High Energy Physics Laboratory
Graduate School of Advanced Sciences of Matter

Crystal channeling for electron/position beams

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- Activity around Japan
  - proton separation experiment at KEK
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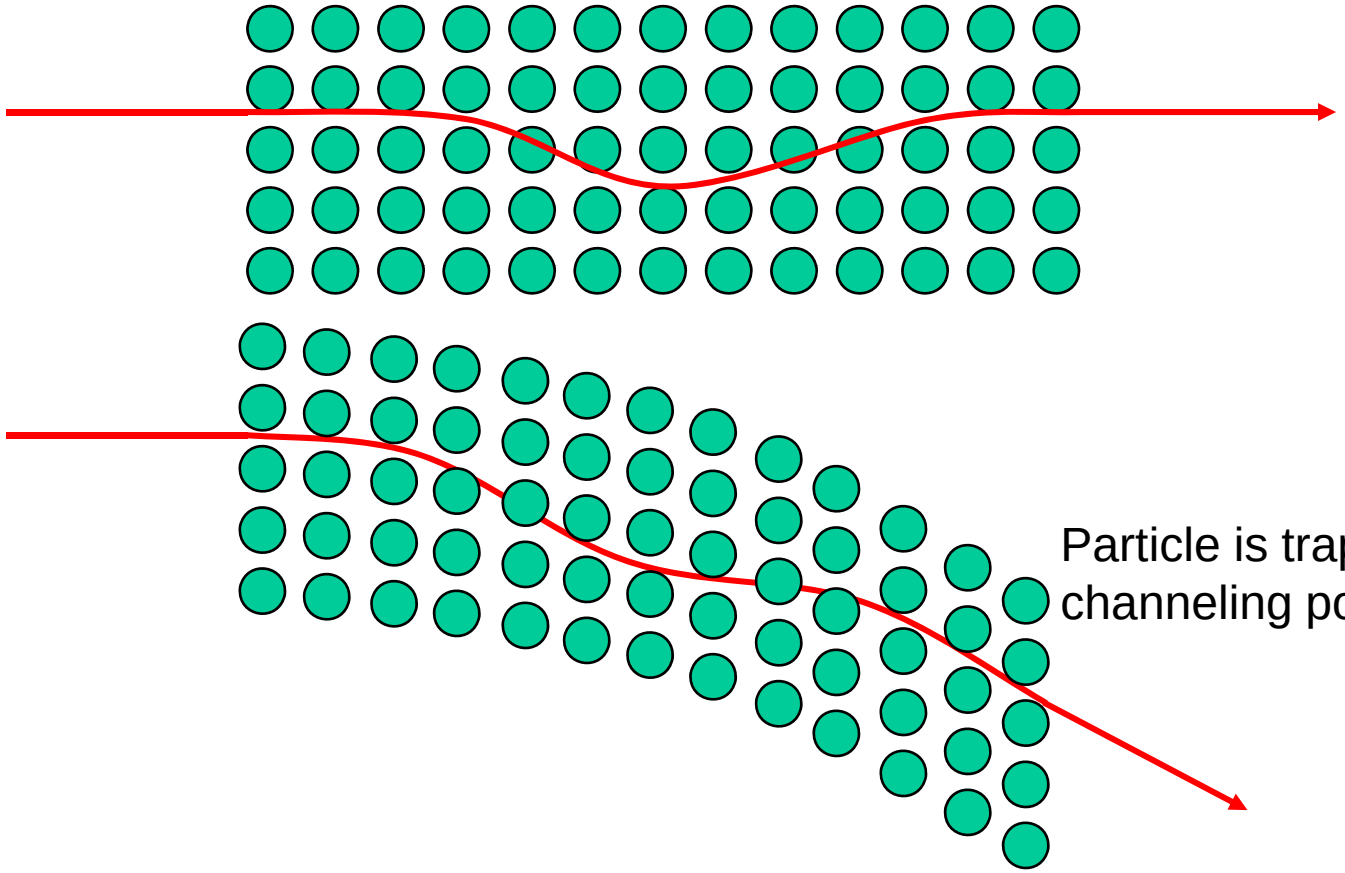
  - crystal fabrication
- Possible R&D

Channeling

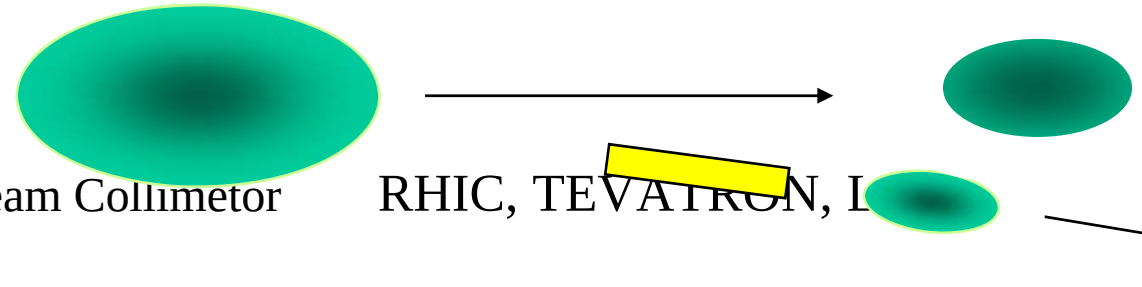


Particle is trapped by the channeling potential

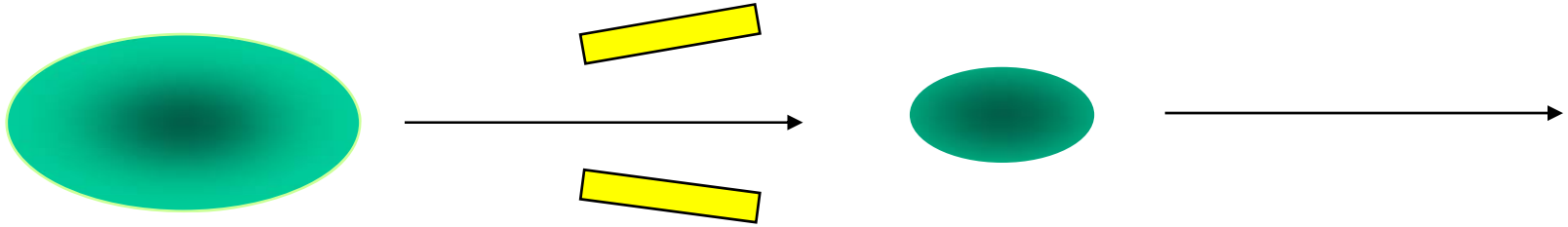
Very strong field → strong bending force

Application for beam handling

– beam extraction　U70（IHEP), TEVATRON



– Beam Collimetor　　RHIC, TEVATRON, L



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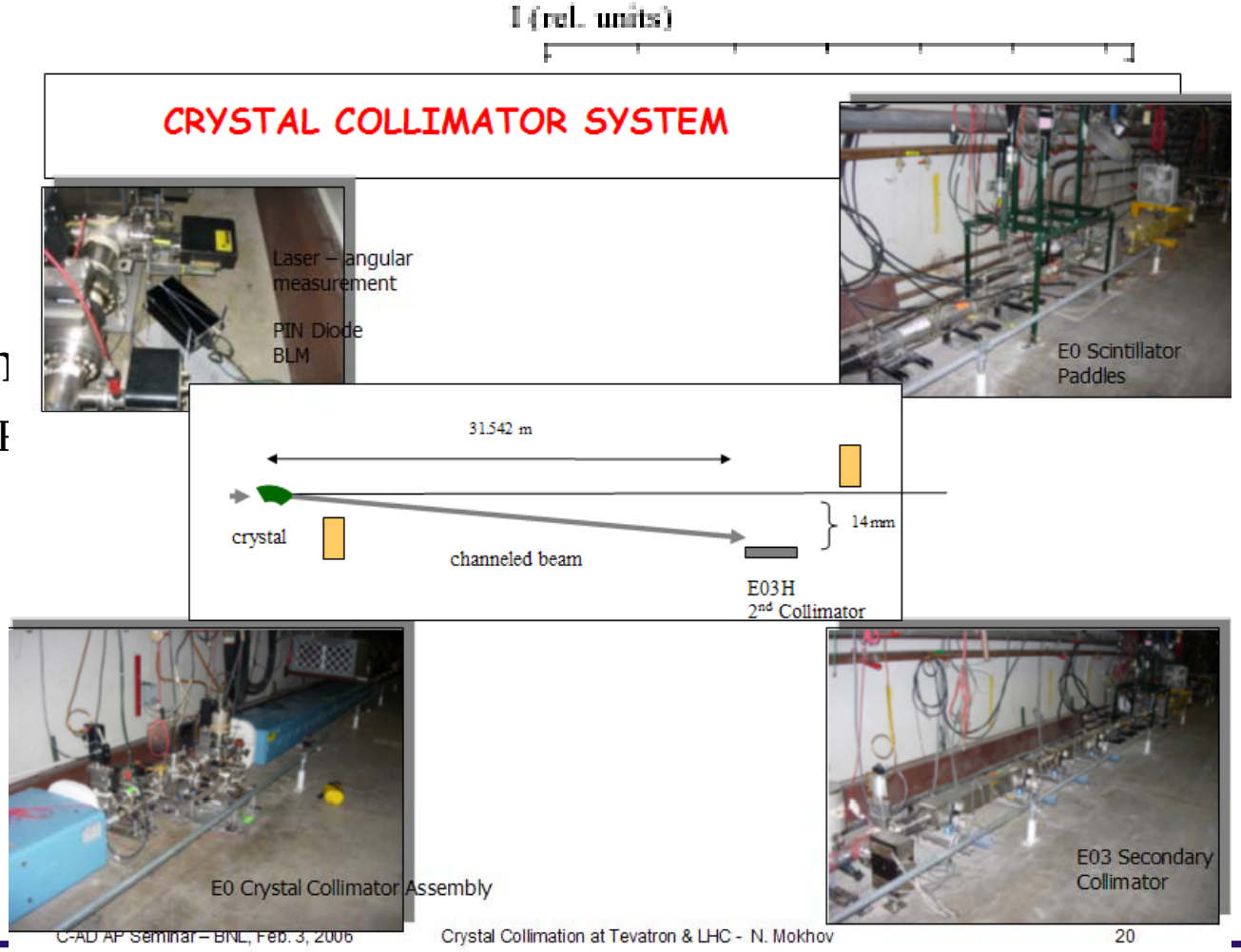
Crystal for Accelerators

