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U.S. DEPARTMENT OF ENERGY | Office of Science

Potential Constraints to Neutrino - Nucleus Interactions Based on Electron Scattering Data

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NuFACT 2022, 23rd International Workshop on Neutrinos from Accelerators
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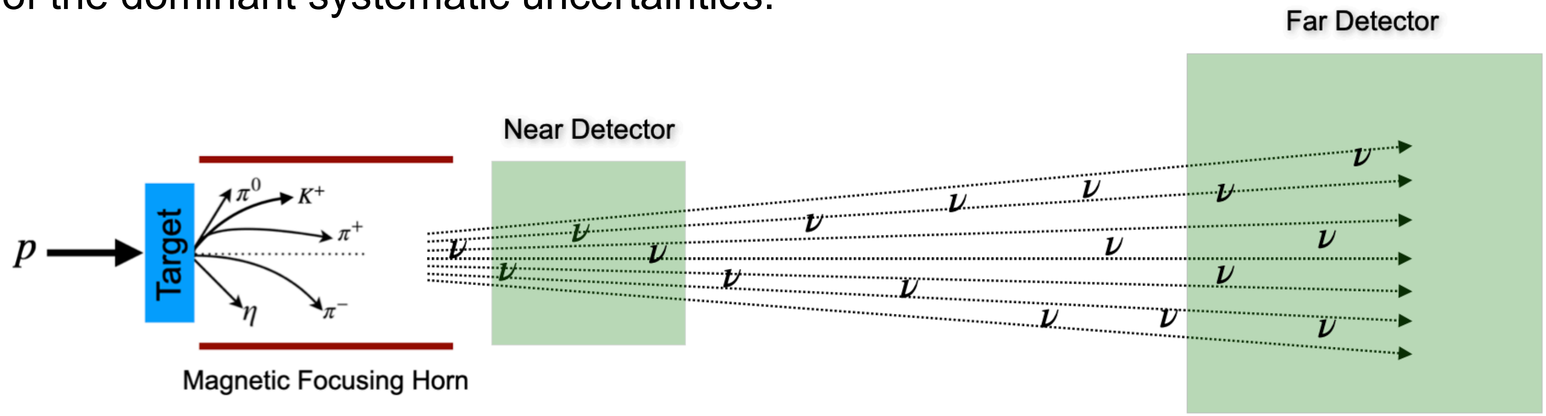
Neutrino-Nucleus Interactions Uncertainty

- In **accelerated-based neutrino oscillation** program, neutrino-nucleus interactions constitute one of the dominant systematic uncertainties.



- near to far ratio doesn't cancel out flux and cross sections dependence.

$$\frac{N_{FD}^{\alpha\to\beta}(E_{\nu,rec}) \propto \sum_i \phi_\alpha(E_\nu) \times \sigma_\beta^i(E_\nu) \times P(\nu_\alpha \to \nu_\beta) \times \epsilon_\beta(E_\nu, E_{\nu,rec})}{N_{ND}^{\alpha}(E_{\nu,rec}) \propto \sum_i \phi_\alpha(E_\nu) \times \sigma_\alpha^i(E_\nu) \times \epsilon_\alpha(E_\nu, E_{\nu,rec})}$$

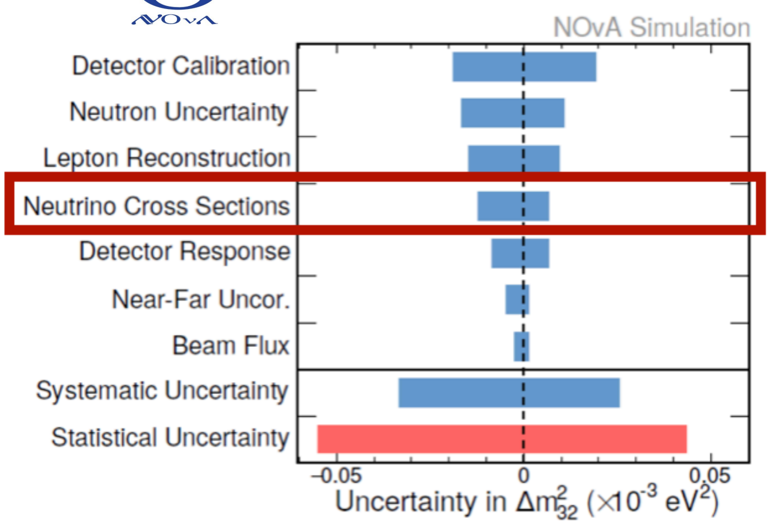
$$P(\nu_\alpha \to \nu_\beta) = \sin^2 2\theta_{ij} \ \sin^2\left(\frac{\Delta m_{ij}^2}{4}\frac{L}{E_\nu}\right)$$

Neutrino-Nucleus Interactions Uncertainty

- In **accelerated-based neutrino oscillation** program, neutrino-nucleus interactions constitute one of the dominant systematic uncertainties.
  - One of the largest uncertainties in current long-baseline experiments, T2K and NOvA.

T2K

	Systematic uncertainties		
Beam mode	**Neutrino**		
SK sample	**1 Ring μ-like**	**1 Ring e-like**	**1 Ring e-like 1de**
Flux	5.1%	4.8%	4.9%
Cross-section	10.1%	10.3%	12.0%
SK	2.9%	4.4%	13.4%



- In future experiments, DUNE and HyperK, the statistics will significantly increase and neutrino interaction systematics uncertainties will be dominant.

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  - One of the largest uncertainties in current long-baseline experiments, T2K and NOvA.
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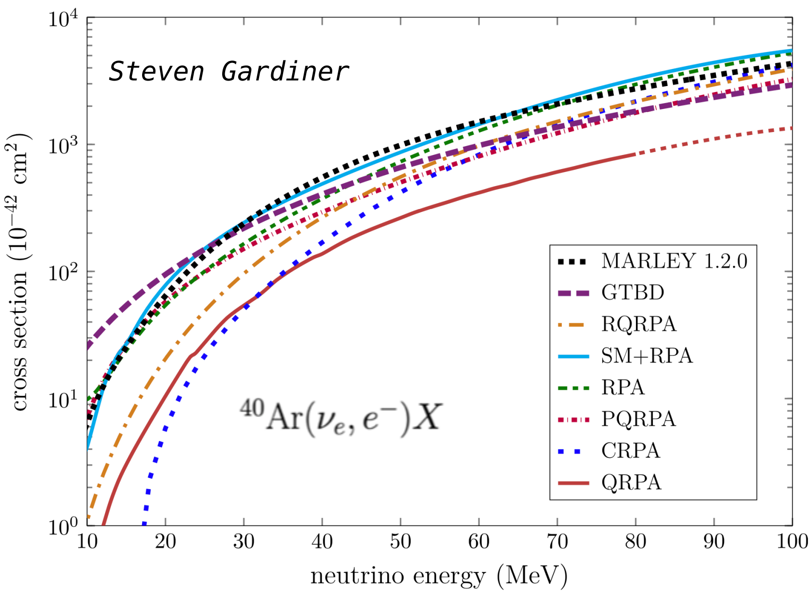
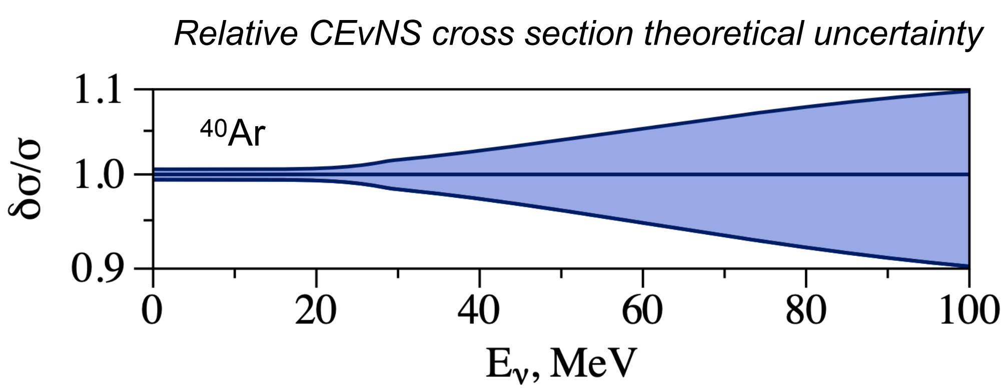
- Similarly for low-energy (10s of MeV) neutrinos:
  - The uncertainties on inelastic neutrino-nucleus interaction, the detection channel for **supernova neutrinos** in DUNE/HyperK is large (often not even quantified).
  - Although theoretical uncertainties are relatively small in **CEvNS** case. Percent level precision might be needed to disentangle new physics signals.





