Transport properties of gases and gas mixtures used in detectors

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Experimental Physics Division
13 July 1984

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

DRIFT AND DIFFUSION OF ELECTRONS IN GASES: A COMPILATION

(WITH AN INTRODUCTION TO THE USE OF COMPUTING PROGRAMS)

Anna Peisert

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Properties of potential eco-friendly gas replacements for particle detectors in high-energy physics

G. Saviano,[a,1] M. Ferrini,[a] L. Benussi,[b] S. Bianco,[b] D. Piccolo,[b] J. Kjølbro,[c] A. Sharma,[c] D. Yang,[d] G. Chen,[d] Y. Ban,[d] Q. Li,[d] S.
[a] Laboratori Nazionali di Frascati dell'INFN and Facoltà di Ingegneria, Rome, Italy
[b] Laboratori Nazionali di Frascati dell'INFN, Italy
[c] CERN, Geneva, Switzerland
[d] Peking University, Beijing, China
[e] Politecnico di Torino, Torino, Italy
nna.saviano@uniroma1.it

detectors for elementary particles require F-based
ns demand the use of environmentally unfriendly
rk studies properties of potential eco-friendly gas
mical parameters relevant for use as detector media
perimental investigation.

aterials for gaseous detectors; Muon spectromete
rs); Micropattern gaseous detectors (MSGC, GEM,
CROMEGAS, InGrid, etc)

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Input from a lot of work : Analytical, simulations and measurements into LHC and other experiments

EPJ Web of Conferences **174**, 05004 (2018) https://doi.org/10.1051/epjconf/201817405004
MPGD 2015

Candidate eco-friendly gas mixtures for MPGDs

L. Benussi[1], S. Bianco[1], G. Saviano[1,2,a], S. Muhammad[1,2,3], D. Piccolo[1], M. Ferrini[2], M. Parvis[4], S. Grassini[4], S. Colafranceschi[5], J. Kjølbro[6], A. Sharma[5], D. Yang[6], G. Chen[6] and Y. Ban[6], and Q. Li[6]

[1] Laboratori Nazionali di Frascati - INFN, Frascati, Italy
[2] University of Rome "La Sapienza" (IT) - Facoltà di Ingegneria, Ingegneria Chimica Materiali ed Ambiente, Italy
[3] National Center for Physics, Quaid-i-Azam University Campus, Islamabad, Pakistan
[4] Politecnico di Torino-Dipartimento di Fisica (DIFIS) Corso Duca degli Abruzzi, 24, I-10129 Torino, Italy
[5] CERN, Geneva, Switzerland
[6] Peking University, Beijing, China

Abstract. Modern gas detectors for detection of particles require F-based gases for optimal performance. Recent regulations demand the use of environmentally unfriendly F-based gases to be limited or banned. This review studies properties of potential eco-friendly gas candidate replacements.

Numerical methods in the simulation of gas-based detectors

R. Veenhof

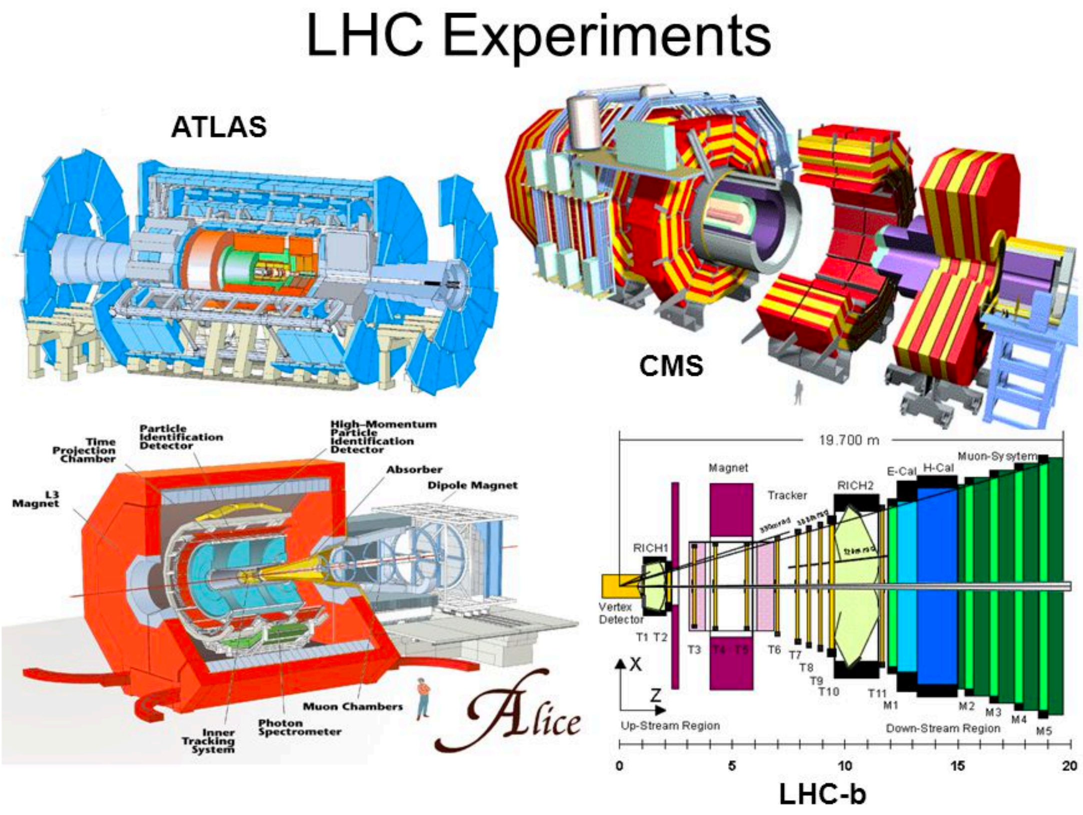
Physics Department, Room 2320 Chamberlin Hall, University of Wisconsin-Madison, 1150 University Avenue, Madison, WI 53706-1390, U.S.A.
CERN, PH department, CH-1211 Genève 23, Switzerland

