

The 25th international workshop on Neutrinos from Accelerators

LOCAL ORGANIZING COMMITTEE

- Meghna Bhattacharya (Fermilab, USA)
- Lynnean Celsner (Argonne, USA)
- Barratt Choudhury (Argonne, USA)
- Zelimir Djuricic (Argonne, USA)
- Simon Corrodi (Argonne, USA)
- Sudeshna Ganguly (Fermilab, USA)
- Mauzy Goodman (Argonne, USA)
- Tim Hobbs (Argonne, USA)
- Alessandro Loretto (Argonne, USA)
- Stephen Magill (Argonne, USA)
- Yuri Okusun (Argonne, USA)
- Athodri Papadopoulos (Argonne, USA)
- Ruthie Quinn (Argonne, USA)
- Alexia Raffique (Argonne, USA)
- Nancy Ryzak (Argonne, USA)
- Linyan Wan (Fermilab, USA)
- Peter Winter (Argonne, USA)

WORKING GROUP CONVENERS

- WG1: Neutrino Oscillation Physics**
 - Banjali Agarwalla (Institute of Physics, Shubhashwar, India)
 - Mark Scott (Innsbruck College, UK)
 - Yun-Tae Tsa (SLAC, USA)
- WG2: Neutrino Scattering Physics**
 - Christophe Broffero (CRK, University of Tokyo, Japan)
 - Raul Gonzalez-Jimenez (Complutense University Madrid)
 - Elena Grammatini (University of Manchester, UK)
- WG3: Accelerator Physics**
 - Megan Friend (J-PARC/KEK, Japan)
 - Sudeshna Ganguly (Fermilab, USA)
 - Natalia Milas (EISS, Sweden)
- WG4: Beam Physics**
 - Simon Corrodi (Argonne, USA)
 - Gavin Hesketh (UCL, UK)
 - Kim Sang Kwan (Dongguk Joo Tong University)
- WG5: Neutrino Beyond PMNS**
 - Kuan Chui (BES, Korea)
 - Julia Herz (Johannes Gutenberg University Mainz, Germany)
 - Mathias Hoster (Harvard)
- WG6: Detectors**
 - Claudio Giordani (INFN CNRS-IN2P3, Paris)
 - Tamas Mohaiy (Indiana University, USA)
 - Nishimura Yasuhiko (Ritsyo University, Japan)
- WG7: Inclusion, Diversity, Equity, Education, & Outreach**
 - Eben Bechtol (JW Marriot, USA)
 - Naoya Hirabayashi (University of Tsukuba, Japan)

SCIENTIFIC PROGRAM COMMITTEE

- Ash Ashkenazi (Tel Aviv University, Israel)
- Adara Auriantes (University of Cincinnati, USA)
- Jeanmichel Blaz (UC Irvine, USA)
- Alain Blondel (University of Geneva, Switzerland)
- Alex Broggio (Jefferson Lab, USA)
- Walter Bruniwold (INFN Cagliari, Italy)
- Stefania Biondi (Universita di Genova, Switzerland)
- Alan D Brees (Fermilab, USA)
- Chris Donkers (STFC, UK)
- Francesca Dordal (INFN Cagliari, Italy)
- Marcus Drasche (IN2P3, France)
- Tord Ekström (Uppsala University, Sweden)
- Mansel Ellwag (ESS, Sweden)
- Yuki Fichi (Mitsubishi, Australia)
- Mauzy Goodman (Argonne, USA)
- Craig Group (University of Virginia, USA)
- Miao He (HEP, China)
- Patrick Huber (Virginia Tech, USA)
- Natalie Jachewicz (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 (IFGA and Sorbonne Universit, France)
- Niel McCauley (Liverpool, UK)
- Jorge Morfin (Fermilab, USA)
- Haino D Motz (CBPF, Brazil)
- Yuri Okusun (Argonne, USA)
- Angela Paga (Pisa, University of Pisa)
- Albert De Ruck (CERN, Switzerland)
- Carsten Roth (University of Utah, USA)
- David Sgalaberna (ETH Zurich, Switzerland)
- Jan Shewmaker (Virginia Tech, USA)
- Kim Blyden (Seoul National University, Korea)
- Paul Suter (University of Glasgow, UK)
- Jian Tang (Sun Yat-sen University, China)
- Francesca Taronna (University of Milano-Bicocca, Italy)
- Friedrich Wasth (Helmholtz, Germany)
- Uthai Yang (Seoul National University, Korea)
- Katsuya Yamahara (Fermilab, USA)
- Jongheon Yoo (Seoul National University, Korea)

