A screening facility for next generation low-background experiments

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Why?

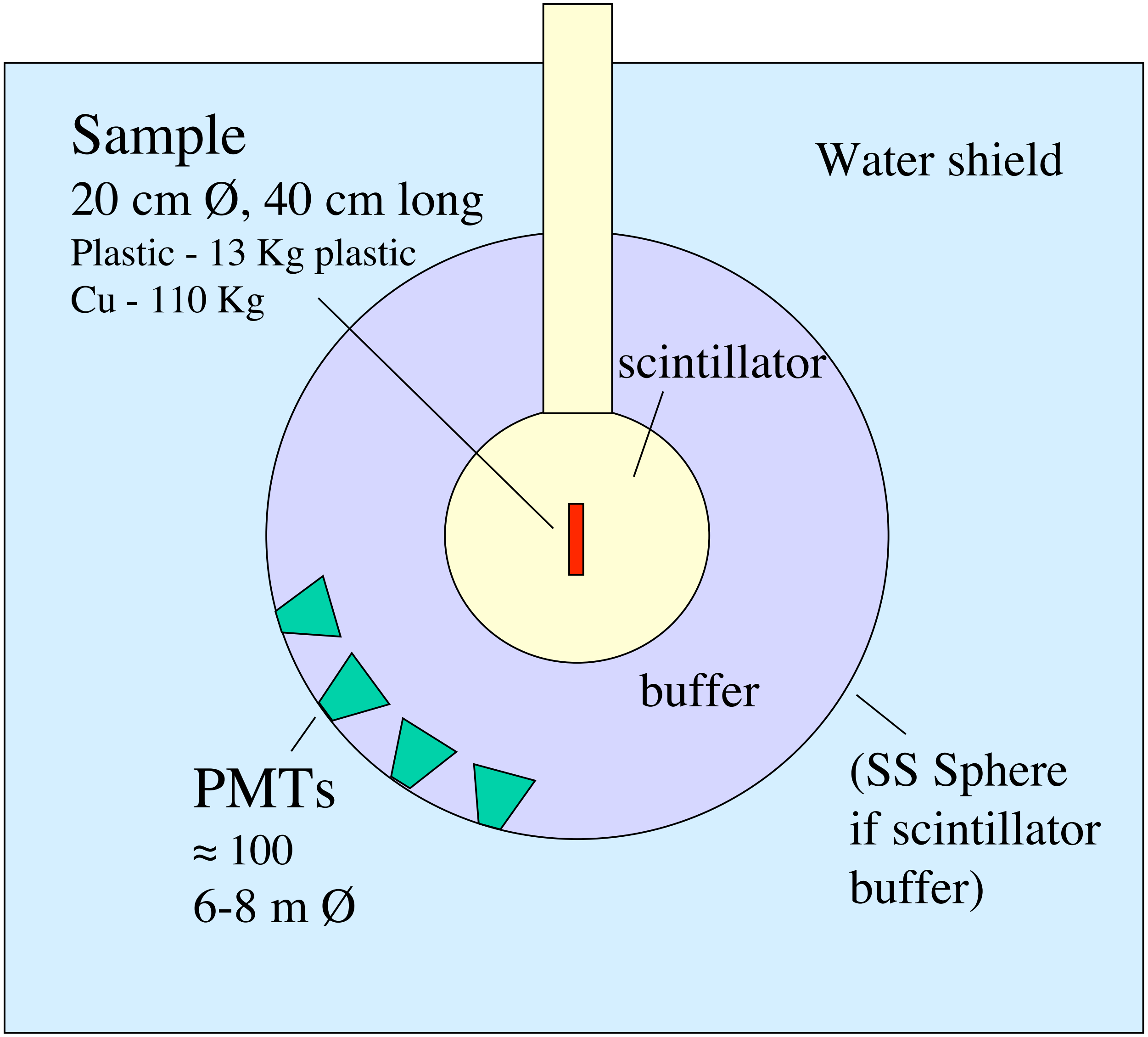
- Next generation experiments require large advances in lower backgrounds.
  - Dark Matter: critical test of SUSY WIMPs
  - Solar Neutrinos: pp neutrinos
  - Double Beta decay: $m < 0.1$ eV
- Major effort on sophisticated detectors.
- Why not a major effort on backgrounds?

We need much better diagnostics!

Current state of the art

- Ge detectors, Cu and Pb shielding
  - Typical best limits in clean materials: U, Th: 20 ppt; K: 50 ppb
  - Factor of several better possible, but only with very long counting (≈ months).
  - Often get only limits, or possible surface contamination: Cu, plastics
- Chemical assays, NAA for U, Th, K
  - With major effort,
    - U, Th at ≈ ppt; K≈ ppb
    - Specialized concentration has done better (Munich)
  - Problems
    - Reliability
    - Tiny sample size (≈g)
    - Insensitivity to dust, other contamination

A new facility



- "Mini-me" version of Borexino
- Whole-body counting of sample
- ^{14}C sets threshold near 250 KeV

Purification of scintillator

- Non-polar solvent
  - Extremely low solubility for ionic impurities
- Purification methods developed
  - Distillation
  - Water extraction
  - N2 stripping
  - Solid-column adsorption
- Expect at least:
  - 10^{-16} g/g U,Th
  - 10^{-14} g/g K.

