

QUEST-DMC ND3 simulation

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**QUEST-DMC Joint
WP1/WP2 Meeting**
16 October, 2025



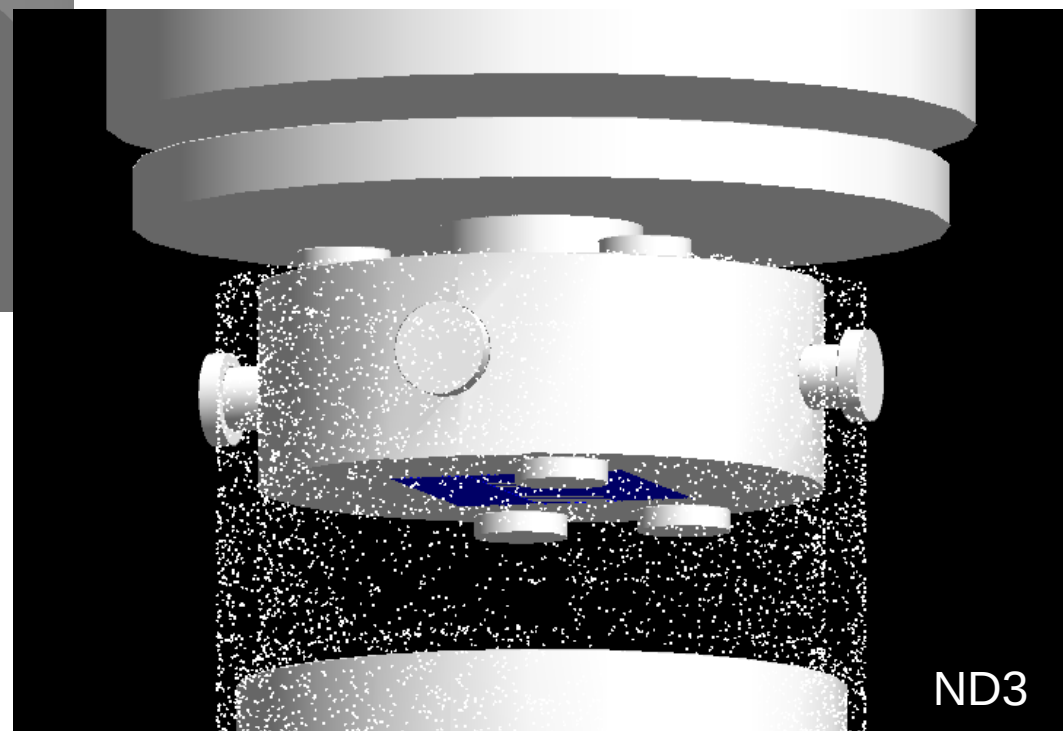
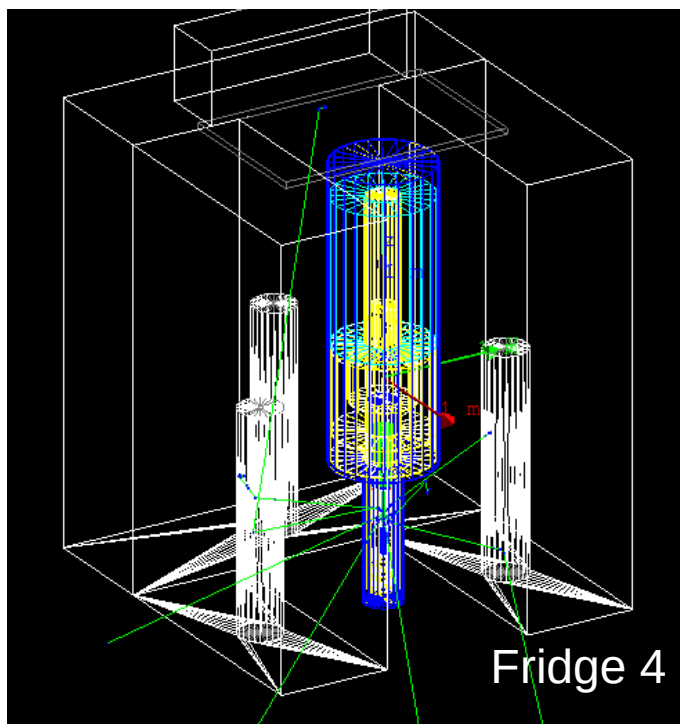
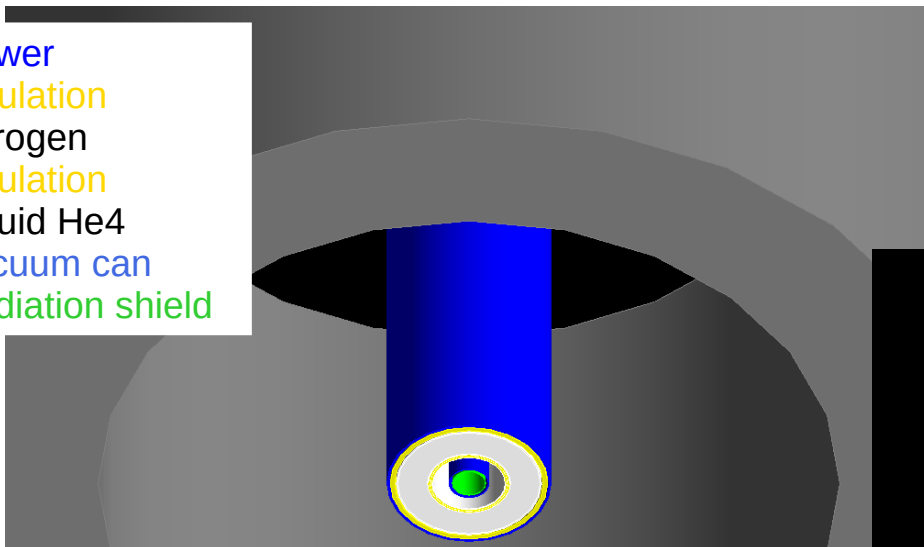
Introduction



- Main goal: **simulate a realistic response of our bolometers**
- Produce a signal trace: frequency variation vs time
 - Use the MC components from the Geant4 simulation
 - Use the real noise from the data acquisition
- To be used as input of the data analysis code and for systematic studies

