Neutrons in gases

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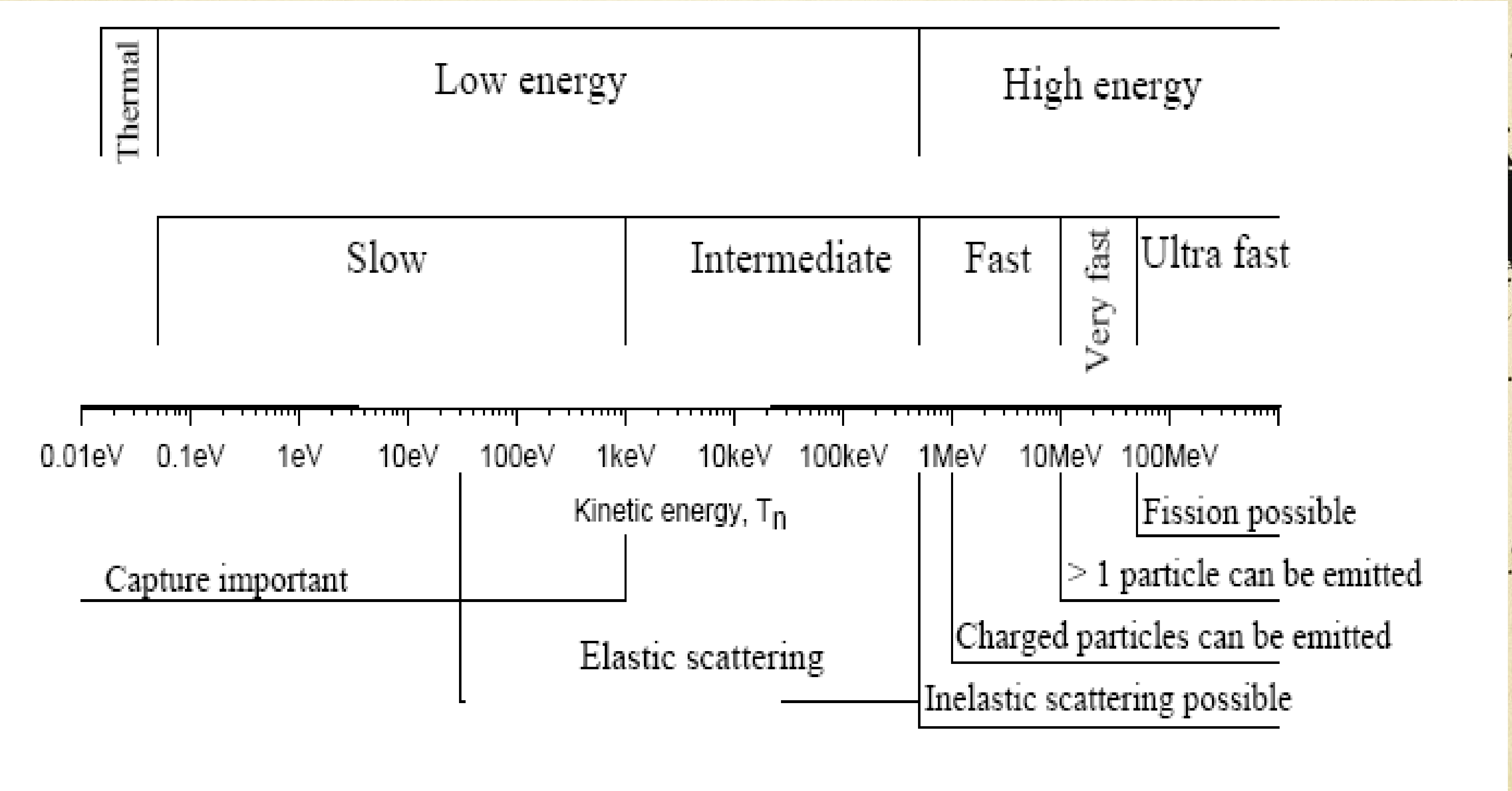
RD51 mini week

Overview

- Types of interaction and importance
- Neutron Cross-Section in Geant4 / Validation
- Neutrons & DM
- Neutrons & mM
- Geant4 / Garfield

Interaction of neutrons with matter

Cross section depends on:
- Kinetic energy T_n
- Nuclear structure



All neutrons are initially Fast Neutrons which lose kinetic energy through interactions with their environment until they become thermal neutrons which are captured by nuclei in matter.

http://www.uio.no/studier/emner/matnat/fys/FYS-KJM4710/v07/undervisningsmateriale/Neutrons_07.pdf

Neutron Contribution at LHC

- En = 1 – 10 MeV
- Noise
- e.g. ATLAS : ~ 10^{14} n/cm^2/year = 10^7 n/cm^2/sec

  Slow neutron flux: ~ 10^9 n/cm^2/sec for L=10^{34} /cm^2/sec

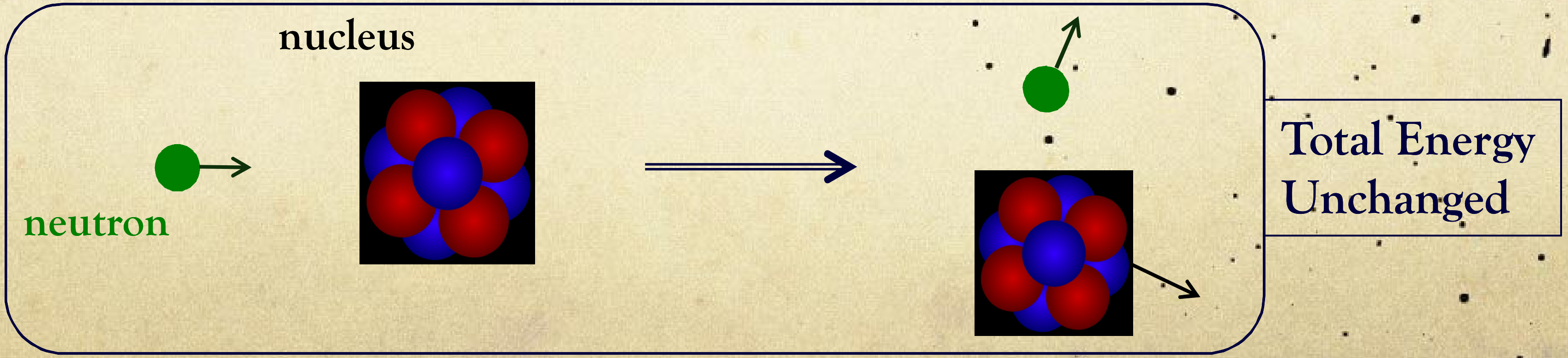
Interaction of neutrons with matter

❖ Elastic Scattering ❖

1. Elastic Scattering

- Neutron collides with atomic nucleus
- Neutron deflected with loss of energy E
- E given to recoiling nucleus
- Struck atoms can also lose orbital electron
- Energy of recoiling nucleus absorbed by medium.

  The recoil nuclei quickly will transfer their kinetic energy to ionisation as they pass through the material.



