Update on Snowmass Activities relevant to CYGNUS

Sven Vahsen (Hawaii)

Welcome to Snowmass 2021

The Particle Physics Community Planning Exercise (a.k.a. “Snowmass”) is organized by the Division of Particles and Fields (DPF) of the American Physical Society. Snowmass is a scientific study. It provides an opportunity for the entire particle physics community to come together to identify and document a scientific vision for the future of particle physics in the U.S. and its international partners. Snowmass 2021 will define the most important questions for the field of particle physics and identify promising opportunities to address them. (Learn more about the history and spirit of Snowmass here "How to Snowmass" written by Chris Quigg). The P5, Particle Physics Project Prioritization Panel, will take the scientific input from Snowmass and develop a strategic plan for U.S. particle physics that can be executed over a 10 year timescale, in the context of a 20-year global vision for the field.

We aim for everyone's voice to be heard. Your contributions and participation are critical for the success of Snowmass and they will naturally occur as part of one or more working groups directed by the conveners. There will be various Town Hall meetings for us to communicate with you and to receive your feedback. You are also welcome to provide input and suggestions on the Slack channel (https://snowmass2021.slack.com/). This Snowmass wiki provides news and announcements and has pages dedicated to each frontier. If you are an early career scientist, we encourage you to join the “Snowmass Young” mailing list (snowmass-young@fnal.gov) by emailing to listserv@listserv.fnal.govwith the body of the message “Subscribe snowmass-young YOUR NAME”. Agendas and presentations of all Snowmass-related meetings are available via this Snowmass Indico link.

Sincerely,

Young-Kee Kim (DPF Chair), Tao Han (DPF Chair-Elect), Joel Butler (DPF Vice-Chair), Priscilla Cushman (DPF Past Chair)

Glennys Farrar (DAP Rep), Gabriela Gonzales (DGRAV Rep), Yury Kolomensky (DNP Rep), Sergei Nagaitsev (DPB Rep)

DPF Community Planning Process

Snowmass process, Instrumentation Frontier

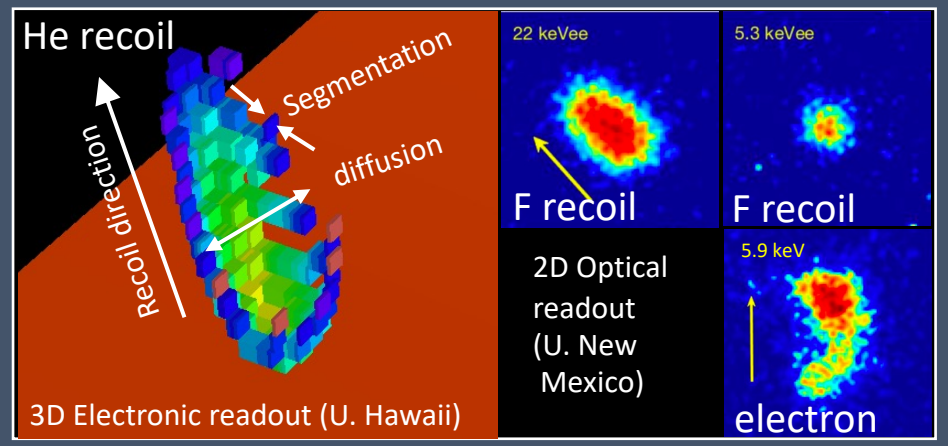
- Community-driven effort on long-term planning for particle physics
- Bottom-up process => your input is needed !!
  - That's the most important aspect at this phase of the process
  - The idea is to get the community at large involved
- Milestones along the way:
  - Letters of Interest due 31 Aug 2020: **DONE**
  - (Virtual) Community Planning Meeting: October 5-8 **DONE**
  - *Definition of the list of White Papers: pre-Christmas 2020*
    - We would like to have all the contributing groups/authors defined by then
    - We will hold another meeting before Christmas to discuss the WPs
  - Summer Study meeting meeting: 11-20 July 2021
  - Contributed Papers due July 31 2021

