

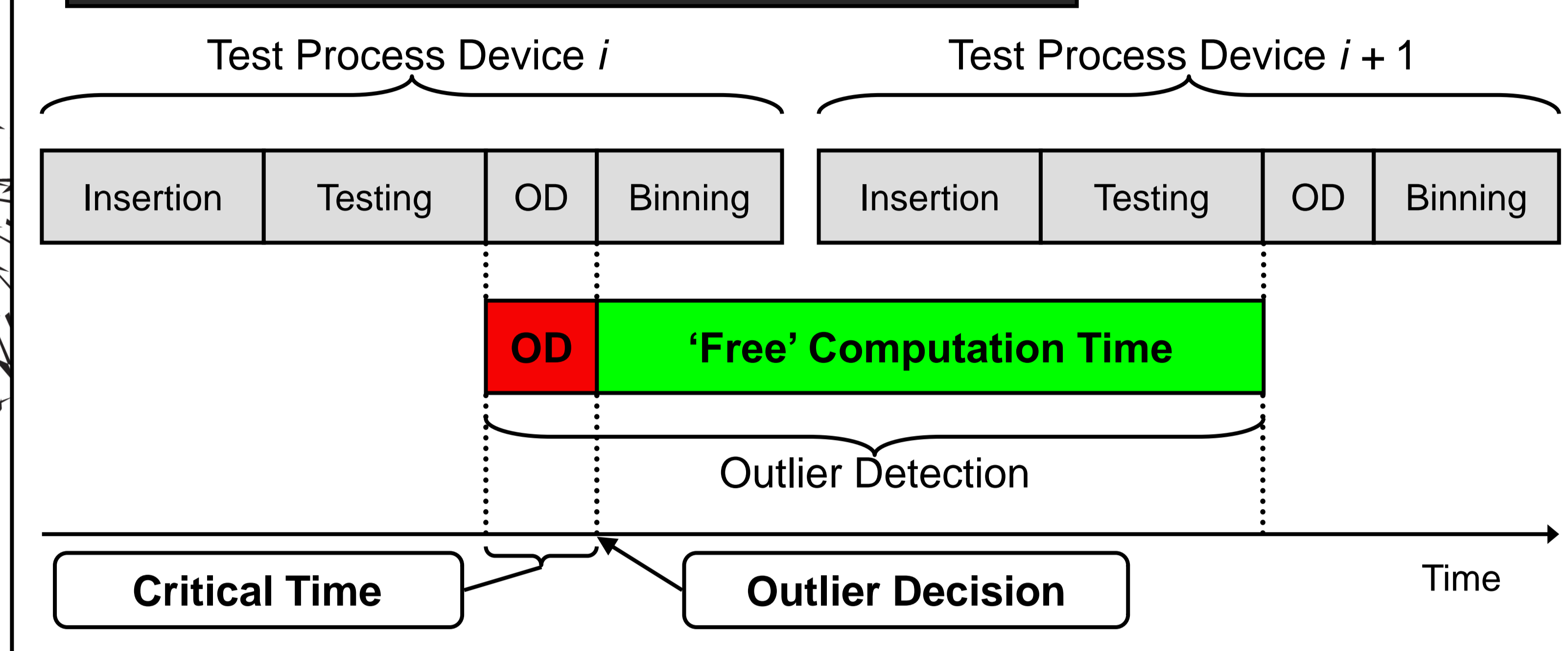
Online Outlier Detection in Testing of Integrated Circuits

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1. Testing of Integrated Circuits

- Measurements of several values, for example current or speed
- Wide specification limits to accommodate to lot-to-lot variation
- Device is accepted if it passes all tests
- No 100% test coverage, so not all pass devices are good

