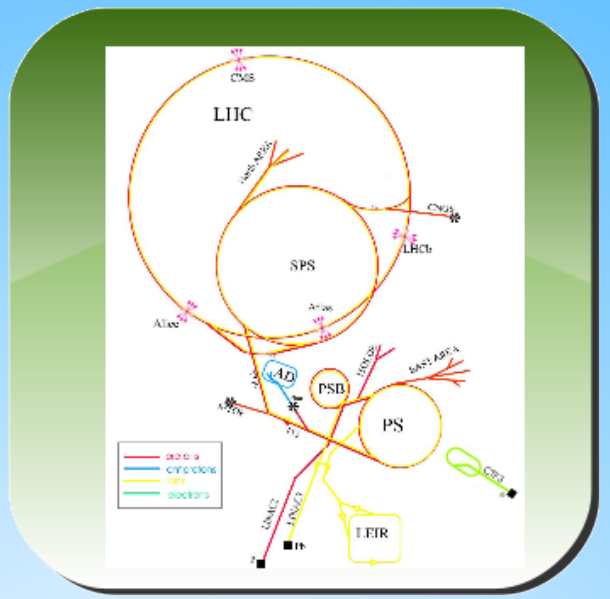
CryM: a crystal channeling emulation program for the UA9 experiment

Introduction

Crystal Model



UA9

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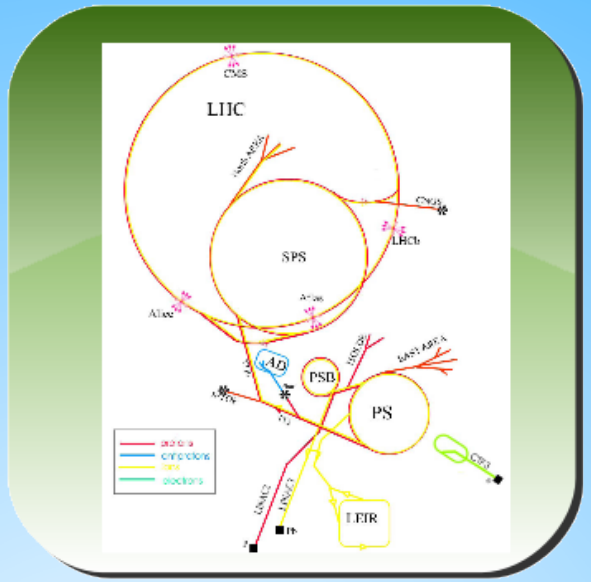
XI th Pisa Meeting

CRYM: a crystal channeling emulation program for the UA9 experiment

Introduction

Crystal Model



UA9

- What are bent crystals?
- Why a bent crystal in high energy physics?

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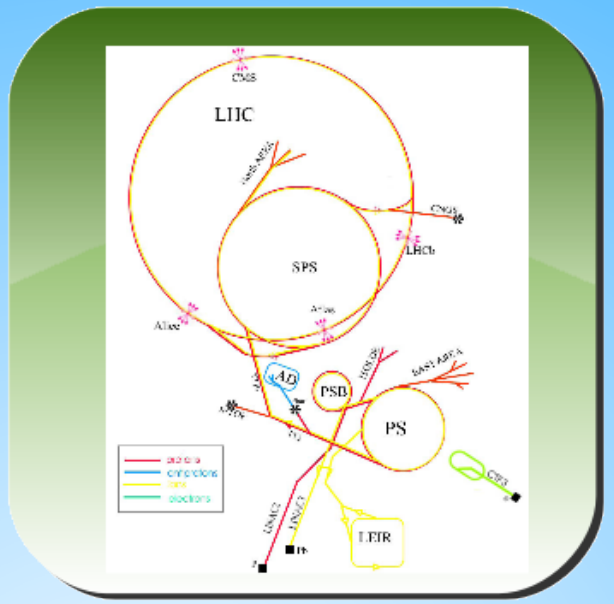
CryM: a crystal channeling emulation program for the UA9 experiment

Introduction

Crystal Model



UA9

- How the bent crystal behaviour can be reproduced?
- How does CRYM work?
- What are its principal features?

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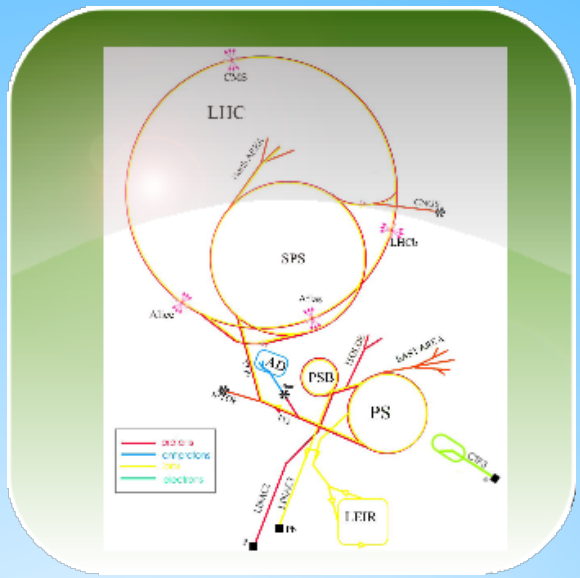
CryM: a crystal channeling emulation program for the UA9 experiment

Introduction

Crystal Model



UA9

- Where will CRYM be used?
- What is the UA9 experiment?

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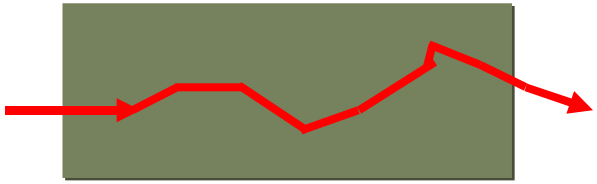
High energy charged particle and crystals

Amorphous material

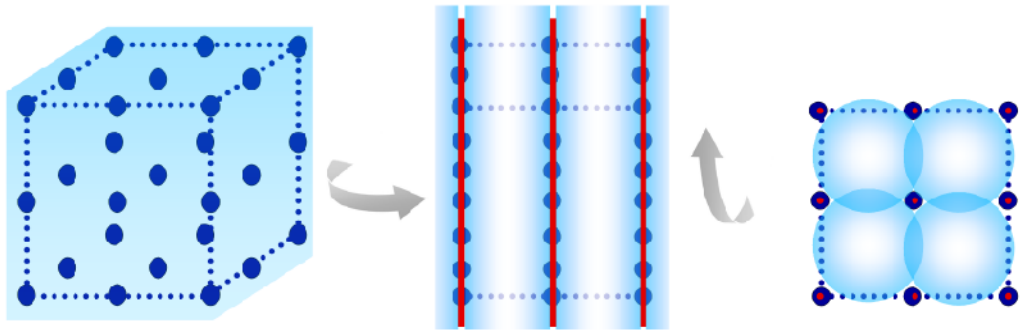


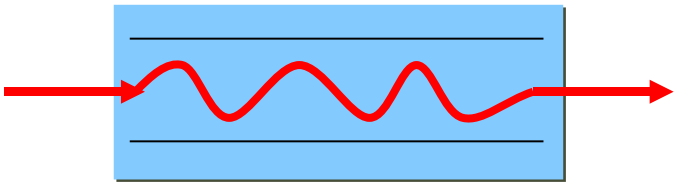
Uncorrelated hits with the atoms

↳ **Multiple scattering!**

Crystal

Ordered structure

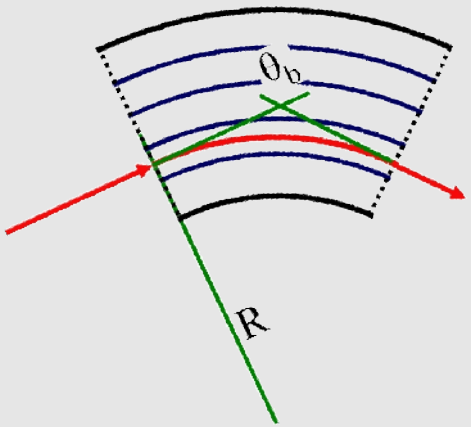




Particle can be trapped between atomic planes

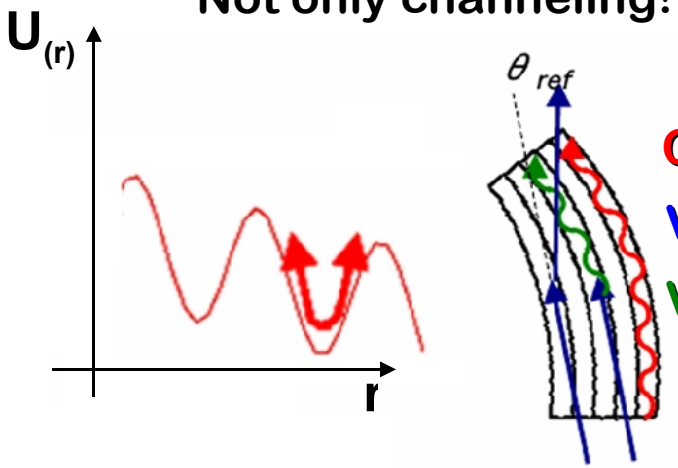
↳ **channeling!**

What are the bent crystals?



A bent crystal deflect the channeled particle like a bending magnet!

Not only channeling!

