

# The 25<sup>th</sup> international workshop on Neutrinos from Accelerators

## LOCAL ORGANIZING COMMITTEE

Meghna Bhattacharya (Fermilab, USA)  
Lynnean Celmer (Argonne, USA)  
Barnali Chowdhury (Argonne, USA)  
Zelimir Djuric (Argonne, USA)  
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Aleena Rafique (Argonne, USA)  
Nancy Rezek (Argonne, USA)  
Linyan Wan (Fermilab, USA)  
Peter Winter (Argonne, USA)

## WORKING GROUP CONVENERS

**WG1: Neutrino Oscillation Physics**  
Sanjib Agarwalla (Institute of Physics, Bhubaneswar, India)  
Mark Scott (Imperial College, UK)  
Yun-Tse Tsai (SLAC, USA)  
**WG2: Neutrino Scattering Physics**  
Christophe Bronner (ICRR, University of Tokyo, Japan)  
Raul Gonzalez-Jimenez (Complutense University Madrid)  
Elena Gramellini (University of Manchester, UK)  
**WG3: Accelerator Physics**  
Megan Friend (J-PARC/KEK, Japan)  
Sudeshna Ganguly (Fermilab, USA)  
Natalia Milas (ESS, Sweden)  
**WG4: Muon Physics**  
Simon Corrodi (Argonne, USA)  
Gavin Hesketh (UCL, UK)  
Kim Siang Khaw (Shanghai Jiao Tong University)  
**WG5: Neutrino Beyond PMNS**  
Koun Choi (IBS, Korea)  
Julia Harz (Johannes Gutenberg University Mainz, Germany)  
Matheus Hostert (Harvard)  
**WG6: Detectors**  
Claudio Giganti (LPNHE CNRS-IN2P3, Paris)  
Tanaz Mohayai (Indiana University, USA)  
Nishimura Yasuhiro (Keio University, Japan)  
**WG7: Inclusion, Diversity, Equity, Education, & Outreach**  
Ellen Bechtol (UW Madison, USA)  
Nagisa Hiroshima (University of Toyama, Japan)

## SCIENTIFIC PROGRAM COMMITTEE

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Adam Aurisano (University of Cincinnati, USA)  
Jianming Bian (UC Irvine, USA)  
Alain Blondel (University of Geneva, Switzerland)  
Alex Bogacz (Jefferson Lab, USA)  
Walter Bonivento (INFN Cagliari, Italy)  
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Alan D Bross (Fermilab, USA)  
Chris Densham (STFC, UK)  
Francesca Dordel (INFN Cagliari, Italy)  
Marcos Dracos (IN2P3, France)  
Tord Ekelöf (Uppsala University, Sweden)  
Mamad Eshraqi (ESS, Sweden)  
Yuki Fujii (Monash, Australia)  
Maury Goodman (Argonne, USA)  
Craig Group (University of Virginia, USA)  
Miao He (IHEP, China)  
Patrick Huber (Virginia Tech., USA)  
Natalie Jachowicz (University of Gent, Belgium)  
Kyung Kwang Joo (Chonnam Natl. U., Korea)  
Ernesto Kemp (UNICAMP, Brazil)  
Yoshitaka Kuno (Osaka University, Japan)  
MyeongJae Lee (Sung Kyun Kwan University, Korea)  
Francesca Di Lodovico (Queen Mary University of London, UK)  
Danny Marfatia (University of Hawaii, USA)  
Marco Martini (IPSA and Sorbonne Université, France)  
Neil McCauley (Liverpool, UK)  
Jorge Morfin (Fermilab, USA)  
Hélio da Motta (CBPF, Brasil)  
Yuri Oksuzian (Argonne, USA)  
Angela Papa (PSI, University of Pisa)  
Albert De Roeck (CERN, Switzerland)  
Carsten Rott (University of Utah, USA)  
Davide Sgalaberna (ETH Zurich, Switzerland)  
Ian Shoemaker (Virginia Tech, USA)  
Kim Siyeon (Seoul National University, Korea)  
Paul Soler (University of Glasgow, UK)  
Jian Tang (Sun Yat-sen University, China)  
Francesco Terranova (University of Milano-Bicocca, Italy)  
Frederik Wauters (Mainz, Germany)  
Un-ki Yang (Seoul National University, Korea)  
Katsuya Yonehara (Fermilab, USA)  
Jonghee Yoo (Seoul National University, Korea)

