Monte Carlo Simulation for Stripping factors of Airborne Gamma-ray Spectrum

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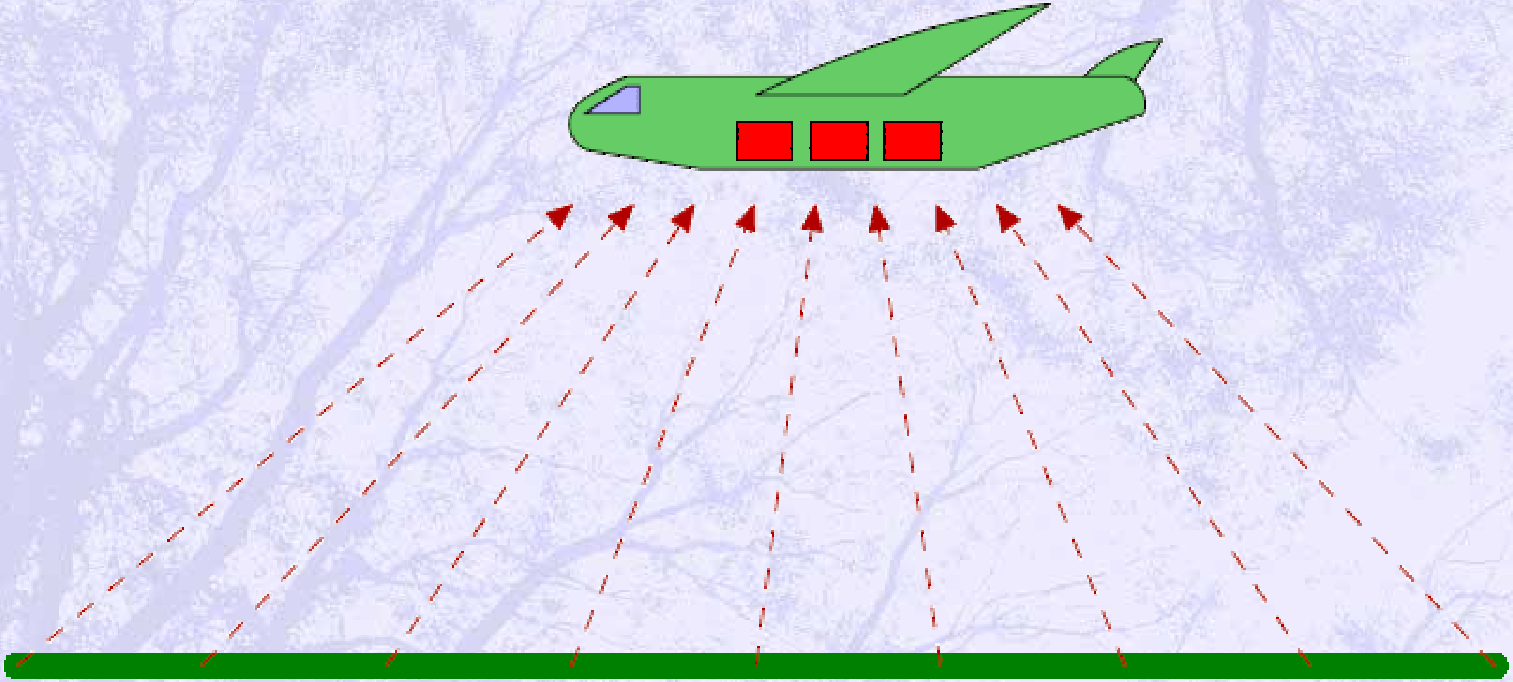
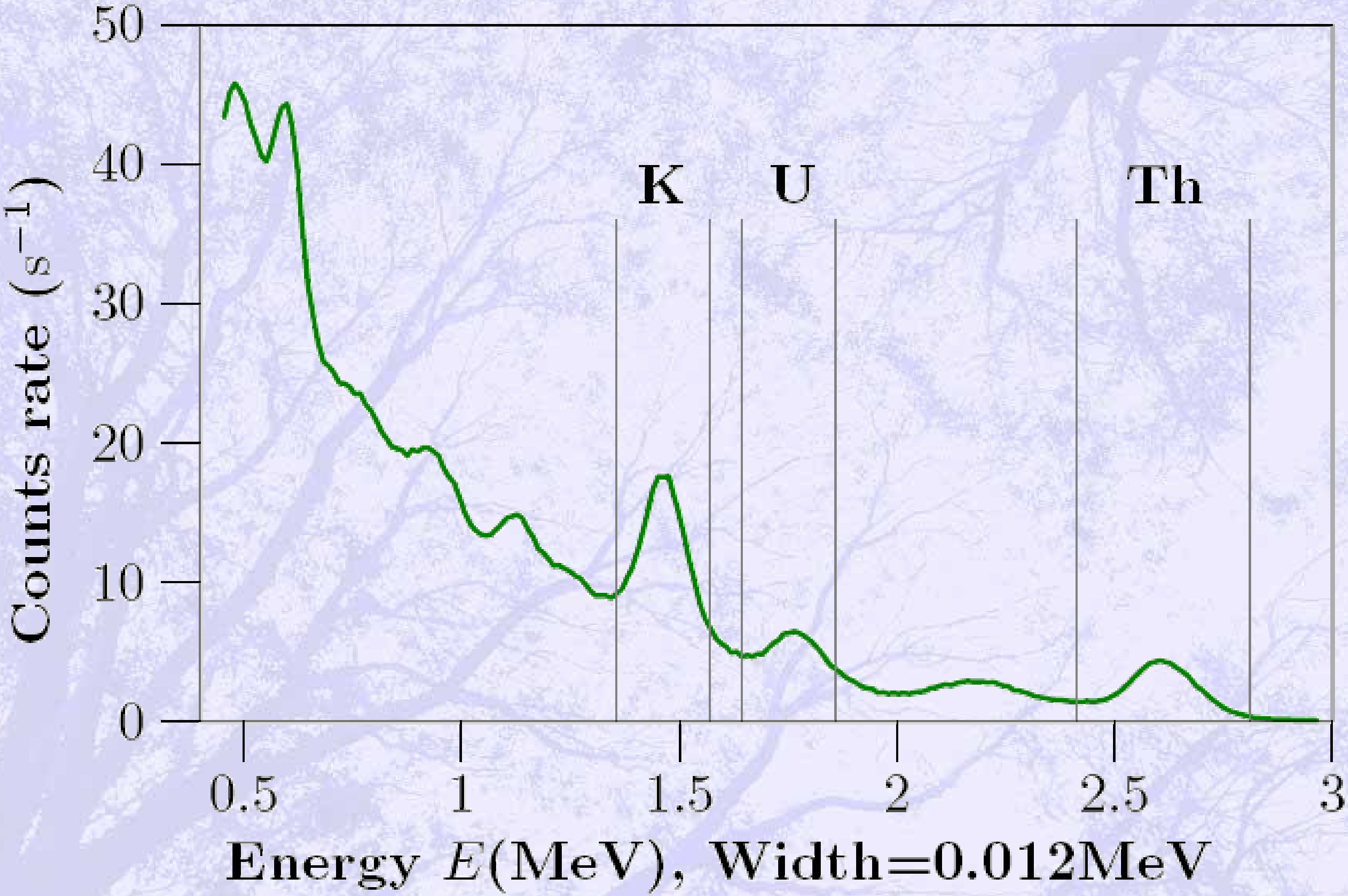
Airborne Gamma-ray Spectrometry



