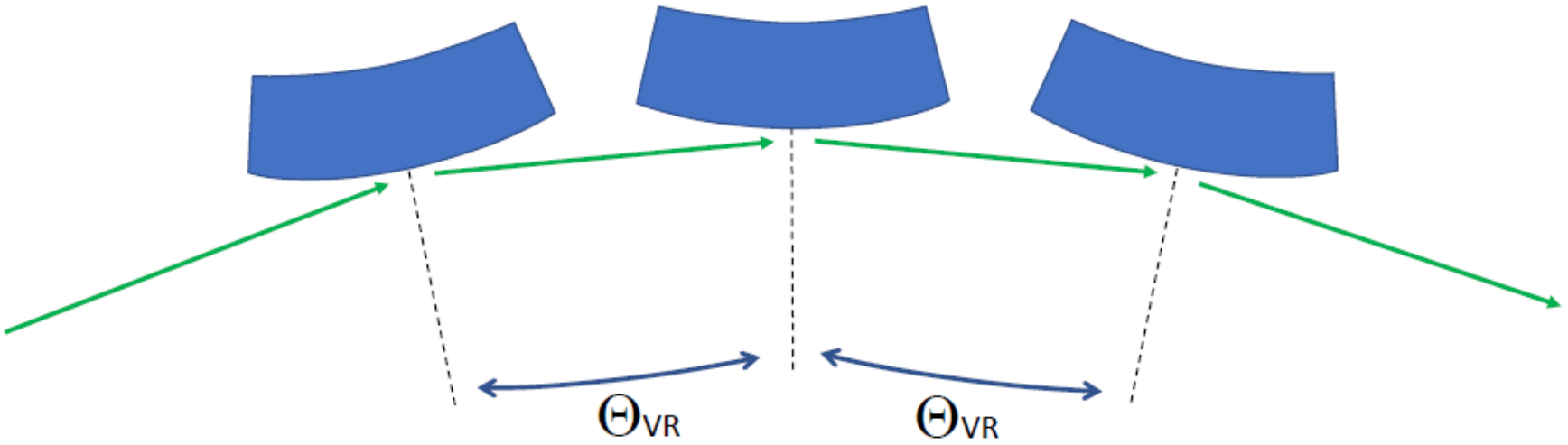




Оптимальная компоновка мульти-кристалла

Обеспечение доворота каждого последующего кристалла на угол Θ_{VR}:

- SPS 180 GeV: Θ_{VR} = ~18 urad
- SPS 450 GeV: Θ_{VR} = ~12 urad
- LHC 6500 GeV: Θ_{VR} = ~3.5 urad



Суммарный угол отклонения мультикристалла:

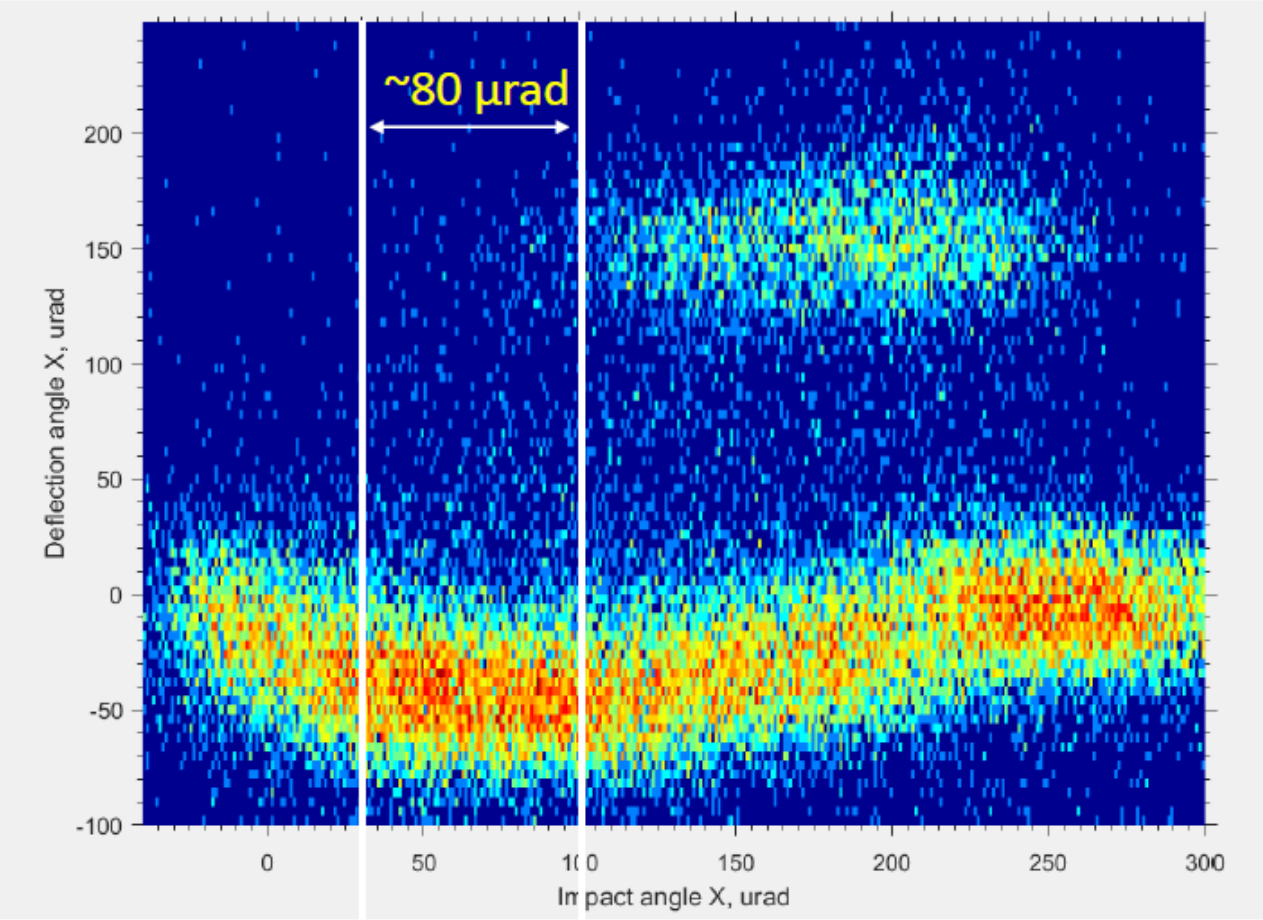
$$3\ Crystals = 3\ \cdot\ \Theta_{VR}$$

Оптическая настройка

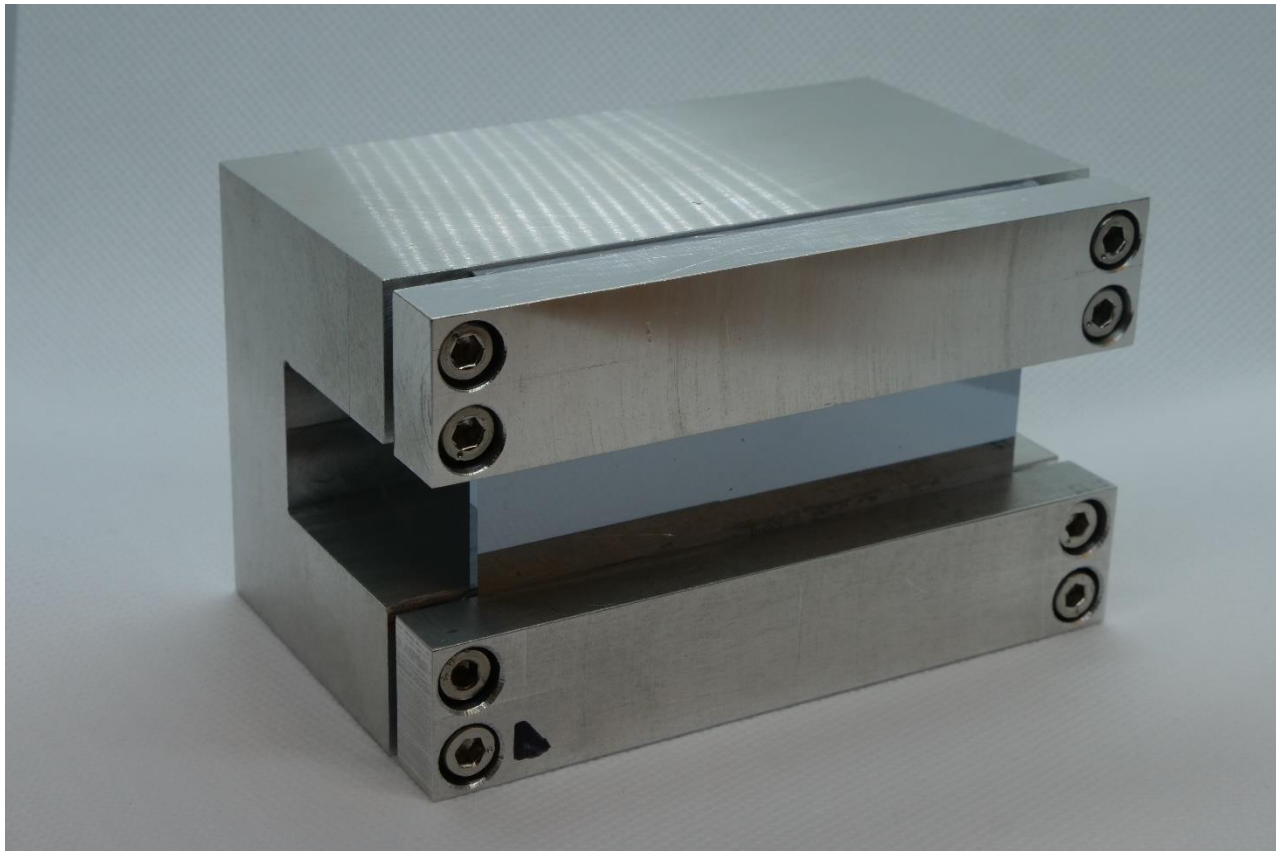
- Разработана методика настройки и юстировки мульти-сборки без пучка
- Бесконтактный оптический метод настройки
- Возможность выстройки угла кристаллов друг относительно друга на уровне 1-2 мкрад

