Activities for application of a crystal for accelerators

KEK-Hiroshima Collaboration

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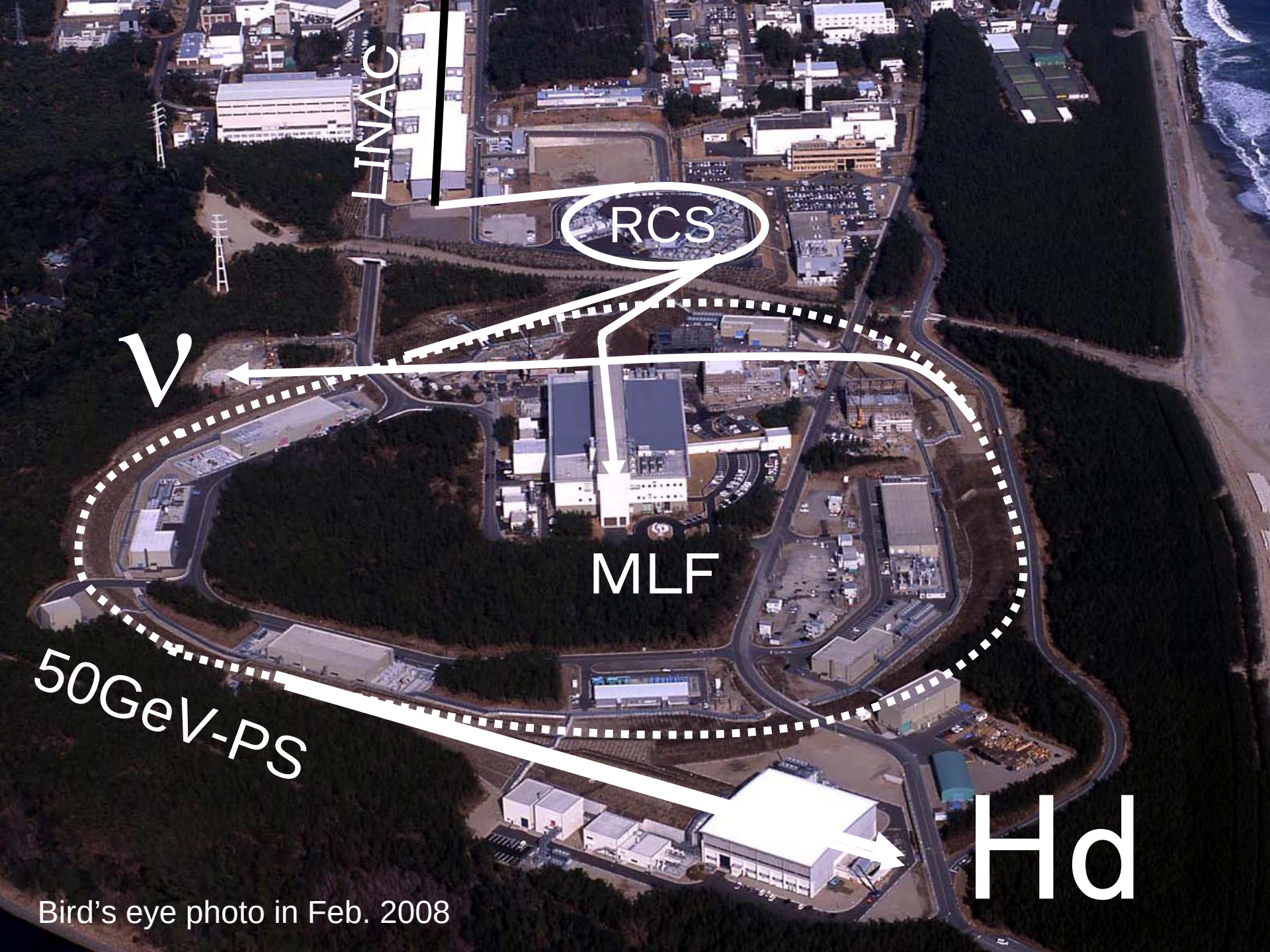
Motivations

- Application to J-PARC
  - Beam separation in a extracted beamline
- Application to ILC
  - Takahashi's talk

Application to J-PARC

- First goal is to realize a beam separation system at a slow extraction beamline.

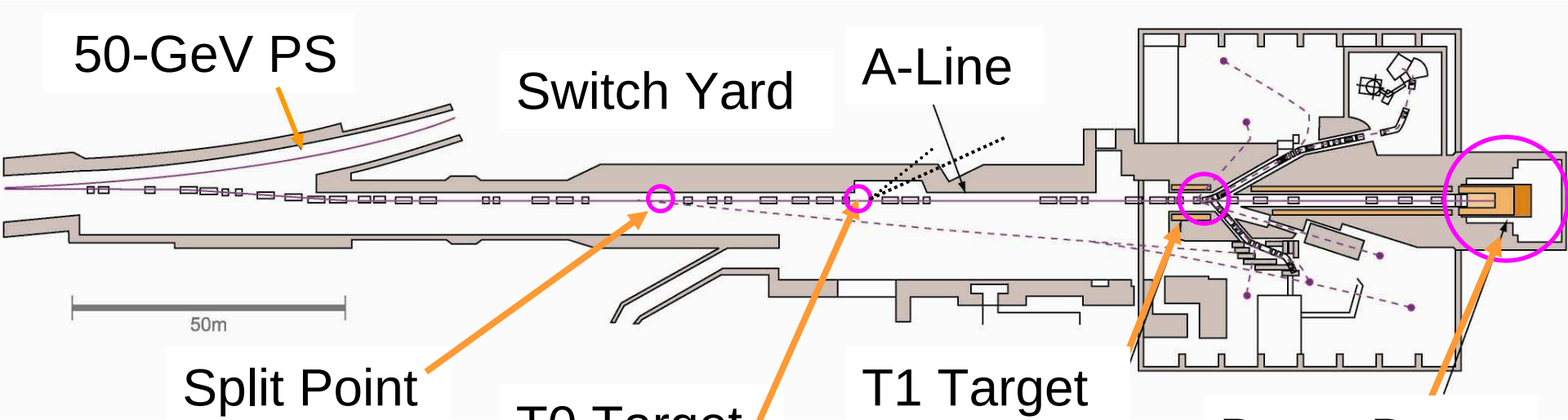
- J-PARC
  - 180MeV Linac + 3GeV RCS + 50GeV MR
  - In December, the 3-GeV facility starts user experiments, and the 50-GeV accelerator starts trial of beam acceleration to 30 GeV.



Bird's eye photo in Feb. 2008

Slow Extraction Beamline (Phase 1)

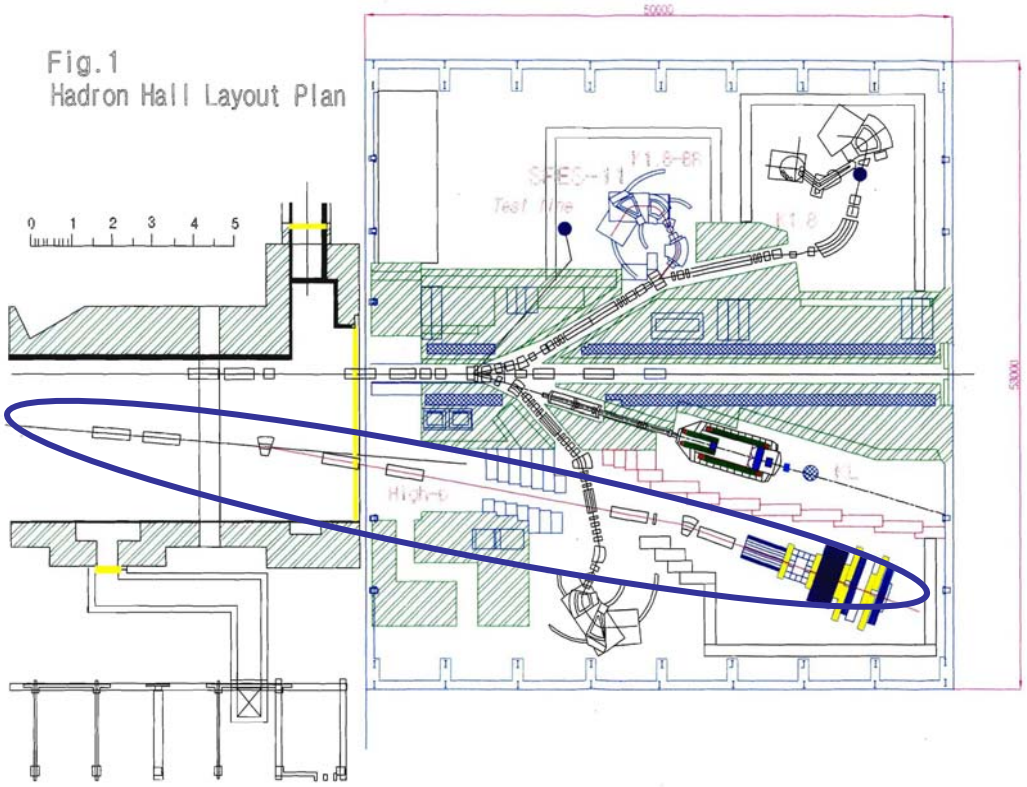
Hadron Hall
56m(L) × 60m(W)



Plan to extend the hall downstream (~50m)
in the Phase 2.

