JLab Positrons & 22 GeV

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PAC51

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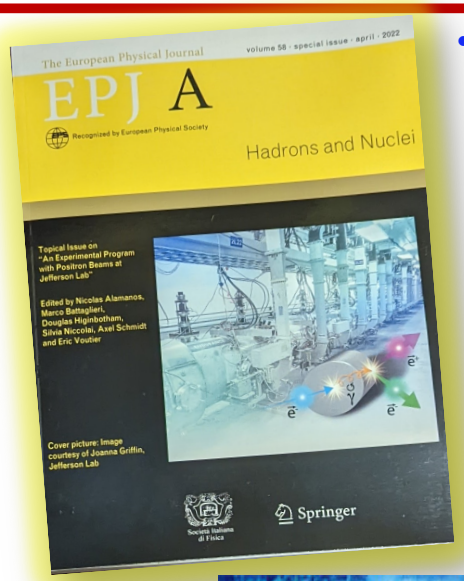
Jefferson Lab
Thomas Jefferson National Accelerator Facility

Science at the Luminosity Frontier: JLab Upgrade Development



- **Topical issue on An Experimental Program with Positron Beams at Jefferson Lab**

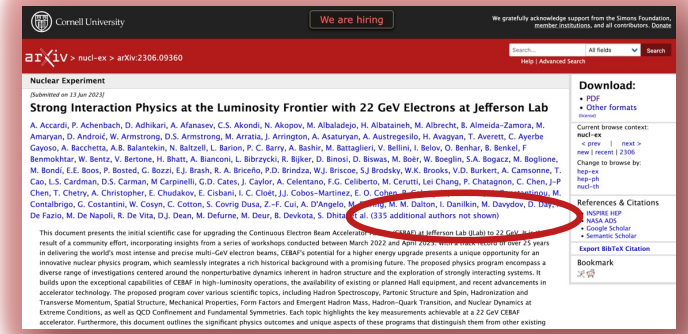
  Eur. Phys. J. A 58 (2022) 3, 45

  JLab PWG = ***~250 Physicists***

- J-Future - Messina (Italy) 28–30 Mar 2022

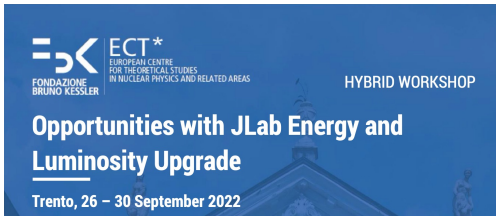
- **Strong Interaction Physics at the Luminosity Frontier with 22 GeV Electrons**

  2306.09360 [nucl-ex] ***435+ authors***



- International Workshop on Physics with Positrons at Jefferson Lab, JPos09, March 2009
- International Workshop on Physics with Positrons at Jefferson Lab, JPos17, September 2017
- XVIIIth International Conference on Positron Annihilation, Orlando (USA), August 2018
- Positron Working Group Workshop –UVA (USA), Mar 2023

- High Energy workshop series 2022 - Jefferson Lab, June - August 2022
- Hadron Physics Opportunities with JLab Energy Upgrade – Pohang (S. Korea), July 2022
- Opportunity with JLab Energy and Luminosity Upgrade- ECT* Trento (Italy), September 2022
- Science at the Luminosity Frontier: JLab at 22 GeV – Jefferson Lab, January 2023

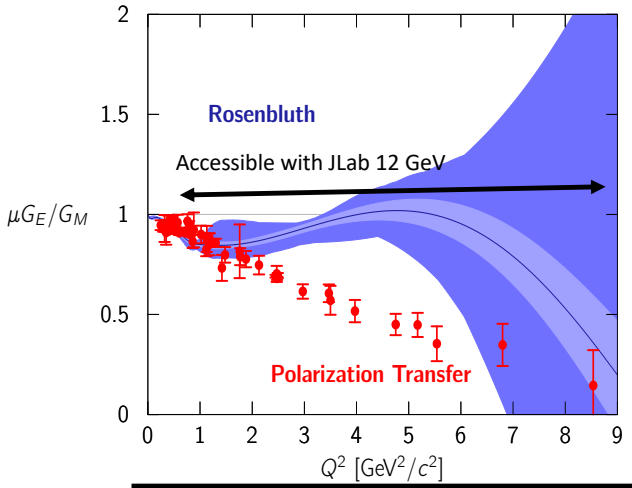


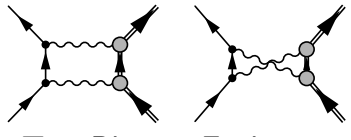
Broad community interest in this science

What a Positron Beam will bring?

