

Mu2e-II workshop

Preparation for Snowmass21

Frank Porter
July 29, 2020
DocDB nnnnn

This meeting will be recorded

What is Mu2e-II?

It is at least:

An upgraded version of Mu2e, improving sensitivity to $\mu \rightarrow e$ conversion according to the ratio:

$$R_{\mu e} \equiv \frac{\Gamma(\mu^- N(A, Z) \rightarrow e^- N(A, Z))}{\Gamma(\mu^- N(A, Z) \rightarrow \nu_\mu N(A, Z - 1)^*)}$$

for an Al target by at least an order of magnitude over Mu2e

- It is also capable of measuring $\mu \rightarrow e$ conversion on a titanium target, and the $\Delta L=2$ process $\mu^- \rightarrow e^+$
- Uses 800 MeV PIP-II linac H^- beam

Is it anything else? Note common interest with other muon CLFV physics measurements

Snowmass21 context

Frontier: RARE PROCESSES AND PRECISION MEASUREMENTS

Convenors: Marina Artuso, Bob Bernstein, Alexey A Petrov

“Topical groups”

<https://snowmass21.org/rare/start>

- [RF1: Weak decays of b and c quarks](#)
- [RF2: Weak decays of strange and light quarks](#)
- [RF3: Fundamental Physics in Small Experiments](#)
- [RF4: Baryon and Lepton Number Violating Processes](#)
- [RF5: Charged Lepton Flavor Violation \(electrons, muons and taus\)](#)
- [RF6: Dark Sector Studies at High Intensities](#)
- [RF7: Hadron Spectroscopy \(new\)](#)

← Rare Frontier RF5 topical group charged to address:

1. CLFV decays ($\mu \rightarrow e\gamma$, $\mu \rightarrow 3e$, tau decays, etc.) and conversion ($eN \rightarrow \mu N$)
2. Muonium-anti-muonium oscillations, LFV leptonium decays
3. Radiative and non-radiative LFV decays of mesons and baryons ($J/\psi \rightarrow e\mu(\gamma)$, $\chi_c \rightarrow e\mu(\gamma)$, etc.)
4. Direct (non-decay) LFV processes at accelerators (μ and τ production)
5. Studies of CLFV at EIC (Electron Ion Collider)
6. Related theory

Mu2e-II resides here

RF5-1: Charged Lepton Flavor Violation (electrons, muons and taus)
Convenors: Sacha Davidson (Lyon), Bertrand Echenard (Caltech)

<https://snowmass21.org/rare/clfv>

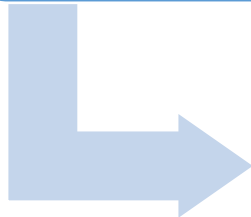
Snowmass21 Schedule

CLFV workshops:

- muons – July 2, 2020
- taus – July 23, 2020
- flavor/direct decays – Aug 13, 2020

August 31, 2020

- Letter of Interest final deadline



October 5-9, 2020

- Snowmass Planning Meeting
- Note change from original Nov 4-6 dates

Precision frontier meeting in planning for around March 2021



April 1 to July 31, 2021

- Contributed papers submission period

Mu2e-II meetings and/or workshops

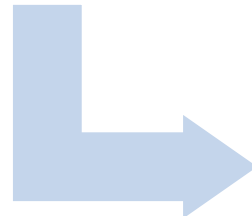
June 18, 2020

July 29, 2020

so far scheduled:

August 26, 2020

September 23, 2020



July 11-20, 2021

- Snowmass meeting
- UW, Seattle

Formation of Mu2e-II Working Groups

In order to provide some organization for addressing the several aspects of Mu2e-II, we have formed several working groups

- Groups and Convenors (thanks!!) on next slide
- If you are interested in contributing to one or more of these areas, please contact the relevant convenors
- Expect that members of the working groups will be authors of the final Snowmass contributed paper
 - There may be additional contributed papers from the working groups individually

