



Physics Opportunities at a Beam Dump Facility at PIP-II and Beyond

Matt Toups
Wed 10 May 2023

Welcome

It is our pleasure to welcome you to Fermilab for this timely workshop on “Physics Opportunities at a Beam Dump Facility at PIP-II and Beyond”



Matt Toups
Fermilab



Jae Yu
UT Arlington



Juan Estrada
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Jacob
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Goals of Workshop

Produce a whitepaper delineating the physics case for a beam dump facility at PIP-II

- To be posted on the arXiv soon after the workshop

This whitepaper is intended to serve as input for ongoing strategic planning processes:

- HEP P5 process (immediate)
- Fermilab strategic planning (near term)
- Fermilab Accelerator Complex Evolution (ACE) (longer term)

Your input at this workshop will help define the physics case for a beam dump program at Fermilab and the corresponding requirements for future upgrades to the Fermilab accelerator complex

Physics Opportunities at the Beam Dump Facility in PIP-II and beyond

author¹

¹Univ

May 10, 2023

Abstract

Explore the physics opportunities at PIP-II beam dump facilities.

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HEP P5 Process

Accelerator-based dark sector searches at the intensity frontier were identified as a major HEP priority at the last Snowmass

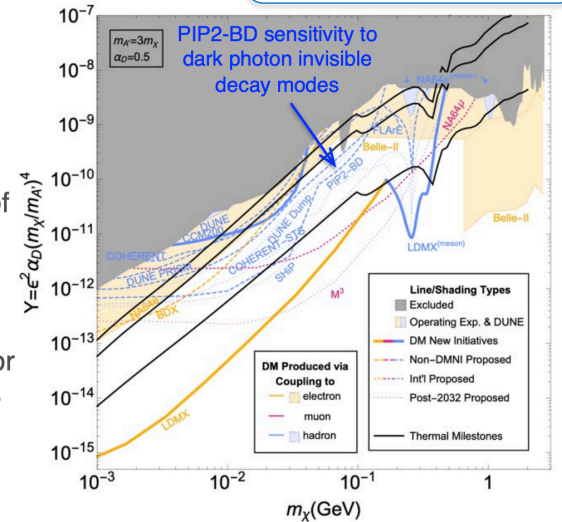
- See Stefania’s [talk](#) at the BNL P5 town hall

Proton beam dump dark sector searches in particular were [highlighted](#) as part of Fermilab’s future program at the Fermilab P5 town hall

This workshop will outline the potential scope of such a physics program at Fermilab

High Intensity Proton Beam to Explore Dark Matter Portals

- ACE will also enable excellent opportunities for accelerator-based dark sector searches at modest cost and scale
 - At high energy, proton beam dump searches can probe new parameter space making use of existing accelerator infrastructure and experiments
 - **At low energy**, proton beam dump searches can form part of a new neutrino and dark sector facility that leverages the full power of the PIP-II beam (1-8 GeV beam)



Fermilab Strategic Planning

PIP-II linac now under construction and will be completed by the end of the decade

- Can provide among the highest-power ~GeV proton beams in the world

Experimental program currently “on the books” in the PIP-II era makes use of only ~1% of the protons PIP-II can provide

- Yes, this Includes DUNE!

This workshop will make the physics case for a beam dump program, which can leverage the excess capacity provided by PIP-II

