Overview of CLAS12

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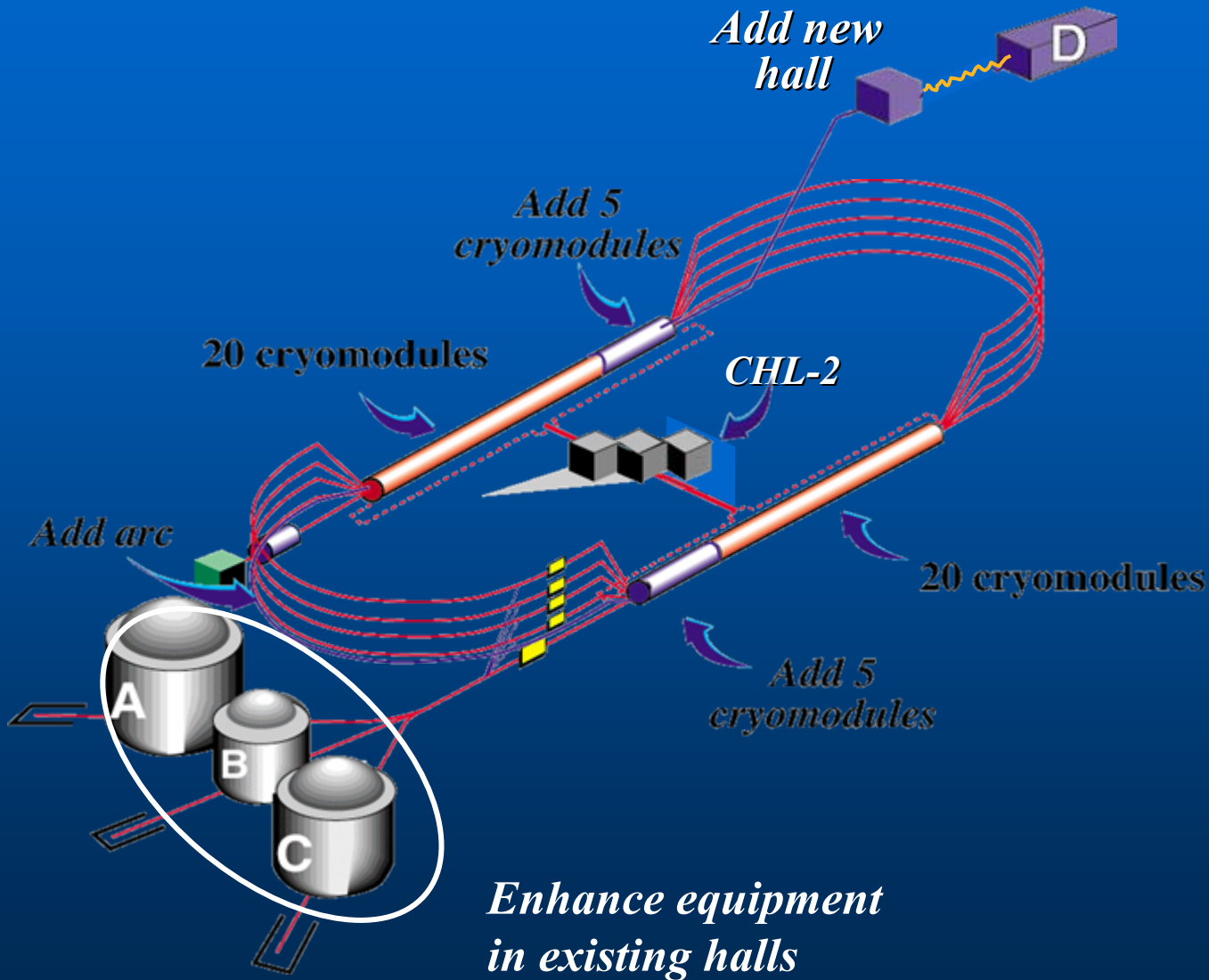
JLab Upgrade to 12 GeV
Overview of CLAS12
The Science Program with CLAS12
Schedule
Conclusions

Workshop on RICH Detector for CLAS12

Jefferson Lab
United States Department of Energy
Office of Science U.S. Department of Energy
JSA Jefferson Science Associates, LLC

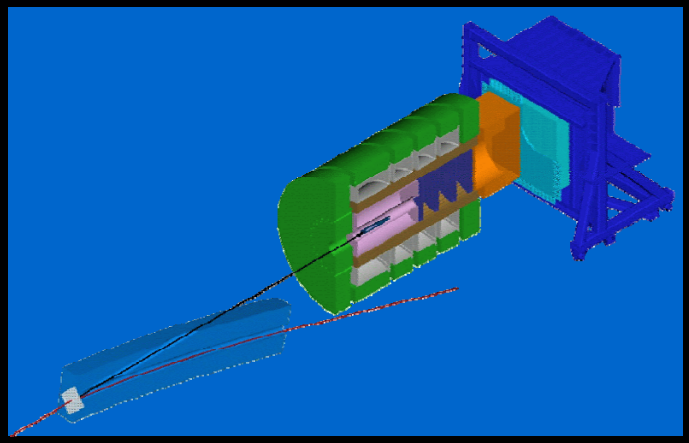
JLab Upgrade to 12 GeV



Enhance equipment in existing halls

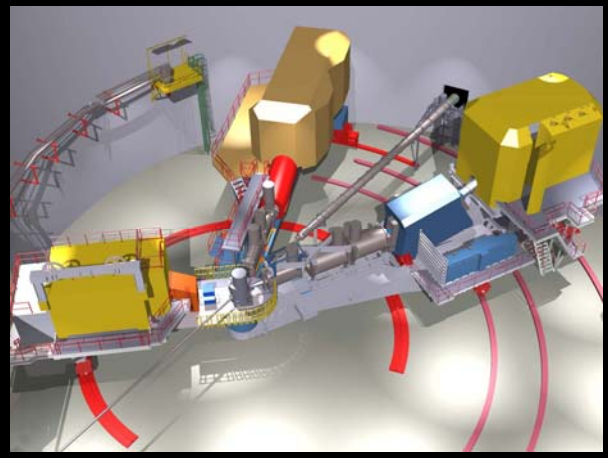
New Capabilities in Halls A, B, & C, and a New Hall D

D



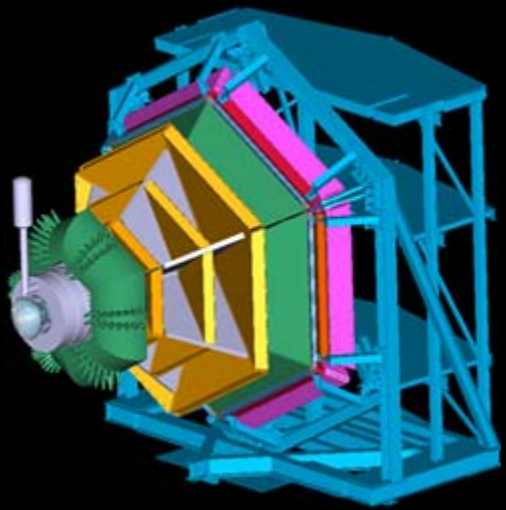
9 GeV tagged polarized photons and a 4π hermetic detector

C



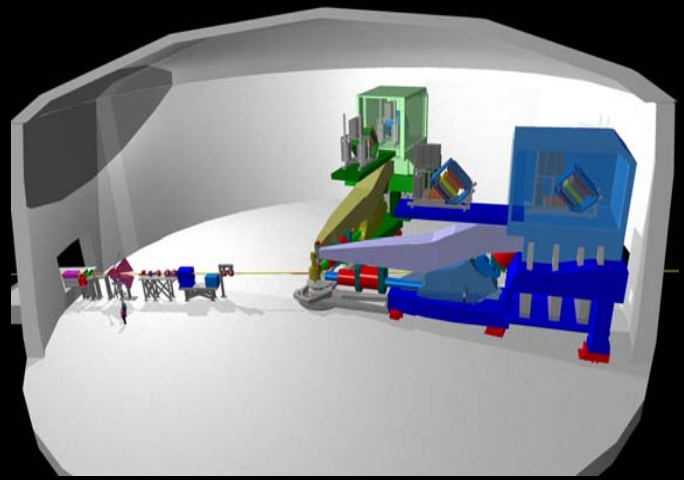
Super High Momentum Spectrometer (SHMS) at high luminosity and forward angles

