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# Status of making $\text{ZnWO}_4$ crystals

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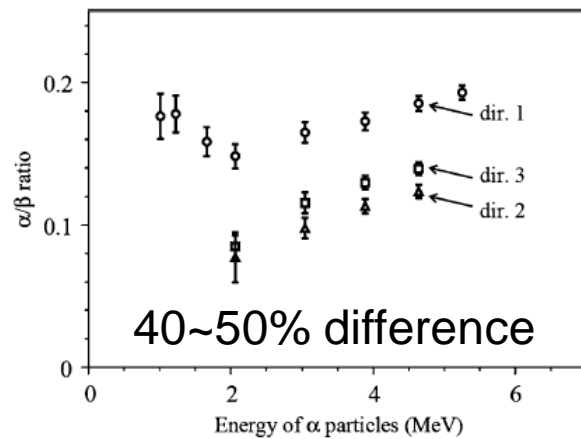
CYGNUS-TPC Mini workshop @ INFN Frascati

# ADAMO's report

## On the potentiality of the $\text{ZnWO}_4$ anisotropic detectors to measure the directionality of Dark Matter

F. Cappella<sup>1</sup>, R. Bernabei<sup>2,3,a</sup>, P. Belli<sup>3</sup>, V. Caracciolo<sup>4</sup>, R. Cerulli<sup>4</sup>, F.A. Danevich<sup>5</sup>, A. d'Angelo<sup>1,6</sup>, A. Di Marco<sup>2,3</sup>, A. Incicchitti<sup>6</sup>, D.V. Poda<sup>5</sup>, V.I. Tretyak<sup>5</sup>

### Directional response with MeV alpha particles



**Fig. 3** Dependence of the  $\alpha/\beta$  ratio on energy of  $\alpha$  particles measured with  $\text{ZnWO}_4$  scintillator. The crystal was irradiated in the directions perpendicular to (010), (001) and (100) crystal planes (directions 1, 2 and 3, respectively). The anisotropic behaviour of the crystal is evident [99]

### “Estimated” quenching factor @ 5keV

**Table 2** Quenching factors for O, Zn and W ions with energy 5 keV for different directions in  $\text{ZnWO}_4$  crystal. Systematic uncertainties are estimated on the level of 20 % using data of [90]

Ion	Quenching factor		
	dir. 1	dir. 2	dir. 3
O	0.235	0.159	0.176
Zn	0.084	0.054	0.060
W	0.058	0.037	0.041

# In case of stilbene crystal

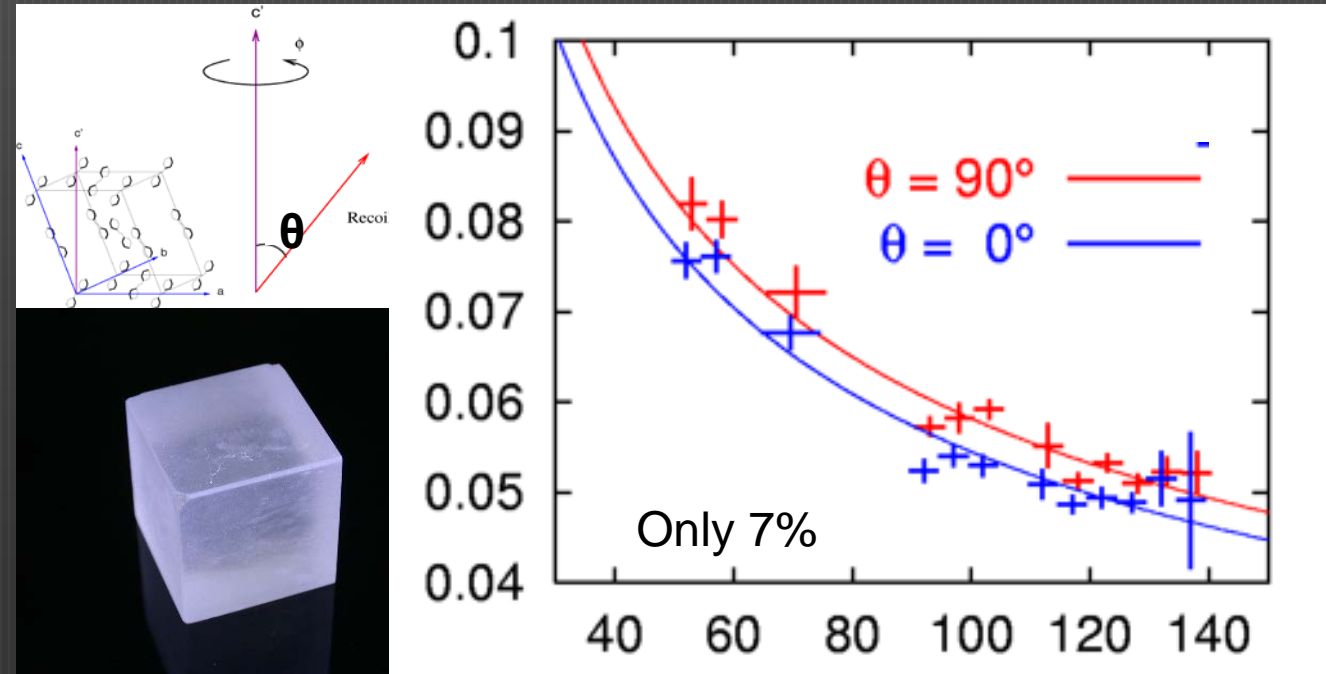
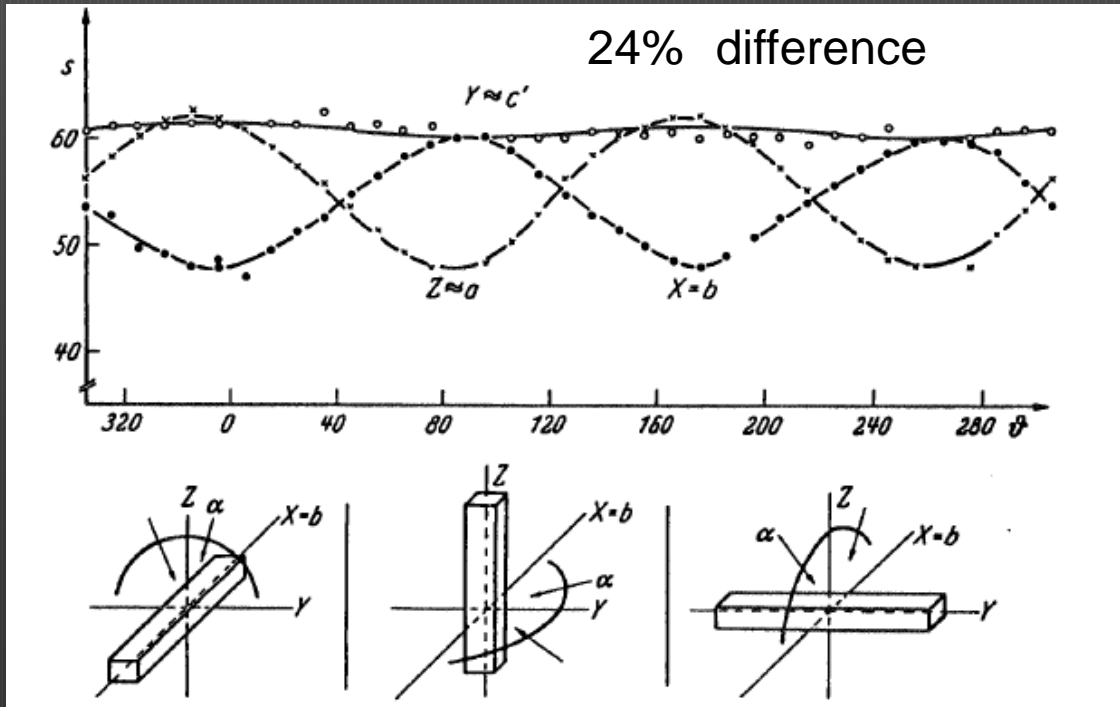
P.H. Heckmann et al., Z. Phys. 162 (1961) 122

