# IF5: Instrumentation Frontier Topical group on Micro-Pattern Gaseous Detectors (MPGDs)

Conveners: Bernd Surrow, Maxim Titov, Sven Vahsen

https://snowmass21.org/instrumentation/mpgd <--- convenor contact info, mailing list

# IF5 White Papers

| | Topic | Executive Summary Length | White Paper Leads |
|---|---|---|---|
| 1 | MPGDs: Recent advances and current R&D | 3 | Klaus Dehmelt, Andy White |
| 2 | MPGDs for nuclear physics experiments | 1.5 | Kondo Gnanvo, Matt Posik |
| 3 | Recoil imaging for DM, neutrino, and BSM physics* | 1.5+1.5+1.5 (IF+NF+CF) | Dinesh Loomba, Ciaran O'Hare |
| 4 | MPGDs for TPCs at future lepton colliders | 1.5 | Alain Bellerive |
| 5 | MPGDs for muon detection at future colliders | 1.5 | Anna Colaleo, Kevin Black |
| | Grand summary table + text | 1 | IF5 conveners |

*Multi-frontier paper with Cosmic and Neutrino Frontiers

Basis for 10-page summary of IF5

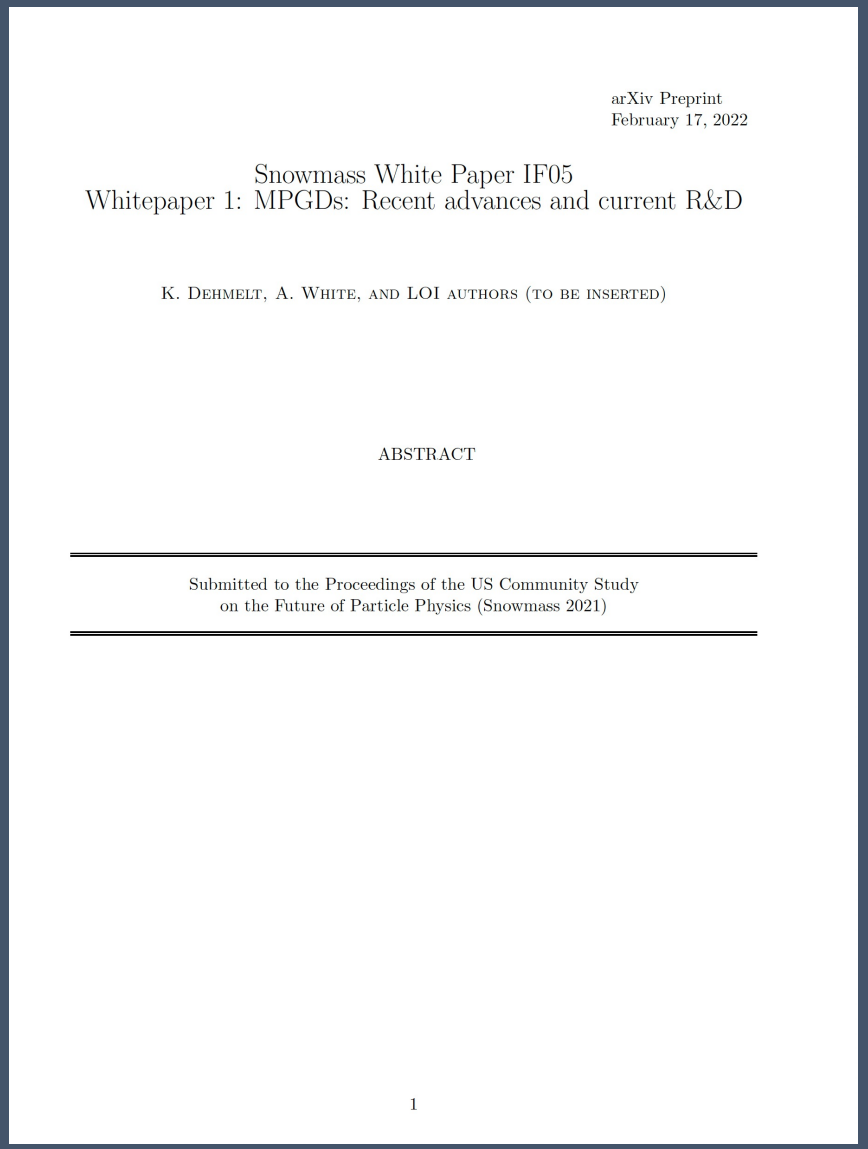
- Advanced drafts of all white papers in place --- PDFs uploaded to Indico
- Thanks to the authors for their tremendous efforts!
- A bit more detailed status on following pages
- Feedback on missing items encouraged within next 2 weeks, please send directly to White Paper leads
- Aiming for 1.5-page executive summary for most WPs → combine into 10-page summary of IF5

