Non-linearity issues when using commercial counters

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Overview

- Count-rate dependency

- Delay Before Burst

- Linearity check results
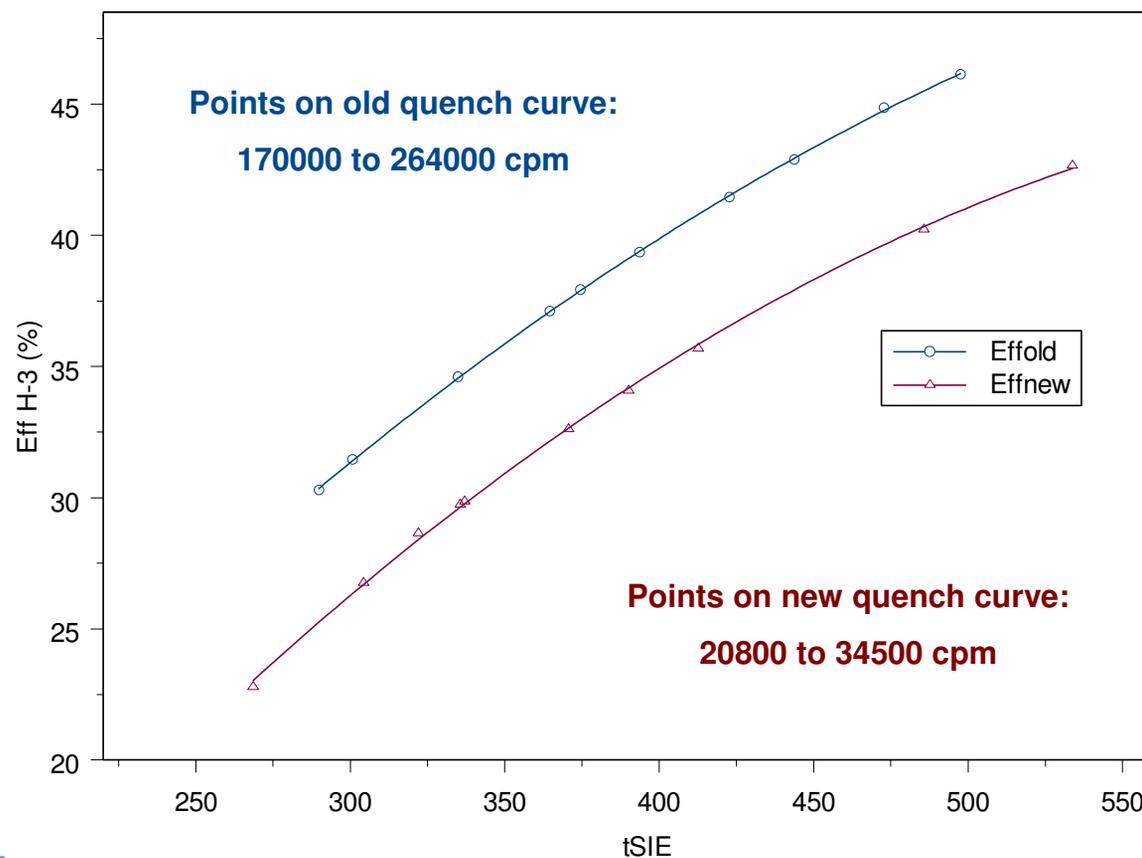
- Primary conclusions

NPL

Count-rate Dependency

- First suspicions when inconsistent results for measurements of ^{3}H at different count rates.

- We will see two examples:
  - The first example shows an unexplained shift in the ^{3}H quench curve, even though:
    - Same batch of scintillant used
    - Identical chemistry in both set of vials
    - Only difference total activity in the vials

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Count-rate Dependency

Example 1: Quench curve has shifted!

