Measurement of Neutrons at ISS by the SEDA-AP on-board JEM

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  Y. Muraki, and T. Yamamoto (Konan University)

- The SEDA-AP has been designed for the measurement of the space environment, but from another point of view as solar physics, the detector may be assigned as the second generation solar neutron detector after Solar Maximum Mission (SMM).

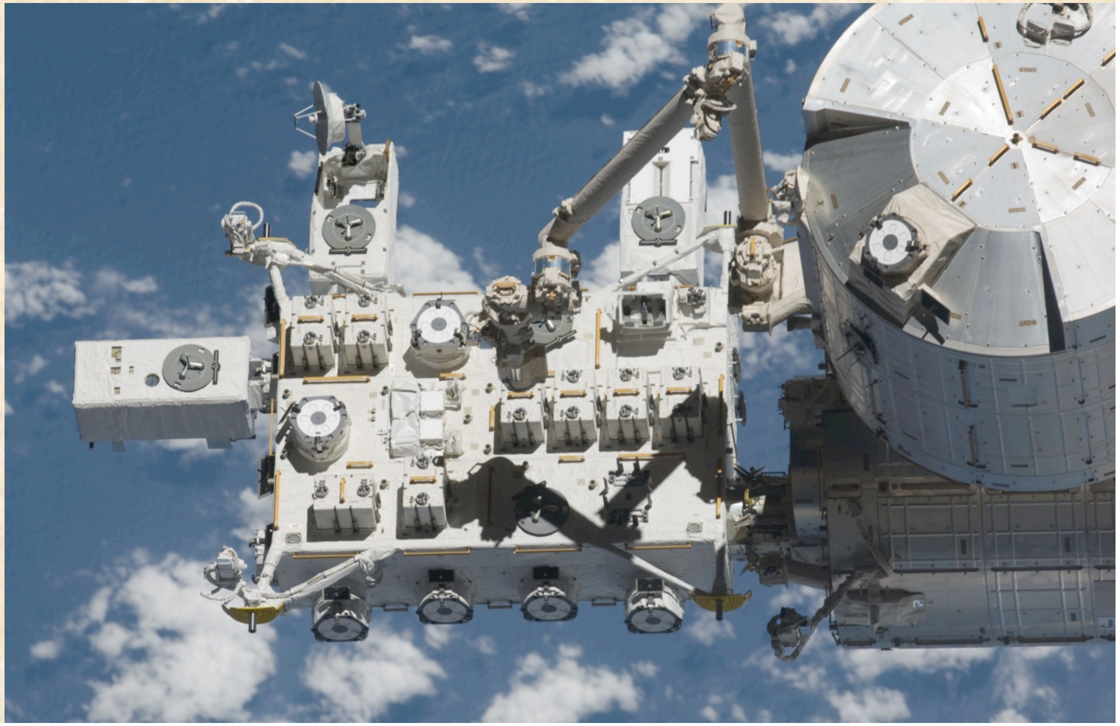
- The SEDA-AP has been on-board Japan Experimental Module on 16th July 2009 by the space shuttle Endeavor, and started to take the data from 25th, August.

- I will introduce the performance of the detctor.

- This paper submitted for 22nd ECRS at Turk, Finland on August 3rd, 2010.

The outline of the talk

- 1. Brief introduction of A long history until the operation at the ISS
- 2. Review of the Scientific purpose of the experiment: especially the measurement of solar neutrons at the space
- 3. Performance of the detectors at the ISS
- 4. First results of the observation of neutrons at ISS
- 5. Future



1. A long history to have been operated at ISS

- The project started in December 1991.

- From 1994 a frontier study group had been organized by 19 members from university, company and NASDA (present ISAS). By them, 11 items had been selected from 20 items of observation.
- As the main subject of the space environment, the measurement of neutrons had been selected with the highest priority. A proposal was written and sent to the selection committee of the government.
- In April 1997, the subject ; measurement of the space environment has been selected as the first use project of the ISS of the Japan Experimental Module by the committee.
- In 2001, the flight module (FM) has been made and it has been kept in a special room for 8 years.

- In August 2009 the module has been launched on the ISS. (totally 18 years have passed ! ）

2. The scientific purposes of measurement of neutrons at International Space Station

- Evaluation of the risk of cosmic rays to the astronaut (**Radiation Physics**)
- Prediction of arrival of dangerous radiations from the Sun in association with large solar flares (**space weather forecast**)
- Establishment of the acceleration process of solar cosmic rays (**solar physics, cosmic ray physics**)

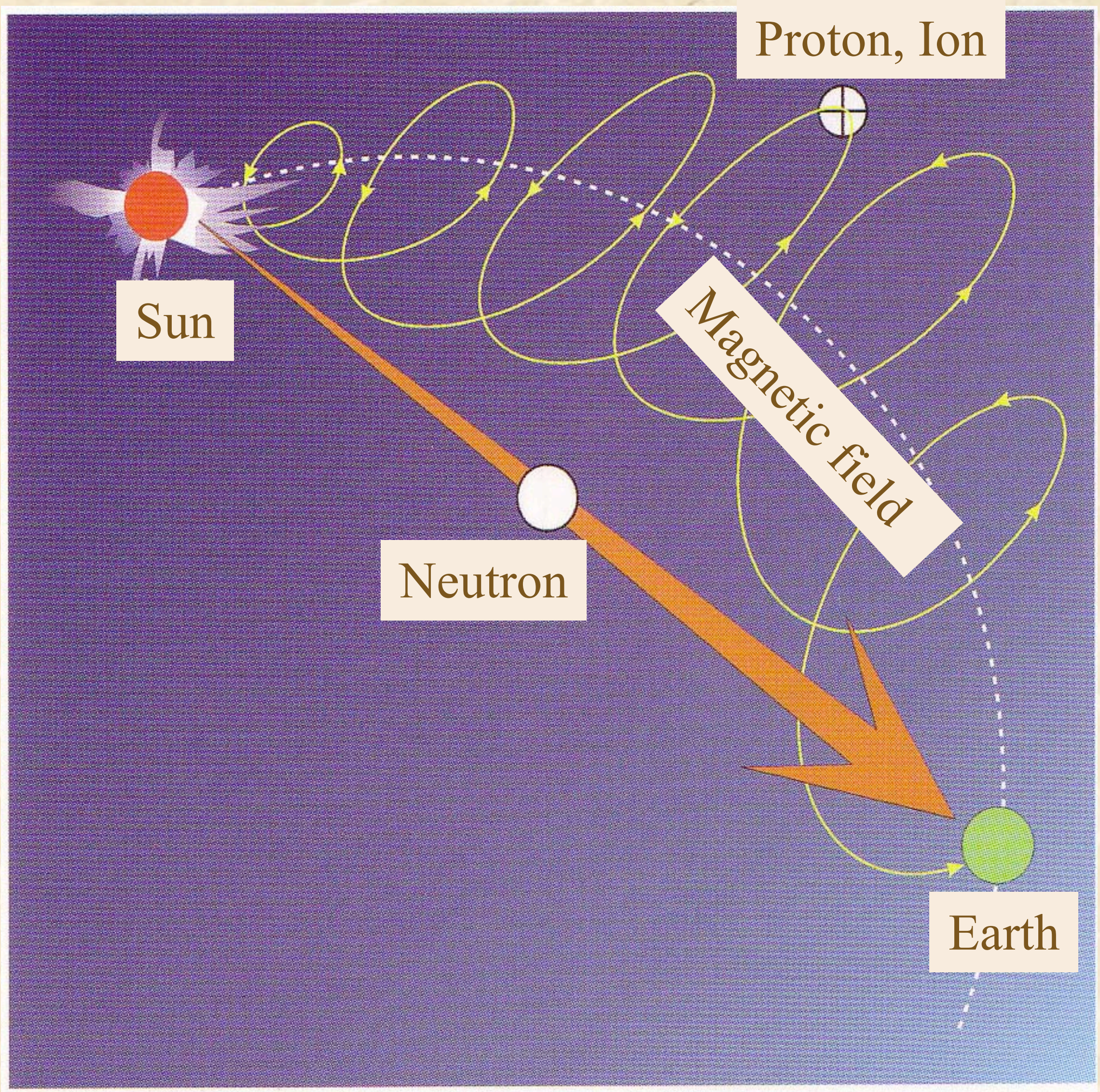
Scientific Purposes

- **Physics aim is to confirm particle acceleration model at the solar surface.**
- **How** and **When?**
- **How** are particles accelerated?
- **When** are particles accelerated?
- **What** is the highest energy of SCR?

up to 100GeV? 1TeV?

However observations of protons do not give us all information to understand them. Protons are usually coming on the Earth a few hours later from the flare. So we must use **neutron information**.