B



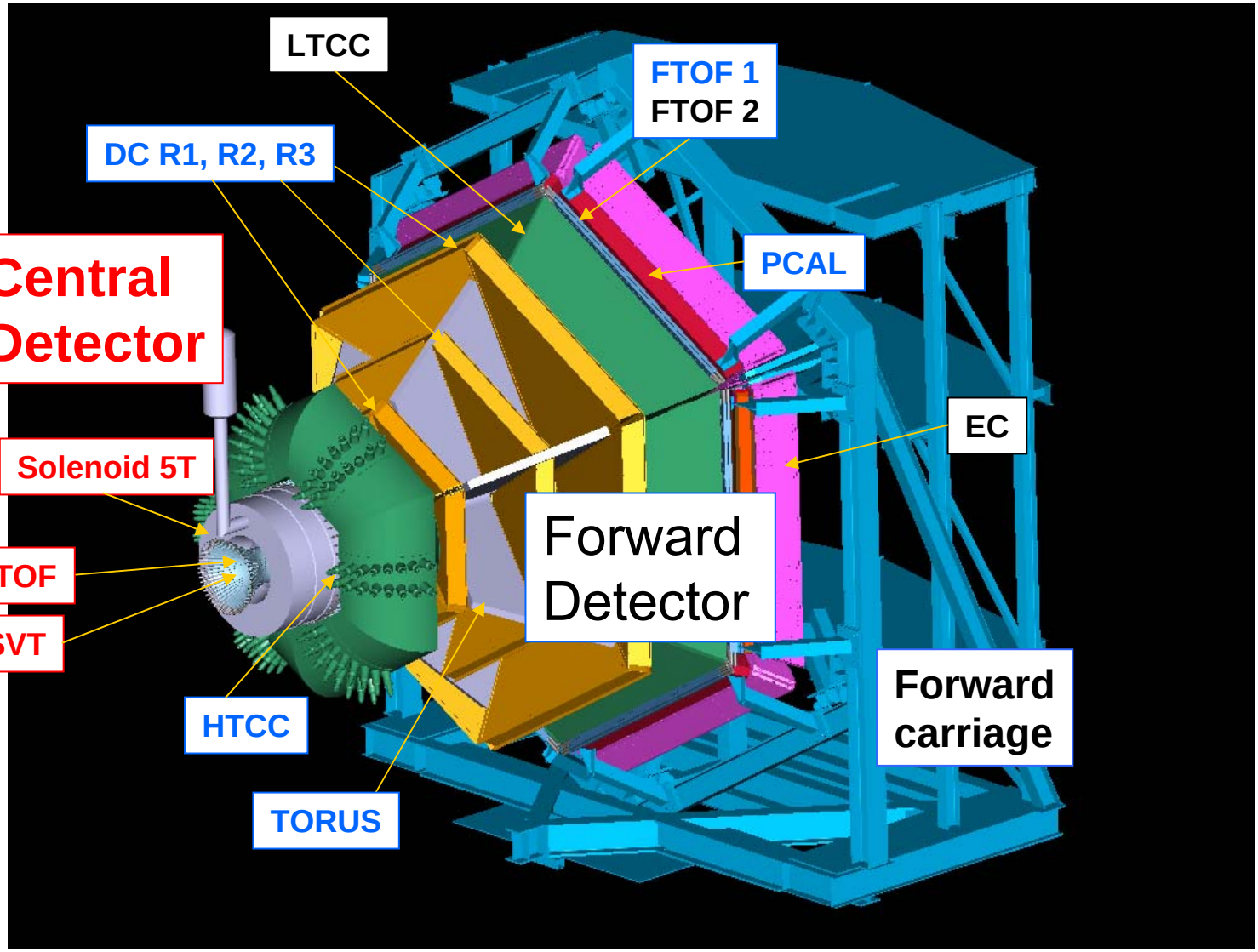
CLAS12 with new detectors and higher luminosity (10^{35} /cm^{2}s)

A



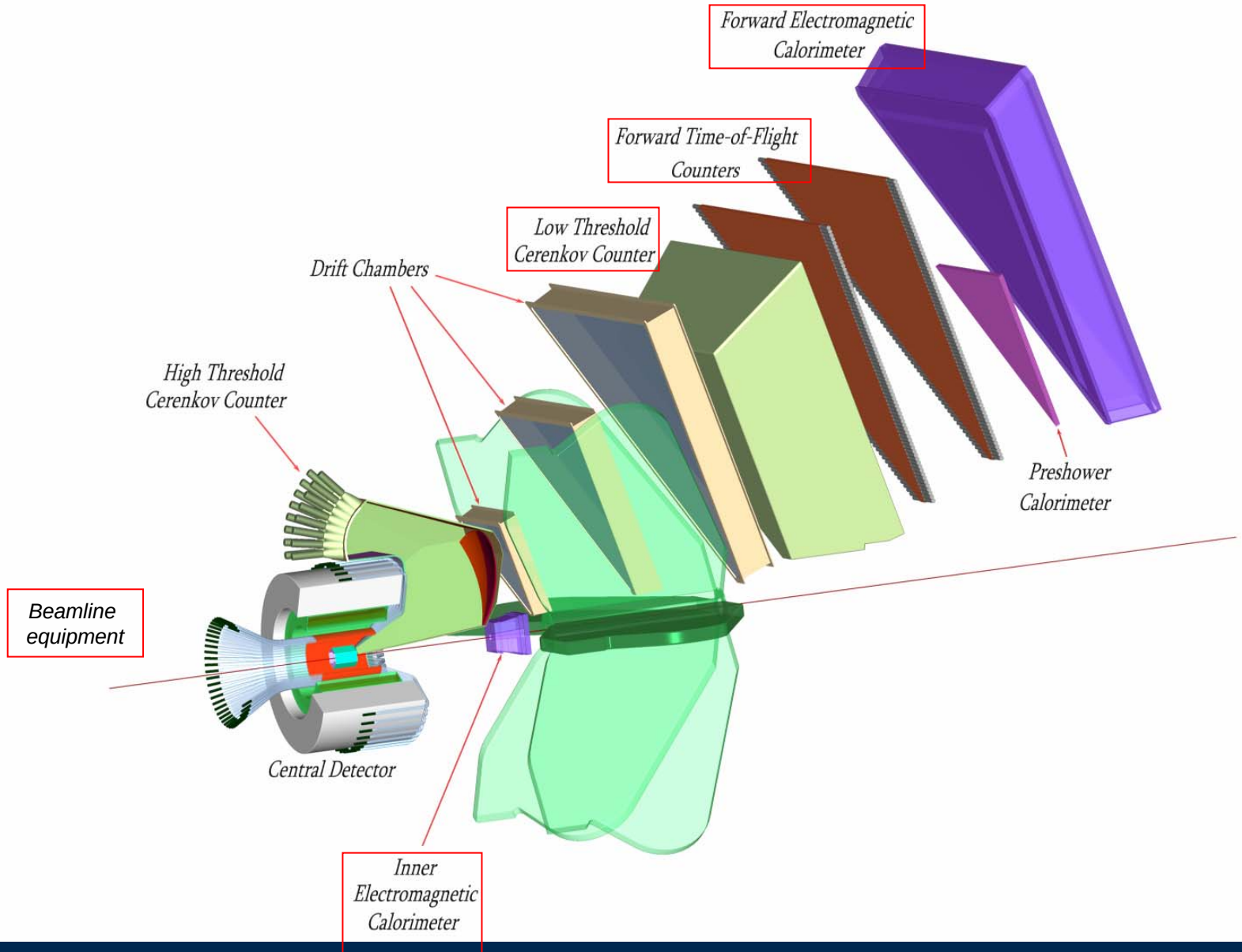
High Resolution Spectrometer (HRS) Pair, and specialized large installation experiments

CLAS12

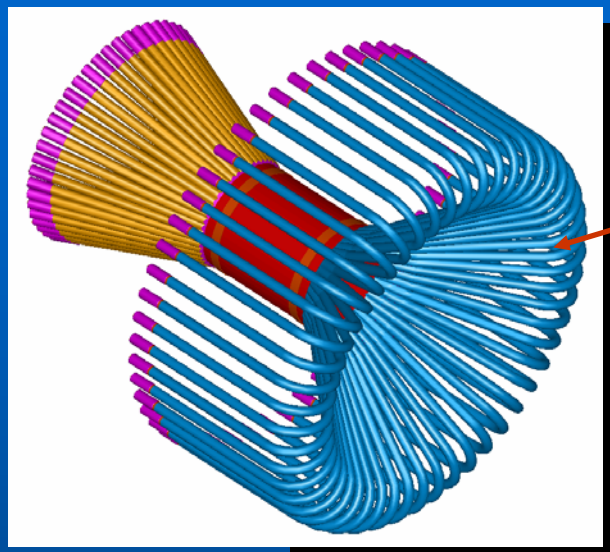

LTCC
FTOF 1
FTOF 2
DC R1, R2, R3
PCAL
Central Detector
EC
Solenoid 5T
Forward Detector
CTOF
SVT
HTCC
Forward carriage
TORUS

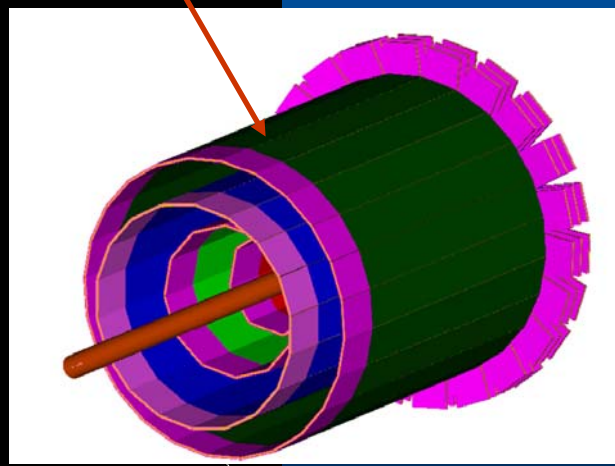
CLAS12

Single sector (exploded view)



CLAS12 – Central Detector

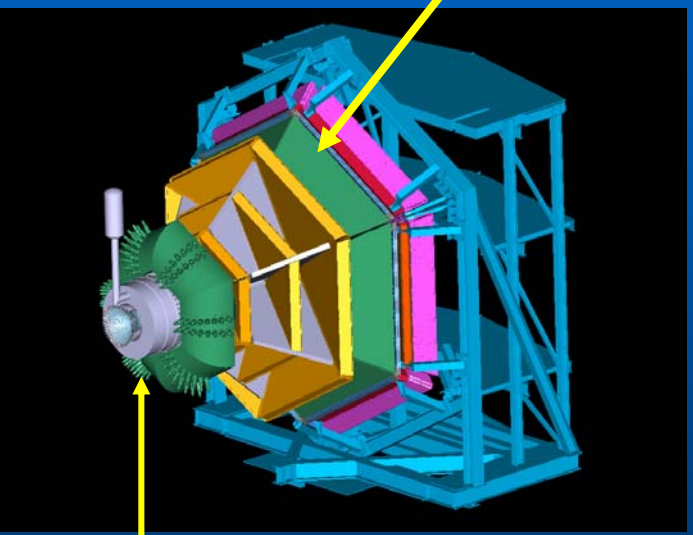




CLAS12

Design Parameters (Base equipment)

