

Update on the annual modulation of atmospheric muons

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Physics Motivation

- Characteristics of the annual modulation in terms of period/phase \rightarrow comparison to DAMA and other experiments (sinusoidal fit and Lomb-Scargle analysis)
- Correlation of relative variations of T_{eff} and of the measured rate $R_{\mu} \rightarrow \alpha_T \rightarrow K/\pi$ production ratio

Processing of the complete data set (2008→ 2012)

- Different daily rate during CNGS-on (TT+RPC) and CNGS-off (TT only) periods:

- TT+RPC: average rate (single muons) $R_{\mu} \sim 3400$ events/day

- TT: average rate (single muons) $R_{\mu} \sim 1950$ events/day,
(nearly stable over the 5 years 2008→2012)

→ Normalized one to the other for each year

overall yearly difference at few ‰ (up to 1% for 2008)

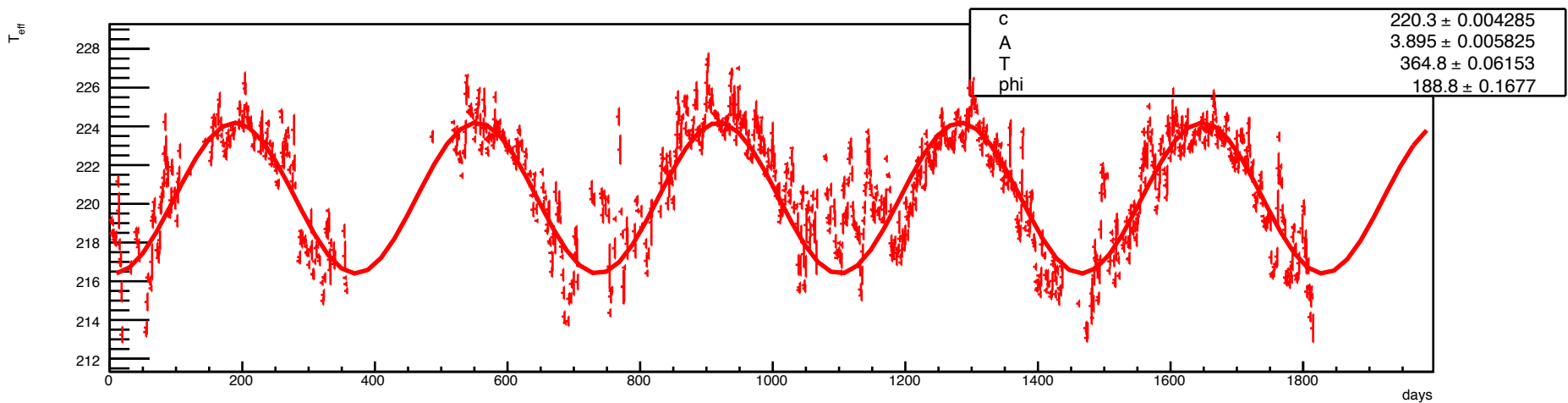
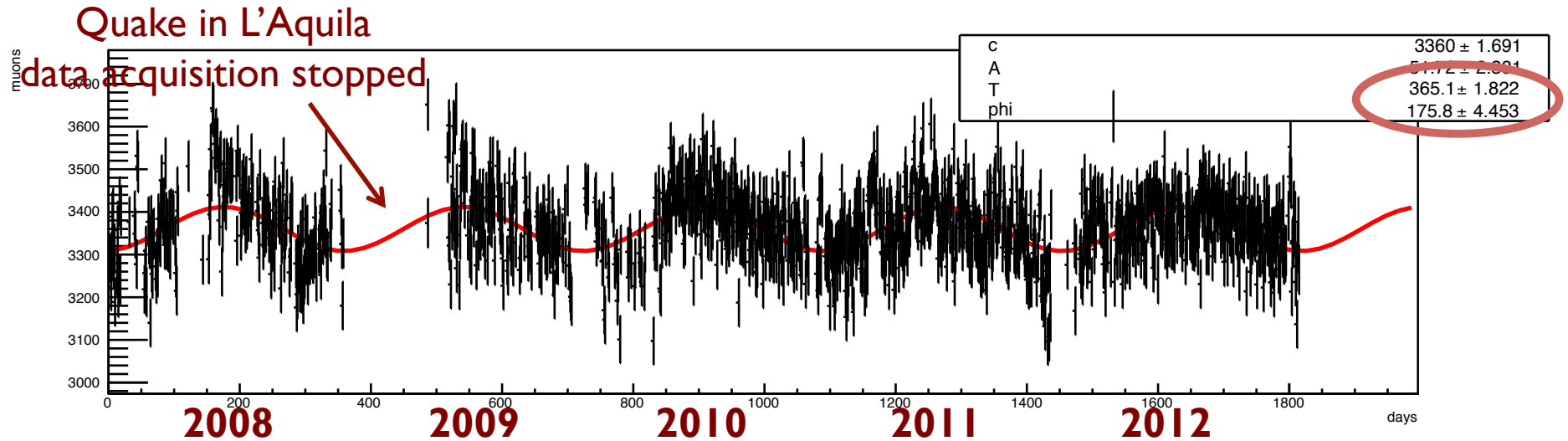
- OPERA acceptance for atmospheric muons coming from above