- Another important thing: application to the space weather forecast



June 21, 1980 event (S09 E72)

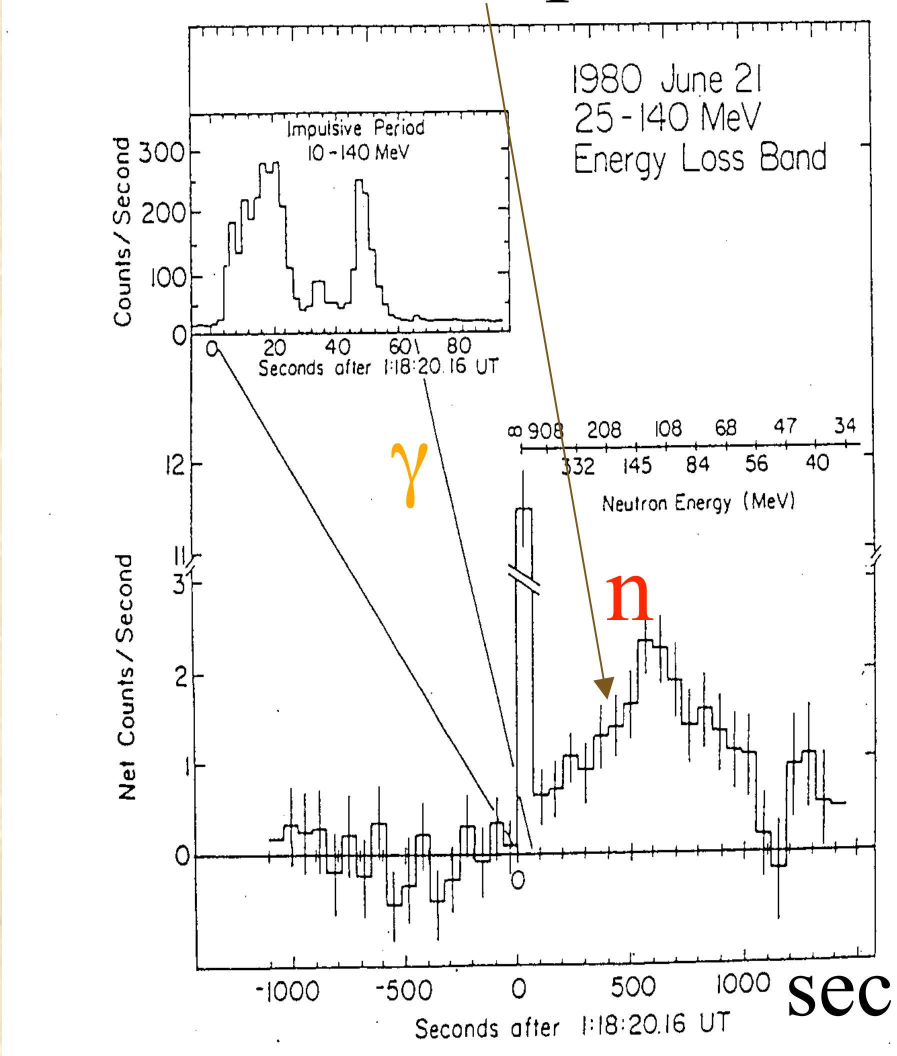
Neutron time dispersion

Satellite data
Solar Maximum Mission

The first solar neutron event can be explained by the impulsive production model with

γ=-3.5±0.1 (diff.)

100MeV→11 min. delay



June 3, 1982 event

(S09 E72)

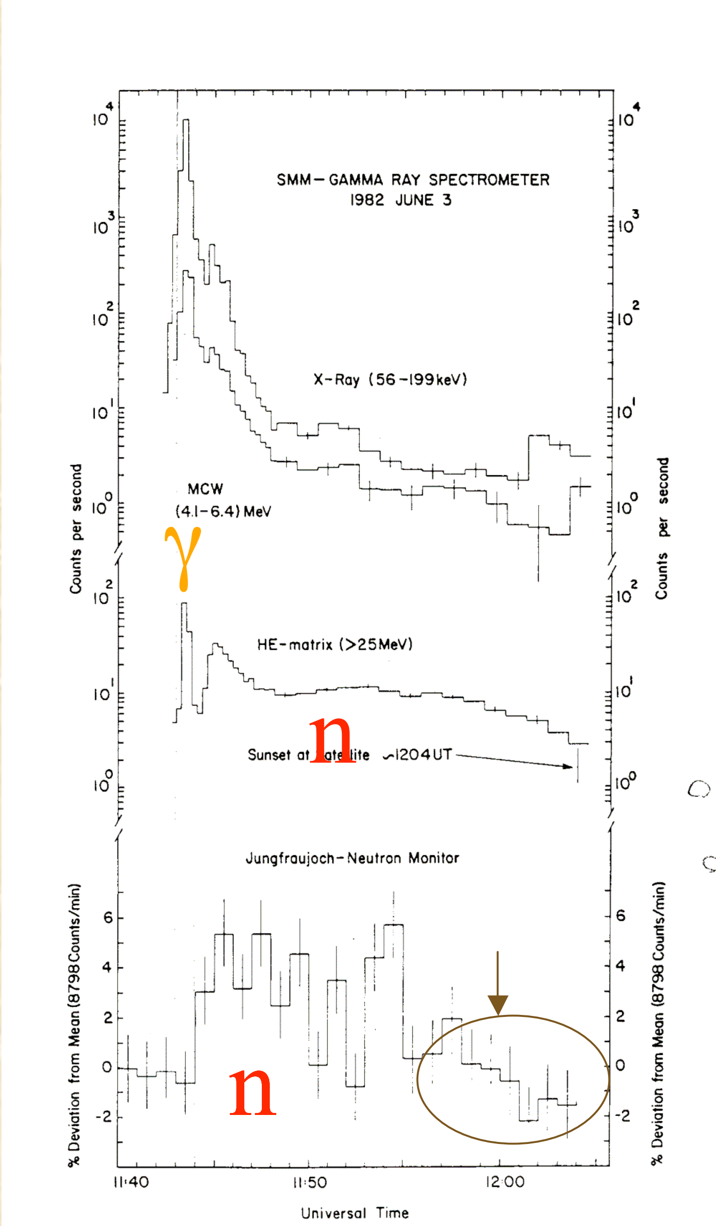
Jungfraujoch neutron monitor

+

SMM mission data

The fast arrival part of neutrons can be explained by the impulsive production model with
γ=-4.0±0.2 (diff.)
but later part must be another process.

100MeV→11 min. delay



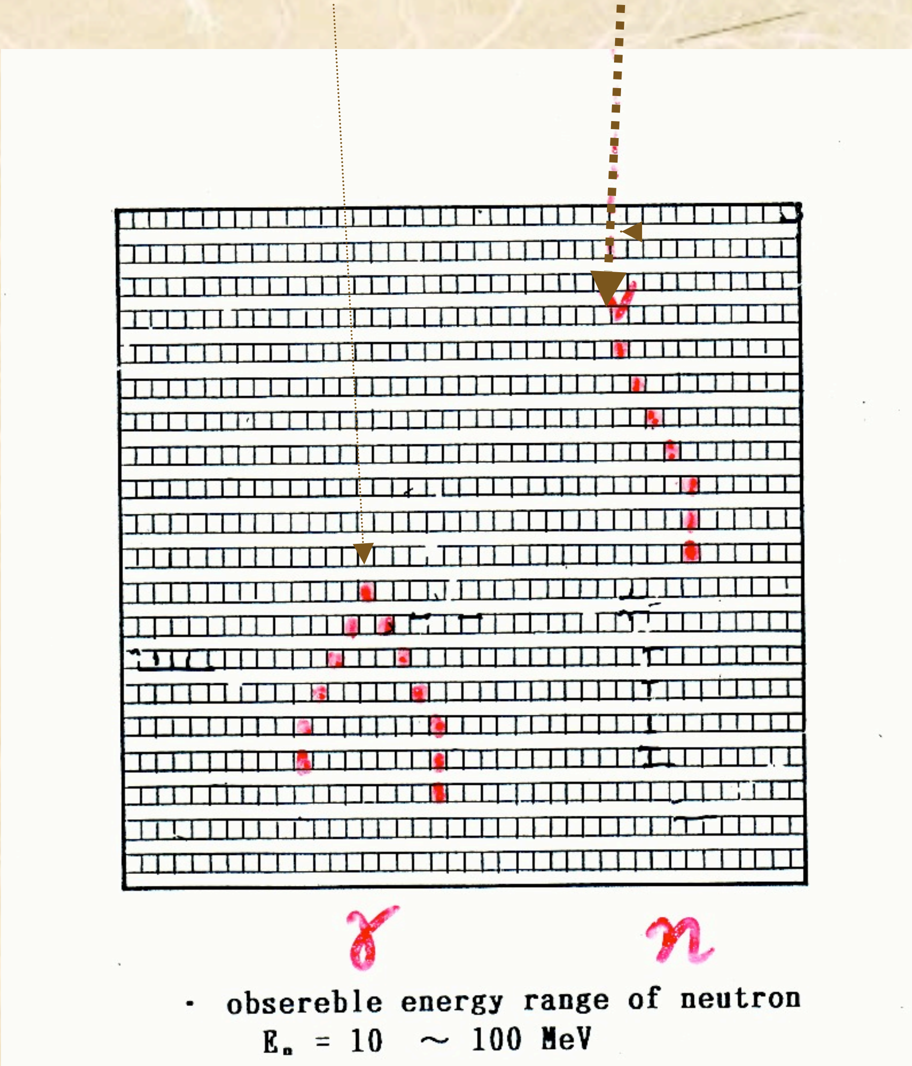
3. The details of new neutron detector

- The energy must be measured
- To separate the impulsive production from the gradual production
- The arrival direction must be measured

FIB detector
in the Space Environment monitor **SEDA**

- The **FIB** detector can measure the energy and the direction of incoming neutrons by the scintillation fibers.

