Calibration Studies (Galactic noise revisited)

Stavros Nonis, Antonios Leisos, George Vittakis, Kostas Papageorgiou

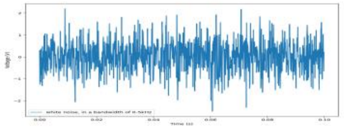
GRAND collaboration meeting, Warsaw, Poland, June the 5th 2025

Galactic noise simulations

- The simulated open circuit RMS voltage square value $(V^{oc}_{rms}(f))^2$ per unit frequency [V^2/Hz] (for each antenna arm) due to the galactic temperature is computed using the formula *:

$$(V^{oc}_{rms}(f))^2 = \frac{Z_0 K_B}{c^2} f^2 \int_0^{2\pi}\int_0^{\pi} T_{gal}(\theta,\varphi) * \left(L^2_{eff_\theta}(\theta,\varphi) + L^2_{eff_\varphi}(\theta,\varphi)\right) * sin\theta d\theta d\varphi \qquad (1)$$

- The corresponding output voltage square $V^{out}_{rms}(f)$ per unit frequency [V^2/Hz] (after the implementation of the RF chain) is :



$$V^{out}_{rms}(f) = rf_{chain}(f) * V^{oc}_{rms}(f) \qquad (2)$$

Assuming Leff is correct we test rfchain

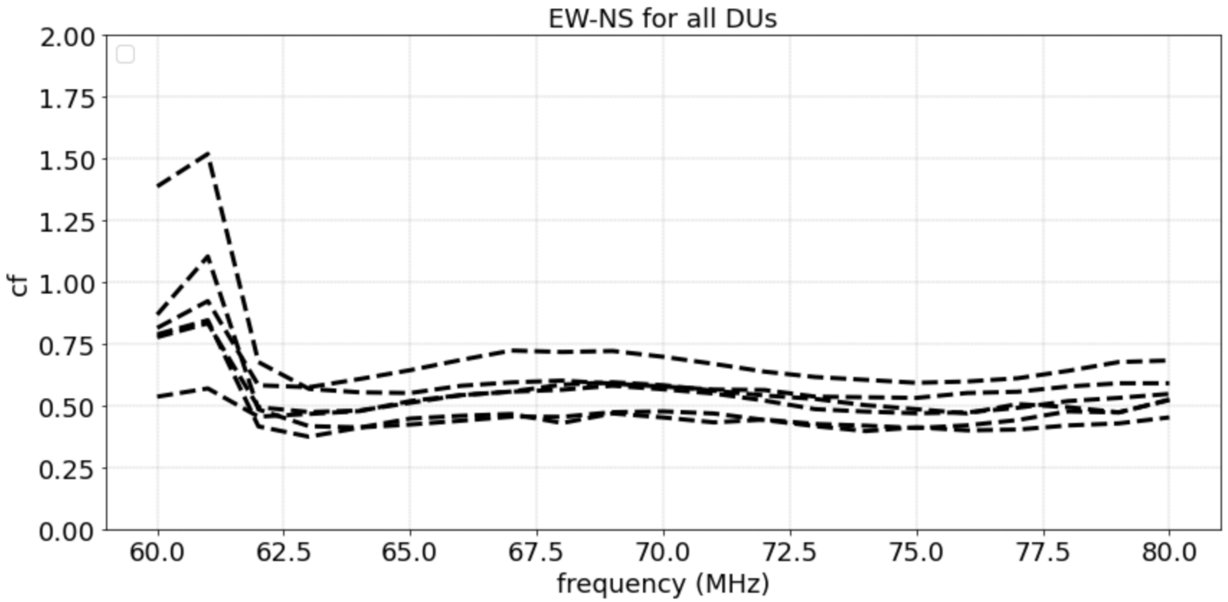
These voltages were calculated for each antenna polarization in the 25-250 MHz frequency band (1 MHz bin) and for 24 LST-bins of 1 hour. Calculations are produced using Lfmap for the galactic temperature.

* (https://forge.in2p3.fr/documents/1324)
* (https://github.com/grand-mother/grand/blob/dev/grand/sim/noise/Compute_Plot_Galactic_Noise.py)

Galactic noise simulations

GRAND Analysis December 5-6 / 2024 Extended Meeting: "Galactic Calibration, by S. Nonis*"

Rfchain(f)→ cf(f)*rfchain(f)

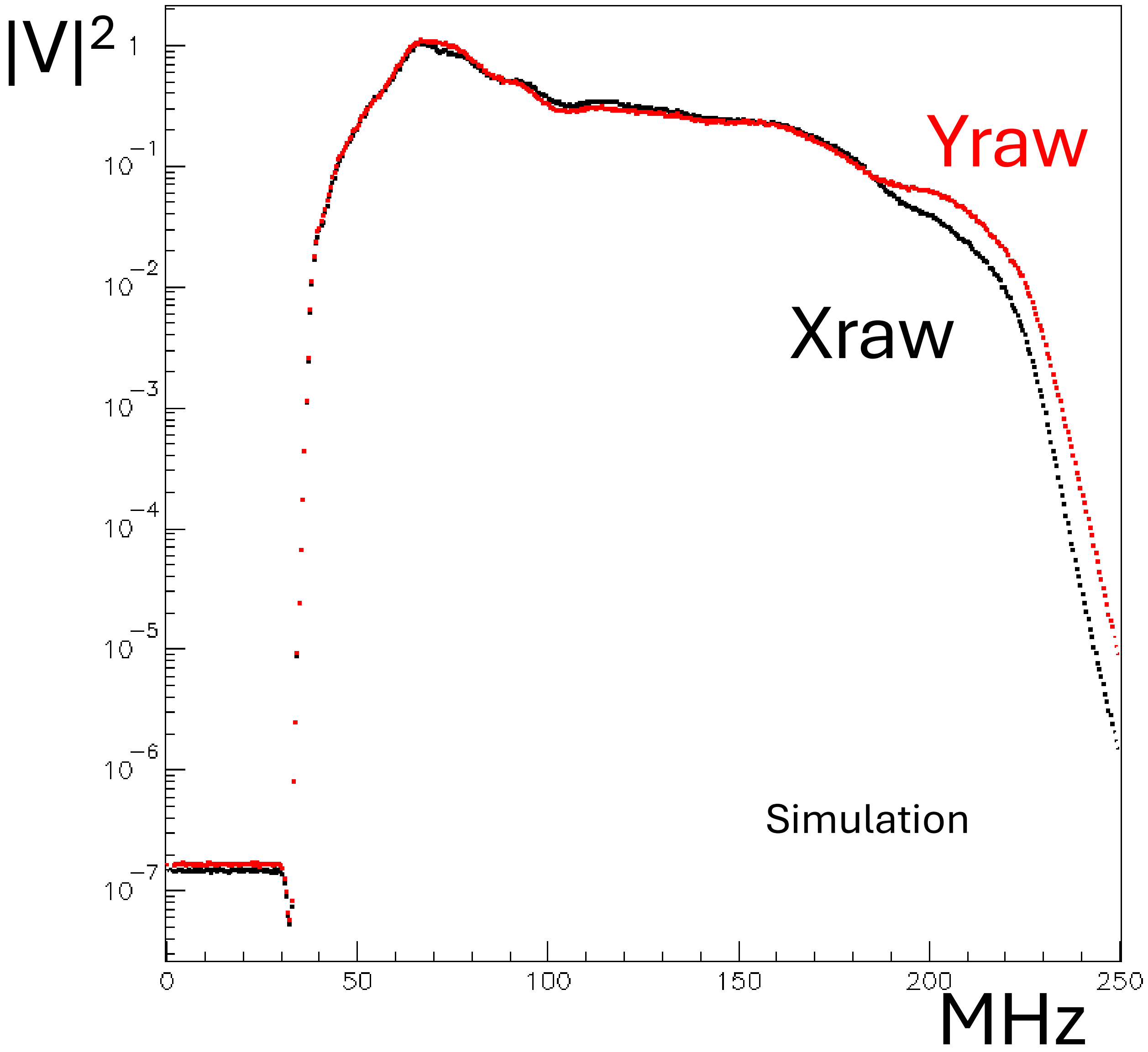


In this analysis we assume that cf does not depend on the frequency and we calculate it in the whole spectrum.

* https://indico.in2p3.fr/event/34166/timetable/#all.detailed

Galactic noise simulations

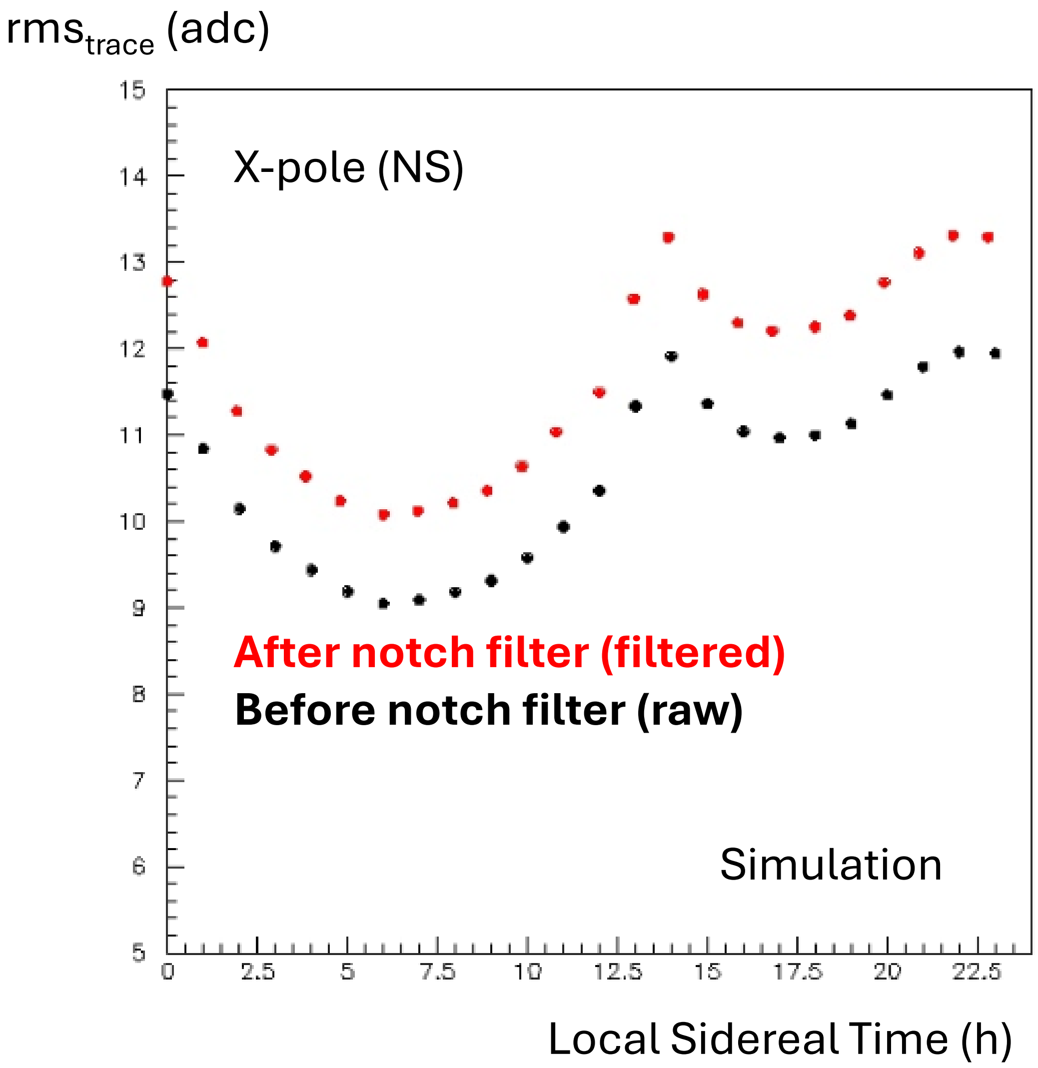
Average Spectrum (over LST)

