Hall-B Run Group H
CLAS12 Experiments with a Transversely Polarized Target

Contalbrigo Marco - INFN Ferrara

For RGH and CLAS Collaboration

Jefferson Lab PAC48, September 25 - 2020

The Run Group

PAC39 2012

Experiment	Contact	Title	Rating	PAC days
C12-11-111	M. Contalbrigo	Transverse spin effect in SIDIS at 11 GeV with a transversely polarized target using CLAS12	A	110
C12-12-009	H. Avakian	Measurement of transversity with di-hadron production in SIDIS with a transversely polarized target	A	110
C12-12-010	L. Elauadrhiri	Deeply Virtual Compton scattering at 11 GeV with transversely polarized target using the CLAS12 detector	A	110

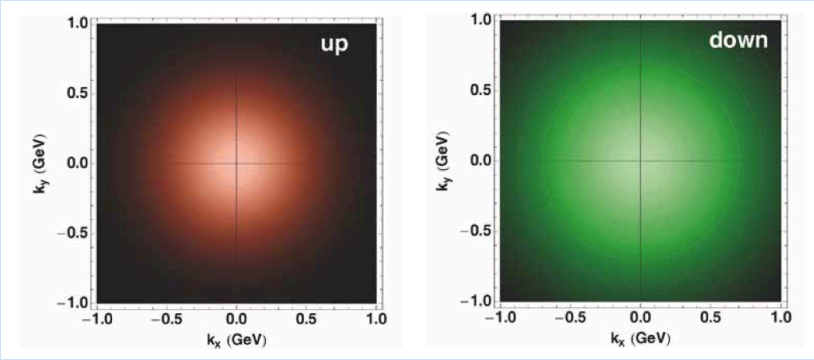
C1 condition: "One has to achieve at least within a factor 2 the figure-of-merit determined by the target design value (I=1 nA, and 60% polarization) and a spin relaxation time of 50 days at 1 nA before the experiments with the transversally polarized target are approved".

All RGH experiments selected among the high impact JLab measurements PAC42 [2014]

Since then: RGH program becomes a pillar of EIC science case

EIC^2
EIC Center at Jefferson Lab

Nucleon 3D: SIDIS



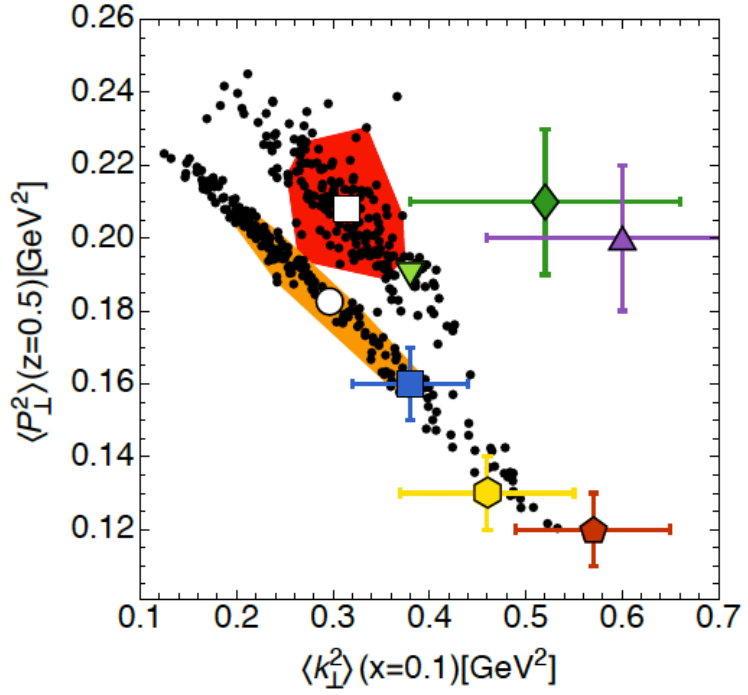
$$\left\langle P_{h\perp}^2 \right\rangle = z^2 \left\langle k_T^2 \right\rangle + \left\langle p_T^2 \right\rangle$$

A. Bacchetta++ [arXiv:1807.02101]

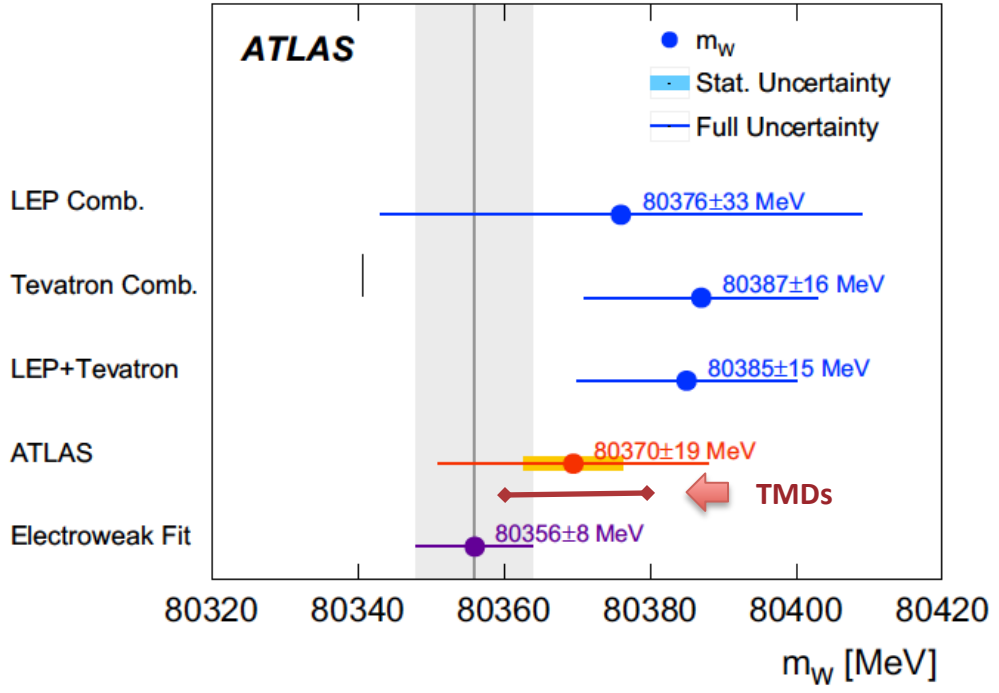
$$m_W = 80370 \pm 7\ (\text{stat.}) \pm 11\ (\text{exp. syst.}) \pm 14\ (\text{mod. syst.})$$

+9 / -6 (TMDs)

A. Bacchetta++ [arXiv:1703.10157]



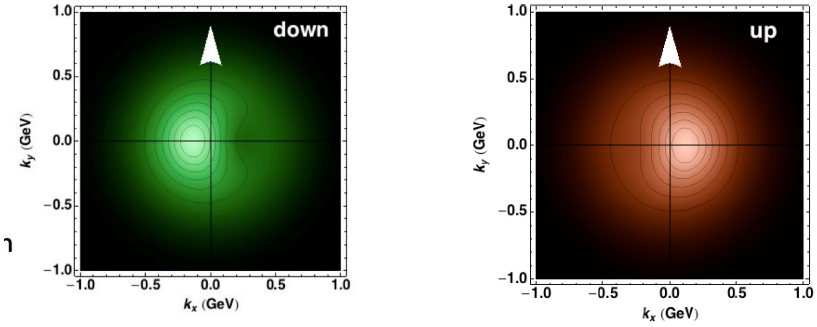
ATLAS++ [arXiv:1701.07240]



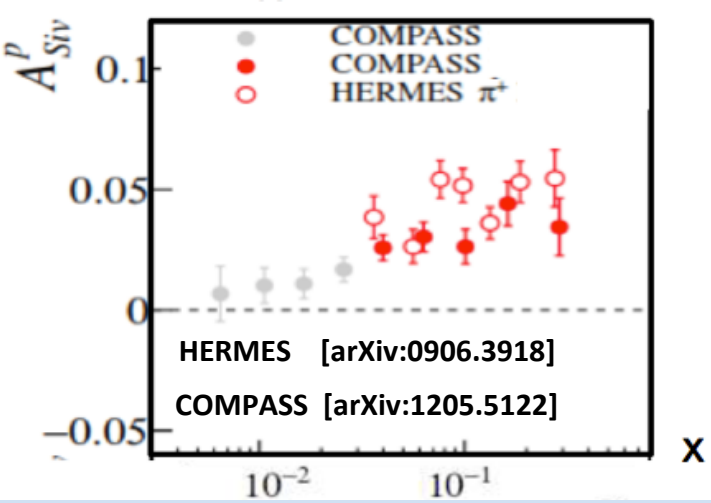
The Sivers Spin-Orbit Effect

$$f_1(x,k_T^2;Q^2) - \frac{k_x}{M} f_{1T}^{\perp}(x,k_T^2;Q^2)$$

Quark distribution imbalance connected oo orbital angular momentum and FSI

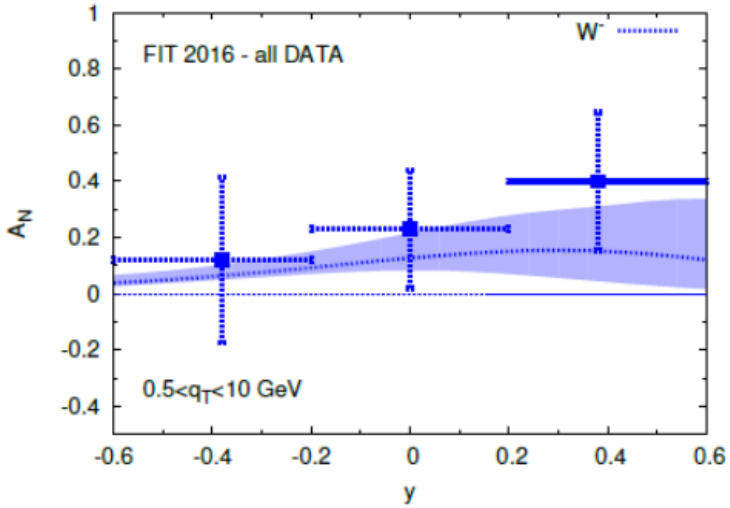


SIDIS data

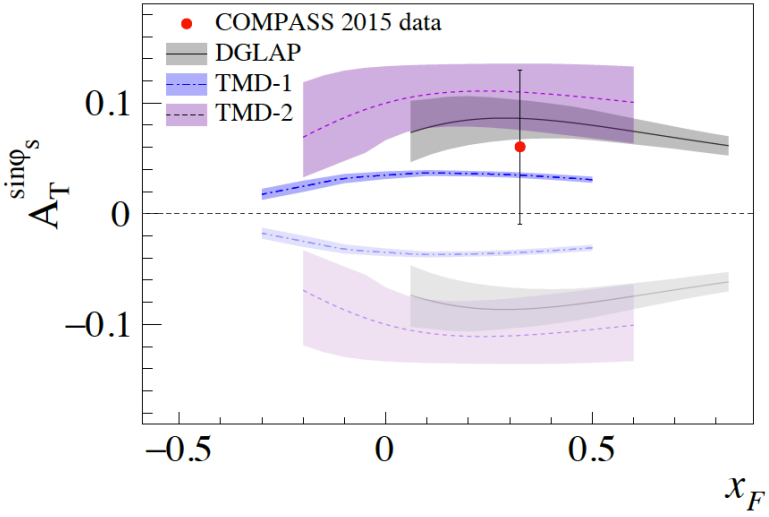


Drell-Yan data

STAR [arXiv: 1511.06006]



