Results of UA9

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For the UA9 collaboration

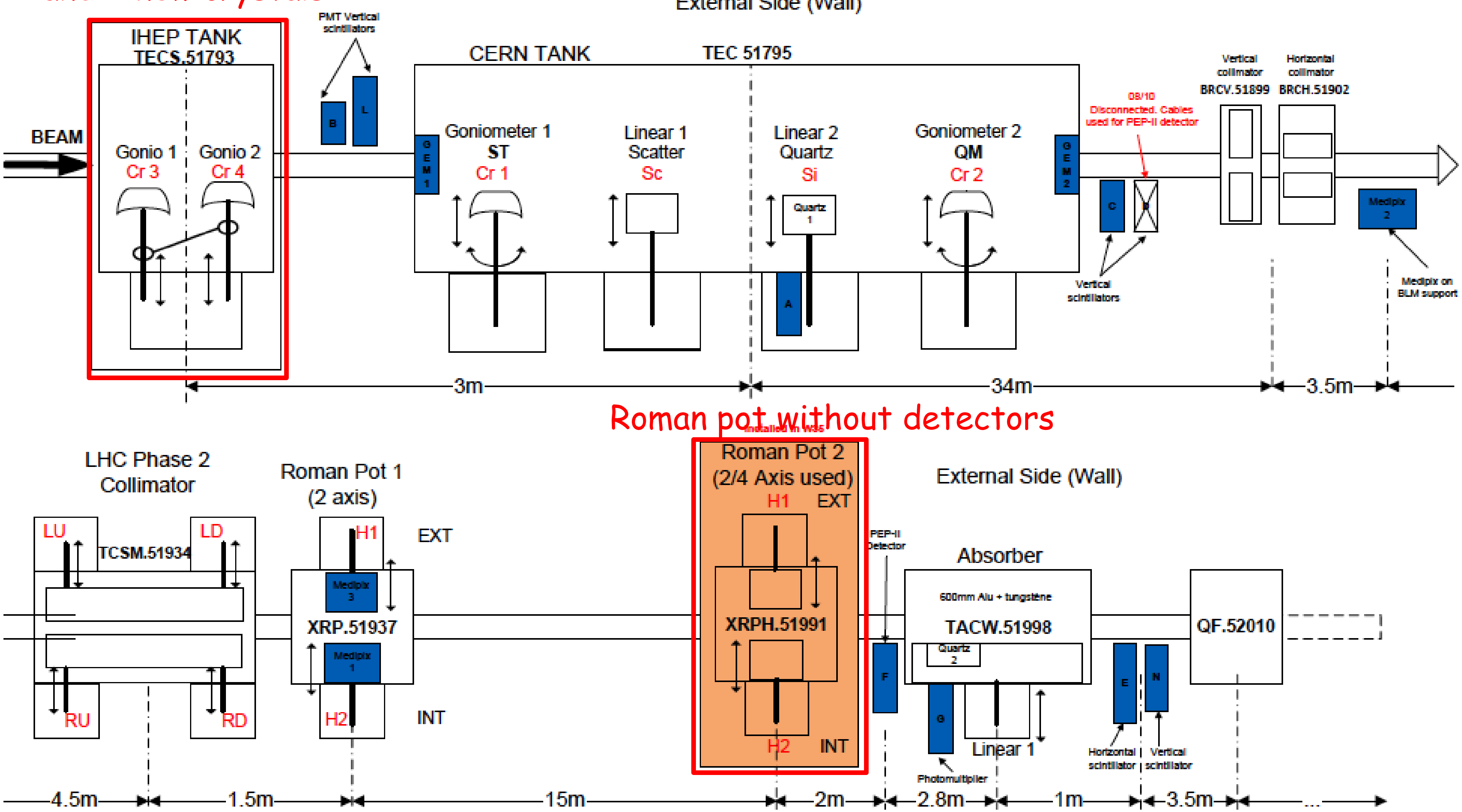
(CERN, INFN, IHEP, Imperial College, PNPI, JINR, SLAC, BNL)