WG3 Summary: Accelerator

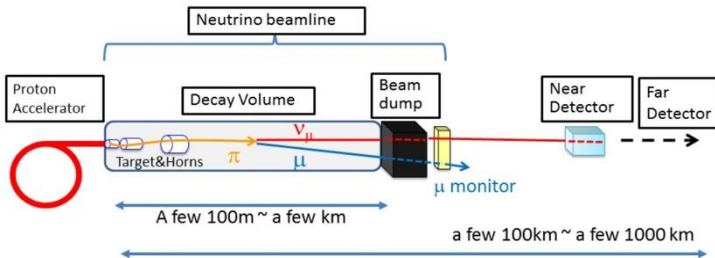
Megan Friend, Natalia Milas, Sudeshna Ganguly

NuFACT 2024,
Lemont, Illinois, USA
September 21, 2024

Statistics

Monday	Tuesday	Wednesday	Thursday
Parallel 1 3 talks	Parallel 2 3 talks	Plenary session 4 talks	Parallel WG 1X3 4 talks
Poster 16:05 session 1 poster	Parallel WG 3X4 3 talks		

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**

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?*

Key Topics Addressed

• Exploring New Target Technologies

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

ACE-MIRT plan motivated by faster delivery of DUNE science

For instance, allows to achieve 5σ mass ordering sensitivity for 100% of δ_{cp} values in 3.5 years instead of 5 years

ACE-MIRT scope to enable >2MW

This component of ACE plan aims to develop the Fermilab accelerator complex capabilities beyond PIP-II, *without new accelerator construction*.

Proposed components offer independent (*) and incremental benefits



Overall efficiency and reliability of operations

- Implement improvements aiming to reduce losses, radioactive activation

Task 1) Improve MI reliability by replacing quadrupole magnets with robust design



Machine capability: Maximum proton flux produced by the accelerator

Task 2) Upgrade MI ramp power system to enable faster cycle time (1.2–0.6s)

Task 3) Upgrade MI RF acceleration system to allow for more beam flux



Ability of target station to convert protons to neutrinos

Task 4) Upgrade LBNF Target and Horns to reliable 2+ MW capability (*)

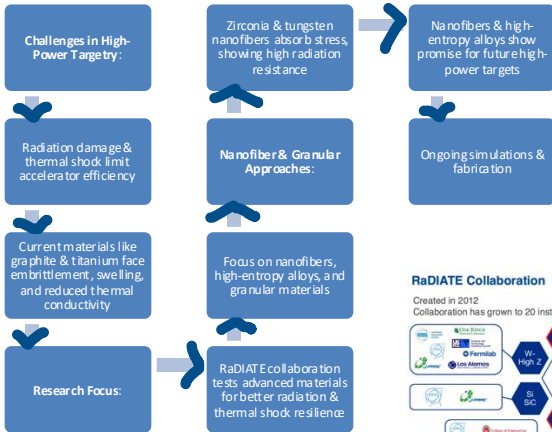
Strategy for ACE-MIRT

- Main Injector
 - Power supplies ~\$100M (DOE O413.3b project), needs alternatives analysis
 - RF ~\$140M (DOE O413.3b project), needs alternatives analysis
 - Abort line upgrade Accelerator Improvement Project (AIP)
 - Provide power supplies for LBNF beamline which need different specifications for fast cycle time
- Targetry
 - Target materials R&D
 - Staged target development for higher beam power
 - Horn analysis and design modification
- Reliability
 - Complete instrumentation AIPs for 20-Hz operations
 - MI magnet testing at faster cycle time, produce spare quadrupoles to install as needed
 - Increment in ops funding eg \$5M/yr for modernization, \$0.5M/yr for SPS

