LABORATORY DIRECTED RESEARCH & DEVELOPMENT

DOE's Engine of Discovery

Jefferson Lab

µRWELL detector developments at Jefferson Lab for high luminosity experiments

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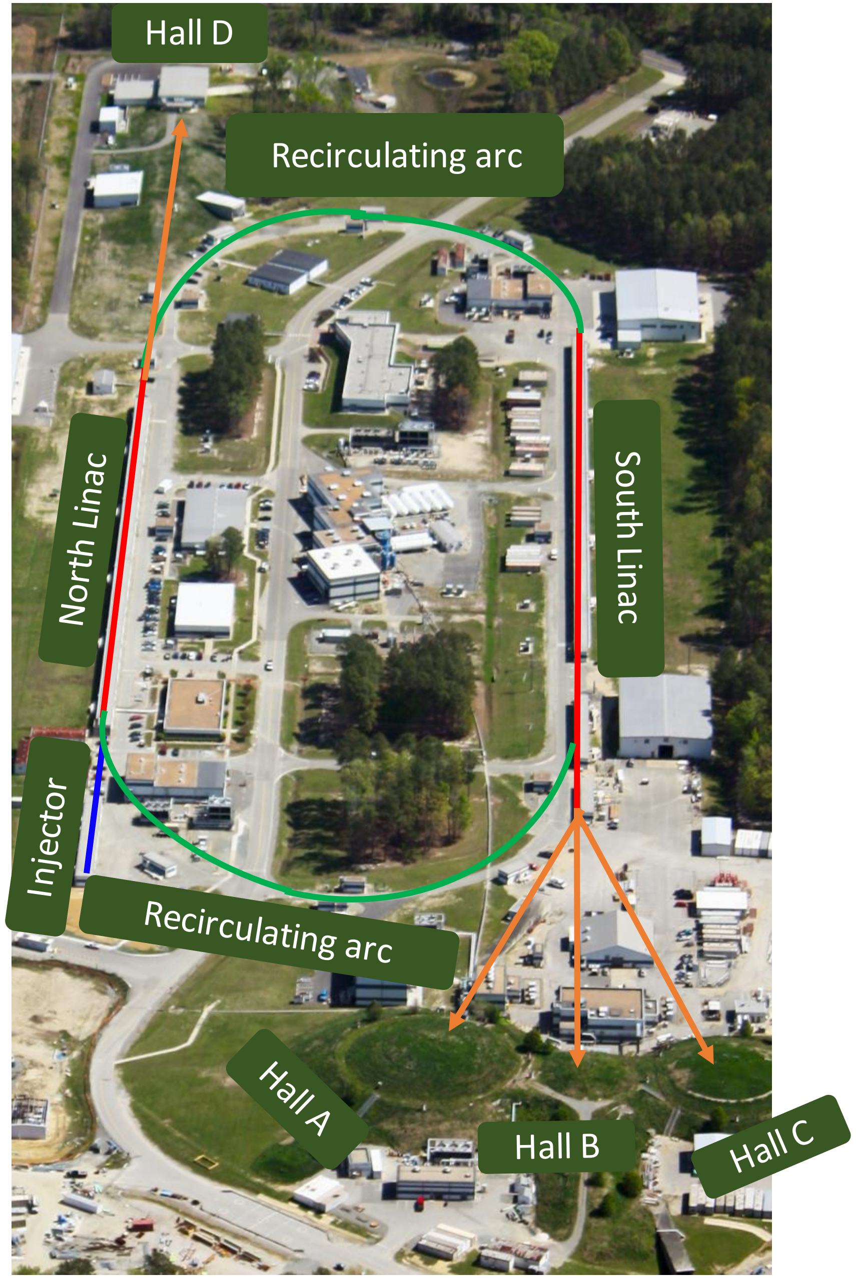
QNP2024 - The 10th International Conference on Quarks and Nuclear Physics

Jul 8 – 12, 2024 Facultat de Biologia, Universitat de Barcelona

Jefferson Lab in Newport News, Virginia

Continuous **E**lectron **B**eam **A**ccelerator **F**acility aka CEBAF

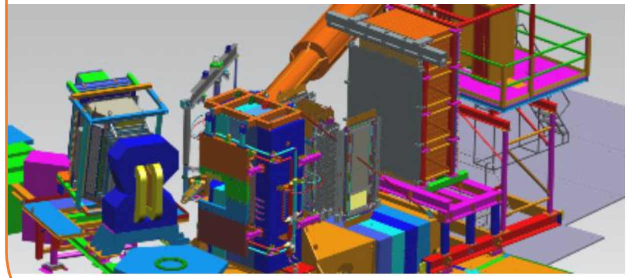
- Running track Shape accelerator
  - Two linear accelerators
  - Two recirculating arcs.
- Simultaneous beam delivery to 4 halls
- High longitudinal polarization (> 85%)
- 100% Duty factor, Continuous Wave beam
- Can reach up to 11 GeV (Halls, A, B and C) and 12 GeV (Hall D)
- Beam power: 1 MW (e.g. 10 GeV @ 100 μA)



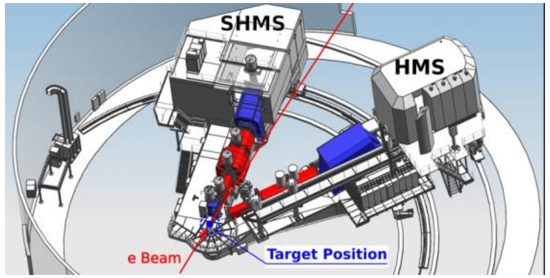
JLab experimental program

High current, low acceptance detectors

Hall-A



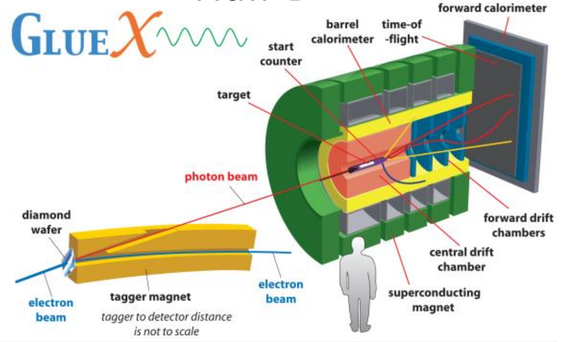
Hall-C



Low current, large acceptance detectors

Hall-B

Hall-D



Broad physics programs

- Electromagnetic Form Factors and Parton Distributions
- Nuclear Femtography (Nucleon 3D structure)
- Hadron Spectroscopy
- QCD and Nuclei
- Test of Standard Model and Beyond

ELSEVIER
Progress in Particle and Nuclear Physics
Volume 127, November 2022, 103985

