Additional input to the next ESPP from DRD1

A. Pastore

on behalf of DRD1 Bari group

The road to DRD1 Collaboration and R&Ds

DRD1 Implementation Team

- ECFA TF1 Conveners : Anna Colaleo, Leszek Ropelewski; Other TF1 Members: Klaus Dehmelt, João Veloso
- ECFA Coordinators Group Member: Silvia Dalla Torre
- MPGDs: Eraldo Oliveri, Fulvio Tessarotto, Maxim Titov
- RPCs: Ingo Deppner, Giuseppe Iaselli, Barbara Liberti
- TPCs: Esther Ferrer Ribas, Jochen Kaminski
- Large volume detectors: Marco Panareo, Francesco Renga
- Straw tubes, TGC, CSC, drift chambers, and other wire detectors: Peter Wintz
- Infrastructure, detector R&D programmes (CERN EP R&D, AIDAinnova): Roberto Guida, Beatrice Mandelli
- Administrative support: Hans Taureg, Florian Brunbauer

Relevant contribution to DRD1 by INFN Bari

2019
Granada Symposium
WGs and Physics Briefing Book

2020
ESPP update
HEP strategic projects

2021
ECFA detector R&D roadmap
TF & community workshops

2023
ECFA DRD proposals

2024
DRD MoUs
collaborations active

2026-27
ESPP update

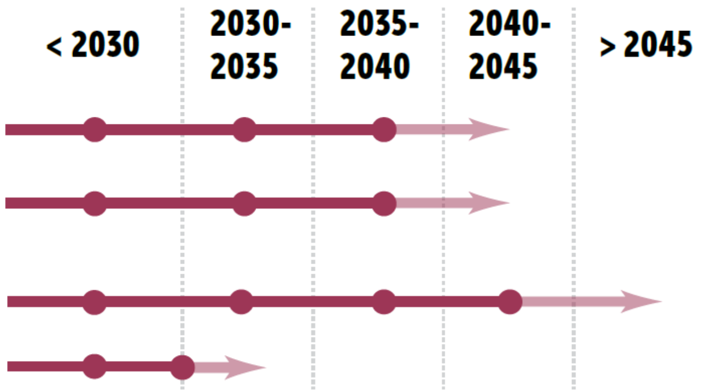
Gaseous

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

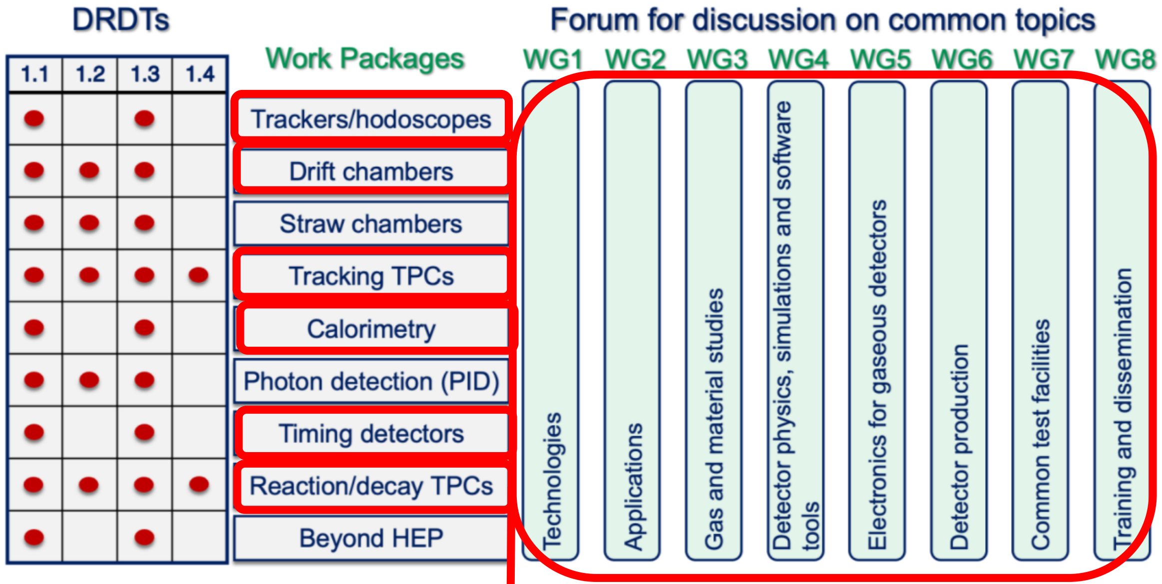
DRDT 1.4 Achieve high sensitivity in both low and high-pressure TPCs



https://cds.cern.ch/record/2784893

ECFA TF1 Conveners : Anna Colaleo, Leszek Ropelewski;

DRD1 Collaboration - common topics and projects



DRDTs

Work Packages	1.1	1.2	1.3	1.4
Trackers/hodoscopes	●		●	
Drift chambers	●	●	●	
Straw chambers	●	●	●	
Tracking TPCs	●	●	●	●
Calorimetry	●		●	
Photon detection (PID)	●	●	●	
Timing detectors	●		●	
Reaction/decay TPCs	●	●	●	●
Beyond HEP	●		●	

Forum for discussion on common topics

WG1	WG2	WG3	WG4	WG5	WG6	WG7	WG8
Technologies	Applications	Gas and material studies	Detector physics, simulations and software tools	Electronics for gaseous detectors	Detector production	Common test facilities	Training and dissemination

DRD1

DRD1 EXTENDED R&D PROPOSAL
Development of Gaseous Detectors Technologies
v1.5

Abstract

Geneva, Switzerland
December 1, 2023

https://cernbox.cern.ch/pdf-viewer/eos/project/d/drd1/Documents/Proposal/DRDC-P-DRD1.pdf?contextRouteName=files-spaces-generic&contextRouteParams.driveAliasAndItem=eos/project/d/drd1/Documents/Proposal

BARI

- R&D on EcoGases (WP1)
- R&D on Wires (WP2)
- R&D on Timing (M)RPCs (WP7)
- R&D on HP TPCs (WP8)

