Electronics validation analysis
Updates from Genoa

A. Caminata, L. Di Noto, S. Repetto

GRAIN Meeting

6 September 2024

Our goals

- **Simulated data**: we simulated photon scintillation emission events in both LAr and in Xenon-doped Argon. Each ROOT output file contains 120 spill events

(/storage/gpfs_data/neutrino/users/ldn/Samples/Spill_Xe/Spill_opt3_STT1_*/output/sensor_all_*.root) ✓

(/storage/gpfs_data/neutrino/users/ldn/Samples/Spill_Ar/Spill_opt3_STT1_*/output/sensor_all_*.root) IN PROGRESS

- **Goal**: we want to select most critical and significative samples and validate the architecture on those samples

Selected samples

1. Channels that need a high number of integration windows for some channels

2. Channels with the highest number of photons within an integration window

3. Channels with the highest number of photons within 20 ns from the true interaction time*

4. Channels with the lowest time between the interaction time* and the previous detected photon

Electronics validation

1. For validating the architecture with 2 Wilkinson and conversion time of 40-50 ns

2. For optimizing/validating the dynamic range

3. Is the electronics capable of detecting such a high number of photons in a small time window?

4. Which amount of channels per interactions have not the right t_0, due to previous photons

*The interaction time is given by true information from MonteCarlo, if a peak of at least 3 photons is detected in the channel

Criterion 1

Events that need a **high number of integration windows** for some channels

New:
- Results as a function of the clock period
- **Scale = 20 us. Improving the scale we expect a better reconstruction at low number of photons**
- **If clk period/n (n=4,8), I_{src} = n*I_{src} (n=4,8)**

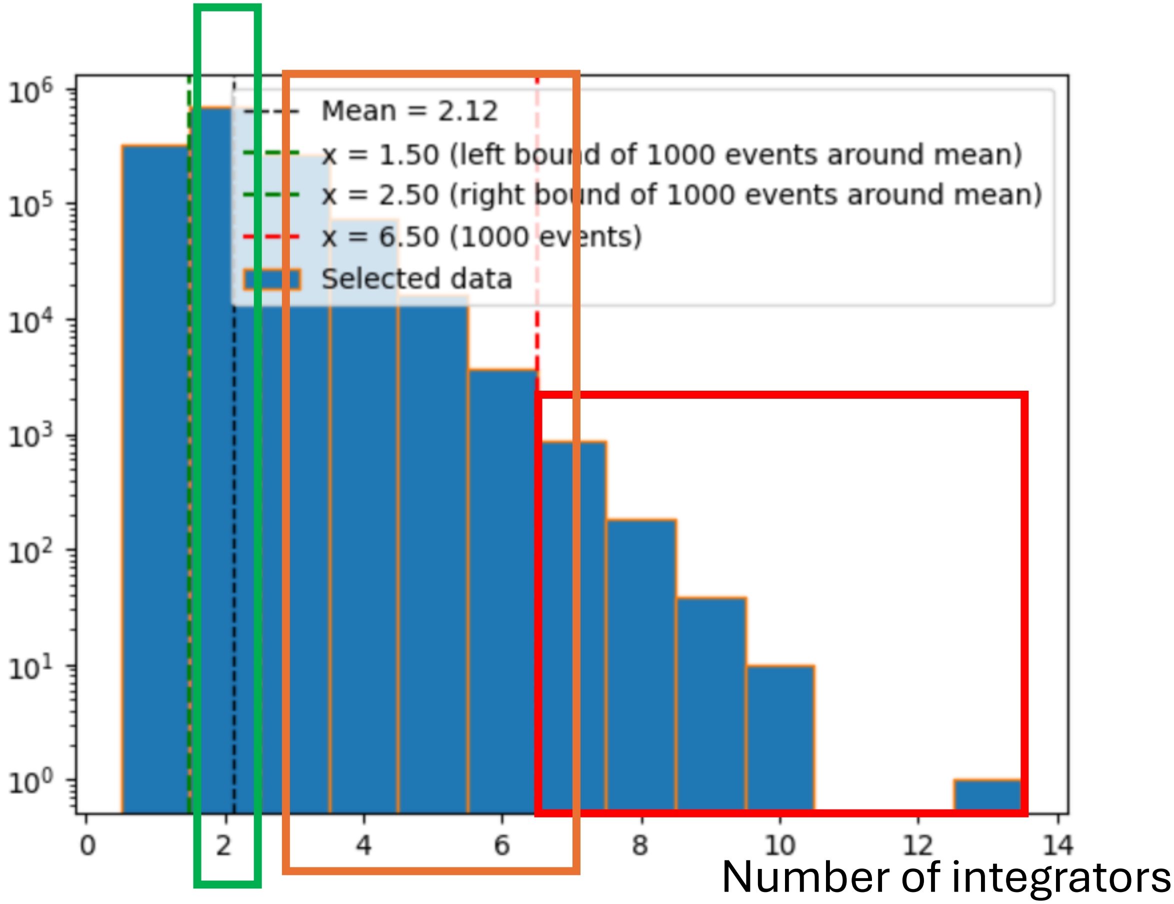
Selected samples: Events that need a high number of integration windows for some channels

Guidelines:

1. Very good reconstruction of the number of photons from the integrated charge for the channels that require 2 integration windows
2. Good reconstruction of the number of photons from the integrated charge for the channels that require between 3 and 7 integration windows

We also select the worst and pathological cases (i.e. the channels that require at least 7 integration windows) but we don't ask for a good reconstruction of the number of photons

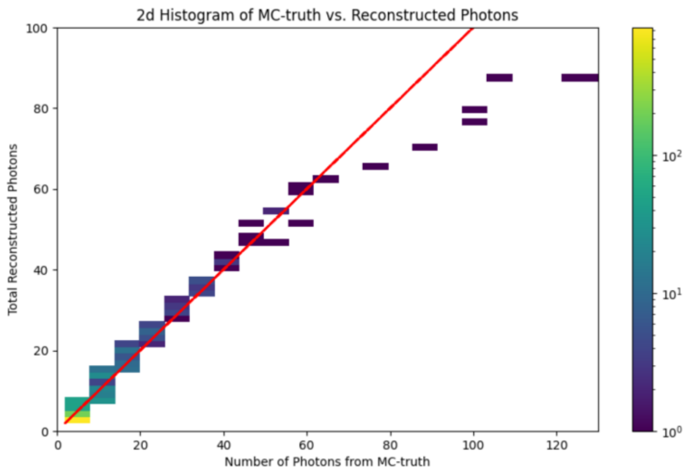
Xenon-doped Ar
720 spill



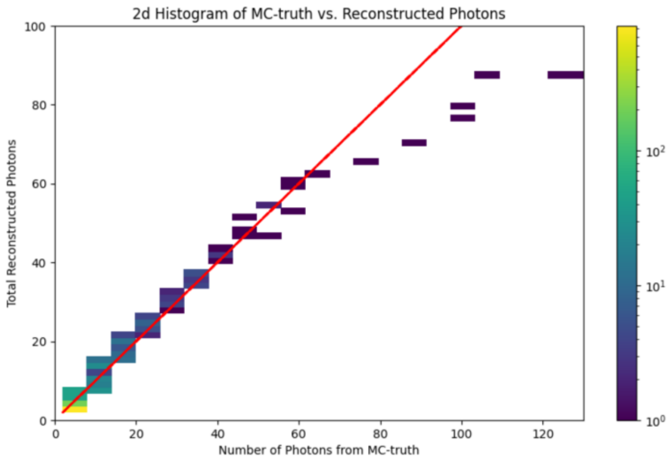
Selected samples: Events that need **about 2 integration windows** for some channels

Nintegrators = 2

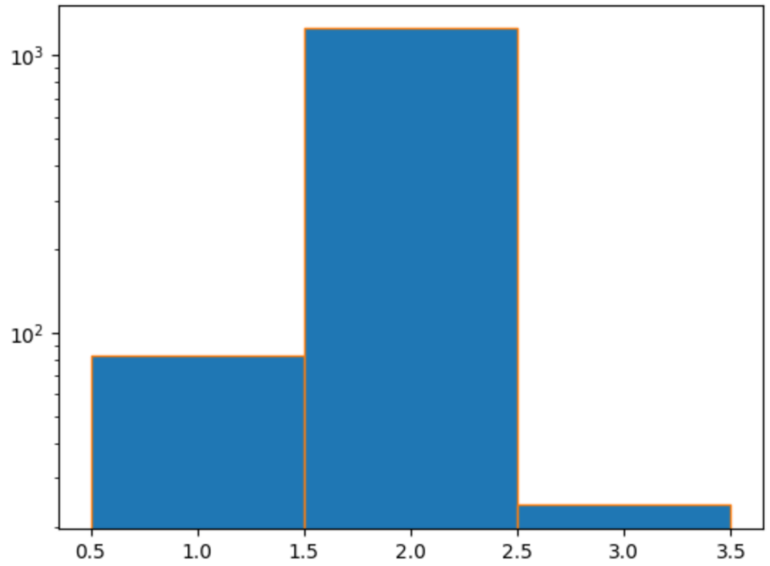
Xenon-doped Ar
720 spill



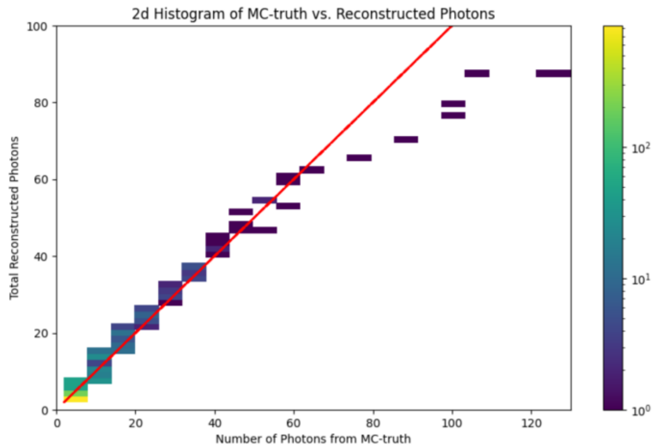
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of integrators from Torino's simulation



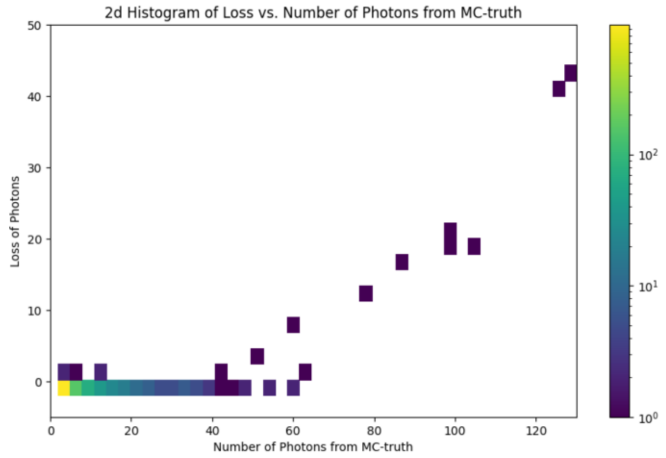
1/8 Clock period = 0.4166 ns

The reconstruction is **accurate until 60 photons**.
No noticeable improvement by changing the clock period

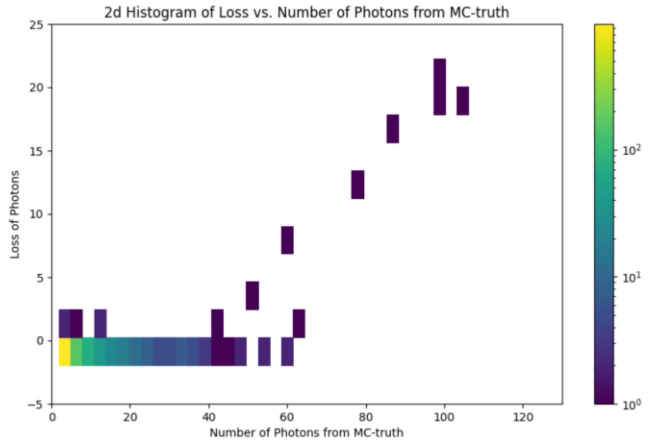
Selected samples: Events that need **about 2 integration windows** for some channels

Xenon-doped Ar
720 spill

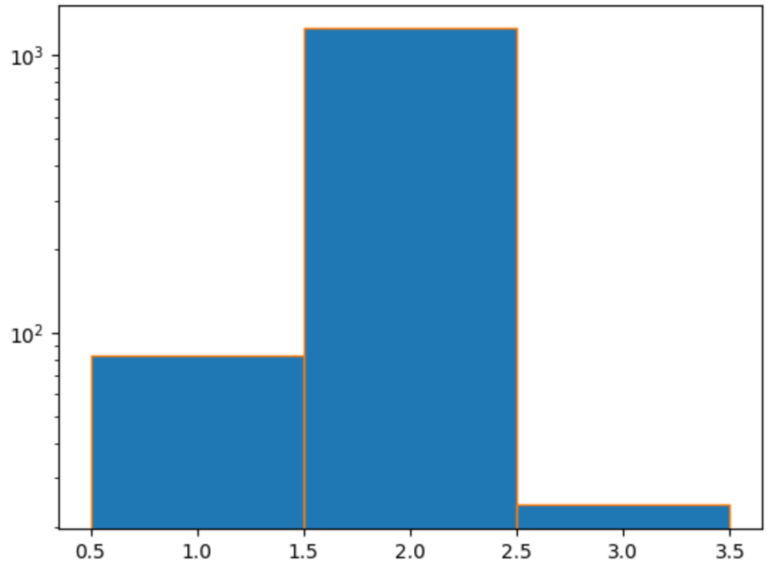
Nintegrators = 2



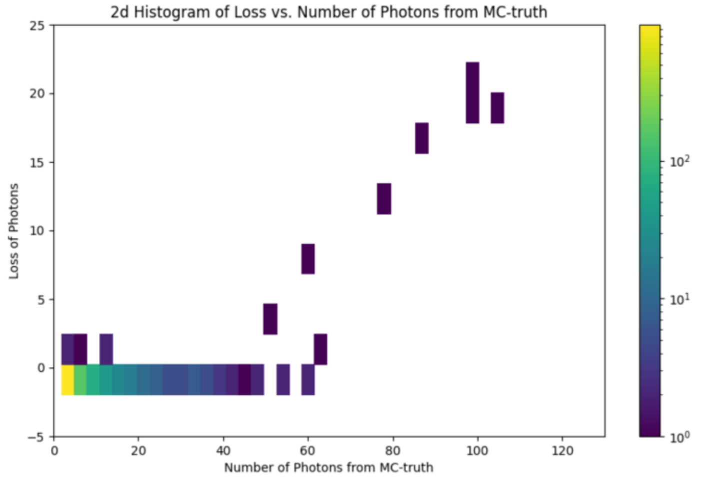
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of integrators from Torino's simulation



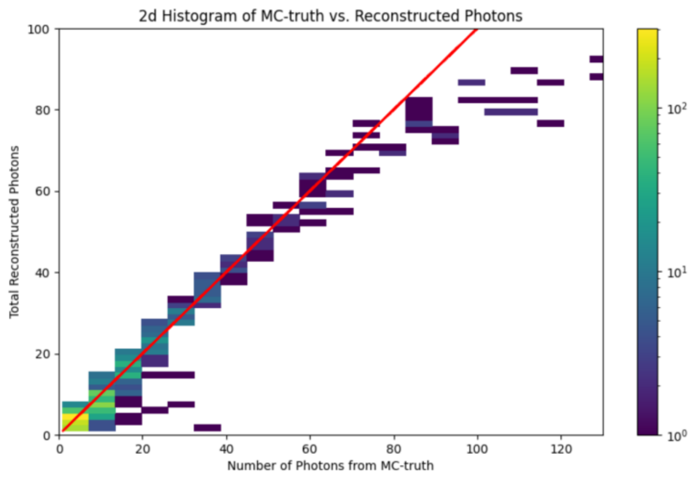
1/8 Clock period = 0.4166 ns

The reconstruction is **accurate until 60 photons**.
No noticeable improvement by changing the clock period

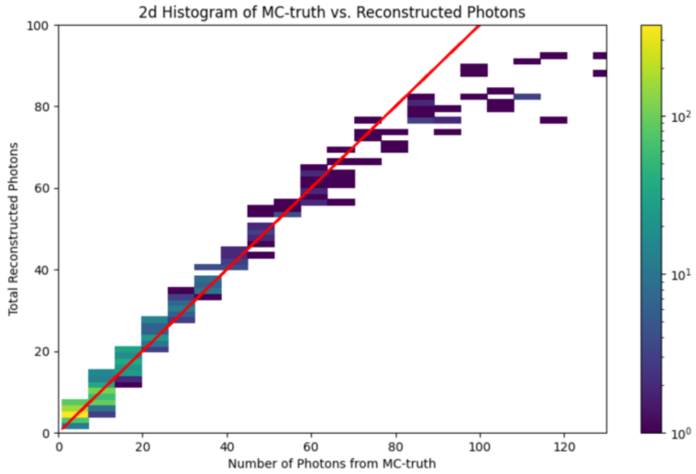
Selected samples: Events that need **between 3 and 7 integration windows** for some channels

Xenon-doped Ar
720 spill

3 < Nintegrators < 7

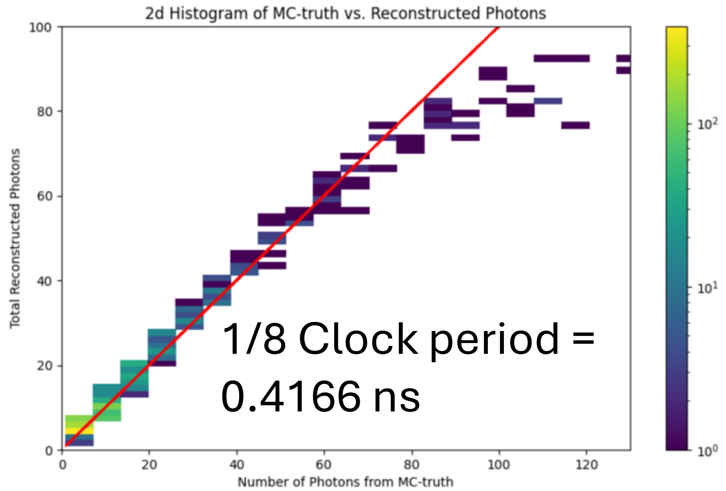


Clock period = 3.333 ns

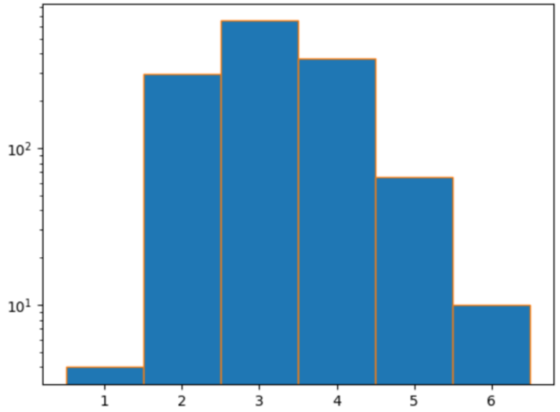


¼ Clock period = 0.833 ns

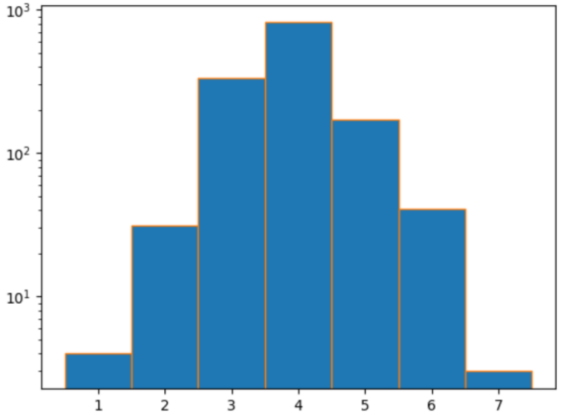
Only with ¼ and 1/8 clock period the reconstruction is **acceptable until 60-80 photons**.
Lowering the clock period improves the reconstruction at low energies.
No improvement in high-energy reconstruction.
¼ clock period is already satisfying



1/8 Clock period = 0.4166 ns



Number of integrators from Torino's simulation for clock period = 3.333 ns



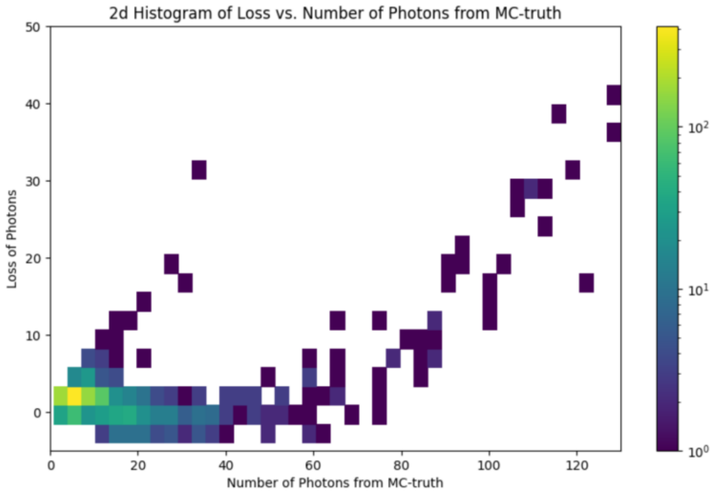
Number of integrators from Torino's simulation for clock period = 0.4166 ns

