

Methods for Pulse Analysis and Data Cleaning with the BeEST Phase-III Heavy Neutrino Search



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1. Introduction

- The Beryllium Electron Capture in Superconducting Tunnel Junctions (**BeEST**) experiment searches for heavy neutrino mass eigenstates
- Large amounts of experimental data collected for high confidence modeling
- Slight differences in experimental conditions may propagate into datasets
- Data cleaning** methods developed to correct or remove distortions in data before combination

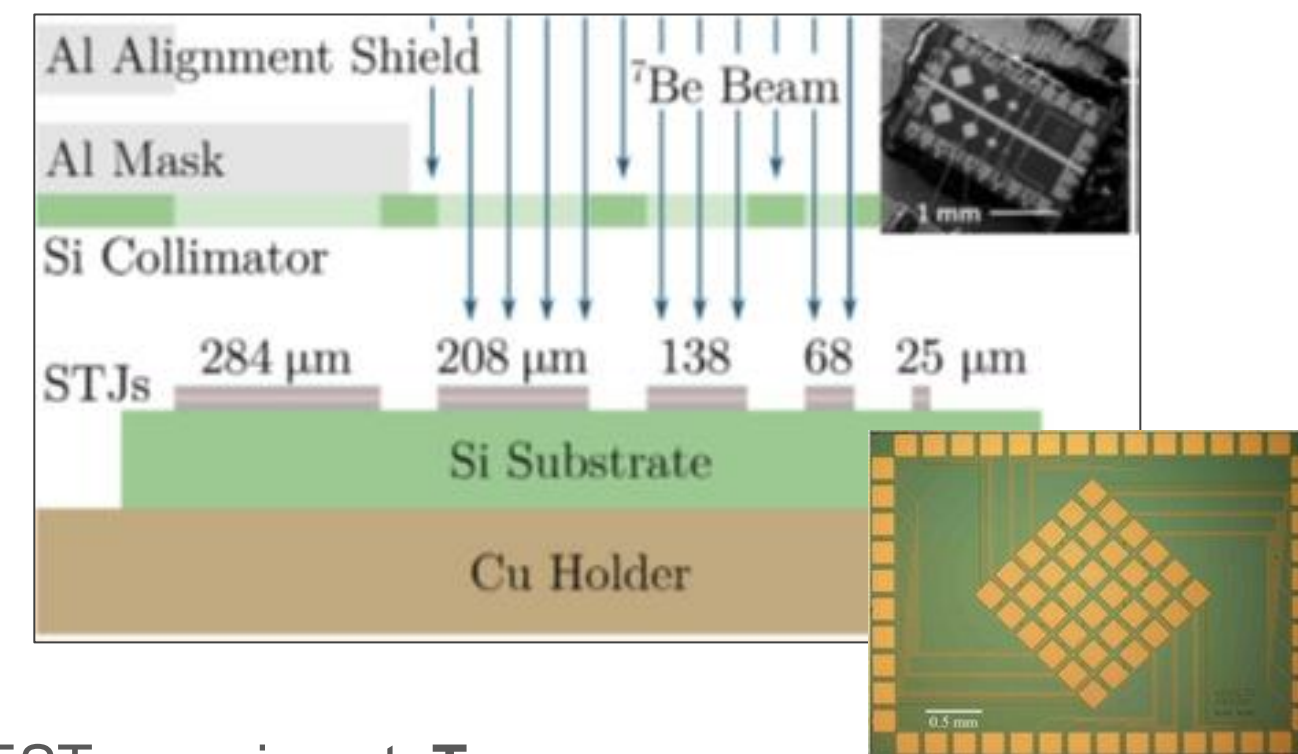


Fig. 1.1: The BeEST experiment. Top: diagram of phase I operation. Lower inset: phase III STJ pixel array.

