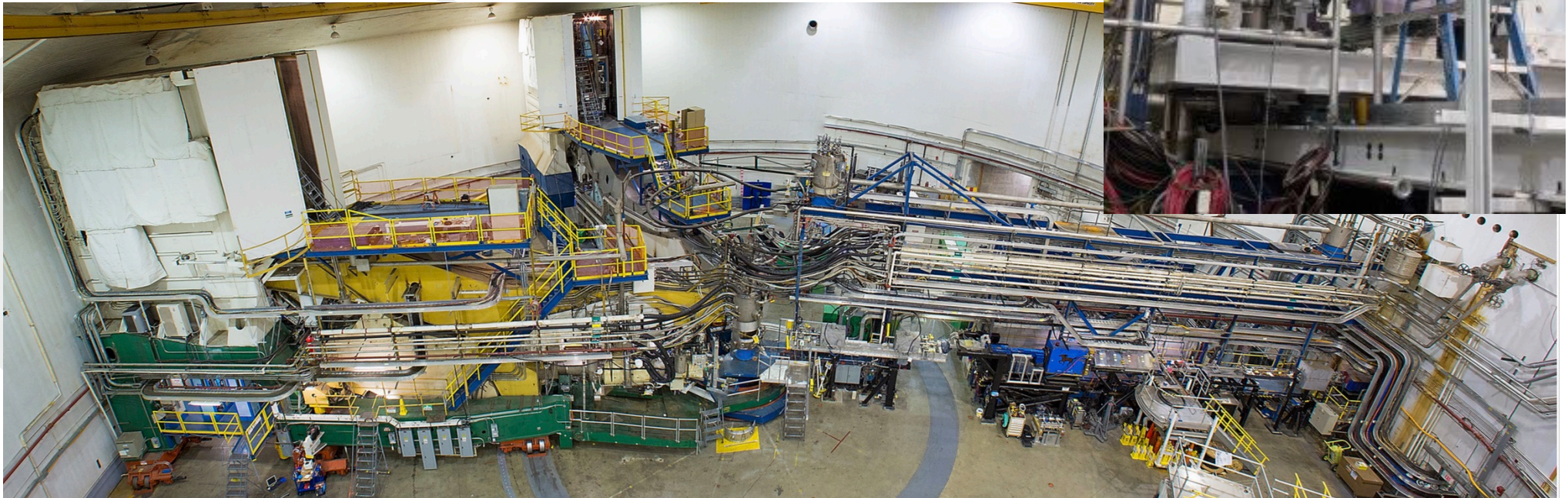


# Hall A Update

*Thia Keppel*

Hall A Collaboration Meeting  
January 2020



# HALL A RUNNING

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2015-2016 – DVCS,  $G_M^P$

2017 - Argon

Fall 2017 - 2018 – Tritium Era

**E12-10-103** MARATHON

**E12-11-112** Short Range Correlations (high X)

**E12-14-011**  ${}^3\text{H}(e,e'p)$   ${}^3\text{He}(e,e'p)$  – momentum distribution

**E12-17-003** Ann search

Spring 2019

**E12-10-009** APEX dark matter

Summer 2019

**E12-11-101** PREX2 neutron skin in Lead

*Now*

**E12-12-004** CREX neutron radius in Calcium



# Hall A Experiment Schedule

(see [https://www.jlab.org/exp\\_prog/experiment\\_schedule/2019/20190606.0.pdf](https://www.jlab.org/exp_prog/experiment_schedule/2019/20190606.0.pdf)

- New NPES schedule should be available SHORTLY!!)

	Spring + Fall	Spring + Fall	Spring	Summer	Fall	Spring 2020	Spring 2021
CY 2017	Ar(e,e'p) + <sup>3</sup> H/ <sup>3</sup> He group*						
CY 2018		<sup>3</sup> H/ <sup>3</sup> He group					
CY 2019/20			APEX**	PREX <sub>2</sub>	CREX	CREX	
CY 2021							SBS GMn + GEn-RP**



Long cryo down, CHL replacement

DVCS,  $G_M^p$  preceding

MOLLER, SoLID to follow

Experiments in red represent PAC "high impact" experiments

\*\* = best effort

GEn-RP also needs ERR finalized

# E12-06-114 DVCS/Hall A Experiment at 11 GeV

100 PAC days approved:

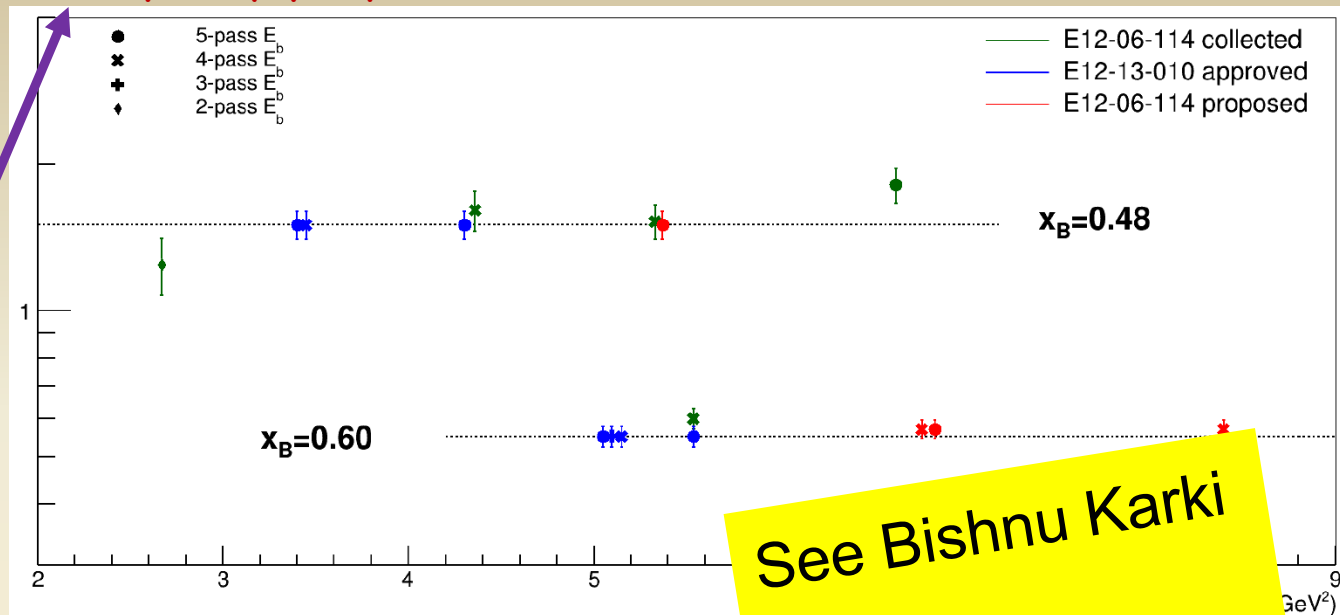
- High impact experiment for nucleon 3D imaging program

- High precision scaling tests of the DVCS cross section at fixed  $x_B$

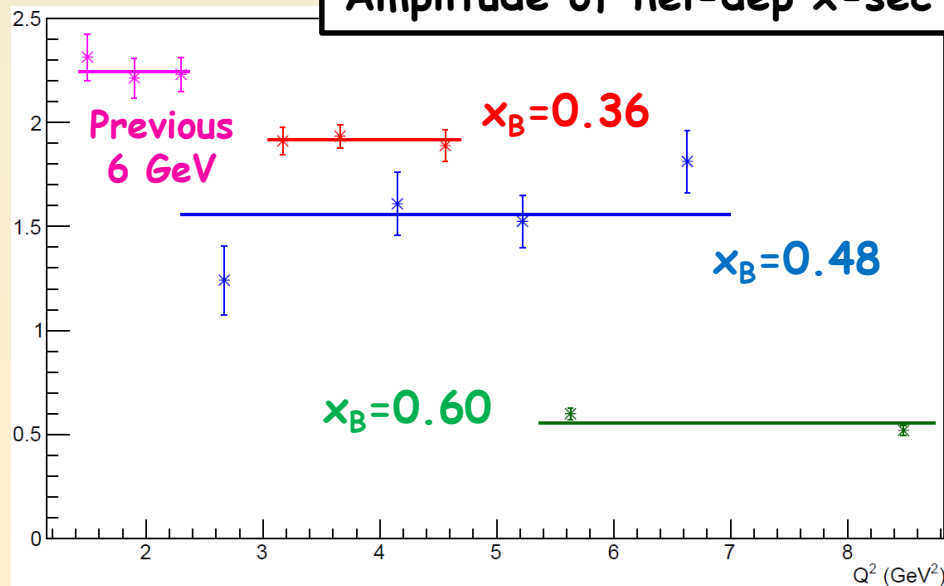
- CEBAF12 allows to explore for the first time the high  $x_B$  region

50% of experiment planned & completed in 2014-2016

Jeopardy proposal to PAC47 - moved to Hall C (NPS)



Amplitude of hel-dep x-sec



Analysis status:

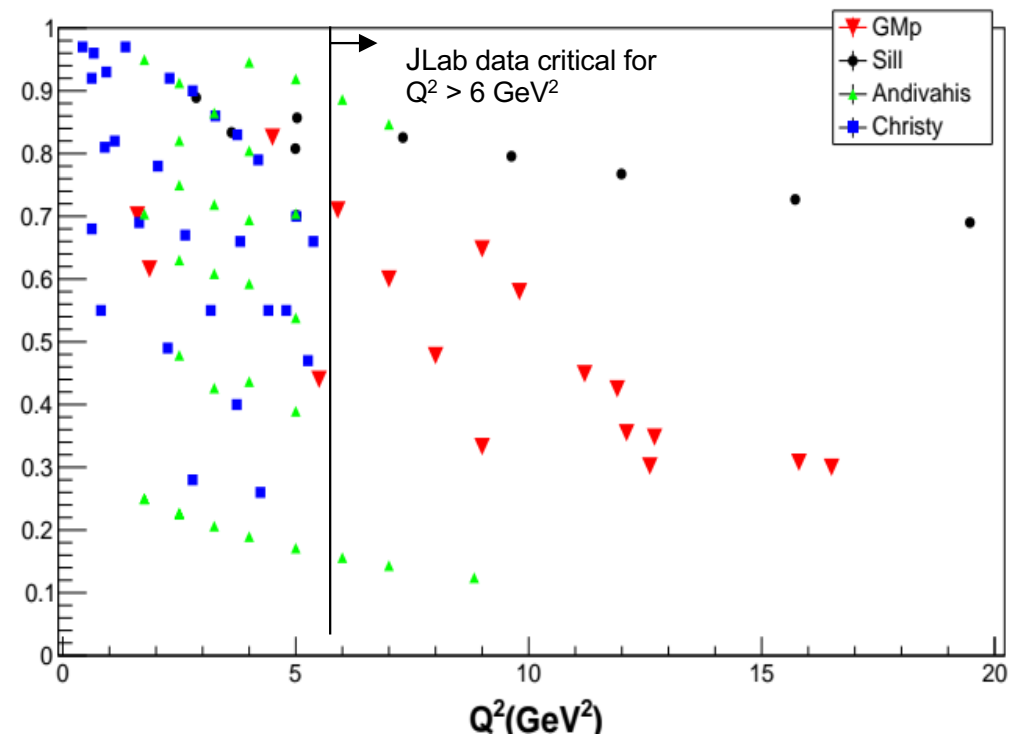
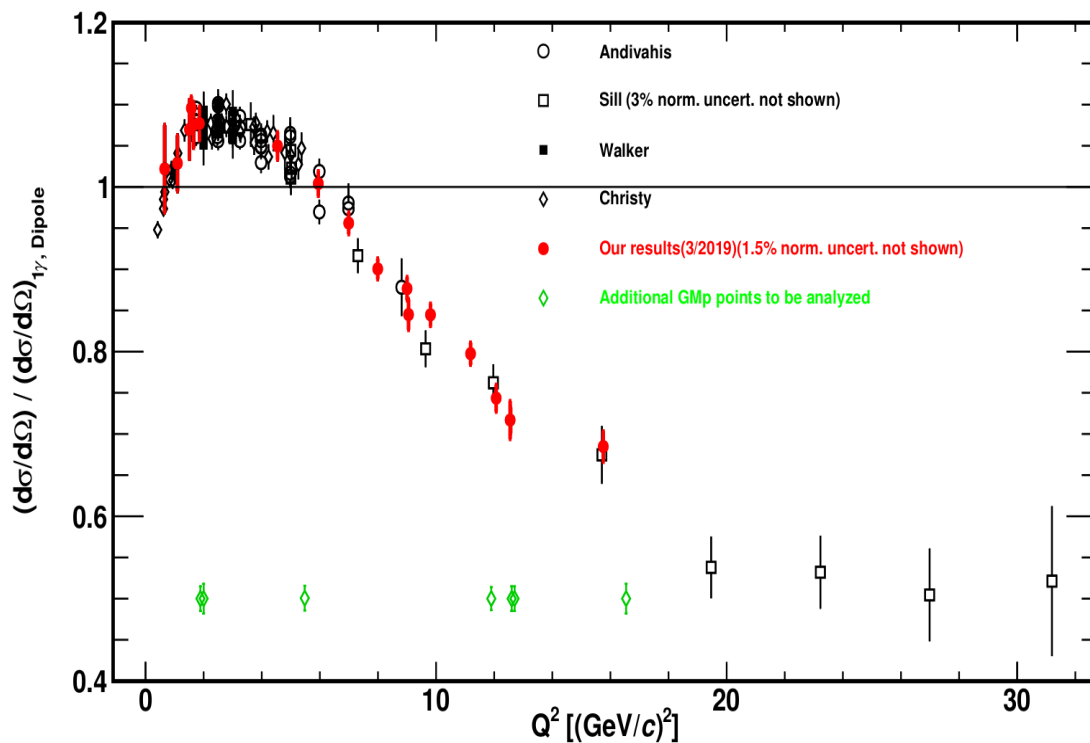
- Analysis of DVCS cross sections completed for *all 9 kinematic settings* (presented at SPIN 2018)
- Publication being drafted, expected to be circulated by the end of **July'19**
- $\pi^0$  electroproduction results and publication will follow soon afterwards