High momentum beamline

- Primary protons (10^9 – 10^{12}/sec) and high mom. 2ndary beams.
- Issues:
  - Budget.
  - Development of equipments at the separation point.
  - Utilities (electric power and cooling water).



R&D efforts so far

- Electron channeling at the 150-MeV storage ring at Hiroshima.
  - To learn fundamental aspects of electron channeling
  - Experimental data was compared with simulation.
- Proton separation at the KEK 12-GeV PS
  - To demonstrate the principle
  - To measure the separation efficiency

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Steering Beam of Charged Particles using Silicon Crystals

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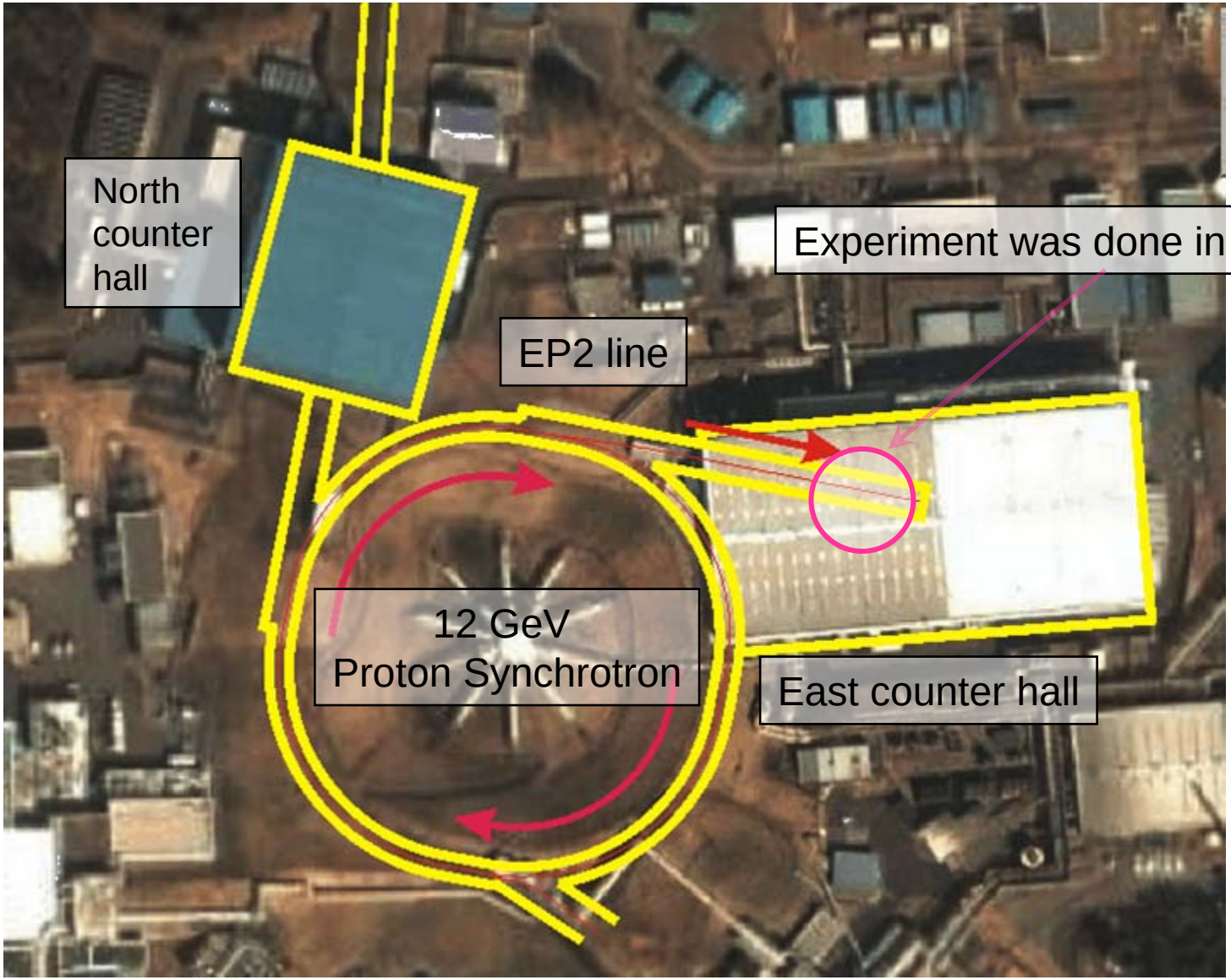
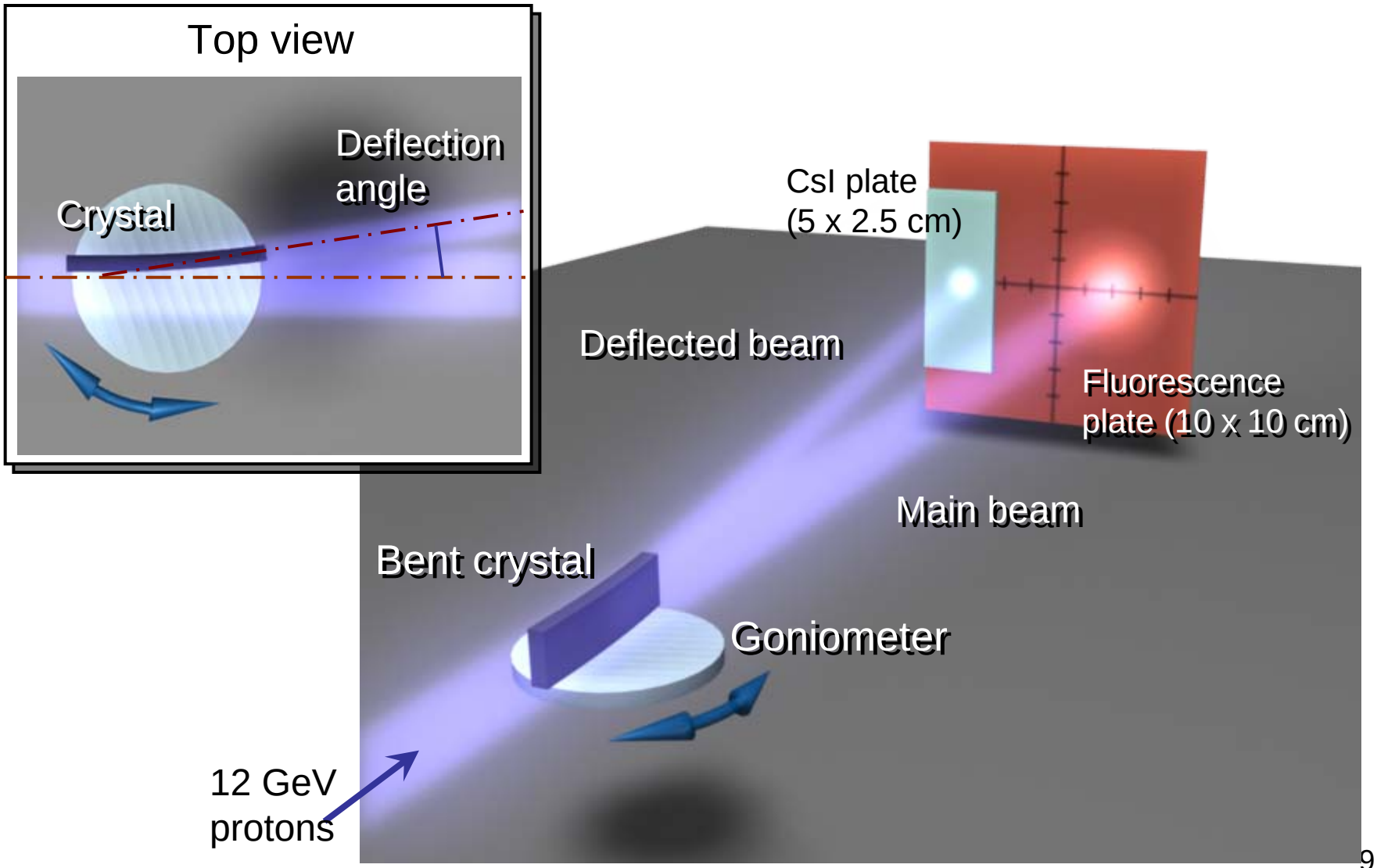
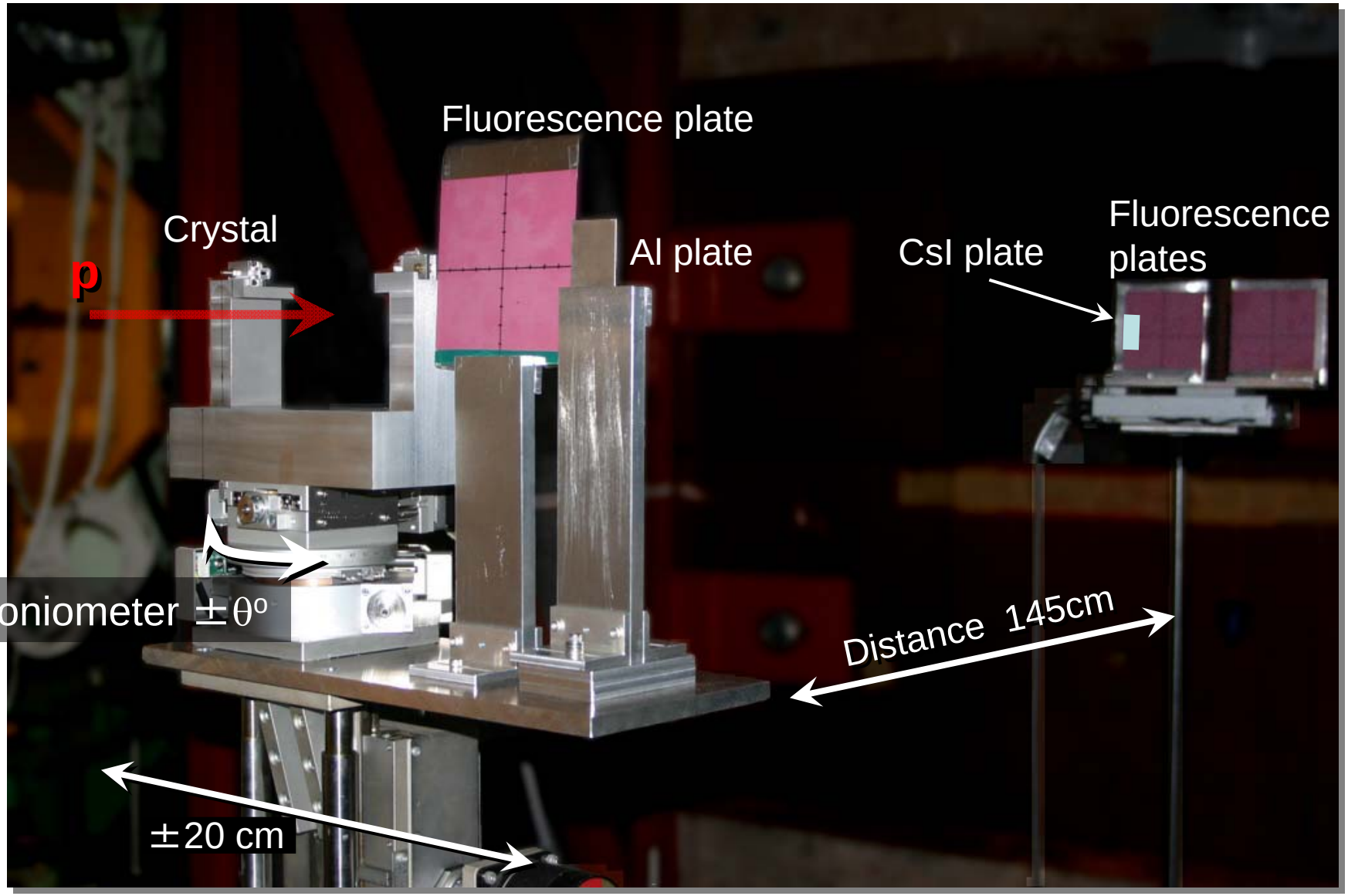
Experiment at KEK-PS



