Analysis of darknoise measurements in Valencia

Statistical characterization of HPK SiPMs for FD1

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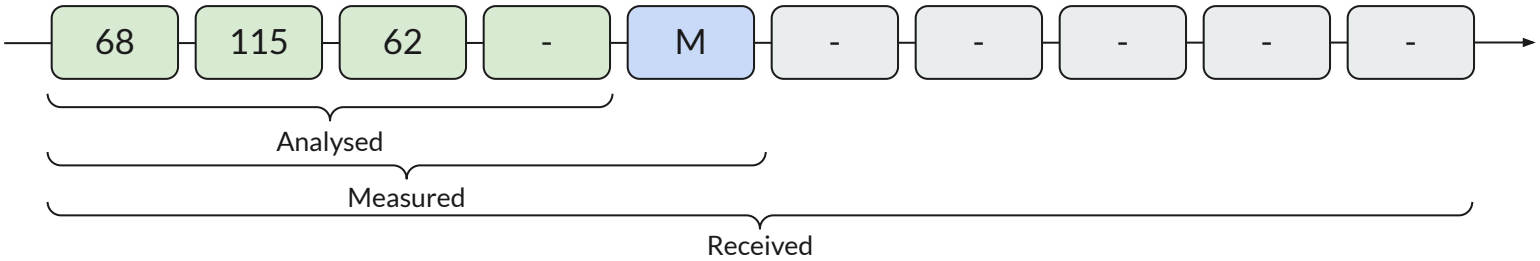
Photosensor WG meeting - 17 Dec 2024

Introduction

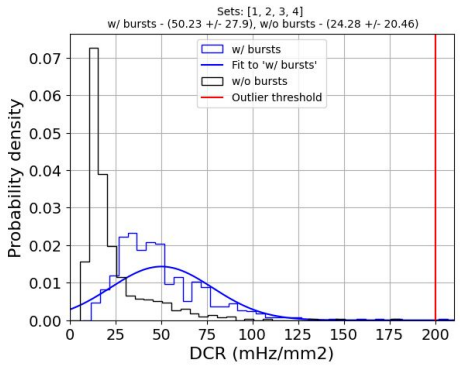
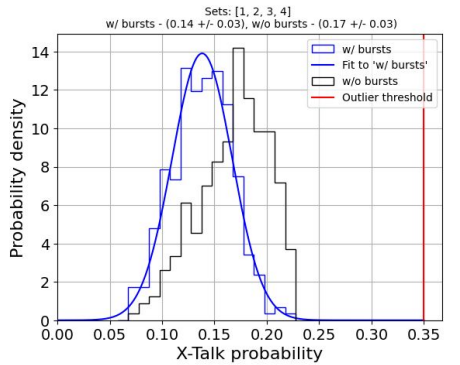
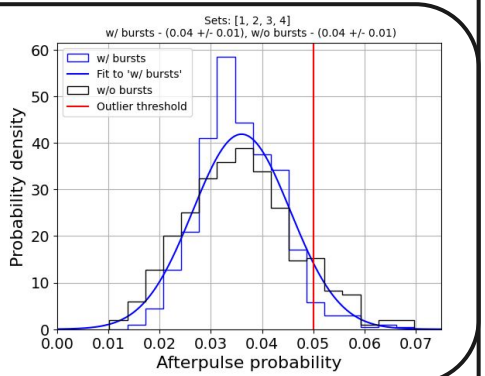
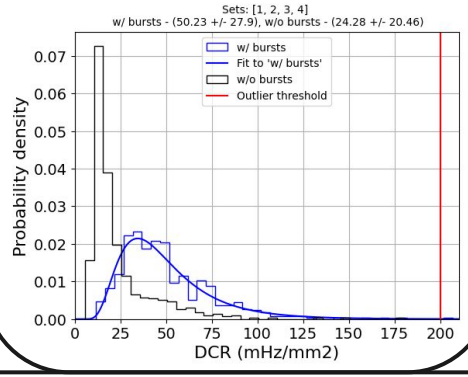
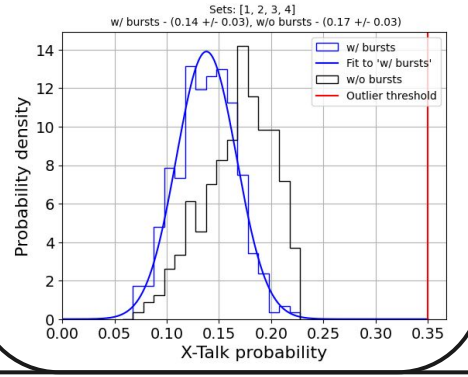
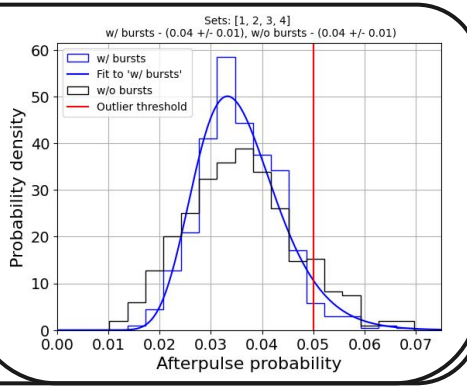
- 5 trays have been measured so far
- The first three trays (68, 115 and 62) have already been analysed and presented