$$A = 599 \text{ m}^2 \text{ sr}$$

Experimental OPERA Rate/MC Rate = ~ 96%

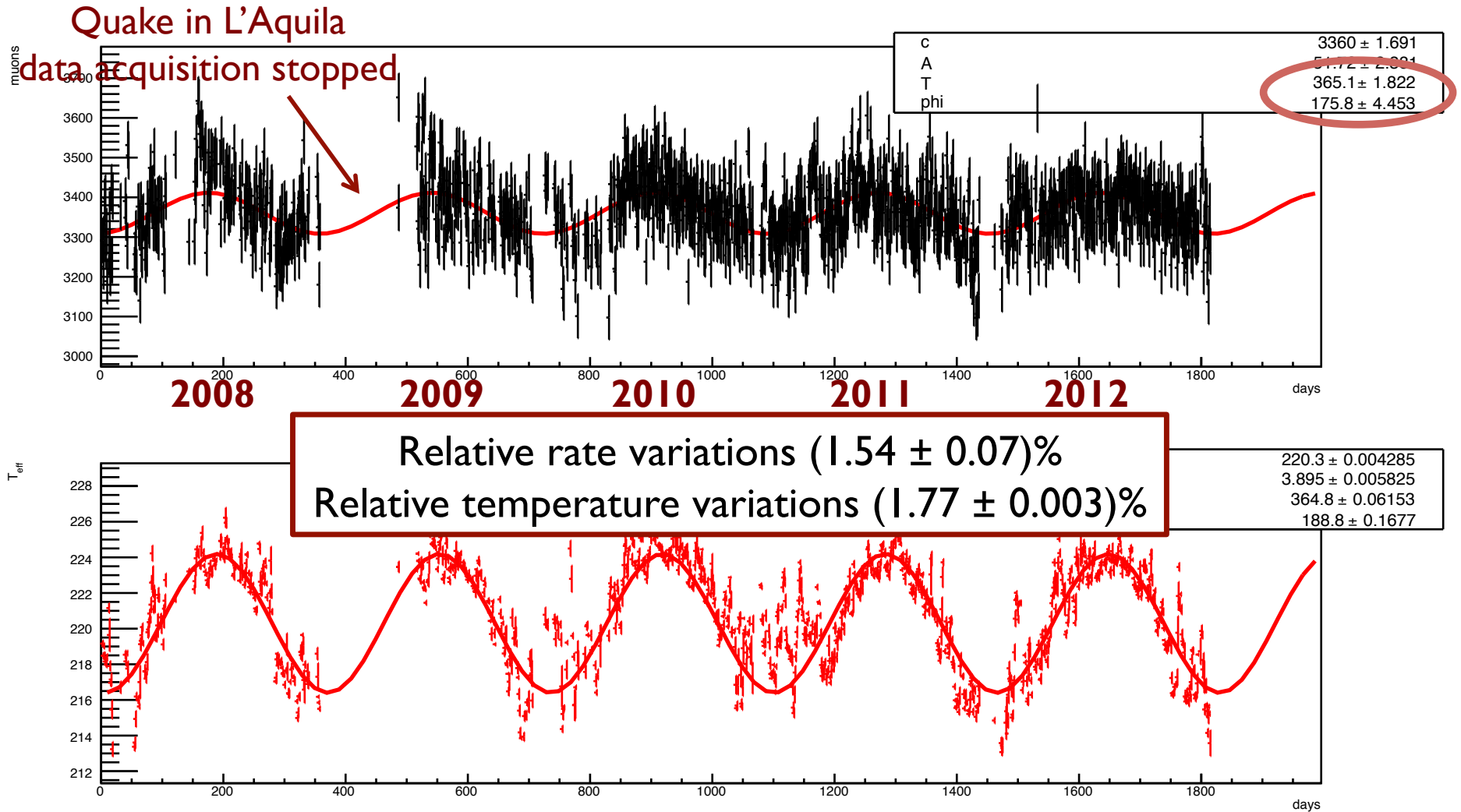
MC based on MACRO parameterization → direct comparison
with their flux – rescaled to OPERA

