

Supporting Information

Tb-Doped MA_{0.89}FA_{0.11}PbBr₃ Perovskite Single Crystals for Gamma-Ray Detection

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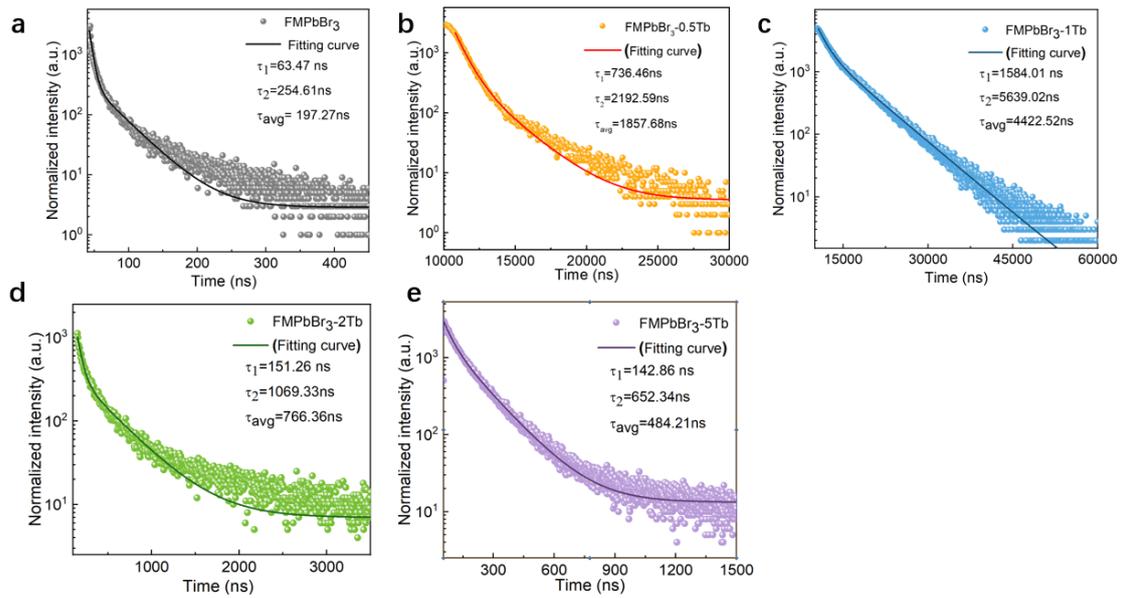


Figure S1. TRPL curves of organic halide perovskite single crystals. (a) $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3$, (b) $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3\text{-0.5Tb}$, (c) $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3\text{-1Tb}$, (d) $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3\text{-2Tb}$ and (e) $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3\text{-5Tb}$.

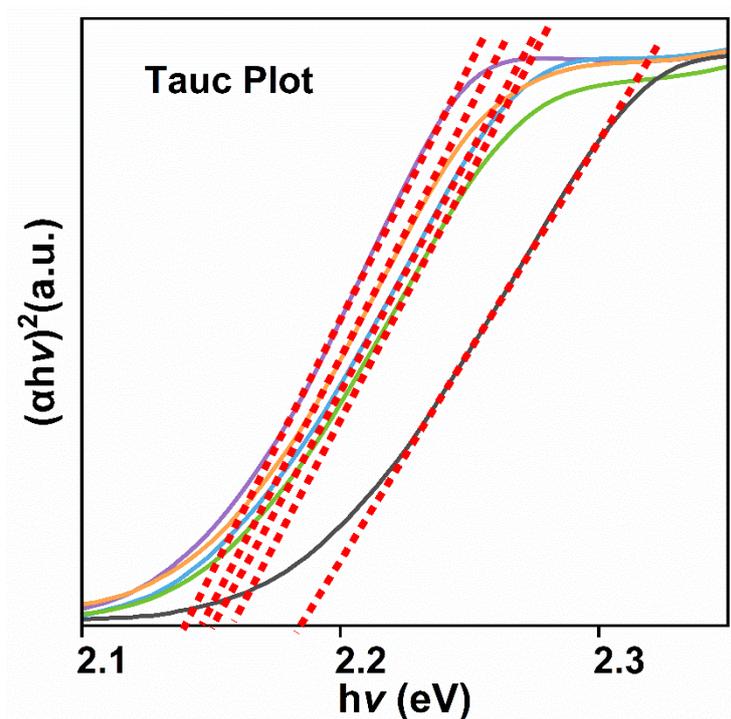


Figure S2. Bandgap determination of $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3$ single crystals using the Tauc plot method derived from UV-Vis absorption spectra. The extrapolation of the linear region (red dashed line) to the x-axis (photon energy, $h\nu$) provides the optical bandgap energy.

