JUNO : the energy spectrum of (reactor) neutrinos

MA1 internship – status report 2

26/11/2025

Files and cuts

- 638 runs of reprodC (from 9789 to 11039) (some missing)
- 30/08/2025 to 02/11/2025
- Total accumulated time : 50.8 days

Not these ones

Data cuts

Criterion	Value / description
Prompt energy	$0.7\ \text{MeV} < E_p < 12\ \text{MeV}$
Delayed energy	$2.0\ \text{MeV} < E_d < 2.5\ \text{MeV}$
Fiducial Volume (FV)	$R < 16.5\,\text{m}$; Remove ($\lvert z\rvert > 15.5\,\text{m}$ and $\rho < 2.0\,\text{m}$)
Prompt-delayed time diff. (Δt)	$5\,\mu\text{s} < \Delta t < 1\,\text{ms}$
Prompt-delayed distance (ΔR)	$\Delta R < 1.5\,\text{m}$
Multiplicity cut	No events in full volume (not vetoed by muons) in [2, 12] MeV energy range within 1 ms before the prompt, 1 ms after the delayed, or between p-d.
Muon and other vetoes	
Muon veto (CD+WP)	5 ms veto after WP NPE > 400 with ±500 ns coincidence with CD event
Muon veto (WP-only)	5 ms veto after WP NPE > 700, no CD npe > 30k with ±500 ns
Muon veto (CD-only)	5 ms veto after CD NPE > 30k, no WP trigger > 400 NPE in ±500 ns and after > 2 ms from last muon
Job veto	First 5 ms for each job
Big gaps	5 ms veto after big gaps, 50 ms for consecutive CD events and 70 ms for consecutive WP events
No header veto	5 ms veto after events with missing headers
Neutron veto	4 m radius sphere for 1.2 seconds around spallation neutron candidates ($20\,\mu\text{s} < \Delta t_\mu < 2\,\text{ms}$, with energy in [1.5, 20] MeV, and hit time standard deviation < 275 ns)
Flasher cut	$\left(\frac{\sigma_{\text{nhit}}-0.55}{0.45}\right)^2 + \left(\frac{\sigma_{\text{hit time}}-170}{80}\right)^2 \leq 1$

Typo ? I took 3.0 m

Analysis

1. Building the main lists

From wp_events :

- Lists “big gaps”
- Lists muons, tagged as “low”/“high”

From cd_events :

- Lists “big gaps” and “start job”
- Lists muons from cd
- List everything, tag “prompt candidates” (events who passes FV and energy cut)

→ muon_candidates, big_gaps_triggers, and cd_events with prompt candidates tagged

- 446 538 381 events in cd (with E > 0.7 MeV)
- 19 737 486 prompt candidates

2. Building the veto trigger lists

From muons_candidates :

- wp muons : check for coincidence with cd
- No coincidence needed for “high” muons
- cd muons : check for no coincidence with wp

→ muons_definitive

From muons_definitive :

- Searches for events in the time and energy window
- Removes duplicates

→ spallation_neutrons

- 9.23 Hz muon rate
- 3.89 Hz spallation neutron rate

3. Enforcing the remaining cuts

From muons_definitive and big_gaps_triggers :

- Removes events in cd_events within veto window

From cd_events :

- For each “prompt candidate”, check for no events within energy window 1ms before, only one event within 1ms after (the delayed), and no events within energy window 1ms after the delayed.

