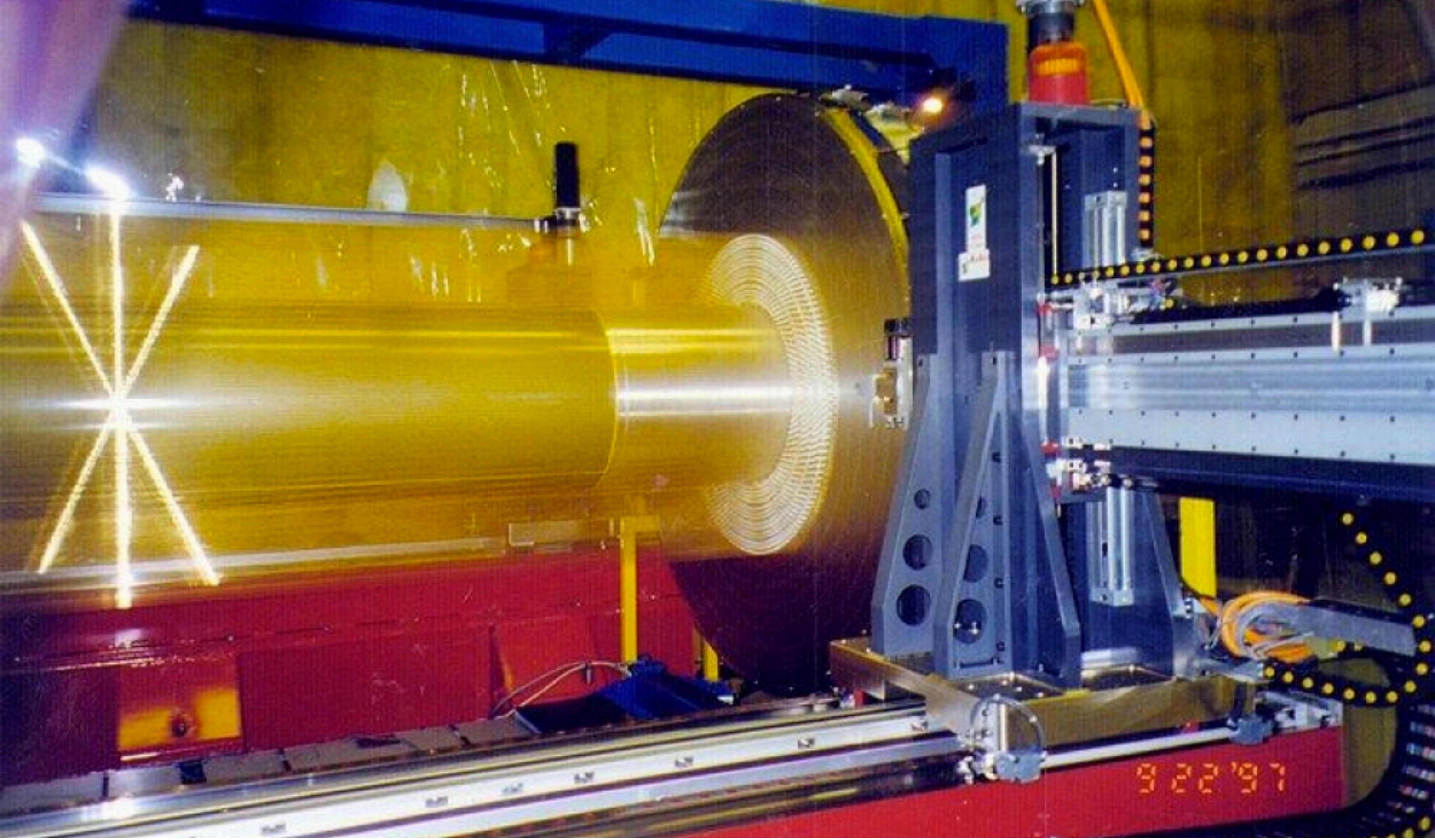


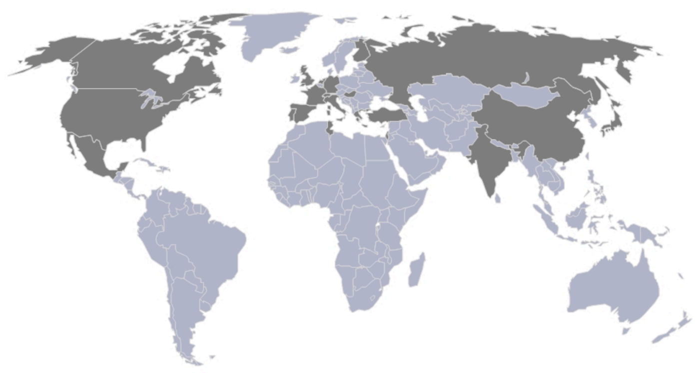
Toward the DRD1 Gaseous Detector Collaboration

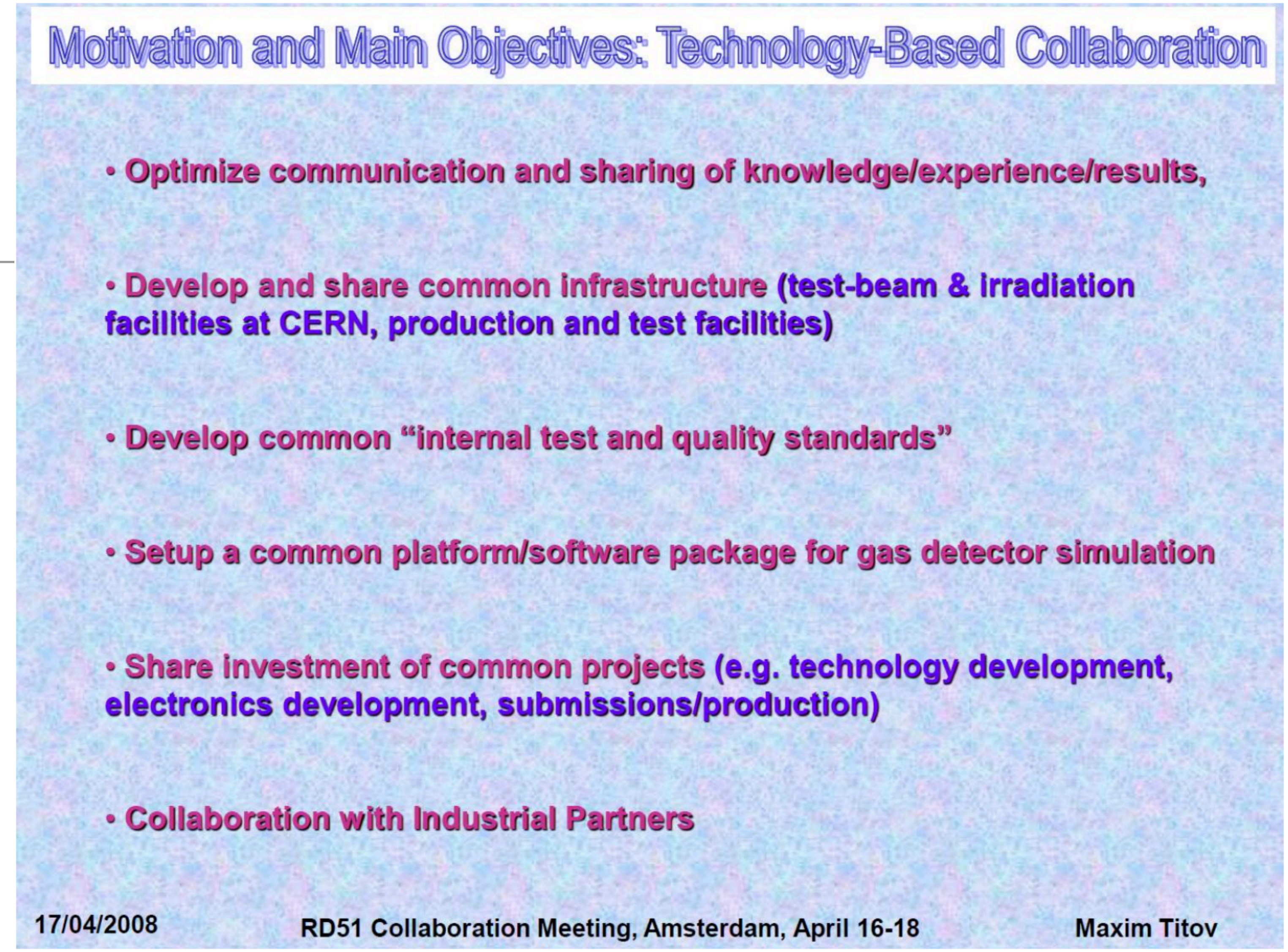
Francesco Renga
INFN Roma

INFN
Istituto Nazionale di Fisica Nucleare

The DRD prototype: RD51

- A technology-oriented collaboration on micro-pattern gaseous detectors (MPGD)





