飛翔体観測(CALET)による高エネルギー宇宙線加速天体の研究

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CALET

令和二年度東京大学宇宙線研究所共同利用研究成果発表会

共同利用研究概要 (2020)

- 共同研究内容
  - CALET観測最適化のためのシミュレーション計算及びデータ解析
- 発表概要
  - CALET概要
  - 観測現状
  - 観測データ解析
  - まとめと展望
- 予算: 旅費 190千円 ➡ 全額繰越申請中
- 共同利用:　計算機(シミュレーション計算)

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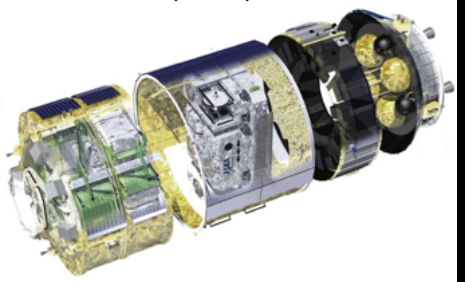
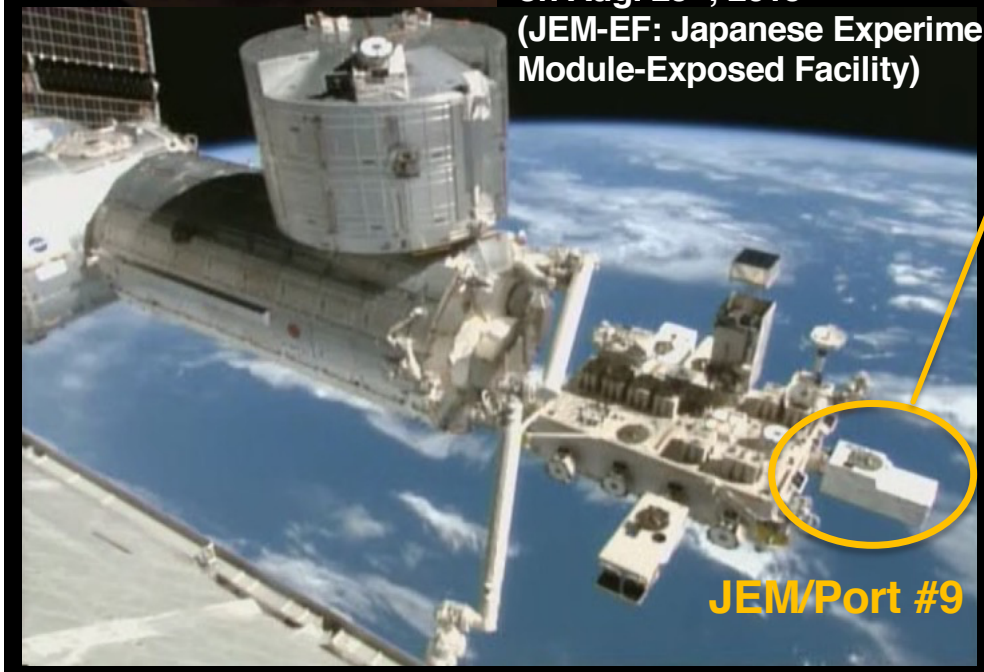
CALET Payload

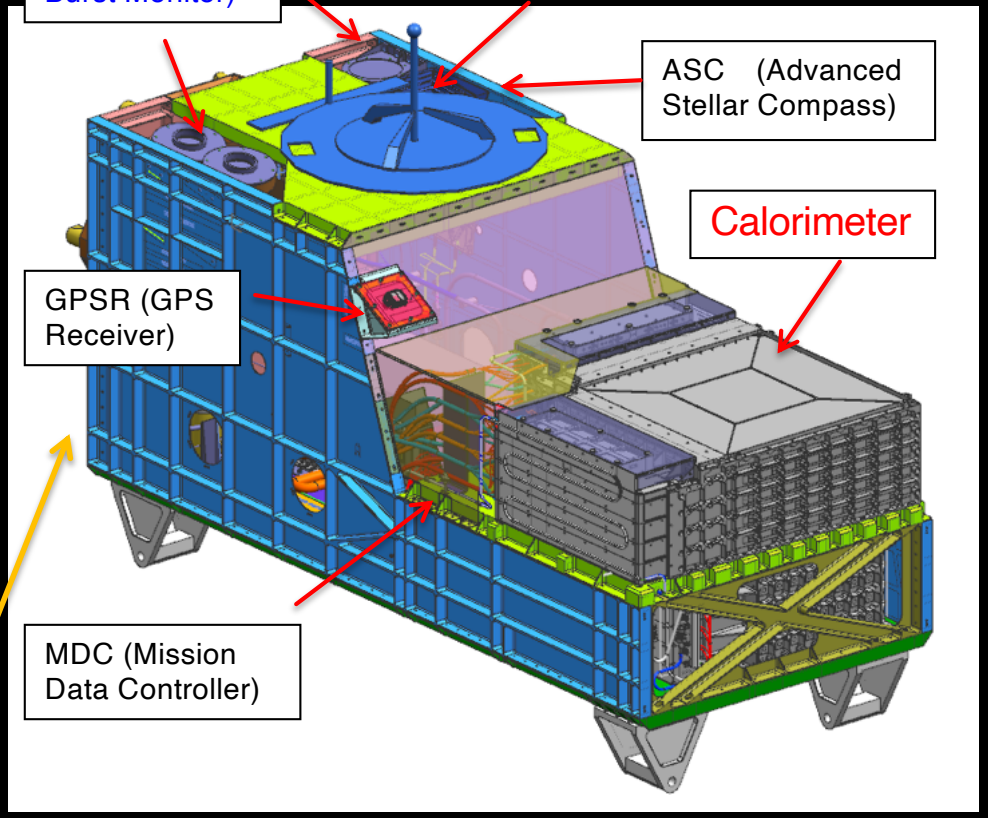
Kounotori (HTV) 5



Launched on Aug. 19th, 2015 by the Japanese H2-B rocket

Emplaced on JEM-EF port #9 on Aug. 25th, 2015
(JEM-EF: Japanese Experiment Module-Exposed Facility)





- **Mass: 612.8 kg**
- **JEM Standard Payload Size:**
  1850mm(L) × 800mm(W) × 1000mm(H)
- **Power Consumption: 507 W（max）**
- **Telemetry:**
  Medium 600 kbps (6.5GB/day) / Low 50 kbps