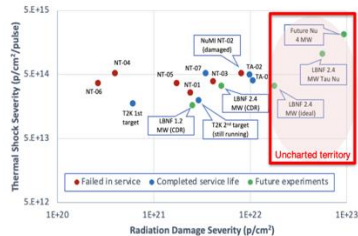
Key Topics Addressed

•Exploring New Target Technologies

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

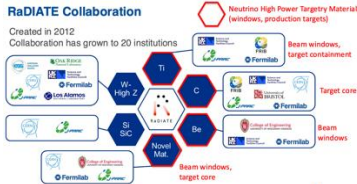


Neutrino HPT R&D Materials Exploratory Map



RADIATE Collaboration

Created in 2012
Collaboration has grown to 20 institutions



Key Topics Addressed



• Exploring New Target Technologies

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

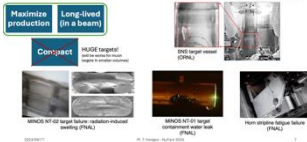
Muon production target wish list



2024/09/17

M. T. Hedges - NuFact 2024

Early target failures: limited beam power



2024/09/17

M. T. Hedges - NuFact 2024

Material Performance:

• Graphite: Lower DPA (~1 DPA/year), more resilient

• Tungsten: Higher DPA (~100 DPA/year), rapid degradation

• Inconel: Used in muon/antiproton targets but prone to melting

Takeaways

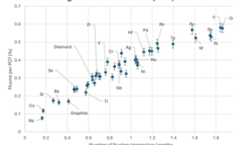
- Increasing target density worsens peak radiation damage faster than muon production increases
- Good news! Lower density targets also absorb less energy, and (usually) run less hot
- Fewer beam studies done with mid-density targets (e.g. TZM)
- Fun fact: Inconel was the material for FNAL antiproton source!

2024/09/17

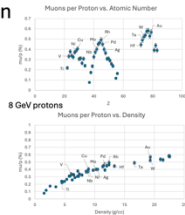
M. T. Hedges - NuFact 2024

G4Beamline yield validation

Source: Madeleine Bloomer, Emory University
FNAL Undergraduate Summer Intern (2024)



<https://pdg.lbl.gov/2024/AtomicNuclearProperties/>





Key Topics Addressed

•Advancing Accelerator Capabilities


•Tuning MI beam for 1 MW beam on target provided valuable lessons learnt

•**Future Upgrades:** Testing new graphite materials for improved thermal conductivity and preparing spare horns for future operations


Beamline updates for 1 MW operations

Timeline of beamline updates for 1 MW operations:

- 2019: Replaced target (Summer)
- 2020: Replaced Horn #1, #2 (Summer)
- 2021
- 2022: Replaced target (Summer)
- 2023: Replaced Horn #2 (January)
- 2024




1-MW NuMI target



1MW horn 1

- 2019 summer: Replaced the 700 kW target with 1 MW target.
- 2020 summer: Updated horn 1 and 2 for 1 MW operations.

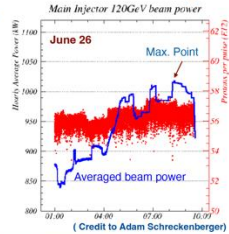


1MW horn 2

- 2022 summer: Replaced the 1 MW target after completing the service duration.
- 2023 January: Replaced the horn 2 after having a stripline failure.

Tuning the MI beam for 1 MW challenge

- o Tuned the MI chromaticity to achieve optimal beam spot size at the baffle for 1 MW challenge.
- o Ramped up the beam power step by step.
- o 04:12 to 06:53 – Solidified MW capabilities
 - Occasional RF trips and LINAC downtime
- o 06:53:20 – Achieved averaged 1 MW challenge
- o 08:21:02 – Achieved one full hour of 1 MW beam with ZERO trips



Finally we recorded the averaged highest beam power
1.018 MW !!