COMPASS [arXiv: 1704.00488]



The Sivers Function

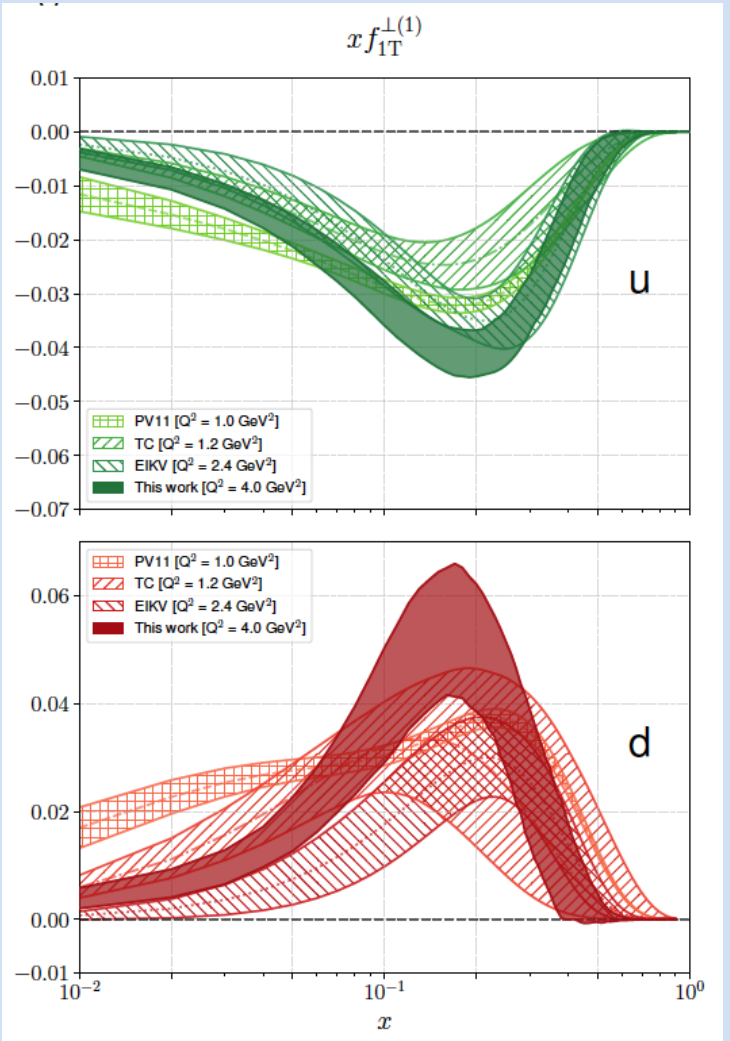
Consistent formalism adopted for TMD f_1/D_1 extraction

Extrapolation outside data range [0.01:0.3] questionable

Largest χ^2 from k- subset of data

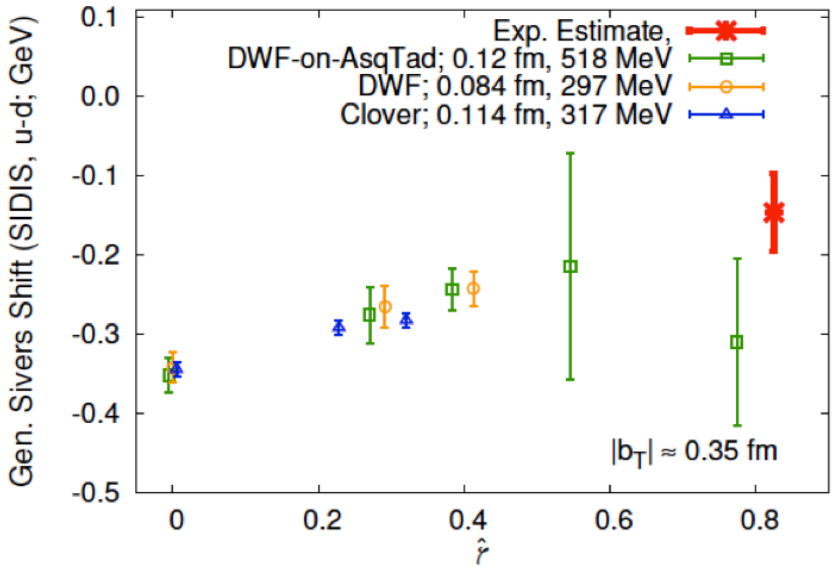
TMD evolution based on a universal non-perturbative term
Selection $P_{hT} < \min[\, 0.2Q, 0.7zQ] + 0.5$ GeV

A. Bacchetta++ [arXiv: 2004.14278]



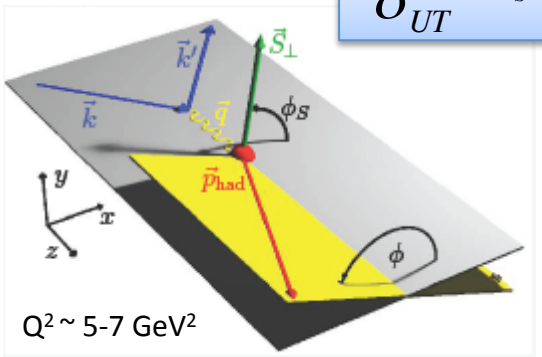
Lattice calculations

Yoon++ [arXiv: 1706.03406]

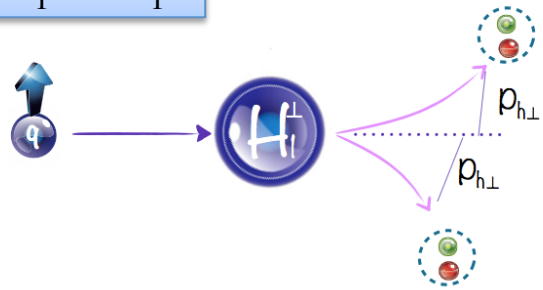


The Collins Spin-Orbit Effect

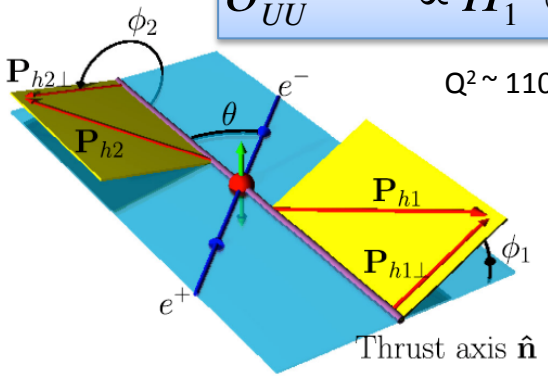
$$\sigma_{UT}^{\sin(\phi+\phi_S)} \propto h_1 \otimes H_1^{\perp}$$



Q^2 ~ 5-7 GeV^2



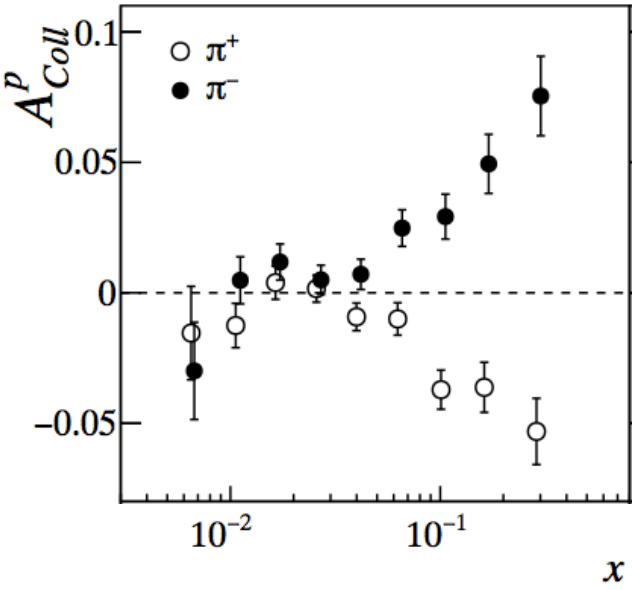
$$\sigma_{UU}^{\sin(\phi_1+\phi_2)} \propto H_1^{\perp} \otimes H_1^{\perp}$$



Q^2 ~ 110 GeV^2

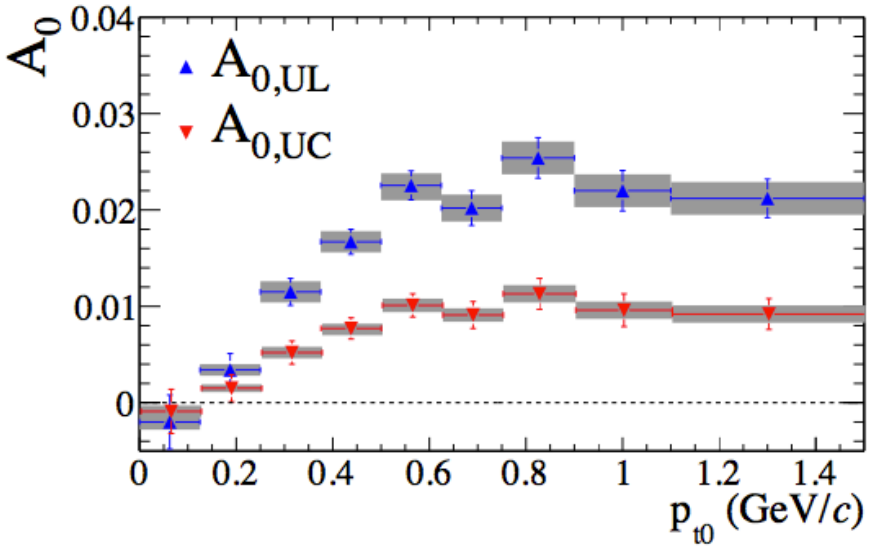
SIDIS

HERMES [arXiv 0408013]
HERMES [arXiv 0906.3918]
COMPASS [arXiv 1005.5609]
COMPASS [arXiv 1408.4405]



e+e- colliders

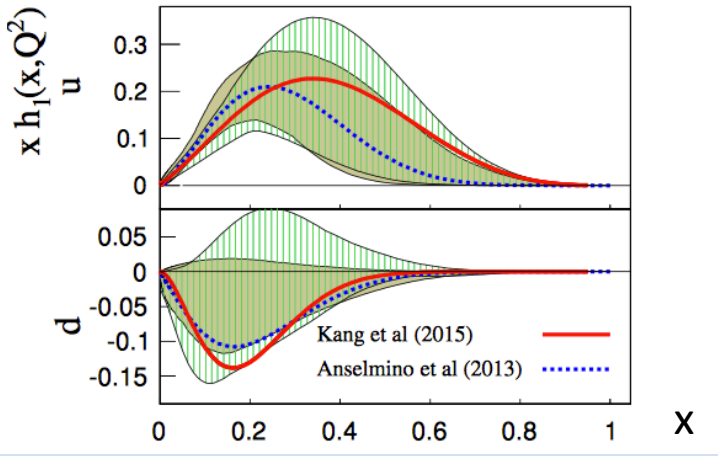
Belle [talk at DIS2014]
BESIII [arXiv 1507.06824]
Babar [arXiv 1309.5278]