Challenges for the future
we are going to discuss in this talk

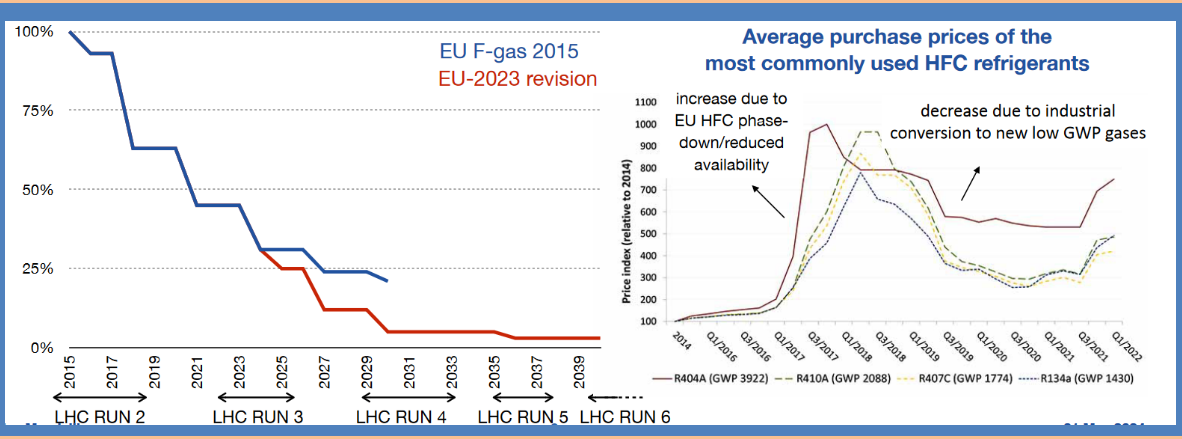
For <u>other DRD1 challenging activities</u>, with overlaps with RD_FCC, RD_MUCOL, CMS Upgrade and LHCb U2 ones, please <u>refer to previous talks</u>

R&D on EcoGases - motivation

Strong need for an alternative eco-friendly gas mixtures, with similar performance wrt the standard ones

EU "F-gas regulation" (517/2014)

- **Limiting the total amount** of the most important F-gases that can be sold in the EU.
- **Banning the use** of F-gases where less harmful alternatives are widely available.
- **Preventing emissions** of F-gases from existing equipment.



B. Mandelli, PMAD2024

#ClimateReport #IPCC

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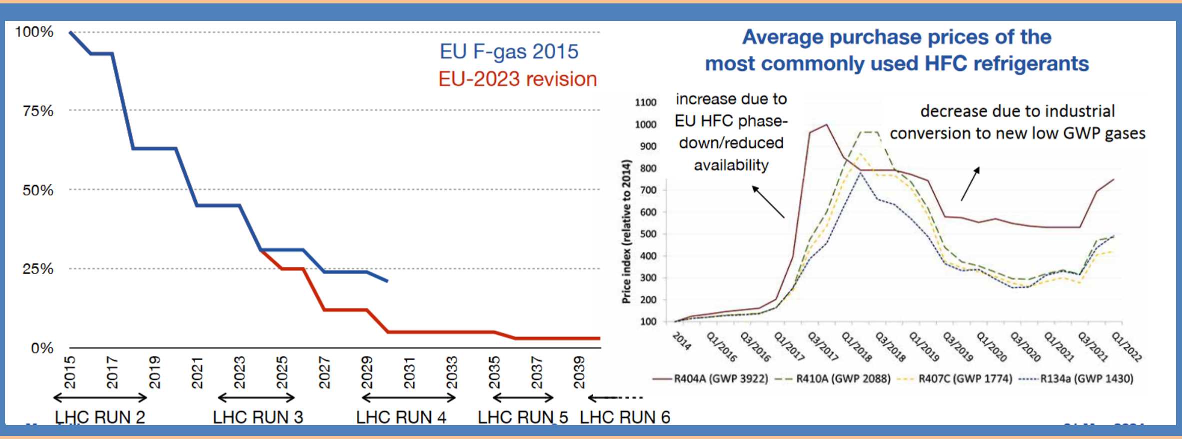


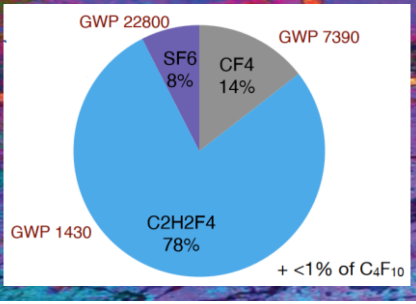
B. Mandelli, PMAD2024

EU “F-gas regulation” 2023 revision (573/2024)

- **23 additional F-gases** to its controls
- It clarifies and **strengthens** rules on F-gas **production**, **use**, **recovery**, **recycling** and **destruction**
- It **strengthens** conditions on the **import**, **export** and **placing on the market** of F-gases, and related equipment
- **establishes** the **total elimination** of hydrofluorocarbons by **2050**

+ PFAS restrictions by ECHA!

relative contribution to GHGs emissions from particle detectors at CERN LHC experiments:

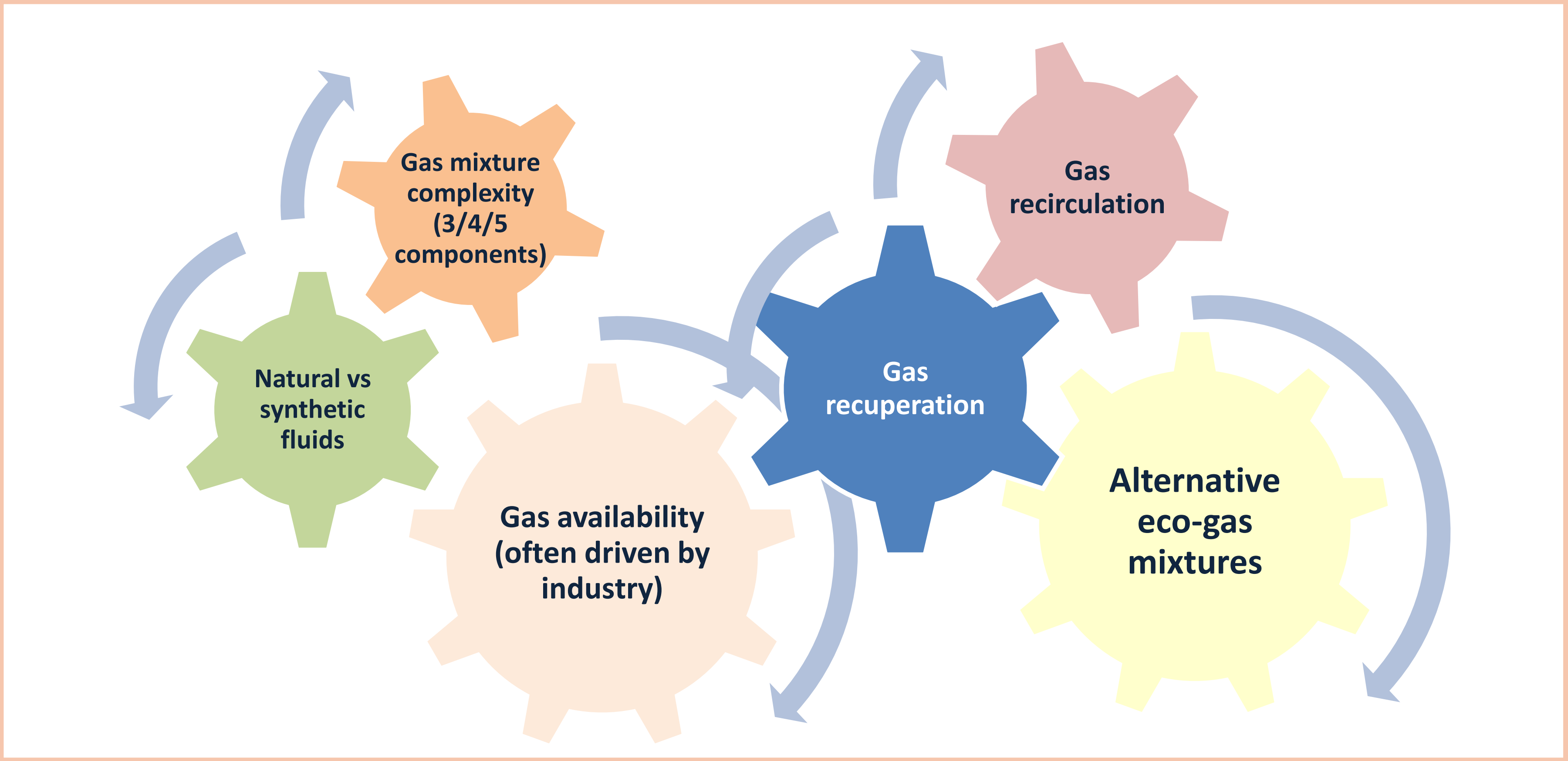


https://hse.cern/environment-report-2021-2022

CERN’s objective is to reduce its scope emissions by 28% by the end of 2024

#ClimateReport #IPCC

R&D on EcoGases - goals



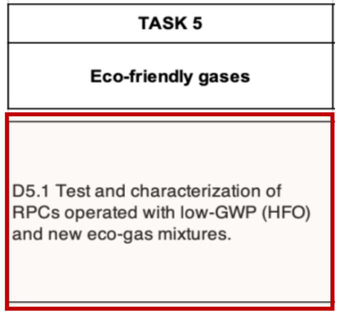
A. Pastore, IFD22

R&D on-going at home-labs and in the framework of the RPC EcoGas@GIF++ Collaboration and -later on- DRD1 Collaboration focus on the performance and longevity of the detectors when operated with eco-friendly gas mixtures

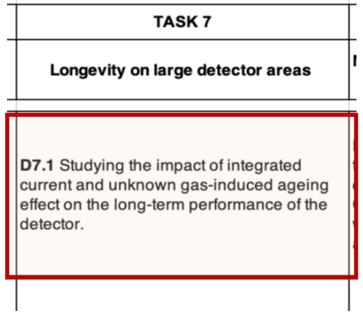
R&D on EcoGases@INFN Bari

M. Abbrescia, L. Congedo, M. De Serio, G. Iaselli, D. Ramos Lopez, U. Lakshmaiah, A. Pastore, G. Pugliese, S. Simone

The example of the DRD1 WP1 (and INFN Bari):



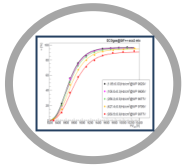
TASK 5
Eco-friendly gases
D5.1 Test and characterization of RPCs operated with low-GWP (HFO) and new eco-gas mixtures.



TASK 7
Longevity on large detector areas
D7.1 Studying the impact of integrated current and unknown gas-induced ageing effect on the long-term performance of the detector.

- **R&D on new gas mixtures for RPC** detectors. **Starting point TFE→$C_3H_2F_4$ and $C_3H_2F_4/CO_2$-based mixt.**
- *green* RPCs **performance evaluation** (wrt RPCs operated with standard mixture)
- **ageing test campaign** and **systematic long-term performance** studies

The example of the RPC ECOGas@GIF++ Collaboration (and INFN Bari):



July 2022

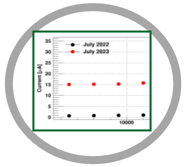
Beam Test @ GIF++

Performance baseline analysis completed

August 2022

Ageing campaign

Start of the RPCs ageing campaign with ECO2 at GIF++, ABS 2.2

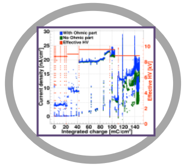


July 2023

Beam Test @ GIF++

Performance comparison analysis on-going

eco2: 35% HFO-60% CO_2-4 % iC_4H_{10}-1% SF_6



October 2024

ECO2 ageing campaign

on-going…

. . . . .

