

**Сессия Ученого Совета ОФВЭ**

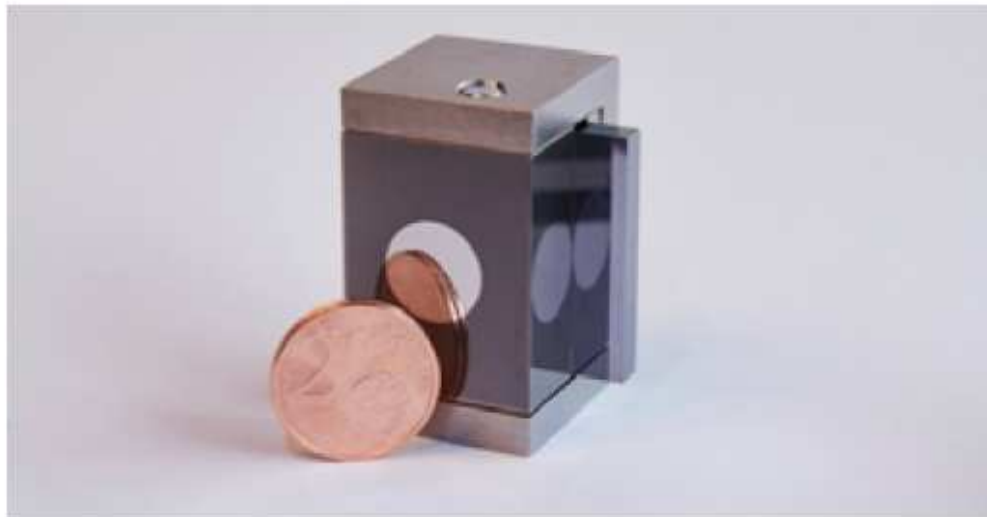
# **Эксперимент UA9 (CERN)**

**Ю.М.Иванов**

**22 декабря 2015**

## CRYSTALS CHANNEL HIGH-ENERGY BEAMS IN THE LHC

Bent crystals can be used to deflect particle beams, as suggested by E. Tsyanov 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.



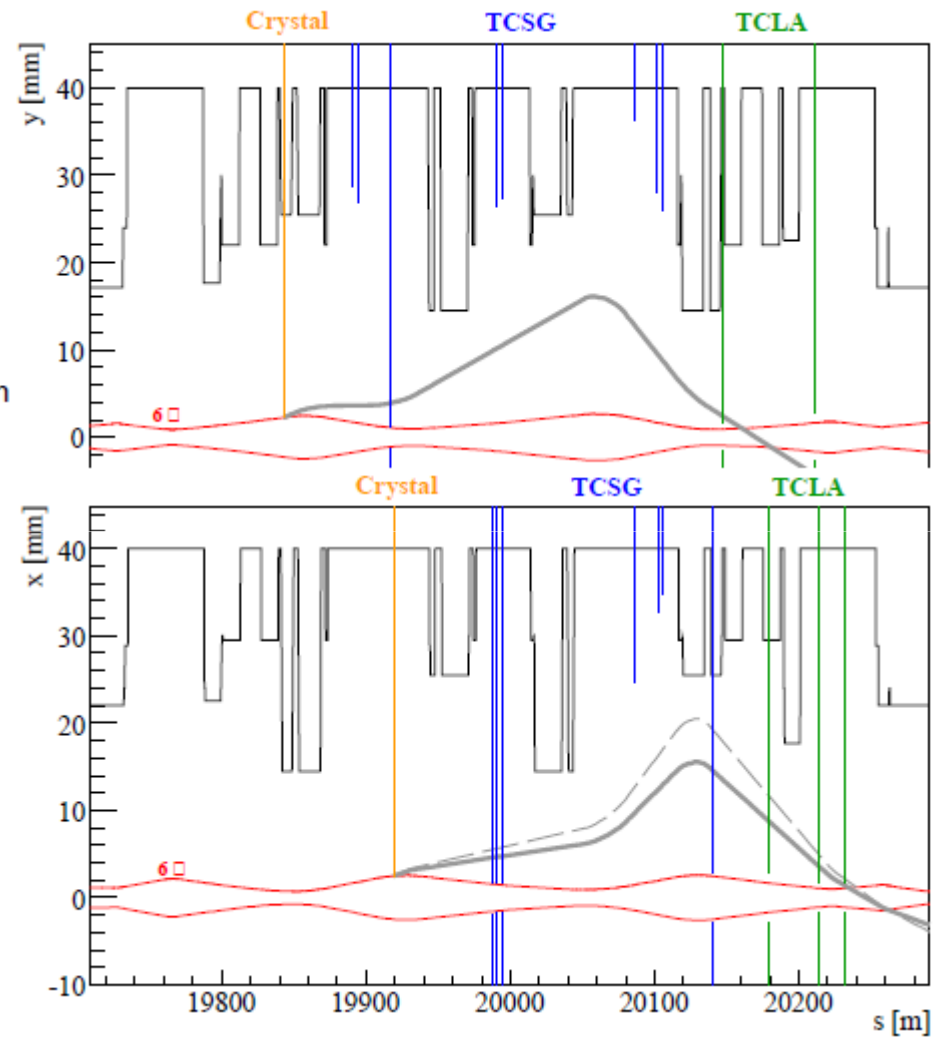
*Quasimosaic crystal for the LHC (developed by PNPI).*