Annual UA9 workshop

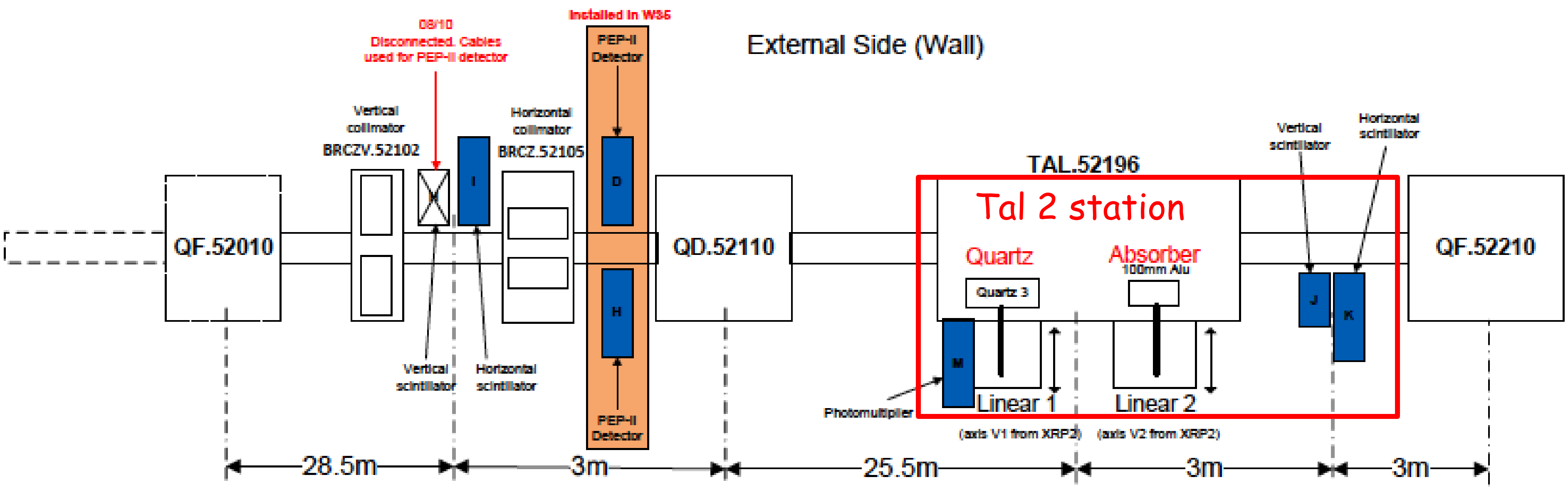
24 October2010

UA9 device in 2010 (1/2)

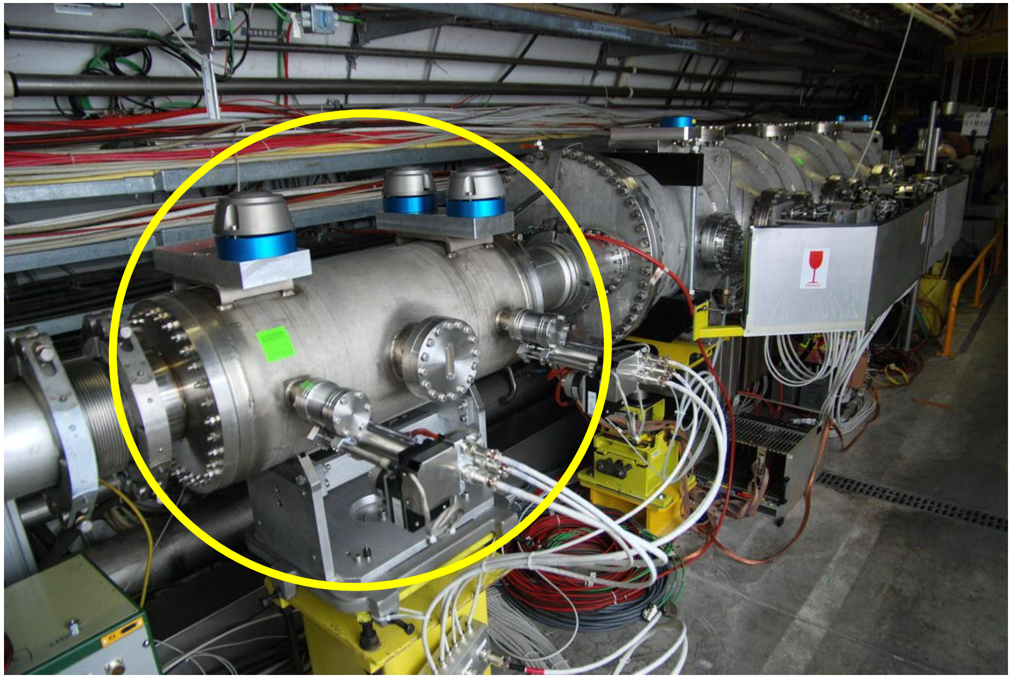
New goniometer
and 2 new crystals



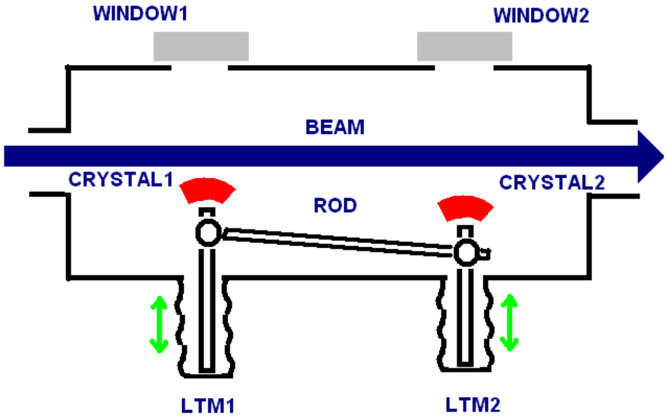
UA9 device in 2010 (2/2)