Preliminary results: rate modulation



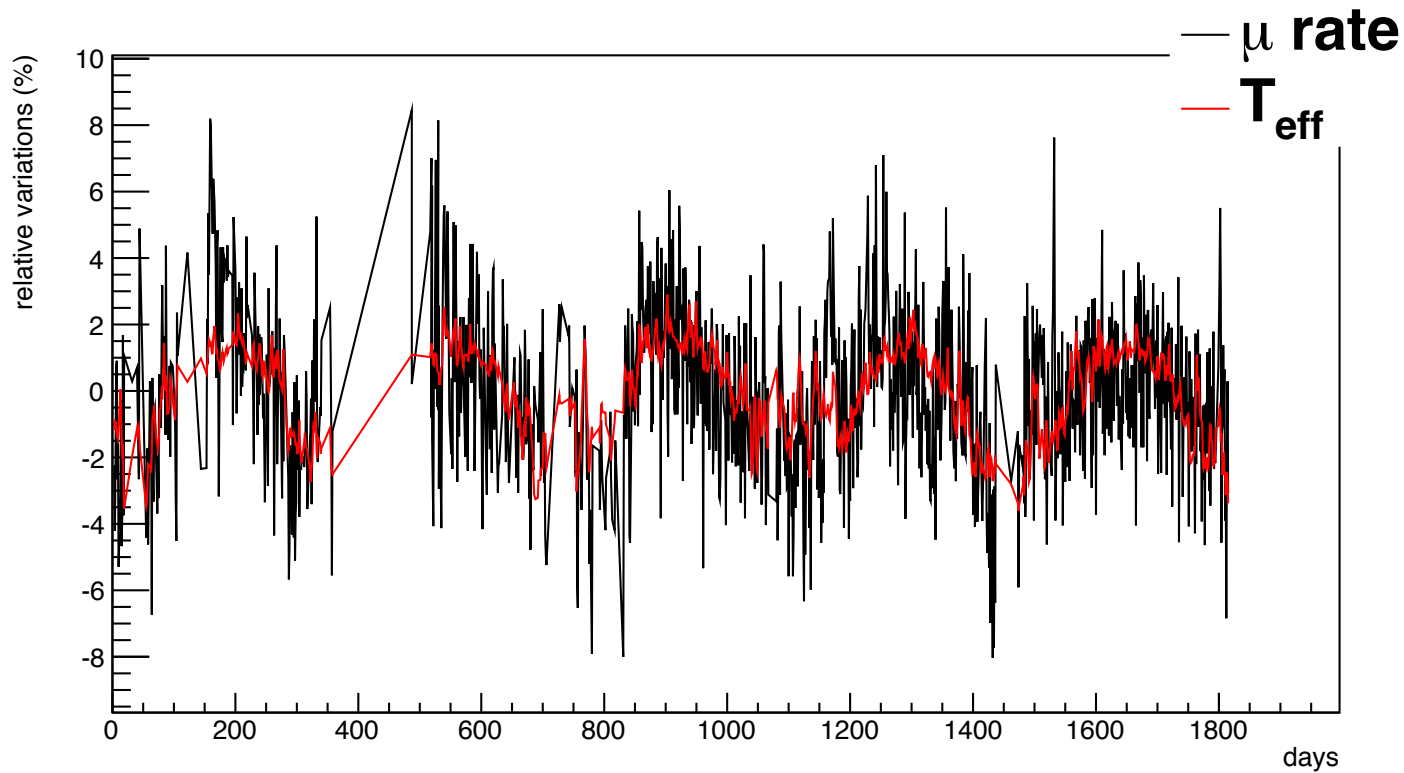
- Only single muons (reconstructed multiplicity in 3D == 1)
- Beam angle window cut in order to eliminate beam contamination

