



ULUN YLIOPISTO  
UNIVERSITY of OULU



New neutron monitor yield function  
computed at several altitudes above the sea level:

## **Application for GLE analysis**

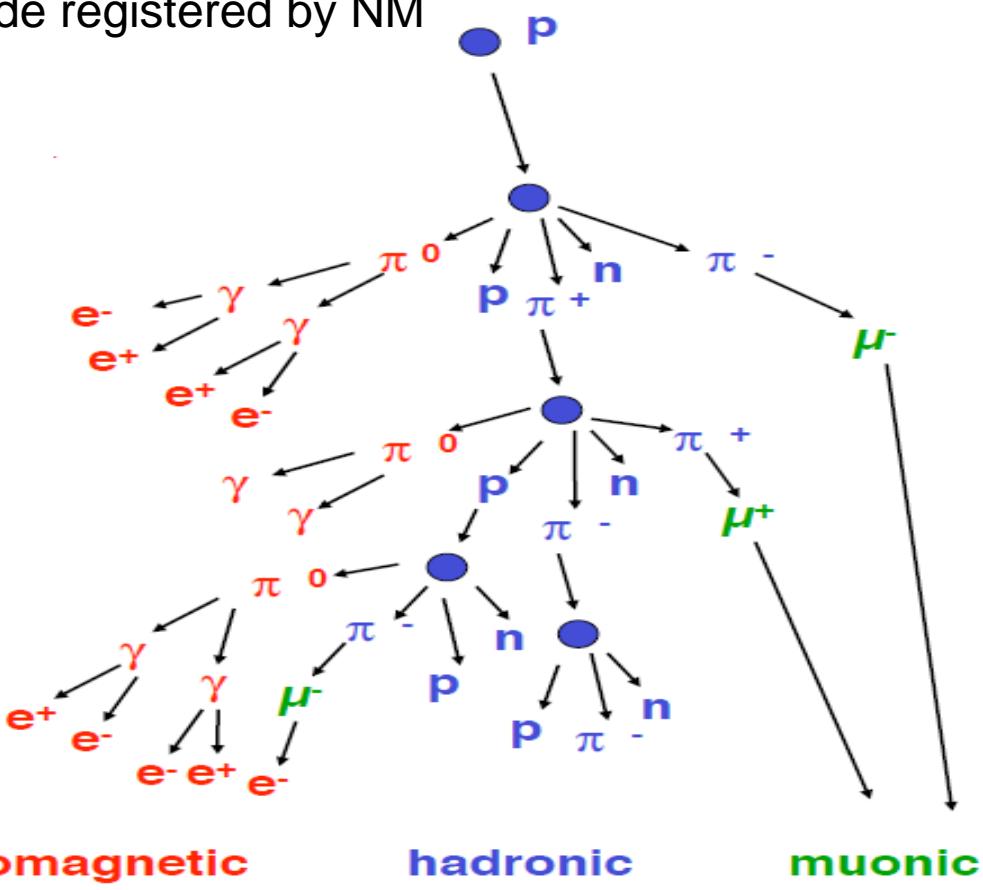
A.Mishev, I. Usoskin & G. Kovaltsov

ReSolve, University of Oulu, Finland

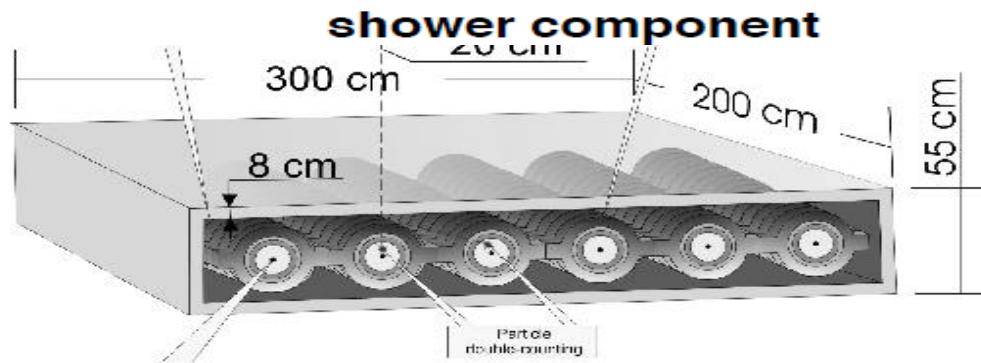
# **OUTLINE**

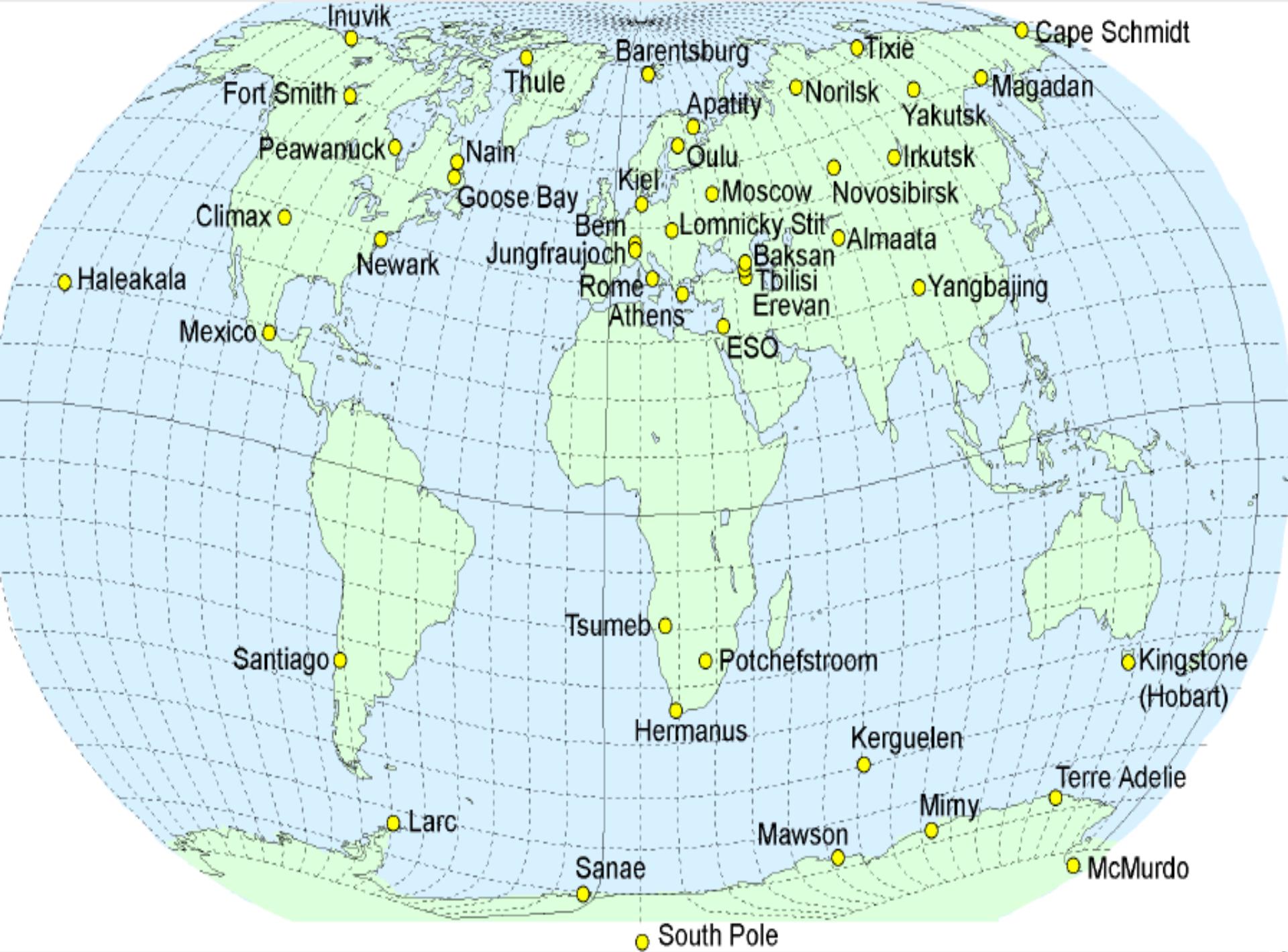
1. Introduction, CR, NM, NMYF
2. New NM yield function
3. GLE analysis
4. Conclusions