# IF05 Whitepaper 1: MPGDs: Recent advances and current R&D

WPLs: Klaus Dehmelt, Andy White

| LOI title | Contact | Status |
|---|---|---|
| Development of the Micro-Pattern gaseous detector technologies: an overview of the CERN-RD51 collaboration | awhite@uta.edu / klaus.dehmelt@stonybrook.edu | → Draft section |
| High precision timing with the PICOSEC micromegas detector | sebastian.white@cern.ch | → Draft section |
| Optical readout of MicroPattern Gaseous Detectors: developments and perspectives | florian.brunbauer@cern.ch | → Duplicate - removed |
| Pixelated resistive MicroMegas for high-rates environment | massimo.della.pietra@cern.ch | → Draft section |
| Trigger extensions for the scalable readout system SRS | hans.muller@cern.ch | → Draft section |
| A high-gain, low ion-backflow double micro-mesh gaseous structure | zhzhy@ustc.edu.cn | → Draft section |
| LOI from NSCL | cortesi@nscl.msu.edu | → Duplicate - removed |

Outline: After discussions with RD51 Management – outline will use RD51 LOI as overall guide, use sections of submission to LHCC for RD51 detailed activities, and add in sections from the other six LOI listed above.



arXiv Preprint
February 17, 2022

Snowmass White Paper IF05
Whitepaper 1: MPGDs: Recent advances and current R&D

K. Dehmelt, A. White, and LOI authors (to be inserted)

ABSTRACT

Submitted to the Proceedings of the US Community Study
on the Future of Particle Physics (Snowmass 2021)

1

- 51 pages
- Mature text
- Missing
  - Integration of chapters
  - Table of contents
  - Executive summary

# IF5 WP2:
# MPGDs for nuclear physics experiments

WPLs: Kondo Gnanvo, Matt Posik

| LOI title | Contact |
|---|---|
| Advanced Micro-Pattern Gas Detectors for Tracking at the Electron Ion Collider | hohlmann@fit.edu |
| Development of large micro pattern gaseous detectors for high rate tracking at Jefferson Lab | kgnanvo@virginia.edu |
| LOI from NSCL | cortesi@nscl.msu.edu |
| The role of MPGD-based photon detectors in RICH technologies | Silvia.DallaTorre@ts.infn.it |
| Snowmass 2021 Expression of Interest: MPGD-based Transition Radiation Detector | yulia@jlab.org |

# Title: MPDG Roles in Nuclear Physics Experiments

**Micro Pattern Gaseous Detectors (MPGDs) for Nuclear Physics**

F. Barbosa[a], M. Cortesi[c], S. Dalla Torre[1], Y. Furletova[a], K. Gnanvo (Lead Organiser)[a,*], M. Hohlmann[f], D. Neyret[d], M. Posik (Lead Organiser)[b]

[a]*Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA*
[b]*Temple University, Philadelphia, PA 23606, USA*
[c]*Facility for Rare Isotope Beams, Michigan State University, East Lansing, MI 48824, USA*
[d]*CEA Saclay IRFU, Université Paris-Saclay, France*
[e]*Florida Institute of Technology, Melbourne, FL 32901, USA*
[f]*INFN Trieste*

Contents



*Corresponding author
*Email address:* kagnanvo@jlab.org (K. Gnanvo (Lead Organiser))

