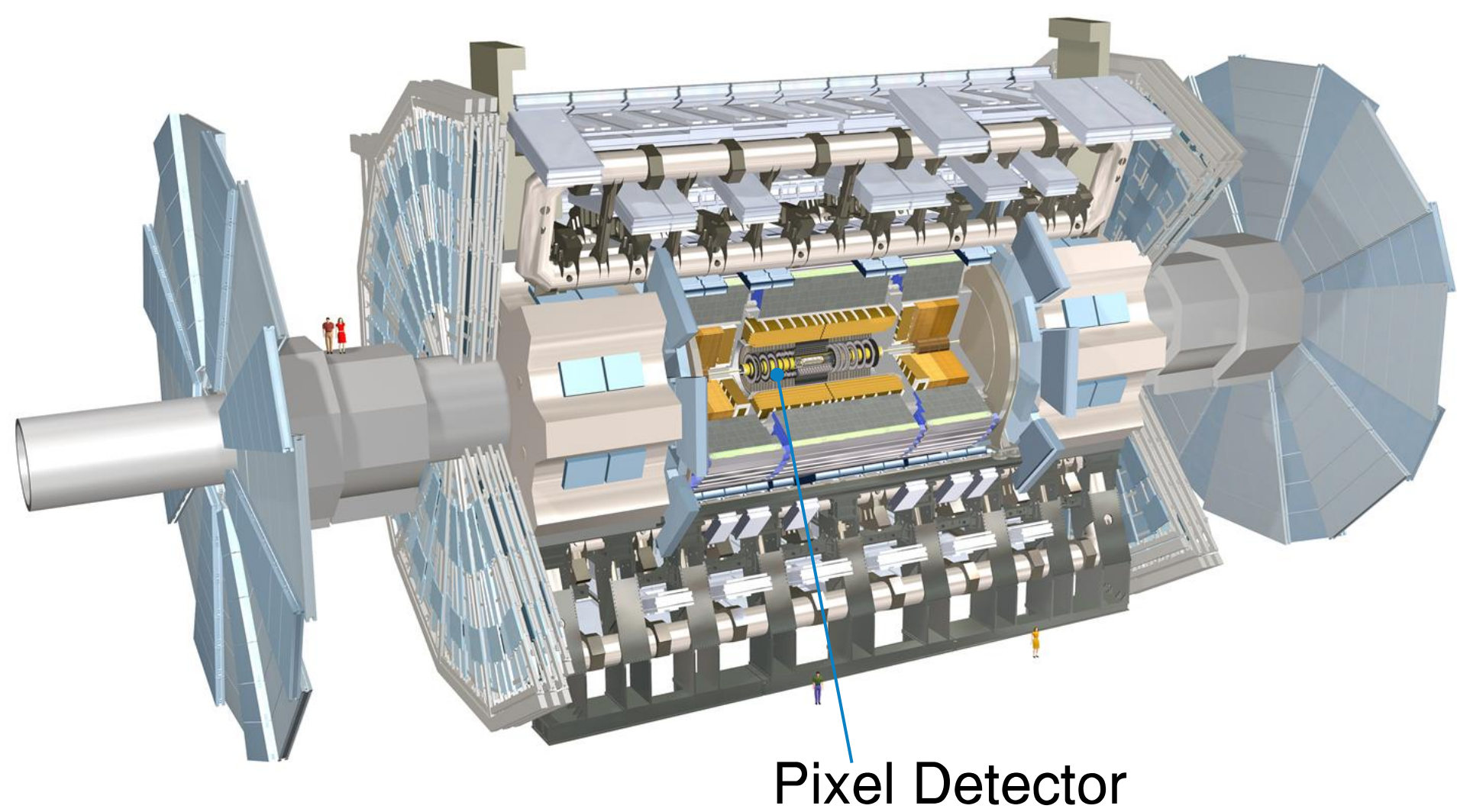


ATLAS PIXEL DETECTOR

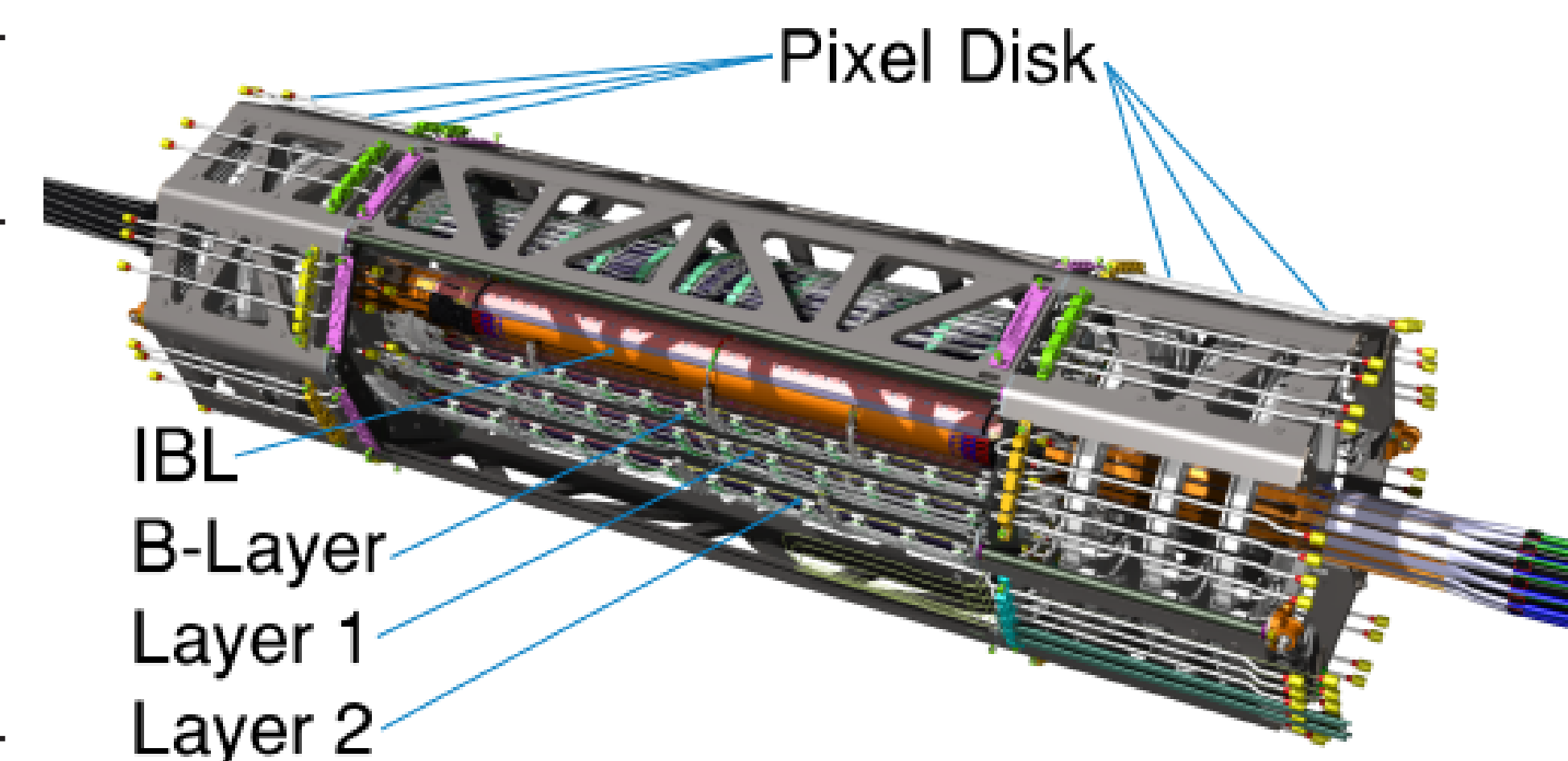
- 4-Layer tracking detector with 2 End-Caps
- Insertable B-Layer (IBL) added during winter shutdown 2013/14
- Covers range of $|\eta| < 2.5$

