INSTRUMENTATION
TECHNOLOGIES

LIBERA

Libera BLM – Calibration feature updates

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CONTENTS

- Introduction:
  - Beam losses and beam loss monitors
  - **LIBERA** BLM and BLD instruments
- Non-idealities and calibration
  - PMT calibration
  - Detector gain compensation
  - Attenuators cascade error
  - Individual factors switches
- Radiation source calibration

Introduction: beam losses and BLMs

Beam losses:

- Beam deviates from trajectory -> damage
- Not always avoidable

Source: DESY

Beam loss monitors:

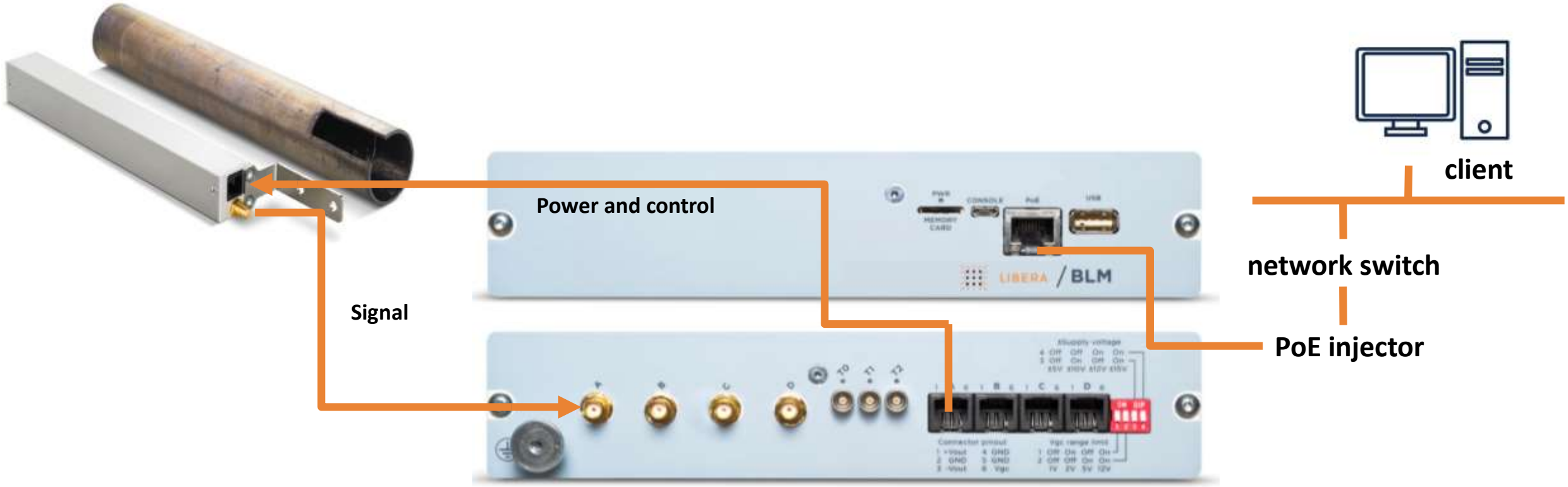
Purpose:

- Machine protection - interlock
- Diagnostics and troubleshooting

Features:

- High sensitivity (single particles)
- Wide dynamic range of loss pulse amplitudes
- Fast sampling and processing: turn-by-turn, injection losses
- Allow monitoring of slow changes in background radiation
- Output signal proportional to beam current

Introduction: Libera BLM and BLD



LIBERA BLD (detector): 4X

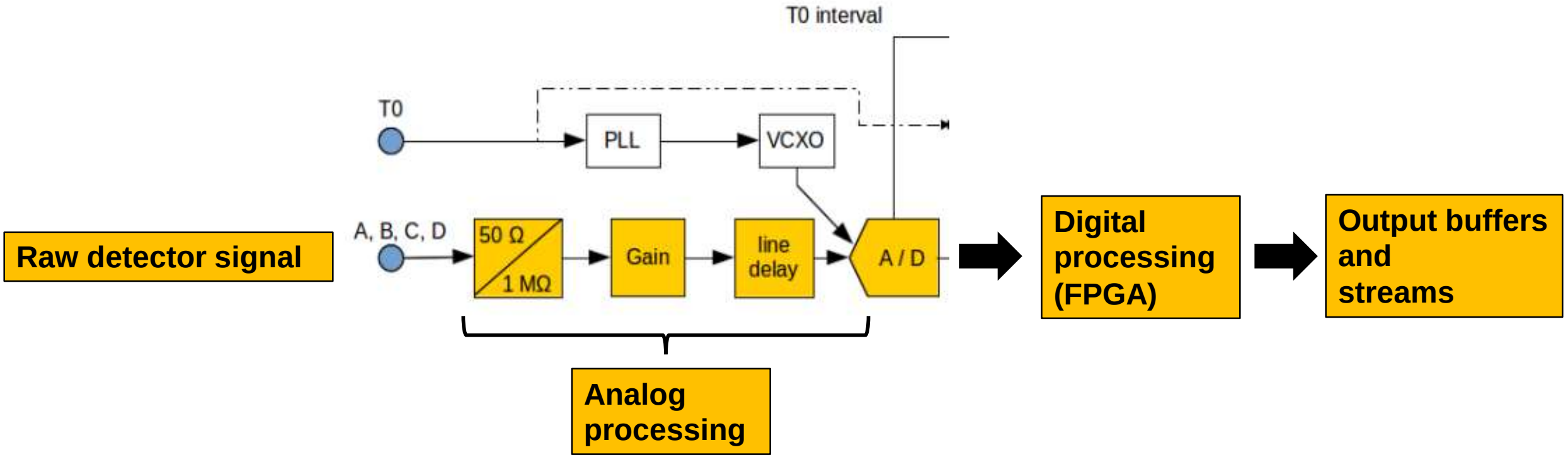
Working principle	Scintillator + photomultiplier tube
Sensitivity	High (gamma, X-ray, e-, p+, n0 ...)
Response time	< 1 ns
Power, control	Directly from LIBERA BLM

LIBERA BLM (processing electronics)

Hardware	125 MHz@14 bit ADC, Zynq FPGA+CPU
Features	Counting modes, processed buffers (SUM, AVG, INT), PM buffer, interlock output
Adjustability	termination, attenuation, detector gain

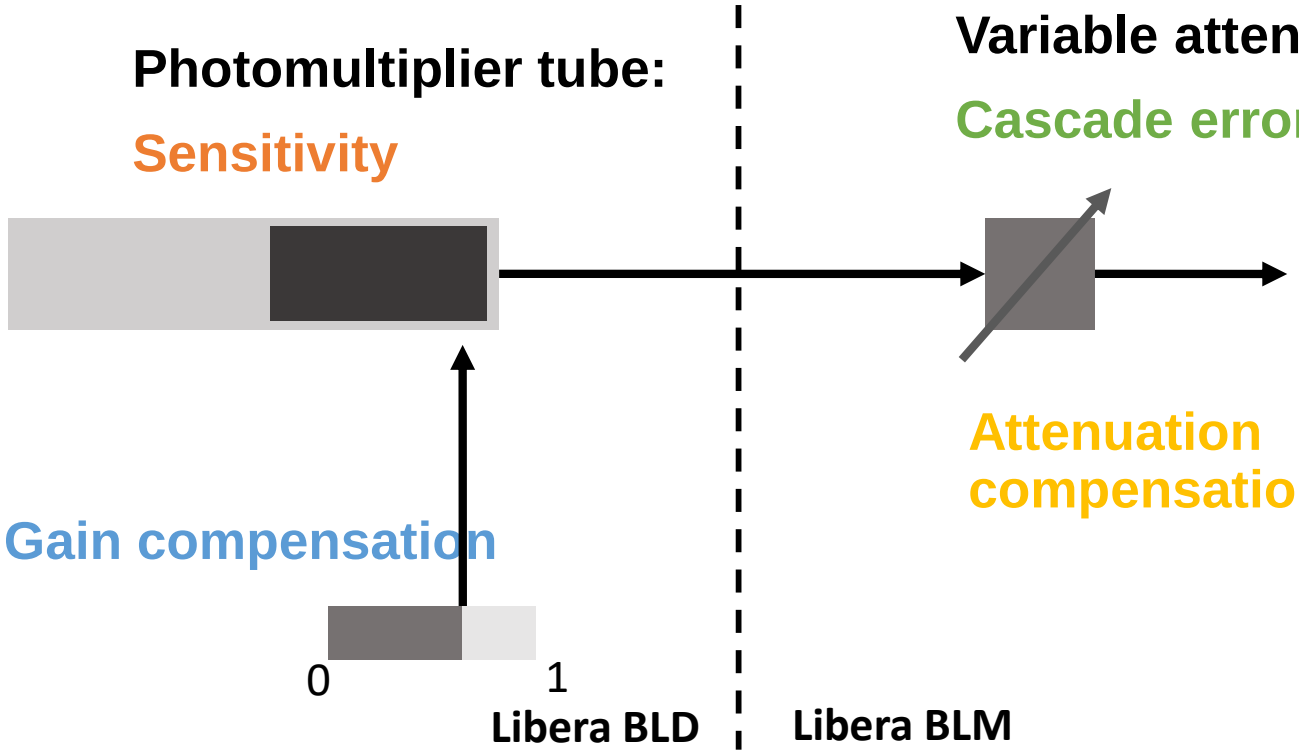
CALIBRATION: high level

Analog signal path



CALIBRATION: high level

Non-idealities chain:



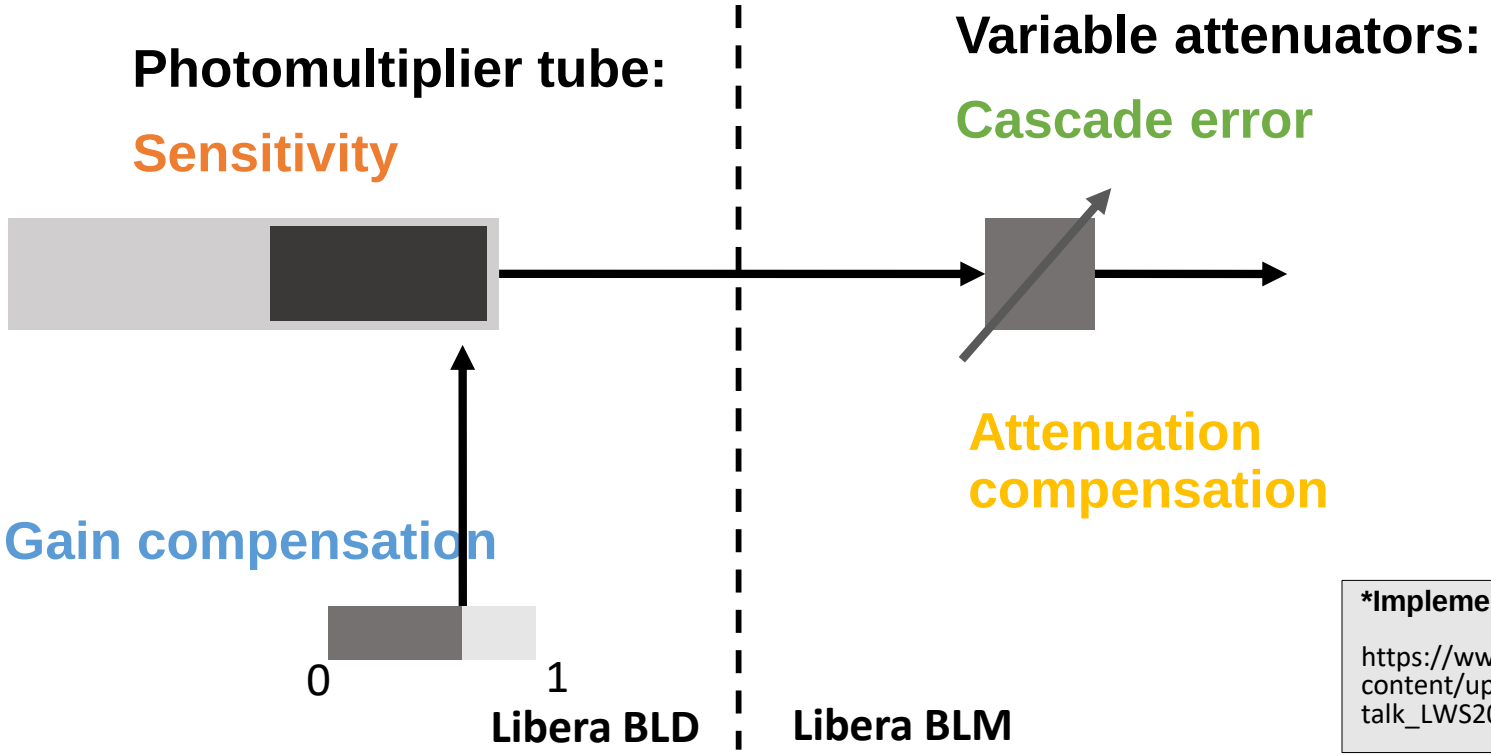
***assumption:** scintillators are a negligible source of discrepancy

CALIBRATION: high level

Calibration: enabling the same output level regardless of non-idealities

Built-in*: $A_{cal} = A_{raw} \times BLD_{Calib} \times G \times AT \times ATT_{Calib}$ ON/OFF → buffers, streams

Non-idealities chain:



***assumption:** scintillators are a negligible source of discrepancy

***Implemented according to user experience:**

https://www.i-tech.si/wp-content/uploads/2020/06/Nicolas-Hubert-talk_LWS2020-compressed.pdf

CALIBRATION: PMT

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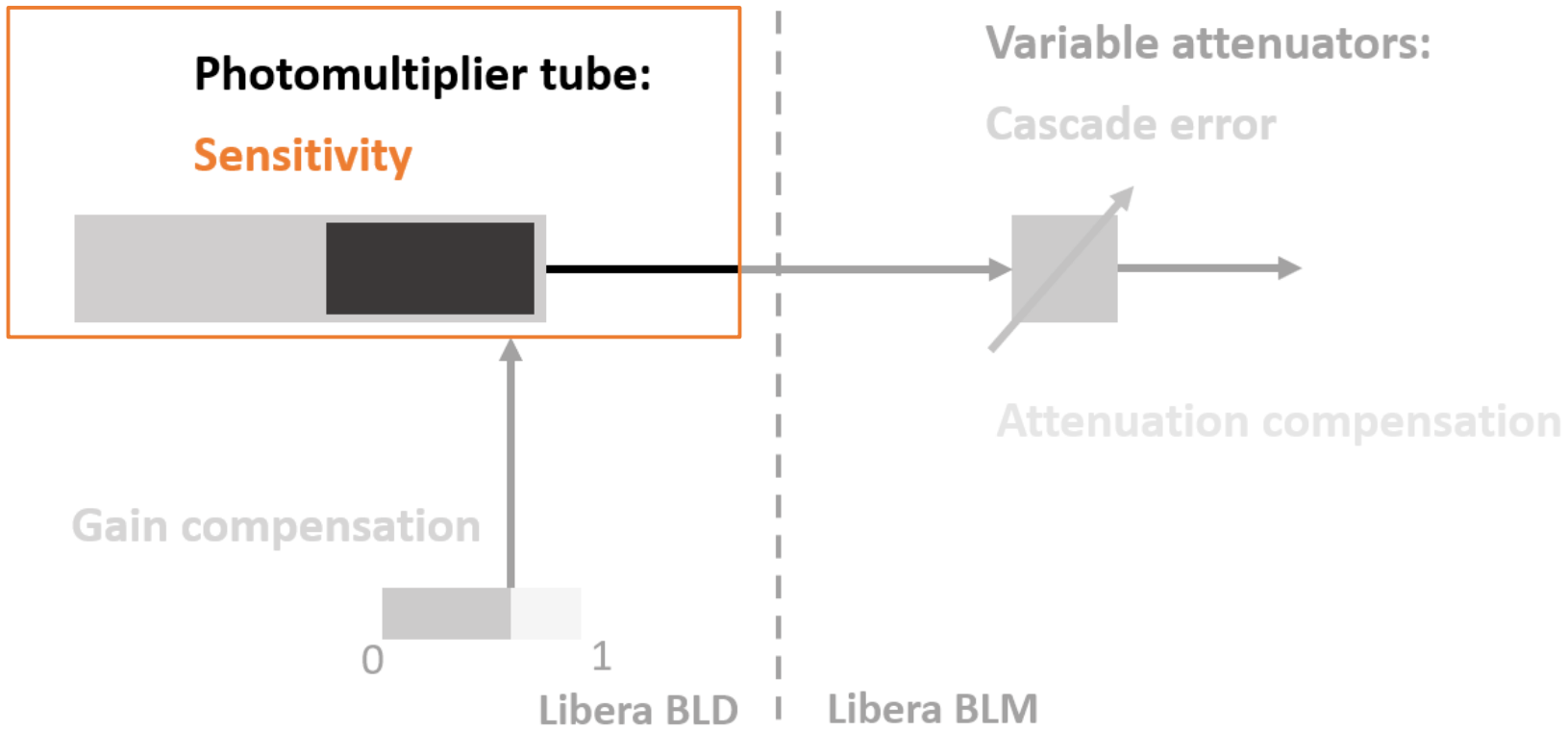
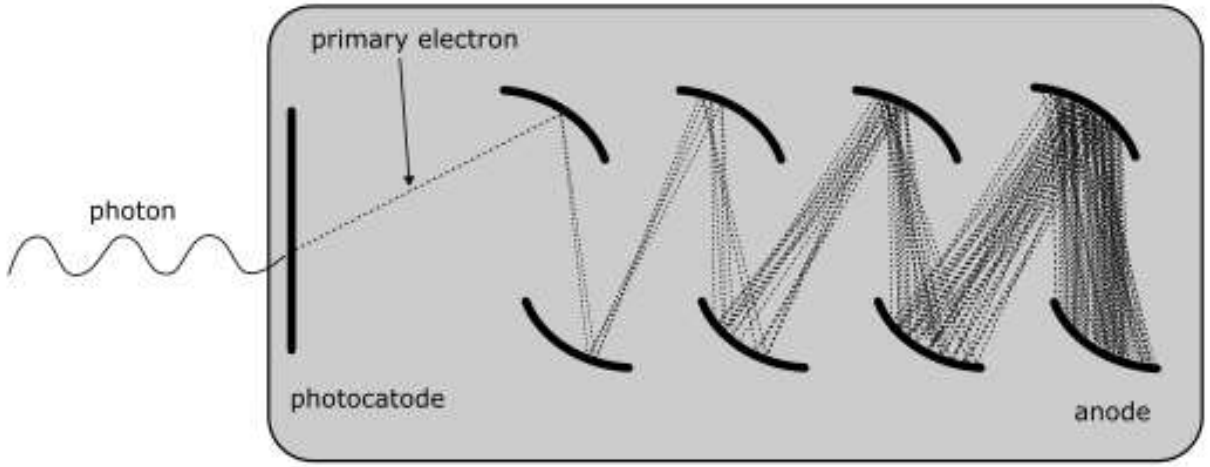
Non-idealities chain:



CALIBRATION: PMT

Photomultiplier tubes:

- Different PMTs (same model, same input) -> different output signal level
- Reason: PMT amplification principle
- PMT output level: linearly proportional to *anode luminous sensitivity* parameter



