ACTS4NP - ACTS Tracking for Nuclear Physics 2025

Development of ACTS based tracking Updates

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2025-05-28

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

ACTS

- **ACTS** - **A** **C**ommon **T**racking **S**oftware

- ACTS - experiment-independent toolkit for (charged) particle track reconstruction in ~~(high energy)~~ HENP physics experiments implemented in modern C++.

- The ACTS project provides high-level track reconstruction modules that can be used for any tracking detector.

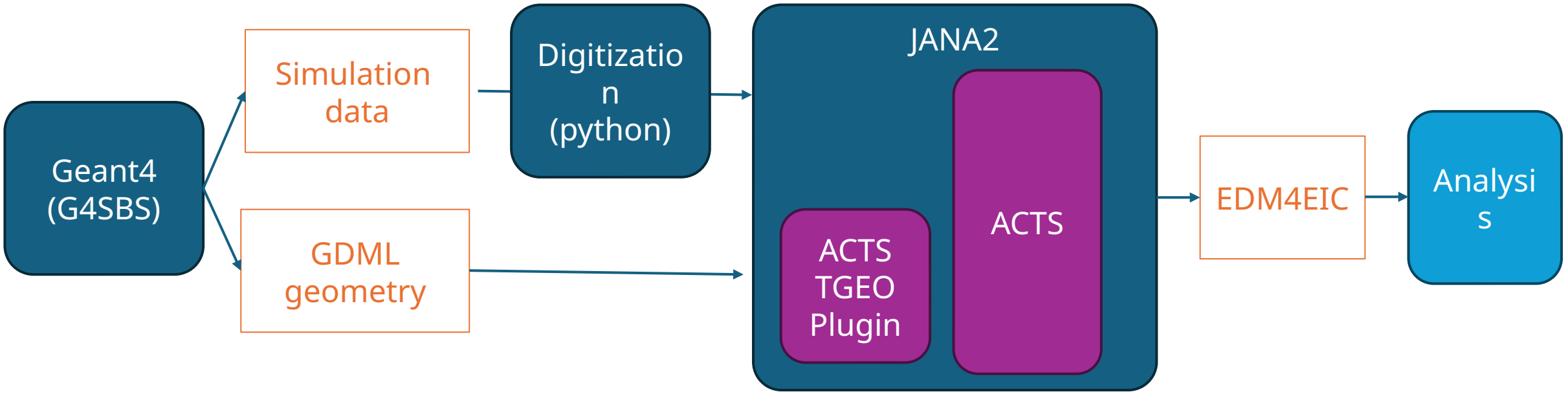
- Documentation link

- GitHub link

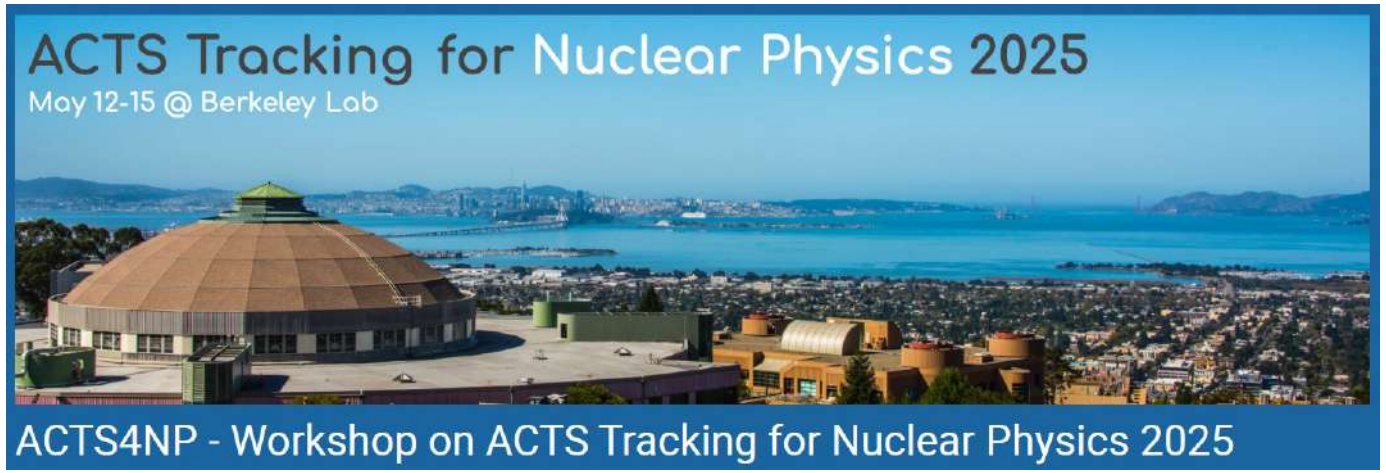
ACTS for TDIS

- Geant4 (g4sbs) -> GDML -> TGeo geometry
- Custom digitization algorithms
- JANA2 (C++ modular framework)
- PODIO (EDM4EIC like tracking scheme)
- ACTS (v37.4.0) + TGeo plugin

- https://github.com/JeffersonLab/tdis



ACTS4NP Conference



May 12 – 15, 2025
Lawrence Berkeley National Laboratory

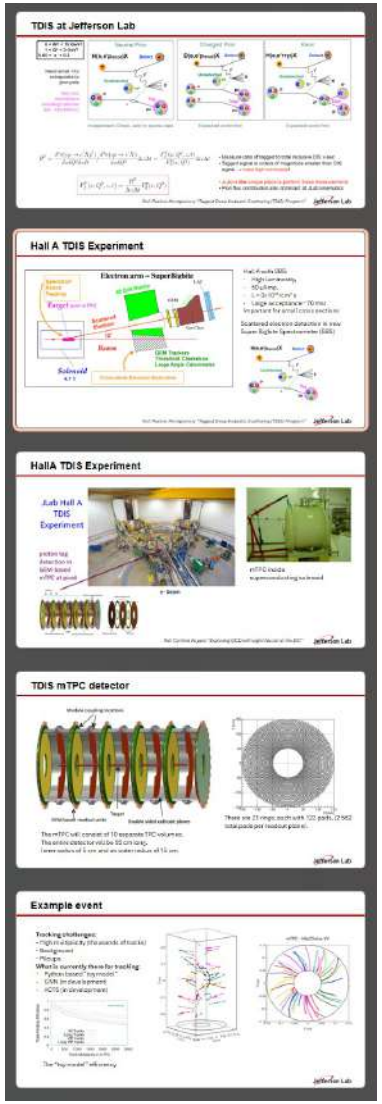
“Bridge the ACTS community + NP experiments that might/already use ACTS”

Conference agenda (freestyle):

- ACTS updates and roadmap
- Use in large CERN experiments
- Use in NP experiments
- Lots of discussion on ACTS in NP
- ACTS Tutorials and ACTS insights
- GPU implementations and AI (GNNs)

Conference outcome

- ACTS developers are interested in TDIS case (for multitude of reasons)
- Worked together on ACTS TDIS code base
- Many discussions of the conference are aligned with TDIS experience:
  - How to deal with non-pileup background?
    E.g. beam cloud background?
  - How new smaller (than CERN or EIC) experiments start with ACTS?
  - How to deal with gaseous detectors and TPC-s in particular?
  - What are the workflow for questions / missing documentation
- Developed further updates in TDIS ACTS:
  - Switch to ACTS based PODIO event model
  - Switch to Gen3 geometry (later)
  - How to do seeding



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The ACTS TDIS global roadmap

- Benchmarks
- Seeding
- Benchmark efficiency at high multiplicity (some seeding tuning)
- Vertexing

THANK YOU!