  Results from tray 68 (set 1), Photosensor WG meeting on 2024/02/13 - https://indico.fnal.gov/event/63323/
  Results from tray 68 (set 1), Photosensor WG meeting on 2024/02/27 - https://indico.fnal.gov/event/63509/
  Results from tray 115 (set 2), Photosensor WG meeting on 2024/05/07 - https://indico.fnal.gov/event/64609/
  Results from tray 62 (set 3), Photosensor WG meeting on 2024/05/07 - https://indico.fnal.gov/event/66372/

- The fourth tray contains a mixture of boards from different trays. From now on, we will refer to the former-trays as *sets*.
- Although we have used the results from the analysis of the fourth set in this presentation, we have not devoted a particular presentation to show them yet. We will do so in coming photosensor meetings.
- In this presentation we show the results of an statistical study performed to assess the number of SiPMs which we need to measure in order to achieve a certain relative error in the statistical characterization of the DCR, XTP and APP for the full HPK production of FD1

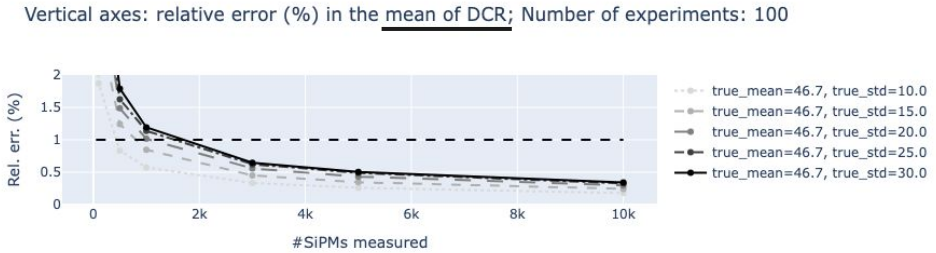


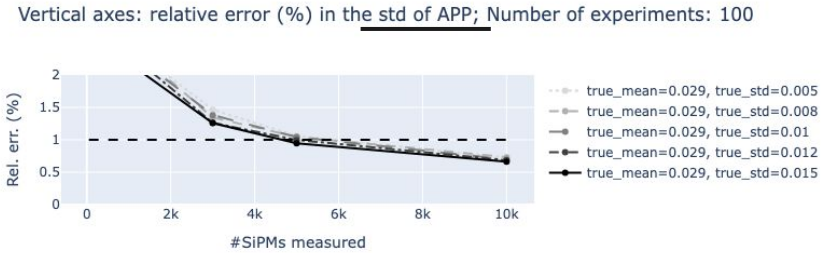
DCR, XTP and APP distributions so far (sets 1, 2, 3 & 4)

