

# TOP status and 2025c readiness

TRG/DAQ workshop 2025  
October 23, 2025

For TOPTRG, see talk by Kimika Arai yesterday

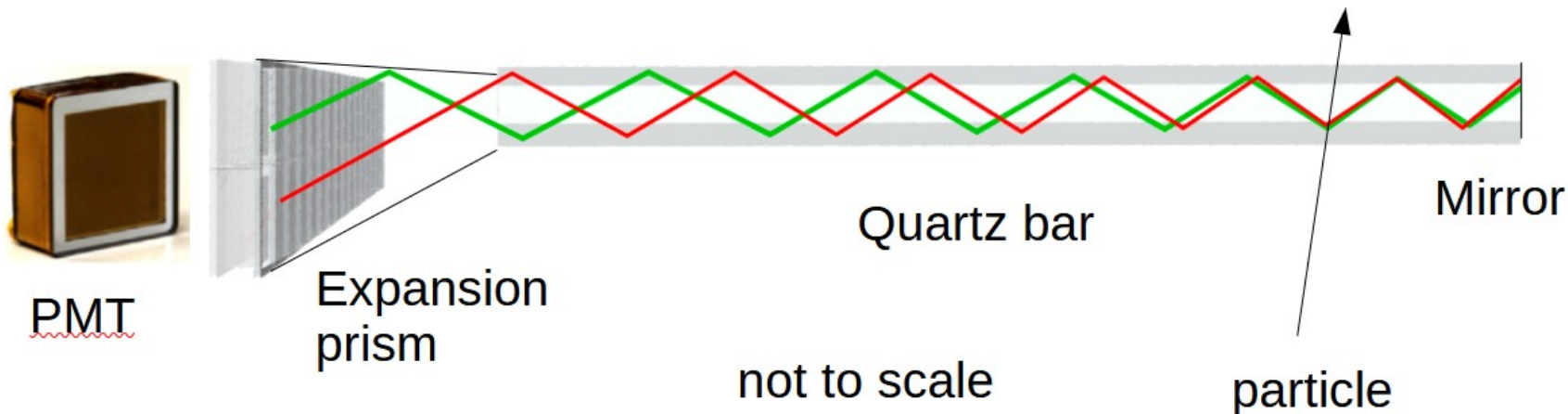
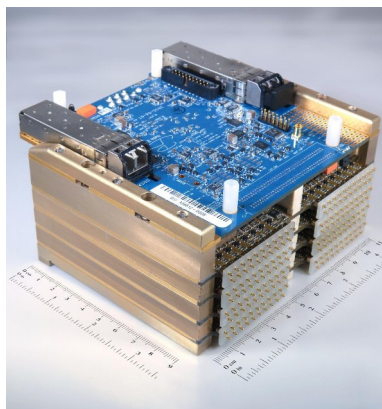
Martin Bessner,  
for the TOP group

# Overview

- TOP concept
- Issues seen in 2024 and mitigation
  - Feature extraction
  - b2llost
  - Other issues
- PMT lifetime
- Plans until LS2
- Plans for LS2

# TOP concept

- Particle identification with precision timing. 100 ps single-photon resolution



Boardstack:

- \* SCROD
- \* 4\*Carrier
  - > 4 ASICs with 8 channels each
- \* HV board

Readout chain:

PMTs convert light to electronic signal  
ASICs digitize hits  
Carriers collect hits and control ASICs  
SCROD collects hits from carriers  
→ sent to PCIe40 boards → readout computers  
→ high level trigger system0

See talk by Kimika:

<https://indico.belle2.org/event/15311/sessions/4749/>

# 2024c issues

- Stopped boardstacks (scrod PS lockup)
  - Solution ready
- b2llost from injections
  - Mitigation ready, might be solved?
- Some smaller SEU effects
  - Some without impact on DAQ
  - Some need run restart
  - Some need masking + power cycling
  - Minor impact. Mostly unchanged for 2025c

