PDS designs and SN triggering

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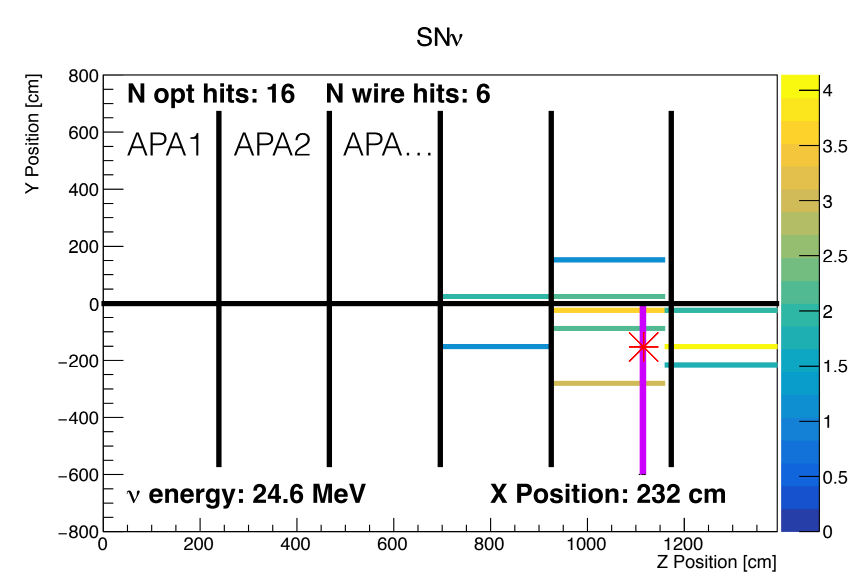
Introduction / Content

- Many PDS systems around…
  - Ganging, noise, ARAPUCA, reflective foils…
  - Test what can be done with each of them and have an idea of what background they produce.
- Ran the SN clustering under different assumptions for the PDS system:
- The first letters are there to compare the designs:
  - DEF → default
  - EFF → only efficiency changes
  - NSE → only noise changes
  - REF → only reflection changes
  - SNR → only S/N changes
- Note: The MCC11-PDS production request has ~20s live-time in a 10 kT module:
  - Below 0.5Hz, background rate is statistically limited.
  - We use background extrapolation to overcome this problem…
- Right now the PDS in MC is not the same as the proposed design:
  - More segmented detector in Y.
  - 1x2x6 used in simulation: a lot of photons actually “escape” the smaller geometry…
  - That’s because it’s hard to come up with efficient and fast simulations that don’t eat up all the RAM on the GPVMs.

Vary one at a time

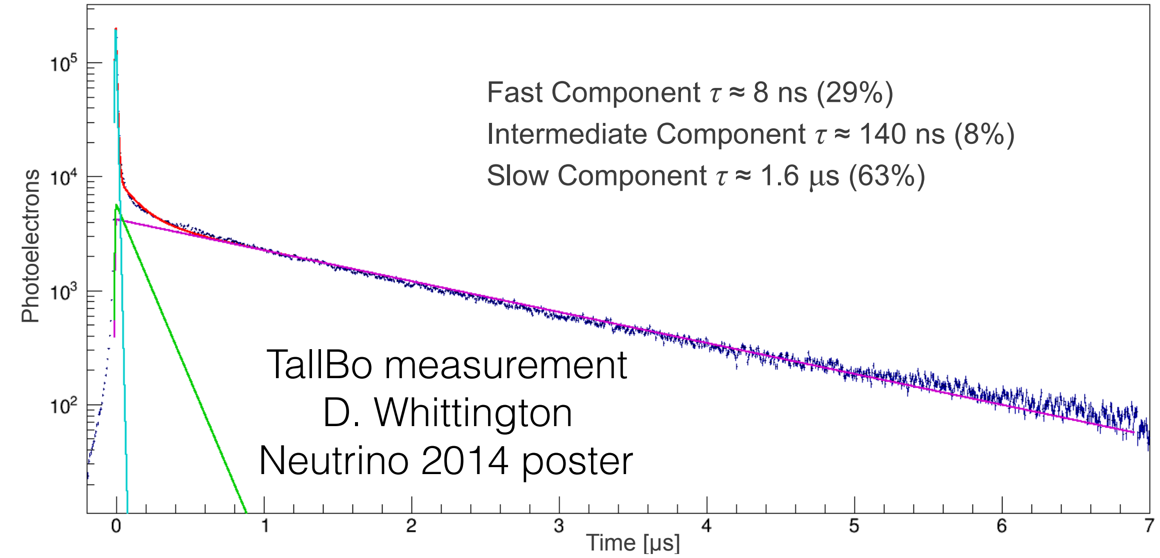
	Light Yield	Dark Rate/ channel	Signal to Noise Ratio	Reflections
	$60\ cm^2$	10 Hz	7	Optimistic
Default Values →	**$45\ cm^2$**	**100 Hz**	**5**	**None**
	$30\ cm^2$	300 Hz	4	Pessimistic
	$15\ cm^2$	1000 Hz	3	
Previous MC Assumptions	$4\ cm^2$	Per channel, not SiPM	1 PE Peak/ Noise RMS	