# Atmospheric cascade registered by NM



electromagnetic      hadronic      muonic





The count rate of the neutron monitor is related to the flux of primary cosmic rays through the Specific Yield Function S(R). The convolution of SYF on a spectrum of protons gives the response function. The response function of the neutron monitor is an expression describing a connection between parameters of primary proton flux outside magnetosphere and count rate of the instrument at a given point of the globe

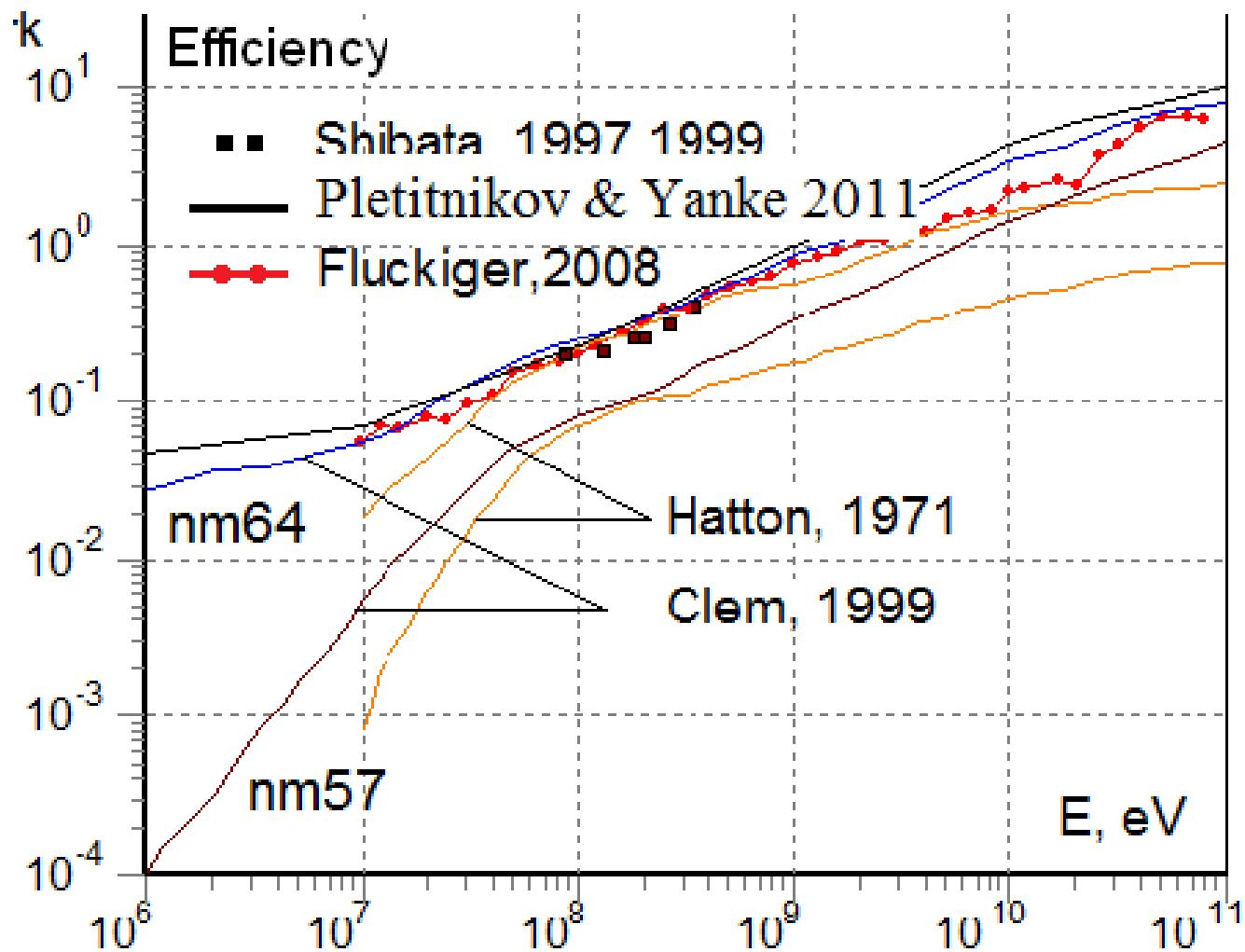
$$N(P_c, h, t) = \int_{P_c}^{\infty} \sum_i Y_i(P, h) j_i(P, t) dP = \int_{P_c}^{\infty} W_T(P, h, t) dP$$

The NM yield function is defined as

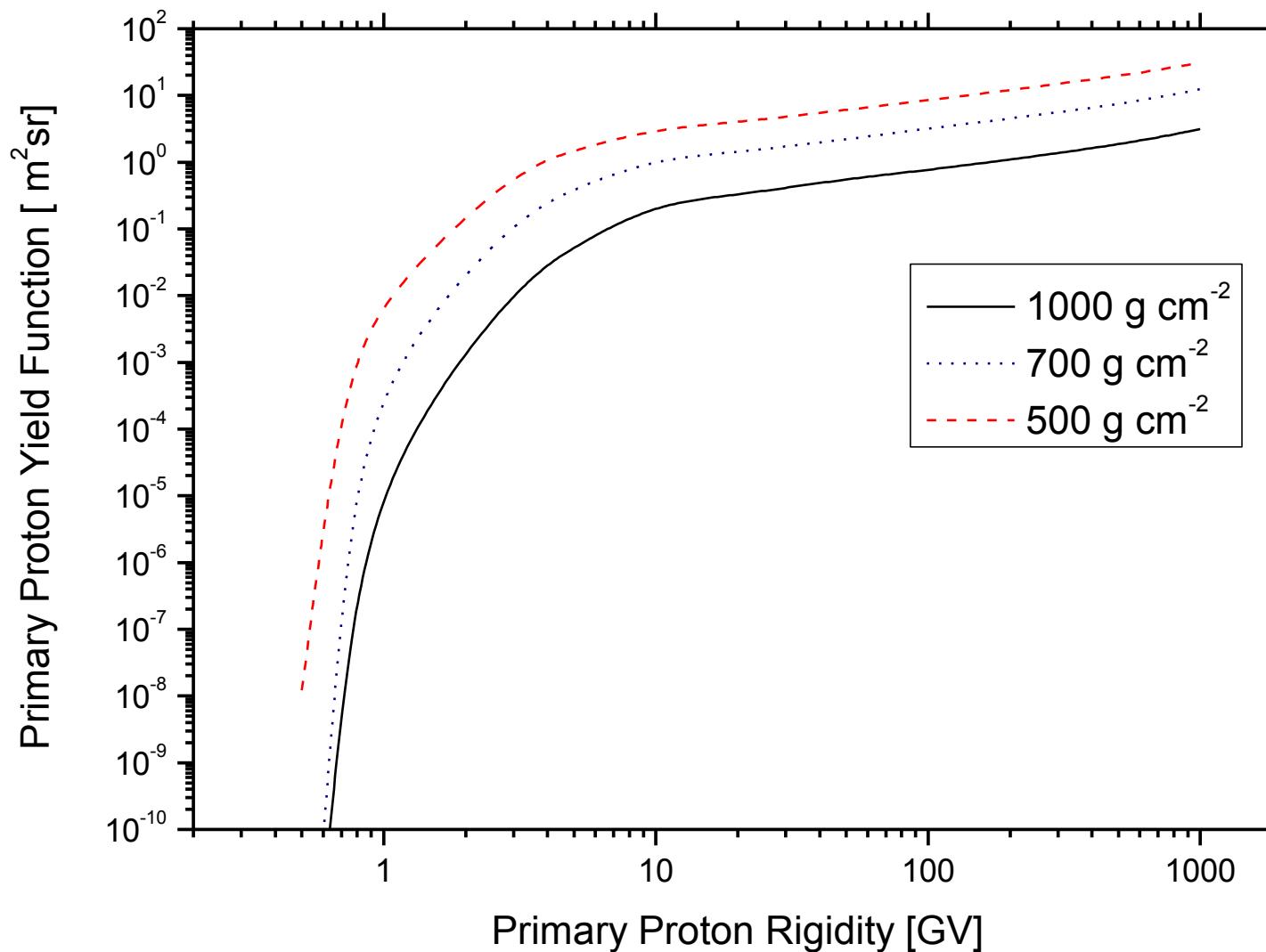
$$Y_i(P, h) = \sum_i \int \int A_i(E, \theta) F_{i,j}(P, h, E, \theta) dE d\Omega$$

