

SBND Flash reconstruction

Xuyang Ning (BNL)

09/24/2026

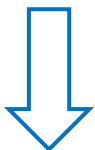
Light reconstruction chain

OpWaveformSource: from raw::OpDetWaveform (larsoft)

- Read the raw photon-detector records

OpDecon: from Deconvolution_module.cc (duneopdet)

- Deconvolve each waveform with its *single-PE (SPE) template*; repair ADC saturation.



self-trigger

OpRoi: similar as WireCell's charge ROI finding

- ROI finding for Full-stream channels

OpHitFinder: OpHitFinderDeco / fcl dune_ophit_finder_deco (duneopdet + larana)

- Turn each cleaned waveform into pulses on single channels
channel, hit time, width, area, amplitude, PE, start time, flash id (-1), fast/total

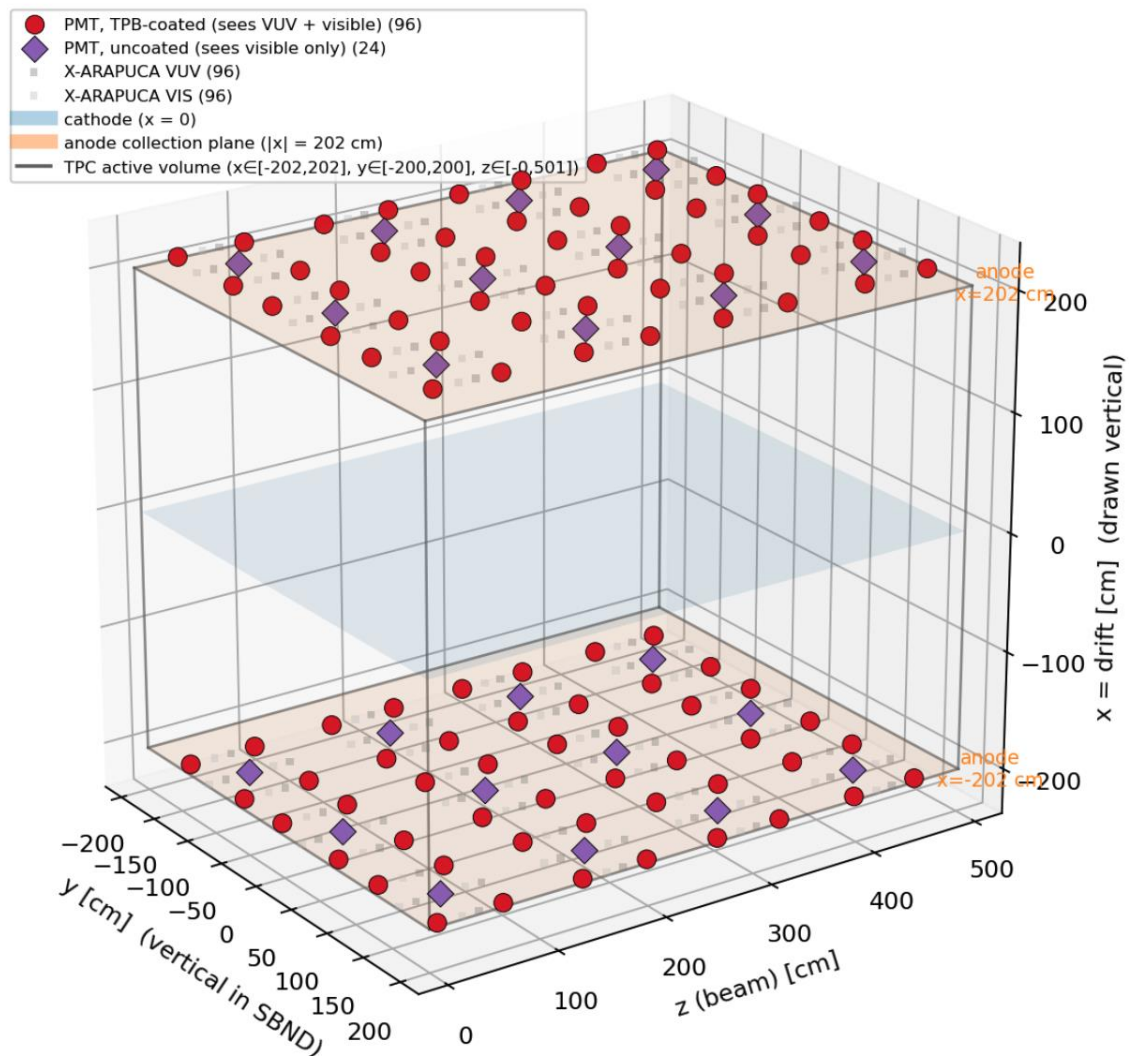
OpFlashFinder: from OpFlashAlg::RunFlashFinder(larana) but improved

- Group time-coincident hits across OpDets into a flash

full stream

SBND light detector

SBND OpDet 3D placement — drift (x) drawn vertical: TPC 1 (x>0) upper, TPC 0 (x<0) lower
cathode x=0 (blue) · anodes |x|≈202 (orange) · PMTs + X-ARAPUCAs behind each anode

