WG2 Summary in the context of the ECFA Detector R&D Roadmap Implementation

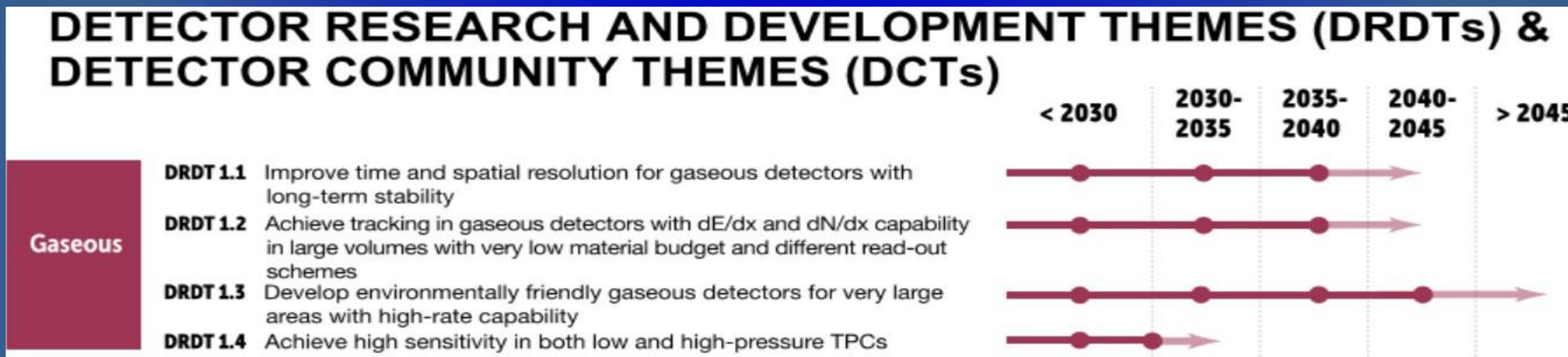
F. Garcia, P. Gasik,
F. Grancagnolo,
D. Gonzalez Diaz,
G. Aielli, G. Pugliese;
A. Colaleo, M. Titov
for the ECFA part

WG2 Conveners

DRD1 Community Kick-Off Workshop,
CERN, March 1-3, 2023

Towards DRD1 Collaboration Structure & WG2

The DRD proposals should establish a programme and a collaborative framework (organisation) to achieve the ECFA roadmap Detector R&D Themes (DRDTs)



Our (DRD1) main goal of the process is to <u>build "community-driven" DRD1 gaseous detector collaboration</u> and accepted by DRDC

Keep RD51 structure in WGs including alignment with the scientific program of the ECFA roadmap, looking more generally to future facilities challenges and specifically to the ECFA Roadmap selected Detector RD Themes (DRDT)

WG2 Applications: Full alignent with the ECFA detector R&D roadmap (DRDT topics)

- **Muon systems**
- **Inner and central tracking with PID capability**
- **Calorimetry**
- **Photon detection**
- **Time of Flight systems**
- **TPCs for rare event searches**

Beyond HEP → many synergies with muon, trackers, calo, PID/TOF, rare events developments

- **Fundamental research applications beyond HEP**
- **Medical and industrial applications**

Interconnection between ECFA DRDTs & WG2 Applications

- ✓ *WG2 will **monitor progress in R&D** aimed at **specific applications** for future experiments*
- ✓ *Keep **various gas detector technology** options and **<u>do not prioritize</u>**. This has the advantage that the technologies can be further developed until specific choices have to made once future experiments are approved.*
- ✓ *Furthermore — and as important — this **keeps a broad community** of detector research groups at universities and laboratories **involved** and increases the chance to **arrive at the best technically possible detector solution** when it has to be built.*