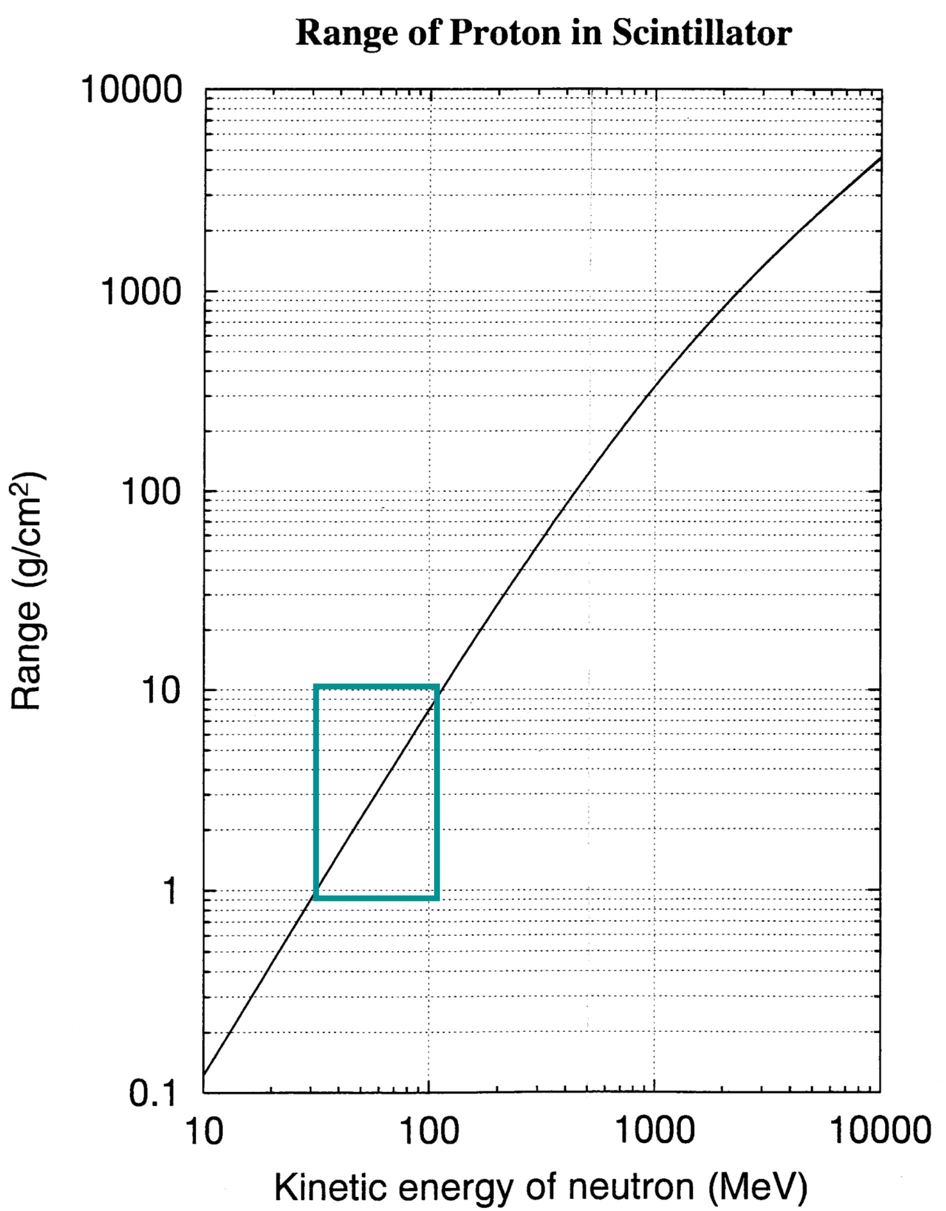
- The **BBD** detector can measure the low energy neutrons less than 30 MeV



Principle of measurement

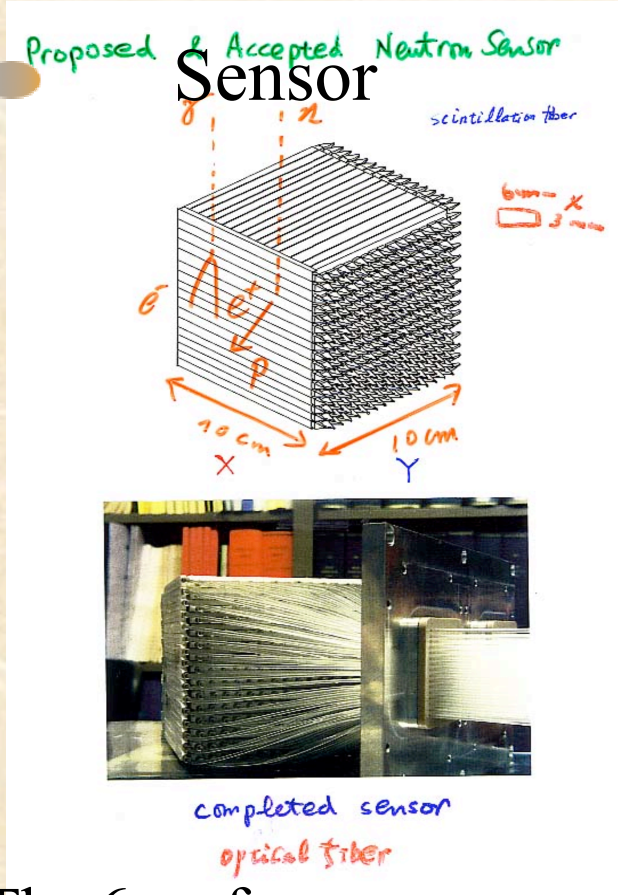
- The energy of neutrons can be measured by the range method.

☐ The green box corresponds to the observation target energy (30-100MeV)



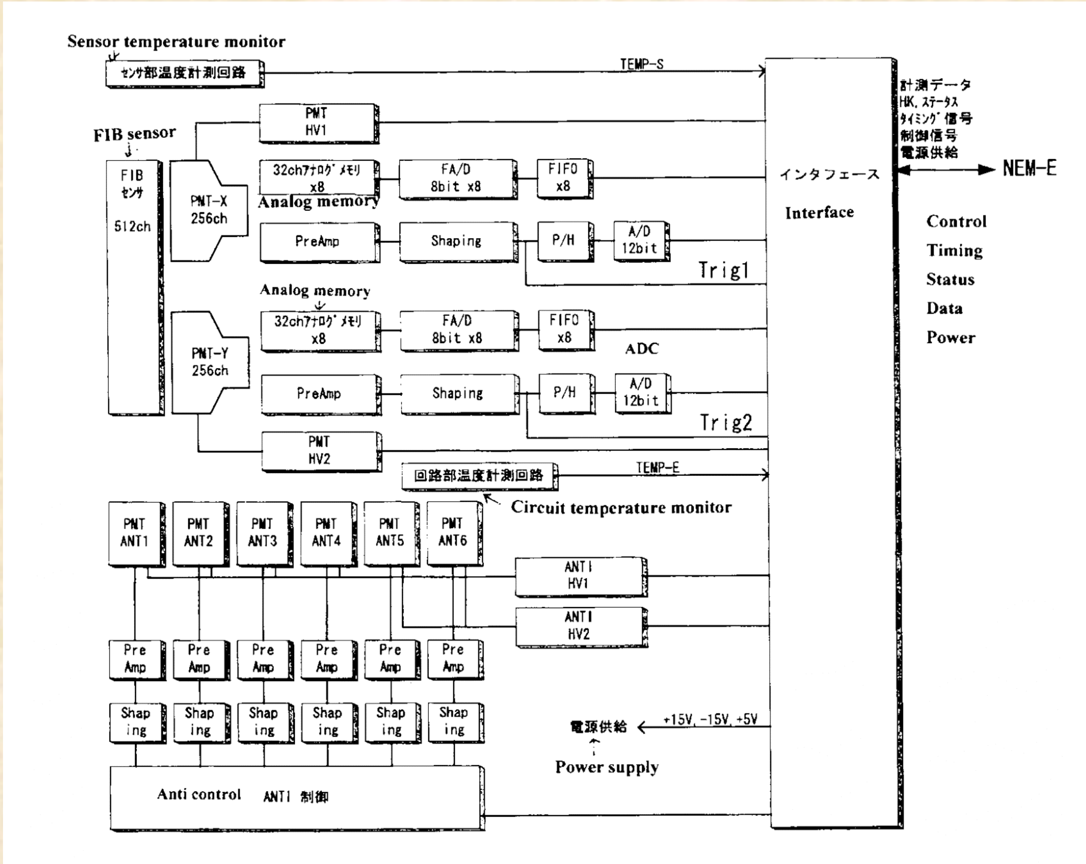
The data taken by **FIB** detector in **SEDA**