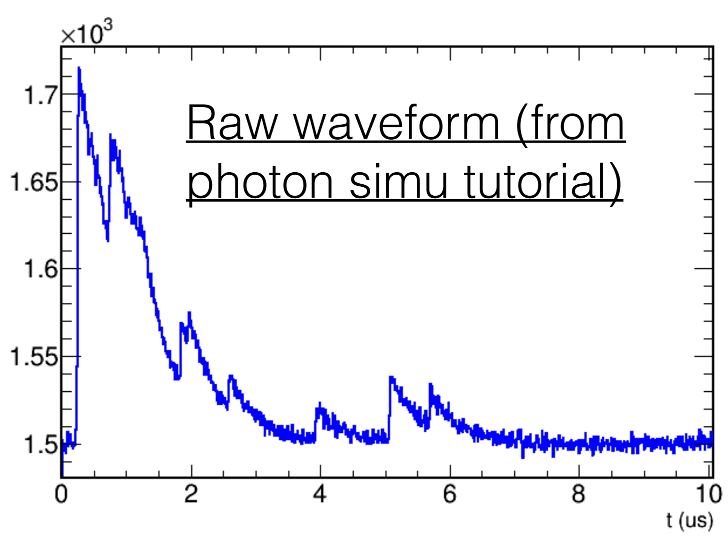
A. Himmel: https://indico.fnal.gov/event/17988/contribution/4/material/slides/0.pdf



Clustering step

- Ran over ~800 files' OpHit for all the PDS configurations (essentially same events/files for all the configurations) → 80,000 events.
  - Z clustering (tolerance = 1APA)
  - T clustering (tolerance = 0.2 μs) ← This is the minimum (or close to the minimum) we trust in the simulations!
  - Bucketing (= max size of clusters = 1 μs)
- No much "tuning" can be done, except for time (this is in fact a fairly simple algorithm).
- Files of very different sizes and very different time for clustering.
- Selecting the clusters with the number of PE.



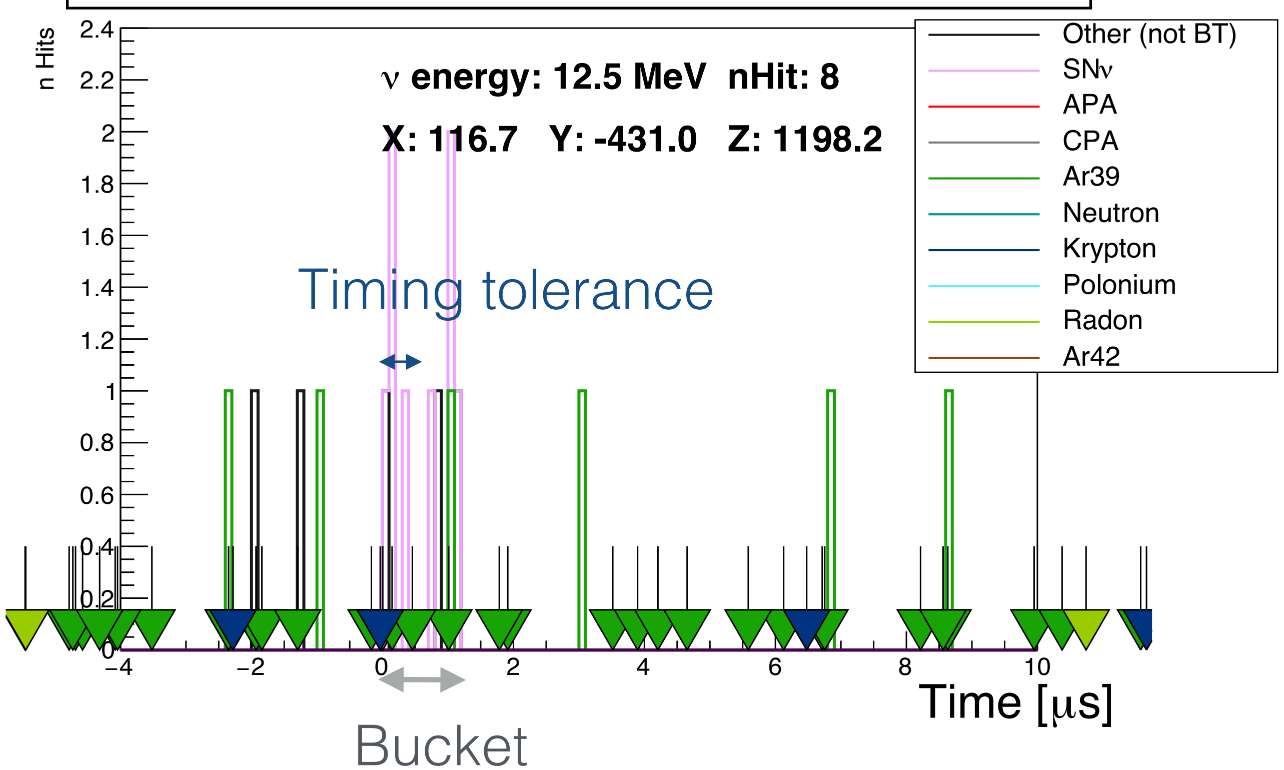


OpHit:

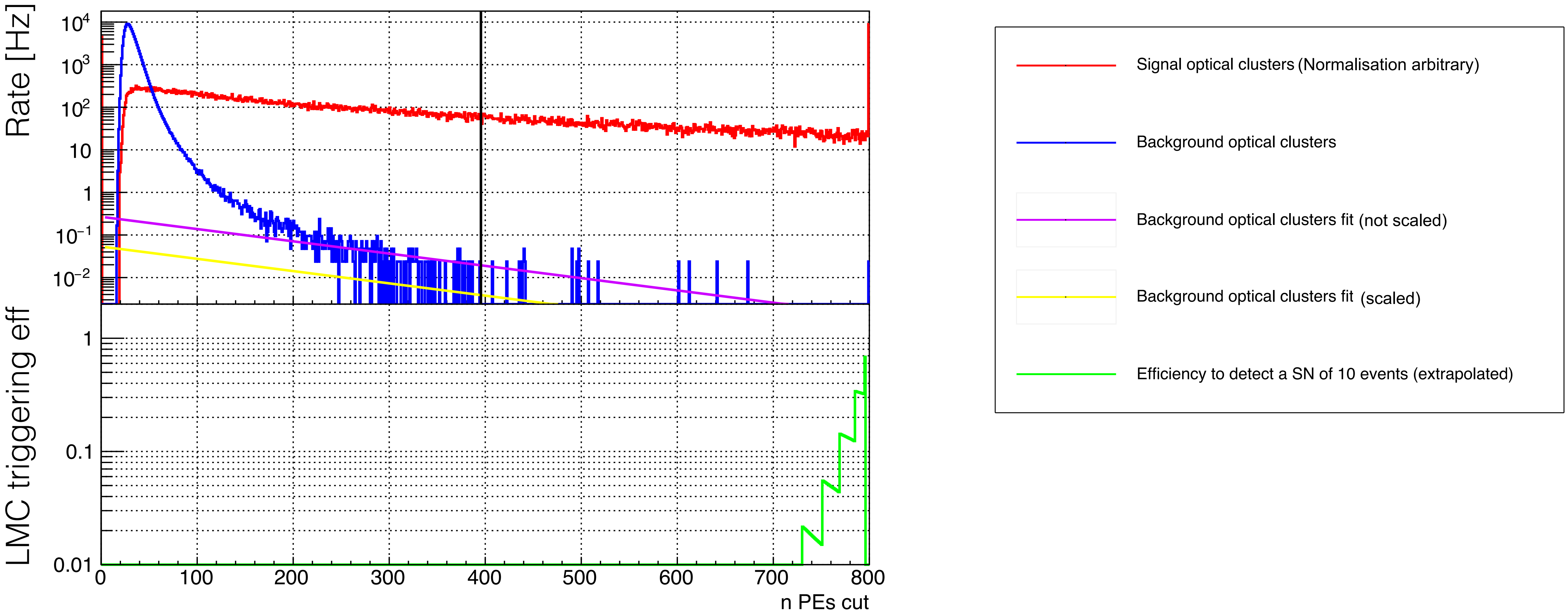
int	OpChannel () const ←
double	PeakTimeAbs () const
double	PeakTime () const ←
unsigned short	Frame () const
double	Width () const
double	Area () const
double	Amplitude () const
double	PE () const ←
double	FastToTotal () const

Histograms: optical hits

↓ True interaction in the detector



An example of the extrapolation

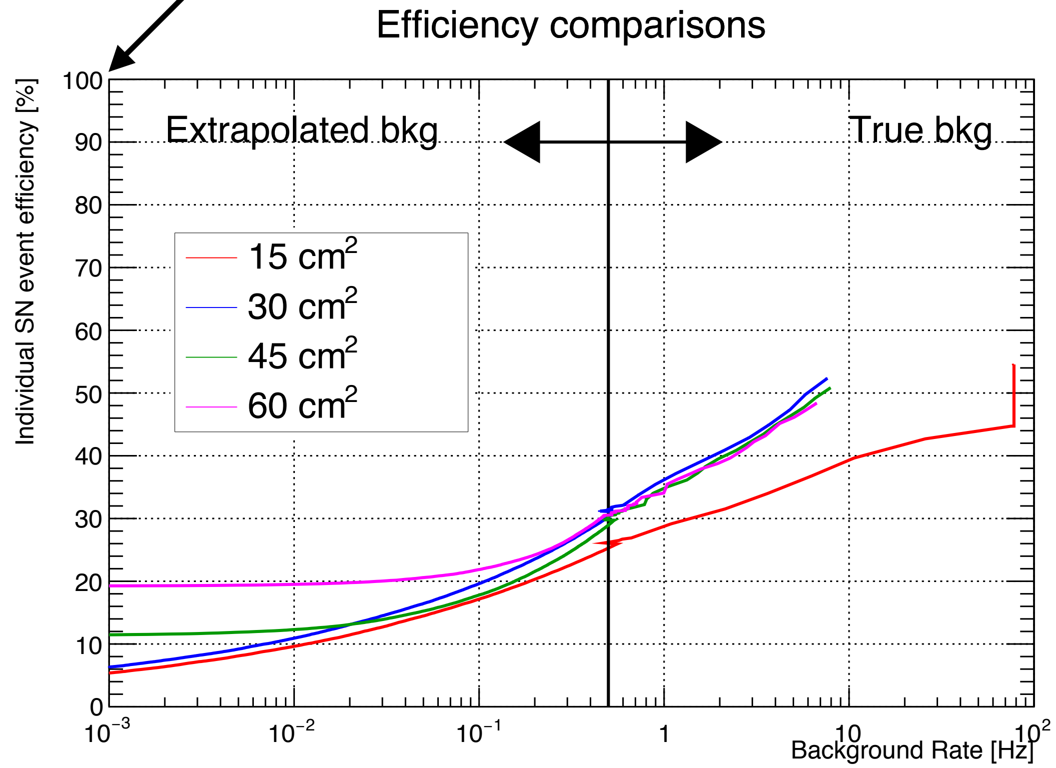


- Default configuration (45cm^2, 100Hz noise, S/N = 5, no reflections)
  - Problem: LMC efficiency is max when the algorithm becomes background-free (very low efficiency and SN triggering threshold at 1)
  - Relying a lot on the extrapolation.
  - Instead, create ROC curves of efficiency vs background rate.

