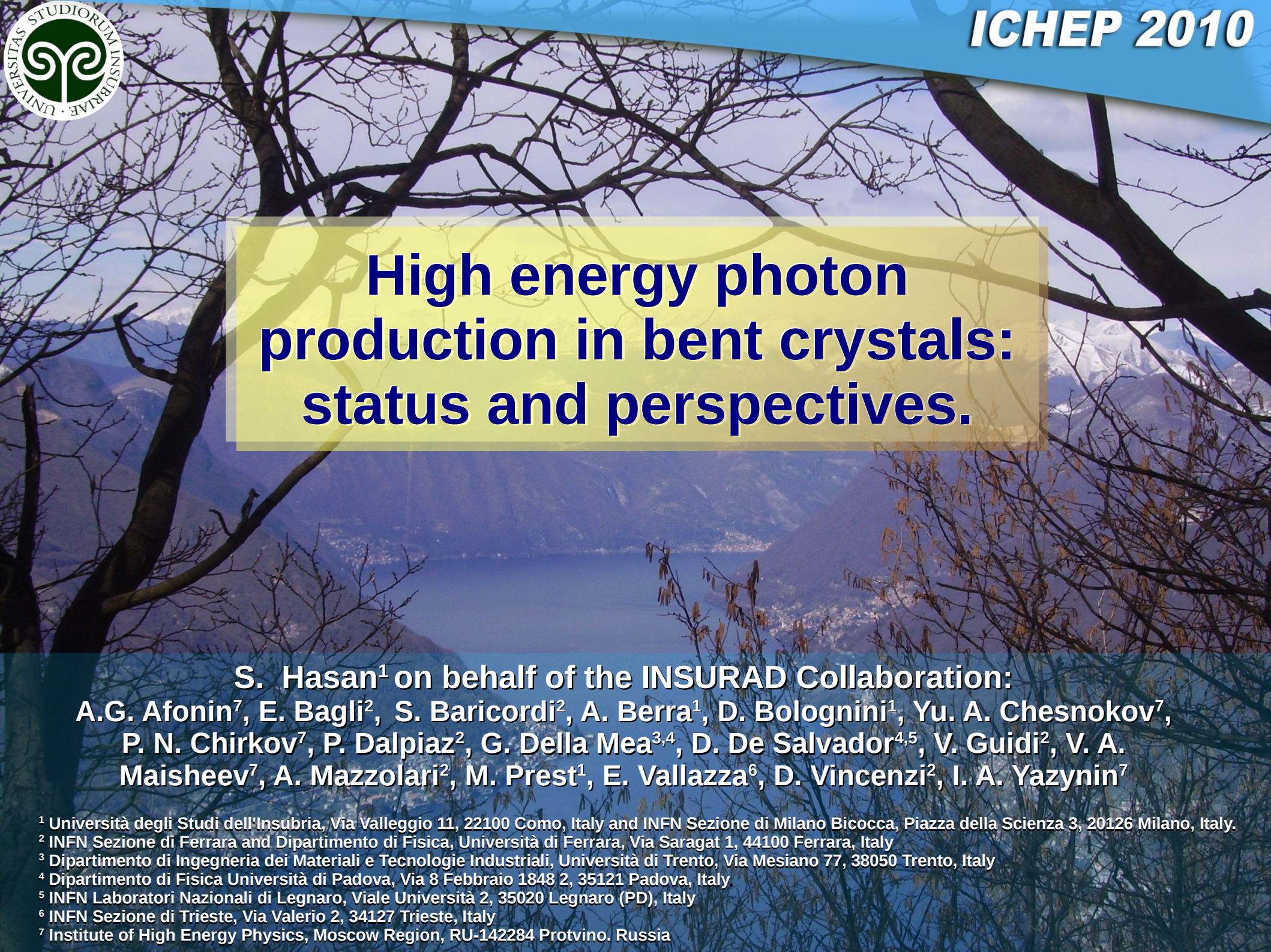


ICHEP 2010

High energy photon production in bent crystals: status and perspectives.

S. Hasan[1] on behalf of the INSURAD Collaboration:
A.G. Afonin[7], E. Bagli[2], S. Baricordi[2], A. Berra[1], D. Bolognini[1], Yu. A. Chesnokov[7], P. N. Chirkov[7], P. Dalpiaz[2], G. Della Mea[3,4], D. De Salvador[4,5], V. Guidi[2], V. A. Maisheev[7], A. Mazzolari[2], M. Prest[1], E. Vallazza[6], D. Vincenzi[2], I. A. Yazynin[7]

[1] Università degli Studi dell'Insubria, Via Valleggio 11, 22100 Como, Italy and INFN Sezione di Milano Bicocca, Piazza della Scienza 3, 20126 Milano, Italy.
[2] INFN Sezione di Ferrara and Dipartimento di Fisica, Università di Ferrara, Via Saragat 1, 44100 Ferrara, Italy
[3] Dipartimento di Ingegneria dei Materiali e Tecnologie Industriali, Università di Trento, Via Mesiano 77, 38050 Trento, Italy
[4] Dipartimento di Fisica Università di Padova, Via 8 Febbraio 1848 2, 35121 Padova, Italy
[5] INFN Laboratori Nazionali di Legnaro, Viale Università 2, 35020 Legnaro (PD), Italy
[6] INFN Sezione di Trieste, Via Valerio 2, 34127 Trieste, Italy
[7] Institute of High Energy Physics, Moscow Region, RU-142284 Protvino. Russia

Outline

INTRODUCTION

- **Bent crystals** are devices designed to **deflect** high energy particles
- Deflection of light particles → **strong radiation emission**

2009 beam test to measure the radiation emission (positrons of 120GeV)

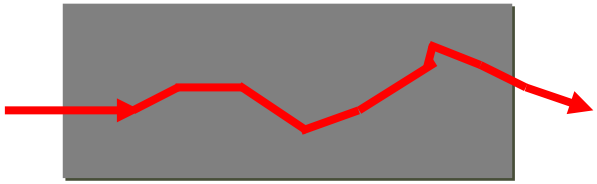
- How we measure **deflection** and **radiation**
- **Results:**
  - ***Channeling*** *and* ***Volume Reflection***
  - ***Comparison with theory***

Going beyond

- Multi crystals and axial effects → **to increase the intensity**

High energy charged particles and crystals

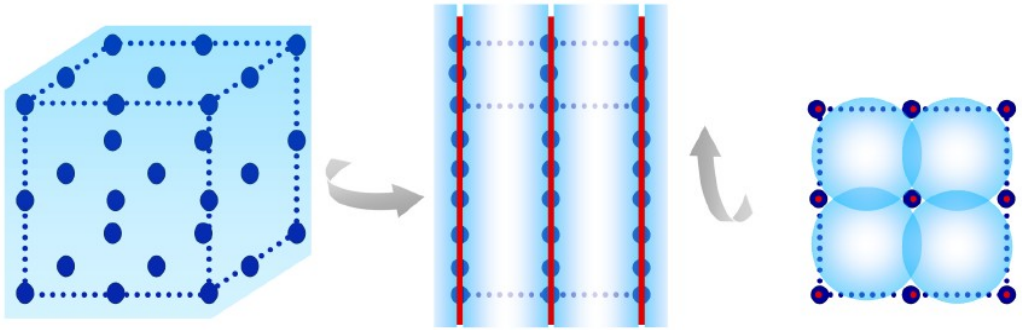
Amorphous material



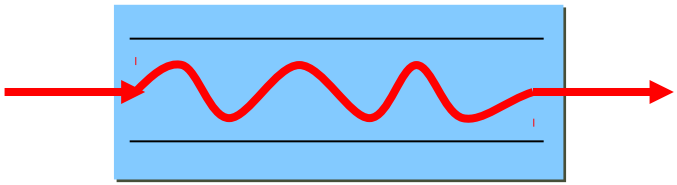
Uncorrelated hits with the atoms

- Multiple scattering
- Bremsstrahlung

Crystal



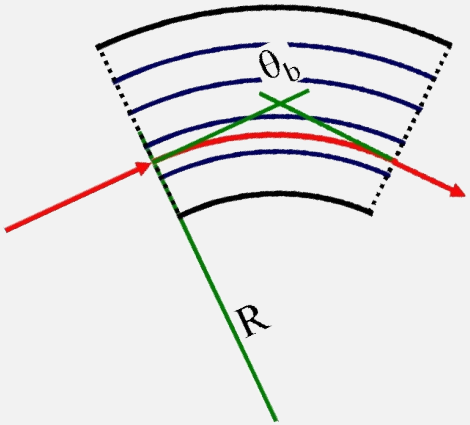
Ordered structure — Planes — Axis



Particle can be trapped between atomic planes

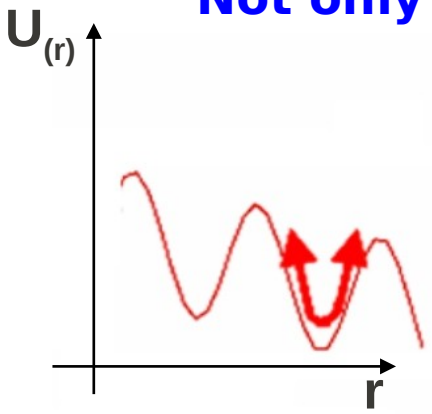
- channeling!

What are bent crystals?



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

Not only channeling!



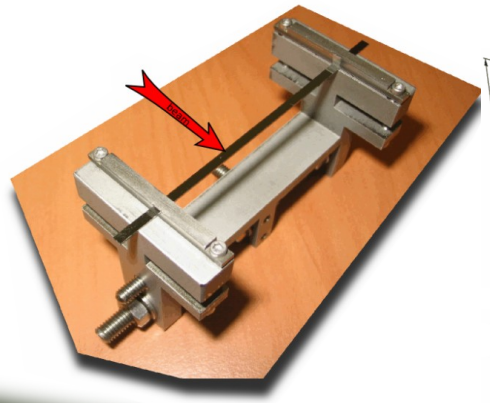
Channeling

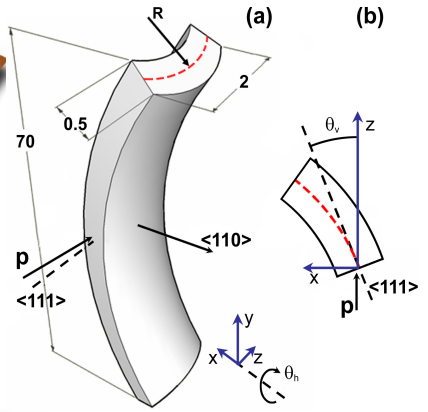
Volume reflection

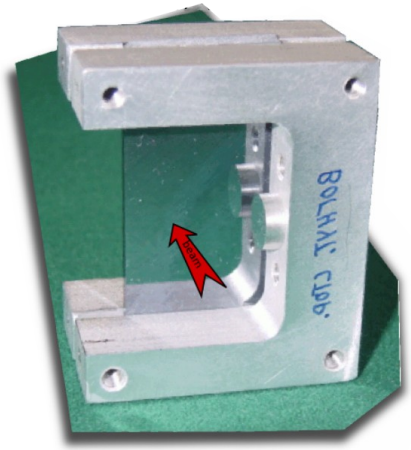
Volume capture

Two examples of mechanically bent crystals

strip







Quasimosaic

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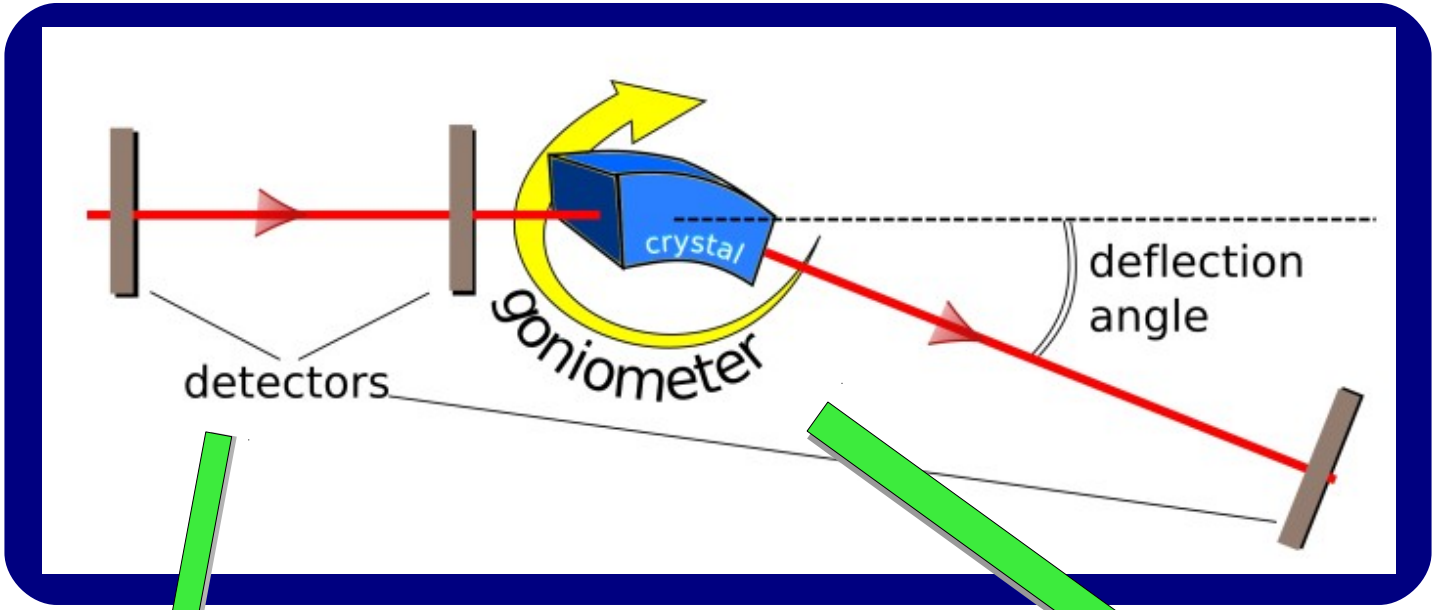
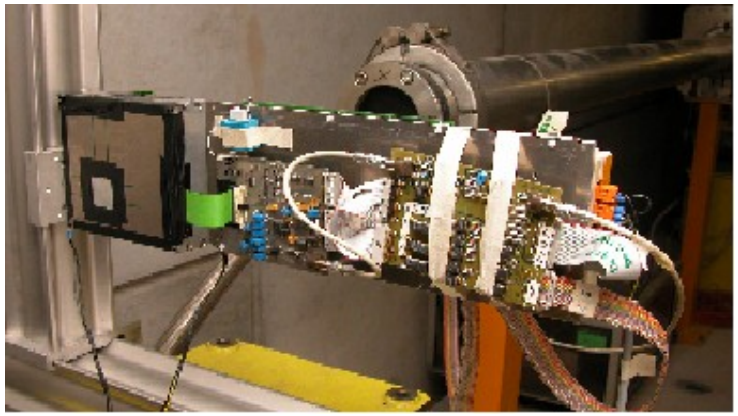
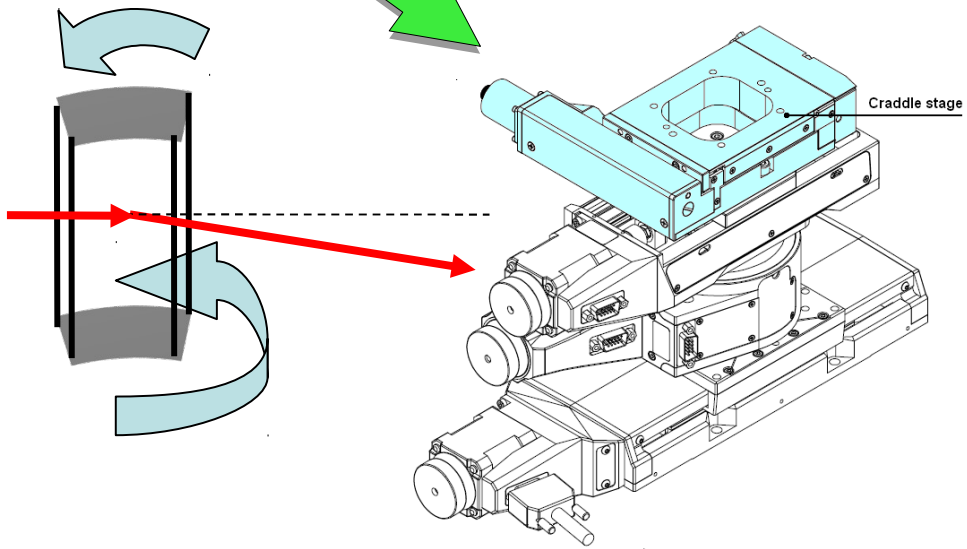
How to measure their deflection properties:



Tracking system



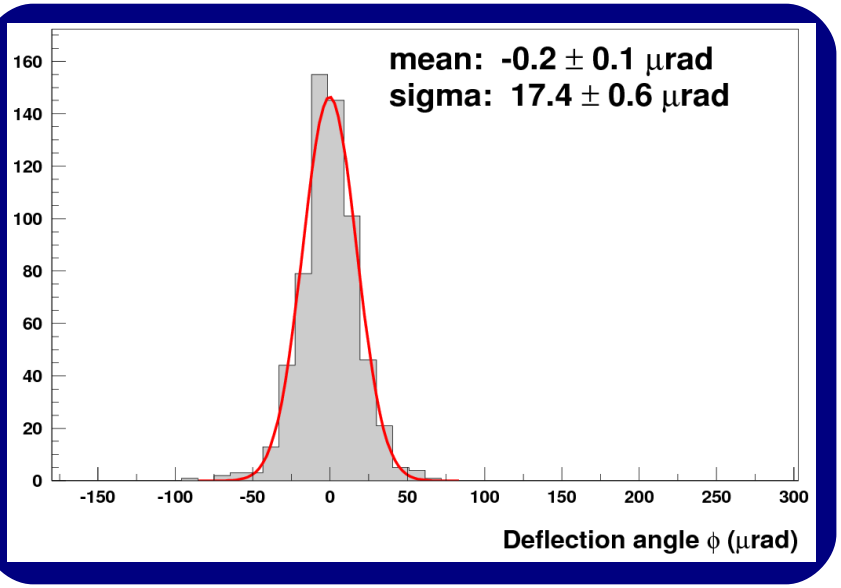
Double sided silicon microstrip detector
Physical strip pitch: 25um
Resolution: 6um