BACK&UP

EIC software stack

Why is a good idea:

- NP physicists became familiar with it
- Future experiments select it or modification
- EDM4EIC Analysis compatibility
- “Algorithms” allows easy algorithms decoupling.
  Should be easy to reuse existing EIC algorithms
- JANA2 developers interested in real life JANA2 + ACTS example

But…

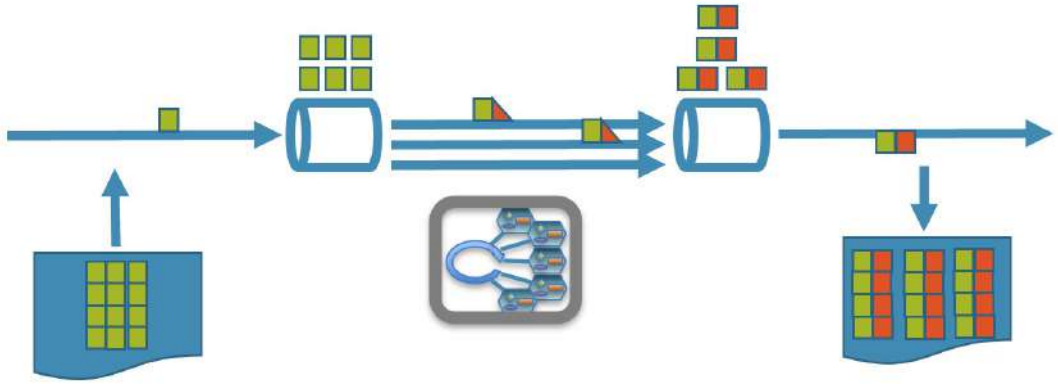
- Do small experiments or detector setups need all that for EIC?
- Do “Algorithms” library really allow to reuse something easily?
- Could we automatically upgrade tracking algorithms as EIC upgrades?
- Etc. etc. etc.

JANA2

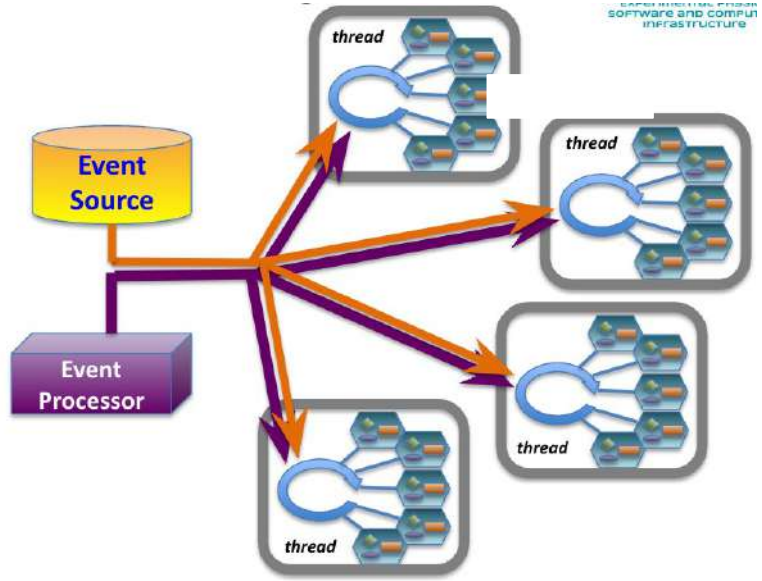
- JANA2 second generation C++ framework with nearly 2 decades of experience behind it

- Modern coding and CS practices
- Streaming DAQ and heterogeneous hardware support
- Active development
- ***EICrecon*** implements algorithms for ePIC in JANA2
  https://github.com/eic/EICrecon

Documentation: https://jeffersonlab.github.io/JANA2/
Examples: https://github.com/JeffersonLab/JANA2/tree/master/src/examples
Example projects: https://github.com/JeffersonLab/JANA2_Examples



JANA2 parallelization



Publications:
https://arxiv.org/abs/2202.03085 *Streaming readout for next generation electron scattering experiments*
https://doi.org/10.1051/epjconf/202125104011 *SRO of the CLAS12 Forward Tagger Using TriDAS and JANA2*
https://doi.org/10.1051/epjconf/202024501022 *JANA2 Framework for Event Based and Triggerless Data Processing*
https://doi.org/10.1051/epjconf/202024507037 *Offsite Data Processing for the GlueX Experiment*

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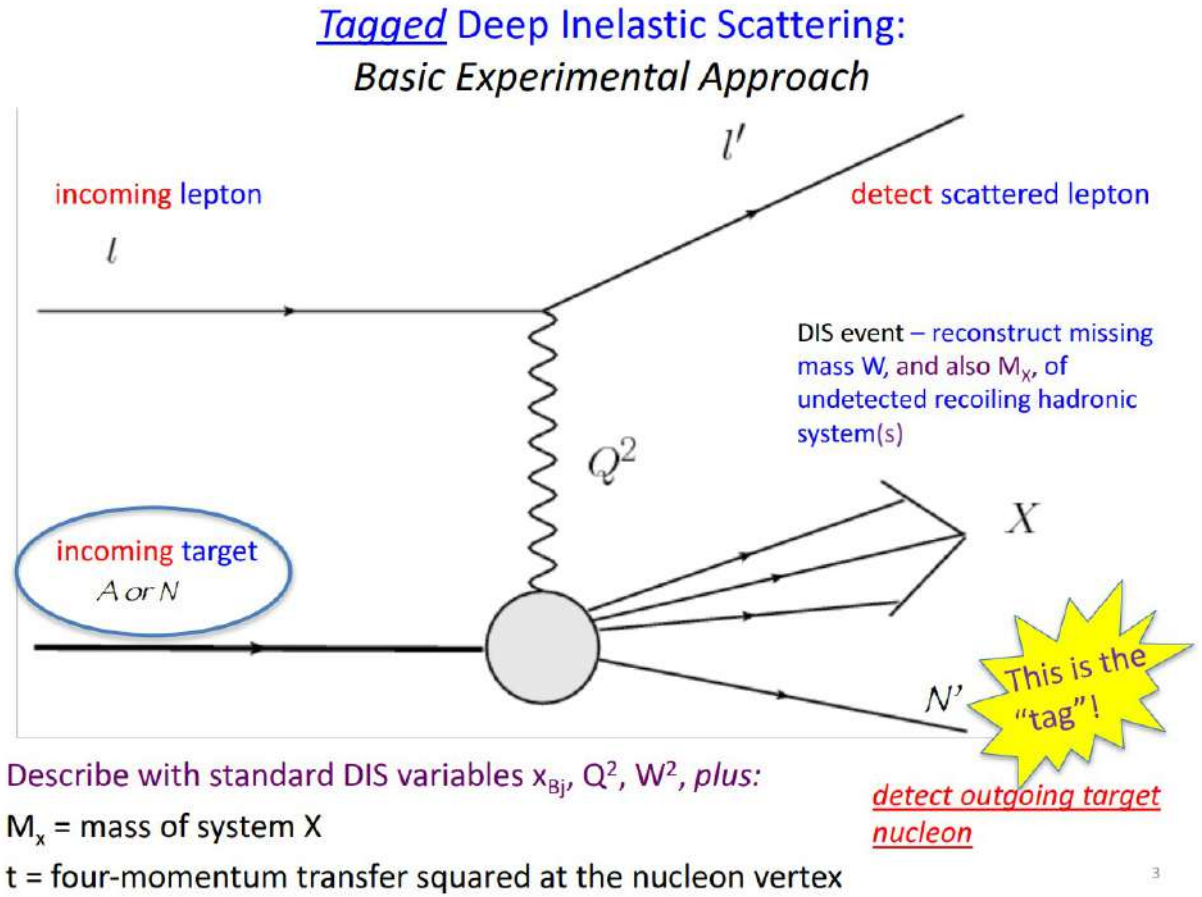
Tagged Deep Inelastic Scattering (TDIS)