"Technical" Start Date of Facility

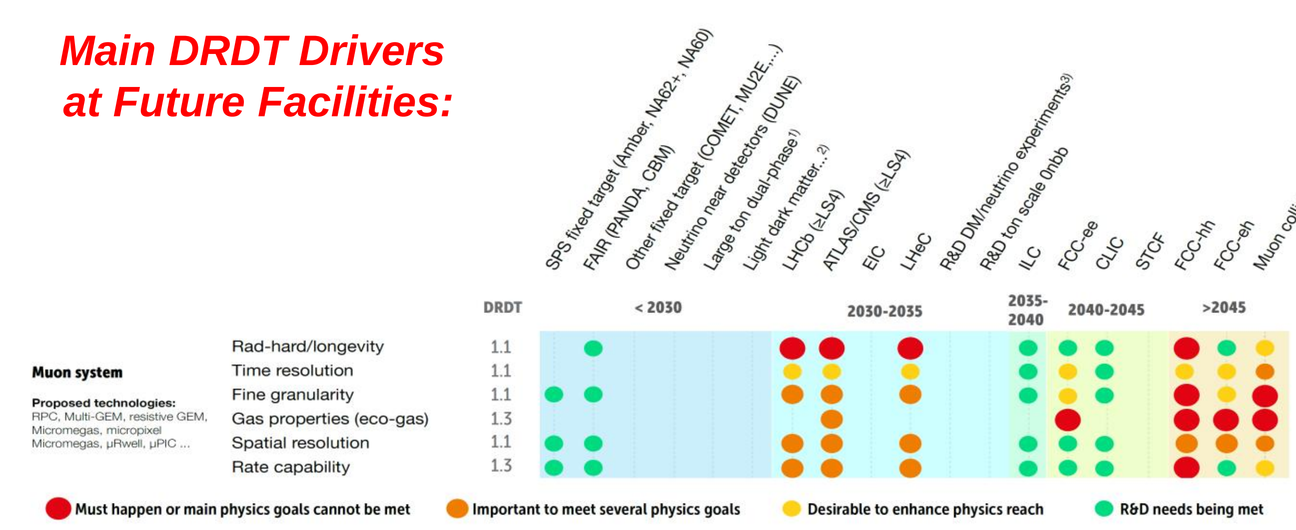
Color code of the cells:
Must happen or main physics goals cannot be met
Important to meet several physics goals
Desirable to enhance physics reach
R&D needs being met

				< 2030						2030-2035						2035 -2040	2040-2045			> 2045		
			DRDT	SPS Fixed Traget (Amber, NA62+, NA60)	FAIR (PANDA, CBM)	Other fixed target (COMET, MU2E, ..)	Neutrino Near Detectors (Dune)	Large Ton dual-phase (PandaX-4T, LZ, DarkSide -20k, Argo 200k, ARIADNE..)	Light dark matter, solar axion,0nbb, rare nuclei&ions and astroparticle reactions, Ba tagging	LHCb ((≥ LS4)	ATLAS/CMS (≥ LS4)	EIC	LHeC	R&D for 100-Ton scale dual-phase DM/neutrino experiments	R&D Ton scale 0nbb	ILC	FCC-ee	CLIC	STCF	FCC-hh	FCC-eh	Muon Collider
Muon system	Proposed technologies: RPC, Multi-GEM, resistive-GEM, Micromegas, micro-pixel Micromegas, μRwell, μPIC...	Rad-hard/longevity	1.1		10^{14} neq/cm²/year					2C/cm												
		Time resolution	1.1							ns												
		Fine granularity	1.1																			
		Gas properties (eco-gas)	1.3																			
		Spatial resolution	1.1		<1 mm					~cm												
		Rate-capability	1.3		500kHz/cm2					900 kHz/cm²												
Central Tracking with PID cap	Proposed technologies: TPC+(multi-GEM, Micromegas, Gridpix), Drift Chambers, Cylindrical layers of MPGD, Straw chambers	Rad-hard/longevity	1.1																			
		Low X0	1.2																			
		IBF (TPC only)	1.2																			
		Time resolution	1.1																			
		Rate-capability	1.3									100 kHz/cm²										
		dE/dx	1.2																			
		Fine granularity	1.1																			
Preshower/Calorimeters	Proposed technologies: RPC, MRPC, Micromegas and GEM,μRwell, InGrid (Integrated Micromegas grid with pixel readout), Pico-sec, FTM	Rad-hard/longevity	1.1																			
		Low power	1.1																			
		Gas properties (eco-gas)	1.3																			
		Fast timing	1.1																			
		Fine granularity	1.1																			
		rate-capability	1.3																			
		large array/integration	1.3																			
Photon detectors/TOF	Proposed technologies: RICH+MPGD, TRD+MPGD, TOF: MRPC, Picosec, FTM	Rad-hard (photocathode)	1.1																			
		IBF (RICH only)	1.2																			
		Precise timing	1.1																			
		Rate-capability	1.3																			
		dE/dx	1.2																			
		Fine granularity	1.1																			
TPC for rare dacays	Proposed technologies: TPC+MPGD operation (from very low to very high pressure)	Low power	1.4																			
		Fine granularity	1.4																			
		Large array/volume	1.4																			
		Higher energy resolution	1.4																			
		Lower energy threshold	1.4																			
		Optical readout	1.4																			
		Gas pressure stability	1.4																			
		Radiopurity	1.4																			

