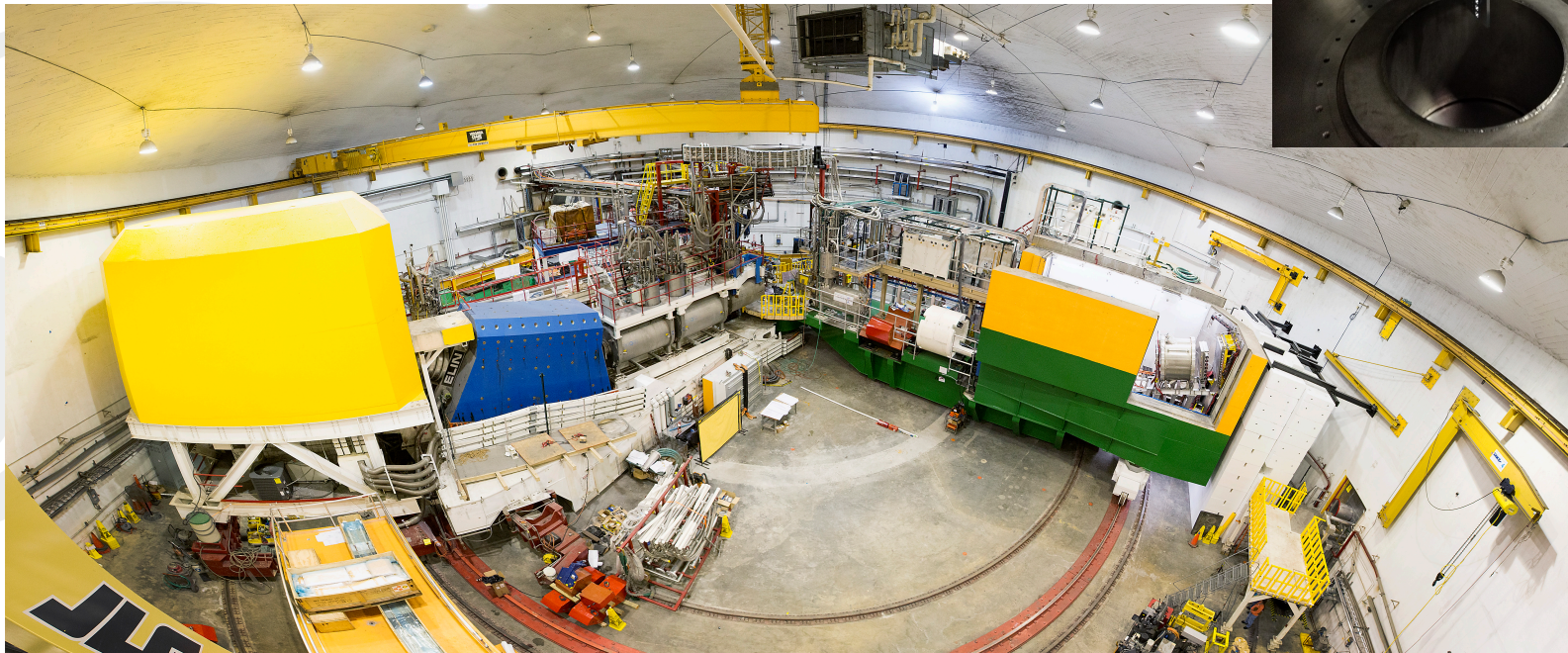


# Hall A and C Status and Plans

*Thia Keppel*

Hall A/C Summer  
Collaboration Meeting  
June 2018



# Hall A Status and Plans

- **Completed** 5\* planned experiments:
  - DVCS, scaling test for GPD science (\*50% planned)
  - GMp, high precision proton elastic for factor
  - Ar(e,e'p), fundamental nuclear input for neutrino experiments
  - MARATHON, enabling extraction of d/u at large x
  - Exclusive SRC, nucleon momentum distributions in A=3 nuclei
- Currently using first tritium target available for electron scattering in ~30 years – *2 more experiments planned for Fall 2018*
- Near term future: septum experiments
  - APEX Spring 2019
  - PREX2 and CREX (common installation) Summer/Fall 2019
- SBS in 2020
- MOLLER, SoLID (ongoing support, not discussing below)



# Hall A Projected Experiment Schedule as of 1/18 (also see

[https://www.jlab.org/exp\\_prog/experiment\\_schedule/2018/20180108.2a.pdf](https://www.jlab.org/exp_prog/experiment_schedule/2018/20180108.2a.pdf) through 12/18)

	Spring	Fall	Spring	Fall	Spring	Summer !!!!	Fall
CY 2017	Ar(e,e'p)	$^3\text{H}/^3\text{He}$ group*					
CY 2018			$^3\text{H}/^3\text{He}$ group	$^3\text{H}/^3\text{He}$ group			
CY 2019					<i>APEX</i>	<i>PREX<sub>2</sub></i>	<i>CREX</i>



Slide from January  
2018 Hall A  
Collaboration  
Meeting – we're  
well on track!



New and exciting news!  
This is the plan...  
...BUT...there are caveats....

*SBS 2020*  
*MOLLER?, SoLID? →*

Experiments in red represent PAC “high impact” experiments

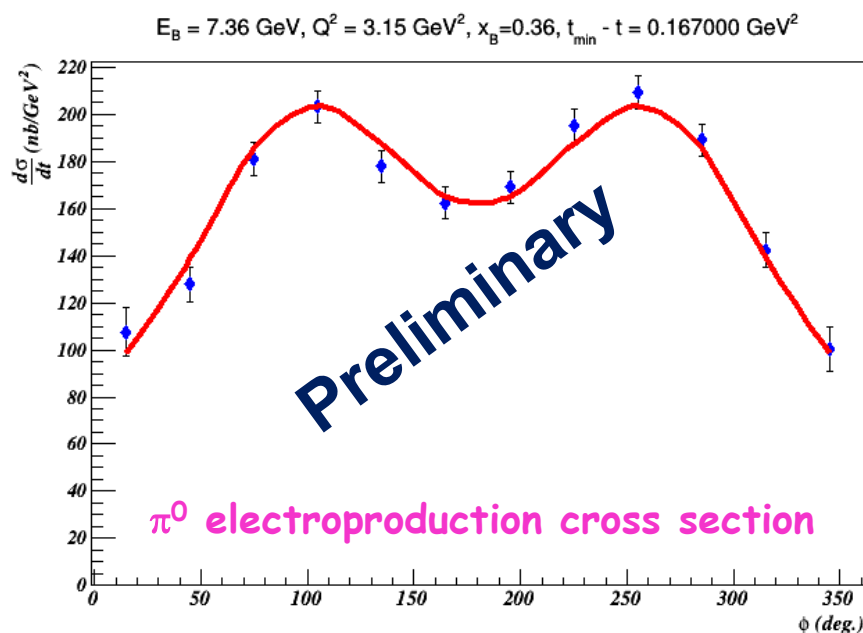
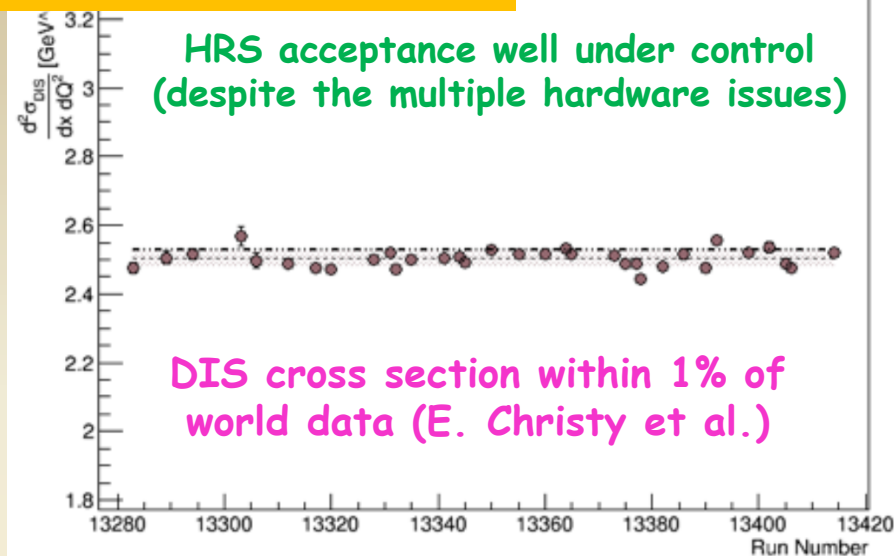
# E12-06-114: Deeply Virtual Compton Scattering

See Carlos Munoz Camacho talk today!

100 PAC days approved:

- High impact experiment for nucleon 3D imaging program
- High precision scaling tests of the DVCS cross section at constant  $x_B$
- CEBAF12 will allow to explore for the first time the high  $x_B$  region

50% of experiment planned & completed in 2014-2016



Data under final stages of analysis  
Publication drafts expected by the end of the year

Analysis path:

- **Jun'18:** Preliminary results on  $\pi^0$  at  $x_B=0.36$
- **Oct'18:** Preliminary results on DVCS
- **Nov'18:** Short paper submitted to PRL on  $\pi^0$
- **Jan'19:** Letter to PRL on DVCS
- **Jul'19:** Long paper to PRC (DVCS &  $\pi^0$ )