Ref: Cynthia Keppel "Exploring QCD with Light Nuclei at the EIC"
Ref: Rachel Montgomery "Tagged Deep Inelastic Scattering (TDIS) Program"

HERA (ZEUS and H1 Collaborations) Leading Neutron Production
COMPASS Experiment at CERN – Pion-Induced Drell-Yan Processes
EIC – considered as TDIS major future platform

JLaTDIS program:

Pion TDIS
- C12-15-006, PAC43 approved
- C1 → subject to technical review

Kaon TDIS
- Run group C12-15-006A,
- PAC45 approved

nTDIS
- Run Group C12-15-006B,
- PAC49 approved

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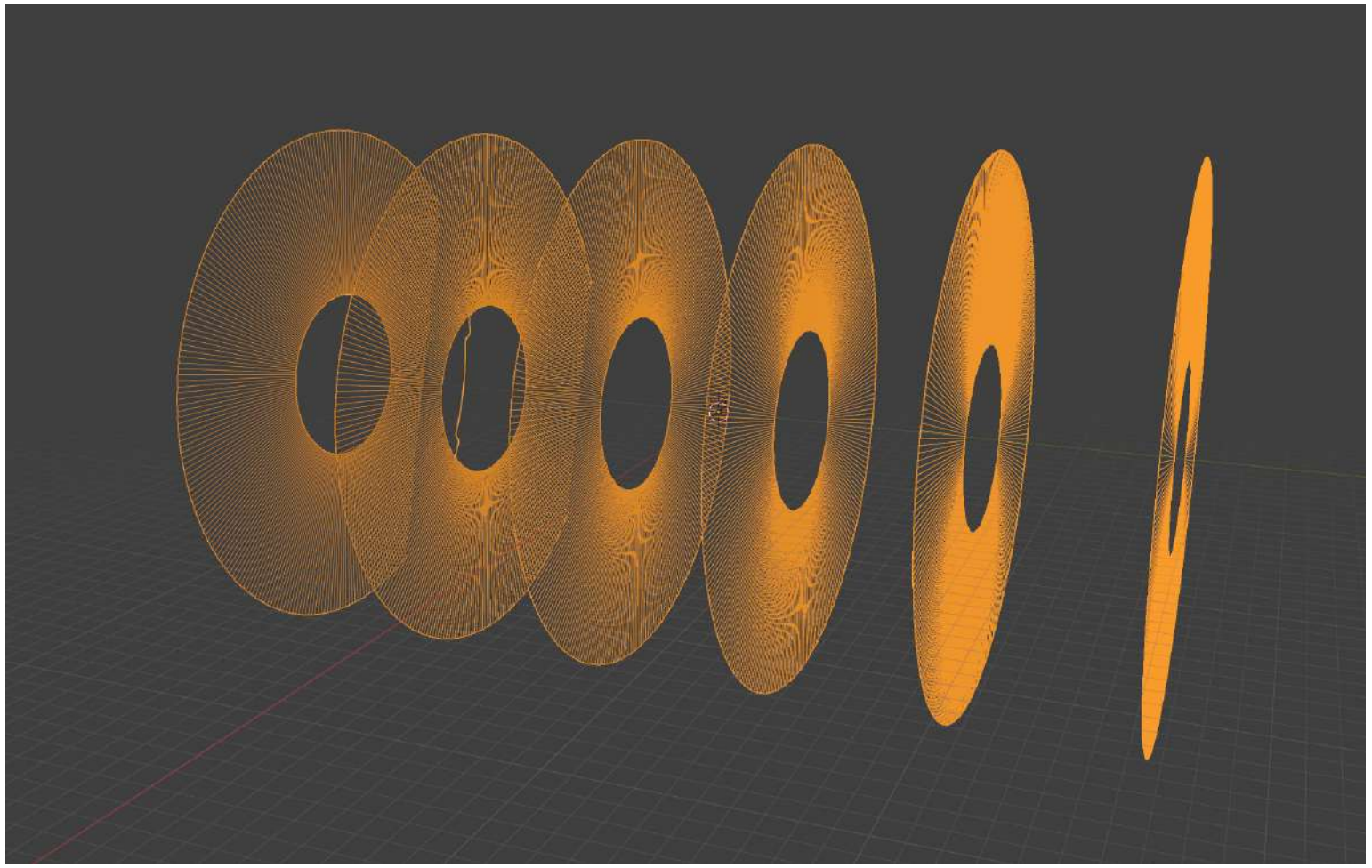
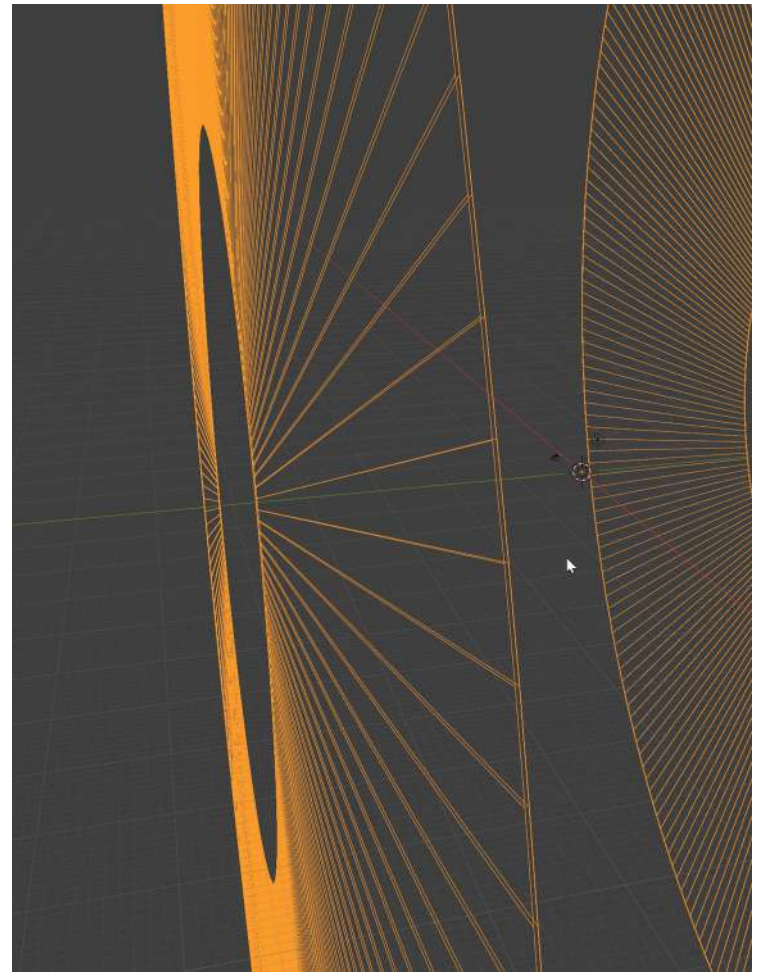
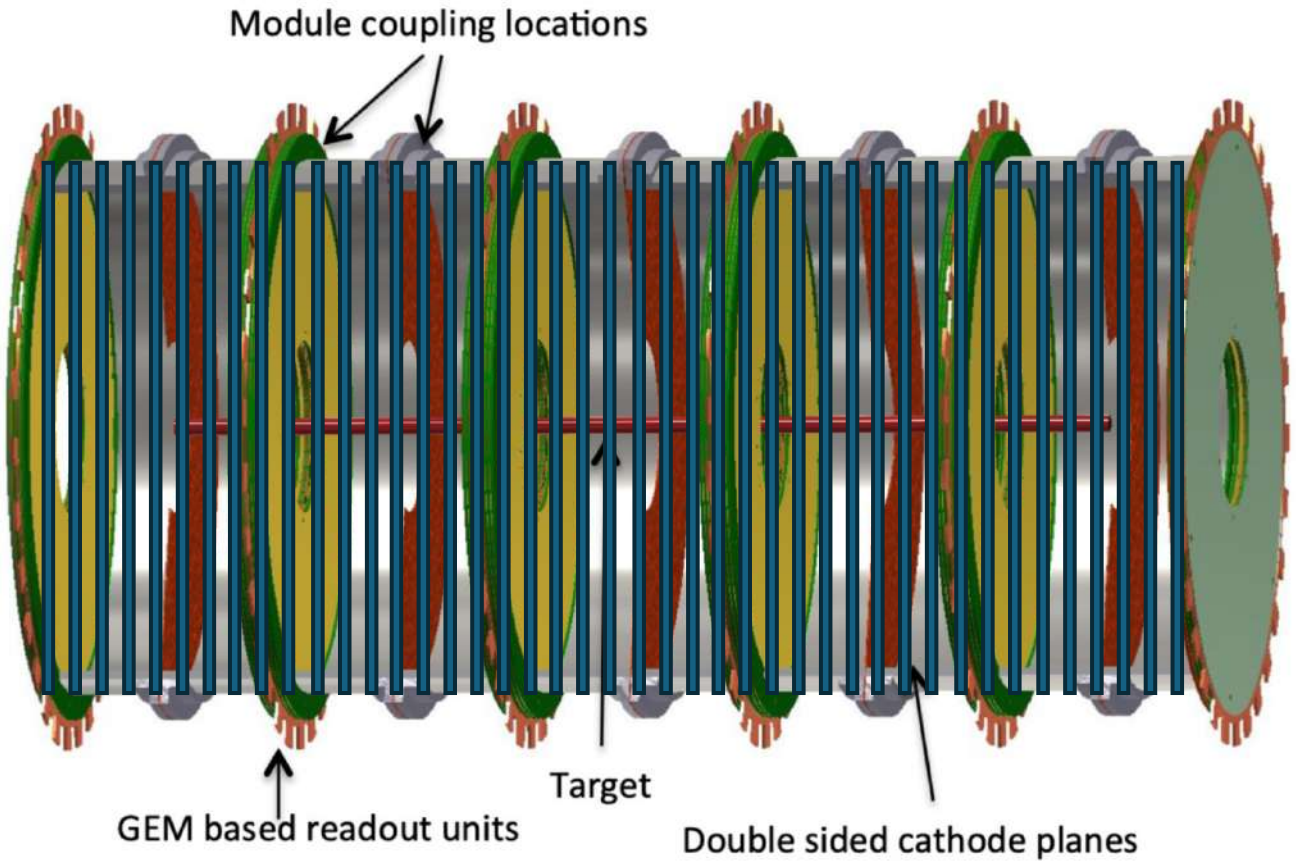
ACTS Geometry (naïve import)