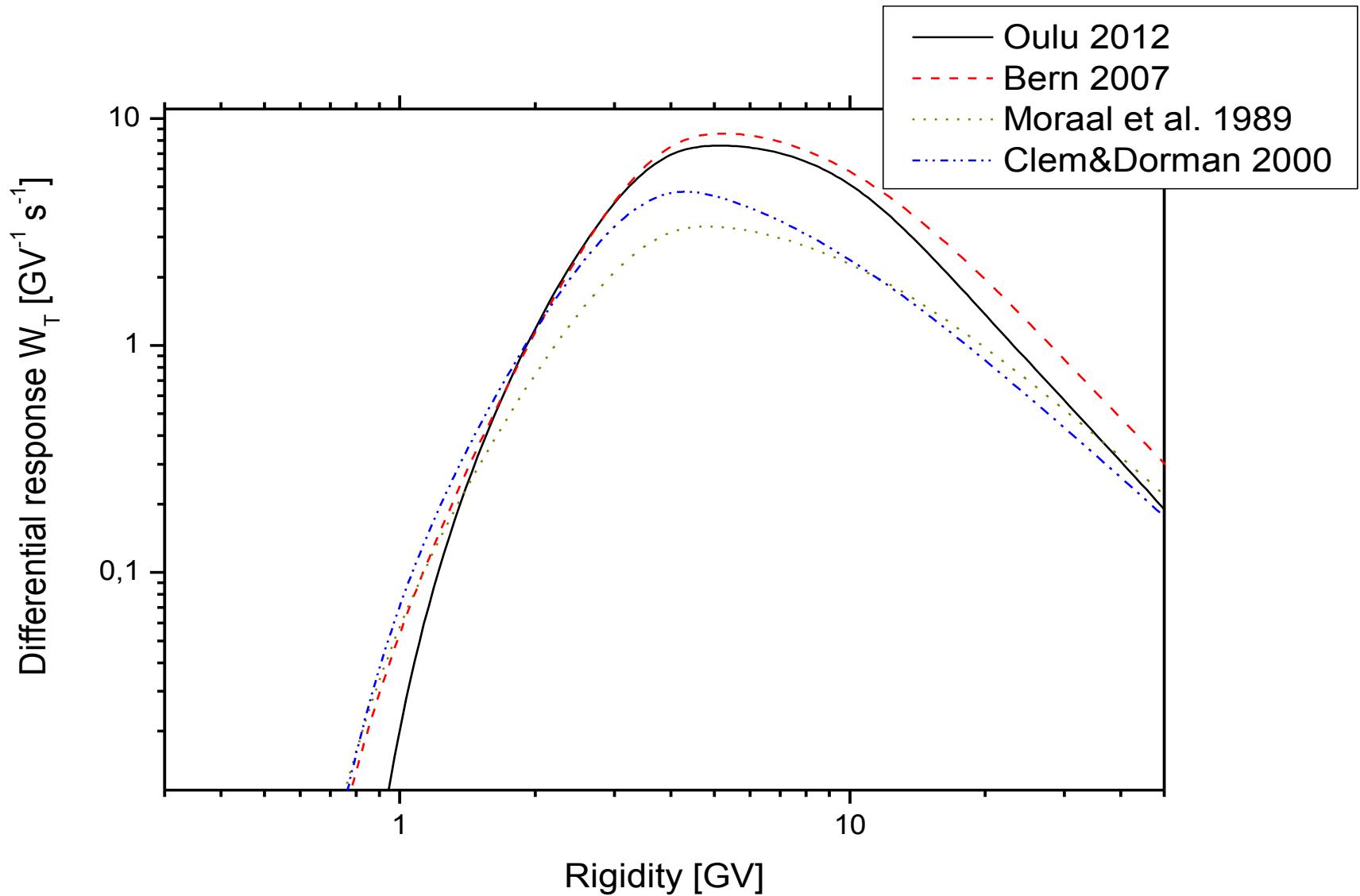
$A_i$  is the effective area (detector area multiplied by registration efficiency),  $F$  is the secondary particle flux,  $E$  is the secondary particle energy

## NM detection efficiency II

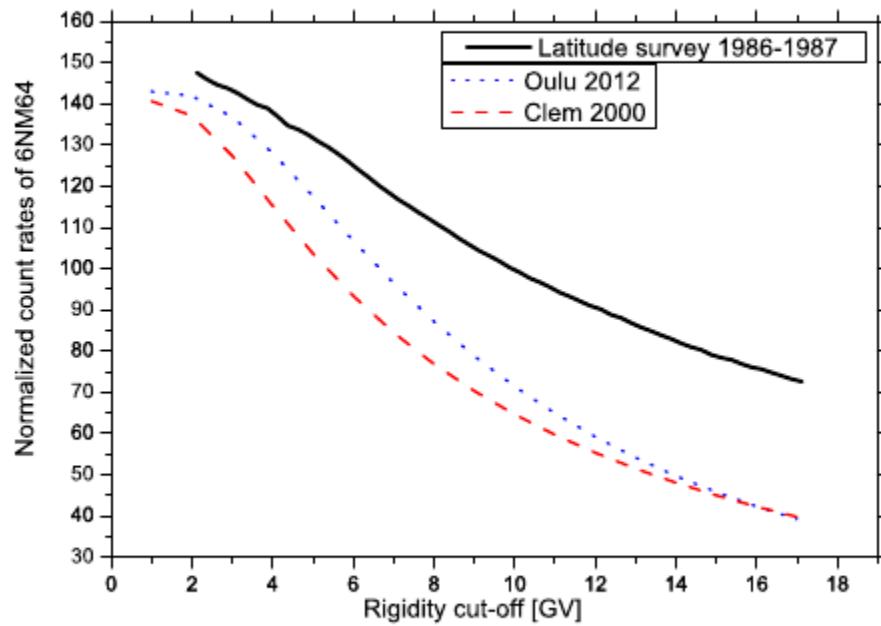


# New computed NM yield function at various atmospheric depths





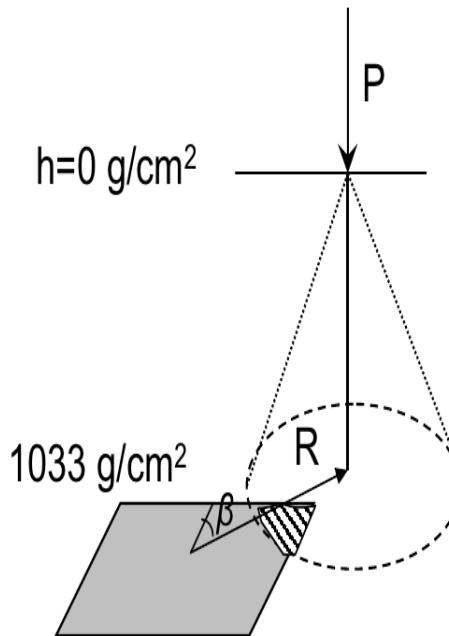
Differential response at sea level, compared with previous computations



