



U.S. DEPARTMENT OF
ENERGY

Office of
Science



News from Jefferson Lab



A. Lung
March 29, 2017

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Outline

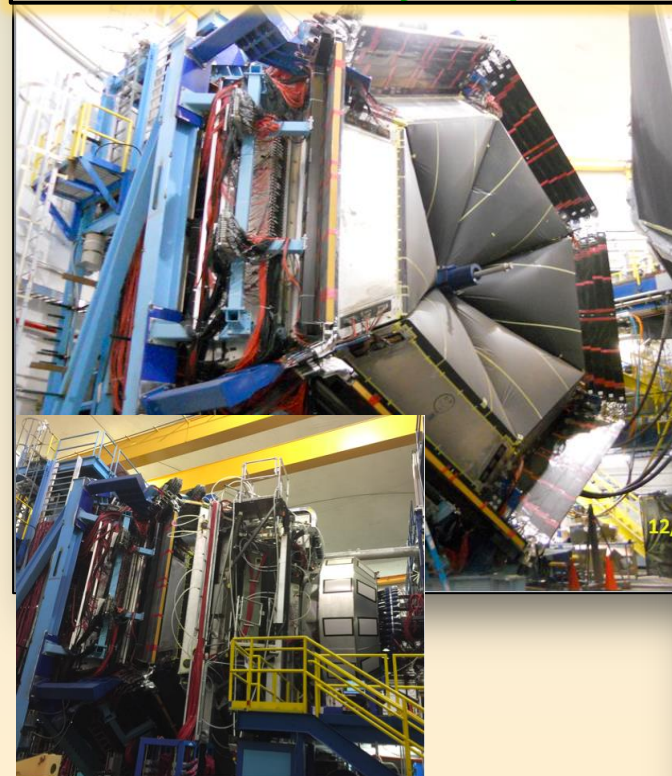
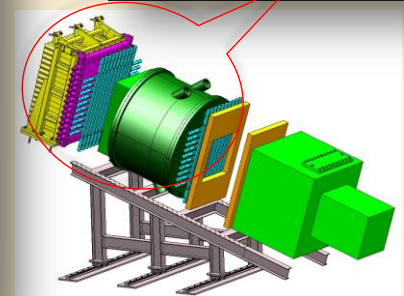
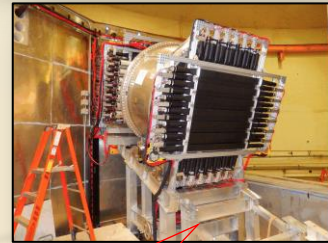
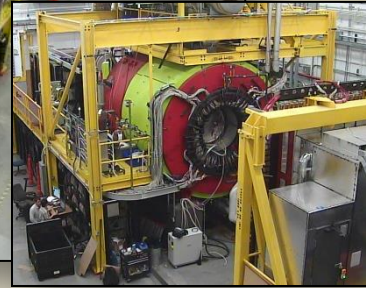
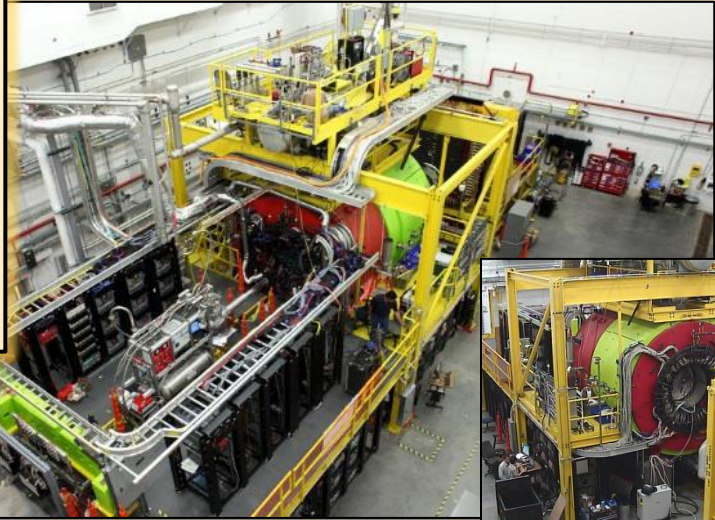
- 12 GeV CEBAF Upgrade - Highlights
- Recent Lab Highlights
- Budgets
- Electron Ion Collider
- Summary & Outlook

12 GeV Upgrade Project

TPC = \$338M
ETC < \$2M

Project Scope (~99.7% complete):

- Doubling the accelerator beam energy - **DONE**
- New experimental Hall D and beam line - **DONE**
- Civil construction including utilities - **DONE**
- Upgrade to Experimental Hall C - **DONE**
- Upgrade to Experimental Hall B - **99%**
 - Solenoid only scope remaining

