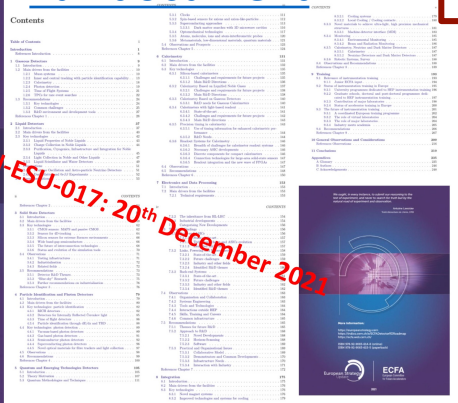
Detector Research and Development – DRD

international collaborations anchored at CERN: implementation

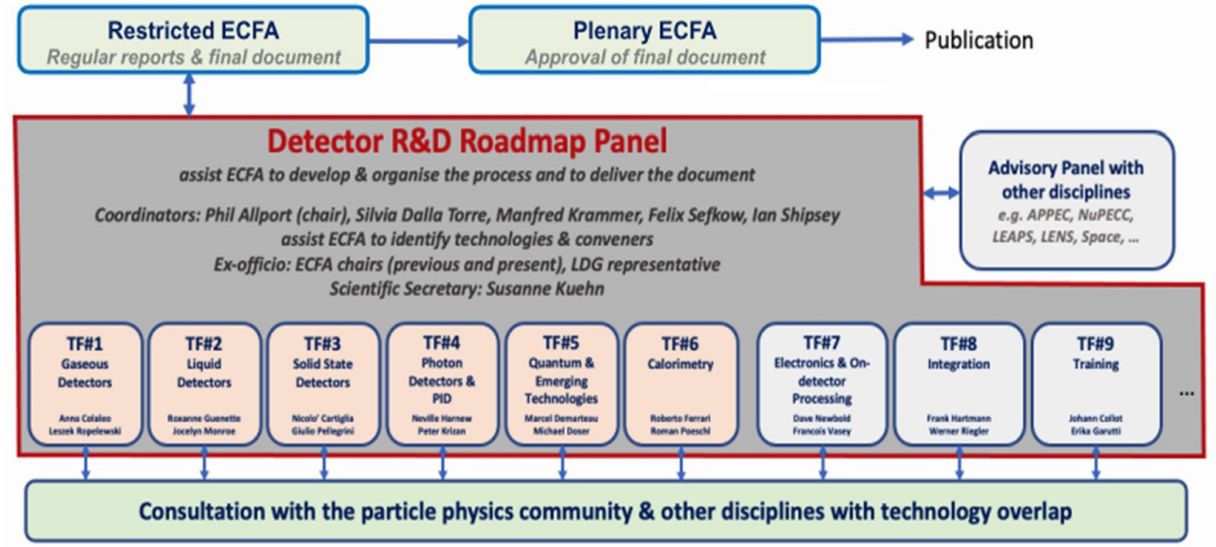
approved by CERN Council – coordinated by ECFA

[ECFA Detector R&D Roadmap]

[Full document]



CERN-ESU-017: 20th December 2021



- **DRD1 – Gaseous Detectors <<== RD51**
- **DRD2 – Liquid Detectors**
- **DRD3 – Solid State Detectors <<== RD50-42**
- **DRD4 – Photon Detectors and PID**
- **DRD5 – Quantum and Emerging Technologies**
- **DRD6 – Calorimetry**
- **DRD7 – Electronics and On-detector Processing <<== RD53**
- (DRD8 – Integration) ➔ Starting
- (DRD9 – Training) ➔ included in others / Starting

U.S. Detector R&D – CPAD

Coordinating Panel for Advanced Detectors

Marina Artuso Syracuse University

@ P5 Town Hall Meeting BNL April 12, 2023

- Develop and maintain the critical and diverse technical workforce
- **Double the US Detector R&D budget over the next five years, and modify existing funding models to enable R&D consortia along critical key technologies for the planned long-term science projects, sustaining the support for such collaborations for the needed duration and scale.**

