SECOND • ECFA • WORKSHOP

on e^+e^- Higgs / Electroweak / Top Factories

Gaseous detector for tracking and muon ID

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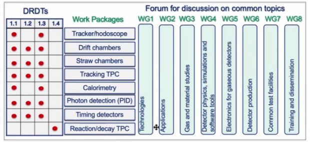
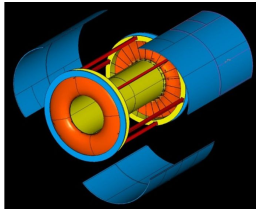
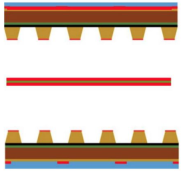
Outline



DRD1 and the gaseous detector technologies



Latest updates on **tracking**: DCH and TPC



Latest update on **muon** ID: MPGD and RPC

Gaseous detector technologies

Primary choice for **large-area** coverage with **low material budget** & **dE/dx** measurement (TPC, Drift chamber) & **ToF** functionality (MRPC, PICOSEC) & **muon** system (MPGD, RPC, DT)

Gaseous detectors have lower granularity than silicon detector but cheaper and very low material budget. They are a valid alternative for track reconstruction in the main tracking volume, definitely a must for muon tracking chambers at large distances.

Upgrades at the LHC for tracking, muon spectroscopy and triggering have taken advantage of the new generation of MPGDs and RPC.

New generation of TPCs use MPGD-based readout: e.g. ALICE Upgrade, T2K, ILC, CepC

Many emerged from the R&D studies within the **CERN-RD51**.

HL-LHC Upgrades: **Tracking** (ALICE TPC/GEM); Muon Systems: RPC, CSC, MDT, TGC, GEM, MicroMegas;
Future Lepton Colliders: **Tracking** (FCC-ee / CepC - Drift Chambers; ILC / CePC - TPC with MPGD readout)
Calorimetry (ILC, CepC – RPC or MPGD), **Muon Systems** (many gas det. are OK)
Future Hadron Colliders: FCC-hh **Muon** System (MPGD - particle rates are comparable with HL-LHC)
Future Election-Ion Collider: **Tracking** (MPGD; TPC/MPGD), **RICH** (THGEM), **TRD** (GEM)

Gaseous detector technologies

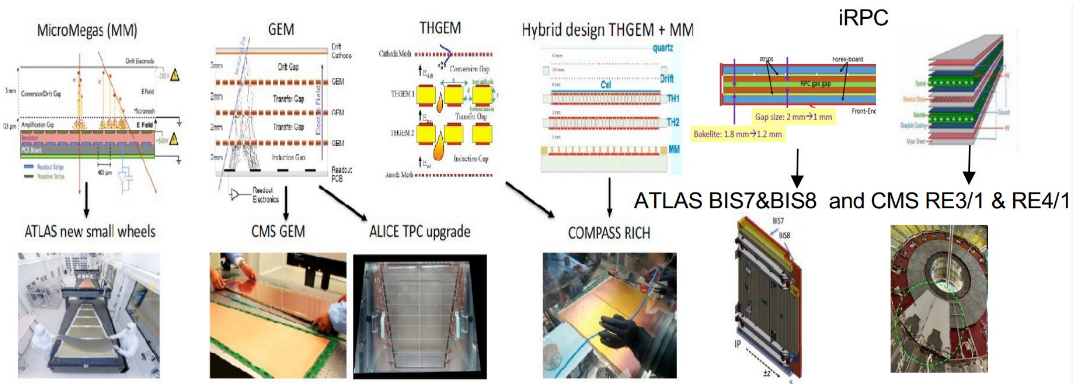
Boosting the LHC upgrade and upcoming experiments

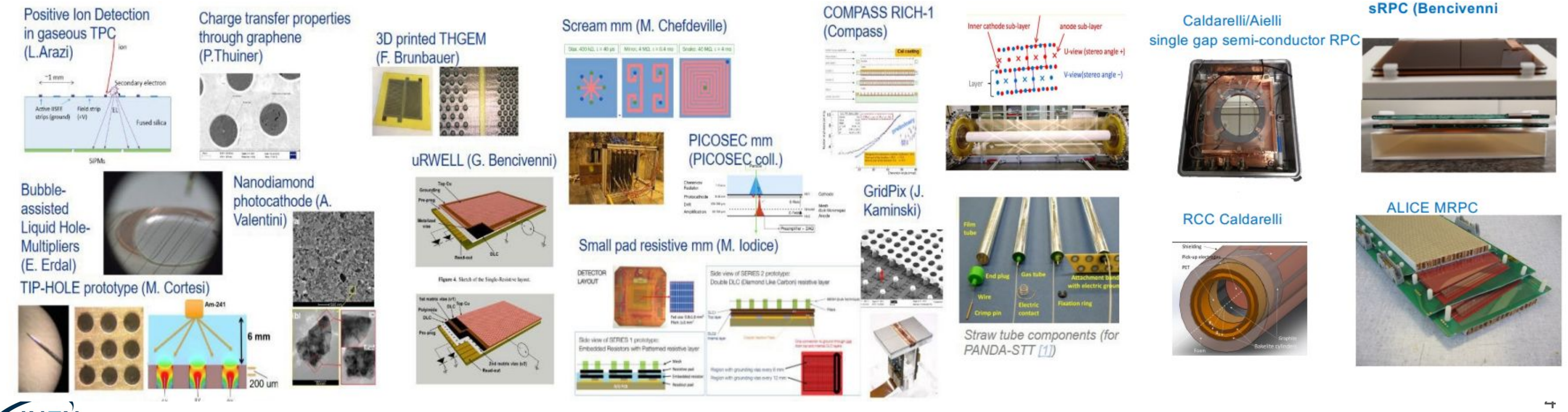
- enhancing Muon Tracking and Triggering with MPGDs, iRPC
- new Generation TPCs with MPGDBased Readouts@ALICE/T2K
- ex.New Cylindrical Drift Chambers for MEGII, Novel StrawTubes at Mu2e, COMETI/II, Panda/@Fair…

Offering competitive performance

- Time Precision with MRPC@Alice TOF and PICOSEC concept

Pioneering Approach: New technologies, Materials, Architectures, and Hybrid Technology





