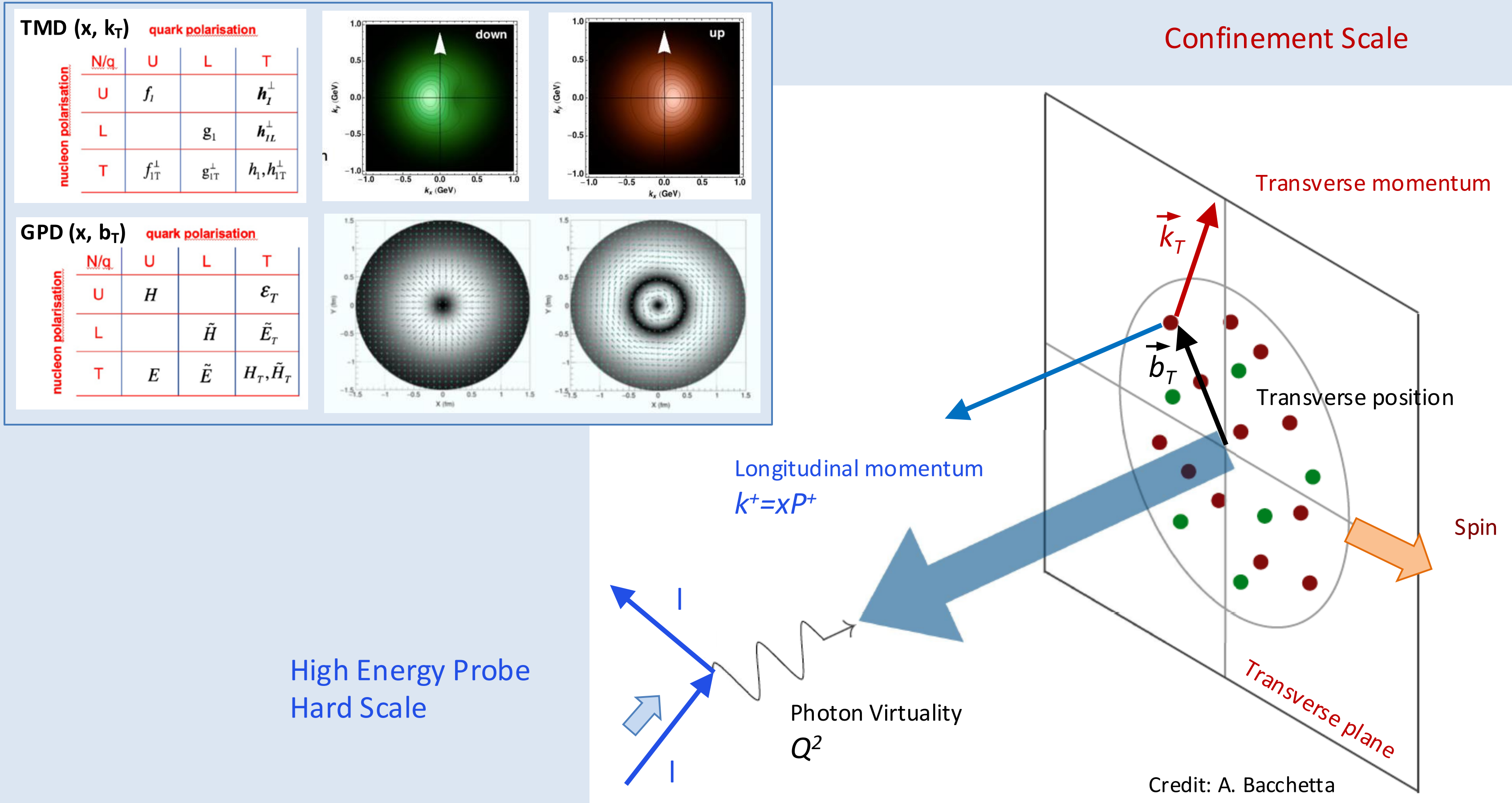
Hall-B Run Group H
CLAS12 Experiments with a Transversely Polarized Target

Contalbrigo Marco - INFN Ferrara

CLAS Collaboration Meeting, 10th July 2025

3D Nucleon Structure by DIS

Confinement Scale



TMD (x, k_T) quark polarisation

nucleon polarisation	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	$h_1, h_{1T}^\perp$

GPD (x, b_T) quark polarisation

nucleon polarisation	U	L	T
U	H		$\mathcal{E}_T$
L		$\tilde{H}$	$\tilde{E}_T$
T	E	$\tilde{E}$	$H_T, \tilde{H}_T$

Transverse momentum

Transverse position

Longitudinal momentum
$k^+=xP^+$

Spin

Photon Virtuality
Q^2

Transverse plane

High Energy Probe
Hard Scale

Credit: A. Bacchetta

Run Group H

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. Elouadrhiri	Deeply Virtual Compton scattering at 11 GeV with transversely polarized target using the CLAS12 detector	A	110

Access to unique observables in

SIDIS hadron

SIDIS Di-hadron

DVCS

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

RGH experiment status (with HDice) confirmed at PAC48 in 2020 (during jeopardy process) with C1 condition on target performance

RGH status modified to C2 in 2024 (during jeopardy process) to proper evaluate the target change

Gather unprecedented information on

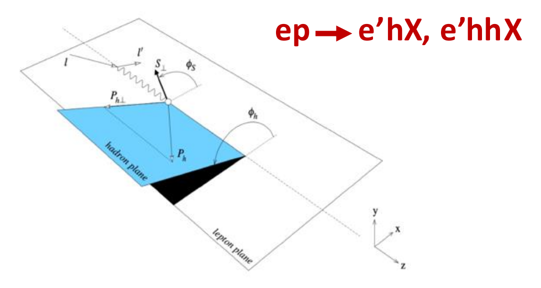
Transversity

Tensor charge

Sivers, $h_{1T}^{\perp}$, $g_{1T}^{\perp}$, $H_1^{\perp}$

CFF and GPD E

What we know: TMDs

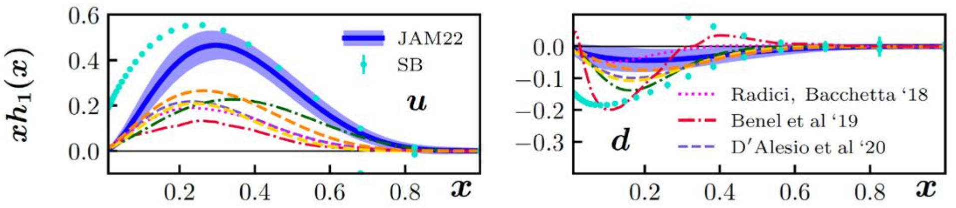


ep → e'hX, e'hhX

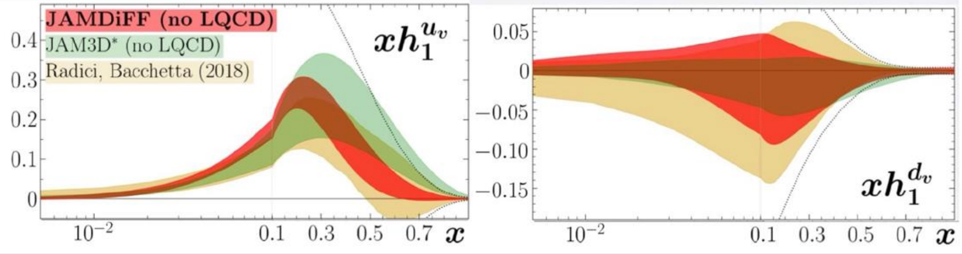
Large sensitivity expected in the valence region
Lack of data above x = 0.3 and no fully differential (4D) analysis available so far