Schematic drawing of the experiment



Experimental setup



Crystal, proton beam

Parameters of crystal

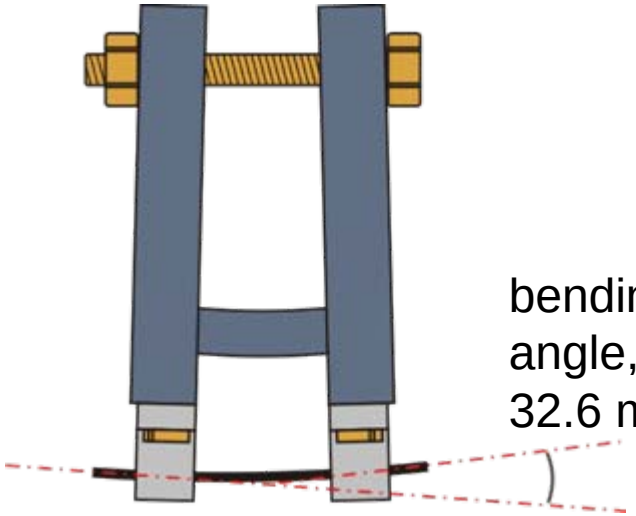
Material: Silicon

Size: 3 x 0.3 x 10 mm

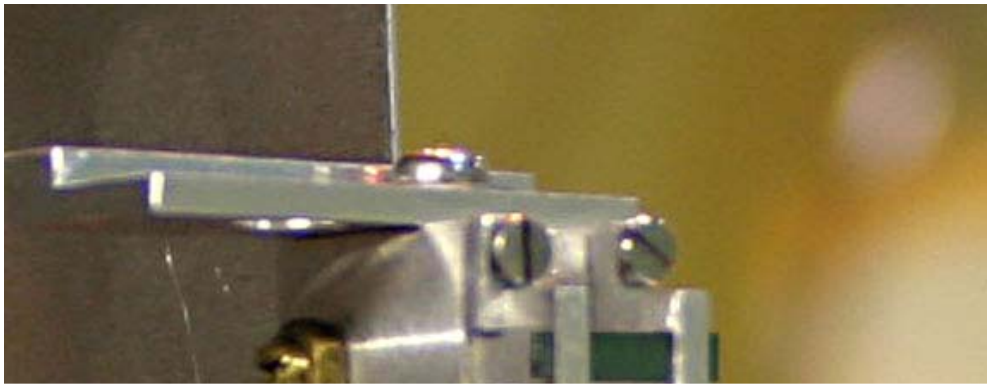
Bending angle: ~ 32.6 mrad

Plane: (111)

