# Verification of Geant 4 neutron propagation.

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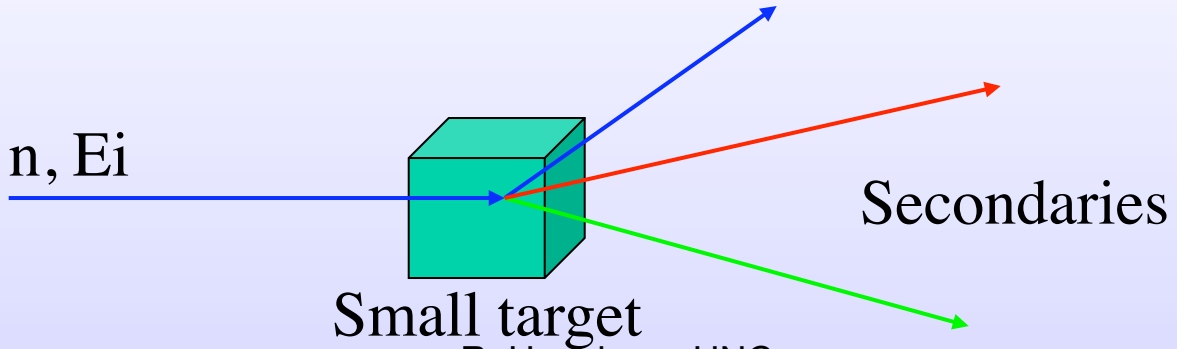
# Introduction

- Geant 4 has several well-known issues with simulating low-energy neutrons of interest to low-background experiments:
  - Incorrect cross-sections.
  - Energy non-conservation.
  - Spontaneous elemental transmutation.
  - Lack of coherent software maintenance.
- Geant 4 collaboration focused on LHC. We have low-priority.
- Geant 4 simulation of neutrons requires verification.