DRAFT LONG-RANGE PLAN

| | | FY18 | FY19 | FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29 | FY30 |
|--------------|---------|-------|-------|-------|-------|-------|-------|-------|-------|--------|---------------|------|------|------|
| LBNF / | SANFORD | | | | DUNE | DUNE | DUNE | DUNE | DUNE | DUNE | DUNE | DUNE | DUNE | DUNE |
| PIP II | FNAL | | | | LBNF | LBNF | LBNF | LBNF | LBNF | LBNF | LBNF | LBNF | LBNF | LBNF |
| NuMI | MI | INERv | INERv | OPEN | OPEN | 2x2 | 2x2 | 2x2 | 2x2 | 2x2 | See Note 4 | | | |
| | | NOvA | NOvA | NOvA | NOvA | NOvA | NOvA | NOvA | NOvA | NOvA | | | | |
| BNB | B | BooN | BooN | BooN | OPEN | OPEN | OPEN | OPEN | OPEN | OPEN | LONG SHUTDOWN | | | |
| | | CARUS | CARUS | CARUS | CARUS | CARUS | CARUS | CARUS | CARUS | ICARUS | | | | |
| | | SBND | SBND | SBND | SBND | SBND | SBND | SBND | SBND | SBND | | | | |
| Muon Complex | | g-2 | g-2 | g-2 | g-2 | g-2 | g-2 | | | | LONG SHUTDOWN | | | |
| | | Mu2e | Mu2e | Mu2e | Mu2e | Mu2e | Mu2e | Mu2e | Mu2e | Mu2e | | | | |
| SY 120 | MT | FTBF | FTBF | FTBF | FTBF | FTBF | FTBF | FTBF | FTBF | FTBF | LONG SHUTDOWN | | | |
| | MC | FTBF | FTBF | FTBF | FTBF | FTBF | FTBF | FTBF | FTBF | FTBF | | | | |
| | NM4 | OPEN | SpinQ | SpinQ | SpinQ | SpinQ | SpinQ | SpinQ | SpinQ | OPEN | | | | |
| LINAC | MTA | | | | ITA | ITA | ITA | ITA | ITA | ITA | | | | |

Construction / commissioning
 Run
 Subject to further review
 Shutdown

Capability ended
 Capability unavailable

Fermilab Accelerator Complex Evolution (ACE)

Plan for the next major upgrade of the Fermilab accelerator complex, seeking support from P5

- See Alexander Valishev's [talk](#) at the FNAL P5 town hall

Several options have been studied for the Booster replacement

- See Brenna Flaugh's [talk](#) next

Output of this workshop will feed into the process for defining the physics requirements for the accelerator design

- [ACE Science Workshop](#) (6/14-6/15)

The Fermilab Accelerator Complex Evolution (ACE)

ACE has two components

- **Upgrades to the Main Injector and target station** will allow DUNE to achieve world-leading results on an accelerated schedule
- **A Booster replacement** will
 - Provide a robust and **reliable** platform for the future of the Fermilab accelerator complex
 - Ensure high intensity for DUNE Phase II → CP Violation *measurement*
 - Enable the **capability** of the complex to serve precision experiments and searches for new physics with beams from 1-120 GeV
 - Create the **capacity** to adapt to new discoveries
 - Supply the high-intensity proton source necessary for future multi-TeV accelerator research



Capability
Capacity
Reliability

5

03/22/2023 Fleming I Fermilab Program

 Fermilab

Beam Dump Opportunity at the PIP-II Linac

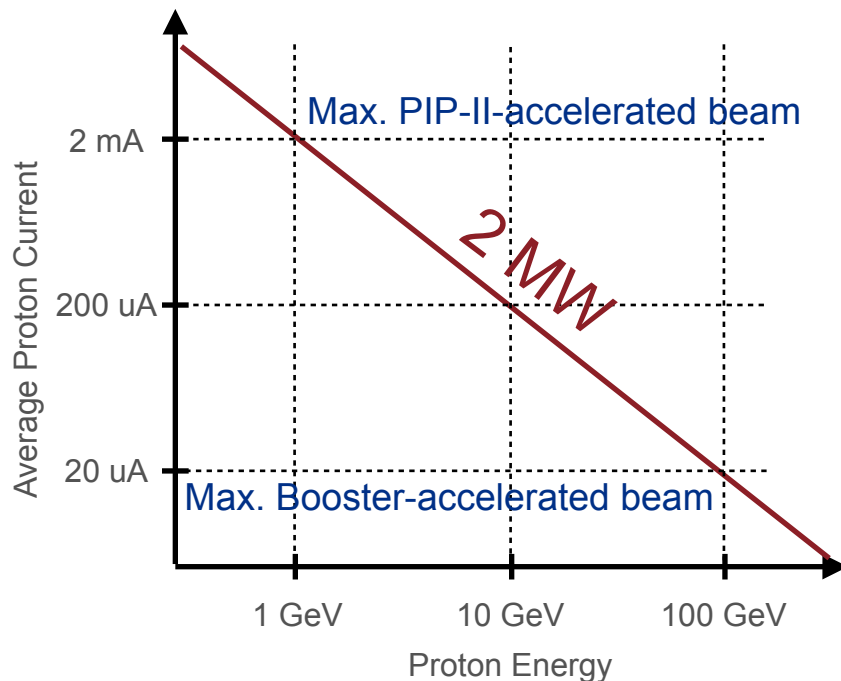
PIP-II linac able to provide significantly more beam than Booster is capable of accelerating