O. Tomalak, P. Machado, V. Pandey, R. Plestid, JHEP 02, 097 (2021)

Neutrino-Nucleus Interactions Uncertainty

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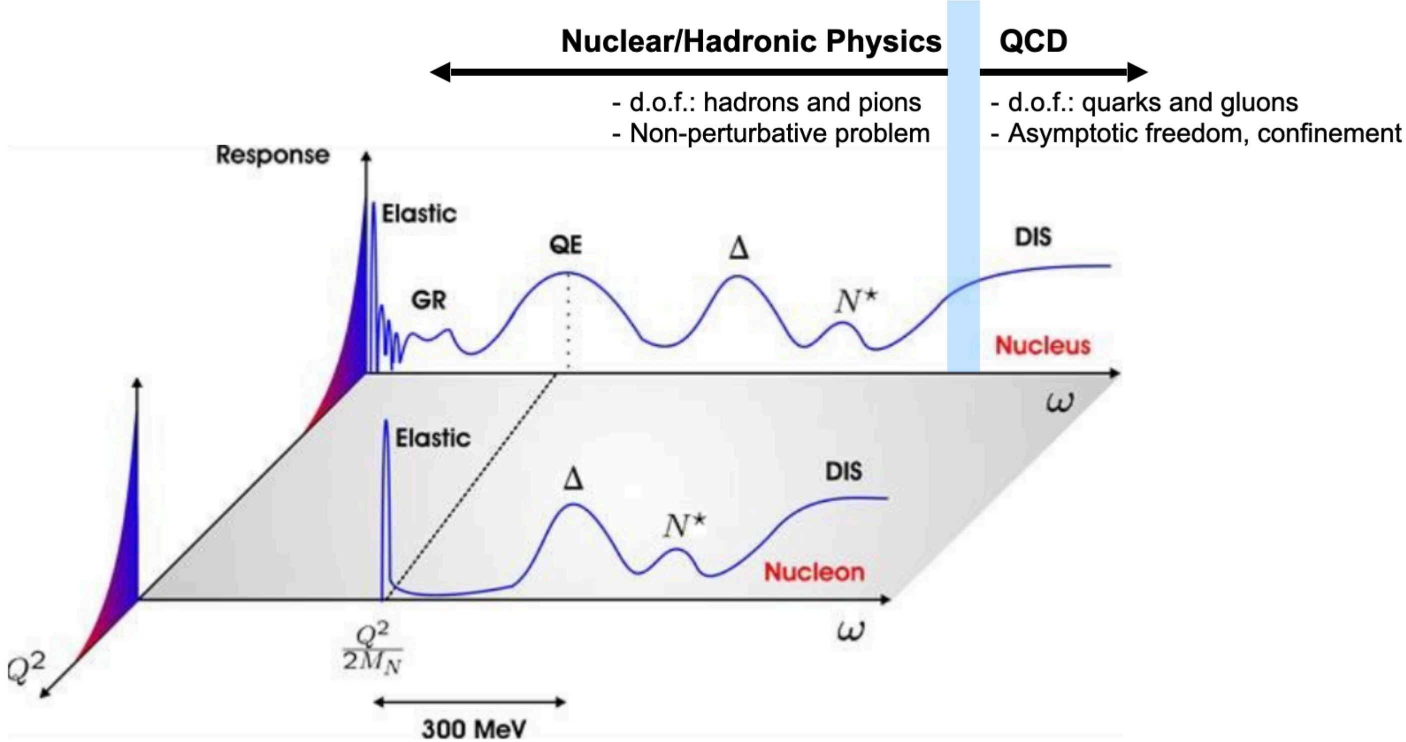
  - Although theoretical uncertainties are relatively small in **CEvNS** case. Percent level precision might be needed to disentangle new physics signals.
- This talks covers **electron-nucleus scattering** efforts (NP-HEP cross-community efforts) that can significantly help constraining neutrino-nucleus interactions physics across these energy ranges.

Neutrino-Nucleus Interactions

- Multi-scale, multi-process, many-body, non-perturbative problem subject to complex nuclear structure and dynamics.
- No unified underlying theory to describe neutrino-nucleus interactions.
- Transition between different degrees of freedom.



- Need a description of initial state target nucleus, its response to the electroweak probe that include several reaction mechanisms resulting into various finals state particles, and final state interactions that further modify the properties of the hadronic system created at the primary interaction vertex.

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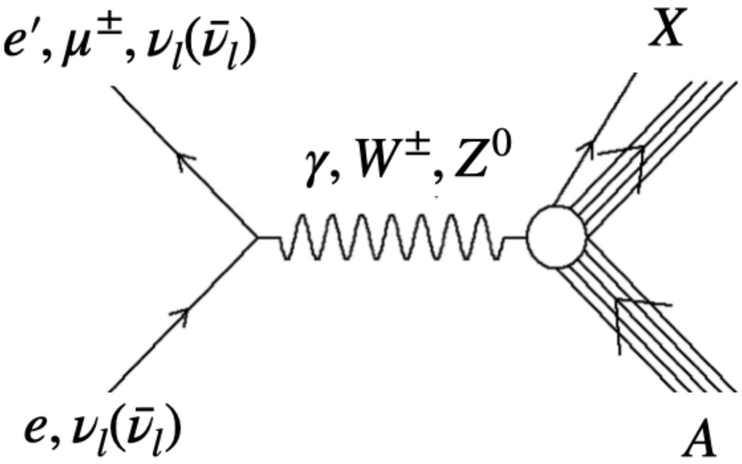
Connections Between Electron and Neutrino Scattering



- **Cross Section:**

$$\sigma \propto L^{\mu\nu} R_{\mu\nu}$$

- Nuclear Response:

$$R_{\mu\nu} = \sum_f < \psi | J^{\dagger}_{\mu}(q) | \psi_f > < \psi_f | J_{\nu}(q) | \psi > \delta(E_0 + \omega - E_f)$$

- $e - A$ **Cross Section:**

$$\sigma_e \propto v_e^L R^L + v_e^T R^T$$

- $\nu - A$ **Cross Section:**

$$\sigma_\nu \propto v_\nu^M R^M + v_\nu^L R^L + 2 v_\nu^{ML} R^{ML} + v_\nu^T R^T \pm 2 v_\nu^{TT} R^{TT}$$

- Initial nucleus description is same
- Coupling at the vertex is Vector for electron and Vector+Axial for neutrinos
  - The vector current is conserved (CVC) between electromagnetic and weak interactions
- Final state interactions effects are same
- With electron scattering we could probe everything except axial components

Connections Between Electron and Neutrino Scattering

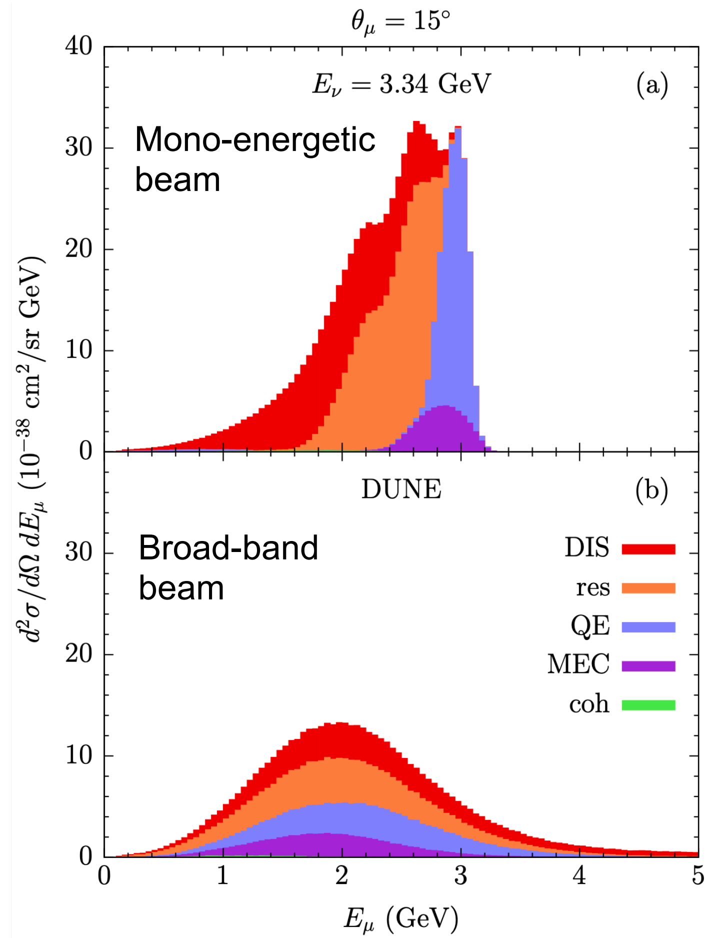
- Advantage of electron beams:
  - Mono-energetic beams

    - electron scattering data can be collected with precisely controlled kinematics (initial and final energies and scattering angles) allows to separate different processes

  - Large statistics
  - High precision

- Various aspects of nuclear structure and dynamics influencing the neutrino-nucleus cross section can be studied in electron scattering. By exploiting electron-scattering data to fix the common physics elements, one will then be able to isolate the ingredients that are specific to neutrino interactions, such as axial couplings.