HS et al., Physics Letters B 571 (2003) 132

Directional response  
with MeV alpha particles

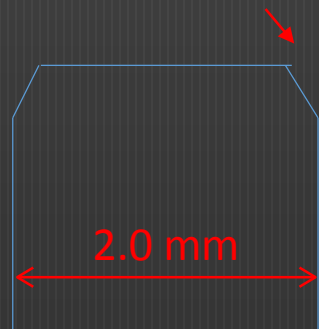
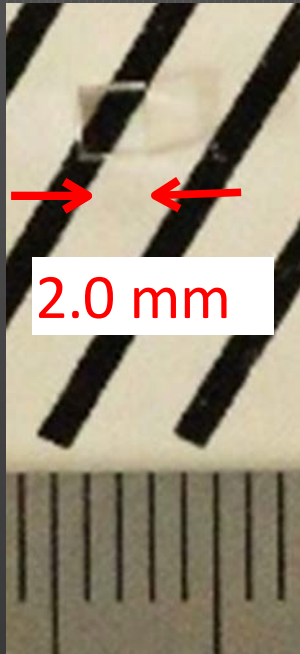
Measured quenching factor @40keV

only 7 % difference



# Review of CYGNUS 2015

- $2 \times 2 \times 2 \text{ mm}^3$  crystal made by Czochralski process



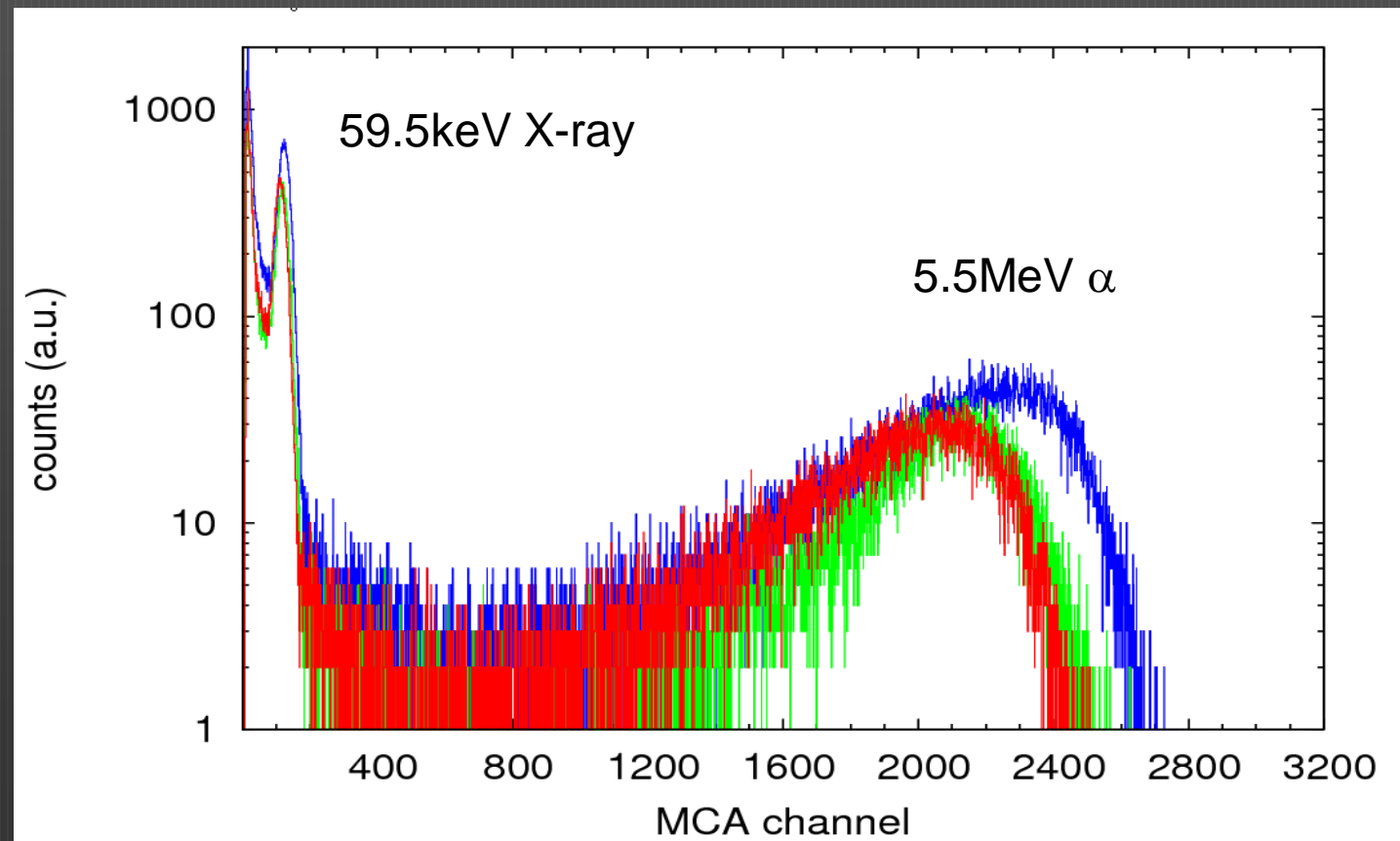
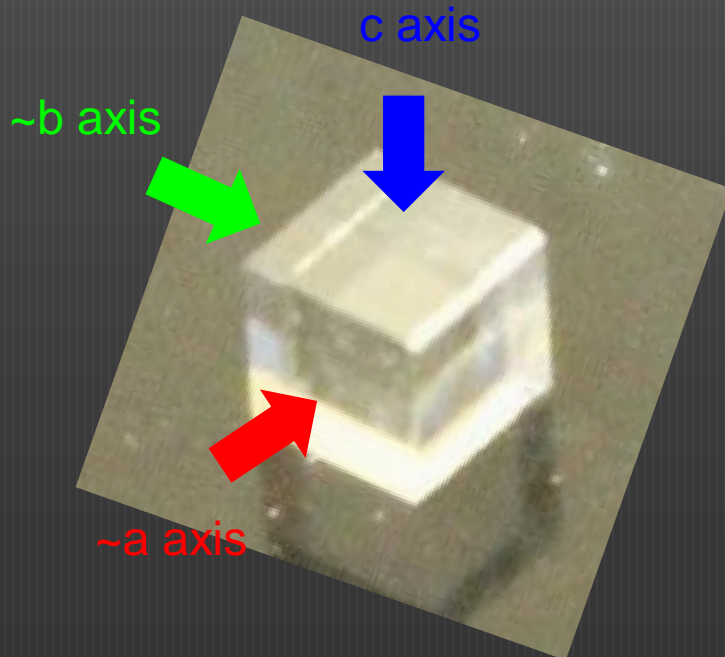
To discern the direction of the crystal

- At Tohoku University
- A 2mm cubic crystal was cut and polished.



