A (Possible) High Gradient Linac at MSU/FRIB

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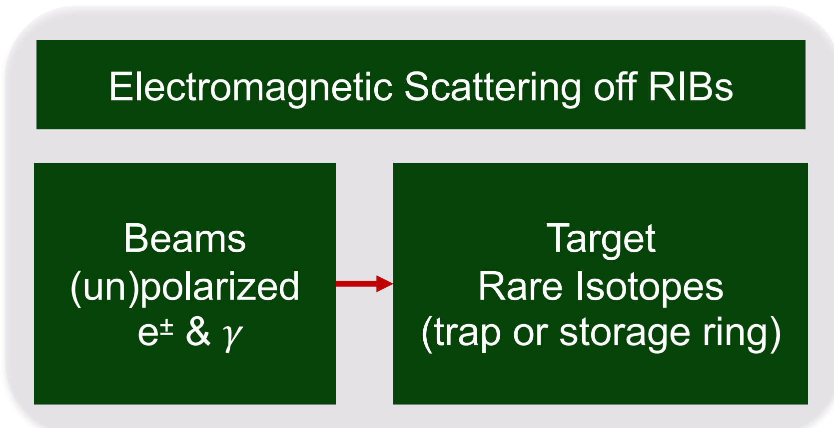
MICHIGAN STATE UNIVERSITY

U.S. DEPARTMENT OF ENERGY | Office of Science

This material is based upon work supported by the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661, the State of Michigan and Michigan State University. Michigan State University designs and establishes FRIB as a DOE Office of Science National User Facility in support of the mission of the Office of Nuclear Physics.

Disclaimer

- This project is not endorsed by FRIB/MSU!
- Side effort by several people to evaluate a possible $e^{\pm}$-Rare Isotope compact facility for nuclear physics & nuclear astrophysics research



Workshop, Symposia & Brainstorming Sessions

- North America Storage Rings & Neutron Captures Workshop
  - June 28-30, 2021
  - https://meetings.triumf.ca/event/235/overview
- APS/DNP symposia
  - October 11-14, 2021
  - JF: Advances and Opportunities in Polarized Targets and Beams I
  - KF: Advances and Opportunities in Polarized Targets and Beams II
- Brainstorming sessions
  - March 25, 2022 and April 01, 2022
  - Participants: Eric Voutier, Toshimi Suda, Maya Wallach, Claude Marchand, Dominic Marchand, Joe Grames, Kei Minamisono, Peter Ostroumov, Kent Paschke, Ryan Richards, Or Hen, Alain Lapierre, Michael Kohl
- $e^{\pm}$-RIB workshop
  - September 5, 2023
  - Participants: possibly 43

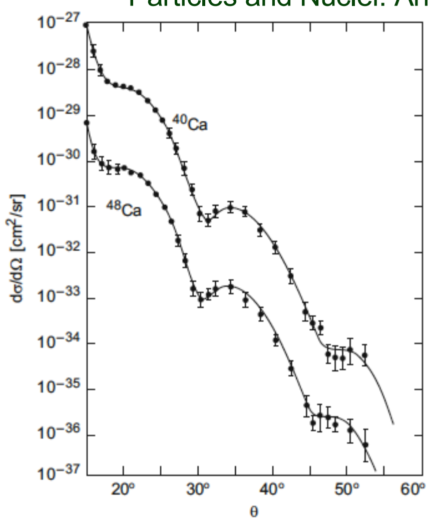
Outline

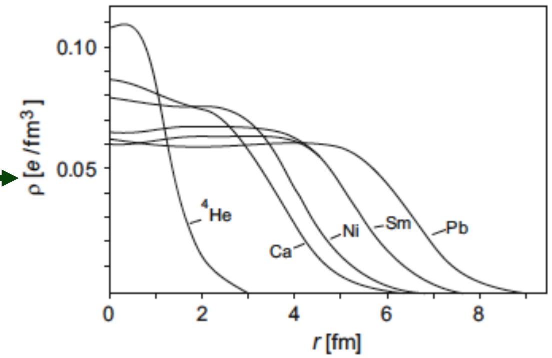
- Probing nuclei with electromagnetic probes
  - Electron/Positron scattering
  - Jefferson Lab electron (CEBAF)/positron (LERF) beams
- Rare Isotopes
  - Facility for Rare Isotope Beams
  - RI masses and nuclear radii … and storage rings
- Possible concept for a $e^{\pm}$-Rare Isotope compact facility at FRIB

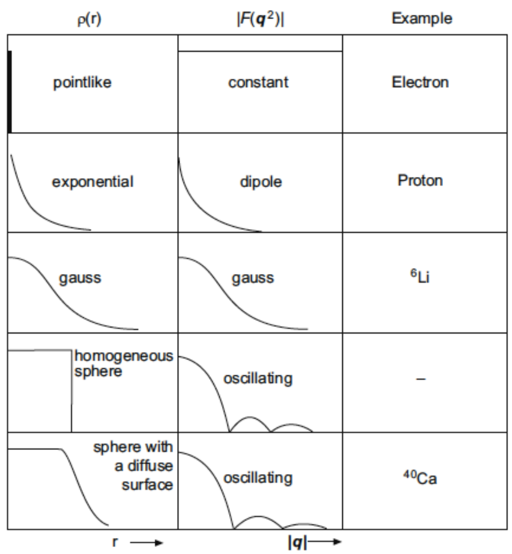
One Primary Focii: Nuclear Radii

Bogdan Povh, Klaus Rith, Christoph Scholz, Frank Zetsche • Werner Rodejohann
Particles and Nuclei: An Introduction to the Physical Concepts

A. Kabir, PhD Thesis (2019)
Low Energy Deuteron Experiment, JLab



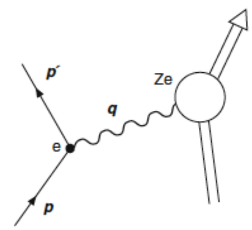


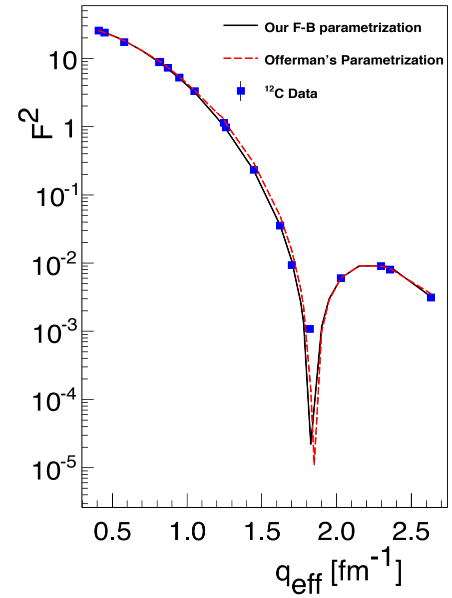


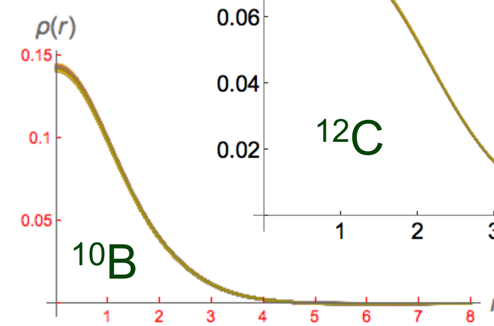
$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{Mott} \mid F(Q^2) \mid^2$$

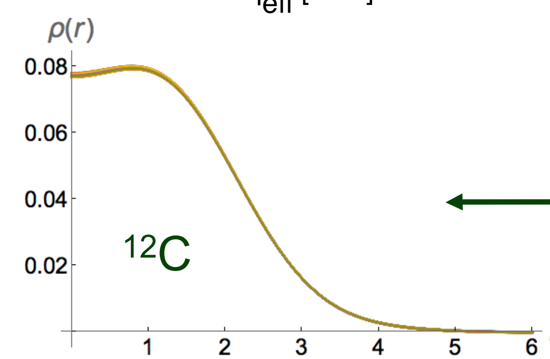
$$F_p(q^2) = \frac{1}{4\pi} \int d^3 r j_0(qr) \rho_p(r)$$

$$\begin{aligned} ZF_p &= 4\pi \int_0^\infty \rho_p r^2 dr \\ &= \sum_{\nu=1}^{\infty} (-1)^{\nu+1} \frac{4\pi R_p}{q_\nu^2} a_\nu \end{aligned}$$



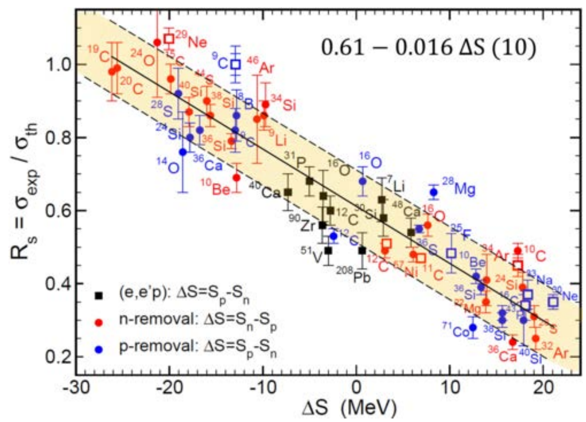


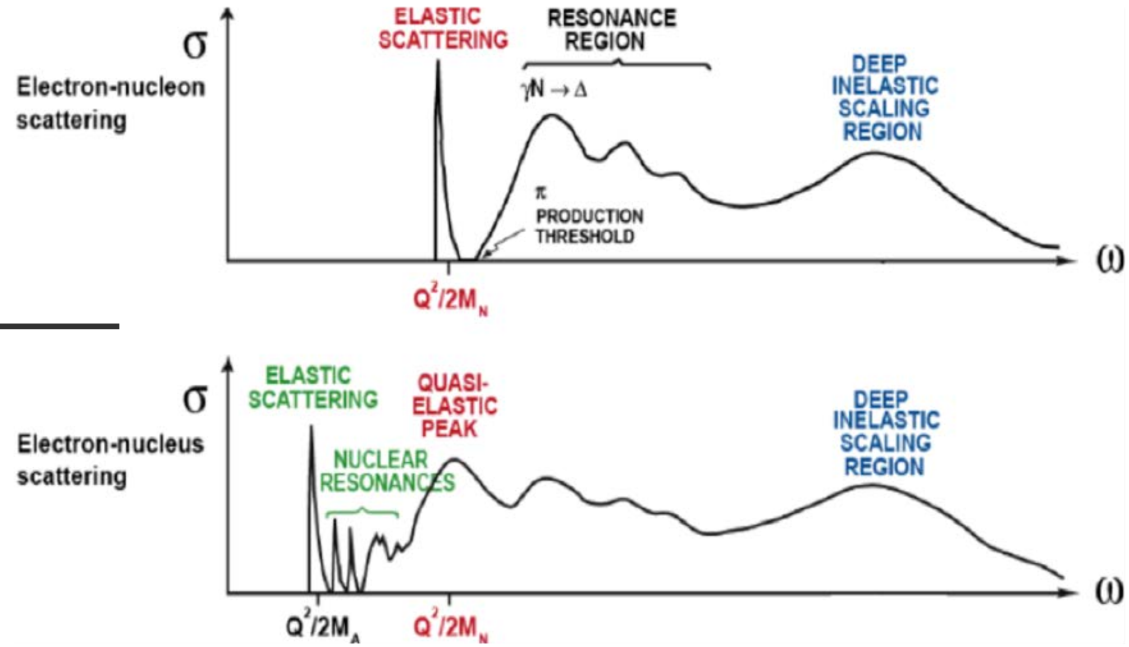


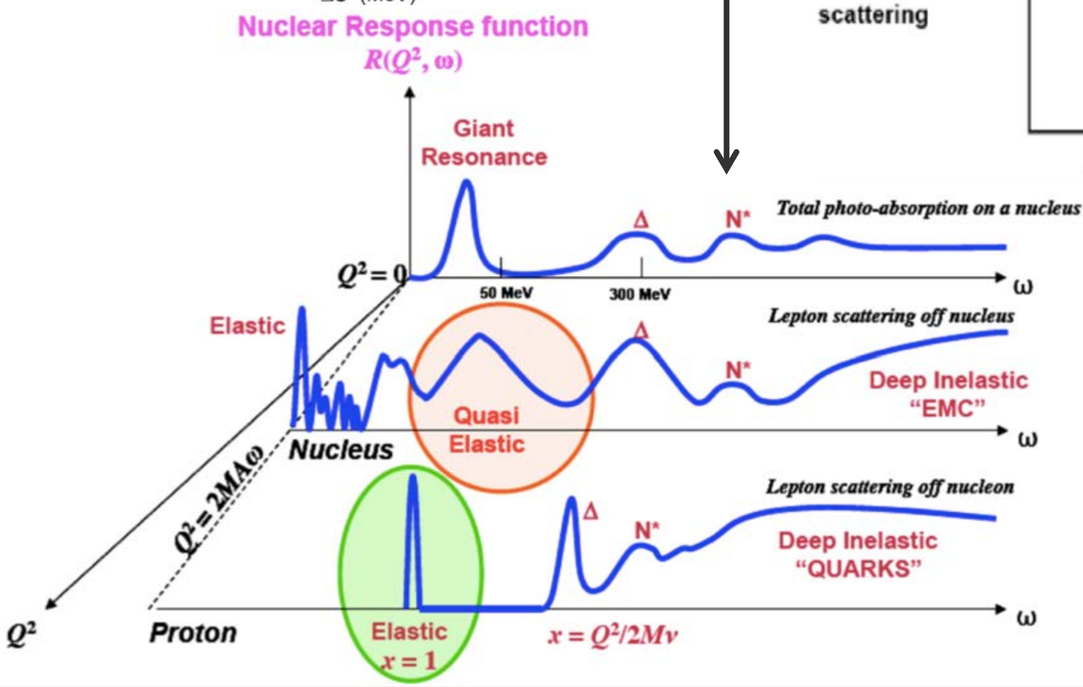


Electron Scattering Experiments

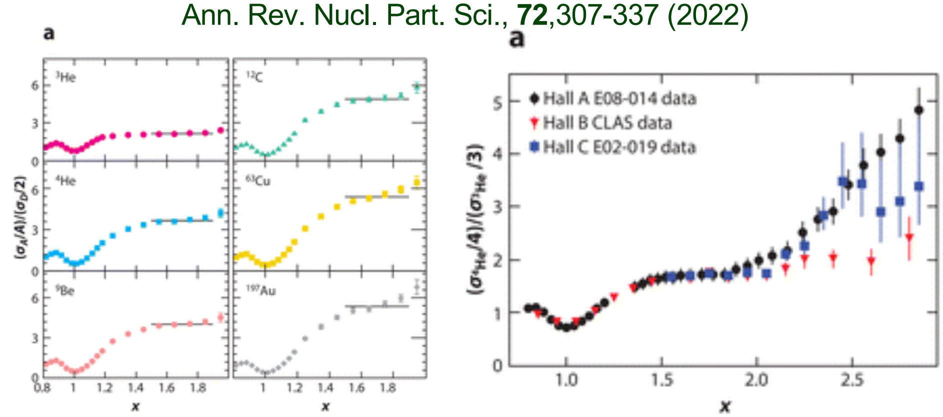
J. A. Tostevin and A. Gade
Phys. Rev. C **103**, 054610 (2021)







J. Arrington, N. Fomin and A. Schmidt
Ann. Rev. Nucl. Part. Sci., **72**,307-337 (2022)



Nuclear Tomography? What About Polarization?