Lindhard angle: 0.056 mrad



bending angle, 32.6 mrad



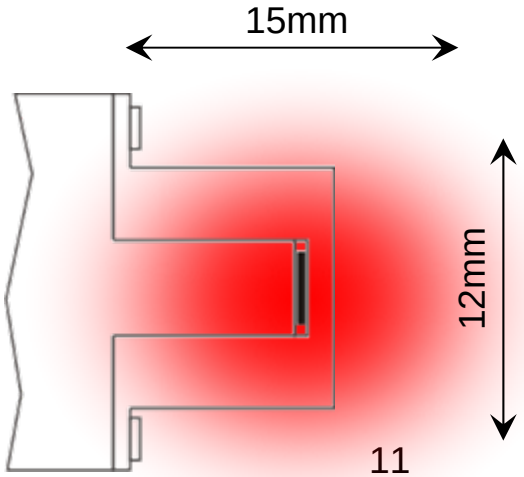
Parameters of the proton beam

Energy: 12 GeV

Intensity: 10^{12} protons/spill

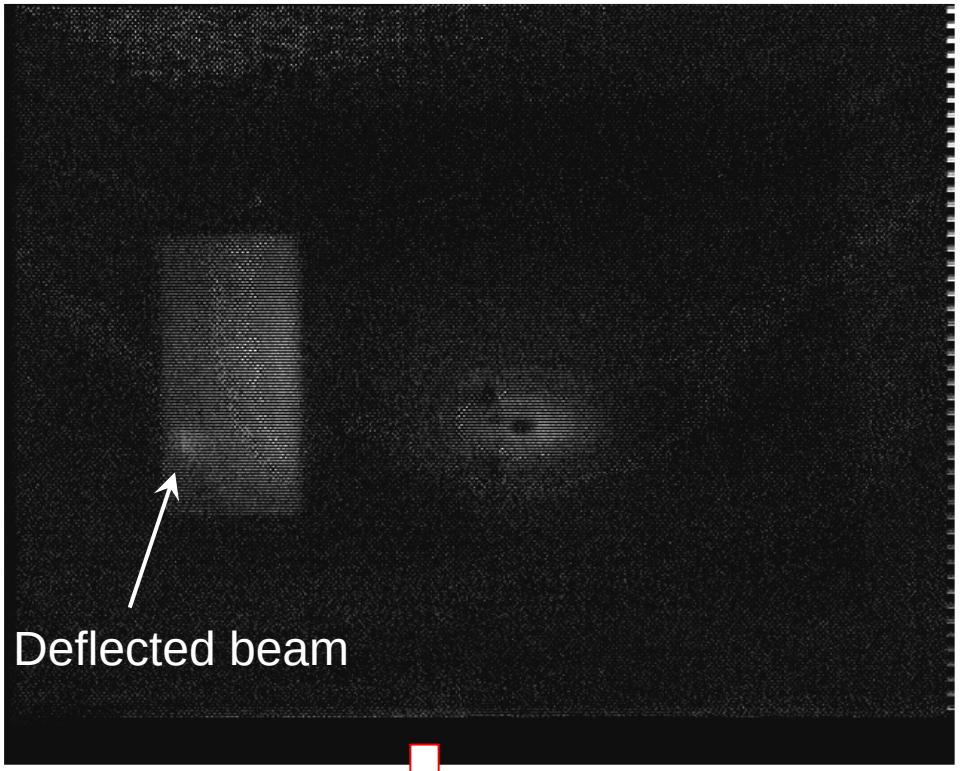
Size: 15 x 12 mm

Divergence: < 5 mrad

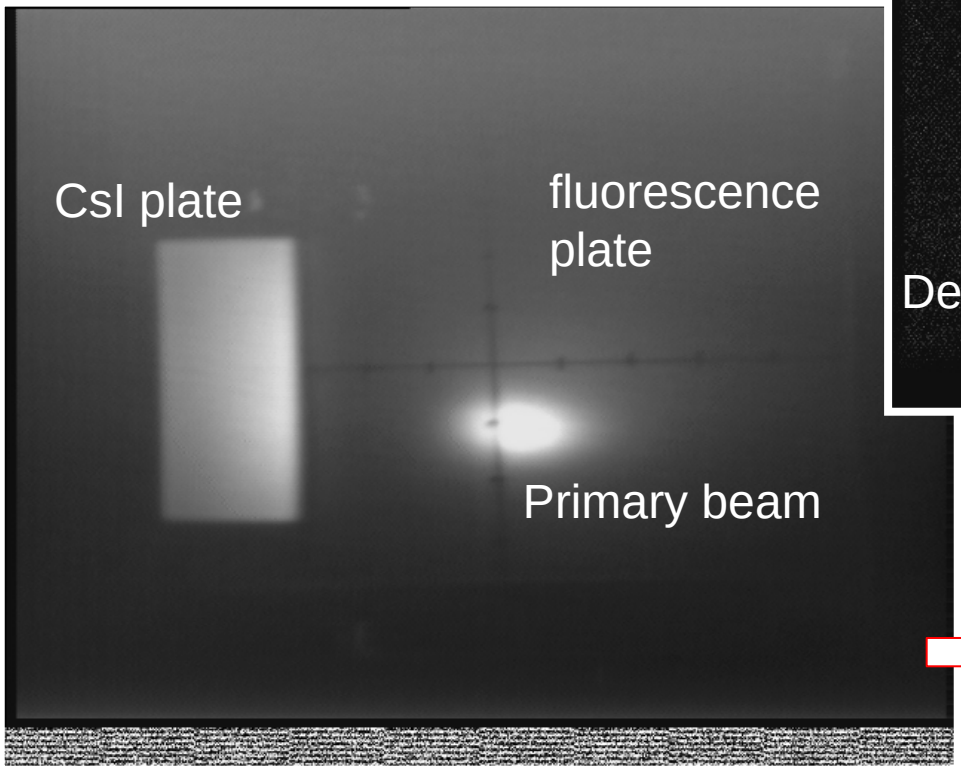


Typical pictures

image after
background subtraction



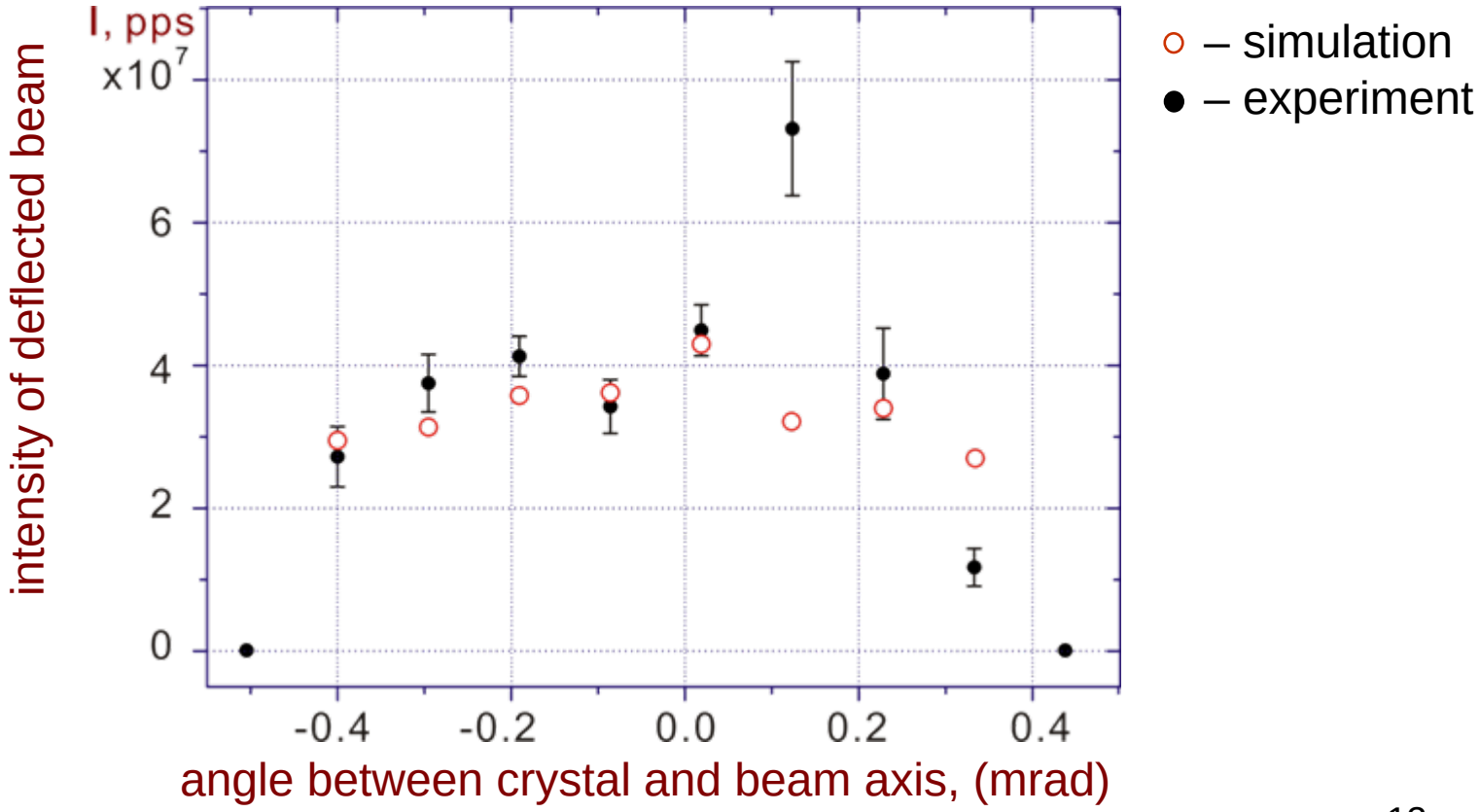
raw image



- intensity of deflected beam
- bending angle
- crystal efficiency

Simulation vs. Experimental data

Experimental intensity of the deflected beam compared with the best fitted simulation (CATCH) for the beam divergence of **0.6 mrad** and normalization factor for the d. b. intensity of **1/0.93**.