Sensitive to:

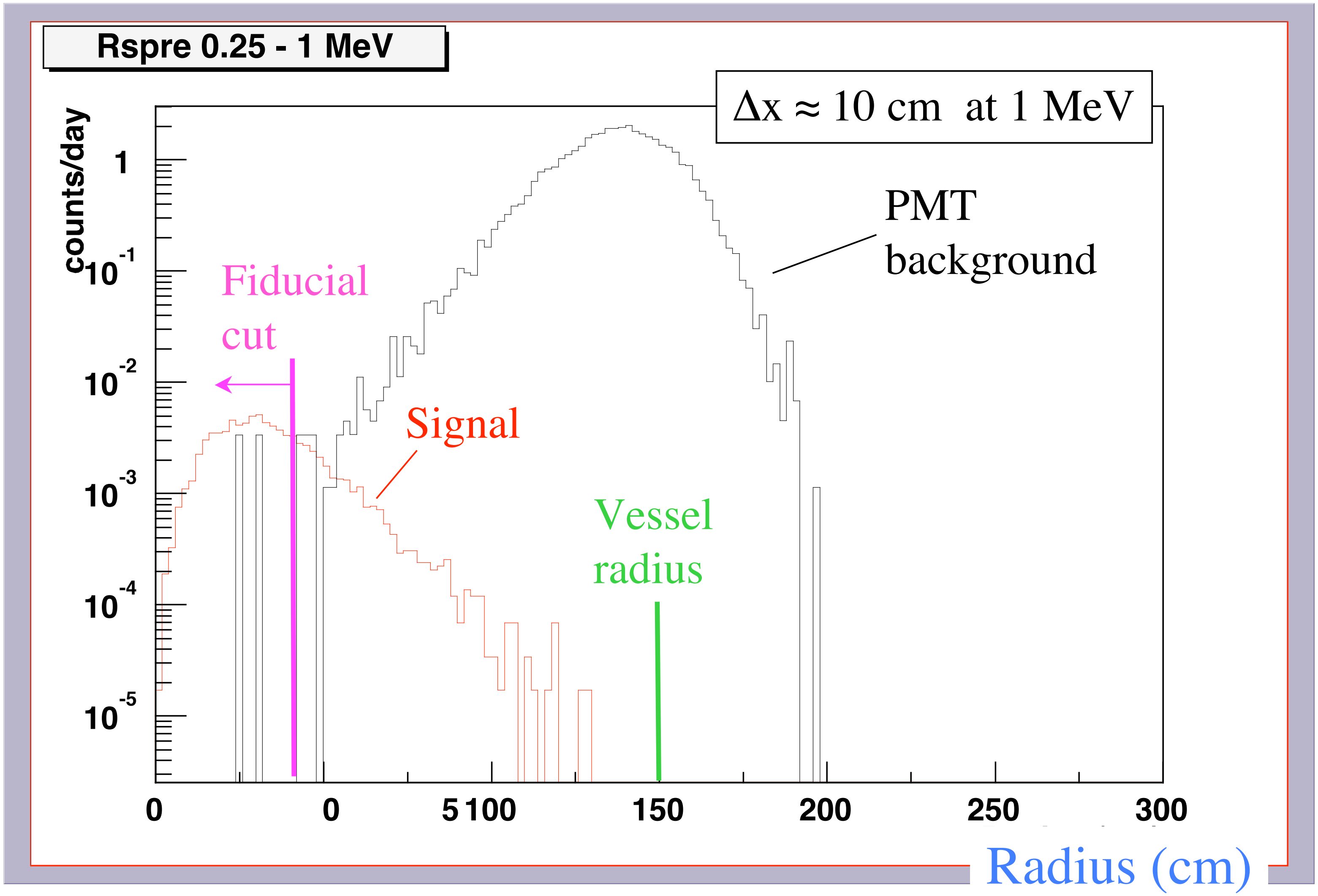
- Photons emerging
- Betas, alphas on surface
  - If sample is attacked by scintillator:
    - Seal in ≈ 50 μm film of nylon
    - Not sensitive to alphas
- Alphas distinguished by pulse-shape
- Betas and photons distinguished by event shape

Backgrounds

- Estimates based on Borexino work
  - PMTs - dominant
  - Nylon vessel (≈ ppt U, Th; 20 ppb K)
  - Nylon plumbing (≈ 50 ppb K)
  - Scintillator (Borexino goal: 10^{-16} g/g U,Th)
  - Buffer
    - Water buffer at level of SNO for Ra, Rn (10 μBq/m^3).
    - Scintillator buffer: better optics, cleaner, simpler vessel.

- Dominant radioactivity is external, so use position reconstruction.