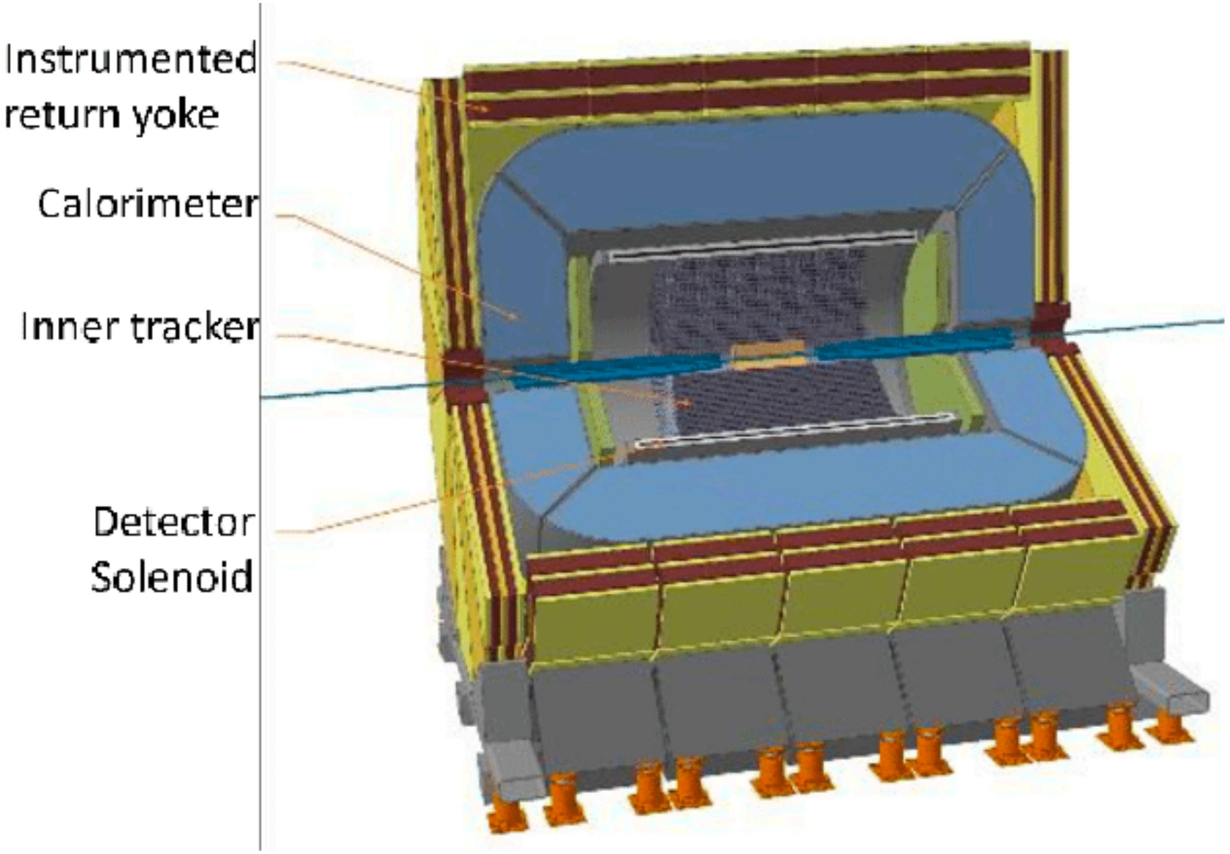
E-mail: Rob.Veenhof@cern.ch

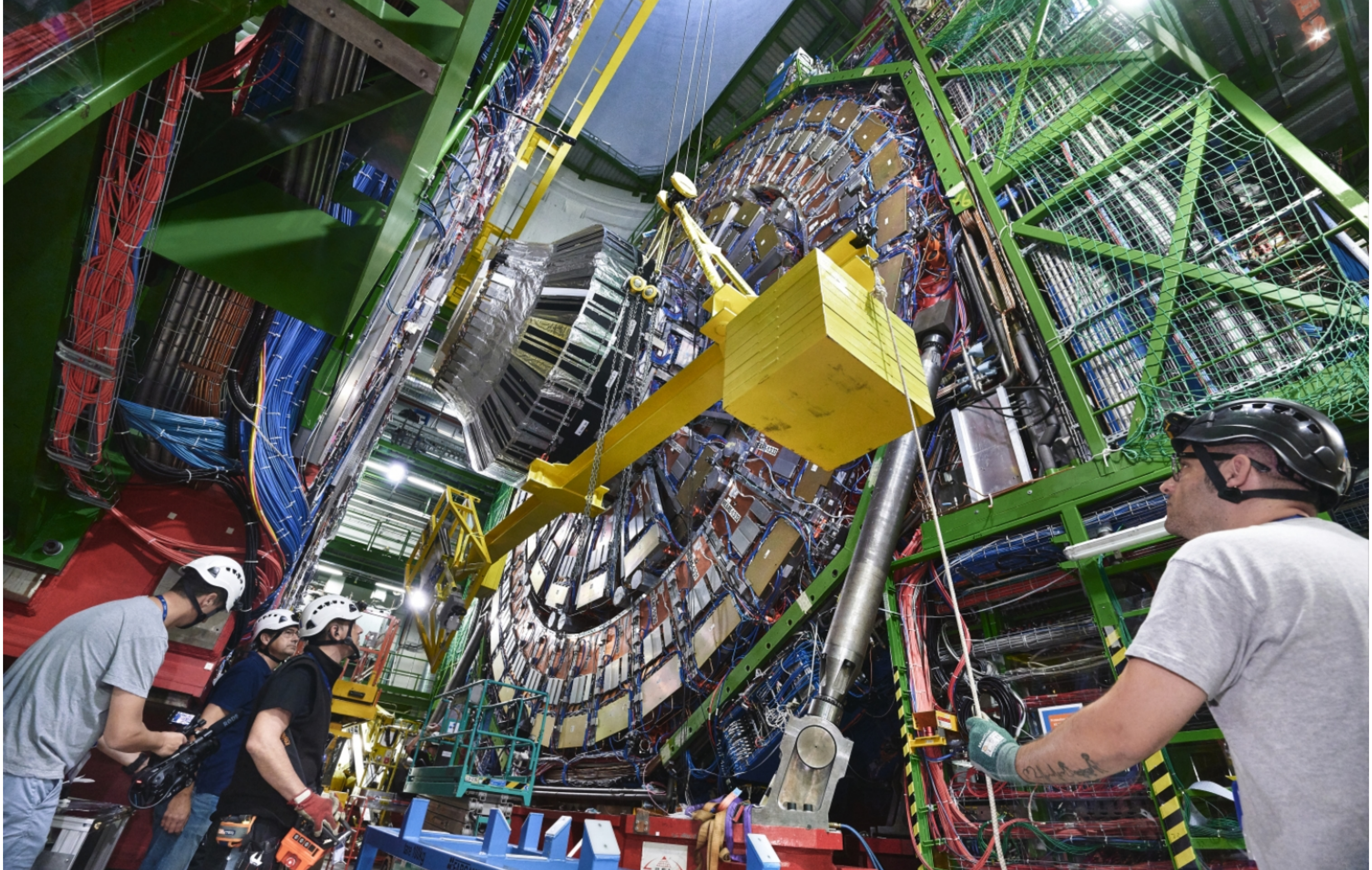
ABSTRACT: Current state and a brief sketch of earlier developments.

KEYWORDS: Detector modelling and simulations II (electric fields, charge transport, multiplication and induction, pulse formation, electron emission, etc); Gaseous detectors; Charge transport and multiplication in gas

2009 JINST 4 P12017


LHC Experiments
ATLAS
CMS
Time Projection Chamber
Particle Identification Detector
High-Momentum Particle Identification Detector
Absorber
Dipole Magnet
L3 Magnet
Muon Chambers
Photon Spectrometer
Inner Tracking System
Alice
19.700 m
Magnet
Tracker
RICH2
E-Cal
H-Cal
Muon-System
RICH1
Vertex Detector
Up-Stream Region
Down-Stream Region
0
5
10
15
20
LHC-b