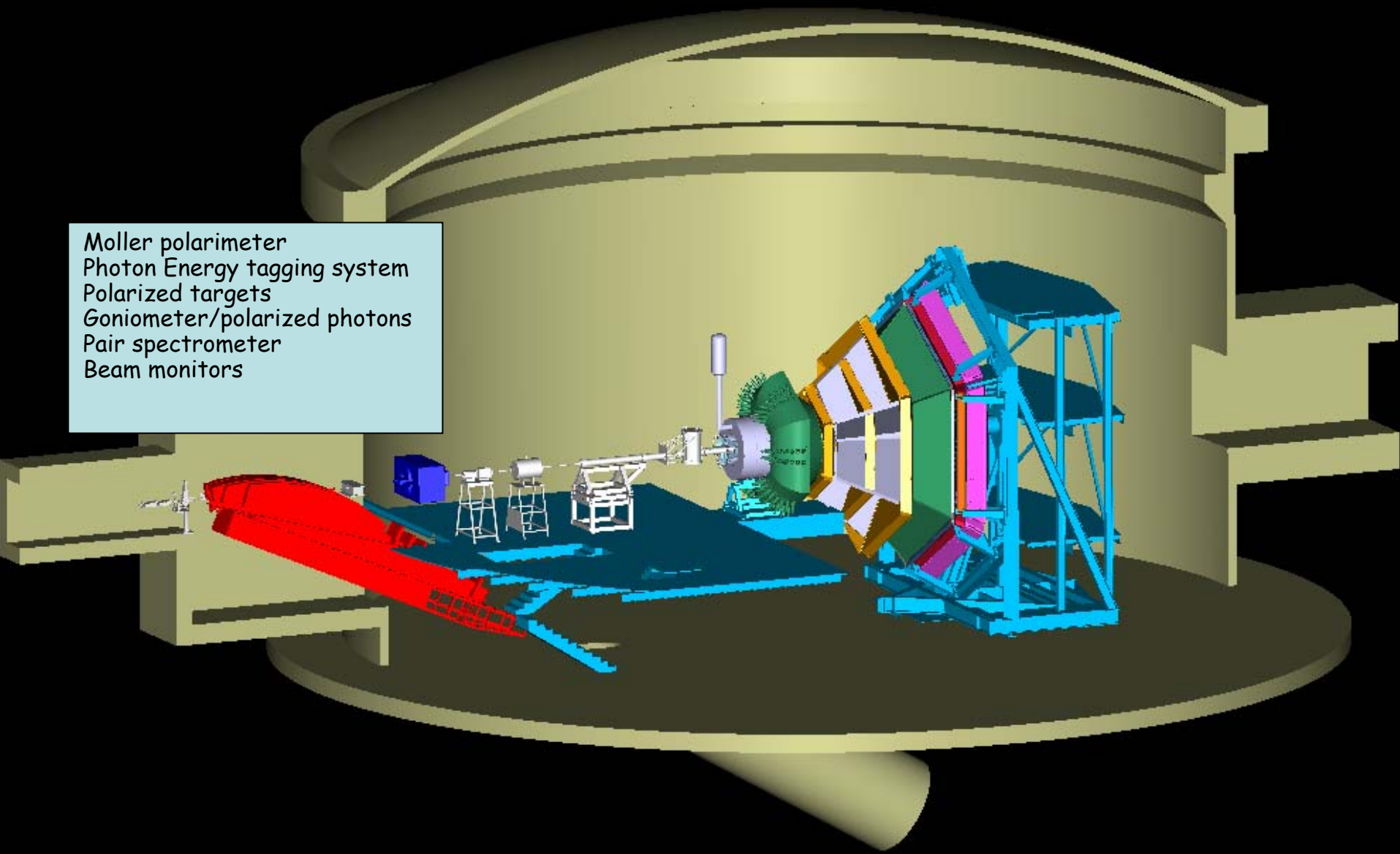
Forward Detector



Central Detector

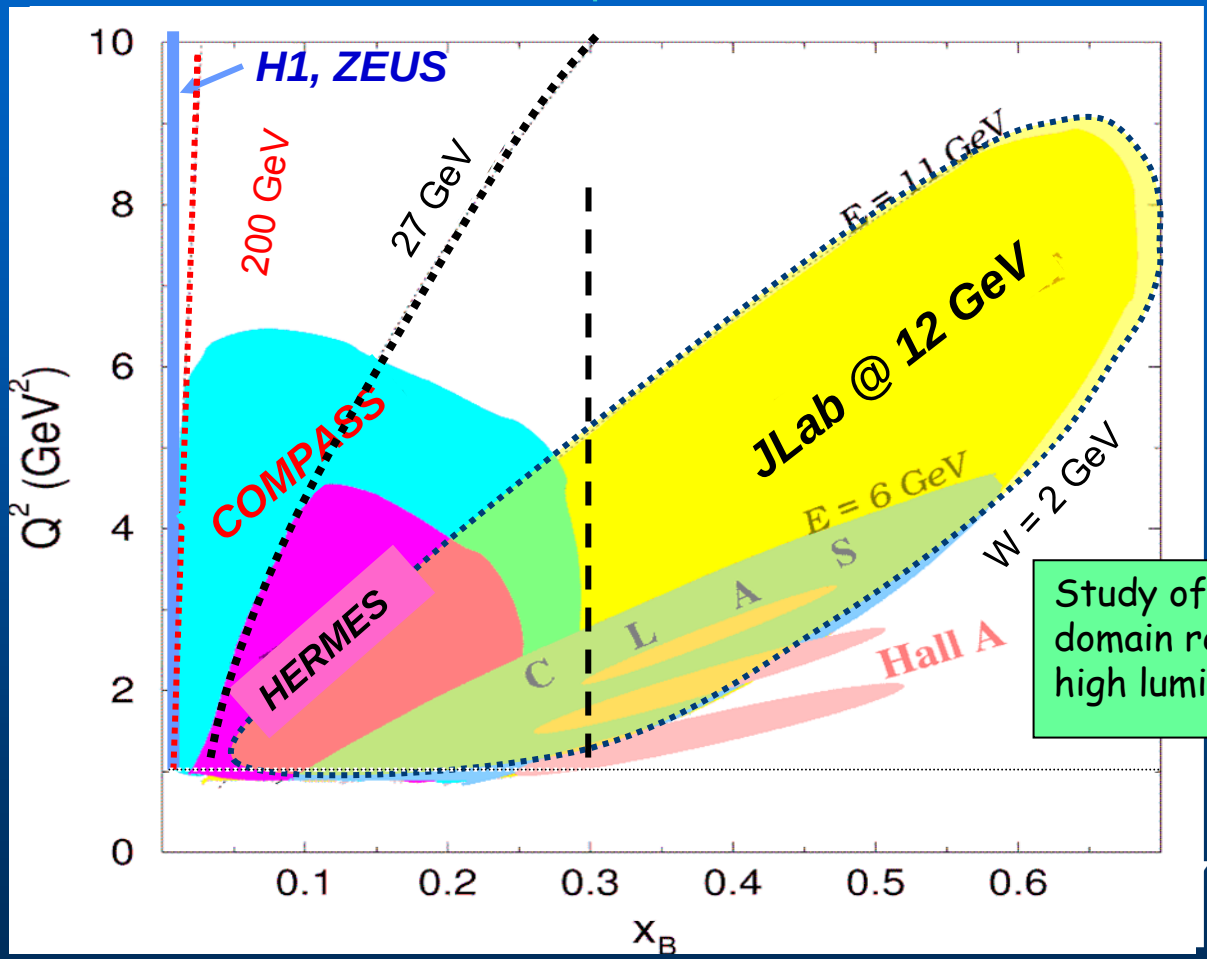
	Forward Detector	Central Detector
Angular range		
Charged Particles	$5^0 - 40^0$	$40^0 - 135^0$
Photons	$2^0 - 40^0$	N/A
Resolution		
$\delta p/p$ (%)	< 1 @ 5 GeV/c	< 3 @ 0.5 GeV/c
$\delta\Theta$ (mr)	< 0.5	< 10
$\delta\phi$ (mr)	< 0.5	< 6
Photon detection		
Energy (MeV)	>150	N/A
$\delta\Theta$ (mr)	4 (1GeV)	N/A
Neutron detection		
N_{eff}	0.1 – 0.6	0.05
Particle ID		
e/π	Full range	N/A
π/p	Full range	$\leq$ 1.2 GeV/c
π/K	Full range	$\leq$ 0.65 GeV/c
K/p	< 4 GeV/c	$\leq$ 0.90 GeV/c
$\pi^0 \rightarrow \gamma\gamma$	Full range	N/A
$\eta \rightarrow \gamma\gamma$	Full range	N/A

CLAS12 in Hall B



Moller polarimeter
Photon Energy tagging system
Polarized targets
Goniometer/polarized photons
Pair spectrometer
Beam monitors

Kinematics of deeply virtual exclusive processes



Study of high x_B domain requires high luminosity

Proposed Initial Physics Program in Hall B

- **GPD's** and **3D-Imaging of the Nucleon**
  - Deeply Virtual Compton Scattering - DVCS
  - Deeply Virtual π/η Production at low/high t

- **Valence Quark Distributions**
  - u- and d-Quark Spin Distributions in Proton and Neutron
  - Neutron Structure Function $F_{2n}(x,Q^2)$, d/u
  - TMD Quark Distribution Functions in SIDIS

- **Form Factors and Resonance Excitations**
  - The Magnetic Structure of the Neutron – G_{Mn}
  - N* Transition Form Factors at high Q^2

