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Time variation of dose quantities obtained by passive dosimeters onboard International Space Station

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Background

Passive dosimeters consisting of CR-39 PNTD and TLD are utilized as a space radiation dosimeter in ISS

- Small, lightweight and easy handle to monitor dose for person with low cost and without electric power
- No information on time (non real-time monitoring)

If passive dosimeters are carried out to monitor dose in several batches through a few years, is it possible to look the time variation of dose quantities using them and show the consistency of dose results with the active detectors ?

Biotrack space experiments

- ✓ Piers-1 module in International Space Station
- ✓ Passive dosimeters
  - CR-39 (HARZLAS/TD-1) PNTD
  - TLD-100 (LiF)
- ✓ 6 experiments with different terms between Jan. 2007 and Oct. 2008 (~2yrs)
- ✓ All of experiments (we call BE01~BE07) have been carried out in the same position using the same detectors

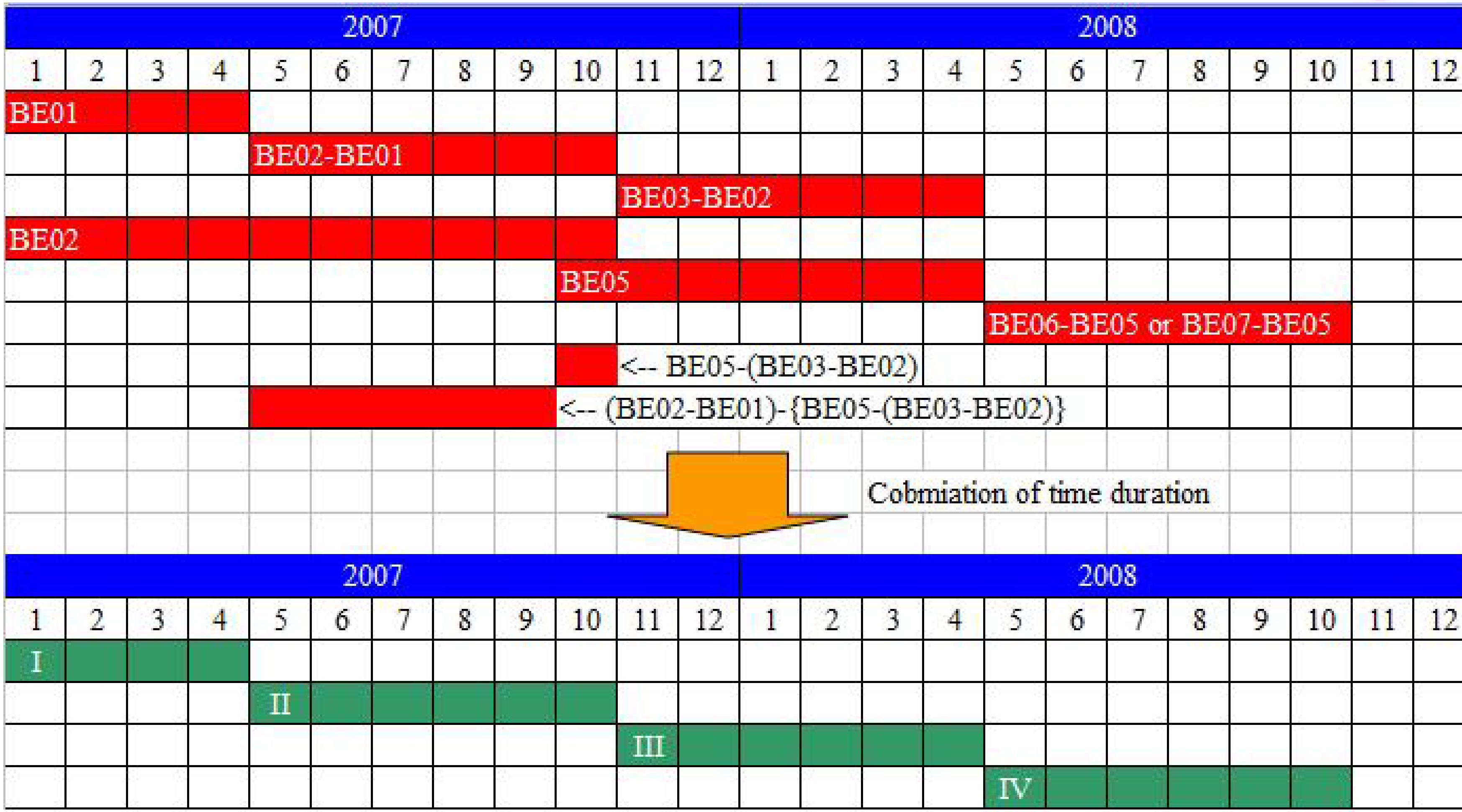
Time line charts of Biotrack space experiments (BE)

Exp.	Flight Schedule	Day [day]
BE01	Jan. 19, 2007 – Apr. 21, 2007	92
BE02	Jan. 19, 2007 – Oct. 22, 2007	276
BE03	Jan. 19, 2007 – Apr. 19, 2008	455
BE05	Oct. 10, 2007 – Apr. 19, 2008	191
BE06	Oct. 10, 2007 – Oct. 24, 2008	380
BE07	Oct. 10, 2007 – Oct. 24, 2008	380

Objectives

- Verifying the time variation of dose quantities in ISS using Passive dosimeters with different durations.
- Comparing with the data of other active detectors

Time combinations



By extracting and merging different or overlapped terms, exposure duration can be separated to 4 terms (I~IV)

Dose derivation using CR-39 and TLD

Absorbed dose: D_{Total} [mGy]

$$D_{Total} = D_{\leq 10 keV/\mu m} + D_{>10 keV/\mu m}$$
$$= \left(D_{TLD} - \kappa D_{CR-39}\right) + D_{CR-39}$$
$$= D_{TLD} + (1-\kappa) D_{CR-39}$$