Fiducial Volume

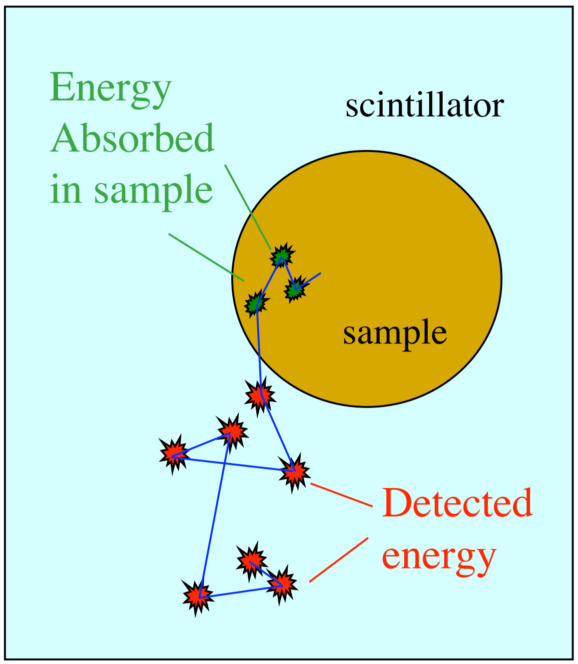


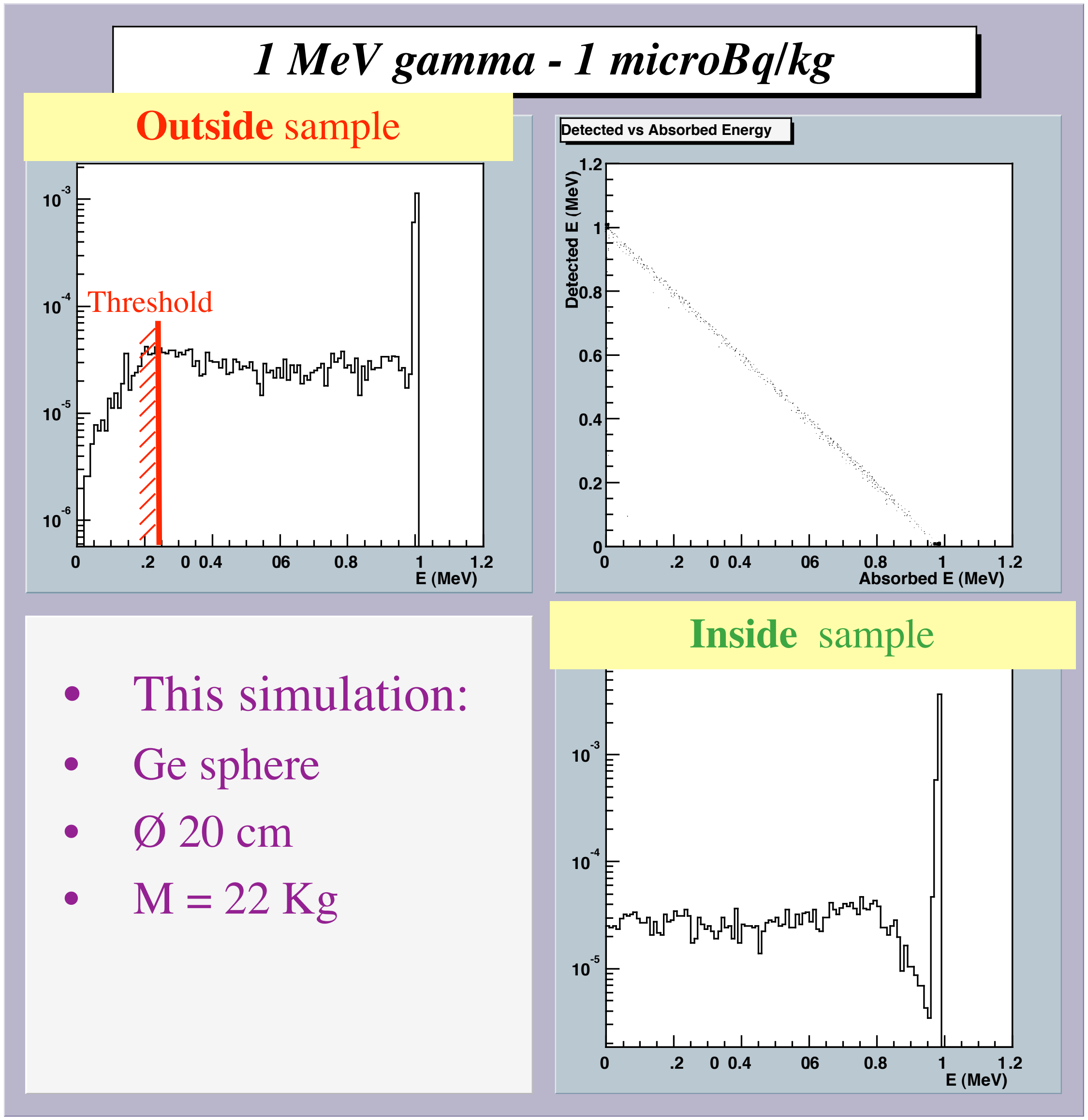
Background

Item	Counts/day
IV Film, 125 μm thick	6.00E-04
End region hardware	0.018
PMTs, E>250 keV	0.094
PMTs, 250<E<1000 keV	0.010
Scintillator at 10-16 g/g U, following cuts	0.03
Total, E>250 keV	0.14
250 < E < 1000 keV	0.06

- At 30 days counting, have ≈ 3 counts.
  - Same as 95 % CL with no counts.
  - ☞ "Background free" detector

