SoLID Test Beam Overview

Eric Fuchey
College of William & Mary

SOLID Collaboration Meeting,
October 9th 2026

WILLIAM & MARY
CHARTERED 1693

Jefferson Lab

Outline

- SoLID test beam goals
- Test beam setup
  - Detectors;
  - DAQ;
  - Magnet and shielding;
  - Installation process;
- 2026 test beam achievements
  - Commissioning;
  - tracking detectors performance (preliminary);
  - Shortcomings/Lessons learned;
  - Ongoing analysis efforts;
- 2027 test beam follow-up
  - SAM TODO-list;
  - 2027 general run plan;
- Summary



SoLID test beam goals

- SoLID test beam goals:
  - ***Key goal*****:** *assess the performance of tracking with GEMs, μRWells, μRGrooves in high background conditions;*
  - test the VMM chip (to replace the APVs).
  - optional: assess the time resolution of the MRPC prototypes;
  - optional: assess the performances of the ECAL supermodule assembly prototype;

- To achieve those goals:
  - build a “mock up spectrometer” to take data parasitically in Hall C at large (93 degrees) and low angle (15 degrees)

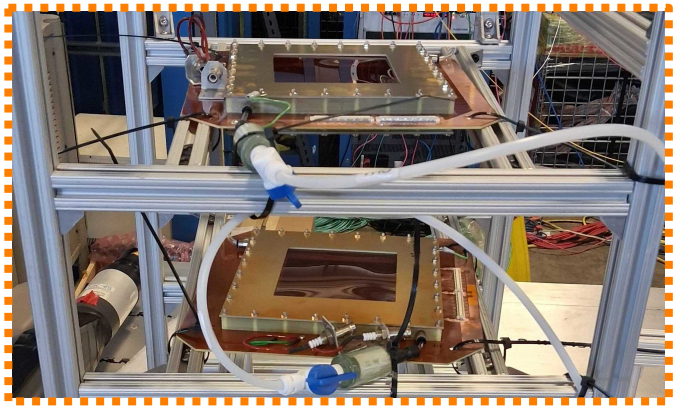


  - A similar test was run in 2022 to test SoLID ECal module prototype, a cherenkov, scintillator paddles for trigger, and a few GEM trackers;

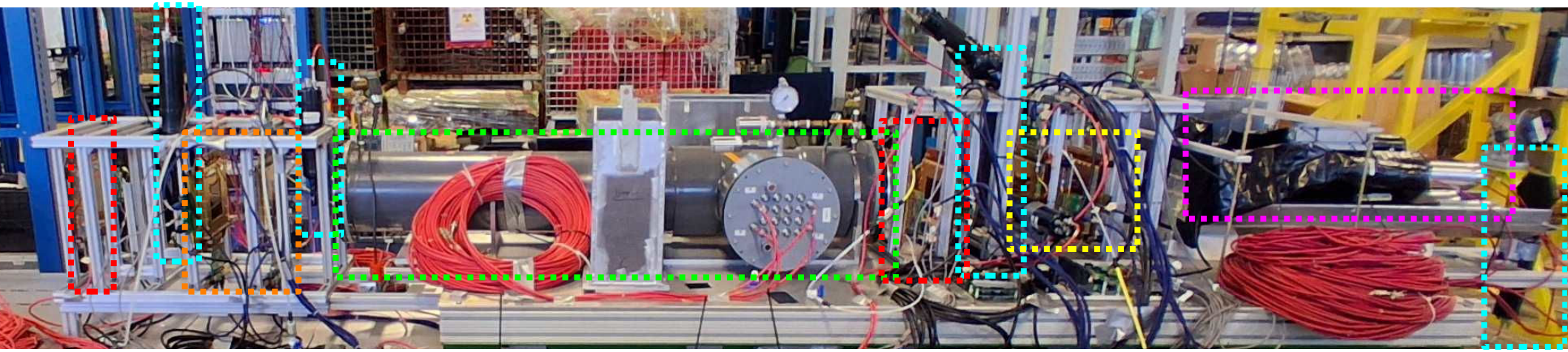
SoLID test beam setup: Detectors

- Test beam setup detectors 2026:
  - ECal 3-module prototype
  - Scintillator paddles;
  - Cherenkov;
  - Tracking detectors:
    - 3 GEMs;
    - 3 uRwells;
    - 2 uRgrooves;