Crystal efficiency

Using both experimental data and the beam divergence from the fitting with simulation

N deflected = Crystal Efficiency x

Angle Efficiency x

N incident upon the crystal.

Crystal Efficiency was 23%

Summary on KEK-PS experiment

- Experiment on the deflection of proton beam by the bent crystal was successfully done – we could clearly observe deflected beam.
- A Monte-Carlo simulation was used to find the beam divergence and normalization factor.
- Using results of simulation and experimental data a deflection efficiency was found to be 23%.

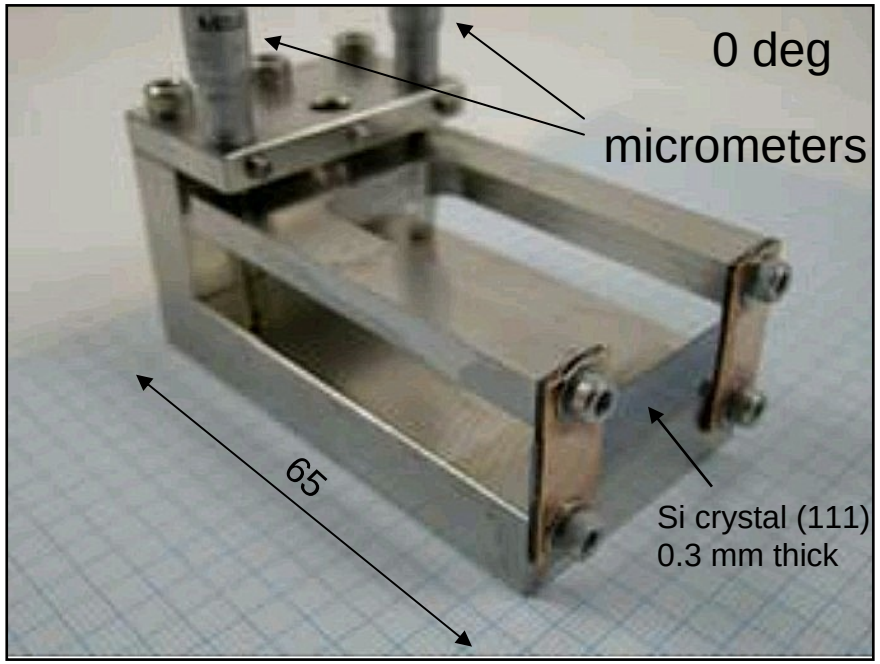
R&D Issues for J-PARC application

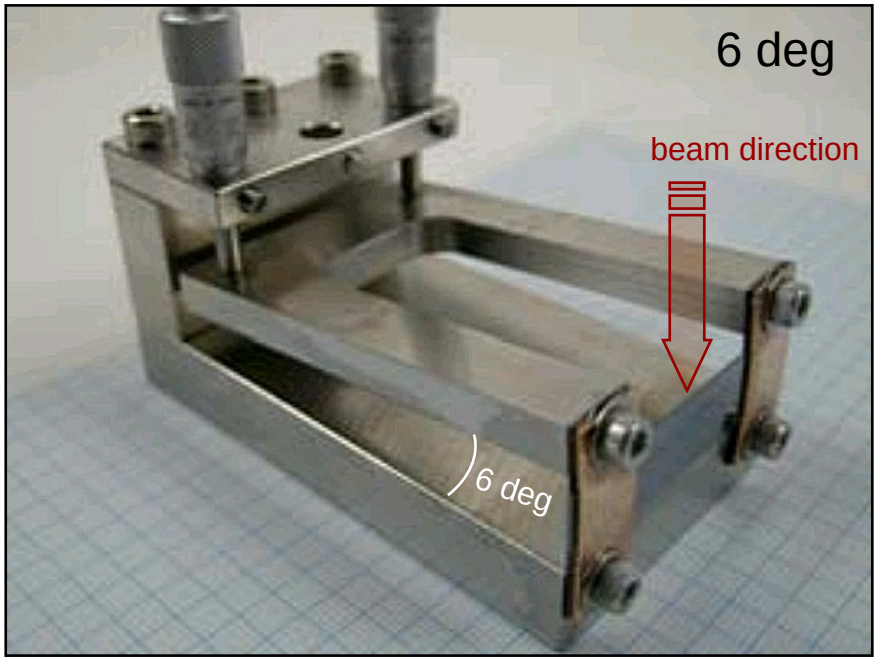
- Crystal fabrication
  - At J-PARC, the beam intensity is very much high, and the size (length in the transverse direction) of the crystal should be large, so that the (metal) holders are well far away from the beam.
  - In order to use the crystals routinely at this high intensity machine, a method to fabricate crystals in a steady manner should be required.
  - A basic trial has just been started with a company in Japan.
- Radiation and heat resistant goniometer system inside the vacuum at the separation point.
  - Not yet started.

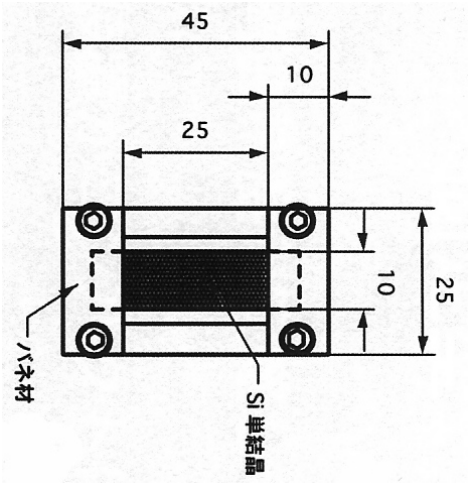
Bent Silicon Crystal

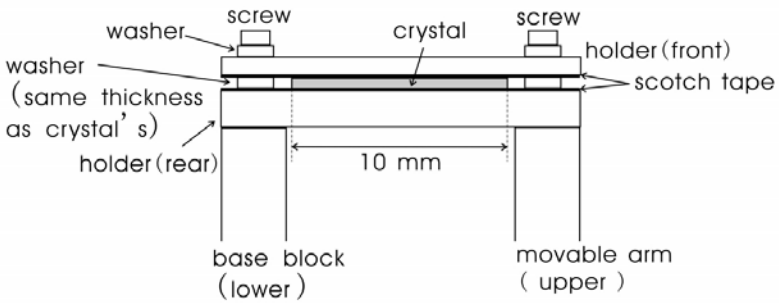
Collaboration of KEK and
Hiroshima University