Delayed one year

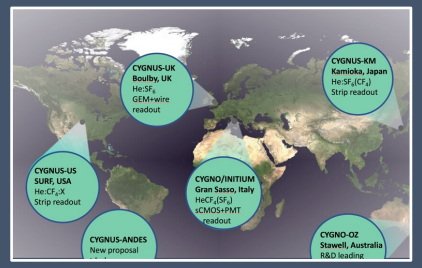
CYGNUS

Directional nuclear recoil detectors for neutrinos, dark matter, and BSM physics

- Gas TPCs with charge readout via MPGDs have enabled directional detection of nuclear recoils and electrons

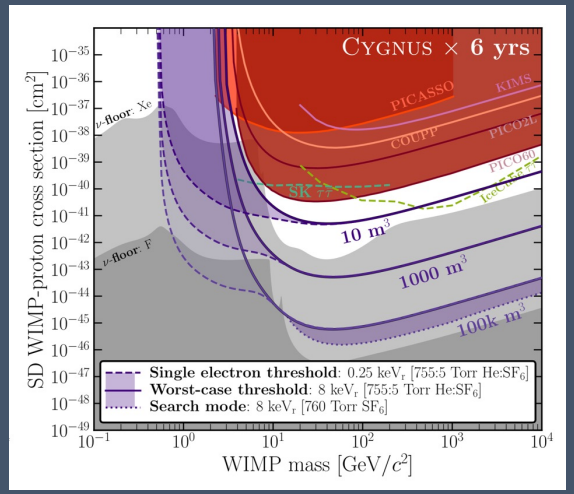


- Electron ID for < 10 keVee, 3d fiducialization
- Directionality provides DM / neutrino discrimination
- Long term vision: multi-site observatory
  - Sufficient exposure to penetrate neutrino floor
  - Maximize directionality via negative ion gas mixture with Helium
  - P=1 atm, T=300 K (!)



- International proto-collaboration formed
- Growing support: funded efforts in EU/Italy/Australia

- Opportunity for long-term program: new physics opportunities for each factor 10 increase in exposure
- *Strawman* design paper: arXiv:2008.12587, focused on DM and neutrinos



Exposure, size

- Migdal Effect measurement
- Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) at either NuMI or DUNE
- Competitive DM limits in SI and SD
- CEvNS from solar neutrinos
- Efficiently penetrating the ν floor
- Observing galactic DM dipole
- Measuring DM particle properties and physics
- Geoneutrinos
- WIMP astronomy

- Many new proposals in HEP community that should be explored
  - New mediators in CEvNS, Low-mass DM, Up-scattered heavy neutrinos and DM, Axion like particles
- New ideas could still have major impact
- Relevant to Cosmic, Neutrino, and Instrumentation Frontiers
- Planning inter-frontier Snowmass CYGNUS Mini-workshop
  → brainstorm and seed white paper effort

Sven Vahsen, sevahsen@hawaii.edu

Snowmass report: https://snowmass21.org/report

- The report endgame is not fully clear (to me)
- White paper deadline: March 15
- Other dates missing?
- Draft TG summaries will be due before white paper → we will need a draft executive summary for your white paper quite a bit before March 15.
- I have contacted the frontier-conveners to learn more, will keep you posted

1. Snowmass Summary for the Public (2 pages) [audience: everyone]

- With help of Kathryn Jepsen, Editor-in-Chief, Symmetry magazine

2. Snowmass Summary Report (~50 pages) [audience: Snowmass community, science community, funding agencies]

1. Executive Summary: ~10 pages
2. Introduction
3. 10 Frontier Executive Summaries (a few pages per Frontier)
4. Executive Summaries of Multi-Frontier Topics
5. Conclusion

3. Snowmass Book (~500 pages) [audience: Snowmass community + P5 Committee] (see Snowmass 2013 Report)

1. Snowmass Summary Report (~50 pages)
2. Frontier Summaries (< 50 pages per Frontier)
3. Multi-Frontier Topic Summaries (~10 pages per Topic)

4. Reports of Ten Frontiers [audience: Frontiers & Topical Groups] - web based (see Snowmass 2013 webpage)

- Each Frontier Summary: < 50 pages
- Topical Group Reports (some groups could be combined): < a few tens of pages per report

5. Reports of Multi-Frontier Topics [audience: Frontiers & Topical Groups]

- Each Multi-Frontier Topic Summary: ~10 page
- Multi-Frontier Topics are topics spanning multiple Frontiers such as Dark Matter and Quantum Science.

