Solar Modulation of Galactic Cosmic-Ray Electrons Measured with CALET

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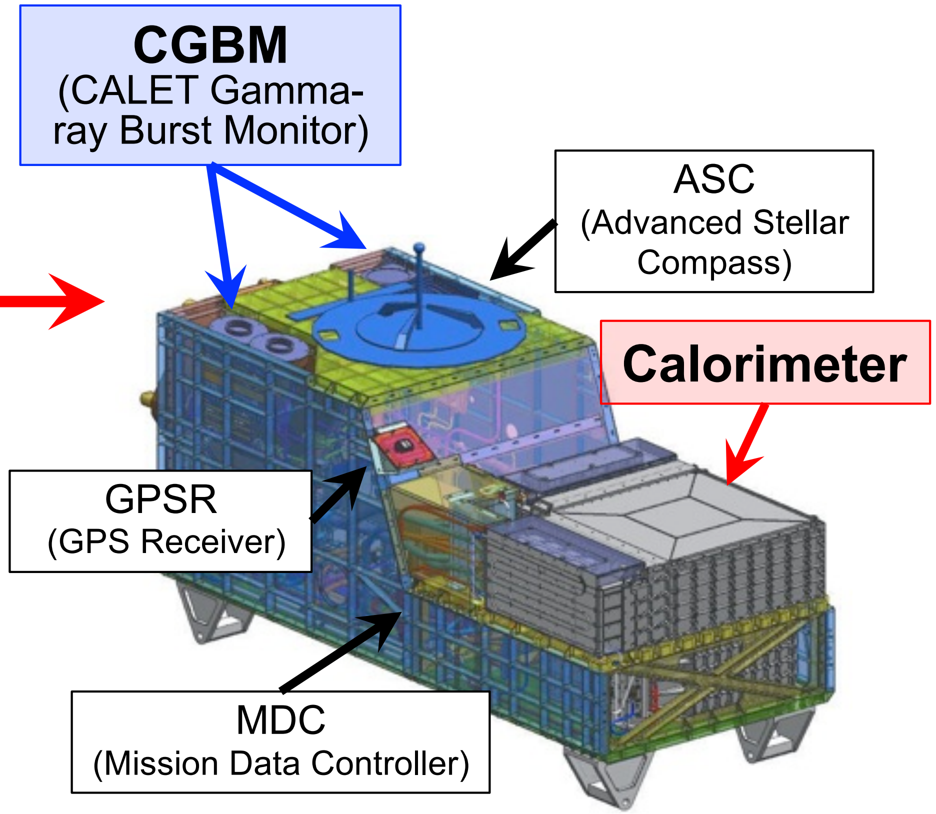
CALET on the ISS

CALorimetric Electron Telescope (CALET)



Launch: Aug. 19, 2015
Observations: Oct. 13, 2015
Observation Targets:

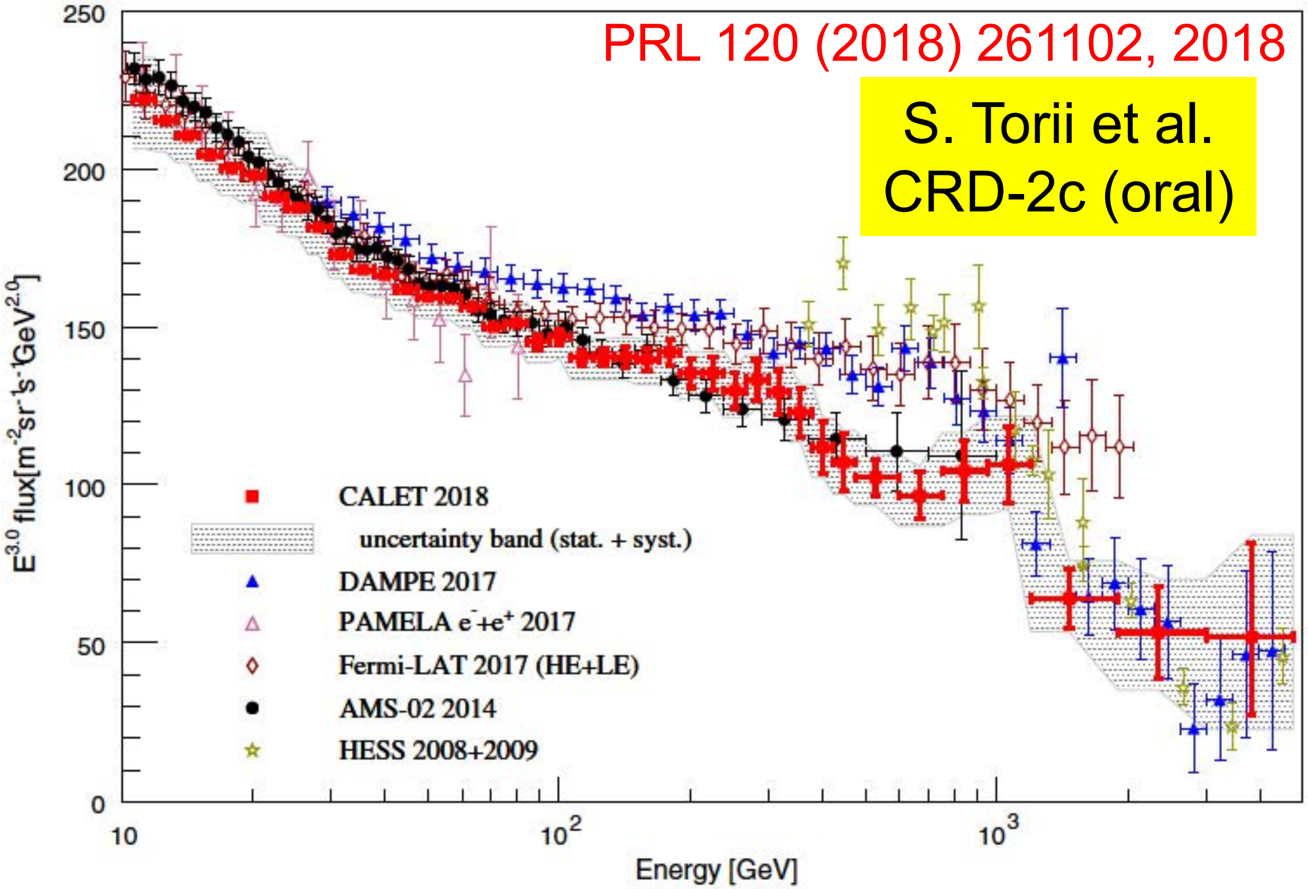
- Electron ($e^- + e^+$): 1GeV – 20 TeV
- p--Fe: 10 GeV – 1000 TeV
- Ultra heavy ions (26<Z<=40): > 600 MeV/n
- Gamma-rays (Diffuse + Point sources): 1 GeV – 1 TeV

Measurements of the CR $e^- + e^+$ with High-Energy Trigger

High-energy shower trigger (HE-Trigger):

- Energy thresholds are set to detect shower events with energies over 10 GeV.
- HE-trigger is always active.

