LHC luminosity monitors

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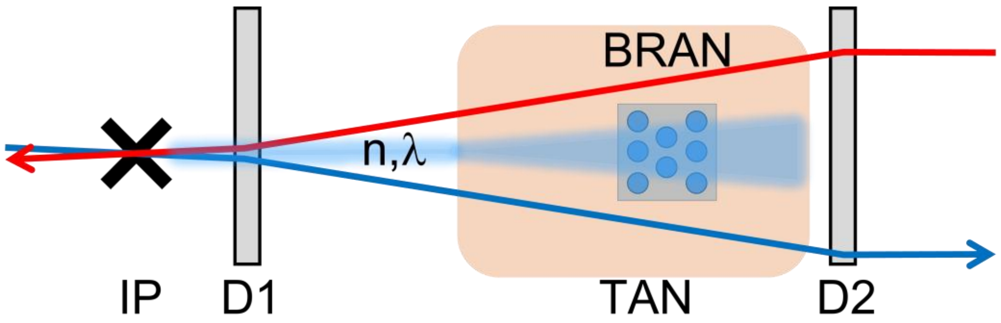
2nd FCC polarisation workshop, 19-30 Sept. 2022, CERN

The BRAN monitor



BRAN: Beam RAte of Neutrals

What: Machine luminosity monitors

Where: IP1/5, IP2/8

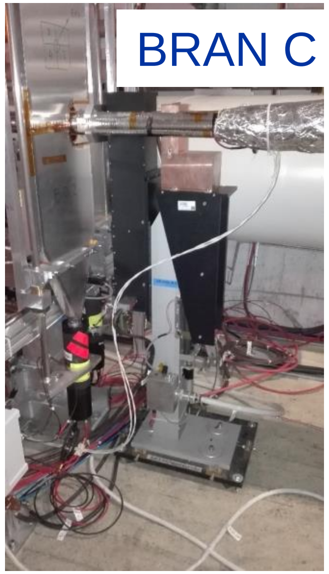
Use cases: Finding collisions, backup instrument for OP (if no data from experiments), cross-check experiments, sanity check, ...

Requirements: ~1% resolution @ 1 Hz (absolute luminosity not necessary), +-5% rel. accuracy (1% nice to have)

Challenges: Large dynamic range, radiation (IP1/5: 180 MGy/year), limited space

For HL-LHC: developments of new BRANs for IP1 & IP5

BRANs in LHC Run 3



IP2/ IP8: "BRAN C" design based on Silica rods + PMTs (Cherenkov light).

- No functional modifications

IP1/IP5: "BRAN A" based on ionization chambers.

- Replace BRAN A with "BRAN-D" evolution of BRAN C. Two goals:
  - Replace ageing BRAN-A for LHC Run 3
  - Test prototype for HL-LHC

