Final design of the luminosity monitor in TAXN and experience with prototype detector during Run3

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BRAN

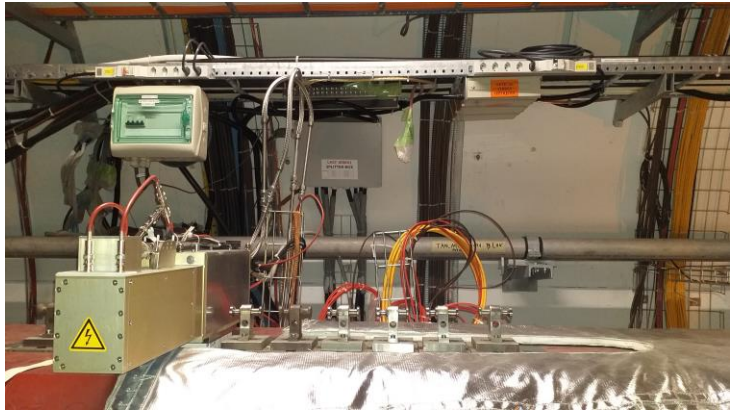
- Beam Rate of Neutrals measures rate of collision products i. e. *relative luminosity.*
- Use case:

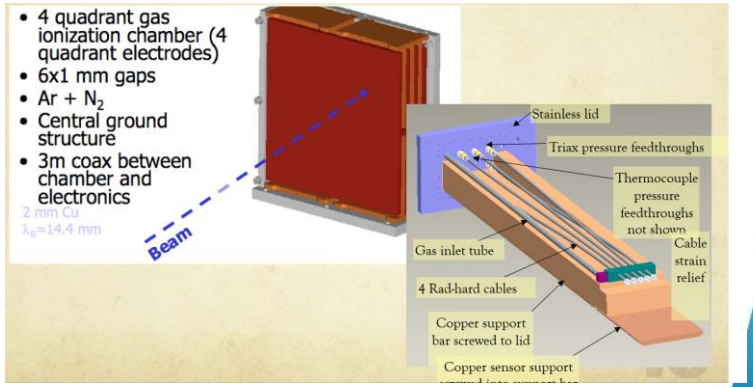
> "Standardized, simple, fast and robust machine luminometers are provided to set up the machine for physics and optimize its performance based on counting rates", BRANs functional specs, EDMS 347396, 2004

- BRANs are installed since Run 1 on both sides of all LHC experiments

BRAN types

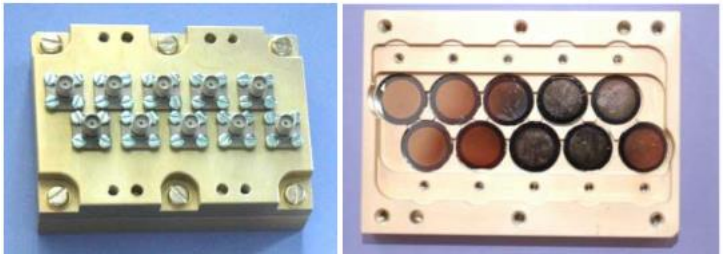
- **BRAN-A**: based on fast ionization gas chambers, developed by LBNL.
- Installed in IP1 & 5 during LHC Runs 1 & 2.
- Replaced by D-type during in 2022 (1R, 5L) and 2023 (1L, 5R)





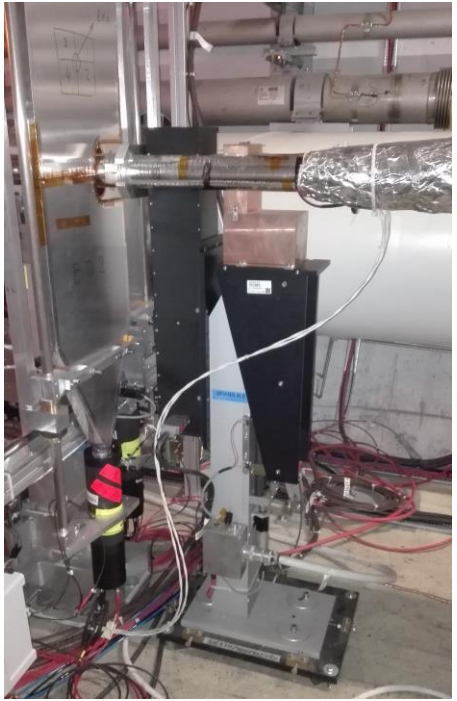
BRAN types

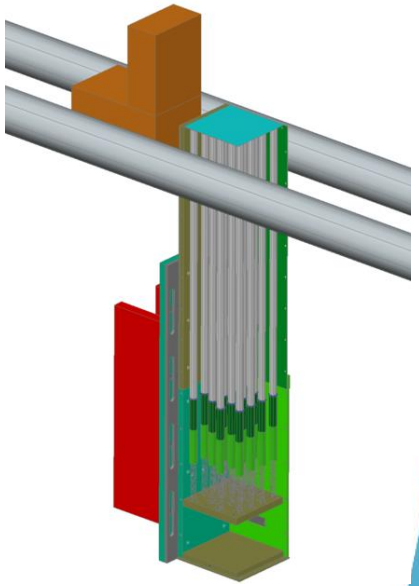
- **BRAN-B**: based on CdTe detector, installed in point 2 & 8. Damaged by radiation. Replaced by C-type



BRAN types

- **BRAN-C**: based on Cherenkov radiation. Installed during Run 2 in IP2 & 8
- Operational.

