Doubly Focusing Monochromator for MACS

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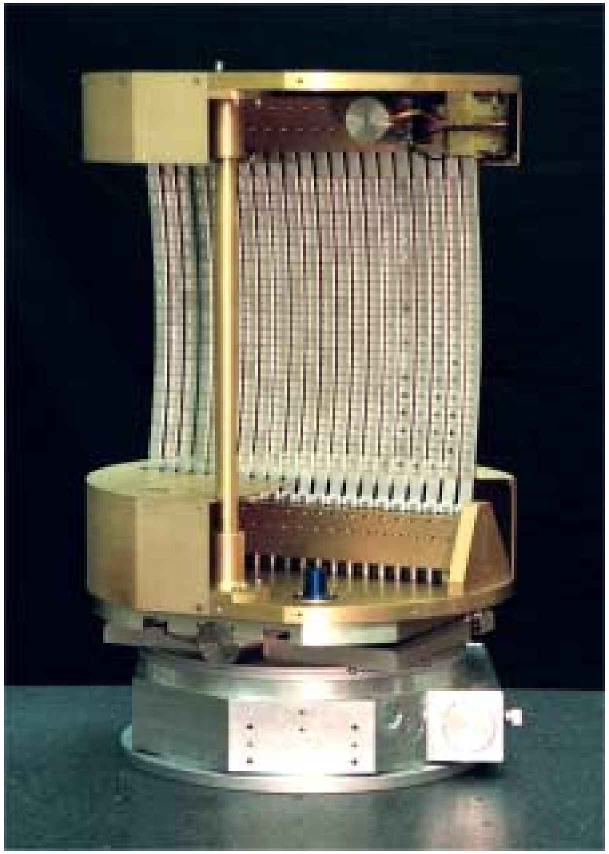
Outline

- Principles
  - neutron spectroscopy
  - The virtues of focusing
  - Geometry of double focusing
- Implementation
  - Bending to an arc
  - Overall design
- Performance
  - Optical tests
  - Predicted performance on MACS
- Conclusions



Goals in Neutron Spectroscopy

- An important tool for condensed matter physics
  - Unique information about dynamic correlations
  - Model independent access to interaction strength
  - Access microscopic structure of dynamic systems
- Limited scope on current instruments
  - Need cm^3 sized crystals
  - Need weeks of beam time
- Increased sensitivity will broaden impact
  - Smaller samples earlier in new materials cycle
  - Parametric studies as in diffraction
  - Comprehensive surveys for tests of theory

Comparing TOF to TAS

TAS like

- Can focus beams with Bragg optics
- Can select range of energy transfer
- Can use reactor CW flux

TOF like

- Larger detector solid angle
- E-scan with "no" moving parts
- Can use pulsed spallation source peak flux

Why cold neutrons and double focusing

- *Q* and *E* resolved spectroscopy requires

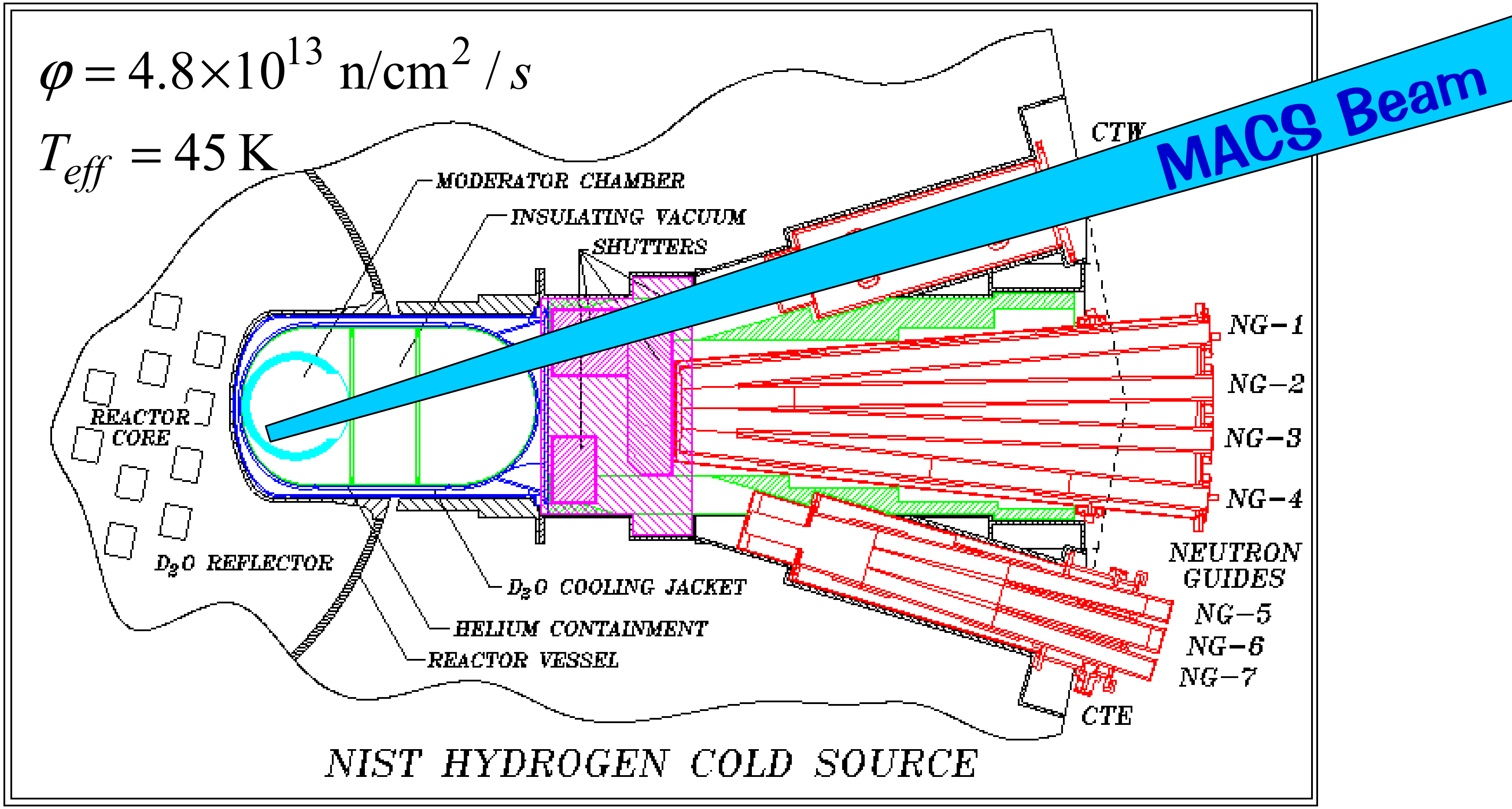
$$\Delta E \approx 0.1 J \qquad \Delta Q \approx 0.1 a^{-1}$$

- Energy scale *J* varies more than length scale *a*

Lattice	Compound	J (meV)	a (Å)
3D Cubic S=5/2	$La_{0.7}Pb_{0.3}MnO3$	8.8	3.9
2D Square S=1/2	La_2CuO_4	132	5.4
2D Kagomé S=3/2	$KCr_3(OH)_6(SO_4)_2$	1.2	3.7
2D Kagomé S=3/2	$SrCr_9Ga_3O_{19}$	10	2.9
1D S=1/2 chain	$Cu(C_6D_5COO)_2 \cdot 3D_2O$	1.5	3.2
1D S=1/2 chain	$KCuF_3$	35	3.9
1D S=1 chain	NENP	4.1	5.2
1D S=1 chain	$AgVP_2S_6$	58	2.9

- To probe solids with low energy scales
  - Reduce *ΔE* by cooling neutrons
  - Increase angular divergence to match *ΔQ*