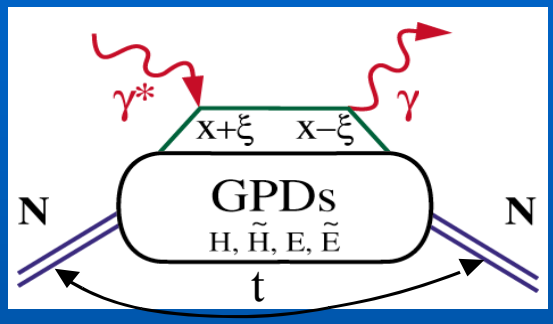
- **Hadrons in the Nuclear Medium**
  - Space-Time Characteristics of Quark Hadronization
  - Color Transparency
  - Short Distance Dynamics of Light Nuclei

CLAS12

PAC30 & PAC32 approved proposals

Proposal	Physics	Energy (GeV)	Requested PAC days
E12-06-119a	DVCS pol. beam	11	80
E12-06-112	$ep \rightarrow e\pi^{+/-/0} X$	11	60
E12-06-108	DVMP in π^0,η prod	11	80
	L/T separation	8.8	20
		6.6	20
E12-06-119b	DVCS pol. target	11	120
E12-06- 109	Long. Spin Str.	11	80
E12-07-107	TMD SSA	11	103
E12-06-106	Color Transparency ρ^0	11	40
E12-06-117	Quark Hadronization	11	60
E12-07-104	Neutron mag. FF	11	56
Total			719

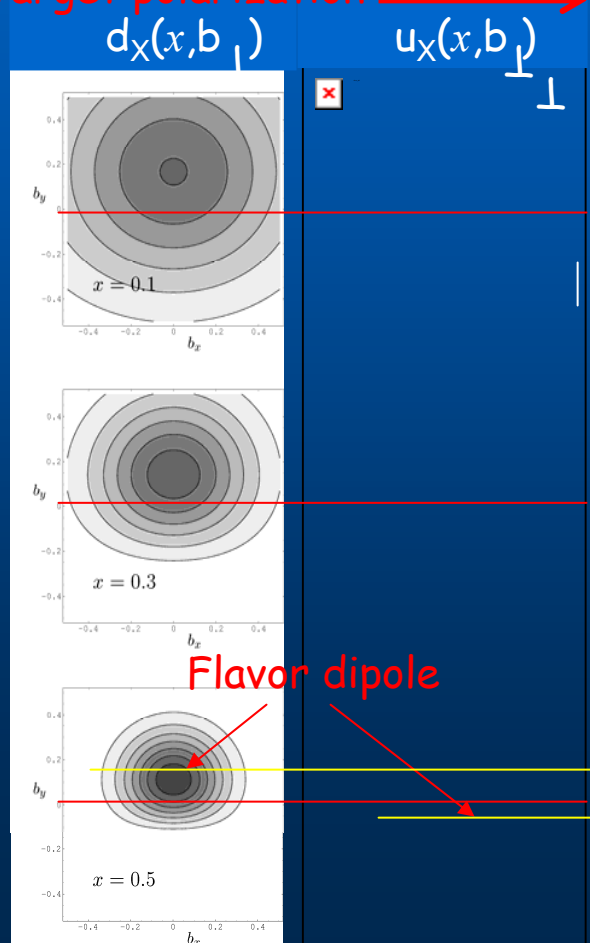
The Promise of GPDs: 2-D & 3-D Images of the Proton



$H(x,\xi,t)$, ...

$$\varepsilon(x,b_\perp) = \int \frac{d^2\Delta_\perp}{(2\pi)^2} e^{i\Delta_\perp b_\perp} E_q(x,\Delta_\perp)$$

Target polarization



M. Burkardt

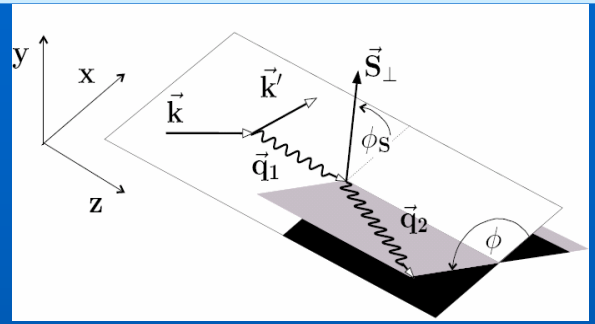
Cat scan of the human brain

Use of polarized DVCS to access GPDs

$$A = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{\Delta\sigma}{2\sigma}$$

$\xi \approx x_B/(2-x_B)$

$k = t/4M^2$



Polarized beam, unpolarized target:

$$\Delta\sigma_{LU} \sim \sin\phi \{F_1 H + \xi(F_1+F_2)\tilde{H} + kF_2 E\} d\phi$$

Kinematically suppressed

$H(x,t)$

Unpolarized beam, longitudinal target:

$$\Delta\sigma_{UL} \sim \sin\phi \{F_1 \tilde{H} + \xi(F_1+F_2)(H + \xi/(1+\xi)E) - ..\} d\phi$$

Kinematically suppressed

$\tilde{H}(\xi,t)$

Unpolarized beam, transverse target:

$$\Delta\sigma_{UT} \sim \cos\phi\sin(\phi_s-\phi)\{k(F_2 H - F_1 E) + ...\} d\phi$$

Kinematically suppressed

$E(\xi,t)$

The path towards the extraction of GPDs

$\vec{e}\,p \longrightarrow epγ$

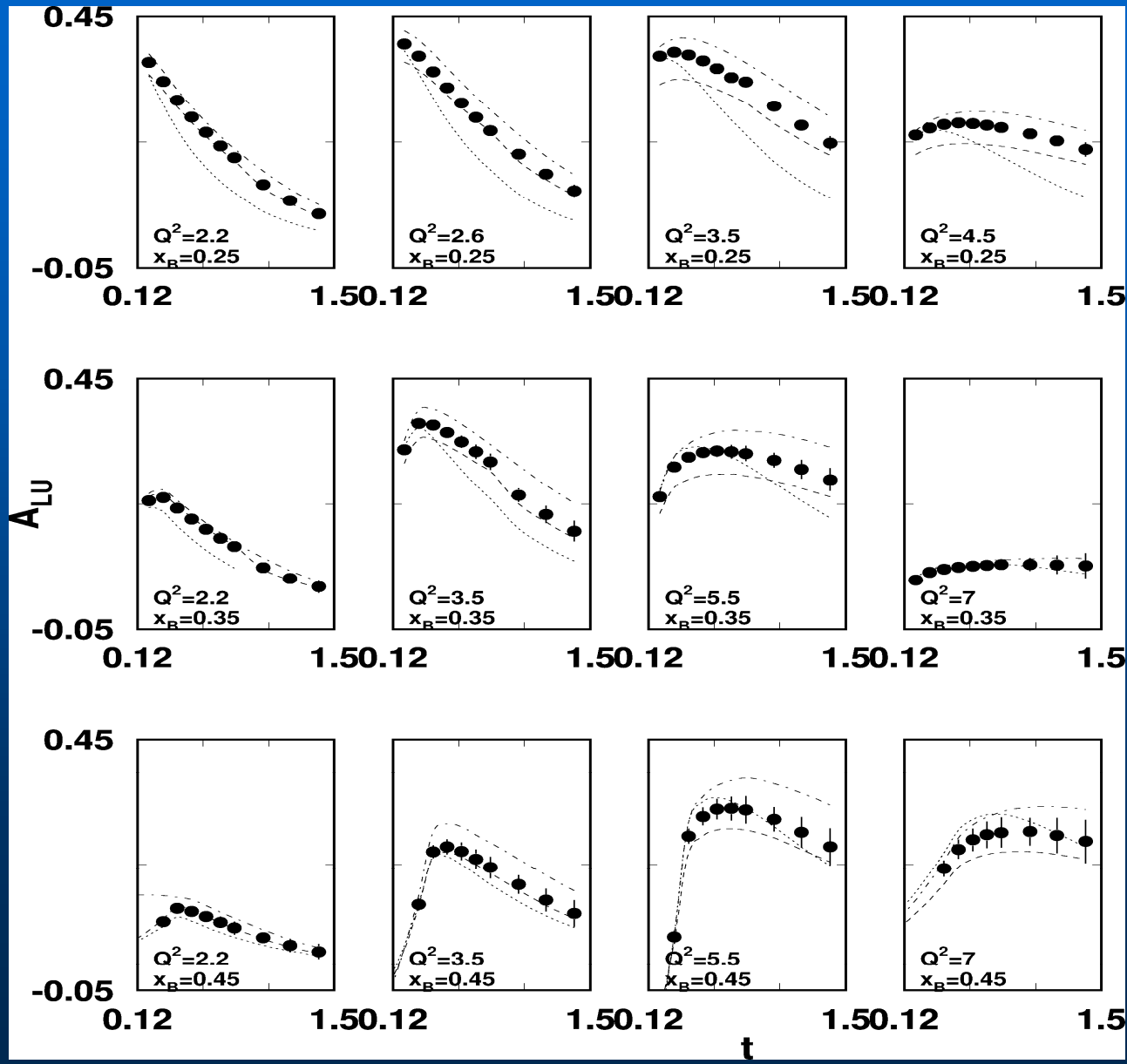
$$A = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{\Delta\sigma}{2\sigma}$$