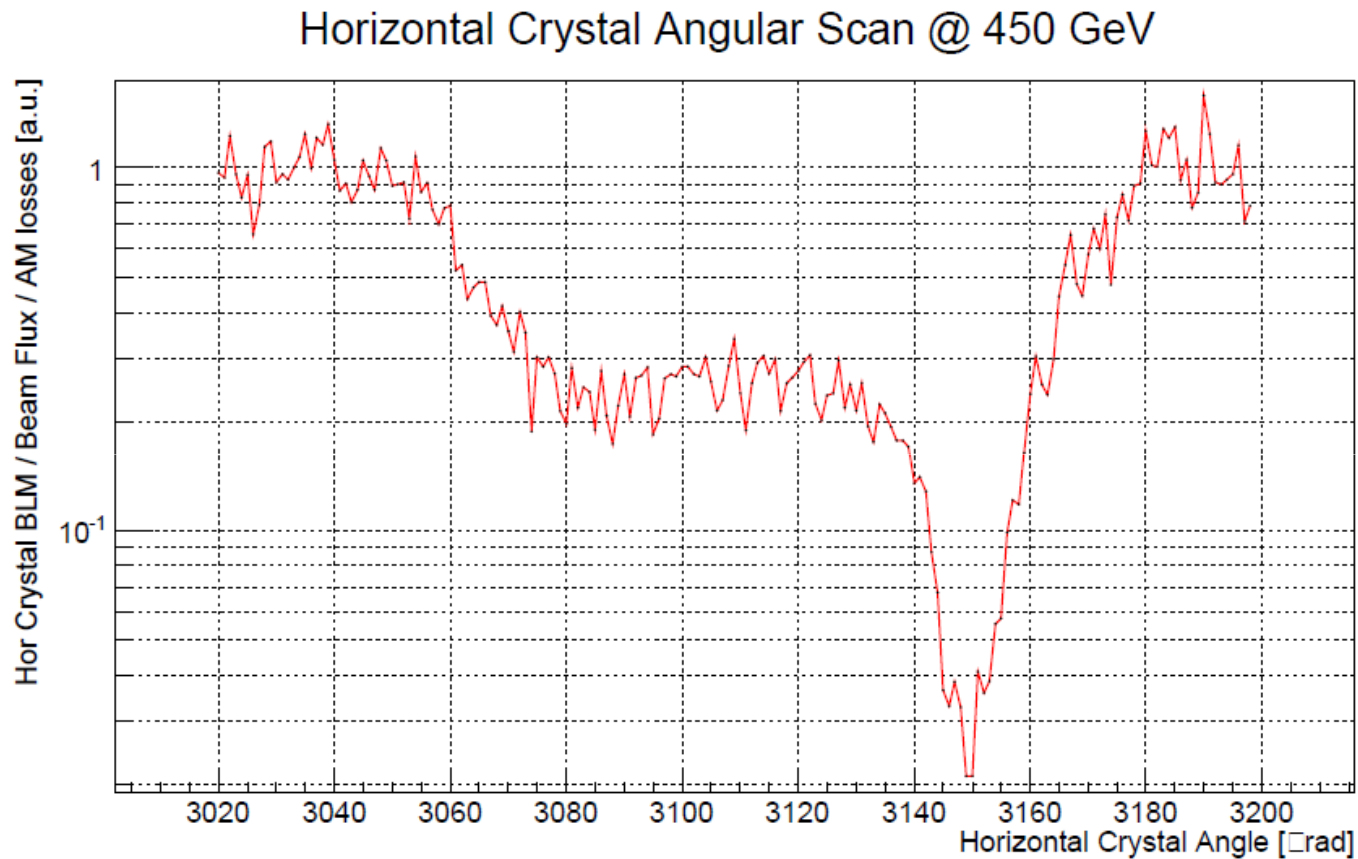
Bent crystal technology was introduced at CERN and further developed for the LHC by the UA9 Collaboration. For about ten years, experts from CERN, INFN (Italy), Imperial College (UK), LAL (France), and PNPI, IHEP and JINR (Russia) have been investigating the advantages of using bent crystals in the collimation systems of high-energy hadron colliders. A bent crystal replacing the primary collimator can deflect the incoming halo deeply inside the secondary collimators, improving their absorption efficiency. "The bent crystals we have just tested at the world-record energy in the LHC were built in Russia and Italy and then meticulously optimised in the H8 line at the SPS North Area," explains Walter Scandale, head of the UA9 collaboration. "The successful results

# Crystal layout in LHC IR7

30/08 – both crystals were tested at injection energy  
06/11 – horizontal crystal were tested at flat top  
02/12 – both crystals tested at injection energy with ion beam