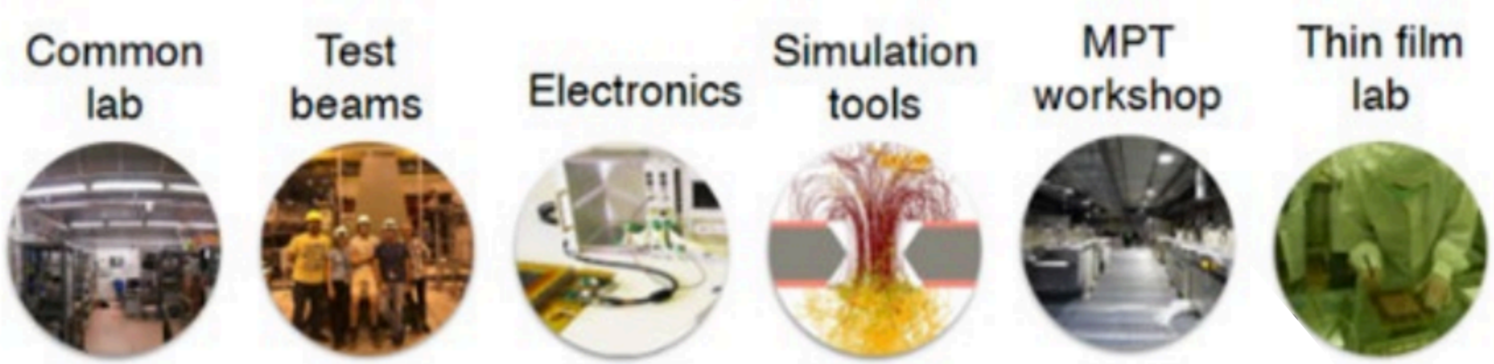
- **Jan 2006** (CERN) Micro-pattern Gas Detectors: status and perspectives (https://indico.cern.ch/event/473/)
- **Sept 2007** (CERN) Micro Pattern Gas Detectors. Towards an R&D Collaboration. (https://indico.cern.ch/event/16213/)
- **Apr 2008** (Nikhef) Micro-Pattern Gas Detectors (RD-51) Workshop (https://www.nikhef.nl/pub/conferences/rd51/) 1st Proposal (draft)
- **July 2008**, CERN, 94th LHCC, Proposal presented @ LHCC open session (https://indico.cern.ch/event/36159/)
- **Sept 2008**, CERN, 95th LHCC, Meeting with Referees (http://cdsweb.cern.ch/record/1132796/files/LHCC-095.pdf) (*).
- **Oct 2008**, Paris, 2nd RD51 Collaboration Meeting (https://indico.cern.ch/event/35172/timetable/?view=standard)
- **Dec 2008**, CERN, 186th Research Board, Approval (https://cds.cern.ch/record/1143639/files/M-186.pdf)(**).

The main RD51 assets:
Networking & Common Tools and Infrastructures

- 2 yearly collaboration meetings + mini-weeks
- MPGD Conference series

- **MPGD2022** - 7th International Conference on Micro Pattern Gaseous Detectors (Rehovot, Israel)
- **MPGD2019** - 6th International Conference on Micro Pattern Gaseous Detectors (La Rochelle, France)
- **MPGD2017** - 5th International Conference on Micro Pattern Gaseous Detectors (Philadelphia, USA)
- **MPGD2015** - 4th International Conference on Micro Pattern Gaseous Detectors (Trieste, Italy)
- **MPGD2013** - 3rd International Conference on Micro Pattern Gaseous Detectors (Zaragoza, Spain)
- **MPGD2011** - 2nd International Conference on Micro Pattern Gaseous Detectors (Kobe, Japan)
- **MPGD2009** - 1st International Conference on Micro Pattern Gaseous Detectors (Kolympari, Crete)

- R&D tools, facilities and infrastructures



The new CERN
Micro Pattern Technology (MPT) Workshop

The main RD51 assets:
Networking & Common Tools and Infrastructures

- 2 yearly collaboration meetings + mini-weeks
- MPGD Conference series

- **MPGD2022** - 7th International Conference on Micro Pattern Gaseous Detectors (Rehovot, Israel)
- **MPGD2019** - 6th International Conference on Micro Pattern Gaseous Detectors (La Rochelle, France)
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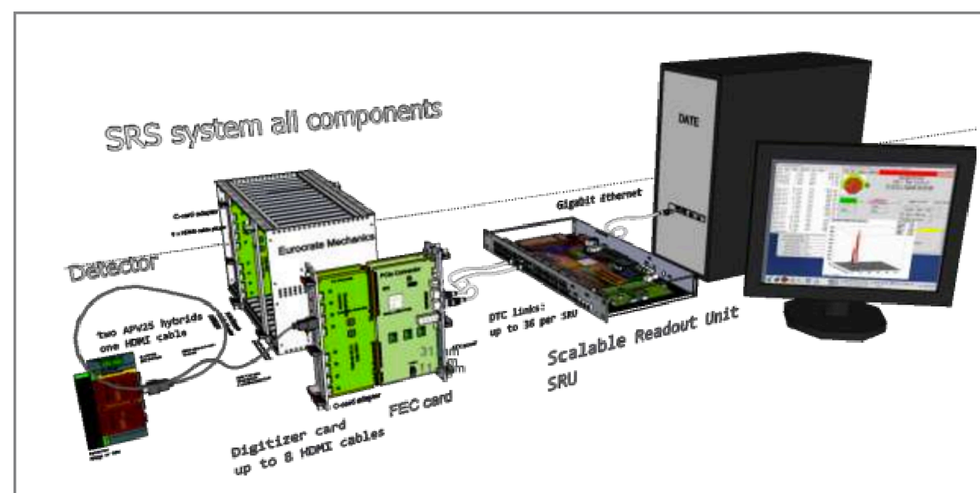
- **MPGD2009** - 1st International Conference on Micro Pattern Gaseous Detectors (Kolympari, Crete)

