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

**Contalbrigo Marco - INFN Ferrara**

for RGH and CLAS Collaboration

CLAS Collaboration Meeting, November 14 - 2024

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]

RGH experiment status (with HDice) confirmed at PAC48 in 2020 (during jeopardy process)

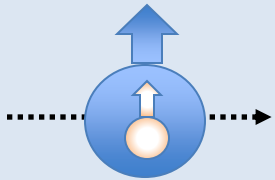
Access to unique observables in

- SIDIS hadron
- SIDIS Di-hadron
- DVCS

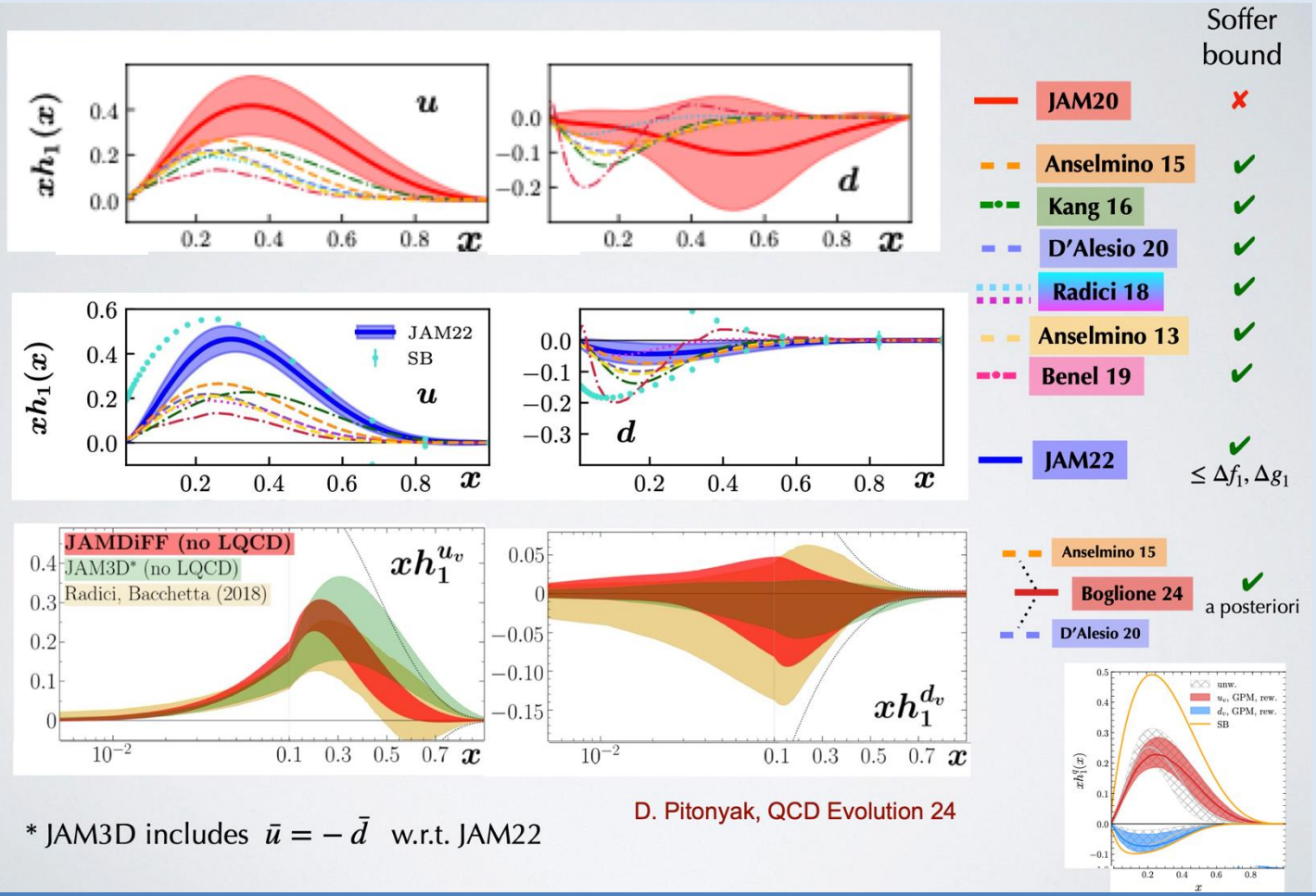
Gather unprecedented information on

- Transversity
- Tensor charge
- Sivers, $h_{1T}^{\perp}$, $g_{1T}^{\perp}$, $H_1^{\perp}$
- CFF and GPD E

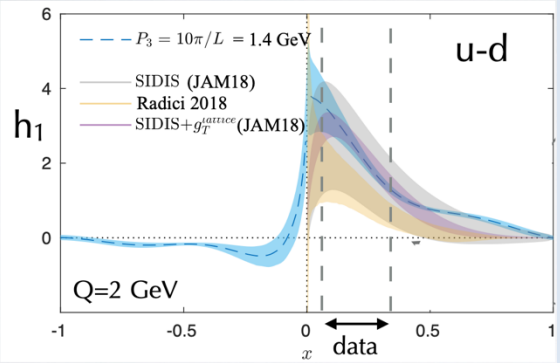
Collins
(TMDs)

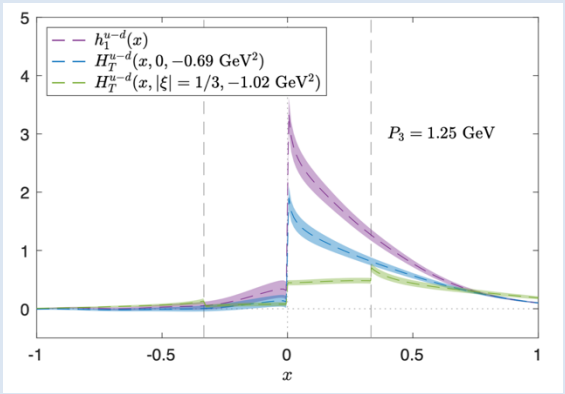


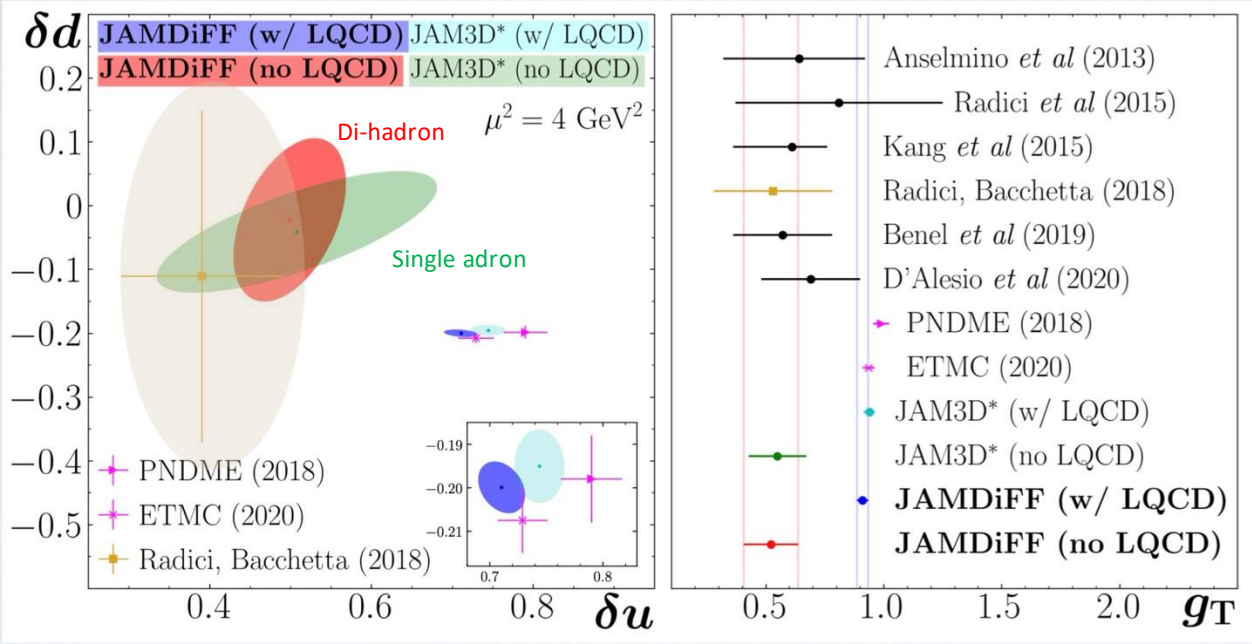
Di-hadron
(Collinear)



Fundamental quantity connected with BSM phsyics: tensor coupling beyond V-A & EDM violating T and CP
Growing interplay with lattice calculations

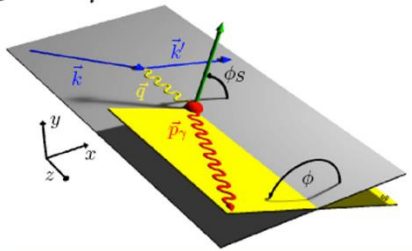


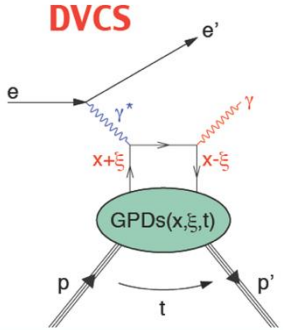



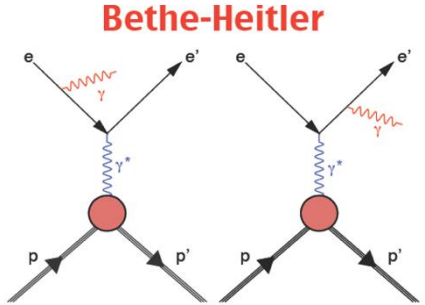

Adapted from D. Pitonyak @ QCD Evolution 24

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

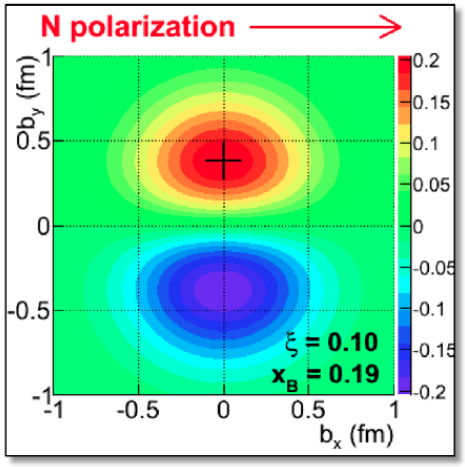



ep → e' γ p'