- Can simultaneously provide MW beam power at 800 MeV and MW beam power at 120 GeV

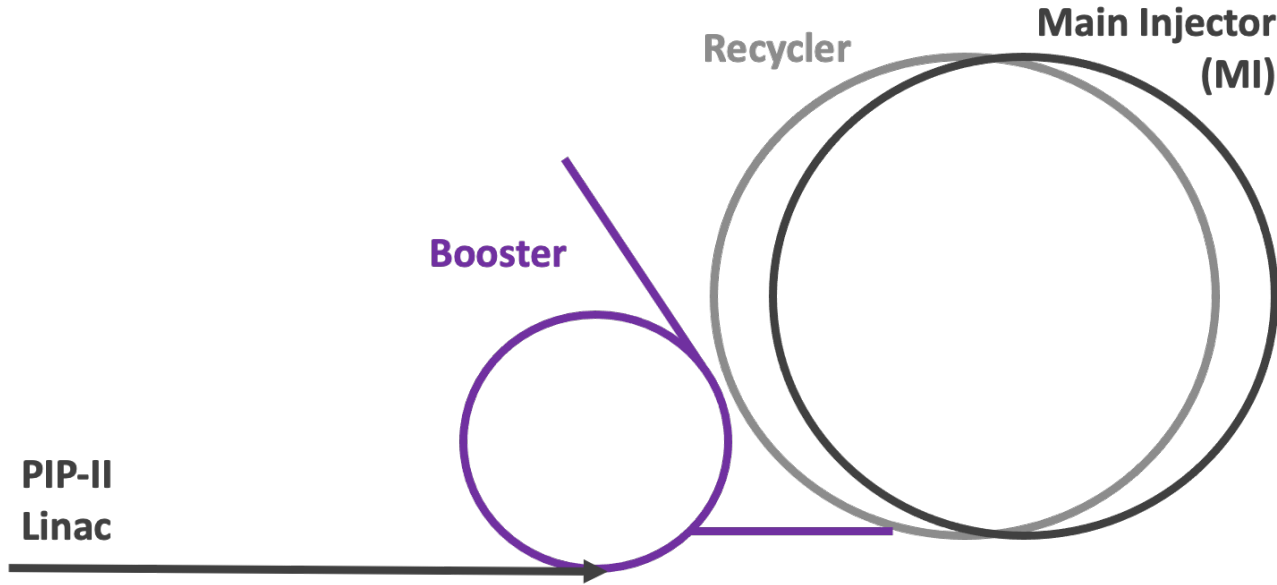
Forward-looking design of the PIP-II linac includes provisions that facilitate future upgrades, including

- CW multi-user mode of operation
- Increase in beam energy to 1 GeV and beyond
- Stub in the beam transfer line to the Booster to provide beam to other users

