PHITS

Multi-Purpose Particle and Heavy Ion Transport code System

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Overview of PHITS (Particle and Heavy Ion Transport code System) (1)

1951	1983	1997	2001	2003
NMTC	NMTC/JAERI	NMTC/JAERI97	NMTC/JAM	PHITS
(ORNL)	High Energy Fission	CG geometry	JAM, GG Magnetic Field	JQMD, MCNP Gravity

PHITS = MCNP + JAM + JQMD

MCNP	Neutron, Photon, Electron Transport by Nuclear Data
JAM	Hadron-Nucleus Collisions up to 200 GeV
JQMD	Nucleus-Nucleus Collisions by Molecular Dynamics

External Field: Magnetic Field, Gravity Optical and Mechanical devices

Language and Parallelism

FORTRAN 77
MPI

Transport Particle and Energy

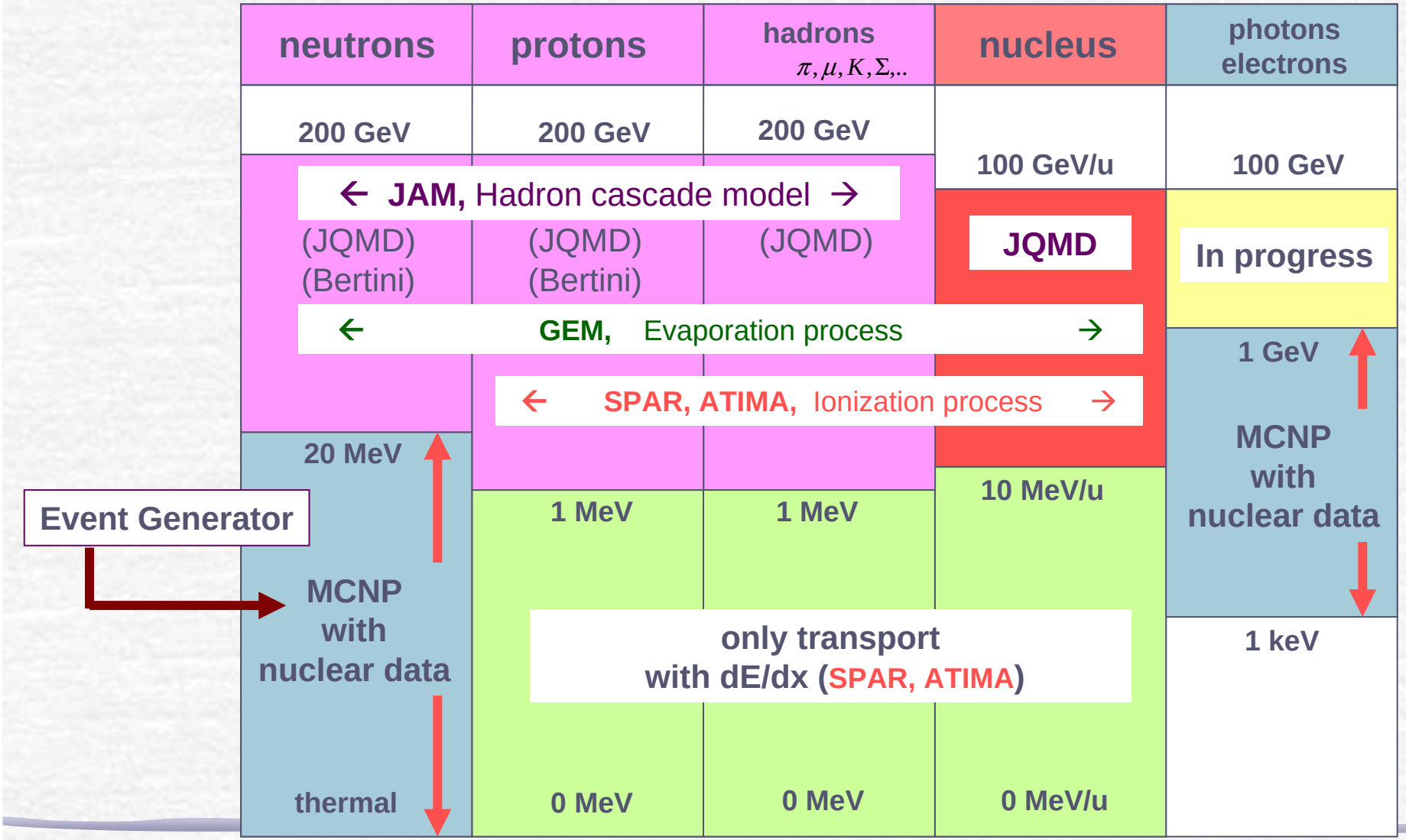
Proton	0 ~ 200 GeV
Neutron	10^{-5} eV ~ 200 GeV
Meson	0 ~ 200 GeV
Barion	0 ~ 200 GeV
Nucleus	0 ~ 100 GeV/u
Photon	1 keV ~ 1 GeV
Electron	1 keV ~ 1 GeV

Geometry: CG and GG

Tally, Mesh and Graphic

Tally: Track, Cross, Heat, Star, Time, DPA, Product, LET
Mesh: cell, r-z, xyz
Counter:
Graphic: ANGEL (PS generator)

Overview of PHITS (Particle and Heavy Ion Transport code System) (2)



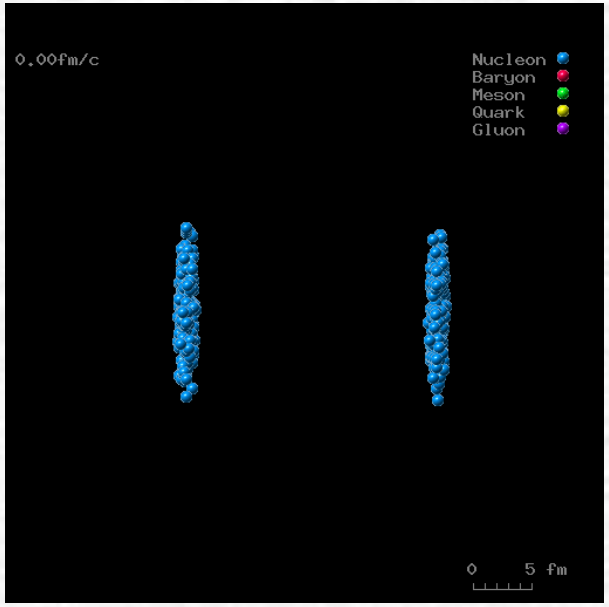
JAM code for Hadron Nucleus Collisions up to 200 GeV

Introducing JAM *(Jet AA Microscopic Transport Model)* Y. Nara et.al. *Phys. Rev.* **C61** (2000) 024901

JAM is a ***Hadronic Cascade Model***, which explicitly treats all established hadronic states including resonances with explicit spin and isospin as well as their anti-particles.