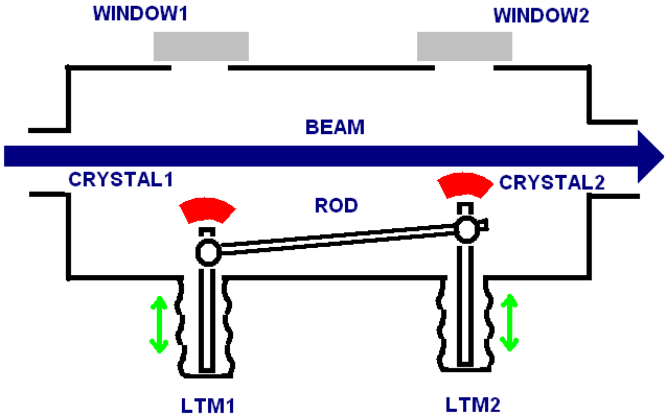


The IHEP goniometer

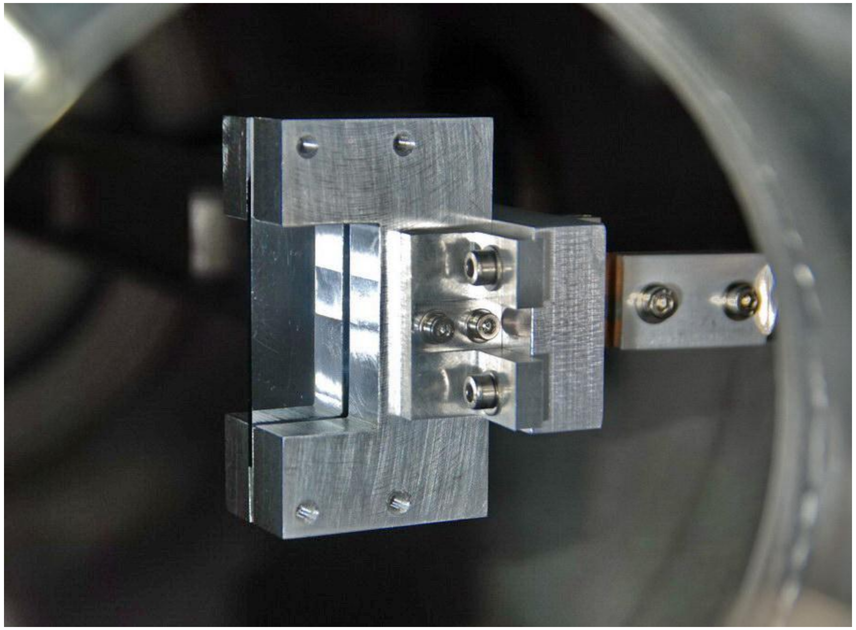


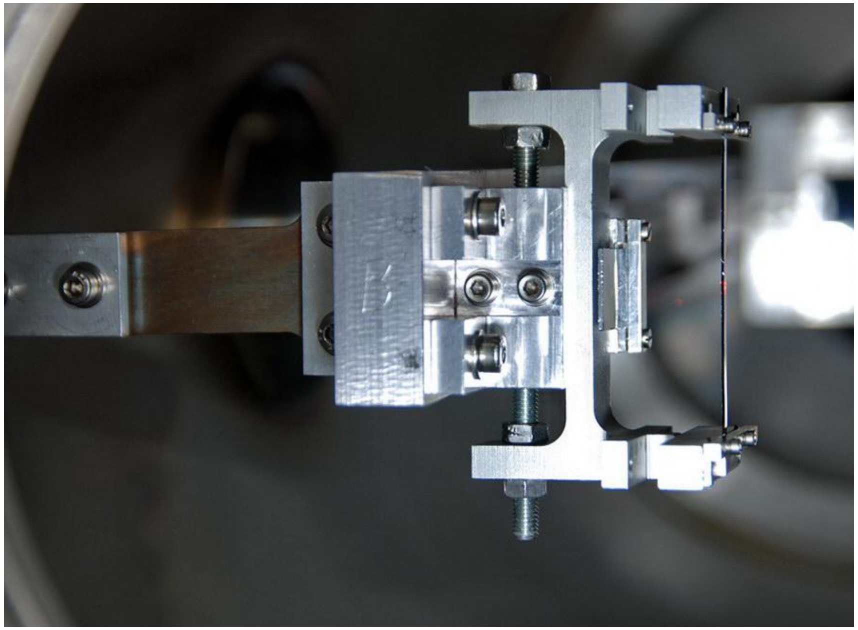
- Installed upstream of the RD22 tank
- It supports two new crystals
- Angular resolution ± 10 μrad





The two new crystals

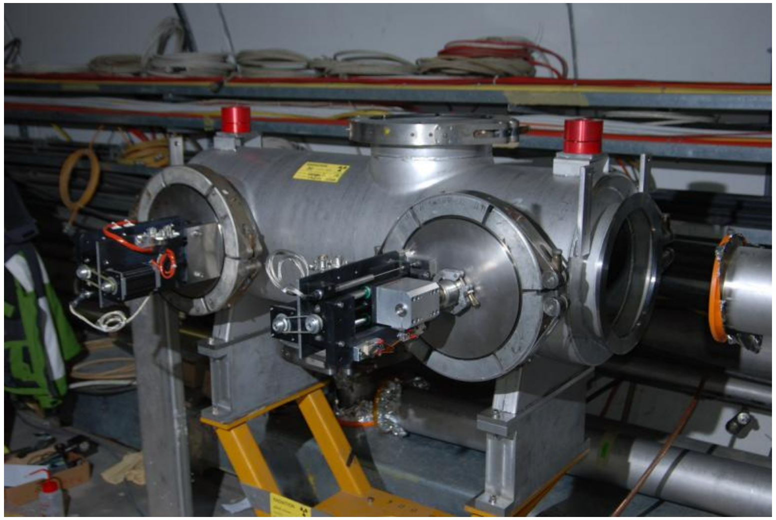


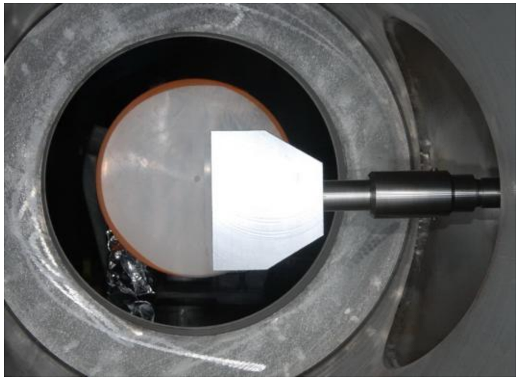


- Quasimosaic crystal supported by a large frame to avoid loss of large amplitude particles
- Strip crystal supported by a large bending frame to avoid loss of large amplitude particles