Start adding technical challenges

A. Colaleo

DRD1 Working Group 2: (1) Muon Systems



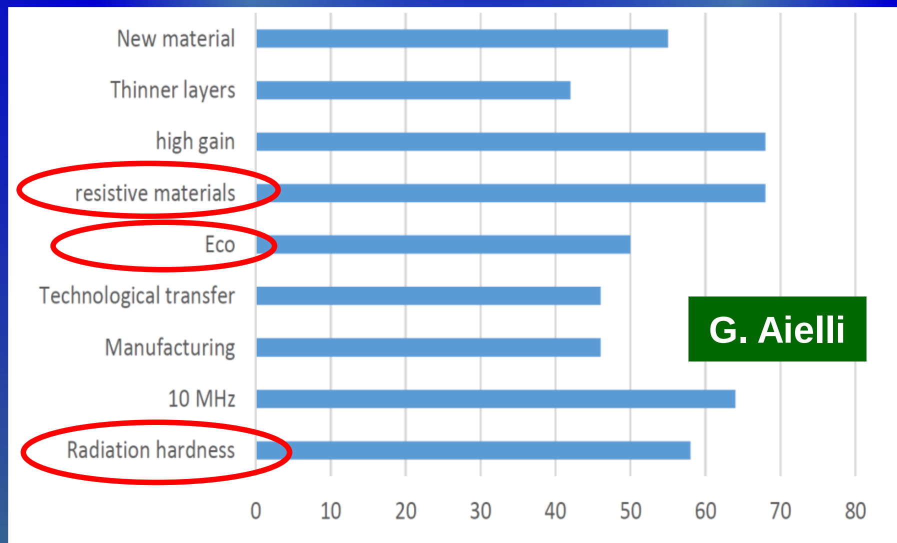
DRDTs vs Technology Challenges:

Muon System	DRDT
• Radiation hardness and stability of large area up to integrated charges of hundreds of C/cm2: - aging issues and discharges;	1.1-1.3
• Operation in a stable and efficient manner with incident particle flows up to ~10 MHz/cm2: - miniaturisation of readout elements needed to keep occupancy low	1.1-1.3
• Manufacturing, on an industrial scale, large detectors at low cost, by means of a process of technological transfer to the industry and identifies processes transferable to industries	1.1
• Identification of eco-friendly gas mixture and mitigation of the issue related to the operation with high WGP gas mixture: - gas tightness;gas recuperation system;accessibility for repairing	1.3
• Study of resistive materials (RPC and MPGD): - higher gain in a single multiplication layer, with a remarkable advantage for assembly, mass production and cost - new material and production techniques for resistive layers for increasing the rate capability	1.1; 1.3
• Thinner layers and mechanical precision over large area	1.1

Some key challenges defining future R&D directions :

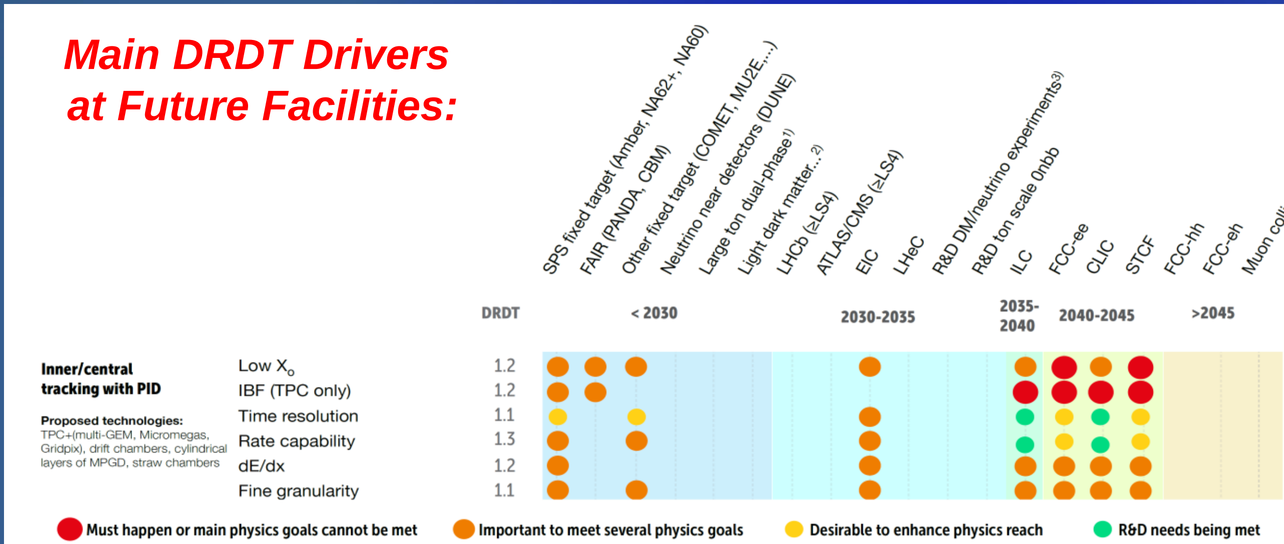
- ✓ ***Radiation hardness, high rate capability, resistive materials***
- ✓ ***Gas properties (eco-friendly gases)***