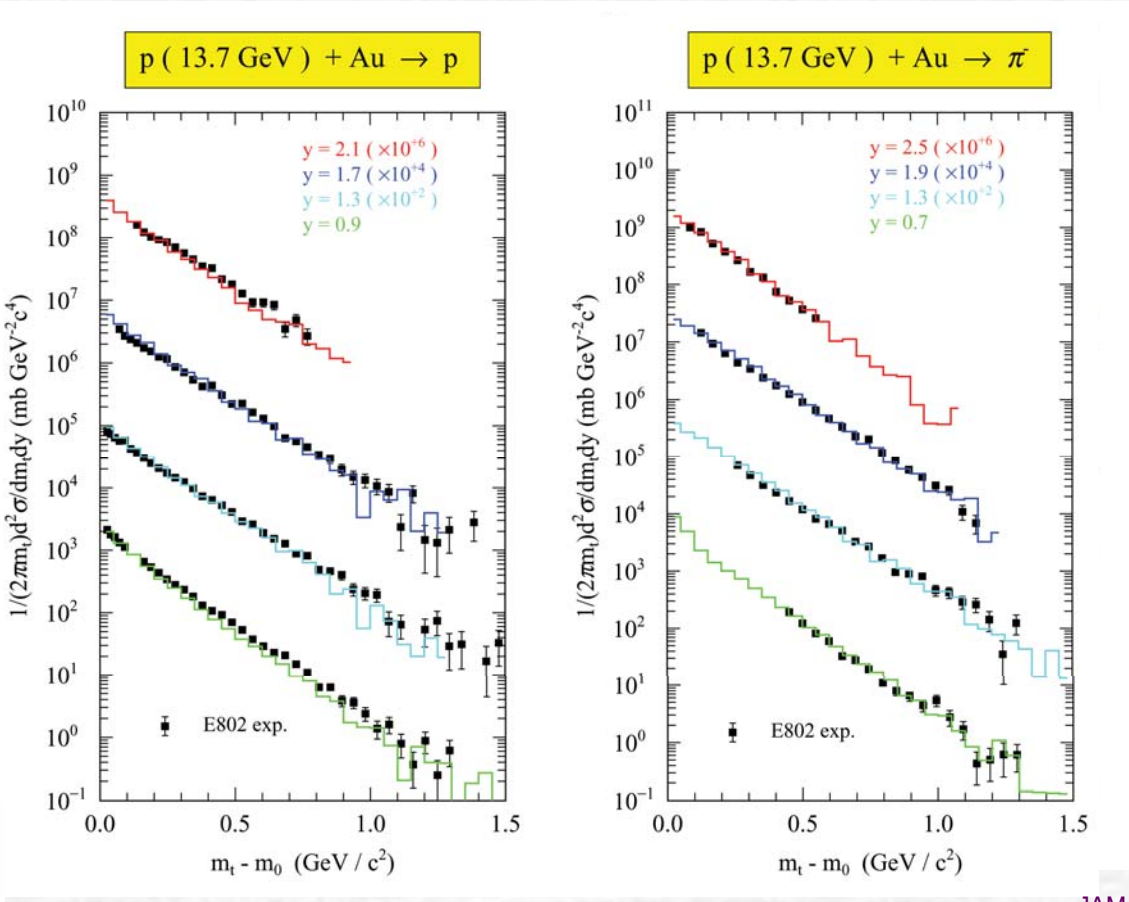
We have parameterized all ***Hadron-Hadron Cross Sections***, based on ***Resonance Model*** and ***String Model*** by fitting the available experimental data.

Au+Au 200GeV/u in cm



119 kinds of Mesons

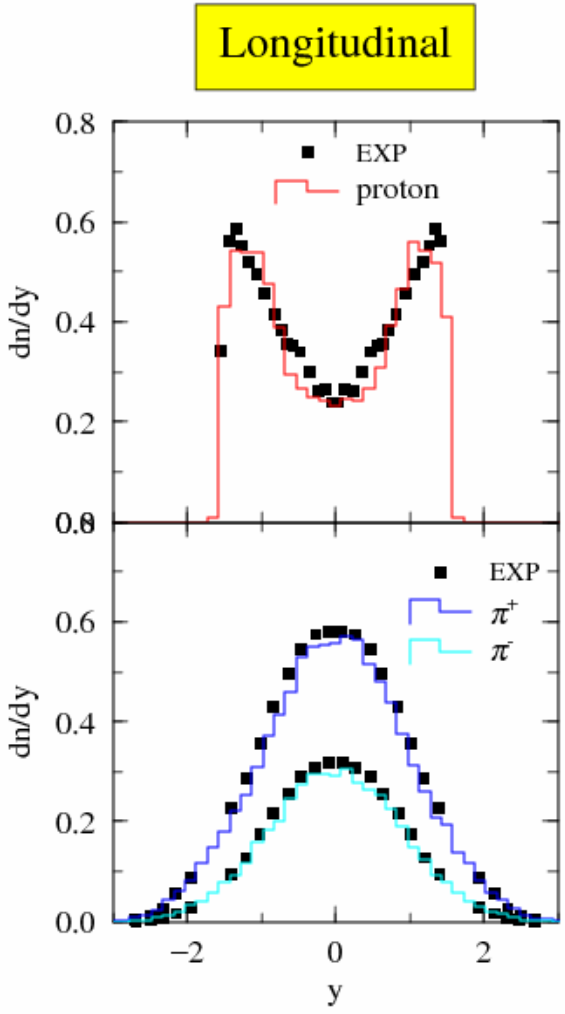
170 kinds of Baryons



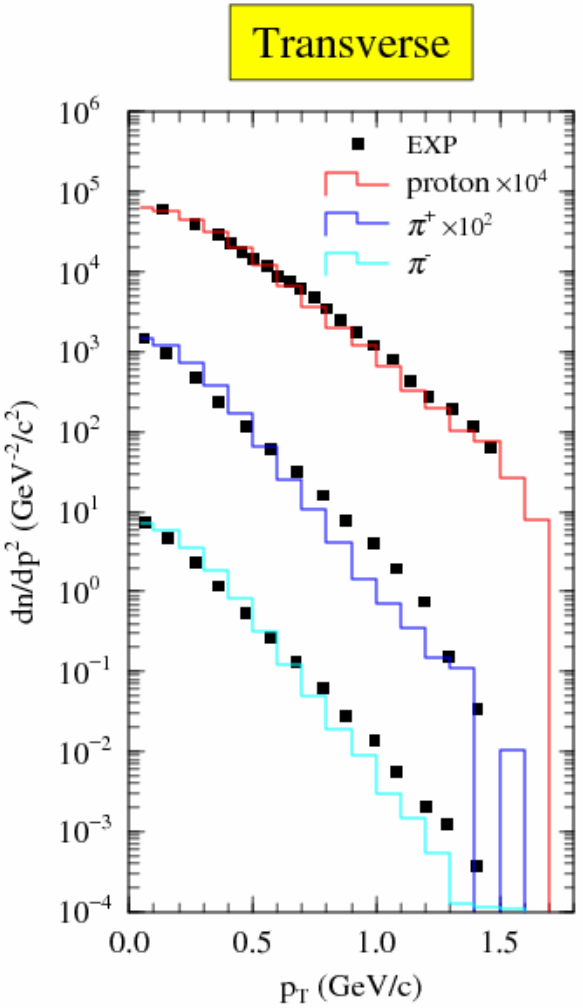
DDX of elementary process, p(12GeV/c) + p , by JAM