CR $e^- + e^+$ spectrum from 11 GeV to 4.8 TeV

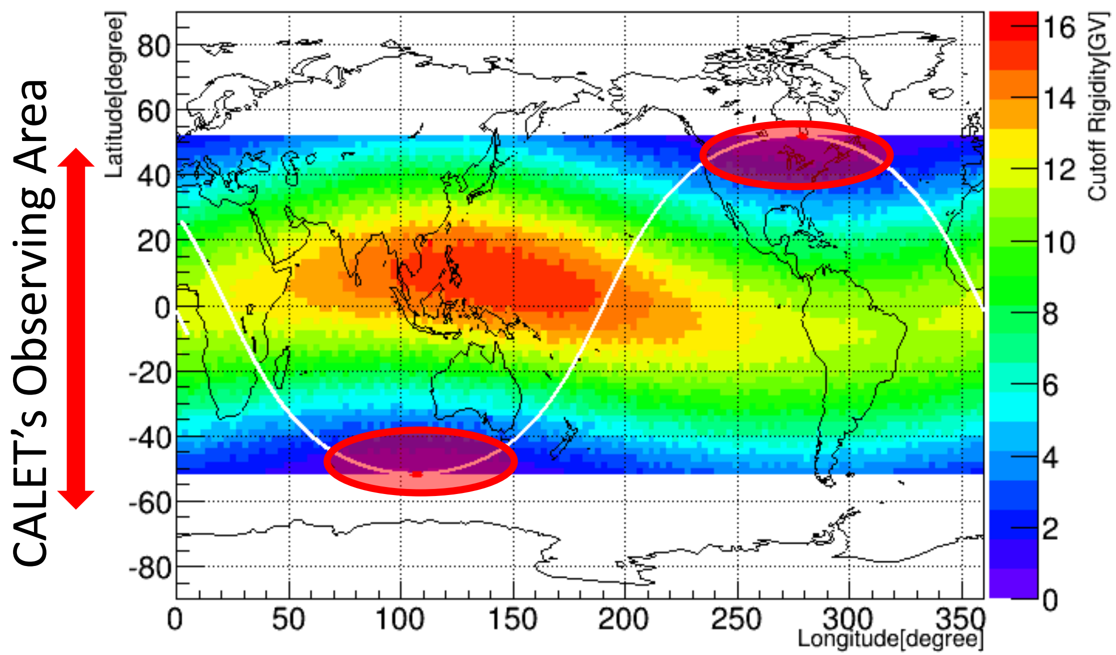


Measurements of the CR $e^- + e^+$ with Low-Energy Trigger

Low-energy shower trigger (LE-Trigger):

- Energy thresholds are set to detect shower events with energies over 1.0 GeV.
- Measurement of low energy electrons (1GeV ~ 10GeV) with LE-trigger is active only at high latitude where maximum cutoff rigidity is 5.0GV.
  →In 1 cycle, LE mode works 2 times for 90 sec

Cutoff rigidity map and ISS orbit



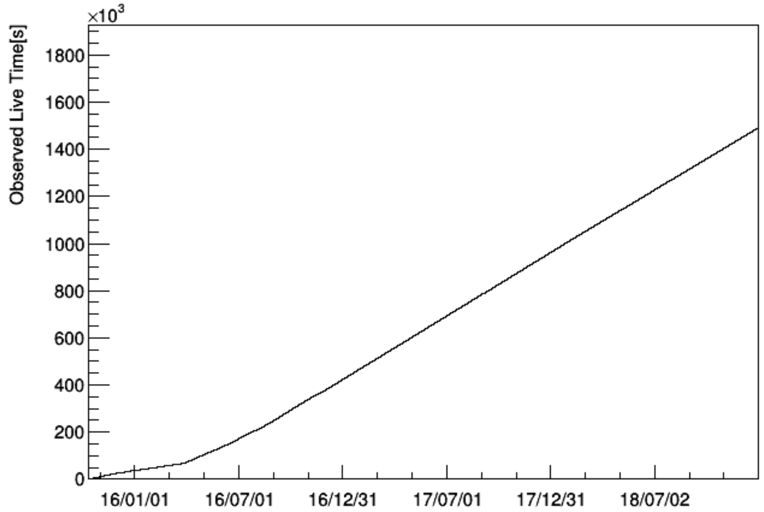
http://www.ngdc.noaa.gov/IAGA/vmod/igrf.html

Oct. 12, 2015 ~ April 30, 2019

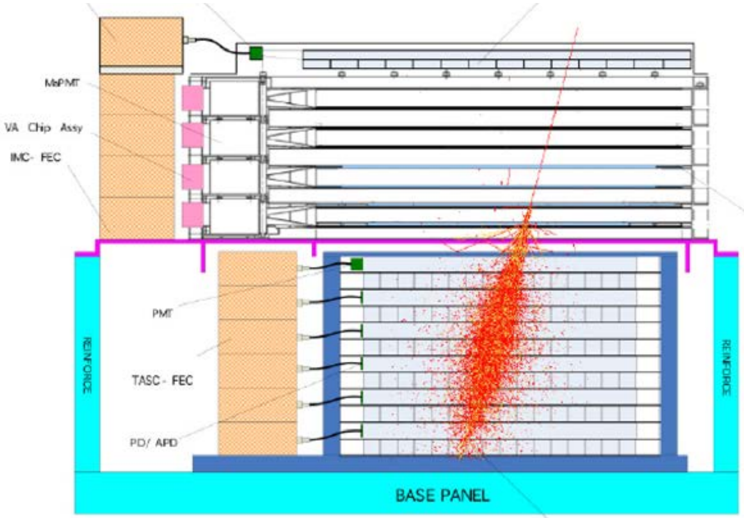
Total Live Time: ~28,213 [hour]

Total events : ~55×10^6 [events]

Integrated live time



Analysis Procedure for Low-Energy $e^- + e^+$



CHD (Charge Detector)

IMC (Imaging Calorimeter)

TASC (Total Absorption Calorimeter)