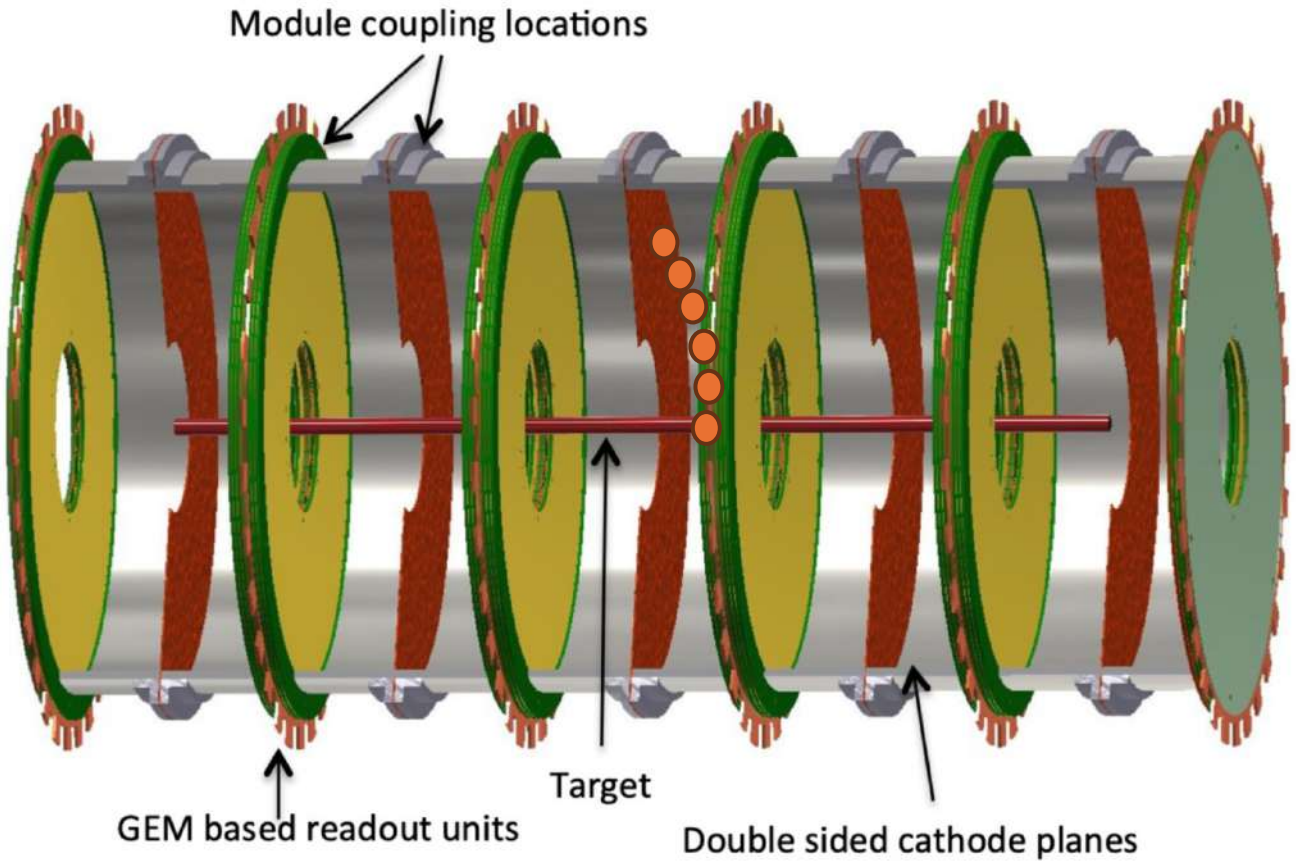




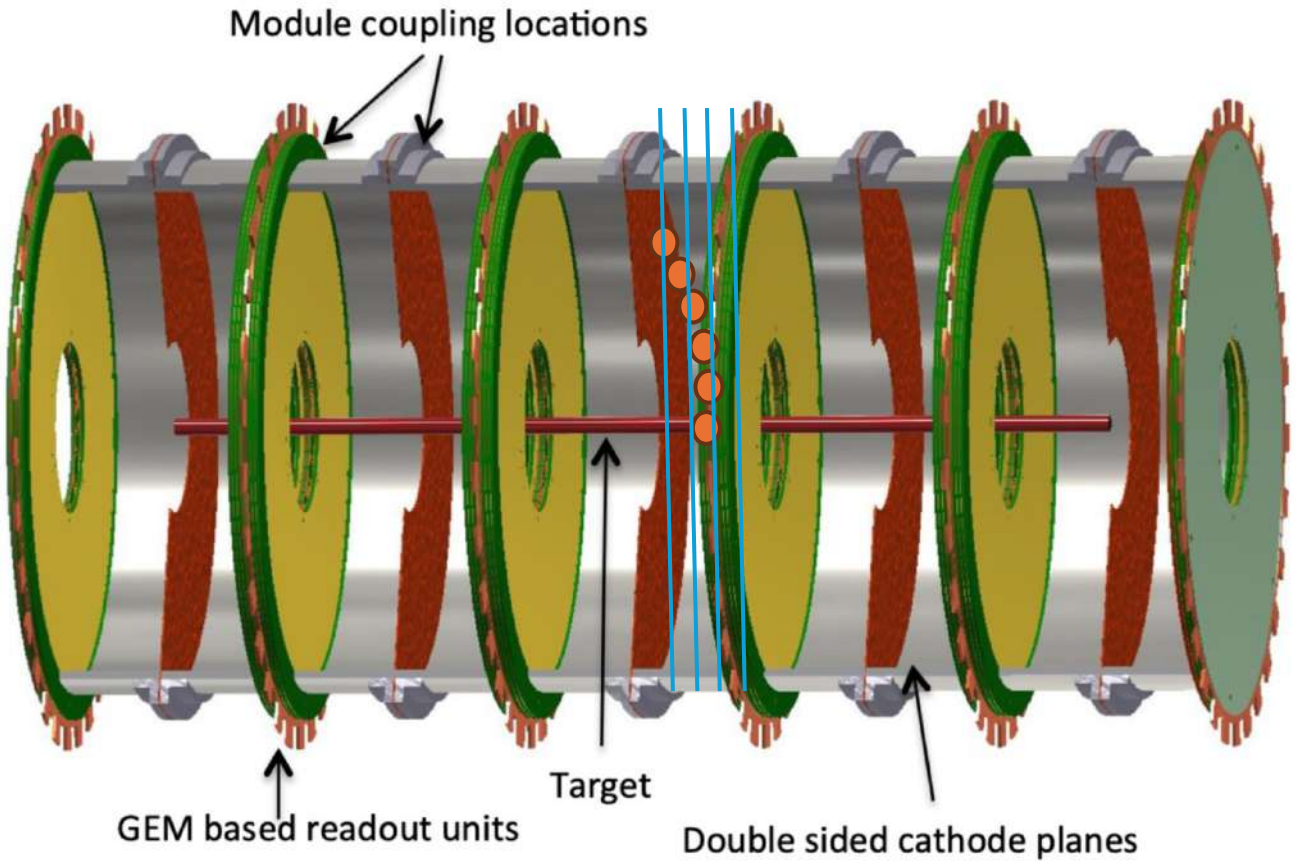
Space grid approach



Adaptive grid approach

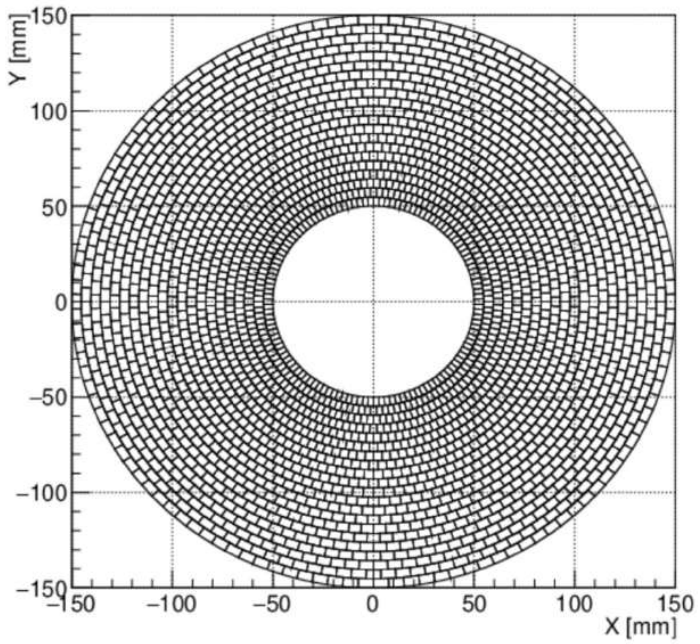