Meson electro-production

$$\frac{d\sigma_v}{d\Omega_\eta} = \frac{|\mathbf{k}|}{k_\gamma^{cm}} P_\alpha P_\beta \{ R_T^{\beta\alpha} + \varepsilon_L R_L^{\beta\alpha}$$
$$+ [2\varepsilon_L (1+\varepsilon)]^{1/2} ({}^c R_{TL}^{\beta\alpha} \cos\phi_\eta + {}^s R_{TL}^{\beta\alpha} \sin\phi_\eta)$$
$$+ \varepsilon ({}^c R_{TT}^{\beta\alpha} \cos 2\phi_\eta + {}^s R_{TT}^{\beta\alpha} \sin 2\phi_\eta)$$
$$+ h [2\varepsilon_L (1-\varepsilon)]^{1/2} ({}^c R_{TL'}^{\beta\alpha} \cos\phi_\eta + {}^s R_{TL'}^{\beta\alpha} \sin\phi_\eta)$$
$$+ h (1-\varepsilon^2)^{1/2} R_{TT'}^{\beta\alpha} \}, \qquad (12)$$

G. Knöchlein, D. Drechsel, L. Tiator
Z. Phys. **A352**, 327-343 (1995)

3D nucleon tomography!!
(DVCs, parton distributions …)

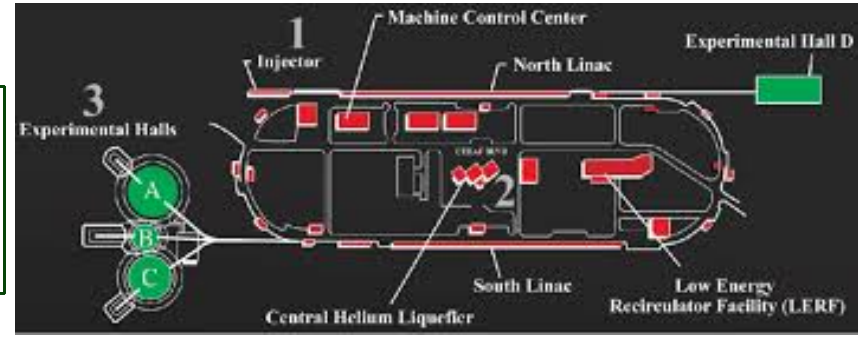
Table 1. Polarization observables in pseudoscalar meson electroproduction. A star denotes a response function which does not vanish but is identical to another response function via a relation in App. A

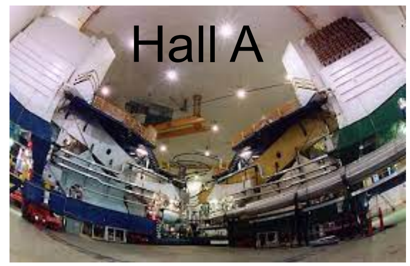
unpolarized | polarized

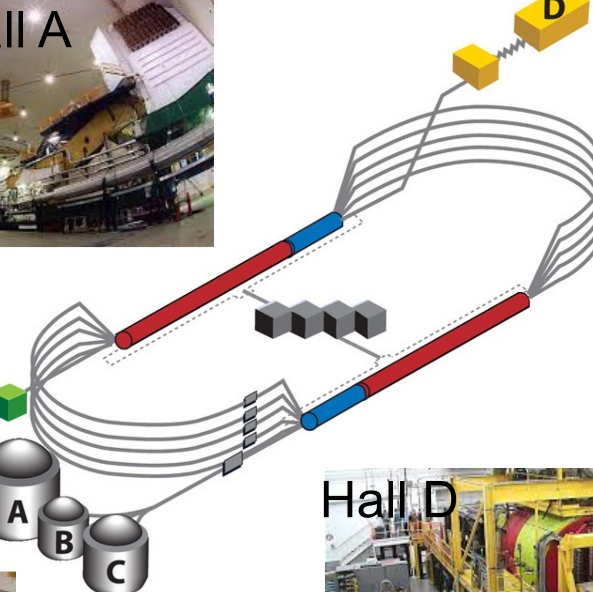
		Target			Recoil			Target + Recoil								
β	–	–	–	–	x'	y'	z'	x'	x'	x'	y'	y'	y'	z'	z'	z'
α	–	x	y	z	–	–	–	x	y	z	x	y	z	x	y	z
T	R_T^{00}	0	R_T^{0y}	0	0	$R_T^{y'0}$	0	$R_T^{x'x}$	0	$R_T^{x'z}$	0	*	0	$R_T^{z'x}$	0	$R_T^{z'z}$
L	R_L	0	R_L^{0y}	0	0	*	0	$R_L^{x'x}$	0	$R_L^{x'z}$	0	*	0	*	0	*
${}^cTL$	${}^cR_{TL}^{00}$	0	${}^cR_{TL}^{0y}$	0	0	*	0	${}^cR_{TL}^{x'x}$	0	*	0	*	0	${}^cR_{TL}^{z'x}$	0	*
${}^sTL$	0	${}^sR_{TL}^{0x}$	0	${}^sR_{TL}^{0z}$	${}^sR_{TL}^{x'0}$	0	${}^sR_{TL}^{z'0}$	0	*	0	*	0	*	0	*	0
${}^cTT$	${}^cR_{TT}^{00}$	0	*	0	0	*	0	*	0	*	0	*	0	*	0	*
${}^sTT$	0	${}^sR_{TT}^{0x}$	0	${}^sR_{TT}^{0z}$	${}^sR_{TT}^{x'0}$	0	${}^sR_{TT}^{z'0}$	0	*	0	*	0	*	0	*	0
${}^cTL'$	0	${}^cR_{TL'}^{0x}$	0	${}^cR_{TL'}^{0z}$	${}^cR_{TL'}^{x'0}$	0	${}^cR_{TL'}^{z'0}$	0	*	0	*	0	*	0	*	0
${}^sTL'$	${}^sR_{TL'}^{00}$	0	${}^sR_{TL'}^{0y}$	0	0	*	0	${}^sR_{TL'}^{x'x}$	0	*	0	*	0	${}^sR_{TL'}^{z'x}$	0	*
TT'	0	$R_{TT'}^{0x}$	0	$R_{TT'}^{0z}$	$R_{TT'}^{x'0}$	0	$R_{TT'}^{z'0}$	0	*	0	*	0	*	0	*	0

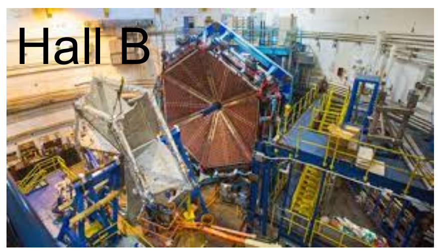
Thomas Jefferson National Accelerator Facility (Jefferson Lab)

12 GeV, 14 kW
Polarized e^-
CW (1.5 GHz)









JLab Beam Parameters

Hall A

Beam Property	Nominal Value/Range					Temporal Stability over 8 hours
Spot size at target (rms) [μm]	Horizontal < 250 Vertical < 200					Horizontal ~ 20 Vertical ~ 20
Angular divergence at target [μrad]	< 20					< 2
Current [μAmp]	1 - 120♦					10%
Charge per bunch [fCoul]	4 - 480					10%
Bunch repetition rate [MHz]	249.5*					NA
Beam position	offsets parallel to diagnostic girder axis within 2.5 mm radius					< 40 μm (slow lock) < 20 μm FFB (at 60Hz)
Energy spread♠ (rms)	Pass-1	Pass-2	Pass-3	Pass-4	Pass-5	
	$< 10^{-4}$	$< 10^{-4}$	$< 10^{-4}$	3×10^{-4}	5×10^{-4}	~ 10% of nominal (linac crested)
Beam direction	± 300 μrad (rasterized at 3 mm x 3 mm)					< 2 μrad (position lock)
Energy range [GeV]	1 - 11					NA
Energy accuracy♥ (rms)	3×10^{-3}					stable
Beam polarization∇	up to 85%					
Charge asymmmetry▲	< 0.1%					
Background beam halo	< 0.1%					
Beam availability (including RF trips)	60%					

Hall B

Beam Property	Nominal Value/Range					Temporal Stability over 8 hours
Spot size measured by 2H01A harp (rms) [μm]	< 100 for 1 GeV - 6 GeV < 200 for 7 GeV - 11 GeV					periodic measurement and adjustment can enforce lower bound
Angular divergence at target [μrad]	< 100					goverened by the formula: emittance/(spot size)
Current [nAmp]	1• - 160♦					< 5% for currents > 5 nAmp
Charge per bunch [fCoul]	4×10^{-3} - 0.64					< 5% for currents > 5 nAmp
Bunch repetition rate [MHz]	249.5*					NA
Beam position♣	as required within ± 2 mm of beam axis as measured on IPM2H00/IPM2H01					< 0.1mm for currents above 30 nA
Energy spread♠ (rms)	Pass-1	Pass-2	Pass-3	Pass-4	Pass-5	
	$< 10^{-4}$	$< 10^{-4}$	$< 10^{-4}$	3×10^{-4}	5×10^{-4}	~ 10% of nominal (linac crested)
Beam direction	Parallel to beam line axis, consistent with ambient field and positions of beam on target and dump					stable to < 20 μrad
Energy range [GeV]	1 - 11					NA
Energy accuracy♥ (rms)	3×10^{-3}					$< 2\times10^{-4}$ (slow locks) $< 3\times10^{-5}$ (fast feedback)

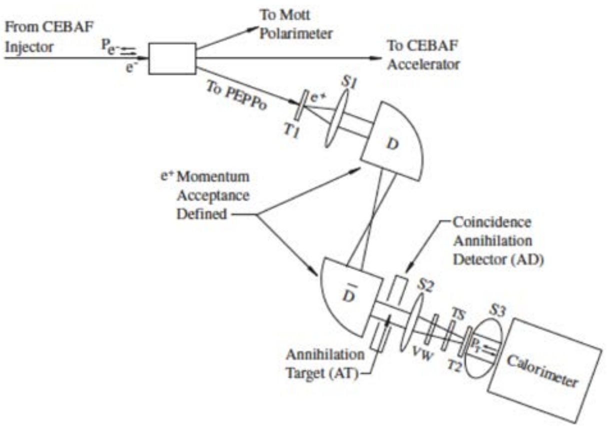
Hall C

Beam Property	Nominal Value/Range					Temporal Stability over 8 hours
Spot size (X/Y)♦ at pivot (rms) [μm]	Pass-1	Pass-2	Pass-3	Pass-4	Pass-5	
	100-190	150-260	175-300	200-275	230-500	20
Angular divergence at target [μrad]	±25					NA
Current [μAmp]	2.5 - 150#					10%
Charge per bunch [fCoul]	10 - 600					10%
Bunch repetition rate [MHz]	249.5*					NA
Beam position	offsets parallel to diagnostic girder axis within 2.5 mm radius					< 40 μm (slow lock) < 20 μm FFB (at 60Hz)
Energy spread♠ (rms)	Pass-1	Pass-2	Pass-3	Pass-4	Pass-5	
	$< 10^{-4}$	$< 10^{-4}$	$< 10^{-4}$	3×10^{-4}	5×10^{-4}	~ 10% of nominal (linac crested)
Beam direction	beam divergence, dump aperture and raster combine to limit imposed angles under 800 μrad					< 20 μrad (position lock)
Energy range [GeV]	1 - 11					NA
Energy accuracy♥ (rms)	3×10^{-3}					stable
Beam polarization∇	up to 85%					stable
Charge asymmmetry▲	< 0.1%					stable
Background beam halo	less than 10^{-4} of integral of Gaussian core					stable
Beam availability (including RF trips)	60%					stable

Hall D

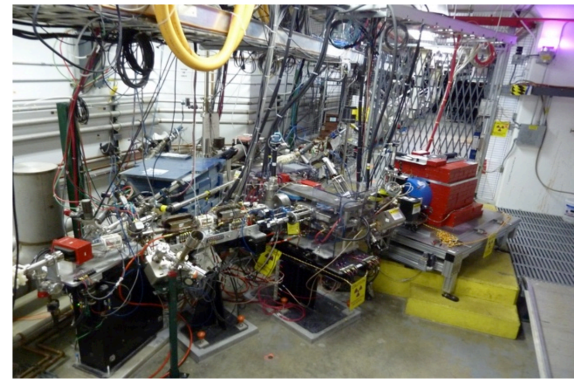
Beam Property	Nominal Value/Range	Temporal Stability over 8 hours
Spot size at target♦ (rms) [μm]	Horizontal < 1000 Vertical < 500	Horizontal ~ 100 Vertical ~ 100
Angular divergence at target [μrad]	< 15	< 1
Current [nAmp]	1 - 2000#	10%
Charge per bunch [fCoul]	4×10^{-3} - 8	10%
Bunch repetition rate [MHz]	249.5*	NA
Beam position	± 1 mm	< 40 μm (with 5C11B lock)
Energy spread♠ (rms)	2×10^{-3} - 3×10^{-3}	~ 10% of nominal (linac crested)
Beam direction	± 30 μrad	< 2 μrad (active collimator lock)
Energy range [GeV]	8.8 - 12.1	NA
Energy accuracy♥ (rms)	3×10^{-3}	stable
Background beam halo	< 0.1%	stable
Beam availability (including RF trips)	60%	stable