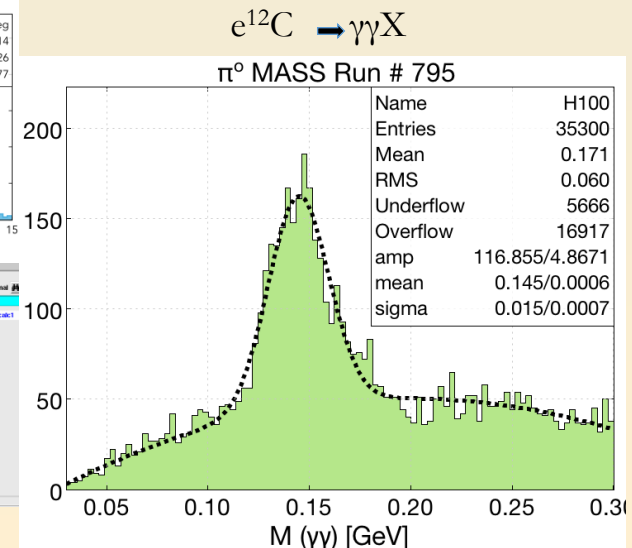
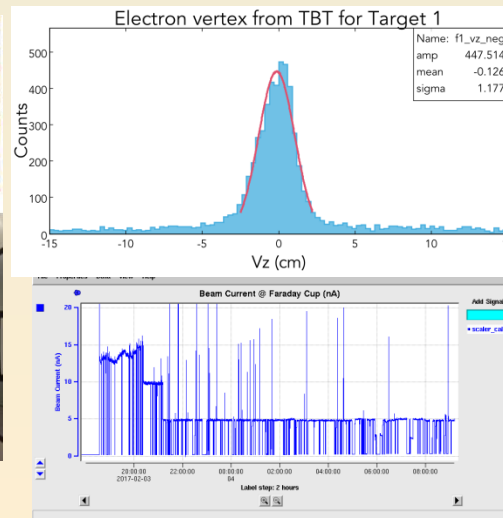
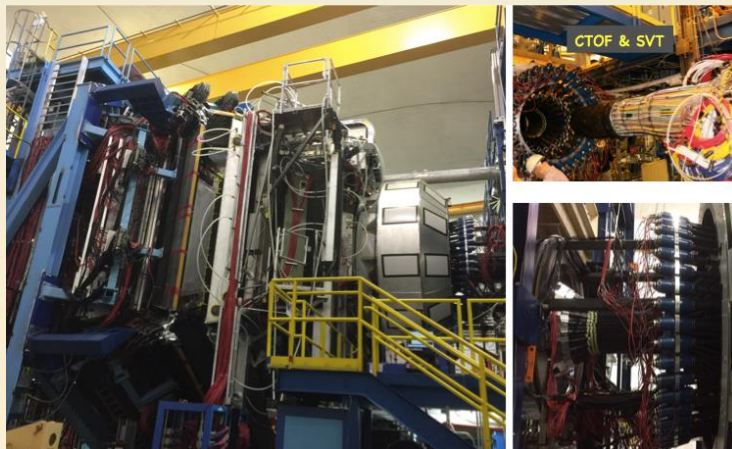


Path to CD-4B: Hall B KPP

Project Execution Plan: Table 5.1B

#	System	Technical Definition – Key Performance Parameter	PEP Date
1	Hall B	Detector operational: events recorded with a > 2 nA electron beam at > 6 GeV beam energy (3 pass)	Feb 2017
2	Hall C	Detector operational: events recorded with a > 2 nA electron beam at > 6 GeV beam energy (3 pass)	Sep 2017
3	Hall D	Detector operational: events recorded with a > 2 nA electron beam at > 10 GeV beam energy (5.5 pass)	Dec 2014

KPP achieved – February 2017 !

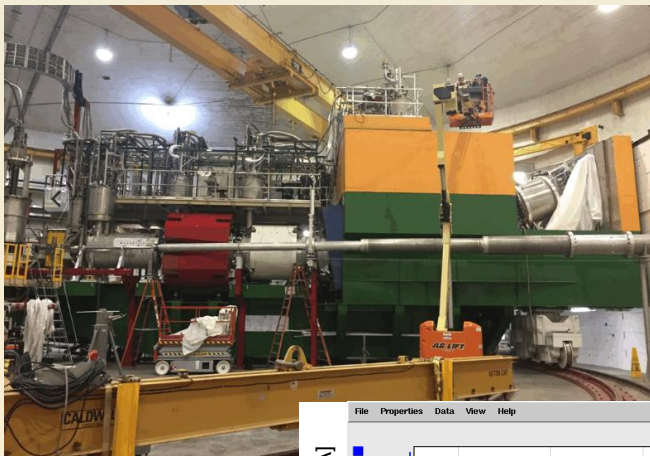


2.5-day run period: <5 nA>, 6.4 GeV electrons

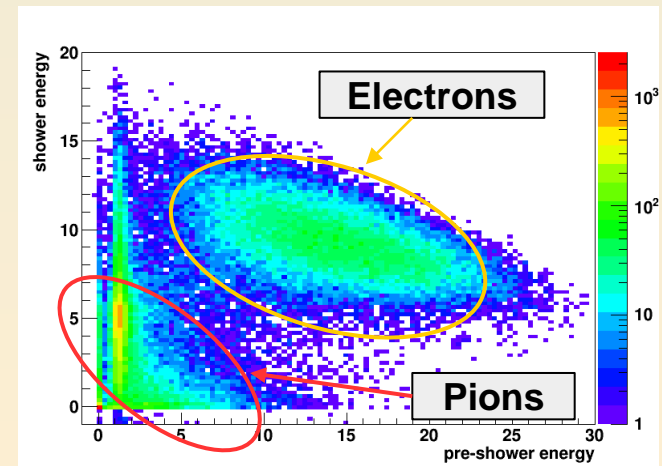
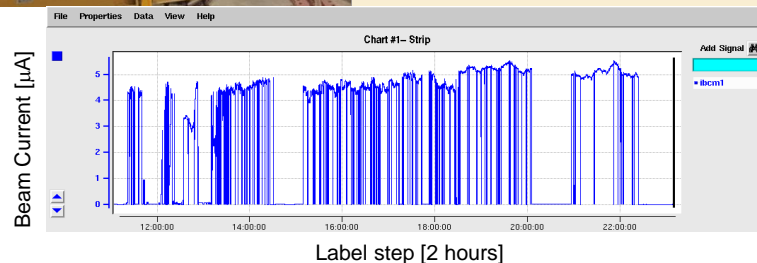
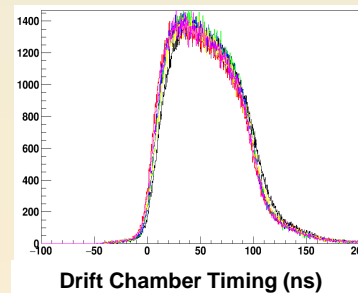
Path to CD-4B: Hall C KPP

Project Execution Plan: Table 5.1B

#	System	Technical Definition – Key Performance Parameter	PEP Date
1	Hall B	Detector operational: events recorded with a > 2 nA electron beam at > 6 GeV beam energy (3 pass)	Feb 2017
2	Hall C	Detector operational: events recorded with a > 2 nA electron beam at > 6 GeV beam energy (3 pass)	Mar 2017
3	Hall D	Detector operational: events recorded with a > 2 nA electron beam at > 10 GeV beam energy (5.5 pass)	Dec 2014



KPP achieved – March 2017 !