Increase brightness at fixed neutron production

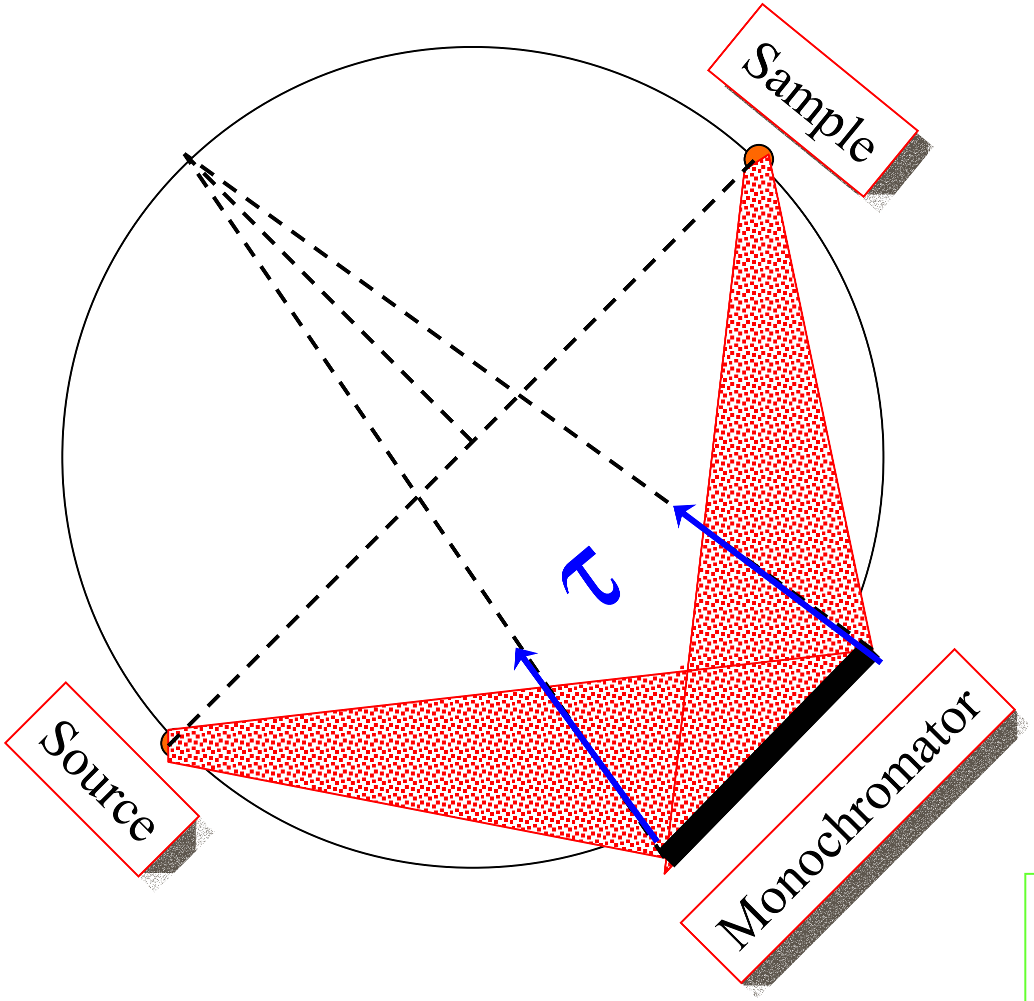


$\varphi = 4.8\times10^{13}\ \mathrm{n/cm^2}/s$

$T_{eff} = 45\ \mathrm{K}$

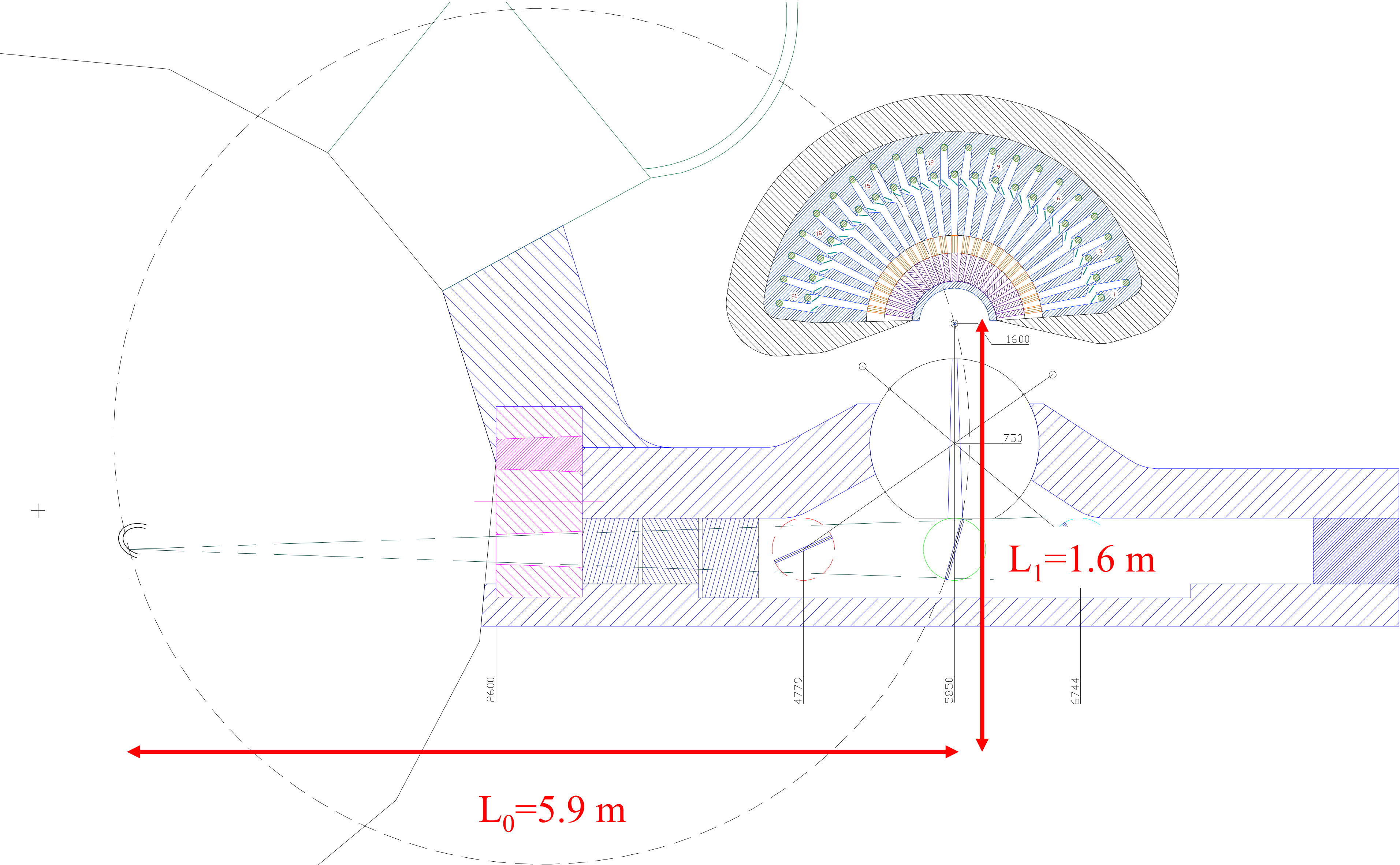
New cold source installed in 2002 has increased flux by 1.8

Symmetric horizontal focusing



Focal point for monochromator
τ-distribution is on its bisector
(symmetric reflection geometry)

Space constraints require $L_0 \approx 3L_1$



L_1=1.6 m

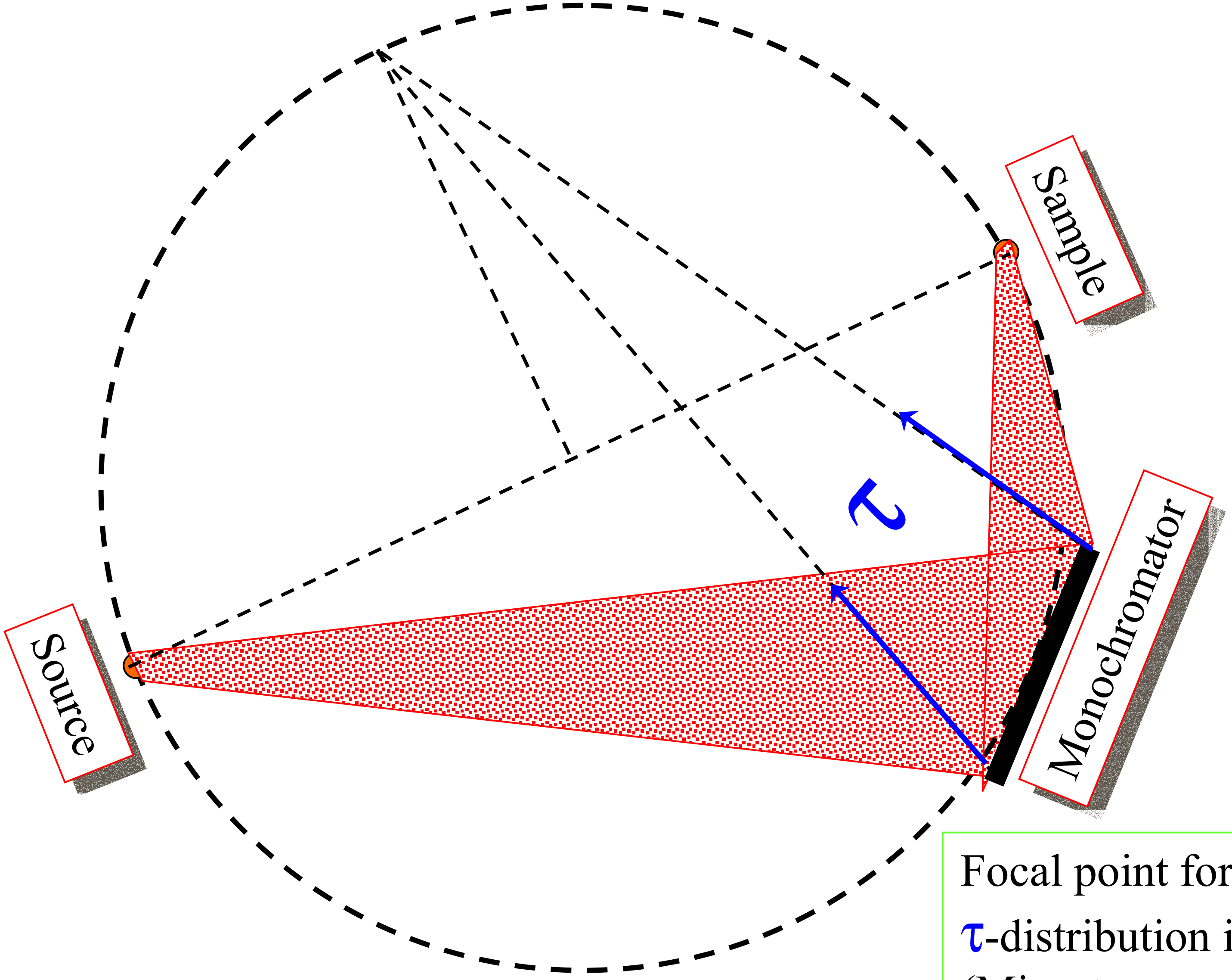
L_0=5.9 m

Solutions to asymmetry problem

- Create virtual source point with super-mirror guide
  - \+ Can close fast neutron aperture
  - – E-dependent angular divergence limited to $\approx m\theta_c$
  - – Inefficient when guide cannot get close to source

- Use focusing monochromator for $L_0 \neq L_1$
  - \+ Can use full solid angle view of source at all E
  - \+ Can vary energy and angular distribution independently
  - – Greater aperture for fast neutrons