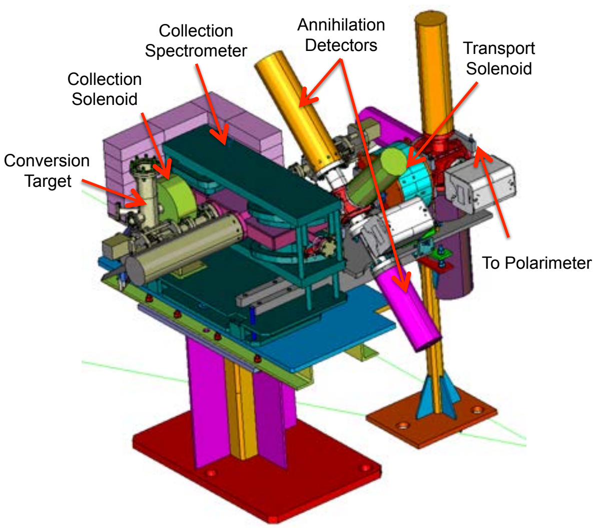
Polarized Positron Beams – 20 years later! (... possible scheme for the EIC)

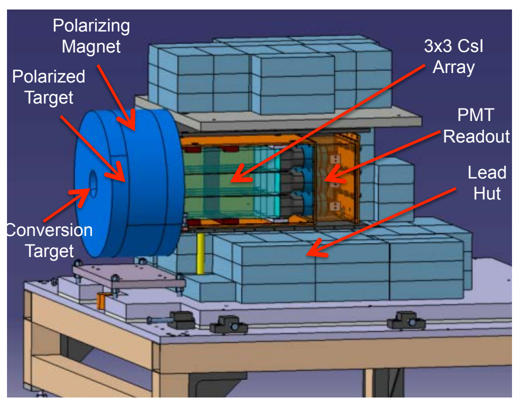


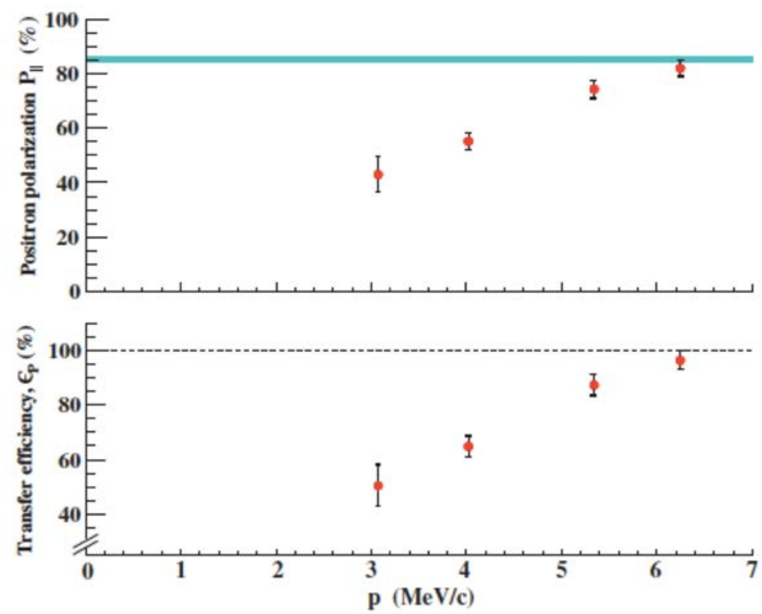
Polarized Electrons for Polarized Positrons
D. Abbott *et al.*, PRL **116**, 214801 (2016)

- Experiment in the CEBAF injector
- Highly polarized positrons
- 80% @ 6.5 MeV
- R&D for EIC
- **Last PhD @ HU (A. Adeyemi, 2016)**

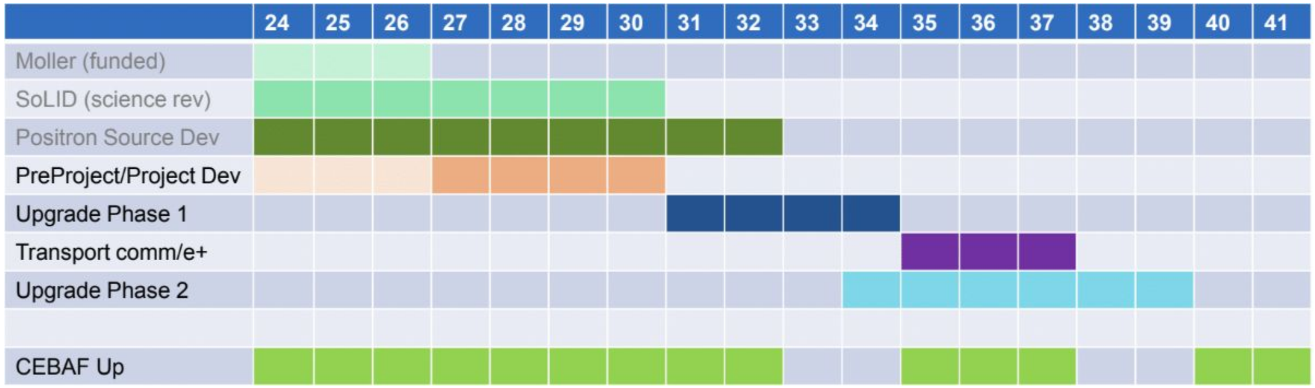








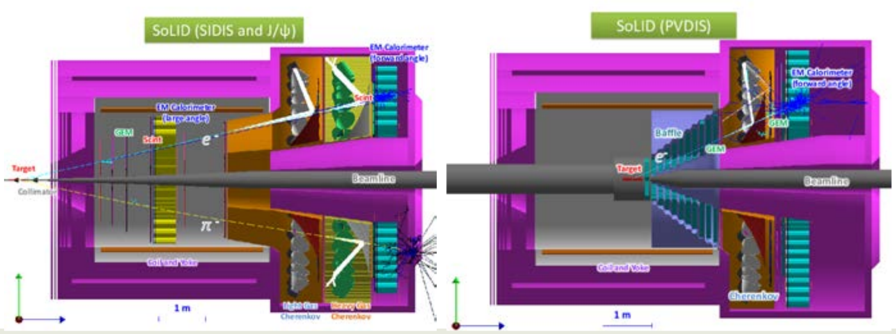
Future of JLab

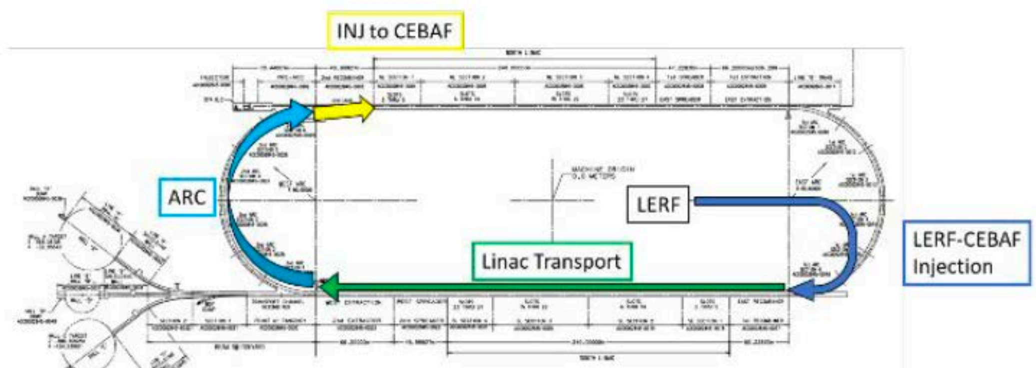


← 22 GeV

Solenoidal Large Intensity Device (SoLID)

- Precision 3D momentum imaging in the valence quark region
- Exploring the origin of the proton mass and gluonic force in the non-perturbative regime
- Beyond Standard Model searches complementary to Möller

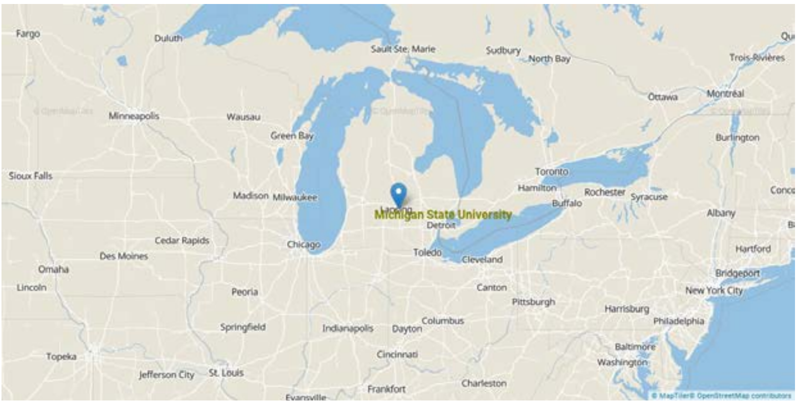


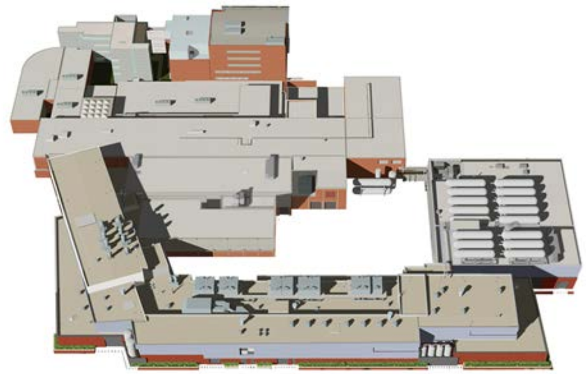


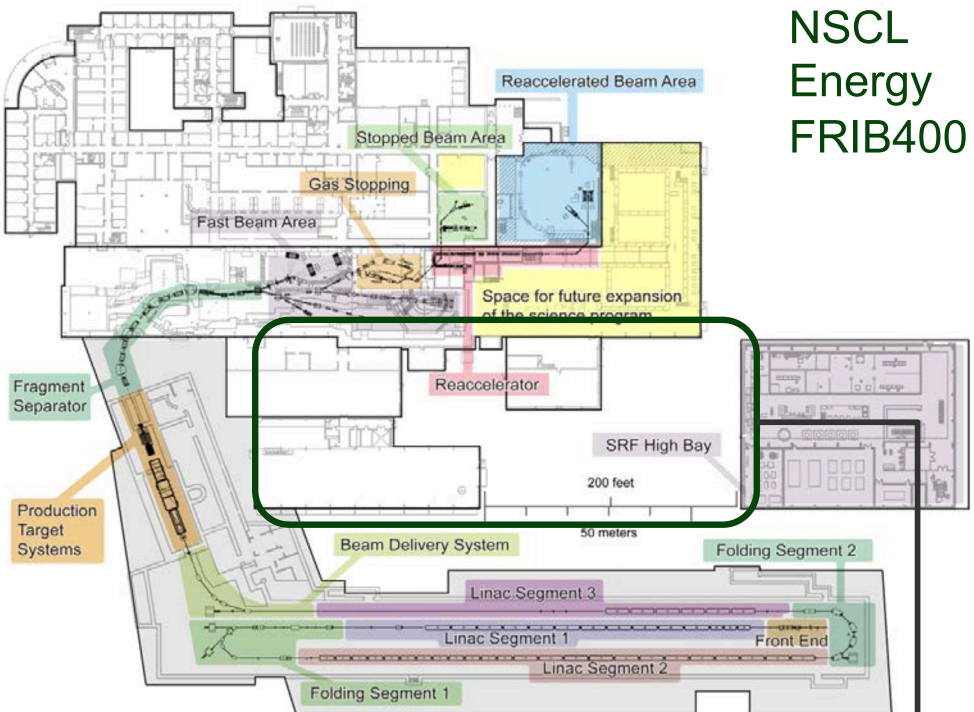
JLab PAC51

21/37 (57%) proposals/LOIs for e^+!!

