NF06 Electron Scattering and Neutrino Physics White Paper

Vishvas Pandey

on behalf of the NF06 Topical Group

Conveners: Jonathan Asaadi, Baha Balantekin, Kendall Mahn, Jason Newby

EC Reps: Steve Gardiner, Tanaz Mohayai, Vishvas Pandey, Jacob Zettlemoyer

NuSTEC Board Meeting, December 6-7, 2021

Snowmass/NF Timeline

Whitepaper drafts/contents

Community

Neutrino Frontier date

All Snowmass date

Time

Topical Group/Frontier

Community Input

Dec 18:
Extended Outline Due
(internal NF deadline)

Feb 28:
Report Draft Due
(internal NF deadline)

Mar 15:
Whitepapers due
(Snowmass deadline)

Whitepapers

March 16-18:
Neutrino Frontier
Workshop

May 10:
NF Preliminary Report due
(internal NF deadline)

TG Reports

NF Report

Sept 30:
Final Report Due
(Snowmass deadline)

Sept 9:
Final Report Due
(internal NF deadline)

July 17-26
CSS, Seattle

May 31:
NF Preliminary Report due
(Snowmass deadline)

Courtesy NF conveners

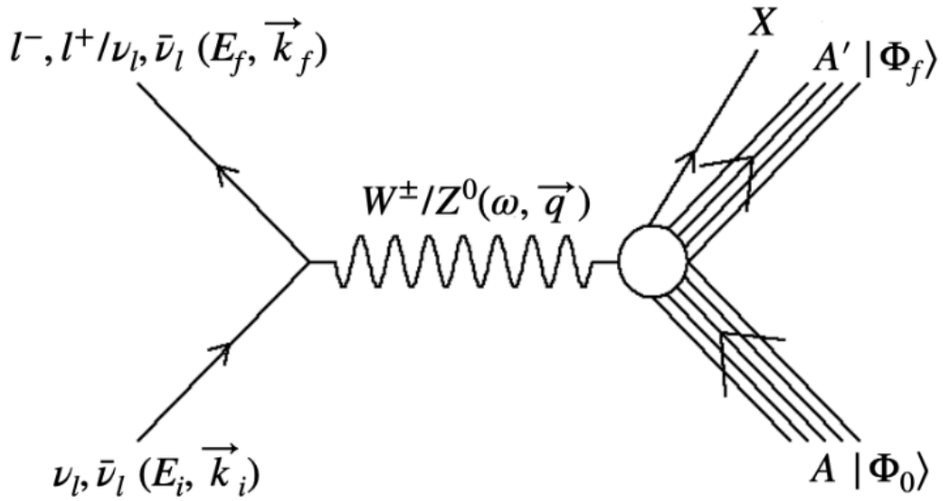
Electron- and Neutrino-Nucleus Scattering

✦ Electron- and neutrino-nucleus scattering probe similar underlying nuclear physics. The vector part of the weak response is related to the electromagnetic response through CVC. Any nuclear model and generator used to describe neutrino-nucleus scattering should first be validated against electron scattering data.

✦ Electron scattering has the distinct advantage of monochromatic beams with well determined energies, allowing for a significantly cleaner kinematic separation of the various production mechanisms.

$$\sum_{fi} |\mathscr{M}|^2 \propto \frac{G_F^2}{2} L_{\mu\nu} W^{\mu\nu}$$

- Leptonic Tensor: $L_{\mu\nu} = \sum_{fi} (\mathcal{J}_{l,\mu})^\dagger \mathcal{J}_{l,\nu}$
- Hadronic Tensor: $W^{\mu\nu} = \sum_{fi} (\mathcal{J}_n^\mu)^\dagger \mathcal{J}_n^\nu$
- Transition Amplitude: $\mathcal{J}_n^\mu = \langle \Phi_f | \hat{J}_n^\mu(q) | \Phi_0 \rangle$



$$\omega = E_i - E_f, \quad q = |\vec{k}_i - \vec{k}_f|, \quad Q^2 = q^2 - \omega^2$$

■ Electron-nucleus cross sections:

$$\left(\frac{d^2\sigma}{d\omega_e d\Omega}\right)_e = \frac{\alpha^2}{Q^4}\left(\frac{2}{2J_i+1}\right)\frac{1}{k_f E_i} \times \zeta^2(Z', E_f, q_e)\left[\sum_{J=0}^{\infty}\sigma_{L,e}^J + \sum_{J=1}^{\infty}\sigma_{T,e}^J\right]$$

$$\sigma_{L,e} = v_e^L R_e^L$$

$$\sigma_{T,e} = v_e^T R_e^T$$

■ Neutrino-nucleus cross sections:

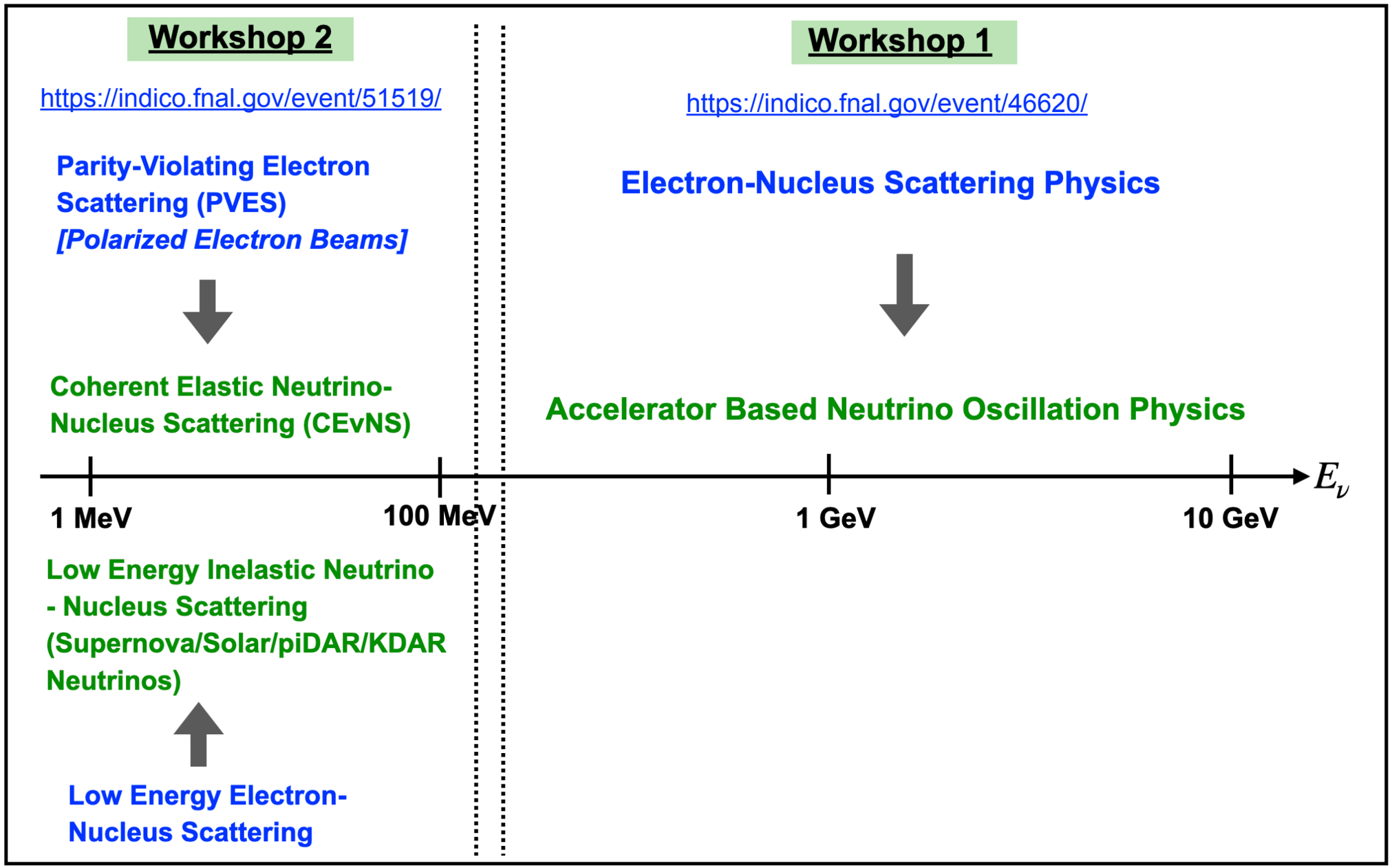
$$\left(\frac{d^2\sigma}{d\omega_\nu d\Omega}\right)_\nu = \frac{G_F^2\cos^2\theta_c}{(4\pi)^2}\left(\frac{2}{2J_i+1}\right)\varepsilon_f\kappa_f \times \zeta^2(Z', \varepsilon_f, q_\nu)\left[\sum_{J=0}^{\infty}\sigma_{CL,\nu}^J + \sum_{J=1}^{\infty}\sigma_{T,\nu}^J\right]$$

$$\sigma_{CL,\nu}^J = \left[v_\nu^{\mathcal{M}} R_\nu^{\mathcal{M}} + v_\nu^{\mathcal{L}} R_\nu^{\mathcal{L}} + 2\, v_\nu^{\mathcal{ML}} R_\nu^{\mathcal{ML}}\right]$$

$$\sigma_{T,\nu}^J = \left[v_\nu^T R_\nu^T \pm 2\, v_\nu^{TT} R_\nu^{TT}\right]$$

NF06 Electron Scattering and Neutrino Physics White Paper

- ✦ We organized two NF06 workshops to explore connections between electron- and neutrino-nucleus scatterings, and in defining the role of the electron scattering data on neutrino physics.
- ✦ A White Paper is commissioned with the scope defined based on the community input from the workshops.
- ✦ One of the key goals of this White Paper is to highlight nuclear physicists' perspective and address NP and HEP boundary conditions.



