"Technical" Start Date of Facility (This means, where the dates are not known, the earliest technically feasible start date is indicated - such that detector R&D readiness is not the delaying factor)				**< 2030**					**2030-2035**					**2035 - 2040**	**2040-2045**		**> 2045**		
				Panda 2025	CBM 2025	NA62/Klever 2025	Belle II 2026	ALICE LS3 [1]	ALICE 3	LHCb (≥LS4)[1]	ATLAS/CMS (≥ LS4)[1]	EIC	LHeC	ILC [2]	FCC-ee	CLIC [2]	FCC-hh	FCC-eh	Muon Collider
Vertex Detector[3]	MAPS Planar/3D/Passive CMOS LGADs	DRDT 3.1 DRDT 3.4	Position precision σ_{hit} (μm)		≃ 5		≲ 5	≃ 3	≲ 3	≲ 10	≲ 15	≲ 3	≃ 5	≲ 3	≲ 3	≲ 3	≃ 7	≃ 5	≲ 5
			X/X_0 (%/layer)	≲ 0.1	≃ 0.5	≃ 0.5	≲ 0.1	≃ 0.05	≃ 0.05	≃ 1		≃ 0.05	≲ 0.1	≃ 0.05	≃ 0.05	≲ 0.2	≃ 1	≲ 0.1	≲ 0.2
			Power (mW/cm^2)		≃ 60			≃ 20	≃ 20			≃ 20		≃ 20	≃ 20	≃ 50			
			Rates (GHz/cm^2)		≃ 0.1	≃ 1	≲ 0.1		≲ 0.1	≃ 6		≲ 0.1	≃ 0.1	≃ 0.05	≃ 0.05	≃ 5	≃ 30	≃ 0.1	
			Wafers area (")[4]					12	12			12			12		12		12
		DRDT 3.2	Timing precision σ_t (ns)[5]	10		≲ 0.05	100		25	≲ 0.05	≲ 0.05	25	25	500	25	≃ 5	≲ 0.02	25	≲ 0.02
		DRDT3.3	Radiation tolerance NIEL (x 10^{16} neq/cm^2)							≃ 6	≃ 2						≃ 10^2		
			Radiation tolerance TID (Grad)							≃ 1	≃ 0.5						≃ 30		
Tracker[6]	MAPS Planar/3D/Passive CMOS LGADs	DRDT 3.1 DRDT 3.4	Position precision σ_{hit} (μm)						≃ 6	≃ 5		≃ 6	≃ 6	≃ 6	≃ 6	≃ 7	≃ 10	≃ 6	
			X/X_0 (%/layer)						≃ 1	≃ 1		≃ 1	≃ 1	≃ 1	≃ 1	≃ 1	≲ 2	≃ 1	
			Power (mW/cm^2)						≲ 100	≃ 100		≲ 100		≲ 100	≲ 100	≲ 150			
			Rates (GHz/cm^2)							≃ 0.16									
			Wafers area (")[4]						12			12		12	12	12	12		12
		DRDT 3.2	Timing precision σ_t (ns)[5]						25	≲ 25		25	25	≲ 0.1	≲ 0.1	≲ 0.1	≲ 0.02	25	≲ 0.02
		DRDT3.3	Radiation tolerance NIEL (x 10^{16} neq/cm^2)							≃ 0.3							≲ 1		
			Radiation tolerance TID (Grad)							≃ 0.25							≲ 1		
Calorimeter[7]	MAPS Planar/3D/Passive CMOS LGADs	DRDT 3.2	Timing precision σ_t (ns)[5]											≲ 0.05	≲ 0.05	≲ 0.05	≲ 0.02		≲ 0.02
		DRDT 3.3	Radiation tolerance NIEL (x 10^{16} neq/cm^2)														≳ 10^2		
			Radiation tolerance TID (Grad)														≃ 50		
Time of Flight[8]	MAPS Planar/3D/Passive CMOS LGADs	DRDT 3.2	Timing precision σ_t (ns)[5]				≃ 0.02		≃ 0.02		≲ 0.03	≃ 0.02	≃ 0.02		≲ 0.01		≲ 0.01	≃ 0.02	
		DRDT 3.3	Radiation tolerance NIEL (x 10^{16} neq/cm^2)														≃ 10^2		
			Radiation tolerance TID (Grad)														≃ 30		

Values are indicative of performance targets and of operating conditions relevant to R&D. The latter are reported for the regions most exposed to radiation. Empty cells indicate either that projects are not concerned; or that specifications are already met or not yet fully established, for instance power consumption depends strongly on granularity and digital features that would be finally implemented.
1) LS3/LS4 are scheduled to start in 2025/2031 at the time of this document.
2) Reported rates are within the bunch trains.
3) LHCb/ATLAS/CMS consider Planar/3D sensors at the time of this document for rates and radiation tolerance. Pixelated LGADs could already be considered for NA62/Klever andfor longer term Vertex Detectors for timing precision for high timing precision.
4) The size of wafers achievable can depend on technology (industrial process) with a general trend to benefits from larger areas.
5) Ultrafast timing ≲ 100 ps could be differently achieved by the various technologies.
6) In trackers, coarser longitudinal granularities could be considered for MAPSs. Thorough performance and cost comparison with Passive CMOS would be needed. Pixelated LGADs could be considered for potentially higher timing precision.
7) Two options exist for calorimetry: pads O(1) mm pitch with analog readout (applying to all technologies) and particle counting digital with MAPSs O(50) μm. LGADs could be considered for potentially higher timing precision. DRT 3.1 apply w/o the X/X_0 constraint. DRT 3.4 could achieve higher compactness and be needed for the digital options to integrate full readout within the sensor area.
8) TOF, as compared to 4D-tracking, concerns dedicated layers for very high pile-up, beam induced background or particle identification with highest possible precision. Timing performance of sensors w/o amplifcation (MAPS, planar/3D/CMOS passive CMOS) is subject to R&D, while LGADs w/ amplification are at this stage expected to potentially provide higher precision. DRT 3.1 and DRT 3.4 of Vertex Detector and Tracker apply with less stringent requirement.

Figure 3.2: This matrix complements Figure 3.1 by showing, in the the same format, the required values of the quantities listed on the vertical axis as a function of time (and facility).

The choice to show the evolution of requirements with time reflects that the technologies discussed in the R&D themes are often valid alternatives for these (depending on which combination of properties is most needed) and in the longer term the distinctions between these different pixel approaches will become blurred as 3D-integration allows