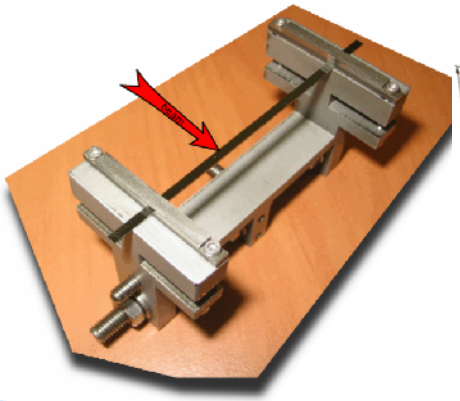


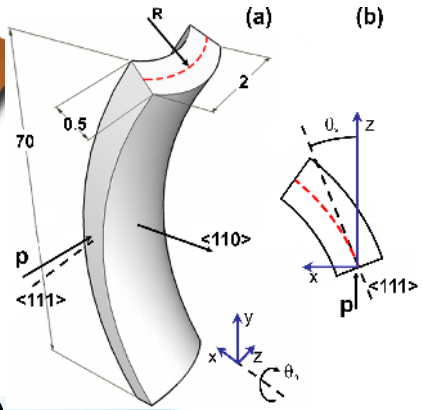
Channelig

Volume reflection

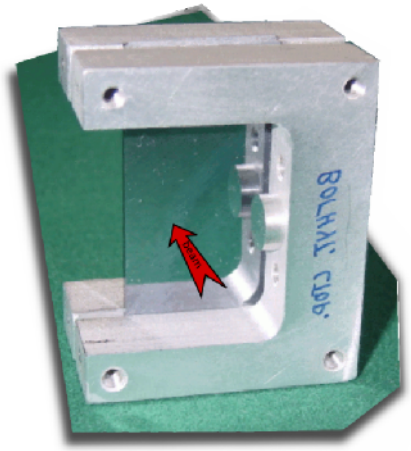
Volume capture

Two example of mechanically bent crystals





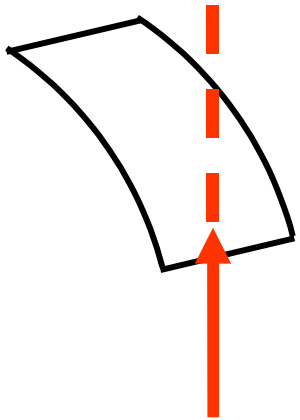
strip

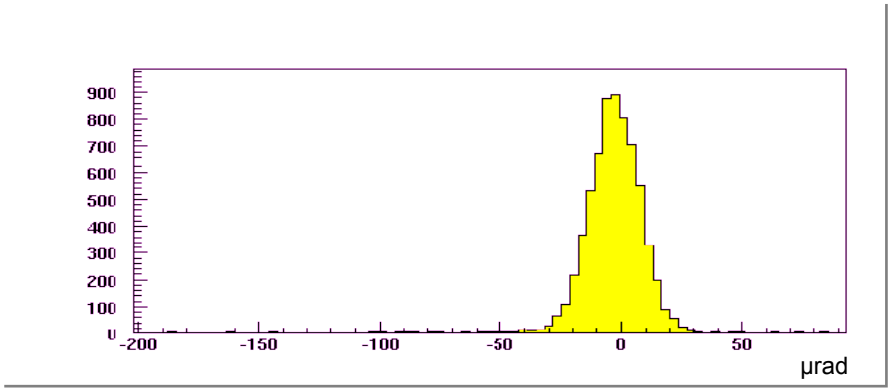


Quasimosaic

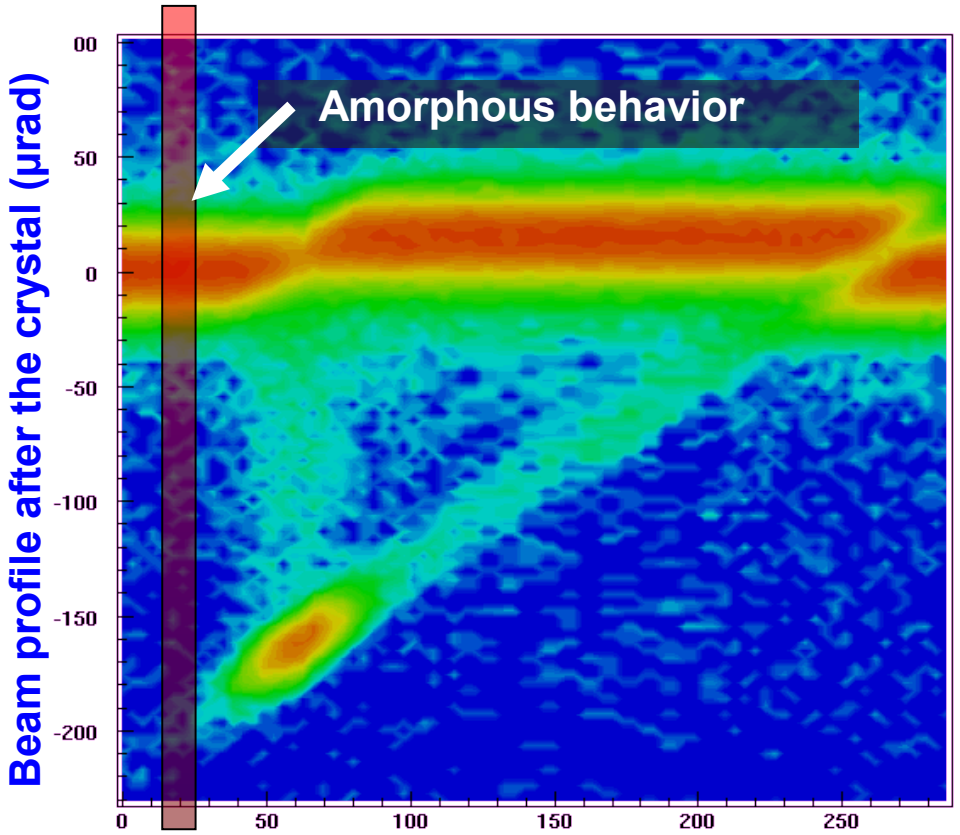
Introduction

Let's go to the experimental result!





Beam profile after the crystal

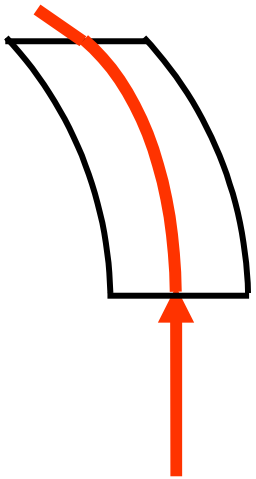


Crystal rotation angle (μrad)

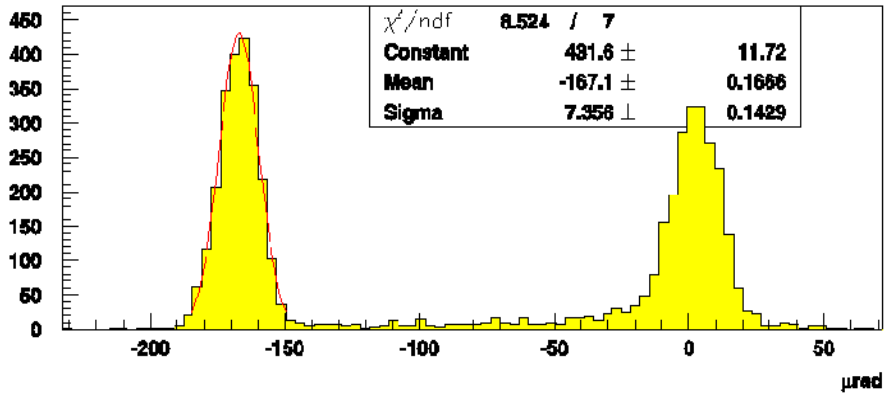
- Data collected by the H8RD22 collaboration on the H8, SPS, extracted beam line with protons of 400 GeV/c

Introduction

Channeling

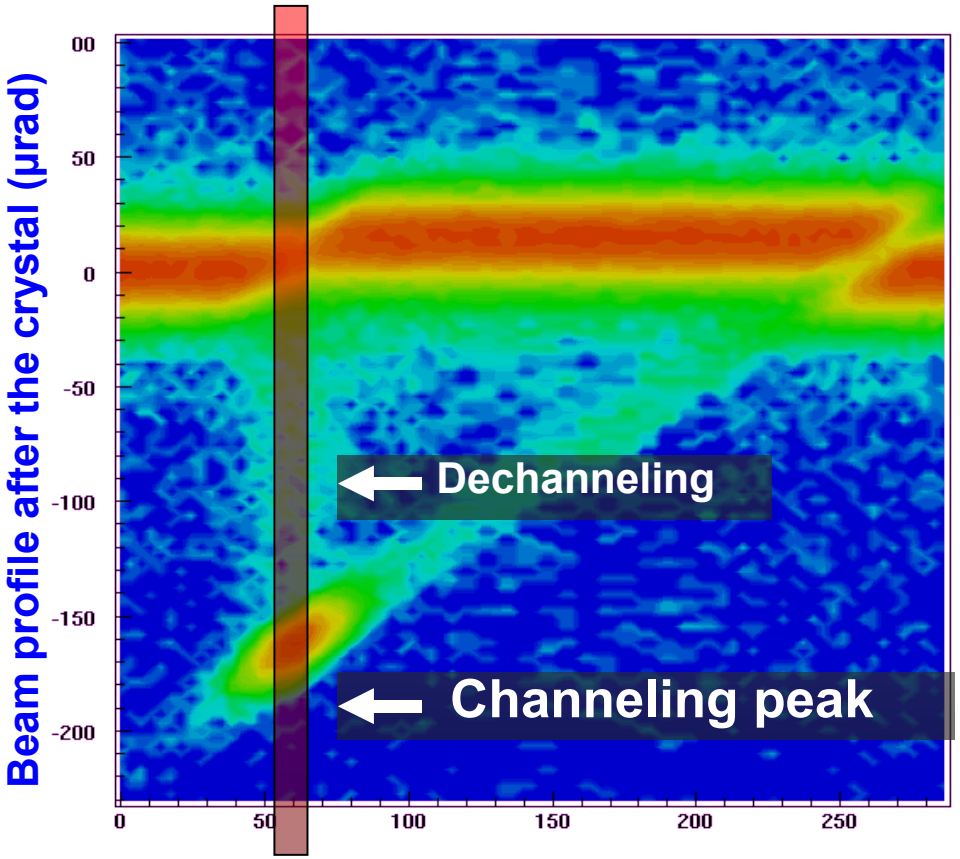


$$\theta_c = \frac{L}{R}$$



Beam profile after the crystal

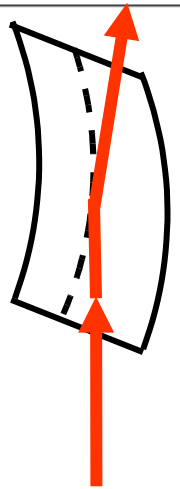
Channeling angle: 162μrad
equivalent to ~70Tesla!

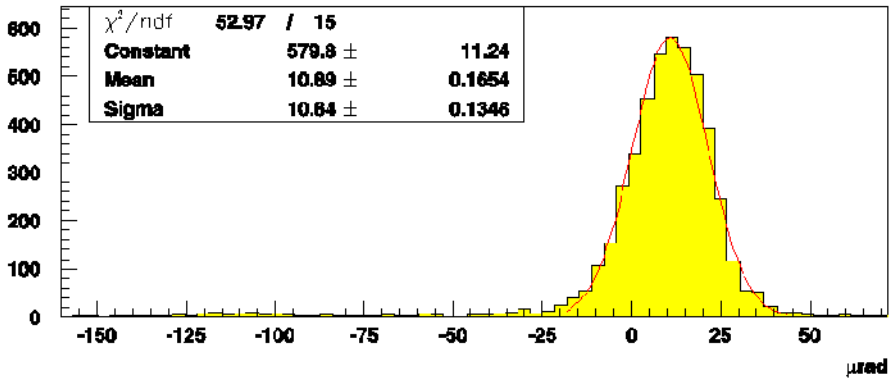


Crystal rotation angle (μrad)