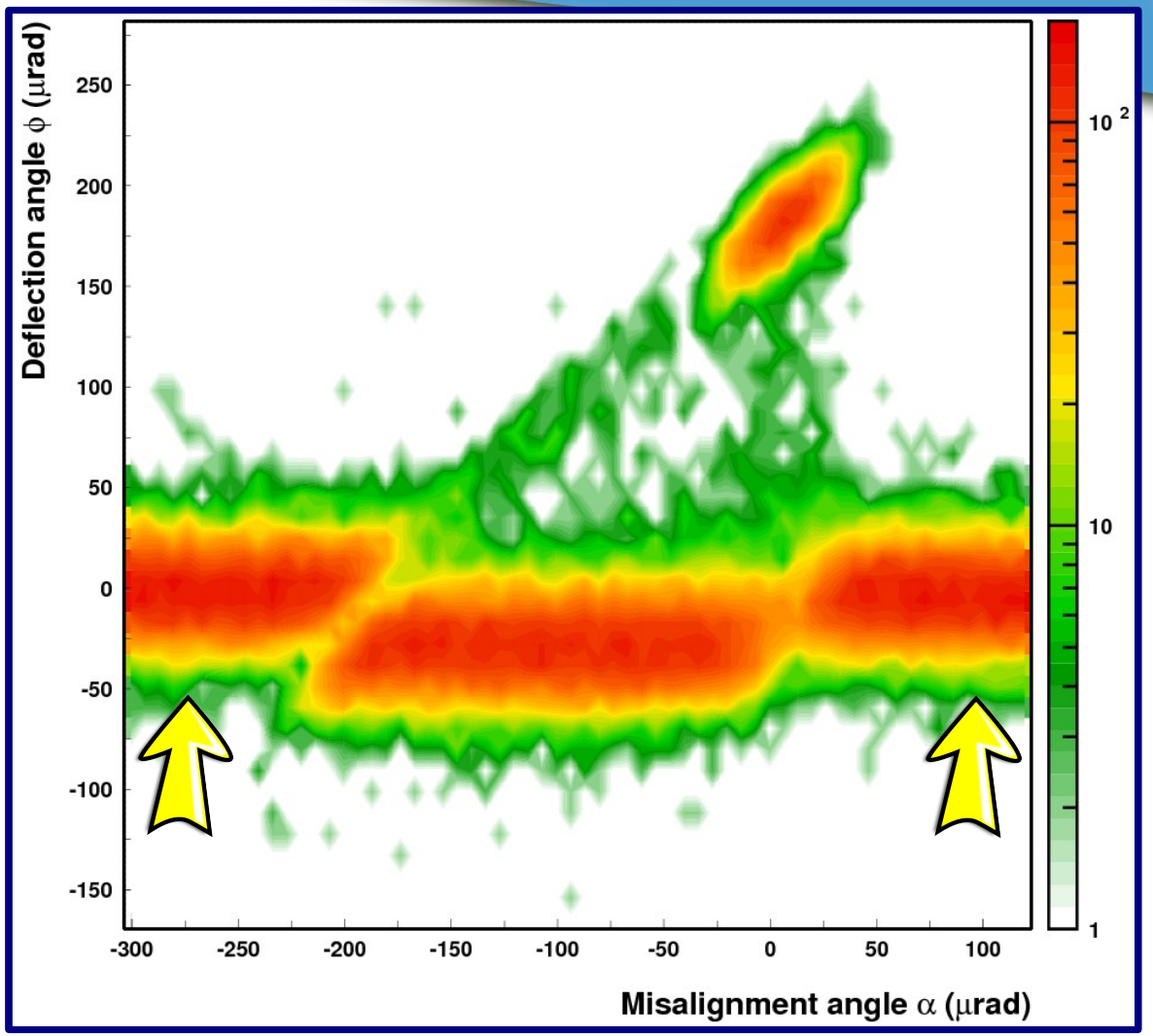


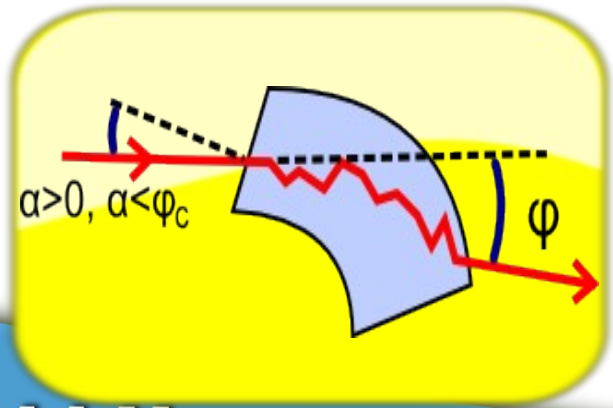
High resolution goniometer (res: ~1urad)
2 rotational and 2 linear movements

Deflection measurements

Misaligned crystal → Amorphous behaviour







2mm silicon strip crystal aligned along the (110) plane

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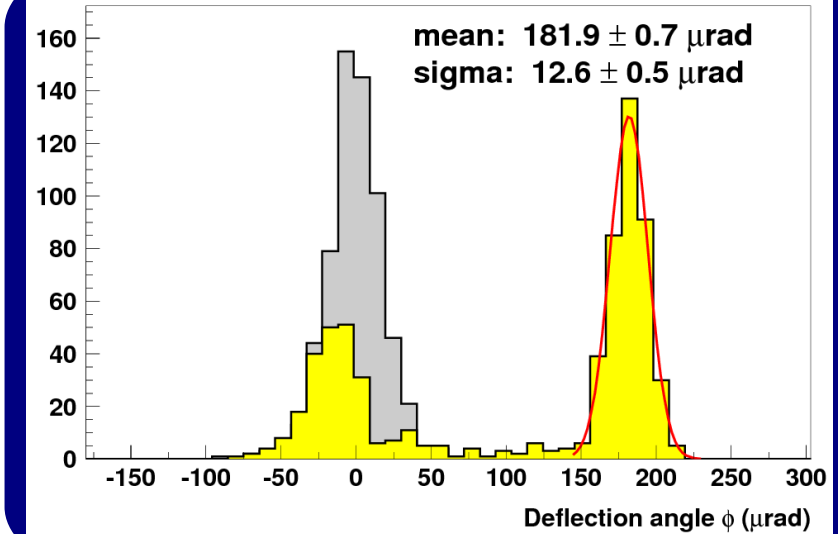
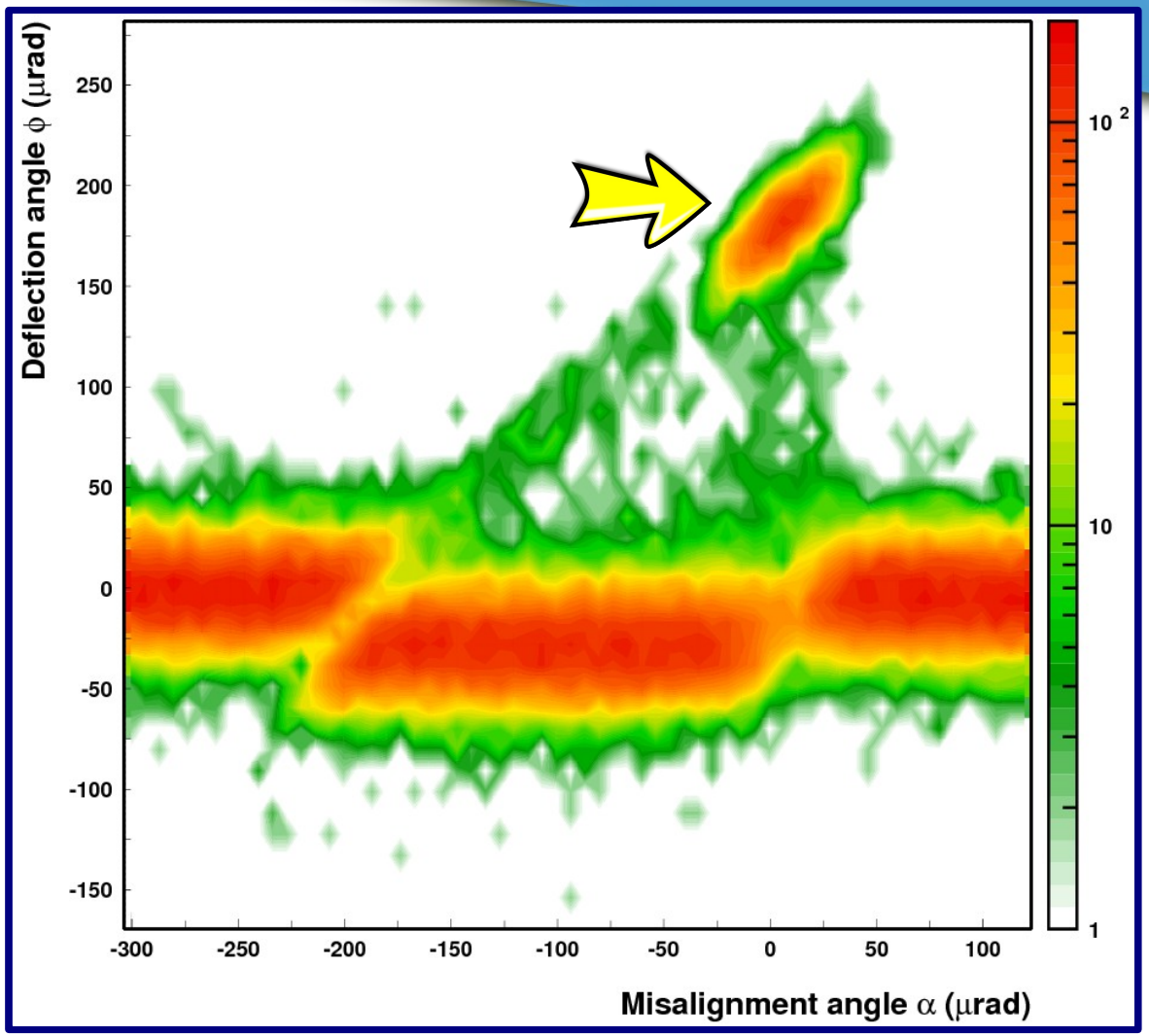
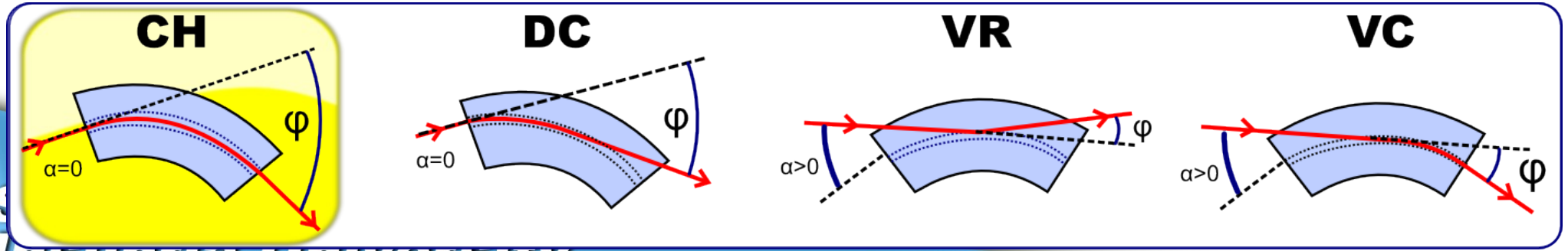
Deflection measurements