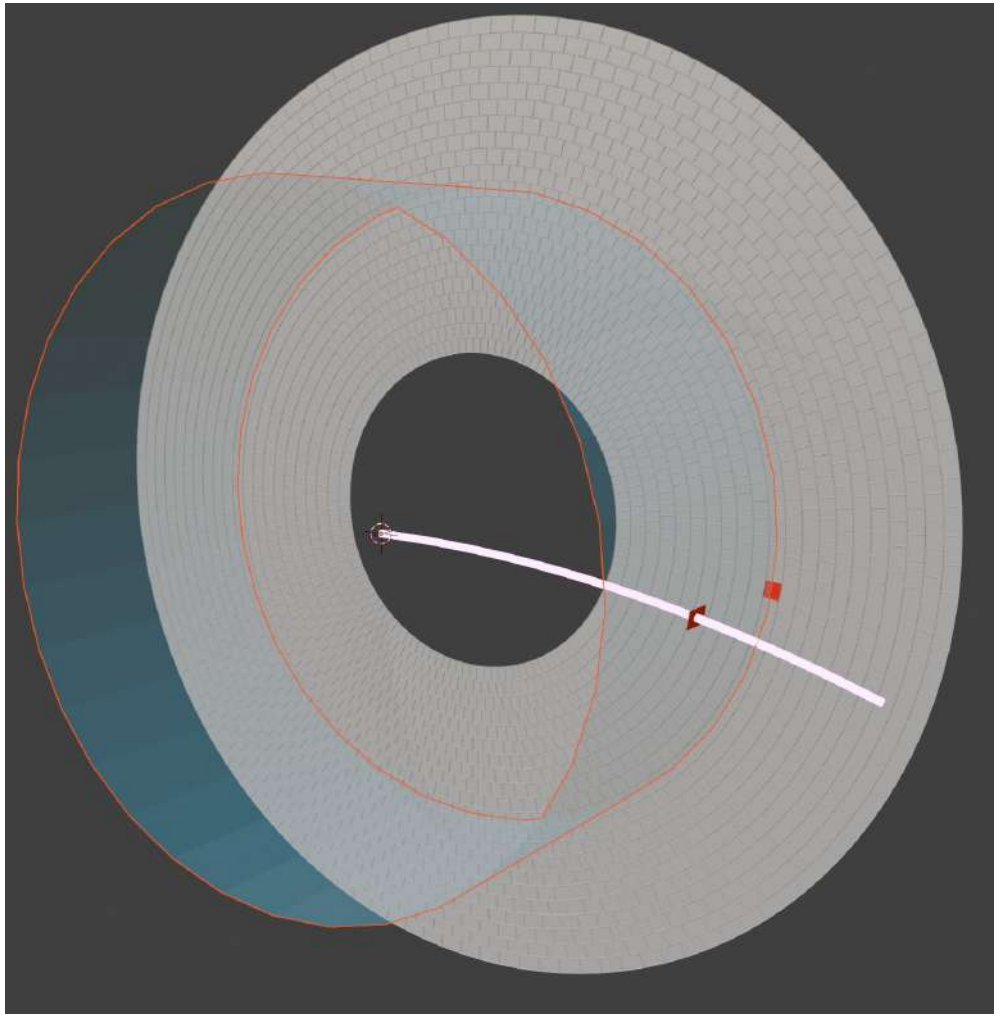
Adaptive grid approach



Tube geometry approach

- Manually create cylindrical surfaces for each ring that go along z for the length of the detector