THIS SAMPLE IS IMPORTANT FOR THE VALIDATION

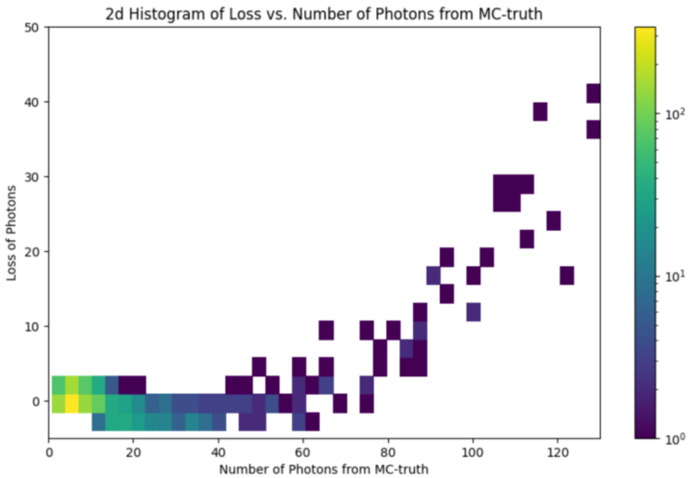
Selected samples: Events that need **between 3 and 7 integration windows** for some channels

Xenon-doped Ar
720 spill

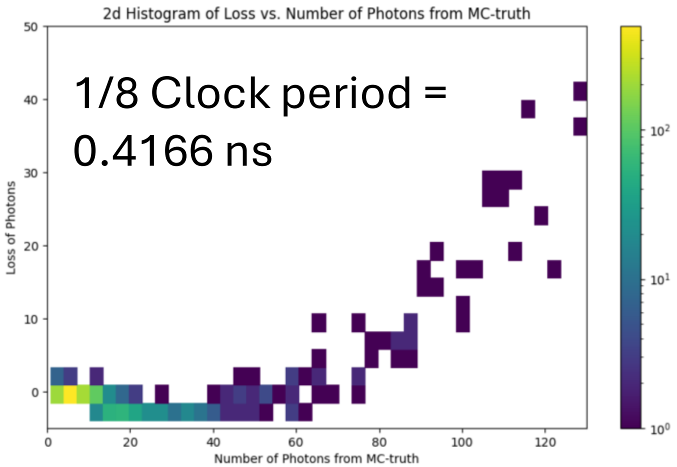
3 < Nintegrators < 7



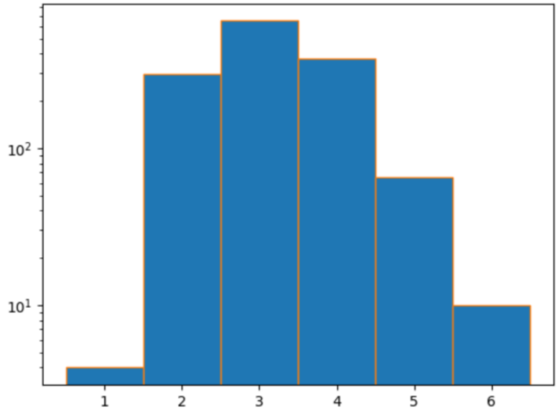
Clock period = 3.333 ns



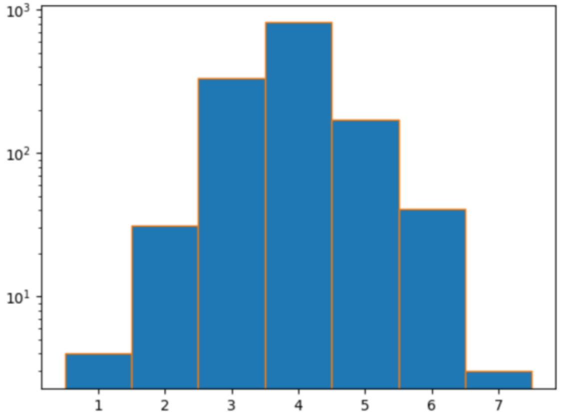
¼ Clock period = 0.833 ns



1/8 Clock period = 0.4166 ns



Number of integrators from Torino's simulation for clock period = 3.333 ns



Number of integrators from Torino's simulation for clock period = 0.4166 ns

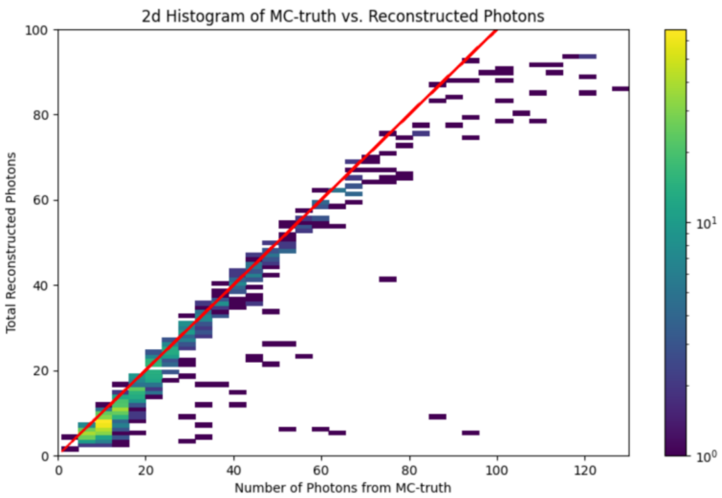
Only with ¼ and 1/8 clock period the reconstruction is **acceptable until 60-80 photons**.
Lowering the clock period improves the reconstruction at low energies.
No improvement in high-energy reconstruction.
¼ clock period is already satisfying

THIS SAMPLE IS IMPORTANT FOR THE VALIDATION

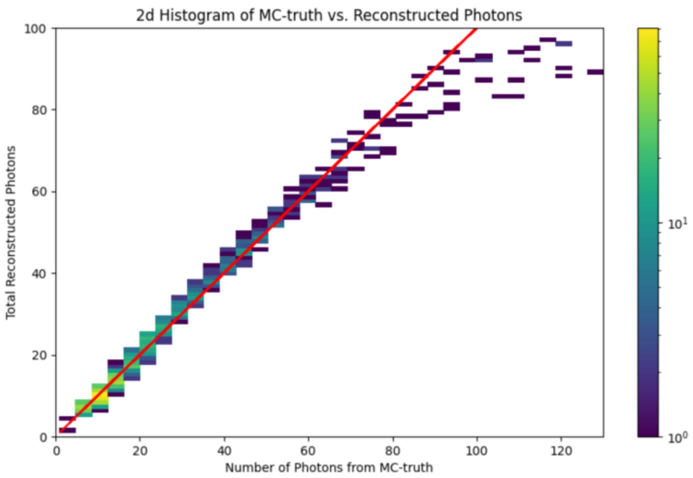
Selected samples: Events that need **more than 6 integration windows** for some channels

Xenon-doped Ar
720 spill

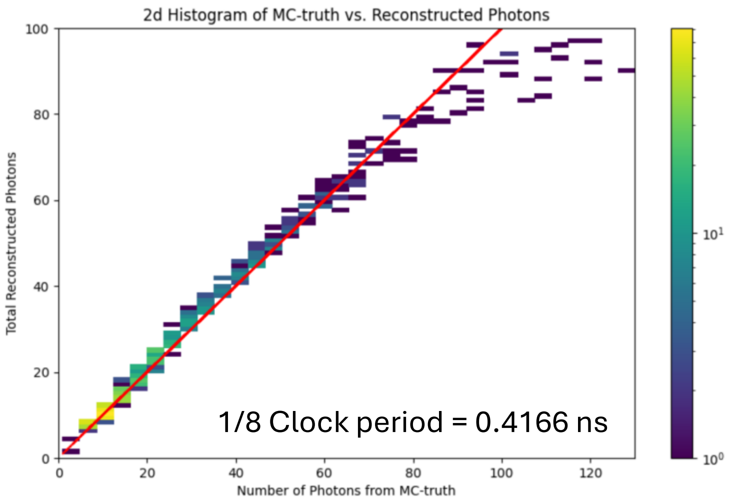
Nintegrators > 6



Clock period = 3.333 ns

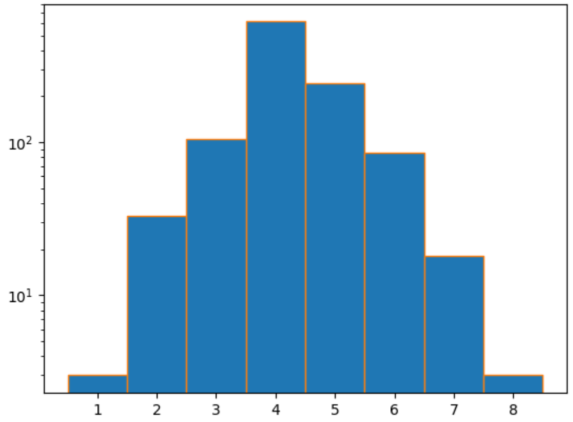


¼ Clock period = 0.833 ns

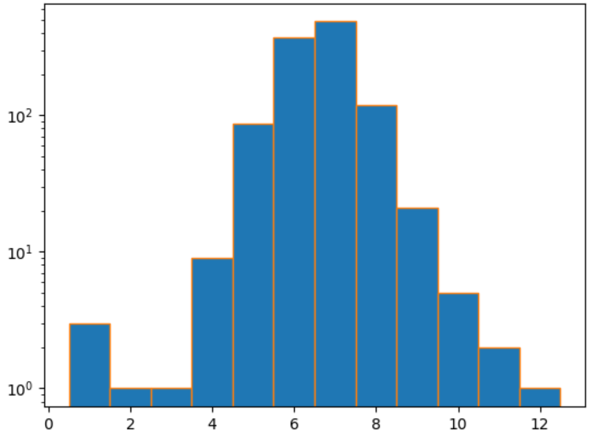


1/8 Clock period = 0.4166 ns

The reconstruction is **good until 70 photons**.
Lowering the clock period improves the reconstruction at low energies.
¼ clock period is already satisfying



Number of integrators from Torino's simulation for clock period = 3.333 ns



Number of integrators from Torino's simulation for clock period = 0.4166 ns

Criterion 2

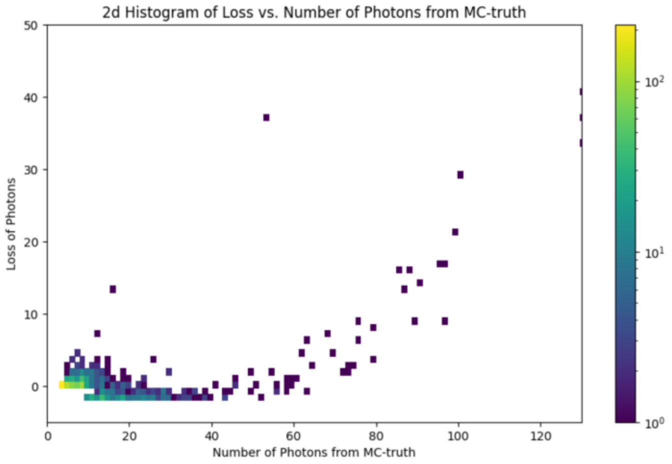
Channels with the **highest number of photons within an integration window**

New:
- Results as a function of the clock period
- **Scale = 20 us. Improving the scale we expect a better reconstruction at low number of photons**
- **If clk period/n (n=4,8), I_{src} = n*I_{src} (n=4,8)**

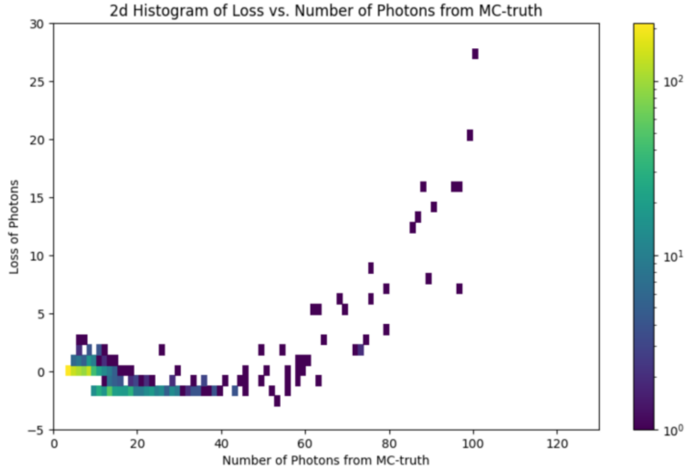
Selected samples: Events with **number of photons between 2 and 100 within an integration window**

Xenon-doped Ar
720 spill

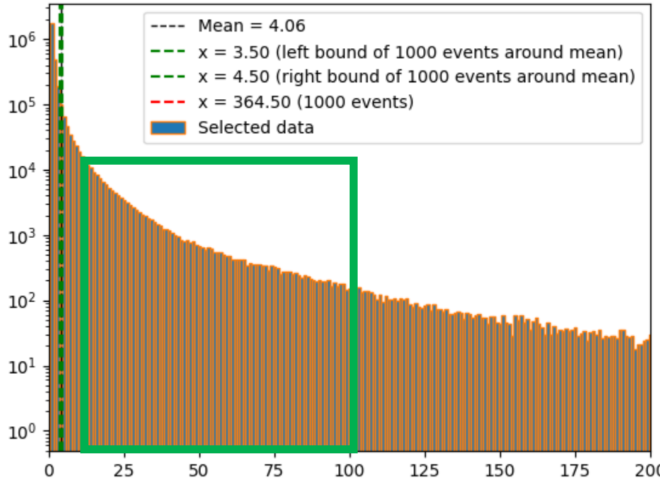
2 < Nphotons < 100



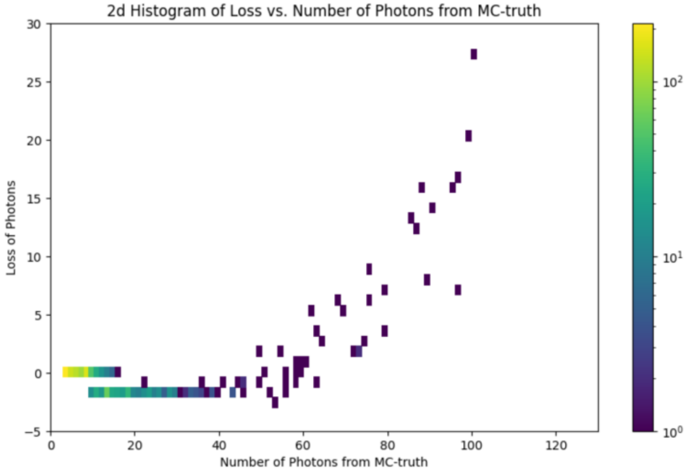
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of photons



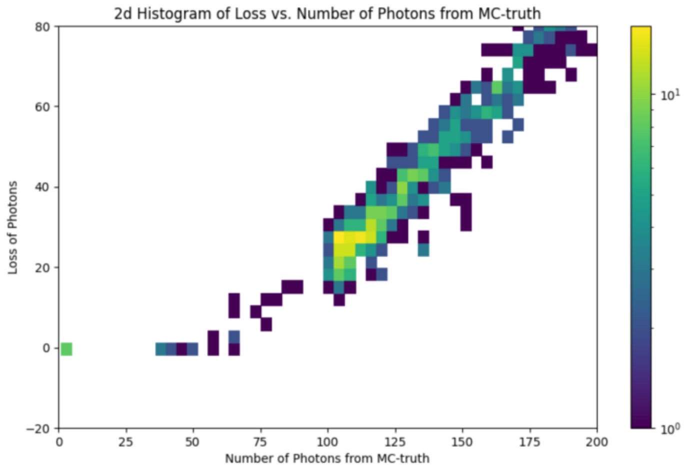
1/8 Clock period = 0.4166 ns

With ¼ clock period the reconstruction is good until **60 photons**. With 1/8 the reconstruction is slightly better. Lowering the clock period improves the reconstruction at low energies but there's always an overestimation between 10 and 60 photons

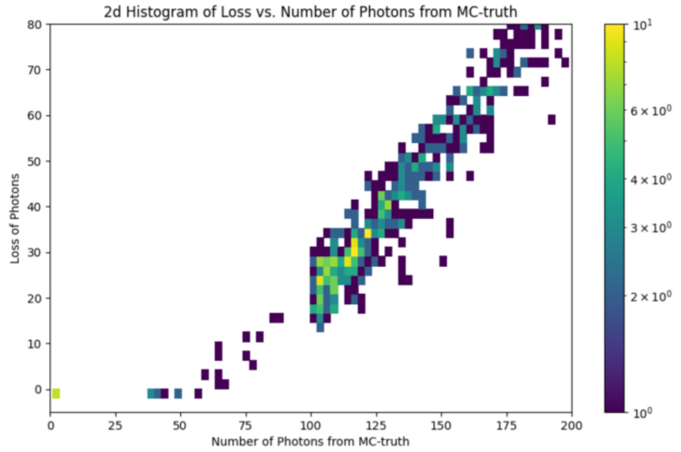
Selected samples: Events with **more than 100 photons within an integration window**

Xenon-doped Ar
720 spill

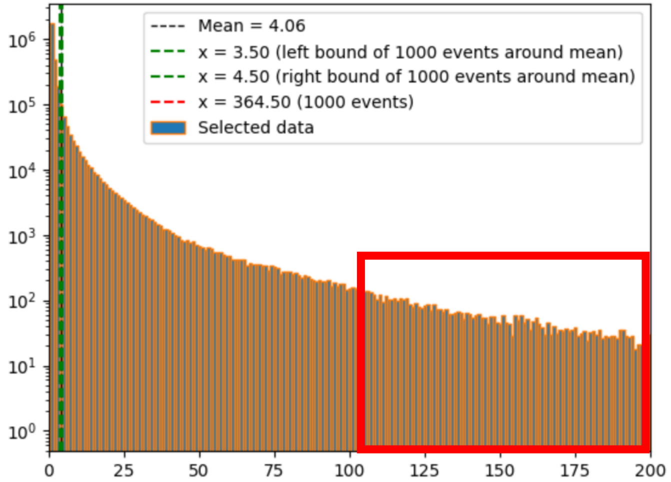
Nphotons > 100



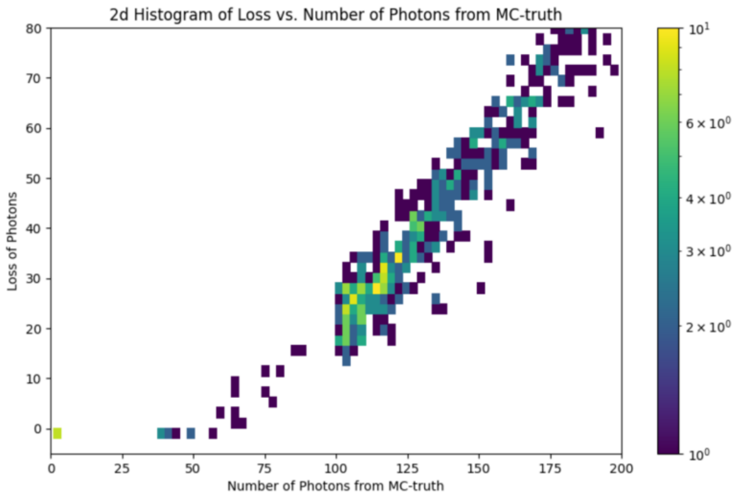
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of photons



1/8 Clock period = 0.4166 ns

Even changing the I_{src} current does not result in a good reconstruction of photon numbers greater than 70/80

Criterion 3

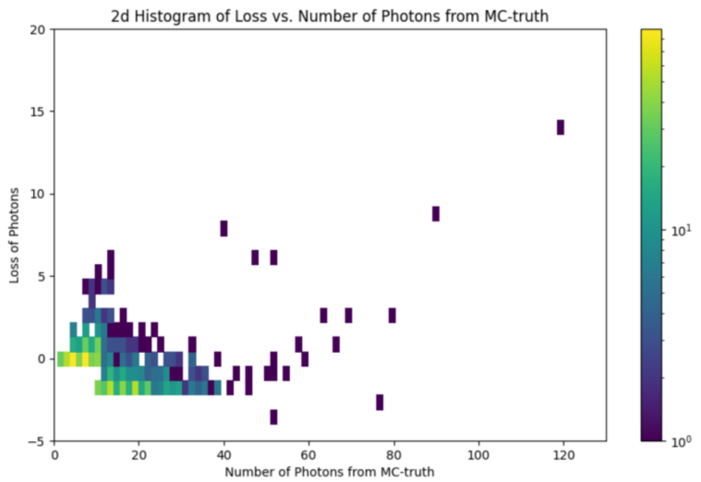
Channels with the highest number of photons within 20 ns from the true interaction time

New:

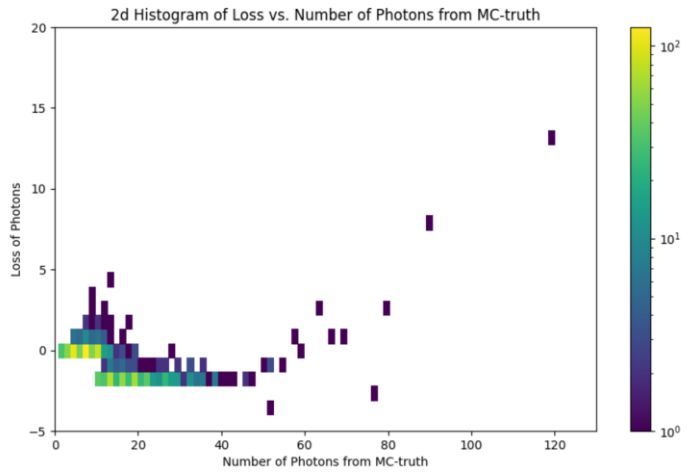
- Results as a function of the clock period
- **Scale = 20 us. Improving the scale we expect a better reconstruction at low number of photons**
- **If clk period/n (n=4,8), I_{src} = n*I_{src} (n=4,8)**

Selected samples: Channels with **a number of photons between 1 and 10 within 20 ns from the true interaction time**

1 < Nphotons < 10

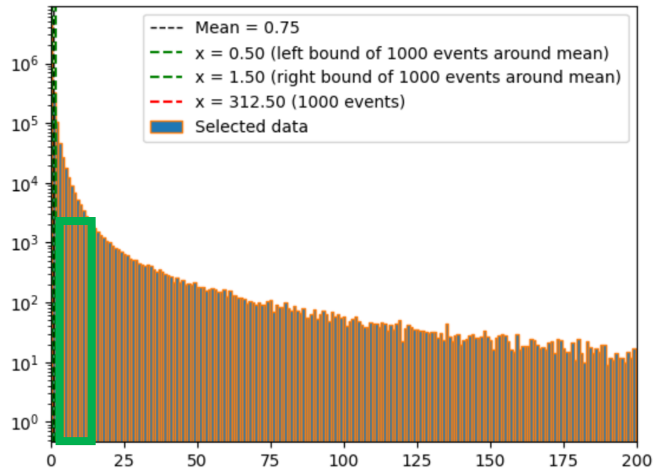


Clock period = 3.333 ns

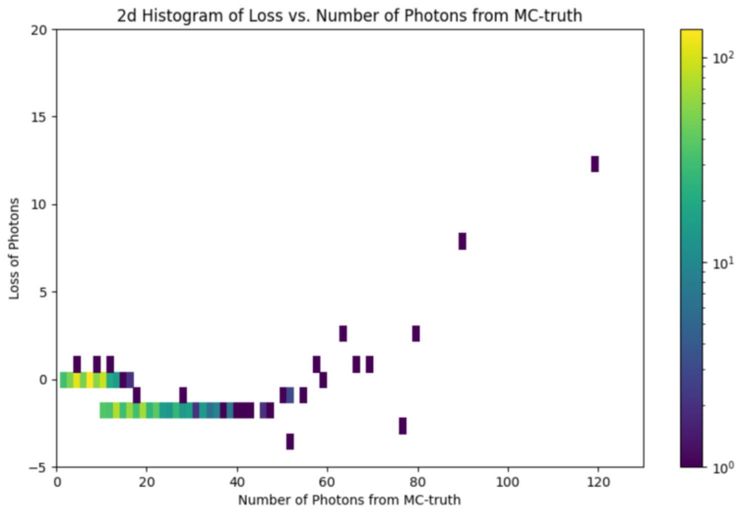


¼ Clock period = 0.833 ns

Xenon-doped Ar
720 spill



Number of photons

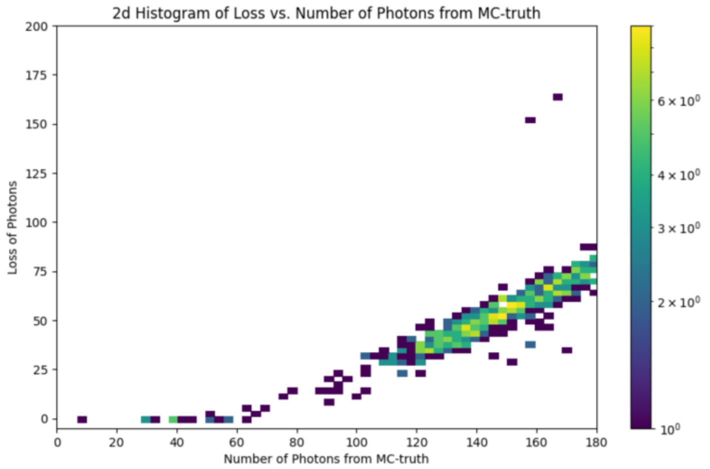


1/8 Clock period = 0.4166 ns

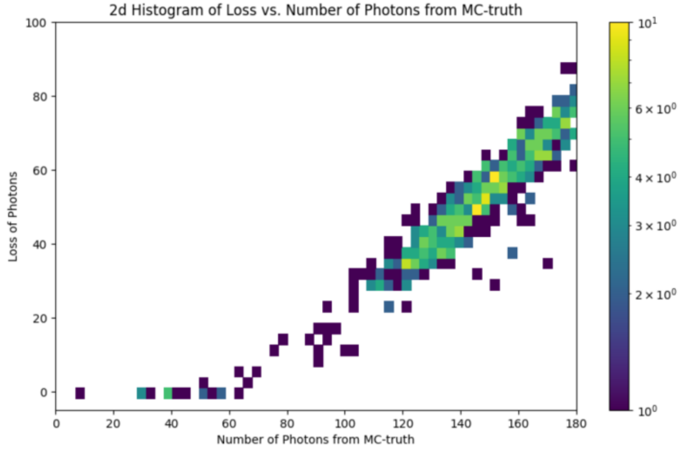
The reconstruction at low energies is good only with 1/8 clock period. There’s a good recostruction until 70 photons

Selected samples: Channels with **a number of photons greater than 80 within 20 ns from the true interaction time**

Nphotons > 80

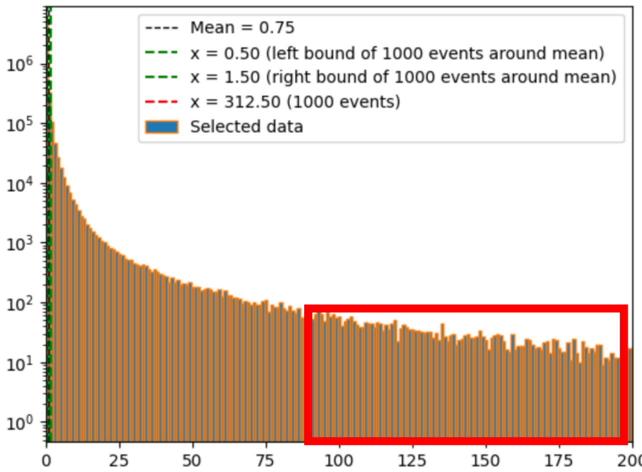


Clock period = 3.333 ns

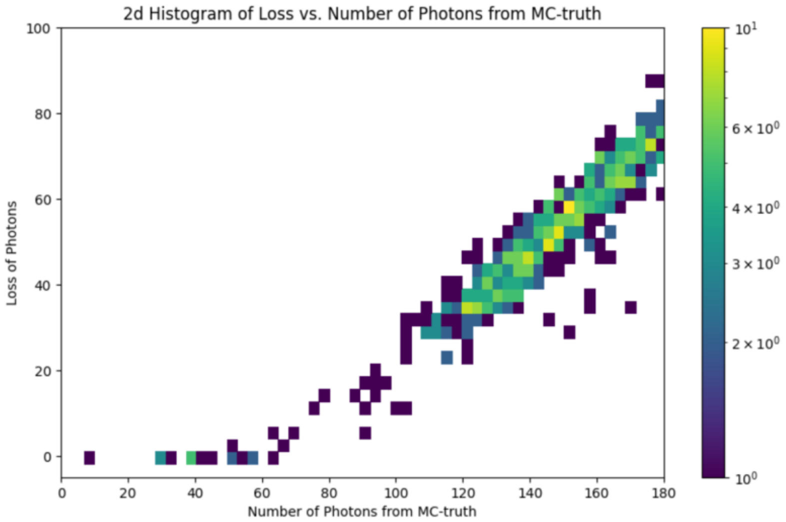


¼ Clock period = 0.833 ns

Xenon-doped Ar
720 spill



Number of photons



1/8 Clock period = 0.4166 ns

Even changing the I_{src} current does not result in a good reconstruction of photon numbers greater than 70/80

Criterion 4

Channels with the lowest time between the true interaction time and the previous detected photon

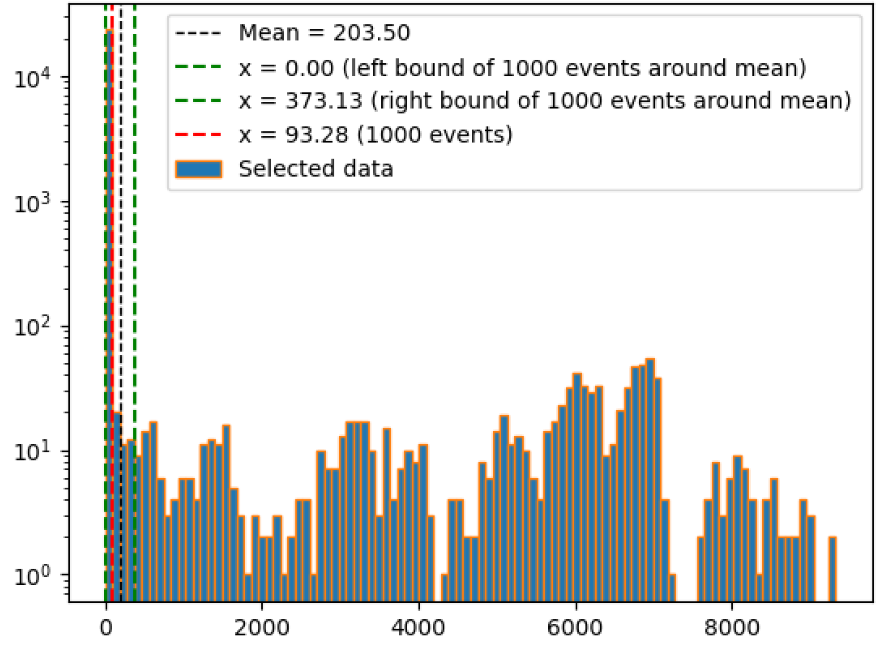
Results

dt distribution in Xenon-doped Ar
t_{slow} = 160 ns

Method used

For each channel:

- Search for the interaction: at least 3 photons within 50 ns from the t_0 of the interaction
- Save the detected time of the interaction t_{int}
- Calculate $dt = t_{int} – (t_{lastphoton}$ before the interaction)



Total entries: 29000
About 300 channels with dt < 200 ns

It's not an issue!

But we will check for the pure Argon (t_{slow} = 1600 ns)

First draft of the report

Electronics validation analysis

A. Caminata, L. Di Noto, S. Repetto

September 6, 2024

1 Introduction

This is a report of the study and analysis performed in order to validate the electronics architecture. The objective of these simulations is to understand and decide what the characteristics of the electronics architecture (produced by the INFN group in Turin) should be in order to have the best reconstruction of the number of photons detected by SiPMs due to neutrino interactions within SAND.

1.1 Simulated data

The simulated data that we use for this validation are neutrino interactions in SAND during a spill time, while the photon scintillation emission is simulated both in pure liquid Argon and in Xenon-doped liquid Argon. Each ROOT output file contains 120 spill events.
The geometry is the final one, consisting of 53 cameras, each with 1024 channels (2×2 mm^2 SiPMs).
The output of these simulations gives informations about the time and position of the photons, taking into account the quantum efficiency. In order to understand from which SiPM the photon was detected, a pixelisation was performed for the SiPM arrays. The coordinates of each pixel correspond to the centre of them and the reference system used is -32 to 32 for both the x-axis and y-axis. The pixel numbering goes from left to right, starting from the top (e.g. pixel 0 has coordinates (-31,31) while pixel 1023 has coordinates (31,-31)). To find out whether the photon has been detected, we check the coordinates of the photon against those of the SiPM: if their distance is less than 1 (because SiPMs have 2 mm sides and the coordinates correspond to their centres), then the photon has been detected.

1.2 Selected samples

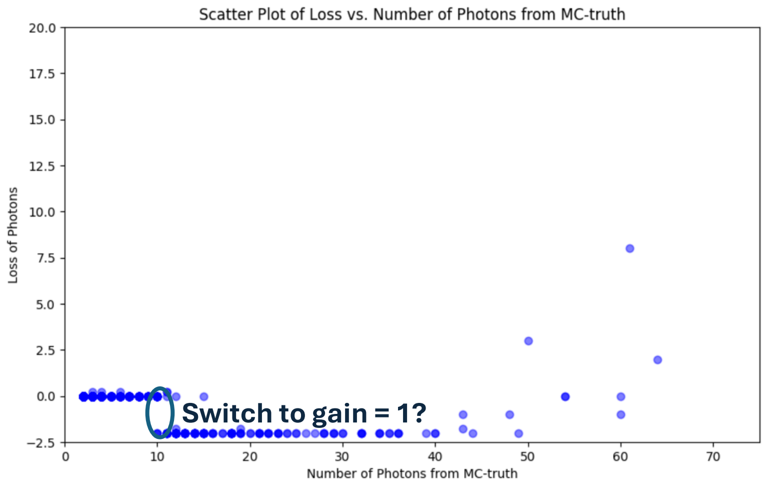
In order to validate the architecture of the electronics, we decided to select 4 different types of events (where event means channel and thus SiPM). In this way, we understand what characteristics the ASIC must have.
The four selected events are:

1. Events that need a high number of integration windows for some channels. This kind of event is necessary to validate the architecture with 2 Wilkinson and conversion time of 40-50 ns.
2. Events with the highest number of photons within an integration window. This sample is needed to optimize and validate the dynamic range.
3. Channels with the highest number of photons within 20 ns from the true interaction time[1]. This sample should stabilize if the electronics is capable of detecting such a high number of photons in a small time window.
4. Events with the lowest time between the true interaction time and the previous detected photon. This last category of channels was chosen in order to understand how likely it is that a revealed photon will open the wrong integration window (i.e. a photon from the previous event will open the integration window of the next event).

[1]The true interaction time is given by MonteCarlo simulation, if a peak of at least 3 photons is detected in the channel.

Conclusions and open questions

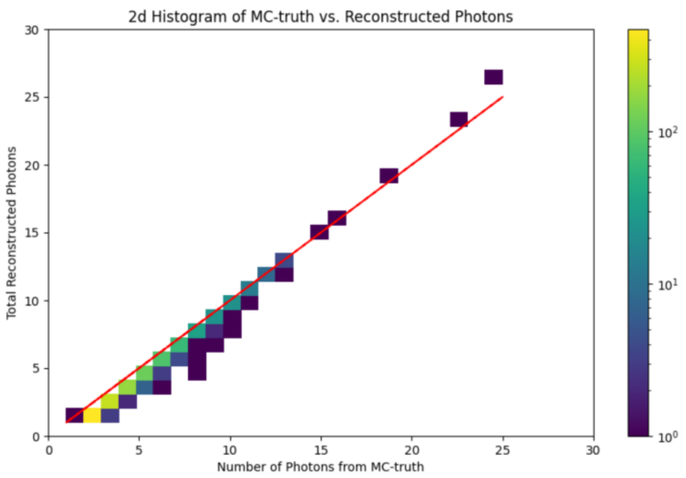
- Changing the Wilkinson ADC current source (I_{src}) according to the change of the clock period, we can conclude that already a clock period of 1/4 allows for a good reconstruction
- Despite the change of I_{src}, in no case you can get a good reconstruction over 60/70 photons
- Is there a way to improve the reconstruction for GAIN = 1?



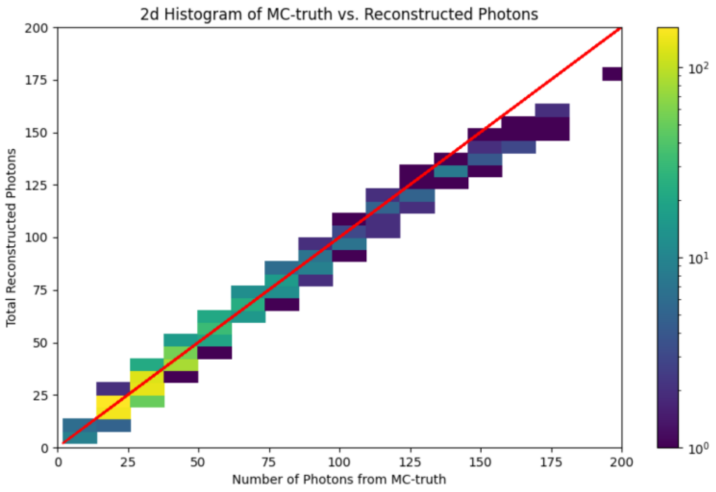
Nintegrators = 2

Clock period 1/4 = 0.833 ns

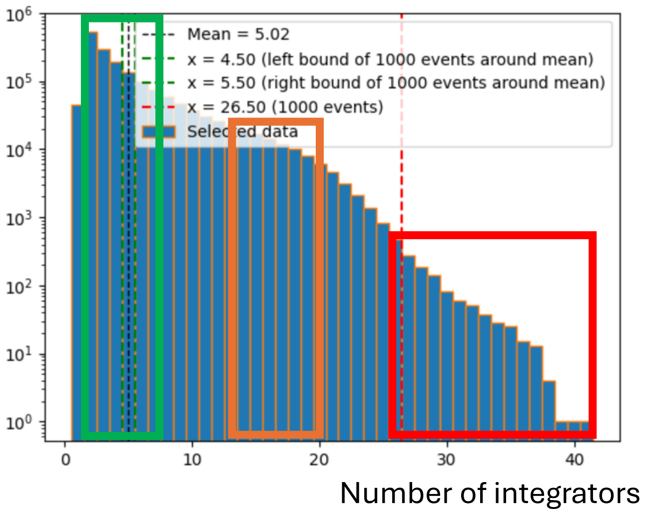
First plots for pure liquid Argon

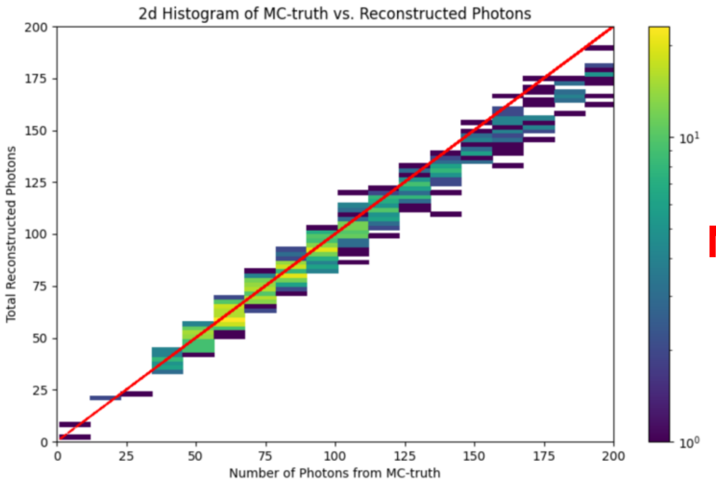


1 < Nintegrators < 7



13 < Nintegrators < 20





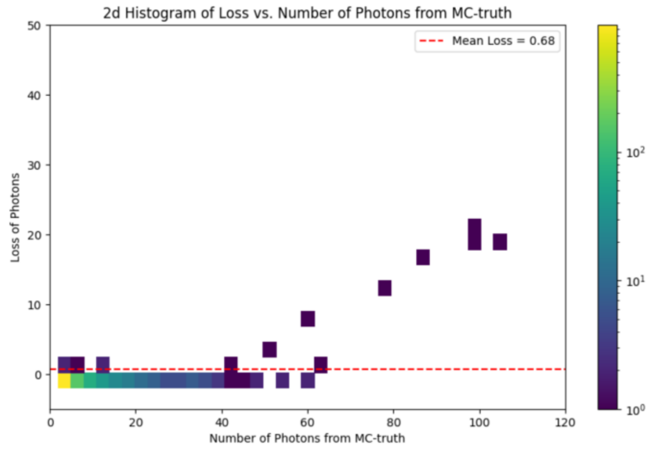
Nintegrators > 27

BACKUP SLIDES

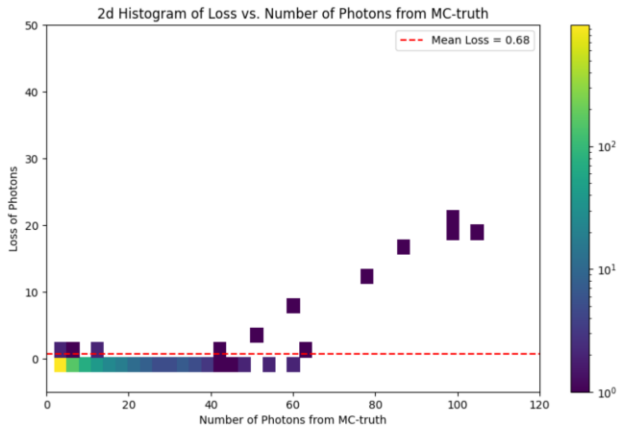
Selected samples: Events that need **about 2 integration windows** for some channels