Dose equivalent: H_{Total} [mSv]

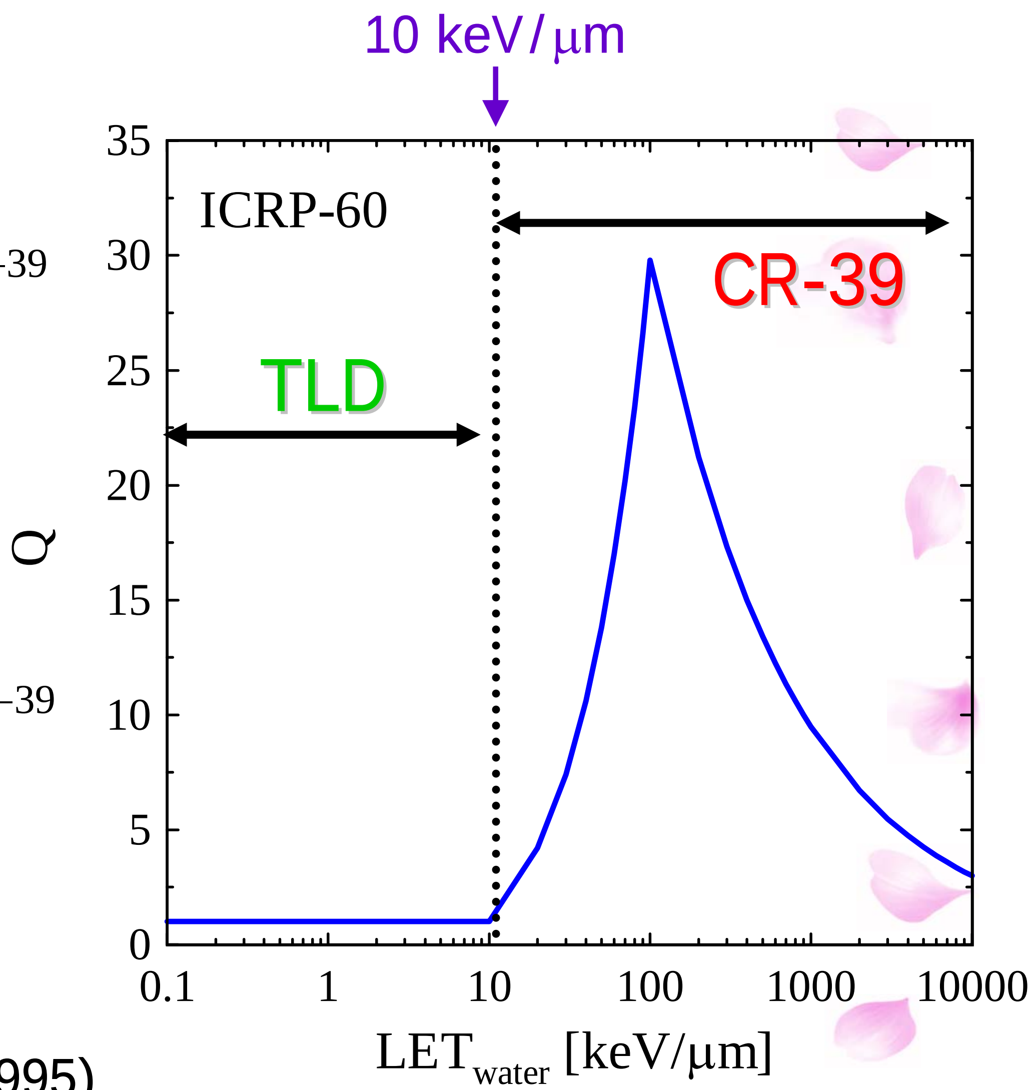
$$H_{Total} = D_{\leq 10 keV/\mu m} + H_{>10 keV/\mu m}$$
$$= \left(D_{TLD} - \kappa D_{CR-39}\right) + H_{CR-39}$$