Interaction of neutrons with matter

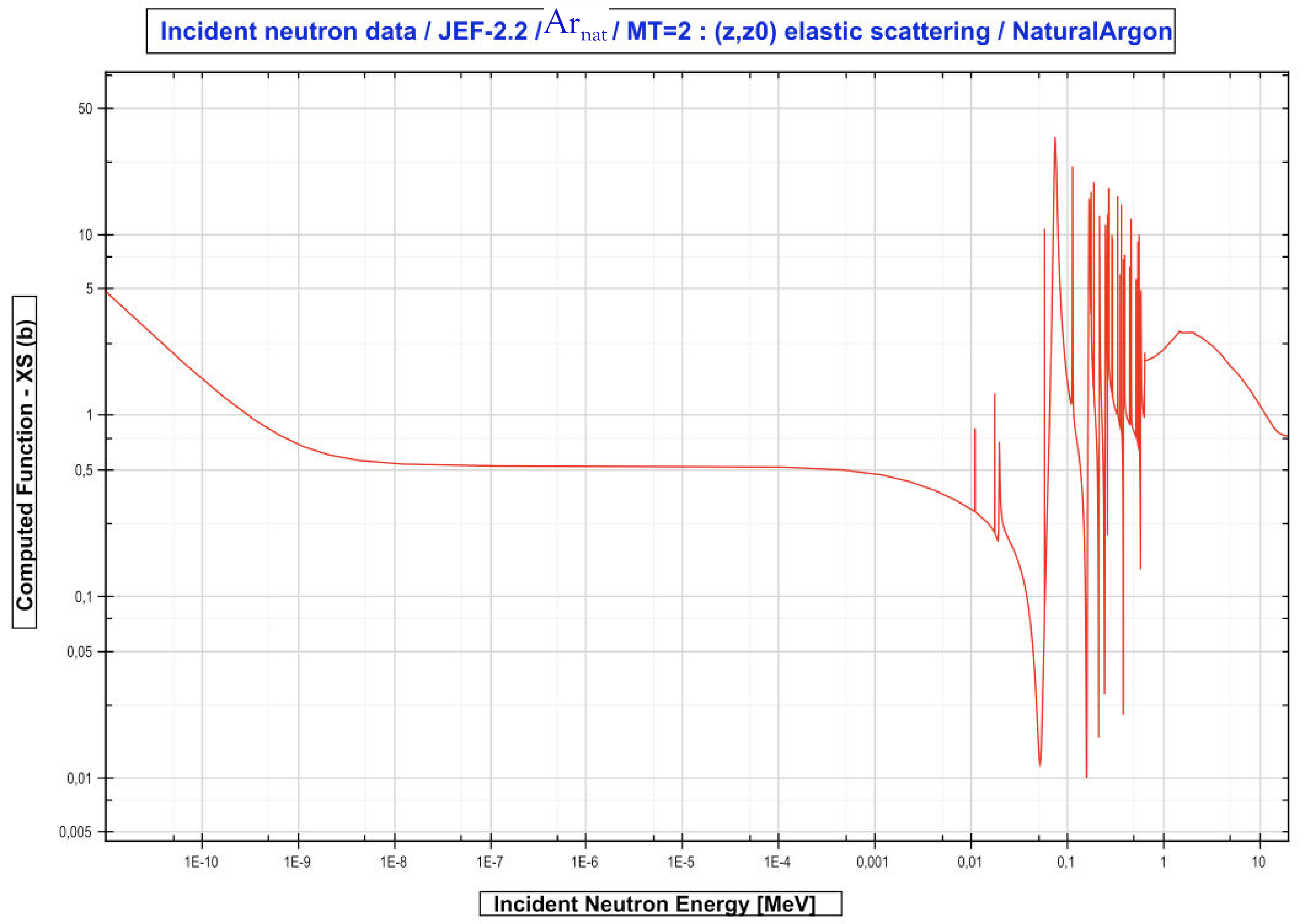
❖ Elastic Scattering ❖

- Conservation of Energy and Momentum:

$$E_{min} = E_0 \left(\frac{M-m}{M+m} \right)^2$$

E_{min} = energy of scattered neutron
Eo = Initial energy of neutron
M = mass of the scattered nucleus
m = mass of neutron **<<< Same relation applies to the recoil of a nucleus caused by a WIMP!**

↠ Hydrogen good for stopping neutrons.



http://www.nea.fr/janis/

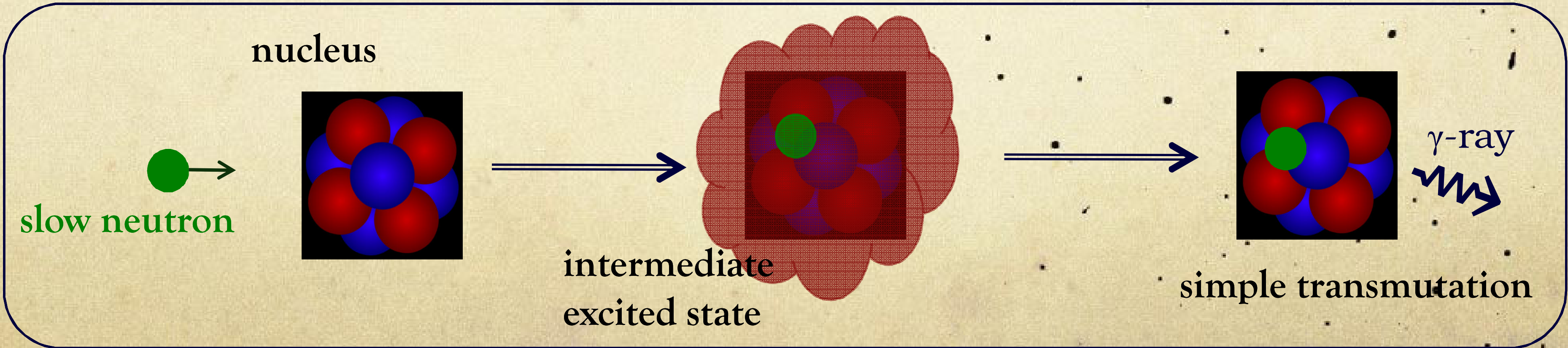
Interaction of neutrons with matter

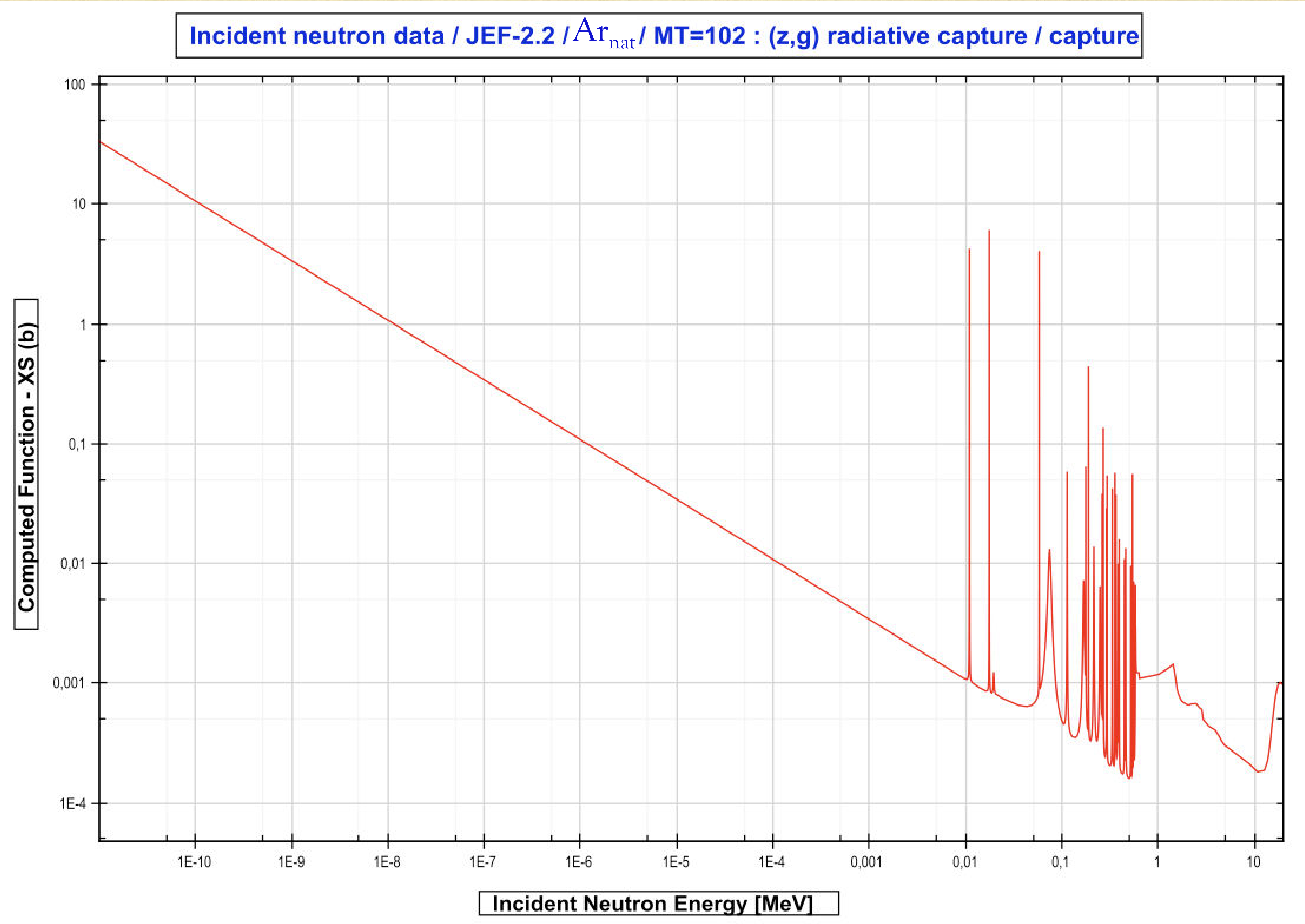
❖ Radiative Capture ❖

3. Neutron Capture

- Neutron captured by nucleus
- Only γray emitted
- Probability of capture is inversely proportional to the energy of the neutron