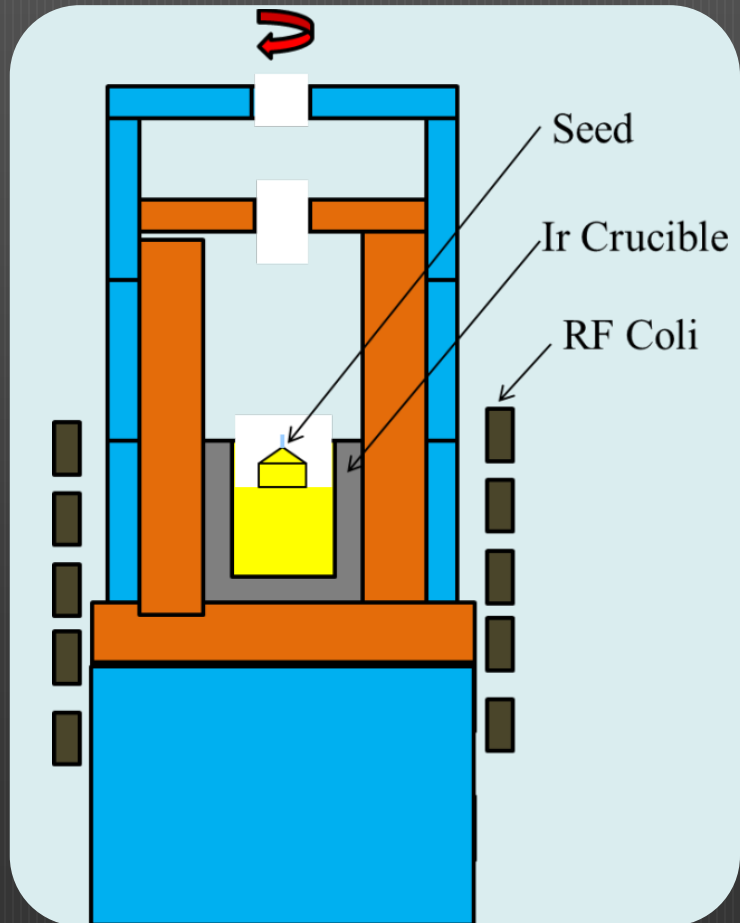
# Response to $^{241}\text{Am}$

- From  $\sim$ a axis direction,  $\sim$ b axis direction, and c axis direction
- $\sim$ 12% difference in 5.5MeV  $\alpha$  peaks, while 59.5keV peaks look same.

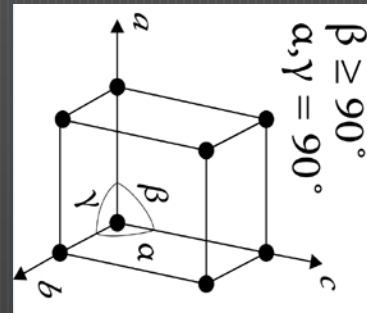


# 2mm crystal was too small

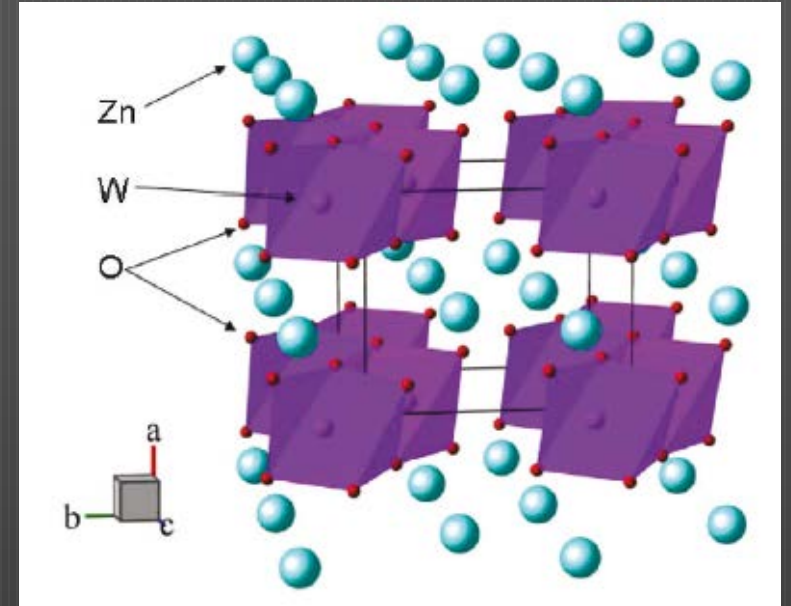
- Make it larger with Czochralski process