# Example: Thickness requirement of acrylic to shield against ($\alpha$,n) from PMTs

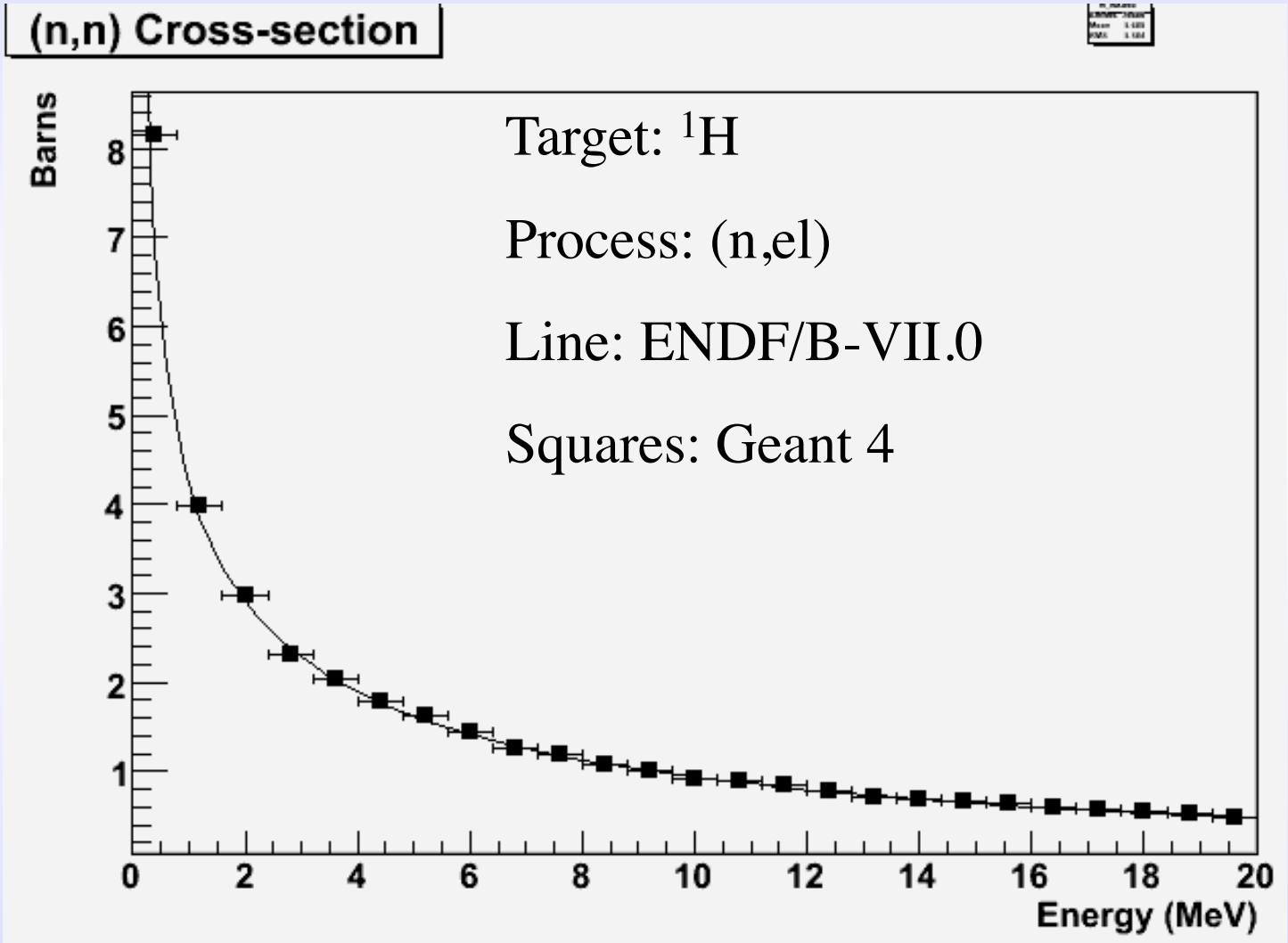
- Need to verify cross-sections of n + C, H, O in range 0 - 20 MeV. Data-driven range of Geant 4.
- Not concerned with thermal neutrons.
- Simulate cross-section measurement in Geant 4 (8.2.p01):