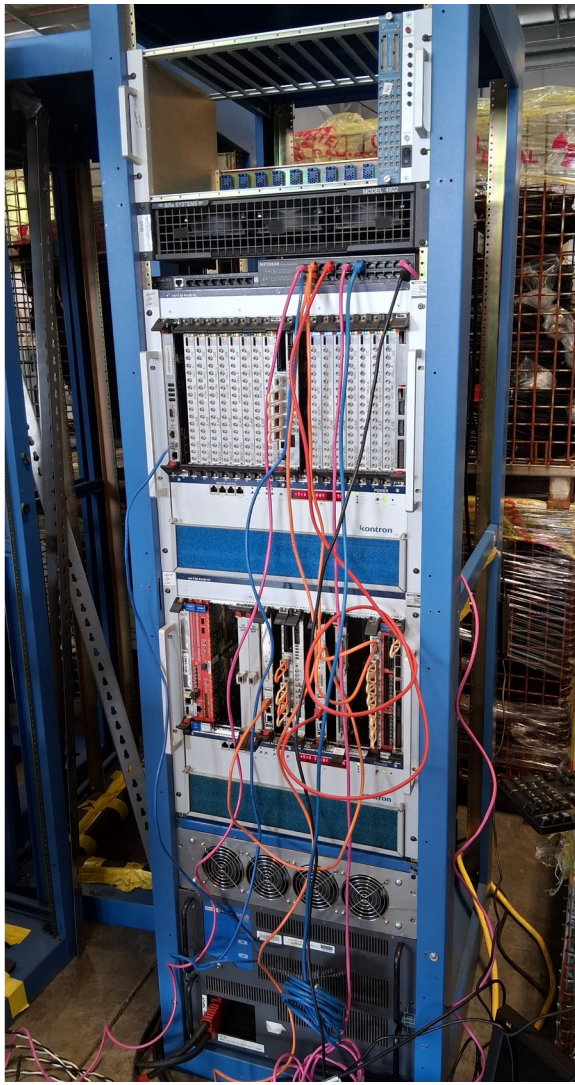


Beam

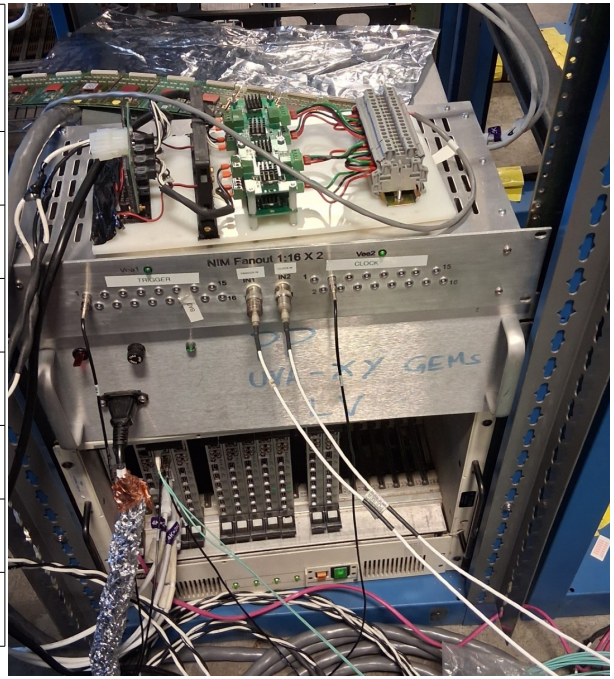


SoLID test beam setup: DAQ

- DAQ:
  - FADC for ECal/Cherenkov/scintillators;
  - VTP for tracking detectors;
  - Front-end for tracking detector:
    - MPD crate, Trackers LV PS, NIM ampli/fanout
- trigger:
  - development of VTP ECal + Cherenkov trigger delayed
  - NIM trigger with 3-out-of-4 scintillators coincidence

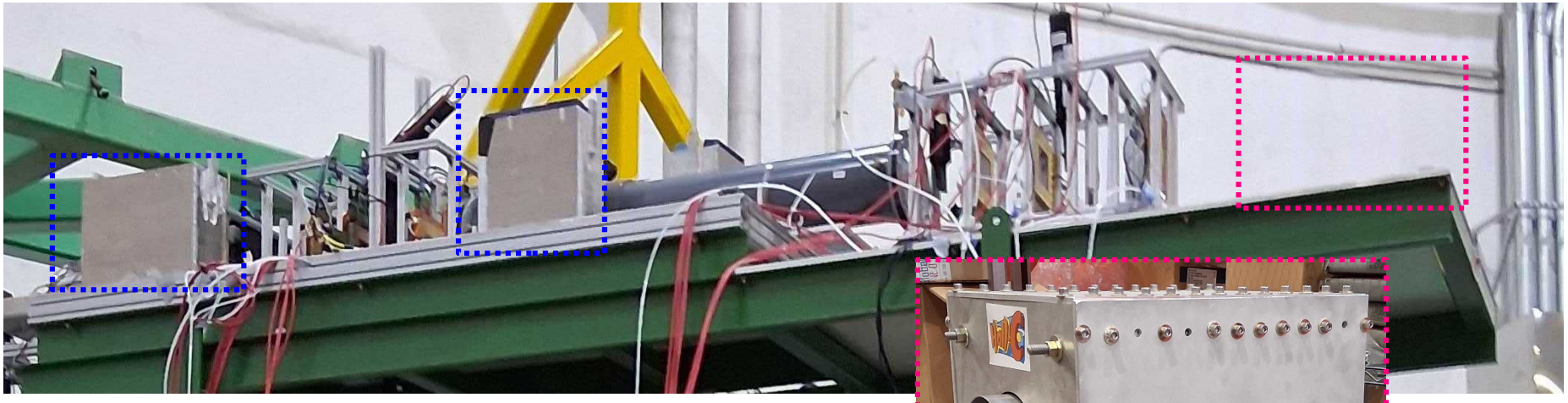


System	Channels	HV Channels
ECAL + PS	6	6
LASPD	2	2
Cherenkov	16	4
Scintillators	4	4
GEMs	1536	3
uRwell	896	3
uRgroove	1024	2



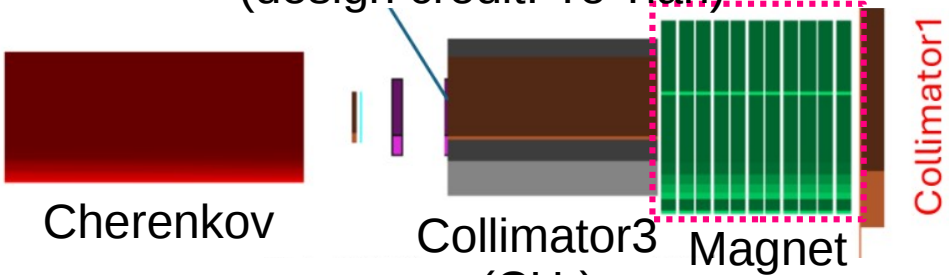
SoLID test beam setup: Magnet and shielding

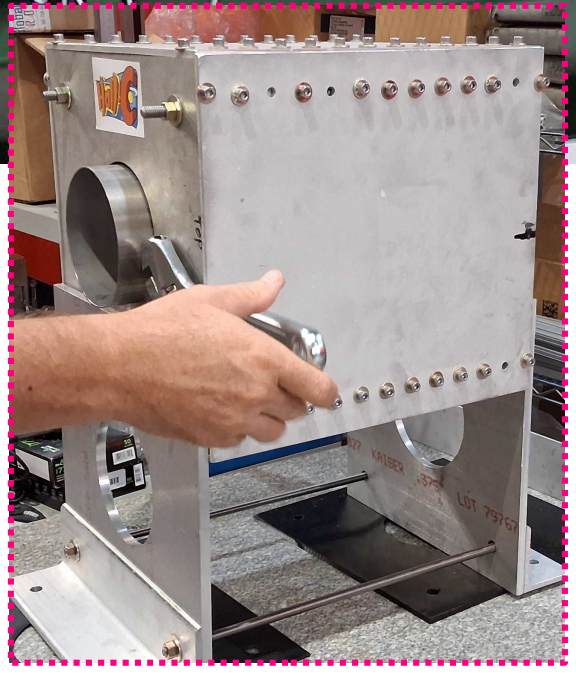
- Test beam setup shielding:
  - lead block assemblies (protect ECal and Cherenkov PMTs)
  - magnet; (deflection of < 30 MeV electrons away from trackers)
    - installed in front of setup, test fitted for installation
    - Lead bricks (“Collimator 1”) to be assembled in front of magnet



  - CH_2 “tunnel” (“Collimator3”) to be built

(design credit: Ye Tian)