Survey: 46 out of 69 institutes interested



Most of technologies (MPGD, RPC, large volume, new) have a good institute coverage (# tech./per inst. ~2)

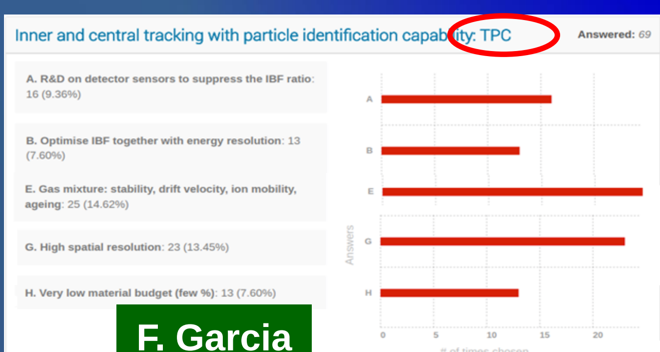
DRD1 Working Group 2: (2) Inner/Central Tracking with PID

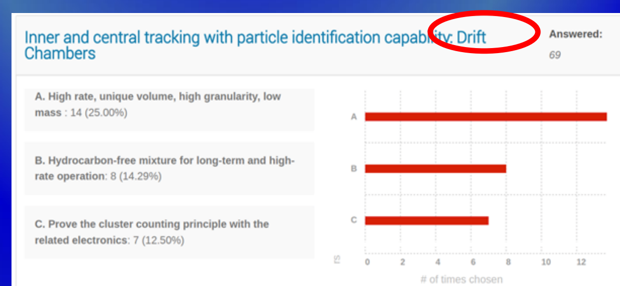


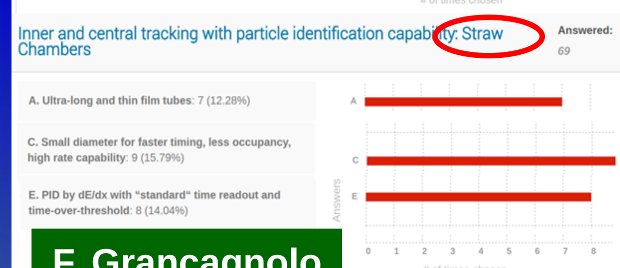
Some key challenges defining future R&D directions :

- ✓ High rate, low mass, granularity, dE/dx & cluster counting
- ✓ Ion backflow suppression (TPC only), gas mixture optimization

Survey: 33 (12 – drift, 5 – straws, 7 – for both, 9 – TPC) out of 69 institutes interested