- **Positron beams, both polarized and unpolarized, open the door to understanding a range of physics that can't be accessed with electrons alone**
  - **E.M. processes (BCA)**
    - Two-photon exchange
    - DVCS
  - **Annihilation processes**
    - Light dark matter searches
  - **Charged-current processes**
    - Inverse beta-decay
    - Strangeness with charm-tagging
    - Charged lepton flavor violation
    - Axial Form Factor

6 Proposals and **5 LOI** submitted to this PAC





Two-photon exchange

- A challenge to calculate
- Leading contribution has opposite effect for e^+
- Measurements of $\sigma_{e^+}/\sigma_{e^-}$ isolate TPE

$$R_{2\gamma} \equiv \frac{\sigma_{e^+p}}{\sigma_{e^-p}} = 1 + 4\frac{\mathrm{Re}\left[\mathcal{M}_{1\gamma}\mathcal{M}_{2\gamma}\right]}{|\mathcal{M}_{1\gamma}|^2} + \ldots$$

Short Name	Experiment Label	Contact	Measurement Configuration Hall	Detector	Target	Polarity	Beam Parameters p (GeV/c)	P (%)	I (μA)	Time (d)
Two Photon Exchange Physics										
Coulomb Distorsion	PR12+23-003	D. Gaskell	C	HMS	LD_2,Au	+	4.4/11.	0	1.0	10
TPE@CLAS12	PR12+23-008	A. Schmidt	B	CLAS12	LH_2	$+/-_s$	2.2/4.4/6.6	0	0.075/0.075	55
Super-Rosenbuth	PR12+23-012	M. Nycz	C	HMS	LH_2	+/−	0.65−11.	0	1.0/20.	56
Polarization Transfert	LOI12+23-008	A. Puckett	A	SBS+BigCal	LH_2	+	2.2/4.4	60	0.200	120
Dispersive Effects	LOI12+23-015	P. Gueye	A,C	HRS or HMS	C,Al,Cu,Ca,Fe,Pb	+	0.6-4.4	0		
Nuclear Structure Physics										
DVCS BCAs	PR12+23-002	E. Voutier	B	CLAS12	LH_2	$+/-_s$	2.2/11.	60/60	0.050/0.050	100
DVCS XSection	PR12+23-006	C. Muñoz Camacho	C	SHMS+NPS	LH_2	+	6.6/8.8/11.	0	1.0	135
Polarizabilities	LOI12+23-001	N. Sparveris	C	SHMS+HMS	LH_2	+/−	2.2	0	5.0/50.	77
Axial Form Factor	LOI12+23-002	D. Dutta	A,C	mTPC+SBS	^2H	+	2.0-6.0	60	0.200	60
Beyond the Standard Model Physics										
Dark Photon Search	PR12+23-005	B. Wojtsekhowski	B	PRad	LH_2	+	2.2/4.4/11.	0	0.050	60
Dark Bhabha	LOI12+23-005	D. Mack	C	Pair Spec.	e^-	+	0.50-11.			

What a 22 GeV Upgrade will bring?