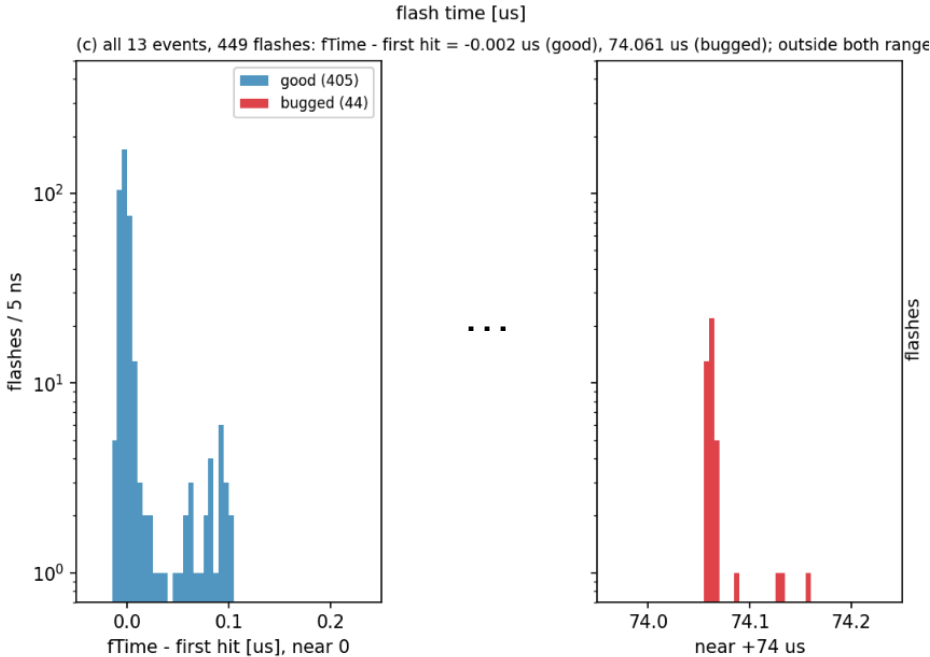


- **light seen by coated vs uncoated PMTs**
- **coated PMT:** its coating turns argon's ultraviolet (VUV) scintillation light into visible light, so it sees **direct VUV light + visible light**.
- **uncoated PMT:** sees **only visible light**. That light mostly comes from the cathode, which is covered with reflective foils that also shift the wavelength.
- ratio X related to coated/uncoated PMT contains the x position information

An issue in current flash

- flash time (**fTime**) = hit-based time – light travel time (0–15 ns)
- Starting and refined time, from the hits.
- Light travel-time correction, from X**
a failed X (–999999) turns the few-ns correction into –74 μs, which swamps the correct hit-based time.
- failed X happens in **small flashes** or **flashes close to the anode**, where the **uncoated PMT** cannot see enough light

X estimate fails for **9.9 %** of MC flashes but only **0.59 %** of data flashes.



