Dispersive effects in unpolarized inclusive elastic electron/positron-nucleus scattering

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Outline

Background on $e^{\pm}$ scattering

Physics Goals

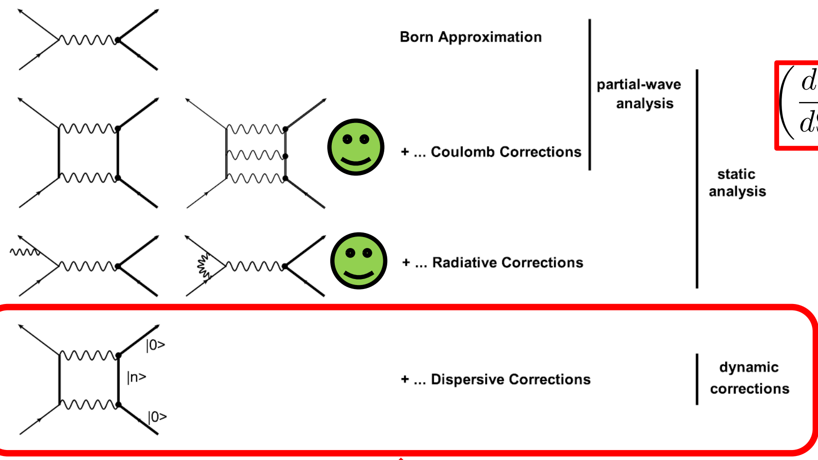
- Nuclear charge radii
- Neutron skin puzzle & single spin asymmetries
- Coulomb Sum Rule
- Rare isotopes & nuclear structure
- Electron dipole moment

PAC53 proposal PR12+25-013

- Overview and request
- Technical Advisory Committee review responses
- Theory review responses

Summary

Background: Electron Elastic Scattering



$$\left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{exp}} = \left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{Mott}} \left|F(q^2)\right|^2$$

After Correction

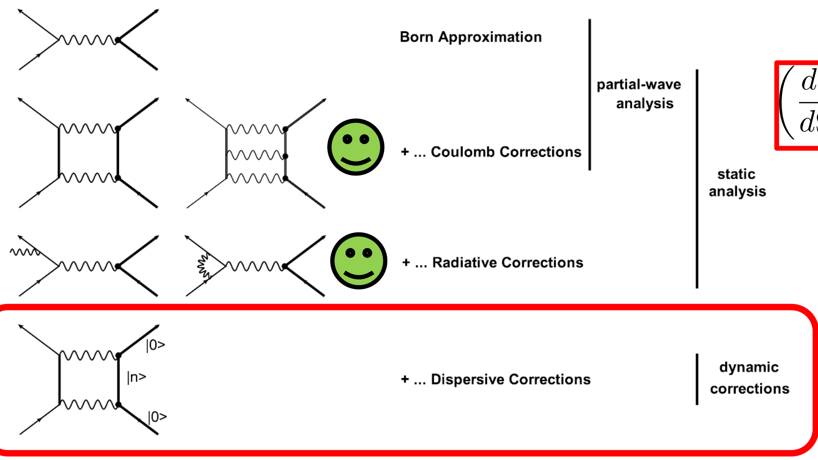
Coloumb & Radiative Effects

$$|\mathcal{M}_{elast+disp}|^2 = (\alpha Z)^2 [F(q^2)]^2 + 2(\alpha Z)^3 [F(q^2)\mathcal{R}e\{G(q^2)\}] + (\alpha Z)^4 [|\mathcal{R}e\{G(q^2)\}|^2 + |\mathcal{I}m\{G(q^2)\}|^2]$$

$$\sigma_{disp} = \sigma_{stat}[1 + \delta_{disp}(E_e)]$$

comparison e^+/e^-

Background: Electron Elastic Scattering



$$\left(\frac{d\sigma}{d\Omega}\right)_{\rm exp} = \left(\frac{d\sigma}{d\Omega}\right)_{\rm Mott} |F(q^2)|^2$$

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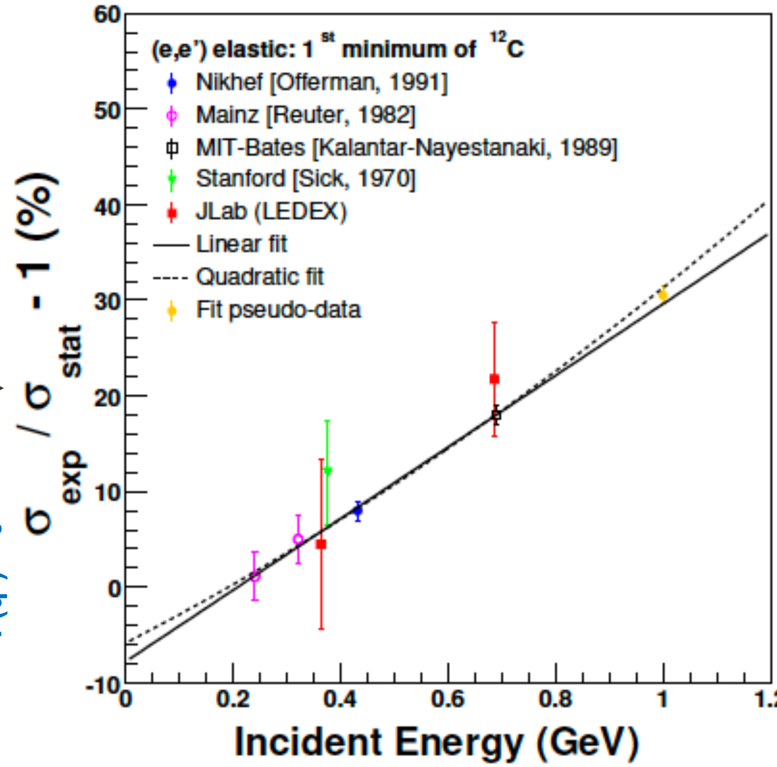
$$|\mathcal{M}_{elast+disp}|^2 = (\alpha Z)^2 [F(q^2)]^2 + 2(\alpha Z)^3 [F(q^2)\mathcal{R}e\{G(q^2)\}] + (\alpha Z)^4 [|\mathcal{R}e\{G(q^2)\}|^2 + |\mathcal{I}m\{G(q^2)\}|^2]$$