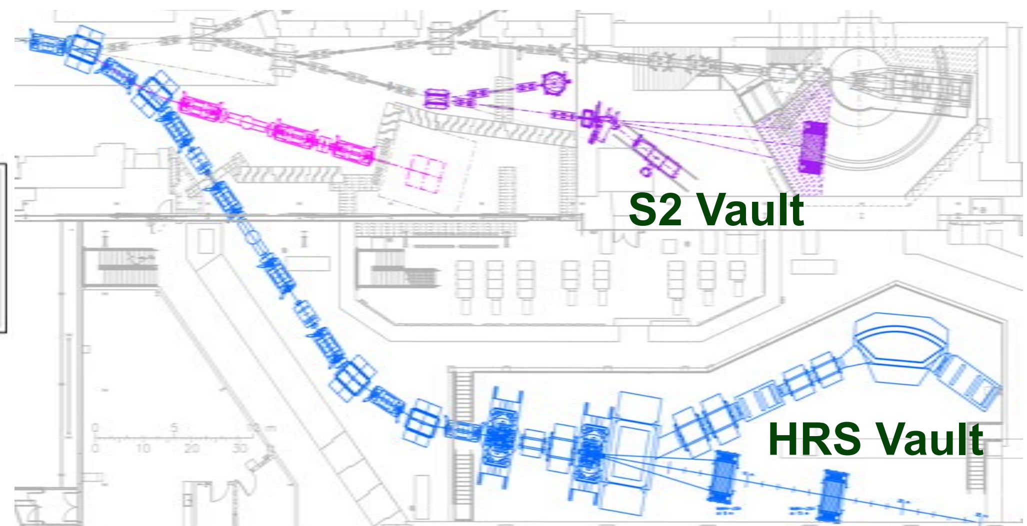
Facility for Rare Isotope Beams
(www.frib.msu.edu; start: May 10, 2022)







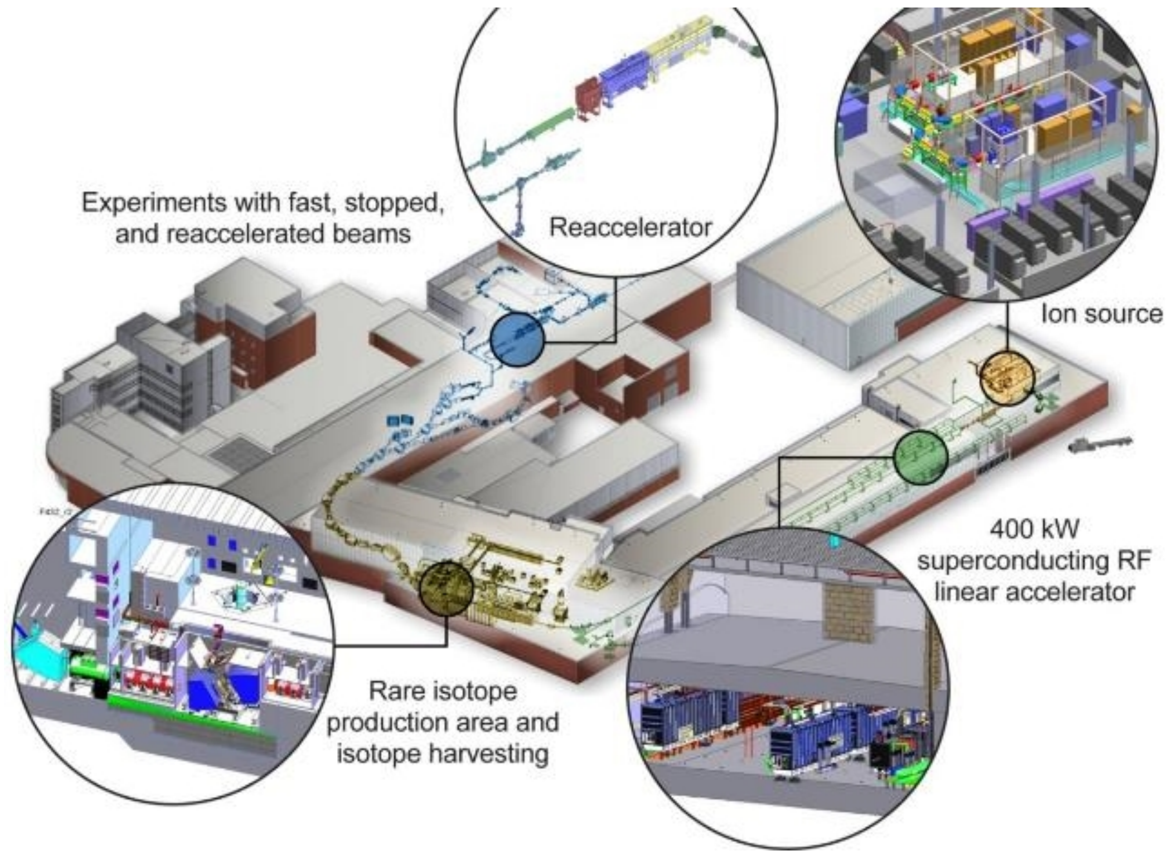
NSCL : ~100 MeV/u
Energy : ~200 MeV/u
FRIB400 : ~400 MeV/u



FRIB
Facility for Rare Isotope Beams
U.S. Department of Energy Office of Science
Michigan State University

Facility for Rare Isotope Beams Offers Discovery Potential

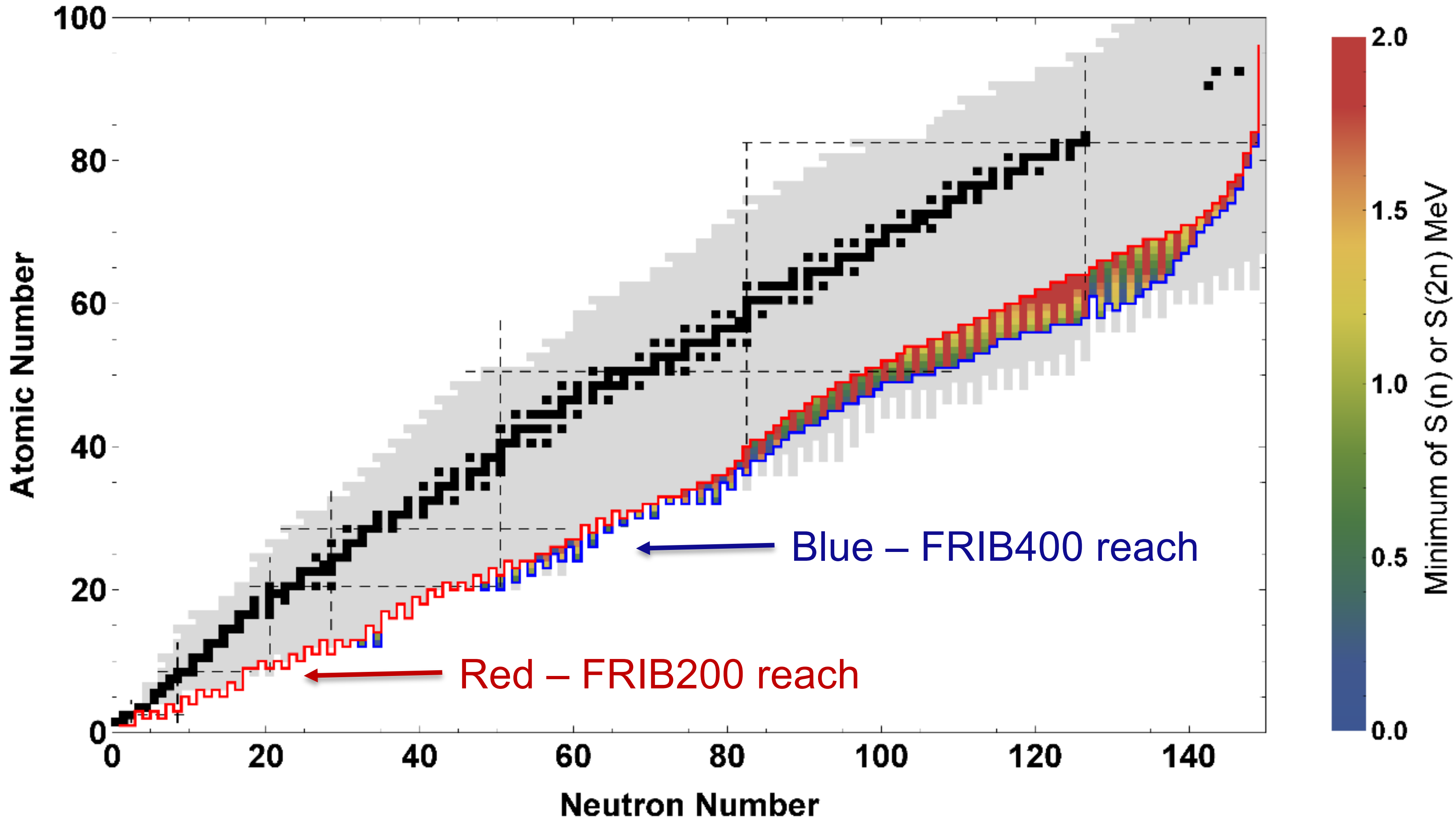
- FRIB is a US Department of Energy Office of Science User facility
  - Open to researchers from around the world based on scientific merit
- FRIB's key feature is 400 kW beam power
  - 8 pμA or 5 x 10^{13} ^{238}U/s
- Experiments with fast (200 MeV/u), stopped (trapped), and reaccelerated beams (0.6 to 10 MeV/u)
- Separation of isotopes in-flight provides
  - Fast development time for any isotope
  - Beams of all elements and short half-lives
- Isotope harvesting capability from beam dump water)



Thomas Glasmacher,
FRIB Laboratory Director

FRIB400 Scientific Reach Extended

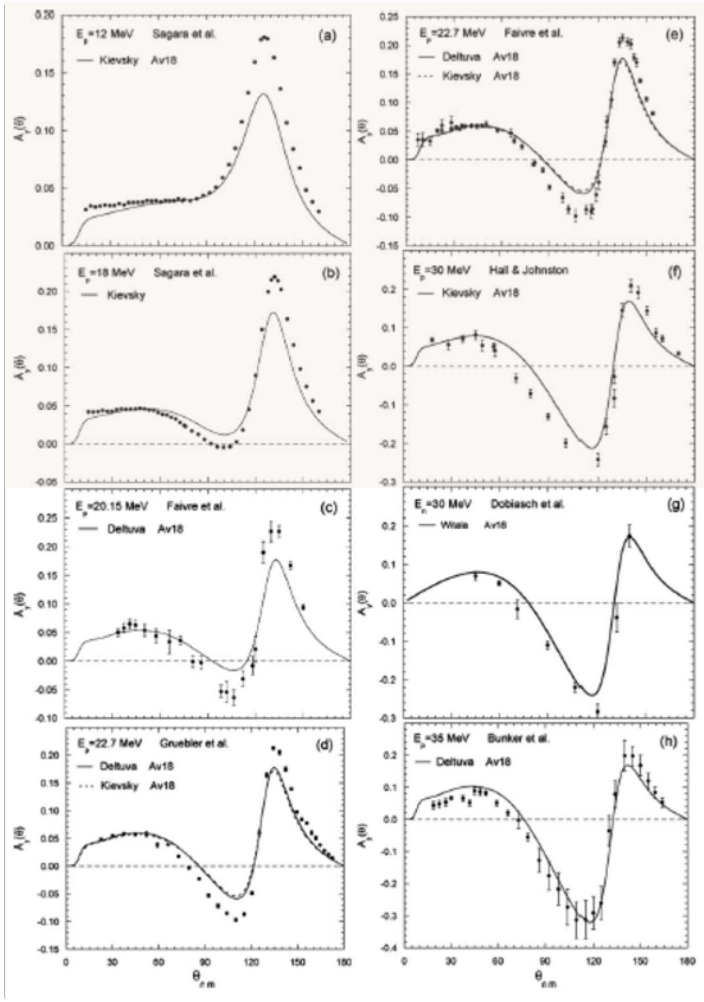
- Drip line extended to Z ≈ 60

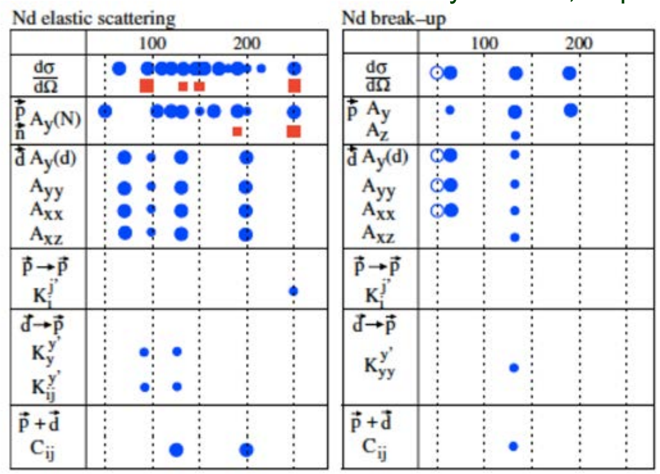


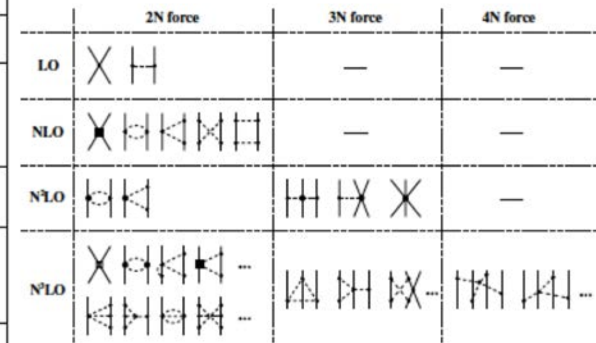
Polarization in Heavy Ion Physics

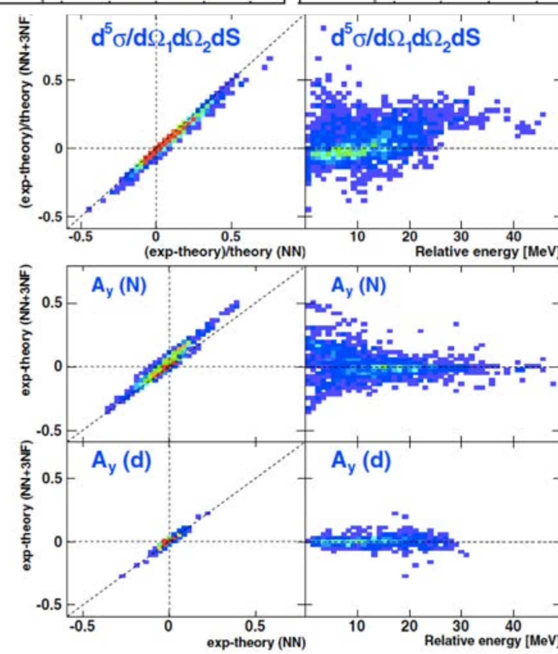
Kalantar-Nayestanaki, Rep. Prog. Phys. **75** (2012) 016301

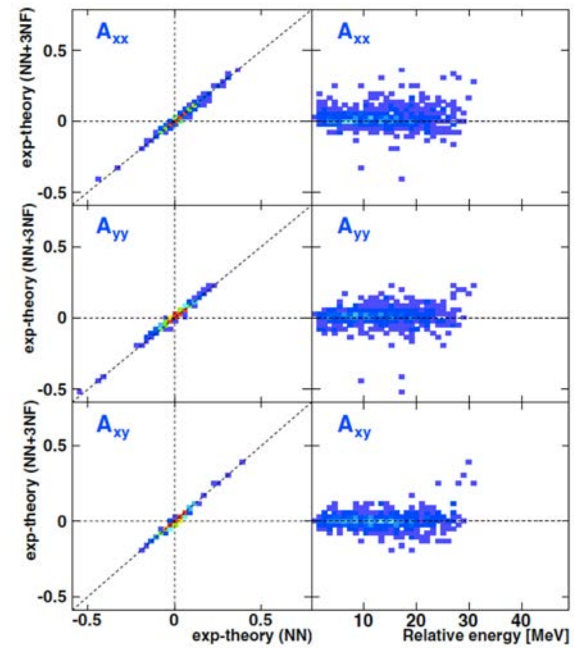
Torrow et al., Nucl. Part. Phys. **35** (2008) 125104