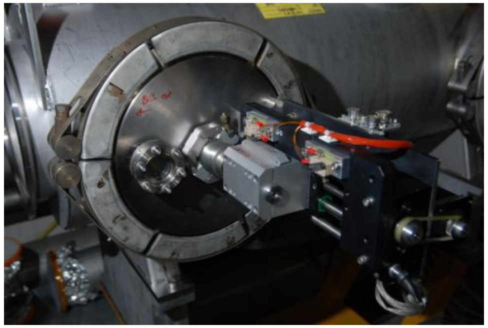
The TAL2 in the dispersive area

- The TAL 2 is installed in the dispersive area of the missing magnet, just down stream of the absorber-TAL
- It should intercept
  - halo not absorbed by the crystal collimation system
  - Off-momentum particles produced in the crystal
- The measurement is based on the scanning of the beam peripheral
- The observable is
  - Either the spray rate produced in a aluminum scraper
  - Or the spray rate measured by the Cherenkov quartz





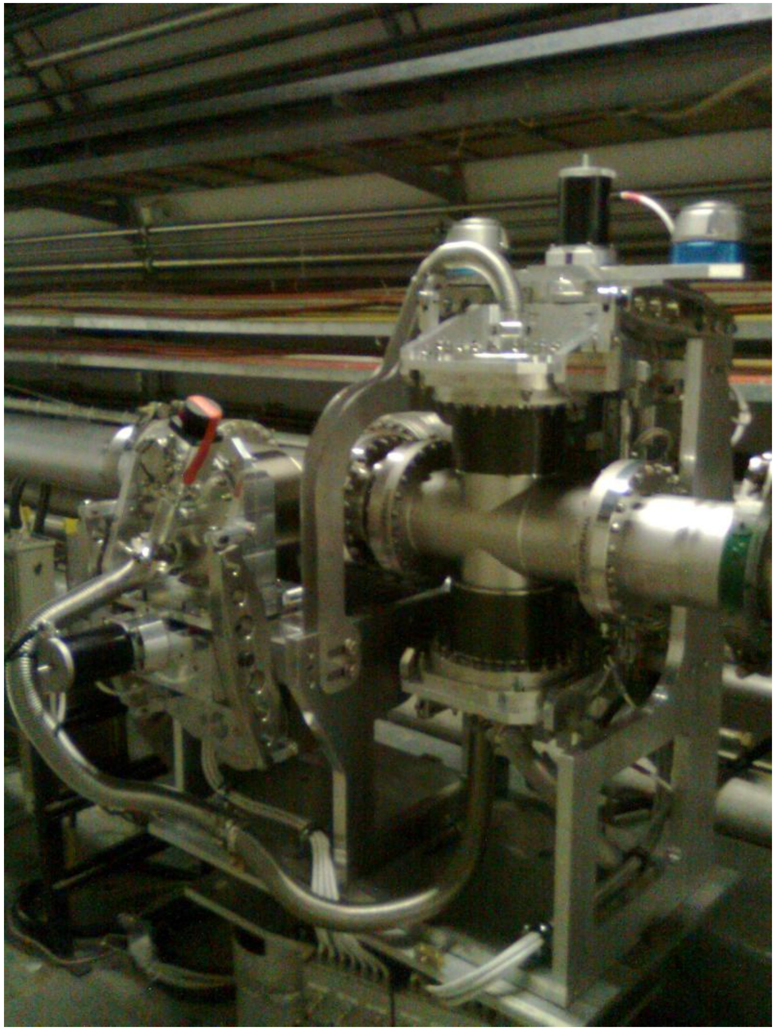
Aluminum scraper



Quartz Cherenkov

The Roman pot 2

- RP2 setup
  - Very close to TAL, better position to see channeled beam!
  - No detectors yet
  - Place to install 4 Medipix (2 Horiz and 2 Vert.)
  - Relevant to measure channeled beam direction in conjunction with the RP1 (from centroids)



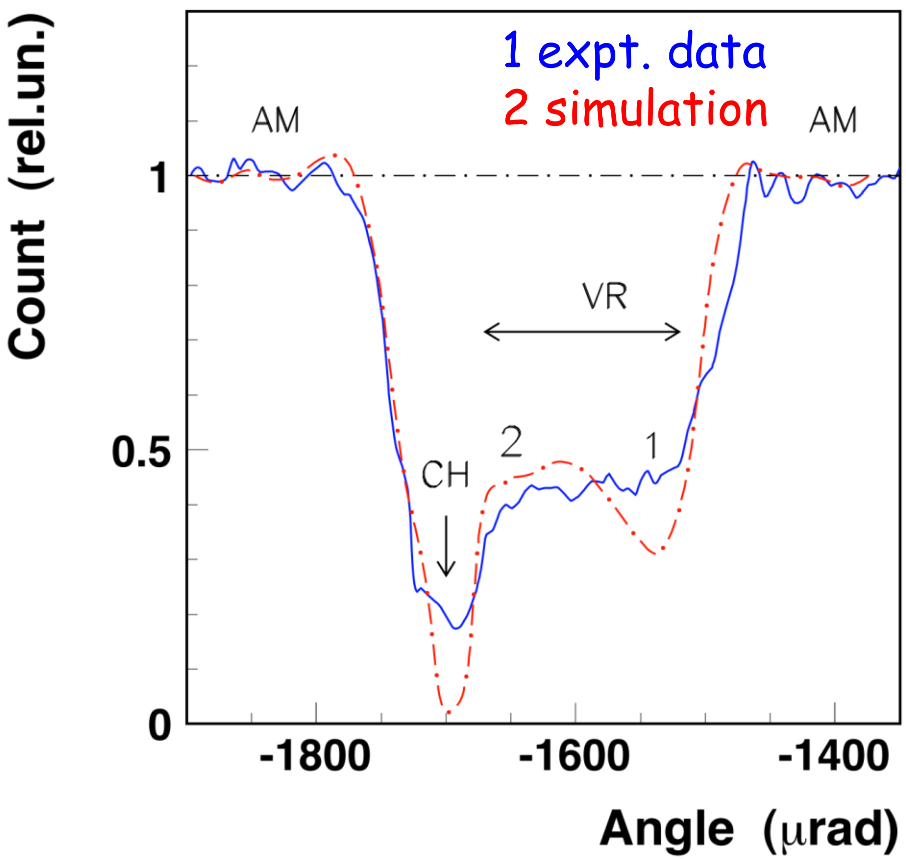
UA9 summary of the main results

- Crystal collimation works very well based on *channeling process*
  - Optimal crystal alignment easily detected and achieved
- *Collimation leakage* in amorphous orientation larger than in channeling
  - *Collimation l*eakage rate reduced by more than a factor of 5 at the TAL2 in the dispersive location (sextant 5, position 22)
- *Nuclear loss rate* (including diffractive) strongly depressed
  - In channeling with respect to amorphous orientation