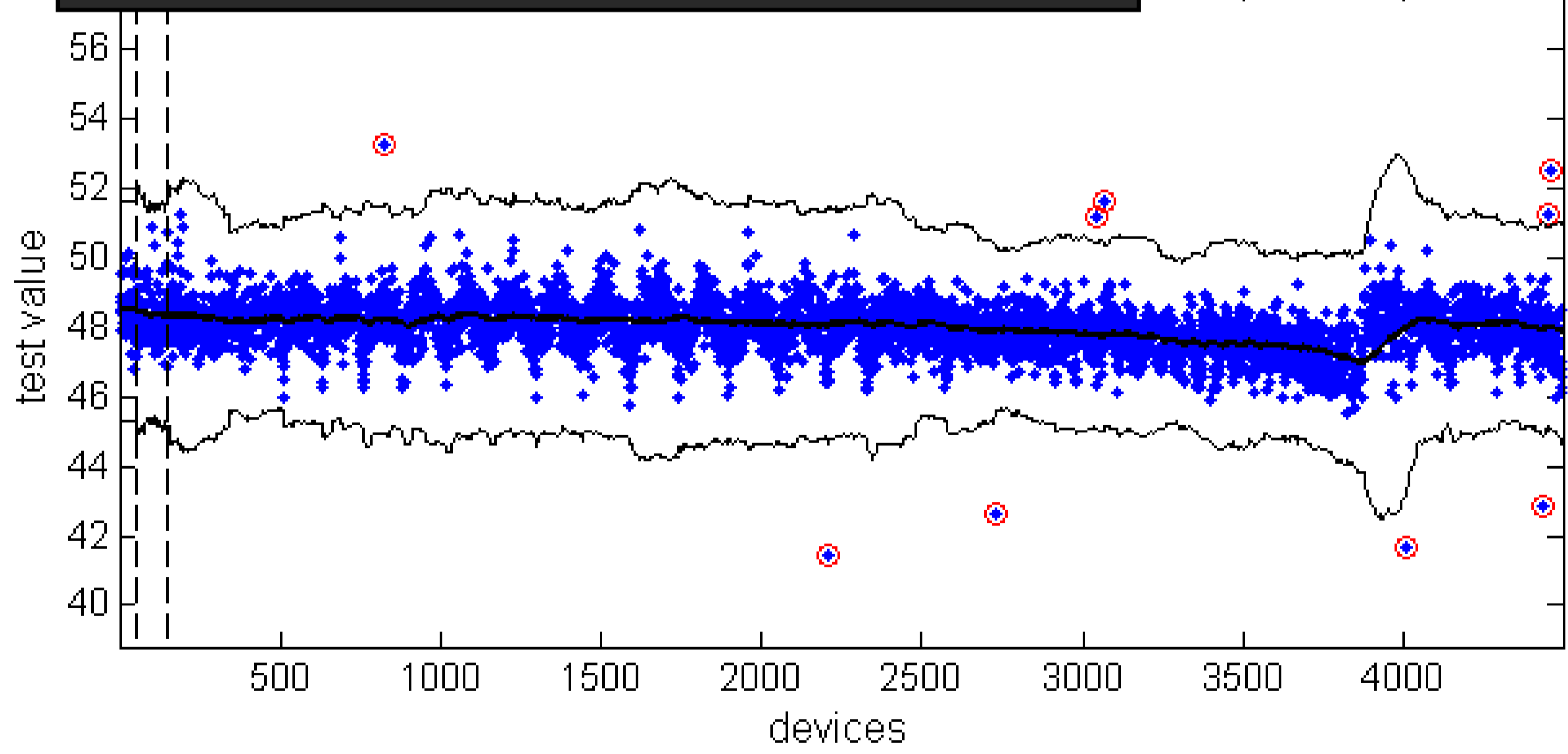
3. Timeline Test Process



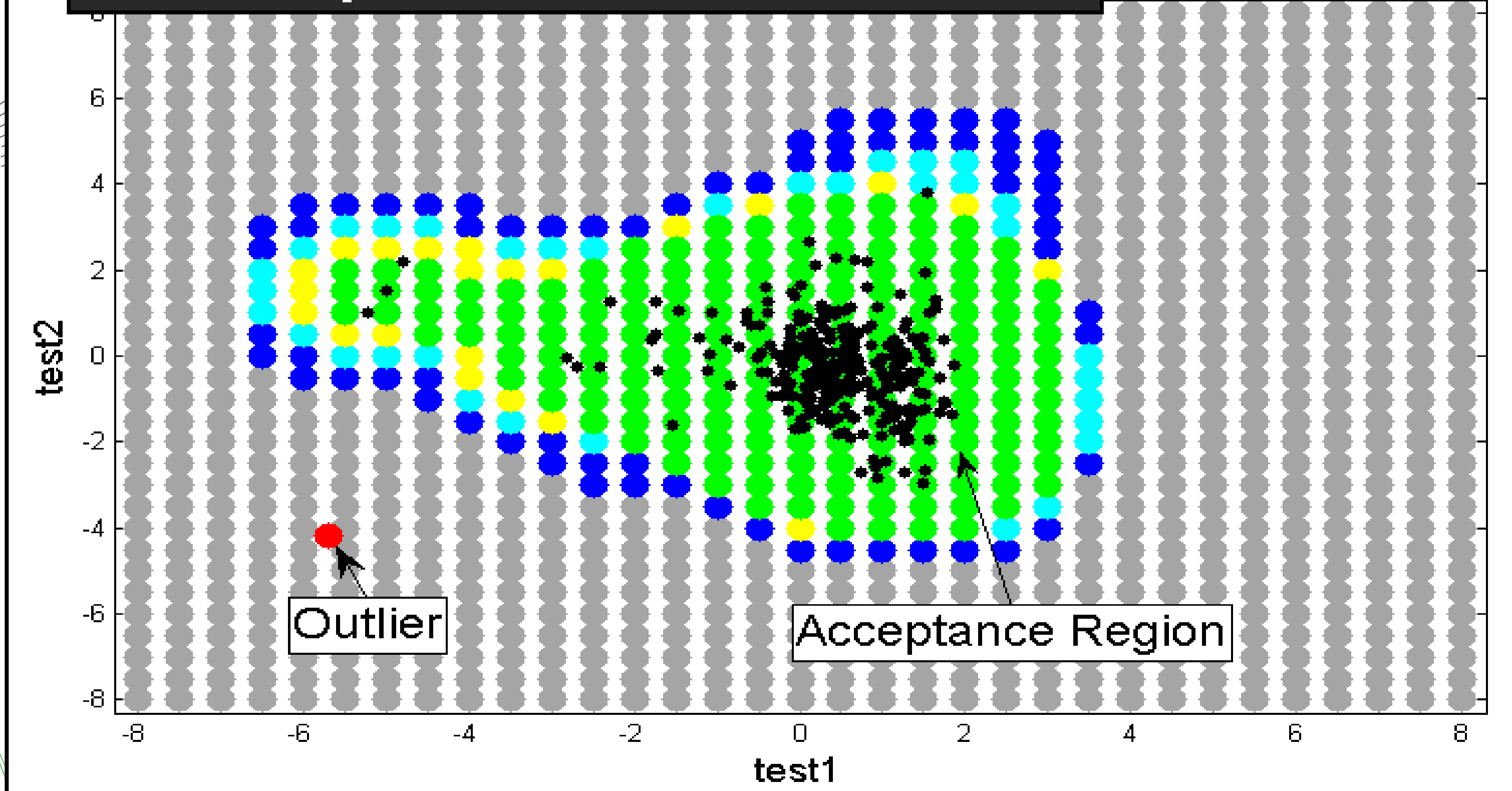
5. Method Ideas (Univariate)

- Use data of previous measurements to construct moving limits for next device
- Use Rolling Horizon of previous n devices to be able to adapt to changing situations, update limits during 'free' computation time
- Baseline Initialization required: use robust statistics (median & MAD) for outlier detection in baseline, since mean and standard deviation are very sensitive to outliers
- Start outlier detection already during baseline initialization

