Dark Wave Lab Workshop

Andrew Sonnenschein
April 15, 2024

Contents

1. Meeting logistics
2. Motivation for this workshop
3. Opportunities for use of 9.4 Tesla solenoid procured for ADMX-EFR
4. What outcomes are we looking for from this meeting?
5. Discussion groups
6. Tours
7. Closeout discussion, Plans for White Paper

Meeting Logistics– Day 1, Monday April 15

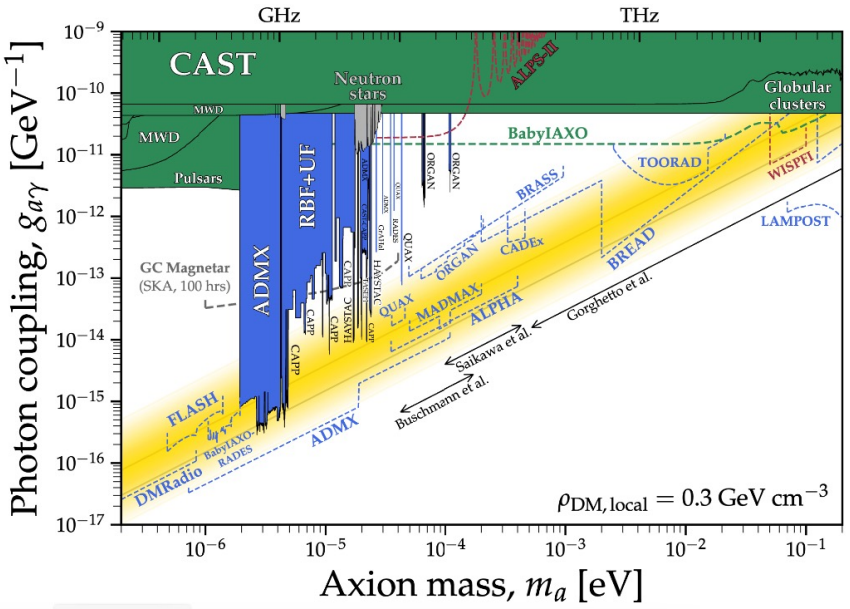
- Welcome to Dark Wave Lab workshop!
- Wilson Hall WiFI: Guest and Eduroam networks are available.
- Indico Link: https://indico.fnal.gov/event/63051/
- Zoom link: https://fnal.zoom.us/j/94359778942?pwd=OUhZYnN5MnV5bG5lOXNJbVhPMzdnQT09
- Speakers: please upload your talks to Indico by start of your session.
- First day of meeting is in Wilson Hall
  - All talks today in One West lecture hall
  - Group photo in atrium during morning coffee break at ~10:40
  - Lunch in atrium cafeteria 12:20-13:00
  - Pierre Sikivie's seminar in One West at 14:00
  - Breakout discussion sessions– cafeteria and 2nd floor atrium dining area
  - Dinner at 6 pm on 2nd foor – go up stairs behind cafeteria.

Meeting Logistics– Day 2, Tuesday April 16

- Tuesday morning talks are in Building 327
- Move to Wilson Hall in afternoon for lunch and breakout discussion groups from 12:30 to 3:30 pm
- Tour buses will leave from Wilson at 1:30 and 2:30 pm (overlap with discussion groups)
- Will show a slide with tour schedule at the end of Tuesday morning session.
- Final coffee break and closeout discussion session is currently scheduled for Building 327– **stay tuned for possible change.**

Motivation for Holding this Workshop

- Experimental axion search field is bursting with new ideas.
- Proposed experiments open up a wide mass range for discovery of QCD axion.
- But only a few experiments have obtained useful sensitivity so far.
- Successful experiments E.g. ADMX, CAPP, CAST benefitted from long term investments in magnets and cryogenic system infrastructure.
- Let's figure out how to provide these resources for a wider range of projects.
- Using shared resources could greatly **accelerate progress** and **reduce costs.**



https://cajohare.github.io/AxionLimits/

Fermilab

Need for National Lab/ University Partnerships

- Techniques exploring axion-photon coupling generally benefit from highest possible magnetic field strength and volume (signal ~ B^2V) and lowest possible temperature for noise reduction.
- Large magnets and cryogenic systems are difficult to build and maintain reliably over long running periods in a university environment.
- Requirements for large-scale infrastructure, technical support and safety best met at a national lab, while universities provide sophisticated sensor development, prototyping and data analysis.
- By leveraging lab resources, university groups can progress quickly from initial concept to a working experiment.