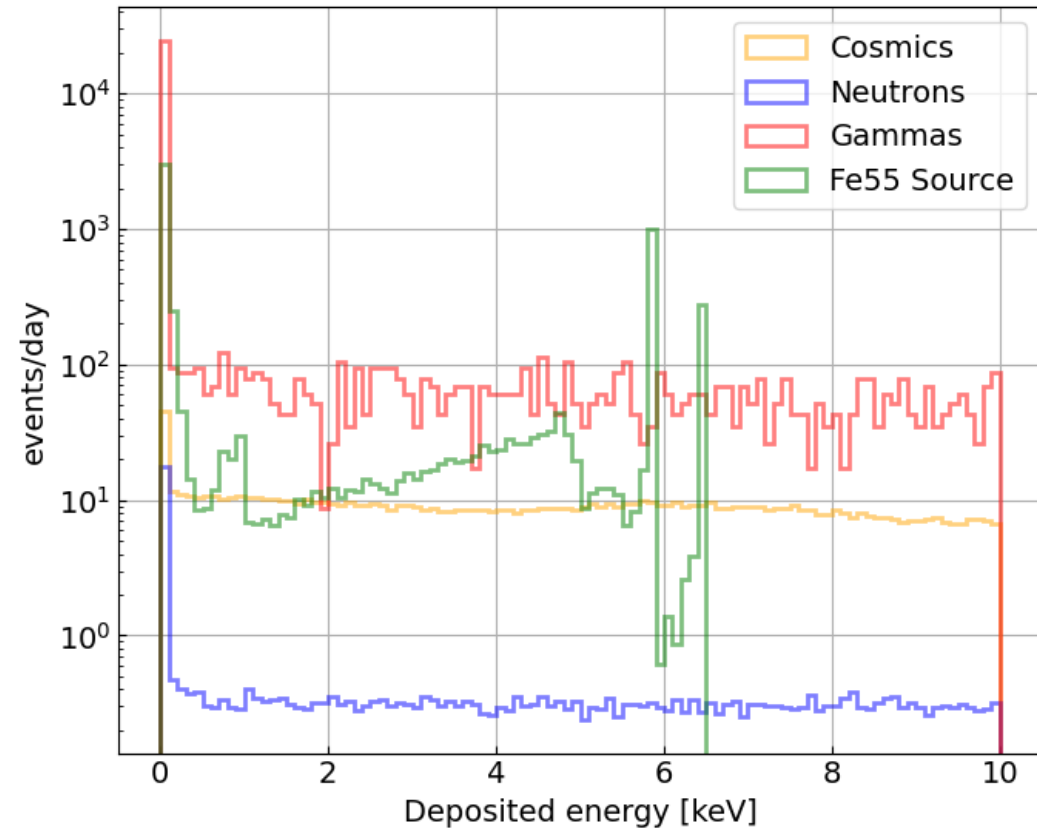
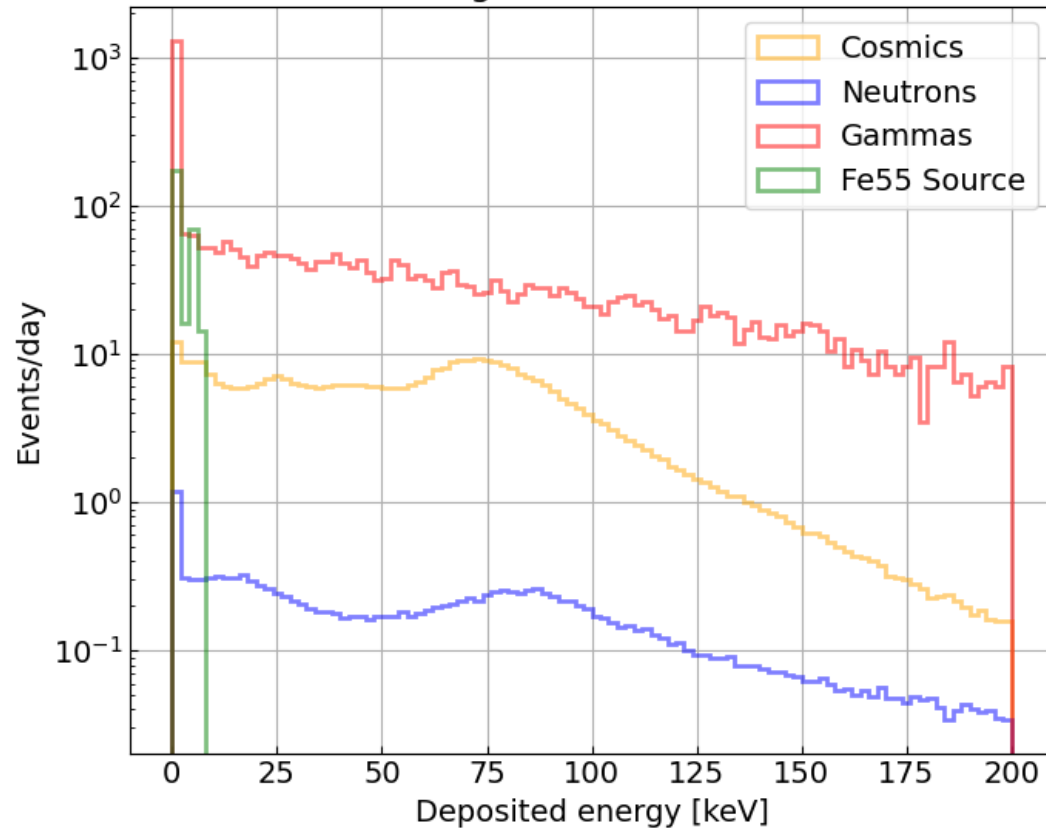
Geant4 models of fridges

- Dewar
- Insulation
- Nitrogen
- Insulation
- Liquid He4
- Vacuum can
- Radiation shield



Background simulation from Geant

Background Simulation



Expected deposited rate [events/day]

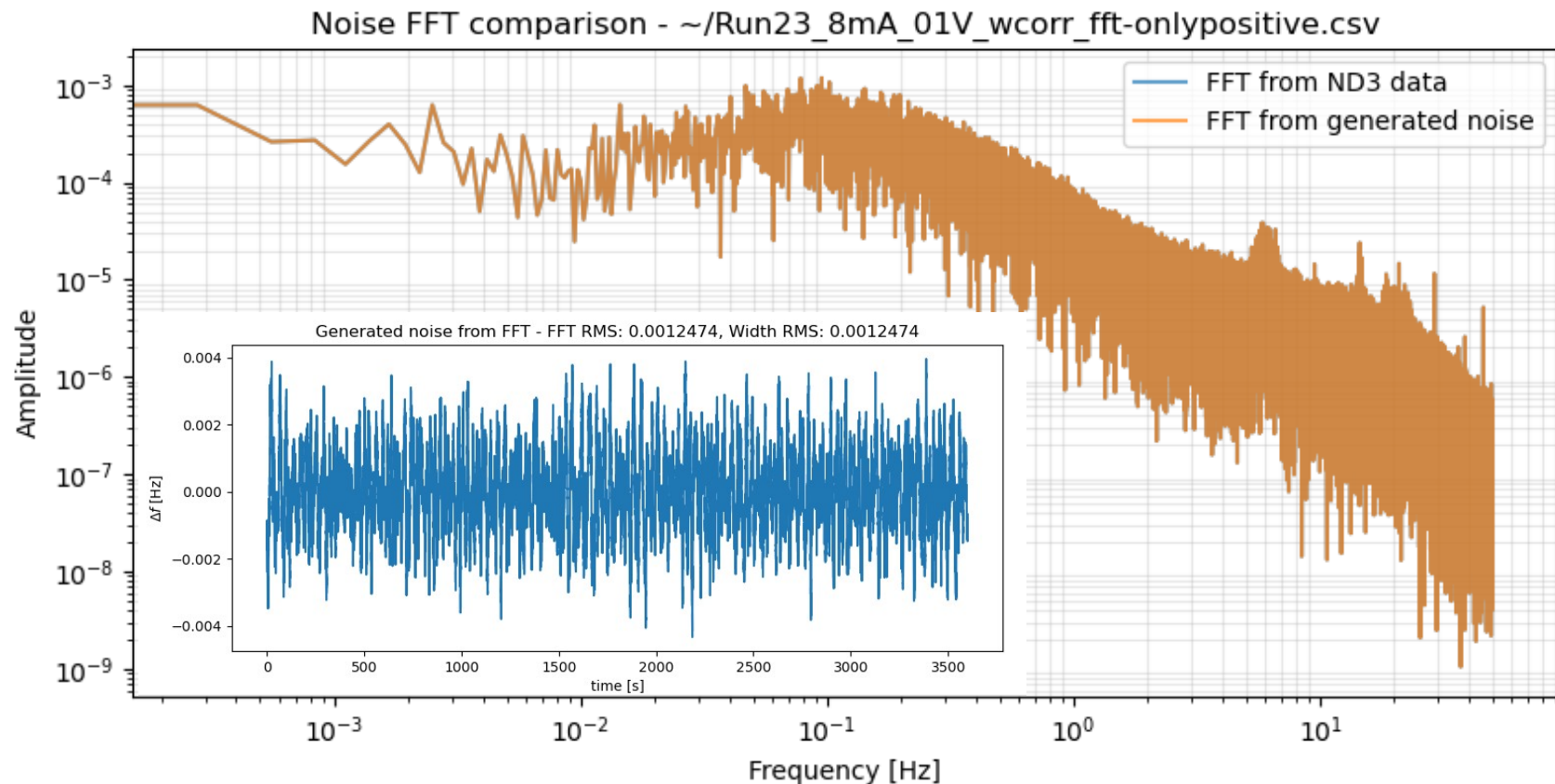
- Cosmics: 800
- Neutrons: 40
- Gammas: 7959
- Fe55 source: 546

+ radiogenic (in progress)