- Any model/generator that doesn't work for electron scattering would not work for neutrino scattering.



A. M. Ankowski et al., Phys. Rev. D 102, 053001 (2020)

Electron Scattering: Archive of Past Measurements

Quasielastic Electron Nucleus Scattering Archive

Donal Day
April 14, 2015

Year	Laboratory	Energies (GeV)	Angles	Targets	Mode	PID	DeltaP/P (%)	In Archive	Citation
1980	Bates	0.1--0.37	90--160	Fe	S	Ckov	<0.1	N	Altemus:1980wt, Altemus:1980
1984	Bates	.15--.3	180	Fe	S	Ckov	<0.1	Y	Hotta:1984
1986	Bates	0.1-0.69	60--160	238U	S	Ckov	<0.1	Y	Blatchley:1986qd, Blatchley:1984
1986	Bates	0.22-0.32	180	2H	S	Ckov	<0.1	Y	Parker:1986
1987	Bates	.537 and .730	37.1	4He, Be, C and O	S	Ckov	<0.1	Y	O'Connell:1987ag
1988	Bates	0.07--0.79	54--134.5	3H, 3He	E	Ckov	<0.1	Y	Dow:1988rk, Dow:1987
1988	Bates	.3--.6	60, 134.5	2H, 3He, 4He	E	Ckov	<0.1	N	Dytman:1988fi
1988	Bates	.29--.44	60, 134.5	2H	E	Ckov	<0.1	N	Quinn:1988ua
1990	Bates	0.28--0.73	60 and 134.5	4He	E	Ckov	<0.1	Y	vonReden:1990a
1997	Bates	0.130--.84	45.5, 90, 140	Ca40	S/E	Ckov	<0.1	Y	Williamson:1997, Yates:1993jg
1971	CEA	1--4	8.5--18	C	E	SC,Ckov		N	Stanfield:1971eg
1974	DESY	2.7	12--15	Li	E	SC,Ckov	1.2	N	Heimlich:1974rk, Heimlich:1973
1974	DESY	2--2.7	15	C	E	SC,Ckov	1.2	Y	Zeller:1973ge
1996	Frascati	.7--1.5	32, 37.1 and 83	16O		SC,Ckov	few %	Y	Anghinolfi:1996vm
1971	HEPL	0.5	60	Li,C,Mg,Ca,Ni,Y,Sn,Ta,Pb	S	Ckov	0.1	Y	Moniz:1971mt, Whitney:1974hr
1976	HEPL	0.5	60	3He, 4He	S	Ckov	0.1	Y	McCarthy:1976re
1998	JLAB	4.045	15-55	2H,C,Fe,Au	E	SC,Ckov	0.1	Y	Arrington:1998ps, Arrington:1998hz
2011	JLAB	5.766	18.00-55.00	2H, 3He, 4He, 9Be, 12C, 64Cu, 197Au	E	SC,Ckov	0.1	Y	Fomin:2010ei
1969	Kharkov	0.6--1.	16--60	C		Ckov		N	Dementii:1969
1969	Kharkov	1.1	25	C		SC,Ckov		N	Titov:1969
1971	Kharkov	1.1--1.2	20--60	C,Al,Ni,Mo,W		SC,Ckov		N	Titov:1971
1972	Kharkov	1.18	16--55	6Li		SC,Ckov		N	Titov:1972
1974	Kharkov	1.2	20--35	Be,Cu, Ag		SC,Ckov		N	Titov:1974
1976	Kharkov			4He				N	Dementii:1976
1983	Saclay	0.120--0.60	36,60,90,and 145	C	S	Ckov	0.1	Y	Barreau:1983ht
1984	Saclay	0.120--0.695	60,90, and 140	40Ca, 48Ca, Fe	S	Ckov	0.1	Y	Meziani:1984is
1985	Saclay	0.12--0.67	36--145	3He	S	Ckov	0.1	Y	Marchand:1985us
1993	Saclay	0.14--0.65	34--145	4He and Pb	E	Ckov	0.1	Y	Zghiche:1993xg
1976	SLAC	6.5--18.4	8	2H	E	SC,Ckov	0.5	Y	Schutz:1976he
1979	SLAC	2.8--14.7	8	3He	E	SC,Ckov	0.2	Y	Day:1979bx
1981	SLAC	6.5--11.3	8	4He	E	SC,Ckov	0.1	Y	Rock:1981aa
1987	SLAC	up to 4 GeV	15-39	4He, C, Al, Fe, Au	E	SC,Ckov	0.1	Y	Day:1987az, Day:1993md, Potterveld:1989wn
1988	SLAC	0.65--1.65	11--55	C and Fe	E	SC,Ckov	0.1	Y	Baran:1988tw, Baran:1989
1988	SLAC	0.8 --1.3	180	2H	E	SC,Ckov	0.1	Y	Arnold:1988us
1989	SLAC	1--1.5	37.5	4He,C, Fe, W	E	SC,Ckov	0.1	Y	Sealock:1989nx
1991	SLAC	9.7-21	10	2H	E	SC,Ckov	0.1	Y	Rock:1991jy
1992	SLAC	1.1--4.3	15 and 85	3He, 4He, Fe	E	SC,Ckov	0.1	Y	Chen:1991vb, Chen:1990kq, Meziani:1992xr
1992	SLAC	1.5--5.5	15--90	2H	E	SC,Ckov	0.1	Y	Lung-thesis:1992
1992	SLAC	2--9.8	15--61	Al	E	SC,Ckov	0.1	Y	Bosted:1992fy
1992	SLAC	2.8--14.7	8	Al	E	SC,Ckov	0.1	Y	Rock-pc
1995	SLAC	2.--5.	15--57	2H, C, Fe, Au	E	SC,Ckov	0.1	Y	Arrington:1995hs
1988	Yerevan	1.9-2.1	16-18	C	S	SC	0.5	Y	Bagdasaryan:1988hp

http://discovery.phys.virginia.edu/research/groups/qes-archive/

- For over five decades, the electron scattering experiments at different facilities around the world have provided wealth of information on the complexity of nuclear structure, dynamics and reaction mechanisms.

- A large data set of high precision electron-nucleus scattering exist, meant to study various nuclear physics aspects, covering many nuclei and wide energy ranges corresponding to different reaction mechanisms.