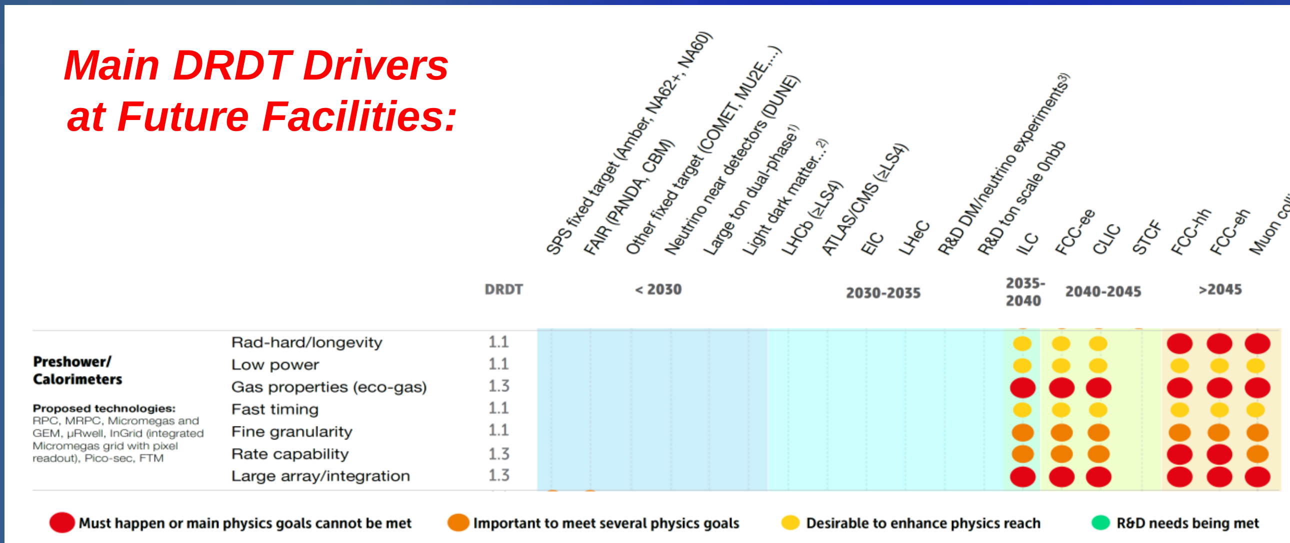




DRDTs vs Technology Challenges:

Inner and Central tracking	DRDT
Drift chambers	
• High rate, unique volume, high granularity, low mass	1.1/1.2
• Hydrocarbon-free mixture for long-term and high-rate operation	1.3
• Prove the cluster counting principle with the related electronics	1.2
• Mechanics: new wiring procedure, new wire materials	1.2
• Integration: accessibility for repairing	1.1
TPC	
• R&D on detector sensors to suppress the IBF ratio	1.2
• Optimize IBF together with energy resolution	1.2
• Gain optimization: IBF, discharge stability	
• Uniformity of the response of the sensors	1.2
• Gas mixture: stability, drift velocity, ion mobility, aging	1.1
• Influence of Magnetic field on IBF	1.1;1.2
• High spatial resolution	1.2
• Very low material budget (few %)	
• Mechanics: thickness minimization but robust for precise electrical properties for stable drift velocity	1.1;1.2
• Integration: cooling of electronics	1.2
Straw chambers	
• Ultra-long and thin film tubes	
• "Smart" designs: self-stabilized straw module, compensating relaxation	1.2
• Small diameter for faster timing, less occupancy, high rate capability	1.2
• Reduced drift time, hit leading times and trailing time resolutions, with dedicated R&D on the electronics	1.1-1.3
• PID by dE/dx with "standard" time readout and time-over-threshold	1.2
• 4D-measurement: 3D-space and (offline) track time	1.2
• Over-pressurized tubes in vacuum: control the leakage rate to maintain the shape	1.1

DRD1 Working Group 2: (3) Calorimetry

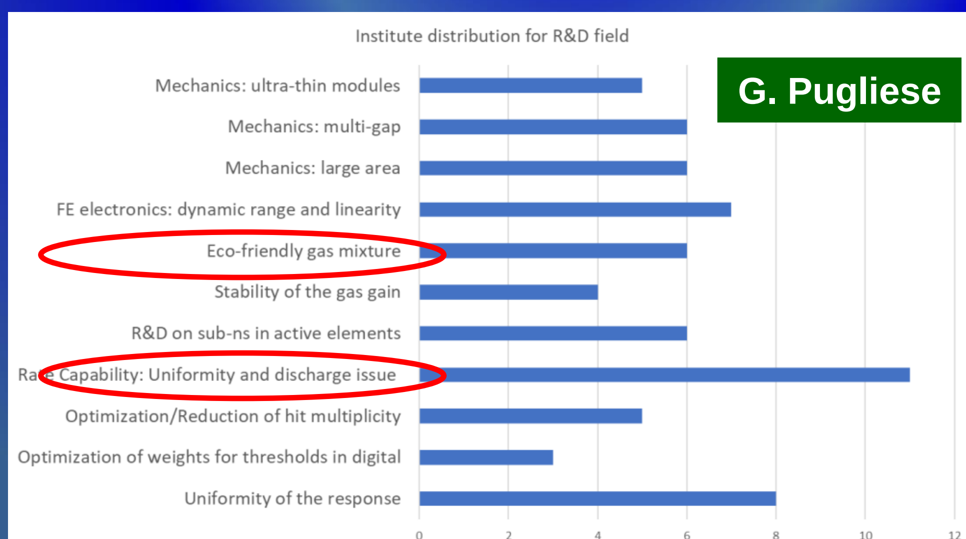


Some key challenges defining future R&D directions

- ✓ *Scalability of technology: Large areas with high uniformity and response stability*
- ✓ *Gas distribution systems; addressing the GWP challenge (eco-friendly gases)*