Review

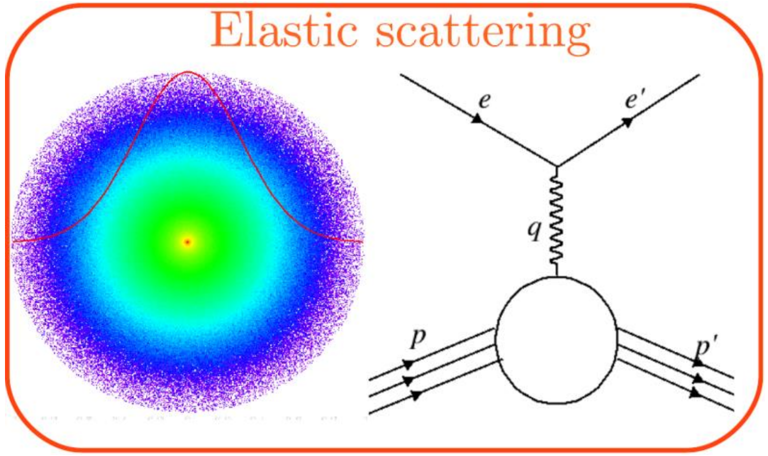
Physics with CEBAF at 12 GeV and future opportunities https://arxiv.org/abs/2112.00060

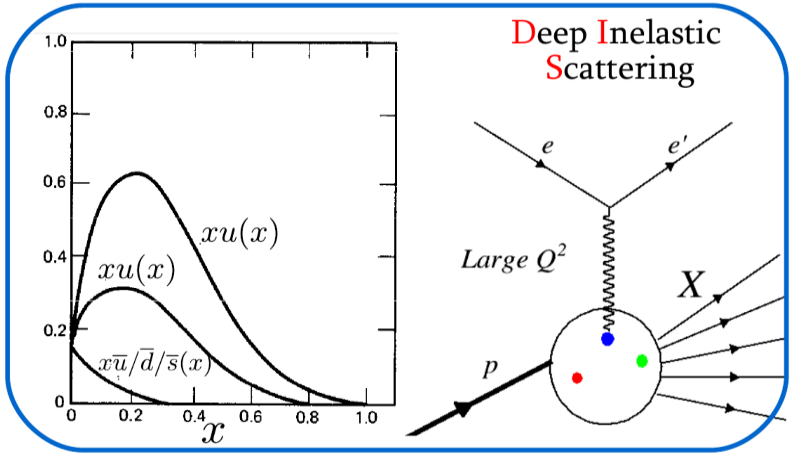
Potential upgrades

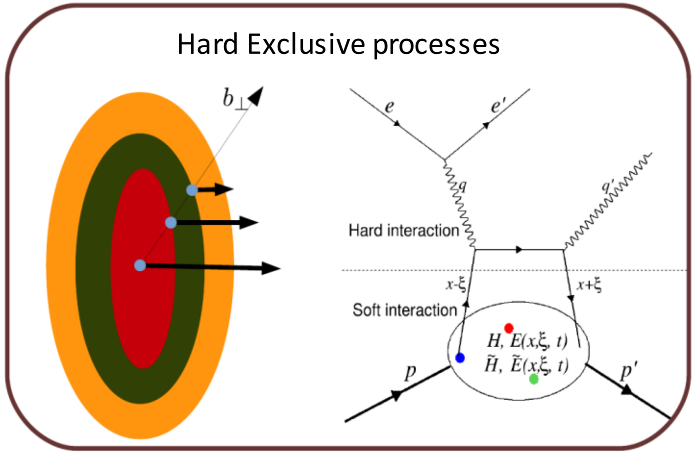
- Energy upgrade of the CEBAF : ~ 22 GeV
- Positron beam
- **Need for high Luminosity facilities: High luminosity large acceptance detectors: CLAS12 (Hall-B) and SOLID (Hall-A)**

Generalized Parton Distributions

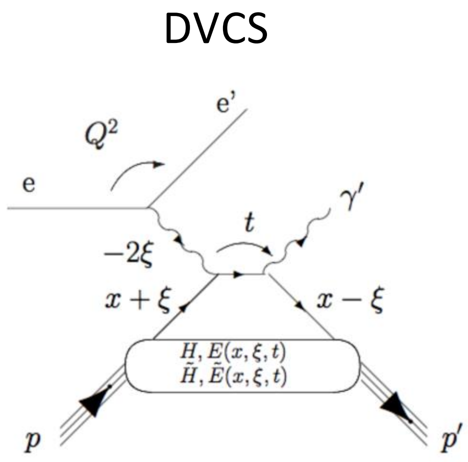
One of flagship experiments at JLab are deep exclusive processes (e.g. DVCS, TCS, DVMP etc), allowing to access **G**eneralized **P**arton **D**istributions (GPDs).

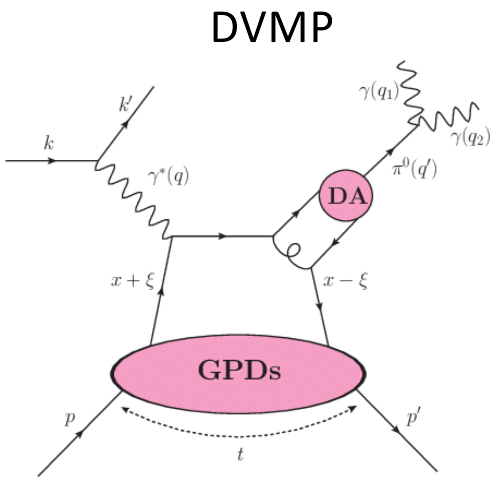


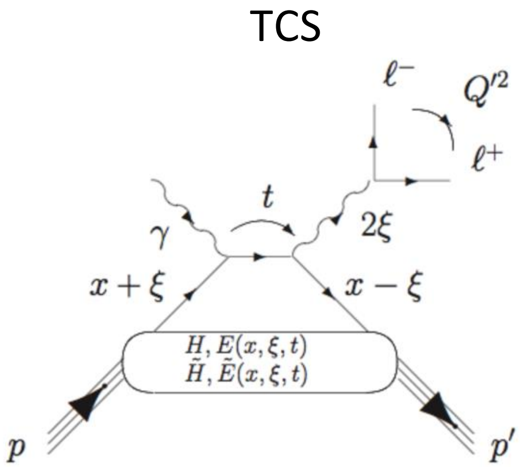




Hard exclusive reactions experimentally studied at JLab







- GPDs are hybrid functions that combine aspects of PDFs and Elastic Form Factors.
- 2D spatial + 1D momentum distributions of partons inside the nucleon
- More than a dozen of completed and planned dedicated experiments at JLab.