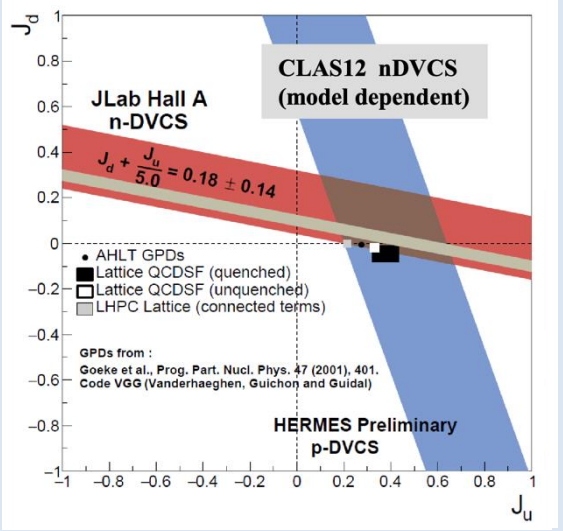

Information on the real and imaginary part of the QCD scattering amplitude



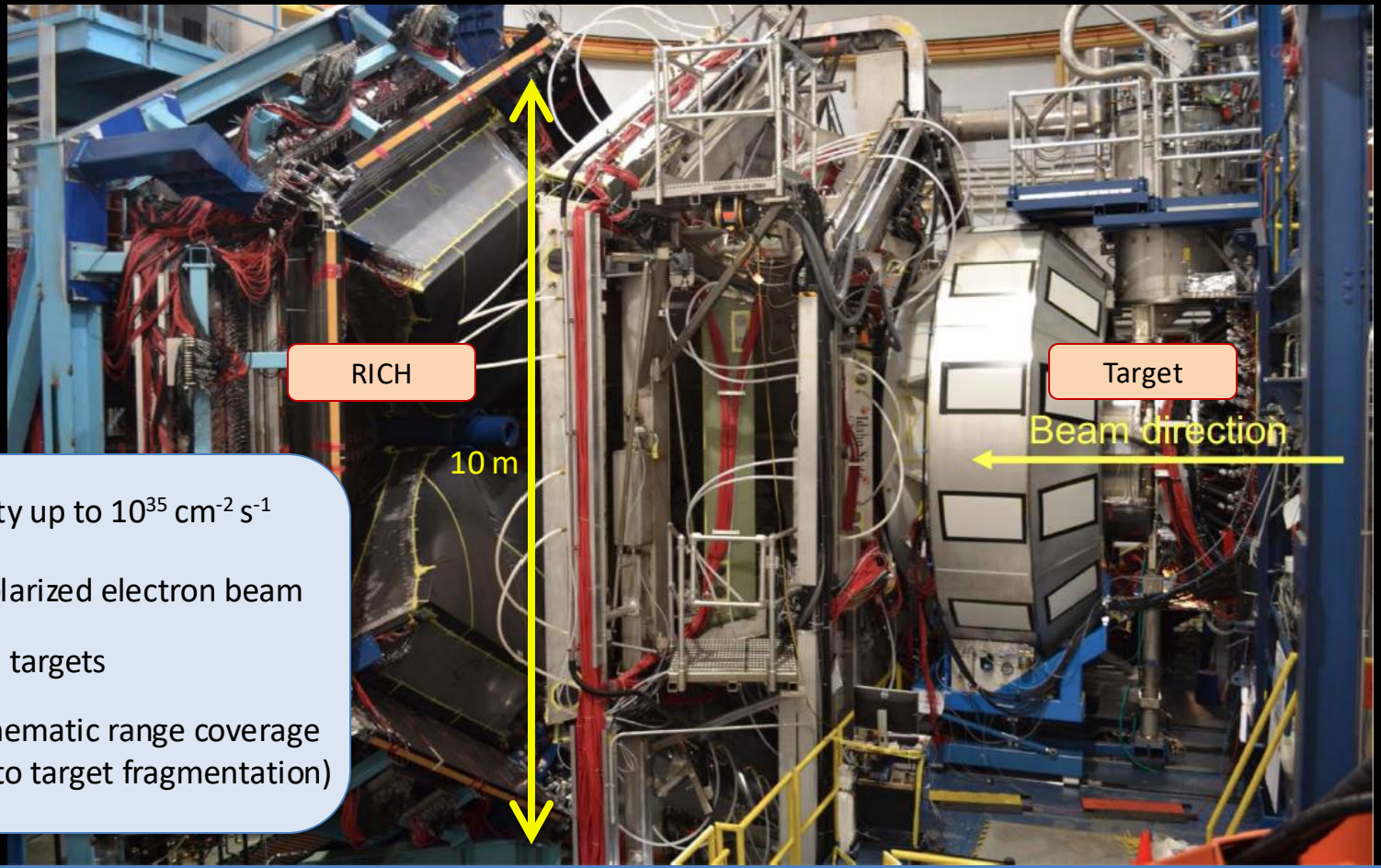

Access to elusive $E_p$ GPD

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

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



Large acceptance spectrometer. Operative since 02/18




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

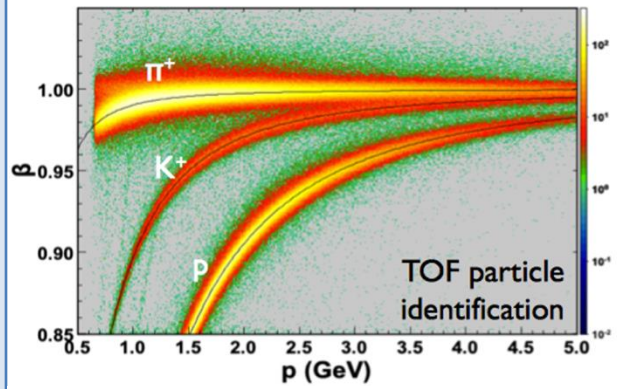
Highly polarized electron beam

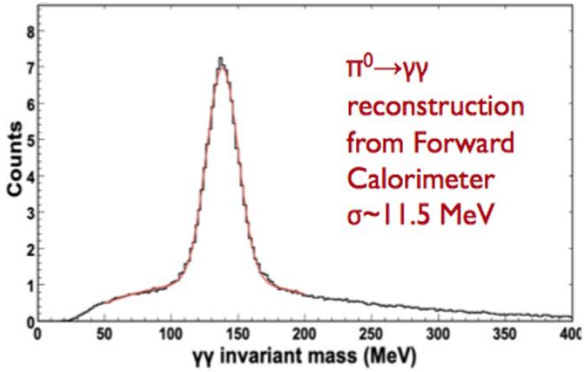
Polarized targets

Broad kinematic range coverage (current to target fragmentation)

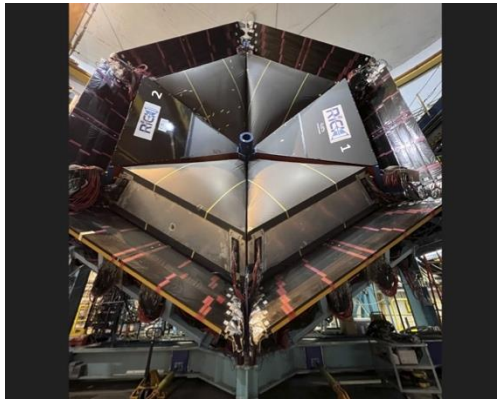
Semi-inclusive physics with unprecedented coverage of valence & flavor sensitivity

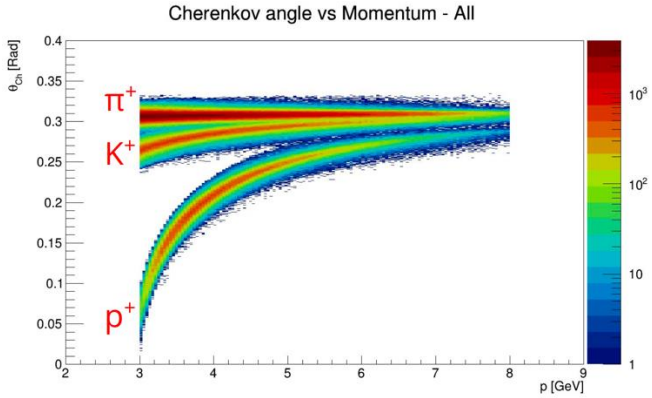
## Time-of-flight system

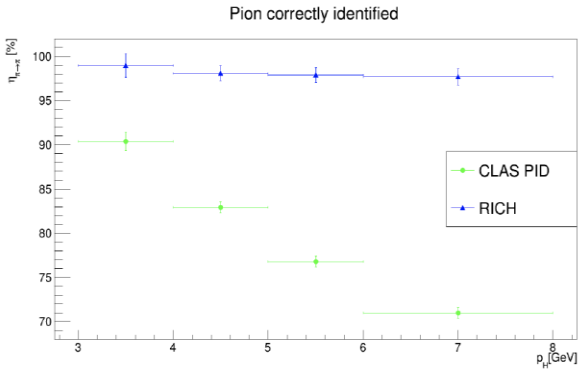


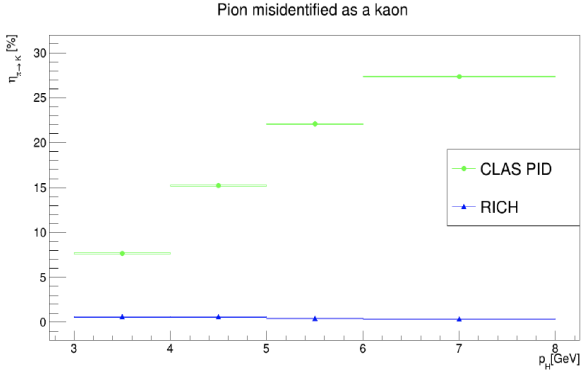




## Ring-imaging Cherenkov (completed in 2022)





HDice (frozen-spin) did not meet RGH specifications

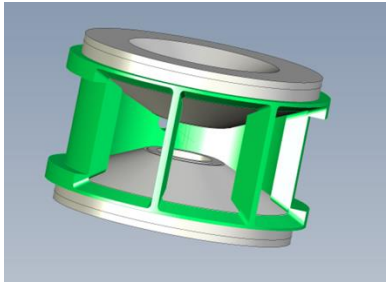
**Most viable solution to prioritize physics vs R&D**

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)

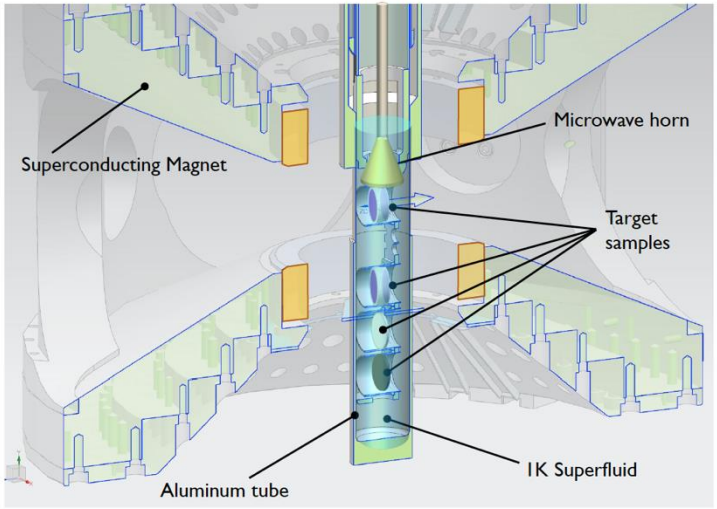

Magnet

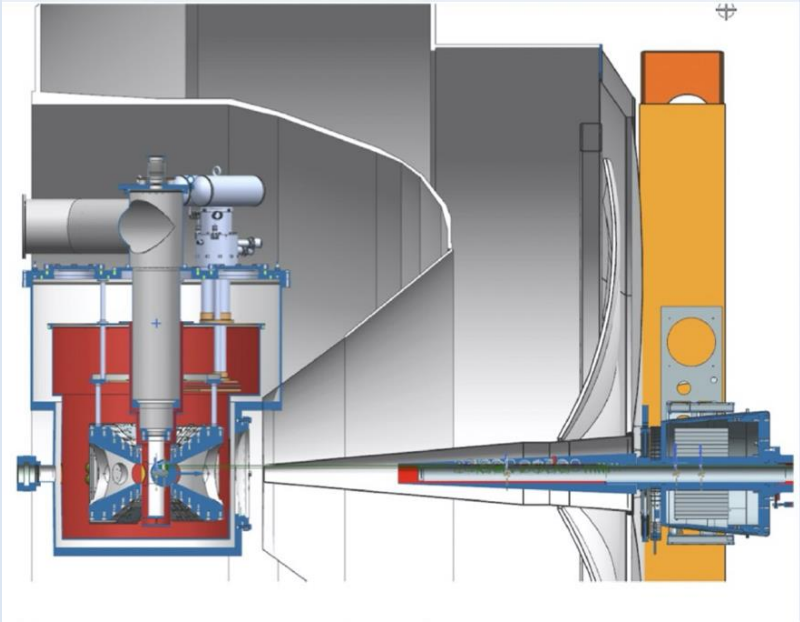


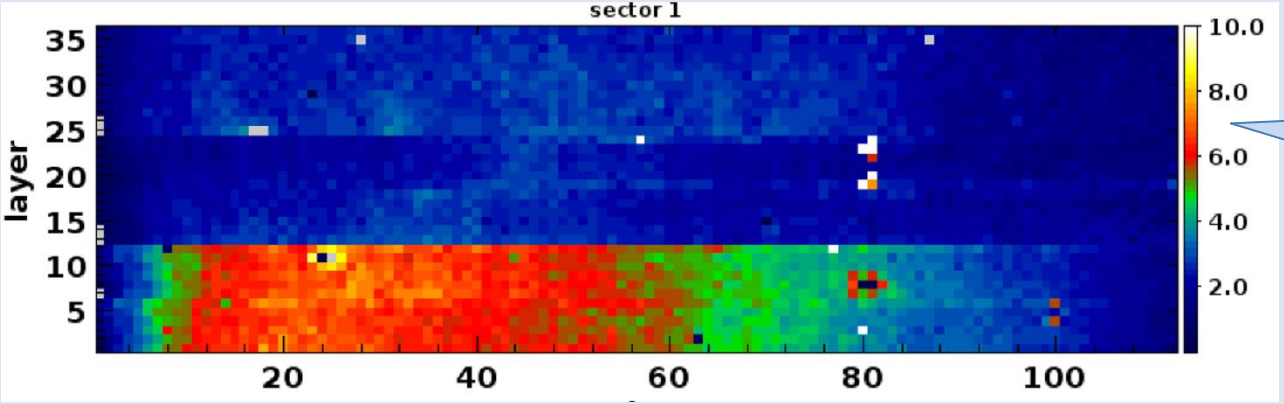
5T dipole acceptance:

$\pm 25^{o}$ horizontal

$\pm 65^{o}$ horizontal



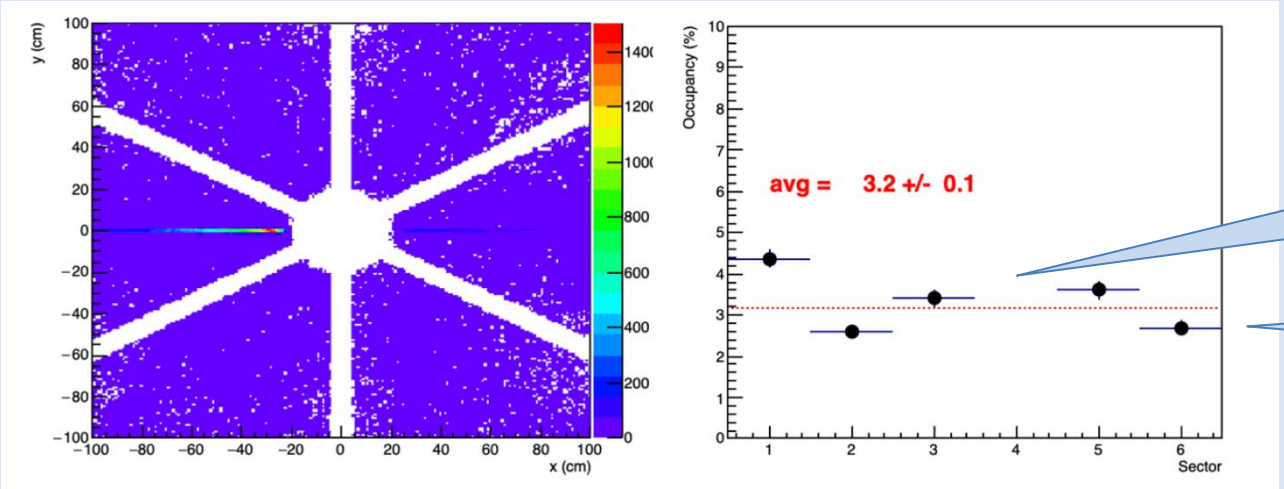



## RGC DATA

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

Within RGH program, HDice was upgraded and tested at UITF and found unable to provide the wanted luminosity

RGH current solution is most viable (no R&D) and superior to the conditionally approved HDice by PAC

PAC stipulated conditions for approval

| Quantity | HD | $NH_3$ |
|---|---|---|
| $(1\text{-}\tau)$ | 0.96 | 0.97 |
| $f$ | 1/3 | 3/17 |
| $P$ | 0.41 | 0.85 |
| $I$ (nA) | 1.0 | 2.0 |
| $\rho$ (g/cc) | 0.10 | 0.87 |
| $x$ (cm) | 5.0 | 1.0 |
| $\mathcal{L} \times 10^{33}$ | 2.5 | 5.0 |
| FoM$\times 10^{32}$ | 0.4 | 1.1 |

Limited by polarization lifetime

Conservative estimate:

Existing or commercial magnets

Consolidated target technology

Target design already in use at JLab

Current CLAS tracking capability

Limited by background

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| J12-24-RunGroupH | CLAS12 Run-Group H: electroproduction on transversely polarized proton with CLAS12 | B | 110 | | | change status to C2 | 4 |

## J12-24-RunGroupH

**Title:** CLAS12 Run-Group H: electroproduction on transversely polarized proton with CLAS12

**Spokespersons:** M. Contalbrigo (contact)

**Motivation:** This run group contains a set of measurements for GPD and TMD studies with a transversely polarized target in Hall B.