Recalculation of NM effective area

Count rate vs latitude survey

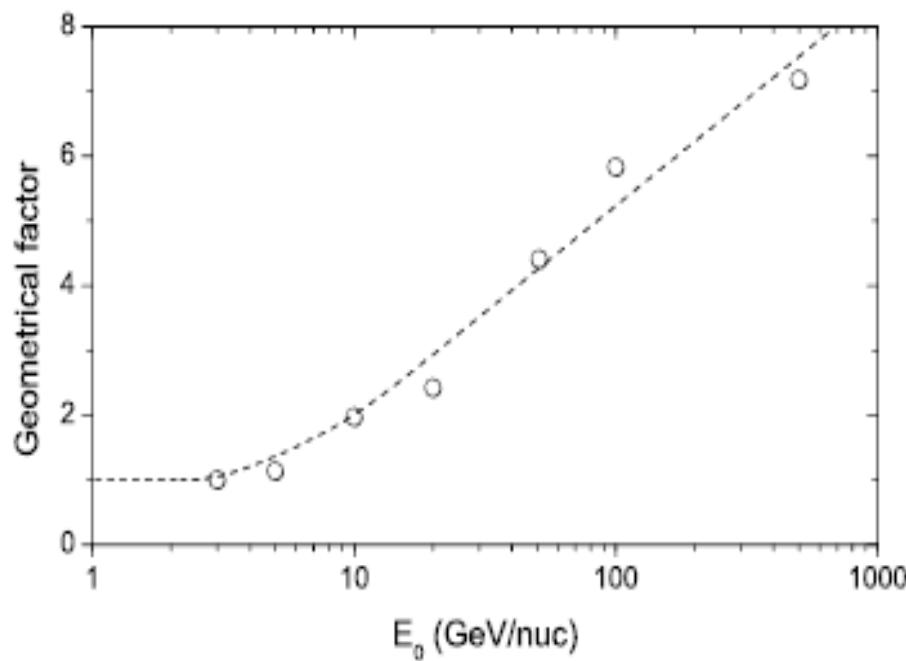
- discrepancy
- long time standing problem

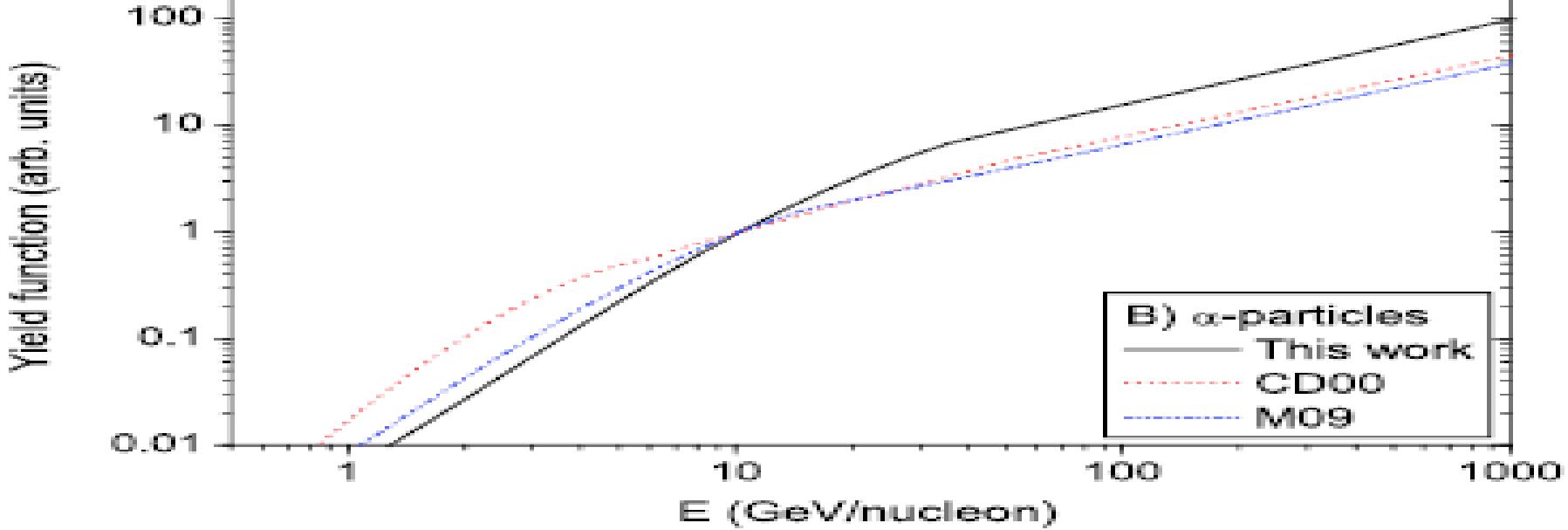
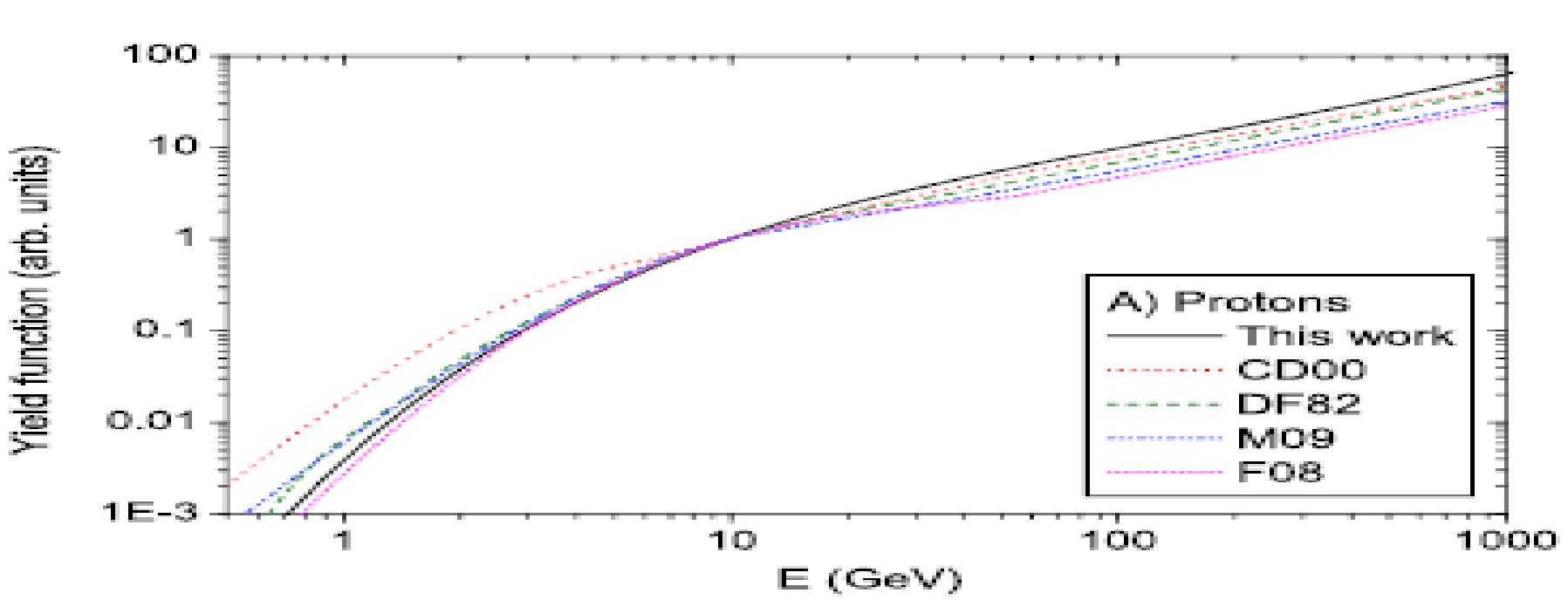