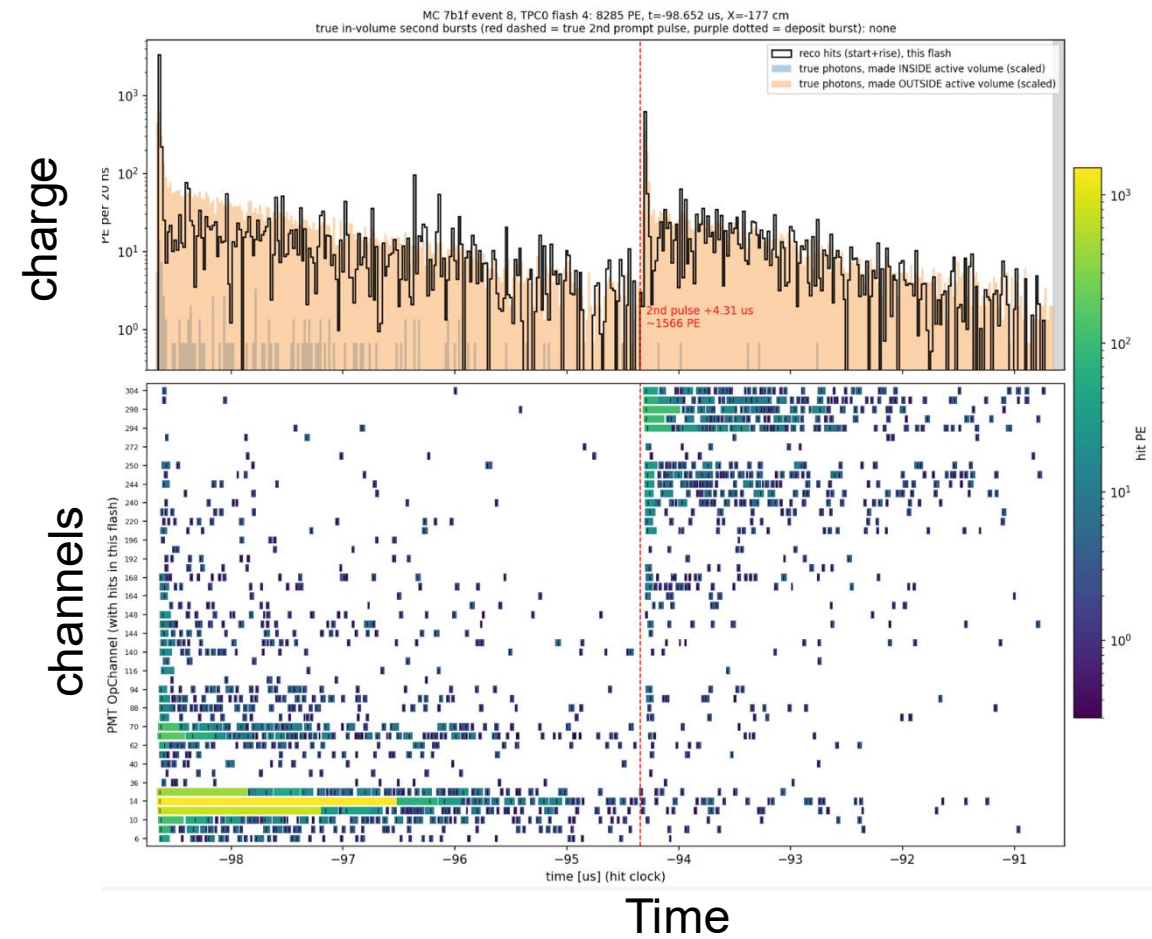
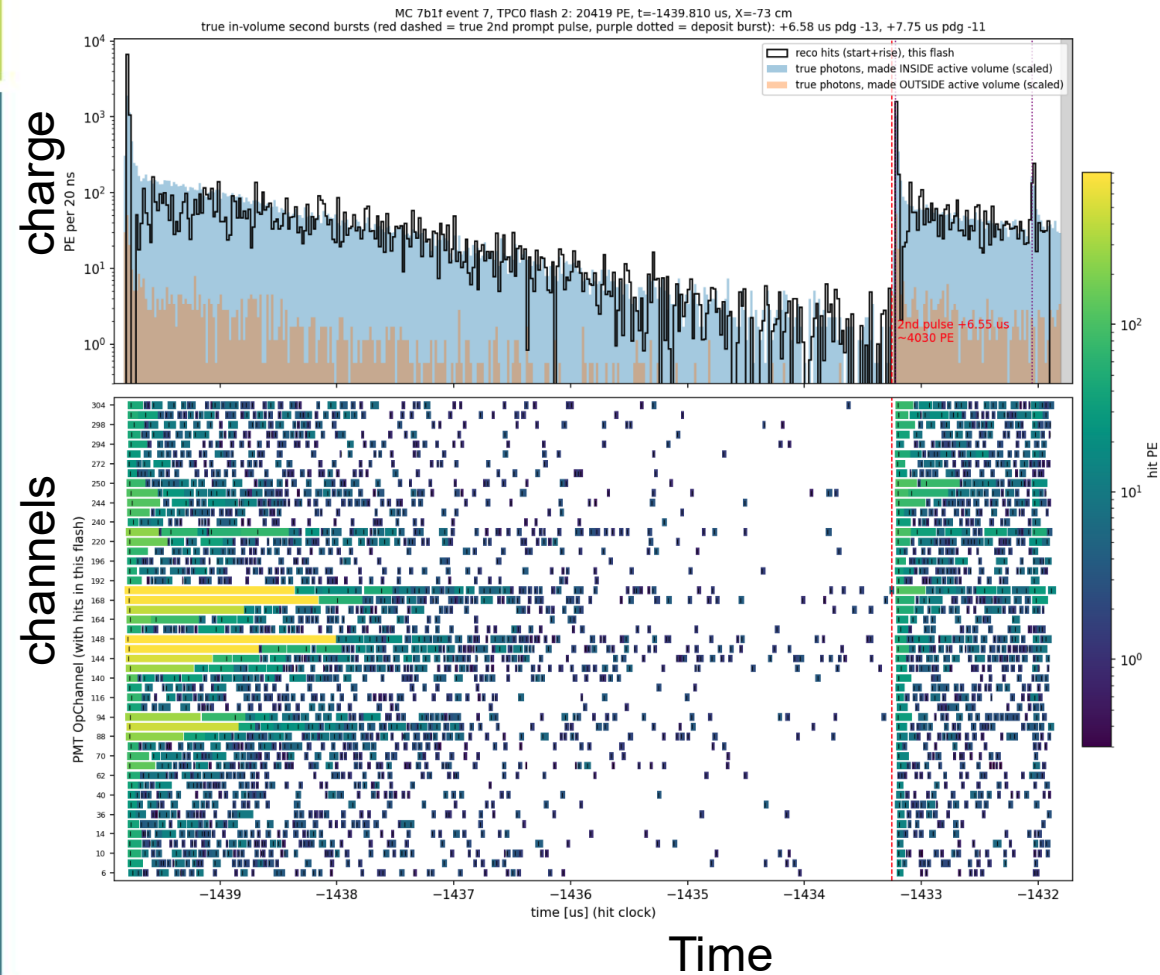
Flash time - first hit time

sample	flashes	failed	rate	TPC0	TPC1
MC, 10 files, 104 events	4,085	403	9.9 % (7.0–12.3 % per file)	9.1 %	10.6 %
data, 2 files, 2,000 events	57,057	336	0.59 % (about 1 per 6 events)	0.47 %	0.71 %

By flash size:

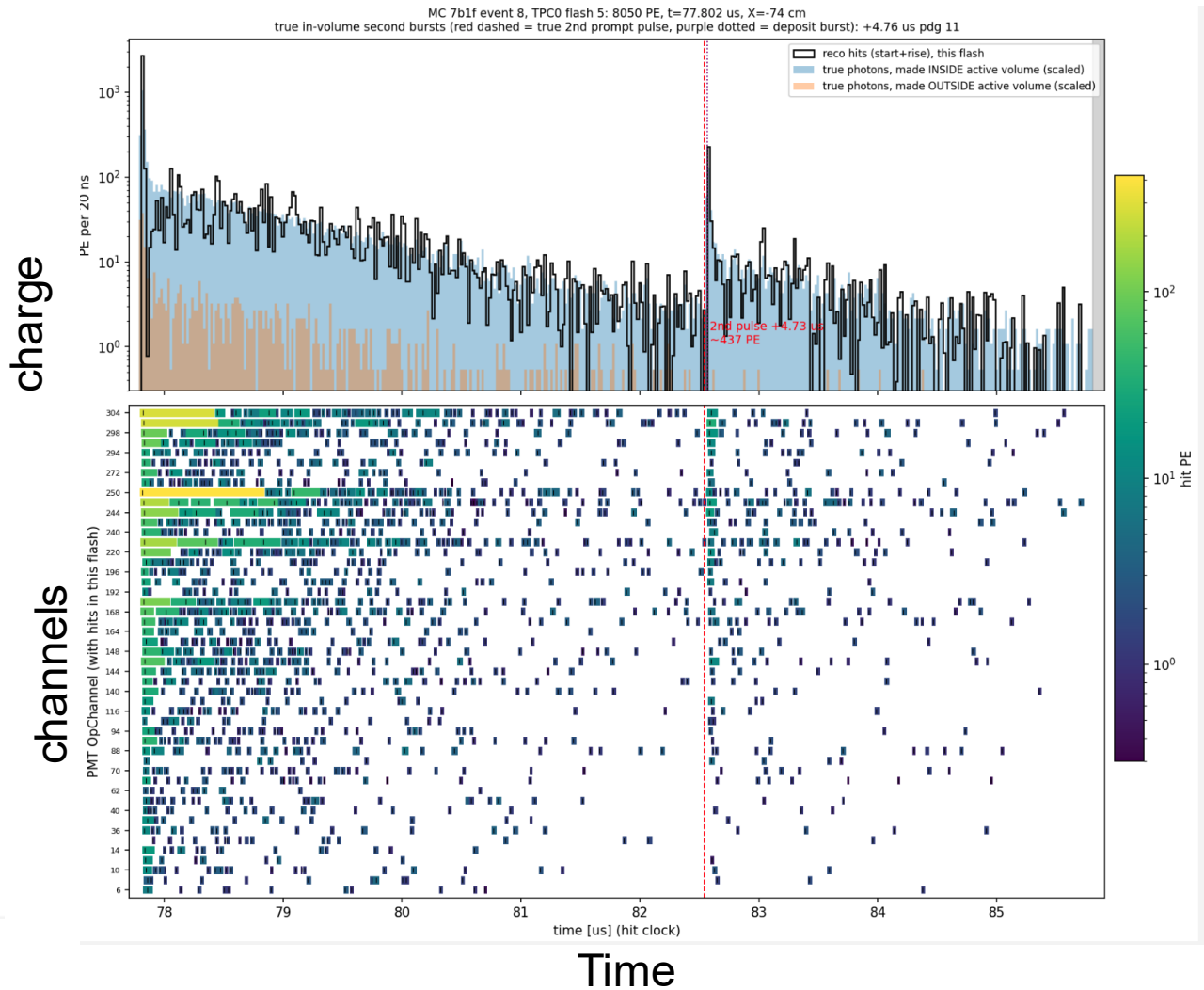
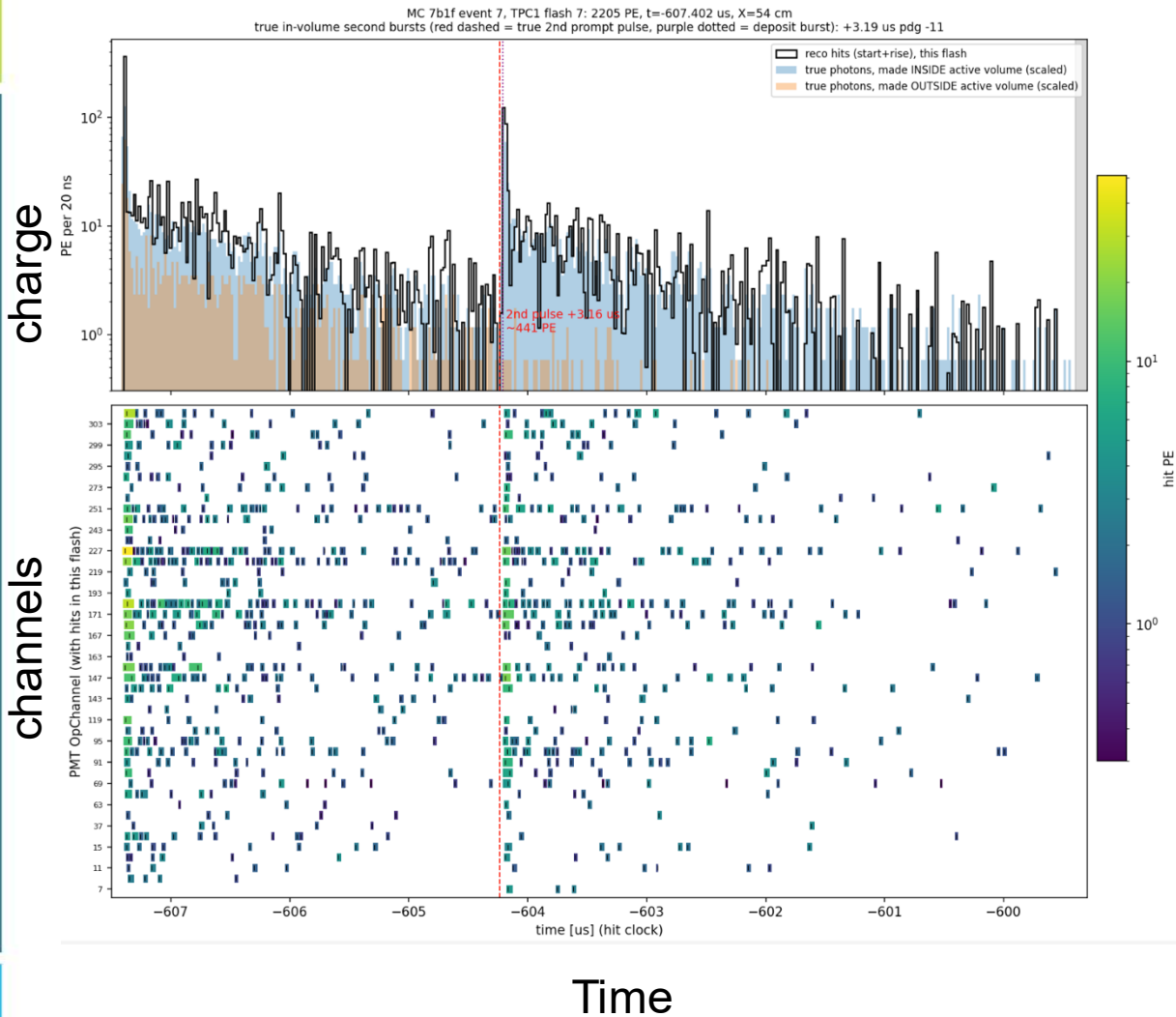
flash PE	20–50	50–100	100–200	200–500	≥ 500
MC	63 %	42 %	26 %	12 %	0.8 %
data	46 %	9 %	0.1 %	0 %	0 %

