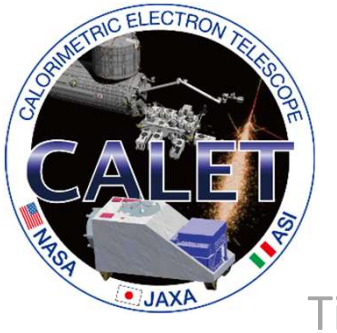


18aC310-12

RITSUMEIKAN

Time variation of particle fluxes in the MeV range observed by CALET

CALETで観測されたMeV領域粒子フラックスの時間変動

立命館大理工[B], 他CALETチーム

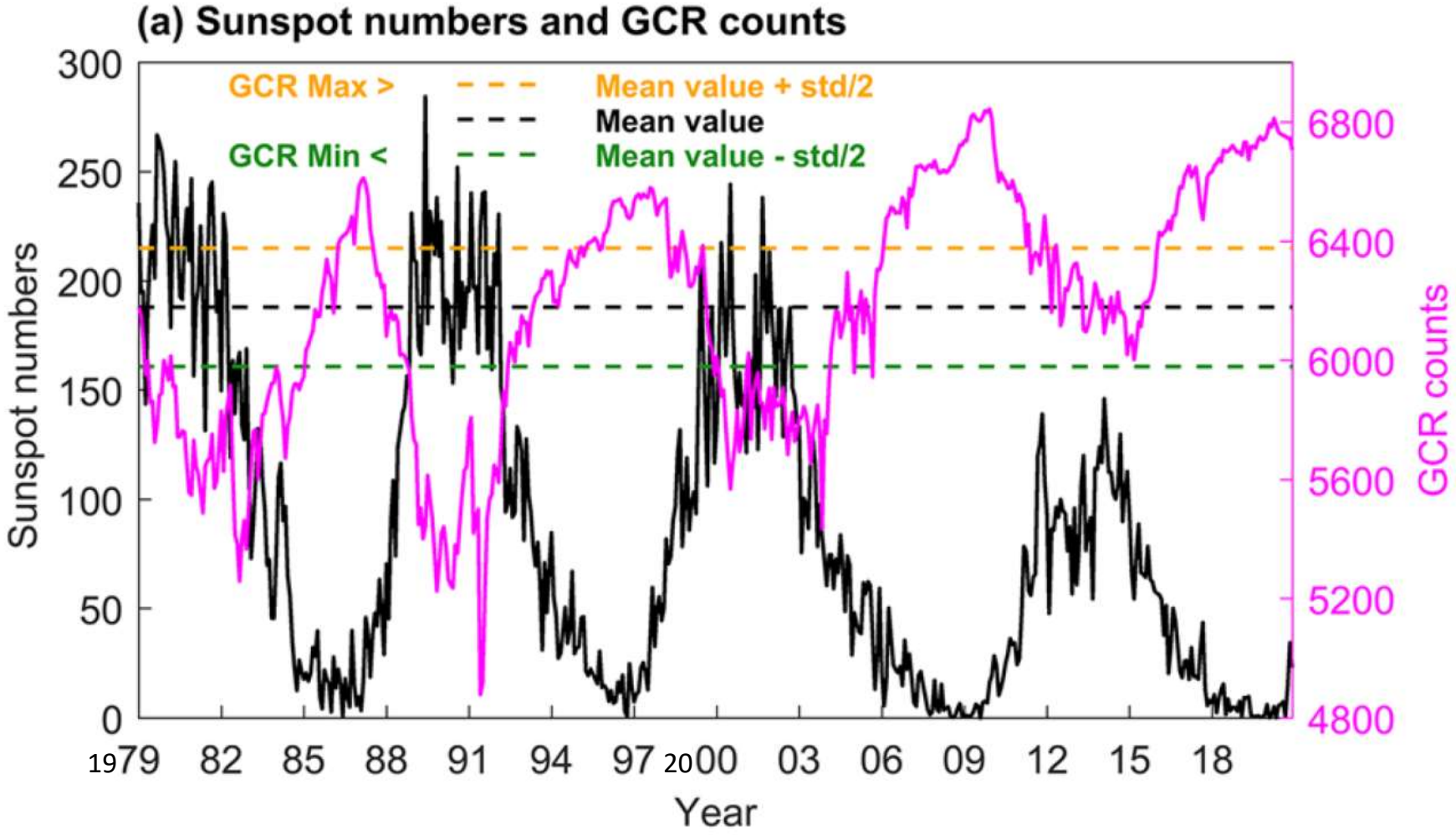
鈴木卓磨, ○森 正樹[B], 他CALETチーム

Takuma Suzuki, Masaki Mori, for the CALET collaboration

日本物理学会第79回年次大会（北海道大学札幌キャンパス）2024年9月16～19日

Cosmic ray variation vs Sunspot numbers

Kumar et al., Scientific Reports 13, 3707 (2023)



Note: here “GCR” means neutron monitor counts (typically at ~3 GV)

Modulation of cosmic ray spectra (~1 GeV)

PAMELA (M. Martucci et al., ApJL 854 (2018) L2)

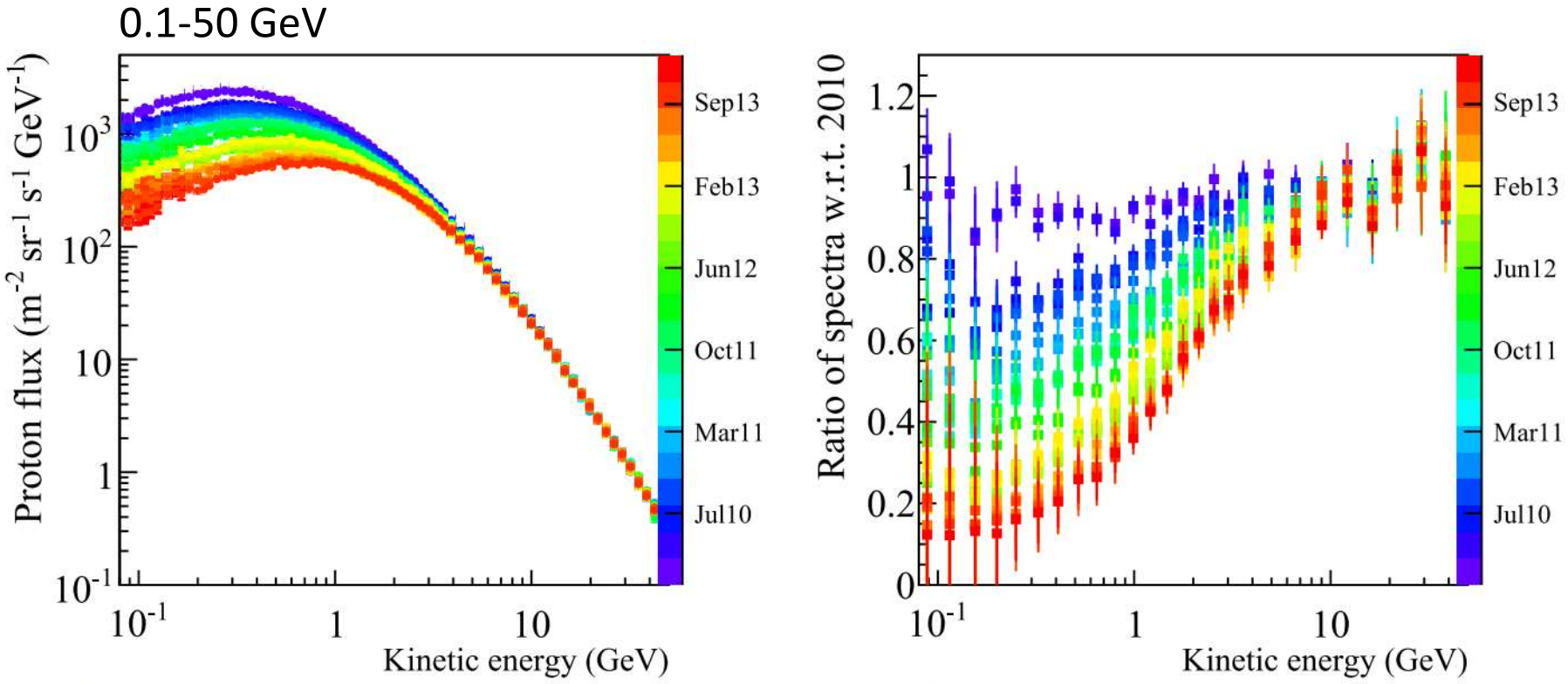
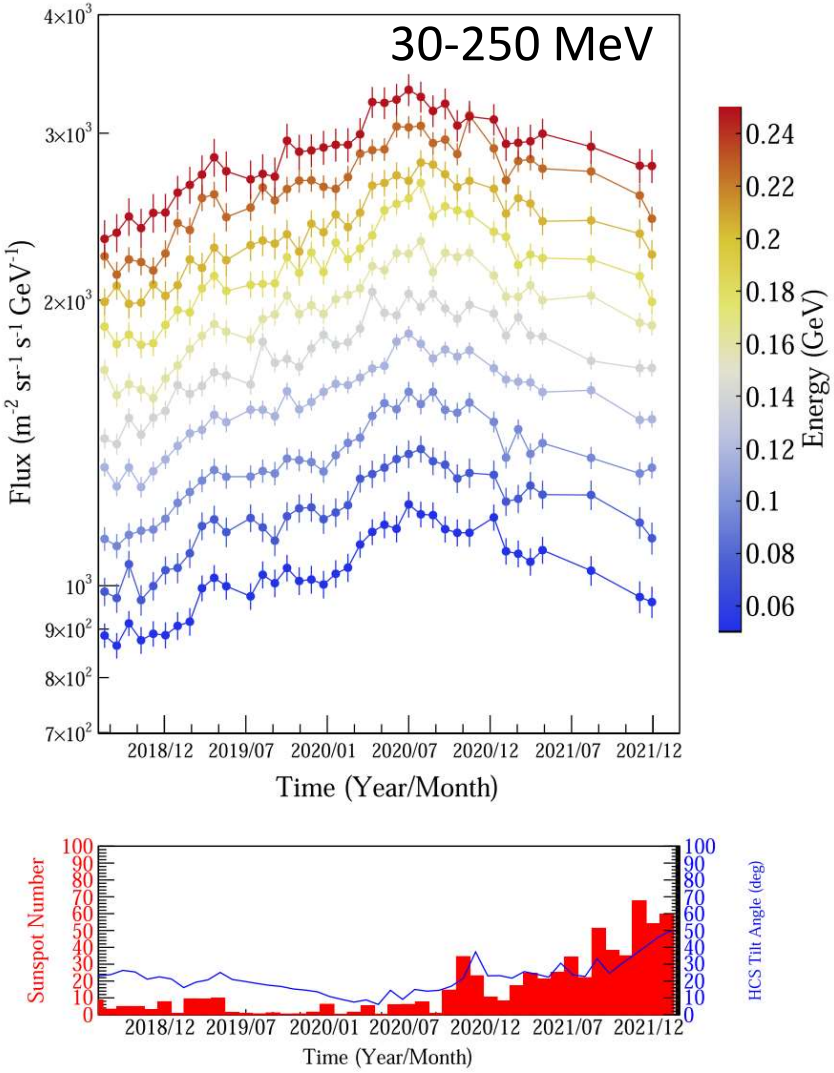