TFE is only the first tile of the puzzle

SF_6, CF_4, C_4F_{10}, … for CSCs, MPGDs, RICHs, RPCs, TPCs

es. R&D LHCb U2 @Bari
studies on ecogas for μRWELL detectors
(→ Marilisa's talk)

IN SUMMARY:
- → *Crucial R&D for future activities*
- → *Results (any) require a long time scale*
- → *Hope for a wise approach, not underestimating the importance of this R&D*

A. Pastore

R&D on large volume drift chambers – motivation, goals and INFN Bari involvement

N. De Filippis, M. Louka, F. Procacci,

- **Electrostatic stability** condition: $\frac{\lambda^2}{4\pi\varepsilon}\frac{L^2}{w^2} < wire\ tension < YTS \cdot \pi r_w^2$

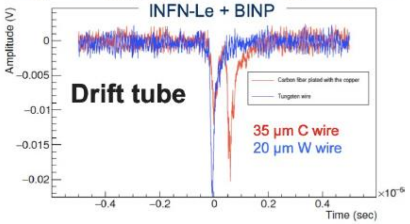
λ = linear charge density (gas gain)
L = wire length, r_w wire radius, *w* = drift cell width
YTS = wire material yield strength

The proposed drift chambers for FCC-ee and CEPC have lengths **L = 4 m** and plan to exploit the cluster counting technique, which requires gas gains ~**5×10⁵**.
This poses serious constraints on the drift cell width (**w**) and on the wire material (**YTS**).

⇒ new wire material studies , wire metal coating studies and ageing for new wire types

- **Non-flammable gas / recirculating gas systems**
  Safety requirements (**ATEX**) demands stringent limitations on flammable gases;
  Continuous increase of **noble gases cost**

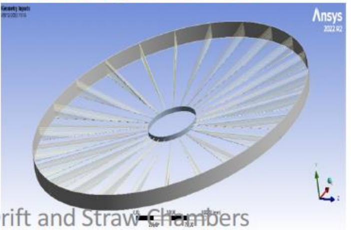
⇒ gas studies

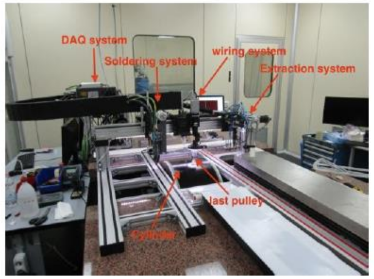


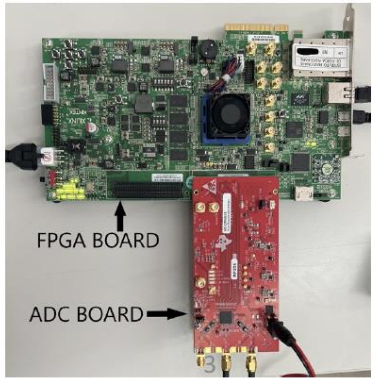
- **Data throughput**
  Large number of channels, high signal sampling rate, long drift times (slow drift velocity), required for cluster counting, and high physics trigger rate (Z_0-pole at FCC-ee) imply data transfer rates in excess of ~**1 TB/s**

⇒ on-line real time data reduction algorithms

- **New wiring systems for high granularities / / new end-plates / new materials**







GARFIELD simulation needed
+ prototypes

01/03/2023 WG2: Drift and Straw Chambers 3

SPECIALTY MATERIALS, INC.
Manufacturers of Boron and SCS Silicon Carbide Fibers and Boron Nanopowder
CARBON MONOFILAMENT

TYPICAL PROPERTIES

Diameter:	0.00136 +/- 0.0001" (34.5 +/- 2.5 μm)	
Tensile Strength:	125 ksi (0.86 GPa)	0.65 GPa
Tensile Modulus:	6 msi (41.5 GPa)	
Electrical Resistivity:	3.6 x 10⁻³ ohm cm	37 KΩ/m
Density:	1.8 g/cc	

Specialty Materials, Inc.
1449 Middlesex Street
Lowell, Massachusetts 01851

Phone: 978-322-1900
Fax: 978-322-1970

CARBON MONOFILAMENT PRODUCT PRICE LIST
Effective October 1, 2017

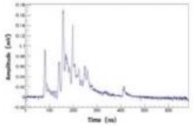
CARBON MONOFILAMENT PRODUCT PRICE LIST EFFECTIVE APRIL 1, 2019

Product	Quantity	Price per LF	
CARBON MONOFILAMENT	1 Million LF	$0.02	60 €/Km
	500,000 LF	$0.03	
	1,000 LF	$0.94	

R&D on large volume drift chambers – motivation, goals and INFN Bari involvement

N. De Filippis, M. Louka, F. Procacci,

The excellent performance of the **cluster finding** algorithms in offline analysis, relies on the assumption of being able to transfer the full spectrum of the digitized drift signals. However …



according to the **IDEA drift chamber operating conditions**:

- 56448 drift cells in 112 layers (~130 hits/track)
- maximum drift time of 500 ns
- cluster density of 20 clusters/cm
- signal digitization 12 bits at 2 Gsa/s

… and to the **FCC-ee running conditions at the Z-pole**

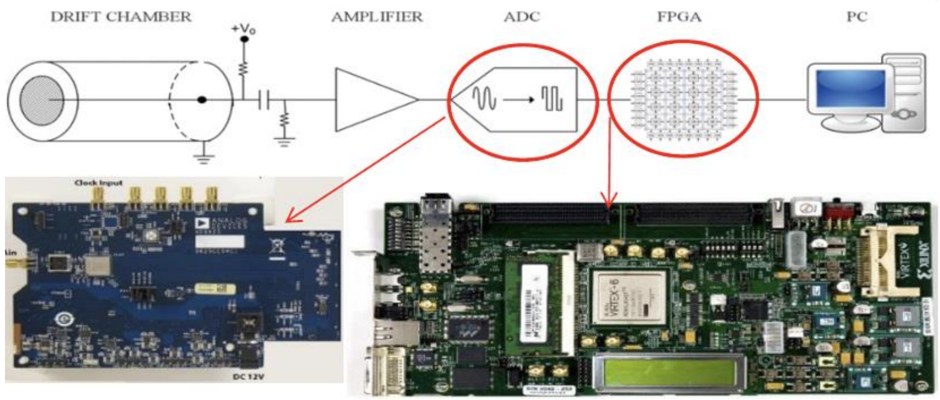
- 100 KHz of Z decays with 20 charged tracks/event multiplicity
- 30 KHz of $\gamma\gamma \longrightarrow$ hadrons with10 charged tracks/event multiplicity
- 2.5% occupancy due to beam noise
- 2.5% occupancy due to hits with isolated peaks

Reading both ends of the wires, ⇨ **data rate ≥ 1 TB/s !**

Solution consists in transferring, for each hit drift cell, instead of the full signal spectrum, only the minimal information relevant to the application of the **cluster timing/counting techniques**, i.e.:

the amplitude and **the arrival time** of each peak associated with each individual ionisation electron.