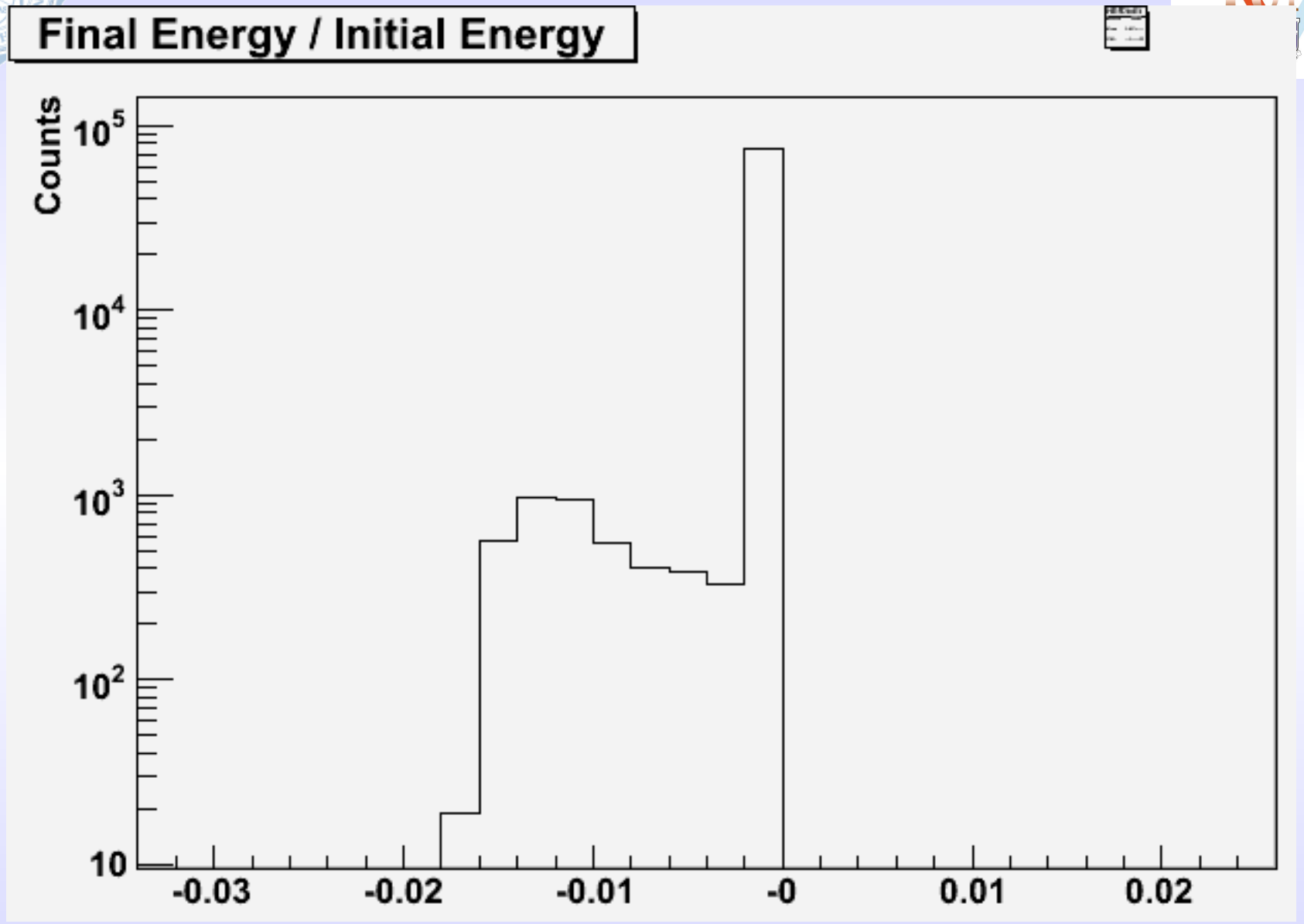


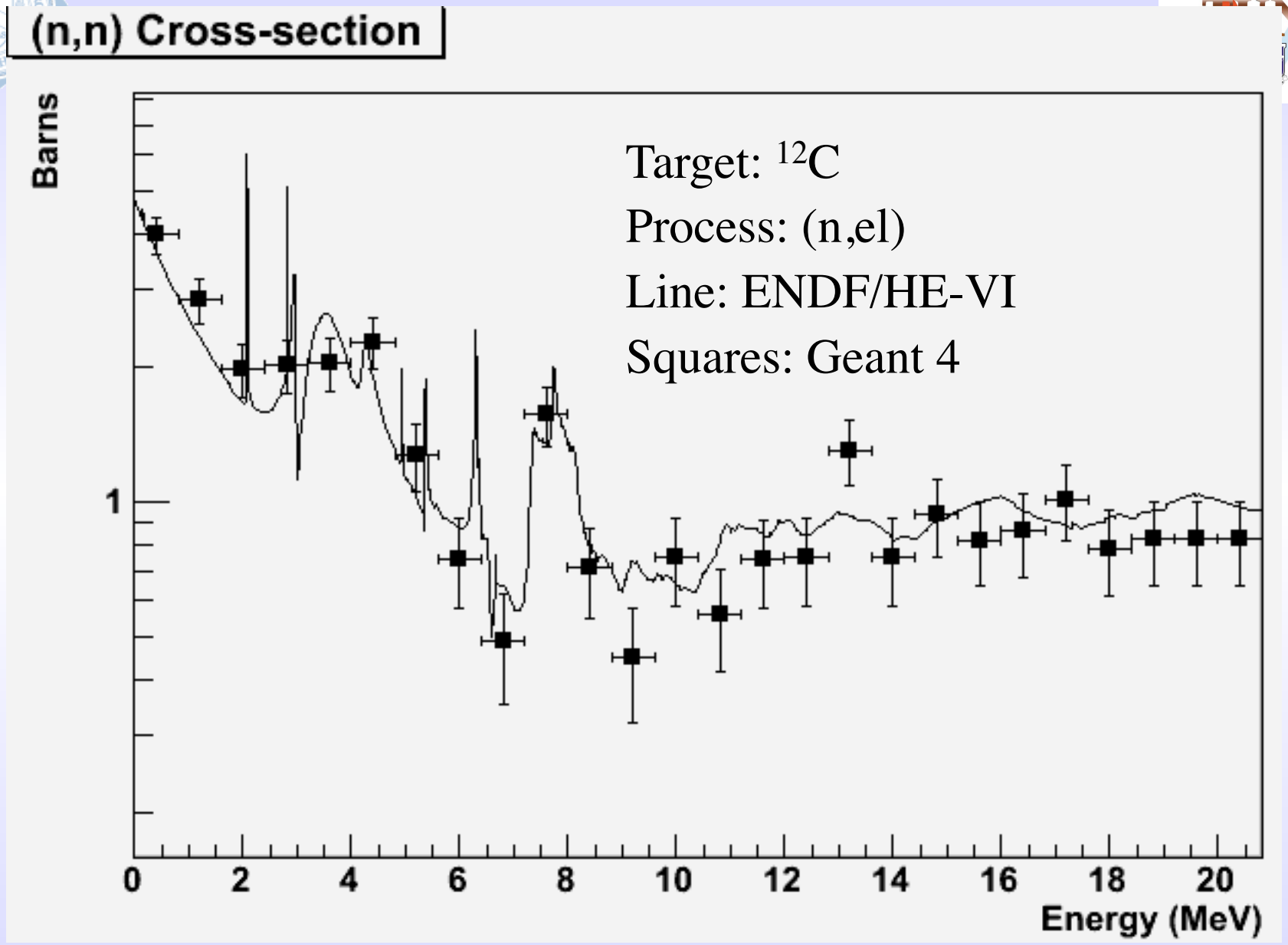
# Solution