## WG3 Introduction: Accelerator

Megan Friend, Natalia Milas, Sudeshna Ganguly

NuFACT 2024,  
Lemont, Illinois, USA  
September 16, 2024

# Main Highlights

- **Accelerators are essential for our physics goals**
- **Ongoing improvements and new facilities are crucial for enhancing our results**

# Key Topics to be Addressed

- **Exploring New Target Technologies**

- *Can fluidized powder or granular targets revolutionize our approach?*

- **Advancing Accelerator Capabilities**

- *What is the roadmap for 2MW and beyond?*

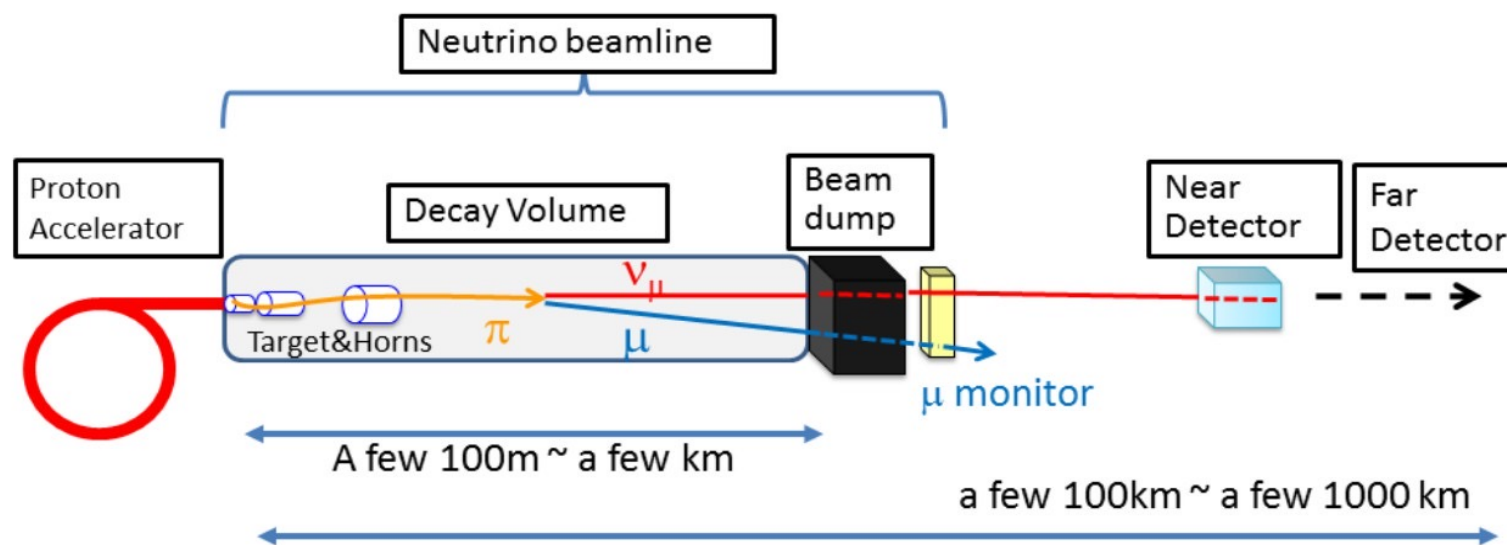
- **Shaping the Future of Neutrino Research**

- *Where do we go after DUNE, T2K, and ESSnuSB?*

- **Leveraging Synergies in Physics**

- *How can collider, neutrino, and muon research intersect?*

# Accelerator for Neutrino Experiments



**Conventional and upcoming world-class neutrino beams require:**

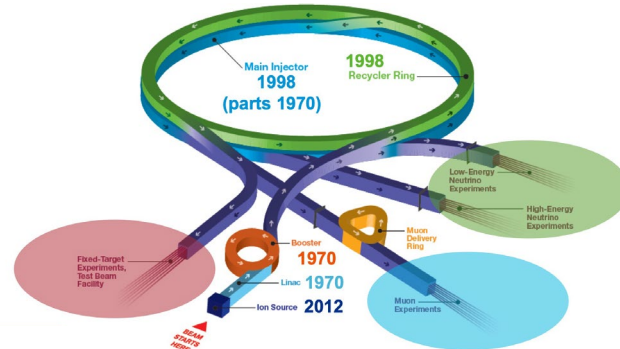
- **High-intensity proton beam**
  - Effective manipulation of high-power beams
  - Stable operation through commissioning
- **Radiation-hard equipment**
  - Durable targetry and monitoring systems
- **Comprehensive beamline modeling**
  - In-depth understanding of beamline dynamics
- **Synergies between neutrino and muon beamlines**