→ prompt_list, delayed_list

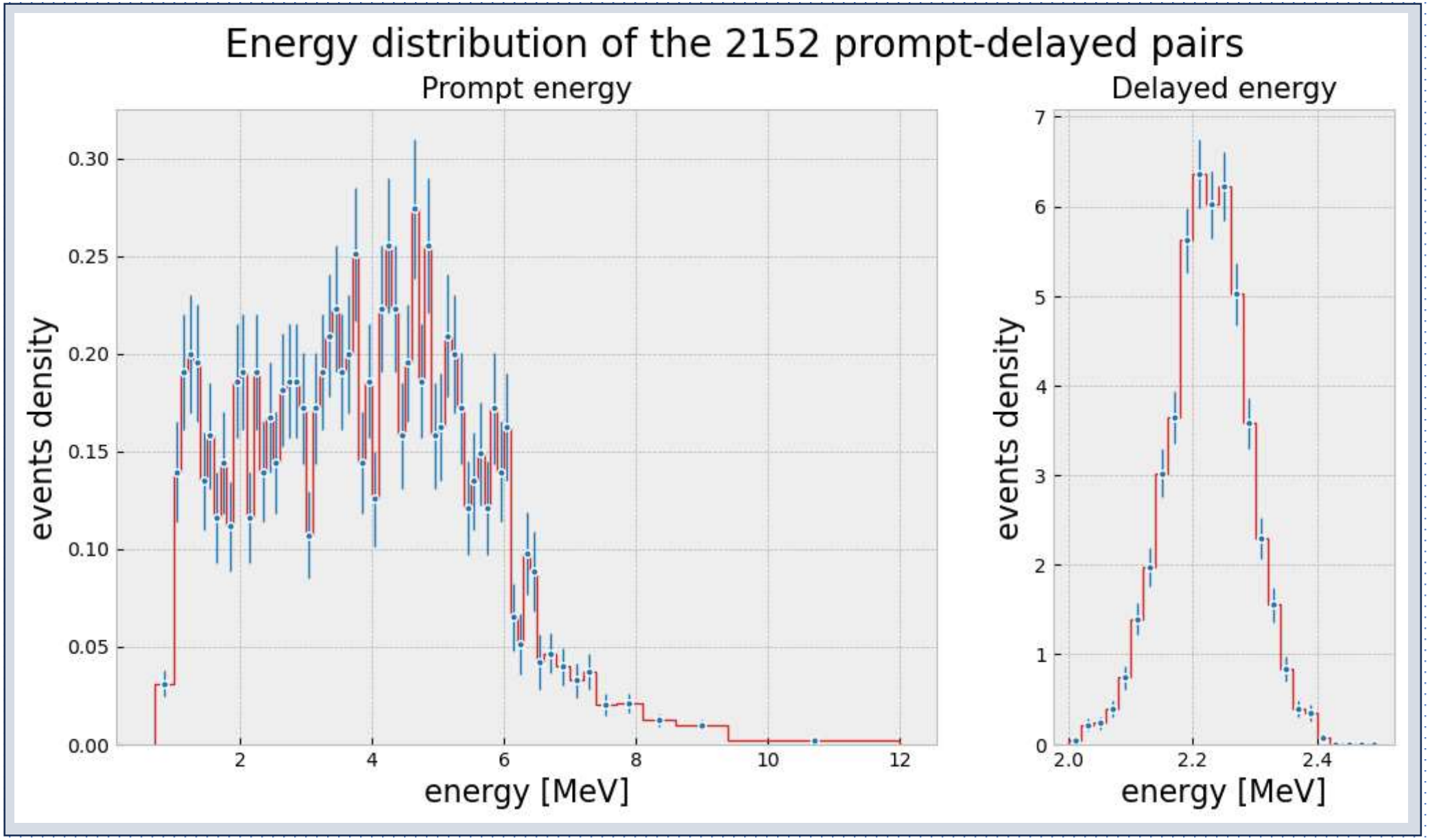
From spallation_neutrons

- For each neutron, searches for events within prompt_list and delayed_list within time and position window. Removes both the prompt and the delayed if at least one is found.

- After muons : 7 324 082 (37.1 % left)
- After multiplicity : 4 550 (0.06 % left)
- After neutrons : 2 152 (47.3 % left)