2. Data

- Pulse data collected for electron capture (EC) and laser events (for energy calibration)
- Pulses aggregated to ⁷Be EC spectra with four characteristic peaks (see Fig. 2.2)

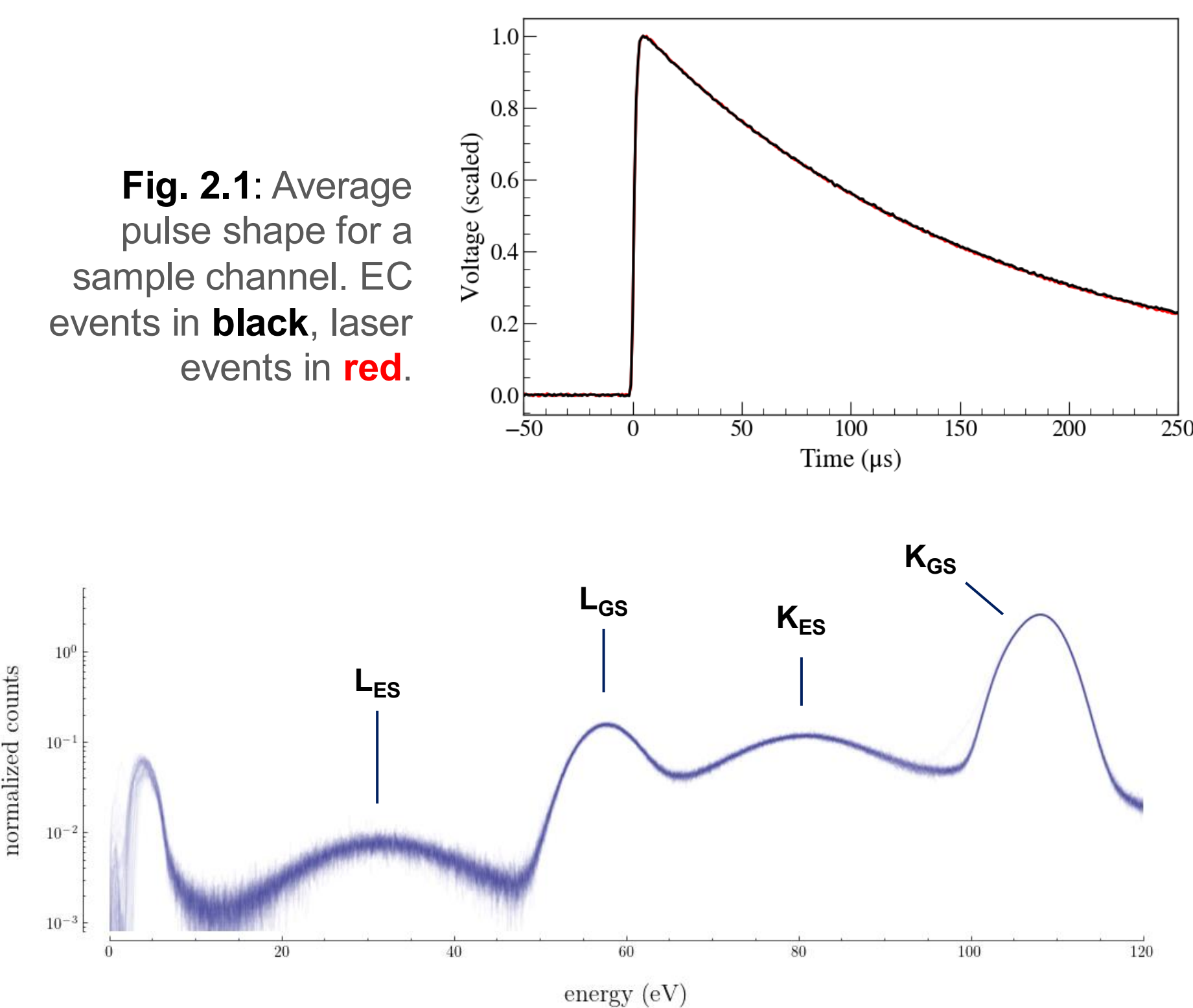


Fig. 2.2: Electron capture spectrum typical of BeEST experiment.