Mean quality factor: Q_{Mean}

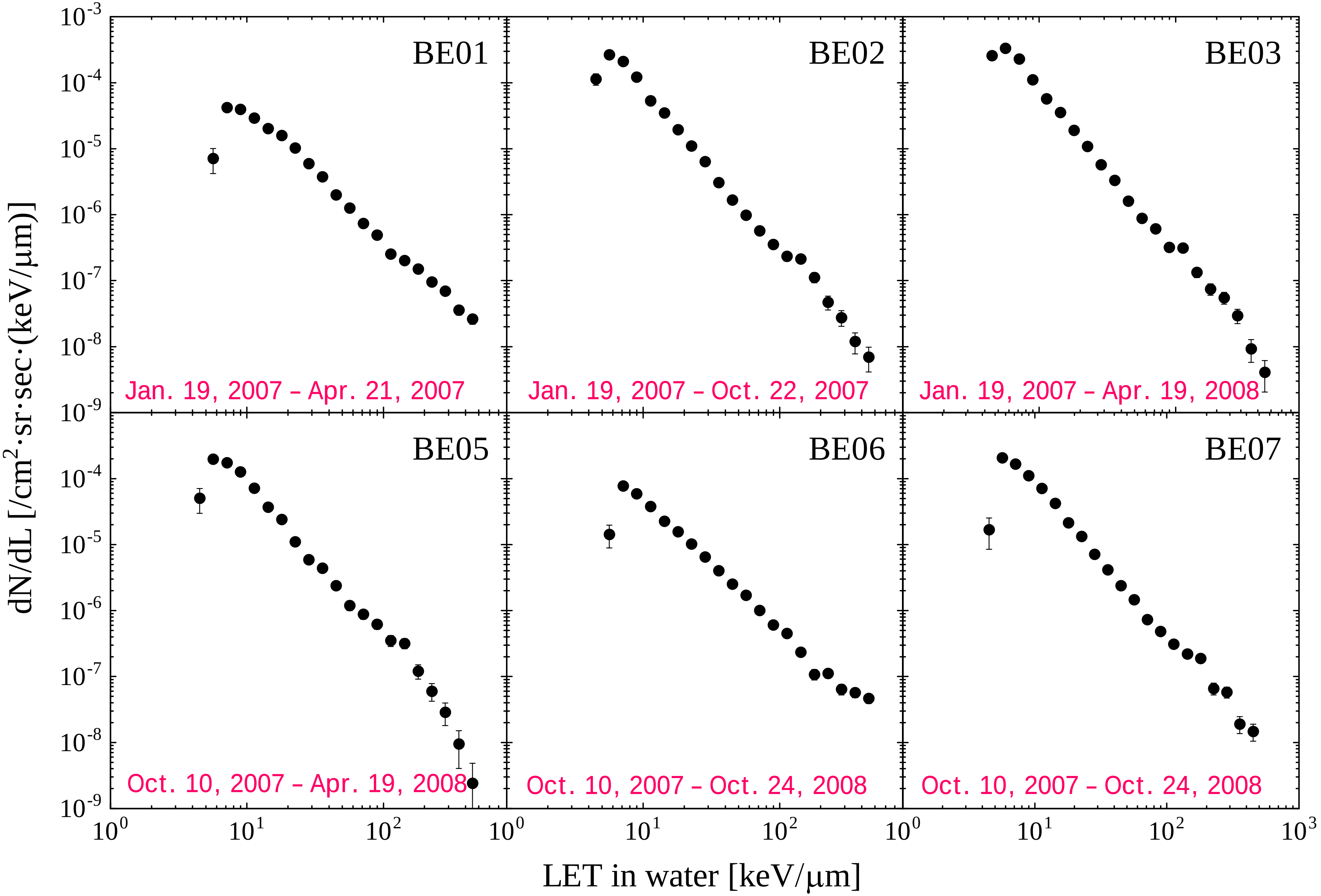
$$Q_{Mean} = H_{Total} / D_{Total}$$

κ: proportional constant

(Doke et al., 1995)