Figure 3. Left panel: the evolution of the proton spectra from the minimum to the maximum activity of solar cycle 24, from 2010 January (blue) to 2014 February (red). Right panel: the variation of the proton differential intensity with respect to the first proton spectrum of 2010.

Modulation of cosmic ray spectra (~100 MeV)

CSES-01/HEPD-01 (M. Martucci et al., ApJL 945 (2022) L39)



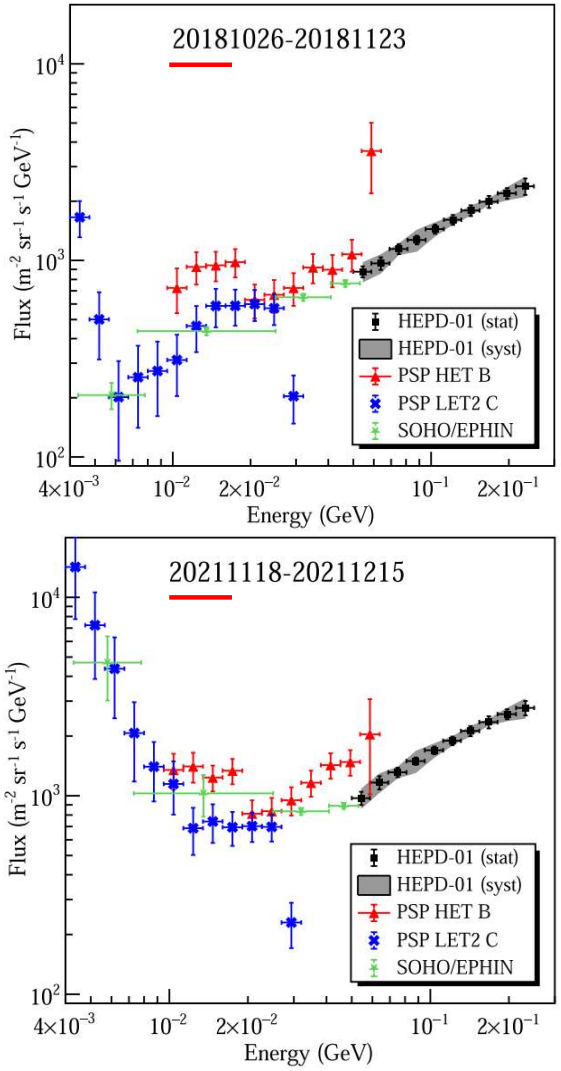
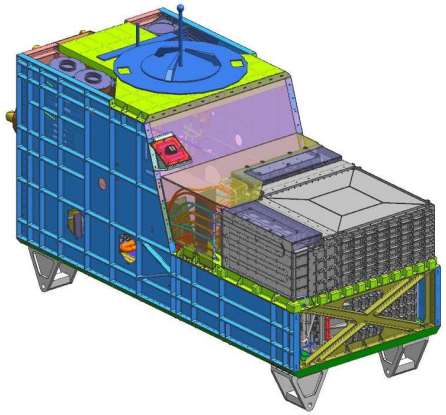


Figure 3. Time profile of GCR protons measured by HEPD-01 in 10 energy intervals (upper panel) between 2018 and 2022. Error bars take into account both statistical and systematic uncertainties. Sunspot number (red) and HCS tilt angle values (blue) as a function of time, in the same period (bottom panel).

CALET (CALorimetric Electron Telescope)



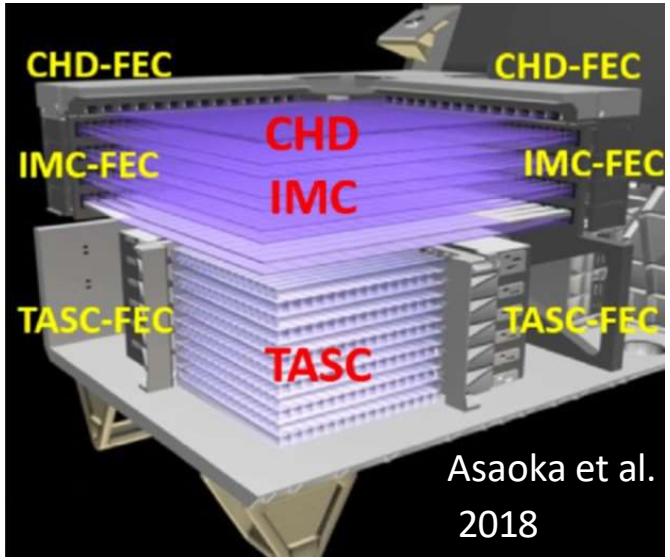
- In operation on the Japanese Experiment Module (JEM) `Kibo'-Exposed Facility of the International Space Station since 2015
- Japan-USA-Italy collaboration

Calorimeter (CAL)

Electrons: 1 GeV - 20 TeV

Gamma rays: 1 GeV – 10 TeV

Protons and nuclei: 10 GeV – 1 PeV



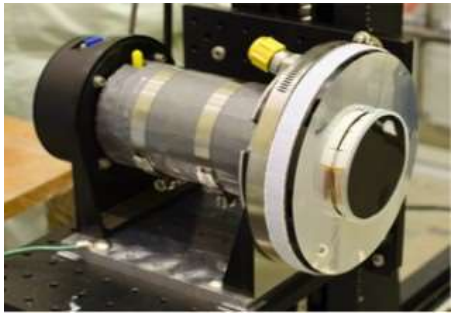
CHD
- charge

IMC
- tracking
- particle ID

TASC
- energy
- particle ID

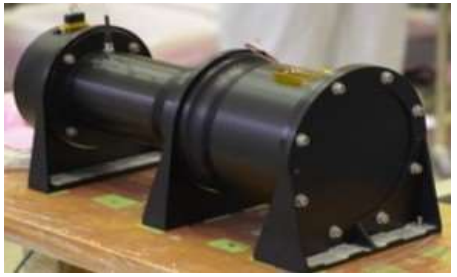
CALET Gamma Ray Burst Monitor (CGBM)