↠ Low energy (=thermal neutrons) have the highest probability for capture





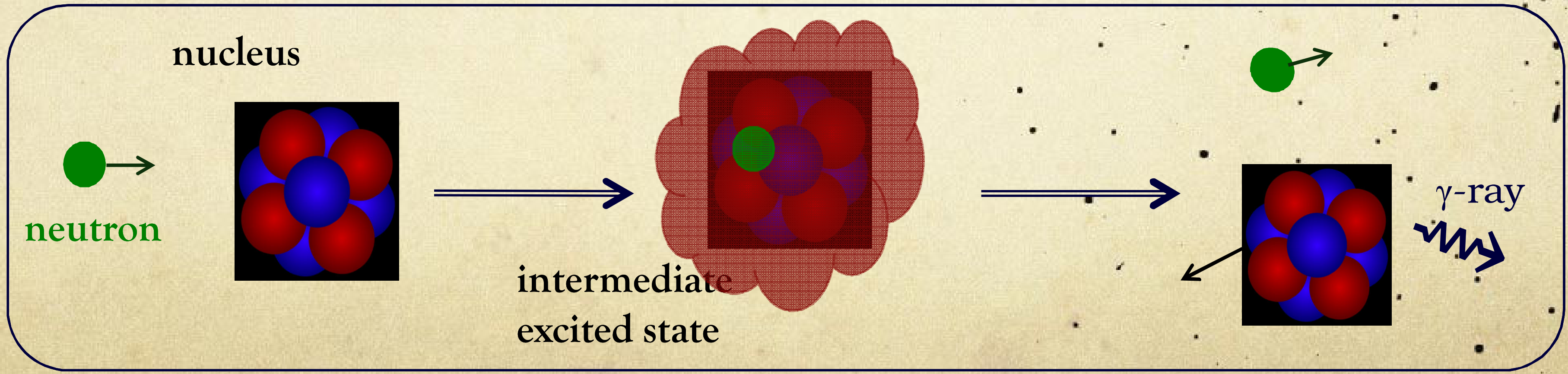
http://www.nea.fr/janis/

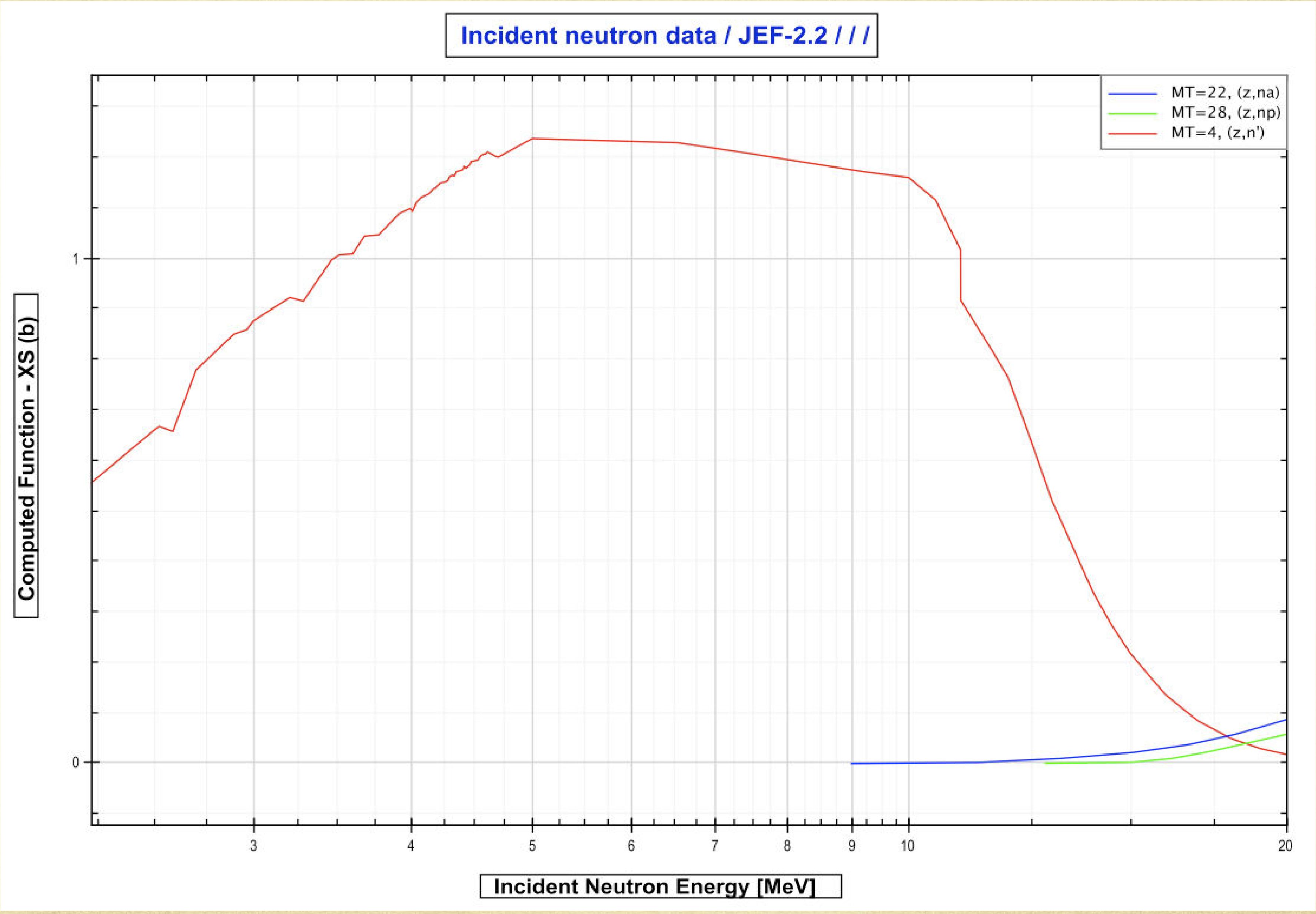
Interaction of neutrons with matter

❖ Inelastic Scattering ❖

1. Inelastic Scattering

- Neutron captured by nucleus
- Neutron reemitted with less energy and nucleus left in excited state
- Nucleus relaxes by emitting γ-rays and/or charged particles (adds to E deposit)