Asymmetric horizontal focusing



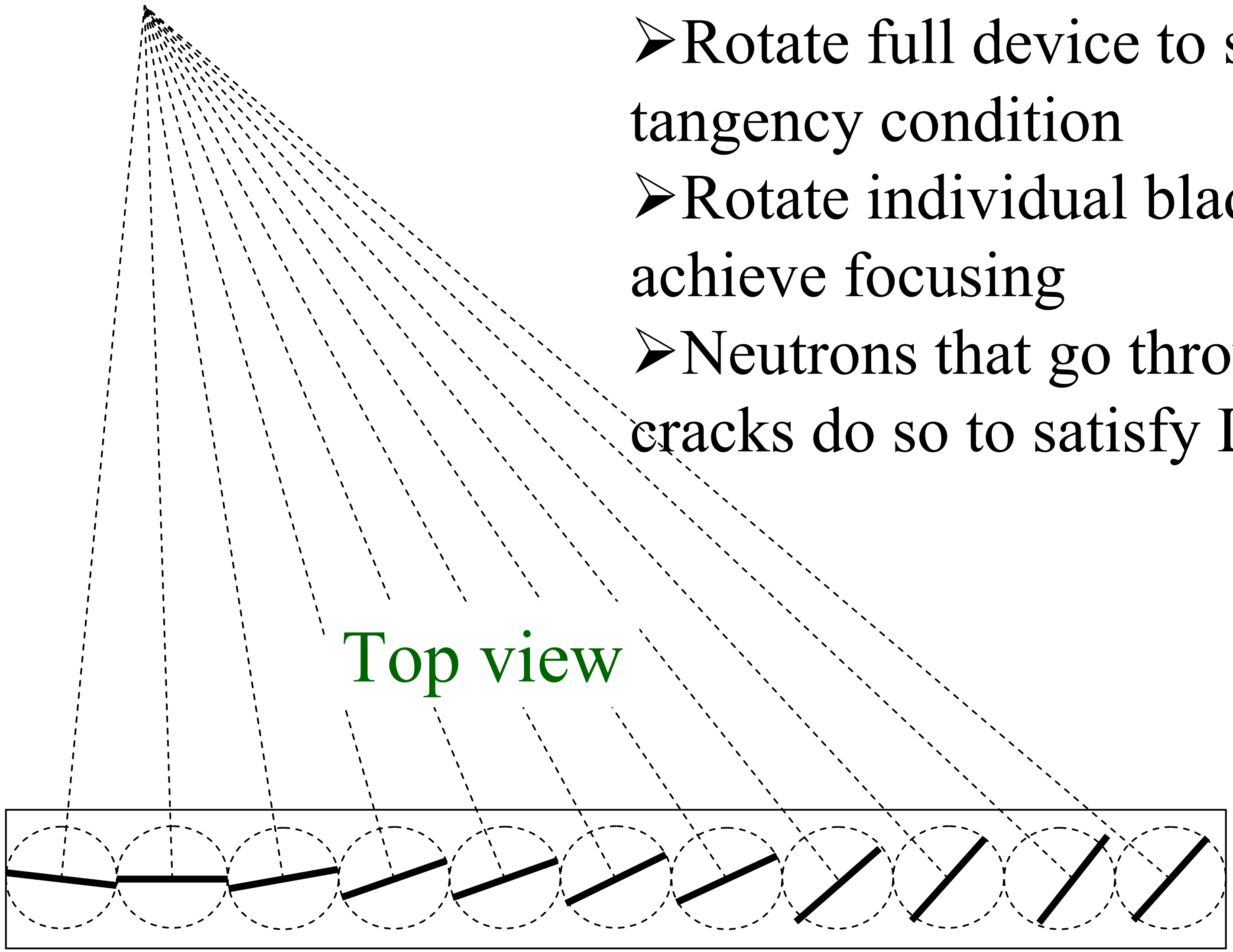
Focal point for monochromator

τ-distribution is not on bisector

(Miscut geometry)

Variable asymmetric horizontal focusing

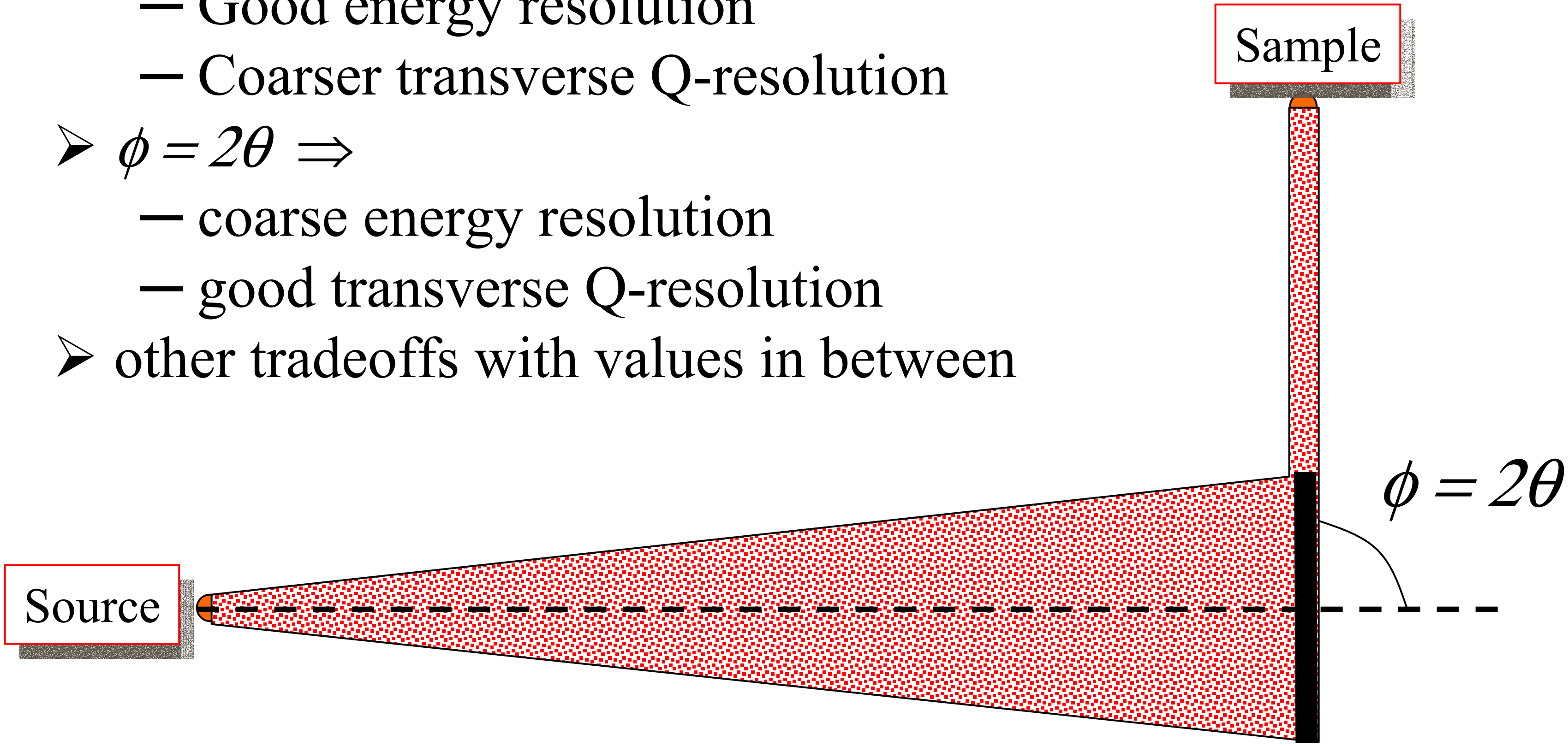
- Rotate full device to satisfy tangency condition
- Rotate individual blades to achieve focusing
- Neutrons that go through the cracks do so to satisfy Liouville


Top view

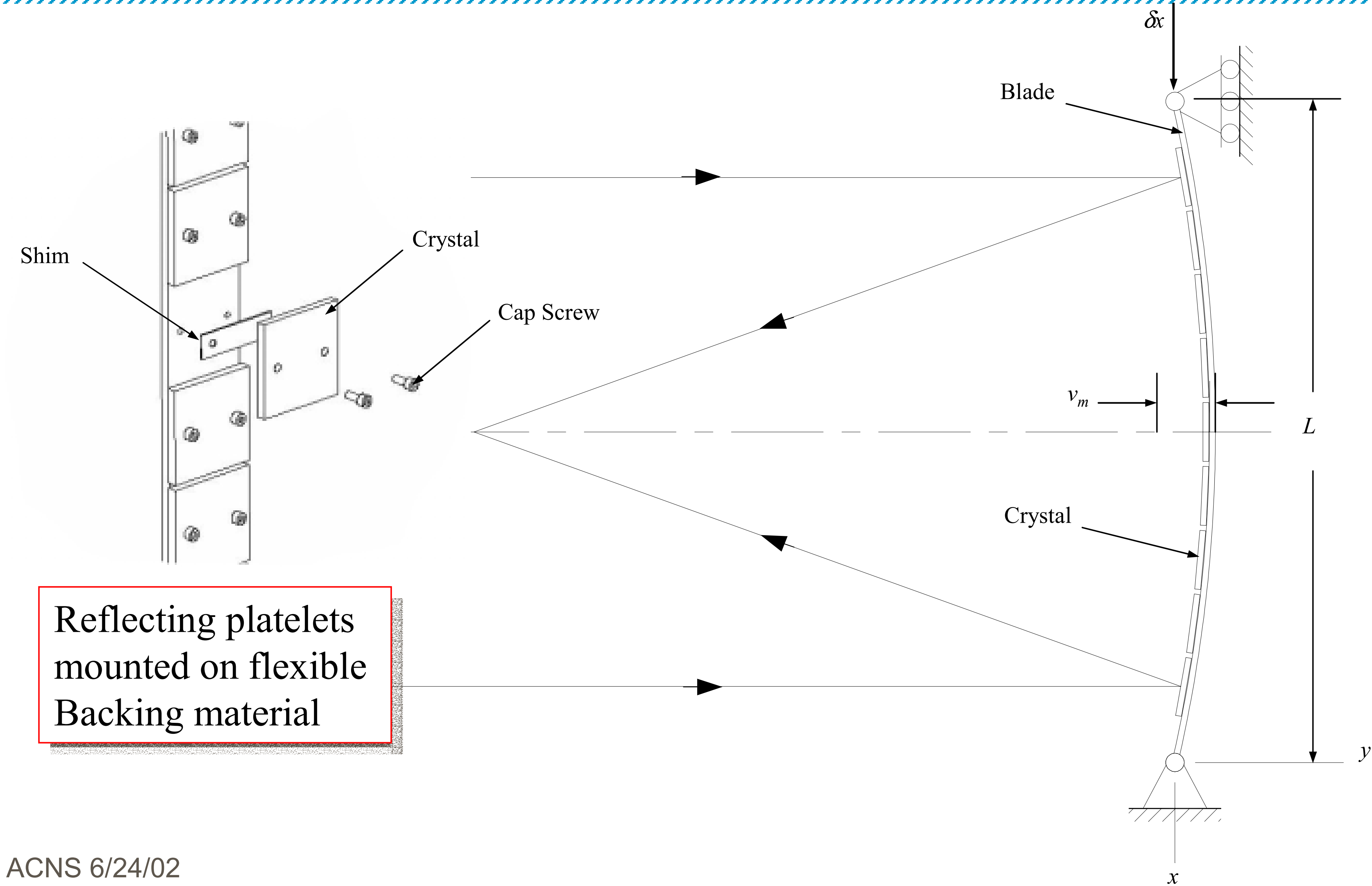
Other Venetian blind monochromator configurations