**1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?**

Yes, as pointed out in several PACs in the past and in the PAC 48 theory report, theoretical work in recent years has sharpened the requirements for interpreting SIDIS measurements in 12 GeV kinematics in terms of parton distributions (PDFs or TMDs). The proponents of this proposal should work with the theory community on impact studies detailing the impact of these data on our understanding of PDFs, TMDs and GPDs, especially because significant beam time and investments in building new equipment are requested. It is also noted that since the original proposal was presented to PAC 39 several new data sets have become available, which constrain the observables under discussion not necessarily in the same kinematic region. This should be considered when assessing the global impact of this Run Group H data. It is noted that both the LHCb polarized target running and the STAR forward upgrade can reach x above 0.4 at higher $Q^2$ than JLab.

**2) If the experiment has already received a portion of its allocated beam time, the spokespersons should present the status of the analysis of the existing data and the projected result for the final complete data set. The goal is to show the physics impact of the beam time requested in the jeopardy update.**

N/A

**4) Should the remaining beam time allocation and experiment grade be reconsidered?**

Yes.

The PAC commends the collaboration and JLab that a technical solution for a transversely polarized target was found. The scientific motivation for the different measurements in the run group remain strong. But the new solution to realize a transverse polarized target leads to a significant change of the experimental setup. Therefore, the PAC asks the collaboration to perform the following studies to understand the impact of the new experimental setup on the different measurements.

- Perform a full GEANT simulation of the entire beamline leading up to the target, to get a good estimate of the background and synchrotron radiation.
- Perform a full GEANT simulation of the different physics measurement to understand the impact of the new acceptance on the different measurements, i.e. SIDIS and DVCS.
- Based on the new simulations, the systematic uncertainties for the different measurements should be evaluated.
- Based on the new simulations, impact studies of the measurements on the physics observables, in particular TMDs and Compton Form Factors, should be determined.

For these reasons the PAC has revised the status of the experiment to C2 (conditionally approved with return to a future PAC).

**Summary:** The scientific motivation of the run group remains strong. Finding a technical solution for a transverse target has been crucial to make the different measurements possible. But due the large changes in the experimental setup compared to the original proposal, the PAC encourages the collaboration to submit a new proposal that details the scientific reach of run group H with the new setup, assessing the statistical and systematic uncertainties as well as the kinematic coverage. The PAC status of the run group is therefore changed to **C2**.

# PAC52 Outcome

PAC report:

- concludes that scientific case remains strong but details need to be sorted out

- does not differentiate between SIDIS and DVCS experiments

- does not inquiry the feasibility of the new setup

- wants the scientific impact to be clarified:

    - update phenomenology vs CLAS12 phase space
    - PAC days vs acceptance

- wants full simulation:

    - background vs systematics
    - beamline
    - recoil details

To answer PAC52 requests we need to continue the effort on beamline, target, shielding and simulations that we have already been doing for releasing C1 condition and moving towards experiment.

In parallel we need to bring forward:

- requested simulations

- specific impact study with phenomenology

- detailed assessment of the recoil detector (hardware, manpower, timeline)

Soon (i.e. early 2025) decide

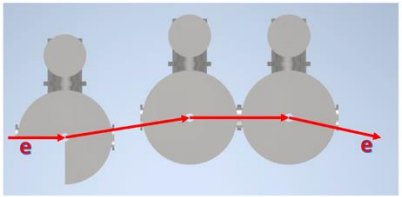
- how to approach PAC53 (which configuration to bring forward)

- if/what can be the possible elements eligible for investment

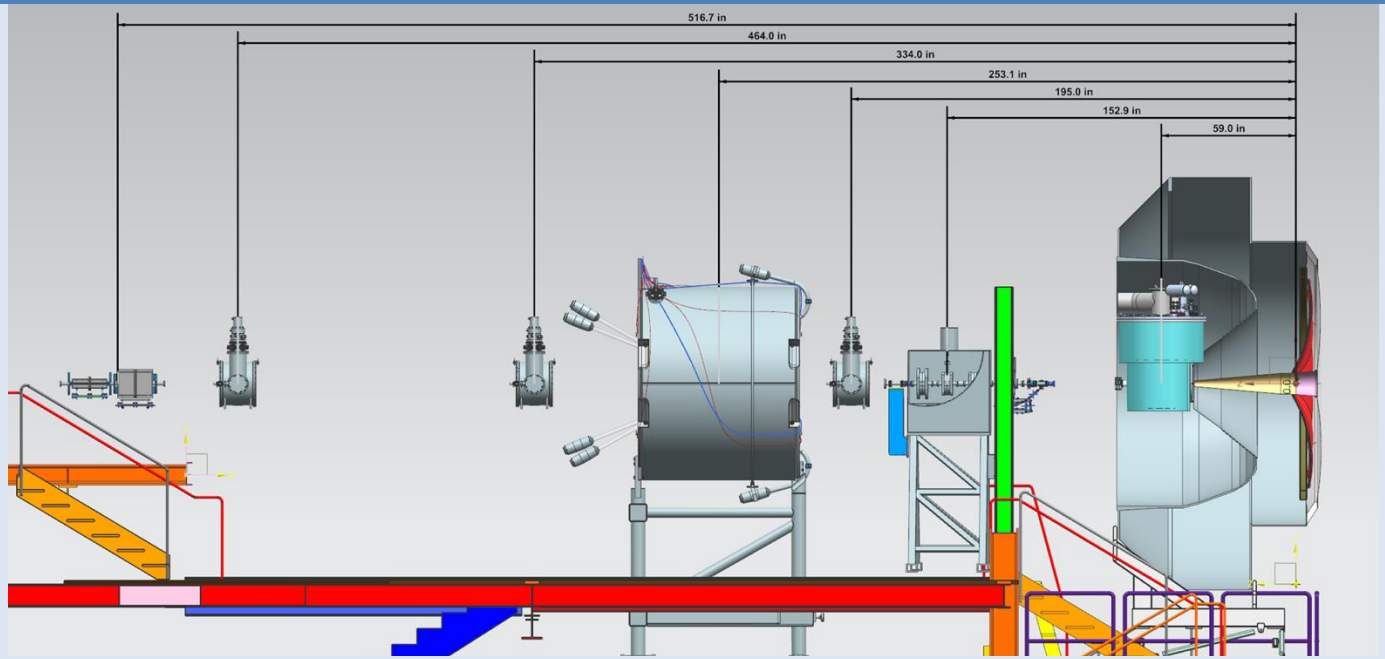
Based on

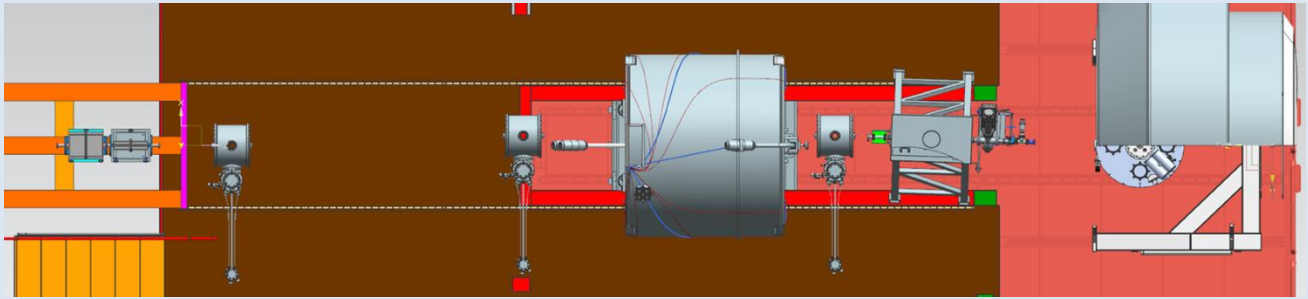
existing 0.7 mm raster

commercial 7.5T magnets



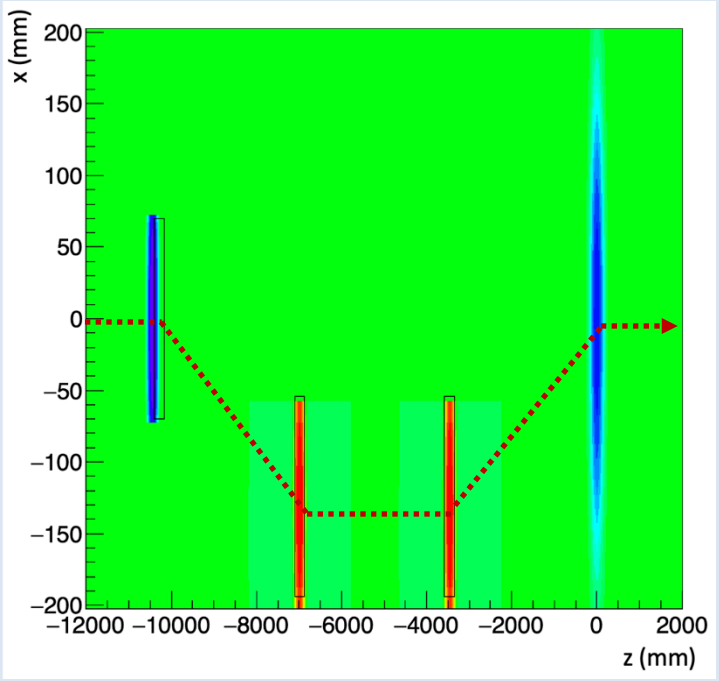

- ✓ space
- ✓ synchrotron radiation
- ✓ beam rastering



From Jay Benesch modeling (May ‘24)

Rescaled by 0.89 to match RGH target $\int Bm$



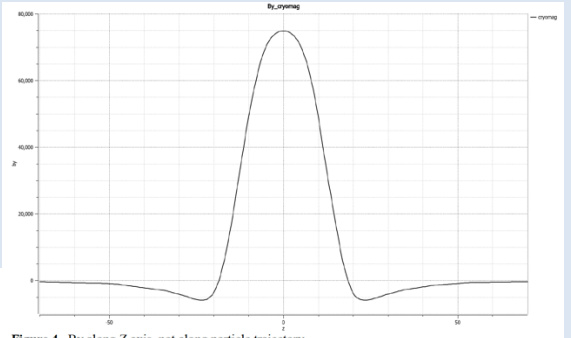




**Figure 4**. By along Z axis, not along particle trajectory.

A field map was created from the model spanning X=[-7,7] Y=[-2,2] Z=[-120,120] with 0.5 cm step size. gzipped file accompanies this TN.

**Dimensions** (inches) operating current 87.32 amps

| | ID(") | OD(") | Width(") | zCen(") | NTurns |
|---|---|---|---|---|---|
| 1 | 4.25 | 4.912 | 2.25 | 2.875 | 377.8 |
| 2 | 4.912 | 5.708 | 2.25 | 2.875 | 523.9 |
| 3 | 5.708 | 6.563 | 2.25 | 2.875 | 711.8 |
| 4 | 6.563 | 7.535 | 2.25 | 2.875 | 1095.5 |
| 5 | 7.535 | 14.407 | 2.25 | 2.875 | 10966.8 |

The five coils are nested with OD of the first the ID of the second and so on. Only the positive Z coils are shown. Magnet was modeled as transverse rather than longitudinal as that is how it will be used.

