A TEST BENCH FOR LOW-COST POSITRON EMISSION TOMOGRAPHY

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OPPENHEIMER MEMORIAL TRUST

70th ANNUAL CONFERENCE OF THE SOUTH AFRICAN INSTITUTE OF PHYSICS

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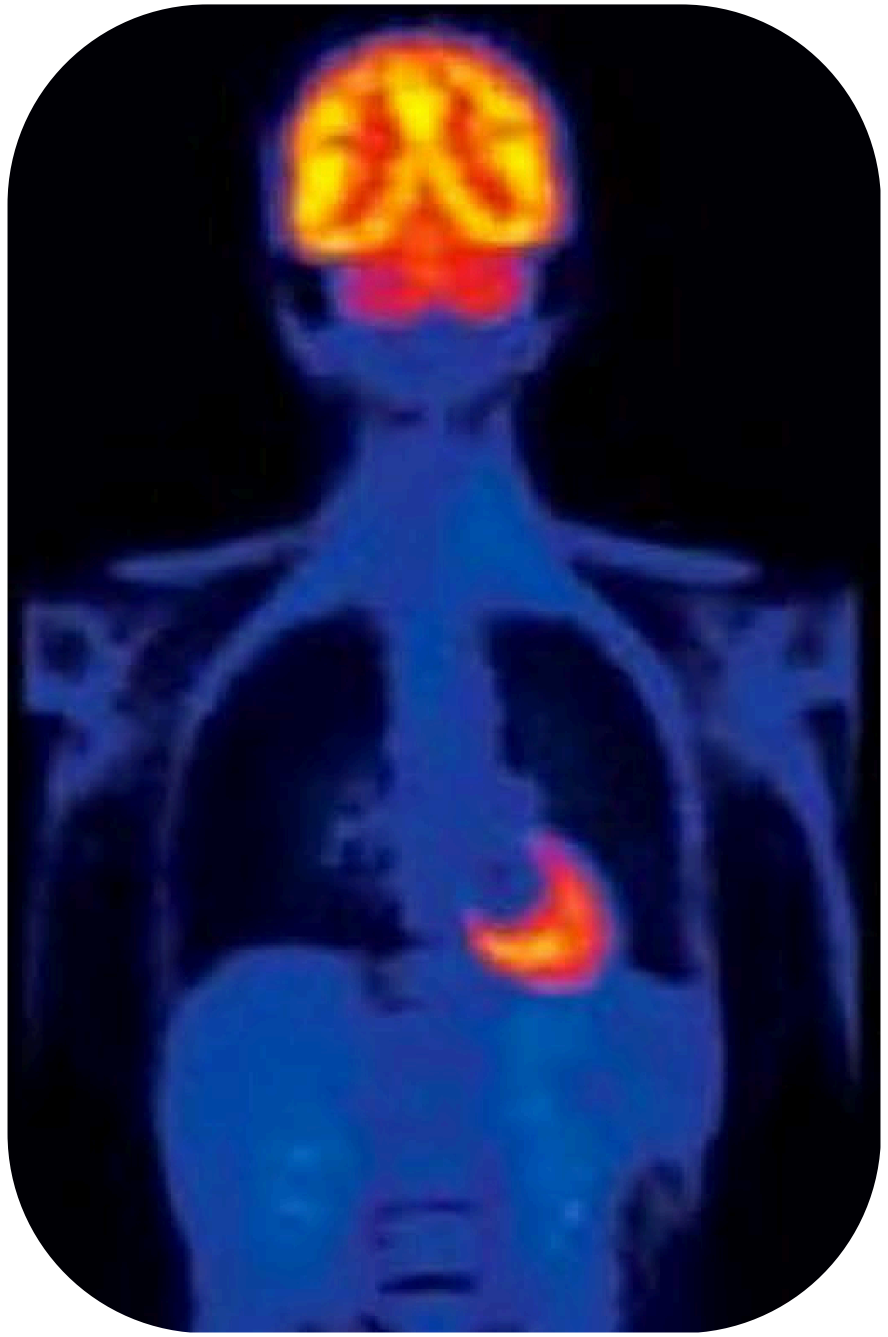
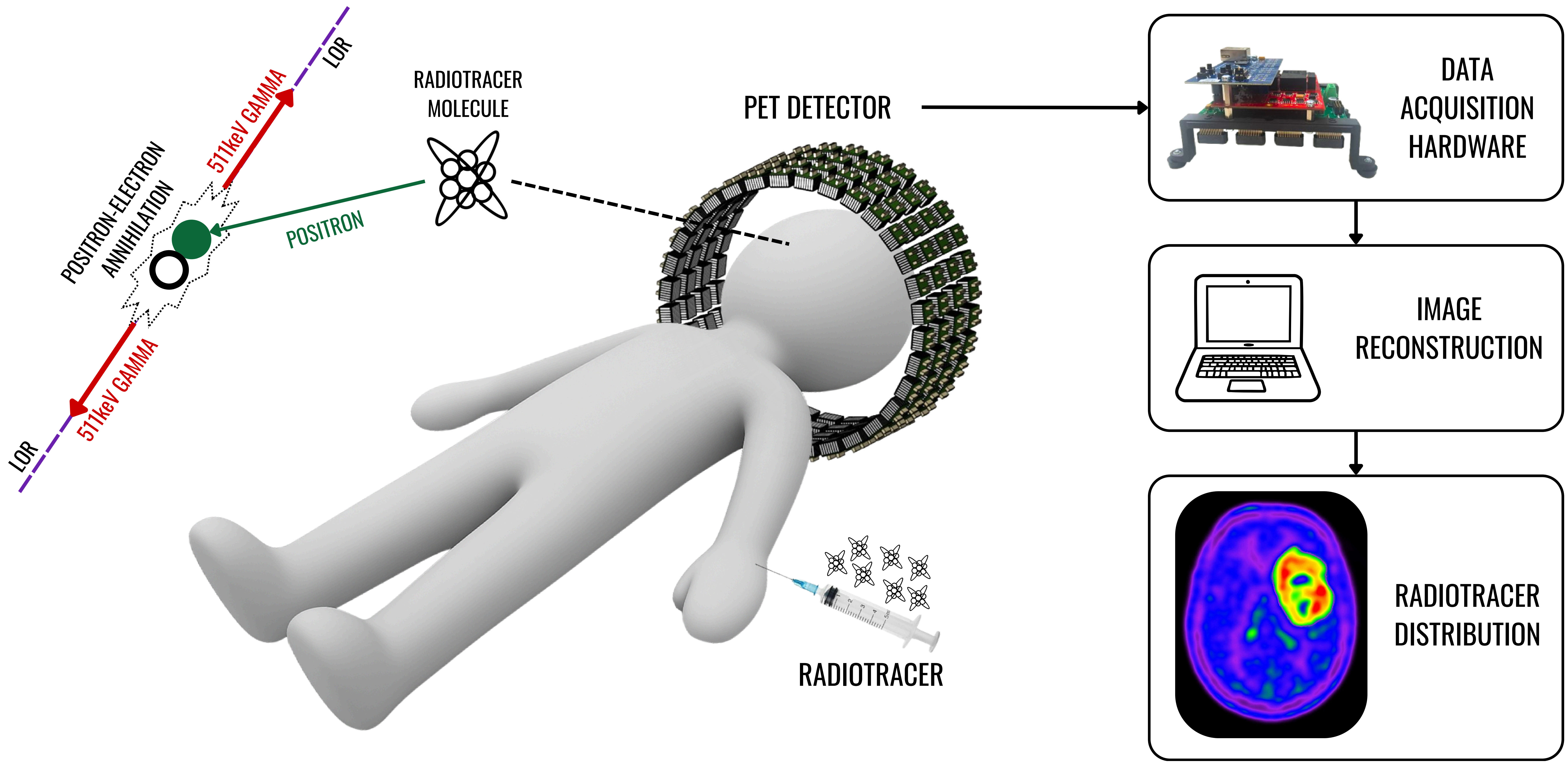
SPES BONA

WE CAN TAKE PICTURES OF CANCER

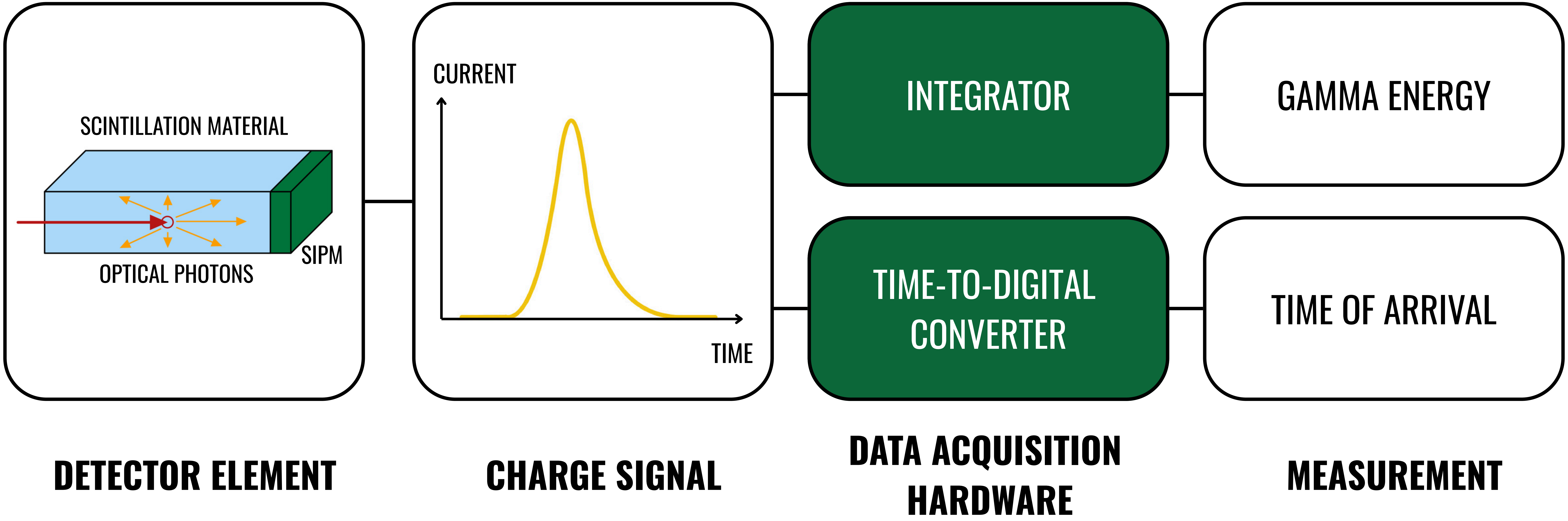


BUT ITS VERY EXPENSIVE

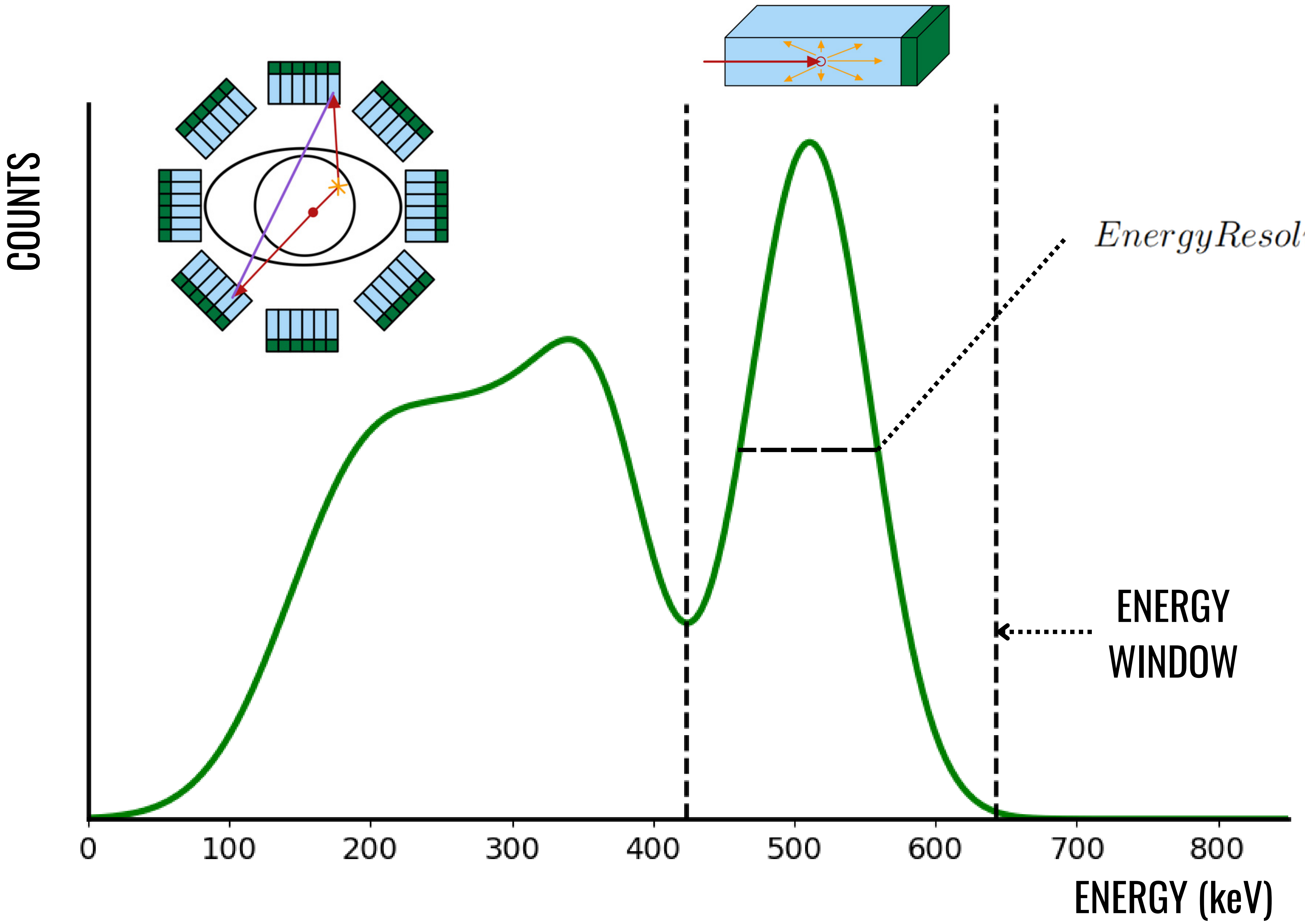
HOW DOES IT WORK?