LET spectra obtained by CR-39



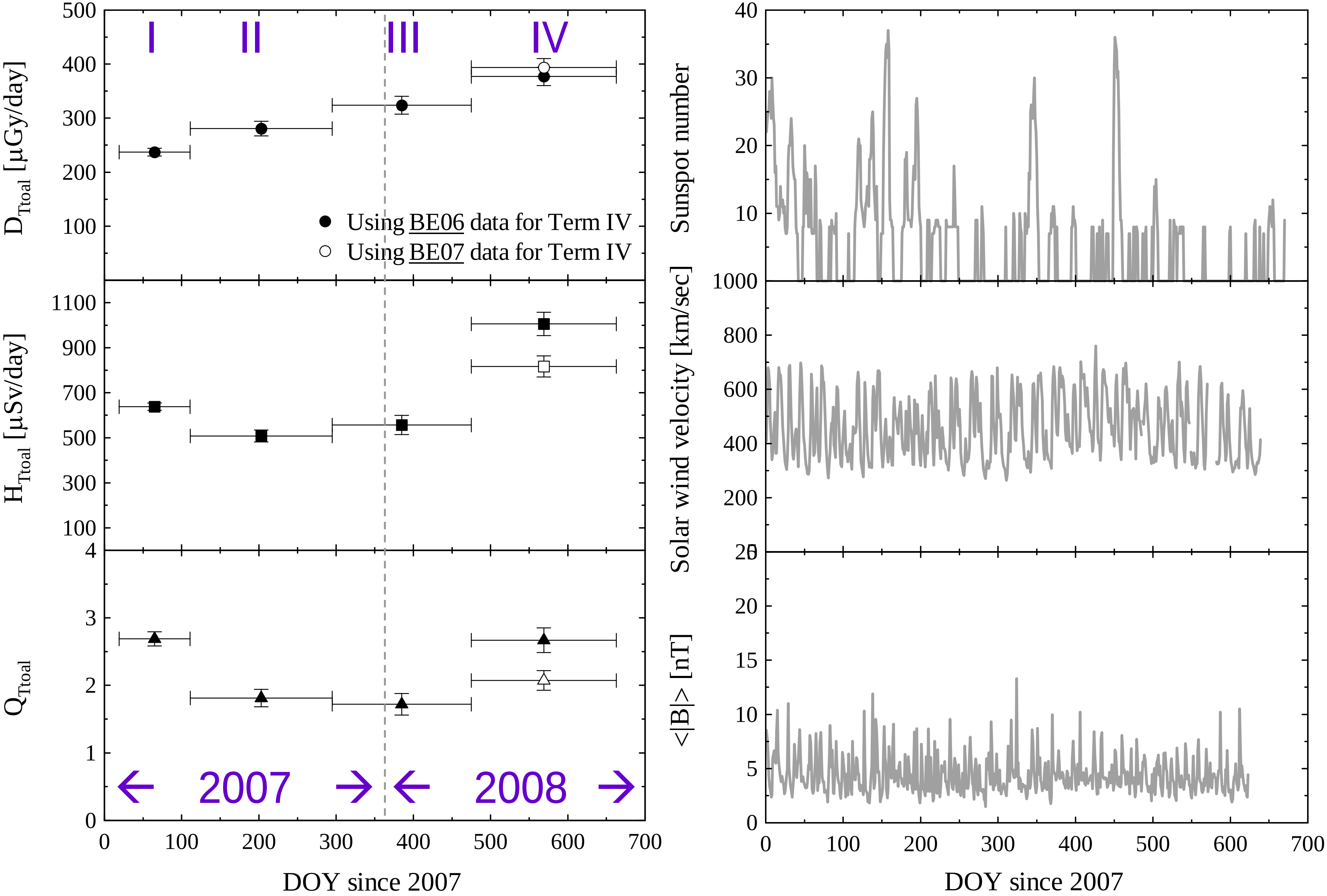
Results of dose quantities

	D_{Total} [mGy]	D_{Total} rate [mGy/day]	H_{Total} [mGy]	H_{Total} rate [mSv/day]	Q_{Total}
BE01	21.8±0.6	237.2±7.0	58.7±1.5	637.5±16.2	2.7±0.1
BE02	73.4±2.4	266.1±8.6	152.2±4.6	551.4±16.8	2.1±0.1
BE03	131.7±1.8	289.5±3.9	252.4±6.1	554.7±13.5	1.9±0.1
BE05	58.5±1.7	306.0±9.2	130.3±4.9	682.1±25.5	2.2±0.1
BE06	129.4±2.7	340.4±7.1	319.4±8.5	840.6±22.3	2.5±0.1
BE07	132.5±2.5	348.7±6.7	283.9±7.3	747.0±19.1	2.1±0.1

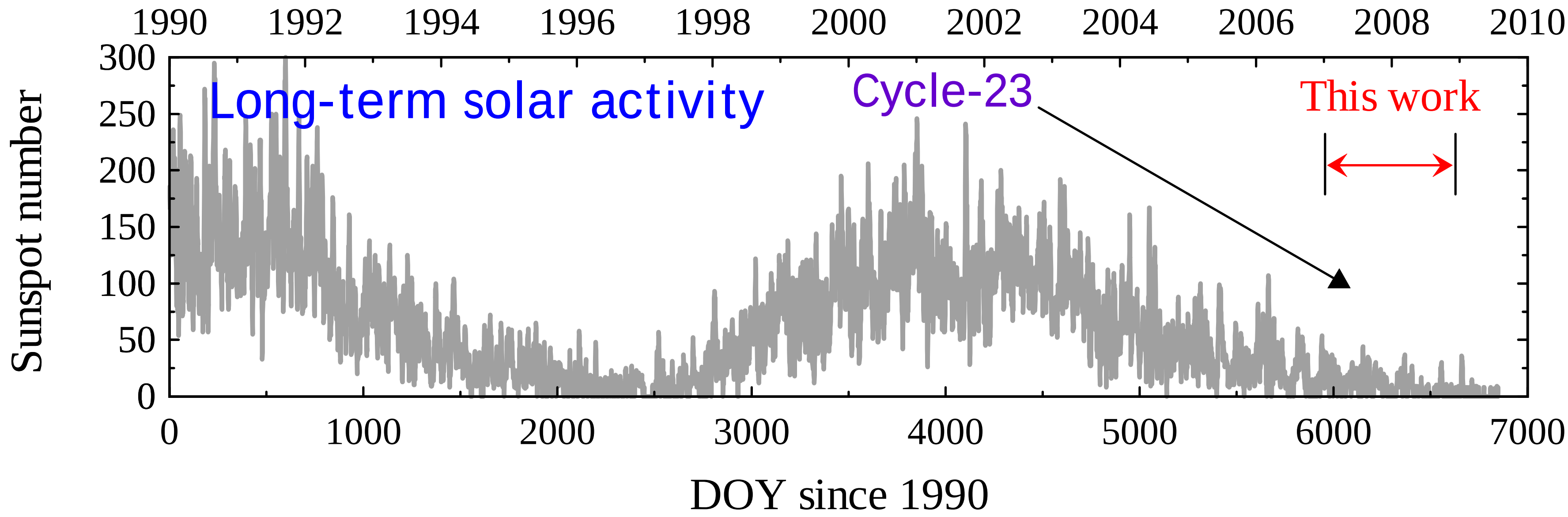
Separated to 4 terms (I~IV)

	Term [DOY] *since 1/1/2007	D_{Total} [mGy]	D_{Total} rate [mGy/day]	H_{Total} [mGy]	H_{Total} rate [mSv/day]	Q_{Total}
I	19 – 111	21.8±0.6	237.2±7.0	58.7±1.5	637.5±16.2	2.7±0.1
II	111 – 295	51.6±2.5	280.5±13.4	93.5±4.9	508.3±26.5	1.8±0.1
III	295 – 475	58.3±3.0	323.7±16.5	100.2±7.7	556.8±42.7	1.7±0.2
IV	475 – 569	70.9±3.2	377.2±17.1	189.1±9.8	1006.0±52.0	2.7±0.2