Gaseous detector @ CMS, ALICE and LHCb upgrades

Experiment / Timescale	Application Domain	Gas Detector Technology	Total detector size / Single module size	Operation Characteristics / Performance	Special Requirements / Remarks
ALICE TPC UPGRADE CERN LS2	Heavy-Ion Physics (Tracking + dE/dx)	4-GEM / TPC	Total area: ~ 32 m^2 Single unit detect: up to 0.3m^2	**Max.rate**:100 kHz/cm^2 **Spatial res.:** ~300µm **Time res.:** ~ 100 ns **dE/dx:** 11 % **Rad. Hard.:** 50 mC/cm^2	- 50 kHz Pb-Pb rate; - Continues TPC readout - Low IBF and good energy resolution
CMS MUON UPGRADE GE11 CERN LS2	Hadron Collider (Tracking/Triggering)	3-GEM	Total area: ~ 50 m^2 Single unit detect: 0.3-0.4m^2	**Max. rate**: 5 kHz/cm^2 **Spatial res.:** 0.6 – 1.2mm **Time res.:** ~ 7 ns **Rad. Hard.:** ~ 0.18 C/cm^2	Redundant tracking and triggering, improved pt resolution in trigger
CMS MUON UPGRADE GE21 CERN L3	Hadron Collider (Tracking/Triggering)	3-GEM	Total area: ~ 105 m^2 Single unit detect: 0.3-0.4m^2	**Max. rate**: 1.5 kHz/cm^2 **Spatial res.:** 1.4 – 3.0mm **Time res.:** ~ 7 ns **Rad. Hard.:** ~ 0.09 C/cm^2	Redundant tracking and triggering, displaced muon triggering
CMS MUON UPGRADE ME0 CERN L3	Hadron Collider (Tracking/Triggering)	3-GEM	Total area: ~ 65 m^2 Single unit detect: 0.3m^2	**Max. rate**:150 kHz/cm^2 **Spatial res.:** 0.6 – 1.3mm **Time res.:** ~ 7 ns **Rad. Hard.:** ~ 7.9 C/cm^2	Extension of the Muon System in pseudorapidity, installation behind HGCAL
CMS MUON UPGRADE RE3.1, RE 4.1 2023-24 (CERN L3)	Hadron Collider (Tracking/Triggering)	iRPC	Total area: ~ 140 m^2 Single unit detect: 2m^2	**Max.rate**: 2kHz/cm^2 **Spatial res.:** ~1-2cm **Time res.:** ~ 1 ns **Rad. Hard.:** 1 C/cm^2	Redundant tracking and triggering
LHCb MUON UPGRADE CERN LS4	Hadron Collider (triggering)	µ-RWELL	Total area: ~ 90 m^2 Single unit detector: From 0,4x0,3 m^2 To 0,8x0,3 m^2	**Max.rate**:900 kHz/cm^2 **Spatial res.:** ~ cm **Time res.:** ~ 3 ns **Rad. Hard.:** ~ 2 C/cm^2	About 600 detectors

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Gaseous detector @ ATLAS upgrades

Experiment / Timescale	Application Domain	Gas Detector Technology	Total detector size / Single module size	Operation Characteristics / Performance	Special Requirements / Remarks
ATLAS MUON UPGRADE CERN LS2 / LS3	Hadron Collider (Tracking/Triggering)	Endcap: Res. Micromegas & sTGC	Endcap area: 1200 m^2 Single unit detect: ($2.2x1.4m^2$) ~ 2-3 m^2	**Max. rate**:20 kHz/cm^2 **Spatial res.:** <100 μm **Time res.:** ~ 10 ns **Rad. Hard.:** ~ 0.5 C/cm^2	Redundant tracking and triggering; Challenging constr. in mechanical precision
ATLAS MUON UPGRADE (BIS78 PILOT) CERN LS2	Hadron Collider (Tracking/Triggering)	Part of Inner Barrel: RPC + sMDT	Barrel area (3 layers): 140 m^2 Single unit det.: ~ m^2	**Max. rate**:1 kHz/cm^2 **Spatial res.:** ~ 7 mm **Time res.:** ~ 1 ns **Rad. Hard.:** 300 fb	Redundant tracking and triggering; 9 layers with 2D hit position + time
ATLAS MUON UPGRADE (BI PROJECT) CERN LS3	Hadron Collider (Tracking/Triggering	Inner Barrel: RPC	Barrel area: 1400 m^2 Single unit det.: ~ m^2	**Max. rate**:10 kHz/cm^2 **Spatial res.:** ~ (0.1 x 1) cm in (η , φ) **Time res.:** ~ 0.5 ns **Rad. Hard.:** 3000 fb	Redundant tracking and triggering; 9 layers with 2D hit position + time
ATLAS MUON UPGRADE (proposed, not approvedt) CERN AFTER LS3	Hadron Collider (Tracking/Triggering) (2.7 ≤|h| ≤ 4.0)	Forward region: Res MM, μWELL, μPIC	Total area: ~ 5 layers x1 m^2 Single unit detect: 0.1 m^2	**Max. rate**: 10 MHz/cm^2 **Spatial res.:** ~200 μm **Time res.:** ~ 5 ns **Rad. Hard.:** ~ 10 C/cm^2	Hit rates falls rapidly with the distance from the beam axis. Given parameters are for extreme conditions at 25 cm from the beam. Miniaturization of readout elements needed there to keep occupancy low

Gaseous detector @ Future collider

Experiment / Timescale	Application Domain	Gas Detector Technology	Total detector size / Single module size	Operation Characteristics / Performance	Special Requirements/ Remarks
ILC TPC DETECTOR: STARTt: > 2035	e+e- Collider Tracking + dE/dx	MM, GEM (pads) InGrid (pixels)	Total area: ~ 20 m^2 Single unit detect: ~ 400 cm^2 (pads) ~ 130 cm^2 (pixels)	**Max. rate**: < 1 kHz **Spatial res.:** <150µm **Time res.:** ~ 15 ns **dE/dx:** 5 %	Si + TPC Momentum resolution : dp/p < $9*10^{-5}$ 1/GeV Power-pulsing
CEPC TPC DETECTOR START: > 2030	e+e- Collider Tracking + dE/dx	MM, GEM (pads) InGrid (pixels)	Total area: ~ 2x10 m^2 Single unit detect: up to 0.04 m^2	**Max.rate:**>100 kHz/cm^2 **Spatial res.:** ~100µm **Time res.:** ~ 100 ns **dE/dx:** <5%	- Higgs run - Z pole run - Continues readout - Low IBF and dE/dx
FCC-ee and/or CEPC IDEA CENTRAL TRACKER START: >2030	e+e- Collider Tracking/ Triggering	He based Drift Chamber	Total volume: 50 m^3 Single unit detect: (12 m^2 X 4 m)	**Max. rate:** < 25 kHz/cm^2 **Spatial res.:** <100 µm **Time res.:** 1 ns **Rad. Hard.:** NA	Particle sepration with cluster counting at 2% level
SUPER-CHARM TAU FACTORY START: > 2025	e+e- Collider Main Tracker	Drift Chamber	Total volume: ~ 3.6 m^3	**Max. rate**: 1 kHz/cm^2 **Spatial res.:** ~100 µm **Time res.:** ~ 100 ns **Rad. Hard.:** ~ 1 C/cm	
SUPER-CHARM TAU FACTORY START: > 2025	e+e- Collider Inner Tracker	Inner Tracker / (cylindrical µRWELL, or TPC / MPDG read.	Total area: ~ 2 - 4 m^2 Single unit detect: 0.5 m^2	**Max. rate**: 50-100 kHz/cm^2 **Spatial res.:** ~<100 µm **Time res.:** ~ 5 -10 ns **Rad. Hard.:** ~ 0.1-1 C/cm^2	Challenging mechanics & mat. budget < 1% X0
ELECTRON-ION COLLIDER (EIC) START: > 2025	Electron-Ion Collider Tracking	Barrel: cylindrical MM, µRWELL Endcap: GEM, MM, µRWELL	Total area: ~ 25 m^2	Luminosity (e-p): 10^{33} **Spatial res.:** ~ 50- 100 um **Max. rate**: ~ kHz/cm^2	Barrel technical challenges: low mass, large area Endcap: moderate technical challenges