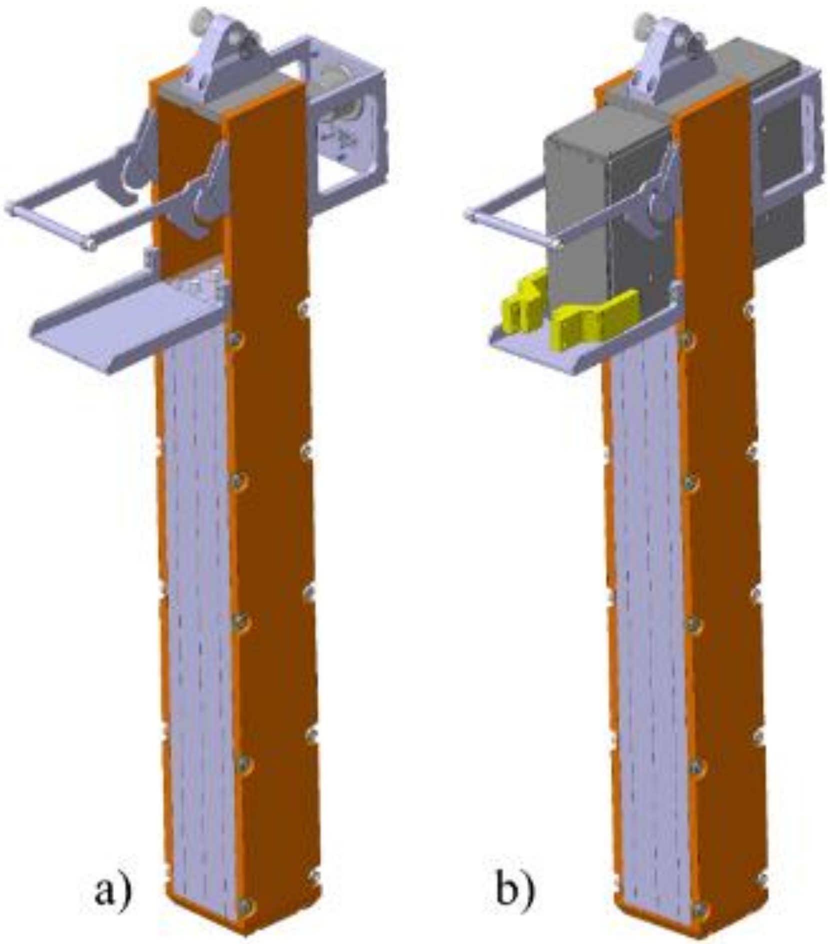
The BRAN-D

Measurement of Cherenkov radiation produced by hadronic showers generated in the TAN.

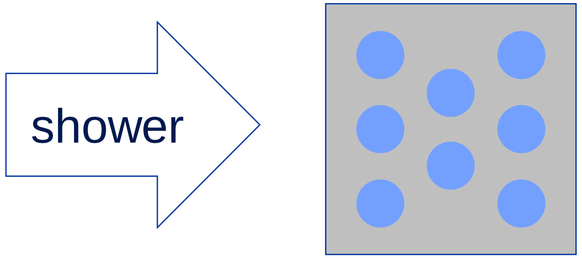
Designed by CERN design office

Two subsystems:

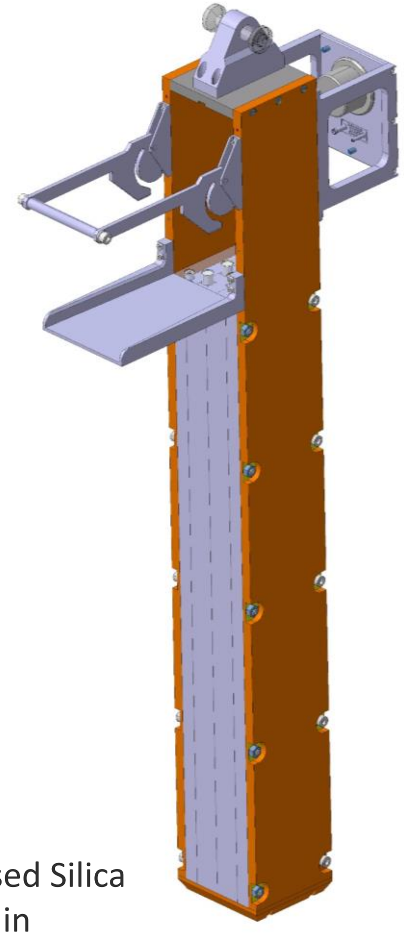
- Glass bars enclosure (a)
- PMT box (top of b)



Glass bar assembly

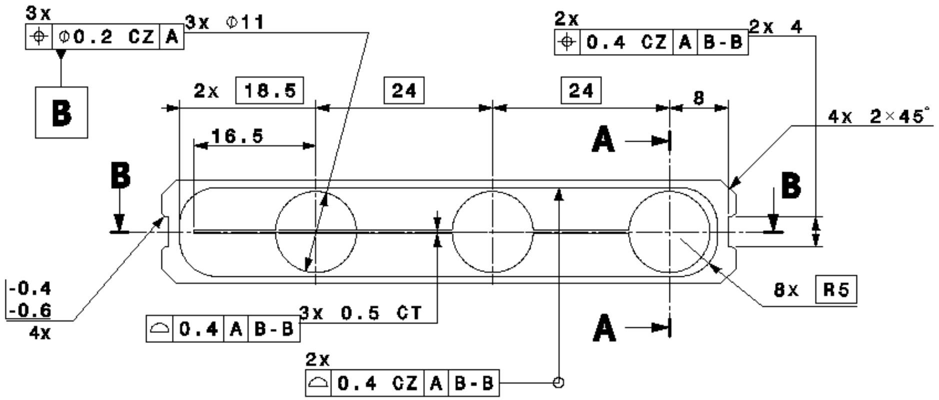


- Eight 603 mm x 10 mm dia Suprasil 3302, low OH, no H2 in a copper enclosure (100 x 100 mm). Material selected after irradiation studies perform during LHC Run 2*.
- Backpanel for PMT box with non-latching connectors for HV & LV supply, PMT signal out
- Main constraints and challenges: radiation, robotic operation, crane operation