$\Delta\sigma_{LU} \sim \sin\phi \{F_1 H + ..\} d\phi$

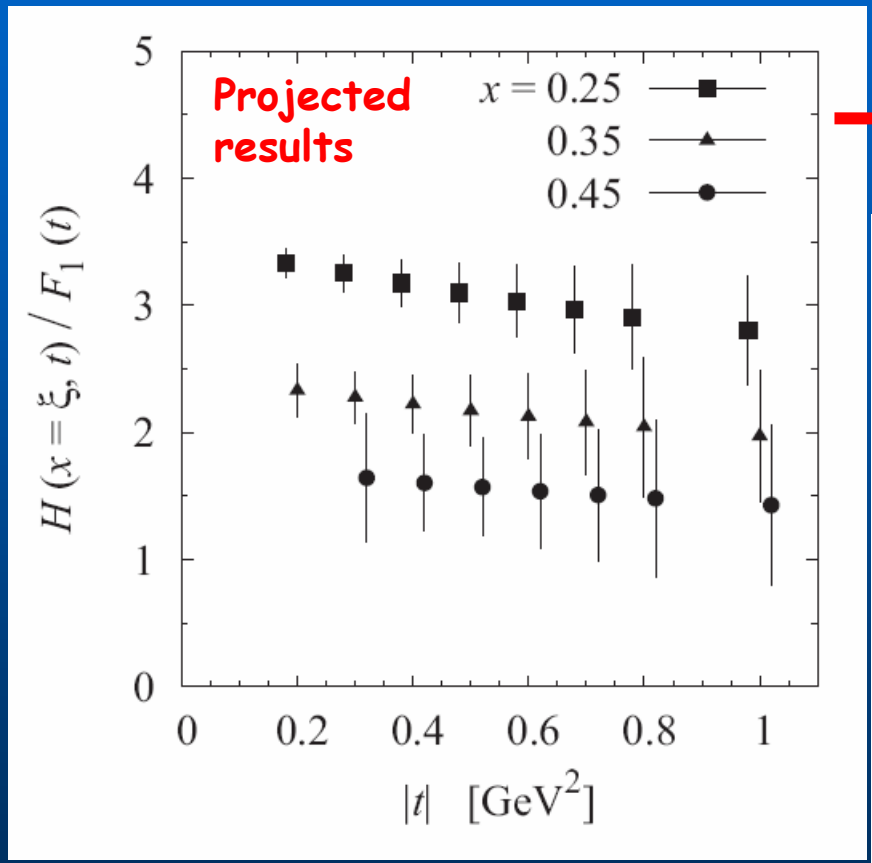
Kinematically suppressed

Selected Kinematics

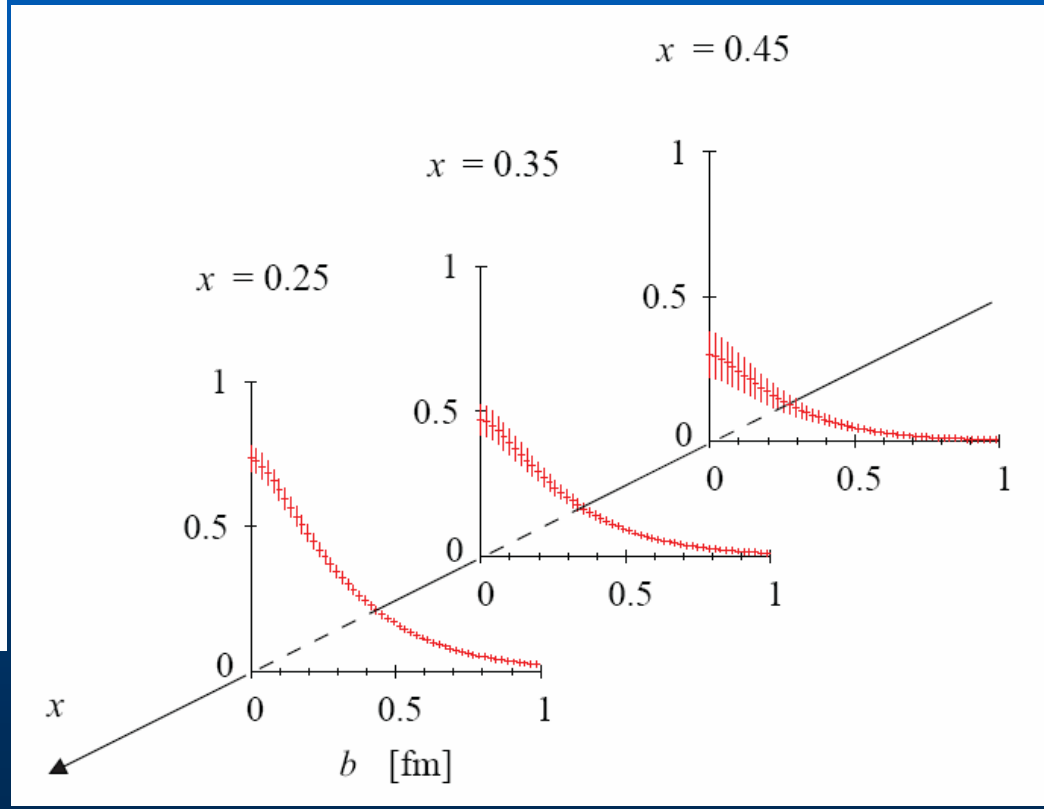
Extract H(ξ,t)



Projected precision in extraction of GPD H at $x = \xi$

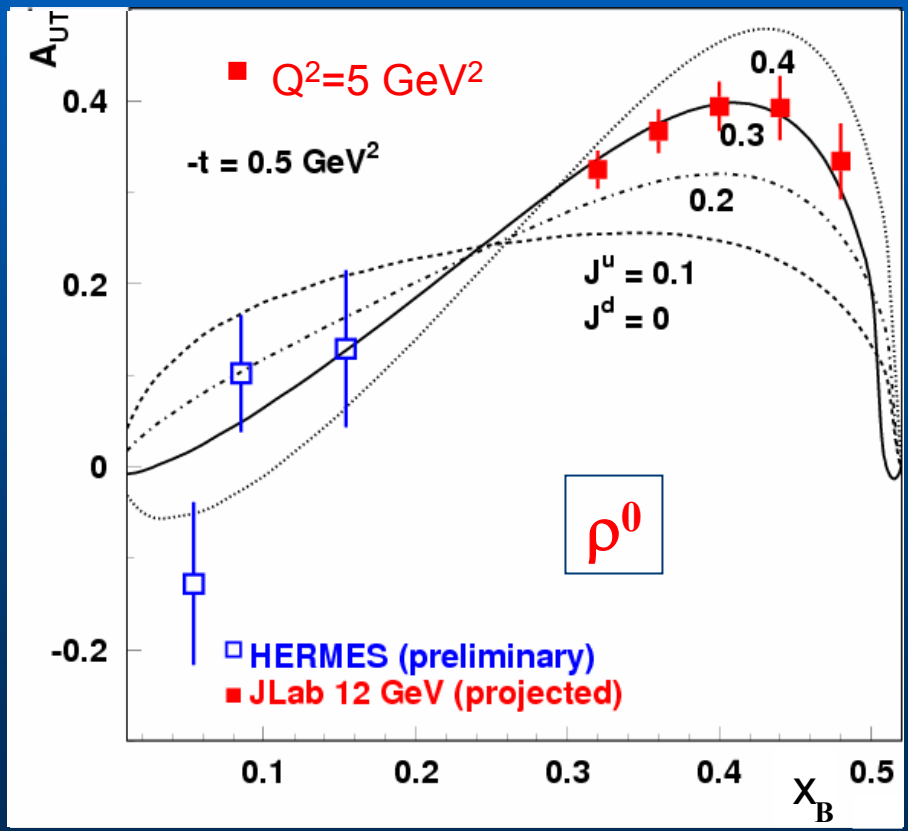


Spatial Image



Exclusive ρ^0 production on transverse target

$$A_{UT} = - \frac{2\Delta_\perp(\mathrm{Im}(AB^*))/\pi}{|A|^2(1-\xi^2) - |B|^2(\xi^2+t/4m^2) - \mathrm{Re}(AB^*)2\xi^2}$$



ρ^0

$A \sim 2H^u + H^d$

$B \sim 2E^u + E^d$

ρ^+

$A \sim H^u - H^d$

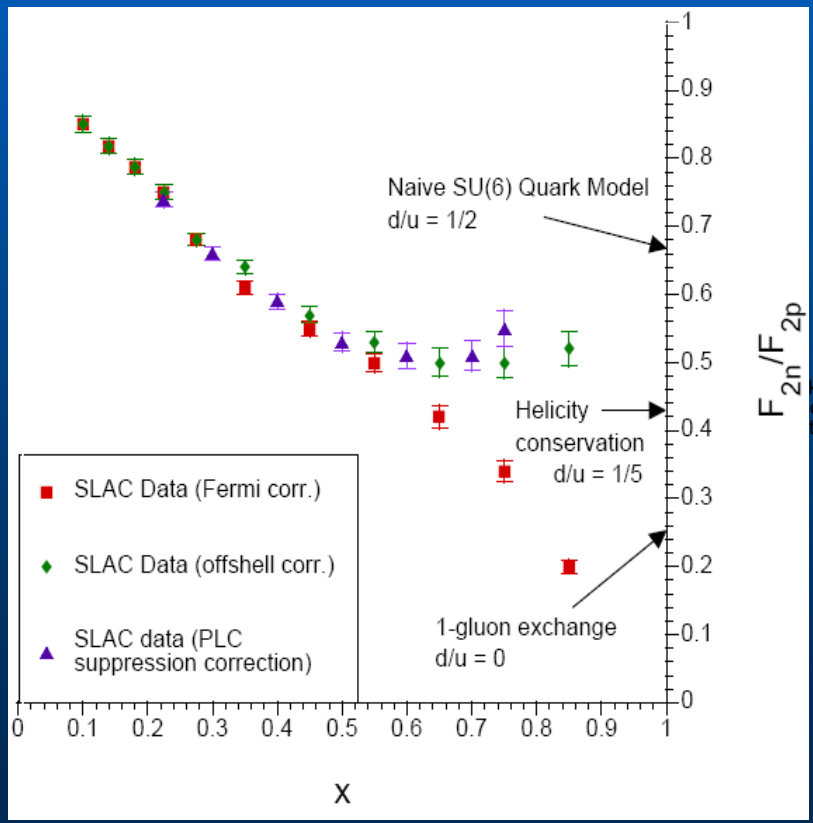
$B \sim E^u - E^d$

E^u, E^d needed for orbital angular momentum sum.