Merged Flash issue



4.2 % of SBND's flashes (17 of 405) were merged

Merged Flash

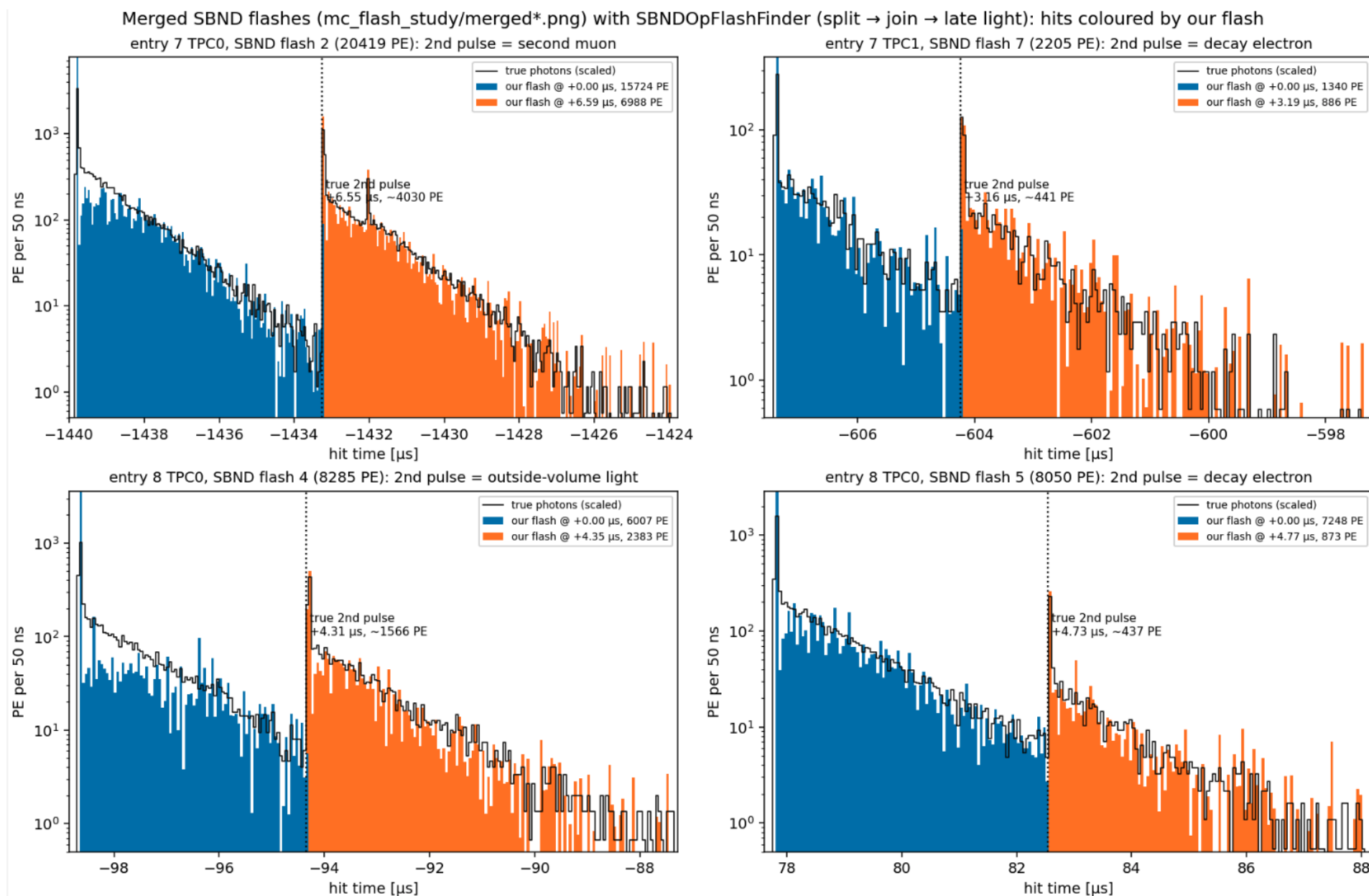


Create a SBNDOpFlashFinder

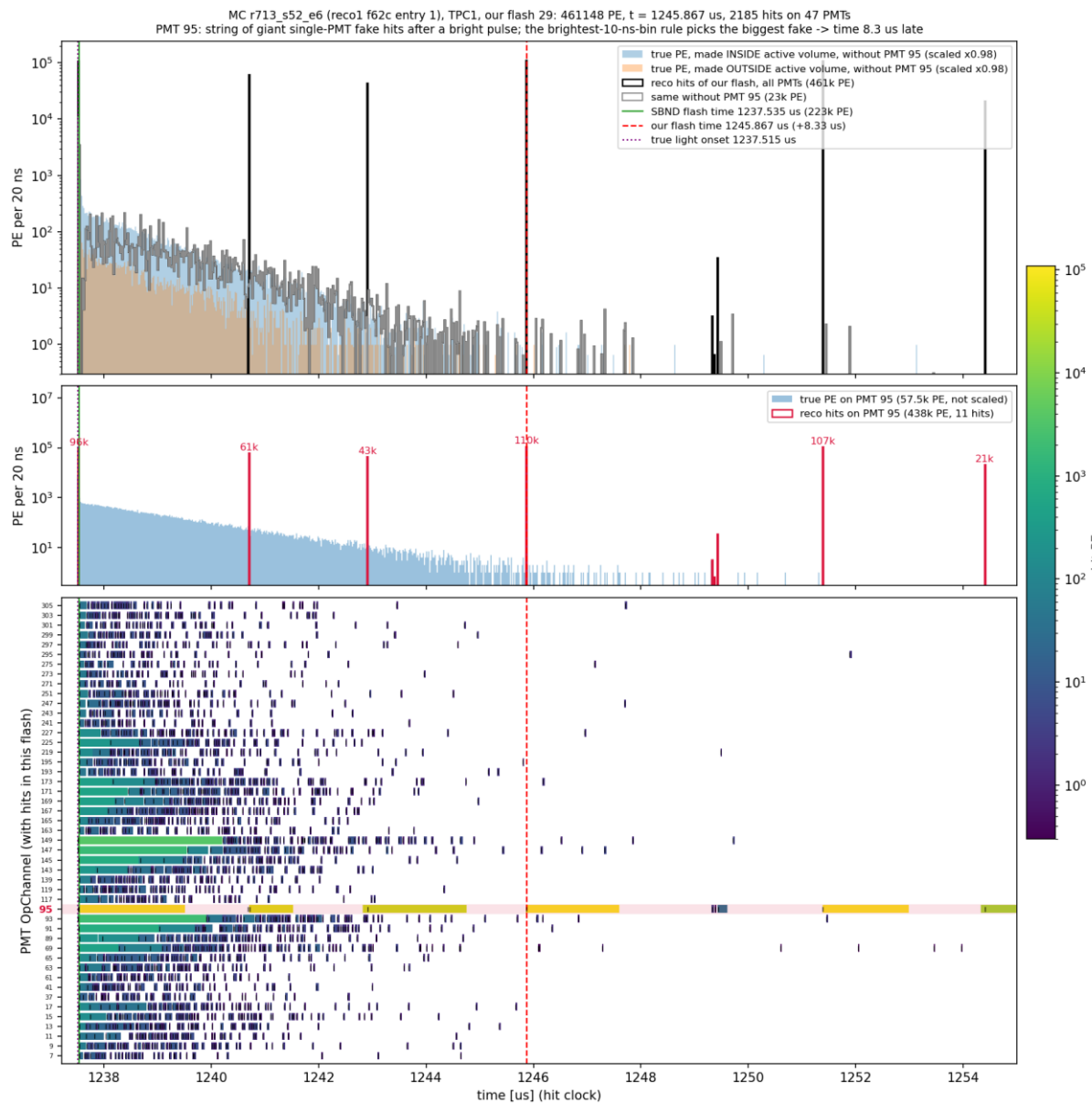
Steps, in order:

1. **Group and claim** in 8 μ s time slices, done as in OpFlashFinder.
2. **Split** a flash where a second sharp burst of light starts.
3. **Join** a leftover piece to the nearest earlier flash if it starts within 1 μ s of that flash's last hit, sits on the same PMTs (at least 90 % of its light), has no sharp burst of its own, and isn't the other half of a split.
4. **Remove late light**: delete a later flash that an earlier flash's glow explains.
5. **Keep flashes on at least 3 PMTs**, and give each SBND's flash time.

