
Muon-Induced Background & Neutrinoless Double Beta Decay

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Second Joint Meeting of the Nuclear Physics Division of the APS & JPS
Kapalua, Hawaii, September 18-22, 2005

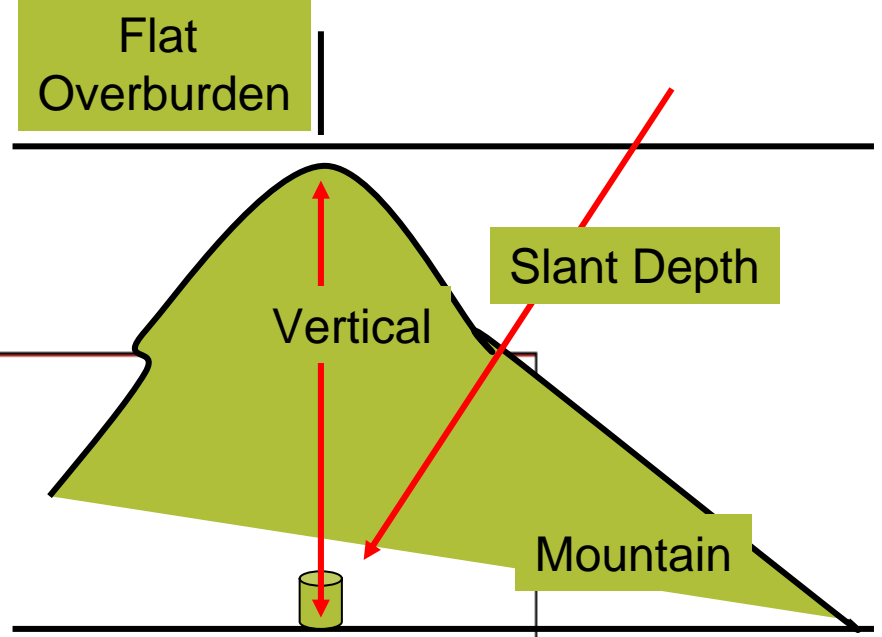
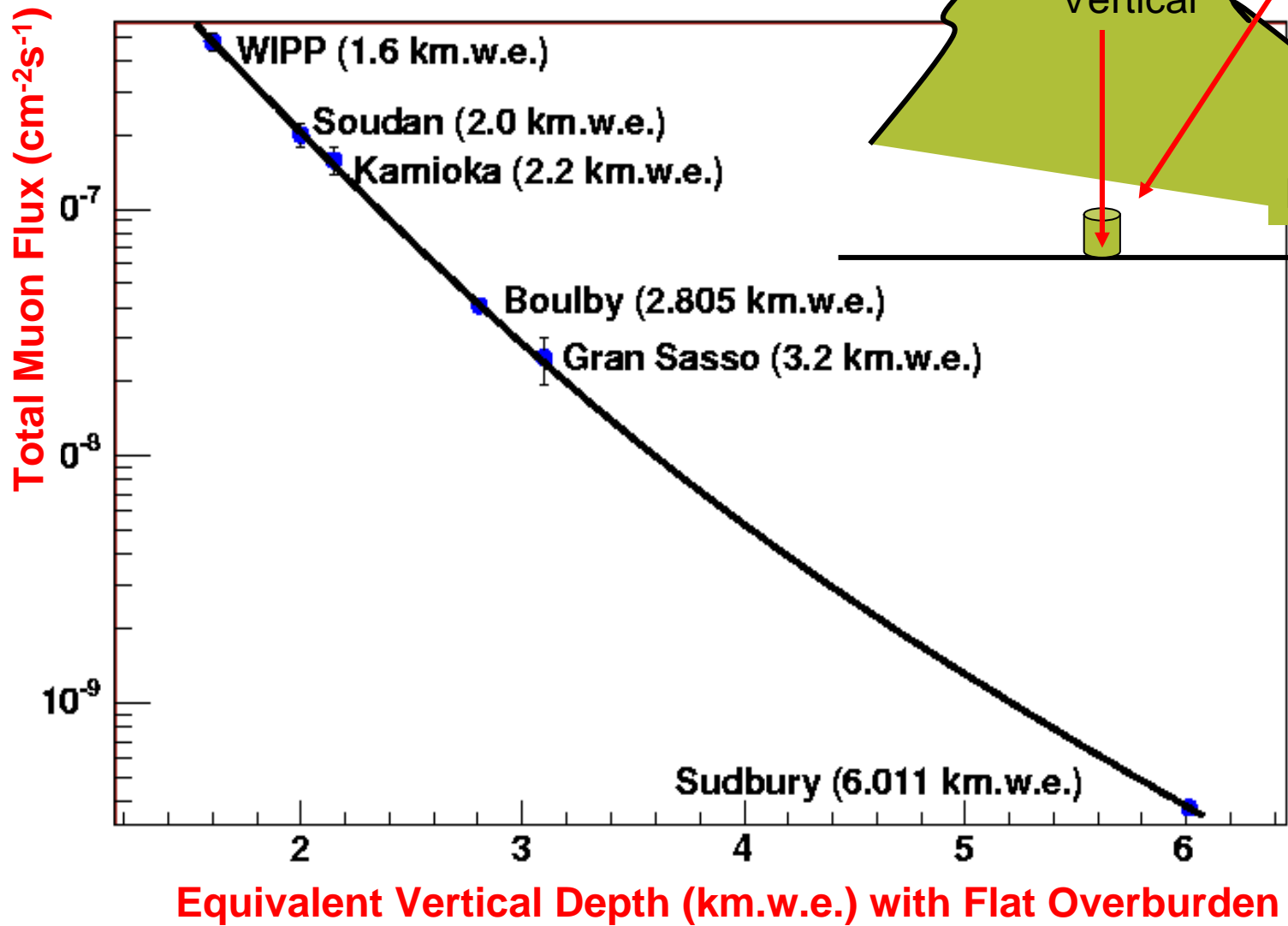
- Muon Flux & Distributions
 - Definition of Depth
 - Input for Muon-Induced Background

- Muon-Induced Fast Neutrons
 - Data v.s. Simulation
 - Fluxes & Distributions

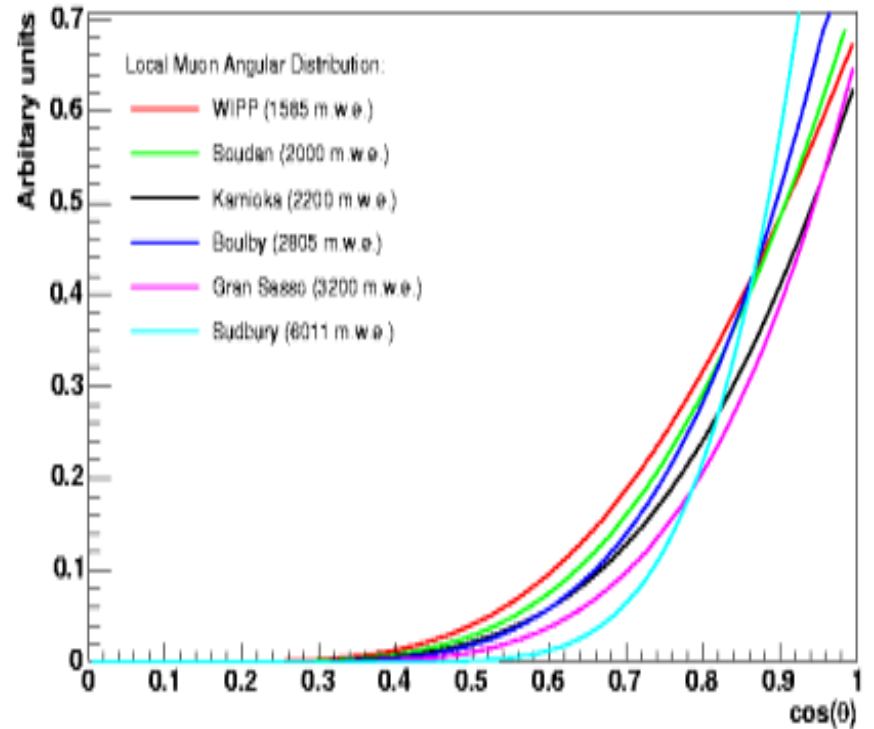
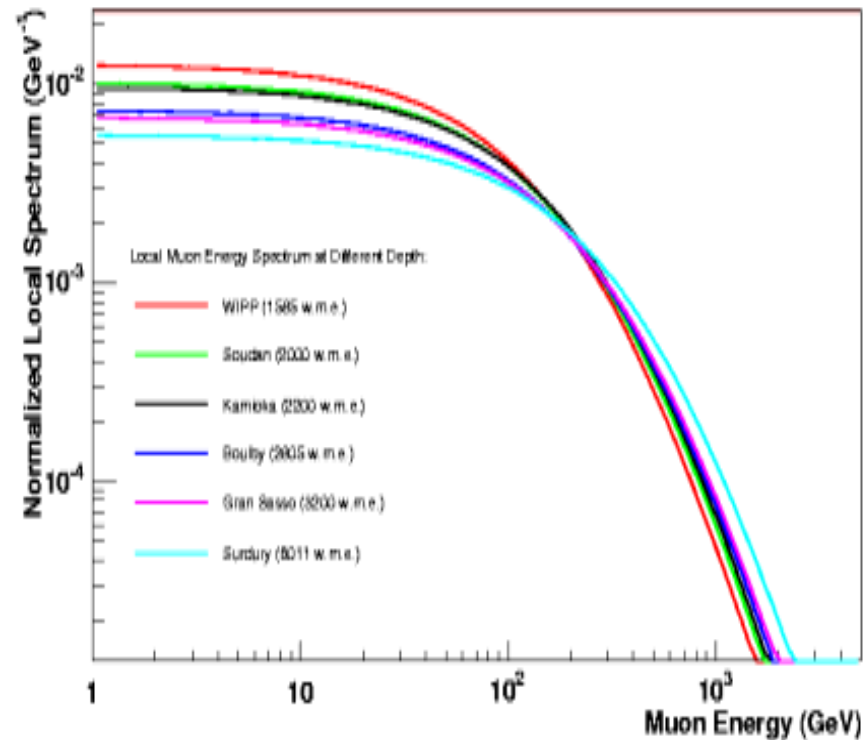
- Depth Sensitivity Relation (DSR)
 - Example for Majorana Module
 - Verification