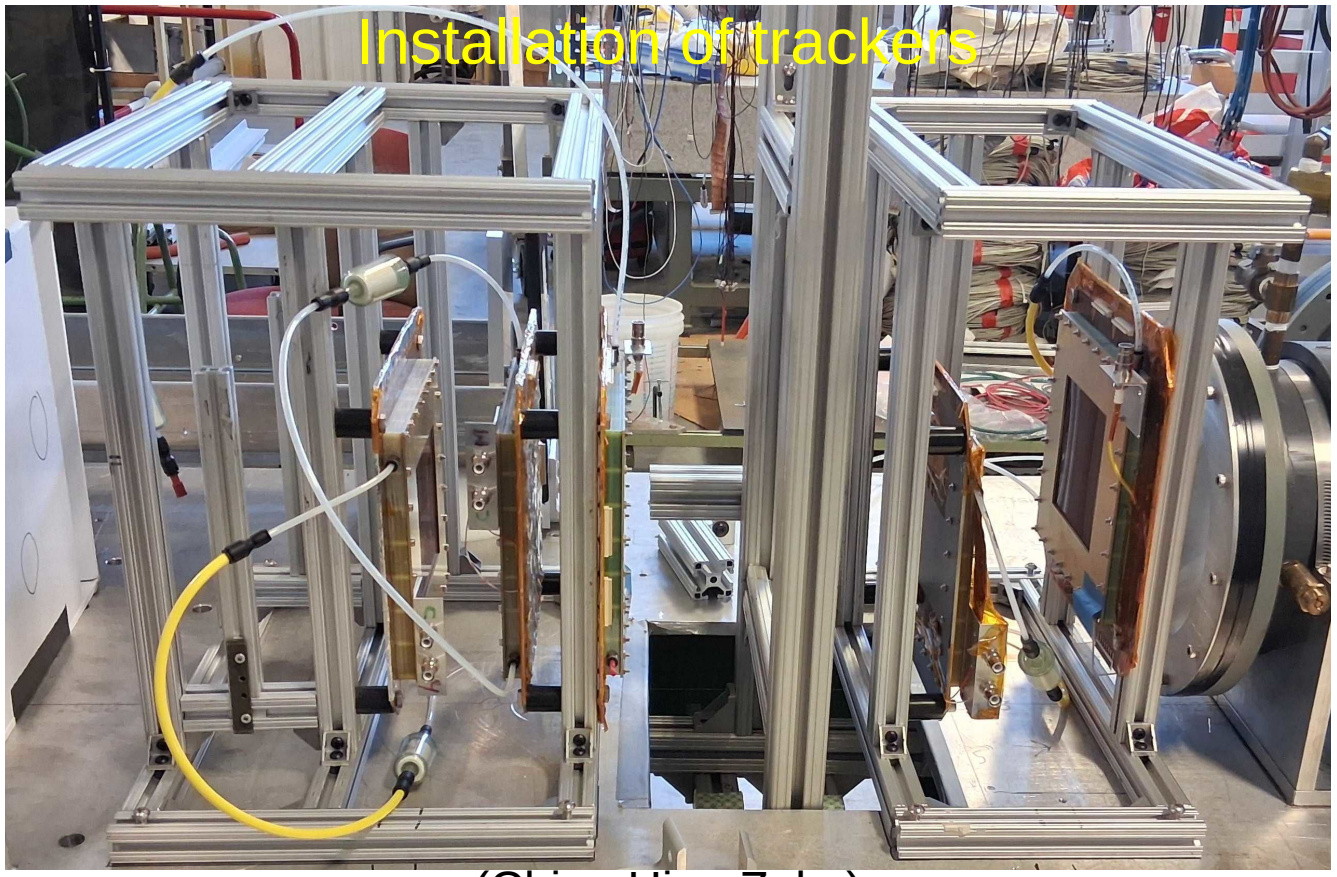




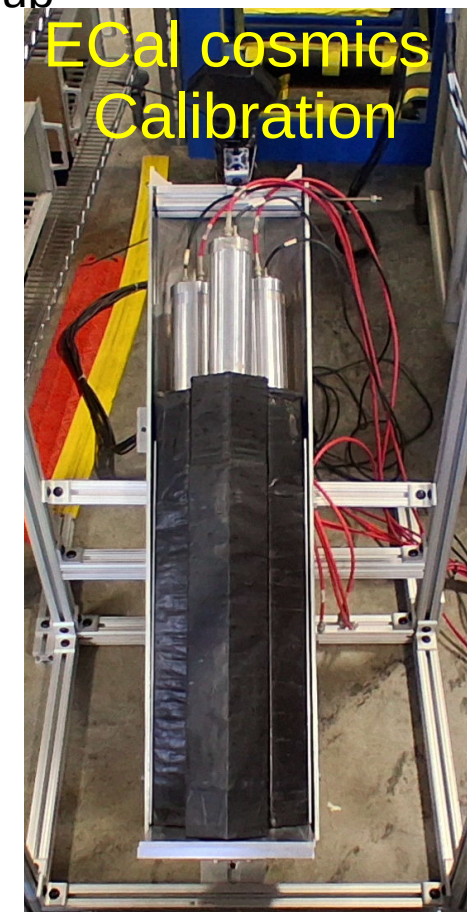
Magnet Assembly: Hayden (W&M), Philipp, Mike, Larry, Jerry (Hall C techs)

SoLID test beam setup: Installation process

- Assembly of setup in ESB from November 2025 to May 2026
  - Installation of all detectors on the platform;
  - Cosmics commissioning of trackers, ECal
  - test fitting of lead shielding assemblies, Ecal, etc;
  - survey/fiducialization of detector platform by survey group



(Ching Him, Zeke)



Michael N.

SoLID test beam setup: Installation process

- Design/construction of test stand:
  Credit: Hunter, Paulo, Jamie (eng)
  Jerry, Larry, Philipp, Mike (techs)

- Installation in Hall C: June 1-12



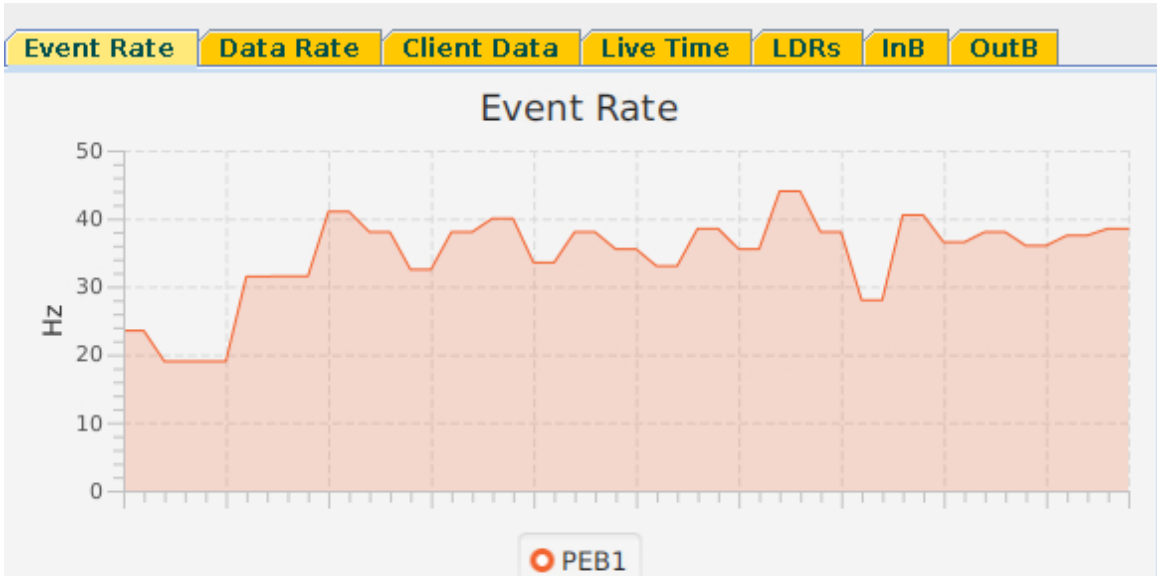




Thank you everyone who participated:
Ching Him, Zeke, Richard, Emily, Michael N., Michael L., Alexandre, ...
and of course Jerry, Larry, Mike, Philipp (Hall C techs)