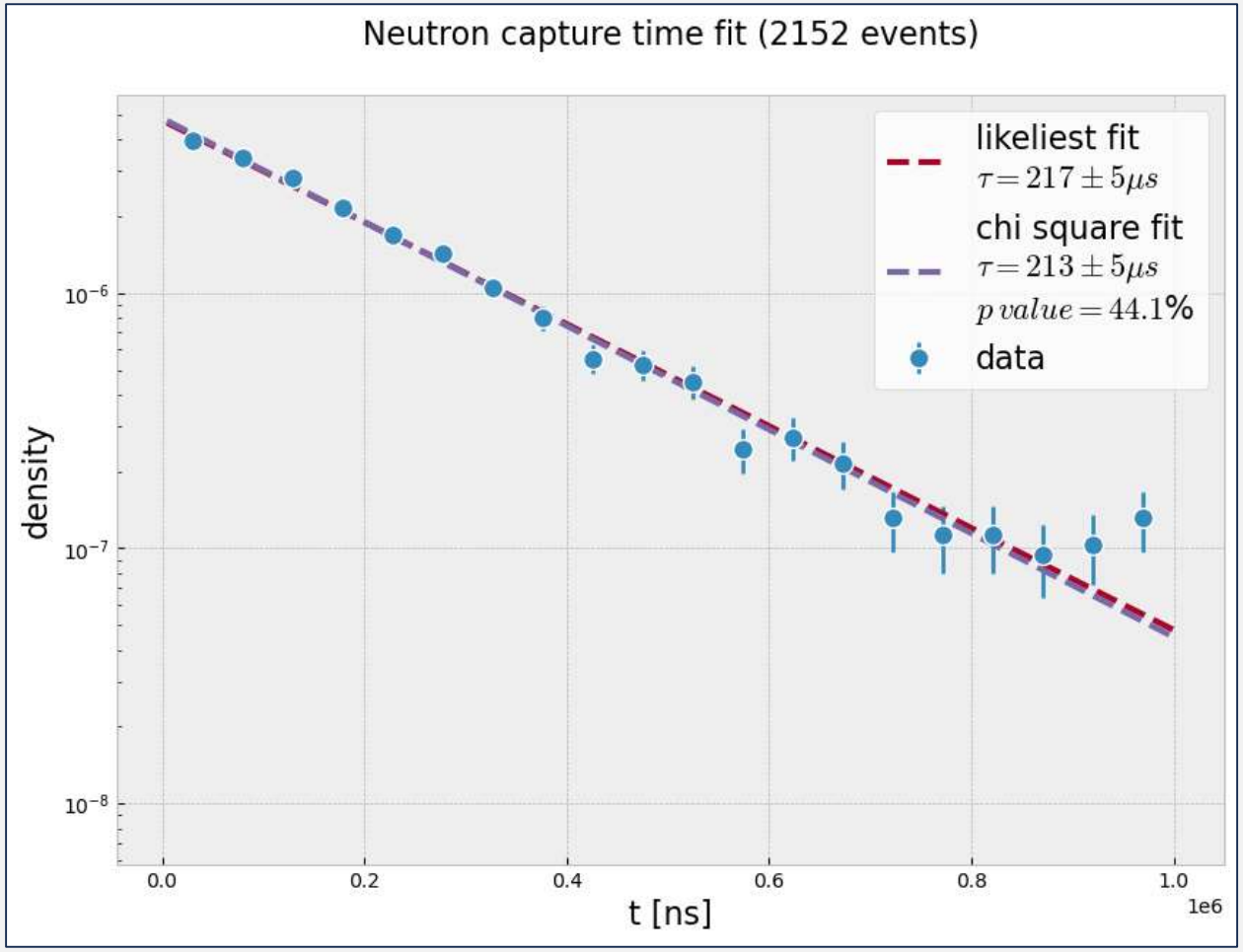
In the 12/11 technote, there are 1928 IBDs for runs 9789 to 10698, with 46.05 days of running time. Here I find 1609 IBDs with 38.63 days of running time (some runs weren’t analysed). The rate in the technote is thus 41.87 IBDs per day, while mine is 41.65 IBDs per day, which seems compatible.