Time variations with solar activities

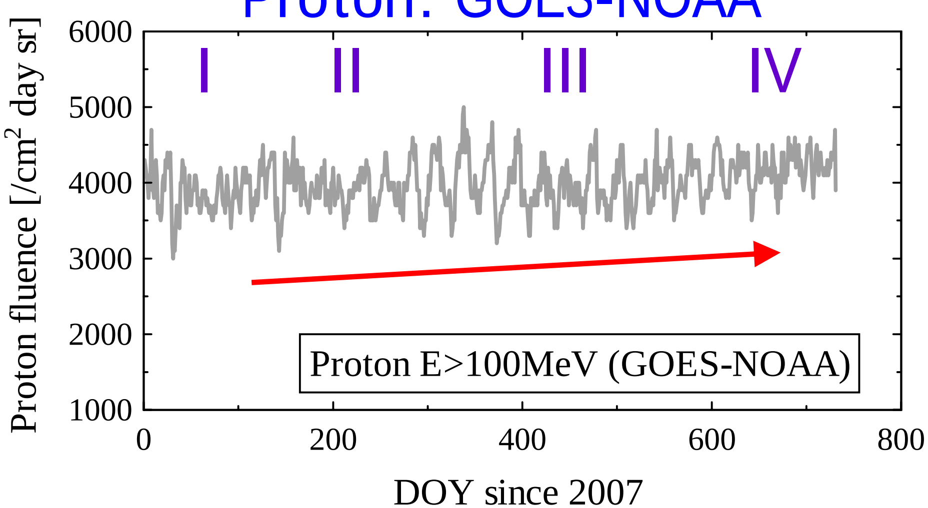


2007~2009: Decreasing the solar activity

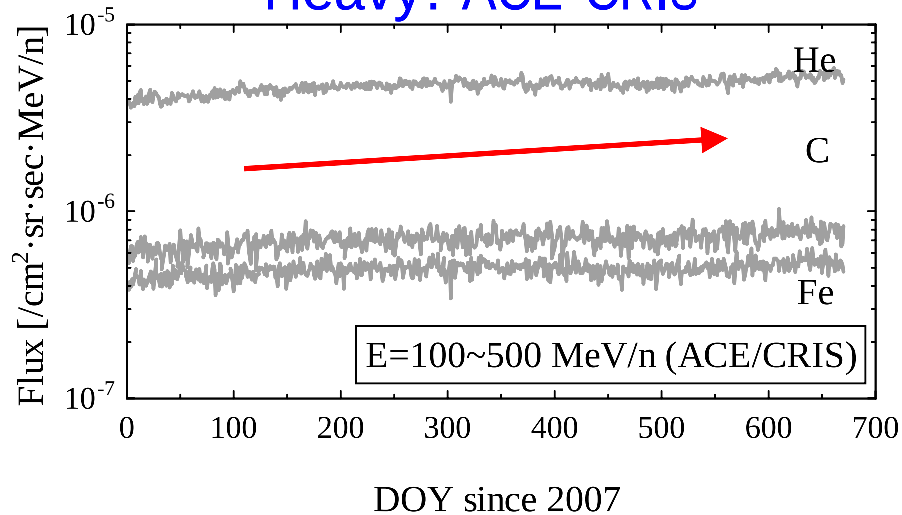


Increasing GCR intensity @ 2007→2009

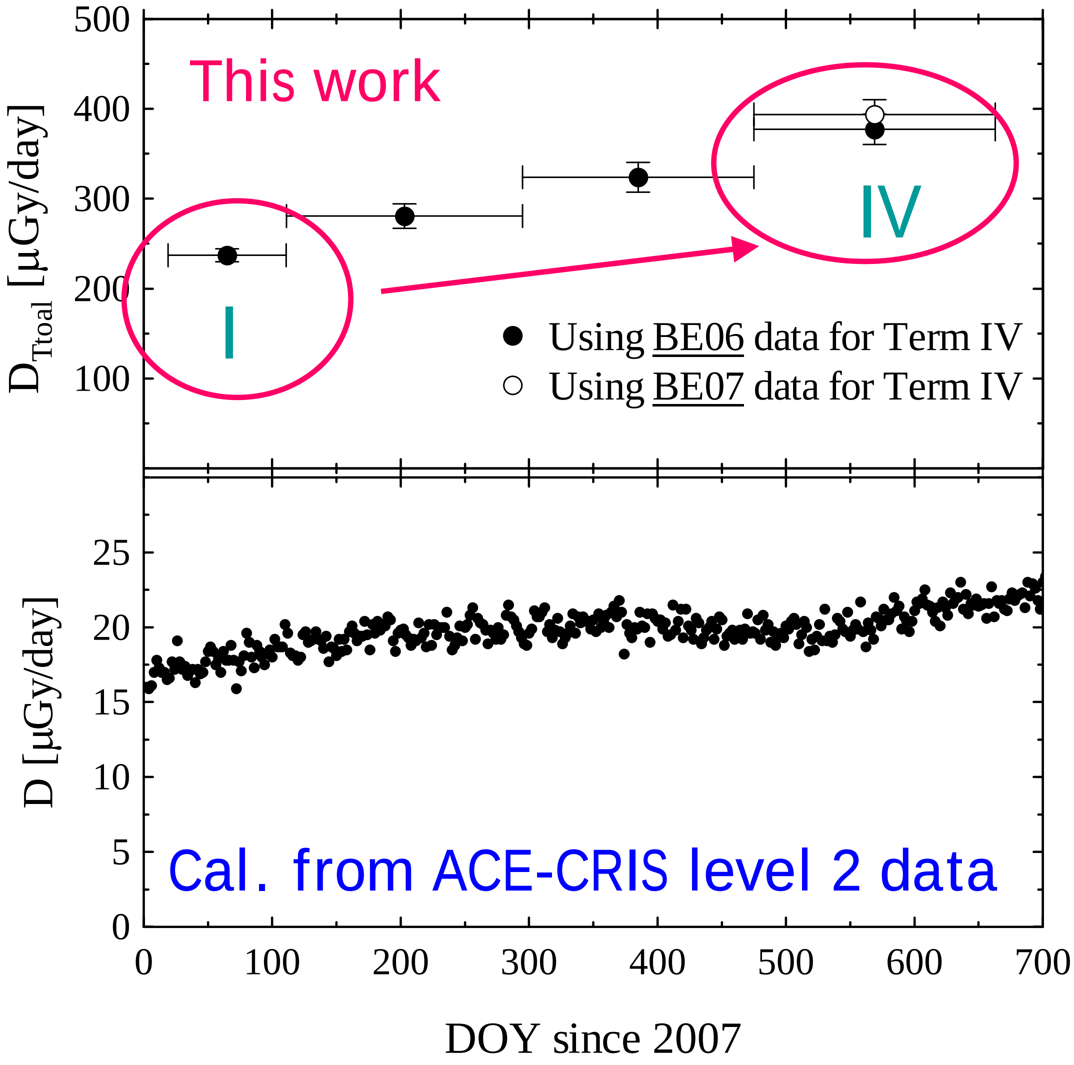
Proton: GOES-NOAA



Heavy: ACE-CRIS



Comparison with ACE-CRIS data (GCR data)



Increasing rate:

$(D_{IV}/D_{I})_{This\ work}$ ~ **+160%**

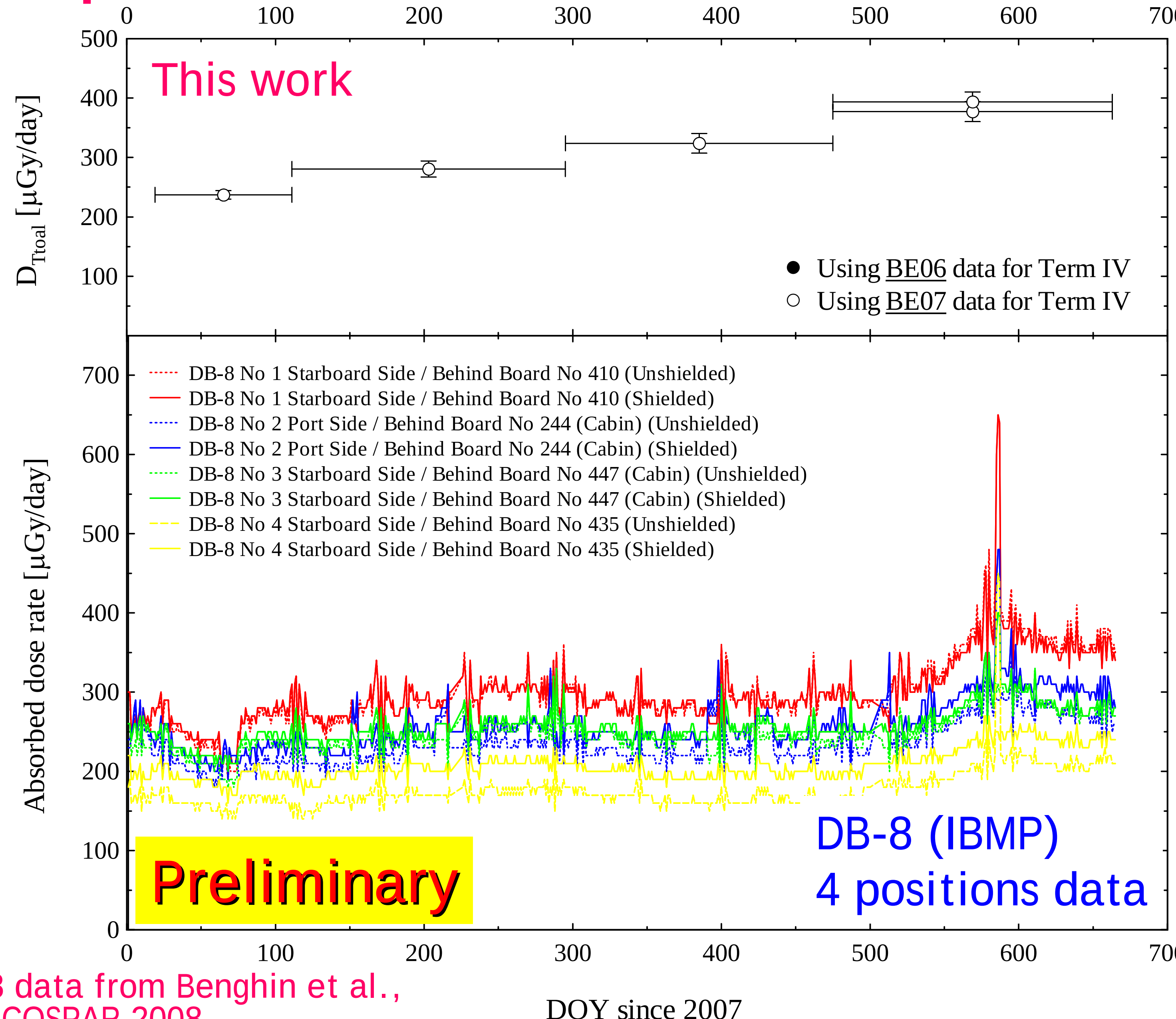
Exceed over +45%

Increasing rate:

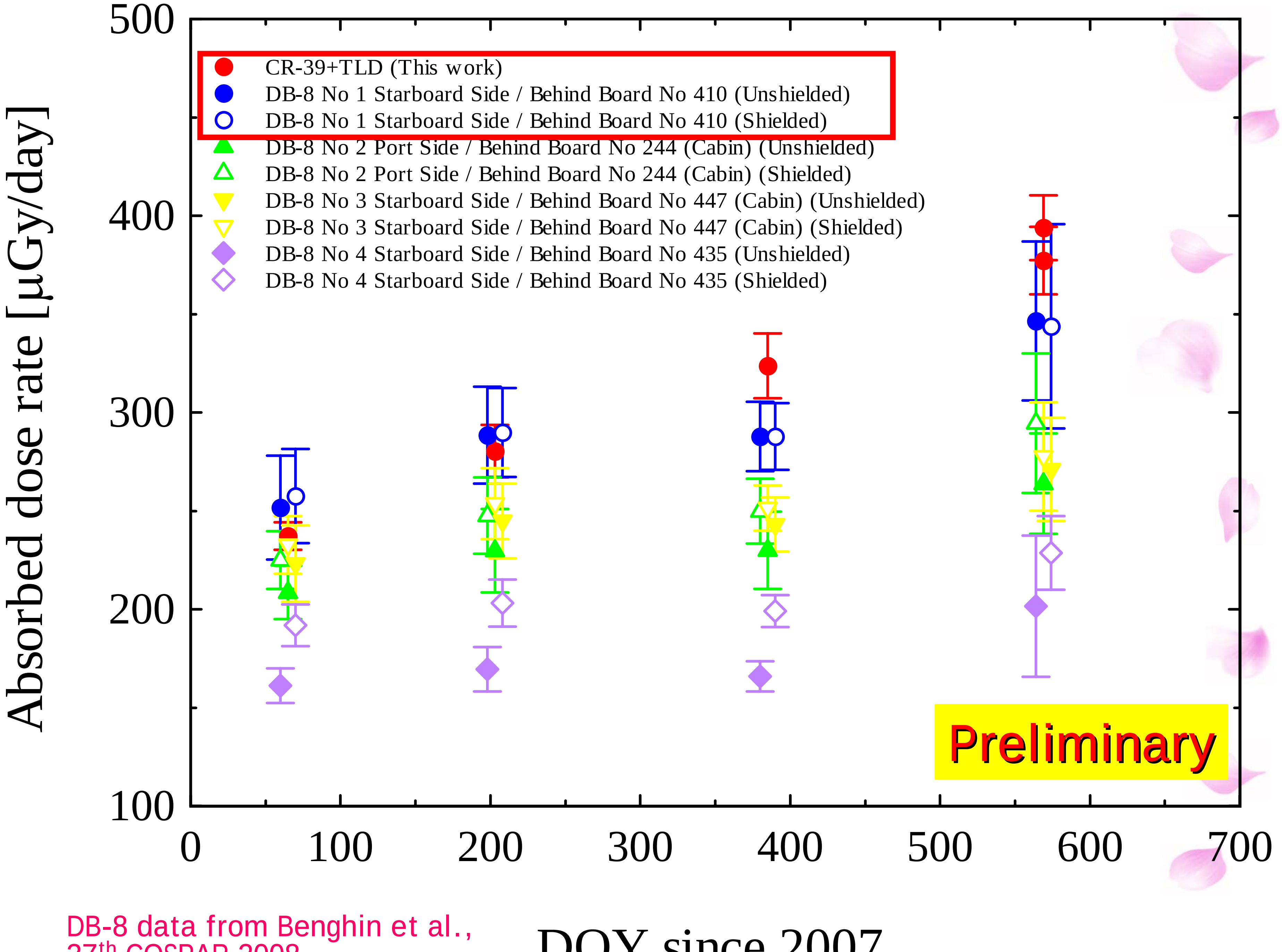
$(D_{IV}/D_{I})_{ACE\text{-}CRIS}$ ~ **+115%**

Effect of thick shielding inside ISS ??

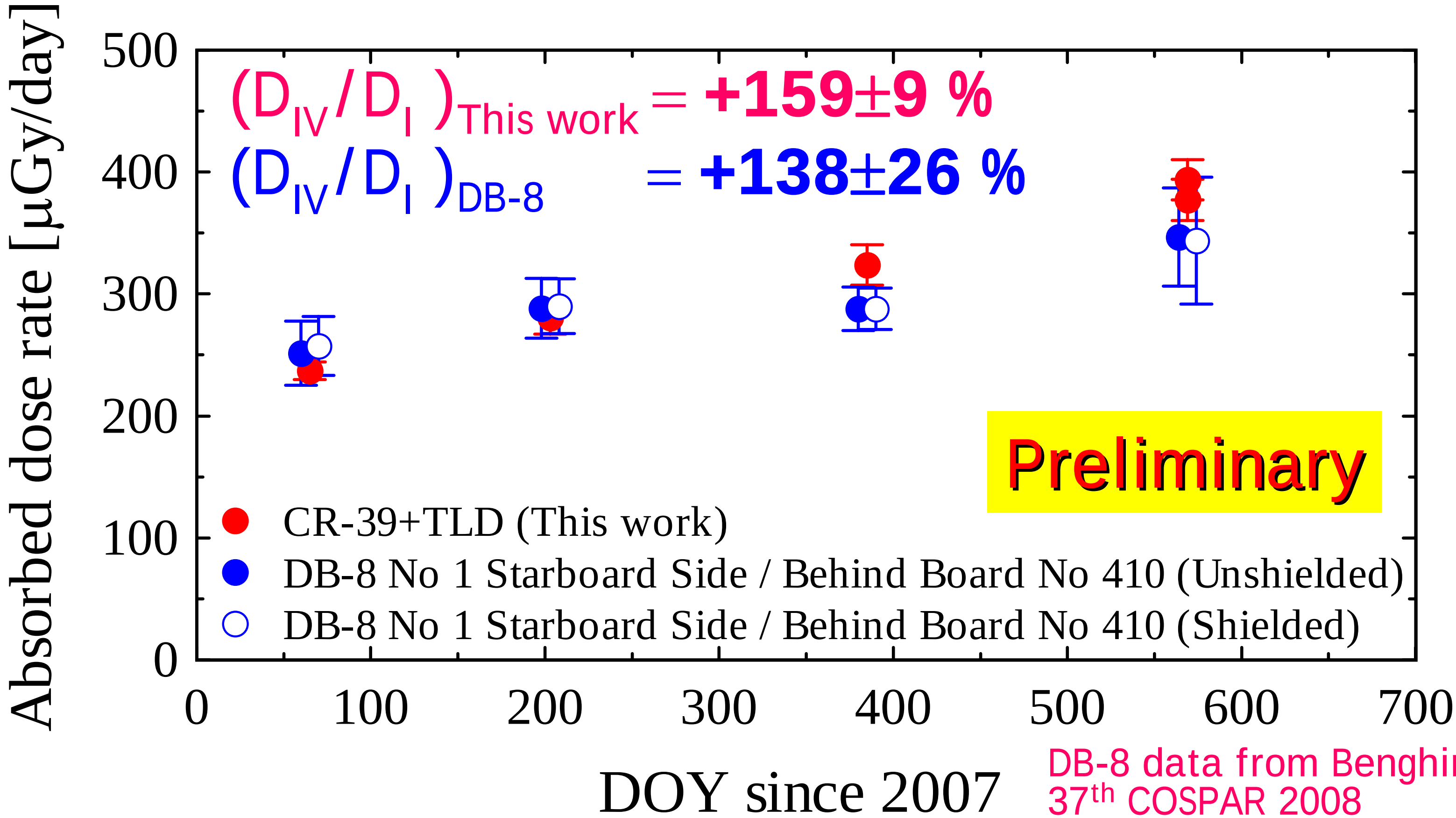
Comparison with DB-8 detector in ISS



DB-8 data from Benghin et al.,
37th COSPAR 2008



DB-8 data from Benghin et al., 37th COSPAR 2008



DB-8 data from Benghin et al., 37th COSPAR 2008

Time variation of absorbed dose and increasing rate obtained by this work are consistent with the results obtained by DB-8 detector within error bar