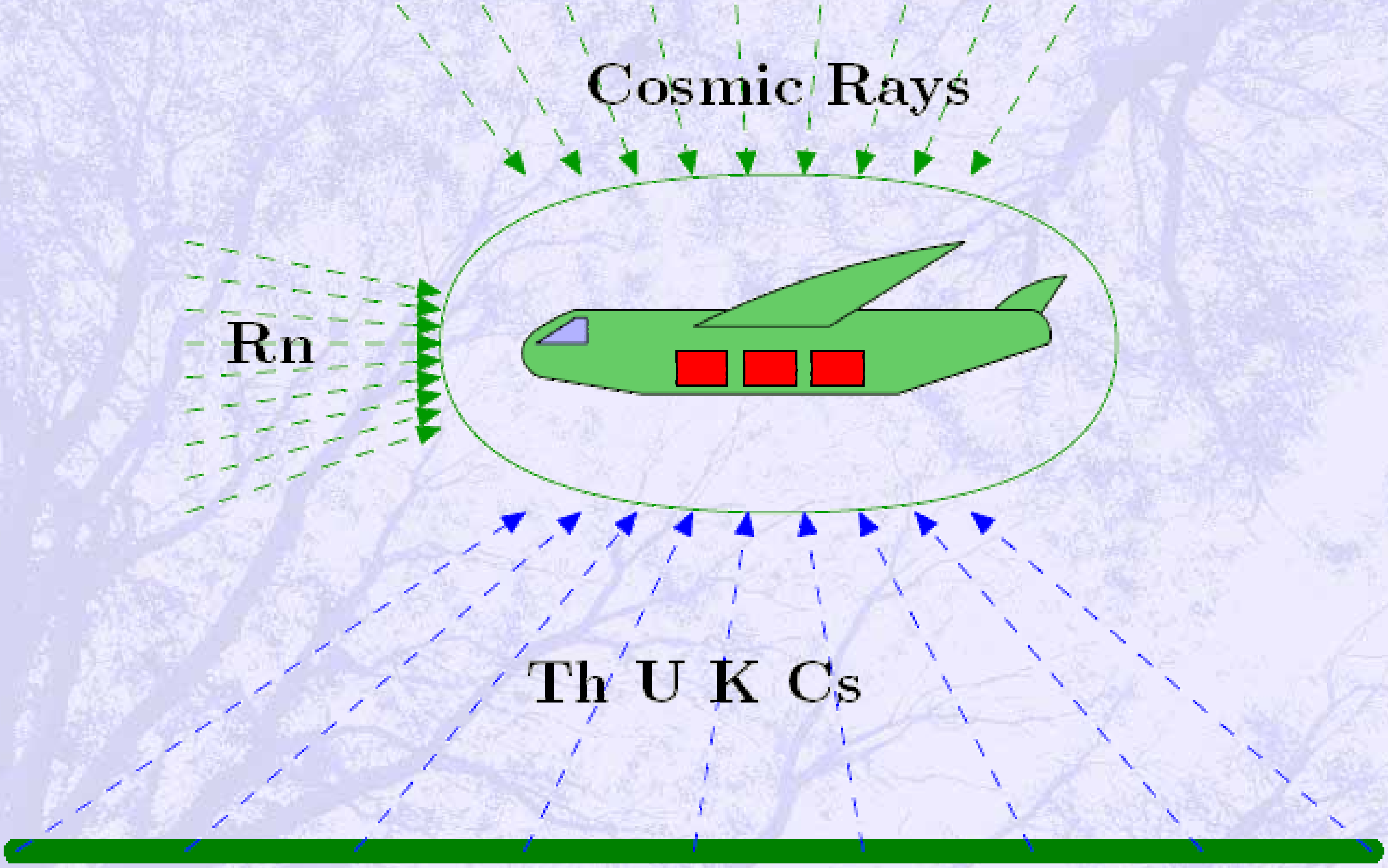
Airborne Gamma-ray Spectrometry

- Large Area
- Low Spatial Resolution
- Qualitative or Semi-quantitative
- Usage
  Exploring
  Radiation Survey