Key Topics Addressed

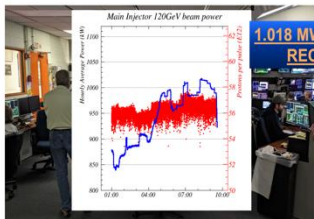
•Advancing Accelerator Capabilities

•At Fermilab, PIP-II upgrades to reach 1.2 MW, followed by ACE-MIRT improvements to achieve 2+ MW, focusing on enhancing Main Injector reliability and target system upgrades

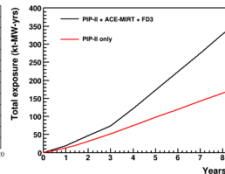
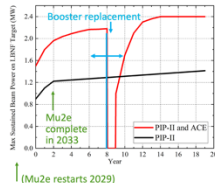
•Shaping the Future of Neutrino Research

•After DUNE, focus shifts to LBNF/DUNE Phase II, aiming for precise CP violation measurements and exploring next-generation experiments powered by a robust 2.4 MW accelerator complex

1.018 MW



DUNE power with a Booster Replacement



Summary

- Fermilab Accelerators have run for decades and are now at a turning point
 - Decades-long plans are being put into action
 - New Challenges and opportunities emerge on an almost daily basis
- The Long Shutdown is approaching in ~ 2027
 - Install LBNF & PIP-II
 - Retire Linac & NuMI
 - Integrate improvements to the complex: ACE-MIRT, AIPs, UIP, ACORN
- Until 2027:
 - Continue to deliver to present and new experiments
 - NOvA, SBND, ICARUS, 2x2, ANNIE, Mu2e, Spinqest, MTA/ITA, FTBF, ...



Key Topics Addressed

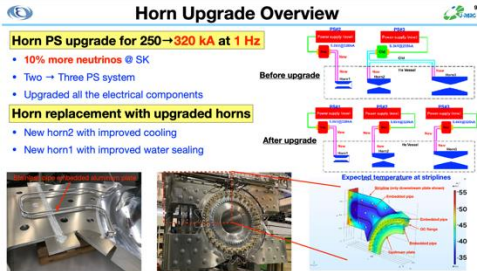
•Advancing Accelerator Capabilities

Increased Neutrino Beam Power: Horn upgrades enabled stable operation at 320 kA, supporting beam power up to 800 kW, with a target of reaching 1.3 MW for future experiments

Enhanced Neutrino Focus: Upgraded horns improve focusing of pions, intensifying neutrino beam by a factor of 15

Improved Cooling & Reliability: New horn designs feature improved water sealing and enhanced cooling, allowing better thermal management during high-power operations

Long-Term Operation: Upgrades ensure reliable, long-term operation of the neutrino beamline for high-precision experiments like T2K and Hyper-K





Key Topics Addressed

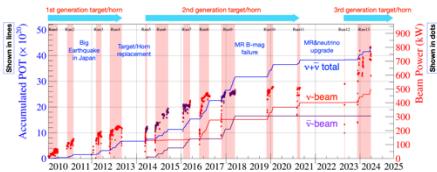
•Advancing Accelerator Capabilities

- Upgrades ongoing toward 1.3 MW operation by FY2028
- Second major upgrade scheduled for FY2026, with improvements to cooling, power supplies, and beamline systems

•Shaping the Future of Neutrino Research

- J-PARC accelerators aim for full 1.3 MW operation by FY2028, supporting future high-intensity experiments

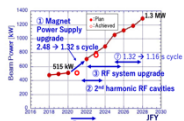
Stable operation at 800 kW after MR PS upgrade achieved in Jun. 2024 run



Total accumulated POT for T2K : 4.35×10^{21} POT (as of Jun. 2024) $\rightarrow 1.0 \times 10^{22}$ POT (T2K goal)
 c.f., 2.7×10^{22} POT (HK 10-years)

- J-PARC neutrino beam for CP violation search in lepton sector
- J-PARC accelerator and neutrino beamline upgrade toward 1.3 MW ongoing
 - MR upgrade toward 1.3 MW by 2028
 - 1st stage major upgrade completed in FY2021-2022
 - 2nd stage major upgrade in FY2026
- All the upgraded systems are working very well at 800 kW operation
- Working on countermeasures for aging of old equipments