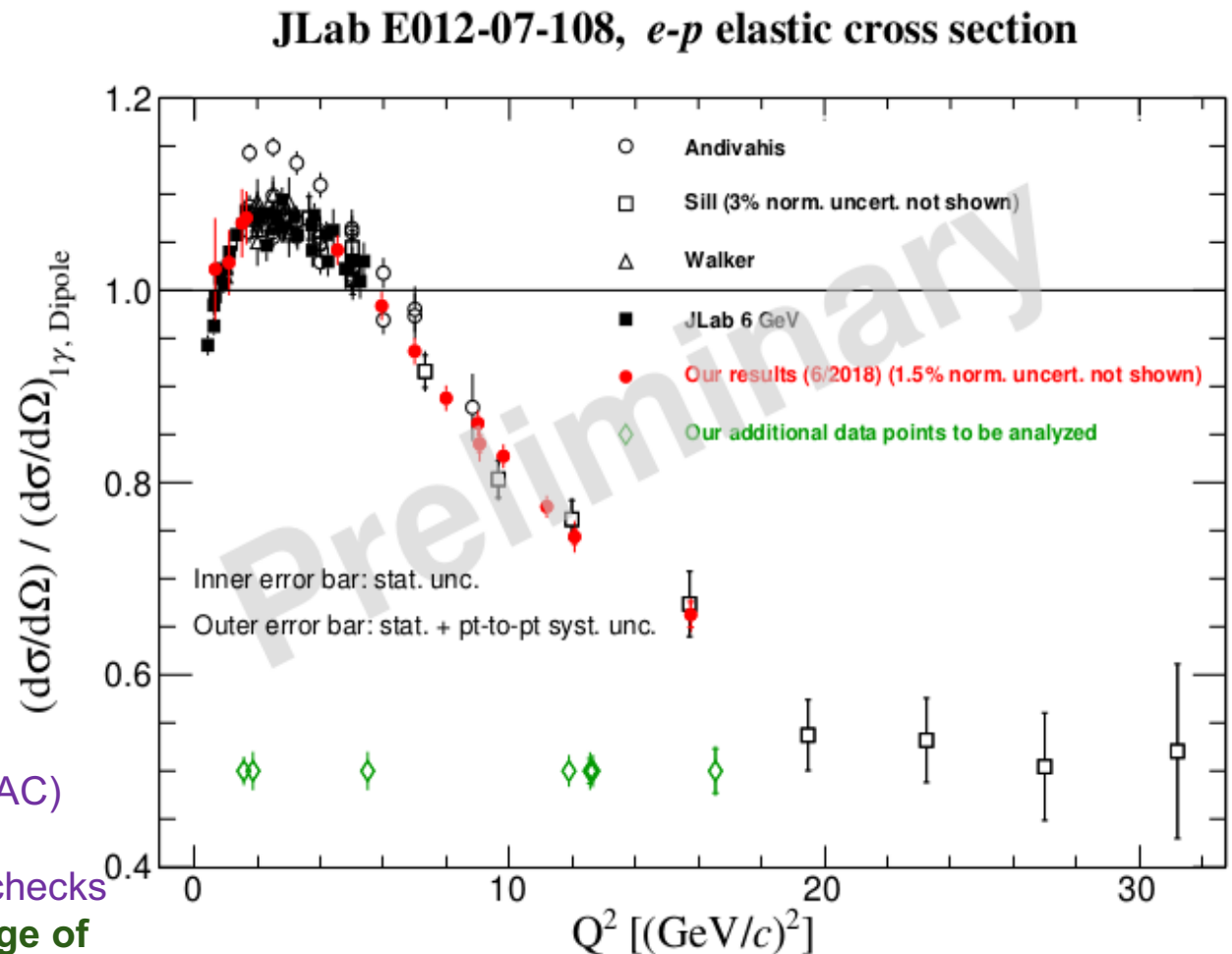
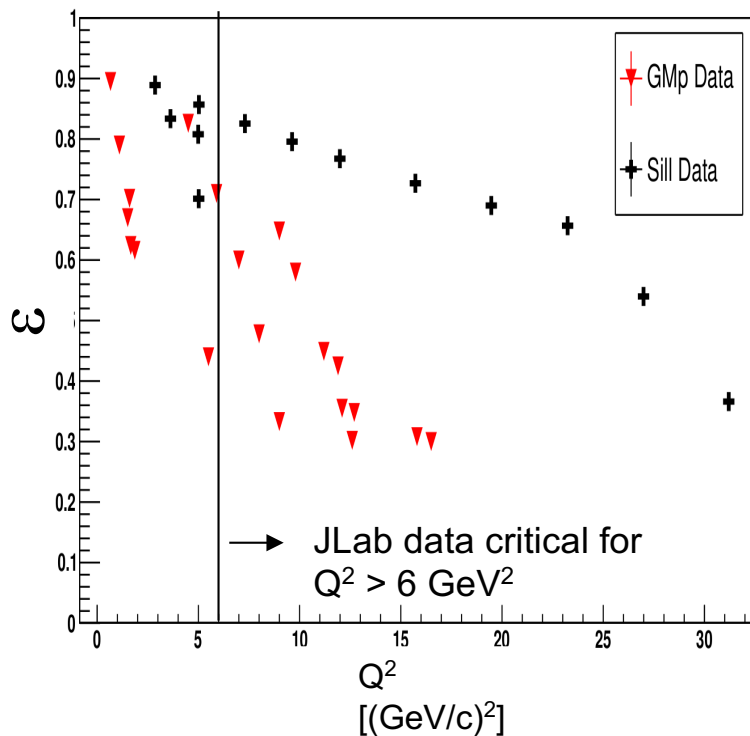


# GMp Experiment E12-07-108

## 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  $G_E^p$ ,  $G_M^p$ ,  $2\text{-}\gamma$  effects at high  $Q^2$  in combination with SBS
- Publication with all data including further reduced systematics in 3-4 months

See Thir  
Gautam talk  
today!

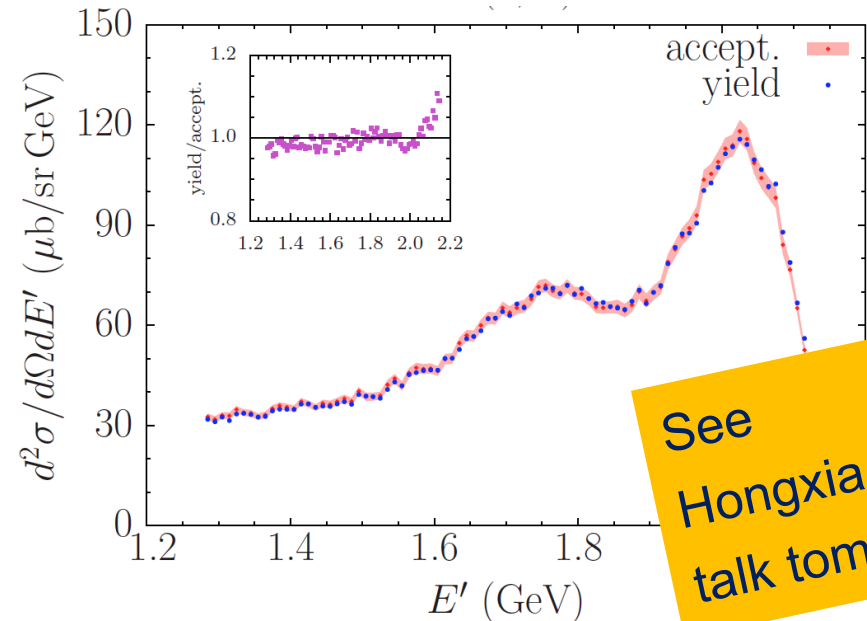
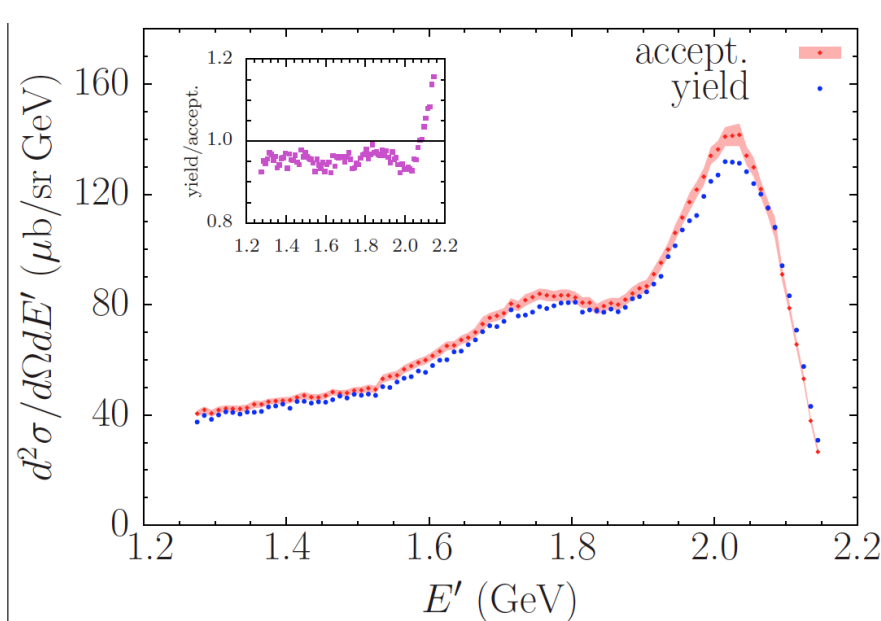


- Prior to E12-07-108 only one set of (SLAC) data above  $Q^2 > 6$  GeV $^2$
- One epsilon, NO range for two photon checks
- **Hall A GMp data provides a large range of epsilon up to  $Q^2 \sim 16$  GeV $^2$**

# E12-14-012: Ti and Ar (e,e'p) Measurements – *completed Spring 2017*

Will further our understanding of these many body systems and reduce uncertainties for neutrino science.

- Three Ph.D. students (2 Virginia Tech, 1 University of Virginia)
- Inclusive Ti and C cross sections paper *submitted* to Phys Rev. C.
- Completed (e,e') analysis on Ar, paper in preparation to be circulated by middle of July.



See  
Hongxia Dai  
talk tomorrow!

Right: Inclusive Titanium cross sections obtained with two different methods, yield ratio and acceptance

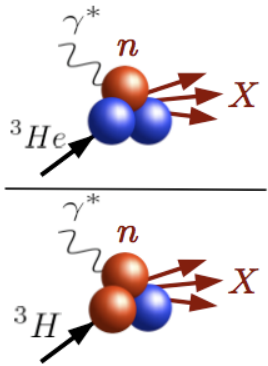
Left: Inclusive Argon cross sections obtained with the two different methods

*Yield ratios include both statistical and systematical uncertainties.*

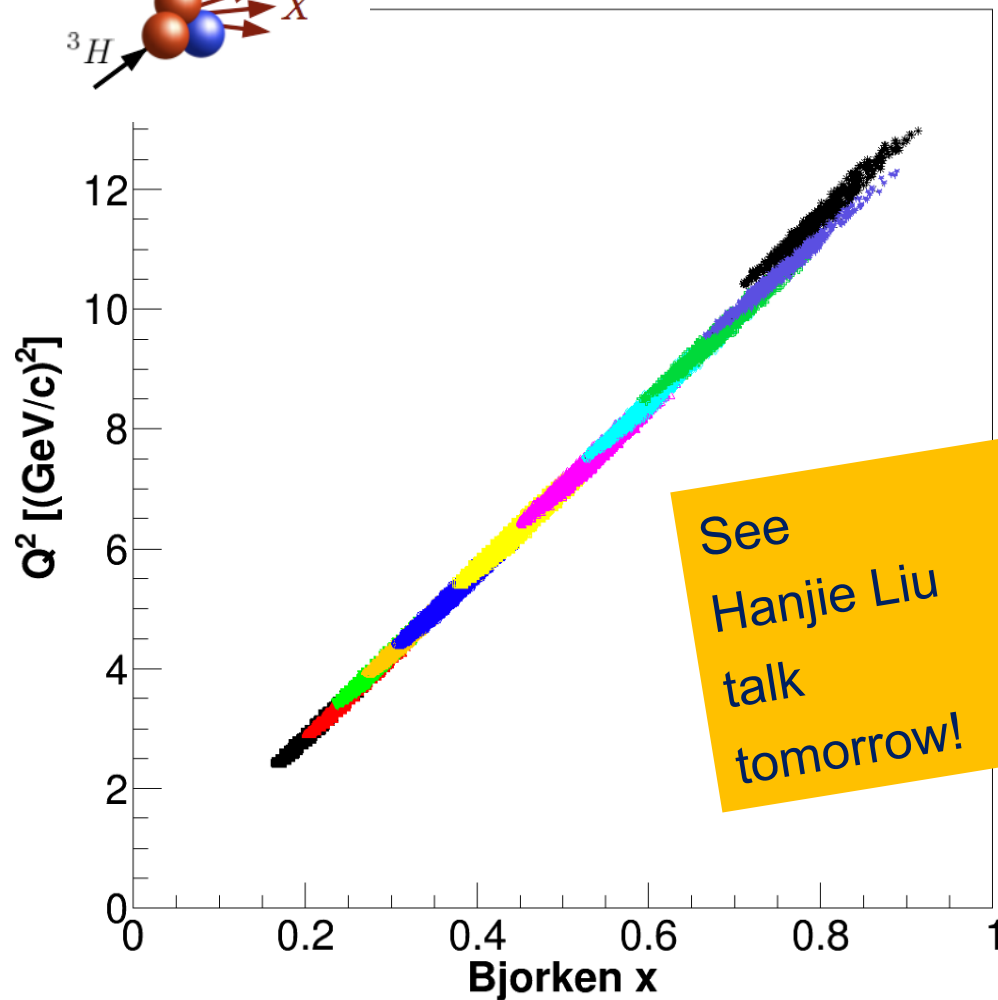
Next steps: exclusive (e, e'p) analysis for Ar and Ti.