resolution function can be manipulated through choice of ϕ

- ϕ: tangent to Rowland circle
  - Good energy resolution
  - Coarser transverse Q-resolution
- $\phi = 2\theta \Rightarrow$
  - coarse energy resolution
  - good transverse Q-resolution
- other tradeoffs with values in between

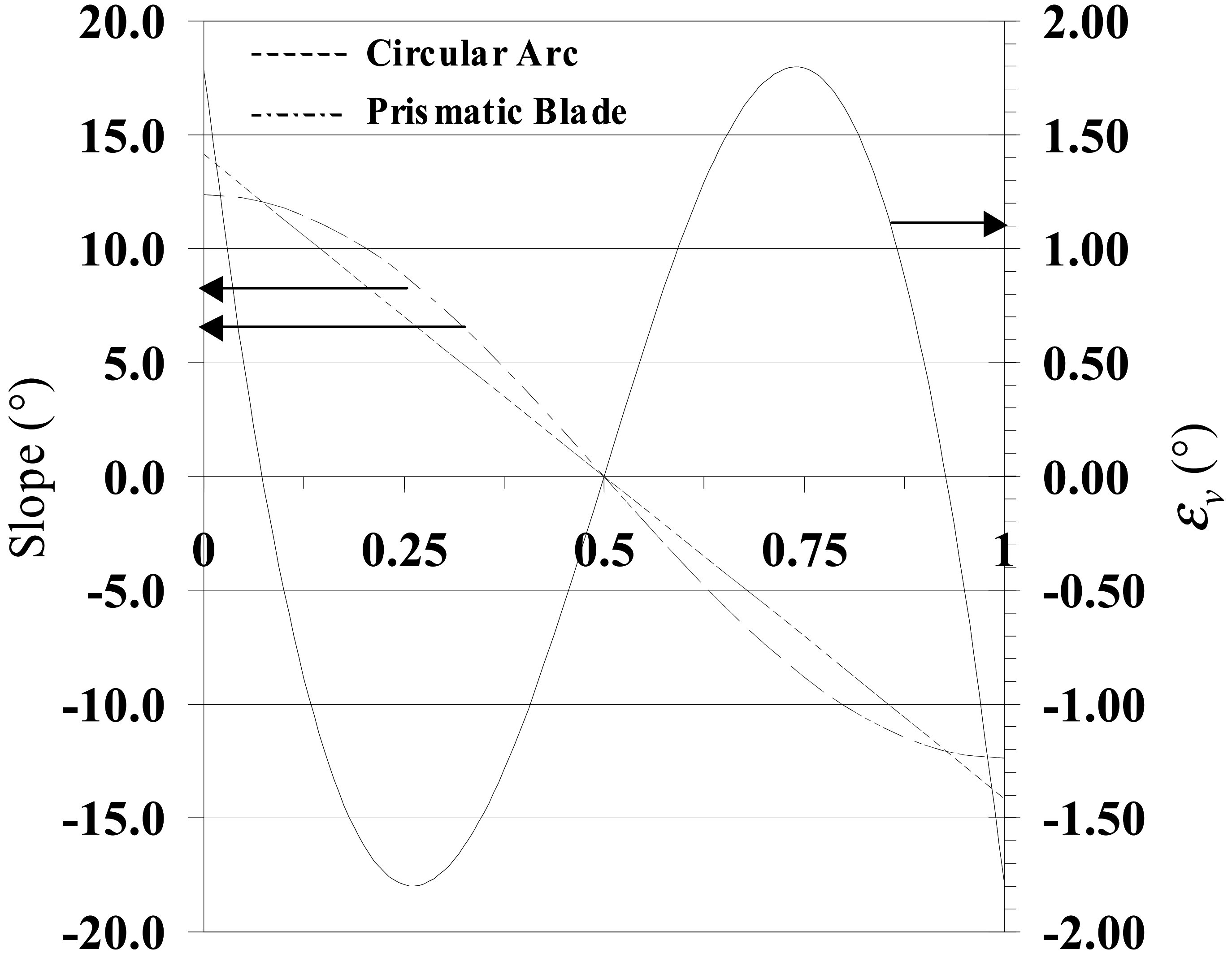


Bend blades for vertical focusing

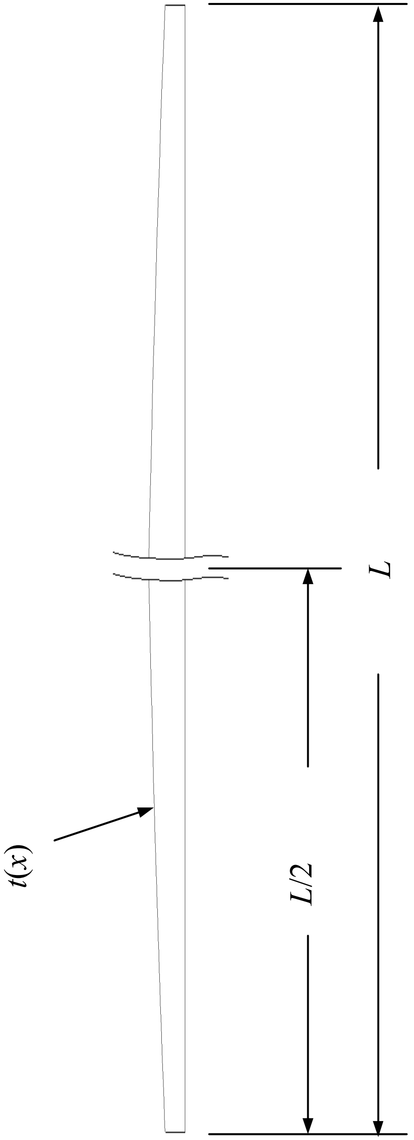


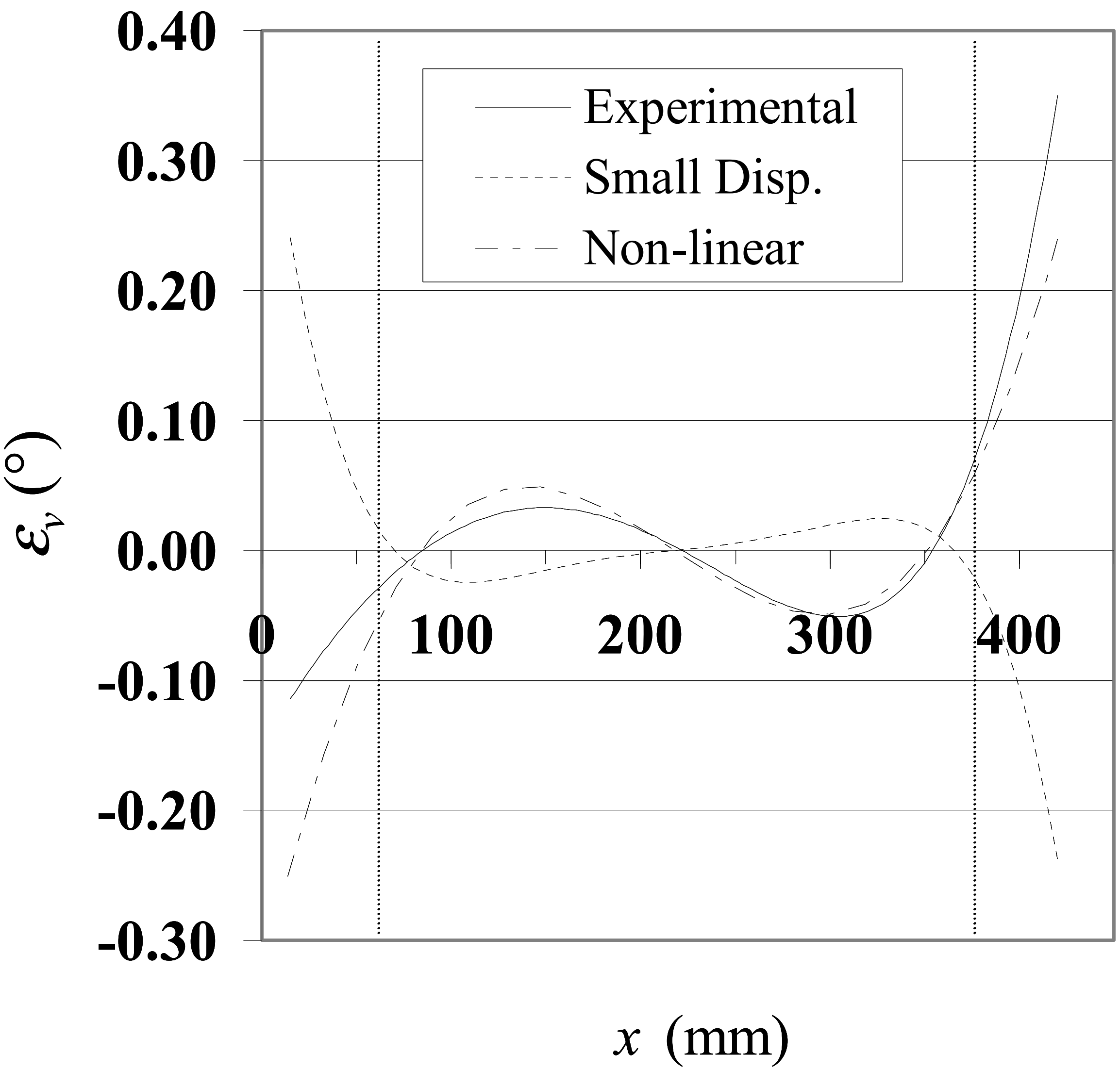
Reflecting platelets
mounted on flexible
Backing material