- R&D tools, facilities and infrastructures

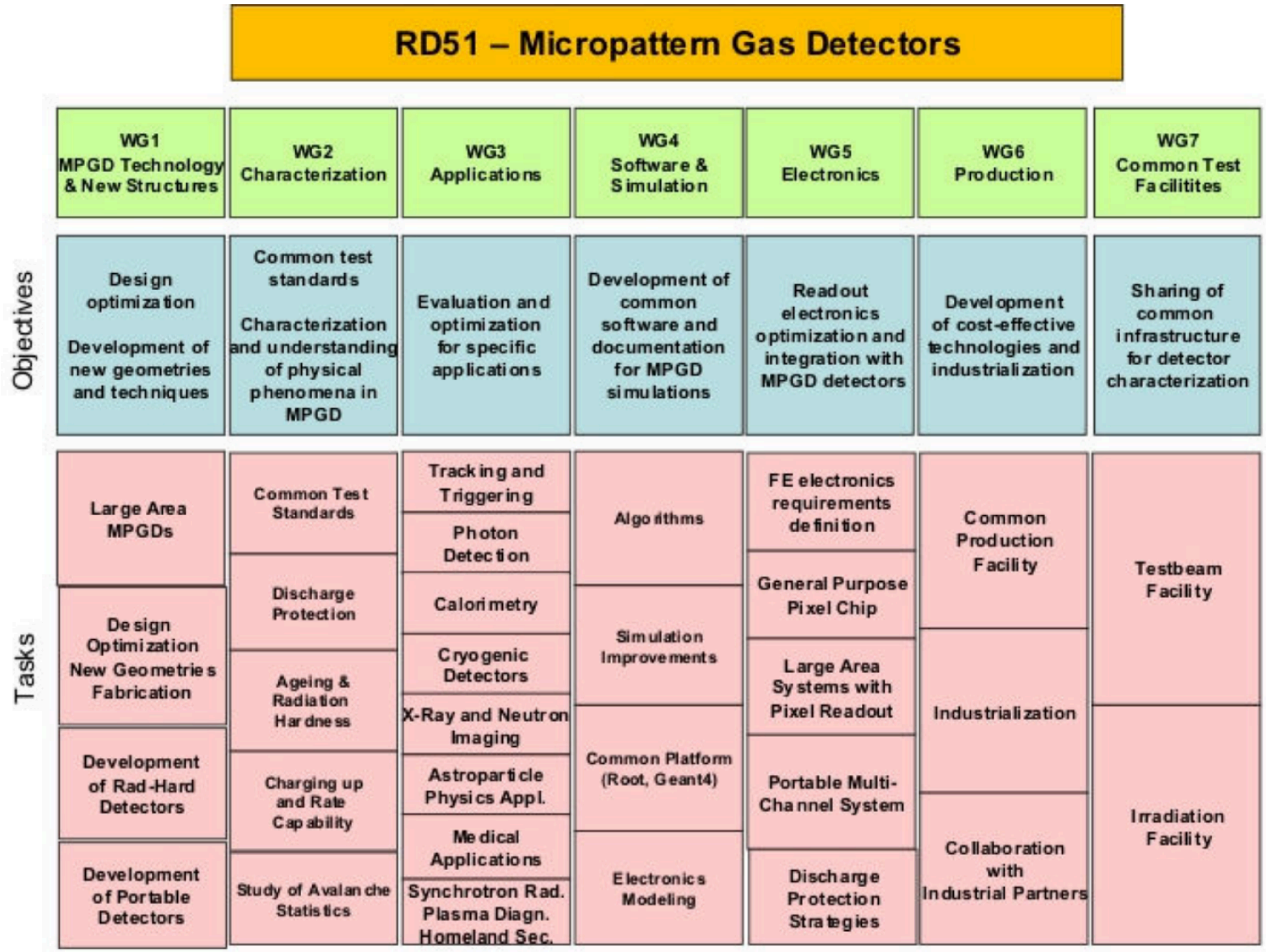
Common lab | Test beams | Electronics | Simulation tools | MPT workshop | Thin film lab

Scalable Readout System (SRS)



RD51 organization

> 90 institutions
> 400 participants
> 30 countries



Toward DRD1 - The ECFA roadmap

DRDT 1.1 - Improve time and spatial resolution for gaseous detectors with long-term stability.

DRDT 1.2 - Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes.

DRDT 1.3 - Develop environmentally friendly gaseous detectors for very large areas with high-rate capability.

DRTD 1.4 - Achieve high sensitivity in both low and high-pressure TPCs.

Drivers from future facilities

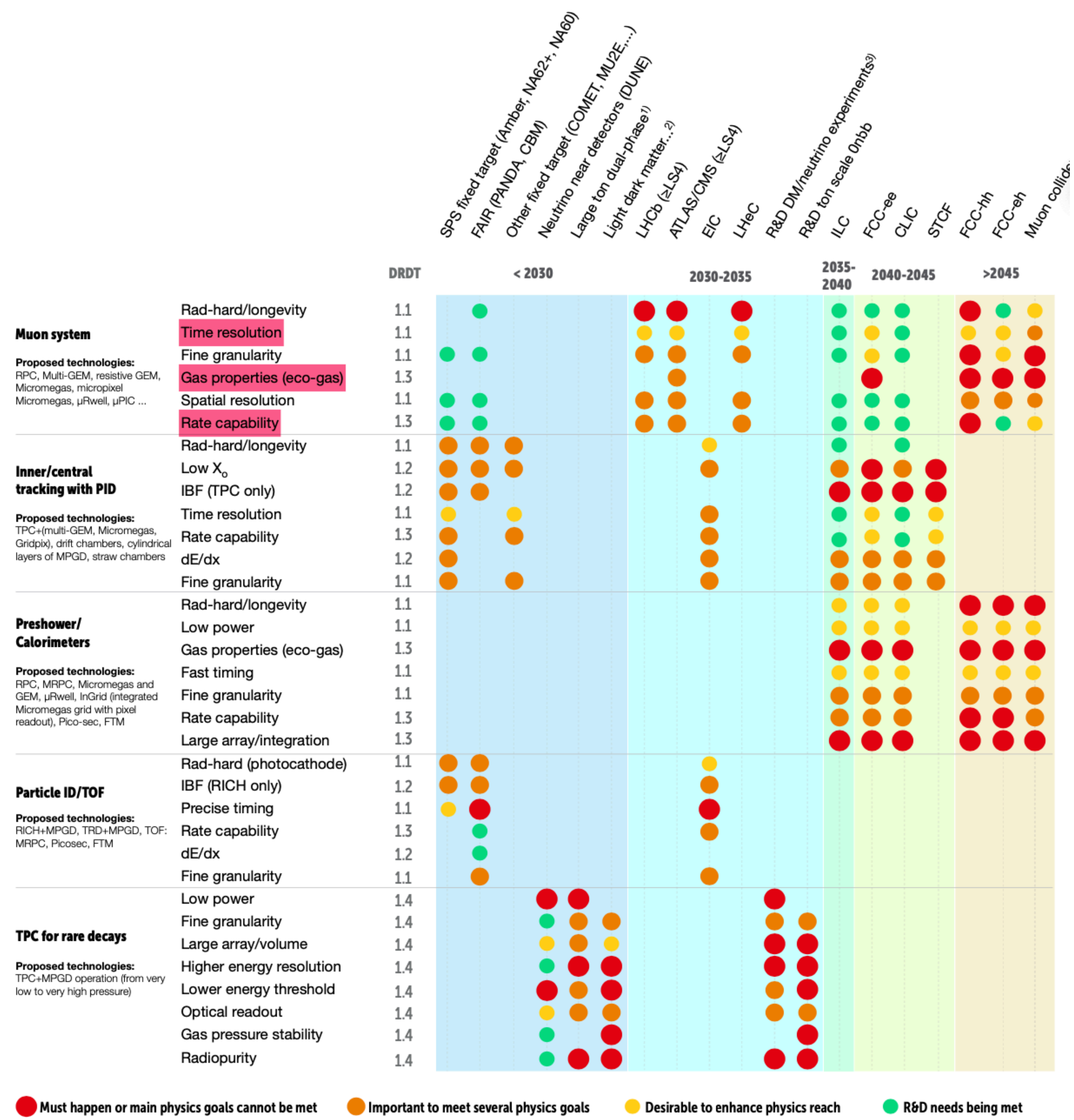
Muon systems

Inner/central tracking with PID

Preshower/Calorimeters

Particle ID/TOF

TPC for rare events



Drivers from future facilities

Muon systems

Inner/central tracking with PID

Preshower/Calorimeters

Particle ID/TOF

TPC for rare events

What:
MPGD, RPC

Why:
Cost-effective, large-area coverage with low material budget, high detection efficiency and precision timing

Challenges:
Rate capability above O(MHz/cm^2)
Miniaturization of readout elements
Eco-friendly gas mixtures