- Both hardware upgrade and beam operation are important
 - Beamline should be ready to take beam for more than 4 months/year for T2K operation
- Second major upgrade planned in FY2026
 - 8 months shutdown required for the remaining upgrades
- Beamline will be ready for 1.3 MW after FY2026 \Rightarrow J-PARC accelerators aim to achieve 1.3 MW by FY2028



S. Igarashi, et al.,
 ITEP vol 2021,
 Issue 3.p33

Acceptable beam power	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027
1.3 MW							
800 kW							
700 kW							
500 kW							
MR PS	Initial	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade
DAQ/control upgrade	Initial	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade
MR mainline cooling	Initial	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade
High power horn	Initial	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade
Radio active water disposal	Initial	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade
Target H ₂ cooling	Initial	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade
MR/MSD water cooling	Initial	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade
High power target	Initial	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade	Upgrade



Key Topics Addressed

•Advancing Accelerator Capabilities

- ENUBET offers technology to produce monitored neutrino beam
- Uses a **hornless static focusing system** to enhance neutrino flux precision with slow extraction
- Employs **normal conducting magnets and quadrupoles** for narrow-band neutrino beams
- Beam tests and GEANT4 simulations** confirm system's ability to achieve <1% flux uncertainty

ENUBET – Summary

*Monitored neutrino beam is not longer an interesting idea, it is now a **matured technology***

We can measure the charged leptons in a decay tunnel using a **horn-less beam**

- DUNE energy range (**ENUBET**)
- DUNE + Hyper-Kamiokande energy range (**SBN@PBC**)
- ESSnuSB energy range (**ESSnuSB+**)

ENUBET design **fulfills all requirements for a new generation of cross section experiments**

- Statistical error <1% with a 500 ton detector
- Flux systematic uncertainties <1%
- Estimate of the neutrino energy with 10-25% precision

Moving towards **an experimental proposal for implementation at CERN** using ProtoDUNE and/or WCTE

Common effort of **ENUBET, NuTAG, and CERN** to overcome current limitations and exploit **time tagging**

16-Sep-24 L. Halić - Ruder-Bellmann Institute 12

•Shaping the Future of Neutrino Research

- Monitored neutrino beams** offer precision crucial for long-baseline experiments like **DUNE**
- Kaon tagging** improves neutrino flux determination from decay modes
- Optimized design sets the stage for next-gen **cross-section experiments** with enhanced energy resolution and minimal systematic errors

Key Topics Addressed

•Advancing Accelerator Capabilities

- ESSvSB proposed next generation long baseline experiment
- 5 MW Proton Beam for high-intensity neutrino production
- Upgrades: H- source, accumulator ring, and target station
- Granular Targets cooled by helium for enhanced reliability

•Shaping the Future of Neutrino Research

- CP Violation: Precision at second oscillation maximum
- Far Detector: 538 kt Water Cherenkov at 360 km
- Extended Physics: Atmospheric neutrinos, proton decay, supernova neutrinos
- ESSvSB+ proposes new physics opportunities with enhancements like Low Energy nuSTORM and far detectors enriched with gadolinium

The European Spallation Source (ESS)

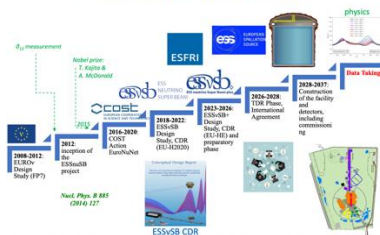
- ▶ The ESS facility is under construction in Lund, Sweden. First beam expected in 2026.
- ▶ Using a powerful proton linear accelerator, designed for $E_{\text{kinetic}} = 2 \text{ GeV}$ and 5 MW power, to produce the world's most powerful neutron source.
- ▶ 14 Hz repetition rate (2.86 ms pulse duration, 10^{15} protons).
- ▶ up to 3.5 GeV with linac upgrades, > 2.7×10^{23} p.o.t./year.