# Horizontal LHC angular scan at 450 GeV

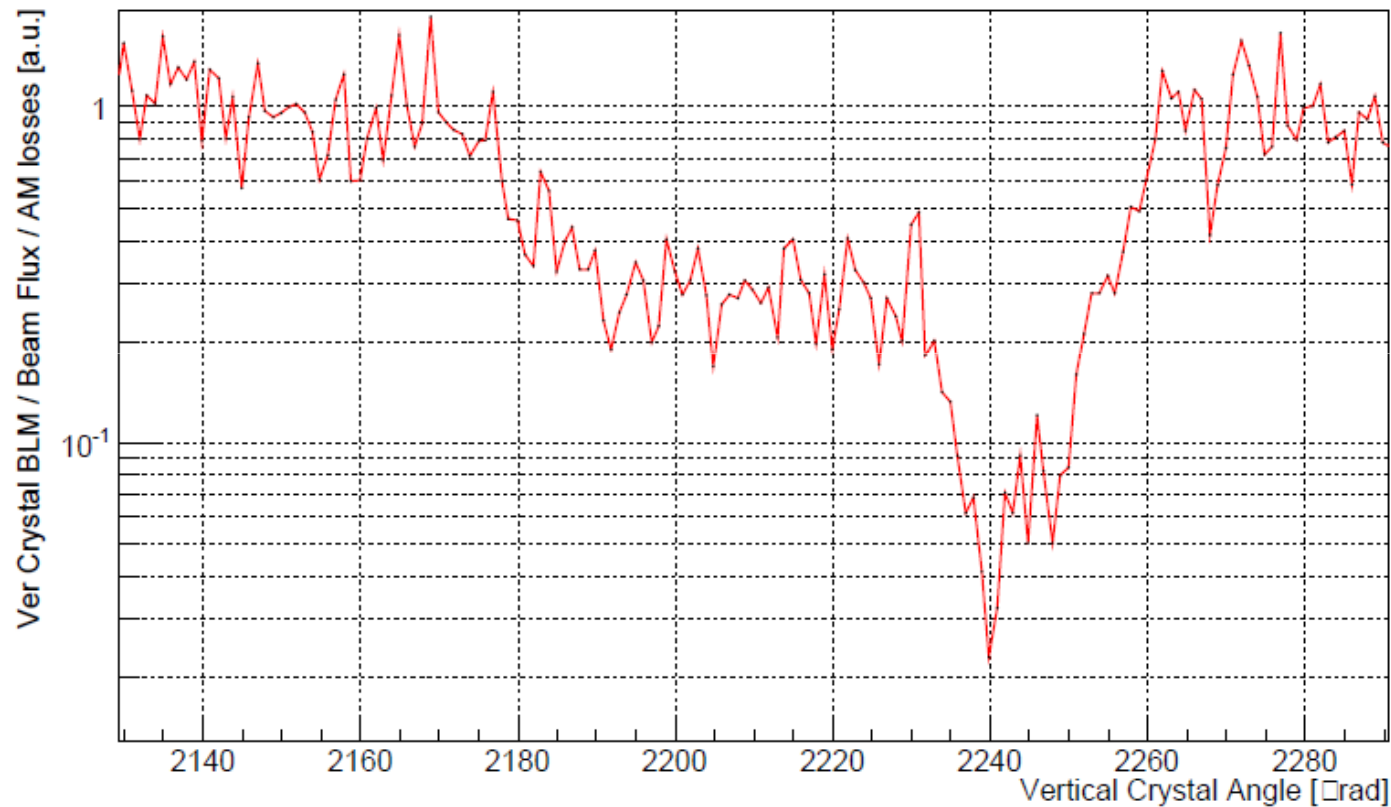


Losses recorded with BLM at goniometer position normalized to beam flux and to loss rate in amorphous.

Crystal @  $5.43 \sigma$   
Reduced Colls Config

# Vertical LHC angular scan at 450 GeV

Vertical Crystal Angular Scan @ 450 GeV



Losses recorded with BLM at goniometer position normalized to beam flux and to loss rate in amorphous.

