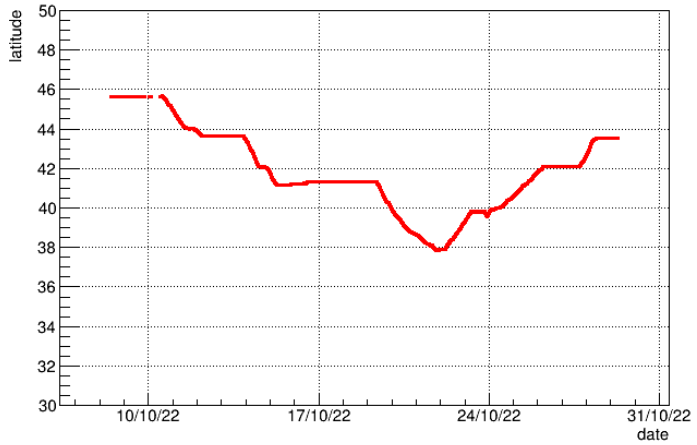
MEASUREMENTS CAMPAIGN ABOARD THE AMERIGO VESPUCCI VESSEL

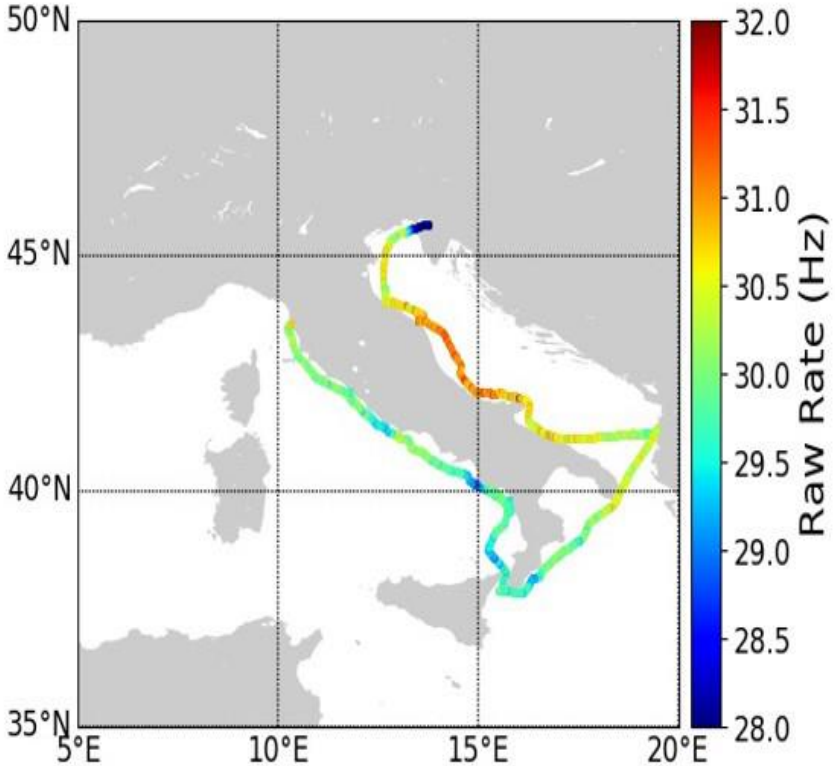
Paola La Rocca

EEE Meeting – July 8, 2025

THE TRIP

- 2022, 8 October: POLA-02 installation in Trieste
- 2022, 29 October: end of the trip in Livorno
- Latitude interval covered: 38° N-45° N
- Minor issues: direct sun light





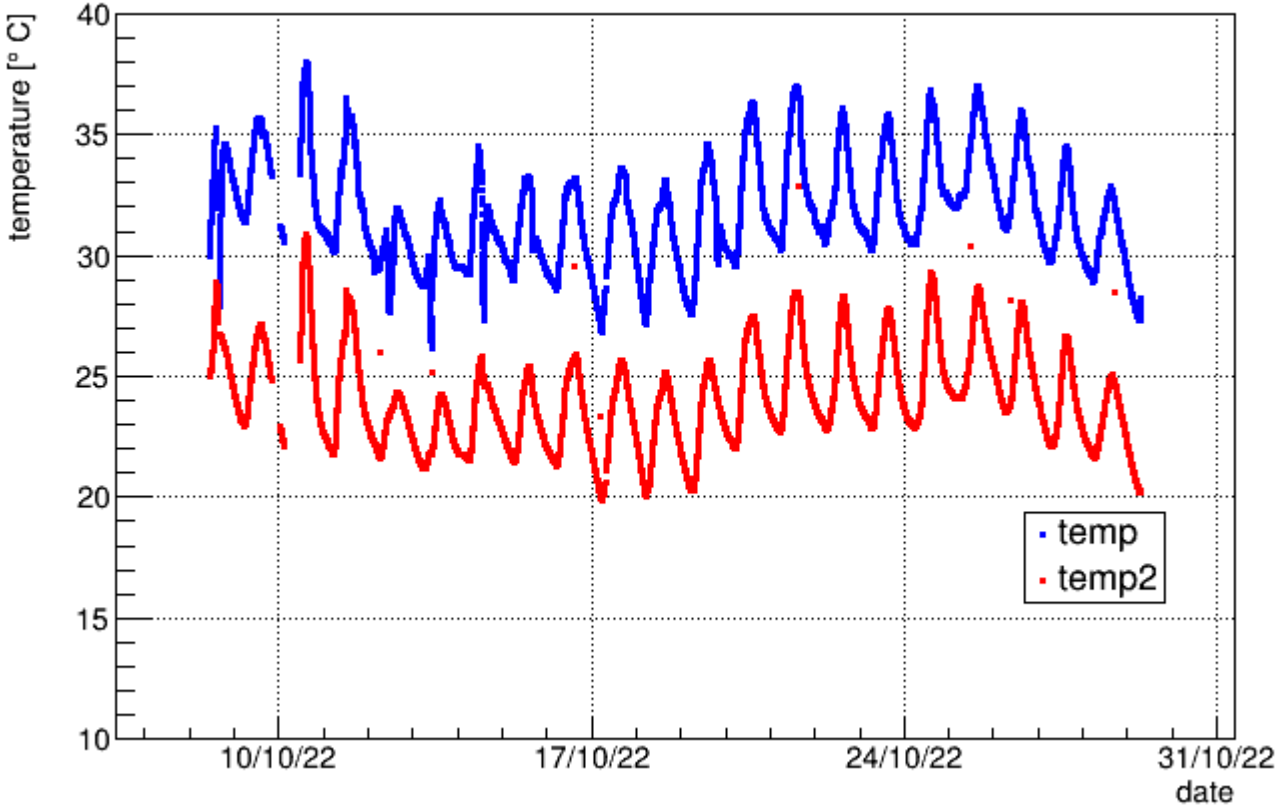
THE DATA SET

- Continuos readout (only a short interruption at the beginning)
- Data reduction → Rates evaluated in 1-minute steps (28699 values)
- Standard data format
- Variable used in the analysis:
  - ts // timestamp from 1 Jan 2007
  - status // status (0=good minute)
  - duration // sampling duration inside the minute (60 = all seconds were acquired)
  - rateRaw // raw rate (=trigger rate) (majority condition)
  - rate // rate majority condition + 1 single track
  - pres // pressure in mbar
  - lat // latitude
  - lon // longitude
  - temp // temperature
  - temp2 // temperature2
  - parRates[2] // rates from slot control output
- Similarly to previuos analyses: majority condition (rate), no pseudo-efficiency applied

BASIC QUALITY CUTS

- **status = 0** (rejected 4863/28699 → ~16.9%)
- **duration = 60** (rejected +0/28699 → 0%)
- **abs(rateRaw - parRates[0]) < 2**
  comparison between the raw rate and the slow control value
  (rejected +500/28699 → ~1.7%)

ENVIRONMENTAL PARAMETERS – TEMPERATURE



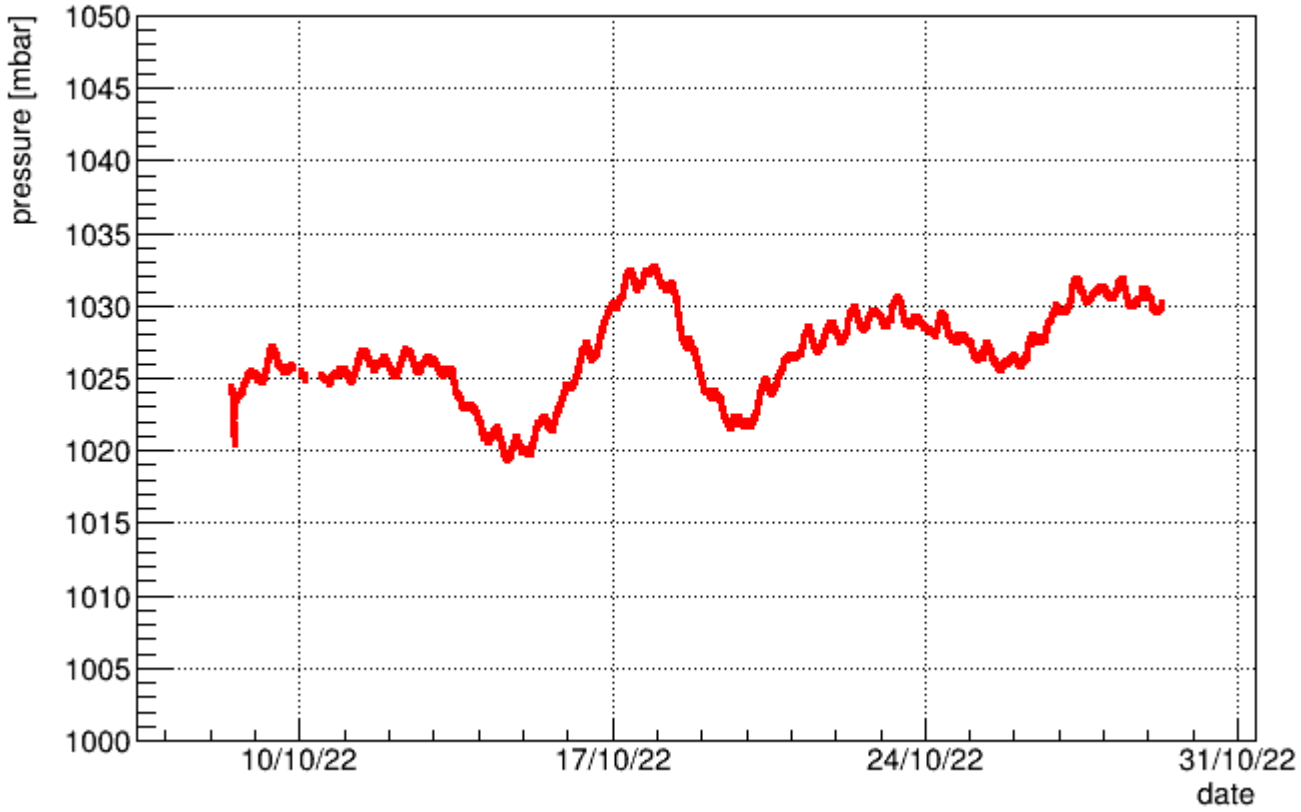
Additional cuts applied

15 < temp < 40

15 < temp2 < 40

(rejected +7/28699 → ~0,02%)