Survey: 13 out of 69 institutes interested

Each institute is involved in > 1 tech. (typically, MPGD + something; all are well-represented)

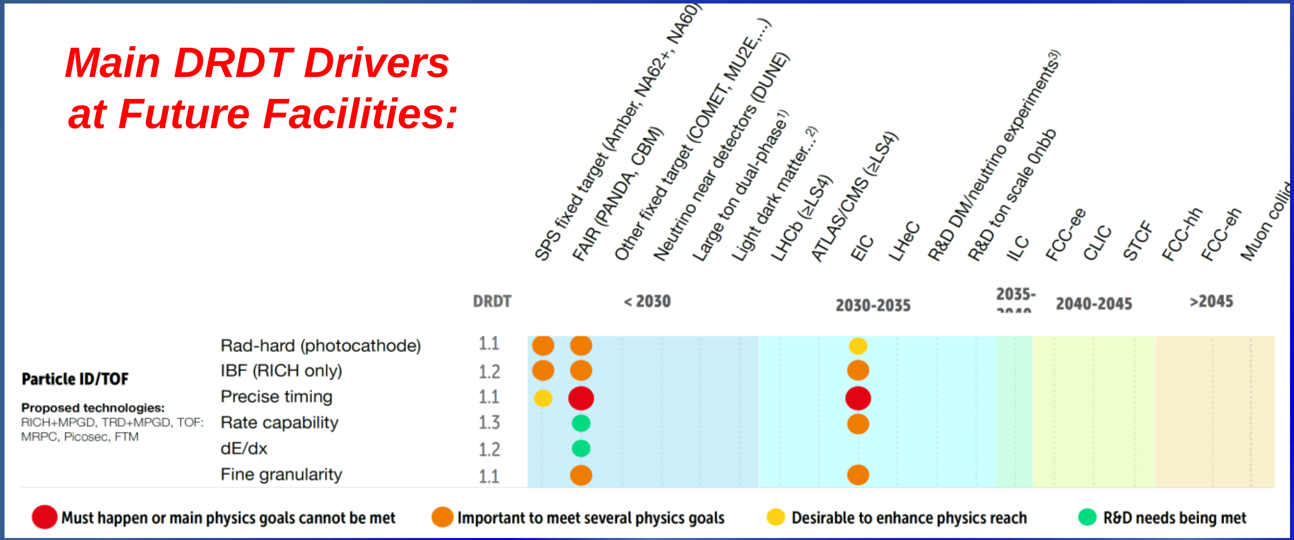


DRDTs vs Technology Challenges:

Calorimetry	DRDT
• Uniformity of the response of the large area and dynamic energy range	*1.1*
• Optimization of weights for different thresholds in digital calorimeters	*N/A*
• Rate capability in detectors based on resistive materials: resistivity uniformity, discharge issue at high rate and in large area detector	*1.3*
• R&D on sub-ns in active elements: resolution stables over wide range of fluxes	*1.1/ 1.3*
• Gas homogeneity and stable over time	*N/A*
• Eco-friendly gas mixture for RPC	*1.3*
• Stability of the gas gain: fast monitoring of gas mixture and environmental conditions	*1.3*
• Mechanics: - large area needed to avoid dead zone: limitation on size and planarity of PCB is an issue - multi-gap with ultra-thin modules: very thin layer of glass and HPL electrodes, gas gap thickness uniformity few micron	*1.1*

DRD1 Working Group 2: (4) PID / TOF

Main DRDT Drivers at Future Facilities:



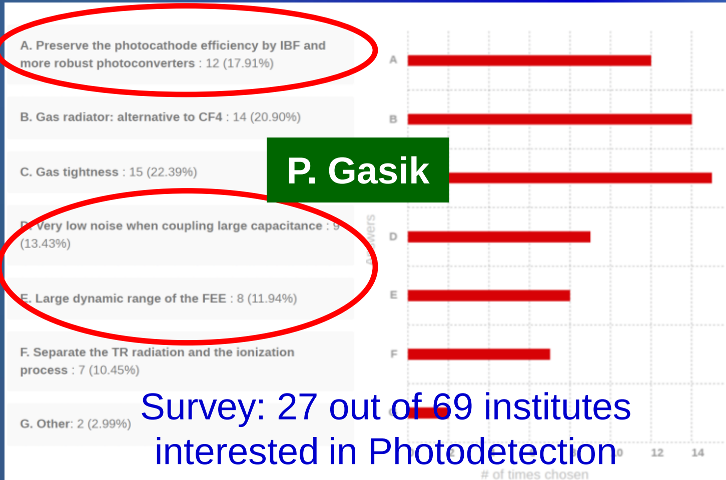
DRDTs vs Technology Challenges:

Photon detection	DRDT
• Preserve the photocathode efficiency by IBF and more robust photoconverters	1.1
• Gas radiator: alternative to CF4	1.3
• Gas tightness	1.3
• Very low noise when coupling large capacitance	1.2
• Large dynamic range of the FEE	1.2
• Separate the TR radiation and the ionization process	1.2
• In TRD use of cluster counting technique and improve it by means of a InGrid	1.2
TOF	
• Uniform rate capability and ...me resolution over large ...tector area	1.1-1.3
New material for high rate (low resistivity, radiation hardness) - uniform gas distribution - thinner structures: mechanical stability and uniformity	1.1-1.3
• Eco-gas mixture	1.3
• Electronics: Low noise, fast rise time, sensitive to small charge	1.2
• Possibly optical readout	1.3
• Precise clock distribution and synchronization over large area	N/A

Some key challenges defining future R&D directions

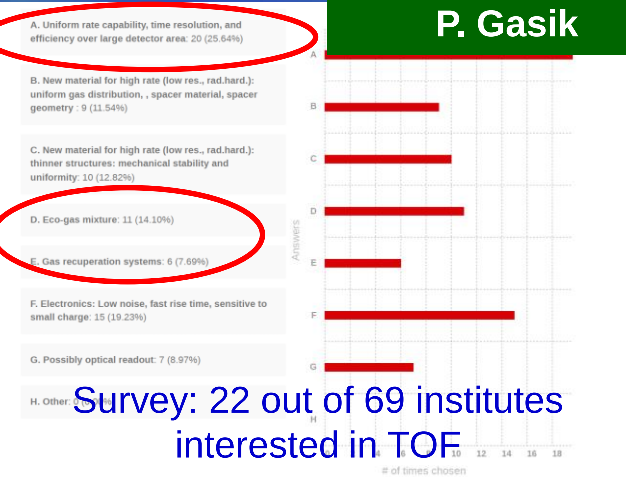
Photon Detection: - Novel photocathodes and photoconverters;
- Low noise electronics coping with high input capacitance and large dynamic range

TOF: - Uniform rate capability, time res. and efficiency over a large area
- Eco gas mixtures, gas recuperation systems



P. Gasik

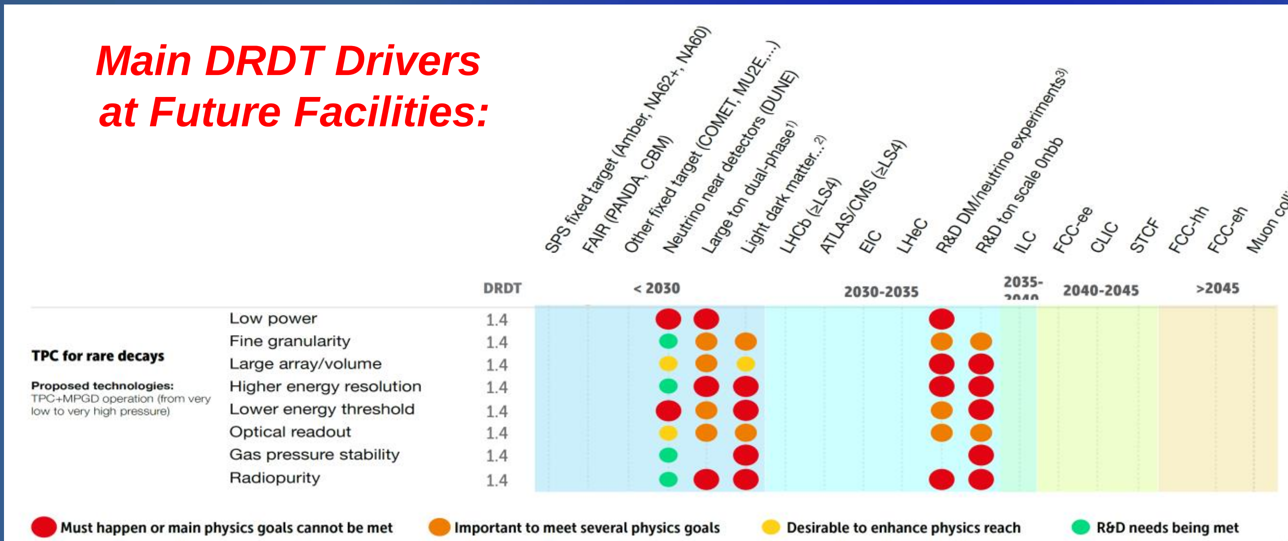
Survey: 27 out of 69 institutes interested in Photodetection