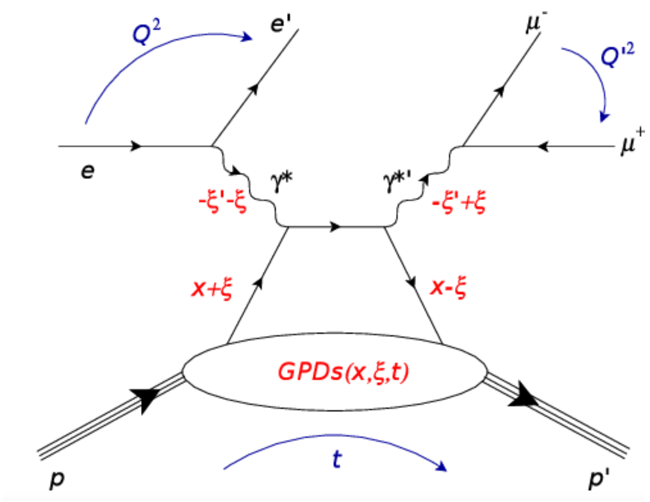
More details in: Prog.Part.Nucl.Phys. 133 (2023) 104069

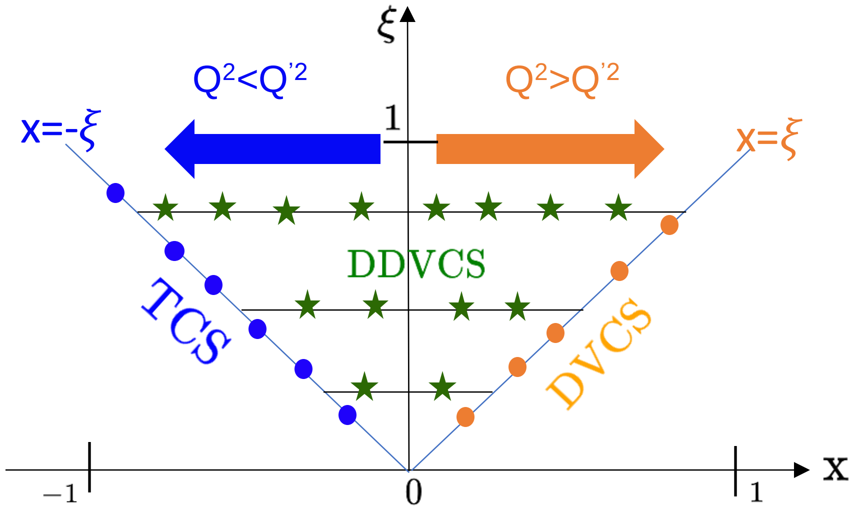
Challenges in the extraction of GPDs

GPDs depend on three variables: x, ξ and t, however they enter into observables as an integral over the quark internal loop momentum x, or they can be accessed through the beam spin asymmetries at $x = \mp\xi$ line.

The reaction, Double DVCS has highly virtual incoming and outgoing photons.

By varying Q'^2/Q^2 ratio one can get deeper inside "x vs ξ" phase space.





- The drawback is DDVCS cross-section is 2-3 orders of magnitude smaller than the DVCS or TCS cross-section.
  - No measurements so far because of the low cross-section
- Two JLab LOIs LOI12-16-004 and LOI12-15-005 intend to do measurements DDVCS measurements in Hall-B and Hall-A with modest modification of the CLAS12 and SOLID experimental setups.

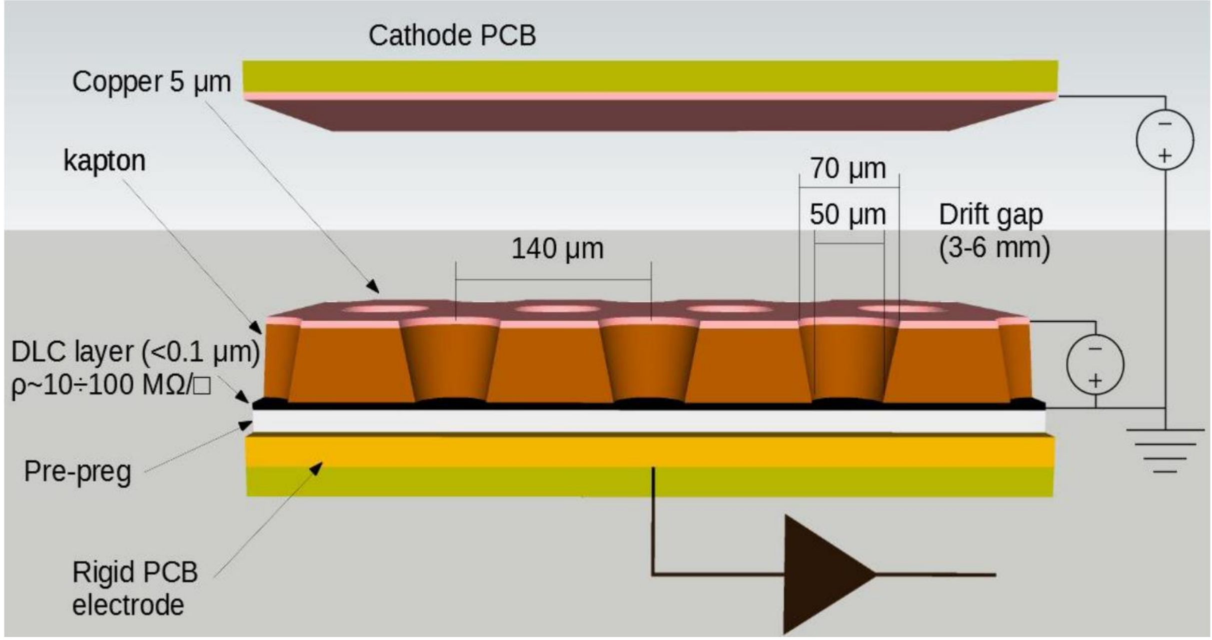
- Need at least: $L > 10^{37} cm^{-2}s^{-1}$ in order to accumulate enough statistics in a reasonable timeframe (1-2 years)

- Requires large area trackers with good spatial resolutions at particle rates of ~few MHz/cm^2

Micro Resistive Well (µRWELL) detectors

A promising solutions is to use Micro-resistive well (µRWELL) detectors

- Amplification occurs inside wells
- The whole amplification charge is collected on the Resistive layer, which is capacitively coupled to readout strips/pads
- Robust against discharges
- Good position resolution
- Low material budget:
- Relatively easy construction
- Lower production cost
- The gain is higher than gain of a single stage GEM



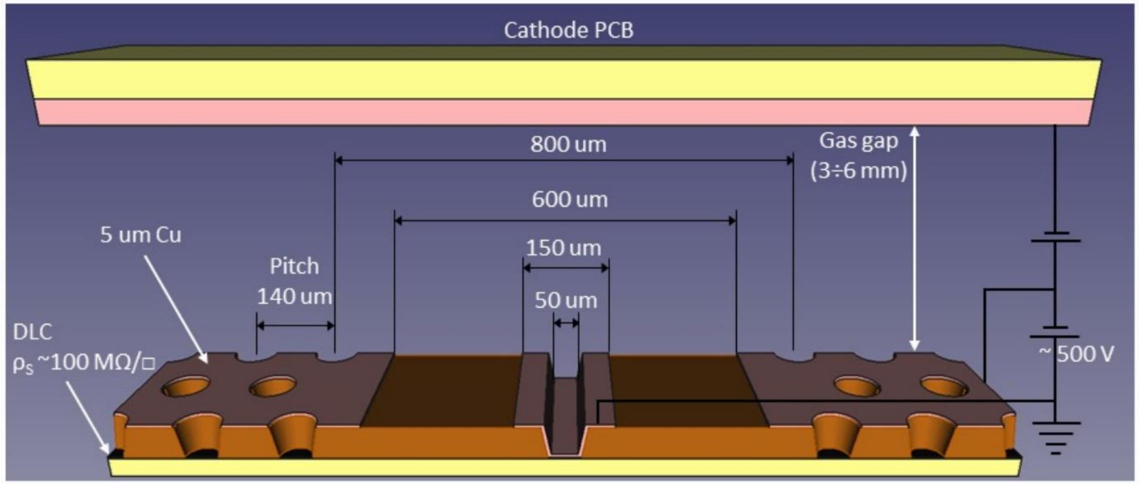
G. Bencivenni et al 2015 JINST 10 P02008

With this initial design, above 100 KHz/cm^2, the gain starts to drop.