- Sensor



The 6 surfaces are covered by the anti-counter

Circuit diagram



Properties of new neutron detector

ΔE/E ≈ 10% @ 50MeV

ELSEVIER

Nuclear Instruments and Methods in Physics Research A 421 (1999) 99–112

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

NIM A421 (1999) 99–112

A new tracking satellite-borne solar neutron detector

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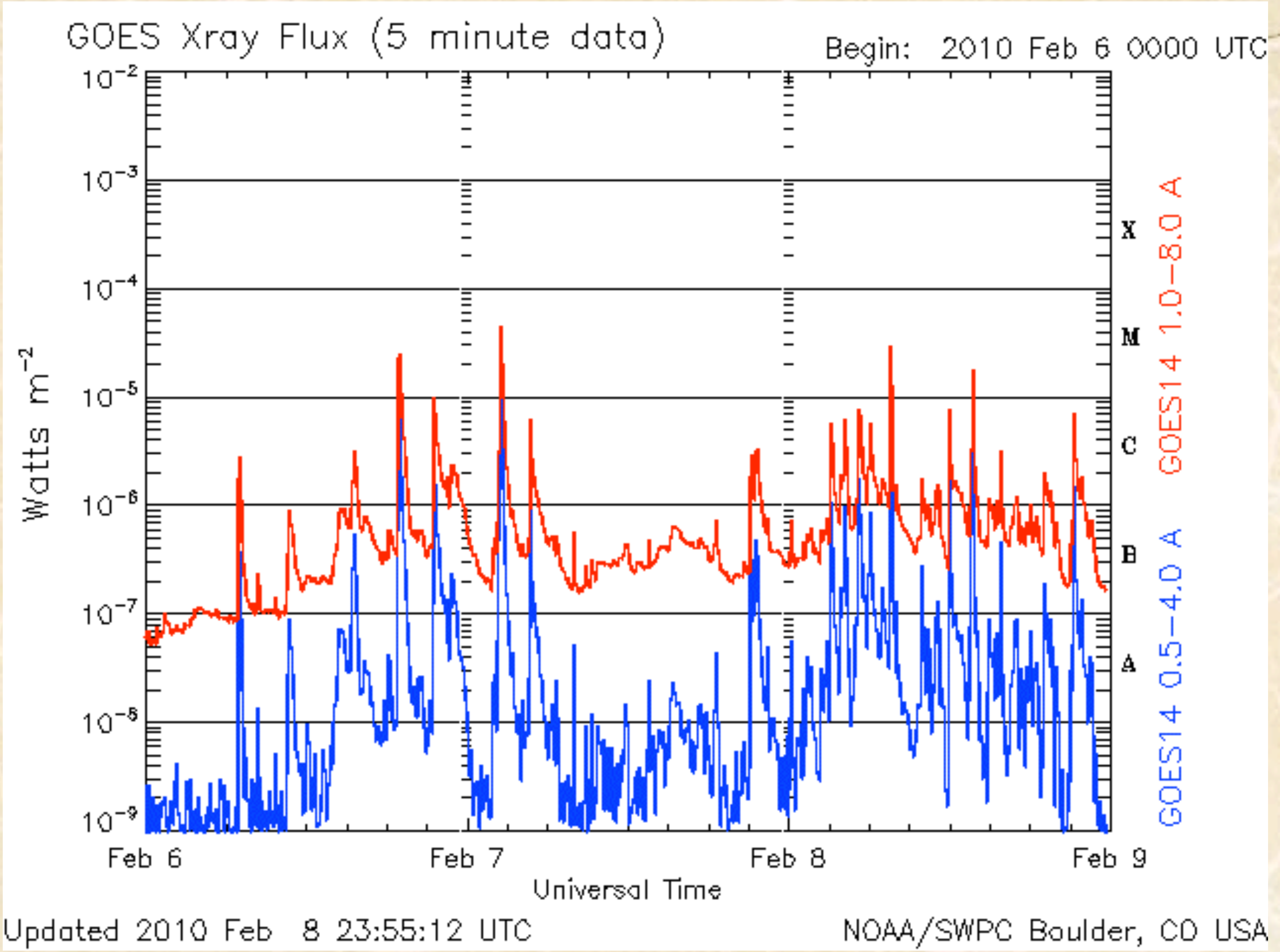
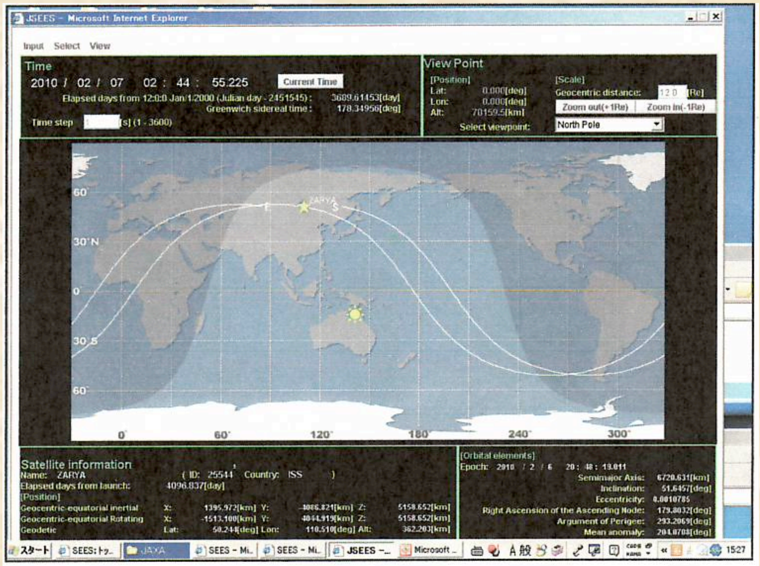
4. First results of the observation

- Since we have not yet experienced a large solar flare after launching the detector, I would like to introduce the performance of the detector.
- Search for solar neutrons in association with the M-class flare of the solar flares on February 6^{th} – 8^{th} , 2010.
- We have also measured the background neutrons at ISS from the main body of ISS at normal region and over SAA.

Search for the solar neutrons in association with the flares on February 6-8th of 2010



The position of ISS at the flare time



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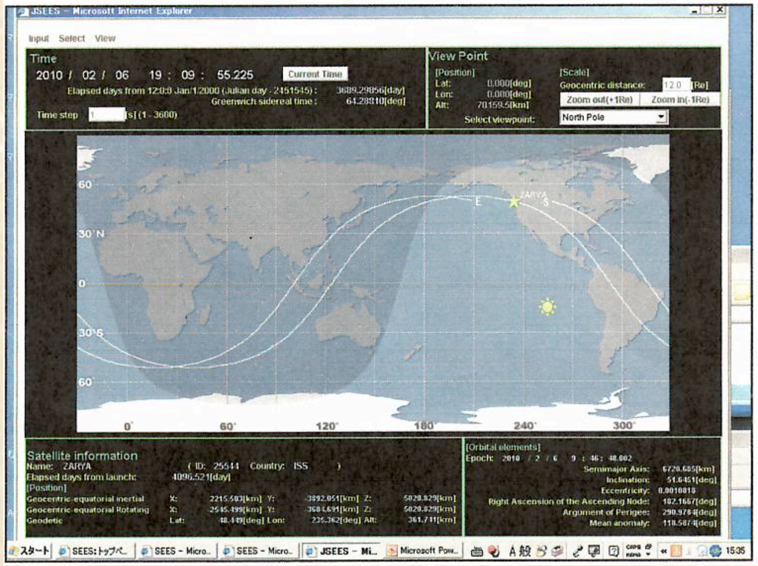

