Preliminary analysis of "POLA" detector rates

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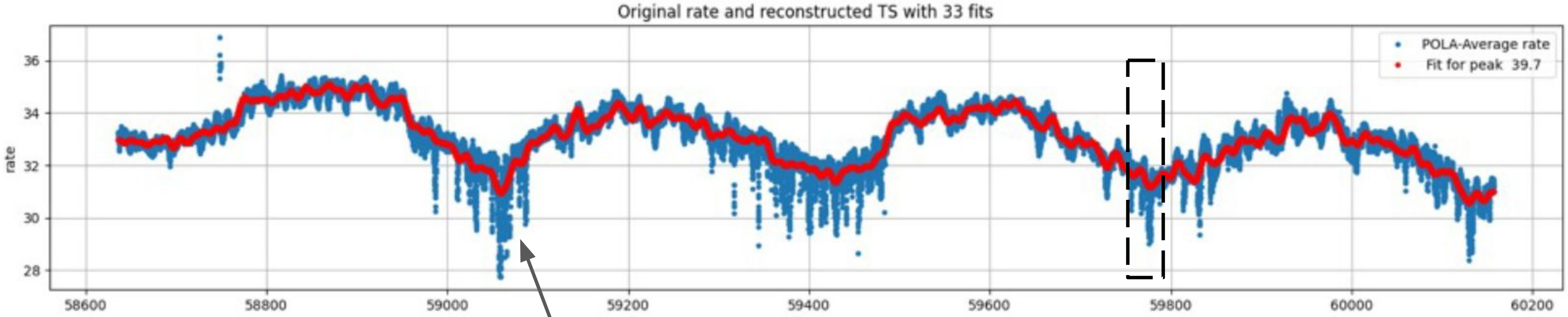
Outlook:

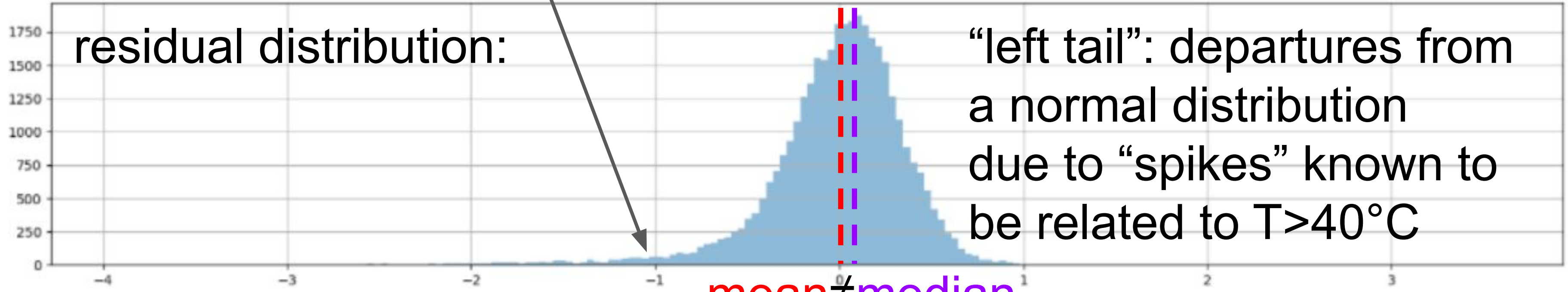
1) Identification/mitigation of “short term” systematics: “spike problem”

2) Identification/mitigation of “long term” systematics: “bimodal distribution problem”

3) Possible effect due to solar modulation

1) The “SPIKE” problem: (from the slides of O. Pinazza nov’23)