# Summary of Talks

Monday	Tuesday	Wednesday	Thursday
Parallel 1 13:45 session	Parallel 2 13:45 session	Plenary 08:30 session	Parallel WG 1X3 13:45 session
Poster 16:05 session	Parallel WG 3X4 16:15 session		

# WG3 Plenary Talks – Wednesday. 8:30 Session

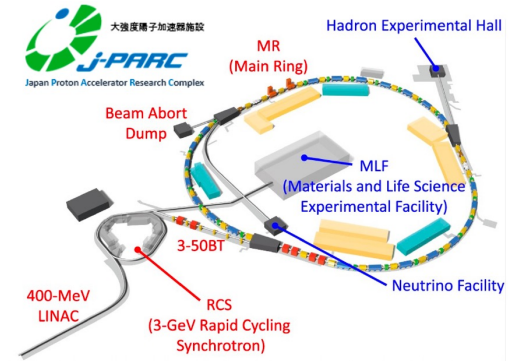
- Status and future of accelerator facilities around the world
- Four invited plenary talks



## Fermilab Accelerator Plans and Schedule

## J-PARC Accelerator and Neutrino Beamline Plans and Schedule

## ESSnuSB Status



## Muon Collider R&D

**What are neutrinos?**

- The lightest fundamental particle
- Elusive and difficult to detect
- Essential – they are everywhere
- Travel as fast as light (almost)
- Three different flavours
- The forces oscillate

**Neutrino Discoveries and Nobel Prizes**

- Pauli 1930/1945 (prediction of the neutrino)
- Cowan & Reines 1956/1995 (discovery of the neutrino)
- Davis and Koshiba 2002 (solar & cosmic neutrinos)
- Kajita & McDonald 1998/2005/2015 (neutrino oscillations)

**What is Matter and Antimatter?**

- There were equal quantities after the Big Bang
- But there is 'no' antimatter now. Why?
- Symmetry was broken. How?
- Otherwise we would not exist.

**... so why was the symmetry broken?**  
= ESSnuSB with the help of ESSvSB+ will provide the answer!

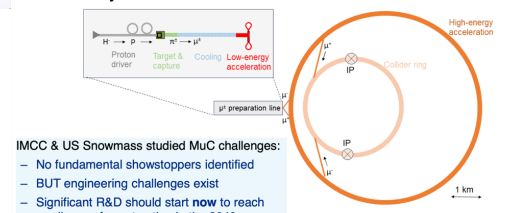
**Layout for ESSvSB+**

**Timeline and Costs**

**Advantages of ESSvSB+**

- ESS Proton Linac accelerates pulses at 5-6 MW
- 3 MW pulses for ESSvSB+ compared to the accelerator ring
- Proton pulses hit the targets producing pions that are focused forward
- More muons generated from more decays at 1.5 GeV/200 ns pulse measured in Detectors #1 and #2 for a cross-section and stable neutrino sources, and muon and positron neutrinos generated from.

- Goal is to get to **10 TeV center-of-mass energy**
- Two approaches: Staging in **energy** (3 TeV to 10 TeV) or in **luminosity**



IMCC & US Snowmass studied MuC challenges:

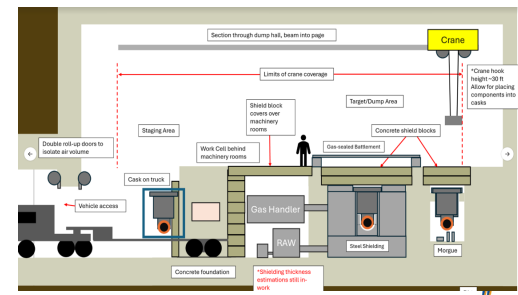
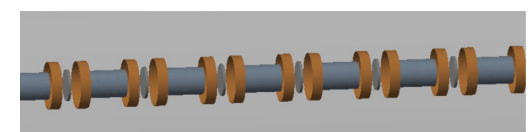
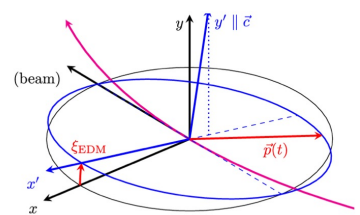
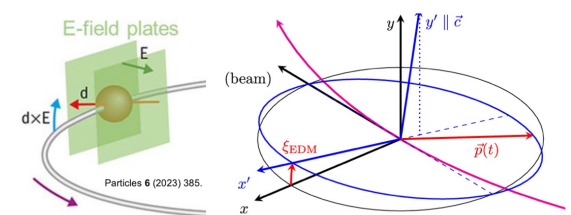
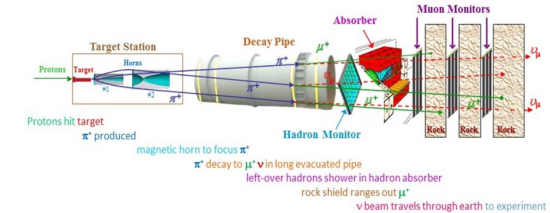
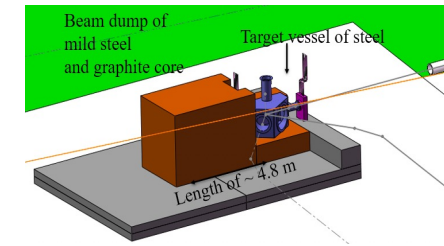
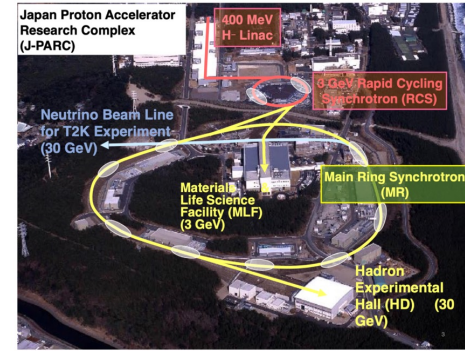
- No fundamental showstoppers identified
- BUT engineering challenges exist
- Significant R&D should start **now** to reach readiness of construction in the 2040s

# WG3 Parallel Talk Highlights

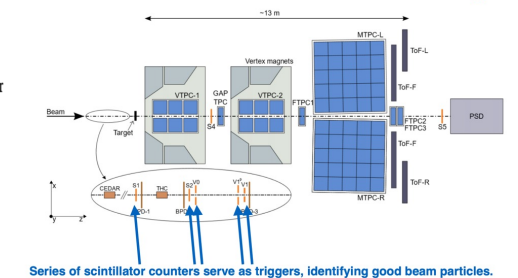
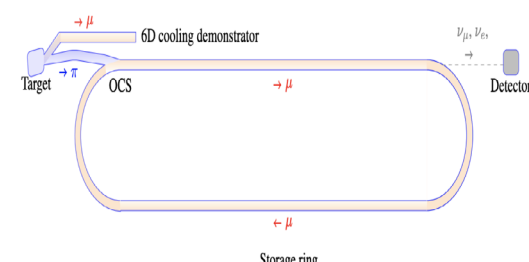
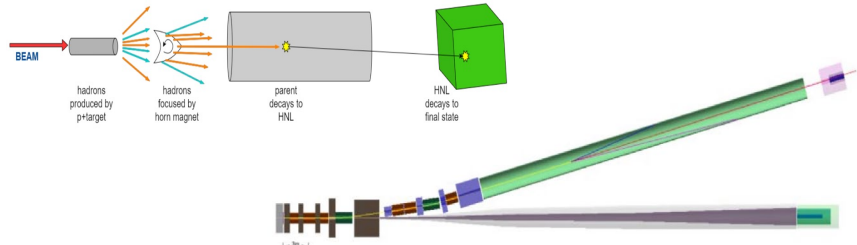
## Accelerator & beamline/target upgrades