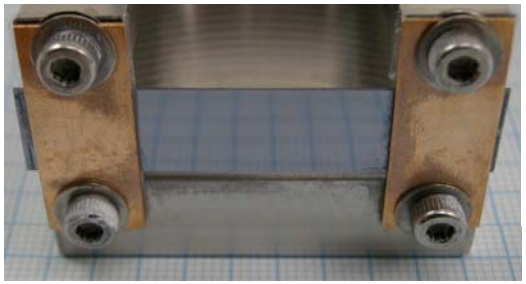
Experimental Setup











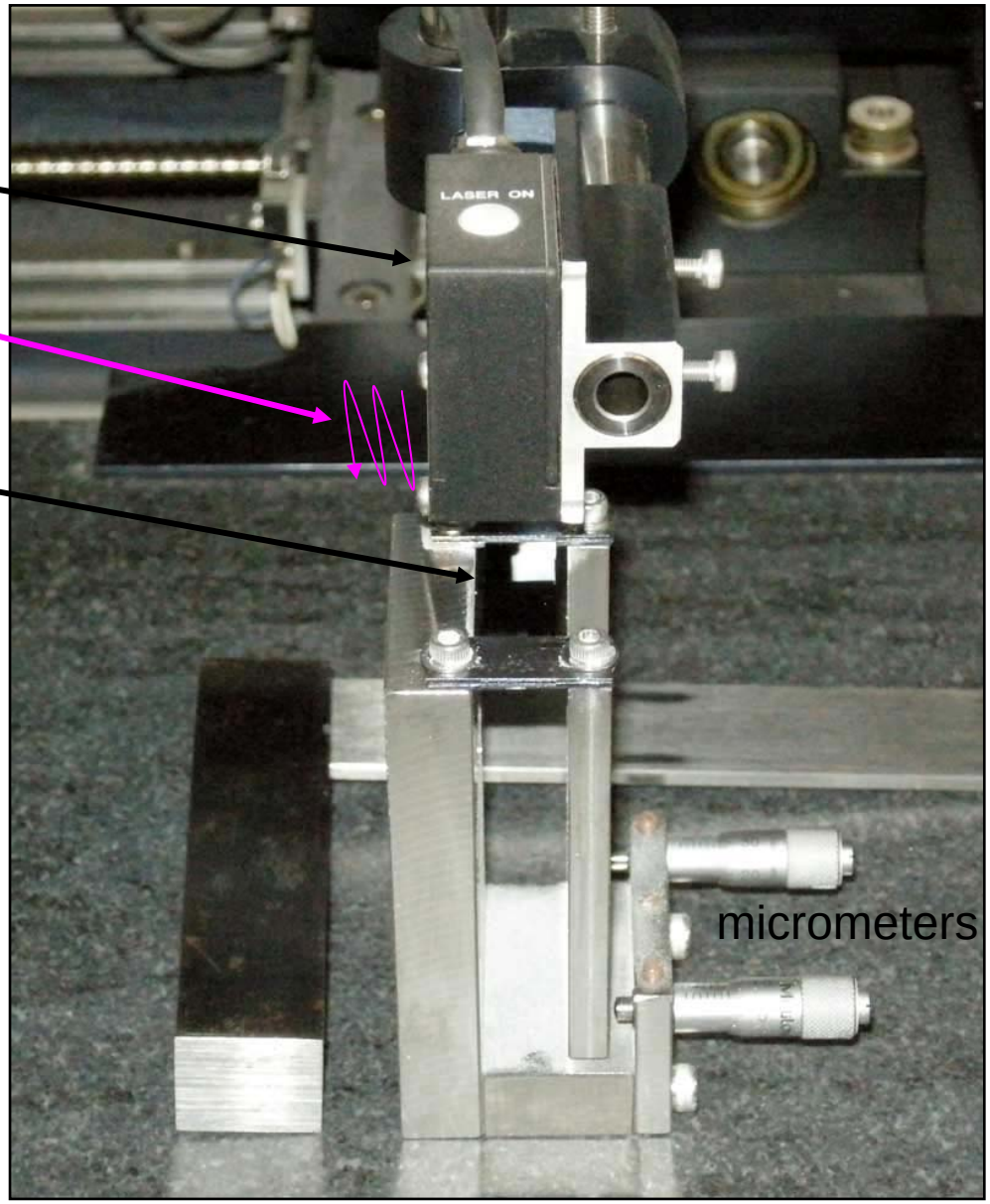
Front holder: steel, thickness 0.5 mm
Rear holder: steel, thickness 1.0 mm