Event selections for low energy $e^- + e^+$

① Energy threshold: IMC7–8 and TASC top layer
- Trigger GeV–energy events

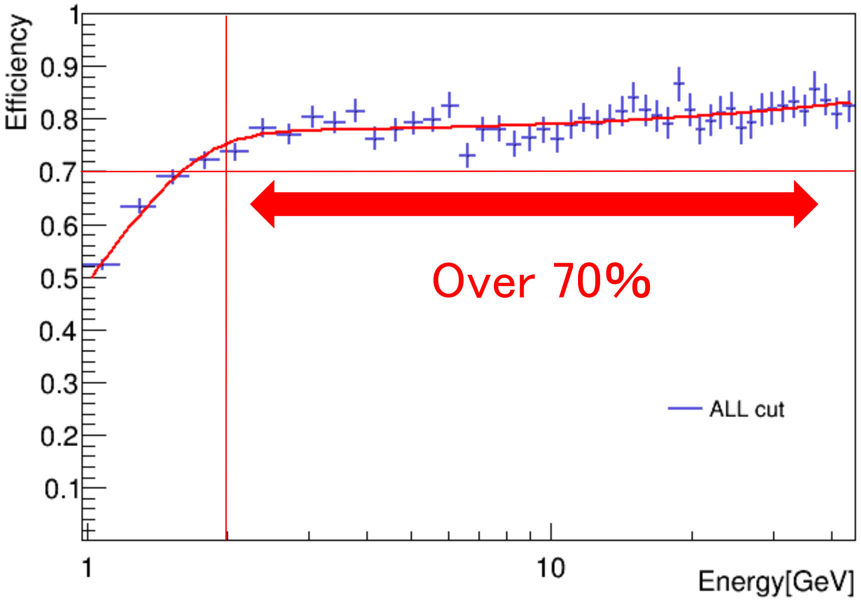
② Tracking and geometry condition: IMC
- Kalman filter track reconstruction with IMC
- Entire trajectory is inside IMC and TASC

③ Charge determination: CHD
- CHD energy deposit to remove Z>=2

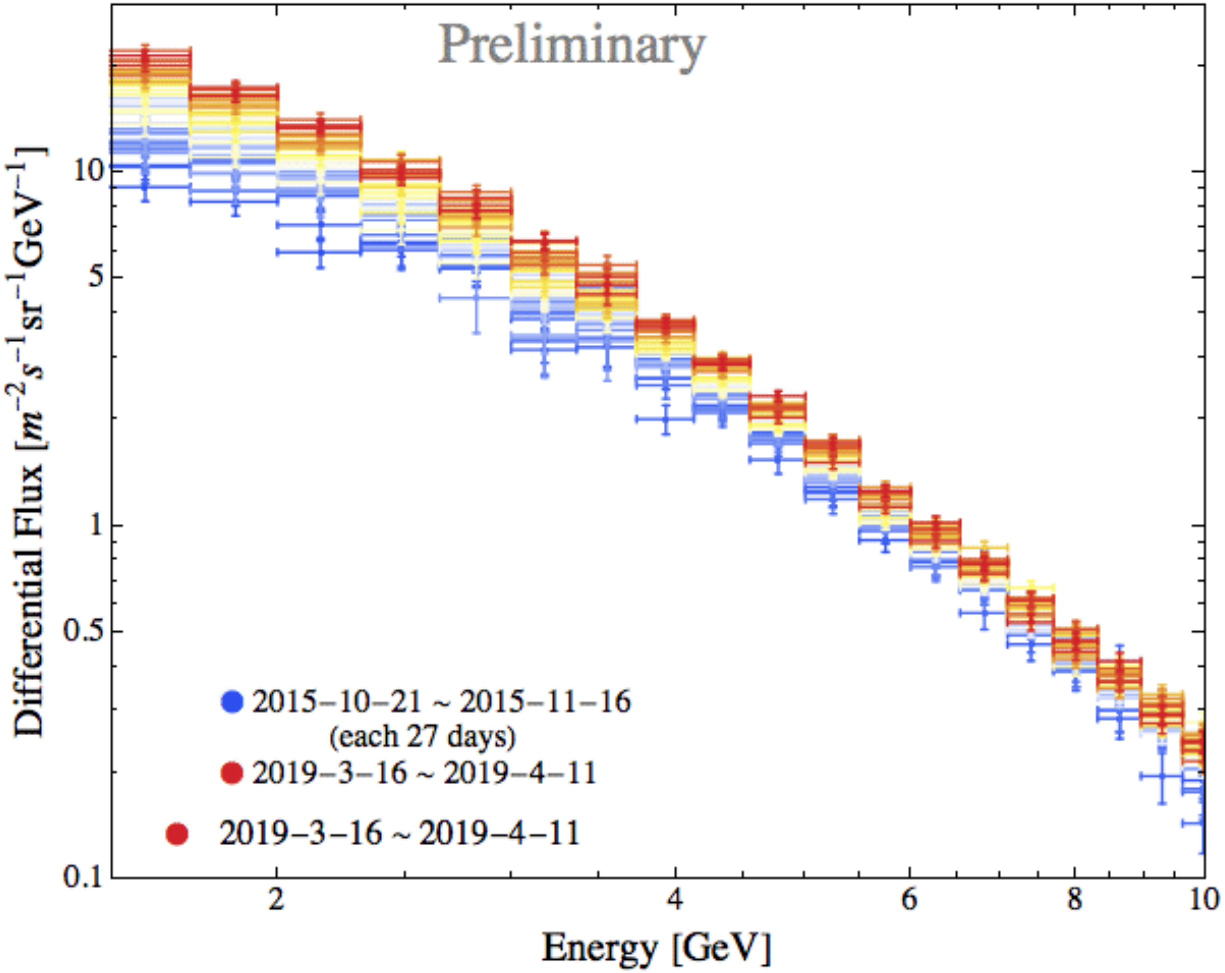
④ e/p separation: IMC bottom layer and TASC top layer
- Energy deposit and Shower concentration of IMC bottom layer
- R_E of TASC top layer