Perfect alignment → channeling

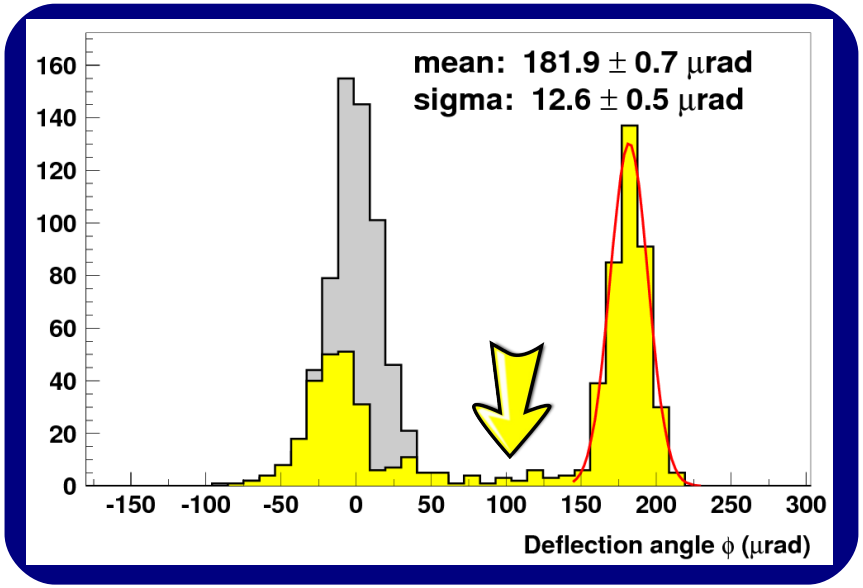


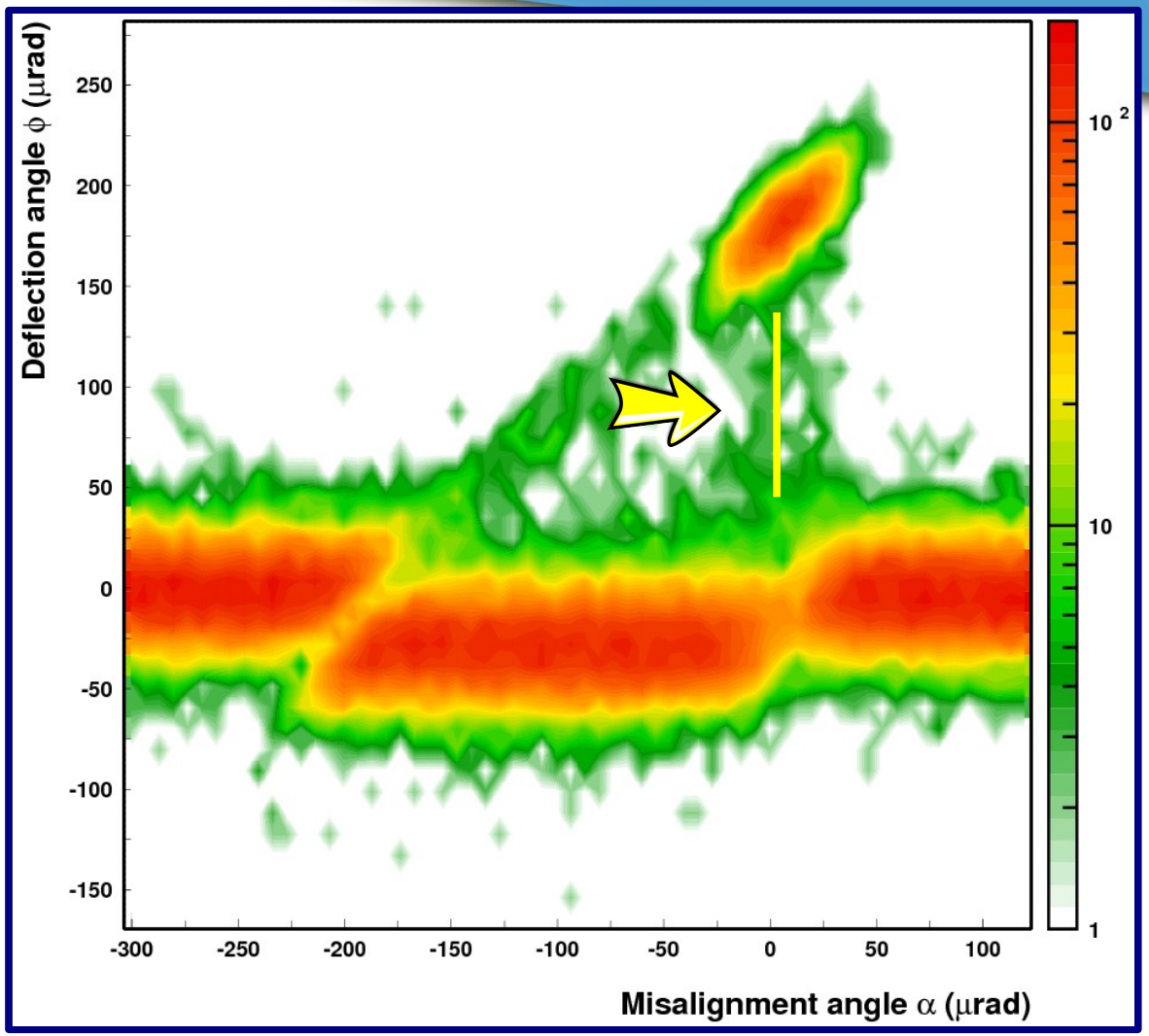


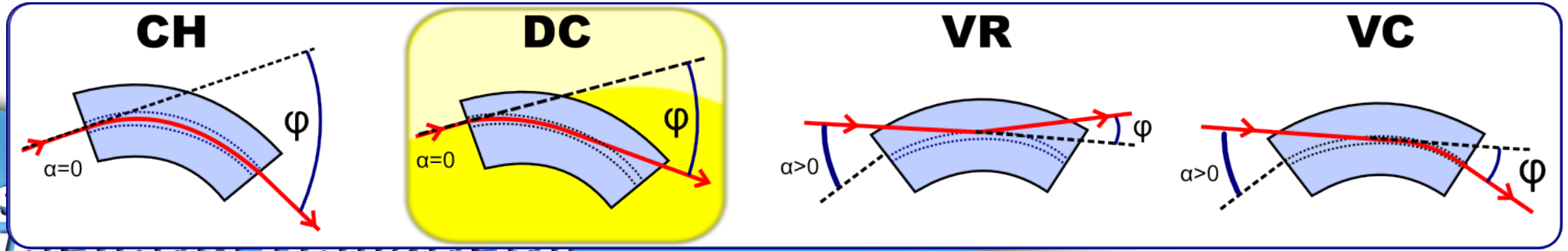


Deflection measurements

Perfect alignment → dechanneling

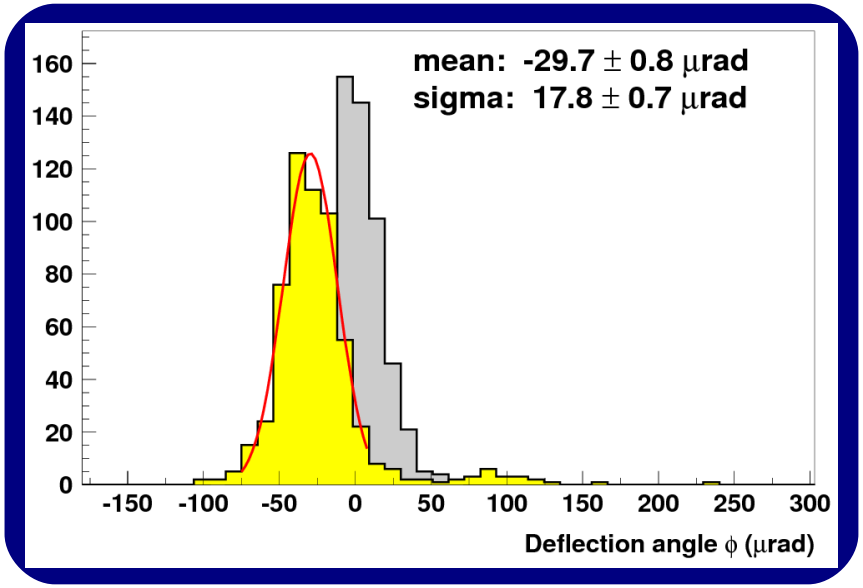


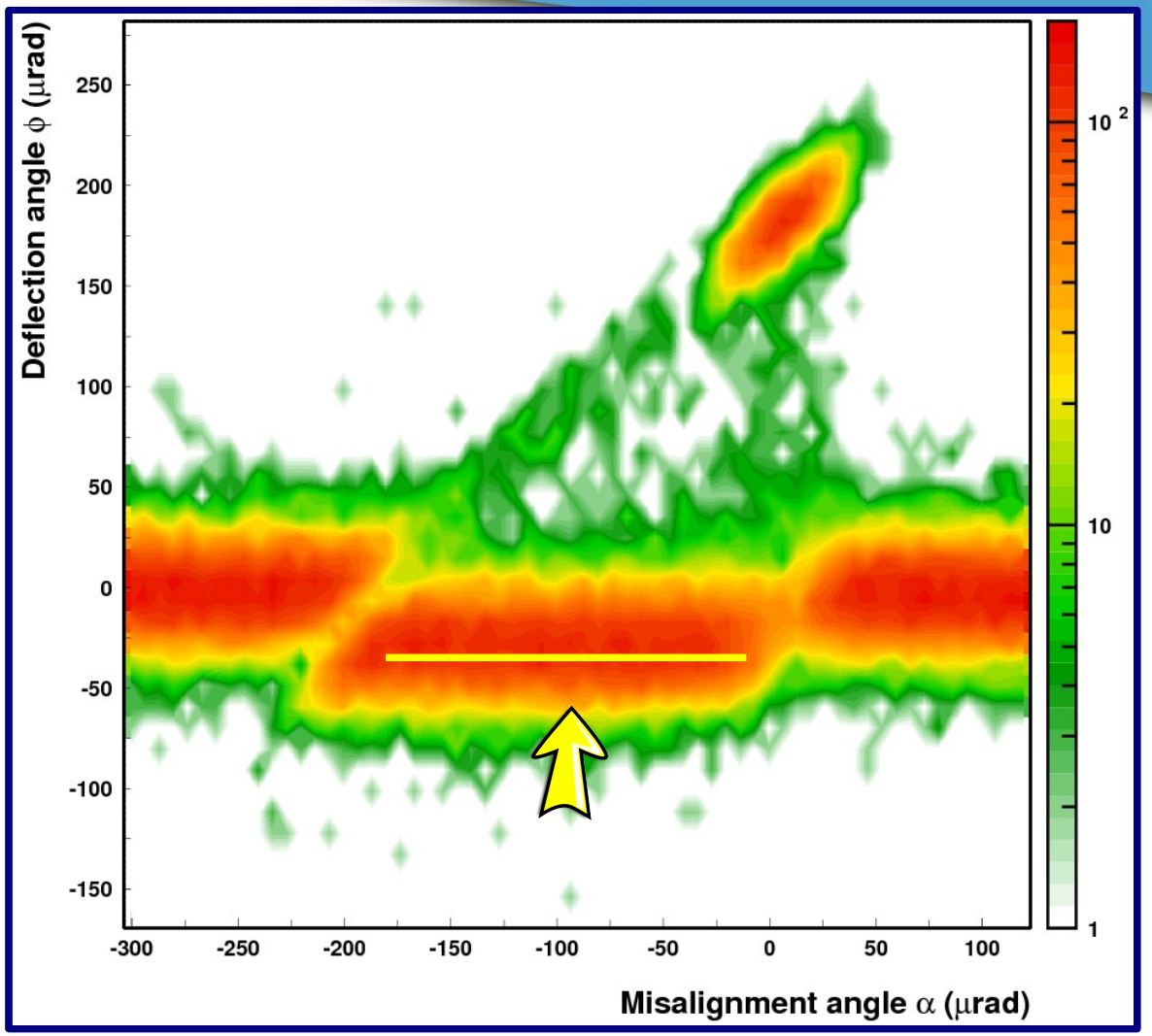


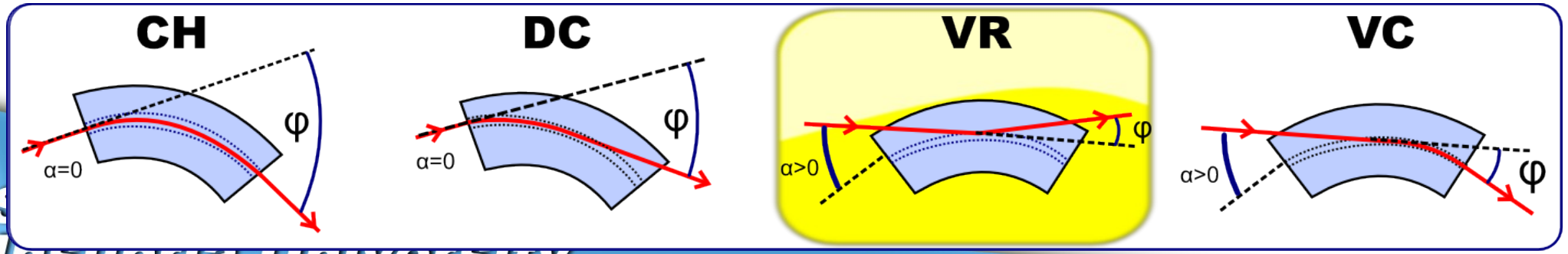


Deflection measurements

Tangency inside crystal → Volume Reflection

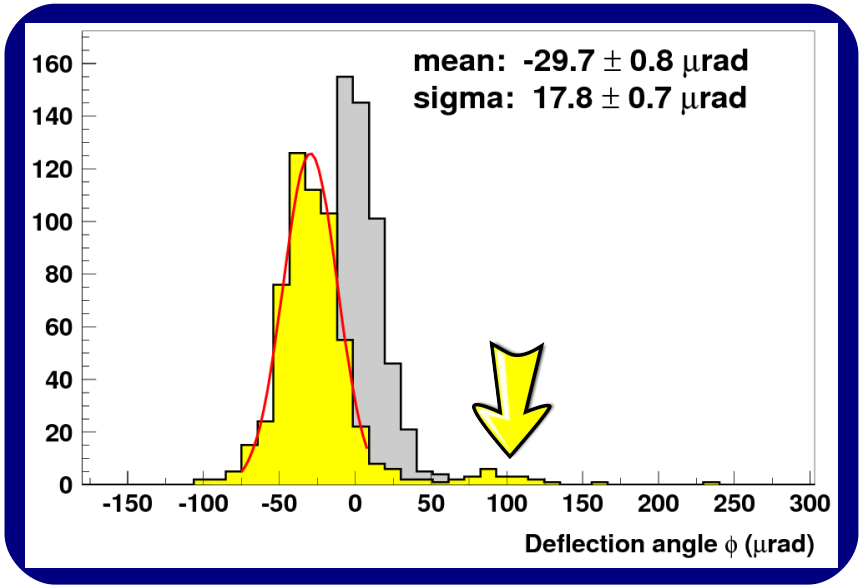


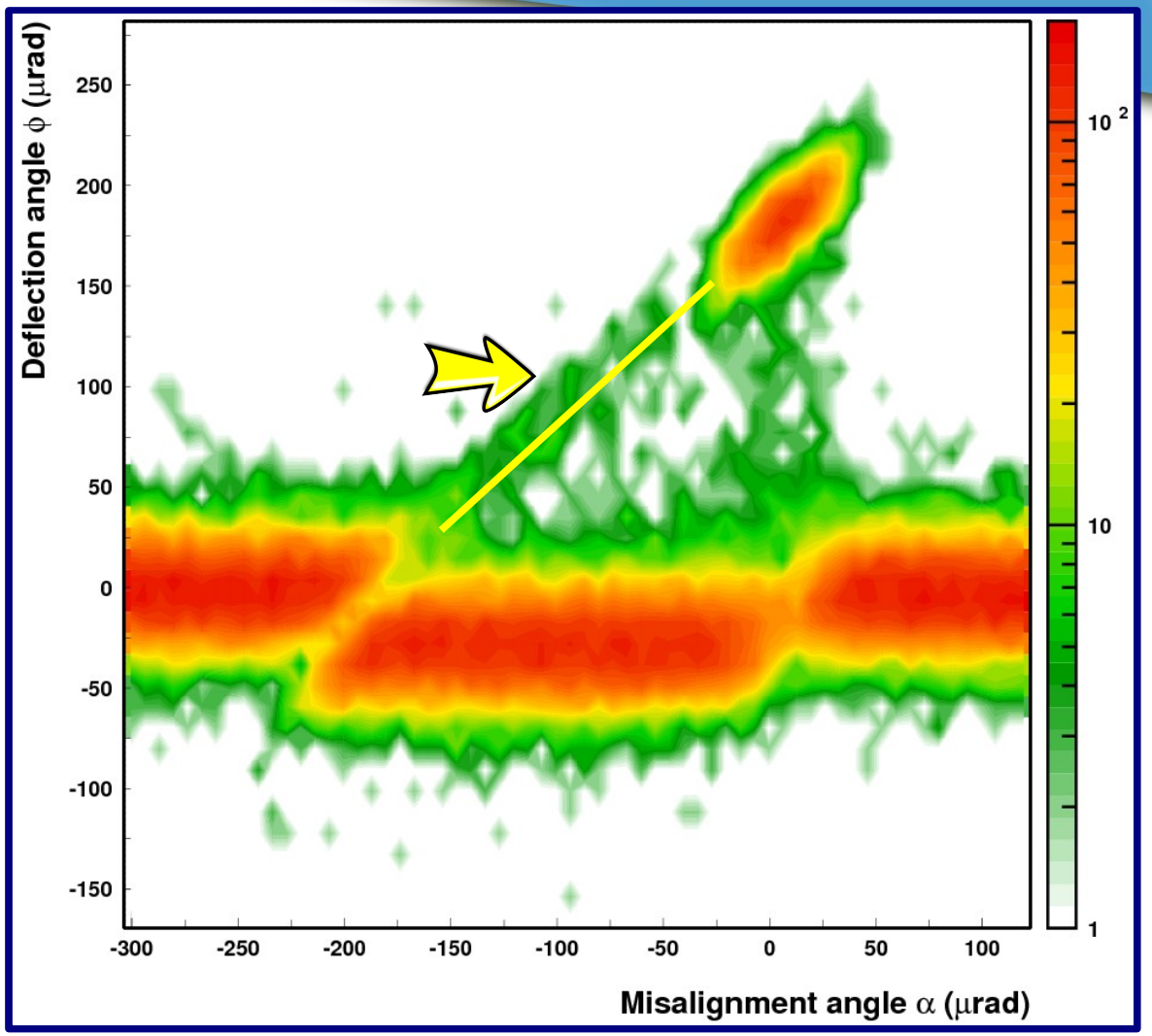


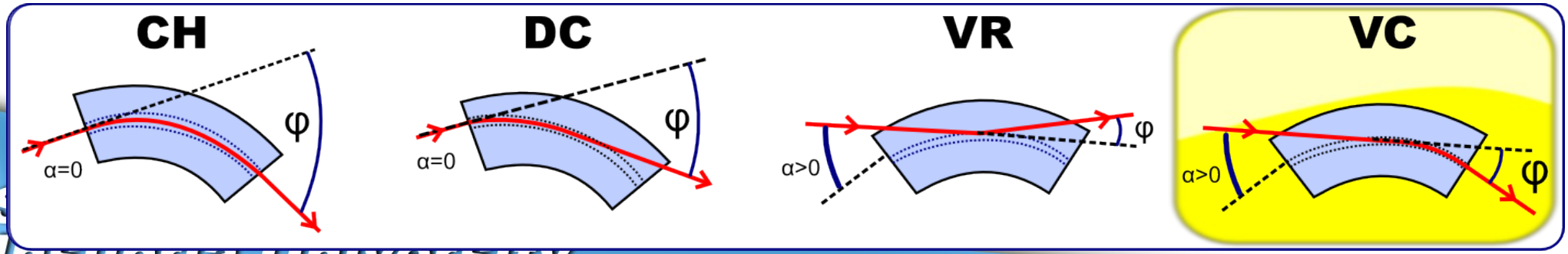


Deflection measurements

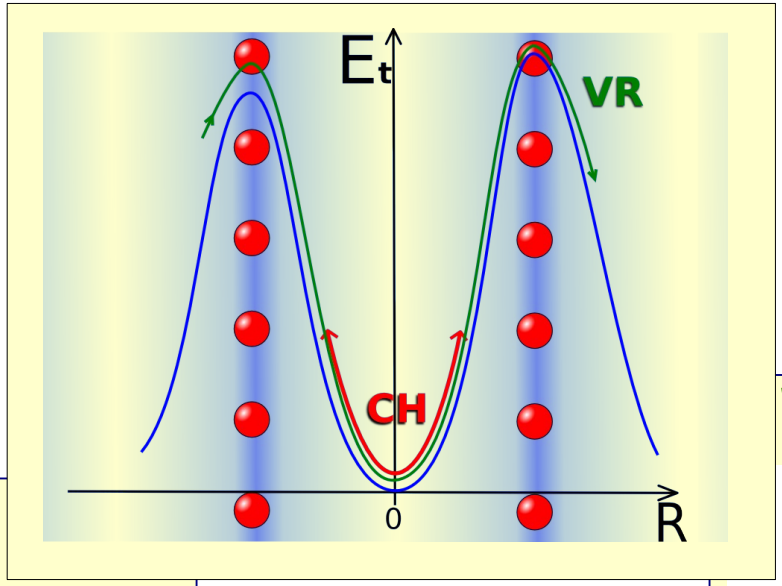
Tangency inside crystal → Volume Capture



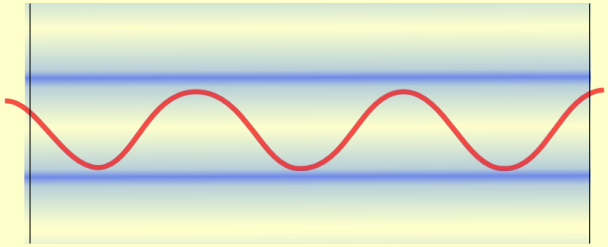




High energy photons from bent crystals

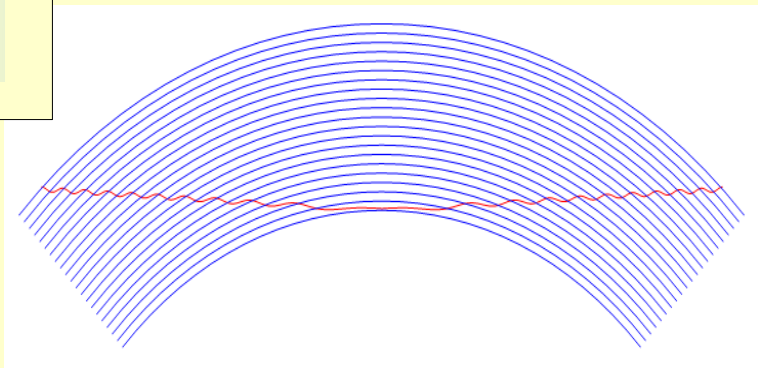


Channeling



particles confined in the interplanar potential that perform quasi harmonic oscillations emitting radiation

Volume reflection



particles slightly over barrier cross the crystalline plane with an angle which varies along the trajectory

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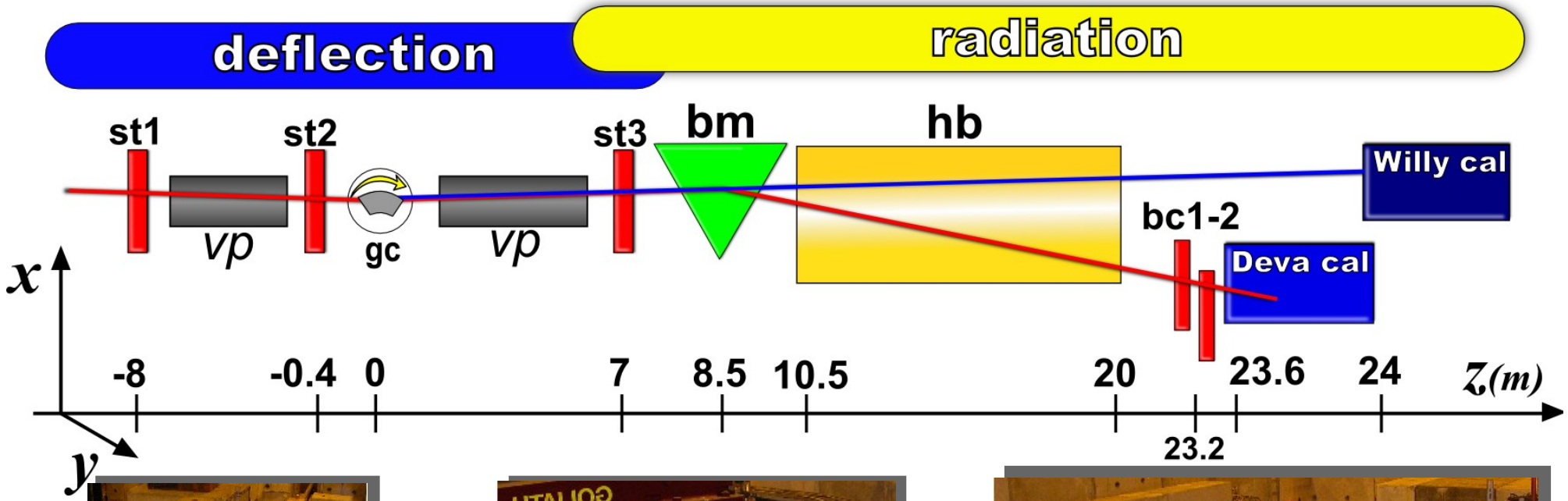
Insubria University

Why measure radiation from bent crystals?