- beam extraction at
  - IHEP, CERN
- beam collimation
  - FNAL, IHEP, CEI



http://photon.qm.adsm.hiroshima-u.ac.jp

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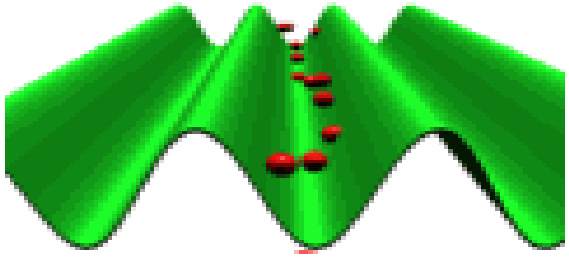
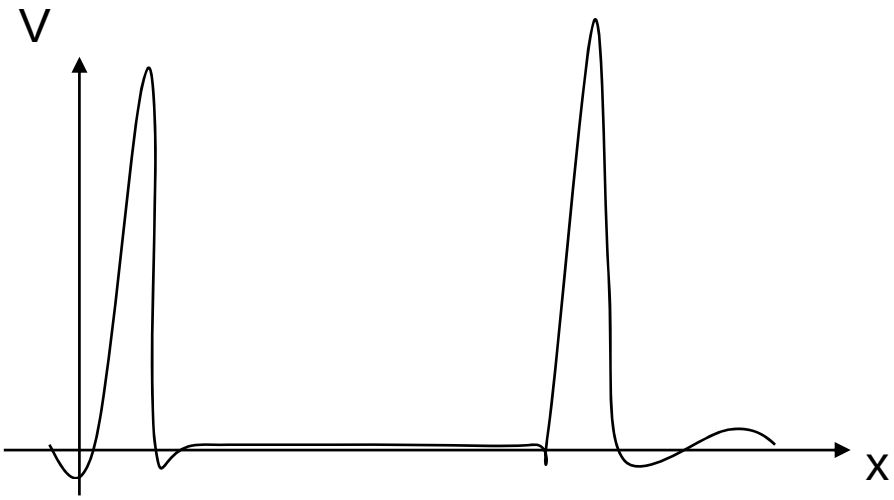
Positrons and Electrons

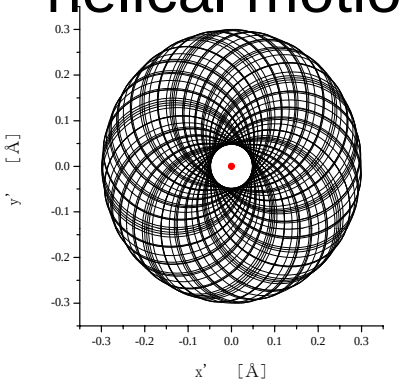
Positrons
trapped in between planes

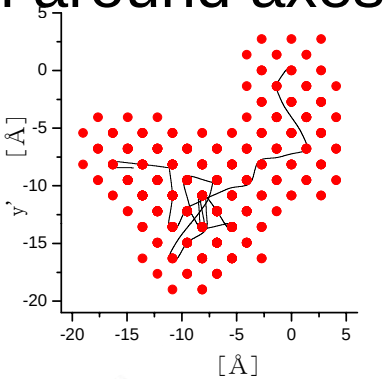


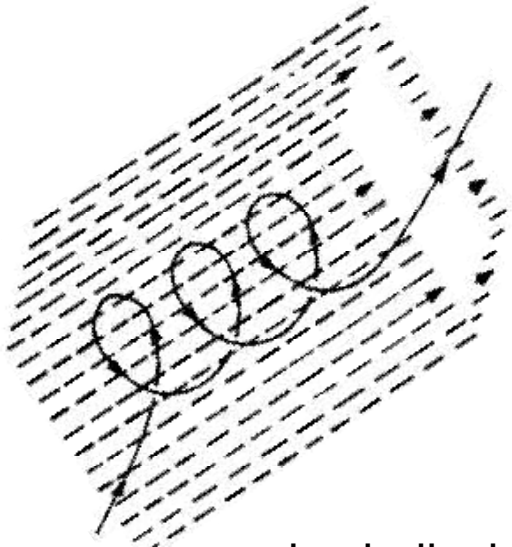


Travels in ~flat bottom of planer potentilal

Electrons
helical motion around axes





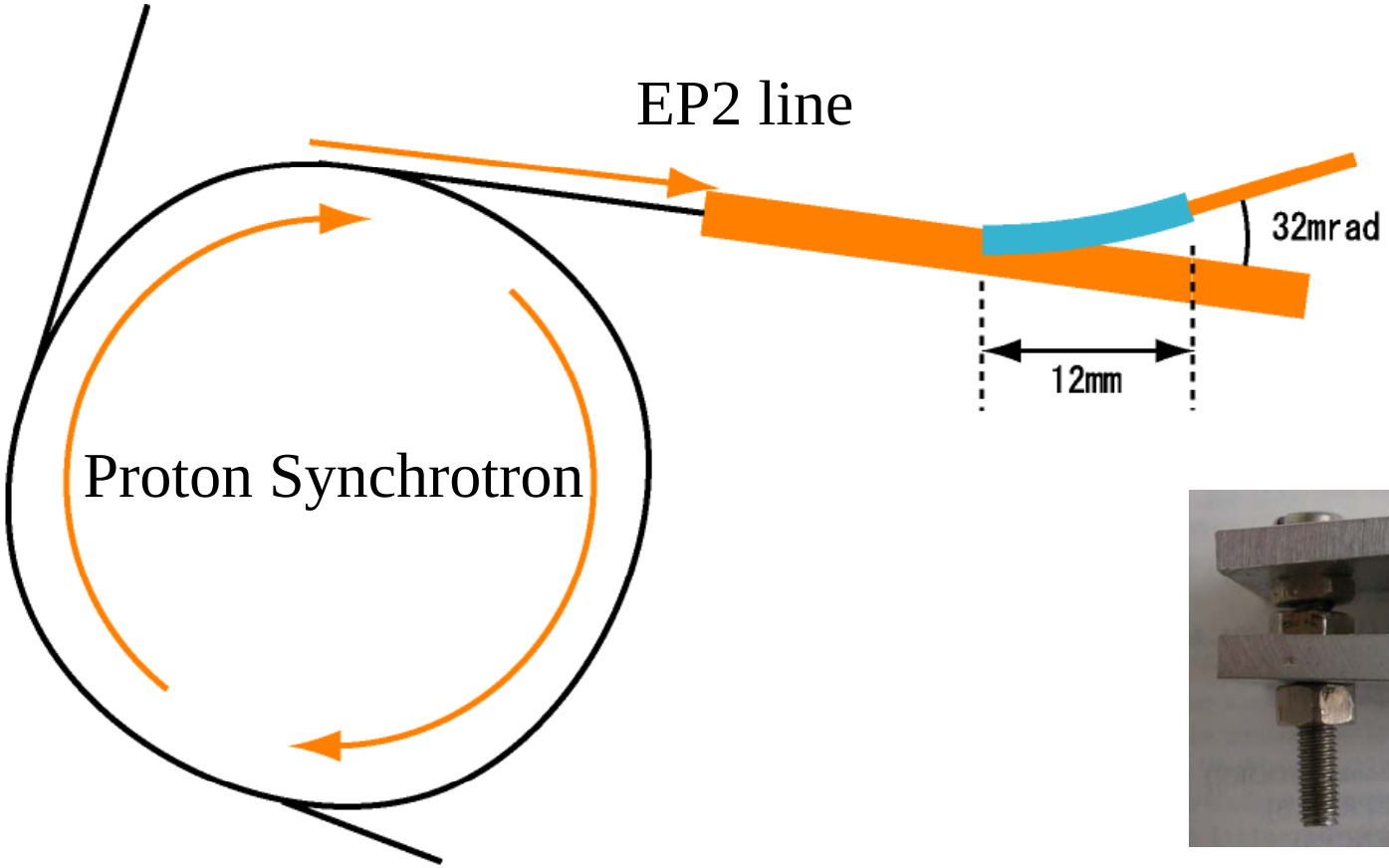


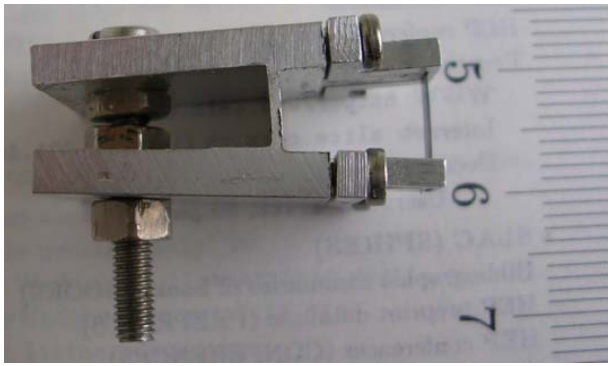
complex helical motion
along axes

electron and positron

- positrons ,,, positive particle
  - similar with protons but radiation
  - actively studied for protons
    - extraction
    - collimation
      - RHIC TEVATRON ,, LHC
- electrons,,, negative particle
  - Complicated behavior in crystals
  - not well studied
  - de-channeling length ~1/10 of positive pariticle?