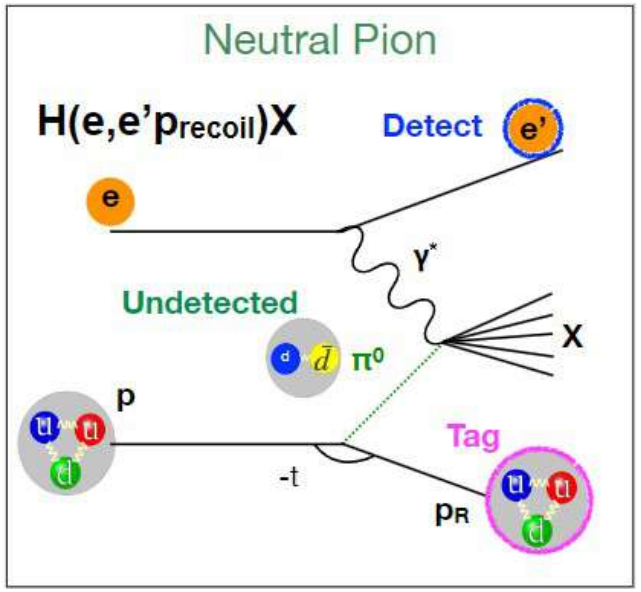


TDIS at Jefferson Lab

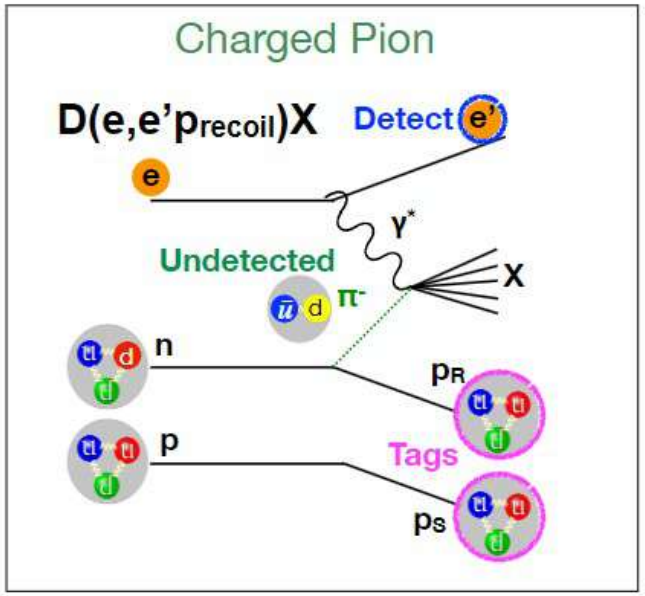
$8 < W^2 < 18\ \text{GeV}^2$
$1 < Q^2 < 3\ \text{GeV}^2$
$0.05 < x < 0.2$

Need small -t to extrapolate to pion pole

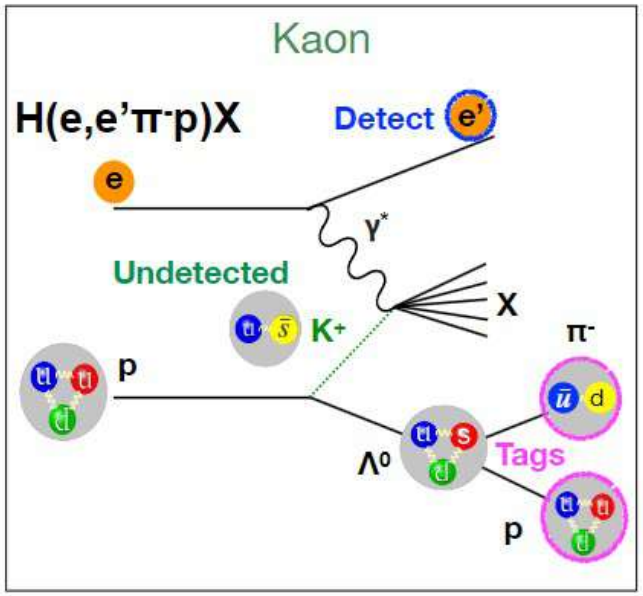
Very low momentum recoiling hadrons (60 - 400 MeV/c)



Independent Check, add to sparse data



Expected world first



Expected world first

$$R^T = \frac{d^4\sigma(ep \to e' X p')}{dx dQ^2 dz dt} \Big/ \frac{d^2\sigma(ep \to e' X)}{dx dQ^2} \Delta z \Delta t \sim \frac{F_2^T(x, Q^2, z, t)}{F_2^p(x, Q^2)} \Delta z \Delta t$$

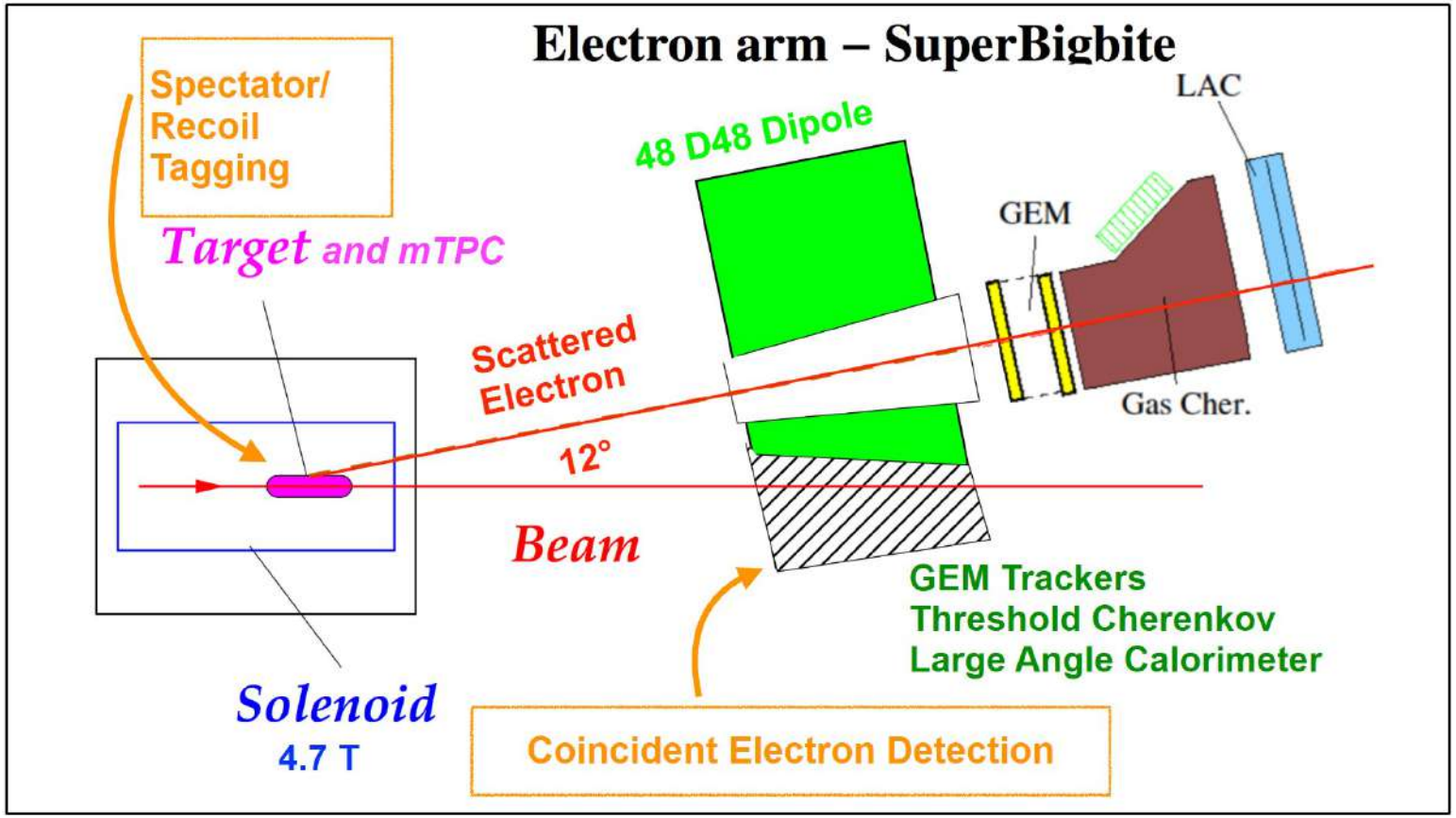
$$F_2^T(x, Q^2, z, t) = \frac{R^T}{\Delta z \Delta t} F_2^p(x, Q^2)$$

- Measure ratio of tagged to total inclusive DIS x-sec
- Tagged signal is orders of magnitude smaller than DIS signal → need high luminosity!