6. Contributed Papers

- Contribute papers (or known as "white papers") are contributions by the community and will be used as input to the frontier and topical group reports. See the submission procedure here.
- Because the submission deadline is after the deadline of preliminary subgroup and frontier reports, authors should communicate with relevant TG conveners about key elements of their paper some months before the submission deadline. Each Frontier will provide guidelines to their community about the communication process.

time

Snowmass ~~2021~~ Report Structure (Preliminary)

Is this figure still relevant?

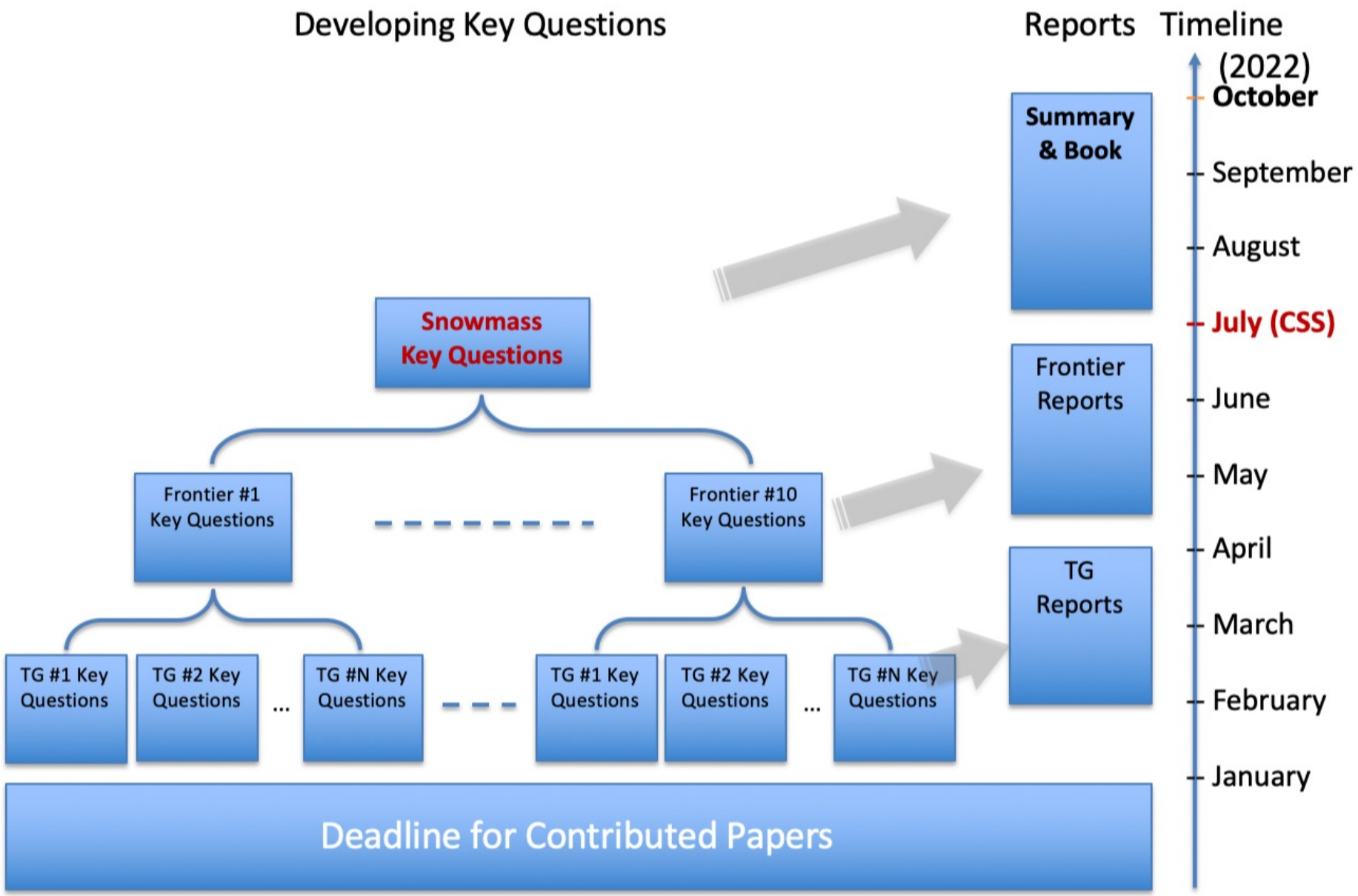
- **Snowmass Summary for Public**
  - 2 pages
- **Snowmass Summary Report**
  - ~50 pages
  - Executive Summary: ~10 pages
  - Introduction
  - 10 Frontier Executive Summaries
  - Executive Summaries of Multi-Frontier Topics
  - Conclusion
- **Snowmass Book**
  - ~500 pages
  - Snowmass Summary Report (~50 pages)
  - Frontier Summaries (~400 pages with 10 Frontiers)
  - Multi-Frontier Topic Summaries (~50 pages)
- **Topical Group Reports**
  - Topical Group Reports: short reports