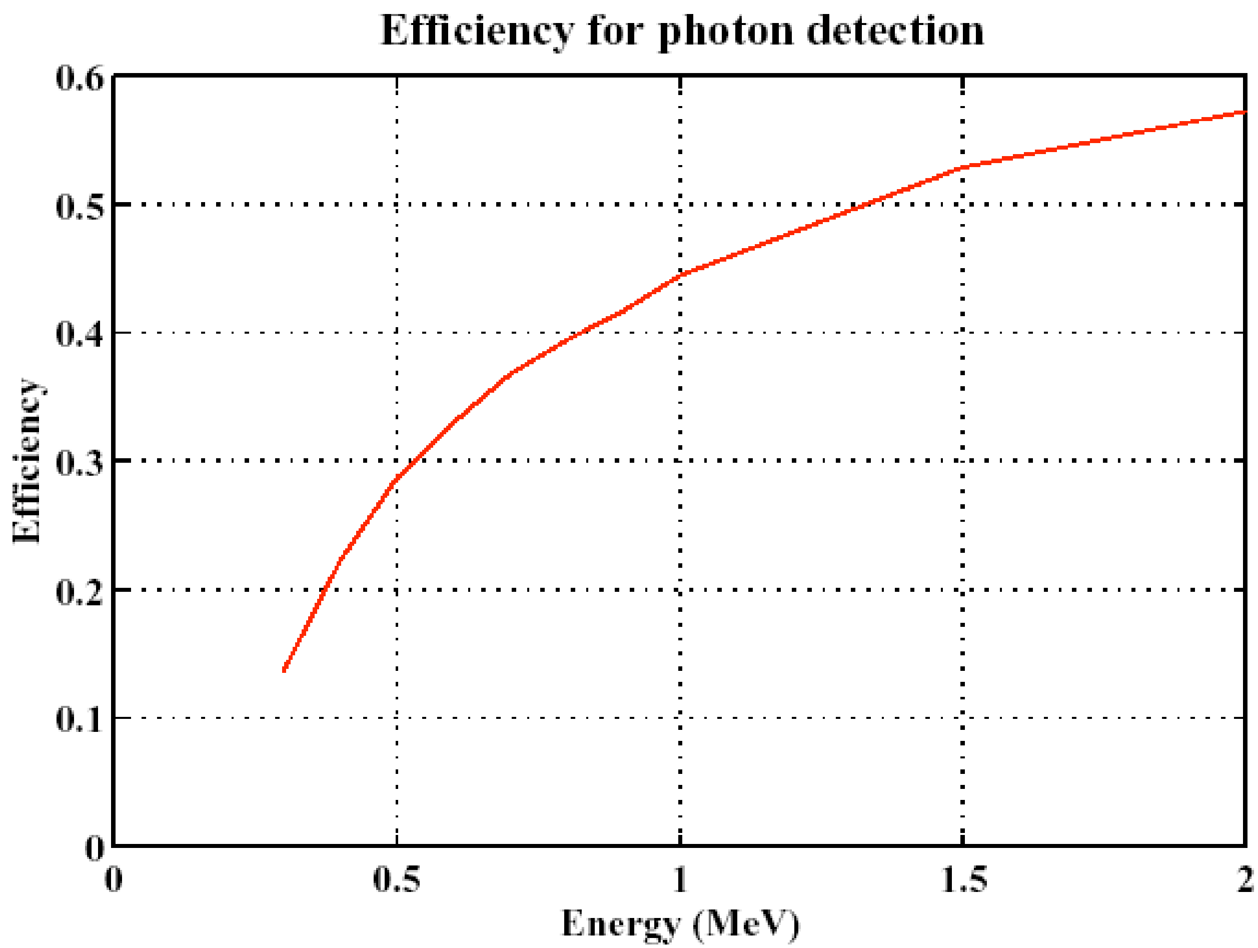
Photons detected outside sample





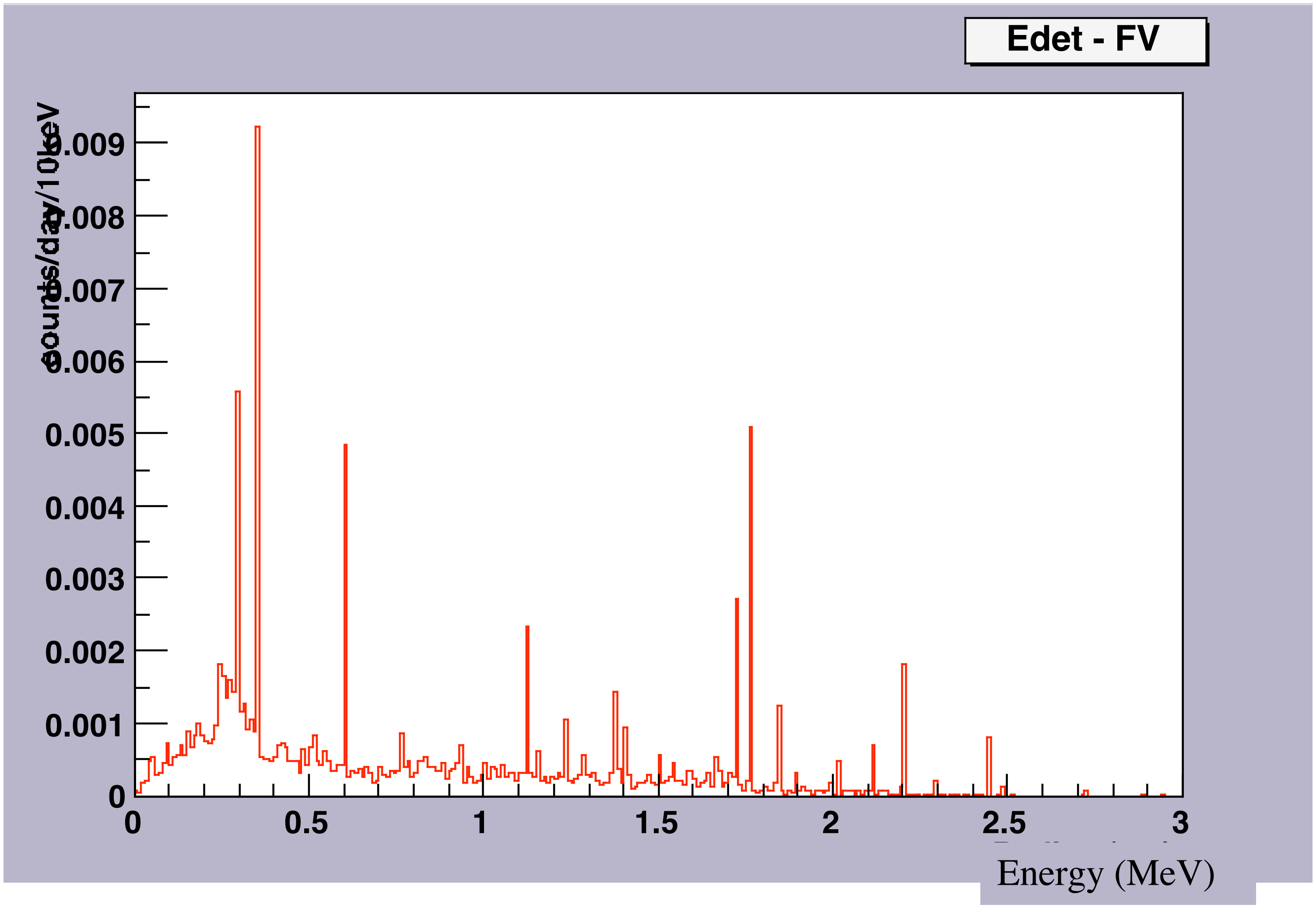
- This simulation:
- Ge sphere
- Ø 20 cm
- M = 22 Kg