$$\sigma_{disp} = \sigma_{stat}[1 + \delta_{disp}(E_e)]$$

comparison e^+/e^-

minimum of diffraction $F(q^2) = 0$

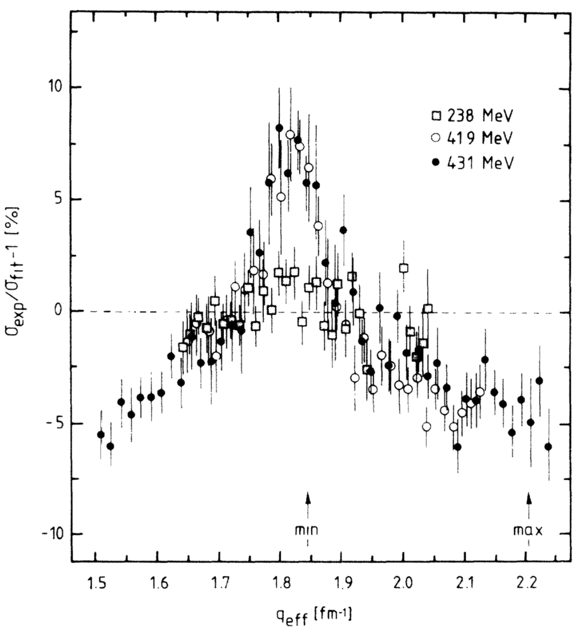


P. Guèye et al., EPJ **A56**(5) 2020
10.1140/epja/s10050-020-00135-7

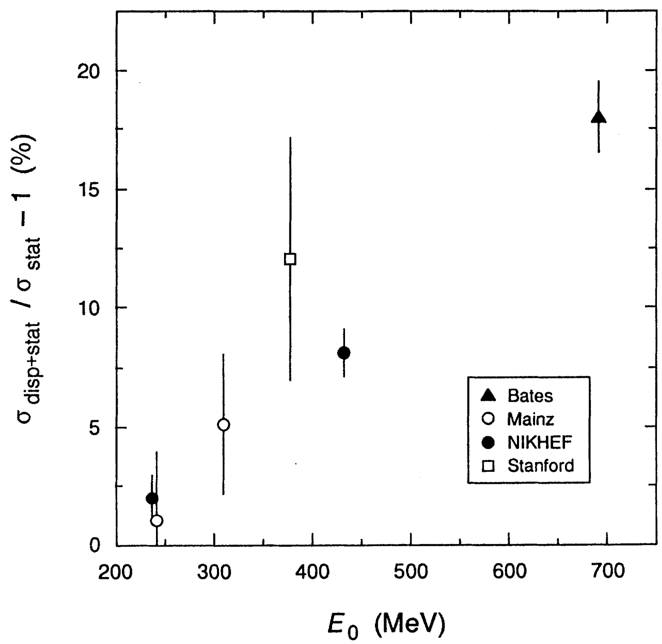
Dispersive Effects Background – Relative Measurements
e$^-$ Experiments at NIKHEF [1]

Nationaal Instituut voor Kernfysica en Hoge Energie-Fysic (NIKHEF)
[The Netherlands]

E. Offerman et al., PRL **57** (13) 1986



E. Offerman et al., PRC **44** (3) 1991



Comparison to static charge density

Fourier-Bessel parameterization

Reuter et al., PRC **26** (806) 1982

L. Cardman et al., Nuc. Phys. **A216** 806 (1973)

E_{beam} = 238, 243, 419 & 431 MeV

Phase 1 (1986)

- <5% for 1.5 < q (fm^{-1}) < 2.3

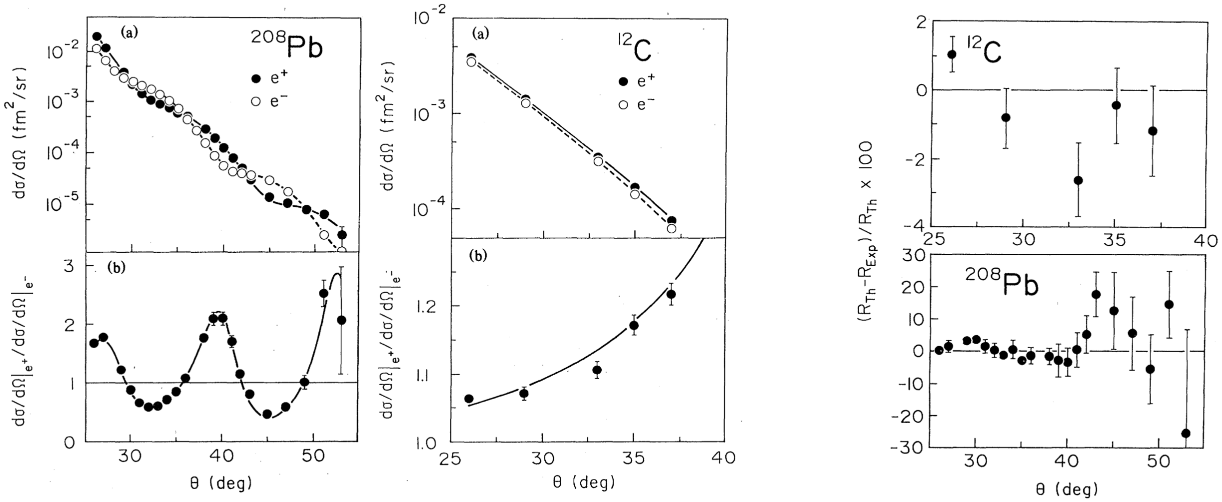
Phase 2 (1991)

- 1st minimum of ^{12}C
- Energy dependence
- Effect on ^{12}C rms: 0.28%

Dispersive Effects Background – Absolute Measurements $e^{\pm}$ Experiments at ALS [2]

Accélérateur Linéaire de Saclay (ALS)
[France]

V. Breton *et al.*, PRL **66** (5) 1991



Comparison to static charge density

- E_{beam} = 450 MeV; I = 20 nA
- <2% for 1 < q (fm^{-1}) < 1.5

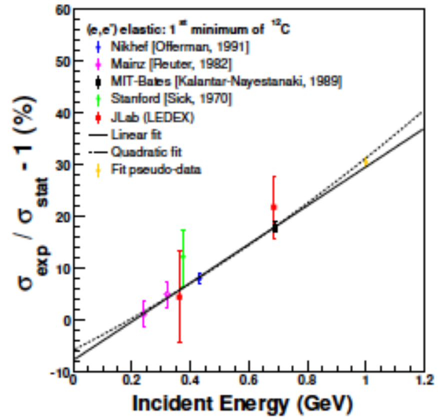
Status on Experiments vs. Theory

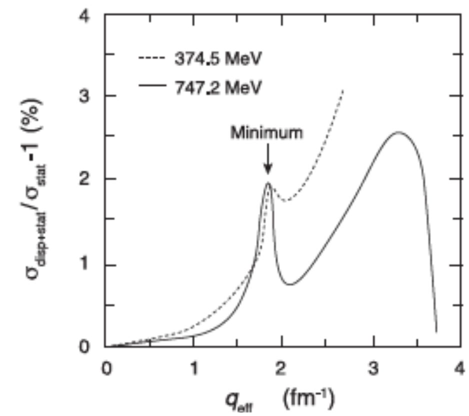
Energy dependence

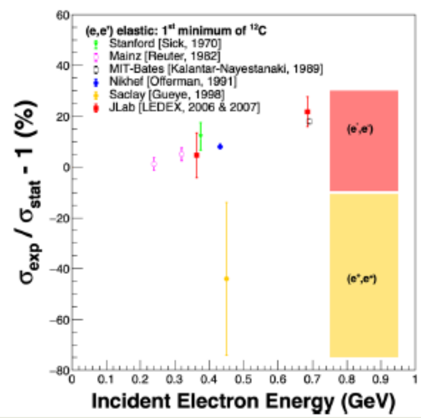
- J. Friar & M. Rosen, Ann. Phys., **87**:289 (1974)
- Theory : no
- Experiment : yes!

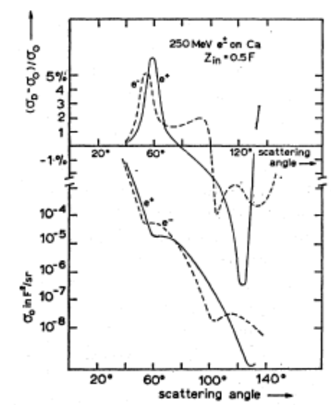
Sign between e⁻ & e⁺ in ^{12}C minimum

- G. Rawitscher, Phys. Rev., **151**:846 (1966)
- Theory : positive
- Experiment : negative!