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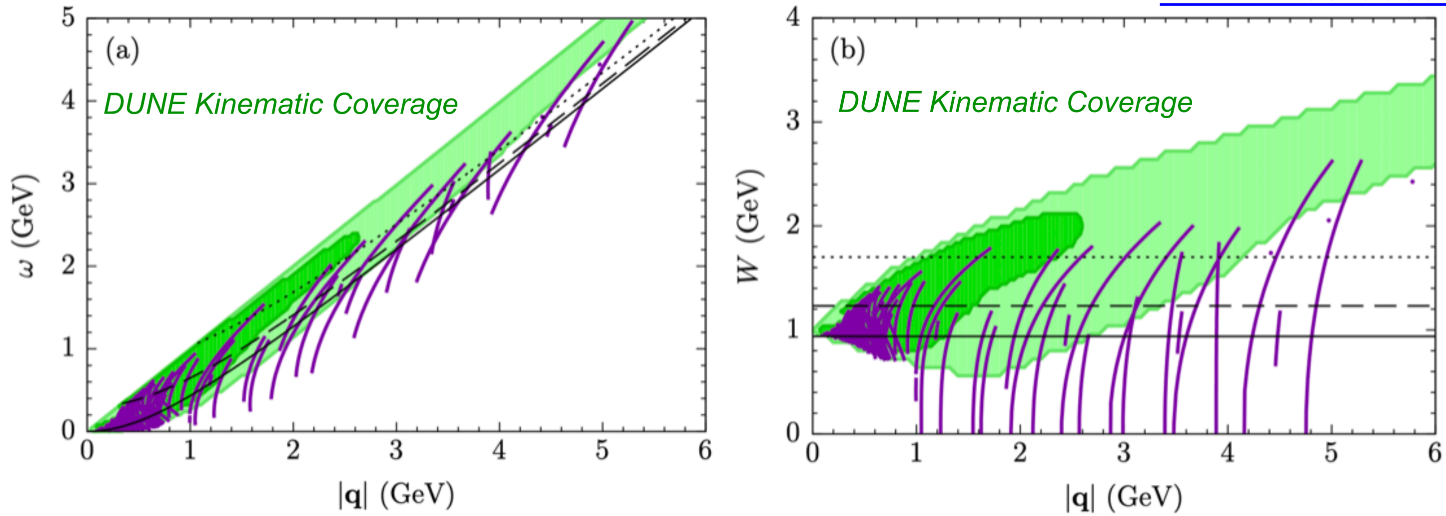
Electron Scattering: Archive of Past Measurements

- While previous and existing electron scattering experiments provide important information, new measurements which expand kinematic reach, information on the final states hadronic system are needed.

  - Kinematic coverage of available data for inclusive electron scattering on carbon, overlaid on the CC ν_μ-Ar event distribution expected in the DUNE near detector according to GENIE 3.0.6

arXiv:2203.06853 [hep-ex]



- The dark and light shaded areas correspond to 68% and 95% of the expected events
- Solid line: quasielastic; dashed line: Δ excitation; dotted line: DIS at W = 1.7 GeV

- Mainly inclusive, need new measurements that include both the outgoing electron and the final-state hadronic system
- Insufficient coverage for large values of the hadronic mass W
- (Almost) No data on argon nucleus

Electron Scattering: Current and Planned Experiments

- New electron scattering experiments motivated by the needs of the accelerator neutrino experiments (NP-HEP cross-community efforts).
- Complementary efforts that cover a broad range of kinematics and carry varied level of particle identification and other detection capabilities.

Collaborations	Kinematics	Targets	Scattering
E12-14-012 (JLab) (Data collected: 2017)	$E_e = 2.222$ GeV $15.5° \leq \theta_e \leq 21.5°$ $-50.0° \leq \theta_p \leq -39.0°$	Ar, Ti Al, C	(e, e') e, p in the final state
e4nu/CLAS (JLab) (Data collected: 1999, 2022)	$E_e = 1, 2, 4, 6$ GeV $\theta_e > 5°$	H, D, He, C, Ar, ^{40}Ca, ^{48}Ca, Fe, Sn	(e, e') e, p, n, π, γ in the final state
LDMX (SLAC) (Planned)	$E_e = 4.0, 8.0$ GeV $\theta_e < 40°$	W, Ti, Al	(e, e') e, p, n, π, γ in the final state
A1 (MAMI) (Data collected: 2020) (More data planned)	50 MeV $\leq E_e \leq 1.5$ GeV $7° \leq \theta_e \leq 160°$	H, D, He C, O, Al Ca, Ar, Xe	(e, e') 2 additional charged particles
A1 (eALBA) (Planned)	$E_e = 500$ MeV - few GeV	C, CH Be, Ca	(e, e')

Electron Scattering: Current and Planned Experiments

■ **E12-14-012 (JLab):**

- Inclusive (e, e') and exclusive $(e, e'p)$ electron scattering data were collected on argon, titanium (and carbon, aluminum) for an electron beam of energy 2.222 GeV at Hall A of Jefferson lab.
- Measuring spectral function of argon (~ initial momentum and energy distributions of nucleons bound in argon nucleus).

Collaborations	Kinematics	Targets	Scattering
E12-14-012 (JLab) (Data collected: 2017)	$E_e = 2.222$ GeV $15.5° \leq \theta_e \leq 21.5°$ $-50.0° \leq \theta_p \leq -39.0°$	Ar, Ti Al, C	(e, e') e, p in the final state
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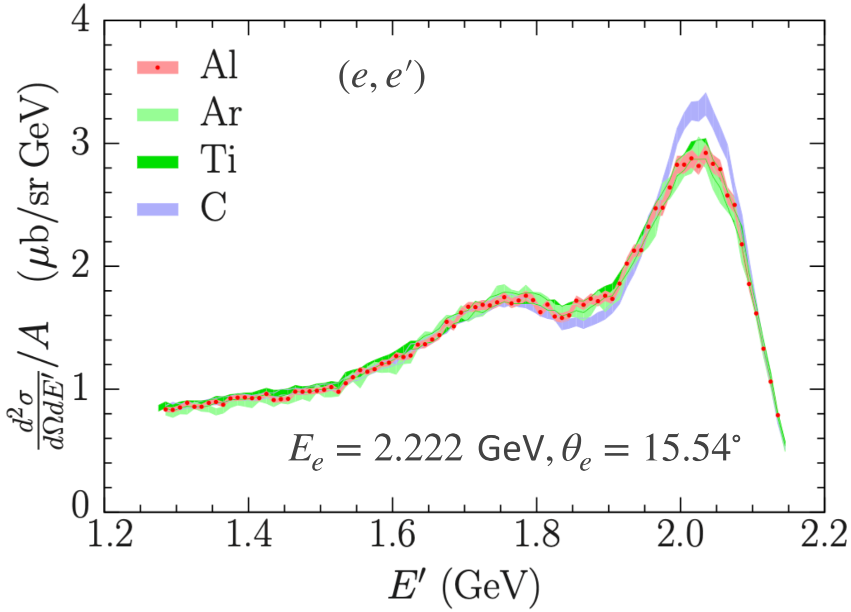

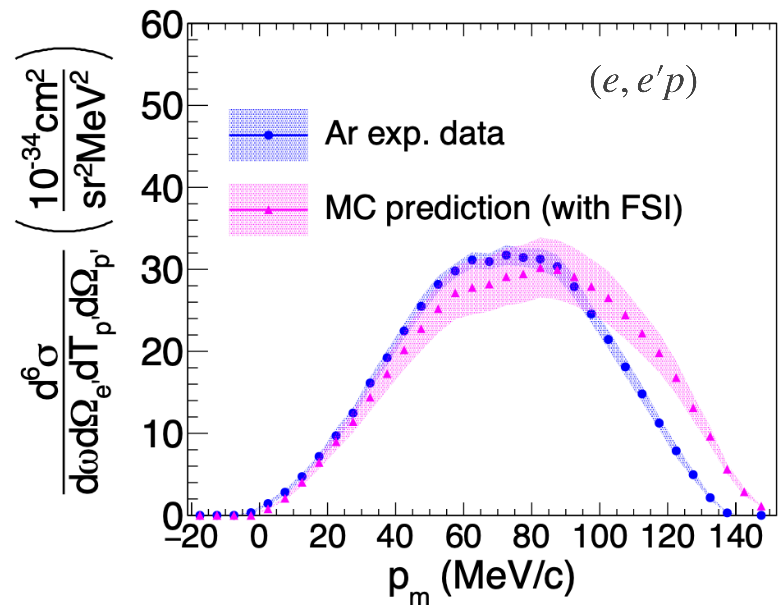

M. Murphy et al. [Jefferson Lab Hall A], Phys. Rev. C 100, 054606 (2019) L. Gu et al. [Jefferson Lab Hall A], Phys. Rev. C 103, 034604 (2021)

Electron Scattering: Current and Planned Experiments

■ **e4nu/CLAS (JLab):**

- A large acceptance detector to measure wide phase-space exclusive and semi-exclusive electron-nucleus scattering at 1 - 6 GeV energies to test energy reconstruction methods and interaction models.
- Includes both existing data taken with the CLAS spectrometer in 1999 and new data taken in winter 2021/22 with the CLAS12 spectrometer. The data analysis is as similar as possible to neutrino-based ones.