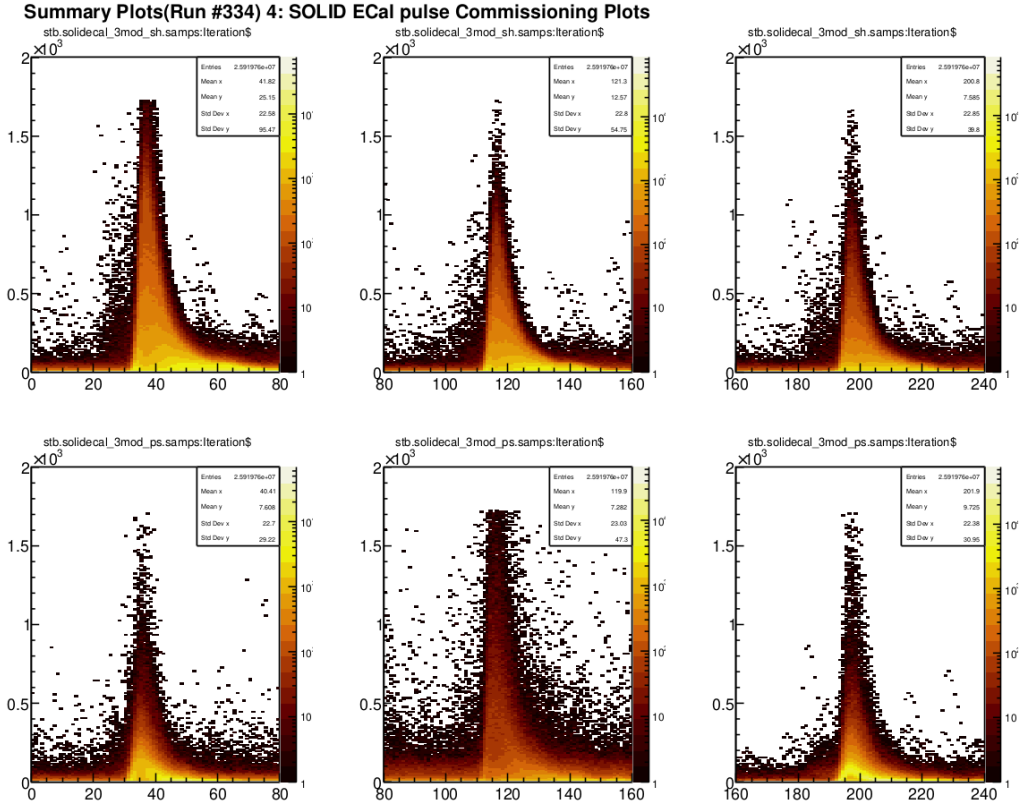
2026 test beam achievements: Commissioning

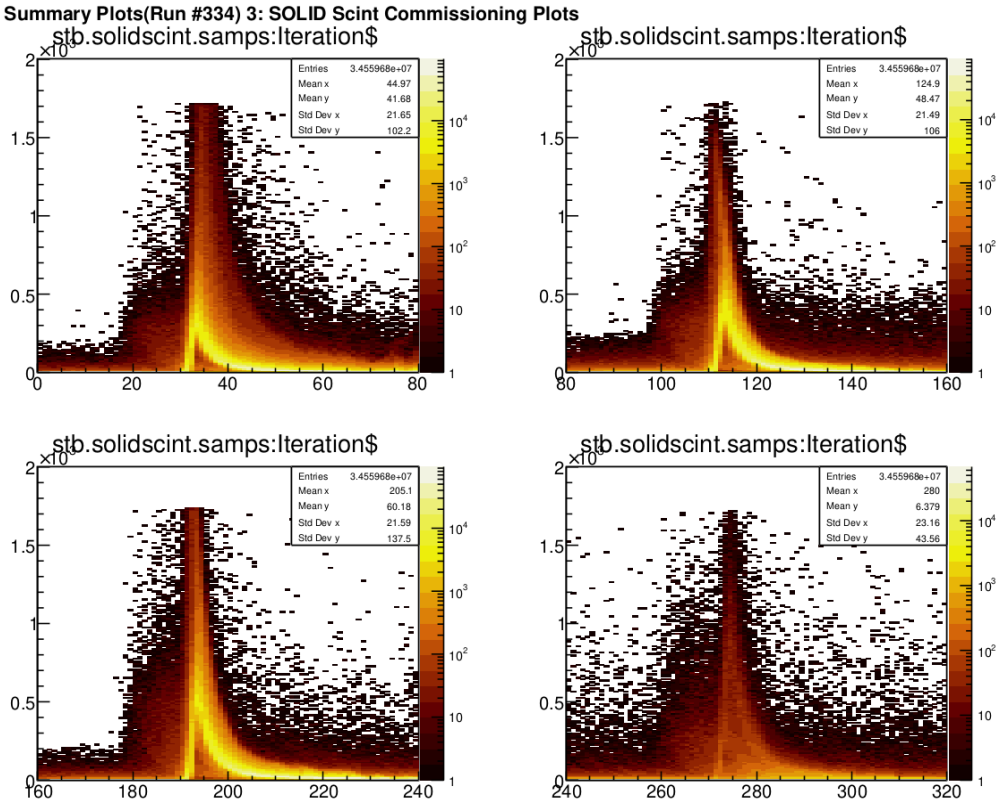
- Commissioning during R-SIDIS/pion-CT
  - Event rates with 3-out-of-4 scintillators NIM trigger at 93 degrees: 10 -100 of Hz (dependent of target and current)
    - 1-10 Hz with “3-out-of-3” scintillators NIM trigger



