EURADOS comparison exercise on neutron spectra unfolding in Bonner spheres spectrometry (BSS)

Practical recommendations for BSS unfolding

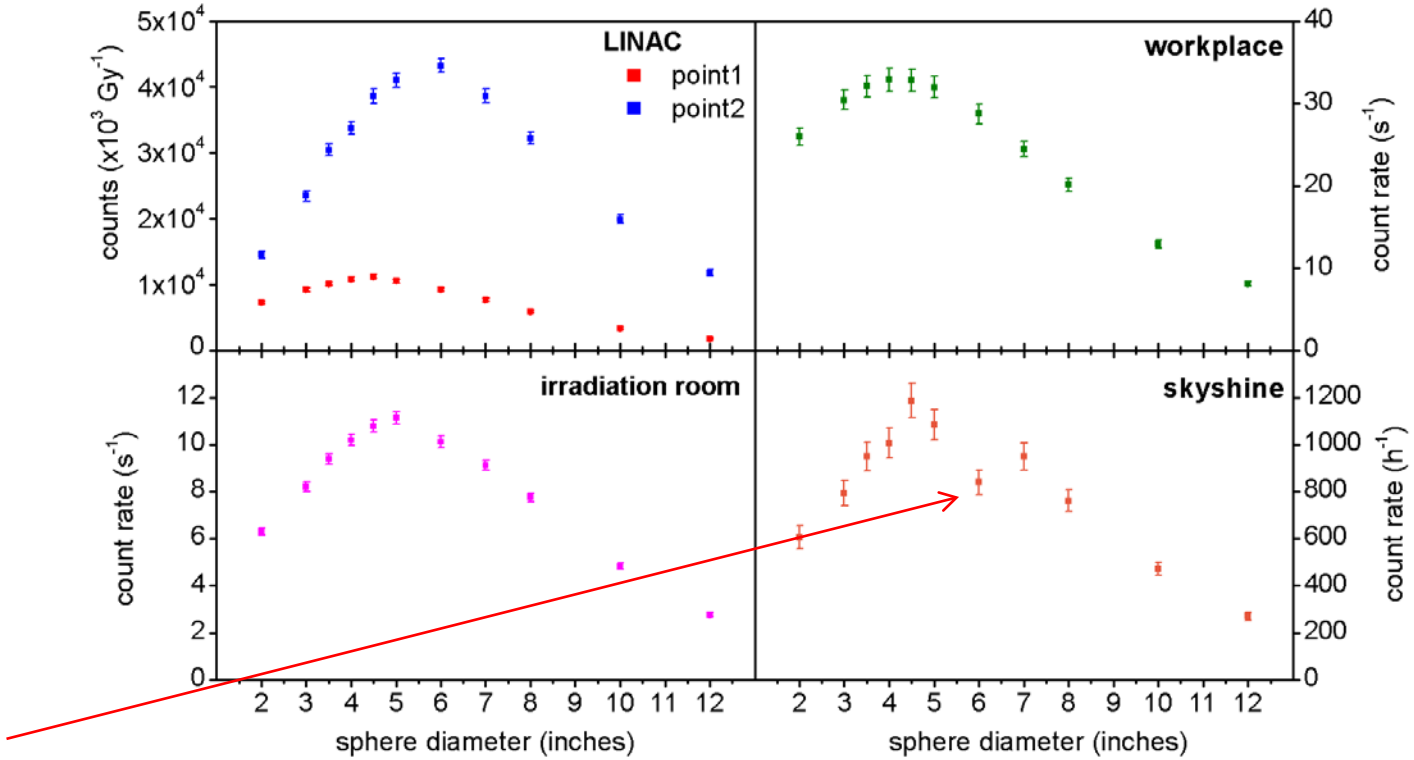
When starting with a BSS problem

Look at the counts profile

These curves should be smooth if the measurements are performed under **stable conditions, using the right monitors, and are not affected by supplementary uncertainties of unexplained origin**.

Alevra, A.V., Thomas, D.J., 2003. Radiat. Prot. Dosimetry 107 (1-3), 37-72.