## Advanced R&D and simulation efforts

## Hadron production & neutrino experiments



NA61/SHINE Experiment



# Plenary- Wednesday

# WG3 Agenda

	<b>Fermilab accelerator plans and schedule</b>	<i>Robert Zwaska</i>
	APS- Building 402, Argonne National Laboratory	08:30 - 09:00
09:00	<b>J-PARC accelerator and neutrino beamline plans and schedule</b>	<i>Tetsuro Sekiguchi et al.</i>
	APS- Building 402, Argonne National Laboratory	09:00 - 09:30
	<b>ESSnuSB status</b>	<i>George Fanourakis</i>
	APS- Building 402, Argonne National Laboratory	09:30 - 10:00
10:00	<b>Muon collider R&amp;D</b>	<i>Diktys Stratakis</i>
	APS- Building 402, Argonne National Laboratory	10:00 - 10:30

Parallels		minutes	title	speaker
Monday	Parallel 1 1345 - 1445 (60 min)	20	Upgrade of J-PARC magnetic horn system towards 1.3 MW beam	Tetsuro Sekiguchi
		20	Updates and Lessons Learned from NuMI Beamline at Fermilab	Don Athula Wickremasinghe
		20	Update on the Target Station and Beamlines of MELODY (2024)	Nikolaos Vassilopoulos
	Parallel 2 1345 - 1445 (60 min)	20	The ENUBET monitored neutrino beam and its implementation at CERN	Fabio Pupilli
		20	High-Power Targetry R&D for Next-Generation Accelerator Target Facilities	Abe Burleigh
		20	The Fermilab Facility for Dark Matter Discovery (F2D2): A Conceptual PIP-II Beam Stop Facility for Dark Sector Physics	Jonathan Williams
Tuesday	Parallel WG3X4 1615- 1735 (60 min)	20	Update on the design of the 6D Muon Cooling Demonstrator	Rohan Kamath
		20	Simulation and design of the neutrinos from STORed Muons (nuSTORM) experiment	Rohan Kamath
		20	High-Power Targetry for Muon Production	Michael Hedges
Thursday	Parallel WG1X3 1345 - 1505 (80 min)	20	Collimated muon beam proposal for probing neutrino charge-parity violation	Alim Ruzi
		20	NA61/SHINE measurements for Neutrino experiments	Laura Fields
		20	Hadron Production Measurements with EMPHATIC	Robert Chirco
		20	Improving Neutrino Experiment Physics with Hadron Production Data	Leonidas Aliaga Soplin



Enjoy the upcoming talks on accelerator physics!

# Backups

# WG3 Plenary Talks – Wednesday. 8:30 Session

- Status and future of accelerator facilities around the world
- Four invited plenary talks

## • Fermilab Accelerator Plans and Schedule:

- Overview of Fermilab's current and upcoming accelerator plans
- Detailed schedule for accelerator upgrades and maintenance
- How these plans support ongoing and future scientific experiments

## • J-PARC Accelerator and Neutrino Beamline Plans and Schedule:

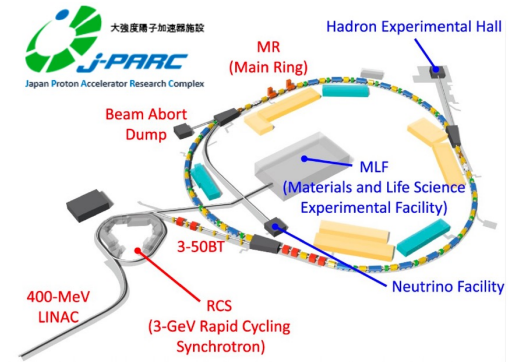
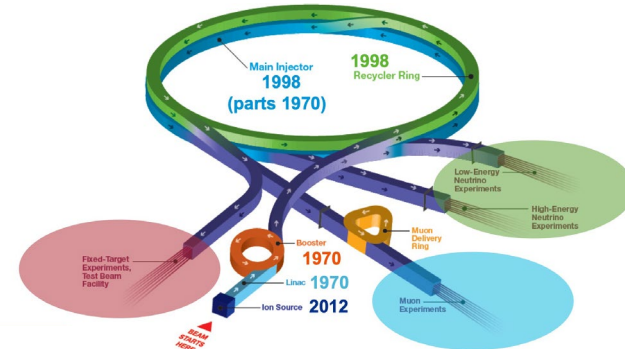
- Status of neutrino beam power upgrade at J-PARC
- Operation after major upgrades and prospects