2026 test beam achievements: Commissioning

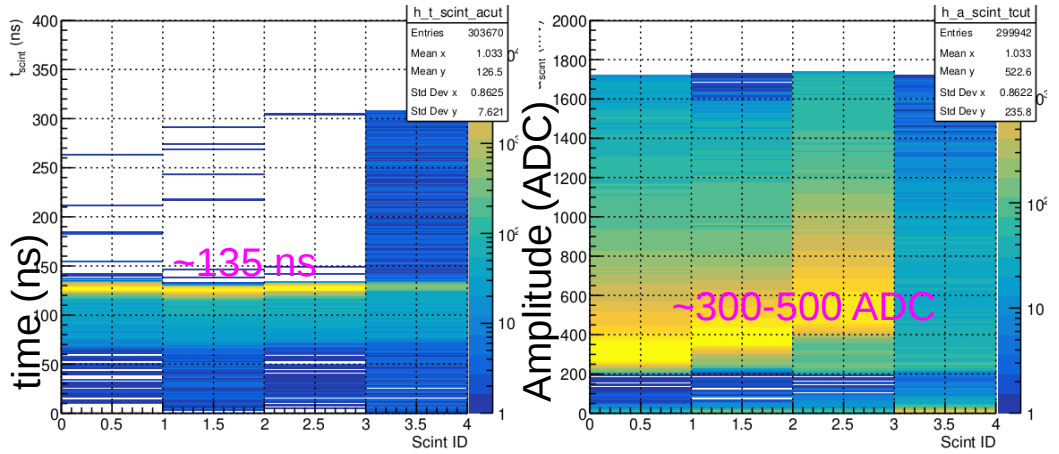
- Commissioning during R-SIDIS/pion-CT
  - Event rates with 3-out-of-4 scintillators NIM trigger at 93 degrees: 10 -100 of Hz (dependent of target and current)
    - 1-10 Hz with “3-out-of-3” scintillators NIM trigger
  - First data taken with only PMT detectors (ECal, scintillators, Cherenkov)
    - HV tuned to optimize use of FADC dynamic range

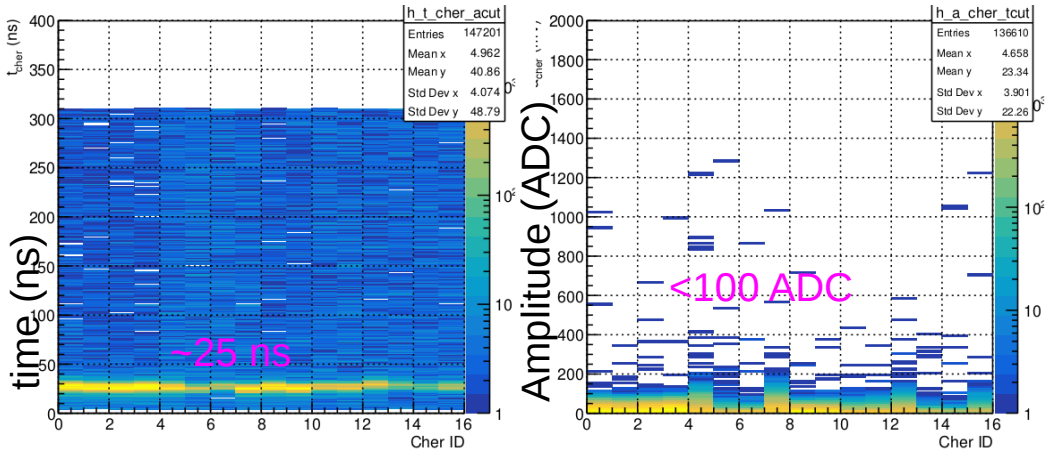




2026 test beam achievements: Commissioning

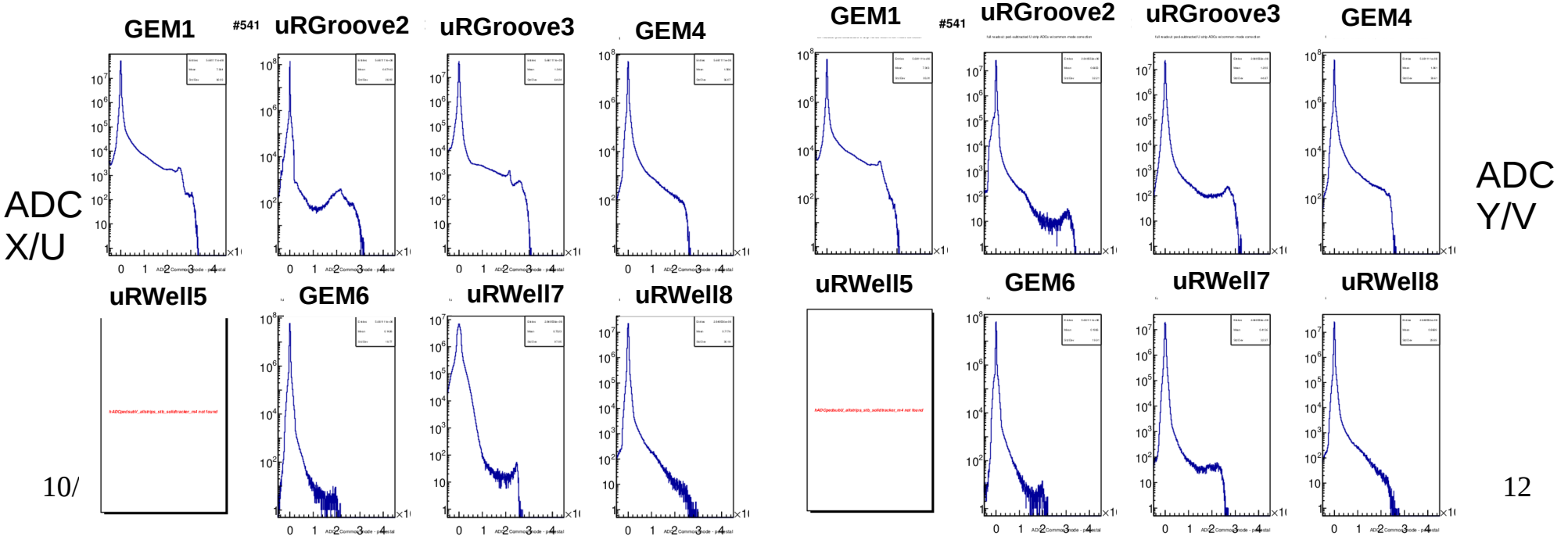
- Commissioning during R-SIDIS/pion-CT
  - Event rates with 3-out-of-4 scintillators trigger at 93 degrees: 10s of Hz (target dependent)
  - First data taken with only PMT detectors (ECal, scintillators, Cherenkov)
    - HV optimization to use most of FADC dynamic range
    - scintillators, ECAL through NIM amplification: similar timing
    - Cherenkov unamplified: smaller amplitude, timing difference due to delay introduced by cables routing signals to amplifiers
    - Ideally, *Cherenkov should also be amplified*





2026 test beam achievements: Tracking detector performance

- Collected data with GEMs, uRWells, uRGrooves
  - GEMs pretty well understood
  - uRWells sensitive to noise
  - uRGrooves require additional understanding for their signal processing
  - Reconstruction parameters optimization in progress
- **Refer to Ching-Him's presentation for more details**



2026 test beam achievements: Shortcomings/Lessons learned

- Shortcomings:

  - *Run interrupted by CHL cryobox failure as we were getting ready to move setup to 15 degrees*