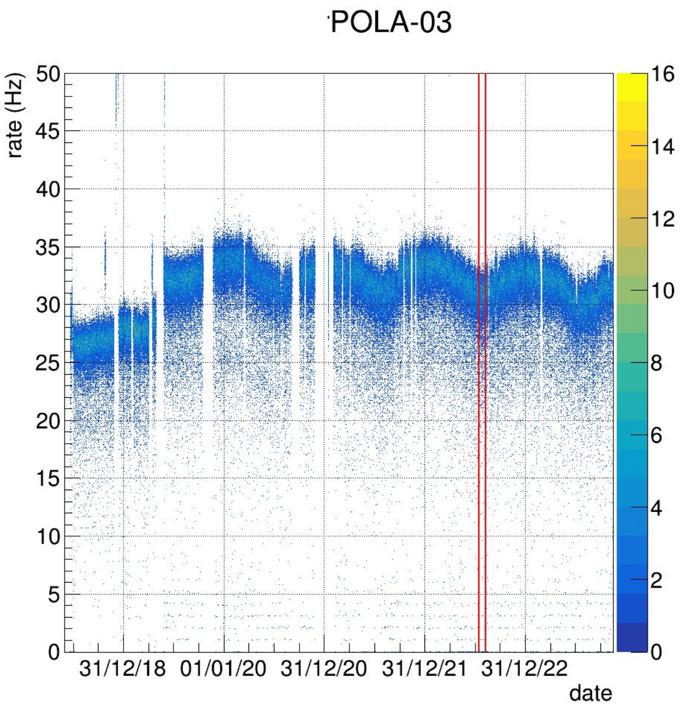
residual distribution:

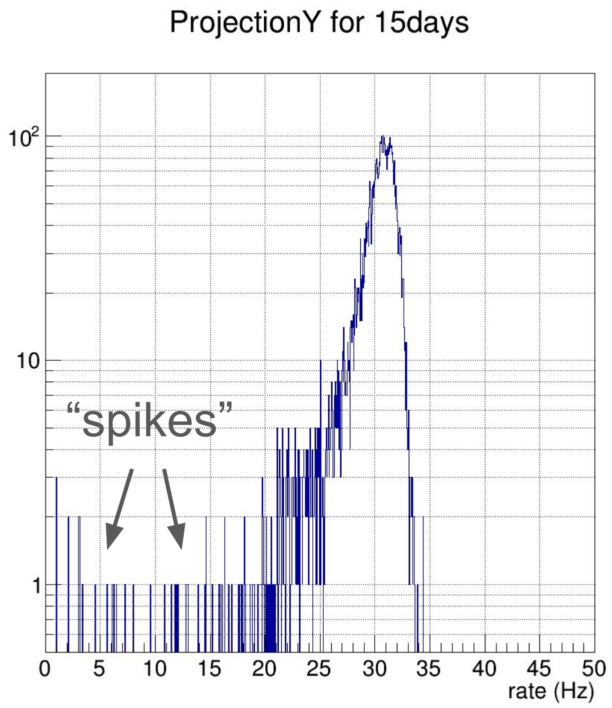
“left tail”: departures from a normal distribution due to “spikes” known to be related to T>40°C

mean≠median

The mean is “pulled down” by spikes, the median is a more robust estimator.
Spikes are a problem for the sub-year periodicity study (must be solved in future)
Now we can publish annual modulation using the median and 15 days bin width