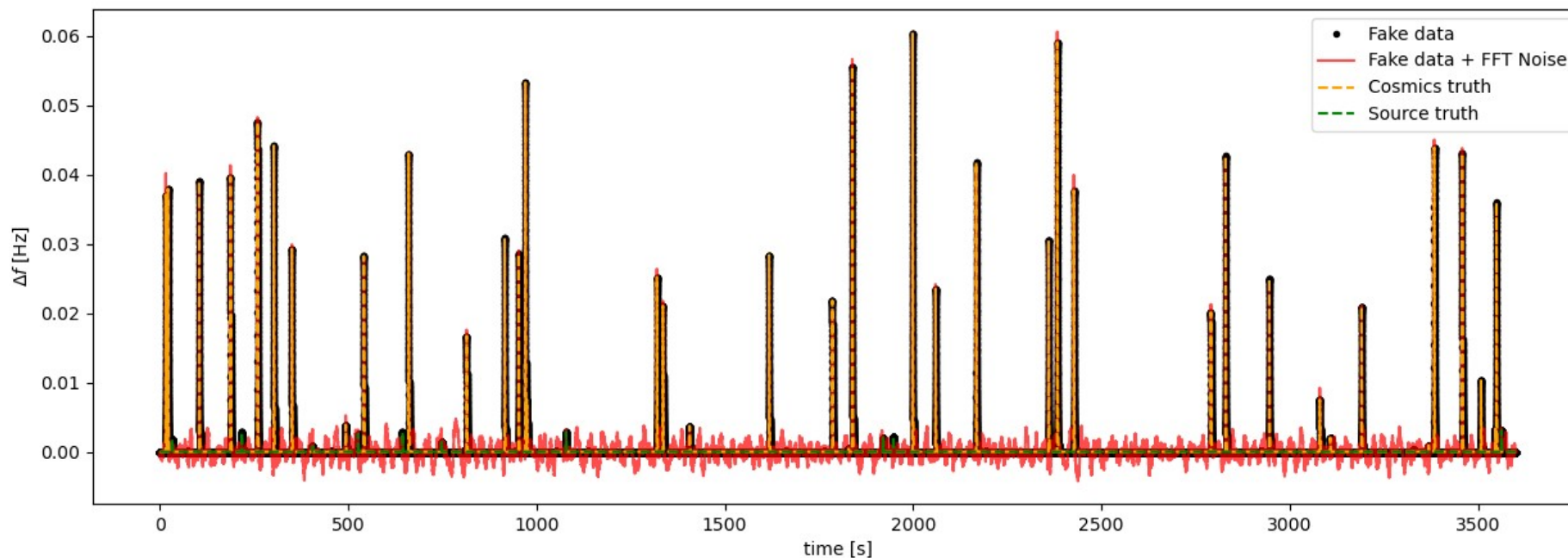
Adding real noise from FFT

FFT from “quite” reconstructed ND3 data, after

- non-linear correction
- STL decomposition

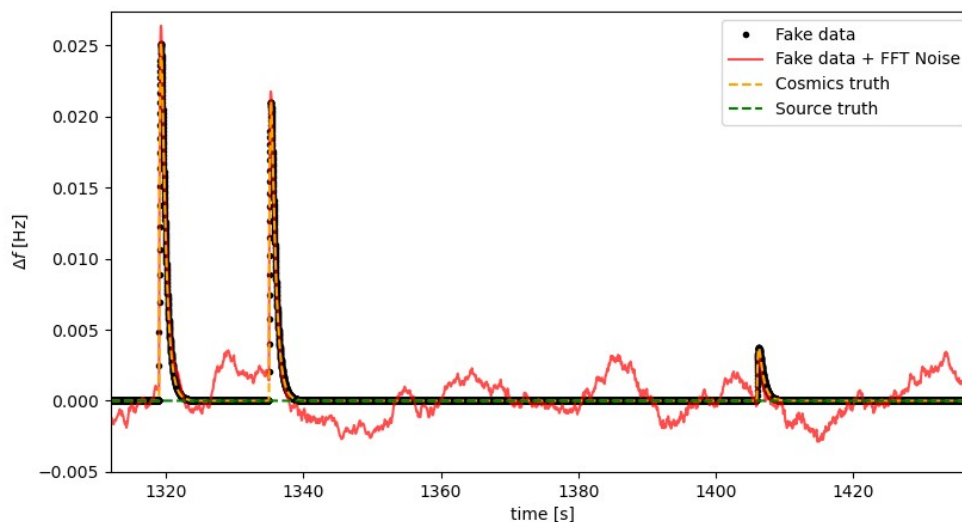


Fake data with noise



Generate a randomised train of “Winkelmann pulses” given the

- rate, and
- *energy to width variation* conversion



MC Truth values

TRUTH: finite number of injected pulses

```
>>> df_truth
```

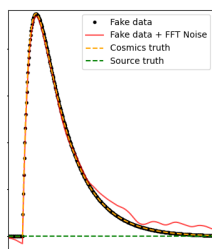
	id	start	energy	description
0	0	67	60650.0	Cosmics
1	1	122	3950.0	Cosmics
2	2	180	66050.0	Cosmics
3	3	265	147550.0	Cosmics
4	4	479	8250.0	Cosmics
..	...	...	...	...
543	543	35352	50.0	Source
544	544	35421	50.0	Source
545	545	35513	5850.0	Source
546	546	35664	150.0	Source
547	547	35801	50.0	Source

TOY: full time trace

```
>>> df_total[df_total['id']==546]
```

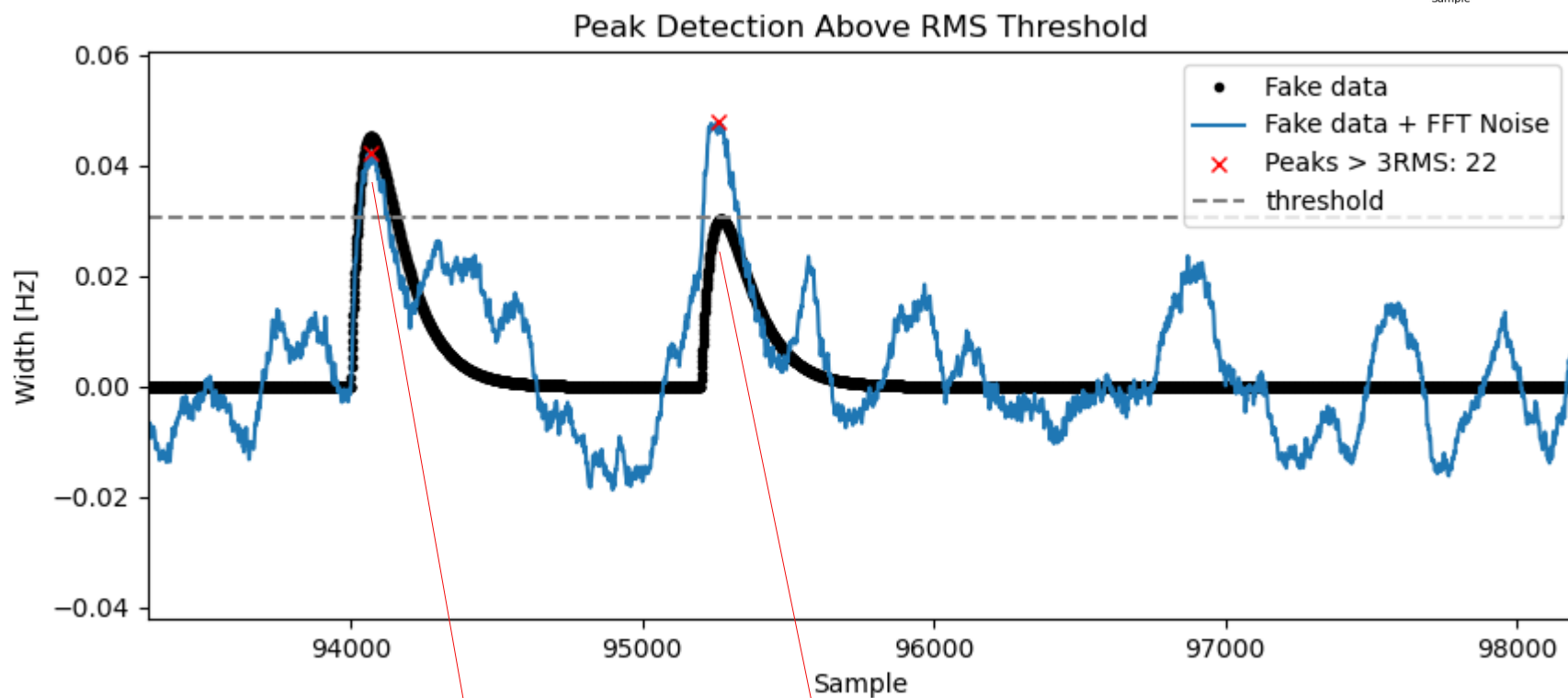
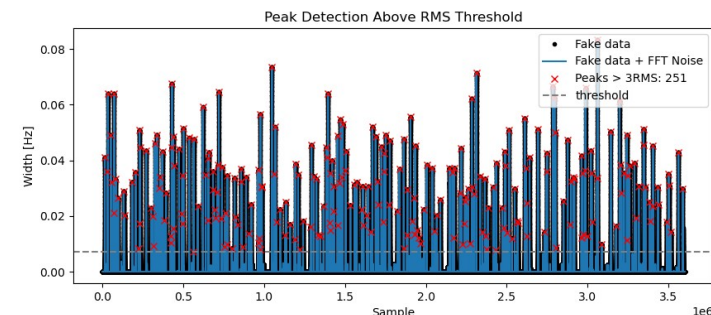
	time	width	energy	id
3566401	35664.01	9.231991e-05	192.944493	546
3566402	35664.02	9.758142e-05	203.940802	546
3566403	35664.03	1.023324e-04	213.870072	546
3566404	35664.04	1.066083e-04	222.806582	546
3566405	35664.05	1.104424e-04	230.819740	546
...	...	...	...	...
3566851	35668.51	1.404781e-07	0.293593	546
3566852	35668.52	1.383335e-07	0.289111	546
3566853	35668.53	1.362215e-07	0.284697	546
3566854	35668.54	1.341419e-07	0.280350	546
3566855	35668.55	1.320939e-07	0.276070	546