Mu2e-II Working Groups and Convenors

Mu2e-II working groups	Convenors
Theory	Julian Heeck Lorenzo Calibbi
Accelerator (including PS, production target, extinction)	David Neuffer Eric Prebys
Radiation mitigation (includes radiation simulation)	Vitaly Pronskikh Michael MacKenzie Stefan Mueller
Tracker	Daniel Ambrose Giovanni Tassielli
Calorimeter (and STM?)	Ivano Sarra Luca Morescalchi David Hitlin
CRV	Yuri Oksuzian Uva person (TBD)
Sensitivity estimate (includes simulation, stopping target)	Lisa Goodenough Sophie Middleton Yuri Oksuzian
Trigger and DAQ	Giani Pezzullo Antonio Gioiosa

Snowmass21 Letter of Interest

Letters of Interest (**LOI**) (submission period: April 1, 2020 – August 31, 2020)

- Allow Snowmass conveners to see what proposals to expect and to encourage the community to begin studying them
- Help conveners to prepare the Snowmass Planning Meeting that will take place on November 4 - 6, 2020 at Fermilab
- Letters should give brief descriptions of the proposal and cite the relevant papers to study
- Instructions for submitting letters at <https://snowmass21.org/loi>
- Authors of letters encouraged to submit a full write-up for their work as a contributed paper

Limited to 2 pages,
plus references

Index:

<https://www.snowmass21.org/docs/files/?dir=summaries/>

Rare frontier:

<https://www.snowmass21.org/docs/files/?dir=summaries/RF>

Currently uploaded:

- LHCb (cross-listed)
- FNAL low-E muon facility
- J/ψ factory
- srEDM

Committee plans to prepare a LOI for Mu2e-II and circulate for signatures of interested people

Snowmass21 Letter of Interest

A draft LOI for Mu2e-II has been written and may be viewed at the link:

<https://www.overleaf.com/read/rmscdsghznbs>

- Please take a look, and send us comments (e.g., to fcp@caltech.edu)
- Note that author list is so far just a few people to check formatting is OK
- **Deadline for comments is Wednesday, August 5, 2020**
- After August 5, we will make a general request for interested people to join the author list
- **Deadline for additions to author list is Wednesday, August 19, 2020**
- Reserve right to make small tweaks/corrections to LOI up to submission
- LOI will be submitted before August 31, 2020

Signing the Mu2-II Snowmass21 Letter of Interest

Signing LOI is open to anyone who is interested in the project

- Not a commitment to work on Mu2e-II for Snowmass21

Signing process starts immediately and ends August 19

(we'll try to accommodate late arrivals if LOI not yet submitted)

- Send email to fcg@caltech.edu
- Include:
 - Your name as you would like it (initials plus surname)
 - Your institution in format (as applicable):
Institution name, Institution address (city, state, mail code, country)
- I'll try to make additions quickly; please check that I got it right

Snowmass21 Contributed Paper(s)

- Submission period: April 1, 2020 – July 31, 2021)
- Will be part of the Snowmass proceedings
- May include white papers on
 - specific scientific areas
 - technical articles presenting new results on relevant physics topics
 - reasoned expressions of physics priorities, including those related to community involvement
- Will help shape the long-term strategy of particle physics in the U.S.
- Part of the permanent record of Snowmass 2021
- Instructions for submitting at <https://snowmass21.org/submissions/>

Will put up a framework in Overleaf after LOI is submitted

- Committee plans to coordinate writing a contributed paper for Mu2e-II with broad participation
- Note that additional contributed papers on specialized topics by smaller groups are encouraged (but if related to Mu2e-II, we would like to reference it)

Mu2e-II Wiki

Mu2e-II has a public wiki page:

<https://mu2eiiwiki.fnal.gov/wiki/Mu2e-II>

- Will continue to work on content
- Will consider whether we also need a private wiki