DETECTING AND MEASURING GAMMAS

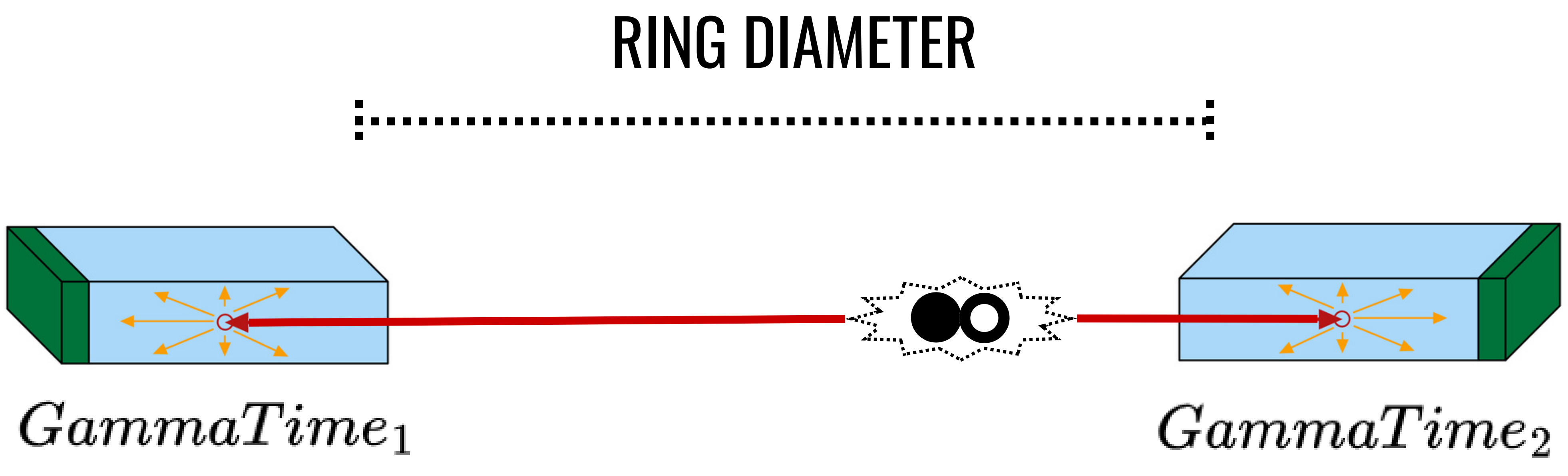


REJECTING SCATTERED GAMMAS



$$EnergyResolution(\%) = \frac{FWHM_{\mathrm{Peak}}}{E_{\mathrm{Peak}}} \cdot 100$$