Example of median & mean estimators for 15 days bin width



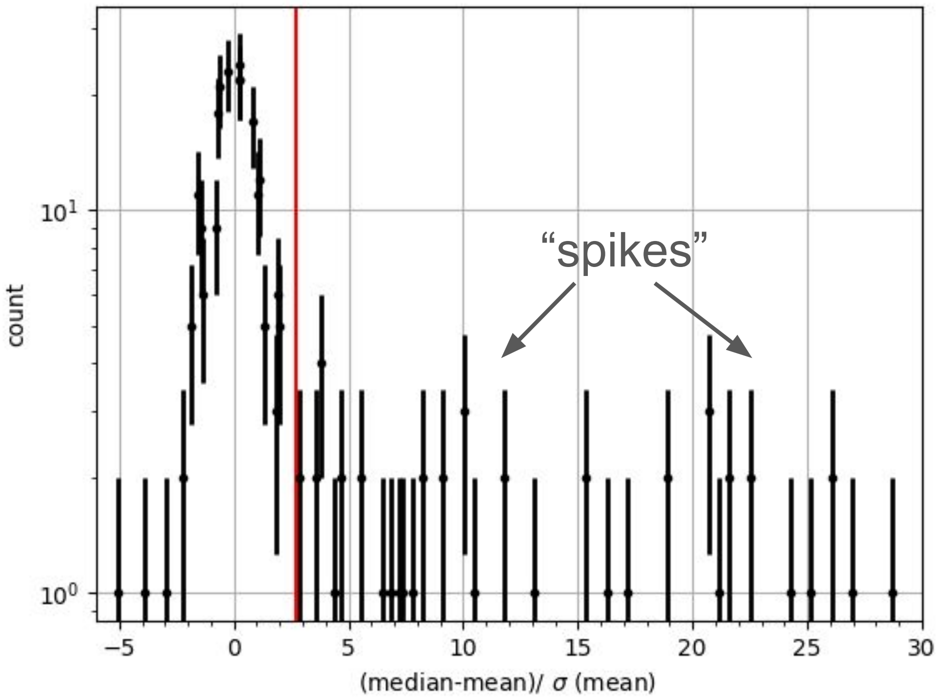


For this slice example:
Mean = 30.32 Hz
Median =30.52 Hz
(median-mean) = 0.2 Hz
$\sigma/\sqrt{n}$ = 0.006 Hz

The effect on mean is statistically noticeable

(selection: status==0)

the "spike detection": median-mean estimator



Another suggestion is to reject data points where |median-mean| > k*σ/√n (k = 4-5 T.B.D.)

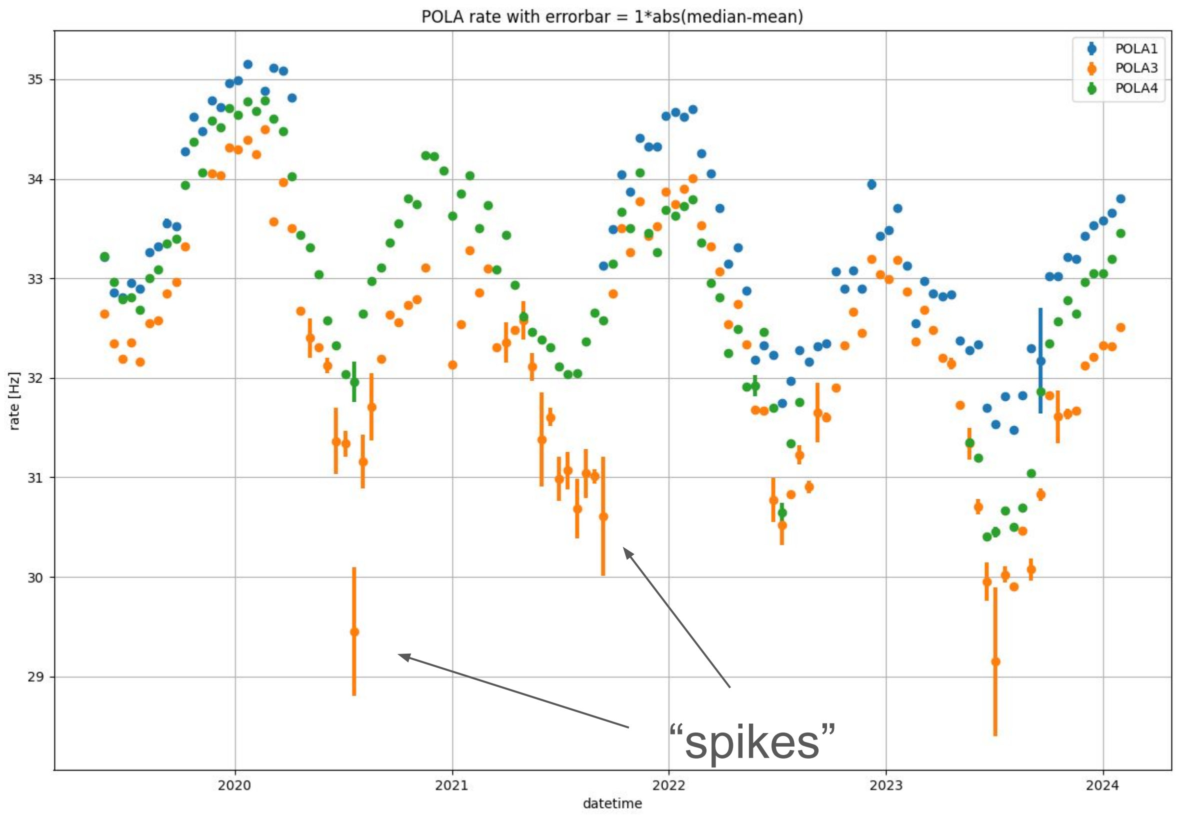
Using median and 15day bins we can correct/mitigate the spike effect

however a cautious approach is to add a systematic uncertainty related to the mitigation of this known effect:
σ_{syst} = |median-mean| x factor

where factor = [0,1] is a safety factor we must decide.