- Summary

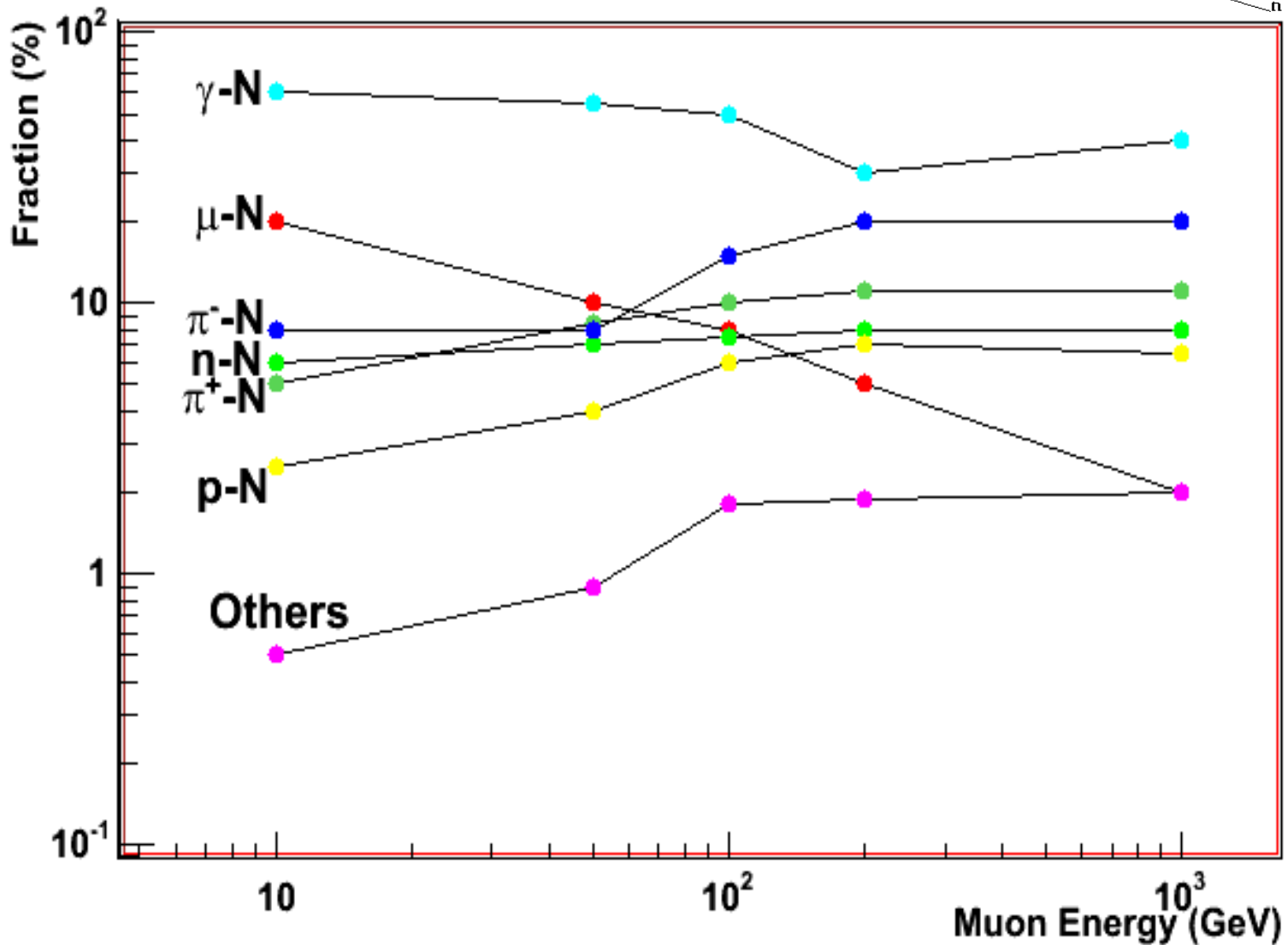
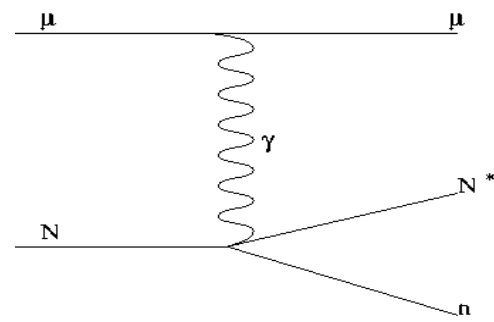
**Total Muon Flux
& Definition of Depth**



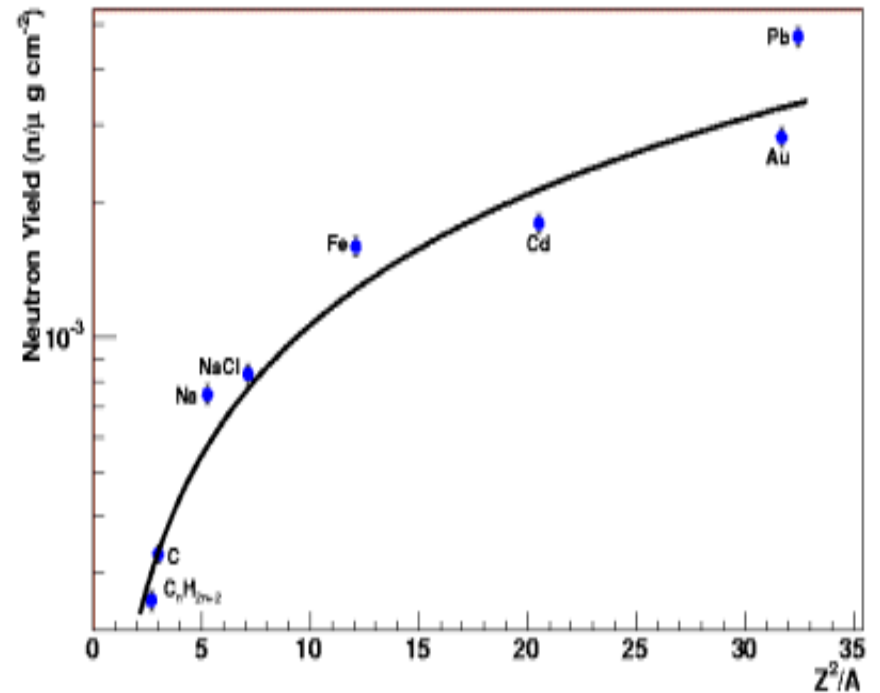
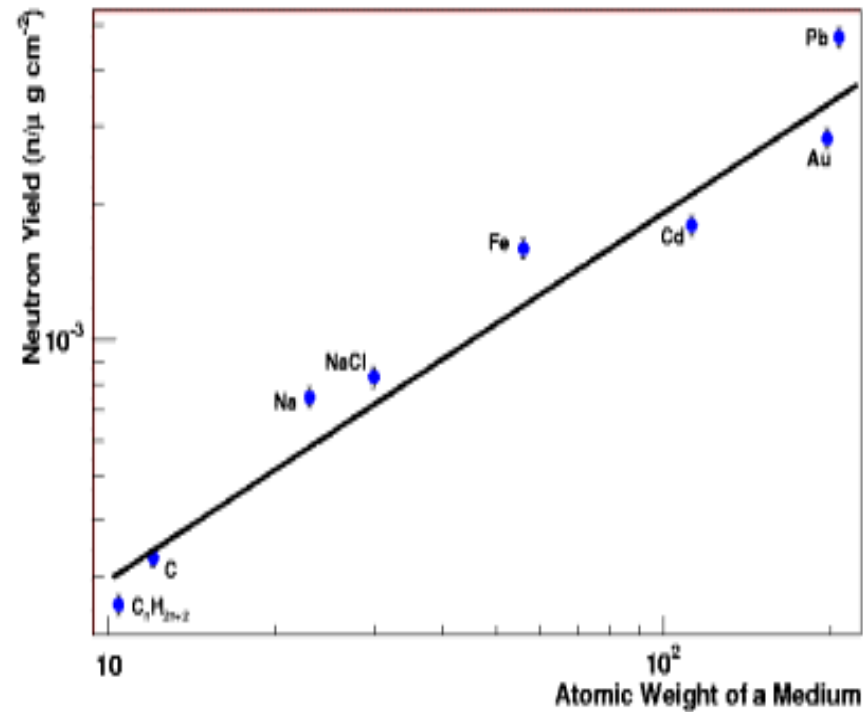
Muon Energy & Angular Distributions



