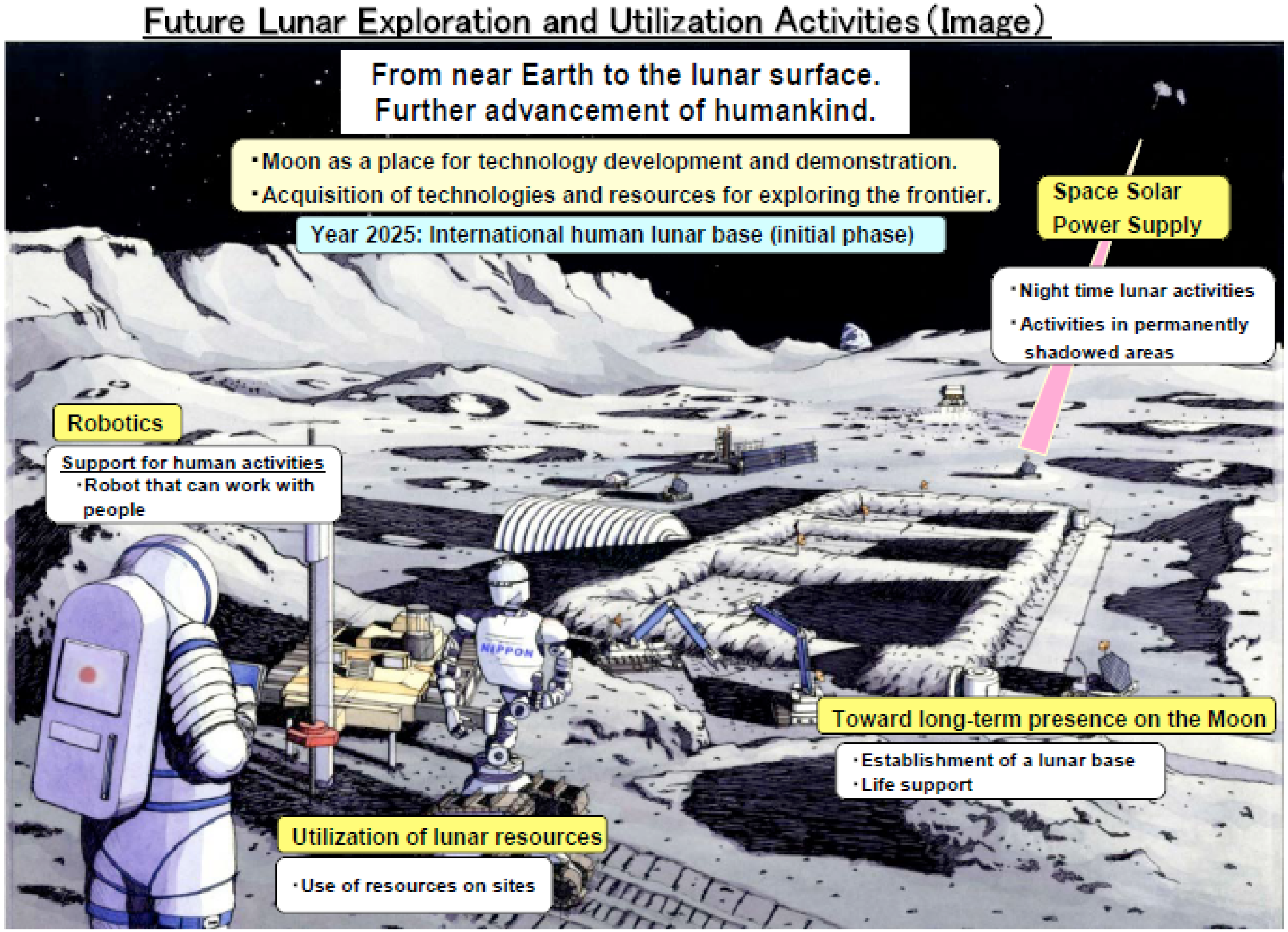
Calculation of Radiation Exposure on the Moon Surface by using PHITS