Typical Spectrum (Mixed)



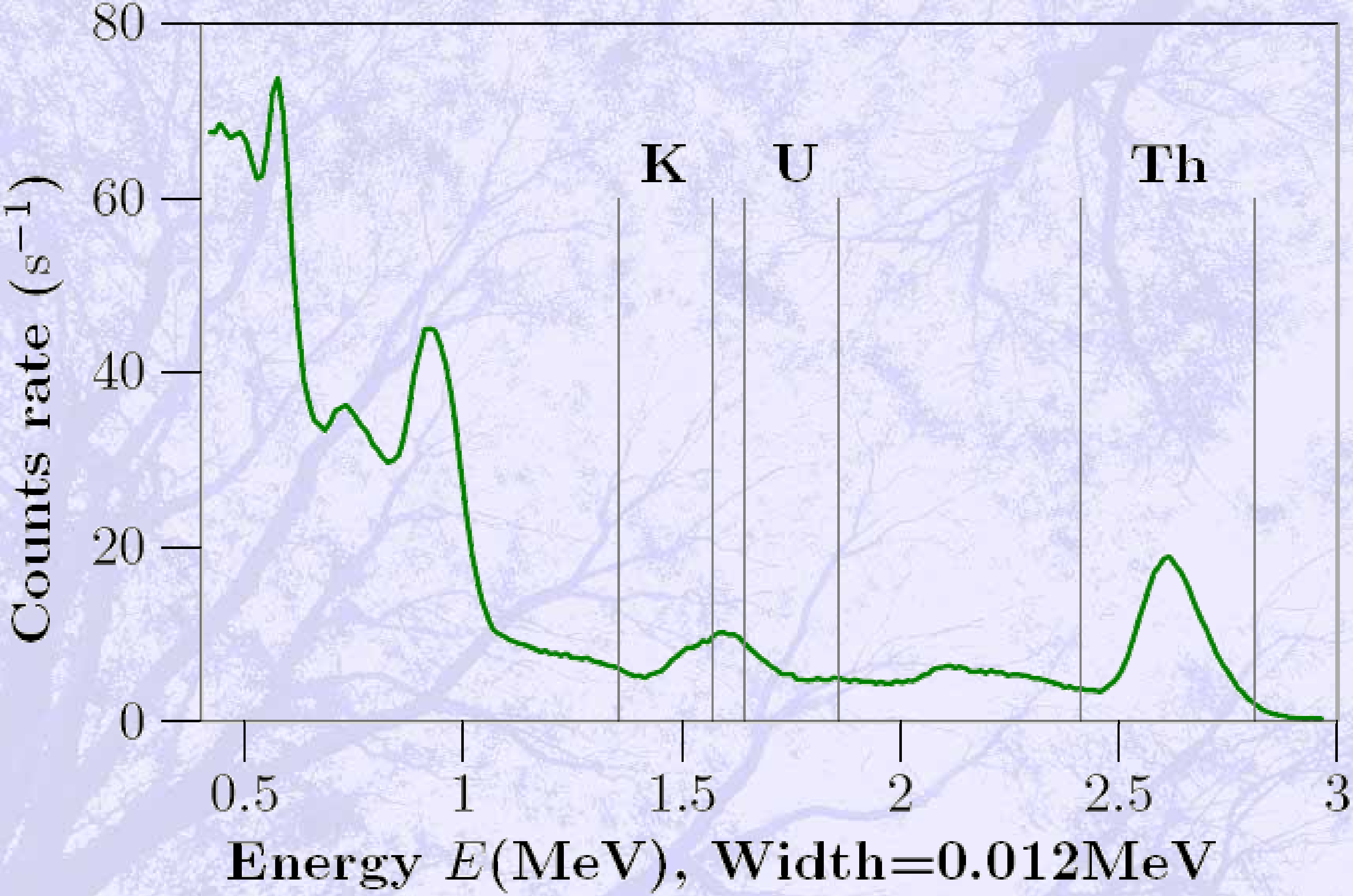
Difficulties in Experiment



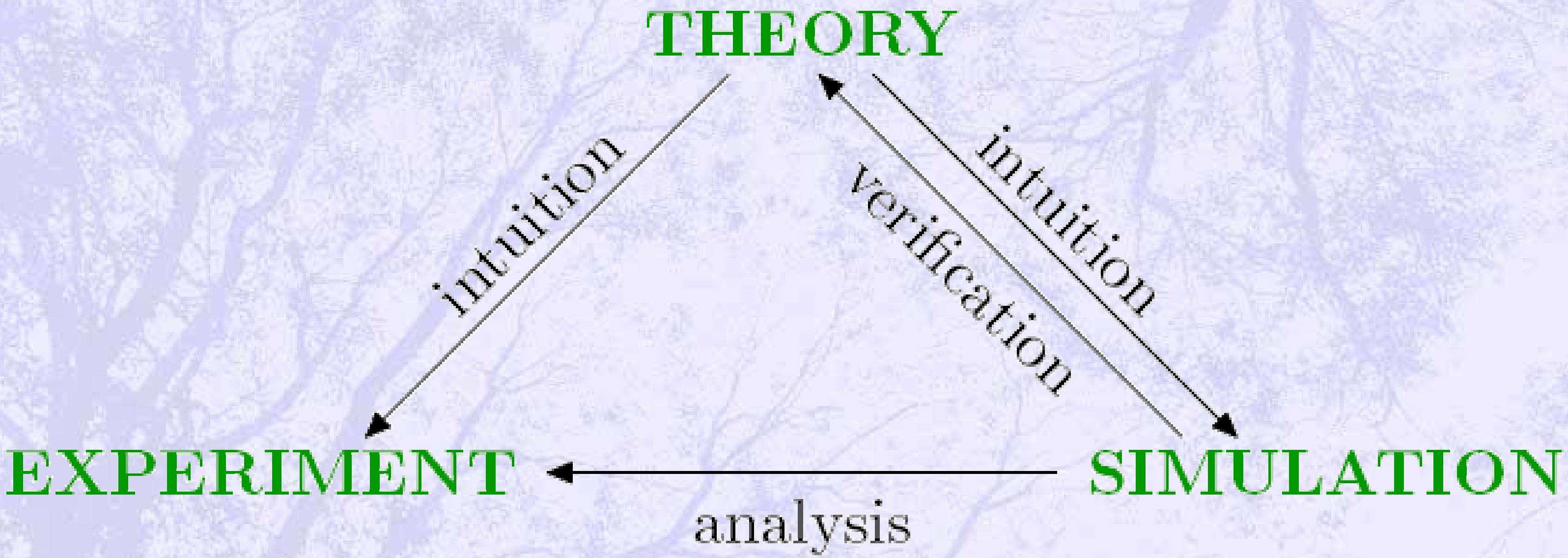
Difficulties in Experiment

- Background
  Rn in Air
  Cosmic Radiation
  K, U, and Th from the Ground
  Strip Them!
- Calibration Source
  Relatively Infinite
  Right Isotope
  Right Distribution
  Known Activity

Typical Spectrum (Thorium Pad)



Experiment and Simulation



Difficulties in MC Simulation

- Details of the Whole System
  Detector
  Plane and Facilities
- Low Probability
  Large Space
  Deep Penetration
  Scattered Gamma Ray
  Energy Spectrum

Variance Reduction Techniques

- Bias
  Biased Sampling