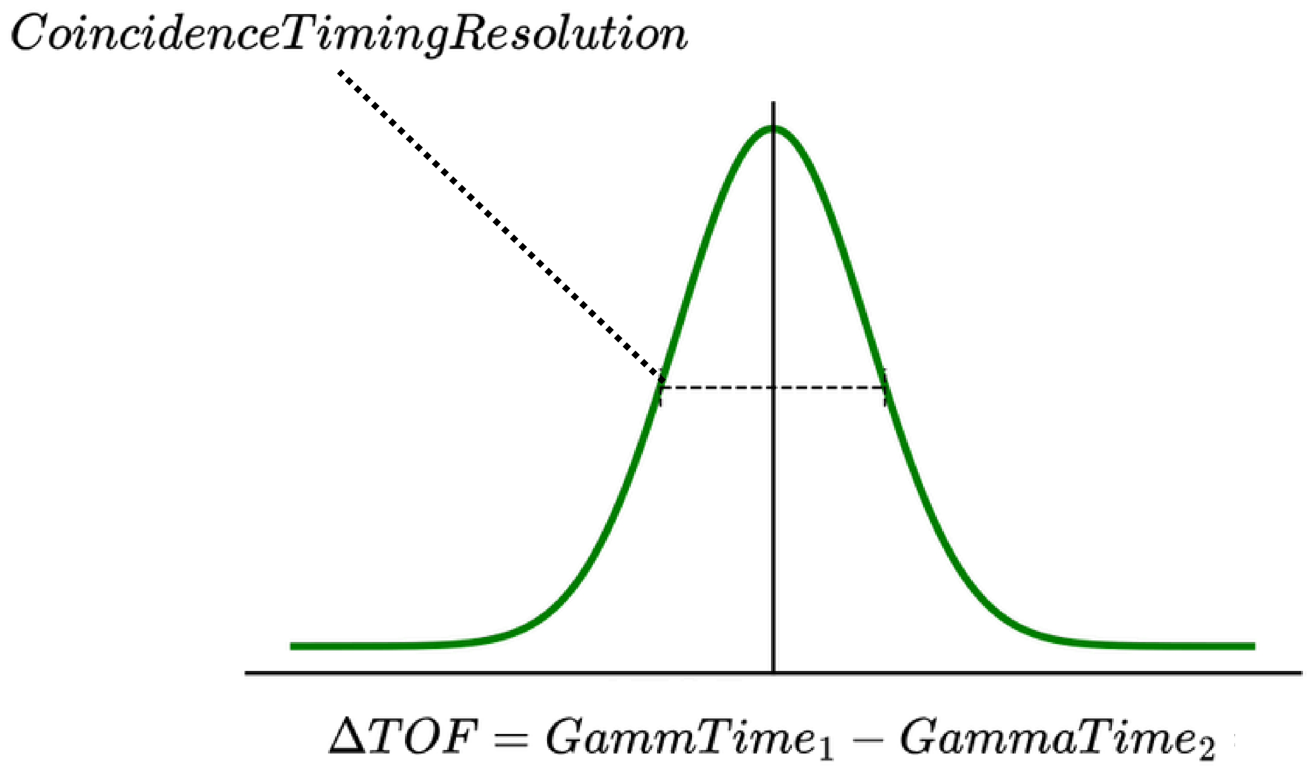
COINCIDENCE MATCHING



$$\Delta TOF = GammaTime_1 - GammaTime_2$$

$$\Delta TOF_{Max} = \frac{RingDiameter}{SpeedOfLight}$$

COINCIDENCE TIMING SPECTRUM

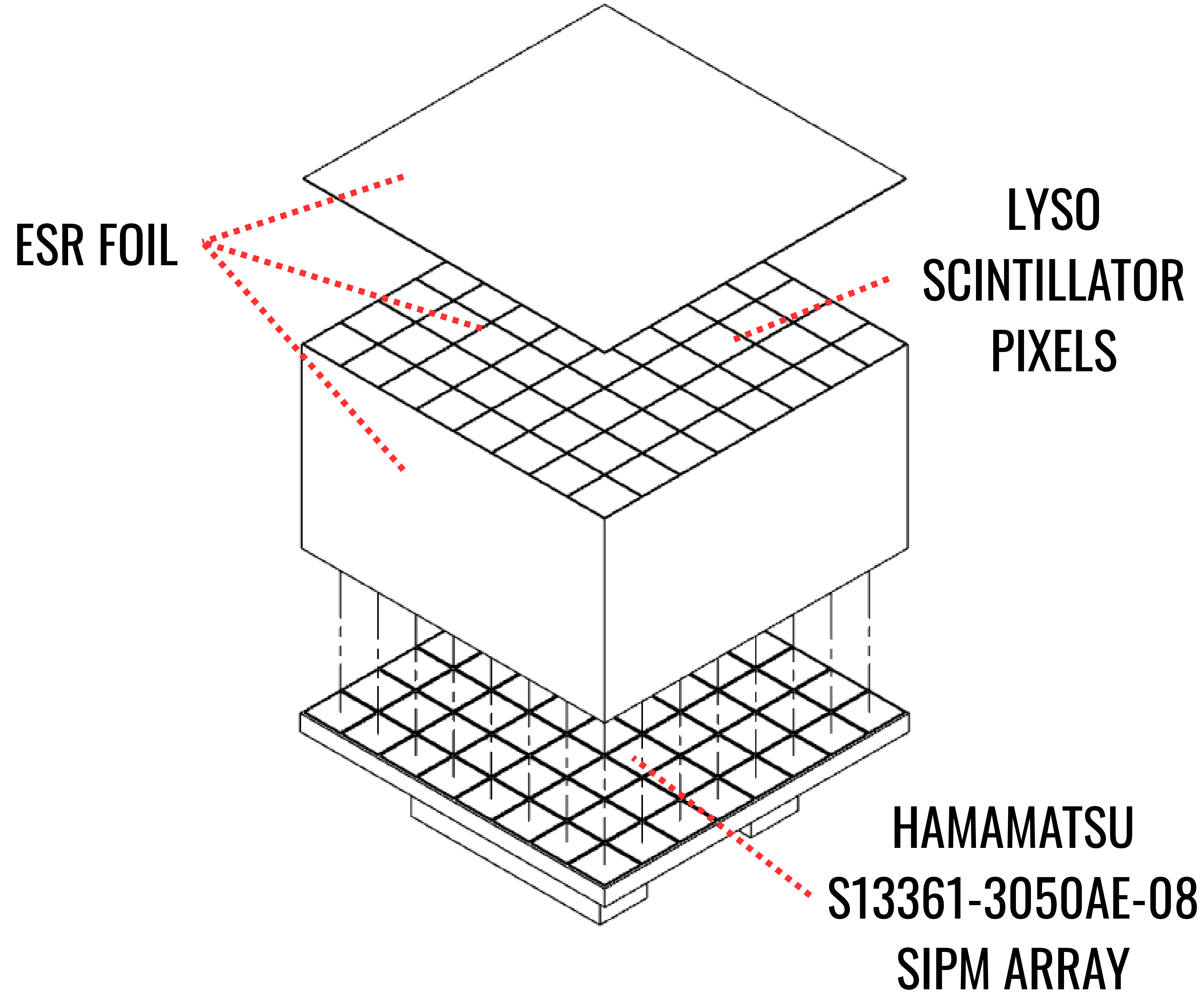


$$CoincidenceTimingWindow = \Delta TOF_{Max} + k \cdot CTR$$

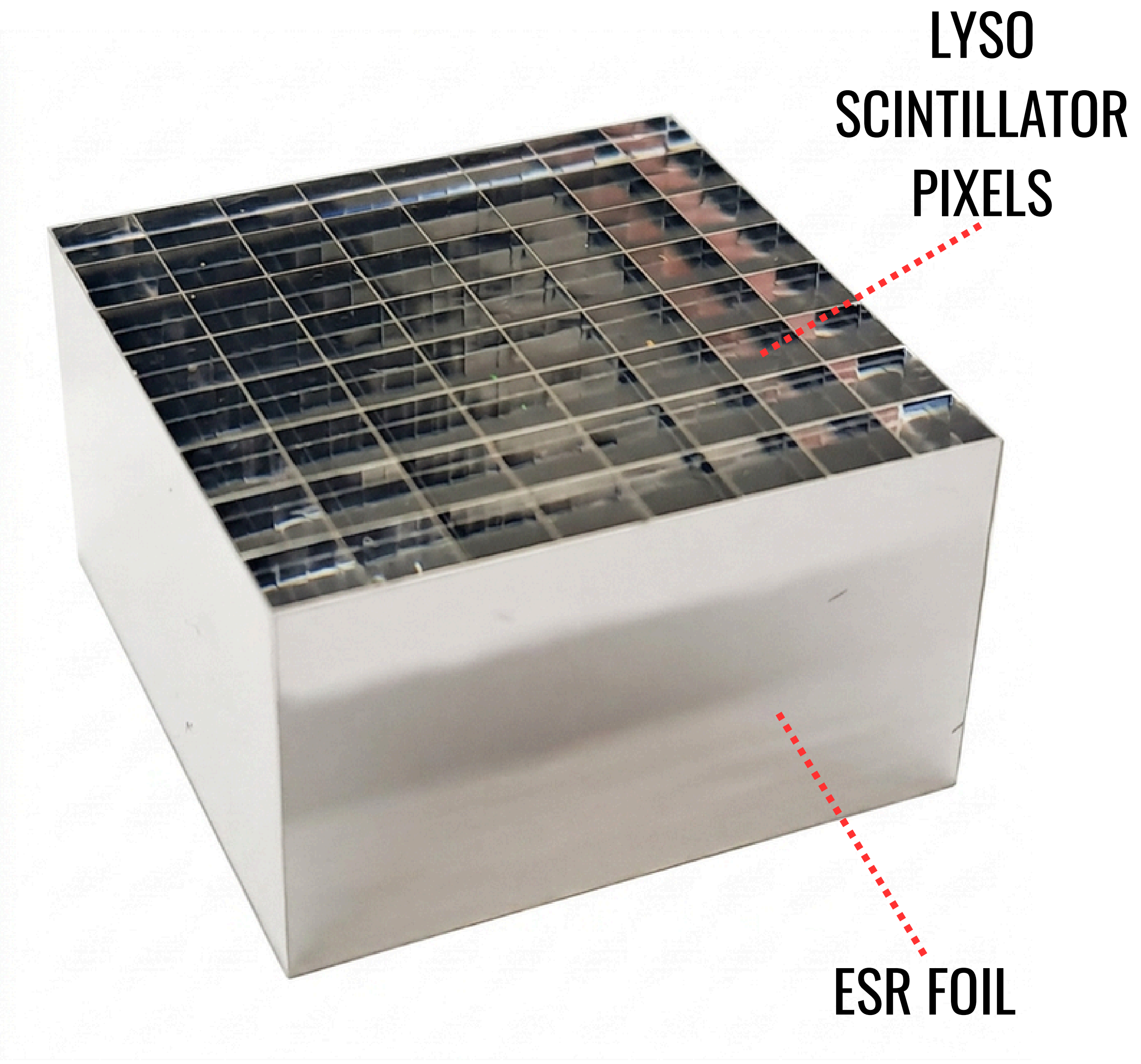
THE TEST BENCH

DETECTOR MODULES

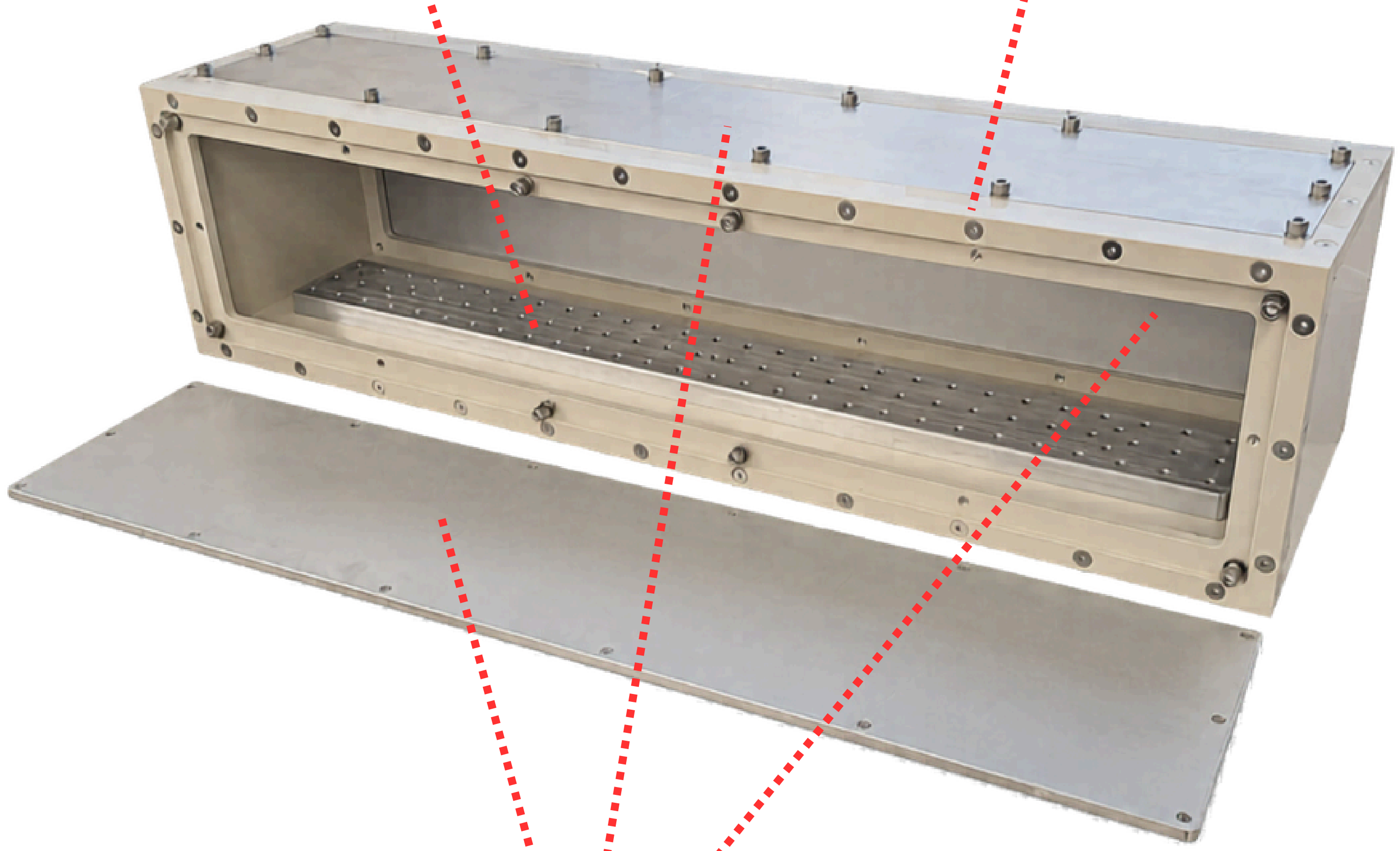
CAD DRAWING

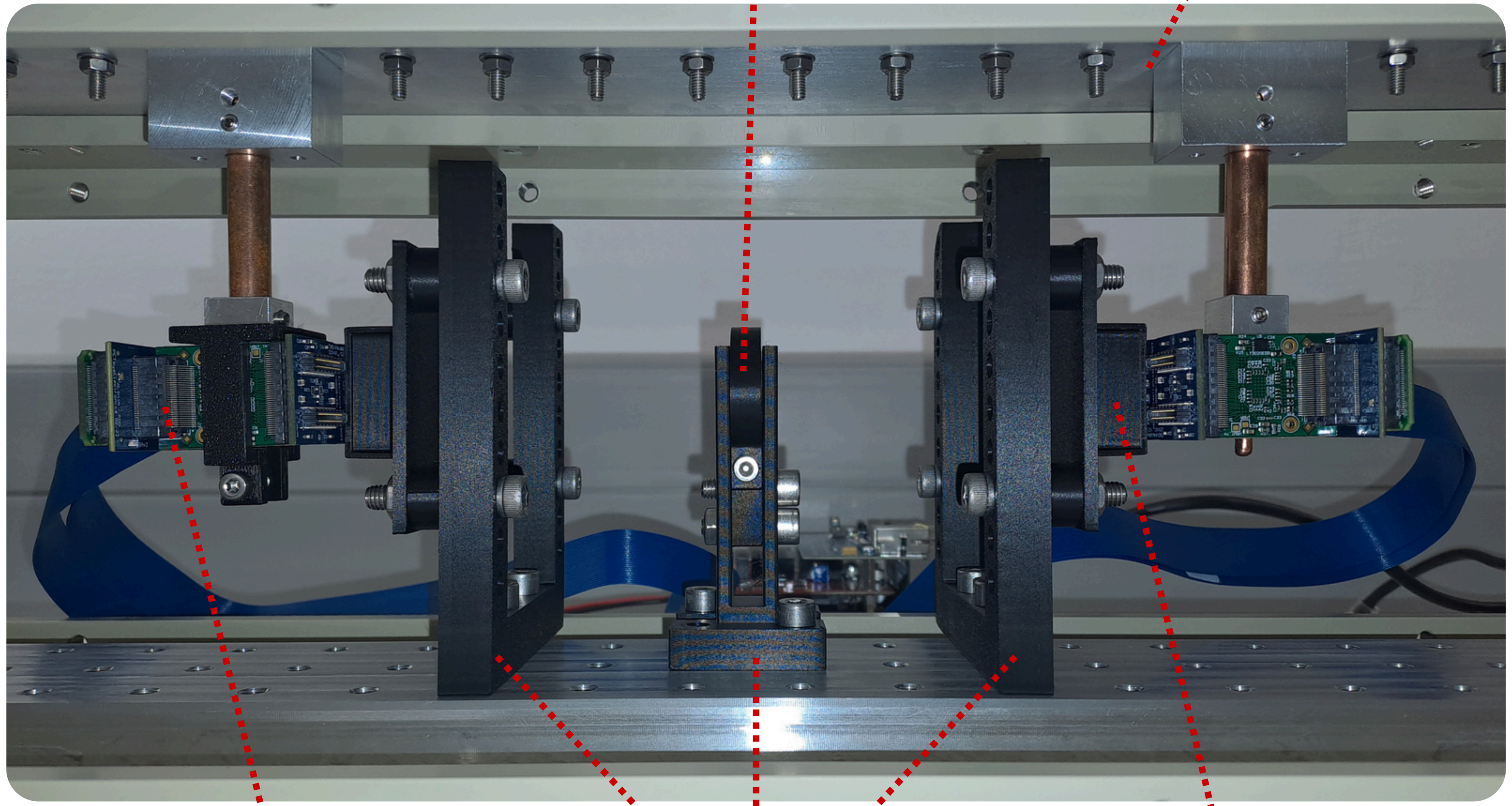


PROCURED MODULE



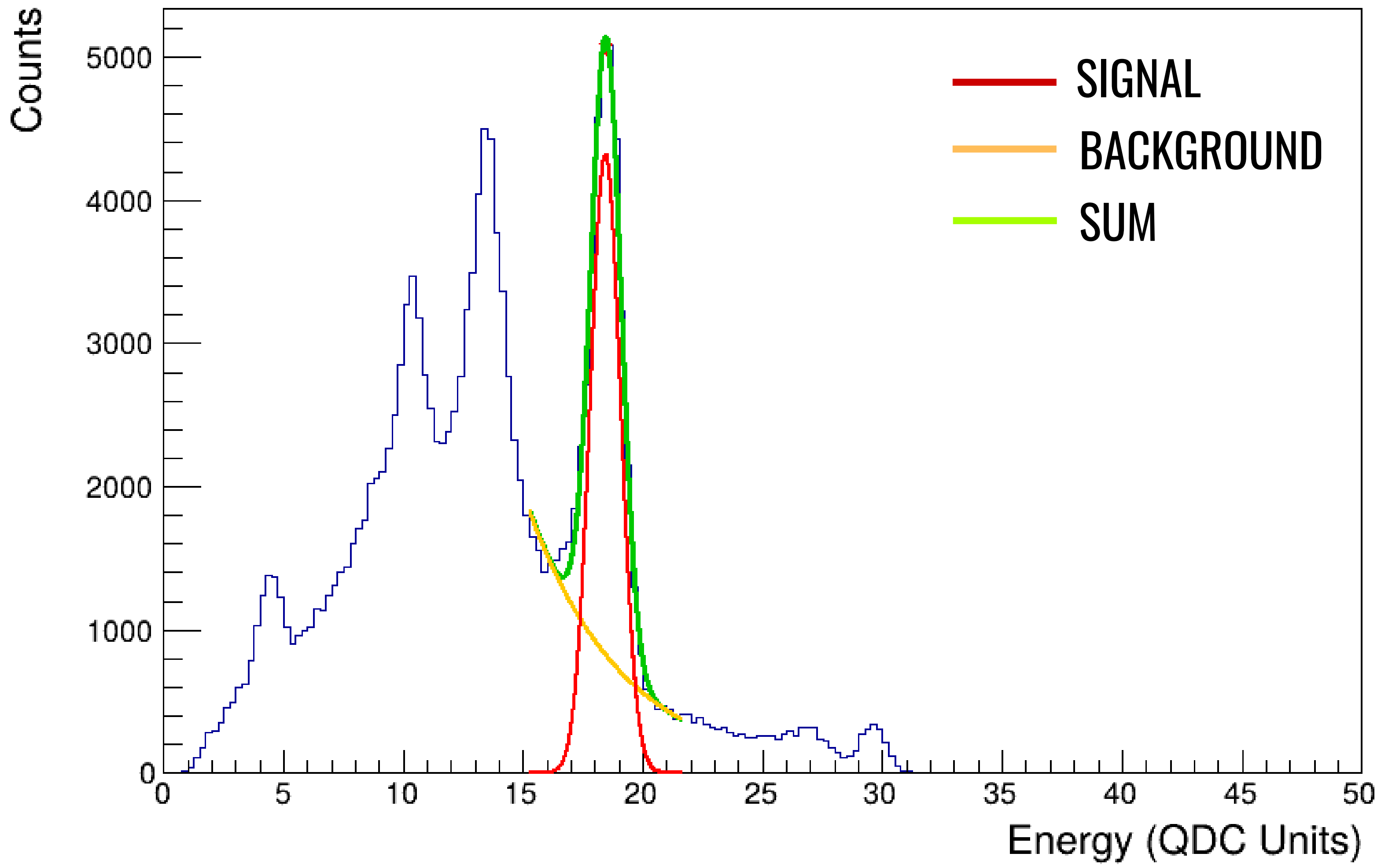
THE TEST BENCH



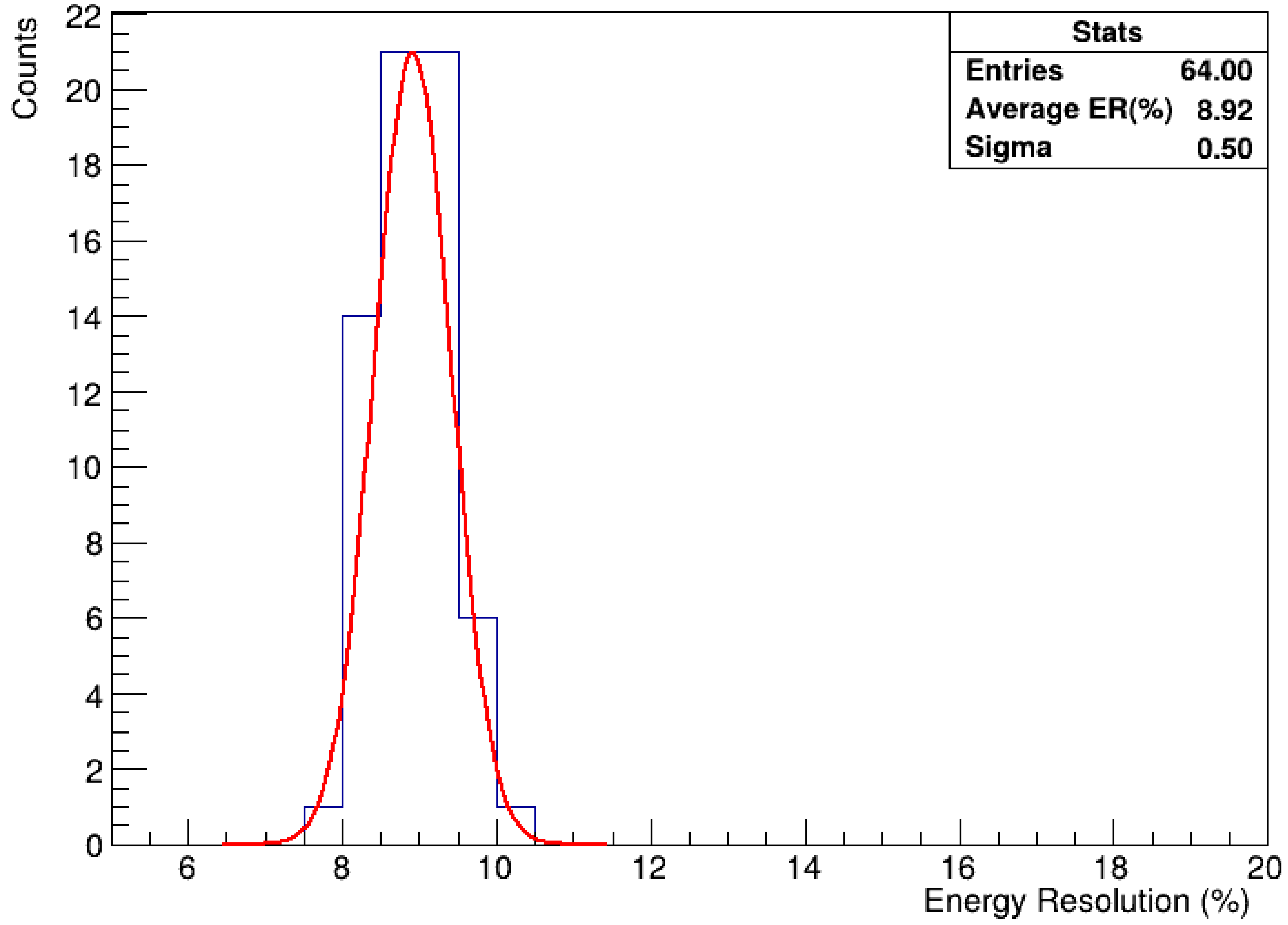


ENERGY RESOLUTION