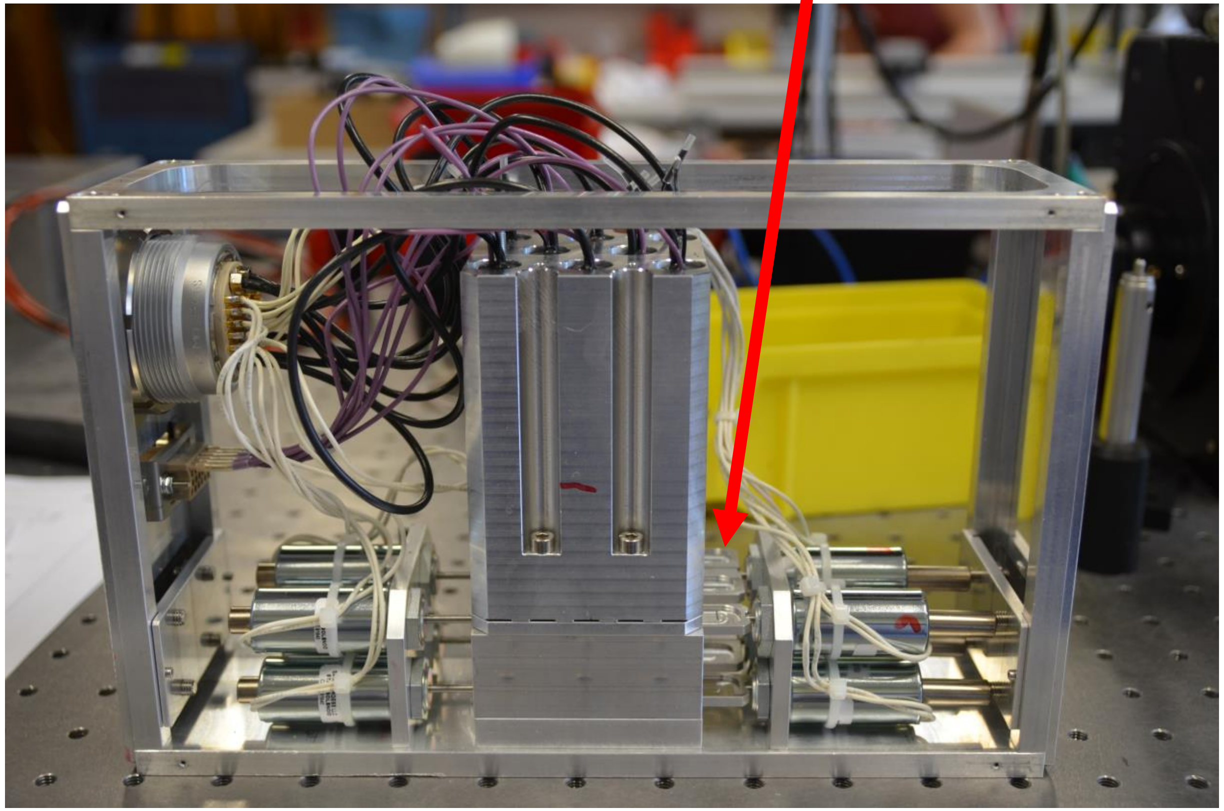


* S. Yang et al. “Optical Transmission Measurements of Fused Silica Irradiated at the CERN Large Hadron Collider”, Manuscript in preparation

PMT box



- Eight PMT (one per rod). Peak QE @ 420 nm, 1.5 kV supply (individually controlled).
- Optical transmission controlled by aperture limitation: two movable slit / hole plates: 100% - 10% - 1%
- Plates moved by push / pull solenoids (eg LEDEX 195205-230, push, 24V intermittent duty)
- Box can be operated by robot. 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