Crystal @  $5.57 \sigma$   
Reduced Colls Config

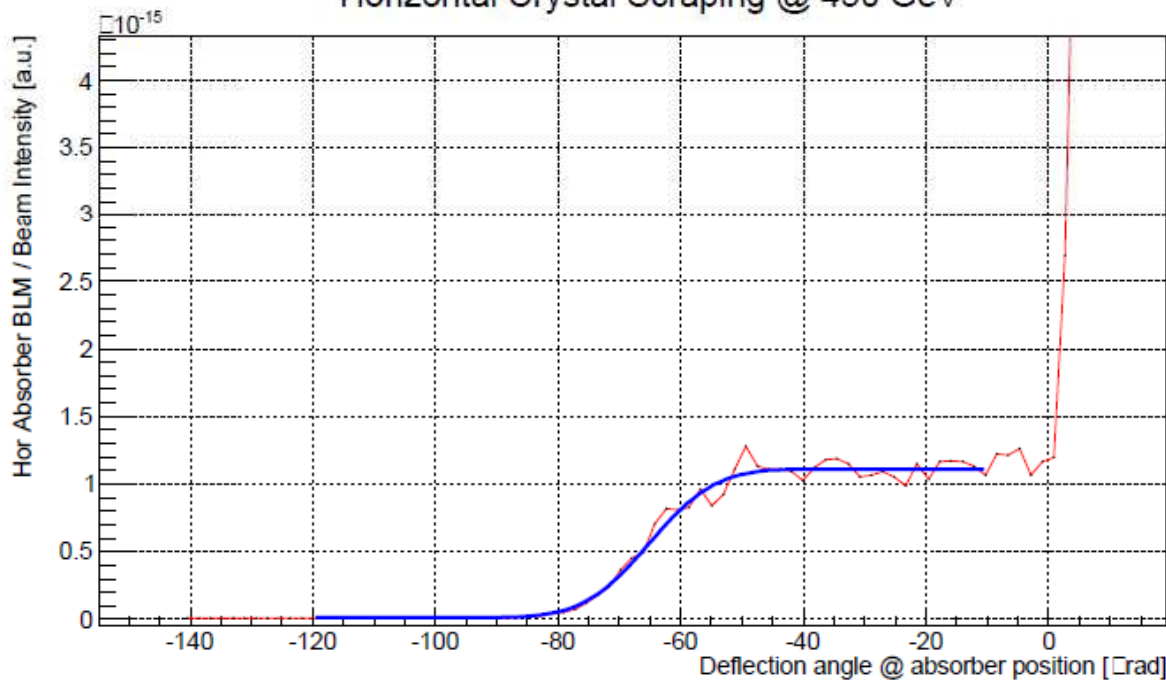
# Horizontal LHC channeled beam at 450 GeV

Losses recorded with BLM at goniometer position normalized to beam.  
The X axis is converted in deflection angle trough using

$$\theta_k(s_{coll}) = \frac{x(s_{coll}) - \sqrt{\beta_{coll}/\beta_{cry}} x_{cry} \cos(\Delta\phi)}{\sqrt{\beta_{cry}\beta_{coll}} \sin(\Delta\phi)}$$

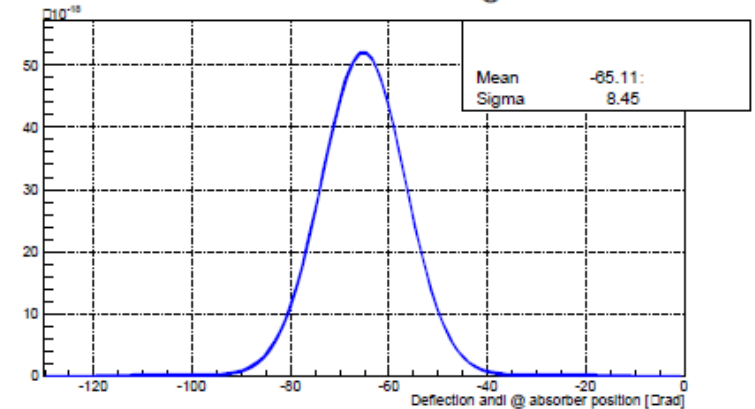
Crystal @ 5.43  $\sigma$   
Reduced Colls Config

Horizontal Crystal Scraping @ 450 GeV



The error function fit gives info about the channeled beam properties as deflection angle and beam sigma

Horizontal Channeled Beam Profile @ 450 GeV



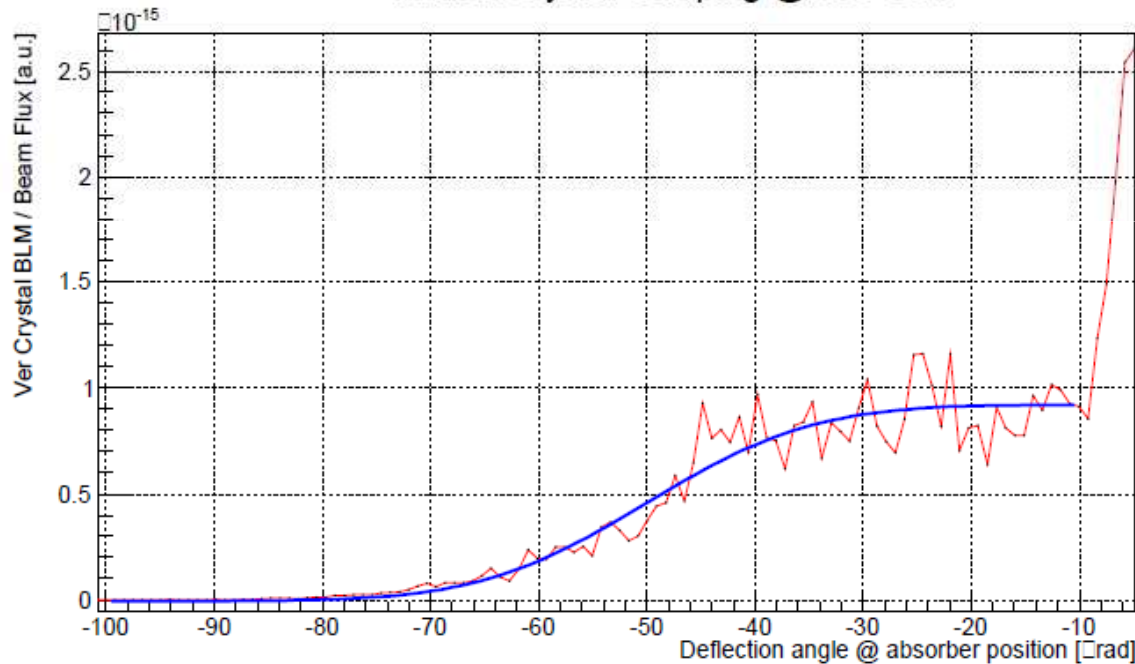
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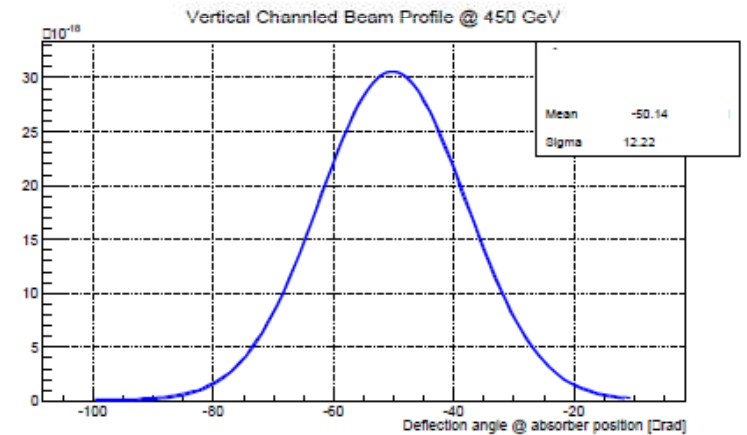
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Crystal @ 5.57  $\sigma$   
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Vertical Crystal Scraping @ 450 GeV