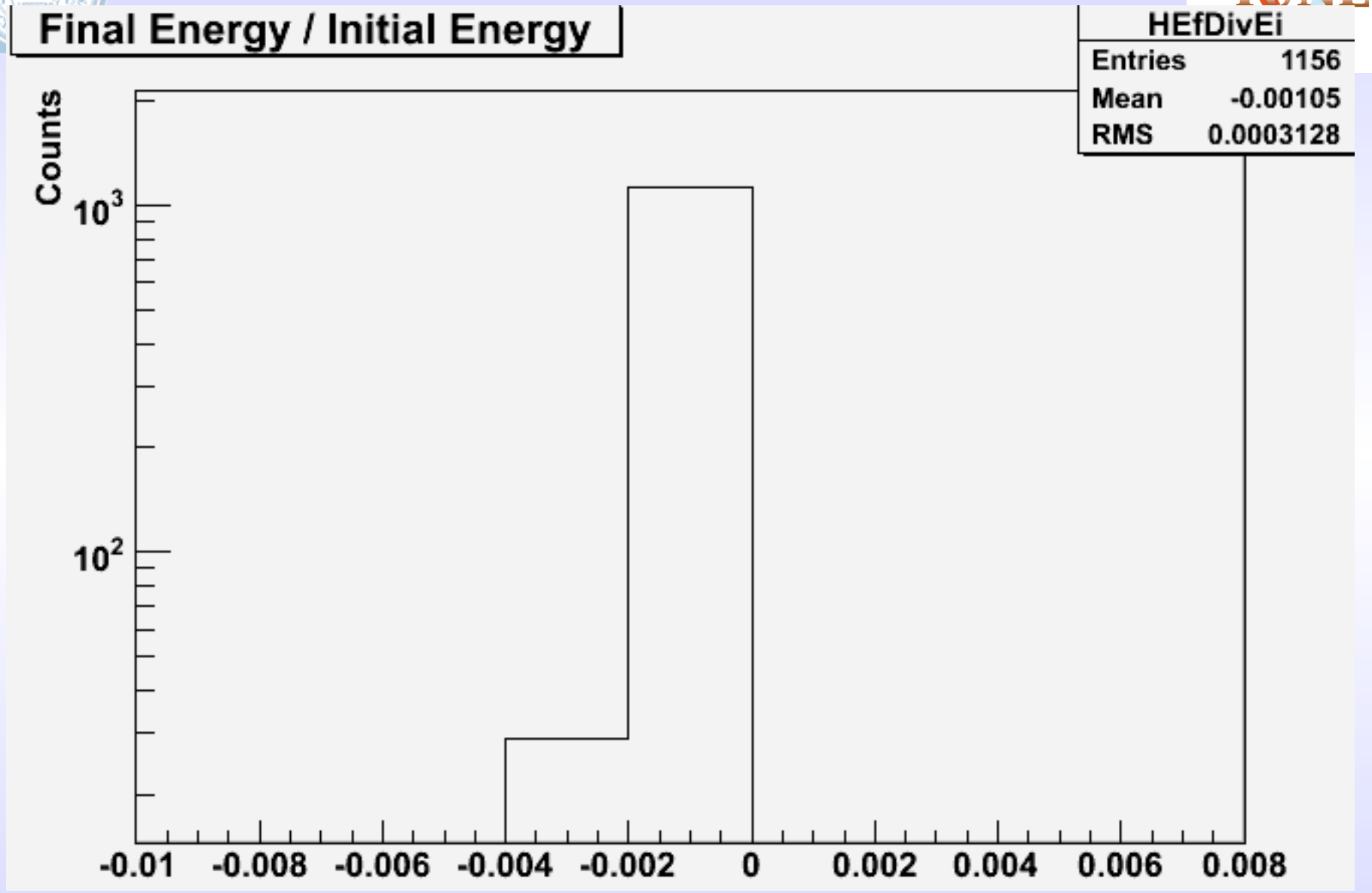
- Neutron interaction simulations complex.
- Impossible to write package that satisfies all requirements.
- Build verification package on case-by-case basis.
- Run verification package with every new release.