- **Hard X-ray Monitor (HXM)**



7 - 1000 keV
$LaBr_3(Ce)$ + PMT
(2 sets)

- **Soft Gamma-ray Monitor (SGM)**

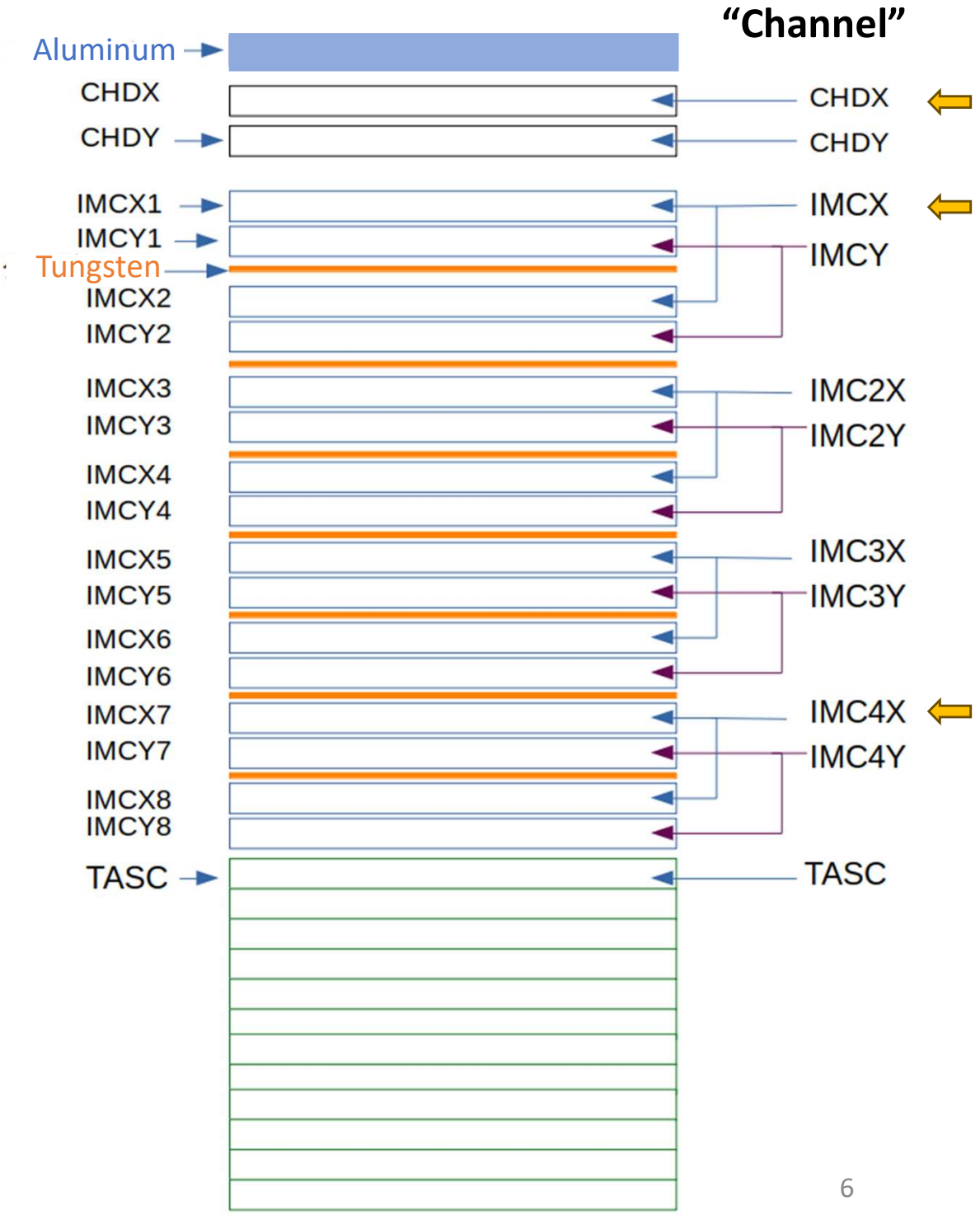


0.04 – 20 MeV
BGO + PMT
(1 set)

Profile of CAL and monitor channels

Scaler counts of each channel are transmitted via slow communication link and saved as housekeeping data.

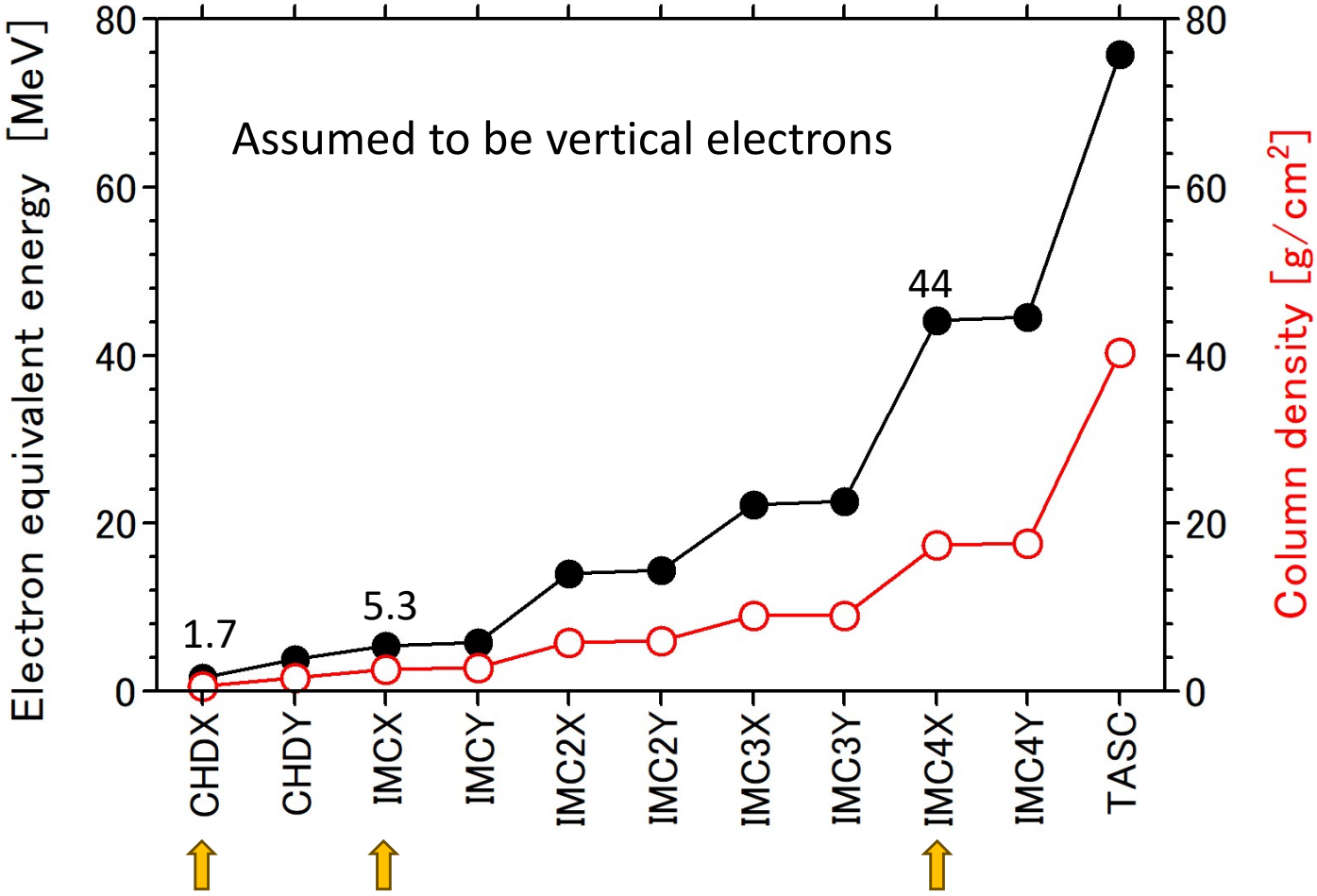
Particle counts above a few to several tens of MeV thresholds, assuming they are electrons.