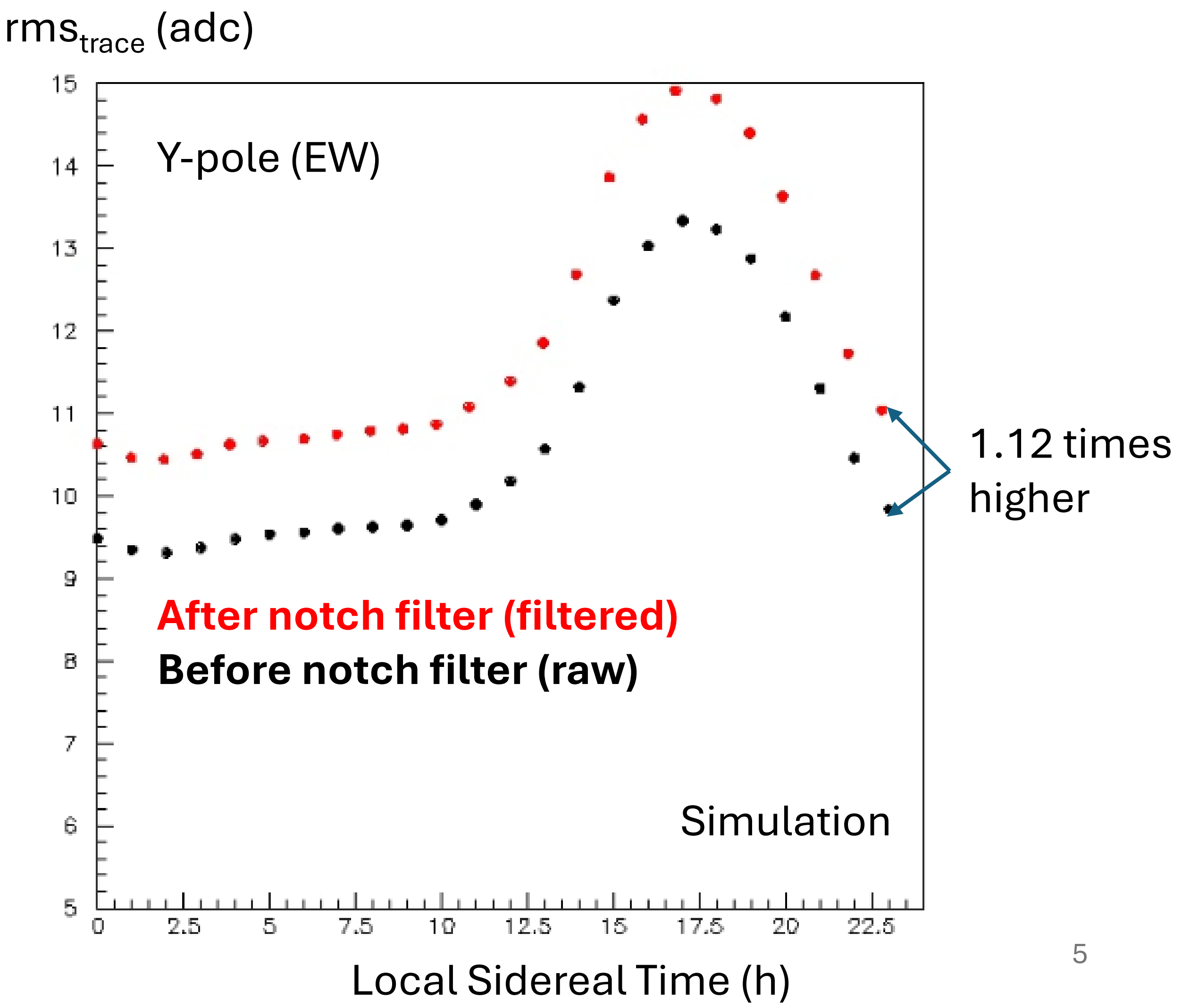


Methodology

- We use the model for the spectrum (see previous slide)
- For each pole, produce pulses according to the spectrum and for any LST (for each LST the spectrum is different)
- Apply notch filter to the pulses (provided by Xin Xu)
- Calculate the rms of the traces
- Find the mean value of the rms for each LST hour
- Compare with corresponding data (rms vs LST)