Acquisition / SW

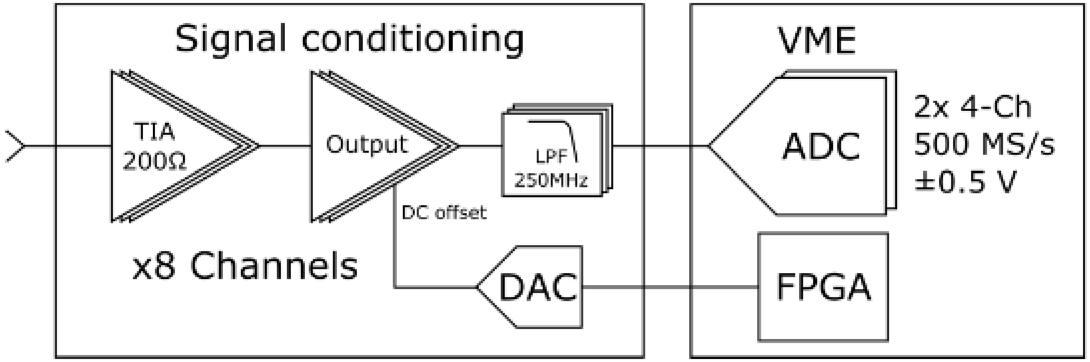
- 8 channels per instrument. Bunch by bunch acquisition integrated over 1 s.

- Due to radiation, amplifier are DAQ in service galleries > long cables (150-200 m) > noise

- Large dynamic range. Operating mode:
  - **Counting** mode for low intensities (“histogram”) over configurable threshold value
  - **Integration** within 25 ns bin for high int (eg pulse height).

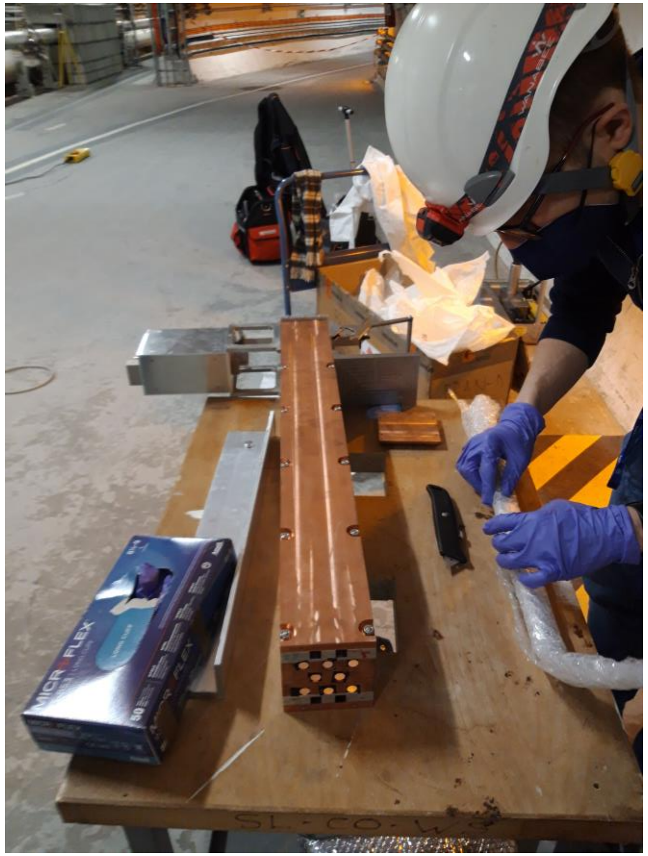
- HW Per instrument: 2x VFC-HD with IAM FMC (4 channel, 500 MSPS 14-bit ADC). DC offset calculated per turn to compensate noise (peak at 600 Hz)

- Data are published and logged through CERN’s Front End server Architecture (FESA)