# 12 GeV Era GMp Experiment: E12-07-108

## Precision Measurement of the Proton Elastic Cross-Section at High $Q^2$

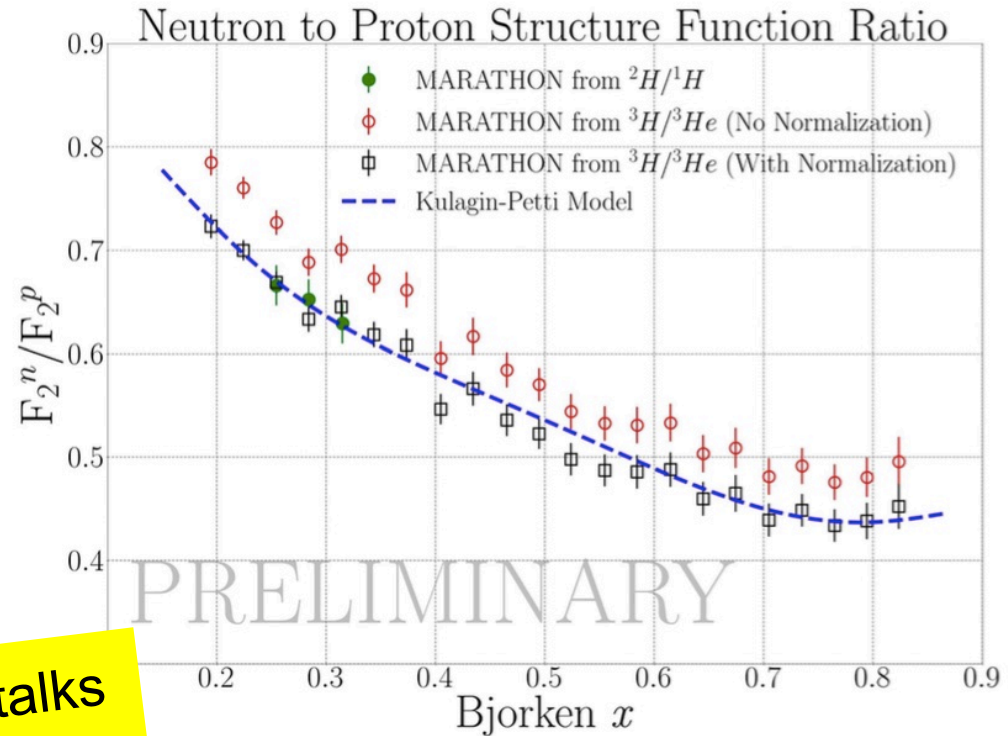
- Precision e-p elastic cross-section necessary for:
  - Baseline cross section for many 12 GeV hadronic physics measurements
  - Determination of  $G_E^p$ ,  $G_M^p$  and 2- $\gamma$  effects at high  $Q^2$  in combination with polarization measurements
- Systematic uncertainties on Fall 2016 LHRS data  $\sim 1.3\%$  (pt-pt), 1.5% (norm)  
RHRS (additional 2% from optics)
- Fall 2016 data finalized. First paper to collaboration in July 2019.



# HALL A TRITIUM (and Argon)

*First tritium target used for electron scattering in three decades!*

MARATHON preliminary results presented at April 2019 APS in Denver



PRELIMINARY

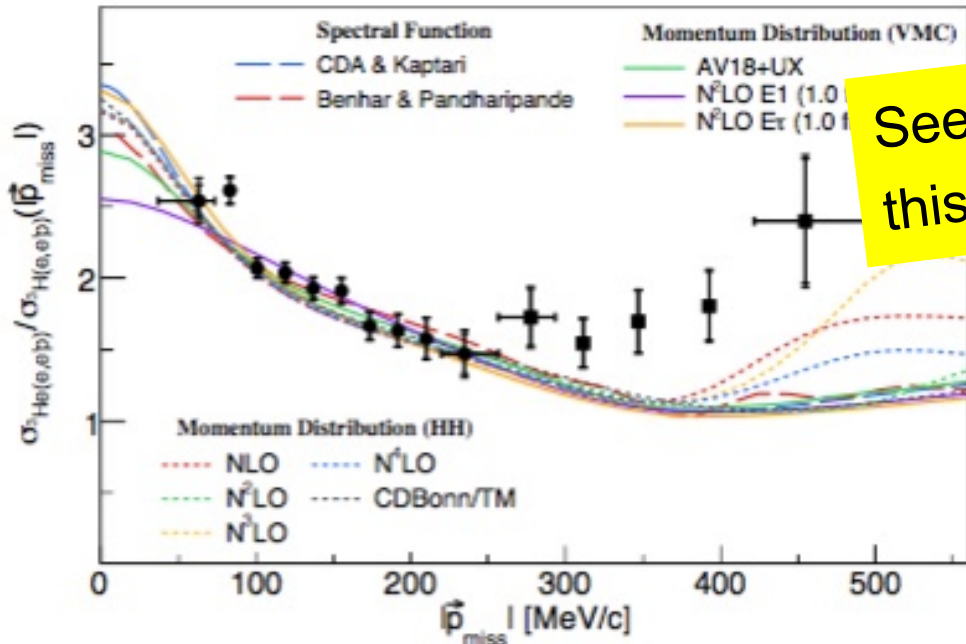
JLAB-PHY-18-2656  
SLAC-PUB-17200

## First Measurement of the $Ti(e, e')X$ Cross Section at Jefferson Lab

H. Dai,<sup>1</sup> M. Murphy,<sup>1</sup> V. Pandey,<sup>1,\*</sup> D. Abrams,<sup>2</sup> D. Nguyen,<sup>2</sup> B. Aljawrneh,<sup>3</sup> S. Alsalmi,<sup>4</sup> A. M. Ankowski,<sup>1,5,†</sup> J. Bane,<sup>6</sup> S. Barcus,<sup>7</sup> O. Benhar,<sup>8</sup> V. Bellini,<sup>9</sup> J. Bericic,<sup>10</sup> D. Biswas,<sup>11</sup> A. Camsonne,<sup>10</sup> J. Castellanos,<sup>12</sup> J.-P. Chen,<sup>10</sup> M. E. Christy,<sup>11</sup> K. Craycraft,<sup>6</sup> R. Cruz-Torres,<sup>13</sup> D. Day,<sup>2</sup> S.-C. Dusa,<sup>10</sup> E. Fuchey,<sup>14</sup> T. Gautam,<sup>11</sup> C. Giusti,<sup>15</sup> J. Gomez,<sup>10</sup> C. Gu,<sup>2</sup> T. Hague,<sup>4</sup> J.-O. Hansen,<sup>10</sup> F. Hauenstein,<sup>16</sup> D. W. Higinbotham,<sup>10</sup> C. Hyde,<sup>16</sup> C. M. Jen,<sup>1</sup> C. Keppel,<sup>10</sup> S. Li,<sup>17</sup> R. Lindgren,<sup>18</sup> H. Liu,<sup>19</sup> C. Mariani,<sup>1</sup> R. E. McClellan,<sup>10</sup> D. Meekins,<sup>10</sup> R. Michaels,<sup>10</sup> M. Mihovilovic,<sup>20</sup> M. Nycz,<sup>4</sup> L. Ou,<sup>13</sup> B. Pandey,<sup>11</sup> K. Park,<sup>10</sup> G. Perera,<sup>18</sup> A.J.R. Puckett,<sup>14</sup> S. Širca,<sup>21,20</sup> T. Su,<sup>4</sup> L. Tang,<sup>11</sup> Y. Tian,<sup>22</sup> N. Ton,<sup>18</sup> B. Wojtsekhowski,<sup>10</sup> S. Wood,<sup>10</sup> Z. Ye,<sup>23</sup> and J. Zhang<sup>18</sup>

(The Jefferson Lab Hall A Collaboration)