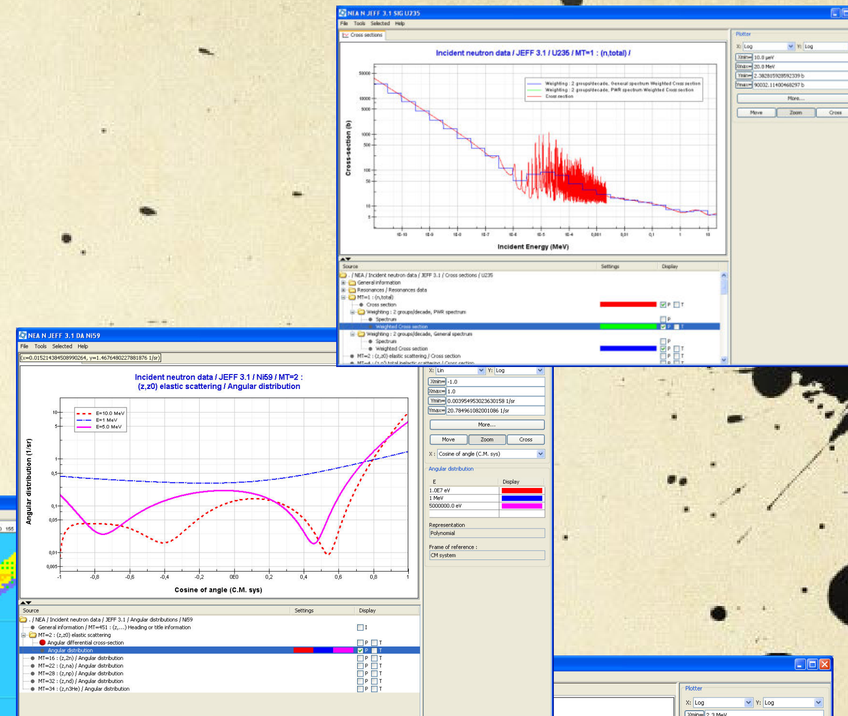
http://www.nea.fr/janis/

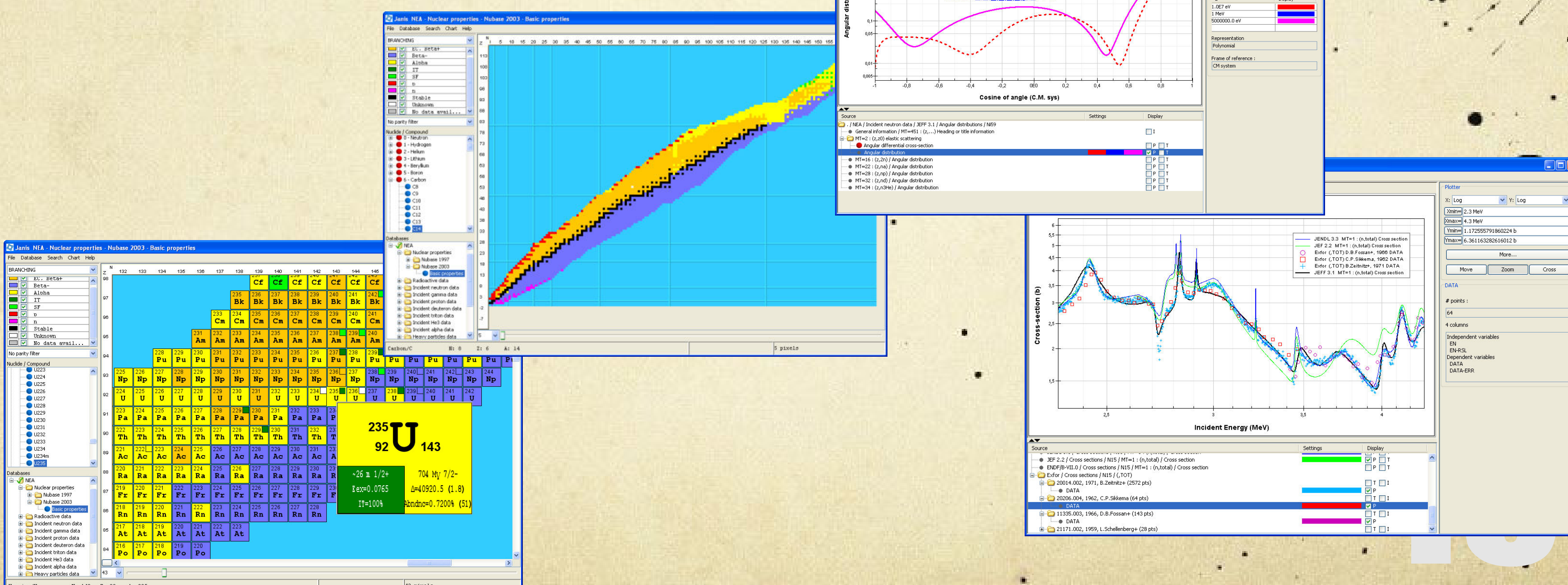
- **neutrons in Geant4**

Neutron Cross-Sections given by JANIS 3.0

(Java-based Nuclear Information Software)

- Interactive Chart of Nuclide
- Plots, Tables, Decay Paths
- Energy distributions
- Angular distributions
- Energy – angle distributions
- Comparing Data
- Access to CINDA, EXFOR, ENDF data





http://www.nea.fr/janis/

- Geant4.9.2p01

>> Physics Lists: QGSP_BERT_HP

Hadronic Example: Hadr00

1. Elastic XS
2. Sum of "Inelastic" and Capture XS → Non Elastic XS

↕

- Data Libraries:

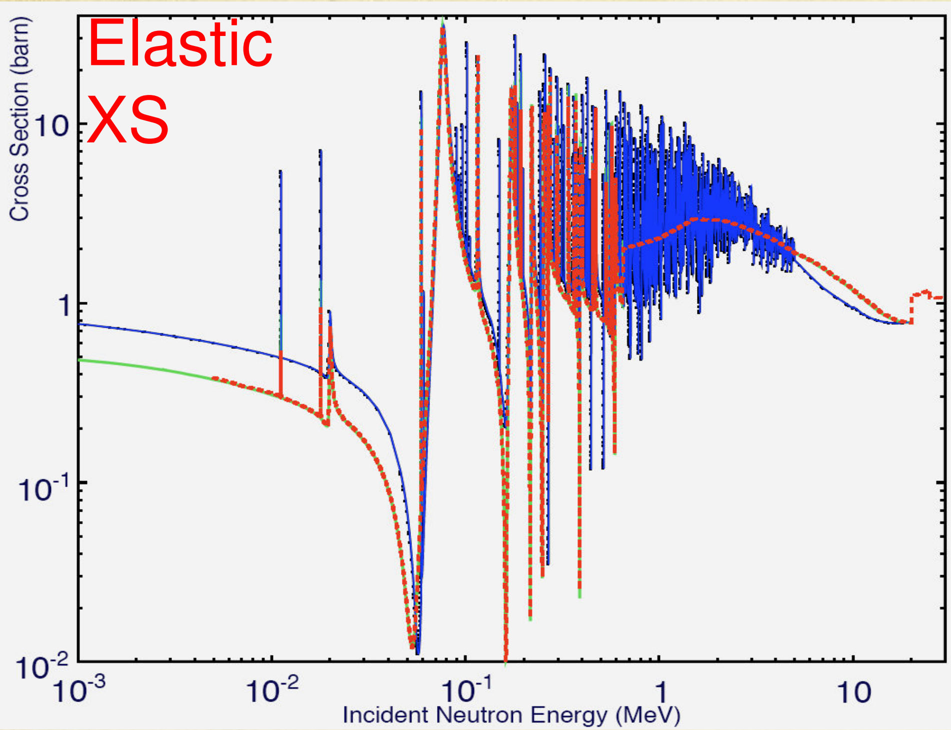
1. Elastic XS
2. Total XS – Elastic XS → Non Elastic XS

Available neutron Data Libraries:

ENDF/B-VII.0 & ENDF/B-VI.8	:	Evaluated Nuclear Data File (December 2006 and 2001, respectively)
JEF-2.2	:	Joint Evaluated File (January 1997)
JEFF-3.0	:	Joint Evaluated Fission and Fusion, "…this library superseded JEF-2.2…" (April 2002)
JEFF-3.1	:	"…this library superseded JEFF-3.0…" (May 2005)
JENDL-3.3	:	Japanese Evaluated Nuclear Data Library (2002)

- There can exist discrepancies between them.
- "New" does not mean "better".

Natural composition of Argon



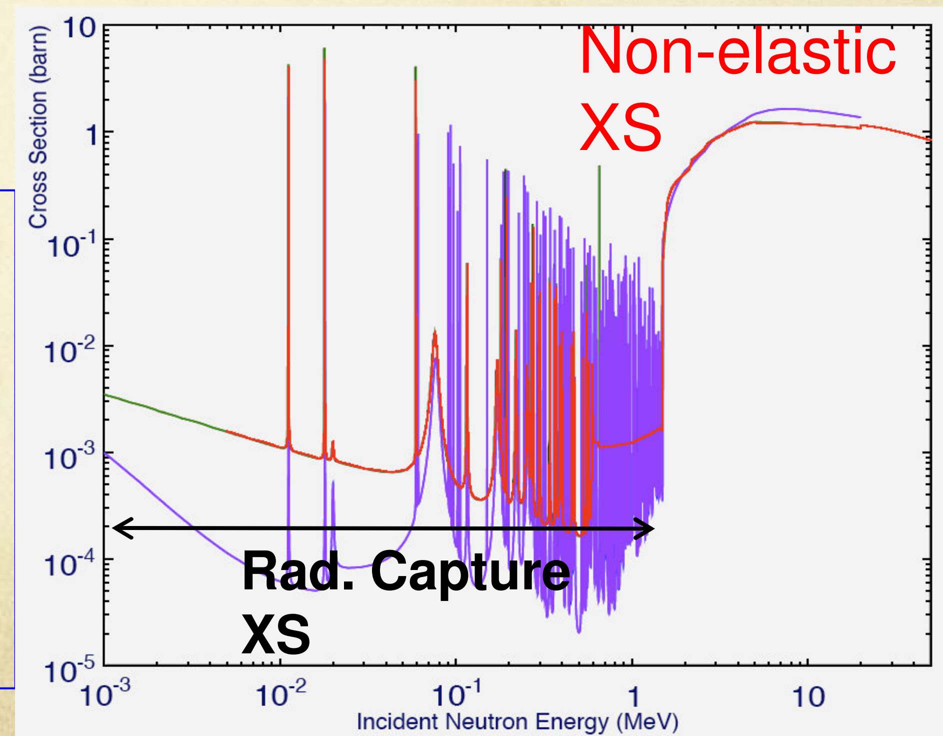
Geant4: Red

JEF-2.2: Black

JEFF-3.0: Green

ENDF/B-VII.0: Blue

JEFF-3.1: Purple



- ➢ Agreement between Geant4 NDL and the "old" libraries at all energy regions. Large discrepancies with "new" libraries.