- η dependent resolution up to $10 \times 115 \mu\text{m}^2 / 10 \times 40 \mu\text{m}^2$ (PIX/IBL)
- Good data quality efficiency of 99.5% in Run-2 (2015-18)
- Accumulated fluence reaches from 4.5 to $9 \times 10^{15} [\frac{\text{n}_{\text{eq}}}{\text{cm}^2}]$ (PIXEL/IBL)
→ 40 – 50% of nominal fluence to be withstand

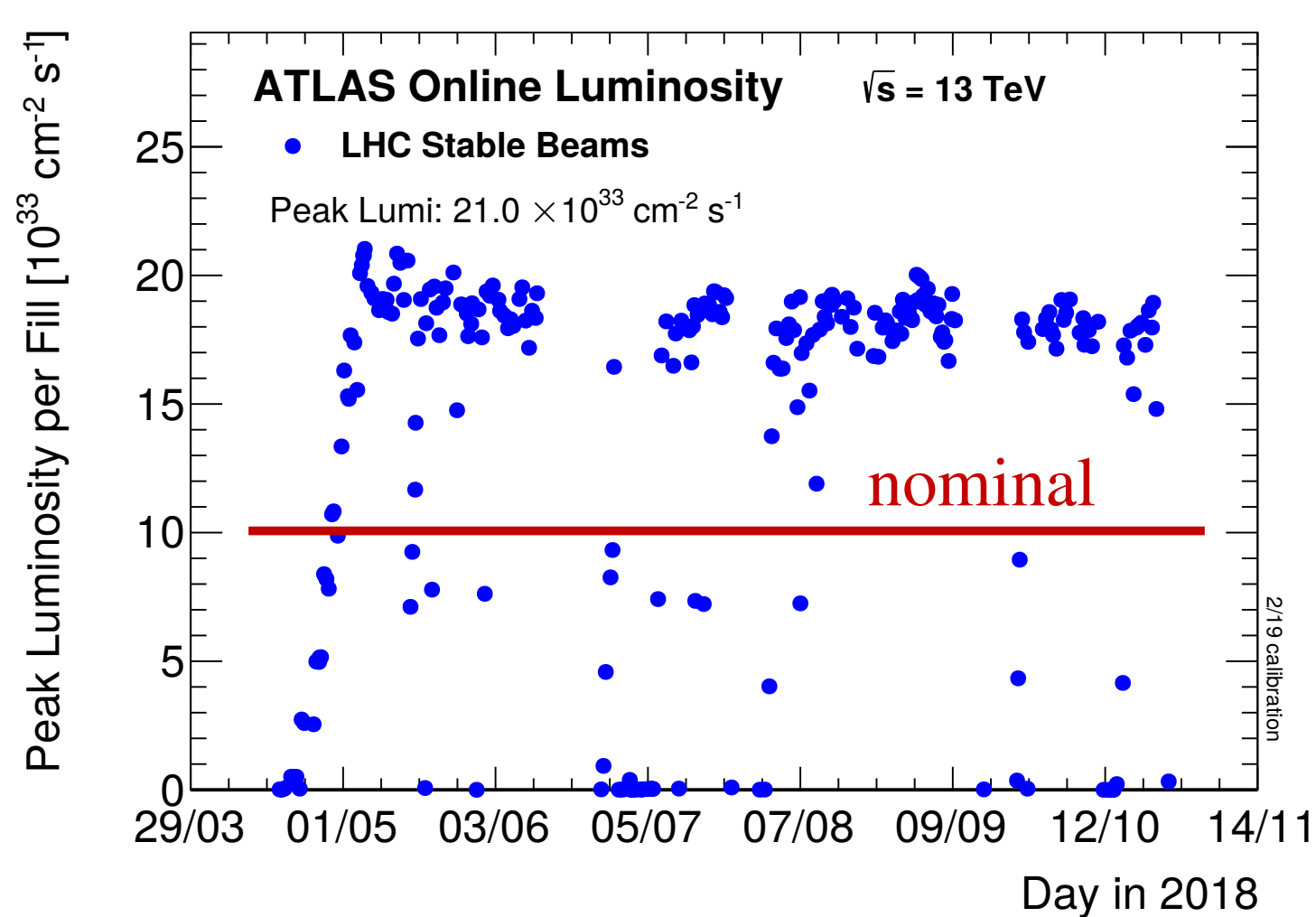
