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

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

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

- All white paper leads (WPLs) are in place
- Aiming for first WP drafts January 15th
- Aiming for 1.5-page executive summary for most WPs → combine into 10-page summary of IF5
- WP draft outlines and milestones in place (see following pages)

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

WPLs: Klaus Dehmelt, Andy White

LOI title	Contact	Outline
Development of the Micro-Pattern gaseous detector technologies: an overview of the CERN-RD51 collaboration	Silvia.DallaTorre@ts.infn.it	Expected ~few days
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	

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.

IF05 – WP 1 - Schedule

- Outlines received (6/7)
- Mid-December – First draft WP sections
- January – iterate with section authors
- Early February – second drafts of sections
- February – compile sections into WP
- March – complete WP

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

Outline

i. Facility for Rare Isotope Beams – Marco Cortesi

ii. Thomas Jefferson National Laboratory -Kondo

- a. Current Experiments
- b. Future Experiments

iii. Electron Ion Collider

- a. Requirements -Matt
- b. MPGDs for Tracking -Matt/Marcus
- c. MPGDs for PID
  - i. RICH -Silvia
  - ii. TRD - Yulia
  - iii. TOF – follow up with Francesco

Time Line

- First meeting with contributors and start bi-weekly meetings – Nov. 22-24th (TBD)
- Collect contribution drafts – Jan 14th
- Send 1st draft on Jan 17th

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 ν_τC 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)

IF5 WP 3: Recoil imaging for dark matter, neutrinos and beyond-the-Standard-Model physics

- **Executive summary (1.5 page)**
  - Define topic: high res detection of NRs and ERs tracks
  - Define scope: benefits of recoil imaging, only cover ionization-based imaging (in gas TPCs?), exclude emulsions, crystals, DNA.
  - Inter-frontier connections
    - DM -> CF1 (particle-like dark matter)
    - Neutrinos -> NF10 (neutrino detectors)
    - MPGD needs -> IF5
- **Current status of recoil imaging (1 page)**
  - Physics of the ionization process?
  - Define TPC, MPGDs, any other important jargon
  - Perhaps give a very brief historical overview of experiments (condensed version of the directional review)
  - Summary of ongoing efforts
- **Dark matter (1-2 pages)**
  - [O'Hare] Search for WIMPs into the neutrino fog
  - [O'Hare] The need for a detector that can prove a discovery of DM
  - [O'Hare] Directional astrophysics and particle physics of a DM signal
  - [O'Hare] ALP/dark photon detection via directional electron recoils
- **Neutrinos (1-2 pages)**
  - [O'Hare] Directional TPCs for solar neutrinos
  - [O'Hare] Non-solar natural neutrinos (SN, Geo, Atmospheric)
  - [Snowden-Ifft] Directional measurement of CEvNS
- **Beyond-the-SM physics (1-2 pages)**
  - [Ferrer-Ribas] MPGD development for solar axion searches and IAXO
  - [Snowden-Ifft] BSM physics with a directional TPC and a neutrino beam

IF5 WP 3: Recoil imaging for dark matter, neutrinos and beyond-the-Standard-Model physics

- **Other applications that benefit from directionality (3-4 pages)**
  - [Loomba] Measurement of the Migdal effect
  - [Loomba/Vahsen] Neutron detection
  - [Loomba/Barachinni] X-ray polarimetry
  - [Loomba+] Rare nuclear decays
- **Detector Requirements (4 pages)**
  - [Loomba/Vahsen] Gas TPC requirements
  - [Contributor?] MPGD Requirements: readout, scale-up, gases
  - [Brunbauer] Optical readout
  - [Muller] Trigger extensions for the scalable readout system (SRS)
- **Blue-sky R&D (5-6 pages)**
  - [Loomba] Negative ion drift
  - [Vahsen] CYGNUS: directional TPC at very large-scale
  - [Gramellini] Sub-millimeter pitch for directional detection
  - [Caratelli] Directional NR detection in gas Argon TPCs

Plans/Schedule

- Send outline to LOI authors, get their feedback and finalize
- We have the OverLeaf doc ready for the authors to add text, etc
- Plan a WP mini-workshop in December to discuss deadlines for 1st, 2nd, final drafts)
- Begin coordinating with the Cosmic Frontier Topical Group 1 and Neutrino Physics TG 10 to ensure that directional detectors are included in their contributions.
- Ask LOI authors who have not done so, to present at IF5 Friday meetings (t.b.d. – we may skip this)

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

Snowmass effort on MPGD White Paper #4
“MPGDs for TPCs at future lepton colliders”
Editor / Author: Alain Bellerive, Carleton University

The paper should cover the following Letters Of Intent (LOIs), with contact persons listed in parentheses:

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

People contacted.