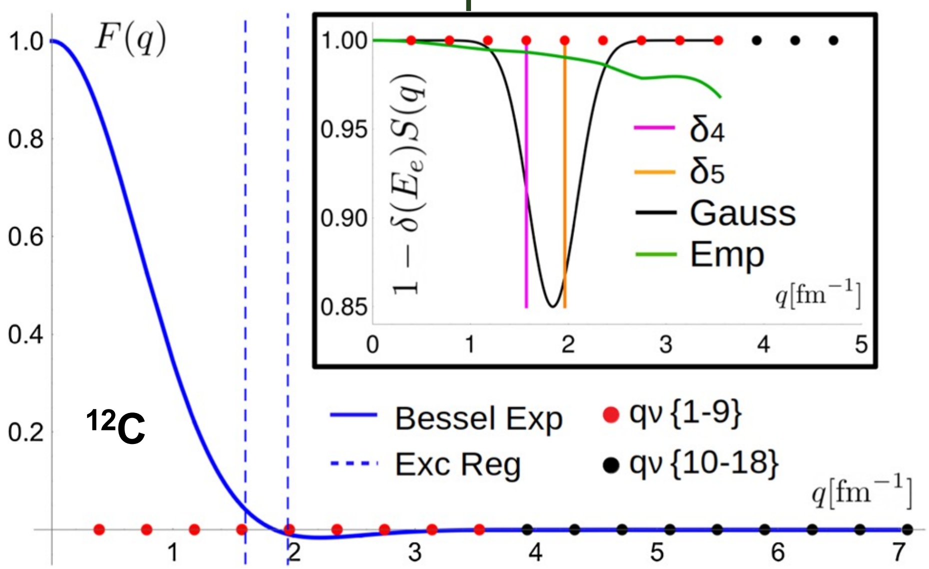


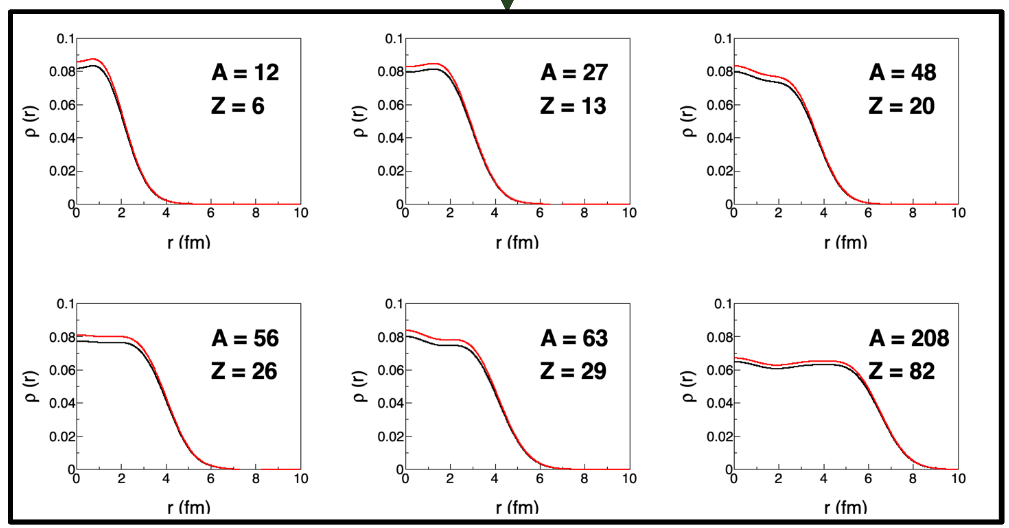


Physics I: Charge Radii and IAEA Recommendation [1]

P. Guèye et al., EPJ **A56**(5) 2020

F(q) = 1 - 0.00833q





	^{12}C	^{27}Al	^{48}Ca	^{56}Fe	^{63}Cu	^{208}Pb
ρ_{disp}(r)/ρ(r) [%]	4.91	4.11	4.58	4.65	4.65	3.49

Physics I: Charge Radii and IAEA Recommendation [2]

IAEA Technical Meeting

- Compilation and Evaluation of Nuclear Charge Radii
- January 27-30, 2025; 20 participants
- https://conferences.iaea.org/event/401

Technical Meeting on Compilation and Evaluation of Nuclear Charge Radii

Jan 27 – 30, 2025
IAEA Headquarters, Vienna
Europe/Vienna timezone

Enter your search term

- Overview
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- Contribution List
- Book of Abstracts
- Registration
- Participant List
- Hotel List Vienna 2024
- Code of conduct (UN)

Contact
- P.Dimitriou@iaea.org
- C.Monfero@iaea.org

A Technical Meeting on "Compilation and Evaluation of Nuclear Charge Radii" will be held from 27-30 January 2025, at the Headquarters of the International Atomic Energy Agency, Vienna, Austria.

The purpose of the meeting is to discuss the revision of the table of recommended nuclear charge radii by Angeli and Marinova (2013), published in ADNDT 99 (2013) 69-95 and accessible from the Nuclear Data Services webpage: https://nds.iaea.org/radii/.

Since 2013, there have been significant developments in both experimental techniques and microscopic theories, improving the quality of the data and our knowledge of nuclear charge radii for a growing number of nuclei. It is therefore, important to capture these developments and improvements in the tables of recommended charge radii.

Some of the topics to be covered:

- New experimental techniques and measurements
- Evaluation methods and uncertainty quantification
- The role of nuclear theory
- Emerging needs and priorities
- Revision and future maintenance of the nuclear charge radii tables

The meeting will comprise presentations with ample time for discussion, and roundtable discussions. A summary of the technical discussions and recommendations will be published in a report.

https://nds.iaea.org/publications/indc/indc-nds-0918/

International Atomic Energy Agency
Nuclear Data Services
Provided by the Nuclear Data Section

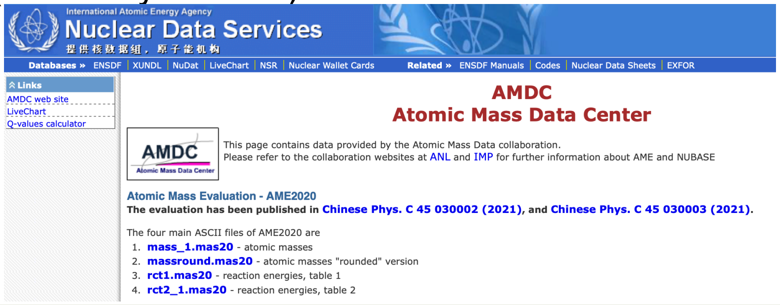
Relevant Links
- NDS Home
- Publications Home
- Conference Proceedings
- IAEA NDS series
- INDC series
- NDS staff publications
- Tecdocs

Title	Compilation and Evaluation of Nuclear Charge Radii
Author	K. Flanagan, H. Staiger, E. Takacs, P. Dimitriou
Date	Jun 2025
DOI	10.61092/iaea.vm5h-hmep
Note	Summary report of the Technical Meeting, 27-30 January 2025, Vienna, Austria
Last viewed	28-Jun-2025
Full text	4.2 M (Ctrl+L for full view)

Physics I: Charge Radii and IAEA Recommendation [3]

Outcomes

- More accurate compilation of rms charge nuclear radii
  - » Angeli, I. & Marinova, K. P
    - Atom. Data Nucl. Data Table, **99**, 69 (2013)
  - » **Large uncertainties: mainly theory**
  - » **Need guidance for experiments**
  - » **Dispersive effects not accounted for in past compilations!**
- Best practices to extract precise RMS nuclear charge radii?
  - » Stable : electron scattering (deVries, 1987!), muon spectroscopy and laser spectroscopy
  - » Unstable : laser spectroscopy (ref. nuclei), electron (SCRIT @ RIKEN and ULQ2 @ Tohoku Univ.)
  - » Standardize : e.g., Barrett moments from μ-spectroscopy (accuracy: ≤0.1%)
- Need to get there
  - » Both experimental and theoretical sides
- Regular charge nuclear radii compilation "à la" AMDC