Xenon-doped Ar
720 spill

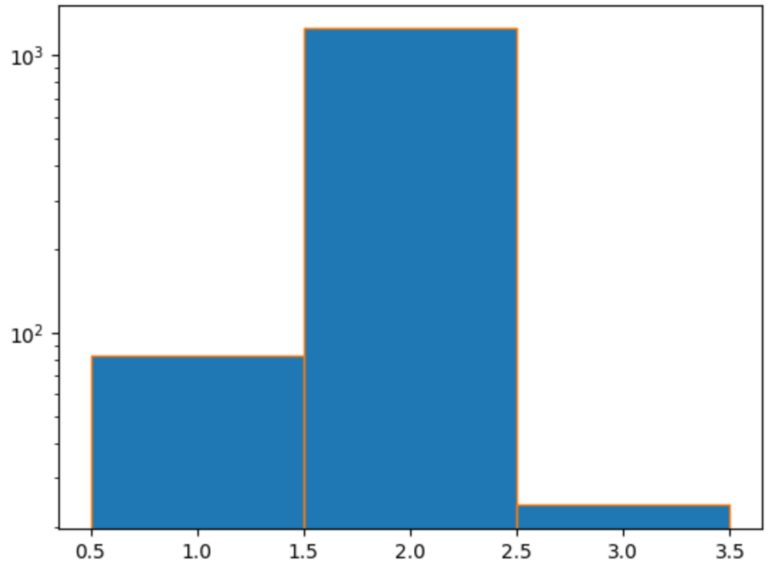
Nintegrators = 2



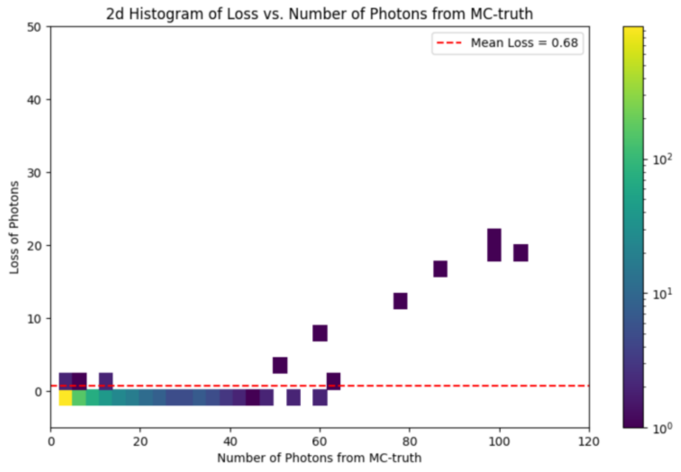
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of integrators from Torino's simulation



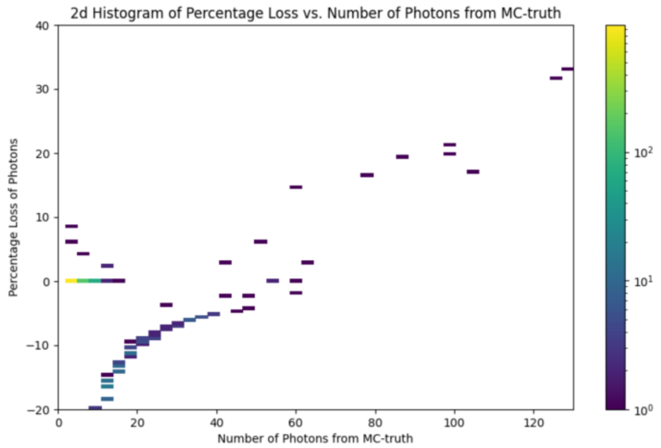
1/8 Clock period = 0.4166 ns

The reconstruction is **accurate until 70 photons**.
Lowering the clock period it's a little bit improved the reconstruction between 50 and 100 photons

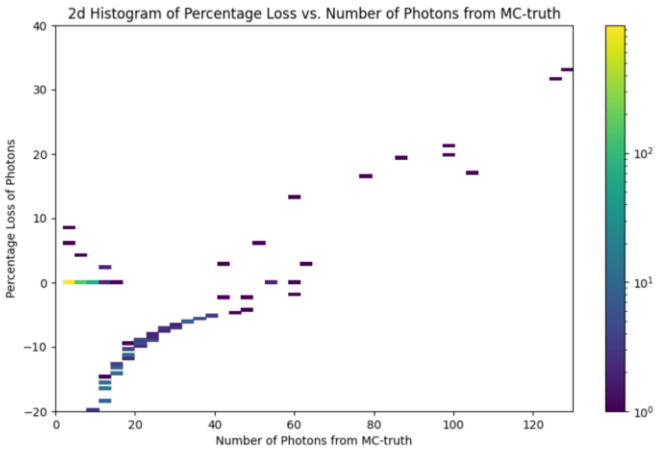
Selected samples: Events that need **about 2 integration windows** for some channels

Xenon-doped Ar
720 spill

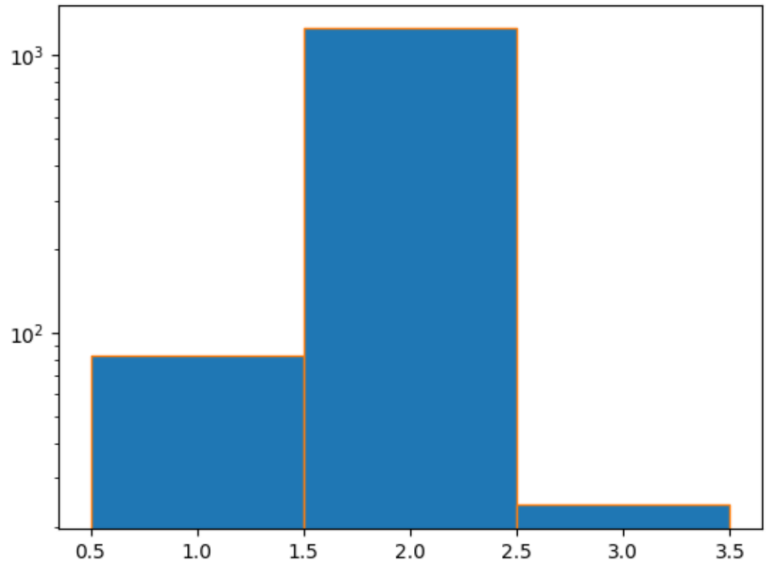
Nintegrators = 2



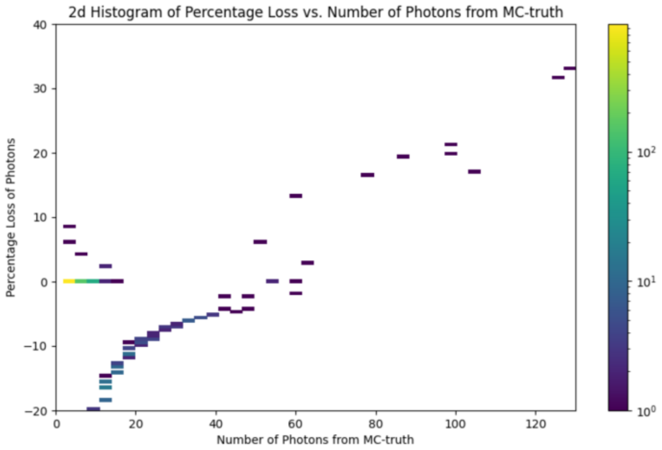
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of integrators from Torino's simulation



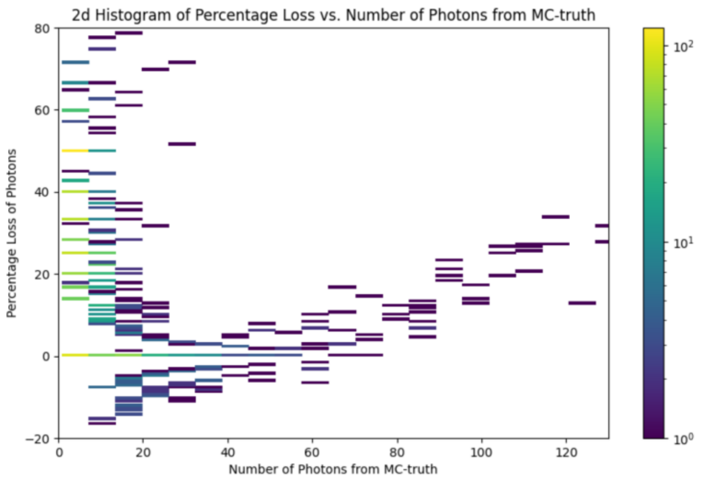
1/8 Clock period = 0.4166 ns

The reconstruction is **accurate until 70 photons**.
It can be noticed an important overestimation of the number of photons between 10 and 50, not noticed keeping the Isrc unchanged

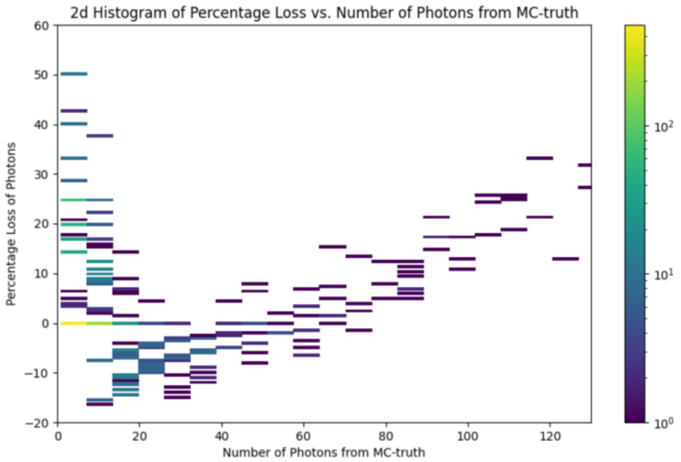
Selected samples: Events that need **between 3 and 7 integration windows** for some channels

Xenon-doped Ar
720 spill

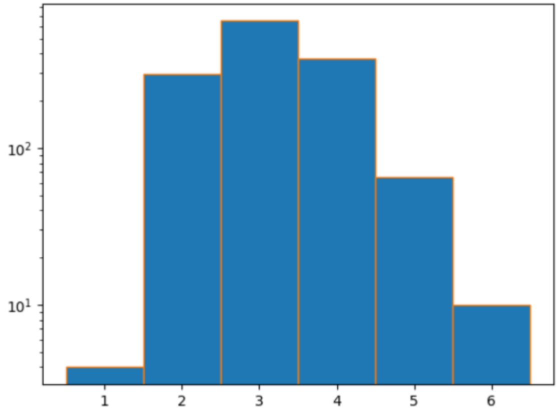
3 < Nintegrators < 7



Clock period = 3.333 ns

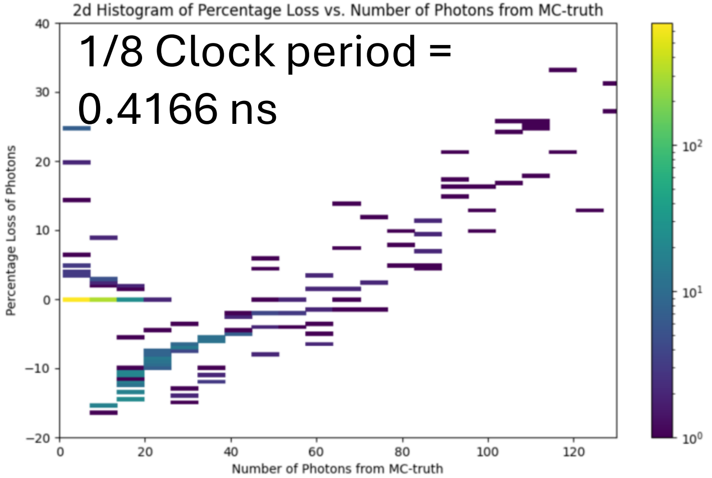


¼ Clock period = 0.833 ns

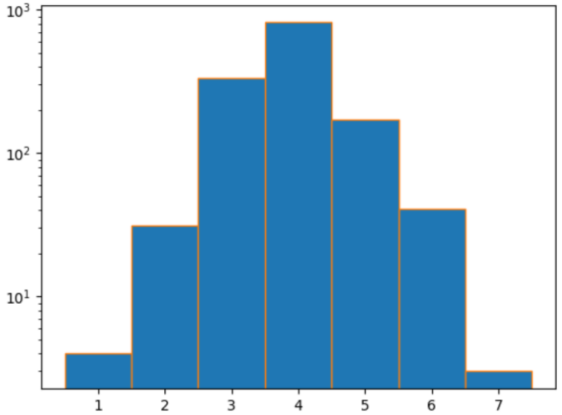


Number of integrators from Torino's simulation for clock period = 3.333 ns

Only with 1/8 clock period the reconstruction is **acceptable until 60-80 photons**.
The overestimation at low energies is not improved lowering the clock period



1/8 Clock period = 0.4166 ns



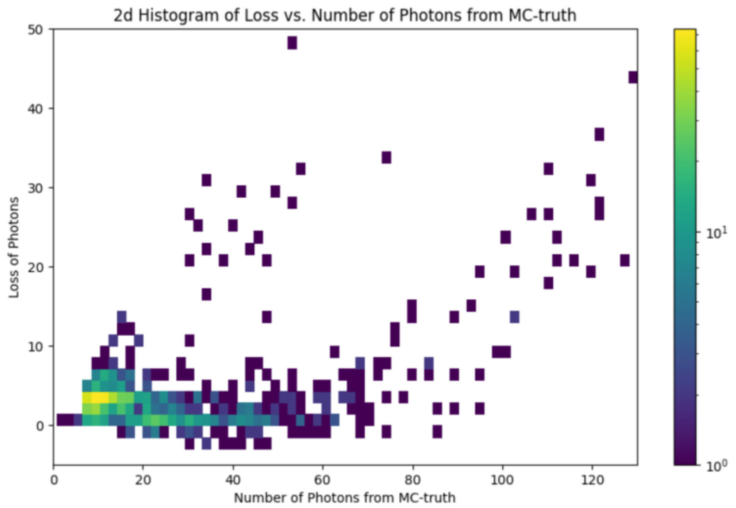
Number of integrators from Torino's simulation for clock period = 0.4166 ns

THIS SAMPLE IS IMPORTANT FOR THE VALIDATION

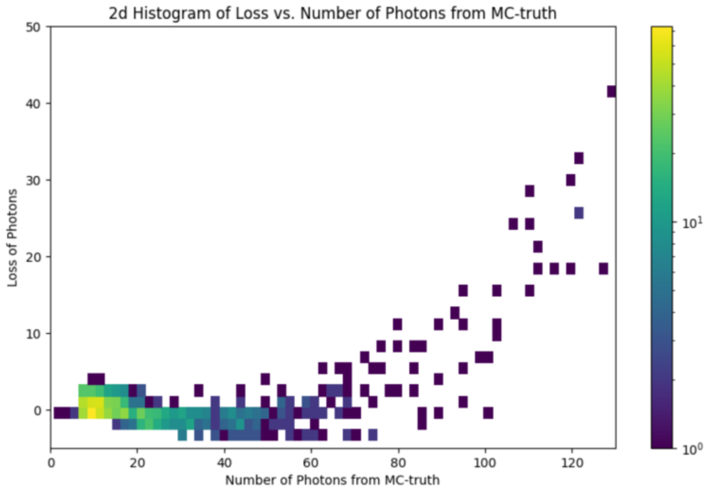
Selected samples: Events that need **more than 6 integration windows** for some channels

Xenon-doped Ar
720 spill

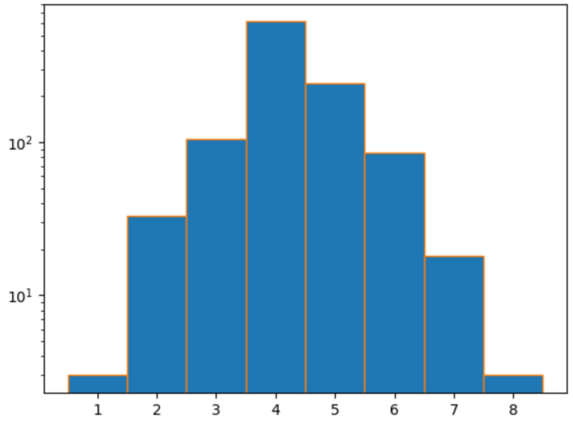
Nintegrators > 6



Clock period = 3.333 ns

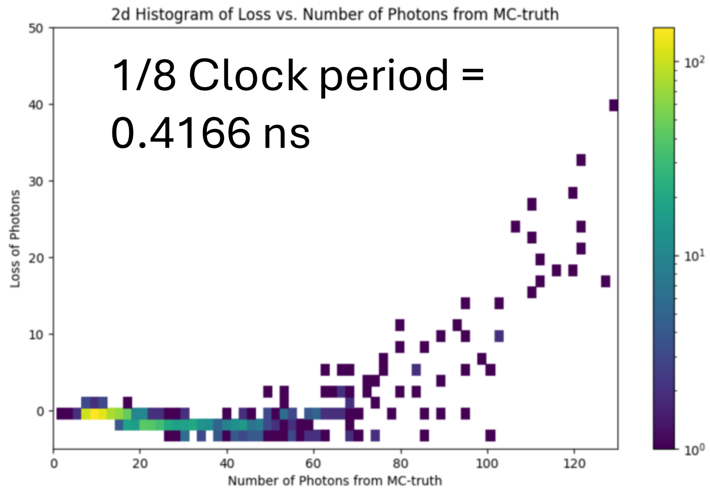


¼ Clock period = 0.833 ns

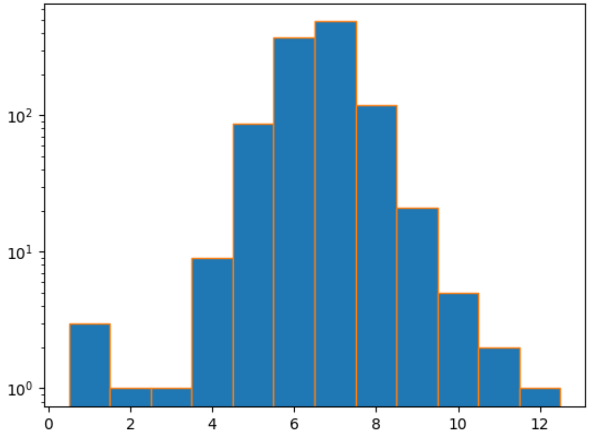


Number of integrators from Torino's simulation for clock period = 3.333 ns

The reconstruction is **good until 70 photons**.
Lowering the clock period improves the reconstruction at low energies



1/8 Clock period = 0.4166 ns

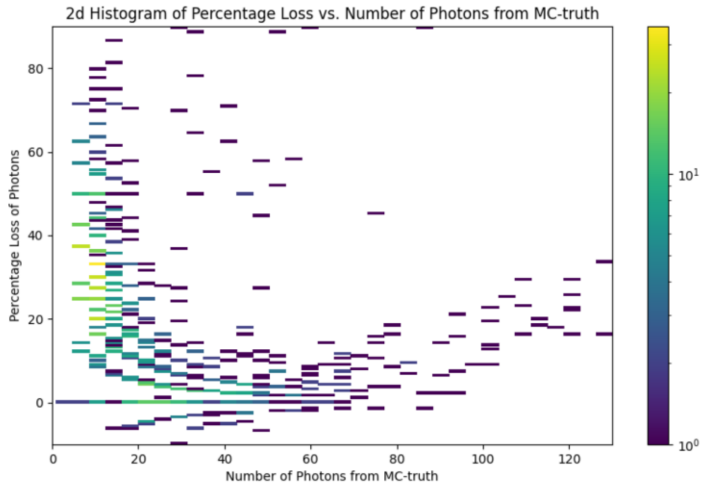


Number of integrators from Torino's simulation for clock period = 0.4166 ns

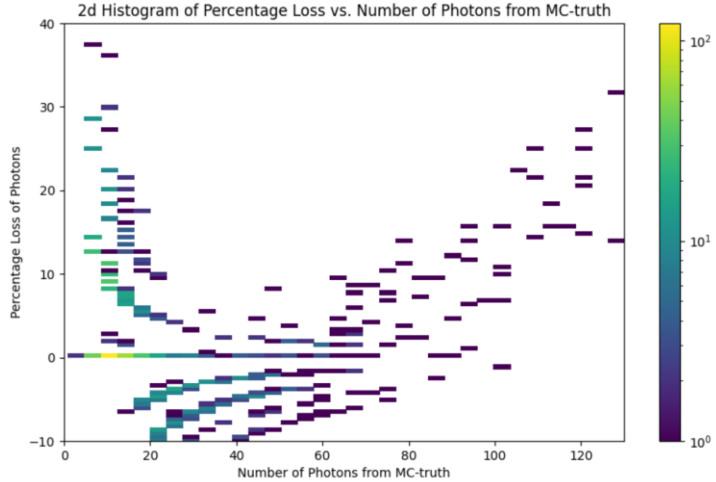
Selected samples: Events that need **more than 6 integration windows** for some channels