# MARATHON: *The first Hall A tritium target experiment*

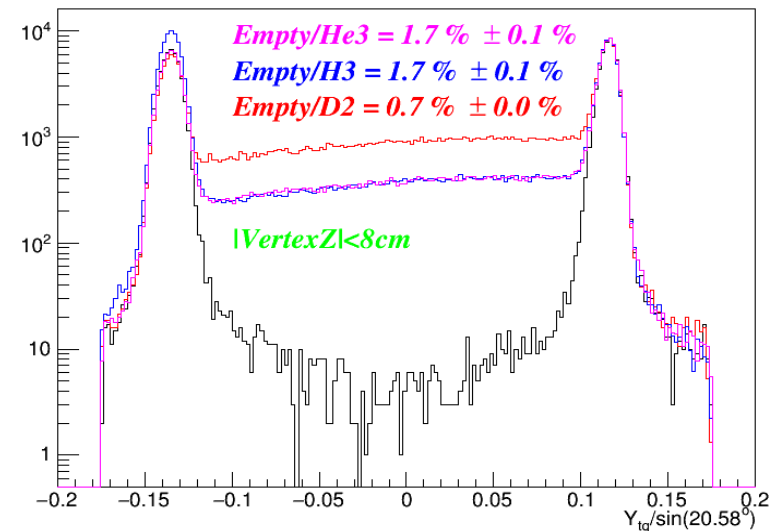


Extract  $F_2^n/F_2^p$  from **ratio** of measured  $^3\text{He}/^3\text{H}$  structure functions



*Final* MARATHON kinematics ( $.15 < x < .85$ )

- 11 GeV beam was used with  $^3\text{H}$ ,  $^3\text{He}$  and  $^2\text{H}$  targets.
- Tritium gas target system (and spectrometers/detectors) performed to expectation
- Preliminary offline analysis in progress.
- Current analysis projects include tracking studies, beam current calibrations, beam-induced gas target density changes, radiative corrections
- Preliminary results expected by Fall 2018
- MARATHON is providing Ph.D. thesis topics for six students.



# Tritium (e,e'p) SRC experiment – *completed Spring 2018*

Analysis Plan: *actual data shown!*

1) Calibrations: ~done\*

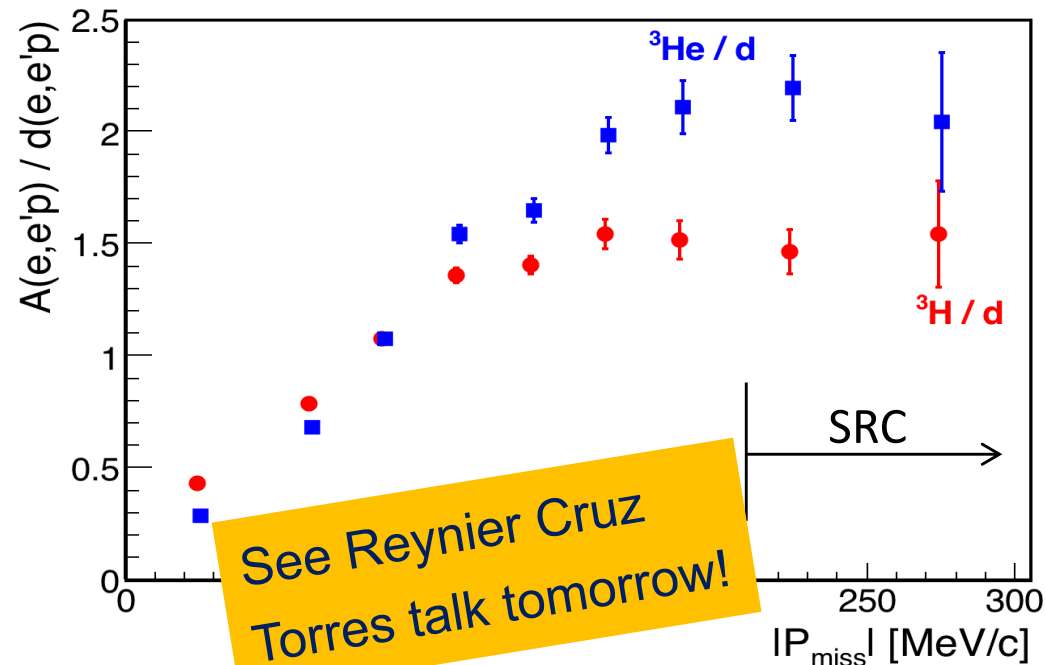
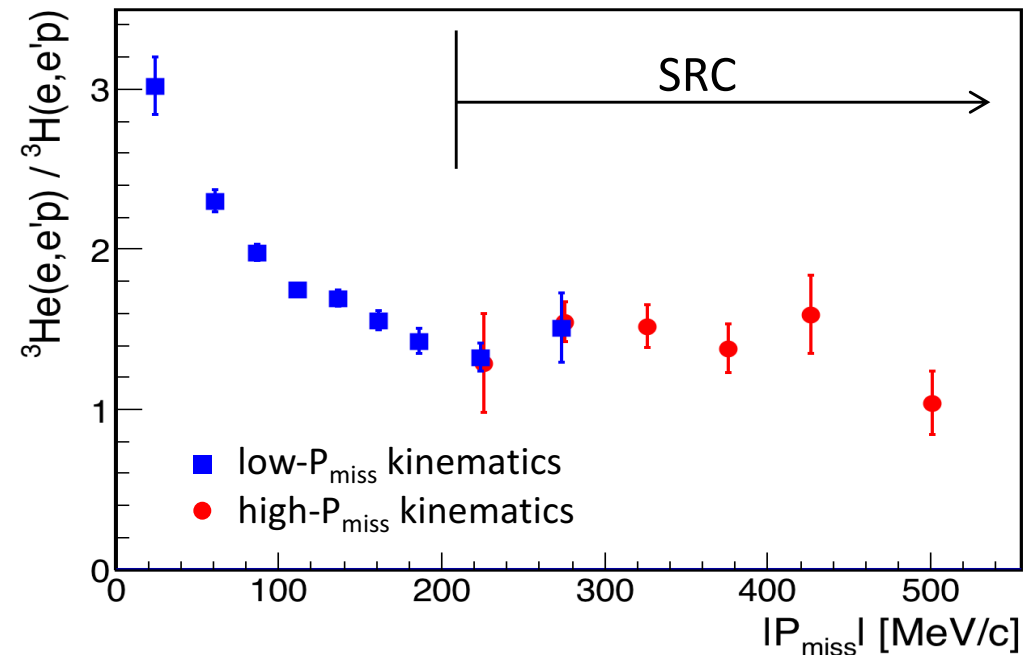
beamline, detectors, timing, optics, ...

2) Physics:

Original Goal:  $\frac{{}^3\text{He}(e, e'p)}{{}^3\text{He}(e, e'n)} \cong \frac{{}^3\text{He}(e, e'p)}{{}^3\text{H}(e, e'p)}$

'Bonus' observable:  $\frac{A(e, e'p)}{d(e, e'p)}$

\* Majority of calibrations completed by GMp and MARATHON students, allowing this experiment to move forward with the physics analysis in a short period of time.



See Reynier Cruz  
Torres talk tomorrow!



# 2019 Run Preparations

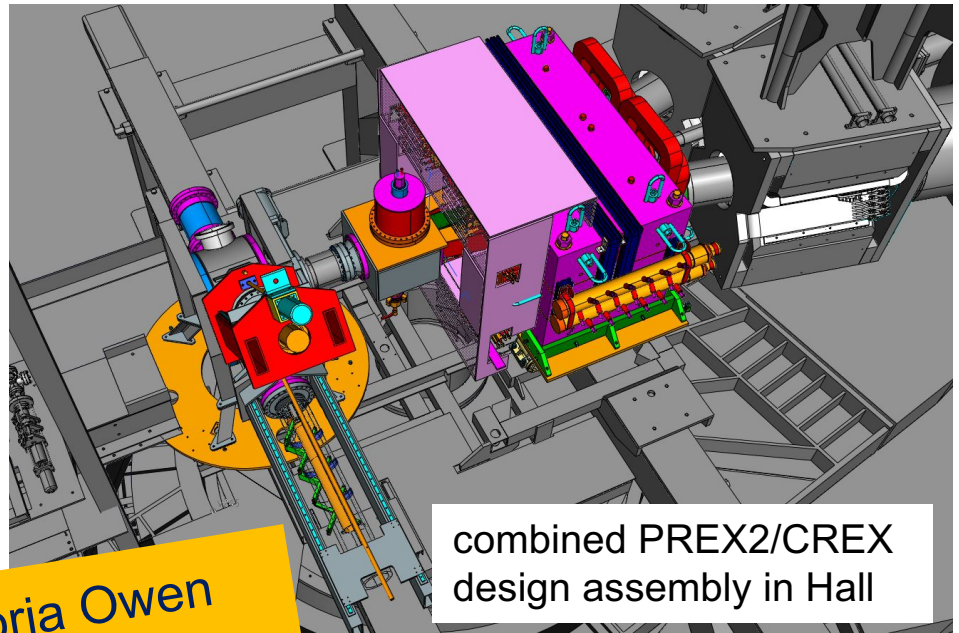
## APEX

- The septum magnet is in the Hall, ready to install vacuum channels and field test.
- Nearly all equipment on site
- Target construction underway
- *Looking towards February 2019 run (but only 2.2 GeV)*

## PREX2/CREX

- Combined target chamber, new target position
- Beam dump modifications underway
- Substantial shielding in design/engineering/procurement
- Computation fluid dynamics for target design, target heating tests
- Polarimetry – Moller now removed from Hall for upgrades
- Regular parity quality beam meetings
- *Looking towards Summer 2019 run*

See Bogdan's talk today!



See Victoria Owen talk tomorrow!