Physics II: Neutron skin puzzle and single spin asymmetries

Coulomb potential

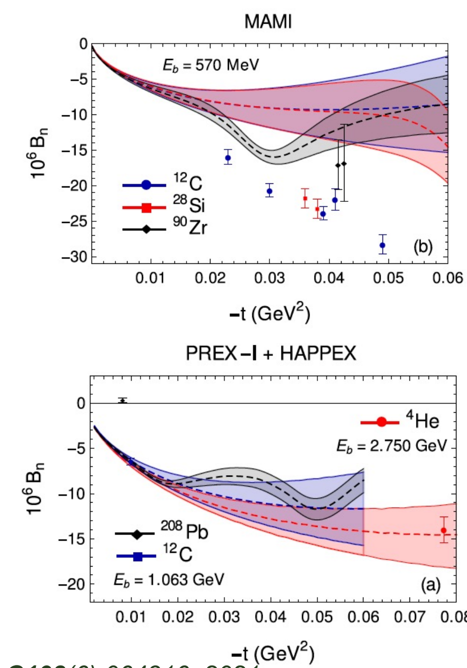
Guèye et al., EPJ **A56**(5) 2020

$$|V_C| = |V_C^{stat}| = \frac{KZ}{\langle r^2 \rangle^{1/2}}\,; K = 1/4\pi\varepsilon_0 \longrightarrow |V_C^{disp}| = |V_C^{stat}|/[1+\beta\delta(E_e)]$$

- ^{208}Pb charge radius: 0.07% effect [5.5012(13) fm → 5.5053(13) fm]

Single spin asymmetries (SSA)

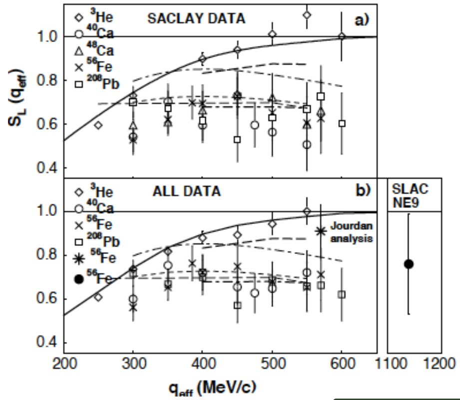
- PV experiments measurements near diffraction minima
- Beam-normal SSA conserves parity
  - But 0 in the first Born (1-γ) approximation
- Past JLab experiments on SSA on nuclear targets [1, 2]
  - Unambiguous evidence of effects beyond the Born approximation
  - Coulomb distortions are insufficient
  - Excitation of nuclei during the scattering process (BNSSA) [3]
    - Played a defining role!
    - Light nuclei: OK
    - ^{208}Pb : not satisfactory



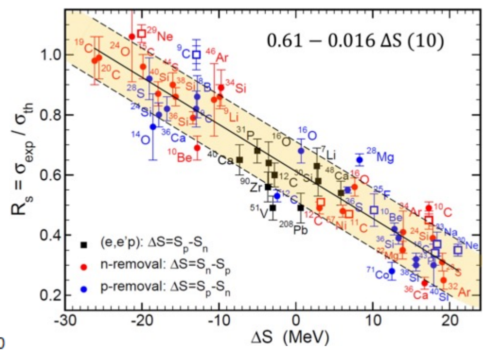
[1] Abrahamyan et al., Phys. Rev. Lett., **109**(19):192501, 2012
[2] Adhikari et al., Phys. Rev. Lett., **128**(14):142501, 2022
[3] Abrahamyan et al., *Phys. Rev.* ***C103****(6):064316, 2021*

Physics III: Coulomb Sum Rule

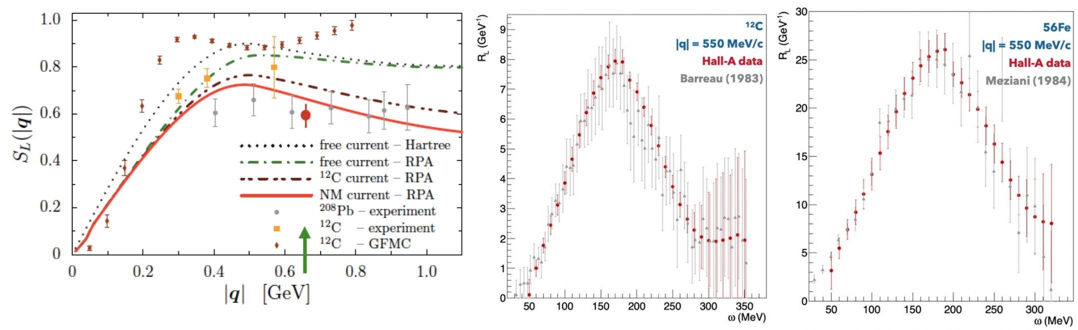
J. Morgenstern & Z. Meziani.
EPJ, **A17**, 451–455, (2003)



J. A. Tostevin and A. Gade
Phys. Rev. C **103**, 054610 (2021)



M. Paolone, JLab e05-110; CSR quenching?
Hall A/C Collaboration (January 2022)



$$S_L(|\mathbf{q}|) = \int_{\omega>0}^{|\mathbf{q}|} \frac{R_L(\omega, |\mathbf{q}|)}{Z G^2_{E_p}(Q^2) + N G^2_{E_n}(Q^2)} d\omega$$

$$G^{disp}_{E_{\rm nuc}}(Q^2) = \frac{G^{stat}_{E_{\rm nuc}}(Q^2)}{1 + \beta\delta(E_e)}$$

P. Guèye et al., EPJ **A56**(5) 2020

$$S^{disp}_L(|\mathbf{q}|) = S^{stat}_L(|\mathbf{q}|) \times [1 + \beta\delta(E_e)]$$

22% in ^{12}C!

Dispersive effects could have a non-negligible contribution to the CSR!

Physics IV: Rare Isotopes and Nuclear Structure [1]

Extension to rare isotopes

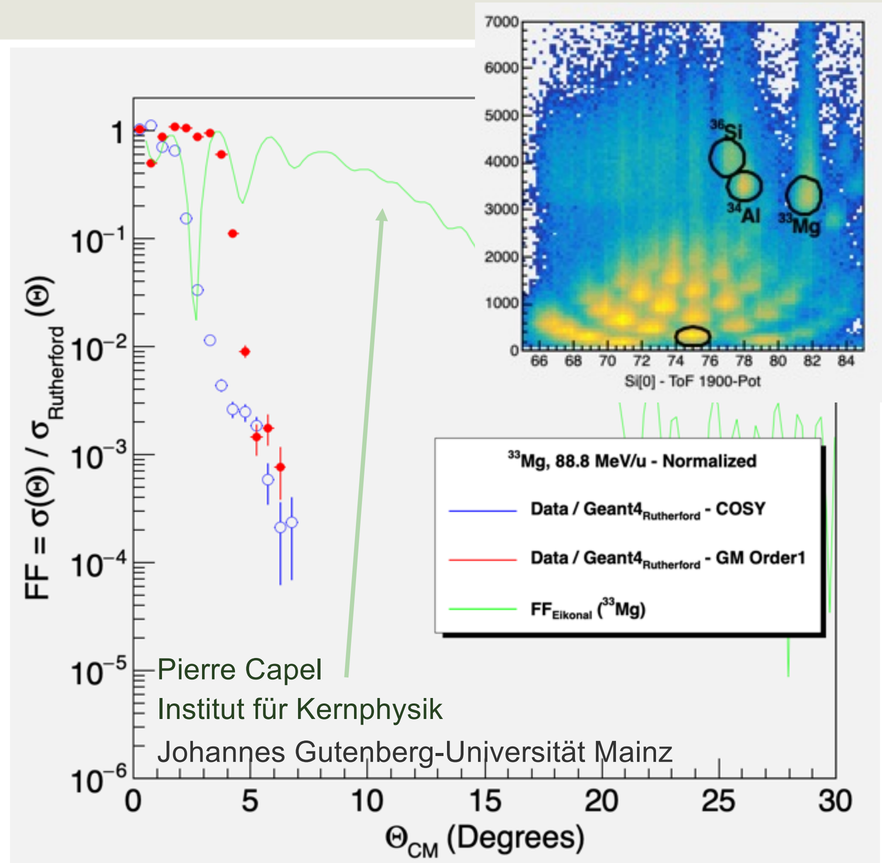
- MoNA Collaboration/PING Program
  - Si-Be segmented target
  - 4 TLPSDs + 3 Be
- Rutherford scattering-like data
- Preliminary results for matter radii
  - Impact from charge radii
  - Sensitivity to neutron distribution (n-rich nuclei)?