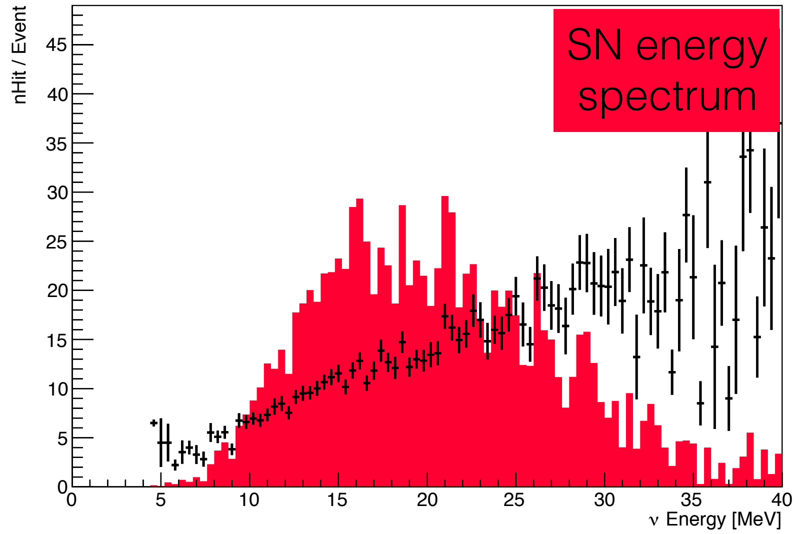
Efficiency comparisons

- Comparing the effects of changing the efficiency of the detector.
- Note, the default PDS design is 10 times more efficient than what was used for previous studies.
- “Averaged efficiency”: missing the energy and distance variables in the MCC11 trees:
  - Very probably the energy threshold gets higher as the background rate decreases.
  - Typical distance of the interaction gets closer to the PDS.
- Without trusting the extrapolation:
  - At constant efficiency, the background rate is much worse in the case of the 15cm².
  - The efficiency and background are the same after 30cm².
- Trusting the extrapolation:
  - The 60cm² is the best.
- Trade-off between background efficiency and signal efficiency.
  - Hard to get rid of the backgrounds in the case of the PDS.

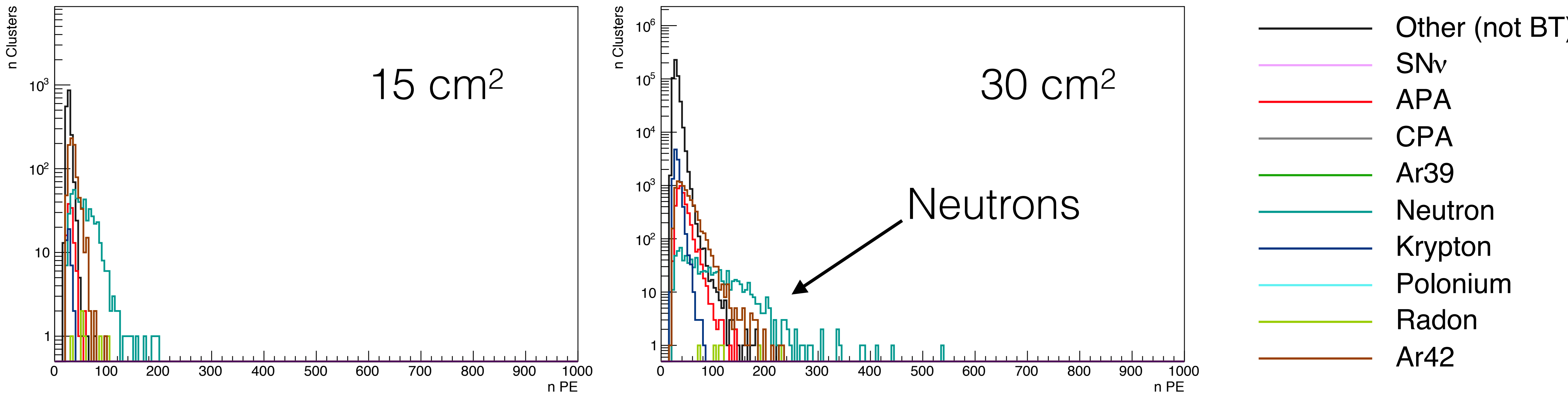
Background free
for a 10s window
(best LMC triggering efficiency)

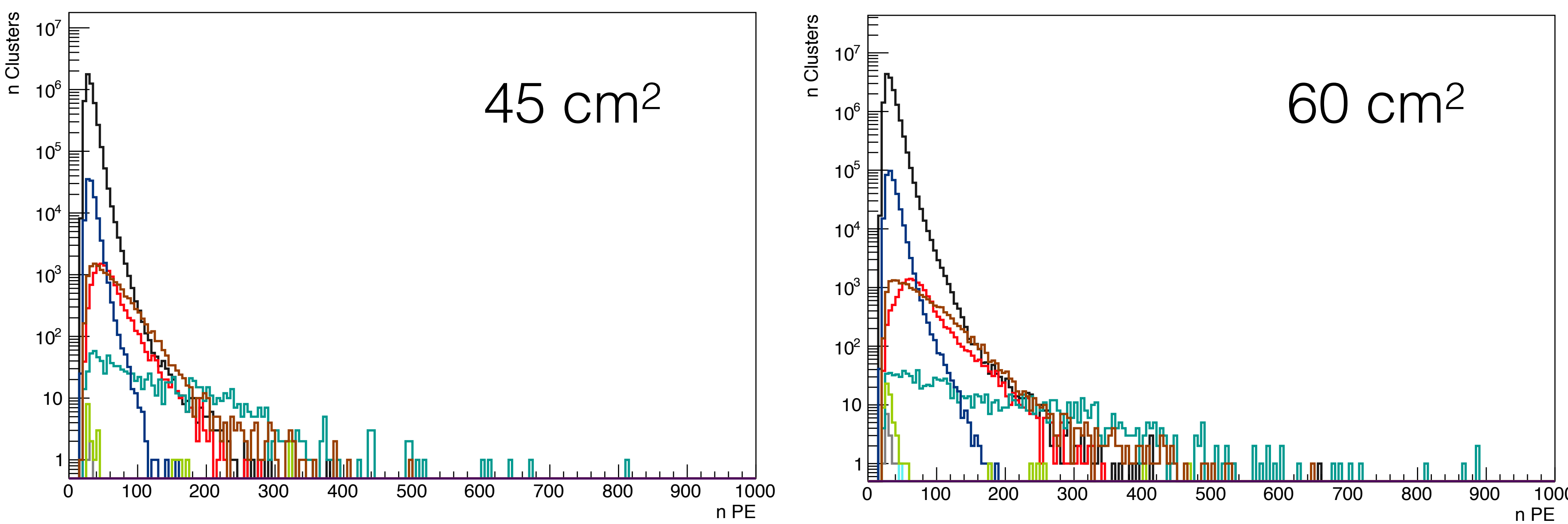


N hit v energy (4cm² case)



Background composition
What are most of the bkg clusters made of?