*Preprint submitted to Elsevier*







- 28 pages
- The structure is almost final
- Editing still ongoing

# IF5 WP3:
# Recoil imaging for DM, neutrino, and BSM physics

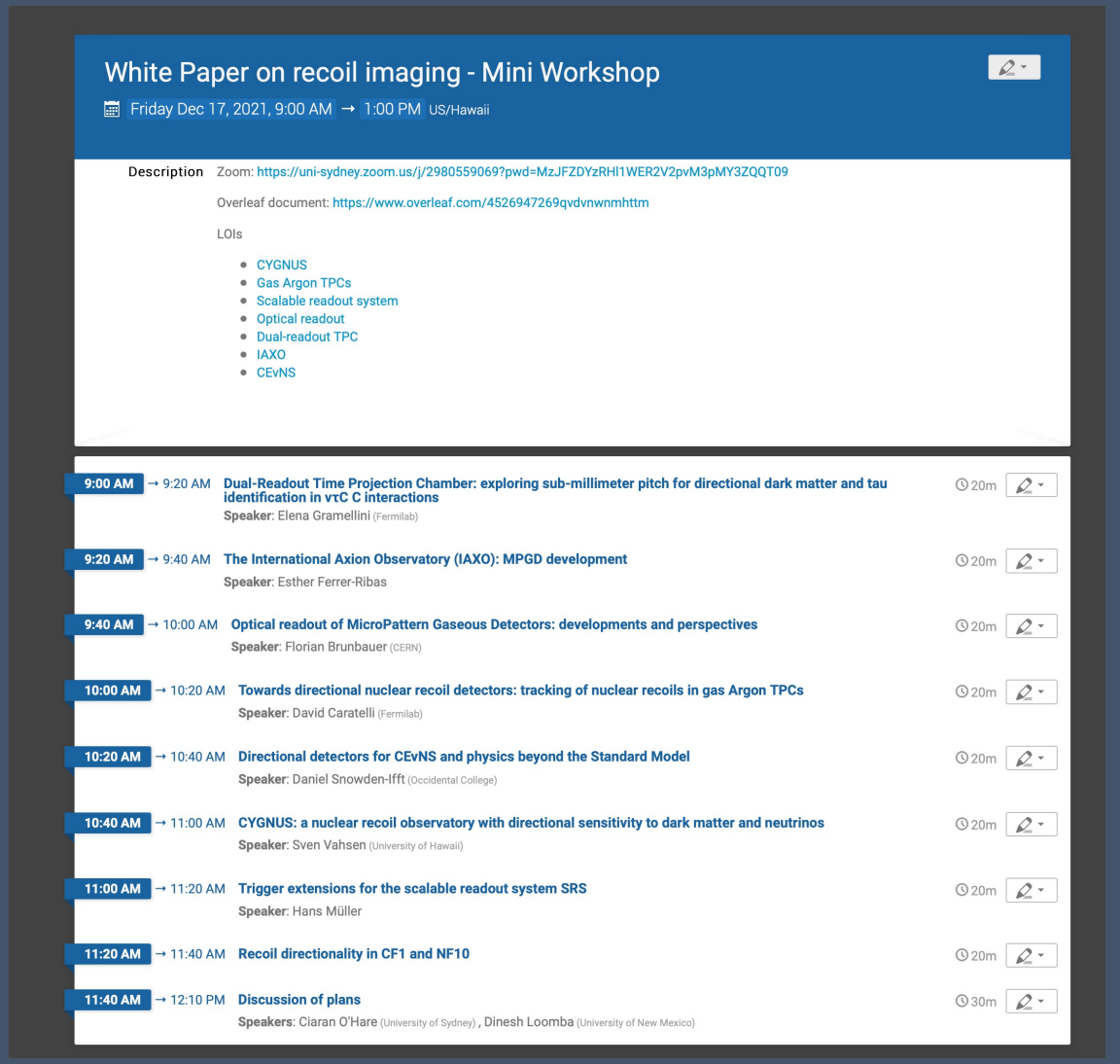
WPLs: Dinesh Loomba, Ciaran O'Hare

| LOI title | Contact |
|---|---|
| CYGNUS: a nuclear recoil observatory with directional sensitivity to dark matter and neutrinos | sevahsen@hawaii.edu |
| Optical readout of MicroPattern Gaseous Detectors: developments and perspectives | florian.brunbauer@cern.ch |
| Towards directional nuclear recoil detectors: tracking of nuclear recoils in gas Argon TPCs | David Caratelli (davidc@fnal.gov) |
| Dual-Readout Time Projection Chamber: exploring sub-millimeter pitch for directional dark matter and tau identification in $\nu_\tau$C C interactions. | Elena Gramellini, elenag@fnal.gov |
| Directional detectors for CEvNS and physics beyond the Standard Model | Difft@oxy.edu Daniel Snowden Ifft |
| Trigger extensions for the scalable readout system SRS | Hans.Muller@cern.ch |
| The International Axion Observatory (IAXO): MPGD development | E. Ferrer Ribas esther.ferrer-ribas@cea.fr |

Inter-frontier (Neutrino, Dark Matter, Instrumentation) White Paper on directional nuclear + electron recoil detection w/ dedicated executive summaries for each Snowmass topical group (including MPGD requirements for IF5)

# https://indico.fnal.gov/event/52282/

Workshop held in December
Video available by request



White Paper on recoil imaging - Mini Workshop

Friday Dec 17, 2021, 9:00 AM → 1:00 PM US/Hawaii

Description Zoom: https://uni-sydney.zoom.us/j/2980559069?pwd=MzJFZDYzRHl1WER2V2pvM3pMY3ZQQT09