ENVIRONMENTAL PARAMETERS – ATM. PRESSURE



Additional cuts applied

800 < pres < 1100

(rejected +0/28699 → 0%)

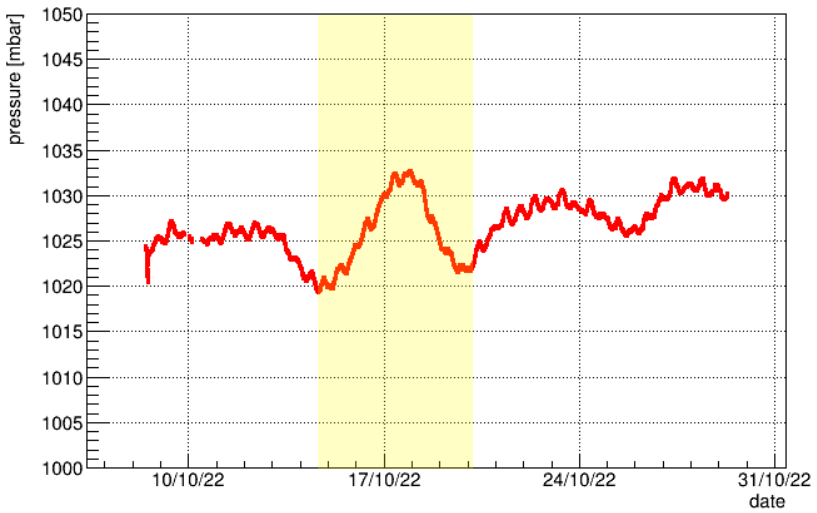
SUMMARY OF QUALITY CUTS

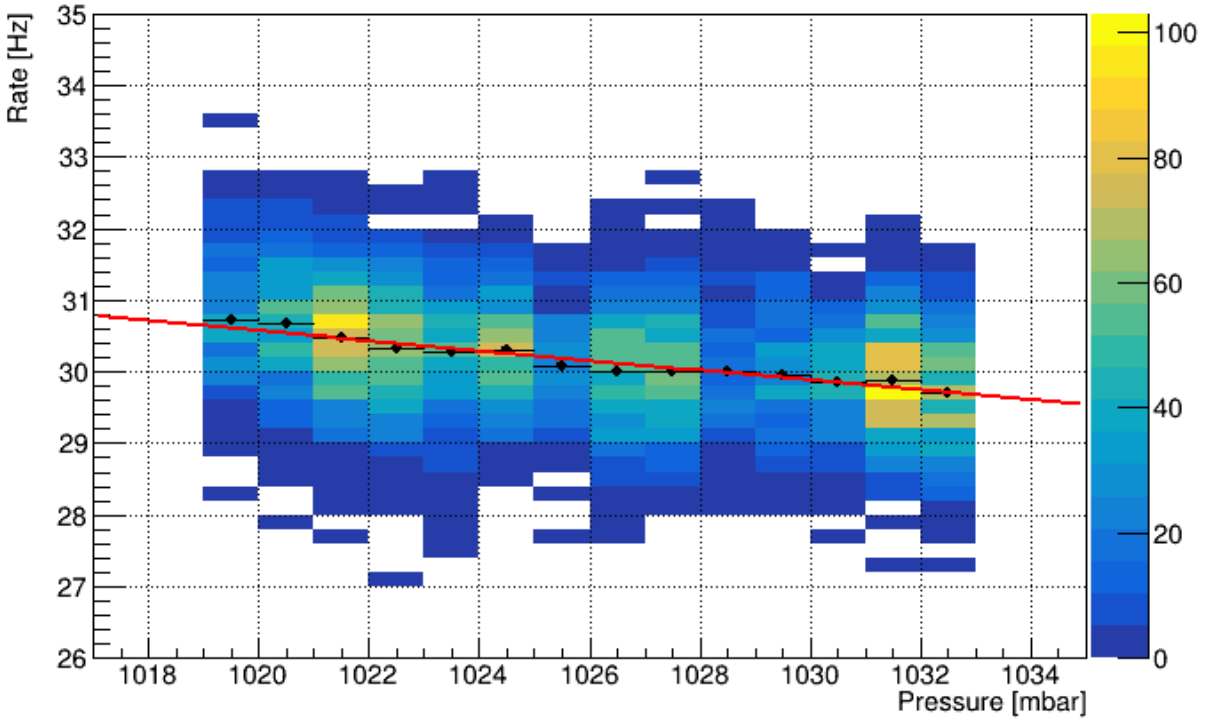
- **status** = 0
- **duration** = 60
- **abs(rateRaw - parRates[0])** < 2
- **pres** > 800 && < 1100
- **temp** AND **temp2** > 15 && < 40

Total number of rejected measures 5370 (18.6%)

BAROMETRIC COEFFICIENT

Time interval 14/10/2022 h 15:00 → 20/10/2022 h 00:33 ($\Delta P \sim 15$ mbar)



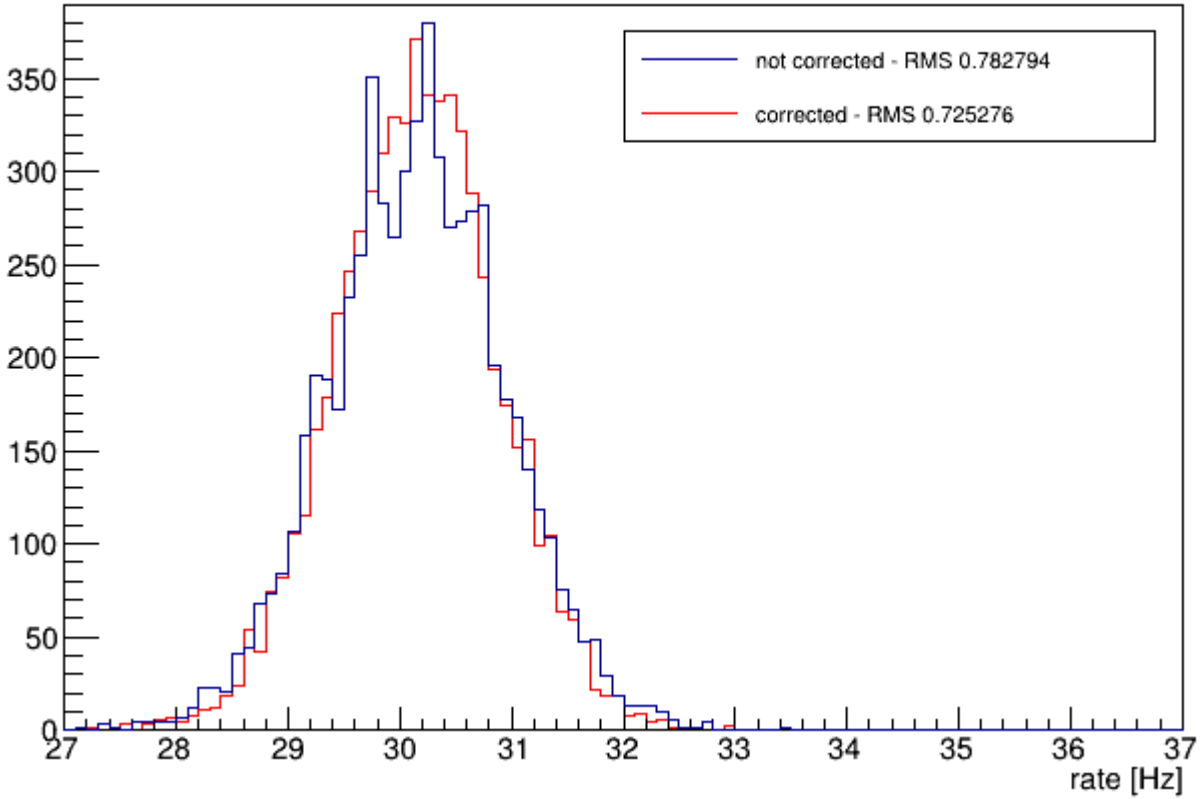


Fit function $R = \exp[\alpha + \beta(p - p_{ref}^*)]$

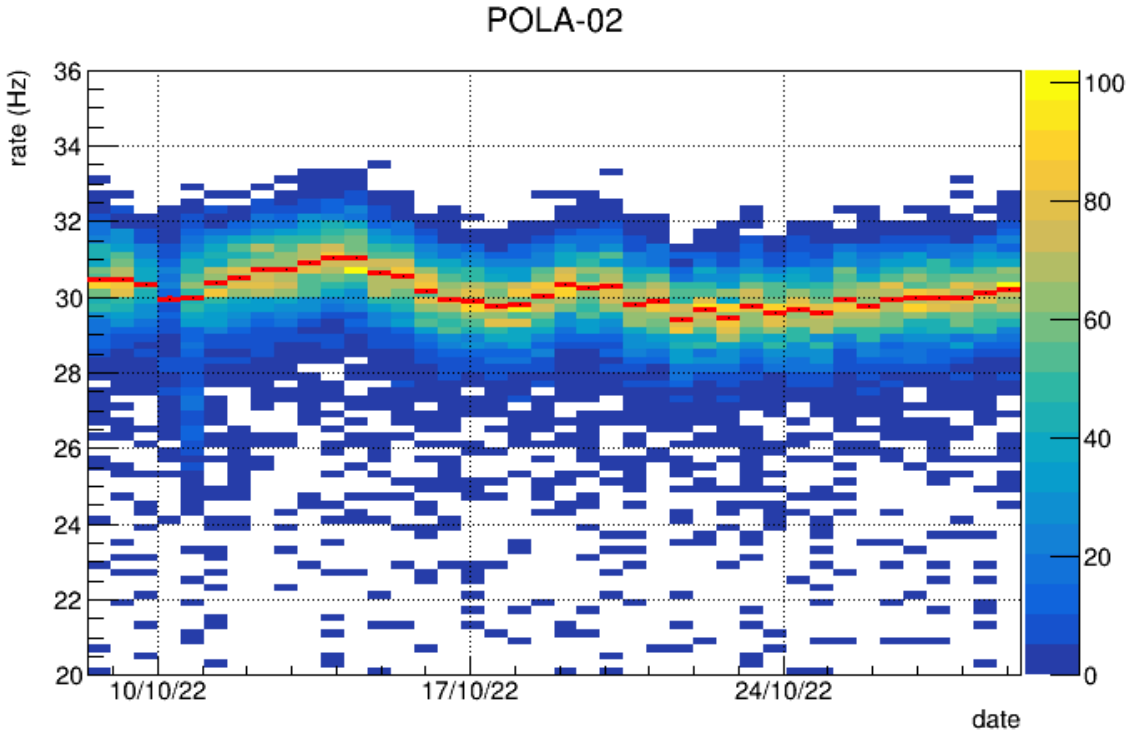
→ $\beta = (-0.228 \pm 0.009)$ %/mbar

(*p_{ref} = average pressures during selected period 1026.03 mbar)