CLAS12 can be the first experiment in achieving a 4D analysis in the valence

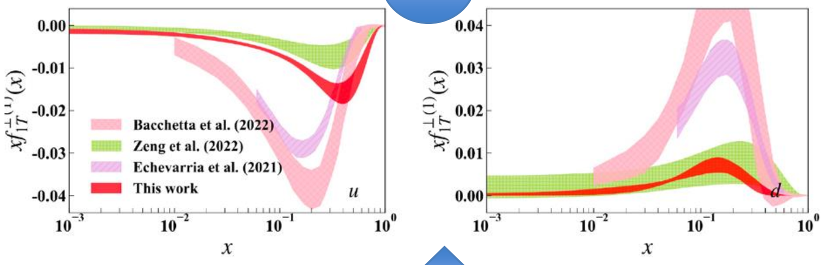
Transversity from single hadron SIDIS



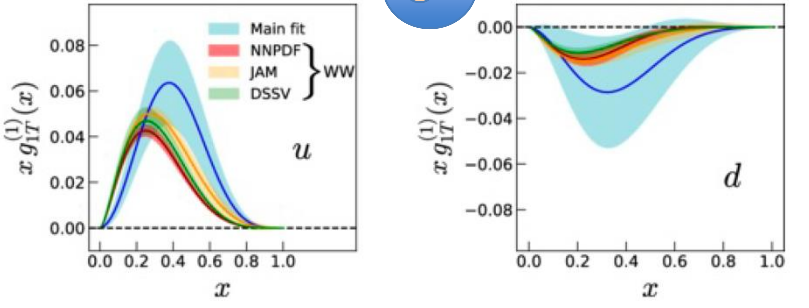
Transversity from di-hadron SIDIS



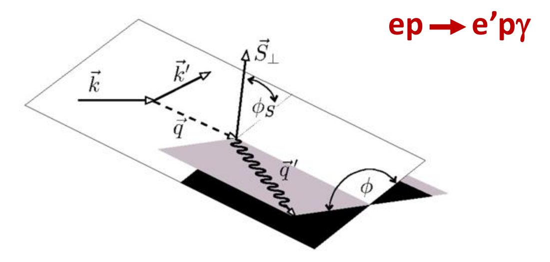
Sivers



Kotzinian-Mulders



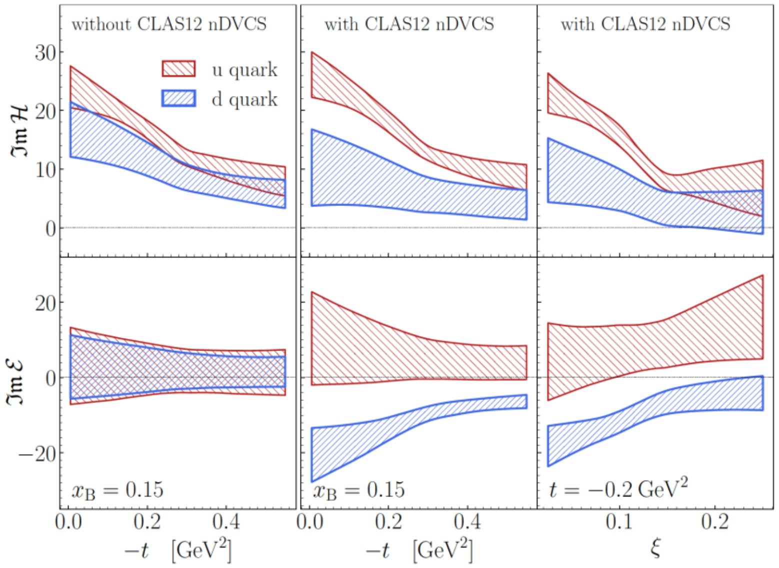
What we know: GPDs



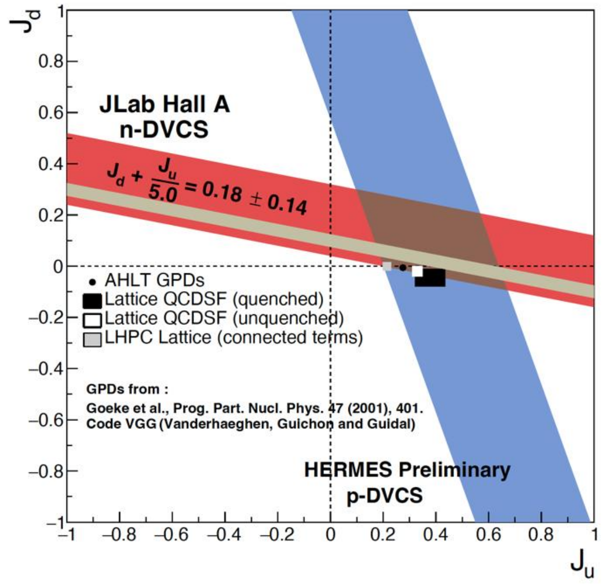
GPD E is essential to pin down the quark dynamics (OAM)
is poorly known and hard to analyze in flavor

CLAS12 can be the first experiment in exploiting both
A_{LU} measurement on neutron with
A_{UT} measurement on proton

CLAS12, Phys.Rev.Lett. 133 (2024) 21, 211903

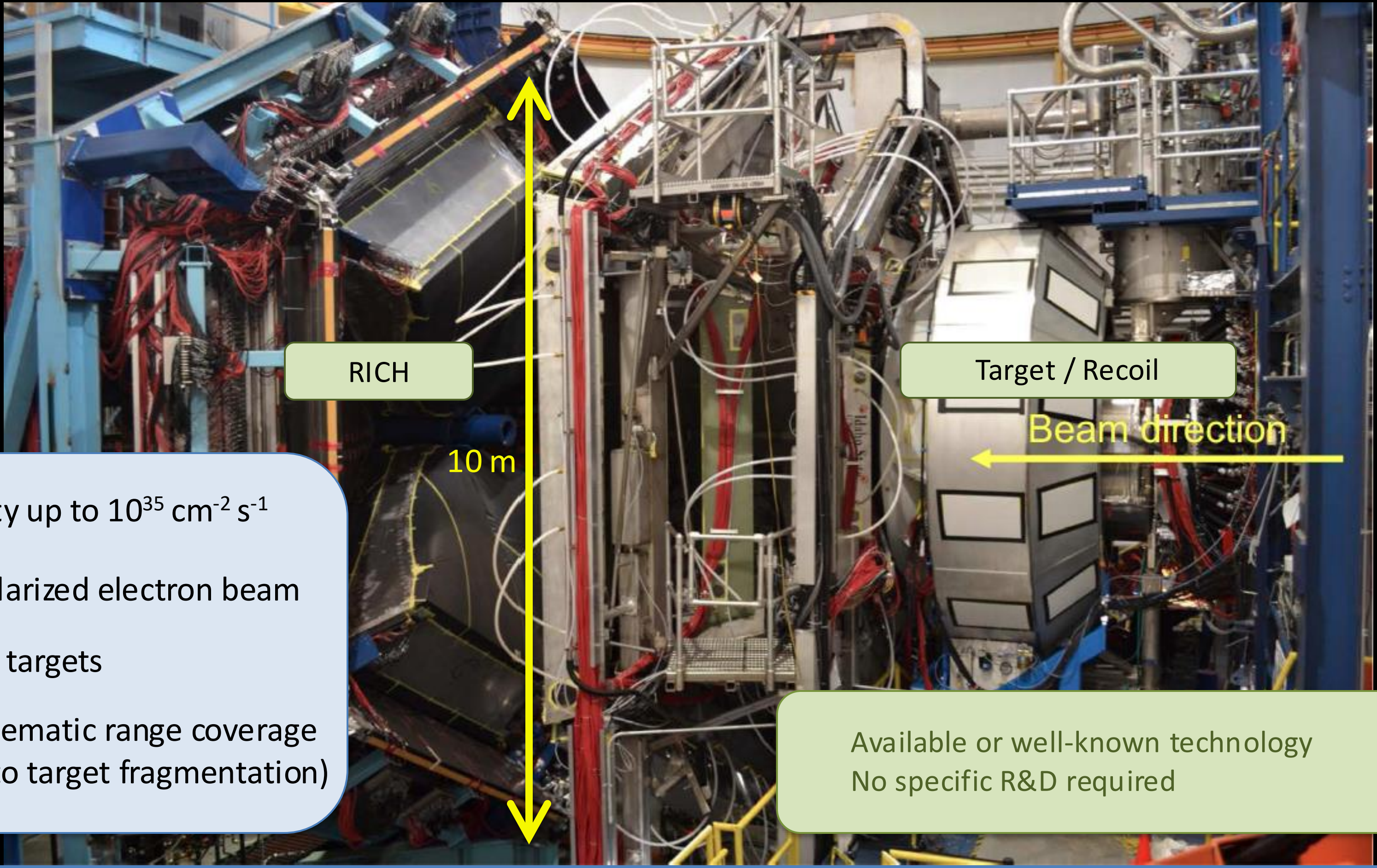


$$J_q = \lim_{t\to 0} \int_{-1}^{1} dx\, x\left[H_q(x,\xi,t) + E_q(x,\xi,t)\right]$$



Run Group H

Large acceptance spectrometer. Operative since 02/18



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

Highly polarized electron beam

Polarized targets

Broad kinematic range coverage (current to target fragmentation)

Available or well-known technology
No specific R&D required

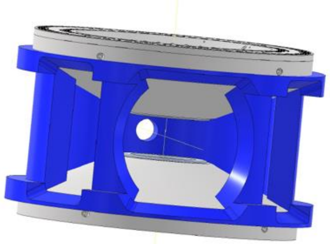
RGH Target & Magnet

Most viable solution to prioritize physics

Consolidated dynamically polarized NH_3 technology

Designed based on already successful realizations

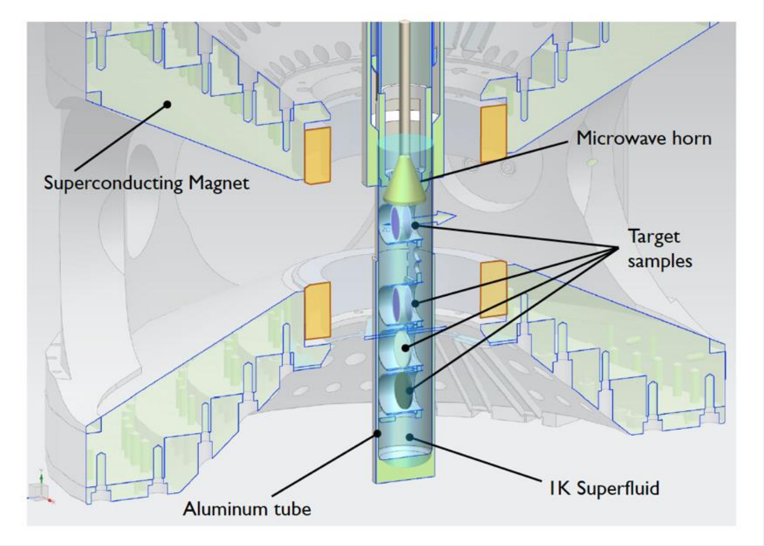
Hall-A G2p-Gep target (copy optimized for HTCC)
Hall-C E12-15-005 magnet (copy optimized for recoil detection)