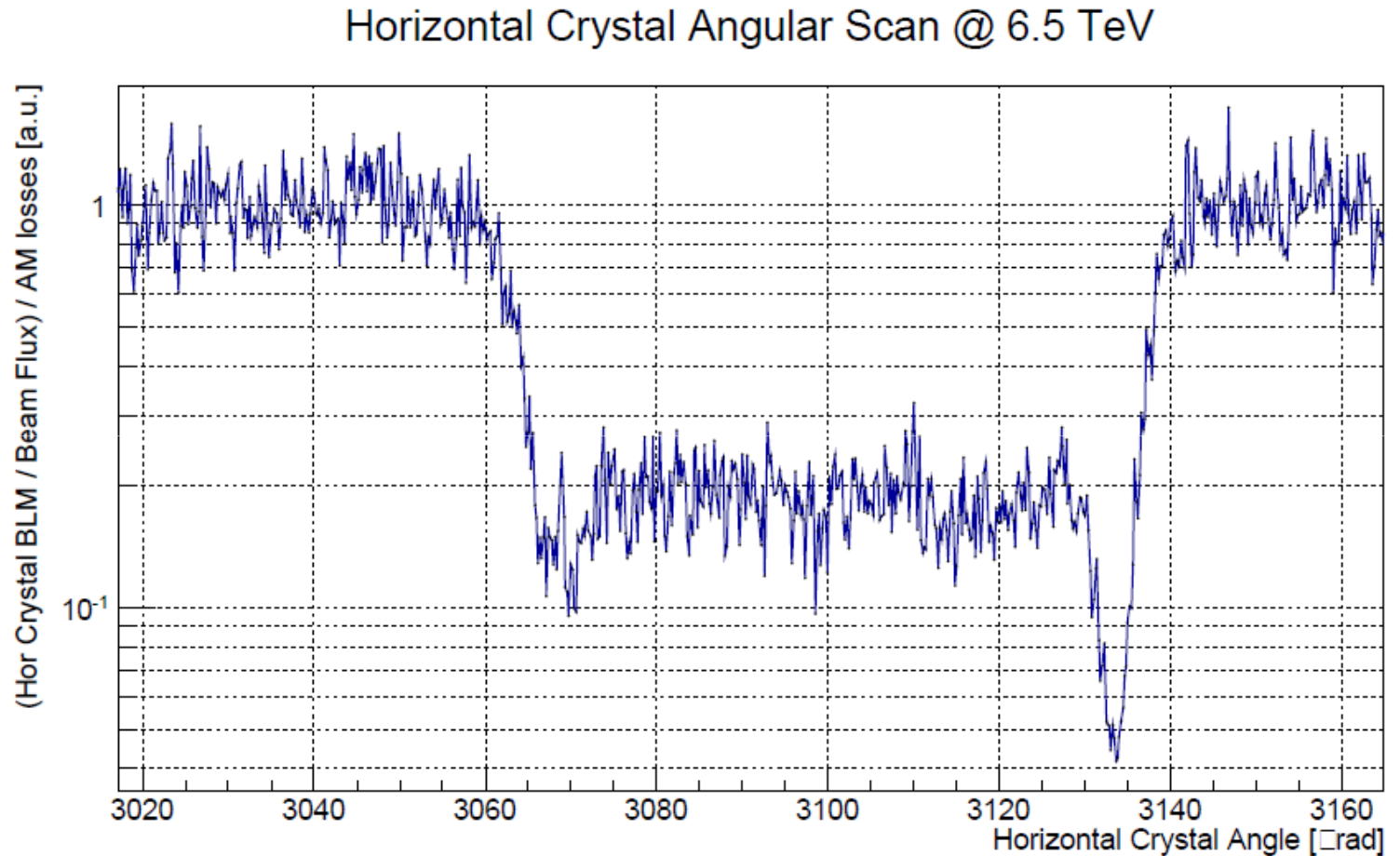
The error function fit gives info about the channeled beam properties as deflection angle and beam sigma



# Horizontal LHC angular scan at 6.5 TeV

Losses recorded with BLM at goniometer position normalized to beam flux and to loss rate in amorphous.