H-3 quench curves

Points on old quench curve:

170000 to 264000 cpm

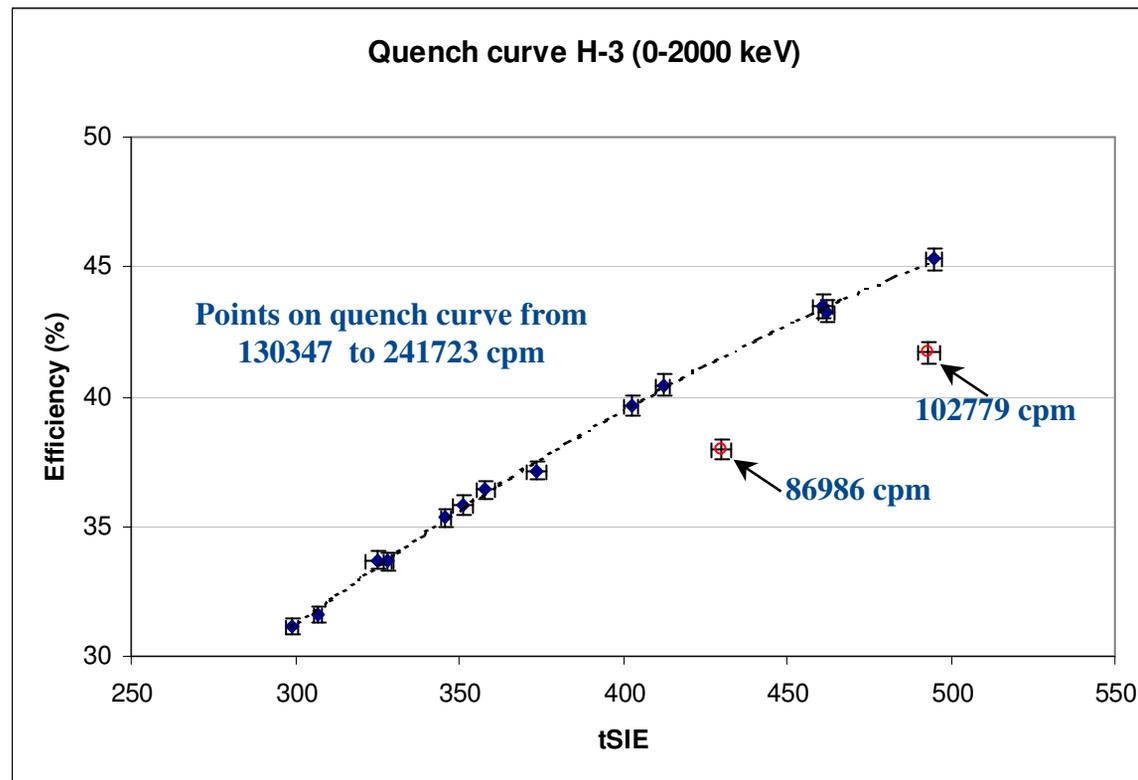Points on new quench curve:

20800 to 34500 cpm

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Count-rate Dependency

- In the new quench curve, the ^{3}H efficiency has dropped from about 5% for the same quench levels!

- Second example is ^{3}H sources (part of the OBT project) measured by Arvic Harms.

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Count-rate Dependency

Example 2: Results for OBT measured by Arvic Harms

Quench curve H-3 (0-2000 keV)

Points on quench curve from 130347 to 241723 cpm

102779 cpm

86986 cpm

Efficiency (%)

tSIE

Count-rate Dependency

↪ For count-rates ~100 000 cpm (~ 2 ks^{-1}) or below, observing count loss. The counter doesn't seem to behave linearly in this region!

- Some further work suggested that the problem was linked with the Delay Before Burst setting

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Delay Before Burst

- Delay Before Burst is "the length of time that the detector delays before looking for additional pulses after the prompt pulse of an event" (Tri-Carb® reference manual R137)

- DBB setting is used to discriminate between background events (produce afterpulses) and true beta events.

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Delay Before Burst

- "However, some scintillators (e.g. Packard Ultima Gold) produce afterpulses which can make a true beta event resemble a background event." […] "This especially important for higher energy beta emitters (e.g. 14C and above)" (Tri-Carb® reference manual R138)

  ↳ Add an extra delay for higher energy beta emitters

  Problem: No changes in count rate is observed for high energy beta but at the opposite for low energy beta!