Phys. Rev. C 98 (2018) no.1, 014617  
Phys.Rev. C99 (2019) no.5, 054608

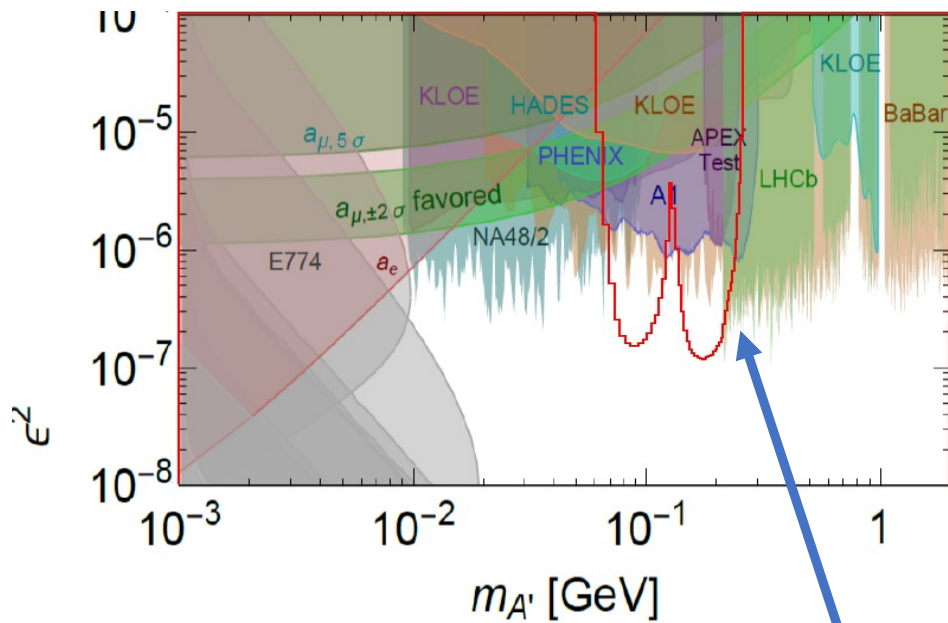
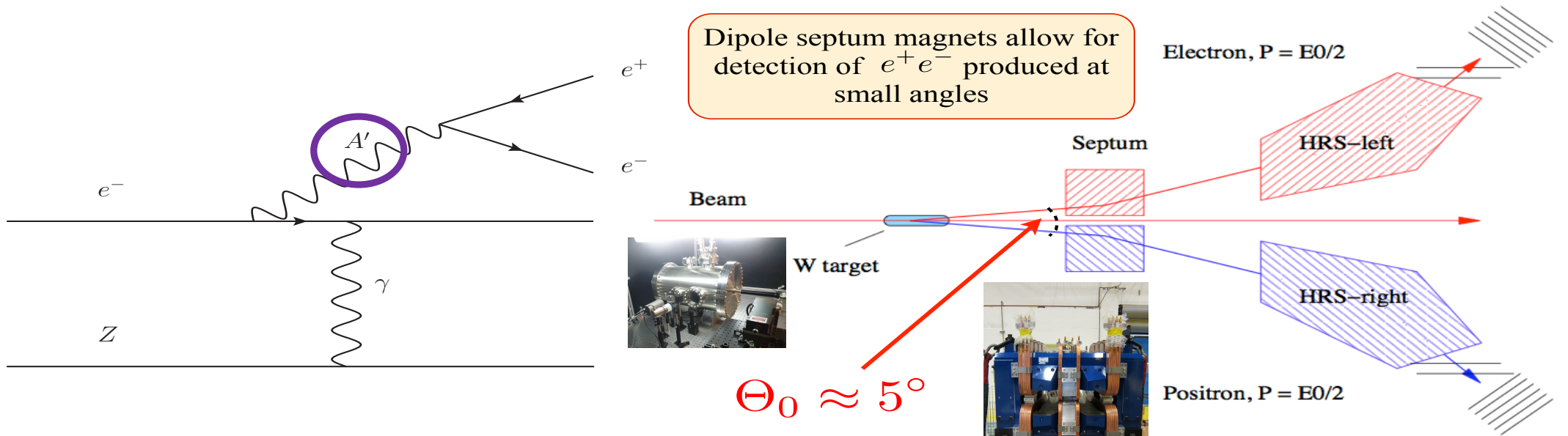


See MANY talks this afternoon!

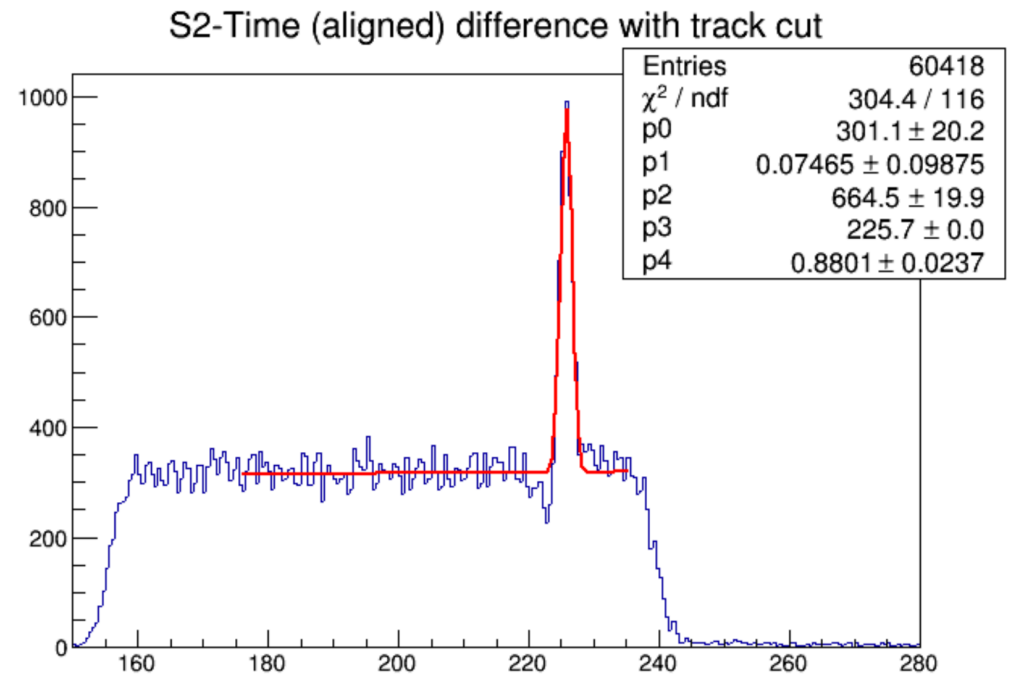
Phys. Lett. B 797 (2019) (R. Cruz-Torres et al.)



# A' Experiment (APEX) Heavy Photon Search



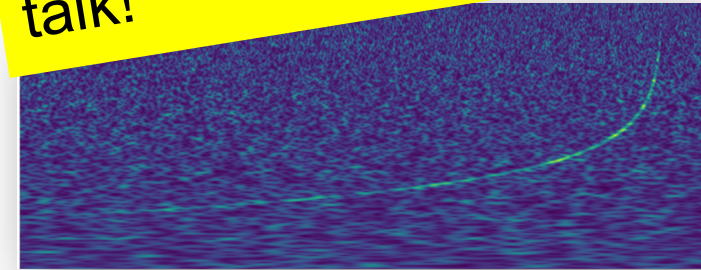
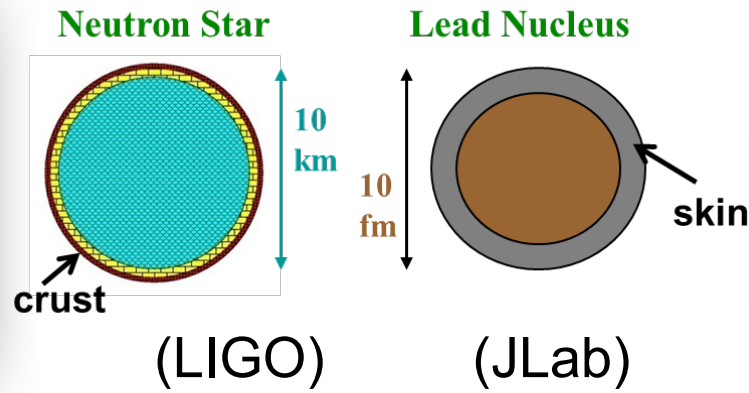
Obtained Spring 2019



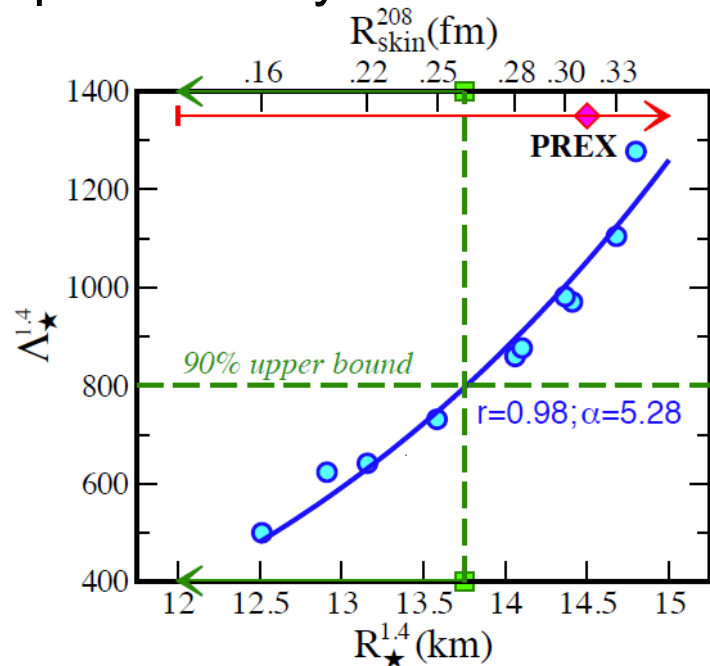
Resolution 0.9 ns

# 2019 Summer Run: PREX2

See Chandan Ghosh talk!



Measurement of neutron skin at JLab constrains tidal polarizability of neutron stars



Phys. Rev. Lett. 120, 172702 (2018)



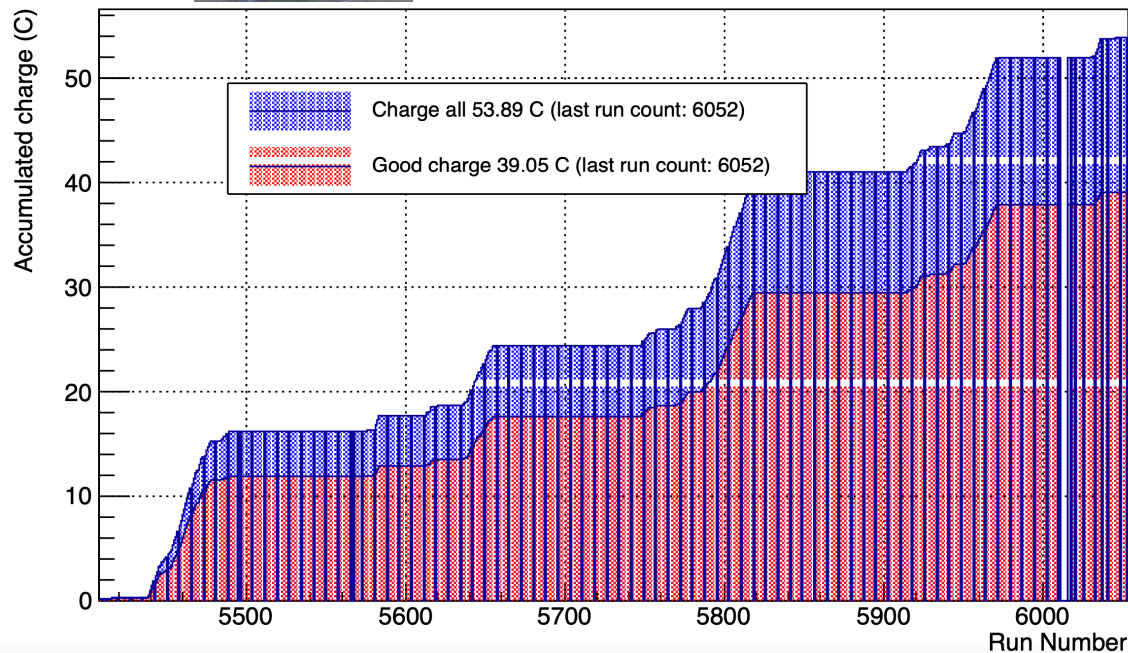
Target(s) in Hall A



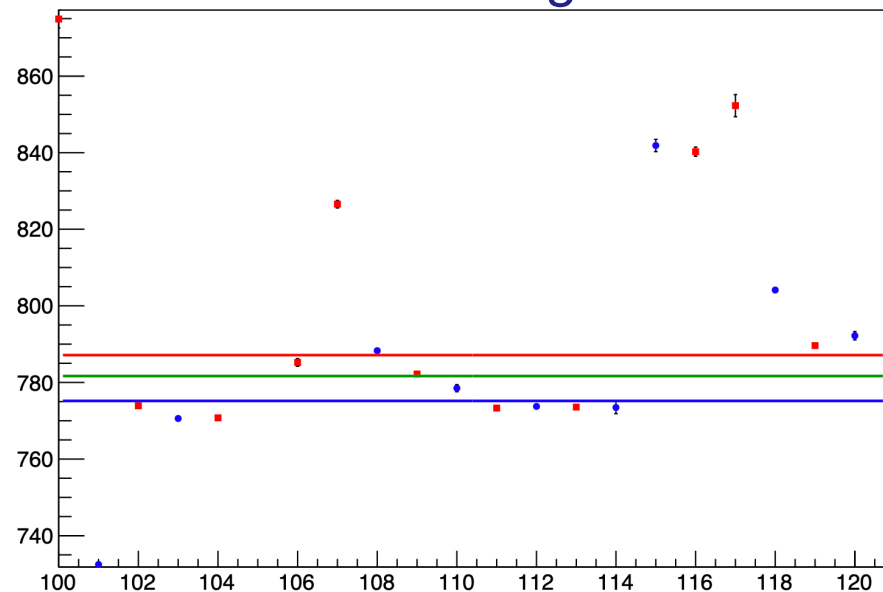
# Now Running: CREX



Charge total vs run



RMS vs "slug"



Right In: 775.181+/-0.298  $\chi^2/NDF: 7547.3/8$

Left Out: 0.000+/-0.000  $\chi^2/NDF: 0.0/0$

Right Out: 787.135+/-0.273  $\chi^2/NDF: 6965.3/11$

Left In: 0.000+/-0.000  $\chi^2/NDF: 0.0/0$

775.181+/-0.298  $\chi^2/NDF: 7547.3/8$

781.678+/-0.201  $\chi^2/NDF: 15388.1/20$

787.135+/-0.273  $\chi^2/NDF: 6965.3/11$

Beam on target charge accumulation as

a function of run number.