Instrumented return yoke
Calorimeter
Inner tracker
Detector Solenoid



Looking at the next generation of experiments

To instrument large areas, gas detector technology will remain unchallenged

In many application

- High rate capability
- Fast timing
- Improved space resolution
- High ion mobility

are required for several applications

Muons systems, tracking and triggering

TPC readout

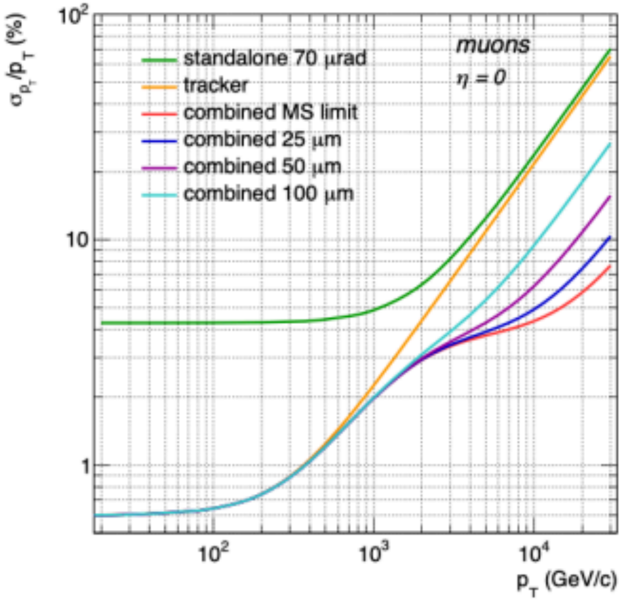
Micropattern detectors

…

BUT

Today ~ 10 - 100 cubic m per detector

Muon Systems



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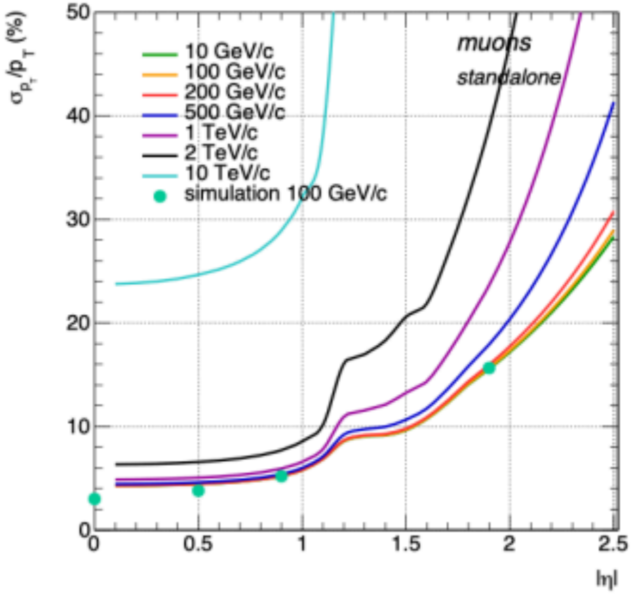
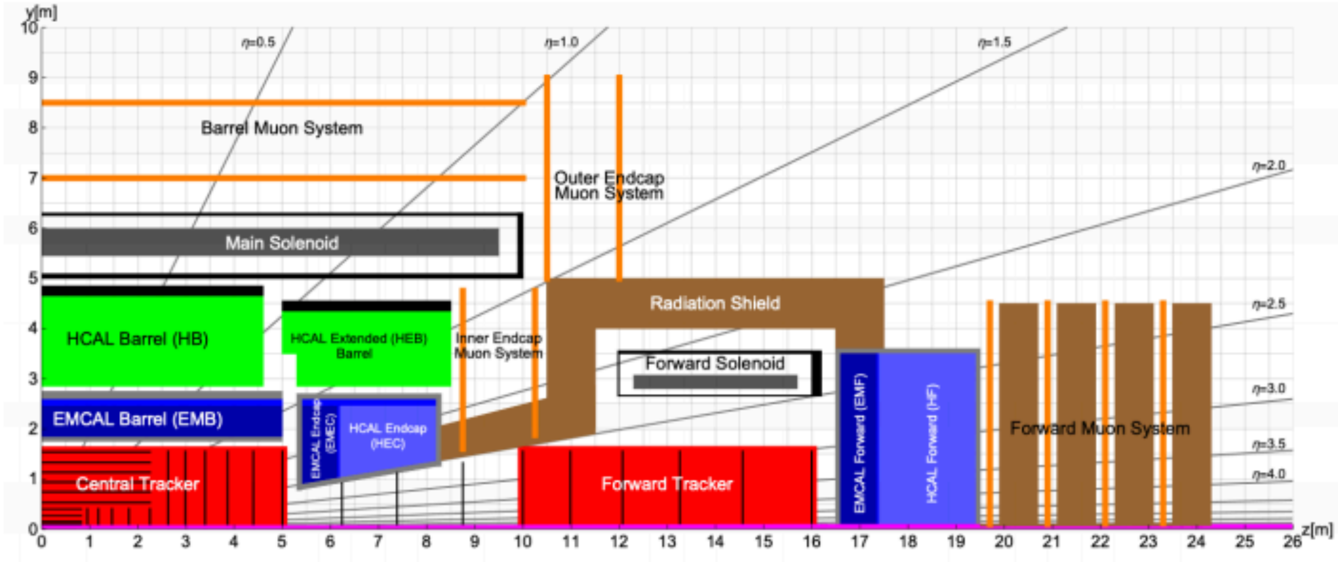




'Standalone' muon performance is not any more a very important criterion. Future detectors rely on a combined tracker/muon system performance.