Main Page

Mu2e-II main page

We propose an evolution of the Mu2e experiment, called Mu2e-II, that would leverage advances in detector technology and utilize the increased proton intensity provided by the Fermilab PIP-II upgrade to improve the sensitivity for neutrinoless muon-to-electron conversion by one order of magnitude beyond the Mu2e experiment, providing the deepest probe of charged lepton flavor violation in the foreseeable future. Mu2e-II will use as much of the Mu2e infrastructure as possible, providing, where required, improvements to the Mu2e apparatus to accommodate the increased beam intensity and cope with the accompanying increase in backgrounds.

from "Expression of Interest for Evolution of the Mu2e Experiment", [arXiv:1802.02599](https://arxiv.org/abs/1802.02599) (<https://arxiv.org/abs/1802.02599>)

[Learn about Mu2e-II](#)

...

[Practicalities](#)

how to stay informed, how to get involved ...

[Relevant Literature and Talks](#)

publications, arXiv articles, talks

[Snowmass21 Information](#)

Mu2e-II Workshops

Nearby workshop dates	Links to recordings
Thursday, June 18	AM: https://caltech.box.com/s/b67edbgtxofaujuoorafm4kfq9owhjd PM: https://caltech.box.com/s/vnsm9nh7qroznt3n6q5n3sn4ut1bswo5
Wednesday, July 29 (today)	
Wednesday, August 26	
Wednesday, September 23	

Email, Communication

Email lists:

- mu2eii@listserv.fnal.gov Primary channel for communications in Mu2e-II community
- To subscribe send email to listserv@fnal.gov with body
subscribe mu2eii <your full name>
- Calorimeter working group also on listserv@fnal.gov
subscribe MU2EII-CALORIMETER <your full name>
- All working groups should announce meetings on mu2eii, or on a subscribable mailing list

Note that we can't count on everyone having a FNAL account, at least for now. Thus we communicate with

- Meeting agendas and slides on public indico pages
- Documents in cloud with links people can use
- Email lists
- Public wiki (do we need a private wiki as well?)

Mu2e-II Workshop agenda

(<https://indico.fnal.gov/event/44541/>)

When	Who	What
10:00-10:20	Frank Porter	Introduction
10:25-10:45	Julian Heeck	Working group reports - Theory
10:50-11:10	Eric Prebys	Working group reports – Accelerator/Extinction
11:15-11:35	Lisa Goodenough, Sophie Middleton, Yuri Oksuzian	Working group reports - Sensitivity
11:40-12:10	All	Break
12:10-12:30	Brendan Casey	Low mass tracker
12:35-12:55	Yuri Oksuzian	Working group reports – Cosmic ray veto
13:00-13:20	Antonio Gioiosa, Gianantonio Pezzullo	Working group reports – Trigger/DAQ
13:25-13:45	Francesco Renga	$\mu \rightarrow e\gamma$, $\mu \rightarrow eee$ at FNAL
14:00	All	End

Additional Material

Some links to literature

1. Search Mu2e DocDB for “Mu2e-II”
 - Northeastern slides
 - LDRD documents
2. Snowmass 2013 Report: <https://www.slac.stanford.edu/econf/C1307292/>
3. Expression of Interest for Evolution of the Mu2e Experiment: <https://arxiv.org/abs/1802.02599>
4. Expression of Interest for the Evolution of Mu2e – Mu2e-II (PAC slides):
<https://indico.fnal.gov/event/17480/contributions/43397/attachments/26855/33285/PAC-Mu2eII-180716.pdf>
5. Summary Report of the Mu2e-II Workshop at Northwestern University: DocDB-23236
6. 2020 European Strategy Physics input on CLFV: <https://arxiv.org/pdf/1812.06540.pdf>
7. Lepton Flavor and Number Conservation, and Physics Beyond the Standard Model:
<https://arxiv.org/abs/1303.4097>
8. The quest for $\mu \rightarrow e\gamma$ and its experimental limiting factors at future high intensity muon beams:
<https://arxiv.org/abs/1811.12324>
9. The hunt for lepton flavor violation with the Mu3e experiment:
https://www.psi.ch/sites/default/files/2019-10/nufact_dittmeier_mu3e_201908_v1.pdf
10. Mu2e-II : next generation muon conversion experiment:
https://indico.cern.ch/event/773605/contributions/3493637/attachments/1899088/3134136/Mu2eII_NuFact2019.pdf

Snowmass21 process

Organized by APS DPF

“Snowmass is an opportunity for the entire HEP community to come together to identify and document a vision for the future of particle physics in the U.S. and its international partners.”

