Multi wire proportional chambers for muon spectrometers

State of the art and challenges
(from the point of view of a learner)

Luca Moleri - 19.06.23 - RD51 collaboration meeting

Disclaimer

- Mine is the small perspective of a recent learner, not an expert, and from a specific angle (TGC)
- Hoping to trigger discussions and to prompt contributions from real experts

MWPC applications

MWPCs found countless applications

- Muon spectrometers
- Photon detector (e.g. COMPASS)
- Nuclear experiments
- Neutron detectors
- TPCs
- Civil applications (e.g. muography)

Invented in the 60's, with new setups being built every year until today.
Could not find a review paper or recent book. Isn't it a good time to write one?

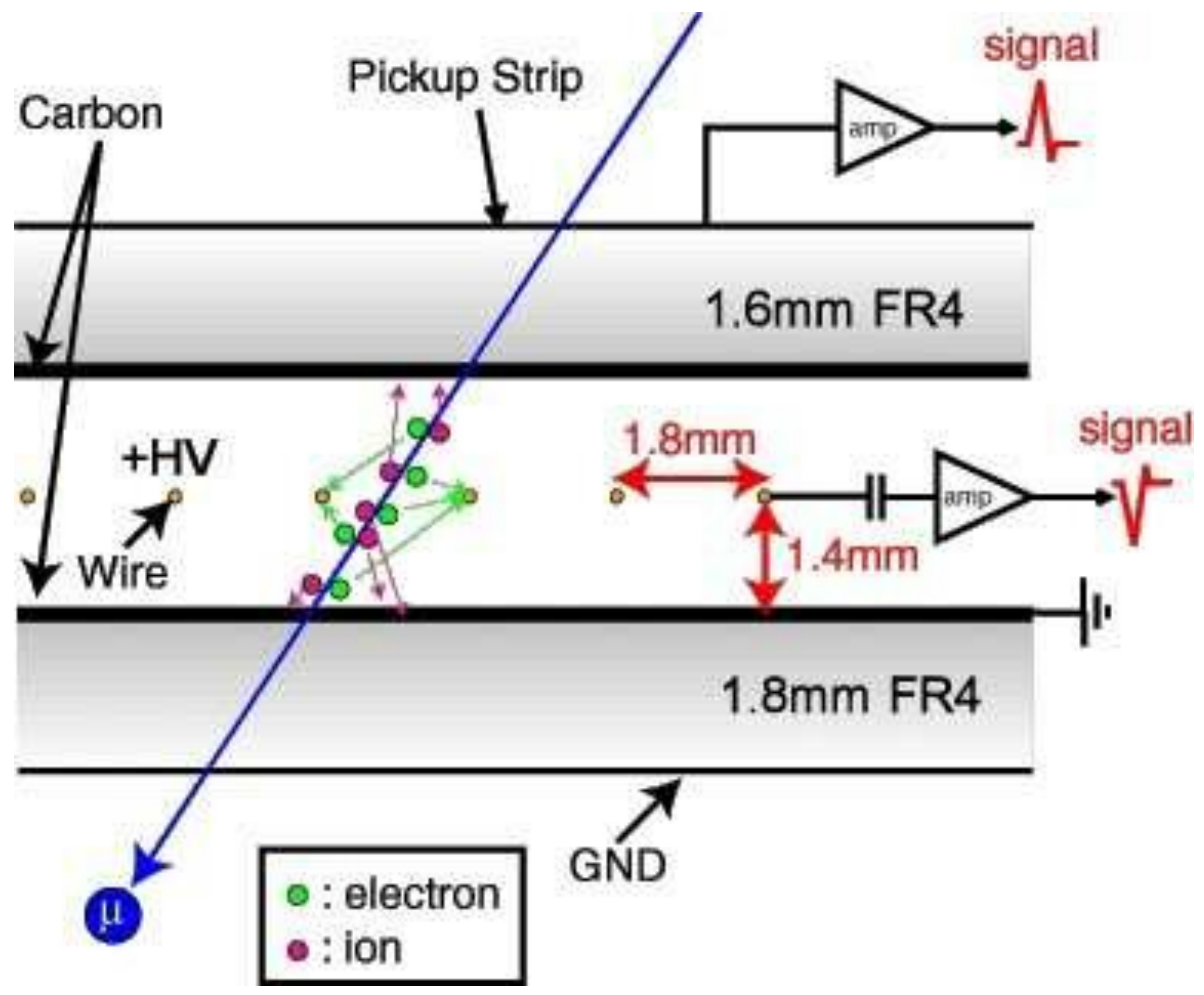
MWPC in muon systems

The case of ATLAS TGC, CMS CSC and LHCb

MWPCs are especially suitable for muon systems

- Position resolution O(10 - 100 μm)
- Timing O(10ns)
- Cost effective coverage of large areas O(1000m^2)
- Max rate O(10^{5}Hz/cm^2)
- Radial field → Less prone to discharge