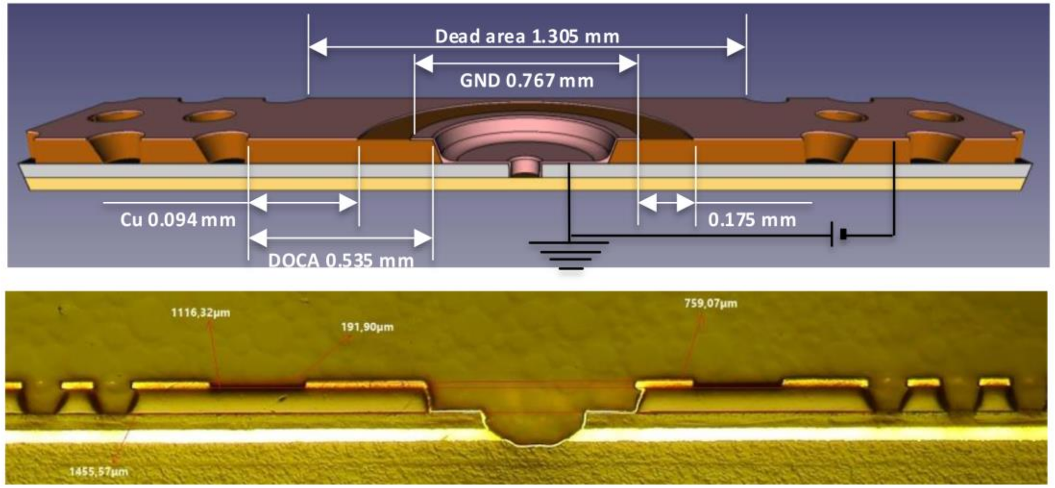
This is mainly due to the resistive layer: the charge doesn't get dissipated fast enough.

High-Rate (HR) version µRWELLs

The Patterning – Etching – Plating (PEP) Groove



PEP Dot



Figures from G. Bencivenni's slide.

- DLC is grounded from top by kapton etching and plating.
- Results to ≈1 mm dead zone around the groove.

- Similarly to groves, the DLC is grounded through PEP dots
- Much smaller geometric dead-zone.

Recent developments @ JLab

A big (1.5 m x 0.5 m) test prototype is being tested for the CLAS12 Luminosity upgrade:

4 small (10cm x 10cm) + 1 (30 cm x 30 cm) prototypes with different options of HR uRwell detectors to be tested soon (thanks to recent **L**aboratory **D**irected **R**esearch and **D**evelopment (LDRD) funding)

Four µRWELL detector to be tested soon

- Detector 1: Dot pitch=2 cm, Well pitch = 140 µm, X,Y readout
- Detector 2: Dot pitch=**1 cm**, Well pitch = 140 µm, X,Y readout
- Detector 3: Dot pitch=2 cm, Well pitch = **100 µm**, X,Y readout
- Detector 4: Dot pitch=2 cm, Well pitch = 100 µm, **X,Y,U readout**