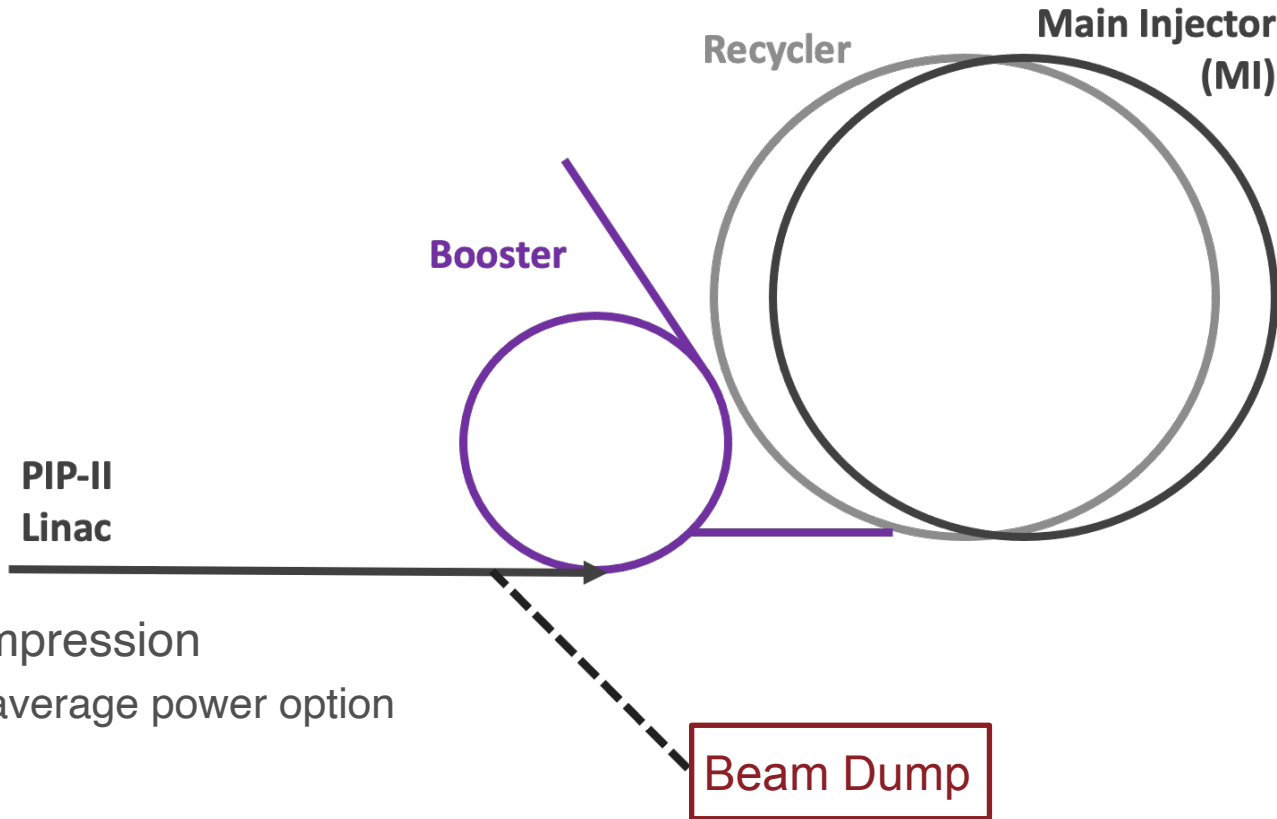
Excellent opportunity for establishing a high-power proton beam dump facility at Fermilab



Default Accelerator Configuration



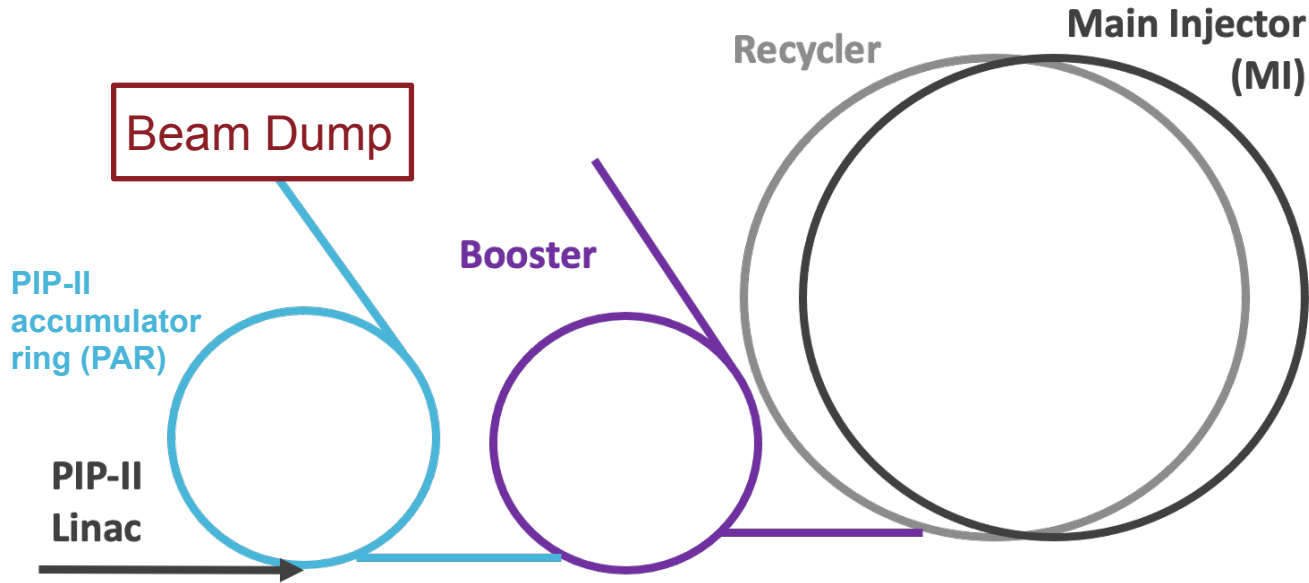
Configuration 1: PIP-II only



No beam compression

- Highest average power option

Configuration 2: PIP-II Accumulator Ring (PAR)