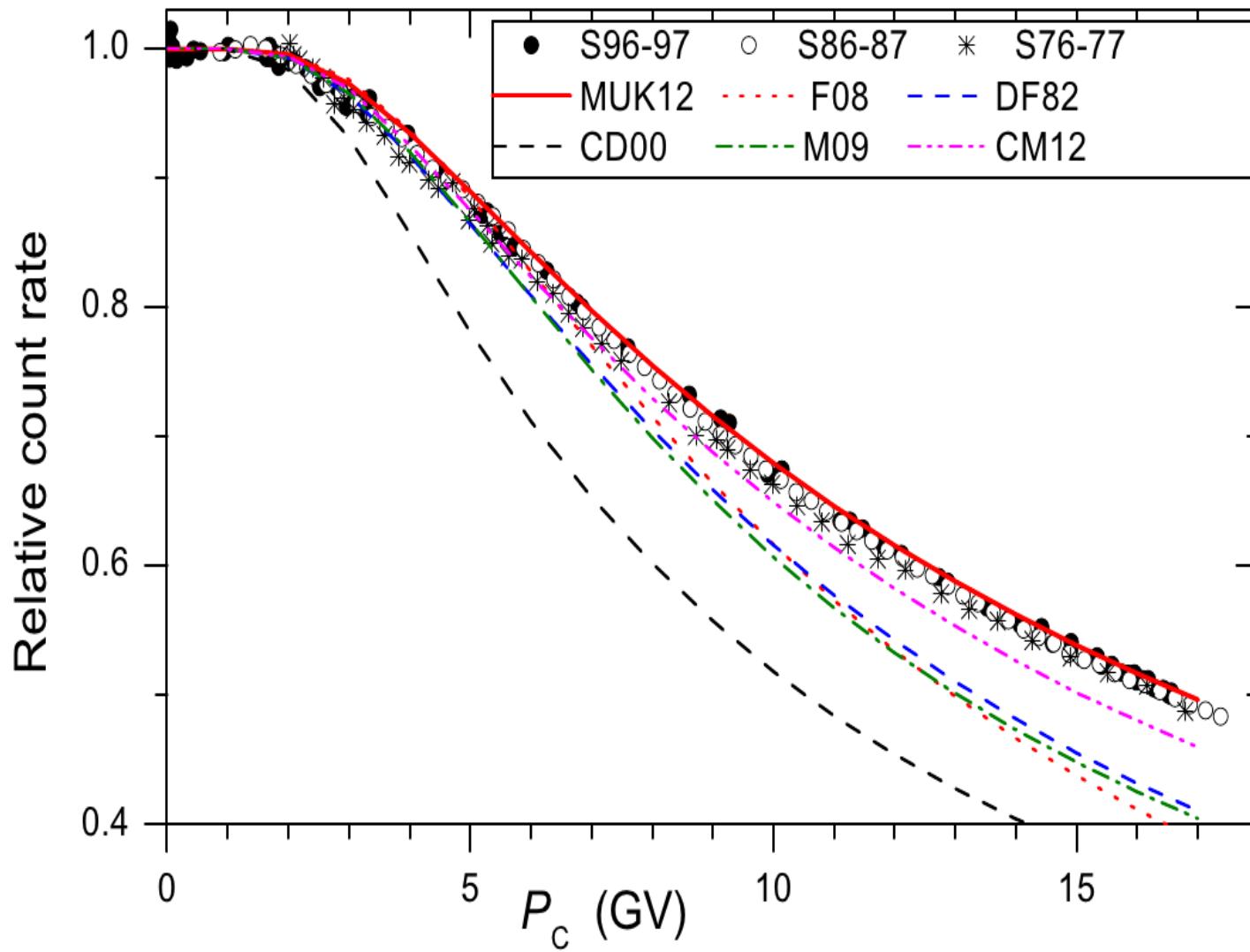
$$w(R, P) = \min[N(R, P); 1].$$



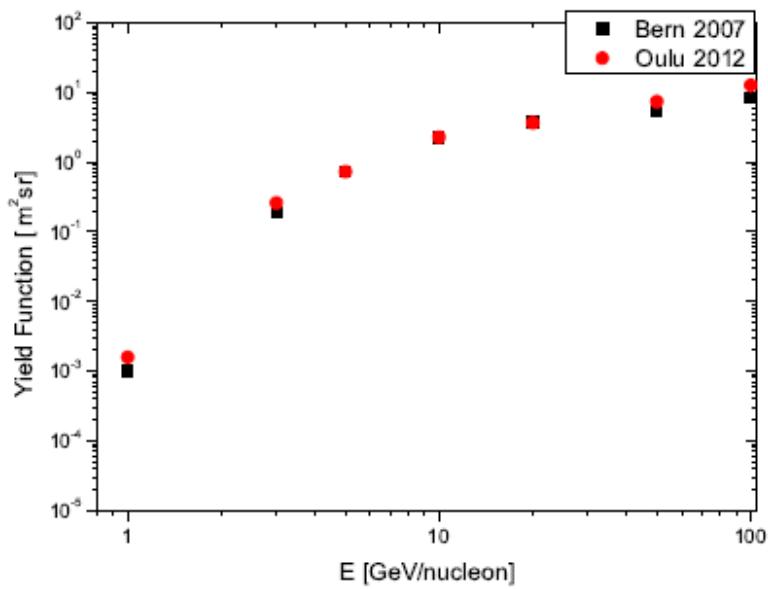
$$G(P) = \frac{2\pi}{S_{\text{NM}}} \int_0^{\infty} R \cdot w(R, P) \cdot dR$$



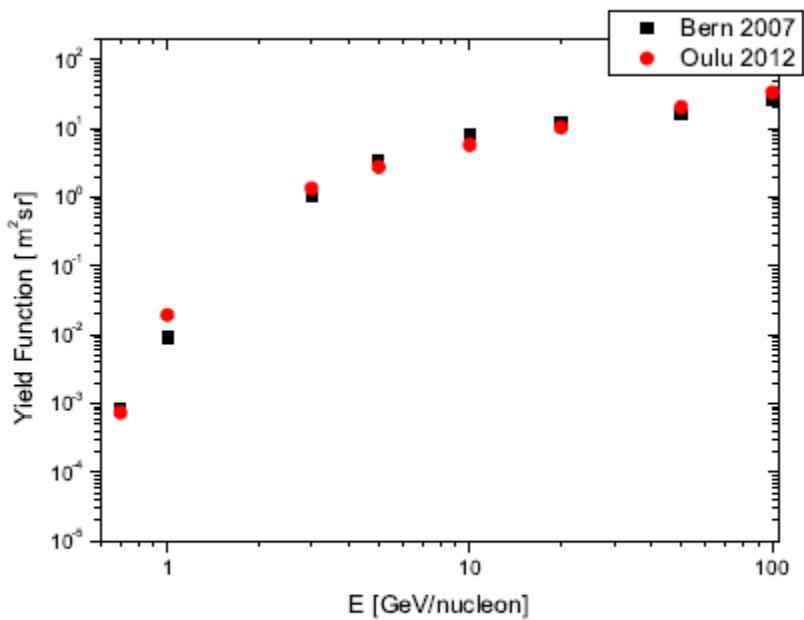




Count rate with corrected Y vs latitude survey



(a) 700 g/cm<sup>2</sup> ( $\approx$  3000 m above the sea level)



(b) 500 g/cm<sup>2</sup> ( $\approx$  5000 m above the sea level)

## The NM count rate modeling

$$\frac{\Delta N(P_{cut}, t)}{N(t)} = \frac{\int_{P_{cut}}^{P_{max}} J_{||sep}(P, t) Y(P) G(\alpha(P), t) dP}{\int_{P_{cut}}^{\infty} J_{GCR}(P, t) Y(P) dP}$$



$$\frac{\Delta N(P_{cut}, t)}{N(t)} = \frac{1}{9} \sum_{i(\theta,\phi)=1}^9 \frac{\sum_{P_{cut}}^{P_{max}} A(P, \theta, \phi) J_{||sep}(P, t) Y(P) G(\alpha(P), t) \Delta P}{\sum_{P_{cut}}^{\infty} A(P, \theta, \phi) J_{GCR}(P, t) Y(P) \Delta P}$$

$$\mathcal{F} = \sum_{i=1}^m \left[ \left( \frac{\Delta N_i}{N_i} \right)_{\text{mod.}} - \left( \frac{\Delta N_i}{N_i} \right)_{\text{meas.}} \right]^2$$

Inverse, constrained nonlinear problem  
Levenberg Marquardt algorithm using MINPACK