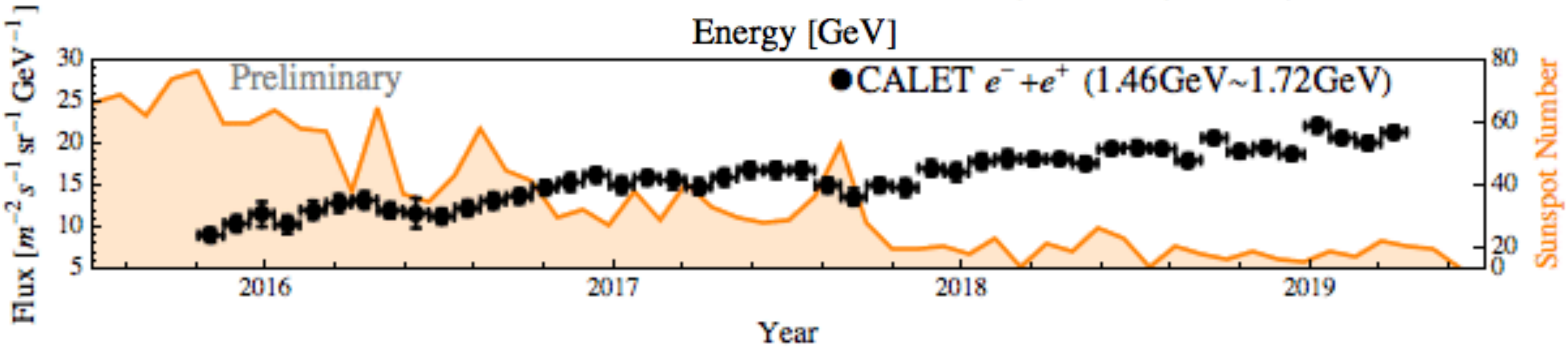
⑤ Energy determination: IMC and top 3 layers of TASC X, Y
- Energy deposit of top 3 layers of TASC X, Y and IMC