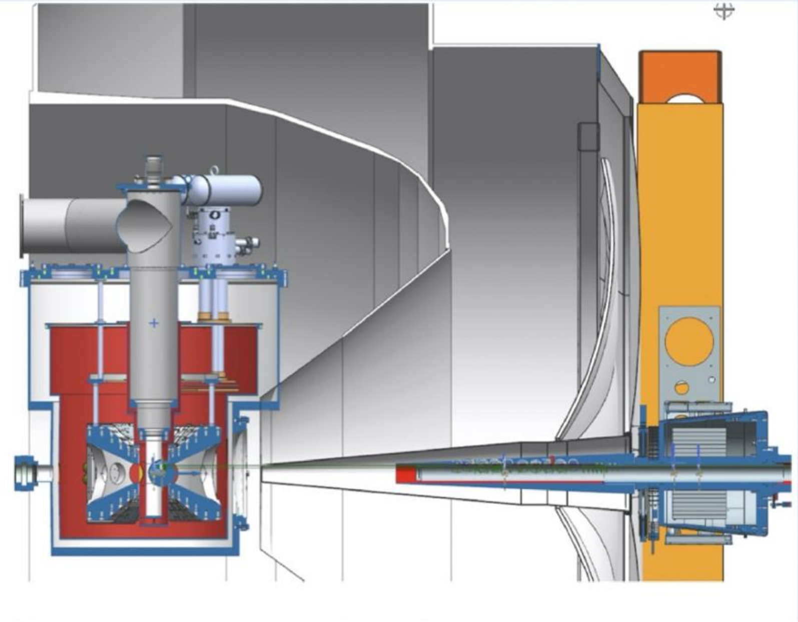


5T dipole acceptance:

± 25° horizontal

± 65°˙ horizontal



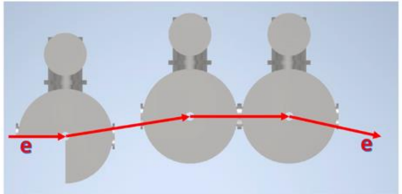


RGH Beam Line

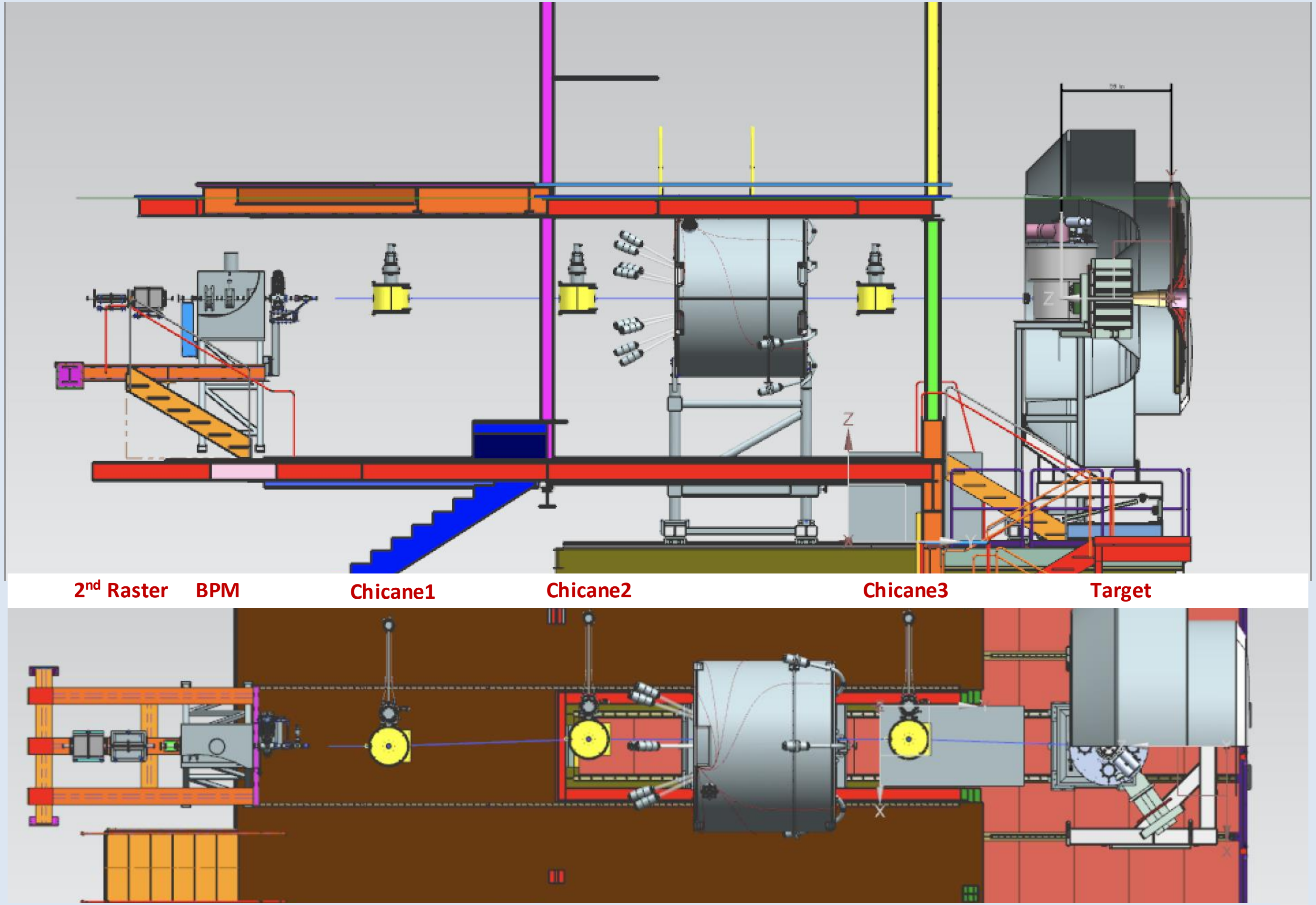
Based on

existing 0.7 mm raster

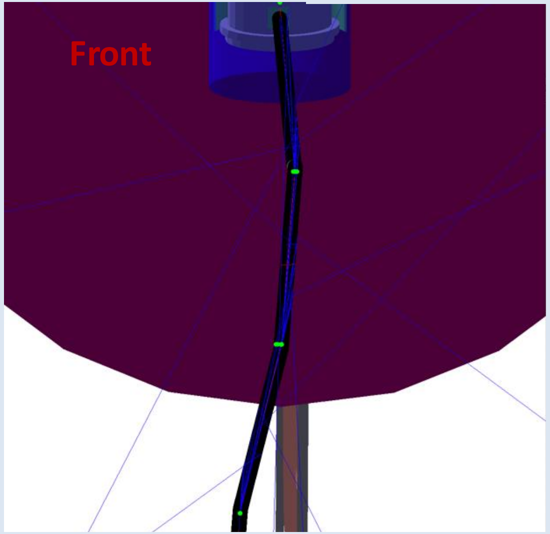
commercial 7.5T magnets



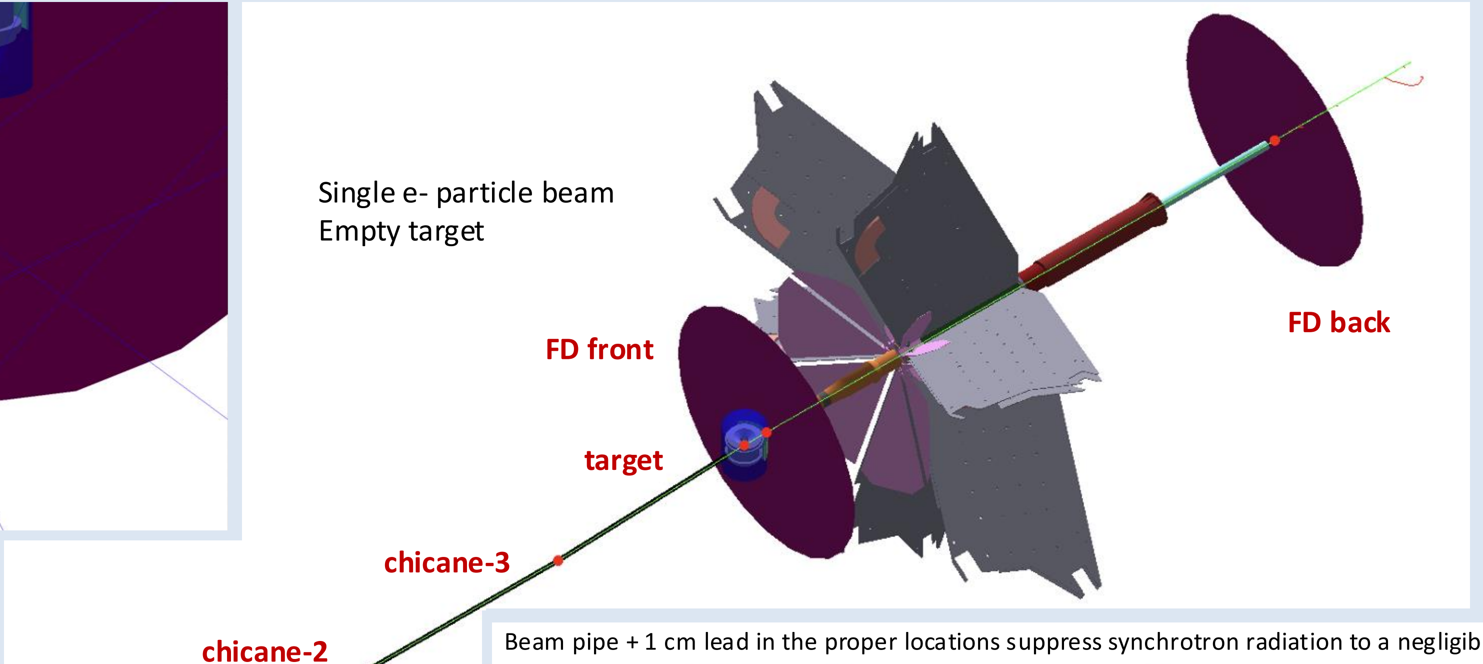
- ✓ space
- ✓ synchrotron radiation
- ✓ beam rastering