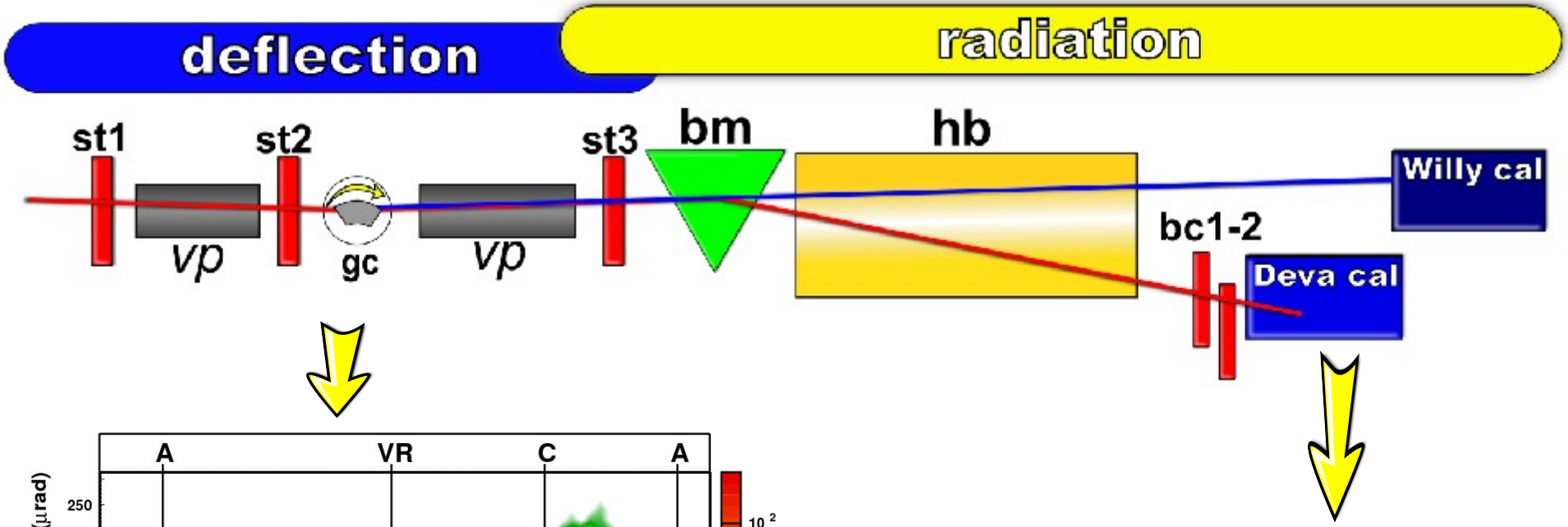
- ***Bent crystals are devices that can be used for many applications; the most important are: beam collimation, beam extraction, beam splitting***
  - At the moment they are addressed to hadron machines (e.g. LHC collimation)
  - A future application to electron-positron machines should take into account the radiation issue
- ***The high amount of energy loss inside a bent crystal can be used to perform collimation in an electron-positron machine***
- ***The electromagnetic cascade inside a bent crystal can be exploited to design a high intensity electron-positron source***
- ***Bent crystals can be used as a high intensity photon source dedicated to nuclear physics studies or detector tests such as calibration***

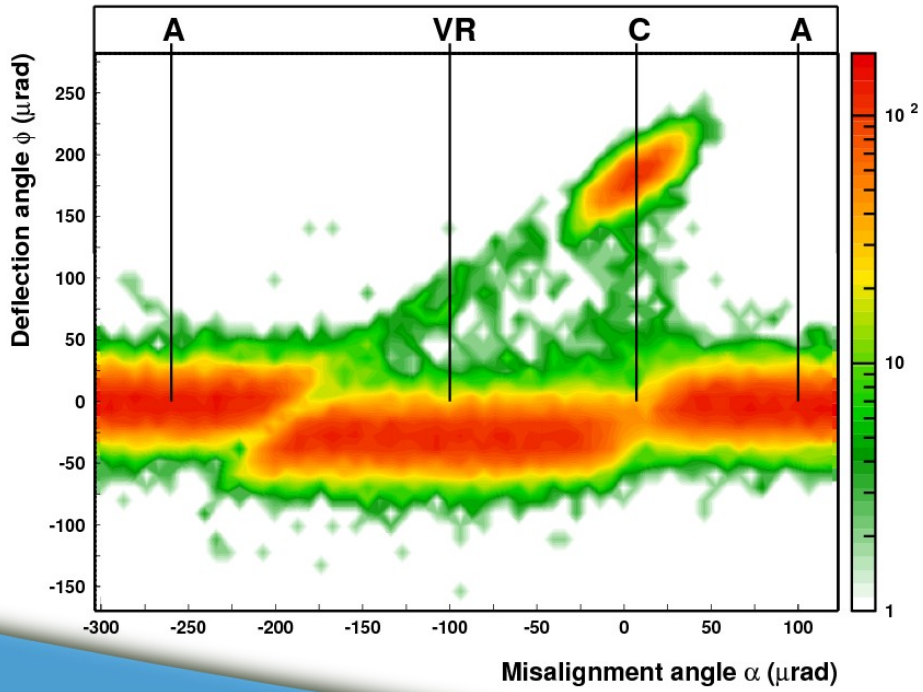
Let's measure it!

September 2009, H4 beam line (CERN, SPS), 120 GeV positrons

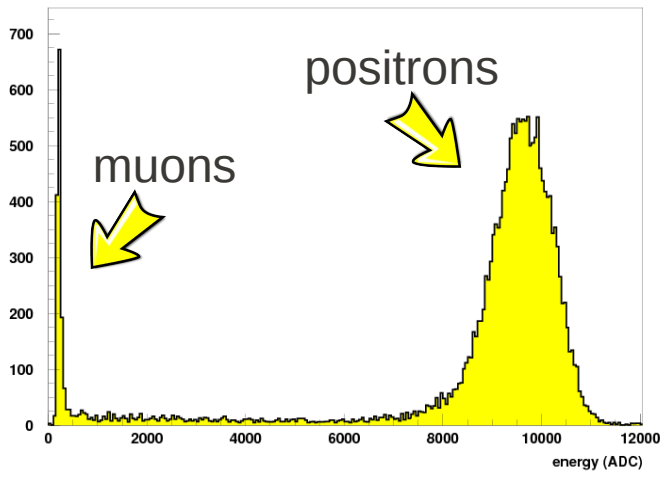


Let's measure it





Identification of the primary particle



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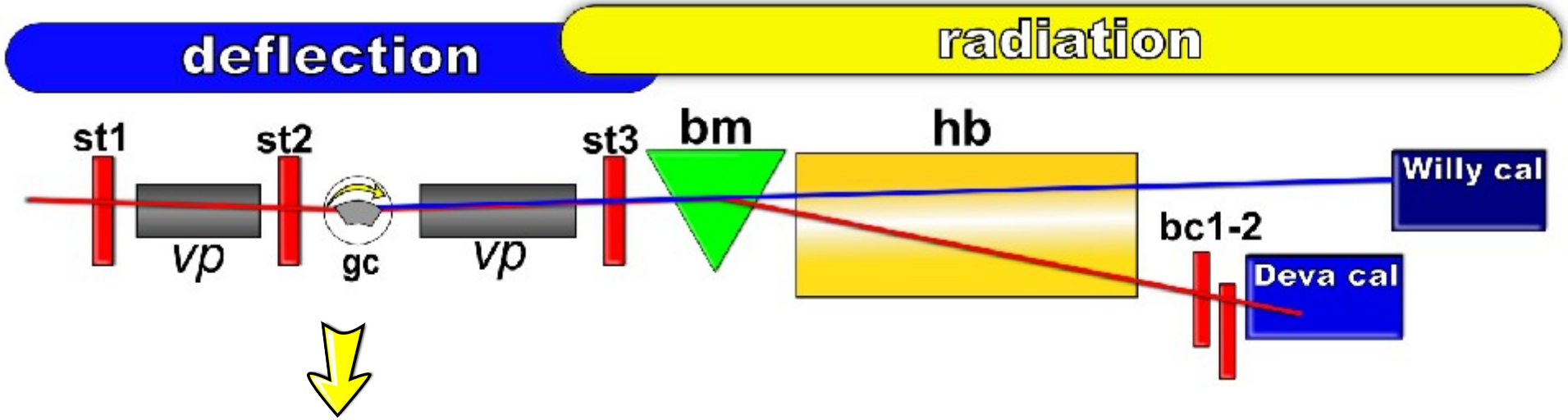
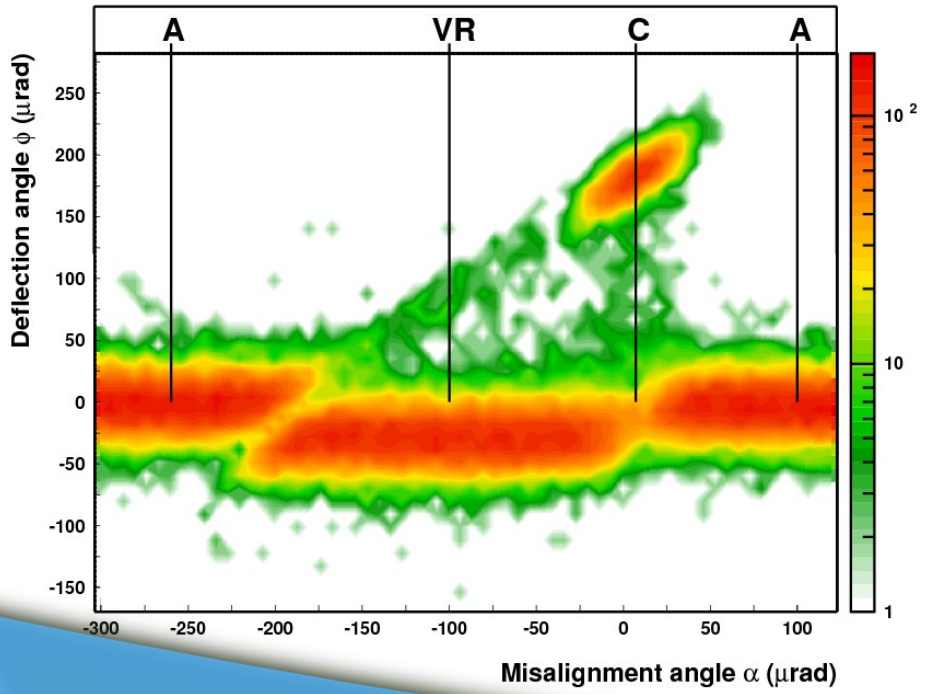
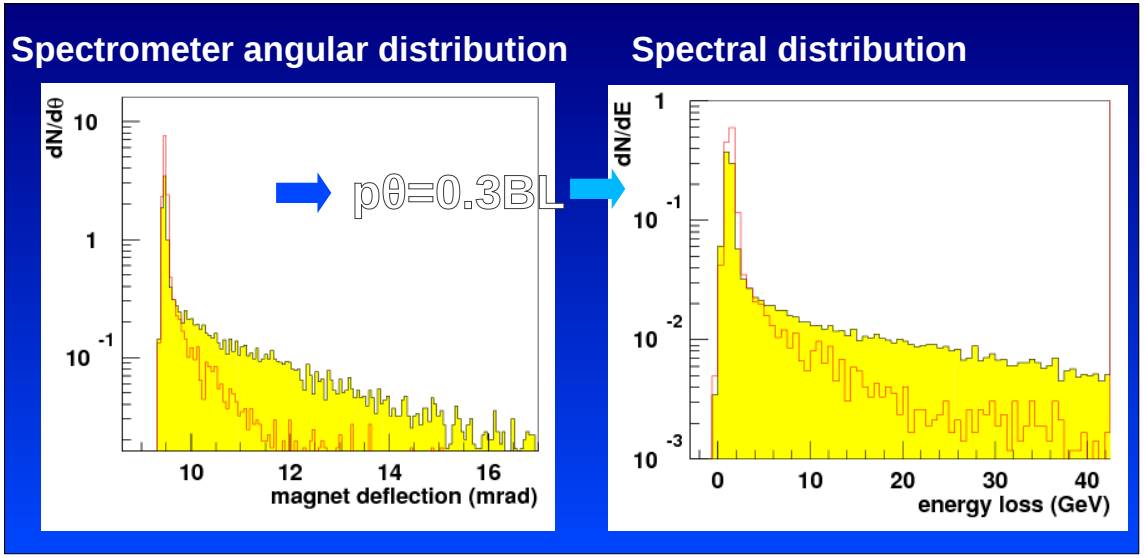
Insubria University

Radiation

Let's measure it







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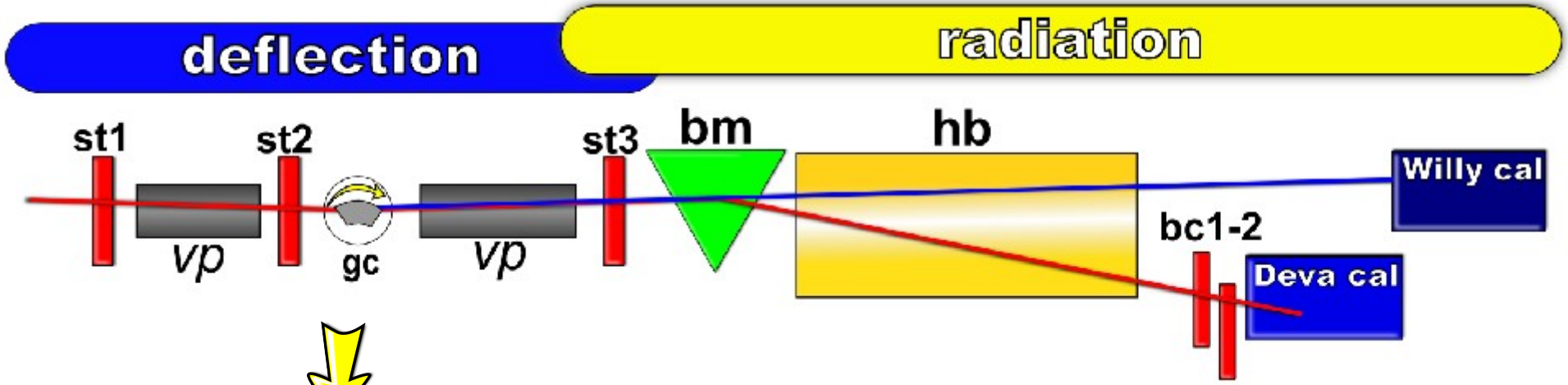
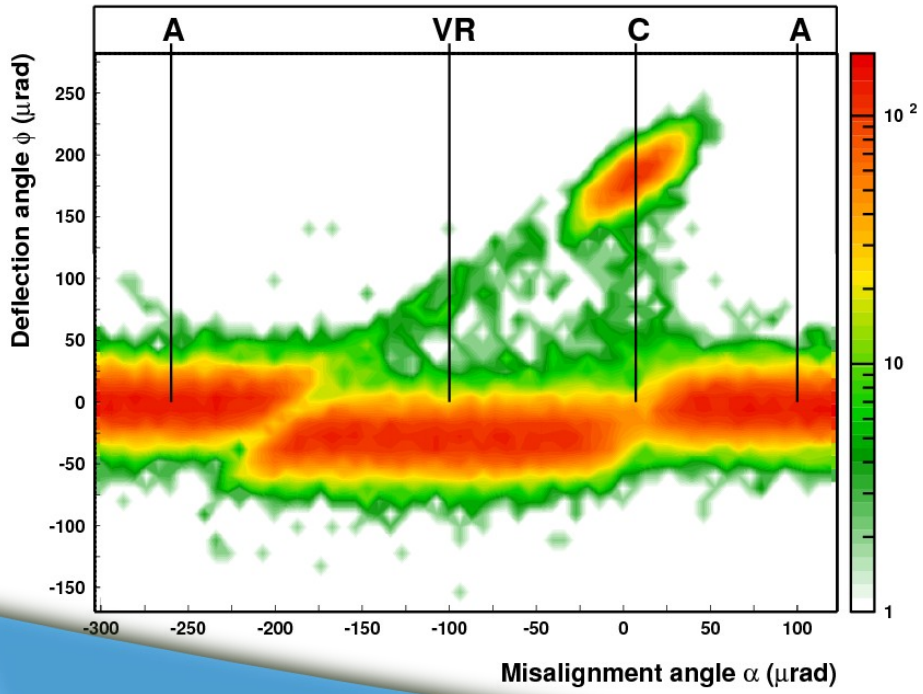
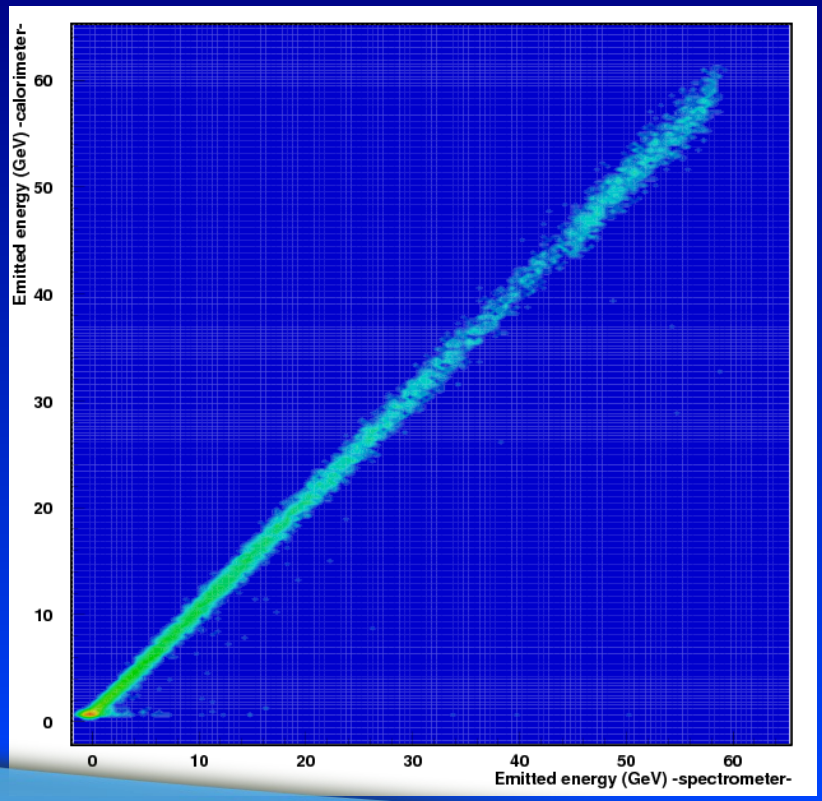
Radiation