	DCR	XTP	APP
Normal fit			
Lognormal fit			

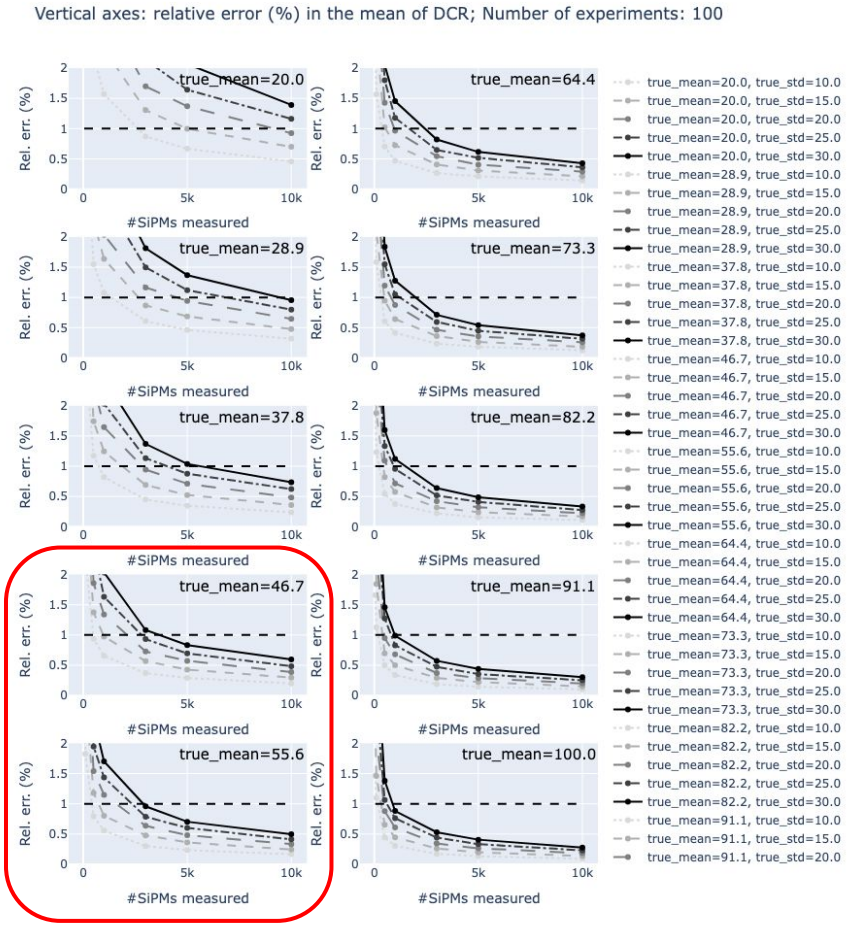
Procedure

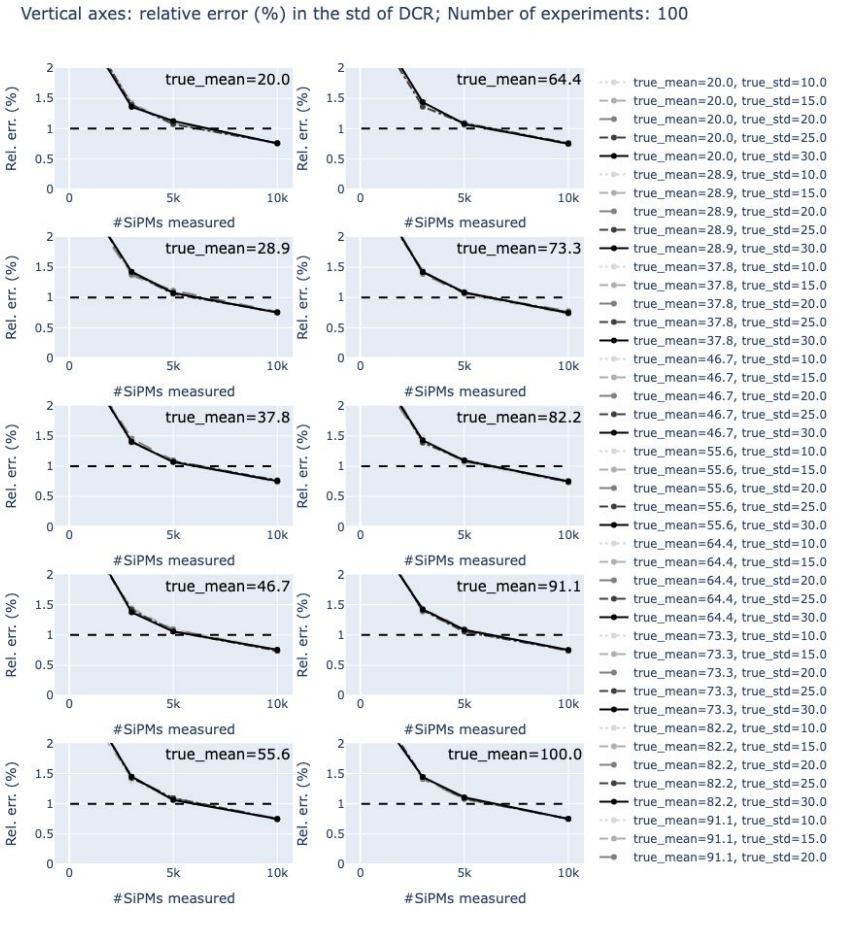
- For every distribution in `('normal', 'lognormal')`:
  - For every magnitude in `('DCR', 'XTP', 'APP')`:
    - Fit the chosen distribution to the histogram of the chosen magnitude using our results from the first four trays
    - Compute a set of `mean`-values and `sigma`-values covering a vicinity of the fitted `mean` and `sigma`
    - For every `(mean, sigma)` pair:
      - For every number-of-SiPMs, `N`, in `(50, 100, …, 5000, 10000)`:
        - Repeat `100` times:
          - Sample the fixed distribution with the fixed `(mean, sigma)` pair `N` times
          - Histogram the resulting samples and fit them to a distribution of the chosen kind
          - Compute the fit error for the fit `mean` and `sigma`
          - Make it relative to the (true) fixed `mean` and `sigma` of the underlying distribution
        - Compute the average relative fit errors for `mean` and `sigma` over the `100` experiments





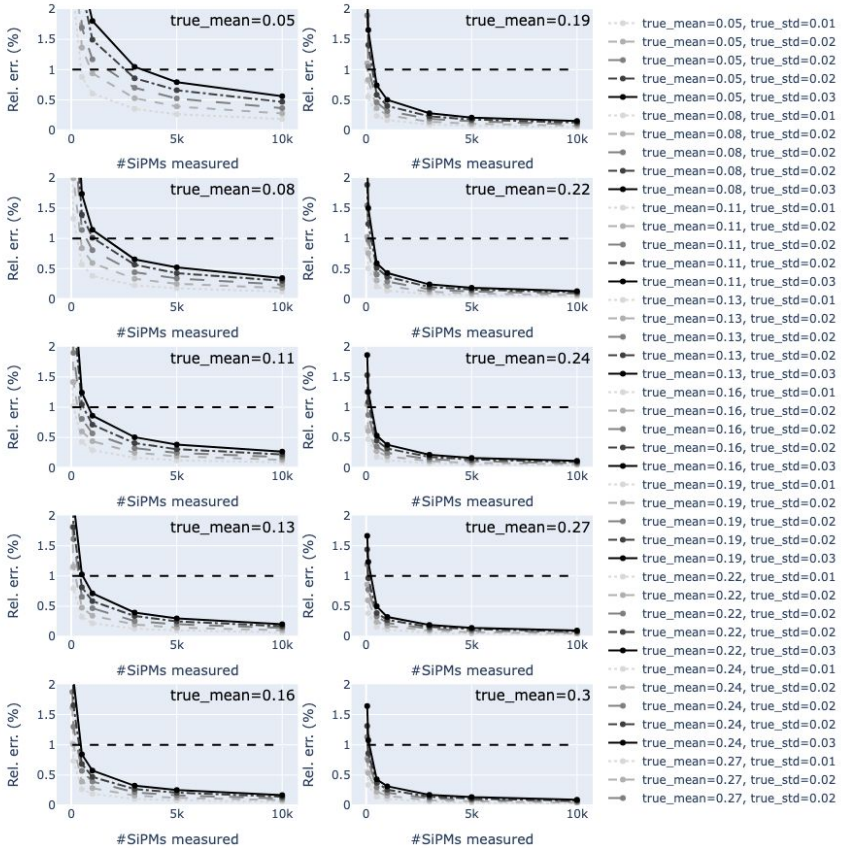
DCR (normal fit)