  Splitting and Russian Roulette
- Semi-analytic
  Next Estimating
- Geometry
  Symmetry
  Equivalence

Distinguished Works from Literature

- K. Saito, P. Jacob, etc.
  1985 YURI Code
  1994 Recommended Reference (ICRU 53)
  1995 Air Kerma, Build-up Factor
  1998 Report with Detailed Data Set
  2002 Phantom Considered
- D.N.Matsukevich, A.I.Borodich, etc.
  1998 EGS4
  Spectrum

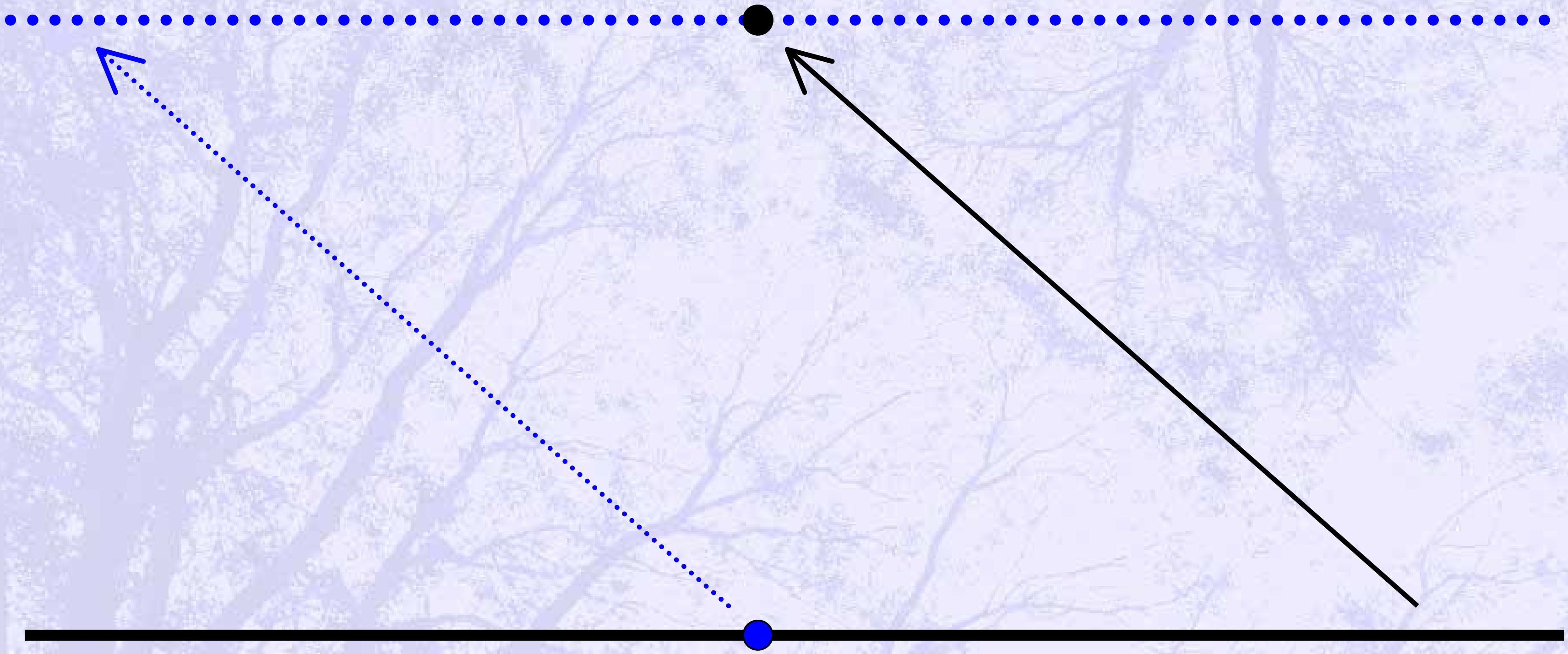
Distinguished Works from Literature

- No Detailed Information of Methods
- Geometry Symmetry
  Reciprocity
- Detector or Phantom
  Two-step Scheme
  Fluent
    - Energy Distribution
    - Angular Distribution
- No Mention of Heterogeneous Source