PS = processing system  
SEU = single event upset

```
elastalert BOT 2:45 AM
busy occurred at 2024-12-27 02:45 JST on sub-system TOP

Aggregation resulted in the following data for summary_table_fields ==>

+-----+-----+-----+-----+-----+
| local_time | detector | source | error | count |
+-----+-----+-----+-----+-----+
| 2024-12-27 02:45 JST | TOP | Not found: 3-2 | busy | 1 |
+-----+-----+-----+-----+-----+

busy source = Not found: 3-2
```

```
elastalert BOT 3:35 AM

Large deadtime in TOP at 2024-12-27 03:35 JST
TOP DAQ dead time is too large (73.2%). Started automatic recovery (~2 min).
CR shifters, if deadtime goes away no further action is needed. Otherwise contact TOP shifters.
TOP shifters, please check deadtime and asic masking status. Mask boardstack if needed.
```

```
elastalert BOT 8:35 PM

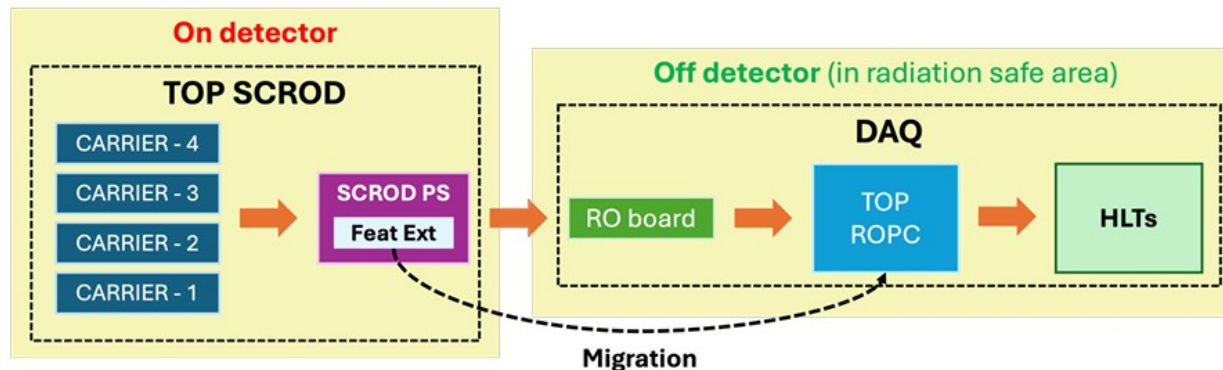
Mismatch between header in data sent from FEE and b2tt data sent from FTSW on TOP s02a at 2024-12-26 20:35 JST
CR shifters: SALS cannot fix the error, please contact the TOP expert.
TOP experts: Please 1) mask the problematic channel s02a and 2) power-cycle.
You can power-cycle and include it back at the next run stop.
```

Many bot messages  
about issues

# Feature extraction on ROPC

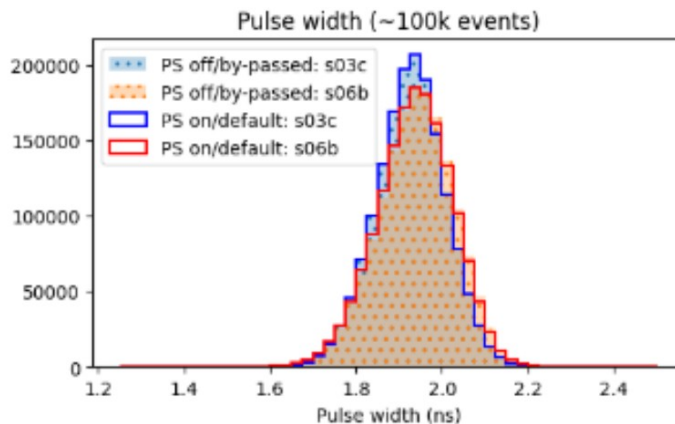
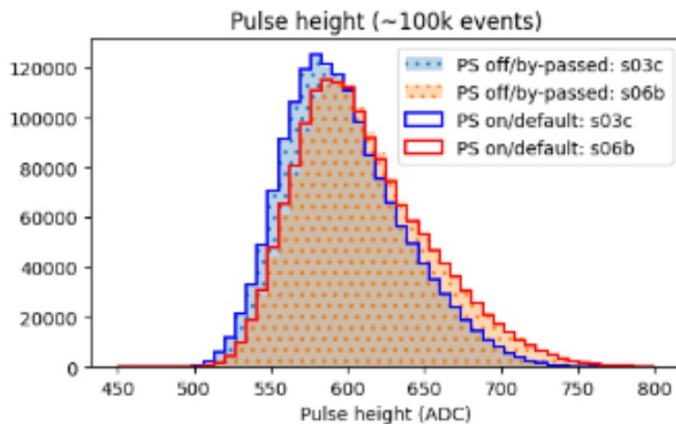
- Mostly developed this year (some work since 2019)
- Largest TOP firmware change since 2018
  - If needed, can go back to old firmware in <30 min
- Scrod sends raw waveforms to PCIe40, feature extraction on ROPC
- Bypasses scrod PS for event processing
  - PS lockups are one of two major run stop reasons from TOP (need masking+power cycling)