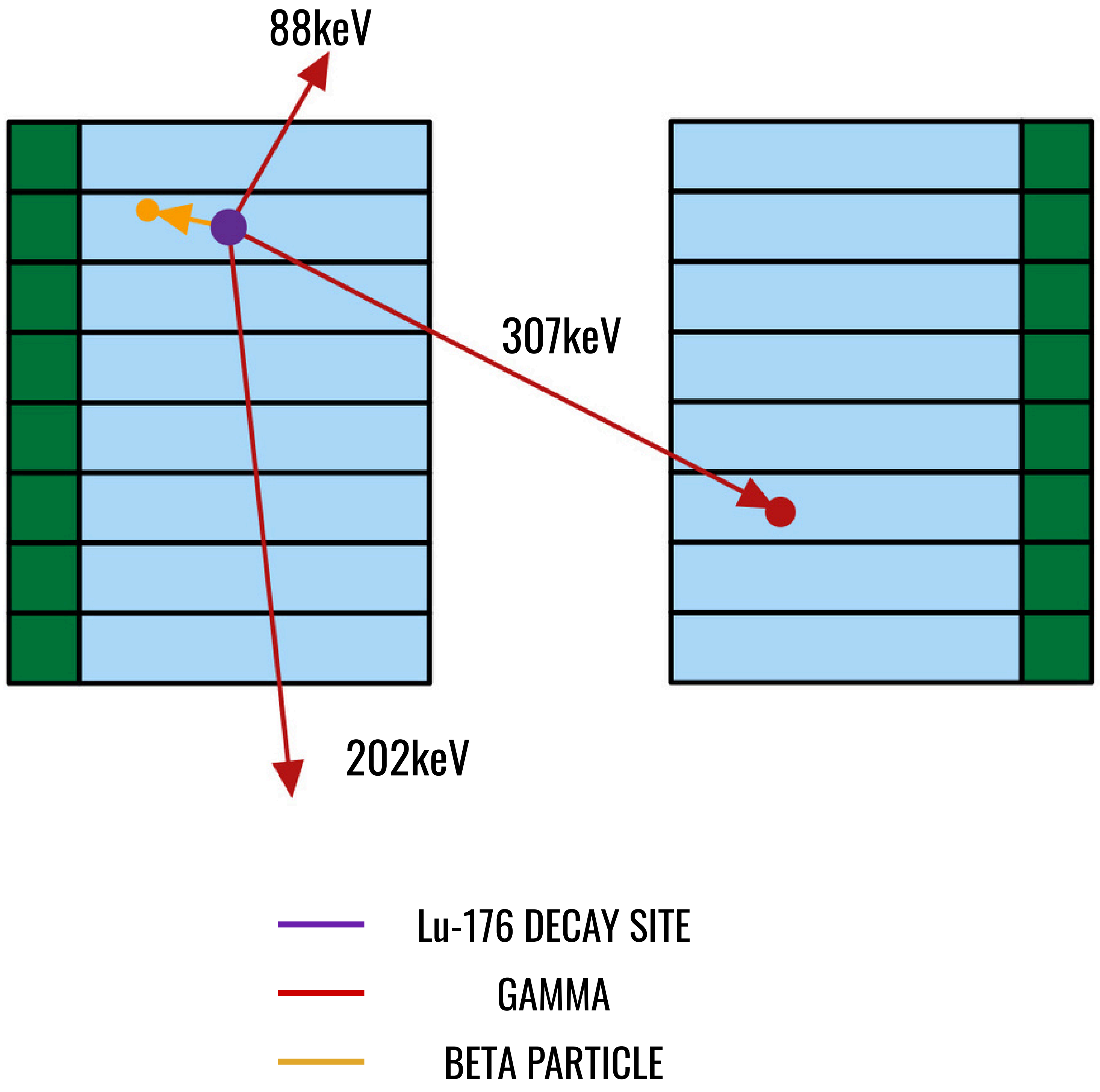
PIXEL ENERGY SPECTRUM



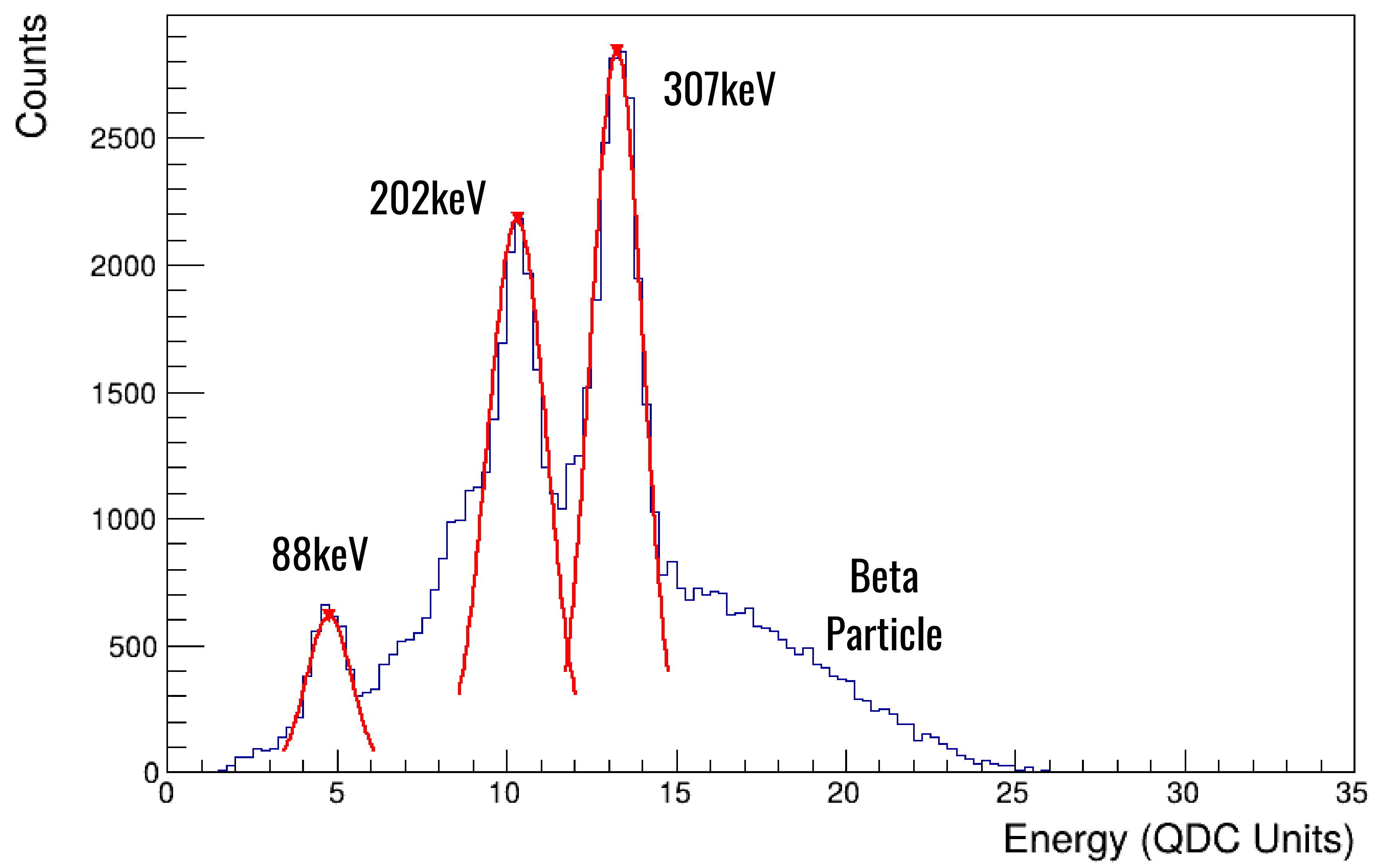
DISTRIBUTION OF ALL PIXEL ENERGY RESOLUTIONS



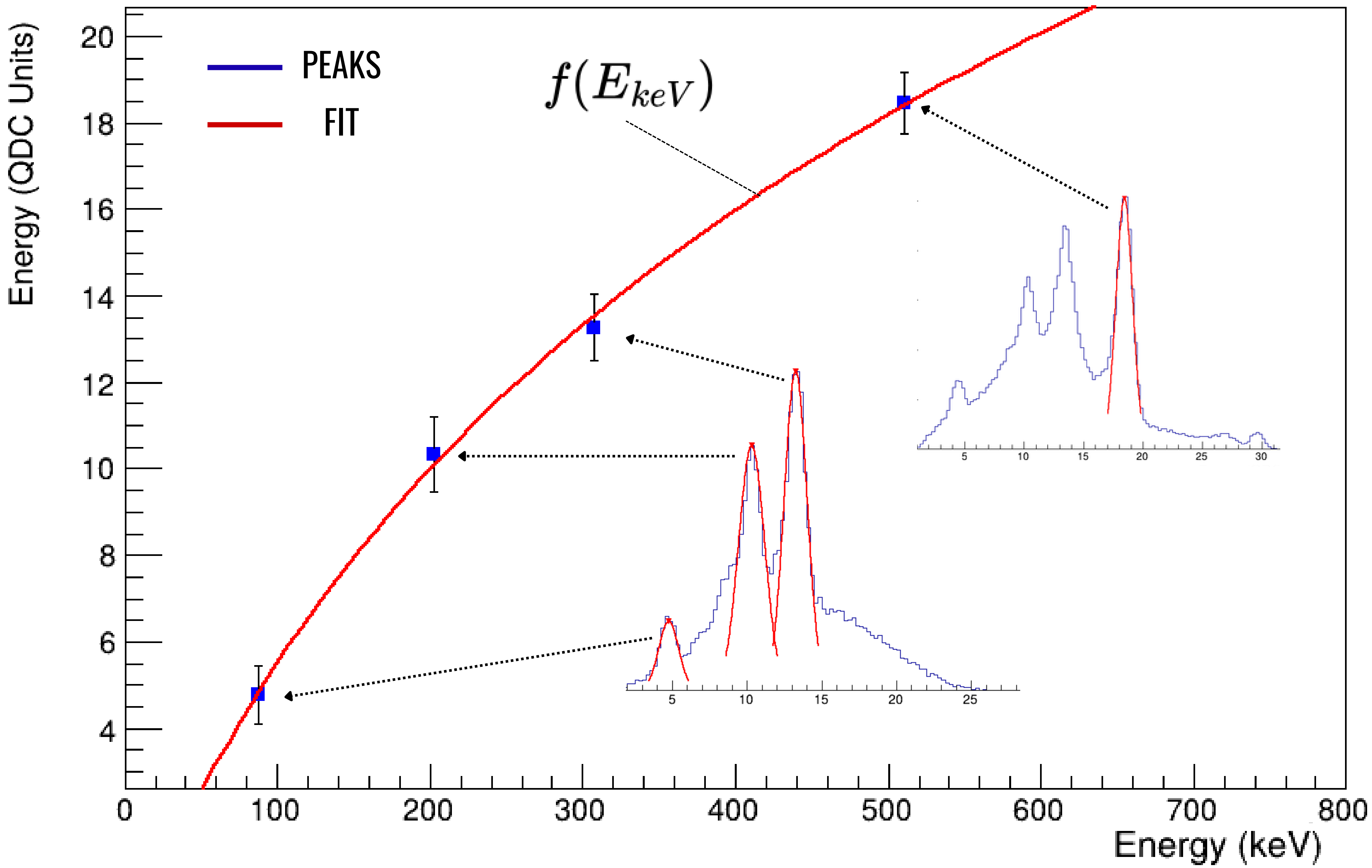
OUR SCINTILLATORS ARE RADIOACTIVE !?!?



PIXEL ENERGY SPECTRUM WITHOUT NA22 SOURCE



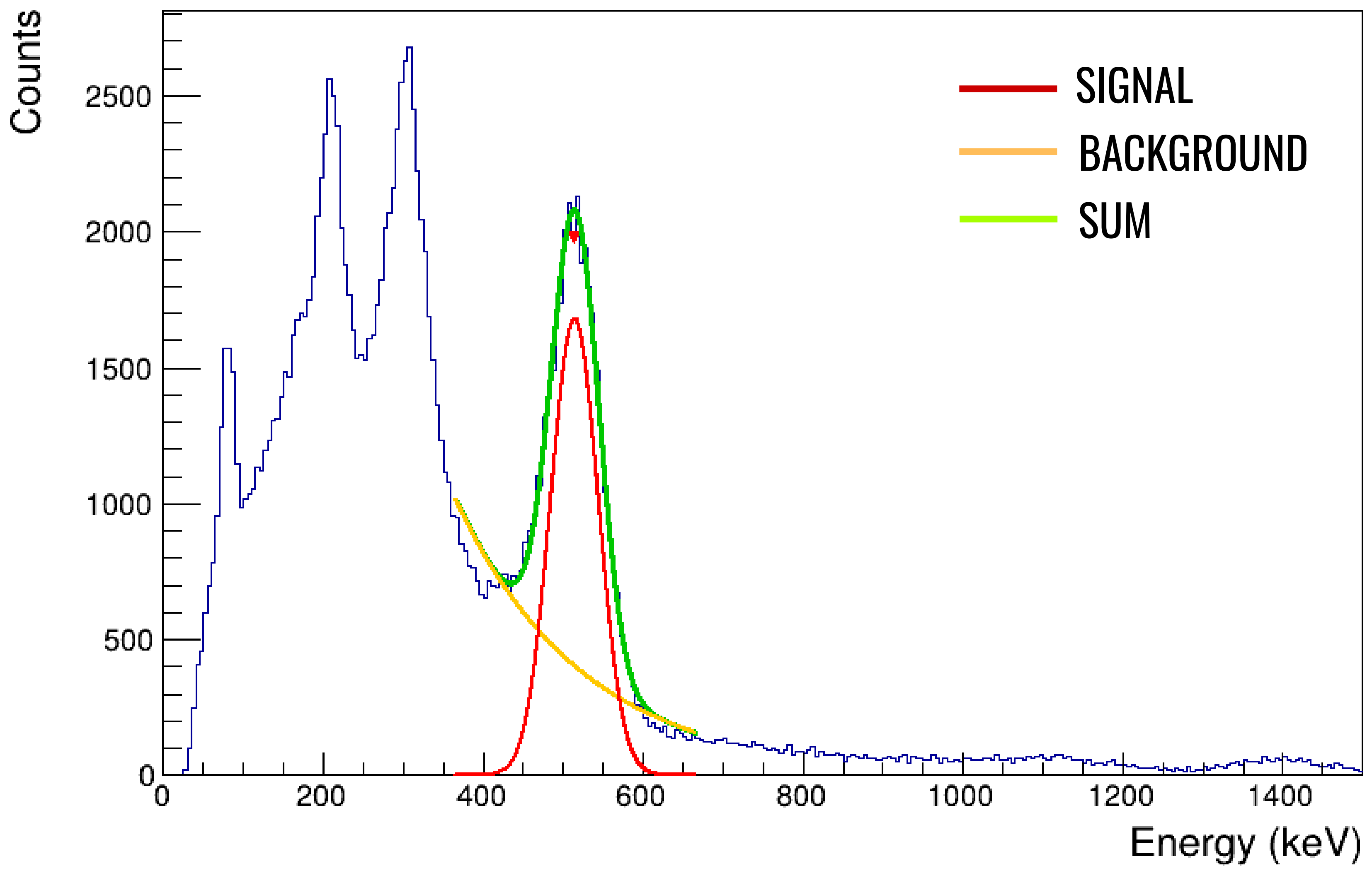
RELATIONSHIP BETWEEN QDC UNITS AND keV?



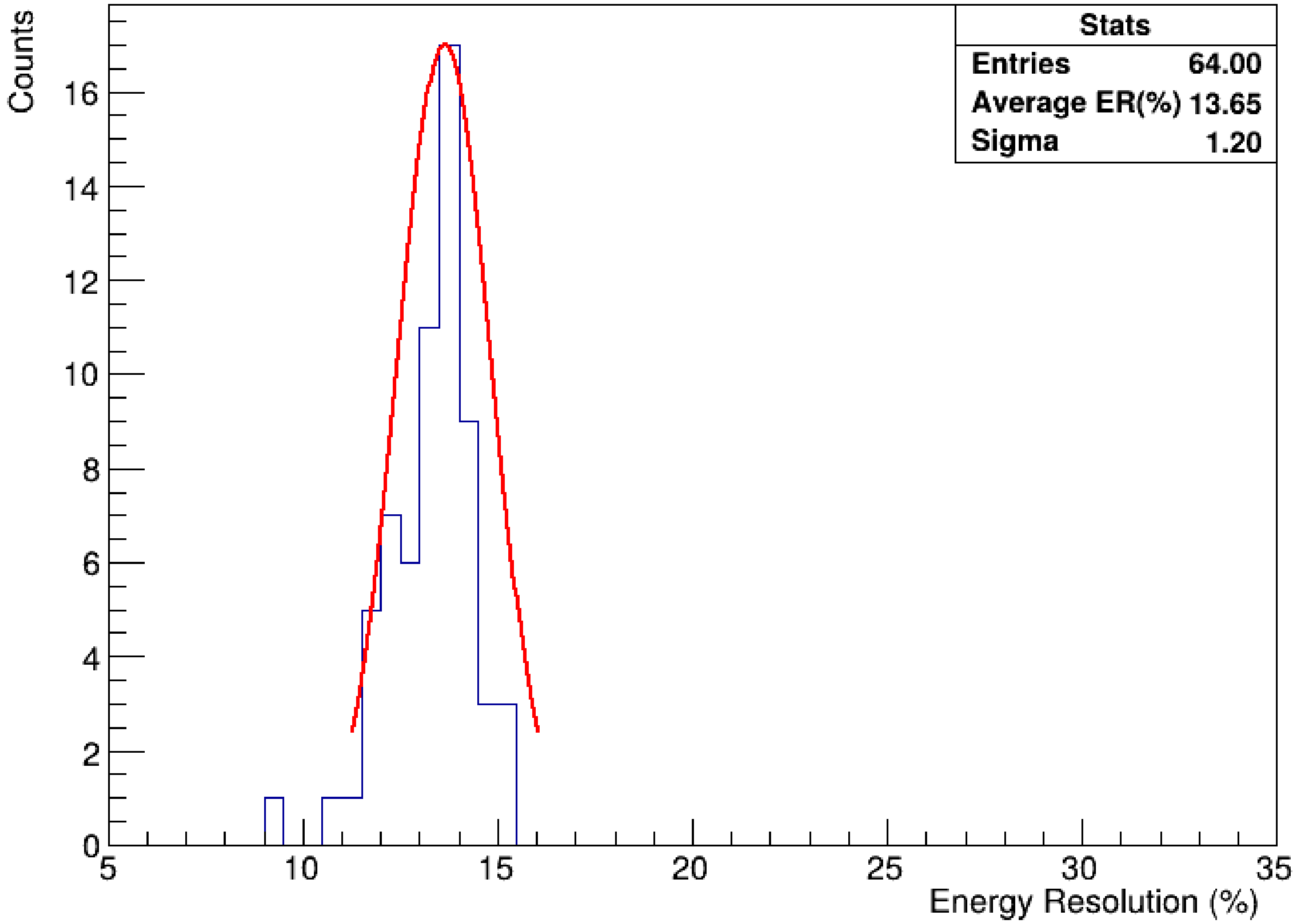
$$E_{keV} = f(E_{QDC}) = P_0 + \frac{P_1}{P_2} \cdot (1 - exp^{-P_2 \cdot E_{QDC}}) \quad \Longleftrightarrow \quad E_{QDC} = f(E_{keV}) = -\frac{P_1}{P_2} \cdot log(1 - \frac{P_2}{P_1} \cdot (E_{keV} - P_0)$$