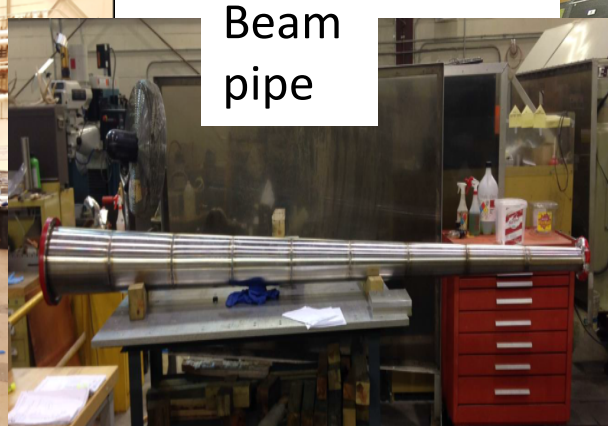


# Looking Towards 2020: All Major SBS Components Now at JLab

*– time to integrate, test!*



Counterweight on floor plates



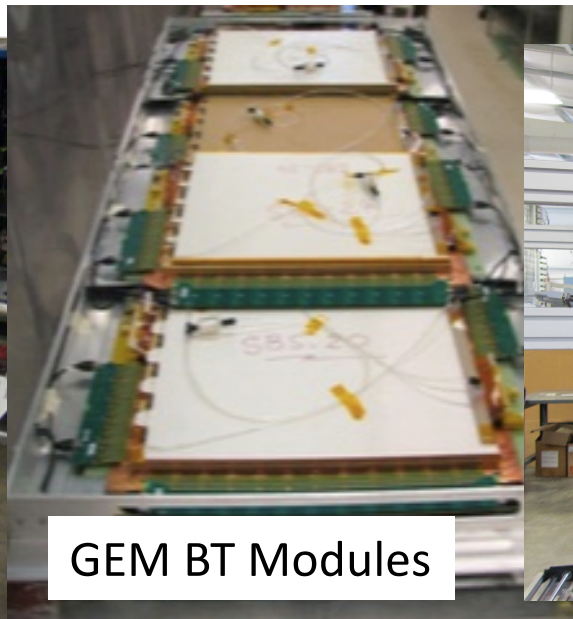
Beam  
pipe



HCal



Coordinate Detector



GEM BT Modules



GRINCH

**But Wait...  
THERE'S  
MORE!**

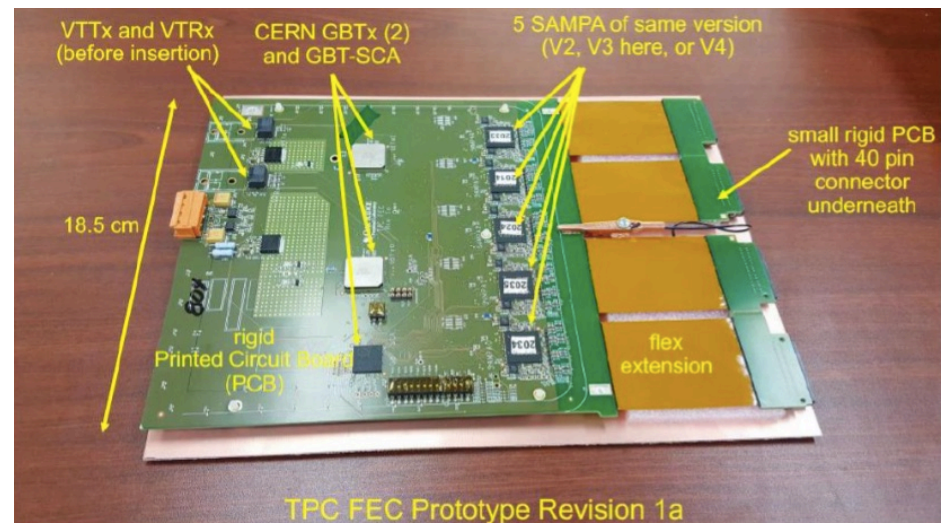


# JLab SBS Activities

- *Currently:*
  - Supporting HCal, GEM, Cdet, GRINCH tests and development
  - Investigating HCal floor plates, movement
  - Testing beamline assembly
  - ECal stand and heating/cooling engineering
  - BigBite assembly and integration
- DAQ development
- Project Management
  - Quarterly Reporting to DOE/NP on progress on dependencies.
- Developing high power cryotarget (MOLLER, SoLID and GEp)
- SBS TDIS/general high rate GEM (SAMPA chip) test stand under development

See Gordon Cates,  
Andrew Puckett  
talks today,  
tomorrow!

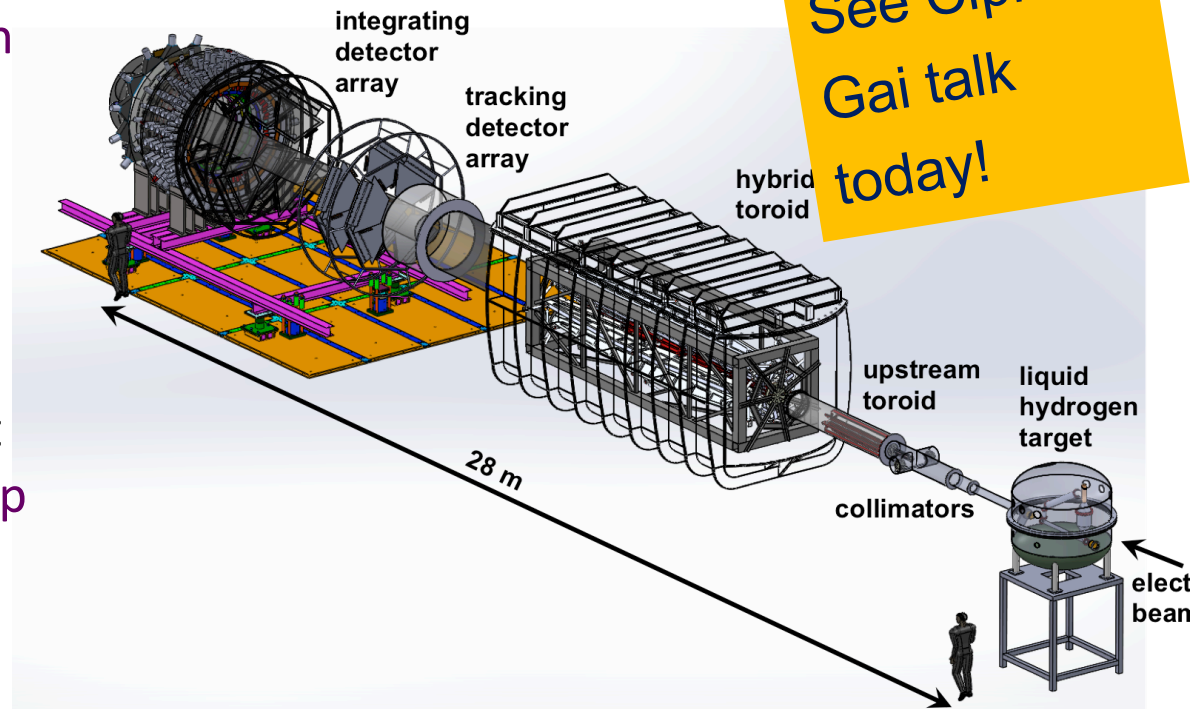
ALICE TPC Upgrade Front End Card  
with SAMPA chips - will modify  
slightly for testing



# MOLLER Status/Timeline

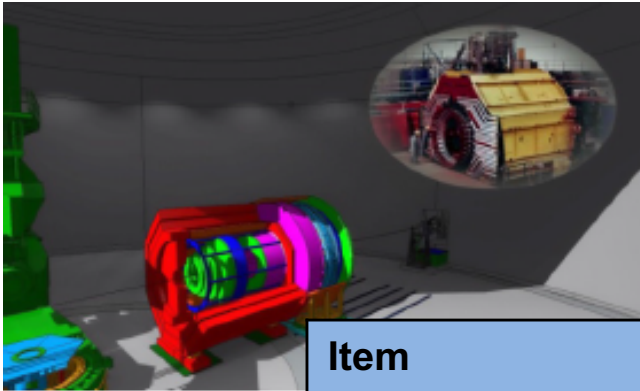
- 2014: DOE Science Review, Strong Endorsement
- December 2016: Director's Technical Cost and Schedule Review
  - "scientific case ... remains as strong as ever", "...Committee finds that the substantial progress since the last Director's Review suggests that the experiment is ready to move to the next stage"*
- **CD-0 achieved on Dec. 21, 2016 with caveat that project is "paused"**
- Work proceeding to address recommendations from 12/16 Director's Review
- Pre-R&D continues to refine design choices and reduce risk

- Project management organization
- Spectrometer magnet and collimator systems conceptual design, coil prototyping  
(*new JLab magnet group*)
- Radiation shielding optimization
- Continued detector development
- Parity quality beam working group with parasitic studies
- High power target development



# SoLID Timeline Overview

## Proposed QCD & Fundamental Symmetries MIE



Unique Capability:

- ✓ High luminosity ( $10^{37-39}$ )
- ✓ Large acceptance detector with full  $\phi$  coverage



Item	Date
Director's Review	February 2015
SoLID User Meeting with DOE/NP	November 2015
Director's Review Recommendations affecting science reach; progress: simulations of core measurements, DAQ rate capability, detector/magnet integration	February 2016
CLEO-II Magnet Disassembly at CESR	Summer 2016
Follow-Up Director's Review	Late 2016
Draft MIE Submission – proposed	February 2017
DOE/NP-led Science Review – proposed	Spring 2017
Annual Budget Briefing – proposed budget profile	February 2018
MIE Start - proposed	FY2020

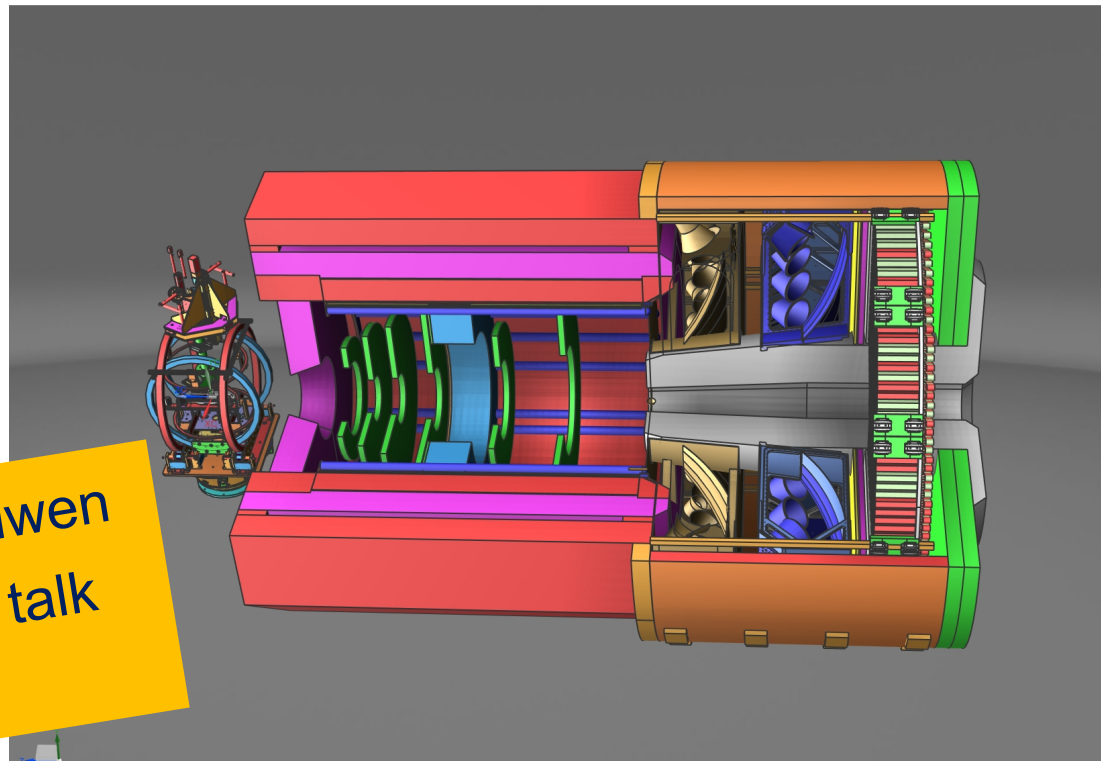
DOE  
discussions  
this summer

2019?



# SoLID at JLab

- Engineering and design
- Magnet testing (P. Brindza et al)
  - Looking towards cold test
  - Will begin purchasing instrumentation and controls (reduce highest schedule risk)
- Data acquisition
  - High rate GEM test stand (TDIS+)
- Slow controls
- Software development
- Polarized  $^3\text{He}$  target development
- Polarimetry
- Regular parity quality beam meetings
- Magnetic field analysis
- Project planning



See Zhiwen  
Zhao's talk  
today!