The task of the muon system is triggering and muon identification.

4-5% standalone momentum resolution can be achieved in at η=0, 30% at η=2.5 by simply measuring the angle at which the muon exits the calorimeters.

In the forward muon system, standalone momentum measurement and triggering can only be achieved when using a forward dipole (like ALICE, LHCb).

The combined muon momentum resolution (tracker + muon system) can better than 10% even for momenta of 20TeV/c at η=0.

Gas detectors similar to the ones employed for HL-LHC are good candidates for the muon systems.

Input required for cross sections of gases & transport parameters

Lack of precise data for the molecular gases involved

Tables needed for input into gaseous detectors of the future systems

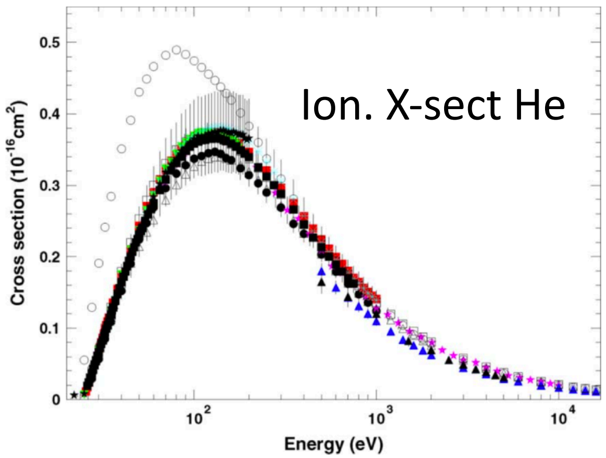


Fig. 17. Cross section, Z = 2: EEDL (empty circles), BEB model (empty squares), DM model (empty triangles) and experimental data from [76] (black circles), [77] (pink stars), [78] (red squares), [79] (blue triangles), [80] (green upside-down triangles), [81] (turquoise asterisks), [82] (black squares), [83] (black triangles) and [84] (black stars).

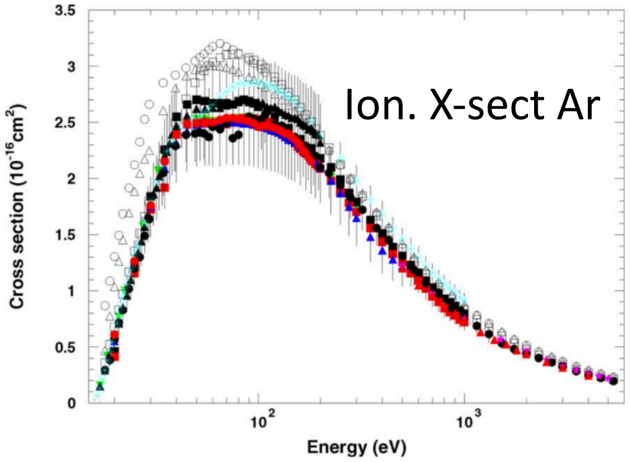


Fig. 31. Cross section, Z = 18: EEDL (empty circles), BEB model (empty squares), DM model (empty triangles) and experimental data from [76] (green upside-down triangles), [112] (black squares), [84] (black triangles), [81] (red squares), [113] (blue triangles), [114] (black circles), [83] (pink stars), [78] (turquoise asterisks), [115] (red triangles) and [80] (red circles).

- Discrepancy between simulation and data at low energy
- Discrepancy between different experimental results

EXAMPLE #1

RPC Community Working on experimental optimisation
NO SIMULATIONS —— EXPERIMENTAL DATA