Detection efficiency vs. Energy

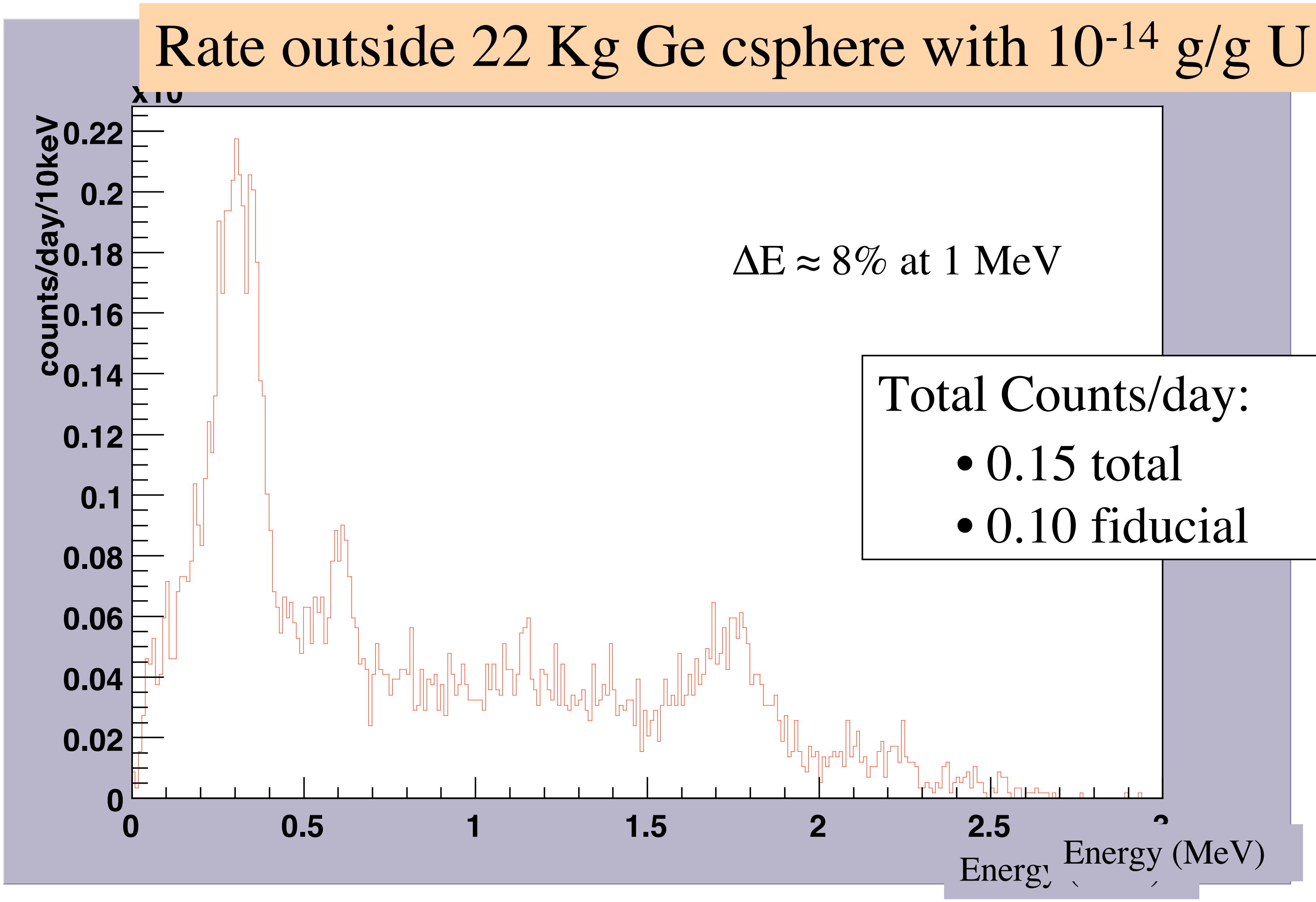


- Reasonably good for E > 500 KeV

Escaping energy from U chain



U, as detected



Sensitivity

- Total background: 0.1 counts/day, E > 250 keV
- U,Th, K Contamination limits, g/g:

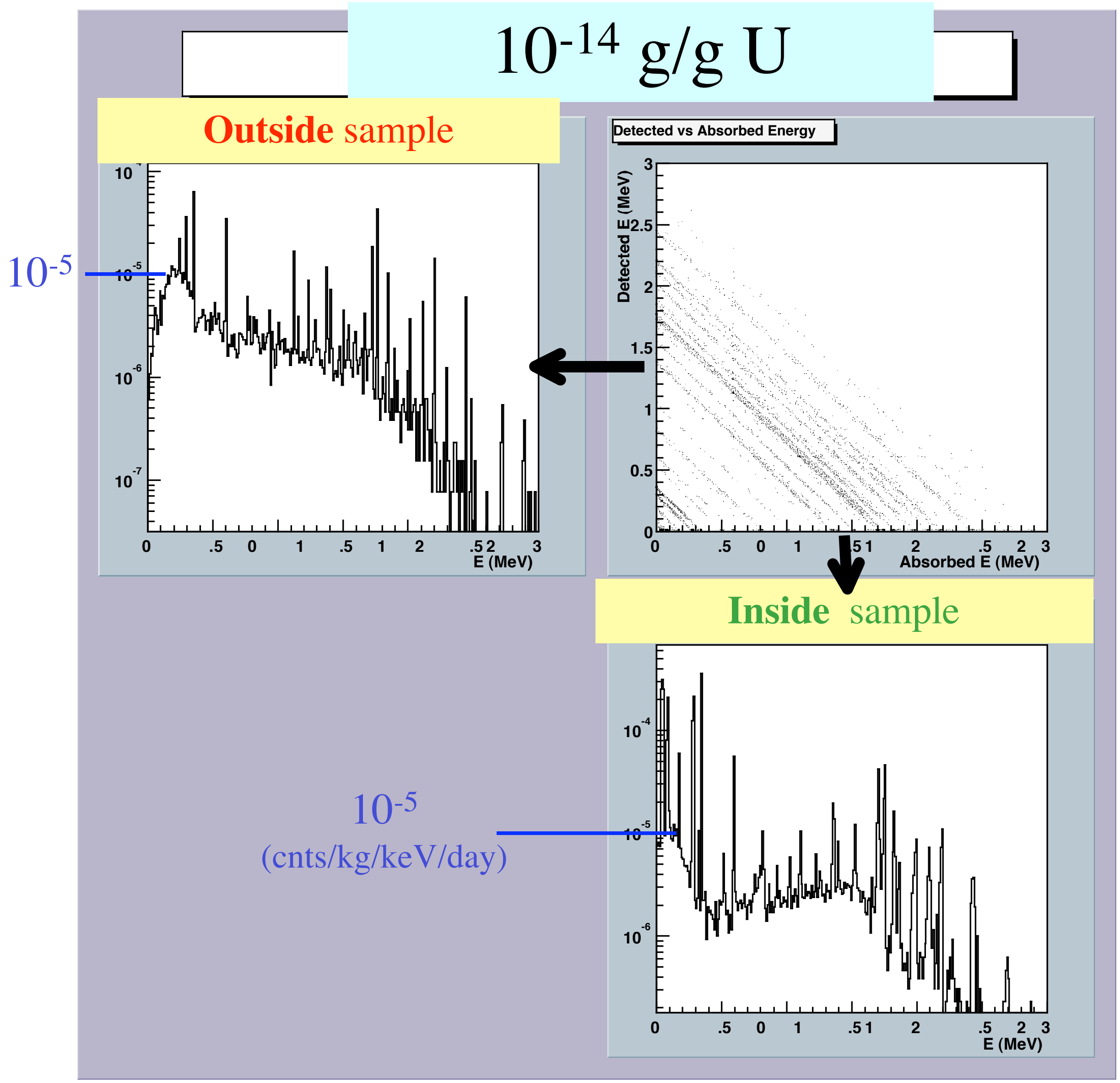
	1 day counting	30 days counting
U	3 E-13	1 E-14
Th	8 E-13	4 E-14
K	2 E-9	8 E-11

- Continuum background of Compton photons:

1 day counting	2 E-4	counts/Kg/keV/day
30 days counting	6 E-6	counts/Kg/keV/day

- Surface □, □ emitters, E > 250 keV: 0.8 cnts/day/m^2
  - (not sensitive to □'s if need to seal sample in film)

Photon sensitivity



- At ≈ MeV, good sensitivity to all photons.
- Below 500 keV, reduced sensitivity.
- Emergent continuum rate ≈ internal continuum rate

Compare to experimental goals

- Final background goals in different experiments.
  - 0 □ □□ decay (Ge)
    - 10^{-6} cnts/kg/keV/day, E=2039 keV
  - 1 Ton WIMP Dark Matter (Ge)
    - 10^{-6} cnts/kg/keV/day, E<50 keV
  - pp solar neutrino elastic scattering
    - $5x10^{-8}$ cnts/kg/keV/day, E<500 keV
- These are within range of screening.
  - For DM, pp solar □, need to worry about low E emitters: ^{14}C, ^{3}H. Others?

General screening

- Several good materials (Cu, plastics) typically only result in limits
- At limit of current sensitivity, hard to distinguish internal and external contamination.
- Big increase in sensitivity could lead to use of much cleaner materials.