ENERGY RESOLUTION AFTER CALIBRATION

SINGLE PIXEL ENERGY SPECTRUM

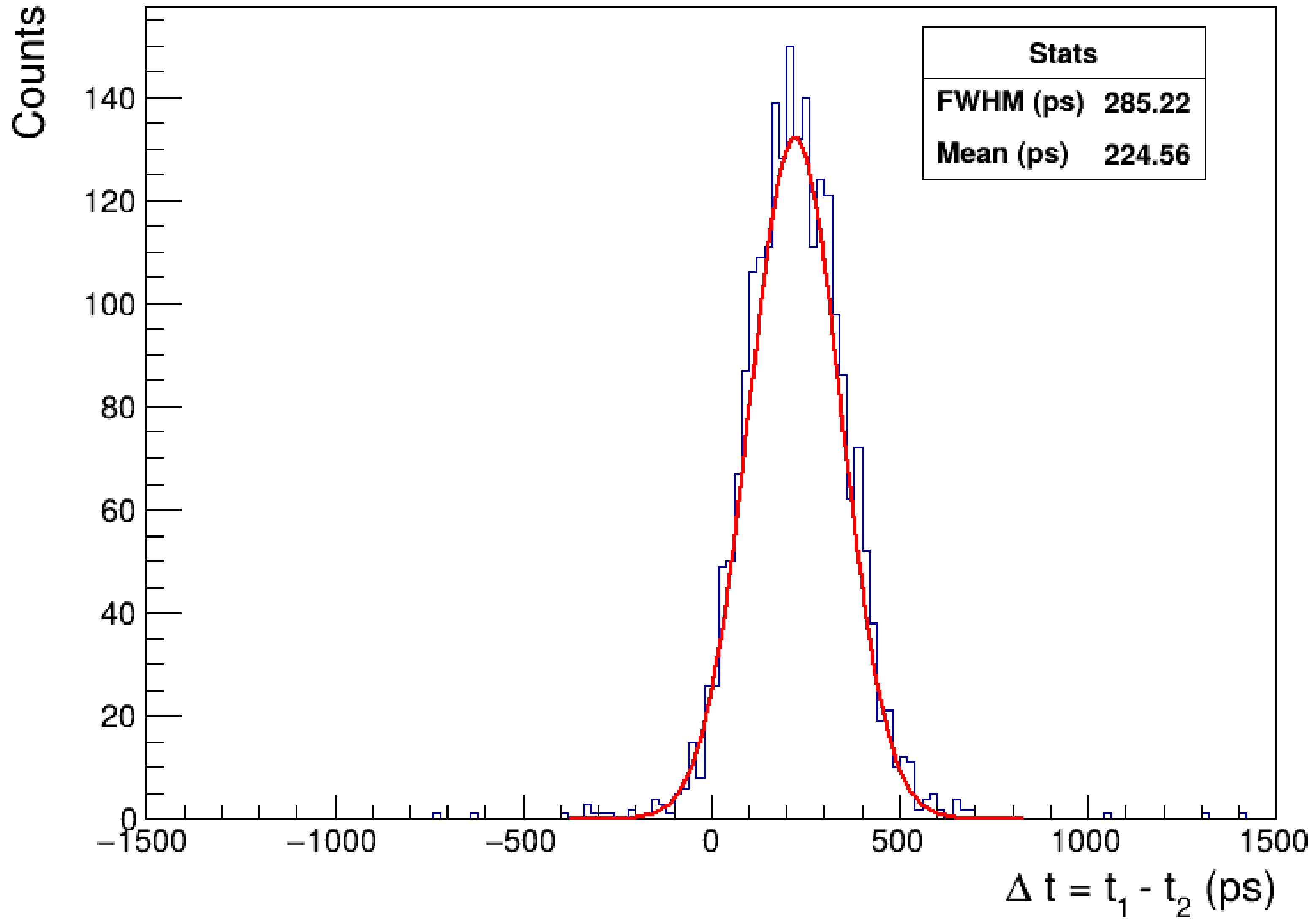


DISTRIBUTION OF ALL PIXEL ENERGY RESOLUTIONS

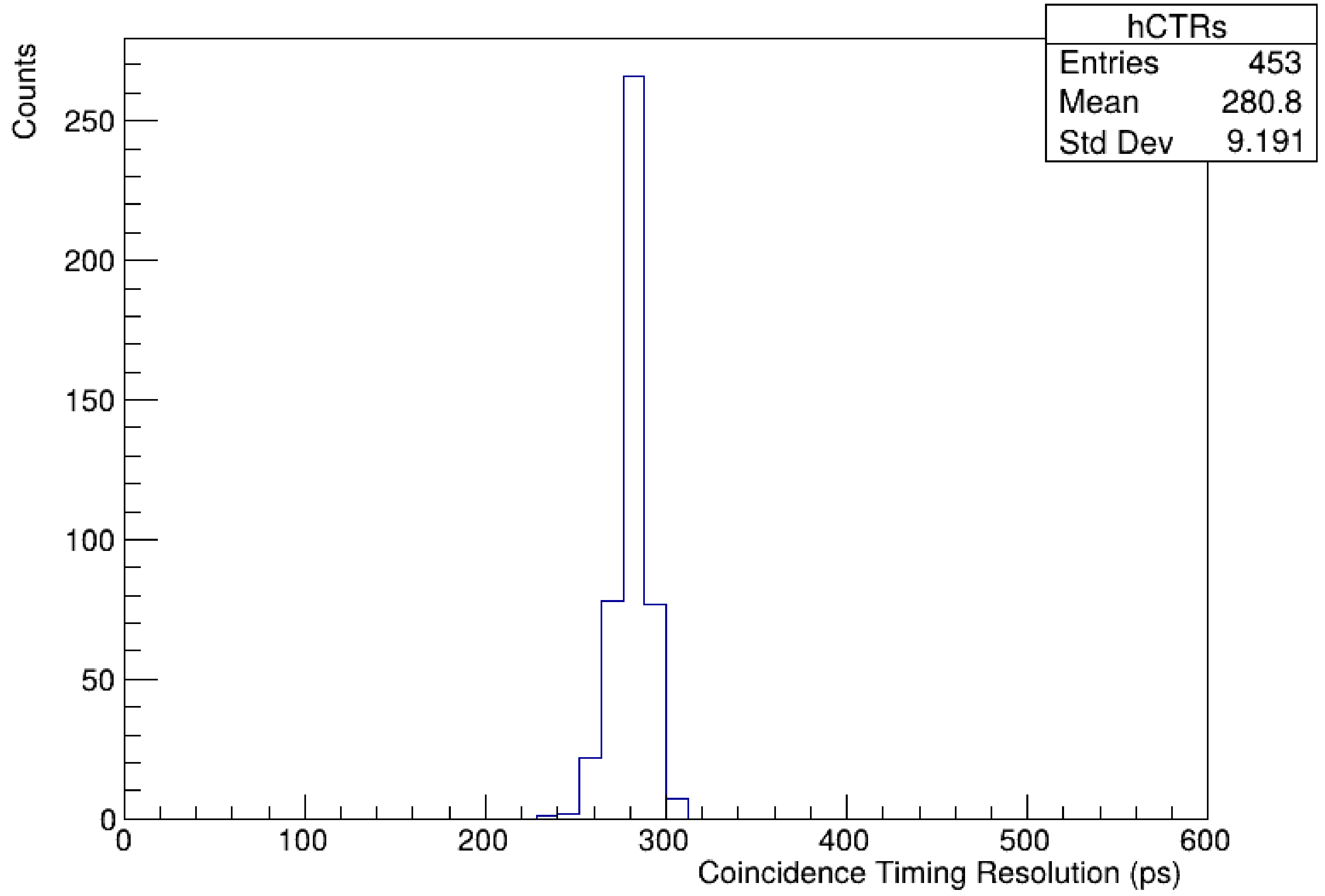


COINCIDENCE TIMING RESOLUTION

SINGLE PIXEL PAIR COINCIDENCE TIMING SPECTRUM

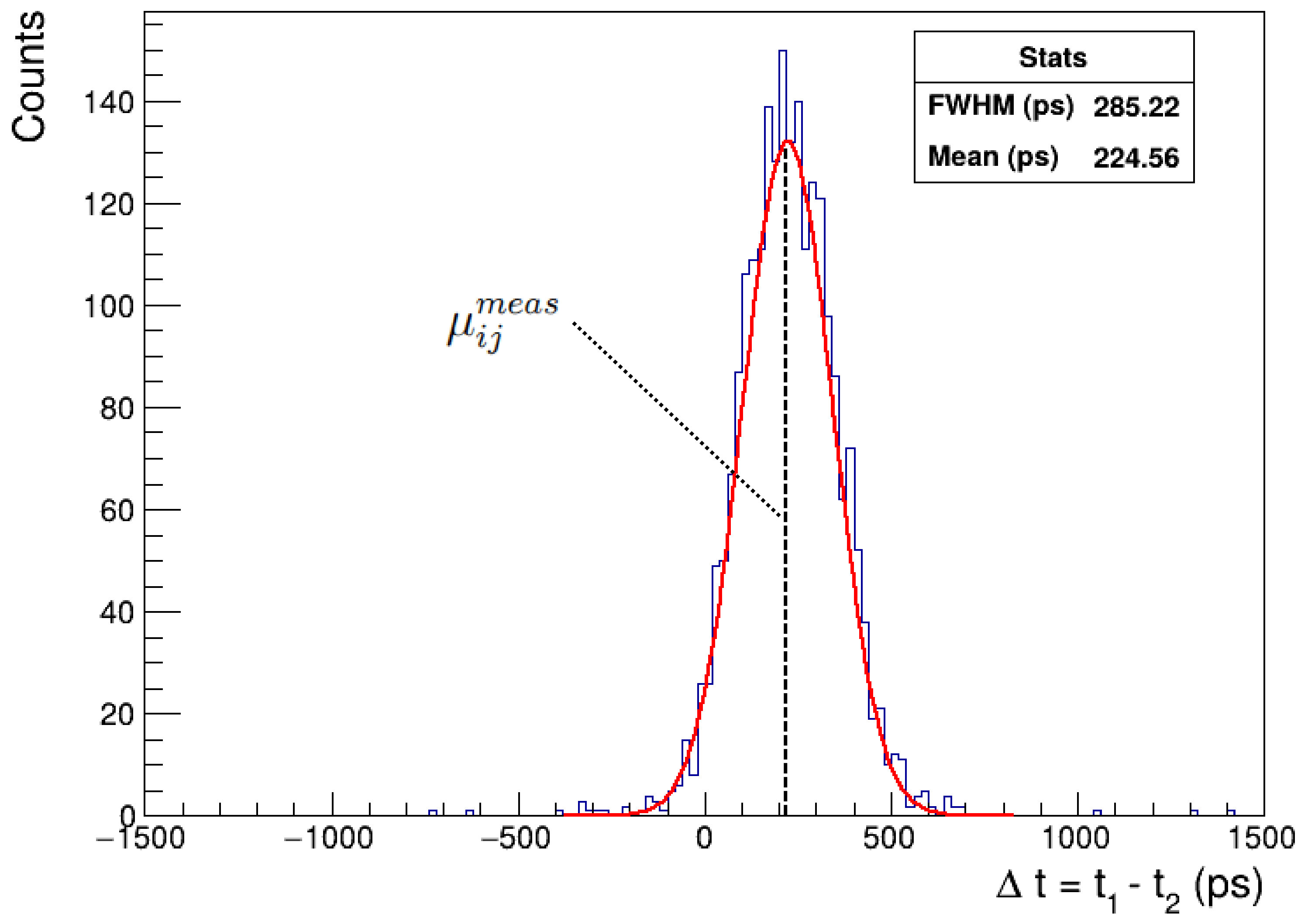


DISTRIBUTION OF PIXEL PAIR COINCIDENCE TIMING RESOLUTIONS



FIXED TIME OFFSETS AT ALL CHANNELS

WHY IS THE MEAN NOT ZERO ?



MEASURED TIME HAS SOME FIXED OFFSET

$$t_i^{meas} = t_i^{true} + \delta_i^{true} + \epsilon_i$$

MEASURE THE FIXED TIME OFFSTES

REMOVE MEASURED OFFSET FROM MEASURED TIME

$$t_i^{corr} = t_i^{meas} - \delta_i^{meas}$$

MEASURING THE FIXED TIME OFFSET

THE MEAN IS EQUAL TO THE DIFFERENCE BETWEEN THE FIXED TIME OFFSETS

$$\mu_{ij}^{meas} = \delta_i^{true} - \delta_j^{true}$$

SYSTEM OF LINEAR EQUATIONS

$$\boldsymbol{A\delta}^{true} = \boldsymbol{\mu}^{true}$$

$$\boldsymbol{A} = \begin{bmatrix} -1 & 1 & 0 & \cdots & 0 \\ -1 & 0 & 1 & \cdots & 0 \\ 0 & -1 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & & \end{bmatrix}_{M \times N} \quad \boldsymbol{\delta}^{true} = \begin{bmatrix} \delta_0^{true} \\ \delta_1^{true} \\ \delta_2^{true} \\ \vdots \end{bmatrix}_{N \times 1} \quad \boldsymbol{\mu}^{true} = \begin{bmatrix} \mu_{01}^{true} \\ \mu_{02}^{true} \\ \mu_{13}^{true} \\ \vdots \end{bmatrix}_{M \times 1}$$