# Hall C Status (slides mostly from Steve)





# Publications and Students in last year

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## Publications:

Experimental techniques and performance of  $\Lambda$ -hypernuclear spectroscopy (HKS)

Nucl Inst Meth A 900, 69 (2018)

Precision measurement of the weak charge of the proton (Qweak)

Nature 557, 207 (2018)

Measurements of the Separated  $F_L$  from Hydrogen and Deuterium Targets at Low  $Q^2$

Phys Rev C 97, 045204 (2018)

Design and performance of the spin asymmetries of the nucleon experiment (SANE)

Nucl Inst Meth A 885, 145 (2018)

Direct measurements of the lifetime of medium heavy hypernuclei

Nucl Phys A 973, 116 (2018)

Separated kaon electroproduction cross section and the kaon form factor from 6GeV Jlab data

Phys Rev C 97, 025204 (2018)

GEp-III – GEp-2y archival paper

Phys Rev C 96, 055203 (2017)

SANE results – submitted (arXiv:1805.08835). Proton FF from SANE expt. – nearing submission

## Graduated Students:

Wade Duvall, Valerie Gray,, Michael Moore, Hend Nuhait, Samip Basnet, Wenliang Li

# $Q_{\text{weak}}$

Published – Nature **557**, 207 (2018)

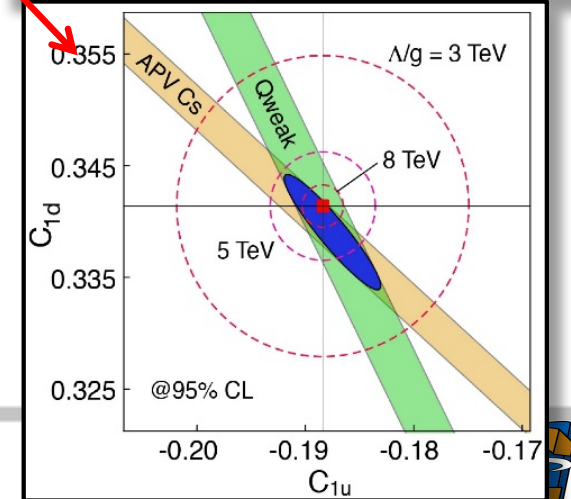
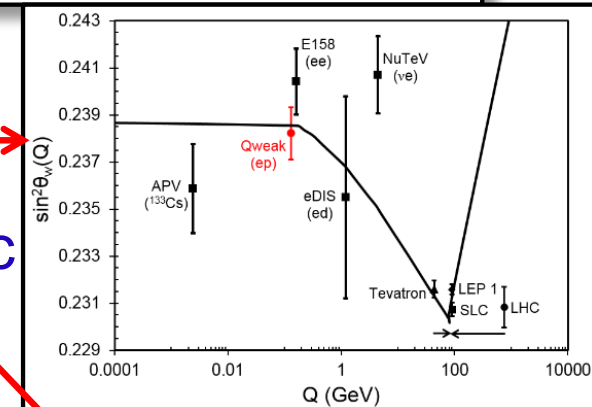
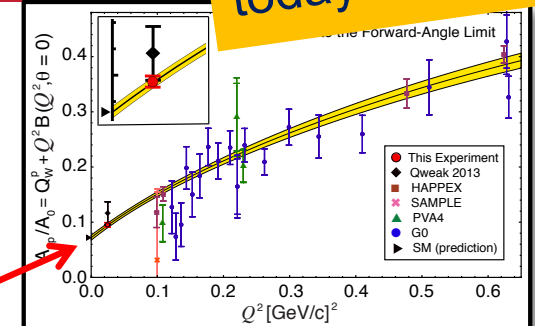
See  
Peng Zang talk  
today!



## Implications:

- Measured  $Q_W^p$  in good agreement with SM
  - Robust result to changes in method used to obtain it
- Sensitive measure of  $\sin^2\theta_W$  at low  $Q$
- Mass reach for new neutral-current semi-leptonic PV physics ruled out at 95% CL for:
  - $\Lambda/g < 7.4$  TeV, ( $< 3.6$  TeV for arbitrary flavor ratios)
- Will play a role in future analyses of bounds (or discoveries) of a variety of new BSM physics
- Completes “weak charge triad” (u, d, e)
- Builds scientific & technical foundation for next generation of measurements

$$\begin{aligned} \Lambda &= -226.5 \pm 9.3 \text{ ppb} \\ Q_W^p \text{ (this result)} &= 0.0719 \pm 0.0045 \\ Q_W^p \text{ (SM)} &= 0.0708 \pm 0.0003 \end{aligned}$$



# Hall C Spring 2018 Run

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Successful run, completing planned Hall C Commissioning “Experiment”.

Commissioned SHMS and recommissioned HMS to higher momentum.

All of E12-10-002 – Large  $x$  &  $Q^2$   $F_2$ .

C(e,e'p) part of E12-06-107 – Color Transparency

Some light nuclei from E12-10-008 – EMC (*also some  $x > 1$* )

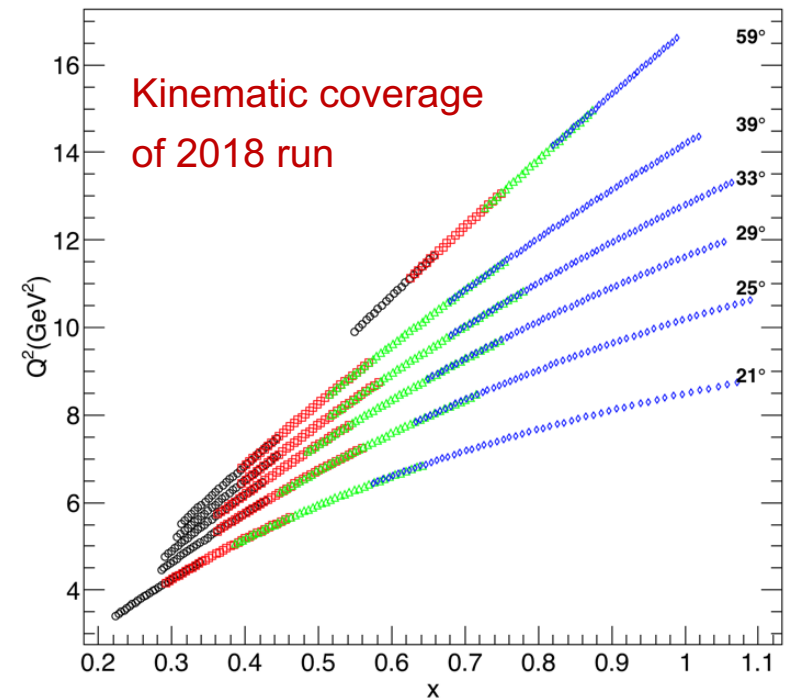
2 kinematics of E12-10-003 – d(e,e'p) at high  $P_m$

+ started (60%) E12-09-017 - Transverse momentum dependence of SIDIS

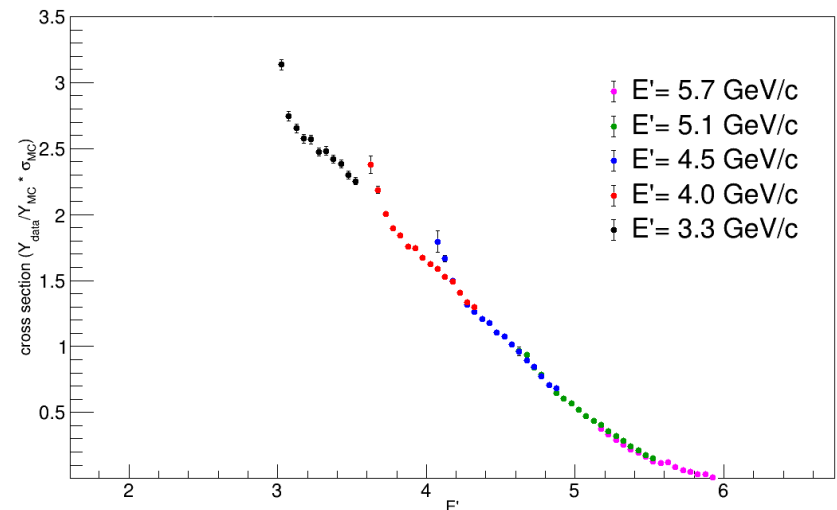
# E12-10-002 Precision $F_2$ structure function at high $x$

Extend proton and deuteron  $F_2$  structure function precision measurements to larger  $x$  and  $Q^2$ . Measuring  $p(e,e')$  and  $d(e,e')$  cross sections to 3% in the resonance region and beyond up to  $Q^2 \sim 17 \text{ GeV}^2$  and  $x \sim 0.99$

- Constrain Parton Distribution Functions at large  $x$
- Distinguish different mechanisms of spin-flavor symmetry breaking (d/u at large  $x$ ) with precision  $F_2^n/F_2^d$  (combining with BONUS/Hall B (E12-06-113)  $F_2^n/F_2^d$ )
- Extend studies of local quark-hadron duality in proton and neutron  $F_2$



cross section vs  $E'$



# EMC effect

Detailed study of EMC effect planned in Hall C. (E12-10-008)

$0.1 < x < 0.9$

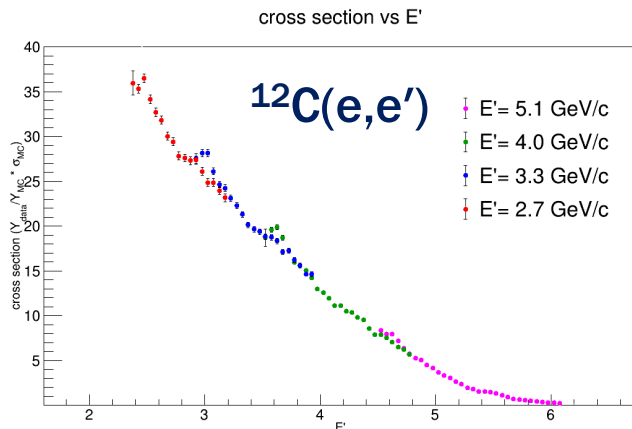
Up to  $Q^2 \approx 15 \text{ GeV}^2$

Light nuclei:  $^1\text{H}$ ,  $^2\text{H}$ ,  $^3\text{He}$ ,  $^4\text{He}$ ,  $^{6,7}\text{Li}$ ,  $^9\text{Be}$ ,  $^{10,11}\text{B}$ ,  $^{12}\text{C}$