Monoclinic system

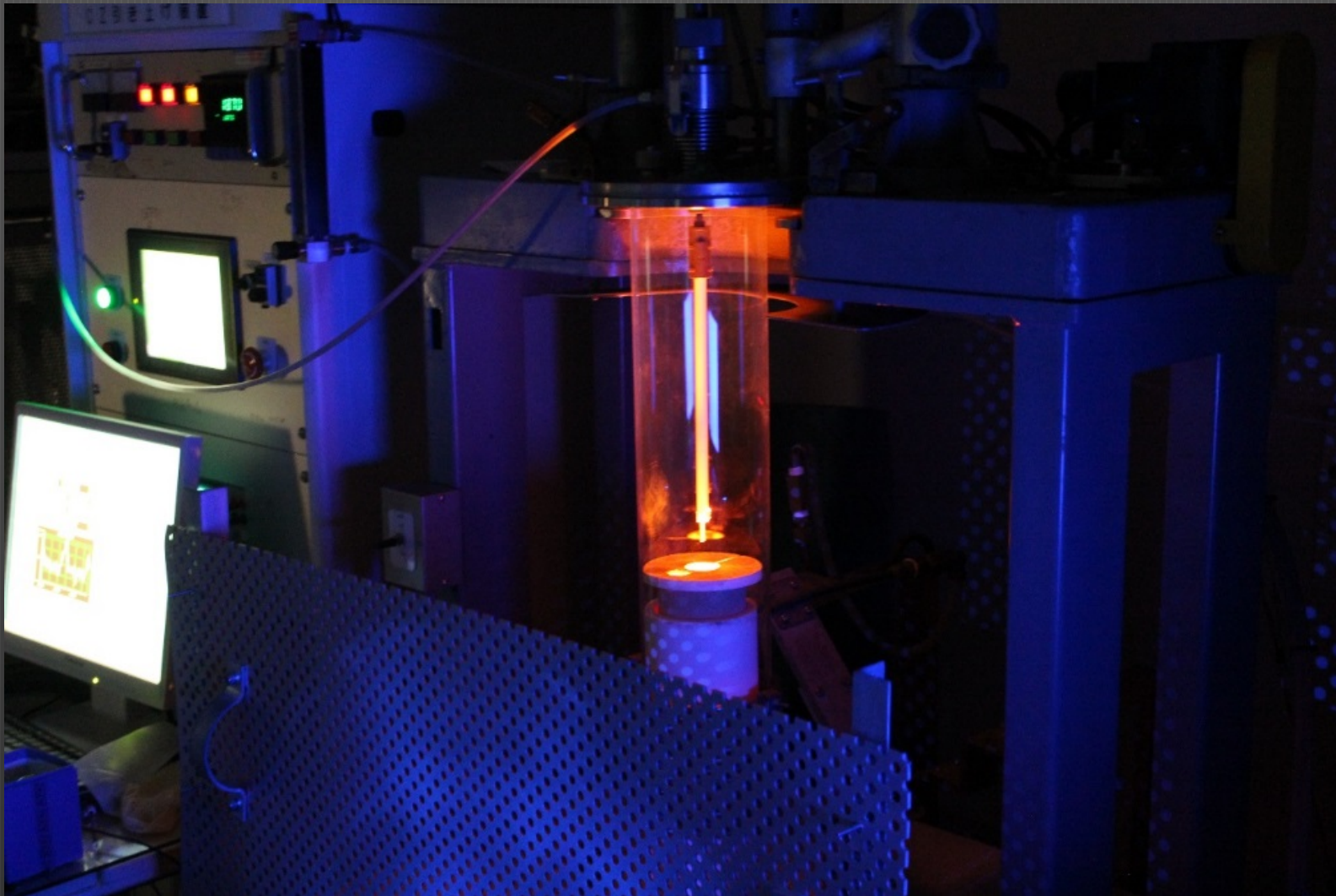


Atuchin + CGD 2011

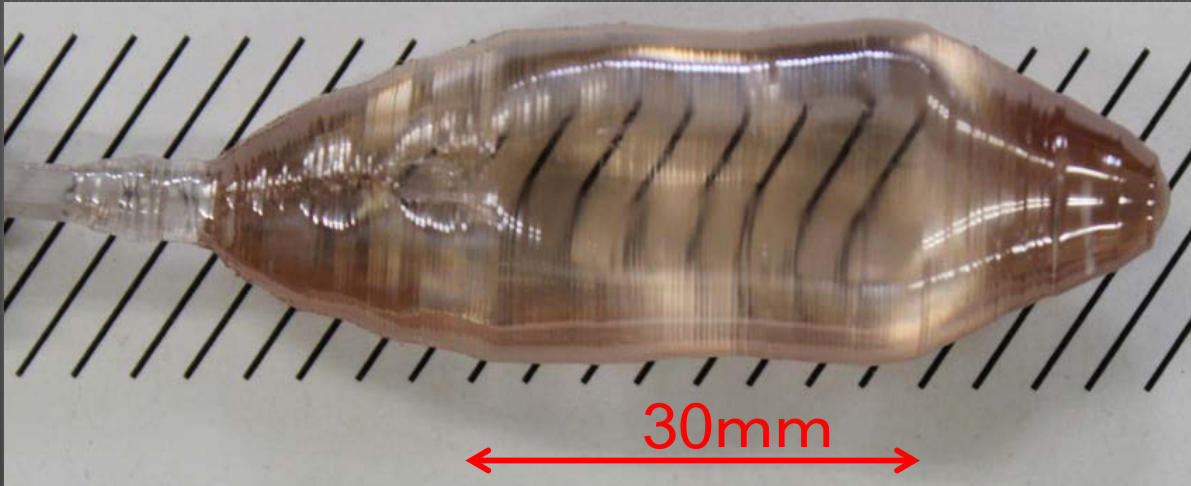


Ingredients	ZnO, WO <sub>3</sub> (purity 99.99%)
Pull-up speed	0.5mm/h
Direction of the seed-crystal	C-axis
Purge gas	Ar+O <sub>2</sub> (2%)
Rotation	12rpm

# What the crystal growth actually looks like



# The obtained crystal



- Brownish crystal
  - oxygen deficiency
  - It is expected to be clear after adding annealing process

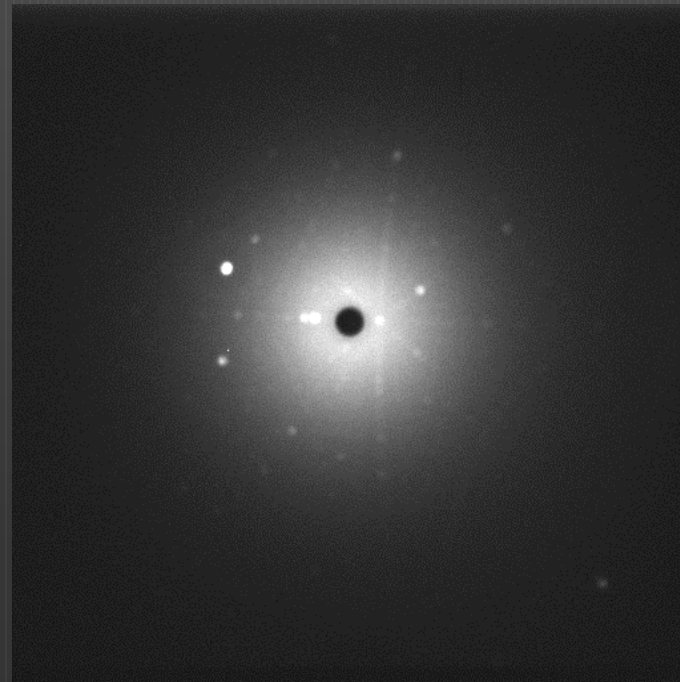
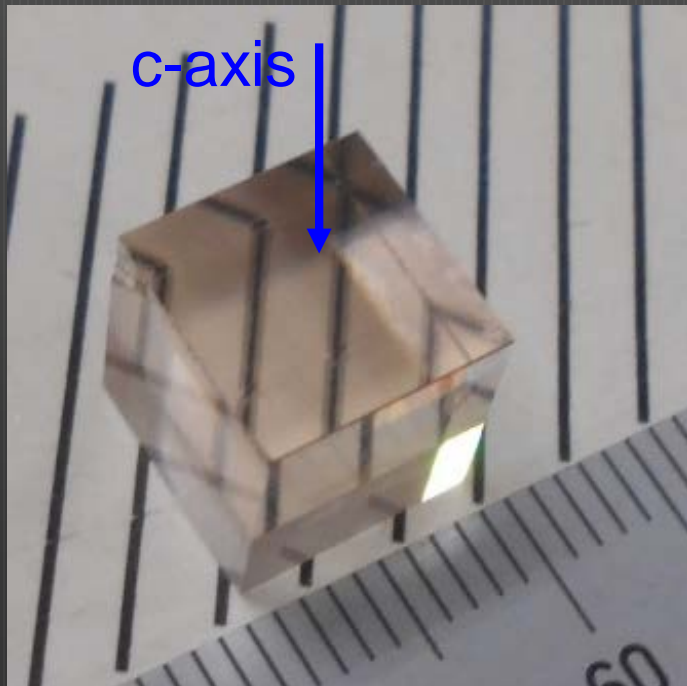