Energy spectrum

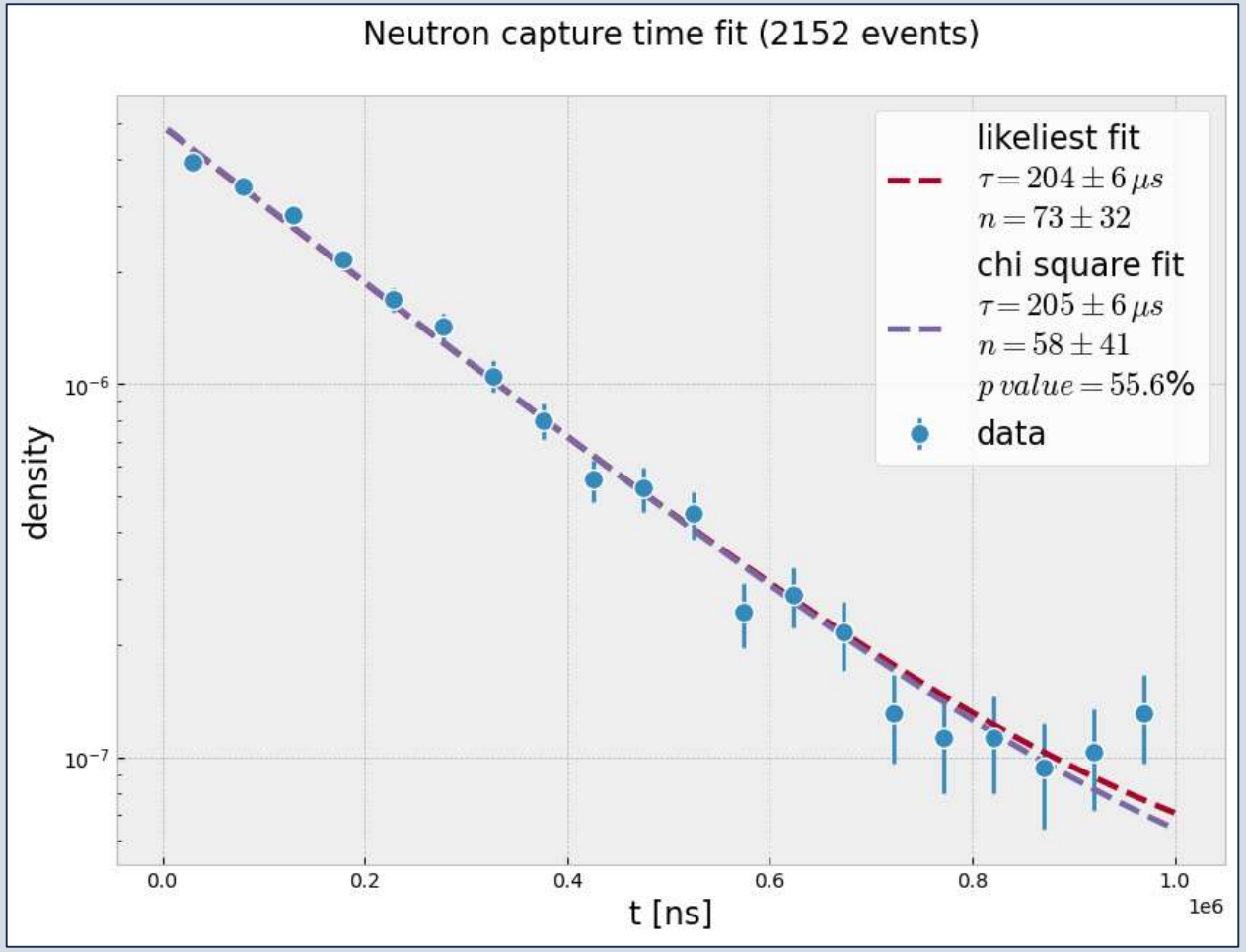


Neutron capture lifetime

1. Exponential distribution