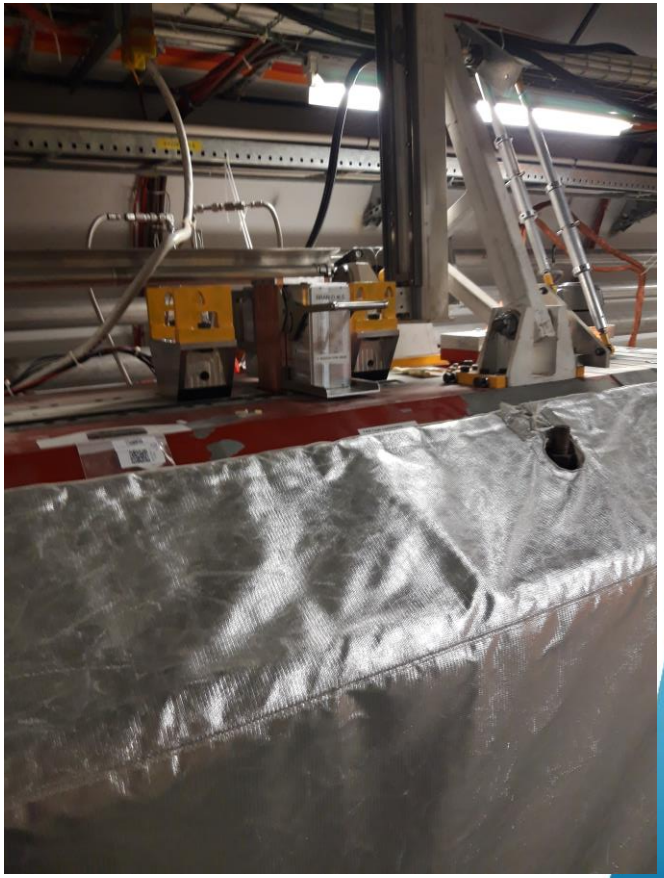




E. Bravin, S. Jakobsen

BRAN types

- **BRAN-D**: based on Cherenkov radiation. Installed during Run 3 in IP 1 & 5
- Operational.
- D-type serves two purposes:
  - operational BRAN for LHC Run 3
  - prototype for high lumi **BRAN-E** due to new absorber and lumi levels

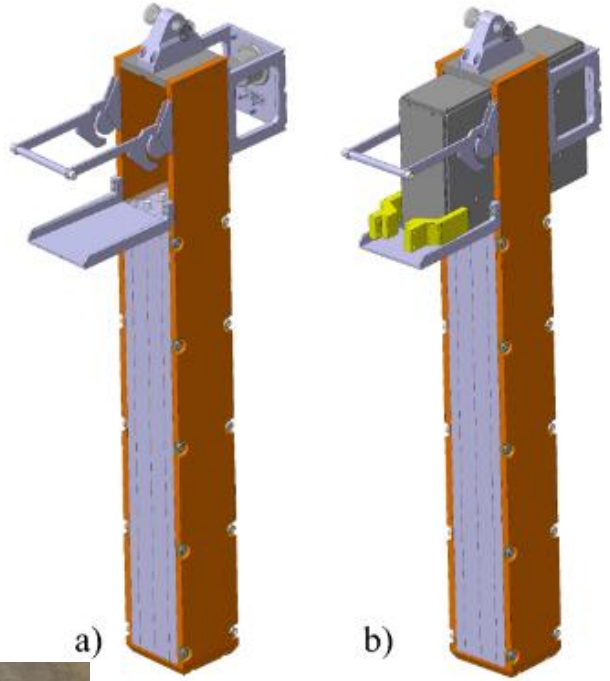


E. Bravin, M. Palm

BRAN-D design

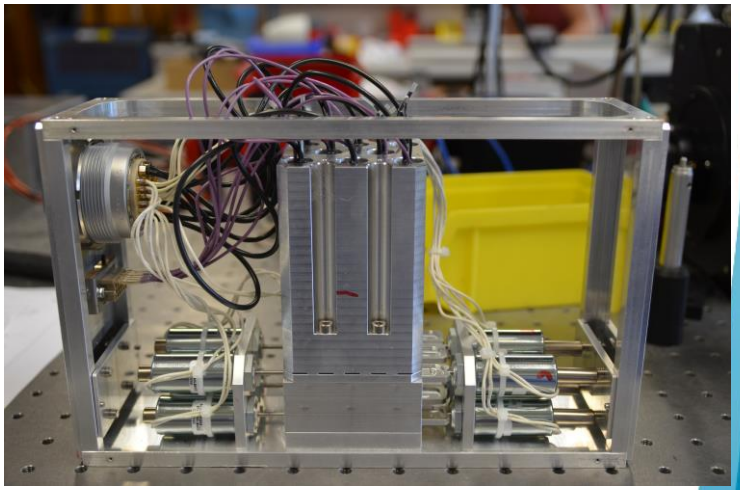
- Detection of Cherenkov radiation produced in ultra-pure Silica rods by hadronic showers produces in the Target Absorber of Neutrals (TAN)

- Eight 603 mm x 10 mm dia Suprasil 3302, low OH, no H2 in a copper enclosure (100 x 100 mm). Material selected after irradiation studies perform during LHC Run 2*.