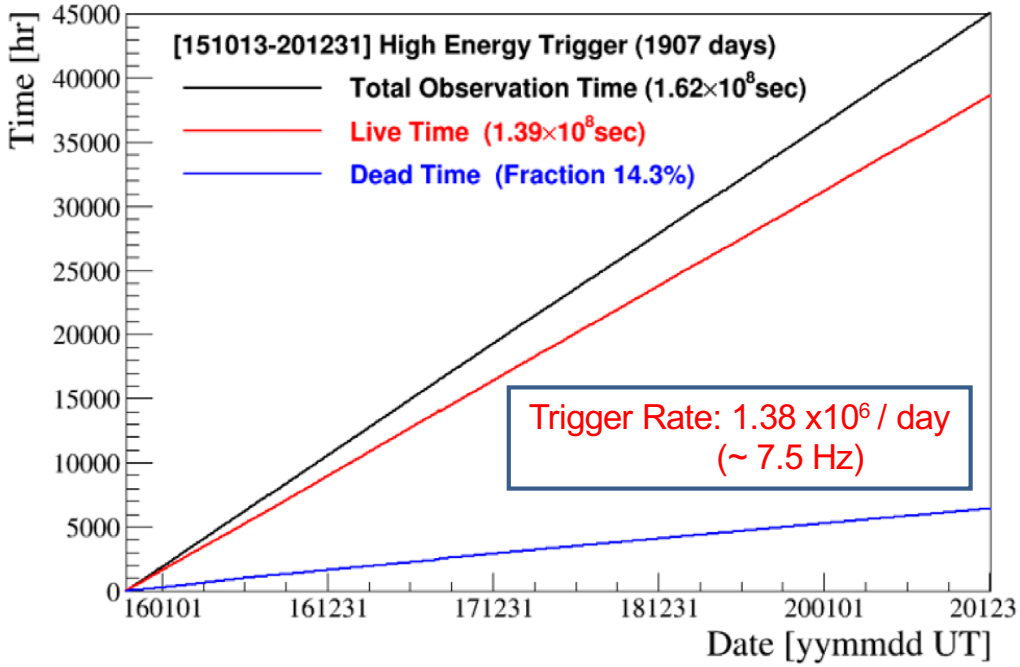
Observations with High Energy Trigger (>10GeV)

Observation by High Energy Trigger for 1907 day : Oct.13, 2015 – Dec. 31, 2020

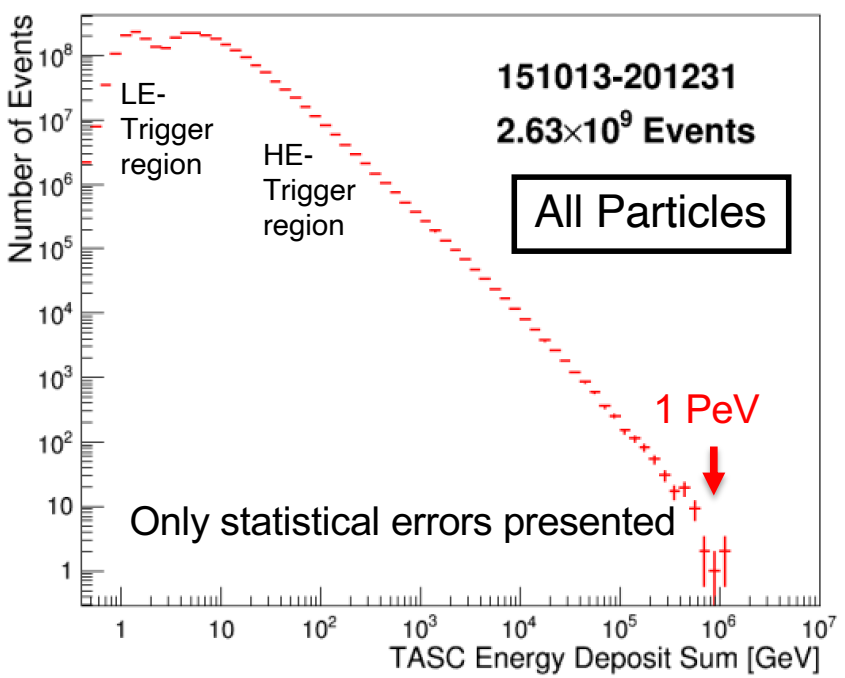
Over 5-year observation has been achieved !!

- The exposure, SΩT, has reached to ~170 m^2 sr day for electron observations by continuous and stable operations.
- Event number of HE triggered events (>10 GeV) is ~1.2 billion with a live time fraction of about 86 %. Total event number triggered over 1 GeV is ~2.6 billion.

Accumulated observation time (live, dead)

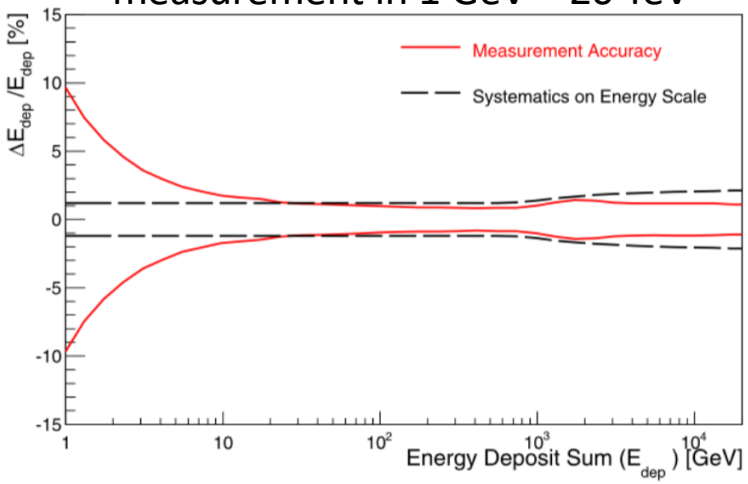


Distribution of deposit energies (ΔE) in TASC

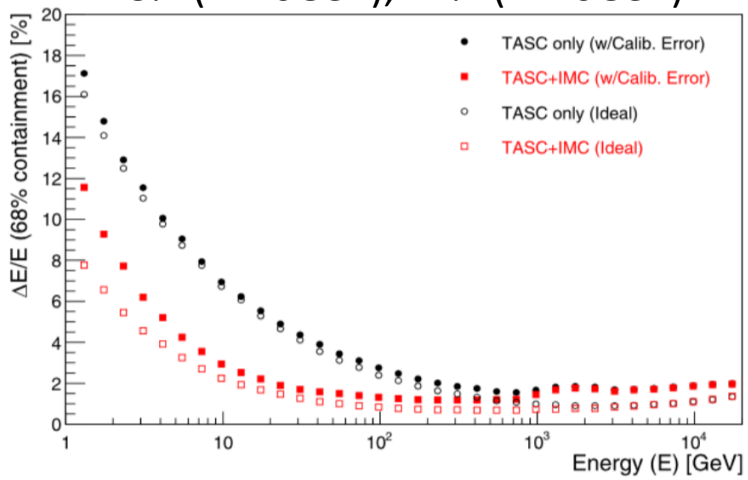


Energy calibration and long-term observation

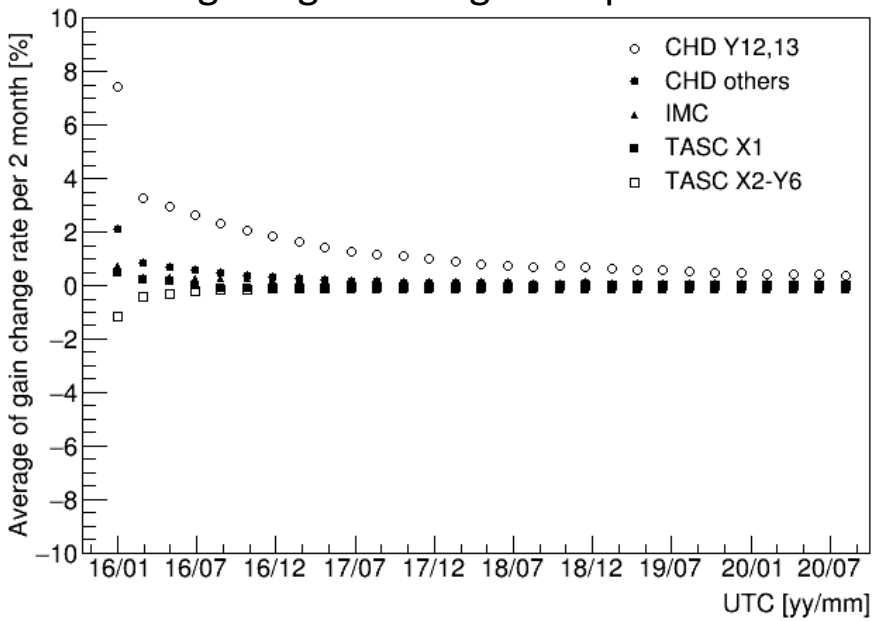
Performance of electron energy measurement in 1 GeV – 20 TeV