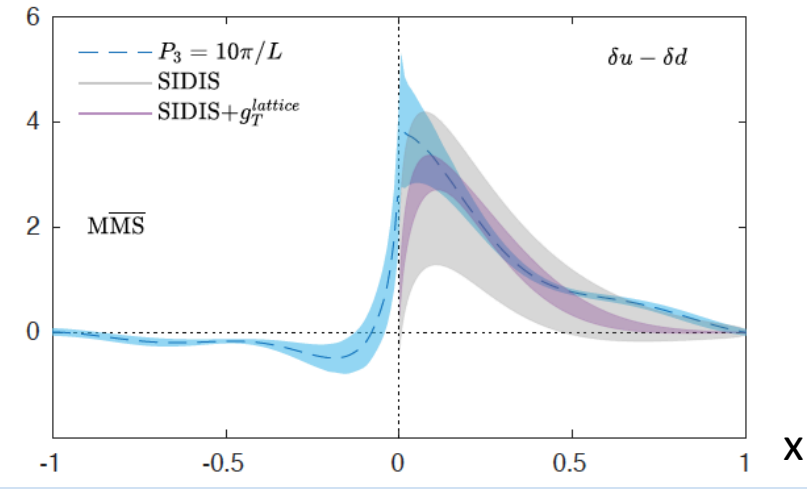
The Transversity

TMD formalism validated for SIDIS, DY, e+e-

M. Boglione++ [arXiv 1511.06924]

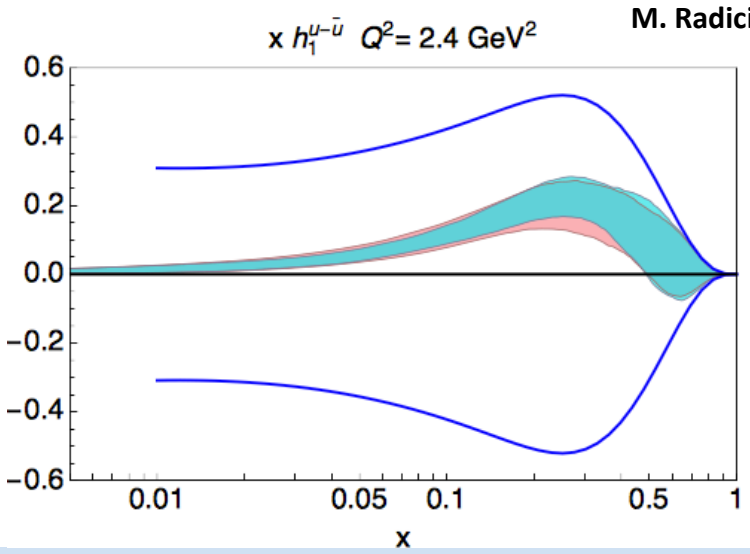


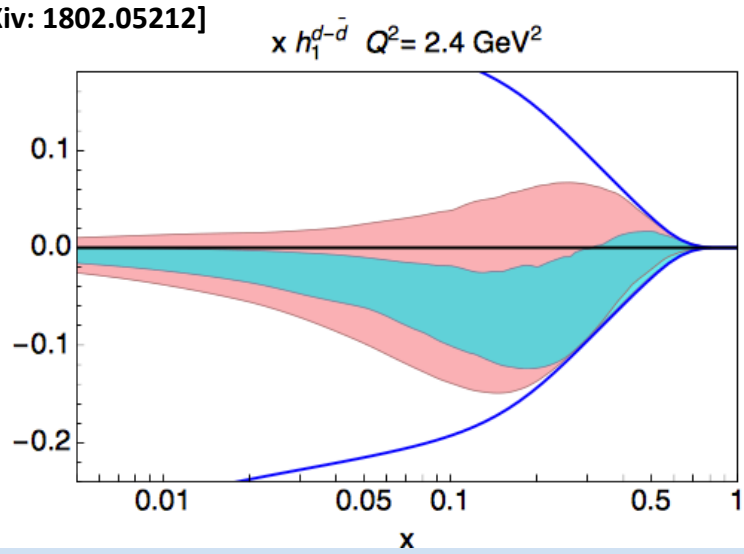
C. Alezandrous++ [arXiv 1902.00587]



Di-hadron: Collinear formalism, access to pp data

M. Radici++ [arXiv: 1802.05212]

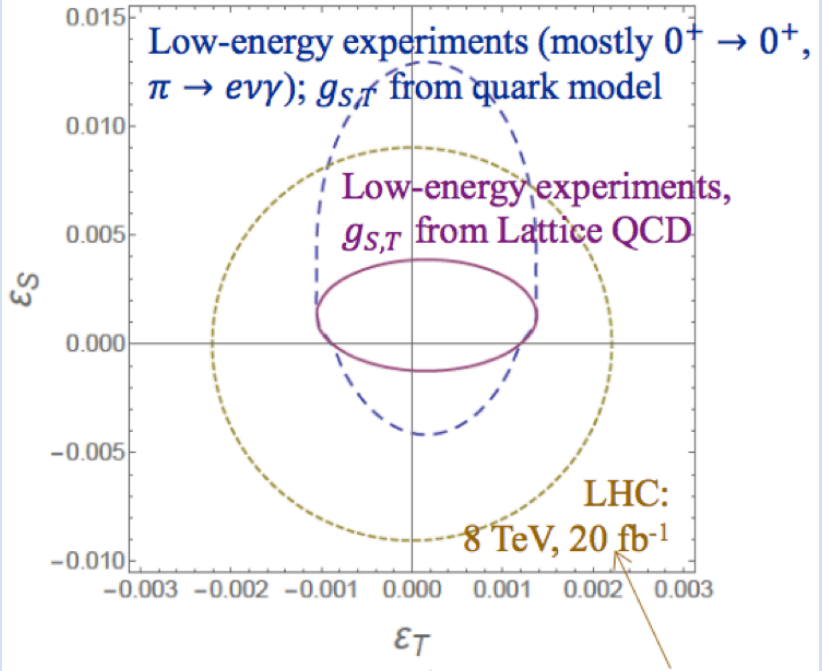




Tensor Charge

A bridge to the BSM couplings

Baessler at MENU 2019



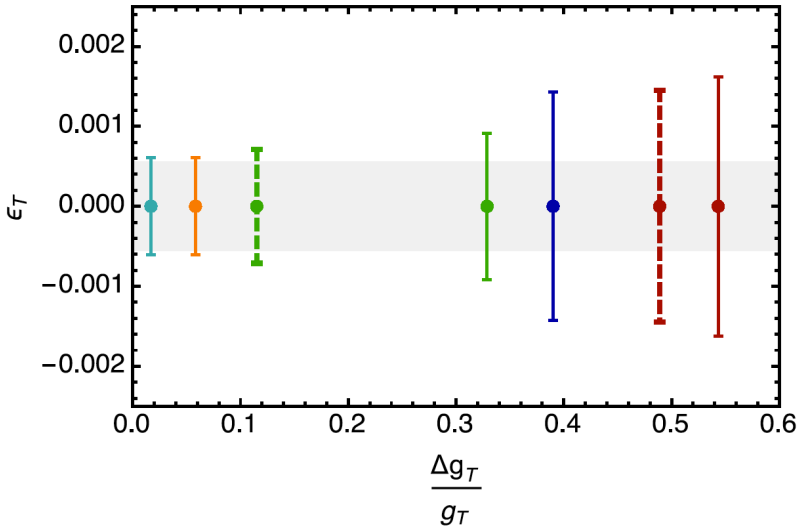
A bridge between nucleon and quark EDM

T. Liu++ [arXiv: 1704.00113]

Proton *EDM*: $d_p = d_u\,\delta_T u + d_d\,\delta_T d$

Neutron *EDM*: $d_n = d_u\,\delta_T d + d_d\,\delta_T u$

A.Courtoy++ [arXiv: 1503.06814]



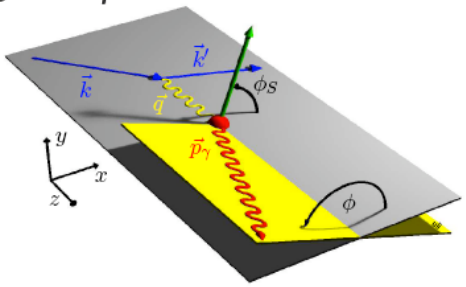
$\varepsilon_T\, g_T \approx M_W^2 / M_{BSM}^2$

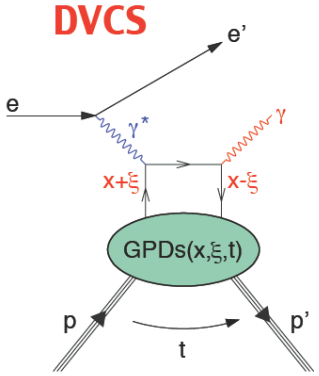
$d_q \sim e m_q / (4\pi \Lambda^2_{BSM})$

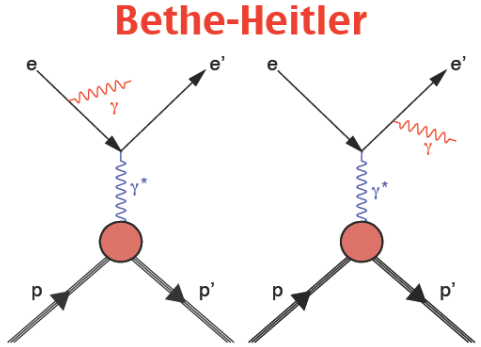
New low-energy measurements can push BSM sensitivity beyond LHC reach

Nucleon 3D: DVCS

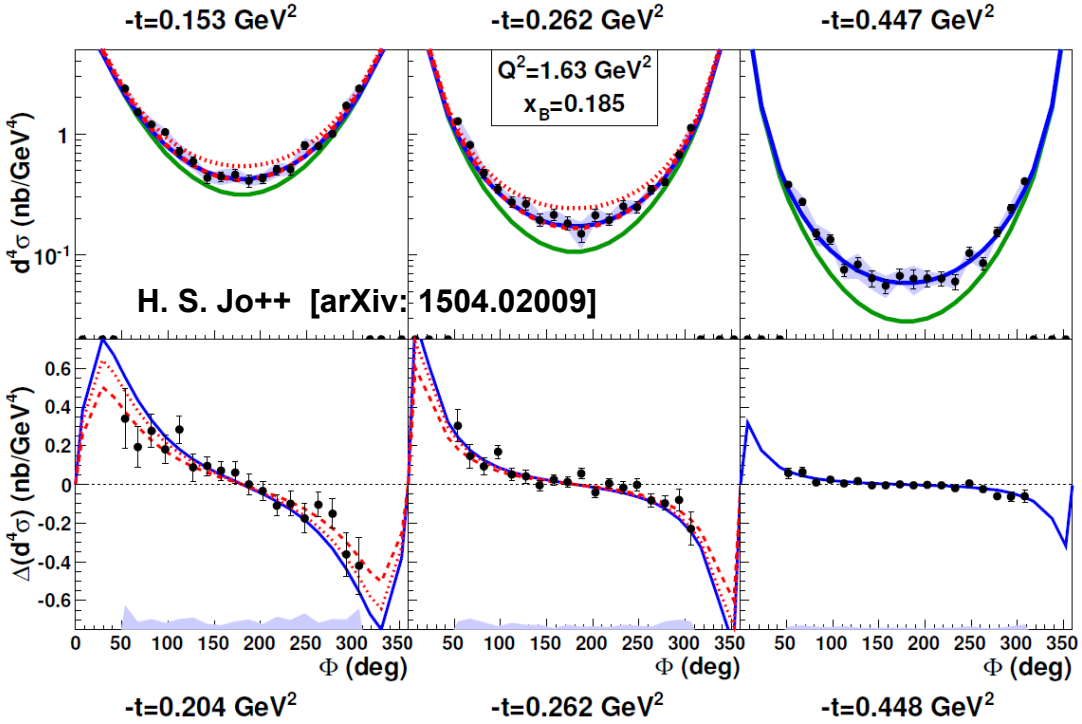
$$\frac{d^4\sigma}{dQ^2\,dx_B\,dt\,d\phi} \propto \left(|\mathcal{T}_{DVCS}|^2 + |\mathcal{T}_{BH}|^2 + \mathcal{I}\right)$$