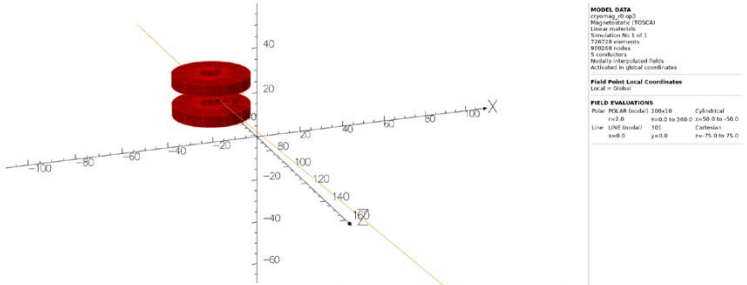
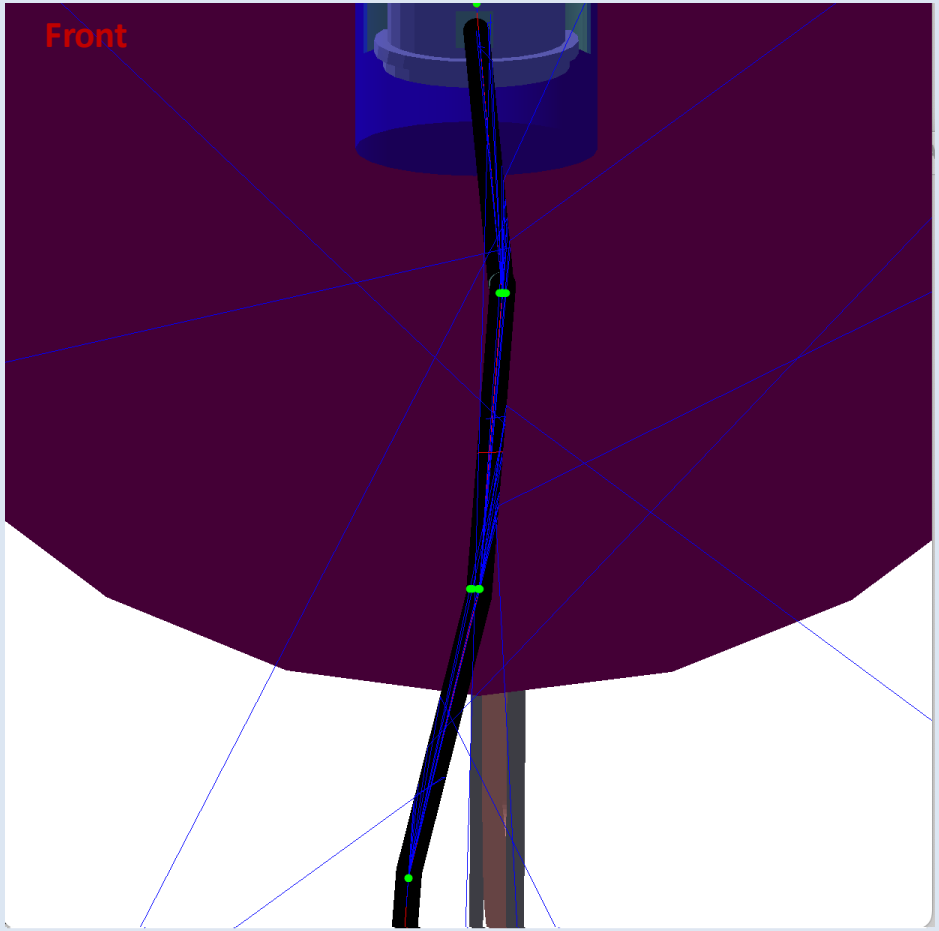
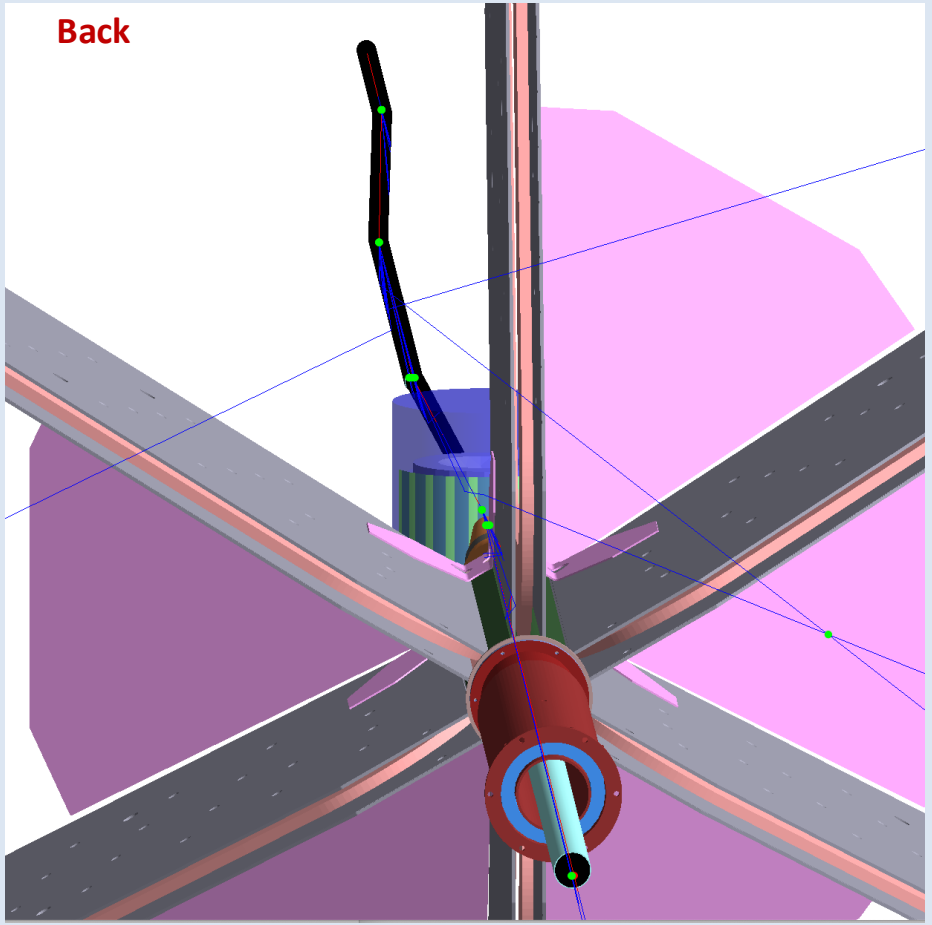


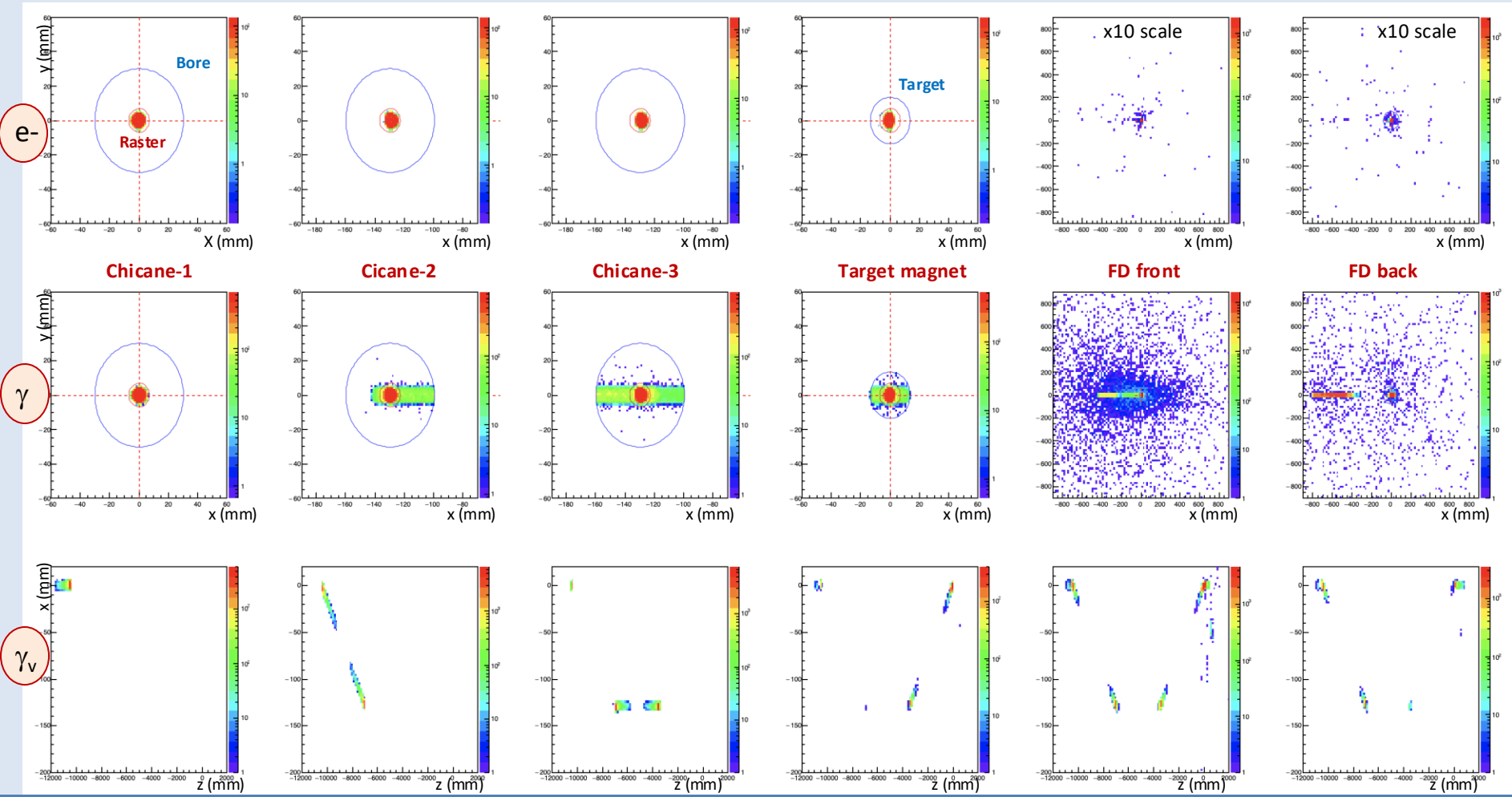

**Figure 1**. Perspective view of model with 11.023 GeV beam starting at (0,0,-125)cm and being deflected horizontally.

# Chicane Pipe



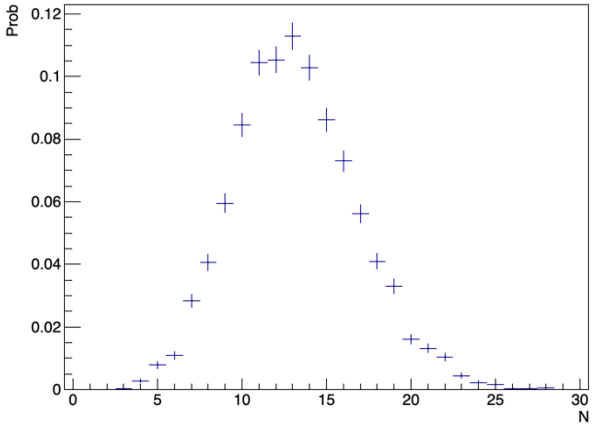



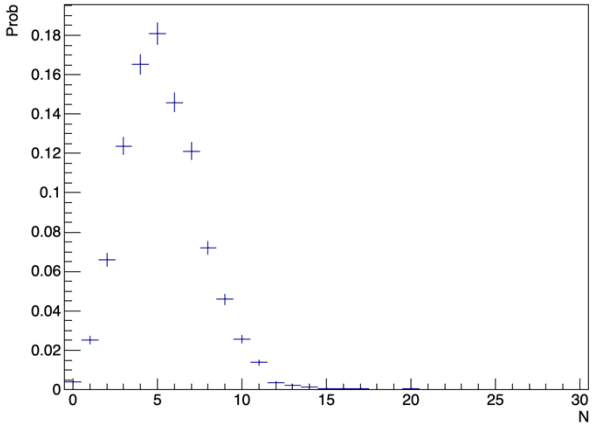
# Recorded Gamma Particles (Empty Target, No pipe)