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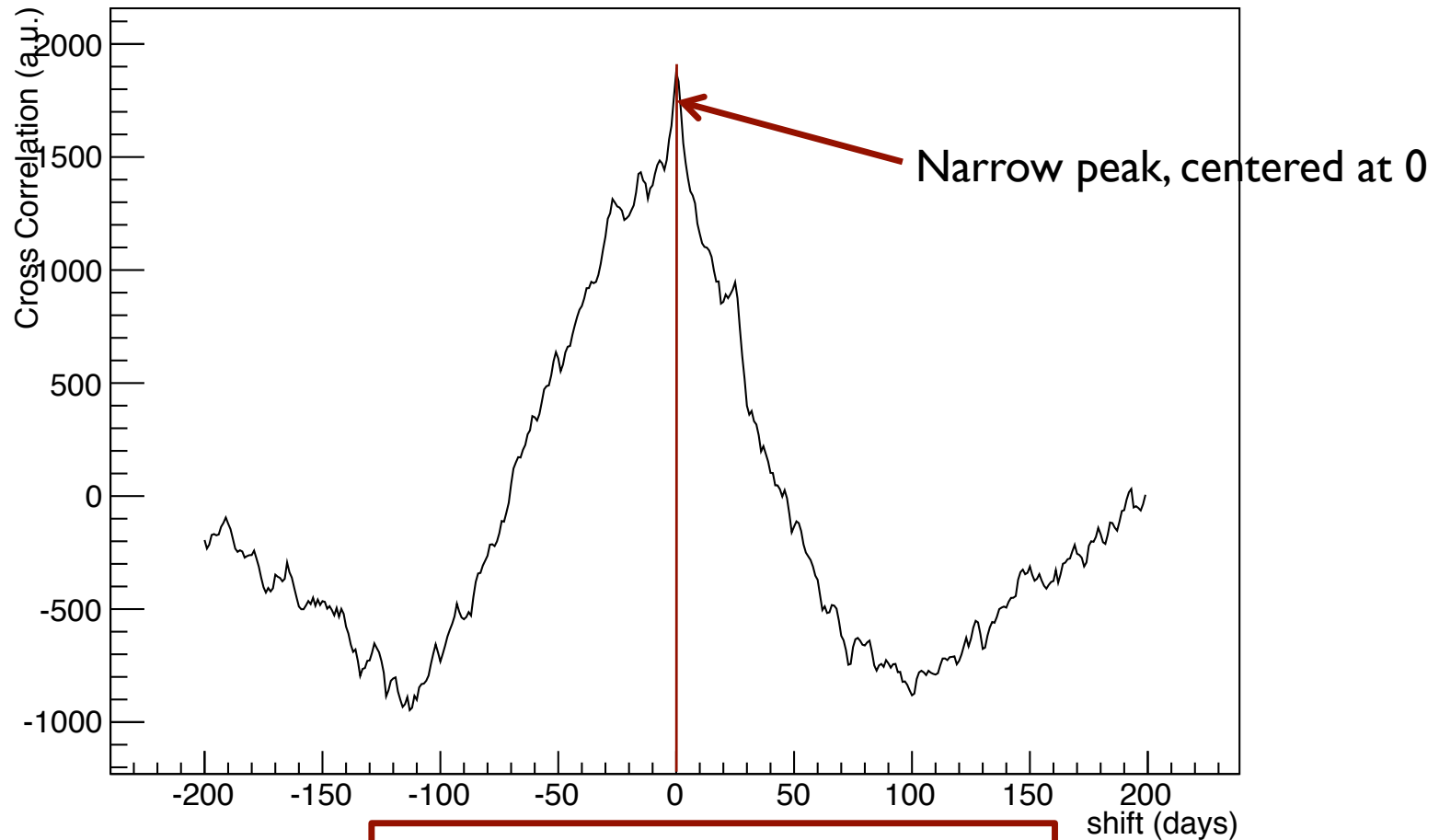
Preliminary results: correlation with temperature variations