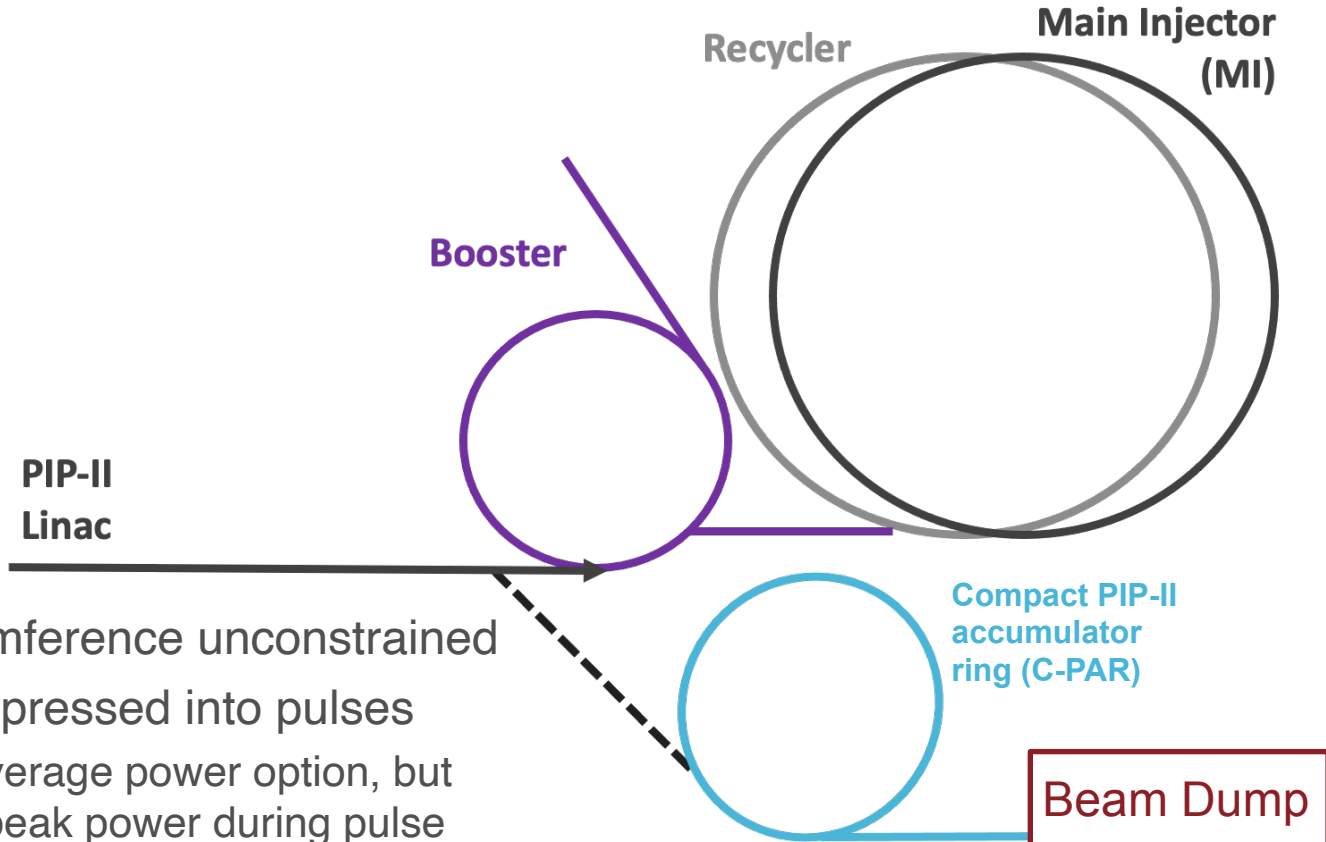


PAR circumference matched to Booster to allow for injection

Beam is compressed into pulses

- Lower average power option, but higher peak power during pulse

Configuration 3: Compact PIP-II Accumulator Ring (C-PAR)