With this approach the fits to the data will be less affected by the points affected by the spikes.

Example of time series with systematic error

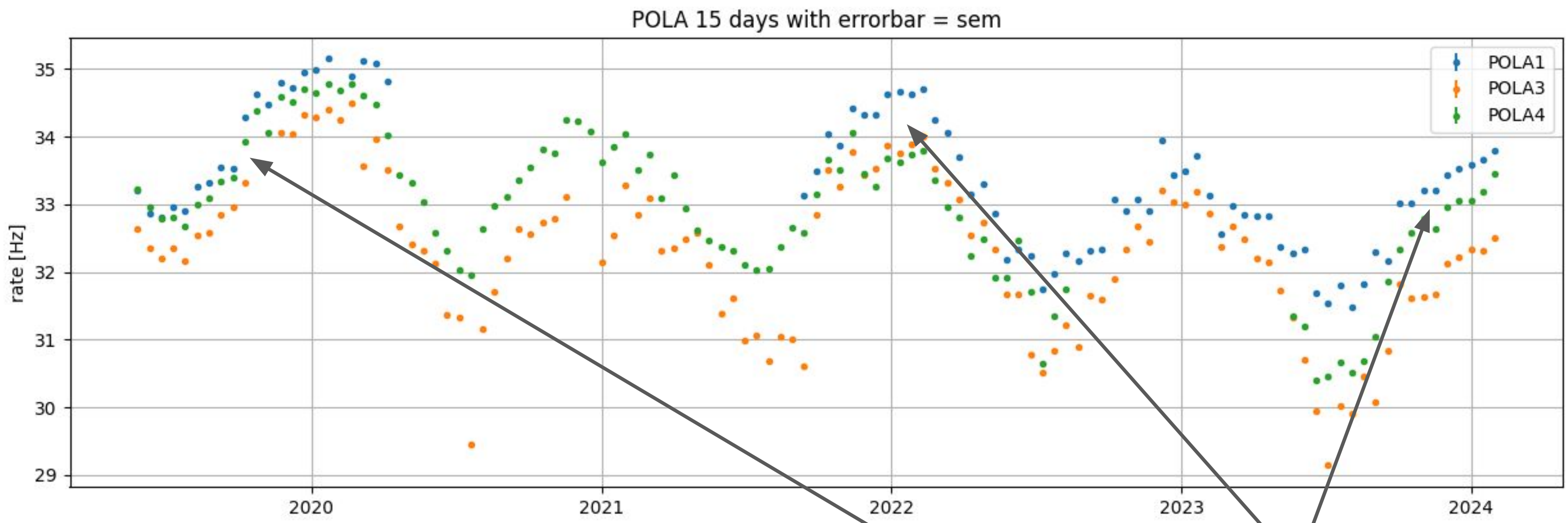


Example of safety factor =1

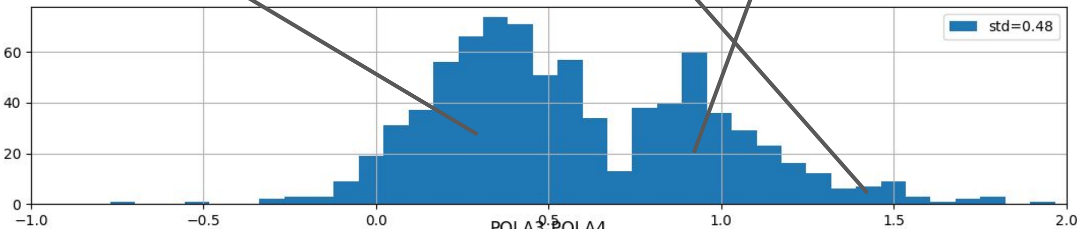
σ_{syst} = 1 x |median-mean|

Period affected by spikes now have bigger uncertainty.