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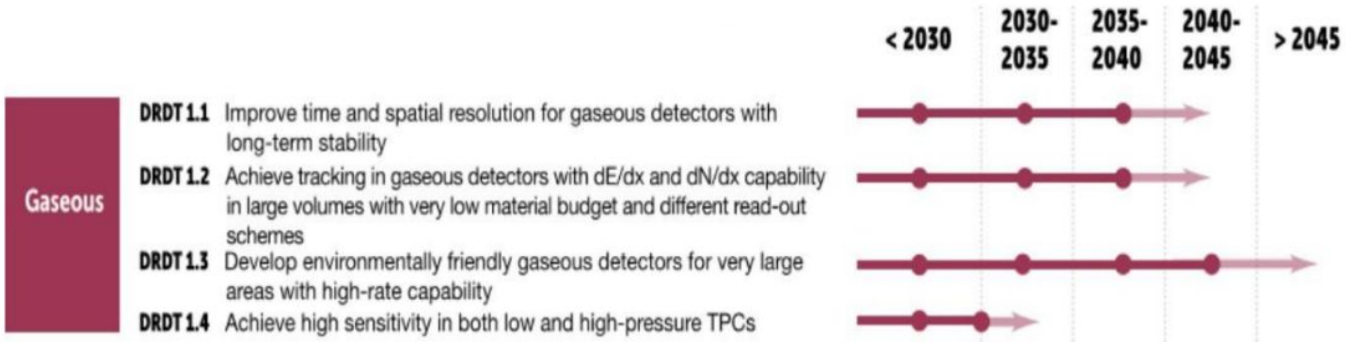
Detector Research and Development Themes (DRDT)



The Roadmap has identified a set of **detector R&D areas** and **themes** which are **required at the future facility** to do not compromised the the physics programmes of experiments. The project realisation must not be delayed by detectors R&D.

Requirements

Future challenges for tracking

Drift chambers:

- high rate, unique volume, high granularity, low mass
- hydrocarbon-free gas mixture for long-term and high-rate operation
- prove the cluster counting principle with the related electronics
- mechanics: new wiring procedure, new wire materials
- integration: accessibility for repairing

TPC:

- R&D on detector sensor to suppress the INF ratio
- optimize IBF together with energy resolution
- gain optimization: IBF, discharge stability
- uniformity of the response of the sensors
- gas mixture: stability, drift velocity, ion mobility, aging
- influence of magnetic field on IBF
- high spatial resolution
- very low material budget (few %)
- mechanics: thickness minimization but robust for precise electrical properties for stable drift velocity
- integration: cooling of electronics

Straw chambers:

- ultra-long and thin film tubes
- “smart” designs: self-stabilized straw module, compensating relaxation
- small diameter for faster timing, less occupancy, high rate capability
- reduced drift time, hit leading times and trailing time resolutions, with dedicated R&D on the electronics
- PID by dE/dx with “standard” time readout and time-over-threshold
- 4D-measurement: 3D-space and (offline) track time
- over-pressurized tubes in vacuum: control the leakage rate to maintain the shape

Future challenges for muon system

Muon system:

• radiation hardness and stability of large area up to integrated charges of hundreds of C/cm2, aging and discharge issues
• operation in a stable and efficient manner with incident particle flows up to ~10MHz/cm2
• 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
• 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
• study of resistive materials (RPC and MPGD); higher gain in a single multiplication layer, with remarkable advantage for assembly, mass production and cost; new material and production techniques for resistive lakers for increasing the rate capability
• thinner layers and mechanical precision over large area

DRD1: a large gaseous detector community

R&D FRAMEWORK

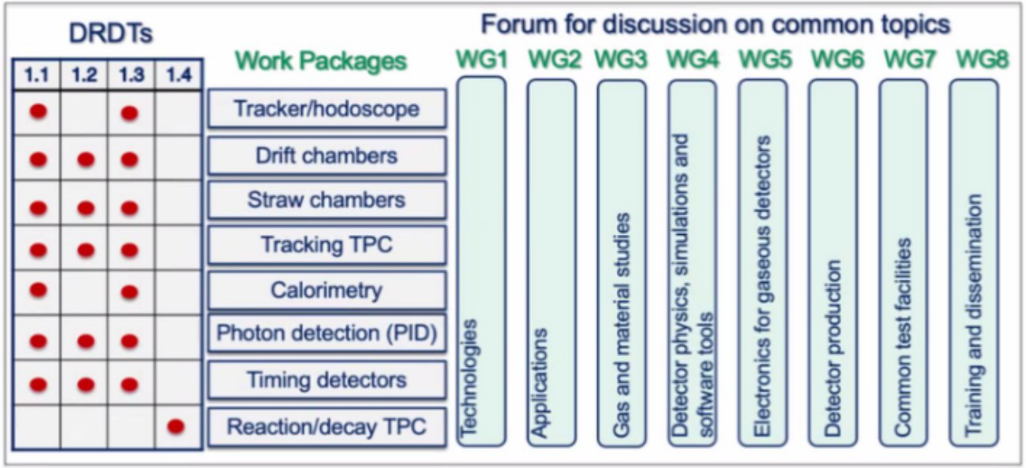
• **Collaboration type: Community-driven** with the R&D environment: common infrastructures (labs, workshops), common R&D tools (software and electronics), cross-disciplinary exchange

• **Scientific organization** in **Working Groups:** provides a platform for sharing knowledge, expertise, and efforts, by supporting strategic detector R&D directions, facilitating the establishment of joint projects between institutes.

R&D PROJECTS

• **Work Packages (WP)**: long-term projects addressing strategic R&D goals, outlined in the ECFA Detector R&D roadmap with dedicated funding lines.

• **Common Projects (CP)**: short-term bluesky R&D or common tool development with limited time and resources, supported by the Collaboration Common funds.



Towards a DRD1 Structure: proposal

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).