Collaborations	Kinematics	Targets	Scattering
E12-14-012 (JLab) (Data collected: 2017)	$E_e = 2.222$ GeV $15.5° \leq \theta_e \leq 21.5°$ $-50.0° \leq \theta_p \leq -39.0°$	Ar, Ti Al, C	(e, e') e, p in the final state
e4nu/CLAS (JLab) (Data collected: 1999, 2022)	$E_e = 1, 2, 4, 6$ GeV $\theta_e > 5°$	H, D, He, C, Ar, ^{40}Ca, ^{48}Ca, Fe, Sn	(e, e') e, p, n, π, γ in the final state
LDMX (SLAC) (Planned)	$E_e = 4.0, 8.0$ GeV $\theta_e < 40°$	W, Ti, Al	(e, e') e, p, n, π, γ in the final state
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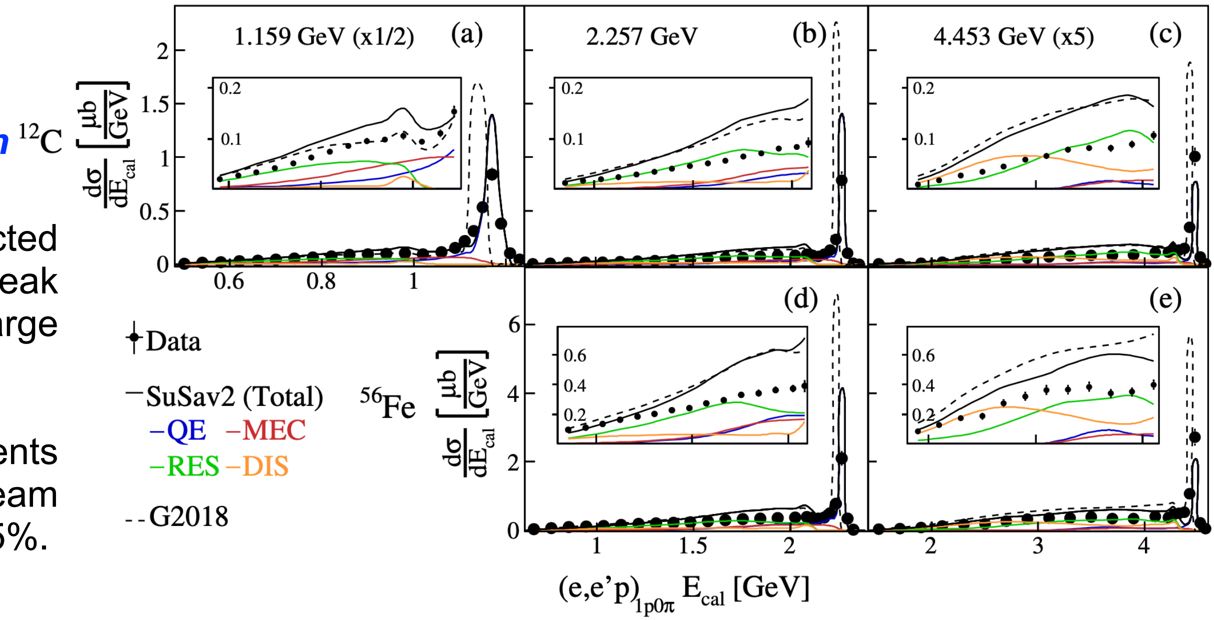
A1 (eALBA) (Planned)	$E_e = 500$ MeV - few GeV	C, CH Be, Ca	(e, e')

More in Afroditi Papadopoulou's talk in the WG2 parallel session this afternoon



- The (calorimetric method) reconstructed electron energy spectra show a sharp peak at the real beam energy, followed by a large tail at lower energies.

- For carbon, only 30–40% of the events reconstruct to within 5% of the real beam energy. For iron this fraction is only 20–25%.

M. Khachatryan et al. [CLAS and e4v], Nature 599, 565-570 (2021)

Electron Scattering: Current and Planned Experiments

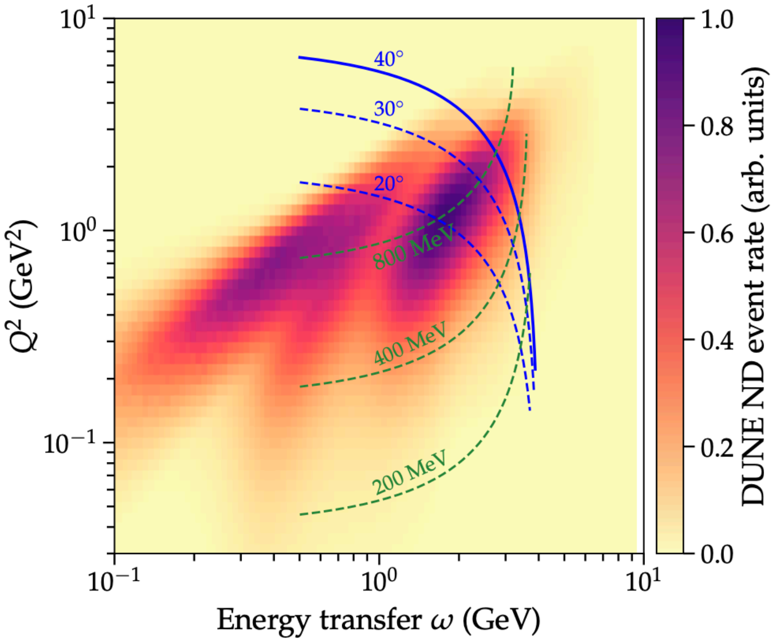
■ **LDMX (SLAC):**

- LDMX (Light Dark Matter eXperiment) is a fixed-target electron-scattering experiment planned to search for sub-GeV dark matter.
- A rich program of inclusive and (semi) exclusive electron-scattering measurements is laid out at LDMX with a 4-GeV beam.

Collaborations	Kinematics	Targets	Scattering
E12-14-012 (JLab) (Data collected: 2017)	$E_e = 2.222$ GeV $15.5^\circ \le \theta_e \le 21.5^\circ$ $-50.0^\circ \le \theta_p \le -39.0^\circ$	Ar, Ti Al, C	(e, e') e, p in the final state
e4nu/CLAS (JLab) (Data collected: 1999, 2022)	$E_e = 1, 2, 4, 6$ GeV $\theta_e > 5^\circ$	H, D, He, C, Ar, ^{40}Ca, ^{48}Ca, Fe, Sn	(e, e') e, p, n, π, γ in the final state
LDMX (SLAC) (Planned)	$E_e = 4.0, 8.0$ GeV $\theta_e < 40^\circ$	W, Ti, Al	(e, e') e, p, n, π, γ in the final state
A1 (MAMI) (Data collected: 2020) (More data planned)	50 MeV $\le E_e \le 1.5$ GeV $7^\circ \le \theta_e \le 160^\circ$	H, D, He C, O, Al Ca, Ar, Xe	(e, e') 2 additional charged particles
A1 (eALBA) (Planned)	$E_e = 500$ MeV - few GeV	C, CH Be, Ca	(e, e')

More in Wesley Ketchum's talk in the WG2 parallel session this afternoon

- Kinematics accessible at LDMX with a 4-GeV beam, overlaid on the charged-current ν_μ-Ar event distribution expected in the DUNE near detector according to GiBUU. Constant scattering angles θ_e and transverse momenta p_e^T of electrons correspond to the blue and green lines, respectively.
- With its nominal selections, LDMX can cover the deep-inelastic kinematics in great detail, and probe the tail of resonance production.



A. M. Ankowski, et al, Phys. Rev. D 101, no.5, 053004 (2020)

Electron Scattering: Current and Planned Experiments

■ A1 (MAMI):

- Mainz Microtron (MAMI) is an electron accelerator at Mainz. The A1 Collaboration hall in particular is devoted to experiments with electrons.
- New data sets for 12C, 40Ar and 40Ca targets.