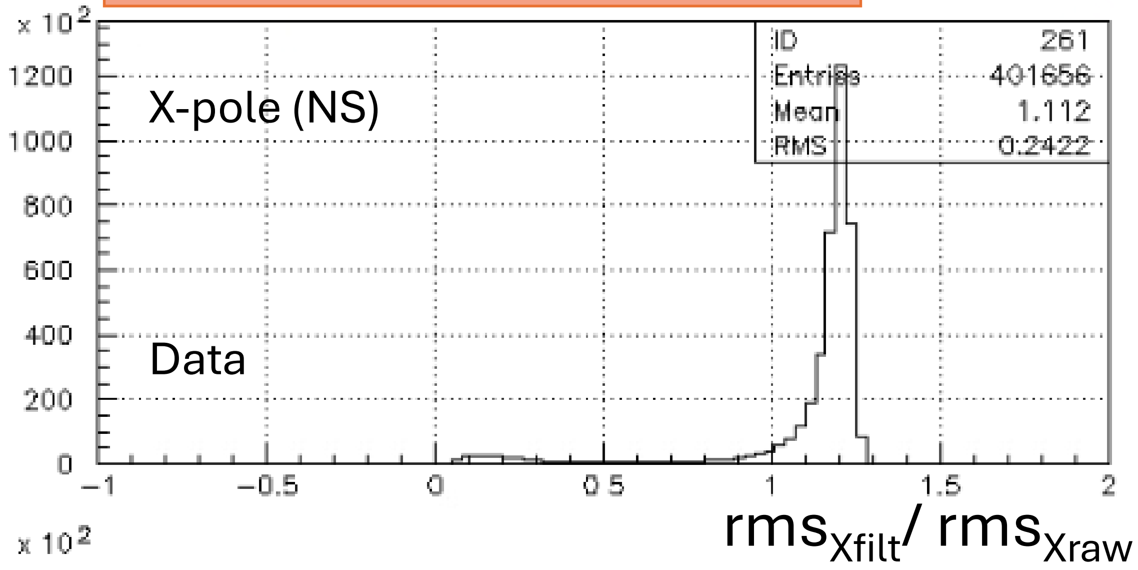
Galactic noise simulations

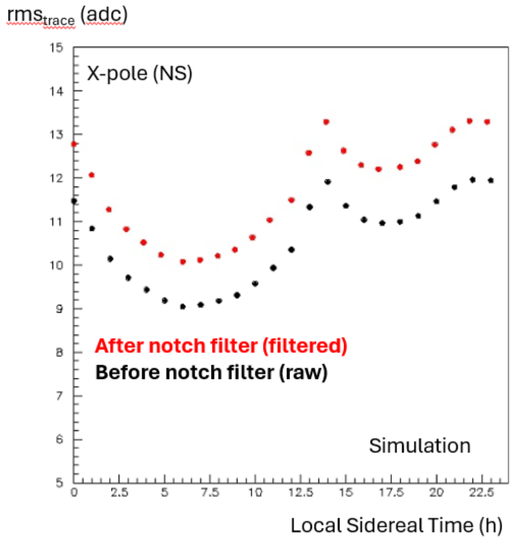


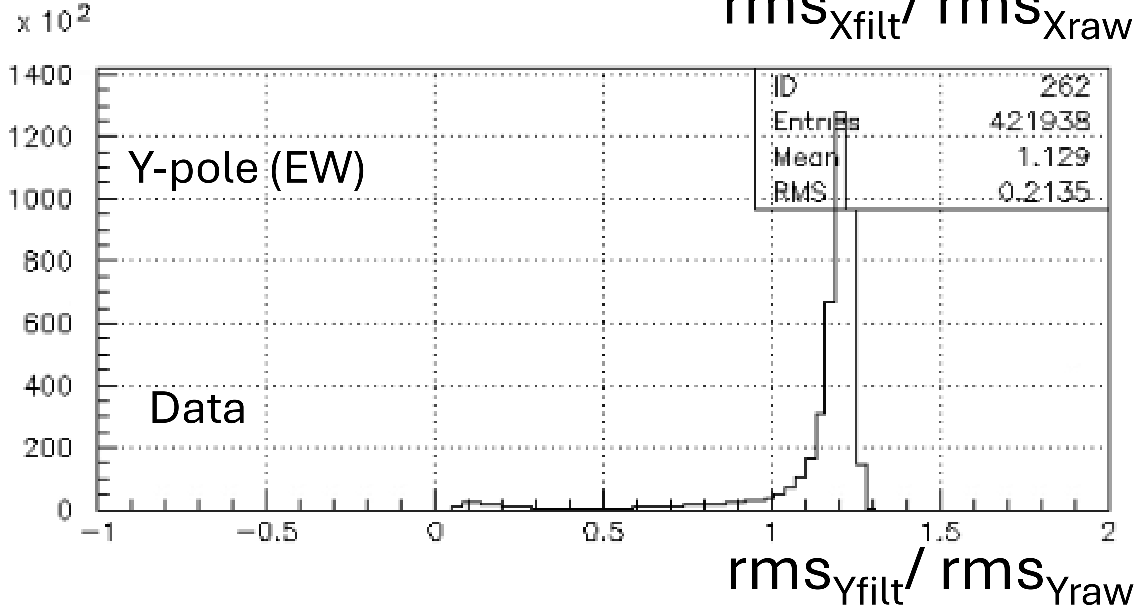


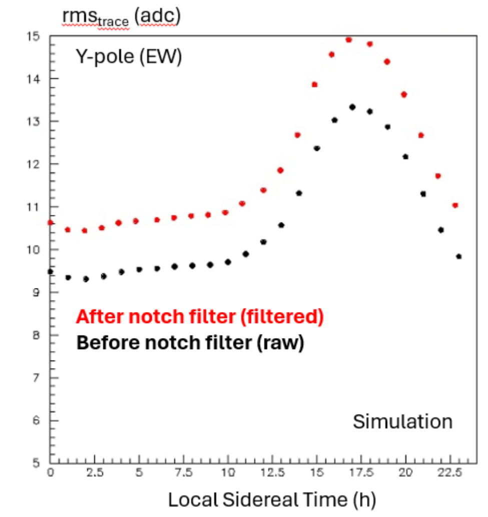
Galactic noise simulations

UD files from November 12-30/2024





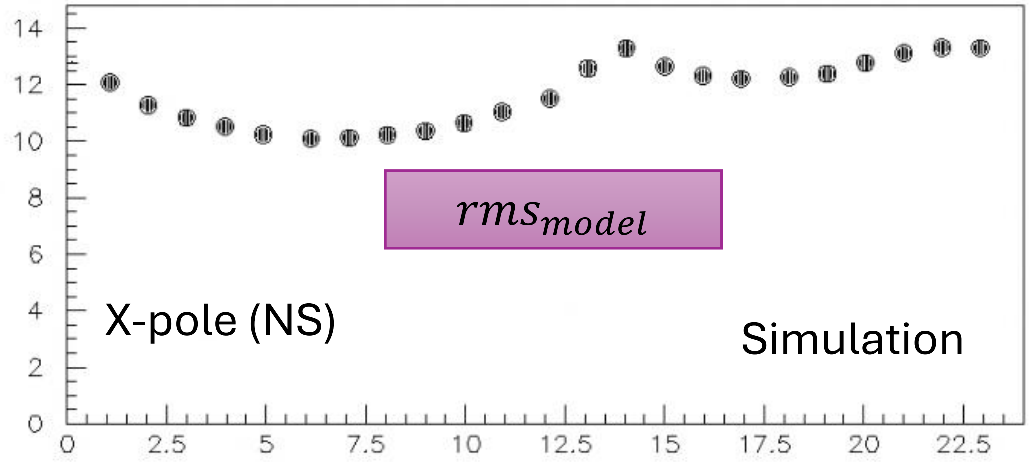




Galactic noise simulations

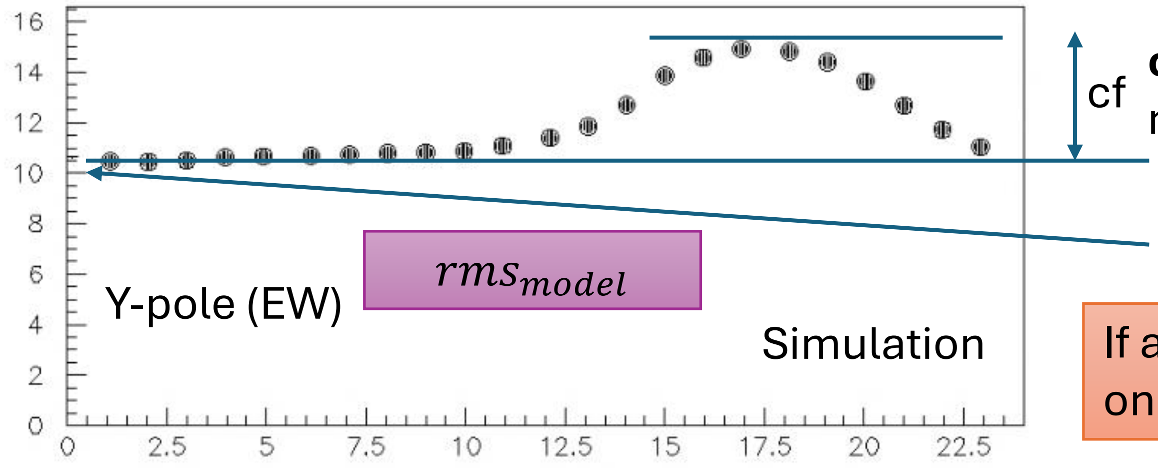
- Compare the rms vs LST between Simulation and Data

rms_{trace} (adc)



Local Sidereal Time (h)

rms_{trace} (adc)



Local Sidereal Time (h)

We apply a χ^2 fit to match the data with simulation, i.e.

$$x^2(cf, V_{rms}^0) = \sum_{i=1}^{i=24} (rms_{data} - rms_{simu})^2$$

$$rms_{simu}(cf, V_{rms}^0) = cf * rms_{model} + V_{rms}^0$$

cf stretches or shrinks the distance between maximum and minimum

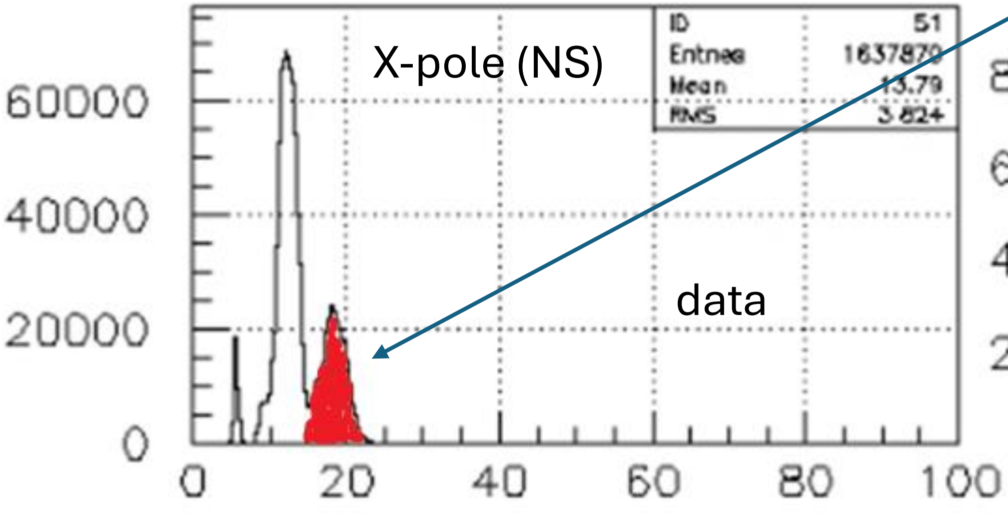
V_{rms}^0 accounts for the vertical shift (average noise)

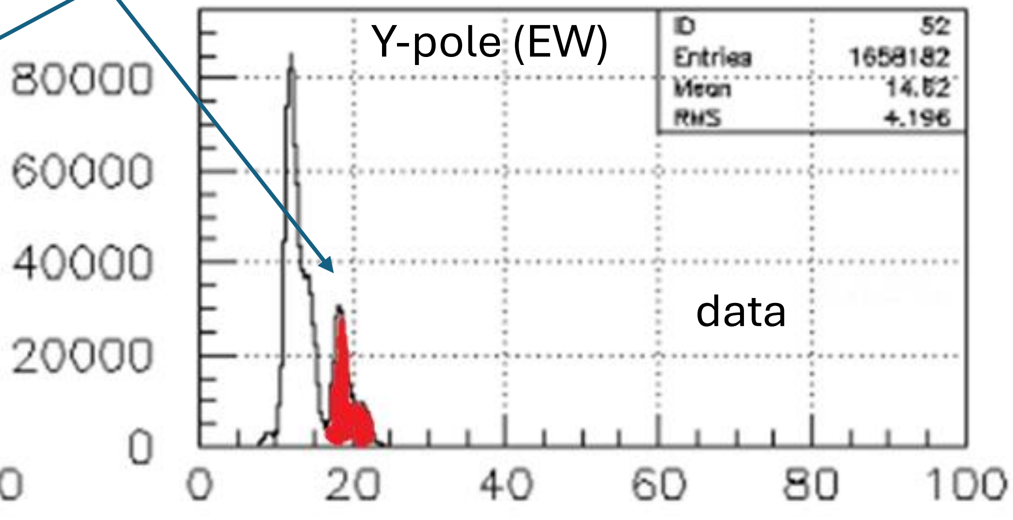
If any other noise does not depend on LST then it contributes only to the constant shift

Data Distributions (MD)

