

## **Specifications of Lead Tungstate Crystals for FCAL-II (April 2019)**

The specifications of the PWO crystals for FCAL-II include four areas. The definitions of these requirements and the testing procedures are described below.

- Visual properties.
- Geometry.
- Optical properties.
- Radiation hardness

### **1. Visual Properties**

Some parameters of the crystal quality such as possible coloring, cracks or any sort can easily be seen by eyes. The visual inspection includes two steps: (1) check each crystal under the regular room light first; (2) then inspect the crystal again with a green laser light in a dark room. The crystals that failed any of one of these two steps are not acceptable and should be rejected before further tests. A checklist for the visual properties includes following:

- The manufacturer label number is written on the front face of the crystal with a marker that can be easily removed with 50% alcohol solution. All other surfaces of the crystal should be free of any chemical films, polishing residues, stickers/labels, or markers of any type (see Appendix I). No visible cracks, chips or scratches, missing material, surface flaws.
- Transparent and colorless. The crystal should be visually clean without any discoloration signs, yellow, brown, or pink tints (see Appendix II)
- No visual distortions, core defect and cloudy regions inside the crystal volume (see Appendix III)
- Chamfers on front and rear faces of the crystal should be uniform. The size of chamfers should not exceed 0.7 mm.
- All faces polished.

### **2. Geometry**

Each crystal module will have simple rectangular shape with the size of 20.5x20.5x200.0 mm<sup>3</sup> (see Fig. 1)

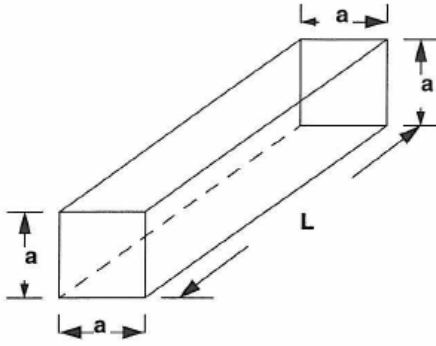


Fig. 1

The dimensions of each crystal are shown in Fig 1 and are specified in the following Table:

	Length (mm)	Tolerance (mm)
a	20.5	$ a-20.5  \leq 0.05$
L	200.0	$ L-200.0  \leq 0.1$

**Tolerances for dimensions:**

- All transversal dimensions should be within +0.05 mm, -0.05 mm;
- The longitudinal dimensions should be within +0.1 mm, -0.1 mm

**Planarity:**

- Planarity for all faces should be kept within 0.020 mm for all faces.

**Angular tolerances:**

- All angular tolerances should be kept within 0.050 mm across a length of 25 mm, except for the back face, which is specified below.

**Perpendicularity:**

- On the back face (opposite to the front face where the manufacturer number is labeled), we will attach a PMT with the length of 80 mm. Therefore we have a special requirement for this face. The Perpendicularity for this face should be kept within 0.2 mm across the length of the crystal 200 mm.

**Chamfers:**

- Chamfers should be made on all 12 edges, with the cut to the limit of 0.3-0.7mm x 45°. The surface finish of chamfers can be left at a roughness of 0.5  $\mu\text{m}$  (lapping)

**Surface Finish:**

- Surface finish for all faces should be "Polished Finish" with the Roughness less than 0.020  $\mu\text{m}$ . It should be done on a polishing machine equipped with a special polishing cloth and using diamond abrasive of grain 3  $\mu\text{m}$  in emulsion. From the surface finish provided by the previous operation (lapping), about 10 minutes are necessary to reach the required surface finish.

### 3. Optical Properties

**Longitudinal transmission** (absolute values):

$\geq 25\%$  at 360 nm;  
 $\geq 55\%$  at 420 nm;  
 $\geq 65\%$  at 620 nm

**Transversal transmission:**

- The non-uniformity of the transversal transmission  $\delta\lambda$  at the transmission value of 50% should be  $\delta\lambda \leq 5$  nm for 5 measurements every 3 cm, starting at 1.5 cm from front face.