Xenon-doped Ar
720 spill

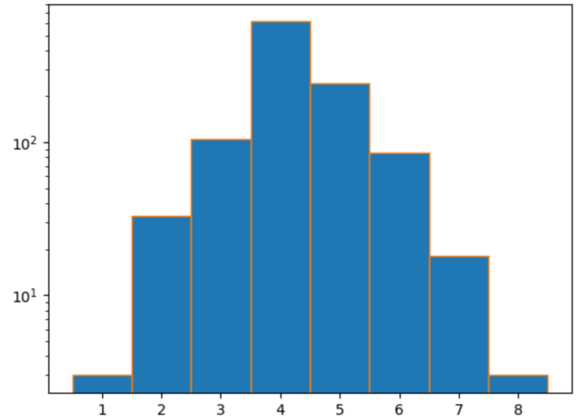
Nintegrators > 6



Clock period = 3.333 ns

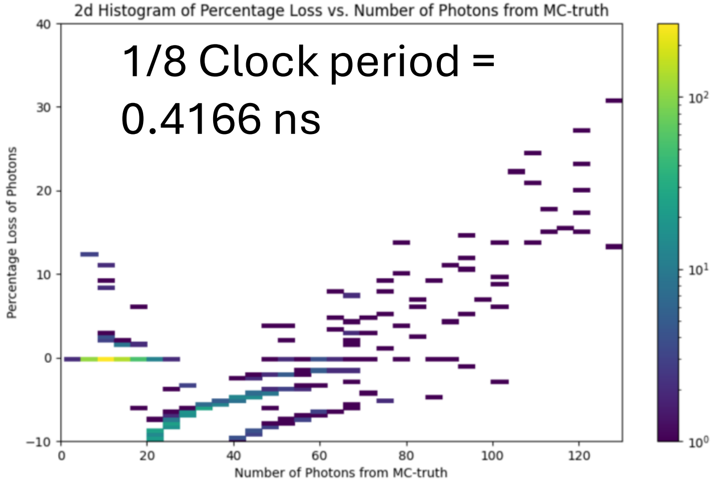


¼ Clock period = 0.833 ns

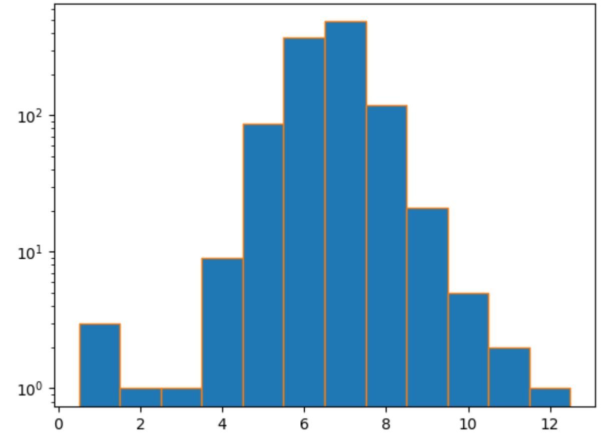


Number of integrators from Torino’s simulation for clock period = 3.333 ns

The reconstruction is **good until 70 photons**.
Lowering the clock period improves the reconstruction at low energies but there’s always an overestimation between 20 and 80 photons



1/8 Clock period = 0.4166 ns

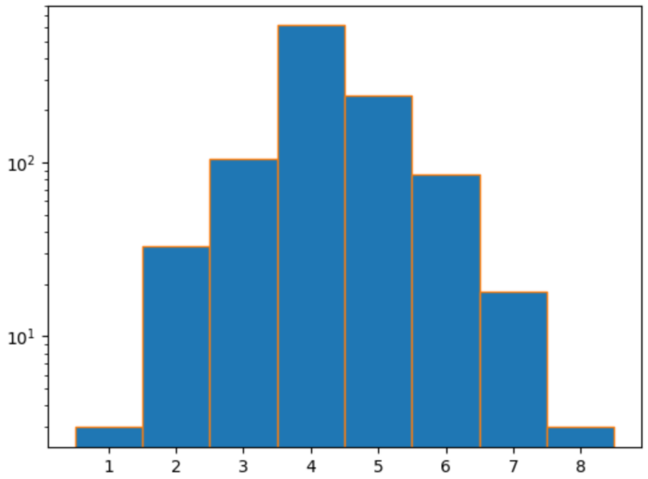


Number of integrators from Torino’s simulation for clock period = 0.4166 ns

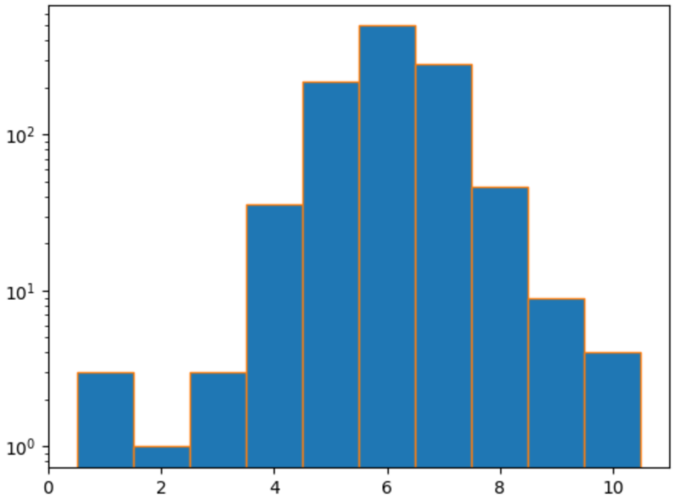
Selected samples: Events that need **more than 6 integration windows** for some channels

Nintegrators > 6

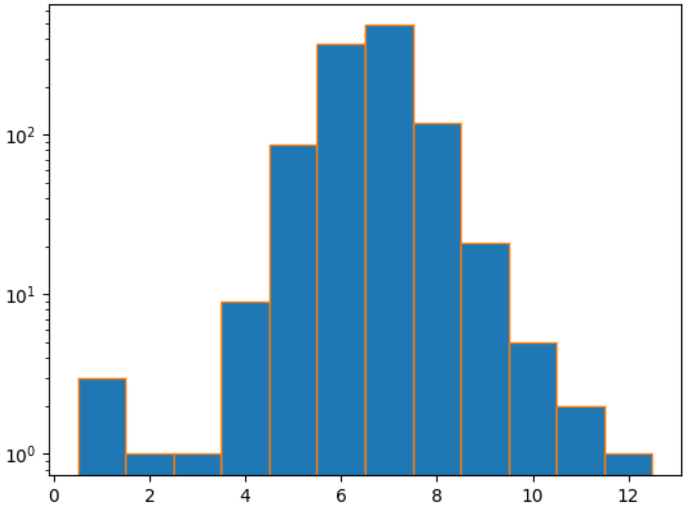
Xenon-doped Ar
720 spill



Number of integrators from Torino's simulation for clock period = 3.333 ns



Number of integrators from Torino's simulation for clock period = 0.833 ns

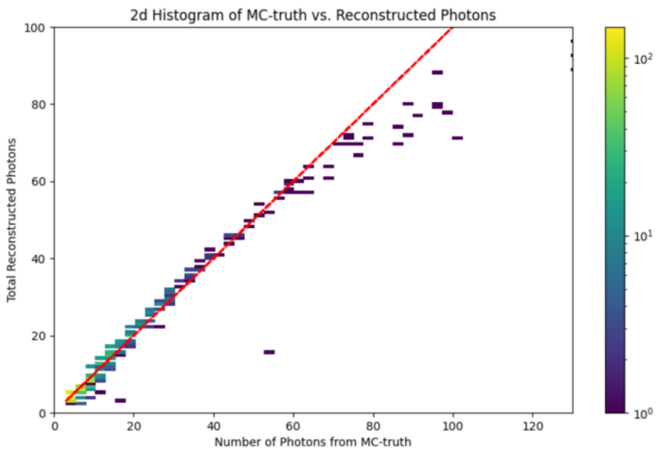


Number of integrators from Torino's simulation for clock period = 0.4166 ns

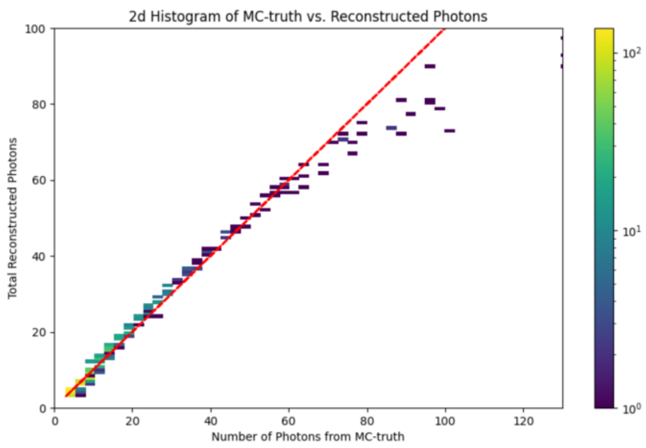
Selected samples: Events with **number of photons between 2 and 100 within an integration window**

Xenon-doped Ar
720 spill

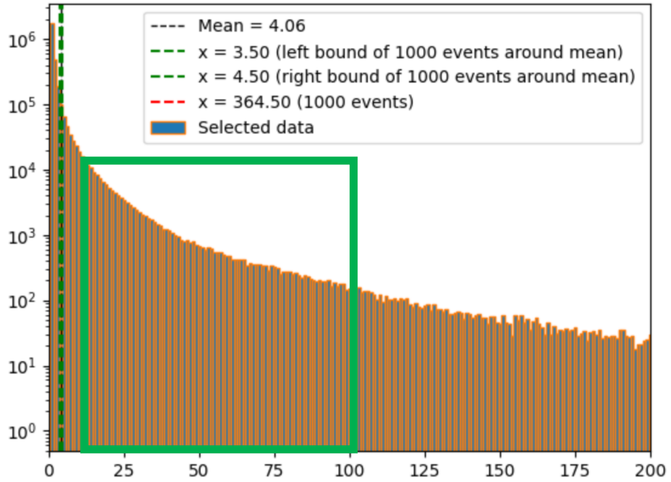
2 < Nphotons < 100



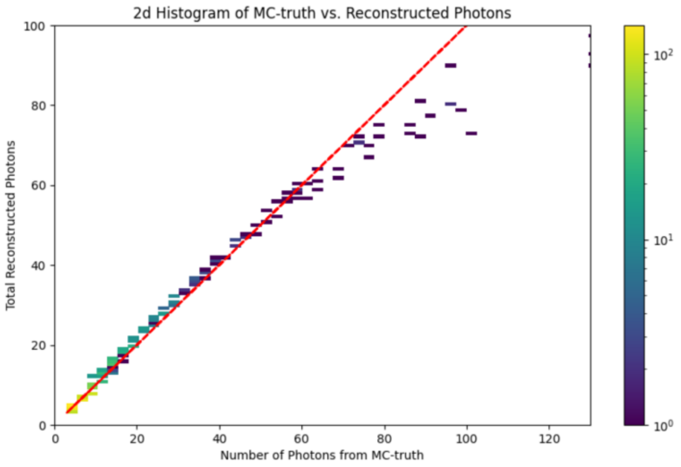
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of photons

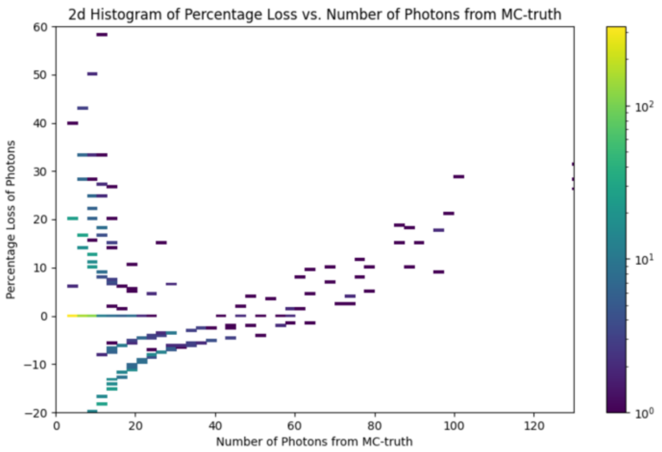


1/8 Clock period = 0.4166 ns

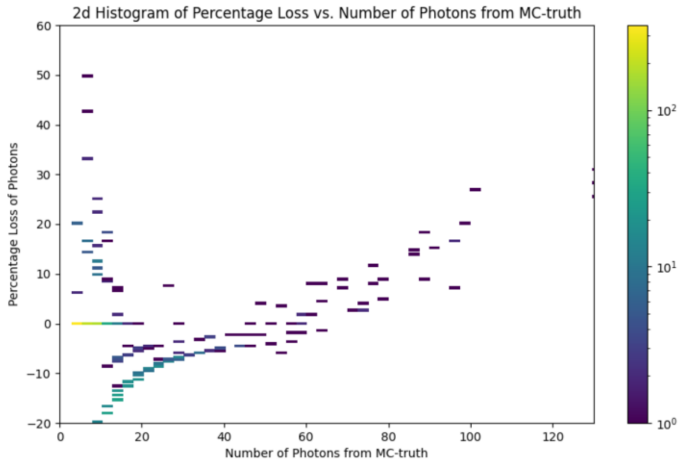
Only with ¼ and 1/8 clock period the reconstruction is good until **60 photons**. Lowering the clock period improves the reconstruction at low energies

Selected samples: Events with **number of photons between 2 and 100 within an integration window**

2 < Nphotons < 100

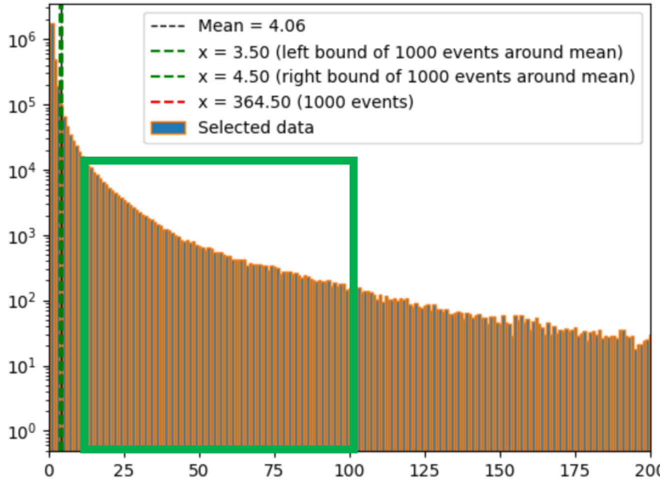


Clock period = 3.333 ns

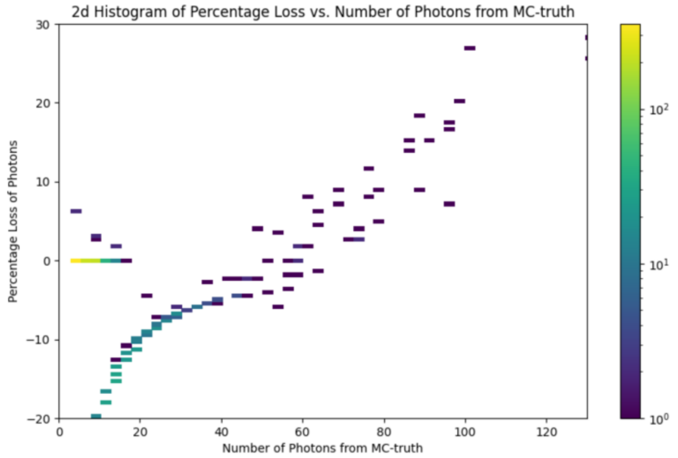


¼ Clock period = 0.833 ns

Xenon-doped Ar
720 spill



Number of photons



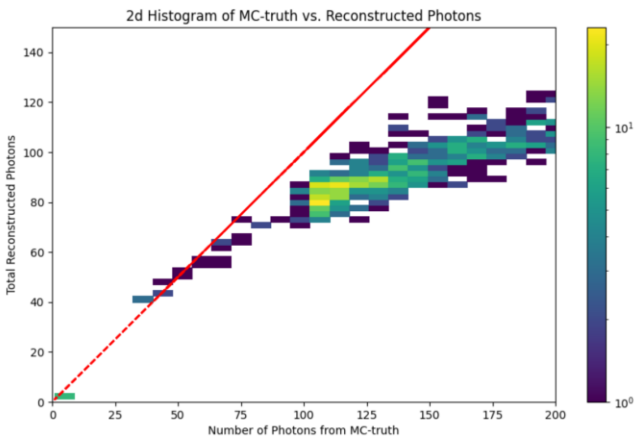
1/8 Clock period = 0.4166 ns

With ¼ clock period the reconstruction is good until **60 photons**. With 1/8 the reconstruction is slightly better. Lowering the clock period improves the reconstruction at low energies but there's always an overestimation between 10 and 60 photons

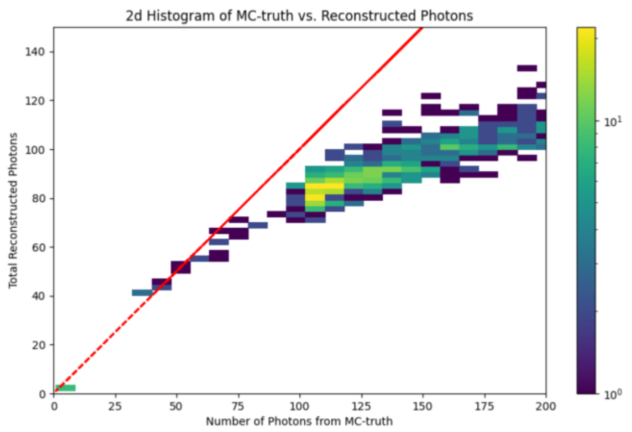
Selected samples: Events with **more than 100 photons within an integration window**

Nphotons > 100

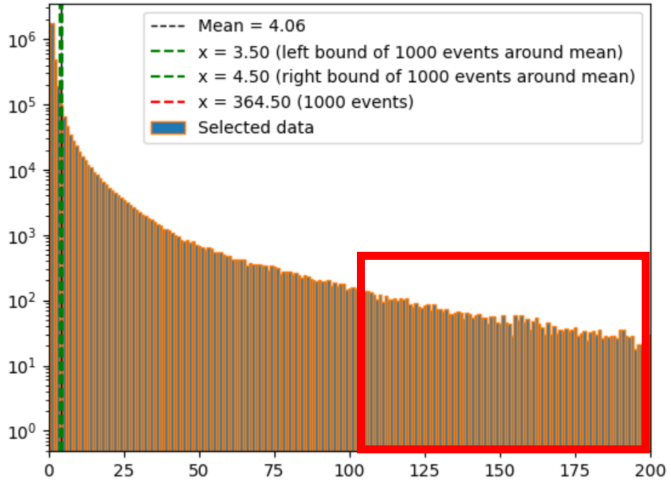
Xenon-doped Ar
720 spill



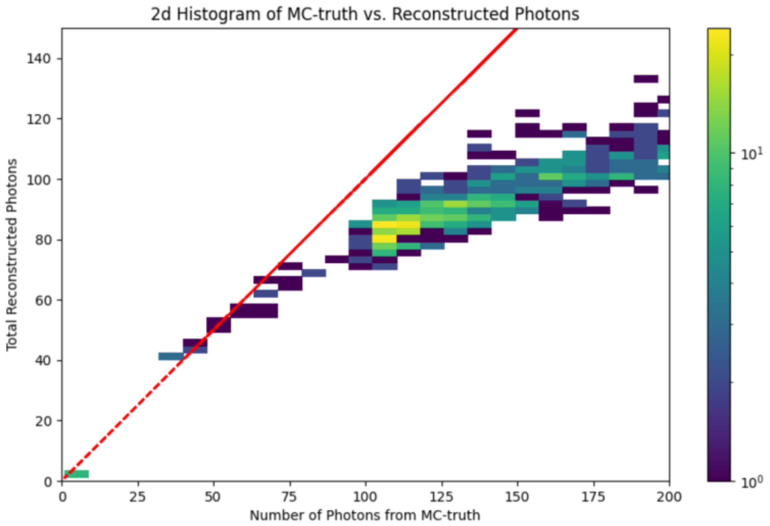
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of photons



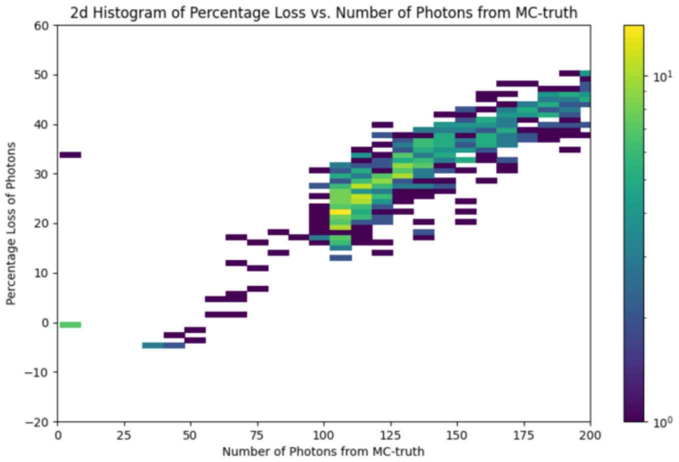
1/8 Clock period = 0.4166 ns

Even changing the Isrc current does not result in a good reconstruction of photon numbers greater than 70/80