All are 10 cm x 10 cm 2D detectors

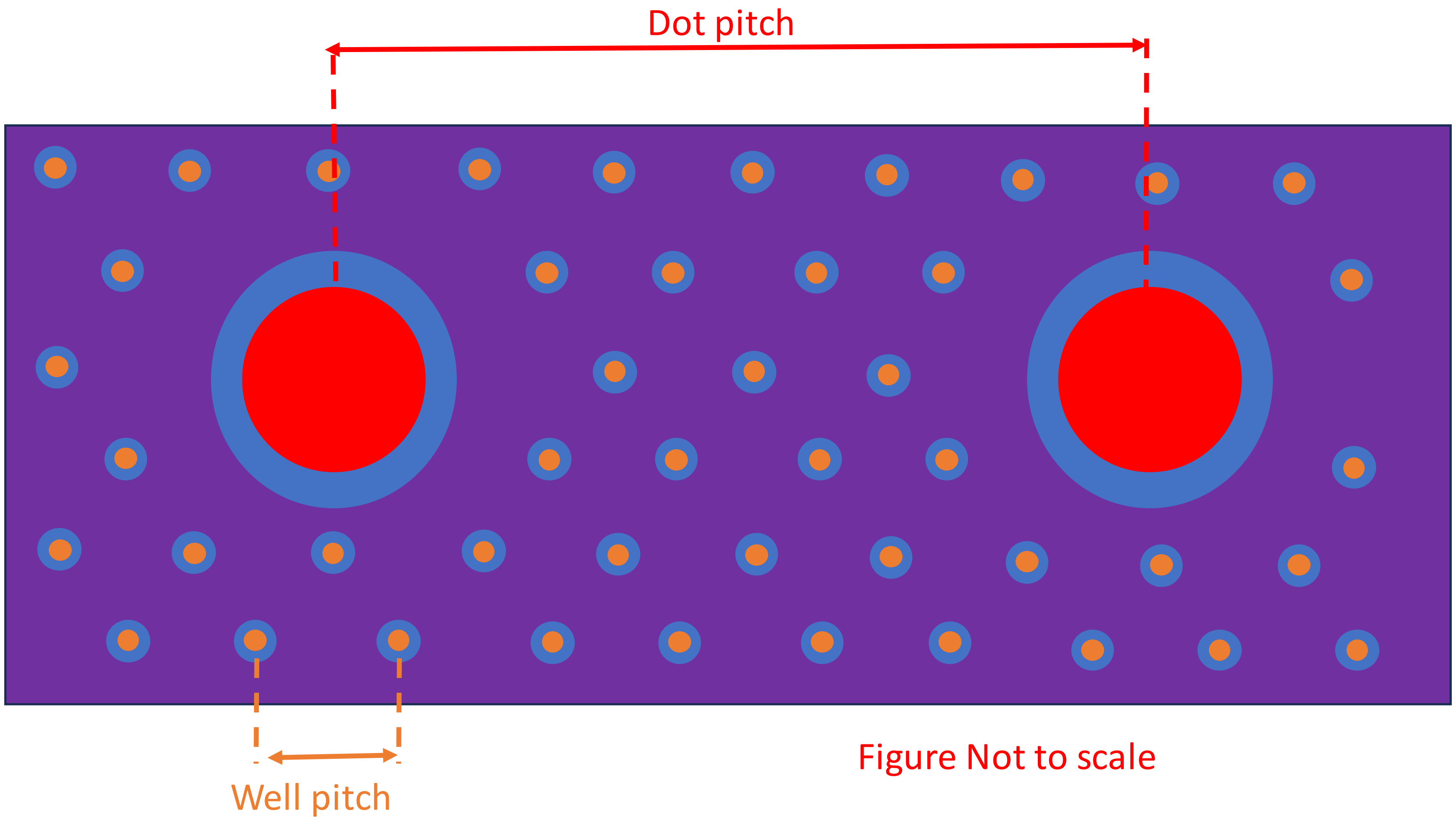
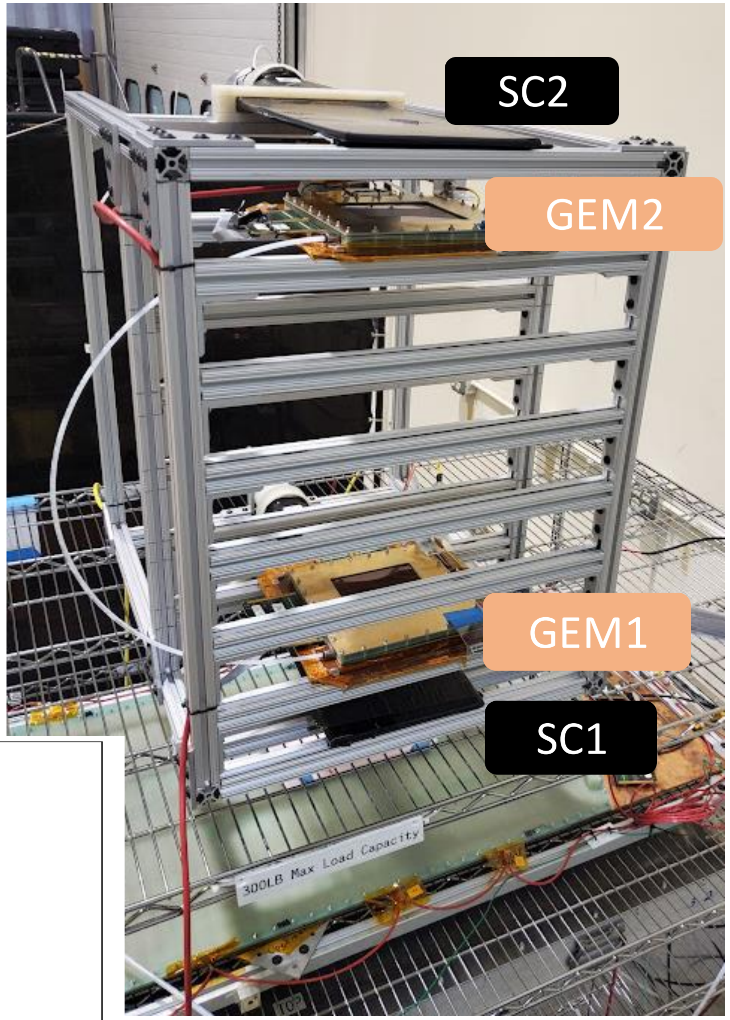
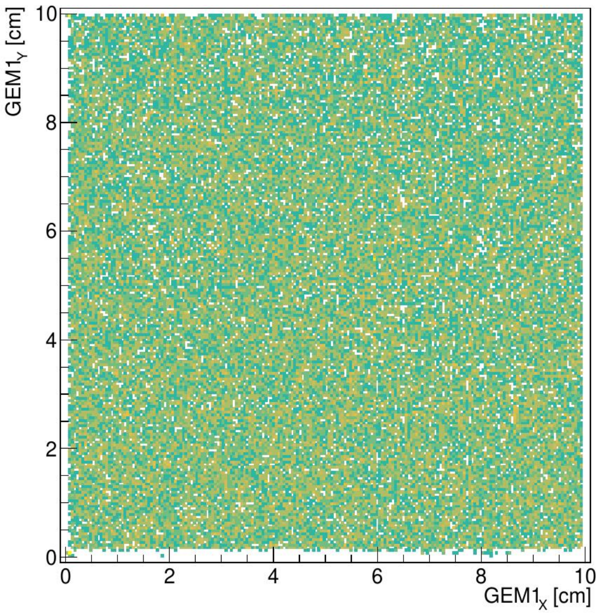


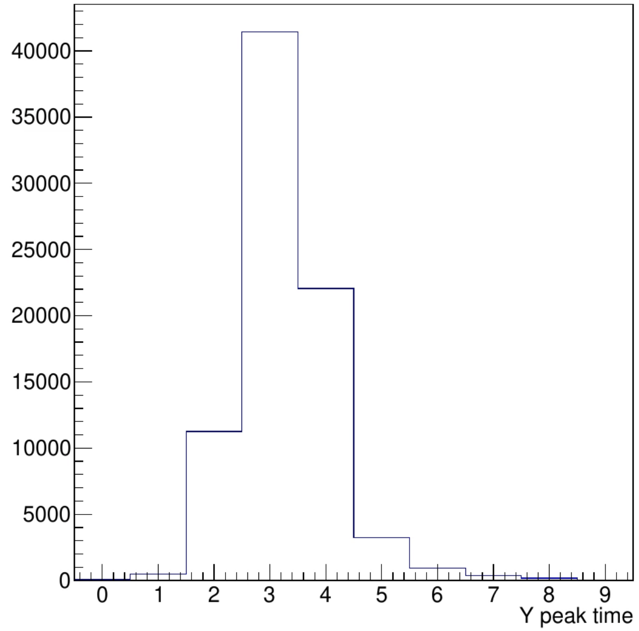
Figure Not to scale

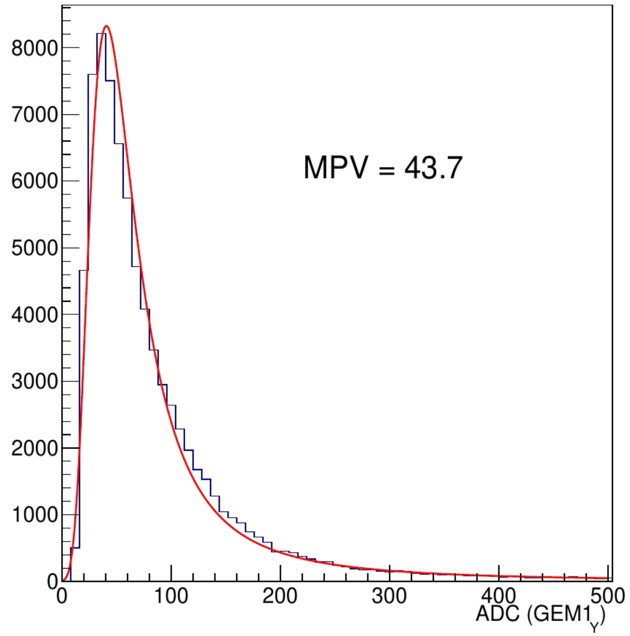
Testing of small detectors

- Four 10 cm x 10 cm detectors will arrive to JLab with next 1-2 weeks
  - In the process of being shipped
- The test stand includes:
  - 2 scintillator bars for trigger
  - 2 GEMs for tagging and tracking cosmic tracks
  - Four slots in the middle are for µRWELLs.
- GEMs used for the software and the DAQ development. Should not take very long to understand basic features of µRWELLs with cosmic test stand.
- Test under beam: ~ early 2025