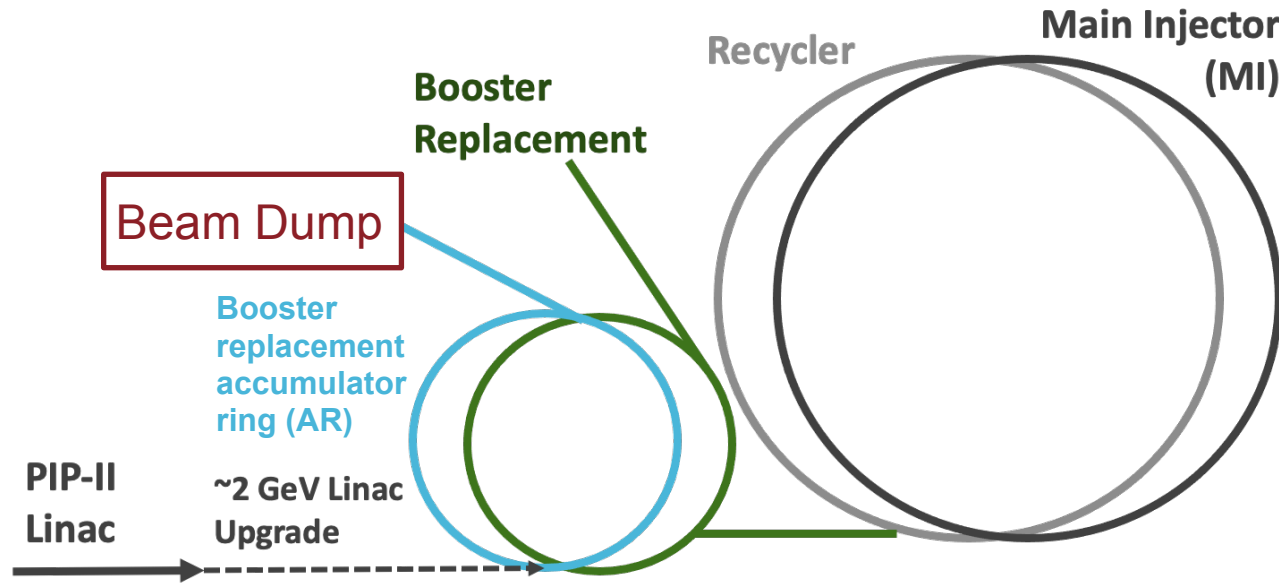


C-PAR circumference unconstrained

Beam is compressed into pulses

- Lower average power option, but highest peak power during pulse

Configuration 4: Booster Replacement Accumulator Ring (AR)



AR circumference matched to Booster Replacement to allow for injection

Beam is compressed into pulses

- Second highest average power option, and also has high peak power during pulse

Not available until timescale of Booster Replacement

Outline of the Workshop

Wednesday afternoon

- Accelerator options
- Theory directions

Thursday morning

- Experiment opportunities and ideas

Thursday afternoon

- Breakout sessions / white paper drafting

Friday morning

- Workshop summaries and farewell

Friday afternoon & Saturday morning

- DAMSA proto-collaboration meeting

| | | |
|-------------------|--|-------|
| 1:00 PM → 2:30 PM | Welcome & Opening Session - Curia II (WH2X0): Introduction Welcome & Opening Session Convener: Juan Estrada Vigil (FNAL) | |
| 1:00 PM | Welcome and workshop goals Speaker: Jaehoon Yu (University of Texas at Arlington) | 🕒 10m |
| 1:10 PM | Opportunities for Beam Dump facilities in the PIP-II and ACE eras Speaker: Brenna Flaughter (Fermilab) DM-BD-ACE.pdf DM-BD-ACE.pptx | 🕒 20m |
| 1:30 PM | PIP-II and the PIP-II Accumulator Ring Speaker: William Pellico (FNAL) | 🕒 30m |
| 2:00 PM | Fermilab Accelerator Complex Upgrades Beyond PIP-II Speaker: Jeffrey Eldred (Fermilab) | 🕒 30m |
| 2:30 PM → 3:00 PM | coffee break | 🕒 30m |
| 3:00 PM → 6:00 PM | Welcome & Opening Session - Curia II (WH2X0): Theory Directions Welcome & Opening Session Convener: Jacob Zetlemoyer (Fermilab) | |
| 3:00 PM | Dark sectors at PIP2-BD Speaker: Bhaskar Dutta (Texas A&M University) | 🕒 30m |
| 3:30 PM | Millicharged particles Speaker: Zhen Liu (University of Minnesota) | 🕒 30m |
| 4:00 PM | Other ideas Speaker: Roni Harnik (FNAL) | 🕒 30m |
| 4:30 PM | Panel Discussion | 🕒 30m |