**Scintillation Light yield:**

- Light Yield  $\geq 12$  photoelectrons/MeV, measured at  $T=18^\circ\text{C}$  and in a 100 ns gate, with  $^{60}\text{Co}$  source at 3 cm from PWO front face, with a Phillips XP2262B photomultiplier covering all rear face, with a n=1.5 silicon coupling grease, wrapped on 4 sides and face in 1 layer of Tyvek.

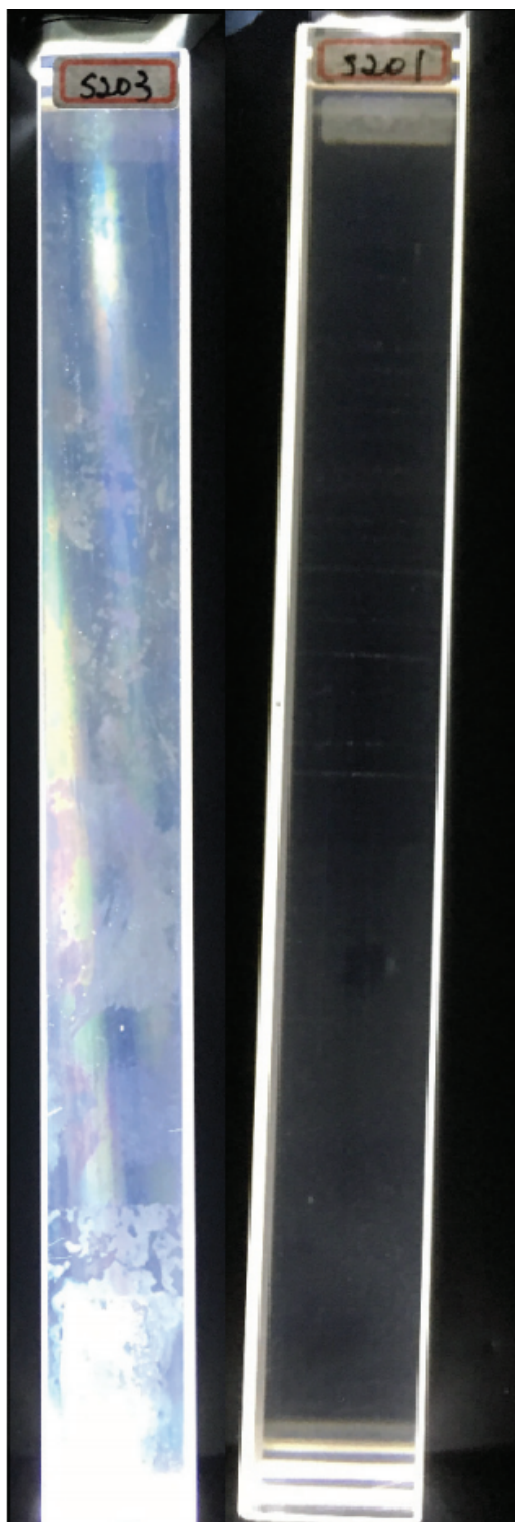
**Decay time:**

- $\text{LY}(100\text{ ns})/\text{LY}(1000\text{ ns}) > 90\%$  at  $T=18^\circ\text{C}$ .
- Afterglow  $\leq 0.5\%$  of peak amplitude with a  $^{60}\text{Co}$  counting rate of MHz.

### 4. Radiation Hardness

- Induced absorption for full crystal saturation:  $\mu \leq 1.5\text{ m}^{-1}$  at 420 nm for lateral  $^{60}\text{Co}$  irradiation,  $>3$  krad, rate of 5-15 krad/h at  $18^\circ\text{C}$ .
- Light yield loss  $< 6\%$  for front  $^{60}\text{Co}$  irradiation, 200 rad, 15 rad/h.
- No recovery time constant shorter than 1 hour.