2) The “bimodal distribution” problem:

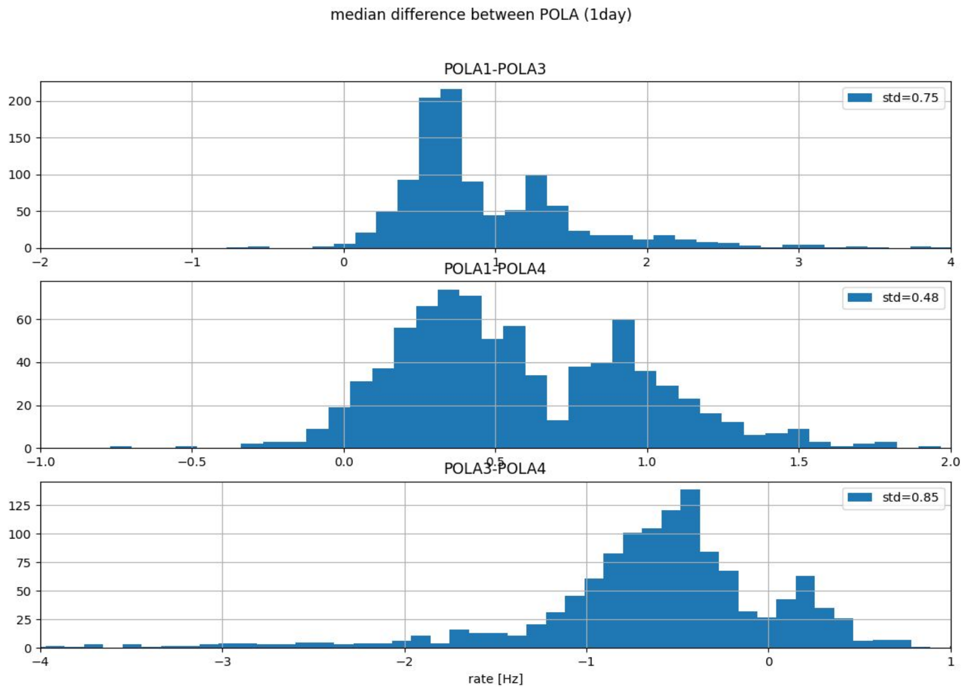


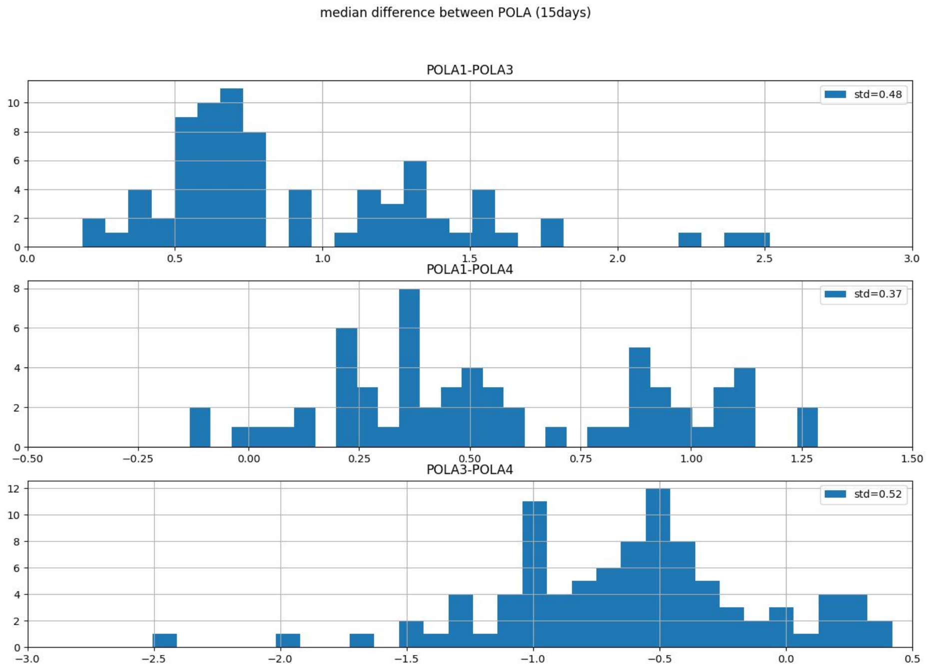
For a sub-set of the overall exposure we can study the difference of the rate measured by 2 different POLA detectors.
This is a “long-term” effect we cannot ignore it for annual modulation study
(and we must understand/solve it in future)



POLA1-**POLA4** [Hz]