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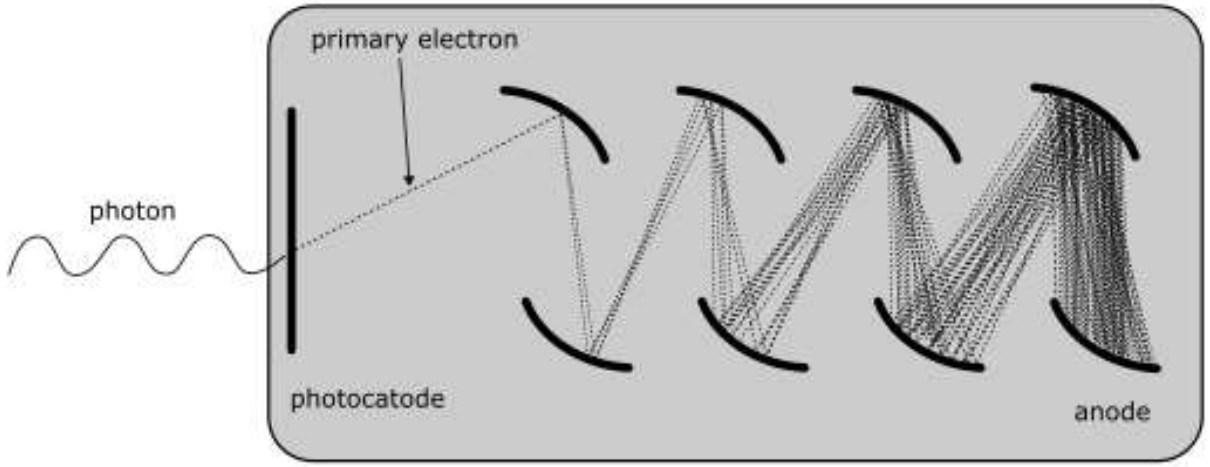
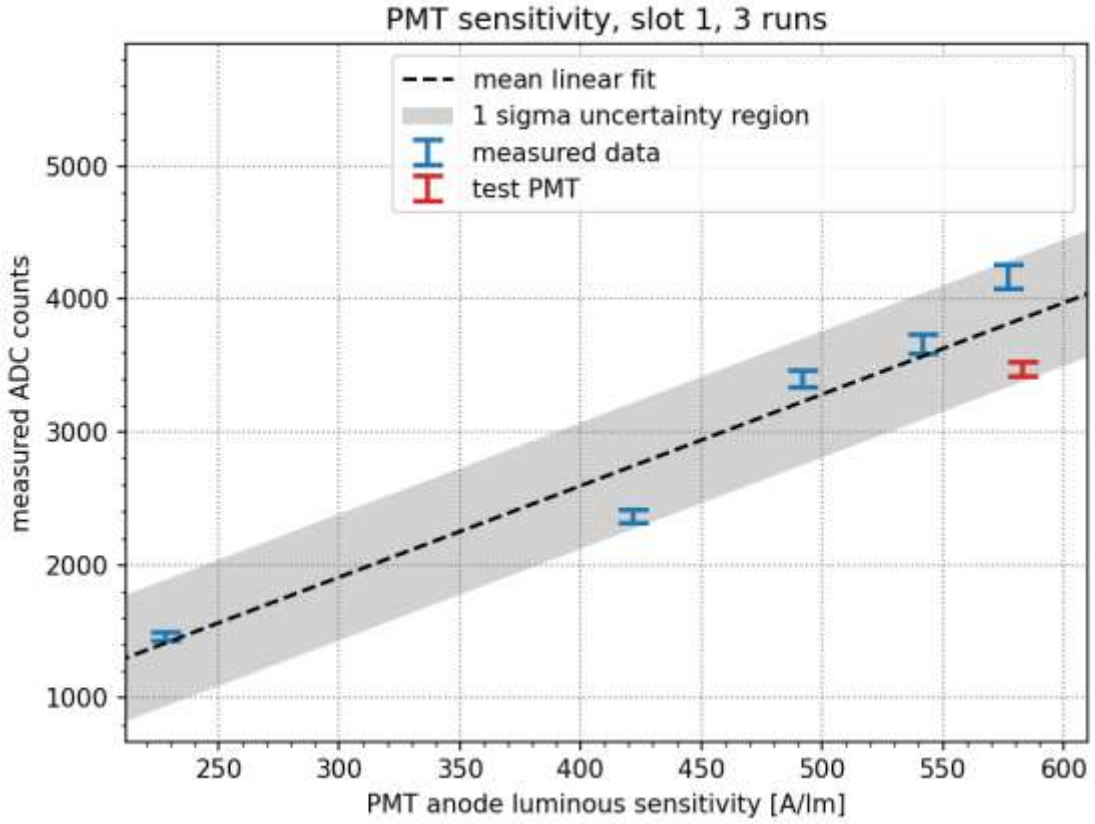


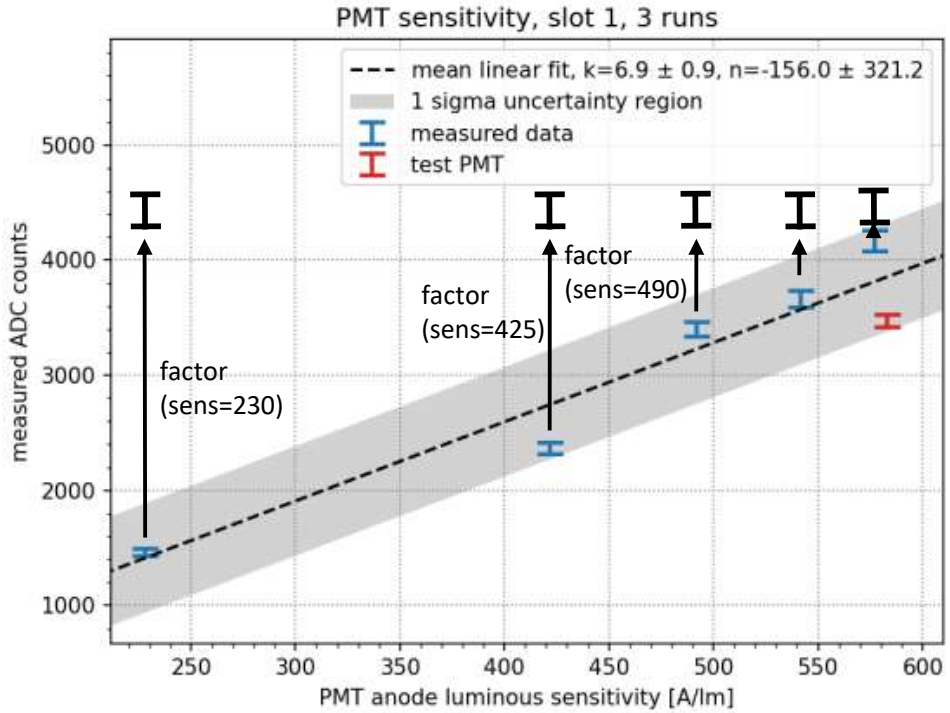


Experimental linear dependence:
sensitivity – output signal level

CALIBRATION: PMT

Calibration factor:

- Output from each PMT multiplied by its dedicated factor -> all PMTs outputs on the same level
- **Factor (PMT_i)** = reference/ **measured** output level
- No need to measure, can use linear dependence on sensitivity



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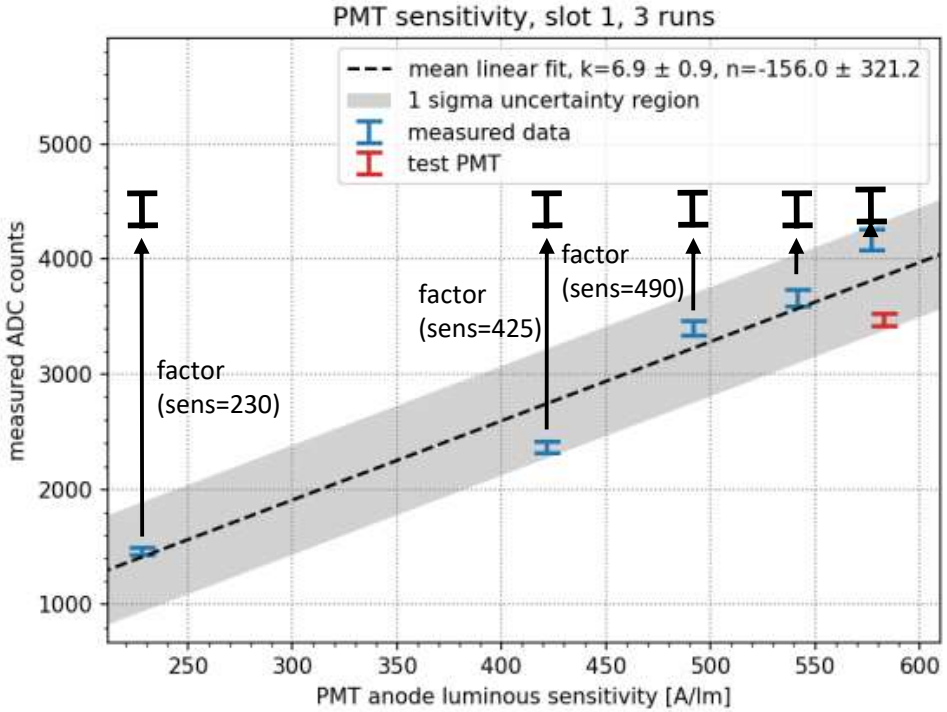
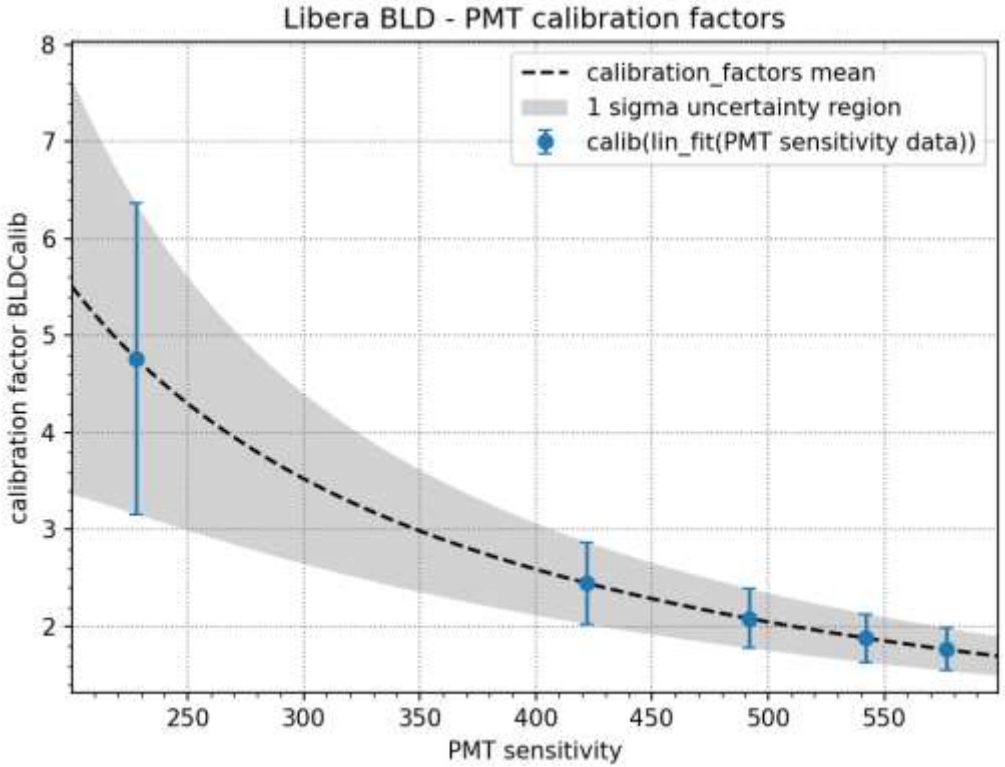


