### Crystal-based extraction of the electron beam circulating in the DESY II Booster Synchrotron\*

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\* A. Sytov et al., The European Physical Journal C volume 82, Article number: 197 (2022)

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# Relationships



- We are a team of physicists and engineers operating in internal environments mainly on activities related to crystals design, manufacturing and characterizations.
- Channeling, x-ray, medical physics, astrophysics, etc...
- Active in channeling field since 2000

INFN Ferrara

# **INFN** infrastructure

Laboratory fully equipped for silicon micro and nanomachining ISO4 certified clean room (130 m<sup>2</sup>)

2X High-resolution x-ray diffraction Dicing and polishing equipment White light and Fizeau inteferferometers







# **INFN** infrastructure

Laboratory fully equipped for silicon micro and nanomachining

Fotolitography Equipment for silicon etching Nanoimprint Plasma activator



### **QUASI-MOSAIC DEFORMATION**



- 60 μm thick crystal bent at 3 cm radius
- (111) Diffracting planes
- Quasi mosaic deformation exploited
- Crystal mounted on a piezo attuated holder to adjust bending and remove torsion

Beam Few tens of um

## Channeling in a bent CRYSTAL





A. Mazzolari et al., Phys. Rev. Lett. 112, 135503

# Channeling in a bent CRYSTAL



T. N. Wistisen, Phys. Rev. Lett. 119, 024801 (2017)

# Channeling in a bent CRYSTAL



A. Mazzolari et al. Phys. Rev. Lett. 112, 135503 (2014)
A.I. Sytov, L. Bandiera et al. Eur. Phys. J. C 76, 77 (2016)
T. N. Wistisen, Phys. Rev. Lett. 119, 024801 (2017)

# Crystal-based extraction: possible setup at DESY-II



#### Advantages:

- Extraction of primary low-emittance and very intense electron beam in a parasitic mode.
- The extraction line including septum magnets already exists -> ideal as a prof-of-principle
- Many GeV electron beam, typical for electron synchrotrons existing in the world.

A. Sytov et al., Eur. Phys. J. C (2022) 82: 197



### **CRYSTALRAD** simulation code

Main idea – tracking of charged particles in a crystal in averaged atomic potential

#### **Program modes:**

- **1D** model particle motion in an interplanar potential
- 2D model particle motion in an interaxial potential
   Simulation of the different physical processes:
- Multiple and single Coulomb scattering on nuclei and electrons.
- Nuclear scattering
- Ionization energy losses
- Crystal geometry
- The code have been used to design a crystal based setup for slow extraction for DESY accelerators

A. I. Sytov, V. V. Tikhomirov, L. Bandiera, Phys. Rev. Acc. And Beams 22, 064601 (2019)

A. Sytov et al., Eur. Phys. J. C (2022) 82: 197



## **Beam parameters**



- $\epsilon_x$ =339 nm,  $\epsilon_y$ =35 nm, E=6 GeV
- $\sigma = \sqrt{\beta} \epsilon_x$  (betatron sigma)
- x\_crystal=  $-3\sigma$ , x\_septum= $4\sigma$

#### Constrains for the extracted beam:

- x > 4 σ = 0.98 cm
- Nturns = 100 (small enough to consider the beam energy as a constant, as well as high enough for charged particles to cross the crystal several times)



Beam angular distribution at the crystal (red curve is gaussian fit). **Divergence**: 0.18 mrad **Critical angle channeling for channeling** : 0.07 mrad (Si, (111))

The distance between septum magnet and crystal fixes the deflection angle of the crystal to 1.75 mrad

### Crystal-based extraction: energy losses





- Energy losses in a 175 µm thick Si bent crystal, bending angle 1.75 mrad
- Largest fraction of particles-> energy loss< 100 MeV</li>

Radiation emission probability as function of the crystal thickness for (red) channeled particles for (yellow) all particles (green) particles with radiation energy losses exceeding 100 MeV (green dots).

## Crystal-based extraction: simulation results





#### **Crystal parameters:**

- Si (111) planes
- bending angle 1.75 mrad
- Crystal length 0.175 mm
- Crystal transverse thickness 1 cm

Extraction efficiency: 16.1 %

### Conclusions

- Electron crystal-based extraction in a parasitic mode by using planar channeling in a bent crystal has been proposed for the DESY-II synchrotron to supply fixed-target experiments by low-emittance and very intense electron beam.
- The **extraction** line already **exists**, only a bent crystal should be installed.
- Simulations of the DESY crystal-based extraction show that the multiturn extraction efficiency could reach 16 %.
- Crystal thickness was optimized to be 0.175 mm for the deflection angle 1.75 mrad.
- An experimental test would become a proof-of-principle of electron crystal-based extraction technique that may be applied at tens of existing electron synchrotrons worldwide.