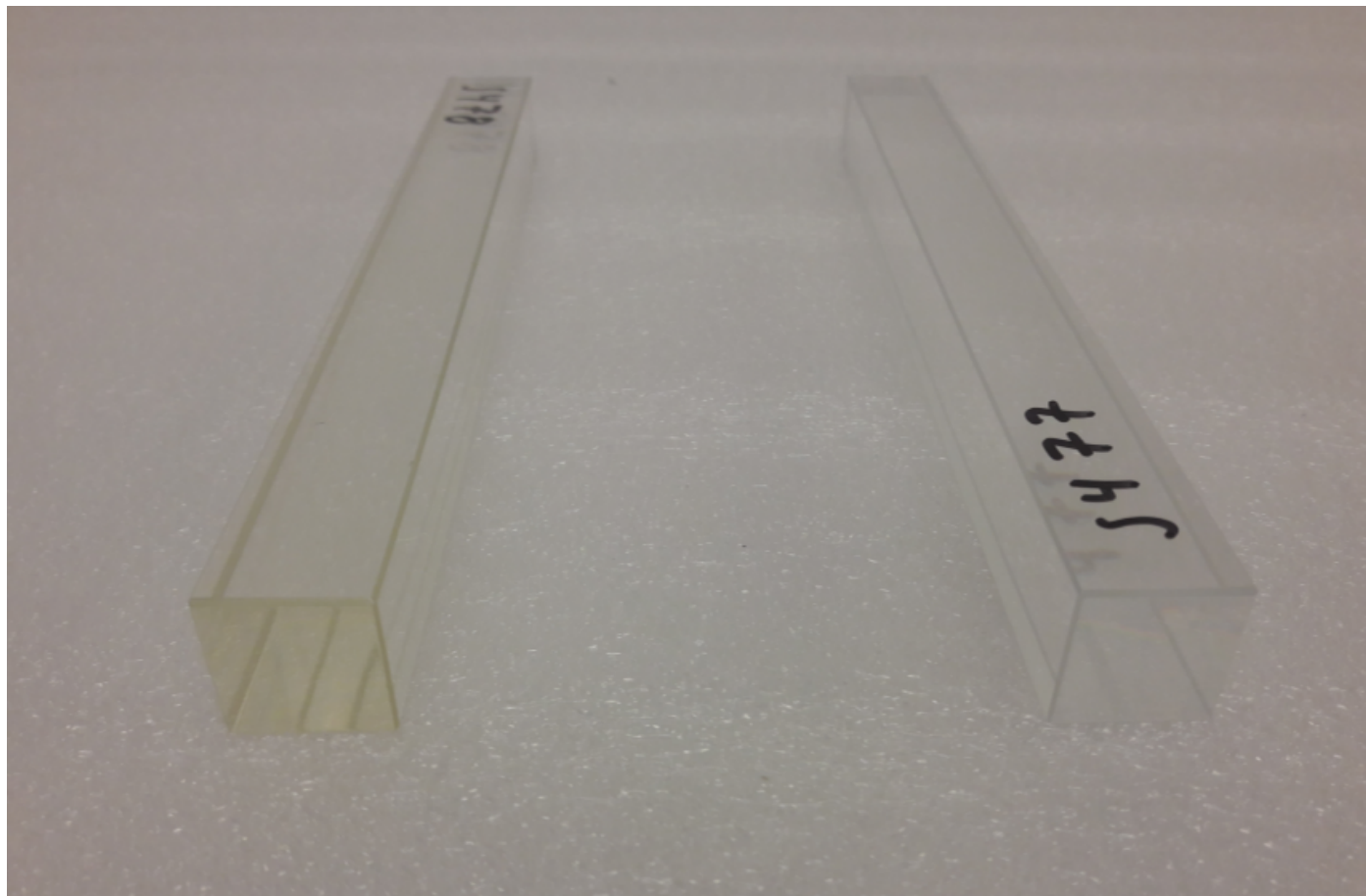
## Appendix I



A crystal with chemical film on surface is shown on the left (not acceptable)