Blue = raw charge

Red = after selection cuts.



The last 6 data points are after Ca48 target recovery: The first 3 are the lower current commissioning, while the last 3 are high current. The width is comparable to before the target incident.

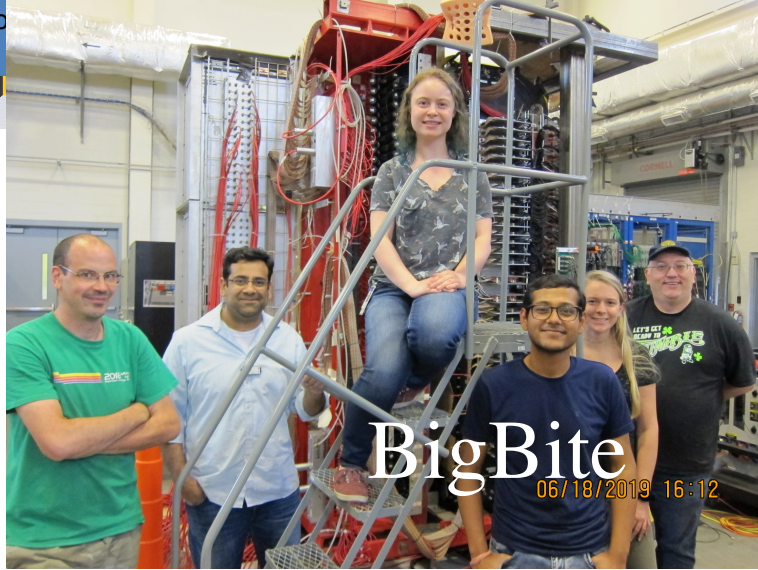
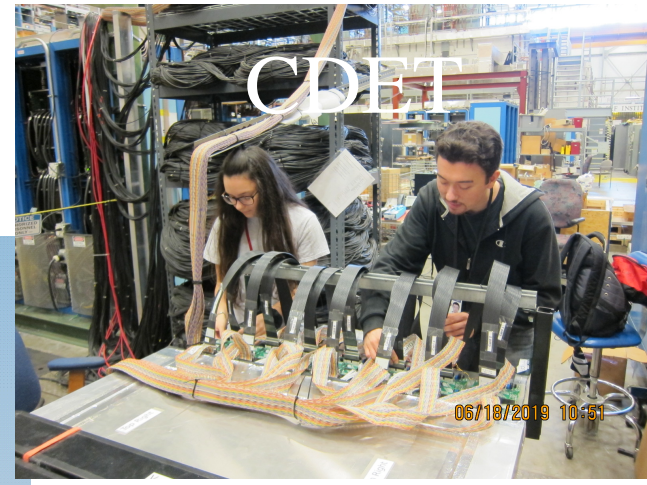
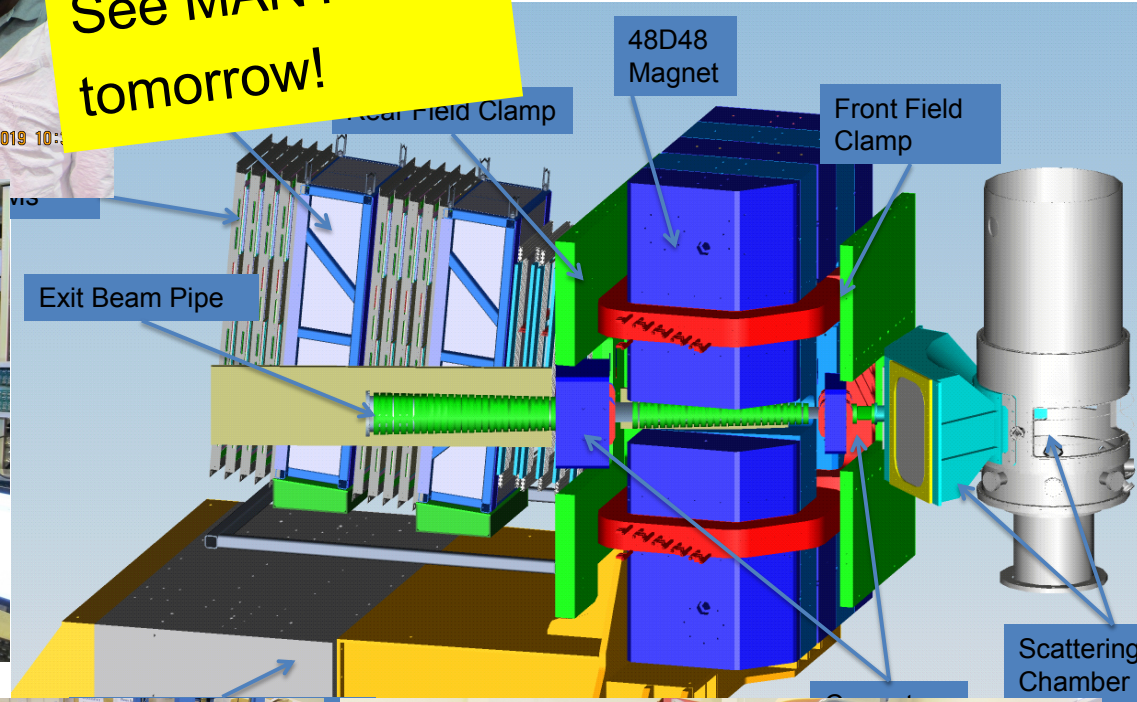


# Installation 2020: SBS

– time to integrate, test,  
be ready for  $G_M^n$  and  $G_E^n$ -RP!



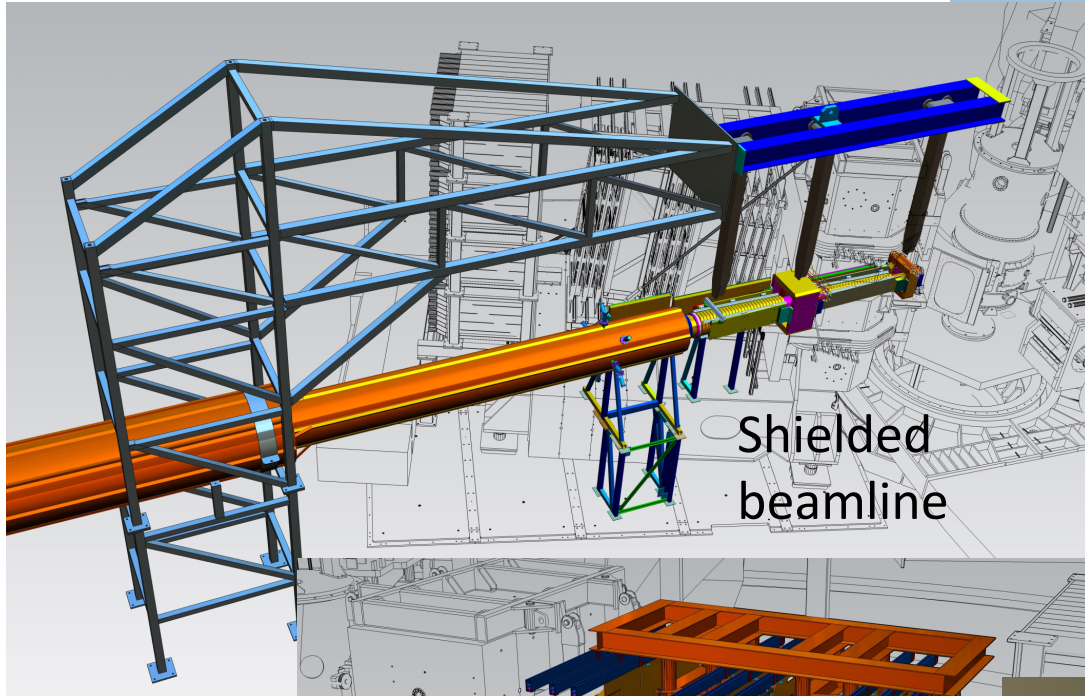
See MANY talks tomorrow!