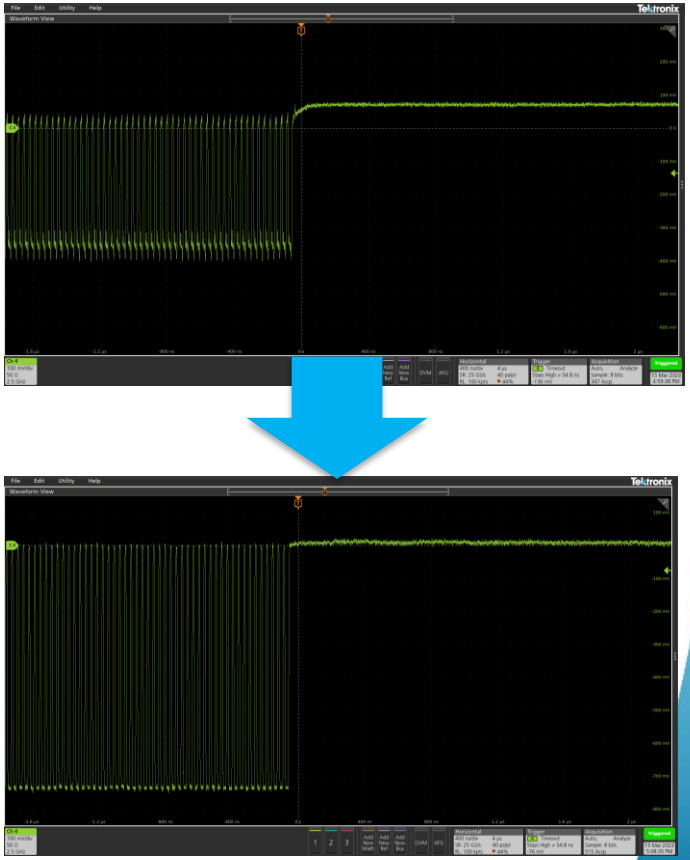
BRAN-D design

- Eight PMT Hamamatsu R2496 (one per rod). Peak QE @ 420 nm, 1.5 kV supply (individually controlled by 12 channel ISEG card).
- Optical transmission controlled by aperture limitation: two movable slit / hole strips: 100% - 10% - 1%
- Strips moved by push / pull solenoids (eg LEDEX 195205-230, push, 24V intermittent duty)
- Fast (de-)installation of PMT box. Budget force 70 N (push / lift?). Lever allows to overcome force budget for connectors (110 N mating, 95 N unmating for LEMO)
- Weight approx. 3.5 kg



BRAN-D design

- New 8-channel variable gain / offset amplifier in US gallery:
  - 50 ohm in / out
  - variable gain up to +/- 8 mA FS max (62.5 V/A) to compensate for loss of transmissivity of rods
  - DC to 500 MHz BW, with 250 MHz LPF
- New amplifier design should reduce tail effect after pulse trains
- Less prone to oscillations

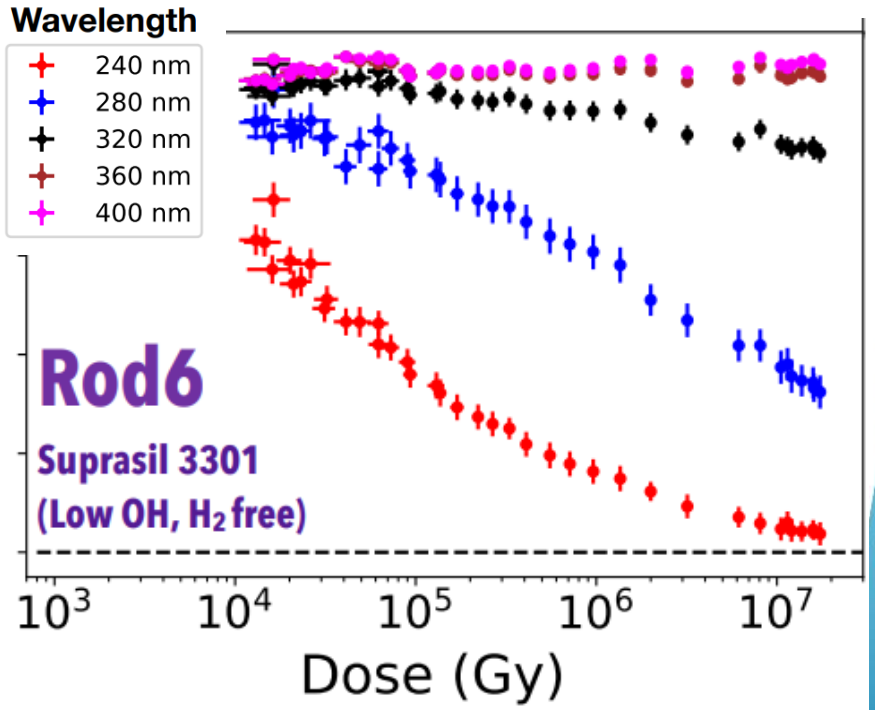


BRAN-D design

- FW performs digital LF (approx. 600 Hz) noise subtraction (Abort gap offset compensation)
- Output is a 3564 x 64 signed bits vector in two exclusive user-selectable operating modes
  - Integrating: cumulation of individual samples over N turns then integration
  - Counting: number of samples in the bunch slot exceeding a given threshold per turn (low luminosity)
- FESA class and GUI ‘BRAND’. Calibrated data are produced in FESA (proportionality and offset for each mode)