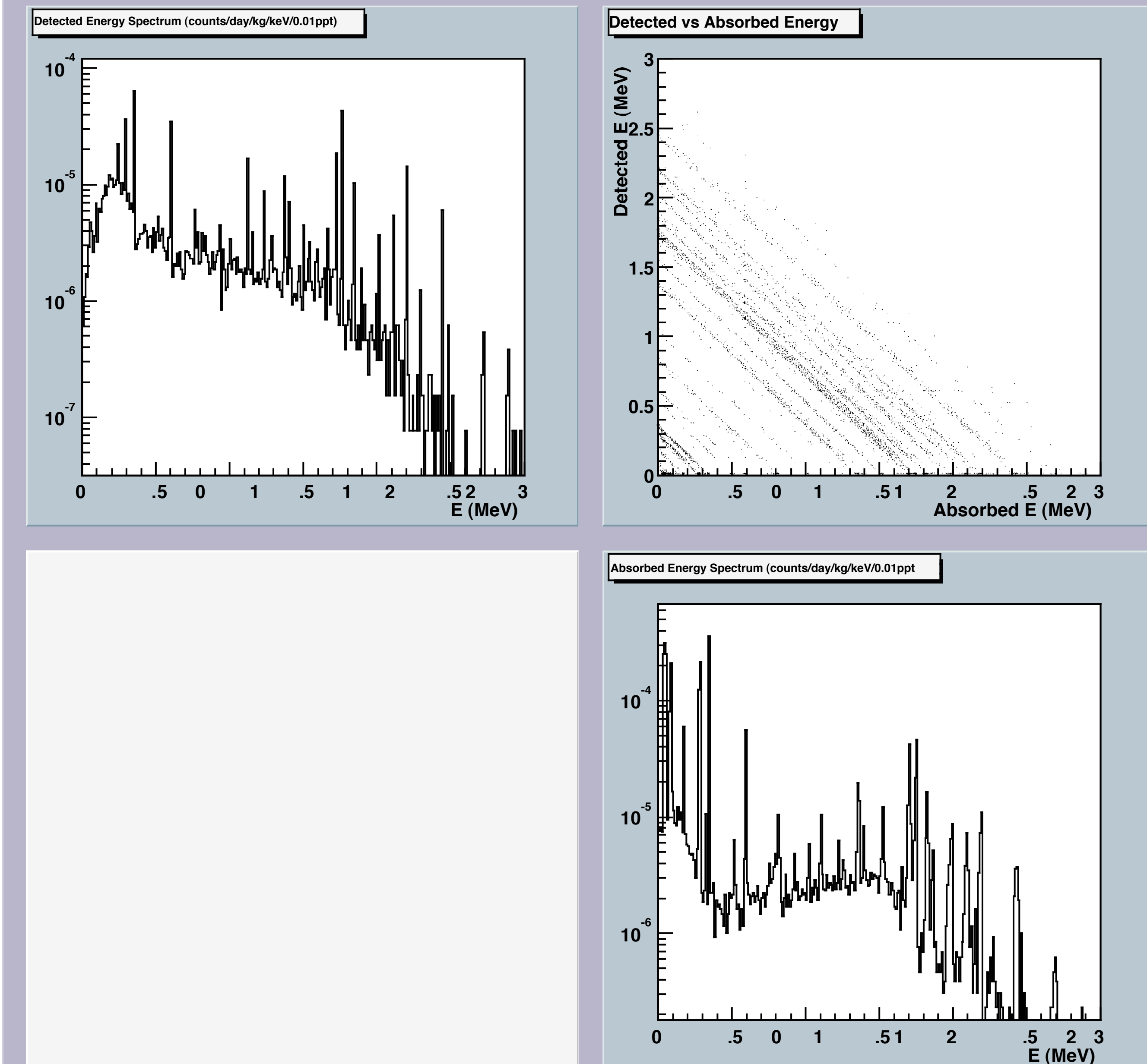
Limitations

- Internal beta, alpha contamination
- High resolution measurement of lines
  - Modest ability to distinguish specific contaminants, especially if several.
- Low energy photons:
  - Reduced efficiency < 500 keV
  - Zero efficiency < 250 keV