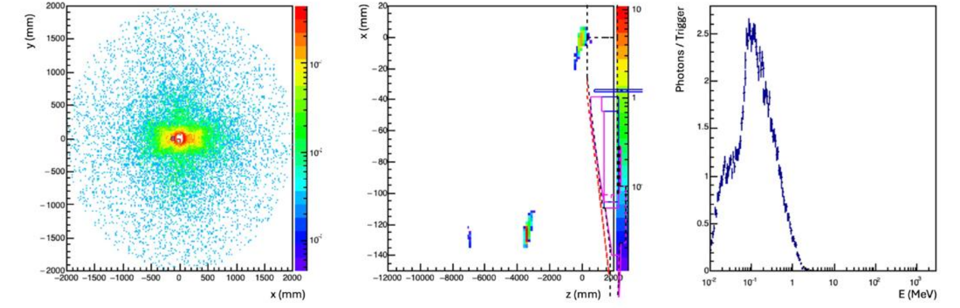
RGH Beam Line



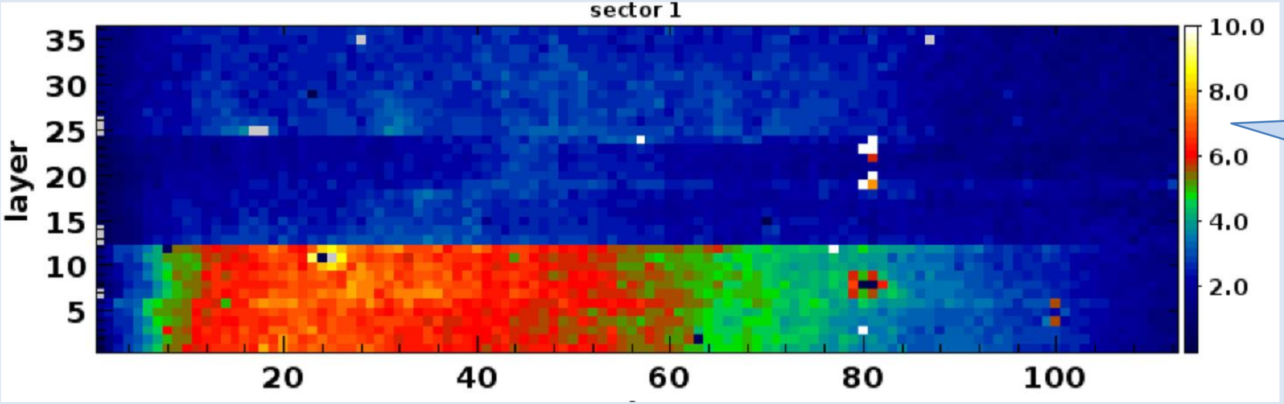
Single e- particle beam
Empty target



Beam pipe + 1 cm lead in the proper locations suppress synchrotron radiation to a negligible level



RGH Background

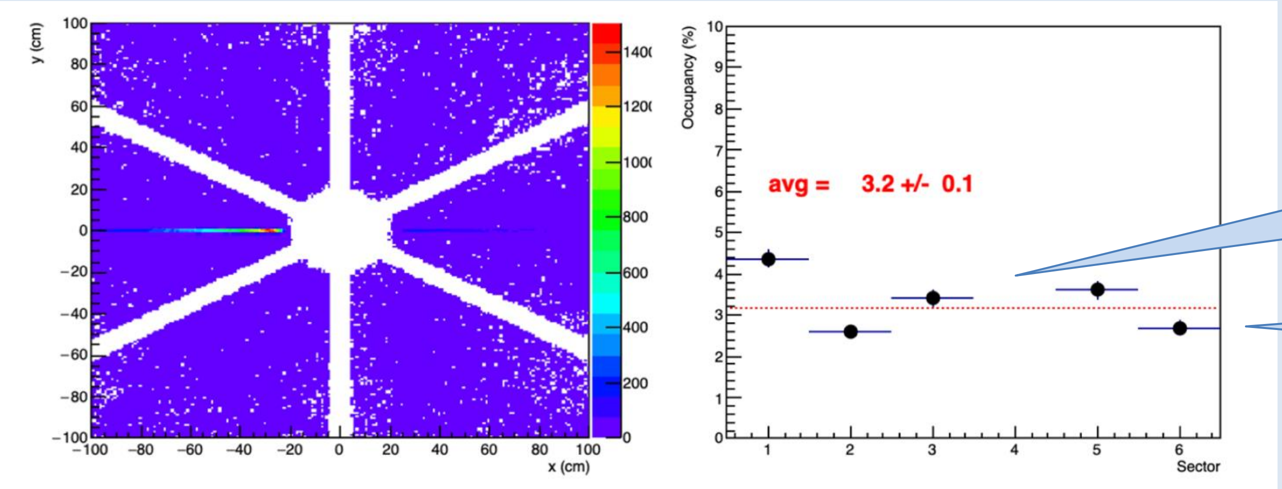


RGC DATA

Present performance*

Typical DC occupancy measured at CLAS12

*No high-lumi



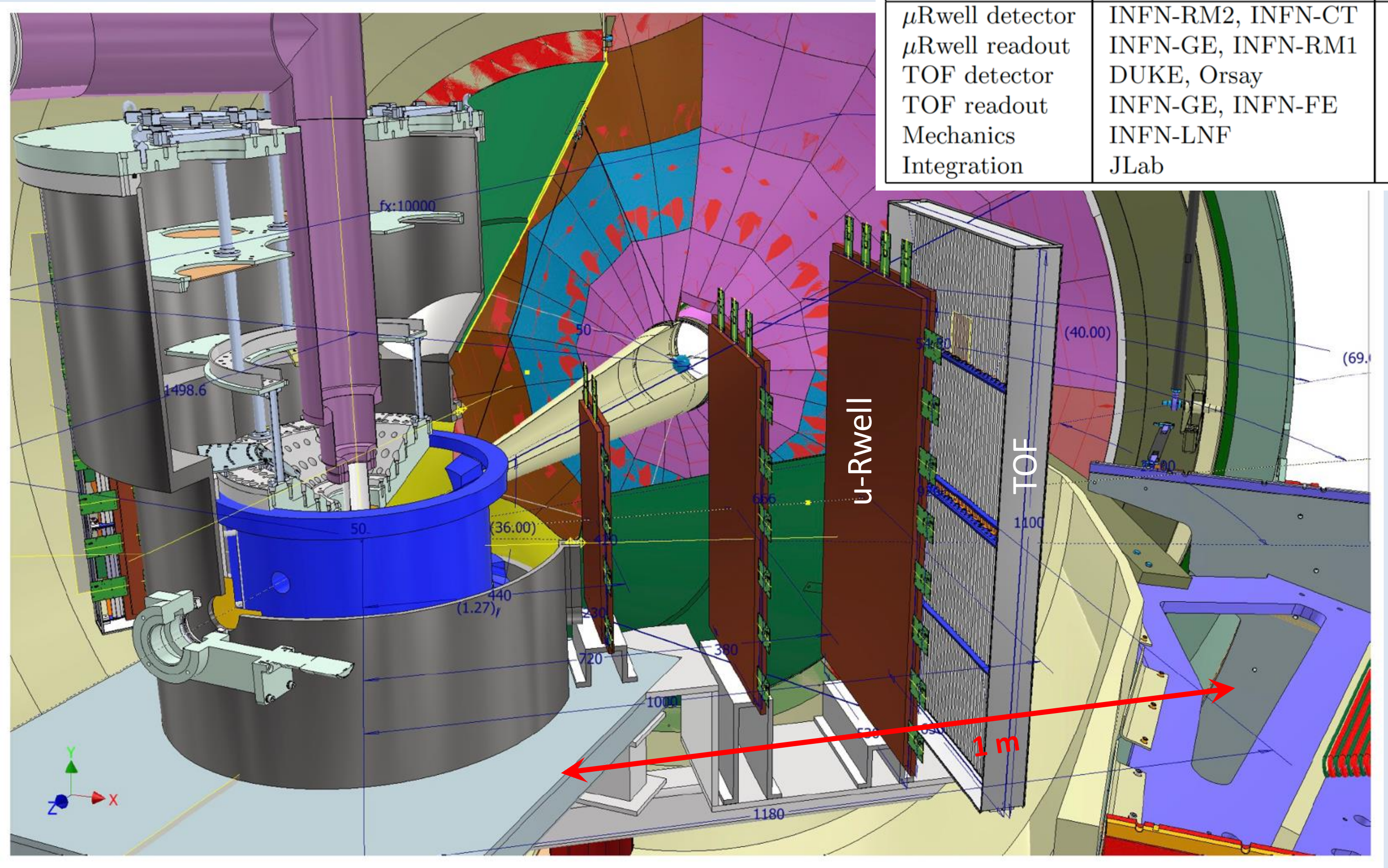
RGH MC

Assume to switch OFF DC in sector 4 RICH in sector 3

x2 with CLAS12 gate

Target & Recoil Detector

Task	Leading Institution	Expertise
μRwell detector	INFN-RM2, INFN-CT	CLAS12 upgrade, ePIC tracking
μRwell readout	INFN-GE, INFN-RM1	SBS GEM tracking readout
TOF detector	DUKE, Orsay	EIC KLM, CLAS12 CND
TOF readout	INFN-GE, INFN-FE	CLAS12 FT and RICH readout
Mechanics	INFN-LNF	CLAS12 RICH mechanics
Integration	JLab	Hall-B infrastructure and beam