Energy resolution for electrons
< 3% (E>10GeV), <2% (E>20GeV)



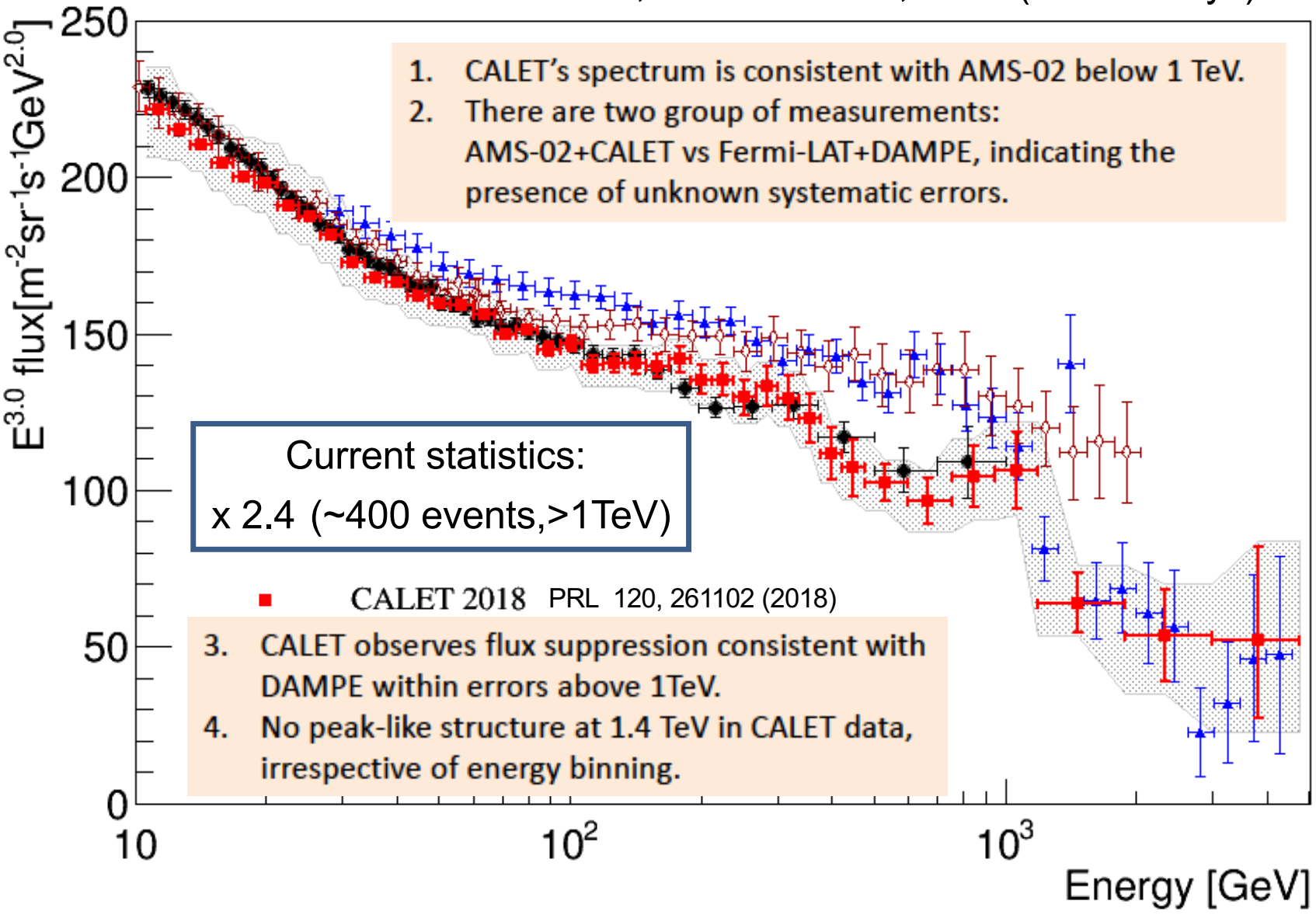
Average of gain change rate per 2 month



- The gain of each channel is calibrated and monitored by proton and helium cosmic-ray events.
- The rate of the gain change to the time is going to nearly zero.
- There are not any dead channels since the start of the operation.

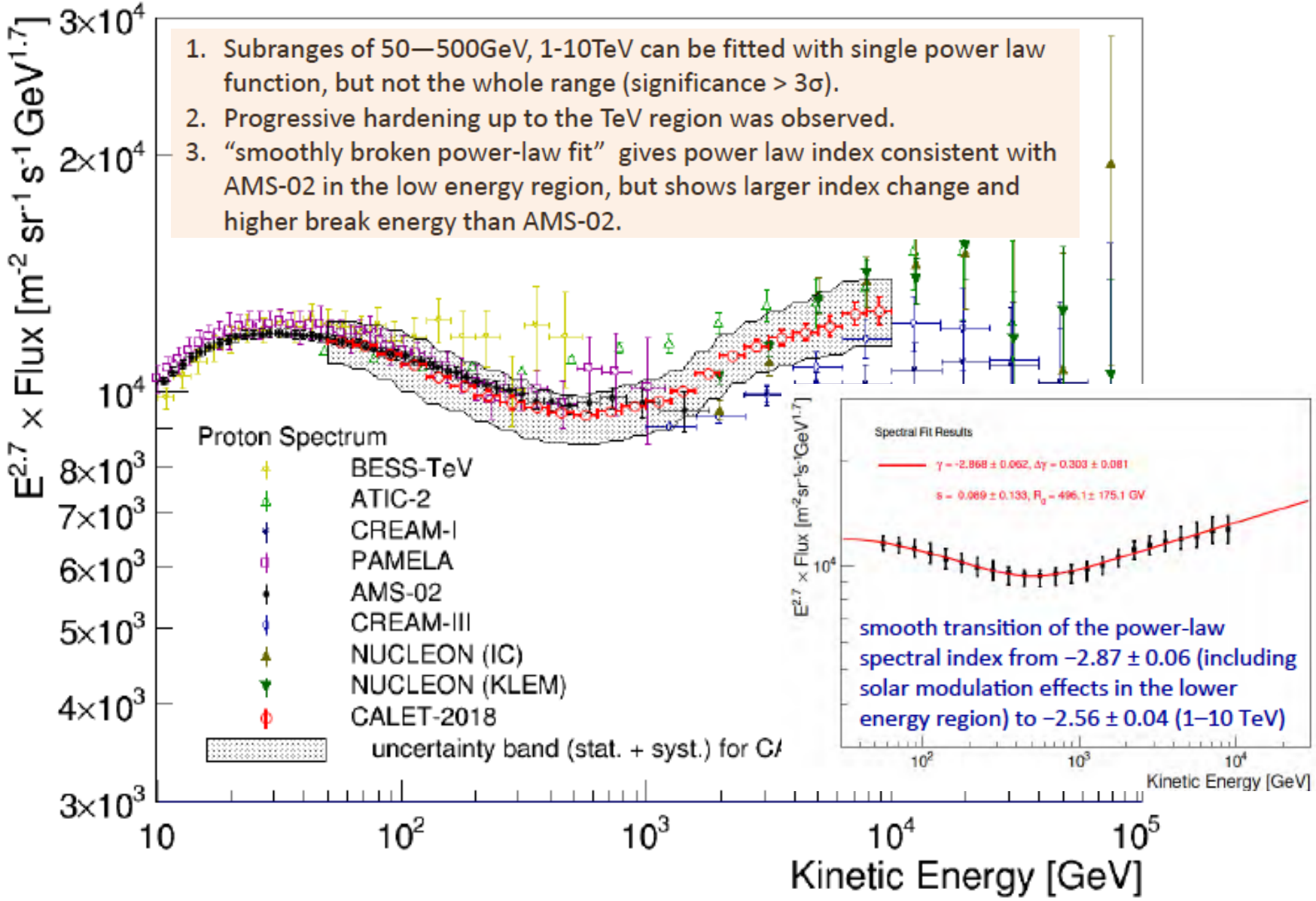
All Electron Spectrum: Comparison between Recent Direct Measurements