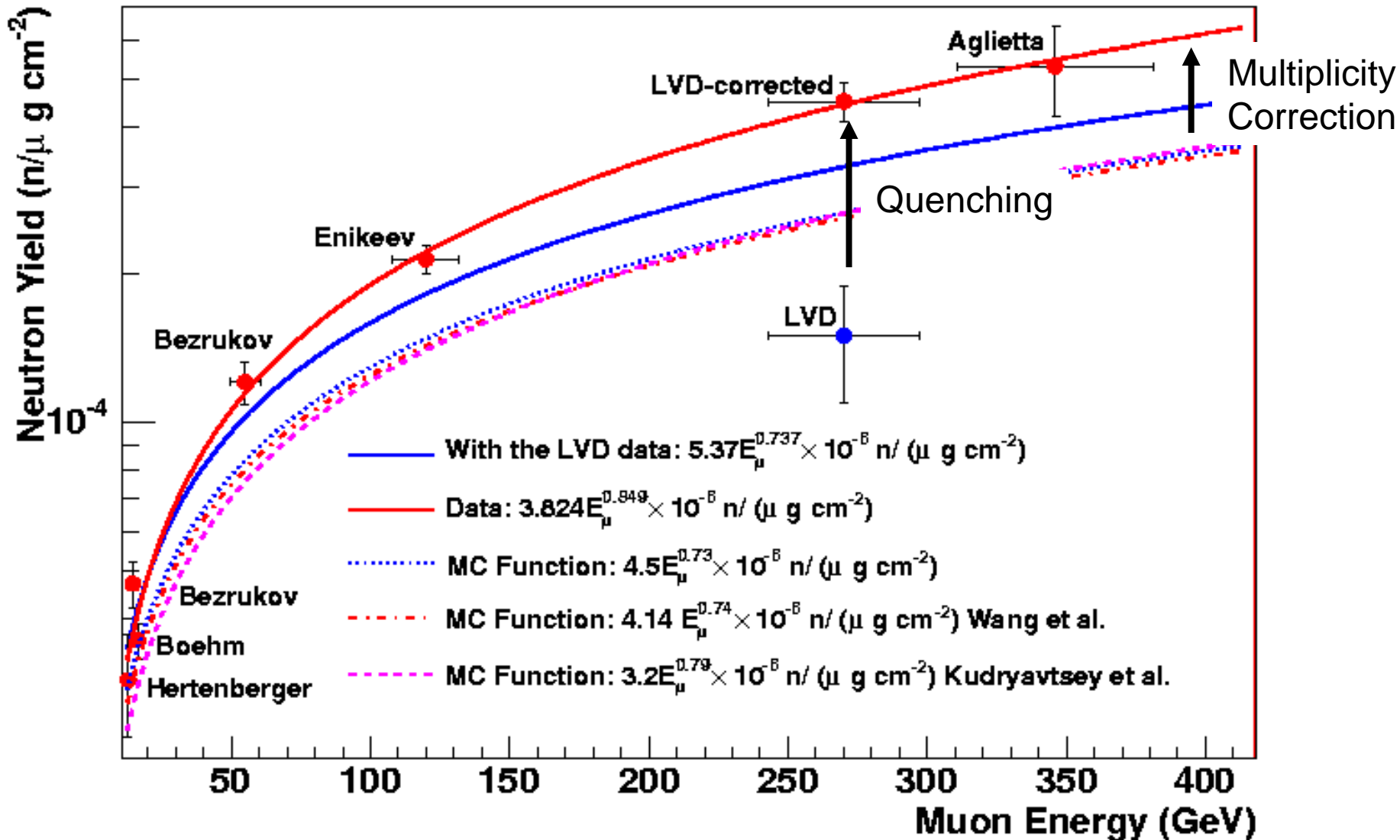
Neutron Production



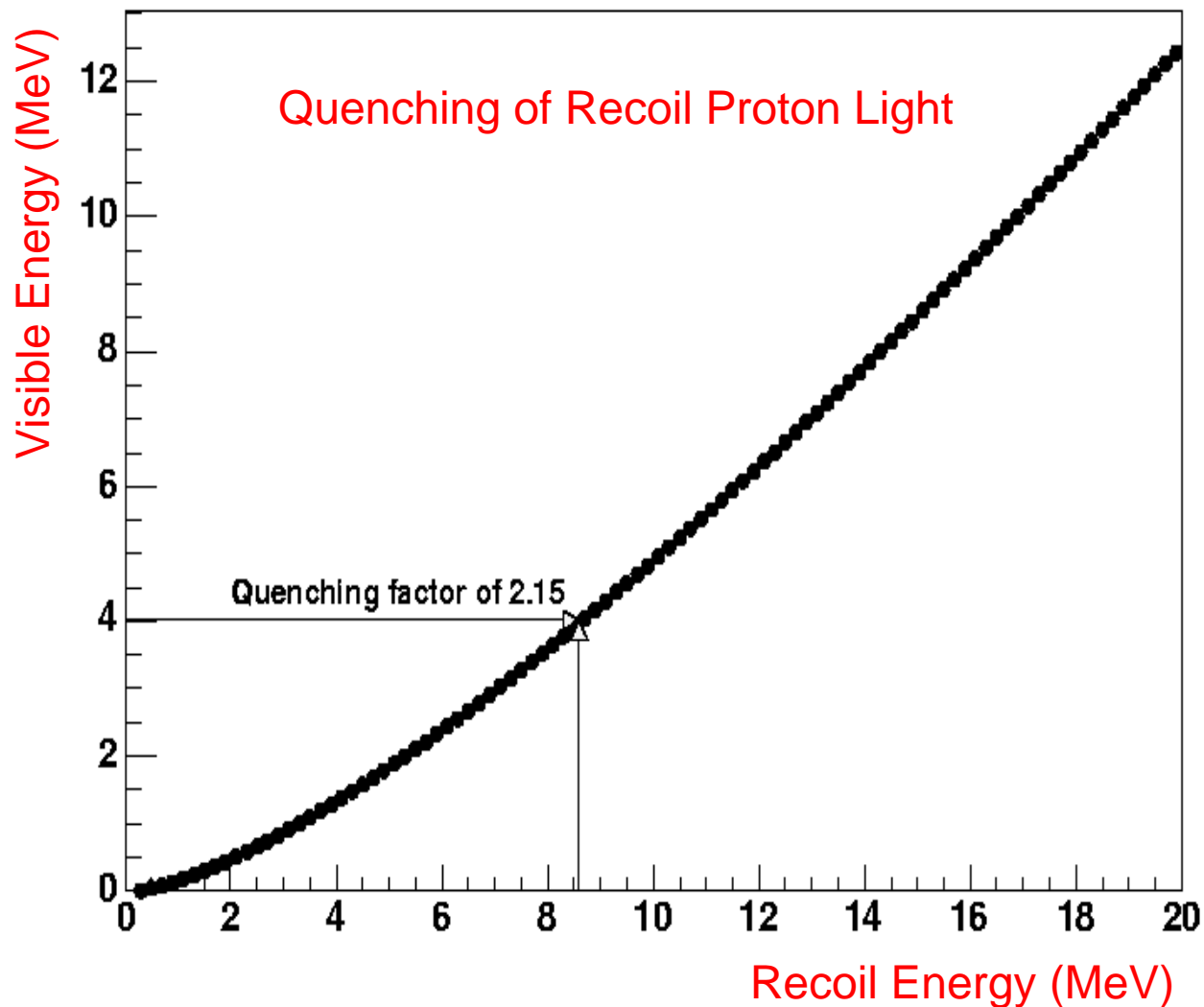
Material Dependence of Neutron Production Rate