JAM: Y. Nara et.al. Phys. Rev. **C61** (2000) 024901

rapidity distribution



transverse momentum distribution



Data : Nucl. Phys. **B69** (1974) 454

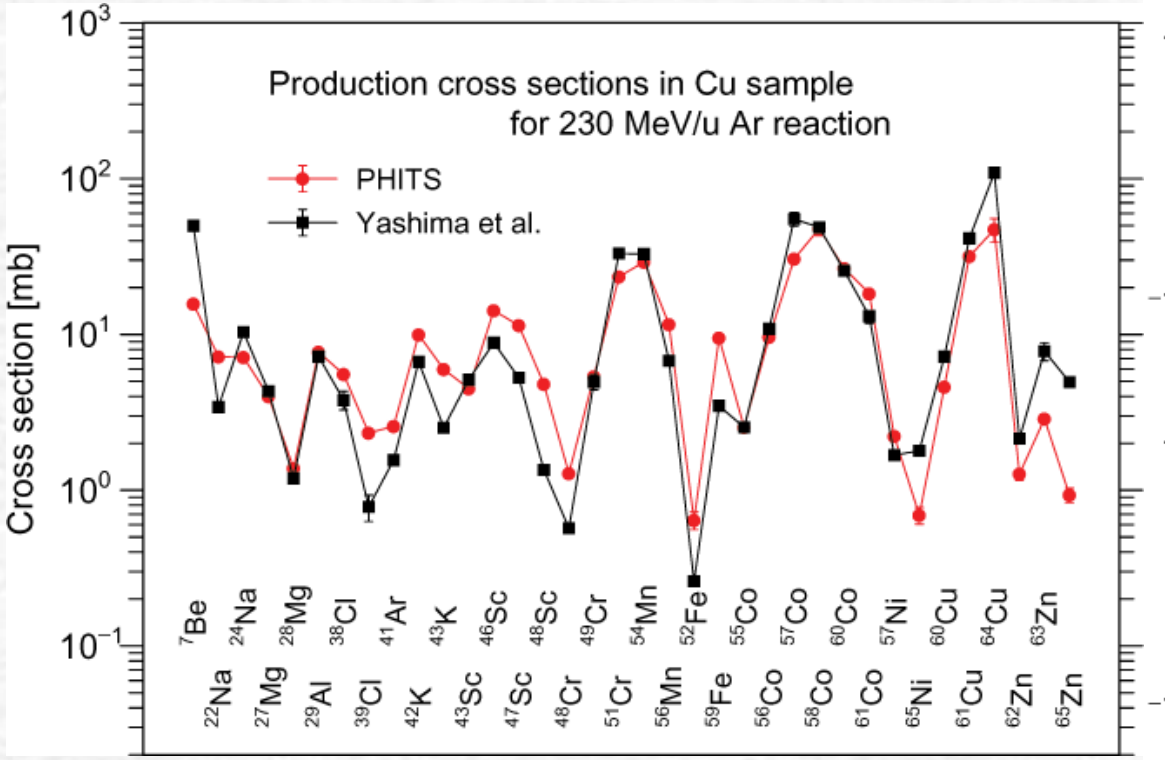
JQMD code *for Nucleus-Nucleus Collisions up to 100 GeV/u*

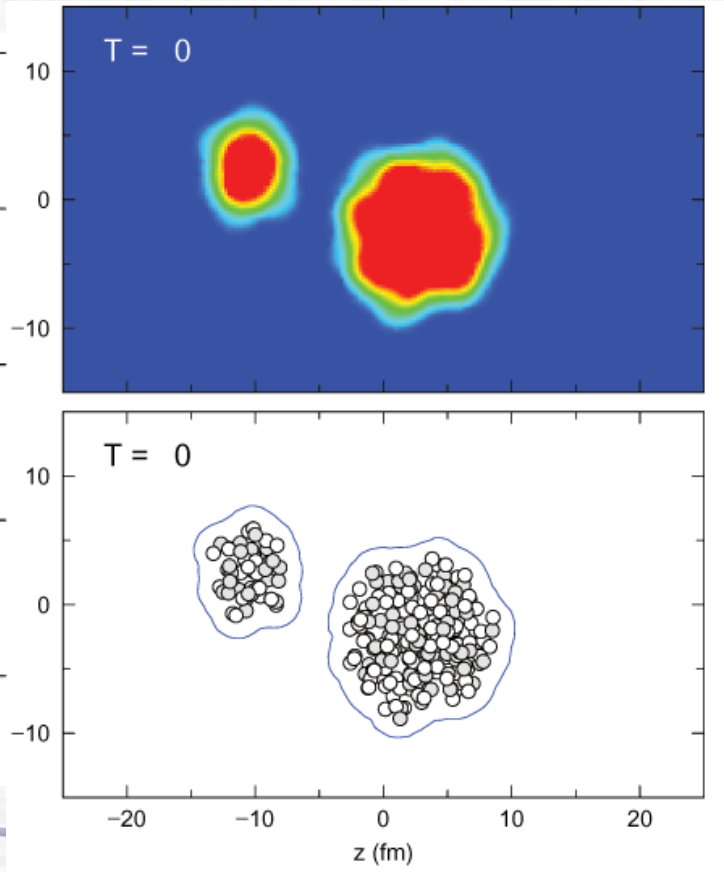
JQMD *(Jaeri Quantum Molecular Dynamics) for Simulation of Nucleus-Nucleus Collisions*