<5 μA>, 6.4 GeV electrons

12 GeV Project: University Detector Work

Hall	University	Activity	Status
B	Idaho State U	Drift Chamber	Complete
B	Old Dominion U	Drift Chamber	Complete
B	U South Carolina	TOF Counters	Complete
B	Moscow State U (RU)	SVT Testing	Complete
C	Michigan State U	HB Magnet	Complete
C	U Virginia	Noble Gas Cerenkov	Complete
D	U Athens (GR)	Monitoring BCAL, FCAL	Complete
D	Carnegie Mellon U	Central Drift Chamber	Complete
D	Catholic U	Tagger Hodoscope	Complete
D	U Connecticut	Tagger Microscope	Complete
D	Florida International U	Start Counter	Complete
D	Florida State U	TOF Counters	Complete
D	Indiana U	Forward Calorimeter	Complete
D	U Regina (CA)	Barrel Calorimeter	Complete
D	U Santa Maria (CH)	SiPM, Lightguides for BCAL	Complete
B, C, D	U Massachusetts	Electronics Testing	Complete

NSF-MRIs funded
Hall B PCAL Detector,
Long. Polarized Target

NSF-MRIs funded most
12 GeV Hall C Detectors

Internat'l contributions
for detectors beyond
base equipment

Enhancements beyond 12-GeV Upgrade

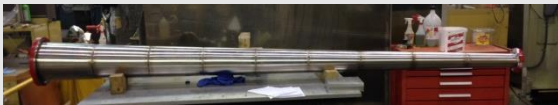
Hall	Item	Users	Status
A	DVCS Calorimeter	France/Orsay	Used/de-installed
A	SBS - WBS1, 2 and 3	JLab	Complete
A	SBS GEMs	Italy INFN, UK	Ongoing
A	SBS Hadron Calorimeter	Italy INFN, CMU	Ongoing
A	PV expts pre-R&D (MOLLER magnet)	MIT	Ongoing
A	SoLID	China, Temple, Duke, ANL	Ongoing
A	APEX Septum	Canada, Stony Brook	Complete
B	Longitudinally Polarized Target	ODU.... (NSF/MRI)	Ongoing
B	Forward Tagger	Italy INFN & NSF/MRI	Complete
B	RICH Sector(s)	Italy INFN, Chile	Near-Complete (1)
B	MicroMegas	France/Saclay	Near-Complete
B	Central Neutron Detector	France/Orsay	Complete
B	Heavy Photon Search	DOE-HEP, France, INFN	Complete
B	H Gas Target for PRad	NSF/MRI	Used/de-installed
C	Kaon Detection System	CUA....(NSF/MRI)	Installed
C	Backward Nucleon Detection	Israel, ODU, MIT	Ongoing
C	Neutral Particle Spectrometer	CUA...(NSF/MRI), France, UK, Armenia	Ongoing
D	DIRC-based Cherenkov	JLab, IU, MIT	Ongoing
LERF	DarkLight Phase-I	MIT...(NSF/MRI)	Ongoing

Note: list is incomplete but generally recognizes contributions >\$0.5M and international efforts

Hall A: SBS Construction Completion

Project started Oct 2012 – **completed Feb 1, 2017**

- 3 major WBS elements and 5 dependencies:
 - (HCAL (CMU), GEM trackers (INFN), Polarized ^3He (UVa&JLab), GRINCH (W&M), ECAL (SBU&JLab))
- Successful 4th annual review Nov 2016
- Preparing for closeout review, transition to operations plan likely includes tracking of dependencies