Overleaf document: https://www.overleaf.com/4526947269qvdvnwnmhttm

LOIs

- CYGNUS
- Gas Argon TPCs
- Scalable readout system
- Optical readout
- Dual-readout TPC
- IAXO
- CEvNS

| | | | |
|---|---|---|---|
| 9:00 AM → 9:20 AM | **Dual-Readout Time Projection Chamber: exploring sub-millimeter pitch for directional dark matter and tau identification in ντC C interactions**<br>**Speaker**: Elena Gramellini (Fermilab) | 20m |
| 9:20 AM → 9:40 AM | **The International Axion Observatory (IAXO): MPGD development**<br>**Speaker**: Esther Ferrer-Ribas | 20m |
| 9:40 AM → 10:00 AM | **Optical readout of MicroPattern Gaseous Detectors: developments and perspectives**<br>**Speaker**: Florian Brunbauer (CERN) | 20m |
| 10:00 AM → 10:20 AM | **Towards directional nuclear recoil detectors: tracking of nuclear recoils in gas Argon TPCs**<br>**Speaker**: David Caratelli (Fermilab) | 20m |
| 10:20 AM → 10:40 AM | **Directional detectors for CEvNS and physics beyond the Standard Model**<br>**Speaker**: Daniel Snowden-Ifft (Occidental College) | 20m |
| 10:40 AM → 11:00 AM | **CYGNUS: a nuclear recoil observatory with directional sensitivity to dark matter and neutrinos**<br>**Speaker**: Sven Vahsen (University of Hawaii) | 20m |
| 11:00 AM → 11:20 AM | **Trigger extensions for the scalable readout system SRS**<br>**Speaker**: Hans Müller | 20m |
| 11:20 AM → 11:40 AM | **Recoil directionality in CF1 and NF10** | 20m |
| 11:40 AM → 12:10 PM | **Discussion of plans**<br>**Speakers**: Ciaran O'Hare (University of Sydney) , Dinesh Loomba (University of New Mexico) | 30m |

# Recoil imaging for dark matter, neutrinos, and physics beyond the Standard Model

**Snowmass 2021 inter-frontier white paper:**
CF1: Particle-like dark matter
NF10: Neutrino detectors
IF5: Micro-pattern gas detectors

Submitted to the Proceedings of the US Community Study
on the Future of Particle Physics (Snowmass 2021)

**Abstract**

Recoil imaging entails the direct measurement of one or more components of a recoiling particle's direction. This is a capability highly sought-after in detectors, with applications across particle and astroparticle physics. However, currently it seems to only be a practical goal for micro-pattern gas detectors (MPGDs). This white paper outlines the physics case for directional recoil detection, and puts forward a decadal plan to advance towards high definition recoil imaging, in the context of the MPGD topical group of the Snowmass 2021 Instrumentation Frontier community study. The science case covered includes the discovery of DM into the neutrino fog, directional detection of neutrino-electron scattering, the precision study of coherent-elastic neutrino-nucleus scattering, the measurement of the Migdal effect, as well as several other applied physics goals. We also describe several ongoing R&D projects that will test crucial ideas such as the use of negative ion drift in MPGDs, the possibility for sub-mm tracking in gaseous argon time projection chambers, as well as the readout and electronics systems needed for detector scale-up to the ton-scale and beyond.

C. A. J. O'Hare (Coordinator)[1], D. Loomba (Coordinator)[2], J. Asaadi[3], D. Aristizabal Sierra[4], C. Awe[5], E. Baracchini[6], P. Barbeau[7], N. F. Bell[8], L. J. Bignell[9], C. Boehm[10], F. M. Brunbauer[11], V. De Romeri[12], B. Dutta[13], D. Caratelli[14], J. B. R. Battat[15], F. Dastgiri[16], C. Deaconu[17], K. Desch[18], C. Eldridge[19], A. C. Ezeribe[20], A. Fava[21], E. Ferrer Ribas[22], M. Froehlich[23], M. Ghrear[24], K. Gnanvo[25], E. Gramellini[26], R. Hall-Wilton[27], R. Harnik[28], J. Harton[29], S. Hedges[30], I.G. Irastorza[31], B. Jones[32], K. Kelly[33], G. Lane[34], P. M. Lewis[35], W. A. Lynch[36], P. Machado[37], K. J. Mack[38], D. Markoff[39], L. J. McKie[40], P. C. McNamara[41], H. Muller[42], K. Miuchi[43], H. Natal da Luz[44], J. L. Newstead[45], E. Oliveri[46], Y. F. Perez-Gonzalez[47], D. Pfeiffer[48], N. S. Phan[49], S. Popescu[50], J. Raaf[51], L. Ropelewski[52], A. Rusu[53], L. Scharenberg[54], K. Scholberg[55], Z. Slavkovska[56], D. Snowden-Ifft[57], N. J. C. Spooner[58], L. Strigari[59], A. E. Stuchberry[60], T. N. Thorpe[61], P. Urquijo[62], S. E. Vahsen[63], J.K. Vogel[64], M. H. Wood[65], and J. Zettlemoyer[66]