G. Rigoletti B. Mandelli and R. Guida

2020 *JINST* **15** C05004

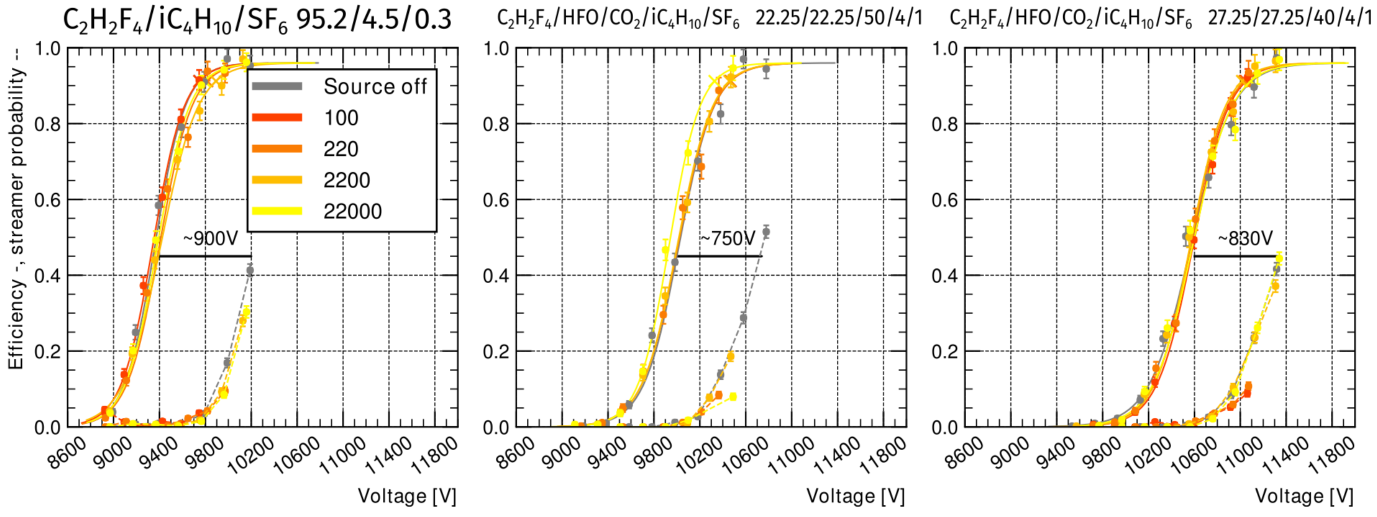


Figure 2. Efficiency and streamer probability curves for the standard gas mixture and two selected HFO + CO_2 gas mixtures for different ABSs. The plateau between efficiency and streamer probability at 50% is slightly smaller for the HFO-based gas mixtures.

Detailed study on the macroscopic behaviour of new gas mixtures at the GIF++ to understand ageing issues.

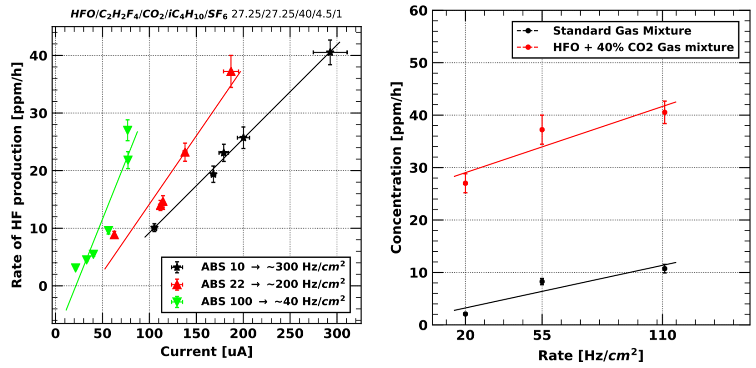
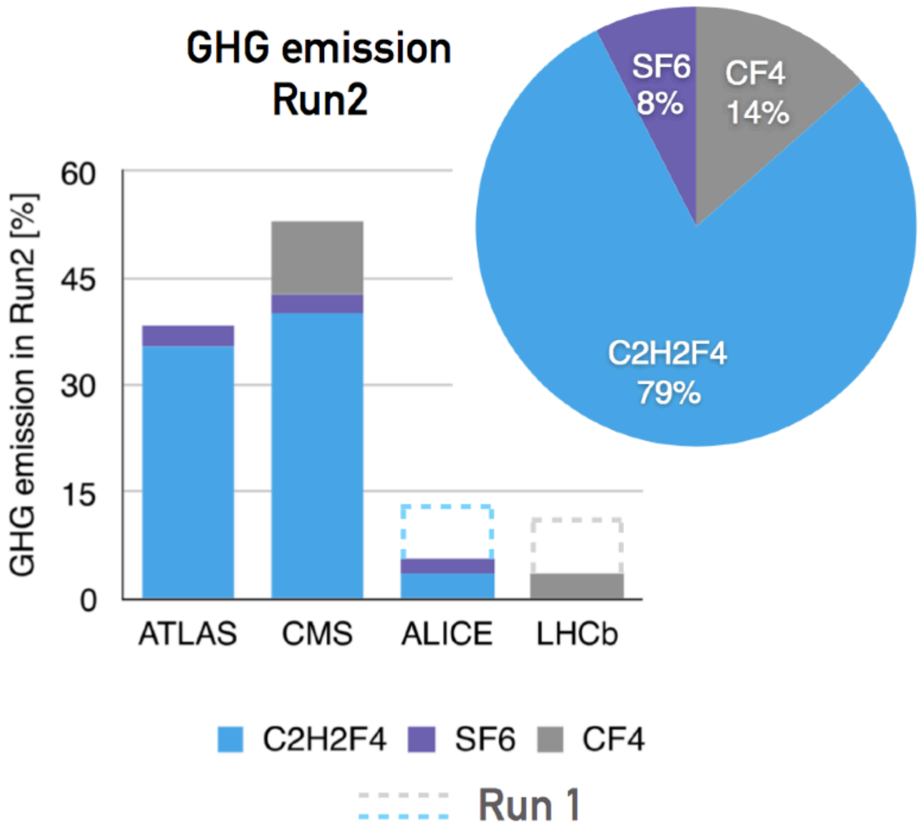