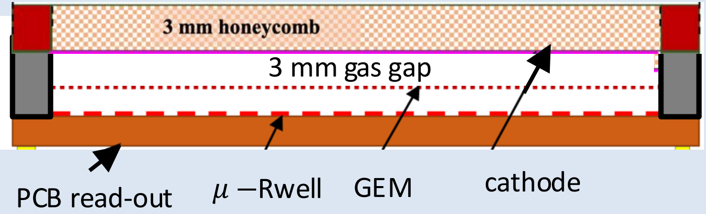


Recoil Tracking

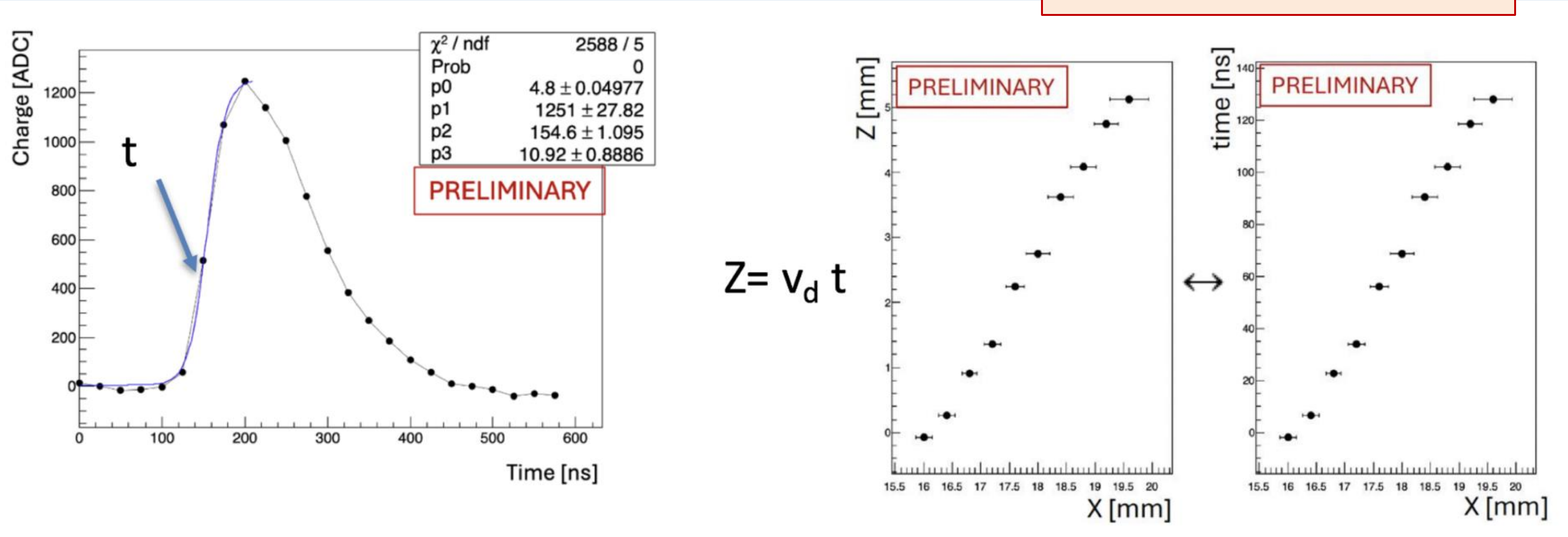
μRwell as spin off of the high-lumi project (various prototypes from 10 x 10 cm^2 up to 40 x 46 cm^2 exist) / synergy with ePIC

GEM-μRwell to provide 2D information with 100 μm resolution

- ✓ Wanted gain/efficiency is preserved below 600 V safe bias
- ✓ 5 ns time resolution can be achieved from signal shape fit
- ✓ TPC-like readout to correct the impinging angle has been proven



Test-beam at CERN in Oct '24



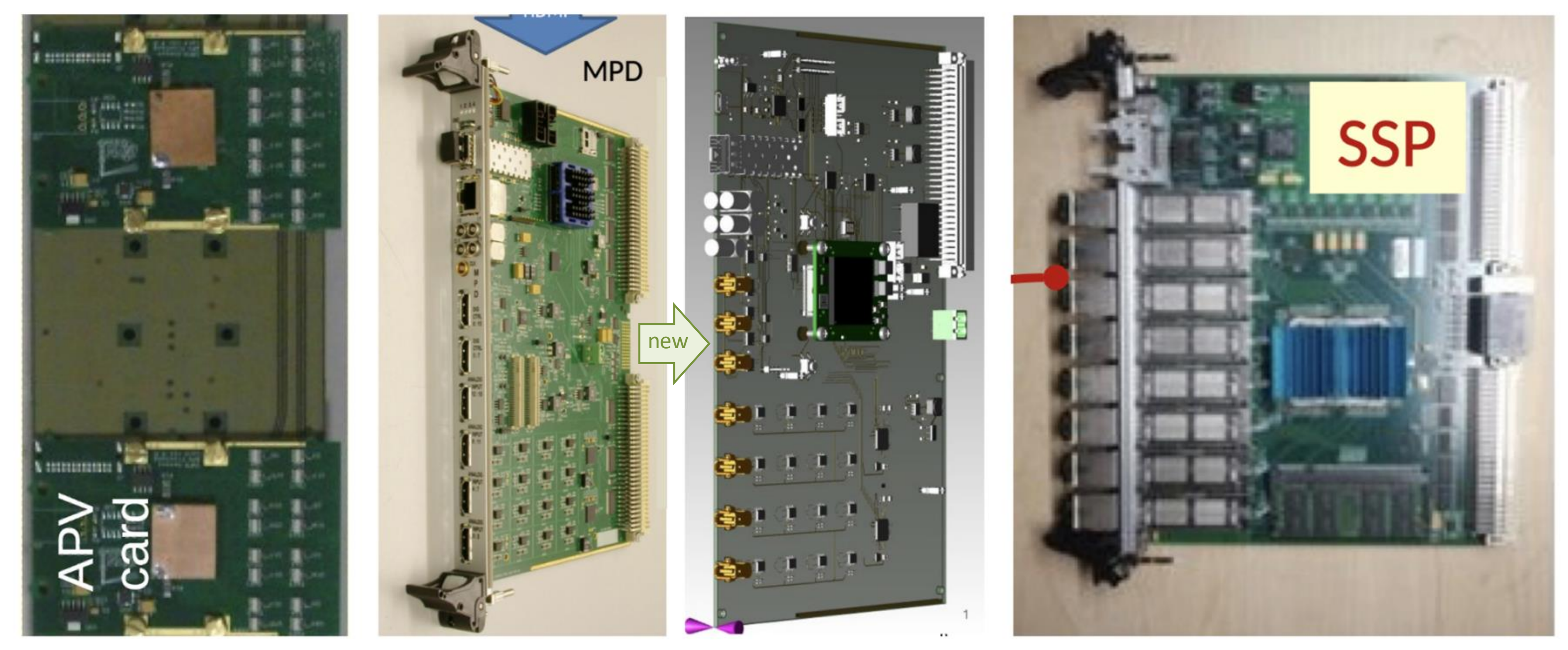
$$Z = v_d\, t$$

Recoil Tracking Readout

Enough (> 10 k) spare channels exist from INFN GEM project for SBS in Hall-A

Based on the well-known APV25 chip + SSP DAQ (upgraded version of MPD under study)

- ✓ Able to cope with 500 kHz/cm^2 and 60% occupancy
- ✓ Same system used with the μRwell prototypes



Recoil TOF

Scintillating bars readout by SiPM

Synergy with ePIC (dRICH tagger)

Proven to match 100 ps, e.g. by PANDA and MUSE.

- ✓ Flexible geometry to provide spatial matching and control of accidentals
- ✓ Compact layout

T. Rostomyan, NIMA 986 (2021) 164801 – MUSE experiment

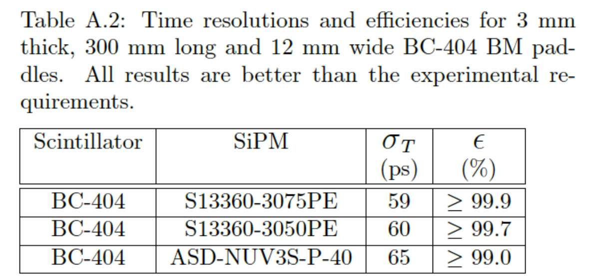
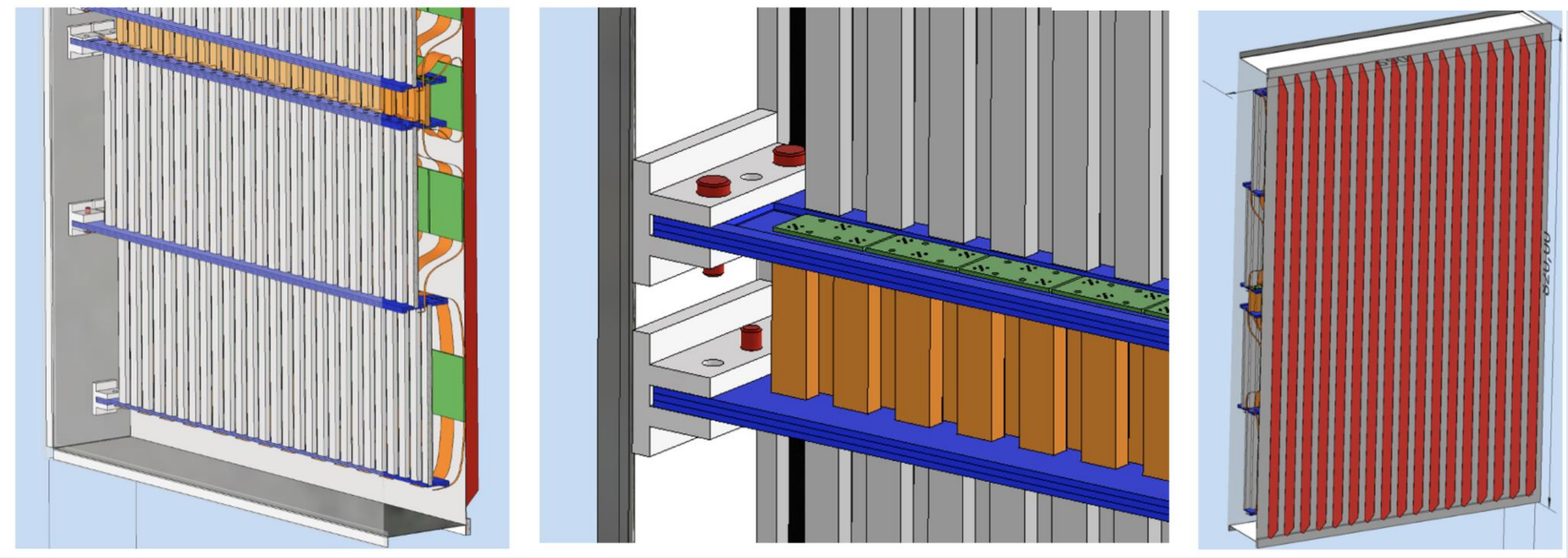


Table A.2: Time resolutions and efficiencies for 3 mm thick, 300 mm long and 12 mm wide BC-404 BM paddles. All results are better than the experimental requirements.