Analysis of the 2009 results

W. Scandale et al. / Physics Letters B 692 (2010) 78–82)

Crystal no. 1 (strip)



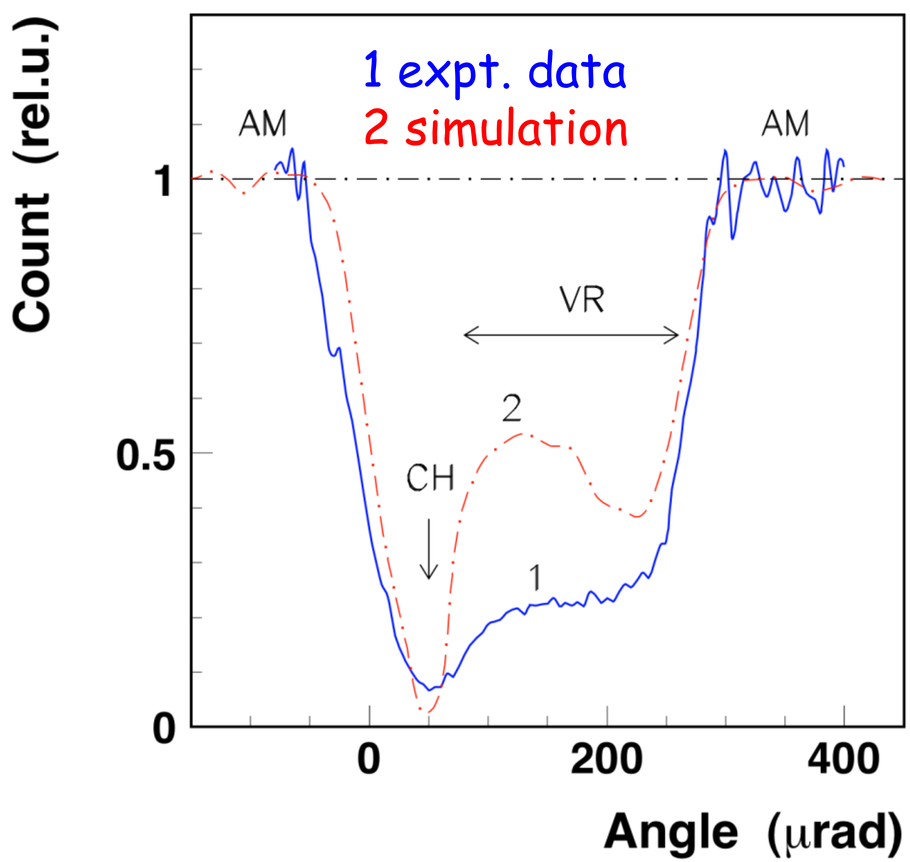
- Loss reduction in channeling mode (× 5)
  - smaller than in MonteCarlo simulation (× 36)
- Deflection angle and loss rate depression varying from scan to scan: alignment errors induced by
  - vertical torsion of the crystal
  - inaccuracy of the Goniometer

Deflection efficiency for crystal 1 and 2 : (75±4)% and (85±5)%

Results in 2010: angular scan of crystal 3

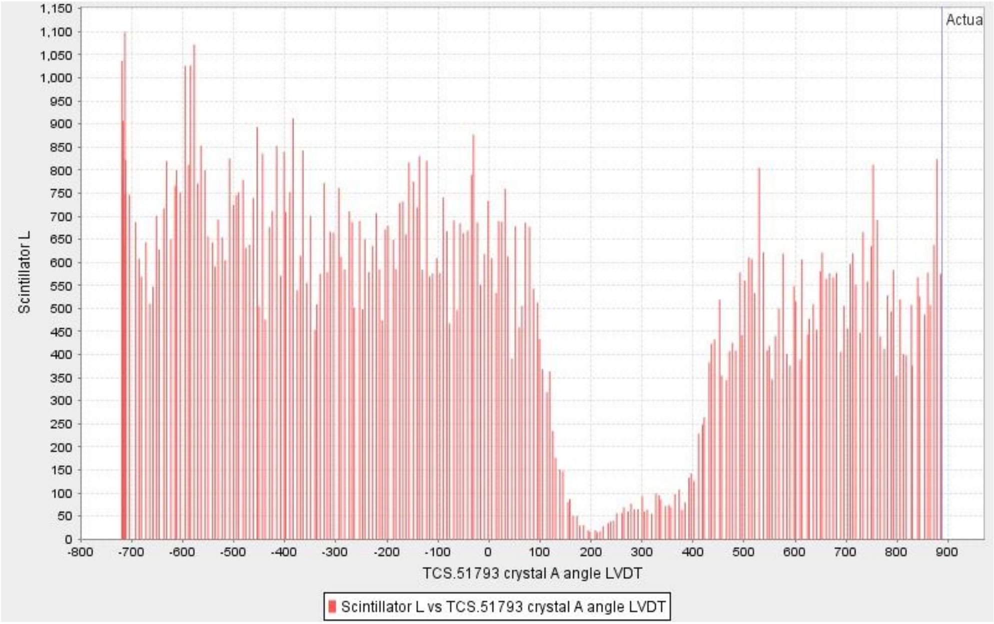
Crystal no. 3 (quasimosaic)