The large prototype for CLAS12

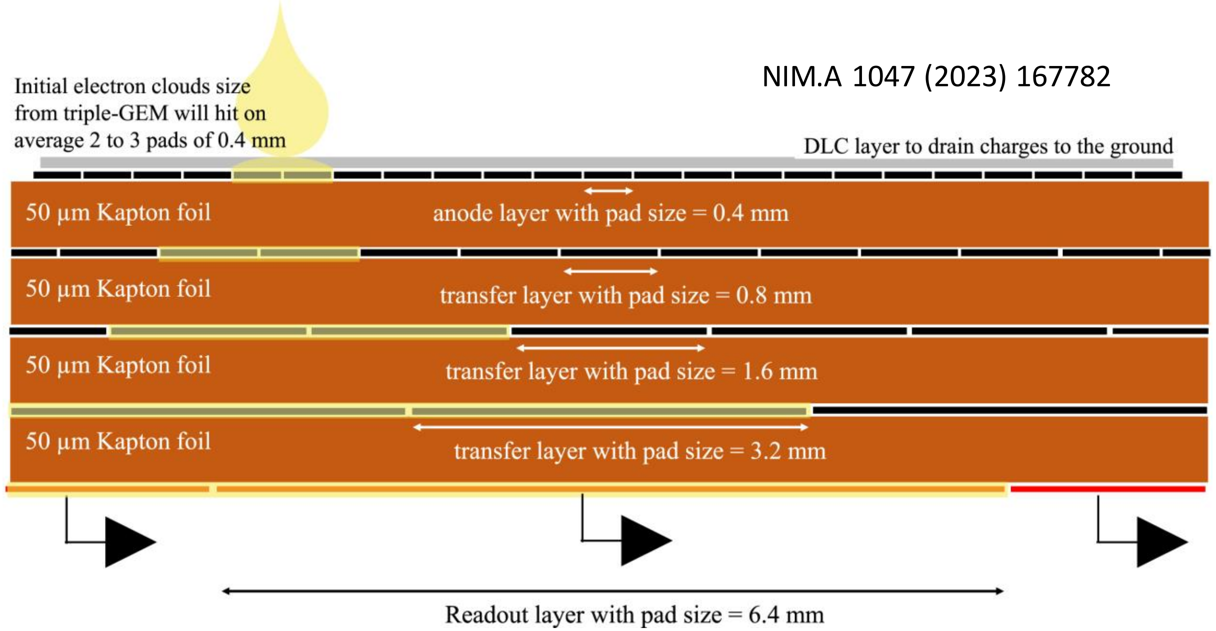
- 2D U/V readout: ±10°
- Strip pitch: 1 mm
- Capacitive sharing
- Different strip widths to find the optimum charge sharing

- Largest µRWELL built so far
- Readout: SRS APVs

146 cm

Capacitive sharing

NIM.A 1047 (2023) 167782

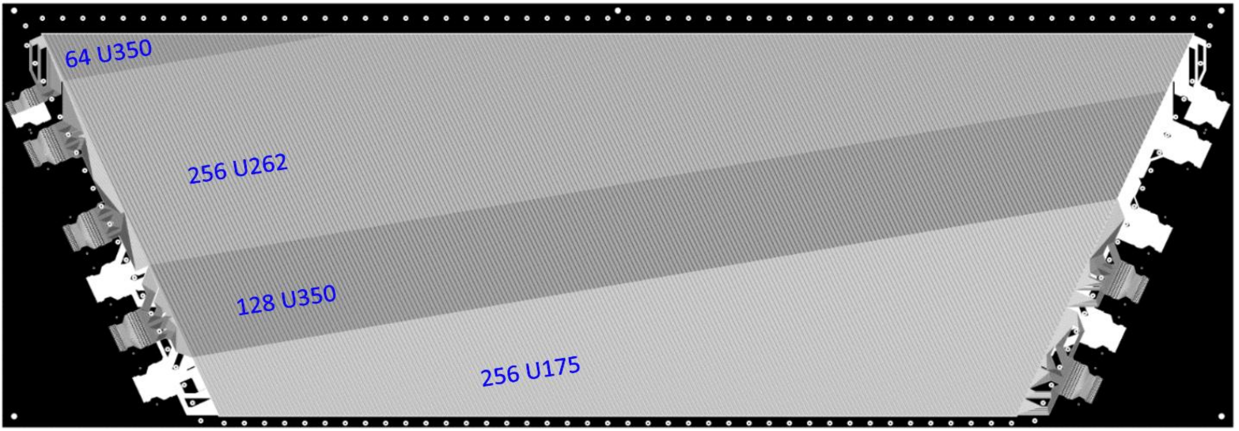


Charge sharing between U and V strips significantly depends on the both of U and V strip widths.

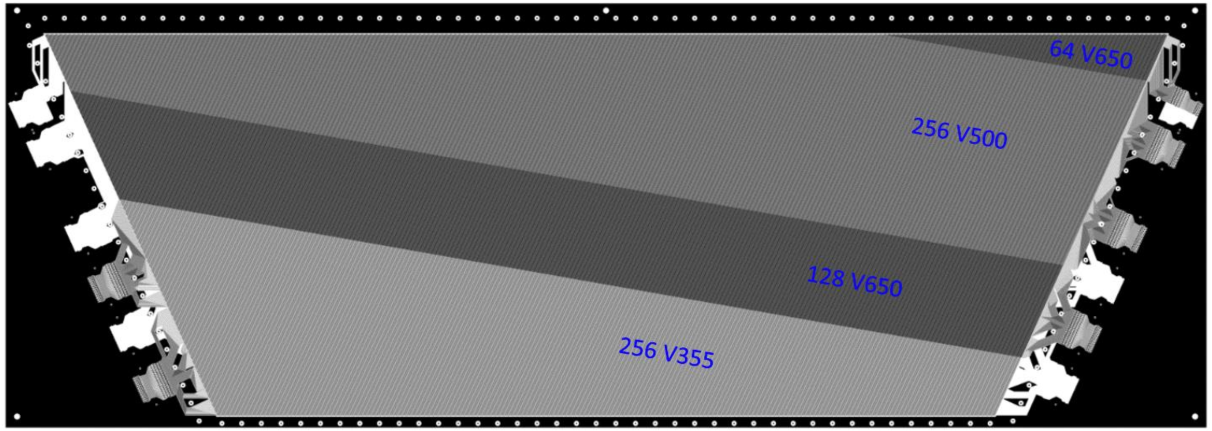
To get the best strip width combination , several strip widths are considered, both for U and for V.

