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Enhanced Crystal-Assisted Beam Manipulation

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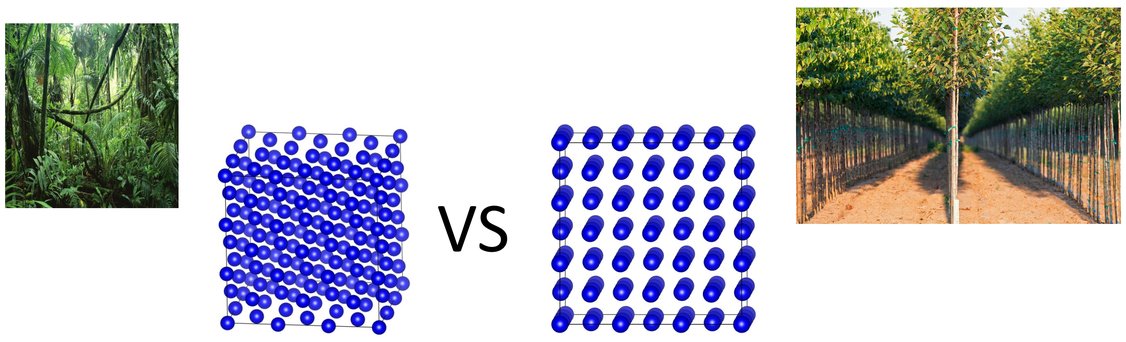
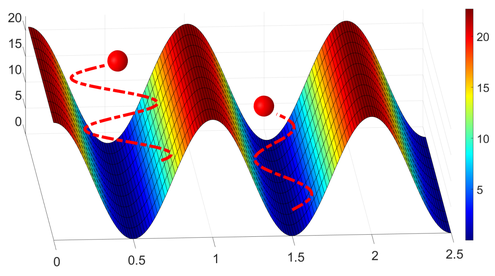
Steering of high-energy particle beam can be achieved by exploiting channeling in bent crystals. Indeed, the atomic planes of a crystal lattice aligned with incoming particles acts similarly to a waveguide and deliver deflection equivalent to hundreds of Tesla magnetic dipole. This effect was investigated and exploited in accelerators since the 70s and is being currently tested at CERN as a baseline element for HL-LHC. Indeed, channeling is particularly efficient for positive particles, achieving deflection for up to ~80% of channeled particles. Nevertheless, the remaining 20% losses are a primary constrain for bent crystal installation and use in accelerators. The GALORE project is currently aiming to overcome this key limitation by developing a new type of bent crystals which could potentially completely suppress such losses. This goal can be achieved by machining of a microscopic structure on the crystal in order to affect channeled particles dynamics. The success of the project would not only improve current setups but also enable completely new schemes for crystal-assisted beam manipulation. We report the latest result of the project and of the crystal prototypes produced.

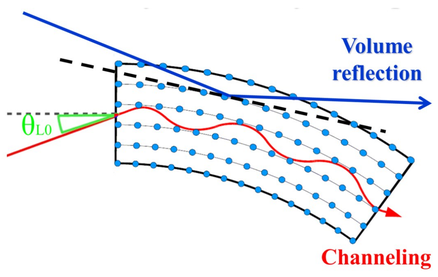
Channeling phenomenon



Interaction of particles within matter can strongly differ between amorphous materials and crystals. Indeed, along specific orientation atoms appears to the incoming particles arrayed along precise planes/axes. Instead of stochastic random interaction with single atoms, the set of atoms organized on planes and axes creates the effect of a continuous potential

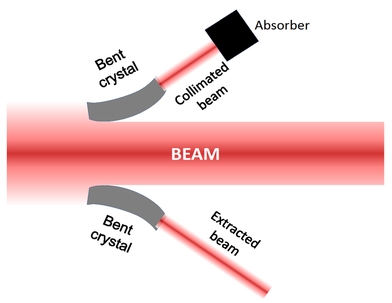


Strong static potential (≈**GeV/cm**) can trap (*channel*) positive particles between two adjacent atomic planes angle



Channeled particles are forced to follow crystal curvature, with steering power ≈ **10^2T** magnetic dipole

Crystal-Assisted Beam Manipulation

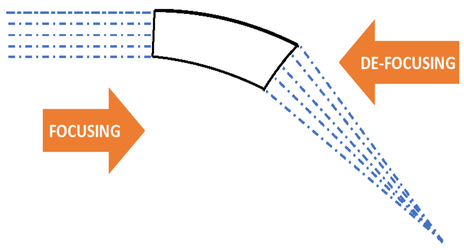


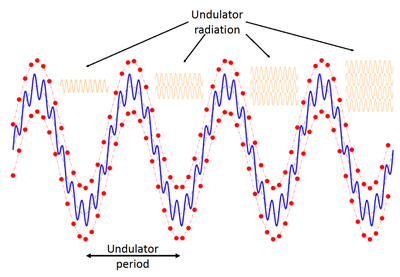
Beam Collimation:
With crystal high control of beam halo separation from primary beam