7. Example Univariate OD



9. Example Bivariate OD



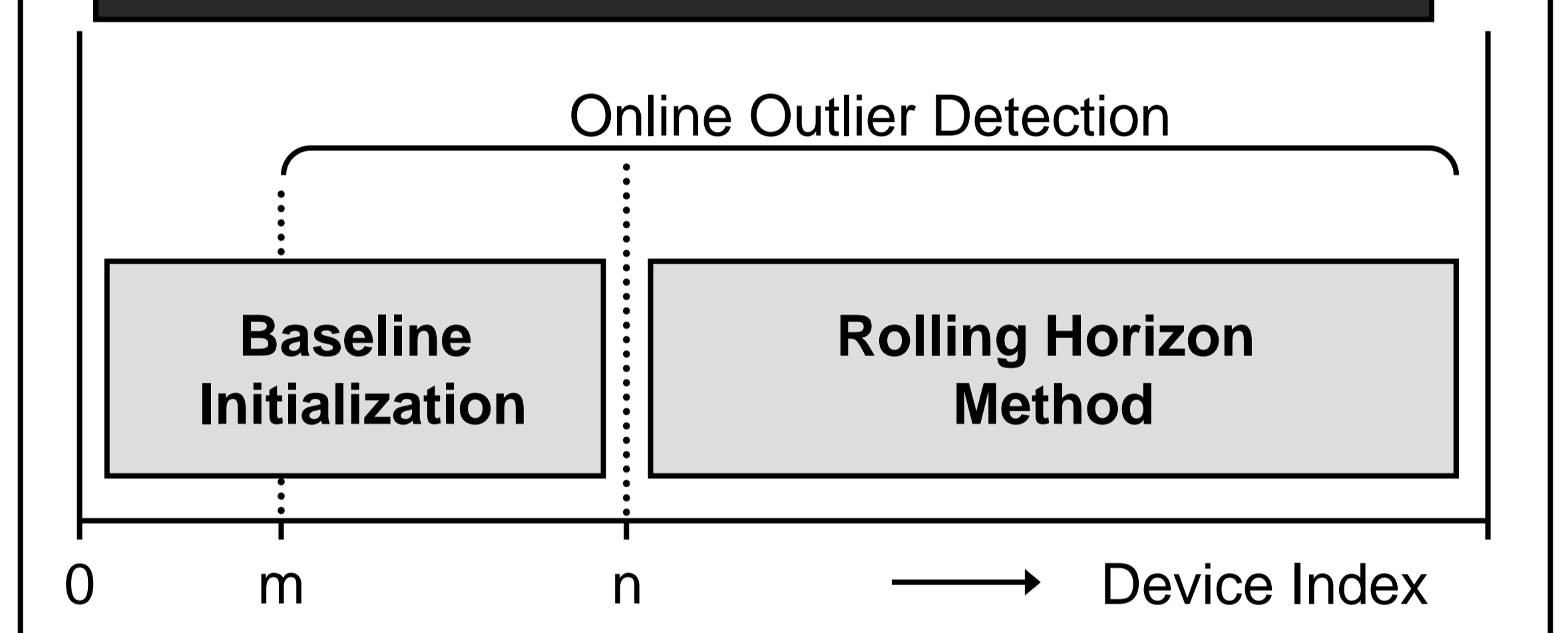
2. Outlier Detection (OD)

- Outliers are measurements within specification limits, but with deviating behavior compared to the other measurements
- Deviating behavior can be caused by a latent defect and hence entails a reliability risk
- Outliers are not necessarily failures. Outlier Detection can be used to find suspicious devices which are tested more extensively, or to distinguish between various levels of quality

4. Online Outlier Detection

- Offline outlier detection is not an option for Final Test, since after testing the devices cannot be identified and filtered anymore
- Measurement data distributions are influenced by process variations and tester condition, hence distributions change over time
- Online outlier detection requires very fast outlier decisions, in between there is some time for updating and analysis (see timeline)

6. Schematic Overview Method



8. Method Ideas (Bivariate)

- Again Rolling Horizon of previous n devices
- Use (online available) standardized results of univariate method to avoid scaling problems
- Use Kernel Density Estimation, if density $f(x)$ is too low \rightarrow outlier

$$f(x | X_1, \dots, X_n) = \frac{1}{n} \sum_{i=1}^n K\left(\frac{x - X_i}{h}\right)$$

- Use grid approximation to enable fast density evaluation, update during free computation time

10. Discussion

- Both methods have very fast evaluation and update time is also limited
- Memory usage might become a problem in bivariate case if grid is too large
- Univariate method cannot be applied to very skewed or multimodal distributions
- Outlier detection should start as soon as possible, in bivariate case baseline initialization can take too many devices