Tatsuto Komiyama, Haruhisa Matsumoto
IAT/JAXA

2008/2/14

JAXA Vision

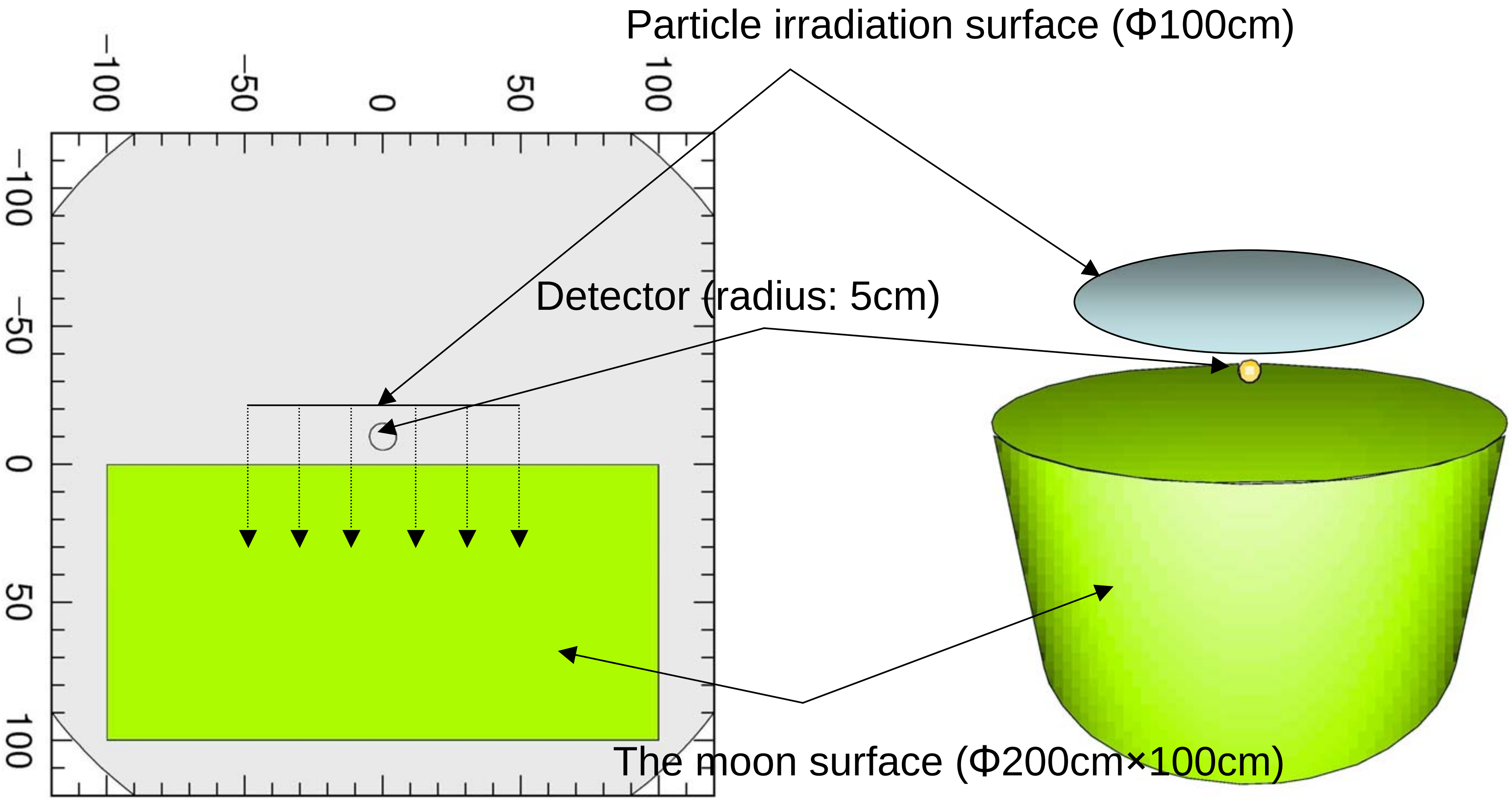


2008/2/14

Method to Calculate Radiation Spectra on the Moon Surface

- GCR model
  - CREME86
    - Using spectra out of magnetosphere
    - Solar minimum
    - Proton - Ni
    - Solid angle: 2π
    - >10MeV/n
- SPE model
  - CREME96 WORST DAY
- Radiation transportation
  - To calculate secondary neutrons and secondary photons from interactions between the moon surface and GCR/SPE by using radiation transportation code “PHITS”. (considering gamma rays from activated nuclei)
- Geometry for calculation
  - Next slide