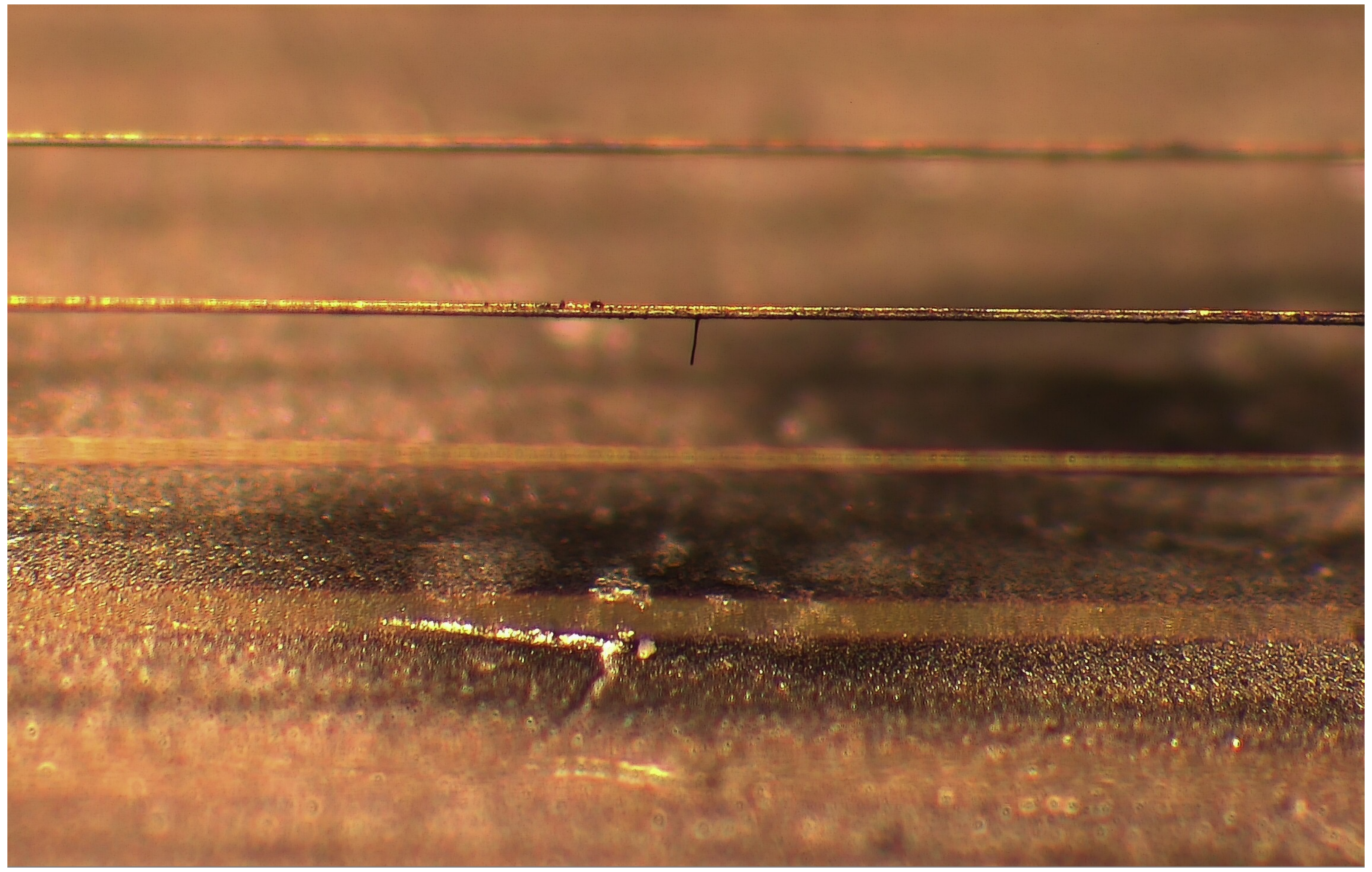
TGC scheme



	ATLAS TGC	CMS CSC	LHCb
Gap [mm]	2.8	9.5	5
Wire [μm]	50	50	30
Pitch [mm]	1.8	3.1	1.5
Cathode	Graphite	Cu	Cu
Gas	CO2:n-pentane (55:45)	Ar:CO2:CF4 (40:50:10)	Ar:CO2:CF4 (40:55:5)

Ageing

- Ageing is usually related to organic or inorganic (e.g. Si) deposits on wires and cathodes
  - Malter effect (LHCb)
  - Conductive filaments (ATLAS TGC)
- Fragile resistive-cathode materials (ATLAS TGC)
- Aggressive gases (solvents, etchants)
- Possible to recover in some cases by applying high currents (e.g. with CF_4)
- Need for robust materials for resistive cathodes



Organic growth in ATLAS TGC cathode

“Proceedings of the International Workshop on Aging Phenomena in Gaseous Detectors” (AGING 2001, DESY)

“Long-term operation of the multi-wire-proportional- chambers of the LHCb muon system” (Albicocco et al 2019)

Gases - gain - electronics

The case of ATLAS TGC, CMS CSC and LHCb

- Properties typically evaluated to chose the gas mixture: gain, diffusion, drift time, quenching, aging
- Current gas mixtures were chosen a few decades ago
  - CO_2:n-pentane → solvent, liquid at RT
  - Ar:CO_2:CF_4 → greenhouse gas
- Contemporary low noise electronics allows for full efficiency at small gain values
- Photon quenching and aging conditions could be relaxed at low gain
- Non aggressive solvents and non greenhouse gas

Gases - gain - electronics

Recent examples: ATLAS sTGC and NA60+

ATLAS sTGC read out by VMM3a ASIC

- Same gas and operation as ATLAS TGC
- Problem: gain too large → saturation
- Solution: attenuator at detector output

This is bad practice, due to the mismatch of old detector scheme and state of the art readout electronics