Introduction

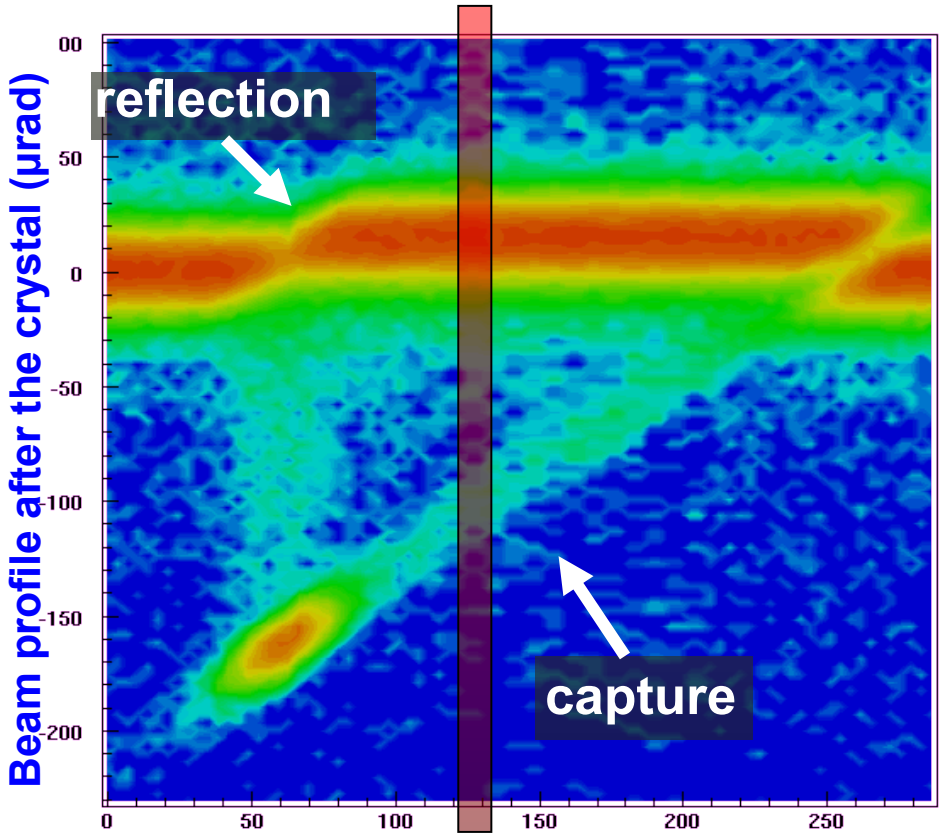
Volume Reflection





Beam profile after the crystal

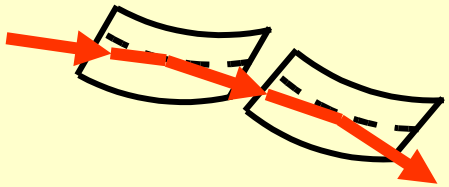
Reflection angle: 13.8μrad

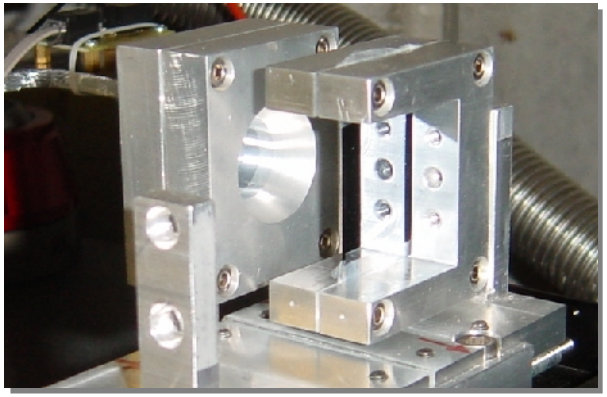


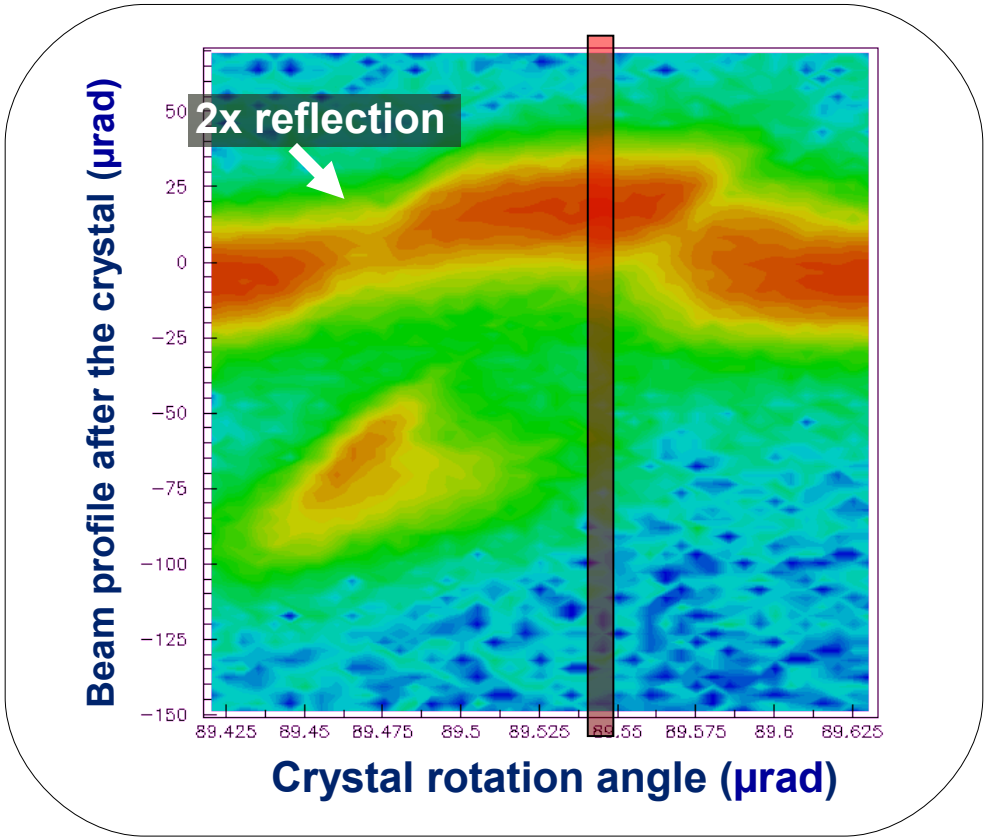
Crystal rotation angle (μrad)

Why just one crystal?

Double Reflecrtion!







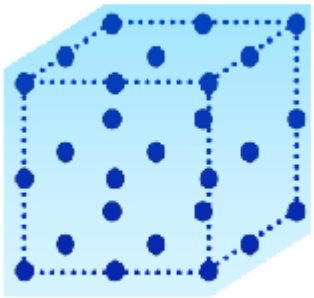
Studies are going on to use assembly of many crystals ~10!

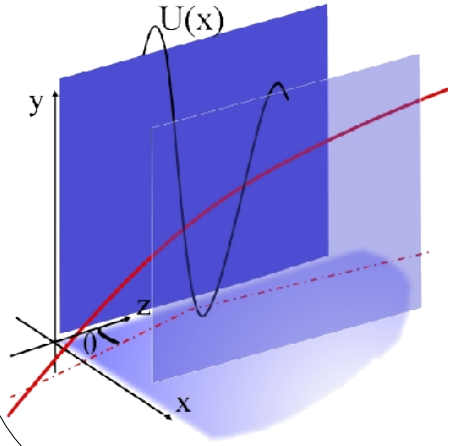
CRYM: CRYstal Model

How can we reproduce the bent crystal behaviour?

simulation

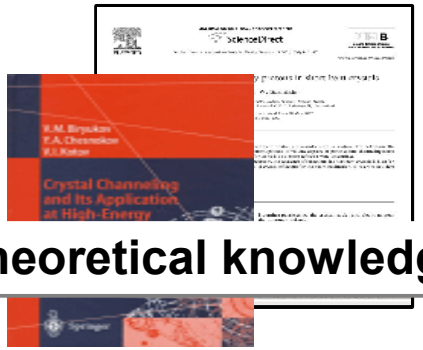
Taking into account the atoms or the atomic potential to track particle inside the crystal



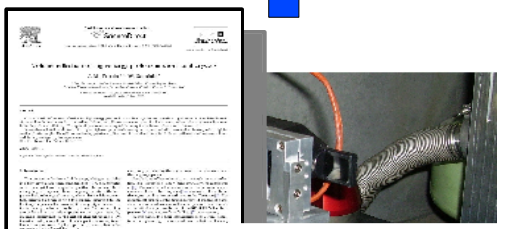


Emulation => CRYM

It is a model of the crystal based on experimental data and theoretical laws



Theoretical knowledge



Experimental data

What are CRYM pros & cons?

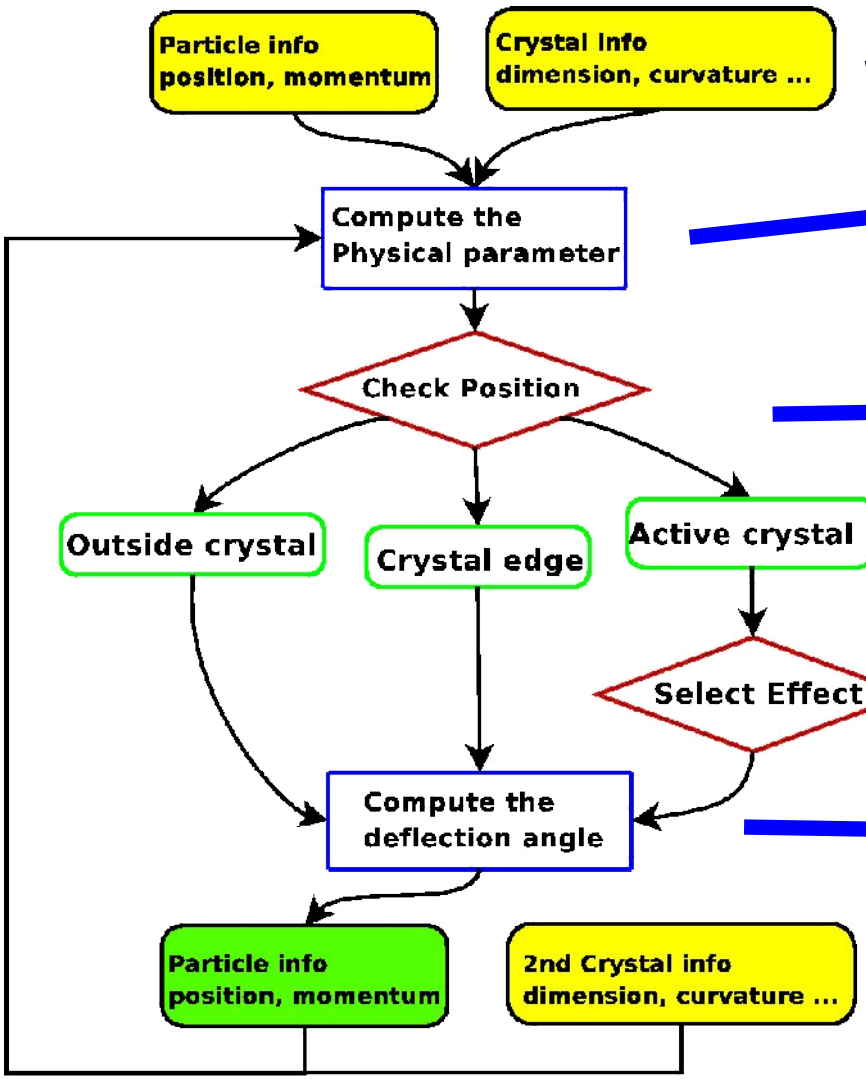
Cons:

- Unknown (not-measured) effects cannot be included
- Possible uncertainties in the emulation of unexplored physical region

Pros:

- Easy integration with accelerator and detector simulations:
  The model reflects our way of thinking
- Possibility of inserting fine (but maybe important) crystal features (eg. torsion or small spatial misalignment)
- It is an attempt to collect all the planar channeling information into coherent model
- *It's fast*

How does it work?