WG1: Technologies

Includes experimental detector physics aspects

•MPGDs
•RPCs, MRPCs
•Large Volume Detectors (drift chambers, TPCs)
•Straw tubes, TGC, CSC, drift chambers, and other wire detectors
•New amplifying structures

WG2: Applications

Full alignment with the ECFA detector R&D roadmap

•Muon systems
•Inner and central tracking with particle identification capability
•Calorimetry
•Photon detection
•Time of Flight systems
•TPCs for rare event searches
•Precision experiments
•Straw chambers in vacuum
•Fundamental research applications beyond HEP
•Medical and industrial applications

WG3: Gas and material studies

•Eco-gases searches
•Light emission in gases
•Ageing
•Radiation hardness
•Light (low material budget) materials
•Resistive electrodes
•Precise mechanics
•Photocathodes (novel, ageing, protection)
•New types of wires (coated carbon monofilaments)
•Solid converters
•Novel materials (nanomaterials)

WG4: Detector physics, simulations, and software tools

•Detector properties studies (simulations) •Software tools development and maintenance •Detector design tools
•Gas cross-section data bases maintenance

WG5: Electronics for gaseous detectors

•Readout electronics (SRS, ASICs, fast electronics, pixel, and optical readout)
•HV systems
•Dedicated lab instrumentation

WG6: Detector production

•CERN MPT workshop
•Saclay MPGD workshop
•Novel detector production methods •Industrialization

WG7: Common test facilities

Includes development of common detector characterization standards

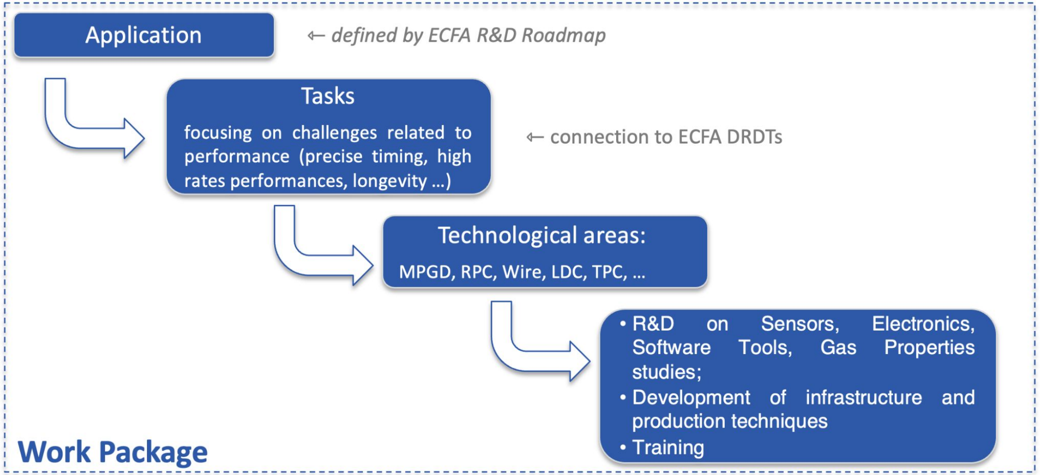
•General purpose detector development labs •Ageing facilities
•Irradiation facilities
•Gas studies facilities
•Test beam facility

WG8: Training and dissemination

•Schools and trainings
•Topical workshops
•Knowledge transfer
•(Young) Researcher Career

DRD1 Work Packages

Work Packages will **consolidate** the activities of institutes with **shared research** interests in specific areas, including **applications** (e.g., TPC, Muon Systems, Calorimetry), **challenges** (e.g. Precise Timing, High Rate, Longevity), **technologies** (e.g. Resistive Electrodes, Photocathodes), detector technologies (e.g., MPGDs, RPCs, Wires), and Working Group **tasks** (e.g., electronics, software). These WPs will actively contribute to the scientific program, R&D environment, infrastructure, and R&D tools within DRD1.



Currently envisaged WPs

- WP1: trackers/hodoscopes
- WP2: Drift Chambers
- WP3: Straw Chambers
- WP4: Tracking TPCs
- WP5: Calorimetry
- WP6: Photon detectors
- WP7: Timing detectors
- WP8: Reaction/Decay TPCs

Additional WP on beyond fundamental physics also considered

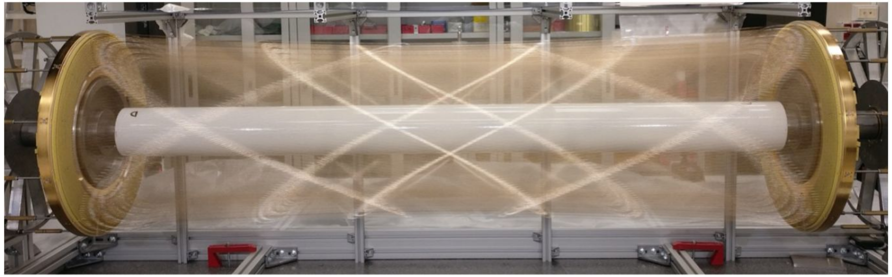
R&D updates on future colliders

F. Grancagnolo

Tracking: Drift chamber

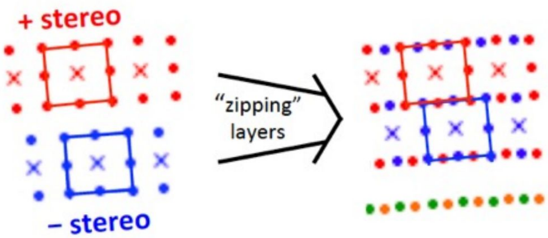
- a **unique-volume**, high granularity, fully stereo, low-mass cylindrical
- gas: He 90% - iC4H10 10%
- inner radius Rin = 0.35m, outer radius Rout = 2m
- **length L = 4m**
- drift length ~1 cm
- 343968 wires in total:

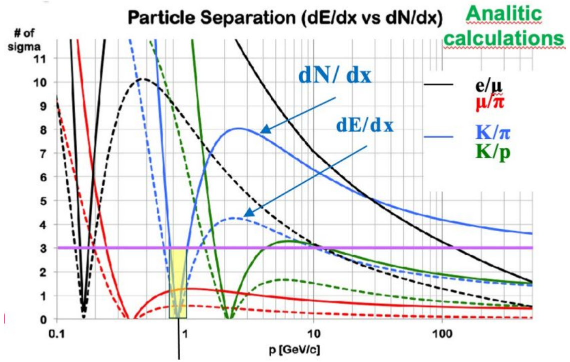
sense wires: 20 μm diameter W(Au) =>56448



- **the wire net** created by the combination of + and – orientation generates a **more uniform** equipotential surface and better **E-field** isotropy and smaller ExB asymmetries)

- a large number of wires requires a **non standard wiring procedure** and needs a feed-through-less wiring system and a novel wiring procedure developed for the construction of the ultra-light MEG-II drift chamber