Crystal @  $5.39 \sigma$   
Reduced Colls Config



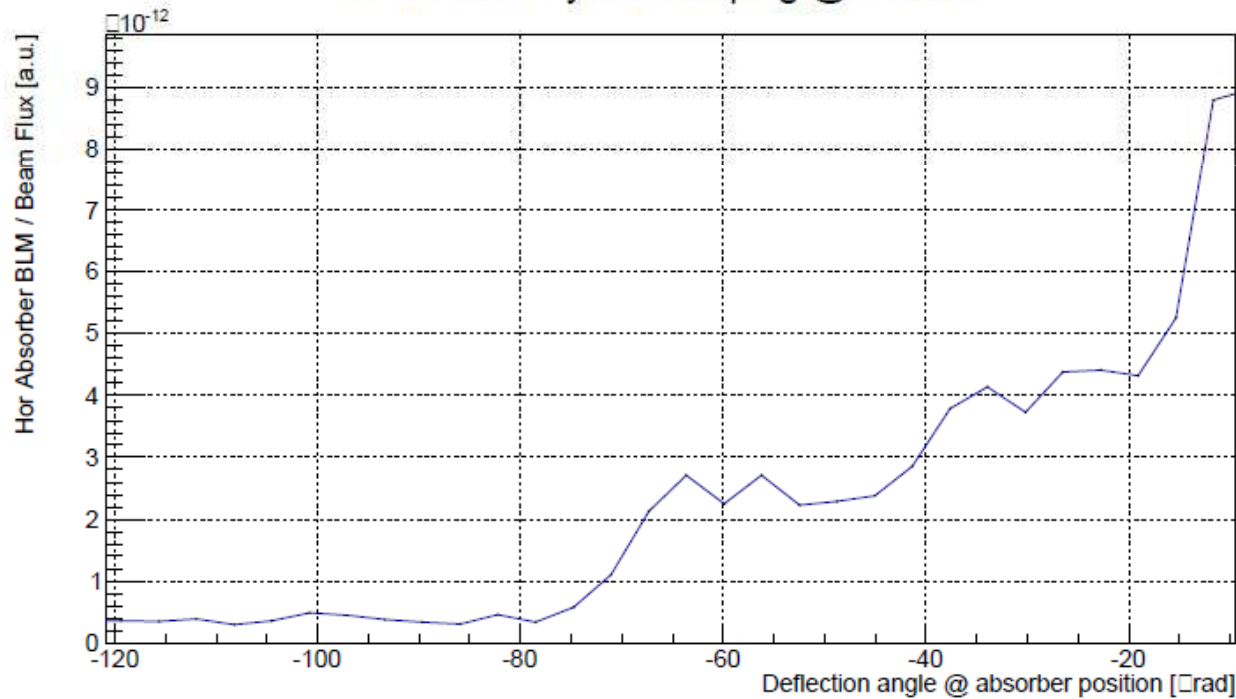


# Horizontal LHC channeled beam at 6.5 TeV

Losses recorded with BLM at goniometer position normalized to beam.  
The X axis is converted in deflection angle trough using

$$\theta_k(s_{coll}) = \frac{x(s_{coll}) - \sqrt{\beta_{coll}/\beta_{cry}} x_{cry} \cos(\Delta\phi)}{\sqrt{\beta_{cry}\beta_{coll}} \sin(\Delta\phi)}$$