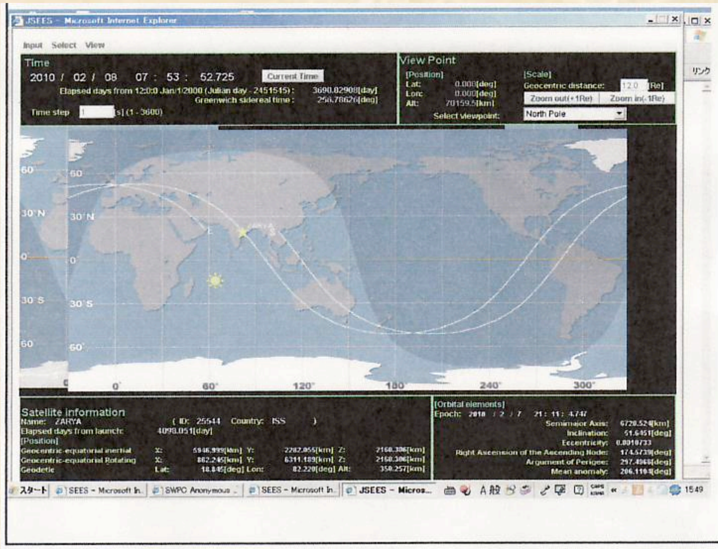

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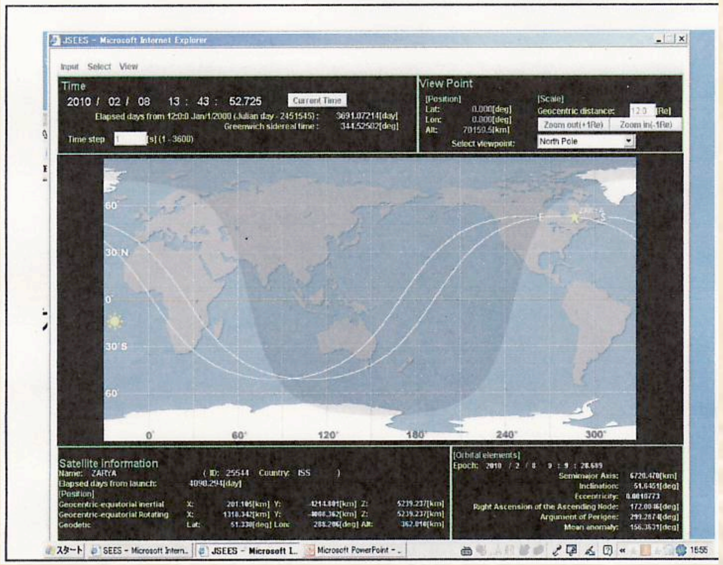
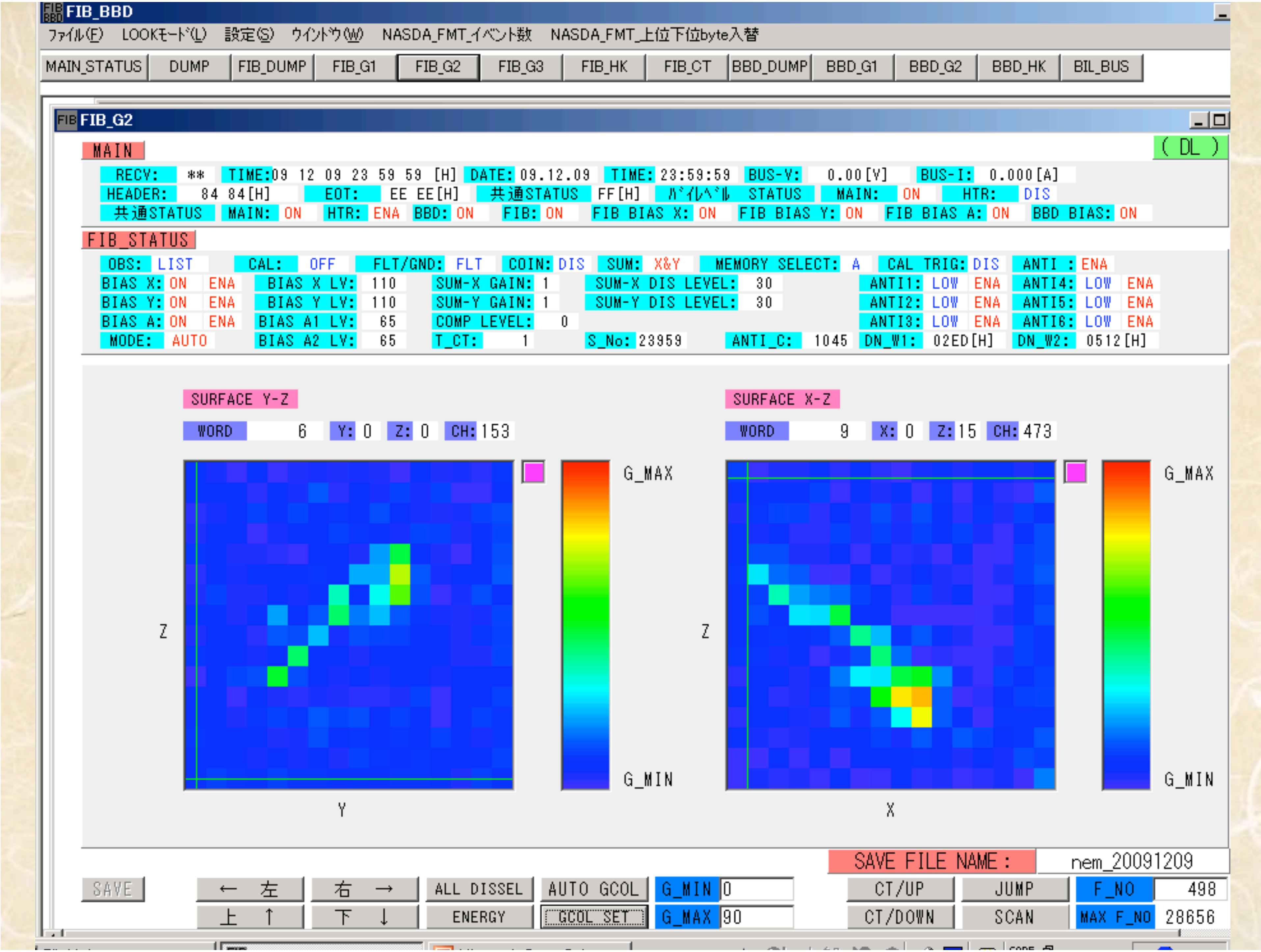
Down 2010.2.8 13:43UT



Results of measurement of solar neutrons

- No evidence of solar neutrons in association with the M-class solar flare of February 2010.
- Therefore we have measured the background over the South Atlantic Anomaly region and over the region except the SAA region.
- Next slides show typical examples of neutrons.


FIB_BBD
ファイル(F) LOOKモード(L) 設定(S) ウインドウ(W) NASDA_FMT_イベント数 NASDA_FMT_上位下位byte入替
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FIB_G2
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FIB_STATUS
OBS: LIST CAL: OFF FLT/GND: FLT COIN: DIS SUM: X&Y MEMORY SELECT: A CAL TRIG: DIS ANTI : ENA
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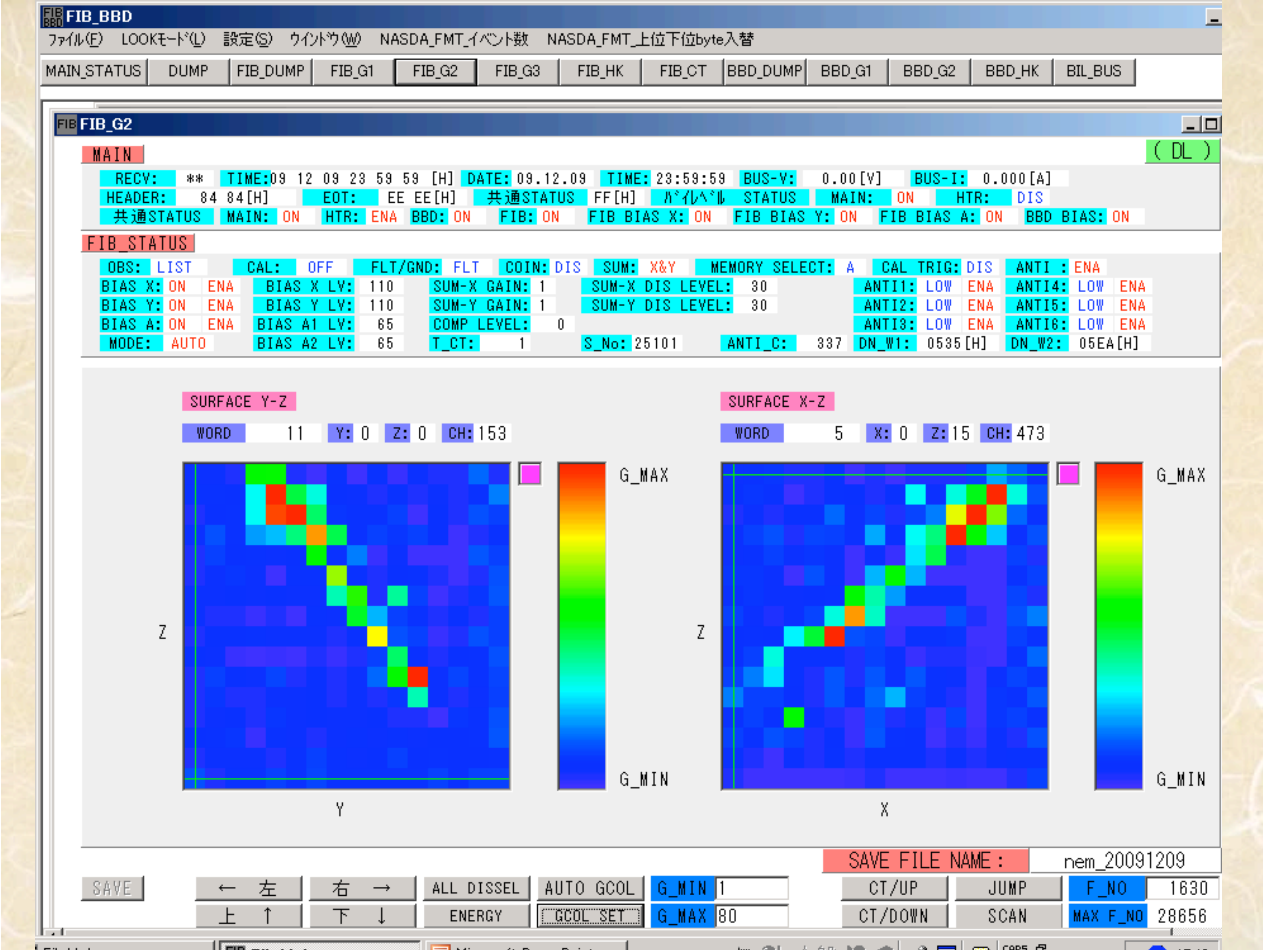