Let's measure it





Comparison calorimeter-spectrometer



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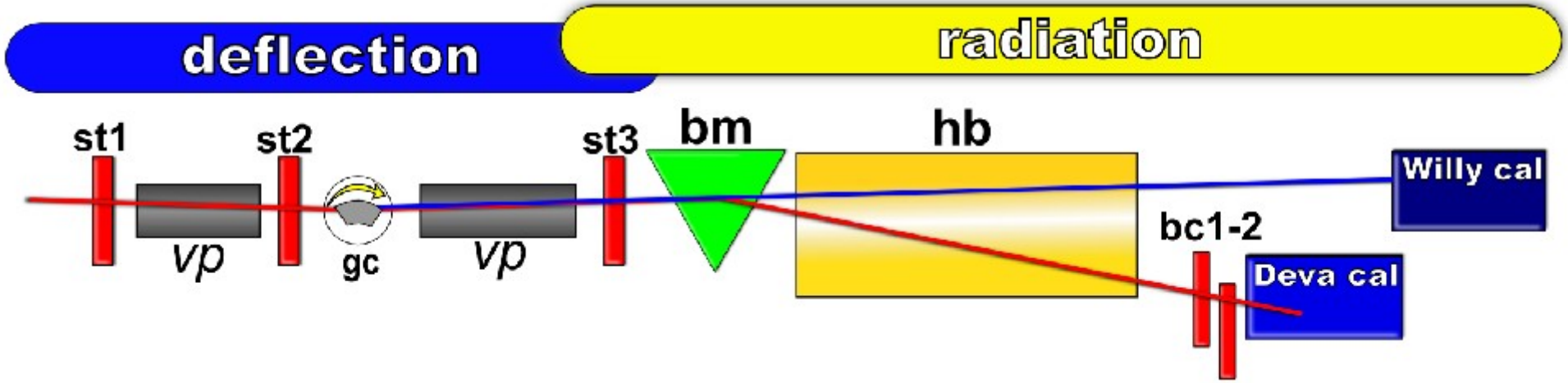
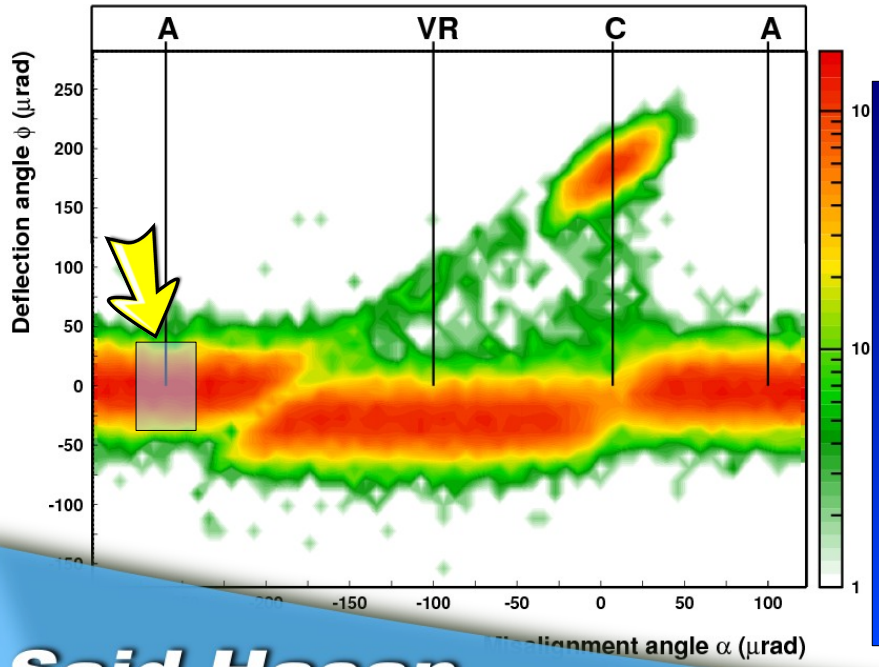
Radiation

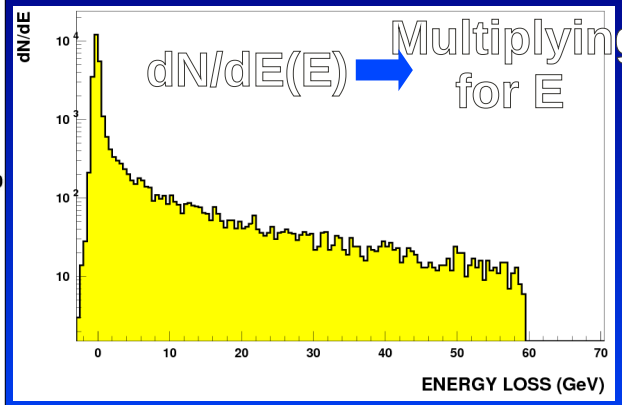
Let's measure it



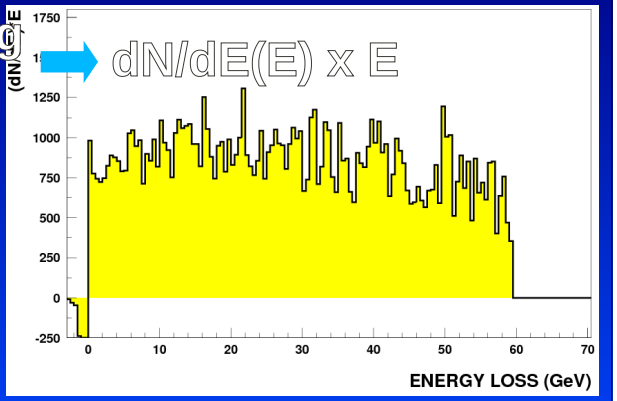
It is possible to "select" an effect and measure its "radiation" properties:



Spectral distribution



Energy loss distribution



Amorphous condition → bremsstrahlung

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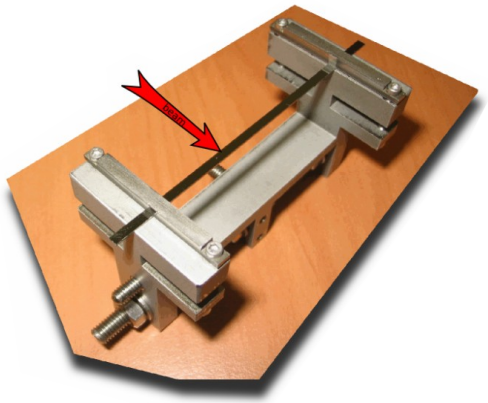
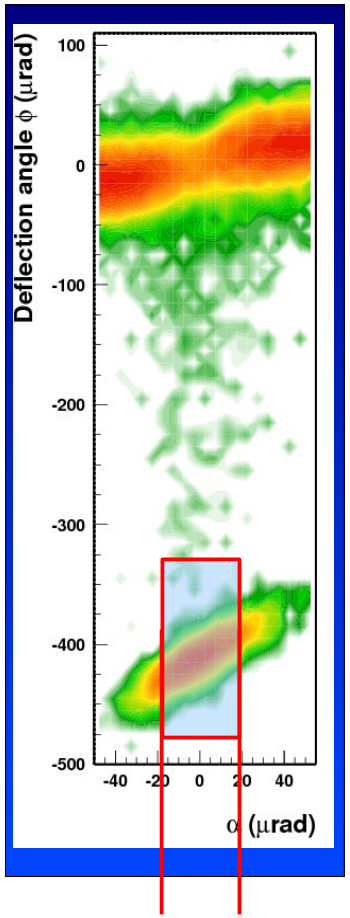
Channeling

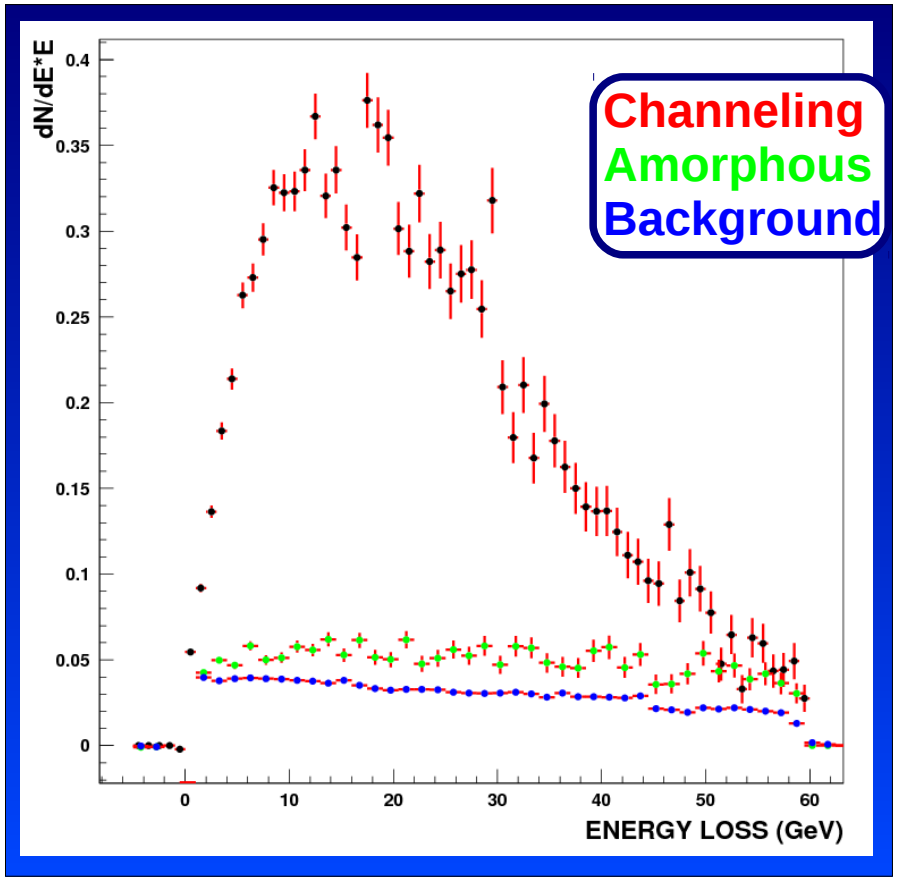
Strip crystal:

2mm of silicon along the beam

~5m bending radius







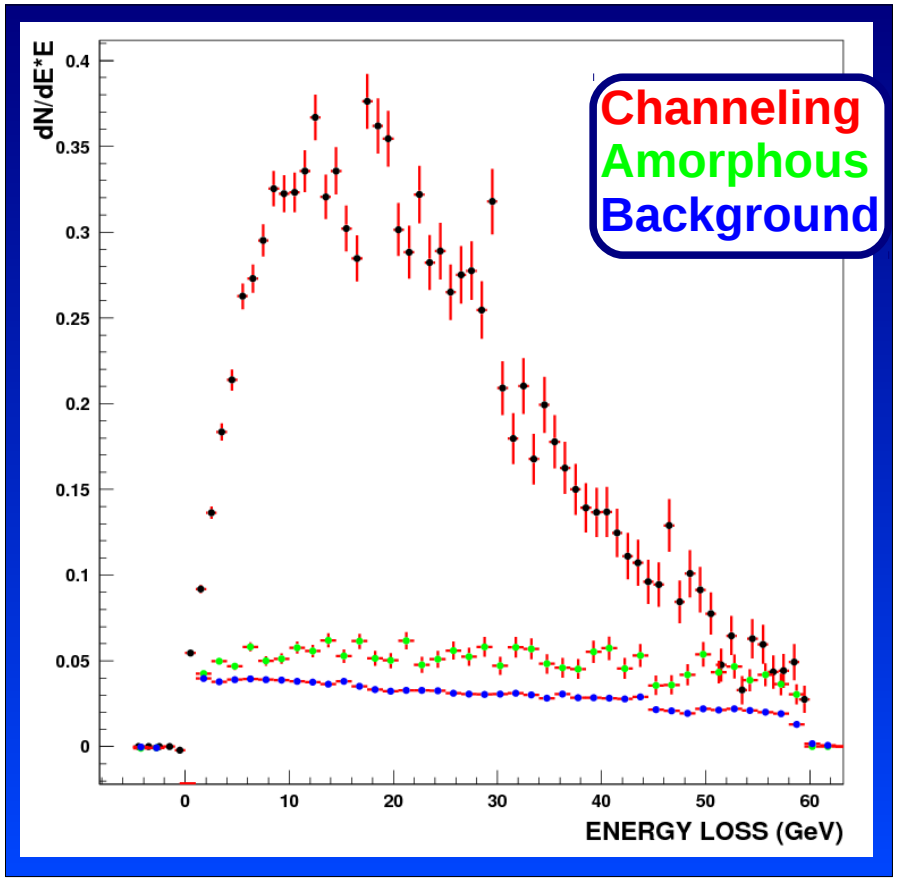
Selected region:

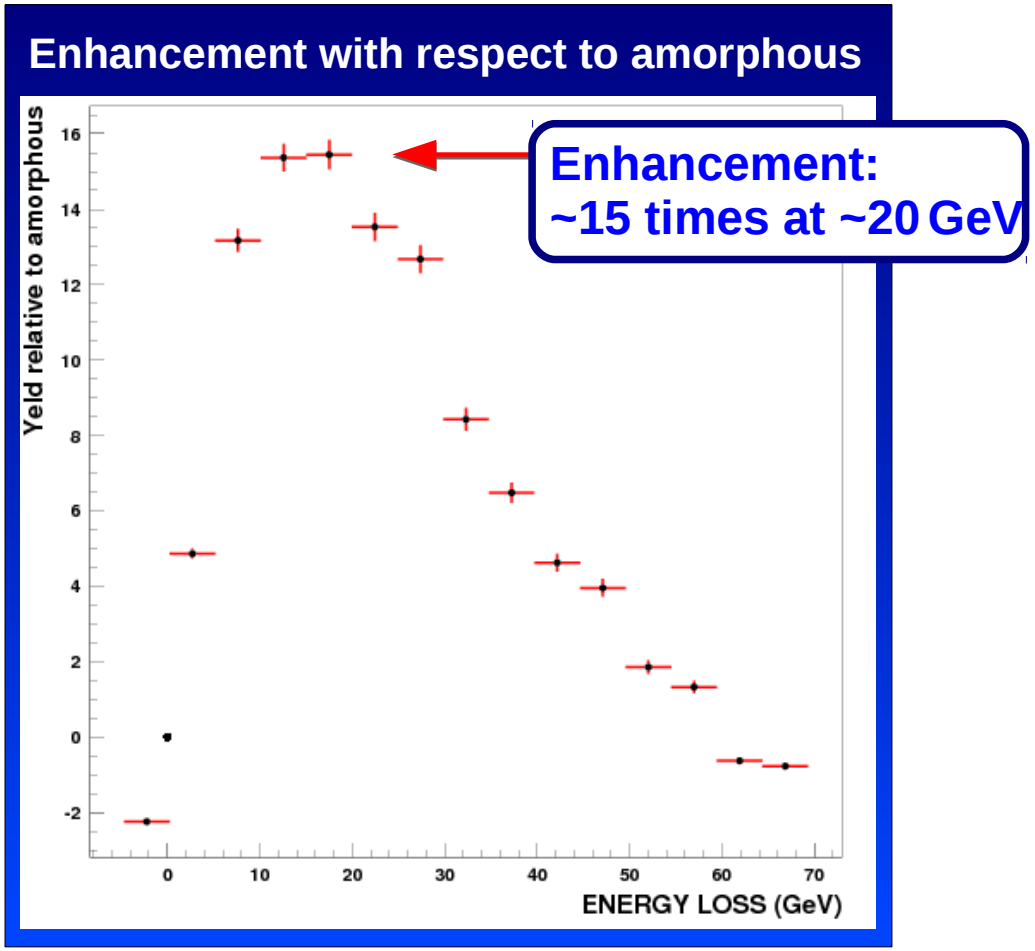
Channeled particle

-9 < α < 9 urad

Radiation Results

Channeling





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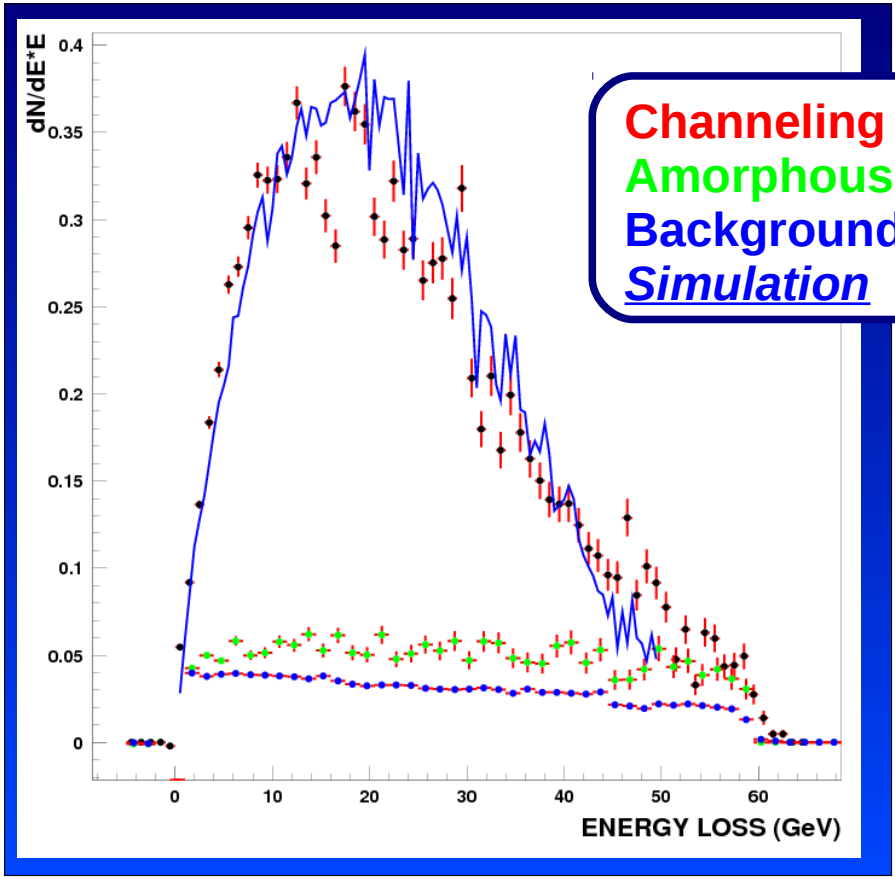
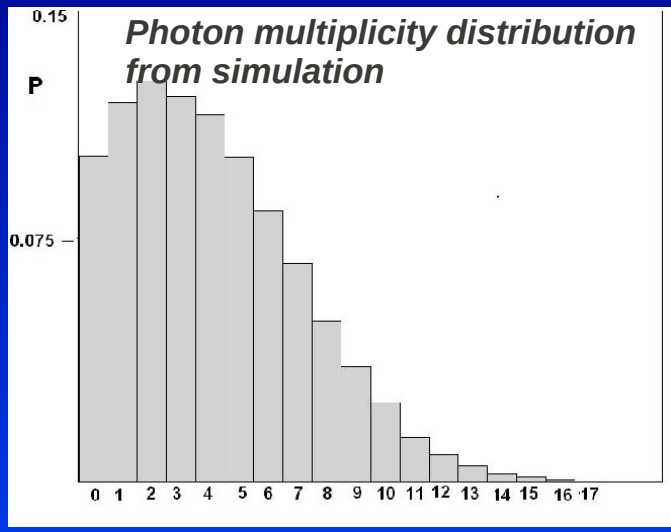
Radiation Results

Channeling



Average energy loss: ~11.7GeV

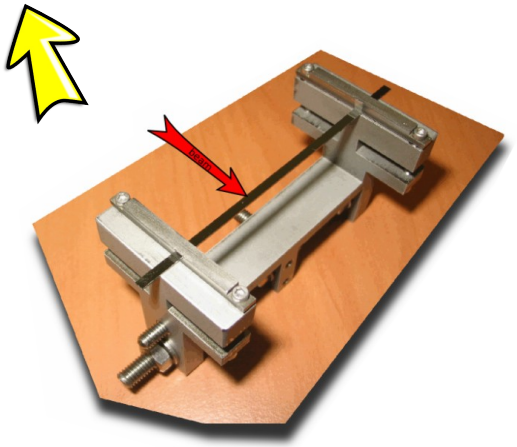


Average photons multiplicity: ~4

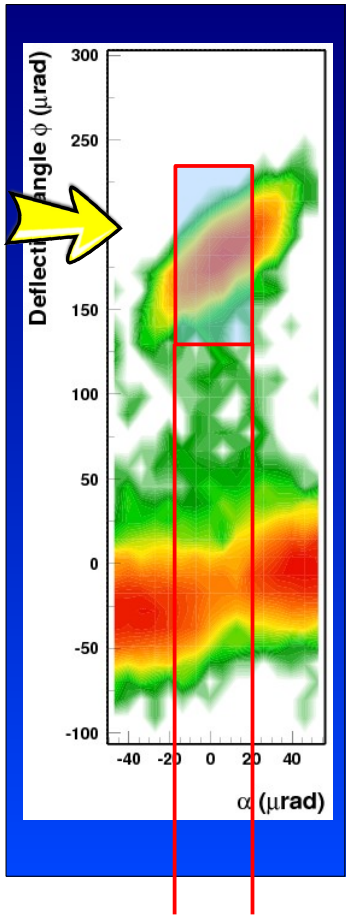
Channeling

The effect of bending is negligible:

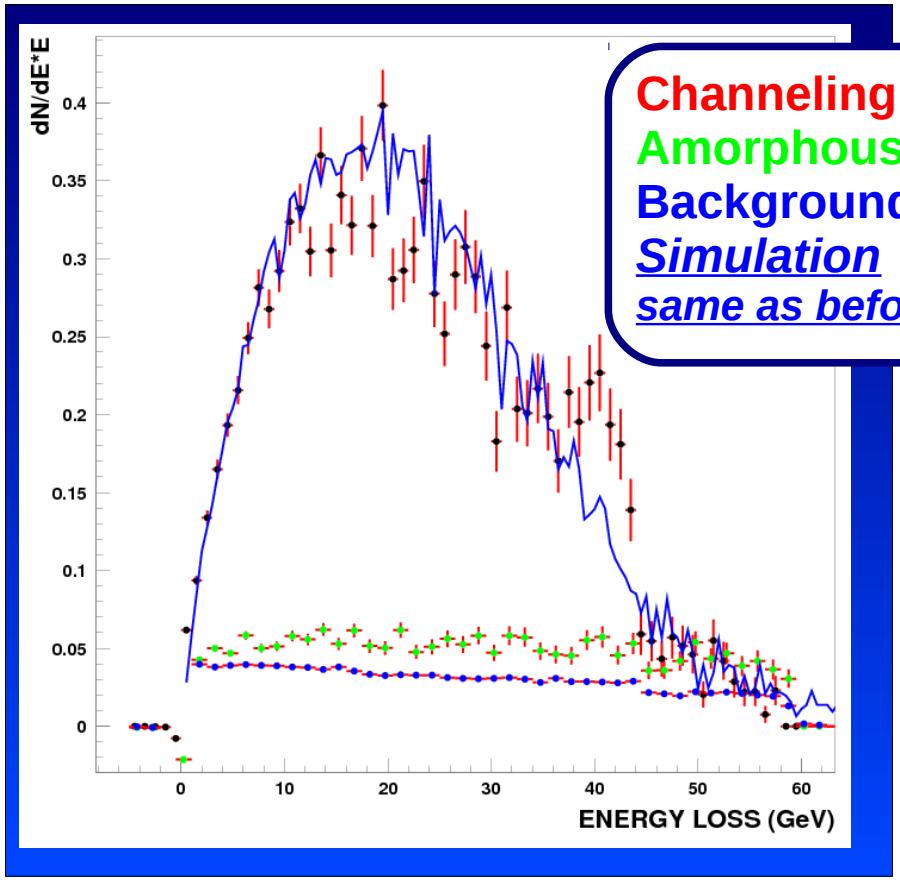
Strip crystal:
2mm of silicon along the beam
~11m bending radius



The same crystal with smaller bending



Selected region:
Channeled particle
-9 < α < 9 urad



Channeling
Amorphous
Background
Simulation
same as before

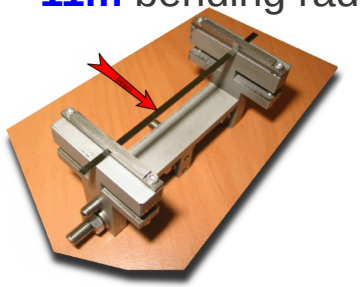
Radiation Results

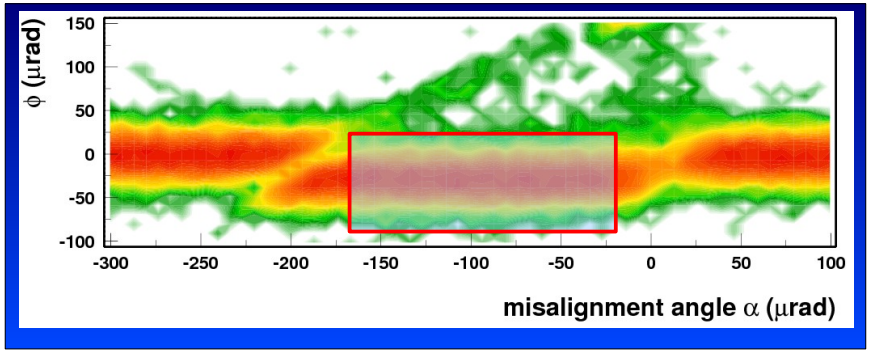
Volume Reflection (present only in bent crystal)

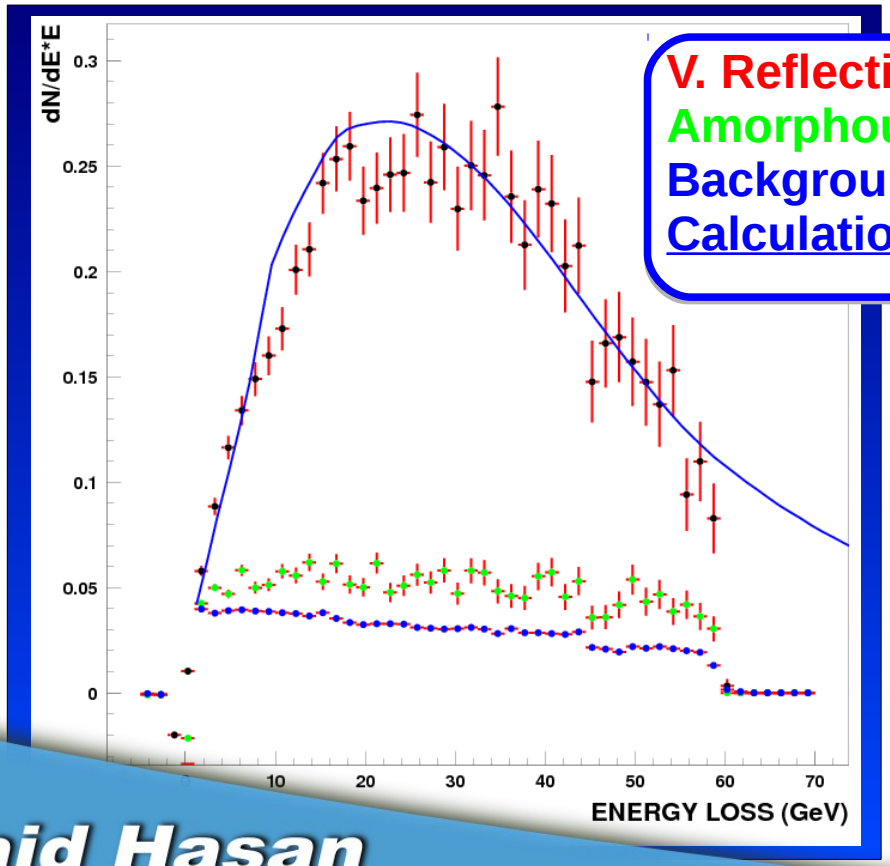
Strip crystal:

2mm of silicon along the beam

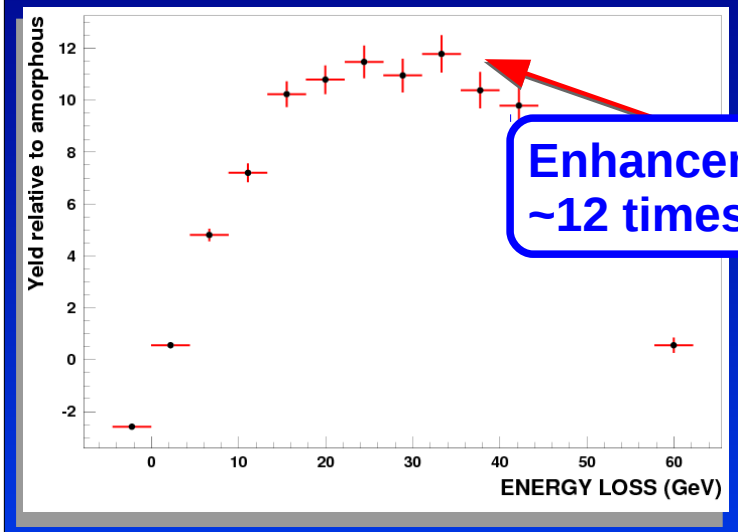
~11m bending radius







Average energy loss: 11.2GeV



Enhancement:
~12 times @ ~30GeV

Average photons multiplicity: ~1.5

The photons spectrum is much harder with respect to the channeling one

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Insubria University

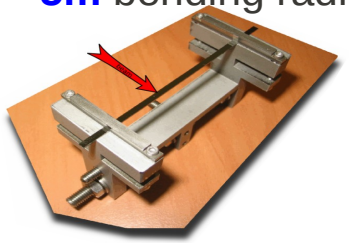
Volume Reflection

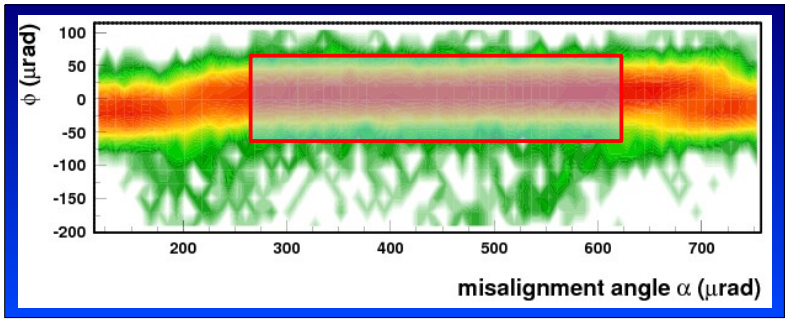
The effect of bending is not negligible:

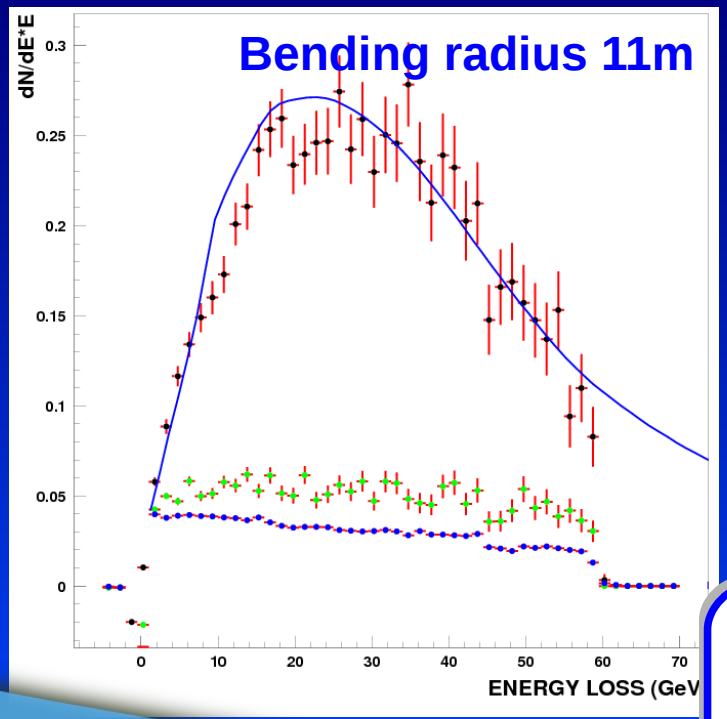
Strip crystal:

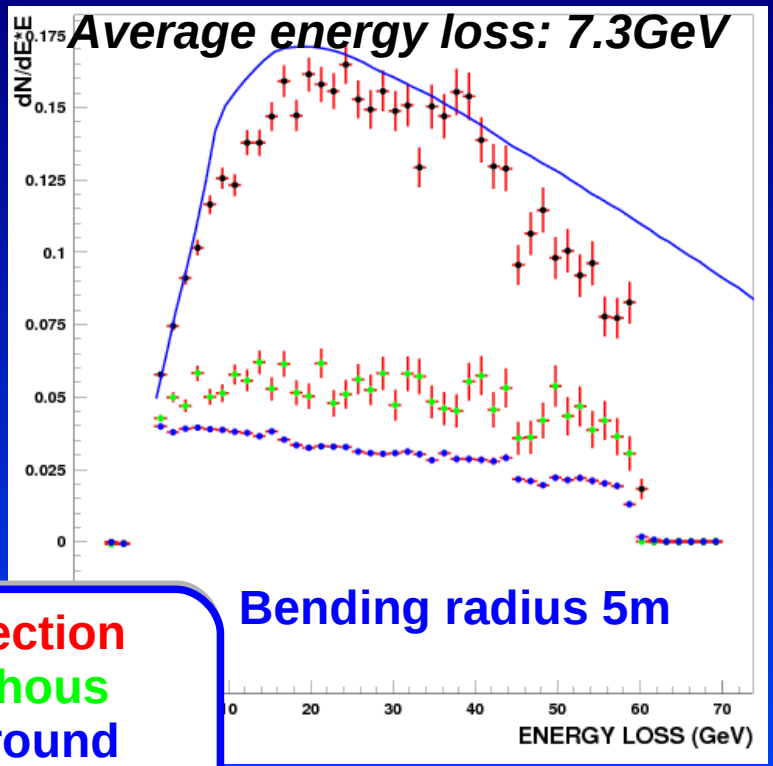
2mm of silicon along the beam

~5m bending radius









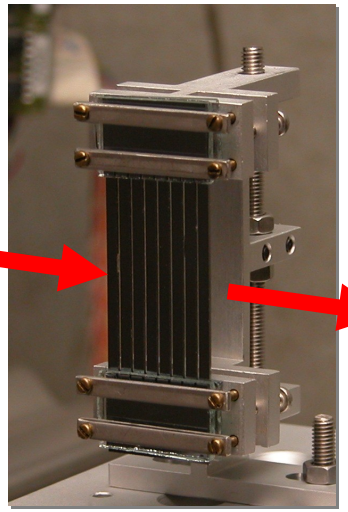
V. Reflection
Amorphous
Background
Calculation

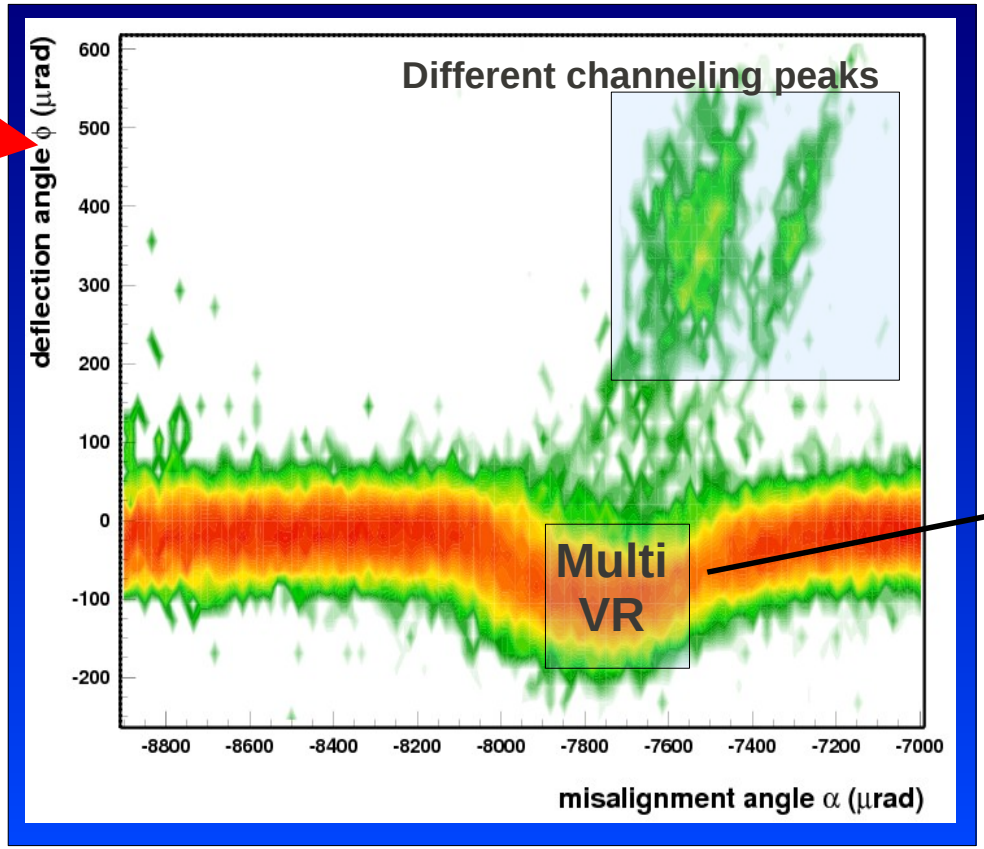
Said Hasan
Insubria University

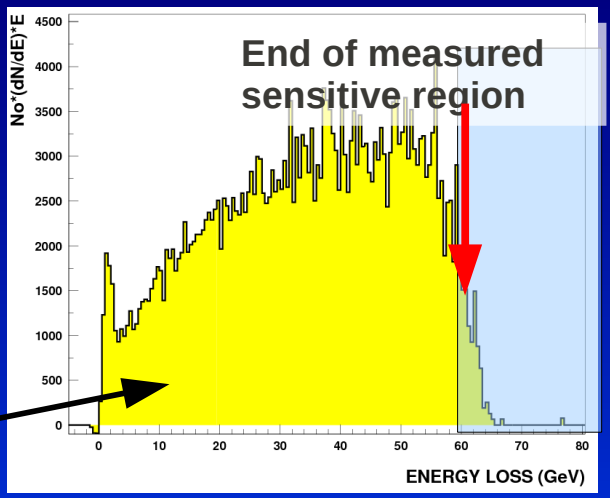
Increasing the emitted energy

Volume Reflection → larger angular acceptance

➡ *Using a series of crystals to increase deflection and radiation is possible!*







The radiation energy loss shows an amplification but it is not possible either to view all the spectrum or to normalize it as the spectrometer is sensitive until ~60GeV

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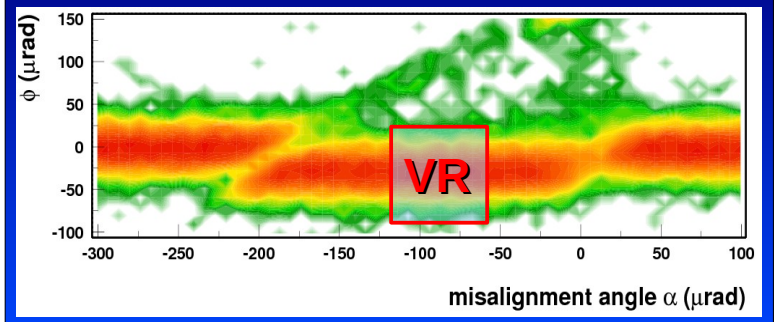
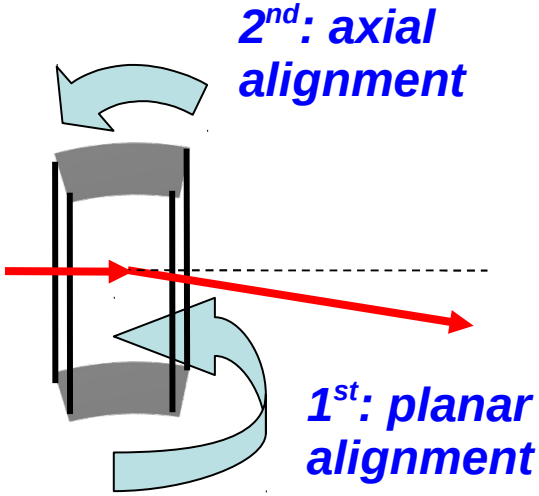
Insubria University

Increasing emitted energy

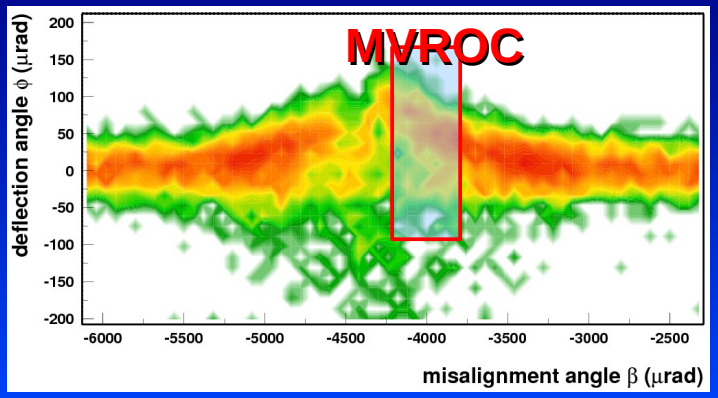
Axial alignment → Multivolume reflection in one crystal

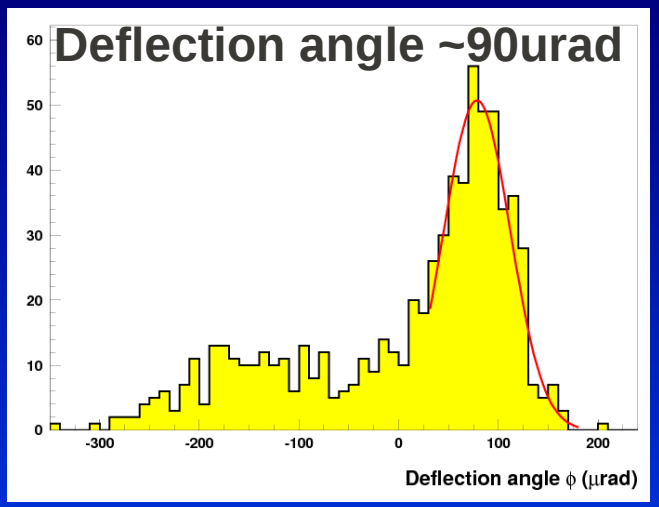
1st: planar alignment

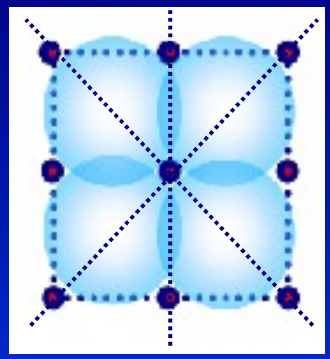




2nd: axial alignment







A crystal axis is the intersection of several planes
If a particle beam impinges onto the crystal at an appropiate angle, it is subject to volume reflections from subsequent planes

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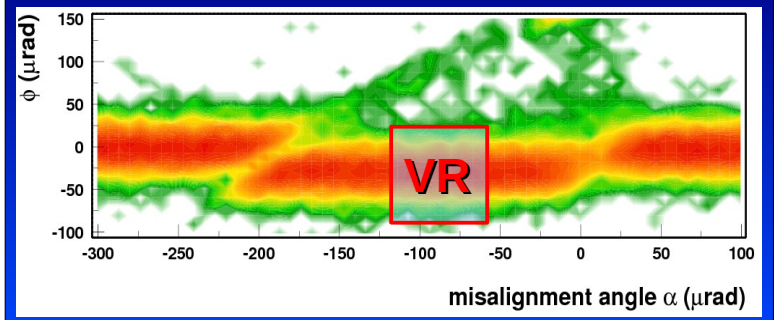
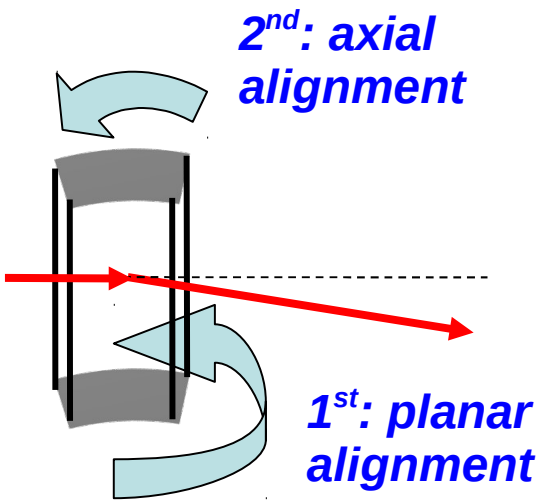
Insubria University

Increasing emitted energy

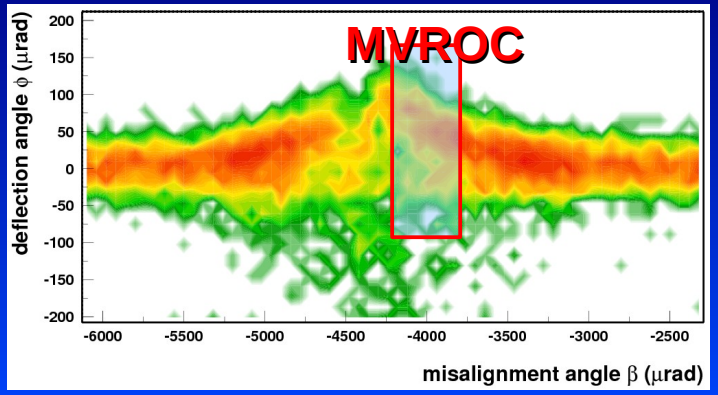
Axial alignment → Multivolume reflection in one crystal

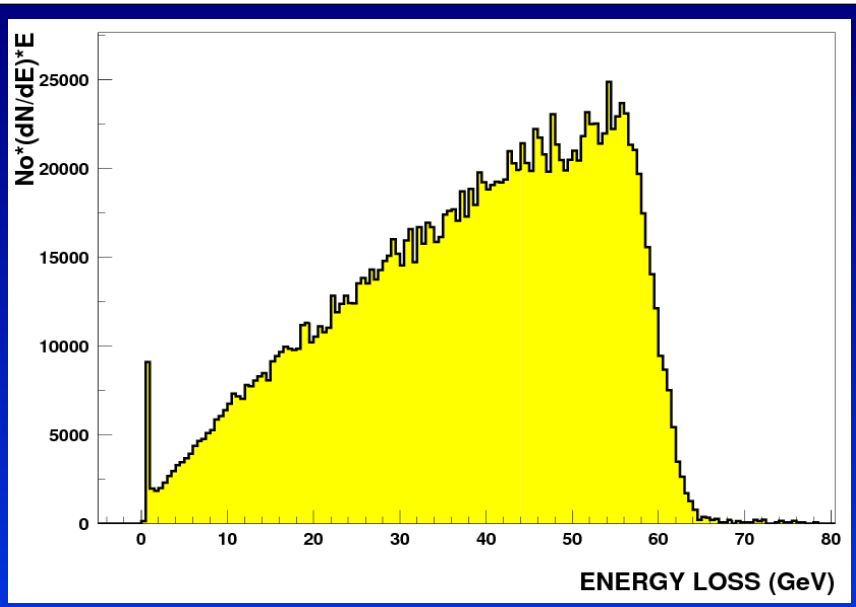
1st: planar alignment





2nd: axial alignment





As well as for the “crystal series” the measurement is limited by the spectrometer acceptance thus it provides only a qualitative result

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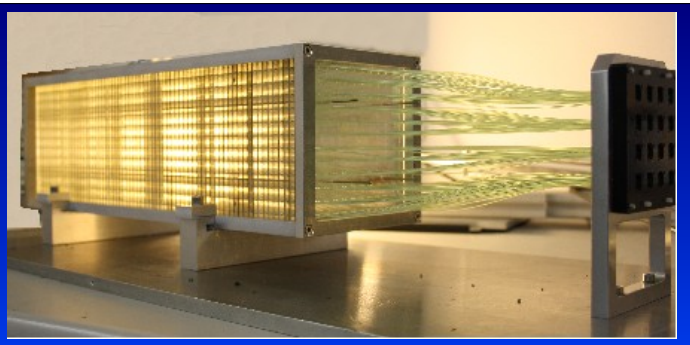
Insubria University

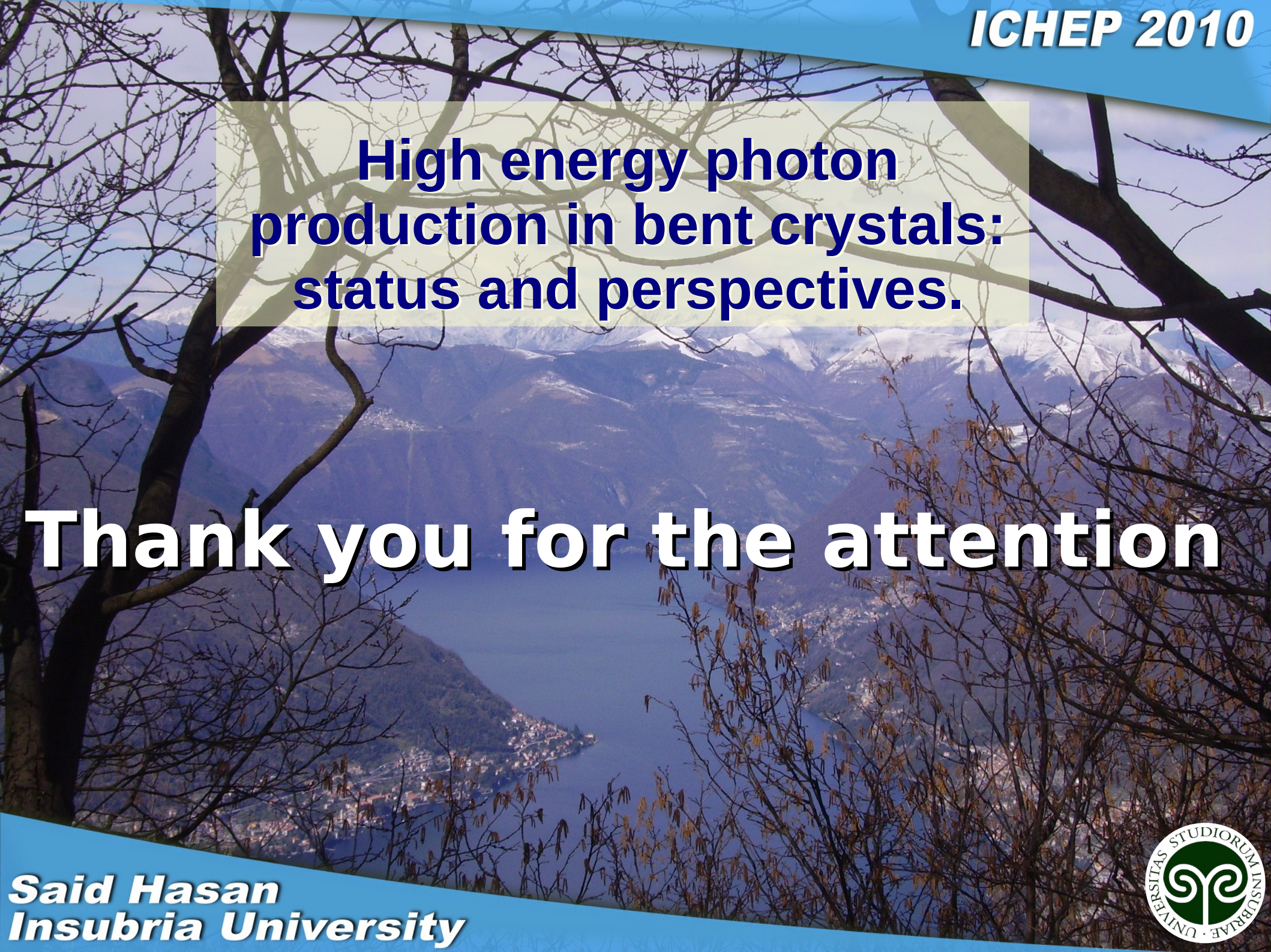
Conclusions and outlooks

- Bent crystals → for particle deflection → radiation emission
  - *Volume Reflection*
  - *channeling*