Beam Extraction:
Surgical redirection of a beam portion, towards a precise location in the machine or in an external facility

Beam Focus
If a bent crystal deflection angle vary in relation to transverse coordinate, then a parallel beam can be focused in a single spot

This Can be accomplished by shaping exit end of the crystal or by exploiting offset between bent lattice planes and crystal surface





Radiation sources (crystal undulator)

Sinusoidally bent crystal impose motion on channeled particles like a free electron laser

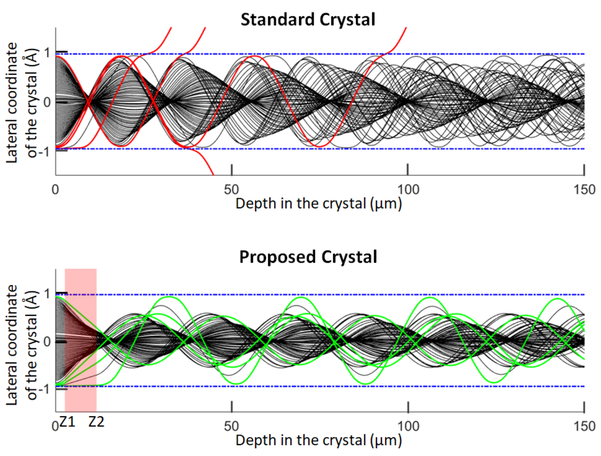
Minimum period is not limited by magnet size: with shorter period, higher energy is achieved

Nuclear dechanneling

Scattering with nuclei **quickly remove** particles from channeling

Rate of nuclear dechanneling is strongly dependent on **impact parameter** on the interplanar channel

The fraction of the beam impacting close to atomic planes is **not deflected**: hard-limit for channeling efficiency set at ≈80%



- At the very **beginning** of channeling, most particles trajectories point towards the **center** of the interplanar channel
- **Before** nuclear dechanneling can occur, the crystal is **interrupted**
- The particles continue to travel in straight line, being «**focused**» **at the center** of the channel
- Once the crystal interruption ends, particles re-enter the crystal **far from nuclei** in zone of **stable** channeling

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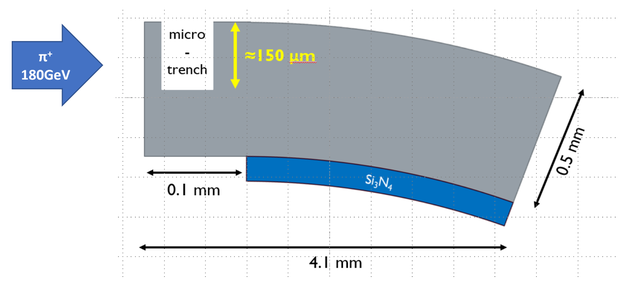
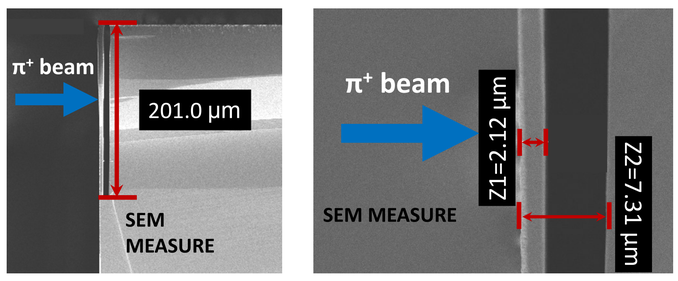
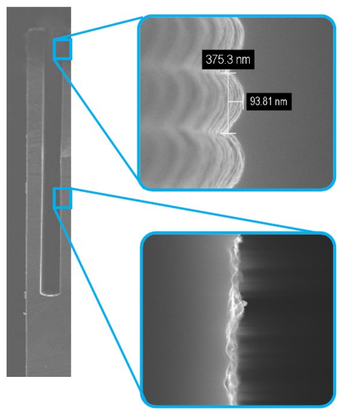
GALORE project

- **Bending** achieved by deposition of Si_3N_4 tensile film
  - Si_3N_4 pattern leave flat area for channeling lens to help atomic planes **alignment**
- The channeling lens is obtained with **DRIE** by fabrication of micrometric **trench**







- **First prototype obtained with size optimized for 180 GeV energy particles.**
- **Size of the micro-trench is suitable for testing: experiment performed at H8 beamline of CERN and data in analysis**

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