FIB_BBD
ファイル(F) LOOKモード(L) 設定(S) ウインドウ(W) NASDA_FMT_イベント数 NASDA_FMT_上位下位byte入替
MAIN_STATUS DUMP FIB_DUMP FIB_G1 FIB_G2 FIB_G3 FIB_HK FIB_CT BBD_DUMP BBD_G1 BBD_G2 BBD_HK BIL_BUS
FIB_G2
MAIN
(DL)
RECV: ** TIME:09 12 09 23 59 59 [H] DATE: 09.12.09 TIME: 23:59:59 BUS-V: 0.00 [V] BUS-I: 0.000 [A]
HEADER: 84 84 [H] EOT: EE EE [H] 共通STATUS FF [H] バイレベル STATUS MAIN: ON HTR: DIS
共通STATUS MAIN: ON HTR: ENA BBD: ON FIB: ON FIB BIAS X: ON FIB BIAS Y: ON FIB BIAS A: ON BBD BIAS: ON
FIB_STATUS
OBS: LIST CAL: OFF FLT/GND: FLT COIN: DIS SUM: X&Y MEMORY SELECT: A CAL TRIG: DIS ANTI : ENA
BIAS X: ON ENA BIAS X LV: 110 SUM-X GAIN: 1 SUM-X DIS LEVEL: 30 ANTI1: LOW ENA ANTI4: LOW ENA
BIAS Y: ON ENA BIAS Y LV: 110 SUM-Y GAIN: 1 SUM-Y DIS LEVEL: 30 ANTI2: LOW ENA ANTI5: LOW ENA
BIAS A: ON ENA BIAS A1 LV: 65 COMP LEVEL: 0 ANTI3: LOW ENA ANTI6: LOW ENA
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SURFACE X-Z
WORD 5 X: 0 Z: 15 CH: 473
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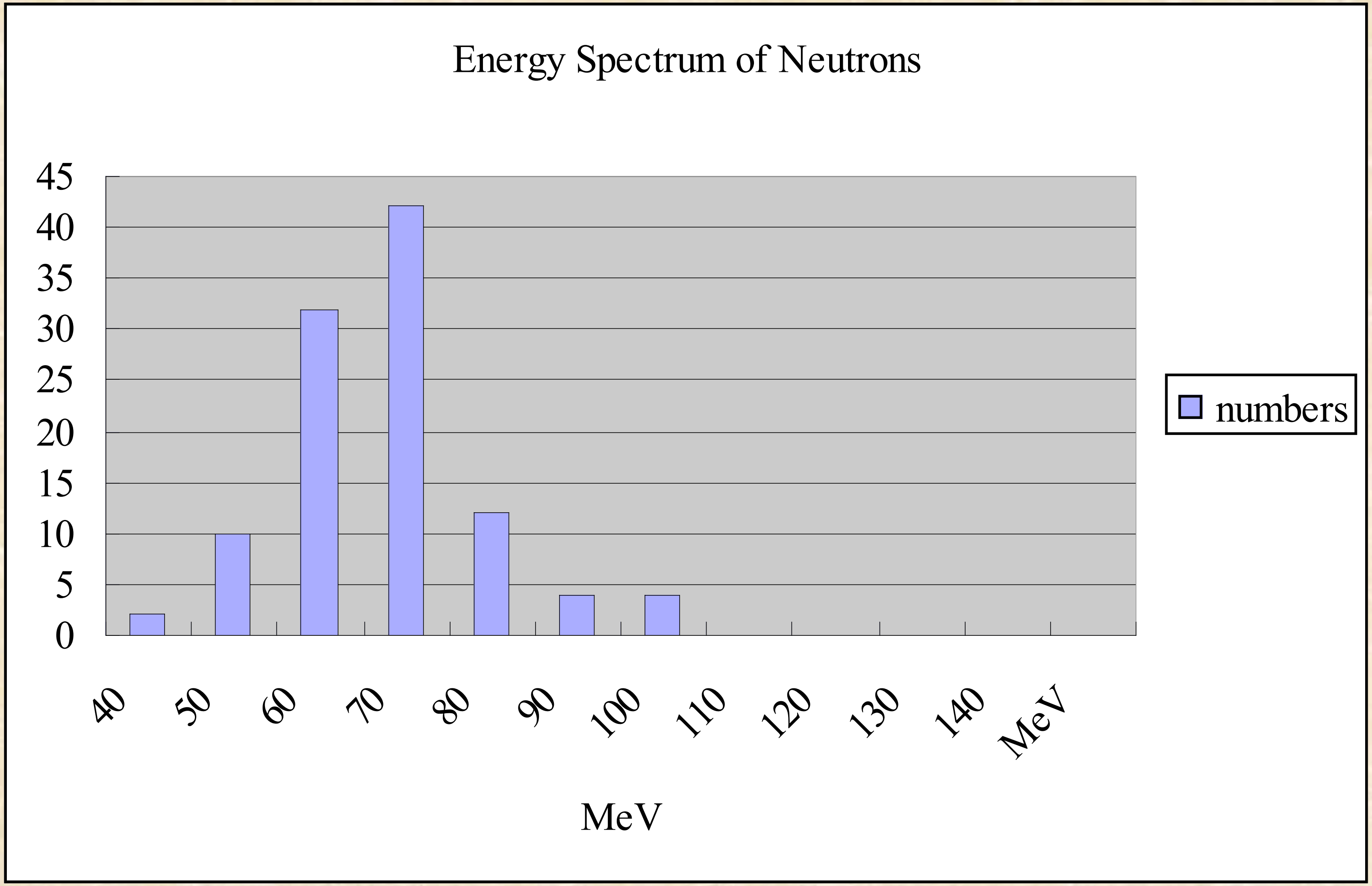
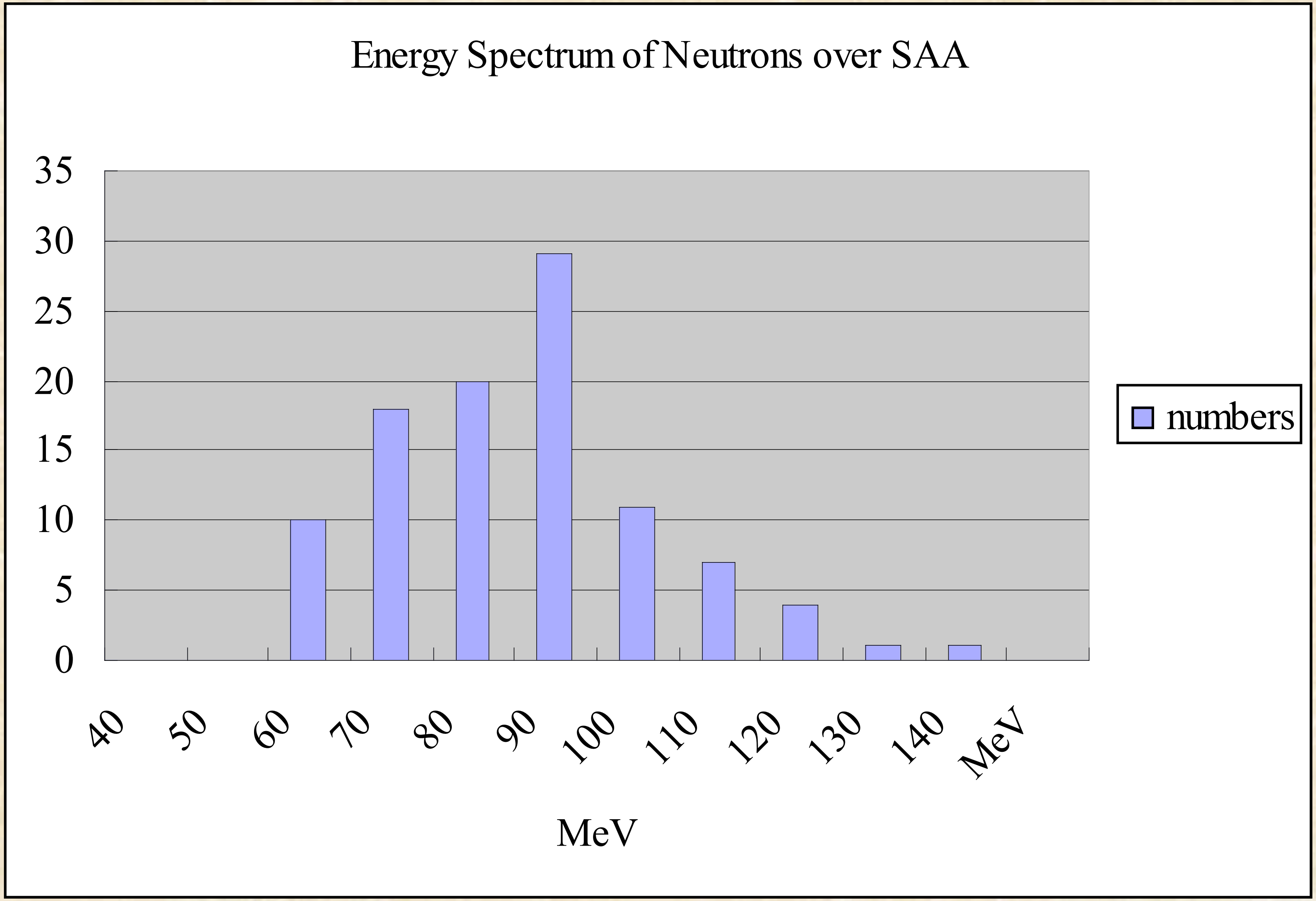
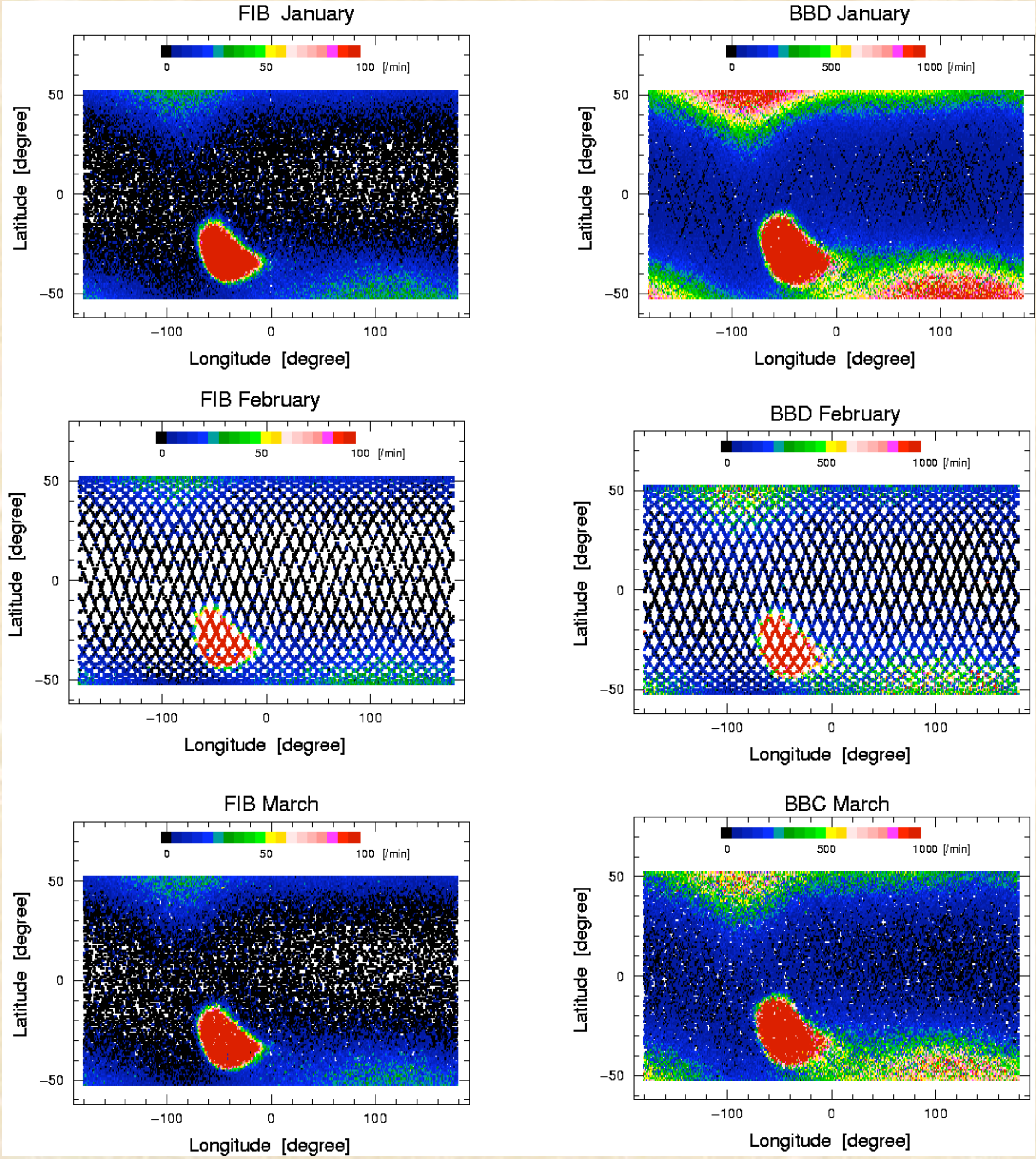
Neutron energy spectrum from ISS main body.
They were induced by GCR ~ 0.047Hz