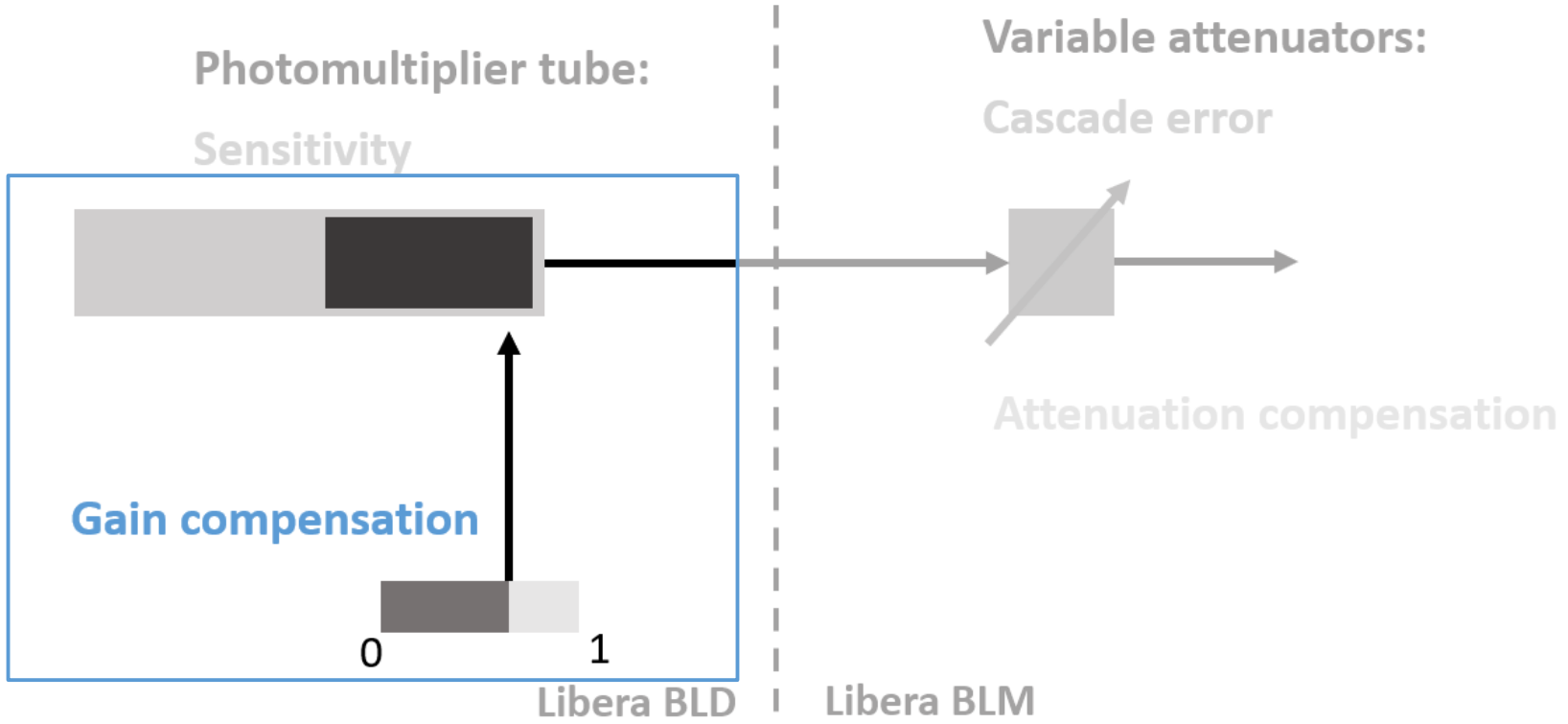


New: *BLD_{Calib}* factor proposed during factory acceptance test for each Libera BLD and listed in the test record

CALIBRATION: Gain compensation

Built-in: $A_{cal} = A_{raw} \times BLD_{Calib} \times G \times AT \times ATT_{Calib}$ ON/OFF → buffers, streams

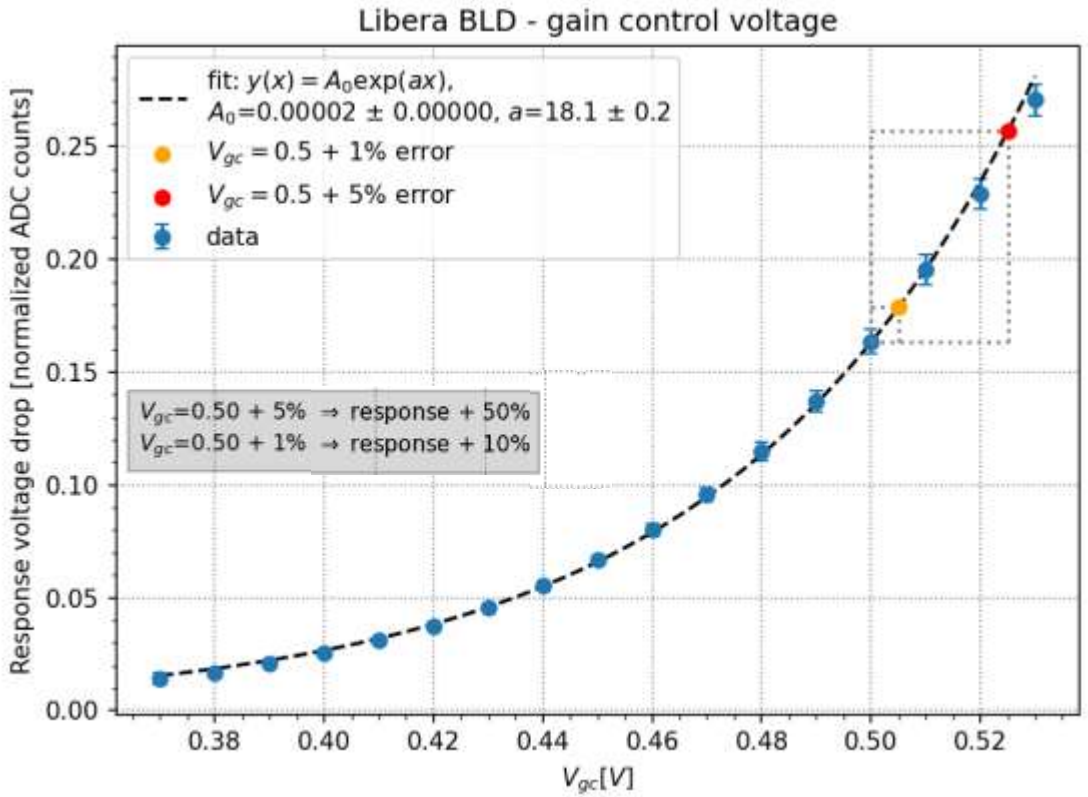
Non-idealities chain:



CALIBRATION: Gain compensation

PMT gain control voltage

- Exponential effect on the output level



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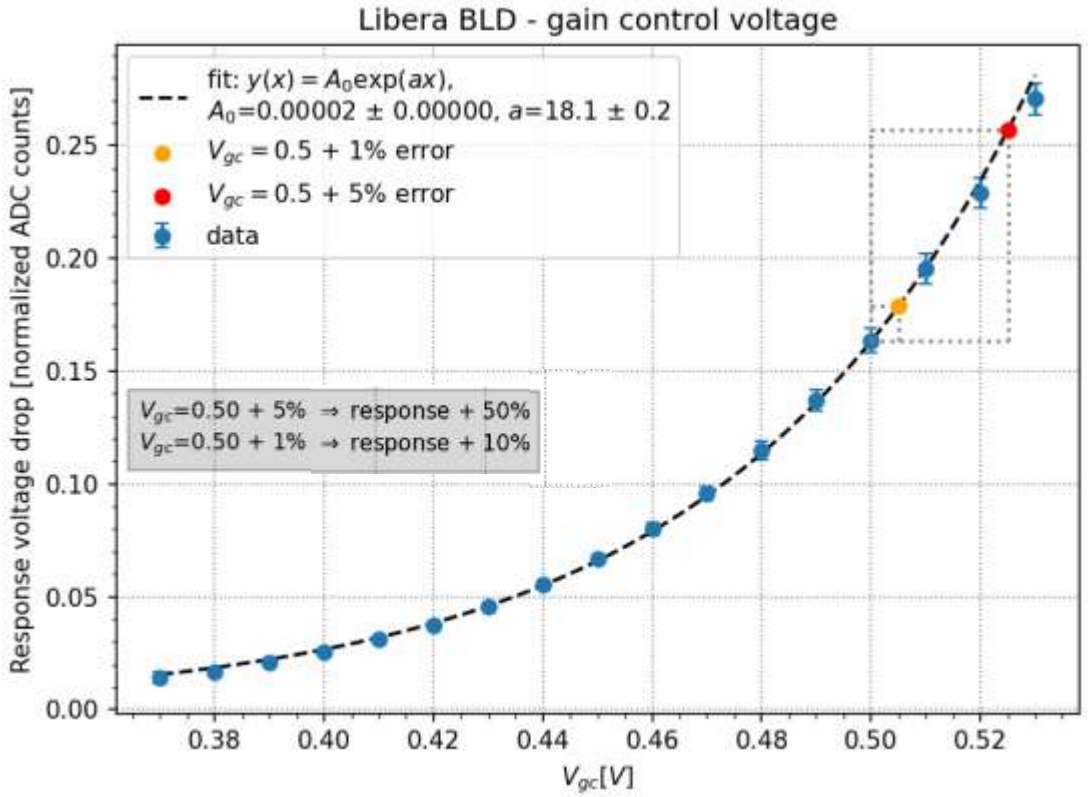

Look-up table: rough resolution

Vgc ref	0.00	0.30	0.40	0.50	0.60	0.70	0.80	0.90
G	NaN	334.5	33.25	4.97	1	0.26	0.0825	0.0313