## • ESSnuSB Status:

- Update on accelerator and target station
- Physics reach of the project

## • Muon Collider R&D:

- Latest developments in Muon Collider research
- Focus on R&D efforts



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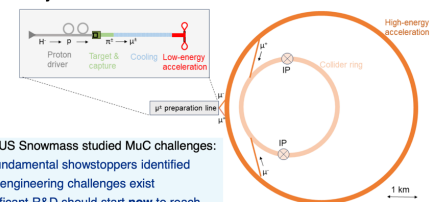
**Layout for ESSnuSB+**

**Timeline and Costs**

**Advantages of ESSnuSB+**

- ① ESS Proton Linac accelerates pulses at 5-6 MW
- ② 3 MW pulses for ESSnuSB compressed in the accumulator ring
- ③ Proton pulses hit the targets producing pions that are focused forward
- ④ Muon neutrinos generated from muon decay at 1.5 GeV/300 ns are measured in Detectors #1 and #2 for cross-section and particle lifetime studies, and muon and electron neutrinos generated from

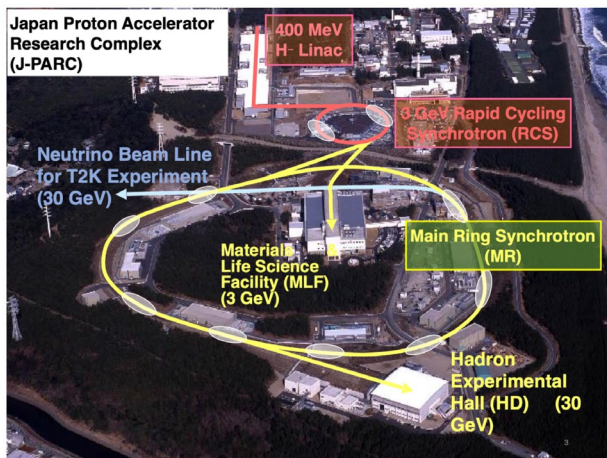
- Goal is to get to **10 TeV center-of-mass energy**
- Two approaches: Staging in **energy** (3 TeV to 10 TeV) or in **luminosity**



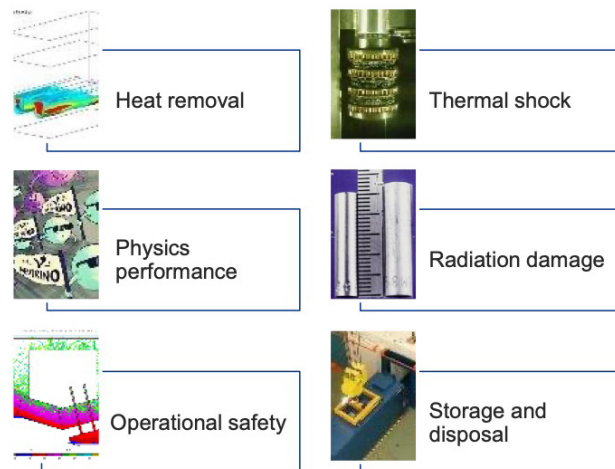
- IMCC & US Snowmass studied MuC challenges:
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  - BUT engineering challenges exist
  - Significant R&D should start **now** to reach readiness of construction in the 2040s

# WG3 Parallel Talks – Monday. 13:45 Session

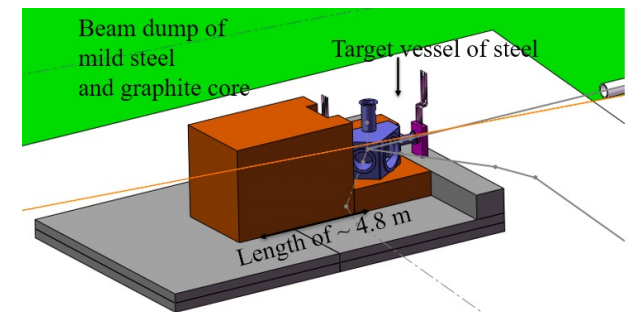
- **NuMI Beamline at Fermilab:** Lessons learned in optimizing and maintaining the NuMI beamline, with a push towards integrating Machine Learning for enhanced monitoring
- **High-Power Targetry R&D:** Tackling material challenges in accelerator targets, focusing on durability and innovative solutions for multi-MW beams
- **MELODY Updates:** Advancing muon production at CSNS with AI-optimized copper targets and refined beamline designs.