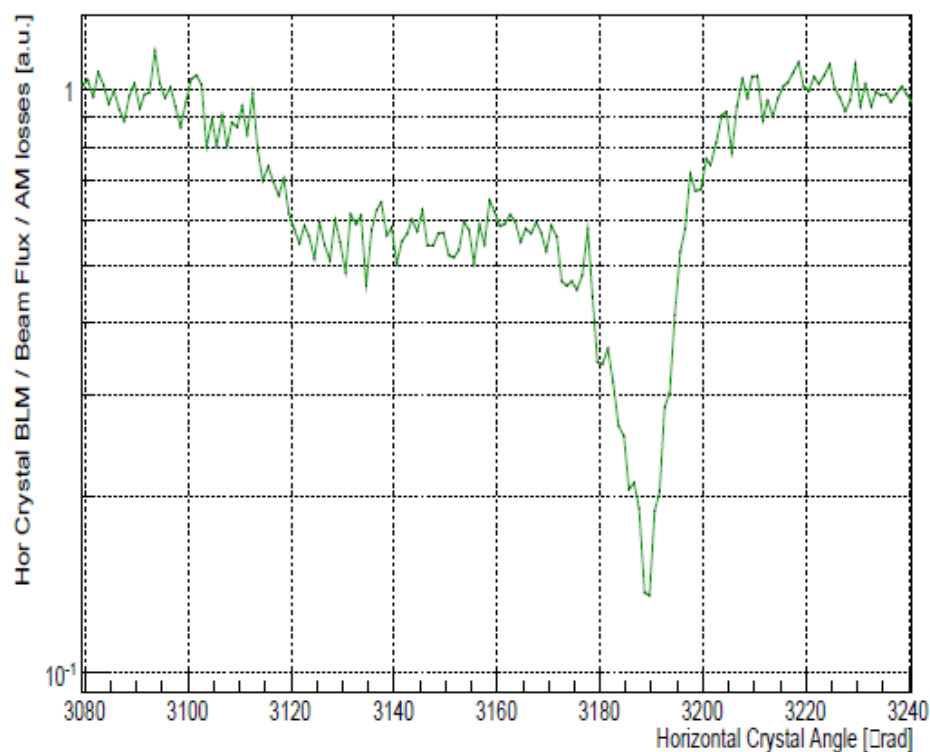
Horizontal Crystal Scraping @ 6.5 TeV



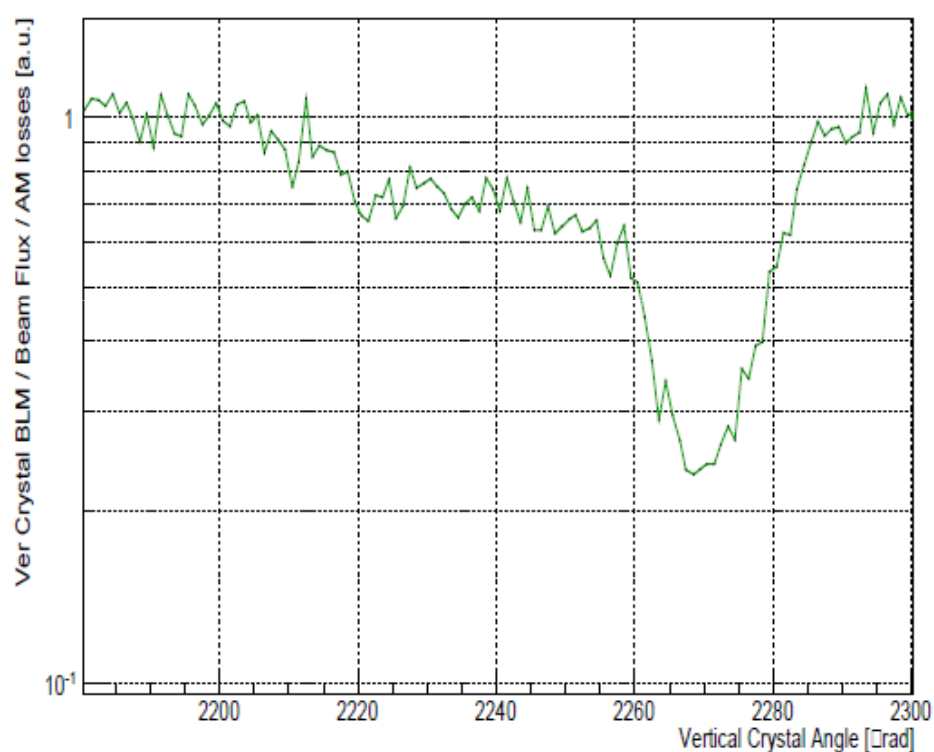
Crystal @ 5.39  $\sigma$   
Reduced Colls Config