Geometry to calculate secondary neutrons and photons

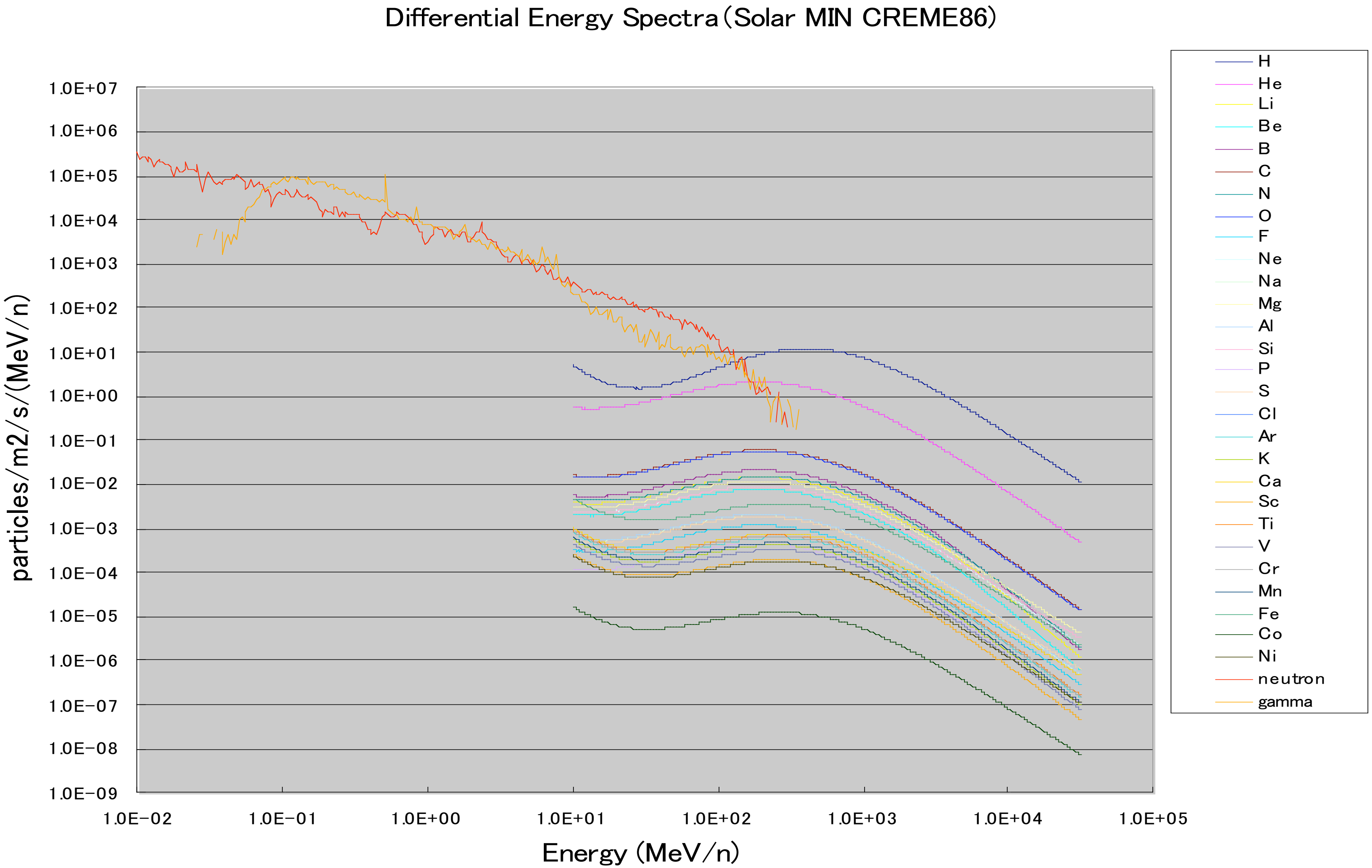


2008/2/14

Chemical Composition of the Moon Surface

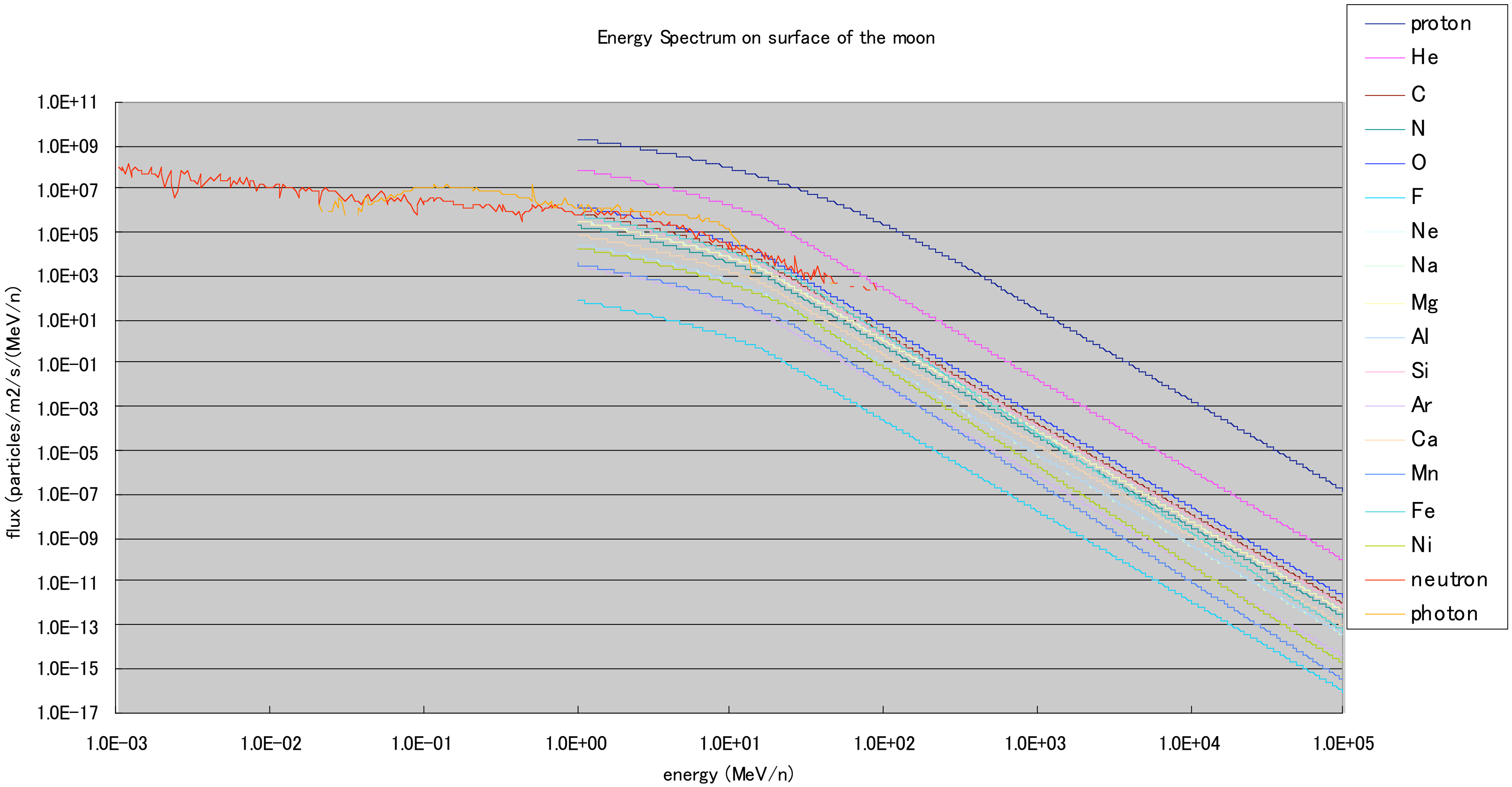
- Fraction by number of atoms
  - O 60%
  - Si 17%
  - Al 4.5%
  - Ca 4.5%
  - Mg 5%
  - Fe 6%
  - Ti 1.5%
- Reference: Haskin, L., and P. Warren, Lunar chemistry, in Lunar Sourcebook, 357-474, Cambridge Univ. Press, New York, 1998.