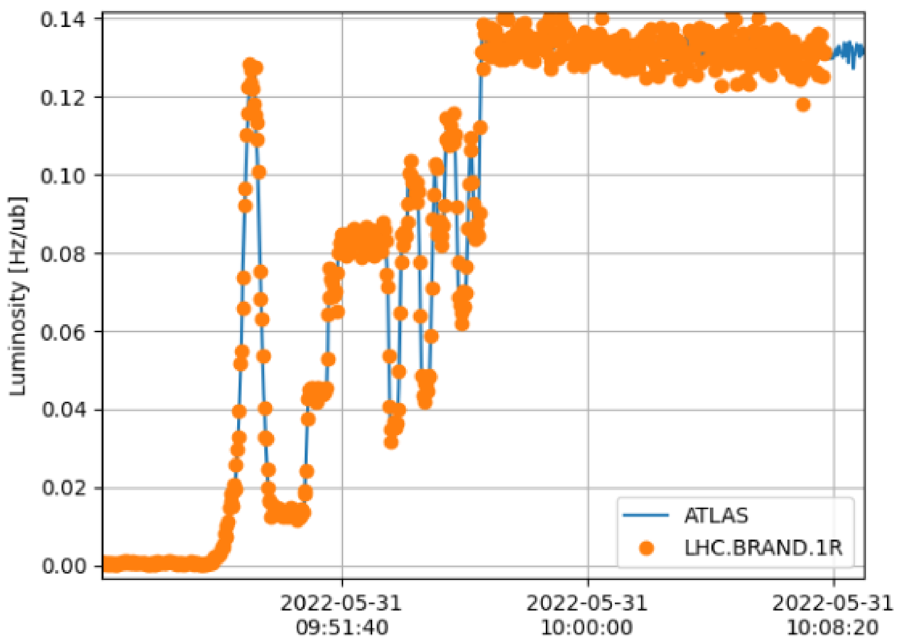
Installation

- Two BRAN-D installed during YETS 22-23 (right if IP1, left of IP5)
- Remaining BRANS will be installed during YEST 22-23 (Feb 23).