CALET Observations: Oct.13, 2015 - Nov.30, 2017 (for 780 days)

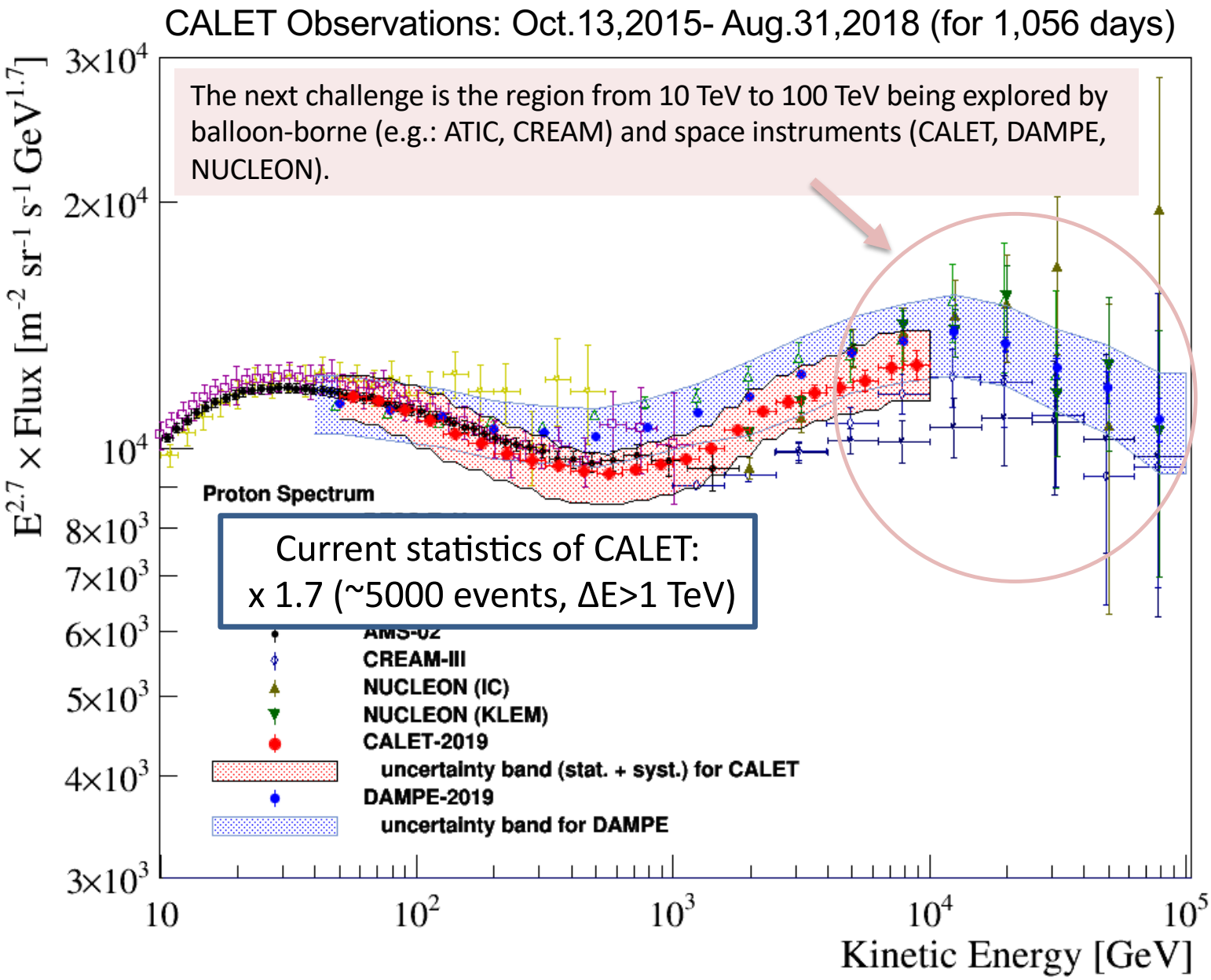


Proton Spectrum: Comparison between Recent Direct Measurements

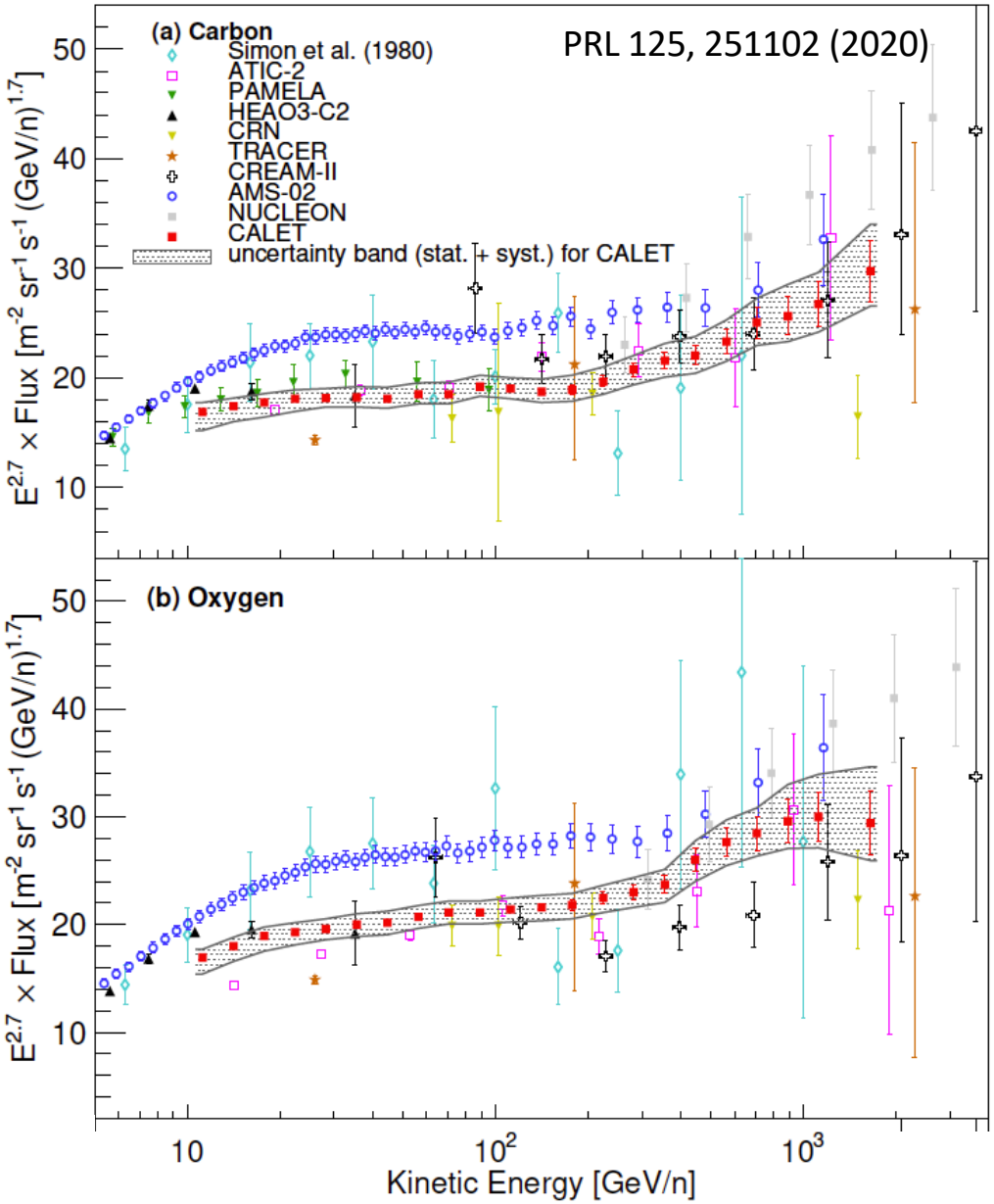
CALET Observations: Oct.13,2015- Aug.31,2018 (for 1,056 days)

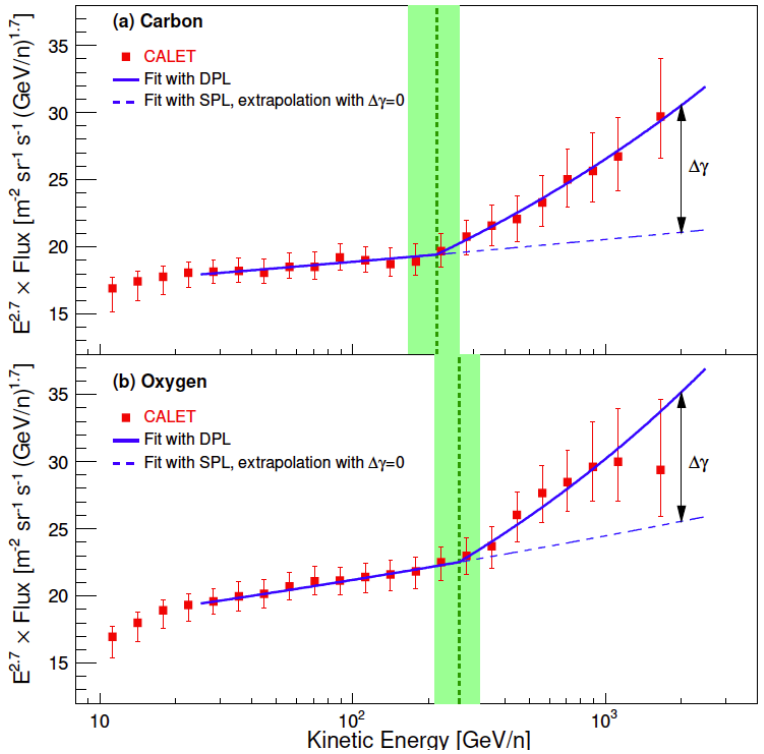


Proton Spectrum : Next Challenge and Current Status



Carbon and Oxygen Spectra





$$\Phi(E) = \begin{cases} C\left(\frac{E}{\mathrm{GeV}}\right)^{\gamma} & E \le E_0 \\ C\left(\frac{E}{\mathrm{GeV}}\right)^{\gamma}\left(\frac{E}{E_0}\right)^{\Delta\gamma} & E > E_0 \end{cases}$$