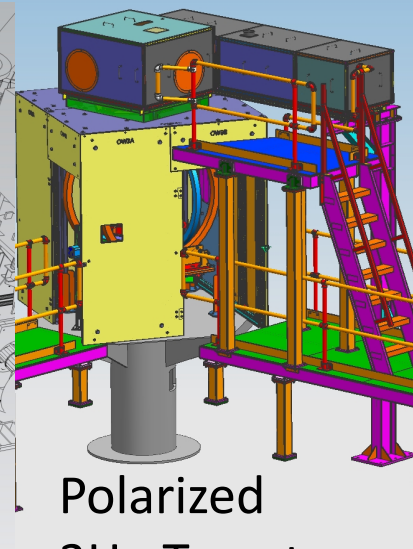


# SBS equipment

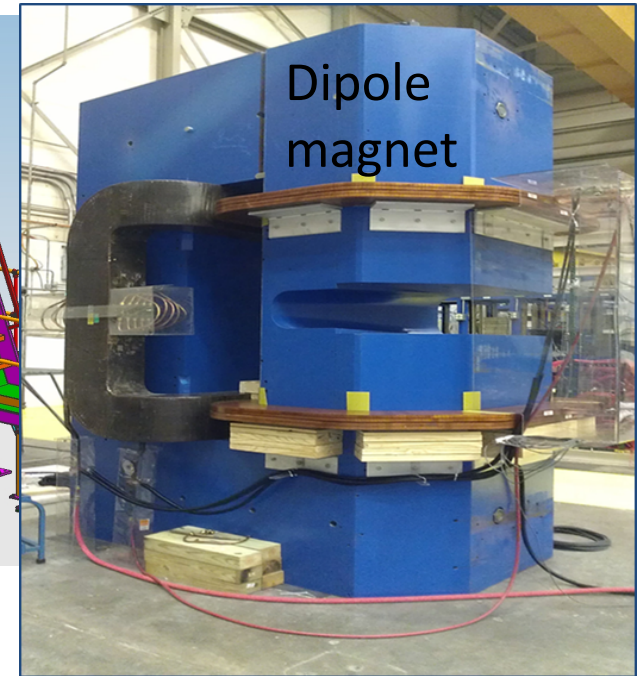
Also power, water upgrades to Hall 2020



Shielded beamline

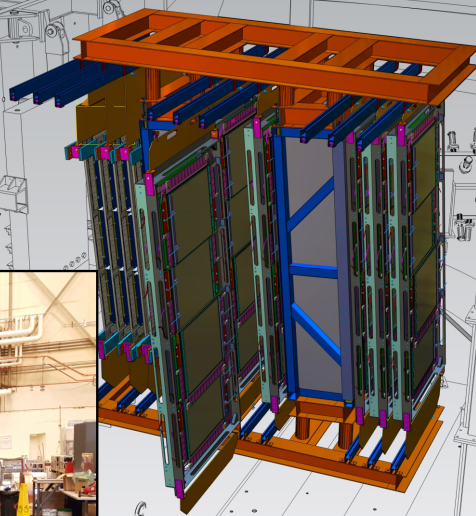


Polarized  $^3\text{He}$  Target

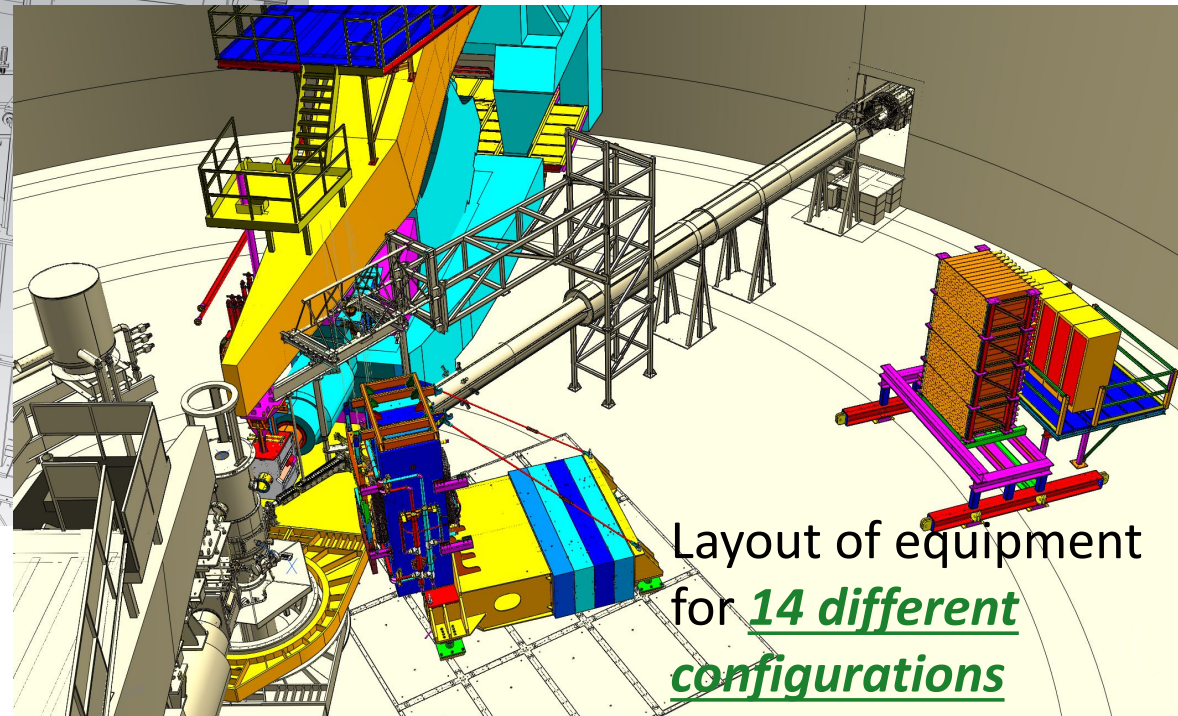


Dipole magnet

Counterweight support



GEM detectors



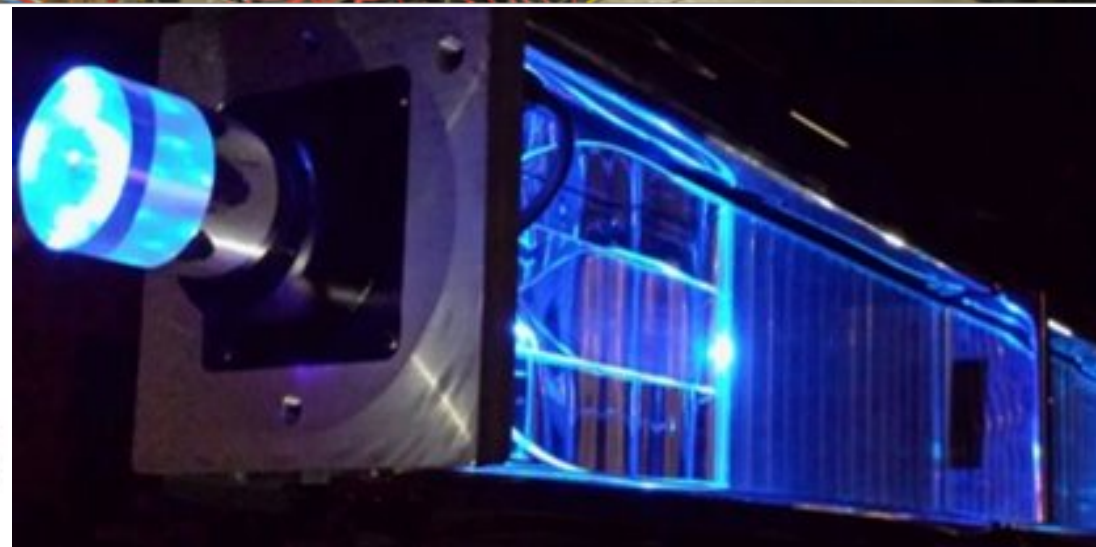
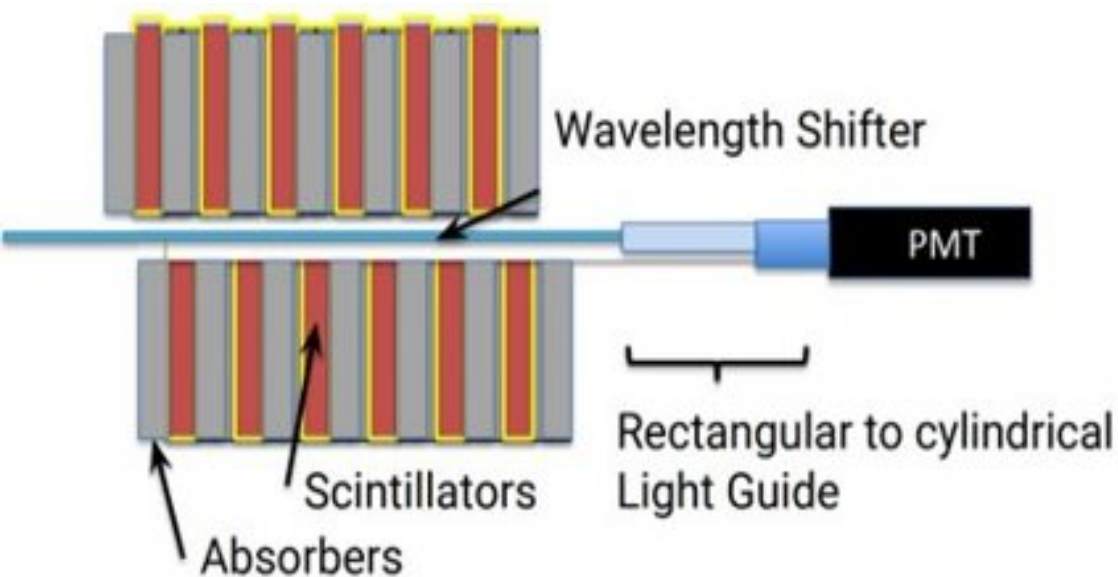
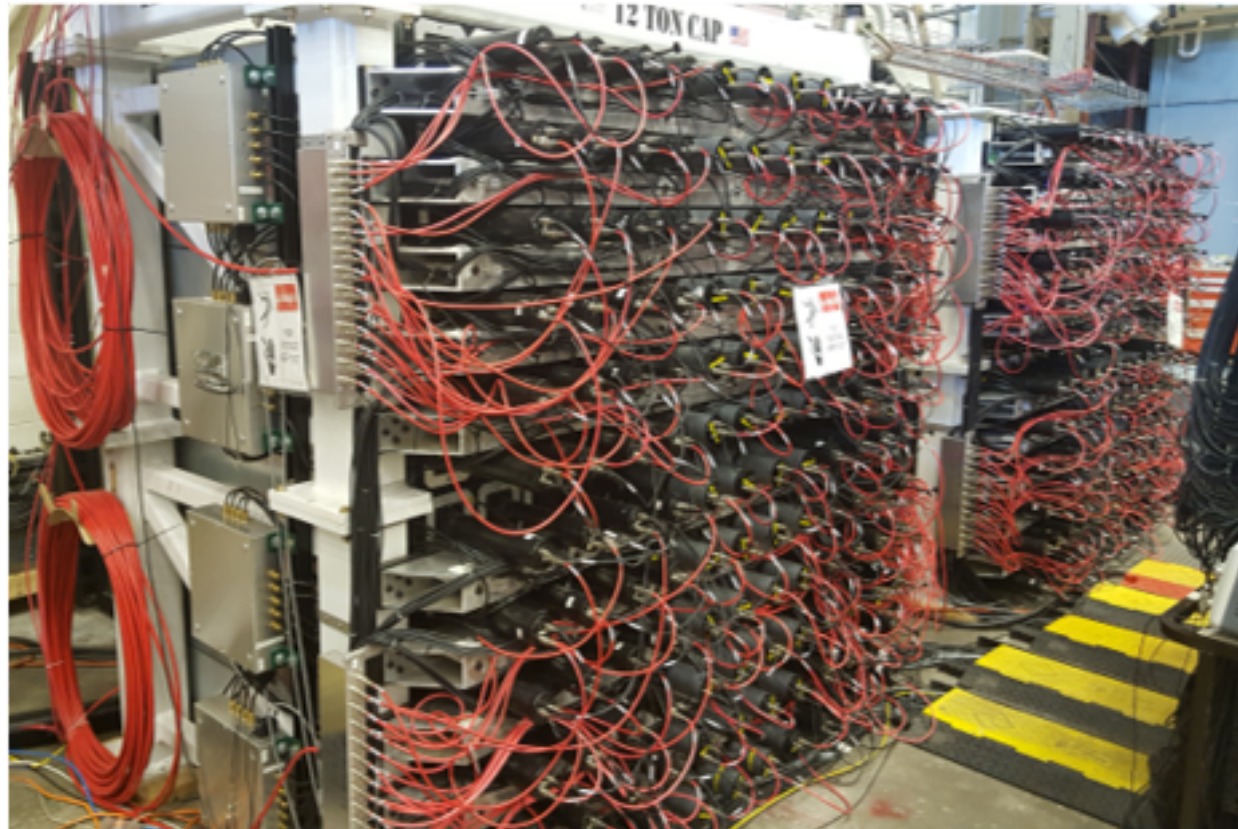
Layout of equipment for 14 different configurations





# Hall A Hadron Calorimeter

- 288 modules over 4 subassemblies
  - *Total weight 40 tons*
- Detects multiple GeV protons and neutrons using alternating layers.
  - 40 iron layers (absorbers) create particle showers.
  - 40 scintillator layers sample energy.
- Wavelength shifter increases photon collection efficiency.
  - Lightguide delivers light to PMTs.