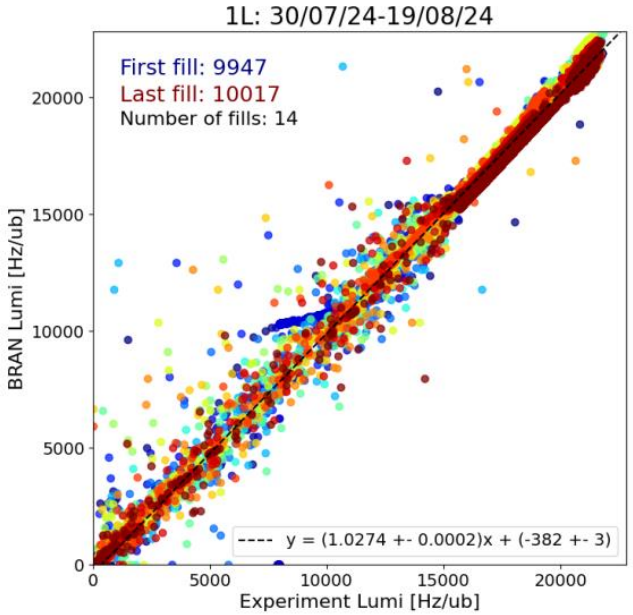
BRAN-D design

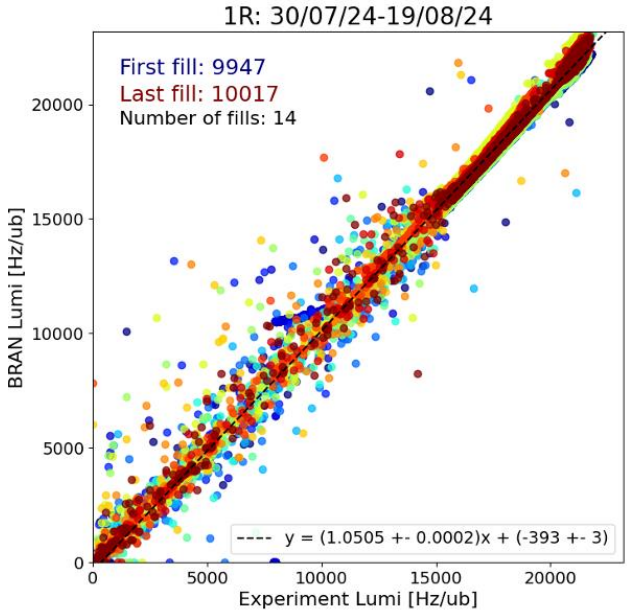
- During Run 2: study on transmissivity: “Optical Transmission Characterization of Fused Silica Materials Irradiated at the CERN Large Hadron Collider”, S. Yang et al. NIMA (2023)
- Suprasil 3301/02 show rapid decrease of transmissivity. Unclear from data where the stabilisation is expected (> 10^7 Gy)
- Visible transmissivity not affected
- Proportionality of signal to rate of collision one of study goal of prototypes



BRAN-D performance

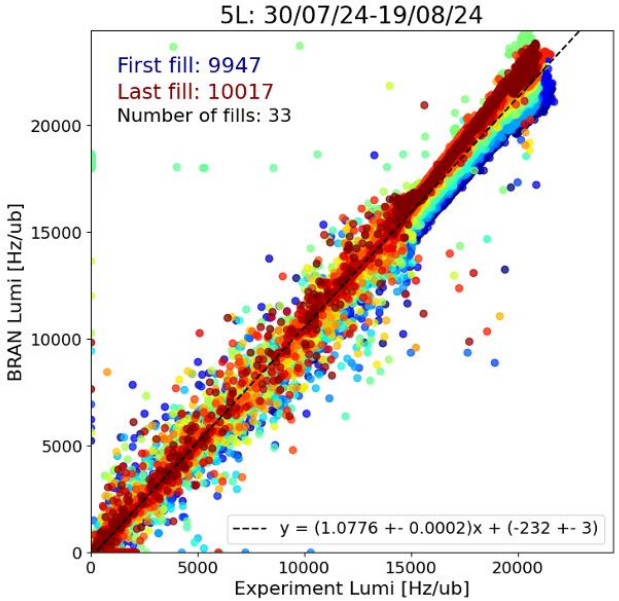
- Systematic analysis of linearity, SNR, proportionality of signal to rate of collision) between 1.4.24 and 2.9.24 by K. Zertova
- Good linearity (ATLAS)