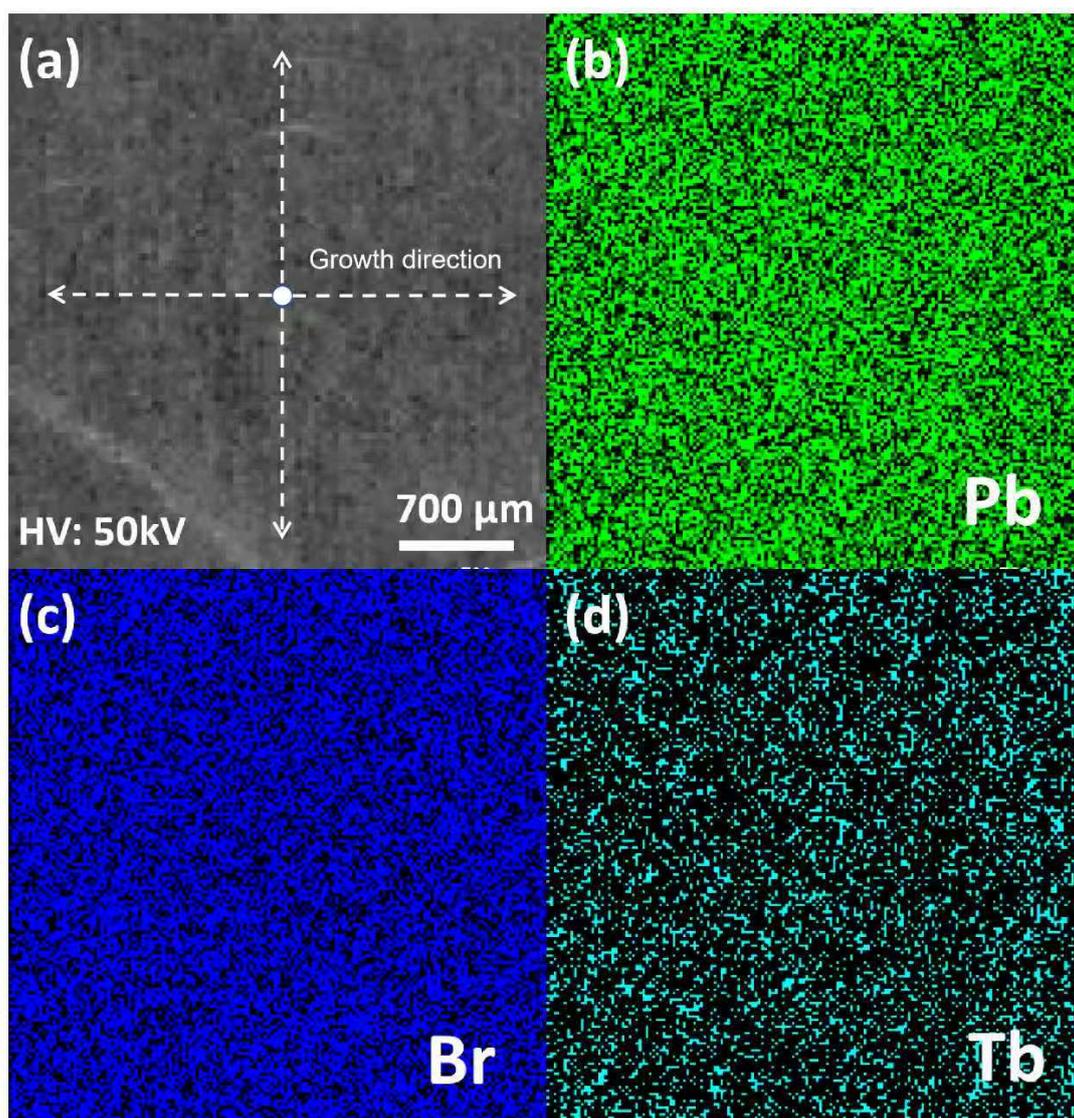


Figure S3. Elemental mapping and distribution analysis of $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3:\text{Tb}$ single crystals. (a) Optical view of the crystal surface captured by the integrated camera of the $\mu\text{-XRF}$ system. (b–d) Corresponding X-ray fluorescence elemental maps for (b) $\text{Pb L}\alpha$, (c) $\text{Br K}\alpha$, and (d) $\text{Tb L}\alpha$ signals, respectively.