Проверка на H8 пучке ионов свинца 150 AGev

- Широкая область мультиобъемного отражения от 3 кристаллов



Прототип кристалла для вывода ТэВ пучков



Подготовка кристаллических образцов для изучения зависимости характеристик кристаллов от значительных доз облучения

ЗАДАЧА: Применение кристаллов для кристаллической коллимации и в системе вывода пучка сопряжено с большими дозами облучения частиц высоких энергий.

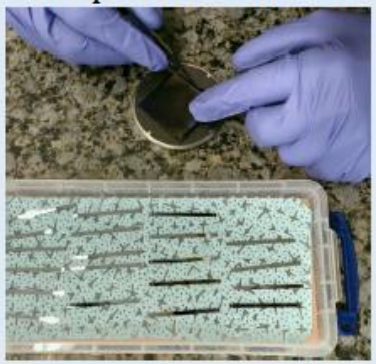
ВОПРОС: Исследование влияния высоких доз на живучесть кристаллов и сохранения их характеристик: угла отклонения и эффективности

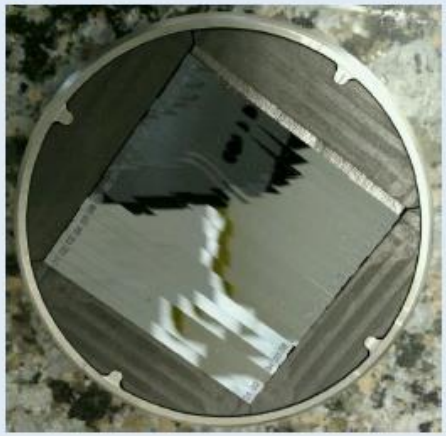
Облучение кристаллов протонным пучком (2018)

BLIP (Brookhaven Linac Isotope Producer)

В лаборатории подготовлены:

- 20 кристаллов 40x2x1 mm





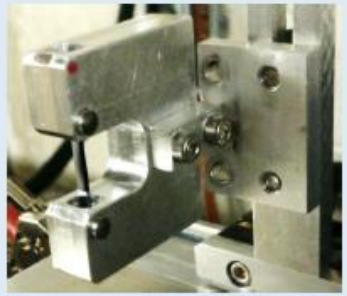
Облучение кристаллов нейтронным пучком (июнь 2018)

SCK-CEN (Belgium), $5 \cdot 10^{20}$ 1/cm² 1 MeV eq. neutrons

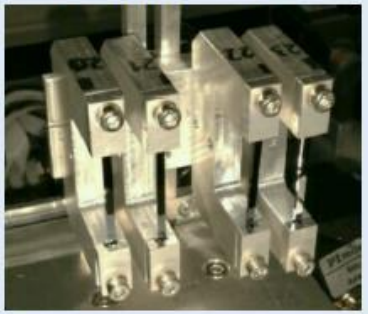
В лаборатории подготовлены:

- 9 кристаллов 40x2x1 mm
- Капсула для облучения

Тест изогнутых кристаллов на пучке H8 в CERN до облучения (апрель 2018)