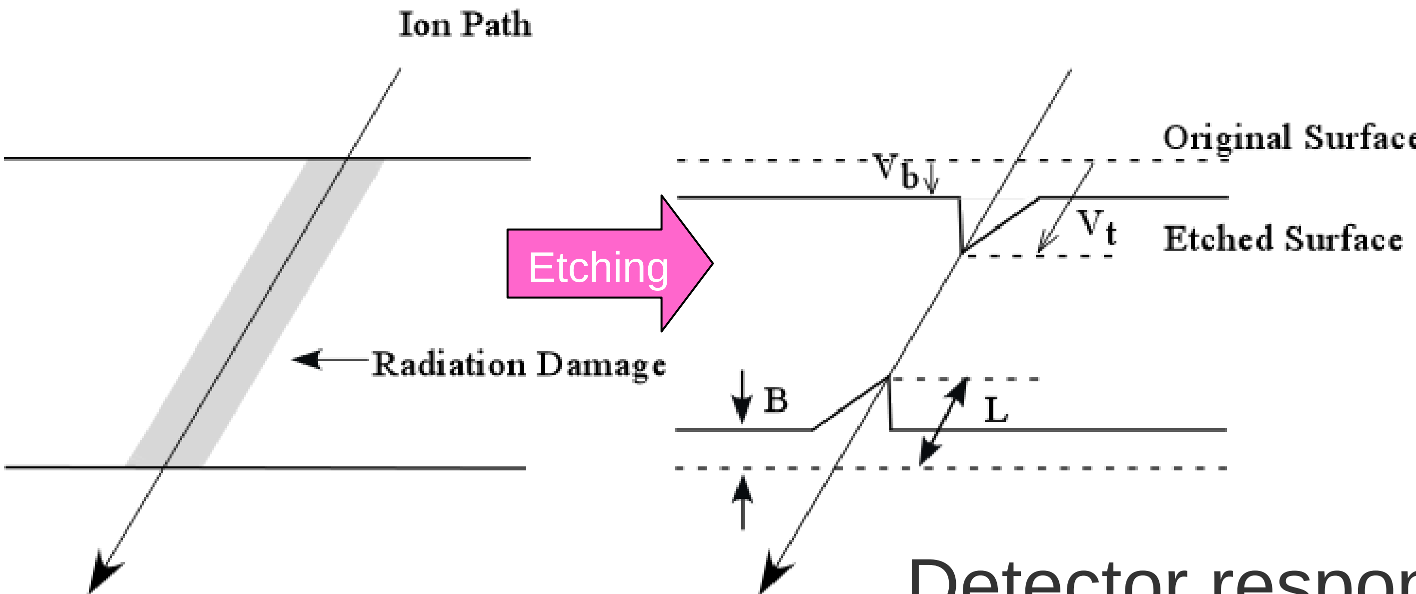
→ One factor of dose excess compared with ACE data is thought to be due to the shielding inside ISS or contribution of trapped particles in radiation belt

Summary

- ✓ Using 6 data (BE01~BE07) with different durations between Jan. 2007 and Oct. 2008 (~2yrs), the time variation of dose quantities using passive dosimeters (CR-39+TLD) was verified.
- ✓ Dose quantity from I to IV terms was increase tendency and the increasing rate of absorbed dose is ~+160% (D_{IV}/D_I ratio), which is not consistent with the estimation of GCR intensity increase (~115%) obtained by ACR-CRIS.
- ✓ Increasing rate obtained by this work is good agreement with the data by DB-8 inside same cabin.

→ The discrepancy with GCR data obtained by ACE might be explained by the effect of thick shielding inside ISS or contribution of trapped particles in radiation belt.

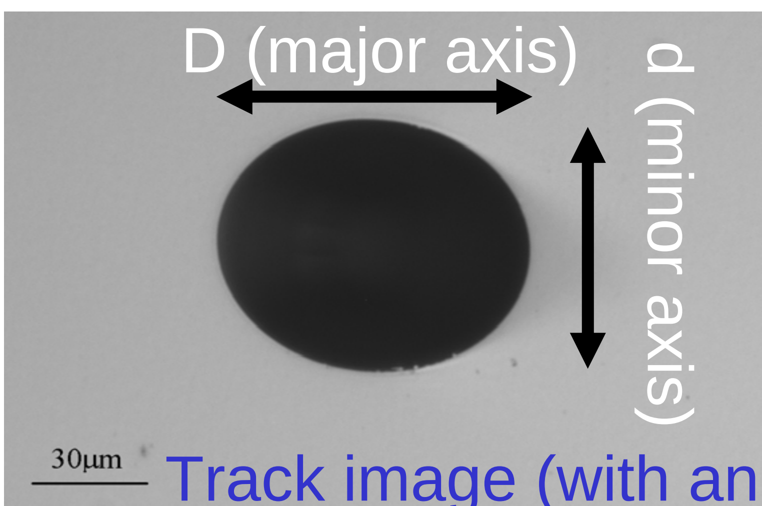
Principle of track detection in CR-39



$$V_t = L \cdot t$$
$$V_b = B \cdot t$$
t : Etching time

Detector response (S):

$$S \equiv \frac{V_t}{V_b} - 1 = f(\mathrm{LET})$$
$$= \sqrt{\frac{16B^2D^2}{(4B^2 - d^2)^2} + 1} - 1$$



Track image (with angle)

→ Absorbed dose (D)
Dose equivalent (H)