MD files from April 2025

After 27/04/2025

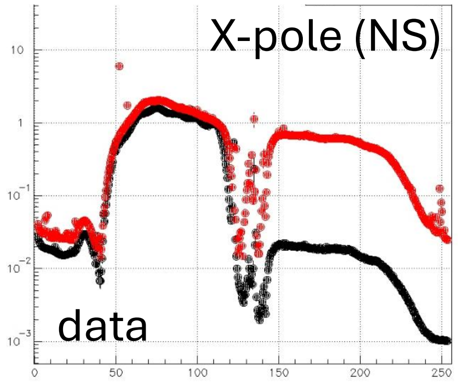




$\mathrm{rms}_{\mathrm{Xfilt}}$

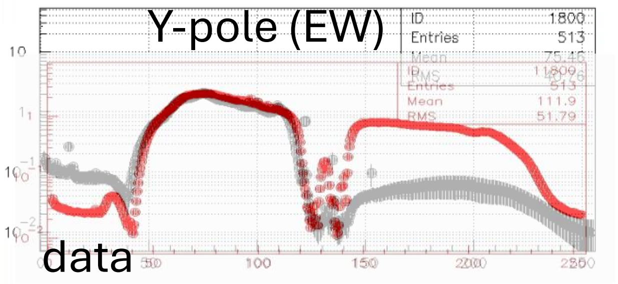
$\mathrm{rms}_{\mathrm{Yfilt}}$

$|V|^2$



MHz

$|V|^2$

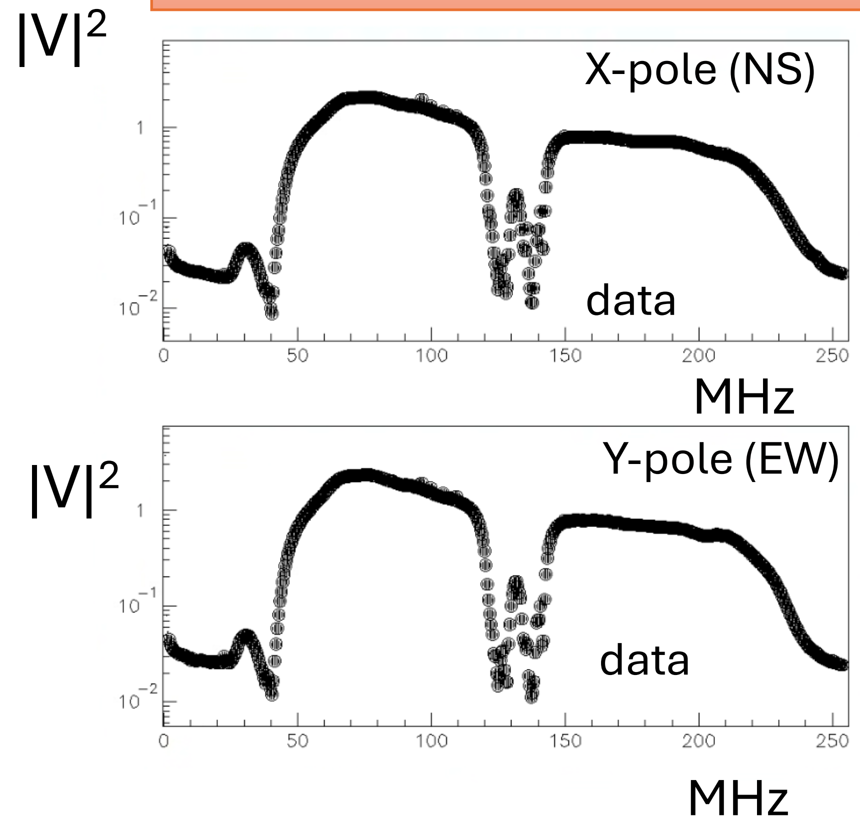


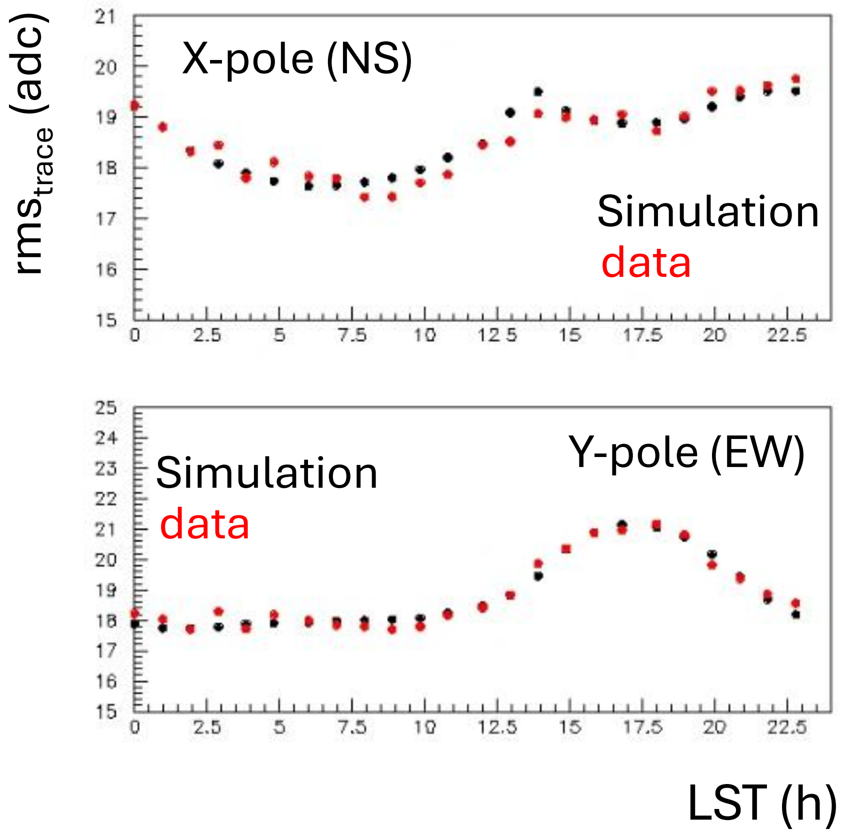
MHz

Data Distributions (MD)

After 27/04/2025

MD files from April 2025



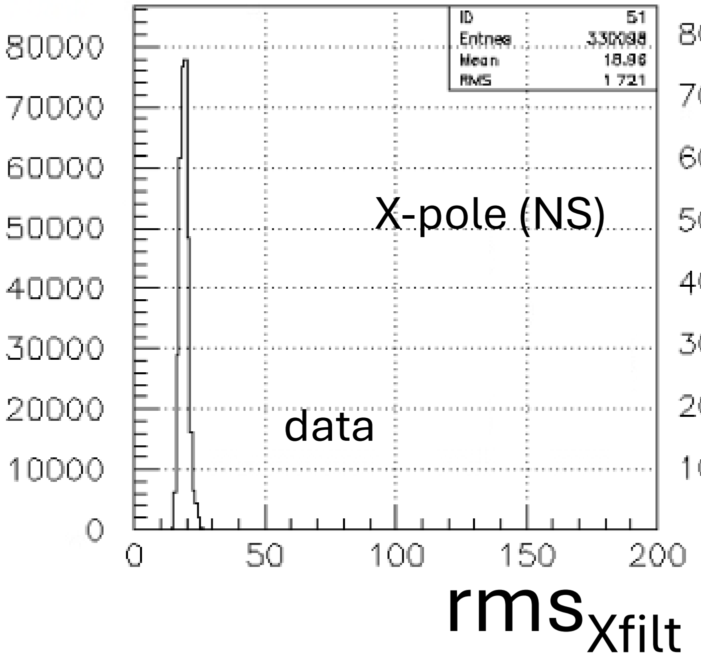


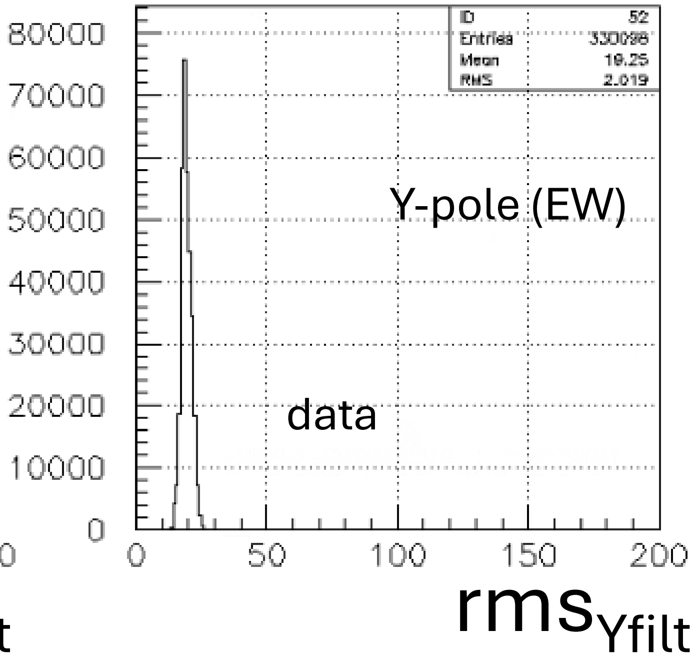
Cf=0.58 V_{rms}^{0} =11.8

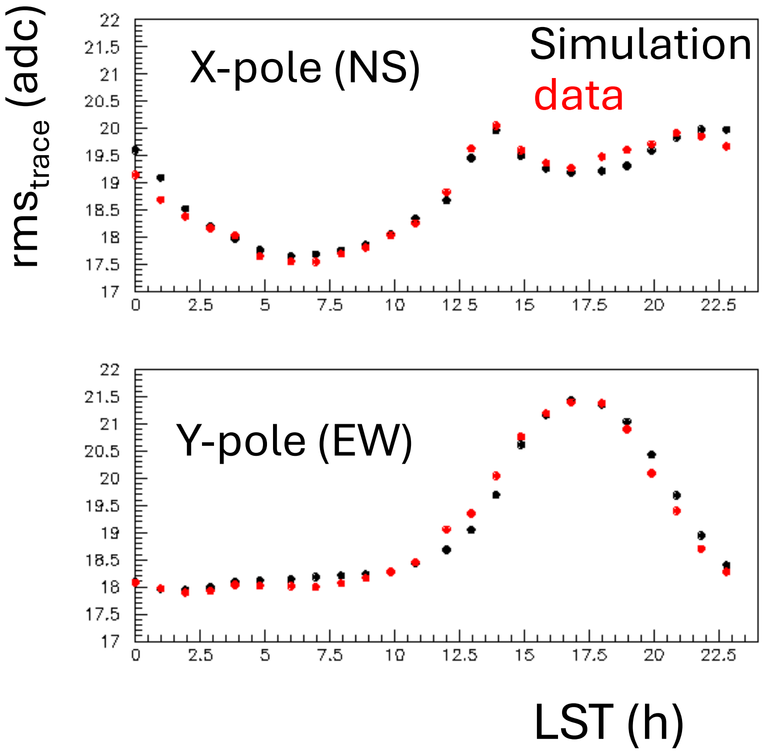
Cf=0.76 V_{rms}^{0} =9.8

Data Distributions (MD)