for $t = n \cdot t_b$ assigns the truth ID
to the peak



Dummy peak finding

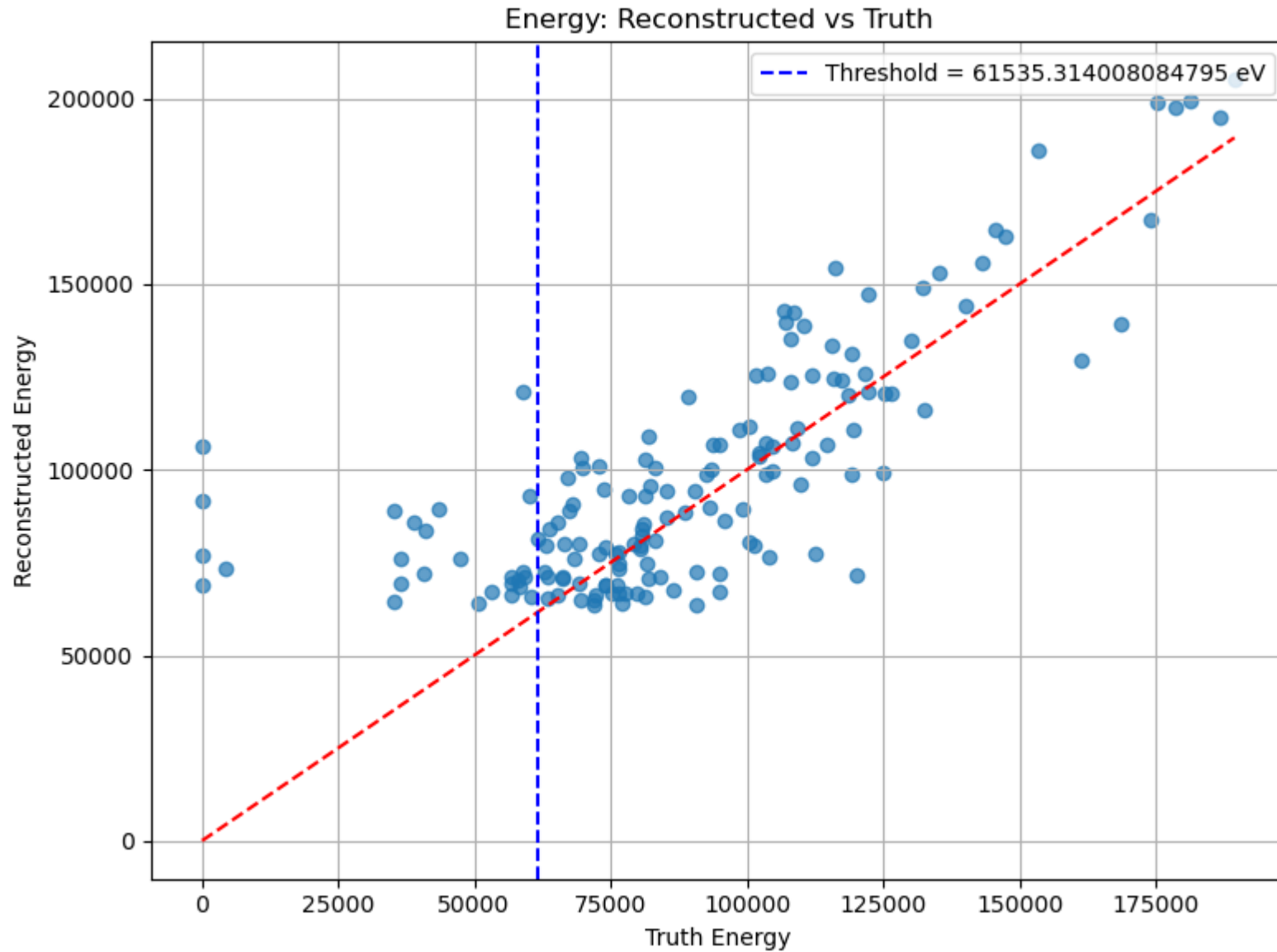
- Reconstructed **time** and **width** (energy)



Truth
ID#7

Truth
ID#12

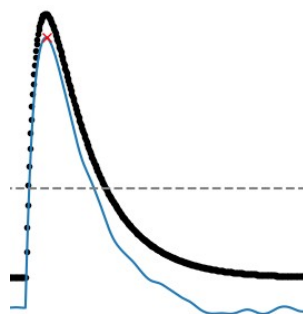
Reco vs truth



Metrics for analysis

- **True positives:**

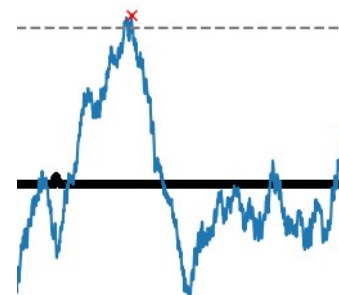
- energy resolution
- time resolution



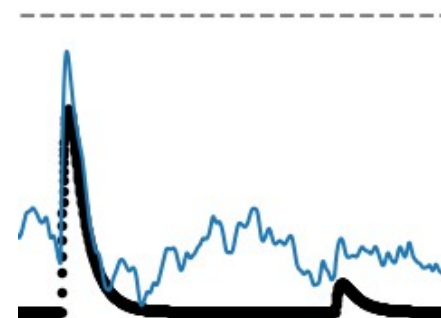
- Number of found peaks = TP + FP
- FP = Number of found peaks - TP
- FN = Number of true peaks - TP