Innovations:
µTPC mode
Diamond-like Carbon

Drivers from future facilities

Muon systems

Inner/central tracking with PID

Preshower/Calorimeters

Particle ID/TOF

TPC for rare events

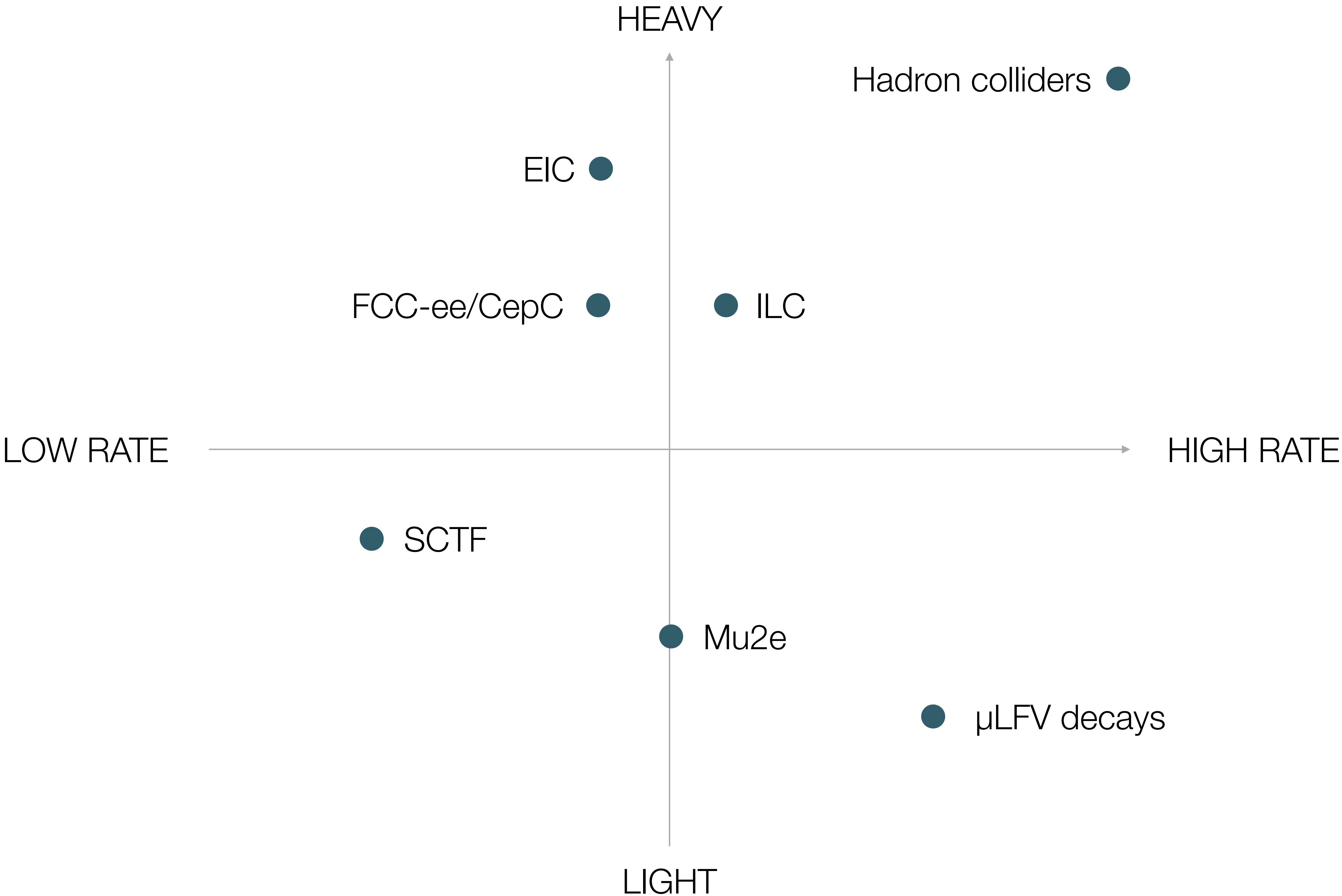
What:
MPGD, DCH, TPC, Straw

Why:
High-rate capability and excellent spatial resolution, minimal material budget and lightweight mechanics

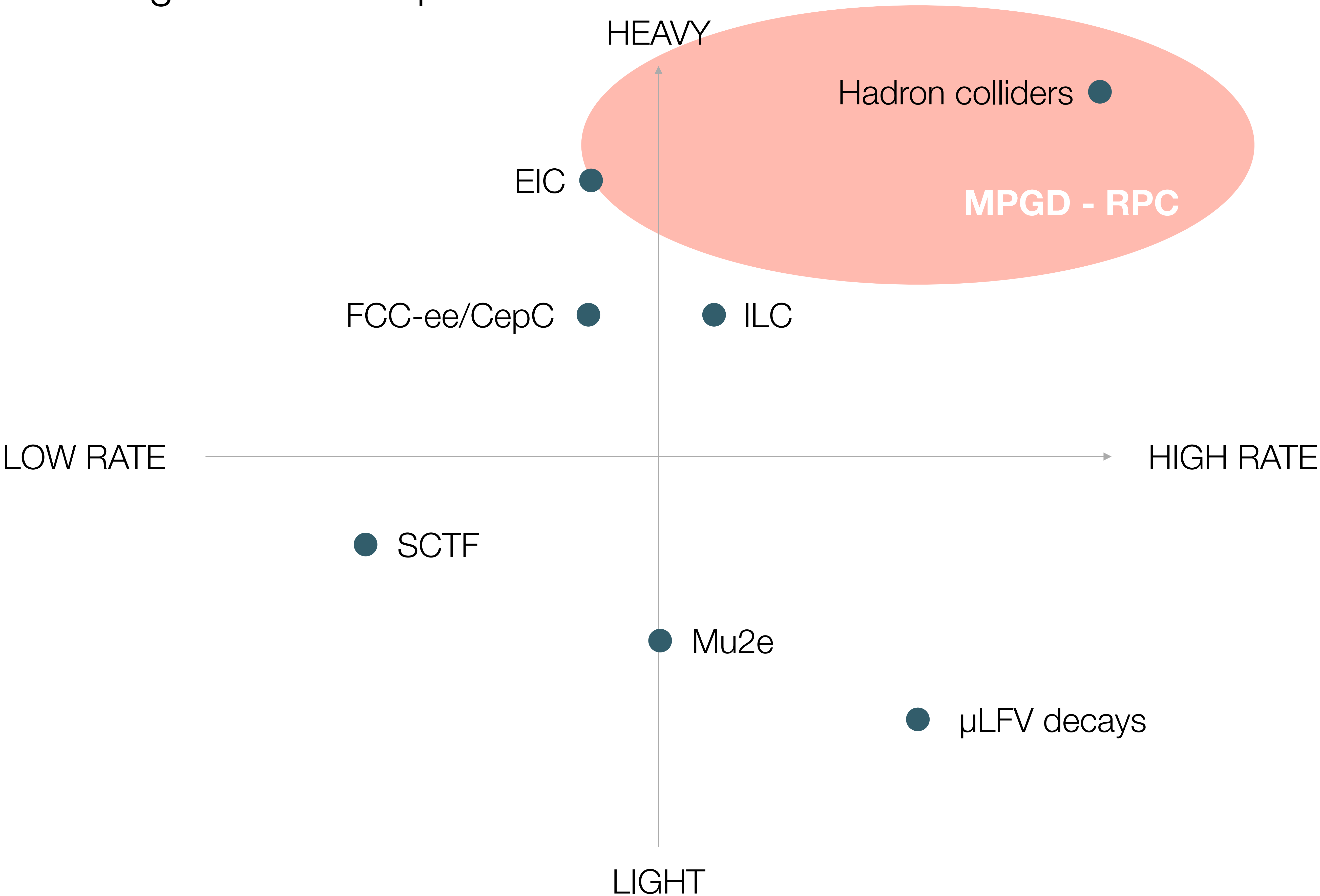
Challenges:
Improved resolutions
Extremely low material budget
High rate (radiation & occupancy)

Innovations:
Alternative materials (DCH, straws), geometries (DCH, TPC) and gas mixtures
Readout with reduced ion back-flow (TPC)