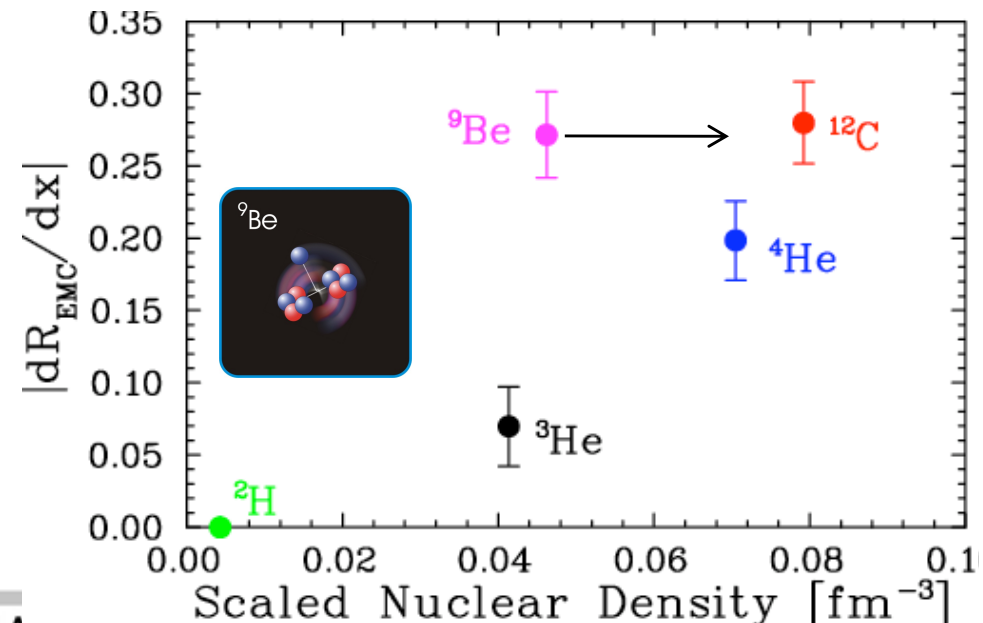
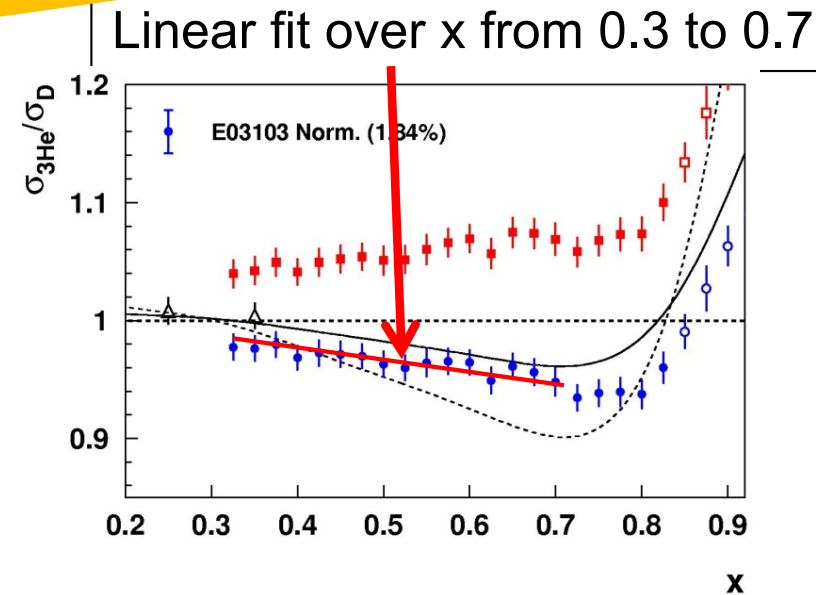
Medium/Heavy nuclei: Al,  $^{40,48}\text{Ca}$ , Ti,  $^{54}\text{Fe}$ , Ni, Cu, Ag, Sn, Au, Th

Early 2018 ran  $^9\text{Be}$ ,  $^{10,11}\text{B}$ ,  $^{12}\text{C}$

Examine single nucleon differences



See Nadia Fomin talk tomorrow!

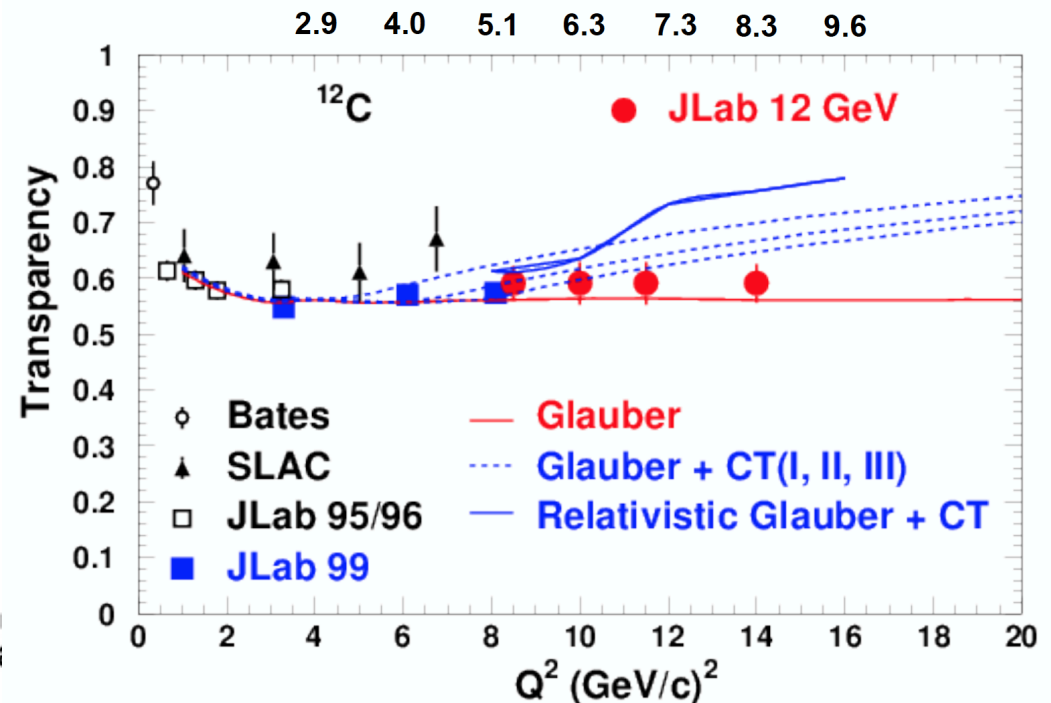
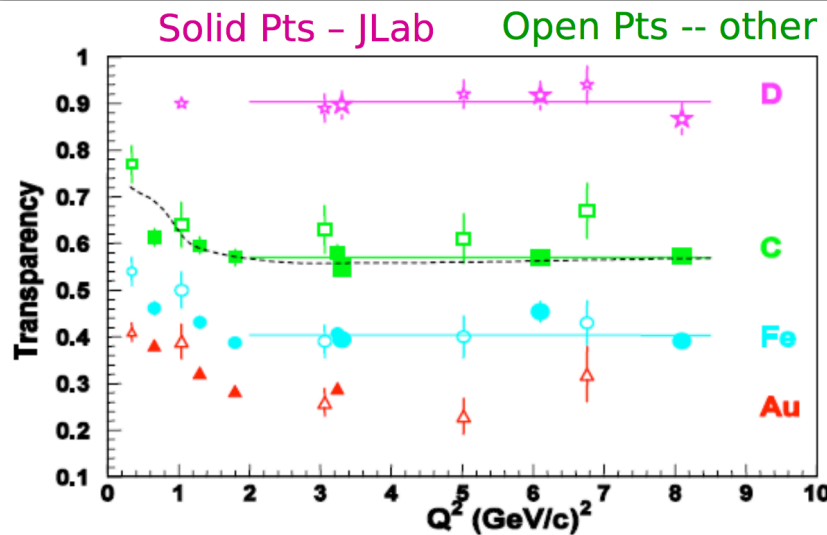
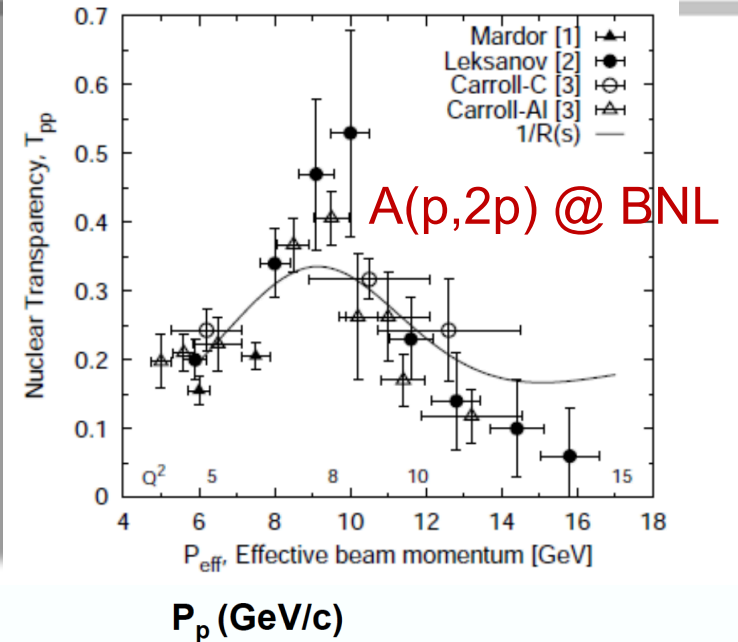
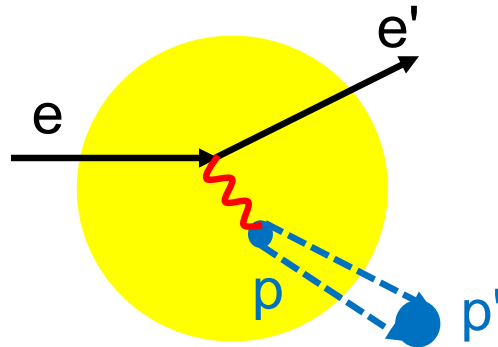




# Color Transparency

See Holly Szumila-Vance talk tomorrow!

$$T_A = \frac{\sigma_{A(e,e'p)}}{Z \sigma_{p(e,e'p)}}$$



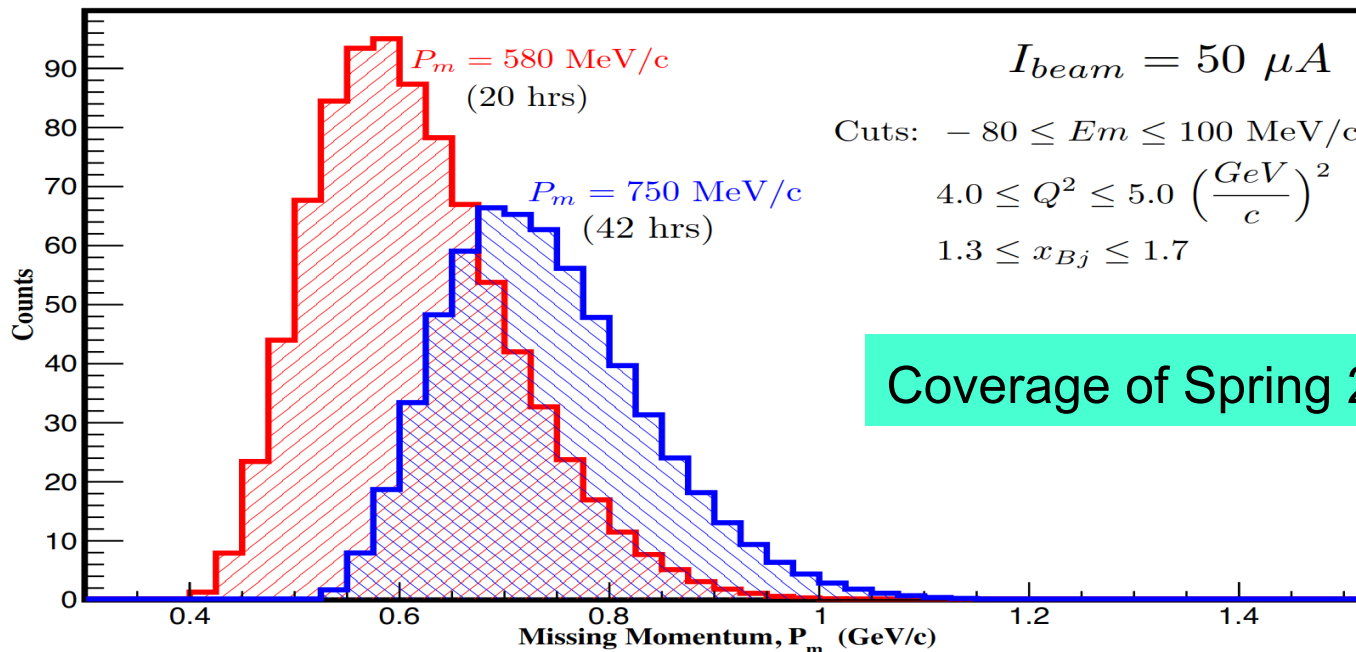
# $d(e,e'p)$

See Carlos Yero talk tomorrow!

## Motivation:

- Explore a new kinematical region of the 2-nucleon system above  $p_m > 500$
- No Deuteron data exist at these kinematics!
- Short range correlation studies cover similar region on missing momenta
- Models are able to reproduce the present data with 20%.
- Signs of a dependence on NN potential at highest missing momentum
- Measure at well defined kinematic settings, selected to minimize contributions from FSI and delta at  $Q^2 = 4.25$

### High Missing Momentum



Coverage of Spring 2018 run

# E12-09-017

# TMD of SIDIS at 12 GeV

See Rolf Ent  
talk today!