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| 9:00 AM → 10:30 AM | Opportunities for Experiments - Curia II (WH2XO): Opportunities by Energy Threshold | |
| 9:00 AM | Opportunities at eV Speaker: Juan Estrada Vigil (FNAL) | ⌚ 20m |
| 9:20 AM | Opportunities at keV Speaker: Jacob Zetzmeyer (Fermilab) | ⌚ 20m |
| 9:40 AM | Opportunities at MeV Speaker: Jaehoon Yu (University of Texas at Arlington) | ⌚ 20m |
| 10:00 AM | Coffee Break | ⌚ 30m |
| 10:30 AM → 12:30 PM | Opportunities for Experiments - Curia II (WH2XO): Experimental ideas Convener: Juan Estrada Vigil (FNAL) | |
| 10:30 AM | CCDs Speaker: Brenda Cervantes vergara | ⌚ 15m |
| 10:45 AM | Cryogenic Detectors for Low Threshold Dark Sector Searches Speaker: Rupak Mahapatra (Texas A&M University) | ⌚ 15m |
| 11:00 AM | DAMSA Experiment Speaker: Jaehoon Yu (University of Texas at Arlington) | ⌚ 15m |
| 11:15 AM | nuBDXDRIFT Speaker: Daniel Snowden-Hft (Occidental College) | ⌚ 15m |
| 11:30 AM | PIP2-BD Speaker: Jacob Zetzmeyer (Fermilab) | ⌚ 15m |
| 11:45 AM | LA-TPC technology Speaker: Yun-Tse Tsai (SLAC) | ⌚ 15m |
| 12:00 PM | CCM@FNAL Speaker: Richard Van de Water (LANL) | ⌚ 15m |
| 12:15 PM | Organization of writing groups Speaker: Juan Estrada Vigil (FNAL) | ⌚ 15m |
| 12:30 PM → 2:00 PM | Lunch | ⌚ 1h 30m |
| 2:00 PM → 5:30 PM | Working groups / writing: breakout | |

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Organizational
talk by Juan

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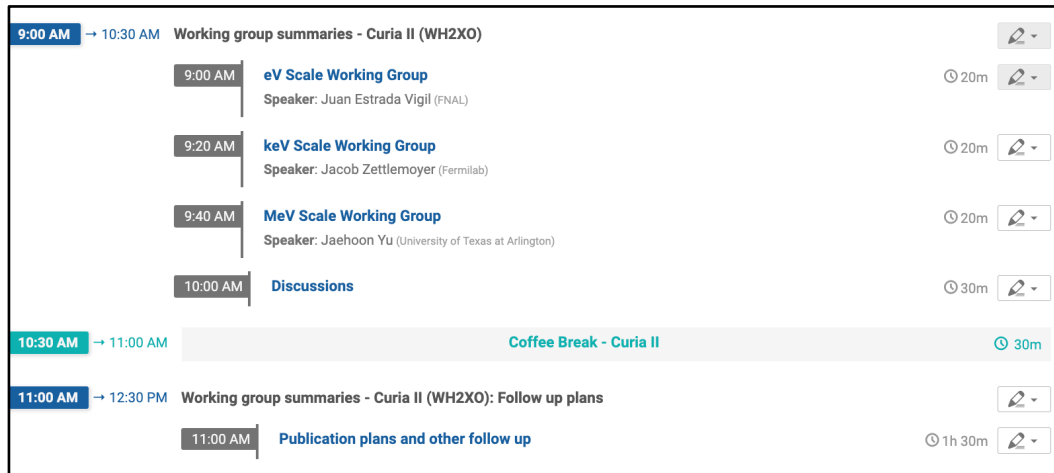
- Breakout sessions / white paper drafting

Friday morning

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Friday afternoon & Saturday morning