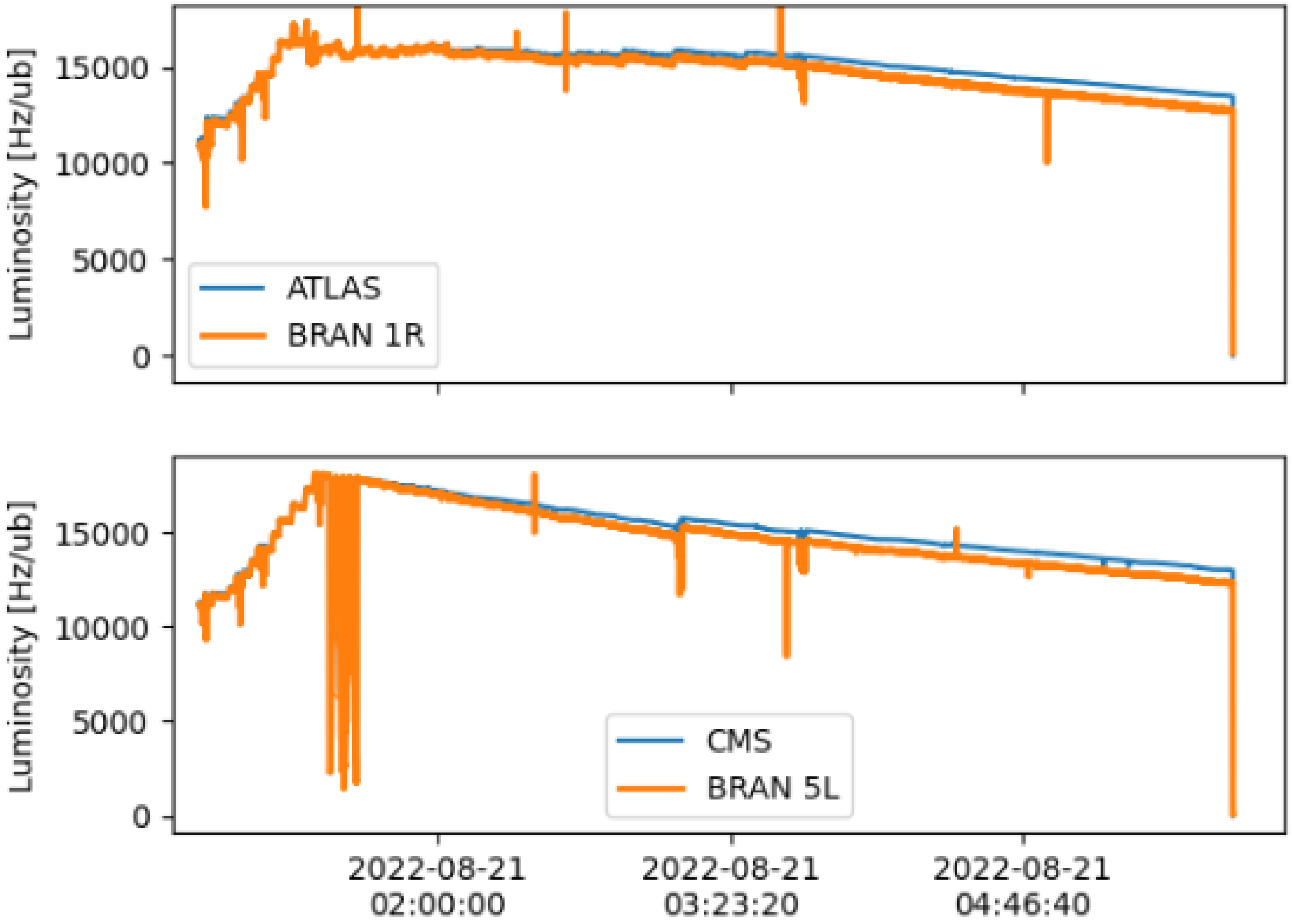
First results from commissioning

- First data from June 22. Collisions at 6.8 TeV with nominal bunch at $\beta^* = 19.2$ m.
- BRAN-D in counting mode and, 100 % optical transmission and irradiated fused silica bars.
- RMS of noise $\sigma_{noise} = 2.3 \times 10^{-4}$ Hz/μb.
- Considering loss of transmissivity due to irradiation, expected **sensitivity per bunch is order of 10^{-3} Hz/μb** (OK for nominals, not OK for pilots)



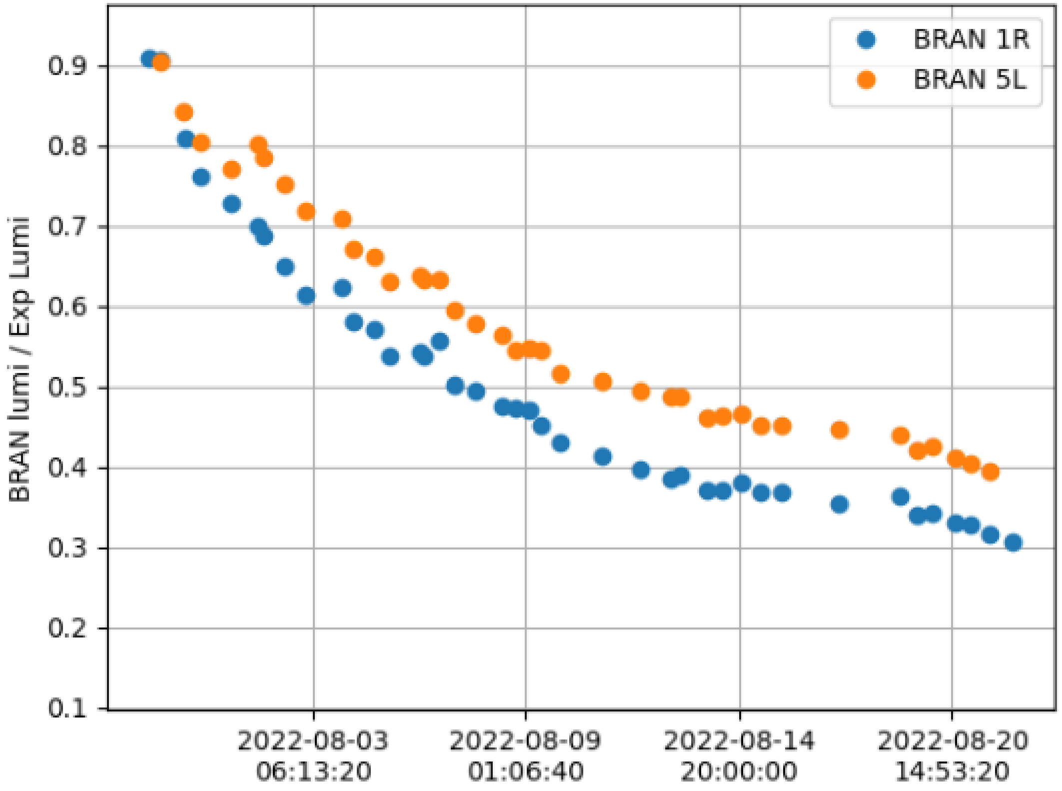
First results from commissioning

- Physics fill: 2500 nominal bunches with β* = 0.3 m can produce inst. luminosity up to 1.7 x 10^4 Hz/μb.
- BRAN in integrating mode, 1% optical transmission.
- Ex. Fill 8147 (2400 colliding bunches). Typical observed resolution is order of 10-2 Hz/μb per bunch, that is **50 Hz/μb total luminostity sensitivity**
- Drop of signal of approx. 5% within fill observed. Irradiation of bars? (next slide)