Emulation Inputs

Such as critical angle and radius

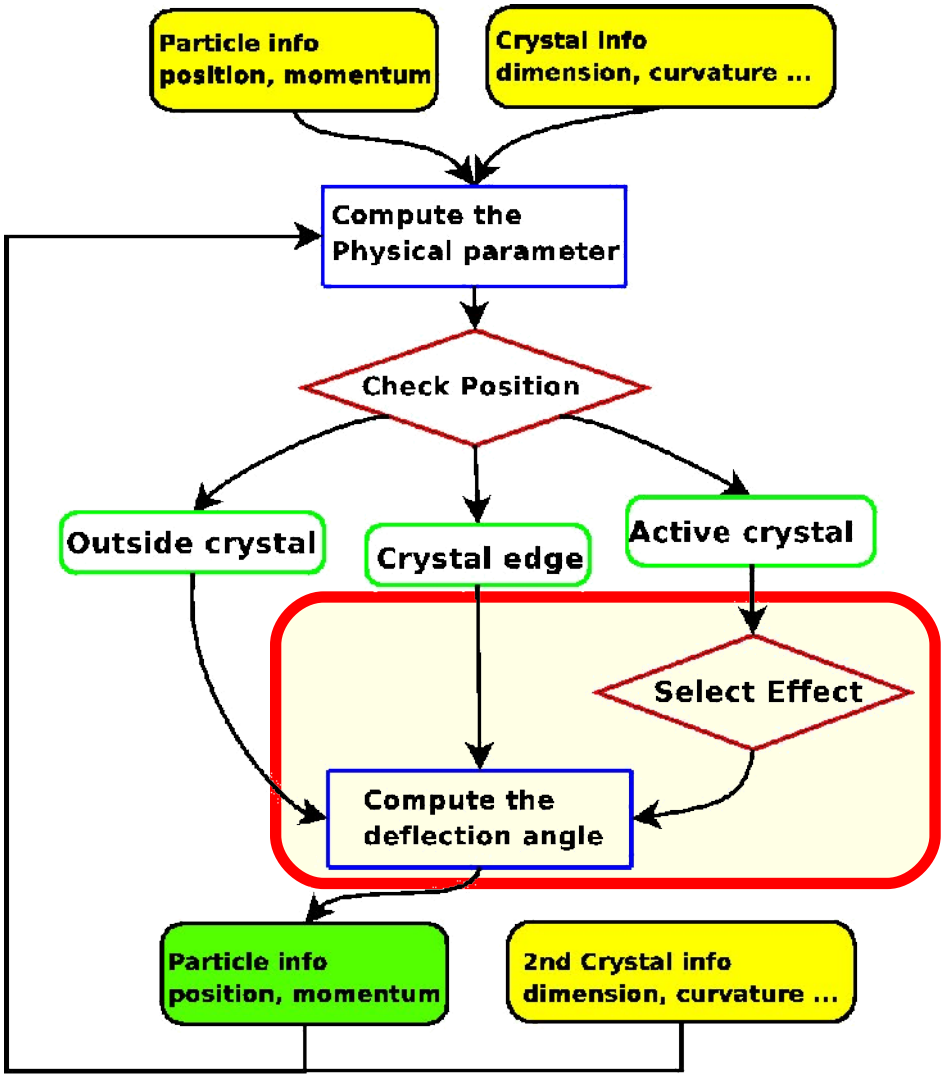
The crystal is inserted in the space

According to angular acceptance and efficiency

Act on the particle trajectory

Multi-crystals easy to be implemented

How does it works?

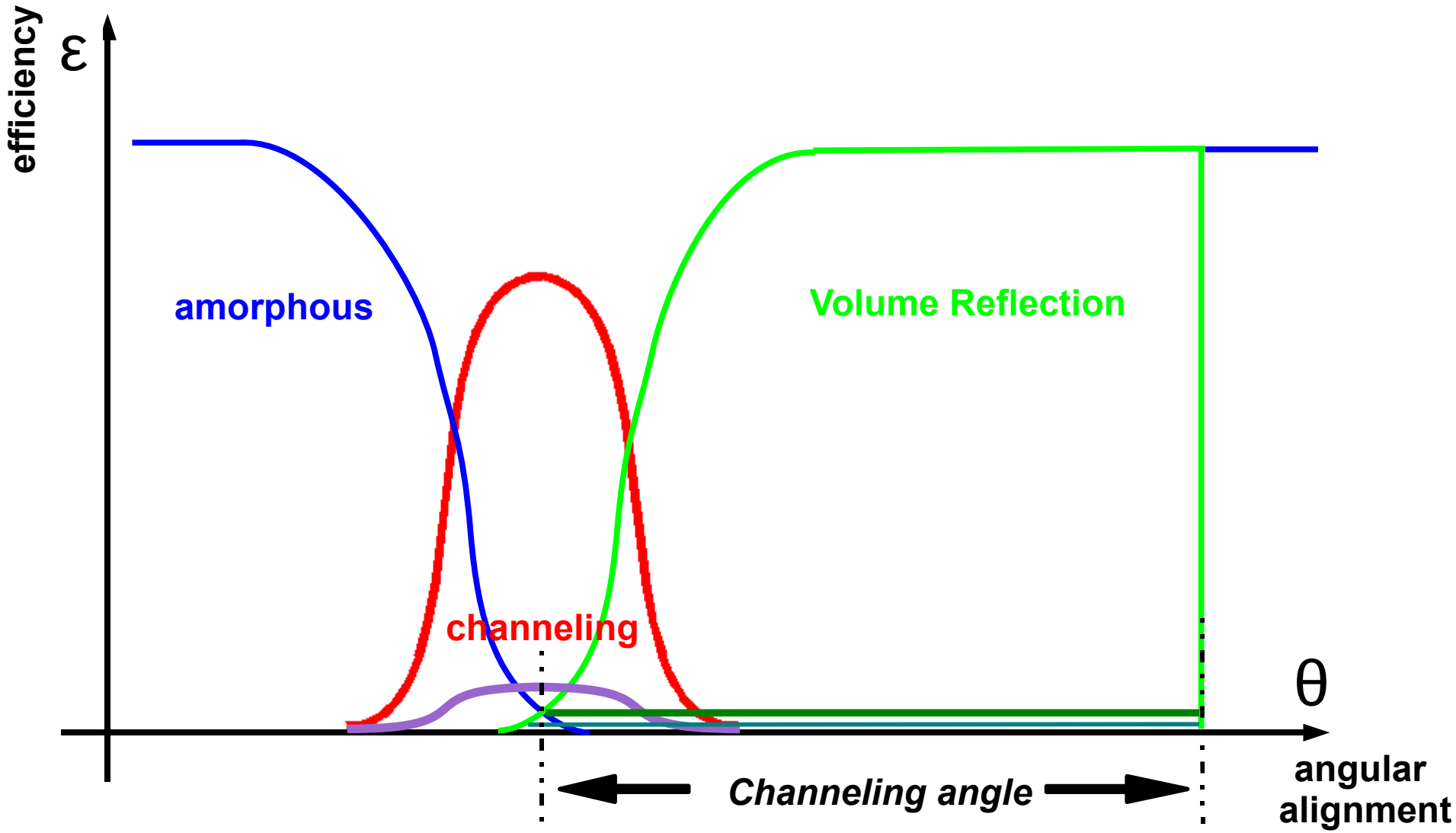


The crystal is described through its effects

Each effect is described mainly by:

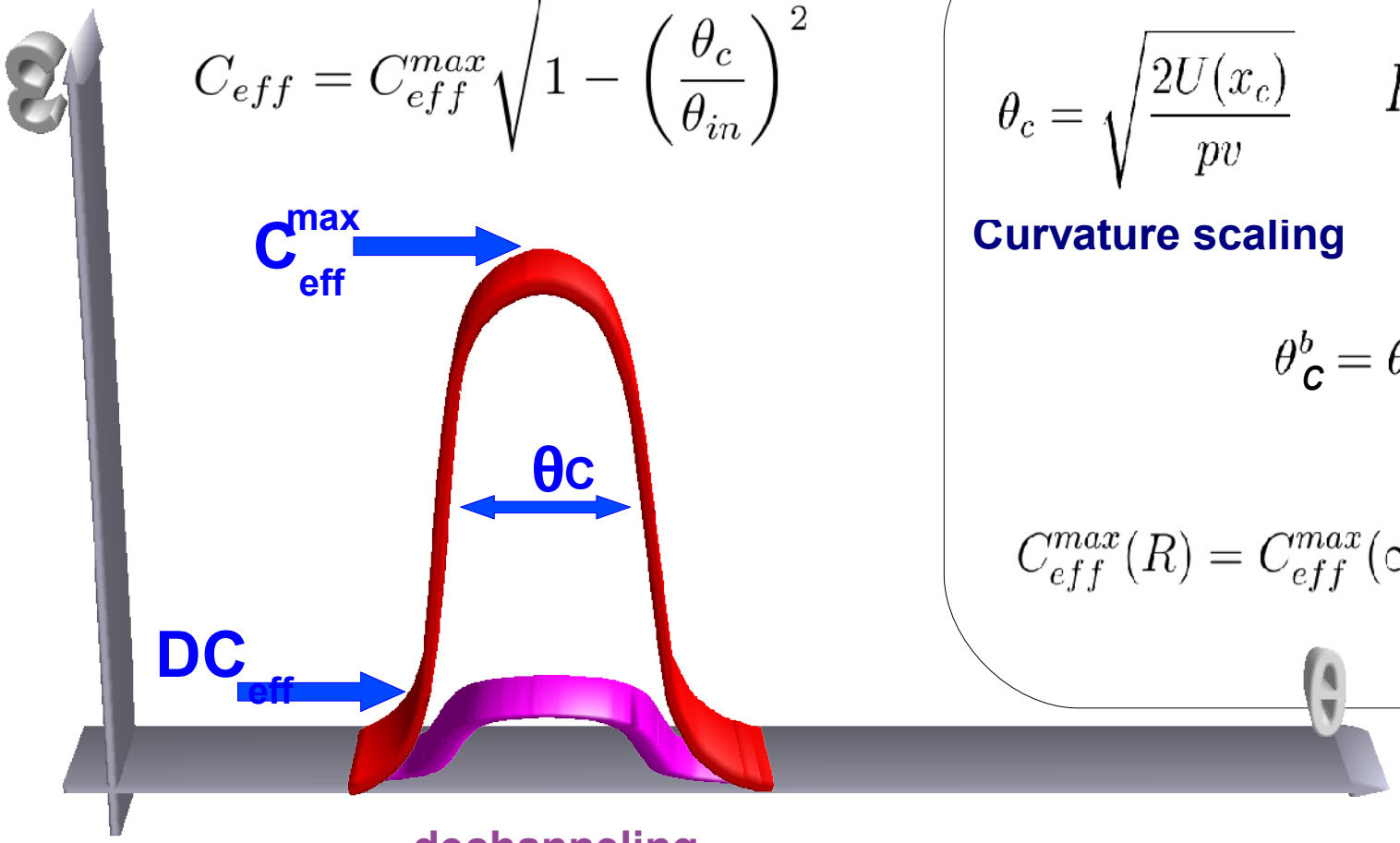
- **Angular acceptance + efficiency**
- **The angular deflection**