- particle ID with dE/dx method and cluster counting technique

F. Grancagnolo

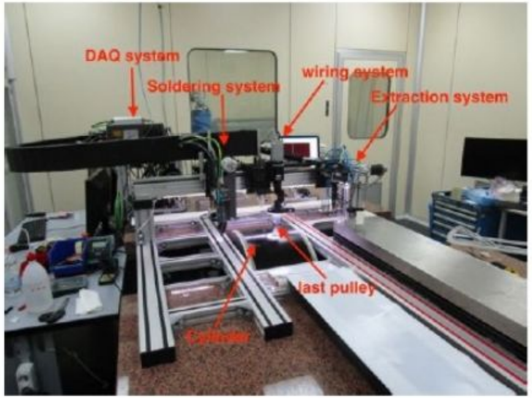
Tracking: Drift Chamber challenges

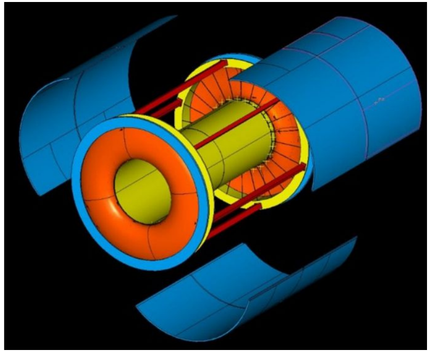
Electrostatic stability condition

The proposed drift chamber for FCC-ee and CEPC have a lengths L=4m and plan to exploit the cluster counting technique which requires gas gains of about 5x10^5. This poses serious constraints on the drift cell width (w) and on the wire material (YTS)

$$\frac{\lambda^2}{4\pi\varepsilon}\frac{L^2}{w^2} < wire\ tension < YTS \cdot \pi r_w^2$$

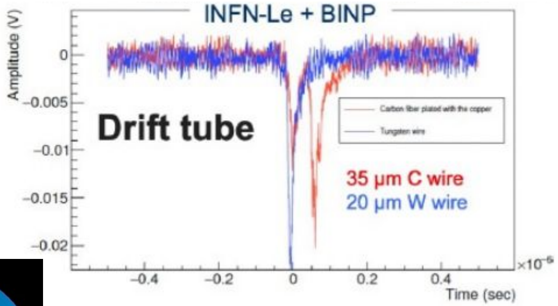
New mechanical system for high granularities, new end-plates and new materials. New concept calls for separating the wire support, by counterbalancing the wire tension with external stays, like in a cable-stayed bridge, from the gas containment.

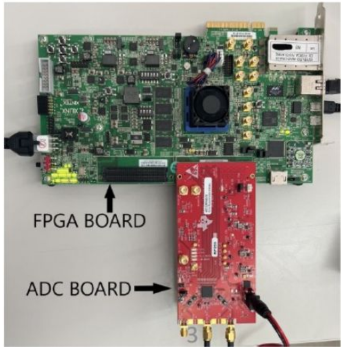




Data throughput

Large number of channels, high signal sampling rate, long drift times required for cluster counting, and high physics trigger rate (Z0 pole) imply data transfer rates in excess of 1TB/s





Non-flammable gas and recirculating gas system

Safety requirements demands stringent limitations on flammable gases; continuous increase of noble gases cost

F. Grancagnolo

Tracking: Drift Chamber activities

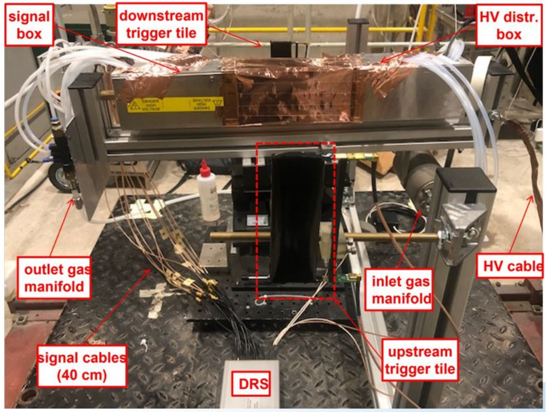
Electrostatic stability condition and New wiring system
tested different wire materials and diameters in the assembly of drift tube prototypes.

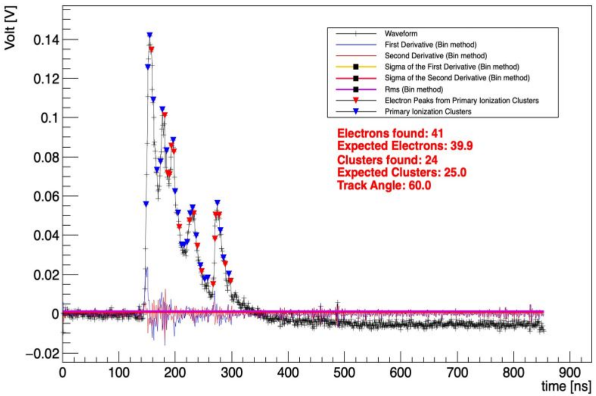
Simulation of the mechanical structure to support 10 tons on each endcap based on FEM analysis. Construction of a full scale prototype starting from 2024.

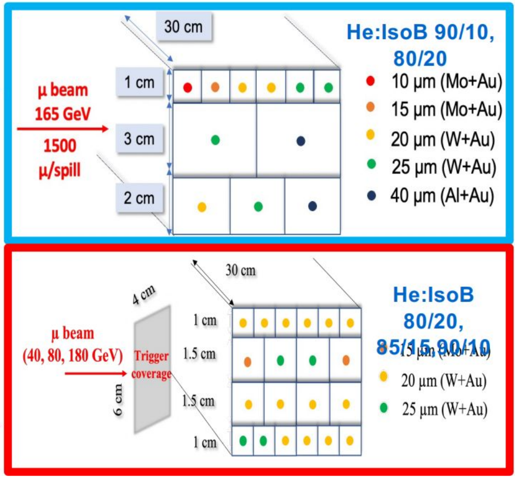
Simulation of the drift chamber in Geant4 and DD4HEP to validate the geometry and the signal reconstruction.

Data throughput
Two muon beam tests performed at CERN-H8 (βγ > 400) in Nov. 2021 and July 2022, a muon beam test in 2023 on going at CERN and an ultimate test at FNAL-MT6 in 2024 with π and K (βγ = 10−140) to fully exploit the relativistic rise.

Testbeam campaign on 2021, 2022 and 2023 to develop and measure the performance of cluster counting technique (wire and cell dimensions, electronics and software algorithms)







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P. Colas

Tracking: Time Projection Chamber

ILC-TPC: Target requirement: point resolution 100 um in transverse plane and dE/dx resolution < 5% reached with all technologies (**GEM, MM and GridPix**)

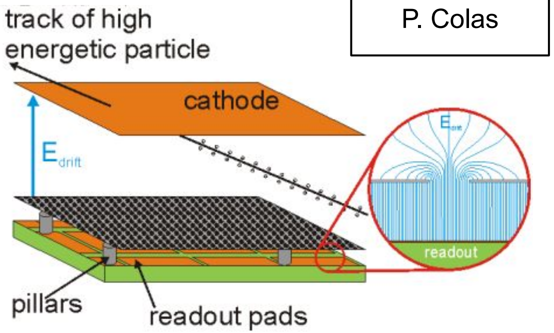
Track Distortions in ILC TPC @ 250 GeV (L~10^34 cm-2), 3.8 T
- beam-beam effects are dominant: primary ion density 1-5 ions/cm3 -> track distortions < 5 μm
- gas amplification 10^3 -> distortions of 60 μm -> **gating device is needed**