**Contents**



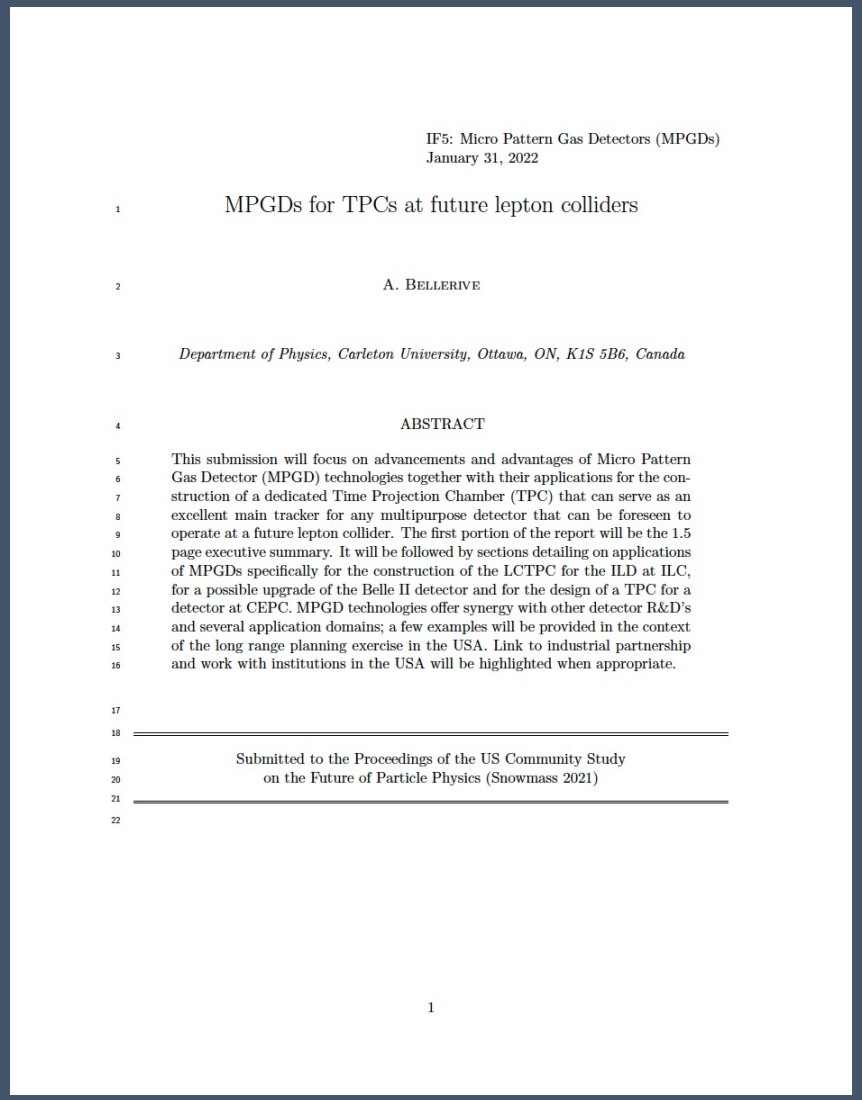


- 53 pages
- Some minor parts missing
- Some self-plagiarized text (plan to rewrite)
- Considering publishing the result

WPL: Alain Bellerive

# IF5 WP4: MPGDs for TPCs at future lepton colliders

| LOI title | Contact |
|---|---|
| Belle II detector upgrades | for TPC: Peter Lewis; lewis@physik.uni-bonn.de |
| Time projection chamber R&D | qihr@ihep.ac.cn |
| A time projection chamber using advanced technology for the International Large Detector at the International Linear Collider | alainb@physics.carleton.ca |
| A high-gain, low ion-backflow double micro-mesh gaseous structure | zhzhy@ustc.edu.cn |