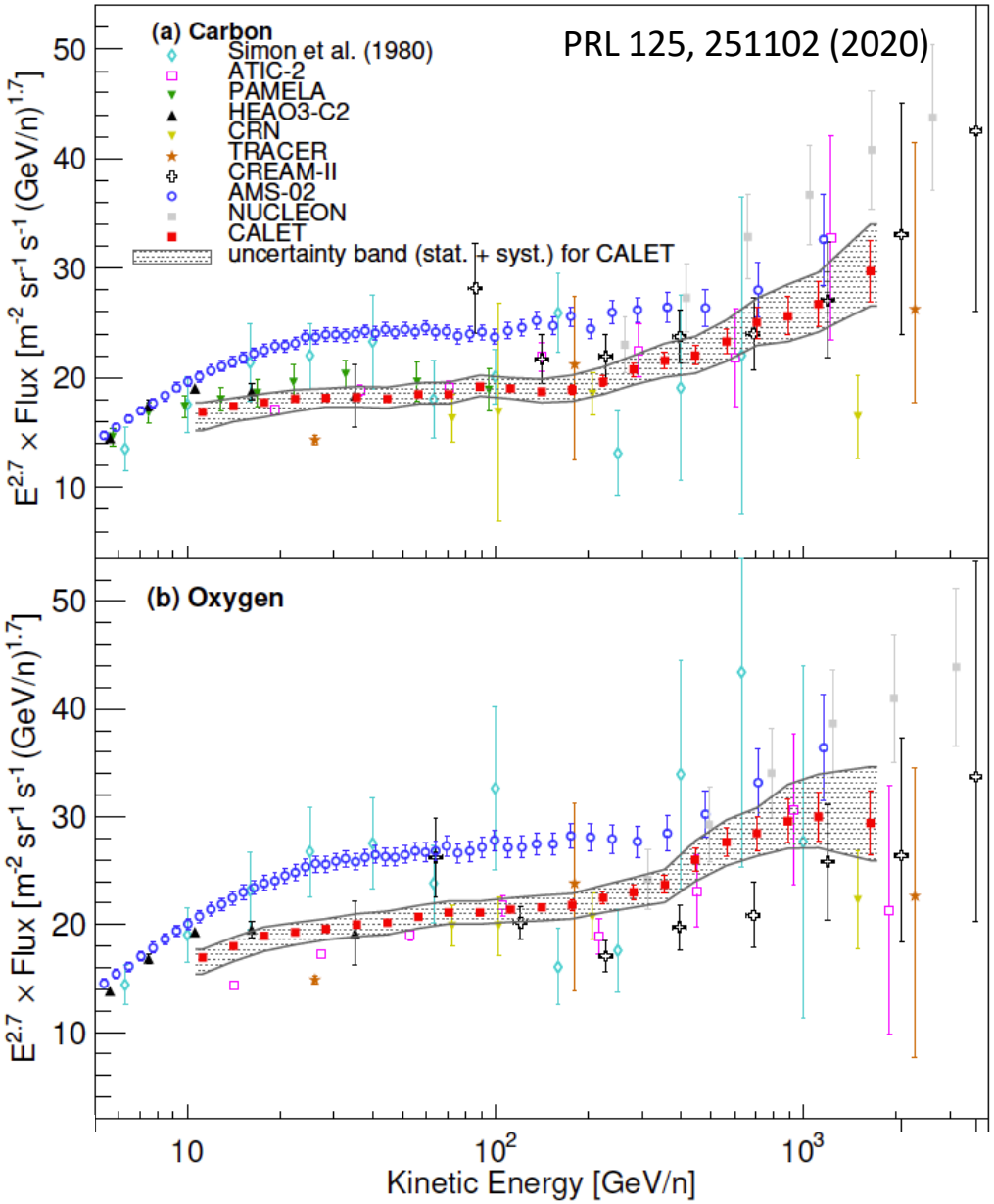
Carbon

$\gamma = -2.663 \pm 0.014$
$E_0 = 215 \pm 54\,\mathrm{GeV/n}$
$\Delta\gamma = 0.166 \pm 0.042 \quad (4.0\,\sigma)$
with $\chi^2/\mathrm{d.o.f.} = 9.0/8$

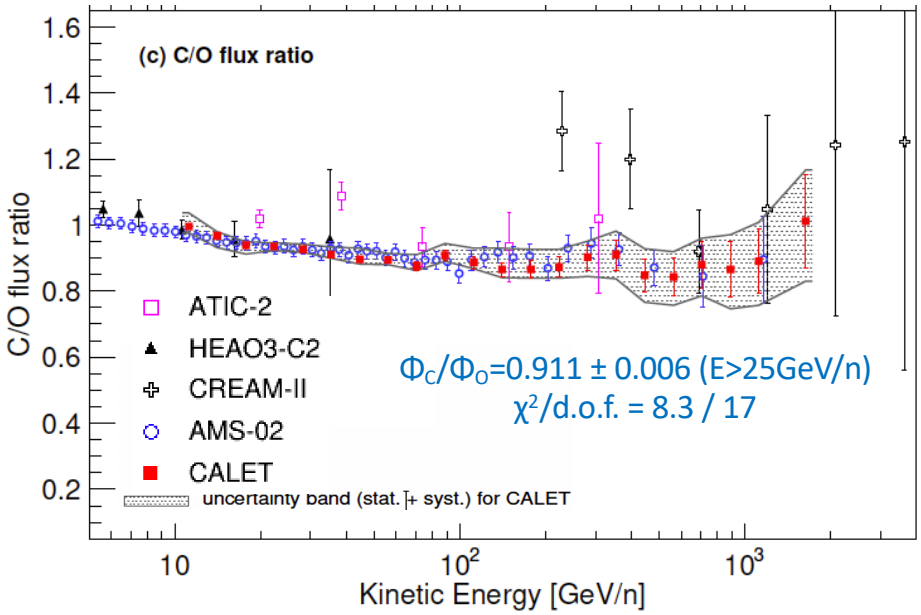
Oxygen

$\gamma = -2.637 \pm 0.009$
$E_0 = 264 \pm 53\,\mathrm{GeV/n}$
$\Delta\gamma = 0.158 \pm 0.053 \quad (3.0\,\sigma)$
