Spares

			Timepix3 (2013)	Timepix4 (2019)
Technology			130nm – 8 metal	65nm – 10 metal
Pixel Size			55 x 55 μm	55 x 55 μm
Pixel arrangement			3-side buttable 256 x 256	4-side buttable 512 x 448
Sensitive area			1.98 cm^2	6.94 cm^2
Readout Modes	Data driven (Tracking)	Mode	TOT and TOA	
		Event Packet	48-bit	64-bit
		Max rate	0.43×10^6 hits/mm²/s	**3.58×10^6 hits/mm²/s**
		Max Pix rate	1.3 KHz/pixel	**10.8 KHz/pixel**
	Frame based (Imaging)	Mode	PC (10-bit) and iTOT (14-bit)	CRW: PC (8 or 16-bit)
		Frame	Zero-suppressed (with pixel addr)	Full Frame (without pixel addr)
		Max count rate	~0.82×10^9 hits/mm²/s	~5×10^9 hits/mm²/s
TOT energy resolution			< 2KeV	**< 1Kev**
TOA binning resolution			1.56ns	**195ps**
TOA dynamic range			409.6 μs (14-bits @ 40MHz)	**1.6384 ms** (16-bits @ 40MHz)
Readout bandwidth			≤5.12Gb (8x SLVS@640 Mbps)	**≤163.84 Gbps (16x @10.24 Gbps)**
Target global minimum threshold			<500 e^-	<500 e^-

Tube: timing resolution setup

Waveform generator

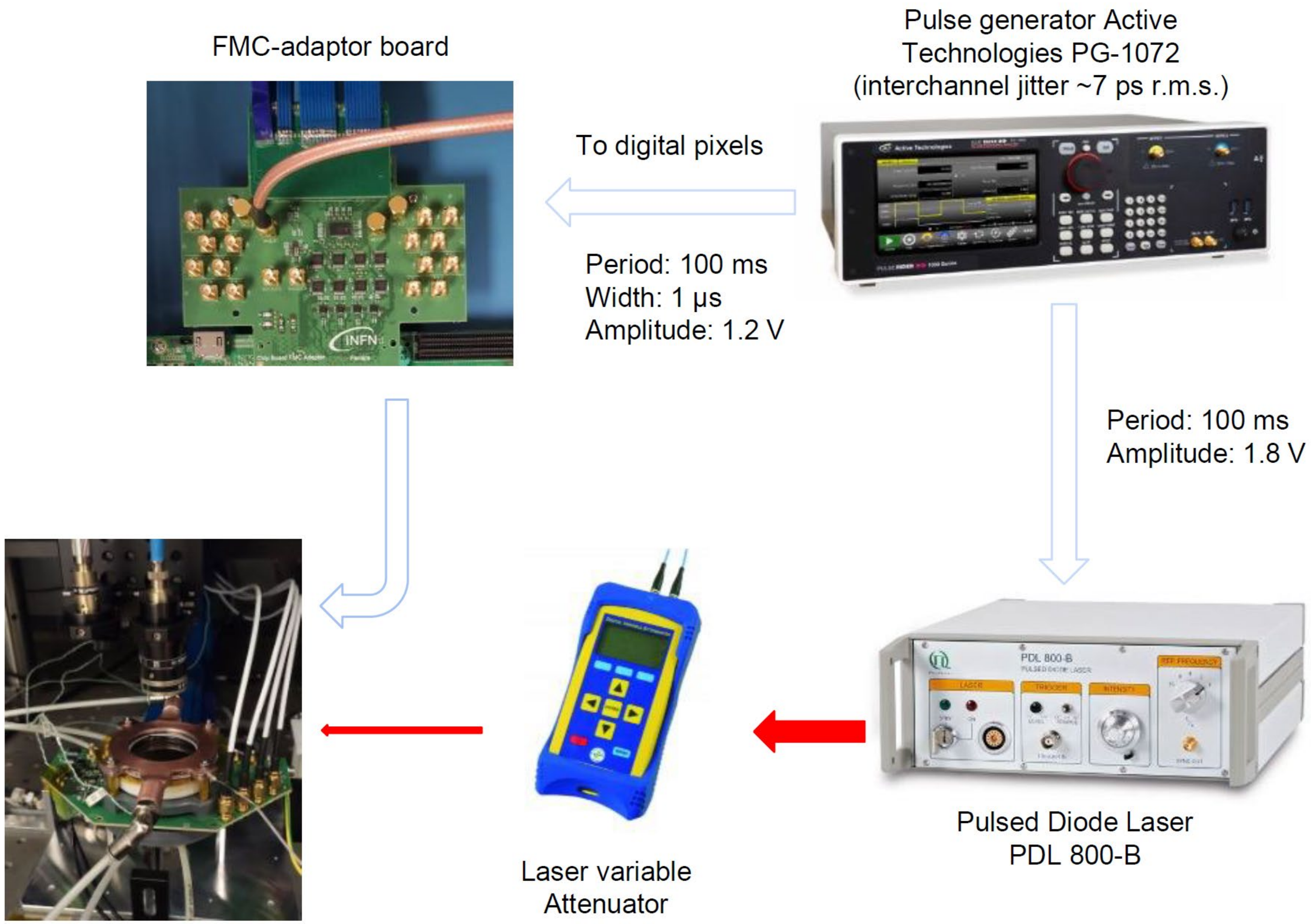
- input signal to digital pixels
- laser trigger