- with a small residual torsion
- operated by the IHEP high quality goniometer



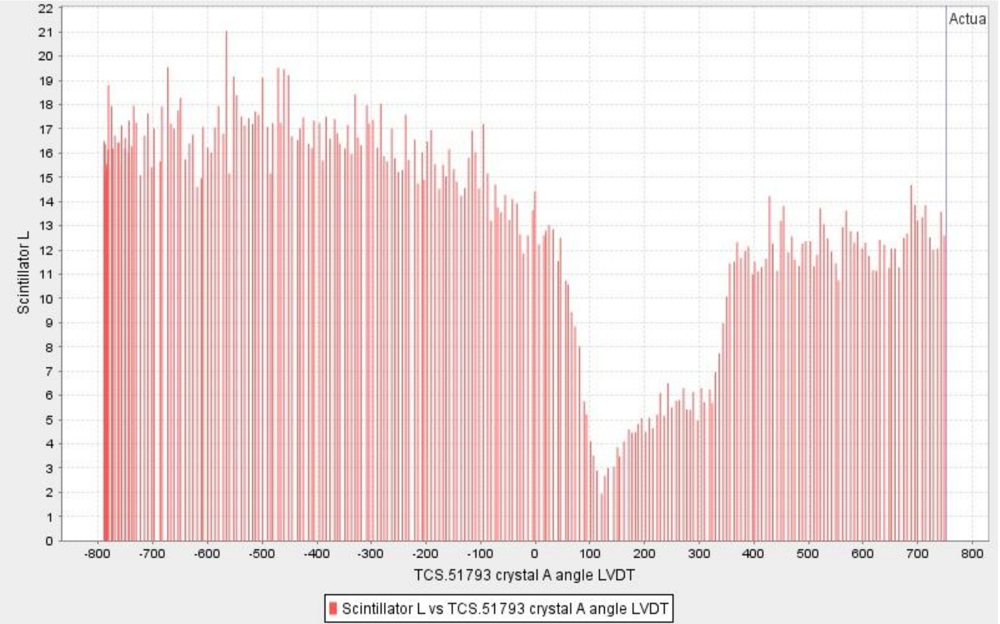
- Loss reduction in channeling mode (× 16)
  - smaller than in MonteCarlo simulation (× 33)
  - larger than in crystal 1 (× 5)
- Small variations of the deflection angle in different scans [better control of the alignment errors]
- Why such an improvement ?
  - Lower vertical torsion of the crystal
  - Smaller inaccuracy of the Goniometer
- Loss depression in VR mode with respect to MonteCarlo simulation still under investigation