Graduate student

- Paula Plazas Isanoa (MSU, Fall 2024)
- Joint thesis project
  - Laser spectroscopy (BECOLA)
  - Matter radii (MoNA Collaboration)

Undergraduate student

- Makaila Parks (Spelman College, PING2024)

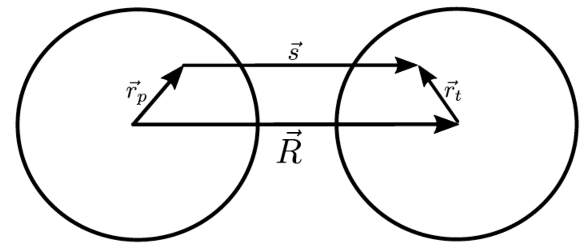


Physics IV: Rare Isotopes and Nuclear Structure [2]

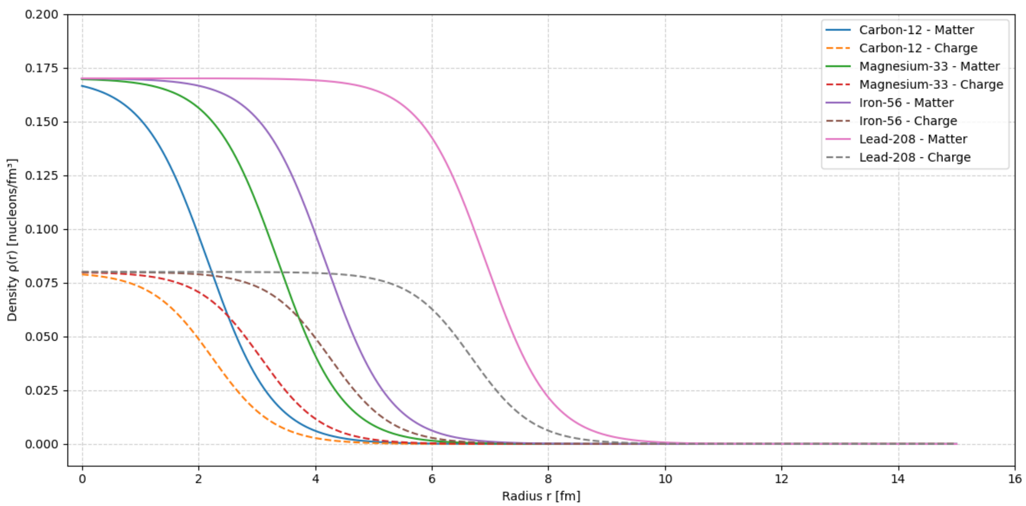
G. Satchler, W. Love, Phys. Rep. **55**(3) (1979) 183–254
L. Chamon et al., Comp. Phys. Com. 267 (2021) 108061

Double-folding model

- Optical potential to describe two colliding ions
  - Average an appropriate N-N interaction over the matter distributions
  - Similar approach as treatment of the Coulomb interaction
- Two components: real (Coulomb) and imaginary (nuclear)
- Use two-Fermi parameter distribution



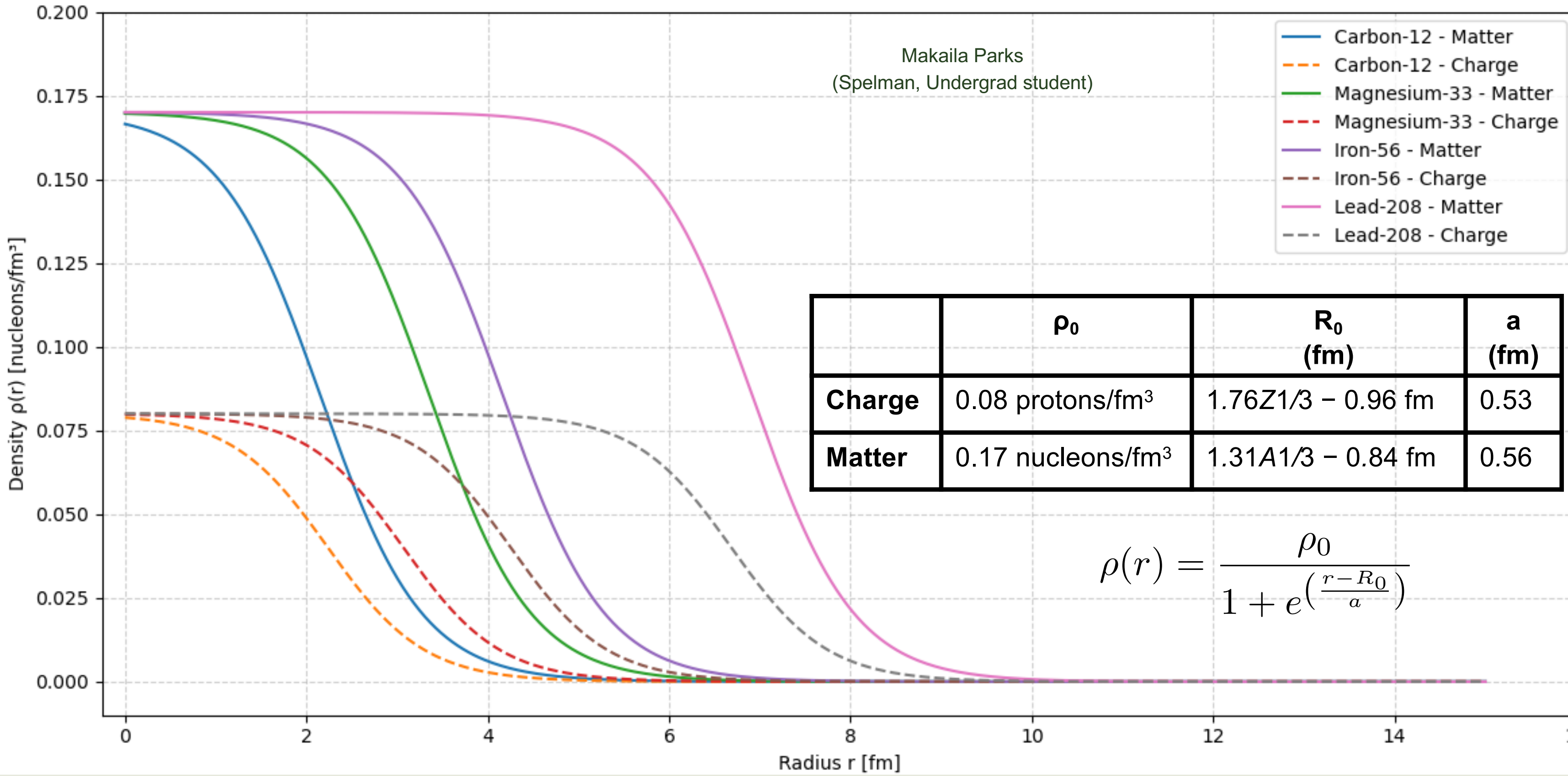
$$\rho(r) = \frac{\rho_0}{1 + e^{\left(\frac{r - R_0}{a}\right)}}$$



	ρ_0 (nucl/fm³)	R_0 (fm)	a (fm)
Charge	0.08	$1.76Z^{1/3} - 0.96$ fm	0.53
Matter	0.17	$1.31A^{1/3} - 0.84$ fm	0.56

Insights about neutron distributions!!