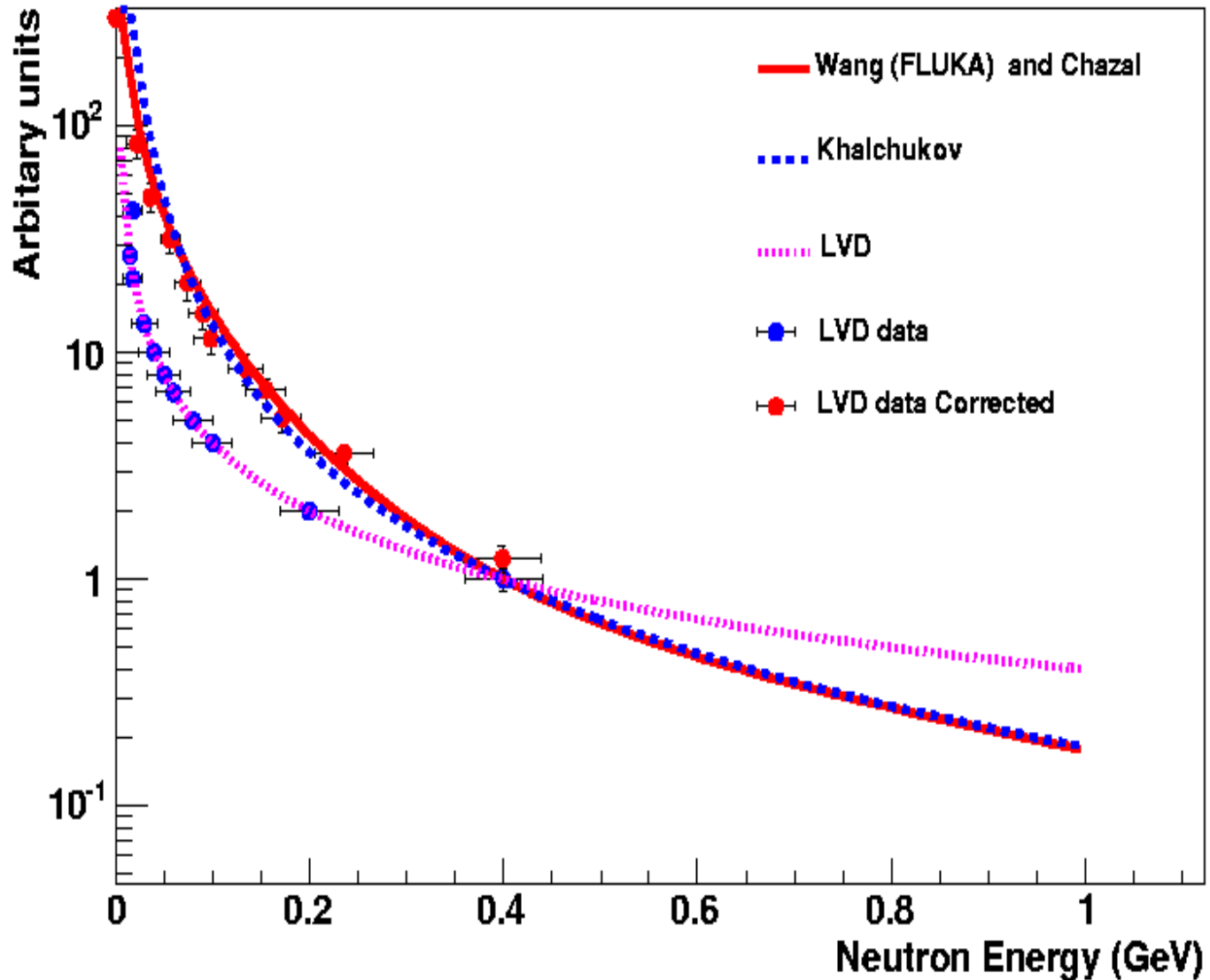
Neutron Production Rate



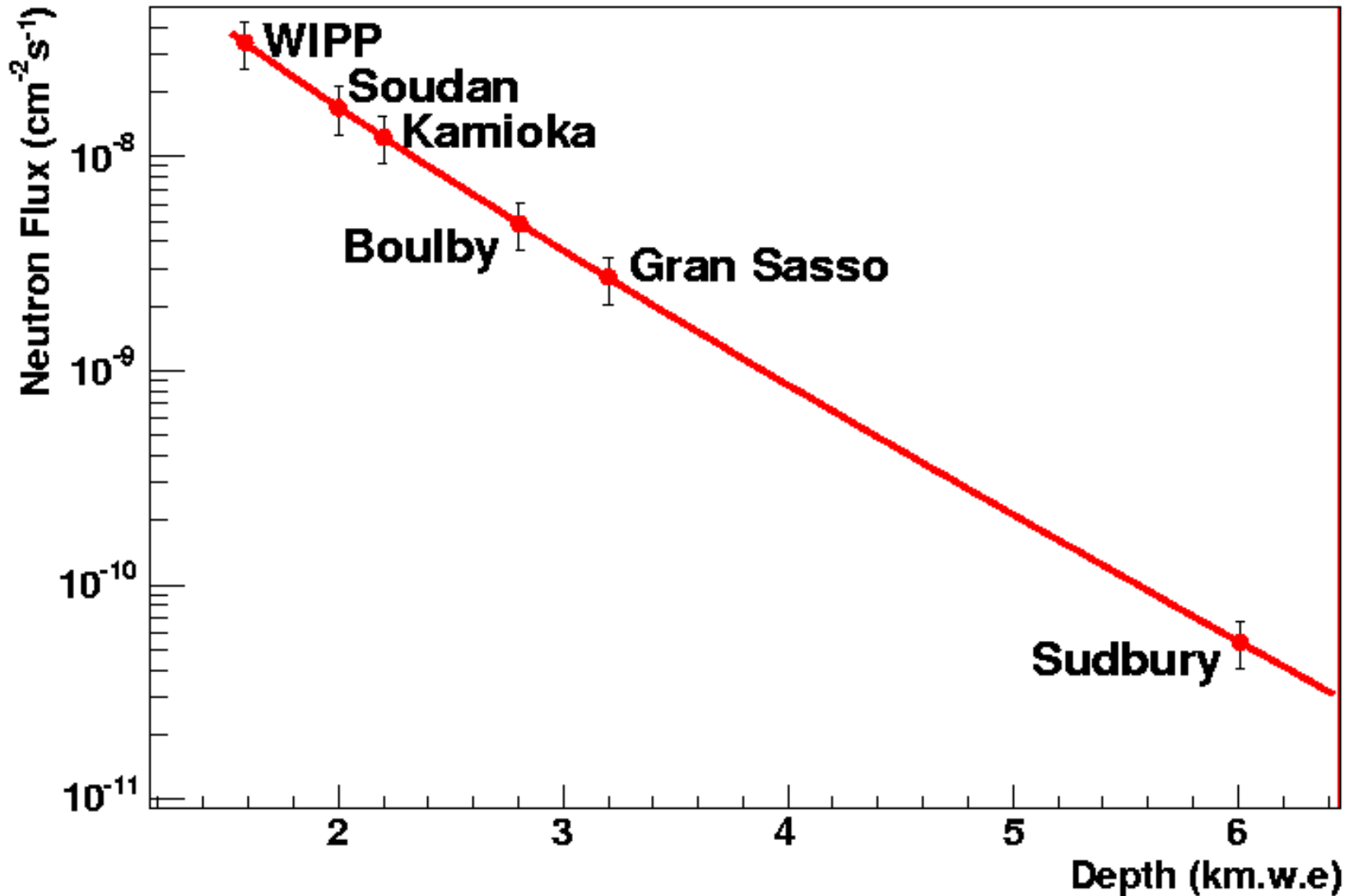
Correction to LVD Data for Quenching



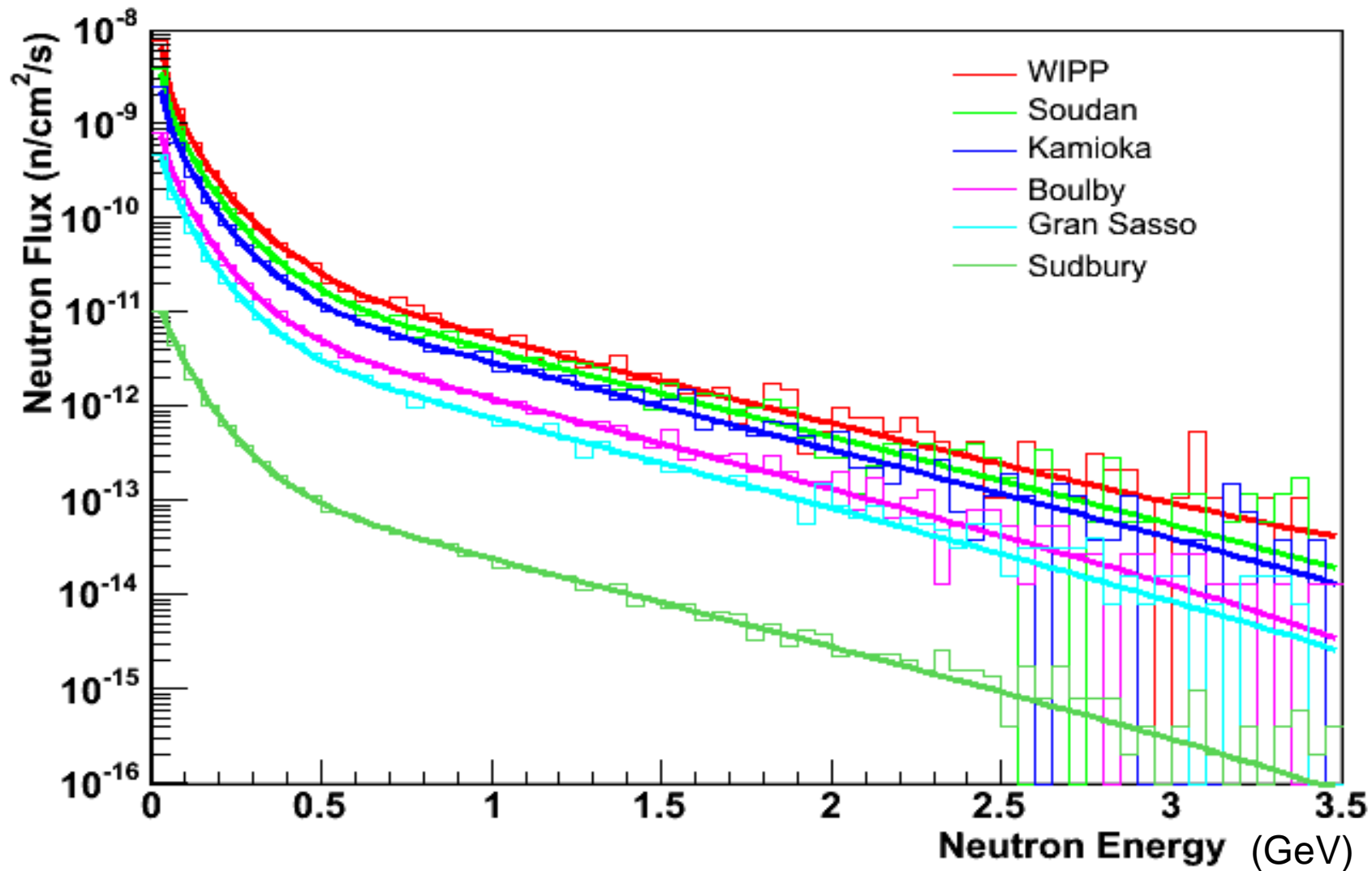
Corrected LVD Neutron Energy Spectrum