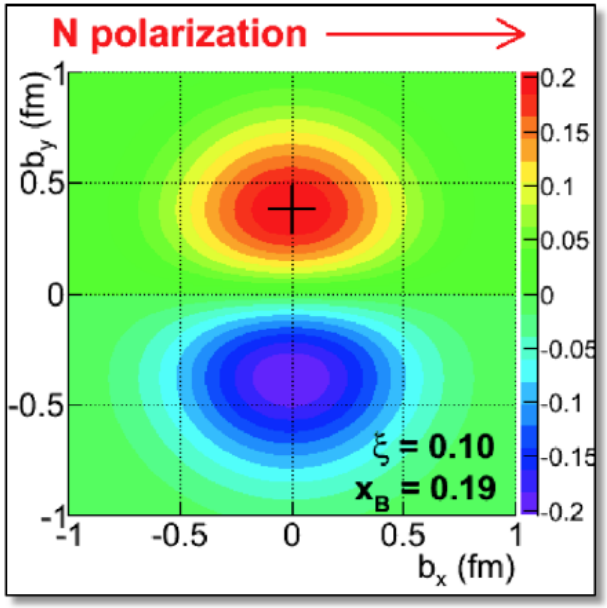






Information on the real and imaginary part of the QCD scattering amplitude





Projected imbalance due to CFF $\mathcal{E}$

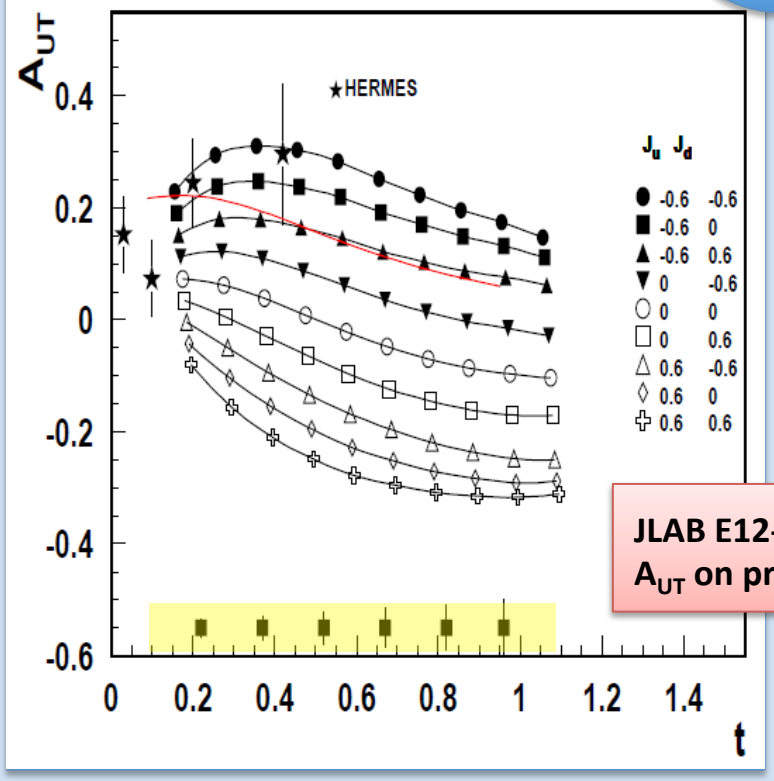
Access OAM $L_q = J_q - \frac{1}{2}\Delta S$ via Ji sum rule

$$J_q = \lim_{t\to 0}\int_{-1}^{1} dx\, x\left[H_q(x,\xi,t) + E_q(x,\xi,t)\right]$$

New: comprehensive approach
same apparatus
To access E_u & E_d both E_p & E_n are needed

RGH

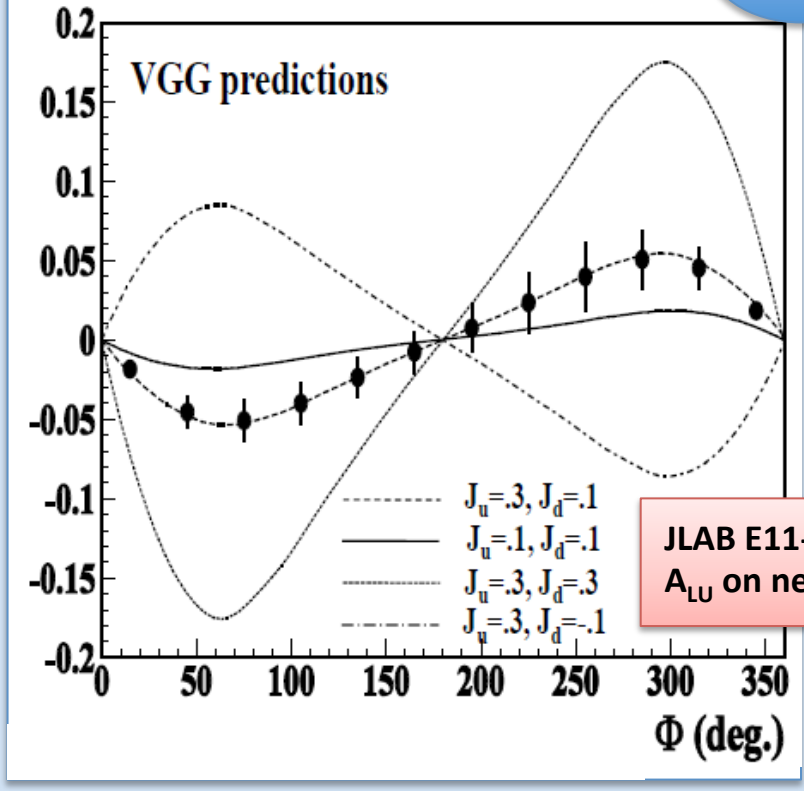
Proton GPD



JLAB E12-010
A_{UT} on proton

RGB

Neutron GPD



JLAB E11-003
A_{LU} on neutron

The CLAS12 Spectrometer

Luminosity up to 10^{35} cm^{-2} s^{-1}

Highly polarized electron beam

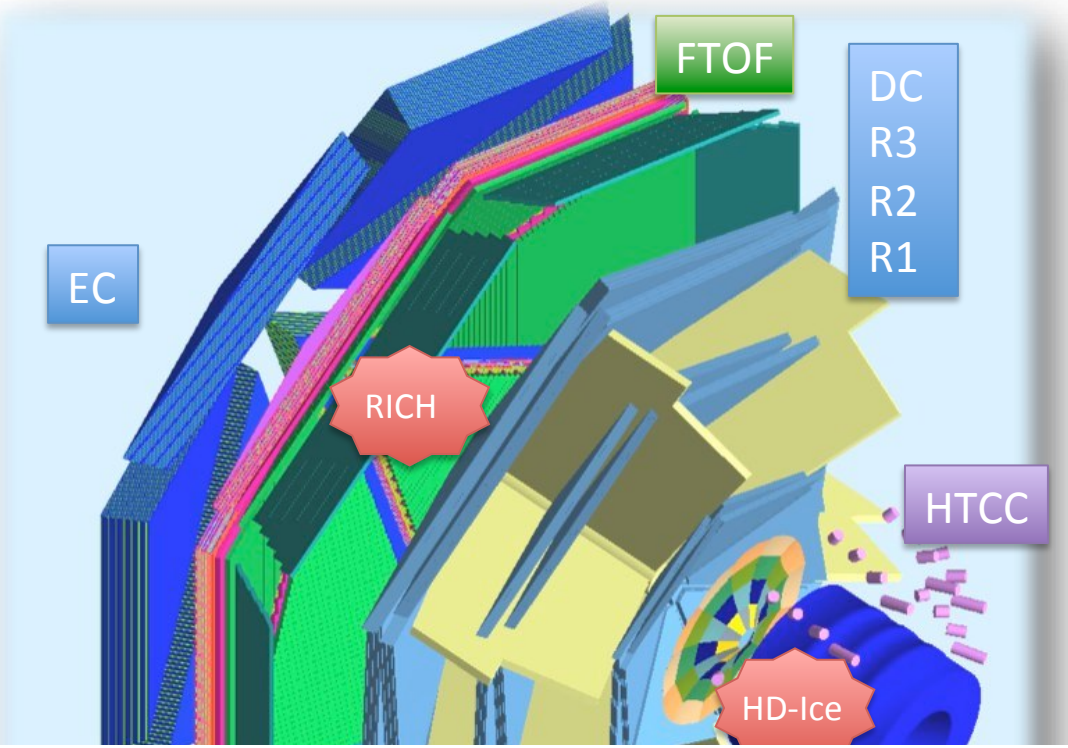
H and D polarized targets

Broad kinematic range coverage
(current to target fragmentation)

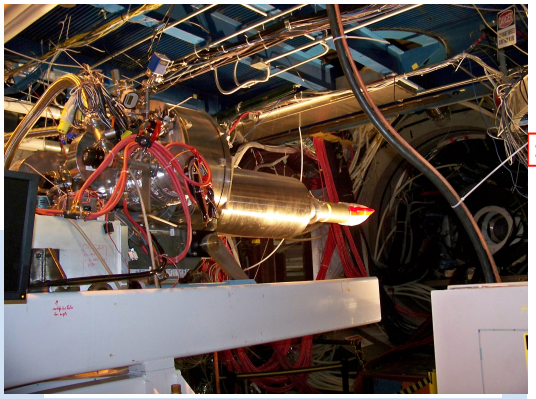
HD-Ice: Transverse Target
new concept
(commissioned with CLAS at 6 GeV
common to PR 12-009, PR 12-010)

RICH: Hadron ID
for flavor separation
(common to SIDIS approved exp.)