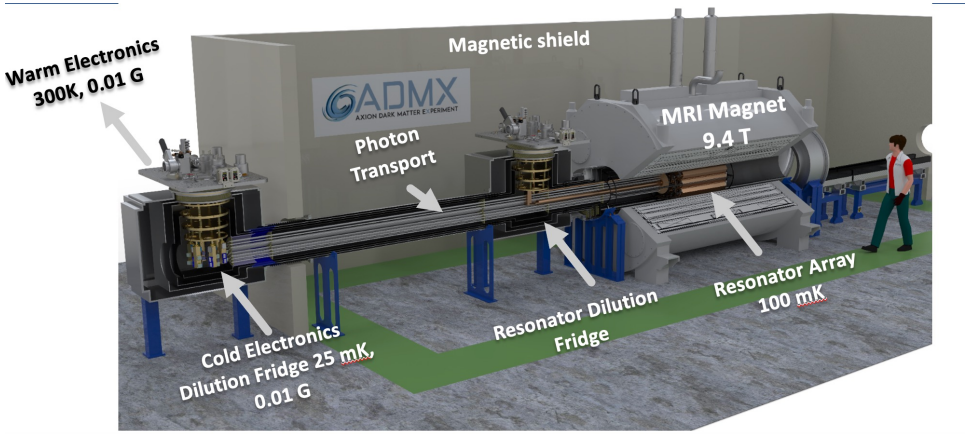
ADMX-G2 Operations

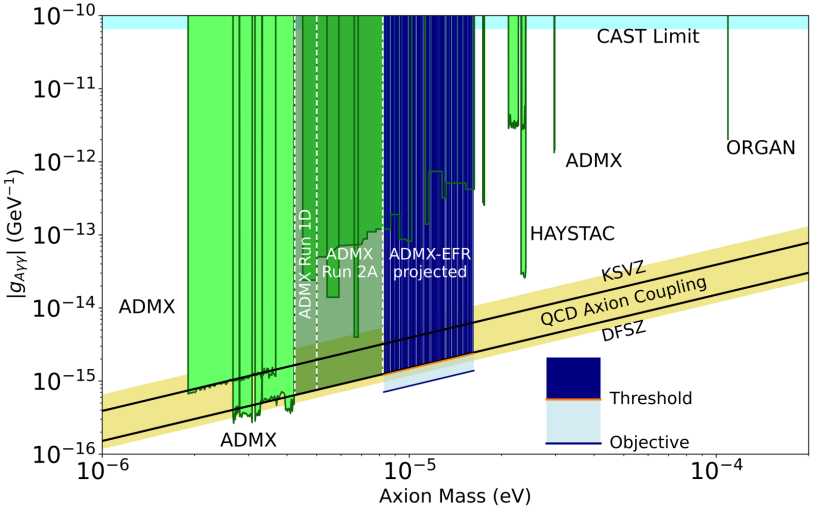
Proposal: Dark Wave Laboratory

- We propose that Fermilab provide a facility able to host several small scale and at least one larger scale axion search experiment.
- We will begin by installing the 9.4 Tesla MRI magnet selected for the ADMX-EFR experiment. This magnet is significantly larger than needed for the ADMX-EFR detector alone and, with careful planning, may host one or more smaller additional experiments.
- The cryogenic system and magnetic shielding will also be planned to allow for additional experiments.
- The Dark Wave Lab will include shop, assembly and testing areas and will have robust, reliable infrastructure for operating cryogenic equipment.
- A mechanism will be put in place for proposal of new experiments to share space in the magnet.
- Over time, responding to identified needs, additional magnets and cryostats will be installed in the Dark Wave Lab.

ADMX-EFR and its 9.4 Tesla MRI Magnet

- ADMX-EFR is the proposed next step for ADMX collaboration after currently operating ADMX-G2 experiment at U. Washington.
- Design studies and magnet testing funded by DOE Dark Matter New Initiatives program in 2019-2025.
- Will use an 18-cavity array with coherent signal combining to scan for QCD axion in 2-4 GHz range (8.3-16.5 μeV in mass)
- See talk by Carosi in this Workshop.





9.4 Tesla MRI Magnet from University of Illinois, Chicago

- ADMX-EFR will reuse a 9.4 Tesla, 800 mm bore MRI magnet currently at University of Illinois Chicago medical center. Was world's highest field whole-body MRI magnet when installed in 2003.
- Current status: final sign off by Fermilab and UIC purchasing and legal departments complete. Rigging plans being reviewed. Preparing for magnet move in late May/ Early June.
- Magnet is currently warm and at zero field. We will reinstall at Fermilab and ramp to full field as a test of magnet reliability.
- An opportunity to do axion physics before start of ADMX-EFR.