with $\chi^2/\mathrm{d.o.f.} = 3.0/8$

Carbon and Oxygen Spectra



CALET Observations:
Oct.13,2015- Oct.31,2019 (for 1,480 days)



The carbon to oxygen flux ratio is well fitted to a constant value above 25 GeV/n, indicating that the two fluxes have the same energy dependence

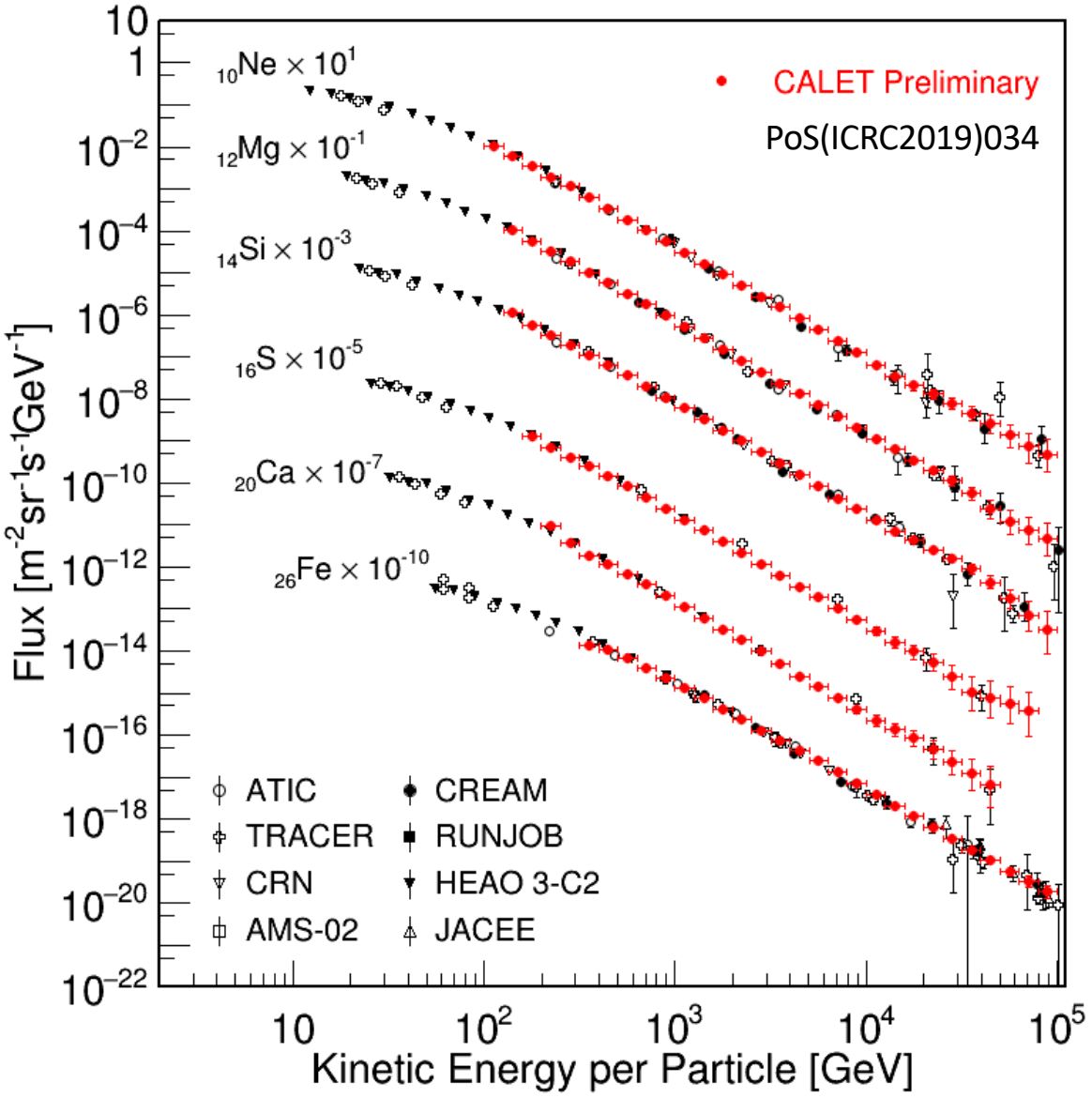
Energy Spectra of Heavy Components

Flux measurements:

$$\Phi(E) = \frac{N(E)}{S\Omega\varepsilon(E)T\Delta E}$$

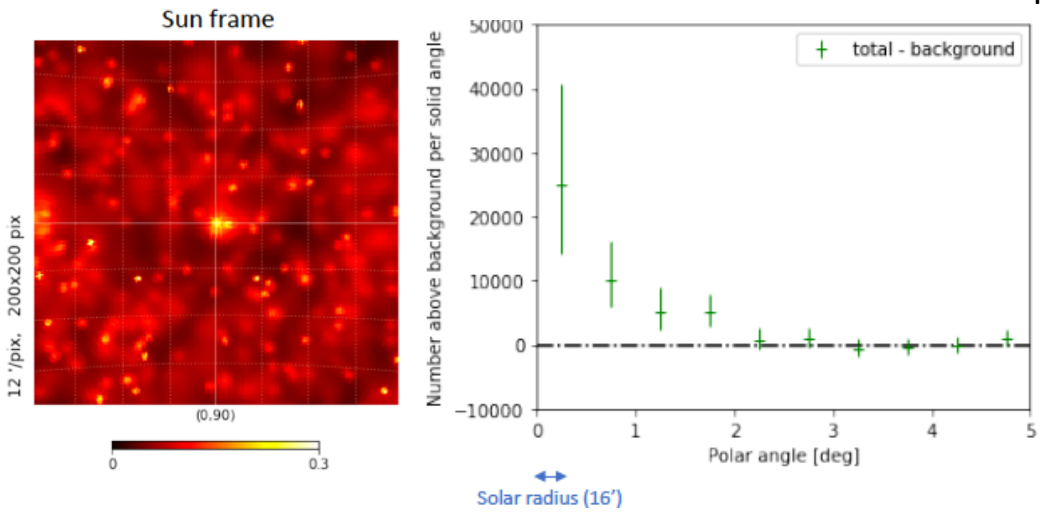
$N(E)$: Events in unfolded energy bin
$S\Omega$: Geometrical acceptance
$\varepsilon(E)$: Efficiency
T : Live Time
ΔE : Energy bin width

Observation period:
Oct.13 2015 – Dec.31 2018
(1,176 days)

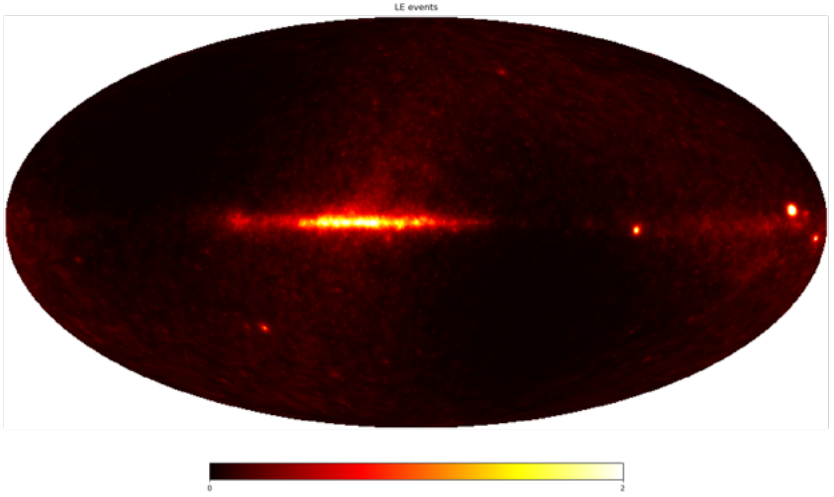


CALET Gamma-ray Sky (>1GeV)

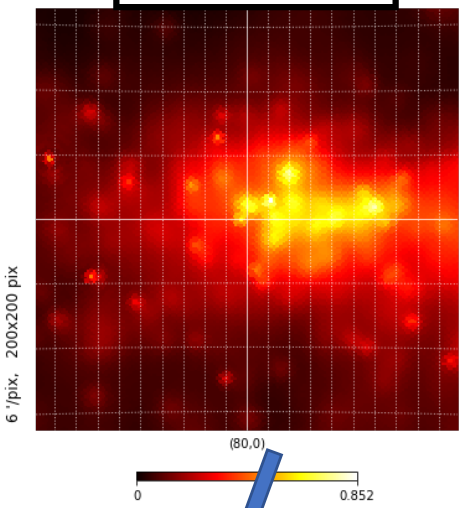
Current Topics: Solar atmospheric gamma-rays



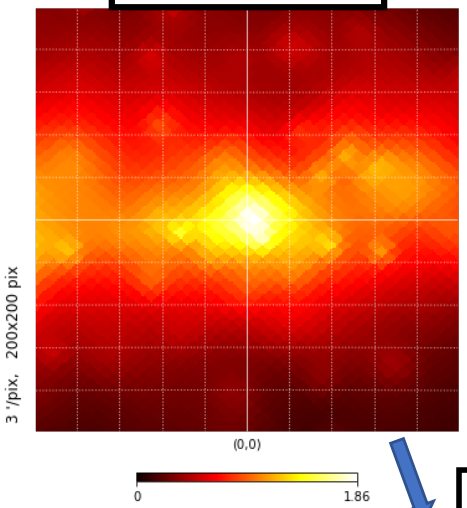
Gamma-ray Sky Map by LE Gamma-ray Mode from 2015/11/01 to 2019/12/31