IF5: Micro Pattern Gas Detectors (MPGDs)
January 31, 2022

# MPGDs for TPCs at future lepton colliders

A. Bellerive

*Department of Physics, Carleton University, Ottawa, ON, K1S 5B6, Canada*

ABSTRACT

This submission will focus on advancements and advantages of Micro Pattern Gas Detector (MPGD) technologies together with their applications for the construction of a dedicated Time Projection Chamber (TPC) that can serve as an excellent main tracker for any multipurpose detector that can be foreseen to operate at a future lepton collider. The first portion of the report will be the 1.5 page executive summary. It will be followed by sections detailing on applications of MPGDs specifically for the construction of the LCTPC for the ILD at ILC, for a possible upgrade of the Belle II detector and for the design of a TPC for a detector at CEPC. MPGD technologies offer synergy with other detector R&D's and several application domains; a few examples will be provided in the context of the long range planning exercise in the USA. Link to industrial partnership and work with institutions in the USA will be highlighted when appropriate.

Submitted to the Proceedings of the US Community Study
on the Future of Particle Physics (Snowmass 2021)

1

- 15 pages
- Close to finished
- Reviewed by LOI submitters, feedback already incorporated
- For the final version (planned next Monday):
  - add references
  - minor grammar & text edits
  - add figure about GridPix (and make a stronger case for dE/dx and resolution)
  - add author list

# WP#5: MPGD for tracking and Muon detection at future high energy physics colliders

WPL: A. Colaleo, K. Black

| Title | **LOI title** | **Contact(s)** | Chapter |
|---|---|---|---|
| Introduction | | Anna.Colaleo@cern.ch<br>Kevin.Black@cern.ch | ok |
| | MPGDs for tracking and muon detection: progress review and updated R&D roadmap | hohlmann@fit.edu | No feedback from proponent. |
| High granularity resistive Micromegas for high rates | Pixelated resistive MicroMegas for high-rates environment | paolo.iengo@cern.ch | ok |
| Advanced GEM detectors for future collider experiments | Advanced GEM detectors for future collider experiments | Antonello.Pellecchia@cern.ch, Jeremie.Merlin@cern.ch | ok |
| μ-RWELL for HEP experiments | micro-RWELL detector | Giovanni.Bencivenni@lnf.infn.it | ok |
| Gas system for HEP | | Beatrice.Mandelli@cern.ch<br>Roberto.Guida@cern.ch | ok |

# Status

- We have recently combined four different articles in one document.
- We need  to still some tweak to get uniform style, acronyms etc.
- Each chapter in very good shape
- Internal review of the authors is still on-going.
- Bibliography, list of author to be finalized.

- Link to the draft document:
- https://www.dropbox.com/s/013w5kqsttk8d13/Snowmass_all_WP5.pdf?dl=0

# MPGD for tracking and Muon detection at future high energy physics colliders

Snowmass Instrumentation Frontier: MPGD White paper 5

K. Black[1], A. Colaleo[2] (Coordinators)
M. Alviggi[3], ,M.T. Camerlingo[4], V. Canale[3], V. D'amico[5], M. Della Petra[3], C. Di Donato[3], R. Di Nardo[5], S. Franchellucci[5], P. Iengo[6], M. Iodice[7], F. Petrucci[5], G. Sekhniaidze[8], M. Sessa[5], A. Pellecchia[1], R. Venditti[1], P. Verwilligen[9], M. Hohlmann[10], J.Merlin [13]. A. Sharma [12], I. Balossino[13], G. Cibinetto[13], R. Farinelli[13], I. Garzia[13], S. Gramigna[13], M. Melchiorri[13], G. Mezzadri[13], M. Scodeggio[13], V. Cafaro[14], P. Giacomelli[14], G. Bencivenni[15], M. Bertani[15], E. De Lucia[15], D. Domenici[15], G. Felici[15], M. Gatta[15], M. Giovannetti[15], G. Morello[15], G. Papalino[15], M. Poli Lener[15], L. Lavezzi[16], R. Guida[12], B. Mandelli[12], M. Corbetta[12], G. Rigoletti[12]

[1] *University of Wisconsin-Madison, US*
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[10] *Florida institute of technology;*
[11] *University of Seoul;*
[12] *CERN - European Organization for Nuclear Research;*
[13] *INFN Sez. Ferrara, Ferrara IT;*
[14] *INFN Sez. Bologna, IT;*
[15] *Laboratori Nazionali di Frascati - INFN, Frascati (RM), Italy;*
[16] *INFN Torino, Italy;*

*E-mail: anna.colaleo@uniba.it, kblack@hep.wisc.edu, paolo.iengo@cern.ch, jeremie.alexandre.merlin@cern.ch, antonello.pellecchia@ba.infn.it, giovanni.bencivenni@lnf.it, beatrice.mandelli@cern.ch*

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)



## Contents









- 81 pages
- Introduction = executive summary?