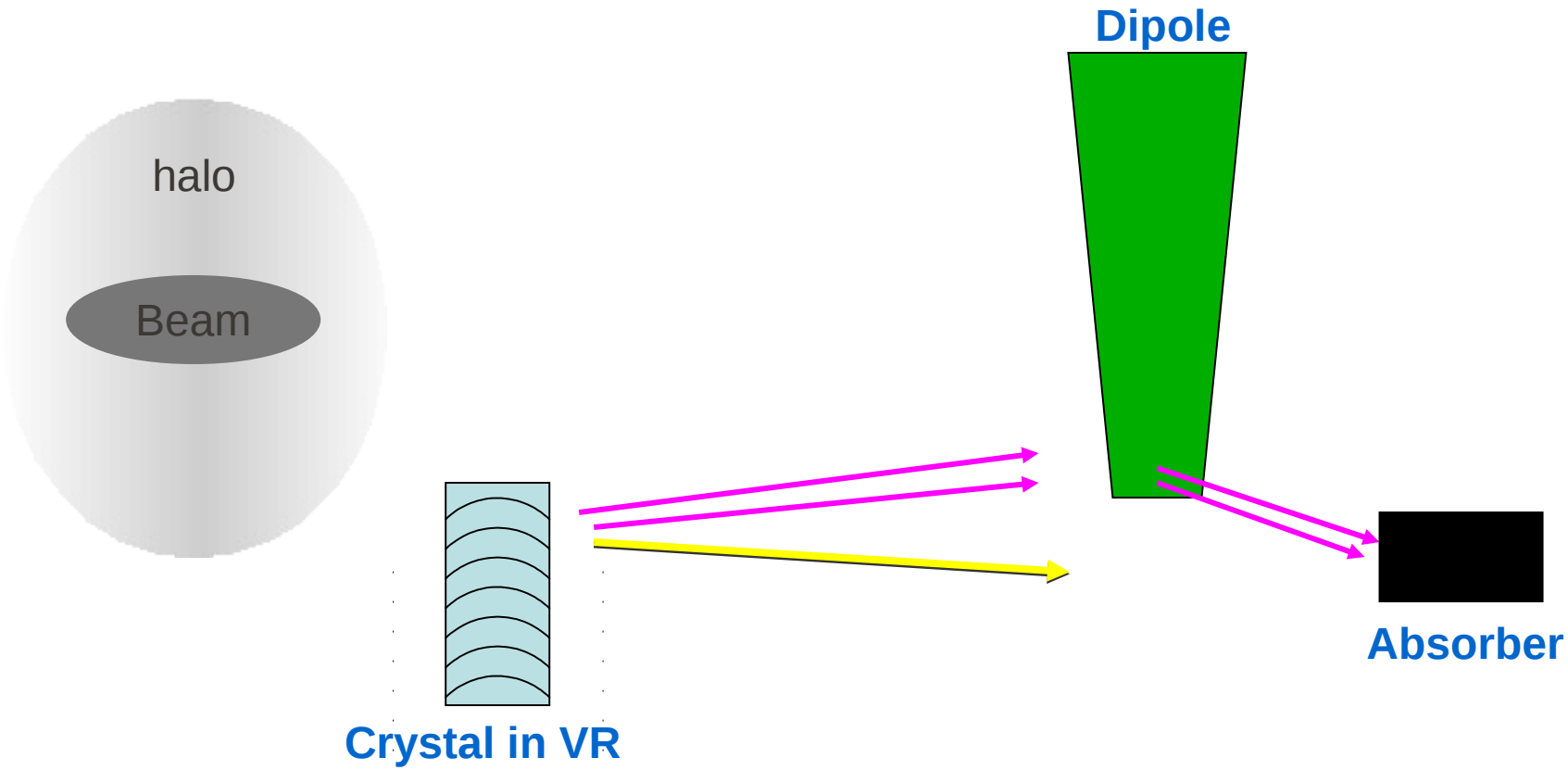
  Characterized from the experimental point of view
  In agreement with simulation and theory
- Different strategies to increase the emitted radiation are possible
  - *Series of crystals, axial orientation (MVROC and other effects)*
    - *Need to measure all the spectrum till 120GeV*
- June 2010: new test beam dedicated to the axial effects *and to the electrons*
  - *Thanks to the new "photon" calorimeter the whole spectrum has been measured, data analysis is ongoing*



Shashlik calorimeter readout by SiPMs


ICHEP 2010
High energy photon production in bent crystals: status and perspectives.
Thank you for the attention
Said Hasan
Insubria University

Backup 1



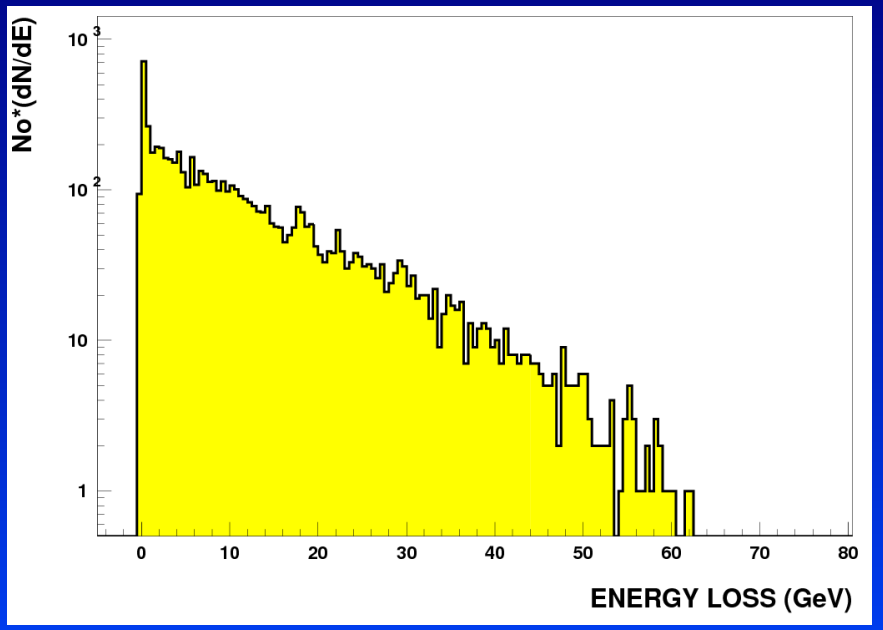
Particles which cross the crystal in VR lose their momentum in radiation and are deflected more by a following dipole

Courtesy of A. Seryi

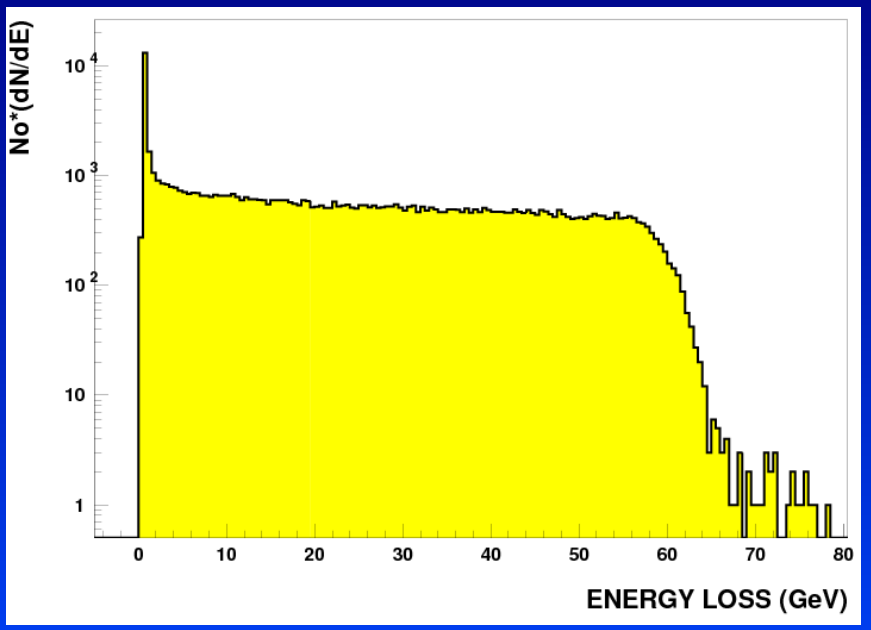
Backup 2

About normalization

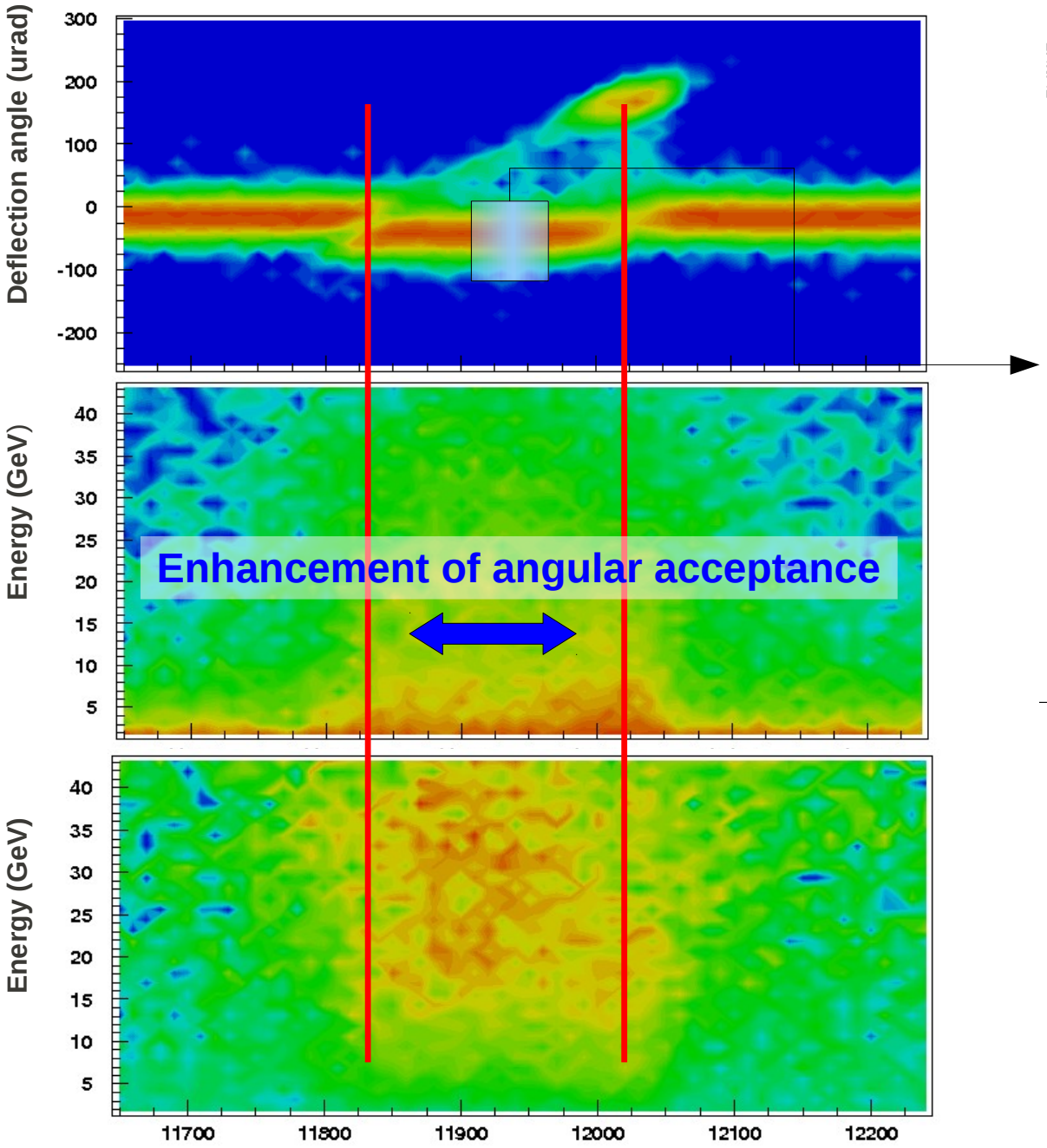
Channeling

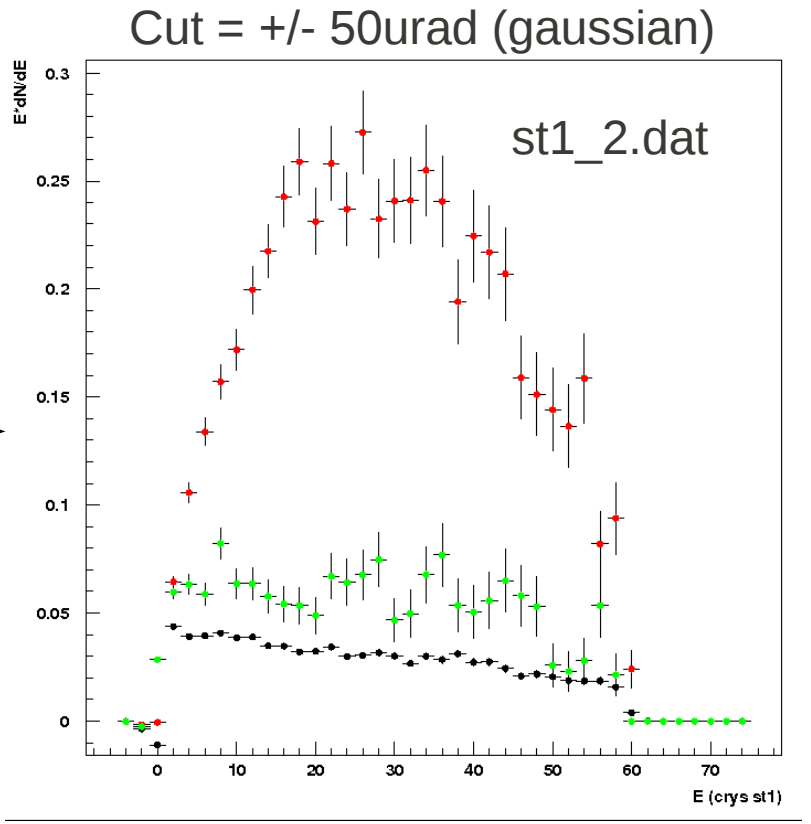


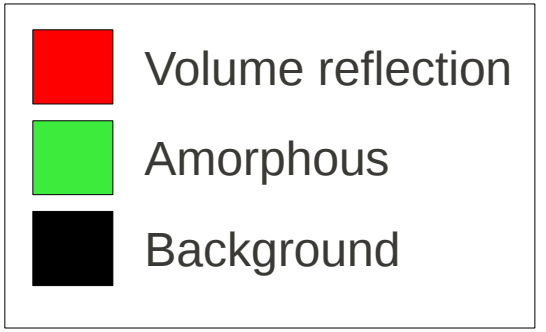
Multi VR



Backup 3


Deflection angle (urad)
300
200
100
0
-100
-200
Energy (GeV)
40
35
30
25
20
15
10
5
Enhancement of angular acceptance
Energy (GeV)
11700
11800
11900
12000
12100
12200
Incoming angle (urad)


Cut = +/- 50urad (gaussian)
st1_2.dat
E*dN/dE
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
E (crys st1)


Volume reflection
Amorphous
Background

S. Hasan[1], A.G. Afonin[7], E. Bagli[2], S. Baricordi[2], D. Bolognini[1], Yu. A. Chesnokov[7], P. N. Chirkov[7], P. Dalpiaz[2], G. Della Mea[3,4], V. Guidi[2], V. A. Maisheev[7], A. Mazzolari[2], M. Prest[1], E. Vallazza[6], D. Vincenzi[2], I. A. Yazynin[6]

[1] Università degli Studi dell'Insubria, Via Valleggio 11, 22100 Como, Italy and INFN Sezione di Milano Bicocca, Piazza della Scienza 3, 20126 Milano, Italy.
[2] INFN Sezione di Ferrara and Dipartimento di Fisica, Università di Ferrara, Via Saragat 1, 44100 Ferrara, Italy
[3] Dipartimento di Ingegneria dei Materiali e Tecnologie Industriali, Università di Trento, Via Mesiano 77, 38050 Trento, Italy
[4] Dipartimento di Fisica Università di Padova, Via 8 Febbraio 1848 2, 35121 Padova, Italy.
[5] INFN Laboratori Nazionali di Legnaro, Viale Università 2, 35020 Legnaro (PD), Italy
[6] INFN Sezione di Trieste, Via Valerio 2, 34127 Trieste, Italy
[7] Institute of High Energy Physics, Moscow Region, RU-142284 Protvino. Russia