Planning Detector Research Consortia

To sign up go to More Information

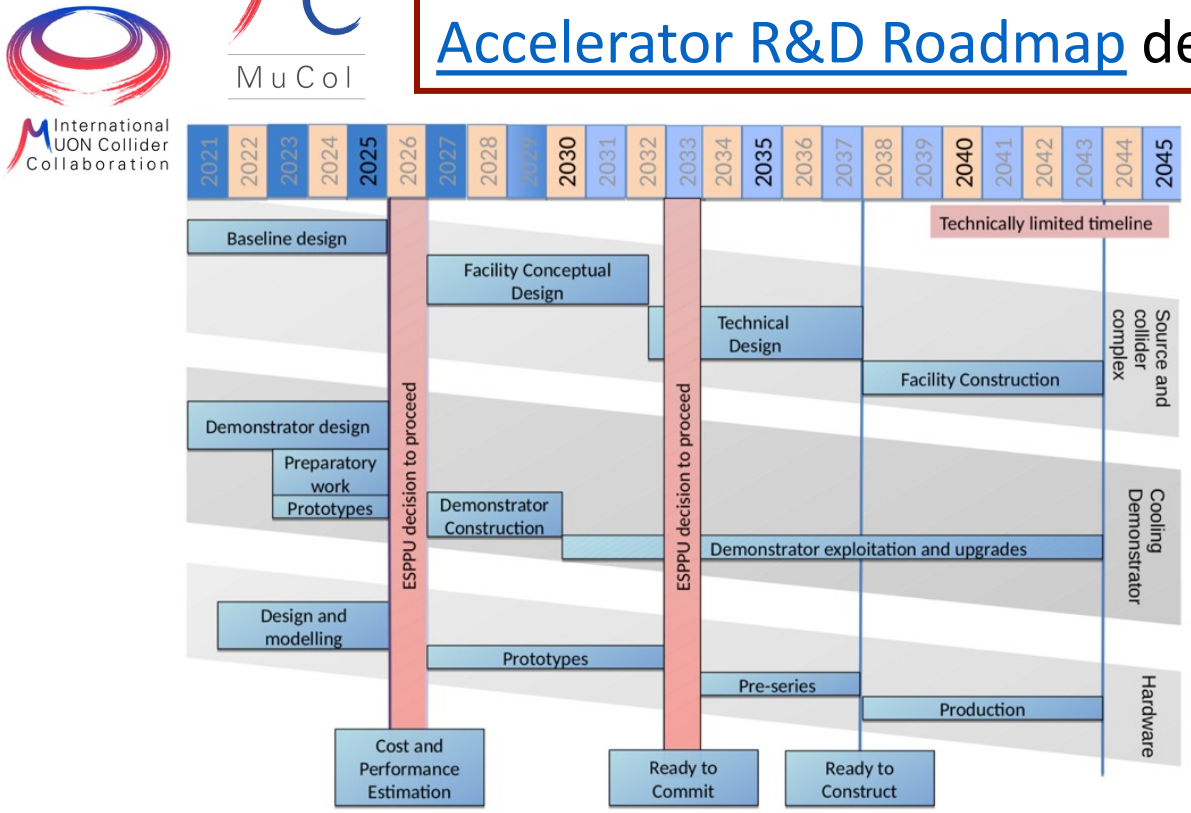
RD	Topic	Mailing list	Current subscribers
RDC1	Noble elements Detectors	cpad_rdc1@fnal.gov	43
RDC2	Photodetectors	cpad_rdc2@fnal.gov	62
RDC3	Solid State Tracking	cpad_rdc3@fnal.gov	71
RDC4	Readout and ASICs	cpad_rdc4@fnal.gov	64
RDC5	Trigger and DAQ	cpad_rdc5@fnal.gov	28
RDC6	Gaseous Detectors	cpad_rdc6@fnal.gov	29
RDC7	Low-background detectors	cpad_rdc7@fnal.gov	38
RDC8	Quantum and Superconducting Sensors	cpad_rdc8@fnal.gov	62
RDC9	Calorimetry	cpad_rdc9@fnal.gov	46
RDC10	Detector Mechanics New		JUST ADDED