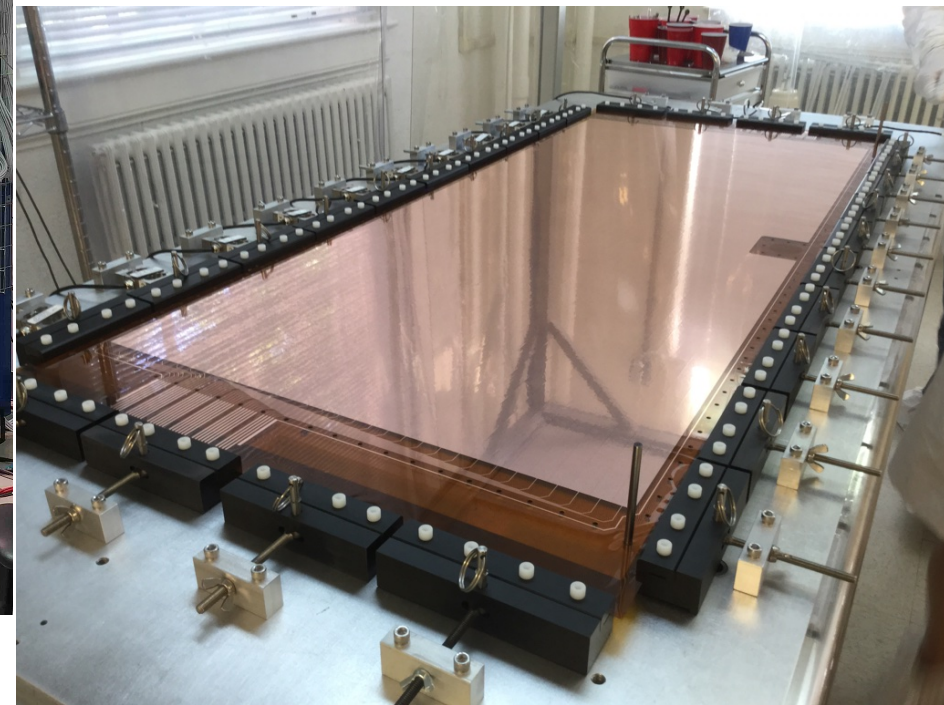
# Gas Electron Multiplier (GEM) Development

See Kondo Gnanvo talk!

48 large area GEM modules successfully built on-time and on-budget, meeting/exceeding specs for the Hall A Super BigBite Spectrometer project.



GEM cosmic testing





# Streaming/High Rate GEM Readout Development

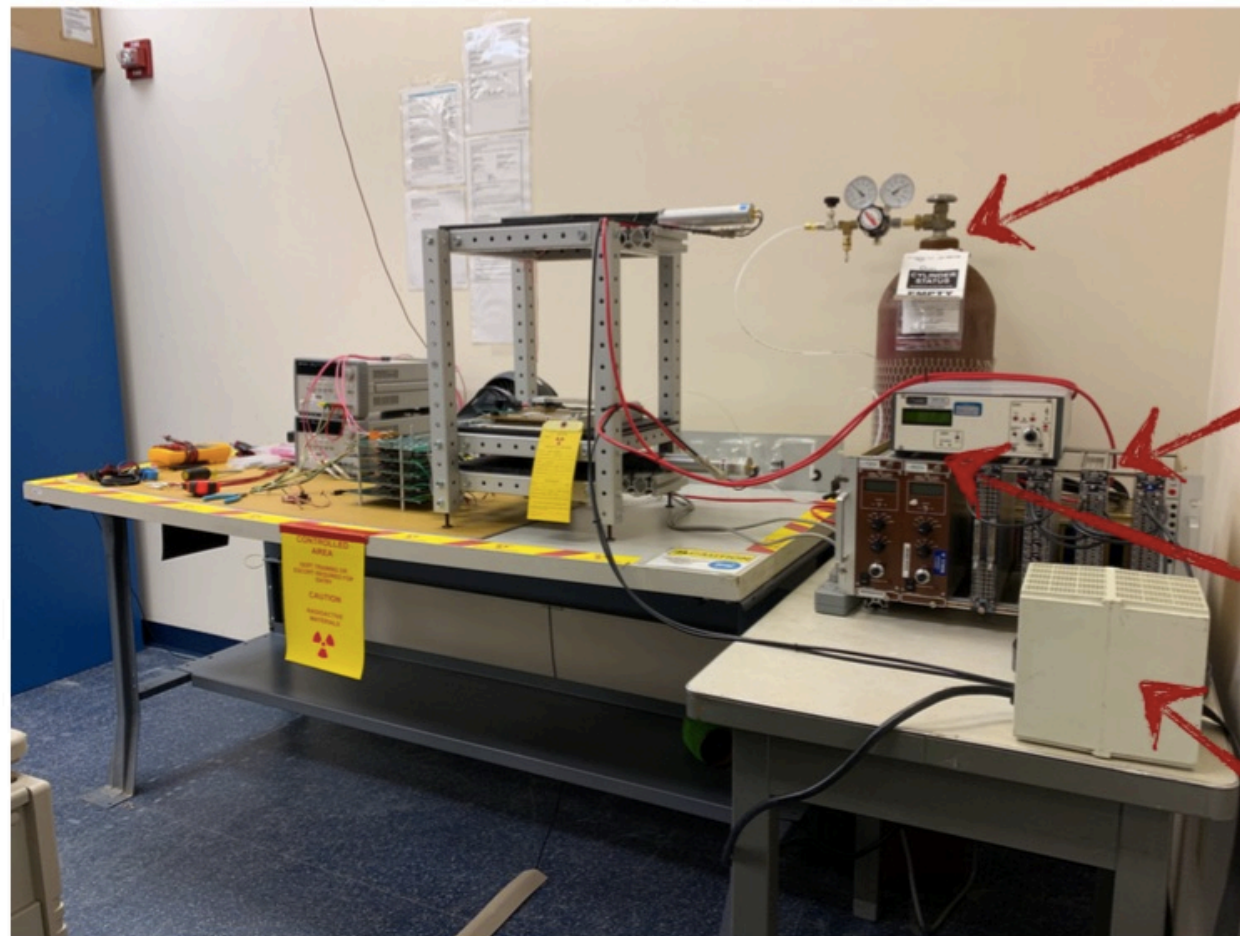
ALICE collaboration (CERN) is currently upgrading their TPC with a GEM based detection system that is read out continuously

- Streaming readout (SRO)
- Continuous time ordered sequences of detector system readout
- ~1 TB/s post zero-suppression

Novel front-end ASIC was developed specifically for this purpose → SAMPA

TDIS (and SoLID and EIC and beyond...) high rate GEM test stand

- GEM → x and y plane (324 channels each)
- TRORC → ALICE/ATLAS readout receiver card with GBT serialization protocol
- FEC → ALICE front end card (JLab version) – 5 SAMPA chips (160 channels)



75/25 Ar/CO<sub>2</sub>  
Gas System

NIM Cosmic  
Trigger

HV Power  
Supplies

Isolation  
Transformer



# TDIS SRO Prototype

- Currently we are streaming trigger-less GEM data (768 channels) in DAS mode at 45 Gb/s via 5 ALICE FEC's
  - GEM → FEC → **TRORC** (30 Gb/s) → PC Memory → Disk
- By implementing the receipt of a trigger, a programmable window of streamed data can be captured by the T-RORC
  - Keeps the data volume to memory (and to disk) at a manageable level
- Will modify the T-RORC firmware to suppress the transmission of unnecessary sync packet data to memory and disk
  - Sync packets keep the serial links from the SAMPAs active when there is no hit data to send
- Then we can acquire data in a truly continuous fashion

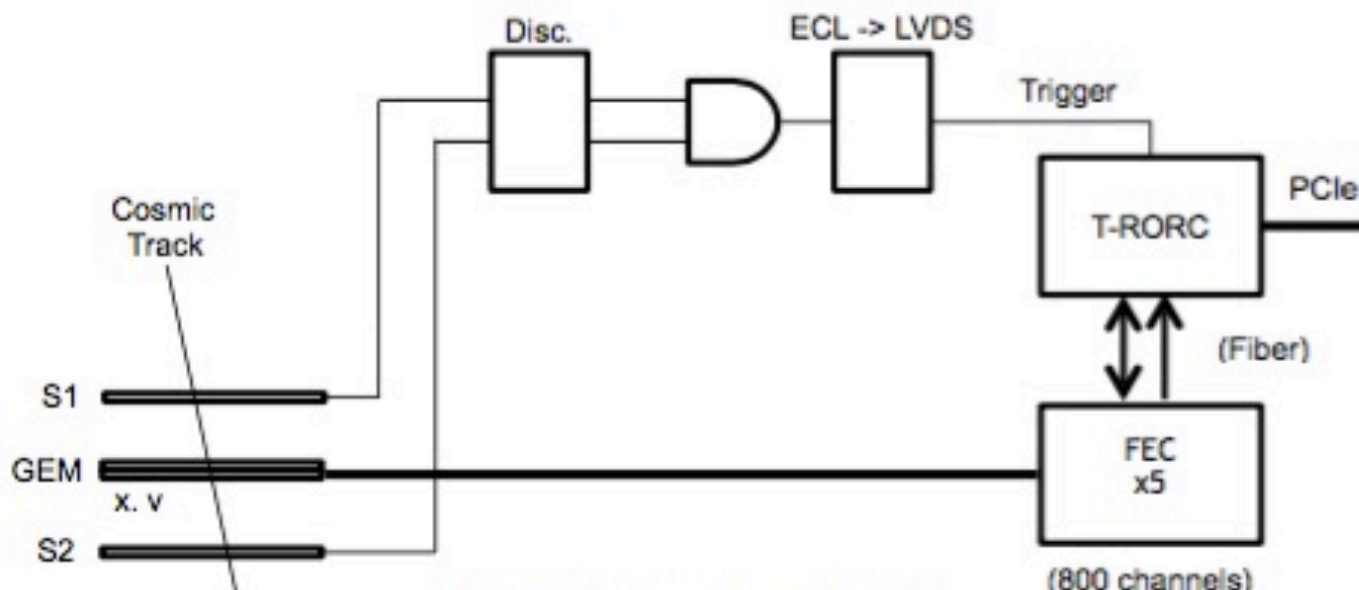


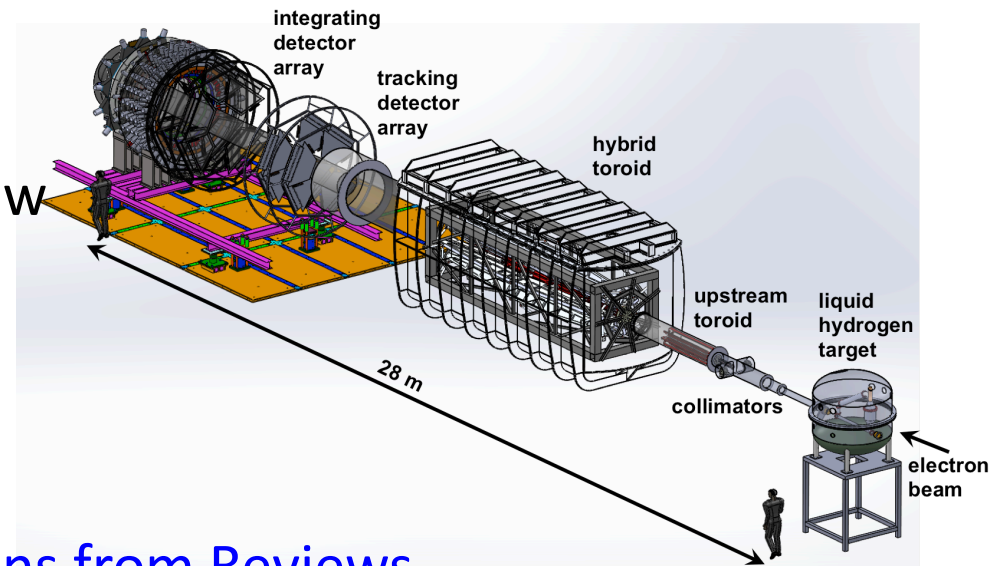
Diagram Courtesy of F. Jastrzemski

07/09/2019

## *On the path to CD-1....*

- 2014 DOE Science Review
- 2016 Director's Technical Cost and Schedule Review
- April 2019 Director's Review
- November 2019 Cost Review
- December 2019 Design and Technical Review
- January 2020 Director's Review
- *Anticipate ~\$2M TEC funds*
- *Anticipate CD-1 Review in 2020*

# MOLLER Status/Timeline



- Work proceeding to address recommendations from Reviews
- In all, 100+ Recommendations and Comments are being tracked/addressed
- Pre-R&D continues to refine design choices and reduce risk

## *At the lab....*

- Project management organization
- Spectrometer magnet and collimator systems conceptual design
- Parity quality beam working group
- Polarimetry upgrades
- High power target development
- ESR-II

See Don Jones  
Talk tomorrow!