# Gamma Background (Empty Target, No pipe)

**Number**

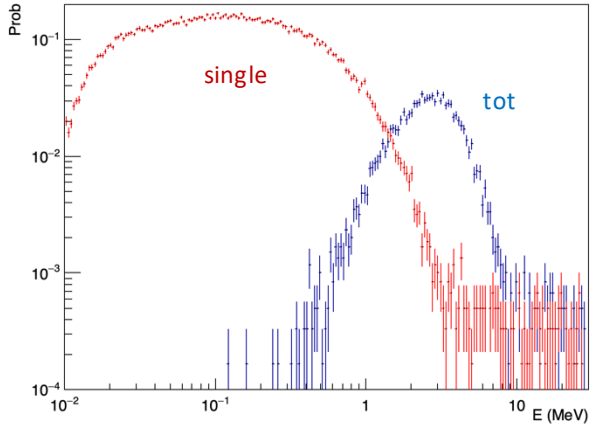


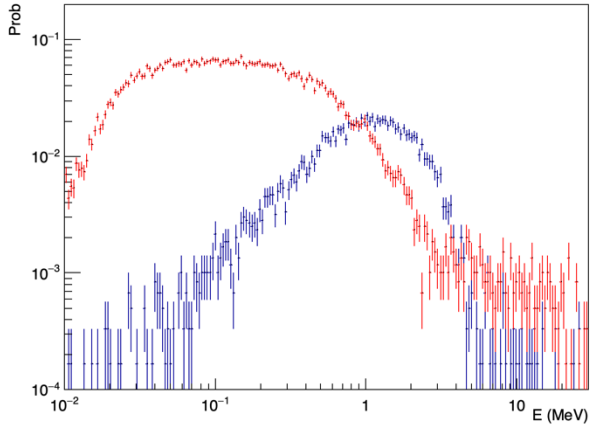




**FD front**

**FD back**

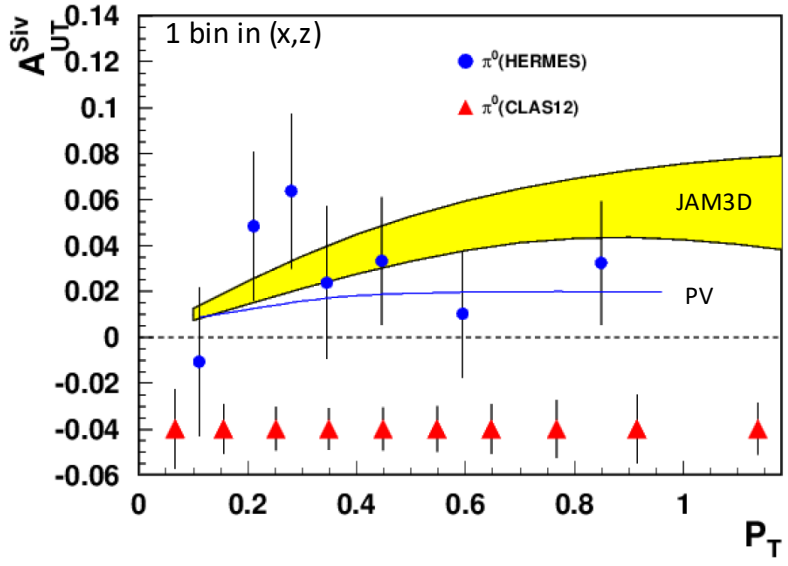
**Energy**



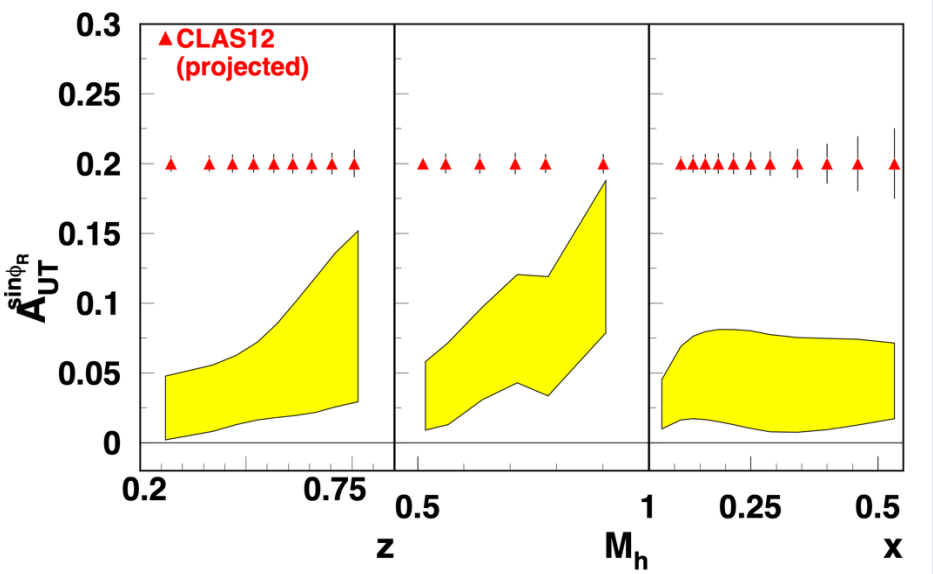



Better than approved FoM (forward phase-space is basically untouched)

Example 1: $\pi^0$ provides clean probe
minor VM and $\gamma_L$ contribution



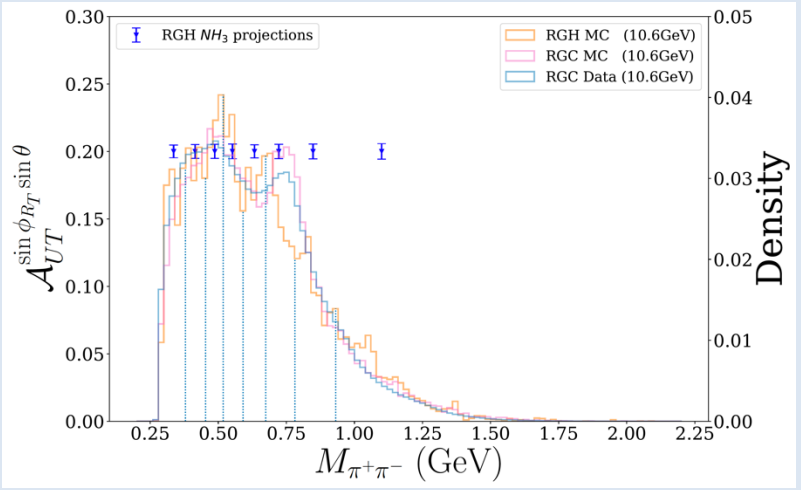

Example 2: di-hadron provides collinear benchmark
validation of TMD formalism

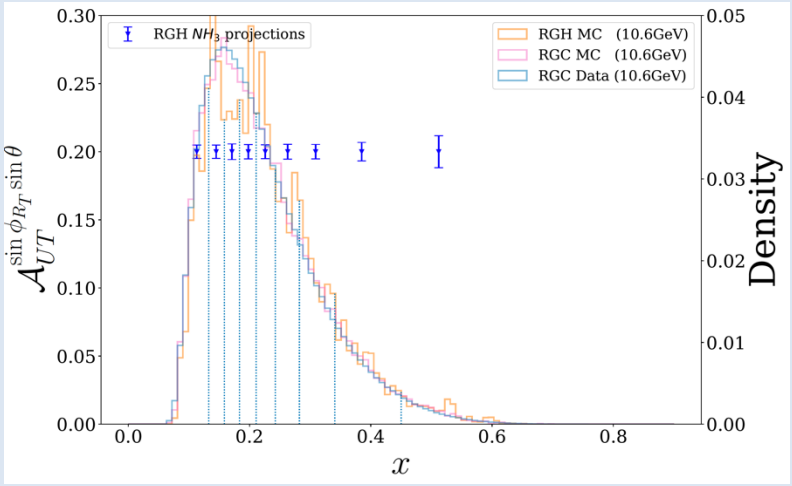


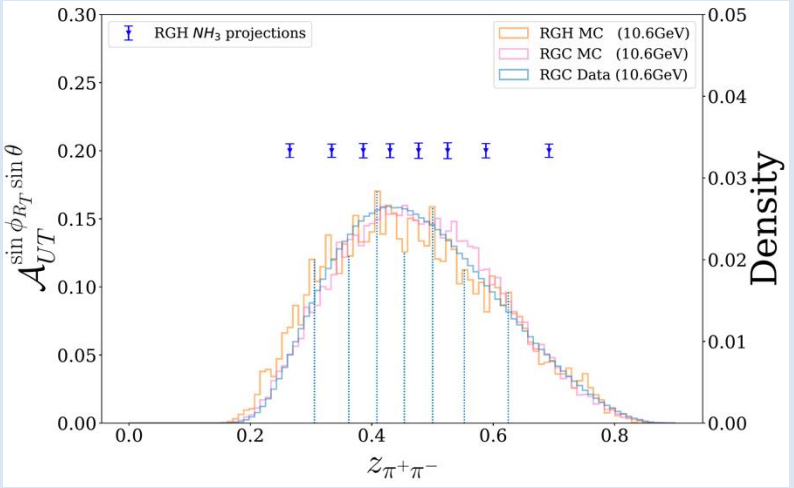
DUKE (Matthew M.)

$$N_{RGH,i} = N_{RGC,i} \cdot \frac{R_{RGH,MC,i}}{R_{RGC,MC,i}} \cdot \frac{\mathbf{100days \cdot 5{\times}10^{33} cm^{-2} s^{-1}}}{\mathbf{17.7days \cdot 2.0{\times}10^{34} cm^{-2} s^{-1}}}$$

Normalized to RGC data to account for as much as possible CLAS12 realistic experimental conditions



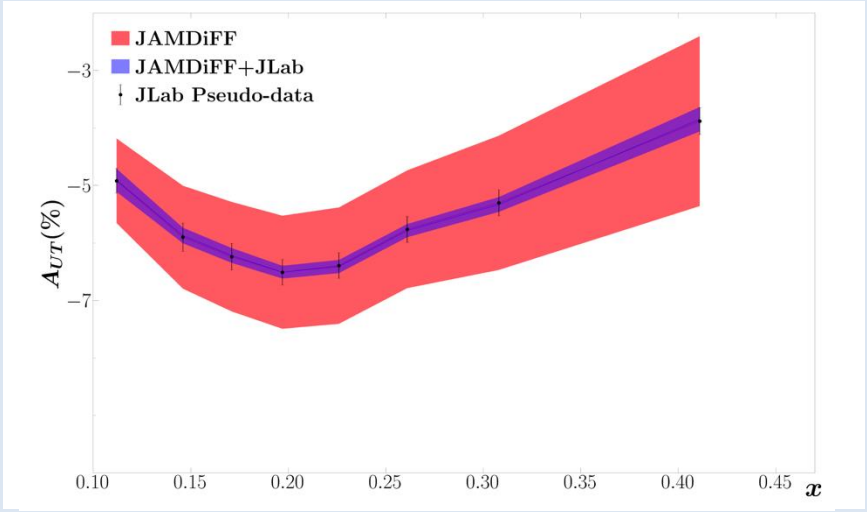



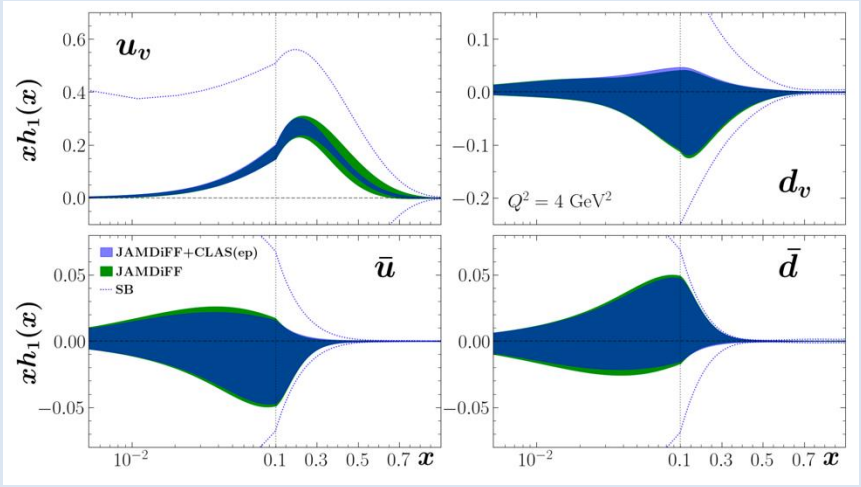



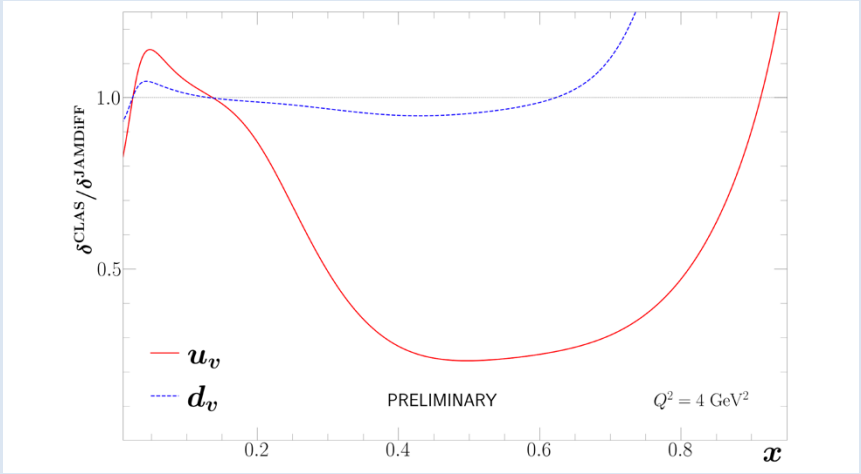
DUKE collaboration with JAM:

Yorgo Sawaya
Andreas Metz
Christopher Joseph Cocuzza

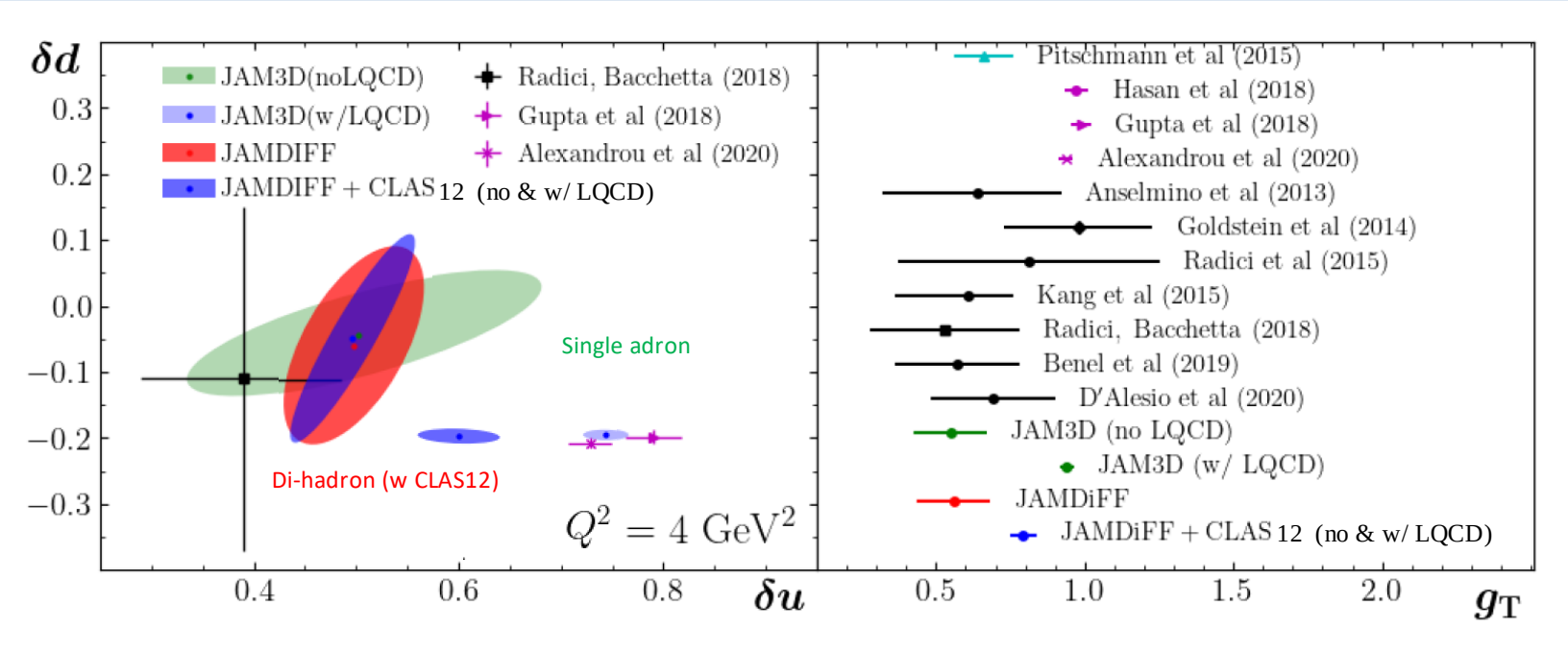
$$\delta u = \int_0^1 \mathrm{d}x\, h_1^{u_v}(x;\mu) \qquad \delta d = \int_0^1 \mathrm{d}x\, h_1^{d_v}(x;\mu) \qquad h_1^{q_v} \equiv h_1^q - h_1^{\bar{q}}$$



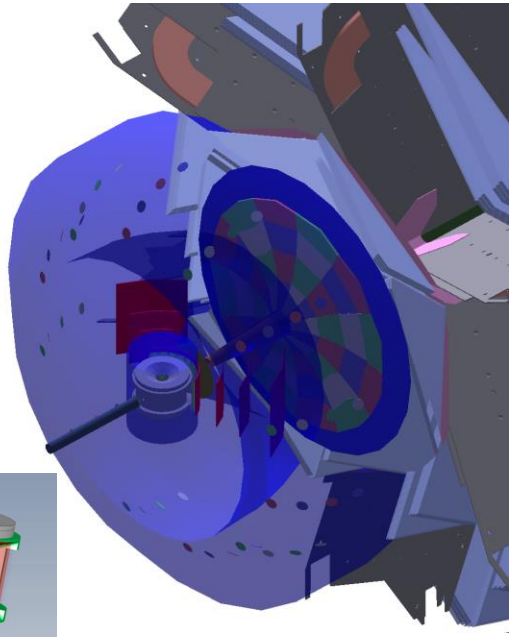



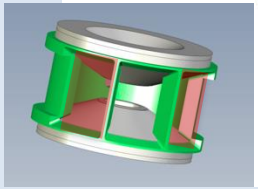
Projections with and without CLAS pseudo-data (with lattice inputs)
Call for a measurement also on neutron



Recoil concept (left-right)
3 tracking layers + 1 TOF layer (50 x 50 $cm^2$)

based on “flux detector”
with reasonable resolution



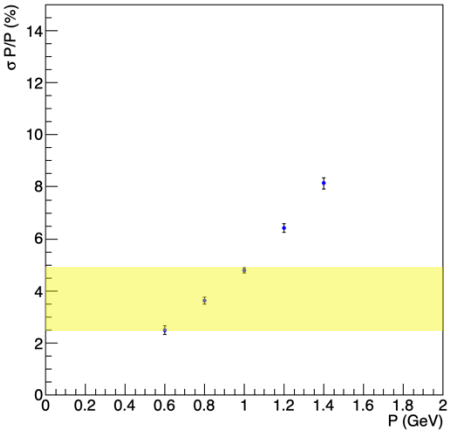


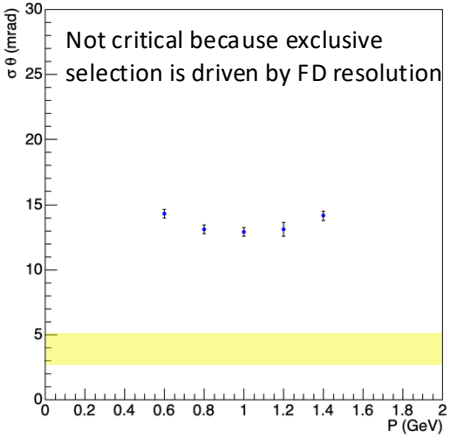
Simulated recoil resolution for

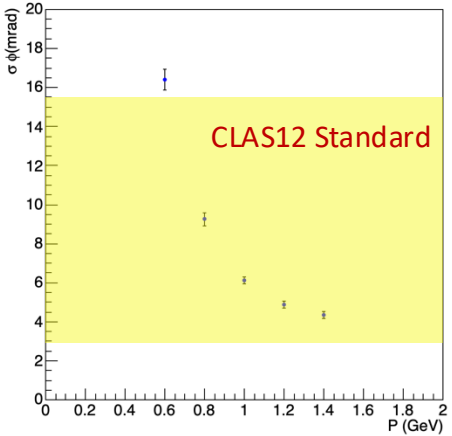
$\sigma_{x,y}$ O(100 μm)

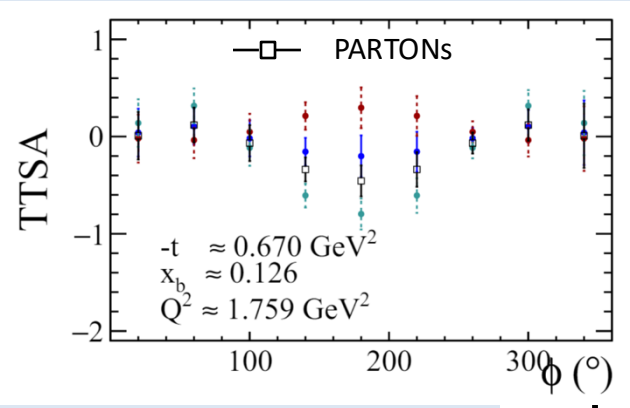
$\sigma_t$ O(100 ps)

and CLAS12 FD tracking resolution



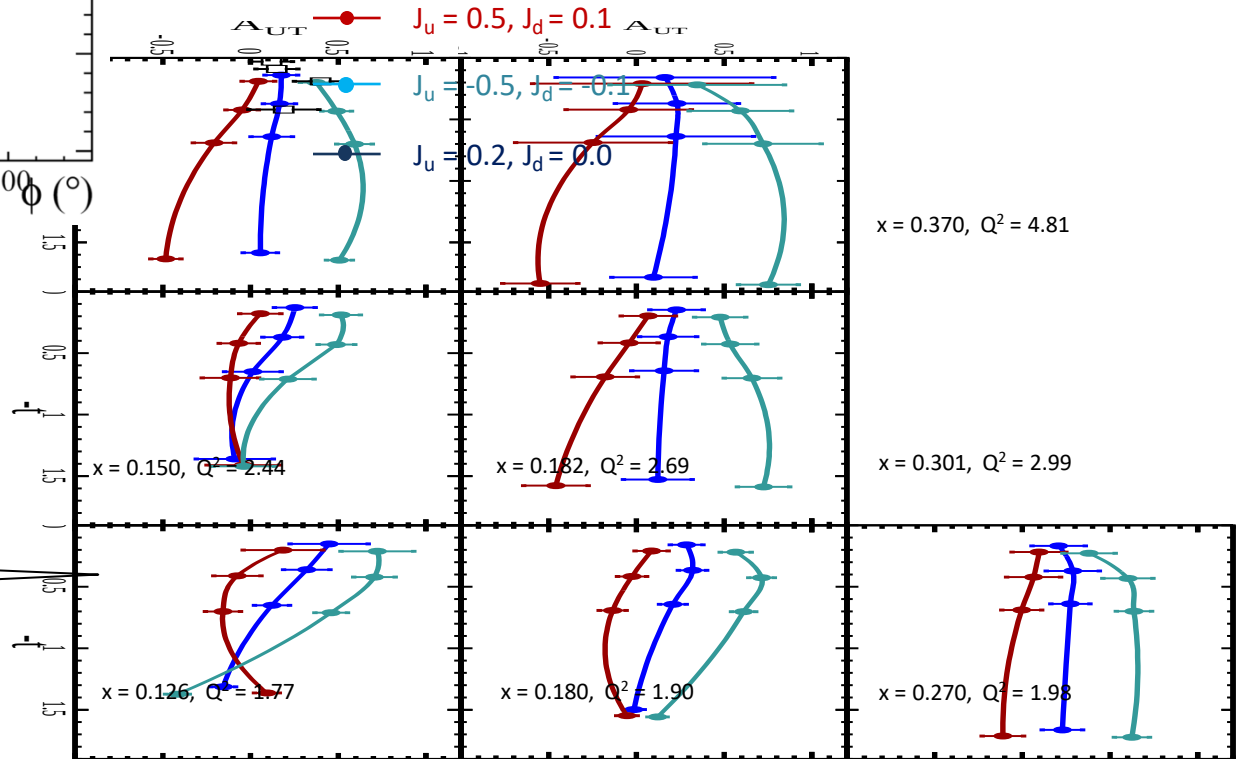





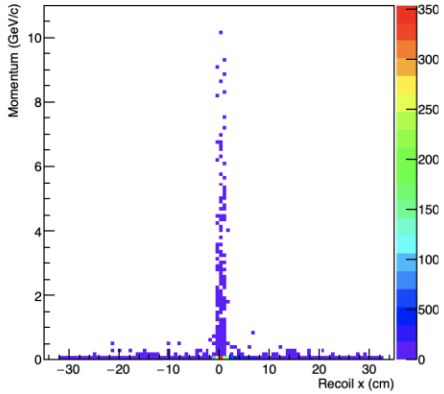

$$Y_{RGH}(i) = Y_{RGA}(i) \cdot \frac{Acc_{RGH}(i)}{Acc_{RGA}(i)} \cdot \frac{L_{RGH}}{L_{RGA}} \cdot \frac{3}{17}$$

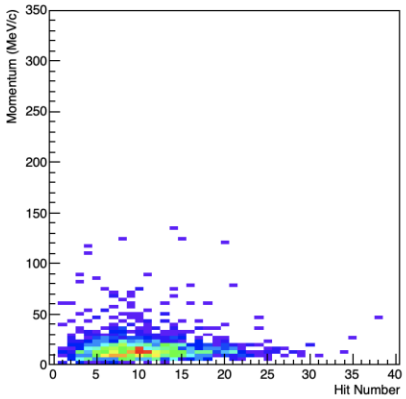
Superior discrimination power between various OAM model hypotheses

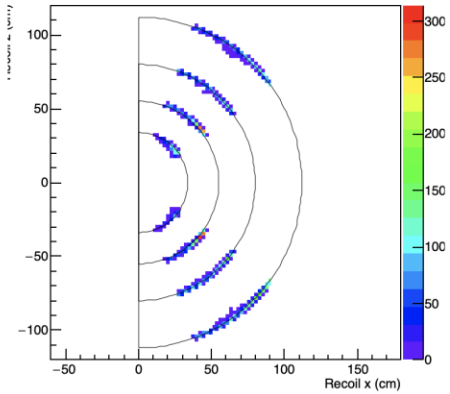
HERMES

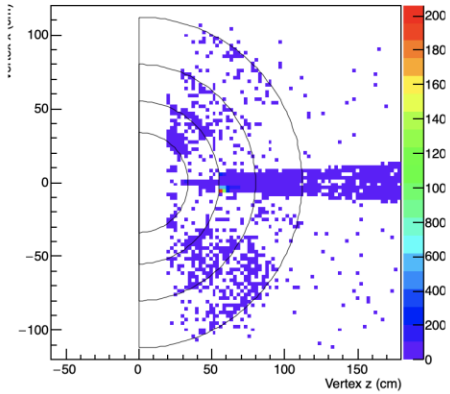


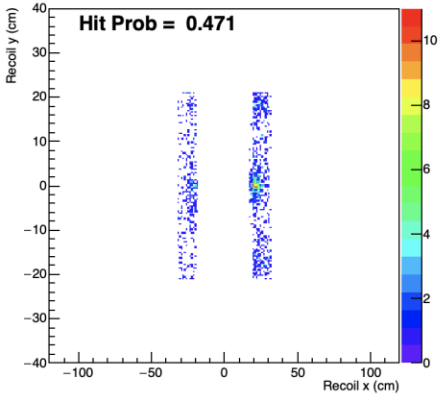
## Particles from secondary downstream interactions