Valence structure function flavor dependence

Neutron Structure Function $F_{2n}(x,Q^2)$ poorly known at large x resulting in large uncertainties for the ration d/u quarks.

Tagging "free" Neutron Structure Function by measuring spectator proton at low momentum, p_s > 70MeV/c in $eD \rightarrow ep_sX$



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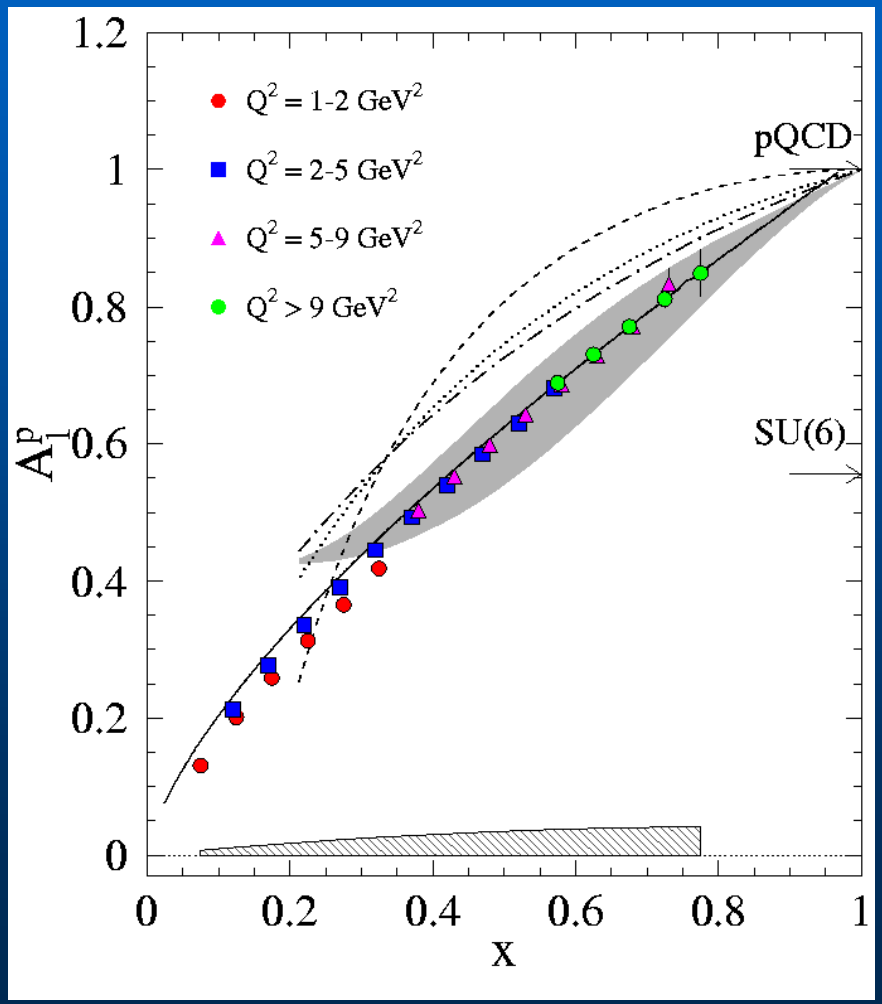
to see this picture.

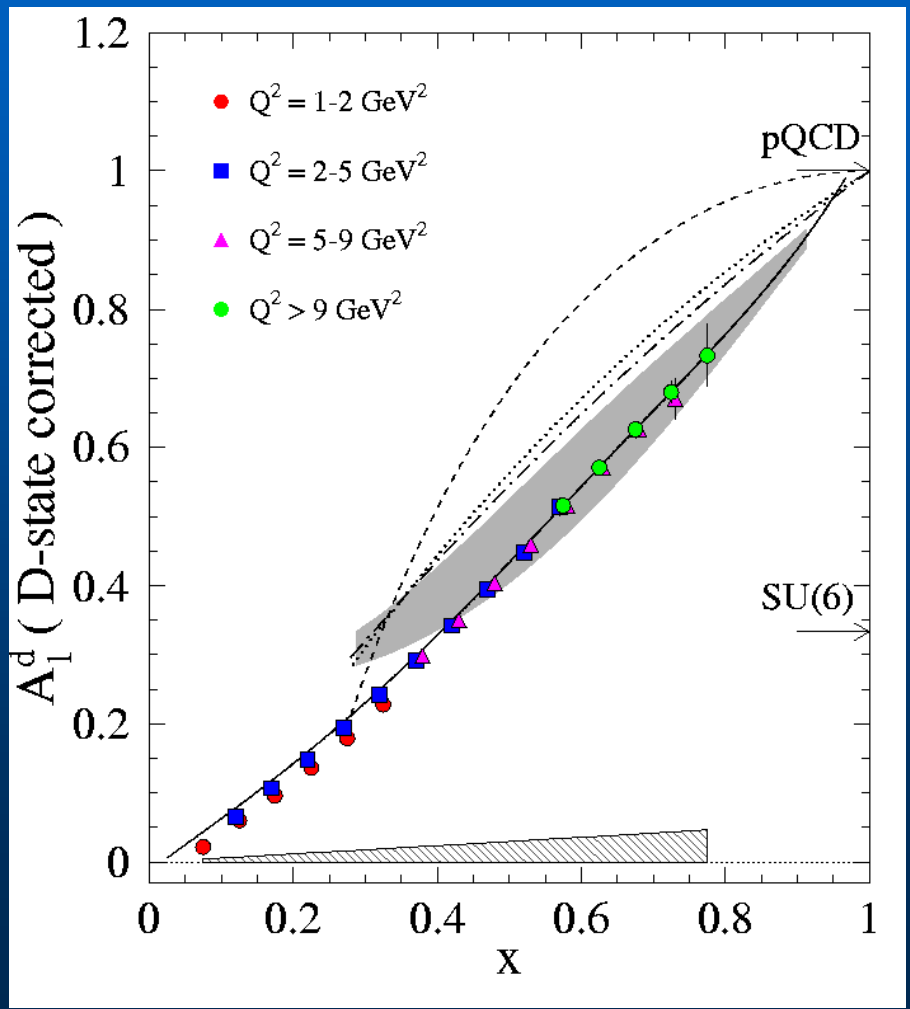
Valence structure function spin dependence