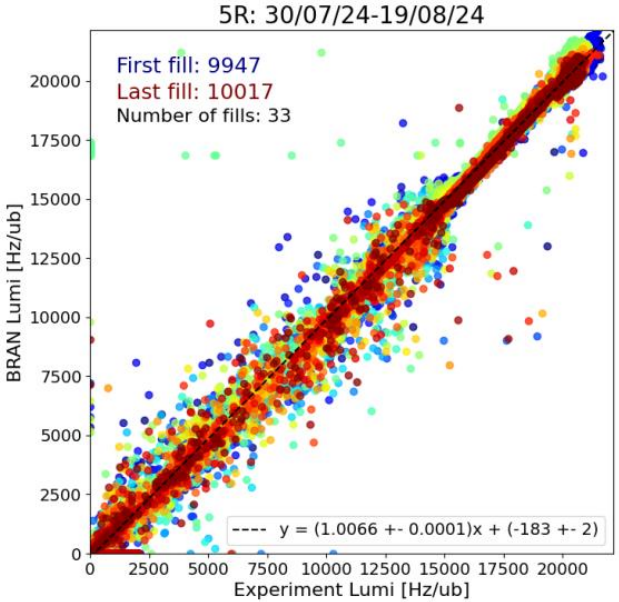




BRAN-D performance

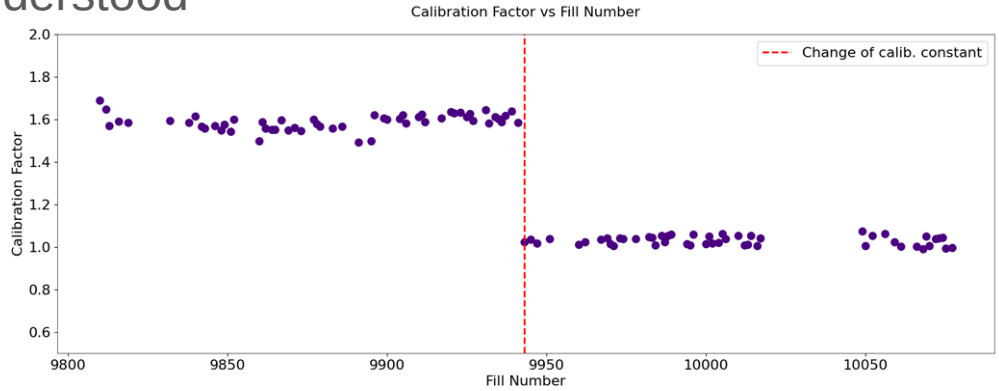
- Systematic analysis of linearity, SNR, proportionality of signal to rate of collision) between 1.4.24 and 2.9.24 by K. Zertova
- Linearity OK (CMS). 5L: worst proportionality to exp. lumi