MD files from March 2025

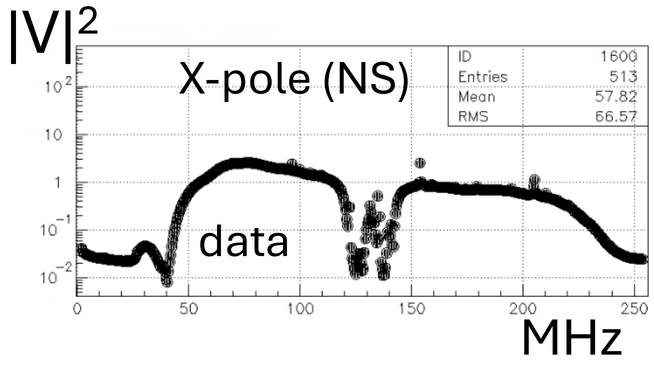


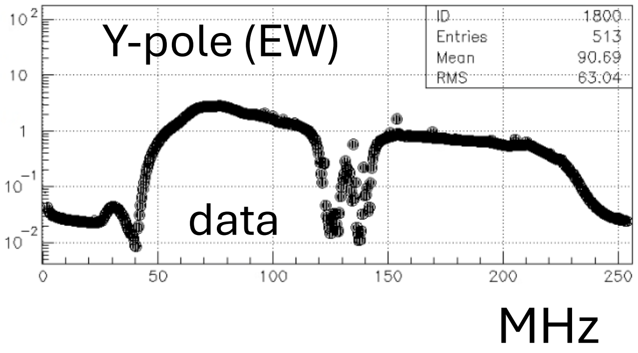




Cf=0.72 V^0_{rms} =10.4

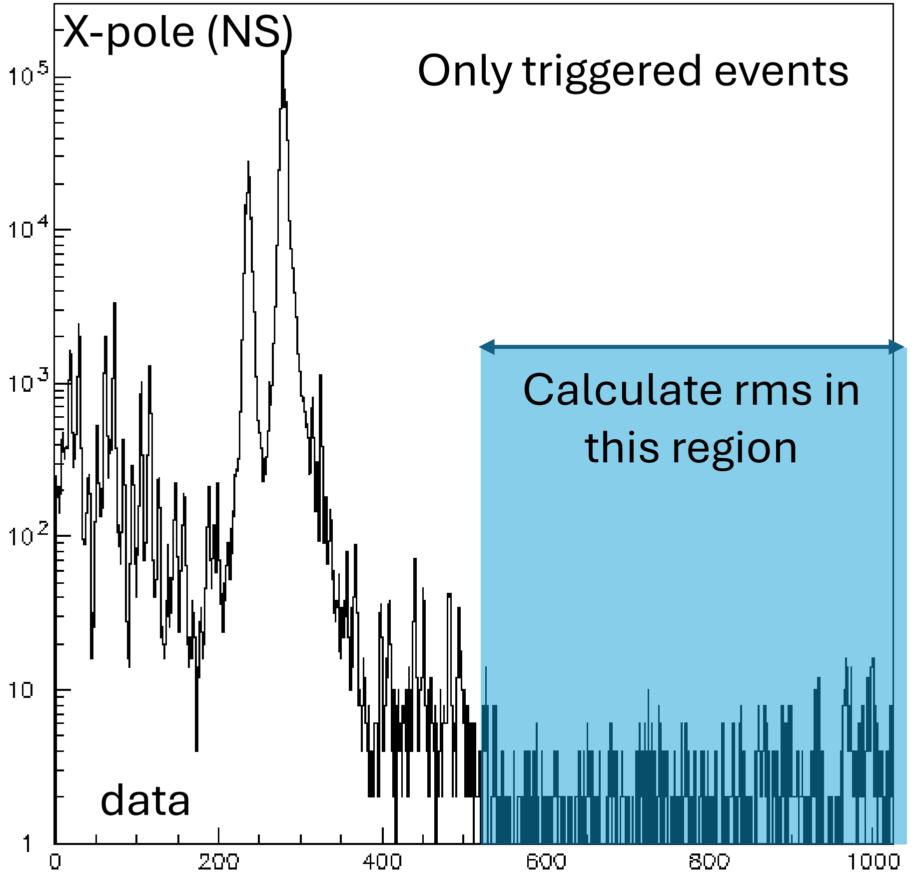
Cf=0.78 V^0_{rms}=9.8



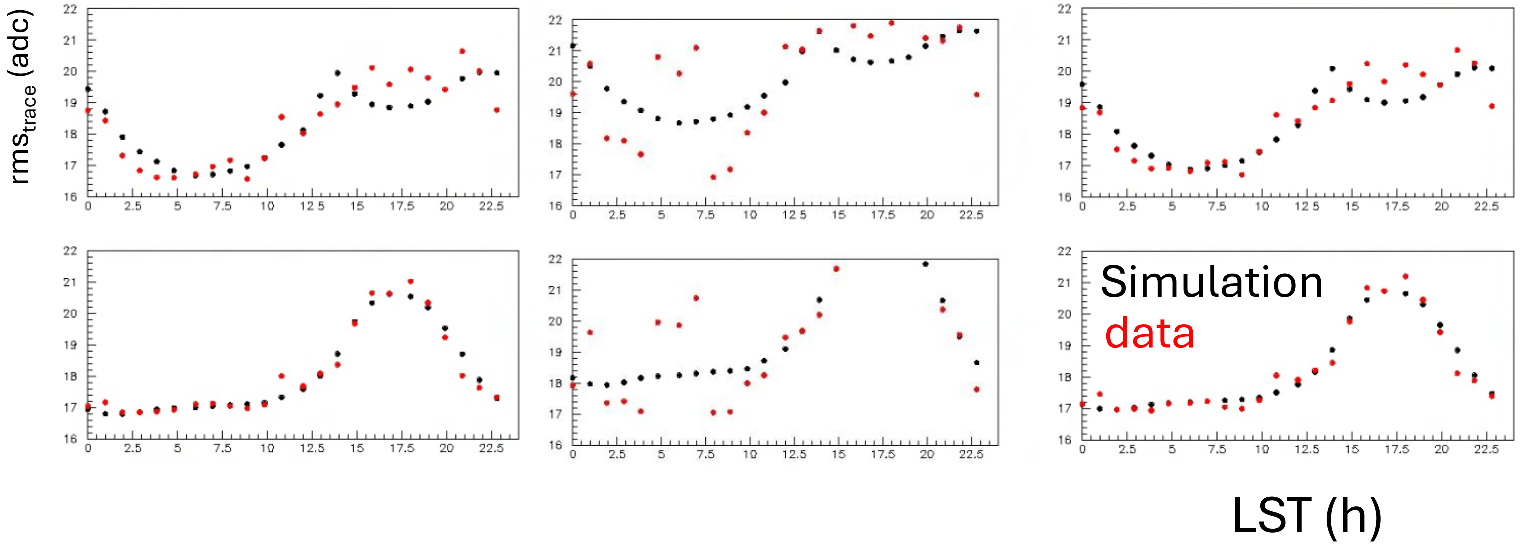


Data Distributions (UD)

UD files November 2024



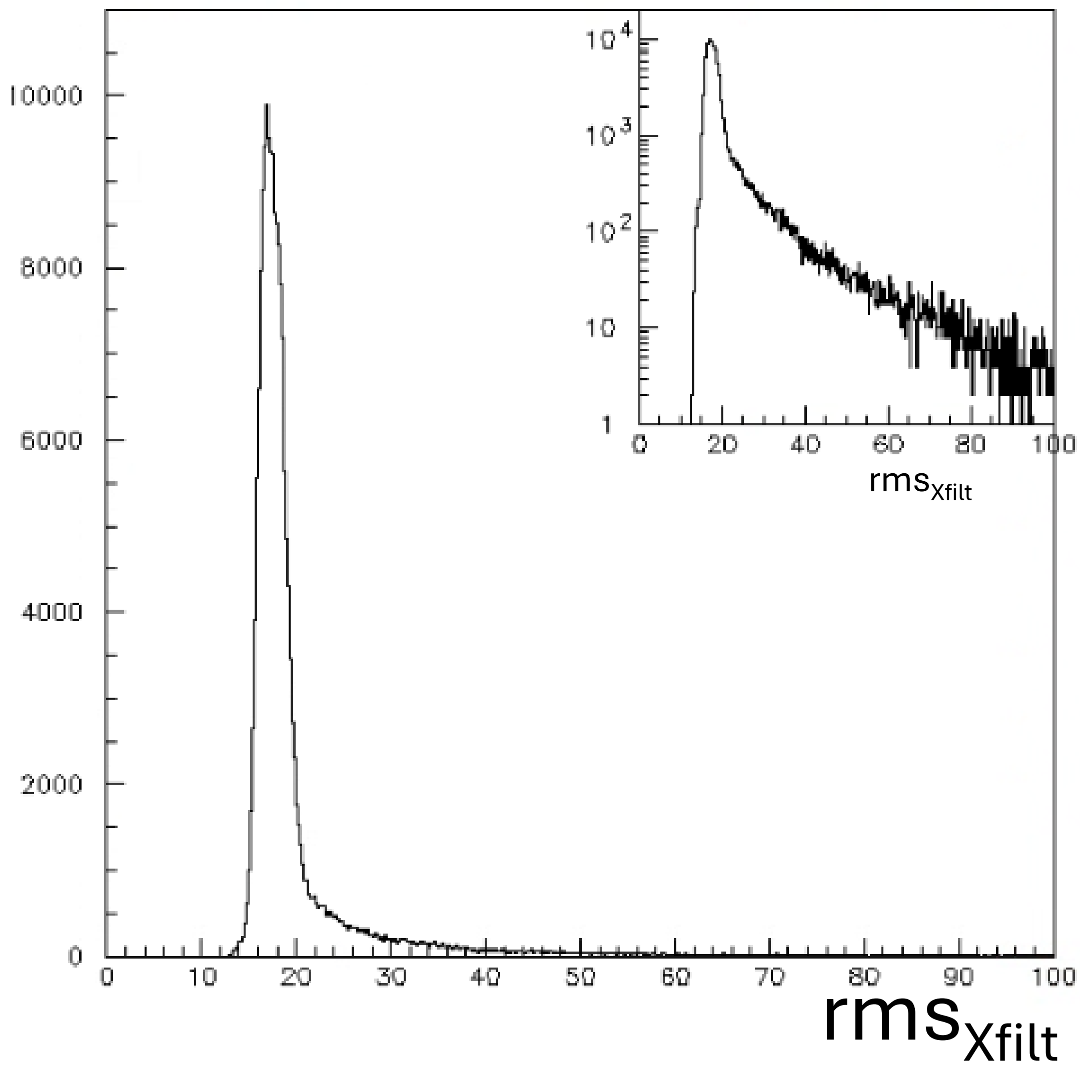
Position of peaks (i.e. |V|>5σ)

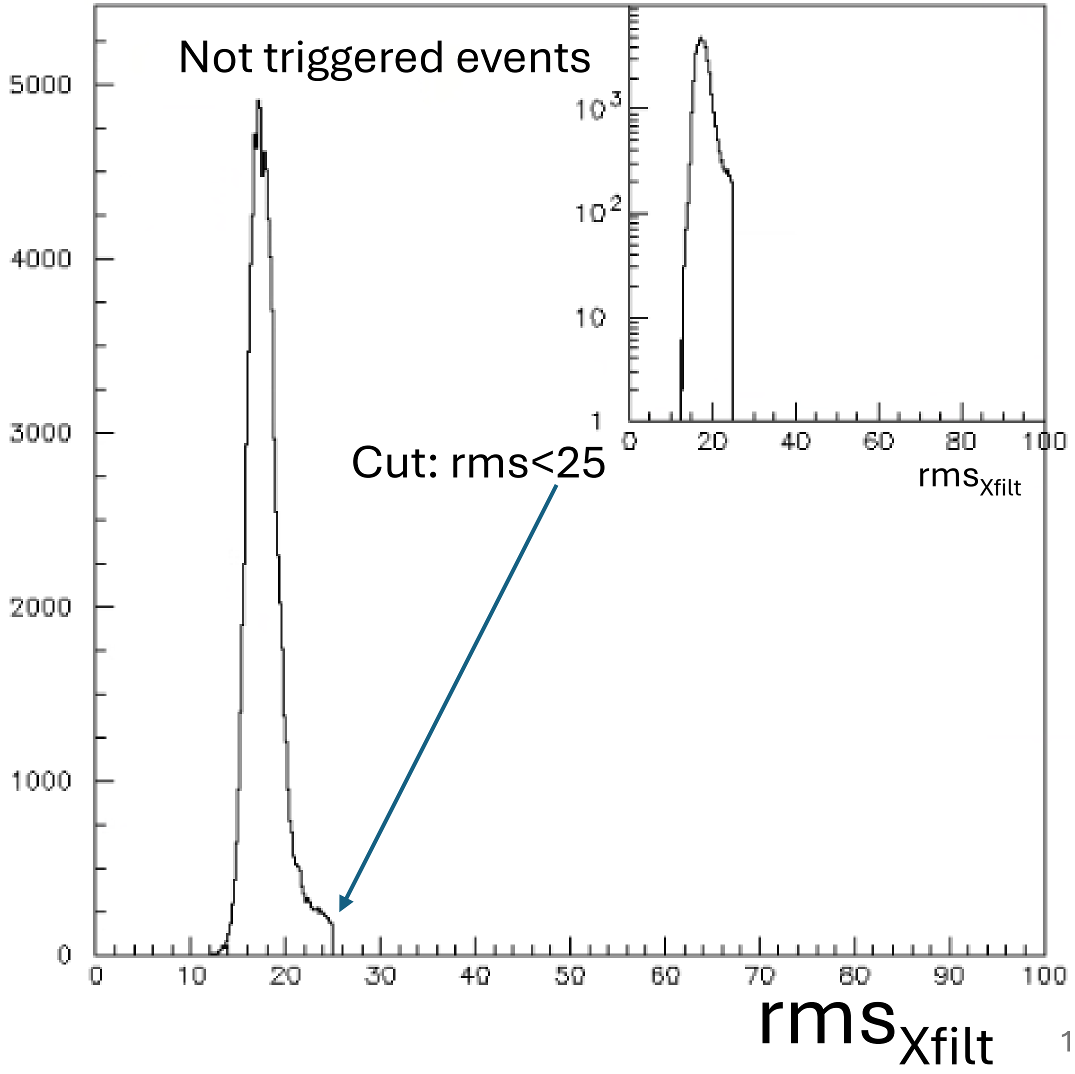


It does not seem to be applicable

Data Distributions (UD)