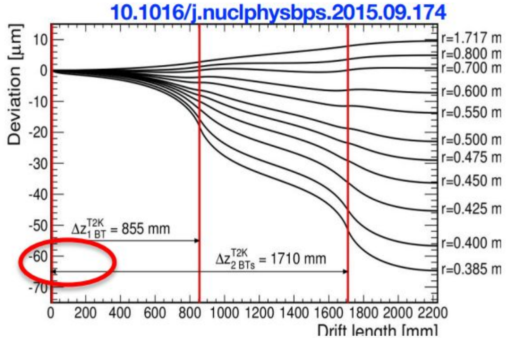
Exploit ILC bunch structure as 1 ms long bunch trains will arrive every 200 ms
Gating GEM gate opens 50 us before the 1st bunch and closes 50 us after the last bunch:
-> Measured electron transparency >80 % (as in simulations) for $\Delta V \sim 5V$

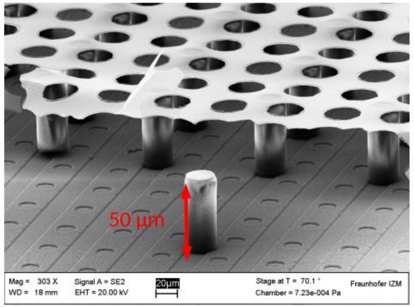
CEPC/FCC TPC: No bunch structure -> continuous beam (cfr. ALICE)
- HZ/WW/tt running -> **Pad readout (MM + GEM)**
- **Z pole running** -> primary ion density 1000 ions/cm^3 -> tracks distortions O(mm)
  -> Pixelated readout -> **GridPix**

MPGDs with pad/pixelated readout reduces occupancy (crucial for high-lumi runs @Z)

Pixelated readout also provides additional advantages:
- Single ionisation electrons are detected with high efficiency
- dE/dx by cluster counting
- Measuring IBF for Gridpix is a priority, expected ~1‰
- High spatial resolution under (lower) 2-3T magnetic field
- Better momentum resolution
- Better two tracks separation





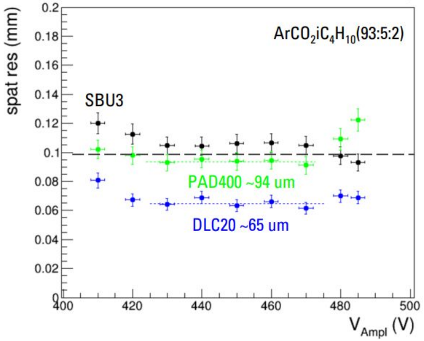


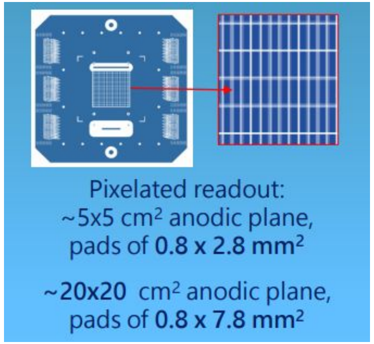
F. Petrucci
H. Qi

Tracking: Time Projection Chamber - Pad activities

Resistive High granUlarity Micromegas

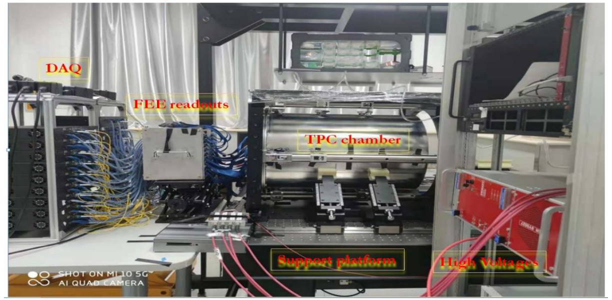
- particle tracking and trigger operation up to rate O(10 MHz cm-2) with stable HV behaviour,
< 100 um spatial resolution for perpendicular tracks;
< 10 ns time resolution;
- Reached a consolidated constructive techniques for large area detectors, to be considered in future experiment proposals (tracking, muon and calorimetry)

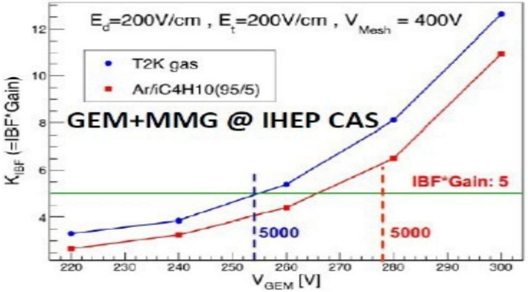




Pad TPC with multiple GEMs or GEMs/Micromegas

- Use of multiple layers of MPGDs significantly reduces ion back-flow (IBF) even without gating (crucial for circular colliders)
- TPC prototype recently developed by CEPC with integrated 266nm UV laser to generate pseudo-tracks
- dE/dx about 3.4% for (pseudo-)tracks with 220 hits (as expected for CEPC baseline detector concept)

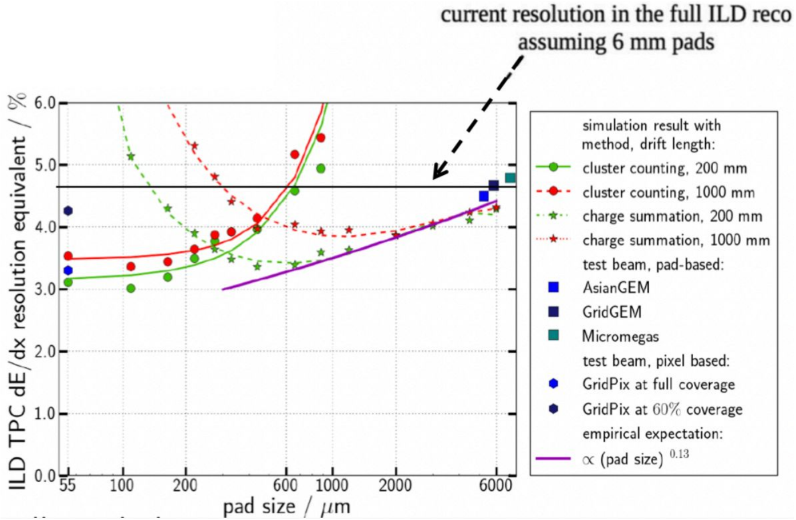


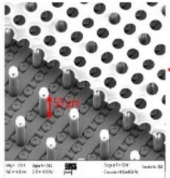


Tracking: Time Projection Chamber - Pixel activities

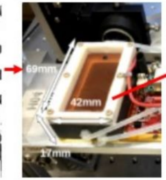
J. Kaminski
P. Colas
H. Qi

- **Timepix3**-based GridPix detector module tests already indicate excellent tracking and dE/dx performance
- Prototype with **160 GridPixes** covering an active area of 320 cm2 (10M pixel detector) also built and tested in beam at B=1T in DESY in June 2021, to prove large-scale production, integration, and readout
easier assembly, better coverage)
- **dN/dx cluster counting**: should be feasible with high granularity readout, challenging for low power consumption, to be addressed by dedicated R&D.
- Preliminary **full simulation studies** (Geant4) foresee, compared to pad TPC w/ 6mm pads:
- **Timepix4** development ongoing (lower power consumption, easier assembly, better coverage)