Proton beam separation at 12 GeV PS

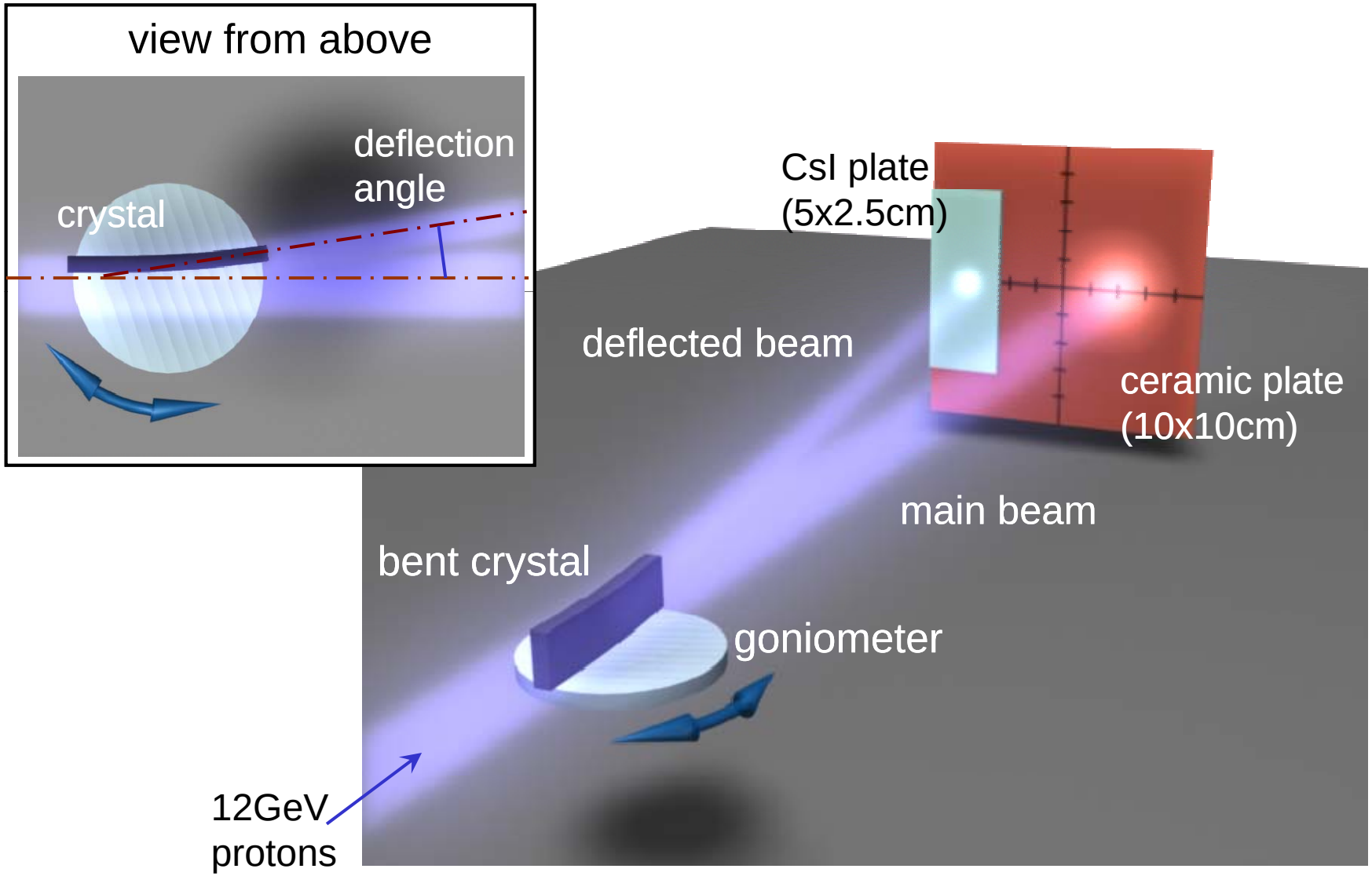




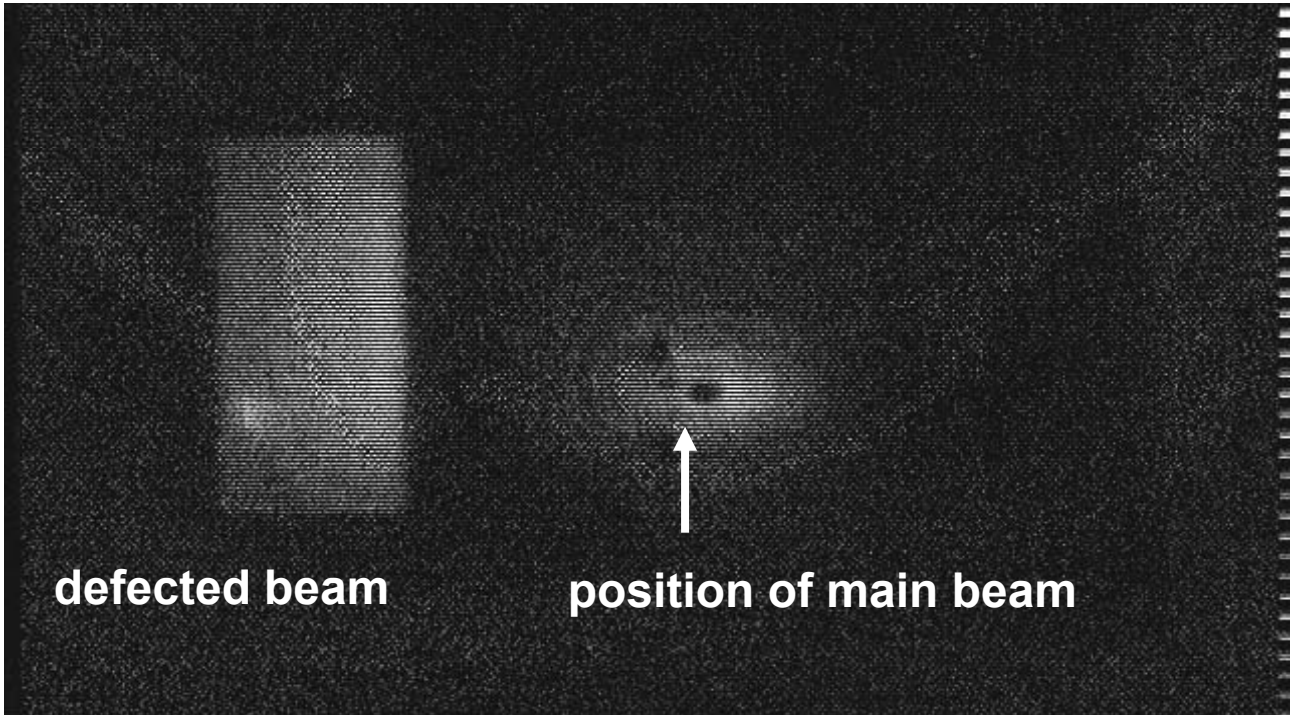
32mr bent in 12mm

→ B = 105T

Schematic of the experiment



Observed deflected beam



$$N_{deff} \approx 5\times10^{-5} N_{beam} = \varepsilon_{ch} \times \varepsilon_{angle} \times \varepsilon_{area} N_{beam}$$