Energy dependence of low–energy e–+e+ Efficiency

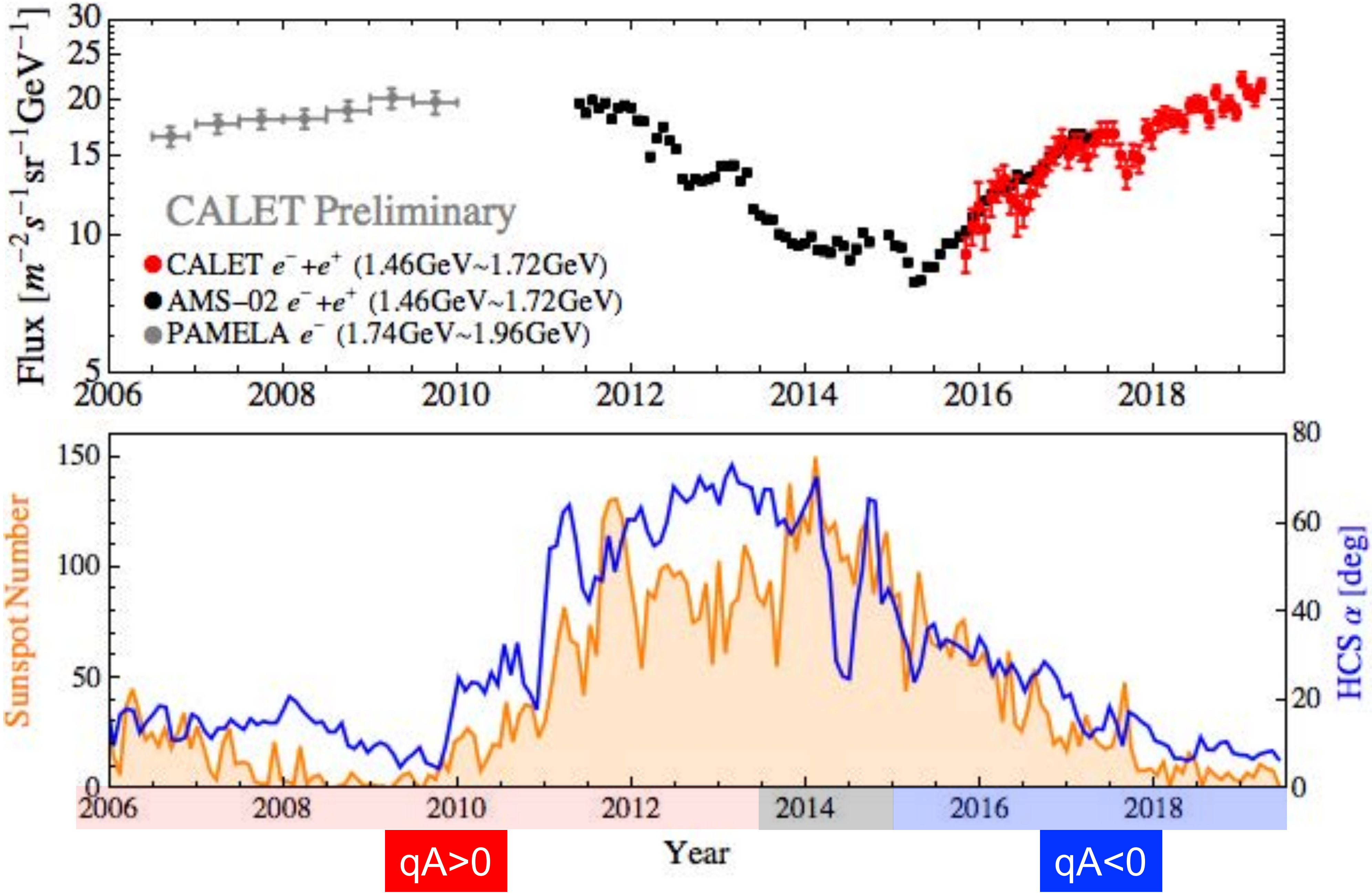


Energy Spectrum of Low-Energy CR $e^- + e^+$

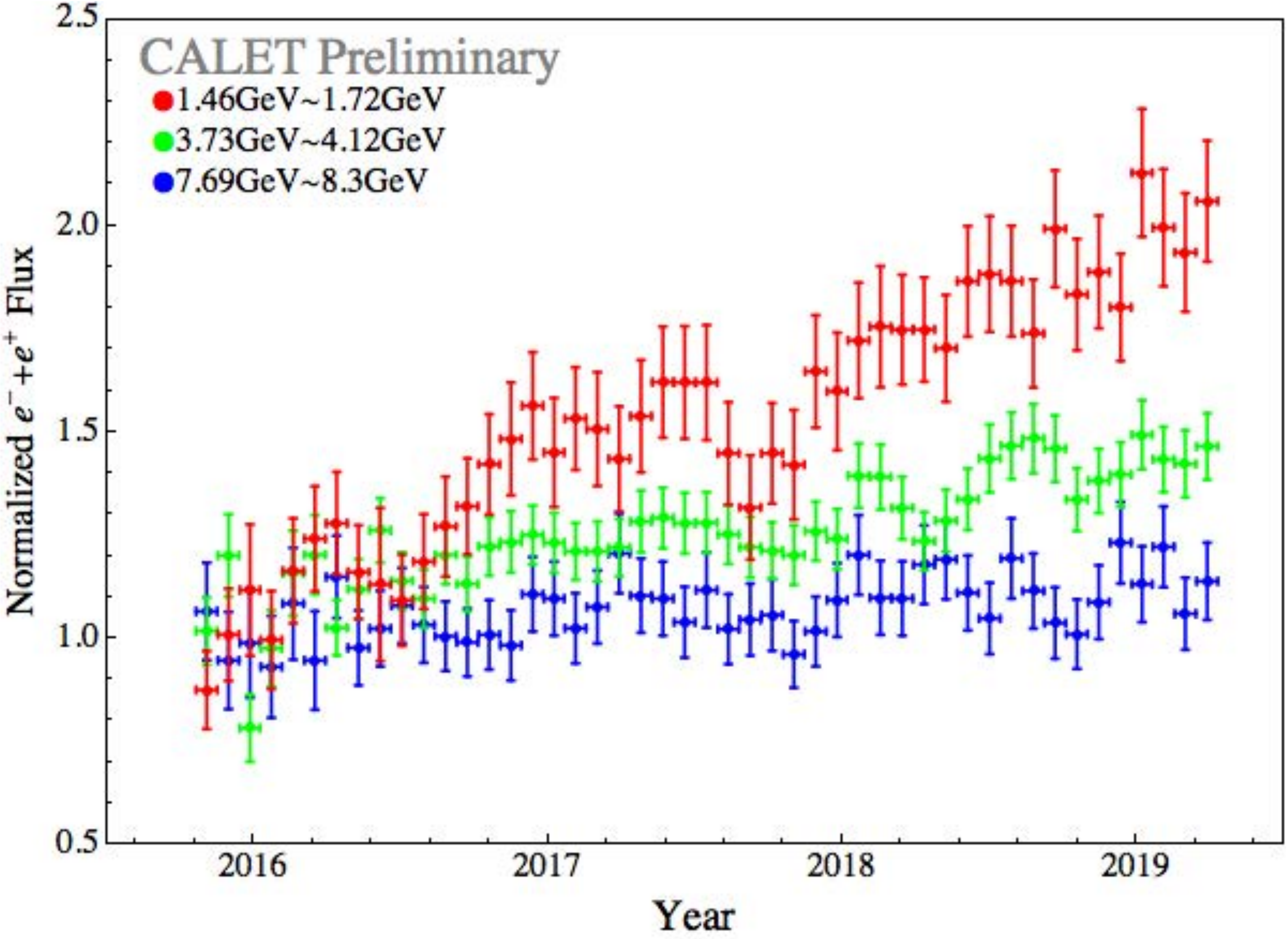




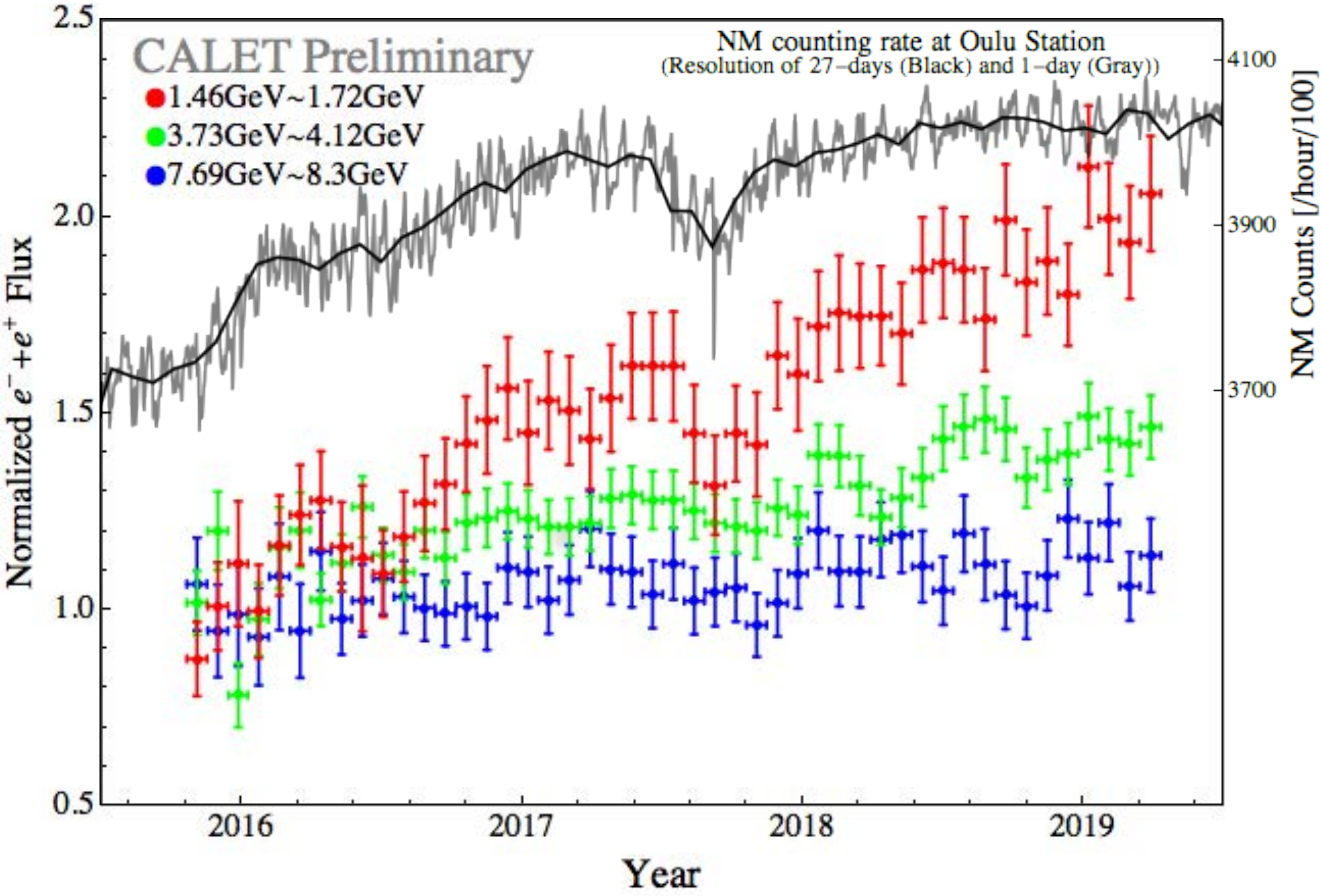
Possible Increases of CR $e^- + e^+$ Flux