This can be accomplished by using a **FPGA** for the **real time analysis** of the data generated by the drift chamber and successively digitized by an ADC.

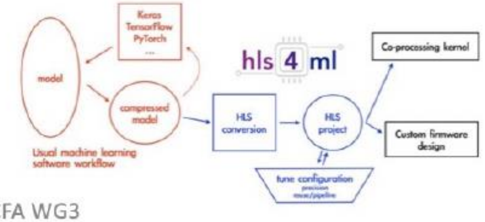


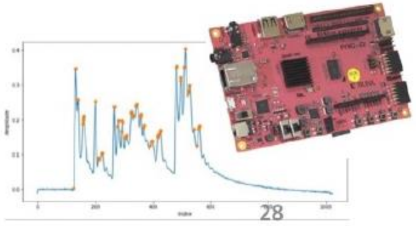
Single channel solution has been successfully verified.

G. Chiarello et al., The Use of FPGA in Drift Chambers for High Energy Physics Experiments May 31, 2017
DOI: 10.5772/66853

With this procedure **data transfer rate is reduced to ~ 25 GB/s**
Extension to a 4-channel board is in progress. Ultimate goal is a multi-ch. board (128 or 256 channels) to **reduce cost** and complexity of the system and to gain flexibility in determining the **proximity correlations** between hit cells for track **segment finding** and for **triggering** purposes.

Implementing ML algorithms on FPGA for peak finding





→ Development of front-end ASIC for cluster counting

→ Development of a scalable multichannel DAQ board

IN SUMMARY:

- *→ R&D for medium/high rate future activities*
- *→ Gas and material studies at the crossroad with several technologies*

R&D on Timing (M)RPCs – motivation and goals

Challenges in view of future collider experiments

The development and/or optimization of (M)RPCs

→ exploring new architectures, optimized electrode patterns, fine structures (narrow gaps) and new materials (f.e. low-resistivity glasses and semiconductors)

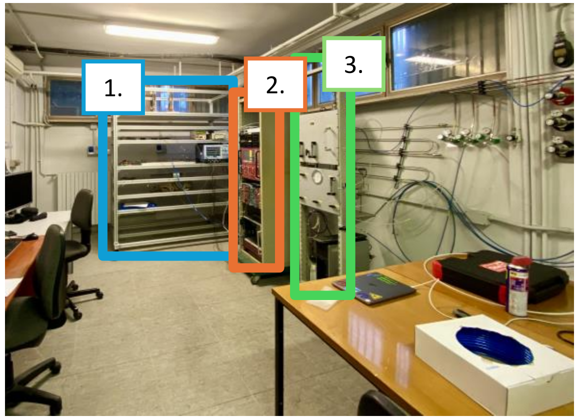
→ to enhance their rate capability (ranging from 10 kHz to 1 MHz per cm^2) and/or fast timing resolution (reaching sub-ns to ps levels)

is a **challenge in view of future high luminosity collider experiments** to **mitigate pile-up effects** and to **reduce uncorrelated beam-induced backgrounds**, while **improving the sensitivity for heavy long-lived particle** searches (e.g. slow muon-like particles with β < 0.9).

R&D@INFN Bari RPC Laboratory

Thanks to the strong collaboration between Bari and Korea University we were able to **test** several RPC **prototypes** with **thinner electrodes & gas gap** and **new electrode materials** for improved timing resolution, rate capability and longevity

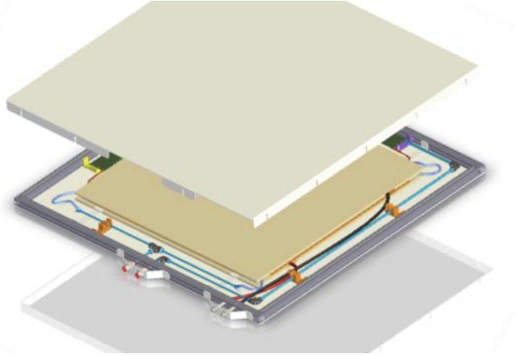
- **Glass Double Gap RPC (see few results on next slides)**
- **New thin ceramic electrode for higher rate capability**