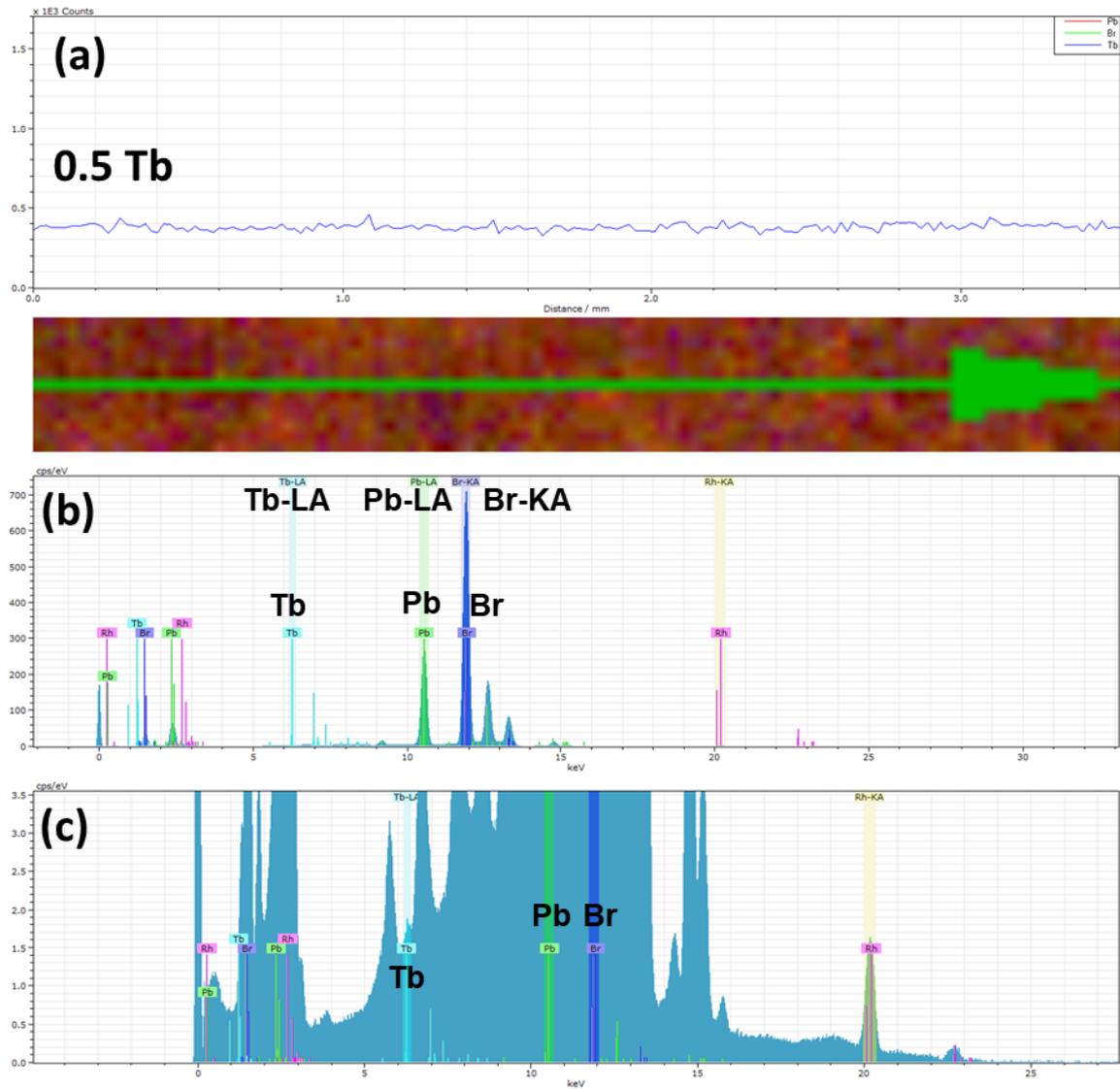


Figure S4. XRF line-scan and spectral analysis of $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3: 0.5\text{Tb}$. (a) Line-scan profile of Tb $L\alpha$ intensity across the crystal surface. The green arrow indicates the crystal growth direction and the scanning path (scan length: 3.5 mm). (b) Full-range XRF spectrum showing characteristic peaks of Pb, Br, and Tb. (c) Magnified spectral region highlighting the Tb $L\alpha$ (6.18 keV) emission lines.