Calculation Result
GCR + secondary neutrons and photons



2008/2/14

Calculation Result
SPE + secondary neutrons and photons

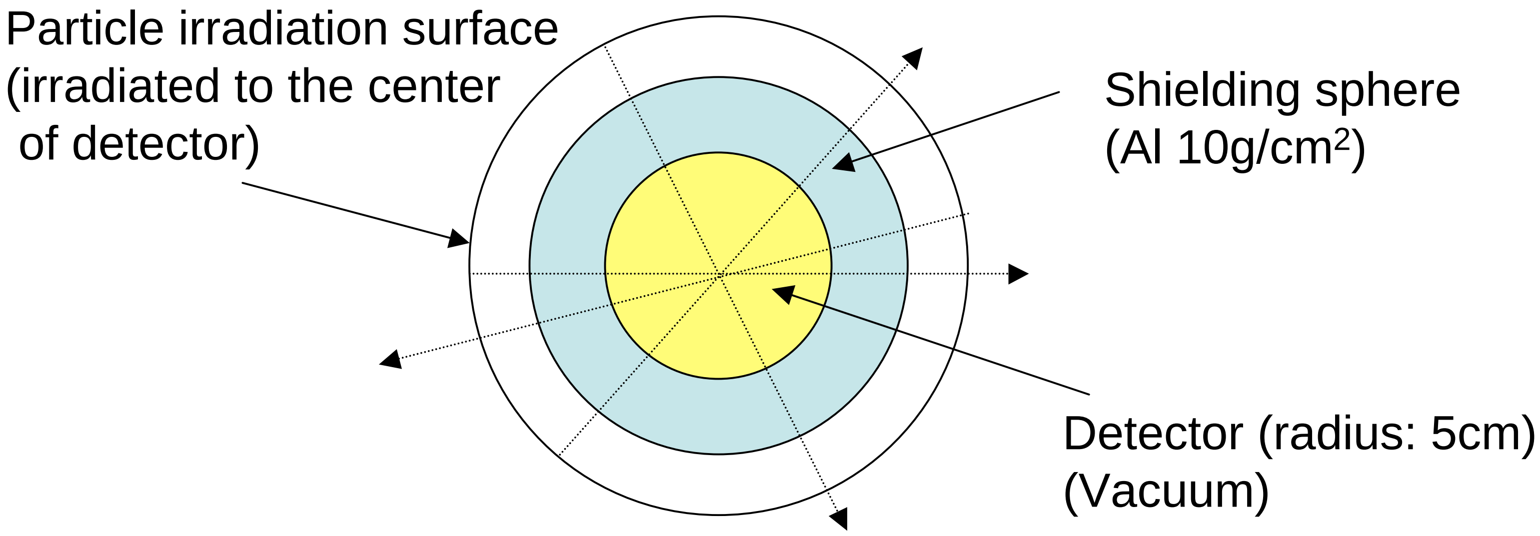


2008/2/14

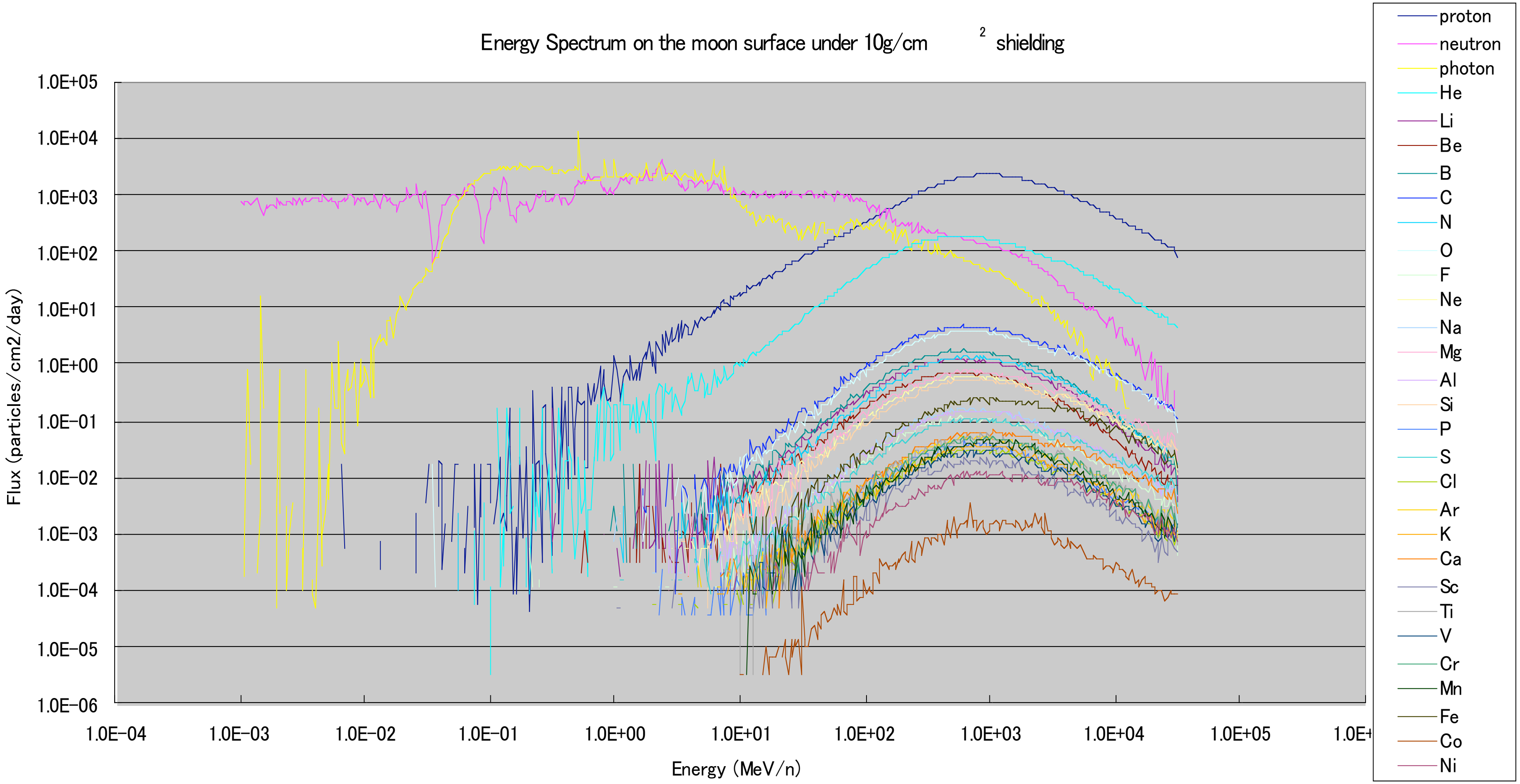
Method to Calculate Radiation Spectra under $10g/cm^2$ (Al) shielding