# Status of MOLLER CD-1 Requirements

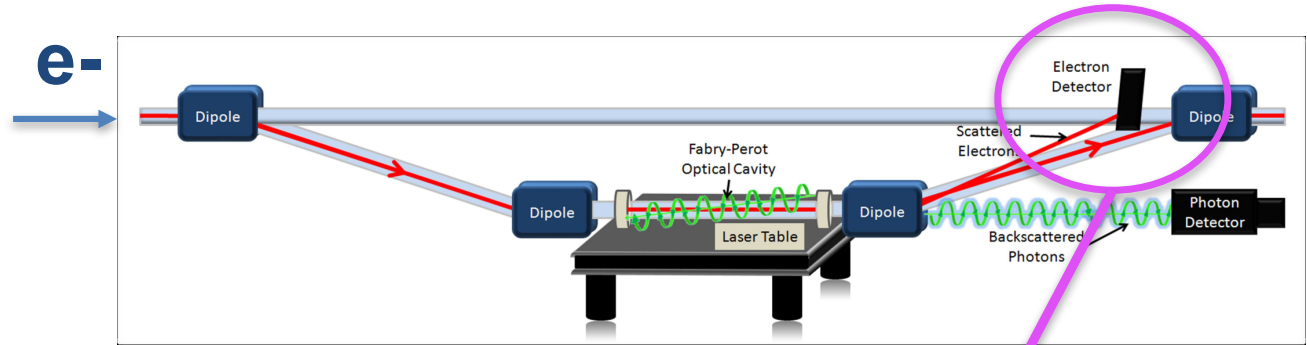
TOTAL PROJECT COST (TPC)		Less than \$50M* to \$20M	Status for MOLLER
DECISION / REQUIREMENTS <sup>1</sup> / APPROVAL <sup>2</sup>			
CD-1--APPROVE ALTERNATIVE SELECTION AND COST RANGE		SC-AD	
PRIOR TO CD-1 - CONCEPTUAL DESIGN	Approve Acquisition Strategy	Reviewed by SC-28 Approved by SC-AD	Not required if TPC <\$50M. Same information is in the pPEP.
	Approve Preliminary Project Execution Plan (PEP)	Reviewed by SC-28 Approved by SC-AD	Posted to Jan. 2020 Director's Review Pre-Brief
	Appointment of the Federal Project Director (FPD)	SC-AD	None
	Approve Integrated Project Team (IPT)	SC-AD	Documented in the pPEP posted to Jan. 2019 Director's Review Pre-Brief
	Develop a Risk Management Plan	Project	Posted to Jan. 2020 Director's Review Pre-Brief
	Comply with the One-for-One Building Space Replacement	Project	N/A
	Complete a Conceptual Design	Project	Complete
	Document High Perf. & Sustainable Bldg. & Sustainable Env. Stewardship considerations	Project	N/A
	Conduct a Conceptual Design Review	Team external to project	Review Performed Dec. 12-13, 2019. Committee Report 1/3/2020
	Complete a Conceptual Design Report	Project	Completed 22-Nov-2019. Posted to Jan. 2020 Director's Review Pre-Brief
	Prepare a Preliminary Hazard Analysis Report	Site Office or Lab	pHAR Posted to Jan. 2020 Director's Review Pre-Brief
	Develop and Implement an Integrated Safety Management Plan	Site Office or Lab	MOLLER is subject to the Existing JLab ISM Plan
	Establish Preliminary Quality Assurance Program (QAP)	Site Office or Lab	Covered by the Existing JLab QA/QC Performance Assessment Plan
	Identify general Safeguards and Security requirements for the recommended alternative	Site Office or Lab	Covered by Existing JLab Integrated Security Management Program.
	Complete National Environmental Policy Act (NEPA) Strategy by issuing a determination (i.e. EIS, EA)	Site Office or Lab	MOLLER is covered by the existing JLab NEPA Strategy.
	Conduct Preliminary Security Vulnerability Assessment, if necessary	Site Office or Lab	Security provided through JLab Integrated Security Management Program.
	Conduct Independent Project Review or External Independent Review	SC-28 Tailored	To be scheduled after the Jan. 2020 Director's Review
	Update PDS, or other funding documents for MIE and OE projects, and OMB 300s, if applicable.	SC-AD	An updated Exhibit-300 is Posted to Jan. 2020 Director's Review Pre-Brief



Also  
November  
2019 cost  
review

Director's Review of MOLLER, January 14-16, 2020

# Precision Polarimetry in Halls A and C

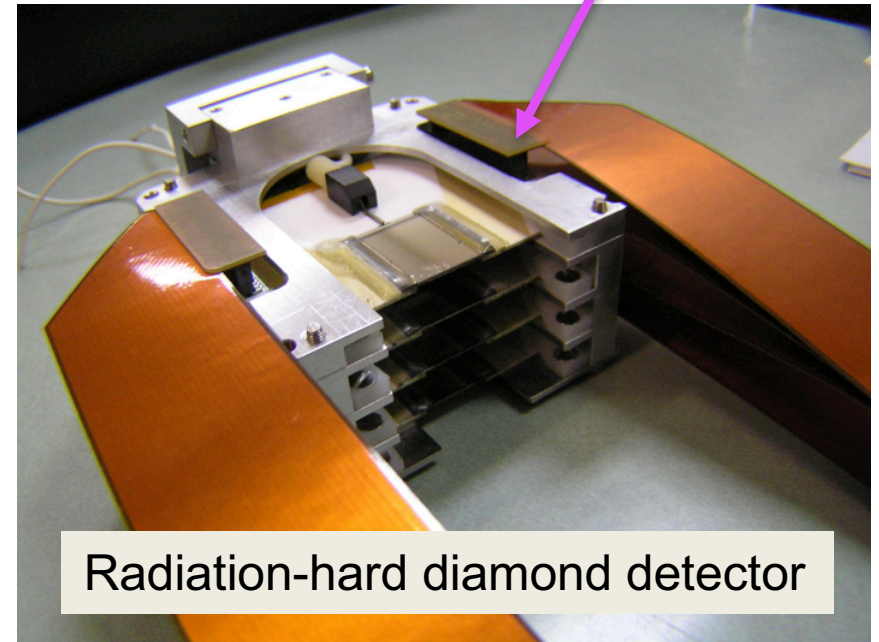


## Compton :

- New laser system for Hall C (low gain -> high gain cavity)
- Upgrade Hall C electron detector DAQ to match Hall A (VTROC)
- New electron detectors for Hall A & C

## Moller :

- Hall A improvements to support MOLLER (tracking GEM, better collimation)
- New superconducting solenoid (identical for Hall C) procured

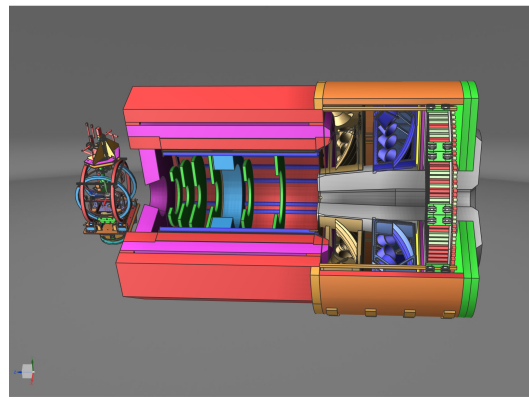


Radiation-hard diamond detector

*Hall C diamond microstrip detectors used to detect scattered electrons*



# SoLID Status Update



## ***On the path to CD-0...***

- 8/26/19 Updated pCDR, proposal sent to Director
- 9/9-10/19 Director's Review (report sent 10/10/19)
- 11/20/19 Updated pCDR sent to Director
- 12/19 Received pre-R&D funding
- Anticipate MIE/pCDR to be sent to DOE next week!

## **Continue Pre-R&D on Sub-systems and Simulations**

- Magnet yoke steel arrived Summer 2019

*new control system*

*preparing for magnet static testing test*

*on to low current testing*

- Study GEM readout, effect on tracking
- ECal fiber testing
- LCG background test with prototype, mirror study
- HGC simulation on performance with different options, gas system, window test

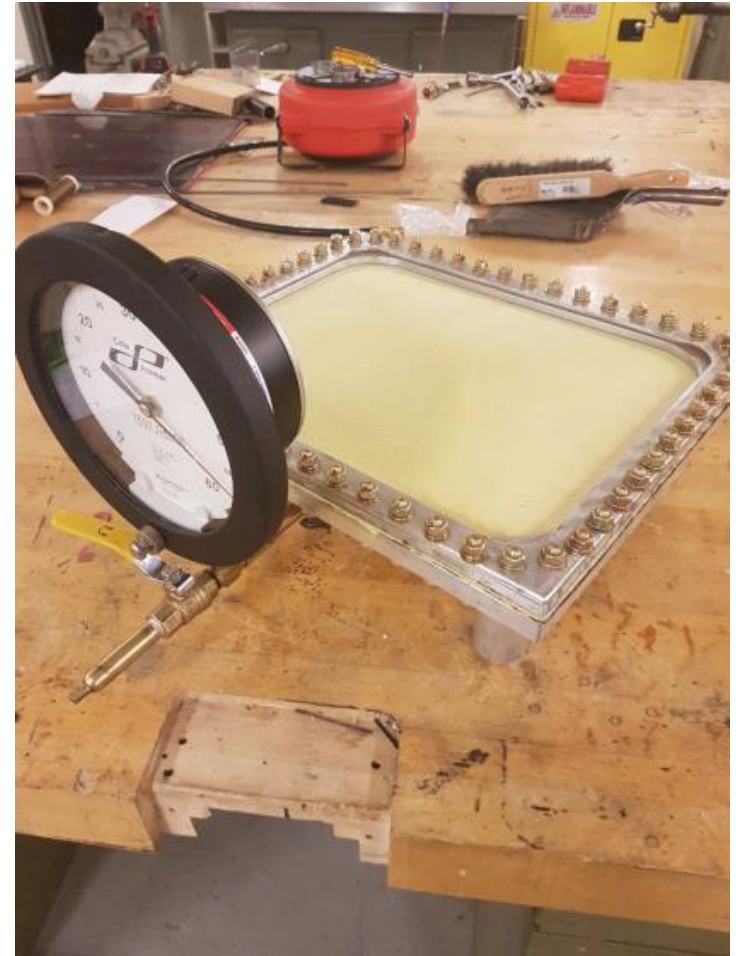
**See Paul Souder  
talk!**



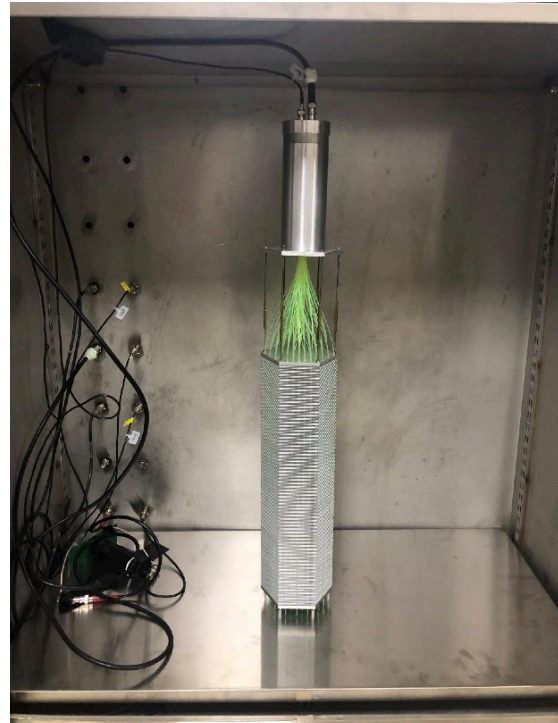
## Light Gas Cherenkov Prototype Test Setup in Hall C