Here are links to the LOIs:

1. https://www.snowmass21.org/docs/files/summaries/IF/SNOWMASS21-IF2_IF7_IF3_IF4_IF5_IF6-056.pdf
2. https://www.snowmass21.org/docs/files/summaries/IF/SNOWMASS21-IF3_IF5-EF1_EF4-183.pdf
3. https://www.snowmass21.org/docs/files/summaries/IF/SNOWMASS21-IF5_IF3-015.pdf
4. https://www.snowmass21.org/docs/files/summaries/IF/SNOWMASS21-IF5_IF0-184.pdf

Timeline
“MPGDs for TPCs at future lepton colliders”

- November 15 – December 15:

  Putting together the material and working on skeleton of the White Paper (A.Bellerive)
- December 21:

  First version of *“MPGDs for TPCs at future lepton colliders” of the WP,* including Executive Summary of 1.5 pages to the TG conveners) distributed to contacts
- Incorporate comments from contacts into the WP, and executive summary
- 15 January:

  Provide the first draft (including the 1.5 pages Executive Summary) to the TG conveners
- January 15 – January 30: iterate with author, contacts and TG conveners
- 1 February: second drafts of WP and executive summary
- 15 February – final draft submitted

WPL: A. Colaleo, K. Black

IF5 WP5:
MPGD for muon detection at future colliders

LOI title	Contact
MPGDs for tracking and muon detection: progress review and updated R&D roadmap	hohlmann@fit.edu
Pixelated resistive MicroMegas for high-rates environment	massimo.della.pietra@cern.ch
Advanced GEM detectors for future collider experiments	Anna.Colaleo@ba.infn.it
micro-RWELL detector	Giovanni.Bencivenni@lnf.infn.it

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

Outline

Executive summary 1.5 pages (A. Colaleo, K. Black)

State of the art

MPGDs for tracking and muon detection: progress review and updated R&D roadmap (M. Hohlmann)

Technologies

(Charge: Description of the technology, Main area of applications focusing on Muon and tracking detectors in high energy physics, mentioning current and future facilities, without prioritizing them; address the challenges, specific integration aspects related to the technology (electronics, cooling, mechanics…), Some recent results of R&Ds, Roadmap for near- to middle-term (long-term?) R&D, Applications beyond HEP)

- High granularity resistive Micromegas for application at high rates (P. Iengo, M. Della Pietra)
- Advanced GEM detectors for future collider experiments (A. Pellecchia, J. A. Merlin)
- The micro-RWELL in high energy physics and beyond (G. Bencivenni)

Infrastructures and integration aspects

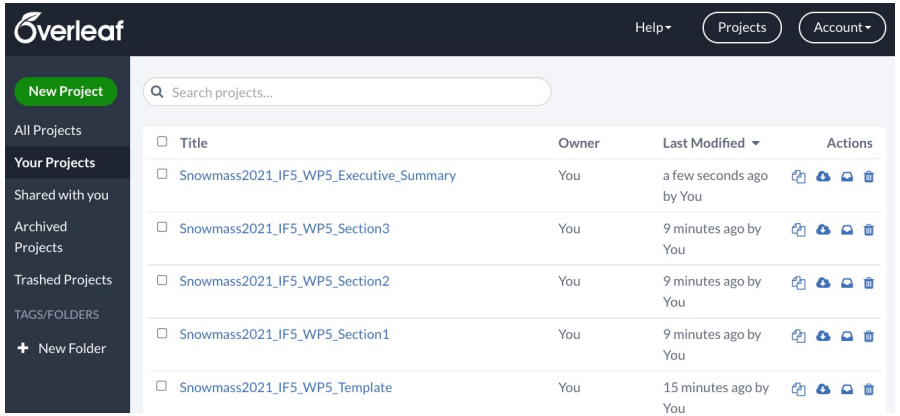
- Electronics and Readout (TBC)
- Gas systems for MPGDs (B. Mandelli, R. Guida)
- Precision manufacturing techniques for large area detectors (TBC)

Schedule

- 12 Nov –first meeting
- 15 December – First draft of each WP sections
- 15 January - provide the first draft (including Executive Summary to the TG conveners)
- January – iterate with section authors
- 1 February – second drafts of each WP sections
- 15 February – final draft
- February – compile sections into WP
- March – complete WP

Status and organizational aspects

- 3 outlines received, 2 outline will be sent in few days
- 2 sections to be confirmed
- We will use the “Snowmass Overleaf template”



BACKUP

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 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