- Three different U strip widths
    - **175 μm**, **262 μm** and **350 μm**
- Three different V strip widths
    - **355 μm, 500 μm, 650 μm**

U strips: 3 different widths

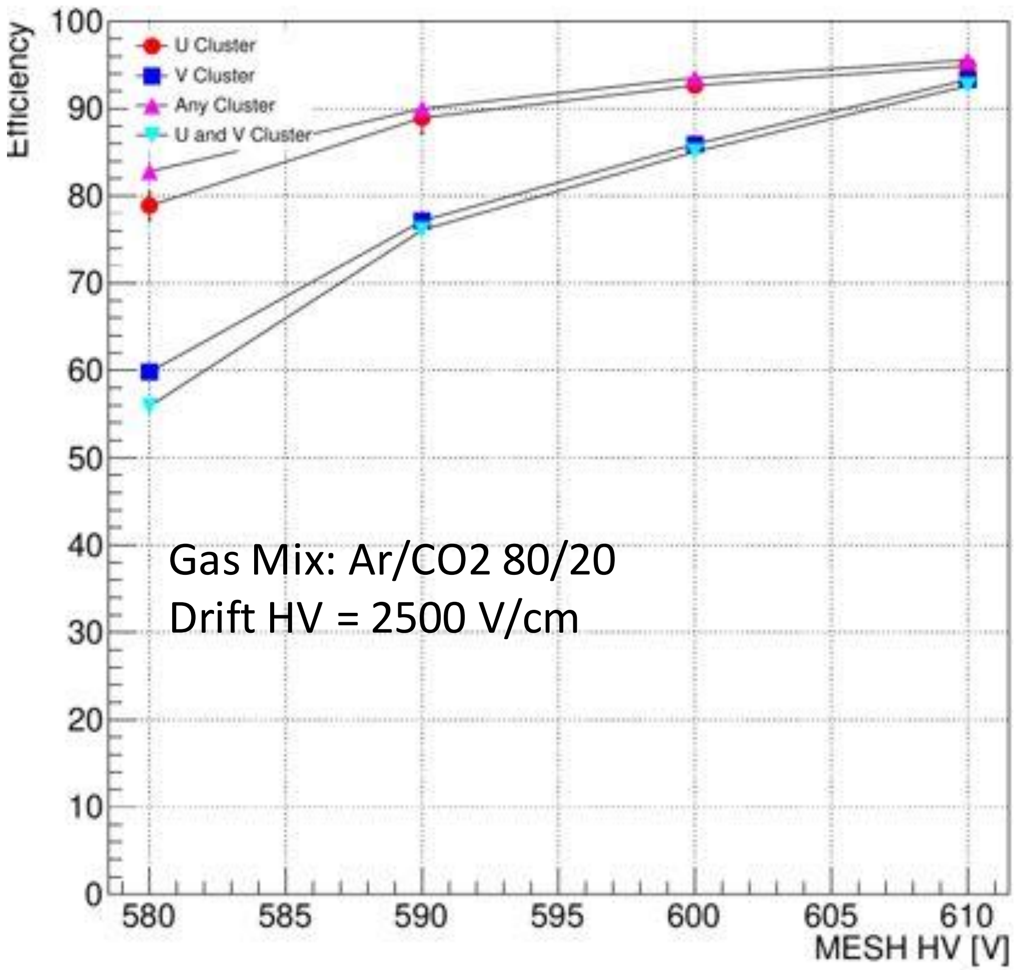


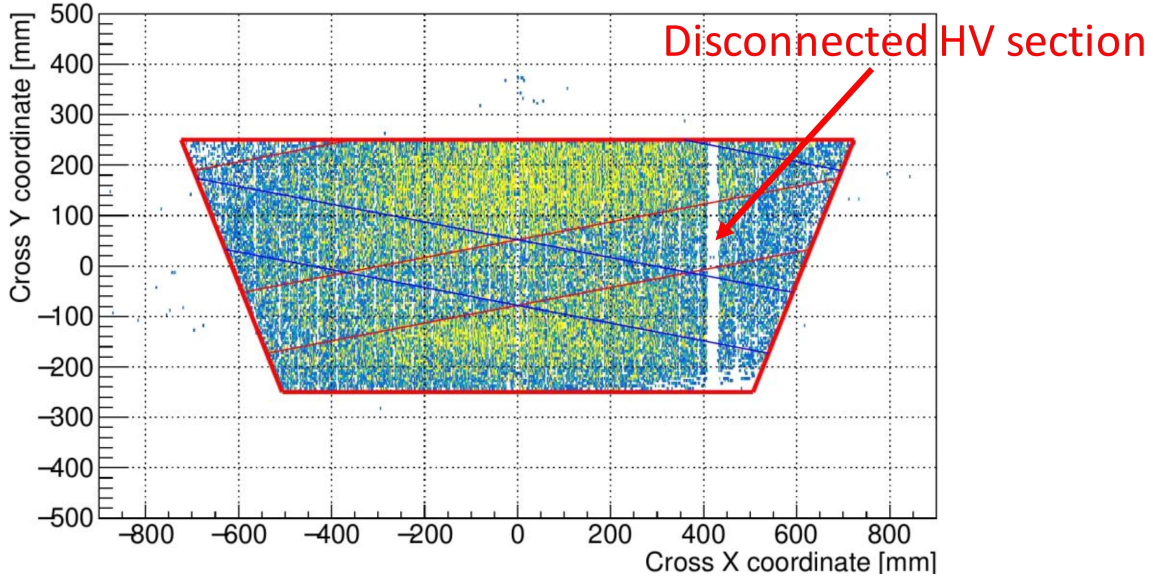
V strips: 3 different widths



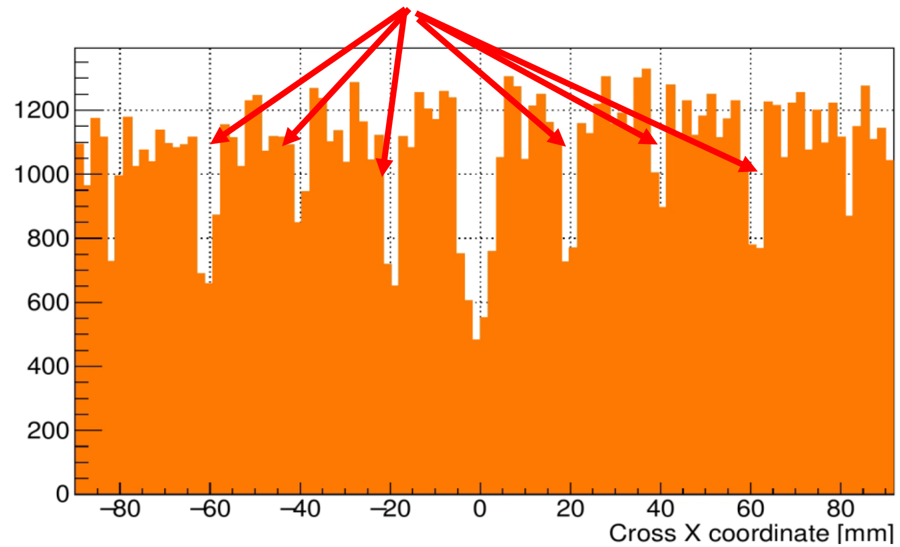
Cosmic data

- Testting with Cosmics: Hit threshold 4σ
- Reaching 95% at about 610 V





Structure of grooves



Summary

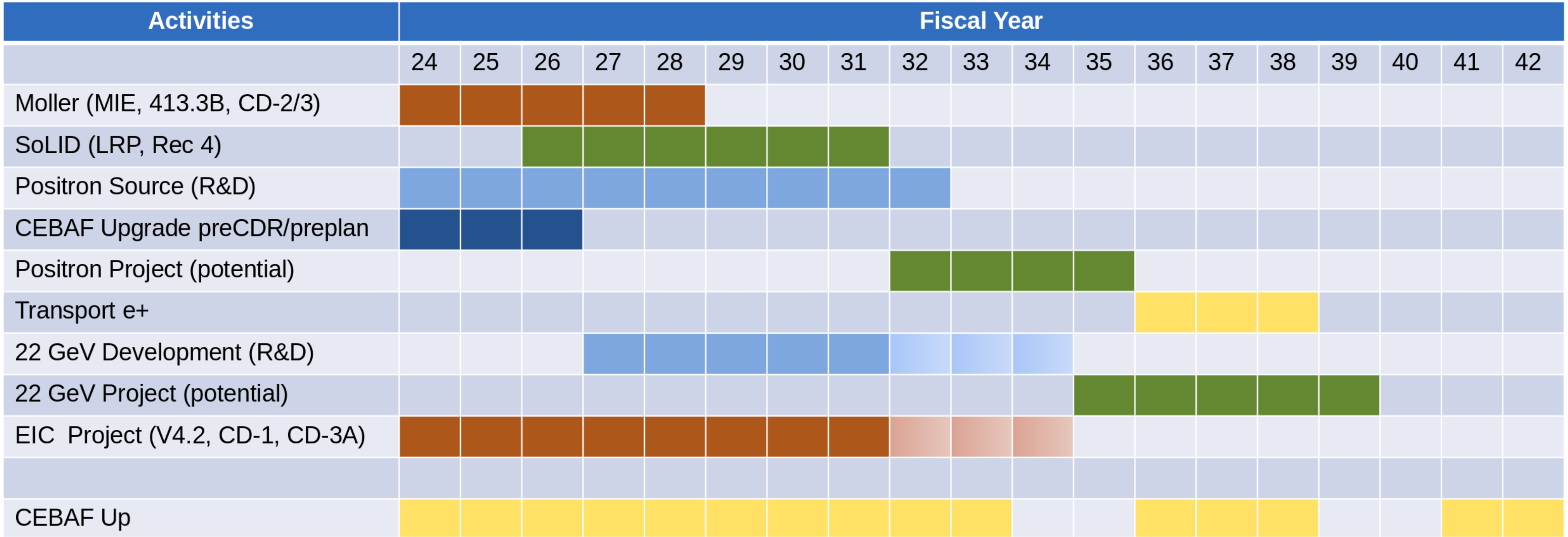
- Jefferson Lab is a unique place to do very low cross-section experiments with an electron beam
- DDVCS is one of such processes, and is a very valuable for the GPD prgram
- DDVCS can be measured with CLAS12 in Hall-B and SOLID in Hall-A with modest modifications of the experimental setup.
- Relatively new type of MPGD detectors µRWELLs, with their relatively simple design, low material budget, good position resolution and a higher gain are a promising type of detectors to be used for a high luminosity experiments.
- At JLab we have started testing high-rate versions µRWELL with cosmic muons.
- Detectors will go under beam test during the next available beam at JLab
- Stay tuned for new updates...

Backup

David Dean's slide: 2024 JLUO Annual Meeting

Notional CEBAF and EIC Efforts on One Chart