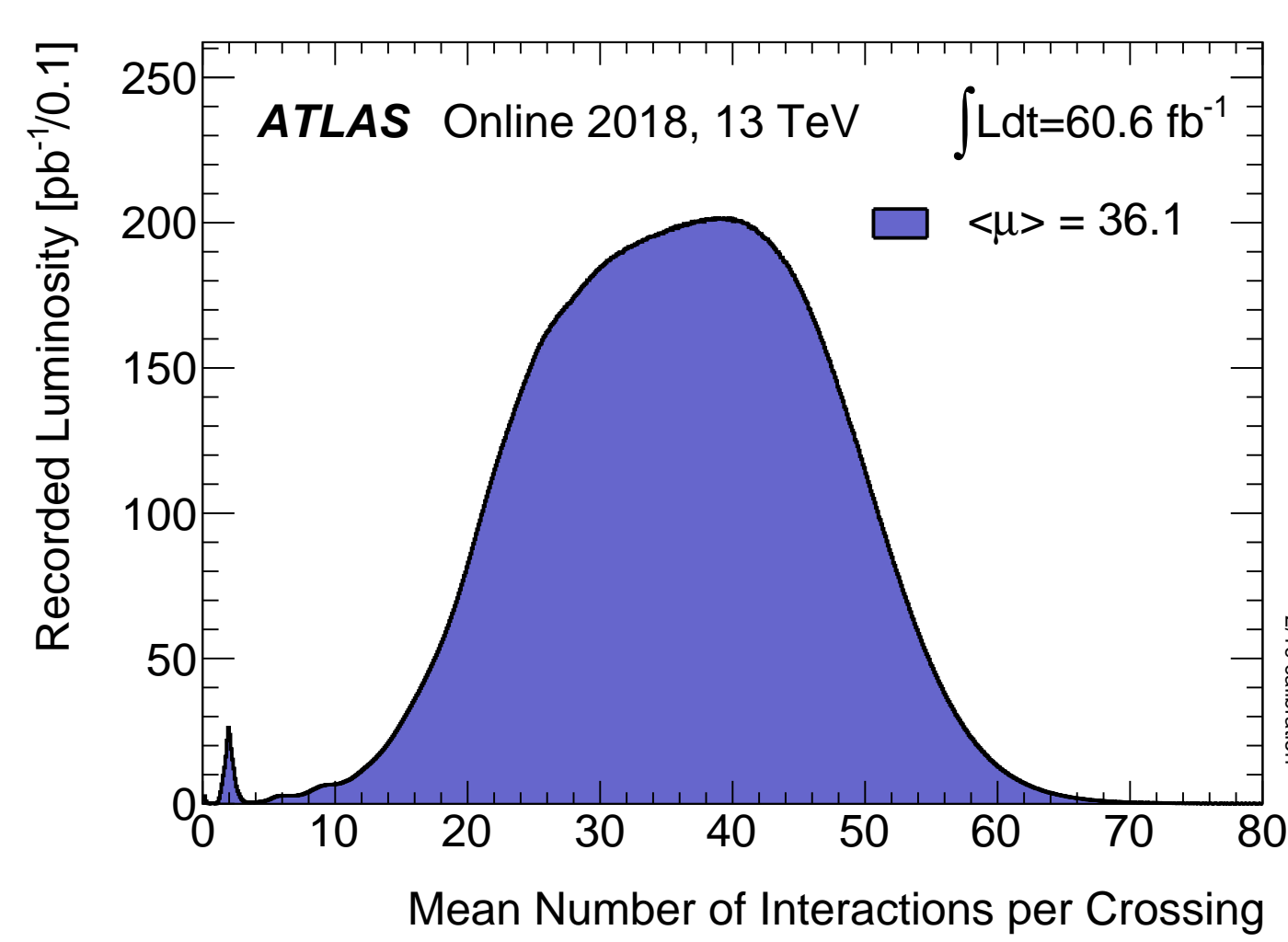
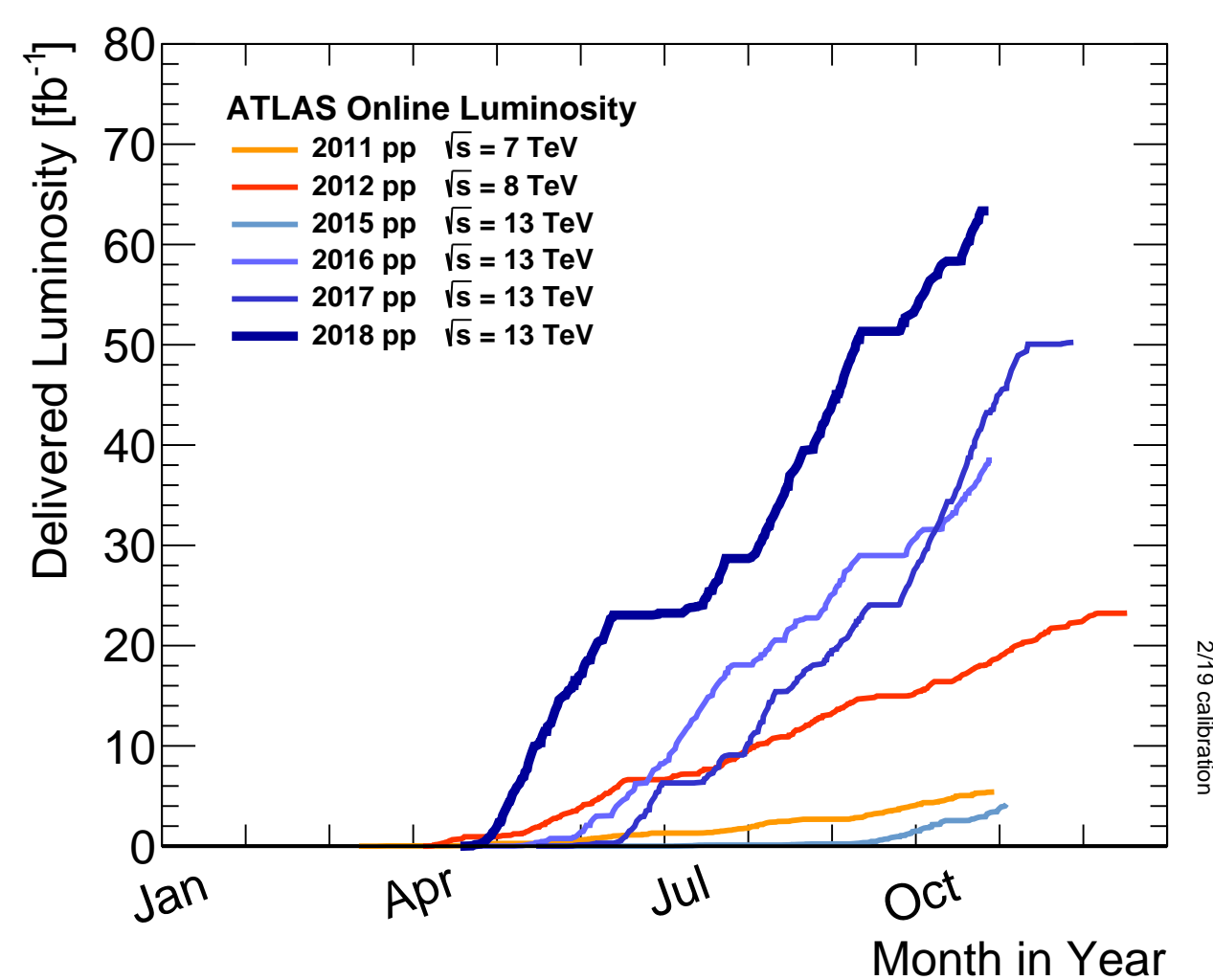


Pixel Detector

	IBL	Other Layers + End-Caps
Radius [cm]	3.2	5.05/8.85/12.25
Front-Ends	448 (FE-I4)	1744*16 (FE-I3)
Channels	12×10^6	80×10^6
Rad. Hardn. [$\frac{\text{n}_{\text{eq}}}{\text{cm}^2}$]	5×10^{15}	1×10^{15}
Cooling	CO ₂	C ₃ F ₈
Installed	2013/14	<2008