<https://snowmass21.org/start>

[This process may be invaluable towards obtaining R&D funding for Mu2e-II technology, e.g., consider Snowmass submissions proposing such work]

Mu2e-II Snowmass21 Committee

Name	Institution	Email
Dan Ambrose	U Minn	ambrose0028@gmail.com
Rebecca Chislett	UC London	rebecca.chislett@ucl.ac.uk
Lisa Goodenough	FNAL	goodenou@fnal.gov
Julian Heeck	U Virginia	julian.heeck@gmail.com
David Neuffer	FNAL	neuffer@fnal.gov
Yuri Oksuzian	ANL	yoksuzian@anl.gov
Frank Porter (chair)	Caltech	fcp@caltech.edu
Giovanni Tassielli	INFN-Lecce	giovani.tassielli@le.infn.it
Robert Bernstein (ex officio)	FNAL	rhbob@fnal.gov
Jim Miller (ex officio)	Boston U	miller@bu.edu

Our focus (partial committee “charge”)

Goal: **Make case for Mu2e-II at Snowmass 21**

The committee will form immediately and continue until the Snowmass process is complete

The committee should move expeditiously to identify the best path forward

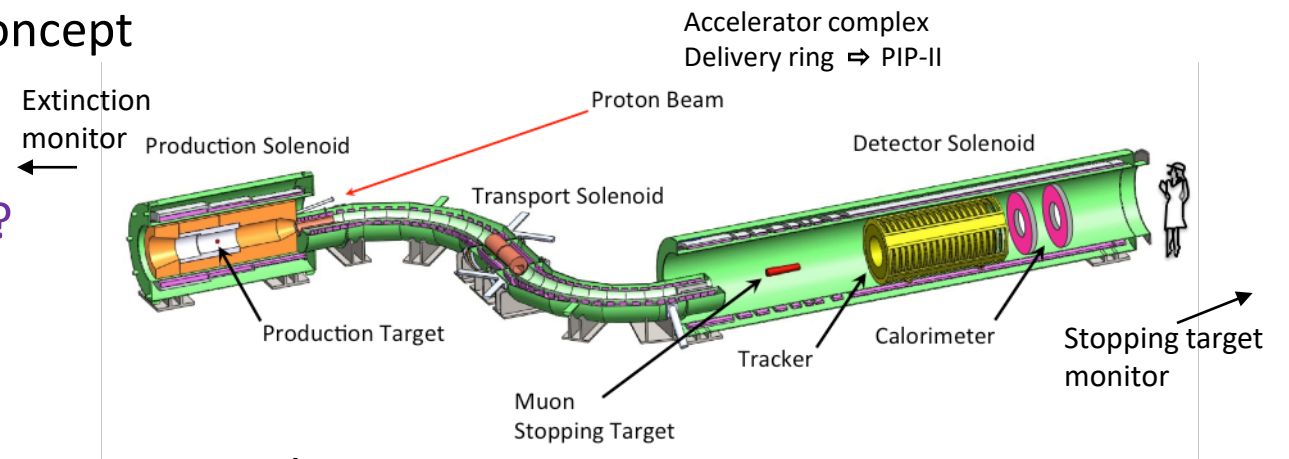
The goal is to

1) develop the preliminary experimental concept

- Accelerator and detector
- What can we keep on Mu2e?
- What needs to be revised/replaced?
- What performance can we expect?
- A rough idea of total cost

2) promote interest among theorists

3) prepare for presenting the theoretical and experimental cases in anticipation of and during the Snowmass process