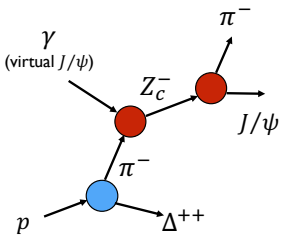
- **A NEW territory to explore → cross the critical threshold into the region where $c\bar{c}$ states can be produced in large quantities, and with additional light quark degrees of freedom.**
- **A BETTER (and needed) insight into our current program → enhancement of the phase space**
- **A BRIDGE between JLab @ 12 GeV and EIC → test and validation of our theory from lower to higher energy and with high precision**

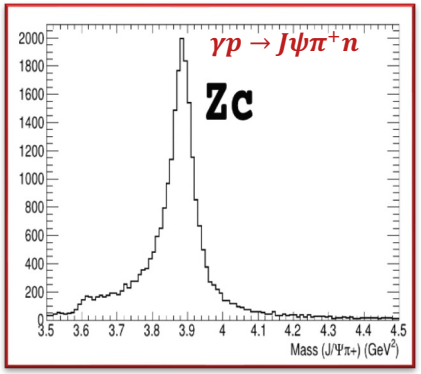
The physics program will:

- **Leverage on the uniqueness of CEBAF HIGH LUMINOSITY**
- **Utilize largely existing or already-planned Hall equipment**
- **Take advantage of recent novel advances in accelerator technology**

Photoproduction of Hadrons with Charm Quarks

- **Potentially decisive information about the nature of some 5-quark and XYZ candidates**
  - Many "XYZ" states observed in B decays, e⁺e- but scarce consistency between various production mech.→ internal structure not understood yet
  - Never directly produced using γ/lepton beam → possibility to study the reaction mechanism without re-scattering effects

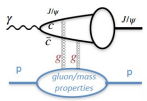


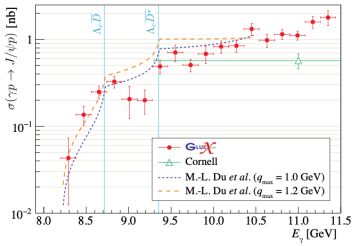


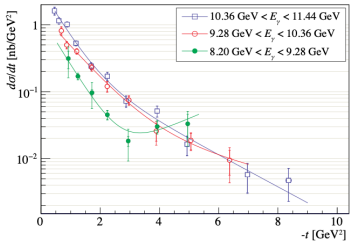
Full CLAS12 signal MC simulation with EXISTING detector → capabilities of the existing detectors to measure these reactions

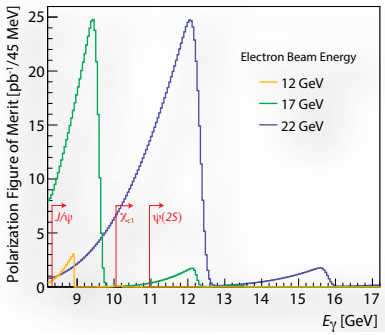
- **Near-threshold J/ ψ photoproduction: a unique method to probe the proton's gluonic structure**
  - gluon GPD
  - mass radius of the proton
  - anomalous contr. to p mass