Snowmass21 NF06 Electron Scattering Workshop

https://indico.fnal.gov/event/46620/

Monday Dec 14, 2020, 9:00 AM → 12:10 PM US/Central

Kendall Mahn (Michigan State University), Vishvas Pandey (University of Florida)

9:00 AM → 9:05 AM **Welcome**
Speaker: Kendall Mahn (Michigan State University)
welcome f...

9:05 AM → 9:35 AM **Electron and neutrino scattering connections, needs and gaps**
Speaker: Natalie Jachowicz (Ghent University)
jachowicz....

9:35 AM → 10:00 AM **Discussion**
Speaker: Kendall Mahn (Michigan State University)

10:00 AM → 10:10 AM **Electron scattering experimental landscape**
Speaker: Vishvas Pandey (University of Florida)
NF06_Elec...

10:35 AM → 10:55 AM **Discussion**
Speakers: Kendall Mahn (Michigan State University), Vishvas Pandey (
Florida)

10:55 AM → 11:05 AM **Break**

11:05 AM → 11:35 AM **Survey discussion**
Speaker: Baha Balantekin (University of Wisconsin)
ES_Survey....

11:35 AM → 12:00 PM **White paper outline and discussion**
Speakers: Kendall Mahn (Michigan State University), Vishvas Pandey (
Florida)
NF06_Elec...

10:00 AM → 10:10 AM **Electron scattering experimental landscape**
Speaker: Vishvas Pandey (University of Florida)
NF06_Elec...

10:10 AM → 10:15 AM **E12-14-012 at JLab**
Speaker: Camillo Mariani (Virginia Tech)
JLab E-Ar ...

10:15 AM → 10:20 AM **JUPITER at JLab**
Speaker: Arie Bodek (University of Rochester)
Jupiter-Sn...

10:20 AM → 10:25 AM **LOI 102: e4nu at JLab**
Speaker: Adi Ashkenazi (Massachusetts Institute
201214_e4...

10:25 AM → 10:30 AM **LOI 91: LDMX at SLAC**
Speaker: Cristina Mantilla
CMS_LDM...

10:30 AM → 10:35 AM **A1 Collaboration at MAMI**
Speaker: Luca Doria
Doria_Sno...

Snowmass21 NF06 Low Energy Neutrino and Electron Scattering Workshop

https://indico.fnal.gov/event/51519/

Friday Nov 12, 2021, 9:00 AM → 1:00 PM US/Central

Baha Balantekin (University of Wisconsin), Jacob Zettlemoyer (Fermilab),
Jason Newby (Oak Ridge National Laboratory), Kendall Mahn (Michigan State University),
Vishvas Pandey (University of Florida)

Low Energy Elastic Scattering: CEvNS/PVES

Convener: Jason Newby (Oak Ridge National Laboratory)

NF06_Workshop_W...

9:00 AM — **CEvNS Overview**

Status and precision needs for the weak form factor and n violating electron scattering and CEvNS: status of the field

Speaker: Sonia Bacca (University of Mainz)

bacca_NF06_2021....

9:20 AM — **PVES Overview**

Overview of the current and planned PVES electron scatte factor and neutron radii.

Speaker: Charles Horowitz (Indiana University)

Horowitz_PVES.pdf

9:40 AM — **Discussion**

Speaker: Jason Newby (Oak Ridge National Laboratory)

White Paper: Discussion

Conveners: Jason Newby (Oak Ridge National Laboratory), Vishvas Pandey

12:00 PM — **Discussion**

Unified electron scattering white paper?
discuss outline, solicit contributions

Low Energy Inelastic Scattering: Low-Energy Inelastic Scattering

supernova/solar/piDAR/KDAR neutrinos

Convener: Vishvas Pandey (University of Florida)

10:00 AM — **Theory Perspective**

Connections between 10s of MeV electron- and neutrino-nucleus scatte what theory is needed, what measurements are needed.

Speaker: Anna Hayes (LANL)

Hayes-Snomass-20...

10:20 AM — **DUNE Perspective**

DUNE perspective of low-energy neutrino scattering physics - what is th kind of external theory and experimental neutrino (and/or electron) scat

Speaker: Erin Conley (Duke University)

Conley_2021Nove...

10:50 AM — **Neutrino Scattering Measurements 10s of MeV and KDAR**

Status and plans of worldwide 10s of MeV inelastic neutrino-nucleus ar measurements, how these measurements will help constrain low-energ program.

Speaker: Taritree Wonjigrad (Tufts University)

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11:10 AM — **Electron Measurements at MAMI at MAINZ**

Status and plans of 10s of MeV electron scattering measurements at M electron scattering measurement.

Speaker: Luca Doria (University of Mainz)

NeutrinosMainz_No...

11:30 AM — **Discussion**

What electron scattering measurement (and what nuclei) can be consic developments are needed?

Speaker: Vishvas Pandey (University of Florida)

Electron Scattering and Neutrino Physics: A Snowmass White Paper

NF06 Contributed Paper to Snowmass 2021

Contents

- Core contributions from NuSTEC board: Adi, Andy, Artur, Camillo, Federico, Natalie, Vishvas, …
- More contributions and help would be welcome! Please get in touch!

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