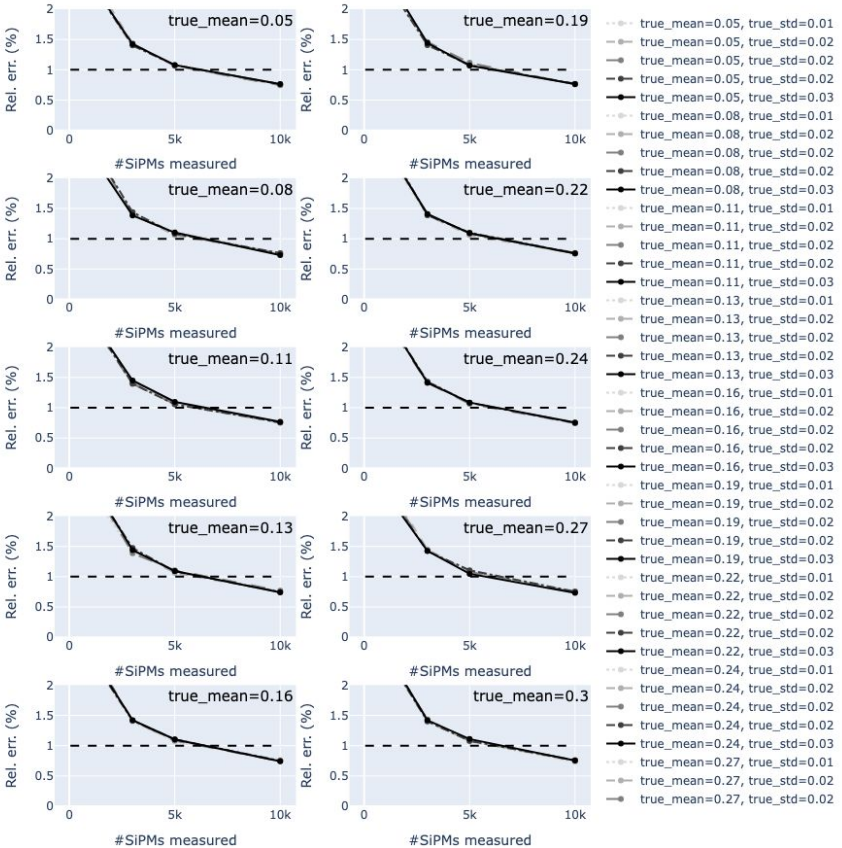


XTP (normal fit)

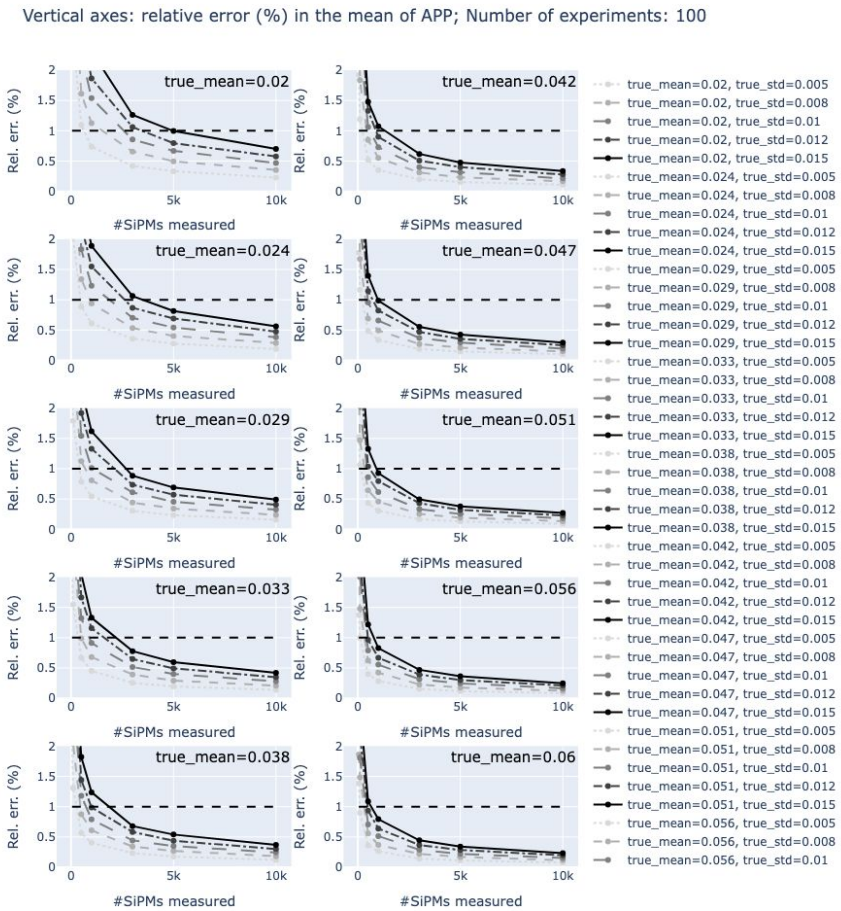
Vertical axes: relative error (%) in the mean of XTP; Number of experiments: 100