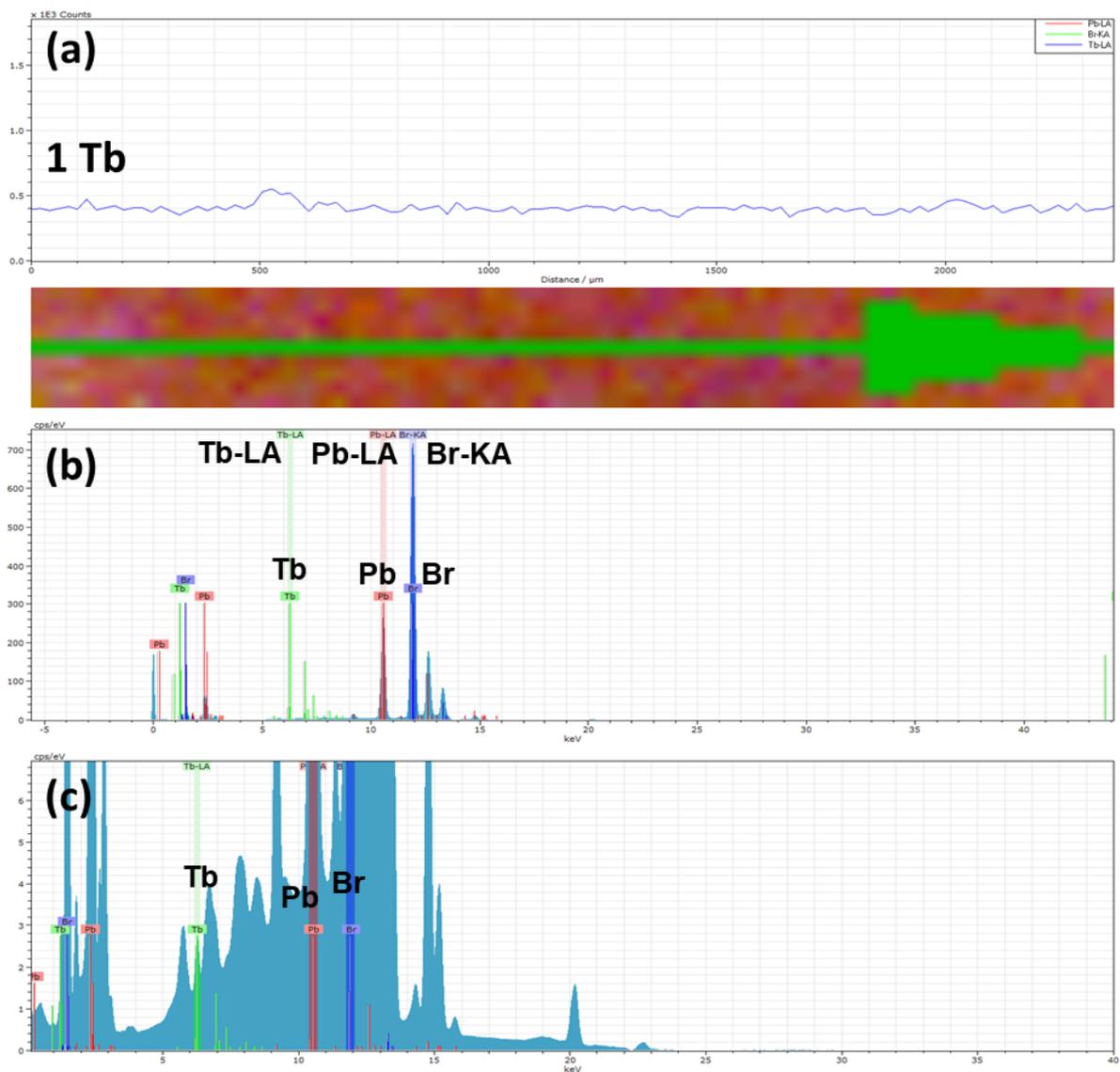


Figure S5. XRF line-scan and spectral analysis of $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3: 1\text{Tb}$. (a) Line-scan profile of Tb $L\alpha$ intensity across the crystal surface. The green arrow indicates the crystal growth direction and the scanning path (scan length: 2.3 mm). (b) Full-range XRF spectrum showing characteristic peaks of Pb, Br, and Tb. (c) Magnified spectral region highlighting the Tb $L\alpha$ (6.18 keV) emission lines.