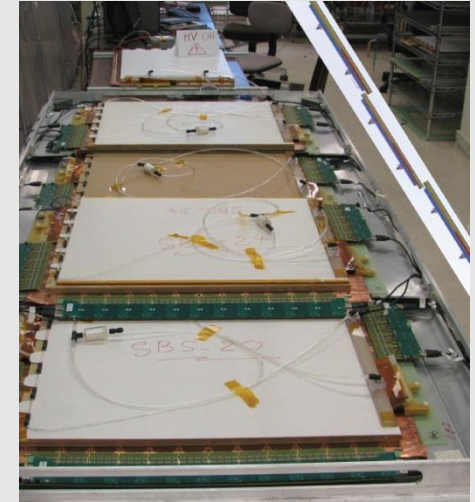


WBS1 Completed 01/22/16



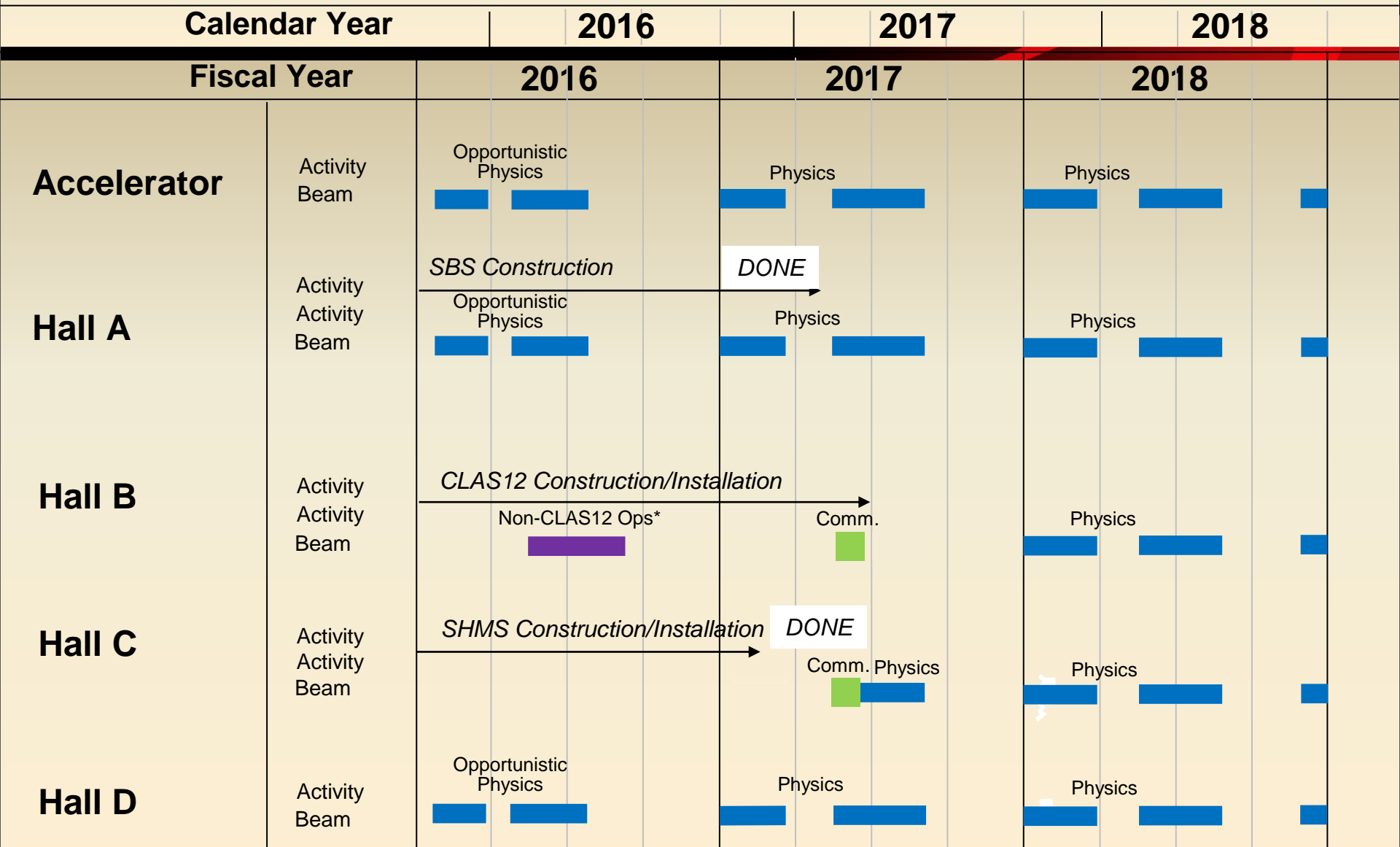
- Mainly Coordinate Detector (CDET), led by Idaho State U including sci. fiber polishing & assembly
- CDET plane assembly and testing led by CNU
- Two planes, each 3 modules, completed Aug 2016

WBS2 Completed 01/23/17



- Scope: GEMs & Electronics
- GEM production at UVa: 40/40
- Status February 2016: 26/40
- All GEM electronics finalized, production at INFN, QA at UVa

WBS3 Completed 02/01/17



* PRad Summer 2016 run

Beam for Commissioning Beam for Physics Non-CLAS12 Ops

CEBAF Highlights

Summer 2016:

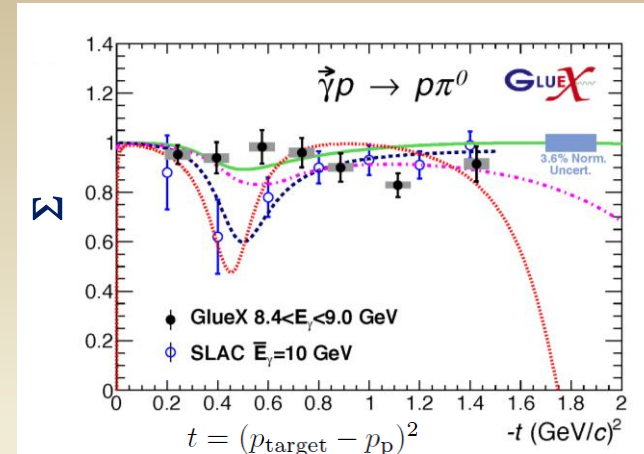
- Hall B - Proton Radius Experiment (PRad)
- First completed experiment in 12 GeV era!

Fall 2016:

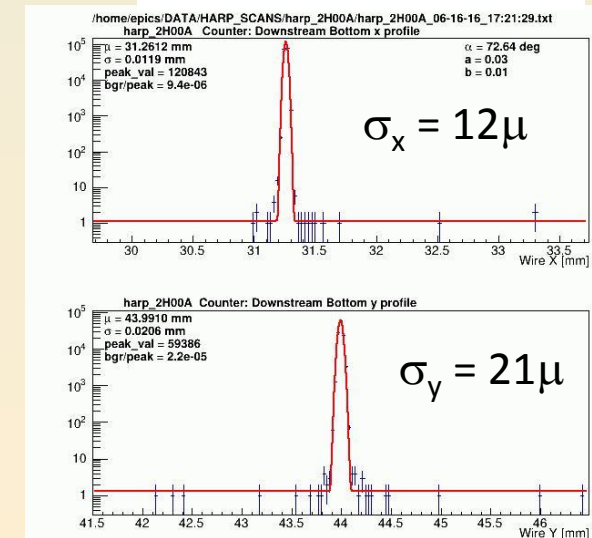
- *Re-plan due to box power supply issue*
- Hall D – short GlueX run verifying physics capability
- Hall A – completed GMp; Phase I DVCS

Spring 2017:

- Hall D – GlueX physics run
- Hall A – Ar spectral function physics run
- Hall B – KPP run
- Hall C – KPP run
- *Early stop due to cryoplant hardware failure*



Hall B – PRad beam scan



Early science - physics running accomplished!