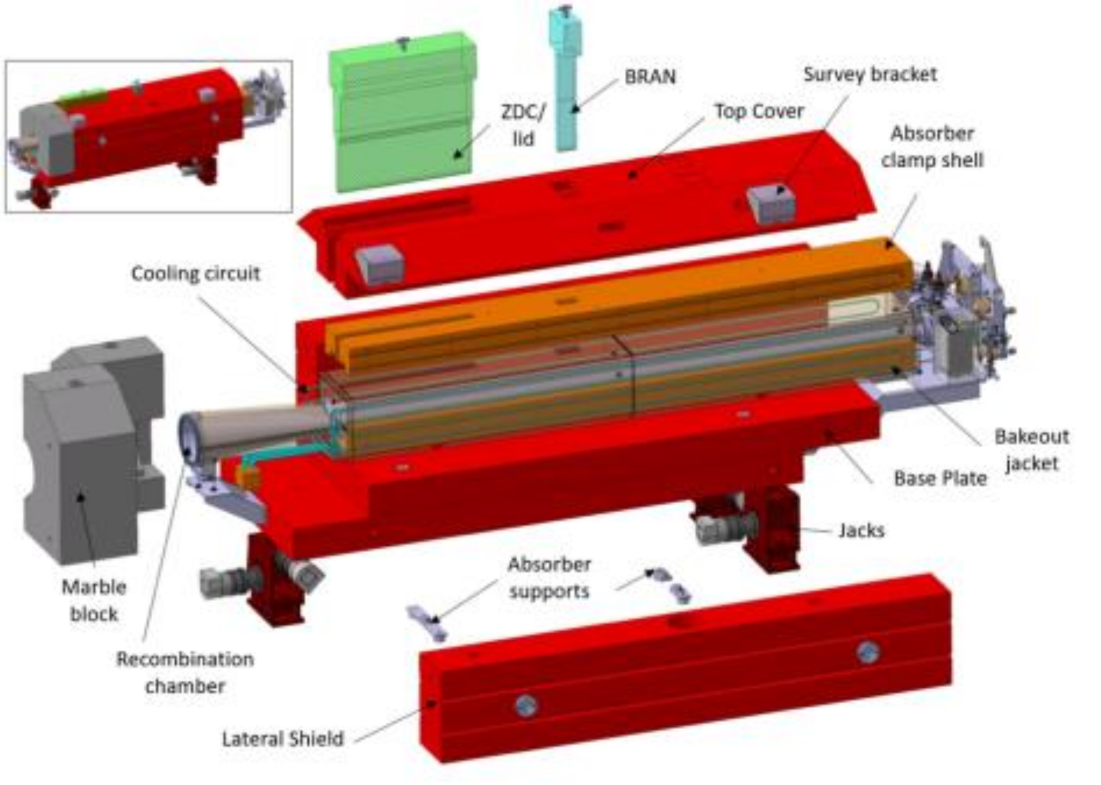


First results from commissioning

- Fused silica bars loose transmissivity when exposed to radiation
- Different kinds of synthetic fused silica were exposed to radiation during Run 2. Loss. Most of transmissivity loss is in the UV (<400 nm), less pronounced in the visible (400<λ<600 nm)
- Low ^2H content samples had fast decay but stable transmissivity
- BRANS exhibit expected loss of signal. Expected steady state is 10-15% of initial value.
- Compensated at steady state by increasing aperture to PMT.



Conclusion and perspectives



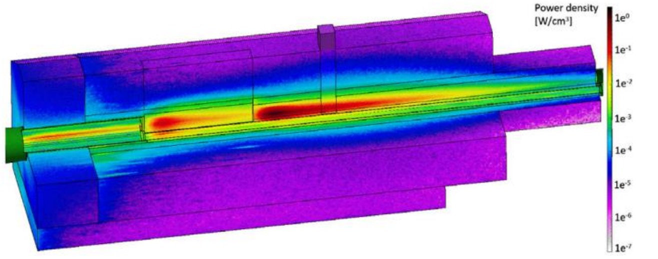
- Commissioning of new Cherenkov luminosity monitors ongoing in LHC Run 3. Performance satisfactory, still working at improving noise reduction, mechanical design.

- Design on new HL version (‘ BRAN-Q‘) just started

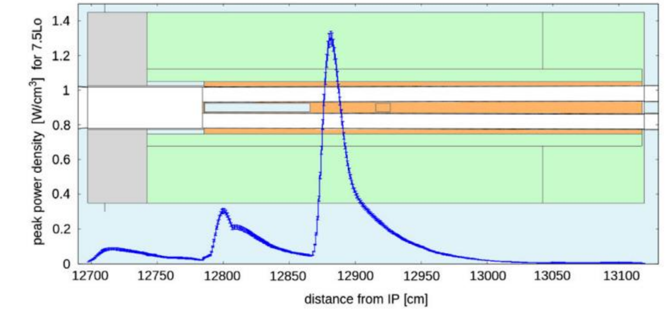
- Expected dose up to 1 GGy / year

- BRANS in pt. 1& 5 will be redesigned to fit in the new absorber TAXN (50 mm gap)

- Full robotic handling of PMT box will be required.