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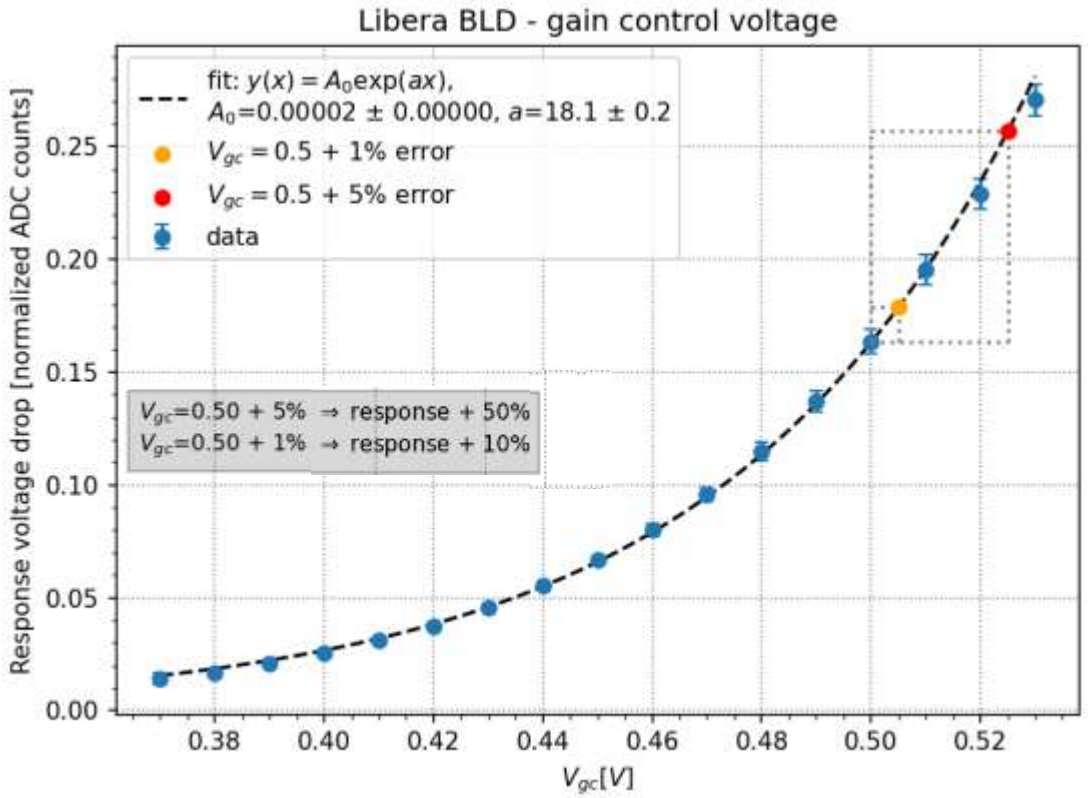

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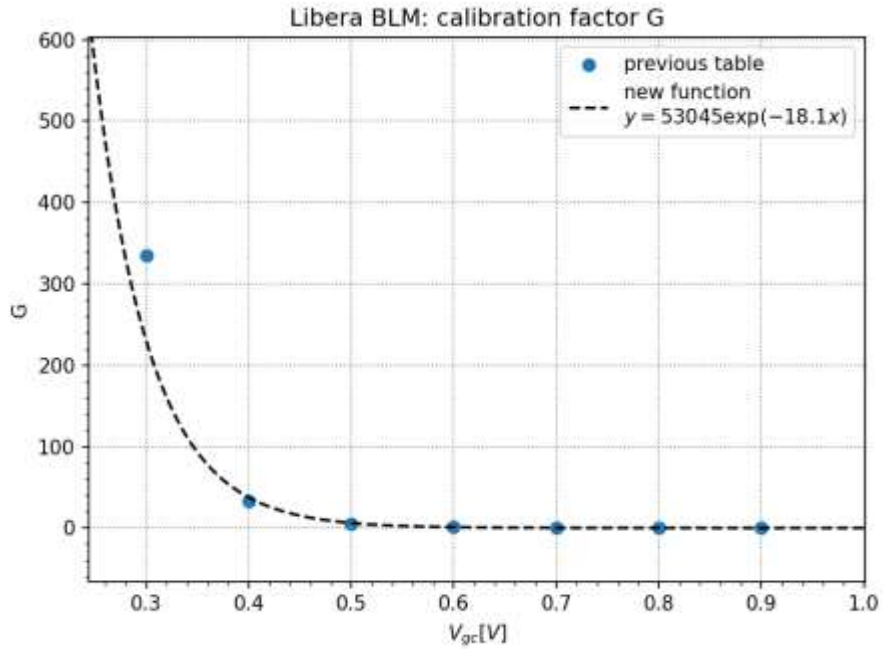
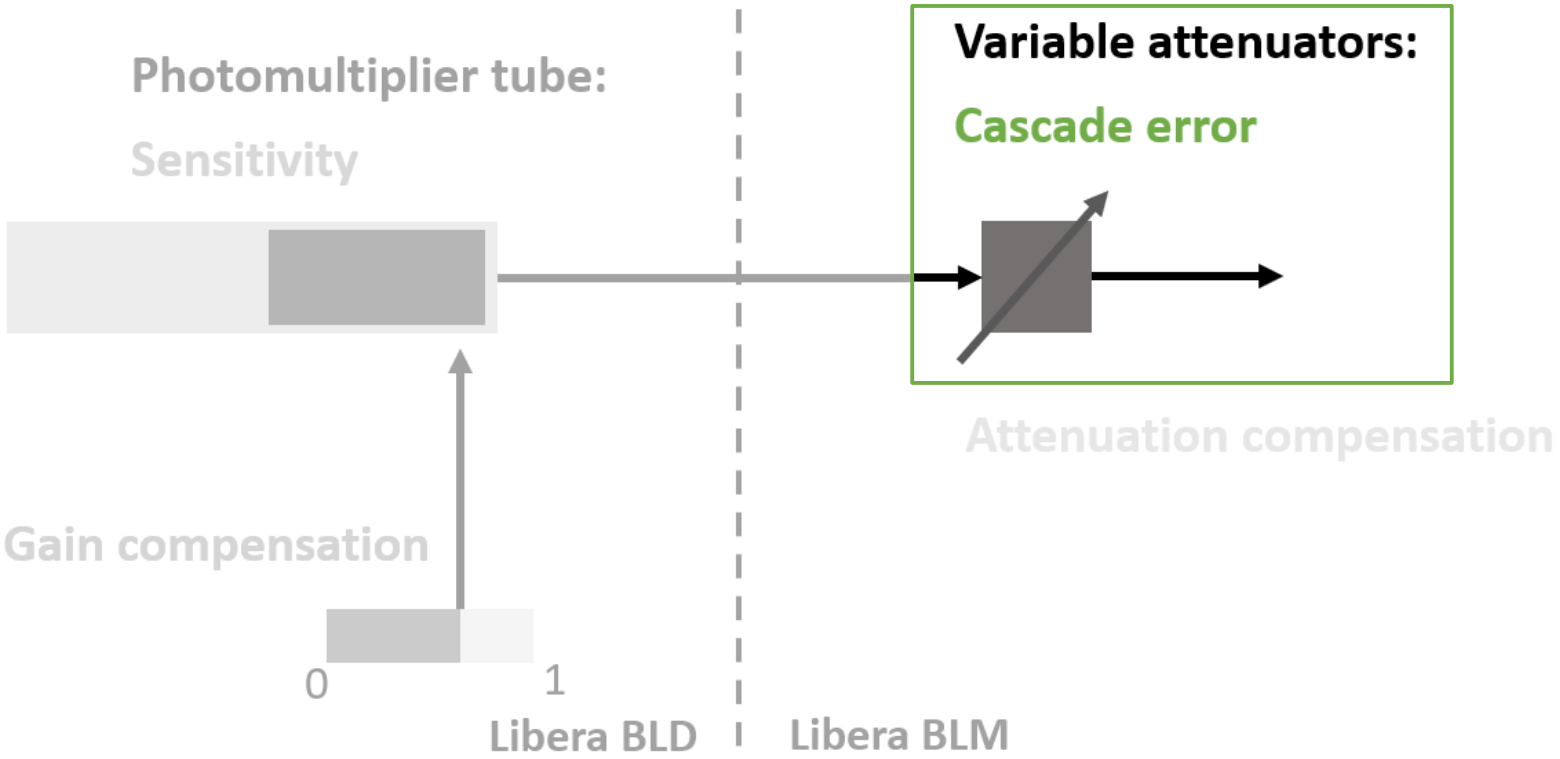
New: Look-up table for **G** replaced by a continuous function



CALIBRATION: Attenuator cascade error

Built-in: $A_{cal} = A_{raw} \times BLD_{Calib} \times G \times AT \times ATT_{Calib}$ ON/OFF → buffers, streams

Non-idealities chain:

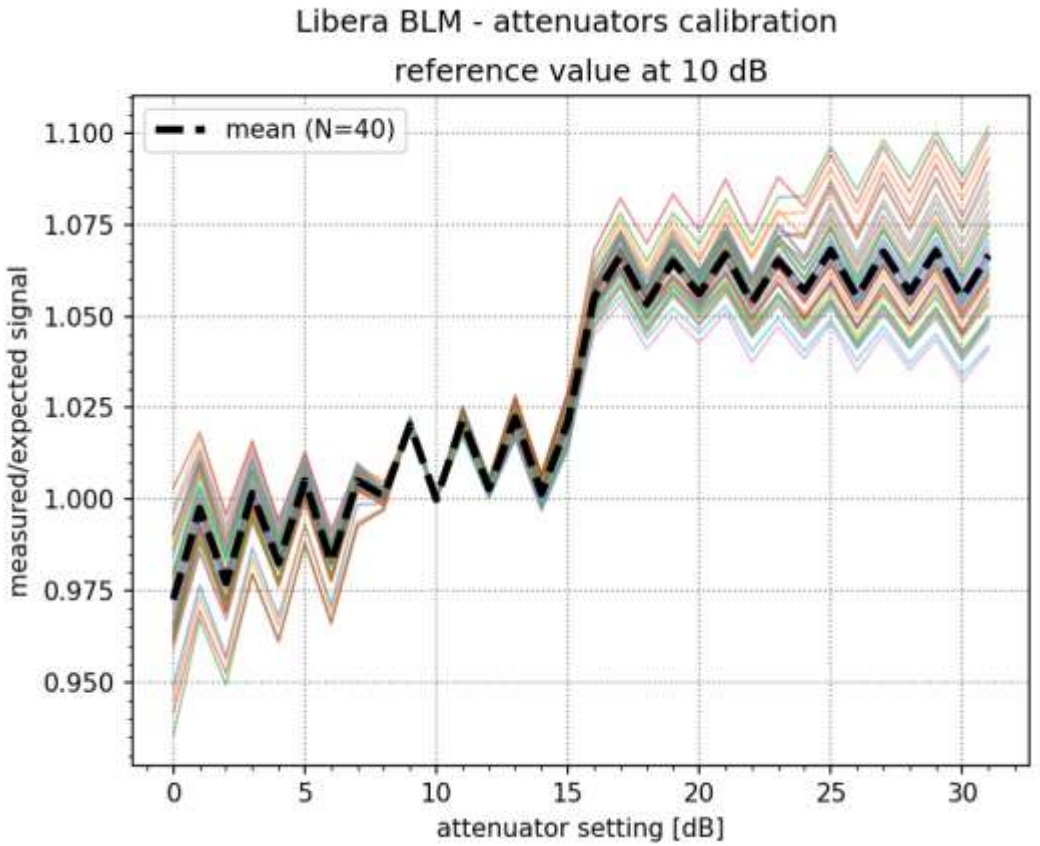


CALIBRATION: Attenuator cascade error

32 dB attenuator combines 5 smaller attenuators:

- **1 dB + 2 dB + 4 dB + 8 dB + 16 dB**

  (each can be ON/OFF)
- Combinations allow setting all values from 1 dB to 31 dB
- Constituent attenuators are periodically turned ON/OFF – saw pattern.
- Most attenuators behave similarly



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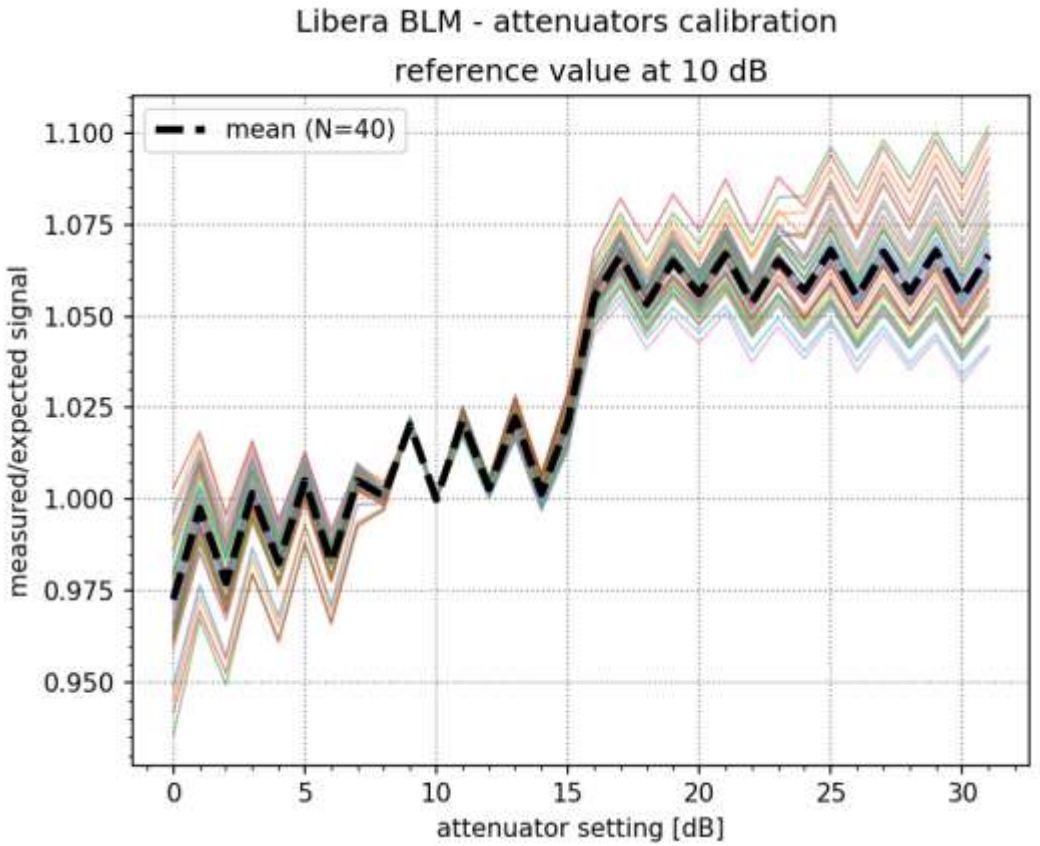

Built-in calibration table:

- Signal multiplication factor for each att setting
- Currently: placeholders for user-custom compensation of cascade error

```
att_calib_factor
  A=[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]
  B=[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]
  C=[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]
  D=[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]
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ON/OFF → buffers, streams

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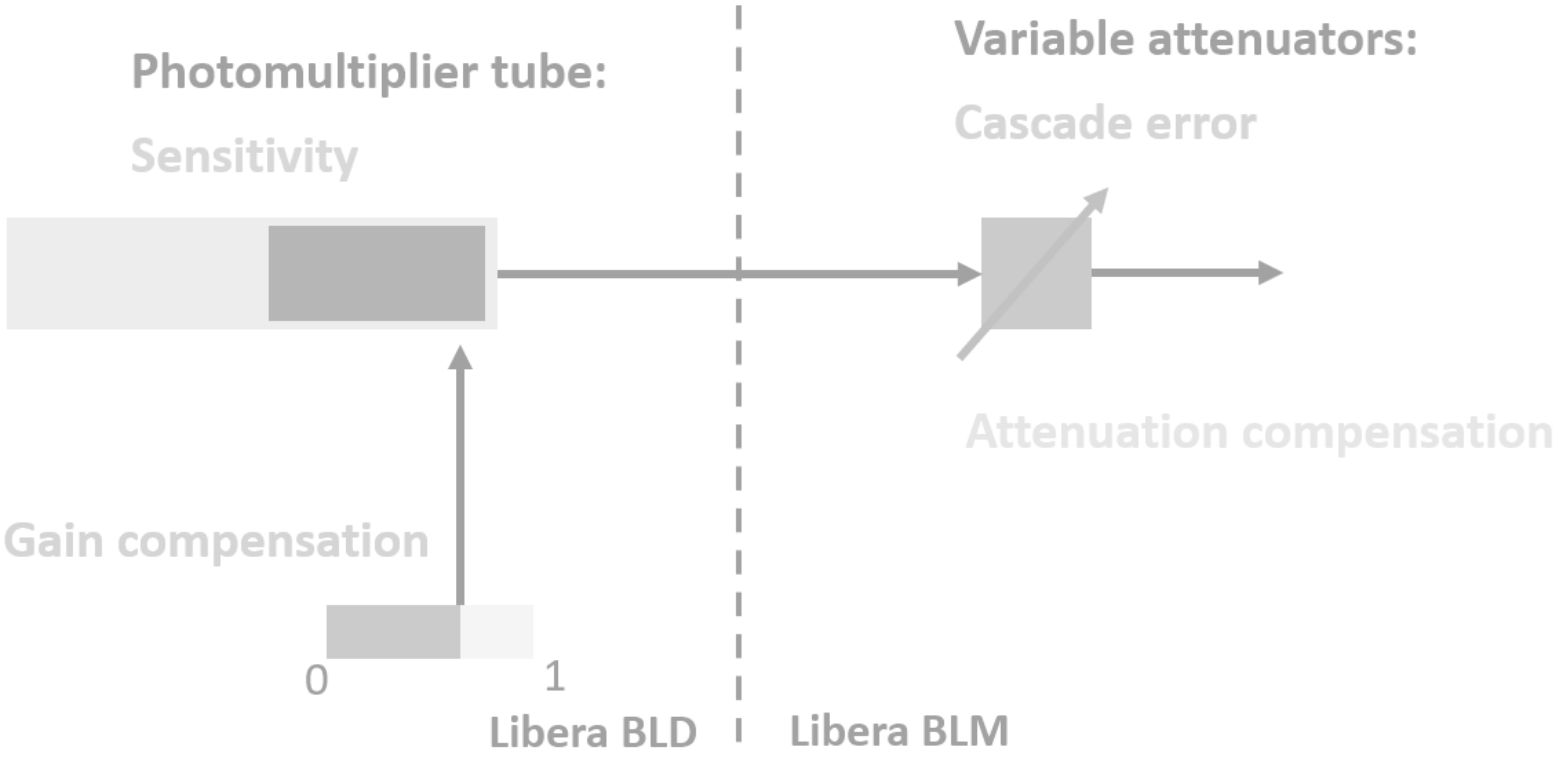

CALIBRATION: Individual factors on/off

$$A_{cal} = A_{raw} \times BLD_{Calib} \times G \times AT \times ATT$$

ON/OFF

Calibration is either fully OFF or fully ON (all factors):

- If ON, the outputs from all detectors are always in the same scale
- Makes 100% sense for BLD_{Calib} and ATT_{Calib} (**calibration** of discrepancies)
- Not necessarily needed for G and AT (**compensation** of gain and attenuation)

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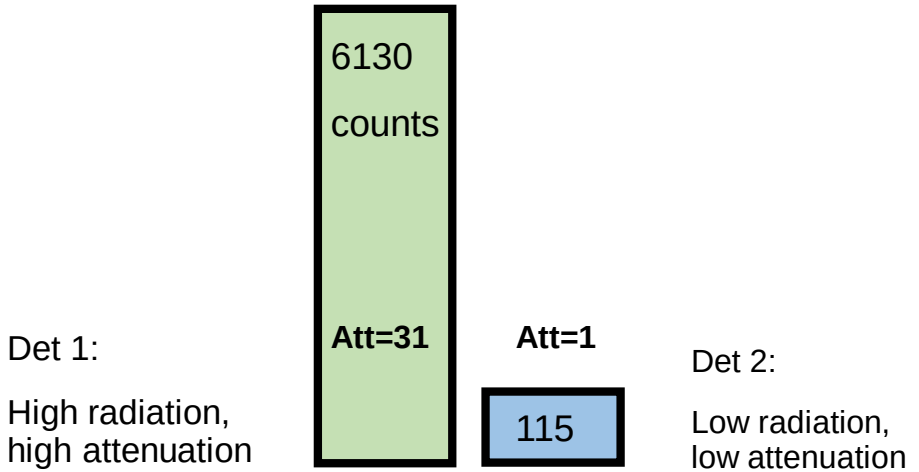

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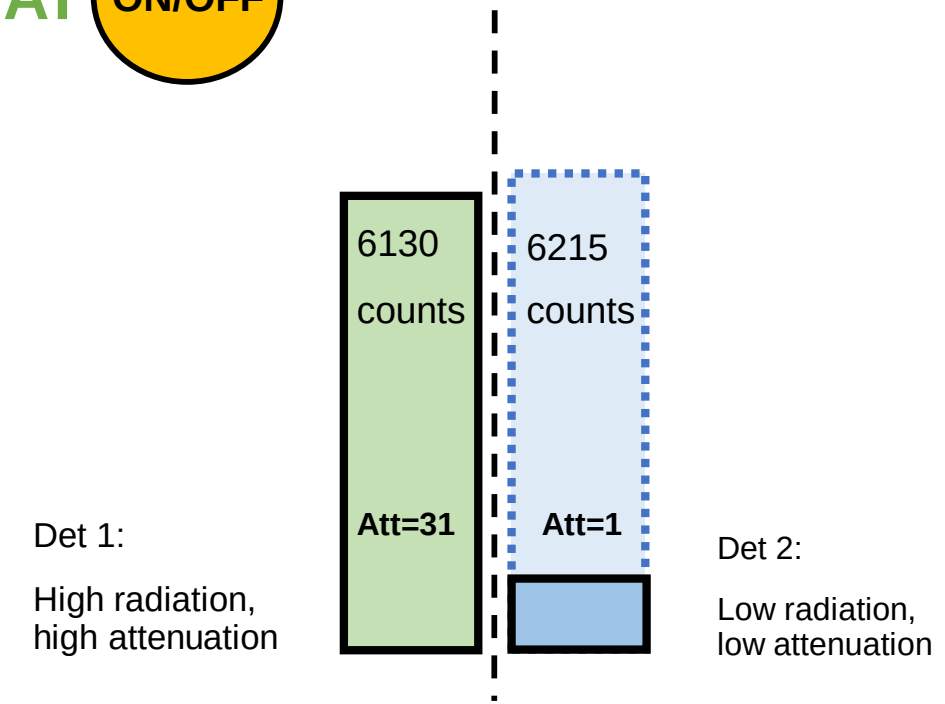
  - Use case 2: each detector "lives in its own world" - no need for comparison between them – ***no need for compensation***



CALIBRATION: Individual factors on/off

ON/OFF ON/OFF ON/OFF ON/OFF

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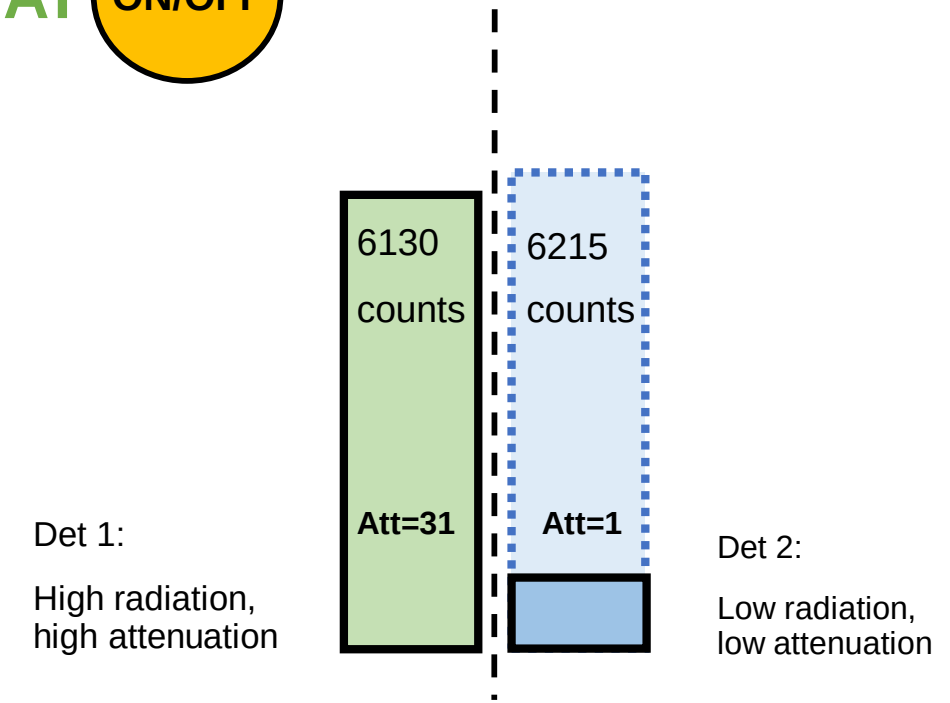

New:

Allow both options to increase flexibility:

Individual factors **on/off**

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- Non-idealities and calibration
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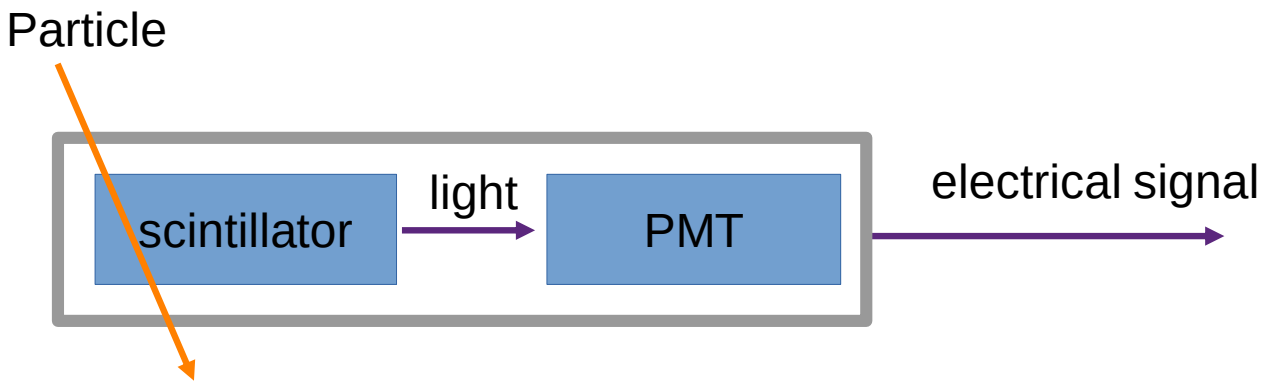
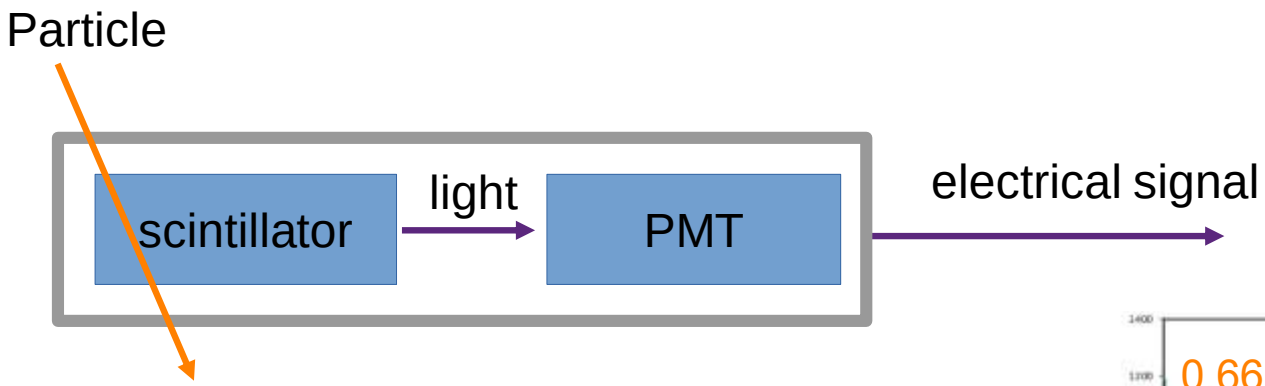
  - Attenuators cascade error
  - Individual factors switches
- Radiation source calibration

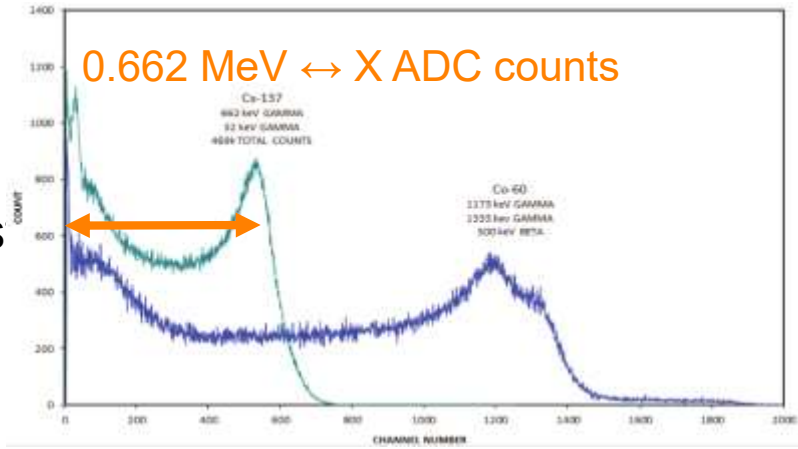
CALIBRATION: radiation source: *currently verifying*



- PMTs (main source of inconsistency): tested and calibrated at I-Tech
- Scintillator: tested with cosmic background, not calibrated (because most of discrepancy comes from PMTs)