Scaler channel energy thresholds

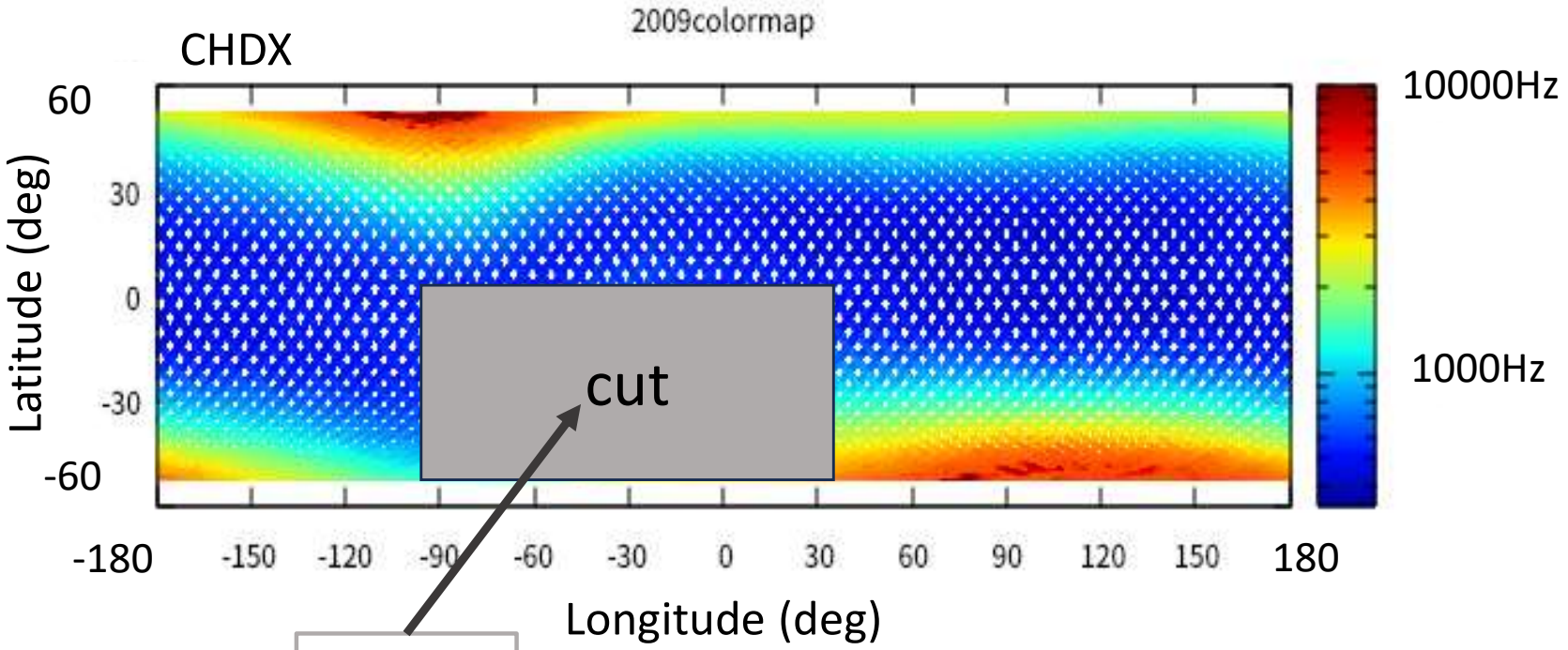
Range $R = \int_0^R dx = \int_T^0 \frac{dx}{dT} dT$

(*T*: kinetic Energy)



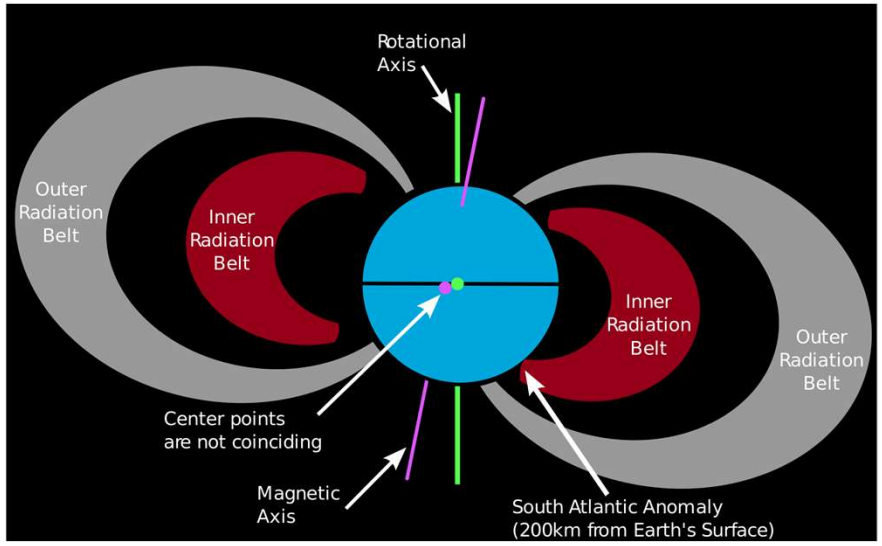
Note that deeper layers are affected by horizontally-incident particles, whose energies could be lower than those for vertical incidence.

Count rate map vs longitude - latitude



South Atlantic Anomaly

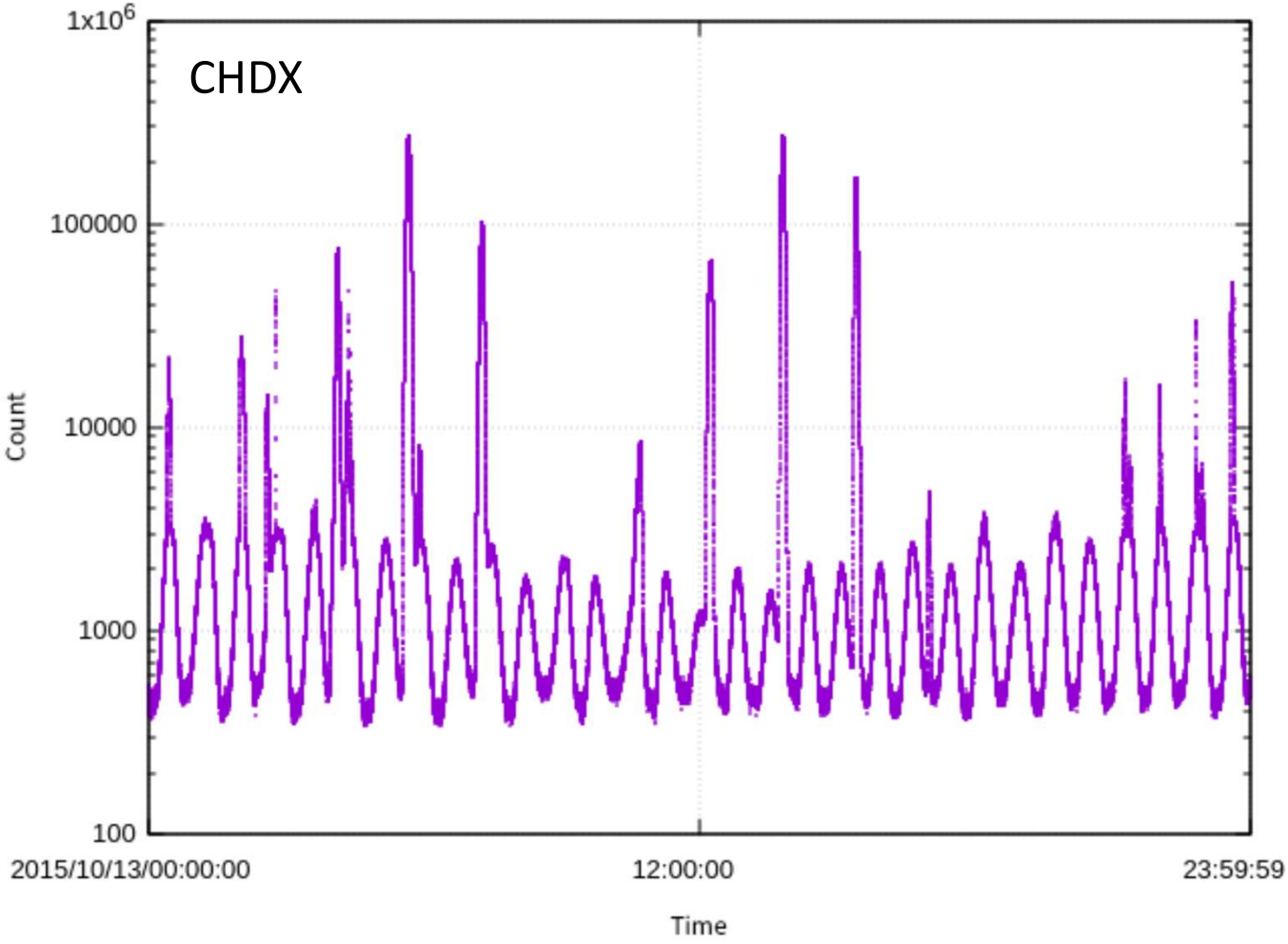
Cut region:
Lat < 5N & -100 < Lon < 40



https://en.wikipedia.org/wiki/South_Atlantic_Anomaly#

Count rate variation (one day)

After SAA cut



Orbital variation (~90 min. period) + peaks (REP)