Physics IV: Rare Isotopes and Nuclear Structure [3]



	ρ_0	R_0 (fm)	a (fm)
Charge	0.08 protons/fm^3	1.76*Z*1⁄3 − 0.96 fm	0.53
Matter	0.17 nucleons/fm^3	1.31*A*1⁄3 − 0.84 fm	0.56

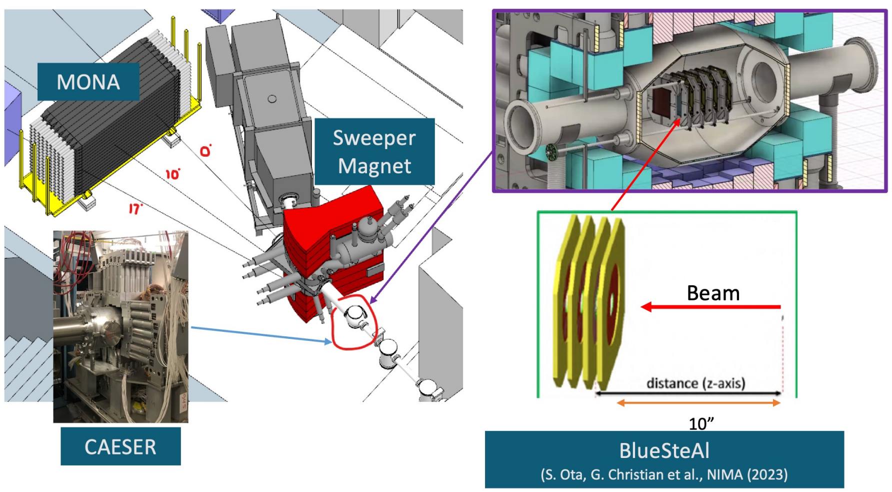
$$\rho(r) = \frac{\rho_0}{1 + e^{\left(\frac{r - R_0}{a}\right)}}$$

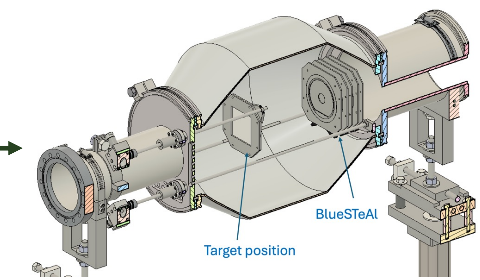
Physics IV: Rare Isotopes and Nuclear Structure [4]

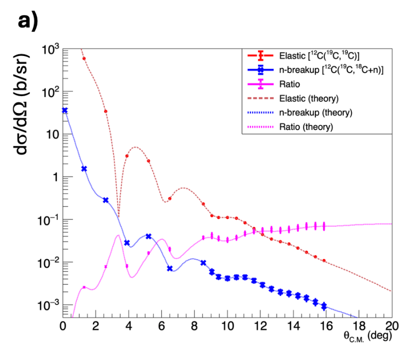
FRIB PAC3 proposal

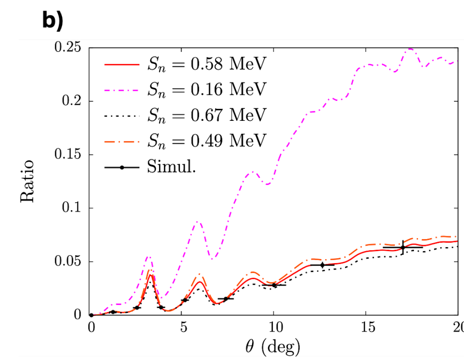
- PR25076: spokespersons are S. Ota (BNL), P. Capel (JHUM) & P. Guèye (FRIB)
- Establish a complete picture of the halo nucleus ^{19}C using a novel technique: the ratio method

$$^{19}\mathrm{C} \rightarrow {}^{18}\mathrm{C} + n \Rightarrow \frac{\frac{d\sigma}{d\Omega}\Big|^{^{19}\mathrm{C}}_{\mathrm{elastic}}(\Theta)}{\frac{d\sigma}{d\Omega}\Big|^{^{18}\mathrm{C}}_{\mathrm{elastic}}(\Theta)} : S_n, r_n$$









S. Ota et al., Nucl Phys. **A20**, 123120 (2025)

Physics V: EDM Search [1]

Collaboration with Jaideep Singh @ MSU

Need: nuclei with spin >0

- Four electromagnetic form factors [1]
  - » F_1 (charge) and F_2 (anomalous magnetic moment)
    - Experimentally measured
    - F_2 lead to 2-photon exchange puzzle [2]
  - » F_3 (electron dipole moment)
    - No non-zero measured but possible [3,4]
  - » F_4 (Zeldovich anapole moment)
    - No experimental evidence
    - Through coupling to off-shell photons (virtual exchanged between 2 fermions) [1]
    - PV through F4 competes with PV through Z0: very hard to disentangle!

$$F_1(0) = Q = e$$

$$\frac{1}{2m}\left[F_1(0) + F_2(0)\right] = \mu \rightarrow a = \frac{g}{2} - 1 = \frac{F_2}{e}$$

$$-\frac{1}{2m}F_3(0) = d$$

$$H_{\text{int}}^{\text{NR}}[F_4] \propto F_4(0)\sigma \cdot \left[\nabla \times \mathbf{B} - \frac{\partial \mathbf{E}}{\partial t}\right]$$

[1] M. Nowakowski, E. A. Paschos and J. M. Rodríguez, Eur. J. Phys. **26** 545–560 (2005)
[2] Bosted P. E., Phys. Rev. **C51** 409–11 (1995)
[3] Commins E. D., Advances in At., Mol. and Opt. Phys., **40** 1–55 (1999)
[4] Regan B. C. et al., Phys. Rev. Lett. **88** 071805 (2002)

Physics V: EDM Search [2]

Goal

- **Constrain EDMs from electron scattering data in a model independent way**
- Note on small Z: **theory predicts that they are immeasurably small**
  - No one has even tried to measure them!
- Experimental verification
  - **Experimental limits (even if crude)**
- Would need polarized experiments
  - **Sensitivity with non-spin 0 targets**

Targets

- Spin 0 : ^{12}C, ^{48}Ca, ^{56}Fe, ^{196}Pt, ^{208}Pb
- Non-spin 0: ^{27}Al (5/2), ^{63}Cu (3/2), ^{209}Bi (9/2)

PR12+25-013: Overview [1]

LOI12-23-015 (PAC51)

- Polarization (no!), theory, simulation

Collaborators

- 54 participants (+20 before PAC53)
- 26 institutions

Endorsement

- Positron Working Group

Main goals

- Measure unpolarized $A(e^{\pm},e^{\pm})$ cross section
- Map dispersive effects
  - » Energy dependence
    - 0.7 GeV – 4.24 GeV
  - » Atomic mass dependence
    - 8 targets
    - ^{12}C, ^{27}Al, ^{48}Ca, ^{56}Fe, ^{63}Cu, ^{196}Pt, ^{208}Pb, ^{209}Bi