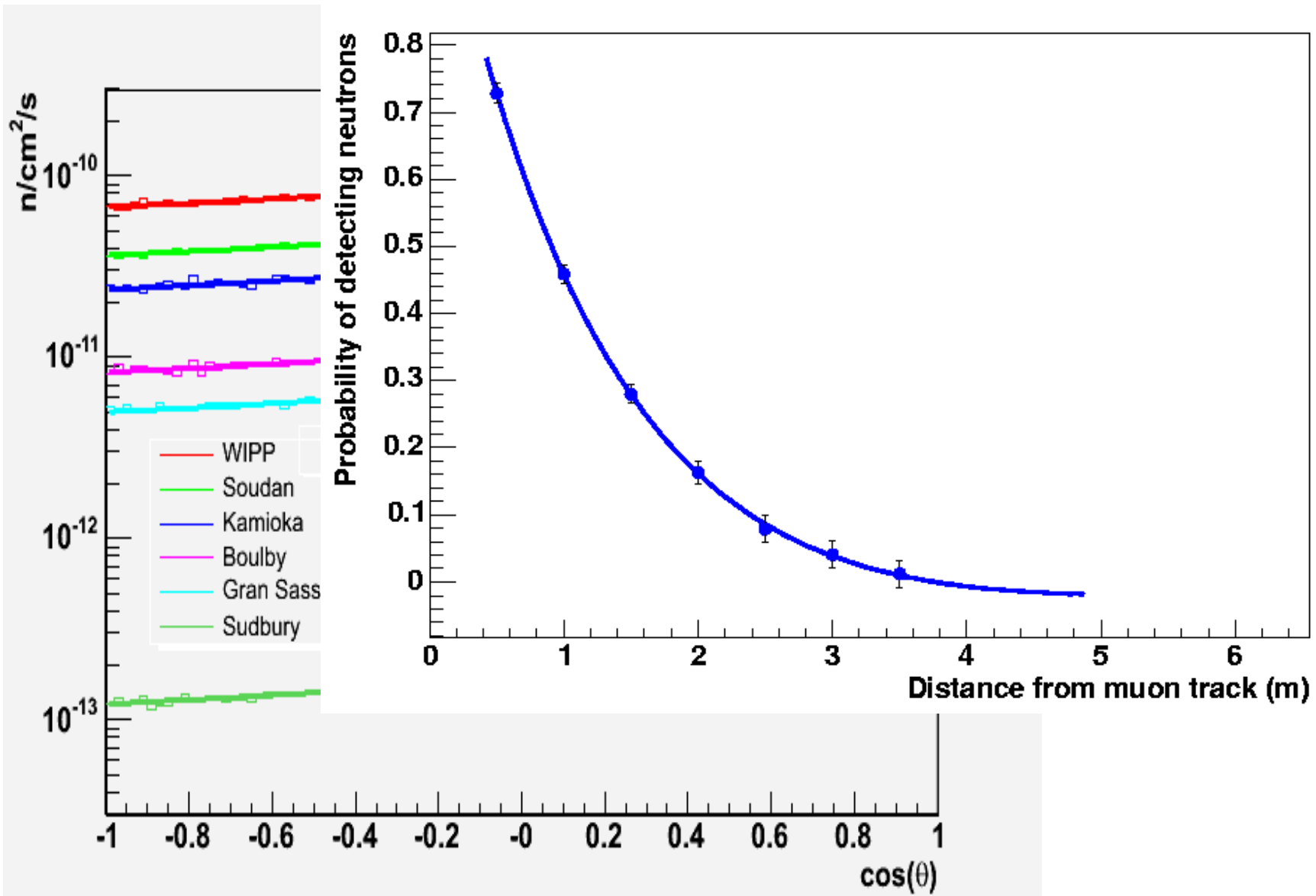
Neutron Flux at Underground Sites



Differential Neutron Energy Spectrum

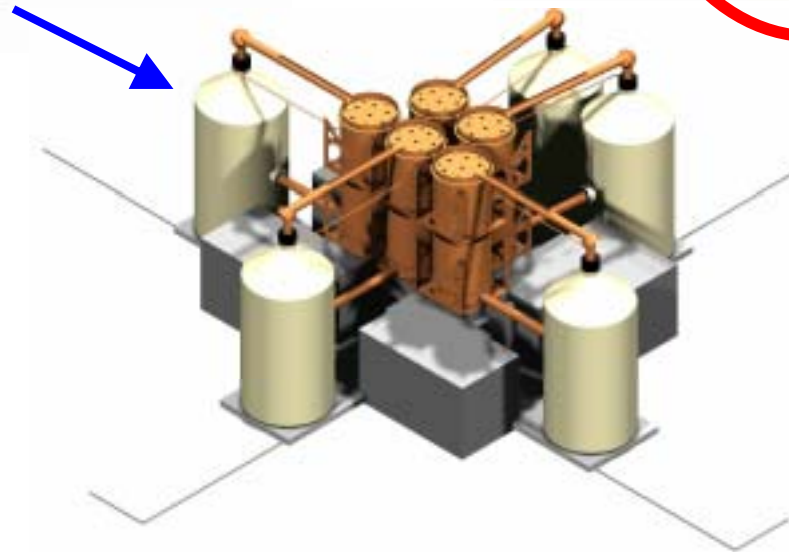
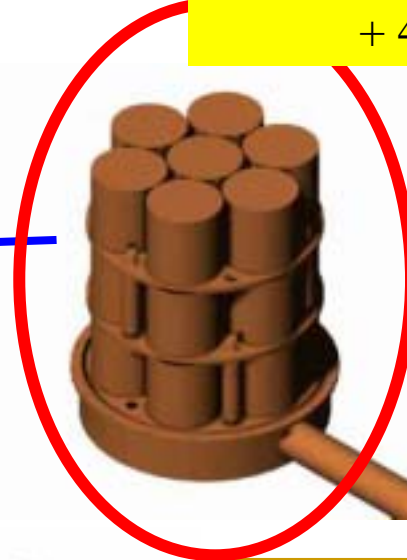
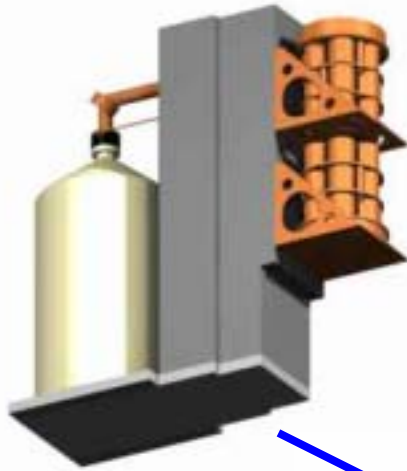