Proton

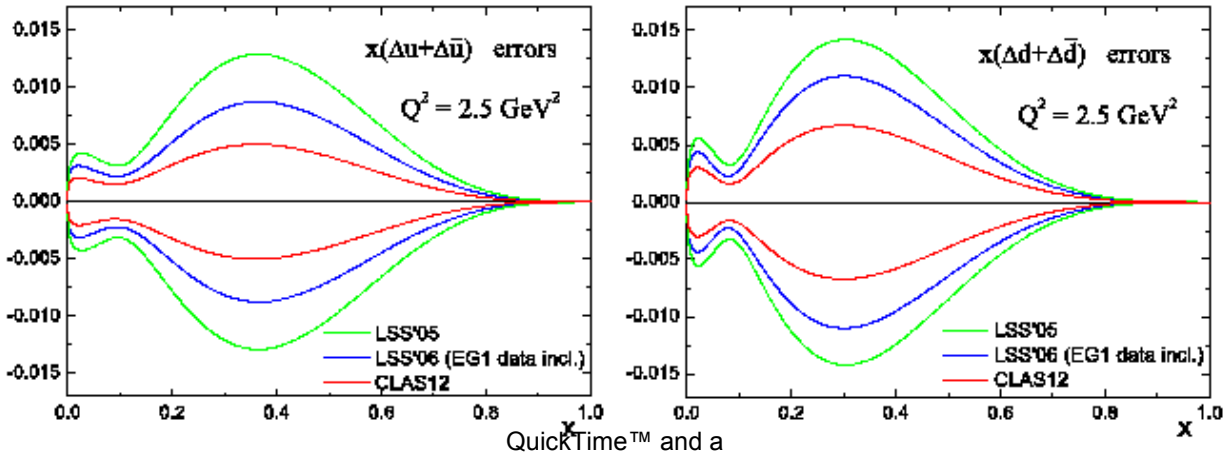
W > 2; Q^2 > 1

Deuteron





Improvements in Δu, Δd, ΔG, Δs



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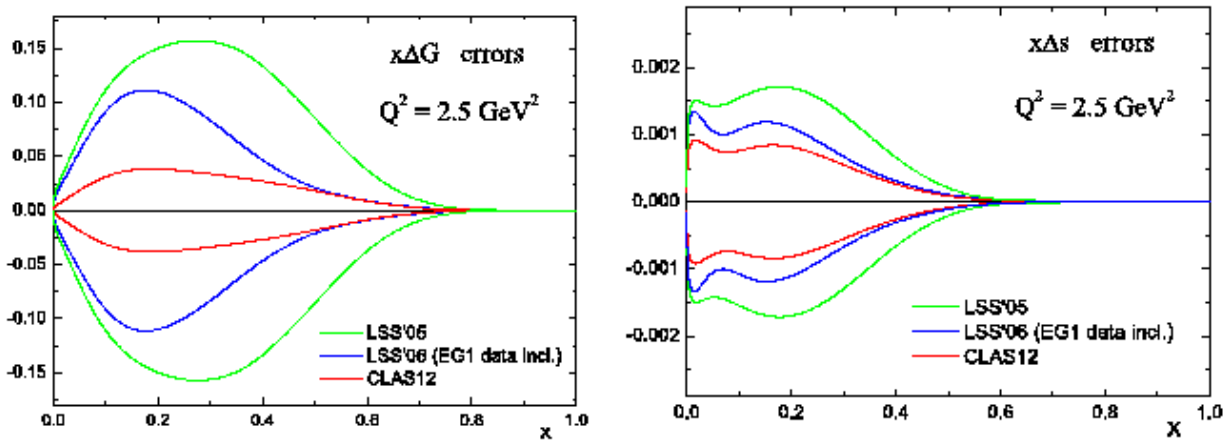
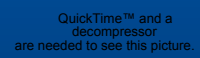
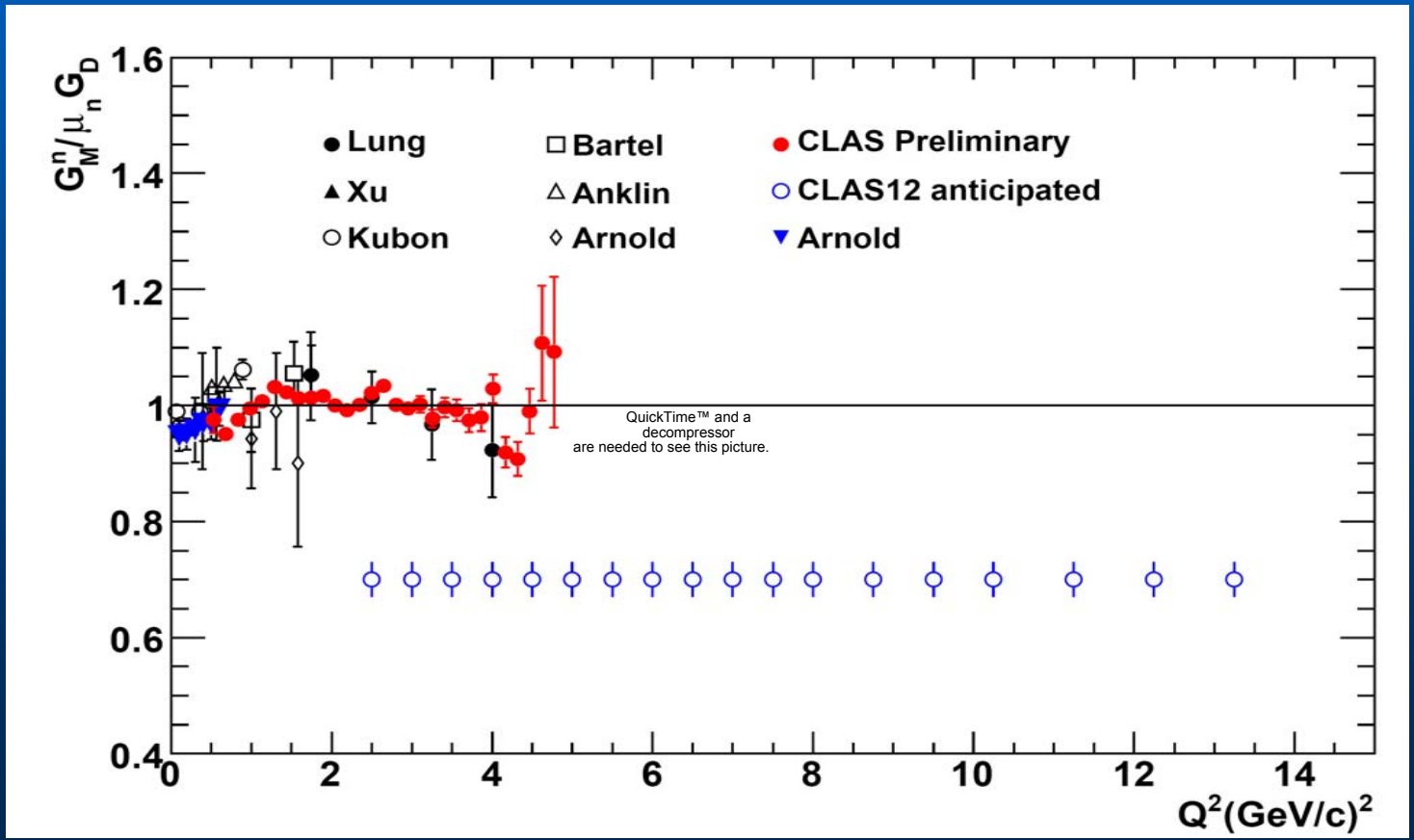


Spin-Flavor Distributions -
Important complement to RHIC Spin data



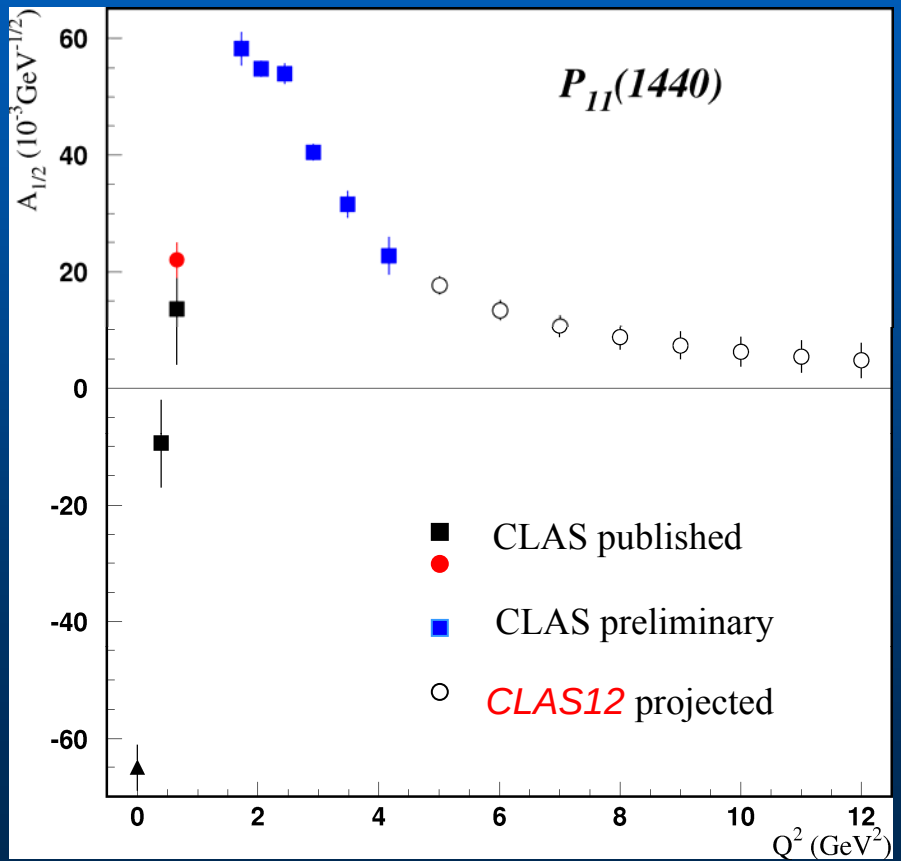
Neutron Magnetic Form Factor

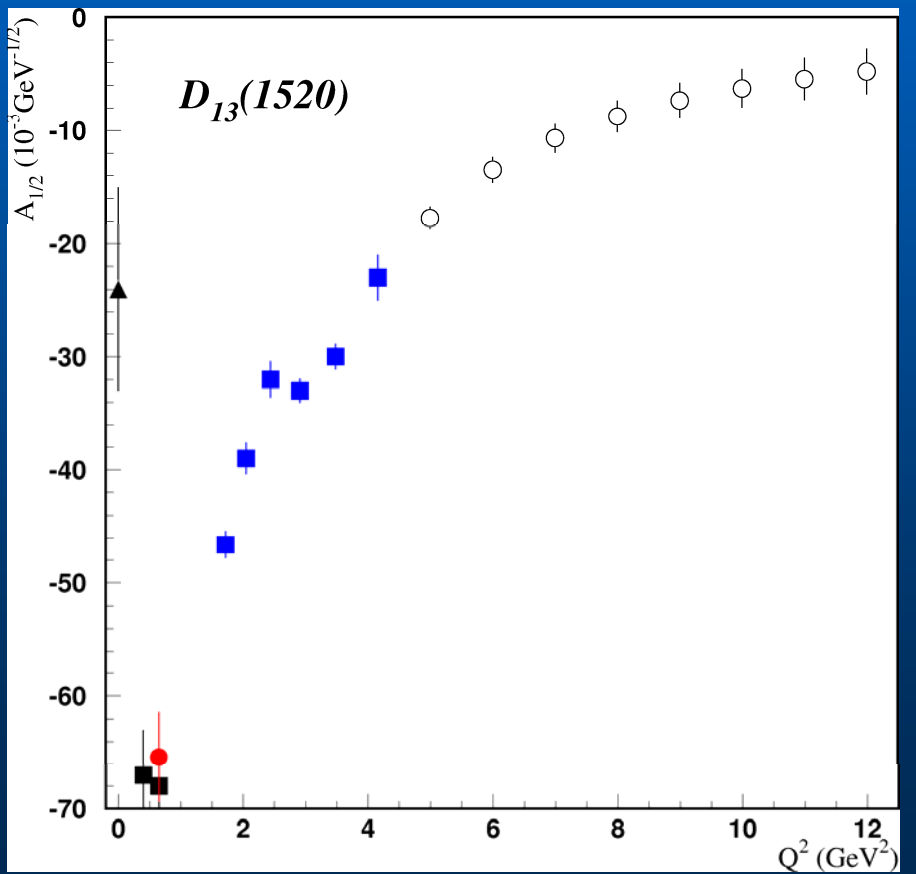
At 12 GeV extend knowledge of magnetic structure of neutron to much shorter distances. Needed for constraints of GPDs at large t; related to moments of GPDs: $F_1(t)=\int H(t,x,\xi)dx$, $F_2(t)=\int E(t,x,\xi)dx$



Projections for N* Transition Amplitudes @ 12 GeV

Probe the transition from effective degrees of freedom, e.g. constituent quarks, to elementary quarks, with characteristic Q^2 dependence.