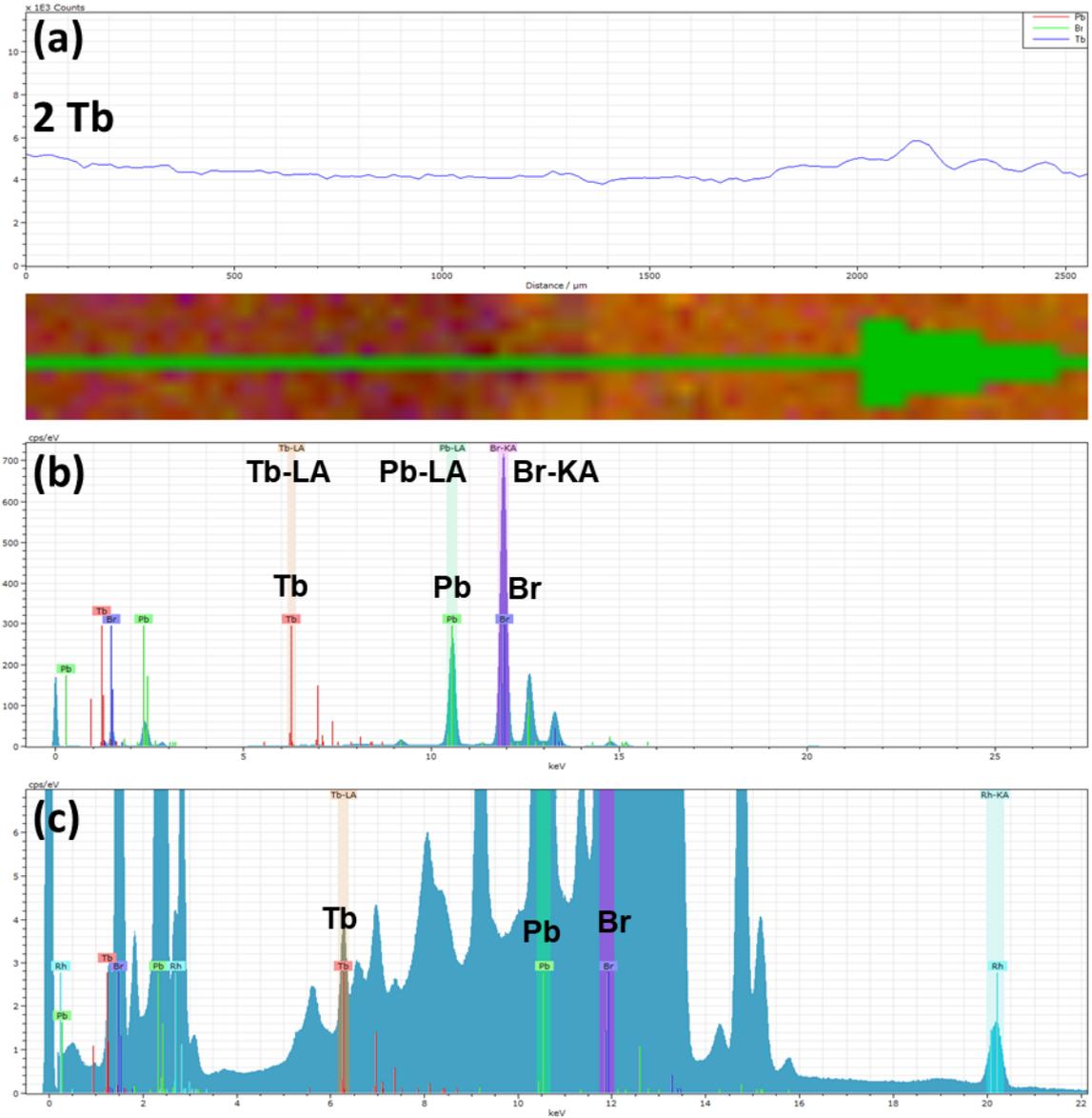


Figure S6. XRF line-scan and spectral analysis of $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3: 2\text{Tb}$. (a) Line-scan profile of $\text{Tb L}\alpha$ intensity across the crystal surface. The green arrow indicates the crystal growth direction and the scanning path (scan length: 2.5 mm). (b) Full-range XRF spectrum showing characteristic peaks of Pb, Br, and Tb. (c) Magnified spectral region highlighting the $\text{Tb L}\alpha$ (6.18 keV) emission lines.