Preliminary

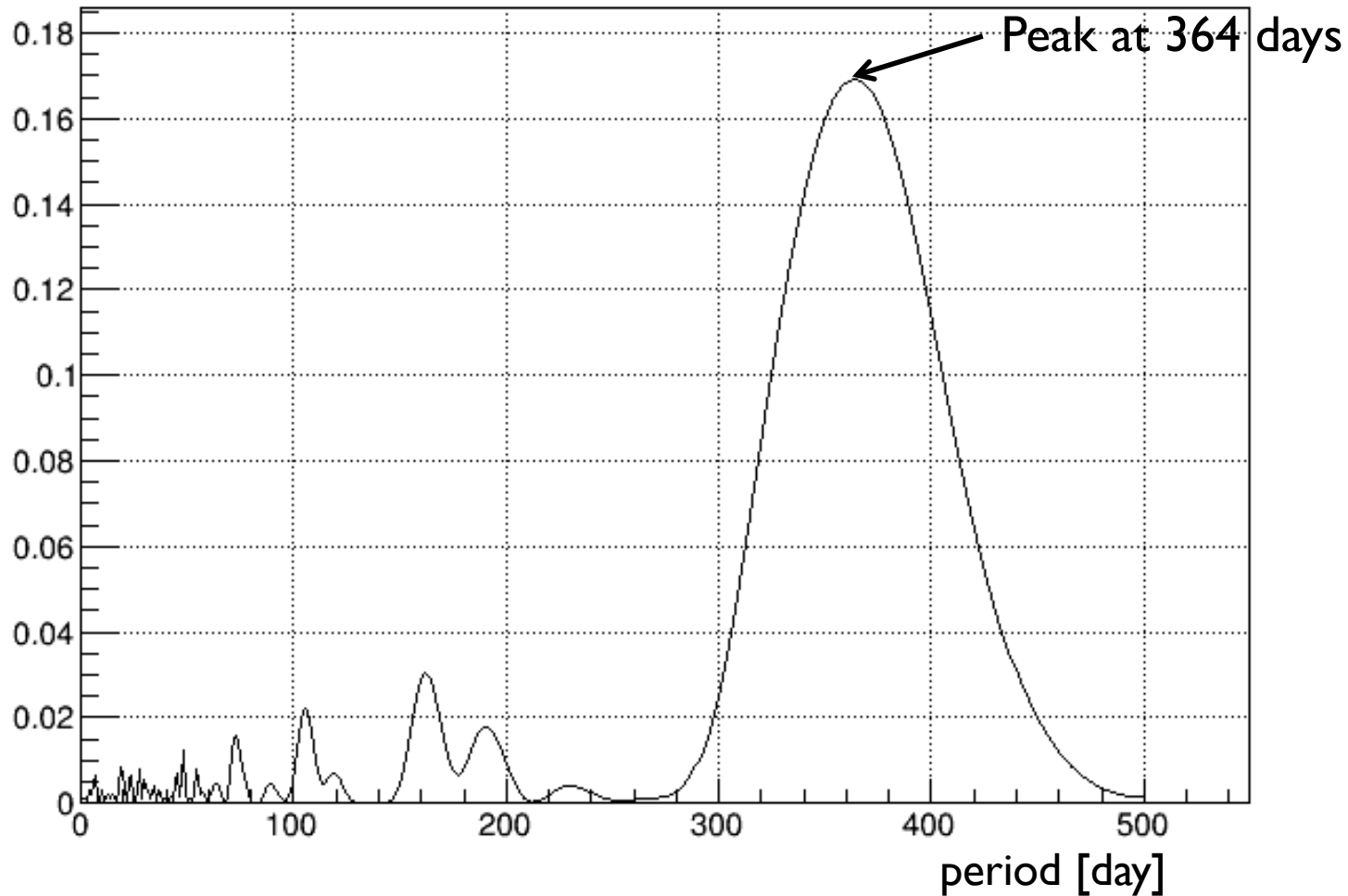
Preliminary results: correlation with temperature variations