Figure 5. On the left: rate of HF production against the current drawn by the detectors at different irradiation levels. It can be observed that the dependence on the current is linear. For different gamma rate the slope is different. In particular, at higher gamma rates the increase of the rate of HF production is lower. On the right: rate of HF production against the gamma rate for the standard gas mixture and the HFO + 40% CO_2 mixture with detector operating at working point. At higher gamma rates the HF production for the HFO-based gas mixture is almost 4 times higher than the standard gas mixture.

Beatrice and Roberto are actively promoting and working in RPC ECOGAS@GIF++ and AIDAInnova

CEPS, and partly EP, for 2019-2026 funded a number EcoGas related studies, and one line of research is
"Detector performance with new environmentally friendly gases and new gas system (collaboration and support to experiments)"
Dedicated to RPC

EXAMPLE #1



The RPC community has been studying the EcoGas issues since several years. Many publications have reported results on different eco-friendly gases operated on RPCs. A new kind of freon, HFO1234ze is the gas that at moment has been considered the most interesting from the RPC performance point of view. Anyway no information are available about its behaviour under long time irradiation periods. In 2019 EPDT, CMS, ATLAS, Alice and recently LHCb/Ship people involved in the studies of ECOGAS for RPCs, have defined a Collaboration named **RPC ECOGAS@GIF++** with the goal to study the RPC operations with Eco-Friendly gas mixtures under irradiation at GIF++. Several chambers of different dimensions and gas gap thickness are under irradiation at GIF++ and the RPCs performance with HFO1234ze-CO2 gas mixtures are studied. In the **AIDAInnova** Project, the RPC ECOGAS@GIF++ Collaboration, with Frascati INFN and CERN groups as beneficiaries, is also proponent of the RPC EcoGas subtask 7.2.2 in WP7.

Davide Piccolo-INFN/Coordinator

EXAMPLE #2

Quencher gases (often Fluor-based) for optimal performance employed
More studies needed for non-F gas

Overview of the greenhouse gases used at the LHC experiments.

Gas	GWP	Experiment and detector type
$C_2H_2F_4$	1300	ALICE RPC; ATLAS RPC; CMS RPC
SF_6	22,200	ALICE RPC; ATLAS RPC; CMS RPC
CF_4	5700	CMS CSC; LHCb GEM, RICH2, MWPC
C_4F_{10}	8600	LHCb RICH1
iC_4H_{10}	3.3	ALICE RPC; ATLAS RPC; CMS RPC
nC_5H_{12}	11	ATLAS TGC

RD51 Workshop on Gaseous Detector Contribution to PID
16 February 2021

PID options with RPCs

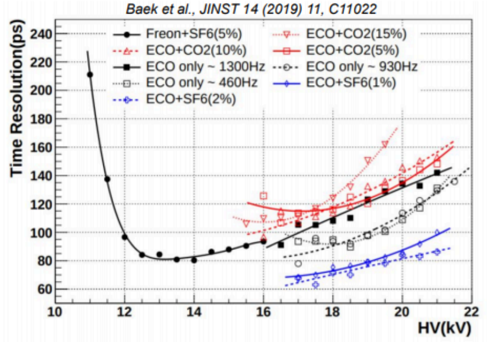
Roberto Preghenella
Istituto Nazionale di Fisica Nucleare, Bologna

MRPC with eco-friendly gas

searching for new eco-gas mixtures
with low Global Warming Potential and reasonable cost
while keeping excellent timing performance and low noise

- **pure ECO or with CO_2**
  - slightly worse performance than STD
    - efficiency plateau unstable
    - higher time resolution
- **adding SF_6 to ECO**
  - very similar performance to STD
    - strongly electronegative gas needed
- **ideas to replace SF_6**
  - try CF_3I (trifluoroiodomethane)
    - GWP < 5
  - try 3-component mixtures