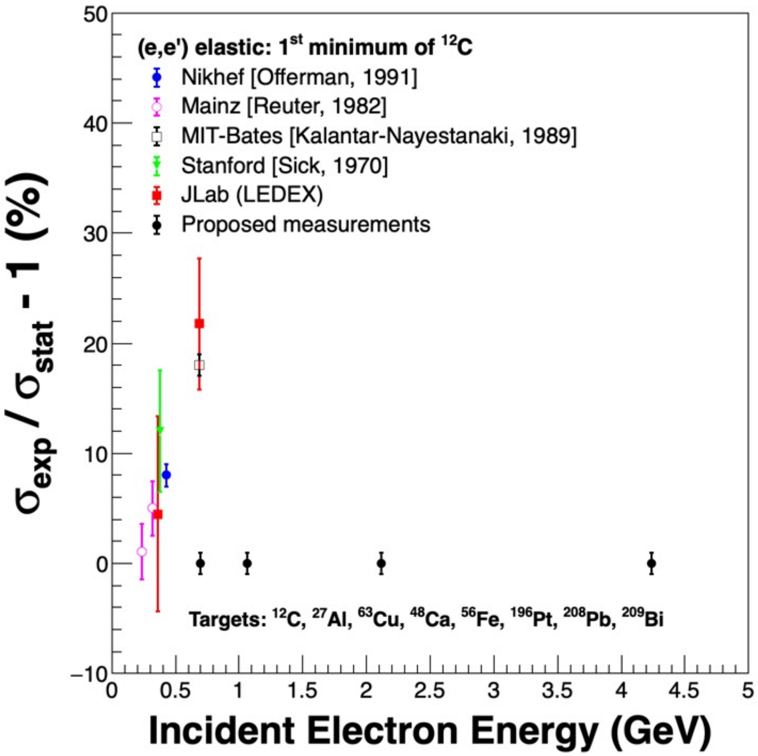
Experiment (Hall C)

- Phase 1: qualitative measurements
  - » Compare $A(e^{-},e^{-})$ with theory
  - » A. Afanasev group at GWU
- Phase 2: absolute direct measurements
  - » Compare $A(e^{\pm},e^{\pm})$ cross sections
- Received TAC comments (05/26/25)
- Received Theory comments (07/08/25)
- Received additional comments (07/08/25)

Physics

1. Nuclear charge radii
2. Neutron skin puzzle & single spin asymmetries
3. Coulomb Sum Rule
4. Rare isotopes & nuclear structure
5. Electron dipole moment

PR12+25-013: Overview [2]



Perform targeted measurements!

Low energy (0.7 MeV)

- Multiple targets for A-dependency

High energies (1.06-4.2 GeV)

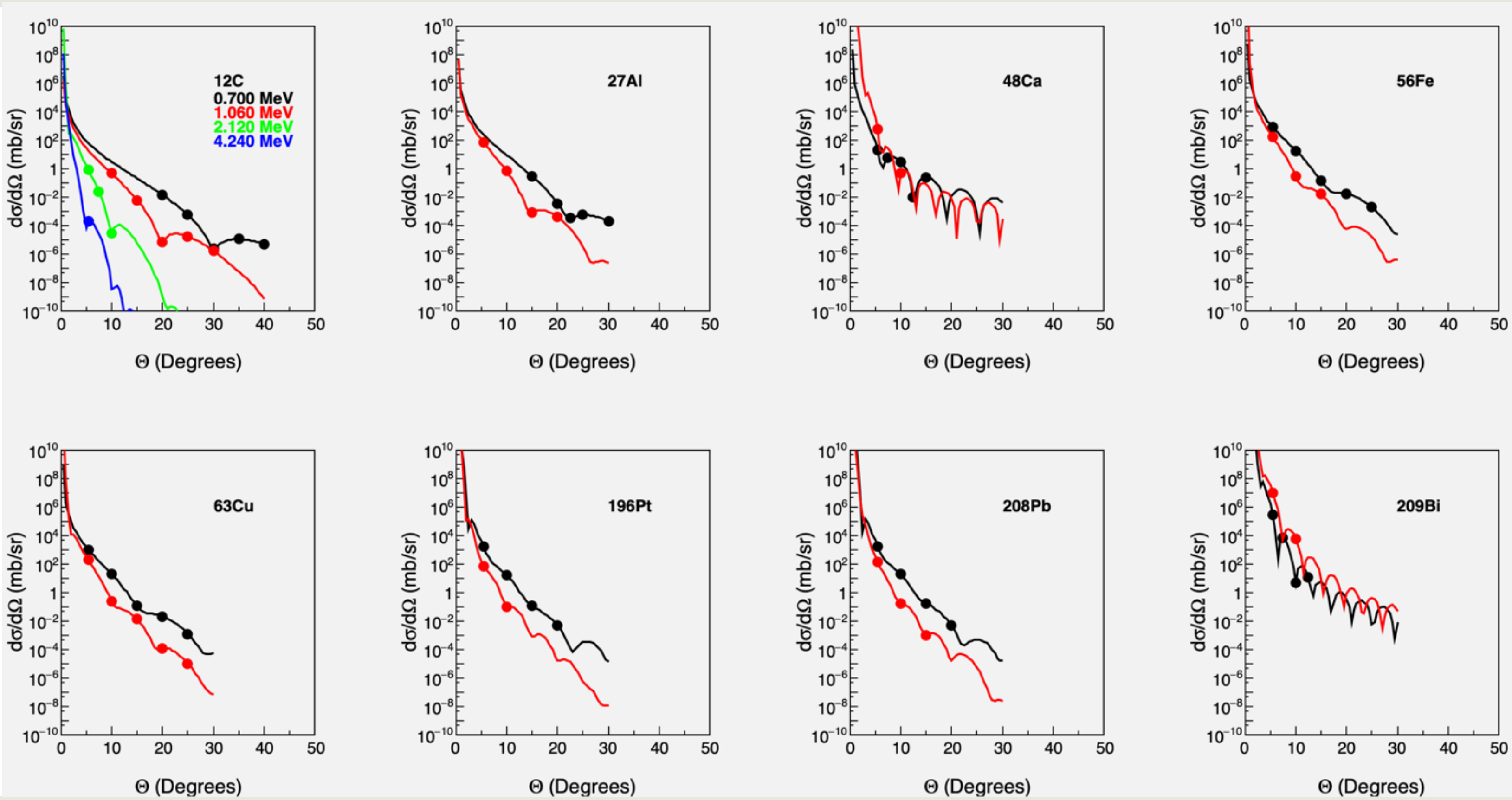
- One target for detailed E-dependence study

Phases

- Phase 1: relative measurements (e^-,e^-) with $\sigma_{exp}/\sigma_{theo(GWU)}$
- Phase 2: absolute measurements ($e^\pm$,$e^\pm$) with $\sigma^-_{exp} - \sigma^+_{exp}$

	Phase 1 (%)	Phase 2 (%)
Statistics	0.1	1.0
Acceptance	1.0	1.0
Tracking Efficiency	0.5	0.5
Radiative corr.	1.2	1.2
Target Thickness	0.5	0.5
Total	1.7	2.0

PR12+25-013: Overview [3]



PR12+25-013: Overview [4]