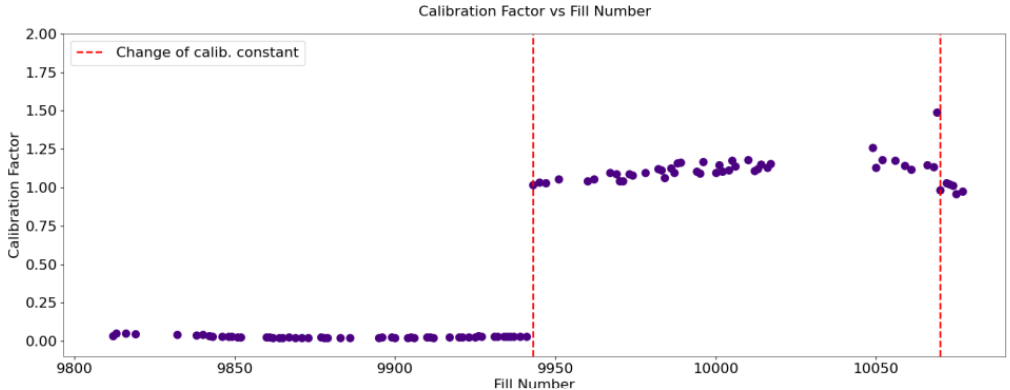




BRAN-D performance

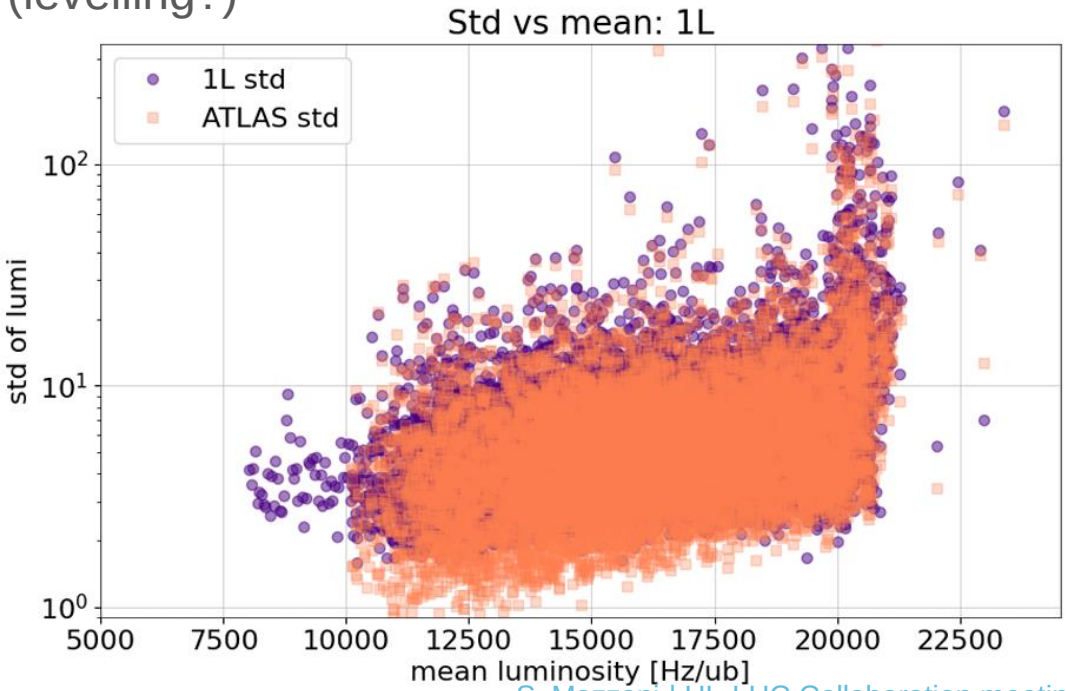
- Proportionality (against experiments): fair for 5R (top), worst for 5L (below), not fully understood





BRAN-D performance

- Noise analysis: std. dev of lumi vs experiments. Typical plot, BRAN systematically noisier than experiments. Higher noise at 20 kHz/ub not understood (levelling?)



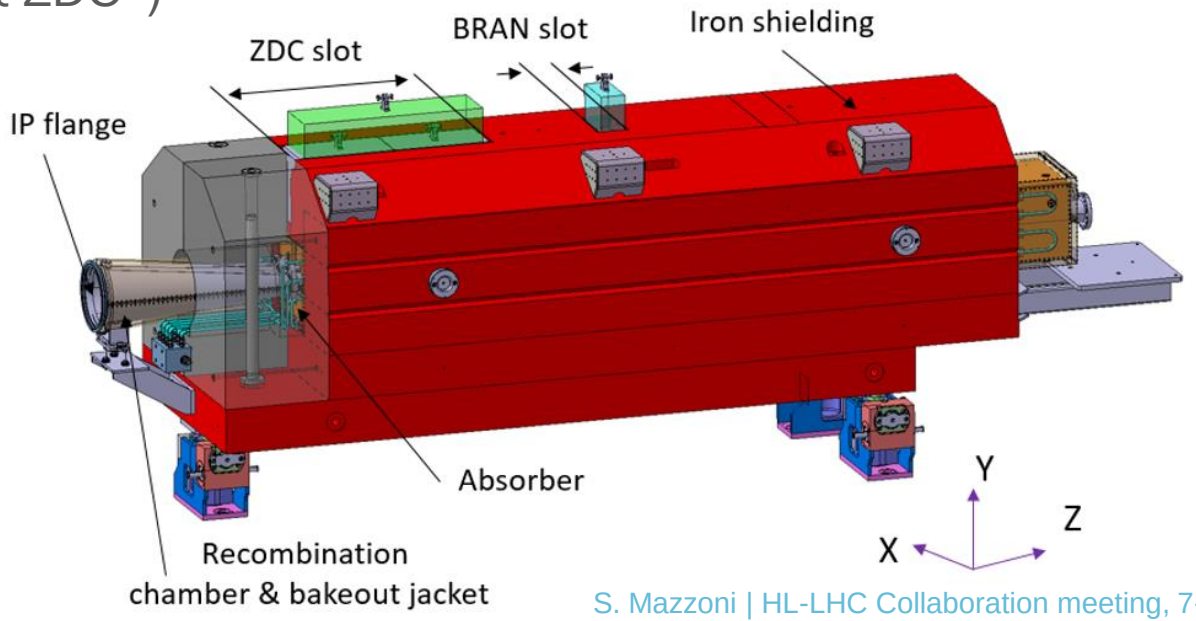
BRAN-D performance

- Overall good linearity during run 3 so far.
- proportionality (= transmissivity of Suprasil bars) not fully understood but so far SNR still OK for BRAN operation
- Noise level allows for +/- 5% (nominal), limit for +/- 1% (nice to have)
- NO faulty PMT throughout Run 3 so far (integrated luminosity up to 190 fb^{-1})

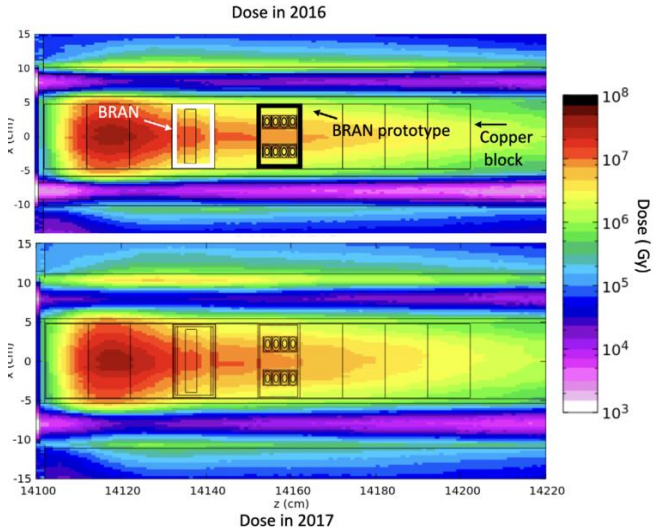
promising for BRAN-E version!