Using this powerful accelerator, we can produce a high intensity neutrino super beam!

The European Spallation Source Neutrino Super Beam (ESSvSB)



ESSnuSB Project Time Evolution



Key Topics Addressed

Shaping the future & synergies



Key Topics Addressed

Muons

- **MELODY Project:** A new target station at CSNS to produce surface, negative, and decay muons for scientific research by 2028
- **Muon Applications:** Supports diverse fields, including superconductivity, magnetism, particle physics, and muon detector development
- **High Muon Yield:** Optimized copper target design and AI-enhanced solenoid focusing for high-efficiency muon production

China Spallation Neutron Source



- CSNS is the only large-scale proton accelerator in China today
- Strong needs from other fields than neutron scattering
- Excellent capability to support multiple platforms like muons
- Phased development from 100 kW (I) → 500 kW (II)
- Instrument tuning and Day-one experiments: January - March 2018; Initial operation: Since April 2018
- Present beam power: 180 kW - stable - in 2024/8

- A new target station in CSNS for a muon source (MELODY)
 - 1.6 GeV proton beam, 20 kW, 1 Hz pulsed beam
- Physics design: Completed.
 - Thick copper target with solenoid to collect muons
 - Optimized for surface muon beamline. Extensible for other beamlines
- Equipment Design: Finalization in progress
- Manufacturing: Expected to commence in approximately one year
- Testing and Installation: Scheduled for completion in approximately two years

Equipment design

2024.10

Equipment manufacturing

2025.12

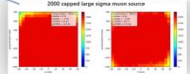
Testing and Installation

2026.10

New analysis for the target selection



Generated surface muons phase space at the target region



- Generate a uniform-like and isotropic distribution of surface muons
- Transport it to the sample position, sample with $\Phi = 3 - 10$ cm
- Trace back the detected by the sample surface muons at the target region

Liu Guangdong / CSNS

Timeline of MELODY

Project has been approved and will be built in 5 years.



Key Topics Addressed

Muon Collider

Advancing Accelerator Capabilities:

• **Multi-MW Proton Drivers:** R&D needed to adapt for Muon Collider requirements

• **Muon Cooling:** Muon ionization cooling demonstrated; significant R&D ongoing for 6D cooling

• **TeV Acceleration:** Conceptual designs up to 10 TeV using rapid cycling synchrotrons in place

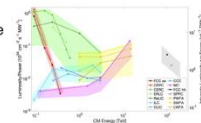
Shaping the Future:

• **Neutrino Radiation:** Innovative mitigation system developed to reduce radiation exposure from muons

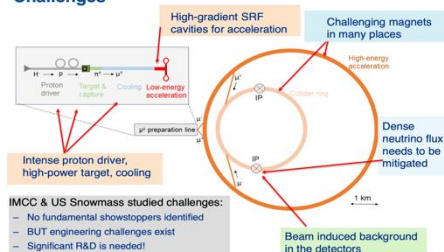
• **US Leadership:** Plans to build a Muon Collider at Fermilab by 2040 with global collaboration

Motivation

- **Muons** as compared to **protons**
 - Are leptons & use all energy in a collision
 - Need less collision energy for same physics
- **Muons** as compared **electrons**
 - Muons emit little synchrotron radiation
 - Acceleration in rings possible to many TeV
- A Muon Collider (MuC) can serve as **energy reach** and **precision** machine at the **same** time
- In a MuC, **luminosity** to power ratio improves substantially with energy



Challenges



Muon Cooling

Advancing Accelerator Capabilities:

nuSTORM: Creates high-precision neutrino flux from stored muons, acting as a testbed for future accelerator technologies

nuSTORM shares targetry and beam instrumentation technologies, supporting R&D for muon collider development

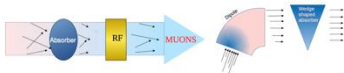
Muon Collider Synergy: 6D cooling demonstrates crucial technology for future muon colliders

Ionization Cooling: Uses absorbers and RF cavities to reduce emittance in all 6 dimensions