P. Santos Diaz et al. “Mechanical and thermal design of the target neutral beam absorber for the High-Luminosity LHC upgrade” , PRAB 2022



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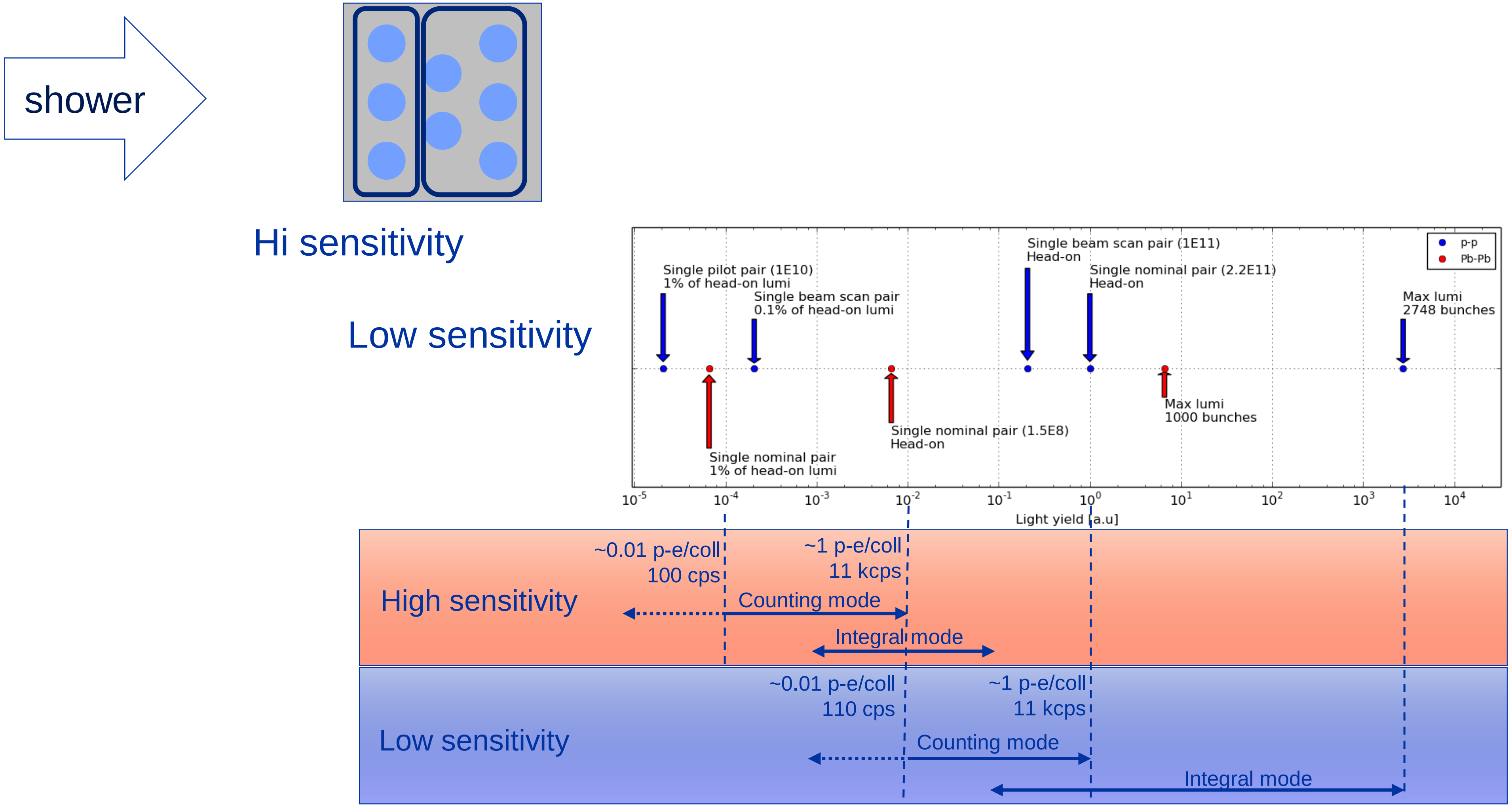
Channel sensitivity range



p-e = photoelectron