BRAN-E

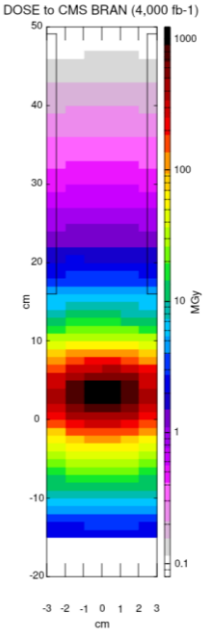
- BRAN-E will be hosted inside TAXN.
- New material budget (ZDC before BRAN): normalized dose?
- New space envelope according to EDMS 2349145 (‘TAXN INTERFACES TO BRAN & ZDC ’)



BRAN-E



- Same order of magnitude normalized dose in TAN and TAXN BRAN positions
- Runs 4 & 5: excess of 500 MGy to bars
- Replace with spares when performance declines.



BRAN-D: 20 MGy per 50 fb-1 (2017) :

500 kGy/fb^{-1}

BRAN-E: order of GGy per 4000 fb-1:

250 kGy/fb^{-1}

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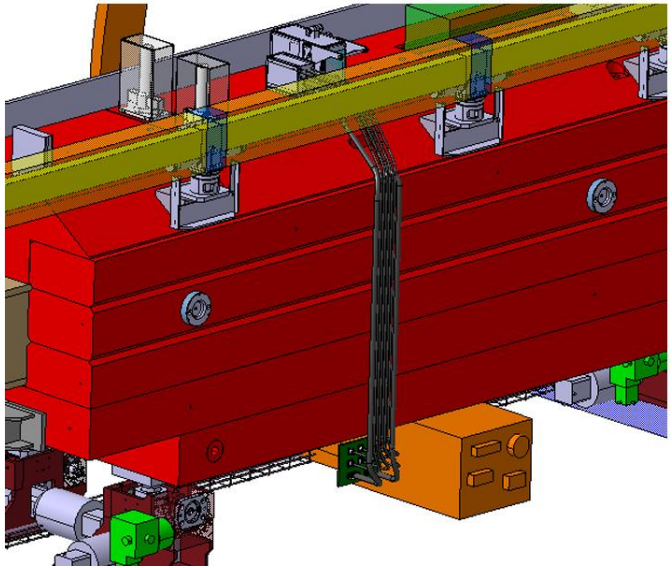
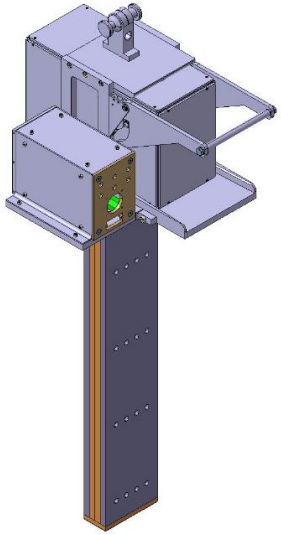
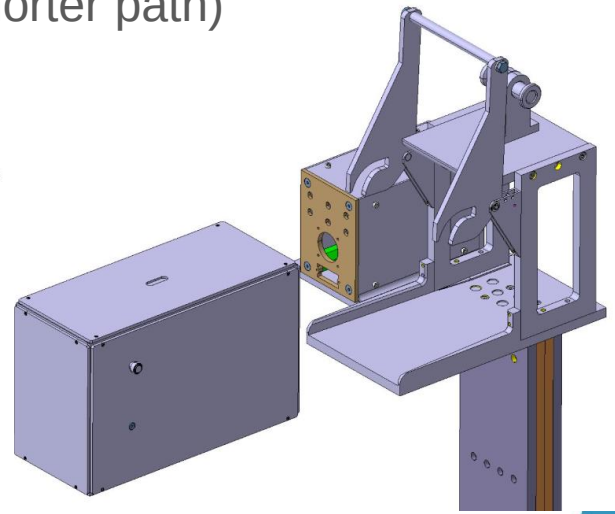
BRAN-E

- New design by MME until end 2024
- Same concept: fast (de-)installation of PMT box. Decided to drop robotic manipulation.
- Cables routing from passage side to new UAs (shorter path)