K. Niiita et.al. *Phys. Rev.* **C52** (1995) 2620 *http://hadron31.tokai.jaeri.go.jp/jqmd/*

Analysis of Nucleus-Nucleus Collisions by ***JQMD***

^{56}Fe 800 MeV/u on ^{208}Pb



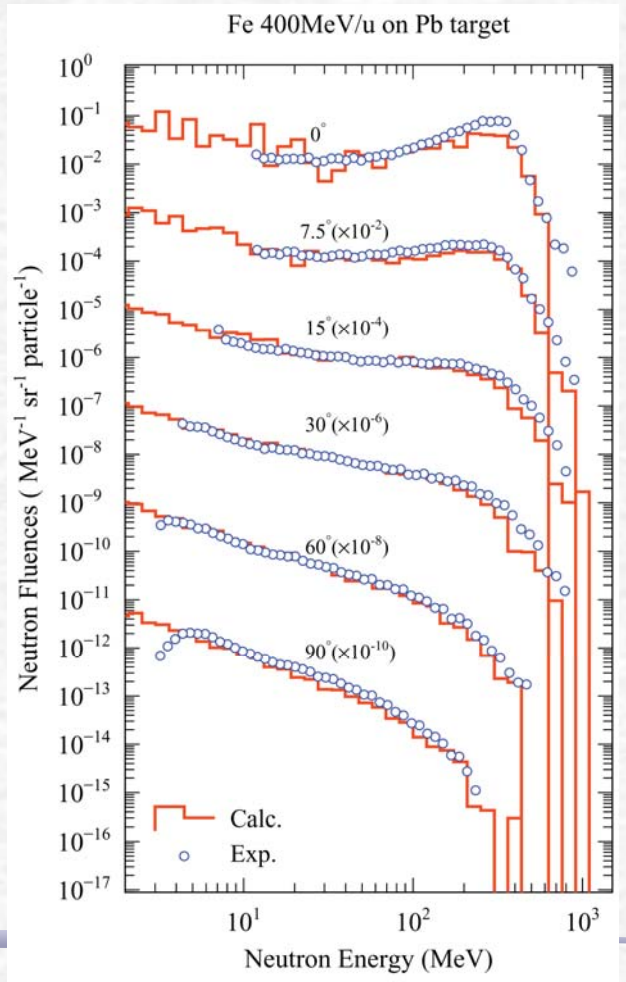


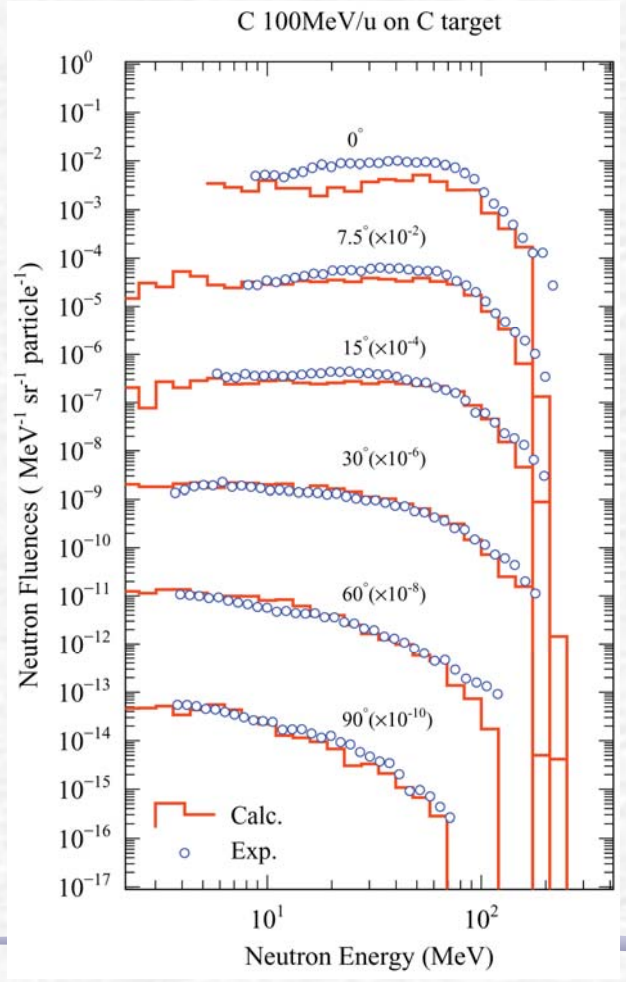
JQMD code in PHITS

Introducing JQMD in PHITS : H. Iwase et.al. *J. Nucl. Sci.Technol.* **39** (2002) 1142

Results of PHITS

Neutron Spectra from Thick Target





Event Generator Mode of PHITS

What are we doing in Monte Carlo calculations for particle transport ?

- **Solving one-body Boltzmann equation by using the evaluated nuclear data.**
  - **MCNP type code** ⇒ **Only one-body observables**
    energy is conserved in average.
    no correlations
- **Simulating real phenomena by using event generators.**
  - **PHITS for high energy by JAM, JQMD.**
    treat all ejectiles of collisions.
    energy and momentum are conserved in each collision.

Event Generator ⇒ **Any observables**

Observables beyond one-body quantities are often required.

Deposit energy distribution in a cell (pulse height tally).
LET distribution in a micro dosimetry,
Coincident experiments, ……

Event Generator Mode for low energy neutrons in PHITS

Neutron data + Special Evaporation Model

We use the channel cross sections and neutron energy spectrum of the first neutron and assume the binary decay of recoiled nucleus.

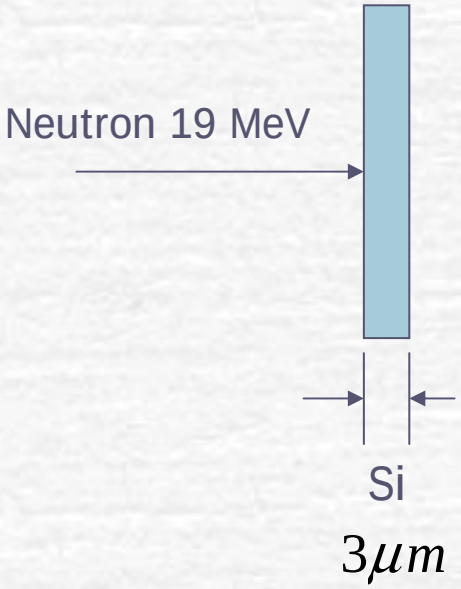
Neutron channels	capture	$\Gamma_n = 0$	charged particle and photon decay
	elastic		final state is uniquely determined
	(n,n')	$\Gamma_n = 0$	charged particle and photon decay after the first neutron emission
	(n,Nn')	$\Gamma_n \neq 0$	all particle and photon decay after the first neutron emission

By this model, we can determine all ejectiles (neutrons, charged particles, nucleus and photons) with keeping energy and momentum conservation.

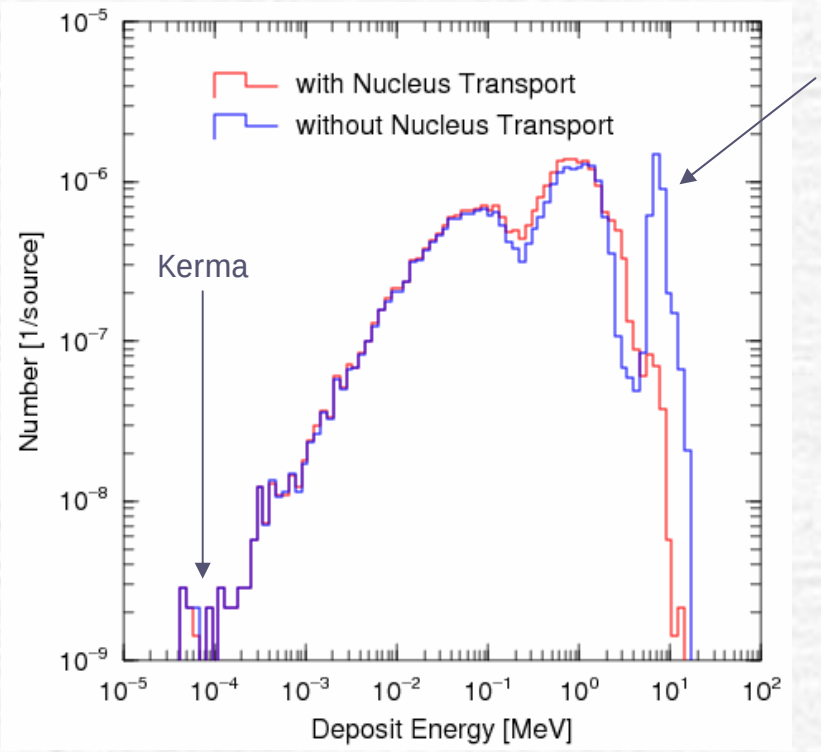
PHITS can transport all charged particle and nucleus down to zero energy and estimate deposit energy without local approximation (kerma factor).