Modified power law

$$J(P) = J_0 P^{-(\gamma + \delta\gamma(P-1))}$$

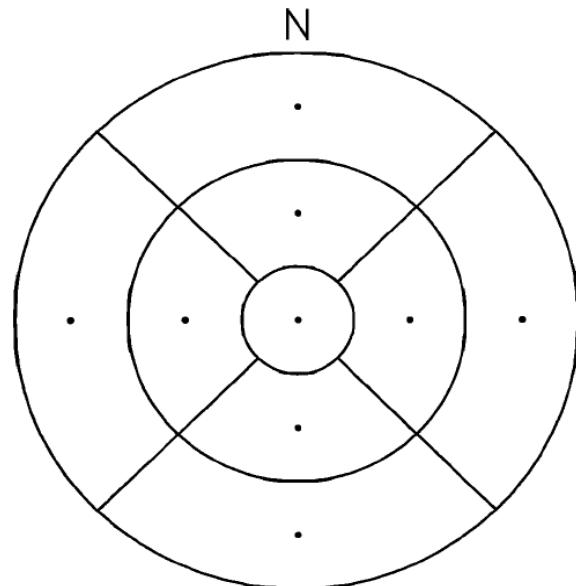
PAD – Gaussian like

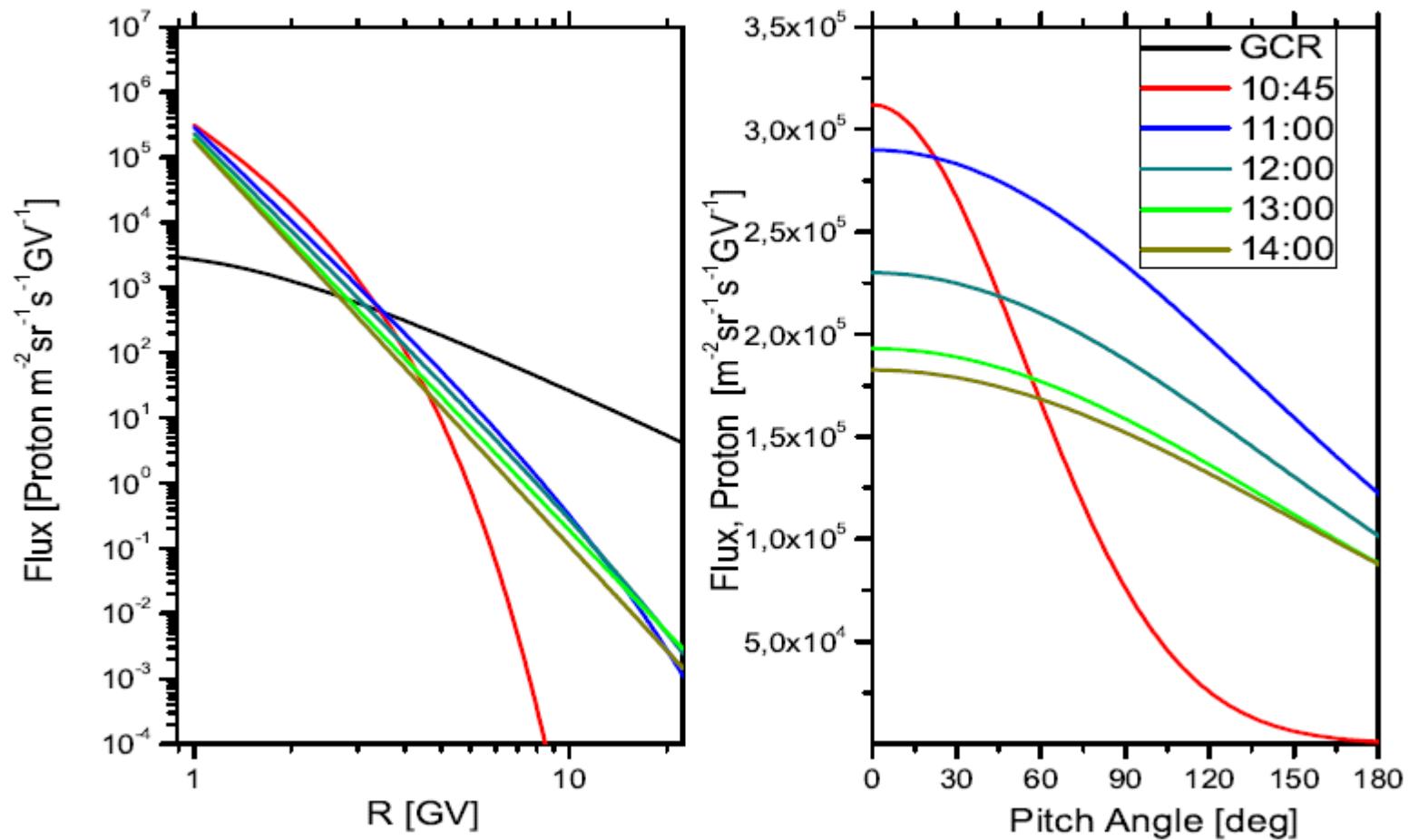
$$G(\alpha) = \sum_i \exp - (\alpha_i - \alpha_{\text{ref}})^2 / \sigma_i^2$$