Laser:

- 405 nm
- variable attenuator

Zaber motion setup

- 3D position regulation
- Few µm precision



LHCb Upgrade II

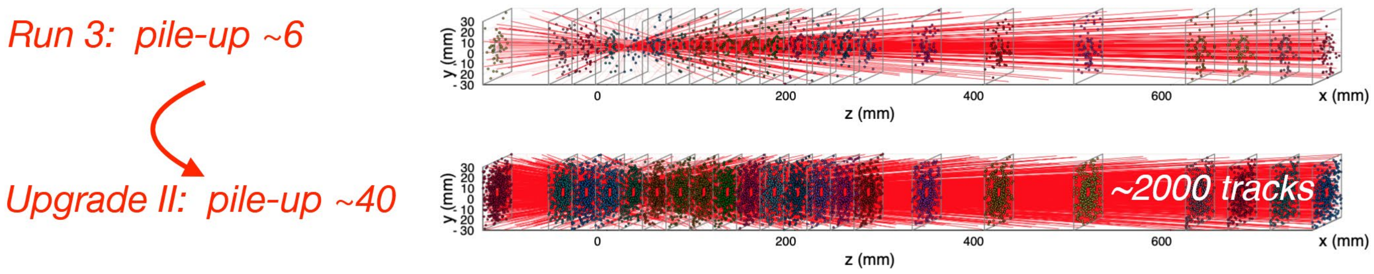
The LHCb experiment is planning a high-luminosity upgrade, targeting a luminosity of 1-2 × 10^{34} cm^{-2} s^{-1}

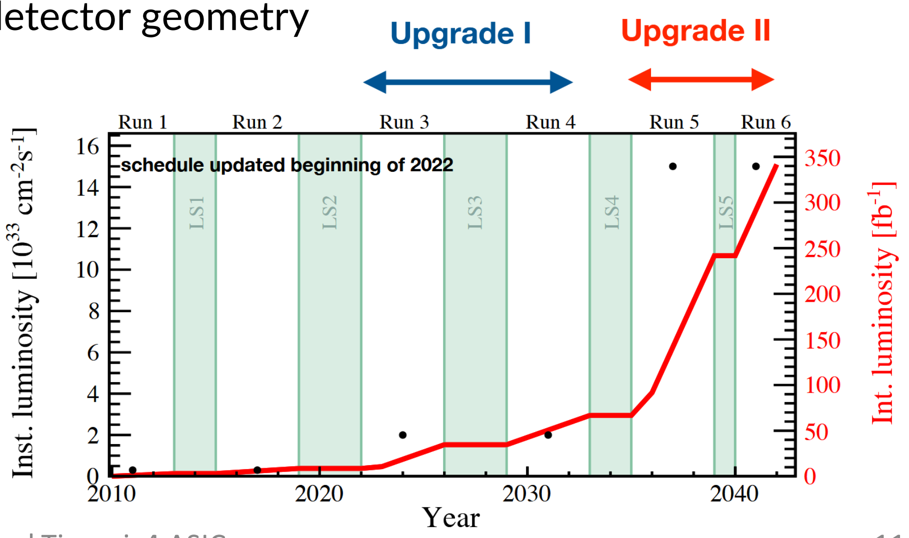
The RICH detector faces significant challenges, as it must achieve performance comparable to (or better than) that of Run 2-3 PID, but under much harsher conditions

Key Requirements:

- Single-photon sensitivity with high quantum efficiency (QE), particularly in the green/red-shifted spectrum
- **Photon hit density** reaching approximately **10 MHz/mm²**, assuming the current detector geometry and scaling with luminosity
- **High granularity**, ensuring **channel occupancy <25%,** with pixel sizes around **1×1 mm²**
- Excellent time resolution, with a target of **<100 ps r.m.s. per single photon**
- **Radiation hardness**, requiring tolerance up to **~2 Mrad TID**, **~3×10^{31} 1 MeV neq/cm²**, and **~1×10^{13} HEH/cm²**
- **No straightforward solution** currently **available** for RICH photodetectors.

State-of-the-art photodetectors **do not fully meet the requirements** for long-term operation at the RICH detector plane, considering the full experiment lifetime (equivalent to 300 fb^{-1} integrated luminosity) under the present detector geometry

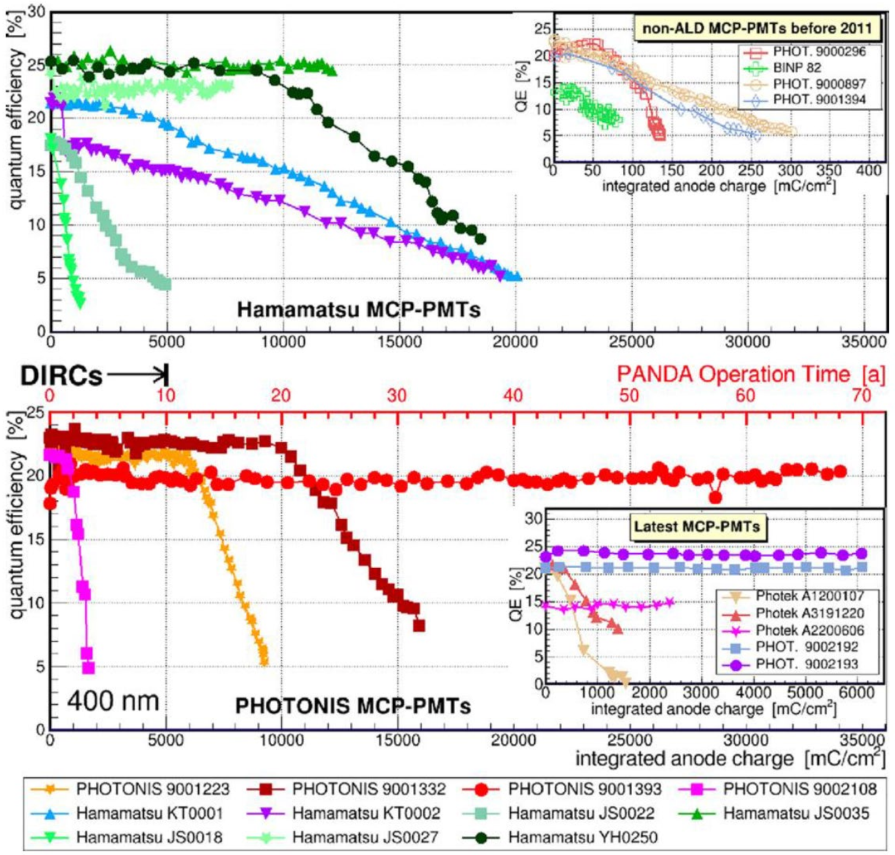




MCP-PMT limitations

- **MCP-PMT lifetime limited by the integrated anode charge**, which leads to a strong QE reduction
  - From **0.2 C/cm^2 to >30 C/cm^2** in recent years thanks to **ALD**
- With the expected photon hit rate (~10 MHz/mm2), assuming a 10^4 gain (very conservative), and an operation of 10 years with 25% duty cycle we have:
  - **Total IAC ~120 C/cm2**
  - **Anode current density ~2 μA/cm^2**
- ALD coating is based on the deposition of resistive and/or secondary emissive layers (could tune MCP properties)
  - Reported adverse effects on saturation current on some model with ALD

https://www.sciencedirect.com/science/article/pii/S0168900223000372?via%3Dihub



Proof of concept: use of a bare ASIC inside a vacuum tube with a microchannel plate (MCP) already demonstrated

- Proc. SPIE 7021 2008 (J.Vallerga, A. Tremsin et al.)]
- JINST 9 C05055 2014 (J.Vallerga, A. Tremsin et al.)]