- ✓ For the case of Argon, G4NDL uses JEF 2.2 / JEFF 3.0 .

Alternative G4 format libraries, using recent evaluations, are being developed.

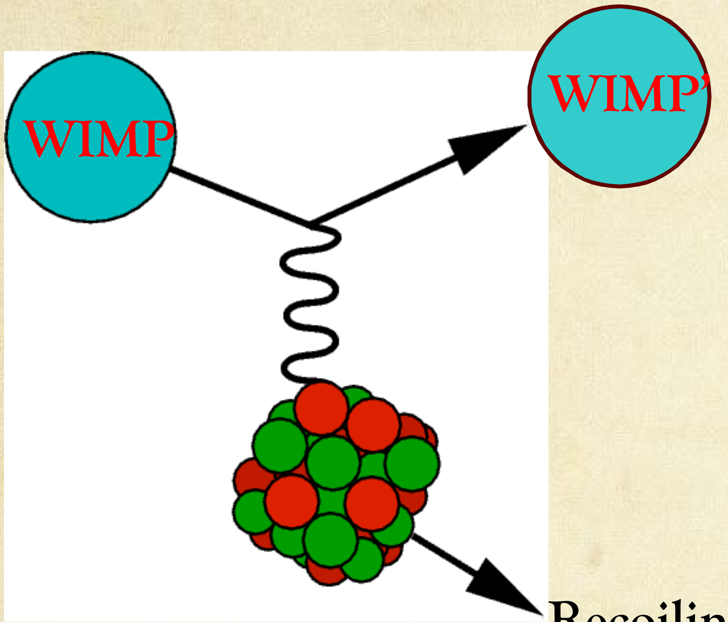
Results available also for natural compositions of:

Hydrogen	☑
Carbon	☑
Oxygen	☑
Helium	☑
Krypton	☑
Xenon	☑

- **neutrons & DM**

Weakly Interacting Massive Particles

WIMP is a general term for a heavy dark matter particle candidate, whose non gravitational interactions are feeble and his interaction with matter resembles that of a "heavy" neutron.

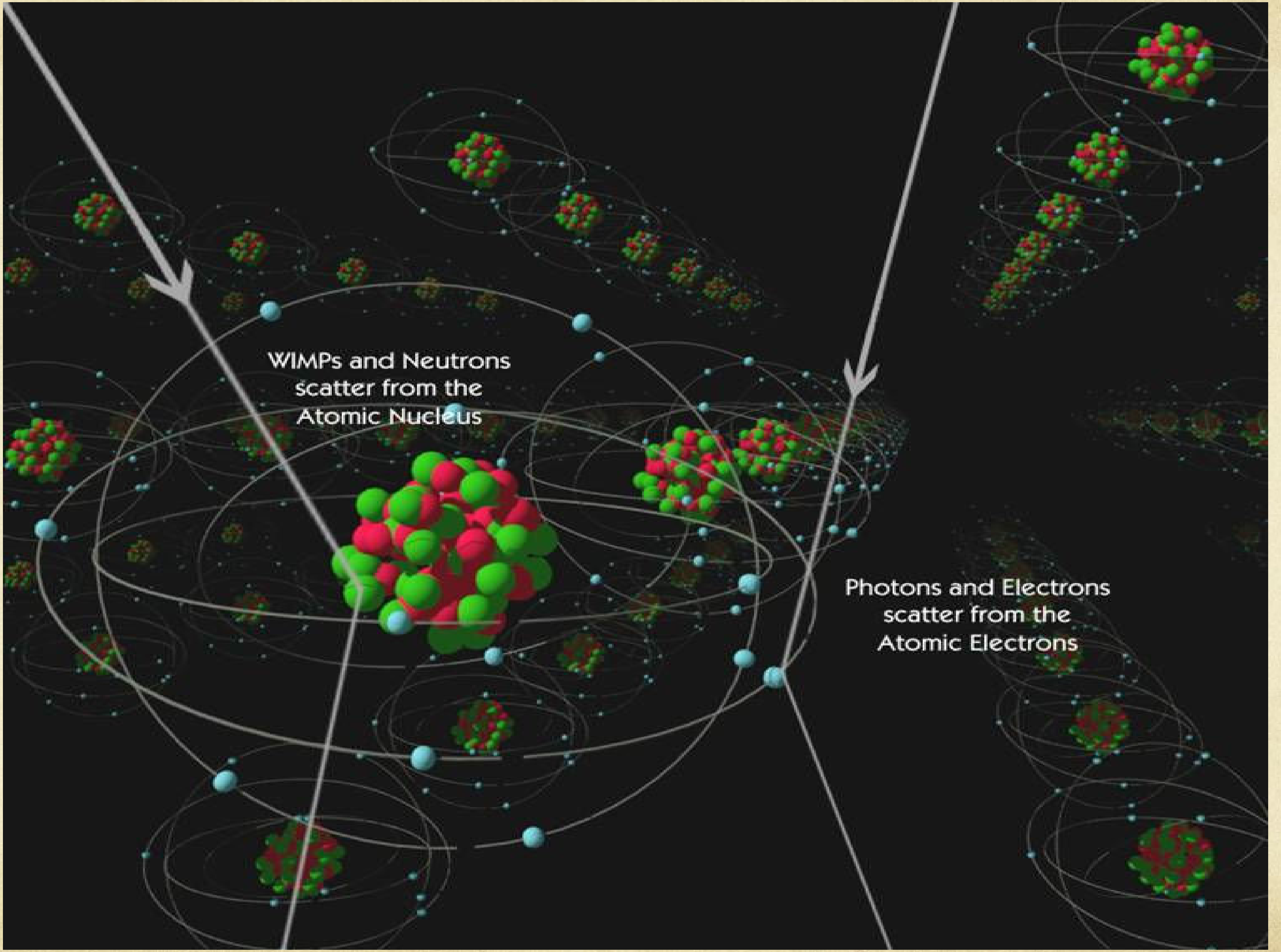


WIMP searches rely on the interaction of a SINGLE particle with a detector.

➔ The detector is a nucleus, such as H, Ar, Ge, ..., Xe ...

"Neutrons - scatter off nuclei ...just like WIMPs! "

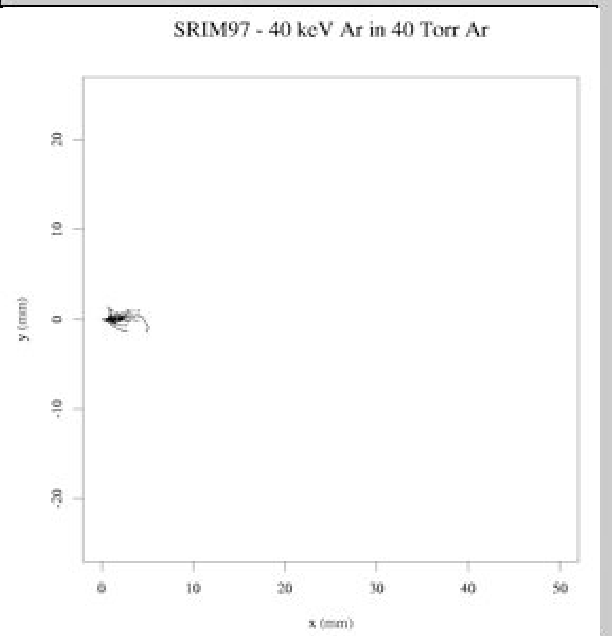
http://www.hep.shef.ac.uk/research/dm/talks/macc-daw.pdf