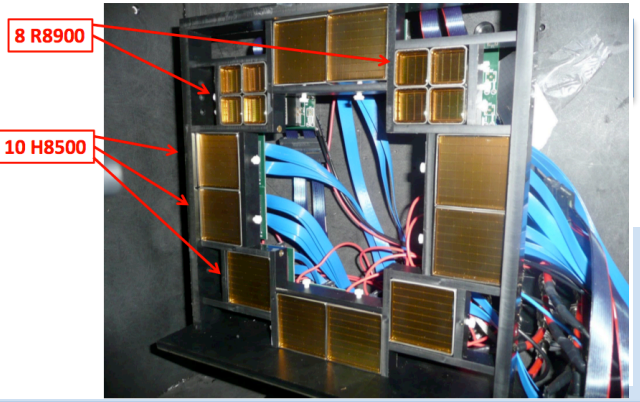
CLAS12 under construction



HD-ice designed for γ beam

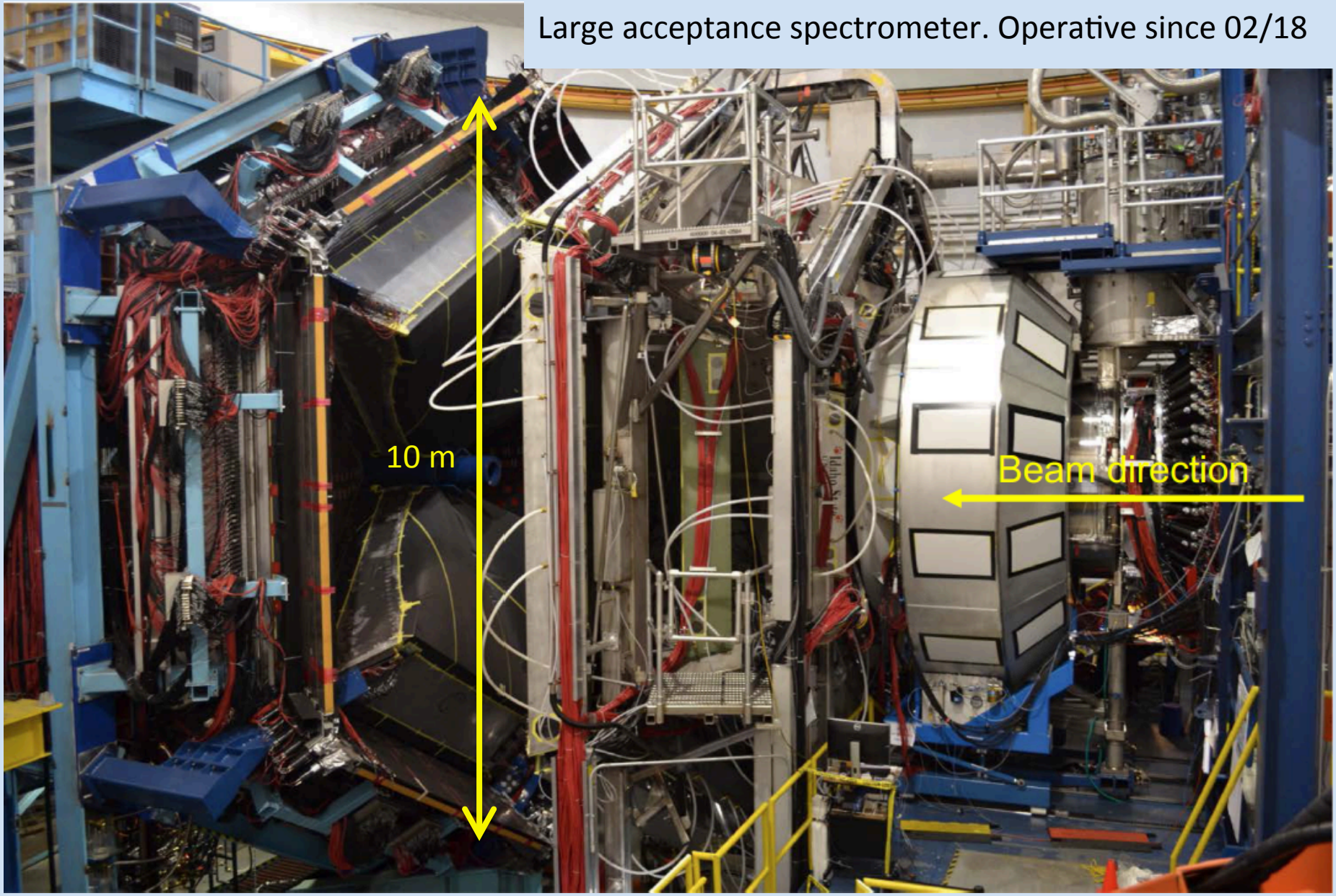


RICH in prototyping stage

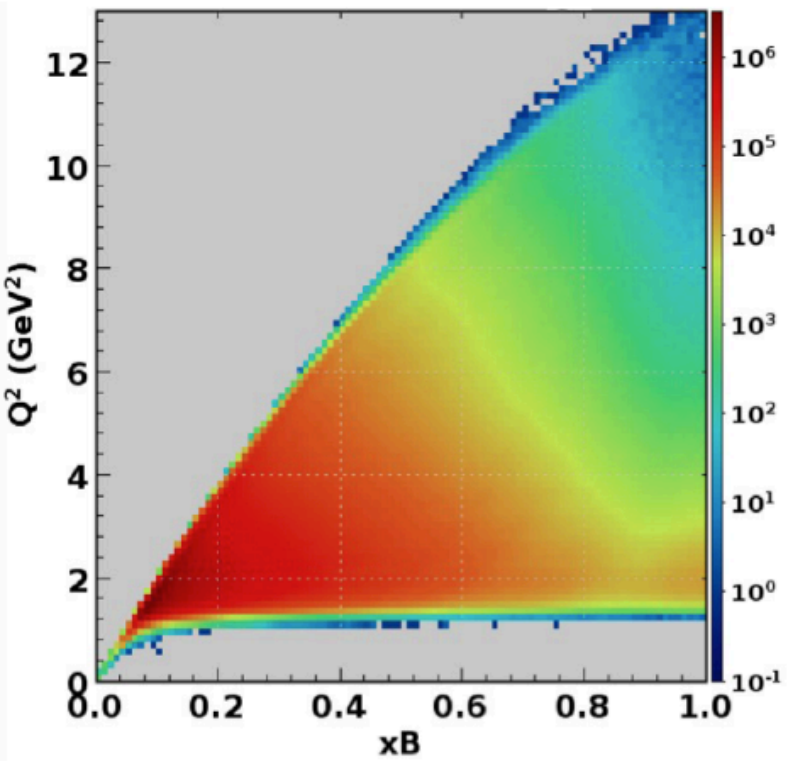


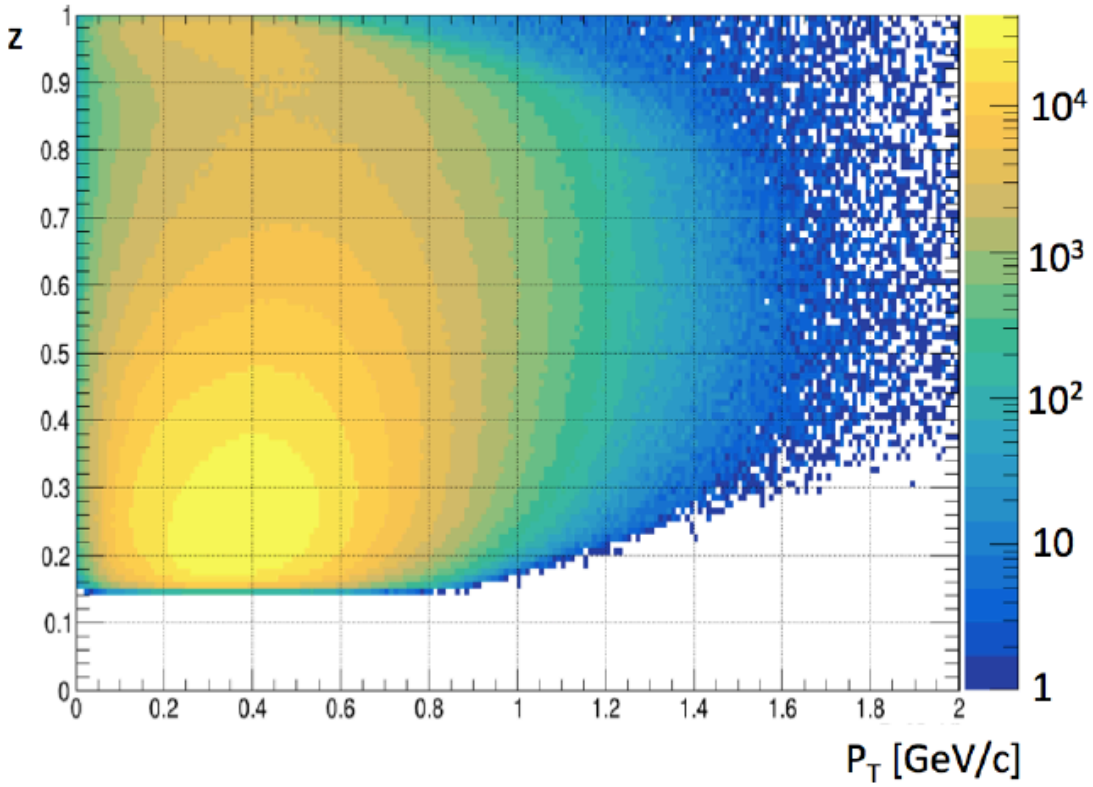
CLAS12 in Hall-B

Large acceptance spectrometer. Operative since 02/18



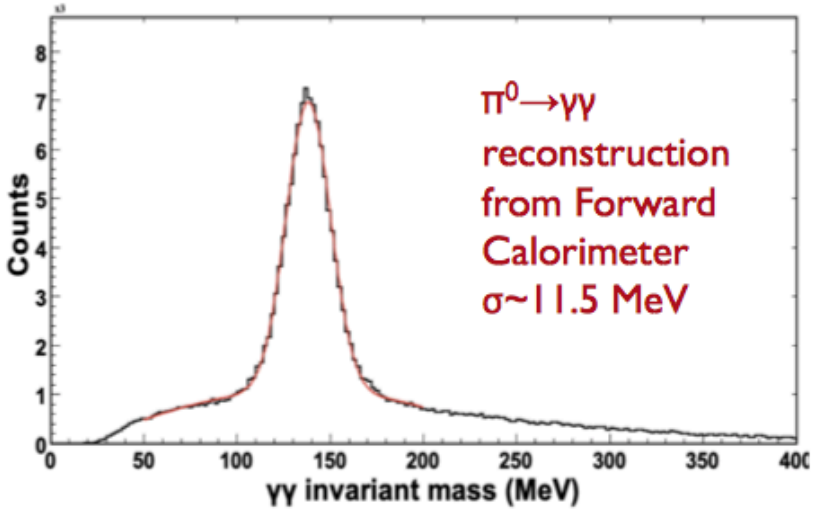
CLAS12 Kinematic Reach

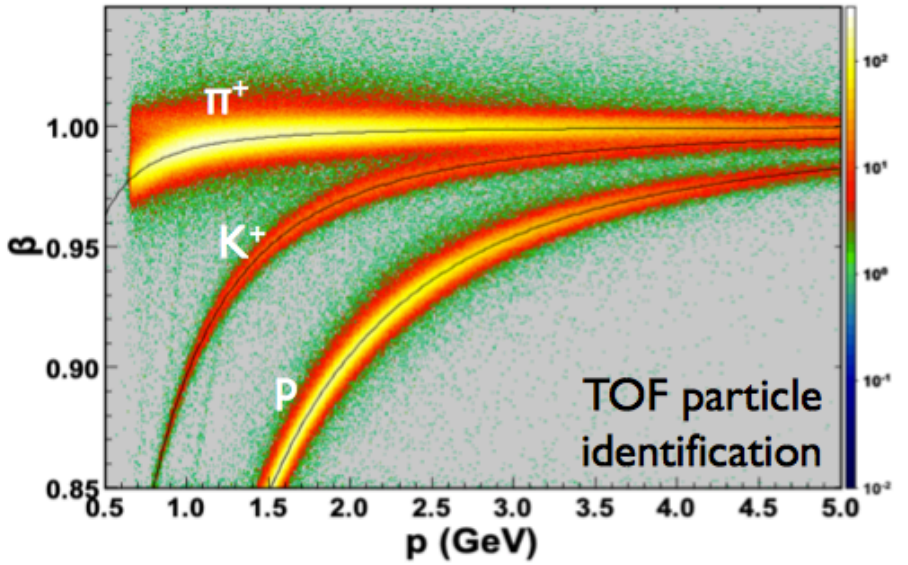


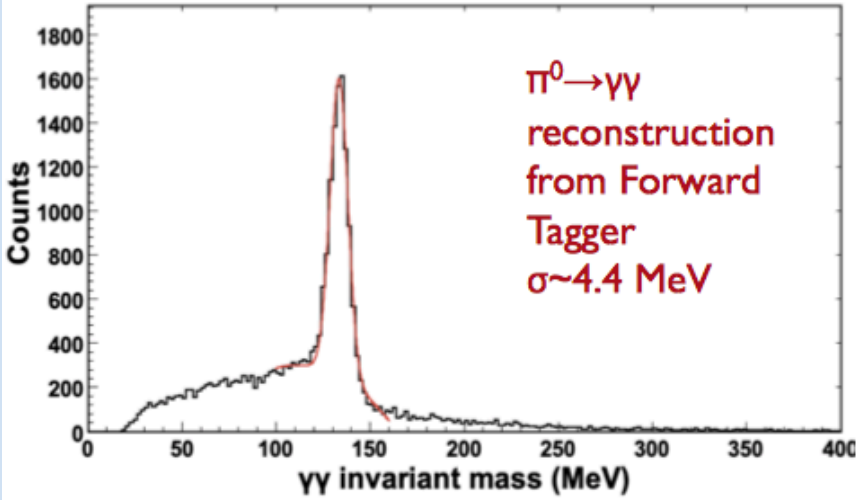


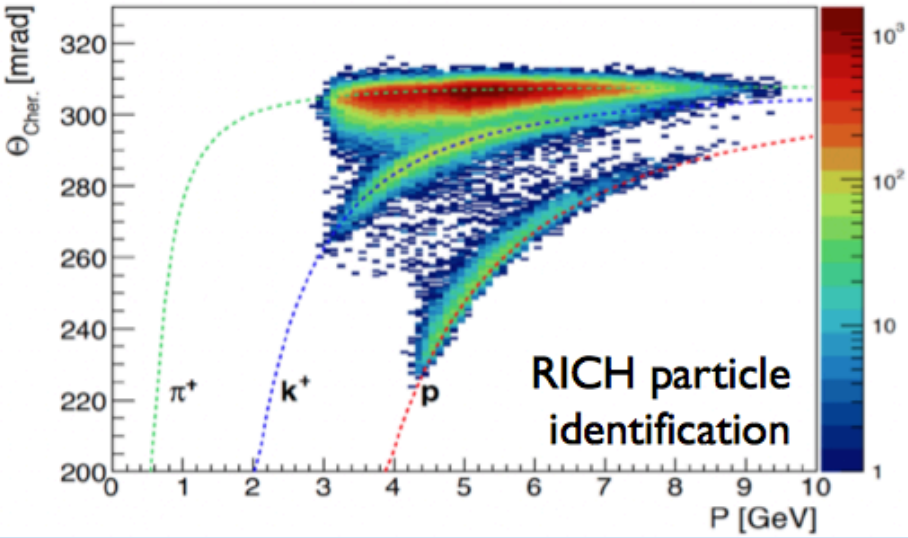
Goal: wide phase space covered, excellent PID and statistics optimized for a multi-D analysis
- disentangle kinematical correlations
- verify expected dependences (e.g. in Q^2) and isolate peculiar regimes (e.g. in z)
- study transition regions (e.g. in P_T)

CLAS12 Event Reconstruction









CLAS12 Data Analysis: SIDIS

Two SIDIS analyses candidates for 1st publication under review