Experimental Setup

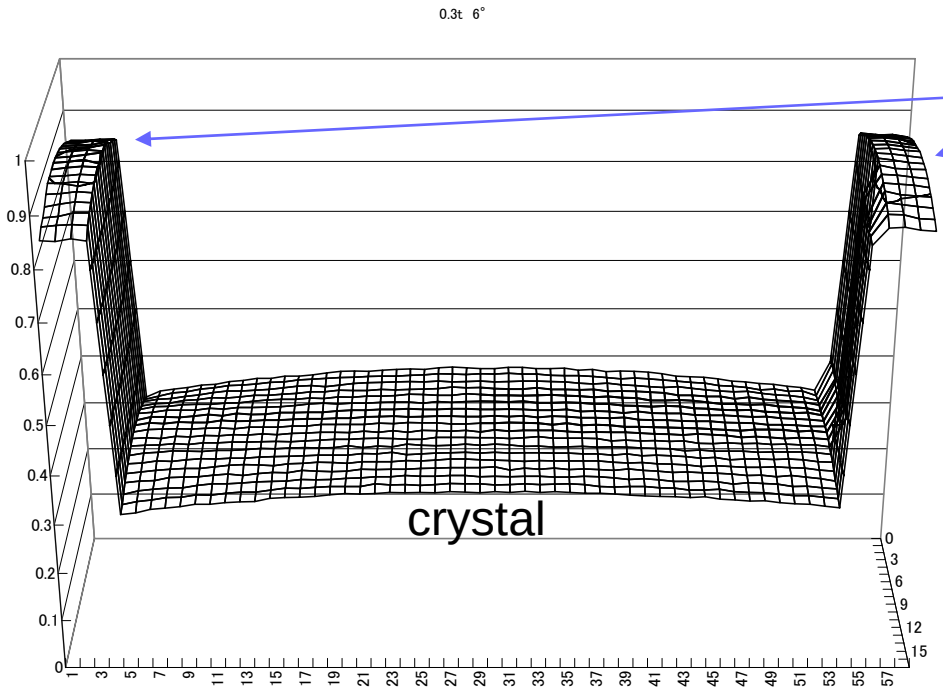
Scanning system with laser

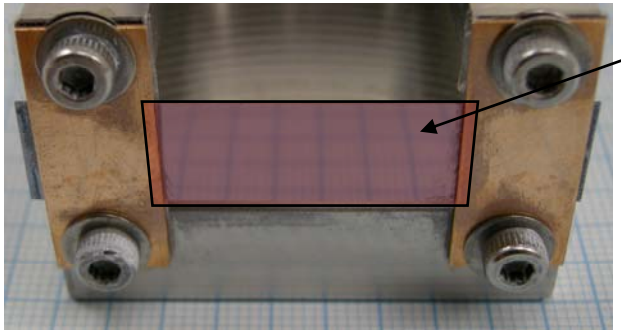
Scan direction

Crystal in a holder



Typical surface profile

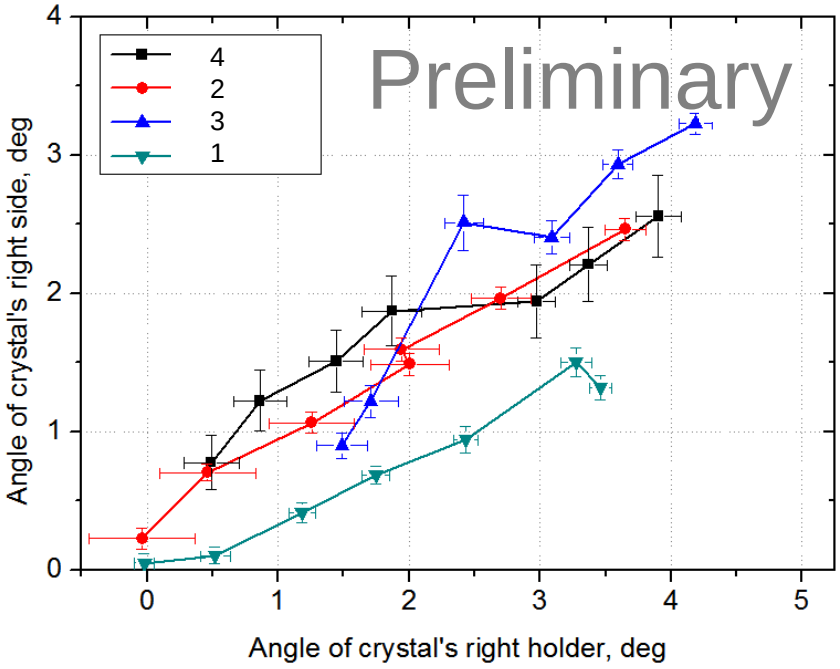




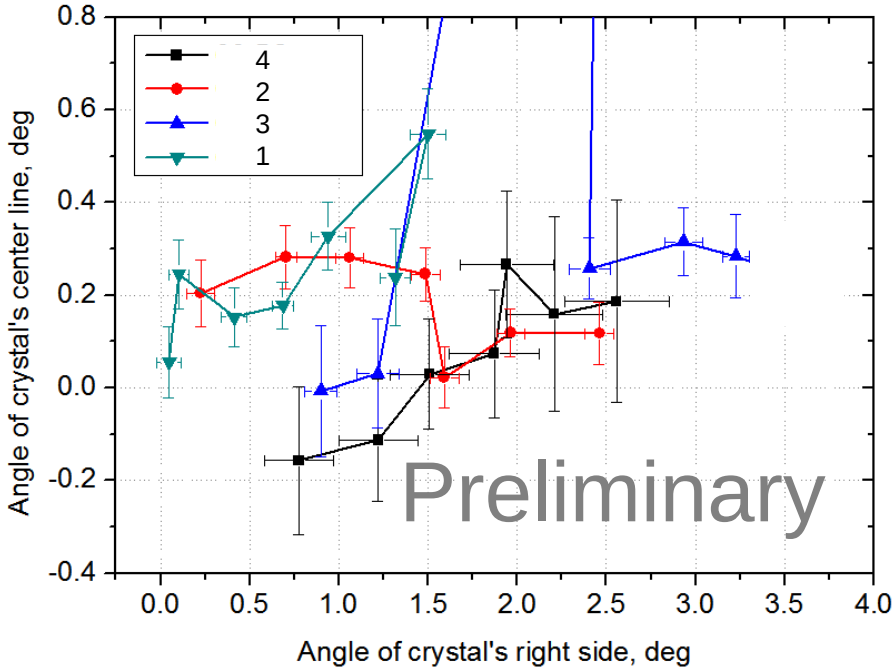
scan area:
29 mm x 9 mm,
step: 0.5 mm
Total points: 1044

Data obtained from the fitting

Angle of crystal's right side



Crystal's central angle



Simulation code

FEM (Finite Element Method) were used to calculate surface profile of the bent crystal

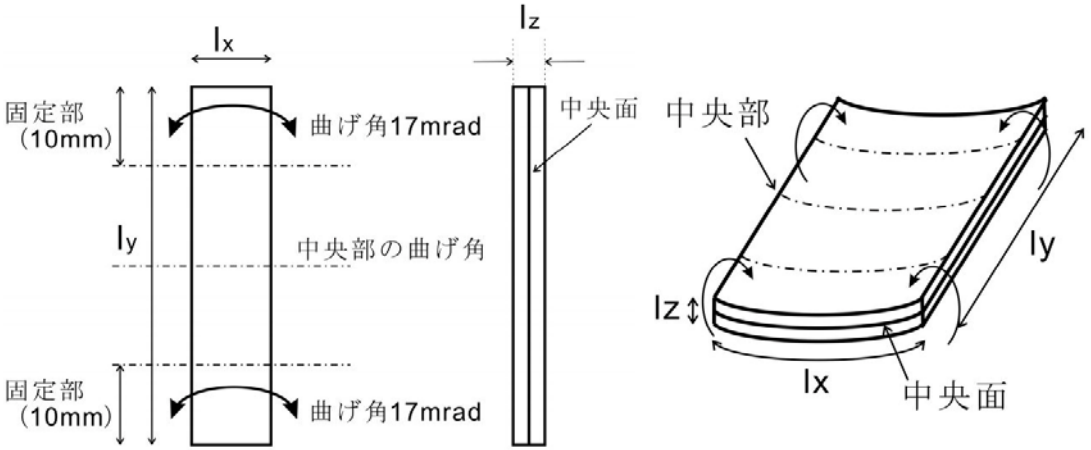
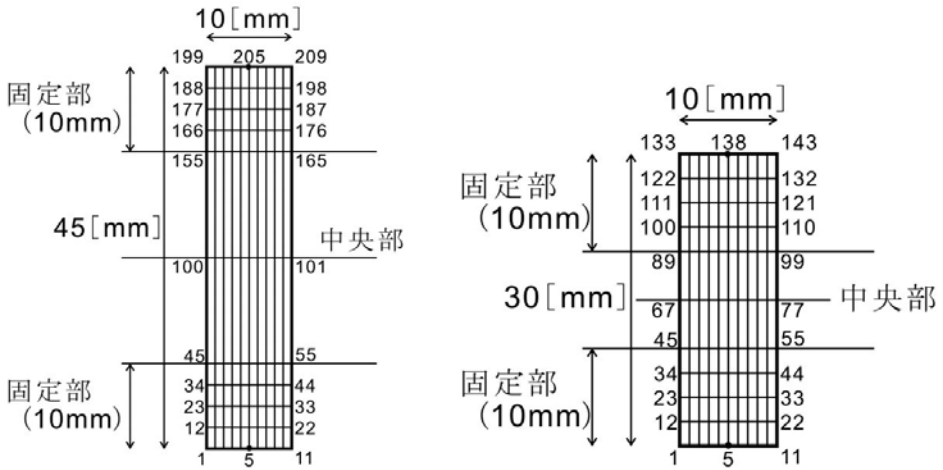


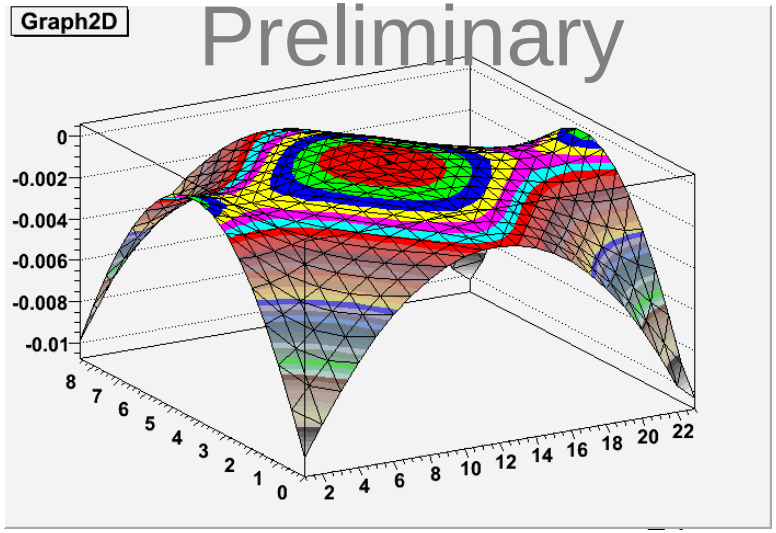
図1 ： 結晶板と 曲げ



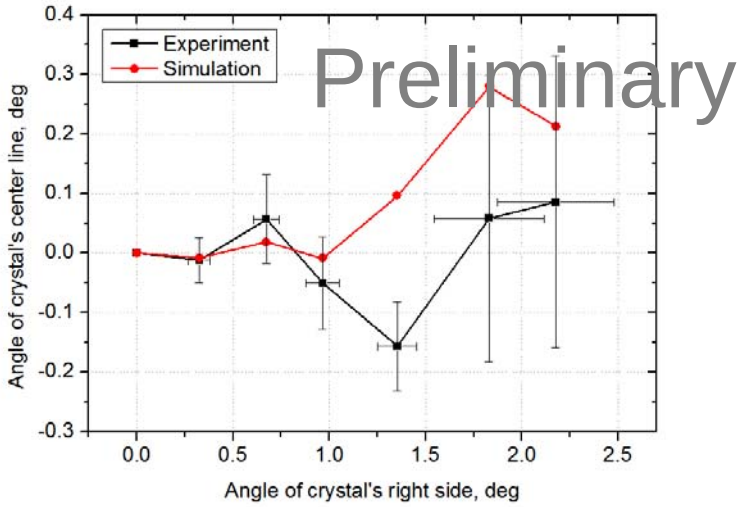
サイズ： 45[mm]×10[mm]　　サイズ： 30[mm]×10[mm]