Fixed examples



A failure Q/L matching case



- A strange sparking channel, huge fake hits is shown.
- it will affect both charge and time.
- Fix: add steps of drop fake hits at the very beginning
- set the flash time using SBND's rule, including the new ≥ 6 PE and ≥ 3 hits condition)

Improved version of SBNDOpFlashFinder

- A table of steps 0–8, in the order the code runs them:
- drop fake hits
- sort hits into 8 μ s time slices
- claim hits, biggest candidate first
- split a flash at a second burst of light
- join cut-off pieces back to the flash before them
- remove light explained by an earlier flash's slow tail
- keep flashes with at least 3 PMTs
- set the flash time (SBND's rule, including the new ≥ 6 PE and ≥ 3 hits condition)
- correct for the time the light takes to reach the PMTs

MC truth flash

The MC file has no ready-made truth flash, so we build one from the true light

1. The only light truth in the file is: For each optical channel it stores how many photons arrived in each 1 ns.

2. **Turn photons into "true PE":**

PMT	direct light	reflected light
coated (96 PMTs)	1.000	0.663
uncoated (24 PMTs)	0 (it can't see this light)	0.911

1. Two groups of PMTs are left out: the 23 masked PMTs, and PMT 64, which is dead in the MC reco.

3. **Cut the light into flashes, for each TPC separately.**

- Add up the true PE of that TPC's PMTs in 10 ns bins.
- A new flash starts where the light jumps up sharply: at least 4 PE within 30 ns, and at least 8 times the tail level of the previous 0.5 μ s.
- The flash owns all the light from its start until the next start, for at most 8 μ s.
- It only counts as a truth flash if it has at least 20 PE on at least 3 PMTs and starts inside the PMT readout (−1506 to +1495 μ s).
- These truth flashes hold 99.7 % of all the true PE.

4. **Give each flash a time.** We apply SBND's own timing rule to the true PE: find the brightest 10 ns bin, then take the mean time of the biggest pieces of light around it. This truth time is when the light **arrives** at the PMTs, not when it was made.

Flash compared to truth

Truth flash vs reco

Beam window $[-8, +8]$ μs : 176 truth flashes

	matched	merged	missed	neutrino flashes matched
ours	160	14	2	91 / 91
SBND	138	14	24	82 / 91

Merged flash ratio:

	reco flashes in the window	merged	truth flashes merged into another flash
SBND	140	14 (10.0 %)	14 / 176 (8.0 %): neutrino 1/91, cosmic 2/11, outside 11/74
ours	174	19 (10.9 %)	14 / 176 (8.0 %): neutrino 0/91, cosmic 2/11, outside 12/74
SBND, all times	4085	309 (7.6 %)	317 / 5846 (5.4 %)
ours, all times	5325	362 (6.8 %)	381 / 5846 (6.5 %)

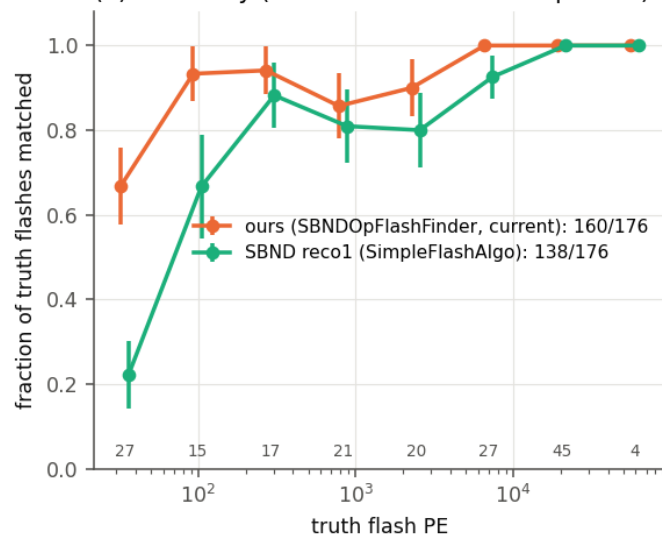
Swallowed flash PE:

	swallowed truth flashes	total swallowed PE	swallowed flashes ≥ 100 PE
SBND	14	19 135	10
ours	19	7 332	6

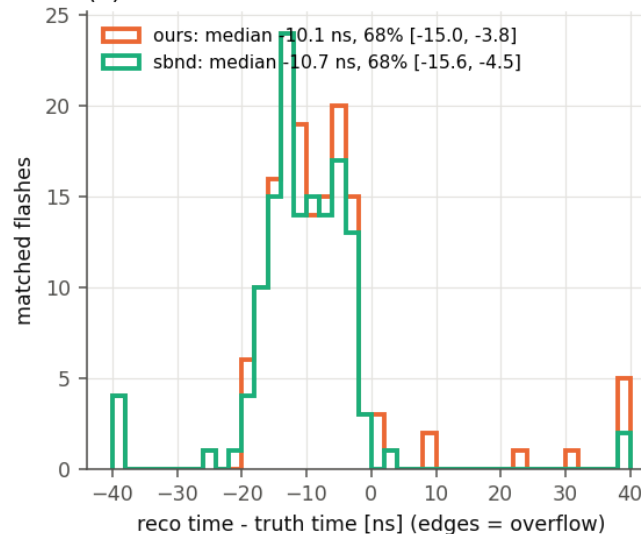
Flash truth comparison

SBND MC, 104 events (10 files): truth flashes in the beam window $[-8, +8]$ us only — current SBNDopFlashFinder vs SBND reco1