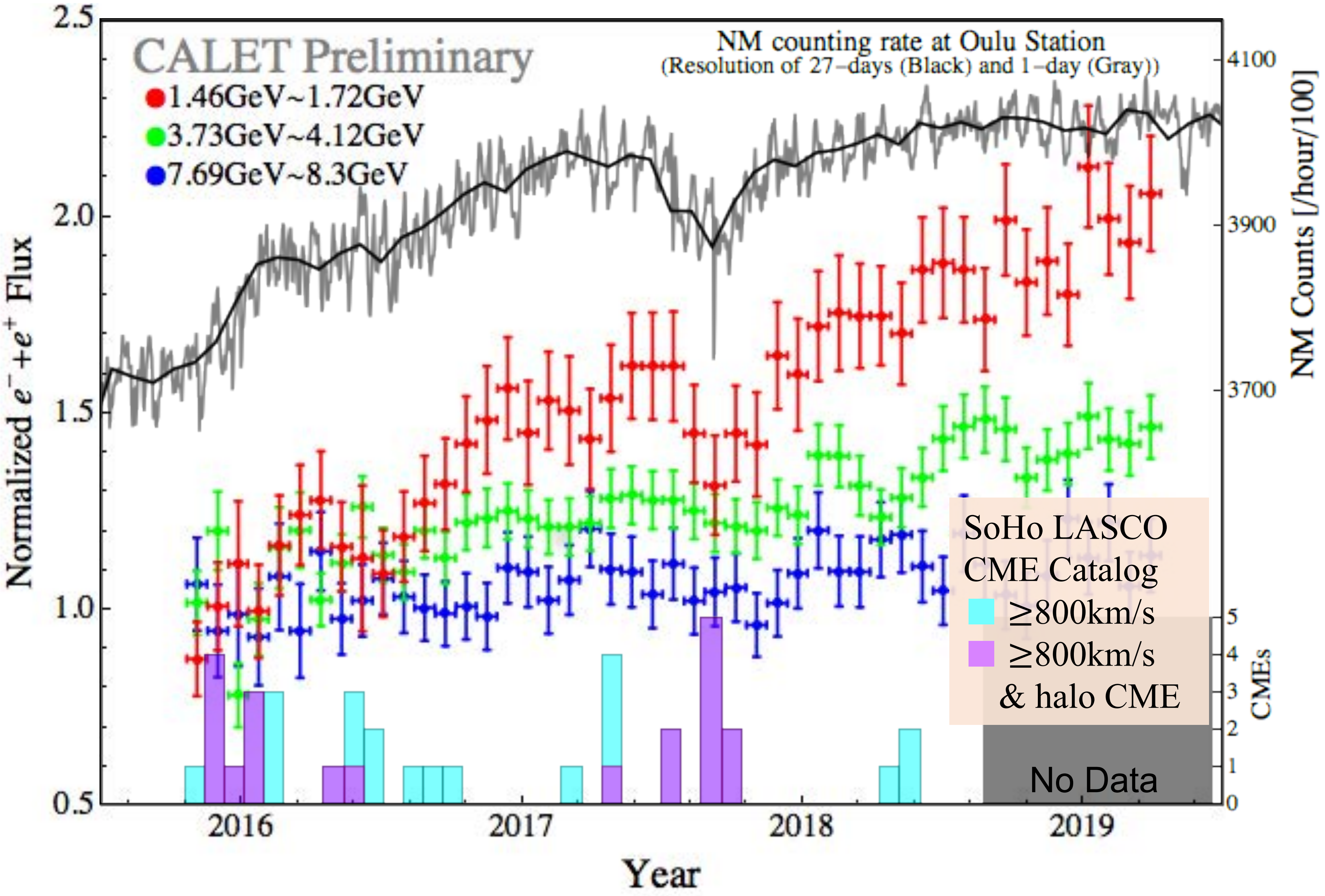
Short-Disturbance of the Monthly Flux of CR $e^- + e^+$



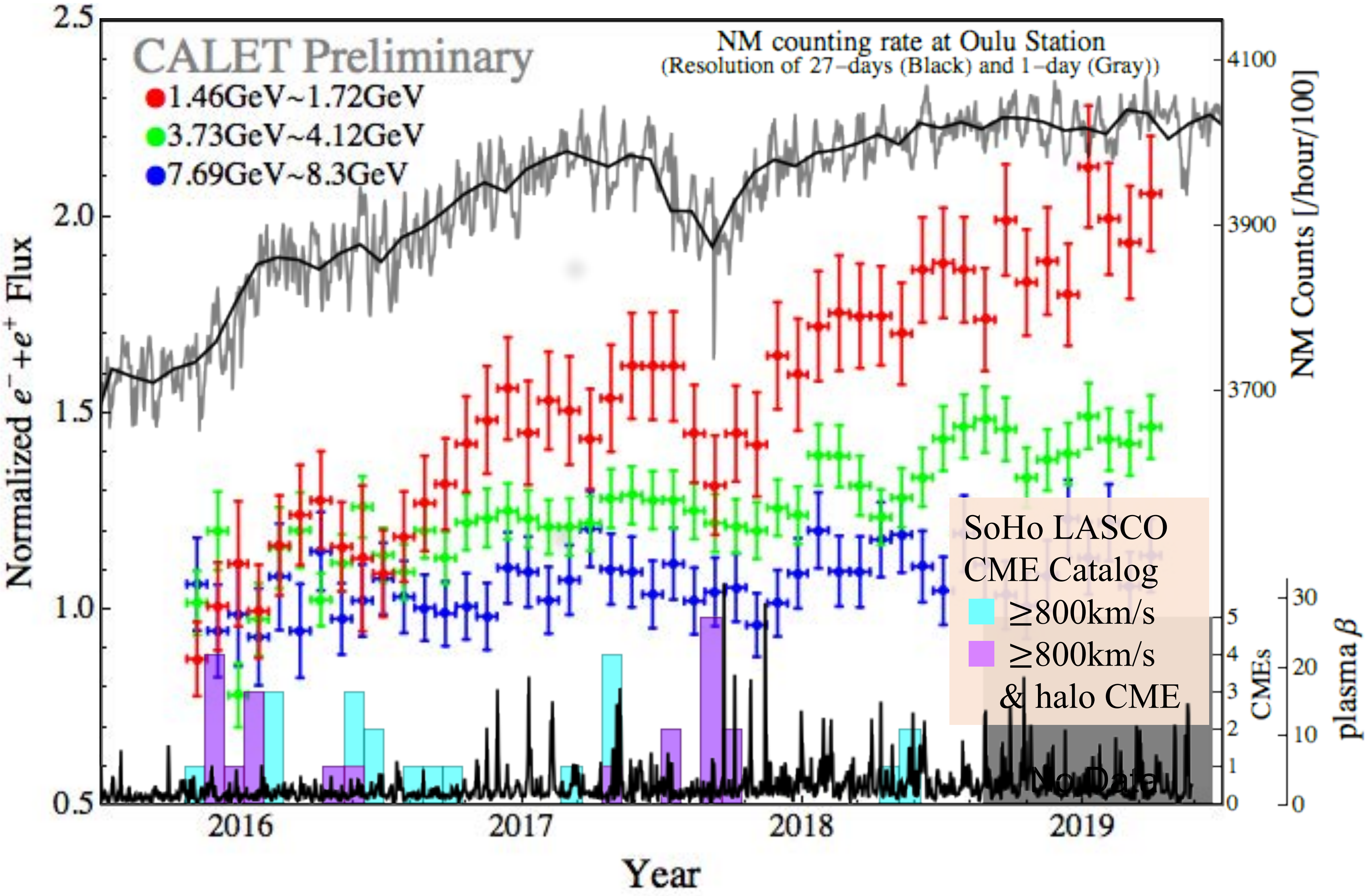
Short-Disturbance of the Monthly Flux of CR $e^- + e^+$