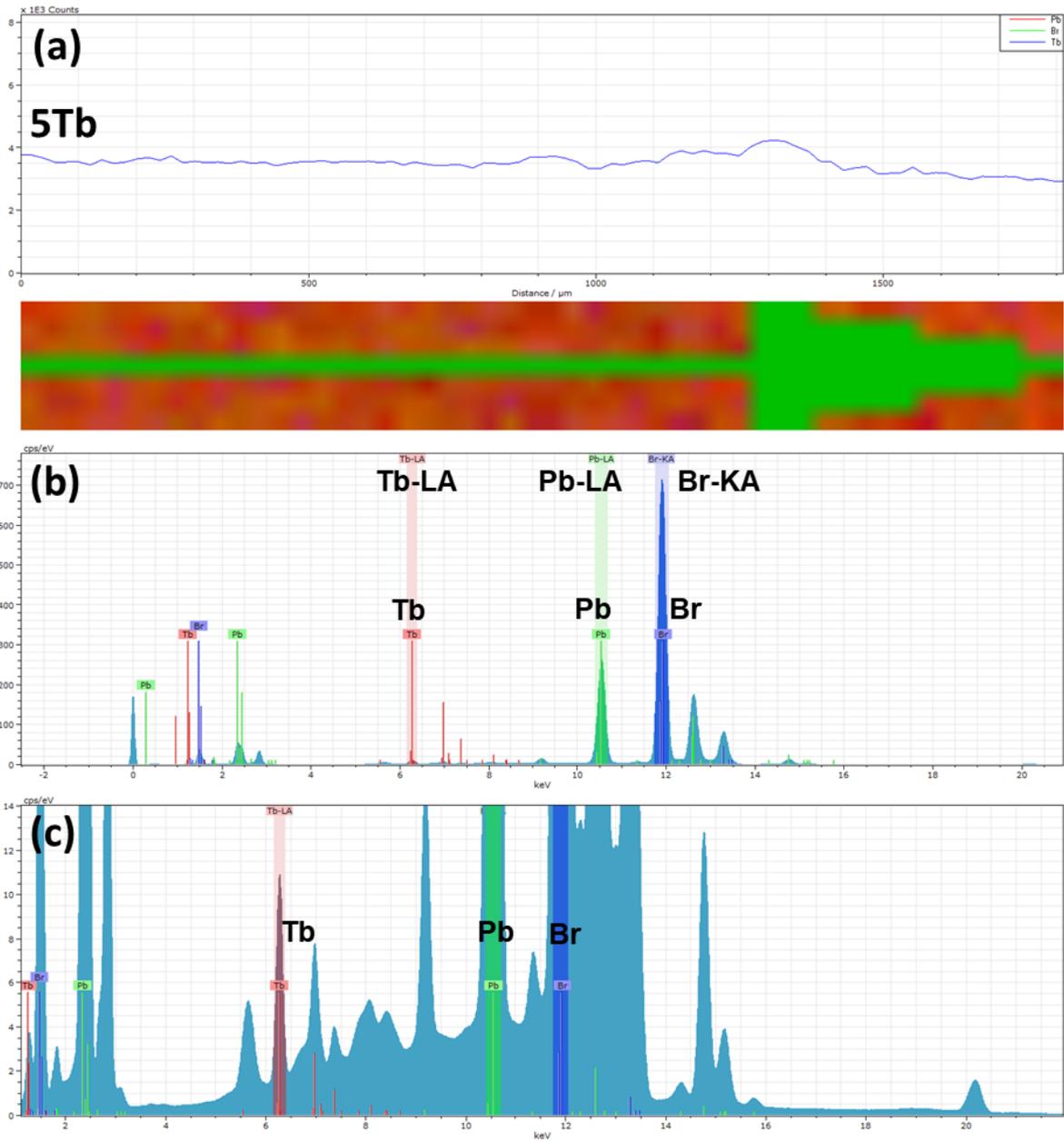


Figure S7. XRF line-scan and spectral analysis of $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3: 5\text{Tb}$. (a) Line-scan profile of $\text{Tb L}\alpha$ intensity across the crystal surface. The green arrow indicates the crystal growth direction and the scanning path (scan length: 1.8 mm). (b) Full-range XRF spectrum showing characteristic peaks of Pb, Br, and Tb. (c) Magnified spectral region highlighting the $\text{Tb L}\alpha$ (6.18 keV) emission lines.

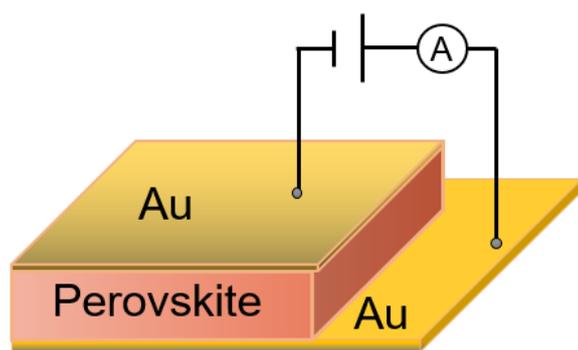


Figure S8. Schematic diagram of the device for SCLC measurement.