## After cut and polish

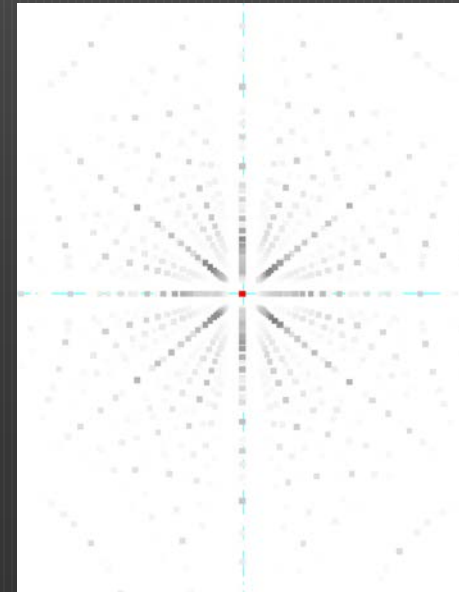
- It is easy to be cleaved along the c-axis.
  - 9mm x 9mm x 9mm crystal was available.

Crystal check by taking Laue pictures

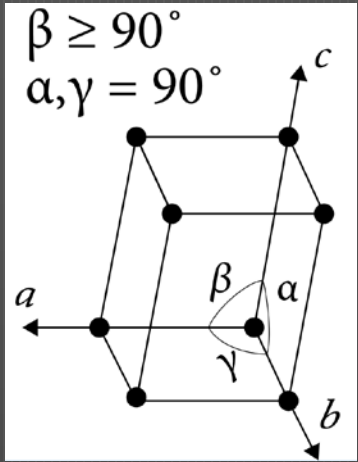
X-ray generator: RIGAKU RAD-IIC with Hamamatsu CCD



Simulated Laue pattern

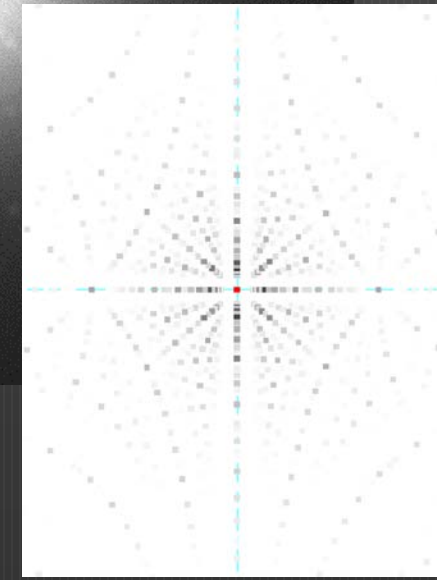
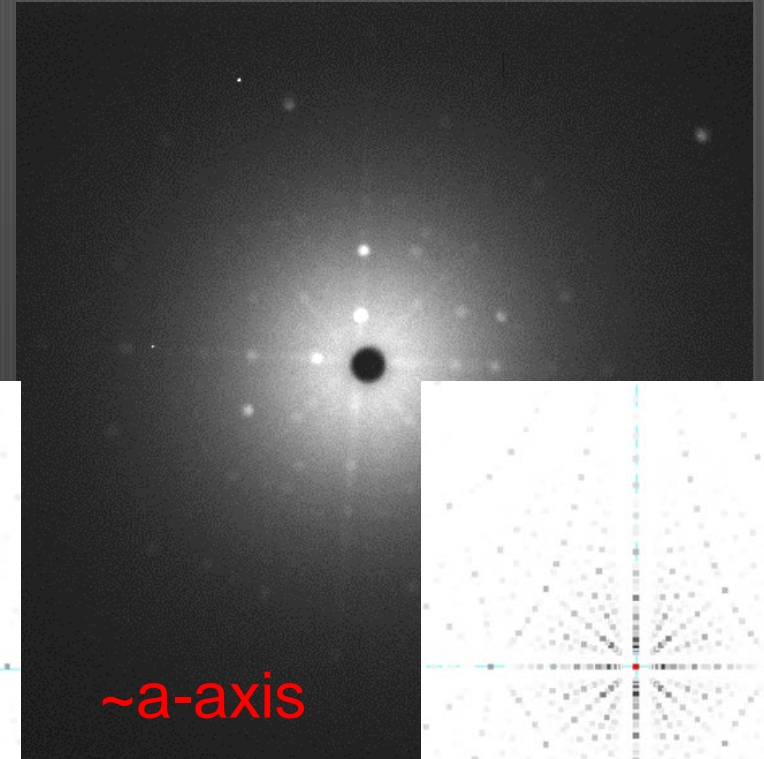
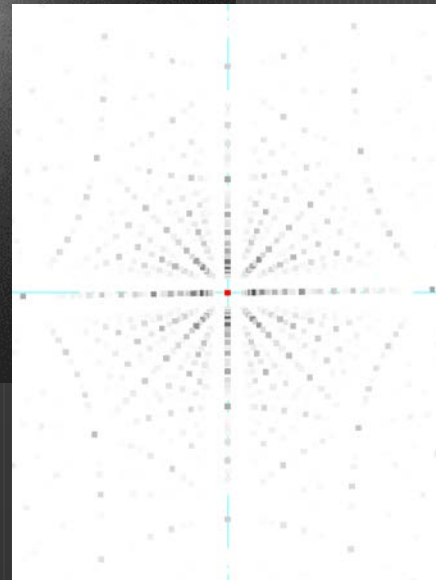
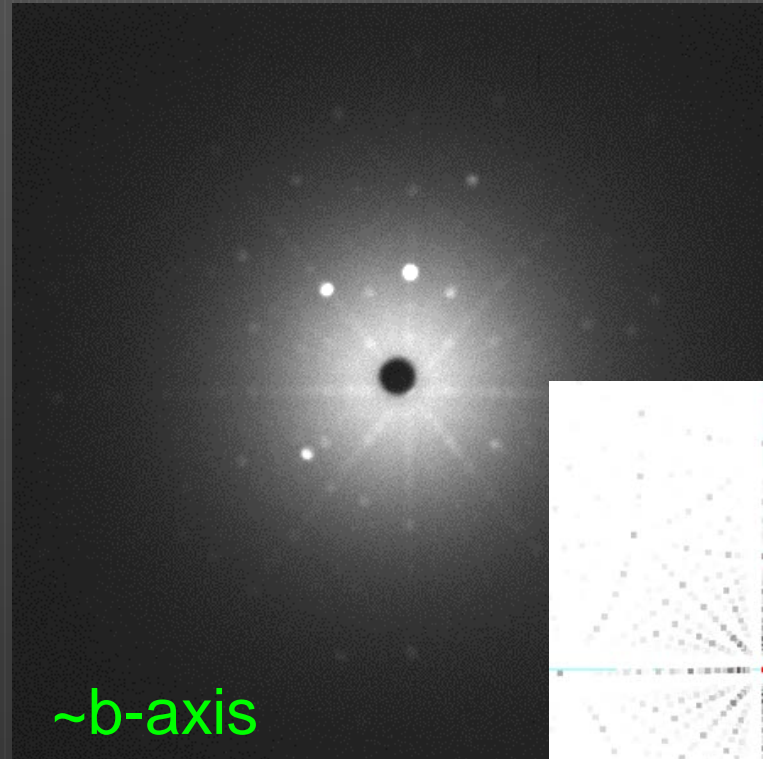
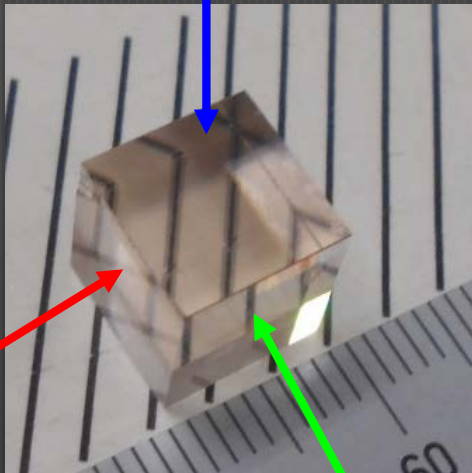