$$\approx 20 \square 85\%$$

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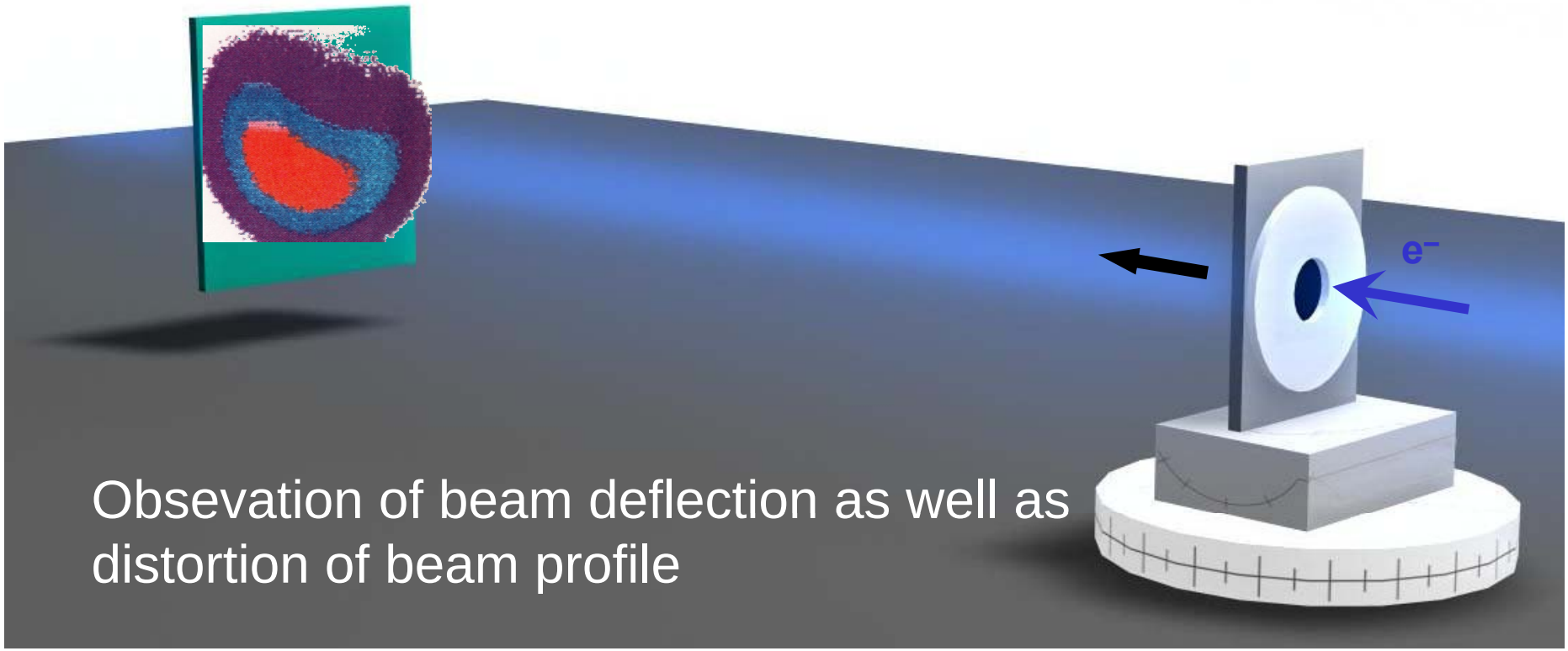
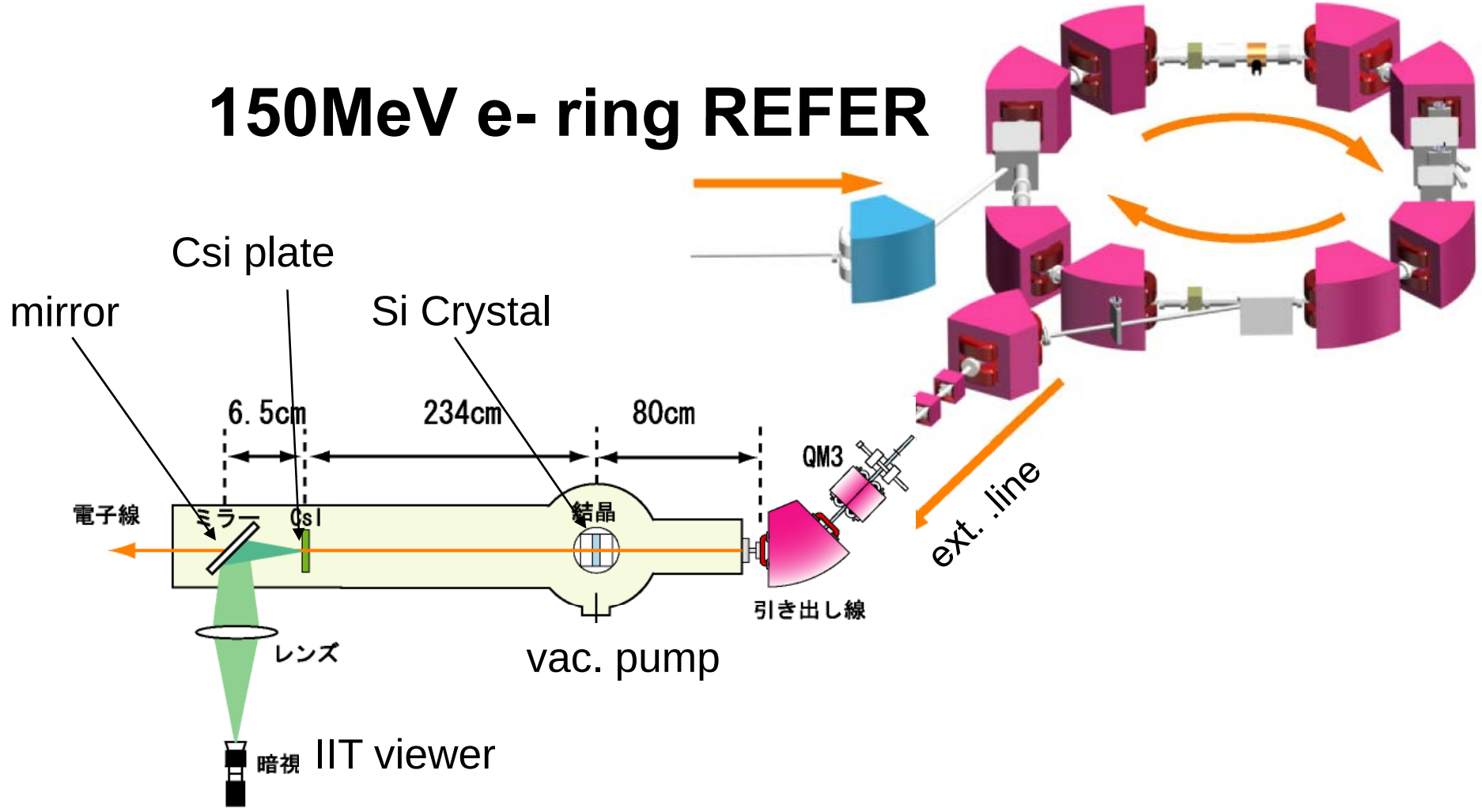
e- beam distortion at INS-ES

- 1.2 GeV e- w/ angular divergence of ~1mr



should be much more clear at ATF as
$x'/y' << \theta_{crit} \sim 0.2mr$

electron beam bending at Hiroshima



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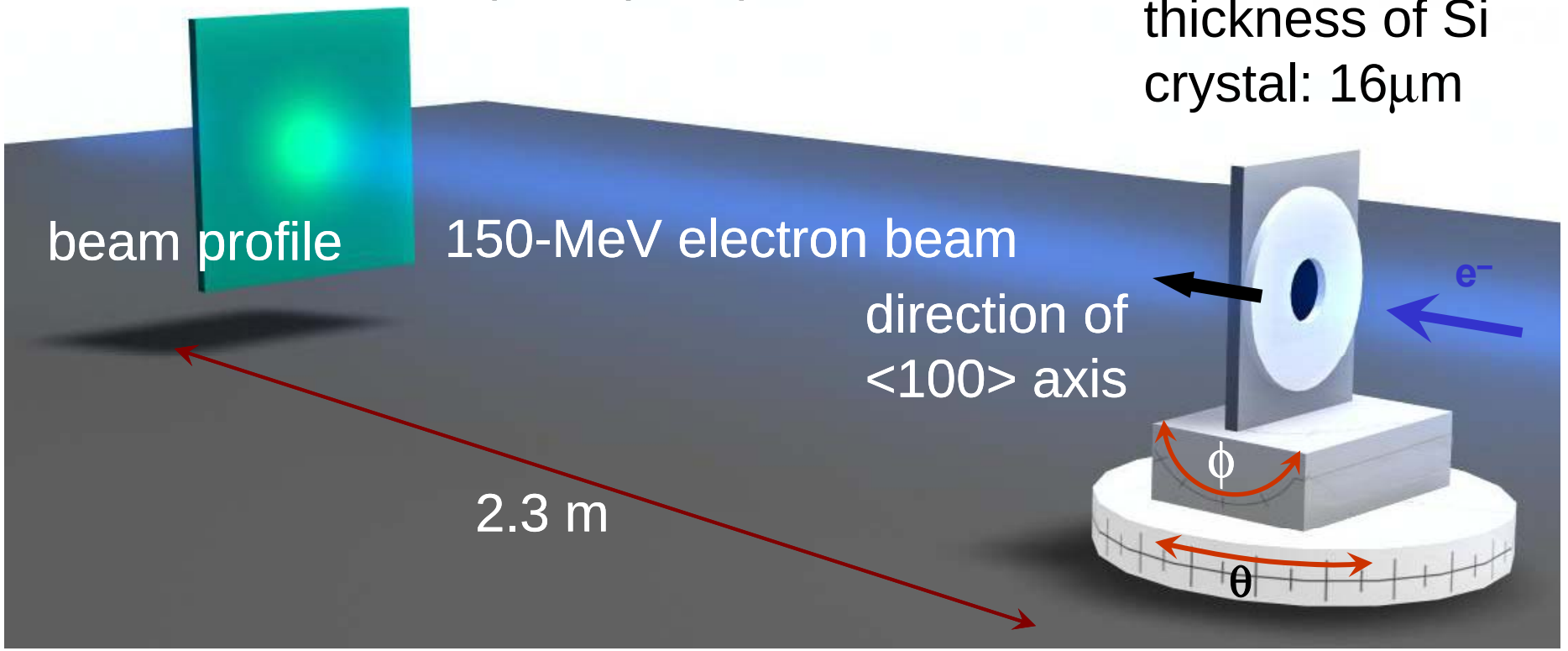
Schematic of the set up

Observation of a beam profile at the FOS plate
in each combination of θ and ϕ angles