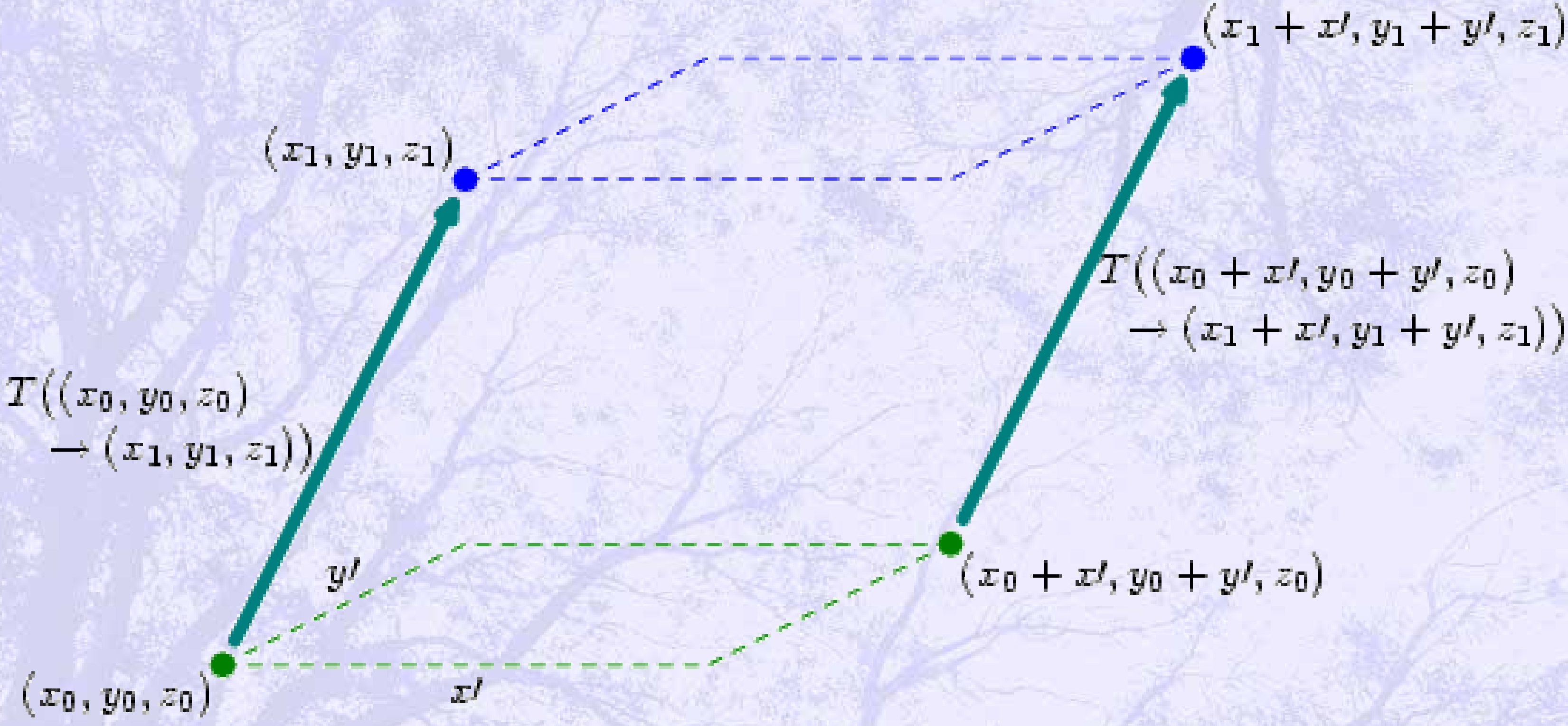
Our Method

- Geometry Equivalence
  Original
  Difference from the Former Works
    Single Step
    Heterogeneous Source
- Doubted by Experts in Different Fields
  Verified Again and Again
- No Other VRT Employed

Our Method



Our Method



$(x_1 + x', y_1 + y', z_1)$
(x_1, y_1, z_1)
$T((x_0 + x', y_0 + y', z_0)$
$\rightarrow (x_1 + x', y_1 + y', z_1))$
$T((x_0, y_0, z_0)$
$\rightarrow (x_1, y_1, z_1))$
y'
$(x_0 + x', y_0 + y', z_0)$
(x_0, y_0, z_0)
x'

Method From Mr. Bielajew's Book

- Fundamentals of the Monte Carlo Method for Neutral and Charged Particle Transport
- 17.3.3 Geometry Equivalence Theorem

$$F(z, \rho_b, \rho_d) = \int^{|\boldsymbol{\rho}'| \le \rho_b} d\rho' \int^{|\boldsymbol{\rho}| \le \rho_d} d\rho \; f(z, |\boldsymbol{\rho} - \boldsymbol{\rho}'|), \qquad (17.17)$$

where $\int^{|\boldsymbol{\rho}| \le \rho_d} d\rho$ is shorthand for $\int_0^{2\pi} d\phi \int_0^{\rho_d} d\rho$. If we exchange integration indices in eq. 17.17, then we obtain the reciprocity relationship,

$$F(z, \rho_b, \rho_d) = F(z, \rho_d, \rho_b). \qquad (17.18)$$

What eq. 17.18 means is the following: If we have a circular beam of radius ρ_b and a circular detection region of radius ρ_d, then the response we calculate is the same if we had a circular beam of radius ρ_b and a circular detection region of radius ρ_d! The gain in efficiency comes

Programming

- EGSnrc
  Free and Open
  Programs for Implementing the Method
- GEB
  To Simulate the Statistical Fluctuation
- Box, Plane, and Facilities
  Slabs of Aluminum and Steel
- Th and U Series