From 5 Up to 14 parameters, express method 3 parameters

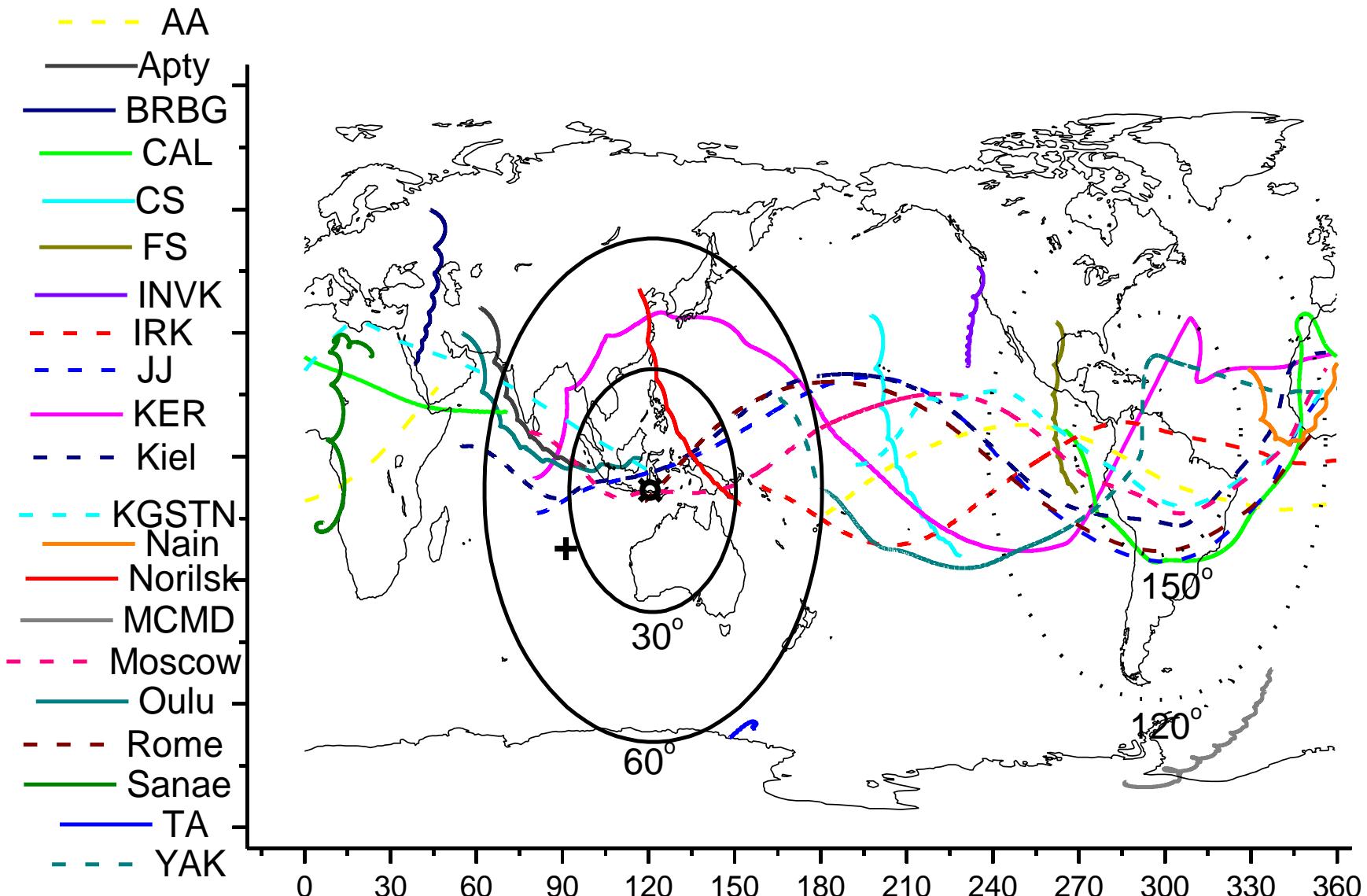
# GLE analysis

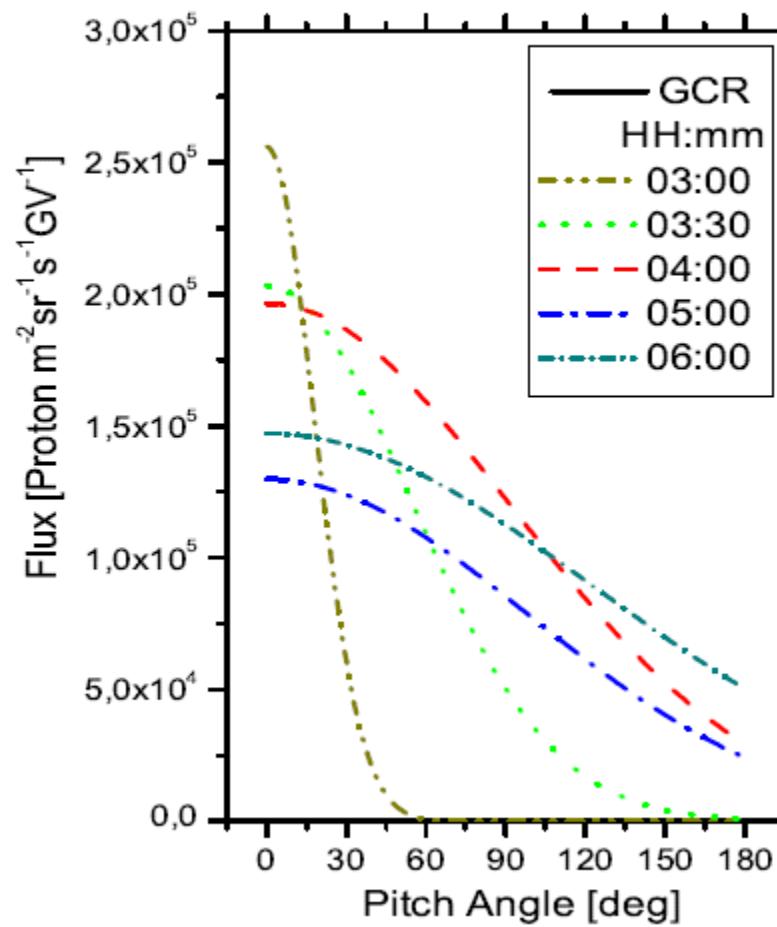
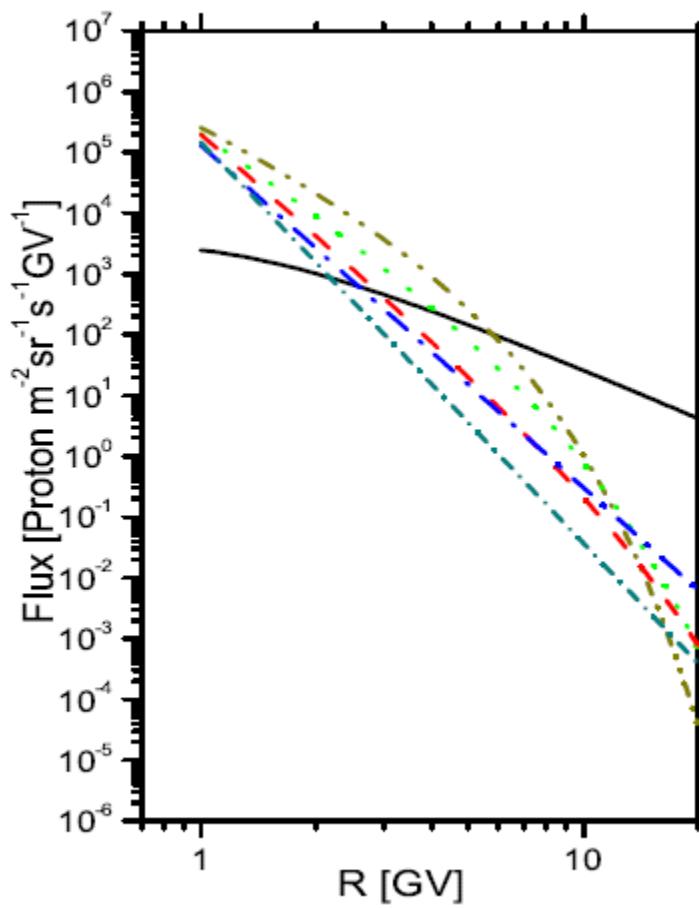
1. Asymptotic cones – model magnetosphere IGRF + Tsyganenko 89
2. Initial guess
3. Inverse method



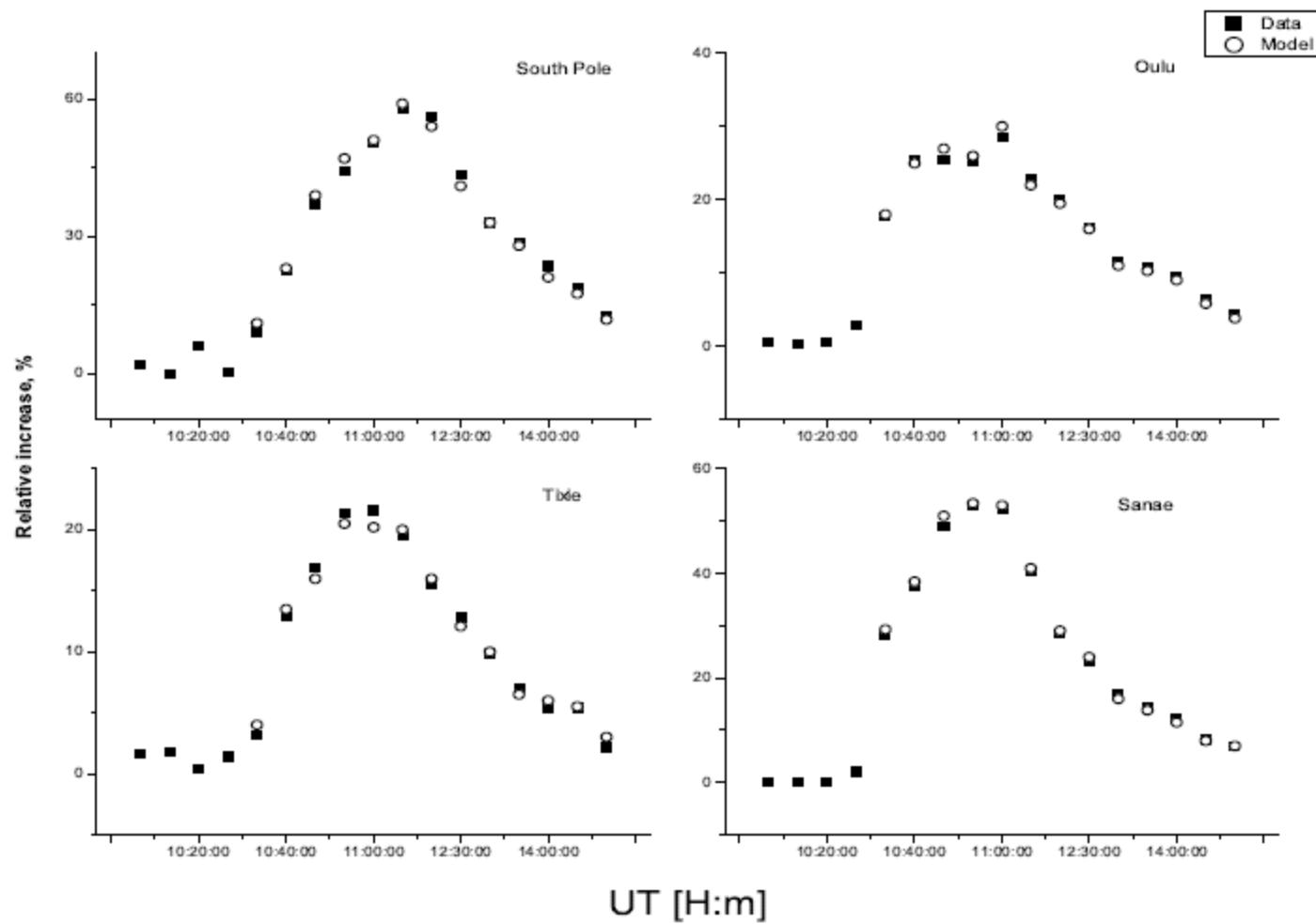


Derived spectral and angular characteristics of SEPs for GLE 59 on 14 July 2000.