Short-Disturbance of the Monthly Flux of CR $e^- + e^+$



Short-Disturbance of the Monthly Flux of CR $e^- + e^+$



Summary

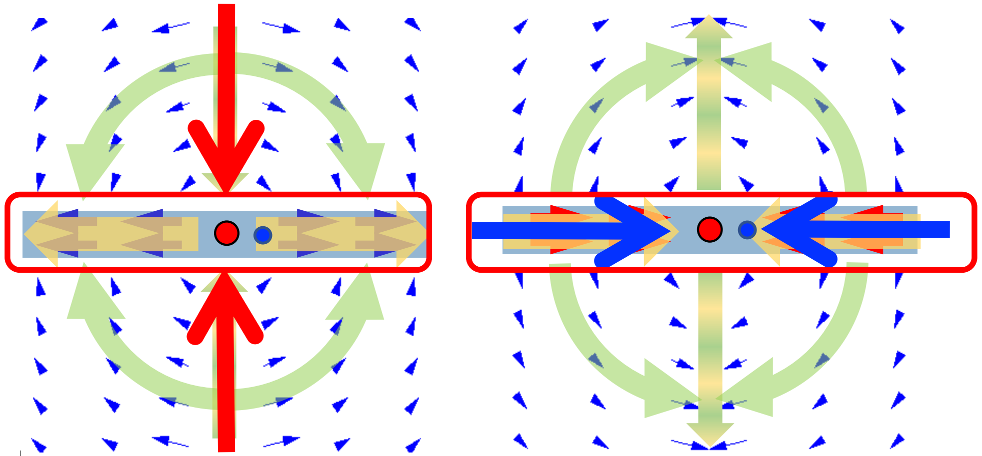
- The ability of CALET low-energy trigger for measuring 1 GeV - 10 GeV $e^{-}+e^{+}$ flux has been successfully demonstrated.
- We obtained the continuous variation of the low-energy electron flux increasing as time passes, which have been expected from a recent weakening solar cycle.
- We also confirmed that there are additional small fluctuations in the flux, that has a potential to be explained by the effects of the interplanetary coronal mass ejections or the co-rotating interaction region of the solar wind.
- Further investigation with continuous measurements of the low-energy electrons by CALET may provide a crucial key to the understanding of the details of the 27-day variation of the solar modulation.

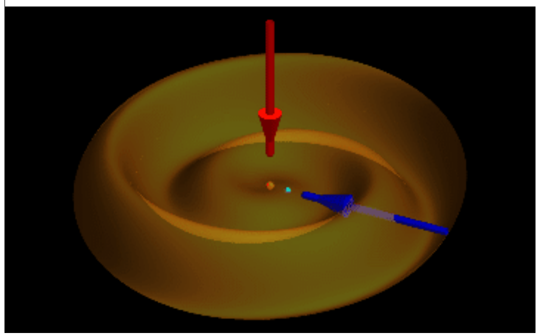
Backup

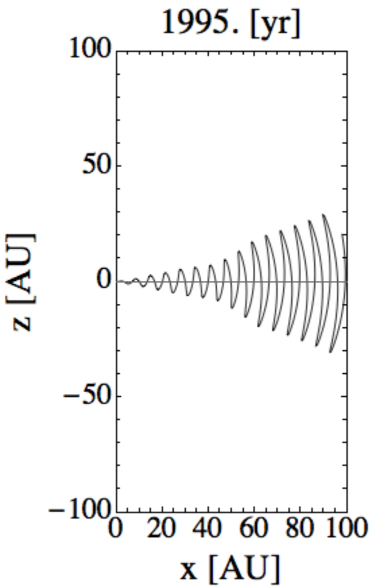
Charge-Sign Dependences of the CR Modulation

Drift pattern of GCRs

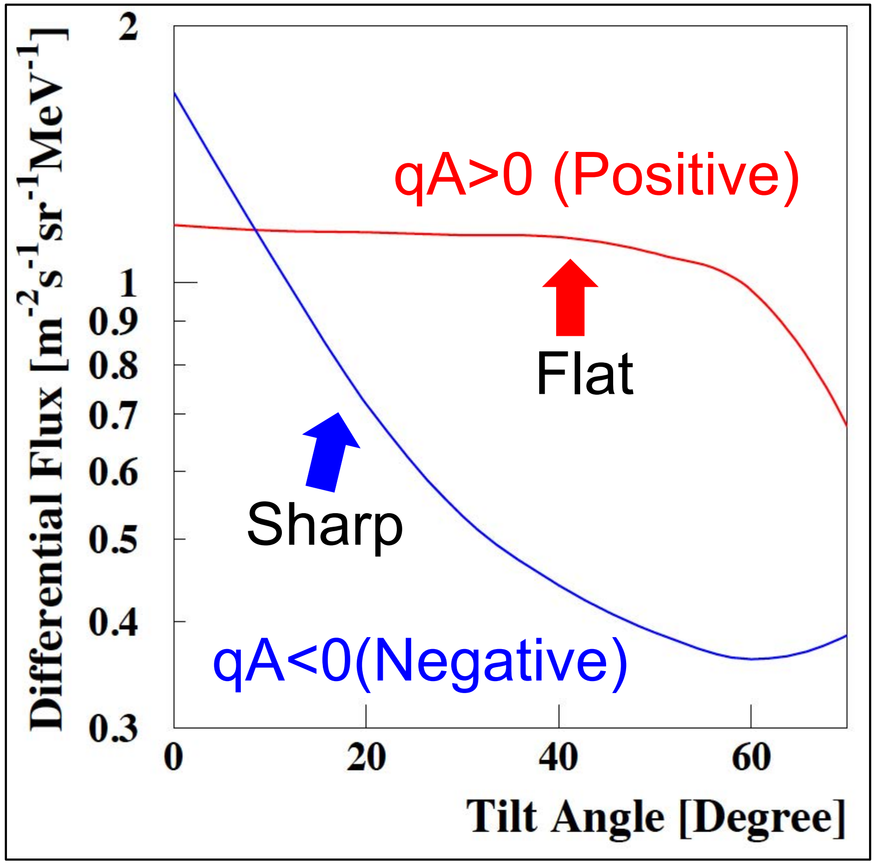
qA>0 (Positive) | qA<0 (Negative)