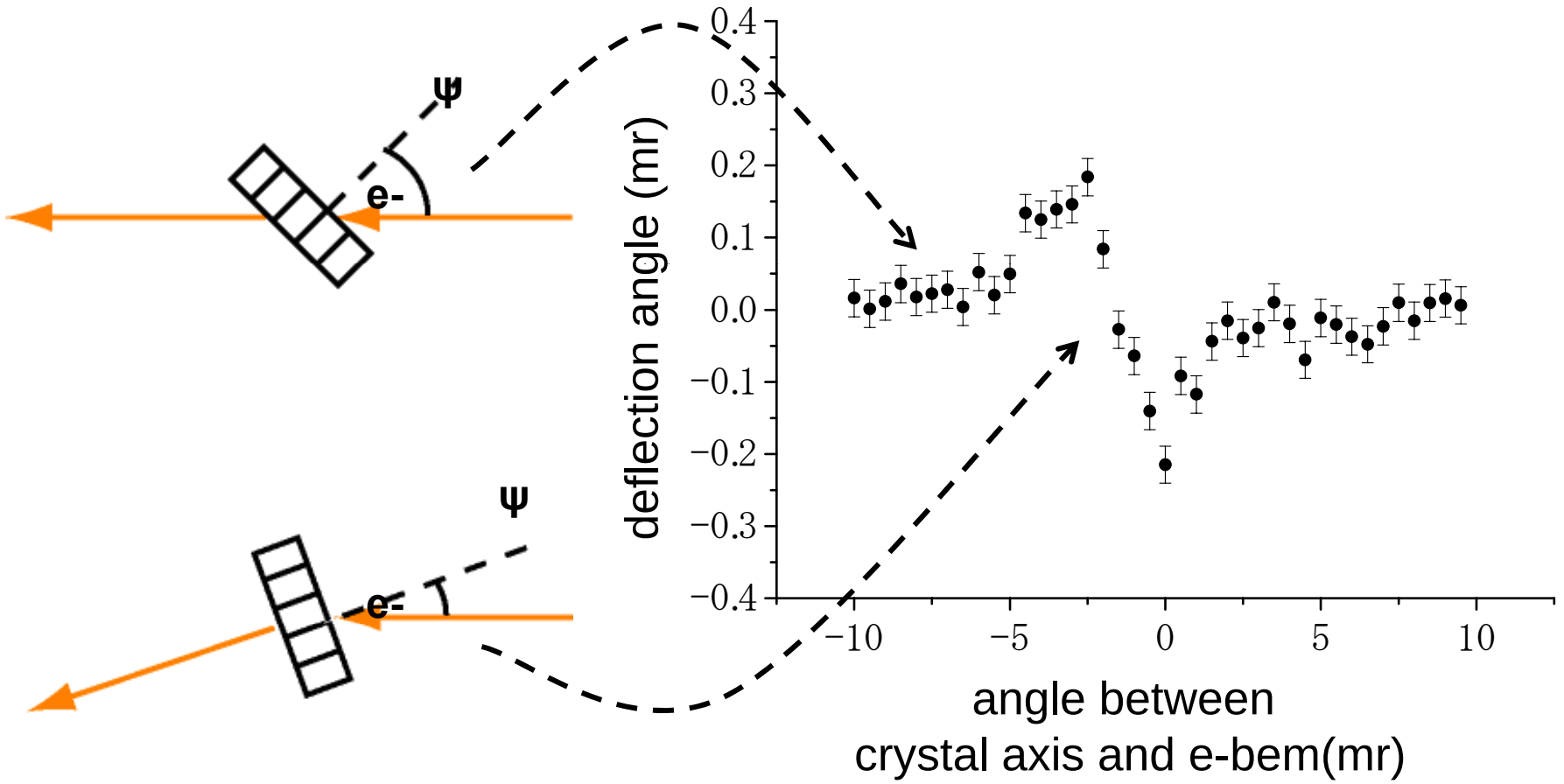
Fiber Optics plate
with a Scintillator (FOS plate)

Linhard angle : 0.7 mrad

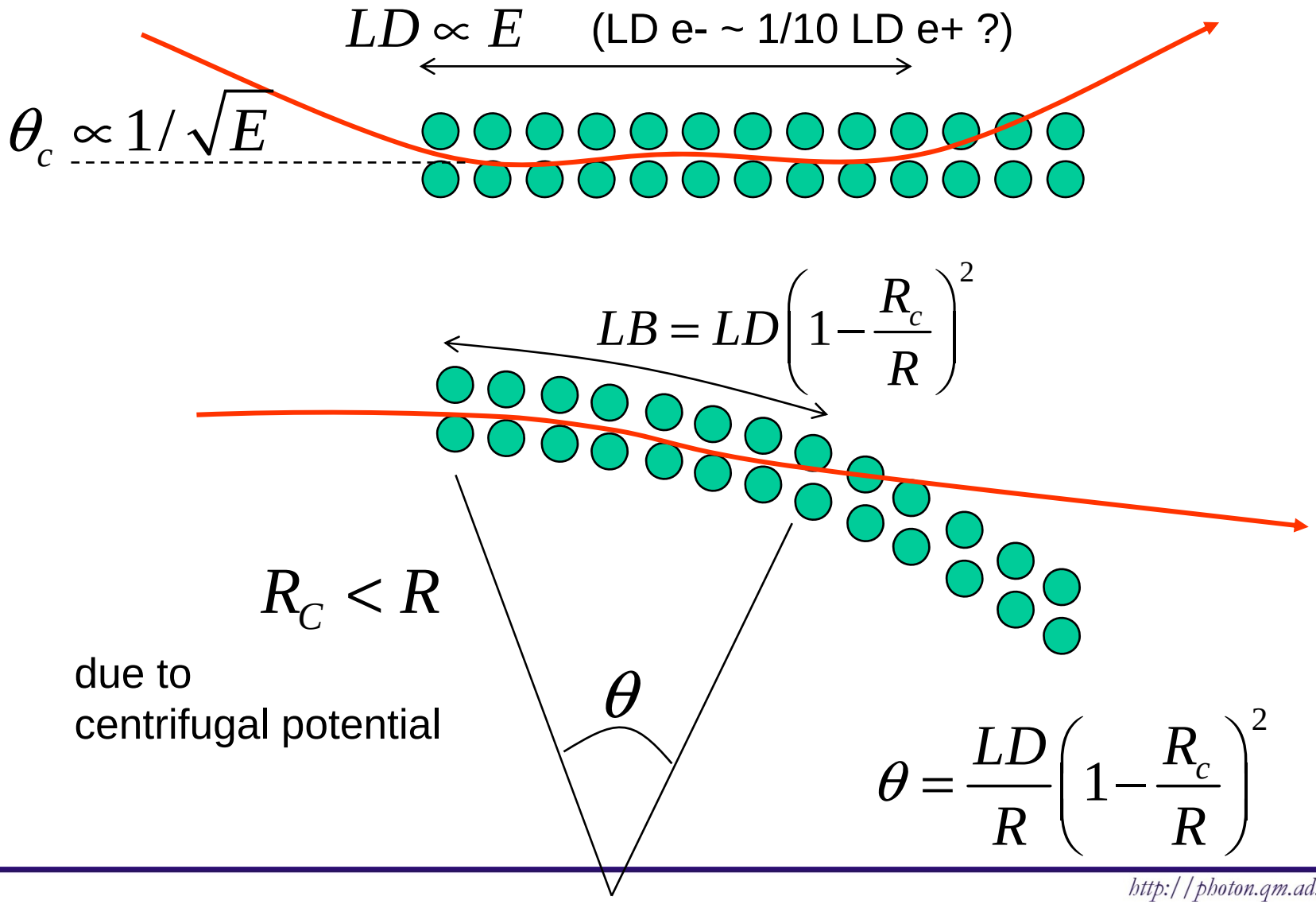
thickness of Si
crystal: 16μm



e- beam deflection w/ 16μm Si



parameter of bent crystal



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Size of Crystals

case for maximum bend w/ Si crystal $\theta_{\max} = \frac{LD}{R}\left(1-\frac{R_c}{R}\right)^2\Bigg|_{R=R\max}$

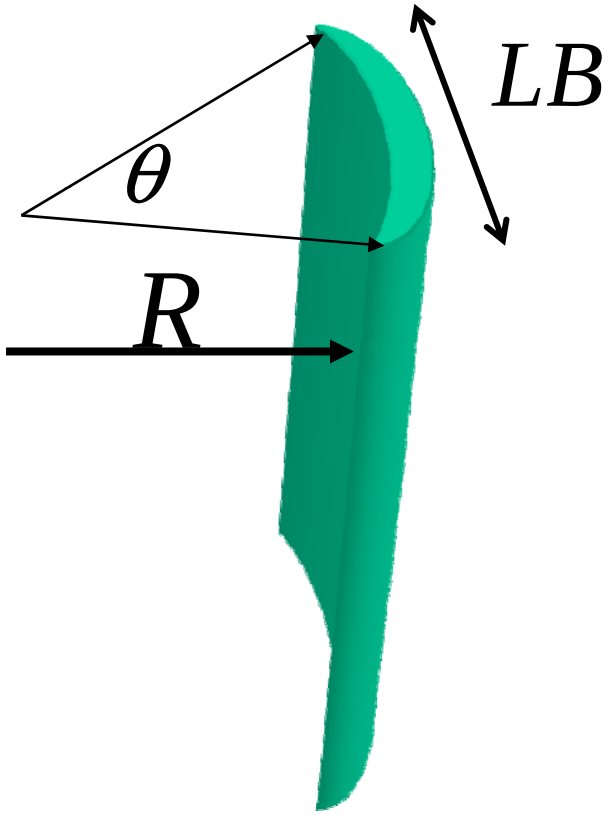
Eb[GeV]	250	40	8	4	1.3
	e+(e-)	e+(e-)	e-	e+	e-
θc[mr]	0.01	0.03	0.069	0.097	0.17
Ld[mm]	54(5.4)	9.5(0.95)	0.2	1	0.037
Rc[mm]	320	51	10	5	1.6
R[mm]	960	150	31	15	5
Lcr(=Lb)[mm]	24(2.4)	4.1(0.41)	0.09	0.5	0.016
θmax[mr]	25(2.5)	27(2.7)	3	31	3.3