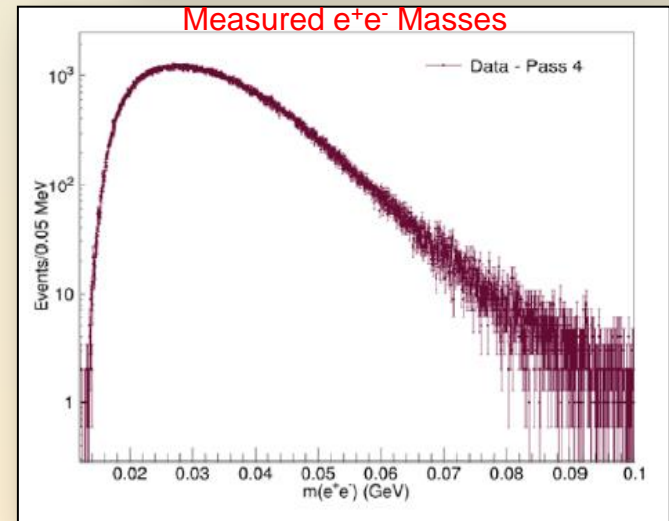
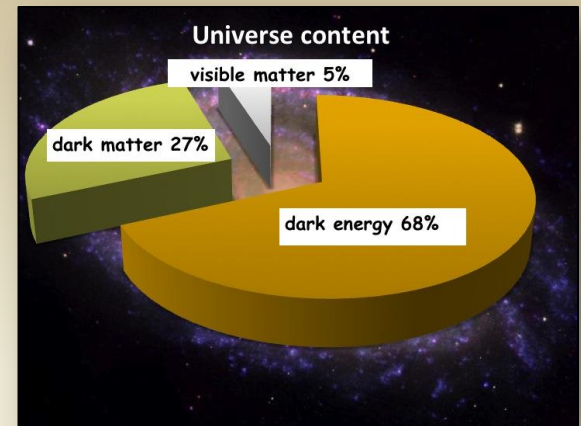


Heavy Photon Search

- HPS searches for an electro-produced hidden sector photon (A') which decays to e^+e^- pairs
- A' 's could mediate dark matter annihilations and interactions with *our* matter
- HPS identifies A' 's with invariant mass and separated vertices

Status:

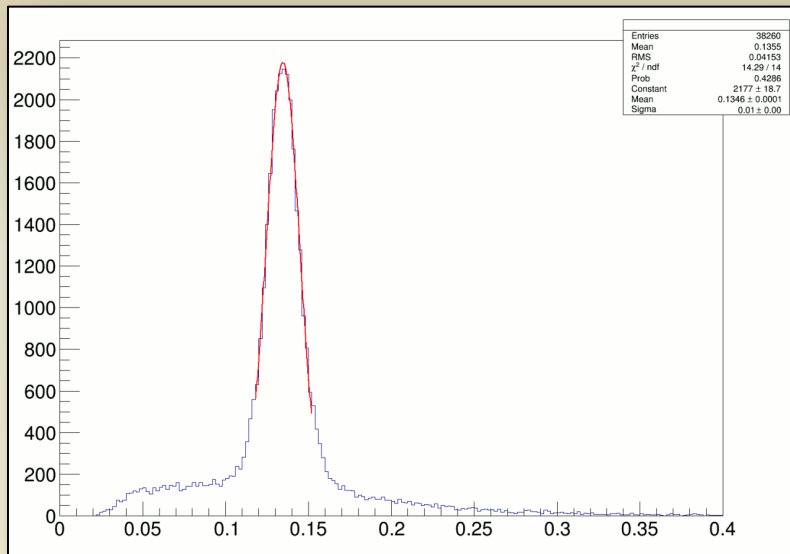
- 1 GeV data under analysis
 - First results expected May 2017
- 2 GeV data acquired in spring 2016
 - Results next year
- More running in the future
- NP-HEP Collaboration



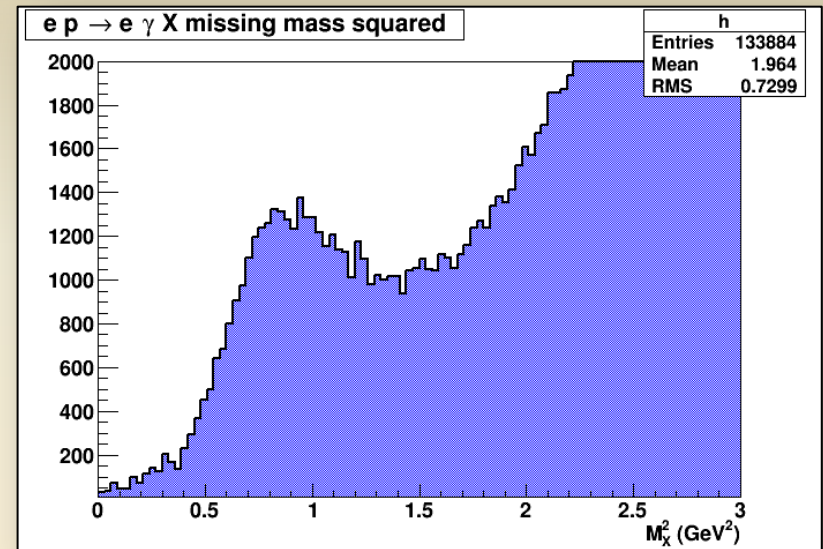
Future Program: more HPS, APEX, DarkLIGHT

3D Imaging Program at 11 GeV

Hall A
Data reconstructed in calorimeter





Missing Mass Reconstruction
(1.5 h of beamtime)



- High impact experiment for nucleon 3D imaging program
- 16% of experiment completed in 2014-2016