Collaborations	Kinematics	Targets	Scattering
E12-14-012 (JLab) (Data collected: 2017)	$E_e = 2.222$ GeV $15.5° \leq \theta_e \leq 21.5°$ $-50.0° \leq \theta_p \leq -39.0°$	Ar, Ti Al, C	(e, e') e, p in the final state
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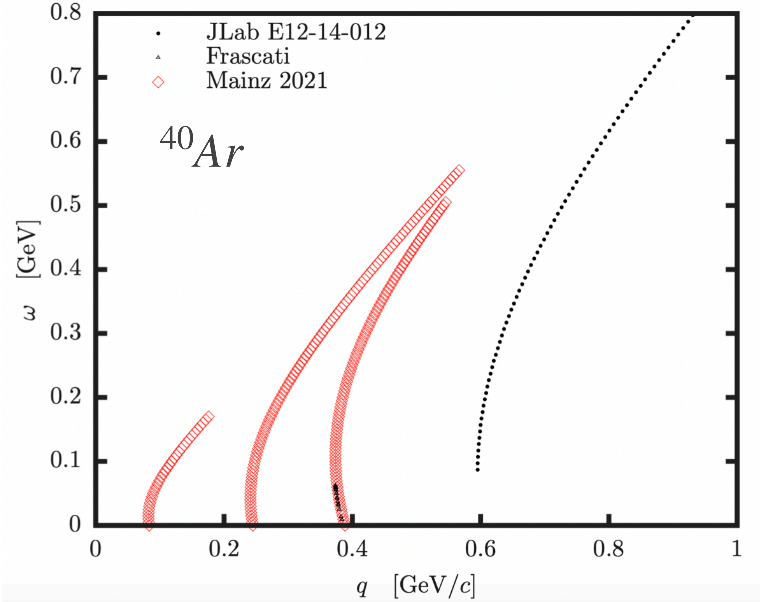
A1 (MAMI) (Data collected: 2020) (More data planned)	50 MeV $\leq E_e \leq 1.5$ GeV $7° \leq \theta_e \leq 160°$	H, D, He C, O, Al Ca, Ar, Xe	(e, e') 2 additional charged particles
A1 (eALBA) (Planned)	$E_e = 500$ MeV - few GeV	C, CH Be, Ca	(e, e')

■ A1 (eALBA):

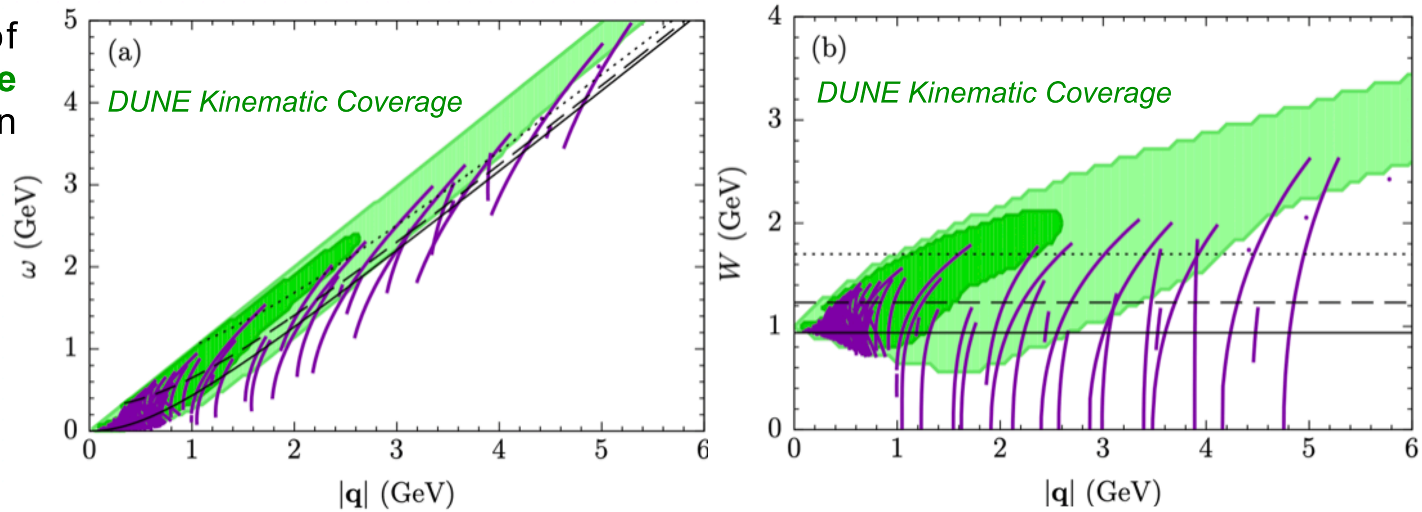
- The proposed instrument (**eALBA**) is a multipurpose electron beam facility, where the electron beam is from the ALBA synchrotron in Barcelona (Spain).
- One of the proposed experimental facilities is devoted to Electron-Nucleus scattering experiments for neutrino studies.



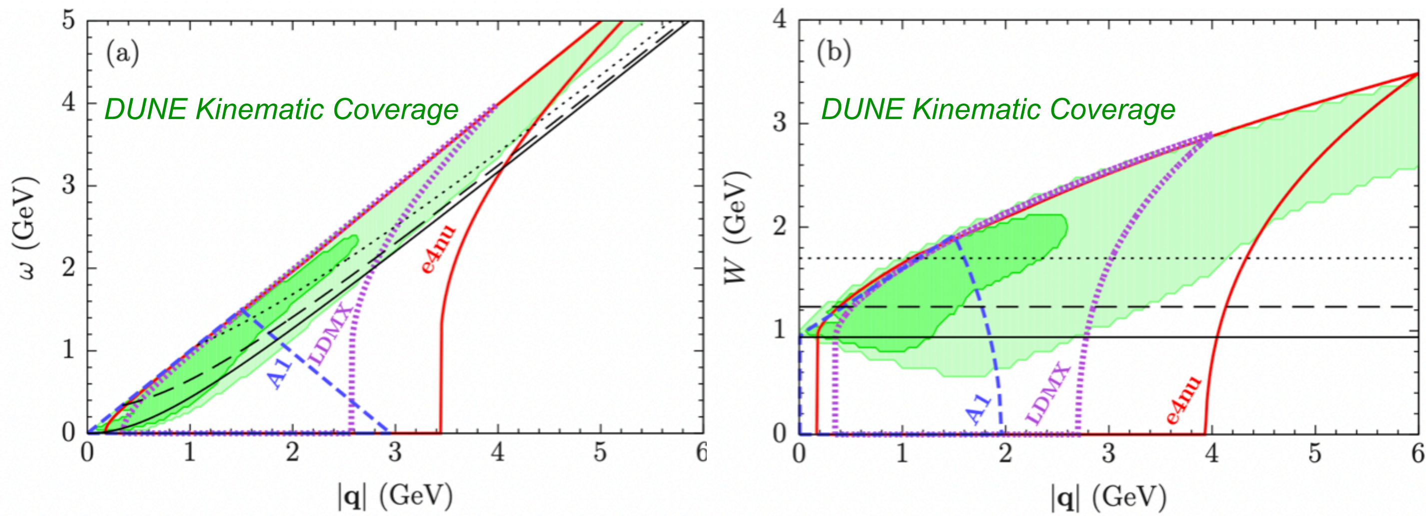
Luca Doria at a Snowmass workshop

Electron Scattering: Current and Planned Experiments

- Kinematic coverage of **available data from the past** for **inclusive** electron scattering on **carbon**.



- Kinematic coverage of **ongoing and planned experiments** for both **inclusive and exclusive** electron scattering on targets including **argon**.



- **Complementary efforts, navigating NP-HEP boundary conditions.**

[arXiv:2203.06853 [hep-ex]]

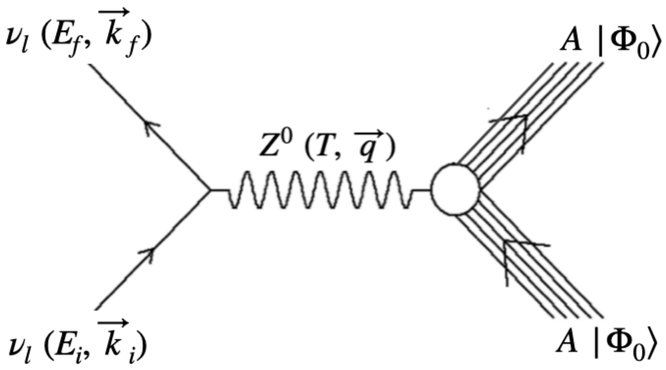
**both overlaid on the CC ν_μ-Ar event distribution expected in the DUNE near detector according to GENIE 3.0.6*