"Outliers" could bias the unfolding process



Pre-information

Participants spectra were “more deviating” in less specified problems:

- Scenario i) LINAC (40% of solutions)
- Scenario iv) Skyshine (70% of solutions).
- 30% of the submitted solutions were incorrect even for scenarios ii) and iii), where the problem was better specified in terms of source, sizes and materials

Because the neutron unfolding problem is underdetermined, it has infinite mathematical solutions.
An amount of pre-information is always required:

Parametric: **right model and initial estimation of parameters**
Altering a “guess spectrum”: **Supply a plausible guess spectrum**

The pre-information should be accurately chosen / assembled, and **all available** a-priori data should be implemented

- Unfolding a radionuclide source with shadow cones? Impose zero thermal neutrons
- Are the minimum/maximum energy known? Impose lower/upper energy cut

Preparing the pre-information

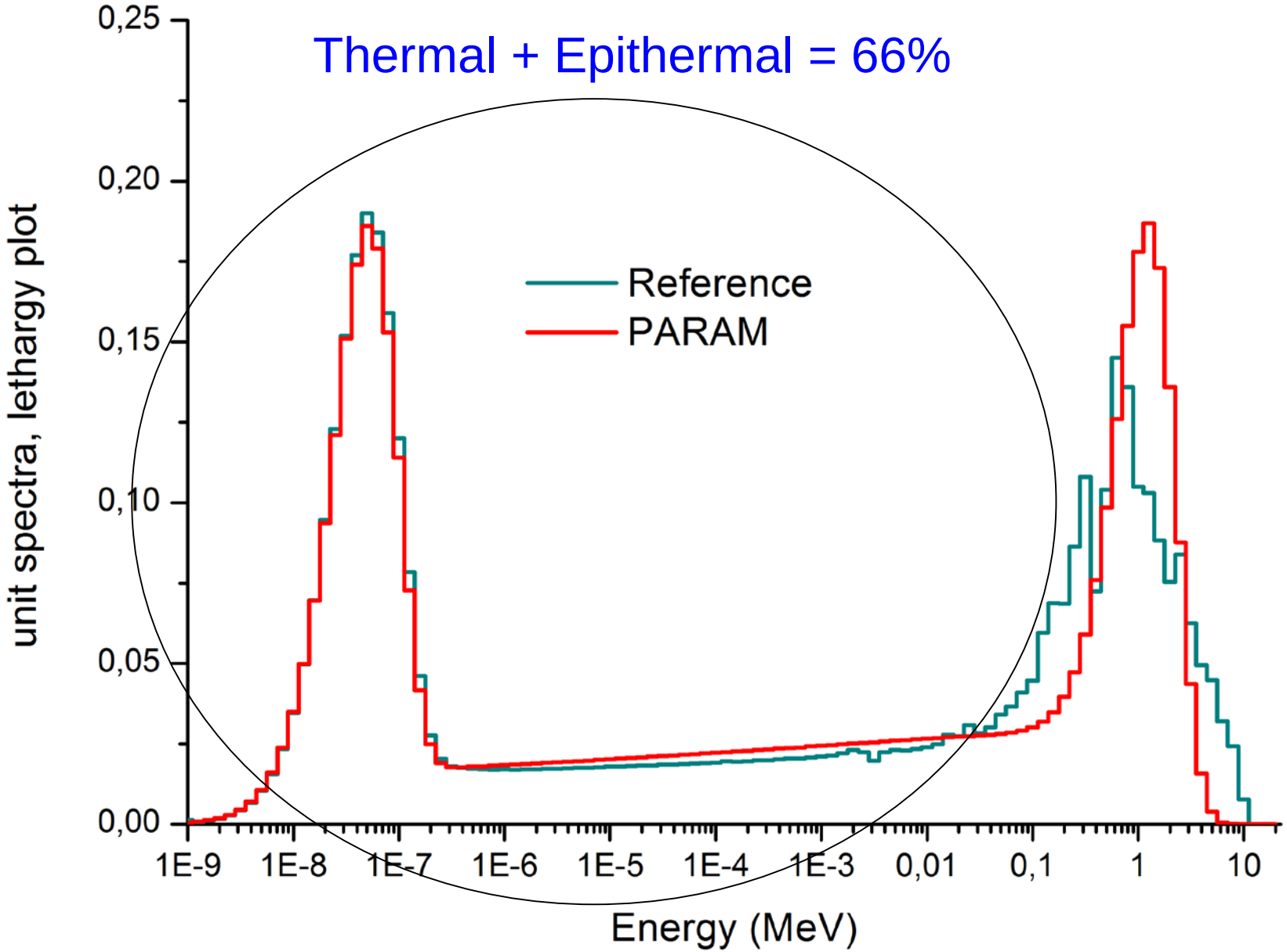
Example: the irradiation room problem (Am-Be + Iron) **(1/3)**