Scintillator	SiPM	σ_T (ps)	ϵ (%)
BC-404	S13360-3075PE	59	≥ 99.9
BC-404	S13360-3050PE	60	≥ 99.7
BC-404	ASD-NUV3S-P-40	65	≥ 99.0



Recoil TOF Readout

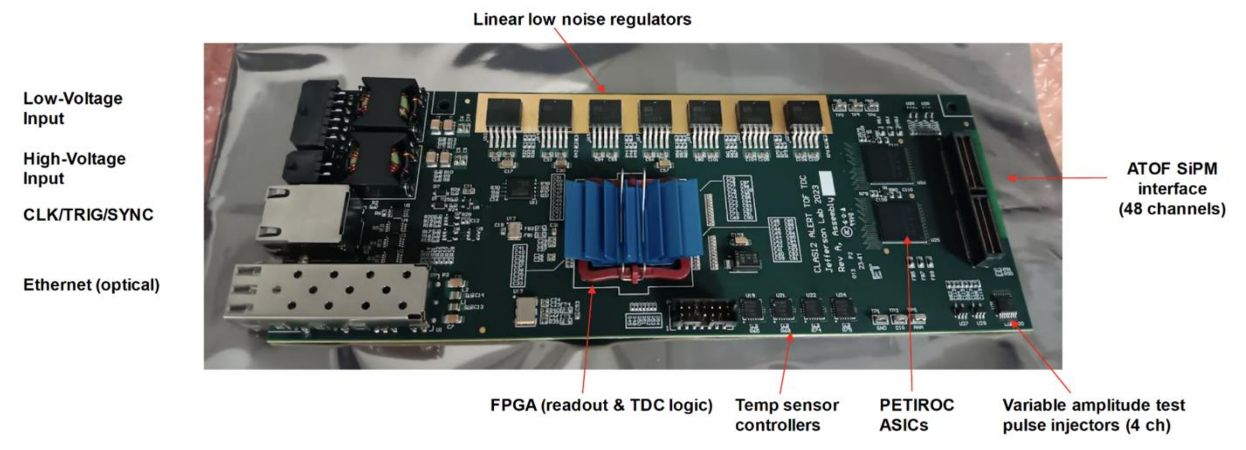
Enough (> 1 k) spare channels from RICH readout to be updated to ALERT firmware to get < 100 ps readout jitter

RICH readout

- ✓ MAROC dynamic range can cope with multi-photon signals
- ✓ Clock distribution supports 100 ps readout precision

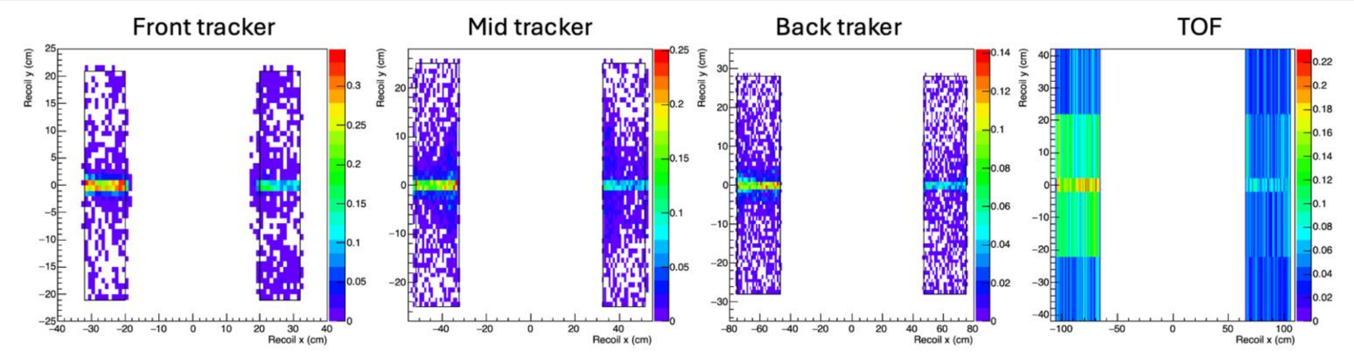
Option to adopt CLAS12-ALERT readout

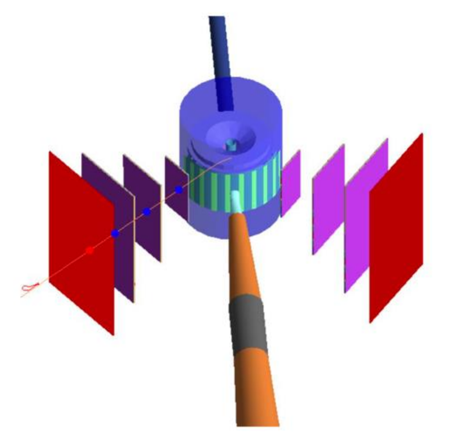
- ✓ PETIROC has a better dynamic range (multi-photons)
- ✓ Clock distribution supports 50 ps readout precision