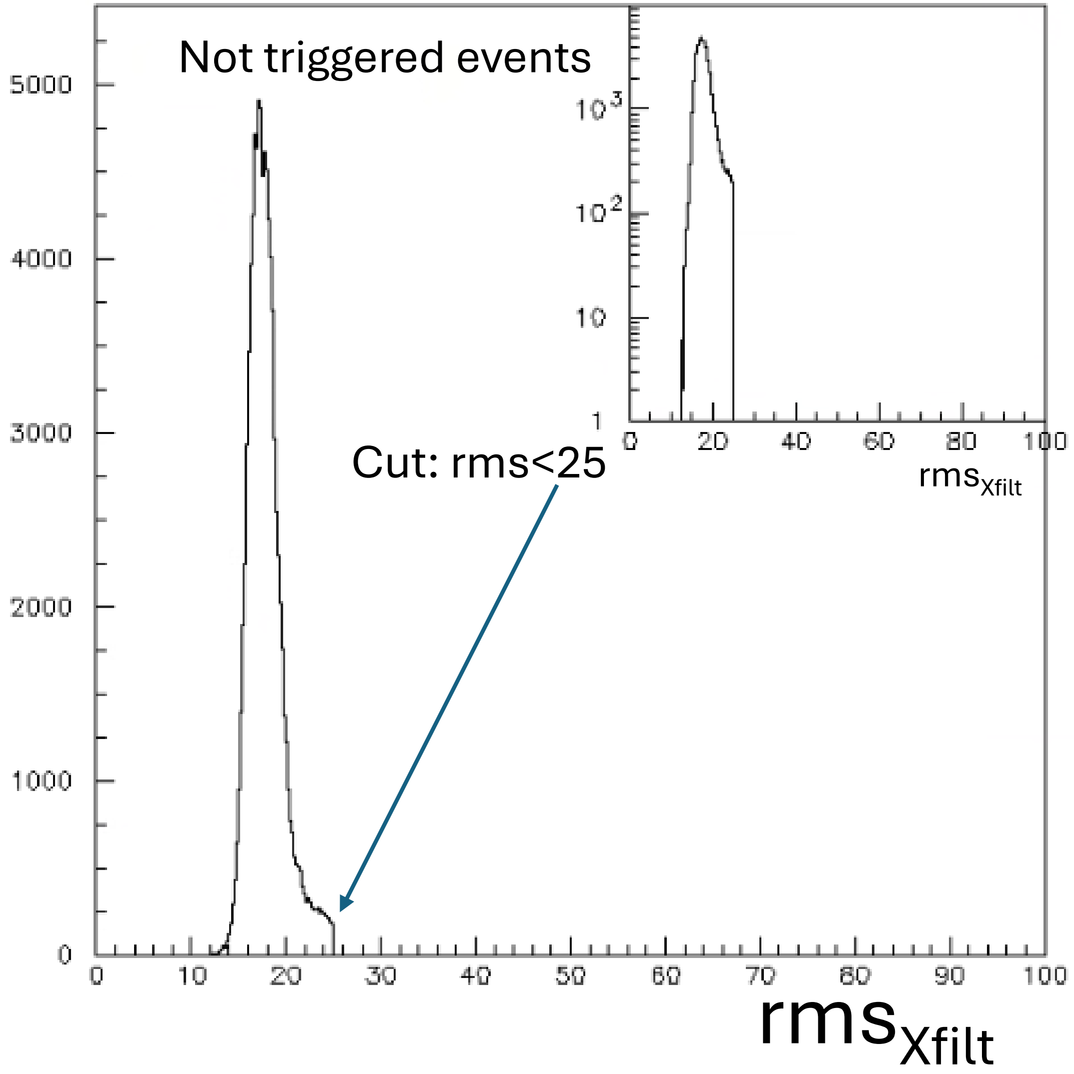
UD files November 2024

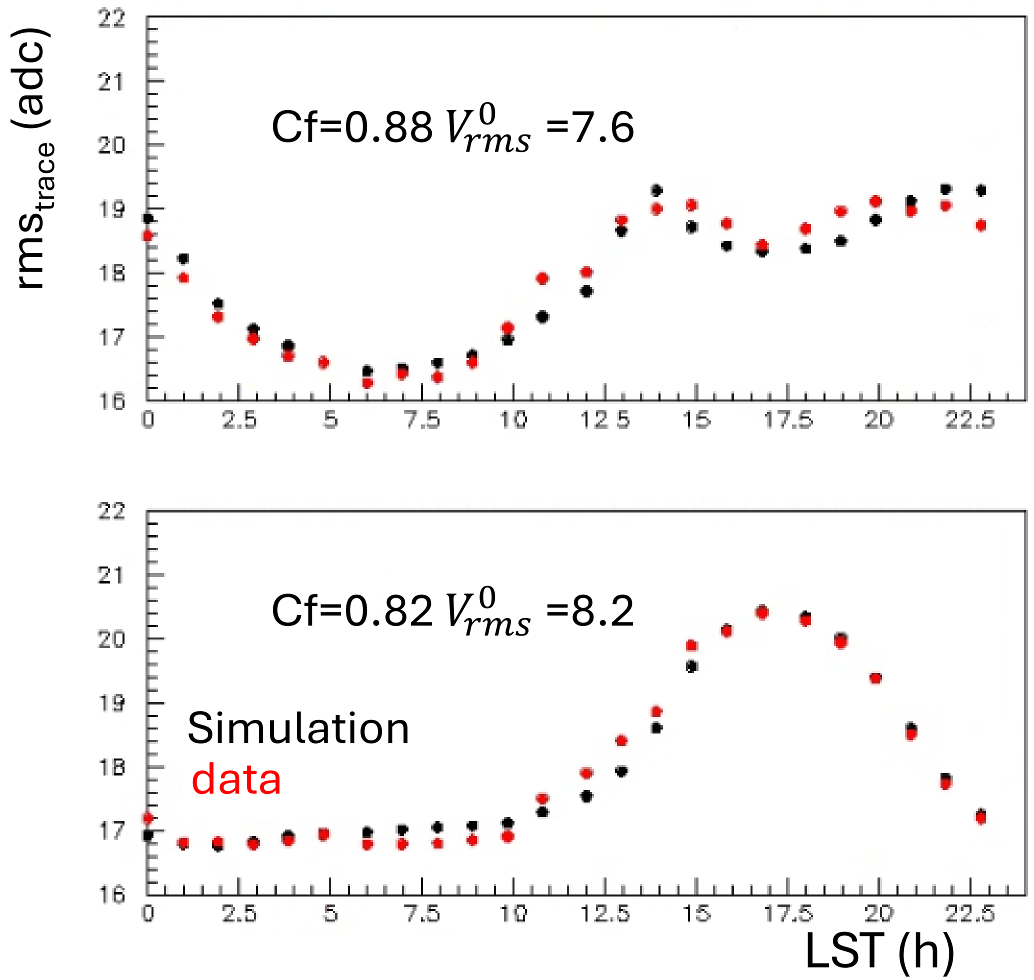




Data Distributions (UD)

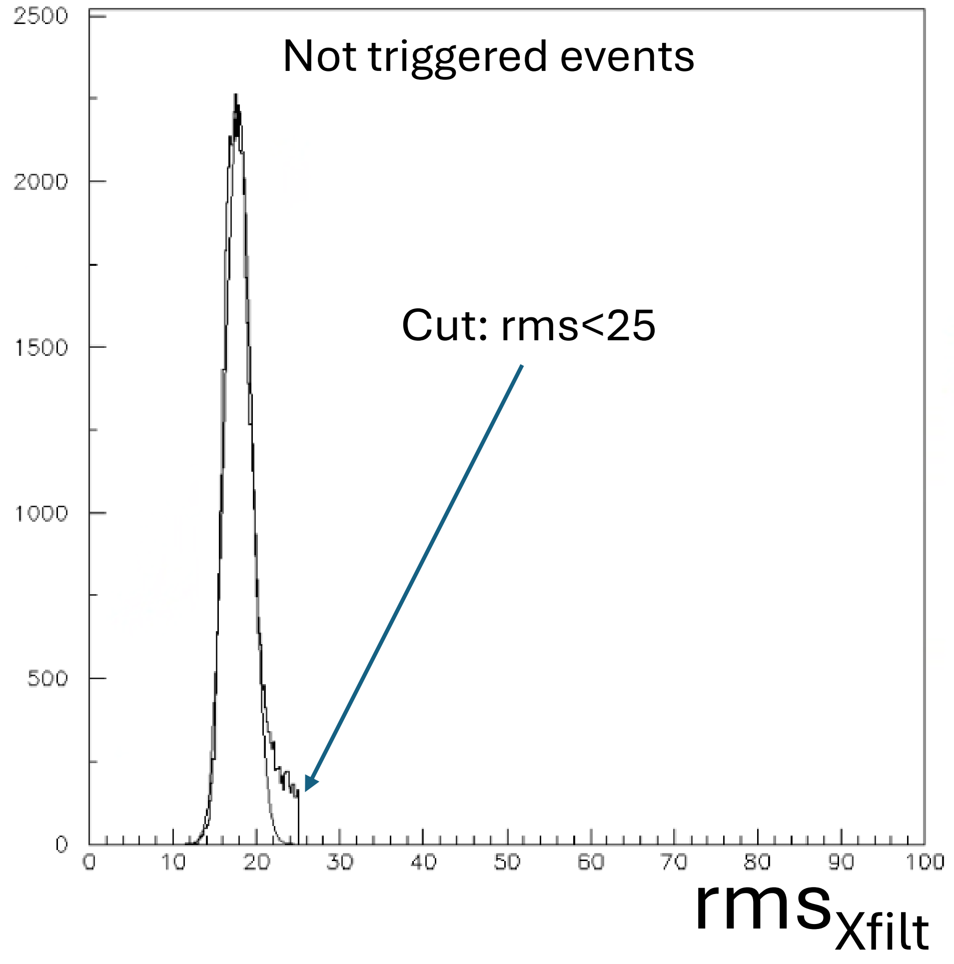
UD files November 2024

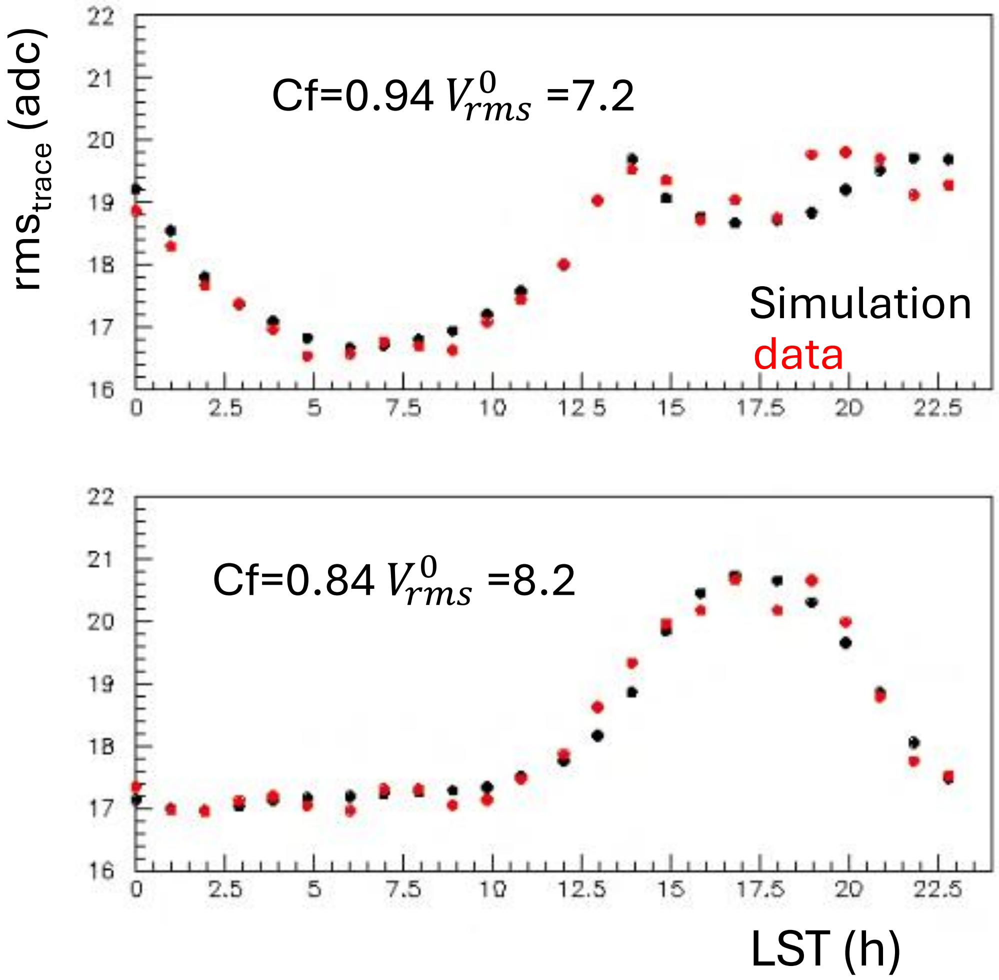




Data Distributions (UD)