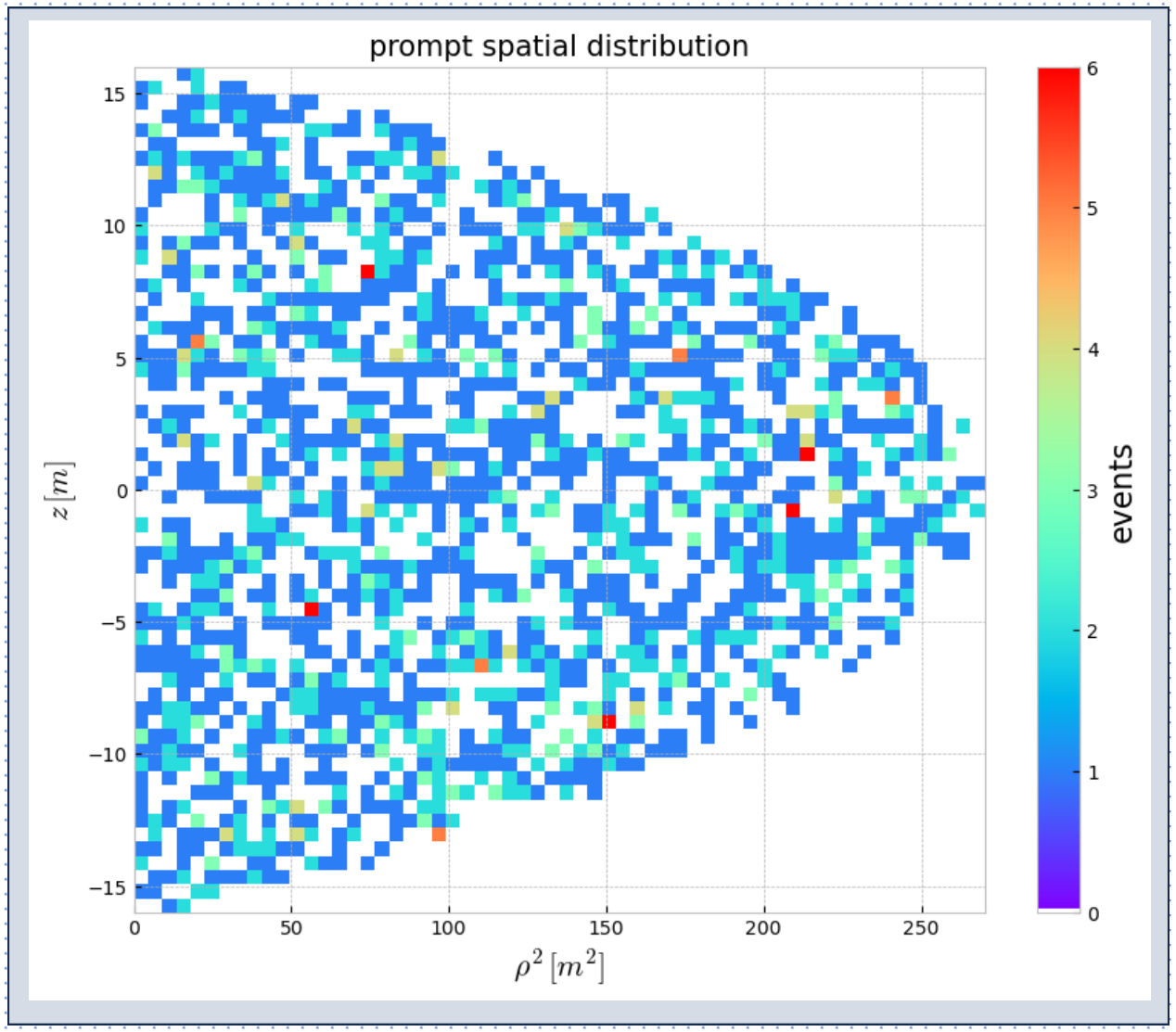


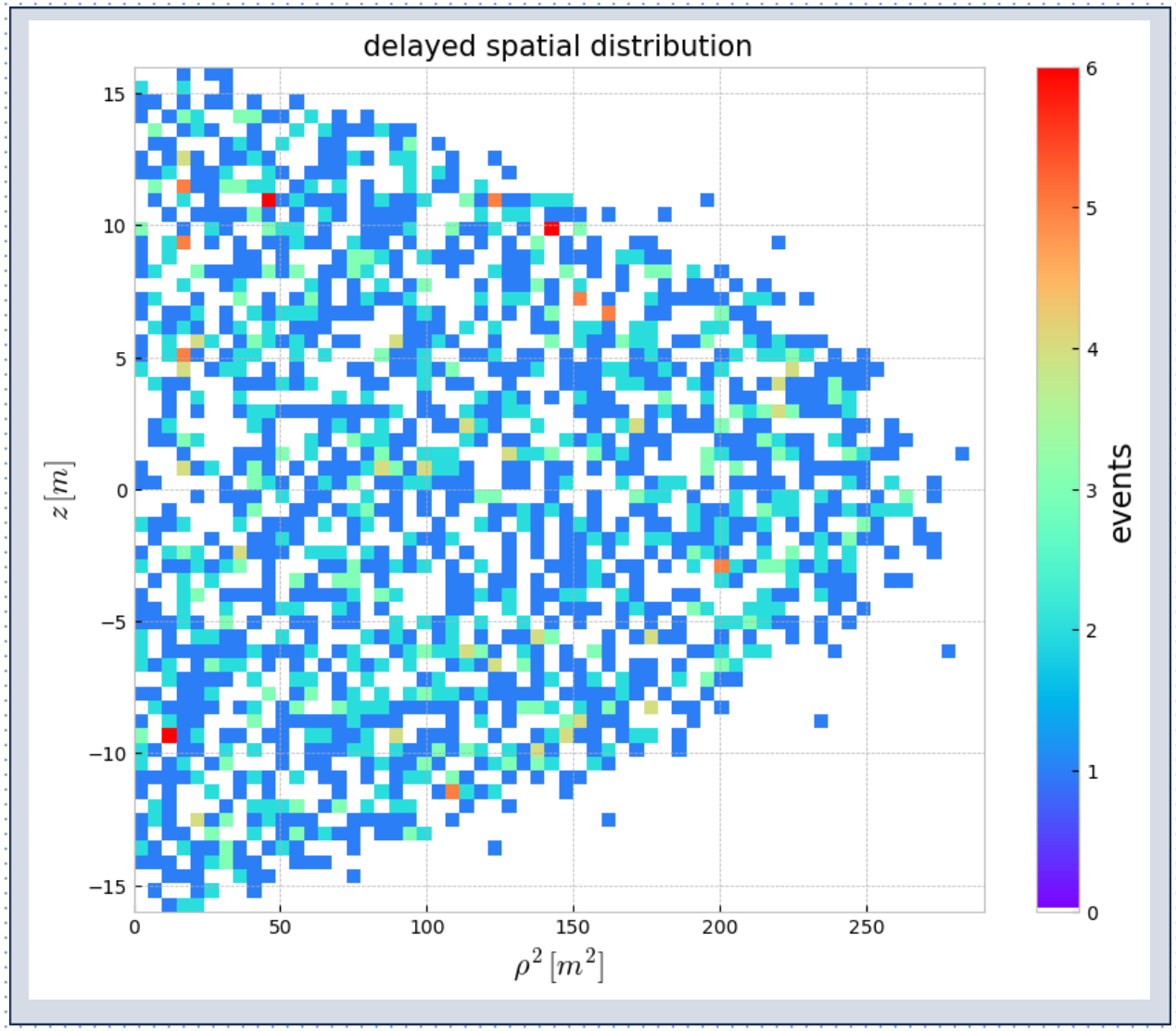
2. Exponential distribution with uniform background