CEvNS and Parity Violating Electron Scattering

- **CEvNS cross section**:

$$\frac{d\sigma}{dT} = \frac{G_F^2}{\pi} M_A \left[1 - \frac{T}{E_i} - \frac{M_A T}{2E_i^2}\right] \frac{Q_W^2}{4} F_W^2(q)$$

$$\begin{aligned} Q_W\ F_W(q) &\approx \langle \Phi_0 | \hat{J}_0(q) | \Phi_0 \rangle \\ &\approx \left(1 - 4\sin^2\theta_W\right) Z\, F_p(q) - N\, F_n(q) \\ &\approx 2\pi \int d^3r\ \left[(1 - 4\sin^2\theta_W)\rho_p(r) - \rho_n(r)\right] j_0(qr) \end{aligned}$$



N. Van Dessel, V. Pandey, H. Ray, N. Jachowicz, arXiv:2007.03658 [nucl-th]

CEvNS and Parity Violating Electron Scattering

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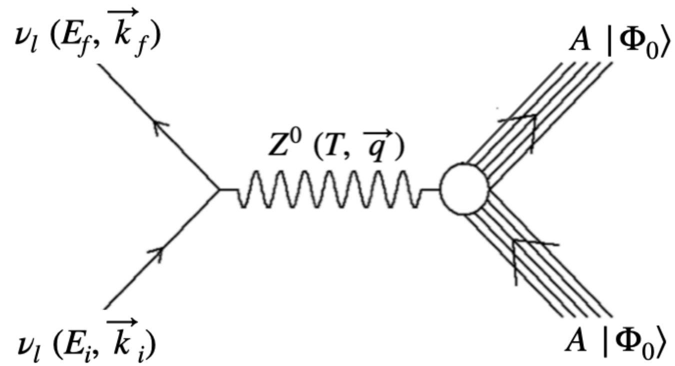

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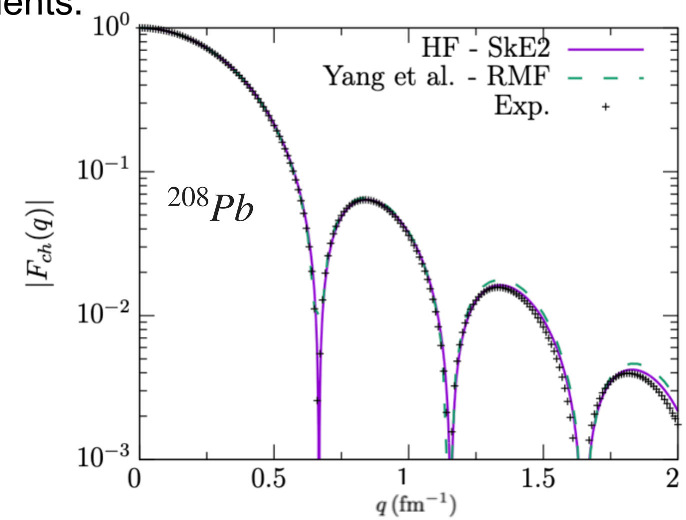
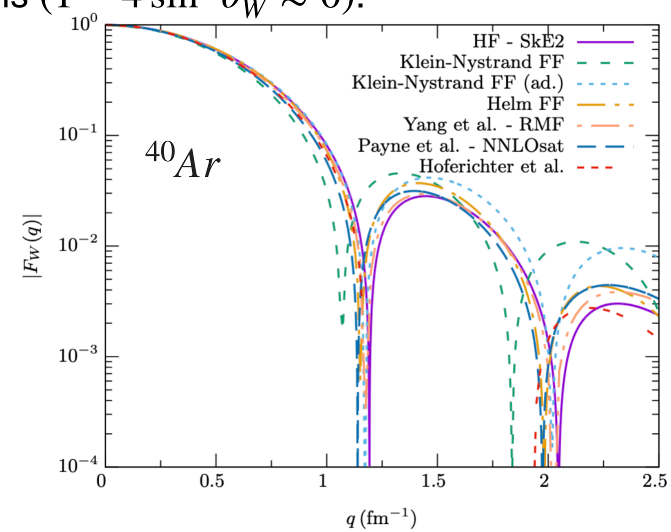
N. Van Dessel, V. Pandey, H. Ray, N. Jachowicz, arXiv:2007.03658 [nucl-th]

Charge density and charge form factor: proton densities and charge form factors are well know through decades of elastic electron scattering experiments.



Data: H. De Vries, et al., Atom. Data Nucl. Data Tabl. 36, 495 (1987)

Neutron densities and neutron form factor: neutron densities and form factors are poorly known. Note that CEvNS is primarily sensitive to neutron density distributions ($1 - 4\sin^2\theta_W \approx 0$).



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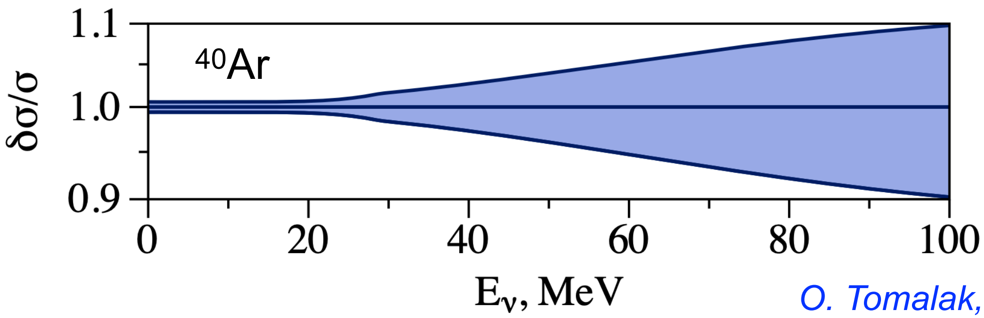
CEvNS and Parity Violating Electron Scattering

- Although theoretical uncertainties are relatively small. In order to disentangle new physics signals from the SM expected CEvNS rate, the weak form factor, which primarily depends on the neutron density, has to be known at percent level precision.

  - Relative CEvNS cross section theoretical uncertainty on ^{40}Ar (includes nuclear, nucleonic, hadronic, quark levels as well as perturbative errors):



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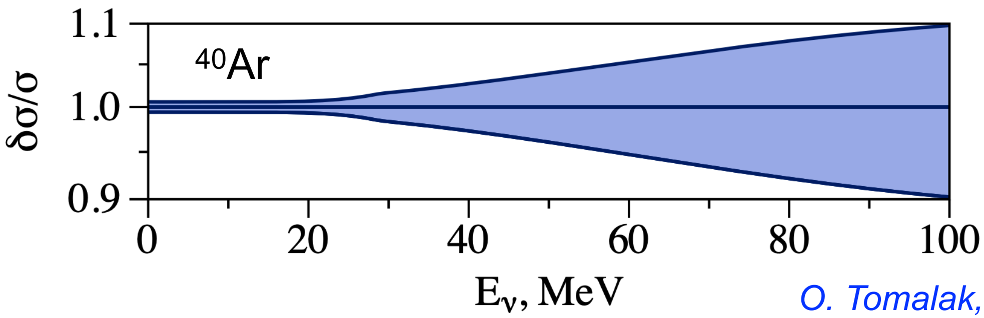

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- **Electroweak probes** such as parity–violating electron scattering (**PVES**) and **CEvNS** provide relatively model-independent ways of determining weak form factor and neutron distributions. The parity violating asymmetry for elastic electron scattering is the fractional difference in cross section for positive helicity and negative helicity electrons.

$$A_{PV} = \frac{d\sigma/d\Omega_+ - d\sigma/d\Omega_-}{d\sigma/d\Omega_+ + d\sigma/d\Omega_-} = \frac{G_F q^2 |Q_W|}{4\pi\alpha\sqrt{2}Z} \frac{F_W(q)}{F_{ch}(q^2)}$$

Experiment	Target	q^2 (GeV^2)	A_{pv} (ppm)	$\pm\delta R_n$ (%)
PREX	^{208}Pb	0.00616	0.550 ± 0.018	1.3
CREX	^{48}Ca	0.0297		0.7
Qweak	^{27}Al	0.0236	2.16 ± 0.19	4
MREX	^{208}Pb	0.0073		0.52