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Linearity check with high energy beta emitter

**Linearity and dead-time check on TriCarb 2700TR
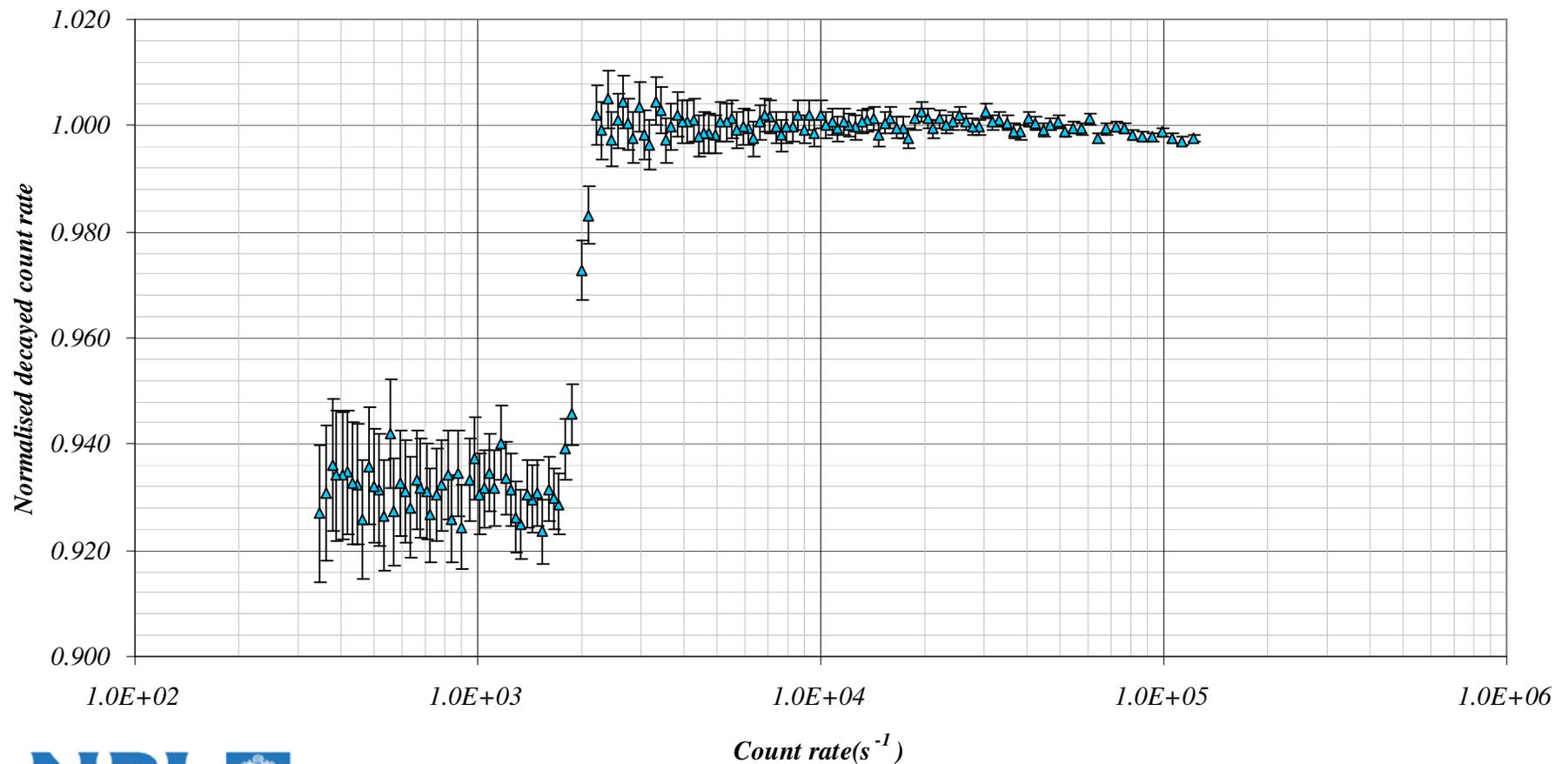with decaying Mn-56 source, DBB normal**
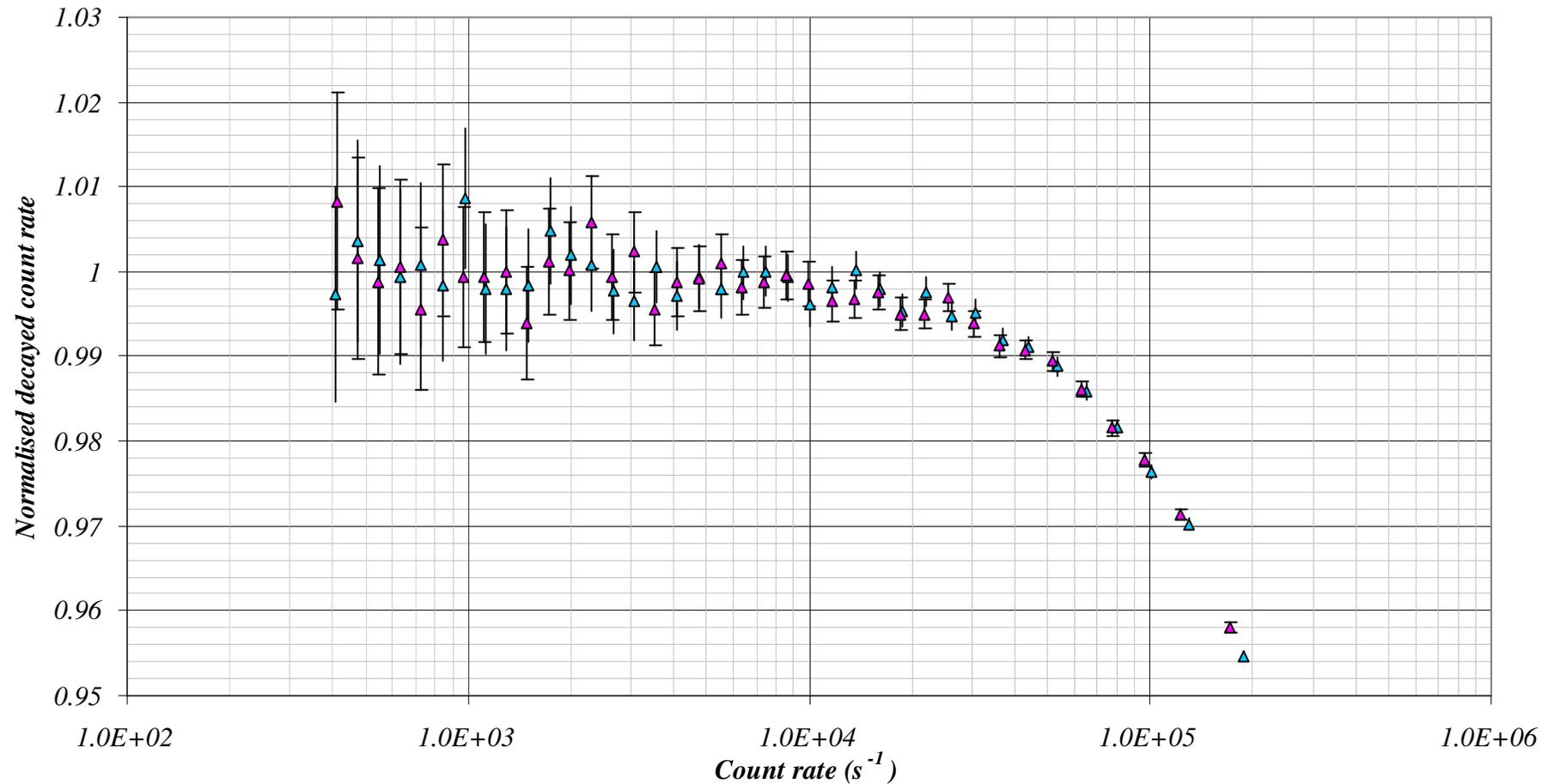
Linearity check with low energy emitter