Unacceptable aberrations for prismatic blade

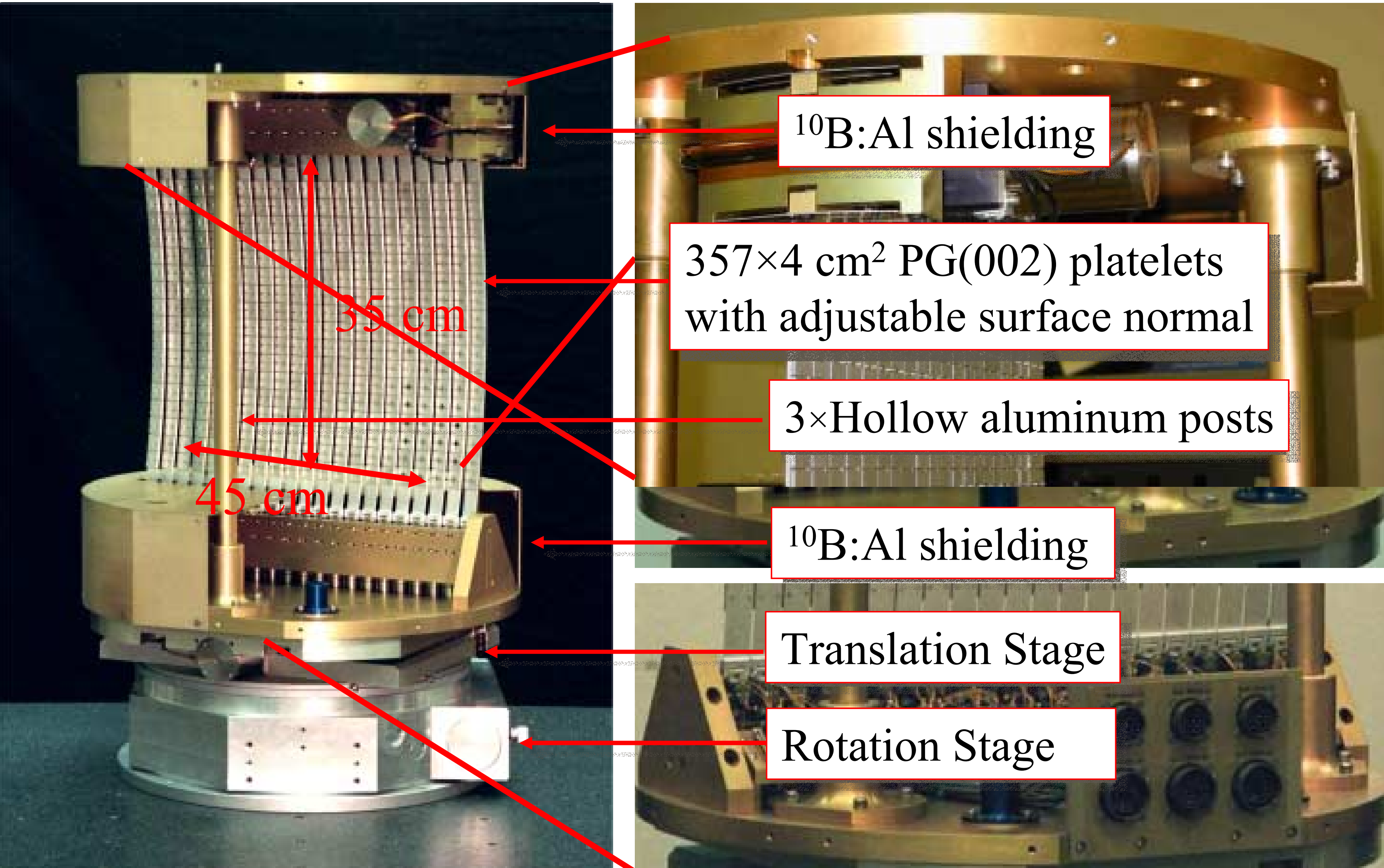


Choose blade profile for circular arc on bending





The MACS monochromator



^{10}B:Al shielding

357×4 cm^2 PG(002) platelets with adjustable surface normal

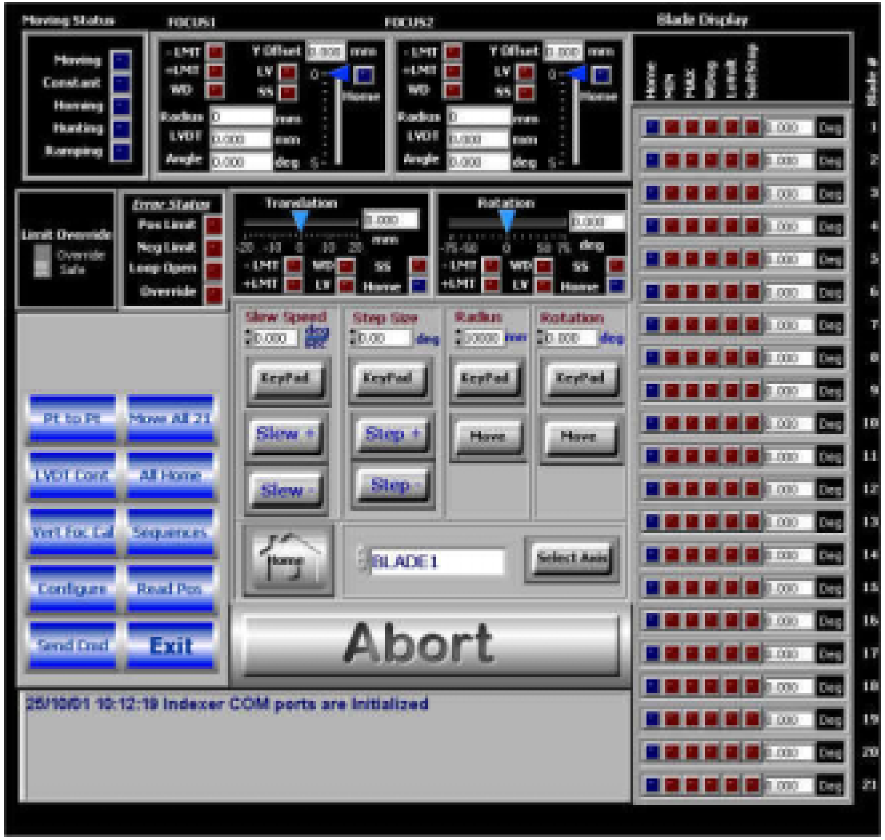
3×Hollow aluminum posts