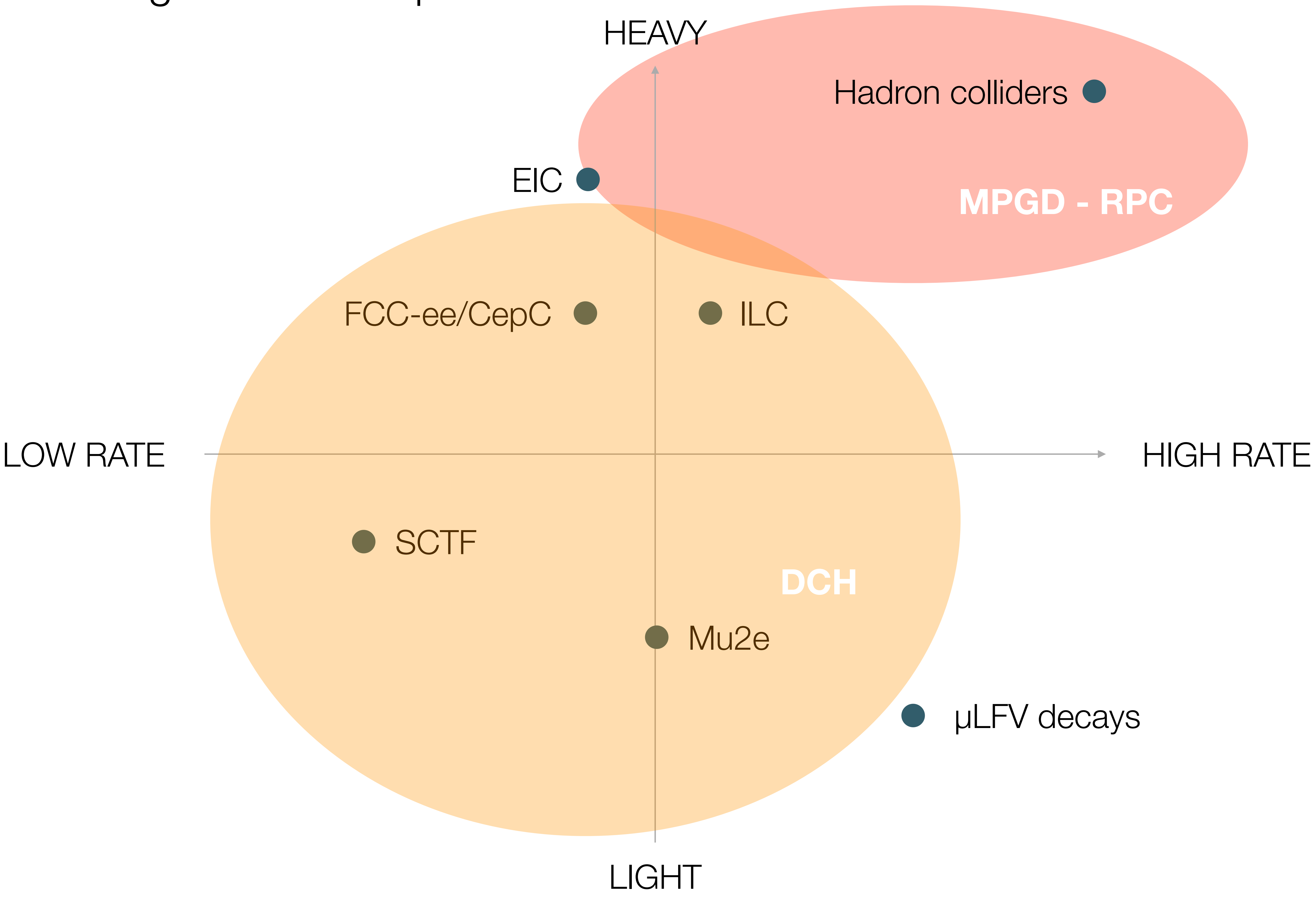
A tracking detector map



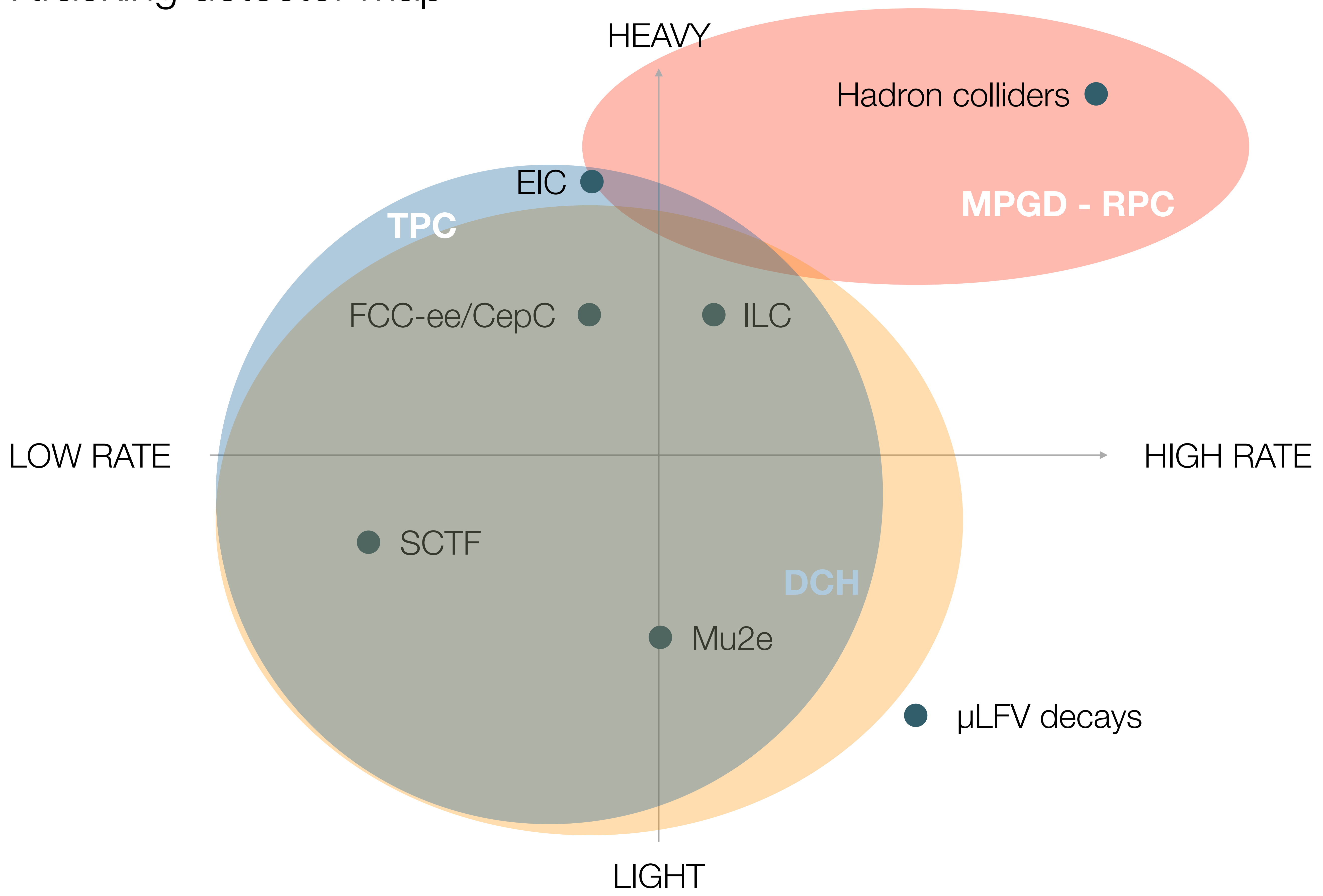
A tracking detector map



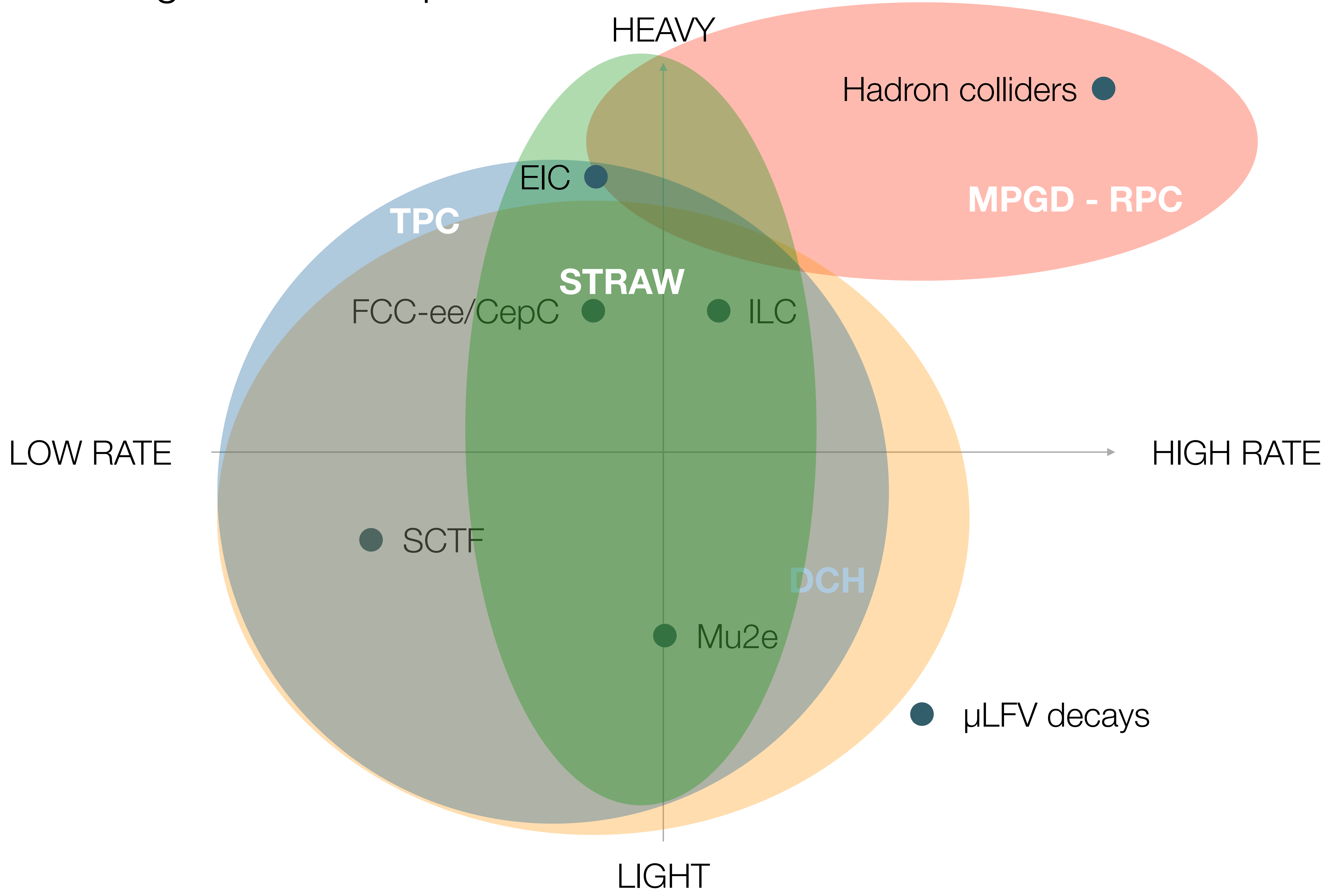
A tracking detector map



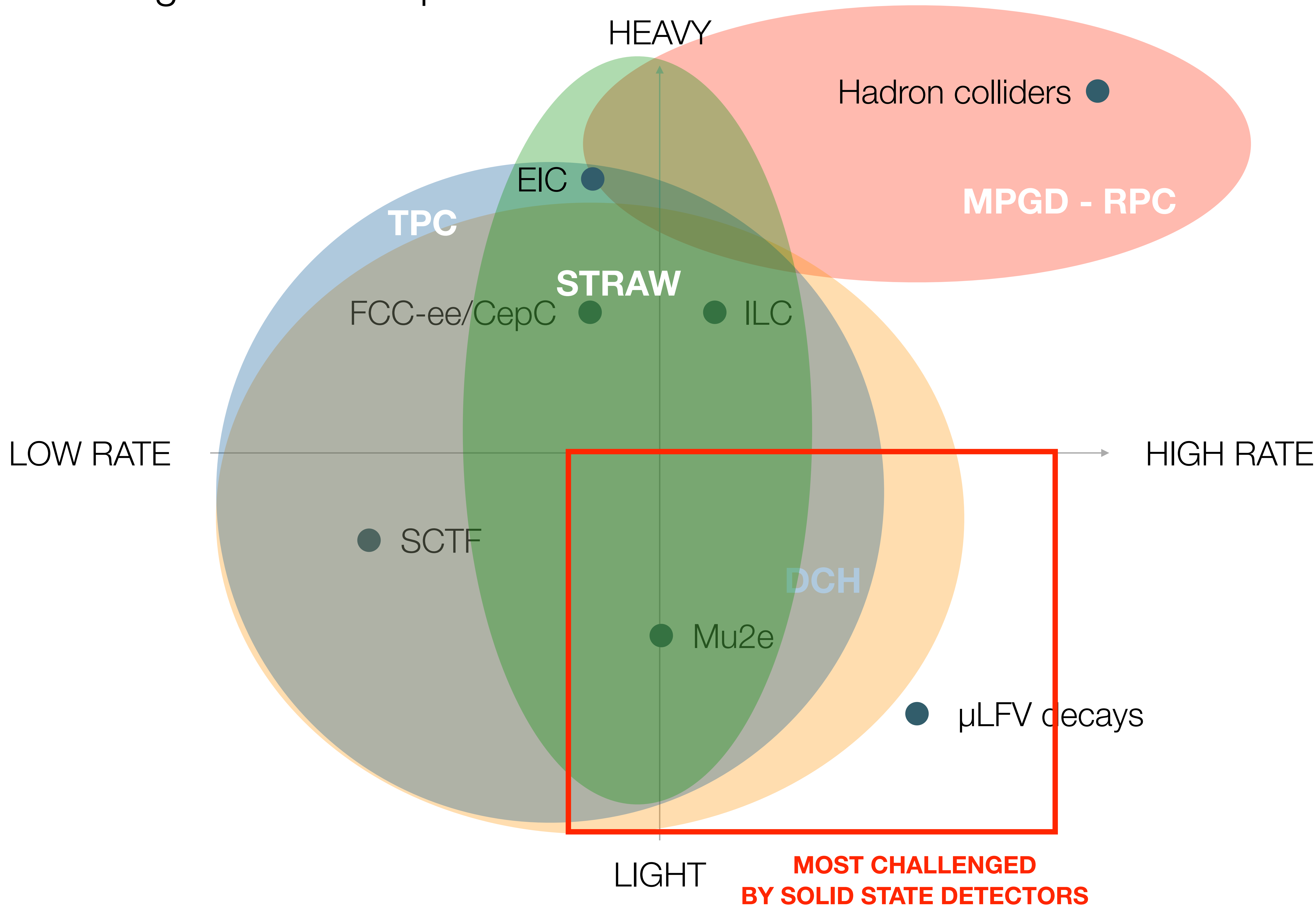
A tracking detector map



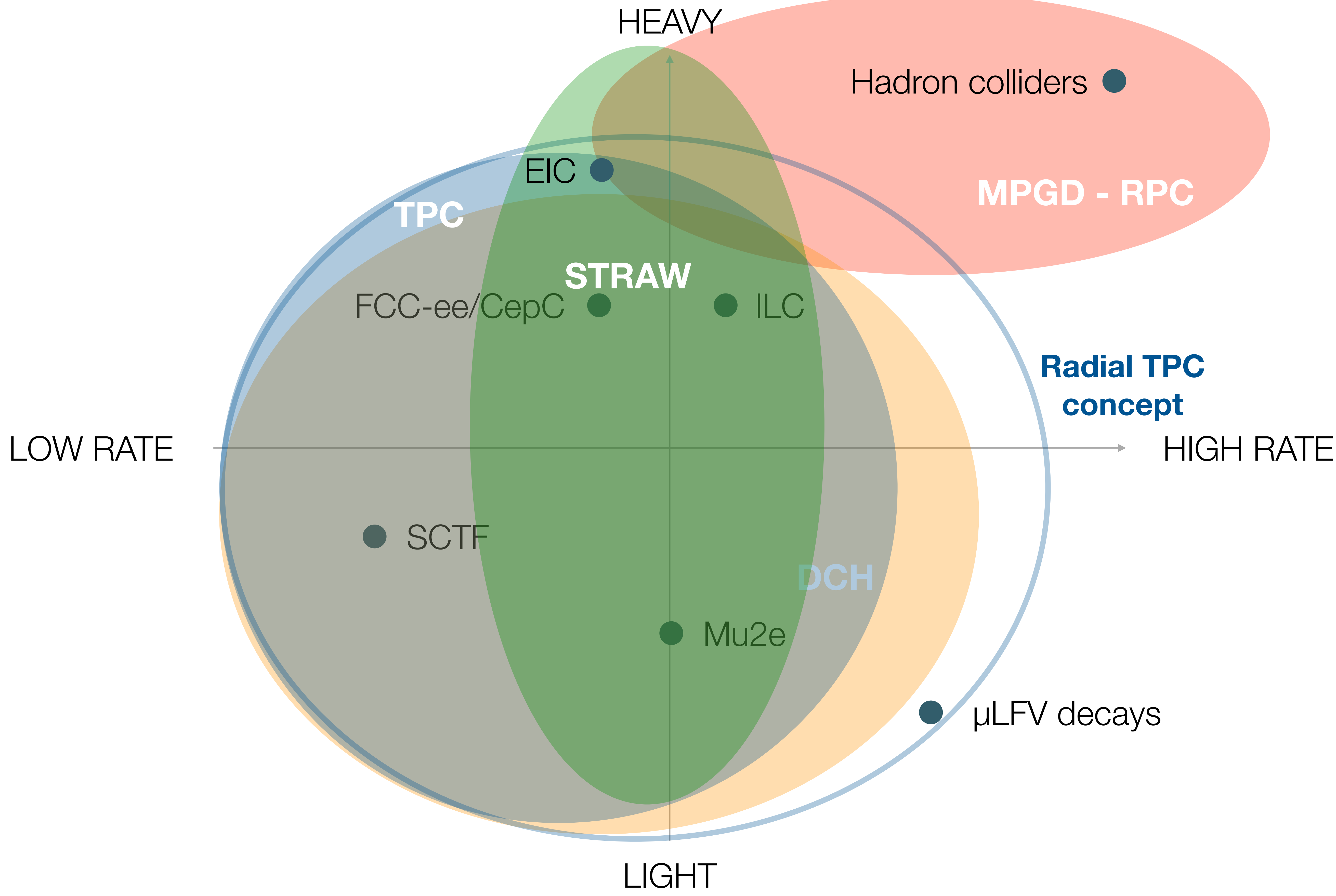
A tracking detector map



A tracking detector map



A tracking detector map



Drivers from future facilities

Muon systems

Inner/central tracking with PID

Preshower/Calorimeters

Particle ID/TOF

TPC for rare events

What:
MPGD, RPC

Why:
High granularity and good timing for particle-flow sampling calorimetry

Challenges:
Stable and uniform of the response over large areas
Excellent timing
Eco-friendly gas mixtures

Innovations:
MRPC, PICOSEC and FTM for fast timing

Drivers from future facilities

Muon systems

Inner/central tracking with PID

Preshower/Calorimeters

Particle ID/TOF

TPC for rare events

What:
MPGD, MRPC

Why:
Cost-effectiveness, very low material budget and minimal sensitivity to magnetic fields

Challenges:
Visible-photon converters (RICH, TRD)
High gain (RICH, TRD)
Excellent timing (TOF)
Eco-friendly gas mixtures
Rate capability

Innovations:
MRPC, PICOSEC and FTM for fast timing

Drivers from future facilities

Muon systems

Inner/central tracking with PID

Preshower/Calorimeters

Particle ID/TOF

TPC for rare events

What:
TPC

Why:
Full 3D reconstruction of the event and flexibility of choosing gas targets

Challenges:
High granularity over large volumes
Very low noise electronics
Radiopurity

Innovations:
Optical readout
Electroluminescence
Microbulk Micromegas
Negative ions

An additional comment

- **Gas procurement is becoming an issue**
  - the **cost** of greenhouse gases (e.g. CF_4), being banned from industry, is becoming **prohibitive**
  - there is a **global shortage** even for the most common gases (Helium, CO_2), only partially related to the Ukrainian crisis
  - the situation could deteriorate further and quickly

***Gas recirculation and recovery**, beside being instrumental to the reduction of greenhouse gas emissions, could be also an asset to reduce operational issues and costs*

(My personal) selection of keywords