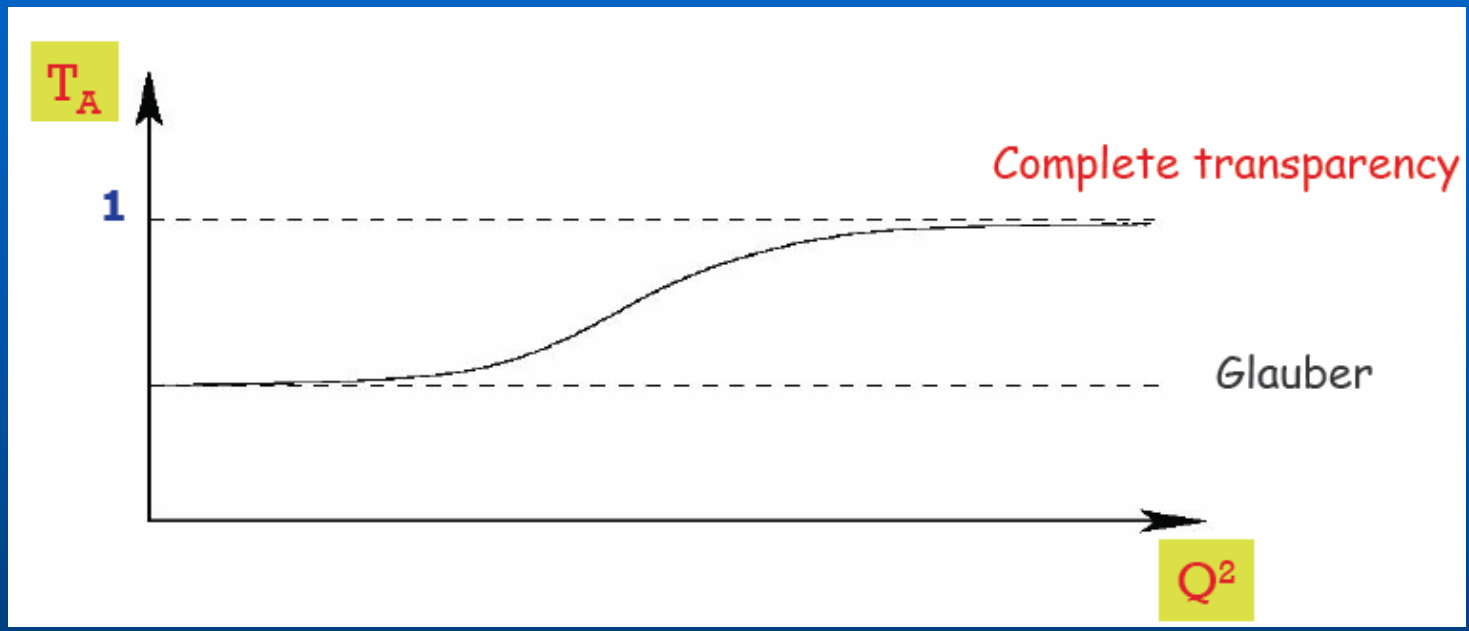


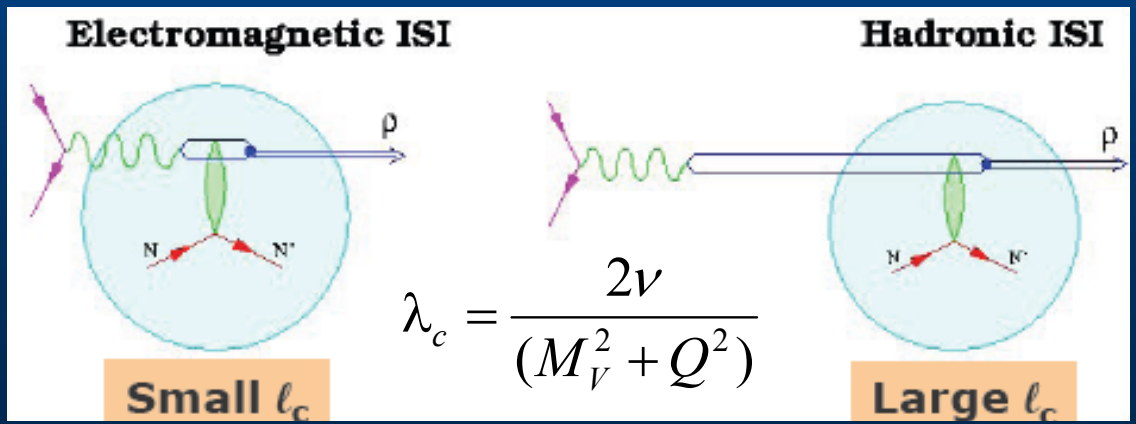


Color transparency in ρ electroproduction

- Color Transparency is a spectacular prediction of QCD: under the right conditions, nuclear matter will allow the transmission of hadrons with reduced attenuation
- Totally unexpected in an hadronic picture of strongly interacting matter, but straightforward in quark gluon basis
- Why ρ ? CT should be evident first in mesons

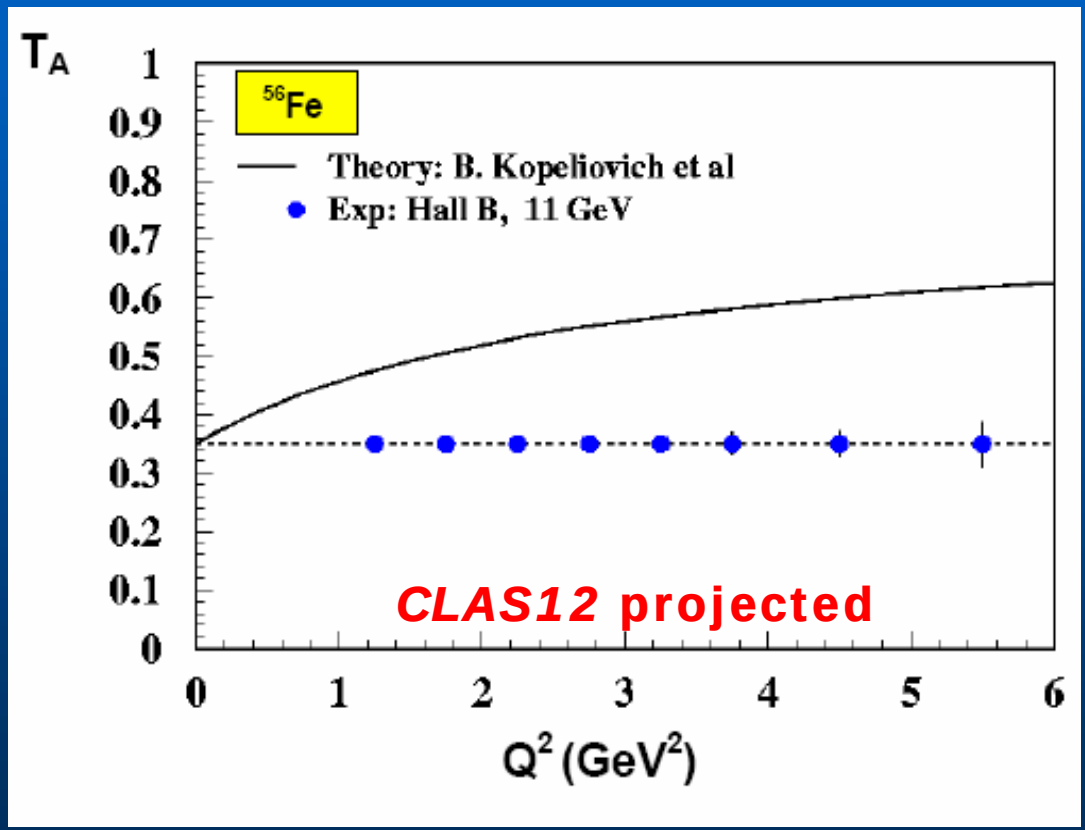
- The signature of CT is the rising of the nuclear transparency TA with increasing hardness of the reaction (Q)





- Measurement at fixed coherence length needed for unambiguous interpretation

Color transparency in ρ electroproduction



- High-precision measurements will permit systematic studies

Summary

- The CLAS12 Detector has physics goals of fundamental importance for the future of hadron physics, addressing in new and revolutionary ways the quark and gluon structure of mesons, nucleons, and nuclei by
  - accessing generalized parton distributions and the 3D imaging of the nucleon
  - exploring the valence quark structure of nucleons at extreme quark momentum
  - understanding quark confinement and hadronization processes
  - extending nucleon elastic and resonance transition form factors to short distances
- The NSAC Long Range Plan has the 12 GeV upgrade as the highest priority nuclear science project, and highlights major parts of the physics program with CLAS12

2007 NSAC Long Range Plan (4 recommendations)

Recommendation 1

We recommend the completion of the 12 GeV Upgrade at Jefferson Lab.

- It will enable three-dimensional imaging of the nucleon, revealing hidden aspects of its internal dynamics.
- It will complete our understanding of the transition between the hadronic and quark/gluon descriptions of nuclei.
- It will test definitively the existence of exotic hadrons, long-predicted by QCD as arising from quark confinement.
- It will provide low-energy probes of physics beyond the Standard Model complementing anticipated measurements at the highest accessible energy scales.

HALL B WBS 1.1.3, 1.2.2.2 & 1.4.2

12 GeV Upgrade FY 08-15 Hall B Level 4