UD files December 2024





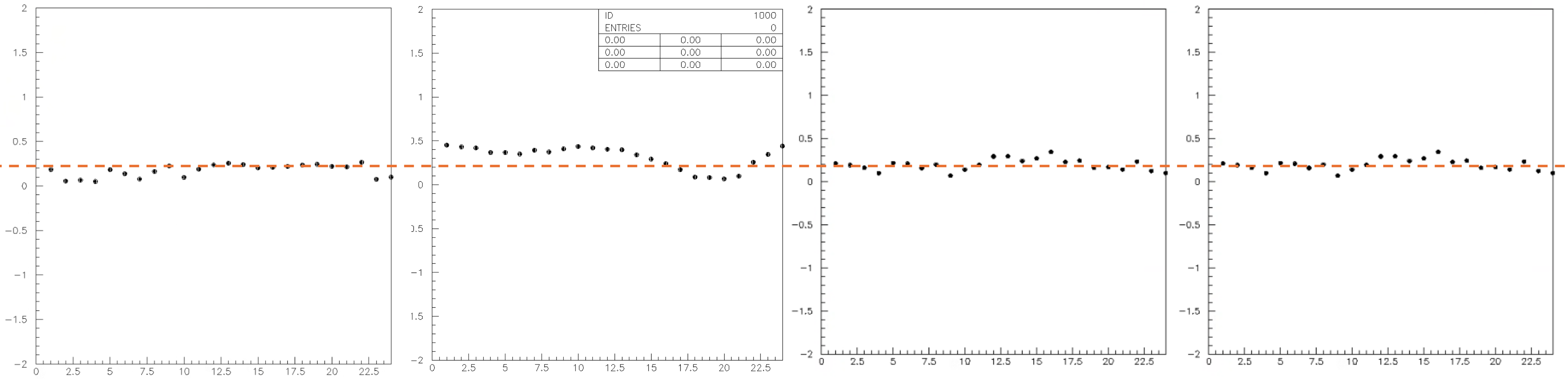
Sum-Up

	Cf (X_{filt})	Cf (Y_{filt})
MD (April)	0,58	0,76
MD(March	0,88	0,82
UD (Nov)	0,84	0,84
UD (Dec)	0,72	0,78
Mean	0,755	0,8

- Simulation Pulse height prediction seems that is should be lowered by 80%.
- This may affect some gain related variables (voltages, pulse risetime, maybe polarization), but probably not SNR or trigger decision.

Correlation (RMS_X-RMS_Y)

ρ (correlation coefficient)

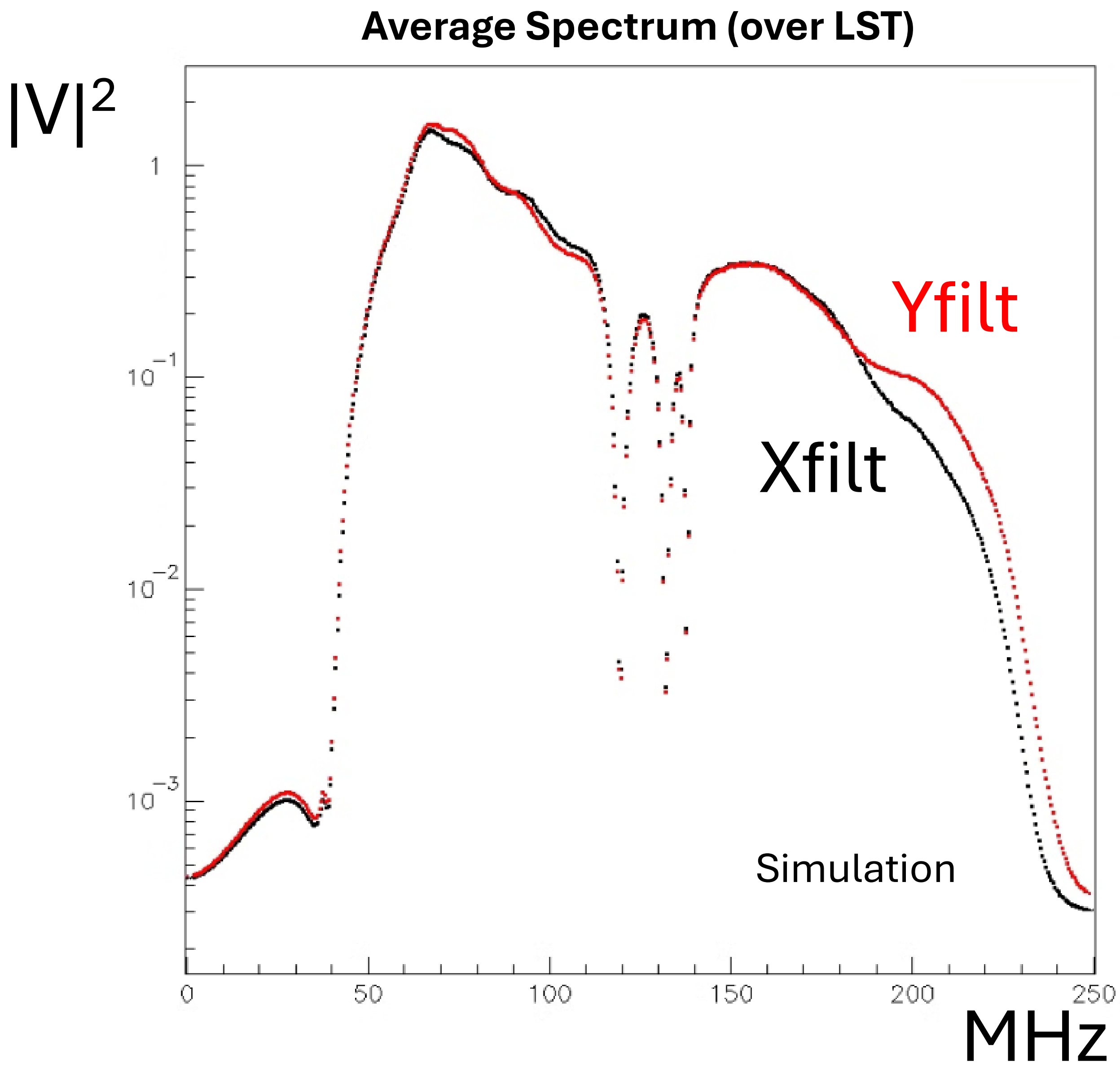


LST (h)

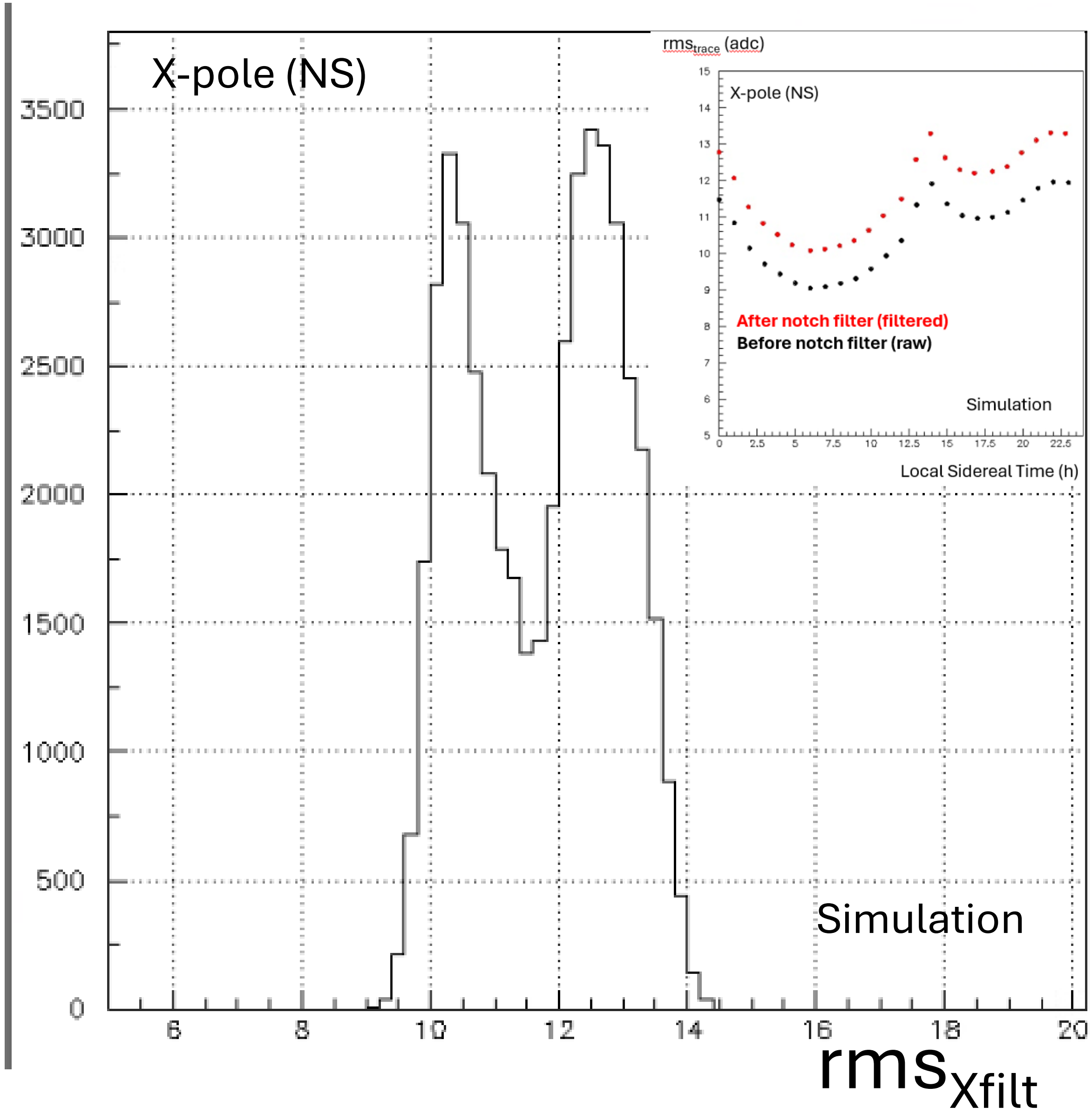
Positive but rather low correlation (but inner noise is also present)