# Summary & Questions

- MPGD Topical Group White Papers in good shape, nearly complete
  - Current PDF for all papers uploaded after this talk on Indico
  - Total of 228 pages!
  - Thanks to the authors for their tremendous efforts!
- Good time for feedback on missing contents / balance of contents. Please provide this no later than two weeks from now.
- Probably too early for feedback on typos and details.
- Questions from IF5 to Snowmass:
  - OK to submit white papers to journals after March 15? We assume yes.
  - Cross-referencing between white papers? Plan: use preliminary citations with full white paper names, working group, and number for now. Replace citations with arxiv citations after March 15.

# BACKUP

# Past IF5 activities

- We held bi-weekly meetings before the Snowmass pause https://indico.fnal.gov/category/1185/
  - Collected input from the community
  - Reviewed technical presentations
  - Encouraged submission of Letters of intent (LOIs)
- 40 LOIs were submitted to IF5
  - https://snowmass21.org/instrumentation/mpgd
- We identified a few additional LOIs relevant to IF5
- Most LOIs were consolidated into five White Papers
  - A few LOIs passed on to other topical groups
- Restarted meetings focused on these White Papers in 2021

WPLs Klaus Dehmelt, Andy White

# IF5 WP1
# MPGDs: Recent advances and current R&D

| LOI title | Contact |
|---|---|
| Development of the Micro-Pattern gaseous detector technologies: an overview of the CERN-RD51 collaboration | Silvia.DallaTorre@ts.infn.it |
| High precision timing with the PICOSEC micromegas detector | Christos.Lampoudis@cern.ch |
| Optical readout of MicroPattern Gaseous Detectors: developments and perspectives | florian.brunbauer@cern.ch |
| Pixelated resistive MicroMegas for high-rates environment | massimo.della.pietra@cern.ch |
| Trigger extensions for the scalable readout system SRS | Hans.Muller@cern.ch |
| A high-gain, low ion-backflow double micro-mesh gaseous structure | zhzhy@ustc.edu.cn |
| LOI from NSCL | cortesi@nscl.msu.edu |

# Scope of IF5

- This Snowmass 2021 topical group will identify and document recent developments and future needs for Micro-Pattern Gaseous Detector (MPGD) technologies, driven by the availability of modern photolithographic techniques.
- Current MPGD technologies include the Gas Electron Multiplier (GEM), the Micro-Mesh Gaseous Structure (MicroMegas), THick GEMs (THGEMs), also referred to in the literature as Large Electron Multipliers (LEMs), the Resistive Plate WELL (RPWELL), the GEM-derived architecture (micro-RWELL), the Micro-Pixel Gas Chamber (μ-PIC), and the integrated pixel readout (InGrid).
- In recent years, there has been a surge in the use of MPGDs. MPGDs are now used in major ongoing particle-collider experiments (e.g., ATLAS, CMS, and ALICE at the LHCb) and are in development for future facilities (e.g., EIC, ILC, FCC, and FAIR). A majority of MPGD developers and users coordinate and collaborate as part of the CERN-RD51 collaboration.
- MPGDs are of interest for particle/hadron/heavy-ion/nuclear physics, charged particle tracking, photon detectors and calorimetry, neutron detection and beam diagnostics, neutrino physics, and dark matter detection, including operation at cryogenic temperatures. Beyond fundamental research, MPGDs are in use and considered for scientific, social, and industrial purposes; this includes the fields of material sciences, medical imaging, hadron therapy systems, and homeland security.

# 6 LOIs were co-assigned to IF5, but another TG should take the lead

| | | | |
|---|---|---|---|
| IF3_IF5_Simone_Mazza-175.pdf | High density 3D integration of LGAD sensors through wafer to wafer bonding | simazza@ucsc.edu | **Suggest IF3** |
| IF6_IF5_Laktineh-Calice-050.pdf | Timing semi-digital hadronic calorimeter (T-SDHCAL) | laktineh@in2p3.fr | **Suggest IF6** |
| IF8_IF5-NF10_NF0_Ben_Jones-070.pdf | Scintillating and quenched gas mixtures for HPGTPCs | ben.jones@uta.edu | Focused on scintillation and gas physics. **Let other TG take lead.** |
| EF3_EF4-IF3_IF5-031.pdf | The IDEA drift chamber for a Lepton Collider | franco.grancagnolo@le.infn.it | **IDEA drift chamber. Tracking. Suggest IF3.** |
| EF4_EF0-AF3_AF0-IF3_IF5_GrahamWilson-119.pdf | Exploring precision electroweak physics measurement potential of e+e- colliders | gwwilson@ku.edu | **Focused on physics, not MPGDs. Needs another TG.** |
| IF7_IF5_H.MULLER-101.pdf | Trigger extensions for the scalable readout system SRS | Hans.Muller@cern.ch | Let IF7 take lead, but **should also be discussed in IF5 whitepaper** |