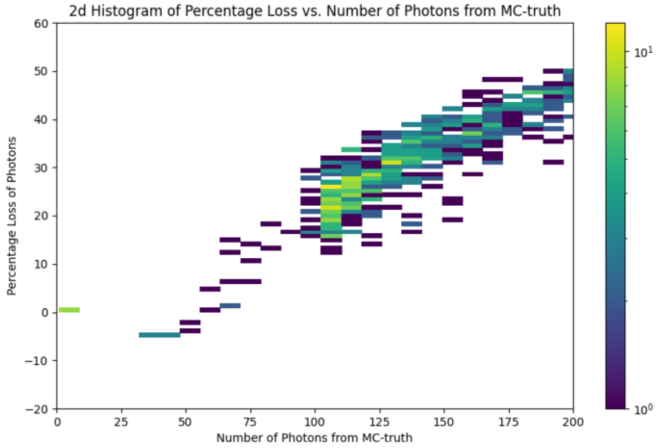
Selected samples: Events with **more than 100 photons within an integration window**

Xenon-doped Ar
720 spill

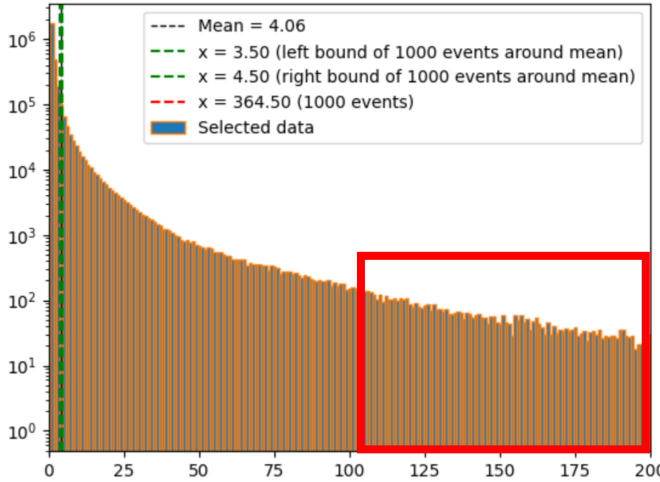
Nphotons > 100



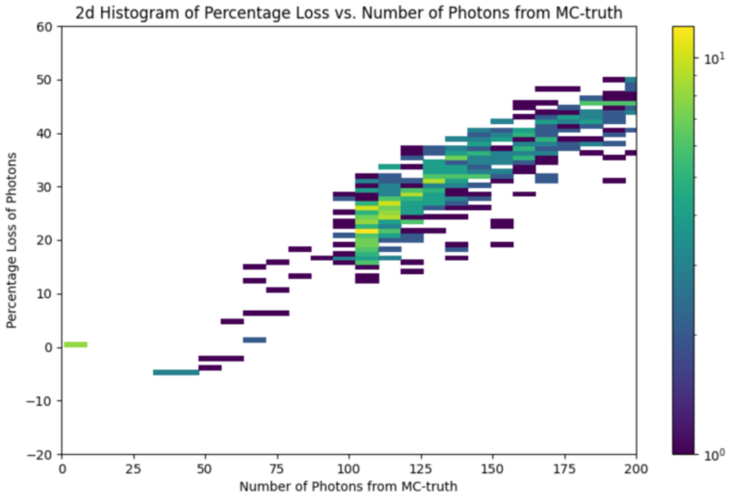
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of photons

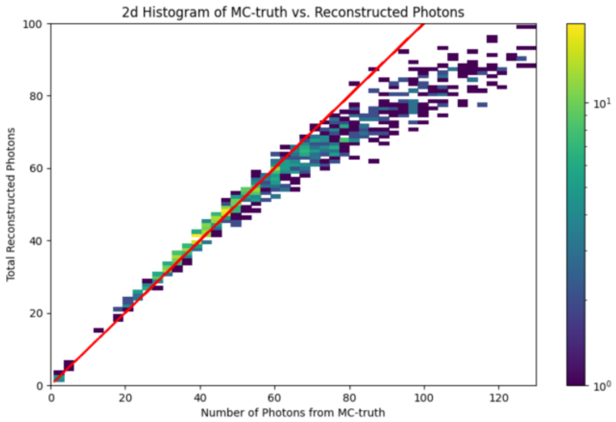


1/8 Clock period = 0.4166 ns

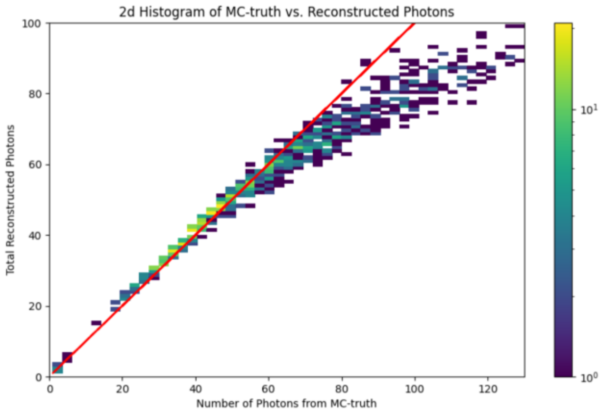
Even changing the Isrc current does not result in a good reconstruction of photon numbers greater than 70/80

Selected samples: Channels with **a number of photons between 11 and 80 within 20 ns from the true interaction time**

11 < Nphotons < 80

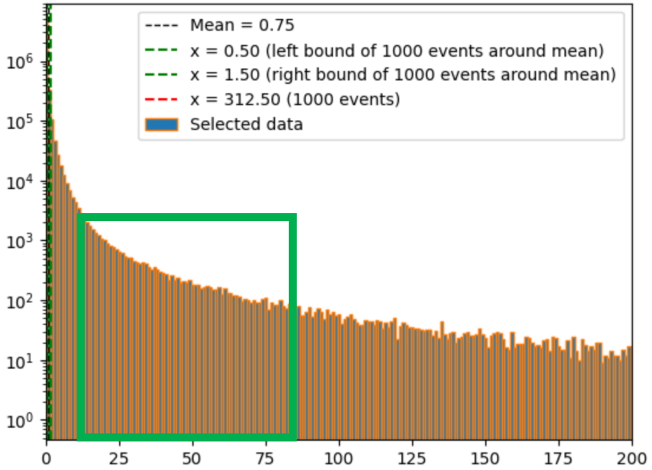


Clock period = 3.333 ns

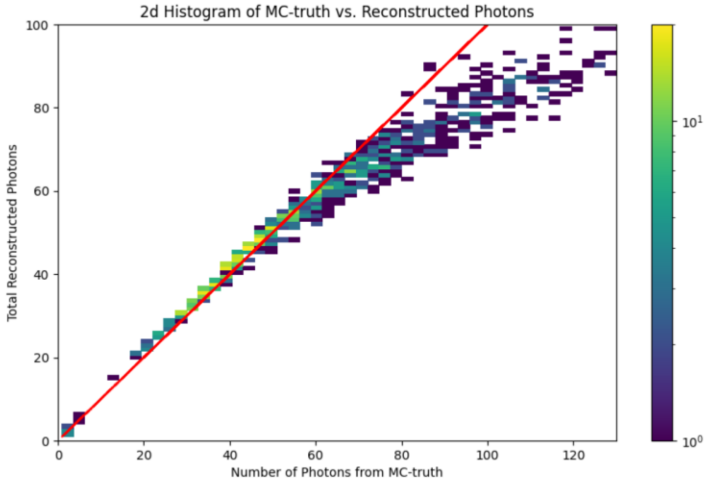


¼ Clock period = 0.833 ns

Xenon-doped Ar
720 spill



Number of photons



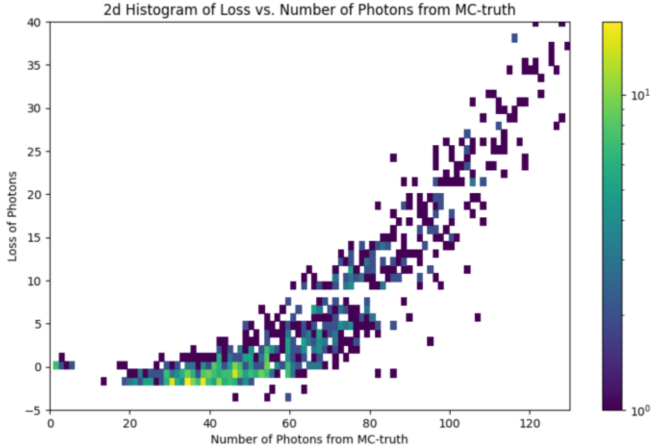
1/8 Clock period = 0.4166 ns

There's not an important improvement in the photon reconstruction lowering the clock period . The reconstruction is good until 60 photons

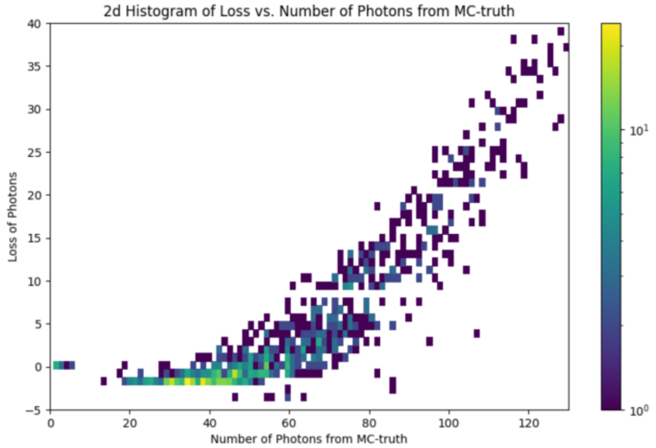
Selected samples: Channels with **a number of photons between 11 and 80 within 20 ns from the true interaction time**

11 < Nphotons < 80

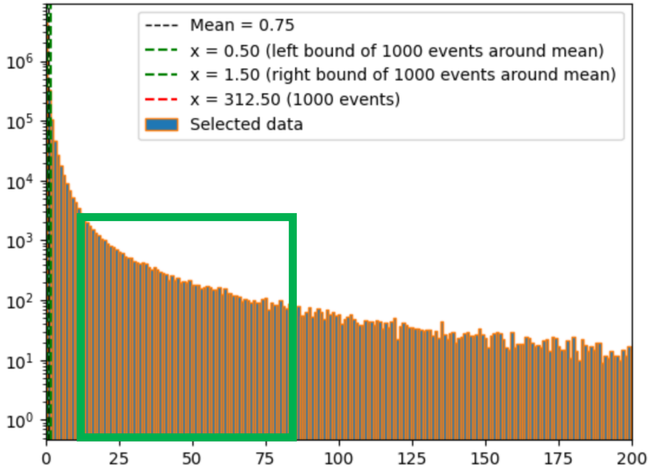
Xenon-doped Ar
720 spill



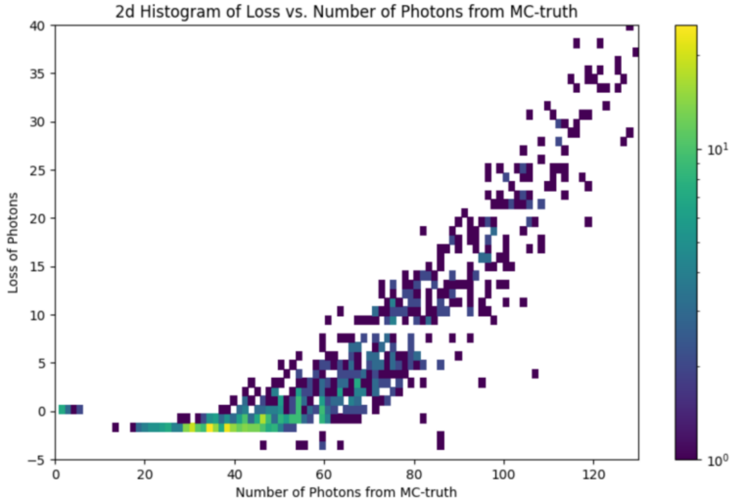
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of photons

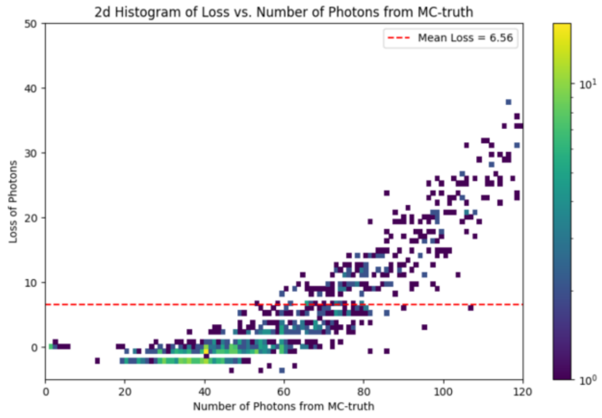


1/8 Clock period = 0.4166 ns

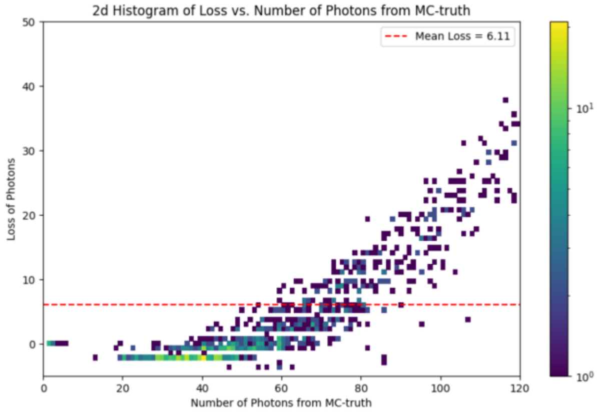
There's not an important improvement in the photon reconstruction lowering the clock period. The reconstruction is good until 60 photons

Selected samples: Channels with **a number of photons between 11 and 80 within 20 ns from the true interaction time**

11 < Nphotons < 80

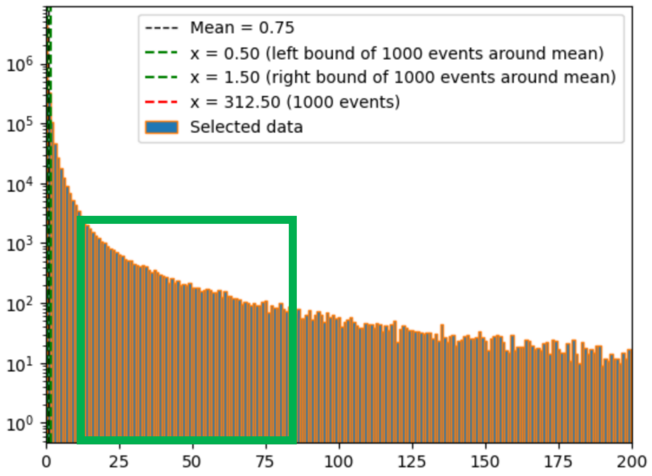


Clock period = 3.333 ns

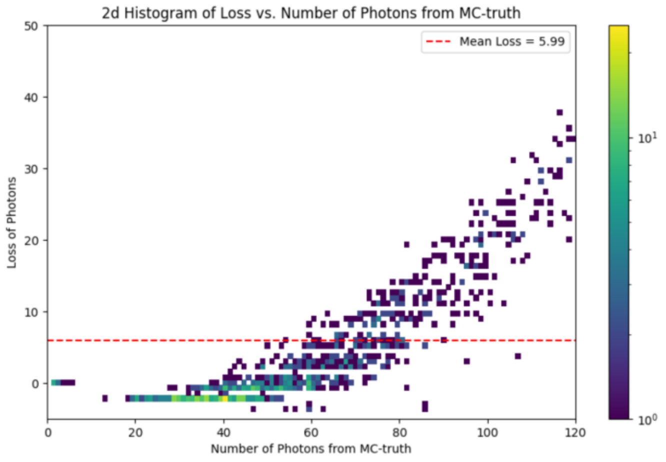


¼ Clock period = 0.833 ns

Xenon-doped Ar
720 spill



Number of photons

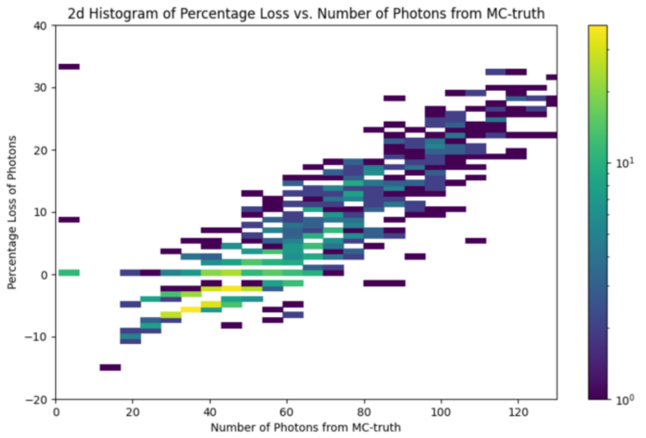


1/8 Clock period = 0.4166 ns

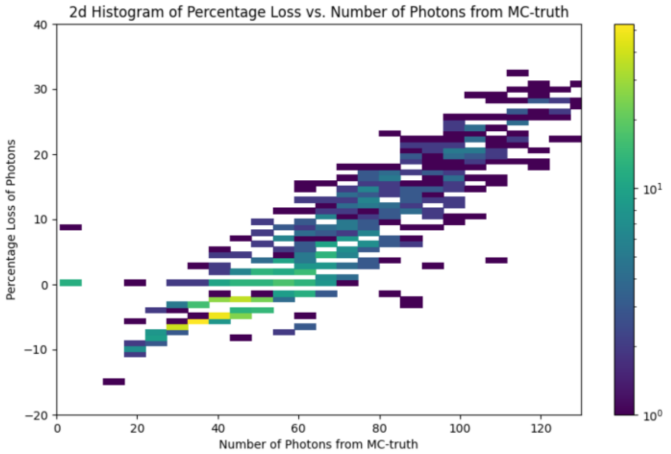
There's not an important improvement in the photon reconstruction lowering the clock period. The reconstruction is good until 60 photons

Selected samples: Channels with **a number of photons between 11 and 80 within 20 ns from the true interaction time**

11 < Nphotons < 80

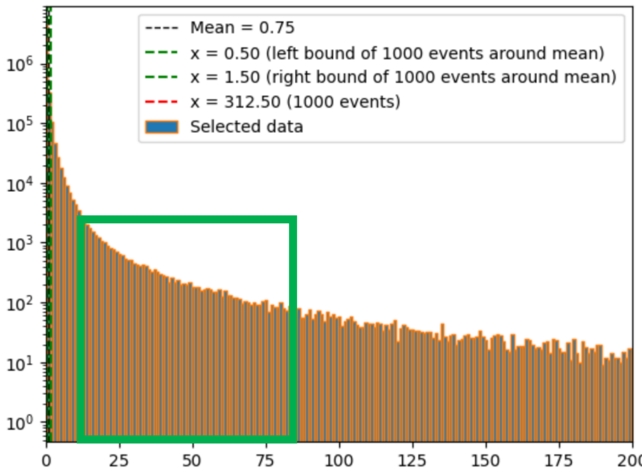


Clock period = 3.333 ns

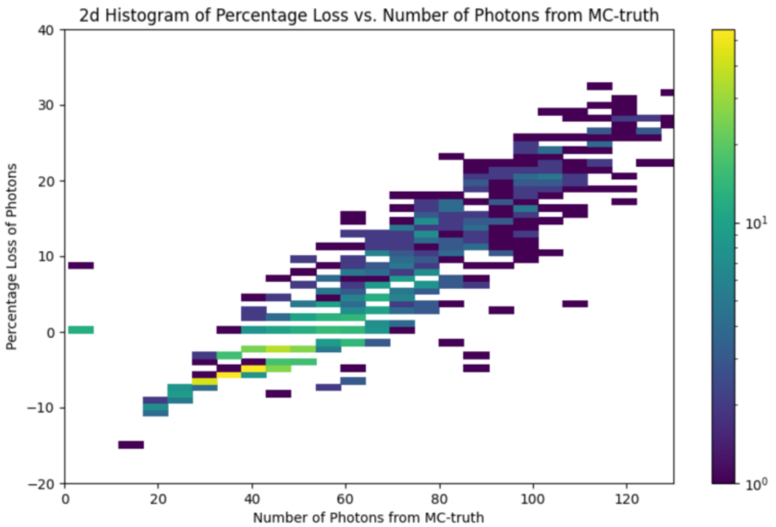


¼ Clock period = 0.833 ns

Xenon-doped Ar
720 spill



Number of photons



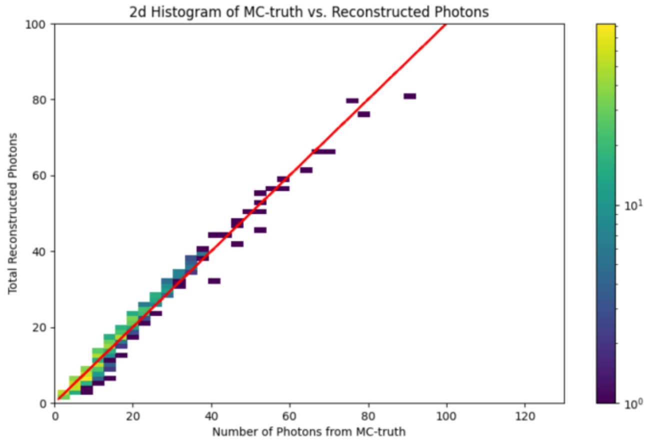
1/8 Clock period = 0.4166 ns

There's not an important improvement in the photon reconstruction lowering the clock period . The reconstruction is good until 60 photons