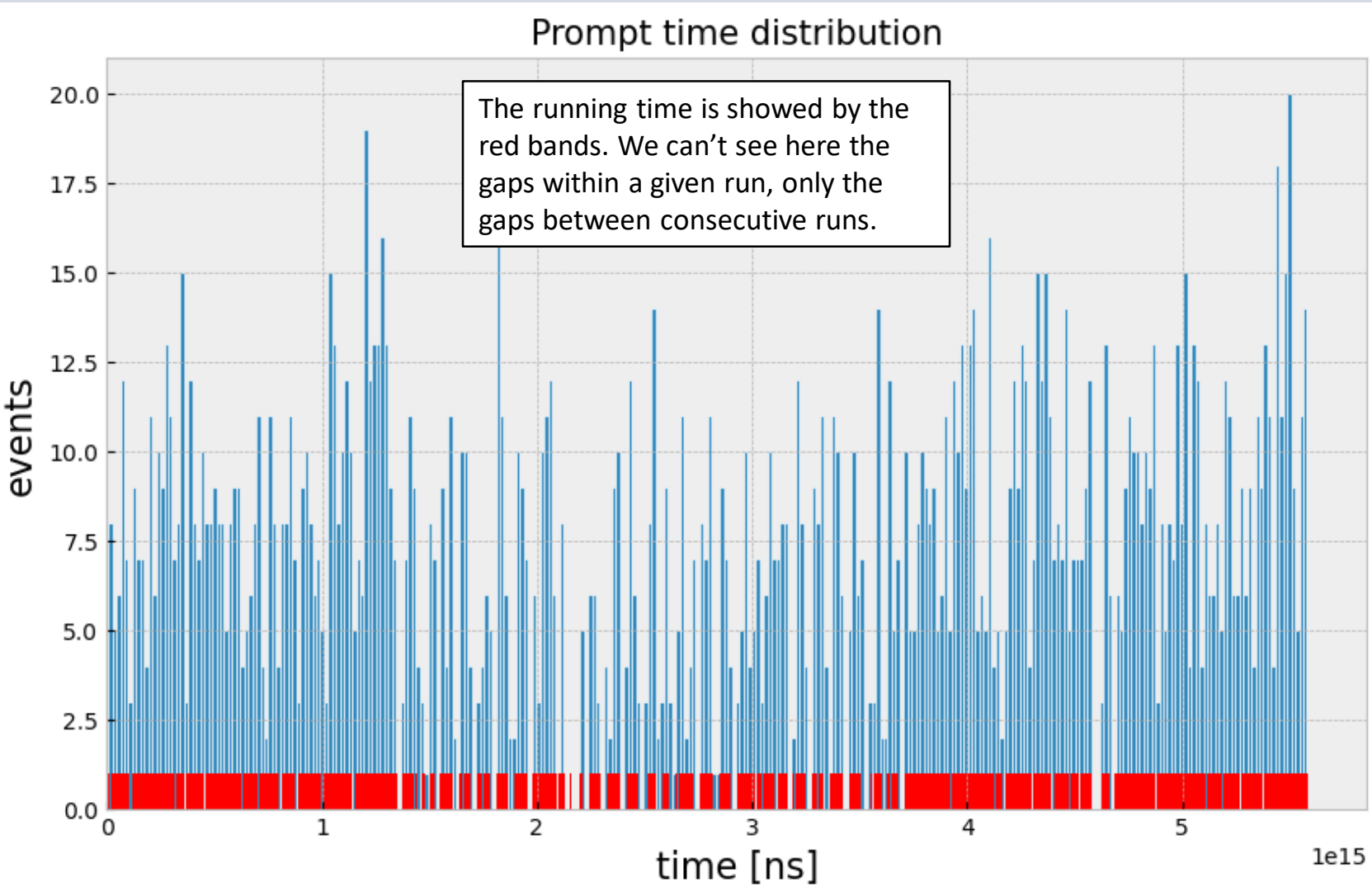
The σ of the noise is comparable to the fit value and the σ of the lifetime increases