NA60+ spectrometer prototype

- Similar to CMS CSC
- Full efficiency with VMM3a and Ar/CO_2 (70:30)

Example of good adaptation of MWPC to state of the art readout electronics

"High rate studies of the ATLAS sTGC detector and optimization of the filter circuit on the input of the front-end amplifier" (Vasquez et al 2023)

"The NA60+ experiment at the CERN SPS: status and prospects" (HADRON2023, Genova)

Industrialization

TGC experience

- All detector parts are produced by standard techniques in the industry (cathode boards, spacers, wires, adapters, etc)
- All the rest is done in academia, with more or less professional tools
    - Resistive layers spraying on cathode boards
    - Wire winding
    - Wire soldering
    - Glueing
    - Soldering resistors, capacitors, adapter boards

In principle all those processes could be industrialized and standardized.
Difficulty could arise for wire winding.

Main ideas
open for discussion

- MWPC are the oldest modern particle detector
- Very mature technology widely used, nowadays R&D on detector physics somewhat neglected
- Still need for investigation of its physics with state of the art tools (e.g. electronics, simulations)
- State of the art technology (e.g. materials, electronics) can solve old problems
- Overall a very efficient and cheap solution.
  If we want to keep it alive and useful for the future we need to invest in it
- Industrialization might be possible. What about a consortium of labs producing MWPCs?

The creation of DRD1 is a golden occasion to take up decades of experience and to rejuvenate MWPCs from within the broader gaseous detector community

Thank you

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