*An example of **Event Generator Mode***

Neutron-induced semiconductor soft error (SEU: single event upset)

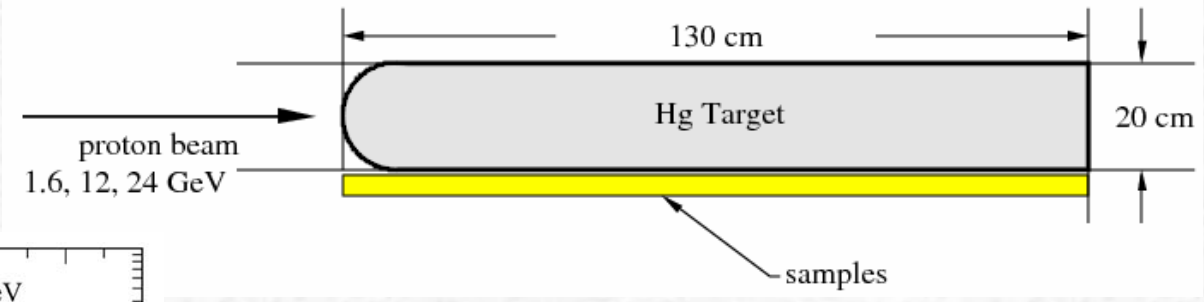


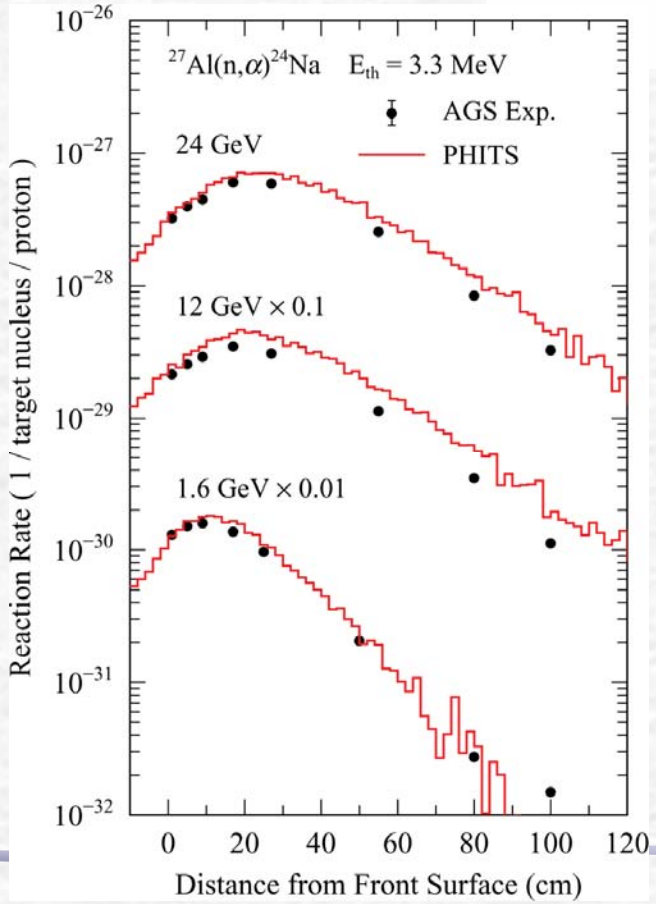
Deposit Energy Distribution by PHITS

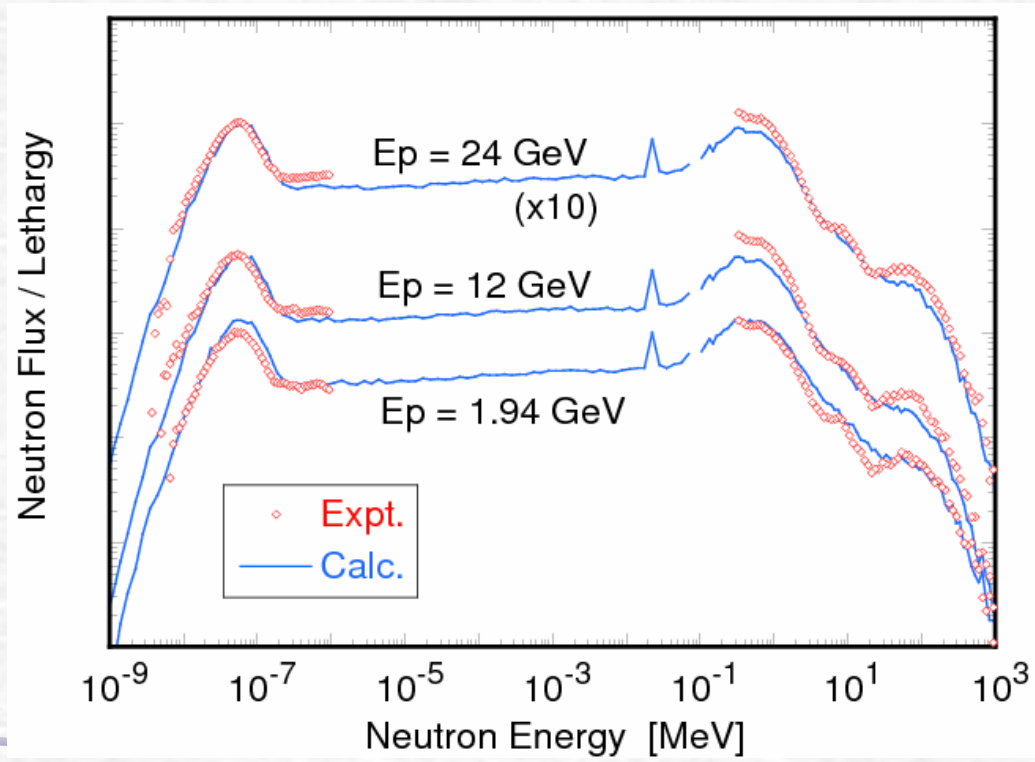


Leakage of recoil nucleus from Si

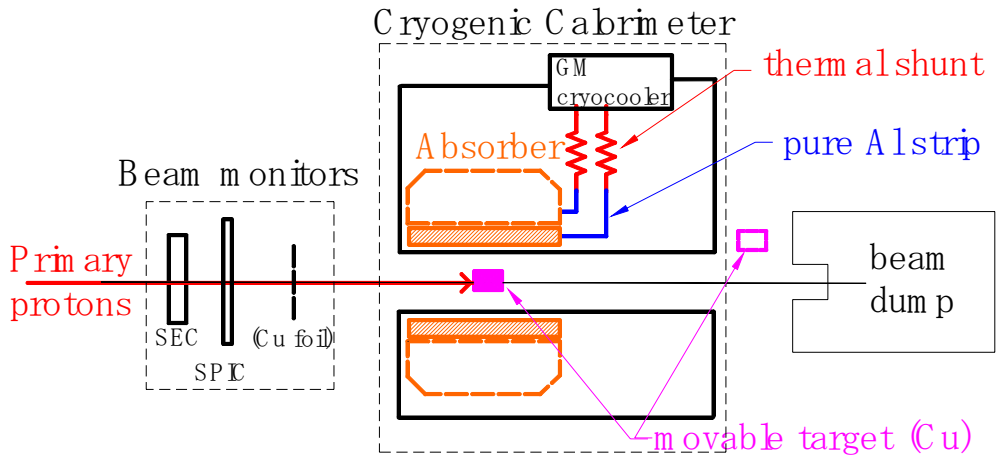
AGS Benchmark Experiments for Spallation Neutron Source