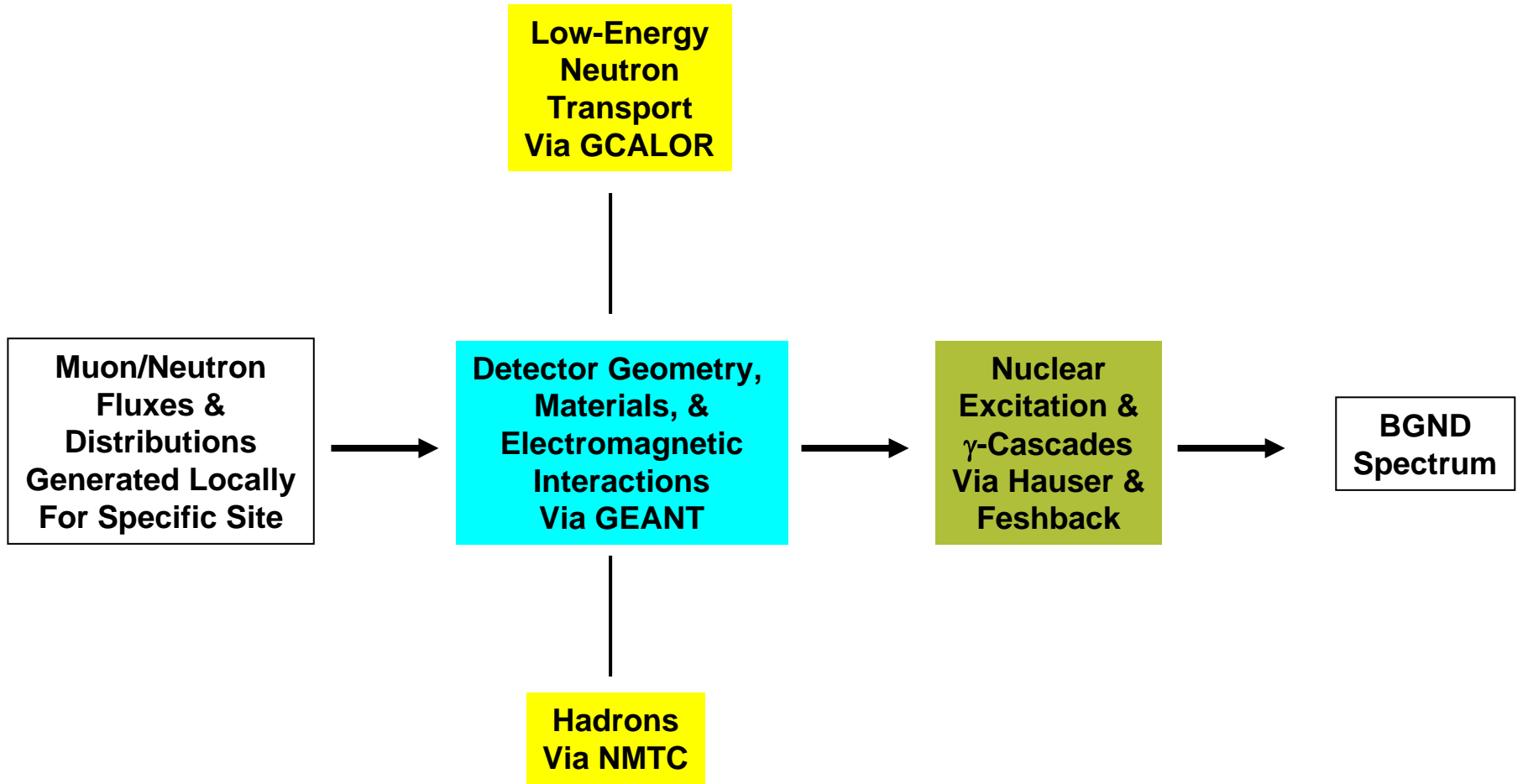
Neutron Angular & Lateral Distributions



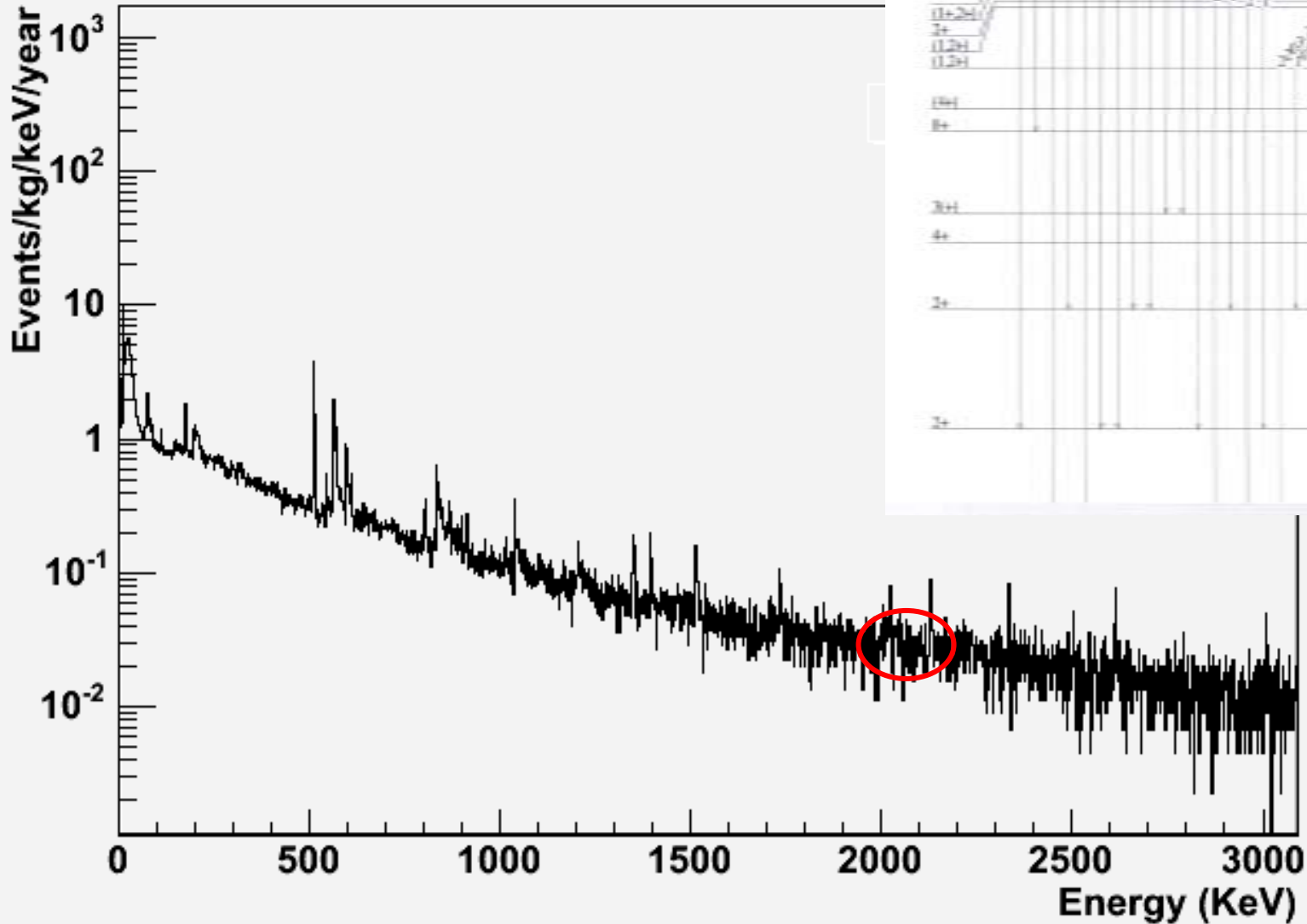
Majorana Layout

Simulate Module
57 x 1.05 kg Enriched ^{76}Ge
+ 10 cm polyethylene
+ 10 cm Cu
+ 40 cm Pb