3. Pulse Analysis

- Observed difference in pulse shapes between EC and laser events
- Residual location shift effect observable in K_{GS} peak
- Analyzing pulse “fastness” (ratio of pulse integration domains)
- Linear correction based on 2D Gaussian fit to each laser event cluster

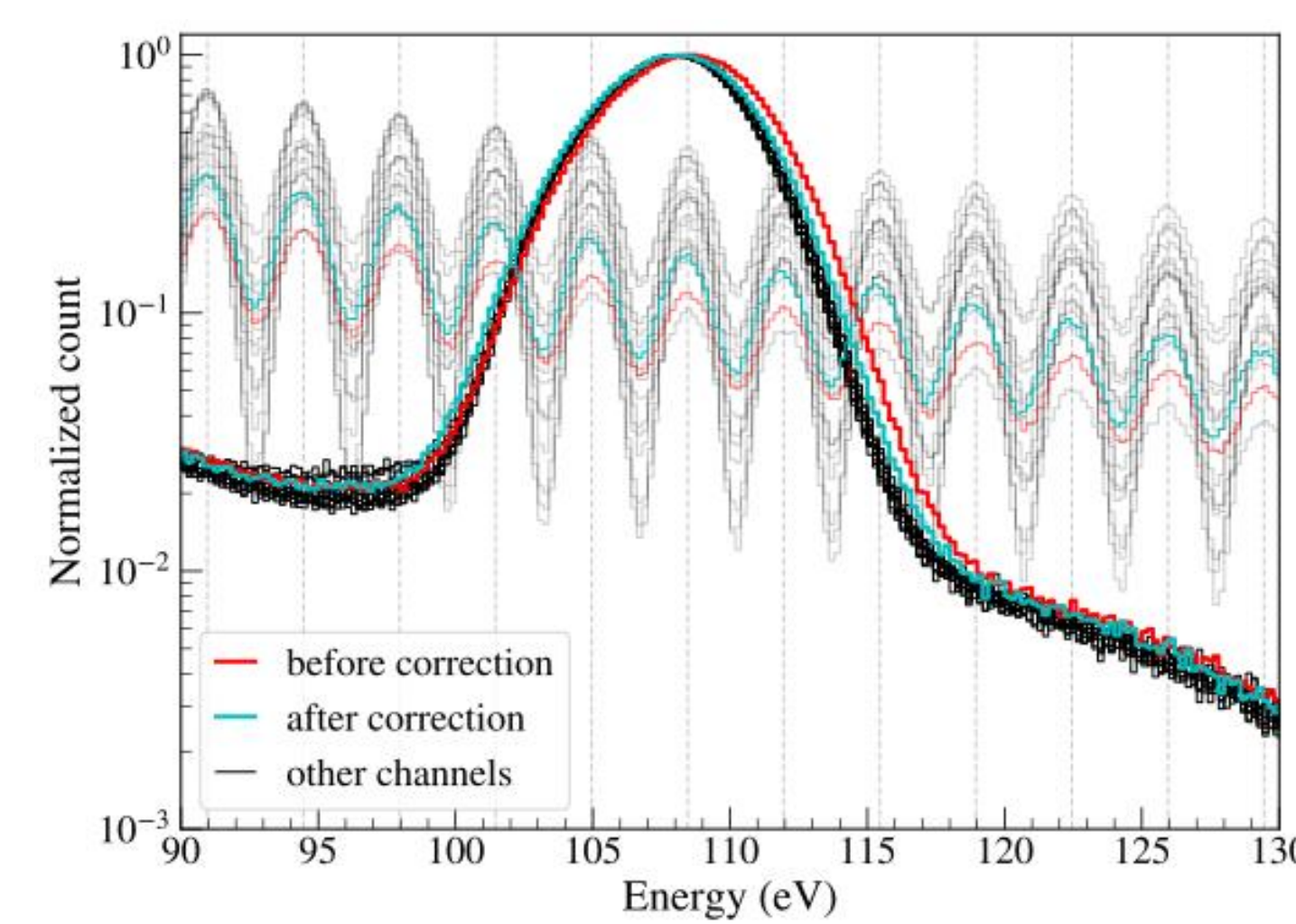


Fig. 3.1: (above) Demonstration of K_{GS} peak shift effect; binned channel 3 data before correction shown in red and after correction in cyan.