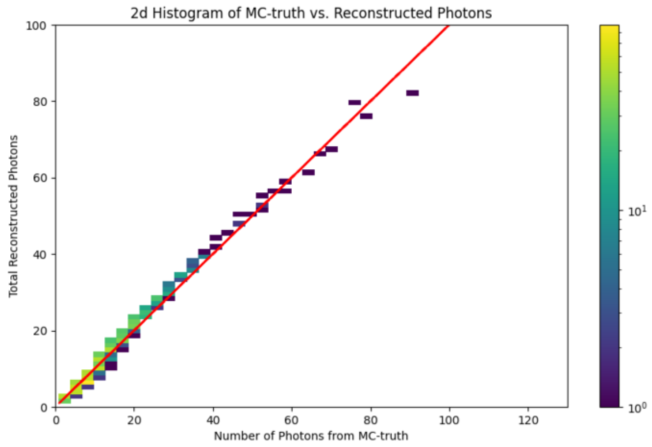
Selected samples: Channels with **a number of photons between 1 and 10 within 20 ns from the true interaction time**

1 < Nphotons < 10

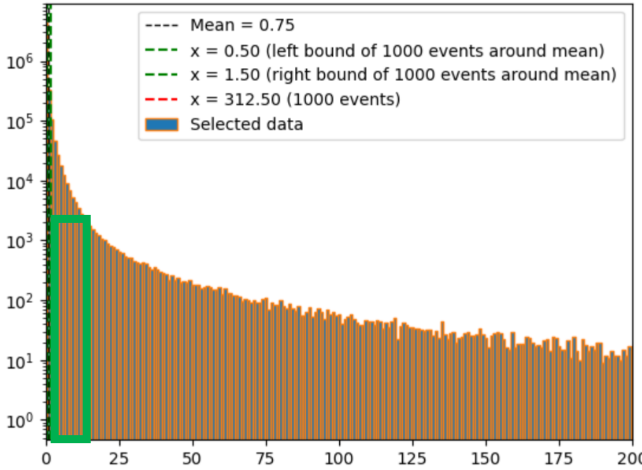
Xenon-doped Ar
720 spill



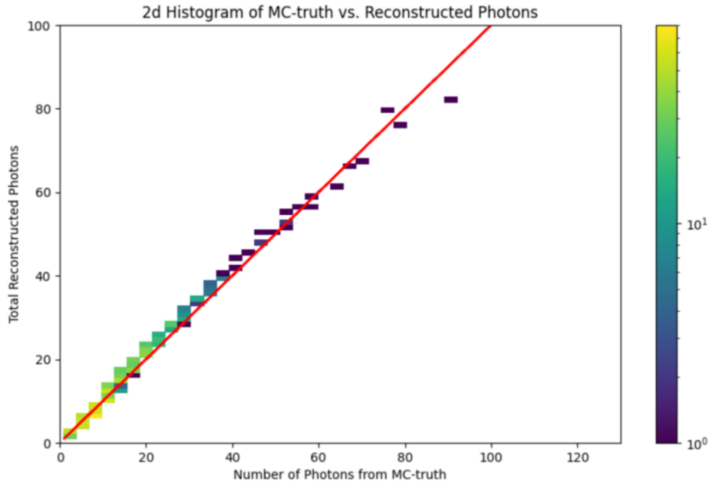
Clock period = 3.333 ns



¼ Clock period = 0.833 ns



Number of photons

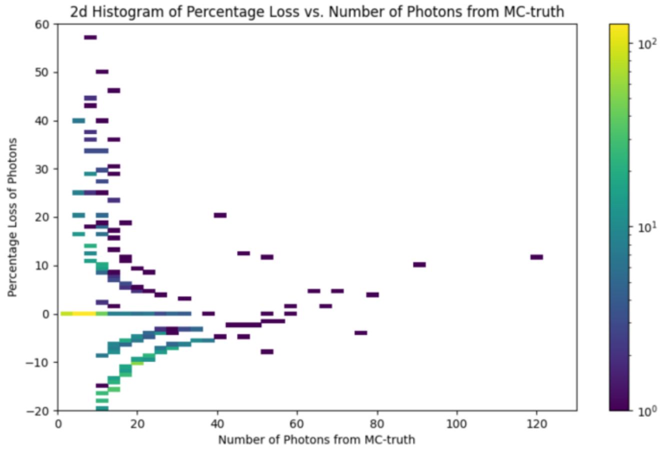


1/8 Clock period = 0.4166 ns

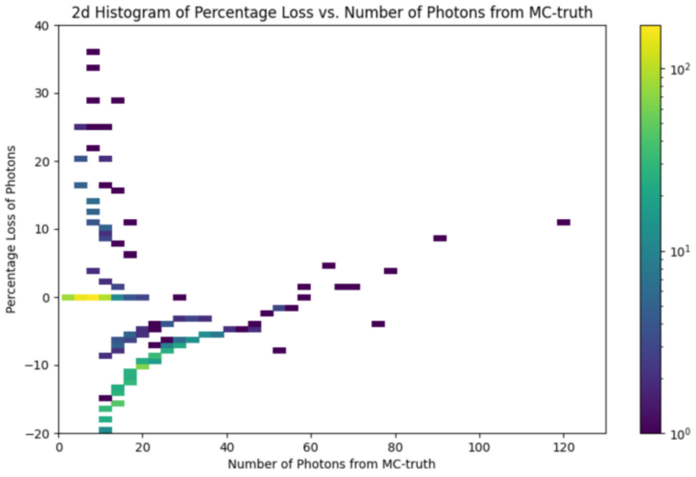
The reconstruction at low energies is good only with 1/8 clock period. There's a good recostruction until 70 photons

Selected samples: Channels with a number of photons between 1 and 10 within 20 ns from the true interaction time

1 < Nphotons < 10

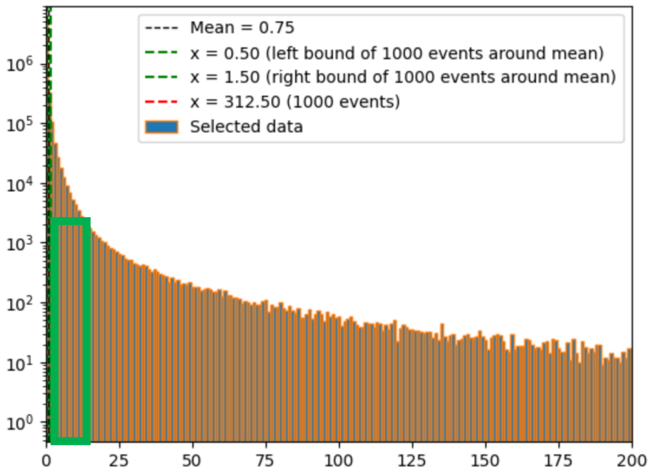


Clock period = 3.333 ns

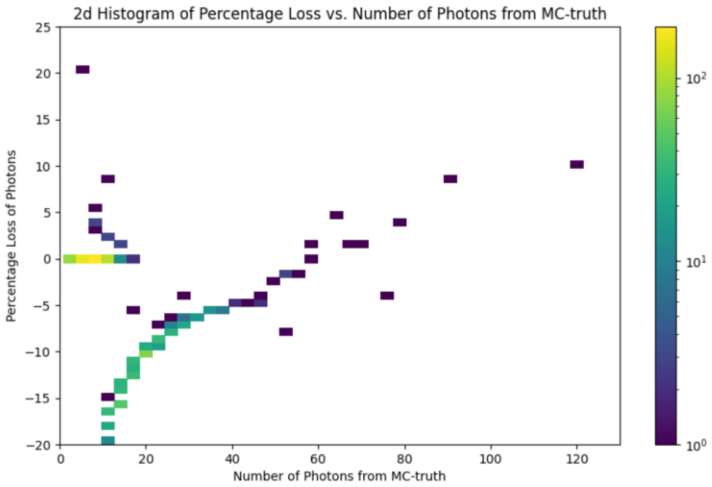


¼ Clock period = 0.833 ns

Xenon-doped Ar
720 spill



Number of photons

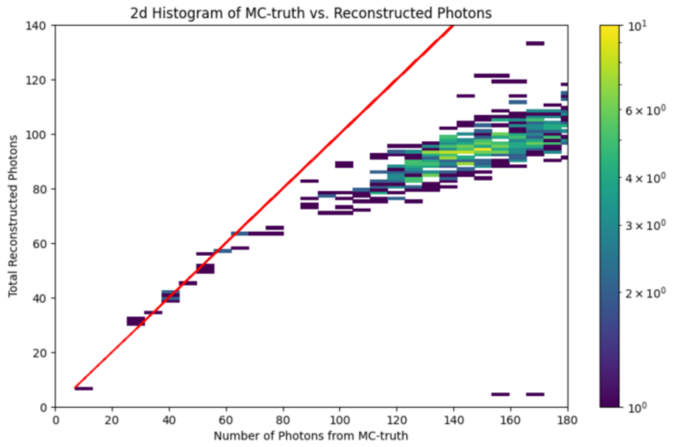


1/8 Clock period = 0.4166 ns

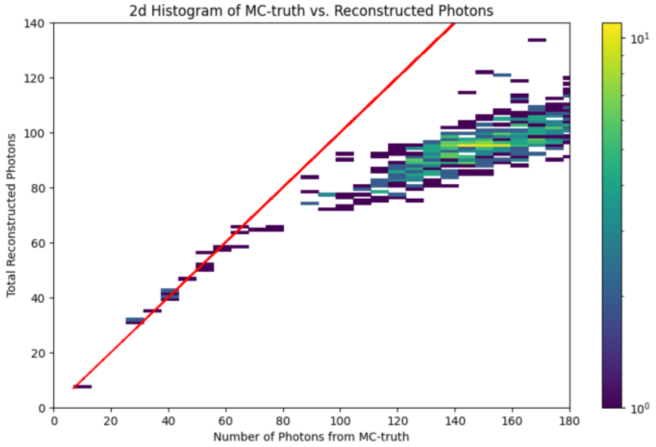
The reconstruction at low energies is good only with 1/8 clock period. There's a good recostruction until 70 photons. However, there's always an overestimation between 10 and 60 photons

Selected samples: Channels with **a number of photons greater than 80 within 20 ns from the true interaction time**

Nphotons > 80

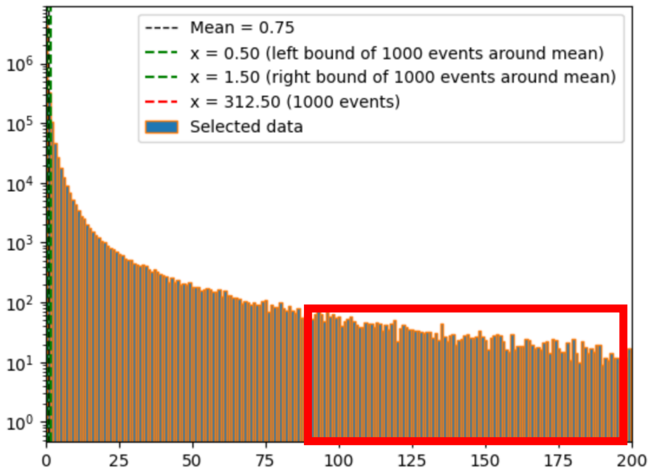


Clock period = 3.333 ns

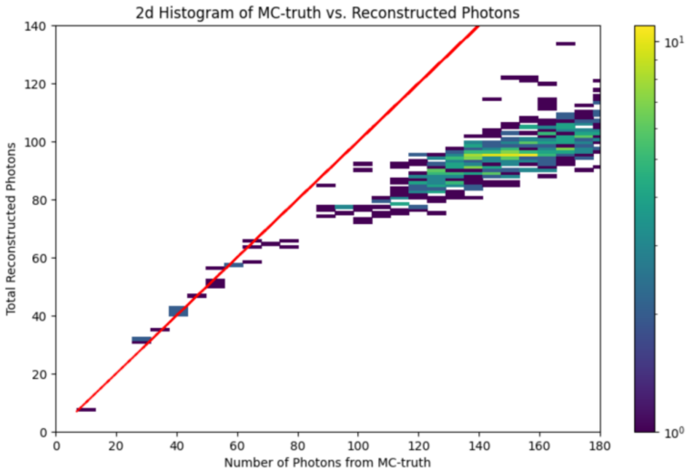


¼ Clock period = 0.833 ns

Xenon-doped Ar
720 spill



Number of photons

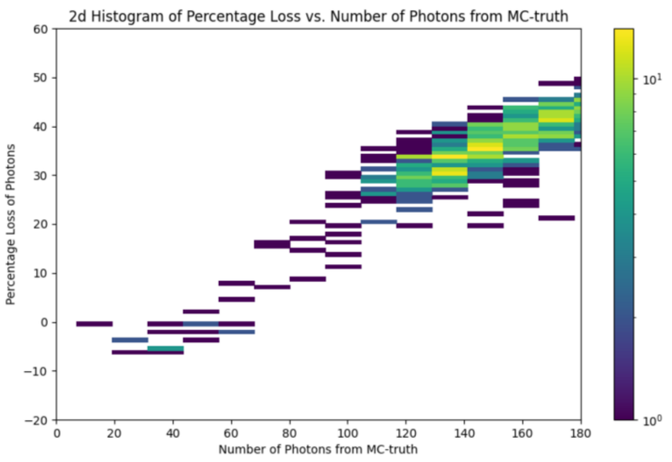


1/8 Clock period = 0.4166 ns

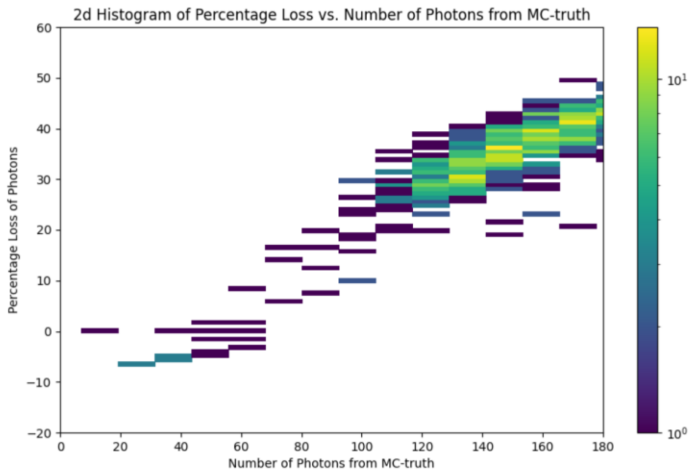
Even changing the Isrc current does not result in a good reconstruction of photon numbers greater than 70/80

Selected samples: Channels with **a number of photons greater than 80 within 20 ns from the true interaction time**

Nphotons < 80

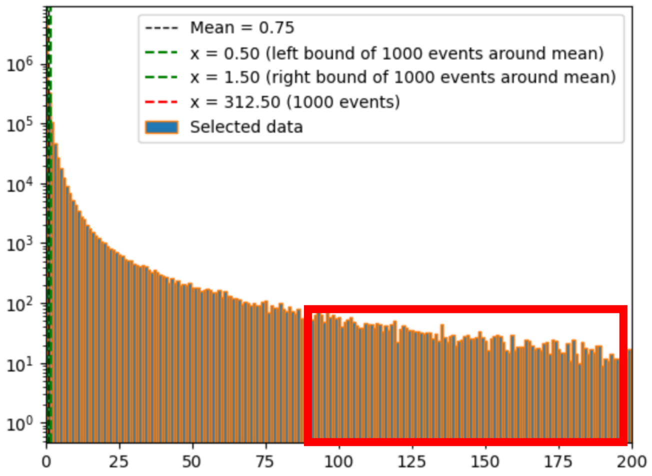


Clock period = 3.333 ns

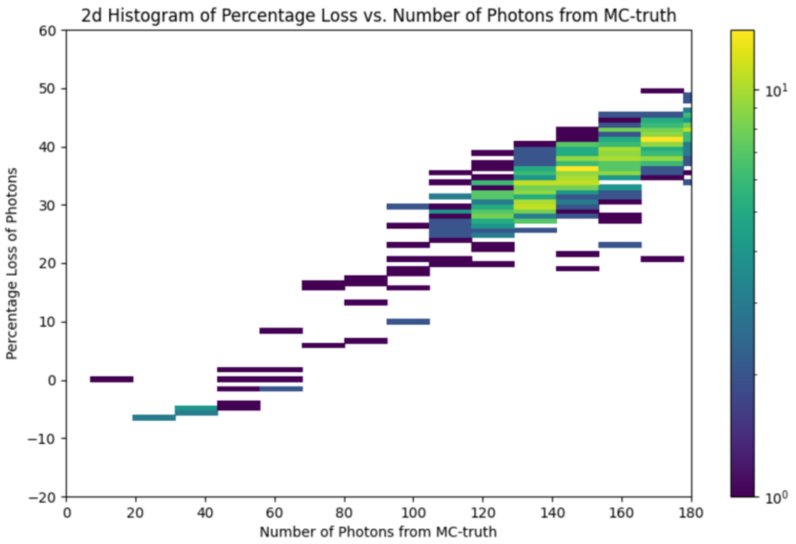


¼ Clock period = 0.833 ns

Xenon-doped Ar
720 spill



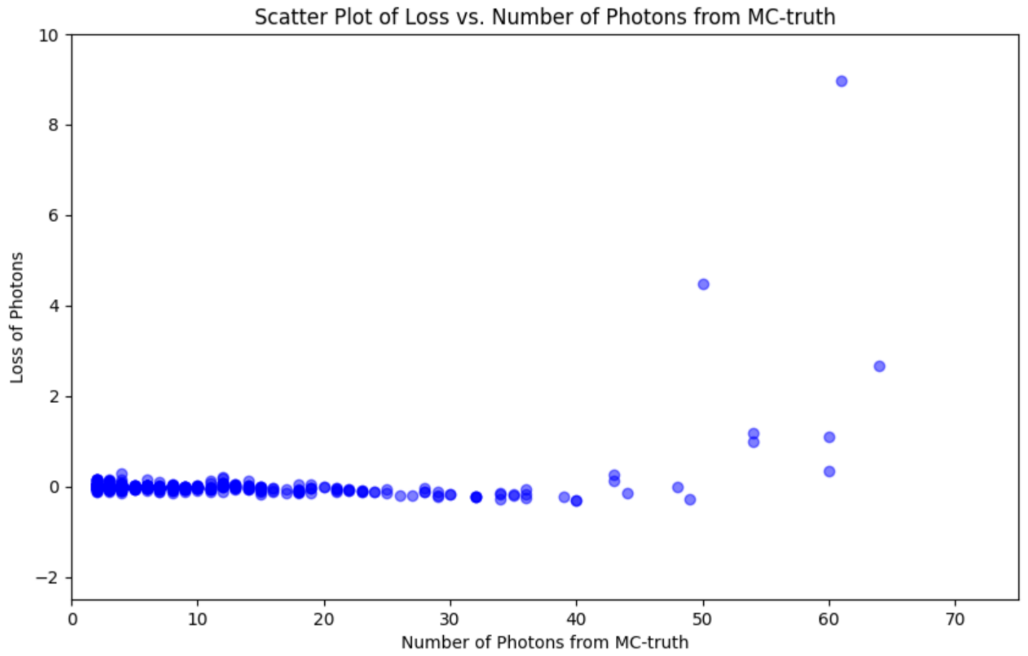
Number of photons



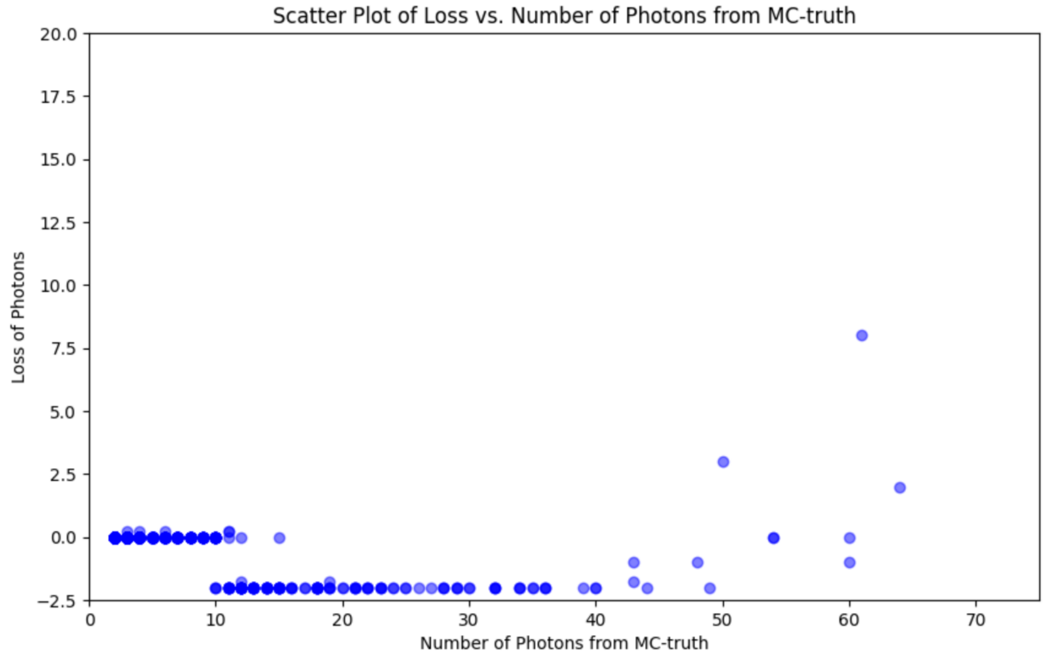
1/8 Clock period = 0.4166 ns

Even changing the Isrc current does not result in a good reconstruction of photon numbers greater than 70/80