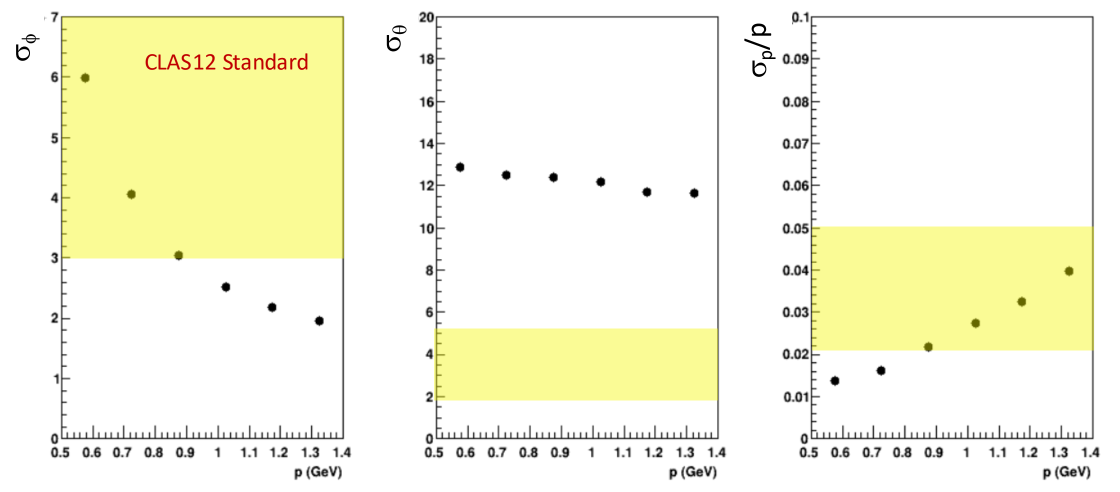


Recoil Performance

Recoil technology can cope with the background rates



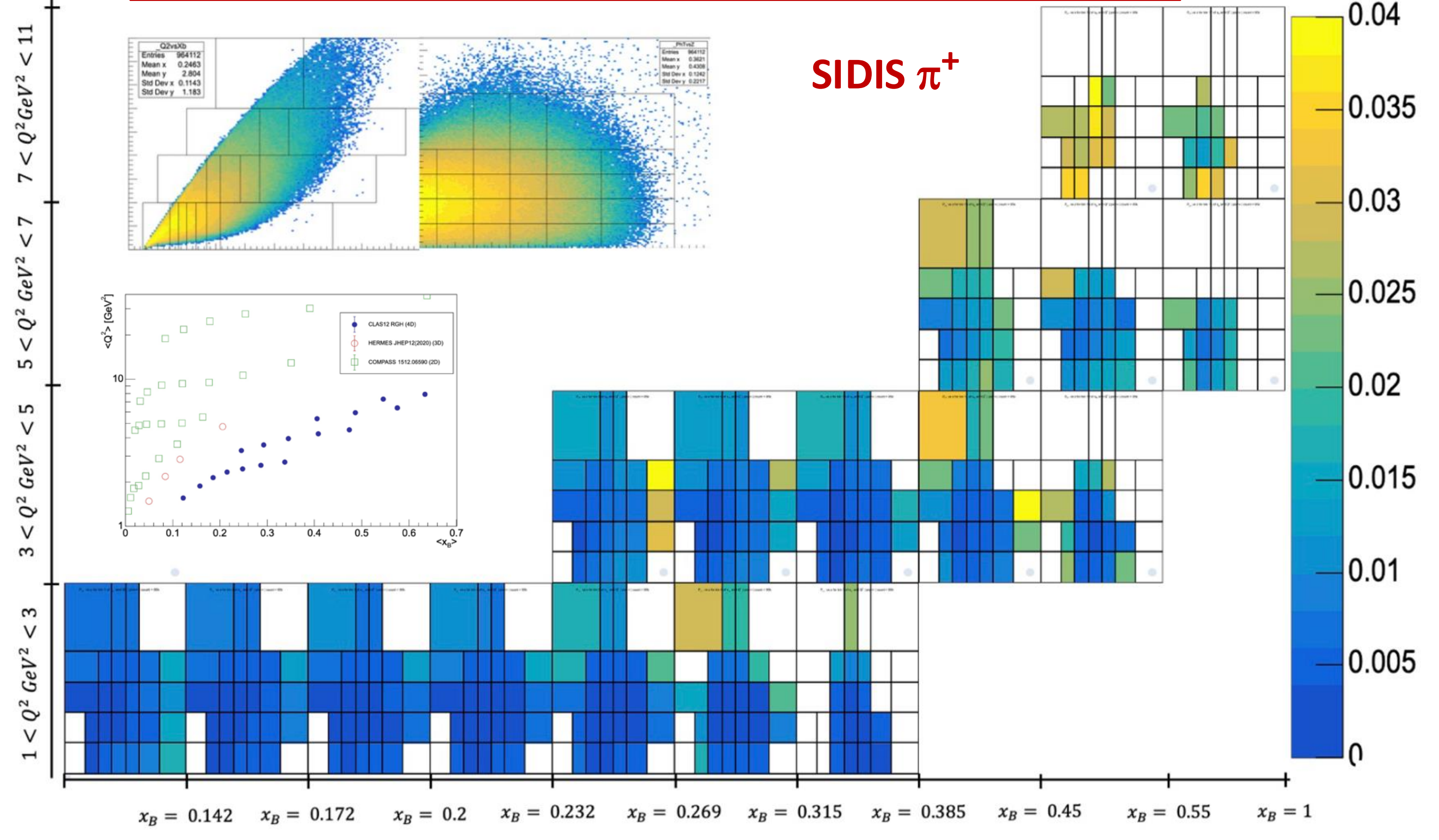




Recoil reconstruction is adequate even in the presence of background

4D Map

100 PAC days reqeusted to achiveve the frst 4D (x, Q^2, z, p_T) measurement

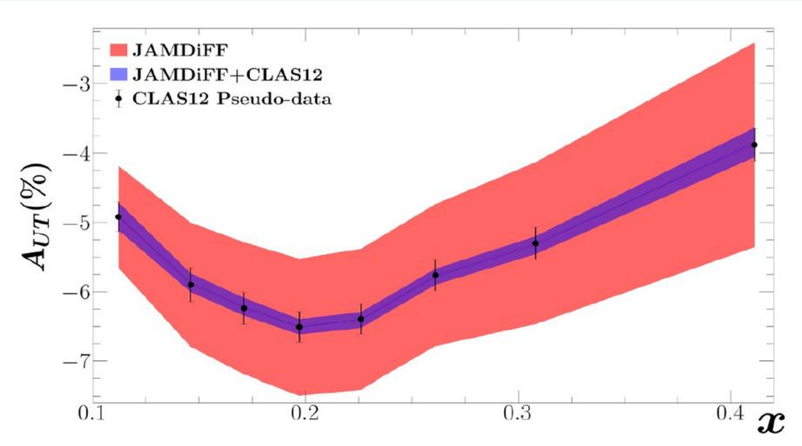


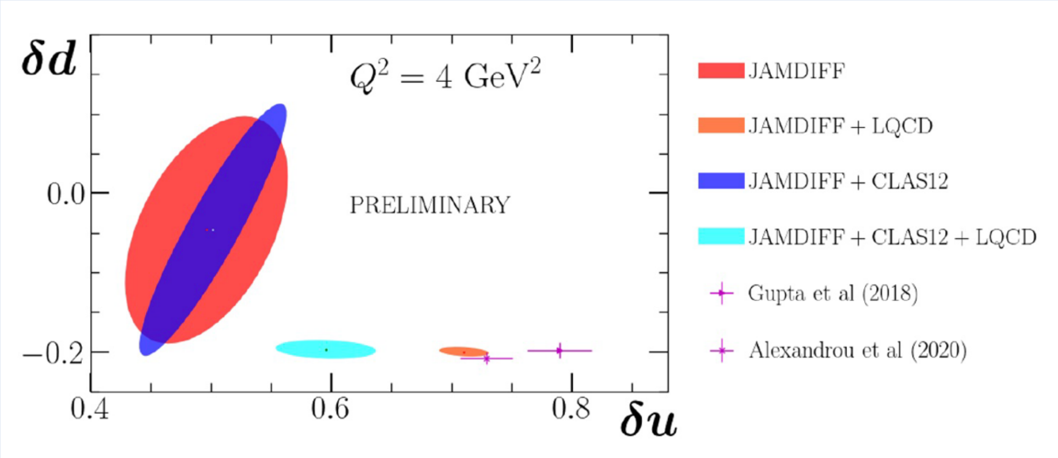
Tensor Charge from SIDIS

Fundamental quantity related to BSM physics: EDM and tensor coupling

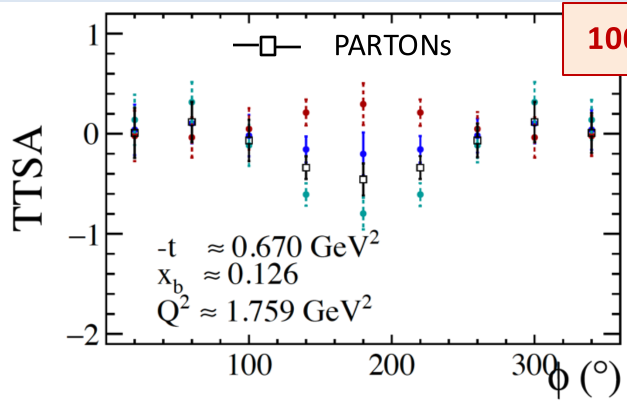
Projections with and without CLAS pseudo-data (with lattice inputs)

100 PAC days requested to be competitive to lattice for δu



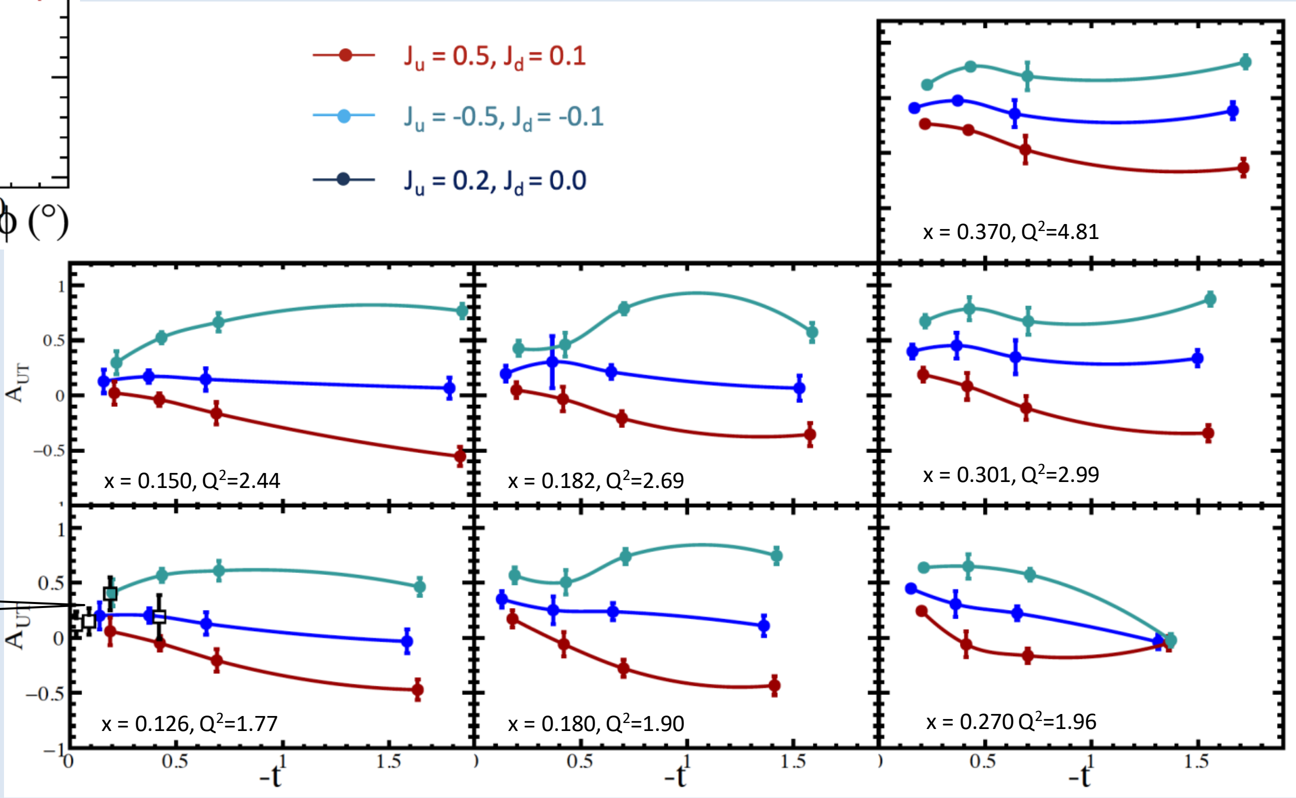


OAM from DVCS



100 PAC days requested to get unprecedented access to elusive quark angular momenta

Supersede the only other A_{UT} measurement. Pair with A_{LU} measurement done by RGB