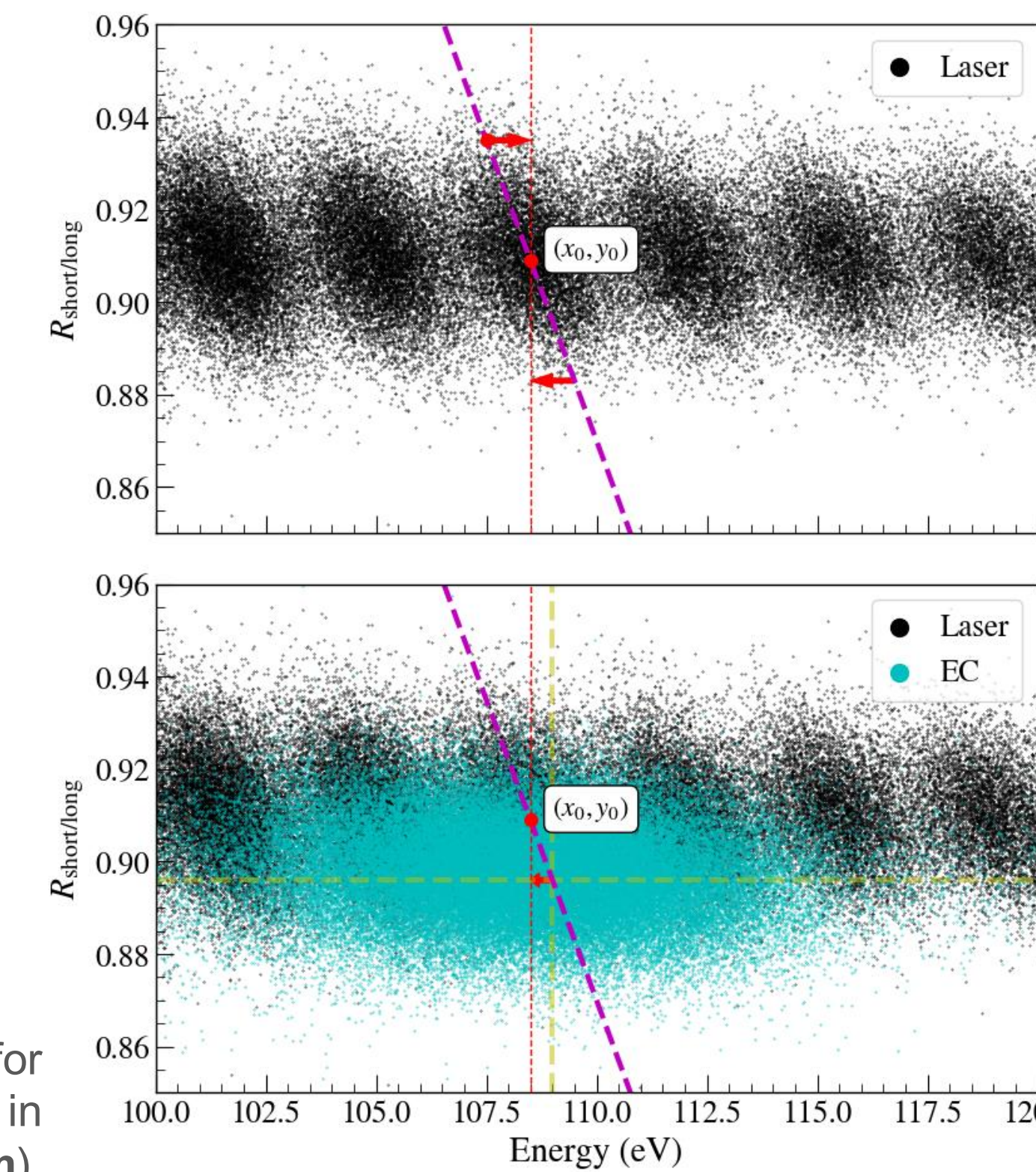


Fig. 3.2: (right) Slope correction shown for sample laser event clusters (top) and shown in context of EC K_{GS} event cluster (bottom).