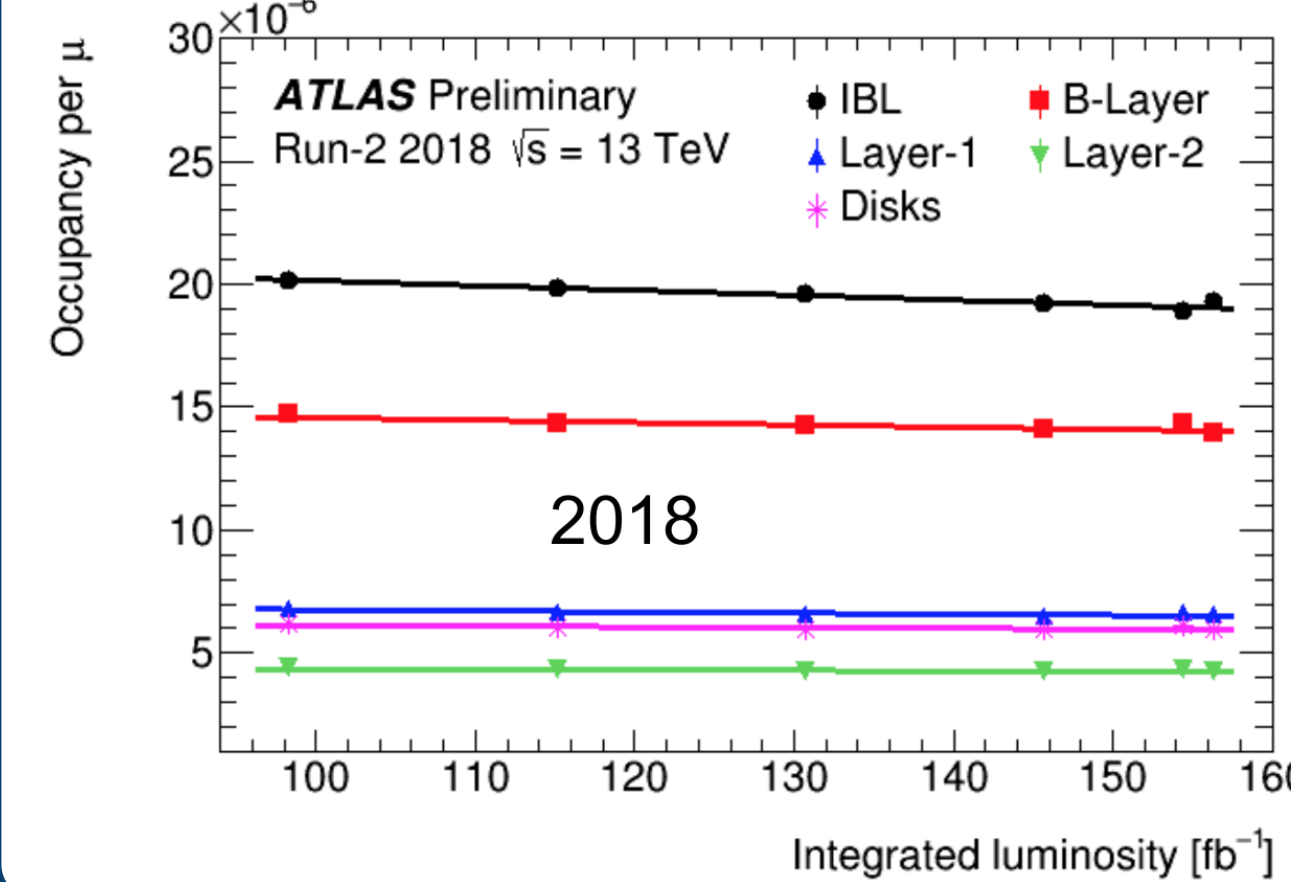
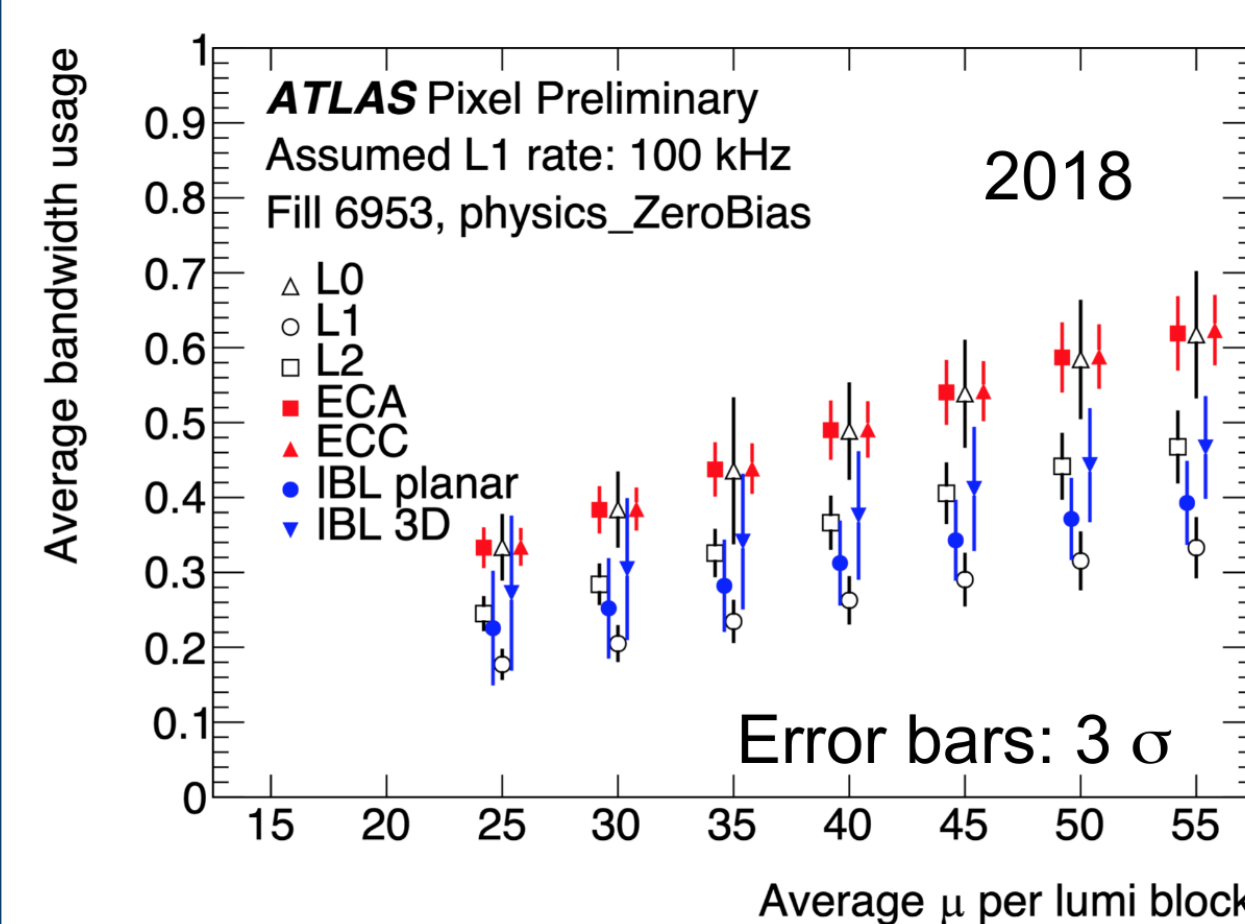