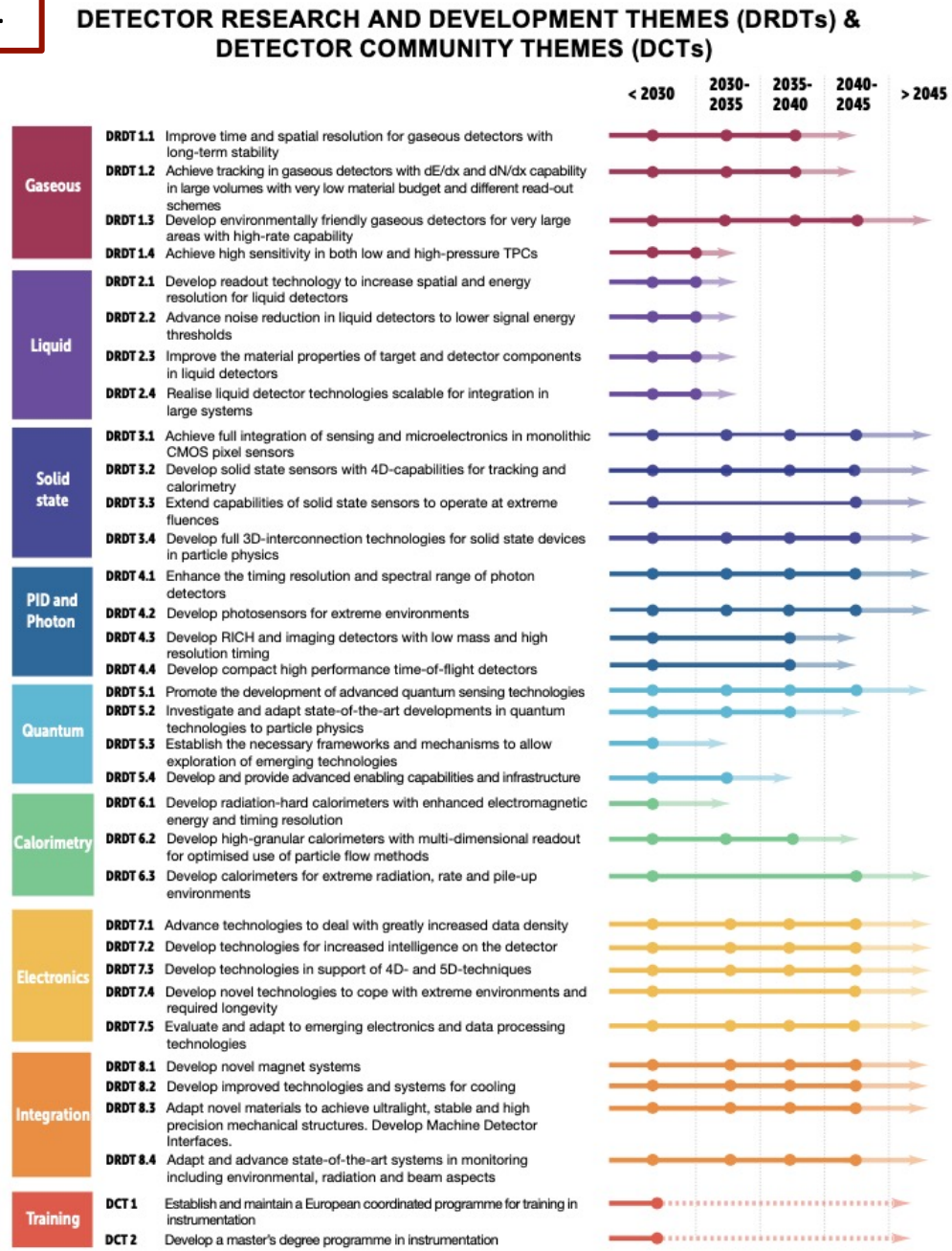
Picosecond timing across technologies consortium is under consideration

CPAD U.S. initiative
– new detector research consortia –

ECFA Detector R&D Roadmap dec 2021

Accelerator R&D Roadmap dec 2021





Update from ECFA detector roadmap

- 200 days/year
- collision rate 100 kHz

Last reference paper: [Towards a Muon Collider]