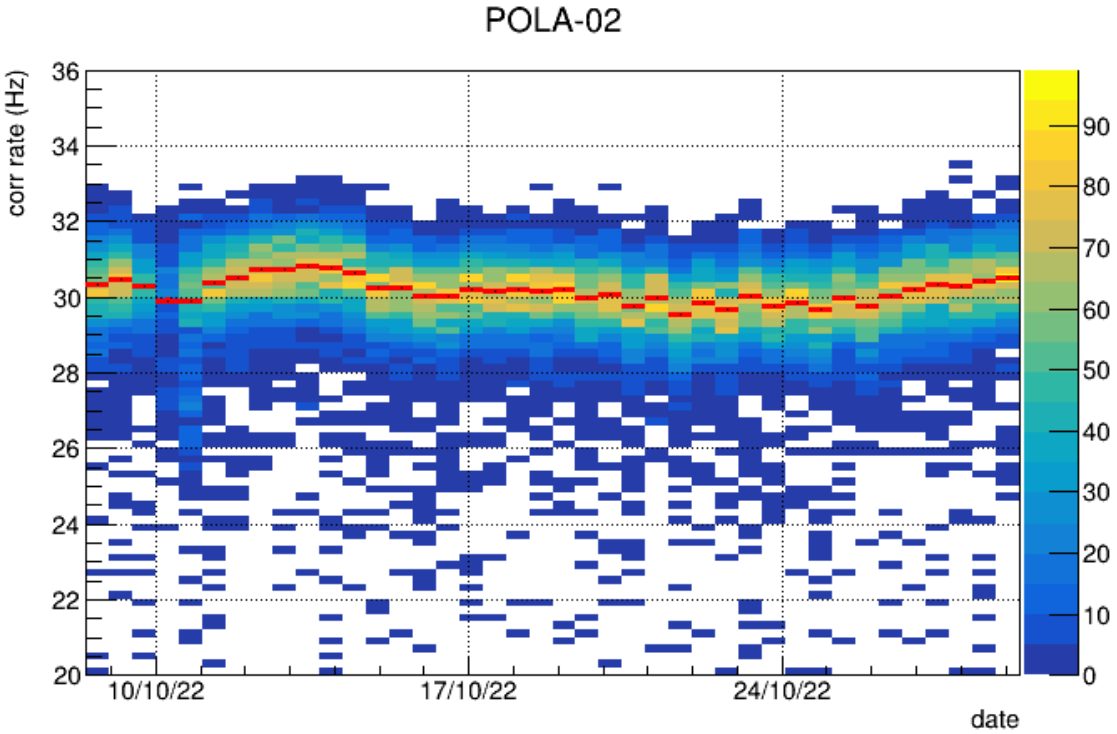
CORRECTION FOR ATMOSPHERIC PRESSURE



RATE VS TIME

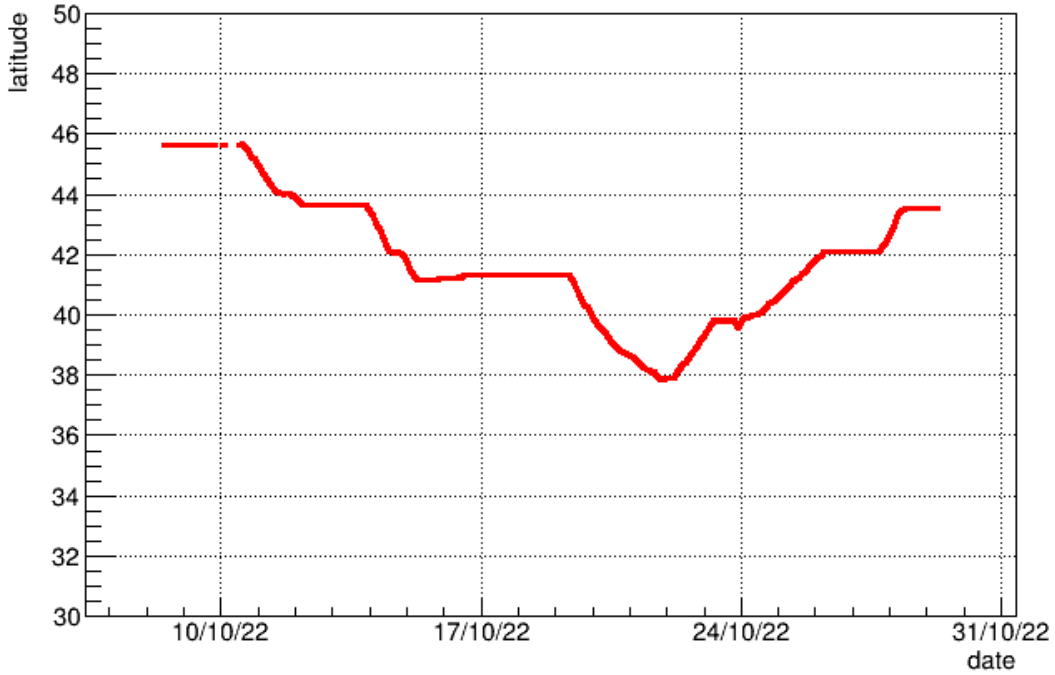


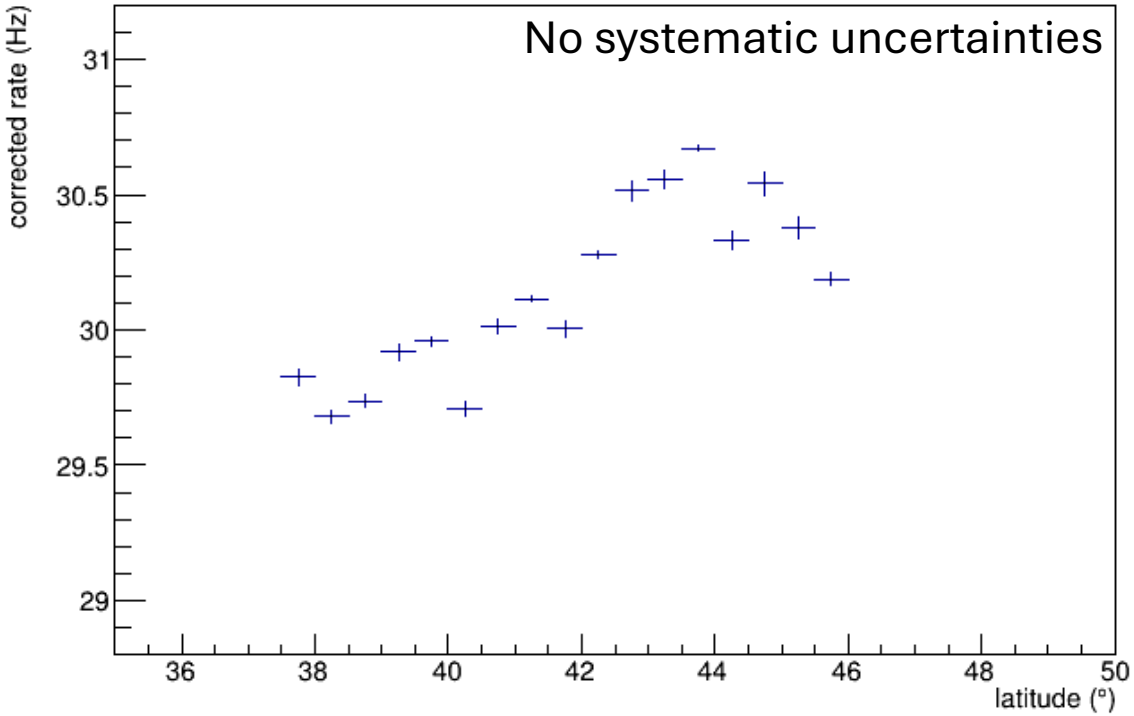
NOT CORRECTED FOR BAROMETRIC EFFECT



CORRECTED FOR BAROMETRIC EFFECT

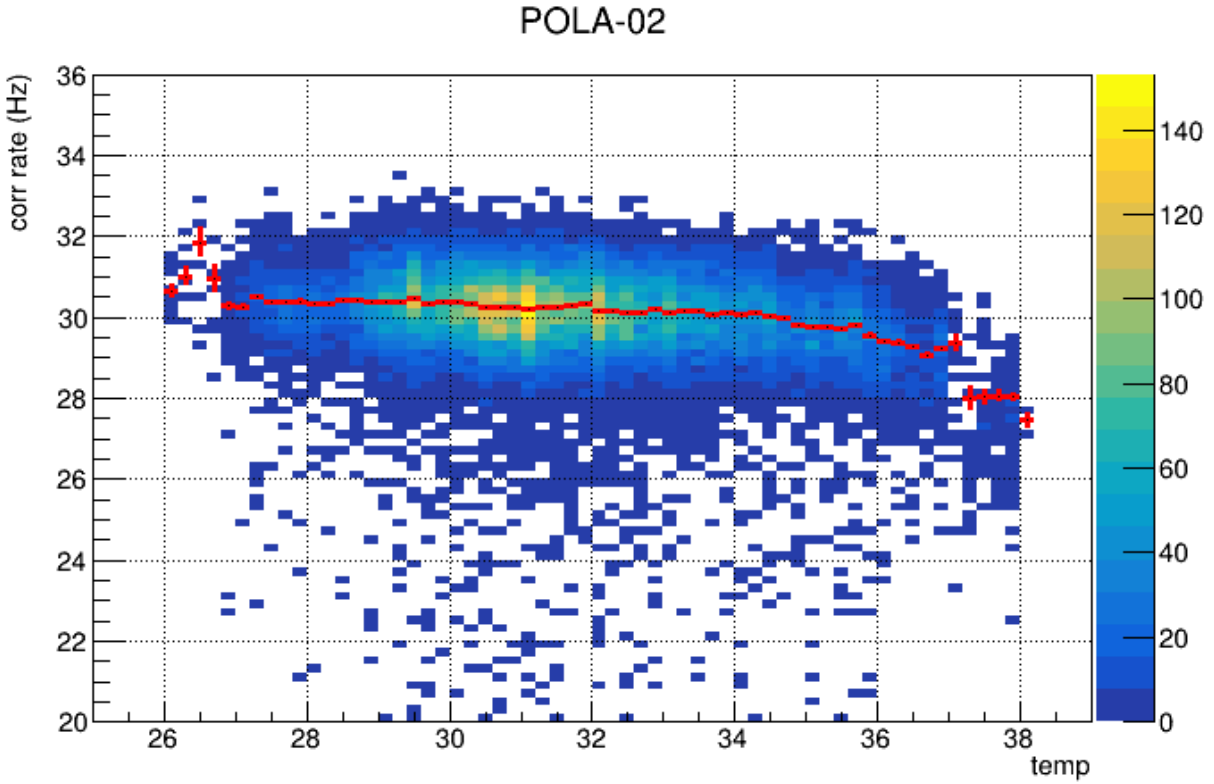
RATE DEPENDANCE ON LATITUDE





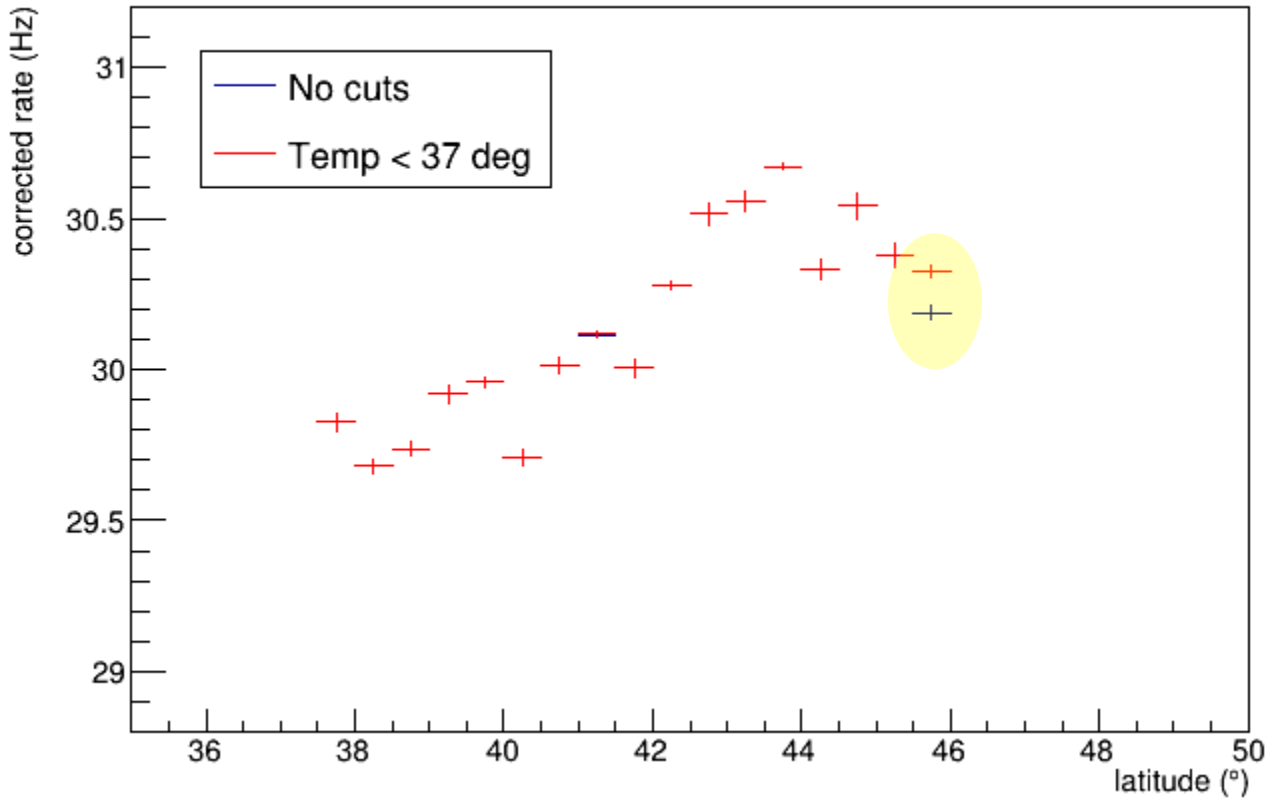
EFFECT OF TEMPERATURE

- Slight dependance on temperature