# Other axes were also confirmed

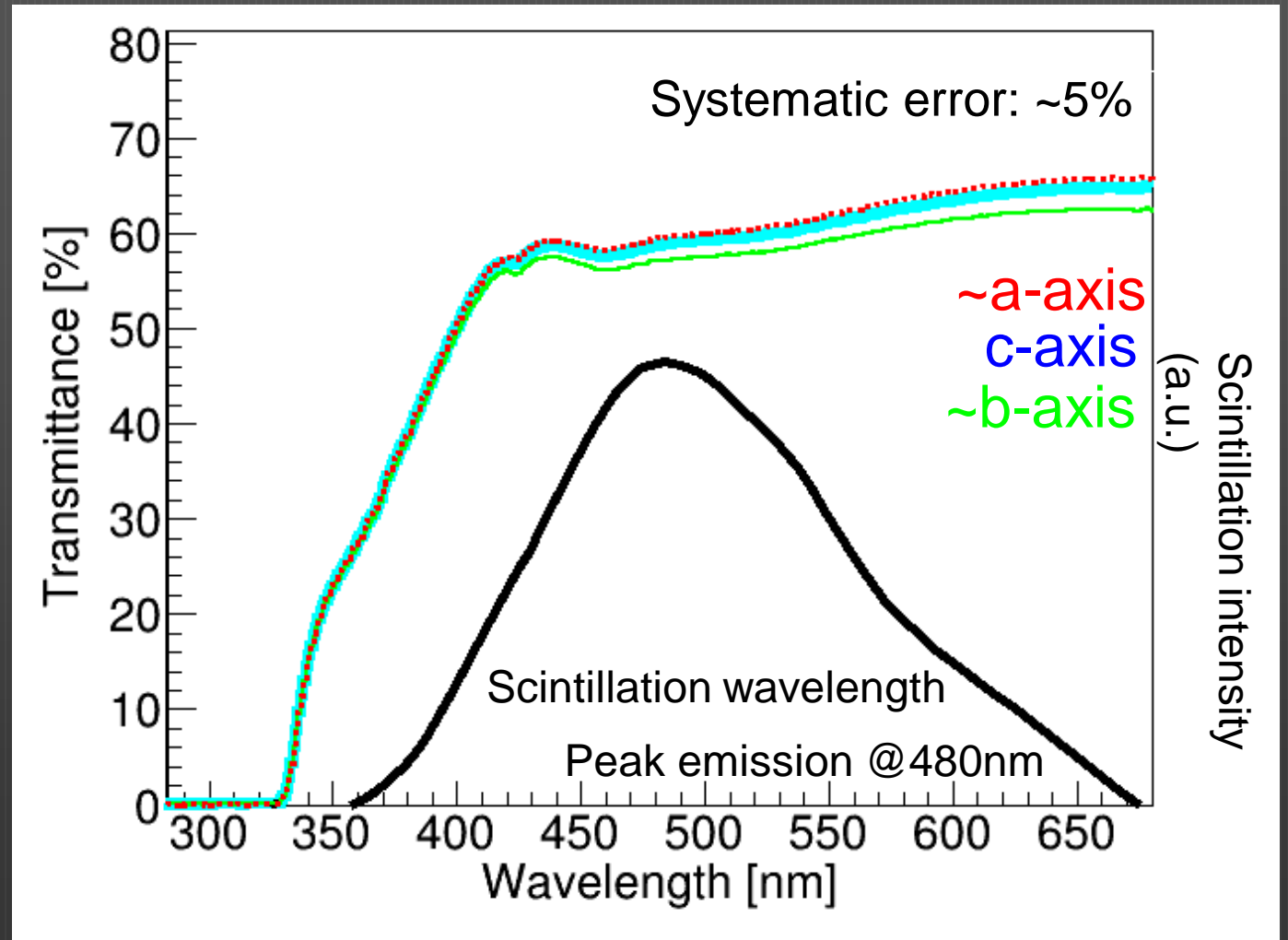
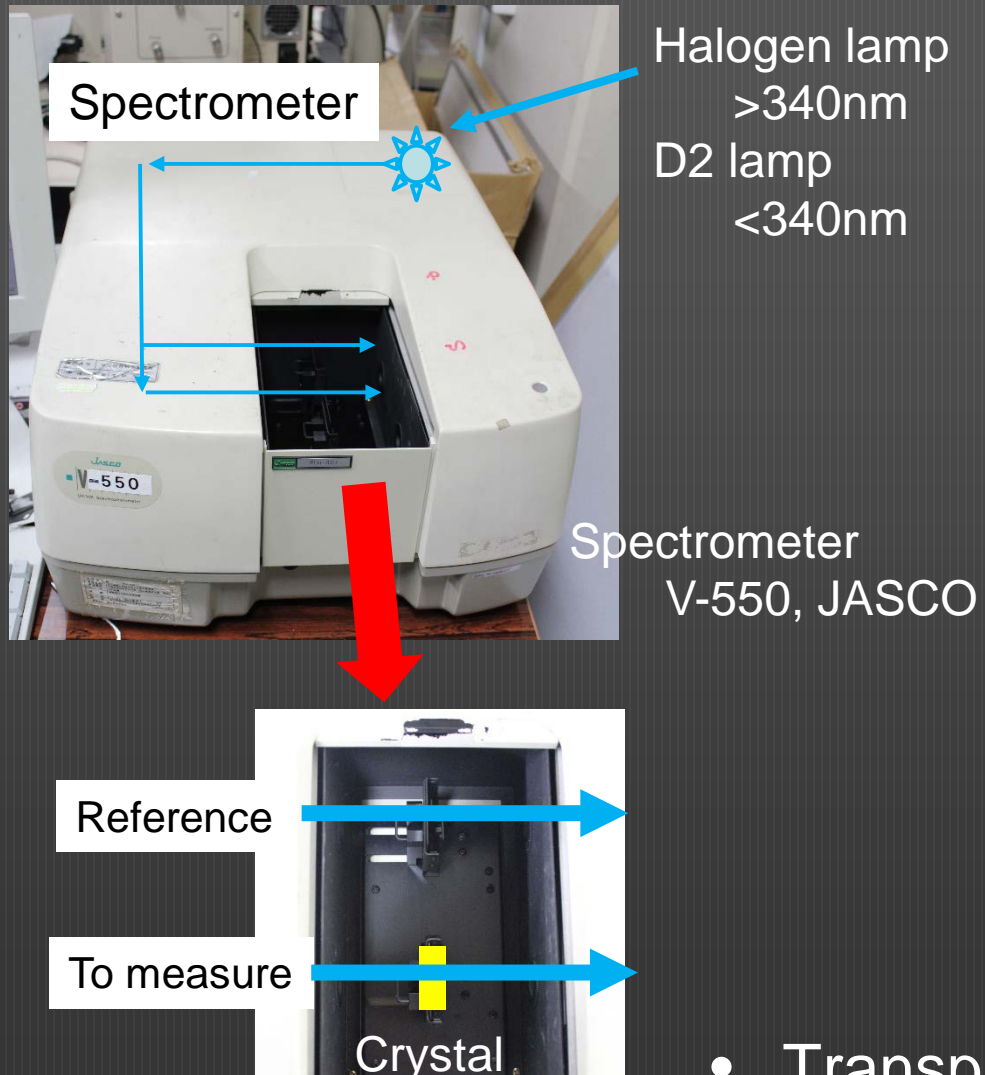