Using a parametric approach where the components are modelled with continuous functions:

$$\left(\frac{E}{T_o^2}\right) e^{(-E/T_o)}$$ Maxwellian for thermal distribution

$$[1 - e^{-(E/E_d)^2}]E^{(b-1)}e^{(-E/\beta')}$$ Epithermal continuous

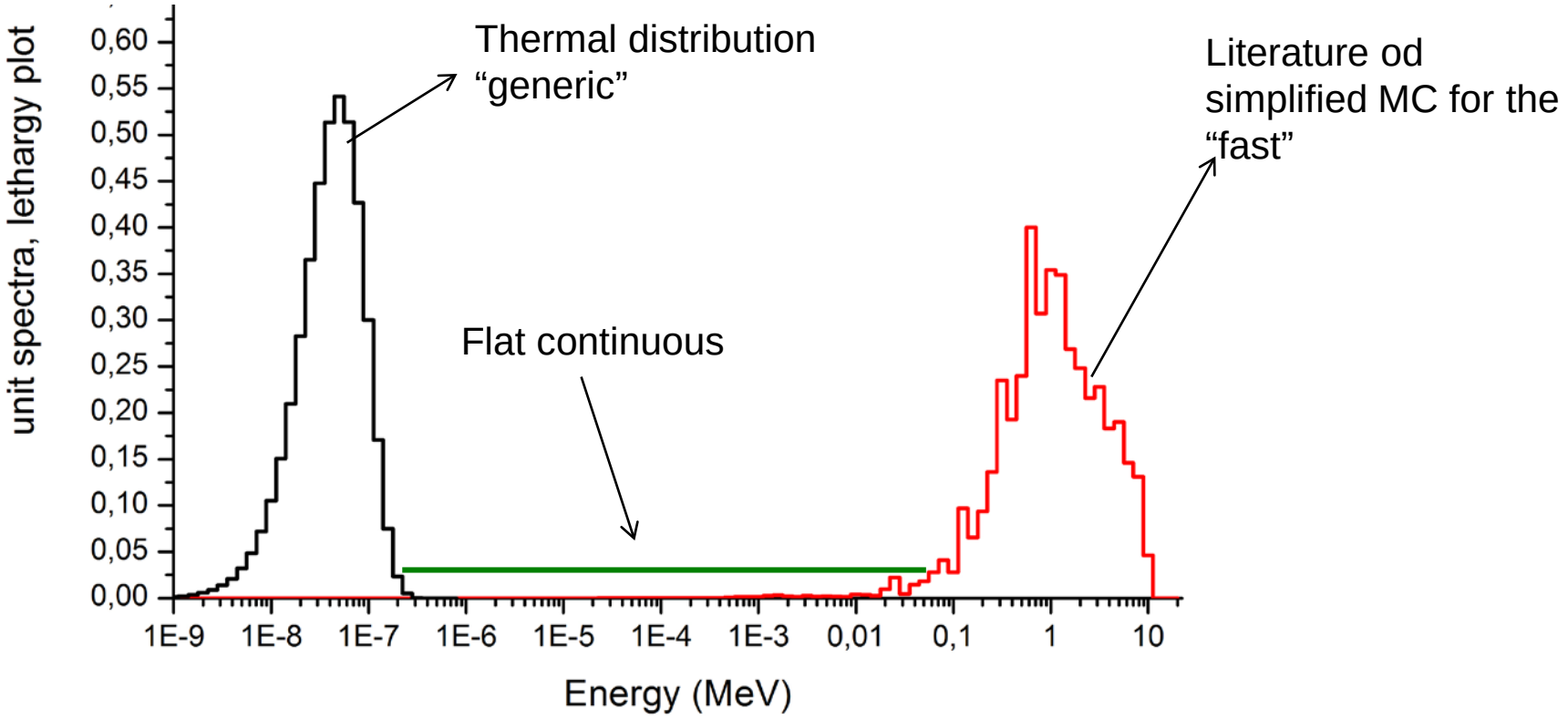
$$E^{\alpha}e^{(-E/\beta)}$$ Watt distribution for fast neutrons


Thermal + Epithermal = 66%
unit spectra, lethargy plot
0,25
0,20
0,15
0,10
0,05
0,00
Reference
PARAM
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
1E-3
0,01
0,1
1
10
Energy (MeV)