Verification

- ICRU Recommended Reference — YURI
- Both the GE Method and Program
- 1072 Figures Compared
- Air Kerma and Fluent of Primary Photons
  Energy 0.1 - 5MeV
  Height 0.1 - 300m
  Depth 0 - 10 cm
- Relative Error < 3%

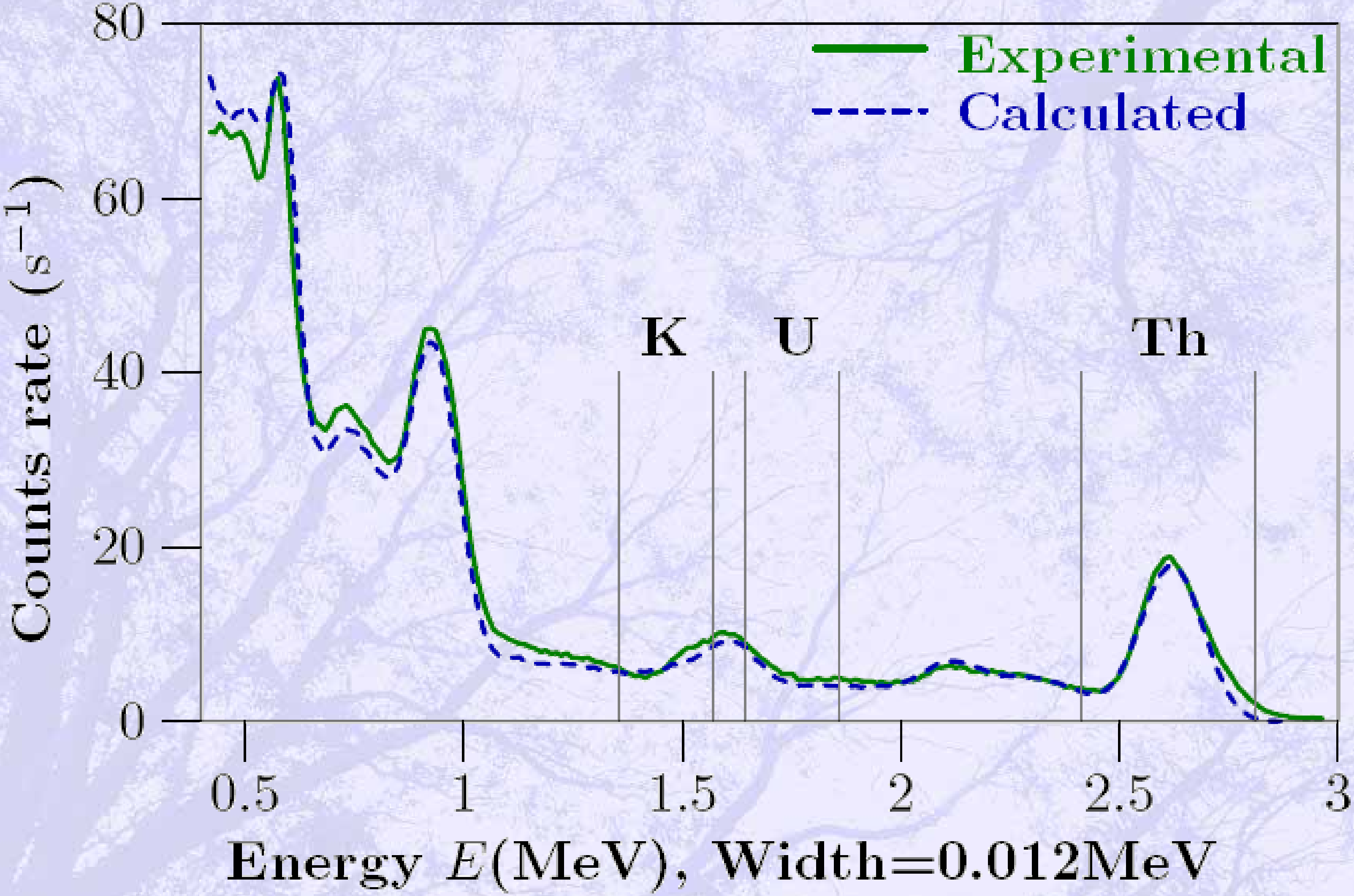
Simulation

- Source
  Size
  Isotope
  Distribution
- Height
- Wood Slab Scheme
  Simulate the Air in Experiment
  To Obtain Striping Factors