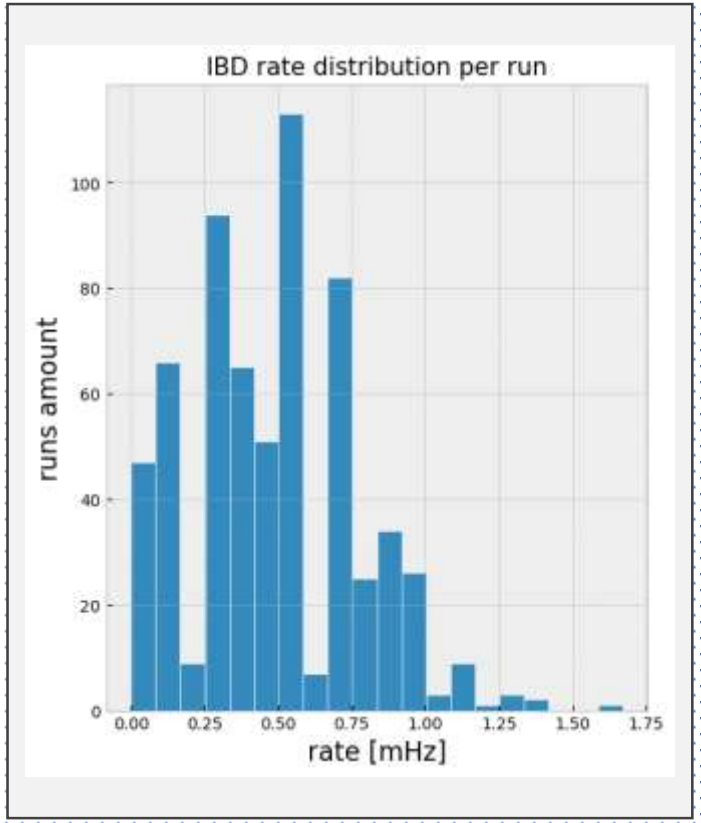
Vertex distribution





Time distribution





Efficiency and next steps

Efficiencies

- FV cut : 80.8 % (geometrical)
- Muon vetoes : 95.49 % (from $\varepsilon \approx \exp(-\Delta t_{veto} \cdot R_{\mu})$)
- Δt cut : 96.75 % (from the simple neutron capture lifetime fit)

Calculating the efficiency for the remaining cuts requires simulated data or other informations.

Next steps

- Redo the analysis with the same cuts as in the publication ?