^{10}B:Al shielding

Translation Stage

Rotation Stage

Dedicated Control electronics



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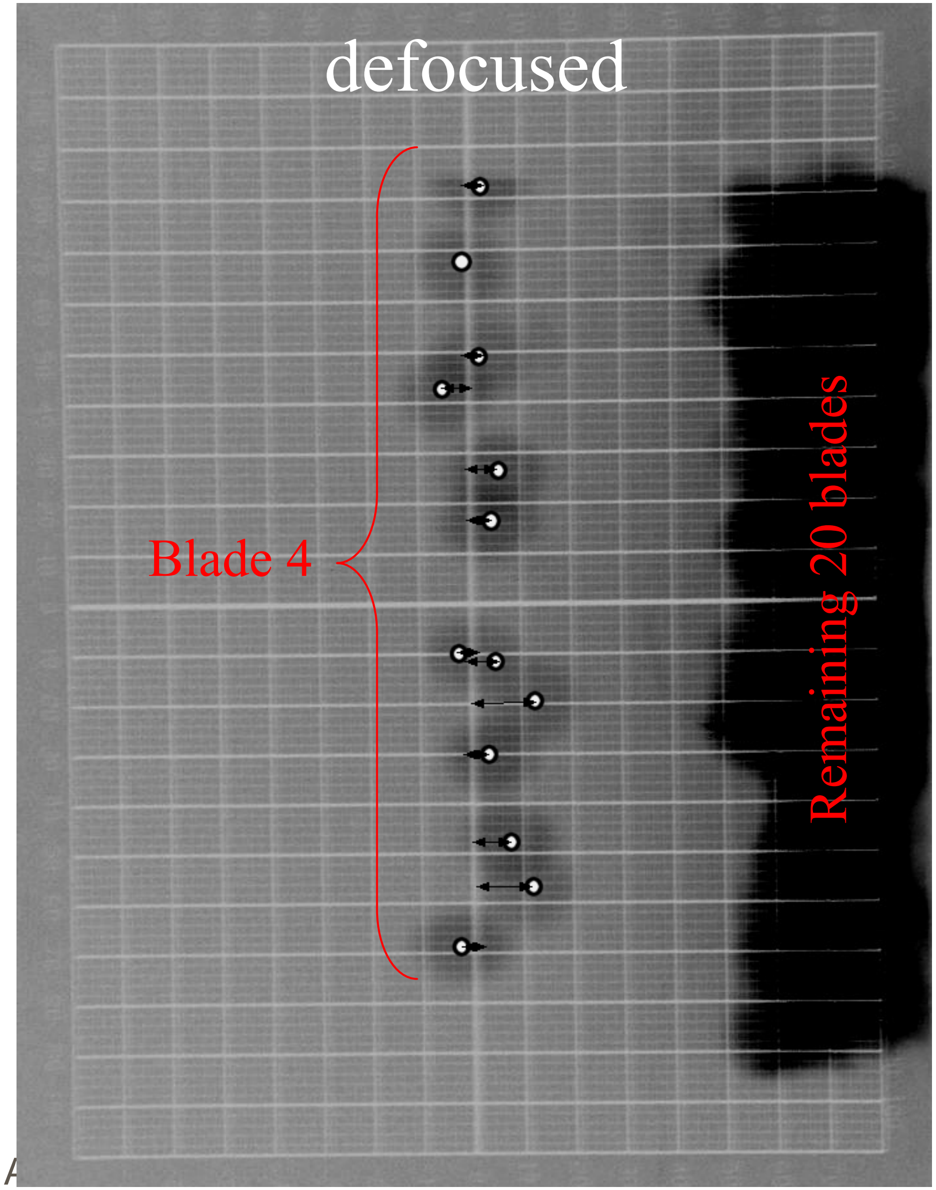
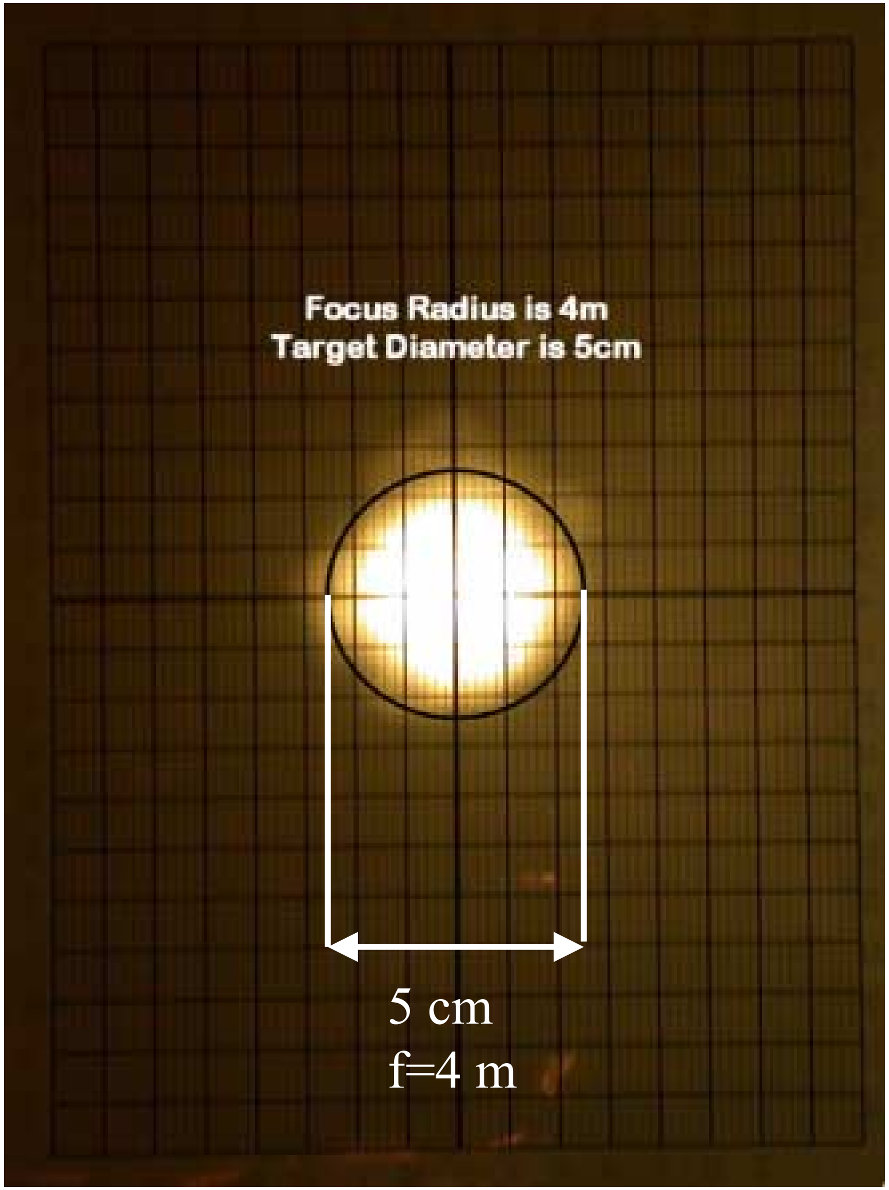
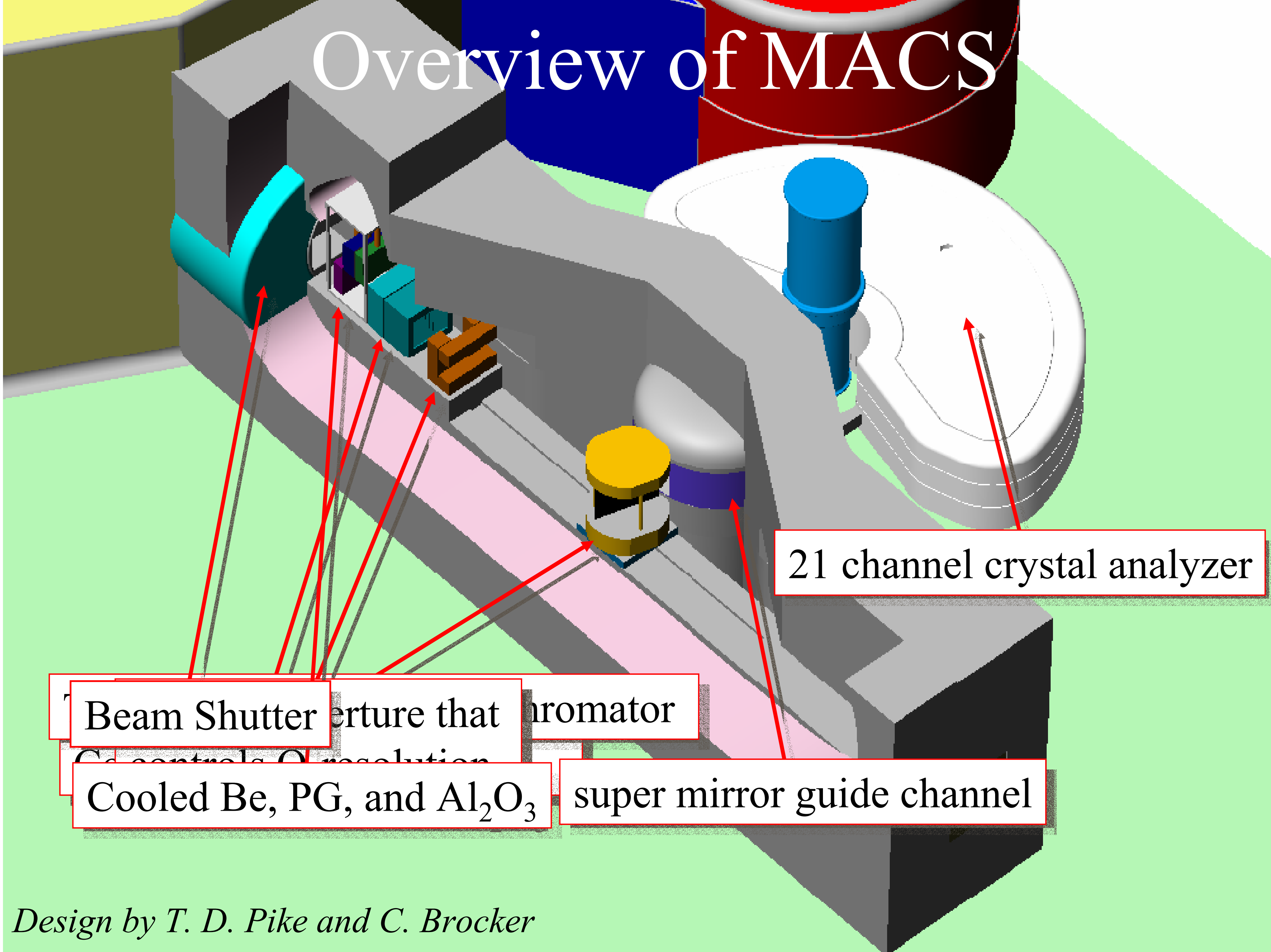
MACS monochromator passes optical test