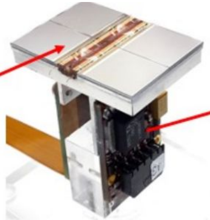




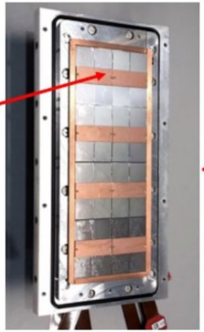
MM grid (InGrid) on Timepix chip



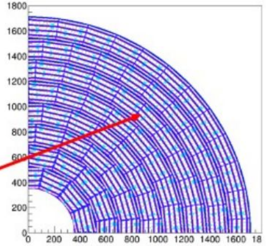
Single chip 2017



Quad 2018



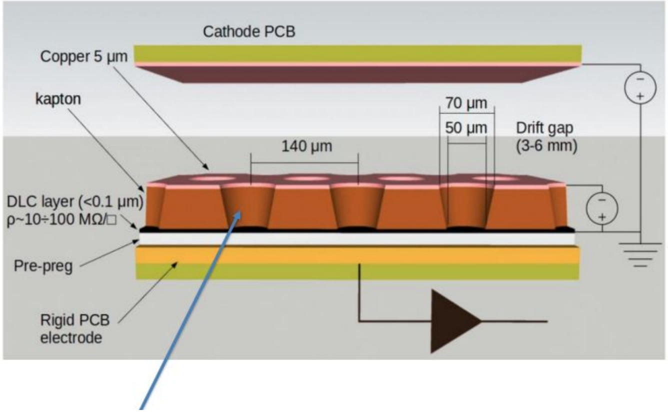
Module - 2019



TPC plane

G. Bencivenni

Muon system: μ-RWELL challenge



The μ-RWELL are the proposed detector of the IDEA preshower and muon system, LHCb muon upgrade, EIC trackers

The technology proved very good performances:

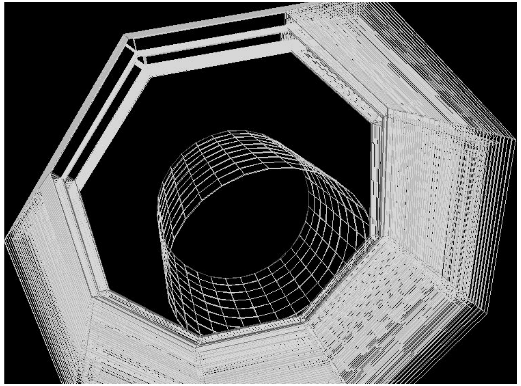
- 50-100 μm spatial resolution
- 1-10 MHz/cm2 rate capability
- 1-5*10^4 gain factor
- 0.5% X0 material budget

The **engineering and industrialization** of the μ-RWELL technology is one of the main goals for large area production (i.e. 1525 m2).

Reduce the **number of channels** to reduce the muon system cost and match the IDEA requirements.

Optimization of the layout is needed to improve the performance and reduce the dead-area.

Resistive layer studies are needed to define a stable manufacturing process to deposit DLC; study possible surface resistivity of DLC changes during the detector manufacturing; study the DLC stability under long-term irradiation.



G. Bencivenni

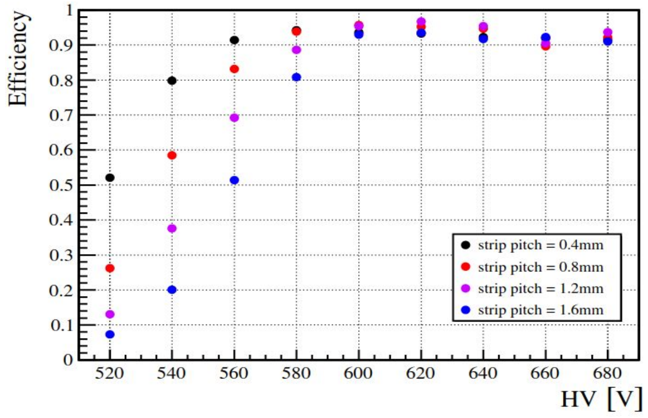
Muon system: μ-RWELL activities

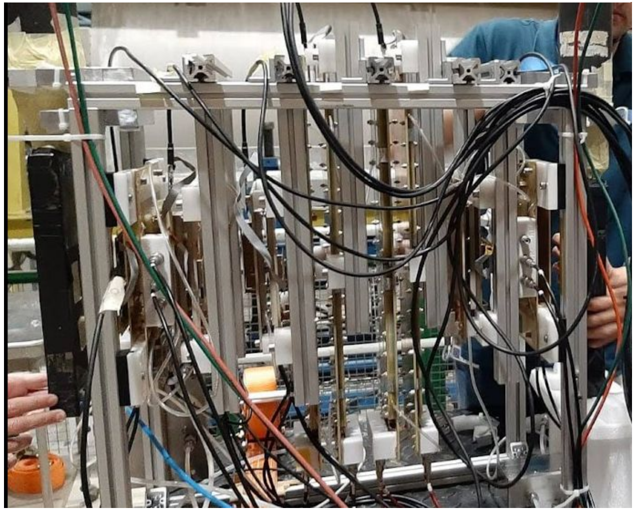
A testbeam campaign is ongoing since 2020 to optimize the detector, focussing on:

- **resistivity** of the DLC (charge dispersion, signal dimension, resolution)
- readout **segmentation** (pitch dimension, electronic noise, performance)
- **2D layouts** (2x1D, charge sharing, TOP segmentation)

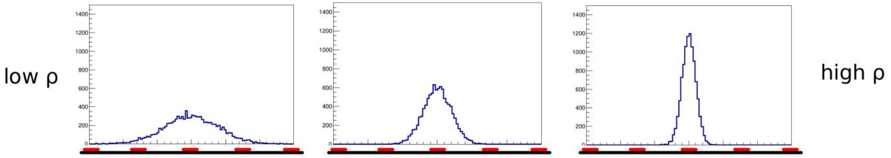
Technological transfer activities are ongoing to move some production steps from CERN to industries and open to large scale and low cost production.