example of bent crystals we want

1.3GeV e-

LB=40~50μm
R~50mm

$\theta \sim 1mr$



250GeV e+

LB=50mm
R~5000mm

$\theta \sim 10mr$

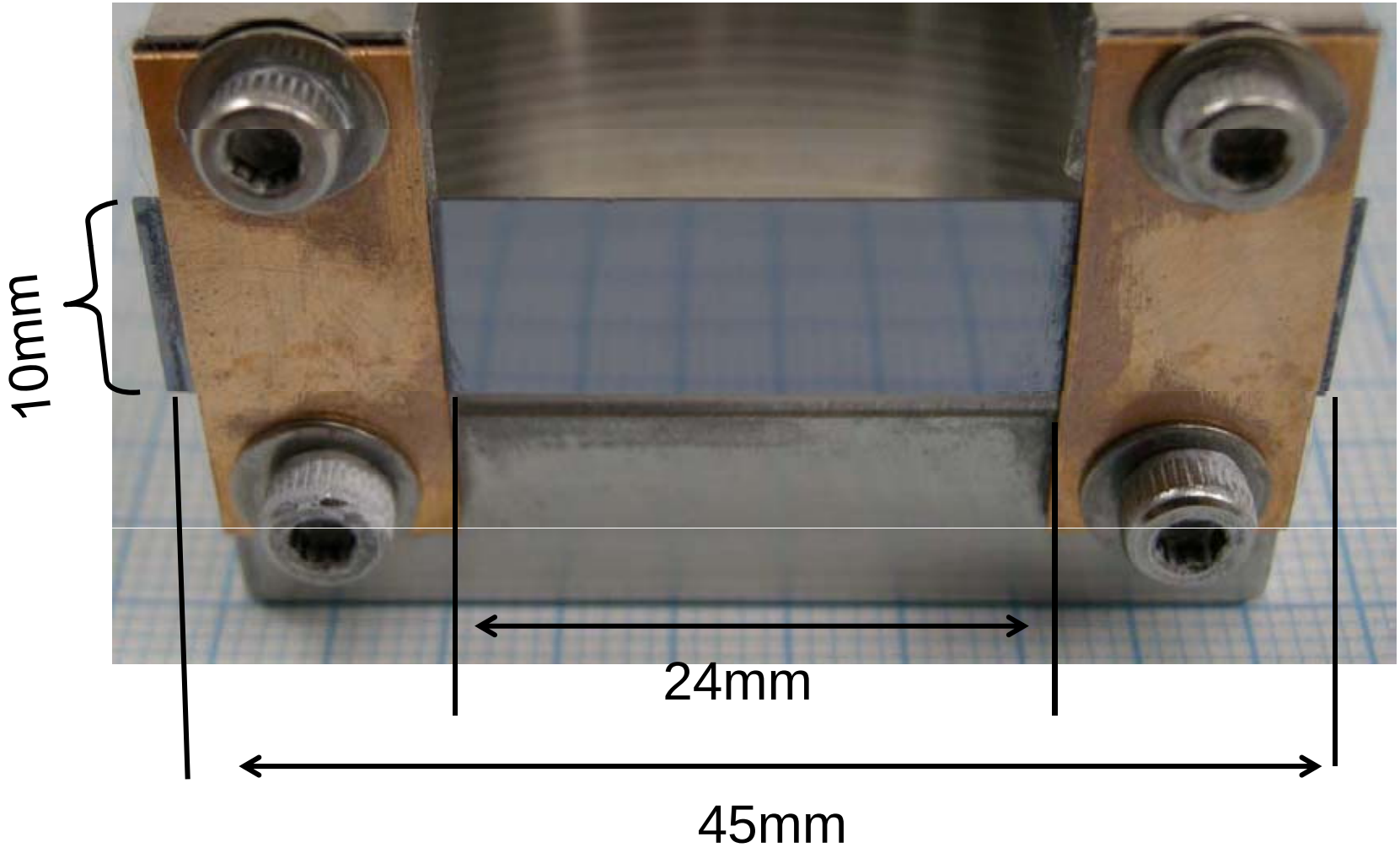
mechanical bent

under study with
Sharan company in Japan

Si
400μm,300μm,500μm
thick

(111) plane

fabrication cont



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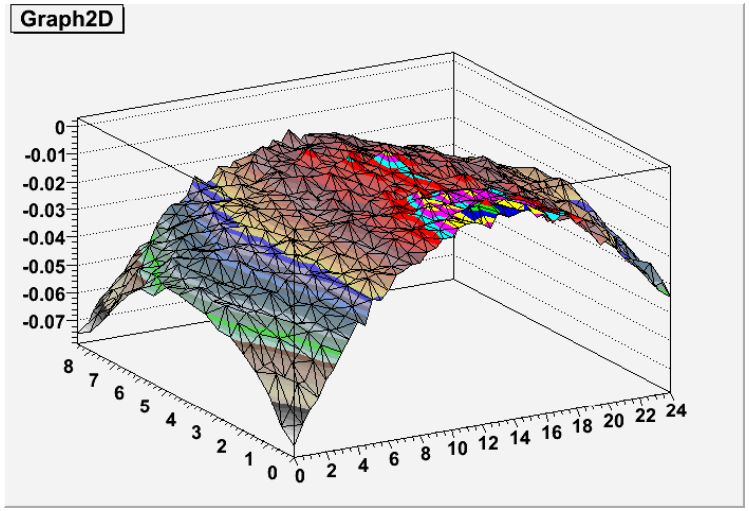
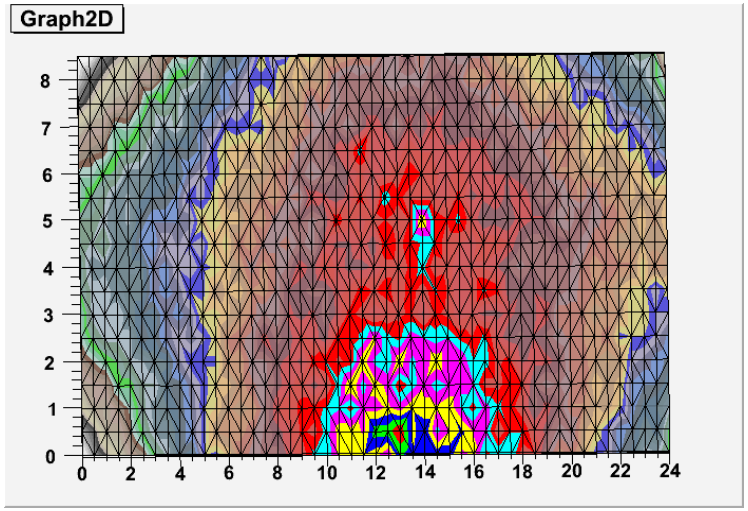
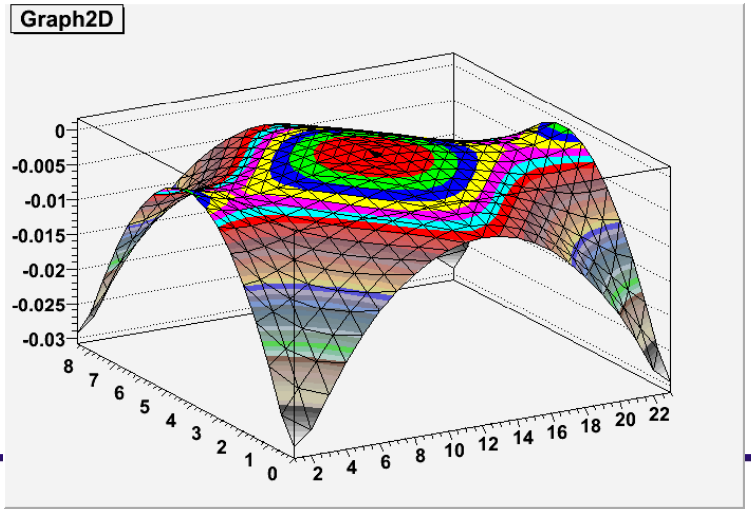
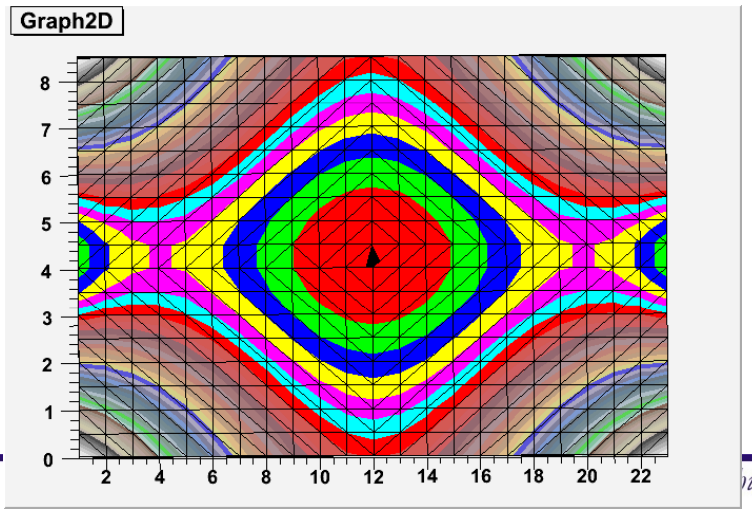
Simulation vs. experiment.
6 deg (really 1.9 deg)