- Number of **true negatives**: rejected lookalike pulses

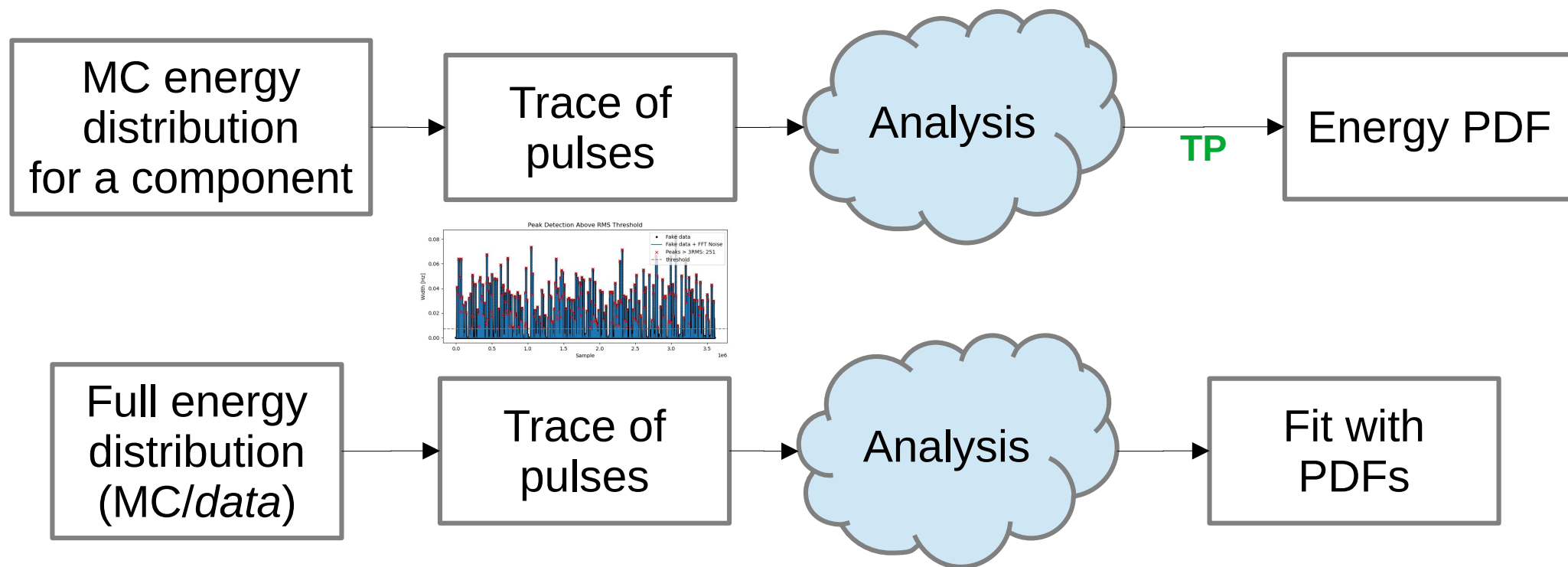
- Number of **false positives**: ghost pulses



- Number of **false negatives**: missed pulses

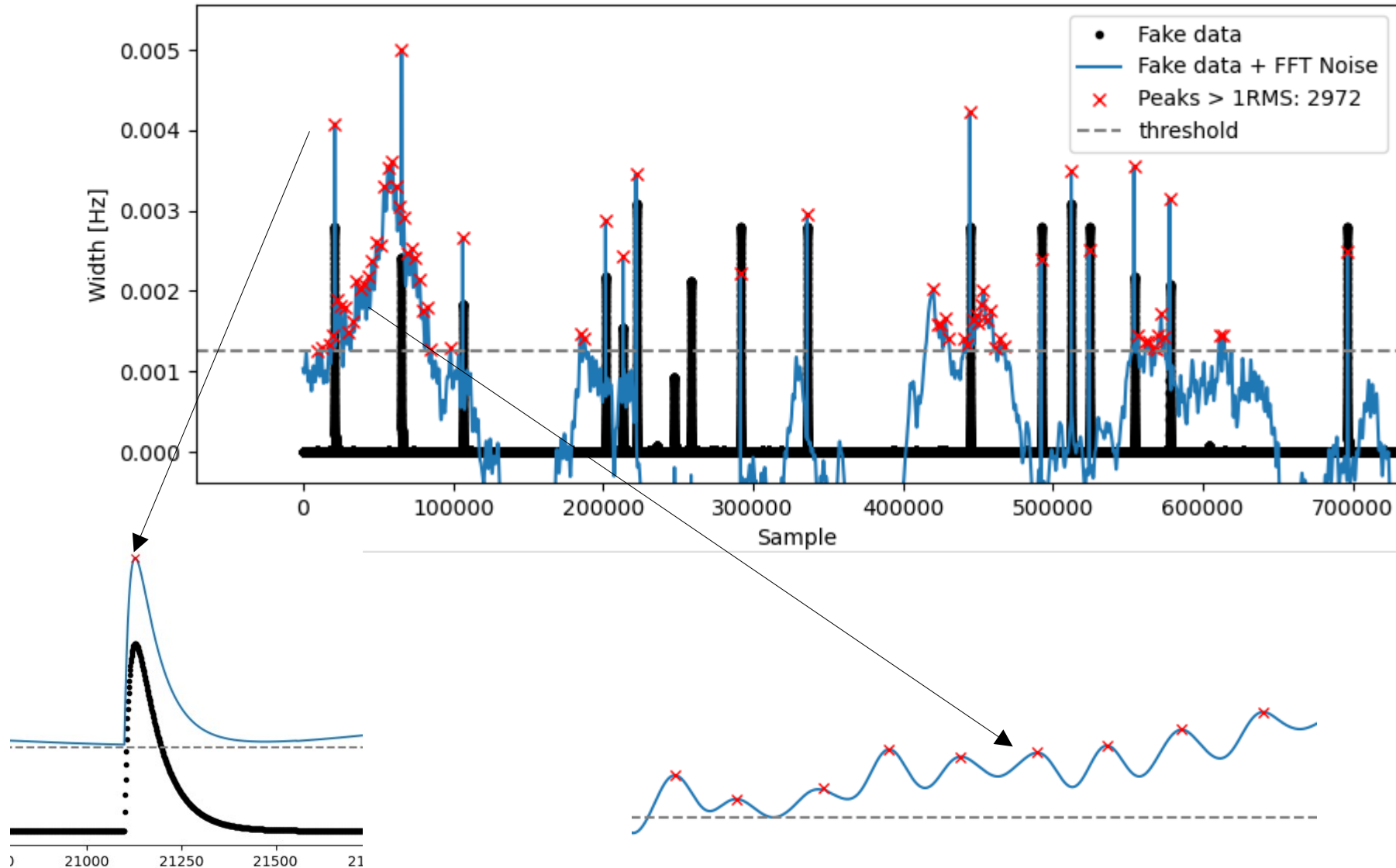


Extract PDFs



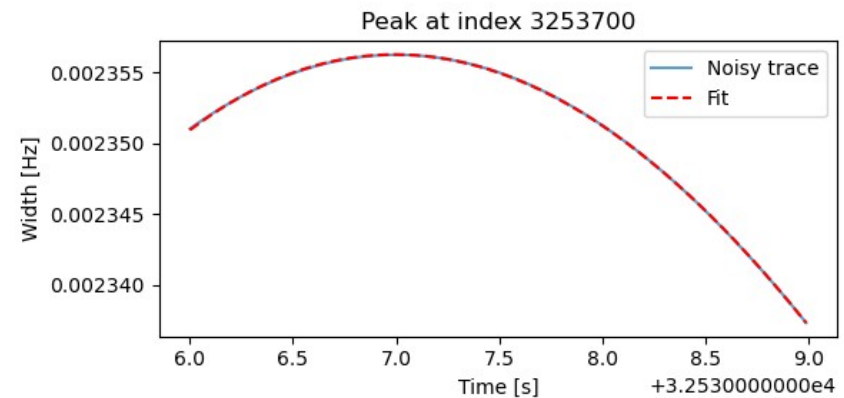
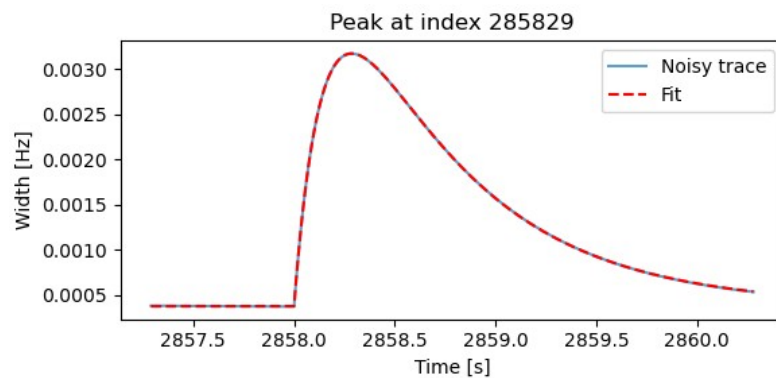
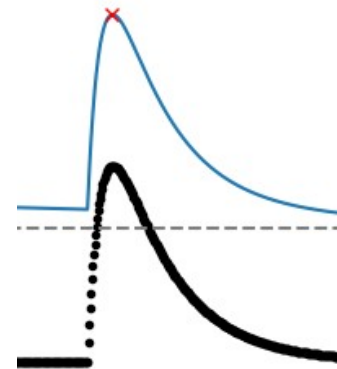
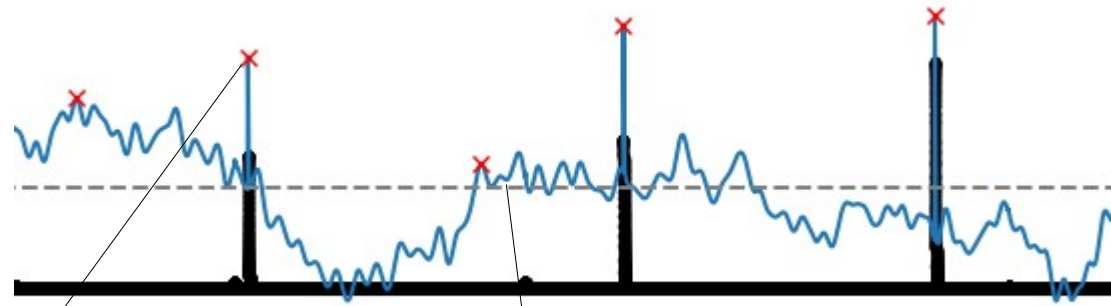
Peak finding