Rare Isotope Nuclear Radii

Ambar Rodriguez Alicea, GS

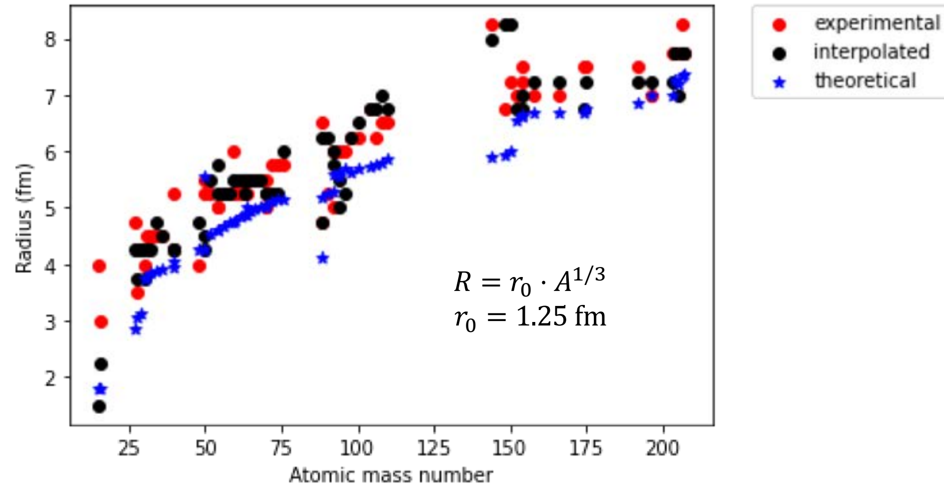
$$\rho(r) = \frac{1}{2\pi^2}\int F(q)\,\frac{\sin(qr\prime)}{qr}\,q^2 dq$$

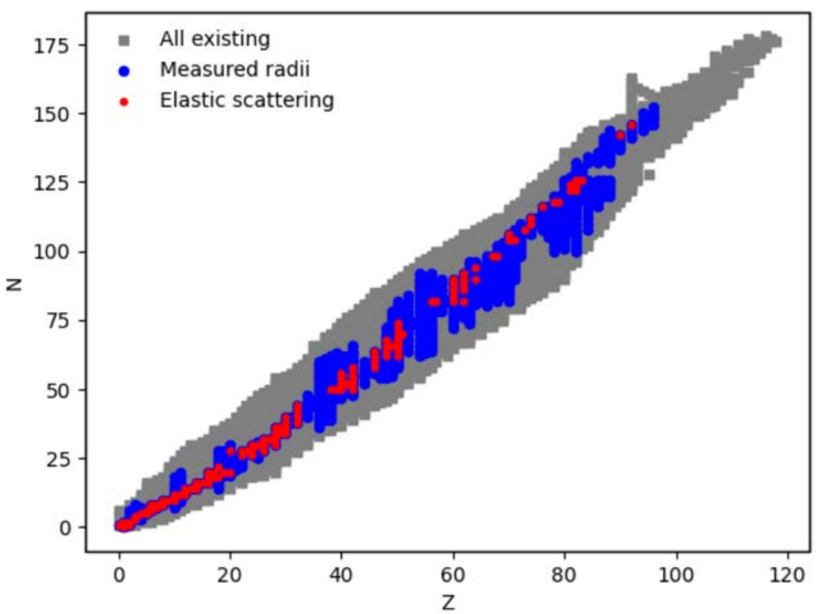
$$= \sum a_\nu j_0(qr)$$

$$F(q) = 4\pi\int \frac{\sin(qr'/\hbar)}{qr'/\hbar} r'^2 \rho(r') dr'$$

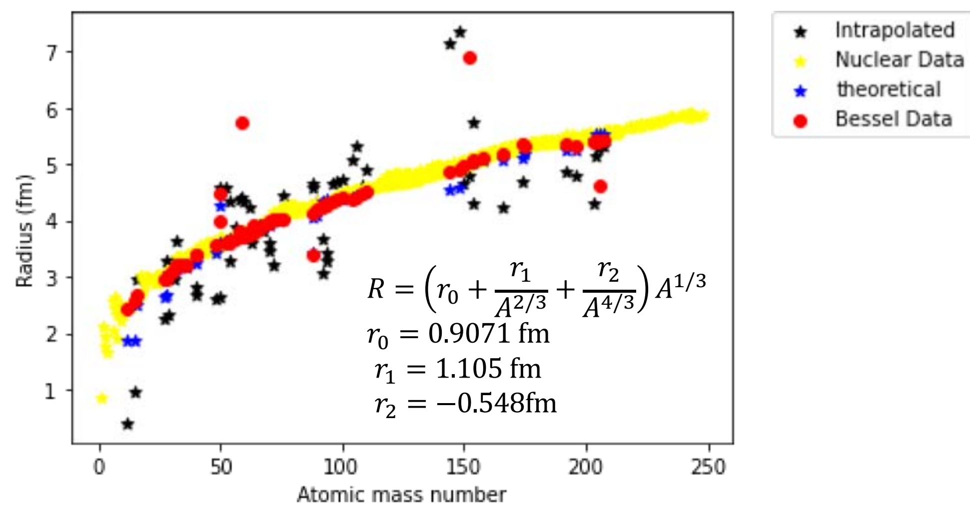
$$j_0(qr) = \sum_{n=0}^{\infty} \frac{(-1)^n (qr)^{2n}}{2^{2n}(n!)^2} = \frac{\sin(qr)}{qr}$$

H. DeVries etal., At. Data Nuc. Data Tables, **36**, 495-536 (1987)



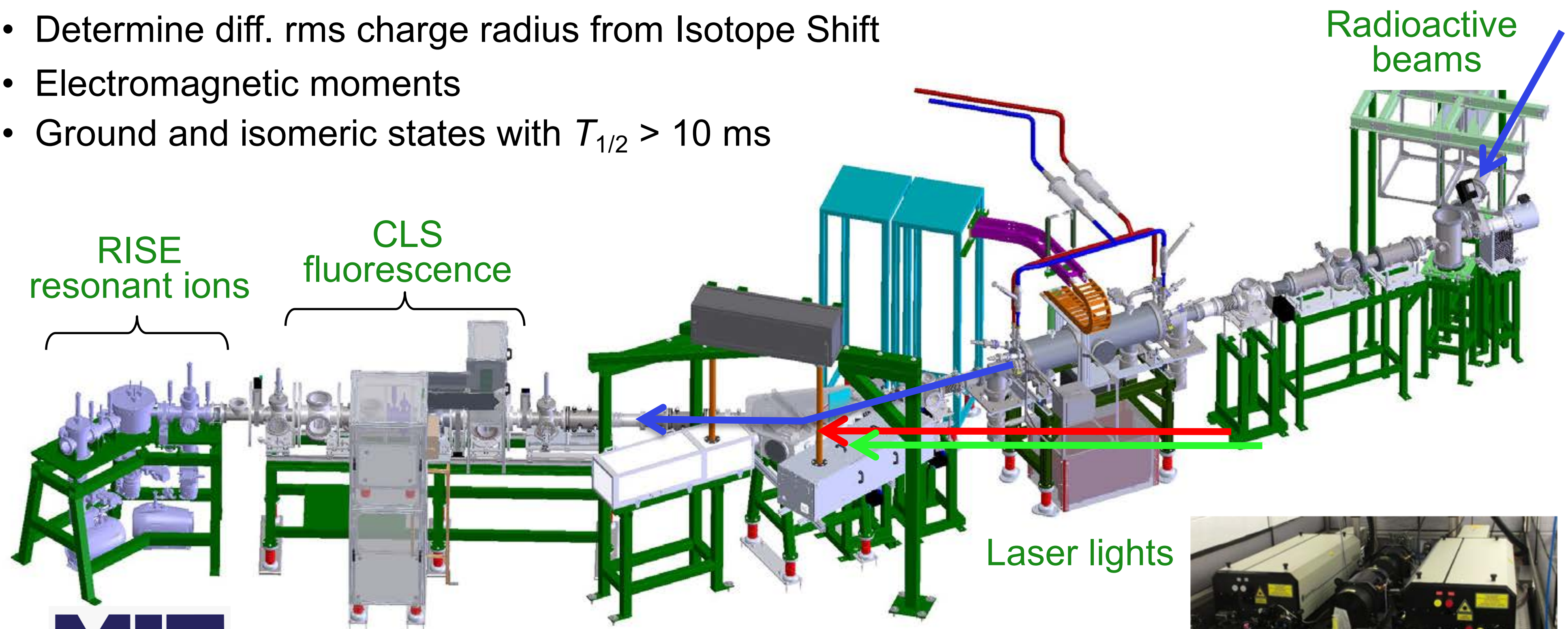


I. Angeli and K. P. Marinova, At. Data Nuc. Data Tables, **99**, 69-95 (2013)



Laser Spectroscopy @ FRIB: BECOLA Facility

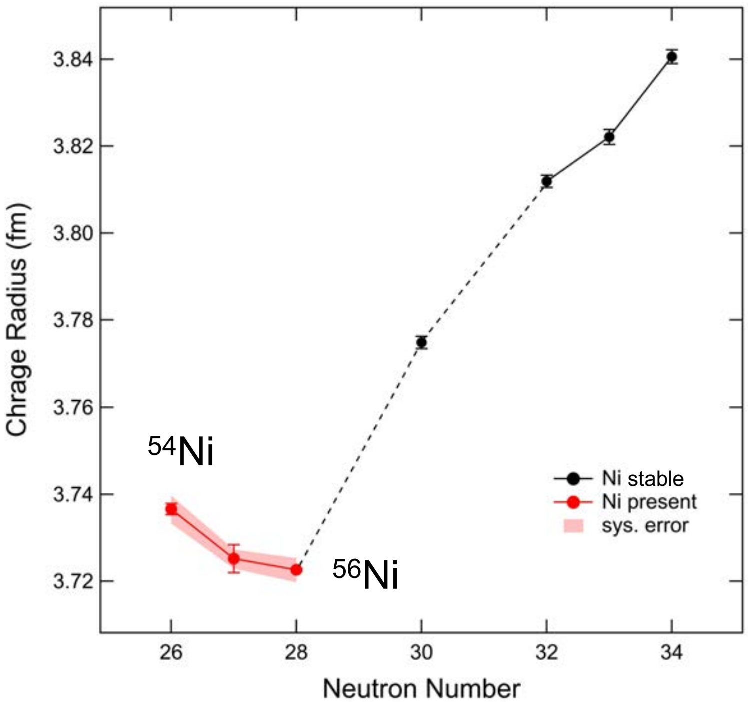
- Beam Cooling and Laser spectroscopy (BECOLA)
- Determine diff. rms charge radius from Isotope Shift
- Electromagnetic moments
- Ground and isomeric states with $T_{1/2}$ > 10 ms

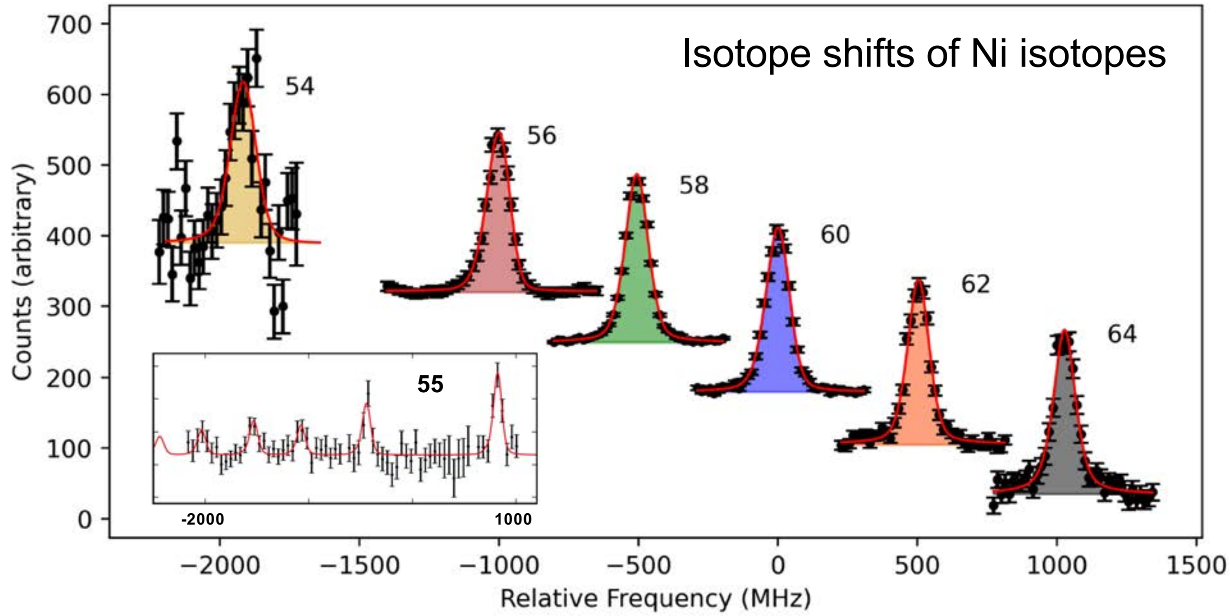


- Fluorescence & resonant ionization measurements
- High sensitive: ~10 ions/s at BECOLA,

Charge Radii of ^{54,55,56}Ni Reveal a Surprising Similarity to ^{48}Ca at N = 28

- Discontinuity, so called the kink structure, in a chain of charge radii is commonly observed at all Magic numbers.
- However, what the strength (steepness) of the kink implies is an open question.
- Kink at ^{56}Ni was investigated, which is know to be "soft" as doubly-Magic nucleus.





Isotope shifts of hyperfine spectra relative to stable ^{60}Ni were measured for the neutron-deficient ^{54,55,56}Ni by laser spectroscopy, from which differential mean square charge radii $\delta\langle r^2\rangle$ were extracted.