S. Suenaga, master thesis, Ritsumeikan U. (2022)

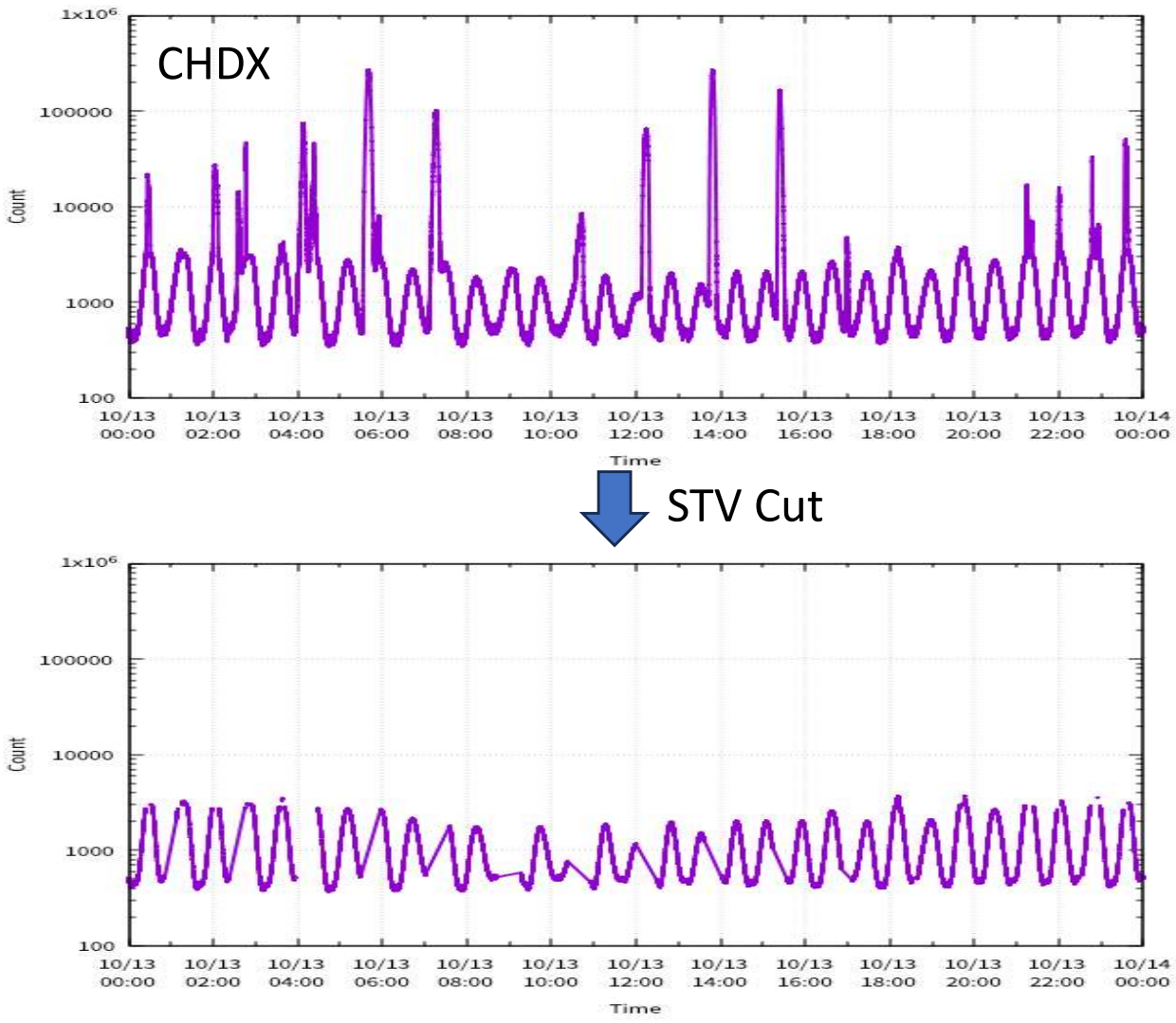
Short-term variation (STV) cut

To study long-term variation, short-term variation (such as REPs) should be deleted.

Cut criteria:

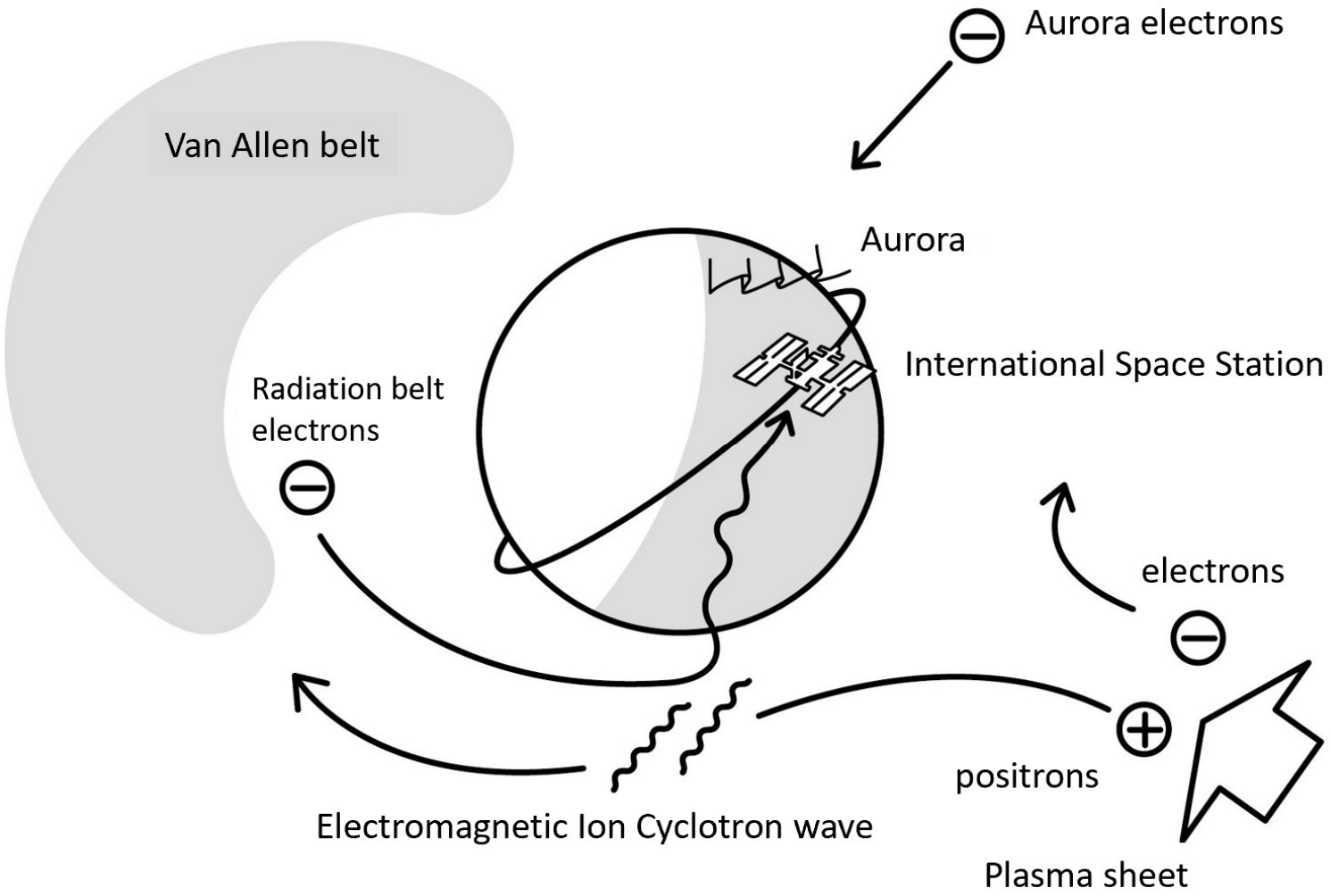
$R_5(t) > R_5(t - 5s) + 40$
or
$R_5(t) > R_5(t + 5s) + 40$
or
$R_5(t) > 5000$

$R_5(t)$: running average of count rate (s^{-1}) within 5s



See Kataoka+ 2016GL068930 (2016); Bruno+ 2016GL097529 (2021)