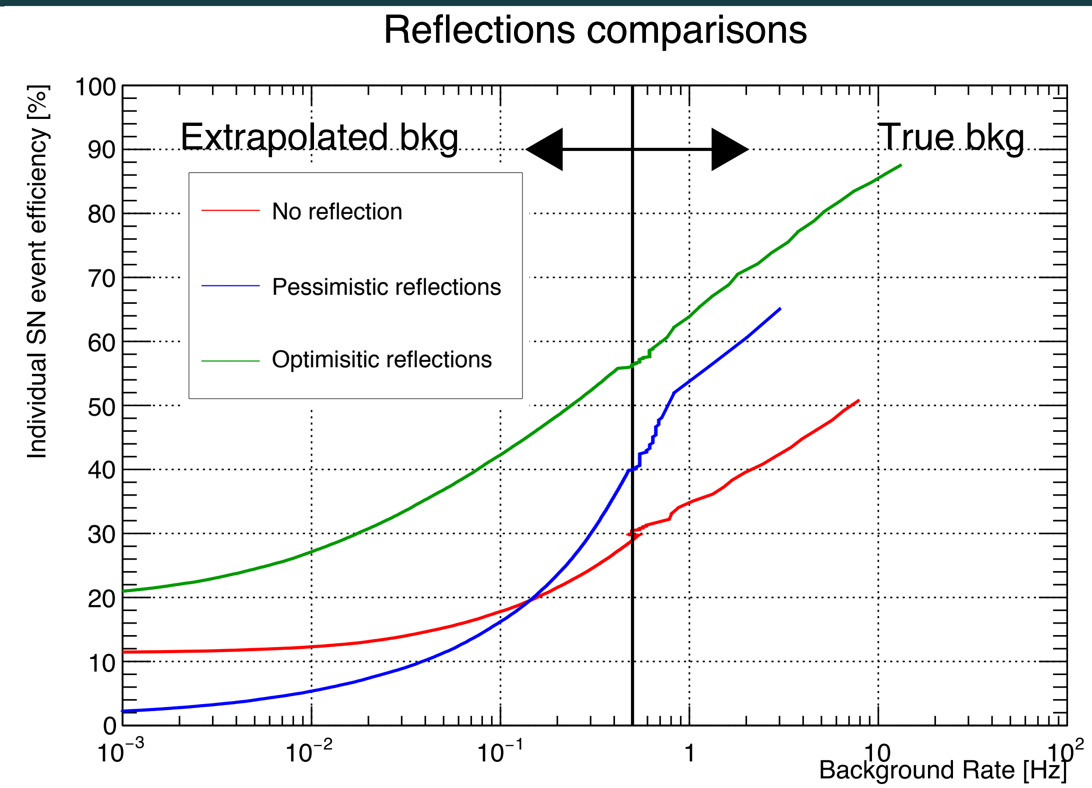




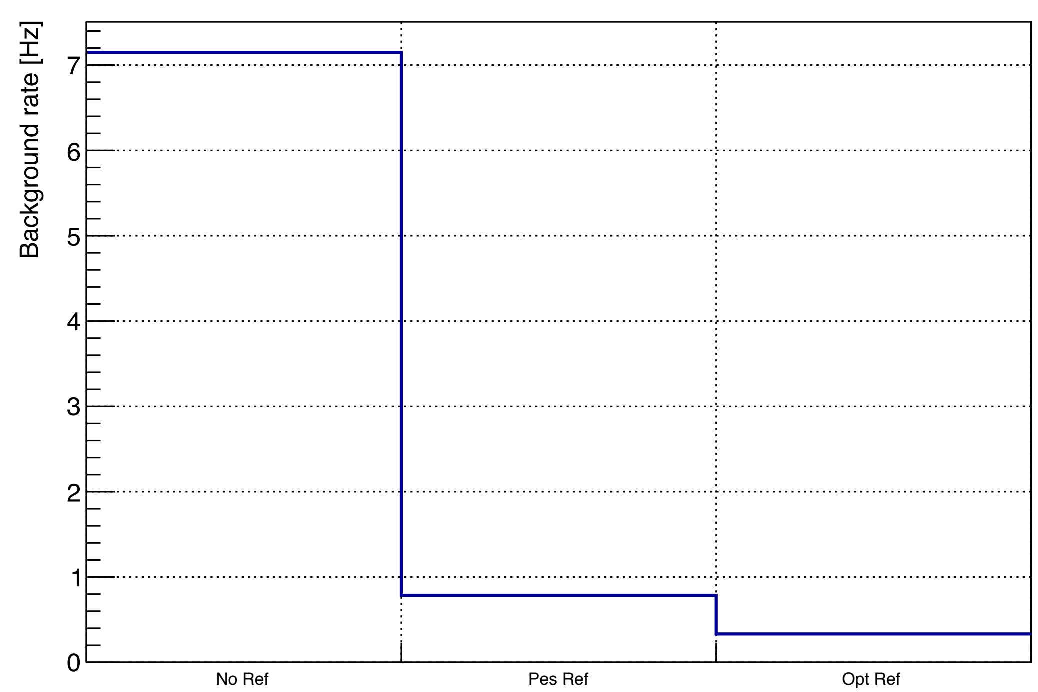
- At low efficiency, the backgrounds are dominated by neutrons.
- At higher efficiency (>45cm²), more backgrounds are present at high PE:
  - n, Ar42, APA & Rd.
  - Noise is also quite high.