Overview of MACS



21 channel crystal analyzer

Beam Shutter

erture that

hromator

controls Q resolution

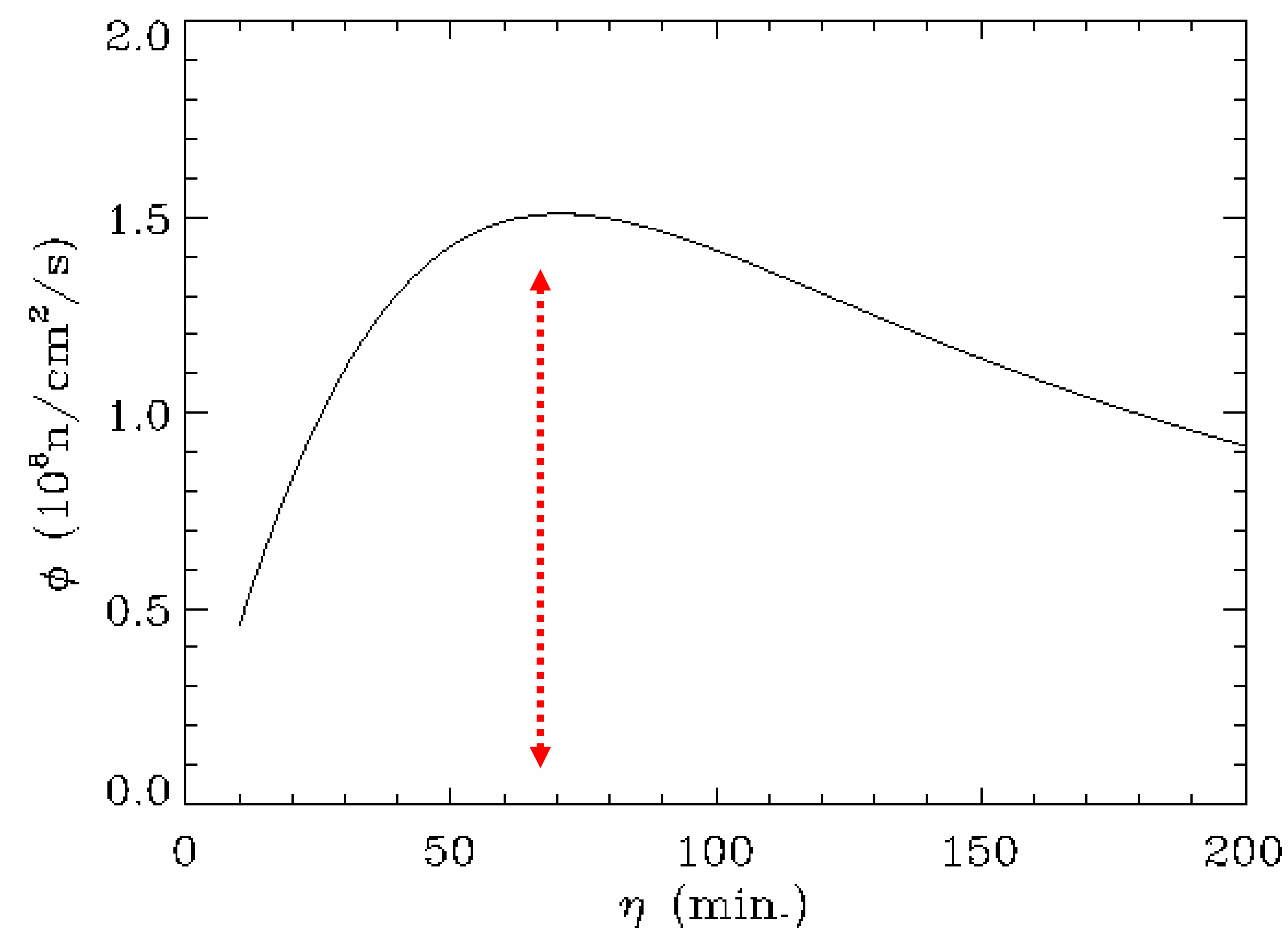
Cooled Be, PG, and Al_2O_3

super mirror guide channel

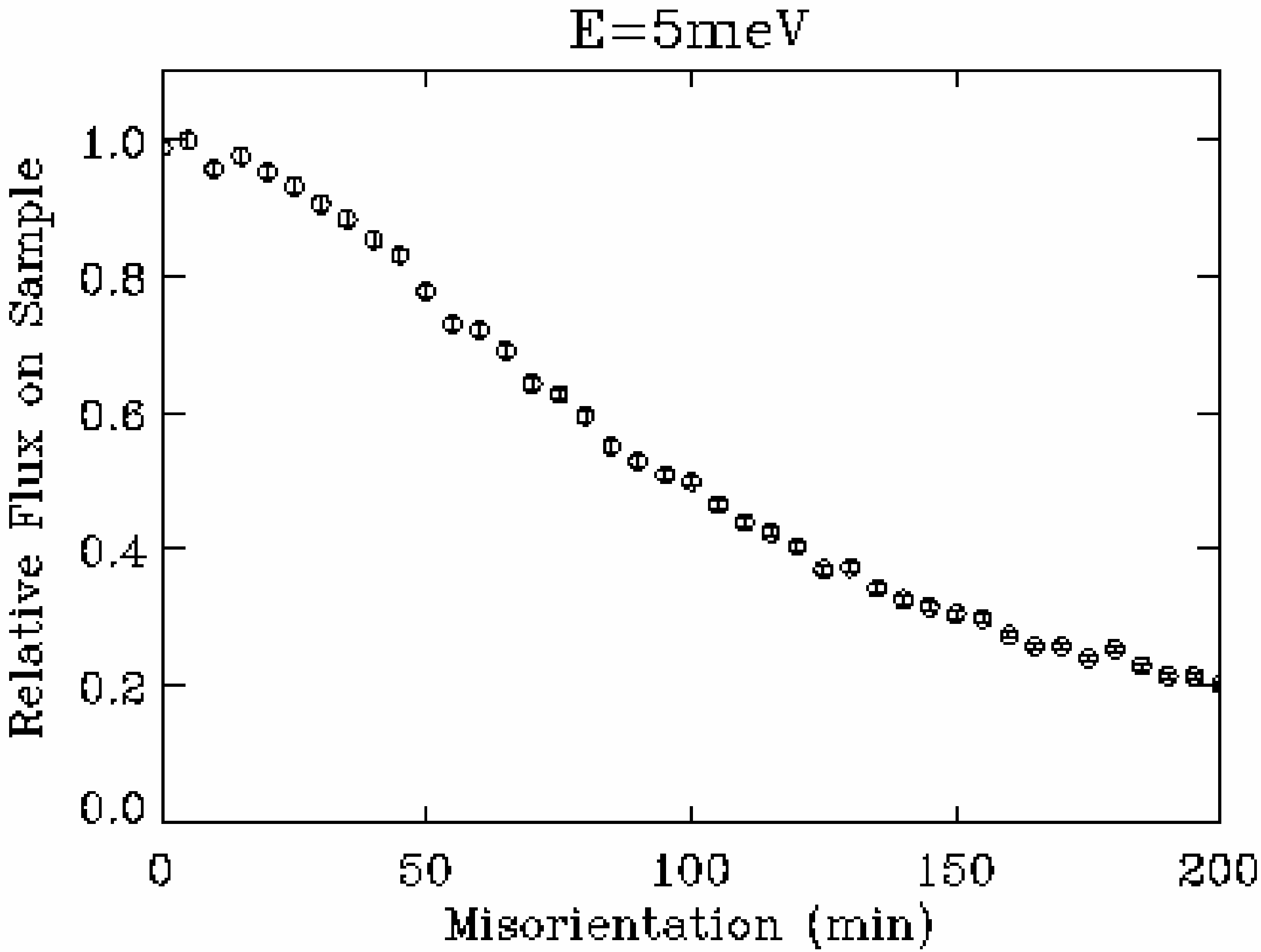
Design by T. D. Pike and C. Brocker

Constrained optimization : crystal mosaic

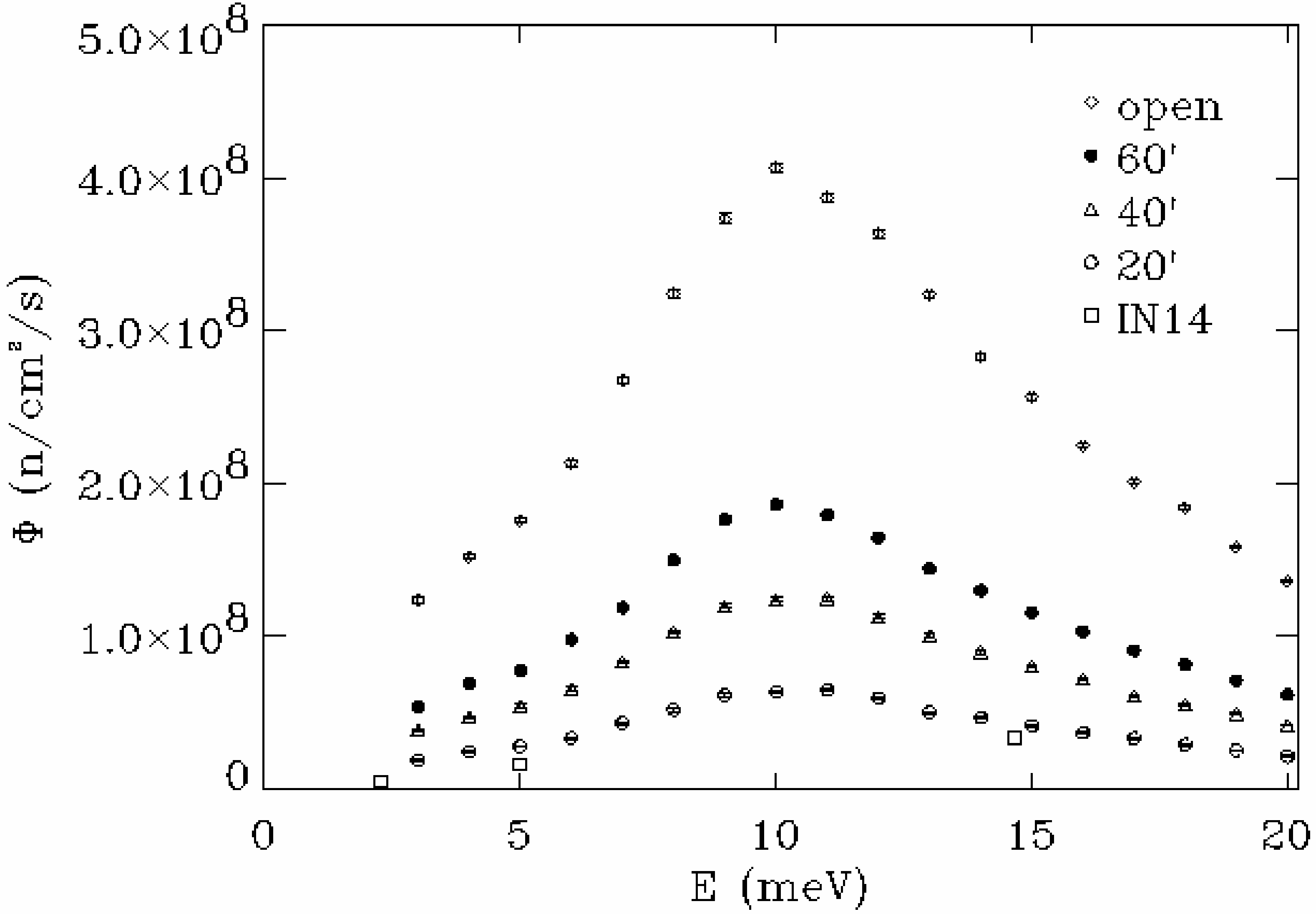
Flux versus mosaic at fixed 0.2 meV energy resolution