- Rate drop for temp > 37 deg



RATE DEPENDANCE ON LATITUDE

TEMPERATURE CUT < 37 DEG

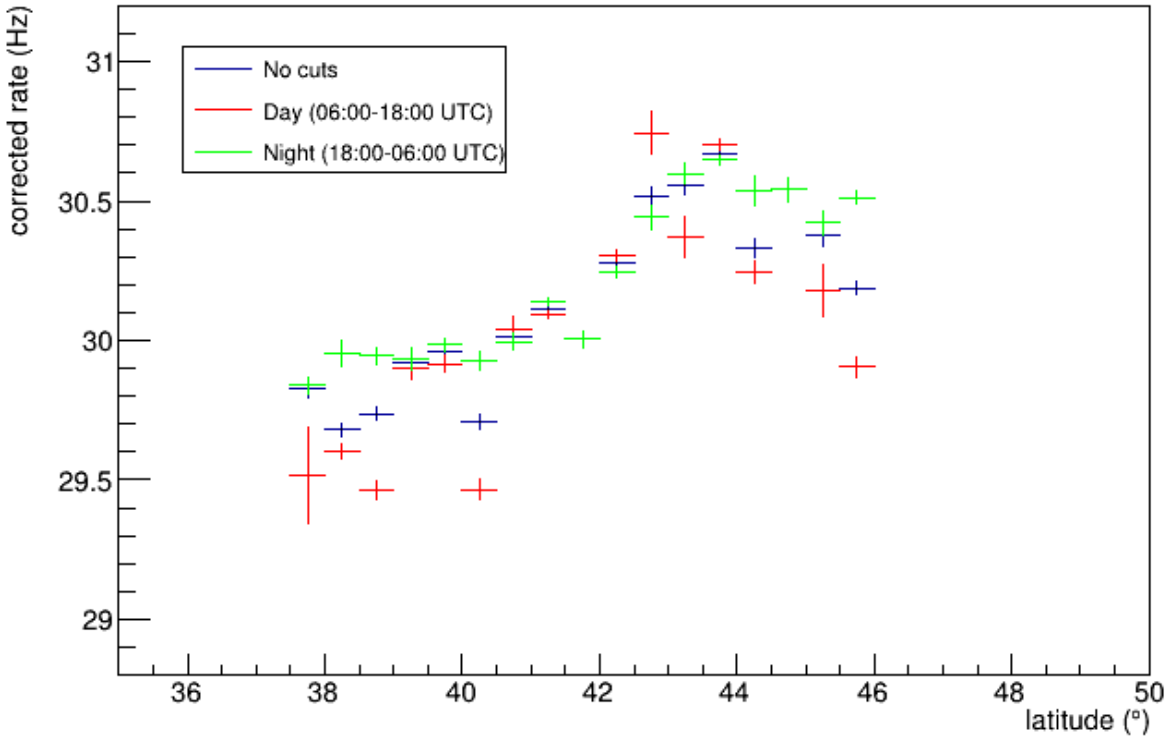


- Average difference wrt 24h profile: 0.03%
- Maximal difference wrt 24h profile: 0.45%
- No evident differences if temp < 37 is required, except for the last bin

RATE DEPENDANCE ON LATITUDE

DAY/NIGHT

DAY 06:00-18:00 UTC; NIGHT 18:00-06:00 UTC (ITALIAN TIME UTC+2)