“bimodal distribution” problem is affecting all the POLA

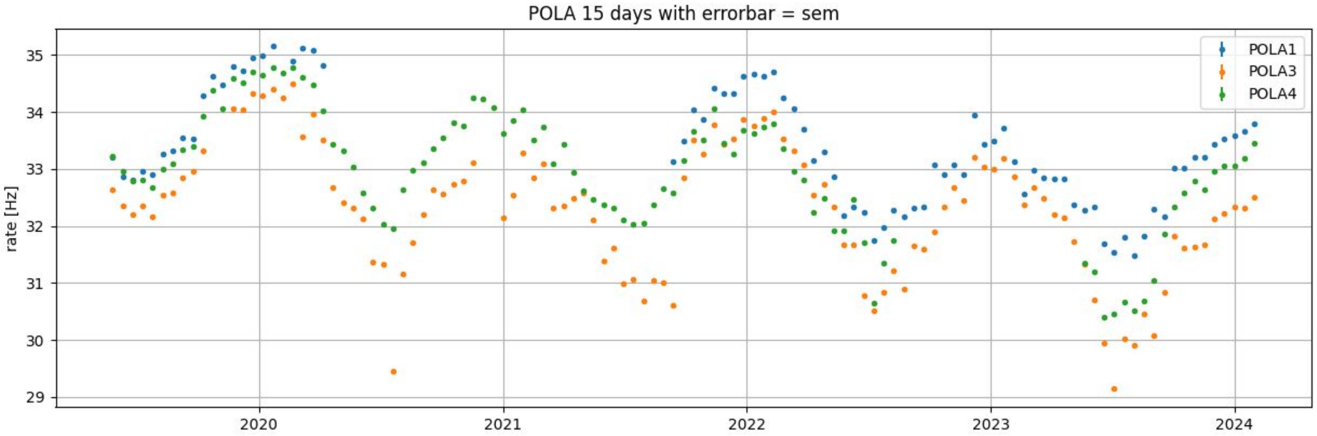


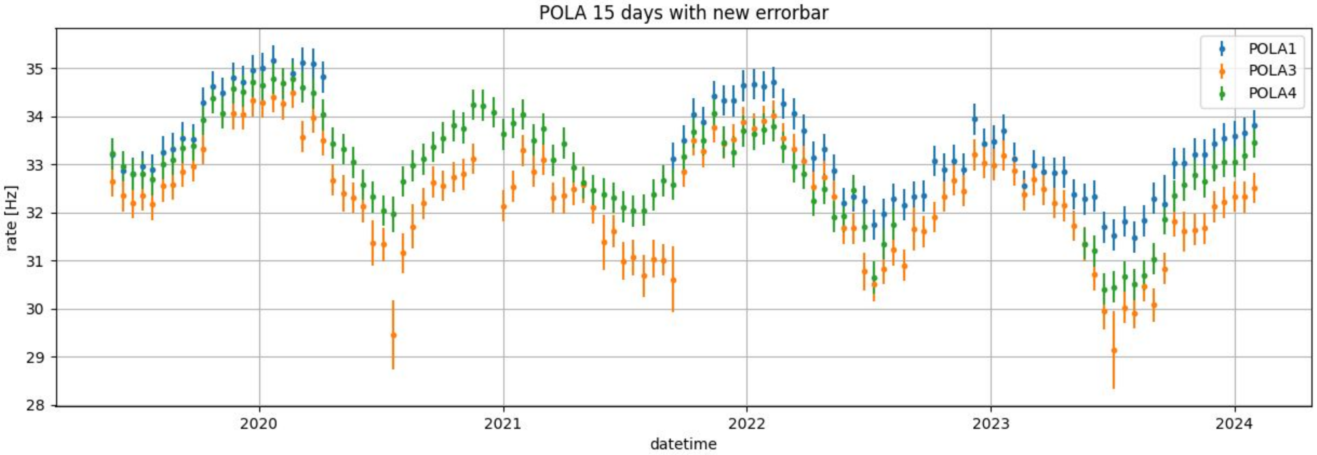


For the moment a “pragmatic” solution is to add a systematic error to account this effect:

$$\sigma_{syst2} = \text{WAVG} \left(\text{STD(POLA1-POLA4)}/\sqrt{2} \; ; \; \text{STD(POLA1-POLA3)}/\sqrt{2} \; ; \; \text{STD(POLA3-POLA4)}/\sqrt{2} \right)$$

Proposed systematic uncertainties:





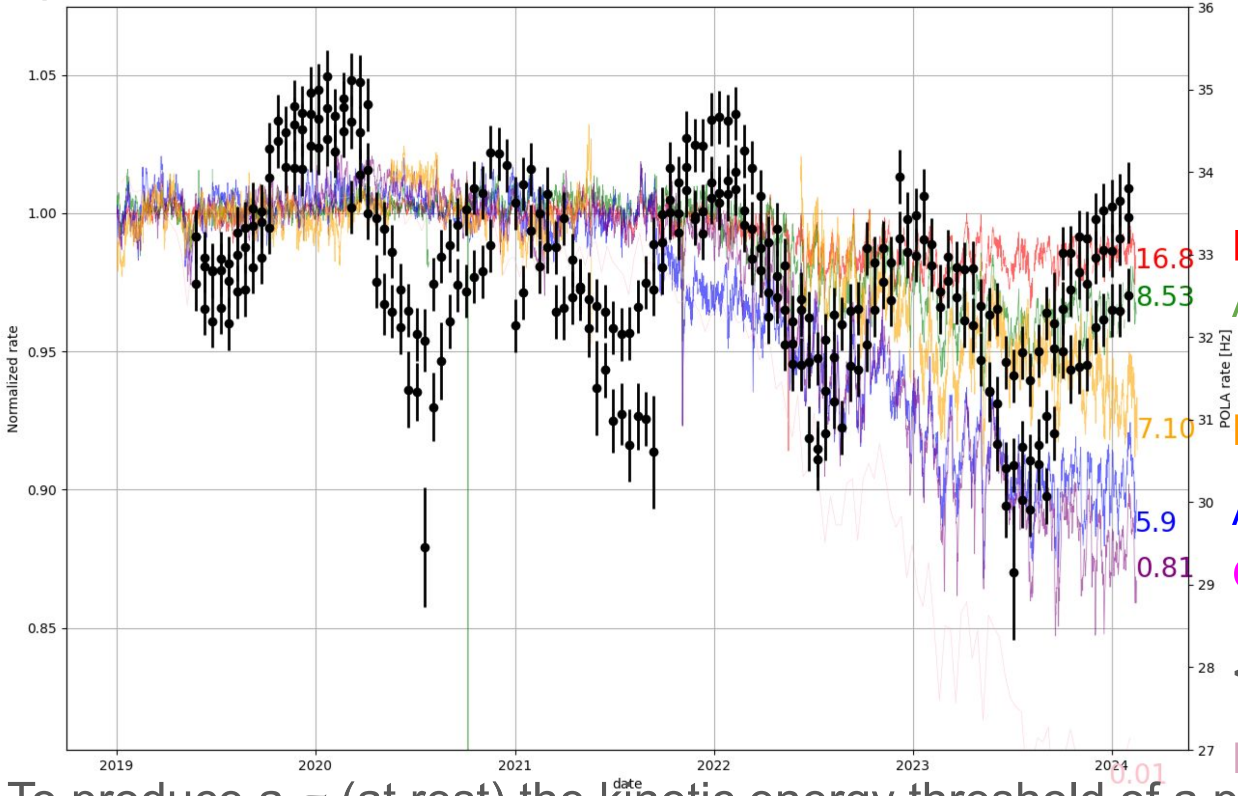
The SEM = σ/√n error bars strongly underestimate the systematic effects.

With syst. uncertainties we could start quantitative analysis of the measured “long term” POLA rates

BUT

these effects must be investigated and solved in future to analyze “short term” periodicity

3) possible interpretation due to solar modulation



Solar modulation affects strongly neutron monitors “located” at low Rigidity cutoff (https://www.nmdb.eu/nest/)

PSNM (Thailand) E_k>15.9GeV

ATHN (Athens) E_k>7.6GeV

NANM (Armenia) E_k>6.2GeV

AATB (Kazakhstan) E_k>5GeV

OULU (Finland) E_k>300MeV

<= Svalbard NM expected

DOMB (Concordia south pole)

To produce a π (at rest) the kinetic energy threshold of a proton is ~300MeV.
However a μ have to cross 1000g/cm^2 they must loss >1.8GeV (... without decaying)
Therefore is reasonable that the effective “cutoff” for the primary proton is E_k>6GeV

Conclusions:

1) “spike problem”: to be solved to study short term periodicity

2) “bimodal distribution problem”: must be solved to study the long term periodicity - solar modulation effects

3) Possible interesting interpretation due to solar modulation