  (Written by TG members including early careers)
- **Reports of Multi-Frontier Topics**
  - Multi-Frontier Topics spanning multiple Frontiers.
  - Each Multi-Frontier Topic Summary: ~10 page
- **Contributed Papers**
  = White Papers
  - References

  (Written by the community including early careers)

https://snowmass21.org/report

Snowmass Timeline & Process (Preliminary)



Instrumentation Frontier

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

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.

Past 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

Proposed list of IF5 White Papers (WPs)

	Topic	Executive Summary Length	Lead organizer(s)
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	Sven Vahsen
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

- WPs can be any length
- Total of executive summaries should be <= 10 pages, to be used for IF5 summary

➔ **need 1.5-page executive summary for most WPs. Draft summary will be needed before WP is done!**

Preliminary IF5 White Paper Schedule

- ✓10/18/21: Finalize white paper leads (WPL)
- ✓10/19/21: TG convenors send guidance to WPL
  - WPL to contact LOI writers w/ requests
  - Prepare outline + contributor list
- ✓10/29/21 Meeting with WPLs
- 11/5/21 Next Open IF5 meeting:
  - WPLs present WP outline + contributor list
- 1/15/21 First WP drafts, including executive summaries
- Tbd: Convenor feedback on WP
- Tbd: 2nd draft
- 3/1/22 Final WP drafts
- < 3/15/22 Submit final version

Instrumentation Frontier White paper 3

IF5 Whitepaper 3:
Recoil imaging for DM, neutrino, and BSM physics

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)

White Paper Outline [highly preliminary!]

- Executive summary
  - Define topic and scope (high-res detection of Nuclear and Electronic Recoils)
    - General benefits of recoil imaging (directionality for neutral particles, particle ID)
    - [Only cover ionization based?]
  - DM → Cosmic Frontier
  - Neutrinos → Neutrino Frontier
  - MPGD needs → IF5
- Applications
  - Directional DM searches
  - Directional Neutrino detection
  - Axion searches
  - Physics of the ionization process
  - Directional neutron detection
- Candidate Technologies
  - Gas TPCs (electronic, optical, e-drift/NID) and their optimization
  - Emulsions
  - Crystal defect spectroscopy
  - …
- MPGD Requirements, Challenges, Open questions
  - Readout
  - Scale-up
  - Gases
- Blue-sky R&D