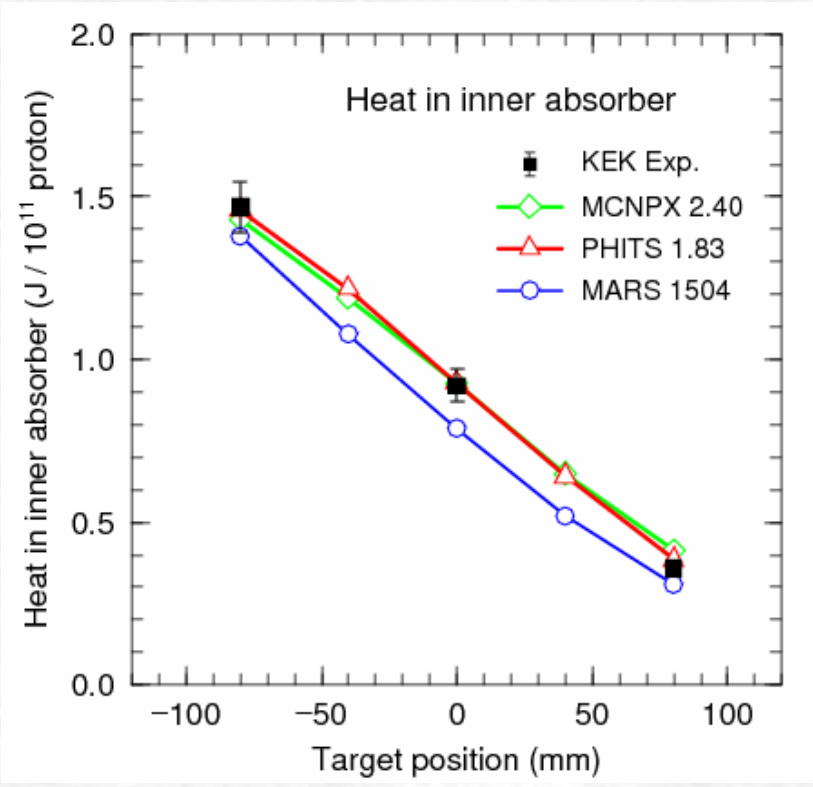


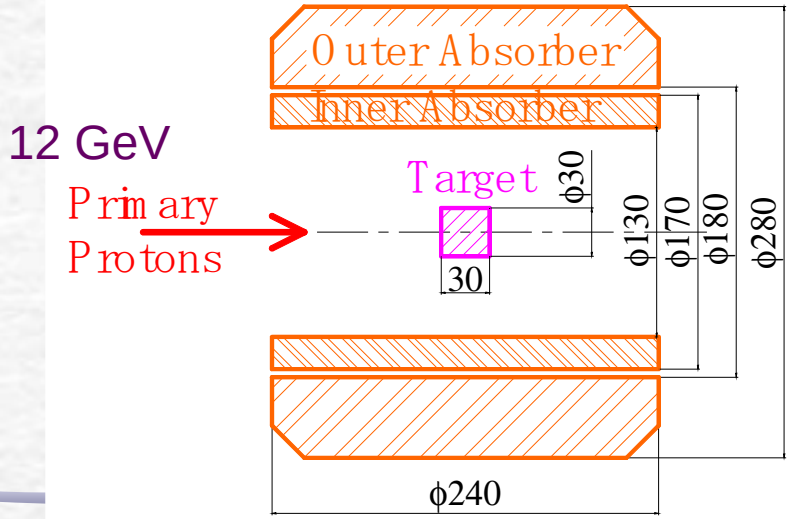


Benchmark test of HEAT : compared with KEK experiment



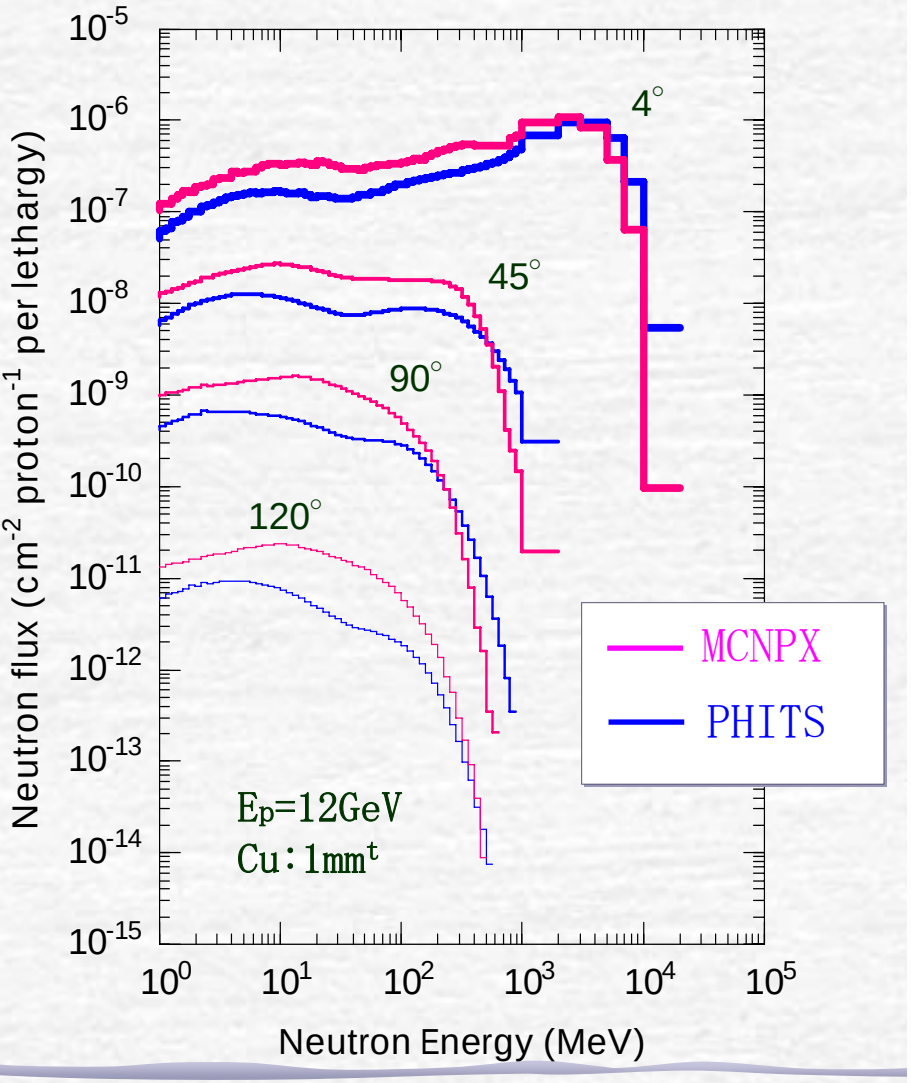
Exp. and Cal. by H. Ohnishi et.al.
Nucl. Instr. and Meth. A545 (2005) 88