4. Spectral Analysis

- Variation in K_{GS} peak location and resolution over time
- Resolution bounds established for each channel based on Gaussian fit of resolution distribution (see Fig. 4.2)
- Optimized gain shift applied to spectrum chunks to correct for location deviations

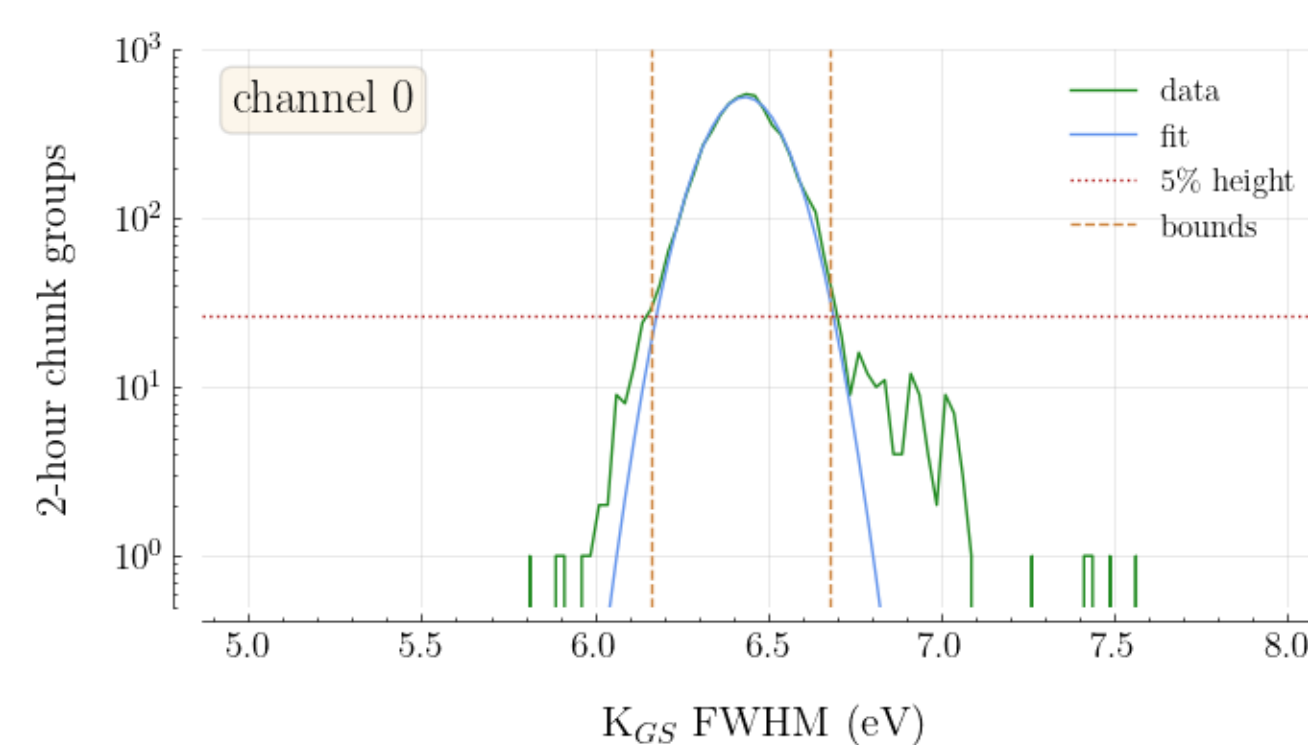


Fig. 4.2: Distribution of K_{GS} FWHM values for 2-hour chunk-groups of spectra. Gaussian fit shown, along with 5% height lines.