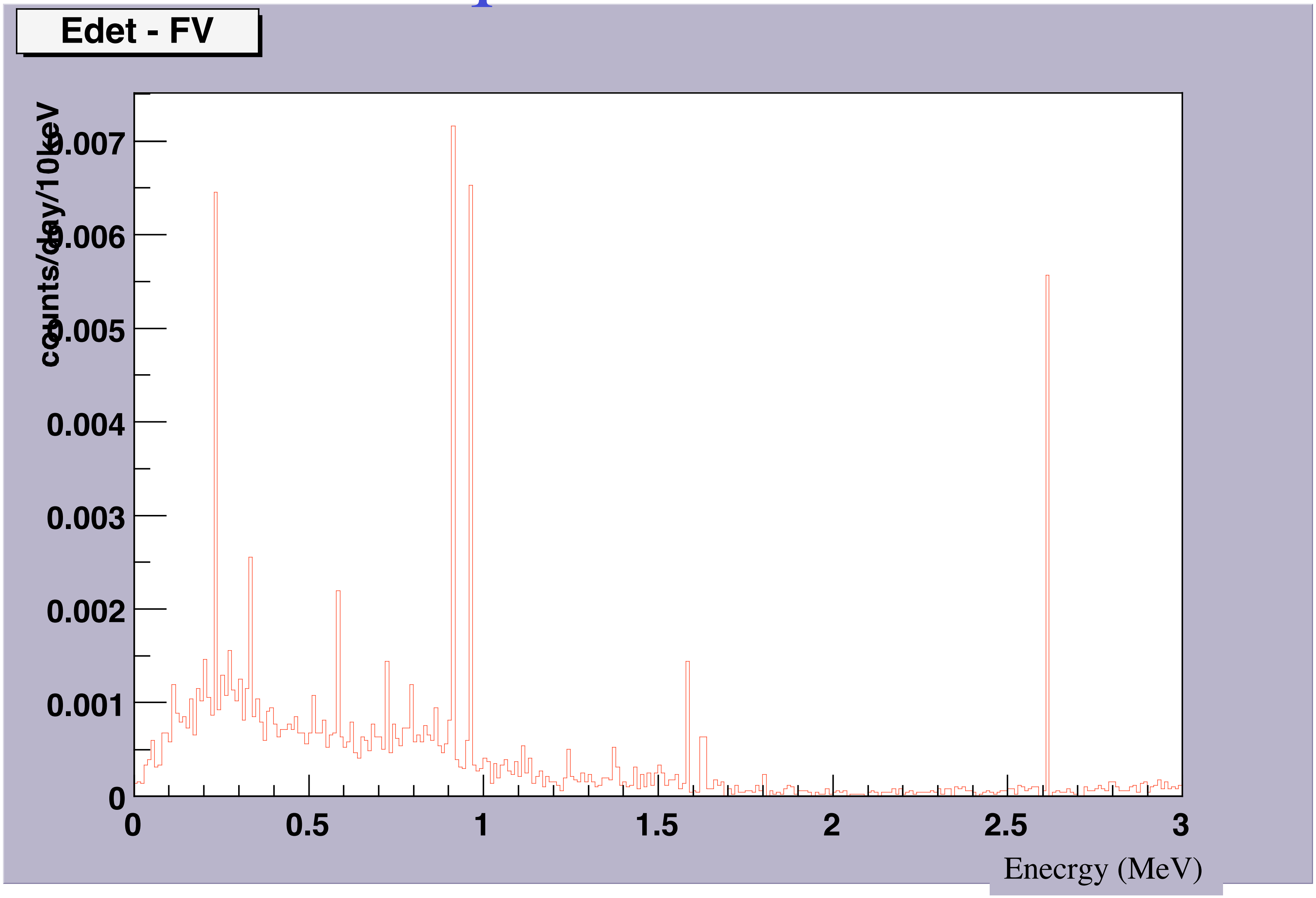
Conclusion

- Long history of using "yesterday's" experiment as today's screening facility.
- Can be built with existing technology
- 2000 - fold increase in sensitivity
  - Old: U,Th ≈ 20 ppt
  - New: U, Th ≈ 0.01 ppt
- Enabling technology for next generation low E solar □DM, □□experiments.
- Unique opportunity with new National Underground Lab.

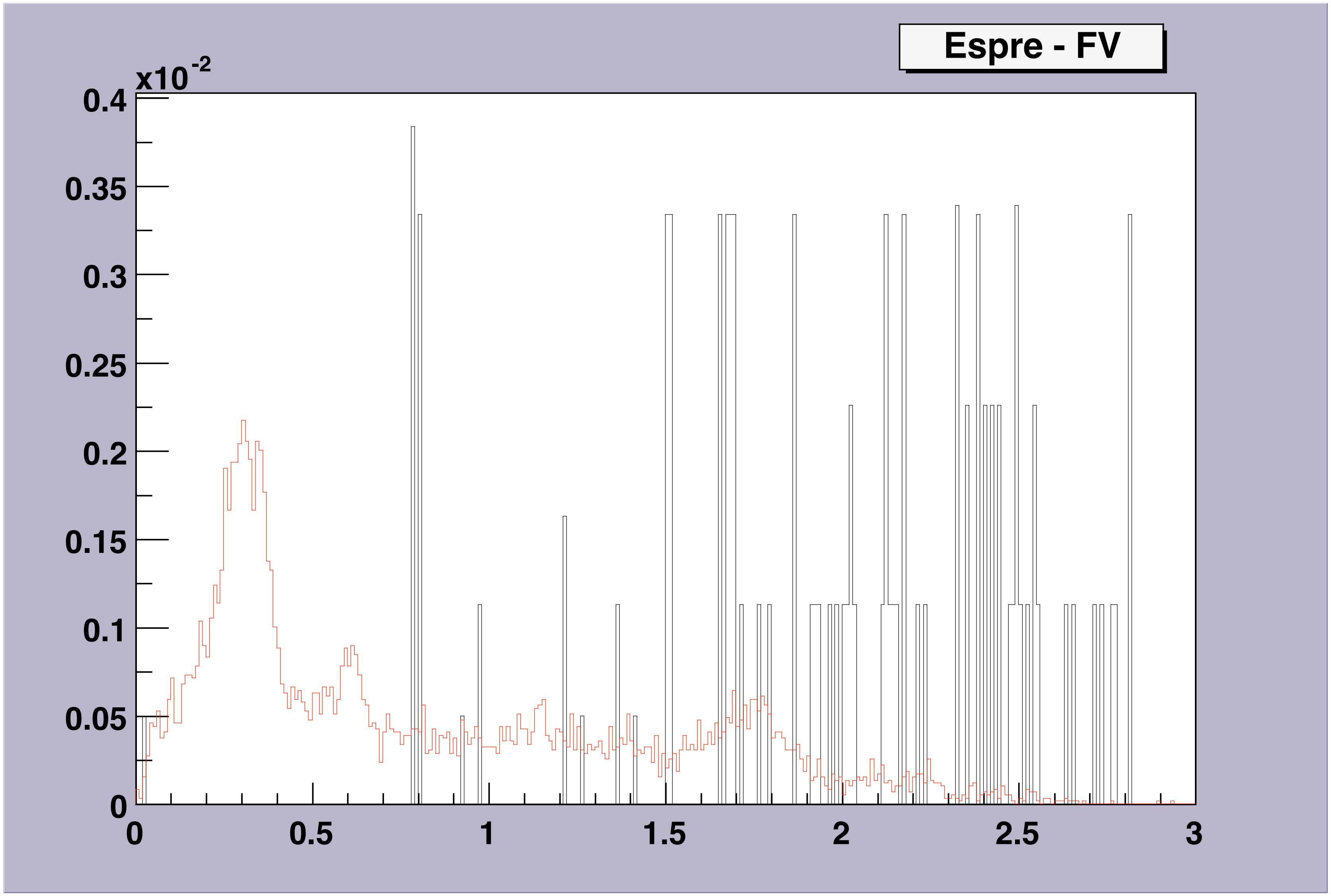
U-238 gamma spectrum



Th equilibrium chain



U and background



Th and background