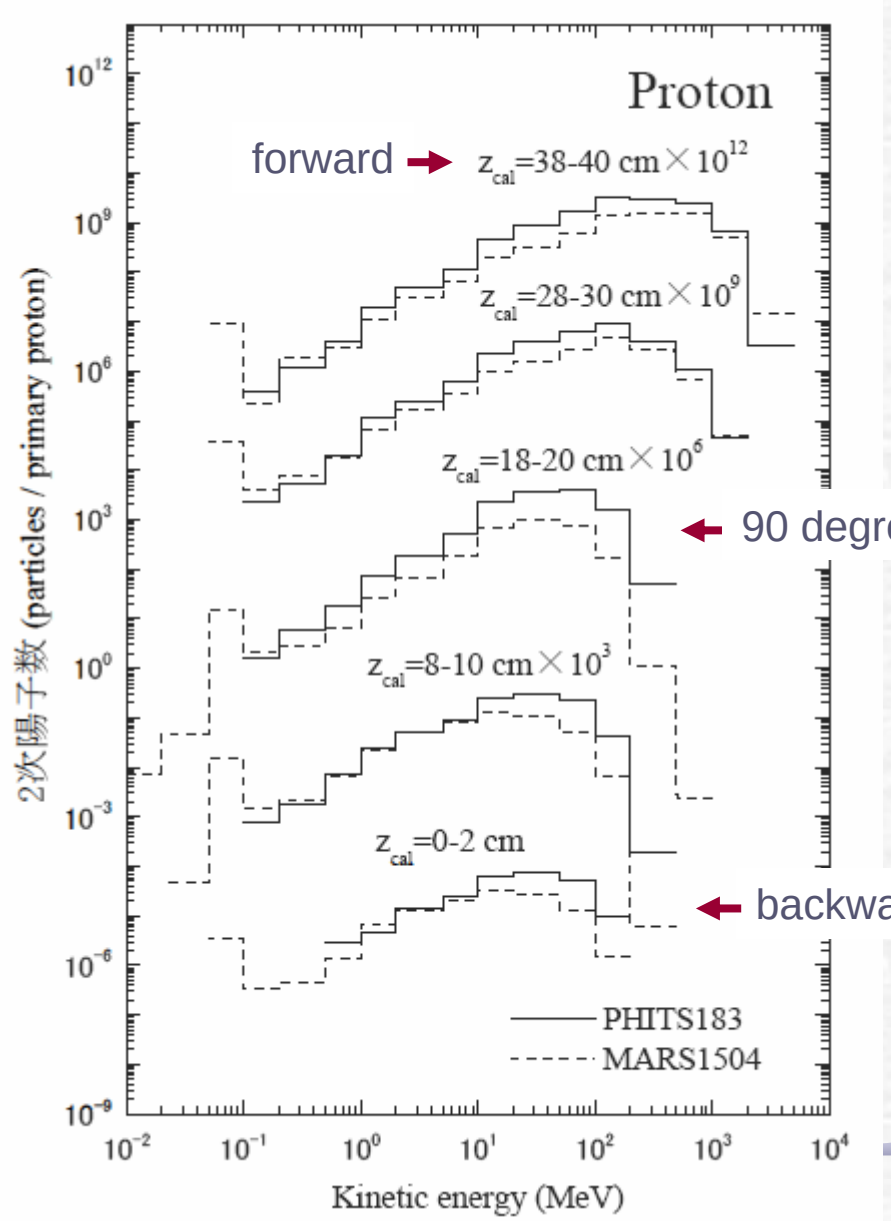




MCNPX: calculated by N. Matsuda

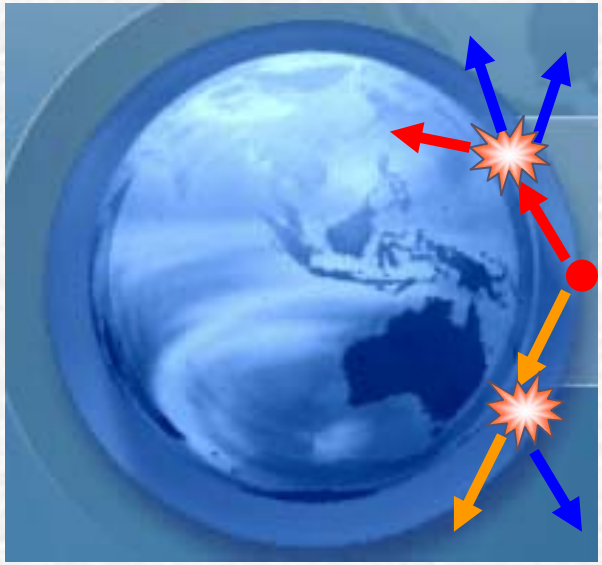
DDX of Secondary Particles





Neutron spectrum in atmosphere

T. Sato and K. Niita; Radiat. Res. **166** (2006) 544



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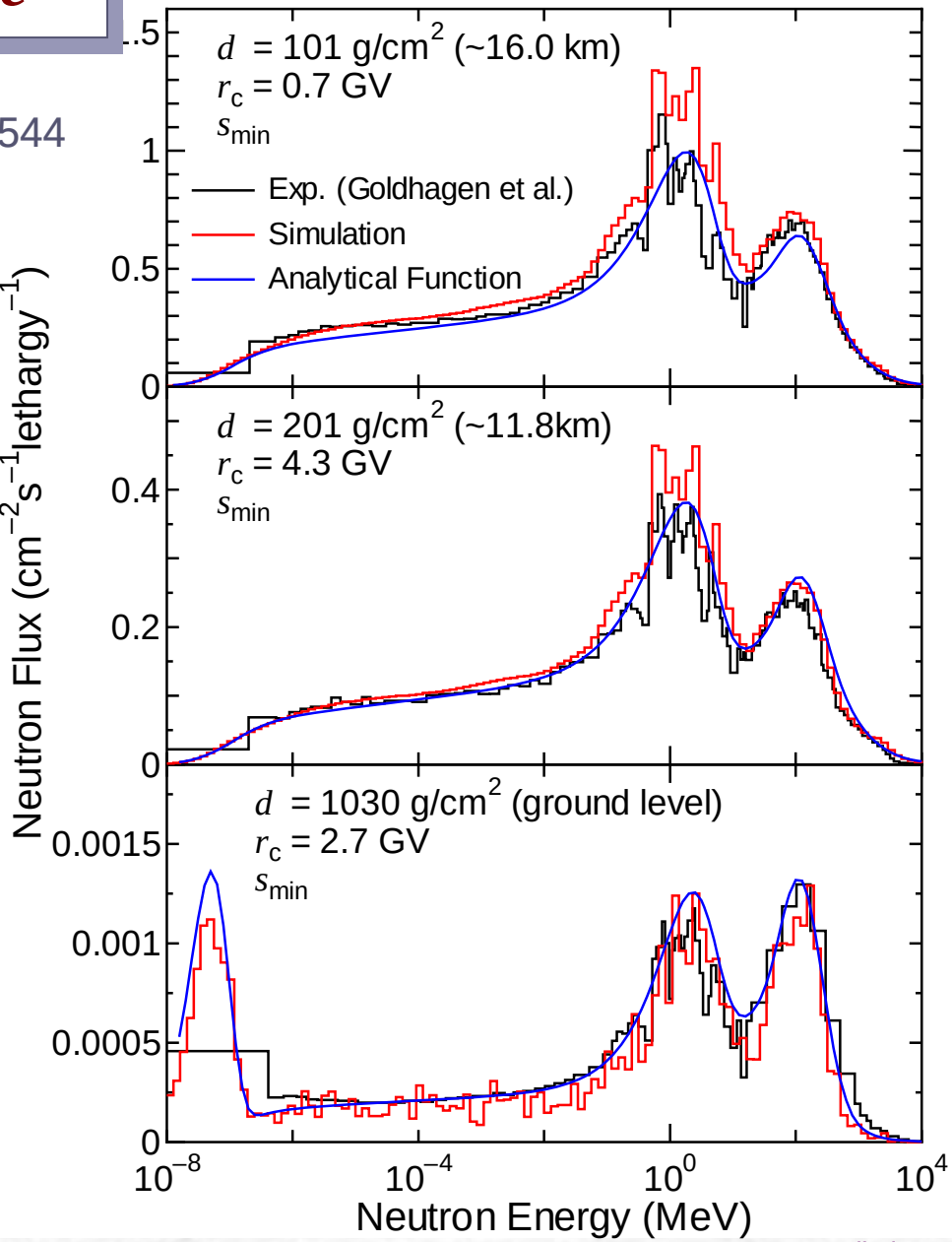
PHITS with JENDL-HEfile