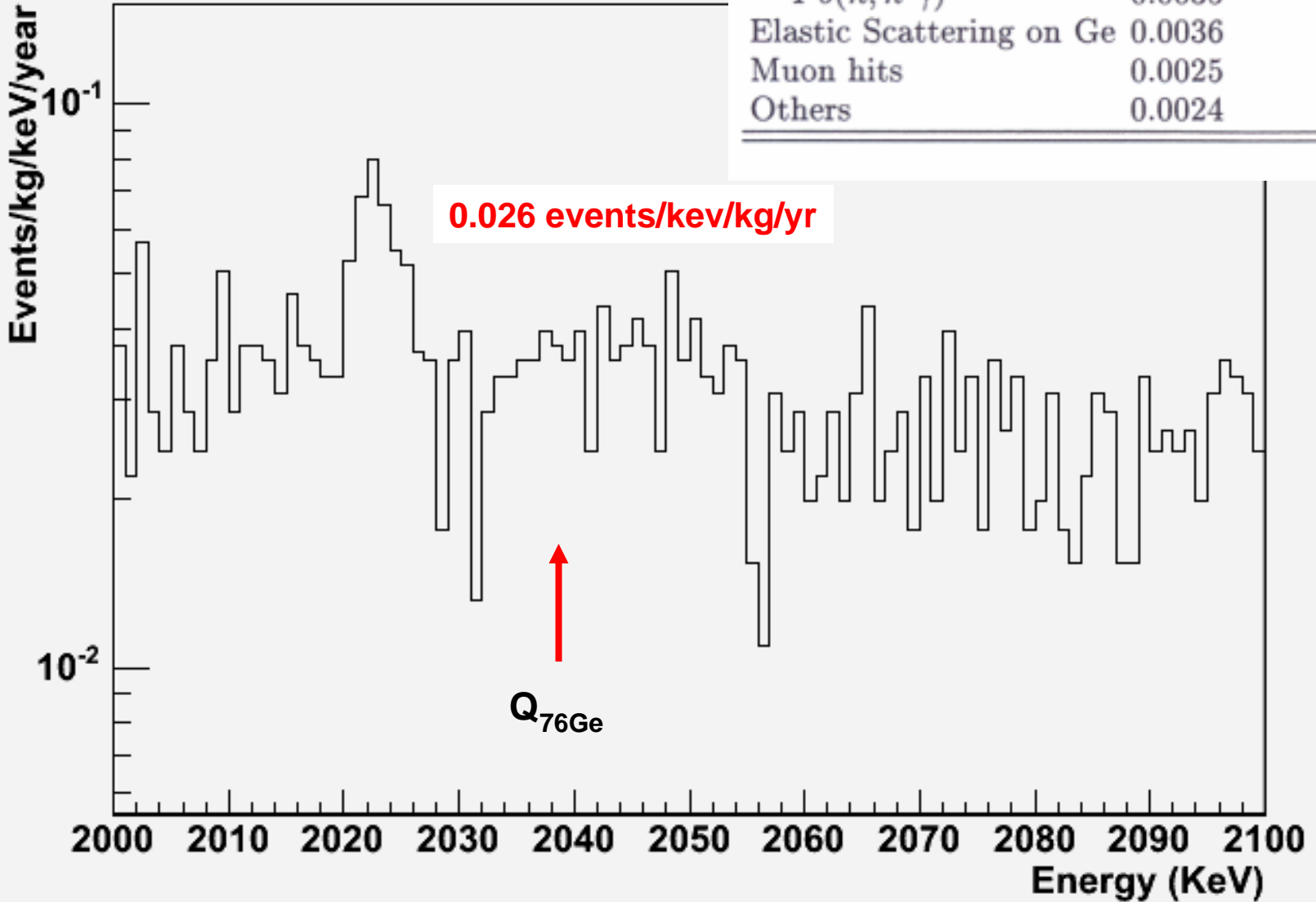




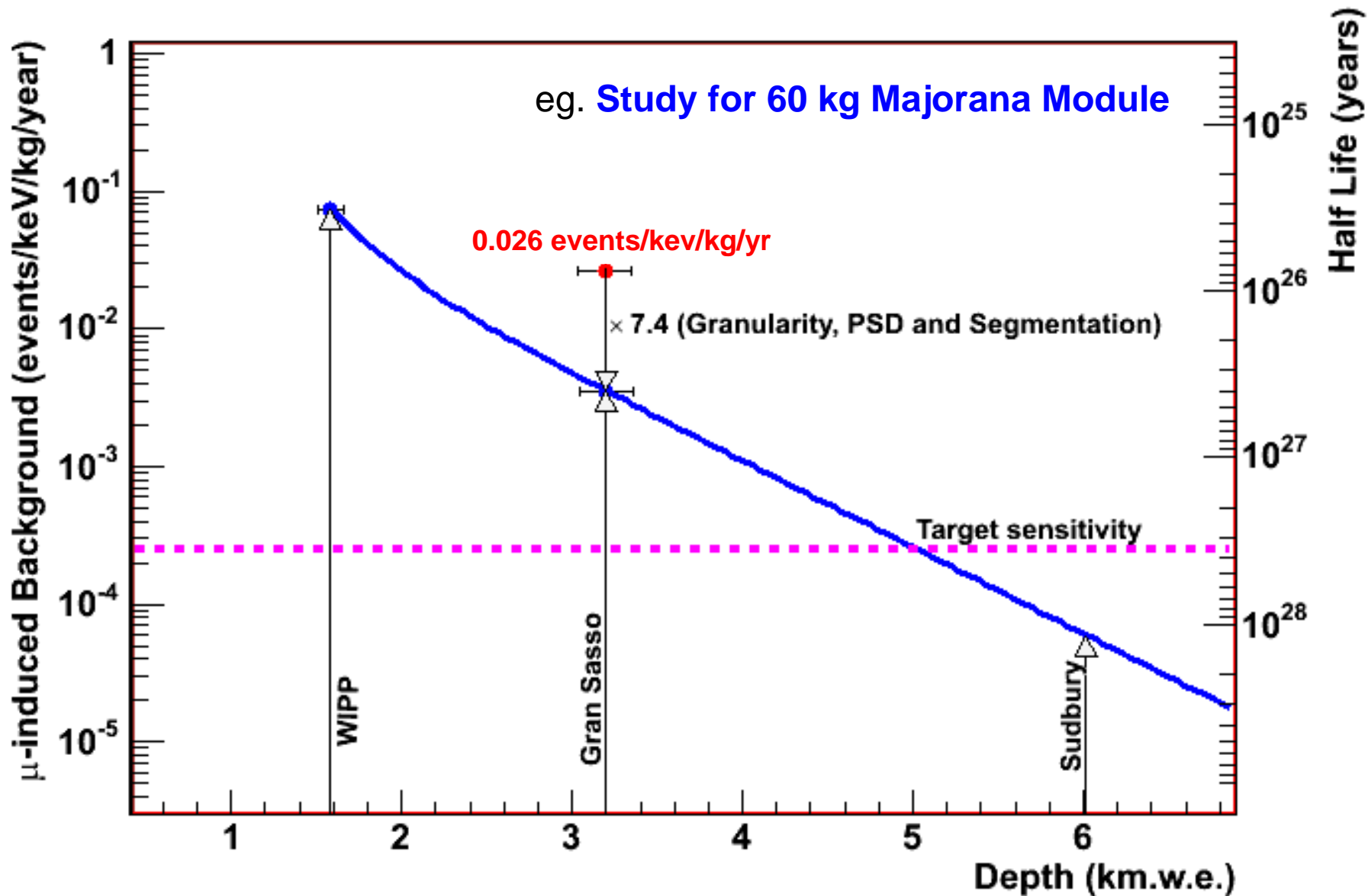
Muon-Induced Background Spectrum
 Dominated by Inelastic Neutron Scattering
 (eg. Majorana at Gran Sasso)



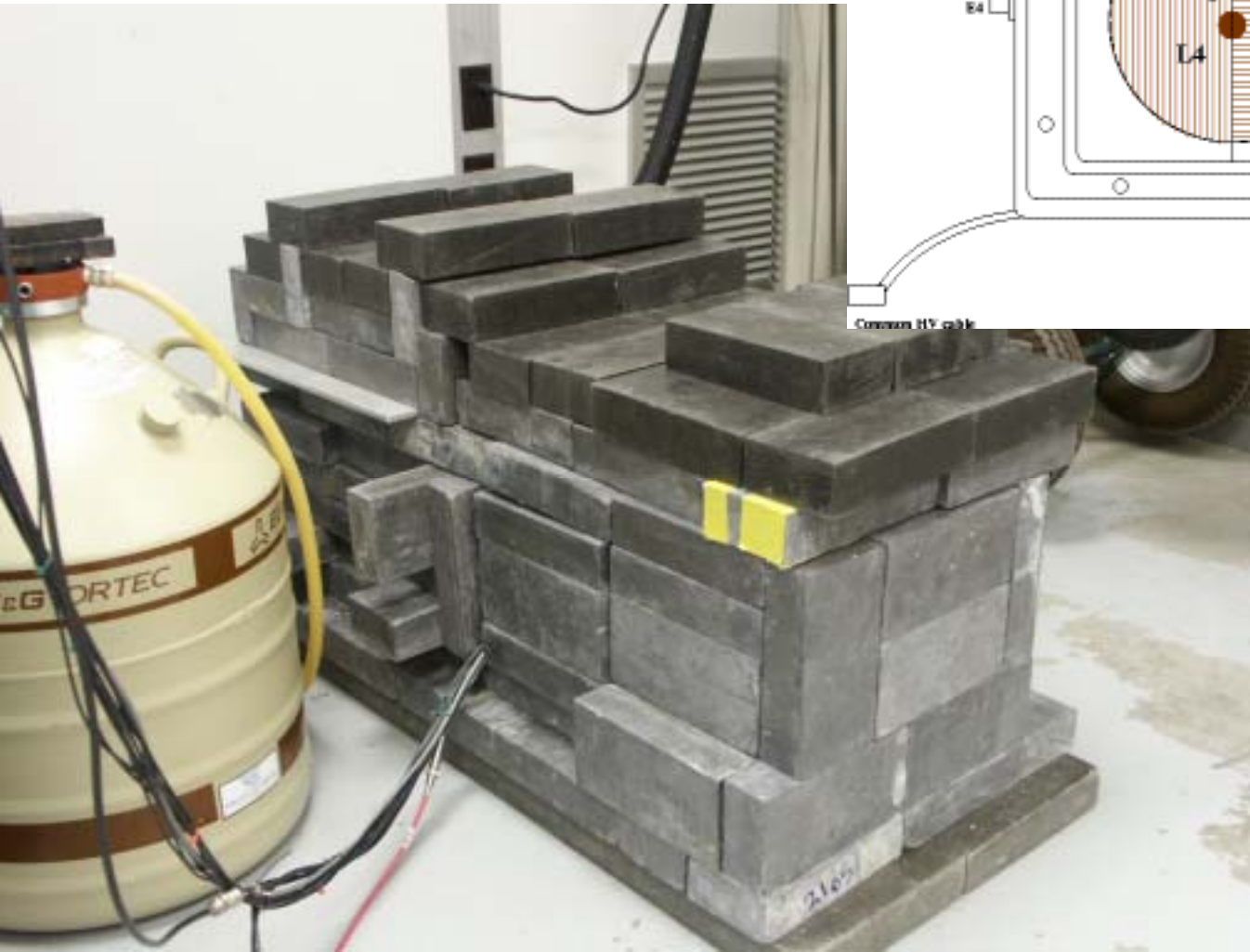
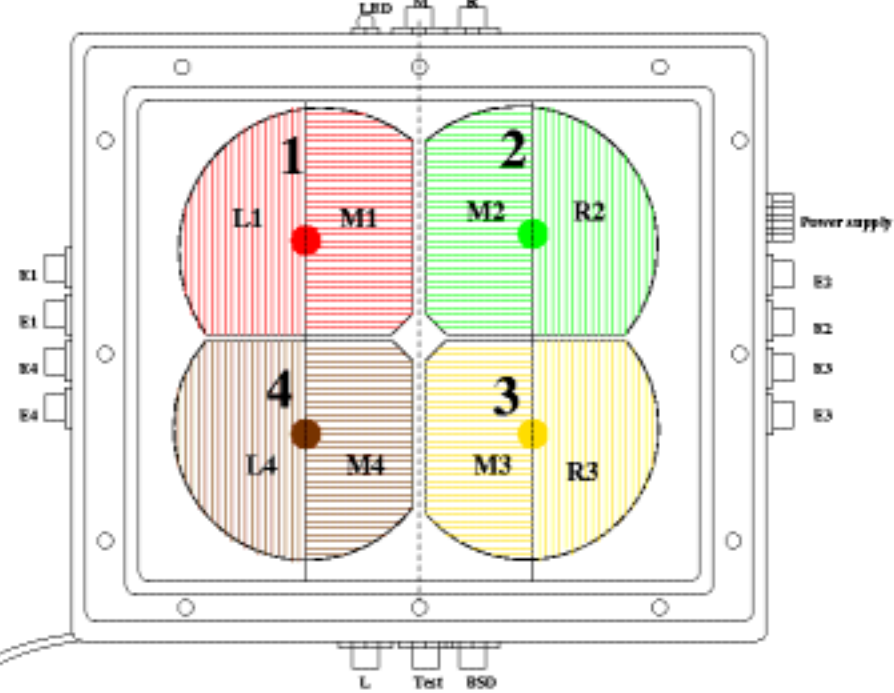
Reaction	Events in the ROI (events/keV/kg/year)
$^{76}\text{Ge}(n, n'\gamma)$	0.01
$^{74}\text{Ge}(n, n'\gamma)$	0.002
$\text{Cu}(n, n'\gamma)$	0.0019
$^{208}\text{Pb}(n, n'\gamma)$	0.0035
Elastic Scattering on Ge	0.0036
Muon hits	0.0025
Others	0.0024