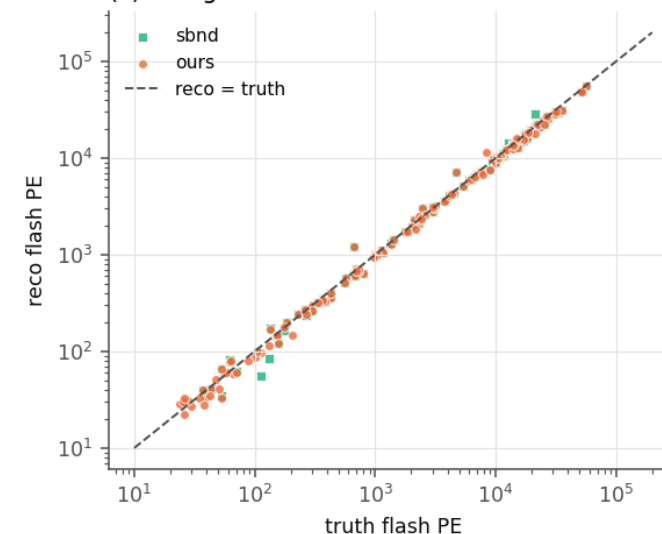
(a) efficiency (numbers: truth flashes per bin)



(b) flash time

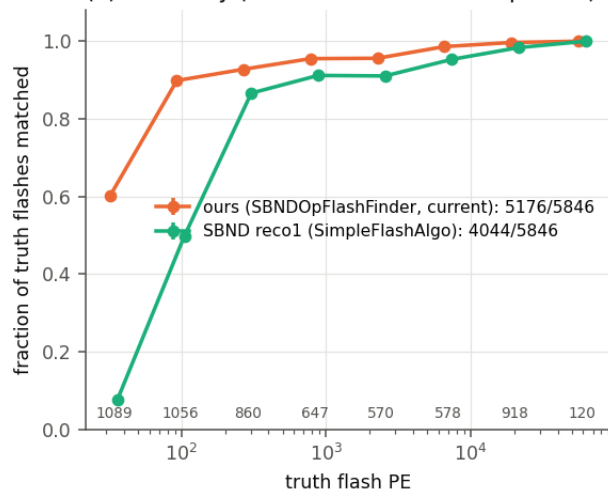


(c) charge

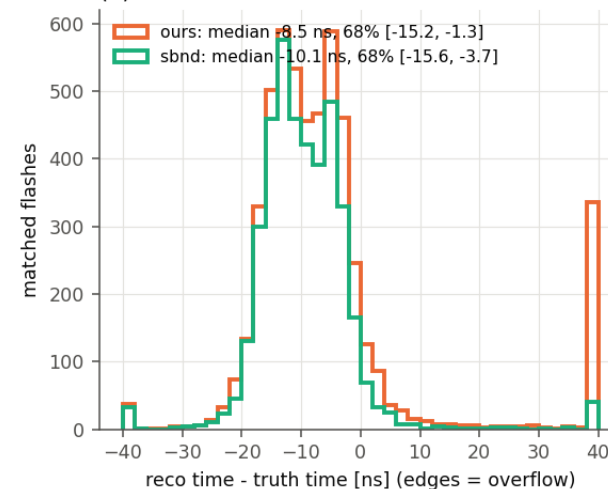


SBND MC, 104 events (10 files): all truth flashes in the readout — current SBNDopFlashFinder vs SBND reco1

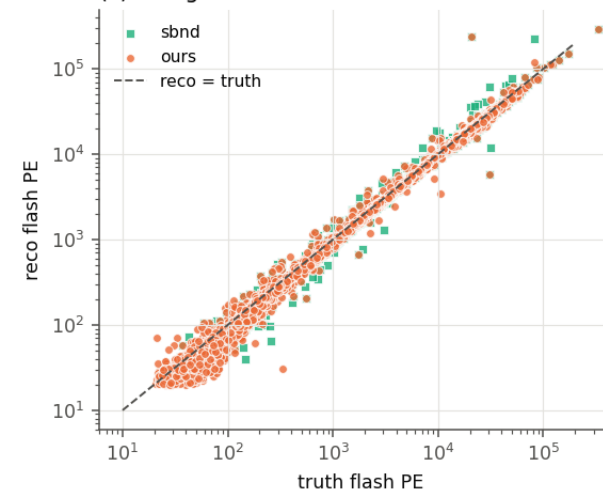
(a) efficiency (numbers: truth flashes per bin)



(b) flash time



(c) charge



QL matching compare

Clusters with true time in $[-8, +8]$ μs (clear truth only: median point–deposit distance ≤ 3 cm):

selection	clusters	SBND right	ours right	SBND right / ours wrong	SBND wrong / ours right
all sizes	145	92 (94.7 % of points)	95 (97.5 %)	2	5
≥ 100 points	80	74 (95.4 %)	76 (98.1 %)	0	2
≥ 100 points, neutrino	73	68 (96.9 %)	69 (97.6 %)	0	1
≥ 100 points, cosmic	7	6 (89.7 %)	7 (100 %)	0	1
≥ 500 points	63	58 (95.4 %)	60 (98.3 %)	0	2
all times, ≥ 100 points	958	843 (94.9 %)	850 (95.3 %)	16	23