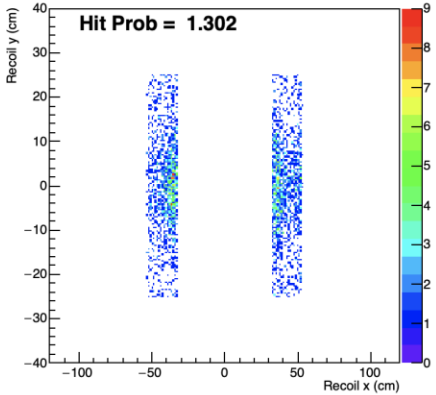


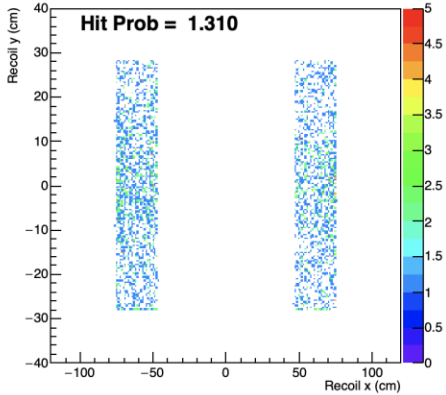



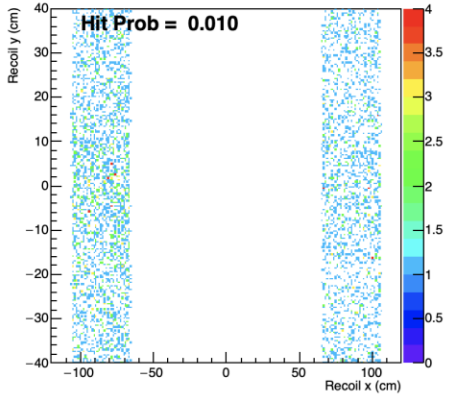



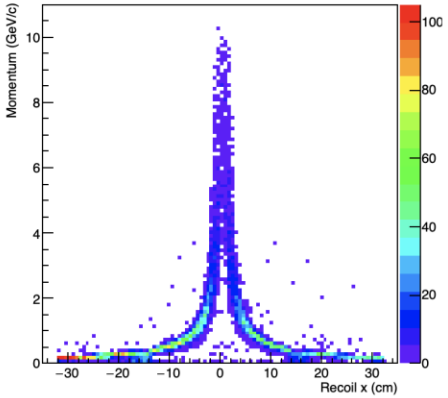



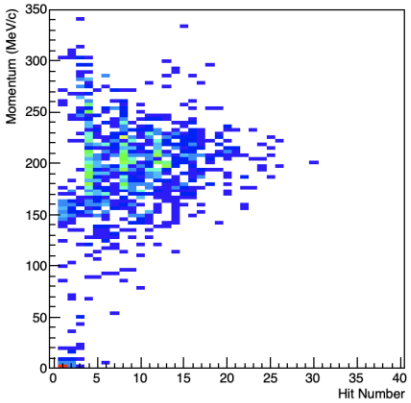



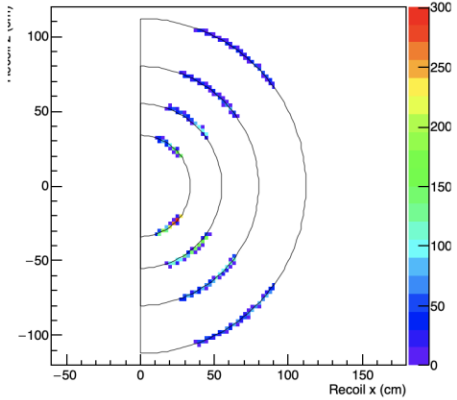



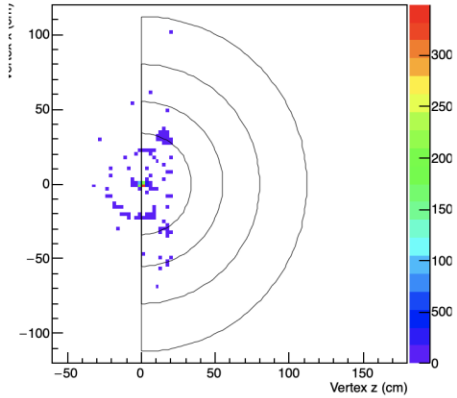



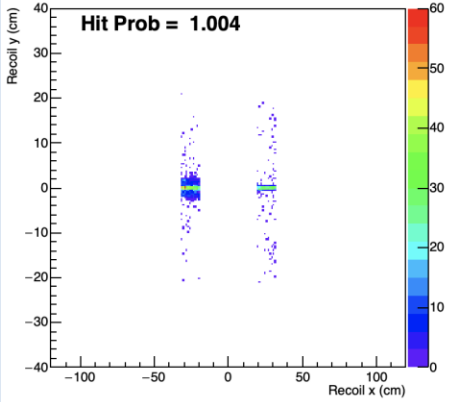
Particles emerging from beam interaction on target

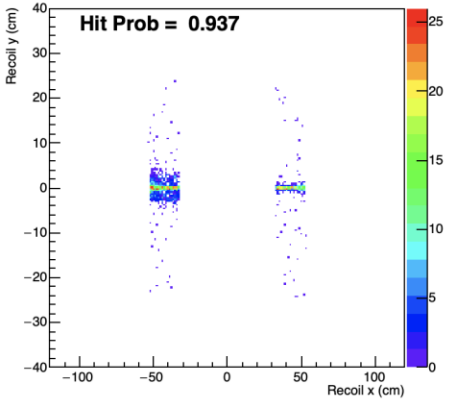


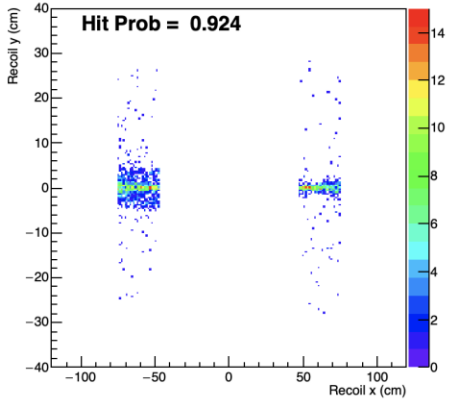



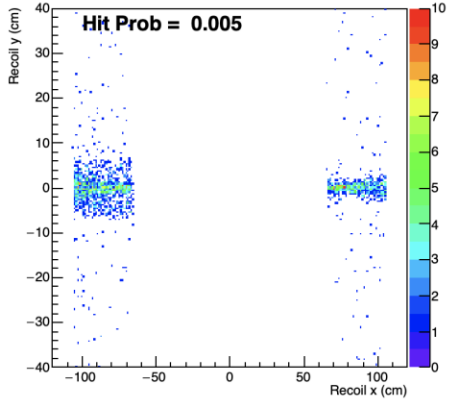



## RGH Recoil Meeting [edit]

Time: Friday morning, 11:00AM Roma time

Zoom link: https://jlab-org.zoomgov.com/j/1617440485?pwd=Nq6OQGkb01gHAYuPlW1adwFZ2CdSTw.1

ID 161 744 0485

Code 537057

- **8 November 2024 RGH Recoil meeting**

DUKE interest in RGH recoil time-of-flight

- **11 October 2024 RGH Recoil meeting**

INFN interest on RGH recoil time-of-flight

Possible spin-off of EIC R&D & CLAS12 CND

Prototypes/test station/simulations

- **27 September 2024 RGH Recoil meeting**

Introduction to Recoil [1] (Marco C.)

Micro-Rwell R&D slides A. D'Angelo

Mirco-Rweel Maerial Budget Calculator [2] A. D'Angelo

Spin-off of CLAS12 HL

Prototypes/test station/simulations

Anybody interested is more than welcome !

# Implementation of the RGH recoil detector in GEMC/Coatjava

Work in progress on both GEMC and Coatjava (Thanks to Raffaella and Mariangela for the precious help to start the project!)

GEMC, created fork:

- Created recoil/ directory copying, and adapting, the CLAS12 high-lumi µRwell codes
- Materials included for the µRwell part
- TOF part still needs to be started – we need to agree on detector concept and geometry (array of scintillators read by SiPM?)

Geometry and positioning need to be defined in Coatjava – created fork:

- Created recoil/ directory copying/adapting HL µRwell one (number of layers, sectors, etc…)
- Managed to compile CJ
- Working on positioning and geometry
  - Following Marco's positioning, but changing from G4Tube to G4Box
  - Using as template the µRwell for the CLAS12 HL
  - Different geometry (trapezoidal → rectangular)
  - Two-layers (x,y) of µRwell

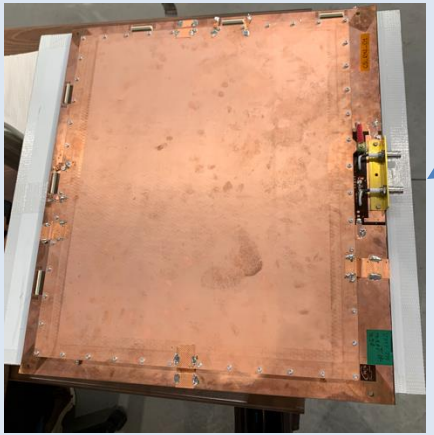
Orsay (Silvia N.)

- TOF part TBD

Results in a couple of weeks, hopefully

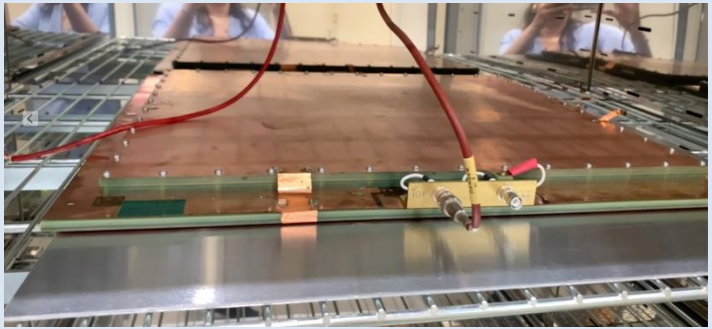
Spatial resolution O(100 μm) with μ-Rwell tecnology under development for the CLAS12 high-lumi project

INFN-RM2 (development), INFN-GE (electonics), INFN-LNF (expertise & mechanics)



HV filter on

Conditioning In the Oven

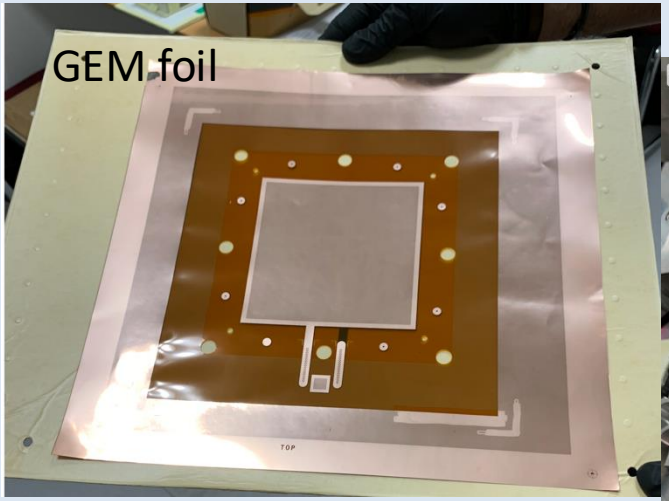


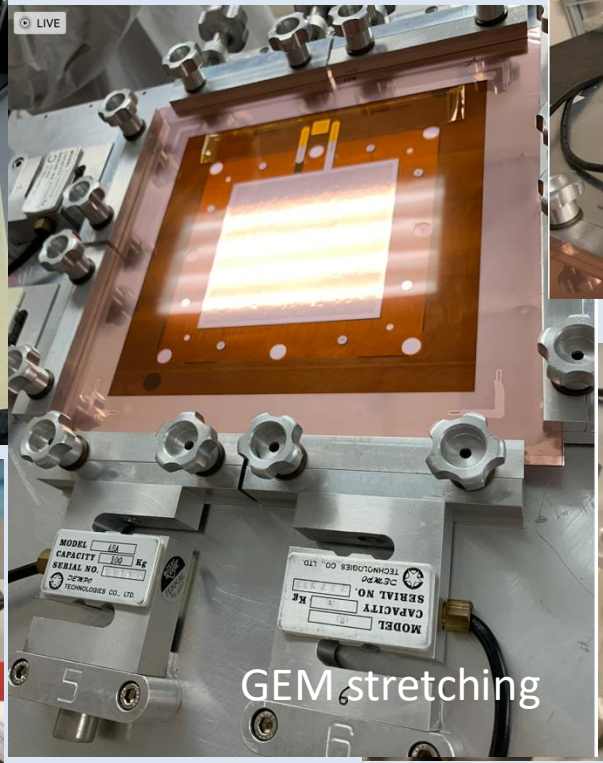
Ongoing R&D: test of Large Area Prototype steps @ LNF: CS - 40x46 cm $^2$