DATA TAKING CONDITION

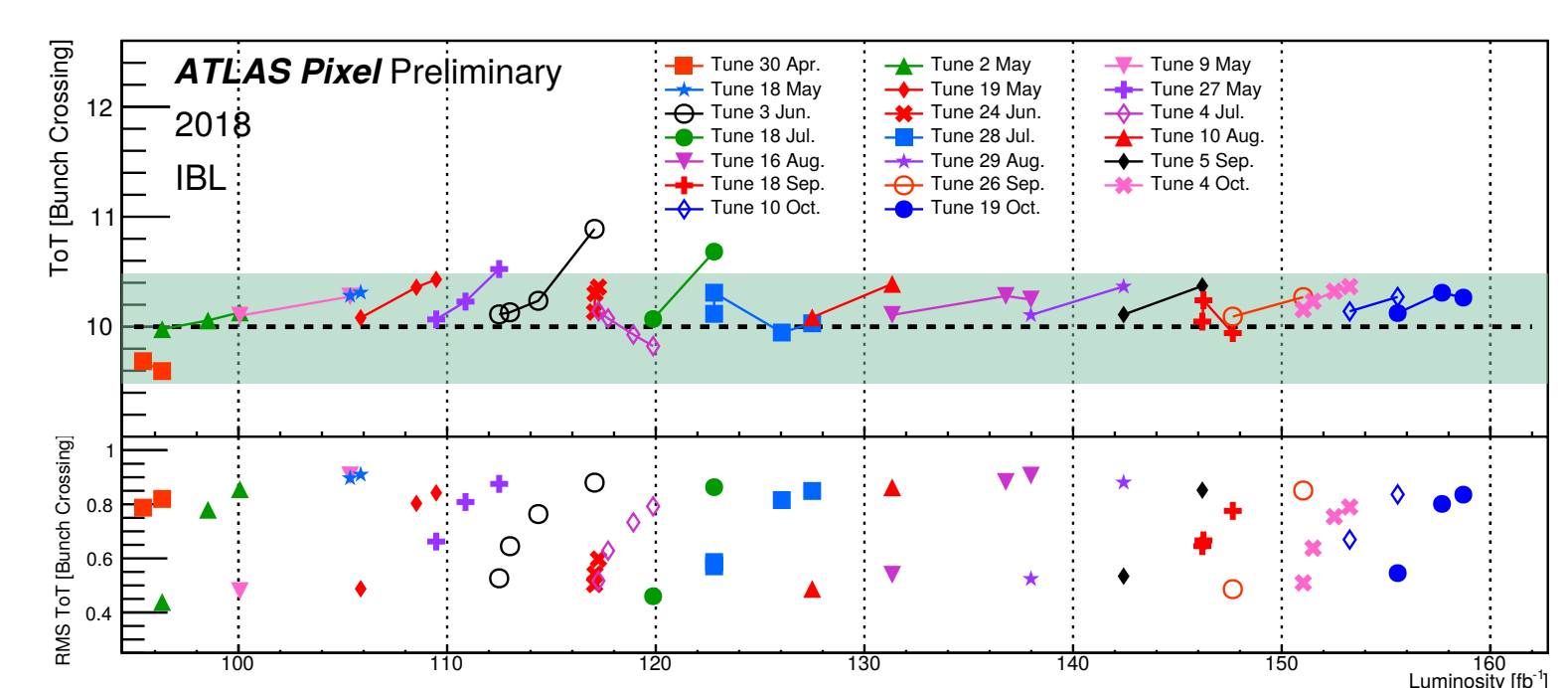


- Pile-up and instantaneous lumiosity increased with time
 - Peak pile-up (≈ 60) clearly above expectation (≈ 25)
 - Instantaneous peak lumiosity ($\approx 2 \times 10^{34}$) consistently above nominal value ($\approx 1 \times 10^{34}$)
- Challenging environment for data taking and hardware