Sensitive to the strong-force correlations within the nucleon

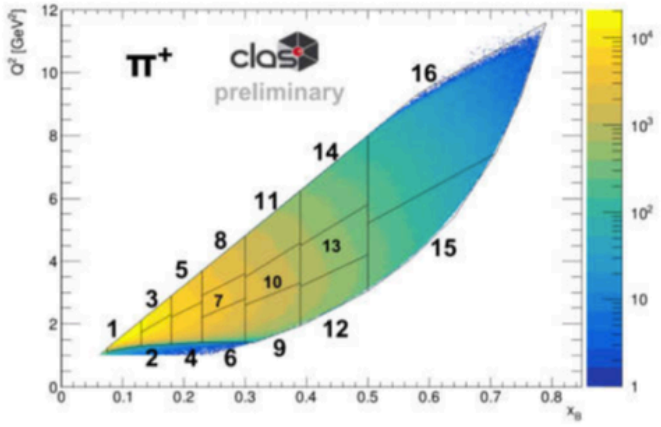
A first multidimensional study of SIDIS π^+ beam spin asymmetry over a wide range of kinematics

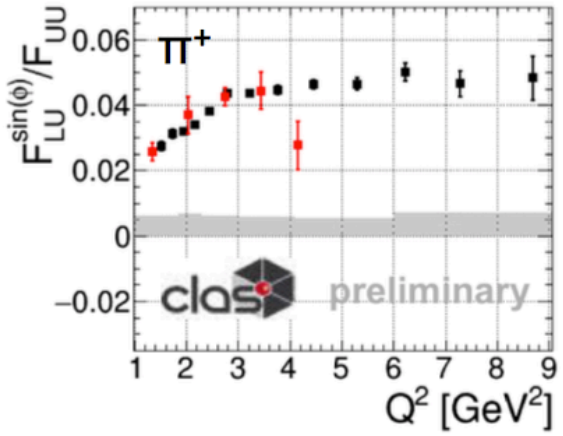
Observation of Beam-Spin Asymmetries in the Process $ep \to e'\pi^+\pi^- X$ with CLAS12
(Dated: August 31, 2020)

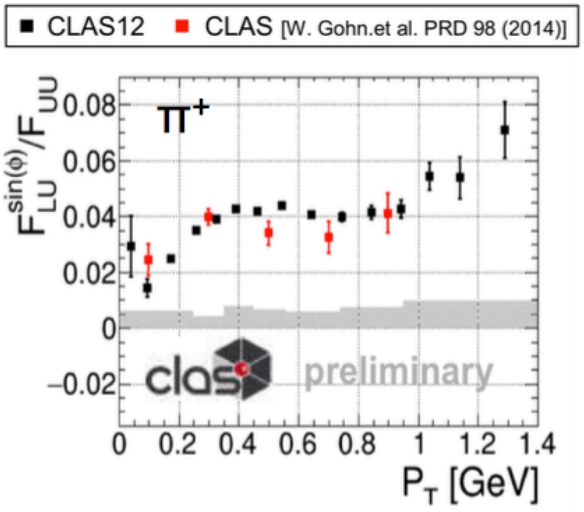
The observation of beam-spin asymmetries in dihadron production in semi-inclusive deep inelastic

With respect CLAS:
- superior statistics instrumental for multidimensional study
- extended range well inside the DIS regime

SIDIS







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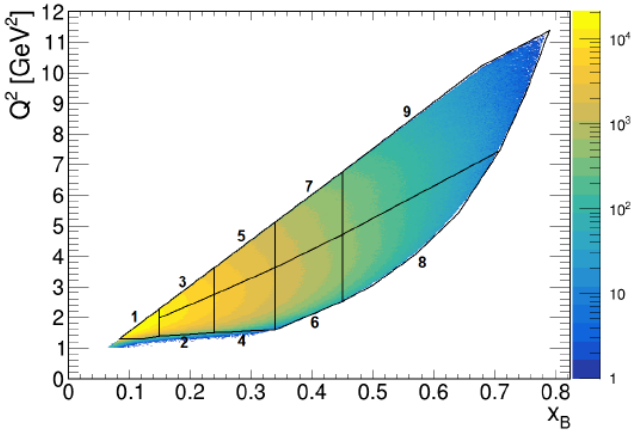
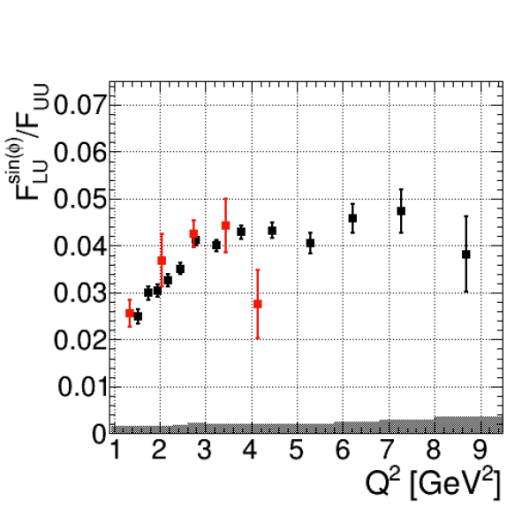
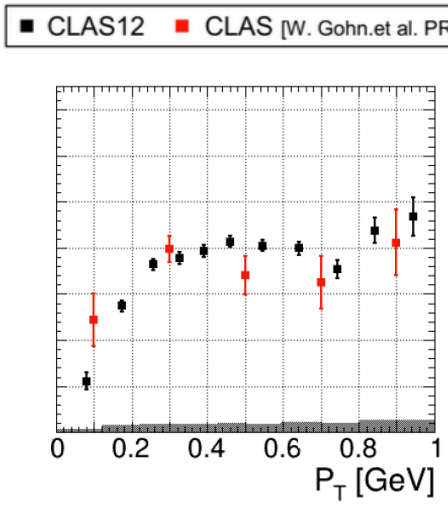
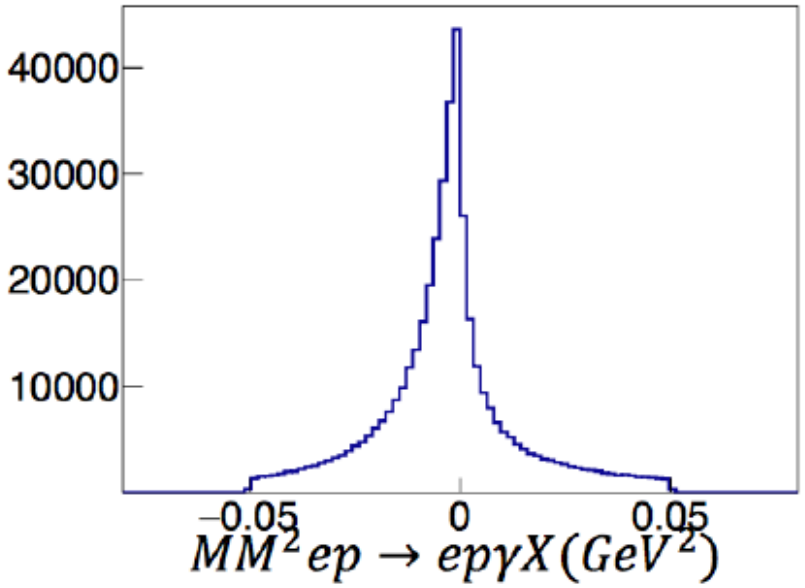