Angular acceptance & efficiency:



Angular acceptance & efficiency:

$$C_{eff} = C_{eff}^{max}\sqrt{1-\left(\frac{\theta_c}{\theta_{in}}\right)^2}$$



Energy scaling

$$\theta_c = \sqrt{\frac{2U(x_c)}{pv}} \qquad R_c = \frac{pv}{U'(x_c)}$$

Curvature scaling

$$\theta_c^b = \theta_c\left(1-\frac{R_c^b}{R}\right)$$

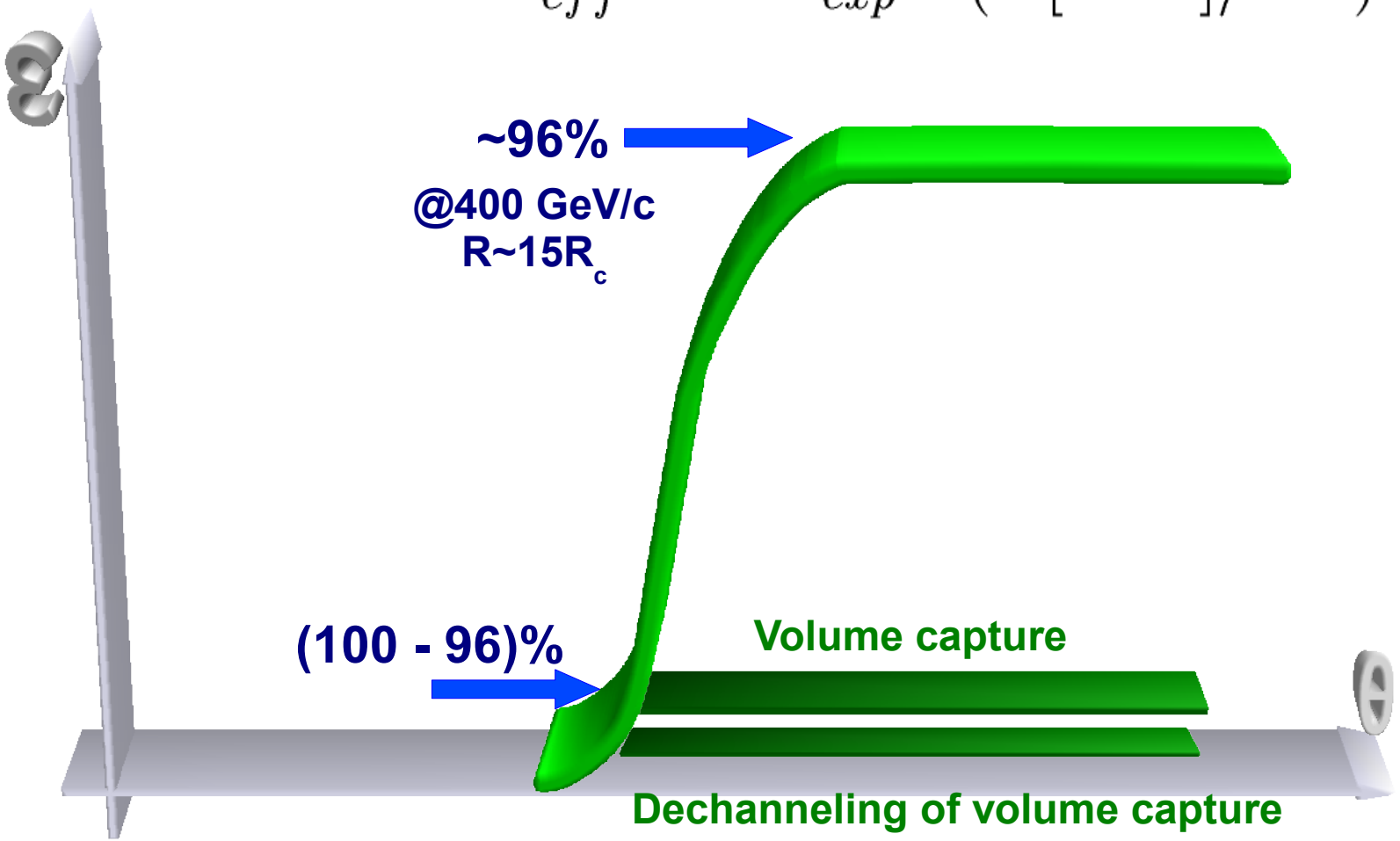
$$C_{eff}^{max}(R) = C_{eff}^{max}(\infty)\left(1-\frac{R}{R_c}\right)$$

DC$_{eff}$ ~20% *(experimental value)*

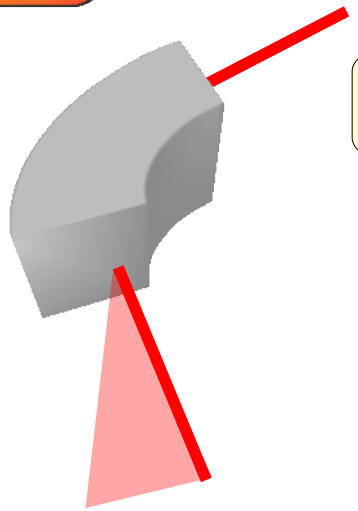
Angular acceptance & efficiency:

Energy scaling

$$VR_{eff} = VR_{exp} * (E[\mathrm{GeV}]/400)^{3/2}$$



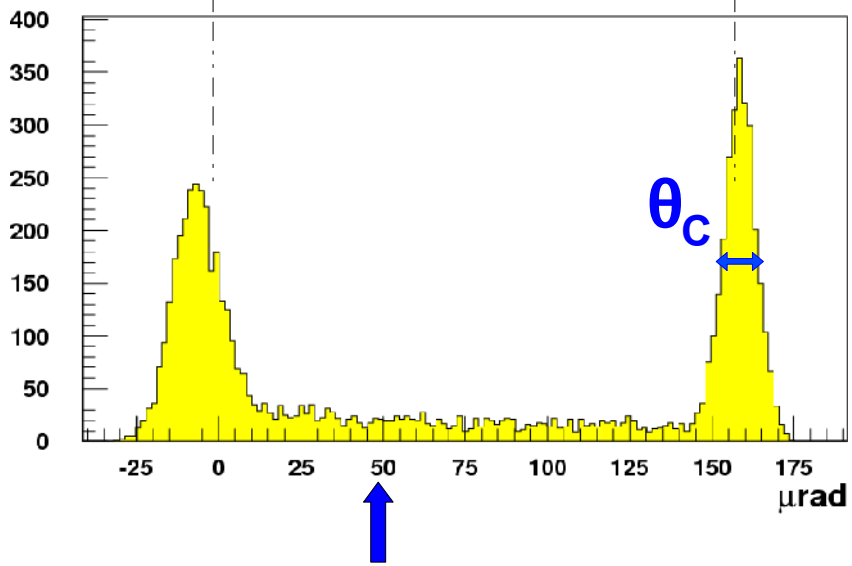
Effects produce deflection!



Channeling and dechanneling

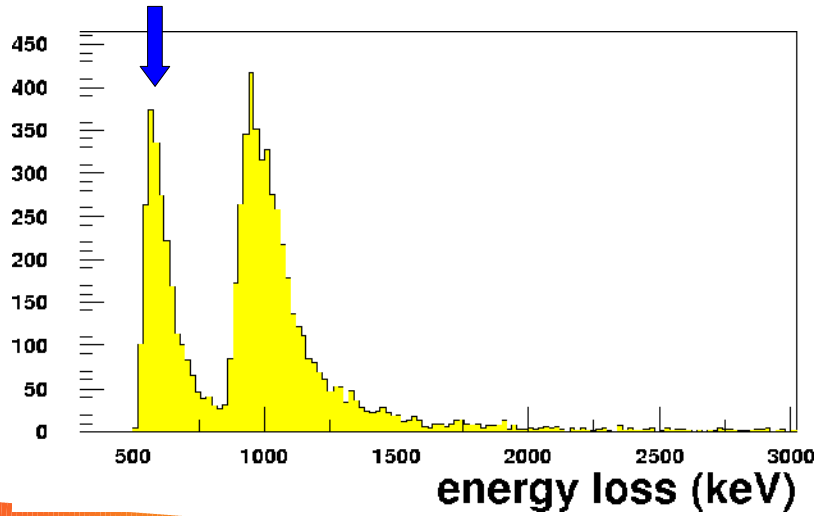
Channeling angle

$\theta_{ch} = L / R$



The dechanneling events are exponentially distributed

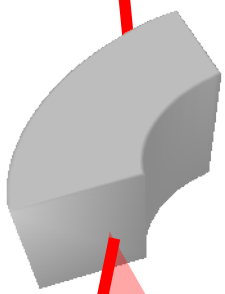
Channeled particles lose less energy, ~60% of the amorphous one