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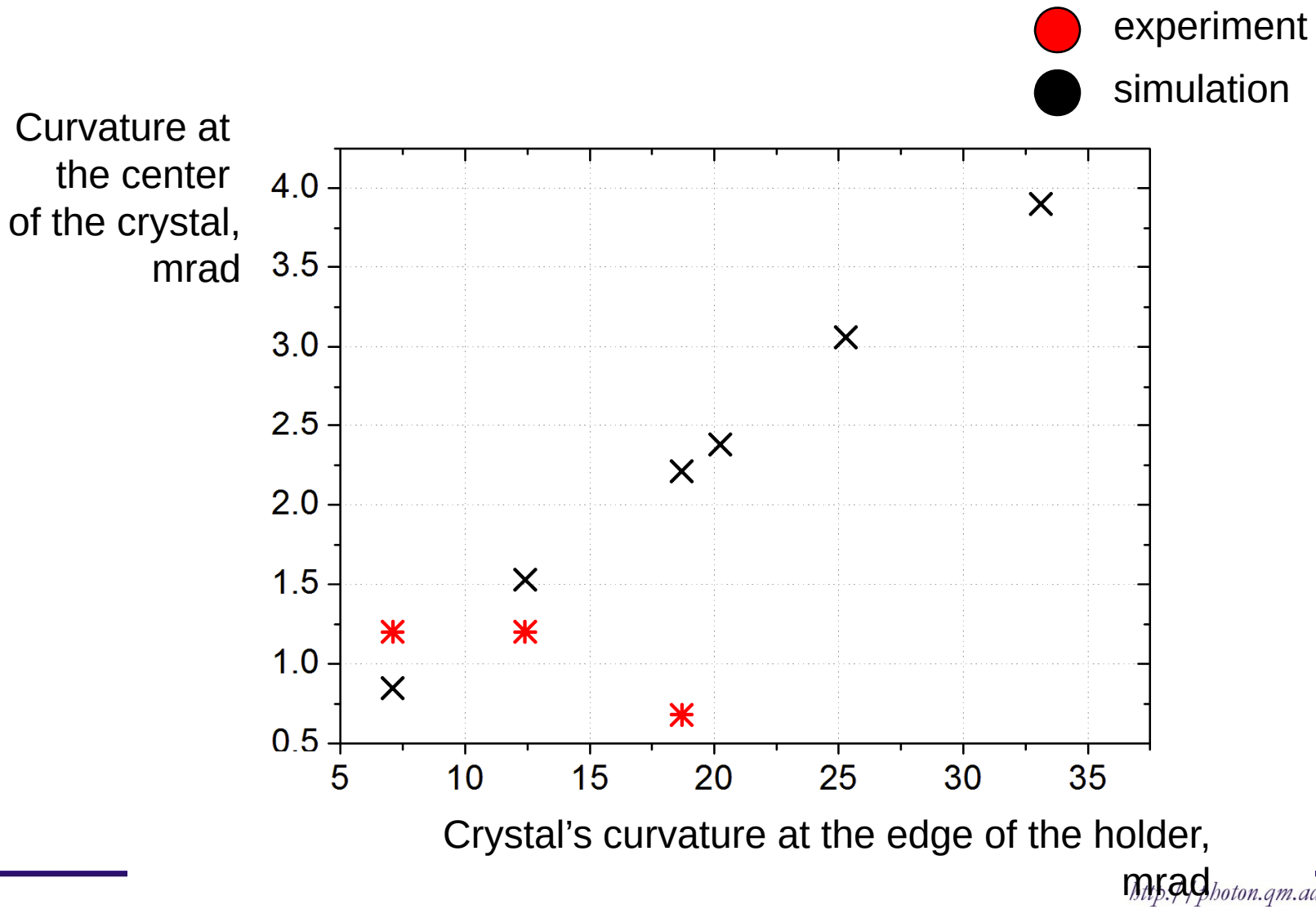
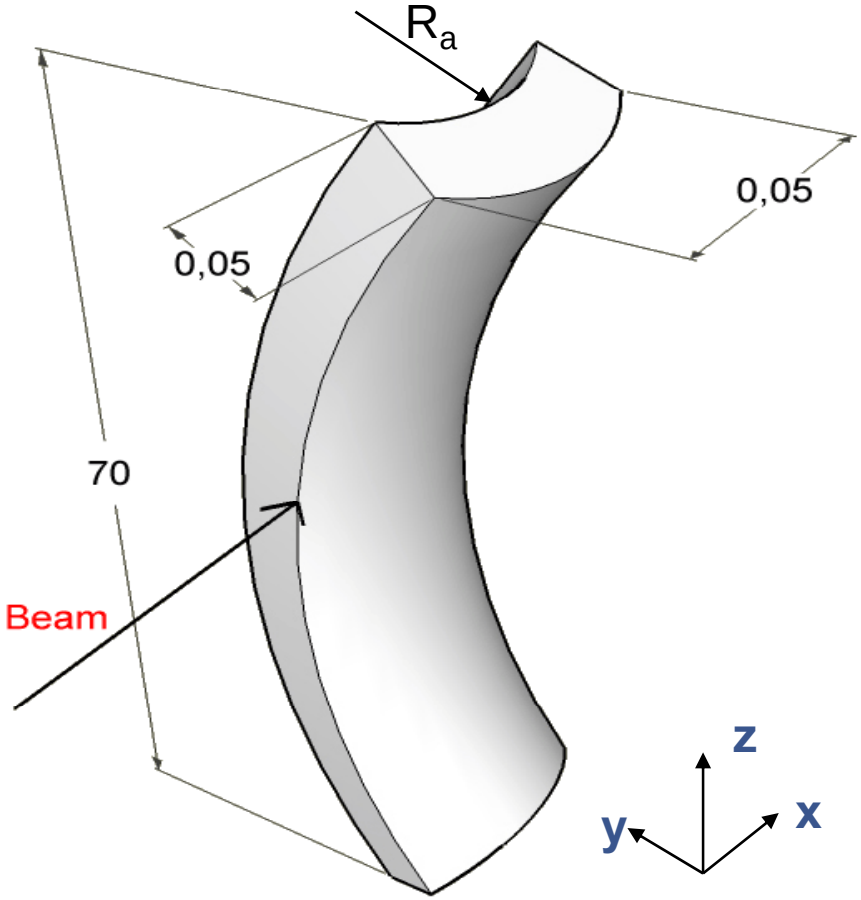
Bending angle

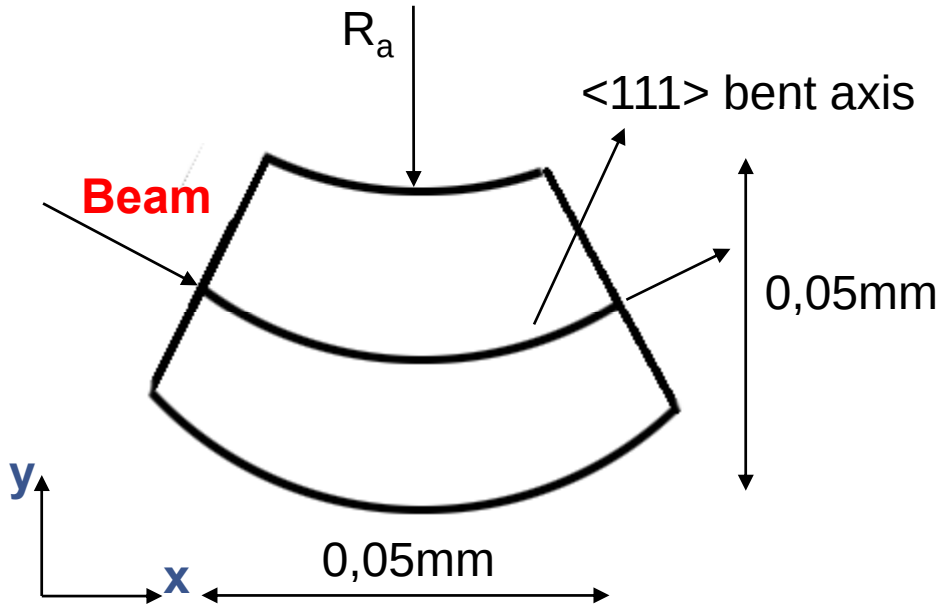


Strip crystals

- Size: 70x0,05x0,05 mm^3
- Channeling axis: <111>.
- Preparation method: pure chemical
- Crystal orientations:
  - x axis along <111> direction,
  - y axis along <110> direction,
  - z axis along <211> direction.



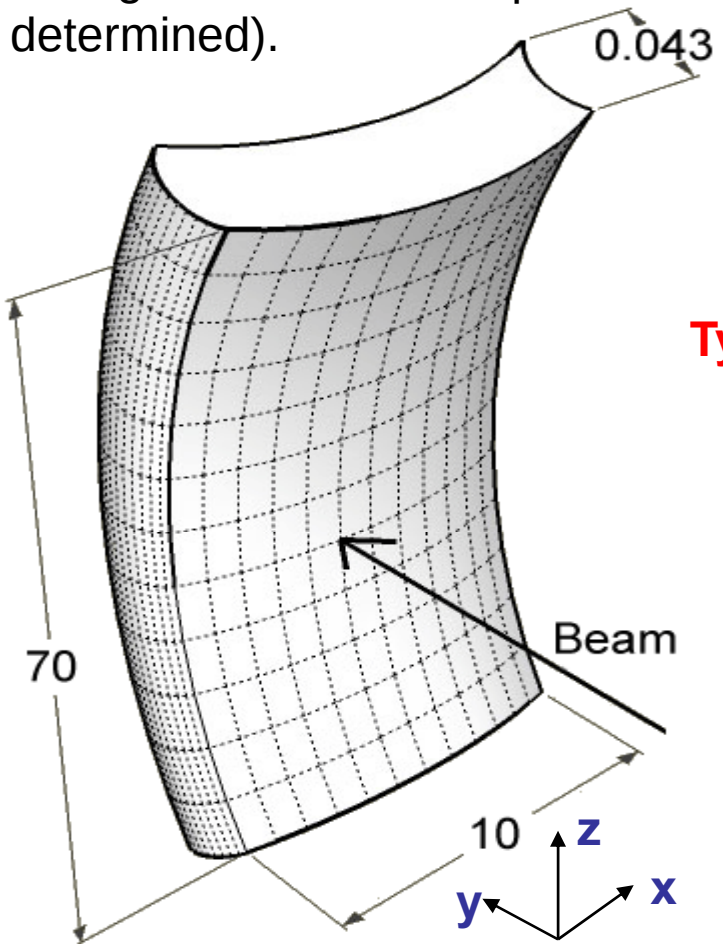
- As conseguence of main bending along the 70 mm direction, a secondary bending, called "**anticlastic**" arises in the x-y cross section of the crystal. In mechanics this is a well know effect.
- **Anticlastic bending radius** is **proportional** to the imposed **main bending radius**