Charge radii were deduced from the $\delta\langle r^2\rangle$ and radius of stable ^{60}Ni.
Kink at the neutron-number N = 28 is clearly observed.

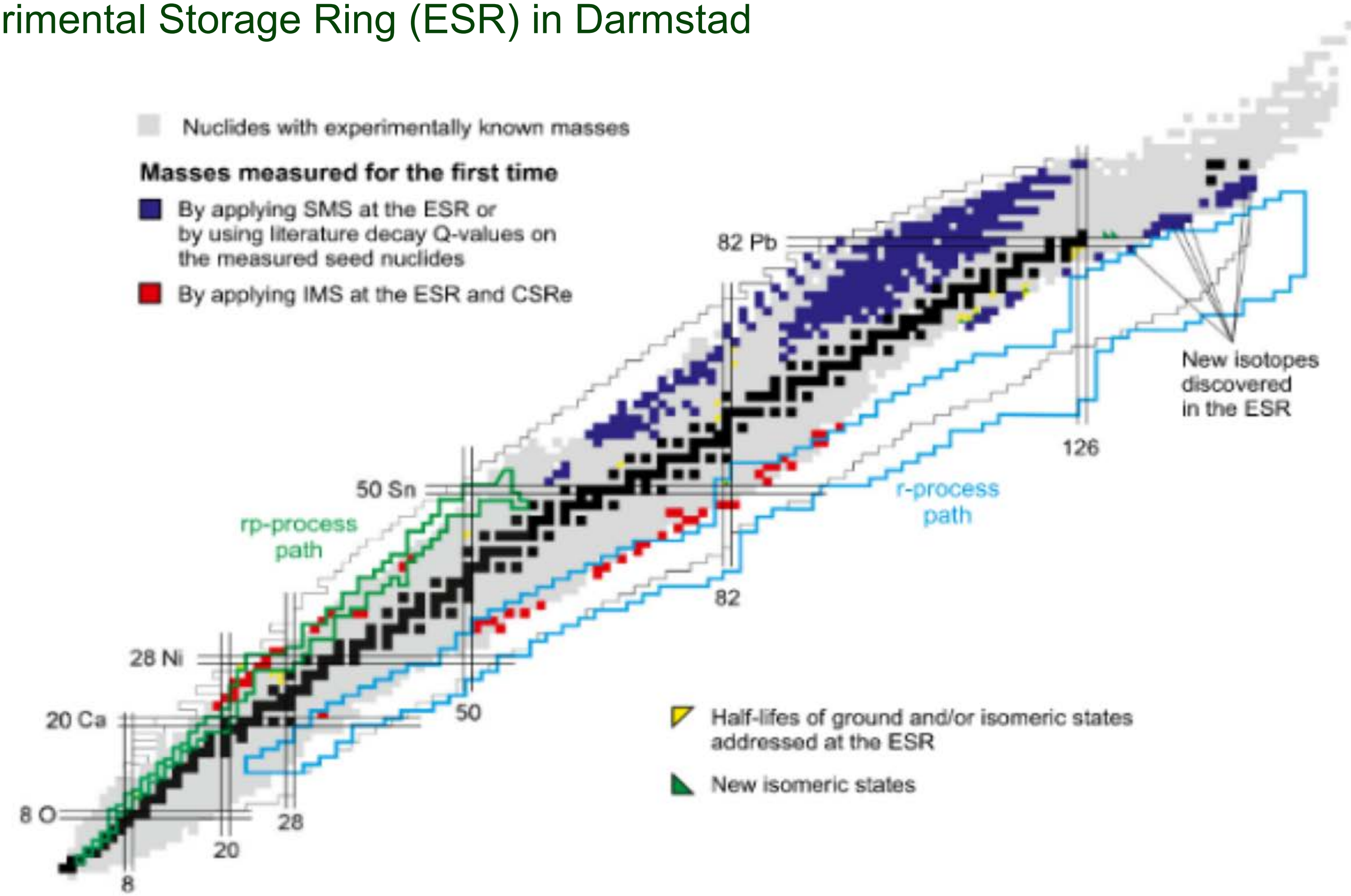
F. Sommer et al., PRL 129, 132501 (2022)

Need absolute charge radii

- **Model independent, *R* can be determined with ~ 0.005 fm**
- **Sensitive to $\delta\langle r^2\rangle$ and requires reference to deduce absolute radius**: $R^2 = \mathbf{R^2_{ref}} + \delta\langle r^2\rangle$
    - R_{ref} can be evaluated from e-scattering and μ-capture experiments.
    - but R_{ref} is not always available with high enough precision we want.
- **Using King plot, *k* and *F* can be experimentally evaluated**,
    - IF there are ≥ 3 (stable) isotopes of the element, whose *R* are know.
    - otherwise need to rely on atomic theories
        - Typically with a few ~ 10% uncertainty
        - ab-initio is feasible for 5 electron systems so far.
- **Once *k* and *F* are known, they can be applied to deduce unknown $\delta\langle r^2\rangle$**
- In general, $\delta\langle \mathrm{r}^2\rangle$ is replaced by $\delta\langle \mathrm{r}^2\rangle + \widetilde{c_2}\delta\langle \mathrm{r}^4\rangle + \widetilde{c_3}\delta\langle \mathrm{r}^6\rangle + \cdots$
    - Contribution is very small and difficult to determine
- **Need absolute *R* of stable as well as radioactive but near stable nucleus to go further away from stable isotopes, where there is enhanced chance of discovery.**

Storage Rings & Mass Measurements

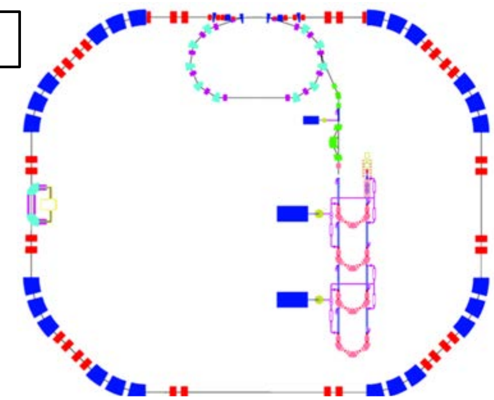
Experimental Storage Ring (ESR) in Darmstad



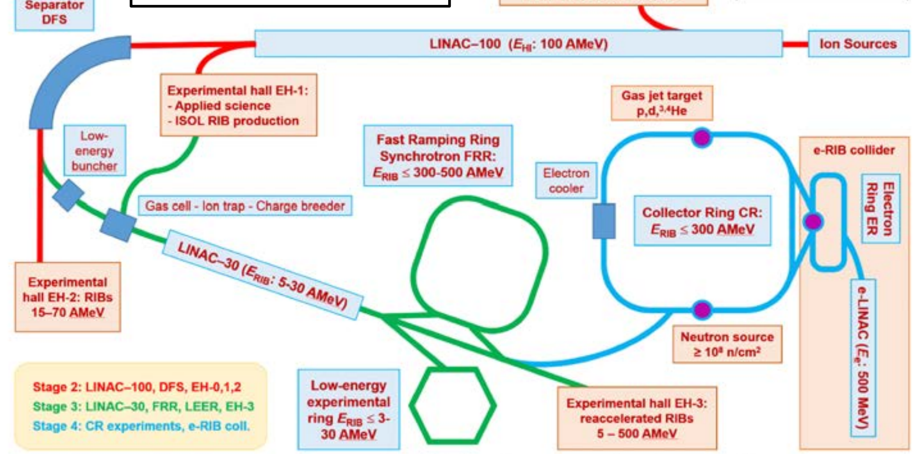
Electron/Rare Isotopes Systems

- RI-RIKEN
  - SCRIT: Self-Confining Radioactive isotope Ion Target
- Facility for Anti-proton and Ion Research (FAIR, Germany)
  - ELISE: Electron-Ion Scattering in a Storage Ring
- DUBNA (Russia)
  - DERICA: Dubna Electron-Radioactive Ion Collider fAcility

ELISE at FAIR

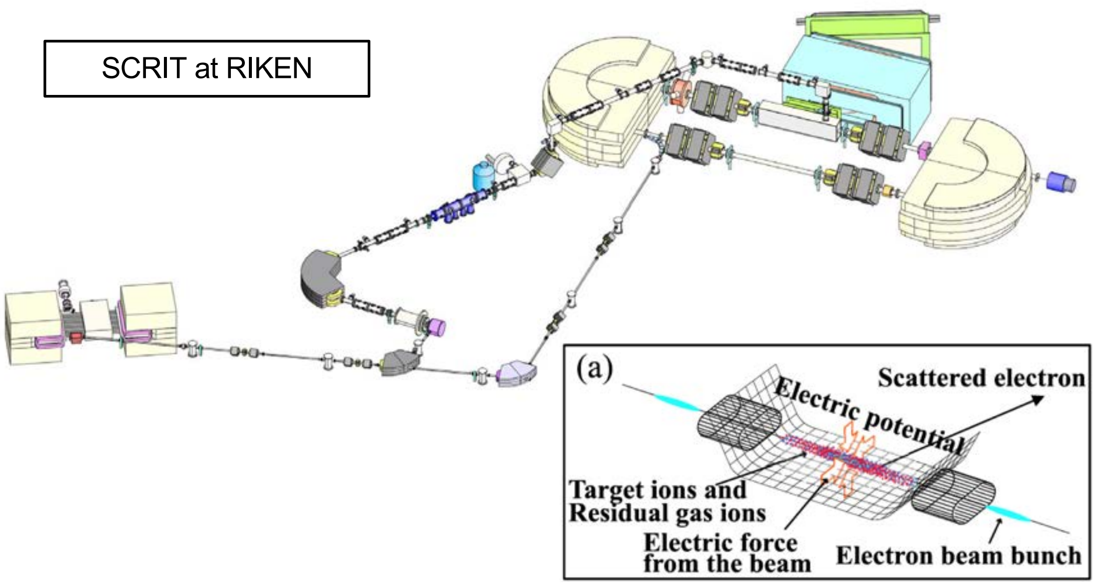


DERICA in DUBNA



K. Tsukada et al., Phys. Rev. Lett. **131**, 092502
https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.131.092502

SCRIT at RIKEN



Some numbers …

T. Suda and H. Simon, Prog. Part. Nucl. Phys., **96**, 1-31 (2017)

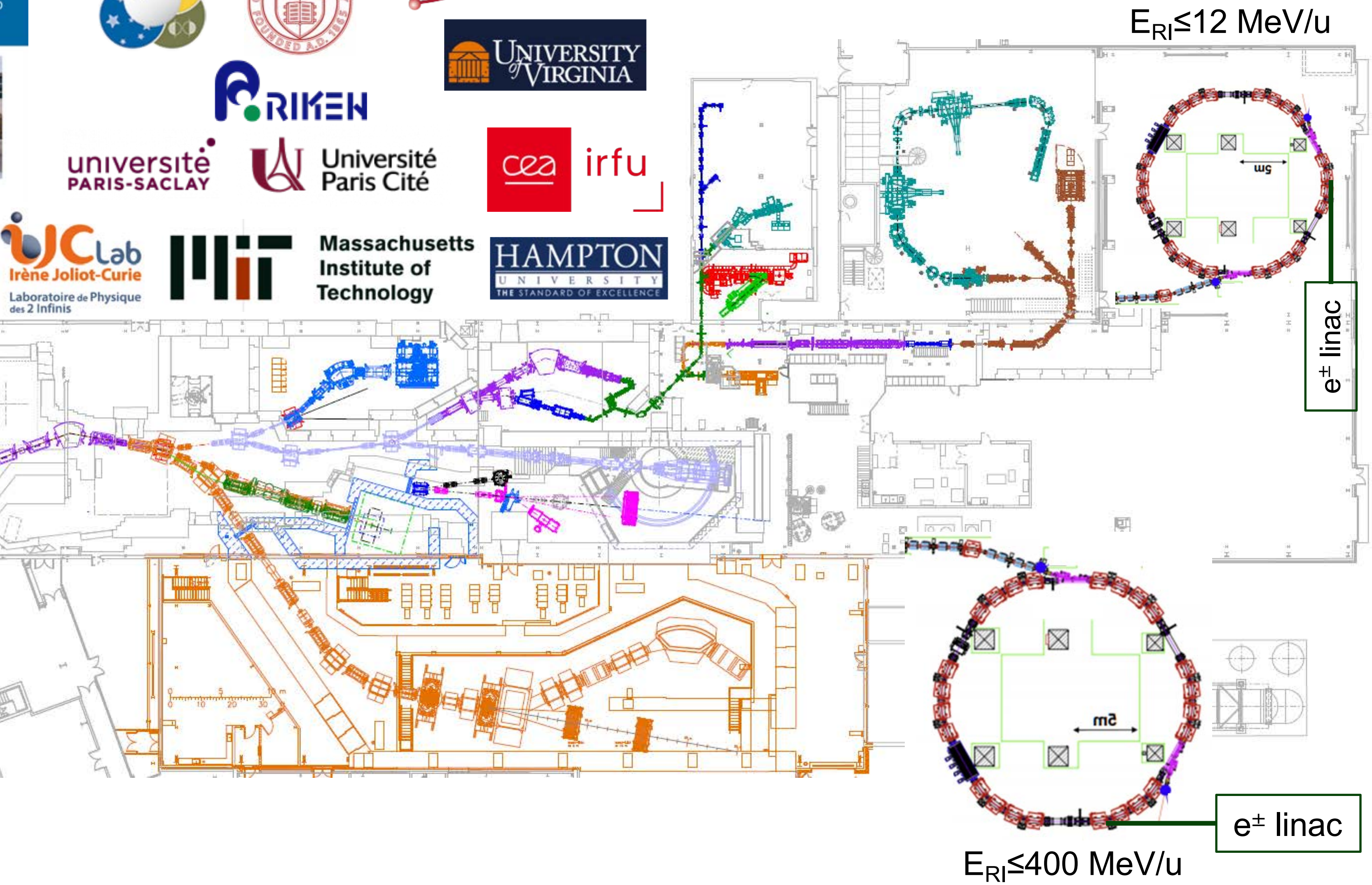
Table 2
Estimate for the required luminosities for different studies in colliding beam kinematics. It is assumed that the maximum running time shall not exceed four weeks.