Peak Detection Above RMS Threshold



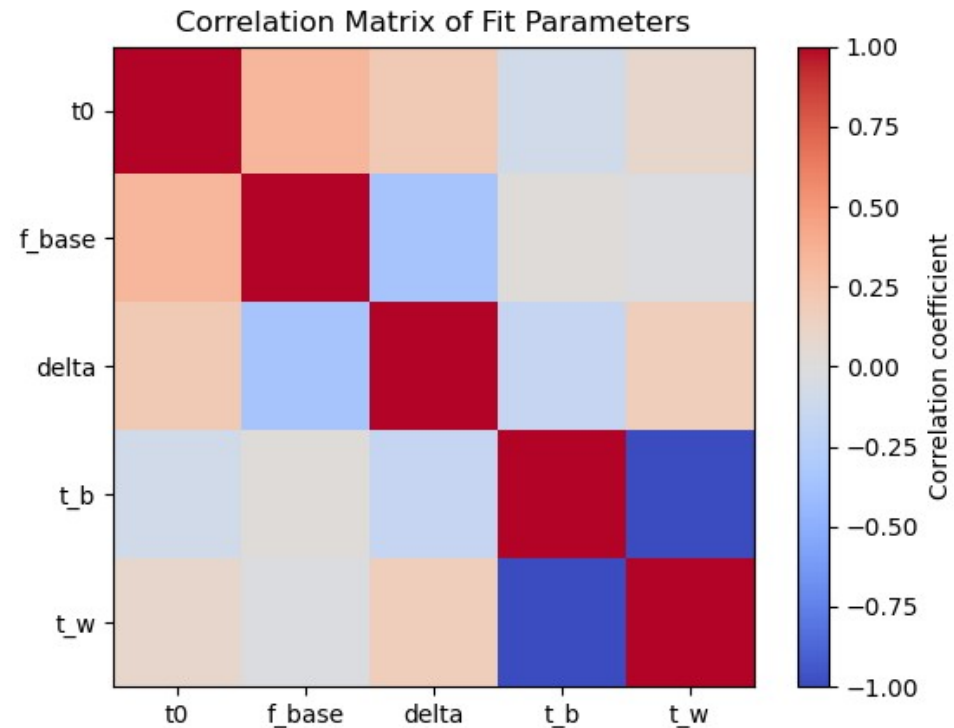
Peak finding

- Peak finding *distance* compatible to the rate
- Fit each single peak with the *Winkelmann template*



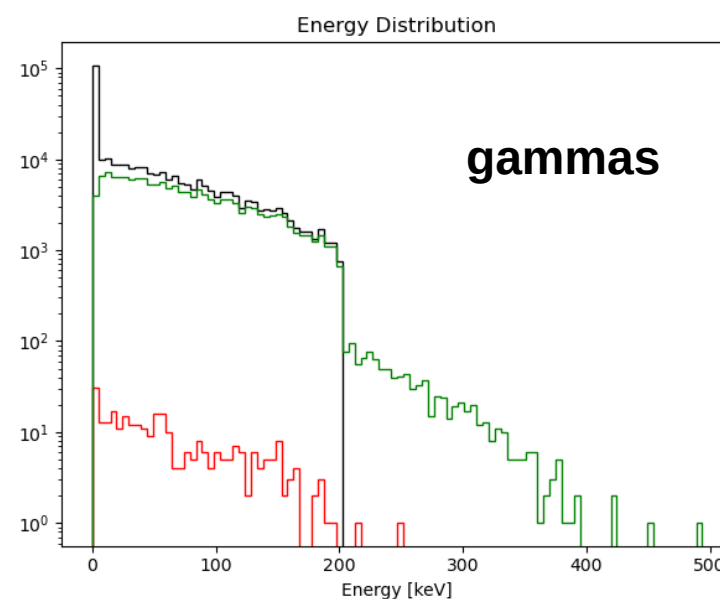
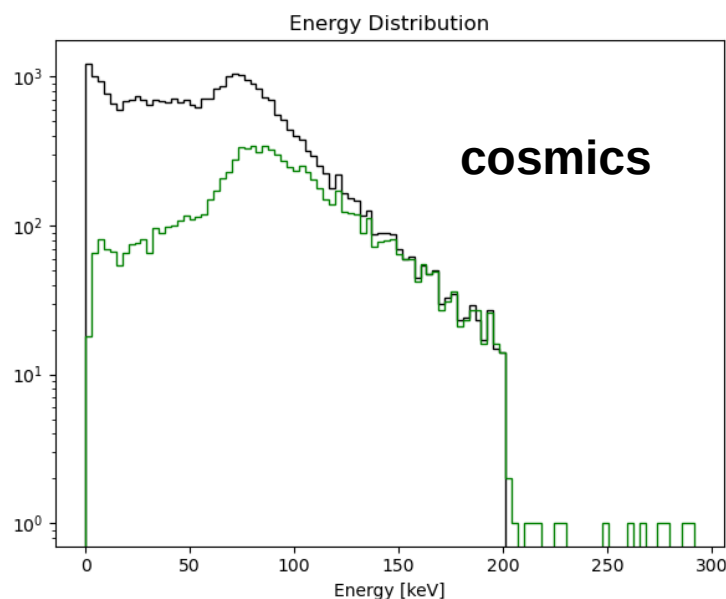
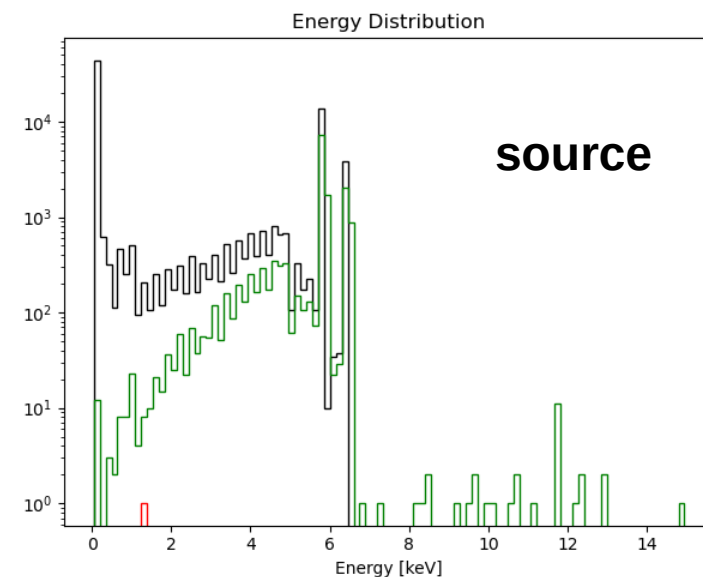
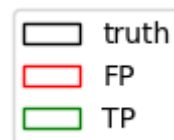
Peak finding

- Cut on the Winkelmann time constants:
 - wire response time: $t_w \pm 0.05$ sec
 - bolometer time constant: $t_b \pm 0.05$ sec