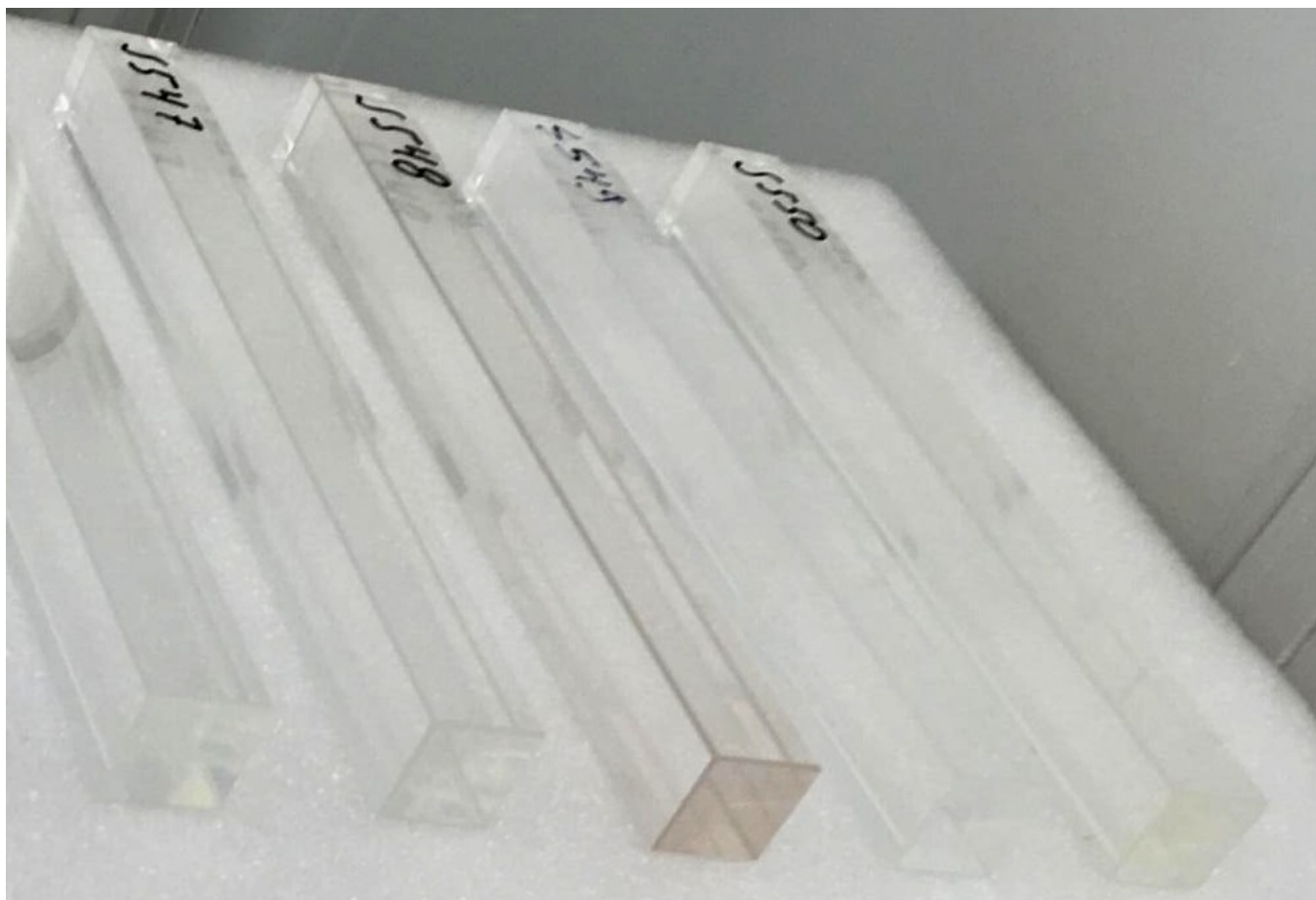
Clear crystal is shown on the right (acceptable)