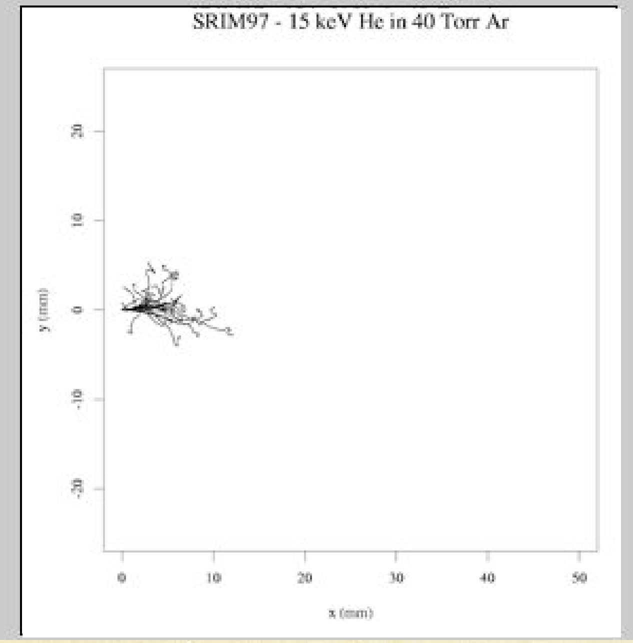
http://cdms.berkeley.edu/Education/DMpages/science/directDetection.shtml