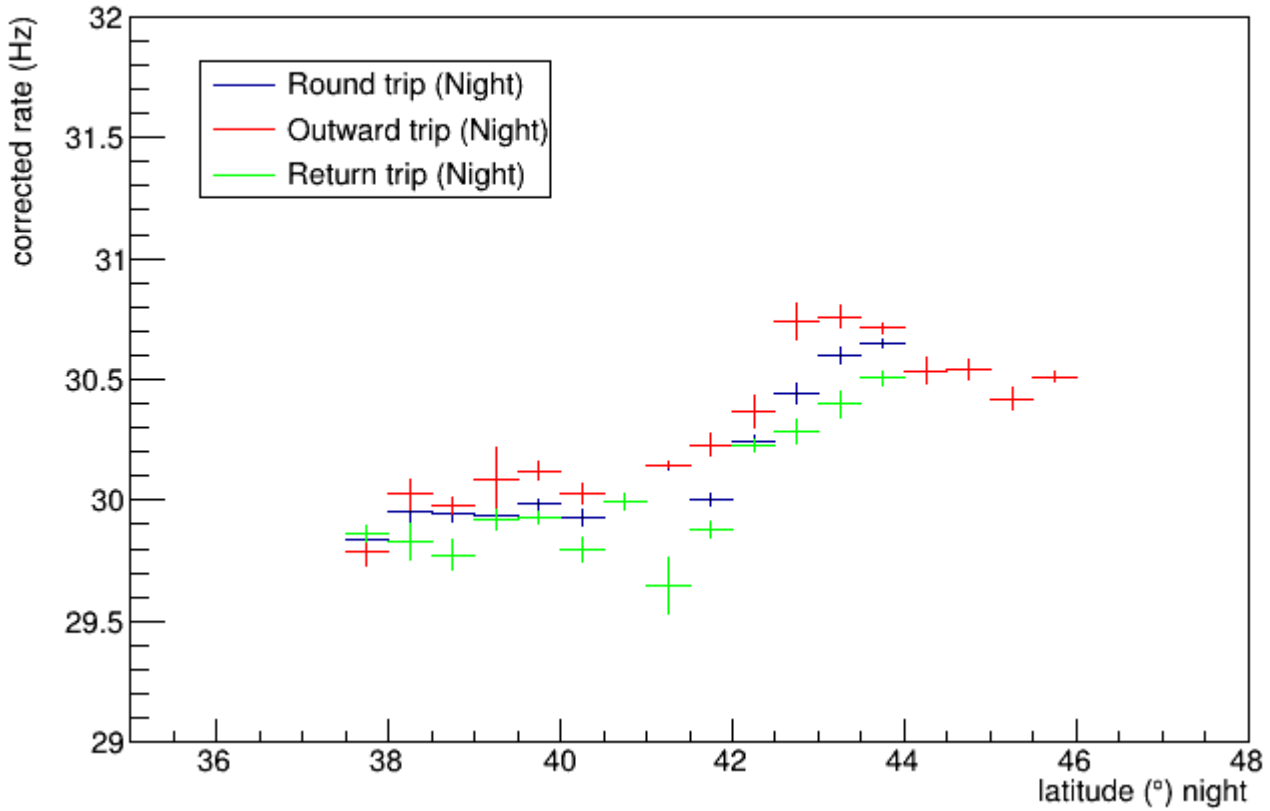
- Average difference wrt 24h profile: 0.36%
- Maximal difference wrt 24h profile: 1.1%

→ **Selecting nighttime data appears to be the safer choice**

From now on, only nighttime data are shown

RATE DEPENDANCE ON LATITUDE

OUTWARD/RETURN TRIP (LONGITUDE DEPENDENCE)
MINIMUM LATITUDE: 37.8552 @ 21/13/2022 21:13:30



- Average difference wrt round trip profile: 0.35%
- Maximal difference wrt round trip profile: 1.6%
- Automatically taken into account in a plot Rate VS geomagnetic cutoff

COMPARISON TO POLA-01 DATA (2018-2019)

Possible contributions to the normalization factor:

- Efficiency correction
- Shielding effect
- Seasonal effect
- Solar cycle effect
- Average pressure

COMPARISON TO POLA-01 DATA (2018-2019)

Possible contributions to the normalization factor:

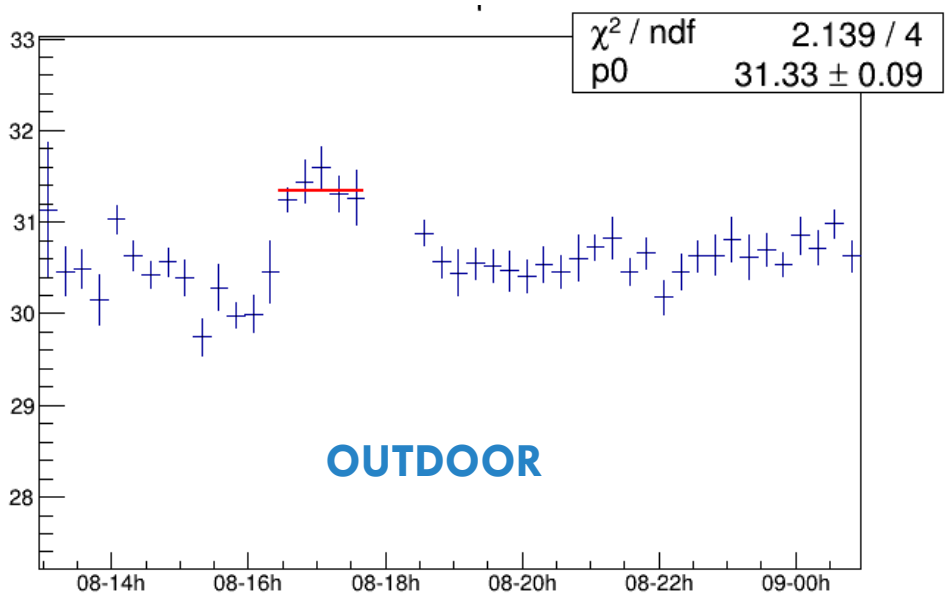
- **Efficiency correction** (96% for POLA-01) → ~ +4% (no pseudo-eff correction*)
- Shielding effect
- Seasonal effect
- Solar cycle effect
- Average pressure

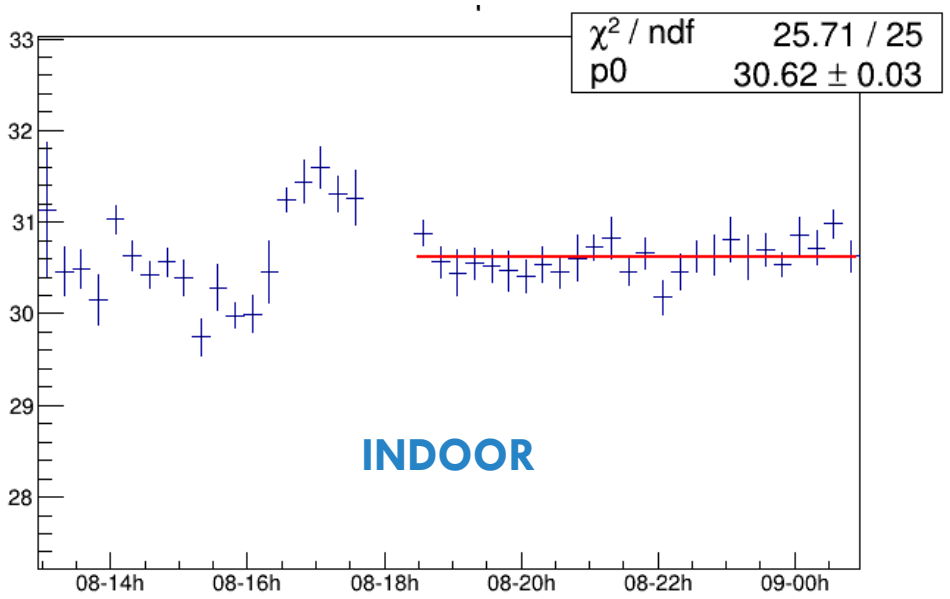
*If a pseudo-efficiency correction is applied, it contributes approximately 2%

COMPARISON TO POLA-01 DATA (2018-2019)

Possible contributions to the normalization factor:

- Efficiency correction (96% for POLA-01) → ~ +4% (no pseudo-eff correction*)
- **Shielding effect** (measurement outside) → ~ +2.3%
- Seasonal effect
- Solar cycle effect
- Average pressure





COMPARISON TO POLA-01 DATA (2018-2019)

Possible contributions to the normalization factor:

- Efficiency correction (96% for POLA-01) → ~ +4% (no pseudo-eff correction*)
- Shielding effect (measurement outside) → ~ +2.3%
- **Seasonal effect**
- **Solar cycle effect**
- Average pressure