CONSTRAIN THE LINEAR EQUATION BY SETTING ONE OFFSET TO ZERO

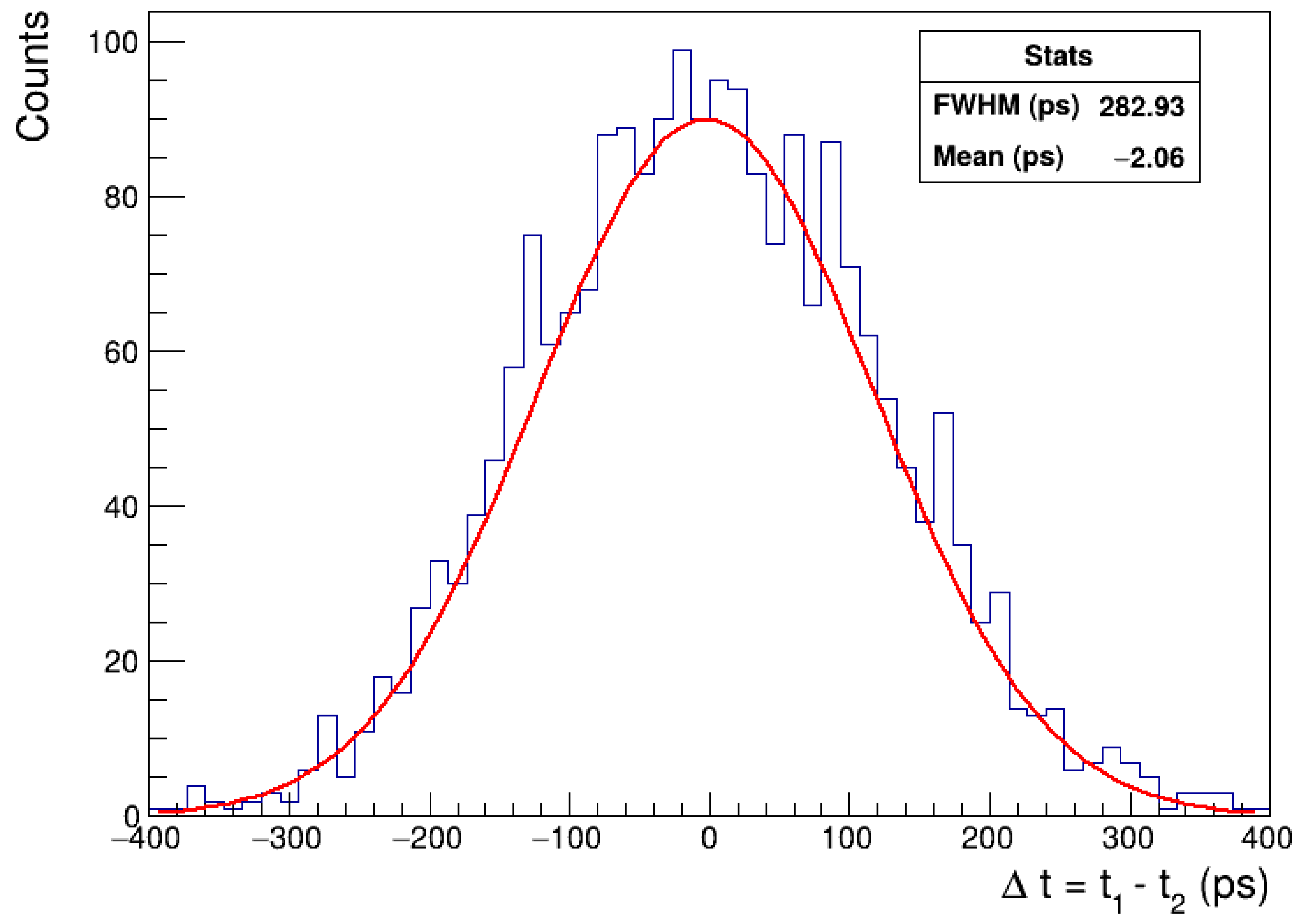
$$\delta_0^{meas} = 0$$

$$\boldsymbol{A\delta}^{meas} = \boldsymbol{\mu}^{meas}$$

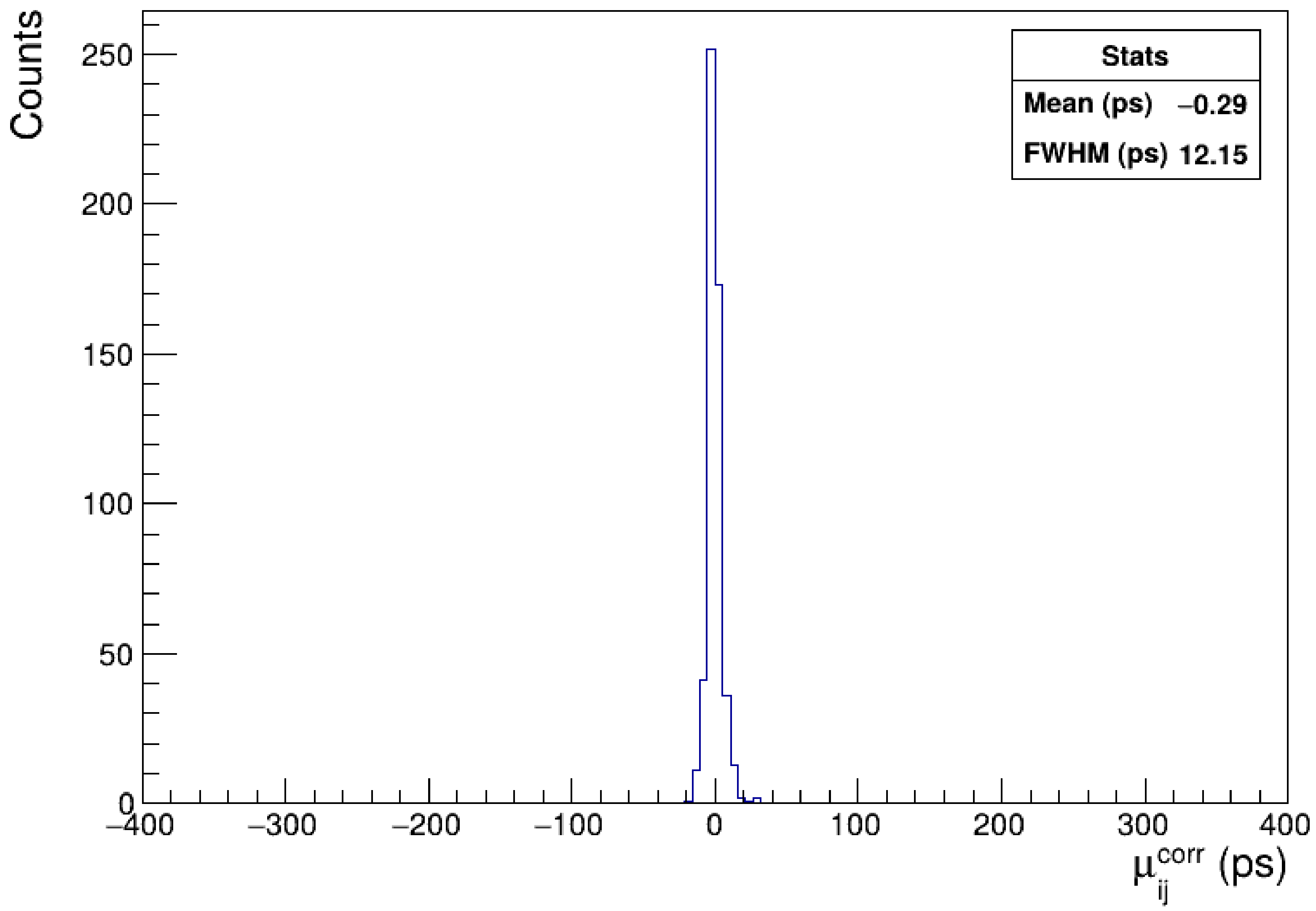
SOLVE EQUATION FOR MEASURED TIME OFFSETS USING LEAST SQUARES REGRESSION

TIME OFFSET CALIBRATION

CORRECTED COINCIDENCE TIMING SPECTRUM

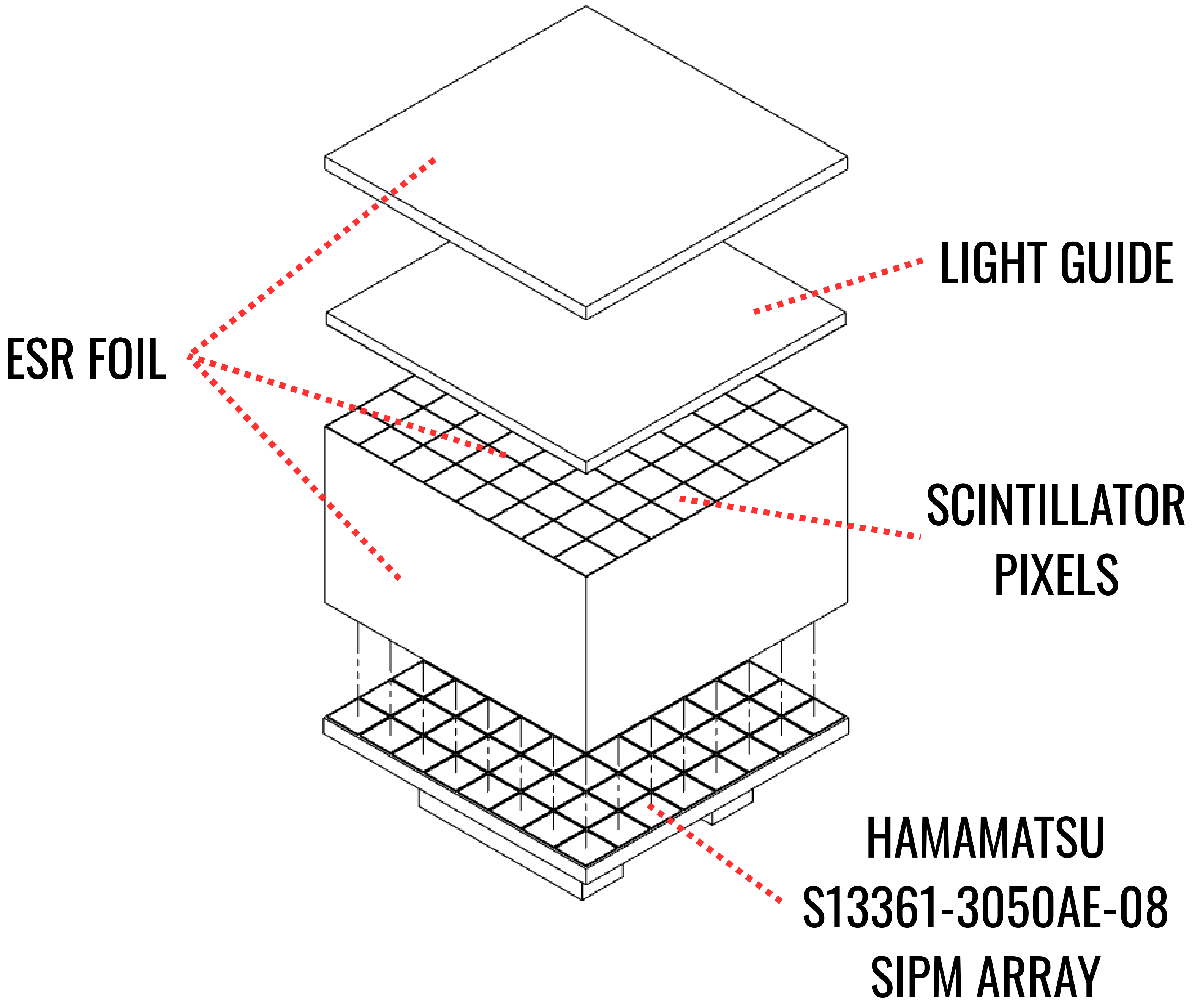


DISTRIBUTION OF CORRECTED COINCIDENCE TIMING MEANS

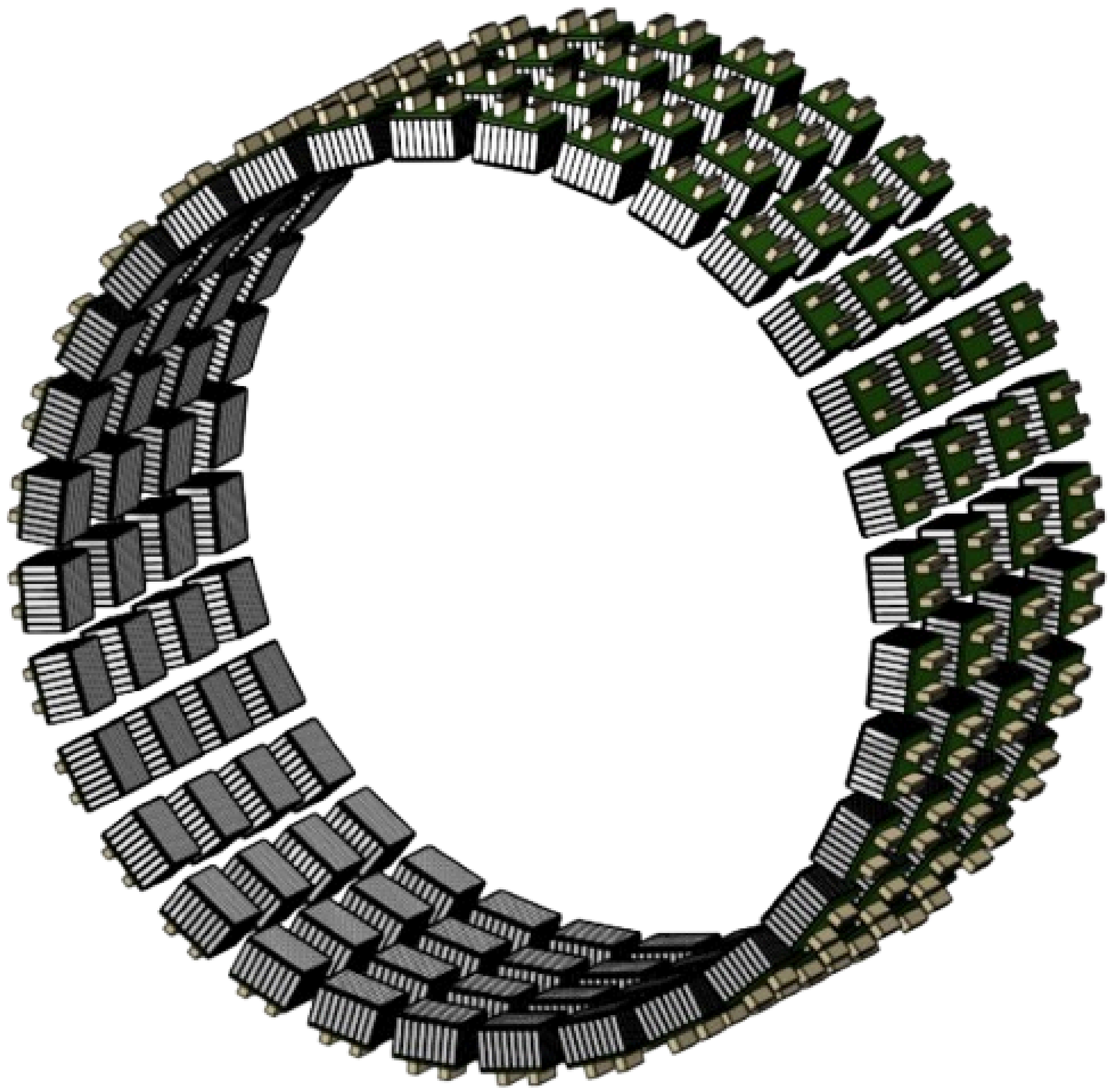


WHERE TO NEXT ?