The energy spectrum of neutrons induced over SAA observed by the FIB detector ~1.7Hz



A sample of the counting rate for three months



5. Future

- Link with ground level neutron detectors will be very important in association with large solar flares.
- Study of the Soft Gamma-ray Repeater (SGR)

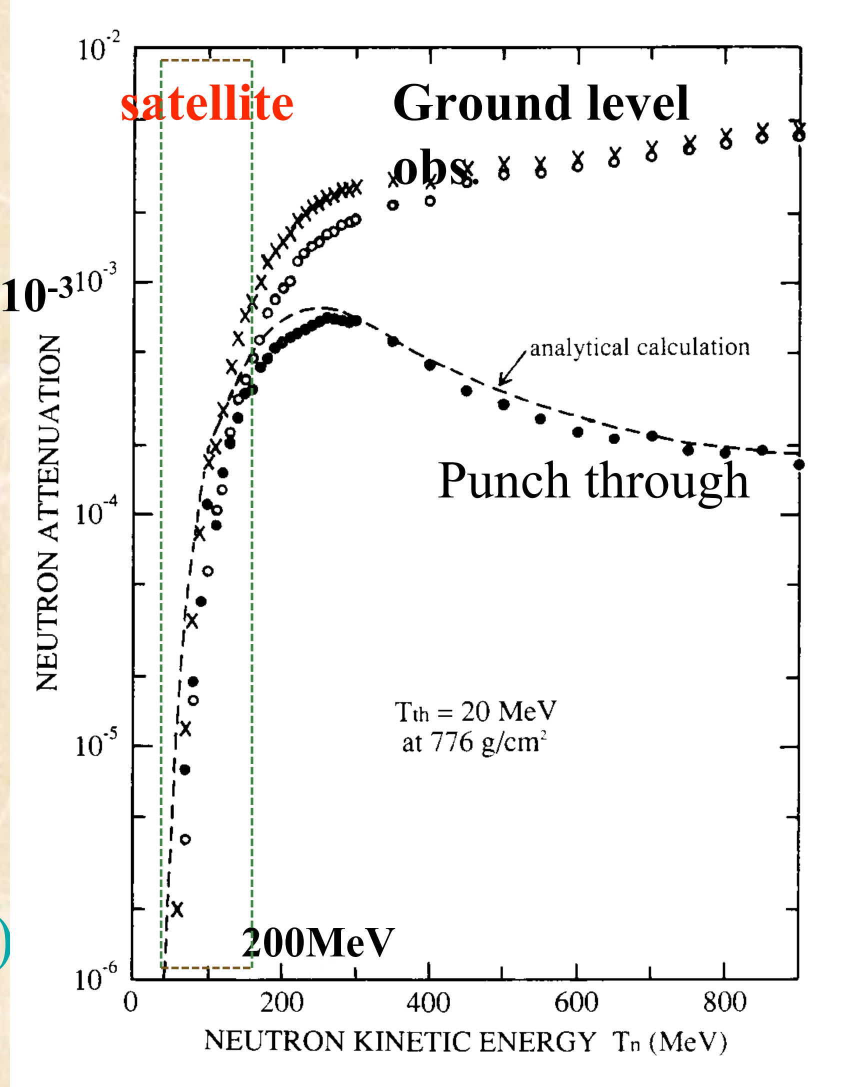
- We are waiting **large solar flares** and **SGRs** !!!
  (> X-class)

Back-up slide

Attenuation curve of neutrons in the atmosphere

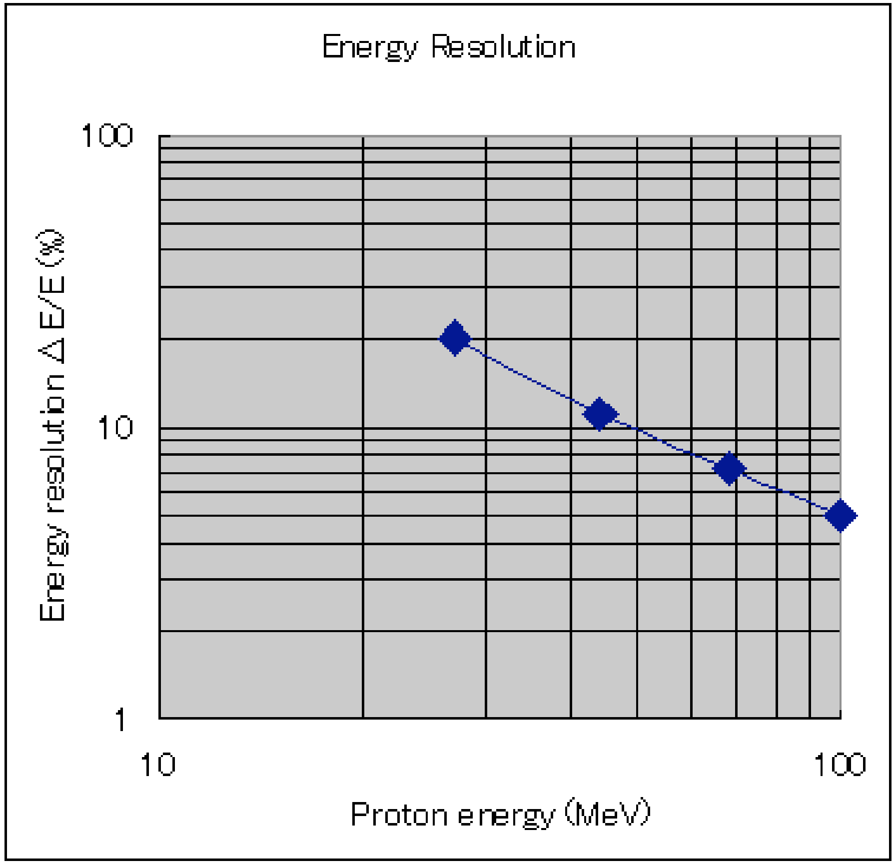
by S. Shibata

- **Absorption** of neutrons in the atmosphere
- **Time dispersion** (the flight time depends on its energy)
- Neutrons decay in flight (70% @100 MeV 27%@1GeV)



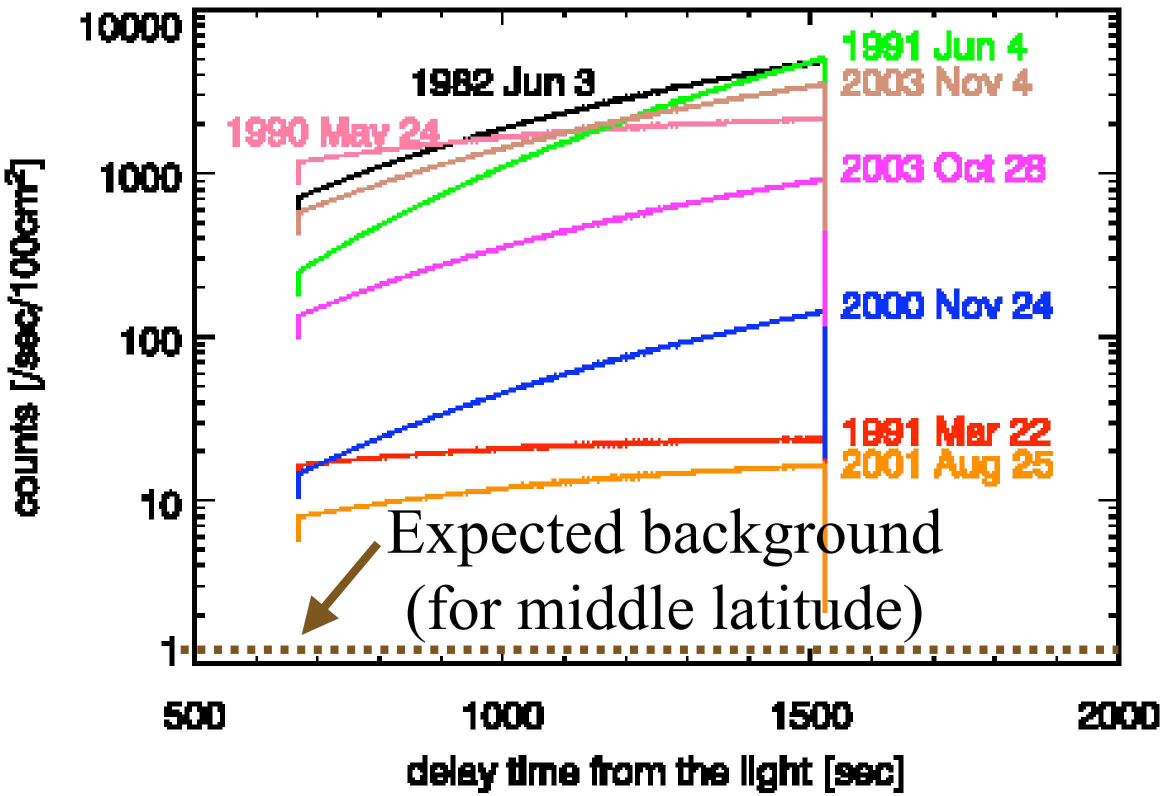
The energy resolution of the FIB detector