J-PARC



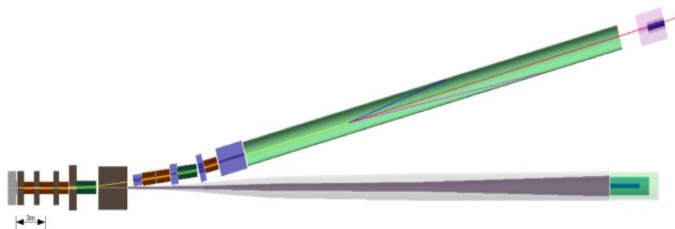
High power Targetry challenges



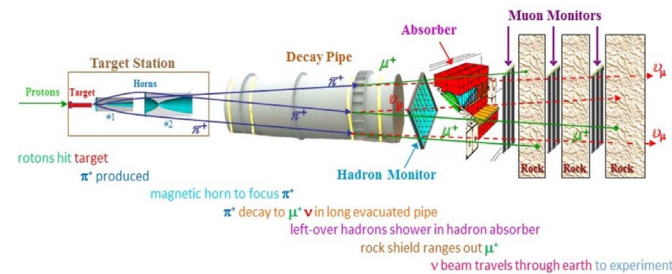
Target design for MELODY

# WG3 Parallel Talks – Tuesday. 13:45 Session

- **ENUBET at CERN:** Achieved 1% precision in  $\nu_e$  cross-section measurements using a horn-less beamline and instrumented decay tunnel; now focusing on site-dependent implementation at CERN
- **J-PARC Horn System Upgrade:** Enhancing the magnetic horn system for 1.3 MW beam power, with increased current and improved cooling for the Hyper-Kamiokande experiment
- **F2D2 at Fermilab:** Conceptual design for a 2+ MW target facility for dark sector physics, addressing the challenges of high-power, low-energy beams from the PIP-II accelerator