D. Gonzalez Diaz, P. Gasik

Survey: 22 out of 69 institutes interested in TOF

DRD1 Working Group 2: (5) TPC for Rare Events



DRDTs vs Technology Challenges:

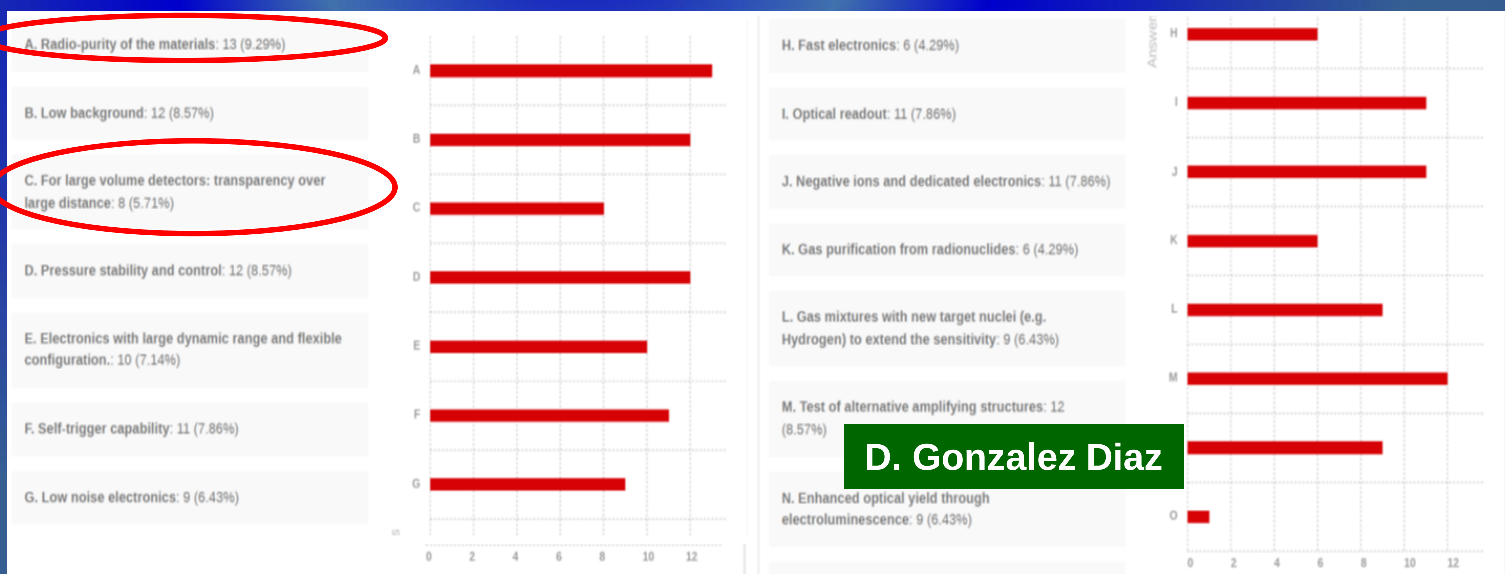
Rare decays	DRDT
• Radio-purity of the materials • Low background • High granularity • For large volume detectors: transparency over large distance • Pressure stability and control • Electronics with large dynamic range and flexible configuration. • Self-trigger capability • Low noise electronics • Fast electronics • Optical readout	ALL 1.4

High performance TPCs** in a variety of high precision experiments (neutrino-oscillations, bb0nu, DM, nuclear physics) → **synergy with tracking DRDT 1.1 & eco gases DRDT 1.3

Some key challenges defining future R&D directions:

- ✓ Low power
- ✓ Radiopurity
- ✓ Large array/ volume

Survey: 27 out of 69 institutes interested; 10 surveys arrived after Feb. 15 (not analysed here)



D. Gonzalez Diaz