ROPC =  
readout PC



# Feature extraction on ROPC

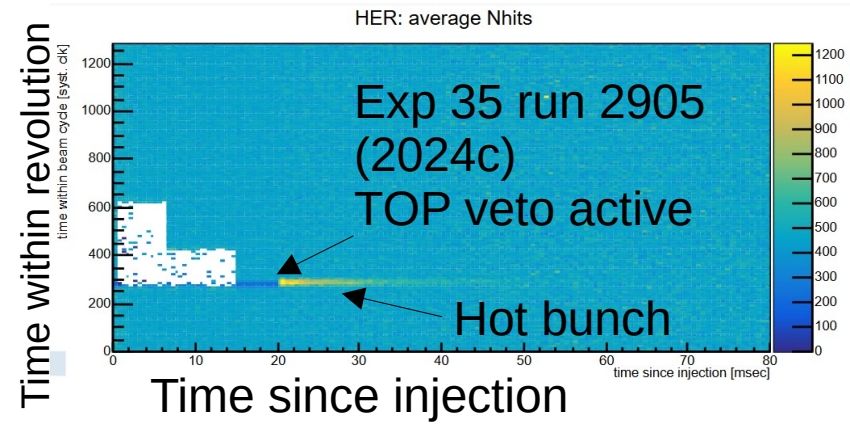
- Matches data with old firmware
- Tested with high occupancy + trigger rate
  - Lower deadtime than with old firmware  
(12% at 30 kHz and 3 times 2024c occupancy, 40% with old FW)
- Tested in cosmics and null runs
  - Very stable so far



Solid lines: old firmware  
Shaded: new firmware  
blue/orange: different boardstacks

# b2llost

- High injection background can cause frequent b2llost
- Could not reproduce it without accelerator. Tried high occupancy + trigger rate combinations, forced digitization of same memory cells, triggering on always the same hot “bunch” and more.
- Still testing it in Hawaii with a laser
- Baseline mitigation: Improved accelerator conditions + non-stop DAQ
  - Need more tests of persistent busy issue
- Backup option: TOP injection veto
  - Flag for events with active veto
- Might be solved with recent FW fix (slide 9)



# Other SEU effects

- Unpacker errors: Do not stop runs. Exclude boardstack if common
- Sometimes random ttlost/b2llost/... not linked to injection

→ non-stop DAQ or SALS

SALS = stop,  
abort, load, start

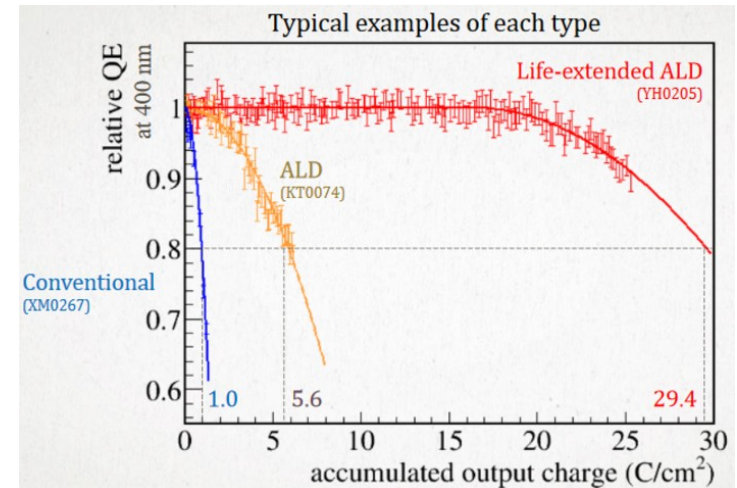
- “high deadtime” mode of asics/carriers/scrods
  - Need to be masked. Automatic process, no run stop needed
- Asic self-masking
  - If asics take too long to respond. Automatic, no run stop needed.
- New FW and bugfix (next slide) might affect these (TBD)
  - Will adjust recovery procedures if needed