# LHC angular scans with ions at 450 Z GeV

Horizontal Crystal Angular Scan @ 450 Z GeV



Vertical Crystal Angular Scan @ 450 Z GeV



# LHC results and plans

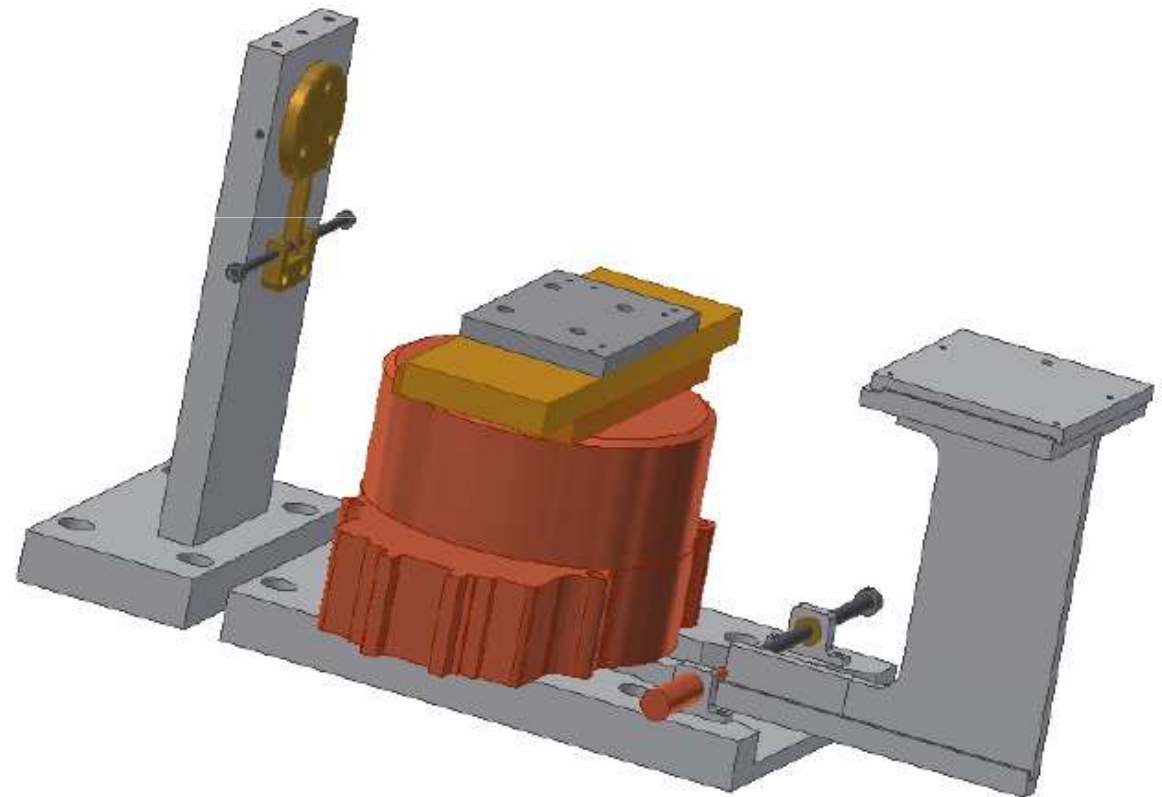
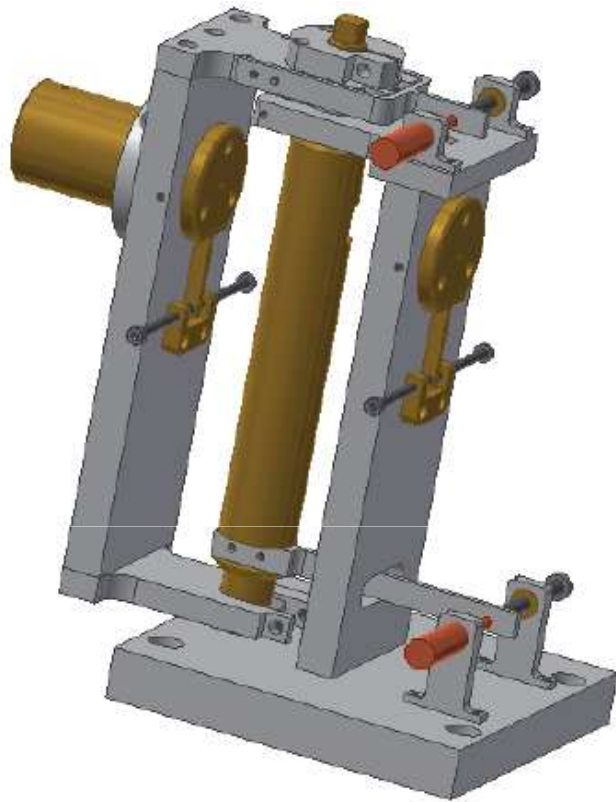
## Several important results

- ✓ Confirmation that layouts and hardware are adequate for beam tests
- ✓ Channeling observed for the first time with LHC beams
  - Protons: 6.5 TeV (record!)
  - Pb ions: 450 GeV (record!)
- ✓ Details scans: 450 GeV + 6.5 TeV for protons, only 450 GeV for ions

## Next steps

- Reduction factors, bending angle and multi-turn channeling efficiency are still **under validation**
- Ions at top energy (still hope to complete this in 2015)
- Detailed cleaning comparisons to present system
- Operational aspects: dynamic changes, higher beam intensities

# Рентгеновская двухкристальная установка для проверки кристаллов ЛНС-типа в CERN



# **РНФ 2016 для научных групп**

## **Каналирование заряженных частиц высоких энергий в упругоквазимозаичных и пьезоквазимозаичных кристаллах**

### **Экспериментальная работа в ПИЯФ:**

- ✓ совершенствование методики изготовления кристаллов**
- ✓ измерения на рентгеновских установках**
- ✓ измерения на протонном пучке**

# LoI: Baryon magnetic moment using bent crystal

Proposal to measure the magnetic moment of the  $\Lambda_c$  at SPS

?

# Публикации в 2015

- Observation of nuclear dechanneling length reduction for high energy protons in a short bent crystal, **Physics Letters B743 (2015) 440–443**
- Observation of strong leakage reduction in crystal assisted collimation of the SPS beam, **Physics Letters B748 (2015) 451–454**
- Comparative results on the deflection of positively and negatively charged particles by multiple volume reflections in a multi-strip silicon deflector, **Письма в ЖЭТФ, т. 101, вып. 10, стр. 755 – 760, 2015**