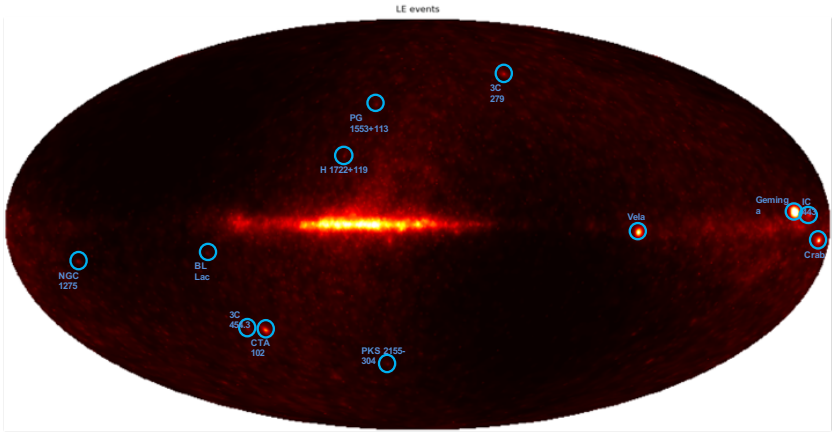
Cygnus Region



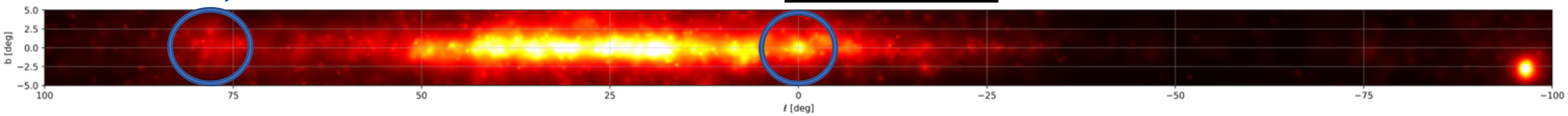
Galactic Center



Extra Galactic Sources



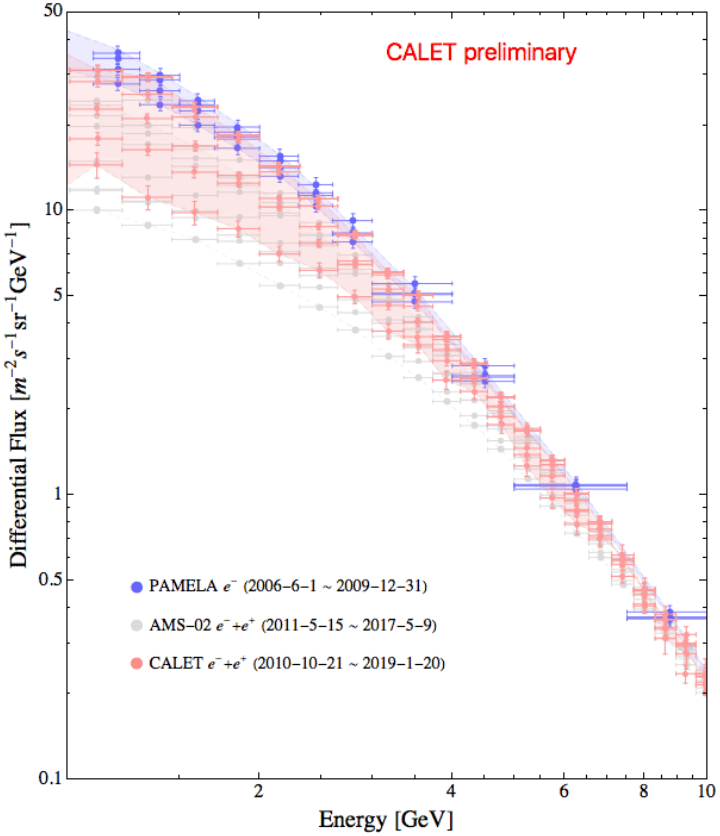
Galactic Plane



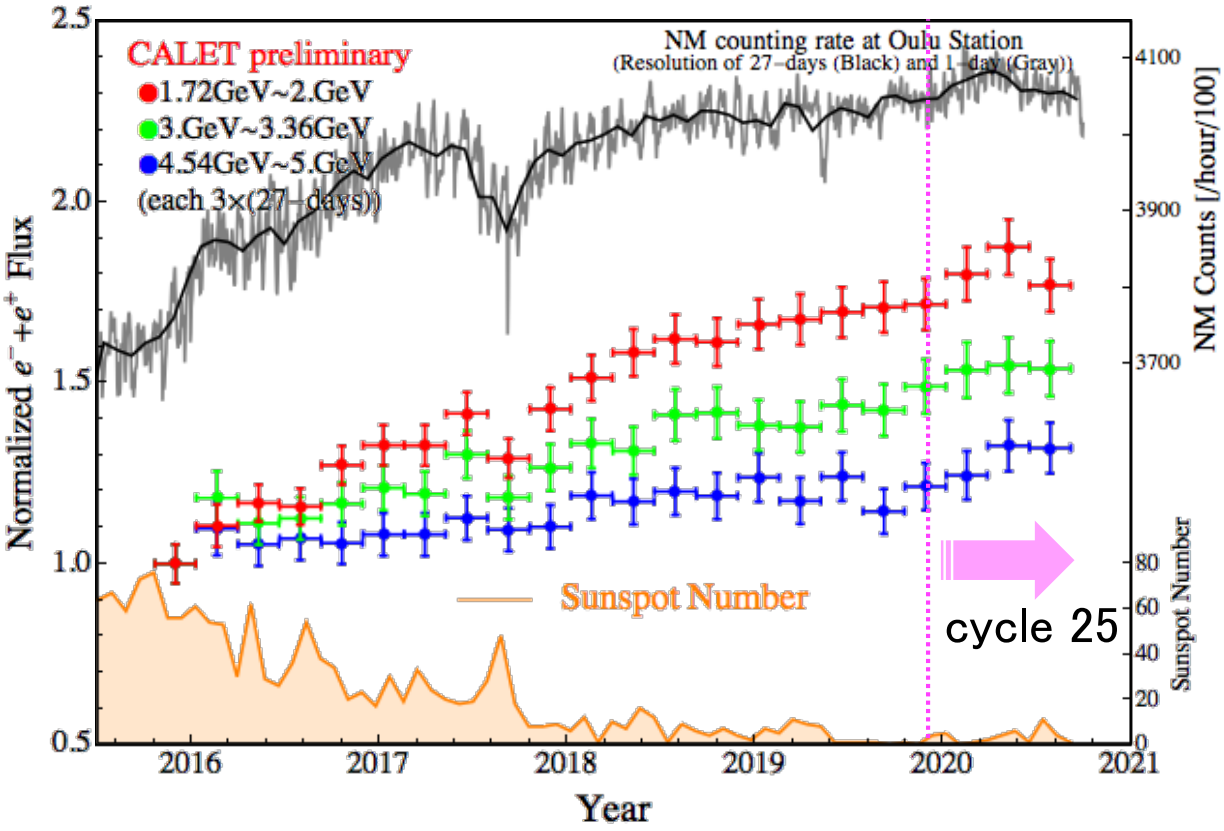
Observations of Solar Modulation during 2015 - 2020

Since the start of observations in October 2015, the increasing of all-electron flux in 1-10 GeV has continuously been observed up to the present time. Especially, the Flux in recent two years has reached to the maximum, which is exceeding to the maximum flux observed with PAMELA in last solar minimum period.

Long-term variation of all-electron energy spectrum observed with CALET



Long-term variation of the all-electron flux compared with NM count rate at Oulu and sunspot number



CALET: Summary and Future Prospects

- As of Dec. 31, 2020, CALET has successfully carried out the 1907-day observations with live time fraction to total time close to 86%. **Nearly 2.6 billion events collected with low (> 1 GeV) & high (> 10 GeV) triggers.**
- **Accurate calibrations** have been performed with non-interacting p & He events + linearity in the energy measurements established **up to 1 PeV.**
- Following results have been achieved by now.
  - Measurement of **electron + positron spectrum in 11 GeV - 4.8 TeV.**
  - Direct measurement **of proton spectrum in 50 GeV- 10 TeV energy range,** and of **Carbon and Oxygen spectra in 10 GeV/n -2.2 TeV/n:** Spectral hardening observed above a few hundreds GeV/n.
  - **Preliminary analysis of primary elements up to Fe.**
  - Study on solar modulation over ~5 years.
  - Observation of diffuse and point sources (+ Sun) of gamma-rays.
  - **Gamma-ray burst detections and follow-up observations of GW events** in X-ray and gamma-ray bands.
- **CALET mission is planed by March 2021 over 5.7 years after launch,** and is expected until 2024 by approval of the current project status.

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