Simulation

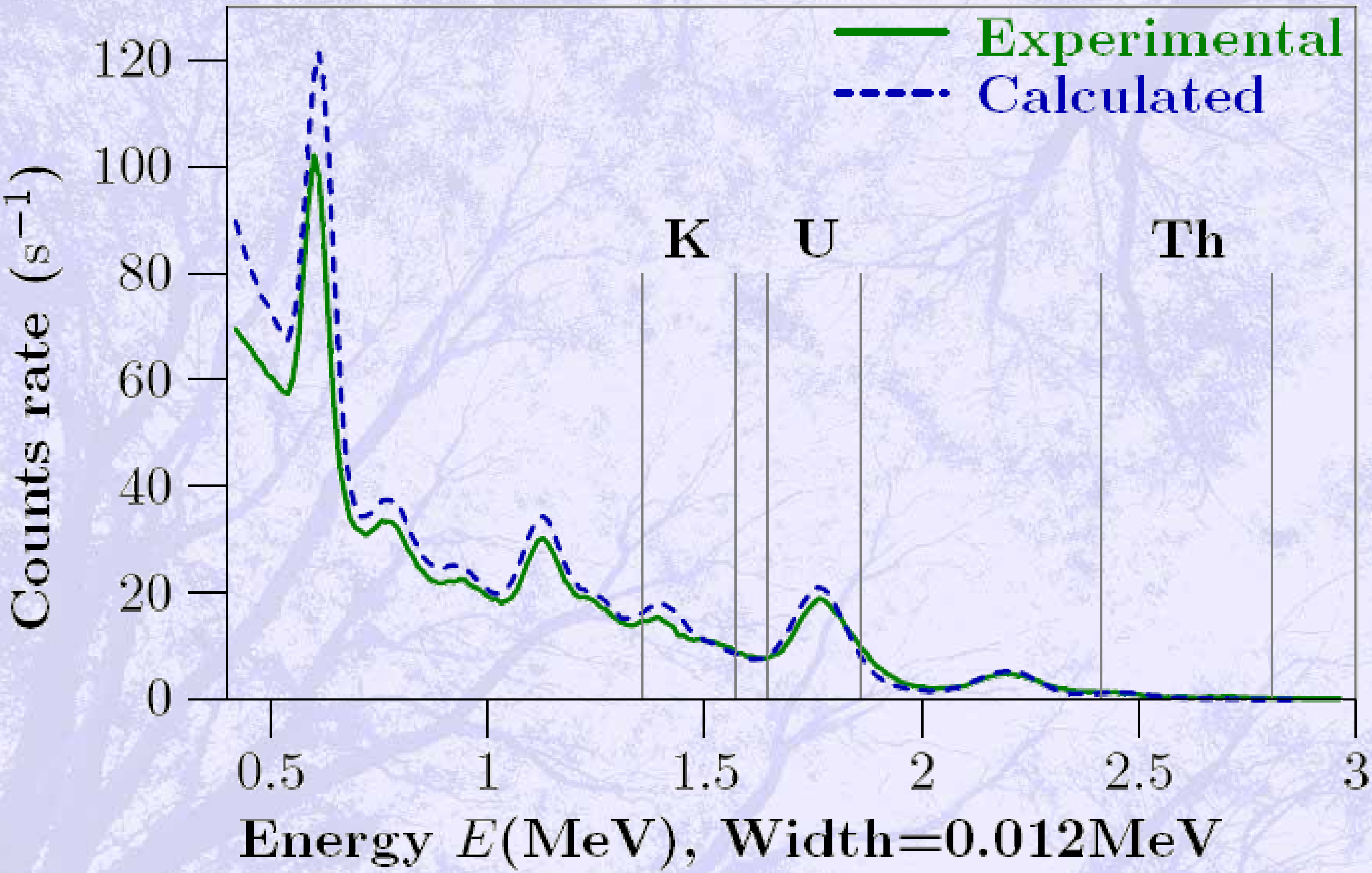
- Radiation Environment in Air
  Energy Distribution
  Angular Distribution
- Efficiency
  Definition
- Spectrum
  Stripping Factors
  Calibration Scheme
- Relative Statistical Error <3%

Thorium Pad



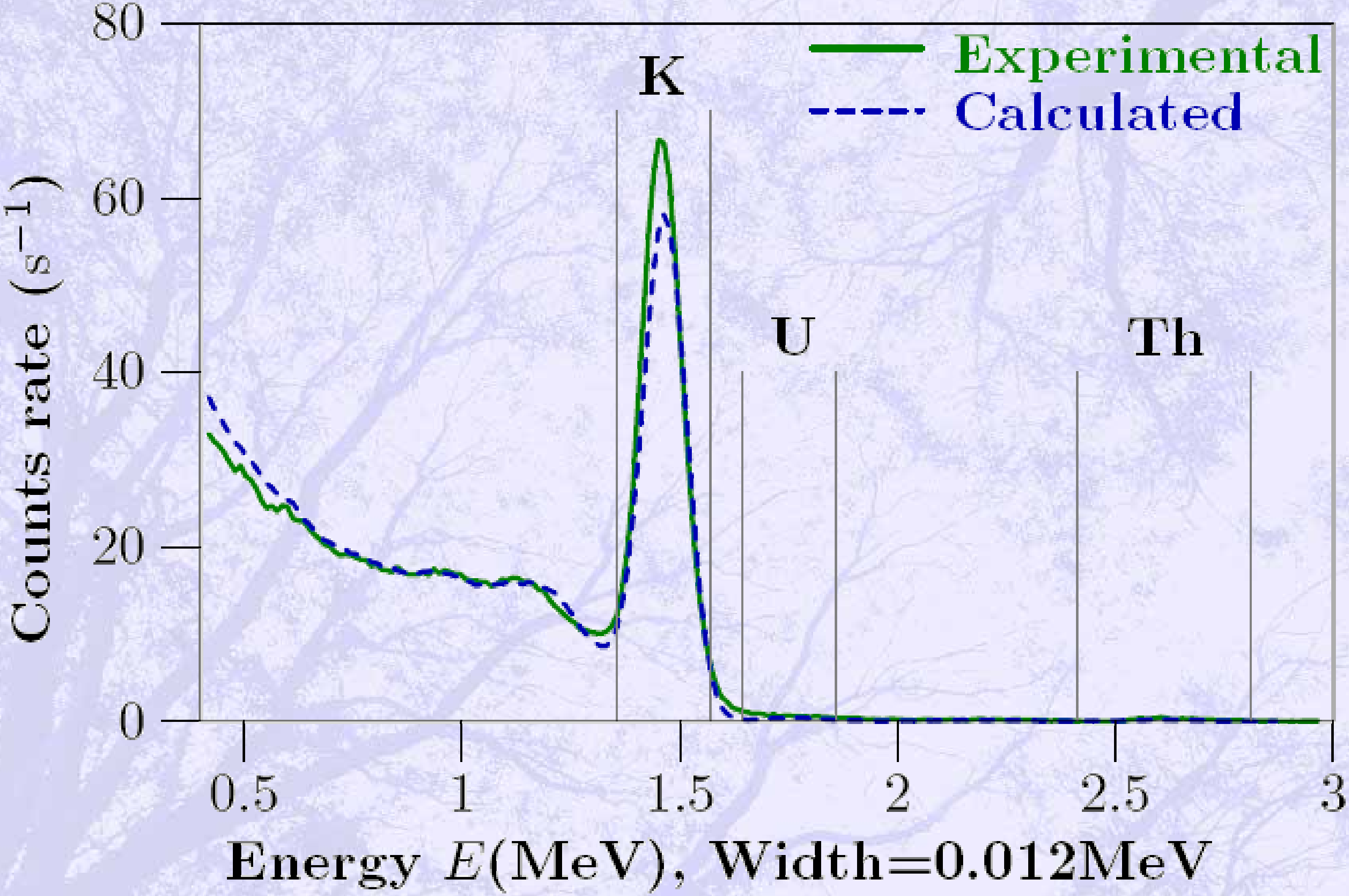
Experimental
Calculated
K
U
Th
Counts rate (s^{-1})
0
20
40
60
80
0.5
1
1.5
2
2.5
3
Energy E(MeV), Width=0.012MeV