TEST NEW DETECTOR MODULES



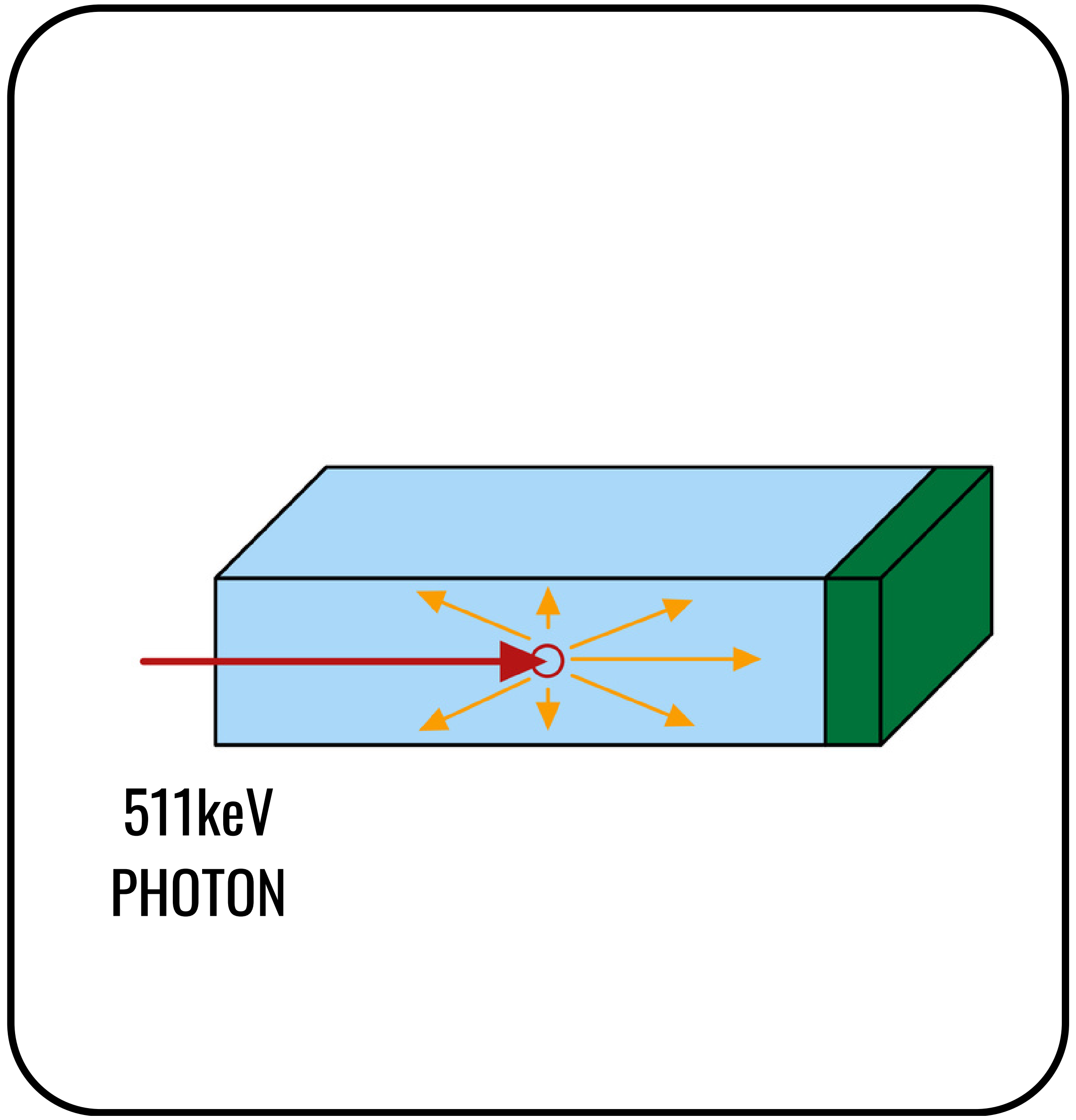
SCALE UP



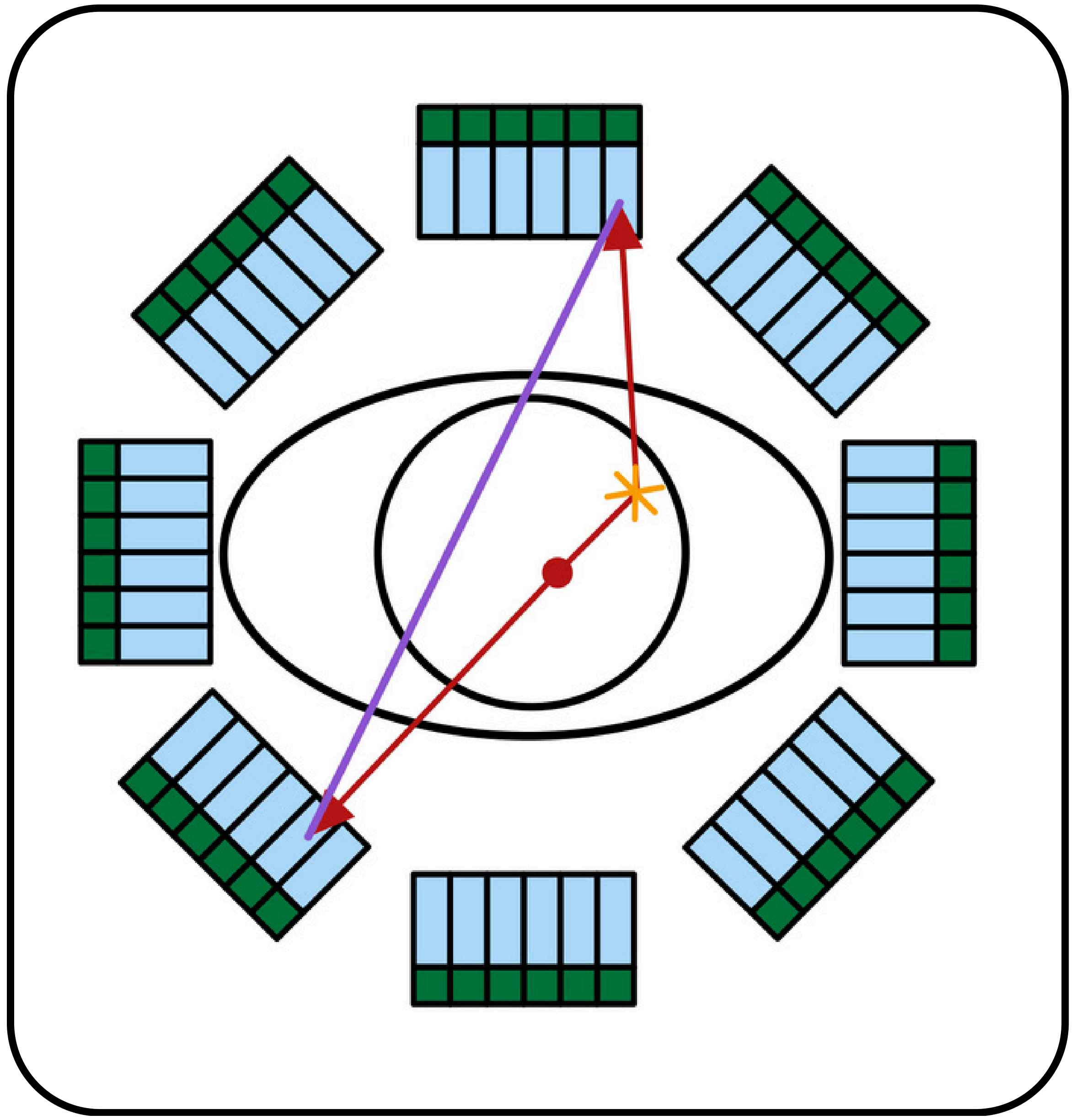
THANK YOU FOR YOUR TIME

ANY QUESTIONS ?

NOT ALL GAMMAS ARE GOOD GAMMAS

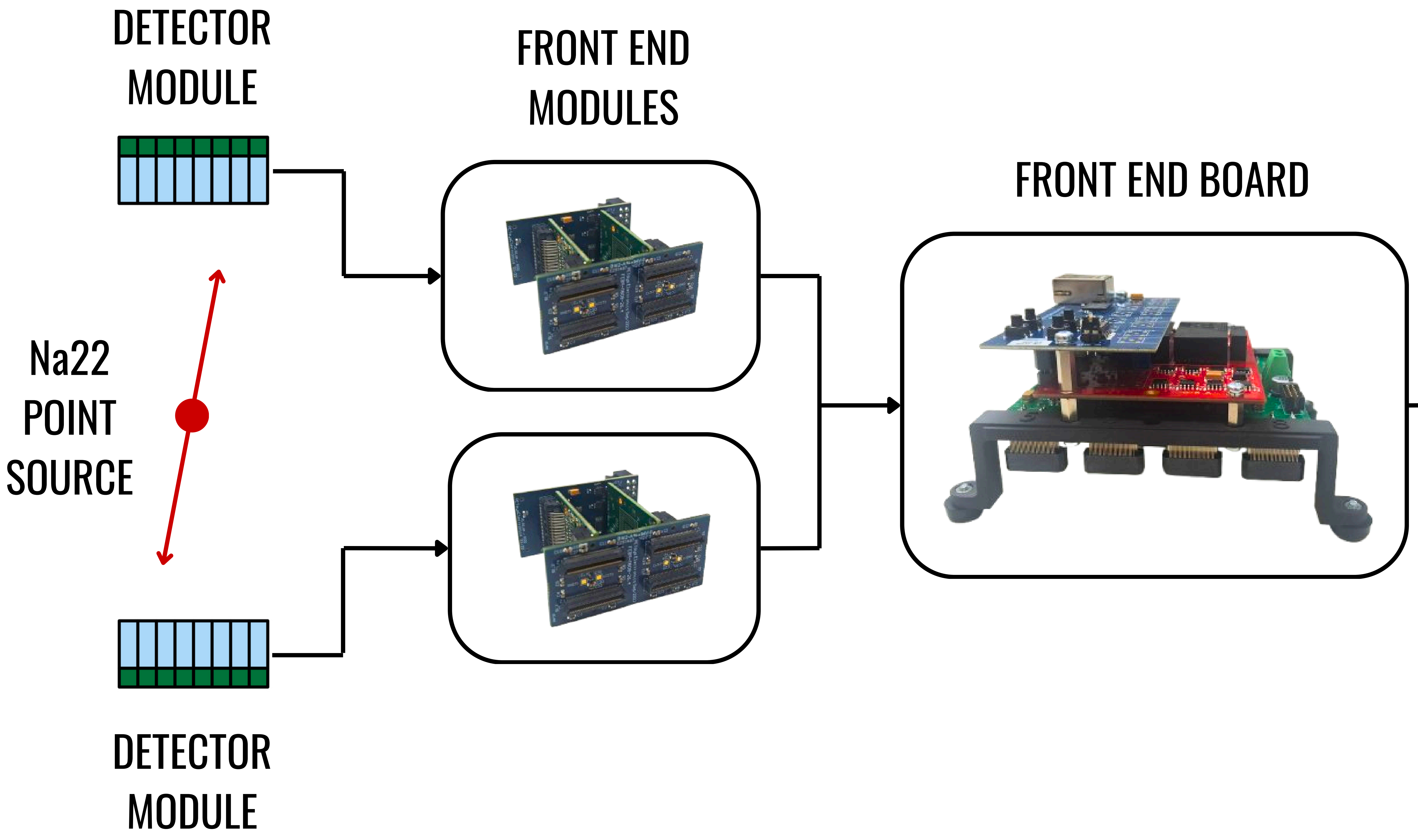


PHOTOELECTRIC
ABSORPTION



SCATTER
IN THE PATIENT

PETSYS DATA ACQUISITION HARDWARE

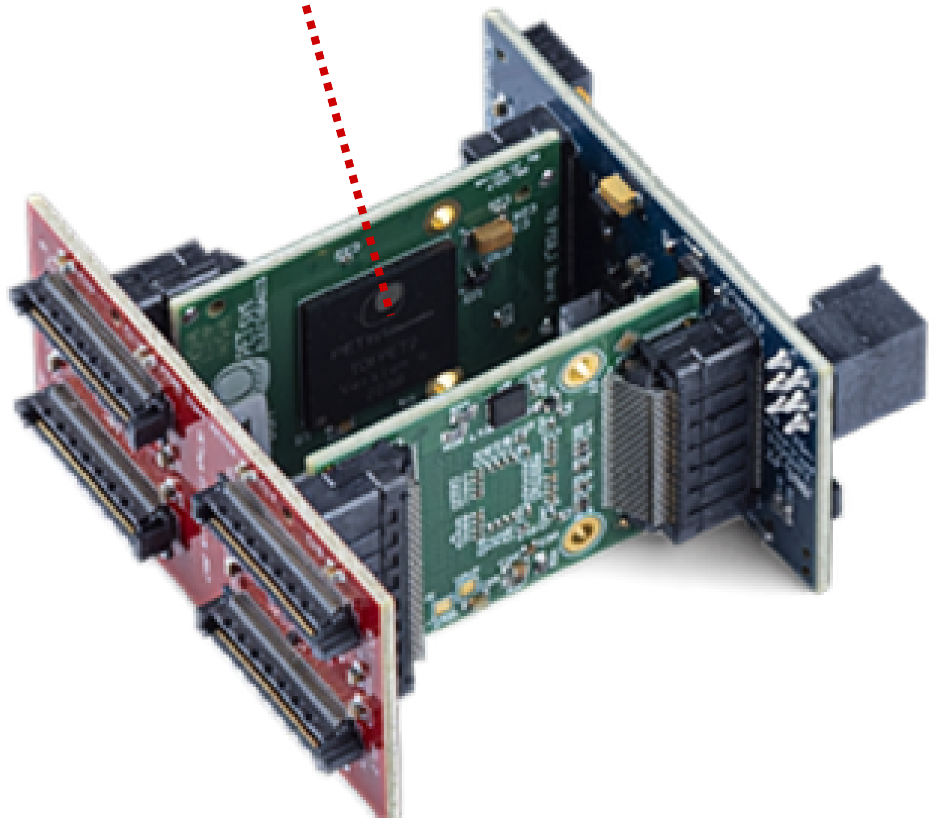


PETSYS RAW DATA

CHANNEL ID	ENERGY	TIME
...	...	...
...	...	...