- Input: spectra of the previous slides
  - GCR
  - SPE
  - Secondary neutrons and photons
- Radiation transportation
  - To calculate spectra of radiation transported through $10g/cm^2$ (Al) shielding by using PHITS
- Geometry
  - Next slide

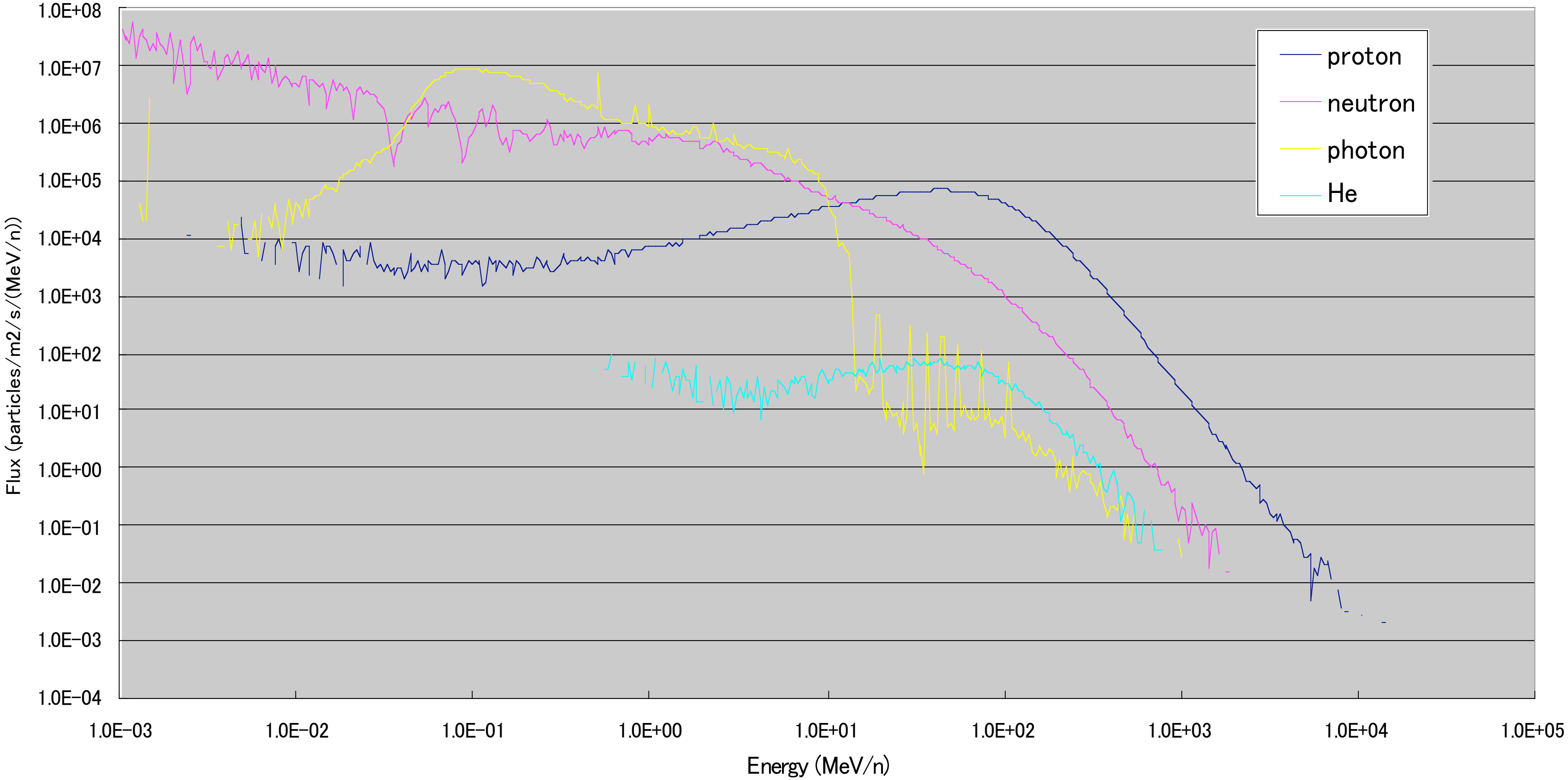
Geometry to Calculate Radiation Spectra under 10g/cm^2 (Al) shielding



Calculation Result
Energy spectra under 10g/cm^2 (Al) shielding in Solar MIN@CREME86