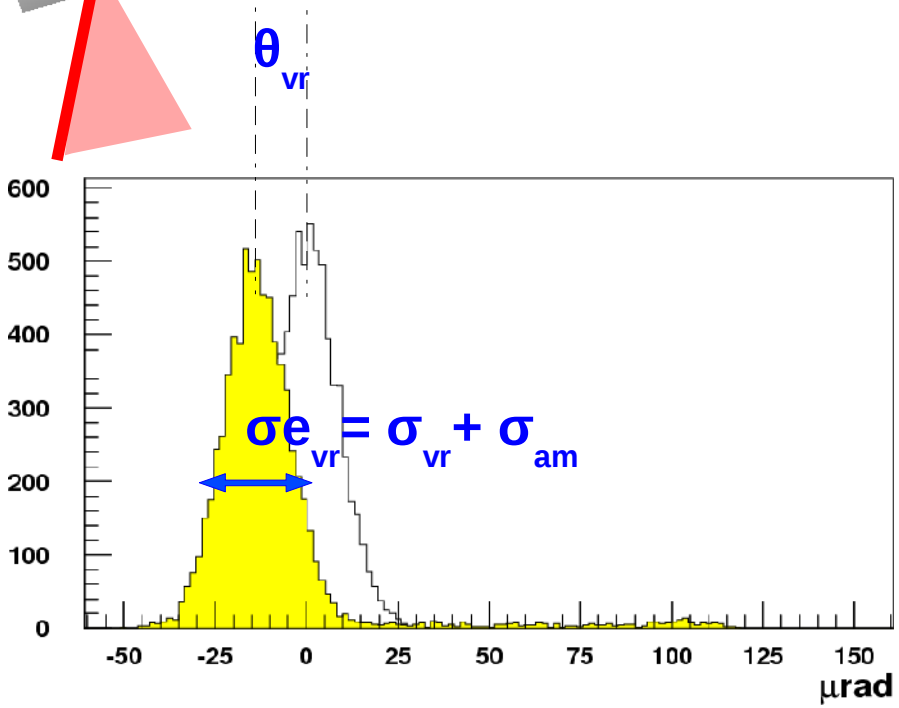


CRYM: CRYstal Model

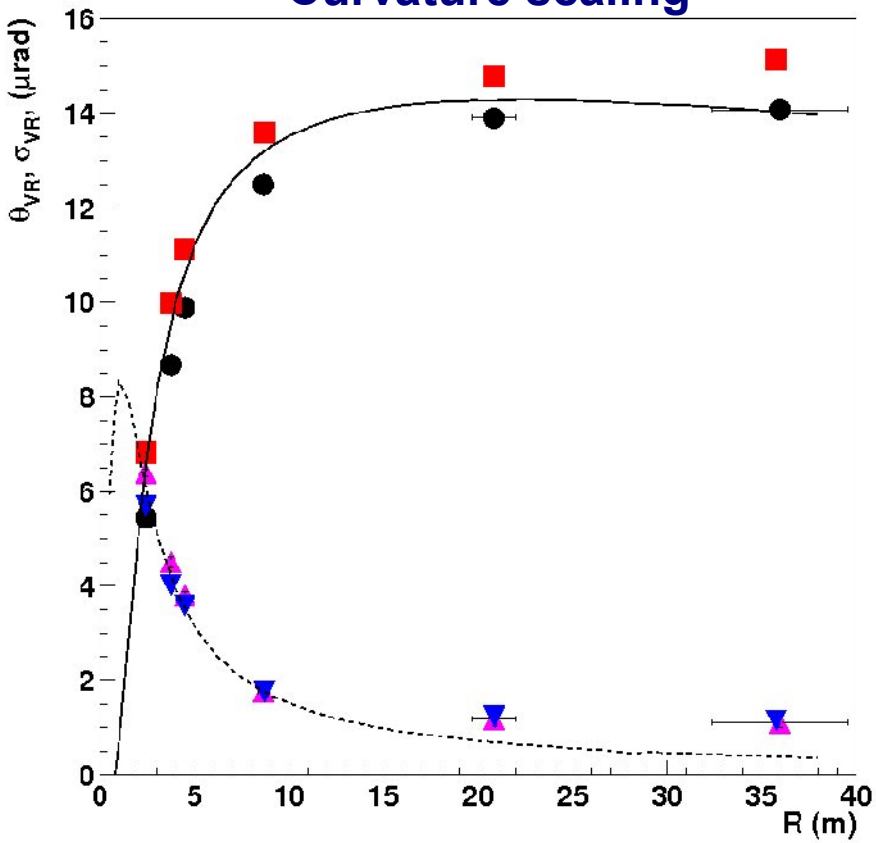
Effects produce deflection!

Volume Reflection and Volume Capture





- Curvature scaling

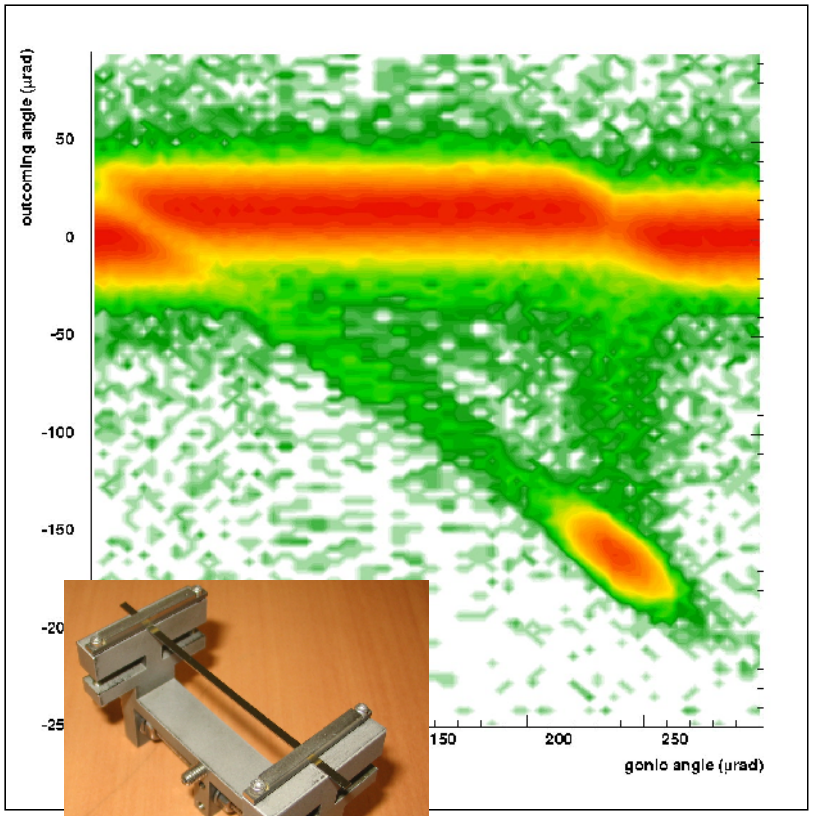


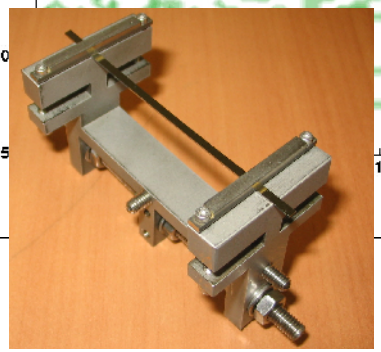
- W. Scandale et al.,"Volume reflection dependence of 400 GeV/c protons on the bent crystal curvature", Phys. Rev. Lett.

CRYM: CRYstal Model

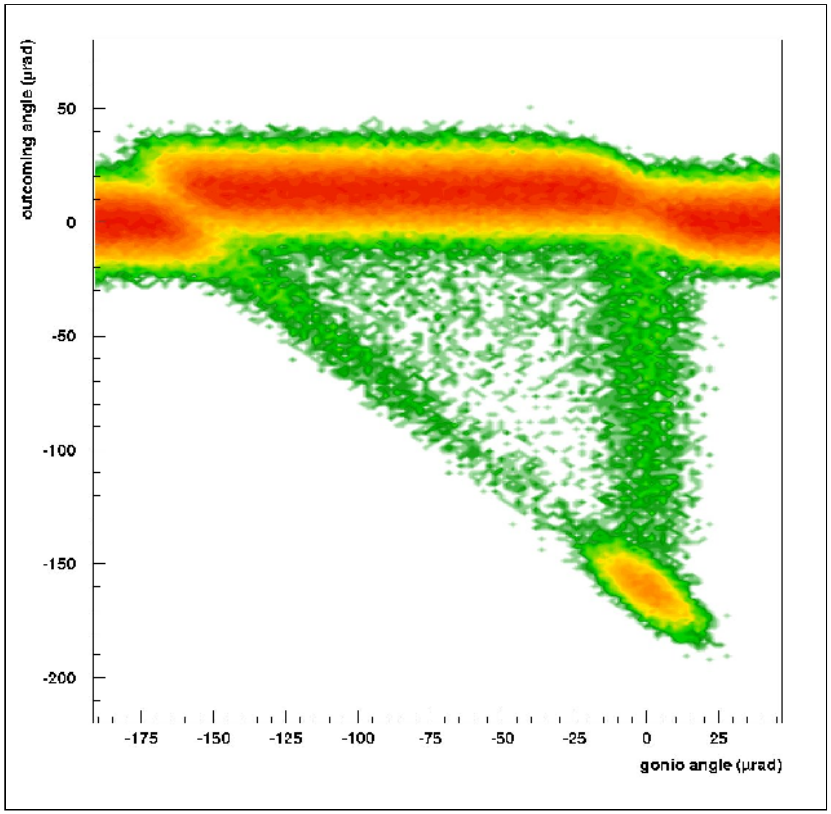
Let's put together the pieces:

- First experimental observation of VR at 400GeV (CERN SPS 2006)





CRYM



Emulation of the ST4 crystal

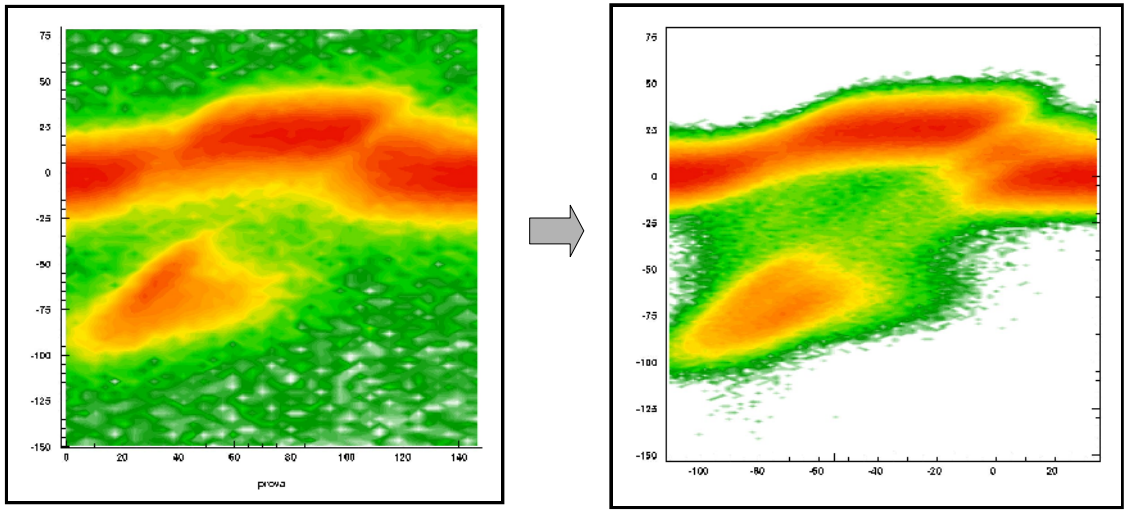
- SCANDALE W. *et al.*, *Phys. Rev. Lett.*, **98** (2007) 154801.