# Scrod FIFO bugfixes

- “U\_EventNumberTimeFifo” is written without check if it’s full. RunReset does not reset it → fixed both
- b2tt FIFO depth is 127 triggers, but TOP only sends BUSY when processing is 150 triggers behind. Still seems to work most of the time (?) → Will change this to  $\leq 127$ .
- Pending event counter now always synchronized to FIFO entries
- Vasily fixed these last week. Still evaluating the impact. Could solve multiple issues (b2llost, other data corruption).

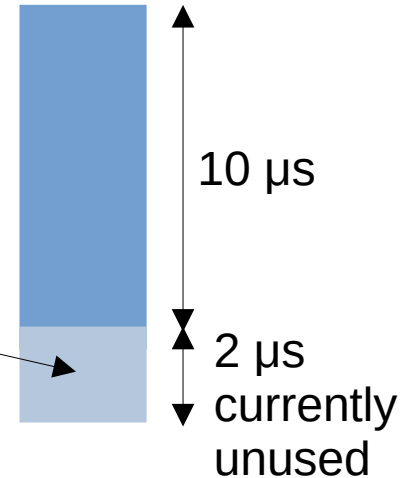
# PMT lifetime

- Not directly a DAQ issue, but critical for future TOP plans
- Integrated charge + heat decreases quantum efficiency
  - lower gain (improve feature extraction)
  - lower temperature (lower power electronics)
- Older PMT types degrade faster than expected
  - Does this also apply to life-extended PMTs? (no degradation seen yet)
- SiPMs studied as alternative
  - No damage from light
  - More noise + need to be colder



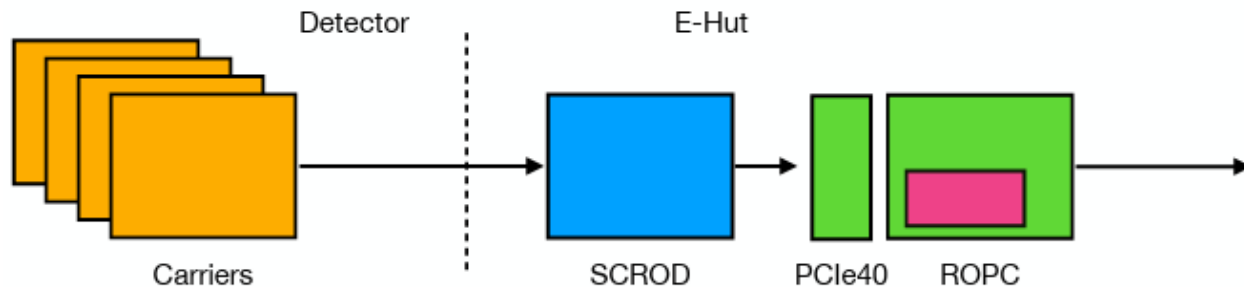
# Before LS2

- $<10\text{ }\mu\text{s}$  (1 rev) max latency from ring buffer in asic
  - Tested  $9\text{ }\mu\text{s}$ , can probably do  $\sim 9.8\text{ }\mu\text{s}$ .
  - *Maybe*  $12\text{ }\mu\text{s}$  with major FW change
- Use spare memory for true deadtimeless readout?
- Trigger rate depends on backgrounds
  - New FW seems to be limited by data rate
  - Large uncertainties in background evolution
- Triggerless readout not possible – can't digitize fast enough
- AI/ML-based feature extraction on ROPC  $\rightarrow$  improved PID
- New HV divider boards (2027-2028)  $\rightarrow$  longer PMT lifetime