Example: the irradiation room problem (Am-Be + Iron) **(2/3)**

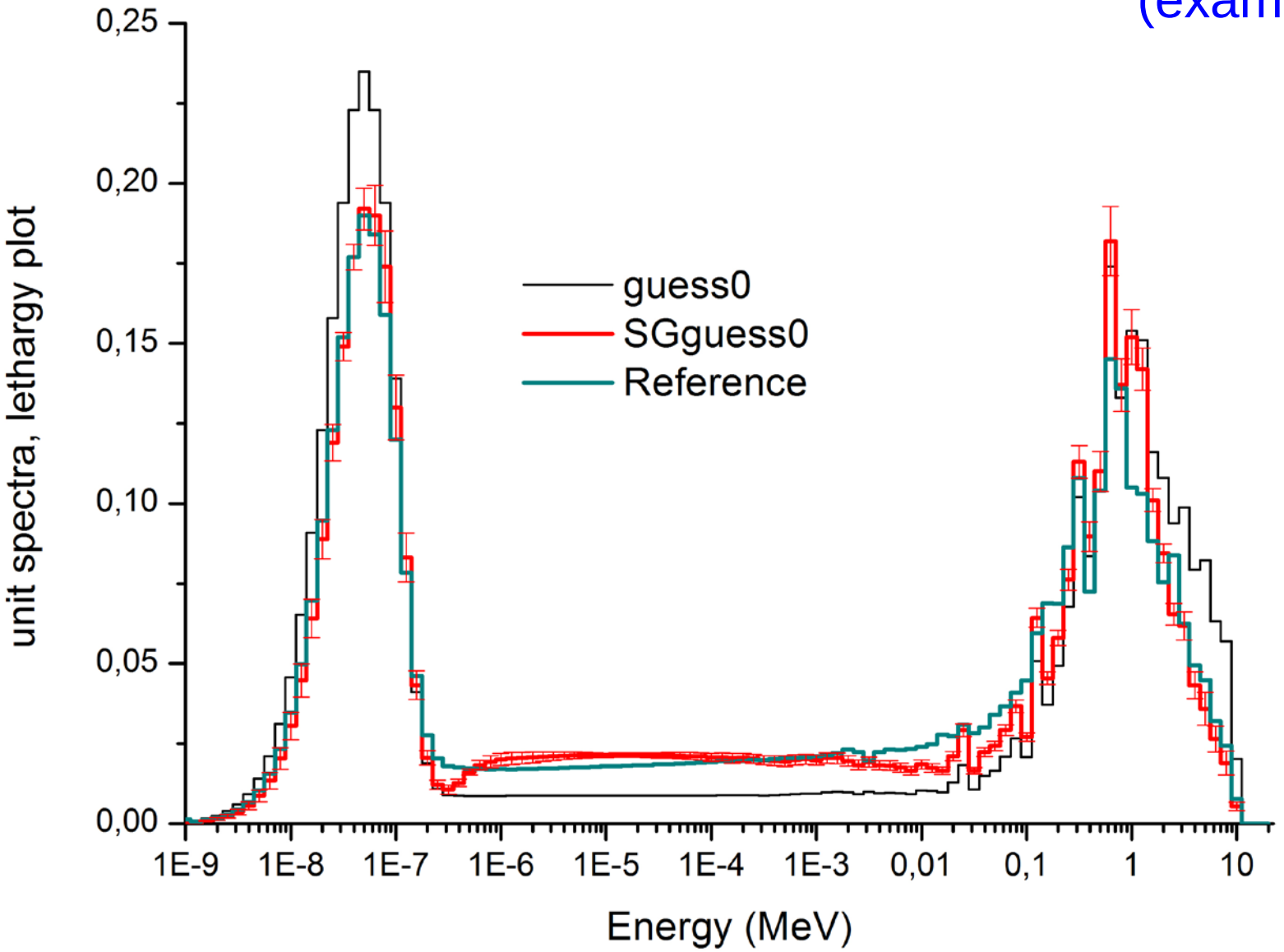
Assembling a guess spectrum by superposing thermal + flat epithermal + fast

- The “fast” being taken from literature or a simplified MC calculation (vacuum, no walls)
- Little attention to the **proportions** of the three components, as unfolding process:
  - ***Can’t*** *add structures that are not included in the guess*
  - ***Can*** *correct the proportions and shapes of existing structures*