Create PDFs

- 1 RMS of the baseline
- Cut on time constants
- Selecting **true-positive**



Fit simulated data with PDFs

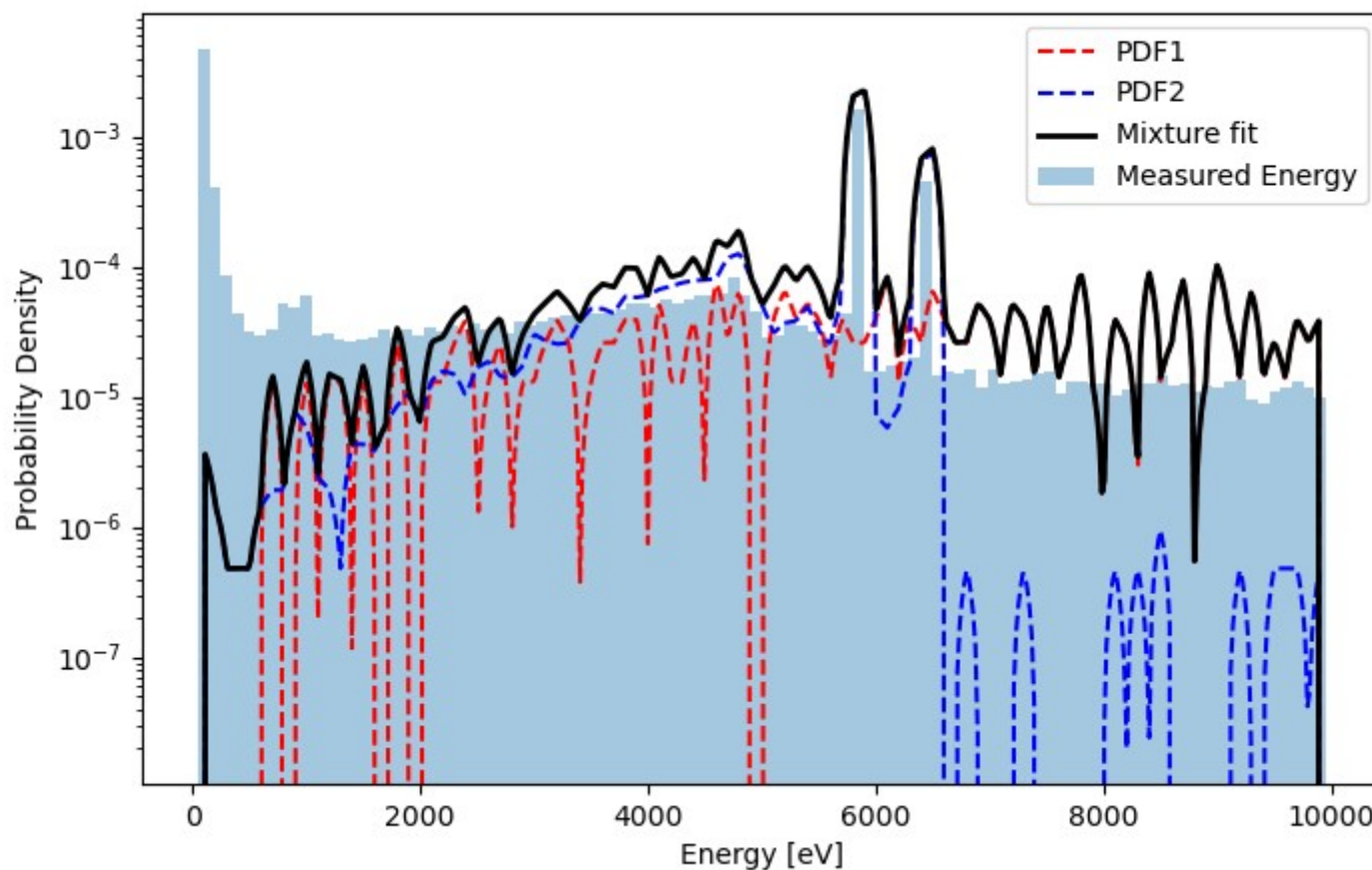
- Minimise the negative log-likelihood (NLL)
- e.g. mixture with 2 PDFs f_1 and f_2