CRYM: CRYstal Model

And …do more:

Multiple reflection in a series of crystals

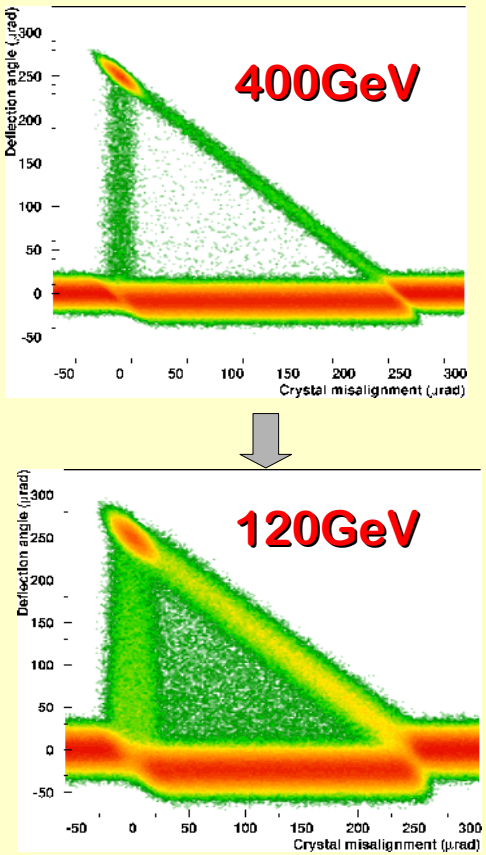
- First experimental observation of multi-VR (CERN SPS 2006)



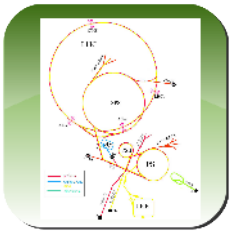
Emulated by CRYM

- W. Scandale et al., "Double volume reflection of a proton beam by a sequence of two bent crystals", Phys. Lett. B, Volume 658, Issue 4, Pages 109-111, 2008

Energy scaling



Inclusion of the mechanical defects: torsion and small misalignment

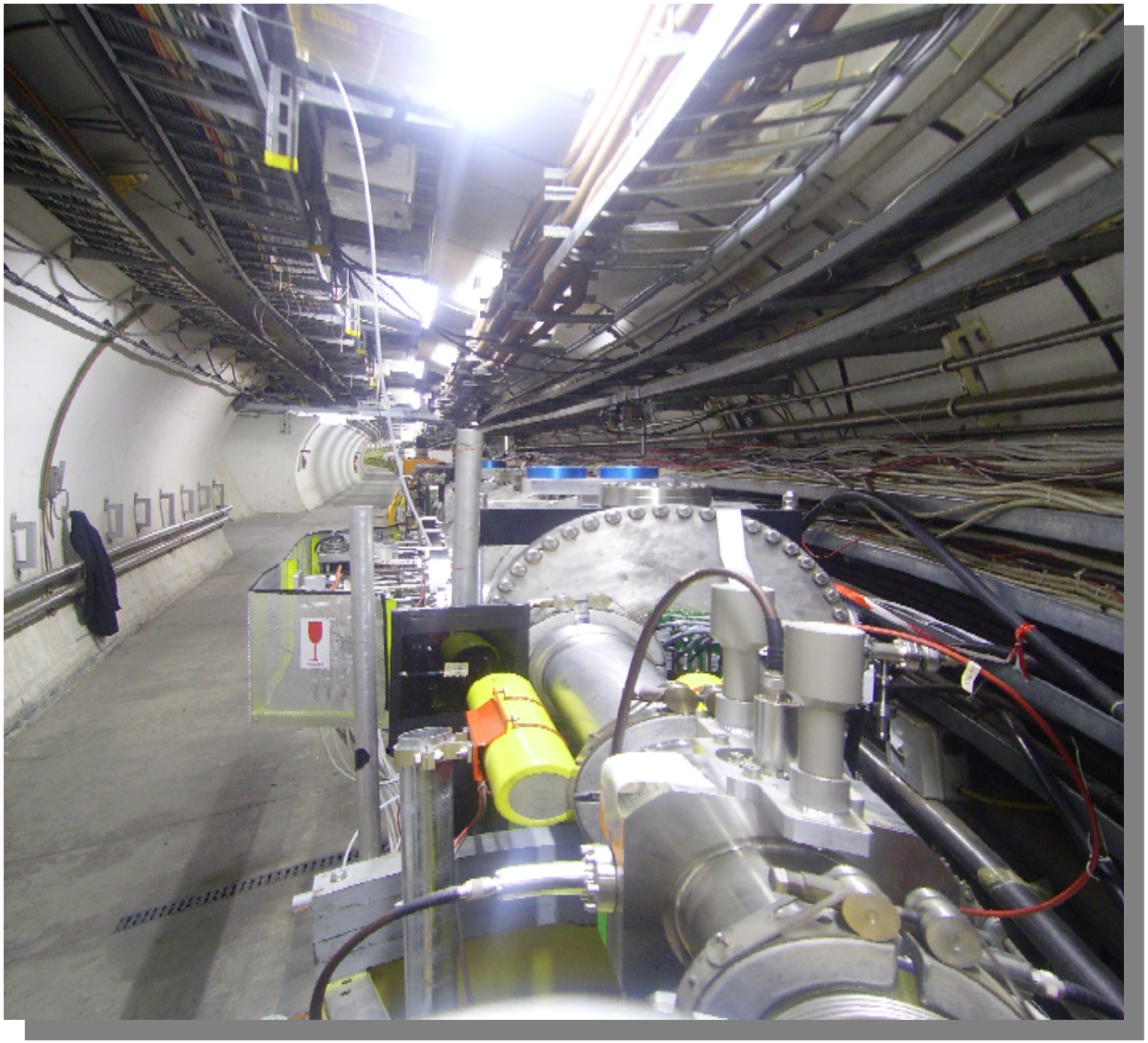


UA9

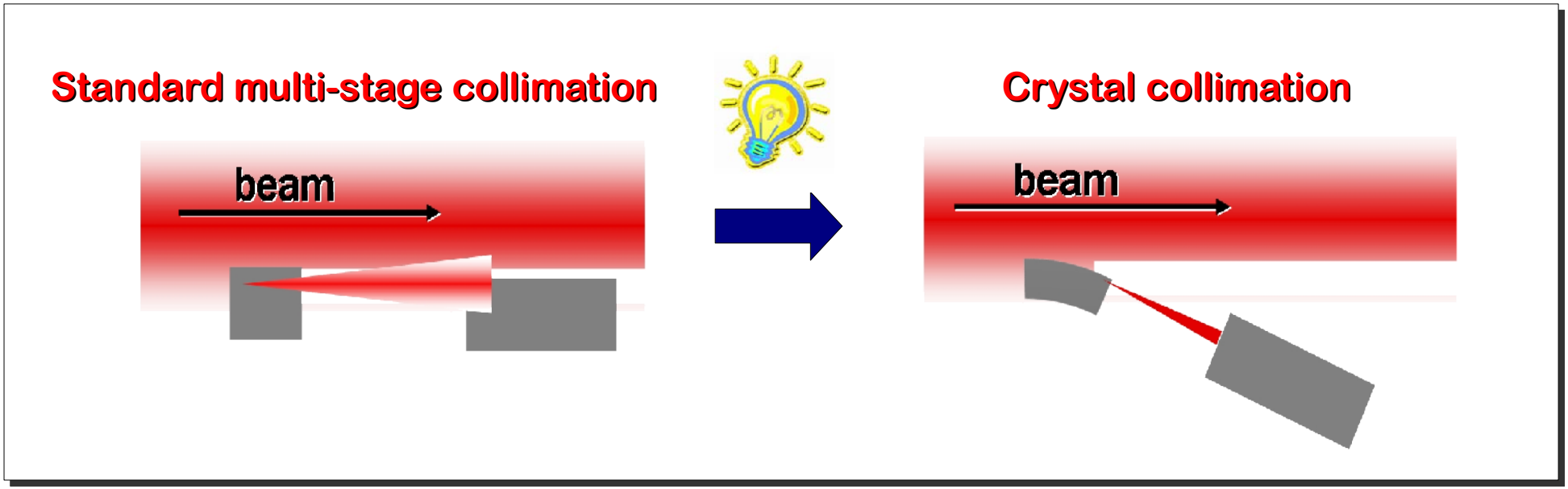
Where can CRYM be used?

To simulate the UA9 experiment

Crystal collimation test on the SPS circulating beam

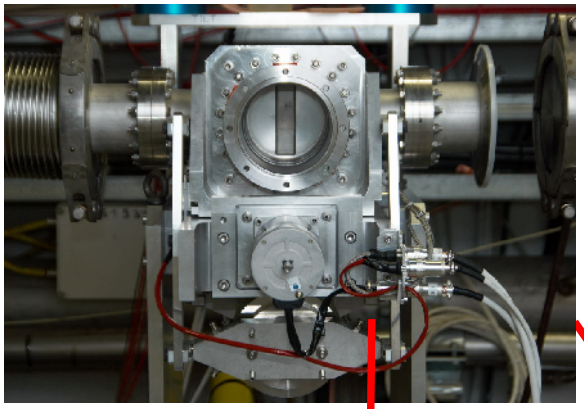


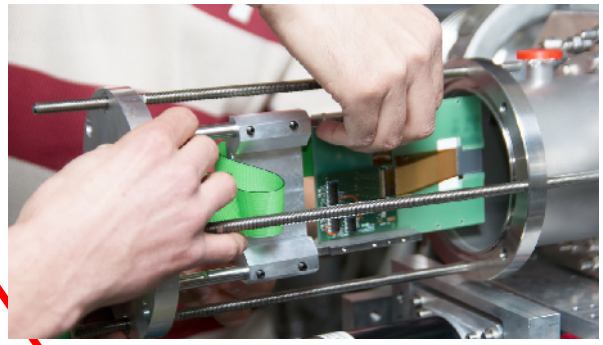
What is the crystal collimation?



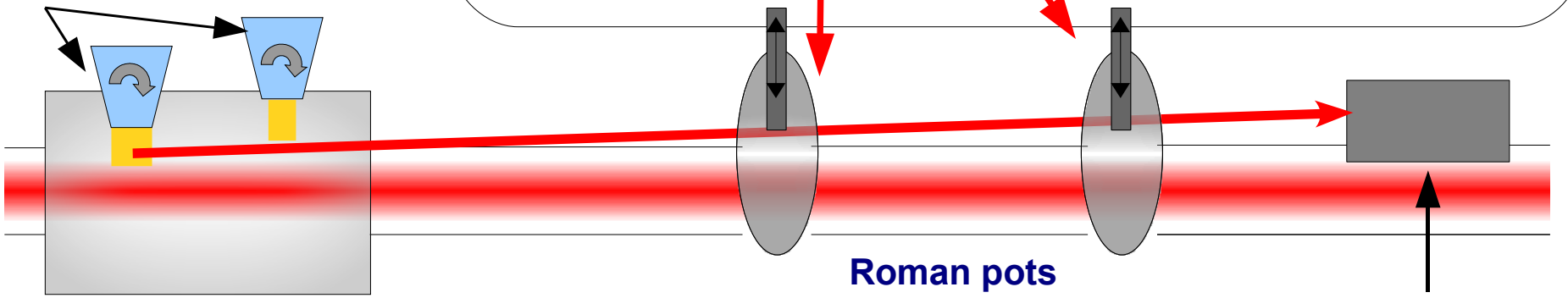
Efficient collimation is a crucial task for the LHC!