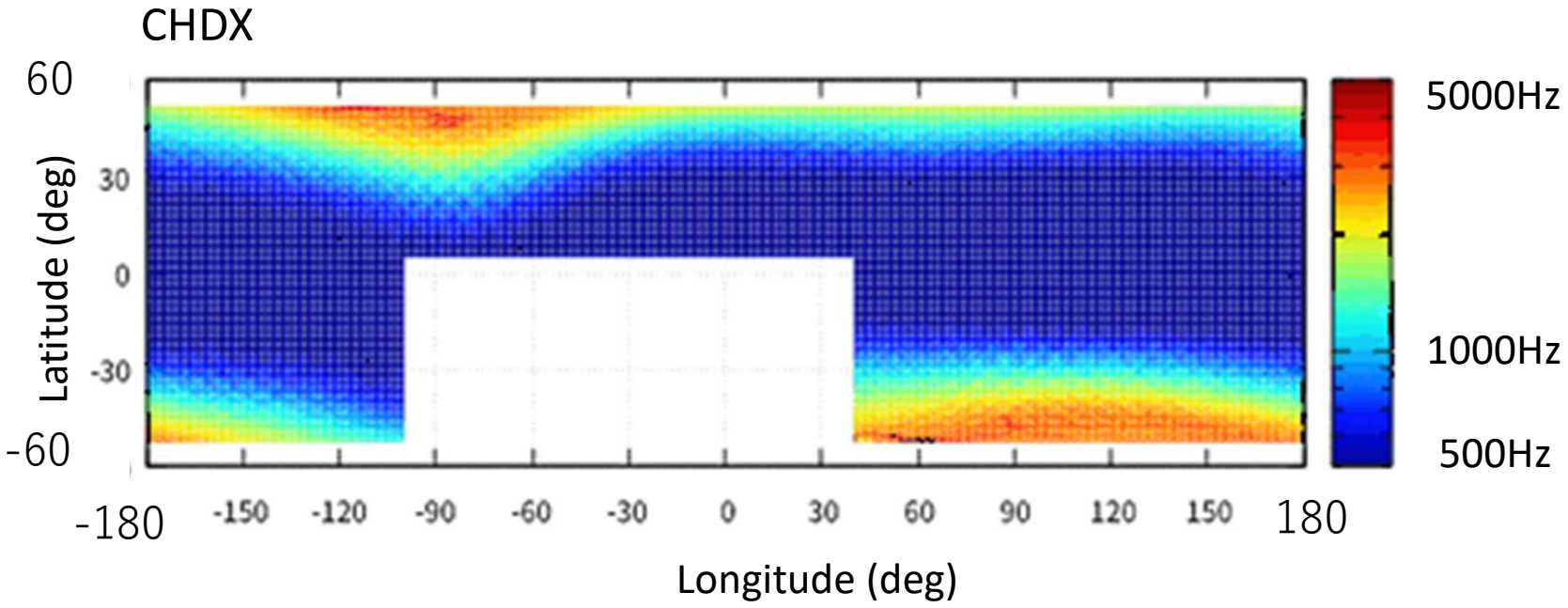
Relativistic Electron Precipitation (REP)



https://iss.jaxa.jp/kiboexp/news/images/calet2.jpg

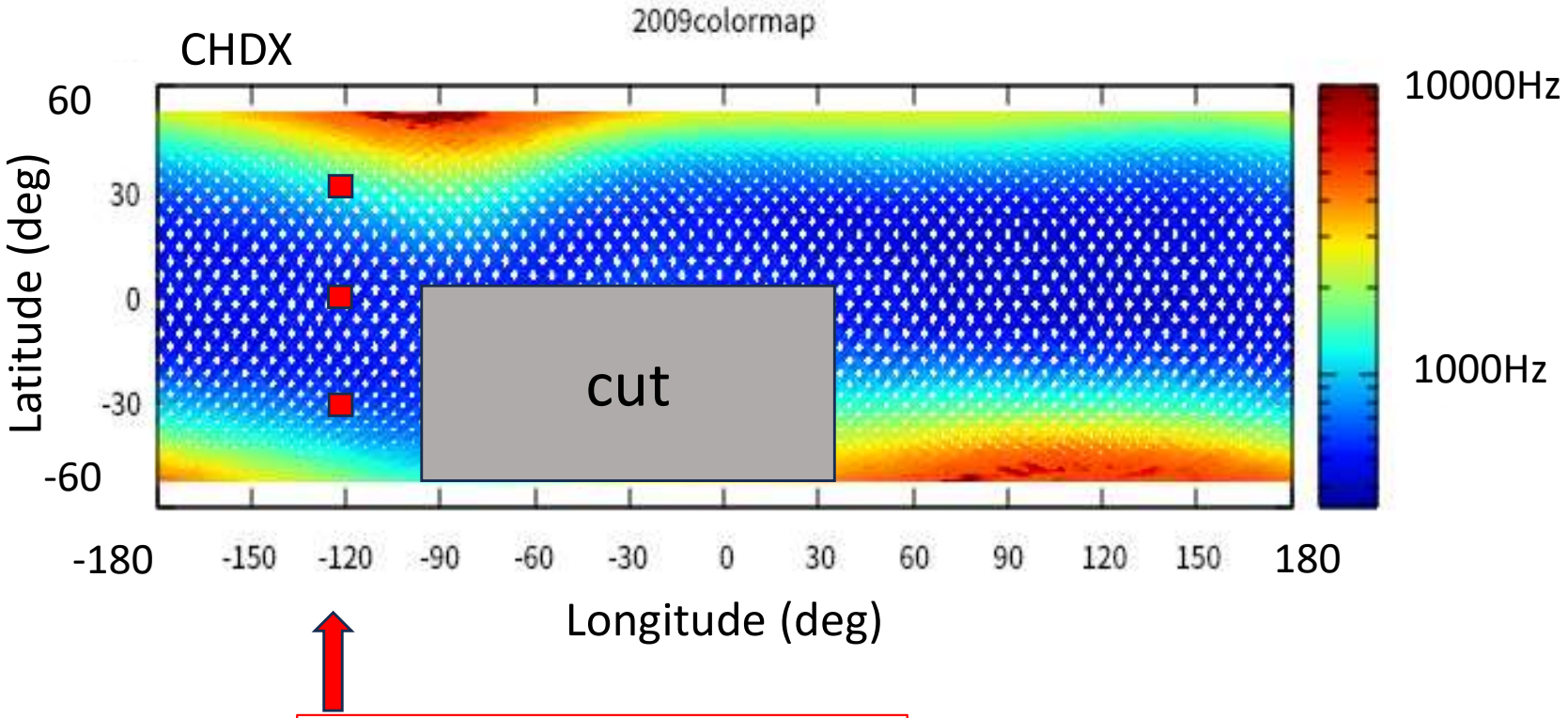
Yearly variation of count rate map (CHDX: 1.7 MeV)

2015



Count rates in the polar region are increasing toward 2020.