- JLab is **the** unique place to perform these measurements
- Pion flux contribution also dominant at JLab kinematics

Ref: Rachel Montgomery "Tagged Deep Inelastic Scattering (TDIS) Program"

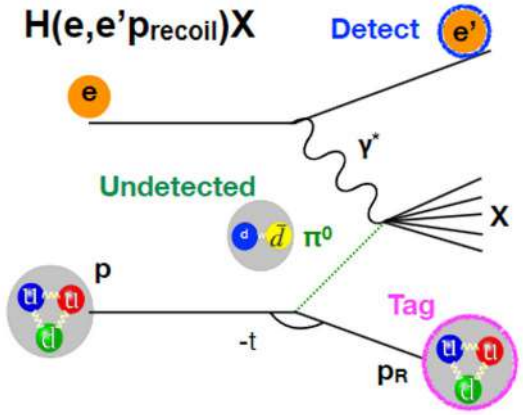
Hall A TDIS Experiment



Hall A with SBS:
- High luminosity,
- 50 μAmp,
- L = $3x10^{36}/cm^2$ s
- Large acceptance ~70 msr

Important for small cross sections

Scattered electron detection in new Super Bigbite Spectrometer (SBS)



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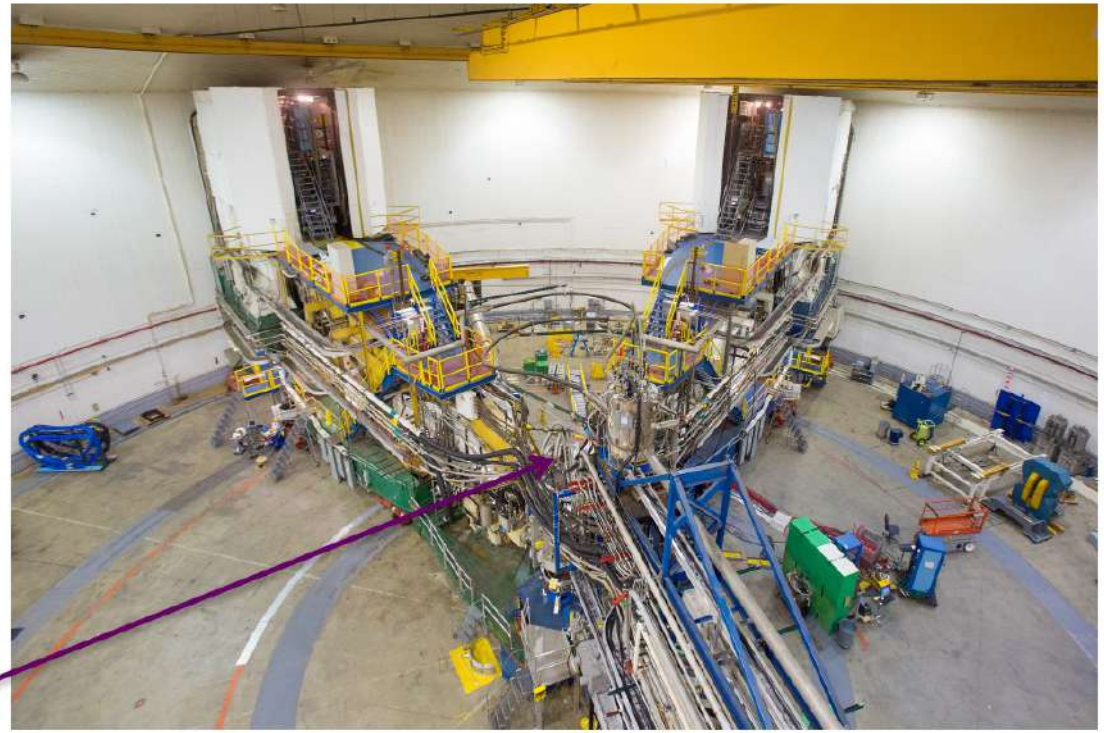
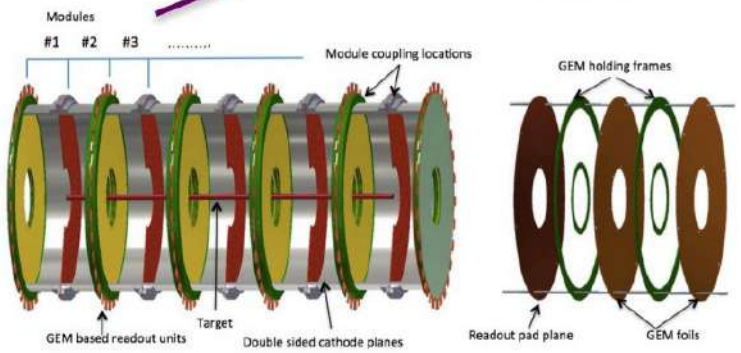
HallA TDIS Experiment

JLab Hall A
TDIS
Experiment

proton tag
detection in
GEM-based
mTPC at pivot



e- beam



mTPC inside
superconducting
solenoid

Ref: Cynthia Keppel "Exploring QCD with Light Nuclei at the EIC"