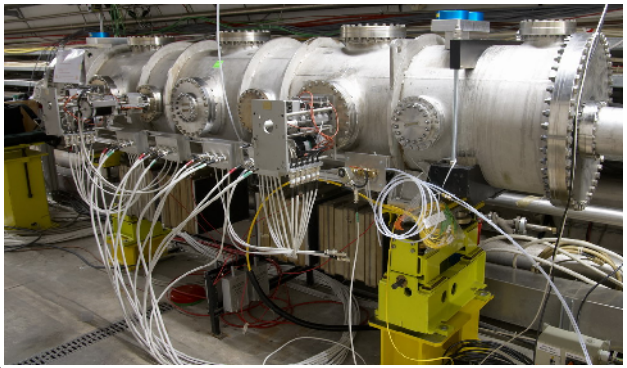
UA9 in two words: collimation + tracking

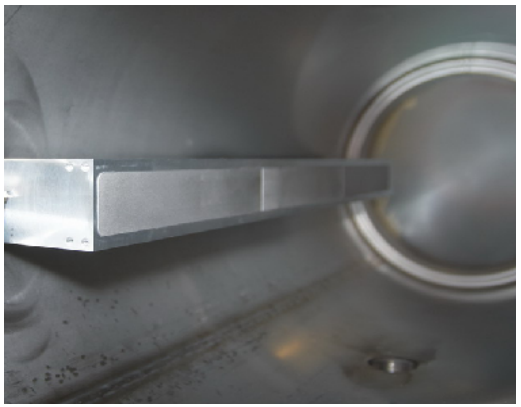




Crystals mounted on goniometer inside vacuum

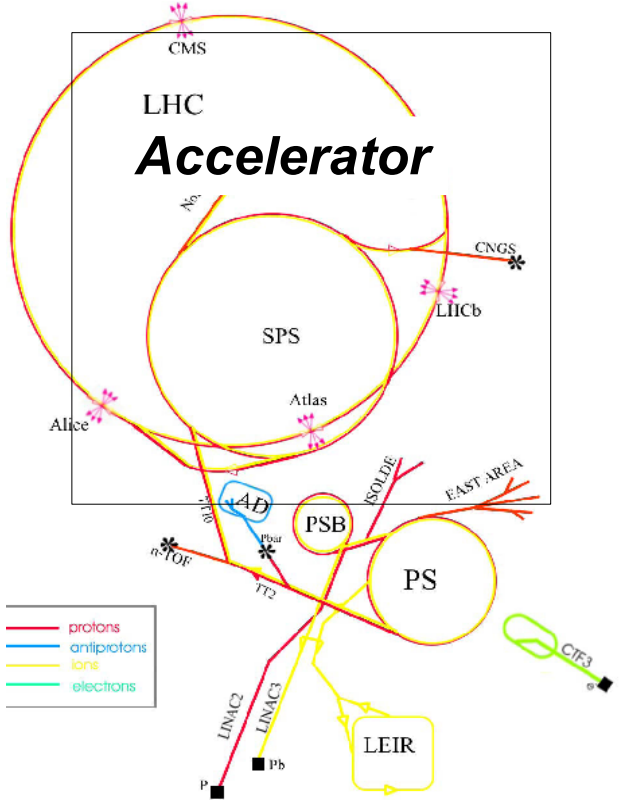






A simulation is needed to interpret the UA9 results

A simulation is the sum of different pieces



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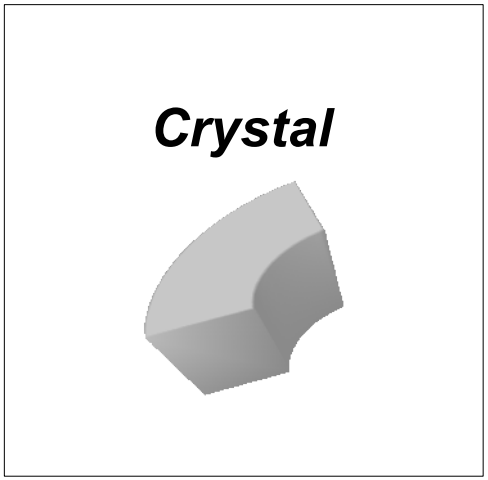

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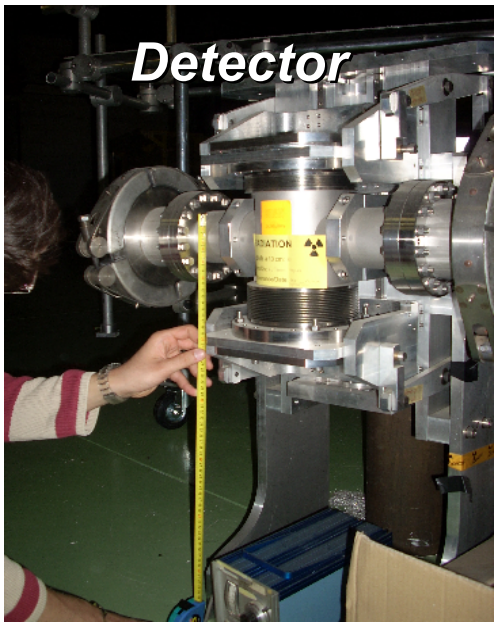
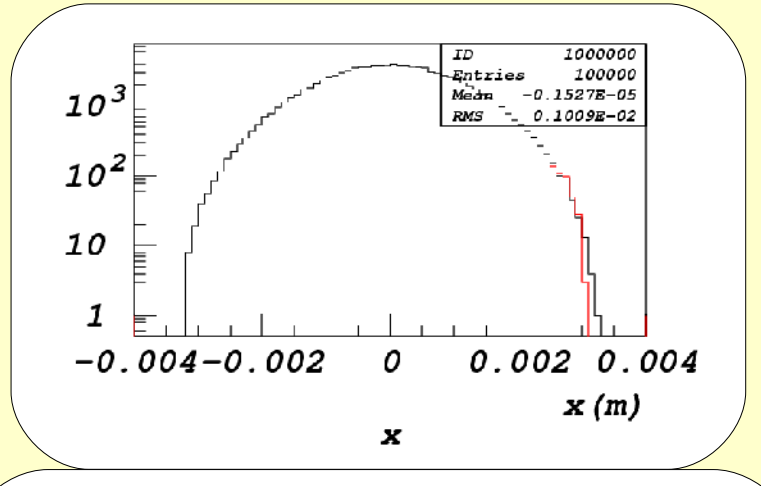
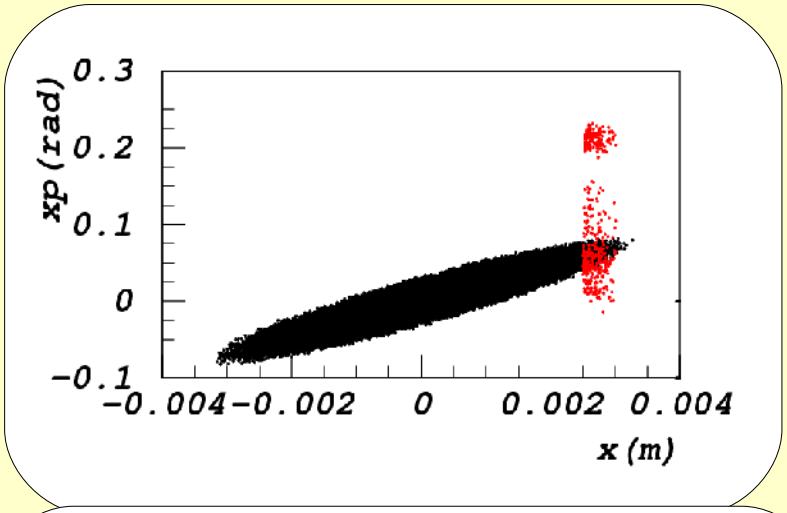


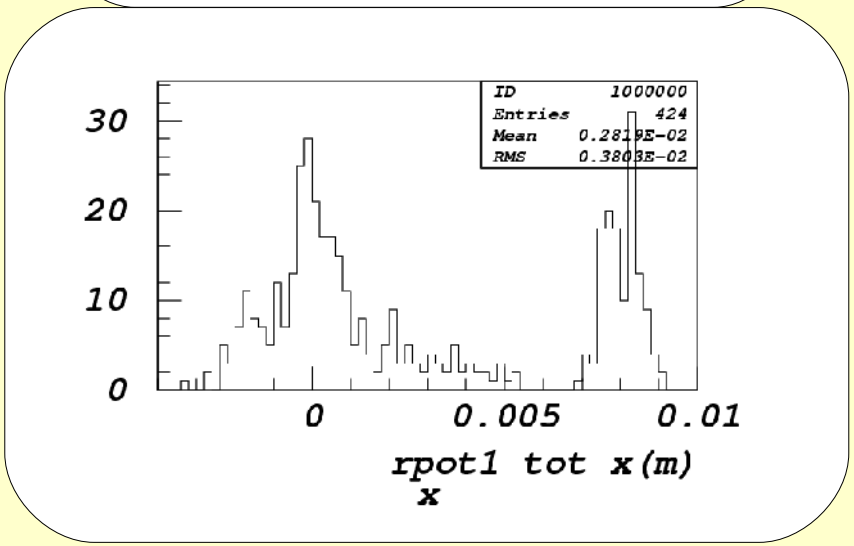
Crym is one of the selected program

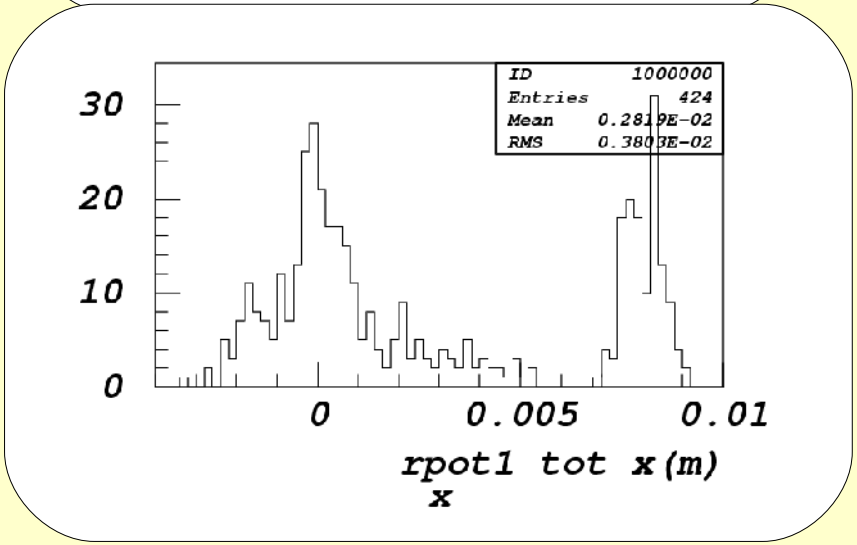
A few millimetres in a tracking of kilometres..
But I hope have shown you that in this case dimensions do not count!

A simulation is needed to interpret the UA9 results









Courtesy of S. Gilardoni
Very preliminary results

CONCLUSIONS

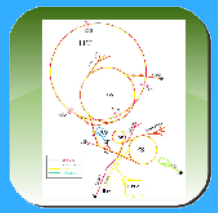
Introduction

- A bent crystal is able to deflect high energy
- Depending on the alignment there are different deflection effect
- Assembly of multi-crystal have been developed to multiply the reflection effect

Crystal Model

- Simulation and emulation approach can be used to reproduce crystal behaviour
- CRYM is an emulation program mainly based on experimental data
- It is designed designed to be “easy” fast and complete!

UA9



- CRYM will be used in the UA9 simulation
- UA9 represents the crystal collimation frontier
- It's main goal it's to proof the crystal collimation on a circulating beam using a silicon tracking system

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