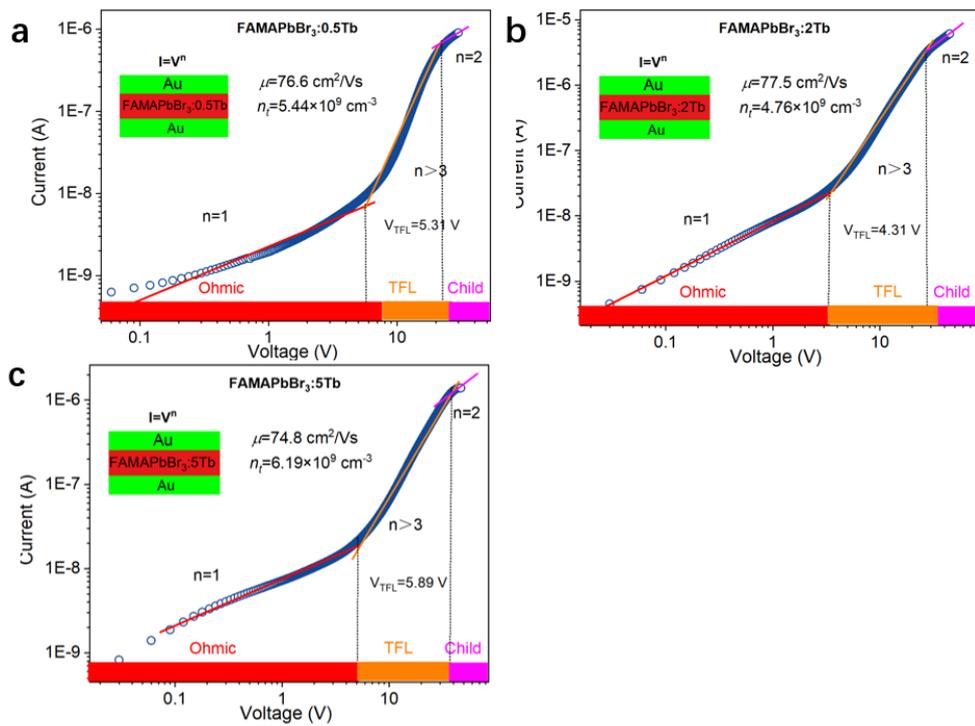


Figure S9. Measurement of Au/Perovskite/Au using the SCLC method; (a) MA_{0.89}FA_{0.11}PbBr₃-0.5Tb single crystal; (b) MA_{0.89}FA_{0.11}PbBr₃-2Tb single crystal; (c) MA_{0.89}FA_{0.11}PbBr₃-5Tb single crystal.

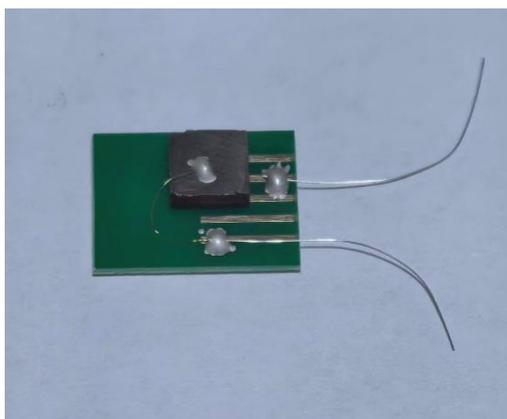


Figure S10. Photograph of the MA_{0.89}FA_{0.11}PbBr₃: Tb single crystal detector device.