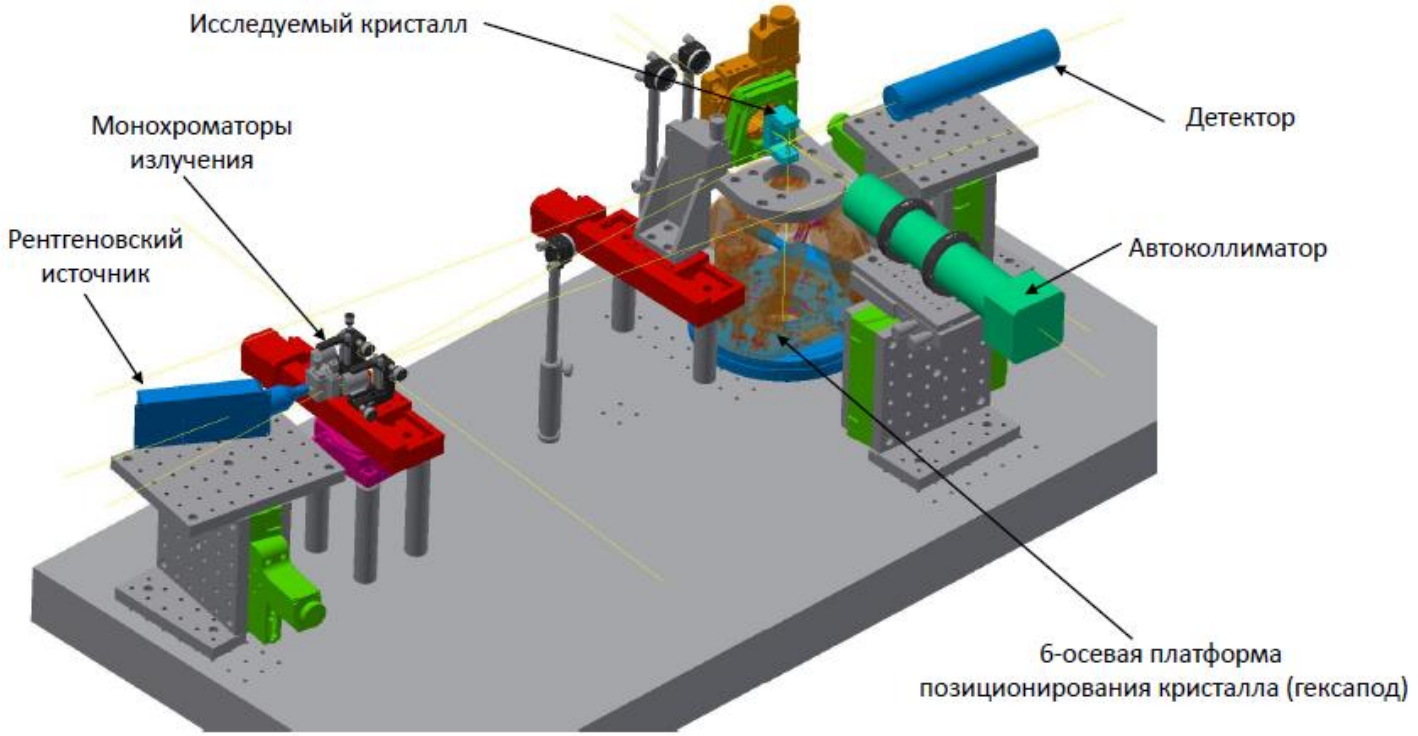


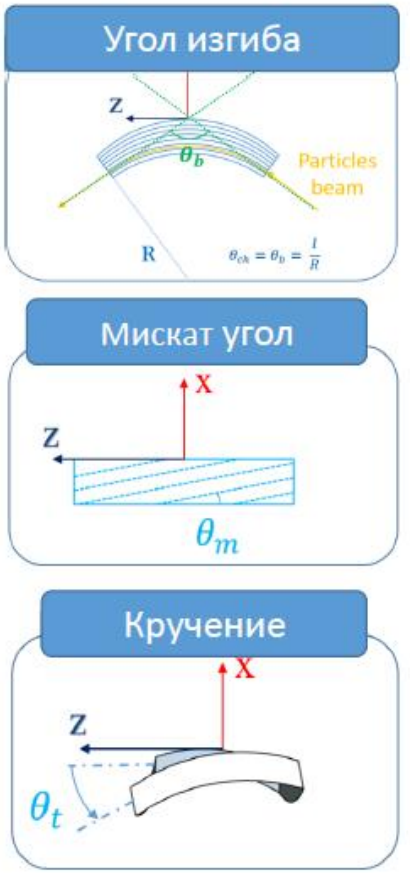
Тест изогнутых кристаллов на пучке H8 в CERN после облучения (сентябрь 2018)



Разработка и изготовление двухкристального рентгеновского дифрактометра для изучения характеристик изогнутых кристаллов

- Разработана прецизионная автоматическая установка для изучения характеристик изогнутых кристаллов на базе ЦЕРН: угол изгиба, мискат угол, кручение кристалла
- Осуществляется сборка установки





Спасибо за внимание
и
С Новым Годом !