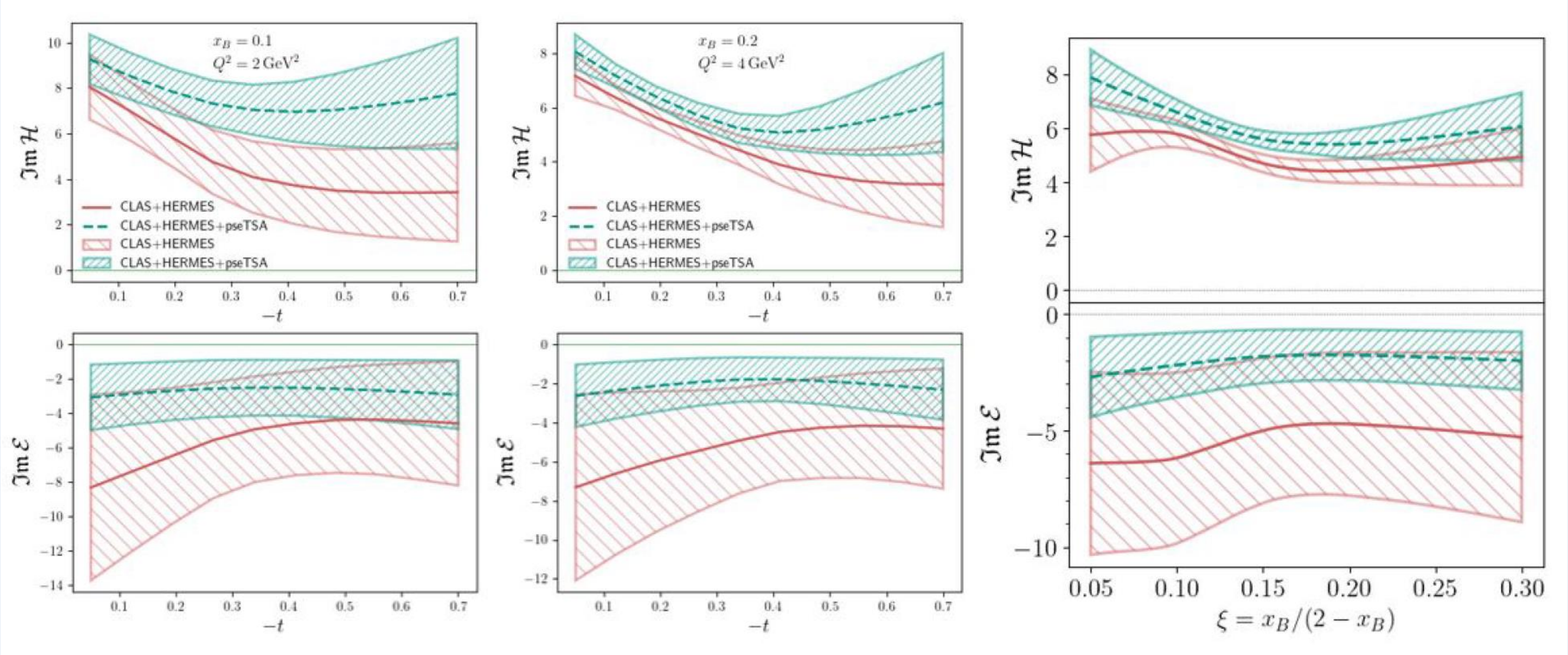
Superior discrimination power between various OAM model hypotheses

HERMES

Compton Form Factors

Analysis of Melany Higuera Angulo using GEPARD framework (LDRD project) and relevant data + RGH pseudo-data

100 PAC days requested to reduce by 2/3 the uncertainty on Im $\mathcal{E}$



Systematics

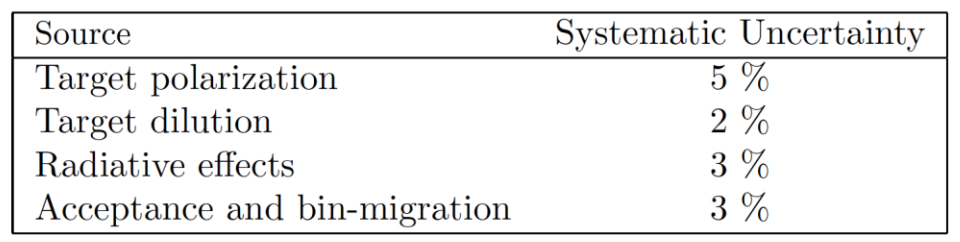
RGH measurement is expected to be dominated by the statistical uncertainty

RGH luminosity is 1/20 the nominal CLAS12 luminosity
Target spin state can be regularly rotated by microwave-induced swap
Physics quantity extractions indicate a minor role of systematics

To be noted: previous high-luminosity CLAS12 experiments provide a solid benchmark e.g.,
unpolarized cross section terms will be constrained by RGA/RGB and target dilutions by RGC

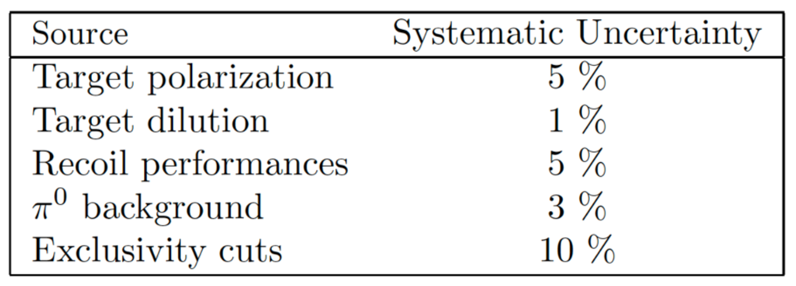
Conservative systematics is derived from previous relevant realizations and analyses,
with a cross-check for RGH acceptance peculiarities.

SIDIS single hadron



Source	Systematic Uncertainty
Target polarization	5 %
Target dilution	2 %
Radiative effects	3 %
Acceptance and bin-migration	3 %

DVCS

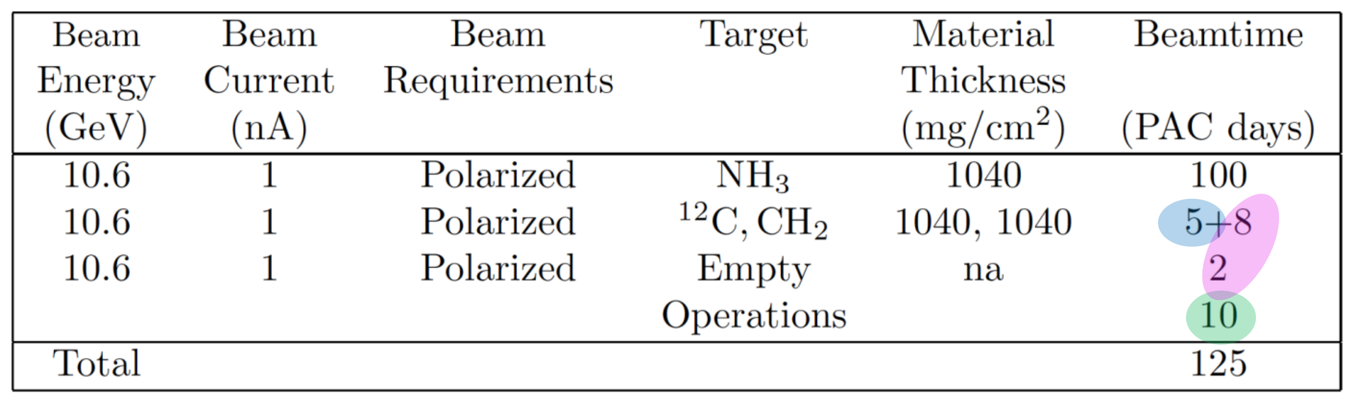


Source	Systematic Uncertainty
Target polarization	5 %
Target dilution	1 %
Recoil performances	5 %
π^0 background	3 %
Exclusivity cuts	10 %

Beam Request

RGH implements the target configuration most sensitive to the 3D nucleon structure study and capitalizes on CLAS12 with a complete set of target polarizations

100 (physics) + 25 (ancillary) PAC days requested to achieve unprecedent precision in the valence region



Beam Energy (GeV)	Beam Current (nA)	Beam Requirements	Target	Material Thickness (mg/cm^2)	Beamtime (PAC days)
10.6	1	Polarized	NH_3	1040	100
10.6	1	Polarized	^{12}C, CH_2	1040, 1040	5+8
10.6	1	Polarized	Empty	na	2
			Operations		10
Total					125

100 days of physics run to achieve the RGH goals

● 5 days for commissioning and alignment

● 8+2 days for background studies (target dilutions)

● 10 days for target annealing and target replacements

PAC Review

Theory Report

RGH measurements are critical for the studies of transverse spin phenomena in QCD with high impact physics such as the elusive nucleon tensor charge that is relevant for a broad community including LQCD and BSM physics.

TAC Report

No major technical hurdle.

Details to be clarified on chicane, beam monitor, and beam polarization uncertainty.

PAC Report

Scientific goals are well aligned with the 2023 NSAC Long Range Plan, preceding and complementing the EIC program.

Awareness of current literature, competing efforts, and theoretical frameworks.

Rare opportunity to get unprecedented access to the parton dynamics in the valence region with a multi-D framework

Acknowledgment of CLAS12 demonstrated capability, established target technology, full GEANT simulation.

Details to be clarified
Instrumentation (vibrations, field mapping, precision in target re-position, chicane geometry, target spin swap,..)

Systematics (background subtraction, unpolarized terms, longitudinal photon component, acceptance effects, radiative effects,…)