  - VTP trigger development delayed
    - required backup NIM trigger

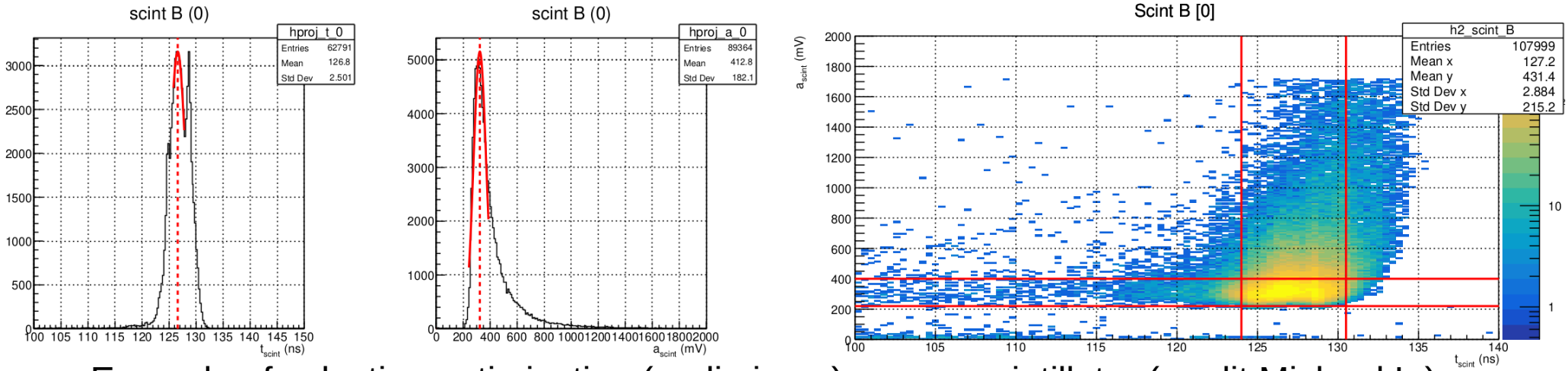
- Lessons learned (so far):

  - all PMT detectors need amplification:
    - at beginning of run, none were amplified;
    - implementation of NIM trigger → amplification of scintillators, ECAL
    - Cherenkov unamplified: signal harder to exploit, timing difference

  - NIM trigger necessary as backup:
    - 3-out-of-4 trigger satisfactory at 93 degrees, not at 15 degrees
    - should upgrade analog trigger (with ECal + Cherenkov), in case of VTP trigger additional shortcomings

2026 test beam achievements: Analysis effort

- Analysis objectives:
  - Ultimate goals:
    - ♦ global tracking efficiency of the apparatus
    - ♦ detection and reconstruction efficiency of all tracking detectors
  - Intermediate tasks:
    - ♦ Time, amplitude calibrations for PMT detectors;
    - ♦ Optimization of selection for events susceptible to include tracks using only PMT detectors



Example of selection optimization (preliminary) on one scintillator (credit Michael L.)

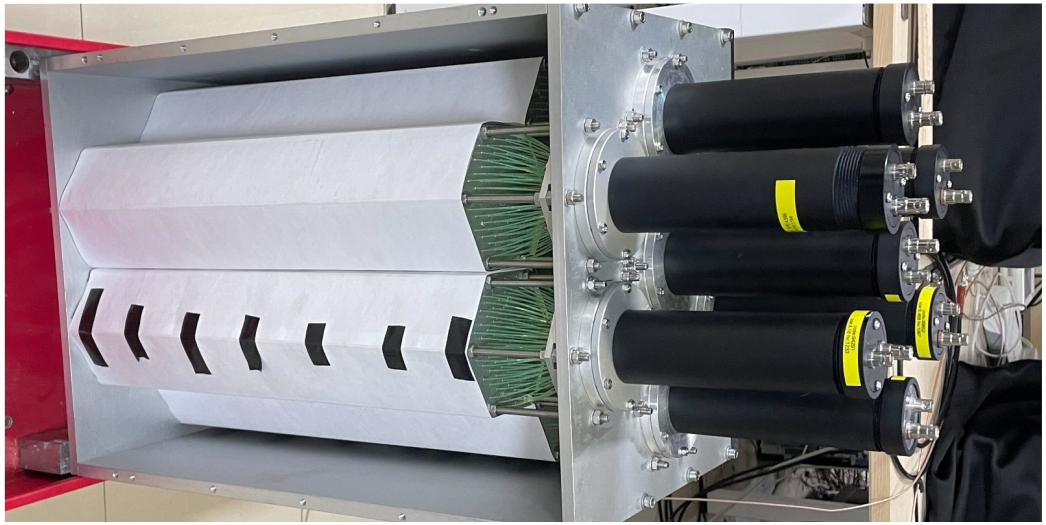
- Analysis effort coordinated by Vlad (MSU), with myself as advisor/expert:
  - List of analysis students/postdocs finalized, will kick-off meetings shortly!

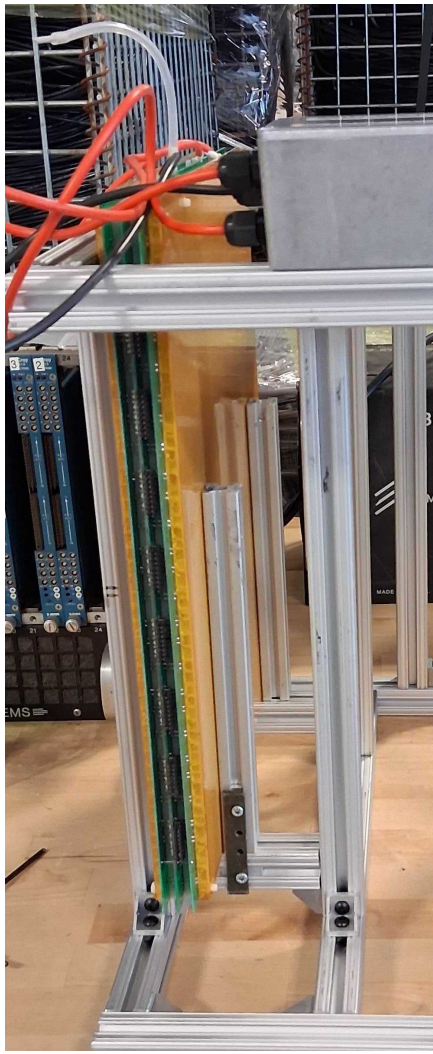
2027 test beam follow-up: SAM TODO list

- List of tasks:
  - **DAQ**: (highest priority)
    - VTP triggers
    - VMM test
    - Upgrade analog trigger if possible;
  - ECAL 7 modules
    - **get out of the customs** (highest priority);
    - test in ESB, cosmics calibration,…
    - installation should be planned *at least* one month before beam;
  - debug tracking detectors:
    - shield uRwells from electromagnetic backgrounds;
    - send uRgrooves to Stony Brook to investigate detectors;
    - proposal to install thin-gap uRwells;
  - Pursue ongoing analysis effort to improve data monitoring
  - Improve slow controls (HVs, drawn currents readable through EPICS);
  - CH2 shielding behind magnet;
  - Optional:
    - MRPCs;

2027 test beam follow-up: Run plan

- Plan for SOLID test beam 2027:
  - Low energy: Data taking at 93 degrees with new detectors
    - ECAL 7 modules;
    - MRPCs;