$a$ [Å]	$b$ [Å]	$c$ [Å]	$\alpha$ [deg]	$\beta$ [deg]	$\gamma$ [deg]
4.69060	5.71820	4.92690	90.0000	90.6210	90.0000

c-axis



# Directional dependence of the transparency?

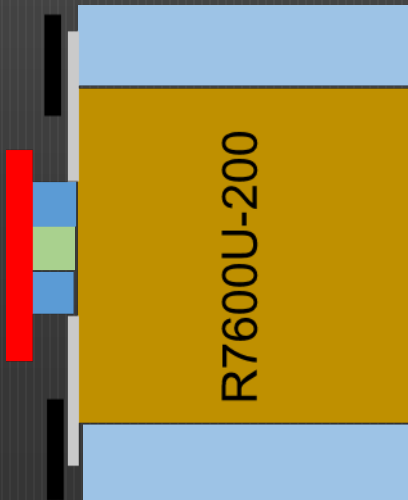
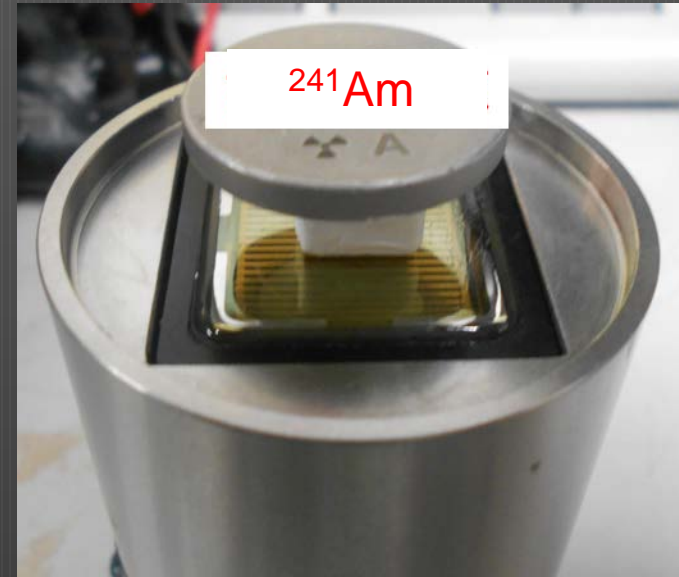
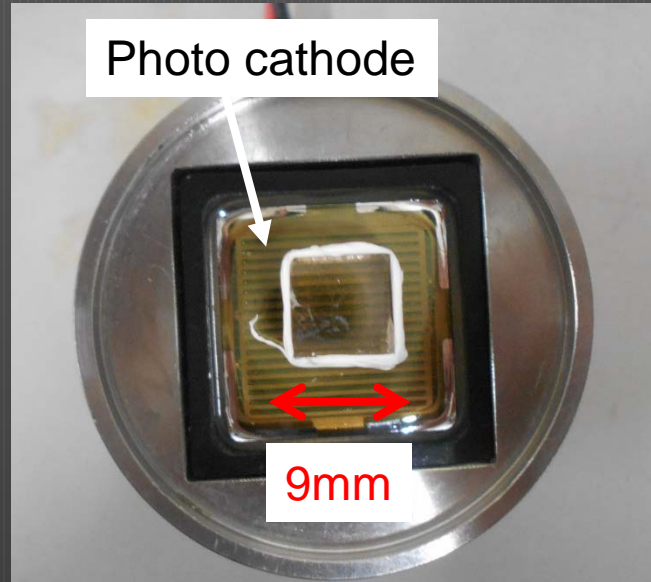


- Transparency does not depend on the crystal orientation.