simulation

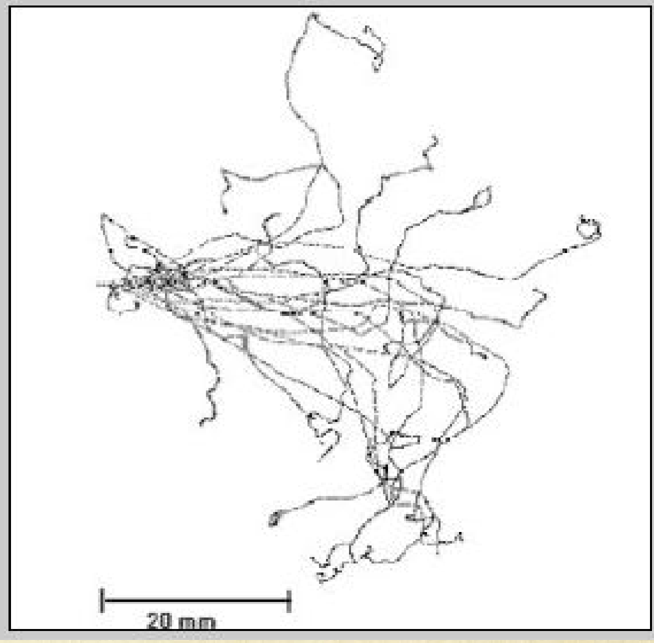
40 keV Ar recoils from WIMPs 500 Nips



15 keV as from radioactivity 500 Nips

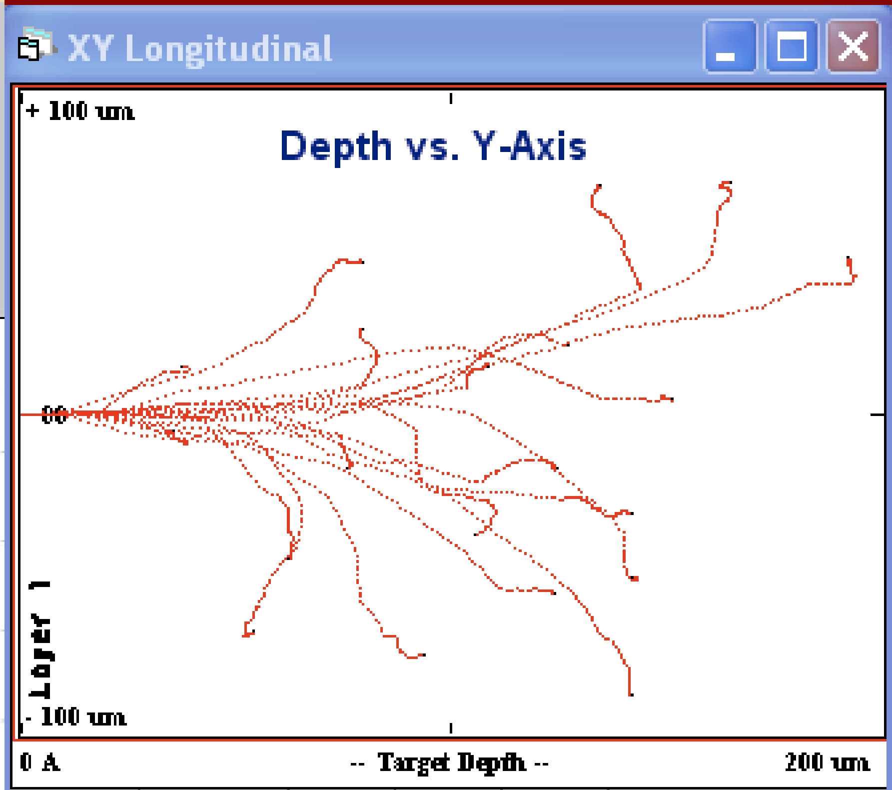


13 keV e$^-$s from radioactivity 500 Nips

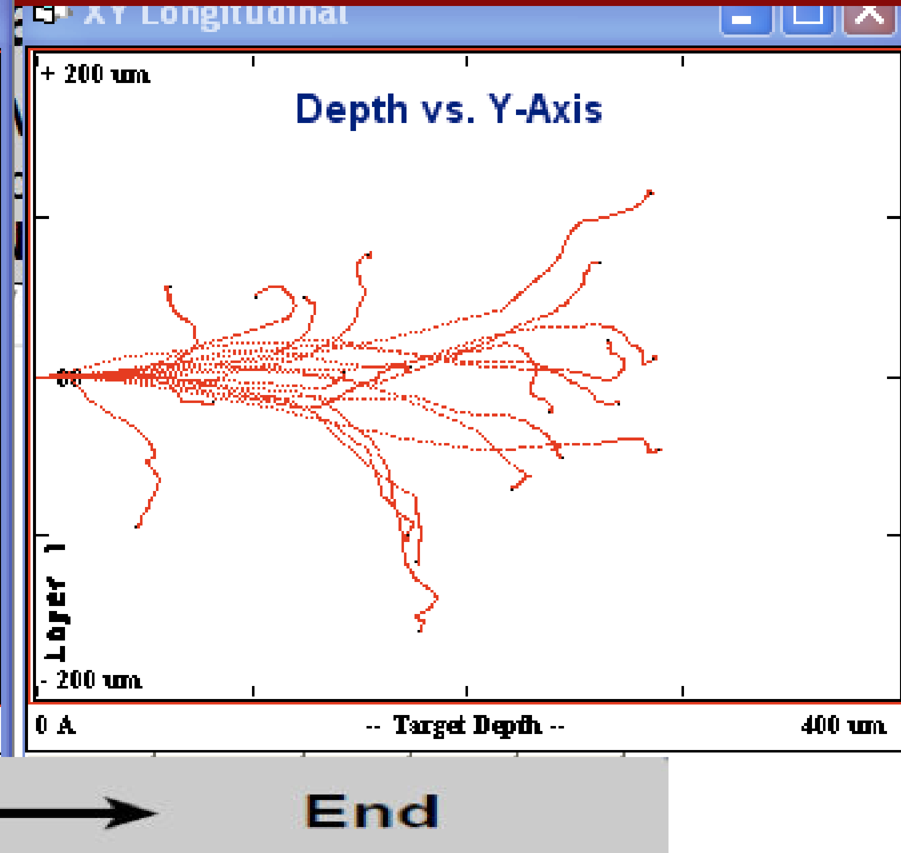


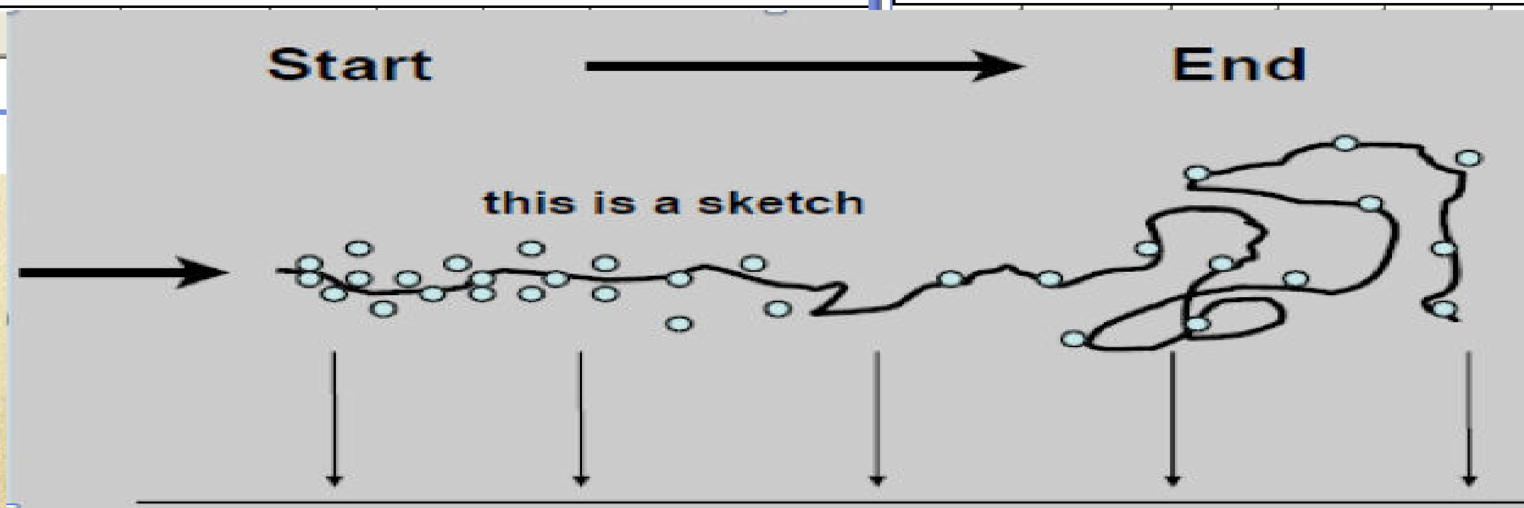
N. Spooner, http://www.hep.shef.ac.uk/research/dm/talks/EXETER2.pdf

Tracks of twenty 50 keV Ar ions in Ar gas (0.001784 g/cm3).

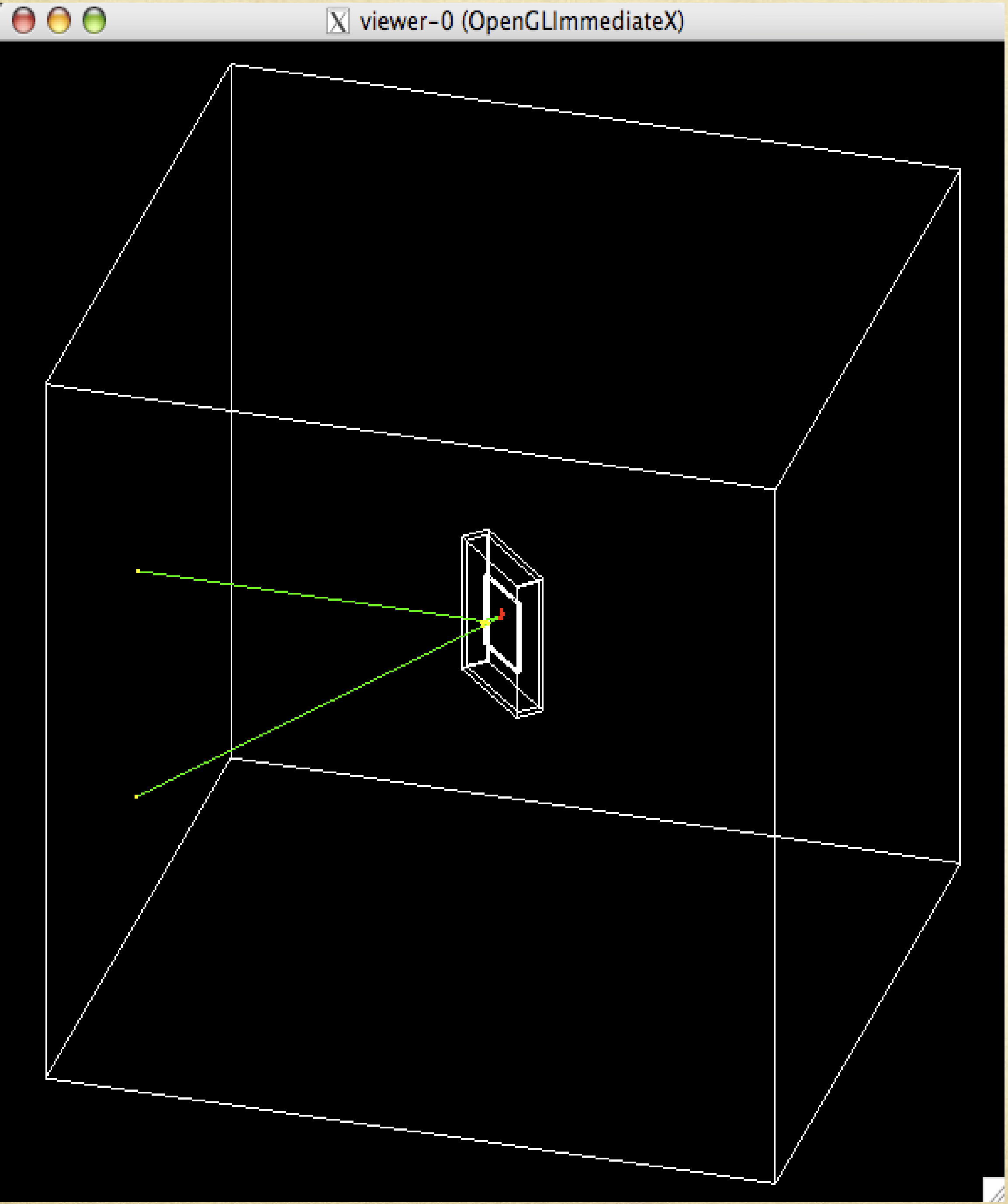


Tracks of twenty 100 keV Ar ions in Ar gas.