Baek et al., JINST 14 (2019) 11, C11022



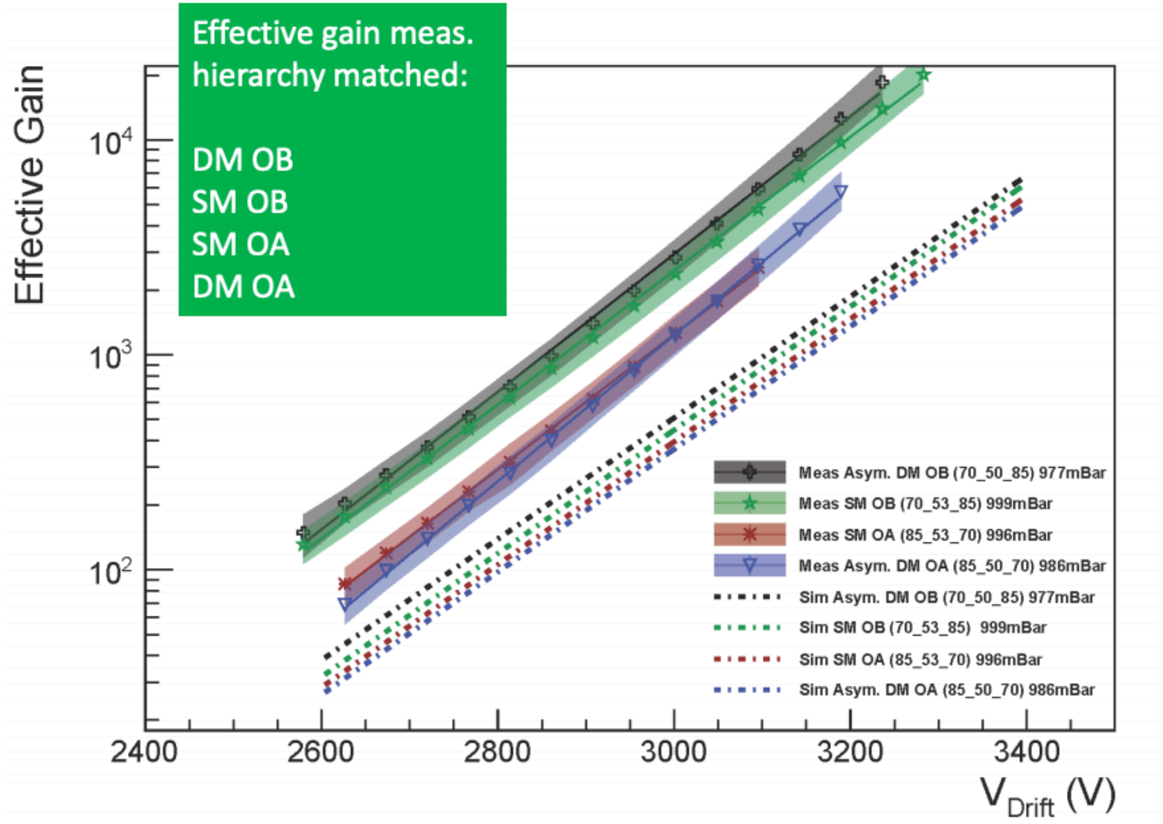
very important and promising directions for the future
do not forget also efforts to reduce flow and improve recirculation systems

EXAMPLE #3

New paper version

Stage	Single-mask asymmetric configuration		average 82-53-70
	Hole diameter Side-1 (in μm)	Hole diameter Center (in μm)	Hole diameter Side-2 (in μm)
GEM1	83 ± 3	51 ± 3	70 ± 3
GEM2	83 ± 3	55 ± 3	71 ± 3
GEM3	80 ± 3	51 ± 3	71 ± 3

Old paper version ➔ SM = 70_53_85



Triple-GEM simulation: hole asymmetry paper

RWTH AACHEN UNIVERSITY
CMS
Francesco Ivone[1], Kerstin Hoepfner[1]
[1] Physics Institute III A, RWTH University, Aachen

Update

Old paper version

Stage	Single-mask asymmetric configuration		nominal 85-53-70
	Hole diameter Side-1 (in μm)	Hole diameter Center (in μm)	Hole diameter Side-2 (in μm)
GEM1	83 ± 3	51 ± 3	70 ± 3
GEM2	83 ± 3	55 ± 3	71 ± 3
GEM3	80 ± 3	51 ± 3	71 ± 3

New paper version

Target

A study group dedicated to coordinated studies on:

- Microscopic transport properties of “novel” gases and gas mixtures
    - Cross sections update
    - Drift, Diffusion, Ion Transport, Magnetic Field, Operation etc..
  - Depending on the case …
- Macroscopic behaviour for detector operations - simulations and experiments
- Share the work across different groups
    - Prepare a ready to use compendium of useable blocks

Contribution from:

- Anna Colaleo
- Leszek Ropelewski
- Eraldo Oliveri
- Roberto Guida
- Beatrice Mandelli
- Piet Verwilligen
- Raffaella Radogna
- Marcello Maggi
- Davide Piccolo
- Michael Tytgat
- Archana Sharma

A Letter of Intent to be prepared …
within RD51 towards creating interest
and group of activities geared towards
future upgrades, experiments ….