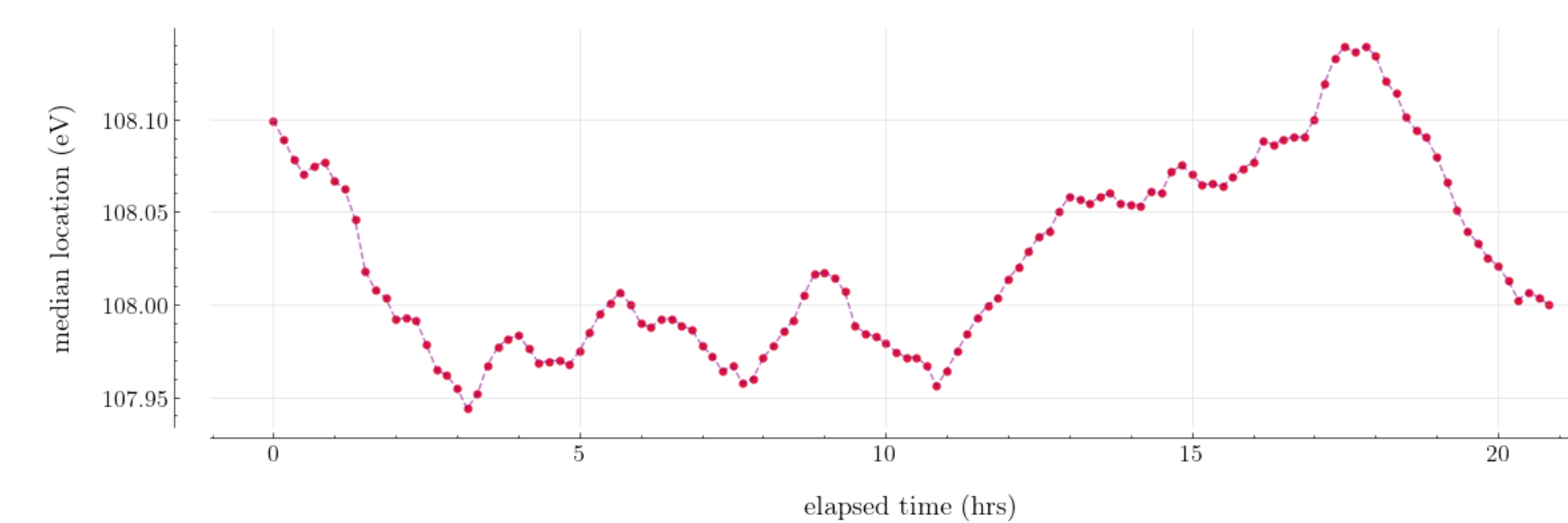


Fig. 4.1: Variation in K_{GS} peak location over a day of experimental data

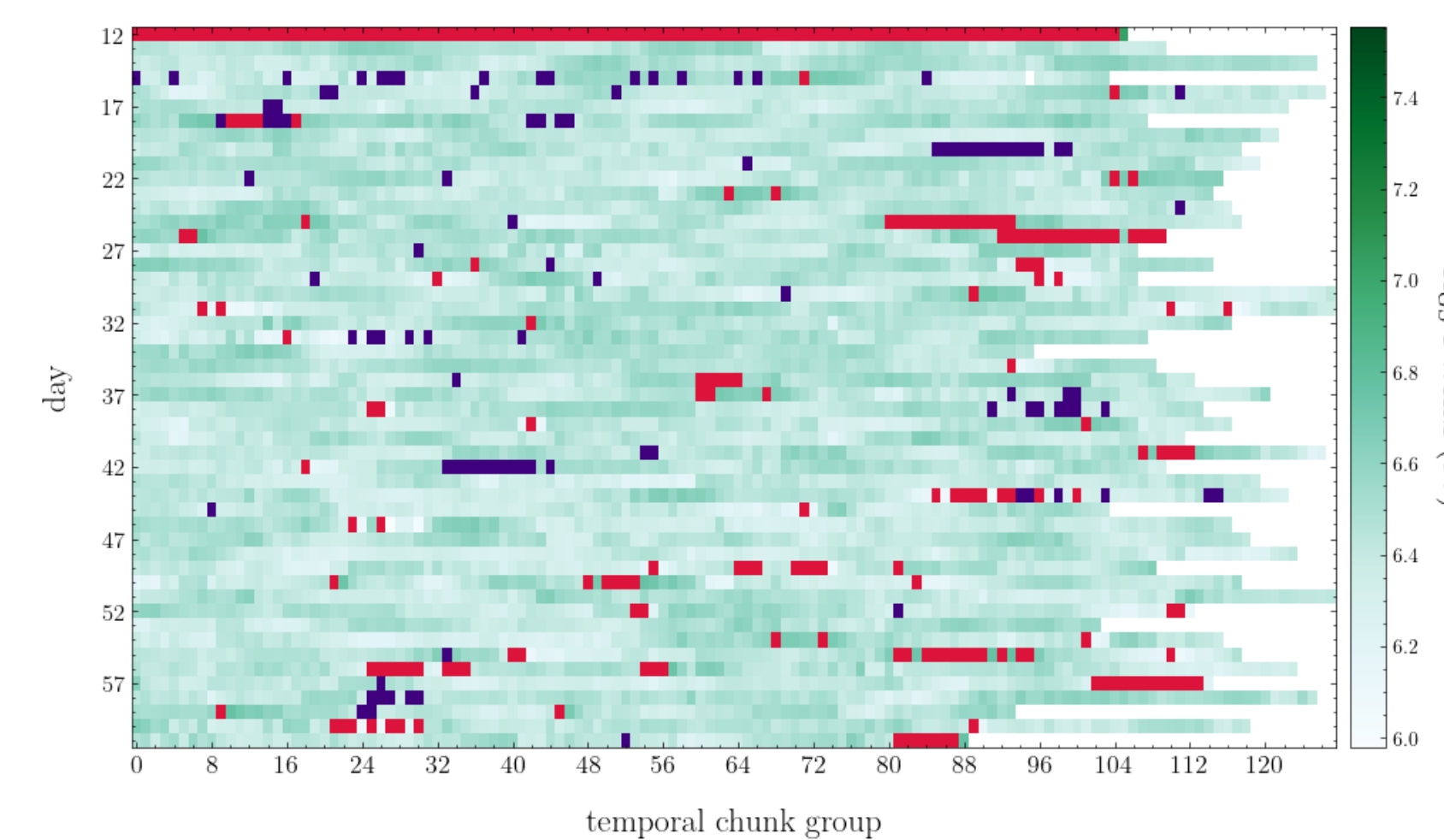


Fig. 4.3: K_{GS} peak FWHM for each spectrum chunk group for a single channel (0). Pruned temporal indexes during preliminary cuts in blue and from resolution pruning in DC in red.

5. Results

- Data cleaning method refined and finalized during stage 1 unblinding
- Results of application to final unblinding dataset shown in Fig. 5.1.d.