$$p(E) = w f_1(E) + (1 - w) f_2(E)$$

$$\log L = \sum_i \log(p(E_i))$$

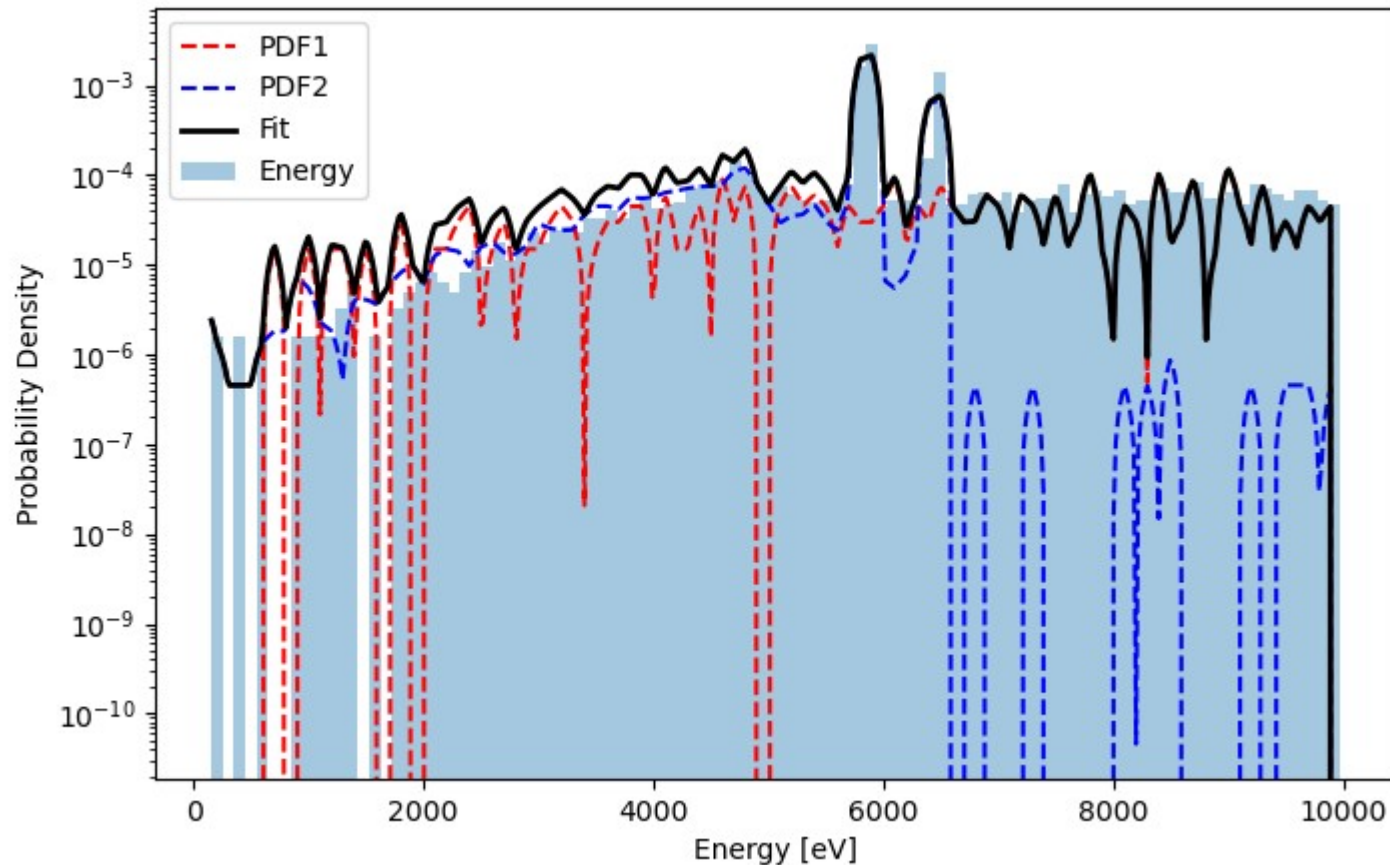
Fit **truth** with the PDFs

- Generate a 2 component hybrid toy



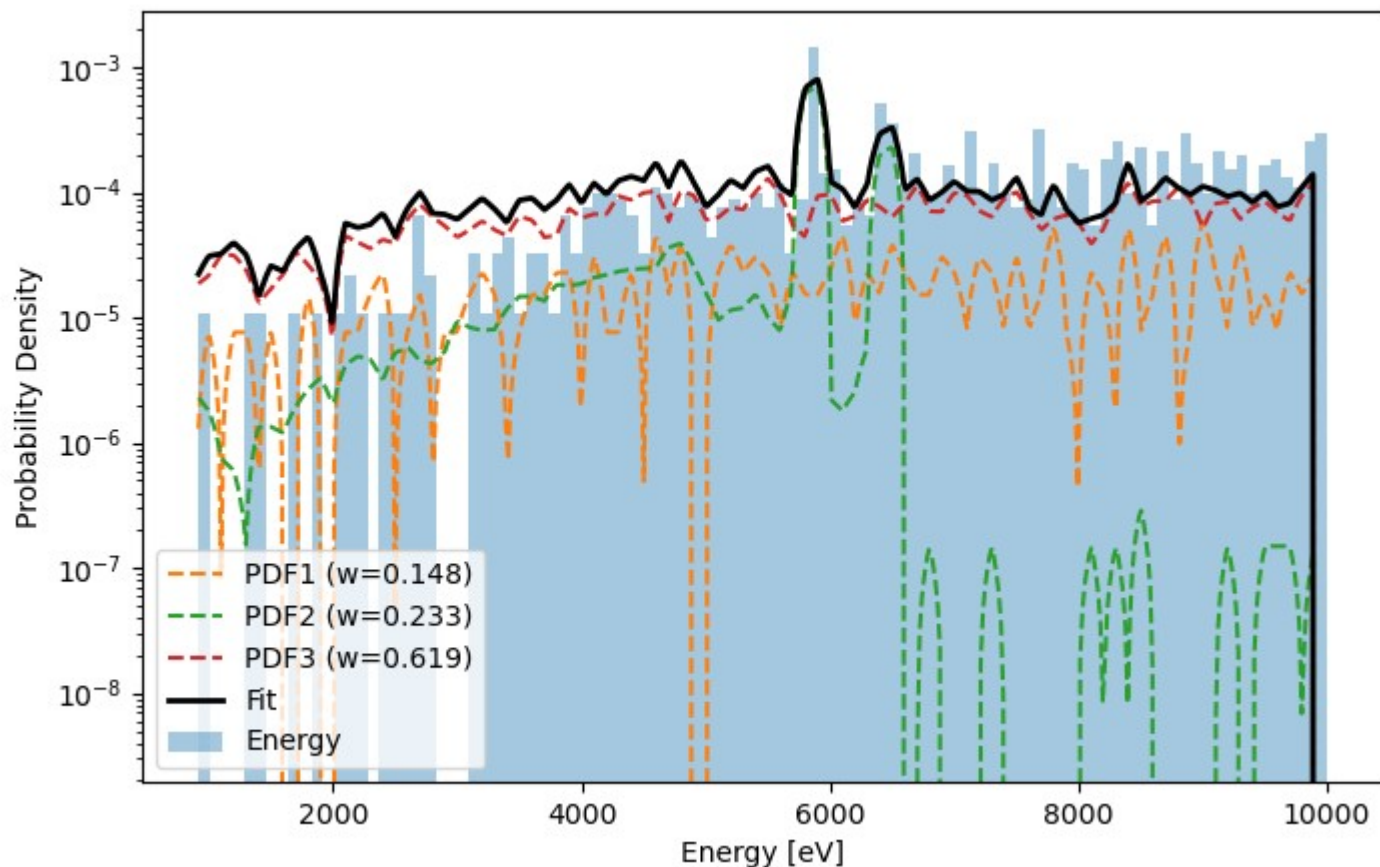
Fit **reco** with the PDFs

- Fit of the reconstructed energy (peak finding)



Fit **reco** with the PDFs

- 3 component toy: cosmics, ion source, gammas



In progress



- Optimise the set of cuts
- Other methods: matched filter? input from data pulses?
- Is this toy reproducing the data? to be of any use for building PDFs?
- Use PDFs defined on the simulation on the data

References



- <https://github.com/QUEST-DMC/QUEST-detector-simulation>
- https://github.com/pfranchini/QUEST-code/tree/master/hybrid_toy

Thanks!

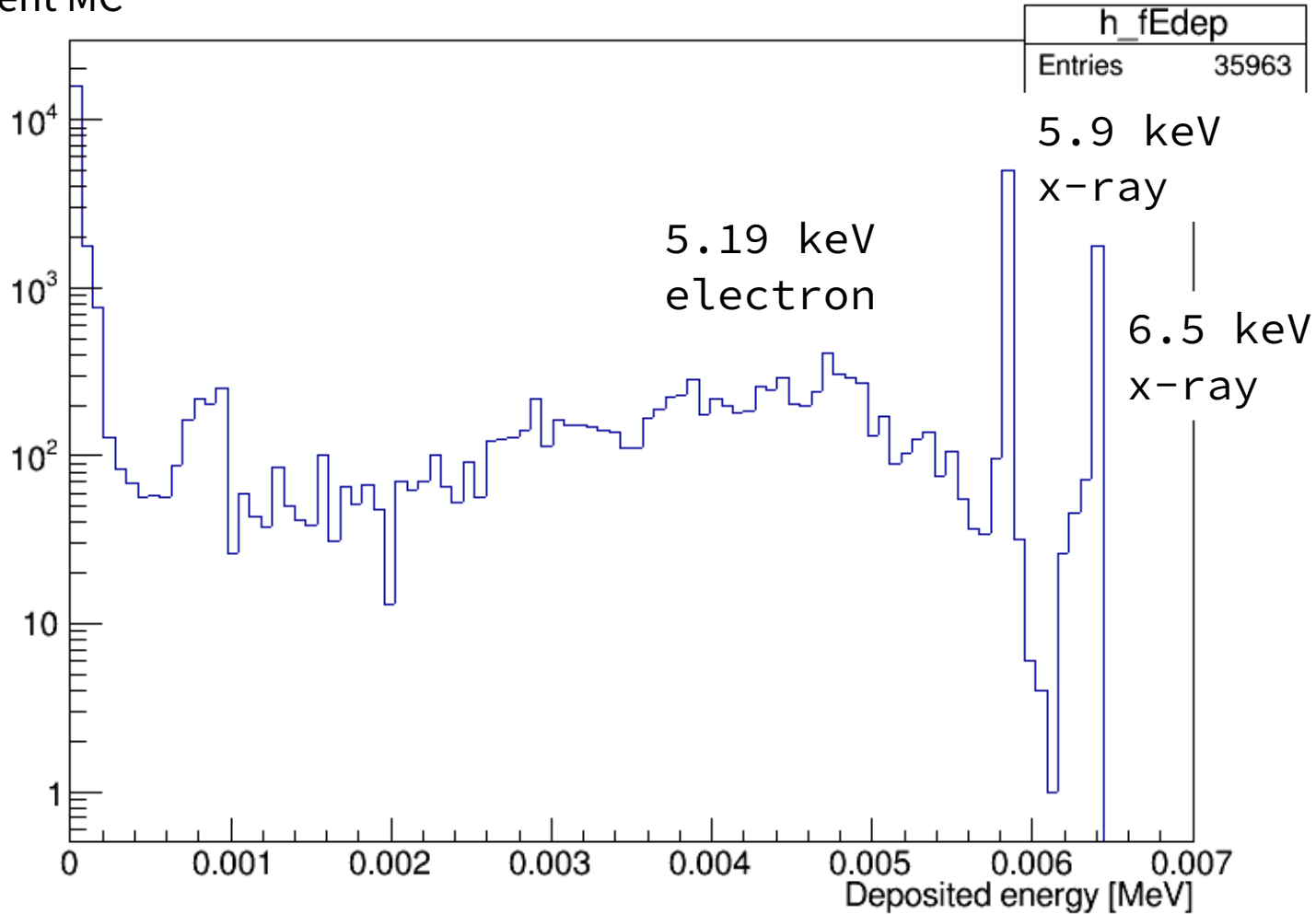
Backup slides



Fe-55 source (80kBq) in inner cell

2 weeks equivalent MC

Full spectrum



- 80kBq $\rightarrow$ deposited 2 events/minute
- 1.8 pW/m³