Guess 0

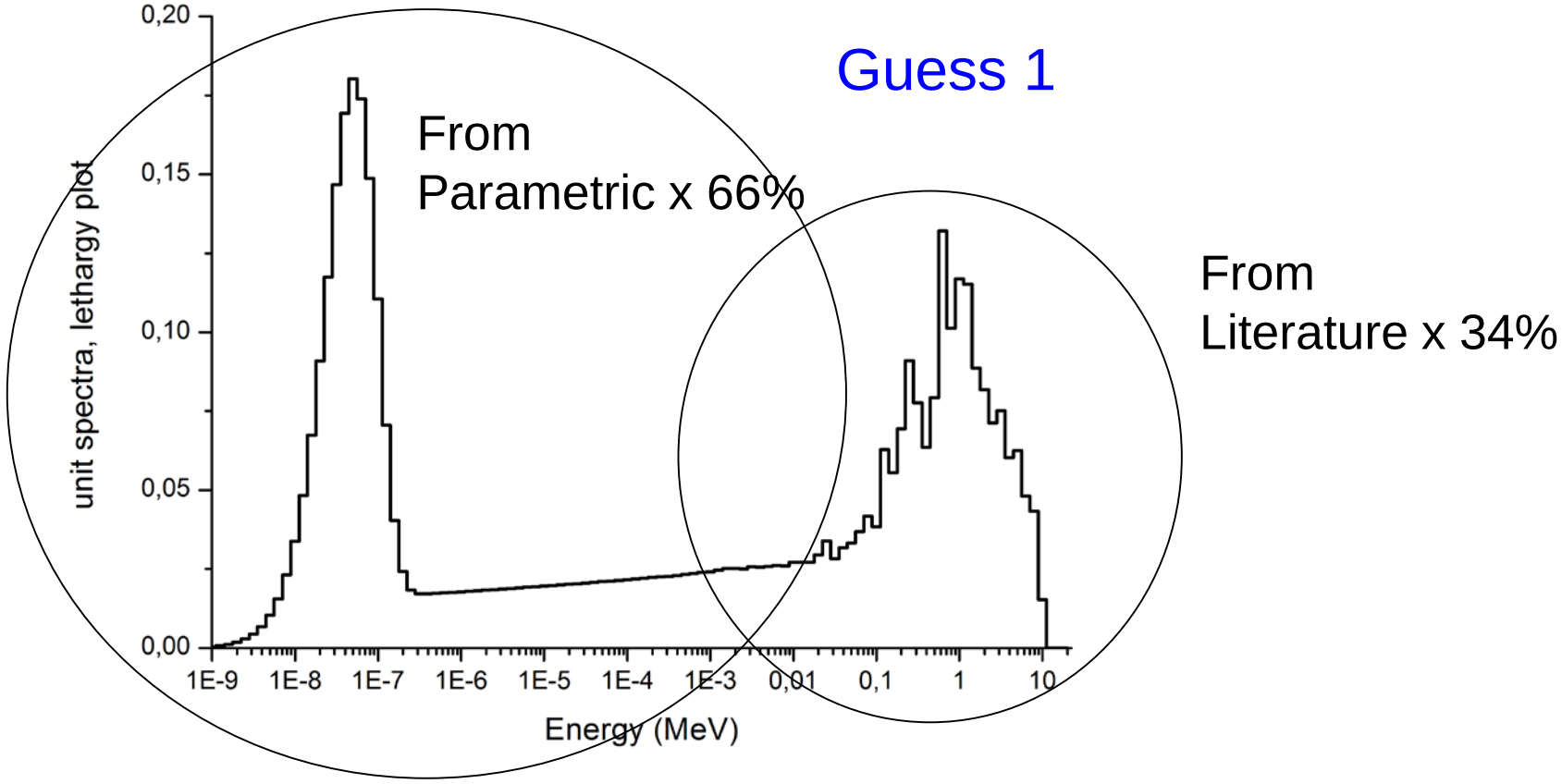
(example: FRUIT-SGM)