CALIBRATION: radiation source: *currently verifying*





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“Classroom” radiation source:

Once the calibration scheme is validated:

- Could provide complete system calibration at I - Tech
- Offered as an extra service

	anode luminous sensitivity (A/lm)	proposed BLDCalib factor (PMT only)	Cs-137 0.662 MeV from histogram [ADC counts]	Proposed BLDCalib (based on Cs-137)
REF	500	100	7001	100
1	189	286	2414	290
2	124	471	1521	460
3	612	81	7600	92

CONCLUSION

- Beam loss monitoring – Libera BLM and Libera BLD
- Calibration:
    - Calibration of PMTs: **in factory**
    - Attenuators non-linearity: **factory default**
    - Gain control: **continuous function**
    - Individual factors: **on/off switches**
    - Radiation source: **full system calibration** in the future

QUESTIONS FOR THE AUDIENCE

- How do you use **LIBERA** BLM + BLD?
    - Raw data/buffers/counting?
    - Fast/slow losses?
    - Interesting results?
- Calibration experience?
    - UV LED vs radiation source?
- Ideas for new functionalities?
- Problems?

Thank you!

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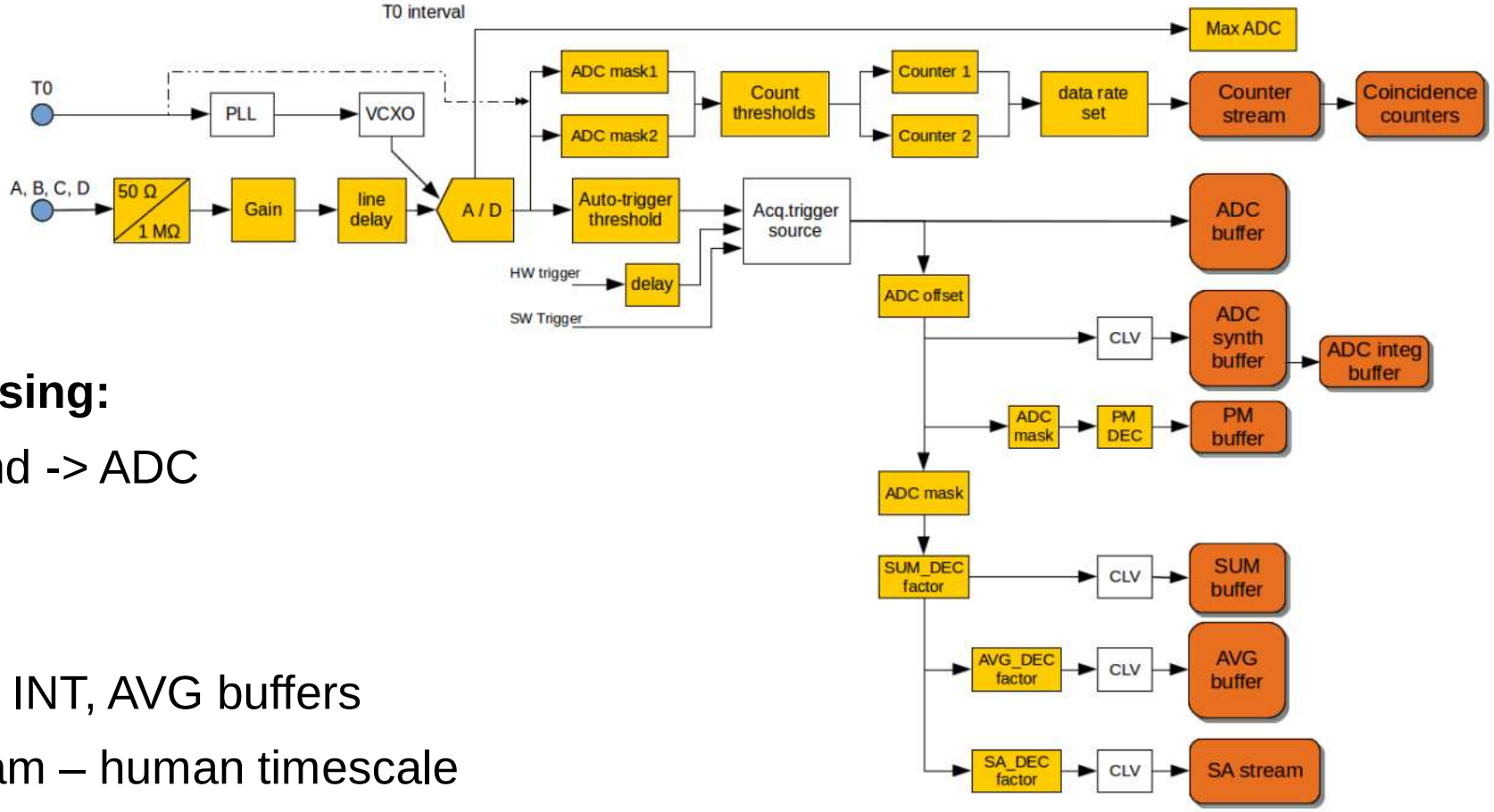
Extra slide: processing functionalities

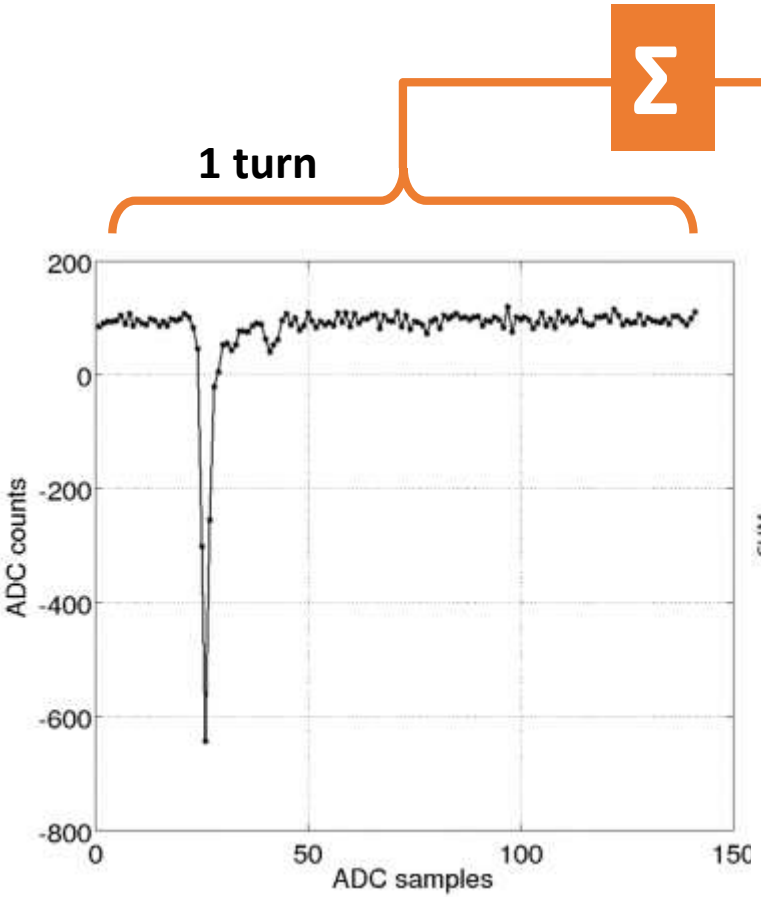
Built-in fast signal processing:

- Input -> analogue front end -> ADC
- Outputs:
  - Raw ADC buffer
  - Offset removal, SUM, INT, AVG buffers
  - Slow acquisition stream – human timescale
  - Loss counting modes

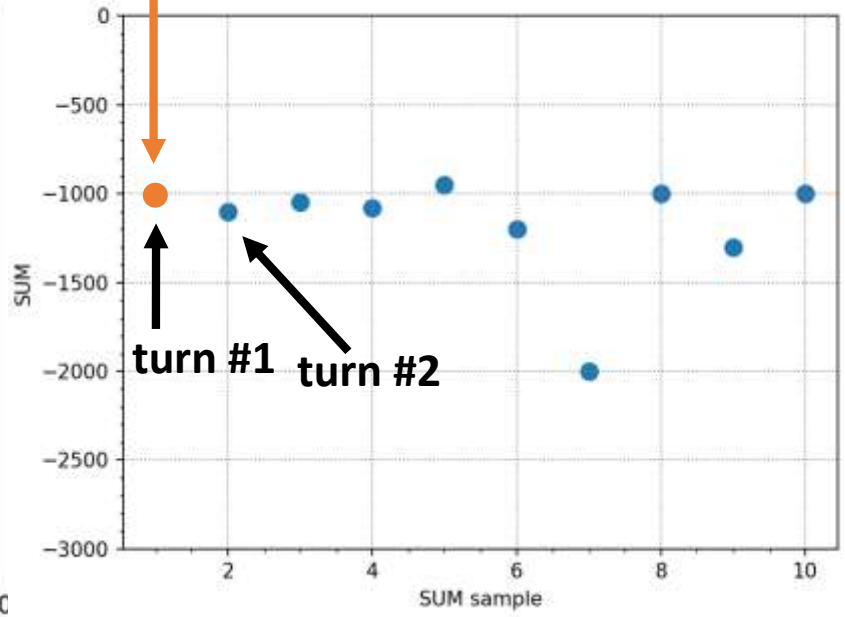


Full processing scheme

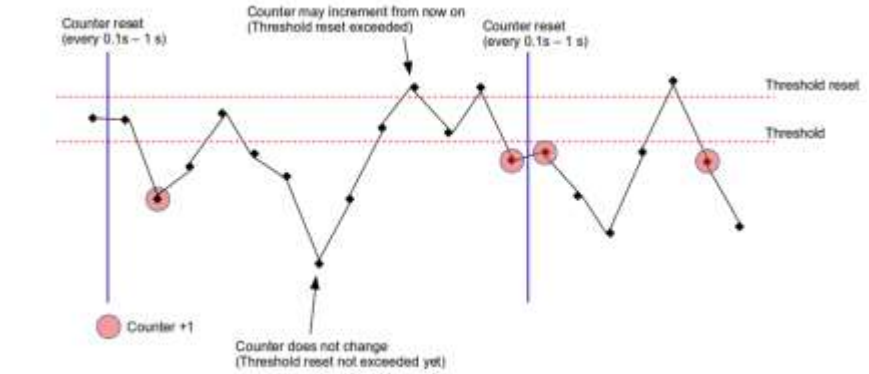
Extra slide: processing and measurement examples

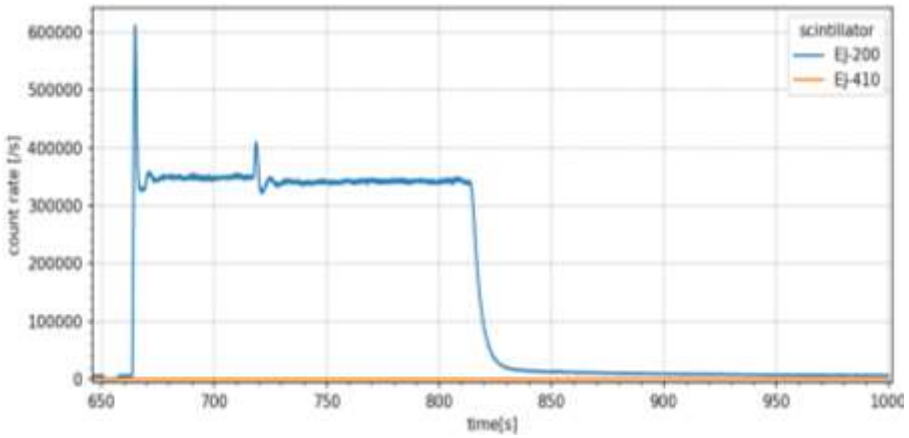


Raw data: typical loss shape (very fast)



SUM buffer: turn-by-turn





Counting mode

Extra slide: exponential gain mechanism

„a“ is the same for all PMT‘s:
Tested experimentally, but it also makes sense because if gain control is described with
Out = A0 * exp(a * Vgc),
a represents the exponential gain mechanism and A0 is just a factor that scales the input value.