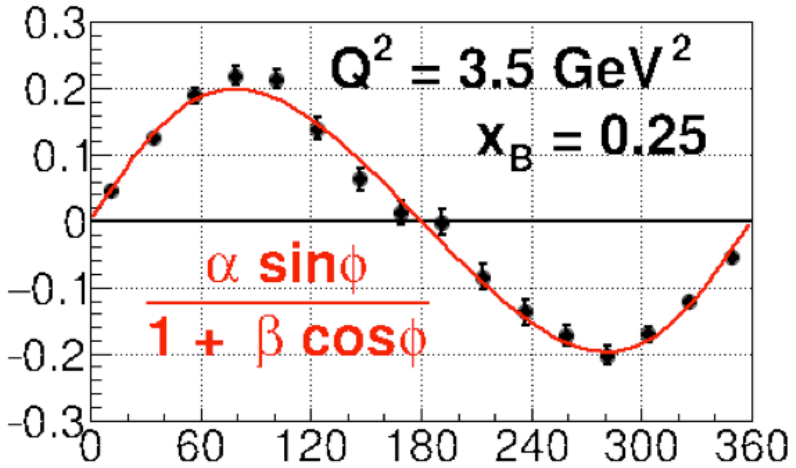




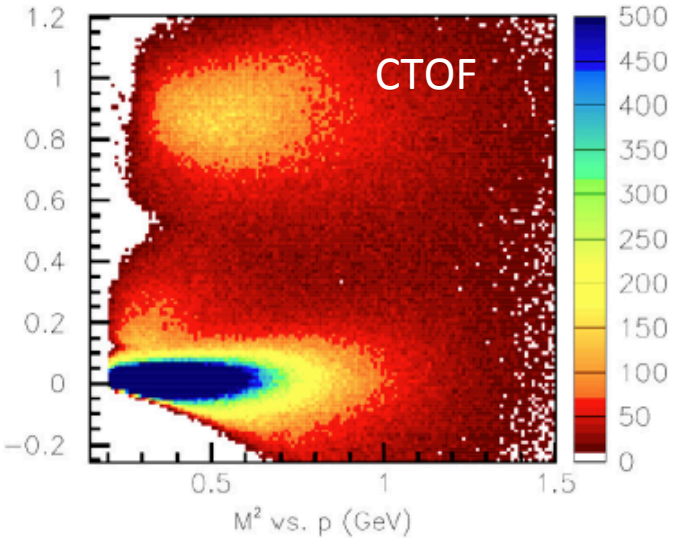
CLAS12 Data Analysis: DVCS

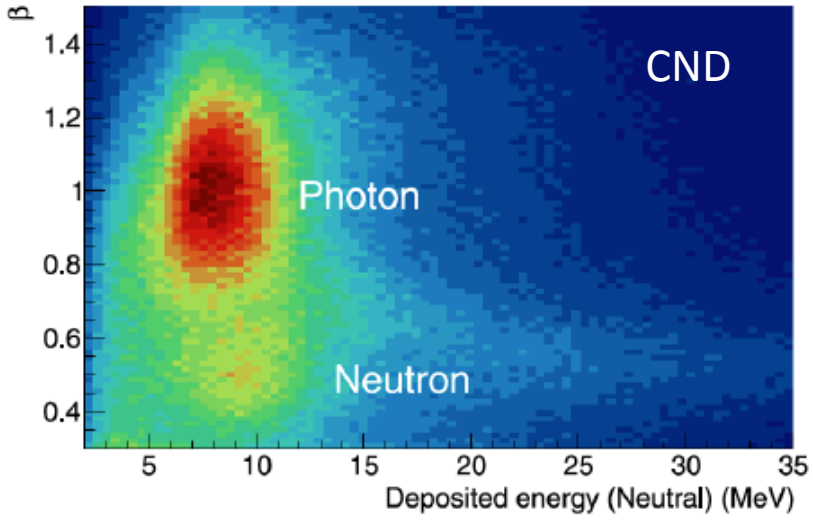


One bin of RGA data



CLAS12 central detector PID





RICH 1

ELSEVIER

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

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The CLAS12 Ring Imaging Cherenkov detector

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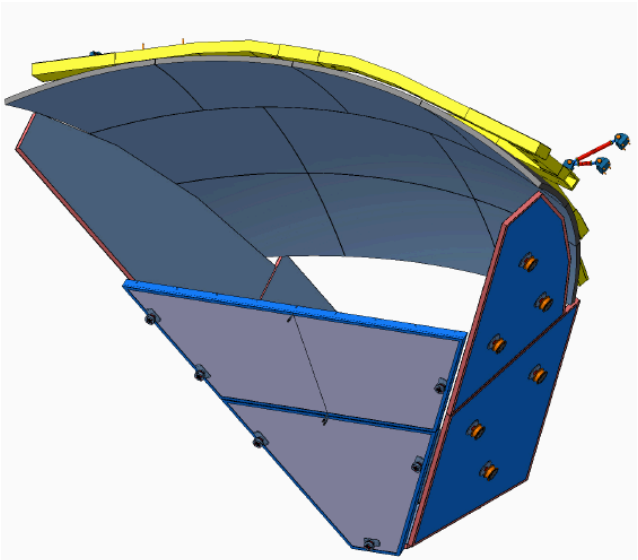
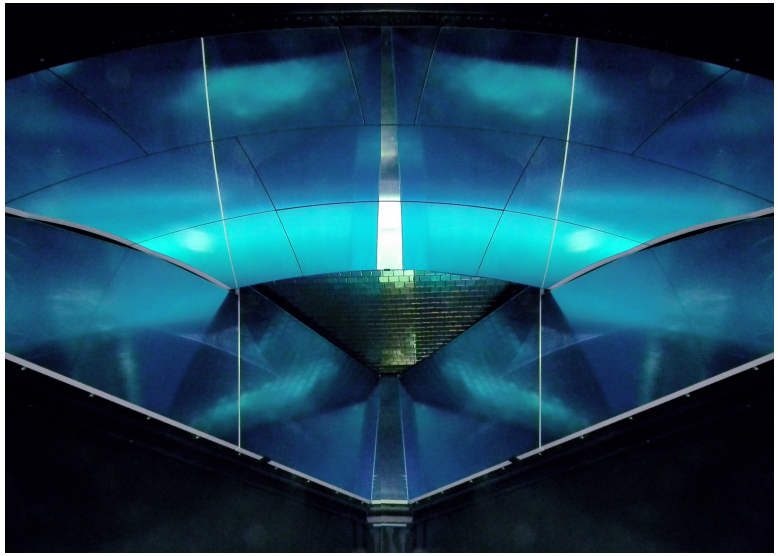
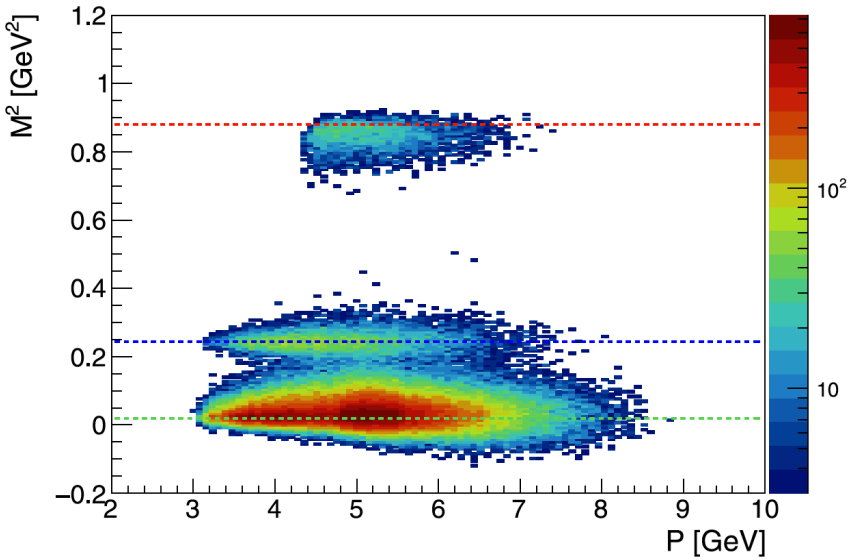






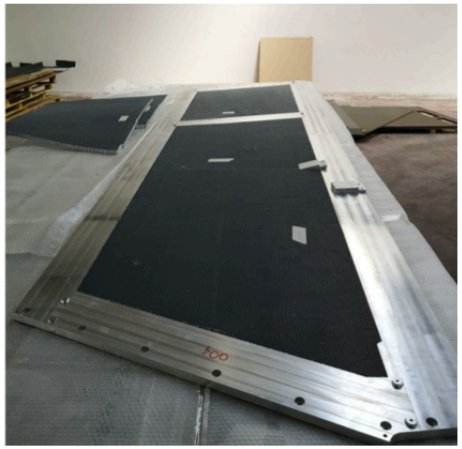
RICH 2

Installation expected at the end of 2021

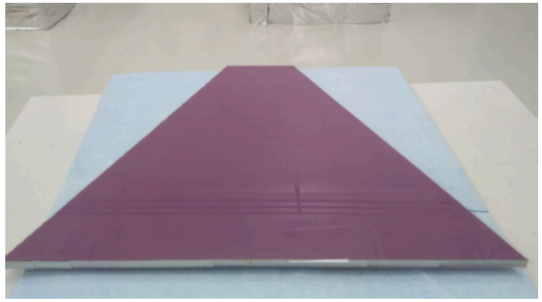
In time to create a left-right symmetric setup for the start of demanding polarized target experiments

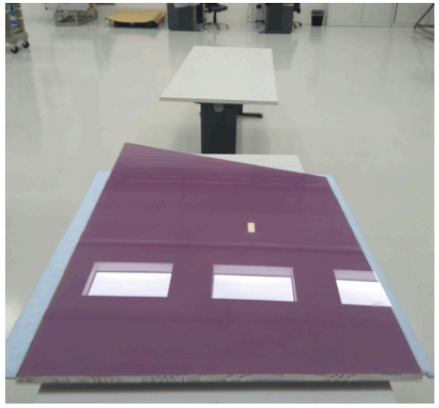
Component production in line with JLab schedule (only ~ 4 months delay due to COVID)

Mechanical composite structure



Glass-skin mirrors





Aerogel storage in dry-cabinets

CLAS12 Transverse Target

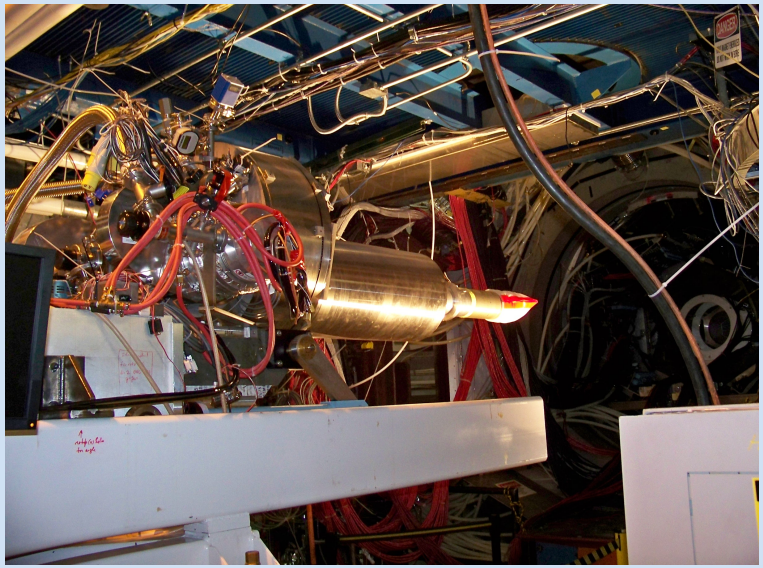
HD-Ice target vs standard nuclear targets (less luminosity for higher purity)

Advantages:

- **Minimize nuclear background**
  smaller dilution, no attenuation at large p_T
- **Weak holding field (BdL ~ 0.1 Tm)**
  wide acceptance, negligible beam deflection

Disadvantages:

- **Very long polarizing times (months)**
- **Sensitivity to local heating by charged beams**