# Setup for checking alpha response

- Hamamatsu R7600U-200 UBA PMT

Temperature 24.1-24.2°C



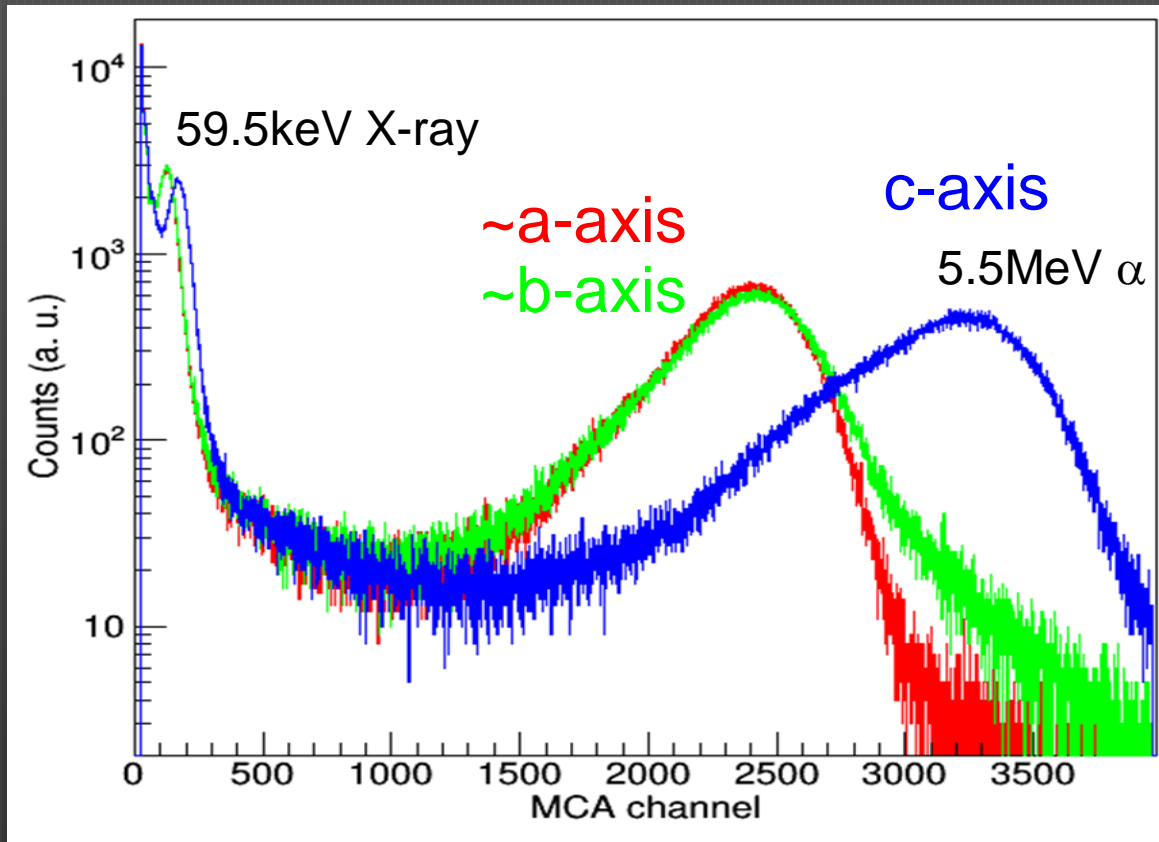
preamp  
ORTEC 113  
C=1000pF

shaper  
ORTEC 572A  
Shaping time: 10  $\mu\text{sec}$

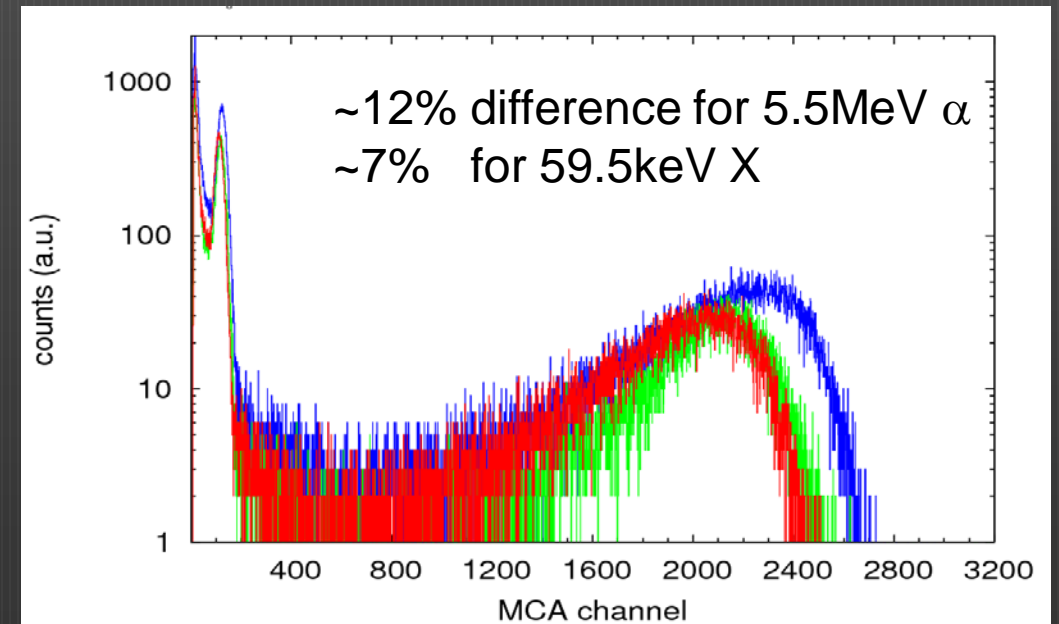
MCA  
AMPTEK8000A

# The result

- Maximum along c-axis,  $\sim a$  and  $\sim b$  are same.
- 37% difference for 5.5MeV alpha, 32% for 59.5keV X-ray



c.f. 2mm crystal @CYGNUS2015

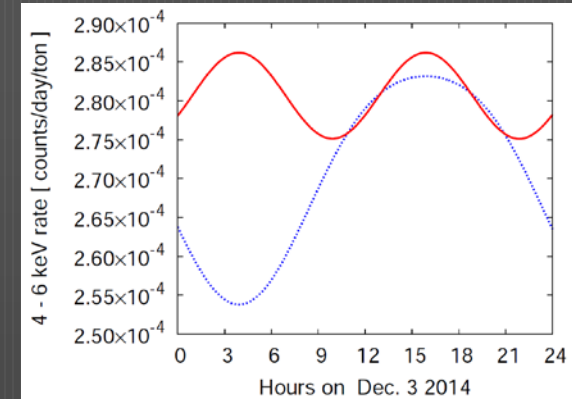
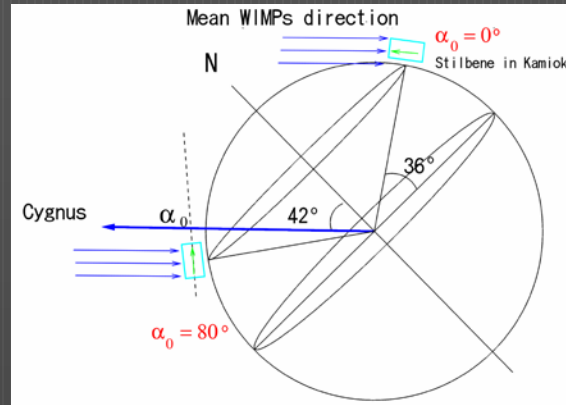


# Conclusion

- ~40% anisotropic response for  $\alpha$  particles was observed with this  $9 \times 9 \times 9 \text{ mm}^3$  sample.
- Similar response for X-ray was also observed.
  - This was not expected...
  - Systematics? True effect? Crystal dependence?
- Surface or bulk?
  - $^{137}\text{Cs}$  662keV test is underway.
  - Neutron calibration is really needed!
- Needs more crystals/statistics.

# Get more information of WIMP direction

- So far, 10 tons are needed



- Phonon channel?

- Total energy deposit vs direction-dependent light output makes the sensitivity better
- Started discussion with AMoRE  
Yong-Hamb Kim

ZnWO<sub>4</sub> or Stilbene ←