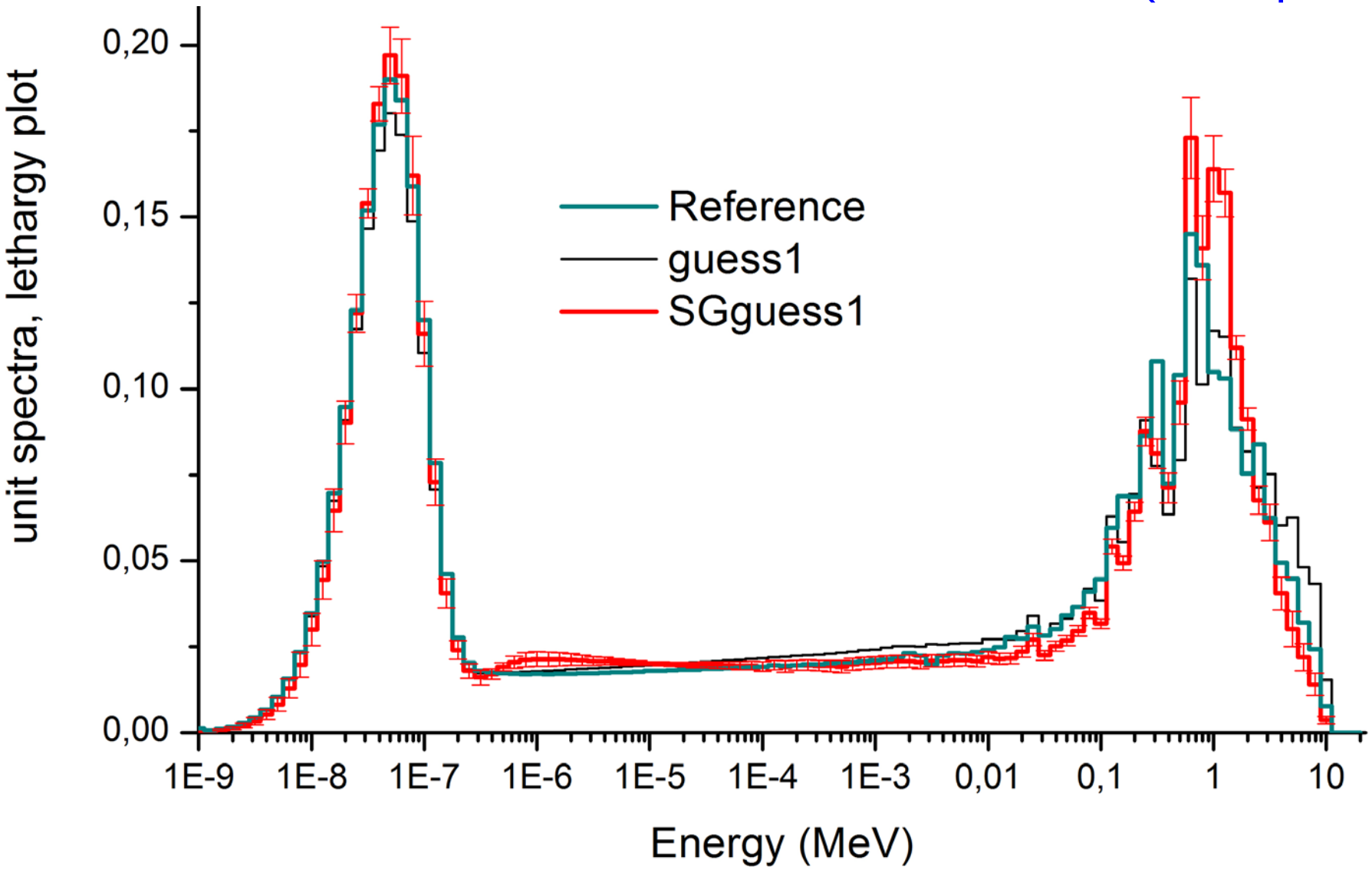
Example: the irradiation room problem (Am-Be + Iron) **(3/3)**

Assembling a guess spectrum by superposing thermal + flat epithermal + fast

- "fast": Like previous example
- Thermal + epithermal taken from the parametric unfolding: they are likely to be right in terms of **proportions** and **shape of the epithermal**



(example: FRUIT-SGM)