# LS2 upgrades

- Full board stack redesign
  - SCROD relocation to radiation-safe area (SEU-resilient system)
  - New carrier board (low-power, higher gain amplifier)
  - New ASICs? (ASoC from Nalu, Open-source ASIC)
- Triggerless readout?
  - Assuming 15 MHz/PMT and 400 bits/hit:  
200 Gbit/s per module, 3 Tbit/s total
  - SiPM: >50 MHz in same area, >10 Tbit/s



LHCb total: 40 Tbit/s

# Summary

- Many issues from radiation and injections seen in 2024c
- Changed feature extraction scheme and fixed firmware bugs
- Need to observe new FW with accelerator running
  - For stability and failure modes. Data quality already verified.
  - Rollback to old FW trivial if needed
- Up to  $\sim 10 \mu\text{s}$  trigger latency is easy with TOP. More is difficult.
- Trigger rate depends on future background conditions.
- Studying LS2 options

# Backup

# TOP data format

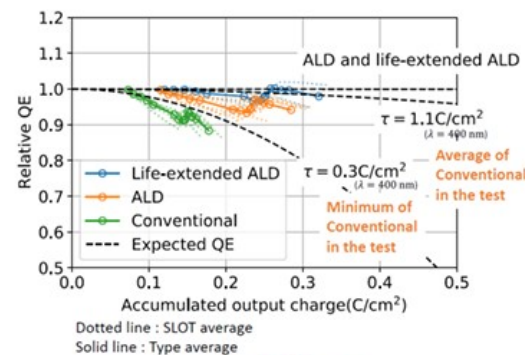
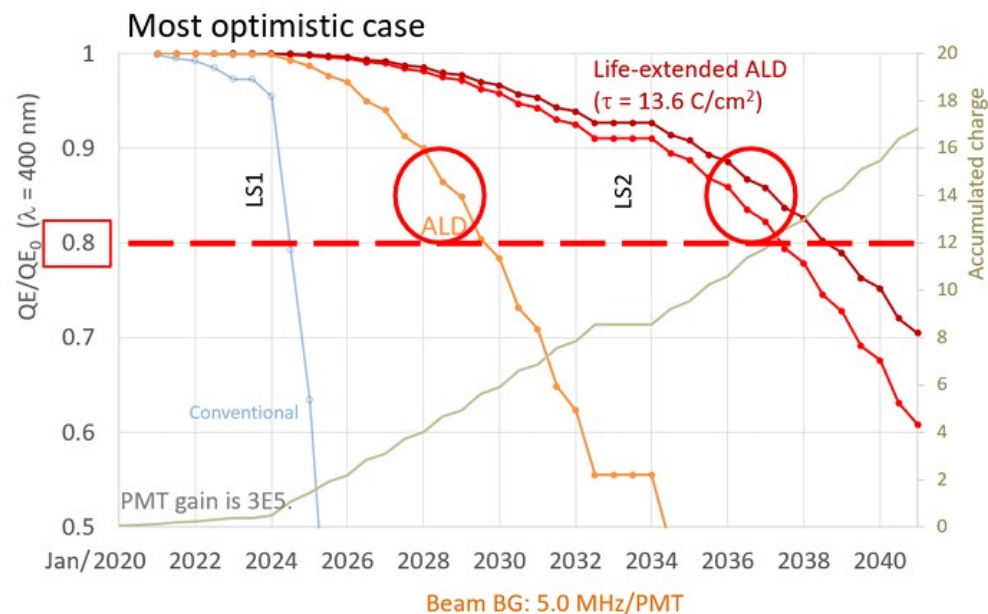
|               | Bits                                       |      |          |         |               |        |                 |    |                 |    |    |    |           |     |               |    |                 |               |    |    |              |    |    |          |                 |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---------------|--------------------------------------------|------|----------|---------|---------------|--------|-----------------|----|-----------------|----|----|----|-----------|-----|---------------|----|-----------------|---------------|----|----|--------------|----|----|----------|-----------------|-----|---------------|----|-------|----|----|----|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| Word          | 31                                         | 30   | 29       | 28      | 27            | 26     | 25              | 24 | 23              | 22 | 21 | 20 | 19        | 18  | 17            | 16 | 15              | 14            | 13 | 12 | 11           | 10 | 09 | 08       | 07              | 06  | 05            | 04 | 03    | 02 | 01 | 00 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 0             | Type (=0x04)                               |      |          |         |               |        |                 |    | Version (=0x02) |    |    |    |           |     |               |    | 0xA             |               |    |    | SCROD_ID     |    |    |          |                 |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1             | EXTRA                                      |      |          |         | NumWordsBonus |        |                 |    |                 |    |    |    |           |     |               |    | Phase(0-8)      |               |    |    | NumWordsCore |    |    |          |                 |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2             | SK                                         | INJ  | PSBypass |         |               |        | ctime (11 LSBs) |    |                 |    |    |    |           |     | Revo9 Counter |    |                 |               |    |    |              |    |    |          |                 |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 3             | ASIC Masks (TimeoutMasks   Register Masks) |      |          |         |               |        |                 |    |                 |    |    |    |           |     |               |    | eventQueueDepth |               |    |    |              |    |    |          | eventNumberByte |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 4             | Carr                                       | IRSX |          | Channel |               | Window |                 |    |                 |    |    |    |           | 0xB |               |    |                 | tFine         |    |    |              | W  | SB | Integral |                 |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 5             | vPeak                                      |      |          |         |               |        |                 |    |                 |    |    |    |           |     |               |    | H/v             | Heap Window 1 |    |    |              |    |    |          |                 | H/v | Heap Window 0 |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 6             | vRise0                                     |      |          |         |               |        |                 |    |                 |    |    |    |           |     |               |    | vRise1          |               |    |    |              |    |    |          |                 |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 7             | vFall0                                     |      |          |         |               |        |                 |    |                 |    |    |    |           |     |               |    | vFall1          |               |    |    |              |    |    |          |                 |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 8             | SampleRise                                 |      |          |         |               |        |                 |    | dSampPeak       |    |    |    | dSampFall |     |               |    | HeaderChecksum  |               |    |    |              |    |    |          |                 |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|               |                                            |      |          |         |               |        |                 |    |                 |    |    |    |           |     |               |    | ...             |               |    |    |              |    |    |          |                 |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| N*(5+EXTRA)+1 | SD_type                                    |      |          |         |               |        |                 |    | Slow data       |    |    |    |           |     |               |    |                 |               |    |    |              |    |    |          | 1 0 1           |     |               |    | Nhits |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Raw waveforms |                                            |      |          |         |               |        |                 |    |                 |    |    |    |           |     |               |    |                 |               |    |    |              |    |    |          |                 |     |               |    |       |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