Excellent timing

High rate capability

High granularity

Eco-friendly gas mixtures

Low material budget

Gas recirculation + recovery

Activities and expertise @ INFN Roma

Excellent timing

ATLAS, JLAB12, LHCb

High rate capability

MEG, CYGNO

High granularity

CYGNO

Eco-friendly gas mixtures

Gas recirculation + recovery

MEG, KLOE

Low material budget

Infrastructures @ INFN Roma

- The refurbishing of **Laboratori Segrè** temporarily deprived us of unique spaces fully equipped for the development of gaseous detectors, with important investments made by INFN over the years:
  - certified installations for explosive and inert gases
  - gas mixing and distribution systems
  - gas analyzers
  - UV laser test facility
  - radioactive sources
  - HV, electronics, etc.
- Some activities continued in the JLAB12 lab @ ISS and with partial and temporary installations @ Dipartimento di Chimica
- A quick restoration of a fully equipped gaseous detector lab in the renewed Lab. Segrè is critical for the survival of this R&D line at INFN Roma
- Availability and classification of **clean rooms** to be also reviewed

Toward DRD1 — The community

MPGD

RPC

Wire chambers

Time Projection Chambers

The RD51 community will migrate almost rigidly into DRD1

A community-building effort is ongoing in the other sectors

Many interplays (TPC + MPGD, electronics, infrastructures…)

Large Volume Detectors

Toward DRD1 — The DRD1 Proposal Team

MPGD
E. Olivieri (CERN), F. Tessarotto (INFN Trieste), M. Titov (CEA Paris/Saclay)

RPC
I. Deppner (U. Heidelberg), G. Iasselli (Politecnico & INFN Bari), B. Liberti (INFN Roma 2)

Wire chambers
P. Wintz (IKP, FZ Jülich)

Time Projection Chambers
E. Ferrer Ribas (IRFU/CEA), J. Kaminski (U. Bonn)

ECFA TF1 Conveeners:
A. Colaleo (U. & INFN Bari), L. Ropelewski (CERN), J. Veloso (U. Aveiro)

ECFA Coordinators Group Member:
Silvia Dalla Torre (INFN Trieste)

Infrastructure, detector R&D programs:
Roberto Guida (CERN), Beatrice Mandelli (CERN)

Administrative support:
Hans Taureg (U. Bonn), Florian Brunbauer (CERN)

Large Volume Detectors
M. Panareo (U. & INFN Lecce), F. Renga (INFN Roma)

Toward DRD1 — On going activities