- Accelerator team has worked up an early schedule and cost estimate
  - Schedule assumptions based on a notional timing of when funds might be available (near EIC ramp down based on EIC V3 profile)
  - For completeness, Moller and SoLID (part of 12 GeV program) are shown; positron source dev shown
- EIC Project is shown



Jefferson Lab
Thomas Jefferson National Accelerator Facility

https://arxiv.org/abs/2112.00060

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Progress in Particle and Nuclear Physics

Volume 127, November 2022, 103985

Review

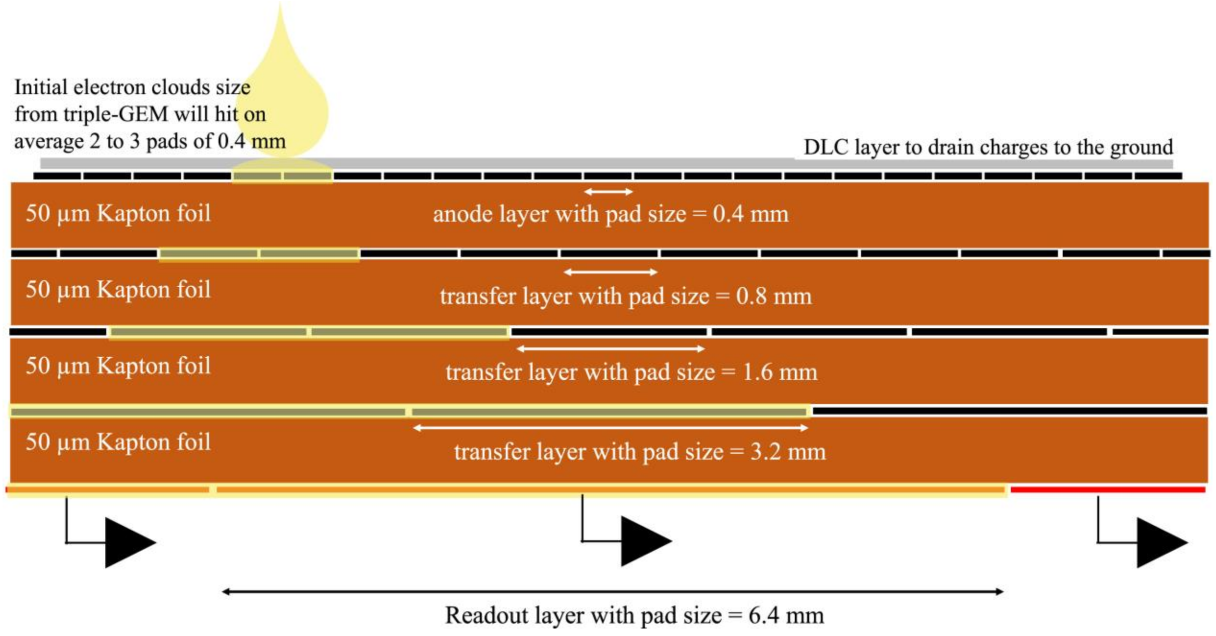
Physics with CEBAF at 12 GeV and future opportunities

J. Arrington [a], M. Battaglieri [b o], A. Boehnlein [b], S.A. Bogacz [b], W.K. Brooks [j], E. Chudakov [b], I. Cloët [c], R. Ent [b], H. Gao [d], J. Grames [b], L. Harwood [b], X. Ji [e f], C. Keppel [b], G. Krafft [b], R.D. McKeown [b h], J. Napolitano [g], J.W. Qiu [b h], P. Rossi [b n], M. Schram [b], S. Stepanyan [b], J. Stevens [h], A.P. Szczepaniak [l m b], N. Toro [i], X. Zheng [k]

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Volume 1047, February 2023, 167782

Performance of a resistive micro-well detector with capacitive-sharing strip anode readout

Kondo Gnanvo [a], Nilanga Liyanage [a], Bertrand Mehl [b], Rui de Oliveira [b]



Strip pitch = 800 µm