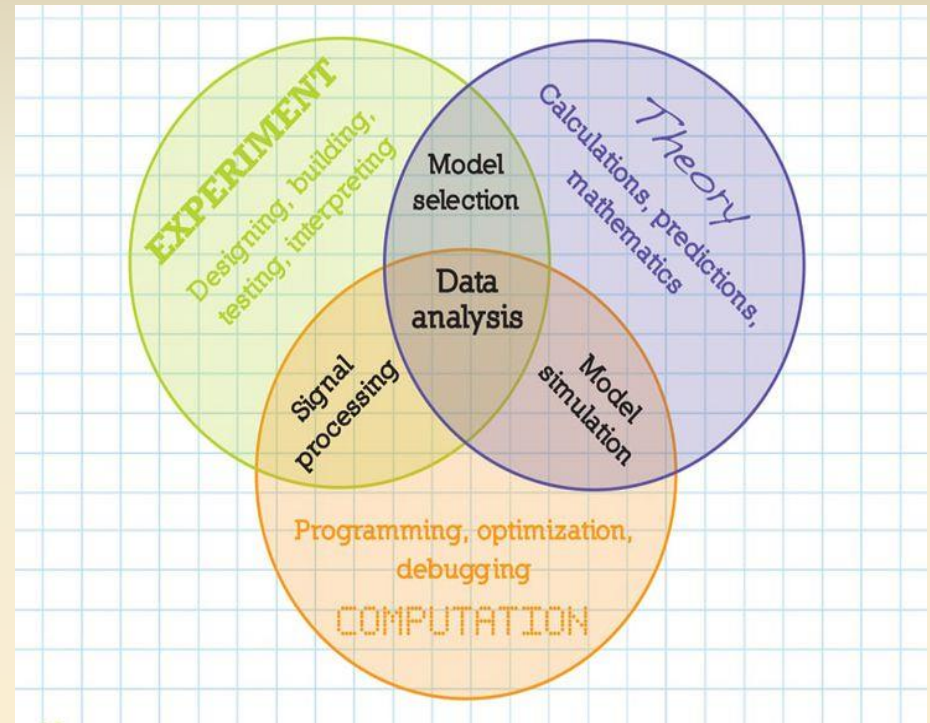
Accelerator Technology

	LCLS II	FRIB
	 <p>Prototype Cryomodule</p>	 <p>Refrigerator Installation</p>
Description	4 GeV superconducting linac in existing SLAC tunnel	New user facility at MSU for rare isotope studies
Collaboration	ANL, Cornell, FNAL, LBNL, SLAC, Jefferson Lab	MSU, State of Michigan, DOE SC, Jefferson Lab
Jefferson Lab Scope	<ul style="list-style-type: none"> • Cryoplant design, acquisition & commissioning • Cryomodule and cavities for half of linac • Qo R&D, LLRF, machine physics 	<ul style="list-style-type: none"> • Cryogenic system design, procurement, fabrication, and integration • Cryomodule engineering and design finalization • Negotiating involvement in Fragment Separator Superconducting Magnet design finalization
Status	<ul style="list-style-type: none"> ✓ CD 2/3A complete ✓ Cryoplant procurements 64% (\$32.4M) placed and going well ✓ All Cryomodule procurements placed ✓ Prototype Cryomodule acceptance testing: <ul style="list-style-type: none"> • 7 cavities meet grad spec (8th limited by coupler) • Addt'l testing in April after shipping test • 1st and 2nd production CM assembly underway 	<ul style="list-style-type: none"> ✓ 4K refrigerator installed ✓ Beta 0.041 design complete ✓ Beta 0.29 design completion end of Feb 2017

Computational Support

Computation is crucial to all aspects of our NP Program

- 3D Nucleon Tomography--
the intersection of Experiment, Theory and Computation!
- Lattice QCD
 - Dedicated LQCD machine at JLab
#397 fastest computer in the world & #10 Green500
 - ASCR: Exascale
- Experimental/computation
 - Best in class multi-threaded framework
 - Balance hardware investments
 - Data repositories for simulated and experimental data
- Accelerator
 - Integrated controls
 - Electron cooling simulations



**Towards the development of a new
Core Capability**

Laboratory Director

Stuart Henderson:

- Accelerator Scientist
- Currently serving as Director of the Advanced Photon Source Upgrade Project at Argonne National Lab
- Prior: Assoc. Lab Director for Accelerators at FermiLab
- Prior: ORNL, SNS, Director of Research Accelerator Division
- Starts Monday, April 3rd



Meet-n-greet opportunity, Monday 10:30am, CEBAF Center Atrium

**Scheduled for week of July 10th
Proposals due Monday, May 22, 2017**

Issues:

- Better communication on previously approved related proposals
- Stricter procedures on conflicts of interest
- Propose new user chair role as observer/watchdog on above issues and others to ensure fairness and QA
- Considering special presentations on
 - Compact photon source
 - International context for K_L beam in Hall D

12 GeV Approved Experiments by Physics Topics

Topic	Hall A	Hall B	Hall C	Hall D	Other	Total
Hadron spectra as probes of QCD	0	3	1	3	0	7
Transverse structure of the hadrons	5	4	3	1	0	13
Longitudinal structure of the hadrons	2	3	6	0	0	11
3D structure of the hadrons	5	9	7	0	0	21
Hadrons and cold nuclear matter	7	3	7	0	1	18
Low-energy tests of the Standard Model and Fundamental Symmetries	3	1	0	1	1	6
Total	22	23	24	5	2	76
Total Experiments - MIE Experiments						
Total Experiments Completed	2.5	1.1	0	0.4	0	4.0
Total Experiments Remaining	19.5	22	24	4.6	2	72.0

12 GeV Approved Experiments by PAC Days

Topic	Hall A	Hall B	Hall C	Hall D	Other	Total
Hadron spectra as probes of QCD	0	319	11	540	0	870
Transverse structure of the hadrons	145.5	185	110	25	0	465.5
Longitudinal structure of the hadrons	65	230	165	0	0	460
3D structure of the hadrons	409	872	212	0	0	1493
Hadrons and cold nuclear matter	208	175	201	0	14	598
Low-energy tests of the Standard Model and Fundamental Symmetries	547	180	0	79	60	866
Total Days	1375	1961	699	644	74	4753
Total Days - Without MIE Days	556.5	1961	699	644	28	3889
Total Approved Run Group Days (includes MIE)	1375	926	637	424	74	3436
Total Approved Run Group Days (without MIE)	556.5	926	637	424	28	2572
Total Days Completed	83	30	0	48	0	161
Total Days Remaining	473.5	896	637	376	28	2411