Results in 2010: angular scan of crystal 3



Crystal at 4.5 σ

- Nuclear loss ratio × 35
- Channeling at 100 µrad



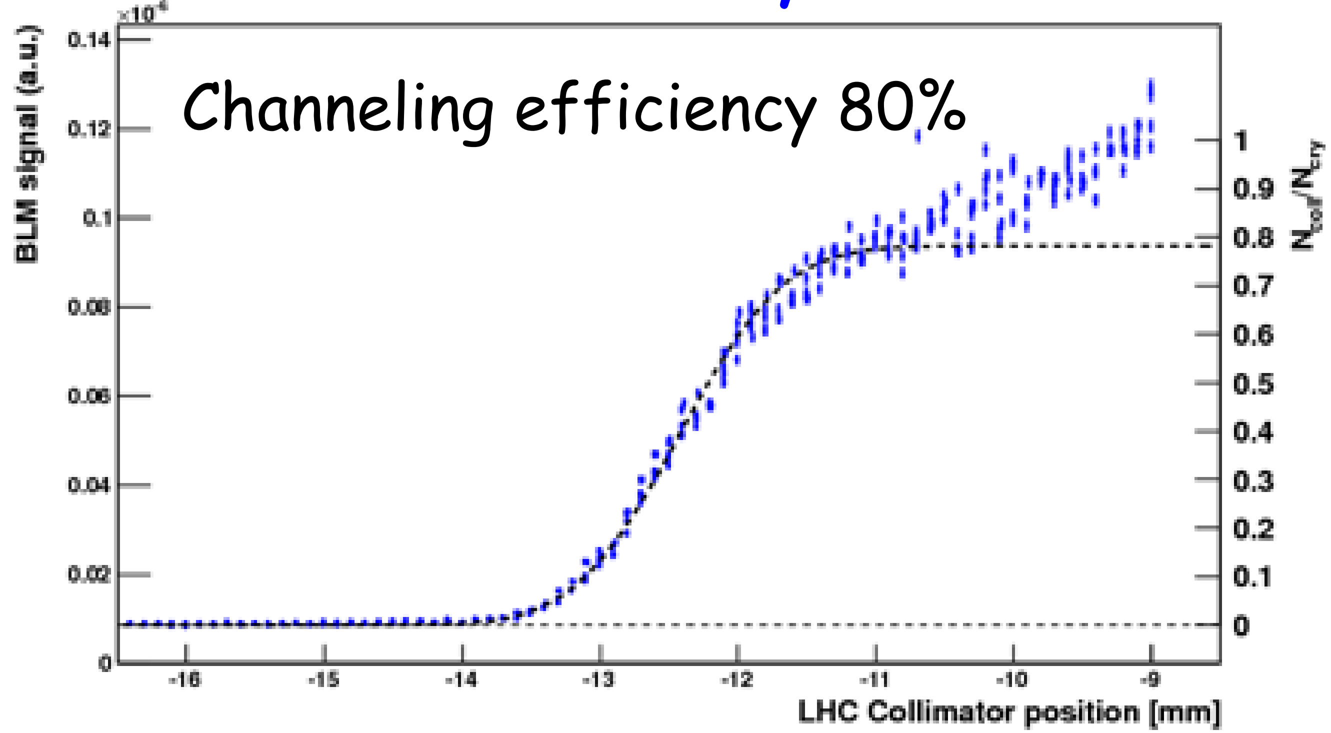
Crystal at 6 σ

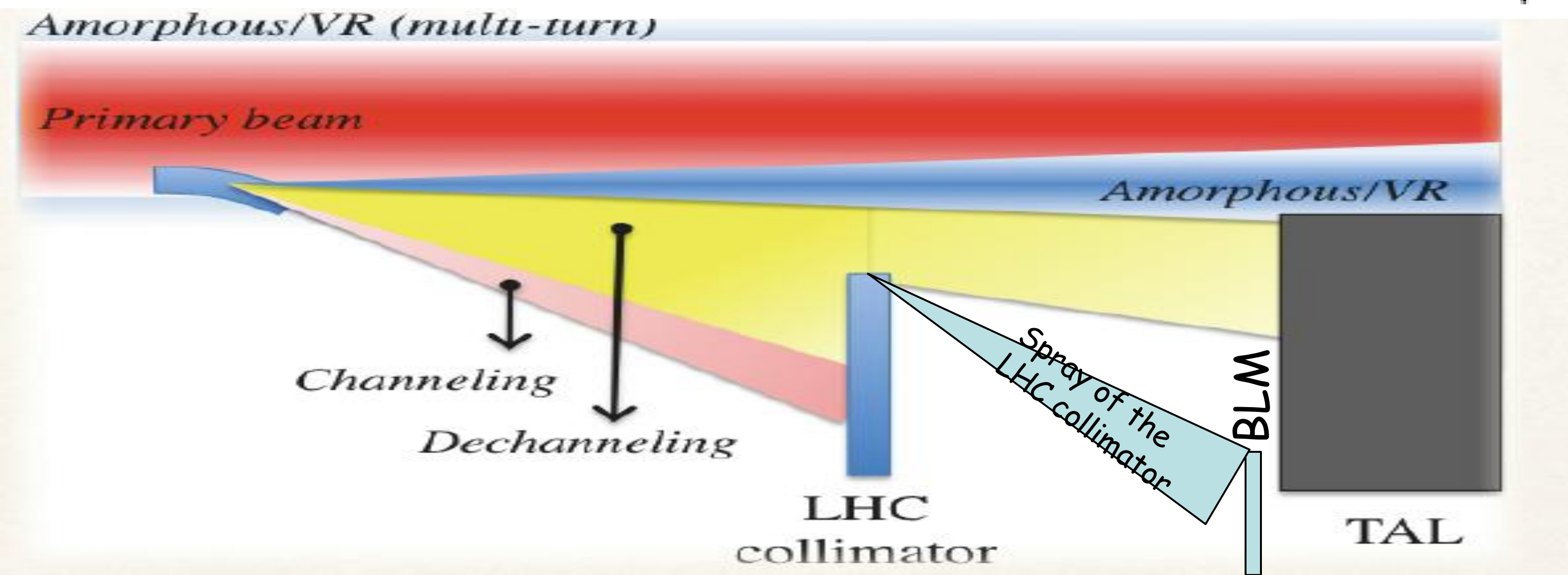
- Nuclear loss ratio × 8
- Channeling at 60 µrad

At the crystal azimuth

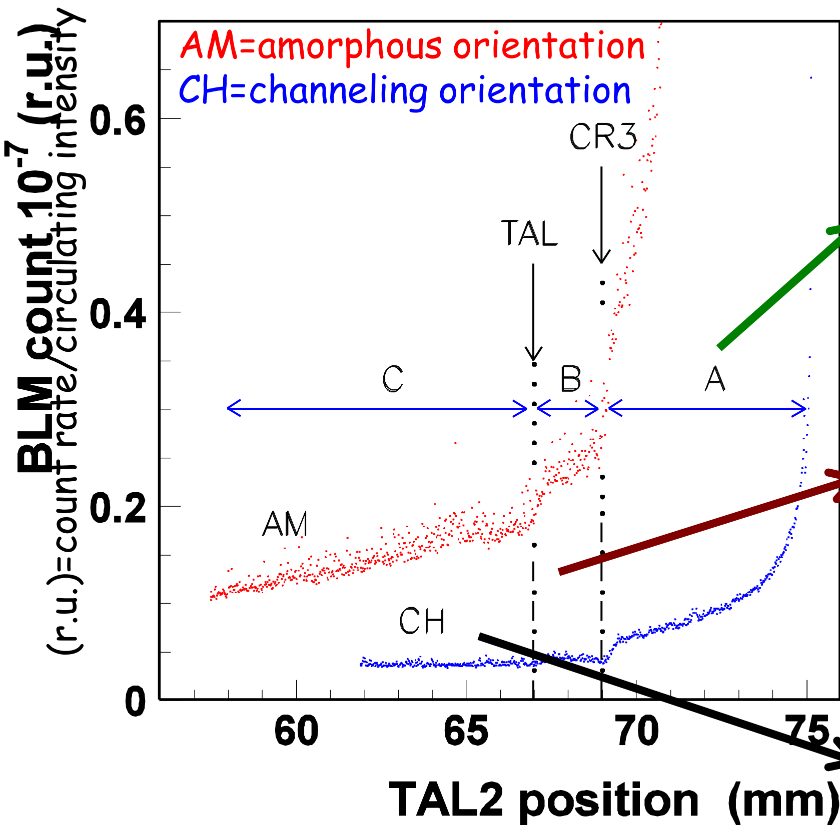
- the beam ellipses is tilted by a negative angle
- for larger ellipses the beam hitting the crystal has a wider angular spread