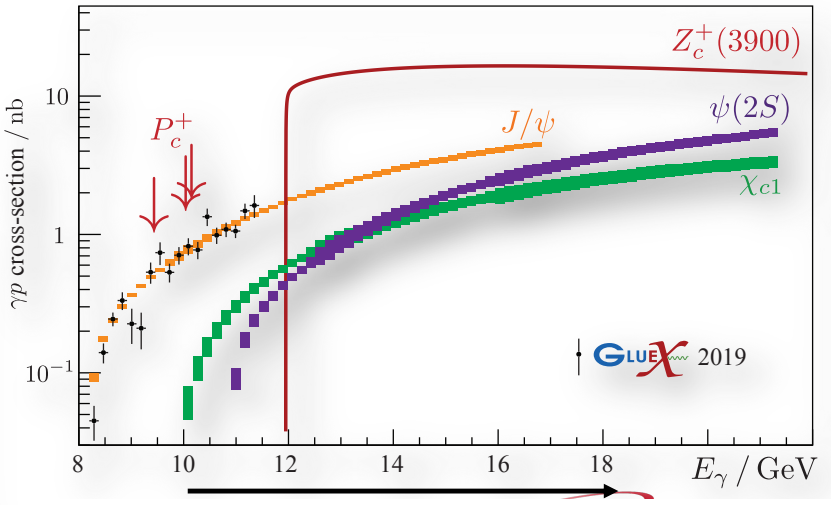
IF









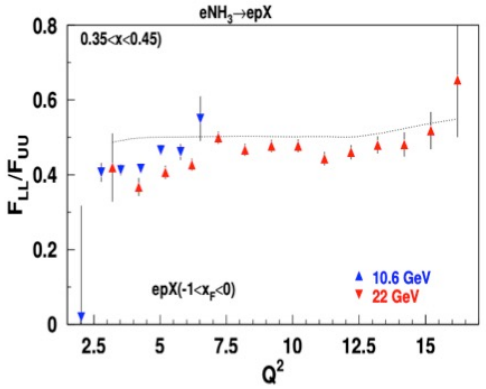


Thresholds crossed and t range opens up at higher energy

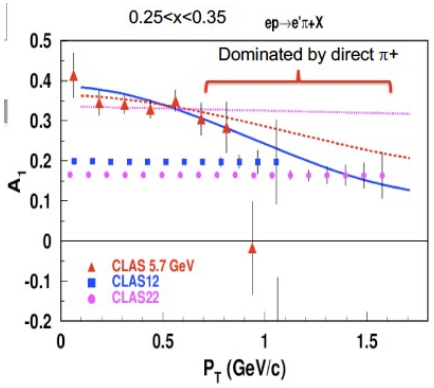
Nucleon 3D Structure

SIDIS - TMD

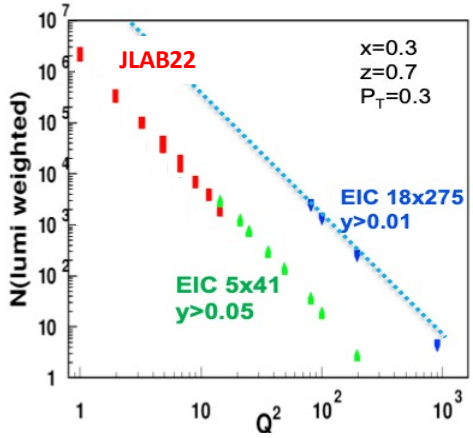
- Q^2 evolution studies possible



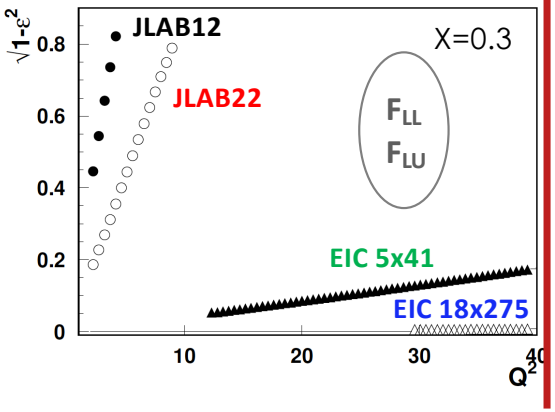
- Enanchement of P_T range



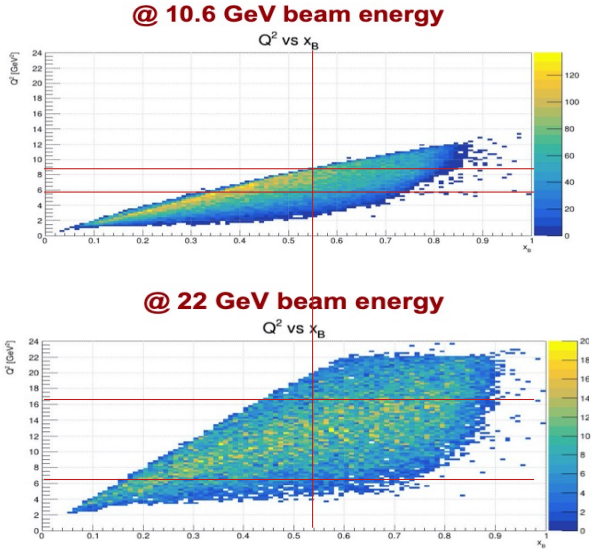
- Complementarity with EIC



- ALL SF measurement possible



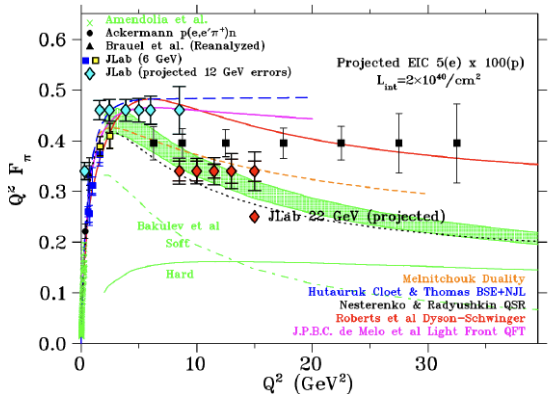
Exclusive Process