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A screenshot of a workshop agenda interface. The agenda is organized into time slots. The first slot is from 9:00 AM to 10:30 AM, titled 'Working group summaries - Curia II (WH2XO)'. It contains four sub-items: 'eV Scale Working Group' (9:00 AM) by Juan Estrada Vigil (FNAL), 'keV Scale Working Group' (9:20 AM) by Jacob Zetlemoyer (Fermilab), 'MeV Scale Working Group' (9:40 AM) by Jaehoon Yu (University of Texas at Arlington), and 'Discussions' (10:00 AM). The second slot is from 10:30 AM to 11:00 AM, titled 'Coffee Break - Curia II'. The third slot is from 11:00 AM to 12:30 PM, titled 'Working group summaries - Curia II (WH2XO): Follow up plans', containing 'Publication plans and other follow up' (11:00 AM). Each item has a duration and an edit icon.

| Time | Activity | Speaker | Duration |
|---------------------|---|---|----------|
| 9:00 AM → 10:30 AM | Working group summaries - Curia II (WH2XO) | | |
| 9:00 AM | eV Scale Working Group | Juan Estrada Vigil (FNAL) | 20m |
| 9:20 AM | keV Scale Working Group | Jacob Zetlemoyer (Fermilab) | 20m |
| 9:40 AM | MeV Scale Working Group | Jaehoon Yu (University of Texas at Arlington) | 20m |
| 10:00 AM | Discussions | | 30m |
| 10:30 AM → 11:00 AM | Coffee Break - Curia II | | 30m |
| 11:00 AM → 12:30 PM | Working group summaries - Curia II (WH2XO): Follow up plans | | |
| 11:00 AM | Publication plans and other follow up | | 1h 30m |

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Friday, March 12

| | | |
|--------------------------|--|-------|
| 1:30 PM → 3:30 PM | DAMSA Experiment Concepts - Snake Pit (WH2NE) - zoom link: https://indico.fnal.gov/event/59430/ | |
| 1:30 PM | Introduction and meeting goals Speaker: Jaehoon Yu (University of Texas at Arlington) | ⌚ 30m |
| 2:00 PM | Potential Physics Topics at DAMSA Speaker: Doojin Kim (University of Arizona) | ⌚ 30m |
| 2:30 PM | DAMSA at PIP-II Beam Dump Speakers: Jacob bogenschuetz, Wooyoung Jang (University of Texas at Arlington) | ⌚ 30m |
| 3:00 PM | Discussions | ⌚ 30m |
| 3:30 PM → 4:00 PM | Coffee Break - Snake Pit | ⌚ 30m |
| 4:00 PM → 6:00 PM | DAMSA Experiment Concepts - Snake Pit (WH2NE) - zoom link: https://indico.fnal.gov/event/59430/ : DAMSA Experiment - Organizations and Plans | |

Saturday, March 13

| | | |
|----------------------------|--|--|
| 10:00 AM → 12:30 PM | DAMSA Experiment Concepts - Snake Pit (WH2NE) - zoom link: https://indico.fnal.gov/event/59430/ : DAMSA Experiment - Follow up and Conclusions | |
|----------------------------|--|--|

Meeting Logistics

Plenary sessions will be held in Curia II (this room, WH2XO): [Plenary zoom](#)

The locations of the breakout sessions Thursday afternoon are as follows:

- Comitium (across the hall, WH2XO): [1st parallel zoom](#)
- Oscillatorium (WH13NW): [2nd parallel zoom](#)
- Dark Side (WH6NW): [3rd parallel zoom](#)

DAMSA sessions on 5/12 and 5/13 will be held in the Snakepit (WH2NE)

Coffee breaks:

- 5/10, 3:30 outside One West (WH1W, down the stairs)
- 5/11, 10:30 outside Curia II
- 5/11, afternoon there is a director's coffee break for the lab at around 3 pm during the breakouts
- 5/12, 10:30 outside Curia II
- 5/12, 3:30 outside Snakepit

Google form for workshop dinner on Thursday at 6:30 pm: [Dinner attendance form](#)













Wrap-up

Thank you again for your attendance at this workshop

As a reminder, this meeting is subject to Fermilab's [Statement of Community Standards](#)

Now, let's have a lively and productive meeting!

We are one Fermilab

-  Everyone is worthy of respect
-  Encourage discussion
-  Genuinely listen
-  Collaborate
-  Respect the messenger
-  Have courage
-  Own your voice
-  Be kind
-  Fresh perspectives lead to innovation
-  Encourage others to speak
-  Own it, mistakes happen
-  Share the air