	ADMX-G2 Magnet	ADMX-EFR Magnet
Peak Field	7.6 T	9.4 T
Bore diameter	530 mm	800 mm
Magnet length	1117 mm	3100 mm
Cryostat diameter	1295 mm	2580 mm
Stored Energy	16.5 MJ	140 MJ
Weight	6 tons	45 tons
Helium consumption	3 liters/ hour	0.35 liters/hour
Current	204 Amps	220 Amps
Persistent current	No	Yes
Orientation	Vertical	Horizontal
Manufacturer	Wang NMR	GE Medical Systems
Manufacture date	1993	2003

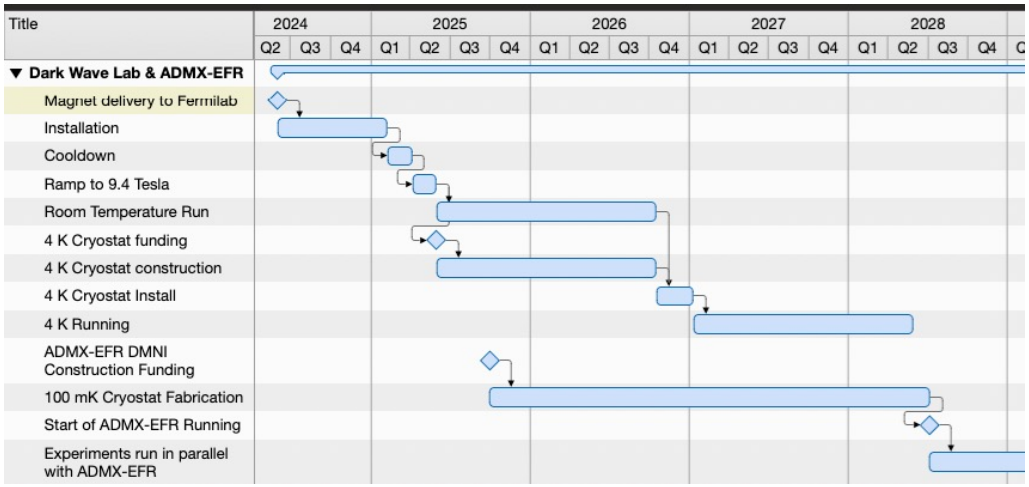
Site for Dark Wave Lab: PW8 Hall

- Fermilab cleared out the PW8 hall for use by ADMX-EFR.
- Had been used for storage last 25 years after discovery of Tao neutrino in DONUT experiment.
- 13,000 square ft available space including adjacent HIL service building— enough for multiple magnets plus significant testing facilities, office and meeting space.
- Could benefit from renovation. Focusing now on putting in reliable services such as helium recovery, chilled water, electrical power.
- 9.4 Tesla solenoid will arrive this summer.
- Tours available on Tuesday afternoon.

Notional Schedule for Dark Wave Lab Operations

- 9.4 Tesla solenoid delivery to Fermilab late May/ Early June 2024.
- ~ 1 year to commission magnet.
- **Potential to run room-temperature pilot experiments in 2025-2026.**
- If funded, a **4-Kelvin cryostat could be available in 2027,** enabling much more sensitive experiments.

preliminary schedule concept



- ADMX-EFR project includes large 100-mK cryostat, which could be ready as soon as 2028 (depends on on DMNI funding decision). May allow space for one or more additional experiment packages to run in parallel with ADMX-EFR.
- Would make sense to add additional magnet and cryostat to Dark Wave Lab in ~2030?

What outcomes are we hoping for from this meeting?

- Assessment of community interest in common facilities.
  - What experiments would likely be proposed and what facilities are needed for them?
  - We ask for your help writing white paper summarizing what we learn here.
- Identify best near-term uses (2025- 2028) for 9.4 Tesla MRI magnet with bore at room temperature or 4 kelvin.
- Form new experiment collaborations & expand the field of potential Dark Wave Lab users.
  - There are quite a few interesting experiment ideas in this field that are not yet being seriously pursued. More good ideas than people or funding.
  - Theorists meet experimentalists- maybe someone will work on your idea.

Discussion Groups

- Many opportunities at this meeting for informal discussions.
- Due to the number of people who registered, we think it will be useful to have more focused breakout sessions on specific topics:

1. Low Frequency <700 MHz
2. Mid Frequency 0.7-10 GHz.
3. Dielectric disk experiments and broadband >10 GHz
4. Quantum sensors and amplifiers
5. Magnets and Cryogenics
6. Additional topics welcome.