*The energy resolution of the FIB detector has been measured by the proton beam at Riken.
*It turns out as $\Delta E/E \approx 10\%/\sqrt{E/(50MeV)}$



Expected Event Rate

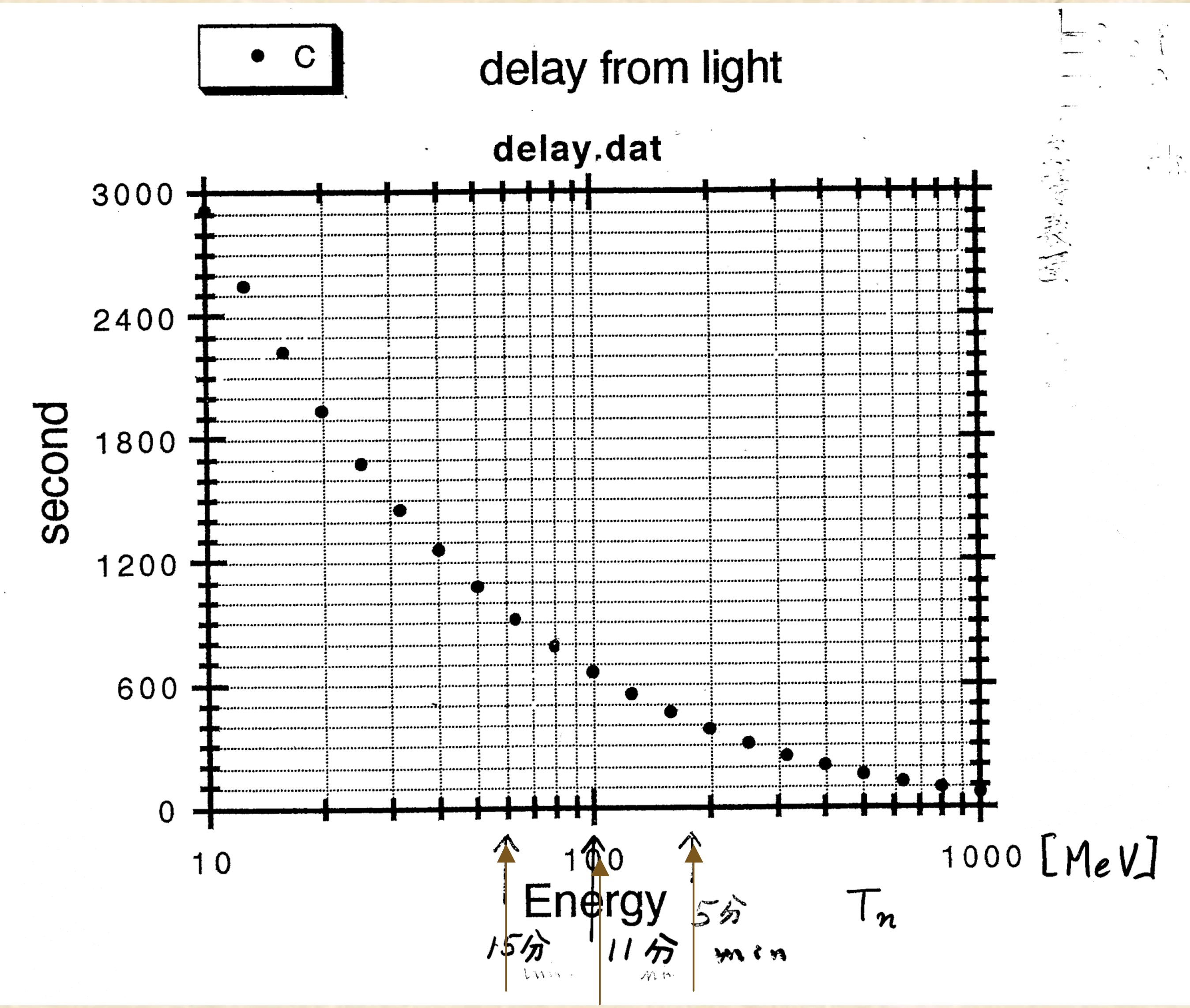
by Kyoko Watanabe



Mission STS 127 at Kennedy space center

on June 13th, 2009

Neutron flight time from the Sun



The basic knowledge to understand them

Let us remind of a fact

○Neutrons cannot travel the space by the speed of the light

The example of **the time dispersion**

E_n		delays
1 GeV	→	1min
200MeV	→	6min
100MeV	→	11min
70MeV	→	14min

○Therefore the measurement of the energy of neutrons is very important to understand the acceleration process, so we have prepared a new solar neutron global network based on the plastic scintillator.

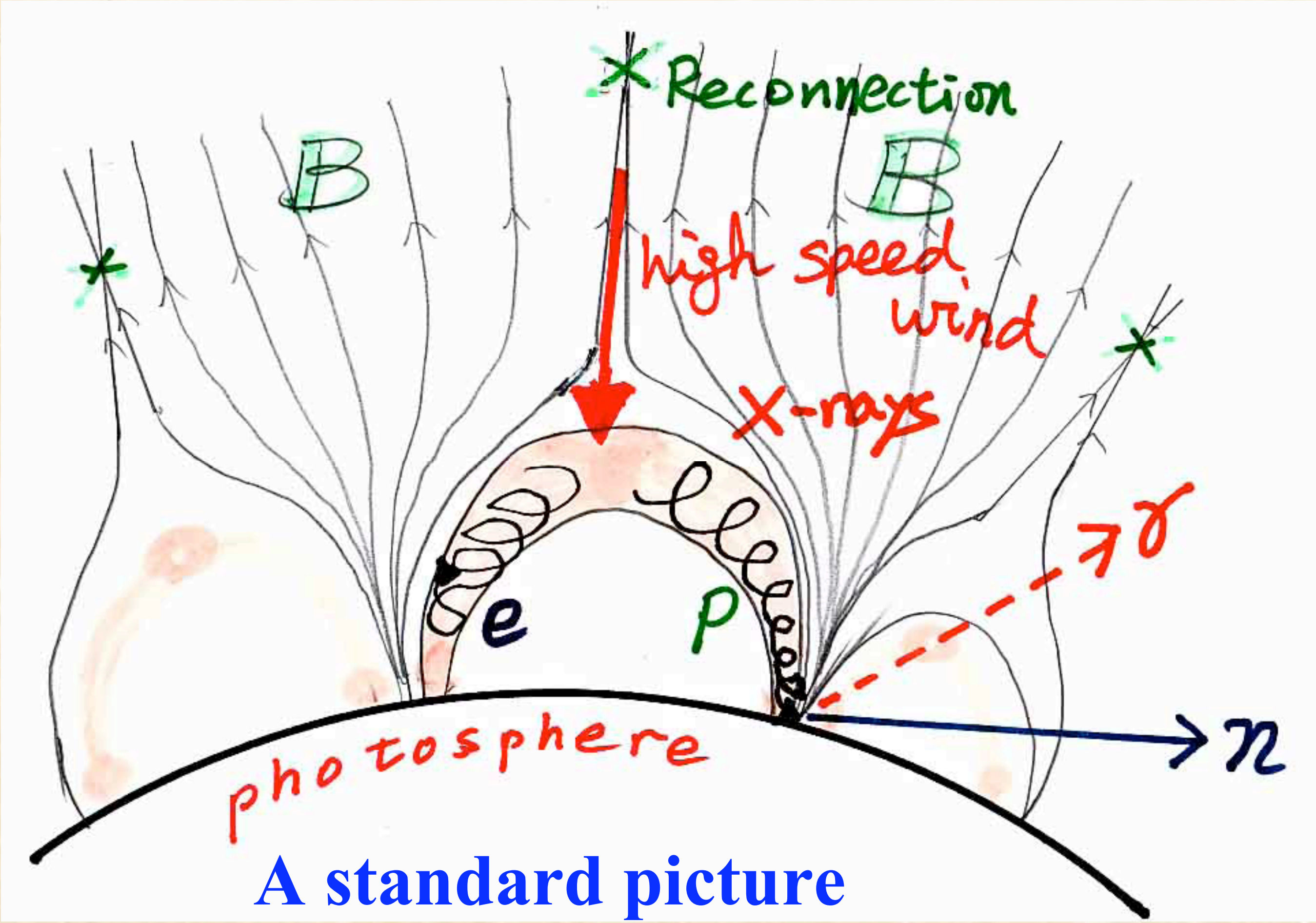
We are studying the acceleration mechanism over the Sun

The dynamical motion of the magnetic loops is the origin of the solar flare and hence the origin of the particle acceleration **Plasma jet** is formed at the top of the Solar surface.

We are searching a deviation from the standard model.

Micro processes

Tension
Plasma heating
~3000km/s
~70sec
from 20MeV
to 40 GeV
n~400 times
P+He collisions
Charge exchange



A standard picture

Space Environment monitor **SEDA** will be mounted in May 2009 at ISS