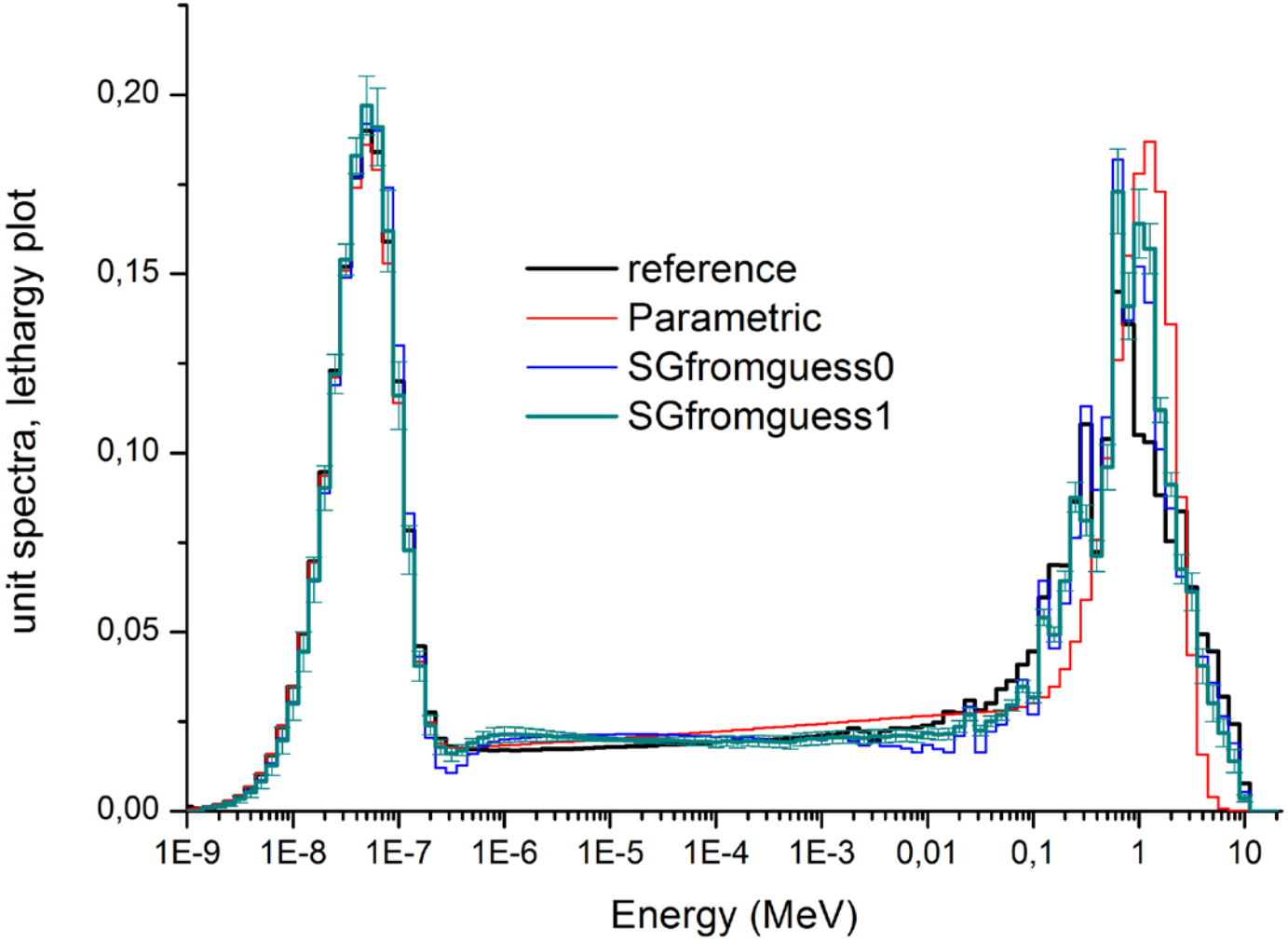
After unfolding

- **Plot the unfolded spectrum. Unrealistic results could be identified by eye:**
  - ✓ Negative fluence values?
  - ✓ Double thermal peak?
  - ✓ Thermal peak shifted to unrealistic energies
- **Fold the response matrix with the "resulting spectrum" and comparing the folded counts with the reference/experimental BSS counts:**
  - ✓ Considerably larger deviations with respect to uncertainties should warn the user
  - ✓ Compatibility of folded vs. reference BSS counts:
    - is a necessary condition BUT it does not guarantee itself the correctness of the spectrum (unfolding is an underdetermined problem)
    - "flat-in-lethargy" guess: the resulting spectrum may possibly give "a rough idea" of the regions with larger fluence, but the spectrum is probably very far from being correct.
    - If the final spectrum "matches" the experimental counts, the spectrum-integrated fluence tends to be correct
    - Not the case of H*(10), heavily depending on the energy distribution!
- **Comparing with literature data for similar scenarios** (IAEA TRS 318 and TRS 403)