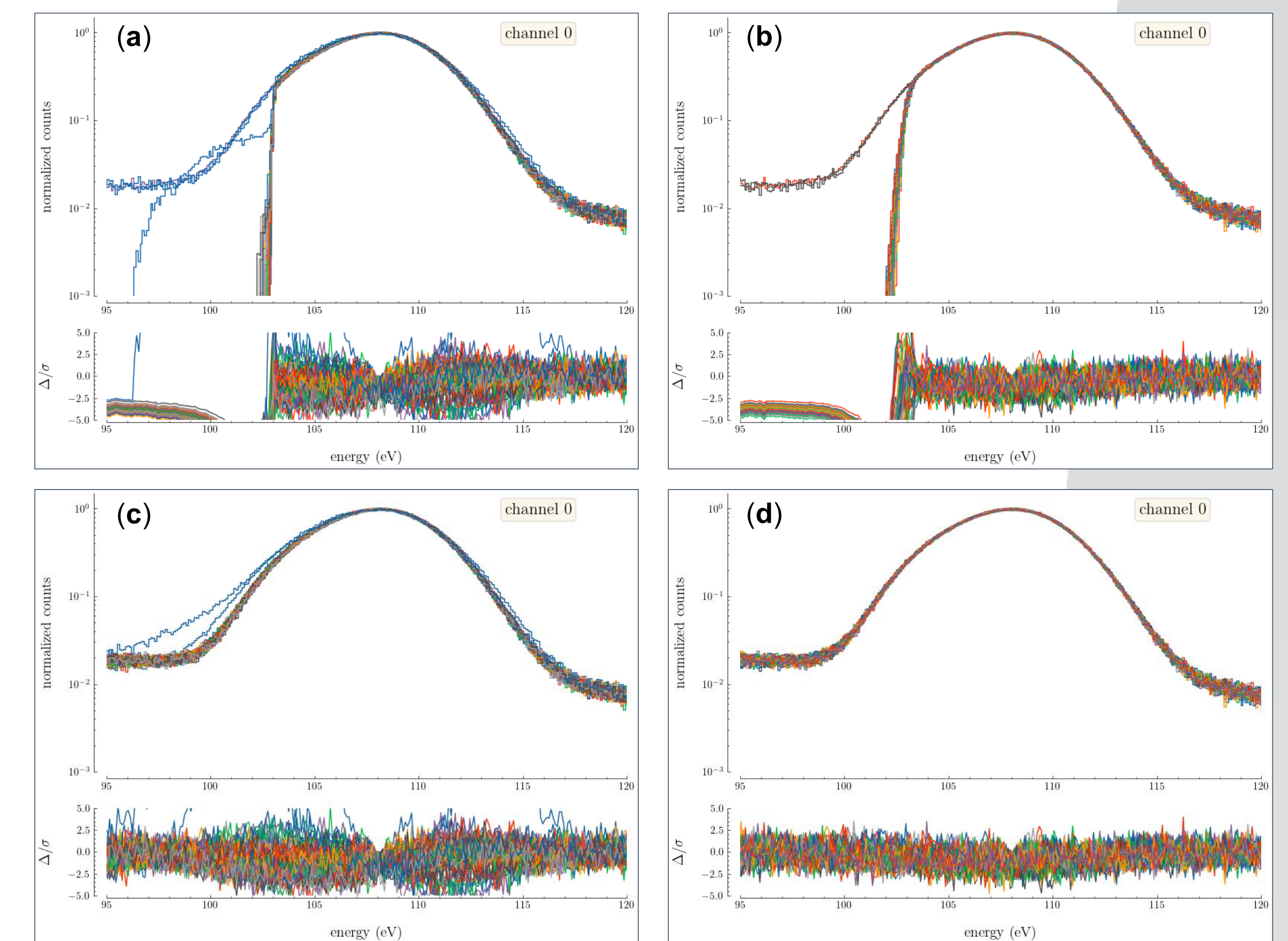


Fig. 5.1: All day spectra (K_{GS} region) overlaid for a sample channel. Stage 1 unblinding data shown at top, pre- (a) and post-data cleaning (b). Final unblinding data shown at bottom, pre- (c) and post-data cleaning (d).

6. Discussion & Next Steps

- Significant improvements in inter-experiment statistical agreement from data cleaning allow for efficient spectral combination
- Final data products proceed to background model evaluation step
- Preparations for BeEST Phase IV
 - Investigating alternative methods for pulse integration
 - Assessing noise characteristics of new experimental setup
 - Automating workflow to handle larger volumes of data

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