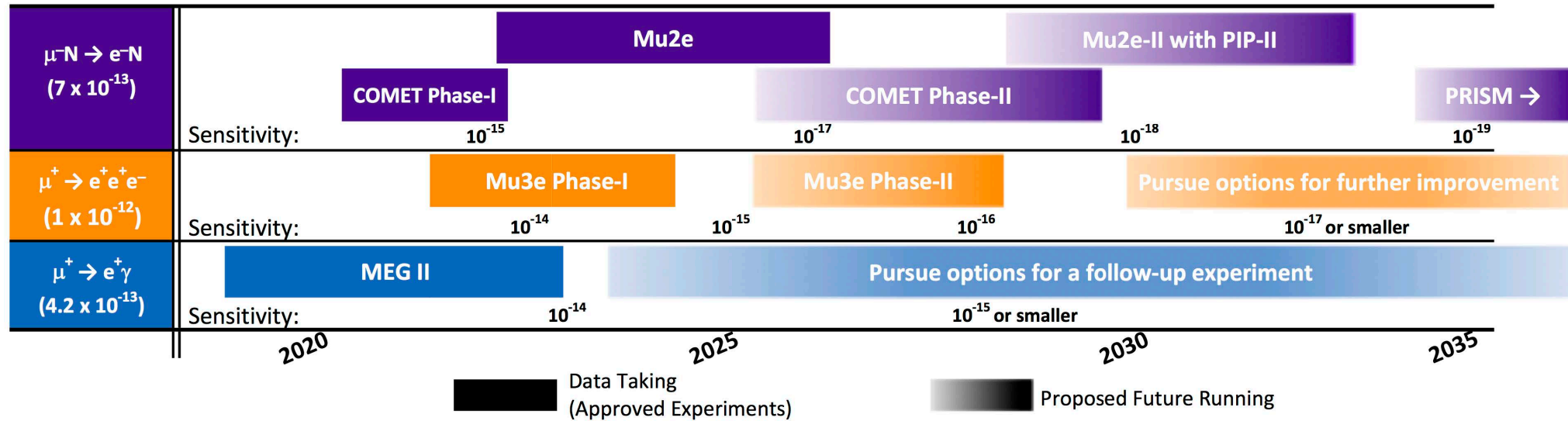


Some tentative parameters, Mu2e-II vs Mu2e

	Mu2e	Mu2e-II	Comments
source	Slow extracted from Delivery Ring	H- direct from PIP-II Linac	Mu2e-II will need to strip H- ions upstream of production target
beam energy (MeV)	8000	800	optimal beam energy 1-3 GeV
p pulse full width (ns)	250	<= 100	from PIP-II could range 40-100 ns for ~100 kW
p pulse spacing (ns)	1695	1699	assumes an Al. target; shorter spacing better for Ti or Au targets
p pulse full width (ns)	250	<= 100	from PIP-II could range 40-100 ns for ~100 kW
protons per pulse	4.00E+07	1.20E+09	
experimental duty factor	25%	>90%	important for keeping instantaneous rates under control
peak pulse rate	590 kHz	589 kHz	
avg. pulse rate	145 kHz	530 kHz	
protons per second	5.80E+12	6.36E+14	
stopped μ per second	1.16E+10	1.17E+11	
run time (sec/yr)	2.0E+07	2.0E+07	
run duration (yr)	3.0E+00	3.0E+00	
Total POT (3+1)y	4.7E+20	4.40E+22	approximate, depends on stopped-muon yield
Total stop- μ 3y	6.96E+17	7.00E+18	
extinction	1.0E-10	1.0E-11	ratio of (out-of-time / in-time) protons
average beam power (kW)	8	80	80kW is approximate; will depend on production target design and transport, which will affect mu-stop yield

Ref: DocDB-180827

CLFV muon decay schedule context



From 2020 European Strategy Physics input on CLFV
<https://arxiv.org/pdf/1812.06540.pdf>