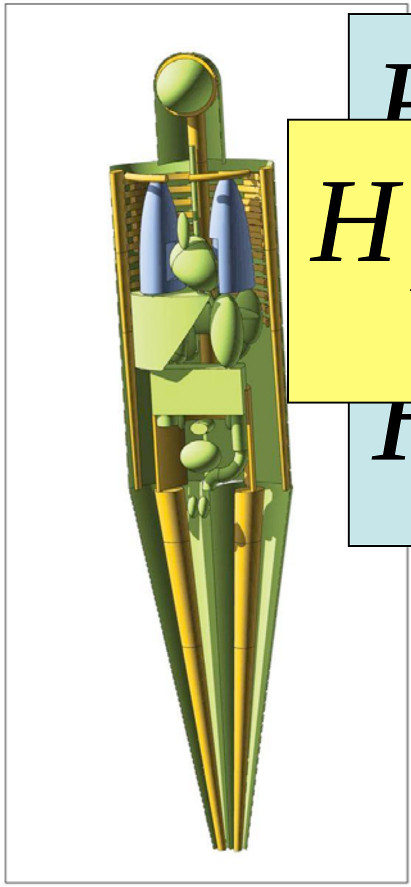
Calculation Result
Energy spectra under 10g/cm^2 (Al) shielding in SPE Worst Day@CREME96

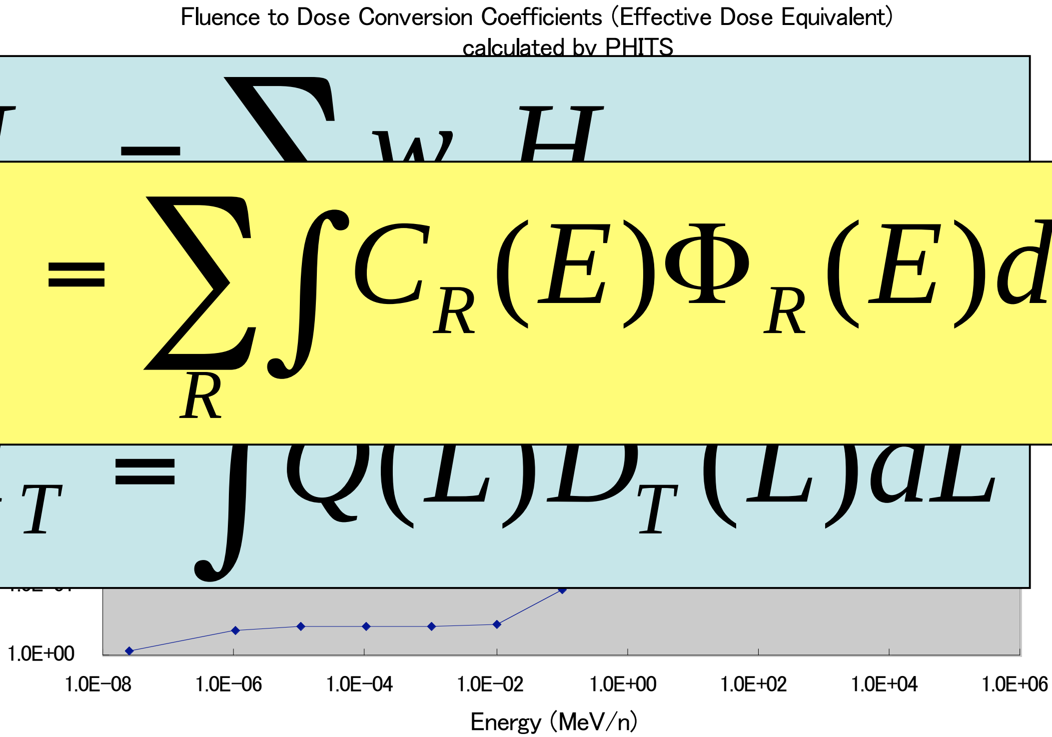


2008/2/14

Method to Calculate dose exposed on the Moon surface

- Using conversion coefficients from fluence to effective dose equivalent calculated by PHITS.





$$H \ = \sum w \ H$$

$$H_E = \sum_R \int C_R(E) \Phi_R(E) dE$$

$$H_T = \int Q(L) D_T(L) dL$$

"Conversion Coefficients from Fluence to Effective Dose for Heavy Ions with Energies up to 3GeV/A" T.Sato, et al., Radiat. Prot. Dosim. 106(2), 137-144(2003)

"Profile of Energy Deposition in Human Body Irradiated by Heavy Ions" T.Sato et al. J. Nucl. Sci. Technol. Suppl. 4 287-290 (2004)