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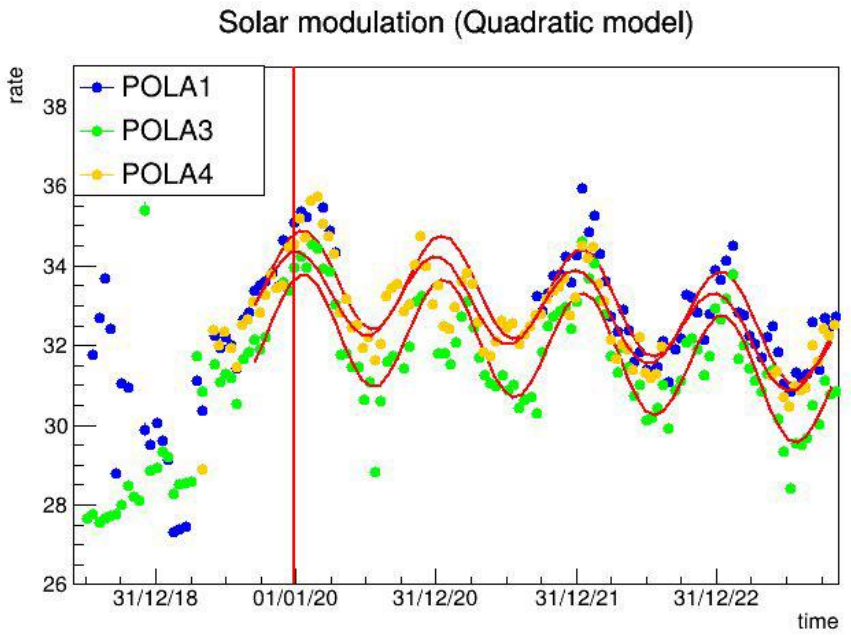
Quadratic fit parameters
--------------------
Rmax [Hz]: 33.0888 +/- 0.468997
k [%/year^2]: -0.332336 +/- 0.0125825
t_SM [year]: 13.001 +/- 0
A [%]: -3.72652 +/- 0.432197
t0 [year]: 12.5416 +/- 0.019269
T [year]: 1 +/- 0
--------------------
```

Solar modulation, Quadratic fit results

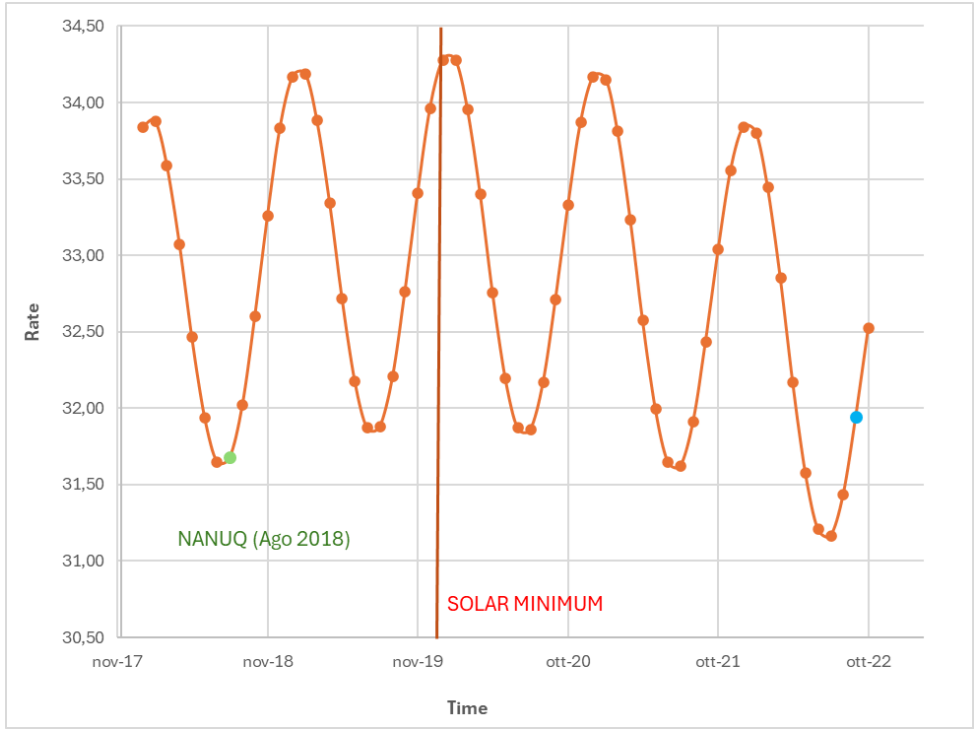
model: $f(t) = R_{max}\left(1 + k(t - t_{SM})^2 + A\cos\left(\frac{2\pi(t - t_0)}{T}\right)\right)$

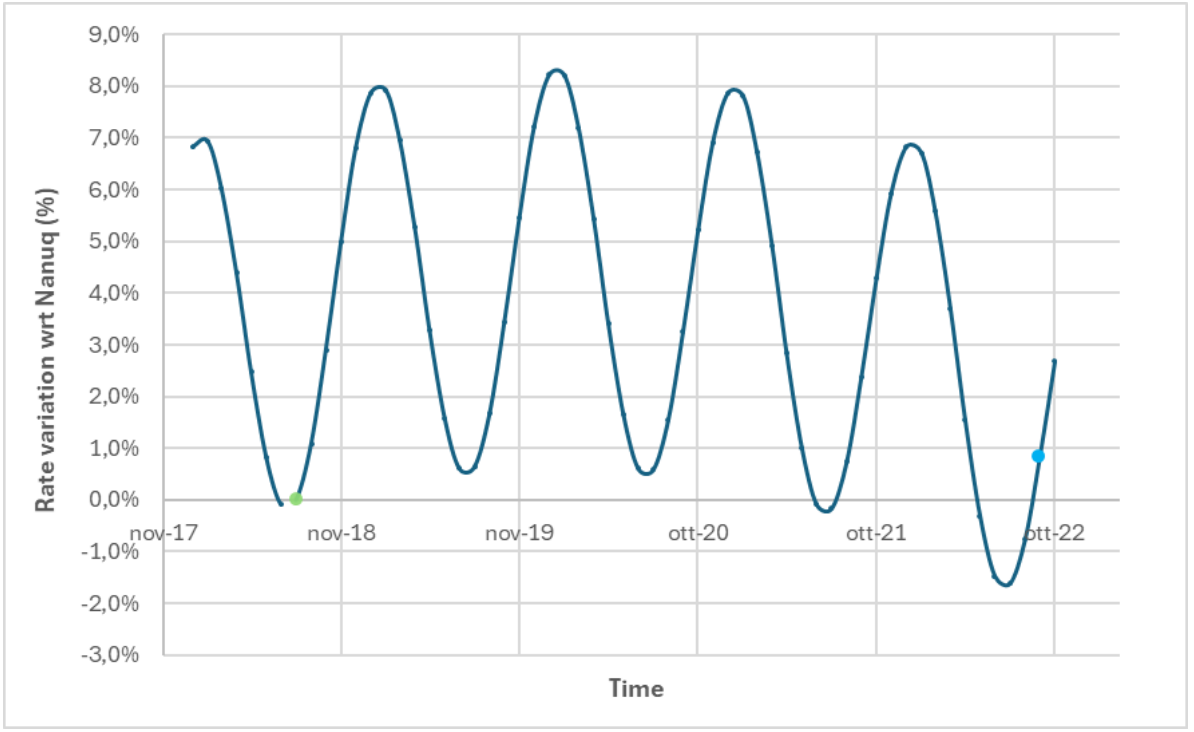
Credits: Luigi and Francesco



*If a pseudo-efficiency correction is applied, it contributes approximately 2%

COMPARISON TO POLA-01 DATA (2018-2019)





Correction → -0.8%

COMPARISON TO POLA-01 DATA (2018-2019)

Possible contributions to the normalization factor:

- Efficiency correction (96% for POLA-01) → ~ +4% (no pseudo-eff correction*)
- Shielding effect (measurement outside) → ~ +2.3%
- Seasonal effect
- Solar cycle effect

  ] → ~ -0.8%

- **Average pressure** → ~ +3.2%

POLA-01: 1011.88 mbar
POLA-02: 1026.03 mbar
β = **-2.28E-3 /mbar**

→ $\beta \times \Delta P$ = **+ 3.2%**

*If a pseudo-efficiency correction is applied, it contributes approximately 2%

COMPARISON TO POLA-01 DATA (2018-2019)

Possible contributions to the normalization factor:

- Efficiency correction (96% for POLA-01) → ~ +4% (no pseudo-eff correction*)
- Shielding effect (measurement outside) → ~ +2.3%
- Seasonal effect
- Solar cycle effect

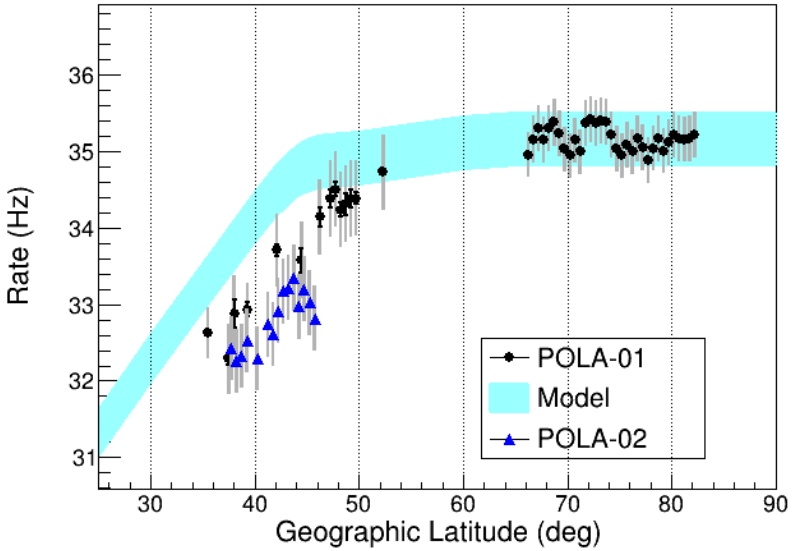
  ] → ~ -0.8%
- Average pressure → ~ +3.2%

TOT. +8.7 %

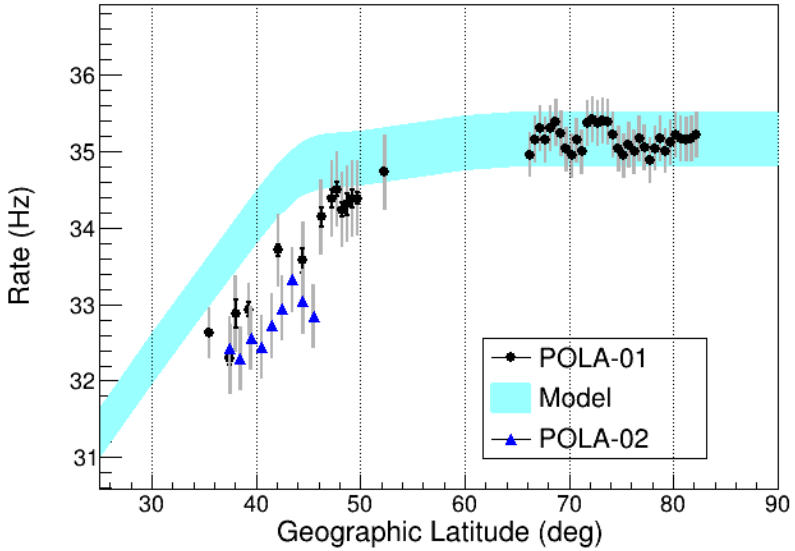