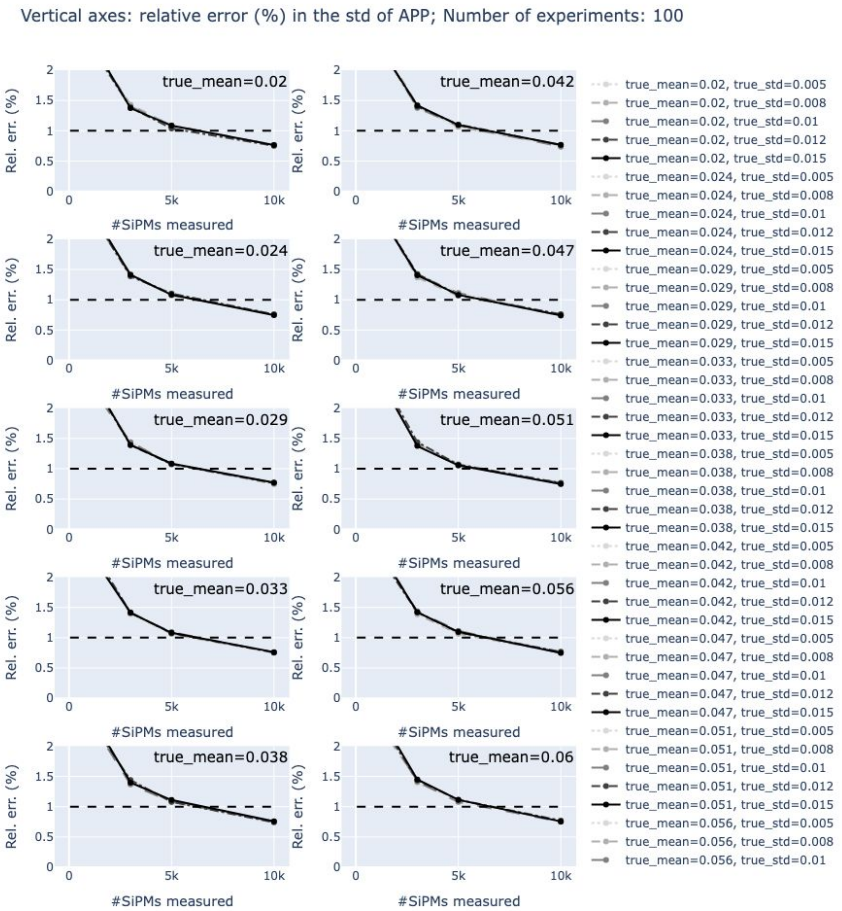


Vertical axes: relative error (%) in the std of XTP; Number of experiments: 100

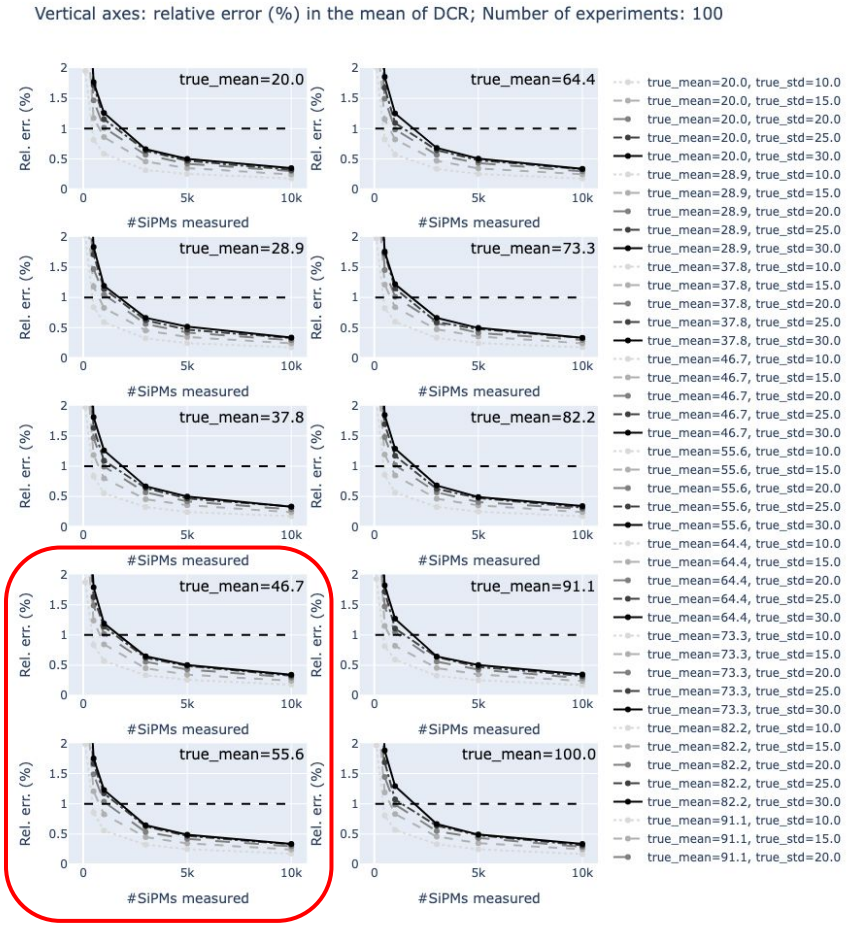


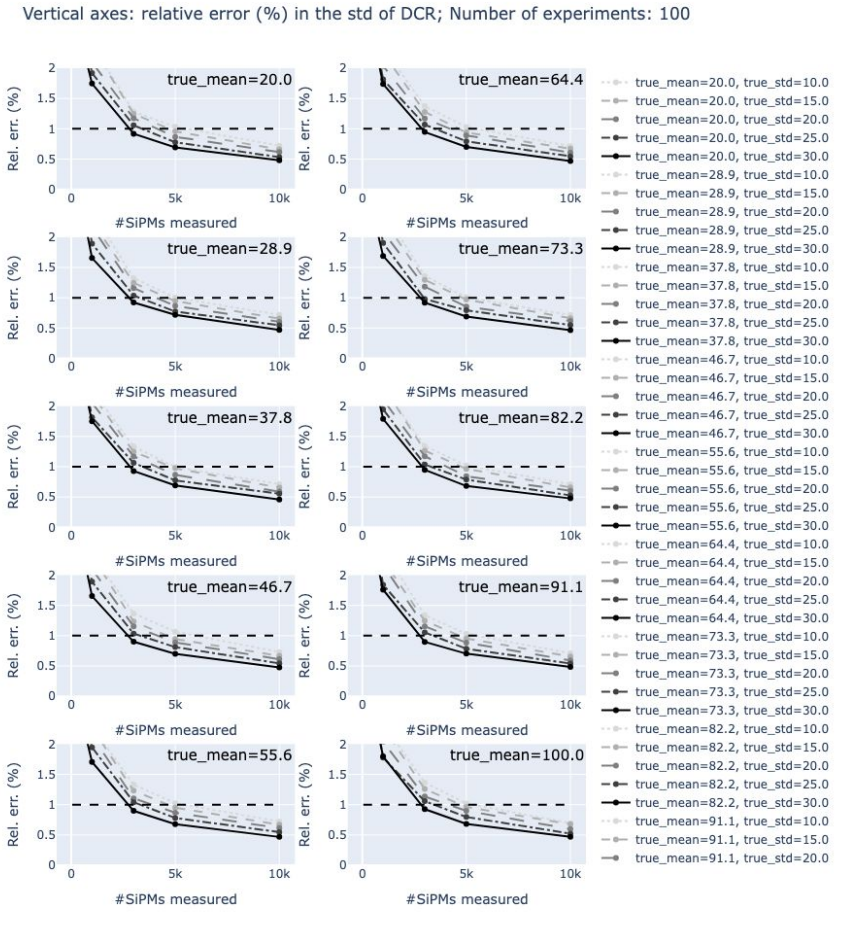
APP (normal fit)