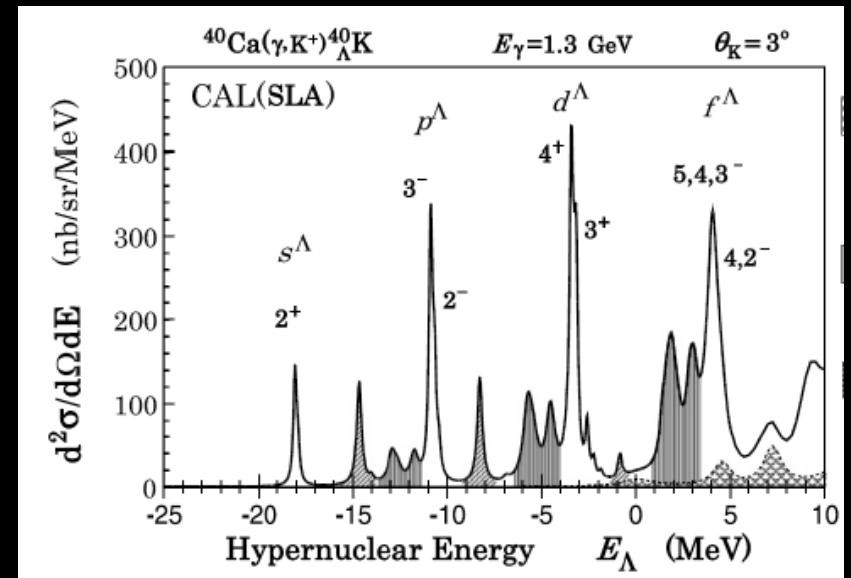
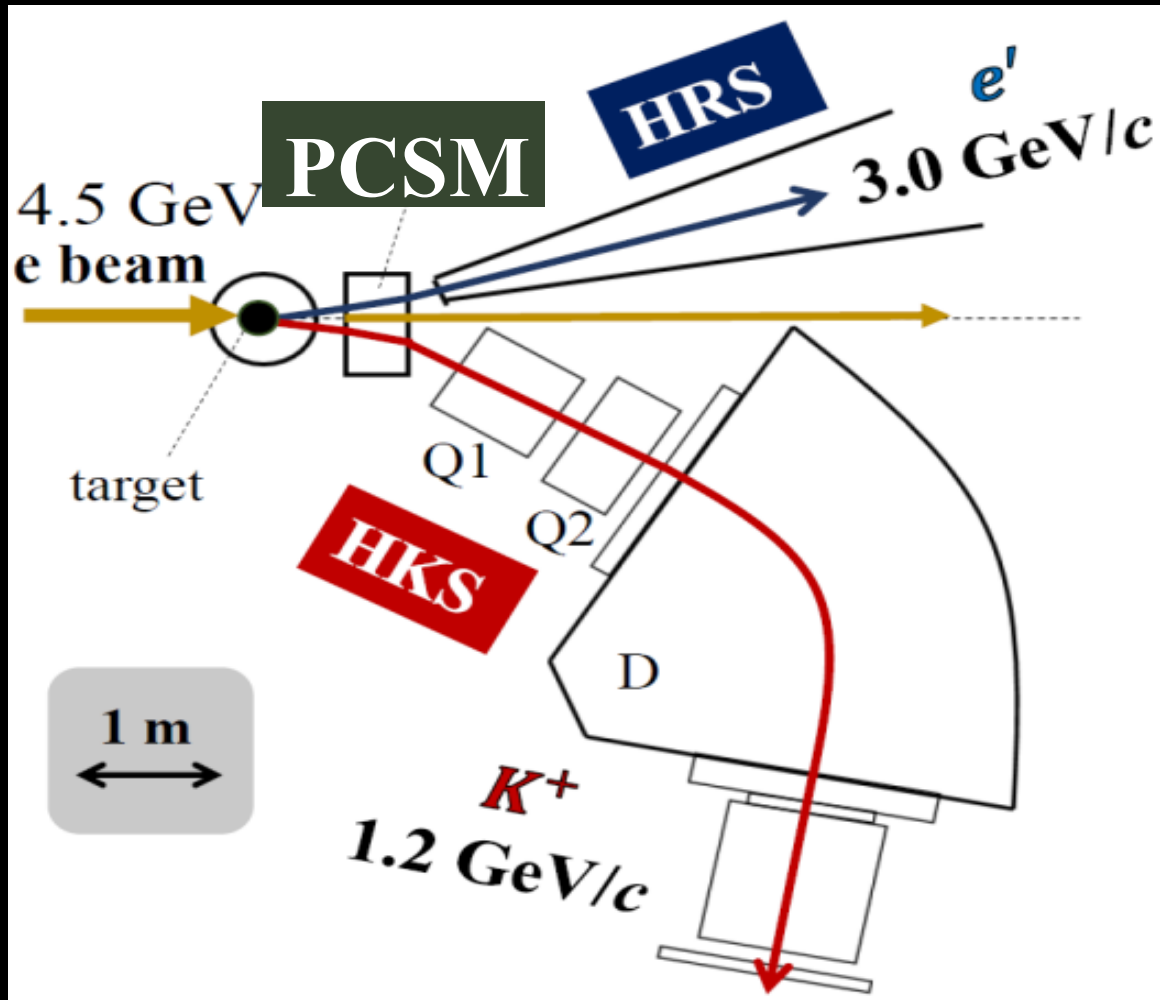
## Heavy Gas Cherenkov Window Test



## ECal Module (Shashlyk) Prototype Test

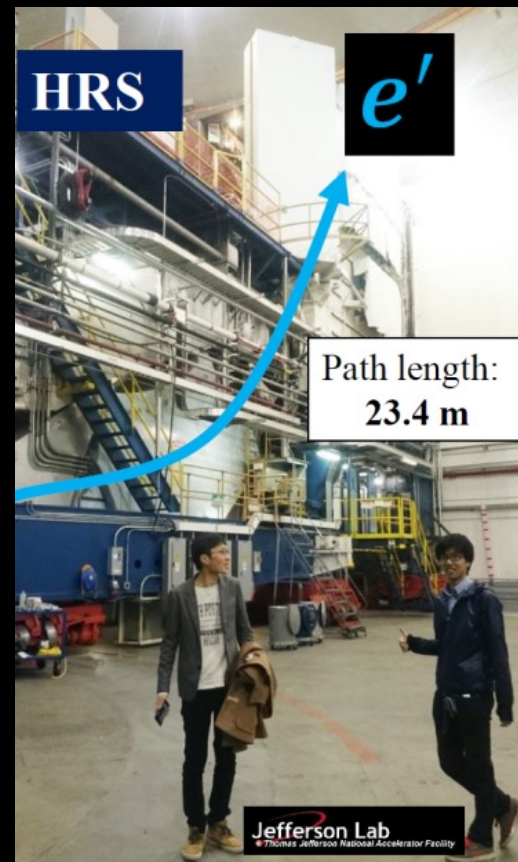


# Hypernuclear Spectroscopy



New PCSM (Pair of Charge Separation Magnets)  
Ca target holder design/construction started

*Ready  
by 2021*



PAC 47 (2019)  
gave C2  
approval to PR-  
12-19-002, *High  
precision  
measurement of  
Lambda  
hyperhydrogens*



# 2019-20(!) Hall A Publications + Students

First Measurement of the  $\text{Ar}(e,e')\text{X}$  Cross Section at Jefferson Lab

*Phys. Rev. C* **99**, 054608 (2019) (H. Dai et al.)

High-resolution hypernuclear spectroscopy at Jefferson Lab, Hall A

*Phys. Rev. C* **99**, 054309 (2019) (F. Garibaldi et al.)

Measurement of double-polarization asymmetries in the quasi-elastic  ${}^3\text{He}\uparrow(e\uparrow, e'\text{p})$  process

*Phys. Lett. B* **788**, 117 (2019) (M. Mihovilović et al.)

Proton charge radius extraction from  $e$  scatt. data using dispersively improved chiral effective field theory

*Phys. Rev. C* **99**, 044303 (2019) (J.M. Alarcón, D.W. Higinbotham, C. Weiss, Z. Ye.)

Density Changes in Low Pressure Gas Targets for Electron Scattering Experiments

*Nucl. Instrum. Meth. A* **940** (2019) 351-358 (S.N. Santiesteban et al.)

Measurement of the single-spin asymmetry  $A_y^0$  in quasi-elastic  ${}^3\text{He}\uparrow(e, e'n)$  scattering at  $0.4 < Q^2 < 1.0$   $\text{GeV}/c^2$

*Phys. Lett. B*, **797** (2019) (E. Long et al.)

The Double Spin Asymmetry of Nitrogen in Elastic and Quasi el. Kin. from a Solid Ammonia Dynamically Pol. target

*Nucl. Instrum. Meth. A* **946** (2019) (Moshe Friedman, Jessica Campbell, Adam Sarty, Douglas W. Higinbotham, Guy Ron)



# 2019-20(!) Hall A Publications + Students

Probing for high momentum protons in  $^4\text{He}$  via the  $^4\text{He}(e,e'p)X$  reaction

**Submitted 2019** (S. Iqbal et al.)

Comparing proton momentum distributions in  $A=3$  nuclei via  $^3\text{He}$  and  $^3\text{H}(e,e'p)$  measurements

**Phys. Lett. B 797 (2019)** (R. Cruz-Torres et al.)

Dispersive Corrections to the Born Approximation in Elastic  $eA$  Scattering in the Intermediate Energy Regime

**arXiv:1805.12441** (P. Guèye et al.)

Measurement of the  $^3\text{He}$  spin structure functions of the neutron ( $^3\text{He}$ ) spin-dependent sum rules at  $0.035 < Q^2 < 0.24 \text{ GeV}^2$

**Submitted 2019** (V. Sulkosky et al.)

Probing few-body nuclear dynamics via  $^3\text{H}$  and  $^3\text{He}$   $(e,e'p)pn$  cross section measurements

**Submitted 2020** (R. Cruz-Torres et al.)

Measurement of the cross sections for inclusive electron scattering in the E12-14-012 experiment at Jefferson Lab

**Phys. Rev. C 100, 054606 (2019)** (M. Murphy et al.)

Deeply virtual Compton scattering off the neutron

**Nature Physics (January 27, 2020) (M. Benali, et al.)**

14 Total, or  
did I forget  
any?

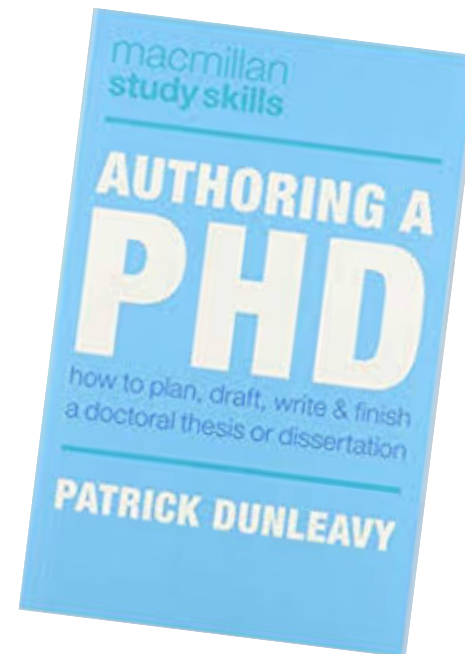




# 2019-20(!) Hall A Publications + Students

12 GeV Era Doctoral Theses (in no particular order): Longwu Ou, Dien Nguyen, Scott Barcus, Thir Gautam, Barak Schmookler, Tyler Kutz, Hanjie Liu, Tyler Hague, Mongi Dlamini, Hongxia Dai, Jessica Campbell, Bill Henry

- This is 12, yay!
- But, who am I missing?!



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Thanks!