## Appendix II



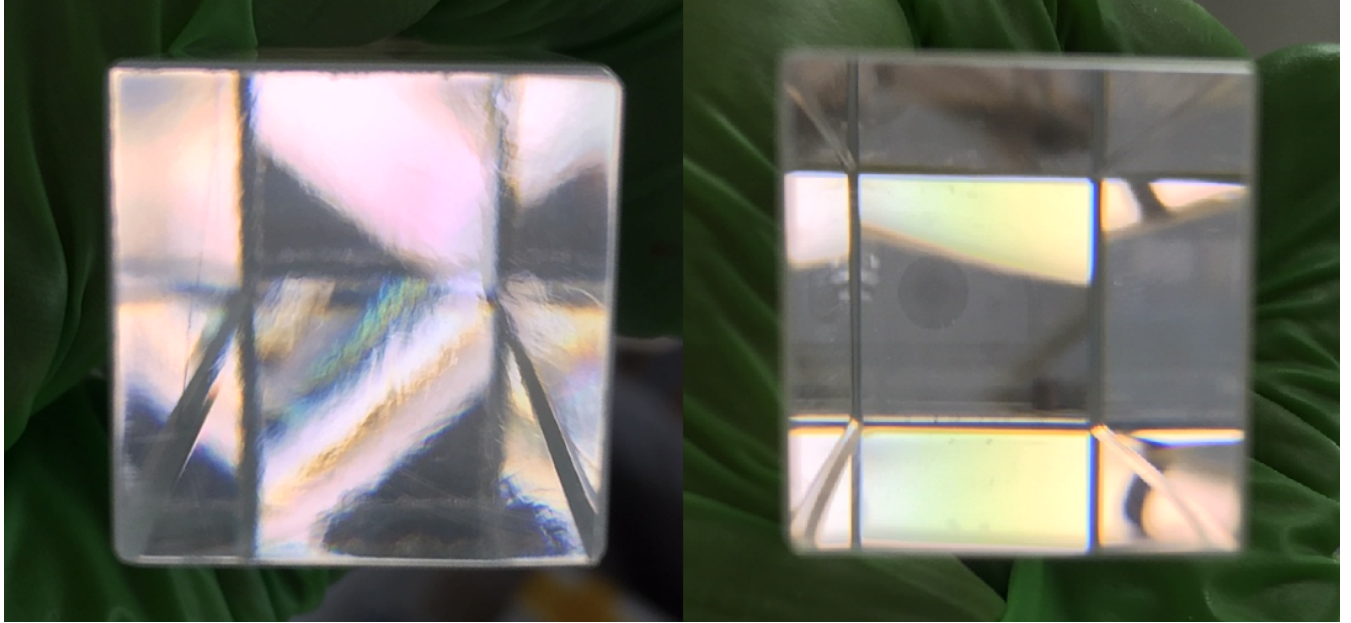
Crystal with yellow discoloration is shown on the left (not acceptable)

Clear crystal is shown on the right (acceptable)



Crystal with brown discoloration is shown in the middle (not acceptable)

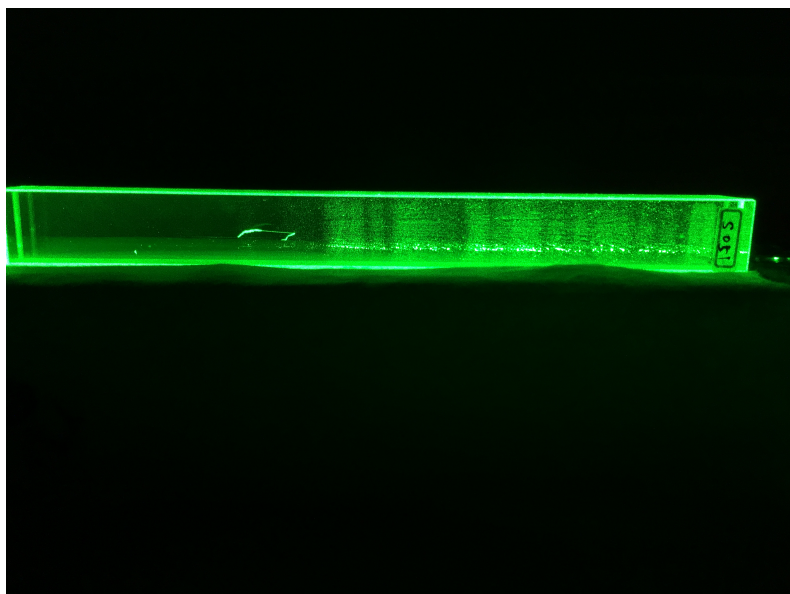
## Appendix III



Cloudy crystal with some indications of optical distortion is shown on the left (not acceptable)

Clear crystal is shown on the right (acceptable)





The crystal with a cloudy region inside the body of crystal is shown in the top photo (not acceptable)

A clear crystal is shown on the bottom photo (acceptable)