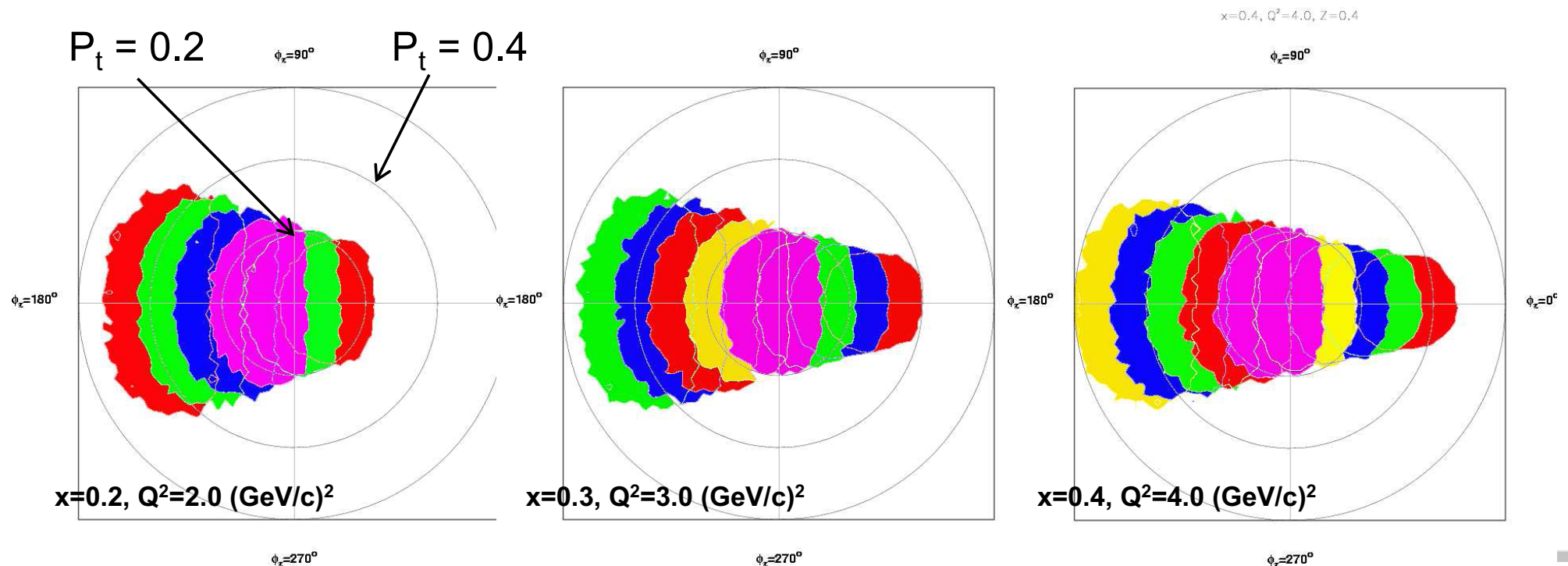
Map transverse momentum dependence of  $(e,e'\pi)$  over range:

$$0.2 < x < 0.5, 2 < Q^2 < 5 \text{ GeV}^2, 0.3 < z < 0.5 \text{ and } P_t < 0.5 \text{ GeV}$$

Combine with CLAS12 data to constrain transverse widths of u/d quarks and fragmentation functions

Obtain some statistics on transverse momentum dependence of  $(e,e'K^+)$

~60% of data acquired, remainder in late 2018.





# Hall C Projected Experiment Schedule as of 1/2018

	CY Spring 2018	CY Fall 2018	CY Spring 2019	CY Fall 2019	CY Spring 2020	CY Fall 2020
Phase I (27 days, F2) + start Phase II Commissioning “Experiment” (SIDIS)						
Phase II Commissioning (SIDIS + L/T), 5q?						
High Impact Experiment(s)				✓ (5q) (A <sub>1</sub> <sup>n</sup> ) ✓ (x>1) ✓ (πFF)		

Commissioning complete: all Hall “capabilities” tested *with physics*

ERR ✓

- Experiments in parentheses in chart are anticipated to be ready and potentially appropriate for the indicated time slot(s), and as such represent potential options **in no particular order.**
- Note:** Run periods may not correspond to PAC days! **A new run paradigm....**

# Published Schedule – blue colored text not on formal plan

---

[https://www.jlab.org/exp\\_prog/experiment\\_schedule/2018/20180511.0\\_ExpSch.pdf](https://www.jlab.org/exp_prog/experiment_schedule/2018/20180511.0_ExpSch.pdf)

- August 23, 2018 – December 19, 2018
  - E12-09-011 (e,e'K+), E12-09-017 (Transverse TMD), E12-09-002 (CSV)
- January 30, 2019 – February 20, 2019
  - E12-16-007 (LHCb Pentaquark)
- February 21, 2019 – March 10, 2019
  - Finish E12-09-002 (CSV)
- June 10, 2019 – June 17, 2019
  - E12-06-101/E12-07-105 – low pass running Pion FF, Pion scaling
- June 18, 2019 – July 1, 2019
  - TBD (VCS)
- October 29, 2019 – December 18, 2019
  - E12-06-110 (A1n)
- *Presumably will continue with  $d_2^n$  in 2020.*

# A New Run Paradigm?... *(caveat! my view here)...*



- Schedules are inherently tied to budget scenarios. The actuals for Fall 2018 and 2019 will depend on the budget situation.
- For example, there is still an outstanding issue for the Fall 2018 operations that they may be delayed to startup in the next FY (i.e., a few weeks delay) due to the FY18 budget shortfall.
- Given this, how to plan?...
- JLab used to run ~30 weeks/year. In this time, PAC days could reasonably be translated to calendar days and fully committed.
- In a reduced beam time scenario the lab and users need to work together to optimize science output (including student theses,...) rather than focus primarily on approved days.
- The focus may switch somewhat from “what experiment can be scheduled” to “what science can maximally be accomplished in a run period?”
- Hall C is doing this somewhat already – we’re pioneering!
- Other practical issues – as ever – will still come into play (cross Hall energy compatibility, beam current requirements, ESR cryogenic load, installation time...).

From January 2018  
Collaboration Meeting





# Hall C Summer 2018

---

Beamline changes LHCb pentaquark exp – radiator for photon beam.  
(Part of work needed to allow polarized  $^3\text{He}$  target.)

Small angle beamline installation, align HMS quad

Providing AC service for Moller Polarimeter quads @ 11 GeV (needed for  $A_1^n/d_2^n$ )

Spectrometer cryo and power supply maintenance.

Some detector work (e.g. replace broken mirrors in ~25 y old HMS Cherenkov)

LAD scintillator planes (CLAS6 TOF) refurbish at ODU completed

NPS magnet assembly

**Prepare for FY19 running:**

Finish TMD SIDIS

E12-09-011 – Kaon factorization (and form factor)

E12-09-002 – Quark Charge Symmetry Violation with SIDIS

E12-16-007 – LHCb charmed pentaquark via J/Psi production

~~E12-06-101/E12-07-105~~ – Short low pass run for pion form factor + scaling

# Polarized $^3\text{He}$ target

Preparing for  $A_1^n$  (E12-06-110) in late 2019.

Engineering/Design complete, parts delivered, preparing drawing book for technicians.

Installation planning ongoing.

Cell production, led by UVA, started. First good cell at JLab for full characterization.

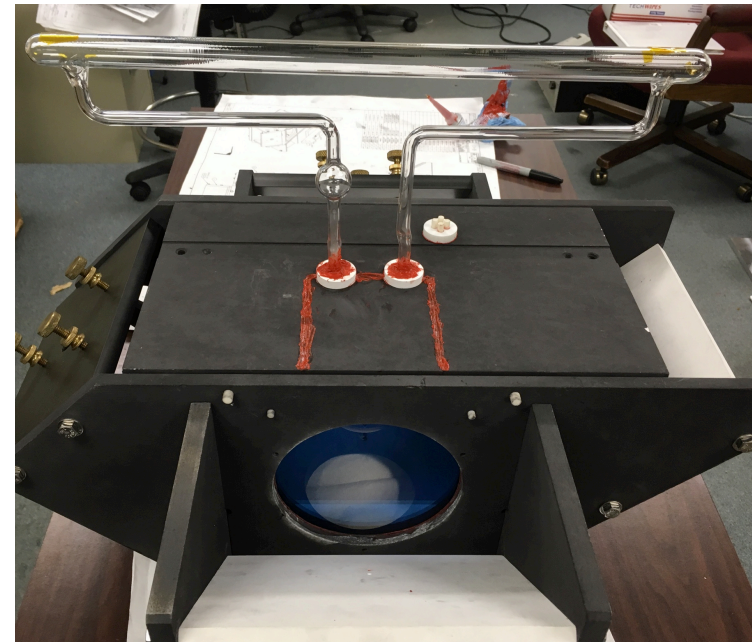
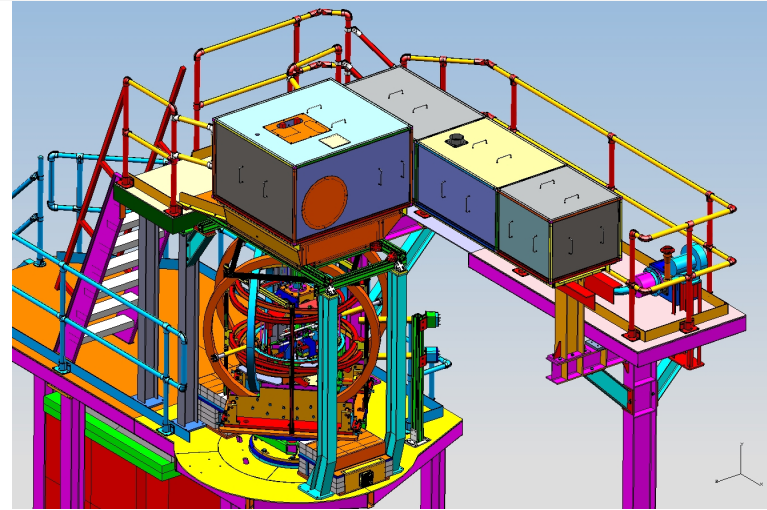
Cell window heating and stress studies done.