EXPACS : *Excel-based Program for calculating Atmospheric Cosmic-ray Spectrum*

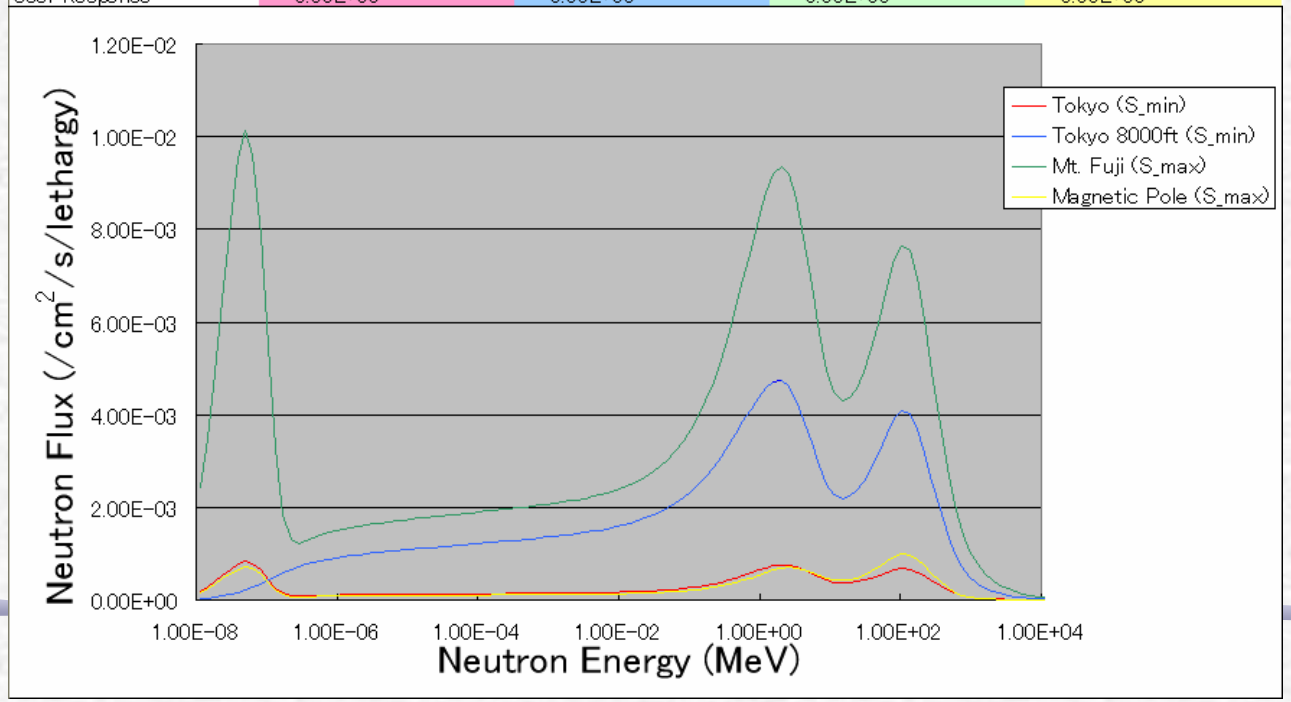
by T. Sato

EXPACS ver. 1.0

Excel-based Program for calculating Atmospheric Cosmic-ray Spectrum, 2006/8/7
developed by Tatsuhiko Sato, Japan Atomic Energy Agency, E-mail: sato.tatsuhiko@jaea.go.jp
Reference : T.Sato and K.Niita, "Analytical Functions to Predict Cosmic-Ray Neutron Spectra in the Atmosphere", Radiat. Res.

Input your requested conditions in the white columns

Title	Tokyo (S_min)	Tokyo 8000ft (S_min)	Mt. Fuji (S_max)	Magnetic Pole (S_max)
Configuration	Ground	Pilot-Location	Ground	Ground
Altitude	0 (km)	8000 (ft)	3.777 (km)	1034 (g/cm2)
Cut-off Rigidity	12 (GV)	12 (GV)	12 (GV)	0 (GV)
Solar Modulation Potential	465 (MV)	465 (MV)	1700 (MV)	1700 (MV)
Local Effect Parameter	0.15 Water Frac.	1 Mass(100ton)	0.1 Water Frac.	1 Water Frac.
H*(10)	5.81E-03 (uSv/h)	3.70E-02 (uSv/h)	7.13E-02 (uSv/h)	6.23E-03 (uSv/h)
Effective Dose	4.41E-03 (uSv/h)	2.81E-02 (uSv/h)	5.51E-02 (uSv/h)	5.26E-03 (uSv/h)
User Response	0.00E+00	0.00E+00	0.00E+00	0.00E+00



New Features of PHITS (Recent Developments, released by ver.2.12)

(1) **Duct Source option**
for Neutron Long Beam Line calculations

(2) **Super Mirror function**
for Neutron Optics: reflection on the wall

(3) **Time Dependent Materials**
for moving material, T0 chopper, ...

(4) **Time Dependent Magnetic Fields**
Pulse Magnet for neutron optics,
Wobbler Magnet (AC magnet)

(5) **Dumpall option**
for re-calculation of whole process
(history tape)

(6) **Event Generator Mode**
a full correlated transport
for all particles and energies

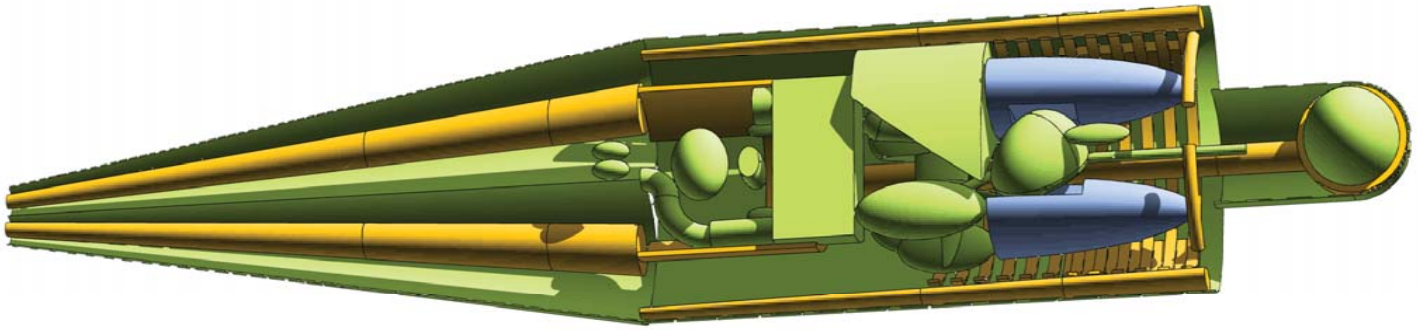
(7) **LET tally**
dose and track length
as a function of LET (dE/dx)

(8) **Deposit2 tally**
correlation of the deposit energy
distribution of two regions

(9) **Timer** (clock of particle)
simulation of TOF with dE correlation

Distribution of PHITS

PHITS *ver.2.13* and **ANGEL** *ver.4.35*
have been released from JAEA.



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RIST. Code Center: *http://www.rist.or.jp*