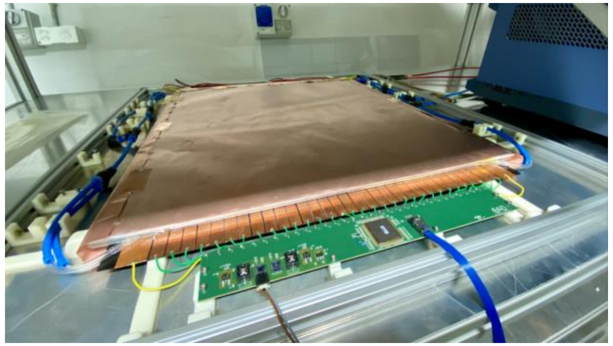


1. cosmic stand
2. Electronic rack
3. Gas system

R&D on Timing (M)RPCs @ INFN Bari

N. Ferrara, G. Iaselli, D. Ramos Lopez, U. Lakshmaiah, G. Pugliese



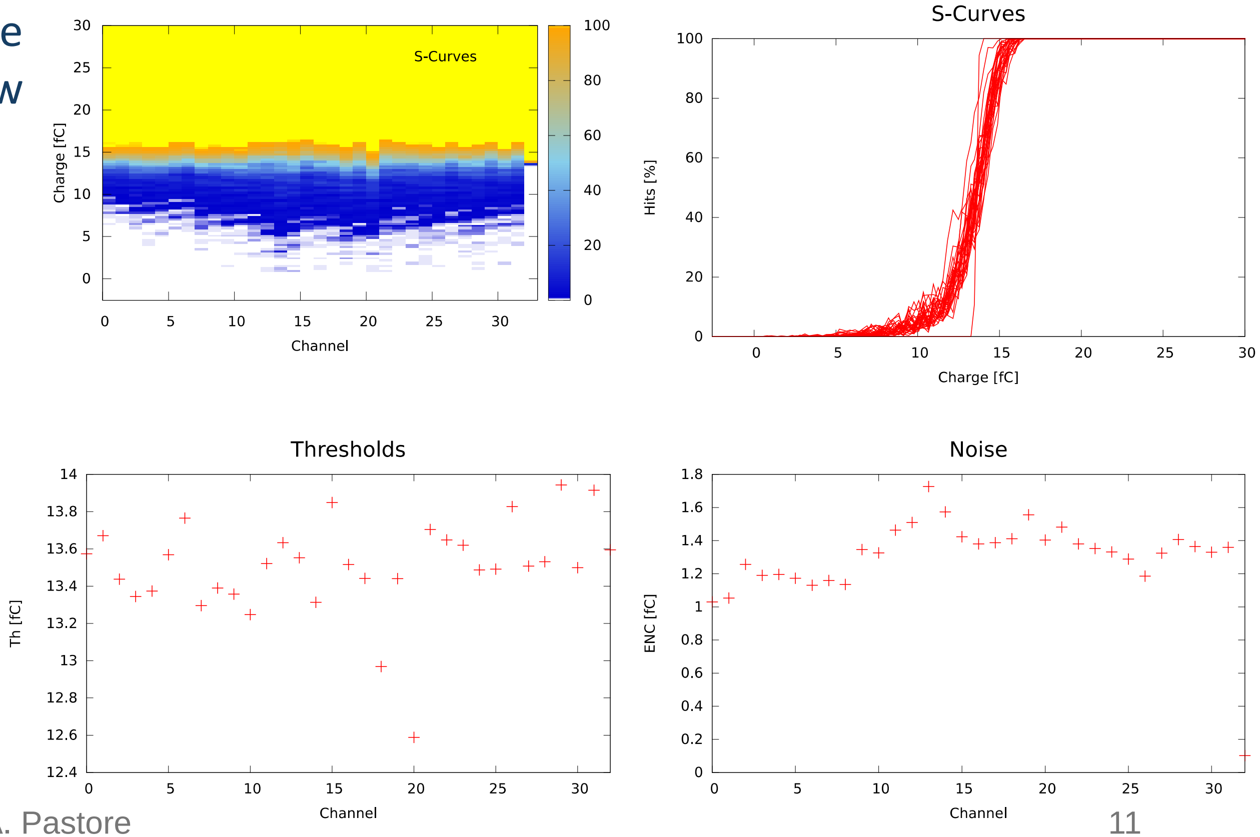


A double-gap glass RPC (1.4 mm gas gap and 1.1 mm glass electrode thickness) was tested with a new readout electronics **based on FATIC2 chip** adapted for RPC signals TDC time resolution ~ **100 ps**

Preliminary calibration (S-Curves and threshold scans) of the new electronics was performed at INFN RPC Lab with low charge thresholds (DRD1 WP7B)

- **Plan:** fine tune the electronics integration and perform dedicated performance studies with cosmics muons. The detector will be operated with the CMS standard gas mixture and few ecofriendly mixture candidates

Fast Discriminator scan report

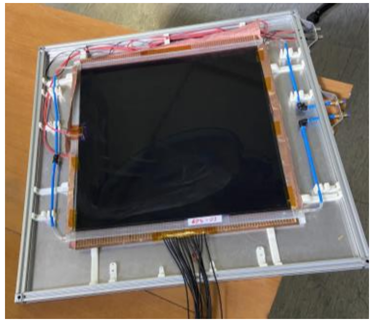


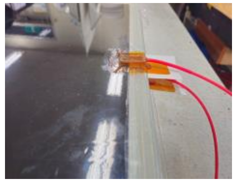
R&D on Timing (M)RPCs @ INFN Bari

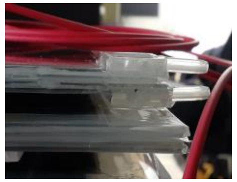
N. Ferrara, G. Iaselli, D. Ramos Lopez, U. Lakshmaiah, G. Pugliese

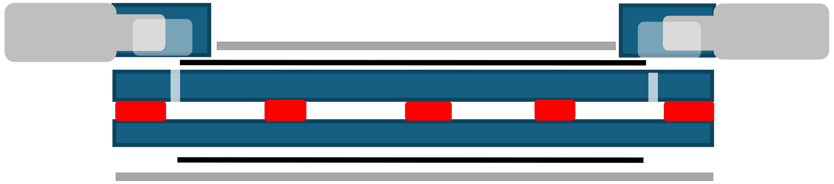
Four 50x50cm^2 **prototype RPC** with gas gap thickness of **0.52 mm** and glass electrodes under test for fast timing RPC studies (DRD1 WP7B).

- One chamber with double-gap assembled
- Characterization of gaps successfully completed Preliminary signal study by using digitizer DT5742 and cosmic trigger.
  Limitation: active area of 10 cm^2



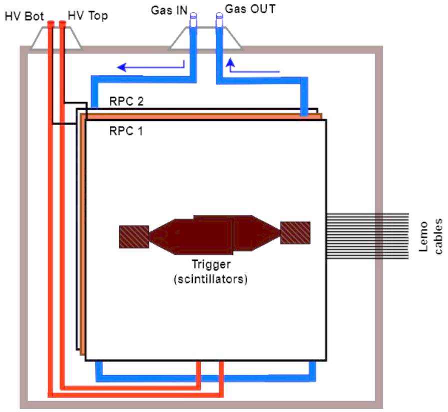


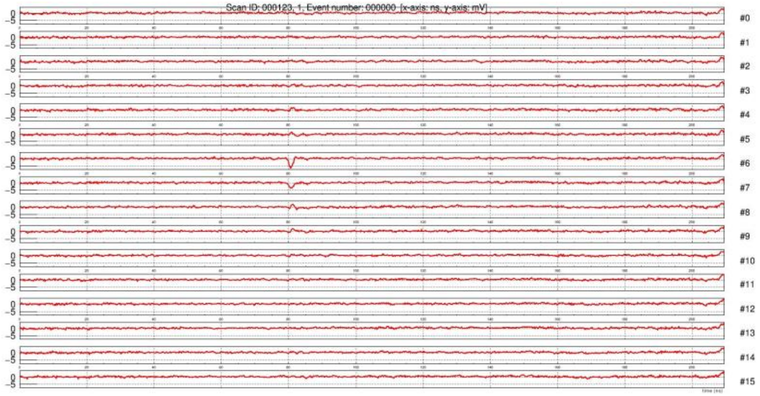




Plan:

- Time resolution measurements with CAEN PicoTDC-based DAQ, with cosmics in the Bari Lab and several gas mixtures (CMS standard and eco-friendly candidates)
- Beam test at GIF++ for performance studies at high radiation background (up to few kHz/cm2)





Signal example

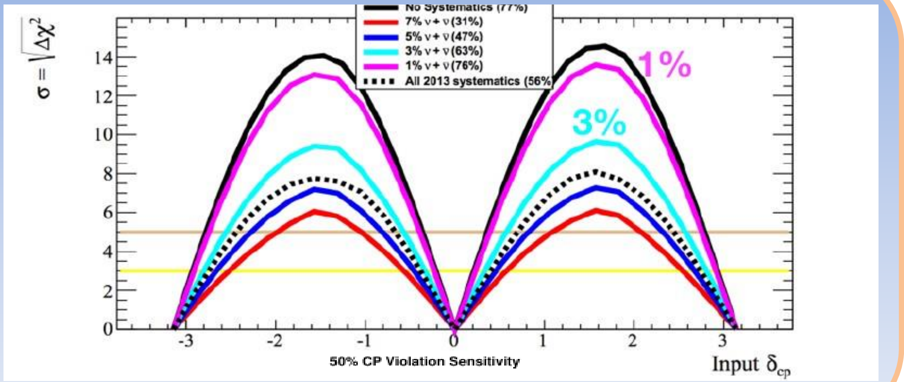
IN SUMMARY:

- → *Crucial R&D for future very high rate applications*
- → *Boost on 4D tracking is a key point*
- → *Material studies at the crossroad with several technologies*

R&D on High Pressure TPCs – motivation and goals

Challenges in view of future neutrino experiments

- Future neutrino oscillation experiments sensitivities rely heavily on the **reduction of the impact of systematic errors at % level**
- **Uncertainties on low energy** (1-5 GeV/c) **cross sections** measurements and on **Monte Carlo models** affect the extrapolation of neutrino fluxes from Near Detectors (ND) to Far Detectors (FD), limiting the precision of the results and has to **be minimized**



Uncertainties in ND→FD extrapolation :

✔	different E_ν distribution (because of oscillation)	⇨ need to reconstruct the neutrino energy from the final state particles
✔	different target	⇨ A-scaling: measure cross-sections on different targets (and/or on the same target of FD)
➔	different acceptance	⇨ measurement of cross-section in the larger possible phase-space: increase angular acceptance of ND
➔	different neutrino flavor (because of oscillation) ν ($\bar{\nu}$) flux has typically a wrong sign component	⇨ measure cross-section asymmetries between different neutrino species (eg ν vs $\bar{\nu}$ important for for δ_{CP})

HP-TPC as neutrino detector at low energy:

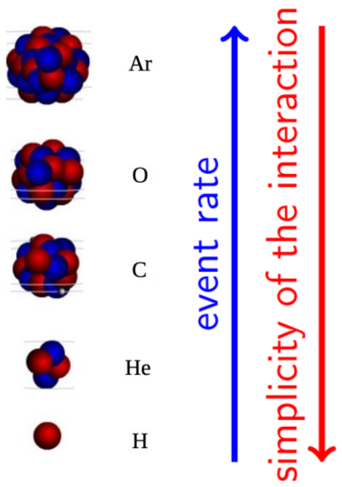
- target = detector
- 3D reconstruction capabilities
- possibility to exchange targets changing **gas**
- low density → low thresholds
- excellent PID capabilities
- almost uniform 4π acceptance
- low # of interactions → requires **high pressure** and large volume
- requires in addition a magnet to measure p and tag ν/anti-ν
- very large volumes require low cost per readout channel (pixel)

R&D on High Pressure TPCs – motivation and goals

R&D on gas mixtures

Addressing nuclear systematic uncertainties

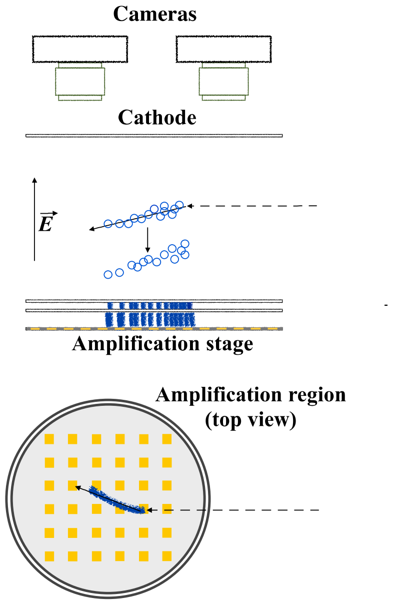
2x2x2 m^3 20°C	5 bars	10 bars
He	6.65 kg	13.3 kg
	520 evt/10^{21}pot	1040 evt/10^{21}pot
Ne	32.5 kg	67.1 kg
	2543 evt/10^{21}pot	5086 evt/10^{21}pot
Ar	66.5 kg	133 kg
	5203 evt/10^{21}pot	10406 evt/10^{21}pot
CF_4	146.3 kg	293 kg
	11450 evt/10^{21}pot	22893 evt/10^{21}pot



Addressing uncertainties on ν fluxes and x-sec

- New ν-H scattering measurements desired for flux constraints and nucleon x-sec (input for Oscillation Analysis)
- H-rich gas mixtures in a HP-TPC could provide new data of ν-H scattering
- T2K experience + MC simulations tell us that, in a HP-TPC, 95% purity for the extraction of ν-H interactions could be achieved with He-CH4 (50-50) or He-C2H6 (50-50) gas mix
- **Research needed to find the ideal mixture**, which still allows **for safe and stable operation of a TPC**