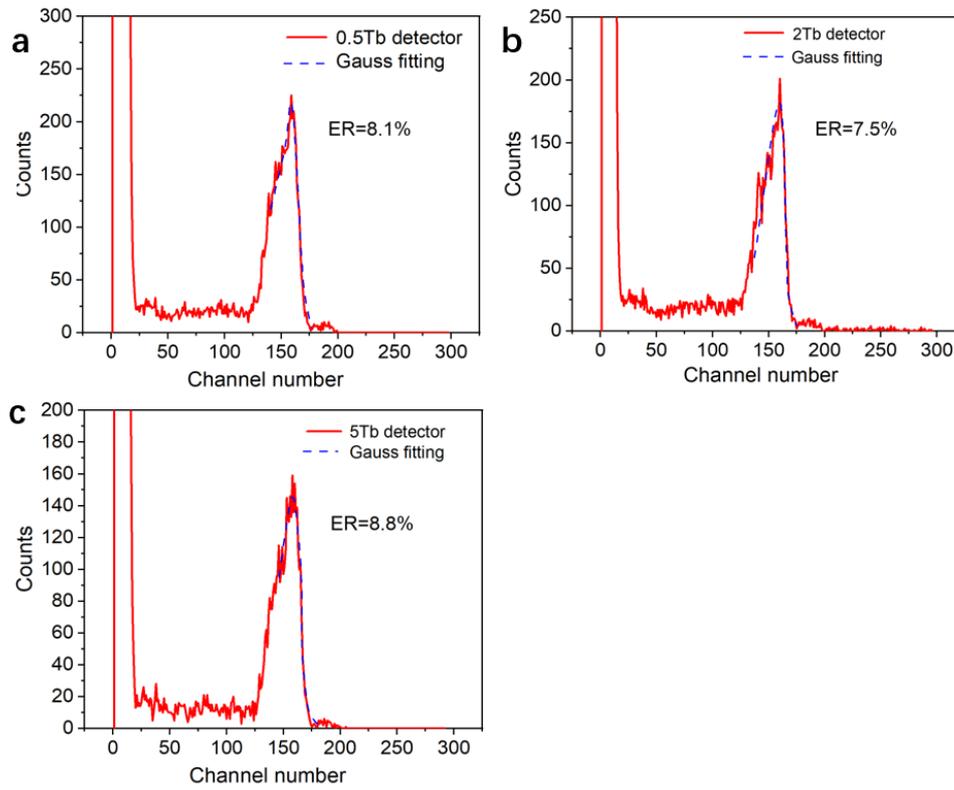


Figure S11. The Energy resolution (ER) of $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3$: Tb single crystals to ^{241}Am γ -rays. (59.5keV). (a) $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3$ -0.5Tb; (b) $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3$ -2Tb; (c) $\text{MA}_{0.89}\text{FA}_{0.11}\text{PbBr}_3$ -5Tb.

Table S1. Cell parameters resolved from powder XRD patterns of MA_{0.89}FA_{0.11}PbBr₃: Tb single crystals.

| Samples | Tb/Pb Doping Concentration (at%) | Cell parameters /Å |
|--|-------------------------------------|--------------------|
| MA _{0.89} FA _{0.11} PbBr ₃ | 0 | 5.931 |
| MA _{0.89} FA _{0.11} PbBr ₃ -0.5Tb | 0.13% | 5.927 |
| MA _{0.89} FA _{0.11} PbBr ₃ -1Tb | 0.35% | 5.923 |
| MA _{0.89} FA _{0.11} PbBr ₃ -2Tb | 0.52% | 5.914 |
| MA _{0.89} FA _{0.11} PbBr ₃ -5Tb | 0.67% | 5.899 |

Table S2. ICP-AES test results of MA_{0.89}FA_{0.11}PbBr₃:Tb single crystals.

| Samples | ICP(Tb/Pb) |
|--|------------|
| MA _{0.89} FA _{0.11} PbBr ₃ | / |
| MA _{0.89} FA _{0.11} PbBr ₃ -0.5Tb | 0.13% |
| MA _{0.89} FA _{0.11} PbBr ₃ -1Tb | 0.35% |
| MA _{0.89} FA _{0.11} PbBr ₃ -2Tb | 0.52% |
| MA _{0.89} FA _{0.11} PbBr ₃ -5Tb | 0.67% |

Table S3. Bandgap determination of MA_{0.89}FA_{0.11}PbBr₃ single crystals.

| Sample | Bandgap (eV) |
|--|--------------|
| MA _{0.89} FA _{0.11} PbBr ₃ | 2.183 |
| MA _{0.89} FA _{0.11} PbBr ₃ -0.5Tb | 2.162 |
| MA _{0.89} FA _{0.11} PbBr ₃ -1Tb | 2.154 |
| MA _{0.89} FA _{0.11} PbBr ₃ -2Tb | 2.146 |
| MA _{0.89} FA _{0.11} PbBr ₃ -5Tb | 2.138 |

Table S4. The electrical performance parameters of MA_{0.89}FA_{0.11}PbBr₃ single crystals.

| Sample | V _{TFL} | μ (cm ² V ⁻¹ s ⁻¹) | n_{trap} (cm ³) | Technique |
|--|------------------|--|-------------------------------|-----------|
| MA _{0.89} FA _{0.11} PbBr ₃ | 9.8 | 55.4 | 1.0×10 ¹⁰ | SCLC |
| MA _{0.89} FA _{0.11} PbBr ₃ -0.5Tb | 5.3 | 76.6 | 5.4×10 ⁹ | SCLC |
| MA _{0.89} FA _{0.11} PbBr ₃ -1Tb | 3.8 | 153.6 | 1.9×10 ⁹ | SCLC |
| MA _{0.89} FA _{0.11} PbBr ₃ -2Tb | 4.3 | 77.5 | 4.8×10 ⁹ | SCLC |
| MA _{0.89} FA _{0.11} PbBr ₃ -5Tb | 5.9 | 74.8 | 6.2×10 ⁹ | SCLC |