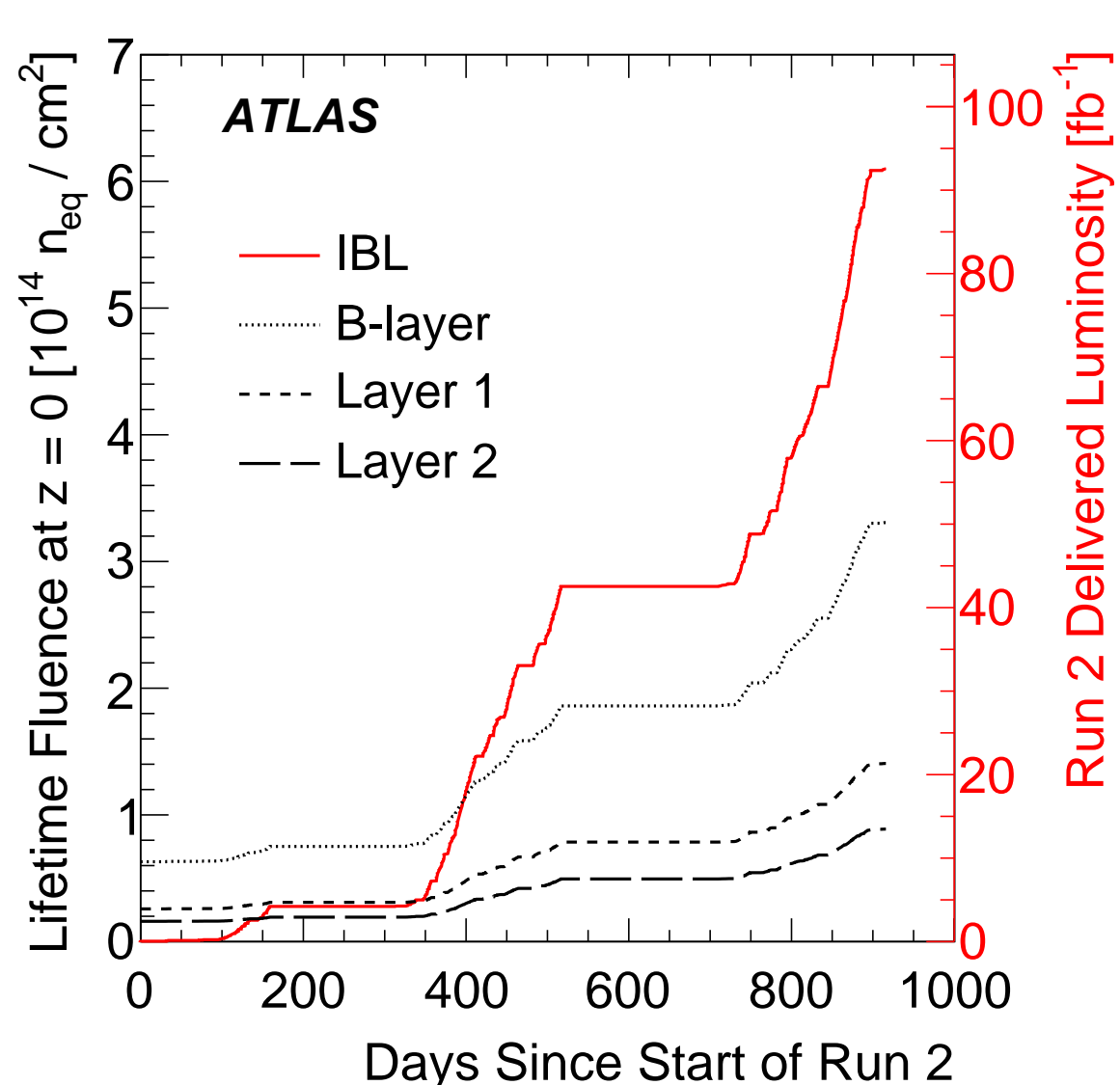
DETECTOR OPERATION



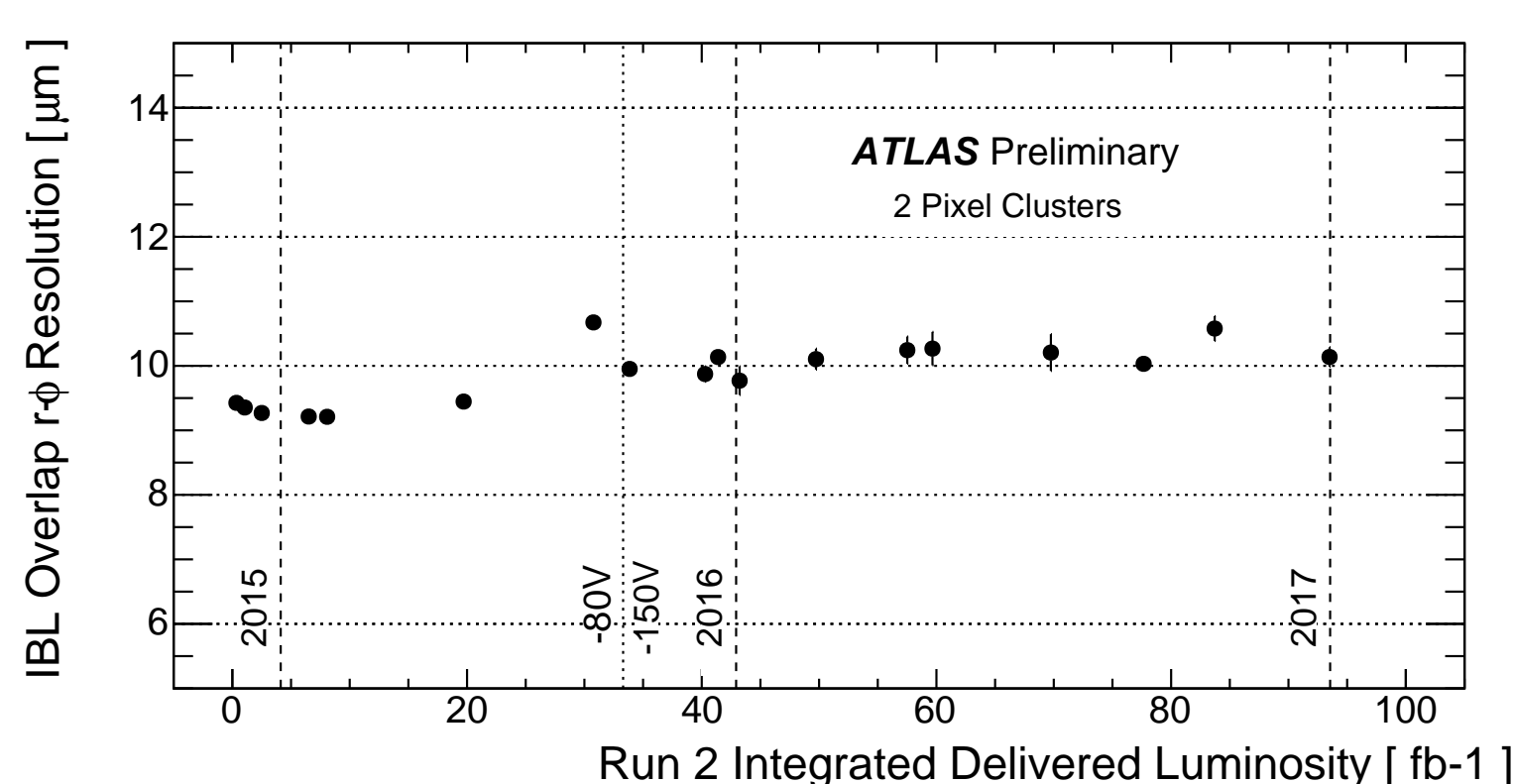
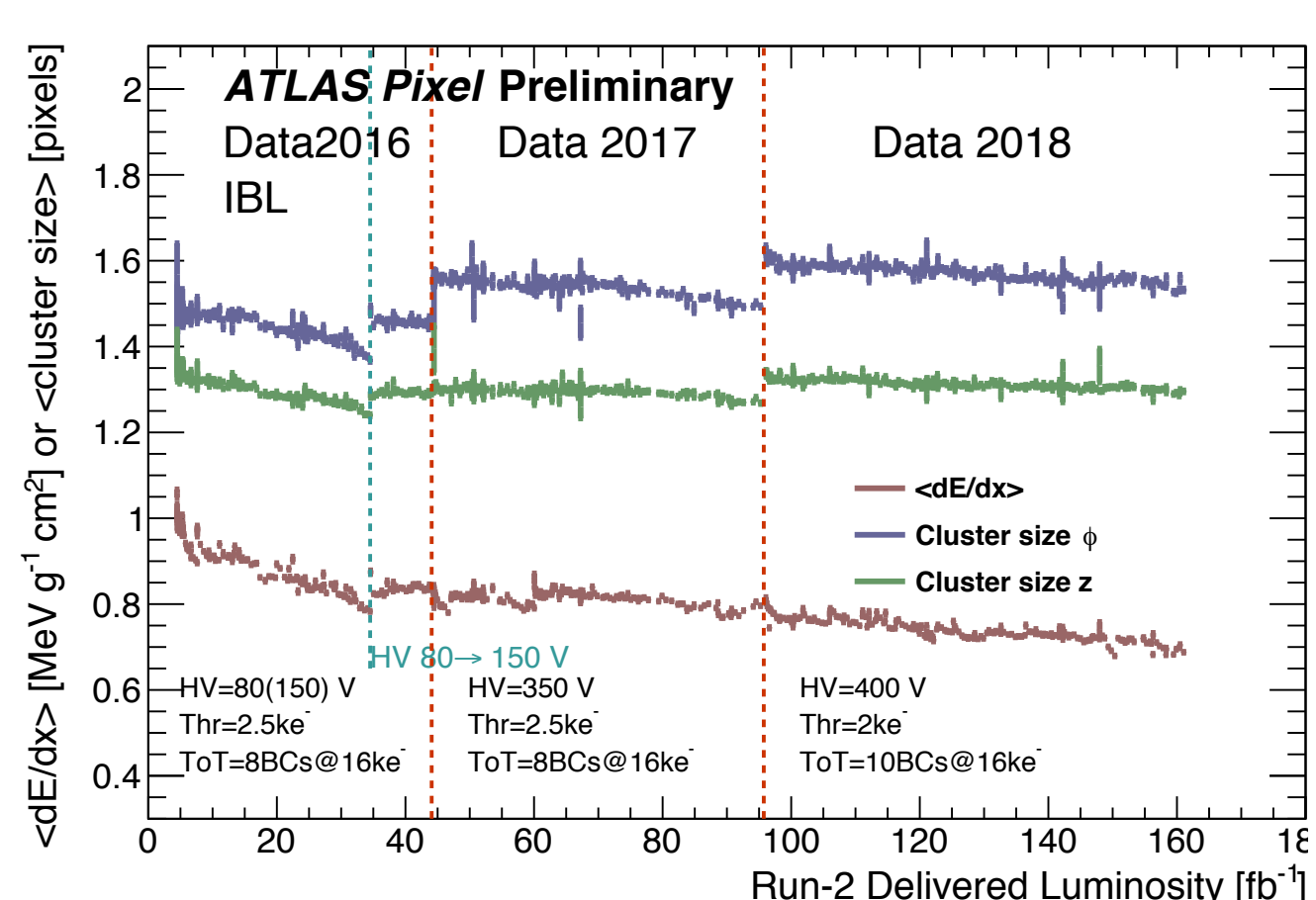
- Bandwidth consumption rises with μ
→ bandwidth saturation, buffer overflow
- Occupancy decreases due to radiation damage
→ thresholds were decreased in 2018
- Effects from total ionizing dose
→ Constant retuning needed (IBL)