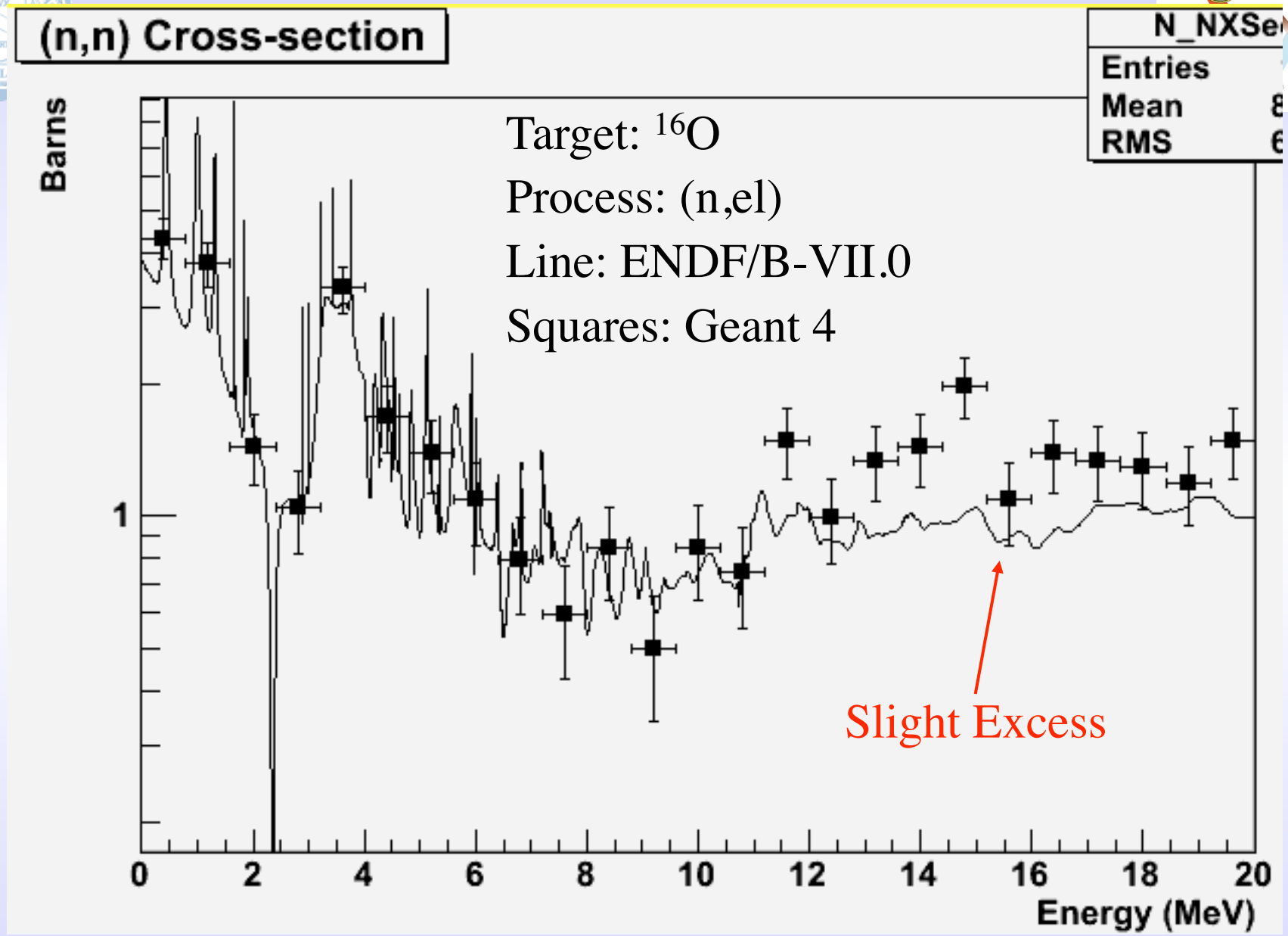
# Results

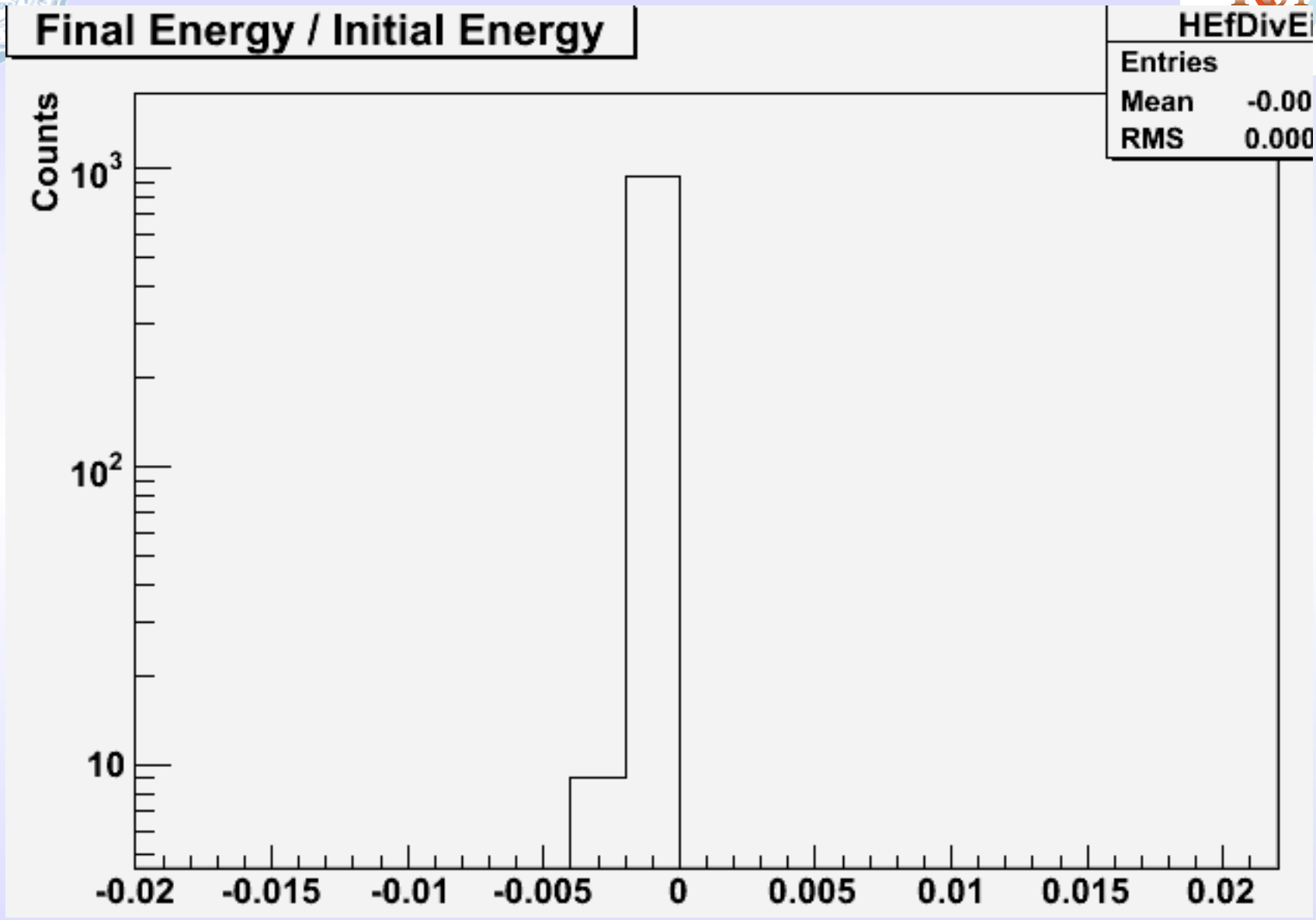

(n,n) Cross-section
Barns
Energy (MeV)
Target: $^{1}$H
Process: (n,el)
Line: ENDF/B-VII.0
Squares: Geant 4


Final Energy / Initial Energy
Counts
$10^5$
$10^4$
$10^3$
$10^2$
10
-0.03
-0.02
-0.01
-0
0.01
0.02


(n,n) Cross-section
Barns
1
Target: 12C
Process: (n,el)
Line: ENDF/HE-VI
Squares: Geant 4
0
2
4
6
8
10
12
14
16
18
20
Energy (MeV)


Final Energy / Initial Energy
HEfDivEi
Entries 1156
Mean -0.00105
RMS 0.0003128
Counts
$10^3$
$10^2$
-0.01
-0.008
-0.006
-0.004
-0.002
0
0.002
0.004
0.006
0.008


(n,n) Cross-section
N_NXSe
Entries
Mean
RMS
Barns
Target: $^{16}$O
Process: (n,el)
Line: ENDF/B-VII.0
Squares: Geant 4
Slight Excess
1
0
2
4
6
8
10
12
14
16
18
20
Energy (MeV)


Final Energy / Initial Energy
HEfDivEi
Entries
Mean -0.00
RMS 0.000
Counts
$10^3$
$10^2$
10
-0.02
-0.015
-0.01
-0.005
0
0.005
0.01
0.015
0.02

# WIP

- **Ne and Ar cross-sections & microphysics**.
- Check angular distributions.
- Material verification.
- ‘Inelastic’ processes.
- Other isotopes -- gets trickier for more complex nuclei.
- Automate this verification so that it can be tested on new releases of Geant 4.

# Conclusions

- Geant 4 appears adequate to estimate thickness requirements for acrylic.
- Additional verification required, but I feel it is OK to proceed with simulations in parallel.
- Other things that did not work:
  - Reverse-engineer Geant 4 HP code -- too complex.
  - Write own neutron package -- too much time + introduced more errors.

# Details of Simulation:

- Neutron HP physics < 20MeV.
- Low-energy EM package.
- Geant 4 8.2.p01
- MacBook Pro/Mac OSX 10.4.9