X-Ray characterization

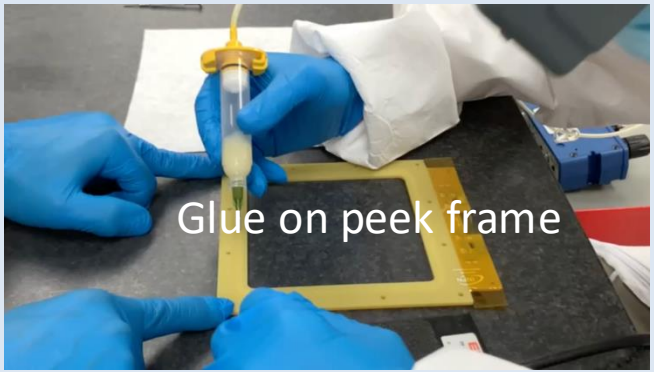

Cosmic-rays Data Acquisition

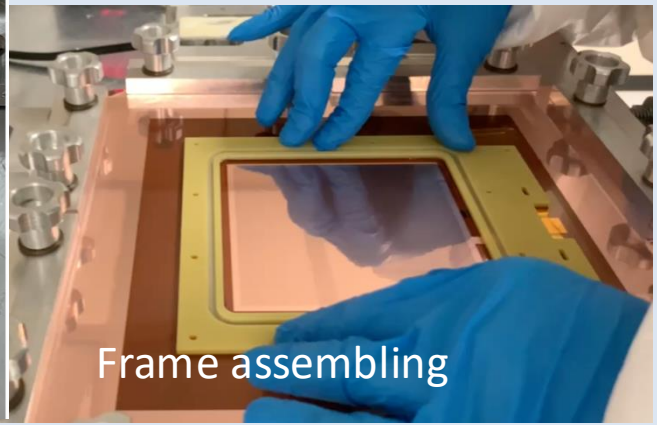
First GEM-$\mu$Rwell 10x10 cm $^2$ prototypes assembly



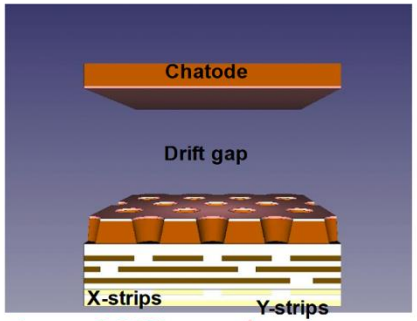







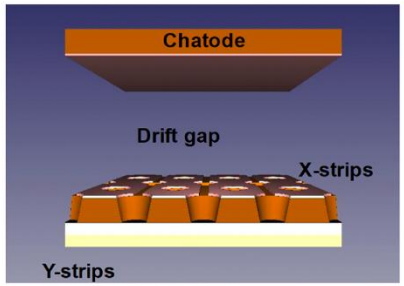



**u-RWELL - Capacitive Sharing r/out**

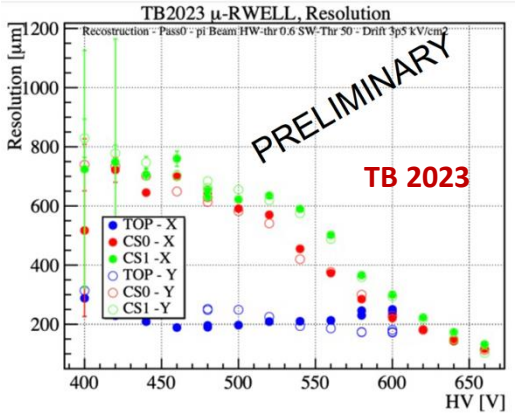



June 2023 test beam

**u-RWELL TOP r/out**

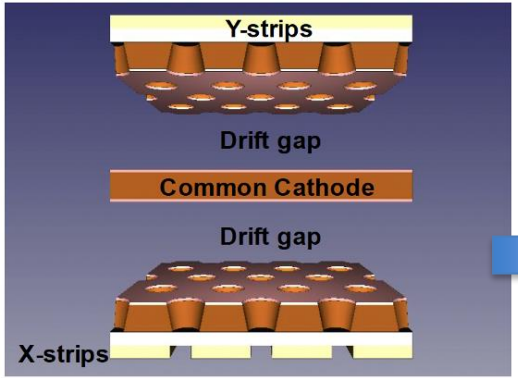


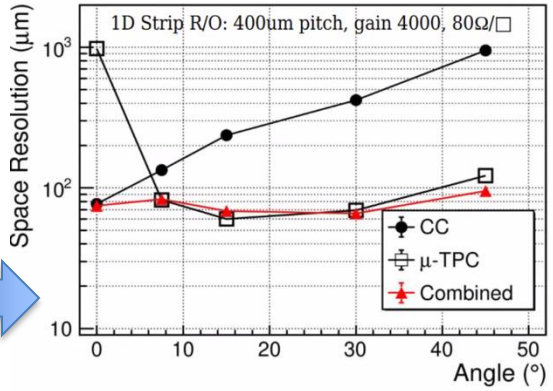

June 2023 test beam



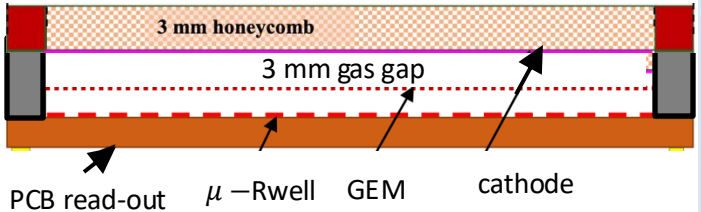

Courtesy of A. D'Angelo

**N.2 u-RWELLs 1D (2⊗1D)**



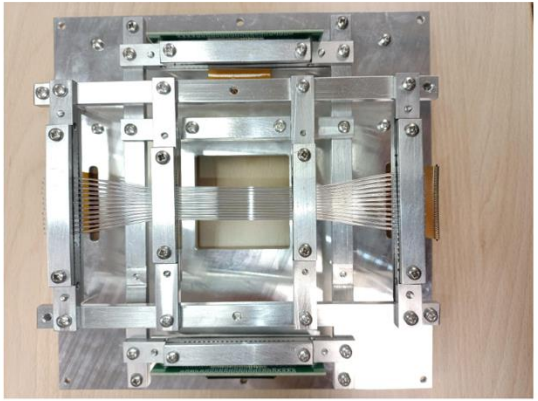

## GEM - $\mu$Rwell Technology

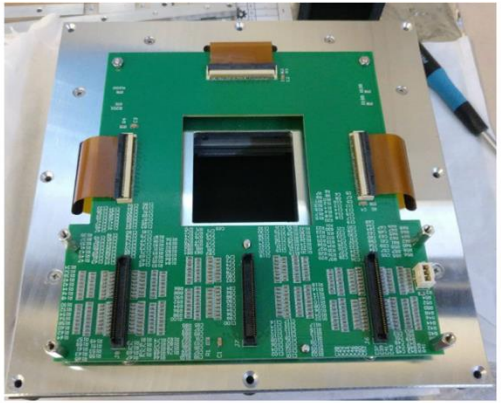


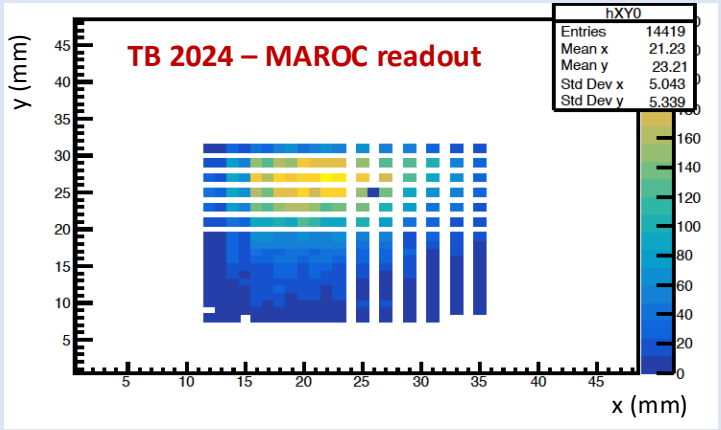

**Next test beam Oct/Nov 2024**

Time resolution O(100 ps) with scintillating technology (CLAS12 TOF)

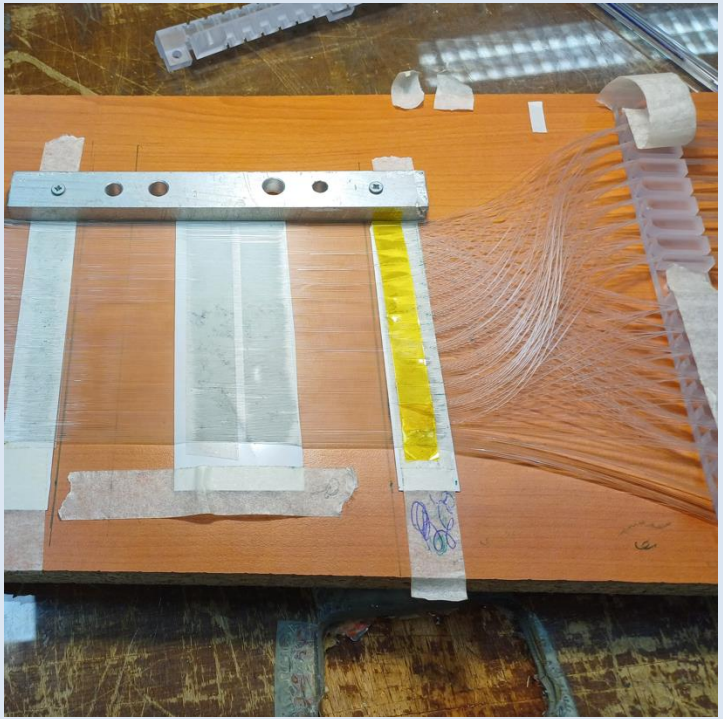
Synergy with other projects, e.g. INFN-FE scintillating fiber fast tracker







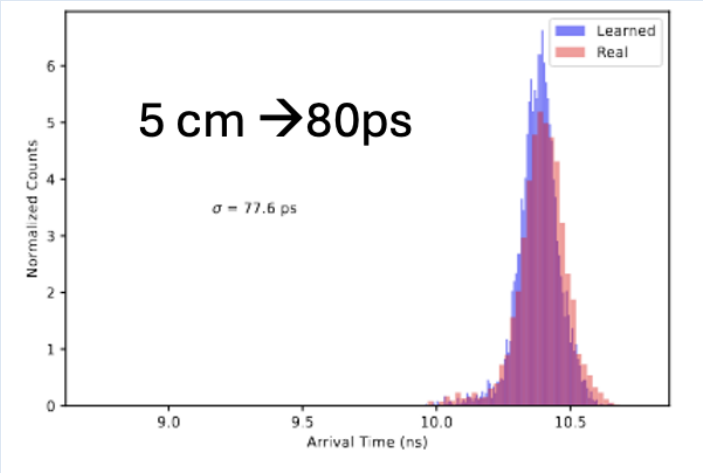

INFN-GE PIC dRICH tagger

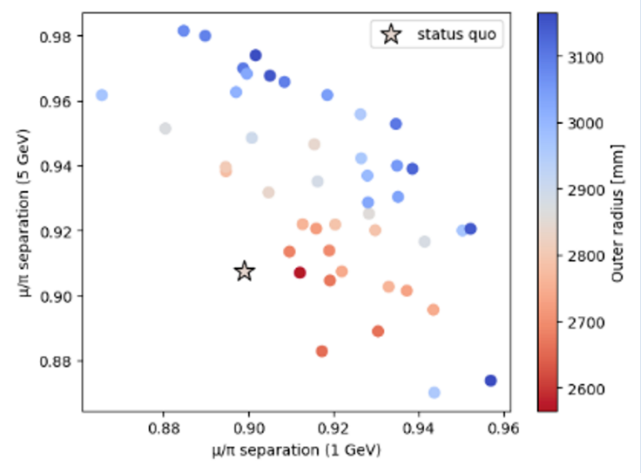


INFN has granted funds in 2025 for a dedicated small-scale RGH prototype

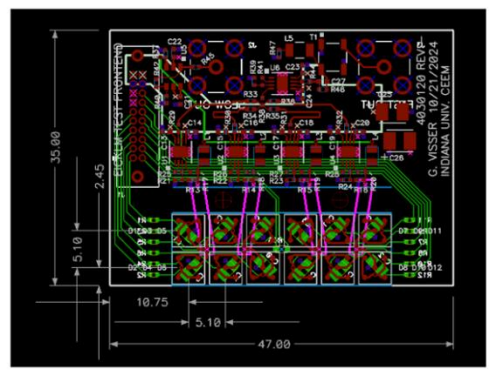
DUKE, USC, IU effort within the generic EIC R&D program for a $K_L$-to-muons detector based on scintillating bars + SiPM

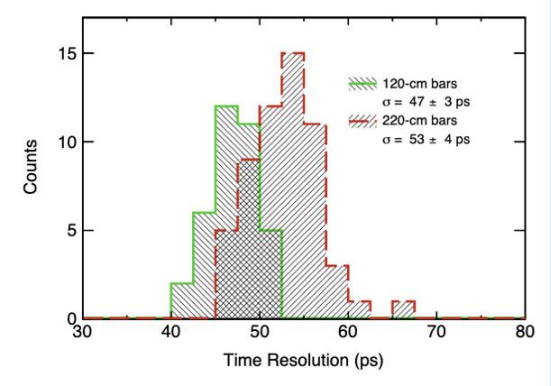
Simulations:




Hardware:



# Conclusions

RGH team is working 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 |

Science: paramount case with novel lattice inputs but awaiting data

CLAS12: up and running, completed with RICH, ideal for SIDIS and exclusive channels

Target: viable solution better than the original PAC condition for approval

Recoil: technology baseline being defined and resources being structured

We are working to clarify the approval condition at the next PAC for the whole physics program