- **Micromegas & neutrons**



Geant4 9.2.p01

PhysList: QGSP_BERT_HP

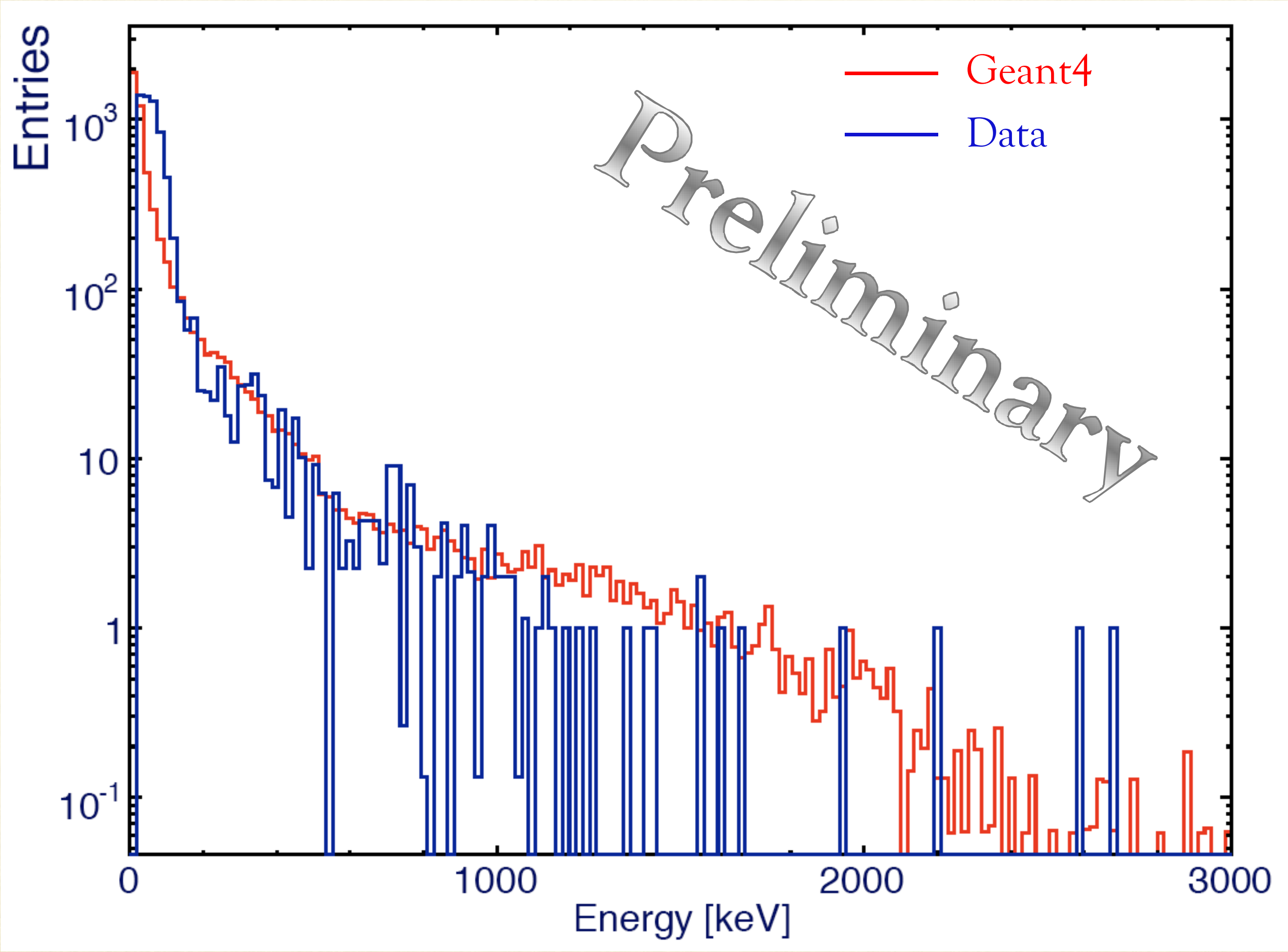
Gas Mixture: 95% Ar + 5% C_4H_{10}

SensitiveDetector: 5.9mmx10cmx10cm

Incident Number of Neutrons: 10^8
Entries: ~**7**x10^4

E_n = ~5.4 MeV

Energy deposited by neutrons in Micromegas detector



T. Geralis, E. Ntomari, M. Tsagri

Geant4 / Garfield

An Interface

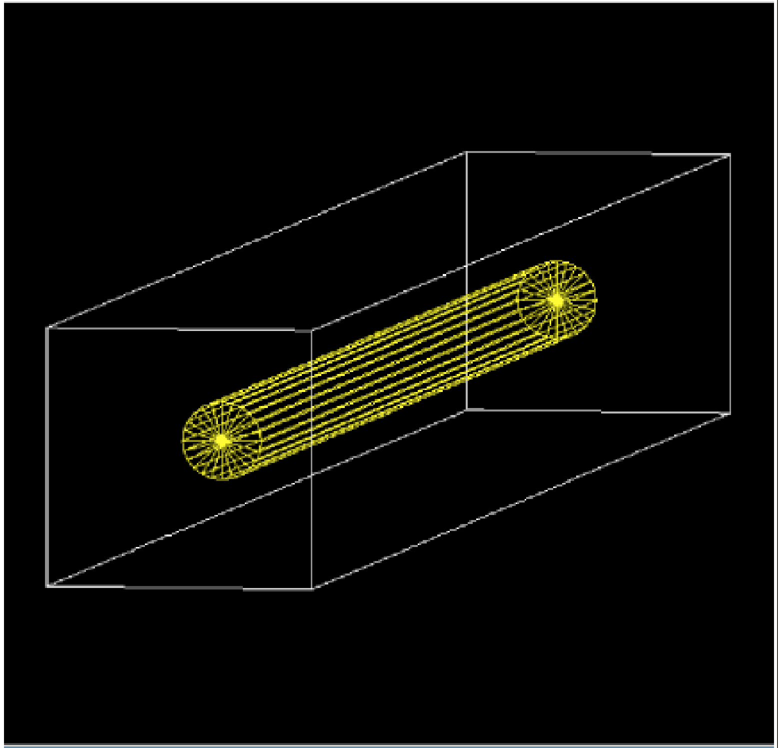
Interfacing Geant4 with Garfield: A First Prototype

Stefan Guindon
Institute of Particle Physics
CERN Summer Student 2008

http://www.ipp.ca/pdfs/guindon_cern08.pdf

ATLAS Muon Tube Prototype

- To illustrate the interface example, a muon tube is created in a Geant4 program
- Shoot a 10 GeV muon at the tube, using Geant4 to find its entrance point (3 Vector) and direction of flight.
- Pass parameters:
  - Hit position, Tubes' radii to Garfield

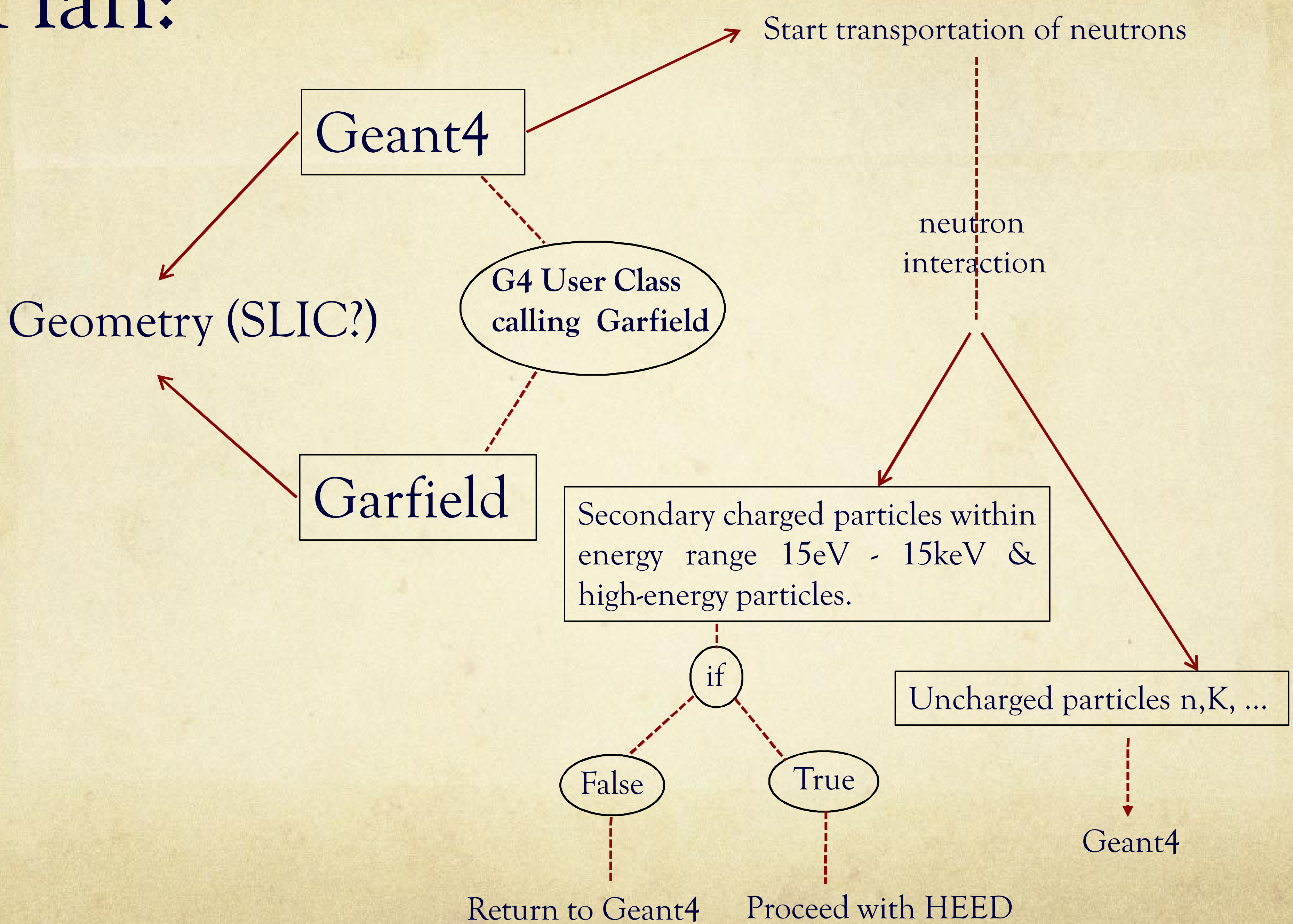


Conclusion and Future Work:

- Interface between Geant4 and Garfield Successful
  - Can run Garfield Simulation in Geant4 and exchange information
- Basic interface complete however Garfield has many more features
  - More ionization models
  - FEA field maps
  - Magnetic fields
  - Signal Calculations

http://www.physics.carleton.ca/~alainb/G4Parameterizing.pdf

Plan:


Start transportation of neutrons
Geant4
neutron
interaction
G4 User Class
calling Garfield
Geometry (SLIC?)
Garfield
Secondary charged particles within energy range 15eV - 15keV & high-energy particles.
Uncharged particles n,K, ...
if
False
True
Geant4
Return to Geant4
Proceed with HEED

Thank you!