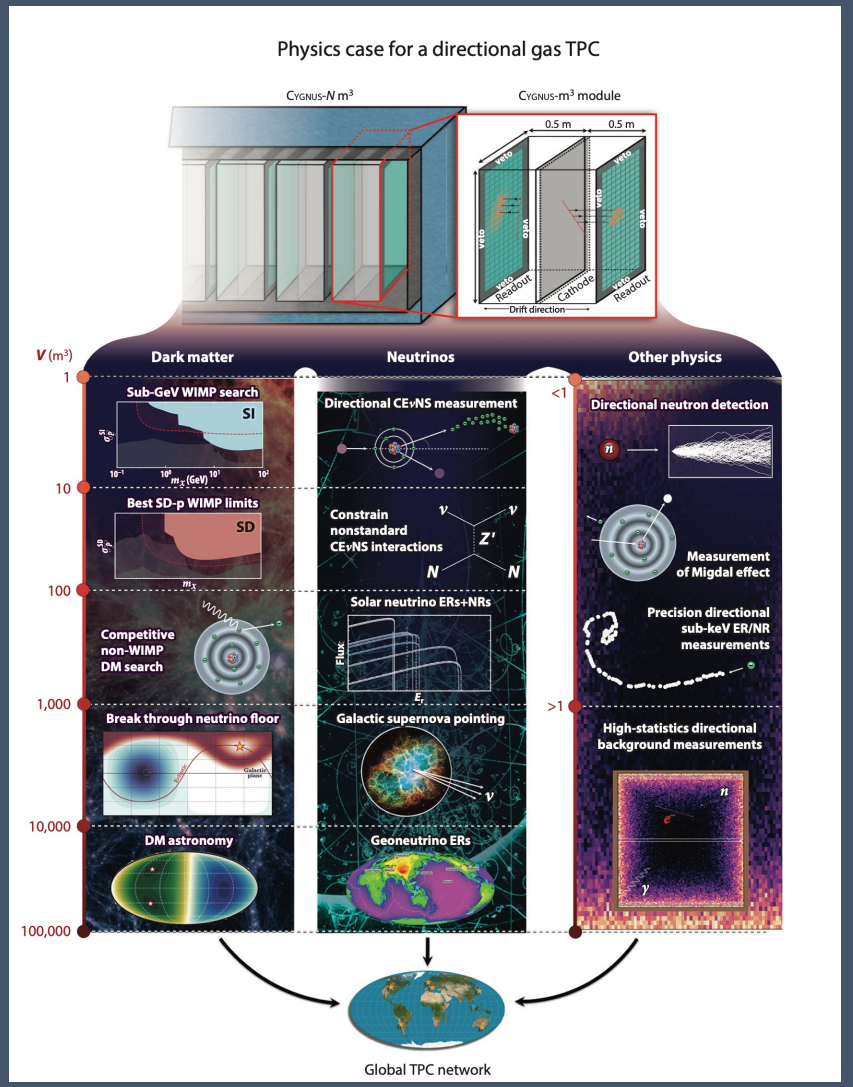
https://www.annualreviews.org/doi/abs/10.1146/annurev-nucl-020821-035016

Annual Review of Nuclear and Particle Science

Directional Recoil Detection

Sven E. Vahsen,[1] Ciaran A.J. O'Hare,[2] and Dinesh Loomba[3]

Contents



Recent review article that covers much of the scope envisioned for the white paper.

Plans

- Finalize scope (gas detectors only? experiment focused?)
- Iterate on outline with LOI authors
- Interface more with neutrino, cosmic frontiers
- Clearly establish role of multi-frontier topics in Snowmass
- Ask LOI authors who have not done so, to present at IF5 Friday meetings
- WP specific mini-workshop, December 2021
- Questions
  - Experiment-specific WP or as broad as possible?
    What do other large collaborations do?
  - Comprehensive or US-interest focused?
  - How does the final snowmass report come together?
  - What is the role of the summer study?