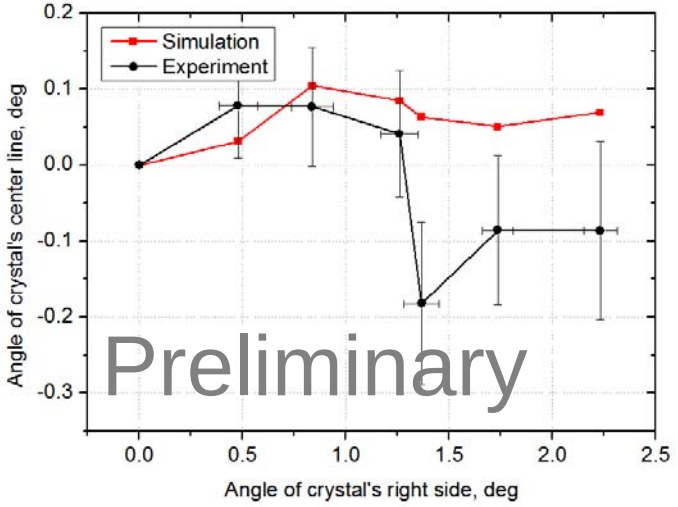
図3 ： メッシュと節点番号

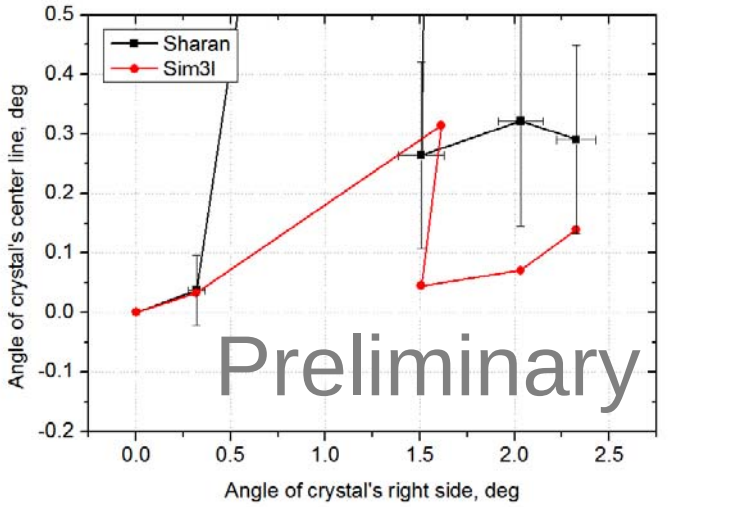
Typical calculated surface profile

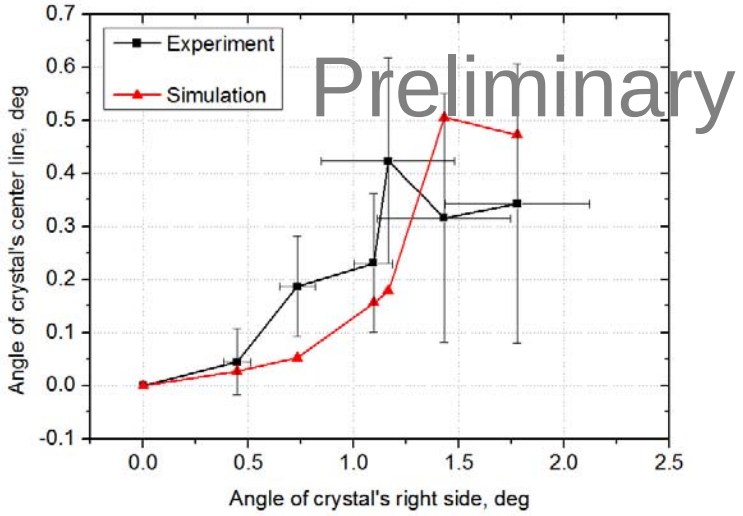


Examples of comparison of the experimental data with the data obtained from the calculation



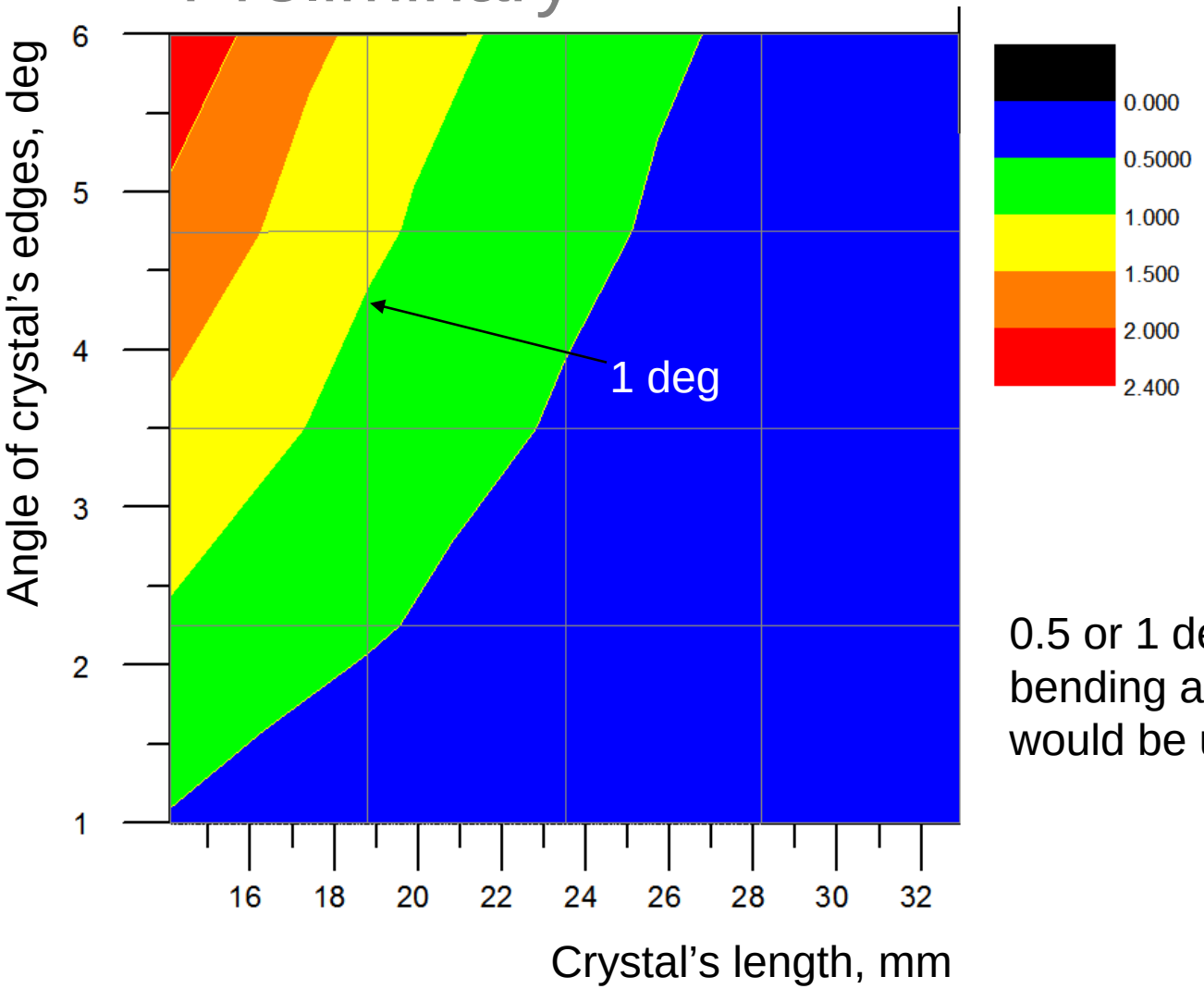






Dependence of the crystal's central angle on the length of the crystal and the angle of the crystal's edges

Preliminary



0.5 or 1 degree bending at the center would be useful.

Summary

- We have been done some R&D studies.
  - 150-MeV electron deflection
  - 12-GeV proton separation
  - Simulation
  - Fabrication of bent crystals
- One of the goals is to realize the crystal separation system of the high intensity proton beam at J-PARC, not as an R&D system but as a routinely operating system under the high rad and heat environment.

Notes

- We’d like to keep discussions on this crystal application.
- Is a test experiment at MI possible?

Thank you