Phase 1: A(e^-, e^-) for 100 μA					
Target	**E_e (GeV)**	**$\theta_{e'}$ (Deg.)**	**q-range (fm^{-1})**	**q^1_{min}/q^2_{min} (fm^{-1})**	**Rates (Hz)**
^{12}C	0.700	20,25,30,35,40	1.2-2.4	1.8	$2.8 - 1.3 \times 10^6$
^{27}Al		15,20,22.5,25,30	0.9-1.8	1.2	$2.6 \times 10^3 - 3.6 \times 10^7$
^{48}Ca		5.5,7.5,10,12.5,15	0.3-0.9	0.4/0.8	$2.6 \times 10^7 - 3.6 \times 10^{10}$
^{56}Fe		5.5,10,15,25	0.3-1.5	1.1	$6.8 \times 10^4 - 5.6 \times 10^{10}$
^{63}Cu		5.5,10,15,20,25	0.6-1.5	0.95	$4.8 \times 10^4 - 1.2 \times 10^9$
^{196}Pt		5.5,10,15,20	0.3-1.5	0.4/0.9	$8.4 \times 10^5 - 8.2 \times 10^{10}$
^{208}Pb		5.5,10,15,20	0.3-1.2	0.4/0.8	$8.1 \times 10^5 - 8.3 \times 10^{10}$
^{209}Bi		5.5,7.5,10,12.5	0.3-0.8	0.3/0.5	$1.6 \times 10^8 - 8.4 \times 10^{10}$
^{12}C	1.060	10,15,20,25,30	0.9-2.8	1.8	$20.8 - 5.2 \times 10^7$
^{13}Al		5.5,10,15,20	0.5-1.9	1.2	$19.9 - 7.0 \times 10^9$
^{48}Ca		5.5,10	0.5-0.9	0.4/0.8	$4.2 \times 10^6 - 6.6 \times 10^9$
^{56}Fe		5.5,10,15	0.5-1.4	1.1	$6.1 \times 10^5 - 1.0 \times 10^{10}$
^{63}Cu		5.5,10,15,20,25	0.5-2.3	0.95	$12.3 - 9.3 \times 10^9$
^{196}Pt		5.5,10,15	0.5-1.4	0.4/0.9	$3.5 \times 10^6 - 1.0 \times 10^{10}$
^{208}Pb		5.5,10,15	0.5-1.4	0.4/0.8	$3.4 \times 10^6 - 1.0 \times 10^{10}$
^{209}Bi		5.5,10	0.5-0.9	0.3/0.5	$4.7 \times 10^7 - 1.0 \times 10^{10}$
^{12}C	2.120	5.5,7.5,10	1.0-1.9	1.8	$1.4 \times 10^4 - 7.8 \times 10^7$
^{12}C	4.240	5.5	2.1	1.8	6.5×10^3

Phase 2: A($e^\pm$, $e^\pm$) for 1 μA				
Target	**E_e (GeV)**	**$\theta_{e'}$ (Deg.)**	**q-range (fm^{-1})**	**q^1_{min}/q^2_{min} (fm^{-1})**
^{12}C	0.700	20,25,30,35	1.2-2.1	1.8
^{27}Al		20,25,30	1.2-1.8	1.2
^{56}Fe		15,20	0.9-1.2	1.1
^{63}Cu		20,25,30	1.2-1.8	0.95/1.8
^{12}C	1.060	15,20,25	1.4-2.3	1.8
^{13}Al		15,20,25	1.4-2.3	1.2
^{56}Fe		15	1.4	1.1
^{63}Cu		15,17.5,20	1.4-1.9	0.95/1.8
^{196}Pt		10,12.5,15	0.9-1.4	0.4/0.9
^{208}Pb		12.5	1.2	0.4/0.8
^{12}C	2.120	7.5,10,12.5	1.4-2.3	1.8
^{12}C	4.240	5.5	2.1	1.8

Phase 2: note on beam switch ($e^{\pm} \rightleftarrows e^{\mp}$)

PWG recommendation for PAC53

- Plan for 1 week for switch $e^{\pm} \rightleftarrows e^{\mp}$

Plan

- Take all data with electrons
- Switch lepton probe
- Take all data with positrons

Assumed 2 hrs/energy setting

- Best case scenario (e.g, bi-polar magnets)
- Total: 0.16 x 4 = 0.64 days (15.36 hrs)

If no bi-polar magnets

- Add 7 days on overall schedule

Energy (GeV)	**Description**	**A(e^-, e^-) (days)**	**A($e^\pm, e^\pm$) (days)**
0.70	Calibration	0.500	1.00
	Production	6.19	1.60
	Spectrometer Rotation	0.38	0.13
	Spectrometer Settings	0.75	0.25
	Target Change	0.03	0.01
	Beam switch ($e^\pm \leftrightarrow e^\mp$)	-	0.16
1.06	Calibration	0.500	1.00
	Production	8.21	24.0
	Spectrometer Rotation	0.30	0.15
	Spectrometer Settings	0.60	0.29
	Target Change	0.03	0.02
	Beam switch ($e^\pm \leftrightarrow e^\mp$)	-	0.16
2.12	Calibration	0.500	1.00
	Production	0.60	2.04
	Spectrometer Rotation	0.03	0.03
	Spectrometer Settings	0.06	0.06
	Target Change	0.003	0.003
	Beam switch ($e^\pm \leftrightarrow e^\mp$)	-	0.16
4.24	Calibration	0.500	1.00
	Production	1.02	0.02
	Spectrometer Rotation	0.01	0.01
	Spectrometer Settings	0.02	0.02
	Target Change	0.003	0.003
	Beam switch ($e^\pm \leftrightarrow e^\mp$)	-	0.16
Total		**20.24 days**	**33.24 days**

PR12+25-013 (PAC53): TAC Review [1]

Courtesy: Dave Meekins

Target purity
- >99%

LH_2 for calibration
- No. Using ^{12}C

Target ladder (J. Arrington)
- Will use the 13 target ladder developed for x>1 experiment
- Used: ^{12}C (60 μA), ^{27}Al (40 μA), ^{48}Ca (60 μA), ^{56}Fe (40 μA), ^{64}Cu (60 μA)
- New: ^{196}Pt, ^{208}Pb, ^{209}Bi

Special cooling for Ca & Pb (D. Meekins)
- Was able to handle the significant power load on the targets (200 W)
- It is cooled by conduction thru the normal cryotarget connections

Heat dissipation for high current: could lower I_{beam} by x100
- ΔN/N: 0.1% (10^6 events) to 1% (10^4 events) → $(\Delta\sigma/\sigma)_{stat}$: 1.7% to 1.98%

PR12+25-013 (PAC53): TAC Review [2]

Low beam energy

- 700 MeV (phase 1) & 1.06 GeV (phase 2): should be possible
- Beam emittance
  - Saclay data with 6.28 mm.mrad (JLab projected: ≤40 mm.mrad) – factor 7 worse!
  - **Most important: same beam properties!**
- Switch lepton probe ($e^{\pm} \rightleftarrows e^{\mp}$): see slide 23
- Beam current uncertainty: should be <1%
- Rates for phase 2: 100 μA to 1 μA so 100x less than phase 1!

PR12+25-013 (PAC53): Theory Review

"Summary: This is a well motivated experiment that could have significant impact."

Comment 1

- More details on data analysis
- Added in previous slides/more planned

Comment 2

- Interpretation of data using modern EFT calculations and two-body current operators
- Will provide data as clean as possible and leave it to theory for interpretation of the data

Comment 3

- Details on separating 2 photon exchange (Coulomb corrections) from dispersive effects
- Subtract Coulomb and radiative corrections (standard analysis procedure)
- Contribution from excited states
  - Can exclude1st excited state: spectrometer resolution $<10^{-4}$
  - Study radiative tail region (excitation energy cut)

1st Excited State					
^{12}C	^{27}Al	^{48}Ca	^{56}Fe	^{63}Cu	^{208}Pb
4.43	0.84	3.83	0.85	0.67	2.61

Summary

First ever comprehensive study and energy dependence of dispersive effects

- Measure elastic inclusive cross section in Hall C at ~1-2% level

Two phases

- **Phase 1: qualitative measurements – 20 days**
  - Compare A(e^-,e^-) with theory
  - A. Afanasev group at GWU
- **Phase 2: absolute direct measurements – 33 days**
  - Compare A($e^\pm$,$e^\pm$) cross sections

Physics

1. Nuclear charge radii
2. Neutron skin puzzle & single spin asymmetries
3. Coulomb Sum Rule
4. Rare isotopes & nuclear structure
5. Electron dipole moment (possible sensitivity)

Thank You!