Calculation Result
Exposed Dose on the Moon Surface

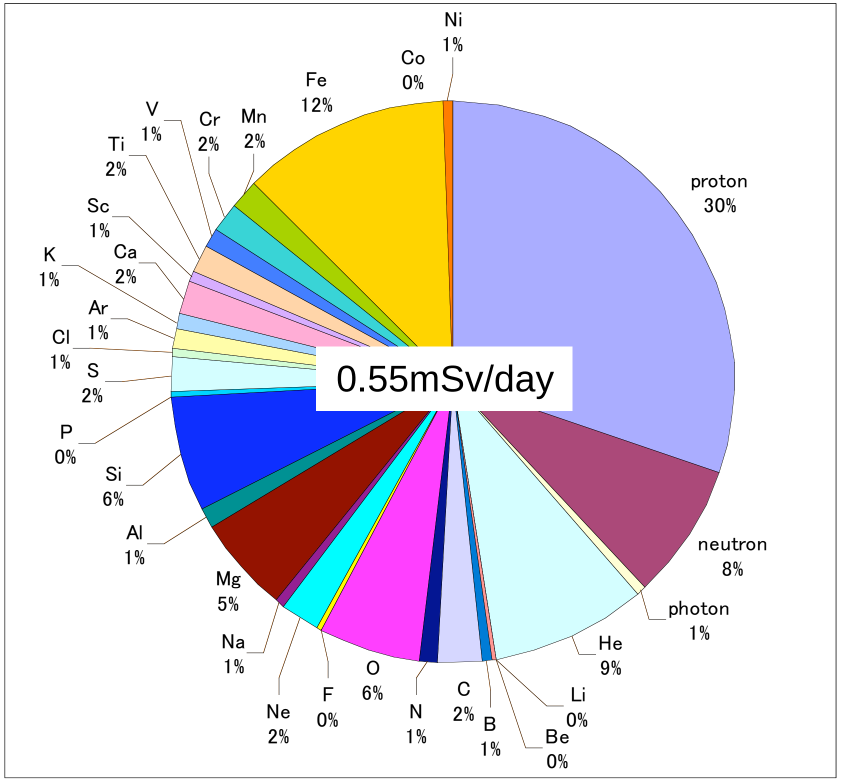
Effective Dose Equivalent

	No shielding		$10 g/cm^2$ (Al) shielding	
	GCR CREME86 MIN	SPE Worst day	GCR CREME86 MIN	SPE Worst day
PHITS	0.71 mSv/day	4100 mSv/day	0.55 mSv/day	36 mSv/day

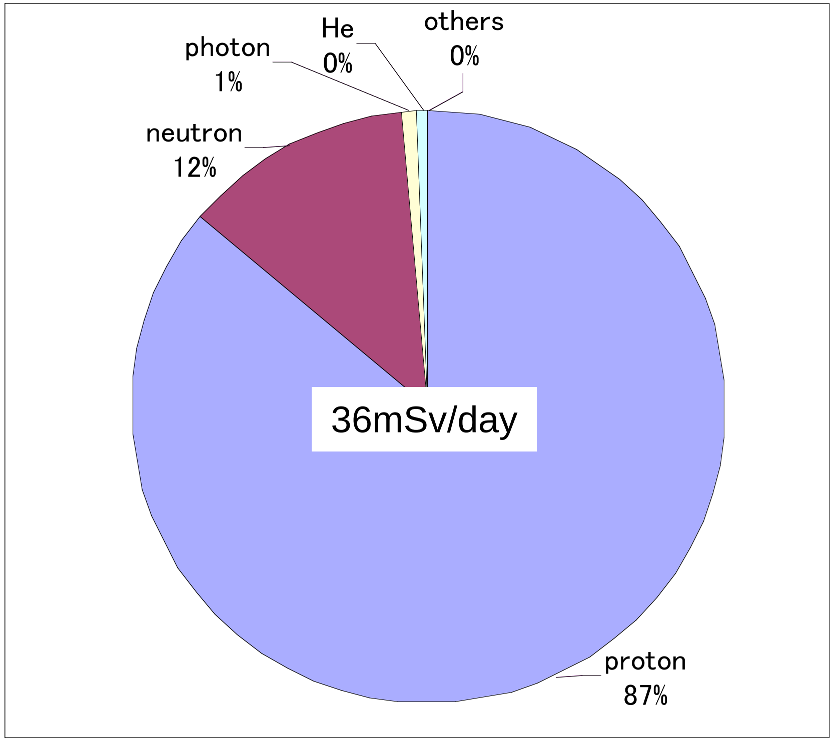
In long term manned mission on the moon, shielding design and space weather forecast are expected to be very important.

Calculation Result
Contribution to dose

・under 10g/cm^2 (Al) shielding



GCR: CREME86



SPE Worst Day

Future Works

- To calculate energy spectra and dose in various shielding thicknesses
- To calculate energy spectra and dose in various shielding materials

Summary

- Radiation environment and exposed dose has been calculated by PHITS.
- It is suggested that shielding design and space weather forecast are to be very important in the long term manned space mission on the moon.
- Calculation of energy spectra and dose under various shieldings will be needed for conceptual design of the manned mission on the moon.