*If a pseudo-efficiency correction is applied, it contributes approximately 2%

COMPARISON TO POLA-01 DATA (2018-2019)

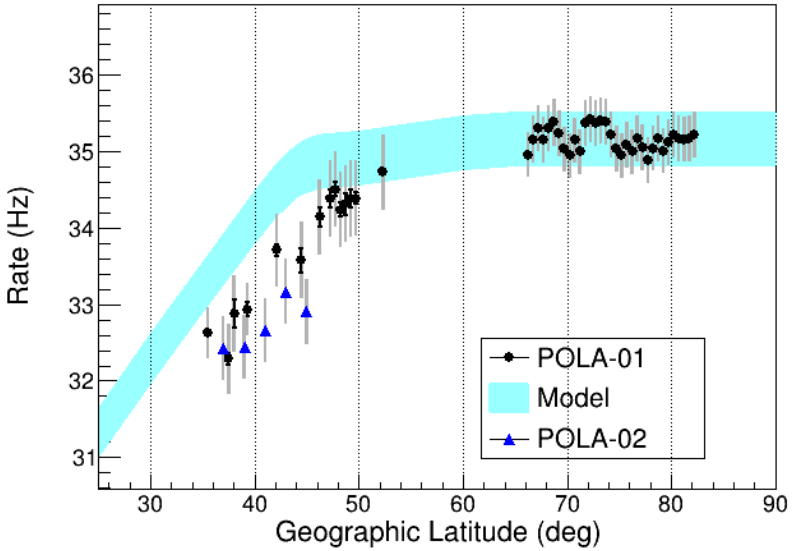
POLA-02 rate corrected for barometric effect only



0.5 deg



1 deg

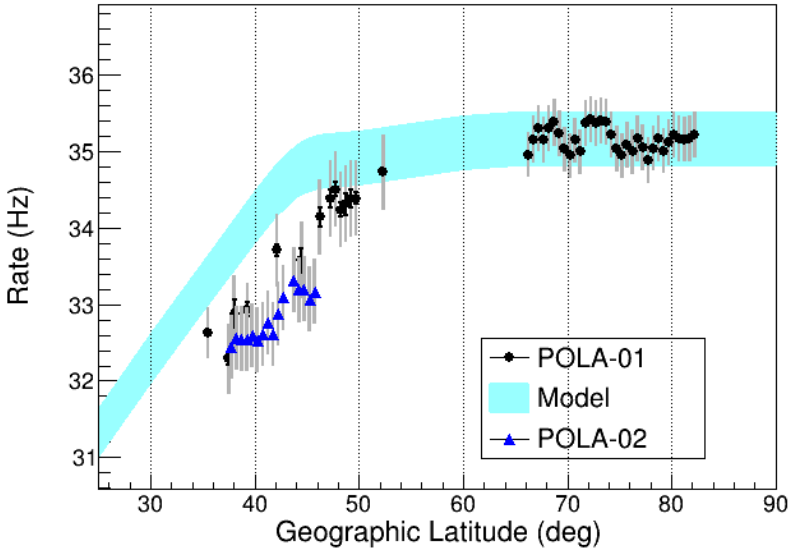


2 deg

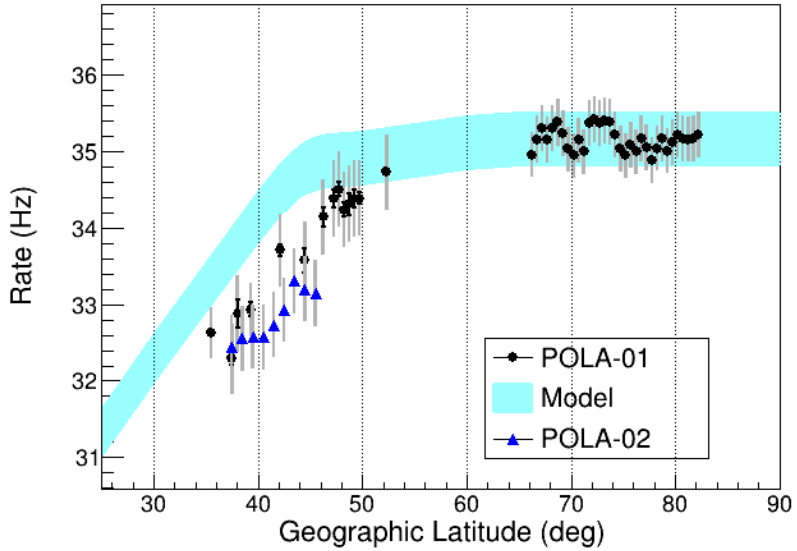
COMPARISON TO POLA-01 DATA (2018-2019)

POLA-02 rate corrected for barometric effect, **night-time**

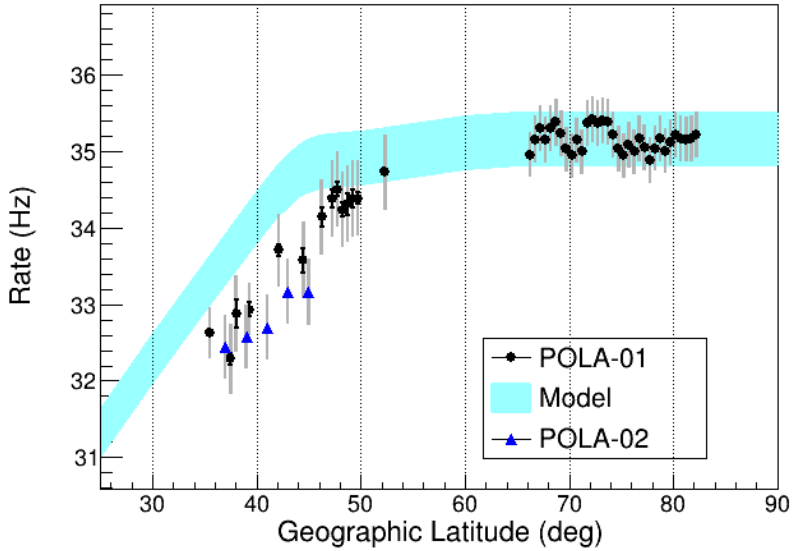
- Preliminary results @ICRC2025
- Systematic uncertainties = 1.4% (highest value estimated from POLA-01 data analysis)



0.5 deg



1 deg



2 deg

SYSTEMATIC UNCERTAINTIES

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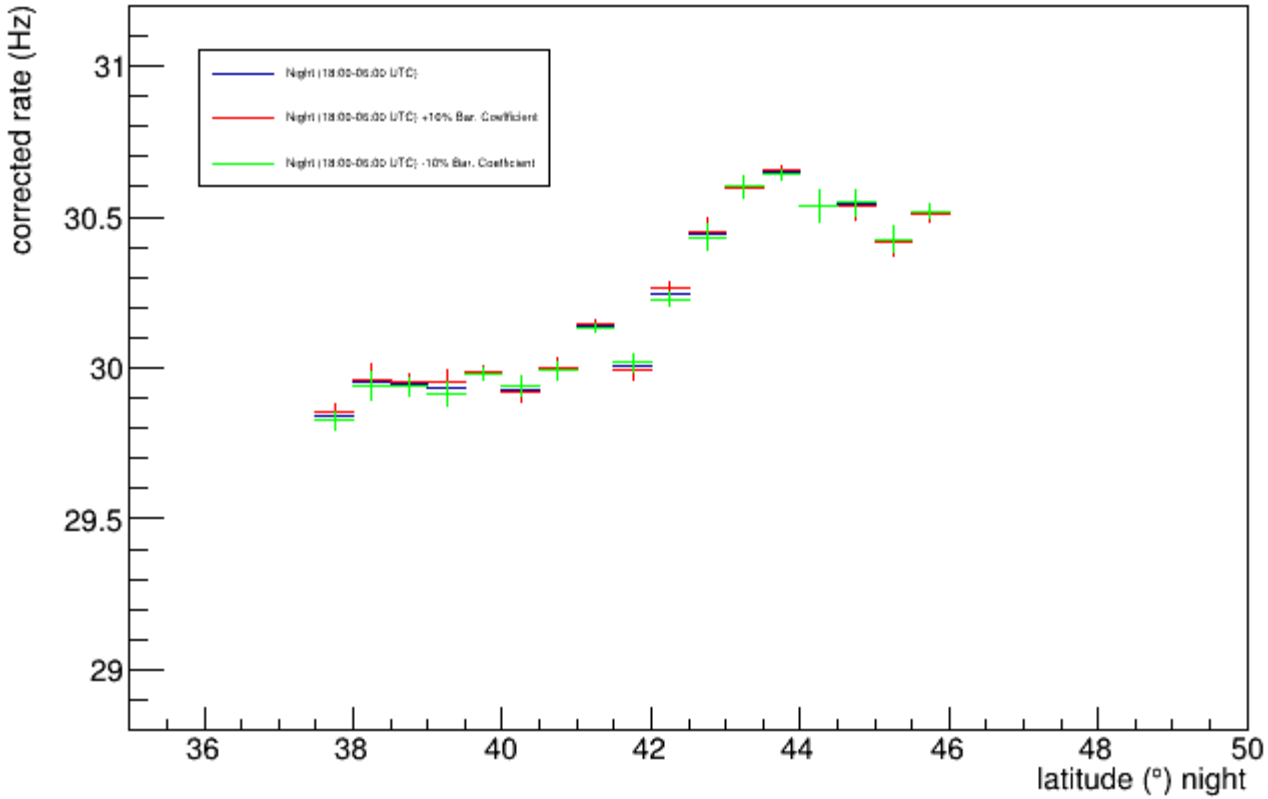
BAROMETRIC EFFECT CORRECTION



The barometric coefficient used to correct for pressure effect was varied by ±10%

Maximal difference with respect the default value was taken as uncertainty
→ **0.06%**

SYSTEMATIC UNCERTAINTIES

SEASONAL AND SOLAR CYCLE EFFECT

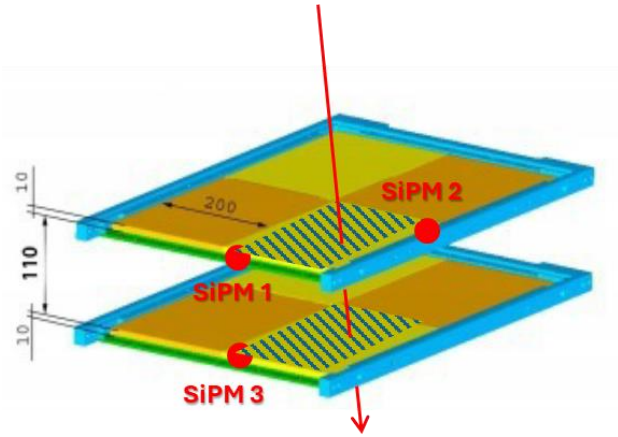
The parameterisation of the seasonal effect was varied by changing the amplitude of the modulation by ±10% and the position of the winter peak by ± 1 week.

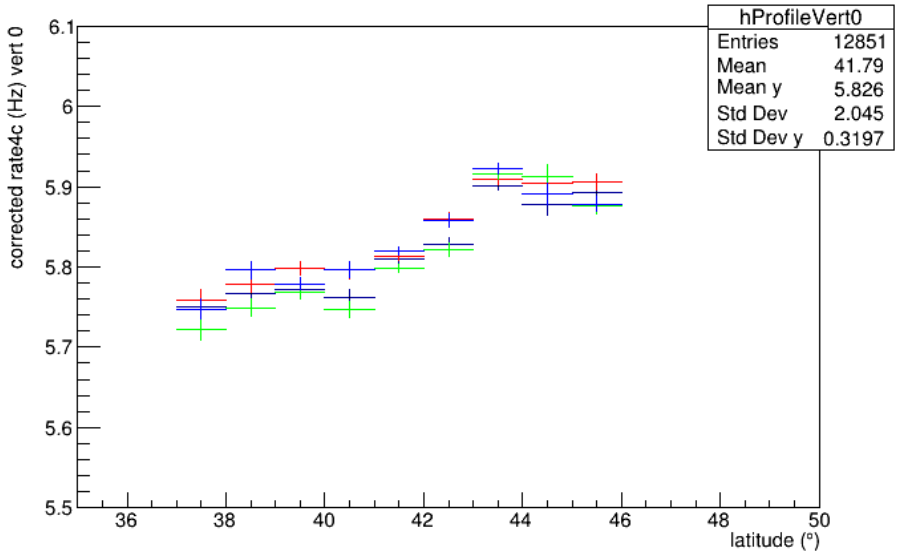
The associated relative uncertainty on the rate was estimated to be at the level of **0.3%** (almost due to solar minimum shift)

SYSTEMATIC UNCERTAINTIES

STABILITY OF THE EFFICIENCY

- Checked by comparing the rates measured independently by the 4 pairs of vertically aligned scintillator counters
- The consistency of the 4 rates was checked and their differences were assigned as systematic uncertainties.