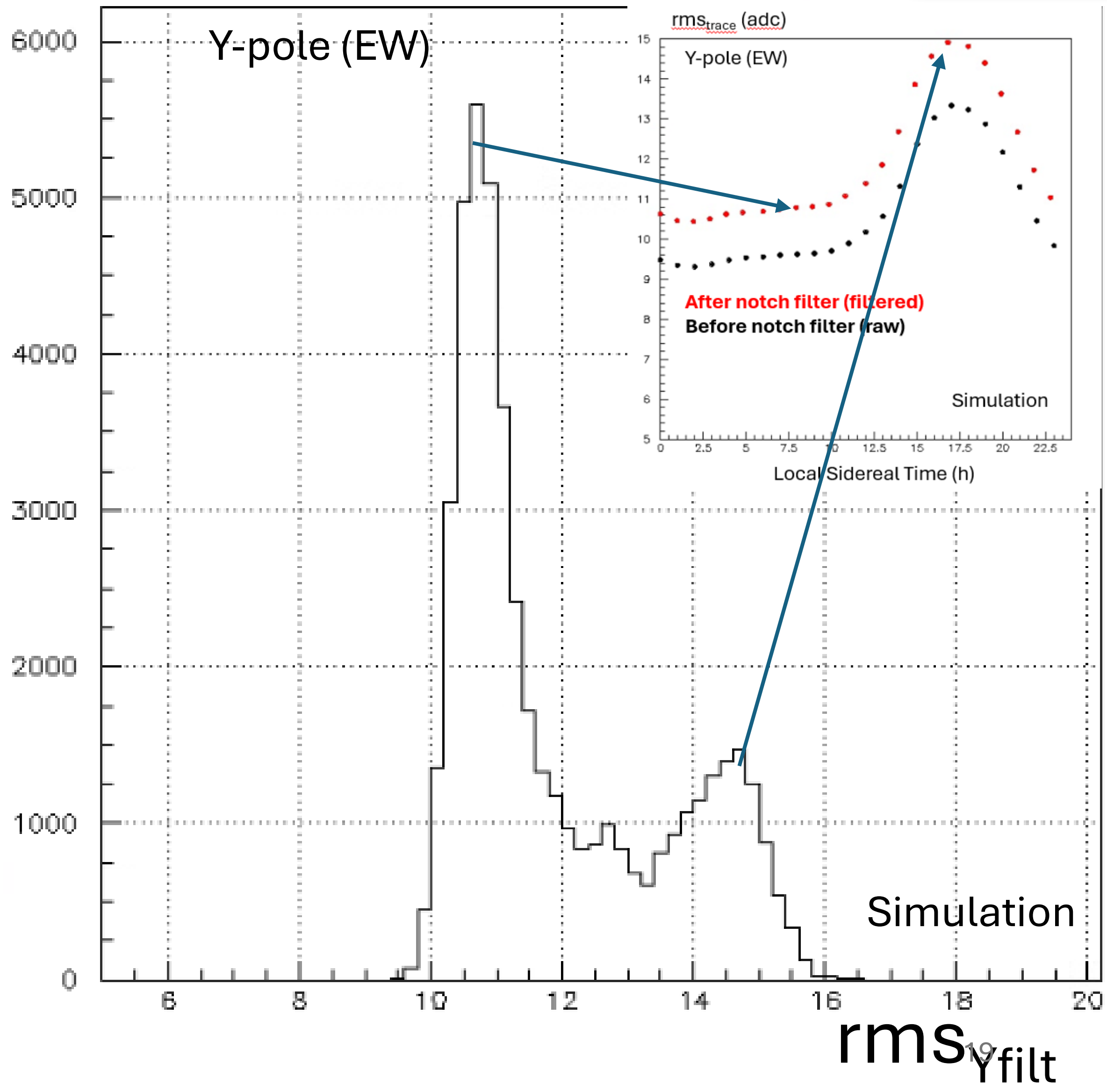
Thank You

Galactic noise simulations



Galactic noise simulations

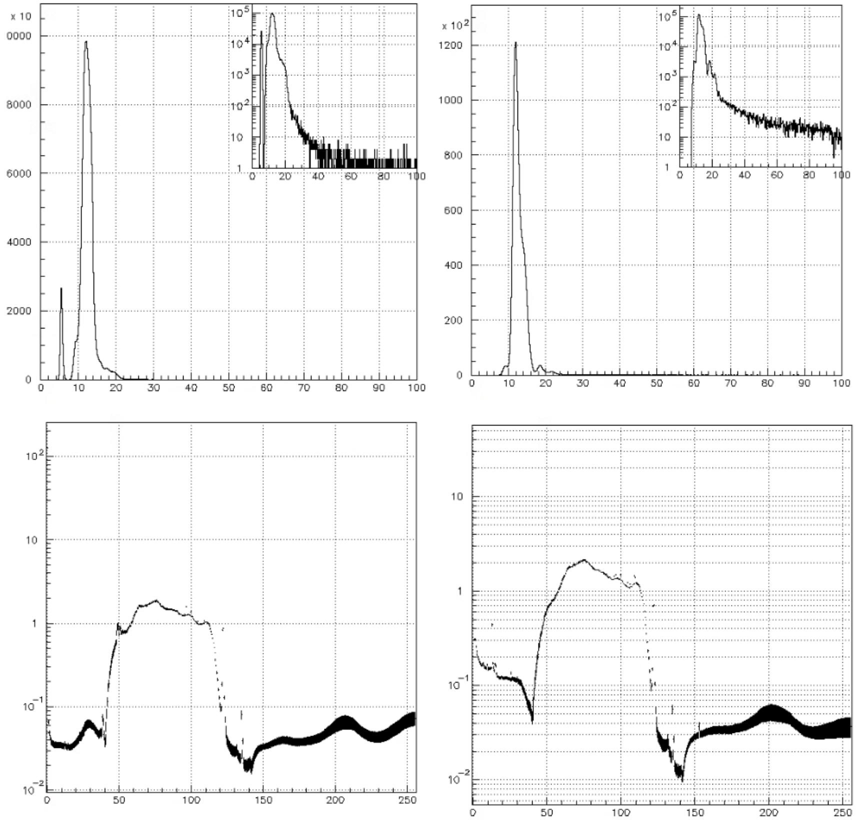


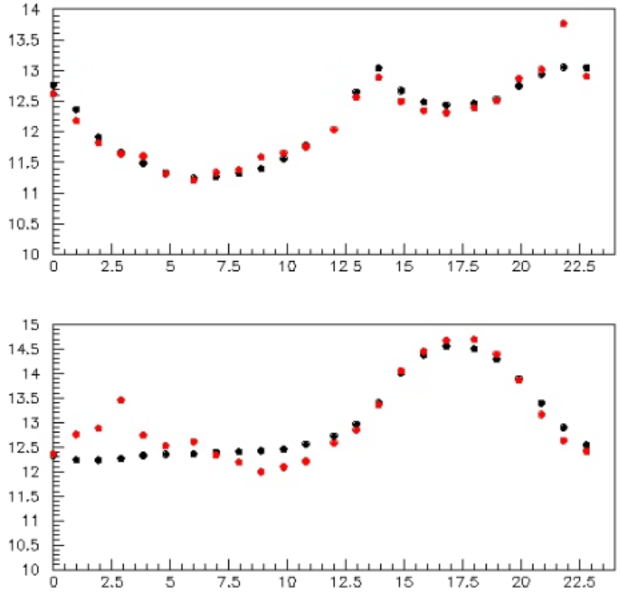


Data Distributions (MD)

before 27/04/2025

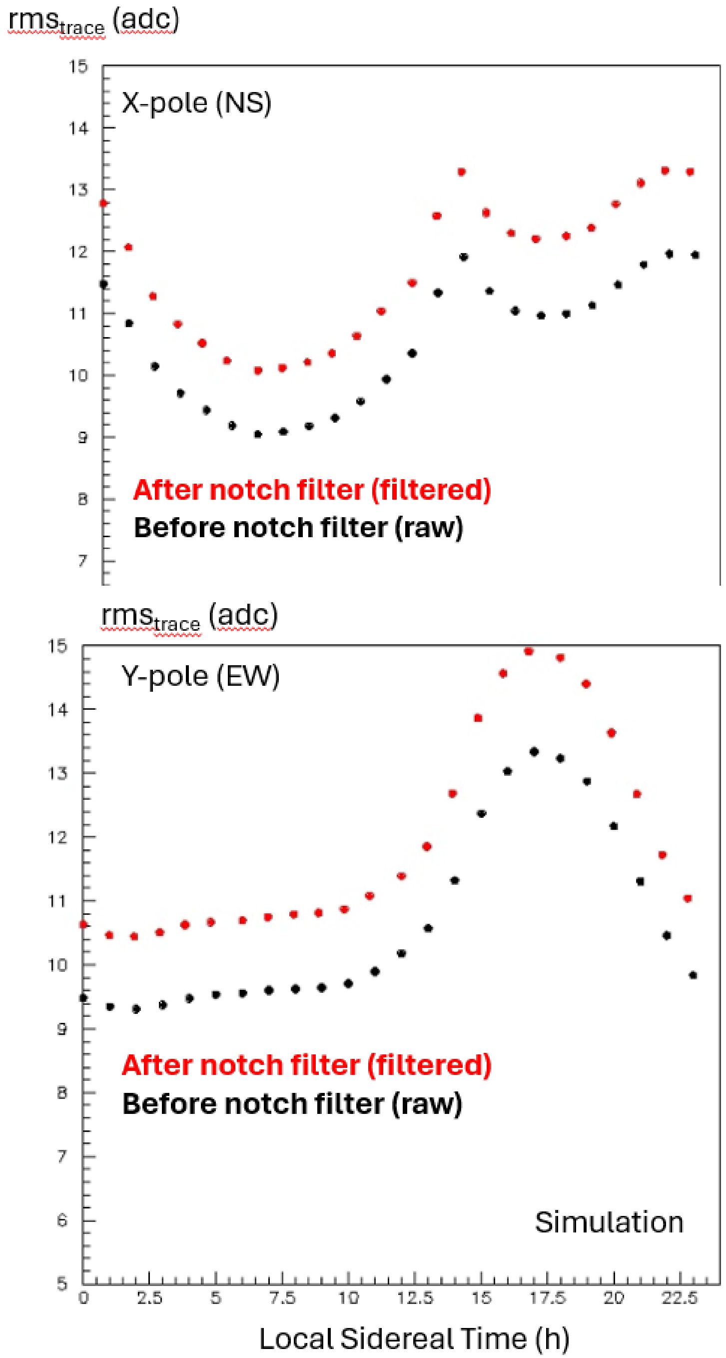
MD files from April 2025





Cf=0.56 rms_0=5.6

Cf=0.52 rms_0=6.8



If we consider the maximum value (15) and 14 for the inner noise then the quadratic sum gives rms=20.5

The distribution of the rms (with mean value 20.50) has a spread approximately $\frac{20.5}{\sqrt{2N}} = \frac{20.5}{\sqrt{2048}} = 0.33$

We expect to have practically up to 20.50+5*0.33=22.15

We apply a cut to retain rms that are < 25