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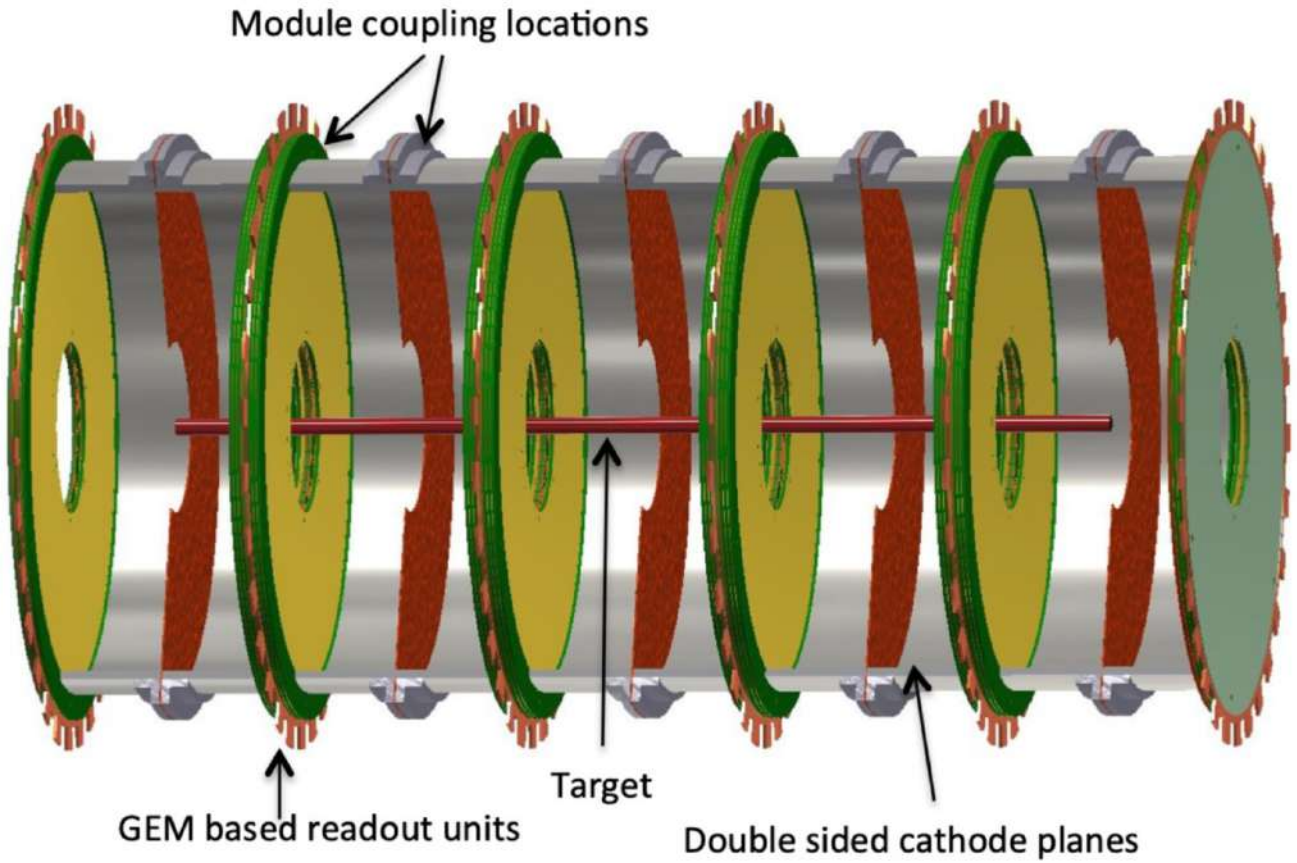
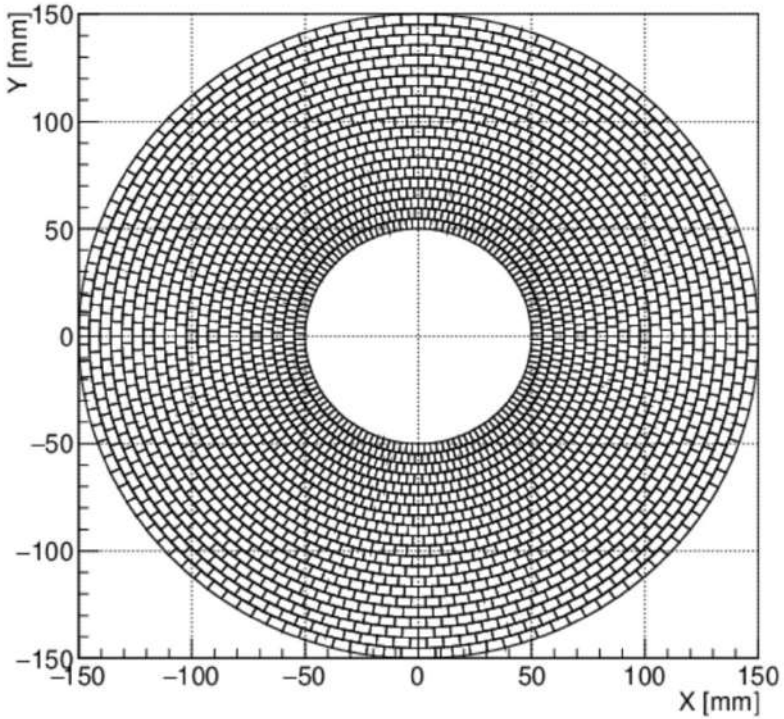
TDIS mTPC detector





There are 21 rings, each with 122 pads, (2 562 total pads per readout plane).

The mTPC will consist of 10 separate TPC volumes.
The entire detector will be 55 cm long.
Inner radius of 5 cm and an outer radius of 15 cm.

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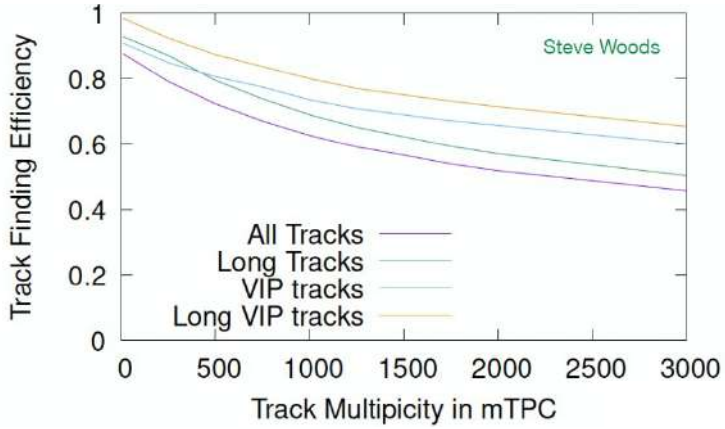
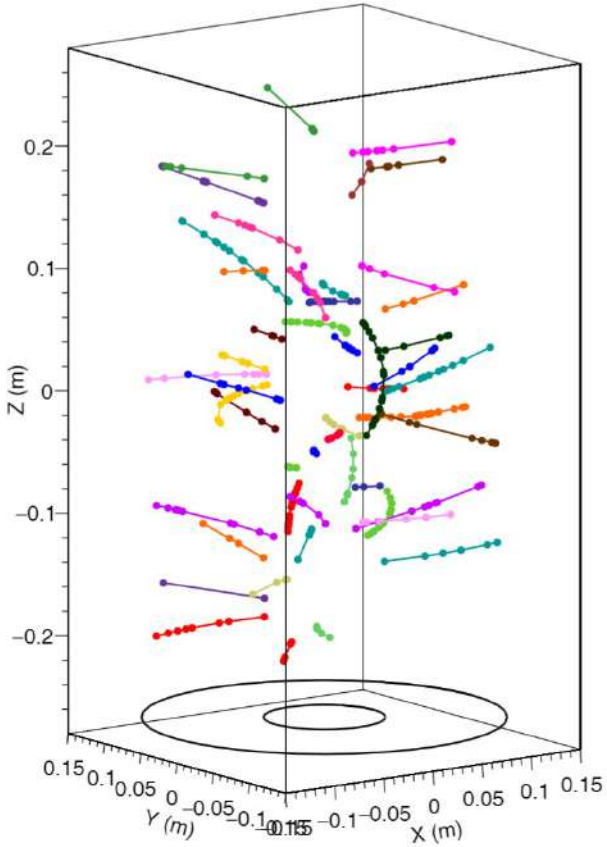
Example event

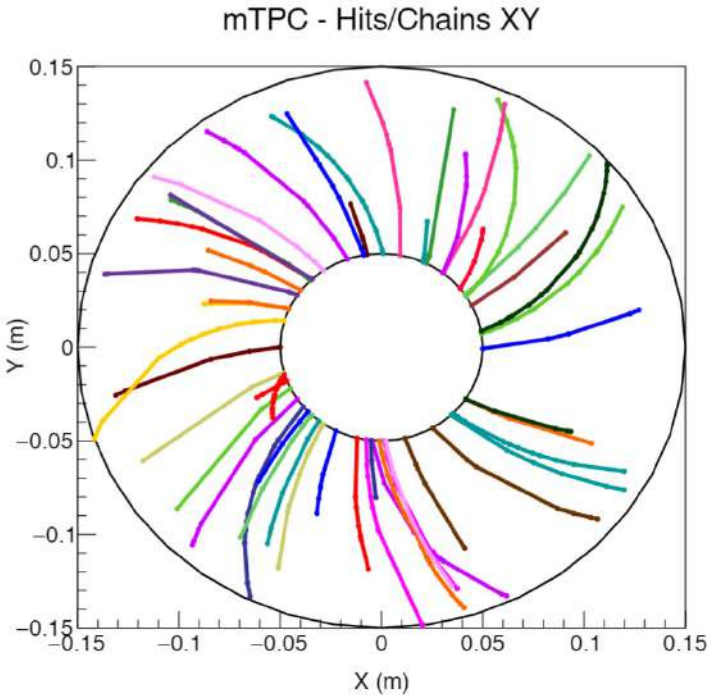
Tracking challenges:
- High multiplicity (thousands of tracks)
- Background
- Pileups

What is currently there for tracking:
- Python based “toy model”
- GNN (in development)
- ACTS (in development)



The “toy model” efficiency





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