# LOIs that did not indicate IF5, but which are relevant to our White Papers

Authors of these LOIs agreed to contribute to White paper #3 (Recoil imaging)

| | | |
|---|---|---|
| IF8_IF0-NF10_NF6_Jacob_Zettlemoyer-150.pdf | Towards directional nuclear recoil detectors: tracking of nuclear recoils in gas Argon TPCs | David Caratelli (davidc@fnal.gov) |
| IF/SNOWMASS21-IF9_IF8-NF3_NF10-CF1_CF0-145.pdf | Dual-Readout Time Projection Chamber: exploring sub-millimeter pitch for directional dark matter and tau identification in $\nu\tau$C C interactions. | Elena Gramellini, (Fermi National Accelerator Laboratory), elenag@fnal.gov |
| | Directional detectors for CEvNS and physics beyond the Standard Model | Difft@oxy.edu<br>Daniel Snowden Ifft |

# Submitted LOIs: 24 (links below are clickable)

https://snowmass21.org/instrumentation/mpgd

| | | |
|---|---|---|
| 1 | CF/SNOWMASS21-CF1_CF0-NF10_NF4-IF5_IF4_Vahsen-189.pdf | 31/08/2020 |
| 2 | EF/SNOWMASS21-EF3_EF4-IF3_IF5-031.pdf | 06/08/2020 |
| 3 | EF/SNOWMASS21-EF4_EF0-AF3_AF0-IF3_IF5_GrahamWilson-119.pdf | 30/08/2020 |
| 4 | IF/SNOWMASS21-IF2_IF7_IF3_IF4_IF5_IF6-056.pdf | 29/08/2020 |
| 5 | IF/SNOWMASS21-IF3_IF5-EF1_EF4-183.pdf | 01/09/2020 |
| 6 | IF/SNOWMASS21-IF3_IF5_Simone_Mazza-175.pdf | 31/08/2020 |
| 7 | IF/SNOWMASS21-IF5-005.pdf | 27/07/2020 |
| 8 | IF/SNOWMASS21-IF5-EF4-007.pdf | 07/08/2020 |
| 9 | IF/SNOWMASS21-IF5_CF2_AF5_Ferrer-Ribas-020.pdf | 27/08/2020 |
| 10 | IF/SNOWMASS21-IF5_IF0-057.pdf | 30/08/2020 |
| 11 | IF/SNOWMASS21-IF5_IF0-184.pdf | 01/09/2020 |
| 12 | IF/SNOWMASS21-IF5_IF0-193.pdf | 08/09/2020 late |
| 13 | IF/SNOWMASS21-IF5_IF0_Brunbauer-096.pdf | 31/08/2020 |
| 14 | IF/SNOWMASS21-IF5_IF0_C.Lampoudis-098.pdf | 31/08/2020 |
| 15 | IF/SNOWMASS21-IF5_IF0_Gnanvo_Hohlmann_Posik_Surrow-044.pdf | 28/08/2020 |
| 16 | IF/SNOWMASS21-IF5_IF0_Kondo_Gnanvo-159.pdf | 31/08/2020 |
| 17 | IF/SNOWMASS21-IF5_IF0_M_Hohlmann-040.pdf | 28/08/2020 |
| 18 | IF/SNOWMASS21-IF5_IF0_Marco_Cortesi-103.pdf | 31/08/2020 |
| 19 | IF/SNOWMASS21-IF5_IF3-015.pdf | 24/08/2020 |
| 20 | IF/SNOWMASS21-IF5_IF6-EF4_EF0_COLALEO-068.pdf | 30/08/2020 |
| 21 | IF/SNOWMASS21-IF5_IF9-EF0_EF0-168.pdf | 31/08/2020 |
| 22 | IF/SNOWMASS21-IF6_IF5_Laktineh-Calice-050.pdf | 29/08/2020 |
| 23 | IF/SNOWMASS21-IF7_IF5_H.MULLER-101.pdf | 31/08/2020 |
| 24 | IF/SNOWMASS21-IF8_IF5-NF10_NF0_Ben_Jones-070.pdf | 30/08/2020 |