- A global survey of interested groups was performed in Nov.-Dec. 2022
  - active connection to known groups/collaborations/experts
  - call for expressions of interest
- A discussion about the collaboration structure started within the proposal team
- A survey of resources and ongoing/foreseen activities by the interested groups will be performed in the next weeks

Toward DRD1 — 1st DRD1 Community Workshop

CERN, 1-3 March 2023

(What to write in the collaboration proposal?
How to organize the collaboration? What is the financing scheme? …)

Backup

Muon systems

Facility	Technologies	Challenges	Most challenging requirements at the experiment
HL-LHC	RPC, Multi-GEM, resistive-GEM, Micromegas, micro-pixel Micromegas, μ-RWELL, μ-PIC	Ageing and radiation hard, large area, rate capability, space and time resolution, miniaturisation of readout, eco-gases, spark-free, low cost	**(LHCb)**: Max. rate: 900 kHz/cm² Spatial resolution: ~ cm Time resolution: O(ns) Radiation hardness: ~ 2 C/cm² (10 years)
Higgs-EW-Top Factories (ee) (ILC/FCC-ee/CepC/SCTF)	GEM, μ-RWELL, Micromegas, RPC	Stability, low cost, space resolution, large area, eco-gases	**(IDEA):** Max. rate: 10 kHz/cm² Spatial resolution: ~60-80 μm Time resolution: O(ns) Radiation hardness: <100 mC/cm²
Muon collider	Triple-GEM, μ-RWELL, Micromegas, RPC, MRPC	High spatial resolution, fast/precise timing, large area, eco-gases, spark-free	Fluxes: > 2 MHz/cm² ($\theta<8^0$) < 2 kHz/cm² (for $\theta>12^0$) Spatial resolution: ~100μm Time resolution: sub-ns Radiation hardness: < C/cm²
Hadron physics (EIC, AMBER, PANDA/CMB@FAIR, NA60+)	Micromegas, GEM, RPC	High rate capability, good spatial resolution, radiation hard, eco-gases, self-triggered front-end electronics	**(CBM@FAIR):** Max rate: <500 kHz/cm² Spatial resolution: < 1 mm Time resolution: ~ 15 ns Radiation hardness: 10^{13} neq/cm²/year
FCC-hh (100 TeV hadron collider)	GEM, THGEM, μ-RWELL, Micromegas, RPC, FTM	Stability, ageing, large area, low cost, space resolution, eco-gases, spark-free, fast/precise timing	Max. rate 500 Hz/cm² Spatial resolution = 50 μm Angular resolution = 70 μrad (η=0) to get $\Delta p/p \leq 10\%$ up to 20 TeV/c