Target goals:

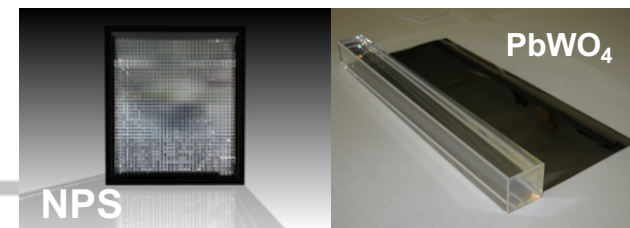
30  $\mu\text{A}$  on 40 cm ,  $\sim 10$  atm,  $L \sim 2.2 \times 10^{36} \text{ cm}^{-2} \text{ s}^{-1}$

In-beam polarization  $\sim 55\text{-}60\%$ ,

Polarization measurement precision  $\sim 3\%$



# NPS Project Status

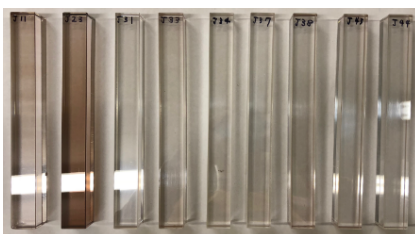
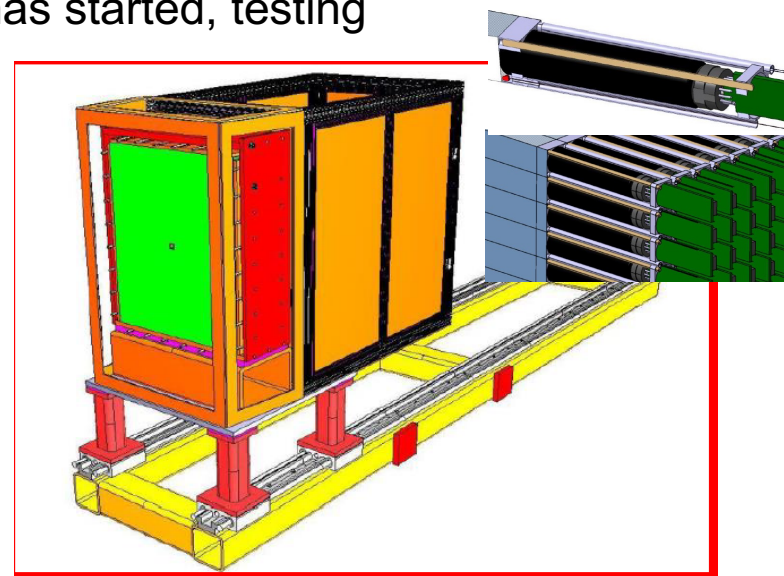


Four fully approved experiments, one conditionally, one PAC46 proposal supported by NSF MRI PHY-1530874 (CUA, OU, ODU), international (IPN-Orsay, Glasgow, Yerevan), JLab



- ❑ **Magnet:** corrector coil, main coil and yoke steel at JLab, assembly has started, testing and field map next

- ❑ **PMT and HV bases:** design drawings final, prototyping, procurement started, first articles received
- ❑ **Frame and integrated systems:** concepts and initial design complete, detailed drawings to be presented later this year, prototype tests ongoing



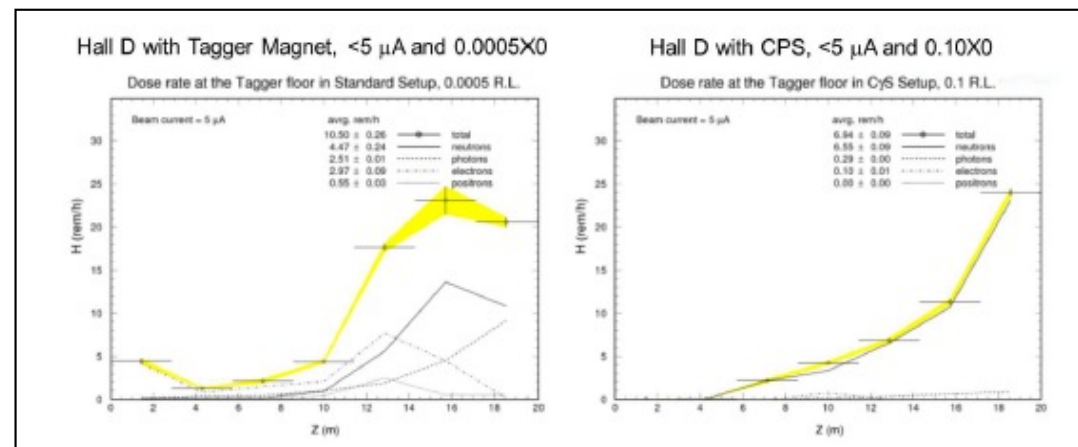
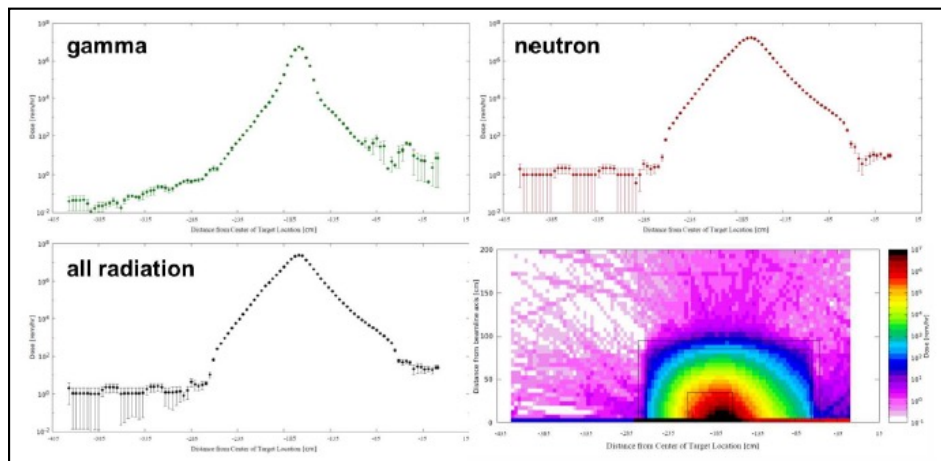
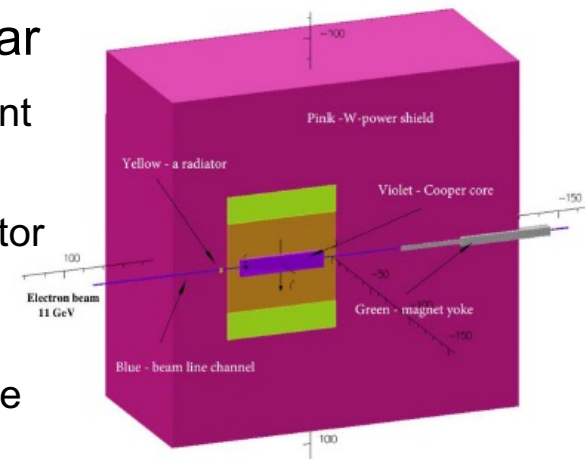
**NPS crystal prototype and irradiation studies**

- ❑ **Crystals:** 460 crystals procured from SICCAS in 2017, 400 SICCAS + 100 CRYTUR procurement ongoing in 2018, full crystal testing facilities established at CUA and IPN-Orsay, chemical analysis and crystal growth in collaboration with Vitreous State Laboratory @ CUA, synergy with EIC crystal calorimeter R&D.



# Compact Photon Source in Halls A/C (& for $K_L$ in Hall D)

- ❑ Novel concept allows high photon intensity and low radiation in the hall
- ❑ Physics: WACS (C12-17-008),  $K_L$  (PAC46), and also: WACS photoproduction, TCS with Polarized Target (PAC46), SRC, photoproduction of few body systems
- ❑ Conceptual Design Study of a CPS completed over last year
  - CPS with optimized shielding provides photon flux of  $1.5 \times 10^{12}$  equivalent photons/s, with a factor of 1000 reduction in prompt radiation dose compared to 2.7  $\mu\text{A}$  (30kW) electron beam current striking a 10% radiator
  - CPS meets the acceptable radiation level requirements for a typical time of 1000 hours with the source located 2-3 m from the target
  - CPS technical design & installation in existing hall infrastructure feasible
  - CPS document submitted to JLab management for review





# LAD – Large Acceptance Detector

E12-11-007: Deuteron EMC –  $d(e, e' \text{ backward } p)$

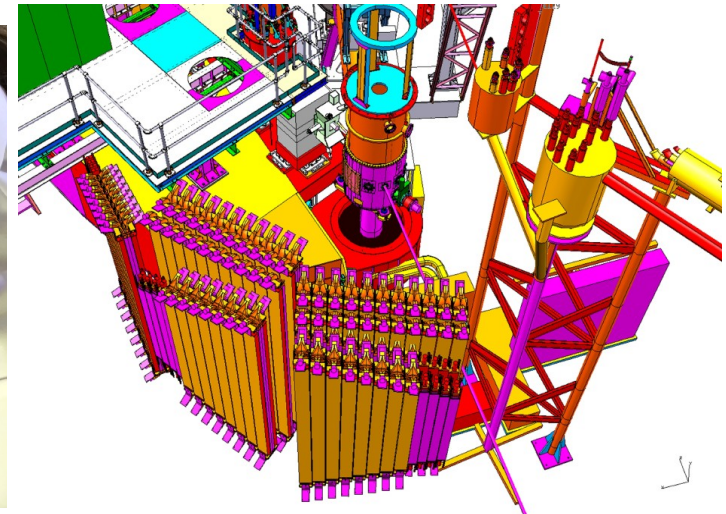
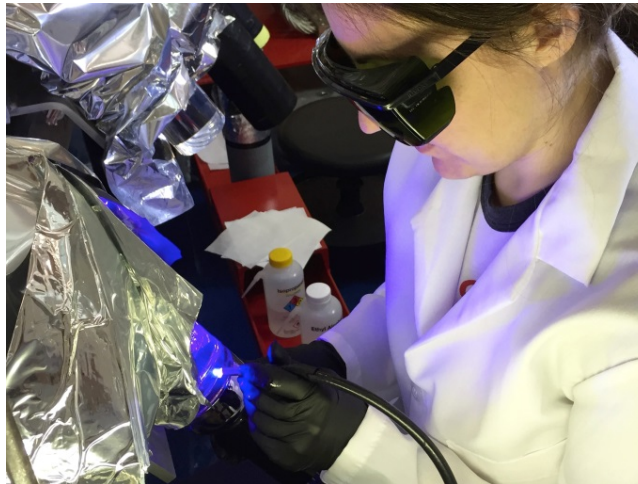
Very large solid angle for  $L = 10^{36} \text{ cm}^{-2} \text{ s}^{-1}$  and  $\theta > 90^\circ$

Optimized for medium momentum nucleons

$$0.3 \leq p_N \leq 0.7 \text{ GeV}/c$$

Needs 5 scintillator planes which are built from old CLAS-6 TOF scintillators.

Five planes refurbished @ODU by ODU, KSU, TAU, MIT, GWU and back at JLab.



# NIM Article on SHMS

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Howard Fenker organizing technical description of the SHMS spectrometer  
(Nuclear Instruments & Methods in Physics Research)

Writing assignments have been made, *but all help is welcome!*

Draft document (mostly outline) at  
<https://userweb.jlab.org/~hcf/shmsnim/>

Meeting today HERE in A110 at 12:15 today to discuss progress.



# Overall, the Hall A/C Outlook is Highly Positive!



- The accelerator is running 4 Halls at 5 pass.
  - 5(.5) pass beam – at high(ish) current in A/C – delivered to 4 Halls
- We have electrons in Hall A on a tritium target!
- The SHMS early commissioning is complete!
- Parts or all of 11 experiments (5 (A) + 6(C)) complete!
  - Theses and publications (*please!*) to come
- We are preparing for APEX/PREX2/CREX/A1n/d2n installations
- SBS – all experiments and equipment - are on track for 2020
- NPS, CPS, MOLLER, SoLID,... also progressing

# Advertisement!

Workshop2018 - Hall A Analyzer - Redmine

6/21/18, 1:07 AM

[Wiki »](#)

## Joint Hall A & C Data Analysis Workshop June 2018

June 25-26, 2018, **ARC Auditorium** ([map](#)), Jefferson Lab



Joint Hall A & C Data Analysis Workshop June 2018

- Resources
- Program
  - Monday, June 25, 2018
    - Morning Session
      - General
      - Hall A Analysis
    - Afternoon Session
      - Farm Use and Workflow Tools
      - Using Python for Analysis Part I
  - Tuesday, June 26, 2018
    - Morning Session
      - Hall C Analysis
    - Afternoon Session
      - Intermediate-Level Analysis with ROOT
      - Using Python for Analysis Part II

*Please register!!*

<https://www.surveymonkey.com/r/V77796G>



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# Thanks