- Best location for small groups to meet is the 2nd floor dining room above the atrium where we will be having dinner today. This is a public access area.
- We also have a number of meeting rooms reserved on the upper floors of the building. Better for larger groups or if you want to show slides. Ask Andrew Sonnenschein if you want one of these rooms for your group.

Questions for Discussion Groups

- What is the Mass/ frequency region you are trying to address?
- What are requirements for your experiment?
  - Magnetic field strength and volume
  - Operating temperature?
  - Are there opportunities for early stage prototypes that could run at room temperature or 4 kelvin?
  - Types of sensors and readout electronics needed. Is a low field region needed for sensors?
  - DAQ and data storage needs.
- What support from the lab would be needed to develop experiment? E.g. engineers and techs for integration of experiment package into magnet and cryostat. Test facilities?
- Who is working on this concept?
- Potential funding sources?
- Notional timeline for prototypes and eventual experiment.

Note Taking

- We would like to record notes that will be useful for summarizing discussions in the closeout session at 4 pm on Tuesday afternoon and later writing a white paper on Dark Wave Lab.
- Suggest appointing one person in each discussion group as note keeper.
- We may ask you to summarize your discussions during Tuesday afternoon closeout.
- Started a google doc to accumulate your notes: https://docs.google.com/document/d/1SCLGFNXNWfVeUGqbE44Fml-F2Tahj1dPtvpAZIIX6Ow/edit?usp=sharing

Available Meeting Rooms for Discussions

- For small groups, there are convenient lounge areas in cafeteria and tables on 2nd floor of atrium.
- We don't have any breakout rooms reserved on Monday for the 3:30-4:30 discussion groups, so the cafeteria (1st floor atrium) or 2nd floor dining room are best option.
- Rooms below are reserved on Tuesday. To access these upstairs meeting rooms, you should have someone in your group with a Fermilab badge to be an escort and tap into the ID scanner in the elevator.

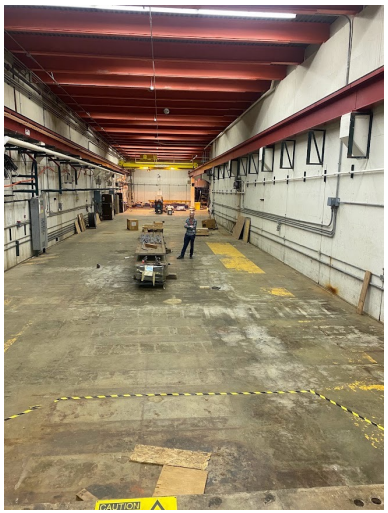
Tuesday, 4/16 - Additional rooms for Breakout Sessions:

West Wing (WH10NW) – 1:30 pm – 5:00 pm
THD Virtual Reality (WH3SE) – 1:30 pm – 3:30 pm
THD Conjectorium Room (WH3E) – 4 pm – 5 pm
Hornets Room (WH8X) – All Day
The Black Hole (WH2NW) – 1:00 pm – 4:00 pm
FS Req Room (WH4NW) – 1:30 pm – 3:30 pm

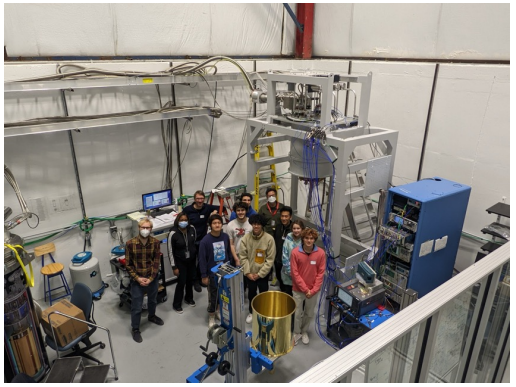
Tours– Will Give More Info Tues

- Limited capacity for tours- we have 2 buses, each with 12 person capacity– about 24 people can see each location.
- Tours are in parallel with day 2 breakout discussion groups- will need to choose between tours and participation in some discussions.
- PW8– Future location of 9.4 Tesla solenoid. Tour guide: Rick Tesarek.
    - Currently an empty building - magnet scheduled for late May delivery
- Axion detector lab in SiDET Lab . Guides: Aaron Chou, Stefan Knirck.
    - Will see ADMX and sensor test stands and BREAD prototype.
- SQMS Quantum Sensor testing facility “Quantum Garage”. Guides: Bianca Giaccone, Raphael Cervantes.

PW8



Axion detector lab @ SiDET



Quantum Garage

Fermilab