MANAGING THE ASIC TEMPERATURE

PETSYS TOFPET2 ASIC



ALUMINIUM BLOCK

COPPER HEAT PIPE

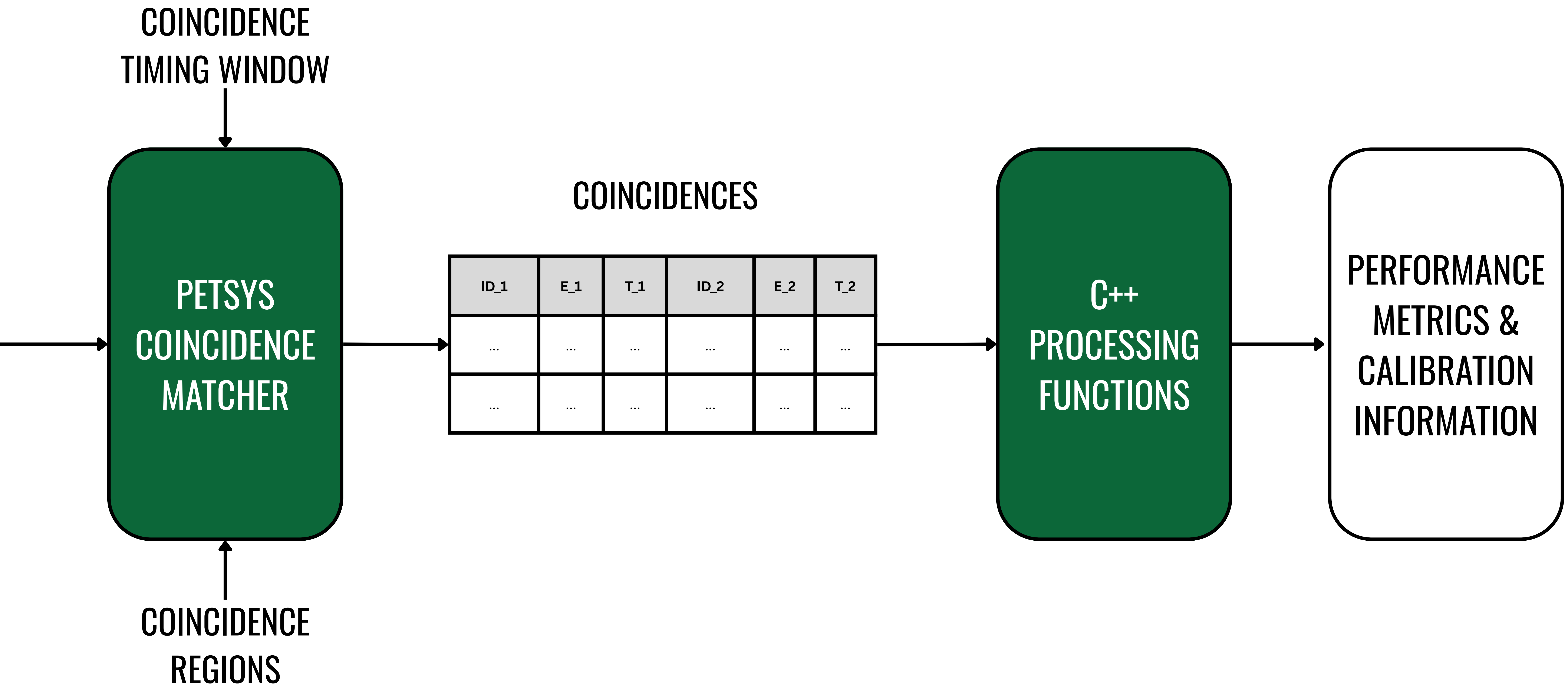
FAN

ALUMINIUM LID

ALUMINIUM BLOCK

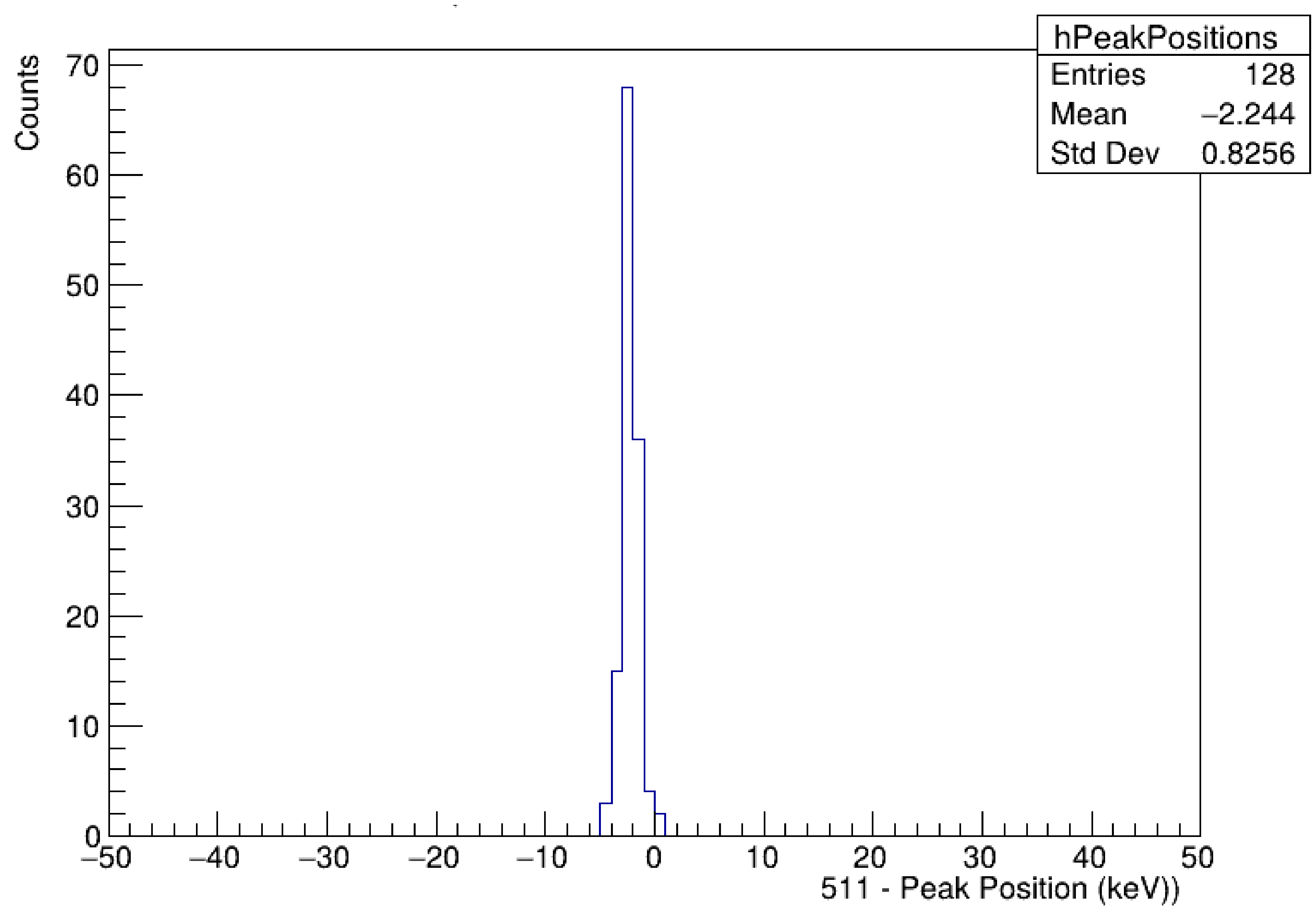
ALUMINIUM MOUNTING PLATE

PROCESSING PETSYS DATA



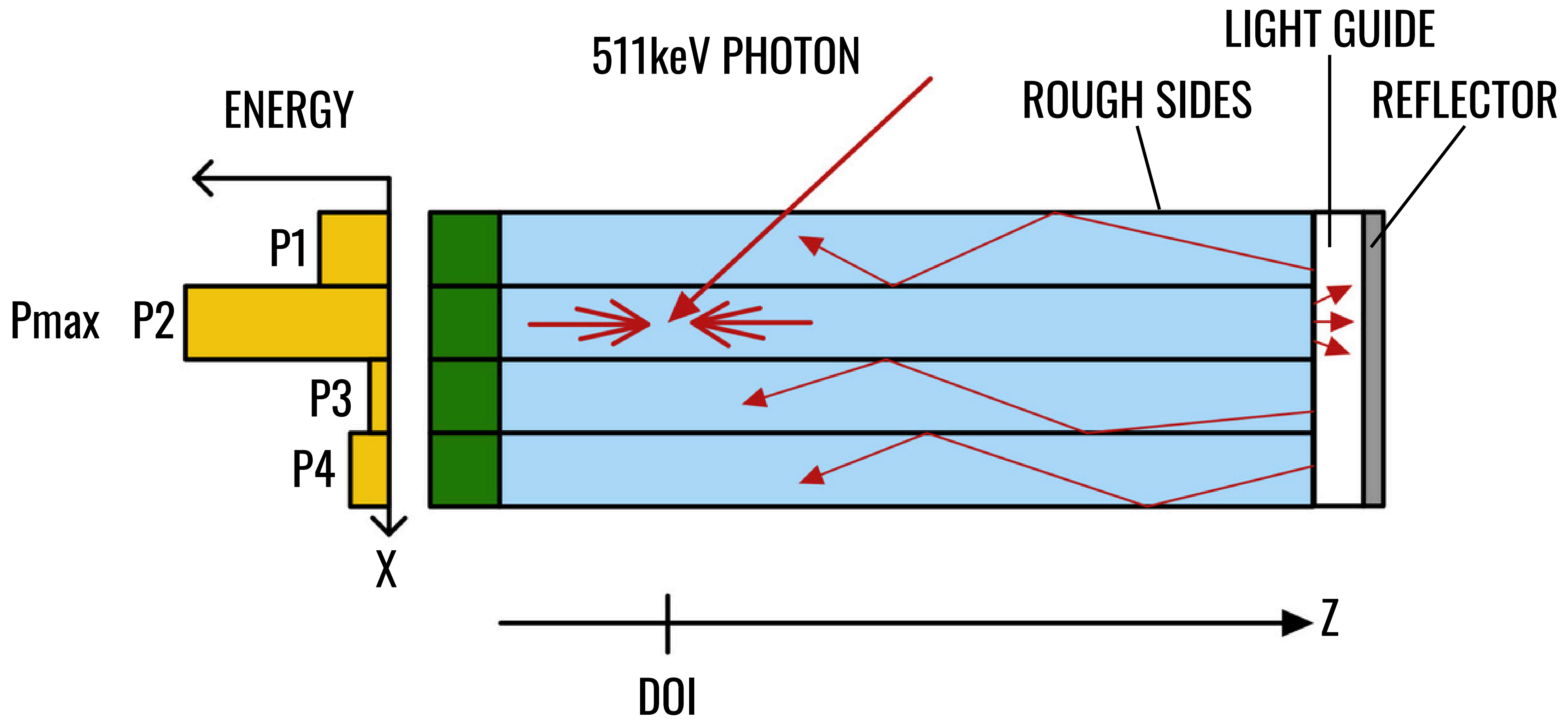
ID_1	E_1	T_1	ID_2	E_2	T_2
...	...	...	...	...	...
...	...	...	...	...	...

CALIBRATED PEAK POSITION ERROR



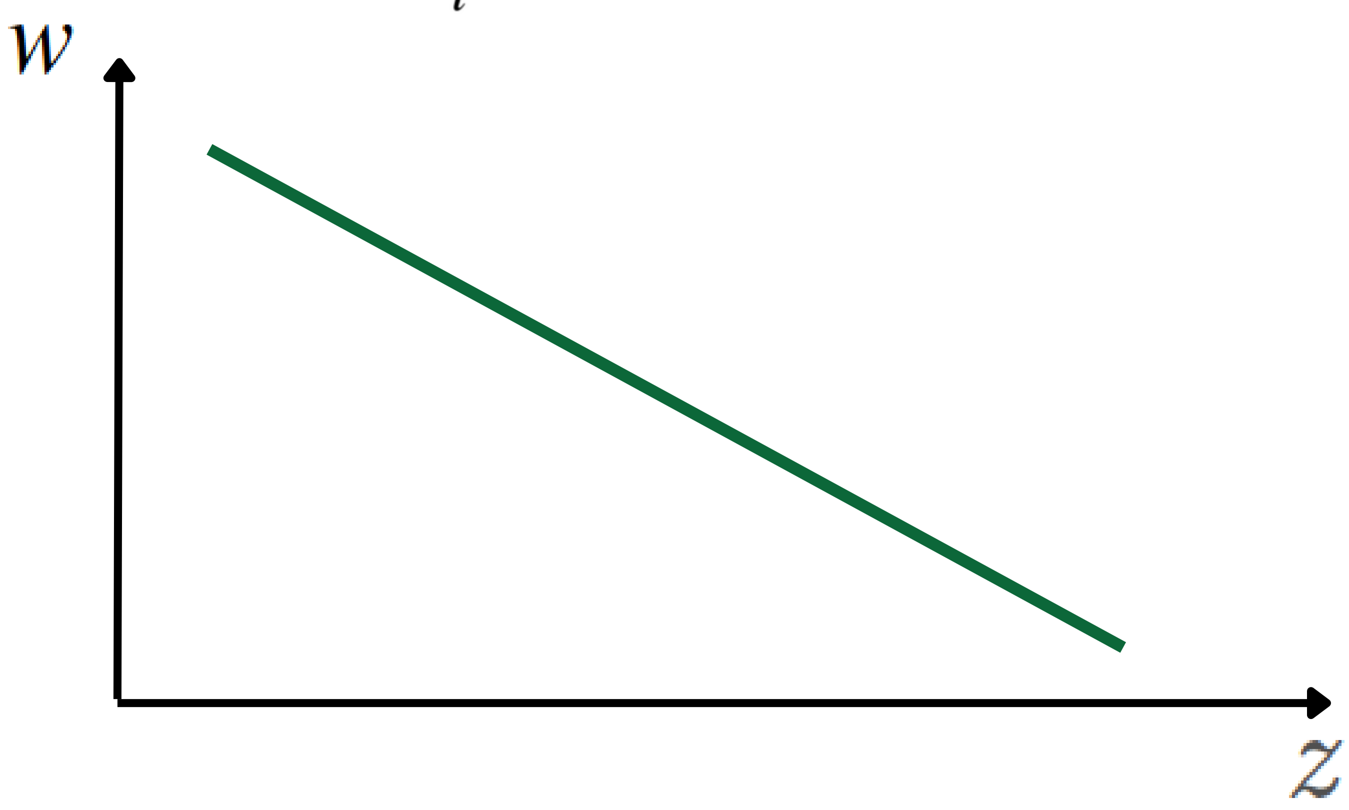
SINGLE SIDED DEPTH-OF-INTERACTION

NEW DETECTOR MODULE DESIGN



APPROXIMATELY LINEAR

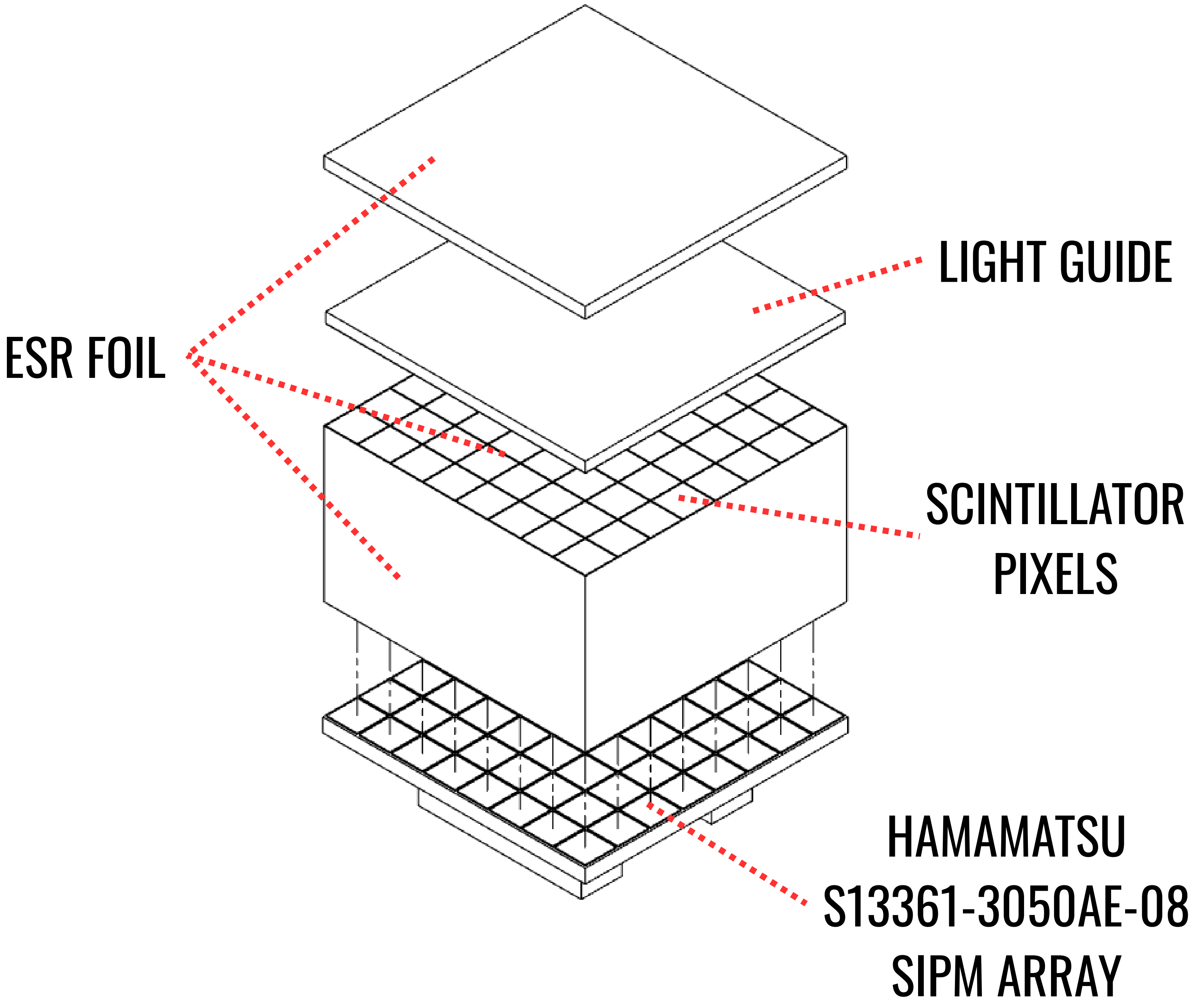
$$P = \sum_{i}^{N} p_i \qquad w = \frac{p_{\max}}{P}$$



WE CAN SHARE THE LIGHT AND MEASURE THE DOI

DESIGNED DOI DETECTOR MODULES

DOI DETECTOR MODULE



DOI DETECTOR MODULE