Effects of cystal misalignment

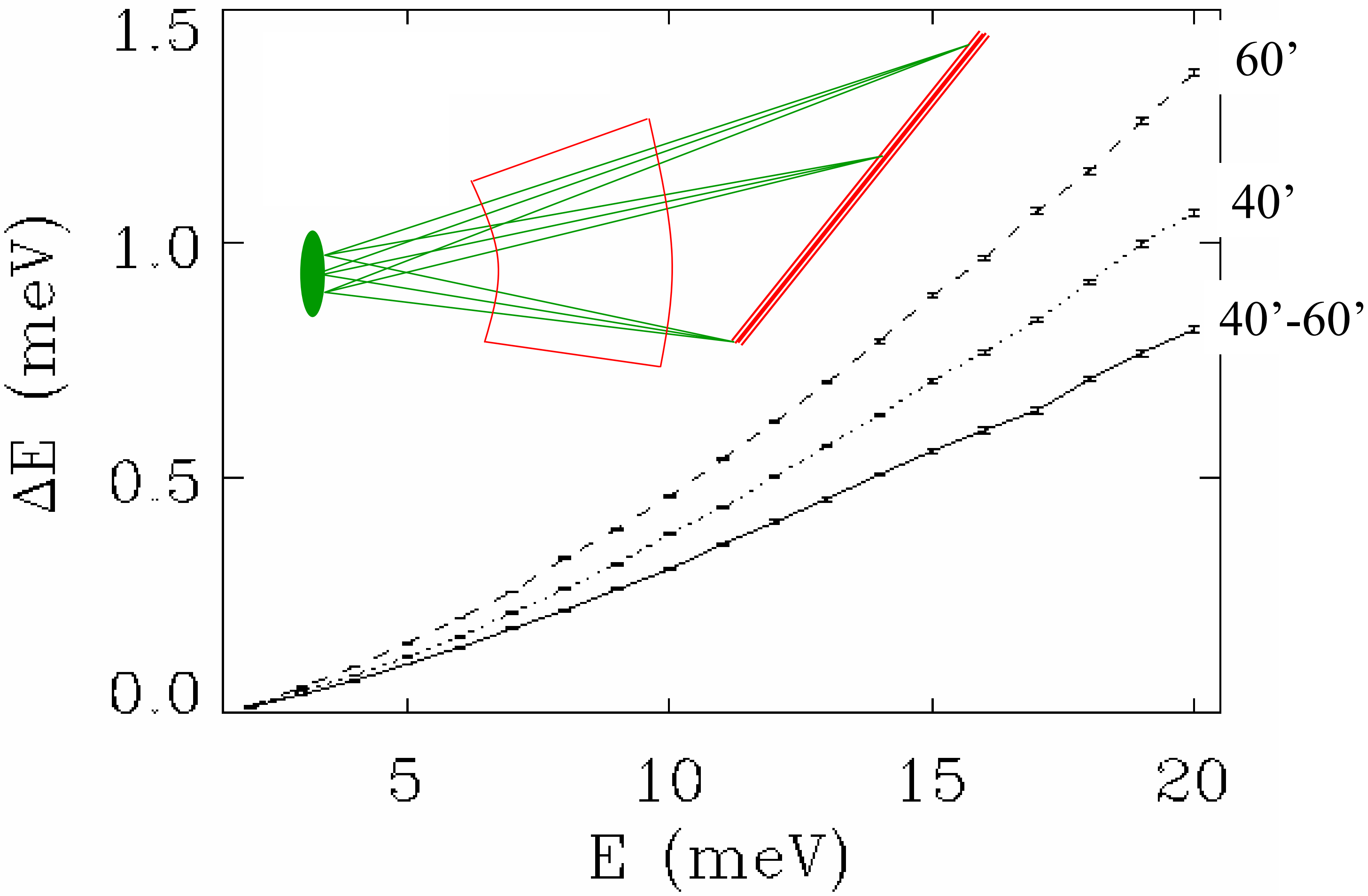


Monte Carlo Simulation of MACS

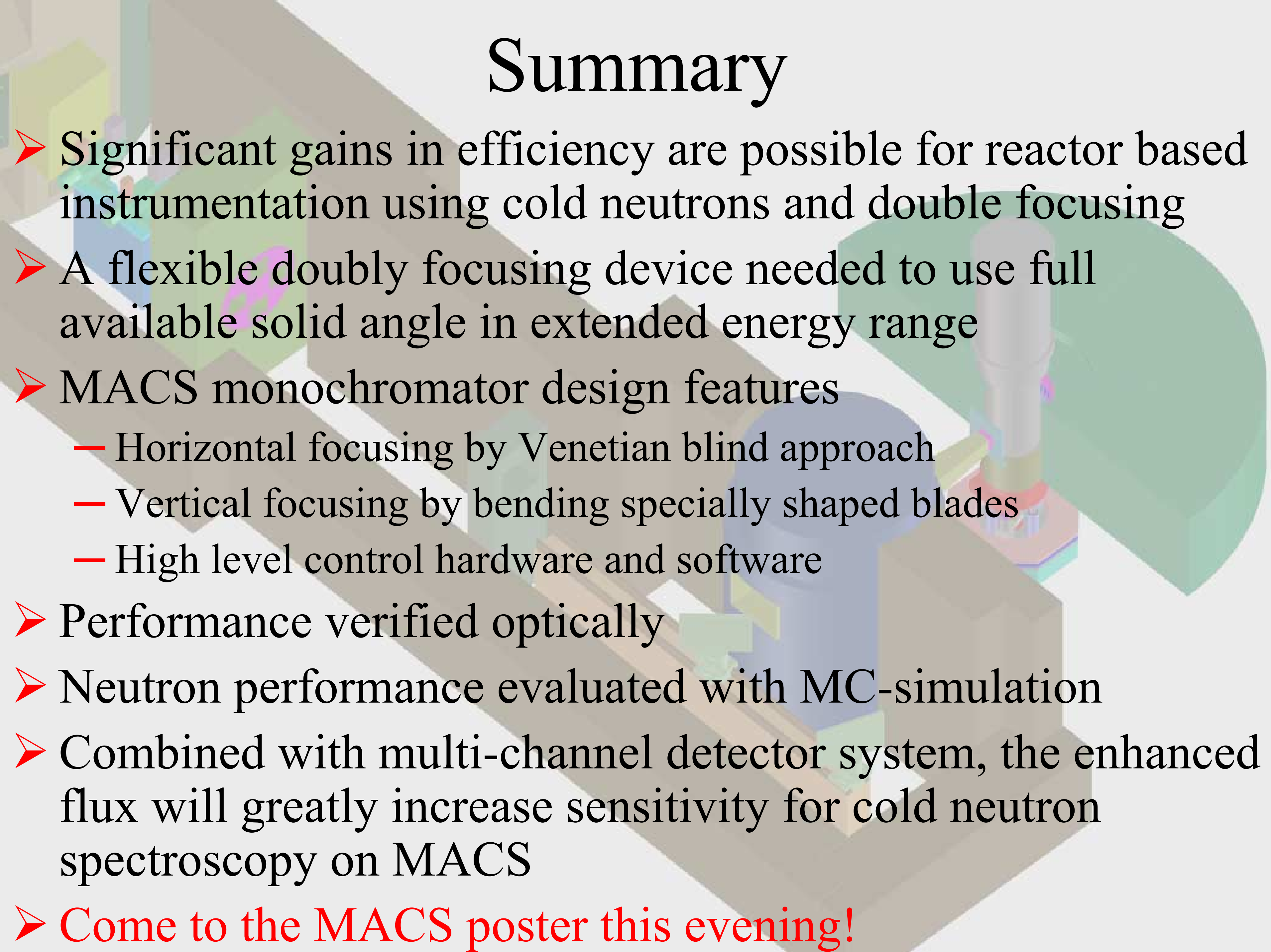


Y. Qiu and C. Broholm to be published (2002)

Incident beam energy resolution



Summary



- Significant gains in efficiency are possible for reactor based instrumentation using cold neutrons and double focusing
- A flexible doubly focusing device needed to use full available solid angle in extended energy range
- MACS monochromator design features
  - Horizontal focusing by Venetian blind approach
  - Vertical focusing by bending specially shaped blades
  - High level control hardware and software
- Performance verified optically
- Neutron performance evaluated with MC-simulation
- Combined with multi-channel detector system, the enhanced flux will greatly increase sensitivity for cold neutron spectroscopy on MACS
- Come to the MACS poster this evening!