Summary

- Snowmass is a HEP planning exercise
- Delayed by one year due to COVID
- Bottoms-up process
- Will impact US funding agencies and US planning for ~10 years
- Relevant to CYGNUS: planning a multifrontier paper on recoil imaging
- We will ask more of the CYGNUS community – worldwide – to help
- Draft paper due in 2.5 months
- Final paper due March 15, 2022
- Planning mini-workshop to collect more input in December

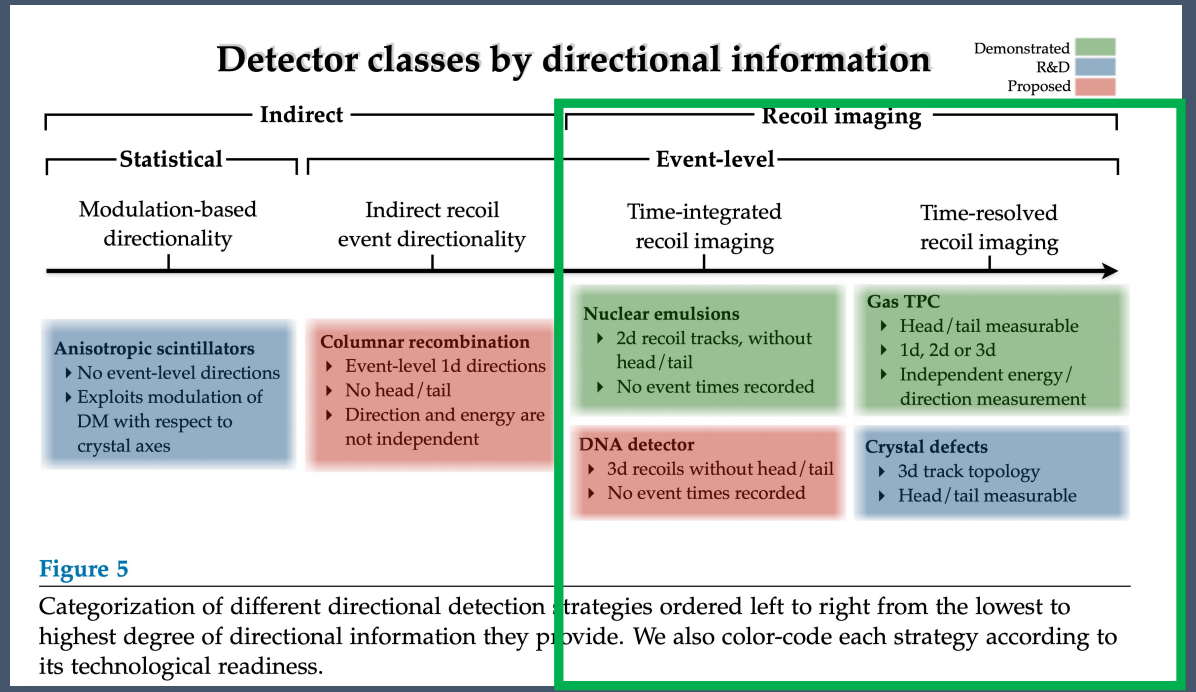


Figure 5

Categorization of different directional detection strategies ordered left to right from the lowest to highest degree of directional information they provide. We also color-code each strategy according to its technological readiness.

BACKUP

Whitepaper 1:
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

Whitepaper 2:
MPGDs for nuclear physics experiments

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

Whitepaper 3:
Recoil imaging for DM, neutrino, and BSM physics

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 ντC C interactions.	Elena Gramellini, elenag@fnal.gov
Directional detectors for CEvNS and physics beyond the Standard Model	Difft@oxy.edu Daniel Snowden Ifft
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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)

Whitepaper 4:
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

Whitepaper 5:
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

IF5 Plans

- Restart bi-weekly IF5 Friday meetings (3 pm Eastern Time)
  - https://indico.fnal.gov/category/1185/
  - Presentations on new ideas for which no LOIs were submitted (most urgent), to capture these as part of the Snowmass process
  - Technical presentations on LOI topics
  - Monitor progress on White Paper
- Finalize all white paper lead authors (5/5 confirmed)
- Re-evaluate milestones and schedule
  - Workshop on recoil imaging (white paper #3)
  - Draft executive summaries: tbd
  - Draft White Papers: tbd
  - White papers completed: tbd

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 vτC 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
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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
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24	IF/SNOWMASS21-IF8_IF5-NF10_NF0_Ben_Jones-070.pdf	30/08/2020