GPDs

One of the most stringent tests of factorization : x-section Q^2 dependence

- σ_L scales to LO as Q^{-6}
- σ_T expectation as Q^{-8}
- As Q^2 becomes large: $\sigma_L >> \sigma_T$



Pion FF

$\sigma L/\sigma_T$ separation **only** possible at Jlab

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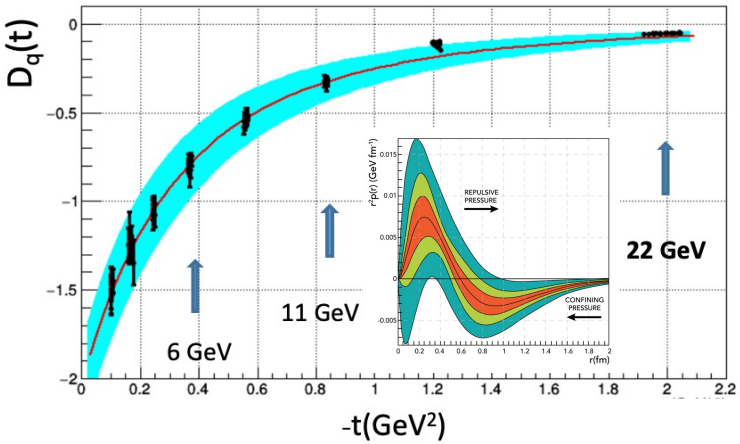
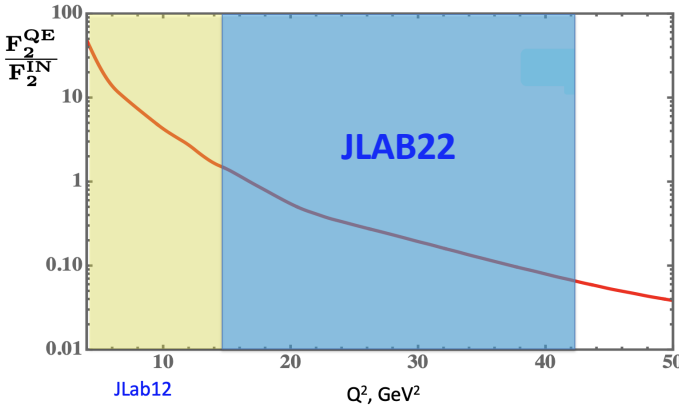
…and More

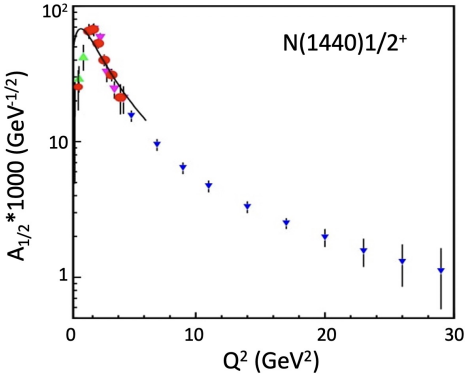
- D(t) term and the determination of the pressure distribution inside the proton