Comparison with the plots shown on 26 th July WG meeting



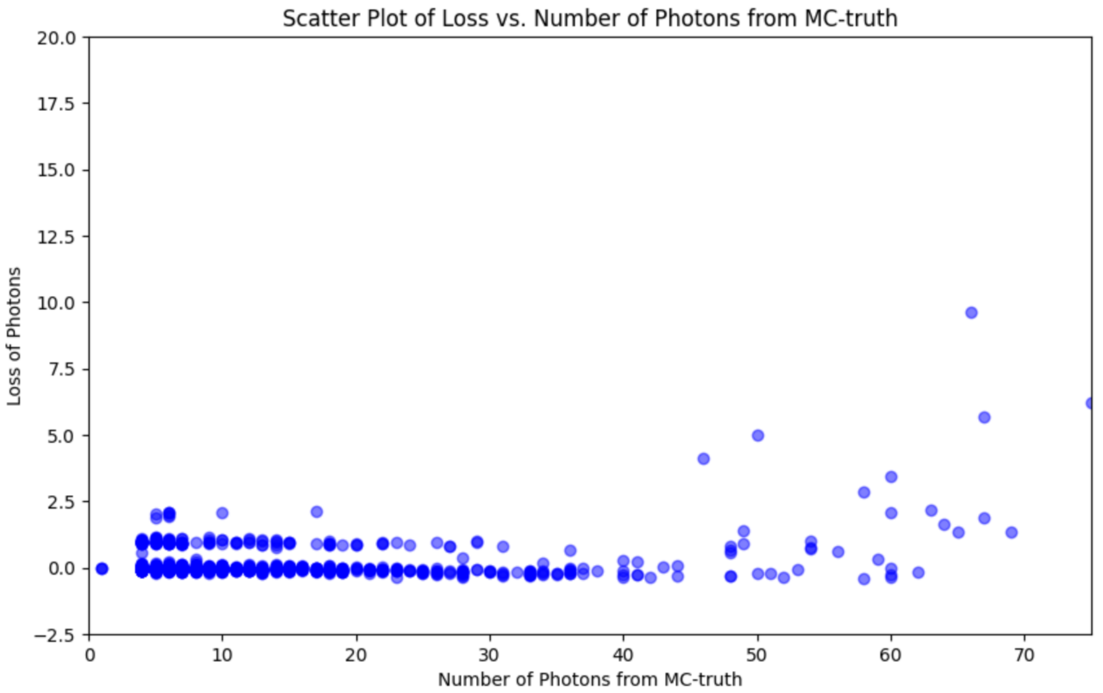
Old result with 1/8 clock period = 0.4166 ns but Isrc unchanged with respect to the configuration of 3.333 ns

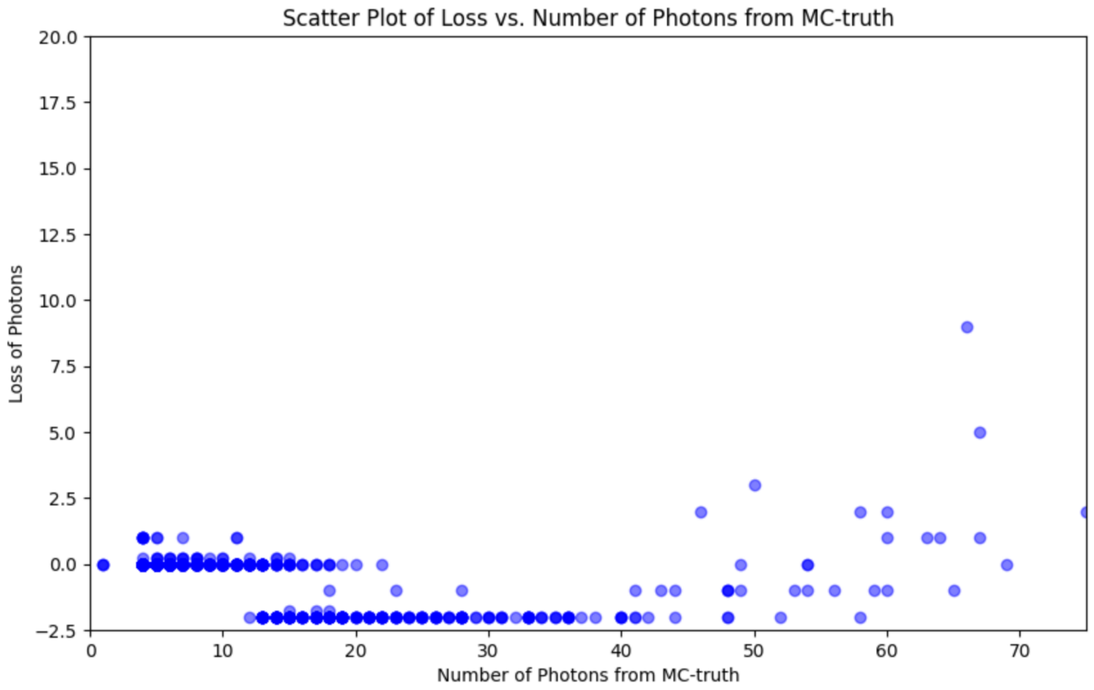


New result with 1/8 clock period = 0.4166 ns and 8*Isrc -> WORSE!
There's an overestimation of the number of photons between 10 and 60, not noticed keeping Isrc = 0.200 uA for the three clock periods

Nintegrators = 2

Comparison with the plots shown on 26 th July WG meeting



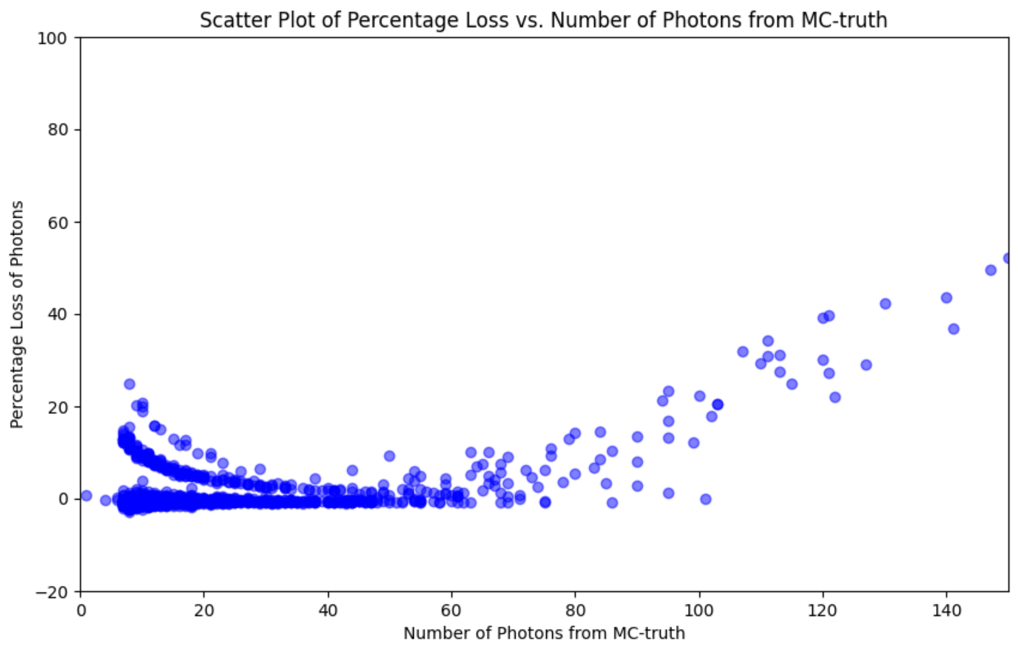


Old result with 1/8 clock period = 0.4166 ns but Isrc unchanged with respect to the configuration of 3.333 ns

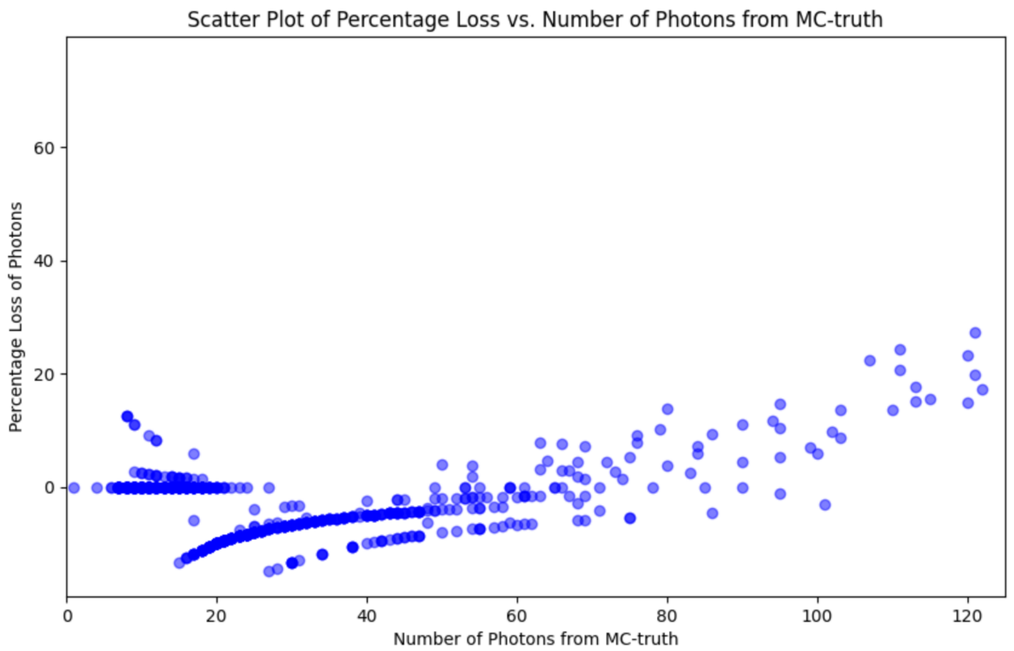
New result with 1/8 clock period = 0.4166 ns and 8*Isrc -> WORSE!
There's an overestimation of the number of photons between 10 and 60, not noticed keeping Isrc = 0.200 uA for the three clock periods

3 < Nintegrators < 7

Comparison with the plots shown on 26 th July WG meeting



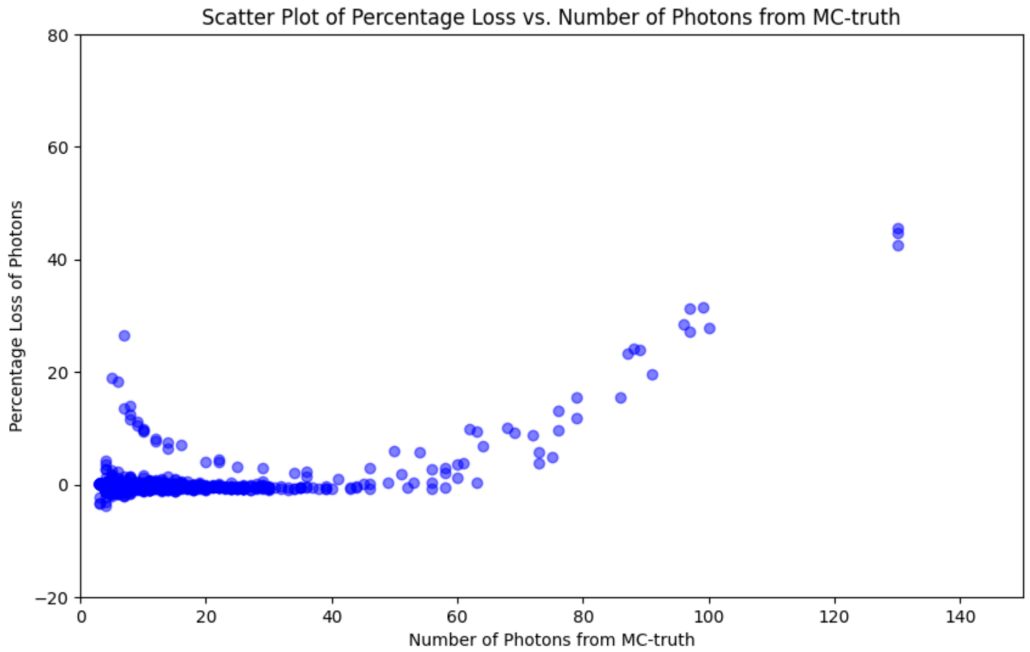
Old result with 1/8 clock period = 0.4166 ns but Isrc unchanged with respect to the configuration of 3.333 ns



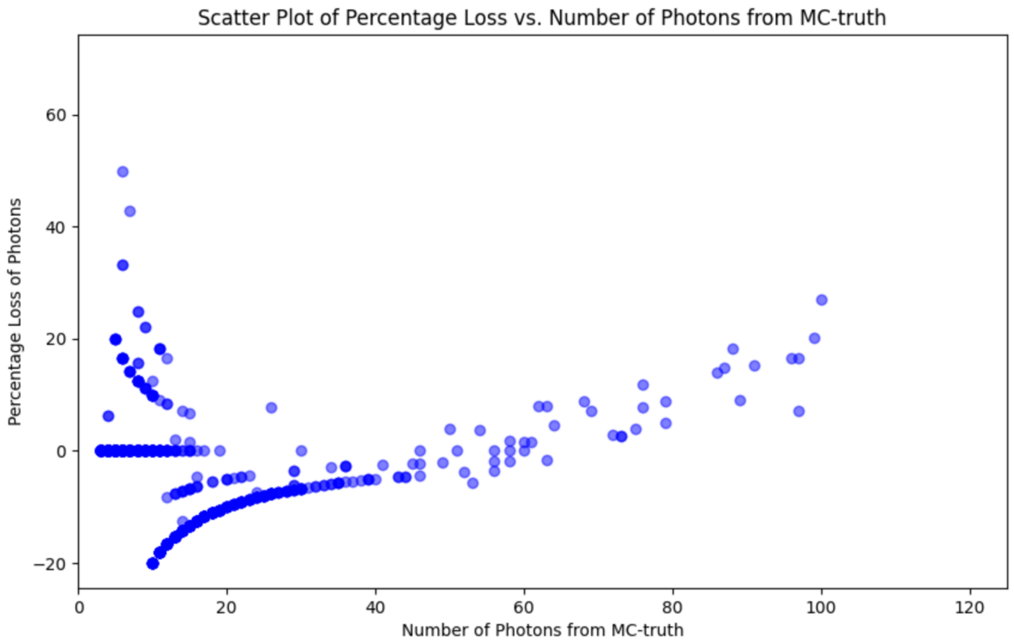
New result with 1/8 clock period = 0.4166 ns and 8*Isrc -> WORSE!
There's an overestimation of the number of photons between 10 and 60, not noticed keeping Isrc = 0.200 uA for the three clock periods

Nintegrators > 6

Comparison with the plots shown on 26 th July WG meeting



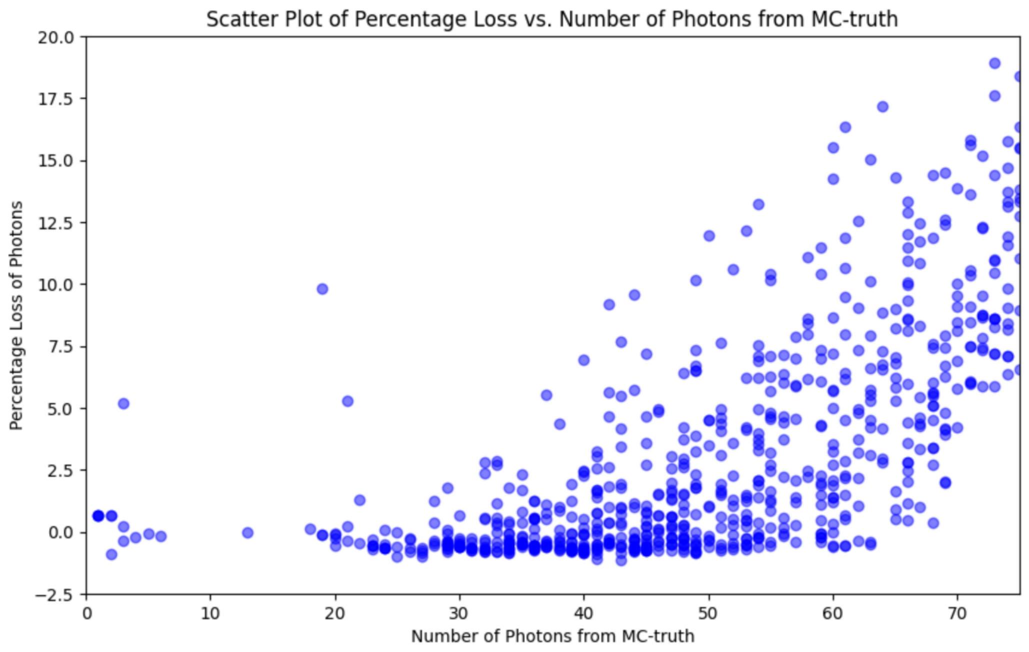
Old result with 1/8 clock period = 0.4166 ns but Isrc unchanged with respect to the configuration of 3.333 ns



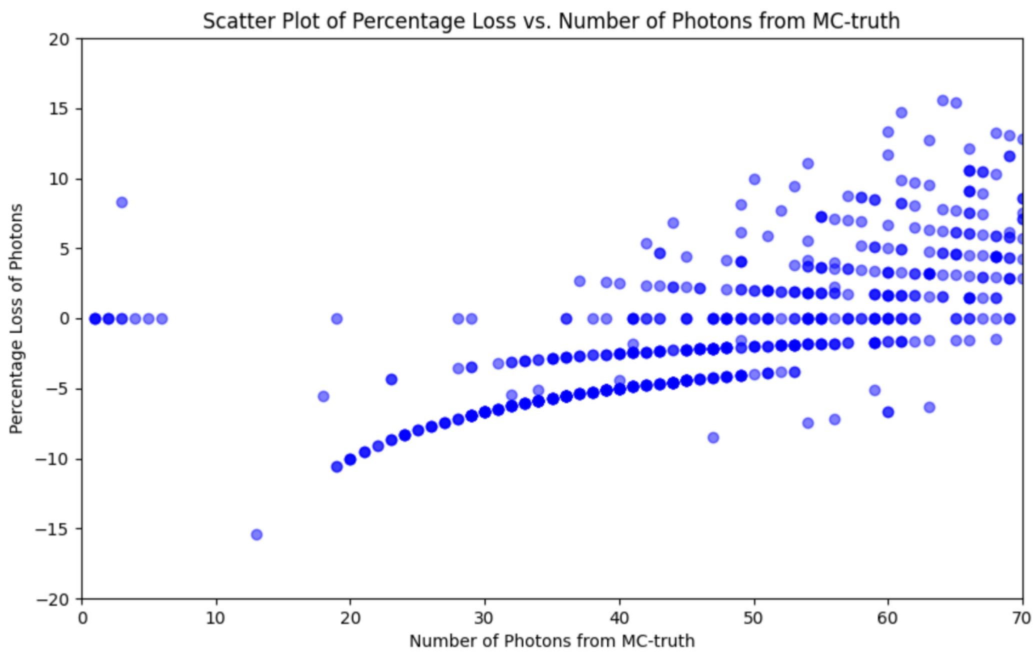
New result with 1/8 clock period = 0.4166 ns and 8*Isrc -> WORSE!
There's an overestimation of the number of photons between 10 and 60, not noticed keeping Isrc = 0.200 uA for the three clock periods

2 < Nphotons < 100

Comparison with the plots shown on 26 th July WG meeting



Old result with 1/8 clock period = 0.4166 ns but Isrc unchanged with respect to the configuration of 3.333 ns



New result with 1/8 clock period = 0.4166 ns and 8*Isrc -> WORSE!
There's an overestimation of the number of photons between 10 and 60, not noticed keeping Isrc = 0.200 uA for the three clock periods

11 < Nphotons < 80

within 20 seconds with respect to the true interaction time