Reflection comparisons

- Not entirely sure I trust these:
  - Adding reflection in the 1x2x6 geometry causes clusters to grow very close to the size of the whole geometry.
- Conclusion is simpler:
  - At constant background, the more reflections there is, the better it is.
  - Long tail of the pessimistic reflections creates the inversion at low background rates (kink at ~1Hz of the blue curve).

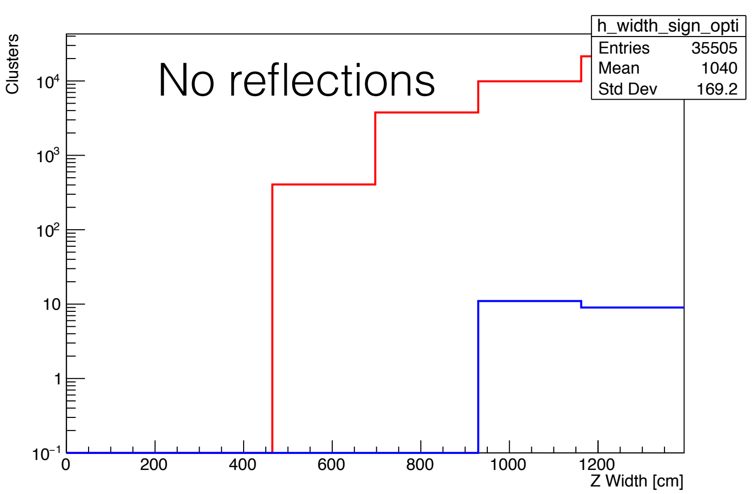


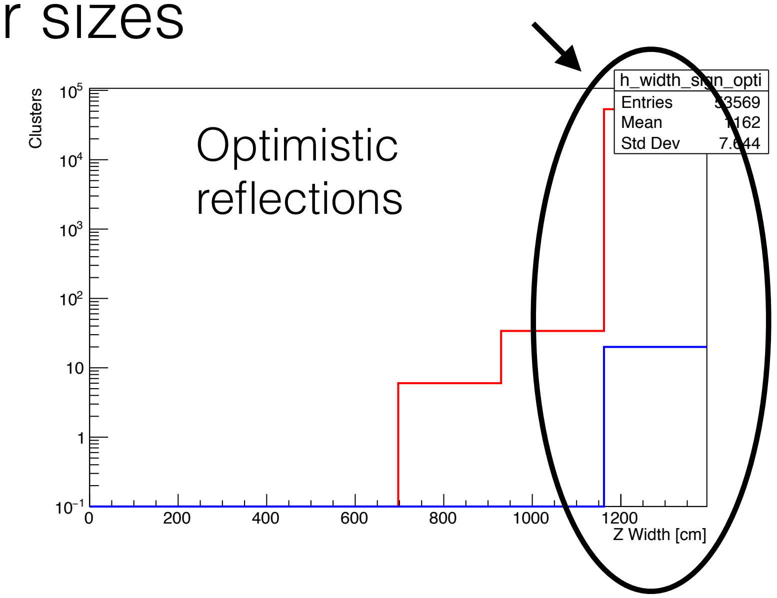
Background rate at 50% efficiency



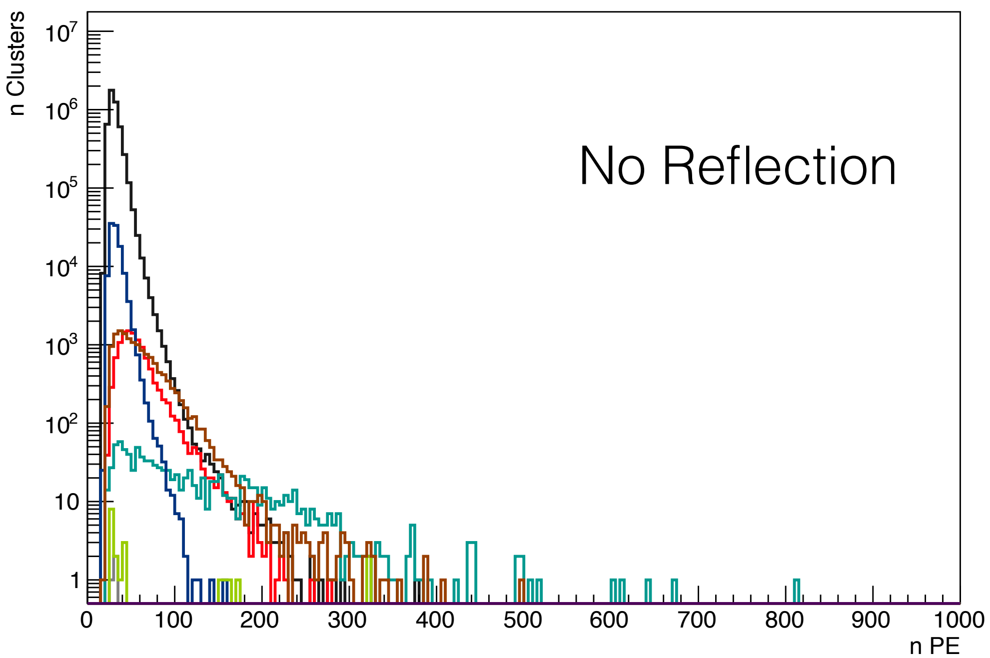
Cluster sizes

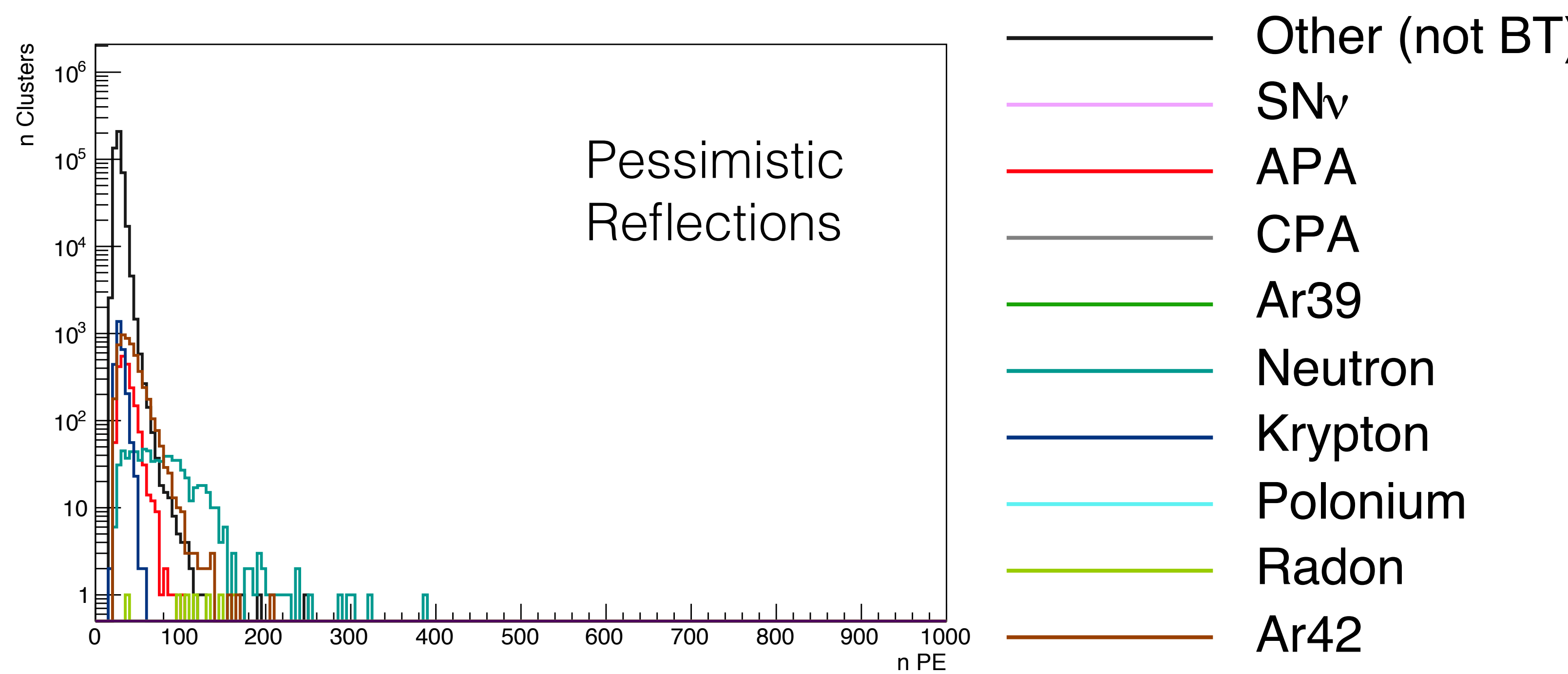
Size of the 1x2x6!

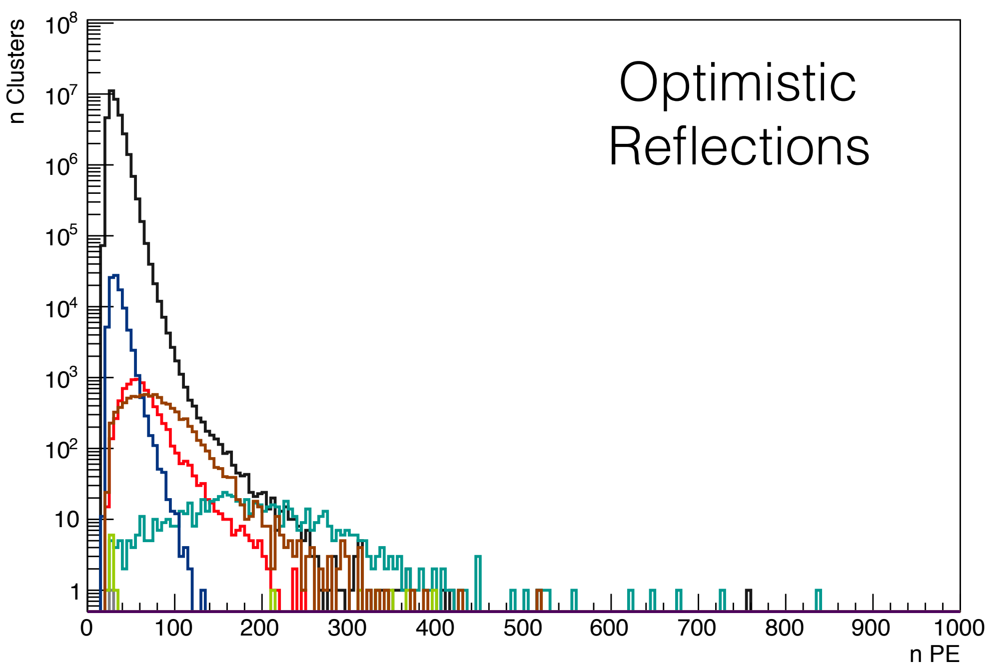




Background composition
What are most of the bkg clusters made of?