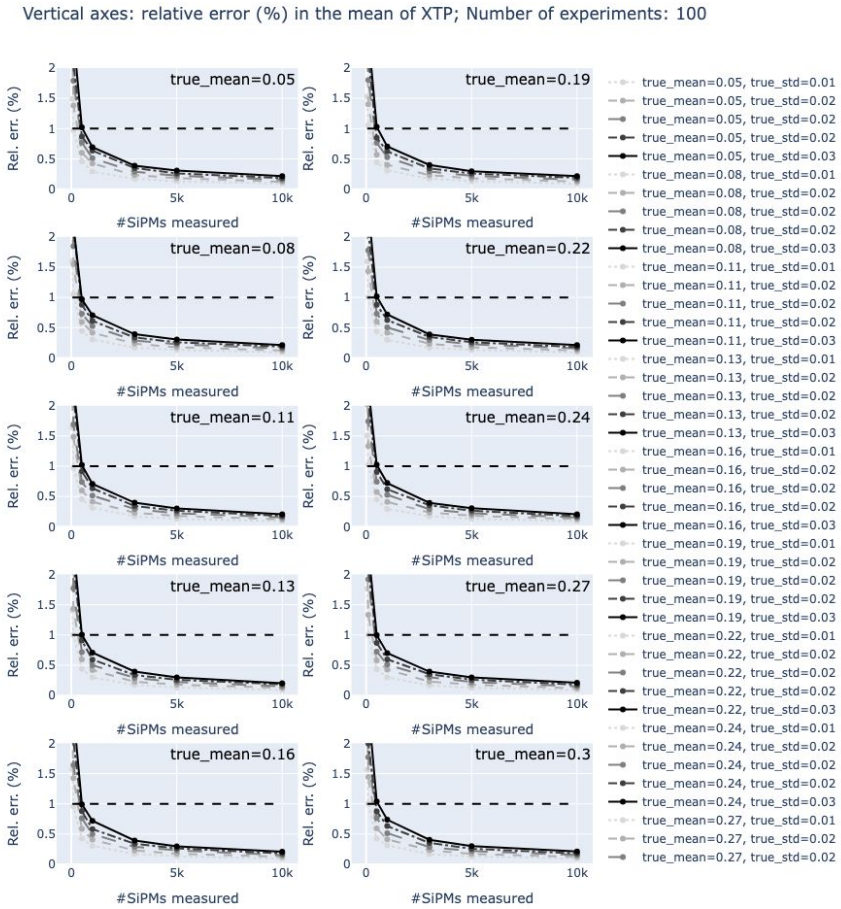


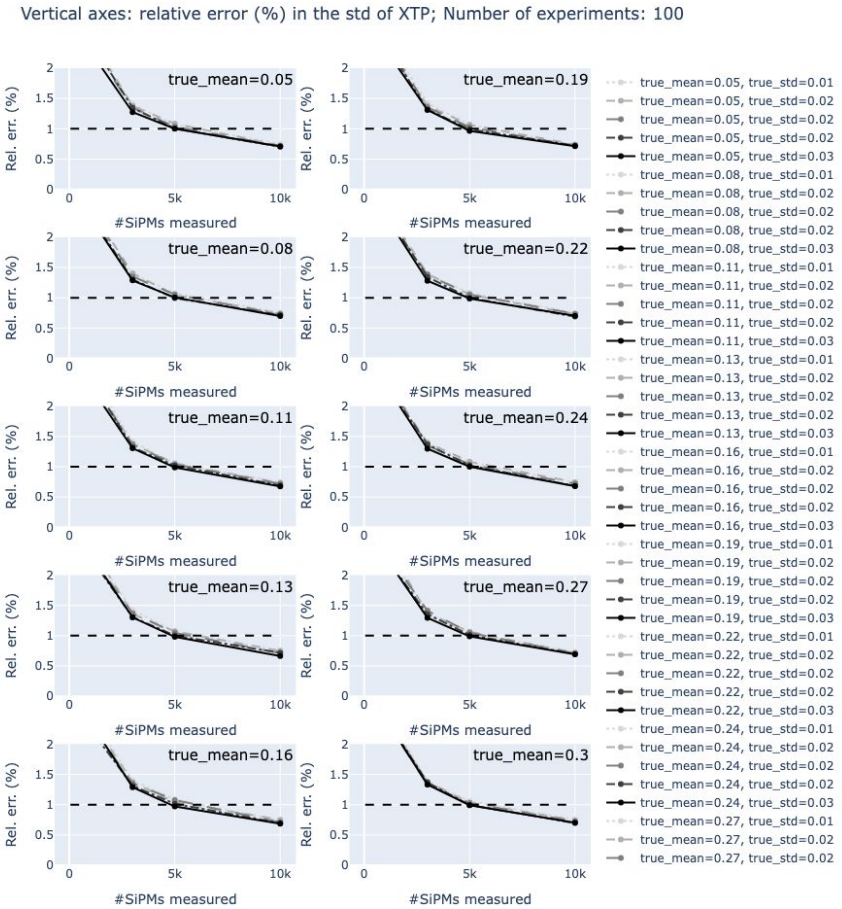
DCR (log-normal fit)