  - Accelerator reconfiguration to high energy:
    - move to 15 degrees (counting on at least 5 days);
  - Take data during pion-CT run for 15 days:
    - pion-CT scheduled for 28 days;
    - need to clear the floor by the end of pion-CT
    - plan two maintenance/RF recovery days to move out;

Summary

- SOLID test beam apparatus installed in Hall C in 2026
  - Enough data was taken to fully debug the software and analysis
  - Run cut short before we had the opportunity to take data at 15 degrees
  - Teething issues:
    - VTP trigger delayed, needed backup NIM trigger
    - uRWells, uRGrooves need more trouble shooting
- New opportunity in 2027
  - additional 93 degrees running to iron out VTP trigger
  - 2+ weeks at 15 degrees with 3-5 days for installation at 15 degrees
  - by then:
    - solve issues on VTP, uRWells, uRGrooves
    - keep optimize software and analysis workflow
- **Any new contributors are more than welcome :)**

Workforce and responsibilities for 2026

- Overall coordination: Eric Fuchey – W&M (alternate: Todd Averett – W&M)

- Detectors:
  - GEMs/uRwell: Ching Him Leung / Zeke Wertz / Florian Hauenstein – JLab / Huong Nguyen* – UVA / Xinzhan Bai* – JLab (*unavailable during PRad / X-17)
  - uRgroove: Jaydeep Datta – SBU
  - ECal: Xiaochao Zheng – UVA / Michael Nycz – UVA / Zhihong Ye – Tsinghua U
  - Cherenkov: Zhiwen Zhao – Duke U
  - MRPC: Sanghwa Park – JLab
  - Scintillator paddles: Todd Averett – W&M (alternate Eric Fuchey – W&M)

- DAQ: Alexandre Camsonne – JLab / Zhongling Ji – Syracuse U / Hanjie Liu – JLab (interactions with Hall C & Computer Center)

- Magnet: Hayden Bennett – W&M / Alexandre Camsonne – JLab
- Slow controls: Bill Henry – JLab

- Software/ Simulation: Vladimir Katchatrian – MSU (alternates Eric Fuchey – W&M, Ching-Him Leung – JLab) Ye Tian – Syracuse U / Zhiwen Zhao – Duke U

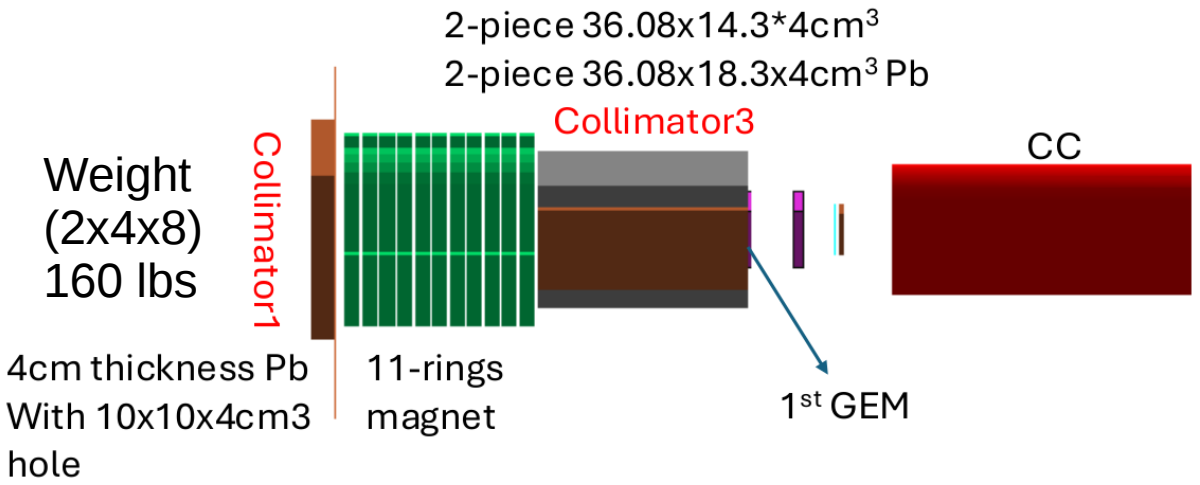
- Platform/support design: JLab Hall C engineers/designers: Hunter Garrett, Paul Medeiros, Jason Clark, Jamie Shiflett

- Installation: Jerry Nines and JLab Hall C techs + Chris Gould and JLab Survey/alignment

Thank you to all the people cited above + “PIs”:
JP Chen – JLab / Klaus Dehmelt – JLab / Xiaochao Zheng – UVA / Todd Averett – W&M / Paul Souder – Syracuse U / Haiyan Gao – Duke U...

SoLID test beam setup: Magnet and shielding

- Magnets and shielding:
  - Preexisting lead shielding to protect ECal and Cherenkov PMTs
  - Magnet for deflection of < 30 MeV electrons away from trackers:
  - New shielding to reduce background in trackers (optimized by Ye)
  - update: Pb "tunnel" (collimator3) behind magnet to be replaced by CH_2



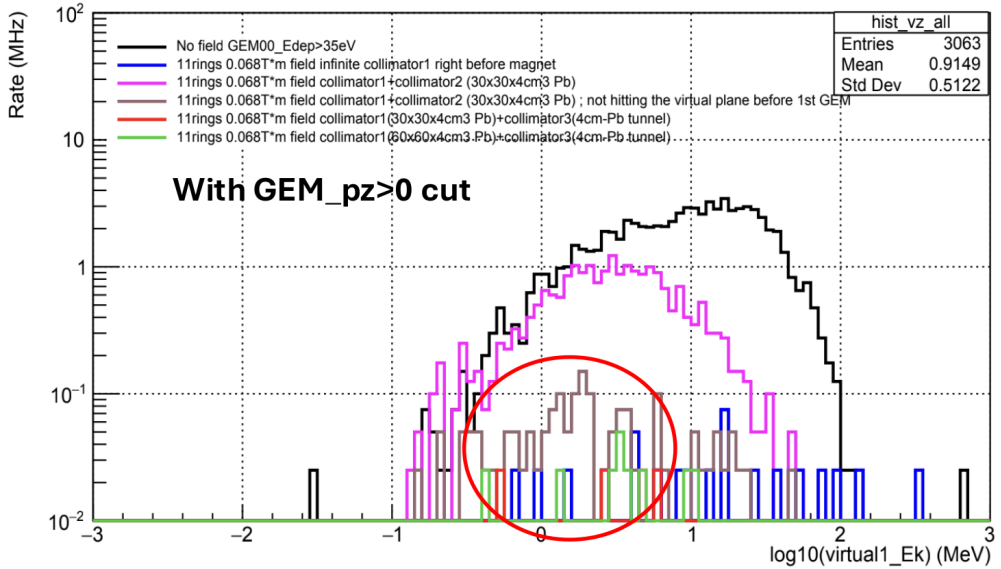
Collimators for 11-rings (magnet weight 155 lb) (2*36.08x14.3*4cm³+2*36.08x18.3x4cm³)Pb tunnel collimator 3)	Reduction factor		**Total collimator weight lb**	**Colli+magnet lb**
	Pz>0	No cut		
+60x60x4cm³ Pb Collimator 1 with 10x10x4cm³ hole	153	48	103.4+132.1+350= **586**	**741**
+30x30x4cm³ Pb Collimator 1 with 10x10x4cm³ hole	190	60	103.4+132.1+80=**316**	**471**