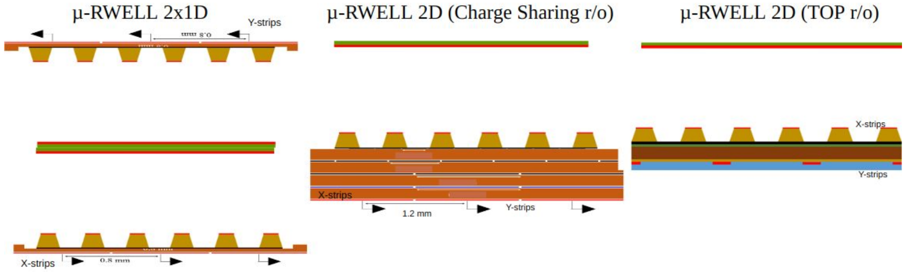
Fast and parametrized **simulation** of the detector and integration with the TIGER **electronics** are ongoing.





Charge distribution example





G. Pugliese

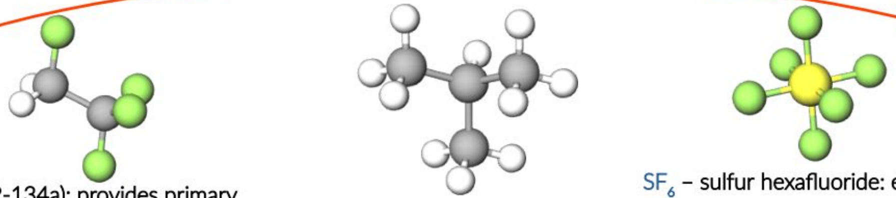
Muon system: RPC challenge

RPC working parameters depend on the gas mixture employed
● The currently-used **gas mixtures** at the LHC grant the following **properties**:
1) High density of **primary** ion-electron pairs
2) Relevant **quenching** properties for capturing recombination photons without further ionization
3) Enough **electronegativity** to capture free electrons, reducing the avalanche size

Gas	GWP-100 years
R134a	1430
SF_6	22800

RPC gas mixtures are based on Fluorinated greenhouse gases that are classified for their Global Warming Potential with respect to CO2

RPC EcoGas@GIF++ collaboration created in 2019 within ALICE, ATLAS, CERN EP-DT, CMS and LHCb/SHiP experiments to search for an eco-friendly RPC gas mixture



Constraints on the new eco-gas mixture:
● **Safety**: gases must be non-flammable, not explosive, not toxic
● **Compliant** with the current systems (i.e. no change on the power systems and Front-End electronics)
● Effective in the **performance** and longevity
● **Cheap** or similar cost with respect to the present gases

G. Pugliese

Muon system: RPC activities

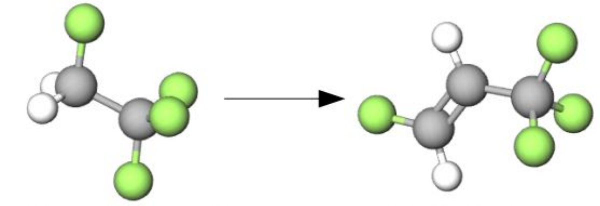
Possible candidate (already used in industrial applications) is **tetrafluoropropene** (C3H2 F4 , HFO-1234ze, HFO), with similar chemical structure as R134a but lower GWP1 ~ 6

Replacement of R134a with **HFO alone not possible** due to its lower first Townsend coefficient → Working voltage above 15 kV

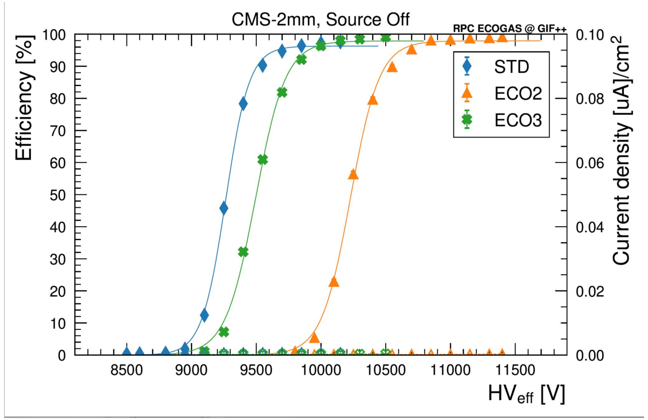
Several HFO based gas mixtures tested with a **fraction of CO2** to lower the HV working point.

Comparable efficiency plateau for ECO3 up to 500 Hz/cm2, lower efficiency but above 90% for ECO2

Aging effects to be carefully evaluated. Work is in progress to study long term aging of detectors under irradiation



Gas mixture	$C_2H_2F_4$	HFO-1234ze	CO_2	I-C_4H_{10}	SF_6
STD	95.2	0	0	4.5	0.3
ECO1	0	45	50	4	1
ECO2	0	35	60	4	1
ECO3	0	25	69	5	1



Conclusion

Technological advancements in innovative materials, new architectures and cutting-edge technical solutions have opened in a new era in the operational capabilities of gas detector, enabling these detectors to work under increasingly demanding conditions. These remarkable developments stand to greatly benefit both upcoming and future experiments.

Success of collaborative efforts from the experience of RD51 has vividly demonstrated that collaborative endeavors yield success and pave the way for sustainable developments in our field.

Some ongoing activities related to tracking and muon ID have been presented focussing on future challenges, but many other are present in the DRD1 WPs.

More information can be found at the DRD1 website or on the DRD1 proposal

References

Giovanni Marchiori, Tracking and particle identification for future ee factories: highlights and plans from WG3 parallel sessions, ECFA workshop

Anna Colaleo, Gas Based Detectors, The 13th International Conference on Position Sensitive Detectors

Anna Colaleo, The ECFADetector R&D Roadmap: gaseous detector, 6th FCC workshop

Nicola De Filippis, Update of the IDEA drift chamber, The 2023 International Workshop on Circular Electron Positron Collider

Huirong Qi, Status of Pixelated and Pad Readout TPC Technology R&D at CEPC, The 2023 International Workshop on Circular Electron Positron Collider

Francesco Grancagnolo, Conceptual Design and Challenges for Drift Chambers, ECFA WG3: Topical workshop on tracking and vertexing

Paul Colas, Conceptual designs and R&D challenges for TPCs, ECFA WG3: Topical workshop on tracking and vertexing

Anna Colaleo, DRD1 (gaseous detectors) status and plans, ECFA WG3: Topical workshop on tracking and vertexing

Luca Quaglia, In-beam performance of a Resistive Plate Chamber operated with eco-friendly gas mixtures, The 13th International Conference on Position Sensitive Detectors

Jochen Kaminski, GridPixes and their Application, MPGD2022 conference

Maxim Titov, Gaseous Detectors R&D for FCC, FCC Week 2023

Riccardo Farinelli, R&D on muon detectors for the IDEA experiment, Second ECFA workshop 2023

Maria Teresa Camerlingo, Pixelised Resistive Micromegas for Tracking Detectors in Future Particle Physics Experiments, TIPP 2023

Gabriella Pugliese, Resistive Plate Chamber: status and future challenges, The 2023 International Workshop on Circular Electron Positron Collider