Conclusions

- Application of unfolding codes needs some experience (training courses, comparison exercises)
- The unfolding task always includes certain degrees of complexity and difficulty (*significant fraction of deviating results in "simple" scenarios*)
- Preparing reliable pre-information for BSS unfolding is crucial: even well-known codes give deviating results if "fed" with non-realistic information.
- The user of unfolding code should:
  (1) have sufficient physical knowledge of the radiation environment
  (2) have minimal mathematical/computational tools to translate that physical knowledge into a priori information adapted to the specific code
  (3) have sufficient experience to correctly judge the results for plausibility and accuracy.

spare


unit spectra, lethargy plot
0,20
0,15
0,10
0,05
0,00
reference
Parametric
SGfromguess0
SGfromguess1
1E-9
1E-8
1E-7
1E-6
1E-5
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0,01
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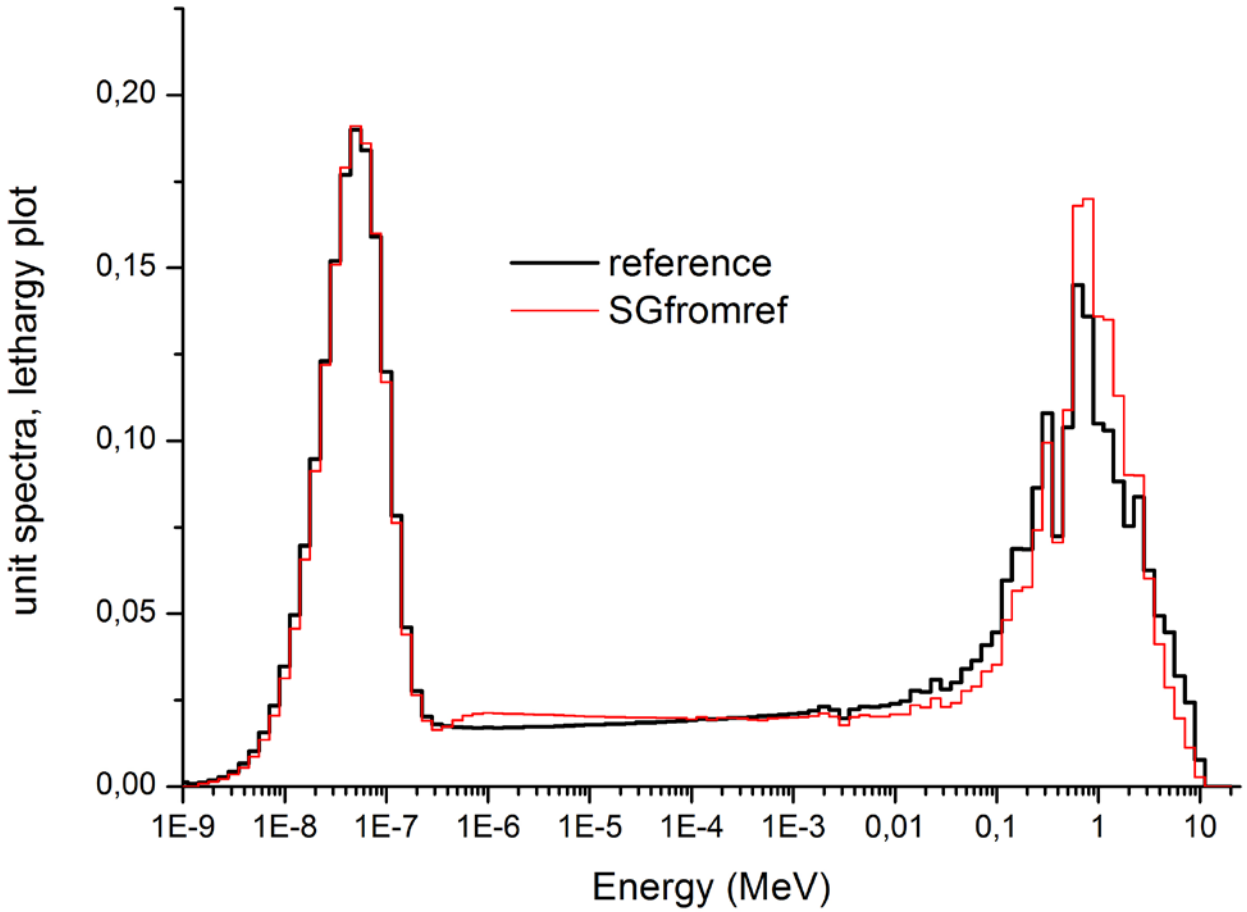
10
Energy (MeV)

spare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1E-4
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1
10
Energy (MeV)