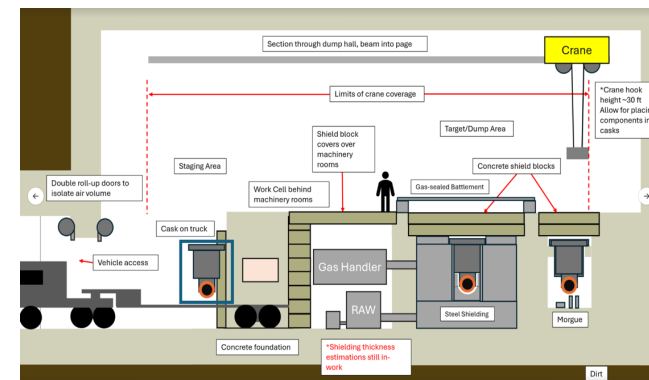


Final design of ENUBET beamline



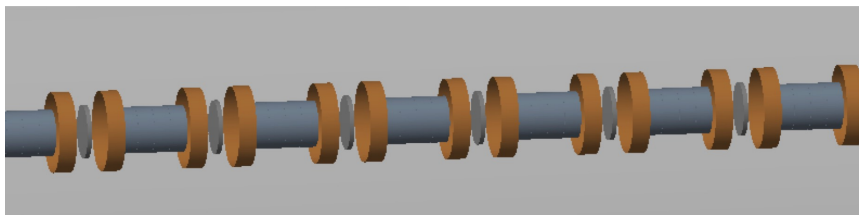
NuMI

## F2D2 Design Plan

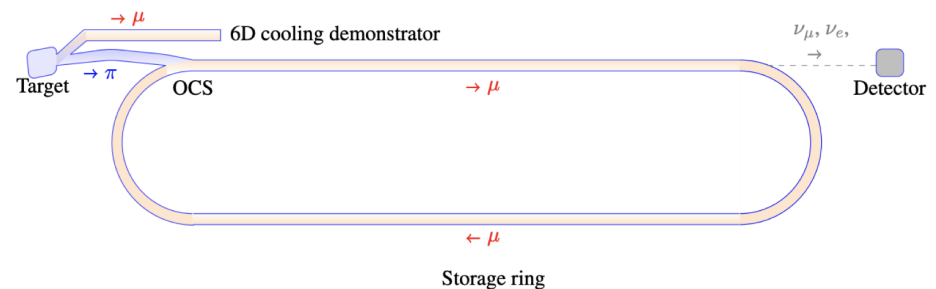


# Joint Parallel Talks WG3X4 – Tuesday. 16:15 Session

- **Update on the design of the 6D Muon Cooling Demonstrator:** Latest design updates on the 6D Muon Cooling Demonstrator, focusing on achieving high beam brightness for a future multi-TeV muon collider
- **Simulation and Design of the Neutrinos from STORed Muons (nuSTORM) experiment:** Update on the design and simulations of the nuSTORM experiment, focusing on muon decay-generated neutrino beams, precise flux determination, and its role as a precursor to a muon collider
- **High Power Targetry for Muon Production:** Challenges and innovative solutions in high-power targetry for producing high-intensity muon beams, focusing on material selection, radiation resistance, and recent advancements in target design



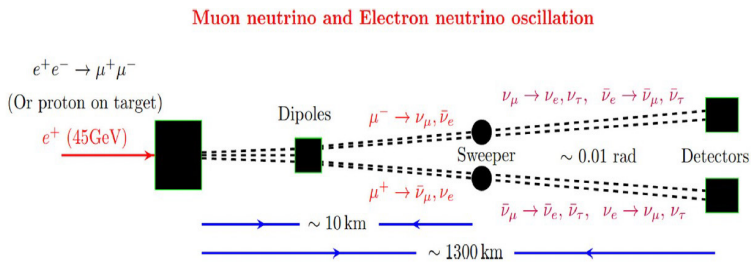
*Cooling lattice in BDSIM*



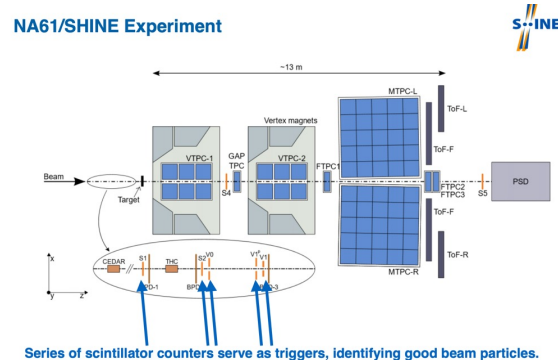
*Schematic of nuSTORM*

# Joint Parallel Talks WG1X3 – Thursday. 13:45 Session

- **Collimated muon beam proposal for probing neutrino charge-parity violation:** experimental setup using collimated muon beams to achieve high-sensitivity probing of neutrino CP-violation, enhancing measurements beyond what current neutrino detectors like DUNE and T2K can achieve
- **NA61/SHINE measurements for neutrino experiments:** Recent NA61/SHINE measurements that reduce systematic uncertainties in neutrino flux predictions for experiments like T2K and DUNE, along with plans for further constraining these uncertainties
- **Improving Neutrino Experiment Physics with Hadron Production Data:** Review the role of hadron production data in reducing neutrino flux uncertainties in experiments like NuMI, BNB, T2K, and discuss the need for new measurements to improve predictions for next-generation experiments



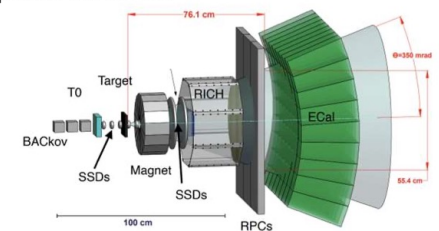
A proposed neutrino oscillation experiment with collimated muon beams



SHINE

## EMPHATIC!! About Hadron Production

- Table-top experiment, simple design optimized to measure HP for energies between 1-20 GeV
- Compact permanent magnet and silicon strip detectors used for momentum measurements, ring-imaging Cherenkov and time-of-flight detectors for particle identification



EMPHATIC spectrometer design.



# Poster Session – Monday.16:05

## **An Updated Simulation of the Booster Neutrino Beam**

Updated GEANT4-based simulation of the Booster Neutrino Beam, enhancing flux predictions for detectors in the Short-Baseline Neutrino program at Fermilab, and enabling more precise studies of hadron production and exotic BSM scenarios