Uranium Pad



Experimental
Calculated
K
U
Th
120
100
80
60
40
20
0
Counts rate (s^{-1})
0.5
1
1.5
2
2.5
3
Energy E(MeV), Width=0.012MeV

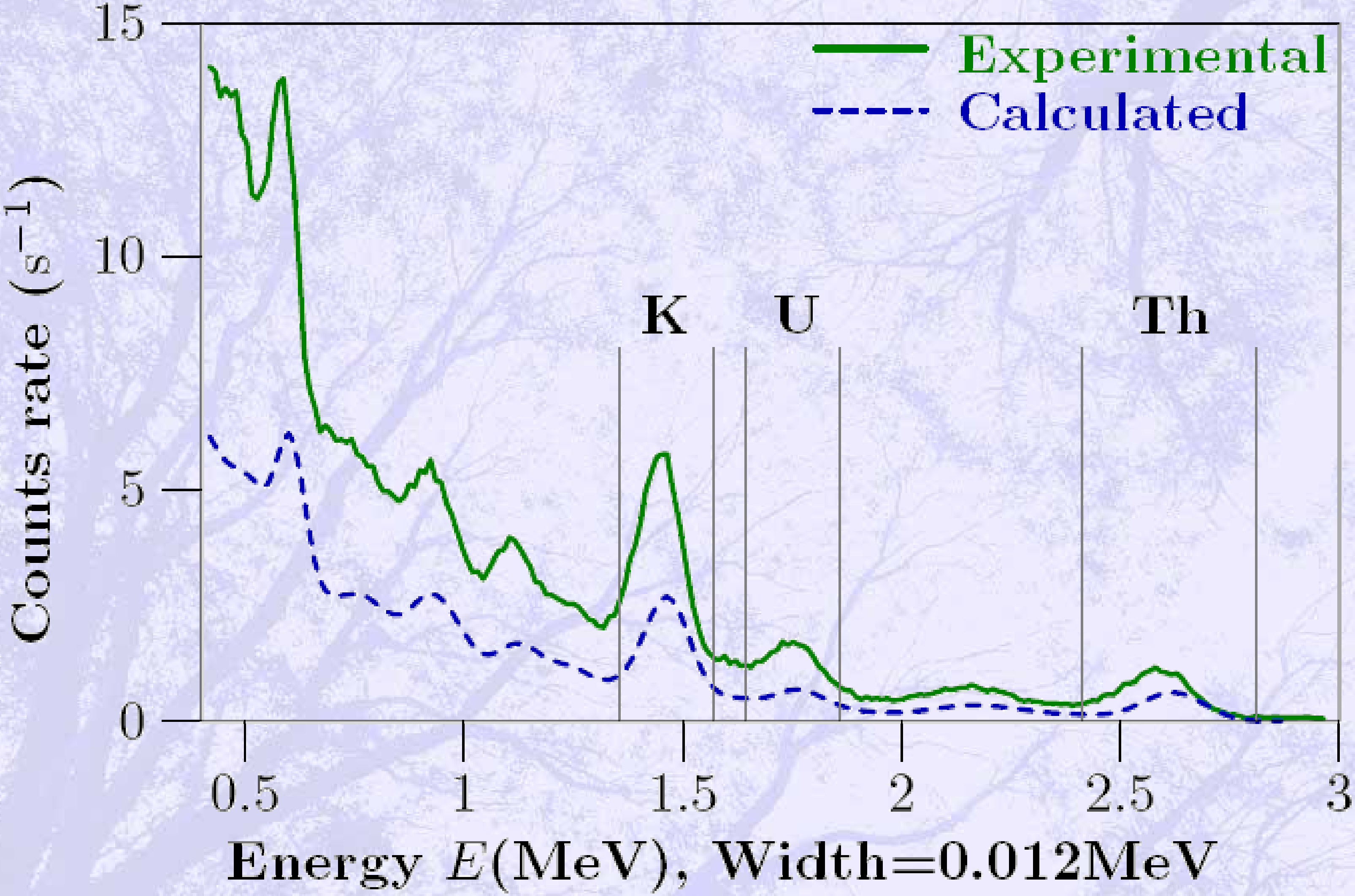
Potassium Pad



Accuracy of Spectrum

- Method
- Gamma Emission From Decay Series
  U 50
  Th 42
- Background
  Experiment
    Caused by Known Source
    Not-known Source
  Simulation

Background Pad



Thanks for Your Attention!