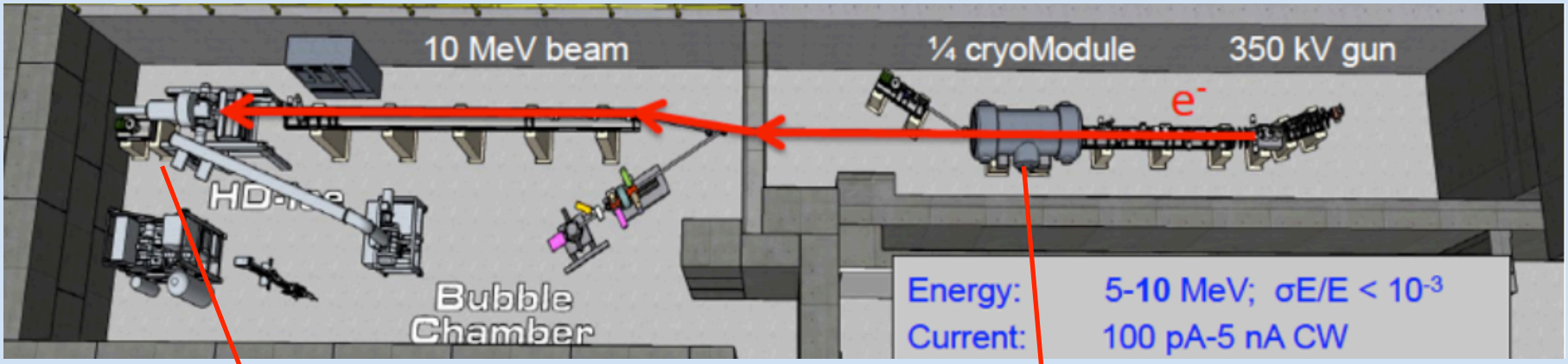
Opportunistic test beam in 2012 identified the critical aspects, now addressed in the new target design

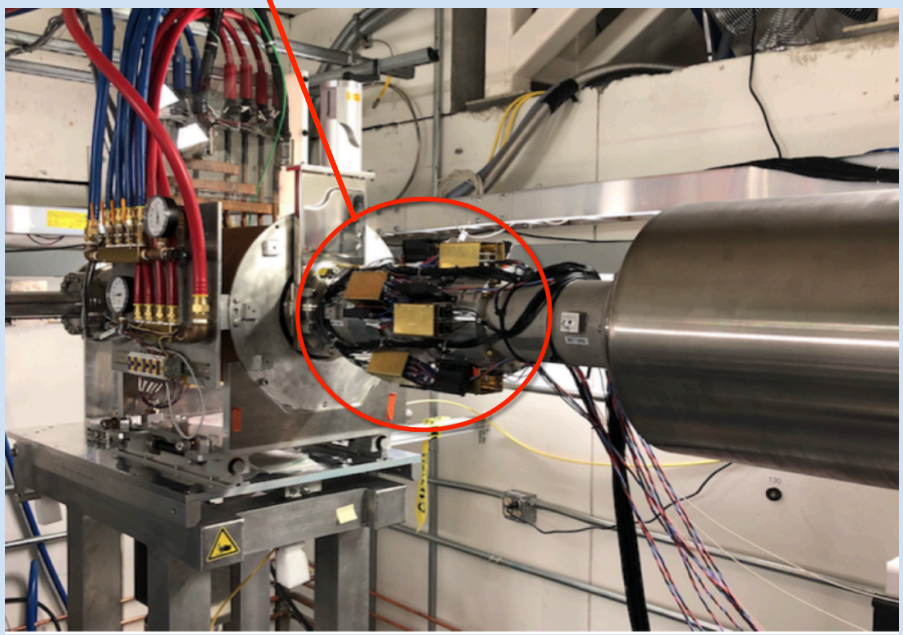
Chemical changes:
excluded by gas analysis

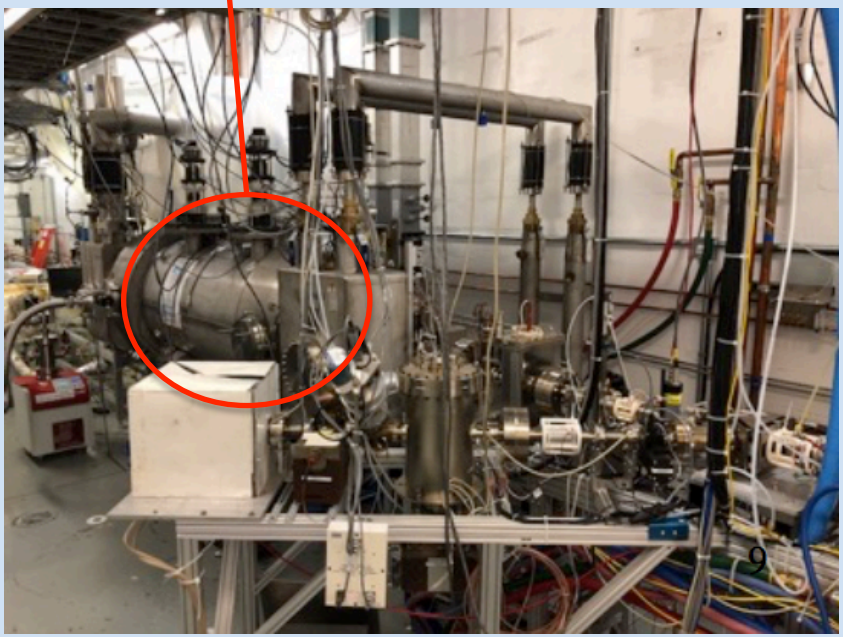
Hyperfine mixing:
use RF to align electron spins

Unpaired electrons:
control local T <-> polarization
faster raster
shorter Al cooling wires
higher purity Al
shorter HD cell

HD-ice Test Beam at UITF



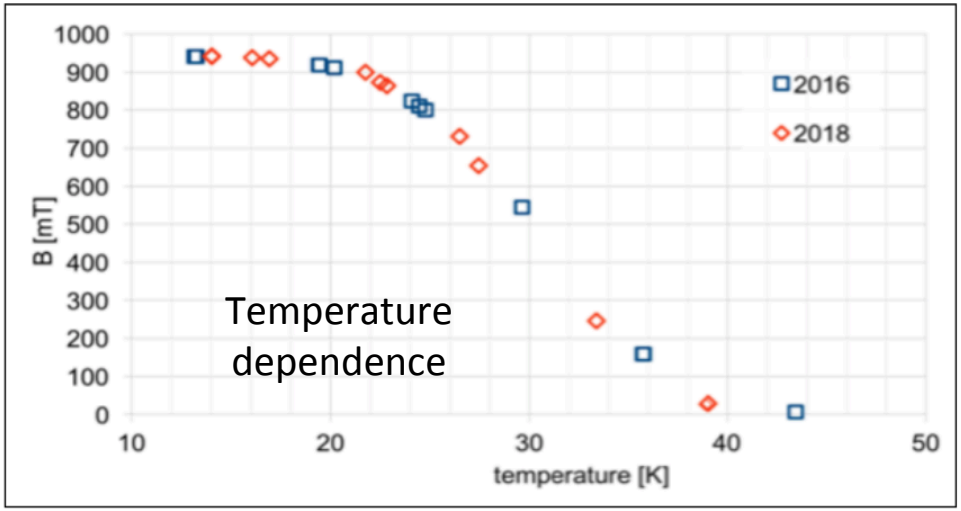


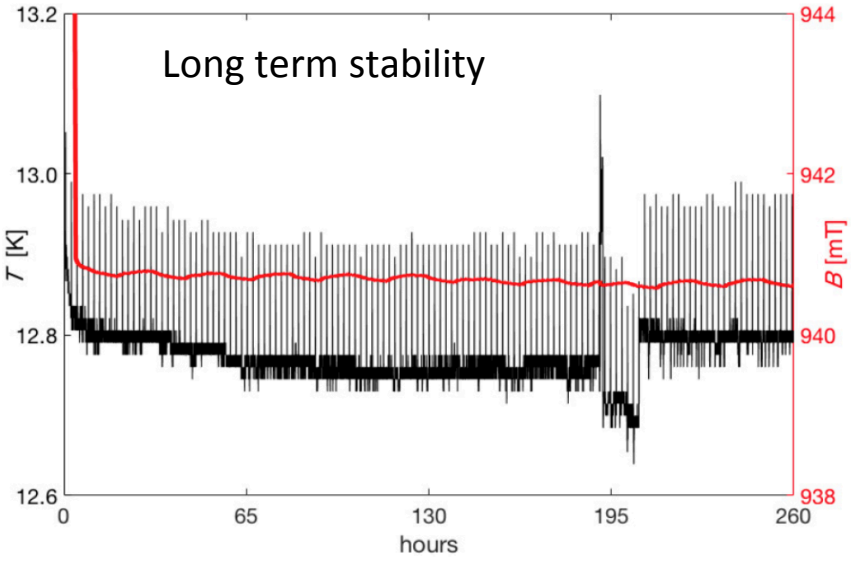


UITF beam line under commissioning: reached the target energy of 9.5 MeV
New target ready. First beam through IBC (empty target) expected within September.

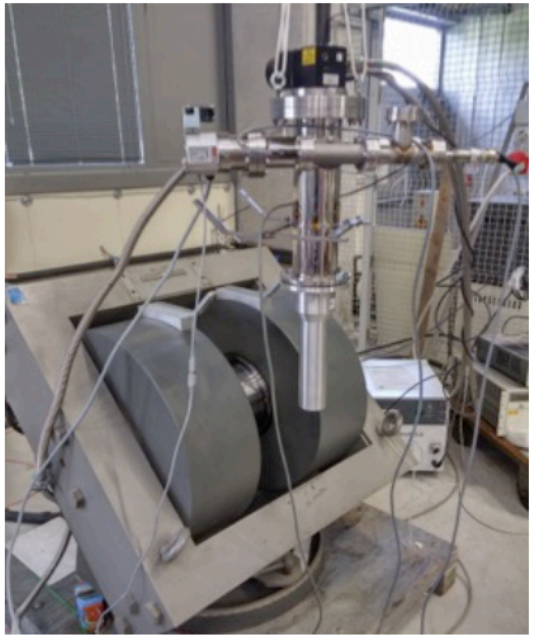
Target Holding Magnet

Bulk superconducting MgB_2 magnet
magnetization frozen at the transition to superconductor





- ✓ Decouple mechanics
- ✓ Reduce material budget
- ✓ Increase acceptance
- ✓ Simplify cryostat
- ✓ Suppress quenches



Run Group H

RGH team is working hard to make high impact RGH experiments a reality

Experiment	Contact	Title	Rating	PAC days
C12-11-111	M. Contalbrigo	Transverse spin effect in SIDIS at 11 GeV with a transversely polarized target using CLAS12	A	110
C12-12-009	H. Avakian	Measurement of transversity with di-hadron production in SIDIS with a transversely polarized target	A	110
C12-12-010	L. Elauadrhiri	Deeply Virtual Compton scattering at 11 GeV with transversely polarized target using the CLAS12 detector	A	110

Important progresses since the original approval:

Science case has inflated towards EIC

CLAS12: up and running
ideal for SIDIS and exclusive channels

RICH: 1st module is already taking data (since day 1) and 2nd module is coming

HD-ice: ready to assess performance vs working conditions at UITF
new magnet configuration to reduce complexity and material budget

We request the PAC to confirm the conditionally approved beam time (110 days)