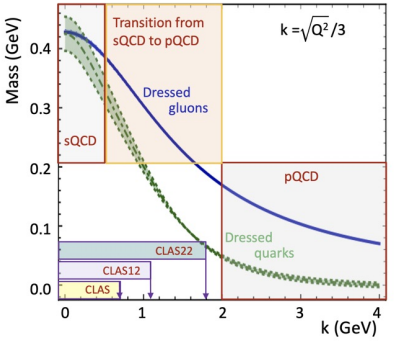


- Reach to the nuclear forces dominated by nuclear repulsion

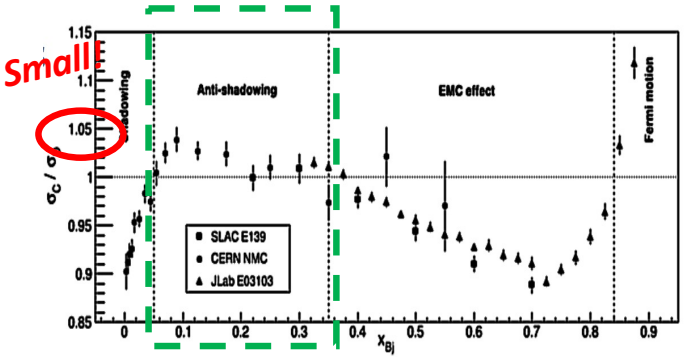


- insight into hadron mass generation & the emergence of the N* structure through the Q^2 evolution of the $\gamma_v pN^*$ electrocouplings (CSM approach)

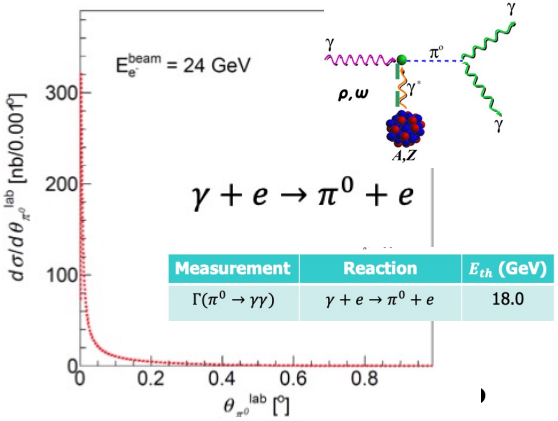




- Access the anti-shadowing region (small effect!) (x~0.1-0.3) at moderate Q^2 using multiples exp. techniques



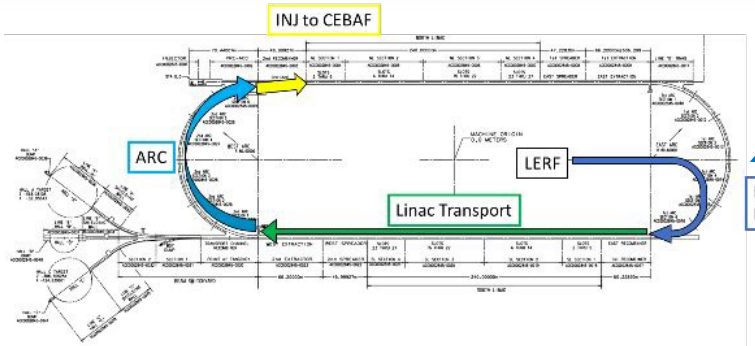
- π^0 Primakoff production off an electron target



Measurement	Reaction	E_{th} (GeV)
$\Gamma(\pi^0 \rightarrow \gamma\gamma)$	$\gamma + e \rightarrow \pi^0 + e$	18.0