Count rate map vs longitude - latitude

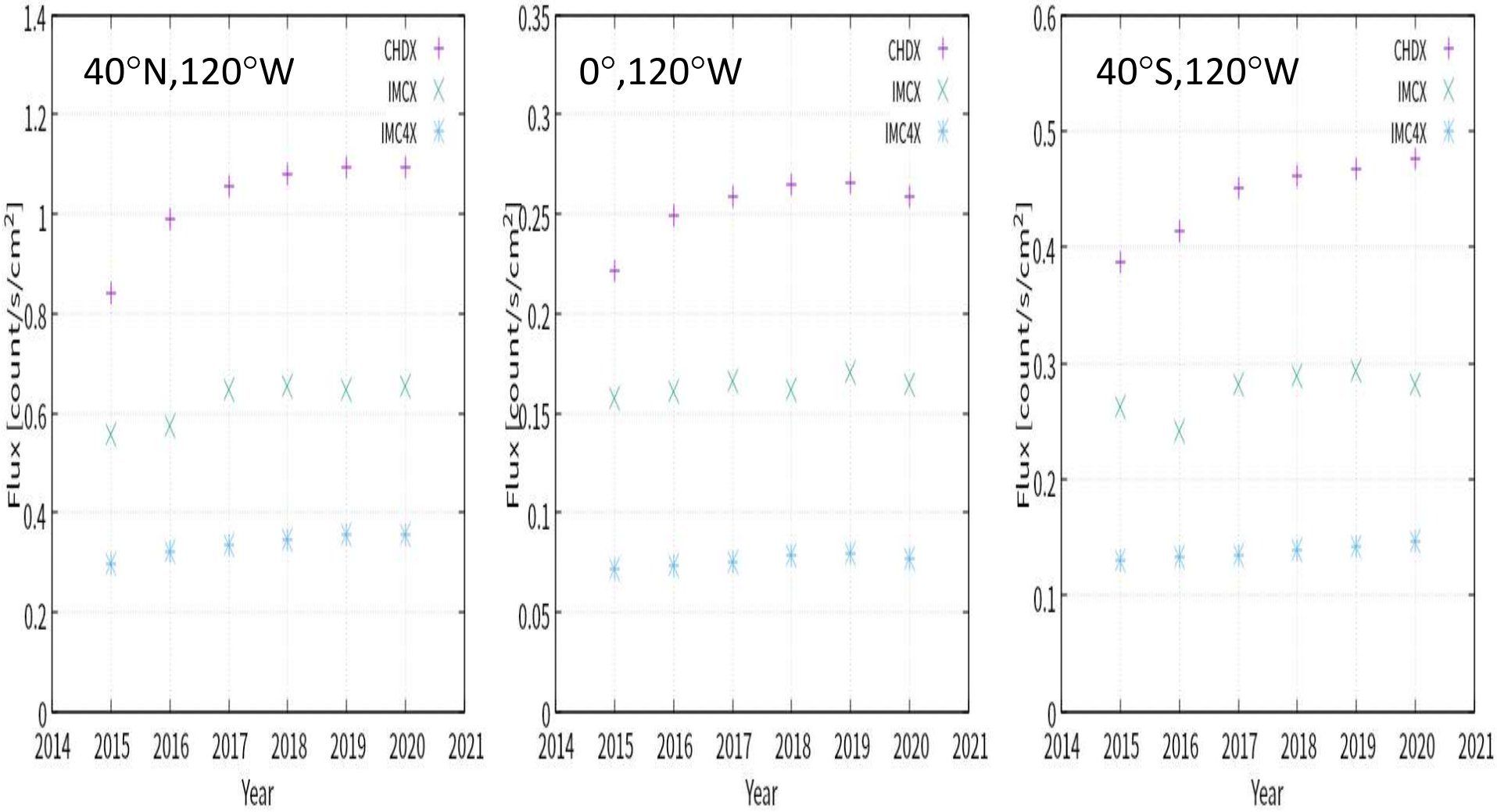


3 points are studied as typical examples:

- 40°N,120°W
- 0°,120°W
- 40°S,120°W

https://en.wikipedia.org/wiki/South_Atlantic_Anomaly#

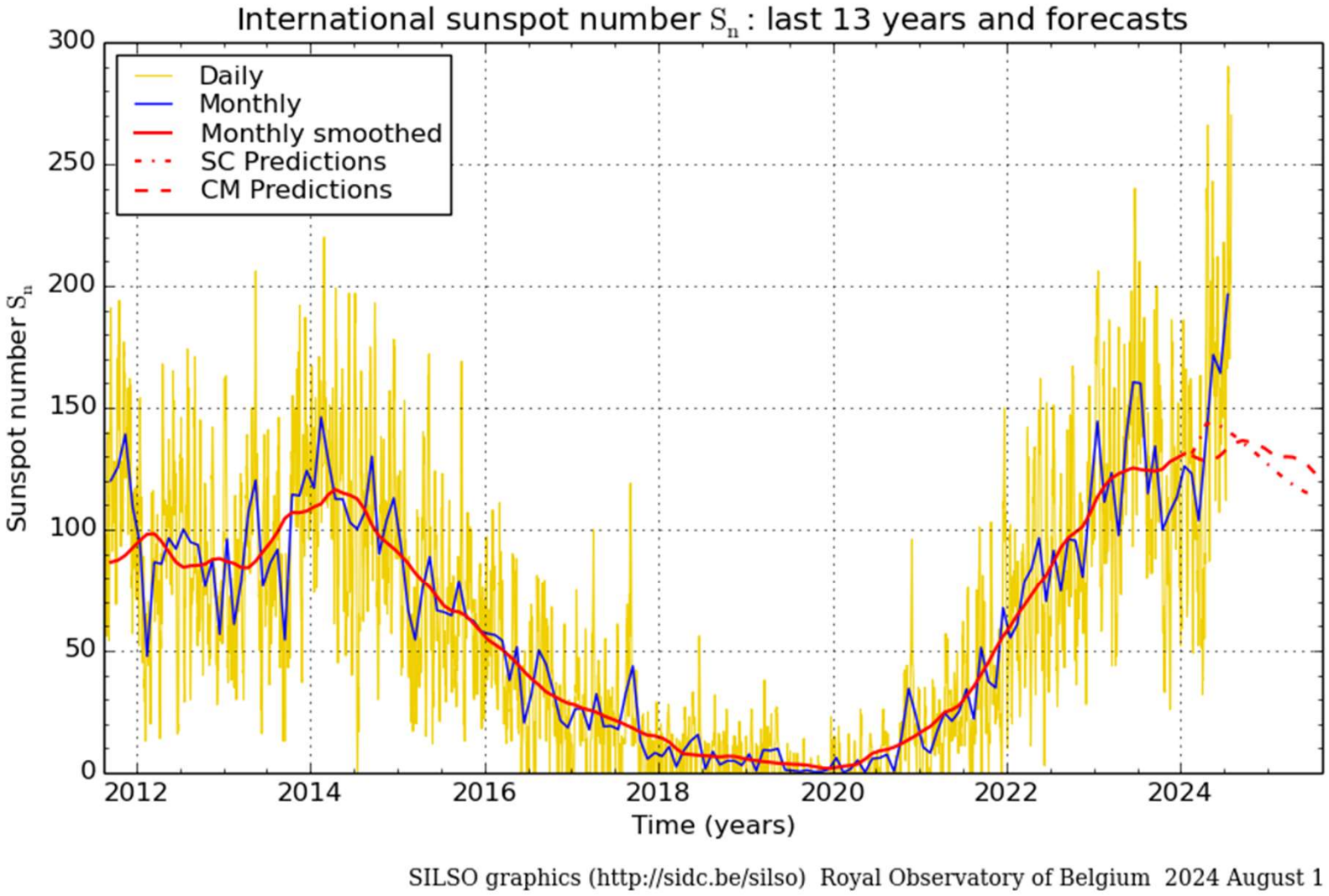
Yearly variation for some points



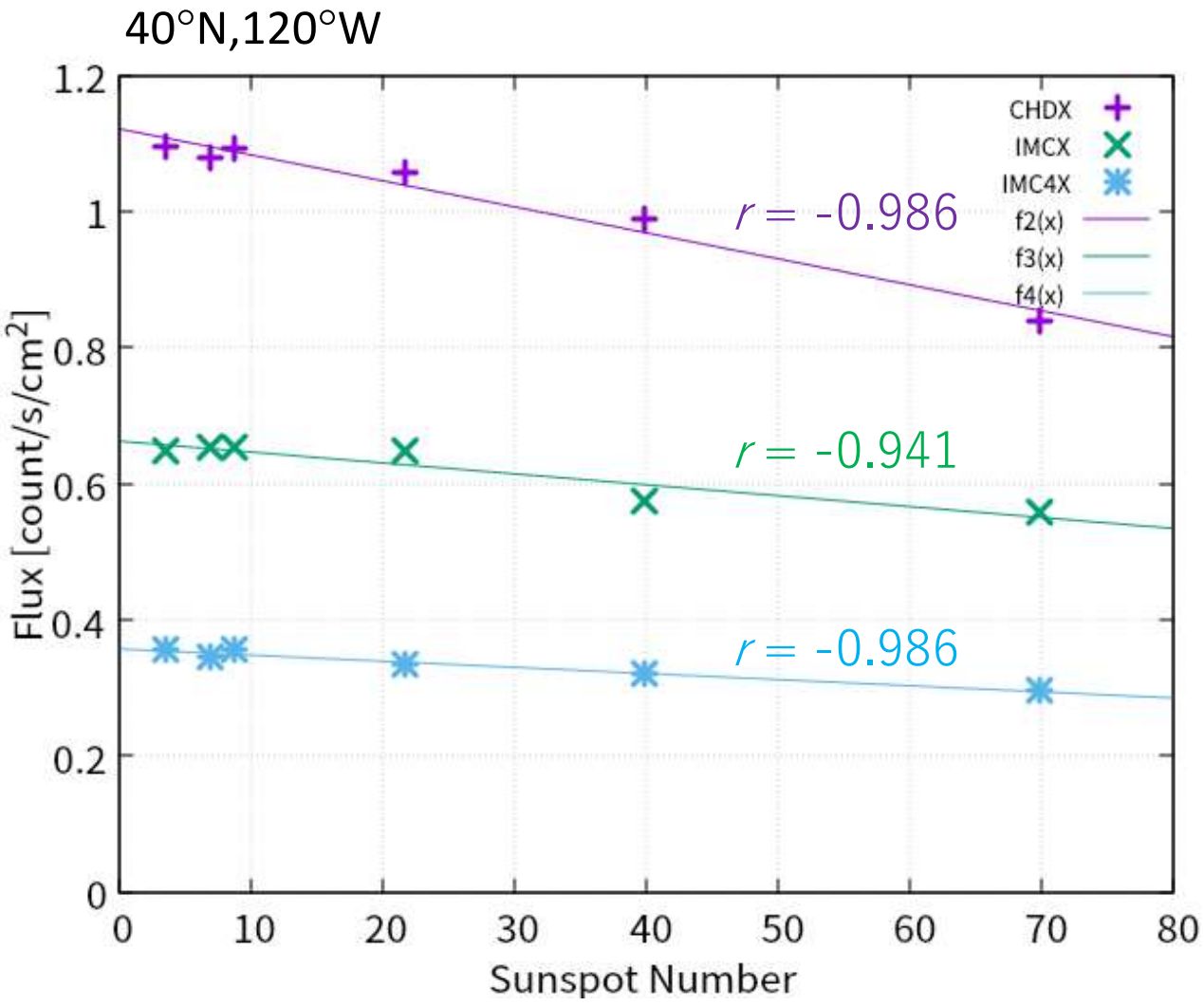
CHDX: >1.7 MeV IMCX: >5.3 MeV IMC4X: >44 MeV

Sunspot number

https://www.sidc.be/SILSO/dayssnplot



Correlation with sunspot numbers?