- These were found to be in the range 0.2–0.4%.





SYSTEMATIC UNCERTAINTIES

SUMMARY

Table 2 Systematic uncertainties

Source	Magnitude of relative uncertainty	POLA-02
Pressure corrections	0.5%	→ 0.06%
Altitude	0.2% at 500 m	→ -
Inclination/Orientation	Negligible	→ Negligible
Seasonal effect	0.25%	→ 0.3%
Daily fluctuations (for data at latitudes > 60°)	0.5%	→ -
Efficiency	0.4–0.7%	→ 0.2-0.4%
Material budget (except for Svalbard, Cosenza and Lampedusa)	1%	→ 1%
Total common systematic error	0.8–1.4%	→ 1.1-1.2%

From Eur. Phys. J. C (2023) 83:293

SYSTEMATIC UNCERTAINTIES

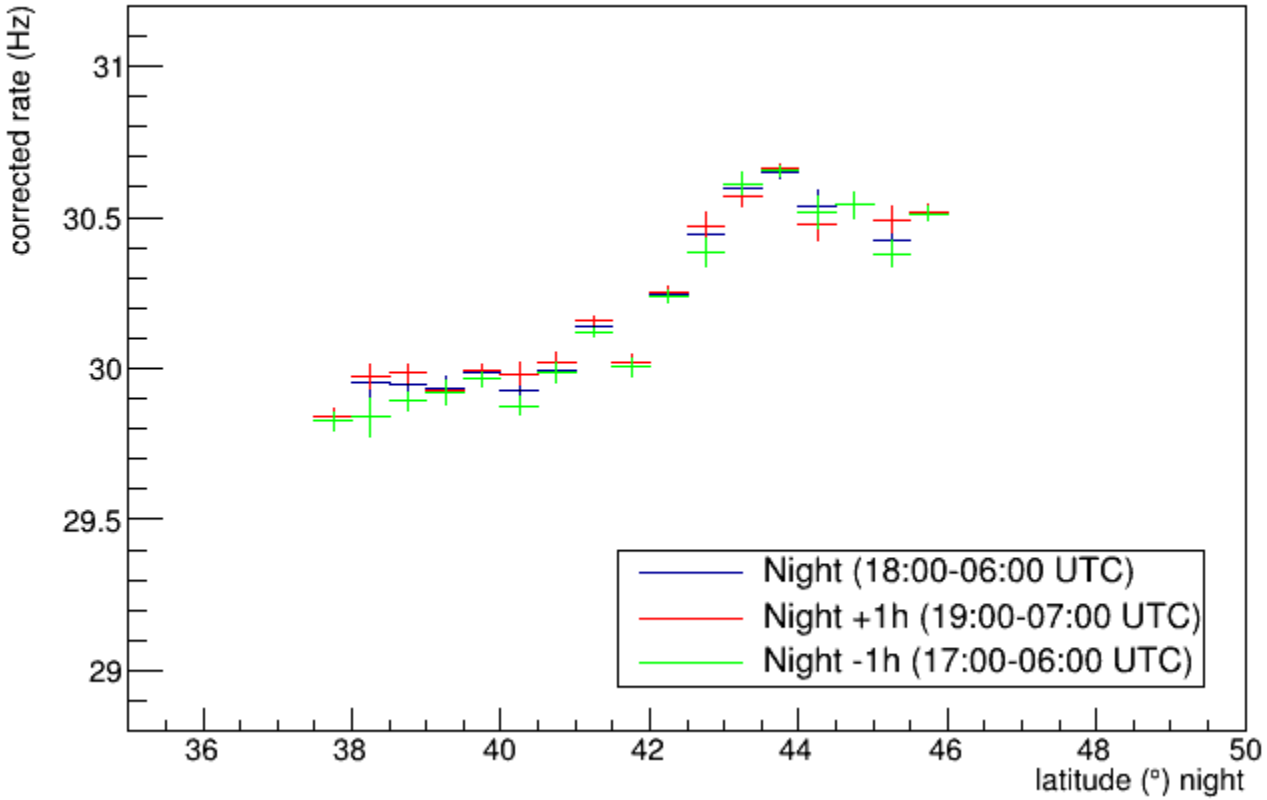
ADDITIONAL CONTRIBUTION – NIGHTTIME SELECTION

Default selection:

- Day 06:00-18:00 UTC
- Night 18:00-06:00 UTC

Selection shifted of +/- 1h

- Average difference wrt default selection: 0.08%
- Maximal difference wrt default selection: **0.4%**



From Eur. Phys. J. C (2023) 83:293

CONCLUSIONS

STRENGTHS:

- Fine-scale analysis as a function of latitude
- Results in agreement with POLA-01 within uncertainties

WEAKNESS:

- Slight systematic shift (~3%) observed between the POLA-01 and POLA-02 results (efficiency?)
- Correction for temperature needed
- Latitude range already explored by POLA-01

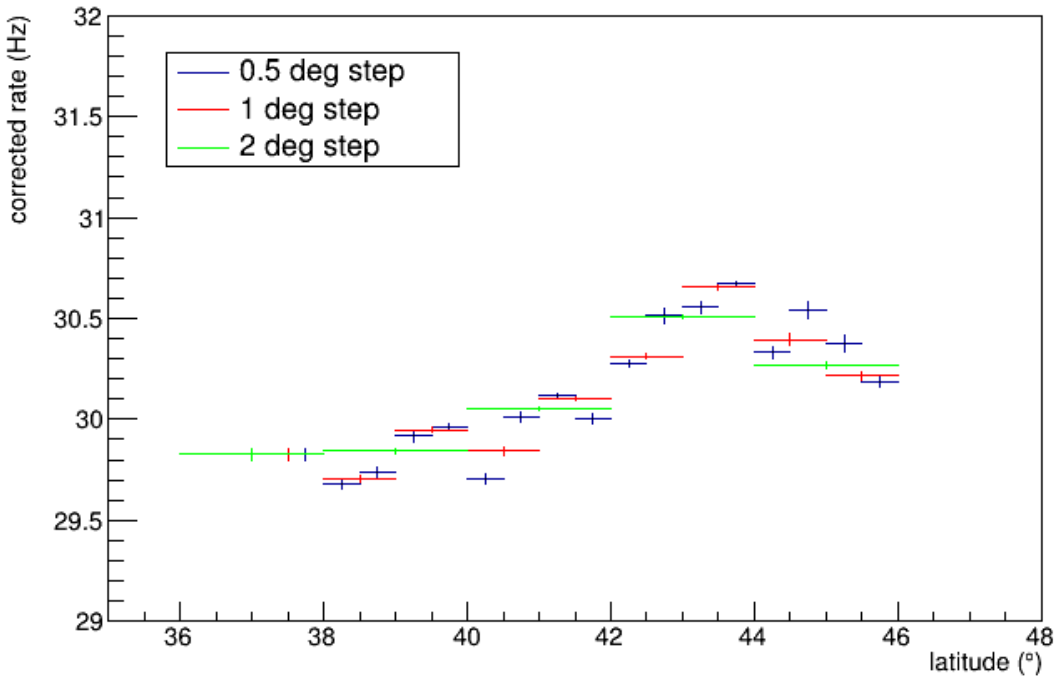
OUTLOOK:

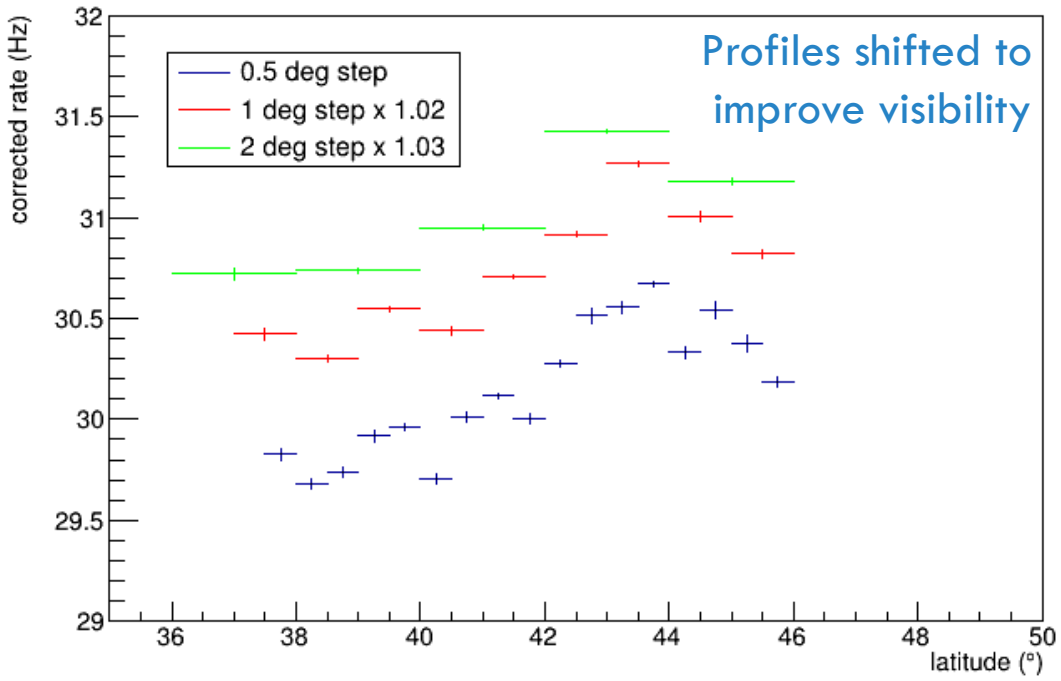
- Improve the estimation of systematic uncertainties
- Plot VS geomagnetic cutoff (to take into account longitude variations)
- Paper preparation ongoing

BACK-UP SLIDES

RATE DEPENDANCE ON LATITUDE

INFLUENCE OF THE LATITUDE BINNING





No evident systematic effect observed depending on the choice of the bin