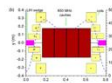
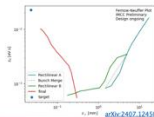
Engineering Innovations: RF cavities and magnet integration under development for effective cooling

Proton Driver Flexibility: Demonstrated or can be sited at CERN or Fermilab, offering versatility for future experiments

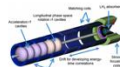
- Ionisation Cooling involves passing the beam through an absorber.
- The beam loses momentum in all direction as it ionises the absorber.
- An RF cavity restores momentum in a single direction.
- Multiple coulomb scattering from the nucleus is mitigated using low-Z materials and having tight focussing using solenoids.
- Having a dipole and a wedge-shaped absorber allows us to cool in all 6 dimensions.



- In the muon collider, first 6D (rectilinear) cooling is done to reduce emittance in all directions.
- This is followed by 4D (final) cooling, which involves cooling only in the transverse direction at the cost of longitudinal emittance.



An example of a rectilinear cooling cell



An example of a final cooling cell

Key Topics Addressed

Rohan Kamath

IMPERIAL

JAI
John Adams Institute
for Accelerator Science

UK
Science and
Technology
Facilities Council

Synergies with Neutrinos

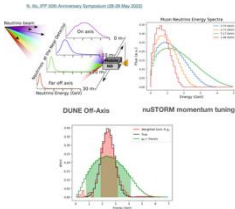
Simulation and design of neutrinos from STOREd Muons (nuSTORM) experiment

• **nuSTORM**: Creates neutrinos from stored muons with %-level precision for high-precision cross-section measurements

Shaping the Future:

- **BSM Physics**: nuSTORM offers sensitivity to rare processes and sterile neutrino searches
- **Synthetic Beams**: Uses linear combinations of fluxes to create quasi-monoenergetic neutrino beams for precision studies

Scientific Program



Cross Section Measurements

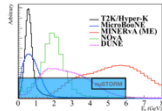
- One of the sources of error in LBL neutrino experiments is the constraint on flux and x-sec models.
- With a %-level precision on the neutrino flux, nuSTORM can constrain these cross section models
- With a tuneable muon storage ring, the neutrino flux can also be tuned to the energy spectrum of current (and future) long baseline neutrino experiments.

Beyond Standard Model Physics

- Combining the well constrained flux with high statistics, many exotic and rare scatterings can be studied.
- nuSTORM can also probe short baseline oscillations and sterile neutrinos, with a 2014 study showing a 10 σ sensitivity to the LSND and MiniBOONE anomalies.

Muon Collider Demonstrator

- As a muon storage ring, nuSTORM exhibits synergies with muon collider research, serving as a test bed for technologies for magnets and beam instrumentation.
- Hence, a Muon Collider Demonstrator complex has been envisioned at CERN, allowing for shared targetry and capture between nuSTORM, the 6D cooling test facility.



Original plot: Kamath, T. JET0018, EPJN, Durham, UK, Jan. 7, 2018

Neutrinos from Stored Muons (nuSTORM)



Muon Collider



Key Topics Addressed

Fermilab Facility for Dark Matter Discovery (F2D2)

Advancing Accelerator Capabilities:

- F2D2 Beam Stop:** Designed for dark sector searches using excess beam from PIP-II

- High Power Targetry:** F2D2 can serve as a testbed for future high-power targets, including muon collider facilities

- Thermal Management:** Advanced cooling systems to handle 2.5 MW

F2D2 Site Layout – Integrated with Future Fixed Target Campus



Shaping the Future

Synergy with PIP-II: Leveraging unused beam power for smaller, focused dark matter experiments

Muon Collider Readiness: F2D2 shares target and cooling technologies with future muon collider developments

R&D for Next-Gen Facilities: Contributes to both neutrino and dark matter experiments while advancing muon collider capabilities

Summary

- We reviewed current accelerator operations, upcoming plans, and explored novel ideas crucial for next-generation neutrino experiments

- Synergies between neutrino, muon, and collider research will drive future breakthroughs

We had many interesting talks and discussions

Thank you!