Reaction	Deduced quantity	Target nuclei	Luminosity $\mathcal{L}$ $cm^{-2}\ s^{-1}$
Elastic scattering at small q	r.m.s. charge radii	Light Medium	10^{24}
First minimum in elastic form-factor	Density distribution with 2 parameters	Light Medium Heavy	10^{28} 10^{26} 10^{24}
Second minimum in elastic form-factor	Density distribution with 3 parameters	Medium Heavy	10^{29} 10^{26}
Giant resonances	Position, width, strength, decays	Medium Heavy	10^{28} 10^{28}
Quasi-elastic scattering	Spectroscopic factors, spectral function, momentum distributions	Light	10^{29}

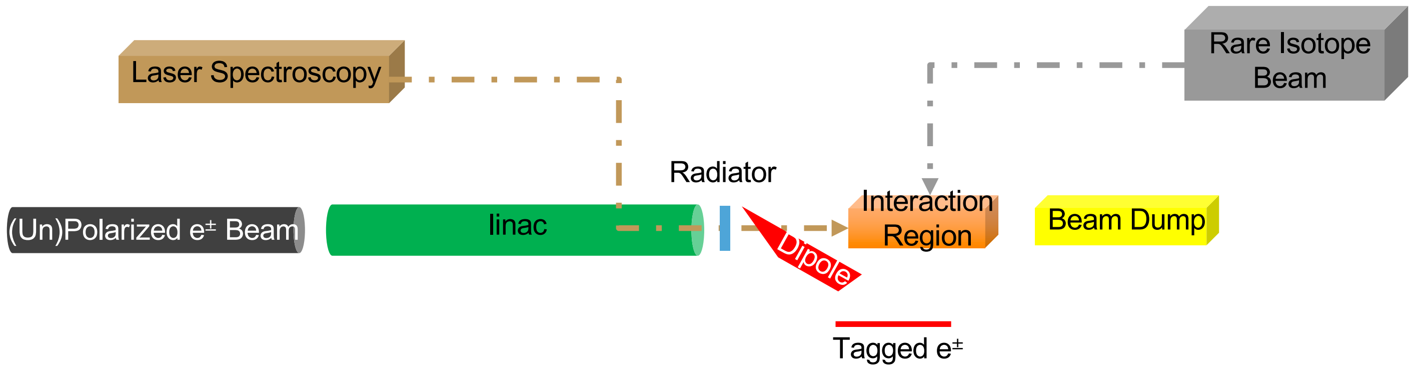
	Ee (GeV)	**Beam Current**	**Ne/s**	**Target (/cm^2)**	**L (/cm^2/s)**
Hofstadter (1950)	0.15	1 nA	6.25×10^{09}	6.0×10^{19}	3.8×10^{29}
JLab	12	100 µA	6.25×10^{14}	6.0×10^{22}	3.8×10^{37}
SCRIT (20 W)	0.15-0.30	300 mA	1.88×10^{18}	1.0×10^{09}	1.9×10^{27}
FRIB (400 kW)	<1 (0.2 calc.)	300 mA	1.88×10^{18}	1.9×10^{13}	3.6×10^{31}
positrons (1/100)	<1 (0.2 calc.)	3 mA	1.88×10^{16}	1.9×10^{13}	3.6×10^{29}

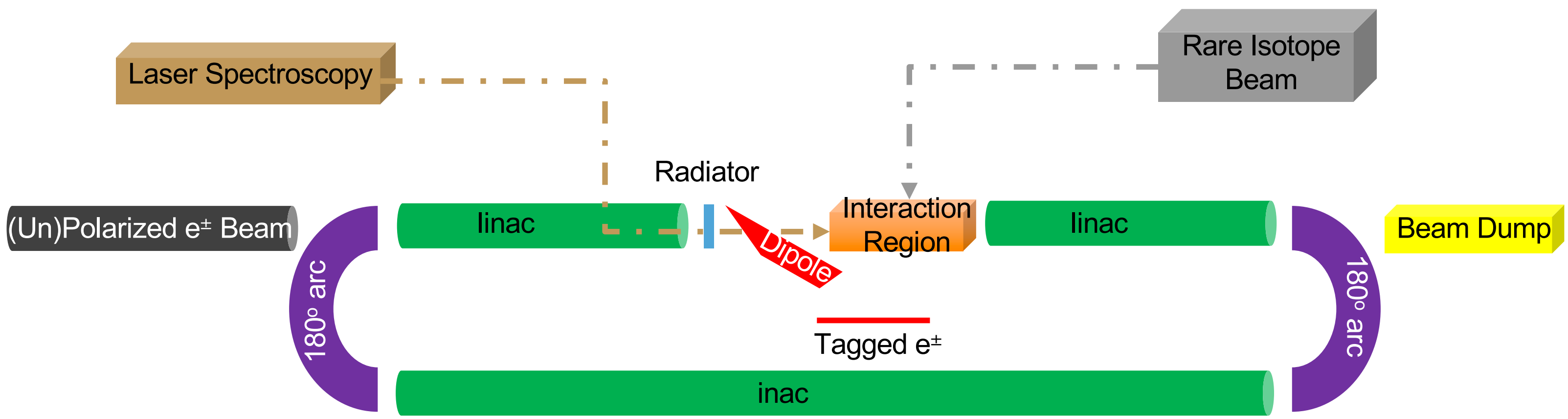
Possible e$^{\pm}$-RIB Concept @ FRIB

White Paper on Nuclear Structure, Reactions, and Astrophysics

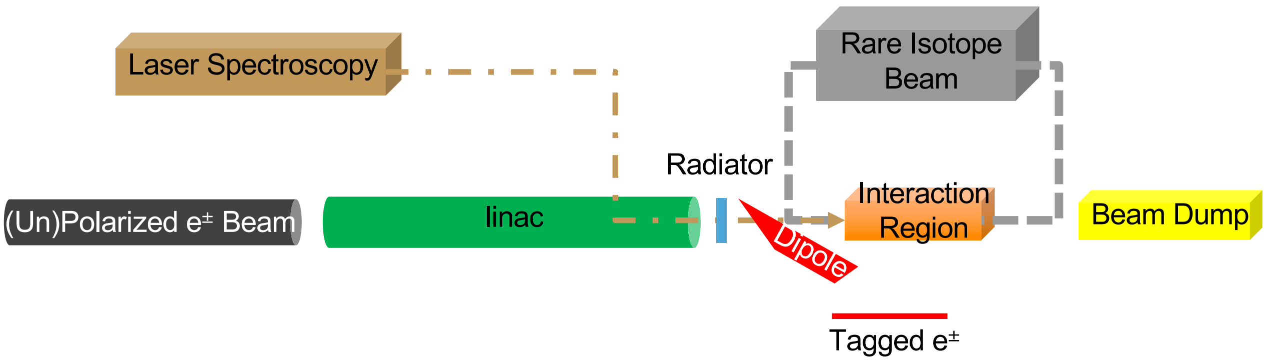


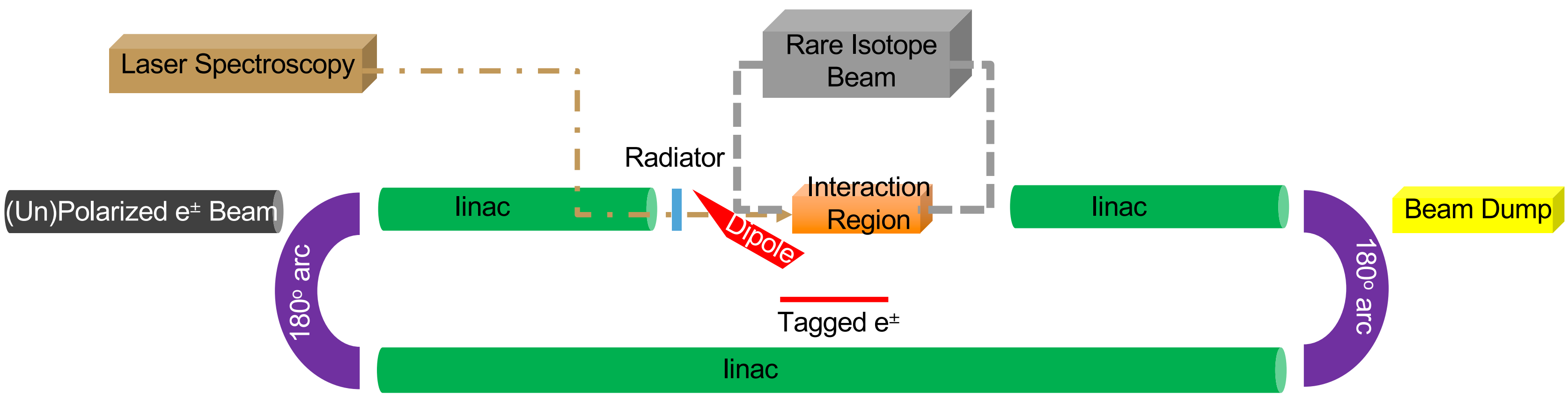
Trap RIB Concept





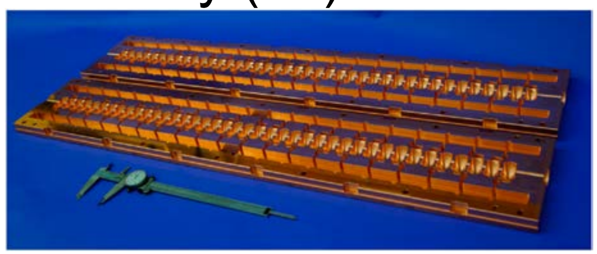
Recirculated RIB Concept



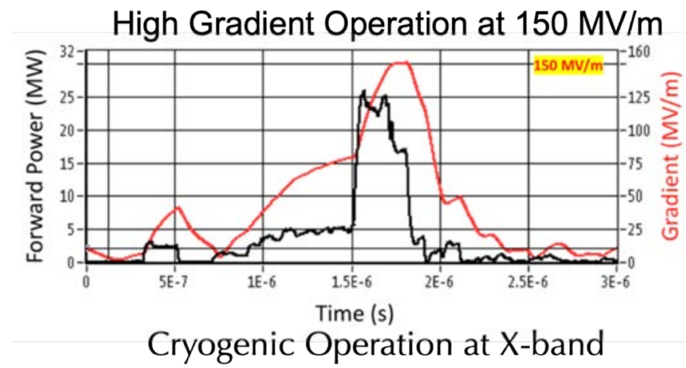


Current Linac Goal

- Build a prototype
  - Photo-gun design: (un)polarized electron beam (A. Rodriguez Alicea)
  - Trap cavity design (A. Lapierre, FRIB)
    - » Dual ports: electron scattering and laser spectroscopy (K. Minamisono)
  - Acceleration: cool copper cavity (C^3) with Cornell
    - » Operation: LN2
    - » Gradient: 150 MeV/m
    - » Length: 1 m
    - » f = 4.712 GHz



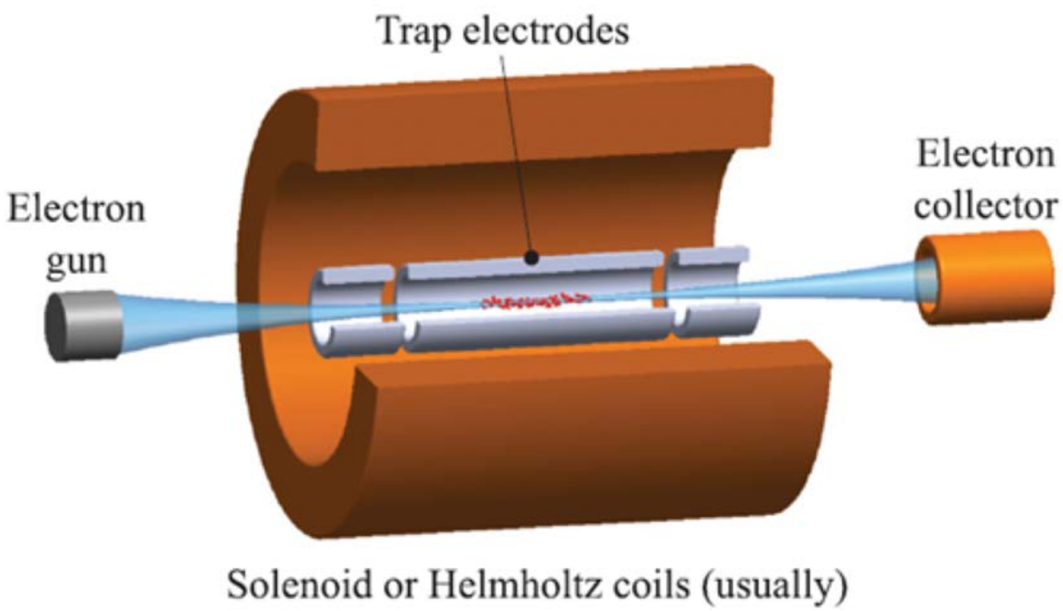
S. Gourlay, T. Raubenheimer and V. Shiltsev, Frontiers in Physics (June 2022)



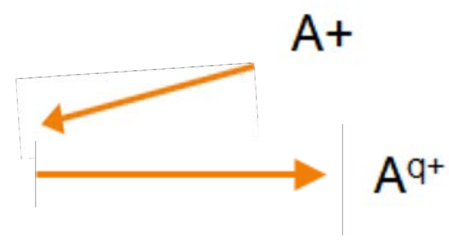
E. Nanni, HEP2022

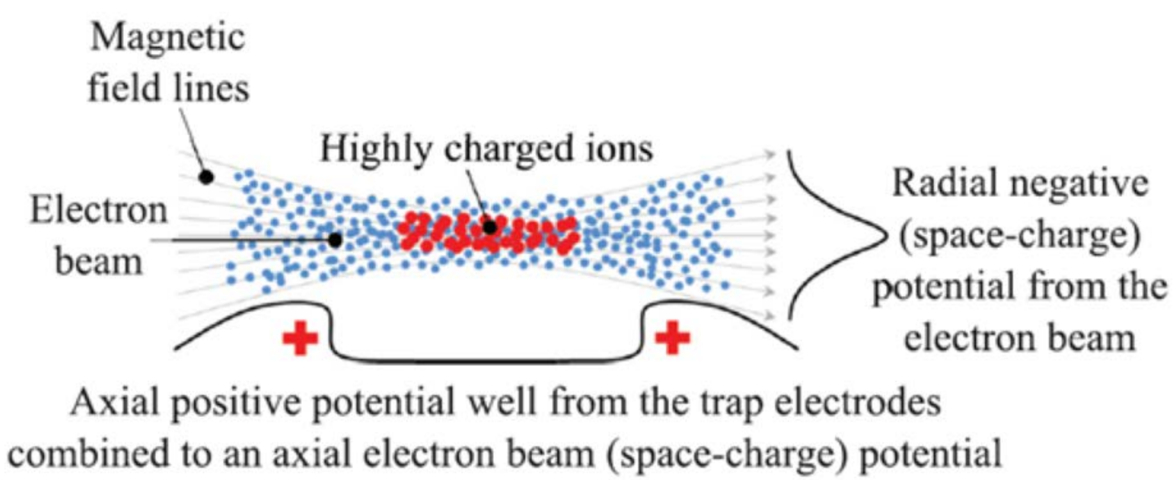
- Ion gun
  - Commercial or ReA3/6/D-line @ FRIB

Working Principle of an EBIS/T



Just a few words...