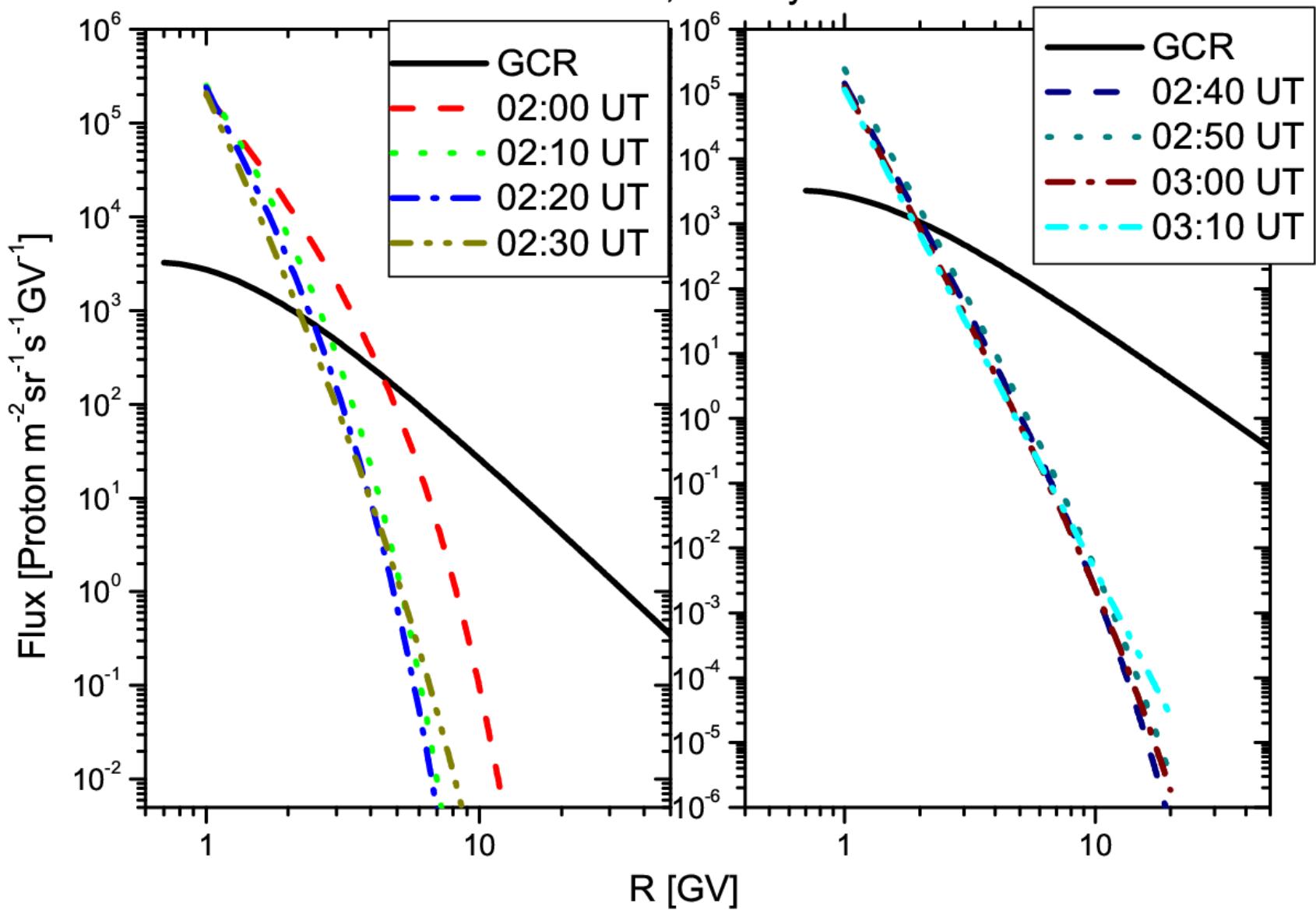


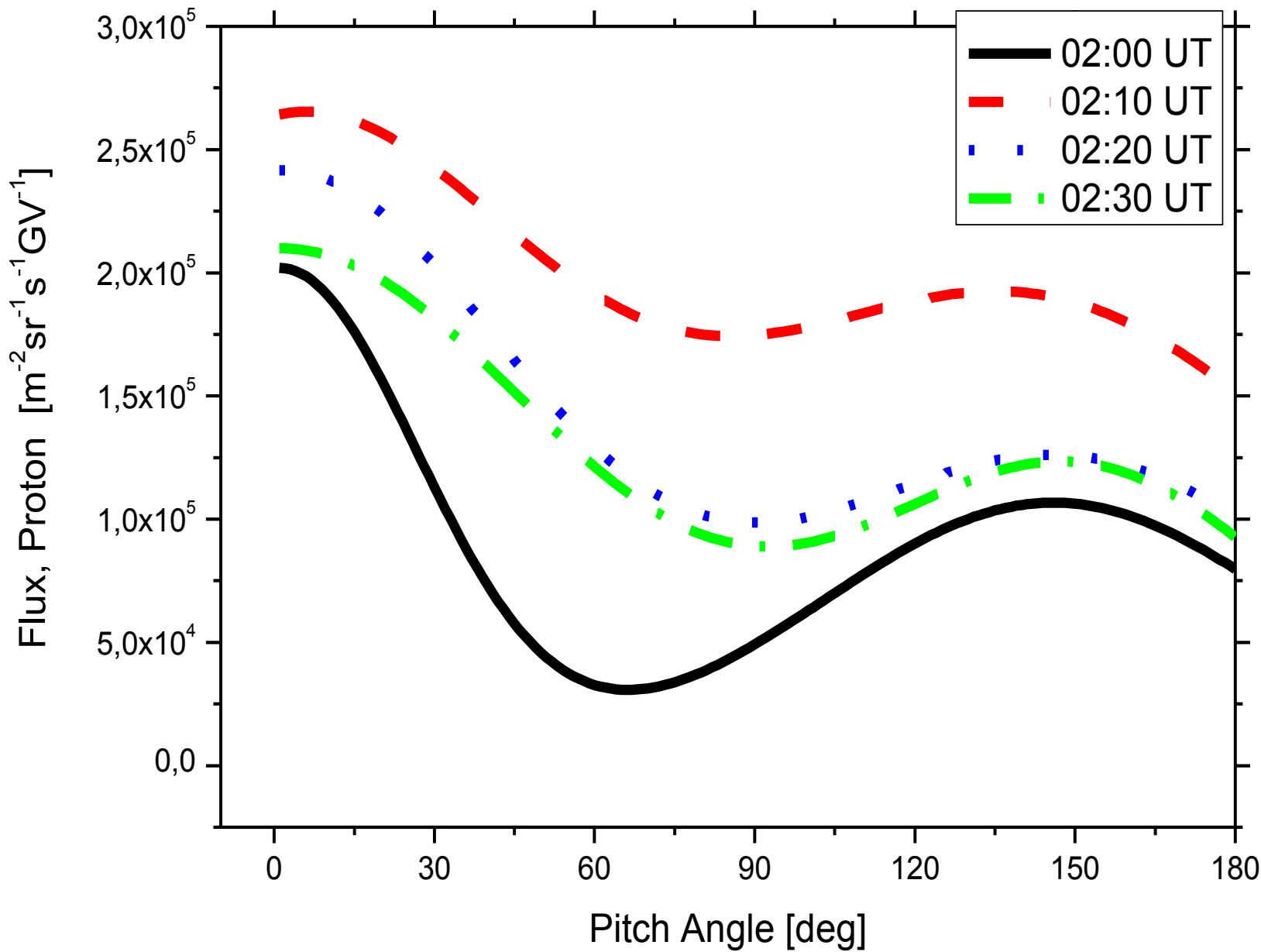


Derived spectral and angular characteristics of SEPs for GLE 70 on 13 December 2006.



GLE71, 17 May 2012





# Conclusions:

1. New 6NM64 yield function
2. Method for GLE analysis
3. GLE59, GLE69 (preliminary), GLE 70 & GLE71  
(SEP spectra 5-10 min resolution, anisotropy, apparent source position)
4. Applications – ion rate production, ionization effect over the event,  
24h and weekly, flight altitude effective dose estimation

# THANK YOU