RADIATION DAMAGE

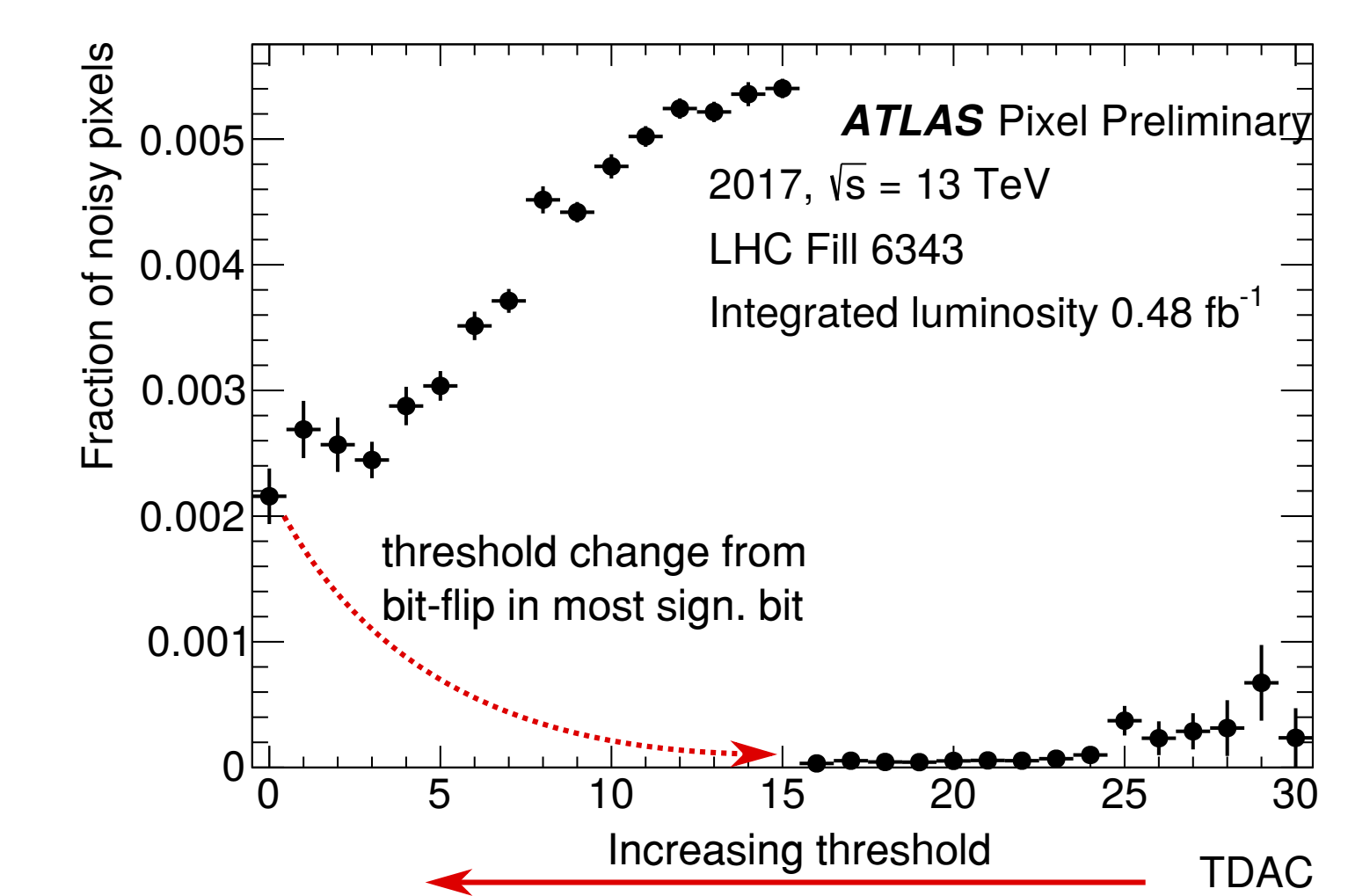
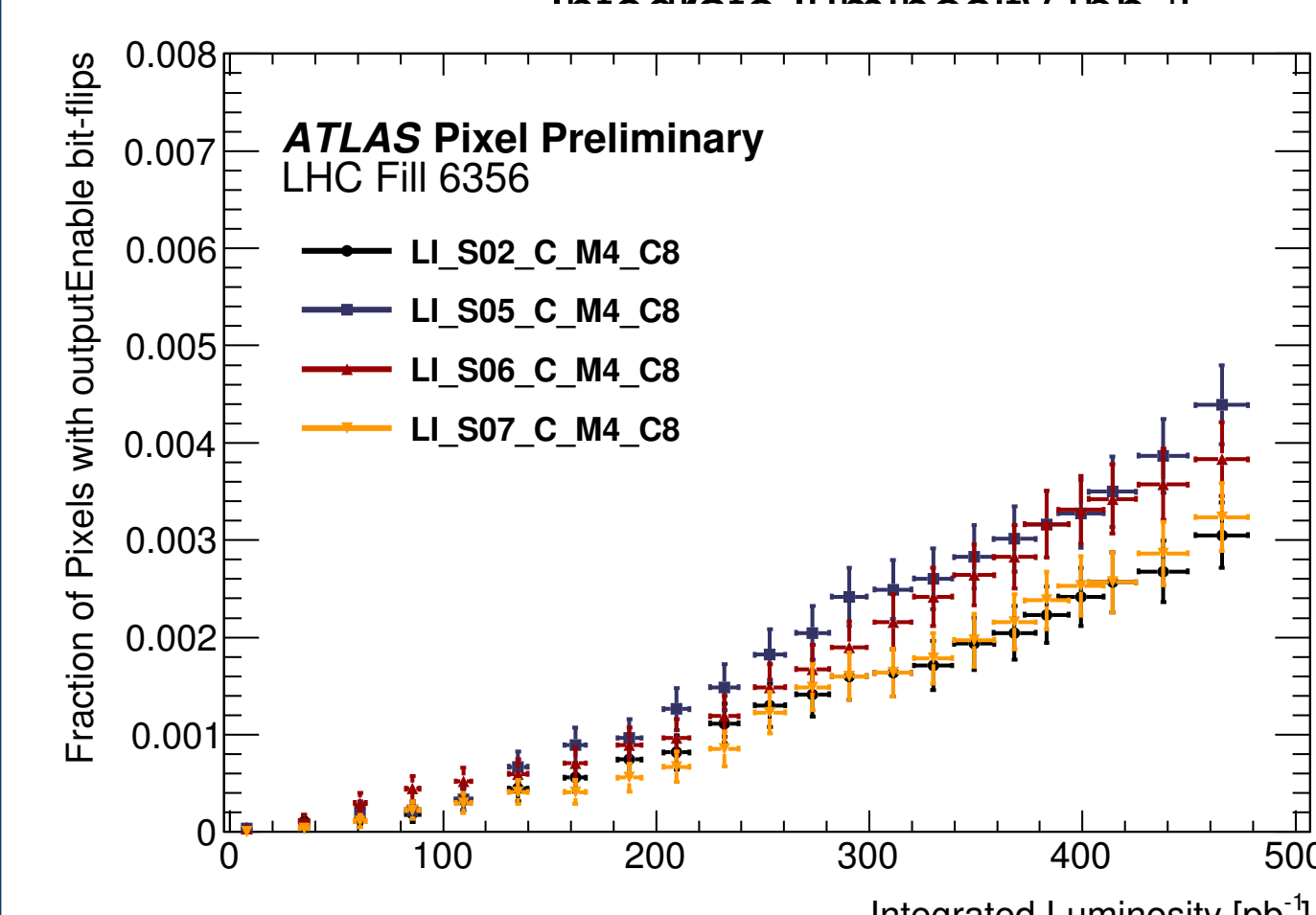
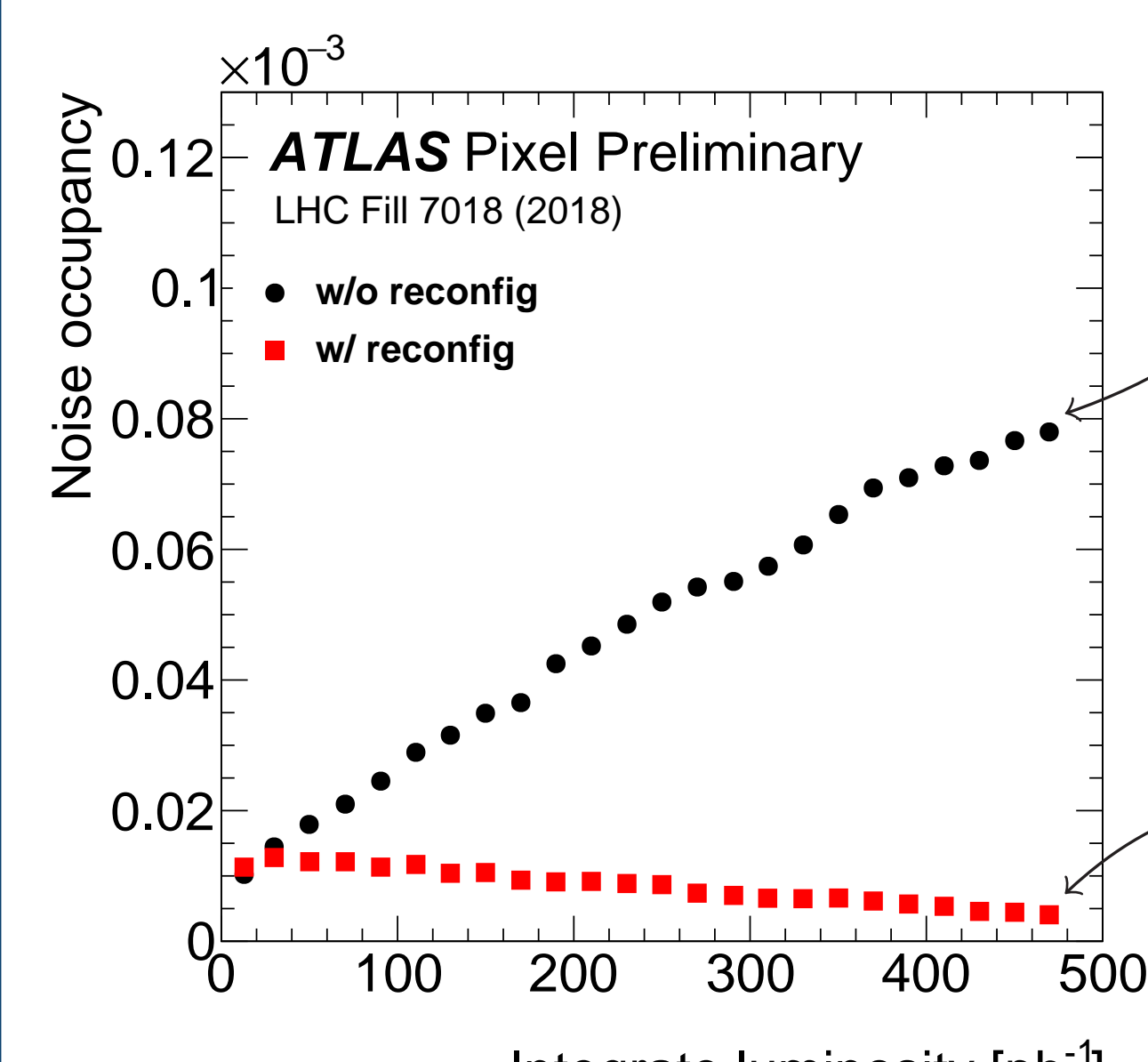


- Radiation damage affects charge collection, stronger effect closer to beam pipe
→ strongest for IBL
- Adjustment of HV, thresholds and temperature allows for counteracting these effects
- Spatial resolution stable despite increasing radiation damage
- New radiation damage model (see talk from Tomasso Lari on Wed.)



SINGLE EVENT EFFECTS

- Effects on global/single pixel registers (paper in preparation)
- SEU: flip of single bit due to nuclei interactions
- Observation: noise increases with lumiosity (accumulated effect)
- Enable bits flip during run (dedicated test with all pixels disabled)
- SEU flip of most significant bit causes reduction of local pixel threshold (TDAC) → noise increases
- Reconfiguration (global and single pixel latch) reduces noise from SEU



CONCLUSION

The ATLAS Pixel Detector was able to deal with the high level of radiation during Run-2. The effects of radiation damage become visible but the detector is operated in such a way that the physics performance stays stable.