A Decade of Experiments

Jefferson Lab Mission: MOLLER

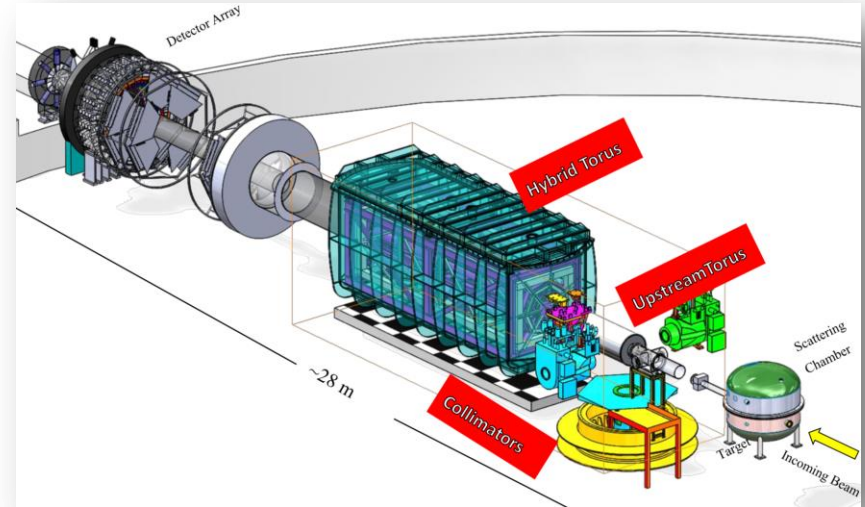
Fundamental Symmetries MIE

- Special Opportunity with 12 GeV Upgrade to Search for New Flavor Diagonal Neutral Currents.
- With the Higgs mass now known a robust Theory Prediction (Purely Leptonic Process)
- No Technical Showstoppers
- Unique Discovery Space for New Physics, beyond that of a 500 GeV lepton collider

MOLLER Reach

$$A_{\text{new}} \quad \text{---} \quad \frac{1}{\Lambda^2} \mathcal{L}_6$$

$$\Lambda_{\text{RR-LL}}^{\text{ee}} \sim 38 \text{ TeV}$$

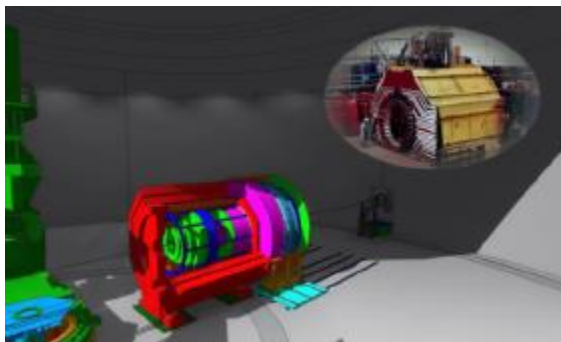


- Ongoing pre-R&D and research
- Director's Technical, Cost and Schedule review Dec 15/16, 2016
- CD-0 approved, project paused due to budget uncertainty

MOLLER	FY18	FY19	FY20	FY21
Proposed (M\$)	(project development)	5.6 Construction	13.0 Construction	6.4 Construction

Jefferson Lab Mission: SoLID

Proposed QCD & Fundamental Symmetries MIE



- Unprecedented **precision** in 3D momentum space **imaging** of the nucleon.
- A search for **new physics in the 10-20 TeV region**, complementary to the reach at LHC.
- Allowing access to threshold of **J/ψ production**, allowing access to the QCD conformal anomaly **with unmatched precision**.

Unique Capability:

- ✓ High luminosity (10^{37-39})
- ✓ Large acceptance detector with full ϕ 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
CLEO-II Magnet move to Jefferson Lab	Fall 2016
Follow-Up Director's Review (in progress)	Late 2016
Draft MIE Submission – goal	February 2017
DOE/NP-led Science Review – possible timing	Spring 2017
Annual Budget Briefing – include budget profile	February 2018
MIE Start	FY2020

- CLEO-II cryostat at JLab, steel follows this Spring
- Working with collaboration to follow up from Director's review and finalize draft MIE