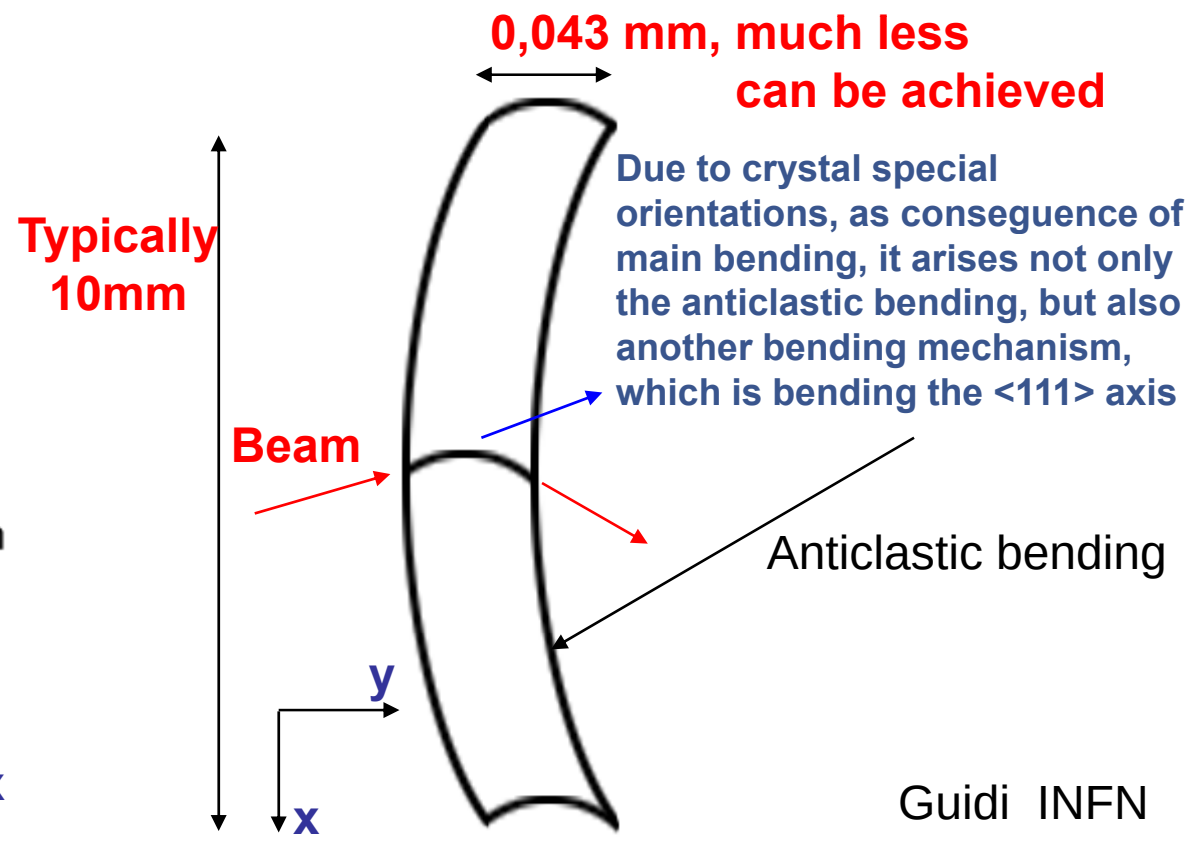


A new generation of crystal suited for axial channeling of negative particles

- Size: 70x10x0,043 mm3
- Channeling axes: <111>.
- Realization method: polishing and chemical etching, no lattice damage.
- Maximum bending angle: unknown (fracture strength needs to be experimentaly determined).

- Using crystals with special orientations, as conseguence of bending along the main direction, it arises not only the anticlastic bending (which now becomes unuseful) but it arises also a seconday bending along the crystal thickness!





Summary

- R&D of beam handling with crystal is on going
  - protons ,,,,, first demonstration at KEK PS
  - electrons,,, test at INS 1.2GeV and 150MeV at Hiroshima
- plan and prospect
  - ATF
    - proposal approved (Hiroshima. KEK, FNAL) but suspended due to ATF2 project
    - energy too low for bent crystal but still good place to study e- chanelling
  - KEK LINAC
  - SLAC LINAC

  } e+, e-
- crystals
  - several way to fabricate crystal are being studied
  - both for a few tens of micron and for tens of mm range

Comparision between different crystals

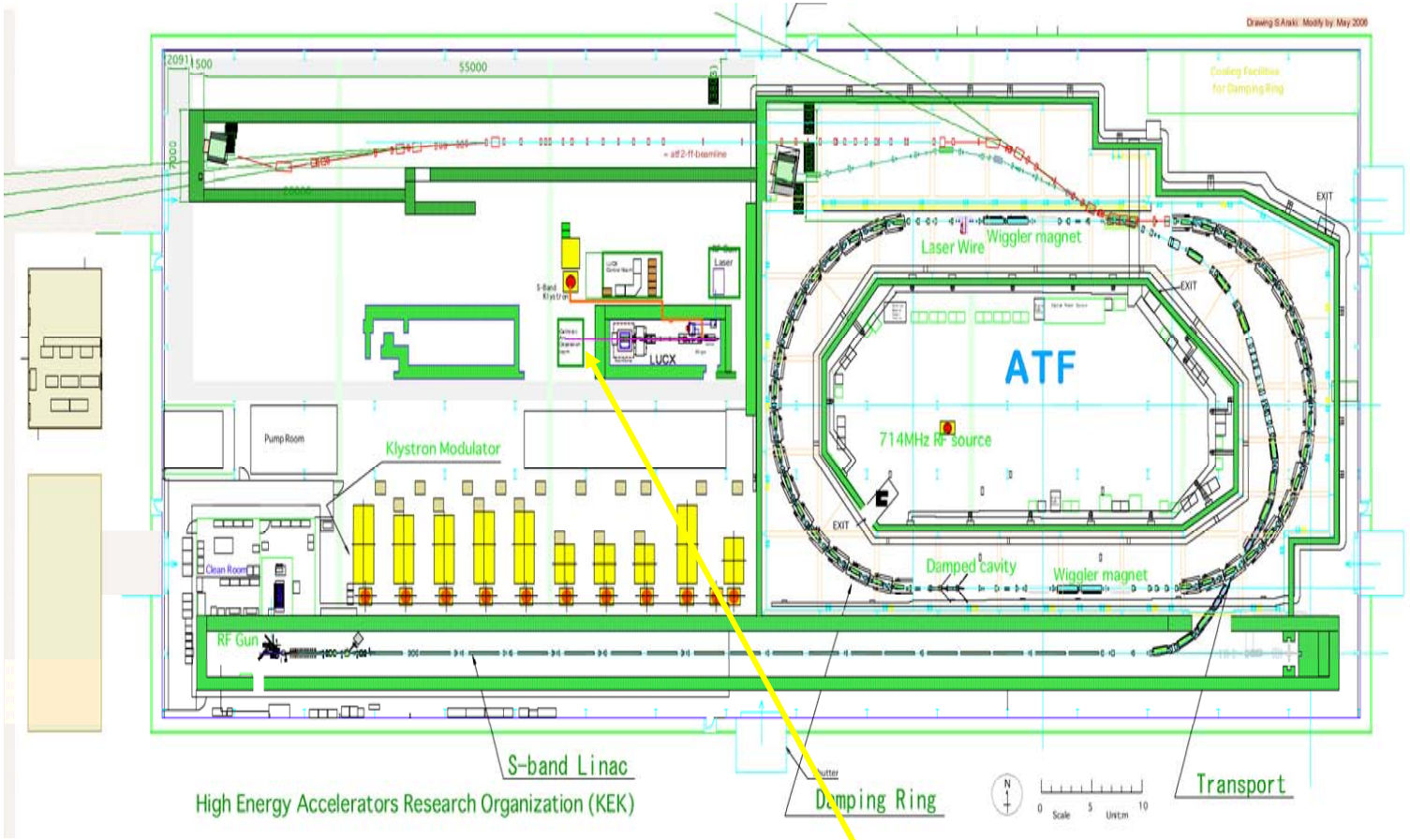
	Your suggested crystal	Ferrara strip crystal	Ferrara new crystal generation
Realization method	Mechanical methods	Chemical methods (no lattice damage)	Polishing methods (no lattice damage)
Geometrical acceptance	Small	Small	High (possibility to intercept the full beam)
Torsional effects	Yes	Yes	Reduced with respect to strips crystals, and easily removable througt an already available crystal holder
Bending angle considering a main bending radius of 10 mm	1,39 mrad (50 µm thick)	0,8 mrad (50 µm thick)	1,22 mrad (43 µm thick) 1,42 mrad (50 µm thick)
Maximum bending angle	Needs to be measured	Needs to be measured	Needs to be measured
Bent axis	<100>	<111>	<111>

The new generation of crystals developed in Ferrara should be the best choice to study axial channeling of negative particles. The method offers a favorable axis, geometrical acceptance larger than for the strip crystal and geometrical distorsions due to mounting conditions can be more easily adjusted.

parameter of bent crystal

- critical angle θ_c
  - incident angle of particle to crystal axis of plane to be trapped
- Dechanneling length LD
  - length that a particle can be in channeling condition
  - not will known for negative particle assume 1/10 of positive one?
- Critical Radius R_C
  - particle is no longer trapper for R < Rc
- Dechanneling length for bent crystal $LB \sim length \quad of \quad crystal$
  - a reference for length of crystals

at ATF



•test for beam deflection/collimation at ATF

→ ATF2