# Feature extraction code revisions

| Version | What's included                                                                                                                                                                                                                                                                                                                                 |
|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1       | <ul style="list-style-type: none"><li>• Core feature extraction</li><li>• Reformatting of data</li></ul>                                                                                                                                                                                                                                        |
| 2       | <ul style="list-style-type: none"><li>• ... version 1</li><li>• Pedestal subtraction for a single BS</li><li>• Noise reduction based on a constant threshold value</li></ul>                                                                                                                                                                    |
| 3       | <ul style="list-style-type: none"><li>• ... version 1</li><li>• Pedestal subtraction for all BS</li><li>• Noise reduction based on a constant threshold value</li></ul> <b>Suitable for physics runs</b>                                                                                                                                        |
| 4       | <ul style="list-style-type: none"><li>• ... version 3</li><li>• Possible to readout raw waveforms</li><li>• Switched to binary pedestal data files loaded in parallel at run start</li><li>• Register-based control for attaching raw waveforms, carrying out pedestal subtraction, etc.</li></ul> <b>Suitable for local &amp; physics runs</b> |

See talk by Harsh in the TOP parallel session, 52<sup>nd</sup> B2GM

- Estimated with lifetime obtained in the test bench
  - Note that PMTs show faster degradation.
- Will replace ALD PMTs in 2028-2029, life-extended ALD PMTs in 2036-2037
  - In most optimistic case.
  - Need additional budget for later PMTs.
    - ~320 PMTs for all life-extended.



K. Inami  
TOP parallel session  
of Feb 2025 B2GM