(slide and study credit: Ye Tian)

SoLID test beam setup: Magnet and shielding

- Magnets and shielding:
  - Preexisting lead shielding to protect ECal and Cherenkov PMTs
  - Magnet for deflection of < 30 MeV electrons away from trackers
  - New shielding to reduce background in trackers (optimized by Ye)

4cm-Pb collimator1+36.1cm-long collimator 3+no poly



11 rings magnet

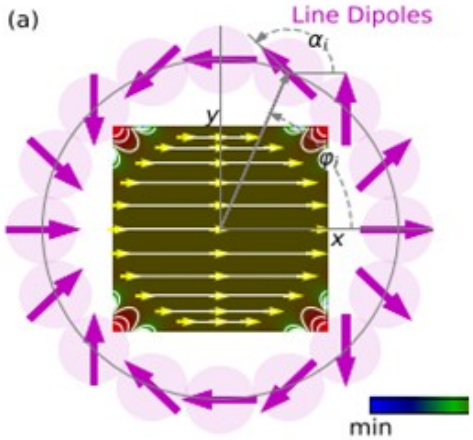
- The magnet bends the high energy background away.
- There is no high energy punch through the Pb collimato material.
- The remaining background is dominated by low energy particles (E < 5 MeV), which are easier to handle.

- Collimator 1 (30x30x4cm^3 Pb with a $\pm 5cm$ hole)+ Collimator 2 (30x30x4cm^3 Pb with a $\pm 5cm$ hole)
- Infinite collimator 1
- Collimator 1 (30x30x4cm^3 Pb with a $\pm 5cm$ hole)+ Collimator 2 (30x30x4cm^3 Pb with a $\pm 5cm$ hole)+Collimator 3 cut (cylinder with a r=7.1cm hole)
- Collimator 1 (30x30x4cm^3 Pb with a $\pm 5cm$ hole)+Collimator 3 (4cm thickness Pb tunnel)
- Collimator 1 (60x60x4cm^3 Pb with a $\pm 5cm$ hole)+Collimator 3 (4cm thickness Pb tunnel)

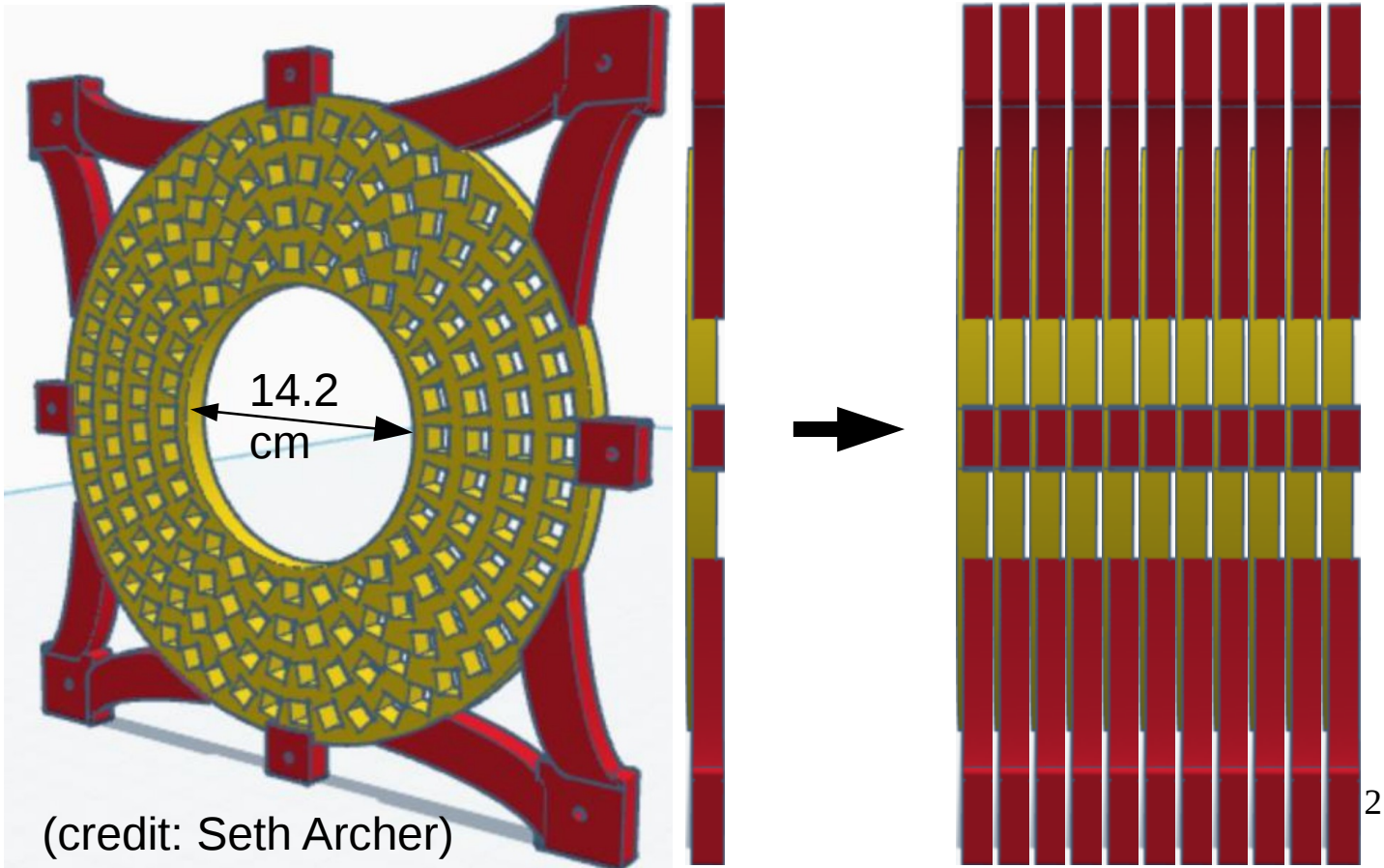
(slide and study credit: Ye Tian)

SoLID test beam setup

- Magnets and shielding:
  - Preexisting lead shielding to protect ECal and Cherenkov PMTs
  - Magnet for deflection of ~ 30 MeV electrons away from trackers:
    - design started by Klaus, continued by Seth **Continued by Hayden!**
    - uses permanent magnets inserted in a 3D printed support
    - contributions from all magnets => 0.2 T field in magnet bore
    - ring layers are stacked to achieve required field integral



(credit: Klaus Dehmelt)



(credit: Seth Archer)