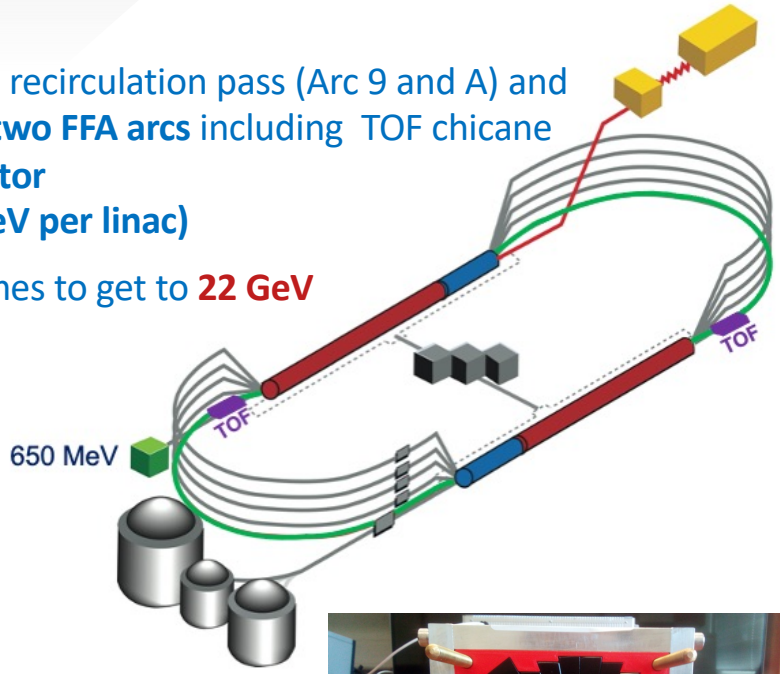
Feasible, Cost effective, Innovative Path from e^+ to 22 GeV

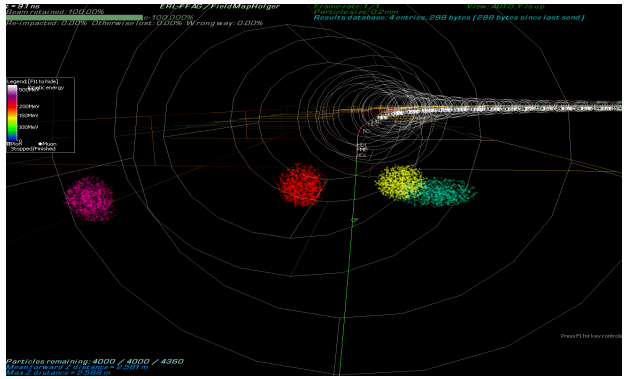
Capitalize on recent science insights and US-led accelerator science and technology innovations to develop a **staged program at the luminosity frontier**



- **Positrons (e+) in the LERF with transport to CEBAF**

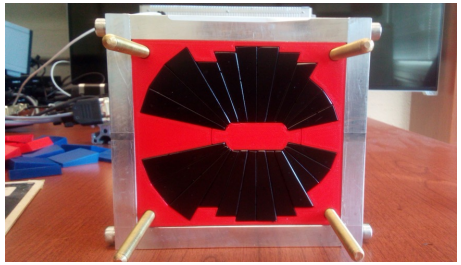
- Remove the highest recirculation pass (Arc 9 and A) and **replace them with two FFA arcs** including TOF chicane
- **New 650 MeV injector**
- **NO new SRF (1.1 GeV per linac)**
- Recirculate 4.5+6times to get to **22 GeV**





- R&D developments on-going supported by Laboratory Directed (LDRD)funds

- **A prototype magnet built and evaluated for mechanical integrity**



Summary

- Understanding the different facets of the dynamics of non-pQCD that manifest in hadron/nuclei structures is a complex problem which requires multiple observables using different approaches and measurements

  - Positron beams, both polarized and unpolarized, are essential tools for a precise understanding of the electromagnetic structure of the nucleon and nuclei, in both the elastic and the deep-inelastic regimes (form factors, PDFs, GPDs,…), but also for search for physics beyond the standard model.

  - With CEBAF at higher energy: a) some important thresholds will be crossed providing new territories to explore, b) a better insight into our current program will be possible, and c) a bridge between JLab @ 12 GeV and EIC will be established. This will be critical to elucidate the properties of QCD in the valence regime.

- **A rich scientific program to leverage existing infrastructure and the uniqueness of CEBAF HIGH LUMINOSITY is being developed and it has been presented at the Long Range Plan of NP**