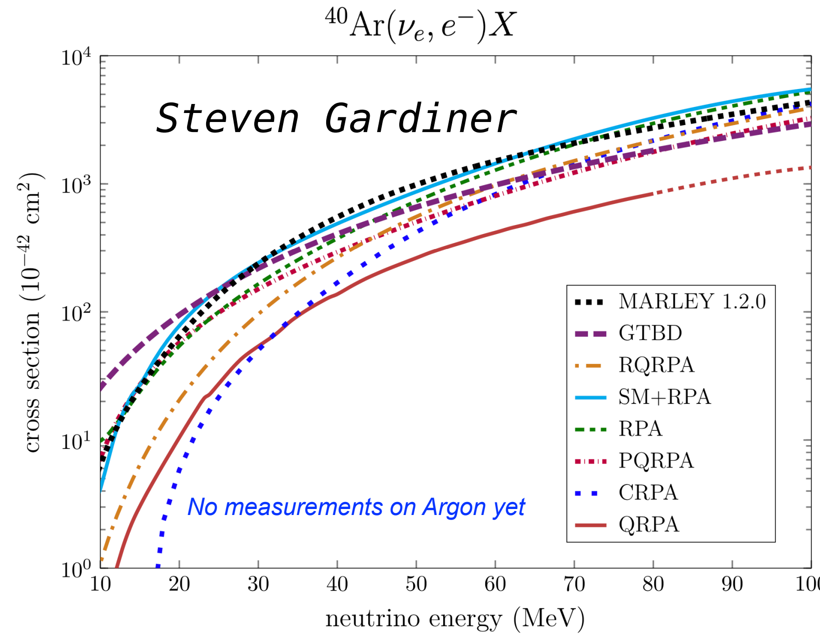
arXiv:2203.06853 [hep-ex]

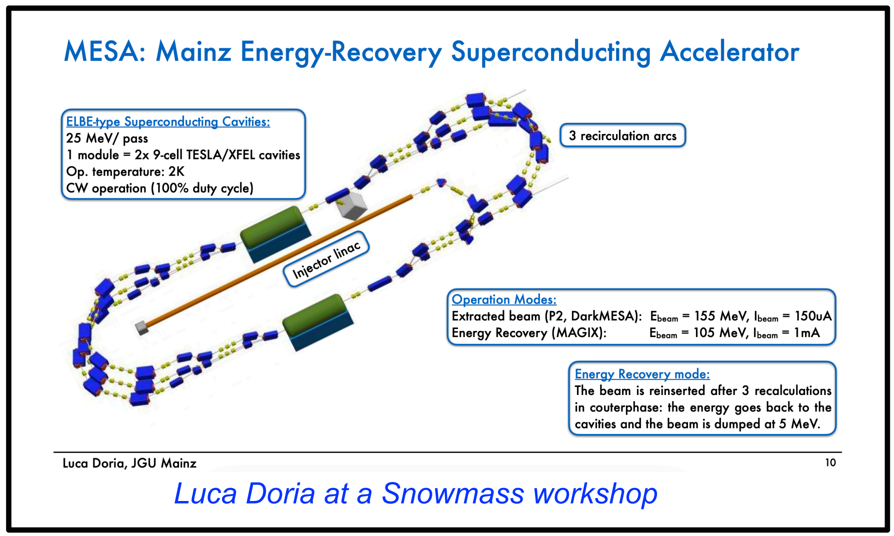
- Here F_{ch} is the charge form factor that is typically known from unpolarized electron scattering. Therefore, one can extract F_W from measurements of A_{PV}

10s of MeV Inelastic Scattering

- **Core-collapse supernova** can be detected (in DUNE, HyperK) using e.g. charge current inelastic neutrino-nucleus scattering process.
- These 10s of MeV neutrinos inelastically scatter off the nucleus, exciting nucleus to its low-lying excitation states, subject to nuclear structure physics.
- The inelastic neutrino-nucleus cross sections in this tens-of-MeV regime are quite poorly understood. There are very few existing measurements, none at better than the 10% uncertainty level. As a result, the uncertainties on the theoretical calculations of, e.g., neutrino-argon cross sections are not well quantified at all at these energies.
- CEvNS experiments at pion-decay at rest facilities - COHERENT at ORNL and CCM at LANL, well suited to make these measurements.
- 10s of MeV electron scattering experiment is planned at MESA, Mainz.

MAGIX Collaboration at MESA (Mainz): MESA, a new cw multi-turn energy recovery linac for precision particle and nuclear physics experiments with a beam energy range of 100-200 MeV is currently being built.





Growing Efforts and Community!

- The NP-HEP cross community collective efforts are playing a vital role in this endeavor.

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

Snowmass21 NF06 Electron Scattering Workshop

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

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

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

Snowmass21 NF06 Low Energy Neutrino and Electron Scattering Workshop

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)

- **White Paper:** arXiv:2203.06853 [hep-ex]

Electron Scattering and Neutrino Physics

A. M. Ankowski, A. Ashkenazi, S. Bacca, J. L. Barrow, M. Betancourt, A. Bodek, M. E. Christy, L. Doria. S. Dytman, A. Friedland, O. Hen, C. J. Horowitz, N. Jachowicz, W. Ketchum, T. Lux, K. Mahn, C. Mariani, J. Newby, V. Pandey, A. Papadopoulou, E. Radicioni, F. Sánchez, C. Sfienti, J. M. Udías, L. Weinstein, L. Alvarez-Ruso, J. E. Amaro, C. A. Argüelles, A. B. Balantekin, S. Bolognesi, V. Brdar, P. Butti, S. Carey, Z. Djurcic, O. Dvornikov, S. Edayath, S. Gardiner, J. Isaacson, W. Jay, A. Klustová, K. S. McFarland, A. Nikolakopoulos, A. Norrick, S. Pastore, G. Paz, M. H. Reno, I. Ruiz Simo, J. E. Sobczyk, A. Sousa, N. Toro, Y.-D. Tsai, M. Wagman, J. G. Walsh, G. Yang

A thorough understanding of neutrino-nucleus scattering physics is crucial for the successful execution of the entire US neutrino physics program. Neutrino-nucleus interaction constitutes one of the biggest systematic uncertainties in neutrino experiments – both at intermediate energies affecting long-baseline Deep Underground Neutrino Experiment (DUNE), as well as at low energies affecting coherent scattering neutrino program – and could well be the difference between achieving or missing discovery level precision. To this end, electron-nucleus scattering experiments provide vital information to test, assess and validate different nuclear models and event generators intended to be used in neutrino experiments.
In this white paper, we highlight connections between electron- and neutrino-nucleus scattering physics at energies ranging from 10s of MeV to a few GeV, review the status of ongoing and planned electron scattering experiments, identify gaps, and layout a path forward that benefits the neutrino community. We also highlight the systemic challenges with respect to the divide between the nuclear and high-energy physics communities and funding that presents additional hurdle in mobilizing these connections to the benefit of neutrino programs.

Comments:	37 pages, contribution to Snowmass 2021
Subjects:	**High Energy Physics - Experiment (hep-ex)**; High Energy Physics - Phenomenology (hep-ph); Nuclear Experiment (nucl-ex); Nuclear Theory (nucl-th)
Report number:	MITP-22-026, SLAC-PUB-17667
Cite as:	arXiv:2203.06853 **[hep-ex]**
	(or arXiv:2203.06853v1 **[hep-ex]** for this version)
	https://doi.org/10.48550/arXiv.2203.06853

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From: Vishvas Pandey [view email]
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A NF06 Contributed White Paper

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)

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A NF06 Contributed White Paper

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)

- https://indico.fnal.gov/event/50863/

Adi Ashkenazi
Joshua Barrow
Luca Doria
Minerba Betancourt
Noemi Rocco
Paola Sala
Raul González Jiménez

Fermilab

Summary

- Neutrino physics has entered a precision era and exciting neutrino experimental programs spanned across energies will lead to discoveries.

- The importance of constraining systematics resulted from neutrino-nucleus interaction physics in key neutrino measurements, in particular at accelerator-based experiments, cannot be overstated.

- The kinematically controlled beams and precise measurements of electron scattering data makes it a key benchmark to assess and validate different nuclear models and generators intended to be used in neutrino experiments.

- While previous and existing electron scattering experiments provide important information, dedicated electron scattering experiments with targets and kinematics of interests to neutrino experiments (CEvNS, supernova, and accelerator-based) will be vital in the development of neutrino-nucleus scattering physics modeling that underpin neutrino programs.

- The NP-HEP cross community collective efforts will play a vital role in this endeavor. The goal of these collective efforts will be to validate and solidify our understanding of the neutrino-nucleus interactions, enabling precision physics goals of neutrino experimental programs.