Cross correlation function of
T and rate time series

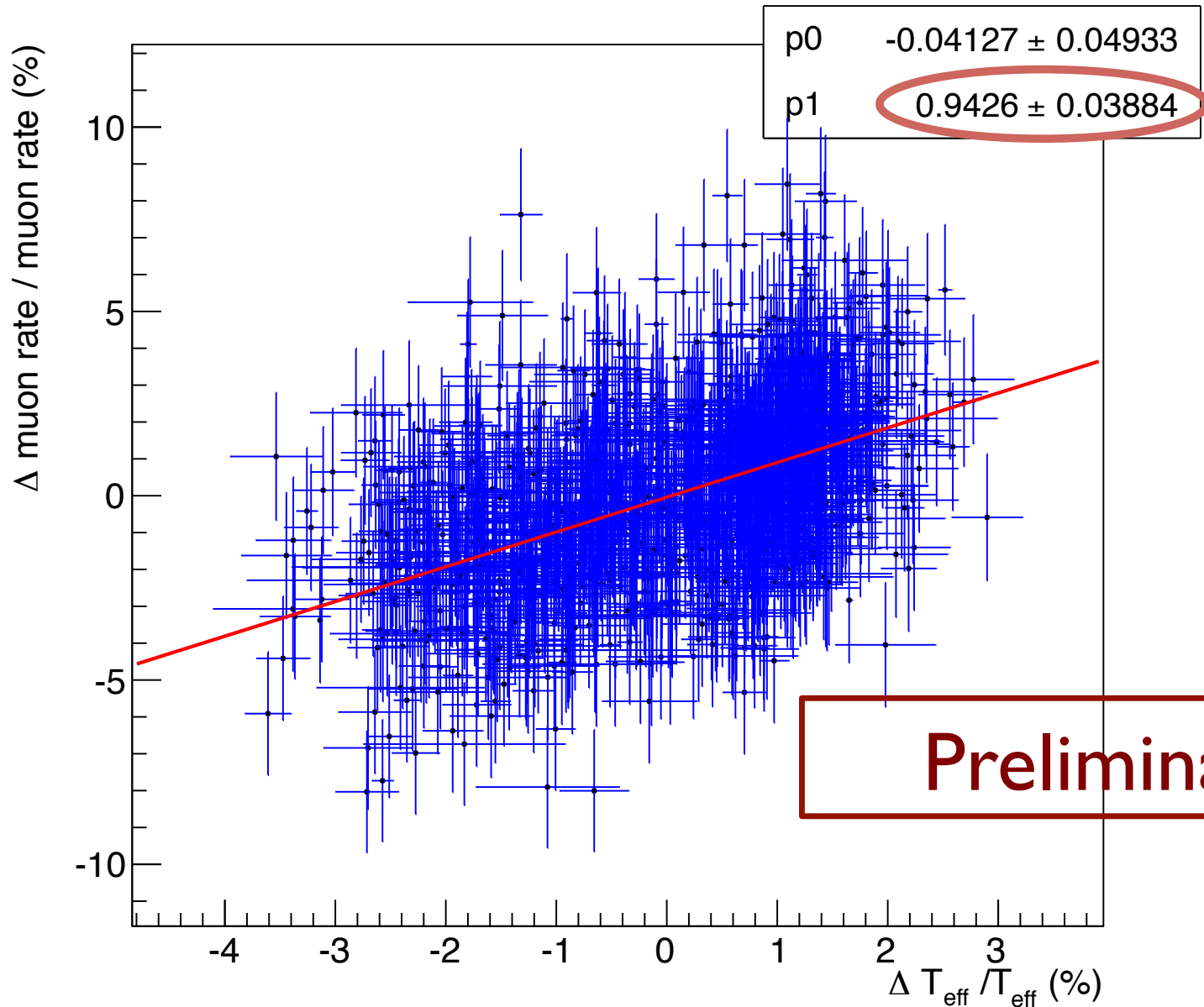


Preliminary

Preliminary results: Lomb-Scargle periodogram



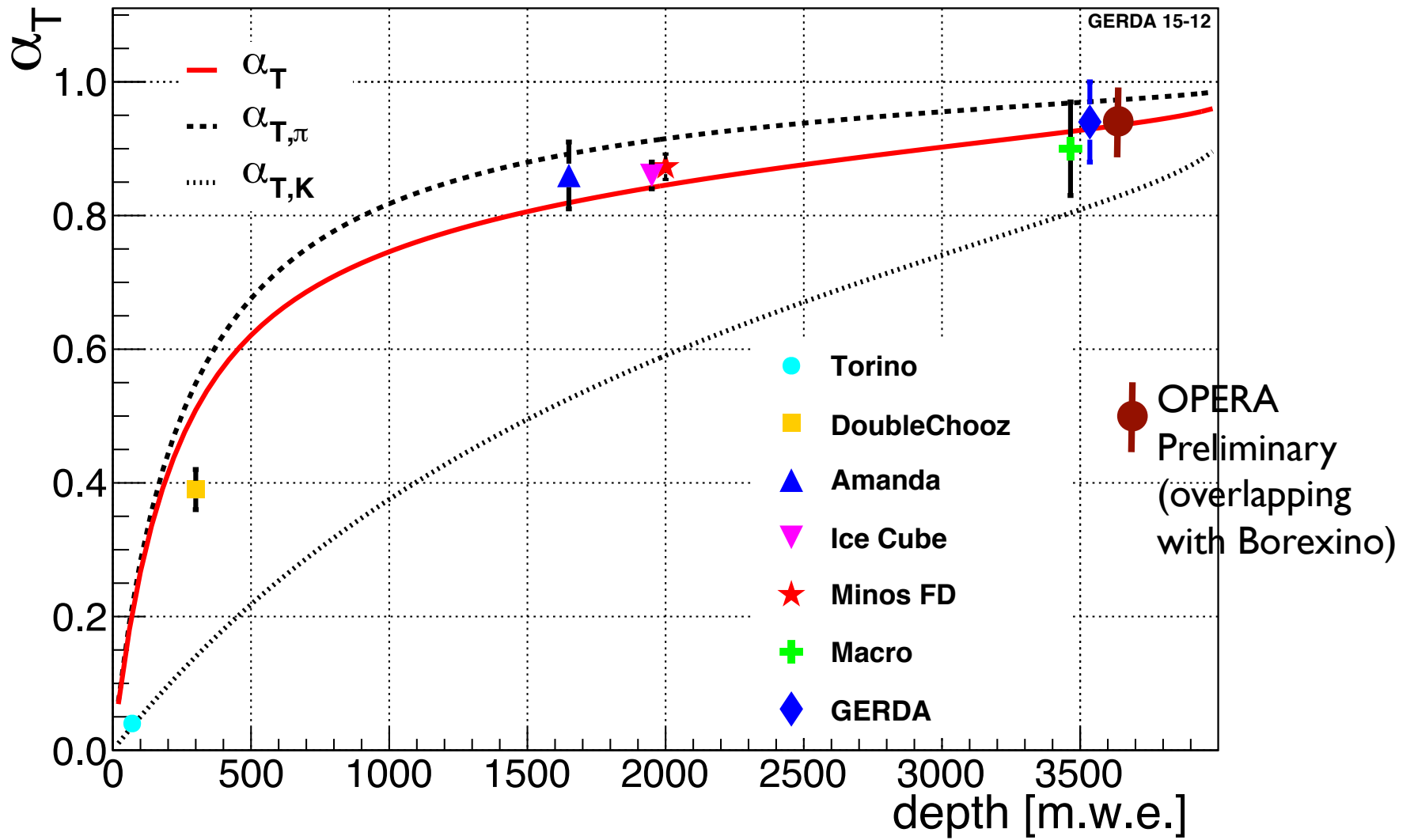
Preliminary results: α_T



Conclusions

- Preliminary results on the annual modulation of atmospheric muons with the complete OPERA data set 2008→2012
 - period $T = (365 \pm 2)$ days and phase = (176 ± 4) days from the sinusoidal fit over the 5 years
 - $\alpha_T = 0.94 \pm 0.04$

both compatible with theoretical expectations and other LNGS experimental results



Outlook

- Improvements in the selection and analysis
- Significance of period and phase under evaluation
- Cross-correlation between Rate and Temperature taking into account also periods in temperature with detector switched off
- Cross-check fixing the period and folding data into one year (Borexino-like)
- Cross-check with TT only data taking and systematics evaluation
- Evaluation of the capability to extract $R_{K/\pi}$ and potential combination with parameters inferred from the Charge Ratio (Z_{pK})