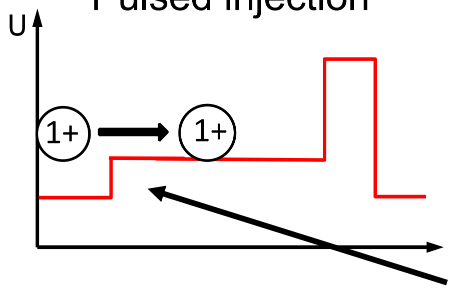


- Produce & trap highly charged ions with a high-current density electron beam
- Magnetic field: Electron-beam compression & Ionization by electron impact
- Trap electrodes: Axial confinement
- Electron beam: Radial confinement

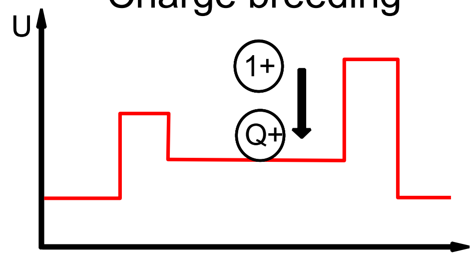
How do we inject & extract ions?
Two ion injection schemes

- Pulsed (dynamic ion capture)

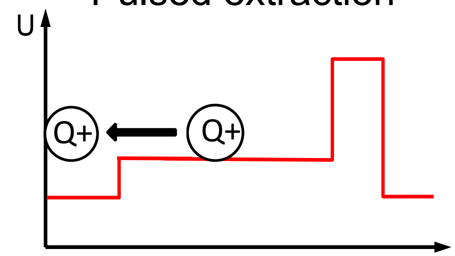
Pulsed injection



Charge breeding



Pulsed extraction

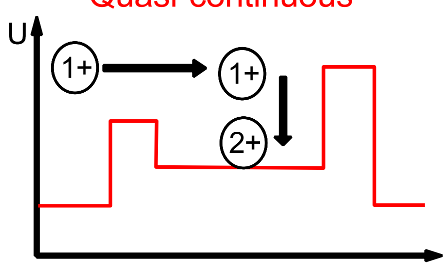


Ions axially trapped with potential well created by 2 barriers

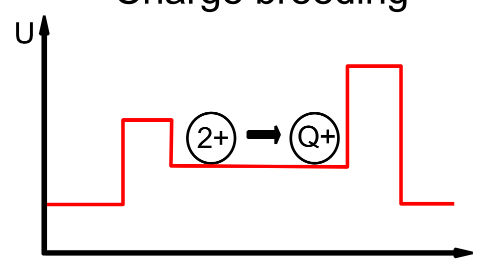
Lower barrier potential

- Quasi-continuous

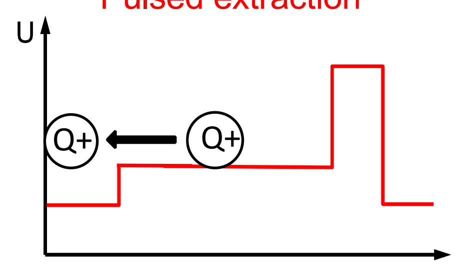
Over-the-potential barrier injection
"Quasi-continuous"



Charge breeding

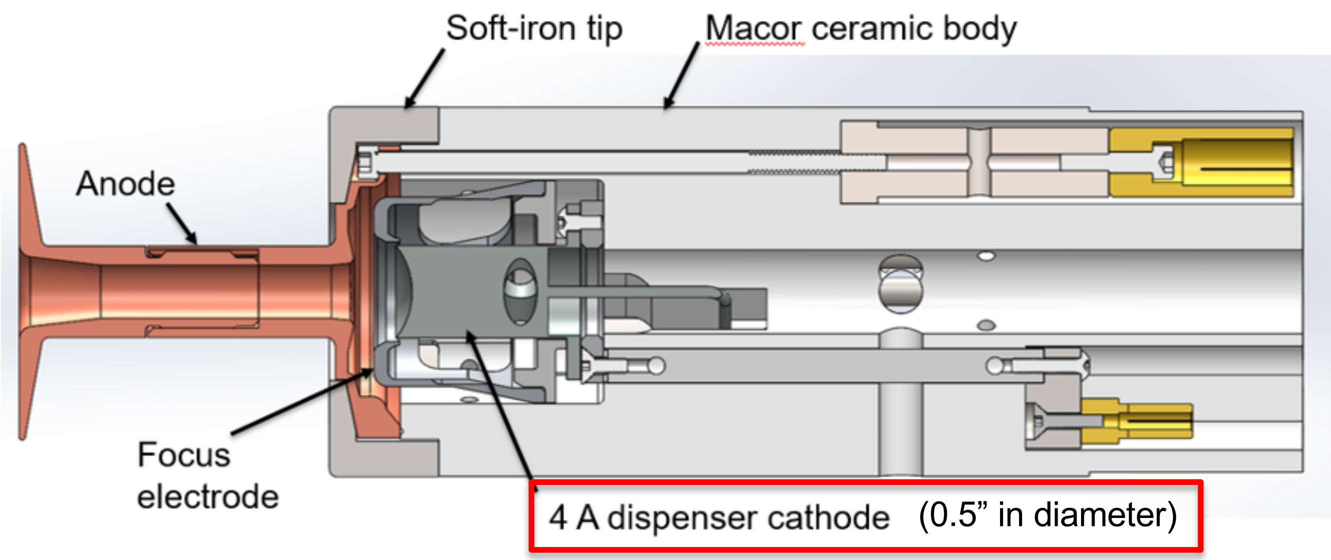


Lower-the-barrier extraction
"Pulsed extraction"

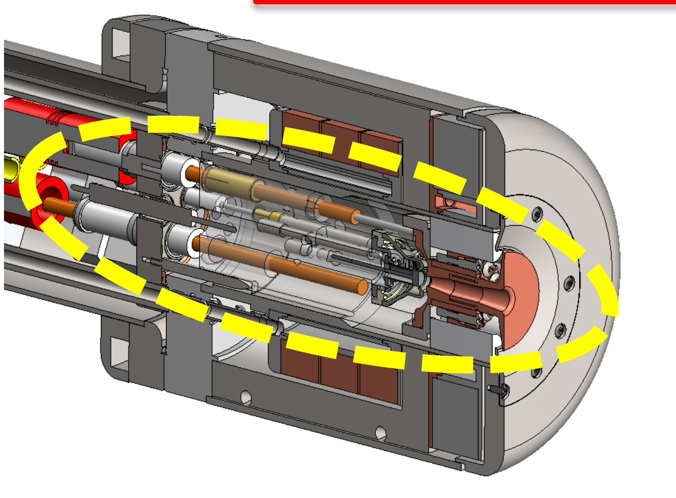


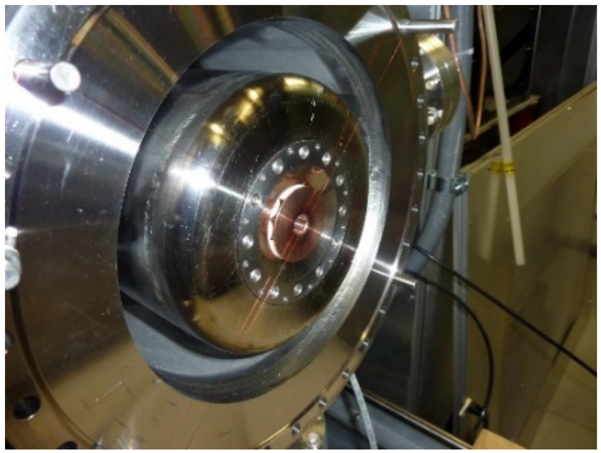
Future Electron-Gun Upgrade for Higher Electron Current

New dispenser cathode modular insert to be placed in the existing EBIT electron gun



- Status
  - Construction completed
  - Installation being scheduled



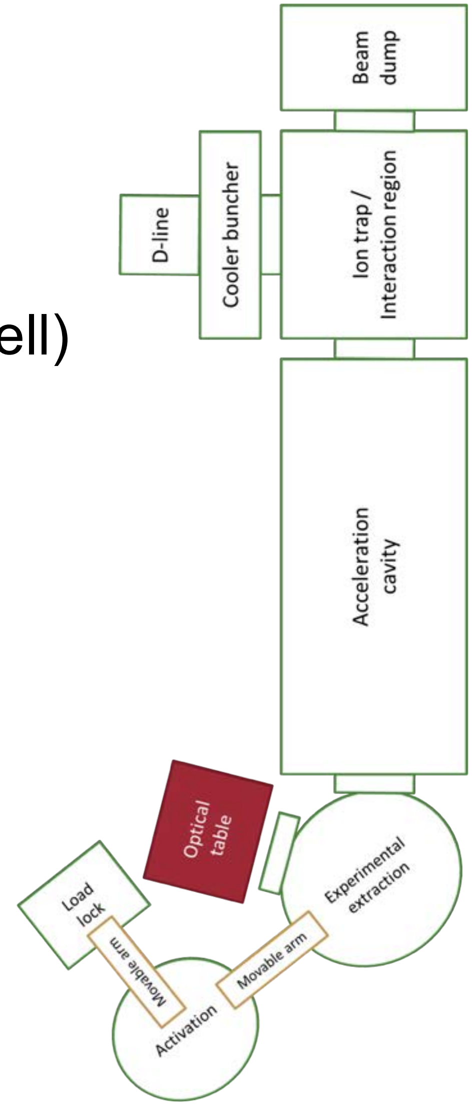


Expected Intensities from the EBIT Upgrade

Parameters/Properties	Present e-gun	Upgrade, Phase 1	Upgrade, Phase 2
Cathode diameter (type)	6.35 mm (Ba/W)	12.7 mm (Ba/W)	12.7 mm (Ba/W)
E-beam current	300 – 600 mA	2 A	4 A
E-beam radius	~200 μm	~400 μm	~400 μm
Current density	170 - 340 A/cm^2	432 A/cm^2	864 A/cm^2
Acceptance	12 mm mrad	40 mm mrad	50 mm mrad
Acceptance pulse width	~40 μs	~40 μs	~40 μs
Charge capacity	2E10 e	1E11 e	2E11 e
Max pulsed Ne^{8+} rate	6E9 pps	6E9 pps	6E9 pps
Max pulsed Ar^{16+} rate	1E9 pps	2E9 pps	4E9 pps
Max DC Ne^{8+} rate	2E10 pps	1.5E11 pps	3E11 pps
Max DC Ar^{16+} rate	8E8 pps	7E9 pps	3E10 pps

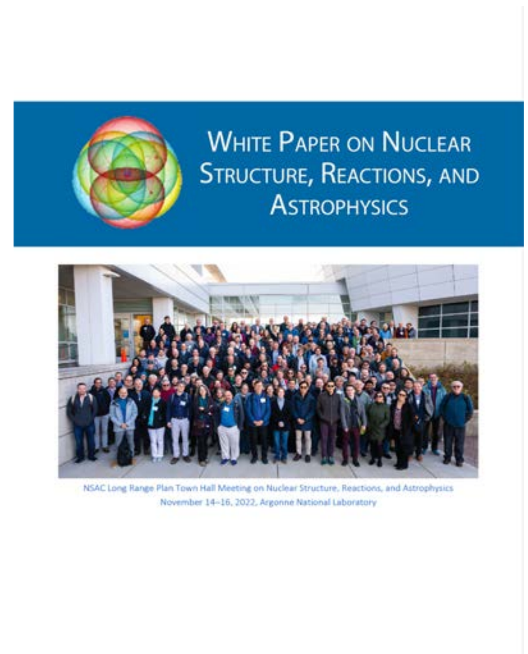
Photogun And Injection System

- Spin polarized electron beam
  - Energy: 100-500 MeV
  - Current: 50 mA – 1 A average
  - Luminosity: ~10^{28} cm^{-2}
  - Electron gun will follow same technology as CEBAF gun
  - Cold copper accelerating cavity (collaboration with Cornell)
- Ion beam
  - From D-line that delivers 10^3 ions with 60 keV
  - Buncher and ion trap to achieve at least 10^8 ions
- Ion trap
  - Use SCRIT technology as foundation/model
  - Detectors: standard nuclear physics systems
    - » Beam: Mott polarimeter
    - » Scattered particles:
      - magnetic spectrometer, drift chambers, timing scintillators



Next Steps

- Science case
  - Rare isotope rings: nuclear/nuclear astrophysics community
  - $e^{\pm}$ scattering: electron scattering community
  - Goals
    - » Series of (hybrid) workshops: fall 2023, spring 2024
    - » Science report: summer/fall 2024
- Accelerator systems
  - RI ring systems: White Paper NSAC LRP
    - » Nuc. Astro. team is working on it
  - $e^{\pm}$ system
    - » Interest: Cornell, BNL … JLab



Thank You!

Paul Guèye

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