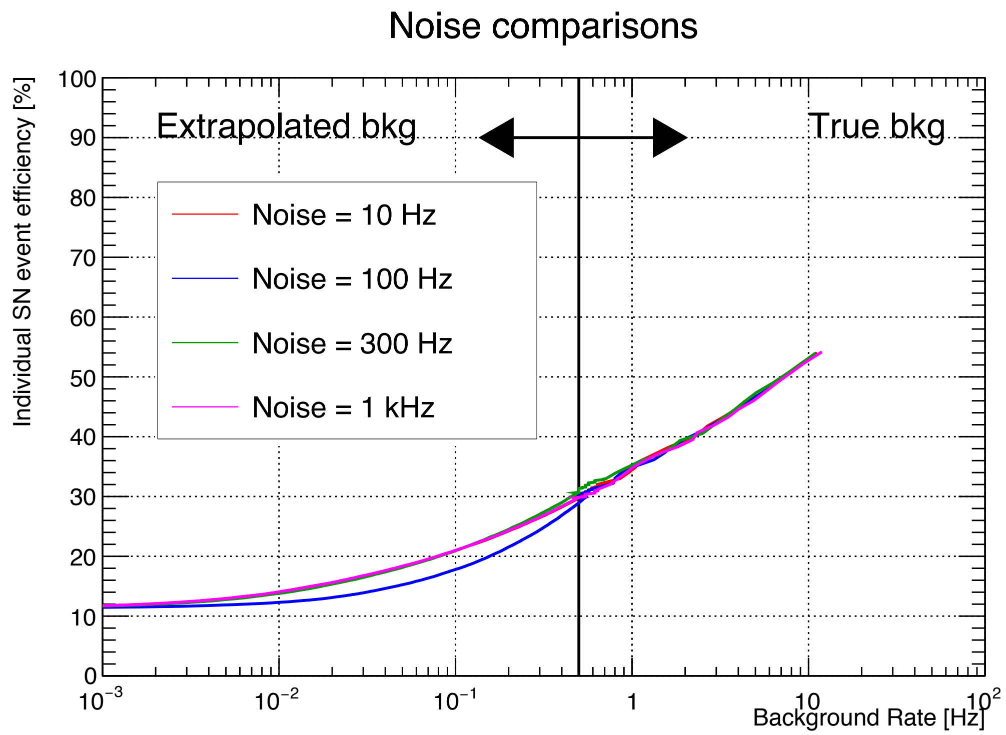


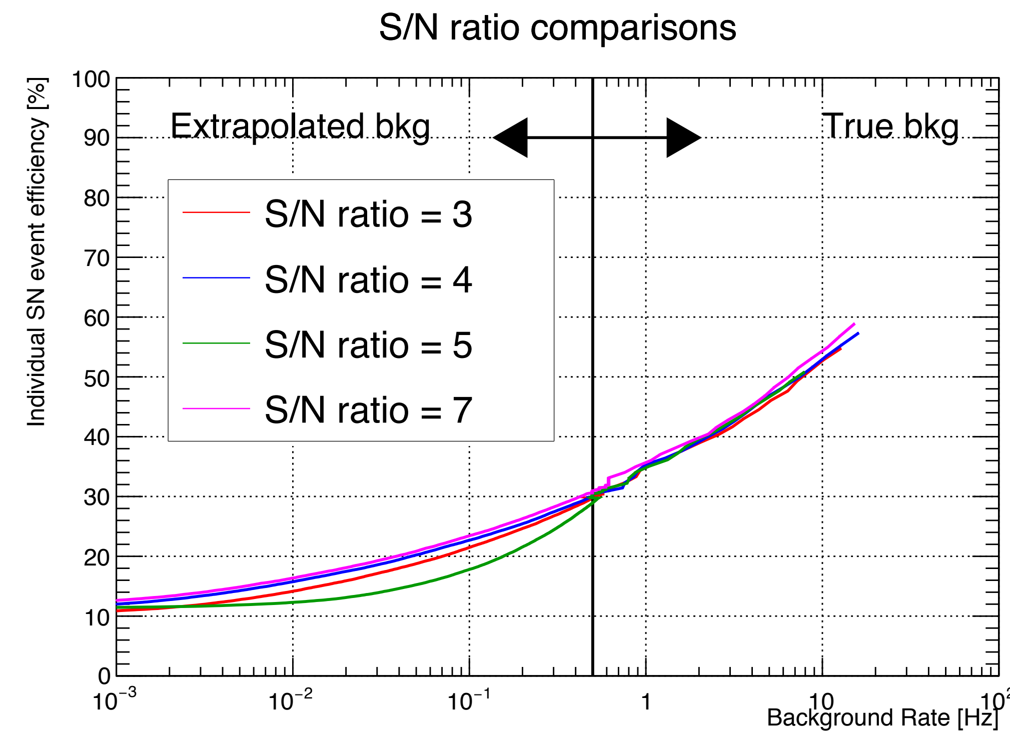




- Again, only neutrons optical cluster survive at high PE (pessimistic reflections)
- Optimistic reflection gets quite a lot of events from Ar42 at high PE.

Noise and S/N comparisons





- Left plot shows that increasing the noise by 3 order of magnitude does not change the SN sensitivity. The cluster all have very low PE and would get cut away anyway to remove the radiological backgrounds.
- Similarly, S/N doesn't matter much.

Conclusion / Future work

- Increasing the efficiency of the PDS system also increases by similar amount the background efficiency after 30cm^2.
- Increasing the reflections in the detector can help us recover some of the missing events and thus get a much better efficiency at constant background.
- The noise and S/N ratio don’t change the sensitivity to SN.
- SN sensitivity curves are without extrapolation.
- Thinking to use a more “integrated” version of the PDS information with the TPC:
    - Shown at the background TF meeting at CM that PDS can also be used online to reconstruct the x-coordinates (online!)
    - Combining the information of the PDS and TPC, do calorimetry.
    - Only uses 1APA information.
    - Only time clustering and PE selection (i.e. very fast).