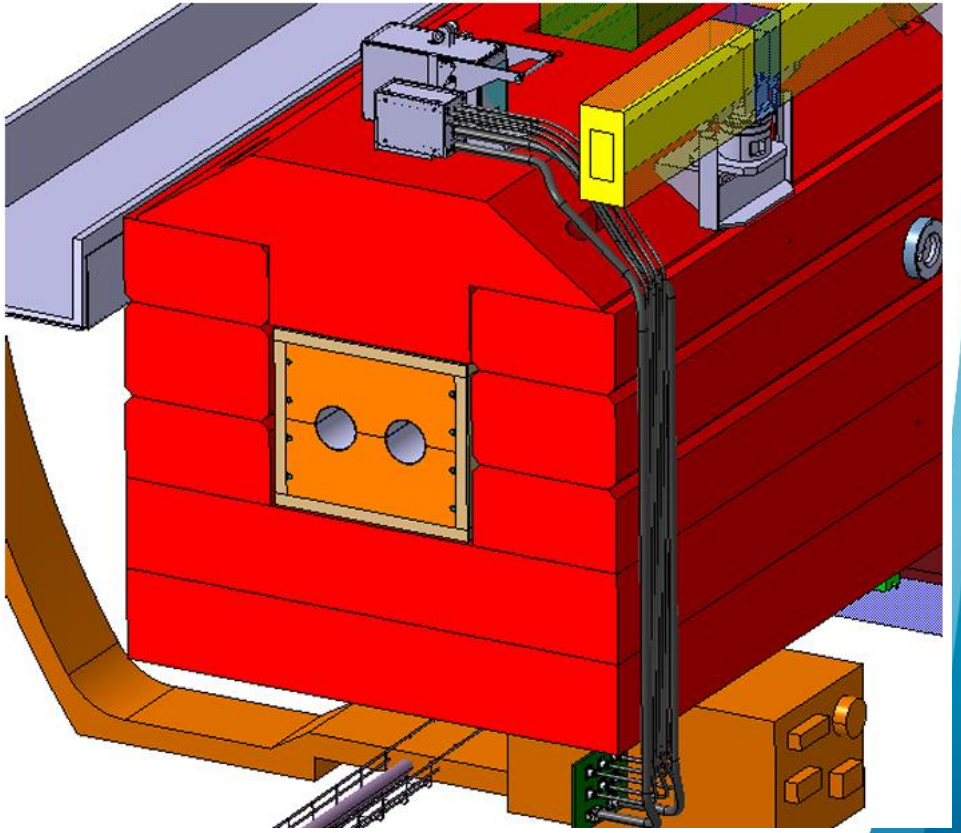






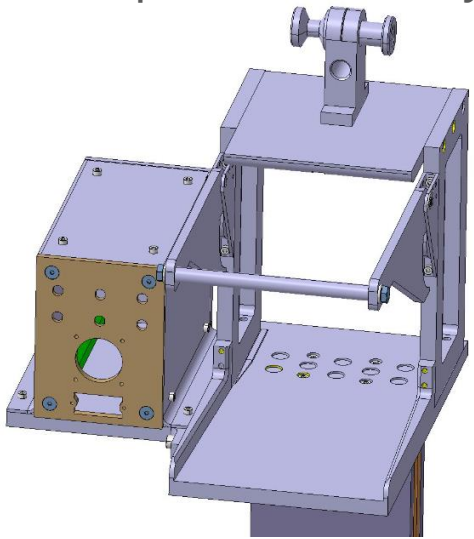
BRAN-E

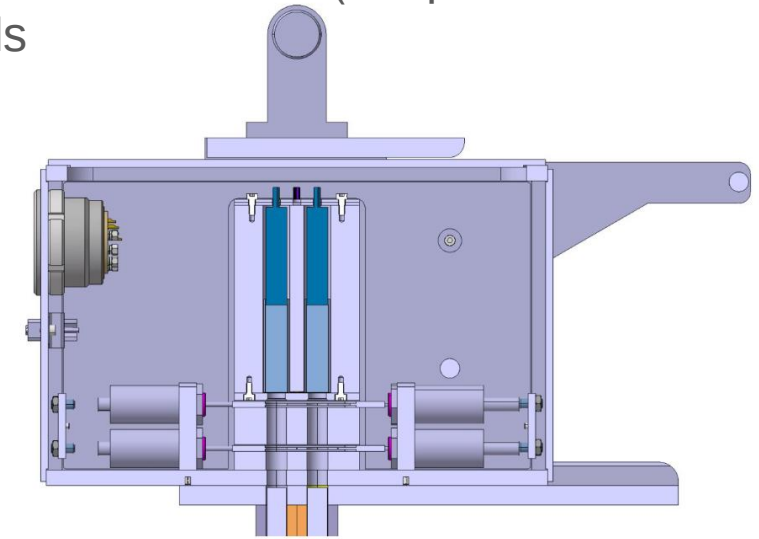
- Conflict with Wire position system solved.
- WPS harness moved longitudinally to allow (de-) installation of PMT box
- cable routing foreseen below WPS to patch panel below TAXN
- Patch panel to UA: need low EMI cable tray! Differential signal transmission foreseen



BRAN-E

- Due to good performance of PMTs (no faults so far) and new 6-channel HV power supply (CAEN), decided to go for 8 > 6 channels per monitor. Possibly keep slots for irradiation studies.
- We'll add switches for position of attenuation masks (not present in BRAN-D). Also drop hi-lo sensitivity channels





Summary

- Overall good performance of BRANs during LHC run 3. Need to keep track of faults and continue studying optical / UV transmissivity evolution with dose.
- No faults due to radiation exposure, confirms goodness of design for Run 4
- BRAN-E design well advanced, to be finalized by end of 2024. Design evolution being followed within WP8 (Thanks Francisco), TREX.
- Some components already procured, production and remaining procurement will start in 2025.

Thanks for your attention