Inner/Central Tracking

Facility	Technologies	Challenges	Most challenging requirements at the experiment
HL-LHC	MPGD	High spatial resolution, high rate/occupancy, radiation hardness, low mass	**LHCb option:** replace Scintillating Fibre tracker Spatial resolution:70 μm bending plane
Higgs-EW-Top Factories (ee) (ILC/FCC-ee/CepC/SCTF)	TPC+(multi-GEM, Micromegas, GridPix), Drift Chambers, Cylindrical layers of MPGD	Ultra-lightweight inner or central tracker, high spatial resolution, high rate/occupancy, radiation hardness, low mass, transparency, cluster counting, TPC continuous mode at high rate, (IBF x Gain) ~1	**Inner tracker (SCTF)** Fluxes: $\geq$10 kHz cm^{-2} s^{-1} Time resolution: 1 ns X/X0 = 1% Spatial resolution: ~100 μm **Central tracker (CepC)** Max. rate: >100 kHz/cm^2 Spatial resolution: ~100 μm Time resolution: ~ 100 ns dE/dx: <5% Particle separation with cluster counting at 2% level
Rare processes, atomic and nuclear physics (SPS Kaons: K^+ Phase, K-Phase, Mu2eII/COMET-II, ELENA)	TPC, straw tubes	High spatial resolution, occupancy, fast/precise timing, radiation hardness, low mass, Gd-deposited MPGD detectors	Max rate = 500 kHz/straw **(Mu2e II)**: Thinner straw material: 8 μm X/X0 ~ 0.02% per layer, X/X0 ~ 1% total **(COMET+)**: Diameter = 4.8 mm Trailing time resolution = 1 ns per track
Hadron and nuclear physics (EIC, AMBER, PANDA and CMB@FAIR, PRES MAINZ, NA60+	Micromegas, GEM, μ-RWELL, straw tubes	High spatial resolution, good timing, radiation hardness , tolerance to magnetic field	**(EIC)** Max rate = 100 kHz/cm^2 Spatial resolution ~50 μm X/X0 = 5% dE/dx=12%, continuos running

Calorimeters

Facility	Technologies	Challenges	Most challenging requirements at experiment
Higgs-EW-Top Factories (ee) (ILC/FCC-ee/CepC,/SCTF)	RPC, Micromegas and GEM, μ-RWELL, GridPix, PICOSEC, FTM	High granularity, excellent hit timing, large area detectors, stabiliy, uniform response, eco-gases	**(ILC)** Max. rate:1 kHz/cm² Granularity (~1 cm²) Radiation hardness: no Jet Energy resolution: 3-4 % Power-pulsing, self-triggering readout
Muon collider	RPC, Micromegas and GEM, μ-RWELL, GridPix, PICOSEC, FTM	High granularity, radiation hardness, excellent hit timing, stabiliy, uniform response, eco-gases	Granularity (~1cm²) Fat jet identification Time resolution= O(100ps) Energy resolution =(5%)/sqrt(E) for fat-jet High radiation hardness
Hadron physics (EIC)	RPC, Micromegas and GEM, μ-RWELL, GridPix, PICOSEC, FTM	High granularity, radiation hardness, excellent hit timing, stabiliy, uniform response, eco-gases	**(EIC option)** DHCAL

Photon Detectors

Facility	Technologies	Challenges	Most challenging requirements at experiment
Hadron and nuclear physics (EIC, AMBER, PANDA and CMB@FAIR)	**Gaseous-RICH** with MPGD-based photon detector **TRD** with GEM or GridPix	- **RICH:** Compact, single photon detection, high gain, fine spatial and time resolution, eco-friendly gas radiator, high pressure; limited IBF, novel photoconverters - **TRD:** cluster counting technique, heavy gas for X-ray absorption, TRD photon -dE/dx separation.	**(EIC-gaseous RICH)** 1 meter of radiator gas High-gain: 10^5 - 10^6 Spatial resolution: O(1mm pitch) Time resolution (even with small signals) $\lesssim$ 1n Tolerance to magnetic field (1.5 - 3 T) Rad-hardness up to 10^{11} neq/cm² option: High Pressure-Rich: Ar @ 3.5 bar **(EIC-TRD)** compactness 10^{-2} rejection in 20-30 cm improved MIP/x-ray identification
Higgs-EW-Top Factories (ee) (FCC-ee/CepC)	**Gaseous-RICH** with MPGD-based photon detector	- **RICH:** Compact, single photon detection, high gain, fine spatial and time resolution, eco-friendly gas radiator, high pressure, limited IBF, novel photoconverters	**(Gaseous-RICH):** High-gain: 10^5 - 10^6 Spatial resolution O(1mm pitch) Time resolution (even with small signals) $\lesssim$ 1ns

Particle ID

Facility	Technologies	Challenges	Most challenging requirements at experiment
Hadron and nuclear physics (CMB@FAIR, SOLID@JLAB, CEE@HIRFL-CSR)	MRPC, MPGD with precise timing (PICOSEC, FTM)	Rate capability, radiation hardness, large area detectors, new material, eco-gas, thinner structures, FEE, system time distribution	**(CMB)** Max Rate = 30 kHz/cm² Full system time resolution < 80 ps Occupancy < 5% Full system area = 120 m² ~100.000 channels, low power electronics

TPC for rare events

Facility	Technologies	Challenges	Most challenging requirements at experiment
WIMP search (DRIFT, MIMAC, CYGNUS, MIGDAL, TREX-DM)	-TPC w/ MWPC/MPGD at 20-130 mbar, charge readout -TPC w/ MPGD at 66 mb/1 bar, charge and optical readout -TPC w/ MPGD at 1-10 bar, charge readout	High granularity, high gain, low background, very low noise level and fast electronics, self trigger capability, gas optimization	**(CYGNUS)** Gain = O(10^6) Spatial resolution = O(100 μm) Energy Threshold = 2 keVee Energy Resolution = 20% at 5.9 keVee Optical readout He:SF_6 or He:CF_4 at P = 1 bar
Solar axion helioscope (IAXO)	-TPC w/ pixelated Micromegas, GridPix, charge readout	High granularity, low background, radiopure electronics, self-trigger capability	High efficiency in ROI (0-10 keV) Spat. res = O(100 μm) Background: 10^{-7} c/keV/cm2 /s Xe at P = 1 bar B = 6 T
Low energy nuclear physics general purpose active target (AT-TPC, ACTAR)	-TPC+MM at 0.05- 3 bar, charge readout	Electronics with large dynamic range and flexible configuration. self-trigger capability, high pressure MPGD	(AT-TPC) B = 2 T P = 0.05-1 bar 3D-layout Generic target gases (H2, He, Ar, CO2. . .)
Neutrino physics and Neutrino-less double beta decay (DUNE-ND, NEXT, PANDAX-II)	-TPC+SiPM+PM: electroluminescence readout, -TPC+MM: charge readout	low background, energy resolution and topological rejection factors, scale to large volume, transparency and long drifting distance, high pressure, Ba++ tagging	**(NEXT)** P = 5-15 bar 3D-reconstruction of tracks through SiPM plane Energy resolution < 1% Ba++tagging
Neutrinos and DM search (Dune, DarkSide-20k, Argo, PandaX-4T, LZ, ARIADNE, Darwin)	- Dual-Phase TPC+MPGD	Large volume (uniform and stability response), ultra-low background, energy resolution, low energy thresholds, high granularity, charge extraction from liquid to gas, background rejection by prompt scintillation light -S1/ signal from the charge -S2 optimisation; Xenon and Argon storage and recuperation techniques	**(Darwin)** - 200 t x yr exposure - Drift/diameter: 2.6 m / 2.6 m - LXe Mass: 40 t - Particle discrimination by S1/S2 - Low-energy threshold of ~1 keVnr - Robust electrode design (up to 50kV) - Ultra-low intrinsic radioactivity materials - 222Rn: factor 100 reduction - (α,n) neutrons (from PTFE) - >99.98% Electron Recoil rejection at 30% Nuclear Recoil efficiency - High light yield (QE) ~ 8 PE/keV **(Darkside-20k /Argo)** - 200 t x yr exposure /Argo = 3000 t x yr) - Drift/diameter: 3.5 m / 3.5 m - LAr Mass: 51.7 t /Argo - 350 t - Particle discrimination by S1/S2 and pulse shape. - Low-energy threshold of ~0.5 keVnr - Highlander scintillation yield ~40 PE/KeV - Membrane cryostat like the ProtoDune - Low radioactivity argon in underground CO2 wells (UAr) with an activity 1400 times lower than atmospheric