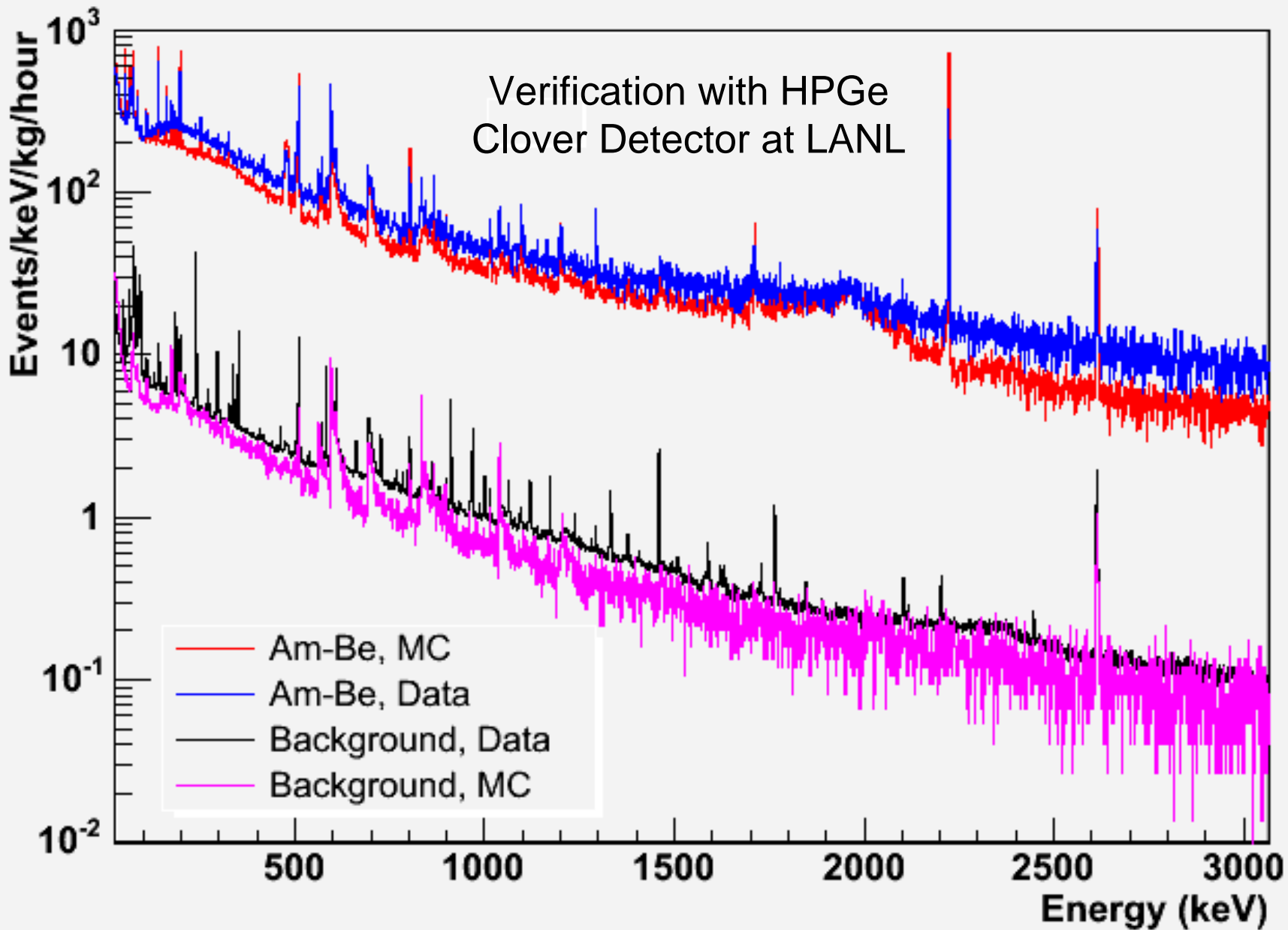


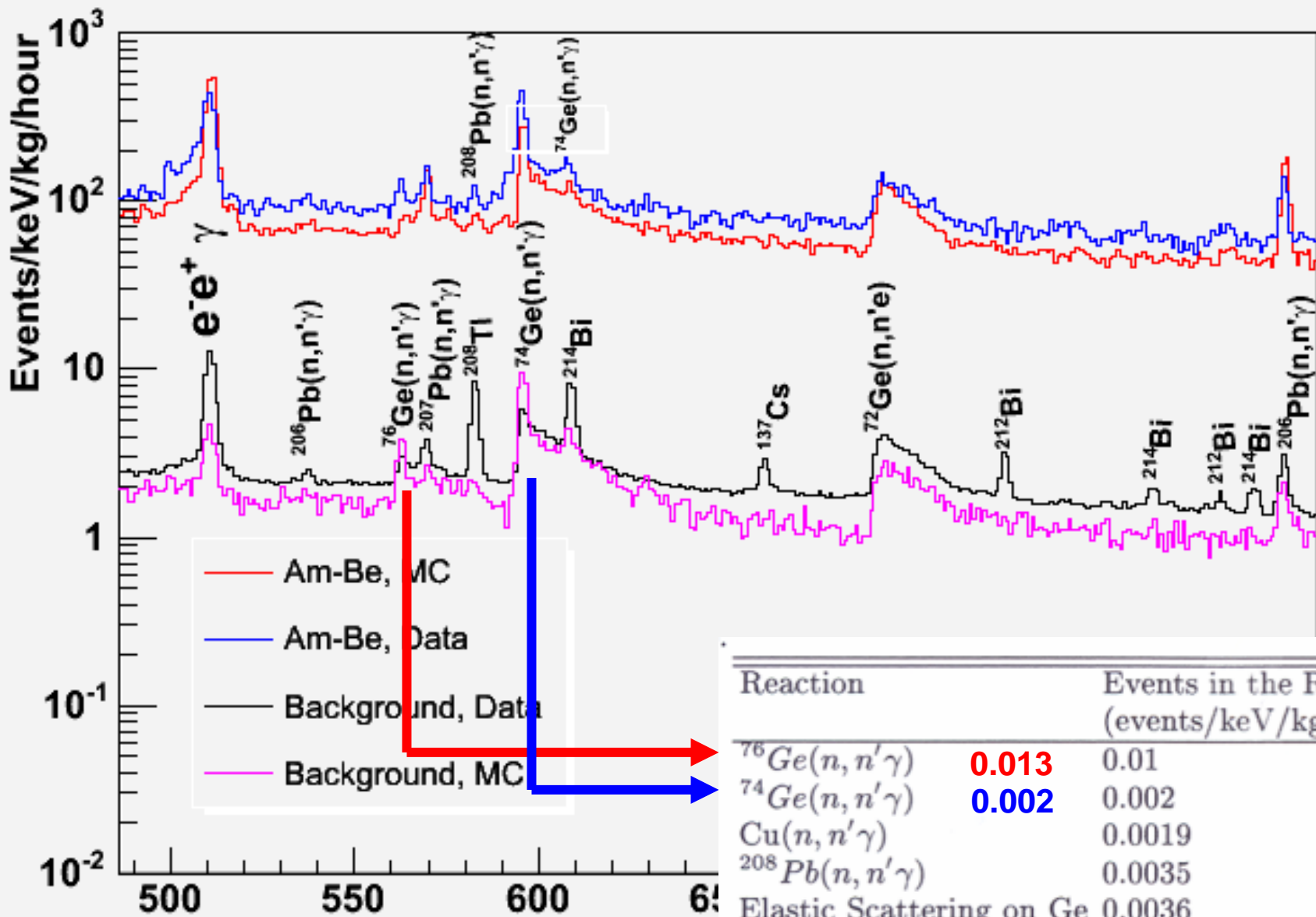
Depth Sensitivity Relation for Double Beta Decay



Verification with HPGe Clover Detector at LANL







Reaction		Events in the ROI (events/keV/kg/year)
$^{76}\text{Ge}(n, n'\gamma)$	0.013	0.01
$^{74}\text{Ge}(n, n'\gamma)$	0.002	0.002
$\text{Cu}(n, n'\gamma)$		0.0019
$^{208}\text{Pb}(n, n'\gamma)$		0.0035
Elastic Scattering on Ge		0.0036
Muon hits		0.0025
Others		0.0024

Summary & Conclusions

- Data on Muon Flux & Distributions
 - Depth defined based upon total muon flux relative to a site with flat overburden ... Good experimental data base for input to muon-induced simulations.

- Fast Neutron Flux & Distributions
 - FLUKA simulations reproduce fluxes & distributions well after appropriate account of multiplicity and corrections to LVD data.
 - Good verification of fast neutron induced background using clover detector

- Depth Sensitivity Relation (DSR)
 - Next generation experiments in search of neutrinoless double beta decay using enriched ^{76}Ge require depths in excess of 5000 m.w.e. to reach sensitivity to the inverted mass hierarchy ... Otherwise heroic efforts are required to tag/veto such background.