R&D on optical read-out



Addressing 3D tracking

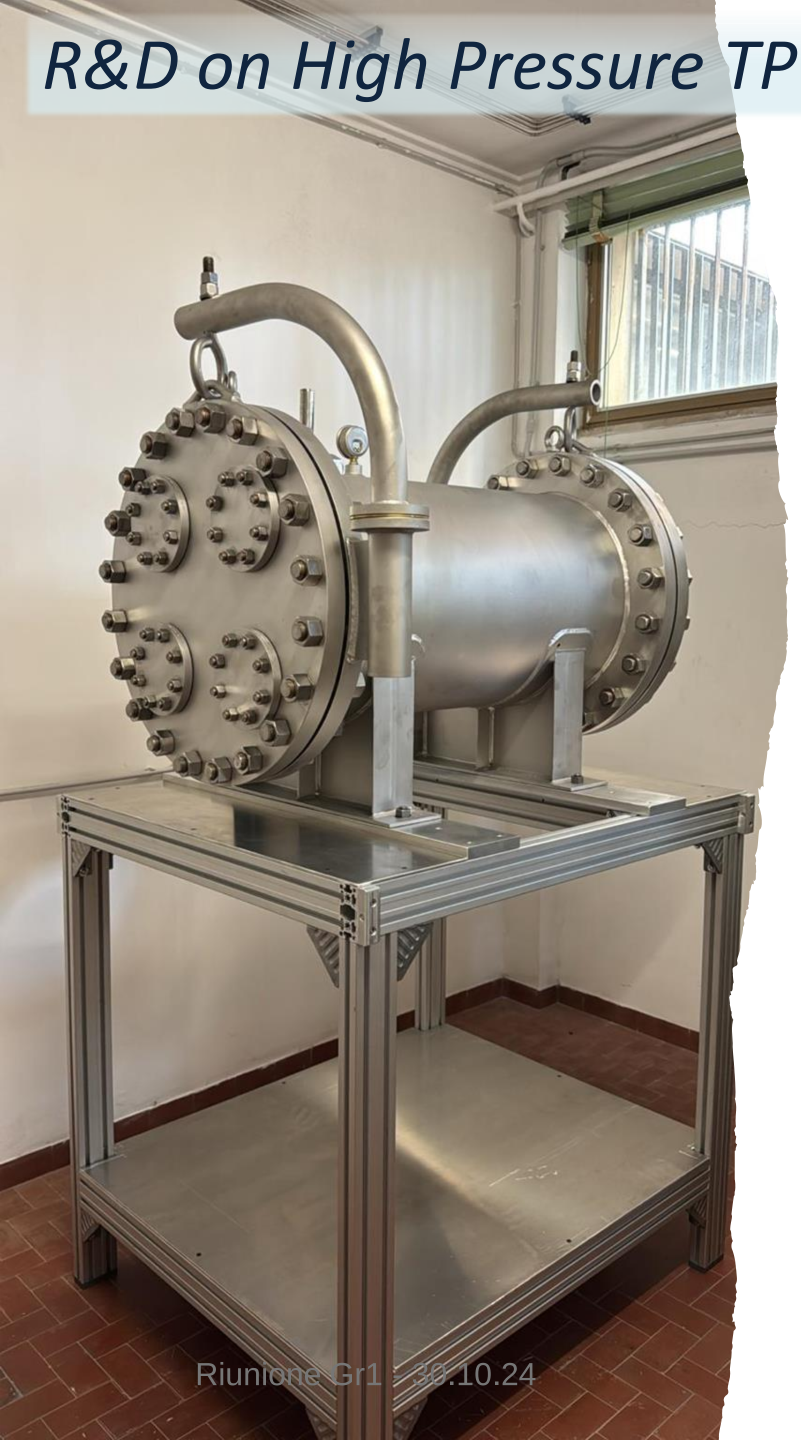
Current **CCD cameras** do not allow to access the longitudinal coordinate due to their **slow readout speed**
The goal is to **combine optical and charge readout** ➔**Full 3D tracking** information (longitudinal coordinate reconstructed from charge signals) ➔ (TimePix or SIPM array)

NB: optical readout is also of great interest for the beam instrumentation case:

1) reduction of the budget material along the beam line
2) readout optimization ➔ low gas amplification factor ➔ high density of tracks

R&D on High Pressure TPCs@INFN Bari

N. F. Calabria, G. Catanesi, L. Magaletti, E. Radicioni



***Plan in DRD1 WP8 Project A*:**

construct and operate a realistic scale (50cm drift, 30cmx30cm transverse) prototype and test facility for high-pressure with different gas mixtures and readout structures. This should serve as the test-bed for a final detector design. Collaborating institutes: U Geneva and IFAE

- Construction of a 10 bar medium-size vessel, large enough to study the effects of readout performance, drift length, attachment, etc in realistic conditions. These will be key in assessing the parameters for a final design.
- R&D with different target gas mixtures based on Ar, Ne, He
- Optimization of the production and collection of photoluminescence light as a function of the gas mix
- On the longer term, evaluation of possible optimizations of the dE/dx performances of such a detector by studying the cluster-counting capabilities in optical-readout mode

IN SUMMARY:

→ Crucial R&D for future neutrino physics landscape

→ R&D on gas mixtures is a key point

→ Optical RO at the crossroad with several technologies

Conclusions

- Several **R&D activities on-going at INFN Bari** on different gaseous detector technologies and in the framework of DRD1, aimed at **meeting the needs of future particle physics experiments**

- **Across technologies**, common research topics are related to **gas and material studies**

- **Regardless** of the **specific research area**, **future** particle physics **experiments** on a medium and long-term scale **will take advantage** of typical stability, robustness, long-term performance and cost-effectiveness **of gaseous detectors as long as the fundamental R&Ds here described will be recognized as strategic, and funded**.

These slides come from a collective work.
Thanks a lot to those who contributed to their preparation.