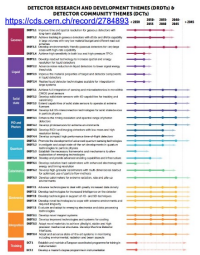
"Technical" Start Date of Facility (This means, where the dates are not known, the earliest technically feasible start date is indicated - such that detector R&D readiness is not the delaying factor)				< 2030					2030-2035					2035 - 2040	2040-2045		> 2045			
				Panda 2025	CBM 2025	NA62/Klever 2025	Belle II 2026	AUCE 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	≤ 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	≤ 0.05
			Power (mW/cm^2)		≃ 60			≃ 20	≃ 20			≃ 20		≃ 20	≃ 20	≃ 50				min possible
			Rates (GHz/cm^2)		≃ 0.1	≃ 1	≲ 0.1		≲ 0.1	≃ 6		≲ 0.1	≃ 0.1	≃ 0.05	≃ 0.05	≃ 5	≃ 30	≃ 0.1		≈ 0.5
			Wafers area (") [4]					12	12			12			12		12		12	TBD best
		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	≤ 0.03
		DRDT3.3	Radiation tolerance NIEL (x 10^{16} neq/cm^2)							≃ 6	≃ 2						≃ 10^3			≈ 0.1/y
			Radiation tolerance TID (Grad)							≃ 1	≃ 0.5						≃ 30			≈ 0.1/y
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		7 tran / 90 long
			X/X_0 (%/layer)						≃ 1	≃ 1		≃ 1	≃ 1	≃ 1	≃ 1	≃ 1	≲ 2	≃ 1		0.2 total tracker
			Power (mW/cm^2)						≲ 100	≃ 100		≲ 100		≲ 100	≲ 100	≲ 150				min possible
			Rates (GHz/cm^2)							≃ 0.16										0.02
			Wafers area (") [4]						12			12		12	12	12	12		12	TBD best
		DRDT 3.2	Timing precision σ_t (ns) [5]						25	≲ 25		25	25	≲ 0.1	≲ 0.1	≲ 0.1	≲ 0.02	25	≲ 0.02	≤ 0.06
		DRDT3.3	Radiation tolerance NIEL (x 10^{16} neq/cm^2)							≃ 0.3							≲ 1			≈ 0.01/y
			Radiation tolerance TID (Grad)							≃ 0.25							≲ 1			≈ 0.001/y
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	< 0.2 arr / < 0.1 integ
		DRDT 3.3	Radiation tolerance NIEL (x 10^{16} neq/cm^2)														≳ 10^3			≈ 0.05/y
			Radiation tolerance TID (Grad)														≃ 50			≈ 0.0001/y
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		TOF not yet considered
		DRDT 3.3	Radiation tolerance NIEL (x 10^{16} neq/cm^2)														≃ 10^3			
			Radiation tolerance TID (Grad)														≃ 30			

Instrumentation R&D

- DOE Detector R&D BRN Report, Snowmass Instrumentation Report – US;
- 2021 ECFA Detector R&D Roadmap – Europe.

ECFA initiative to establish new detector R&D “groups” (DRD”X”).
CPAD initiative planning new detector research consortia (RDC”X”).
The two initiatives closely connect in structure and objectives.

RD	Topic
RDC1	Noble elements Detectors
RDC2	Photodetectors
RDC3	Solid State Tracking
RDC4	Readout and ASICs
RDC5	Trigger and DAQ
RDC6	Gaseous Detectors
RDC7	Low-background detectors
RDC8	Quantum and Superconducting Sensors
RDC9	Calorimetry
RDC10	Detector Mechanics



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Muon Collider Detector R&D

Solid-State Detectors (TF3/DRD3, RDC3)
- Radiation-hard silicon detectors with O(10ps) timing resolution
- Integrated or hybrid design

Calorimetry (TF6/DRD6, RDC9)
- High-granularity (transverse and longitudinal); good radiation hardness
- good timing resolution and low integration time (esp. ECAL)
- Scintillator or Silicon-based sampling; Crilin: semi-homogenous w/ SiPMs readout

Gaseous Detectors (TF1/DRD1, RDC6)
- Mostly Muon spectrometer: micromegas, GEM, etc.. focus on good timing resolution, sustainable gas mixtures

Photon-Detectors and PID (TF4/DRD4, RDC2)
- Less explored so far, but PID can offer additional physics oportunities

Electronics (TF7/DRD7, RDC4)
- Radiation-hard ASIC design (HL-LHC levels)
- Small feature size for more complex on-chip processing (tracker, calo?)

Trigger and DAQ (RDC5)
- Triggerless readout requires large real-time data handling

Detector Mechanics (RDC10)
- Lightweight structures, nozzle support design,