- A ^{99m}Tc source was used to check the linearity of the counter for low energies (conversion electrons of 2.17 keV).

- Counting conditions: Two liquid scintillation vials were counted for 3 days with identical protocols with the exception of the DBB setting. The first vial was counted with a "normal" DBB (75 ns), the second vial had a DBB of 800 ns.
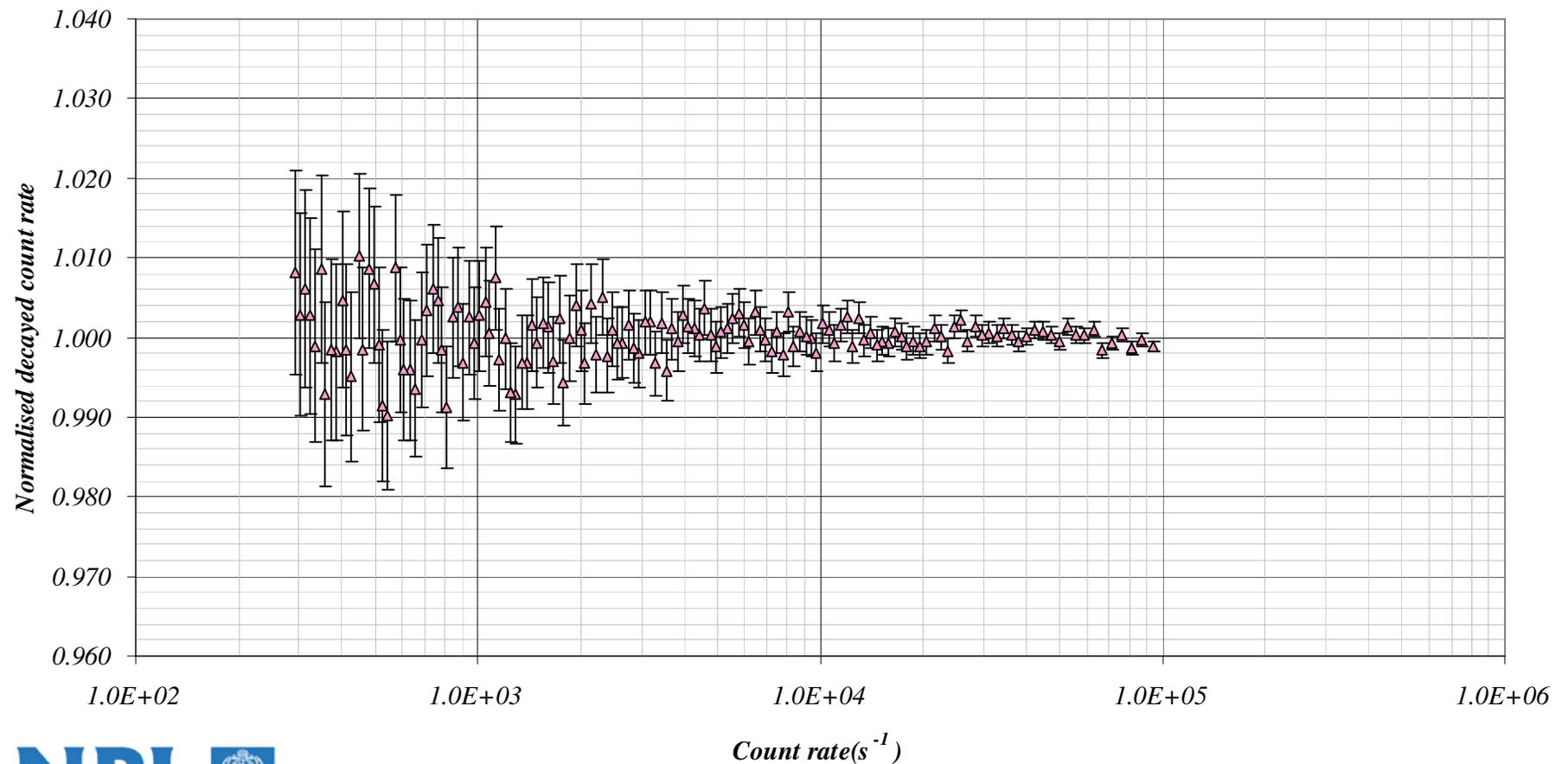
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Linearity check on Tricarb 2700TR with decaying Tc-99m source, DBB normal

DBB setting at 800 ns

**Linearity check on Tricarb 2700TR with decaying
Tc-99m source, DBB 800 ns**

Primary conclusions

Non linearity of the counter for a count rate below 2 ks^{-1} and a "normal" setting for the DBB.

- When count loss occurs, the 0-1 keV channels of the spectrum contain very few counts. This explains why the low energy emitters are more affected than the higher energy emitters.

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Primary conclusions

- The cause of the problem is not apparent

- It is a major problem if quench curve is made with sources above 2 ks^{-1} (~120000 cpm) and the measured sources are below 2 ks^{-1}

- Has anybody else observed similar problems with their counters?

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