LHC collimator scan of crystal 3

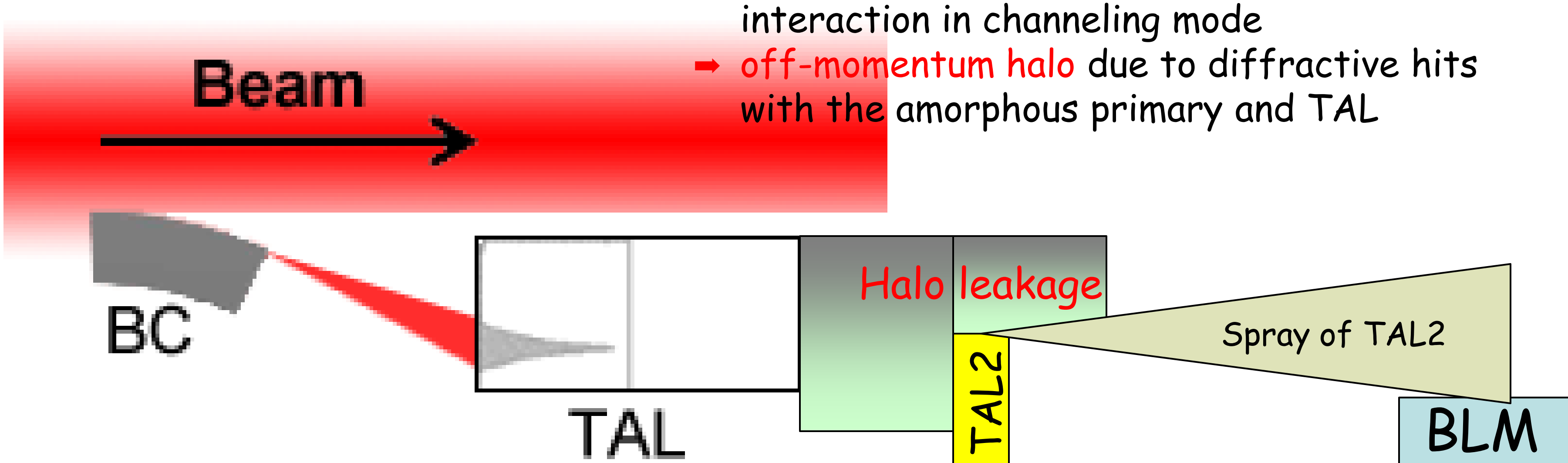




Collimation leakage in a high dispersive area



- **A) tail of the circulating beam**
  - ➡ fast depletion in channeling mode
  - ➡ linear descent of the population in amorphous orientation (or with the tungsten scatterer)
- **B) multiple Coulomb scattering area**
  - ➡ fast depletion by high probability of prompt channeling at the first crystal hit
  - ➡ slow depletion due to multi-turn hits of the amorphous primary (very slow extraction)
- **C) shadow of the absorber**
  - ➡ low population due to low probability of nuclear interaction in channeling mode
  - ➡ off-momentum halo due to diffractive hits with the amorphous primary and TAL



Publications in 2010

- *Observation of channeling and volume reflection in bent crystals for high-energy negative particles* Physics Letters B 681 (2009) 233–236
- *First observation of multiple volume reflection by different planes in one bent silicon crystal for high-energy protons* Physics Letters B 682 (2009) 274–277
- *Multiple volume reflections of high-energy protons in a sequence of bent silicon crystals assisted by volume capture* Physics Letters B 688 (2010) 284–288
- *Probability of inelastic nuclear interactions of high-energy protons in a bent crystal* Nuclear Instruments and Methods in Physics Research B 268 (2010) 2655–2659
- *IPAC10 (INT. CONF. ACC. PART. 2010)*
  - CRYSTAL COLLIMATION EFFICIENCY MEASURED WITH THE SPS UA9 EXPERIMENT
  - UA9 BEAM LOSS MONITOR OPERATION AND DATA ANALYSIS
  - MEASUREMENT OF NUCLEAR REACTION RATES IN CRYSTALS USING THE CERN-SPS NORTH AREA TEST BEAMS
  - UA9 INSTRUMENTATION AND DETECTORS IN THE CERN-SPS
  - MANIPULATION OF NEGATIVELY CHARGED BEAMS VIA COHERENT EFFECTS IN BENT CRYSTALS

acknowledgments

- The EN/STI group was of an extraordinary support to UA9
- BE/OP-BI-RF and PH/ESE groups carefully prepared the SPS for our needs
- Special thanks to out funding agencies

2011 road-map for a test in LHC

- Crystals in preparation at PNPI and INFN-Ferrara to be tested in H8
- Goniometer in preparation with and industrial partnership with CINEL, to be tested in H8
- Special instrumentation [loss detectors and mini-Roman pots] in preparation at CERN with the help of INFN and Imperial College to be tested at the SPS
- Layout and simulations under investigation at CERN

Parameters	Obtained in 2009	Obtained in 2010	Required for LHC
Channeling efficiency, %	75	80	90-95
Nuclear loss reduction	5	16 - 20	20 - 30
Goniometer angular accuracy, μrad	30 - 40	10	1 - 2
Crystal bend angle, μrad	140 - 150	150 - 170	50 - 100
Crystal torsion, μrad	20 - 30	5 - 10	0.5 - 1
Amorphous layer on crystal	About zero	About zero	About zero
Collimation leakage reduction	-	5	Should be analysed