1 GeV proton flux



Effects of interplanetely CMEs and CIRs

Global Merged Interaction Region

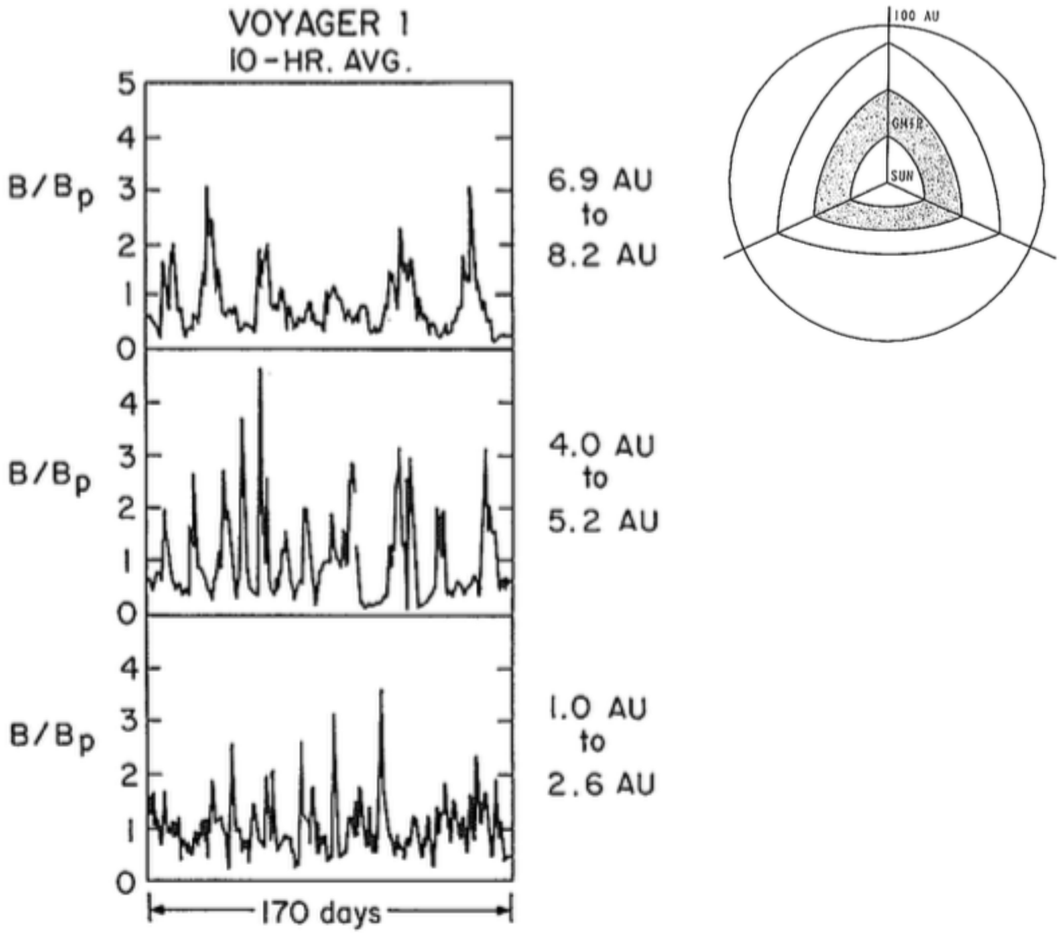


Figure 8. Formation of merged interaction regions with increasing distance from the Sun. The magnetic field strength, normalized with respect to a nominal value B_p from Parker's spiral field model, are shown for three different distance intervals (figure from Burlaga 1984).

(McDonald and Burlaga, in Jokipii et al. (Eds.), 1997)

27-day variations

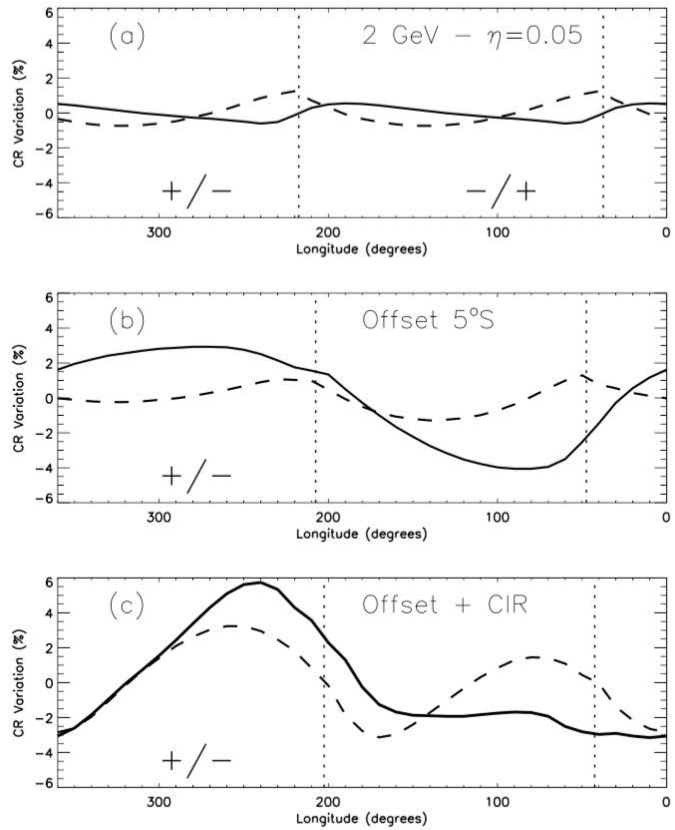


Fig. 1. Simulated azimuthal (27-day) variation of 2 GV cosmic-ray protons at the Earth's orbit for $A > 0$ (solid lines) and $A < 0$ (dashed lines). The tilt angle $\alpha = 30^o$. Dotted vertical lines indicate sector crossing. Panel (a) illustrates the effect of drifts for a symmetric HCS without CIRs. Panel (b) shows the result of a displacement of the HCS to the south. Panel (c) includes displacement plus CIRs (see text).

(Kota and Jokipii, ICRC 2001)