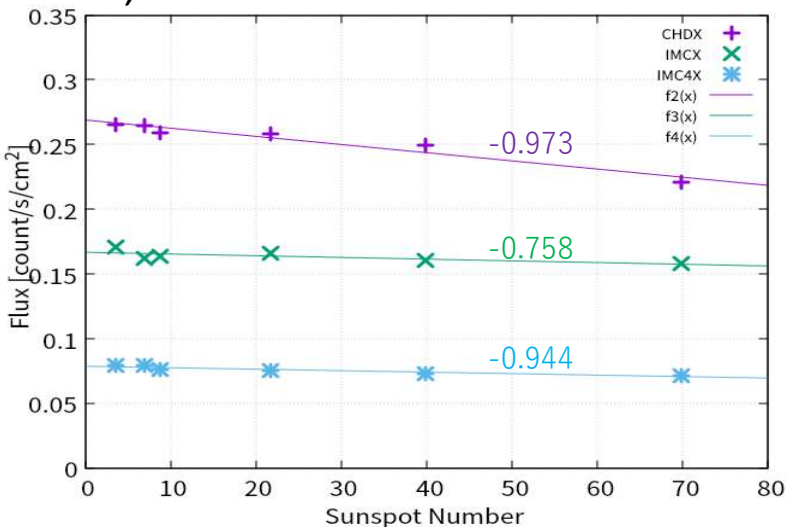
CHDX: 1.7 MeV　IMCX: 5.3 MeV　IMC4X: 44 MeV

Anti

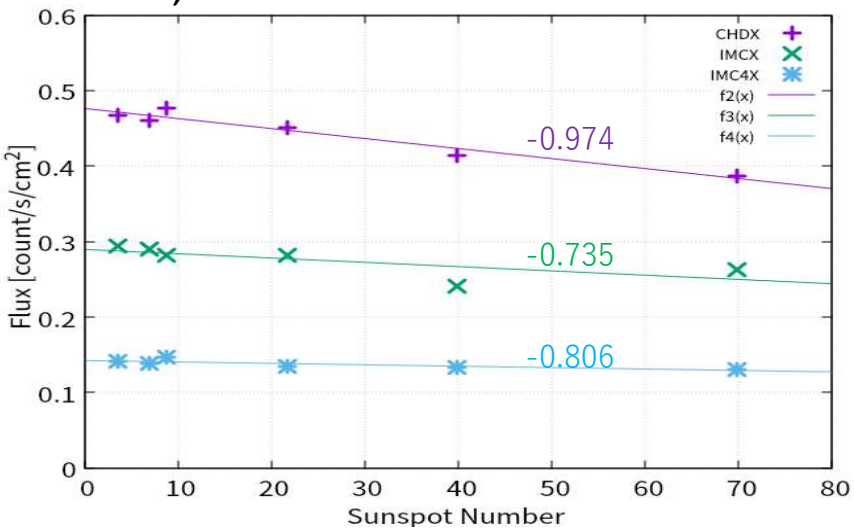
Correlation with sunspot numbers

Location	Correlation coefficient		
	CHDX (>1.7 MeV)	IMCX (>5.3 MeV)	IMC4X (>44 MeV)
40°N, 120°W	-0.986	-0.941	-0.986
0°, 120°W	-0.973	-0.758	-0.944
40°S, 120°W	-0.974	-0.735	-0.806

0°,120°W



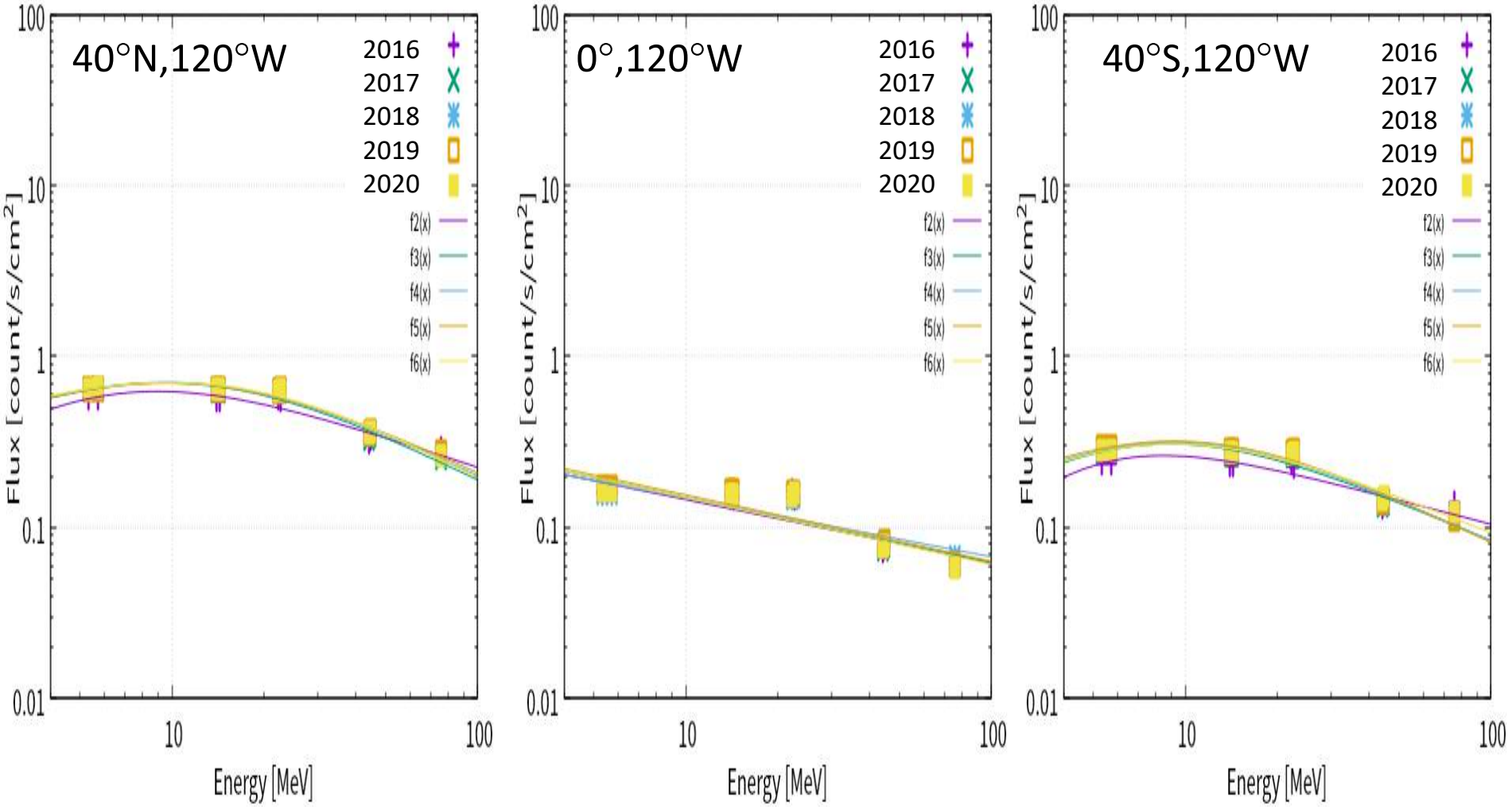
40°S,120°W



Preliminary

Flux variations for each layers

Fits just to guide eyes: $f(x) = a(\frac{x^d}{x^d + c}) \times x^{-b}$



Now assuming vertical injection: *Acceptance corrections to be applied…*

Summary

- Counting rates of CALET layers are analyzed in the 2015-2020 period to monitor cosmic-ray fluxes in the MeV region.
- SAA and REP events are removed to observe long-term behavior of the fluxes.
- Corrected counting rates show yearly variation.
- Yearly average of counting rates in the MeV region are closely anticorrelated with sunspot numbers.