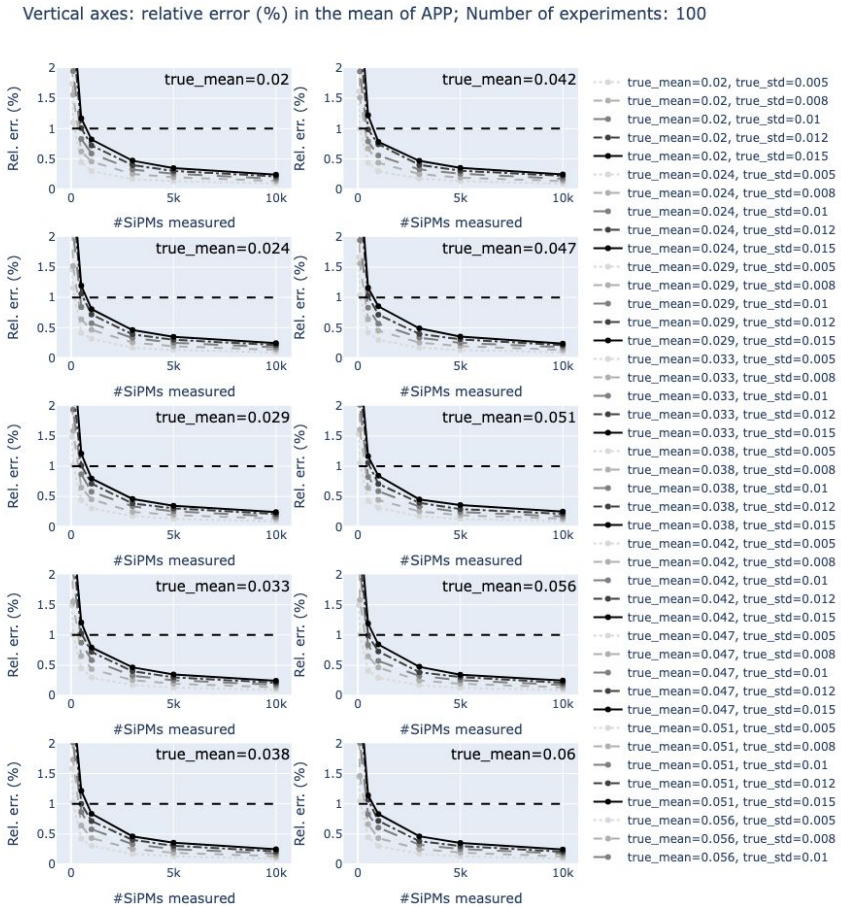


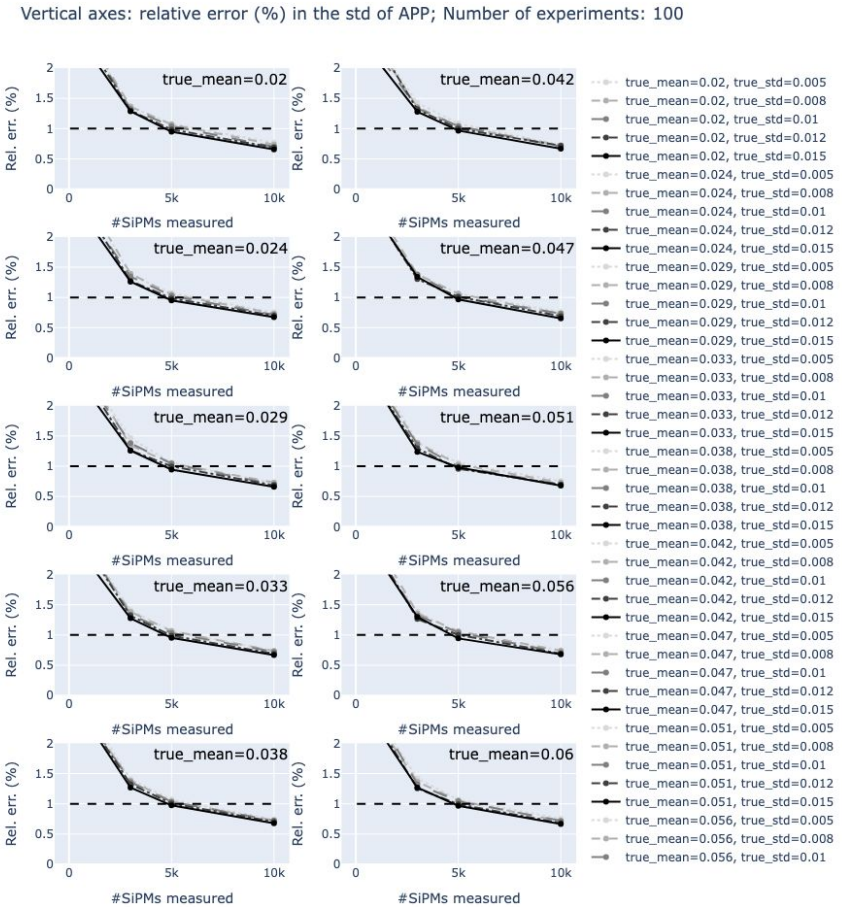
XTP (log-normal fit)





APP (log-normal fit)





How many SiPMs do we need to measure? (normal/log-normal distribution assumption)

- As far as the **mean** is concerned, the limiting factor (the one which requires a bigger number of measured SiPMs to achieve a fixed relative error) is the DCR. Assuming a DCR of ***~50 mHz/mm2 mean with a 28 mHz/mm2 sigma*** (typical value from sets 1, 2, 3 and 4) we would need to measure 3000 SiPMs to achieve a ~1% relative error in the mean.

- The relative error for the **sigma** seems *almost* unaffected by the true mean and sigma. In whichever case, we would need to measure 3000 SiPMs to achieve a ~<1.5% relative error, and 5000 SiPMs to achieve a ~1% relative error.

3000 SiPMs add up to a ~1% of the FD1 SiPMs. Equivalently, they are 25 trays (so far we have received 10 trays, from which Carlos has measured 5 and I have analysed 4)

From *DUNE TDR Vol. I: Introduction to DUNE*

An SP module is instrumented with three module-length (58.2 m) anode planes constructed from 6 m high by 2.3 m wide anode plane assemblies (APAs), stacked two APAs high and 25 wide, for 50 APAs per plane, and 150 total. Each APA consists of an alumninum frame with three layers of active wires, strung at angles chosen to reduce ambiguities in event reconstruction, that form a grid on each side of the APA. The relative voltage between the layers is chosen to ensure

Novel silicon photomultiplier (SiPM) based photon detectors (PDs) called ARAPUCAs[4] are placed in the inactive space between the innermost wire planes of the APAs, installed through slots in the APA frame. Each APA holds ten PD modules, for a total of 1500 per SP module. Of these, 500 are mounted in the APAs of the central anode plane and collect light from both directions, and 500 each are mounted in the outer APA frames and collect light from only the inner-facing direction.

48 SiPMs/supercell x 4 supercells/PD module x 10 PD modules/APA x 50 APAs/plane x 3 planes/FD1 = **288000 SiPMs/FD1**

Summary and further questions

- The measured DCR distribution is better fit by a lognormal PDF rather than a normal one. Although less significant, XTP and APP also show heavier tails towards bigger values. For the moment we lack a fundamental reason to explain this.

- Based on the 480 SiPMs measured and analyzed in Valencia so far, we estimate that **in order to characterize the DCR, XTP and APP distributions within a ~1% error for the full HPK FD1 production** (without batch distinction) **we need to measure 3000** (HPK) **SiPMs.** This is our current baseline goal.

- **Additionally, do we want to discriminate between batches?**
  - If so, how do we define a production batch?
    - Can we track production batches? I.e. SiPMs that were manufactured simultaneously
    - If that's not the case, then do we want to define a batch as the 1600 boards that are sent by HPK in the same delivery?
      - Is this definition useful from an sipm-characterization point of view?

- Do we want to discard entire batches based on the measurements?
  - If so, what should be the threshold for the fraction of SiMPs not fulfilling requirements in order to discard a batch?

- Do we want to discard individual boards based on measurements?
  - In this case, notice that our results would not be representative of the accepted sample (we'll be only measuring a 1% of the HPK production)