FY17 Budget

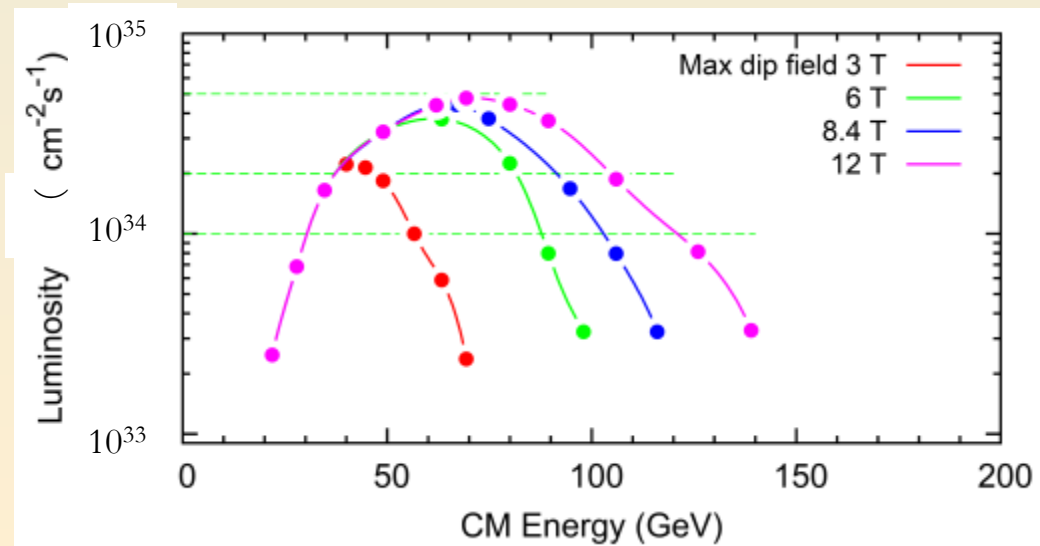
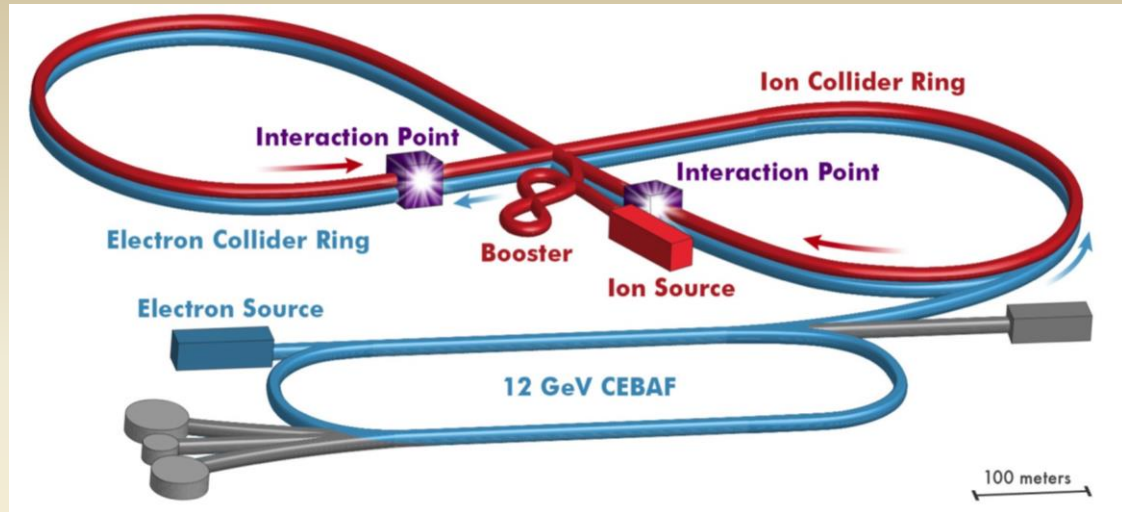
- Pres. Obama Budget : DOE NP at \$636M, an increase of \$18M (3%)
 - Major increases in isotope program (\$8M) and RHIC/BNL (\$7.5M)
 - JLab ops up \$5.5M but insufficient for full operation
- Senate mark: \$636M
 - Language for FRIB construction and RHIC ops
- House Mark: \$620M
 - Language for FRIB construction, RHIC and CEBAF ops
- Now Continuing Resolution (flat budget) at least until April 28th
 - \$5.5M below Pres. Budget (DOE NP is \$15.4M below Pres. Budget)
 - Execute Fall 2016 run as planned, Spring 2017 run limited to 5 weeks
 - Non-labor spending constrained at significantly less than FY16

JLab Outyear Budget

- Weeks of Operation:
 - Historically (FY01-FY12), CEBAF ops averaged 34.5 weeks/year
 - For 12 GeV era, we estimate “optimal” operations at 37 weeks/year
 - FY17 Pres. Budget would fund 23 weeks (+3 weeks 12GeV Project)
 - FY18+ at cost of living implies 23 weeks/year running (62% of optimal)
 - JLab proposal to DOE NP: FY18+ at 30 weeks/year (81%)
 - will require ~\$6M increase from FY17 Pres. Budget level
- FY18 Budget:
 - Pres. Trump Budget released last week
 - Referred to as "Skinny Budget" due to lack of detailed information
 - Includes DOE Office of Science reduction, but no details
 - Now starts the iteration/negotiation with House and Senate
 - JSA working with Congressional reps to communicate the value of our mission, our science, and our User community

JLEIC Realization

- **Energy Range:**
 \sqrt{s} : 20 to 65 - 140 GeV
(magnet technology choice)
- **Figure 8 Layout:**
Optimized for high ion beam polarization \rightarrow polarized deuterons
- Utilizes existing CEBAF for polarized electron injector
- Fully integrated detector/IR
- **JLEIC achieves initial high luminosity, with technology choice determining initial and upgraded energy reach**



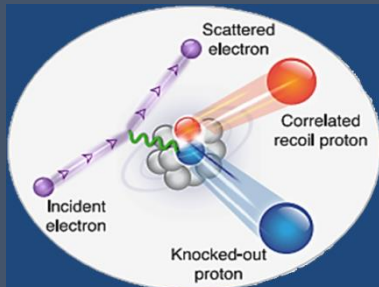
EIC Developments

- EIC User meeting at ANL July 7-10, 2016
 - UG charter, elections (IB chair – Christine Aidala, SC Chair – Abhay Deshpande)
 - Website: <http://www.eicug.org/web/>
 - 2017 EIC UG Meeting in Trieste, Italy – July 17-22
- DOE-NP will increase EIC accelerator R&D in FY17
 - Through ‘tax’ on JLab and BNL
 - Peer review held for November 29-December 2
 - report released in February
 - FOA for proposals in DOE approval chain
- National Academies Study underway
 - Co-Chairs: Gordon Baym (UIUC), Ani Aprahamian (Notre Dame)
 - First meeting February 2017

Summary and Outlook

- Experiments on the floor have done well – hope for early results soon (esp. Hall B!)
- Summer: 12 GeV Upgrade complete
- Fall: Commissioning CLAS12 & SHMS; Physics in Halls A & D
- Spring: Full 4-Hall physics operations
- PAC45 week of July 10, 2017
- MOLLER teed up with CD-0, SoLID making progress
- Operations budgets appear challenging
- EIC science and JLEIC design is making good progress

JLab: A Laboratory for Nuclear Science



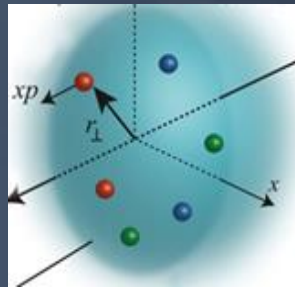
Nuclear Structure



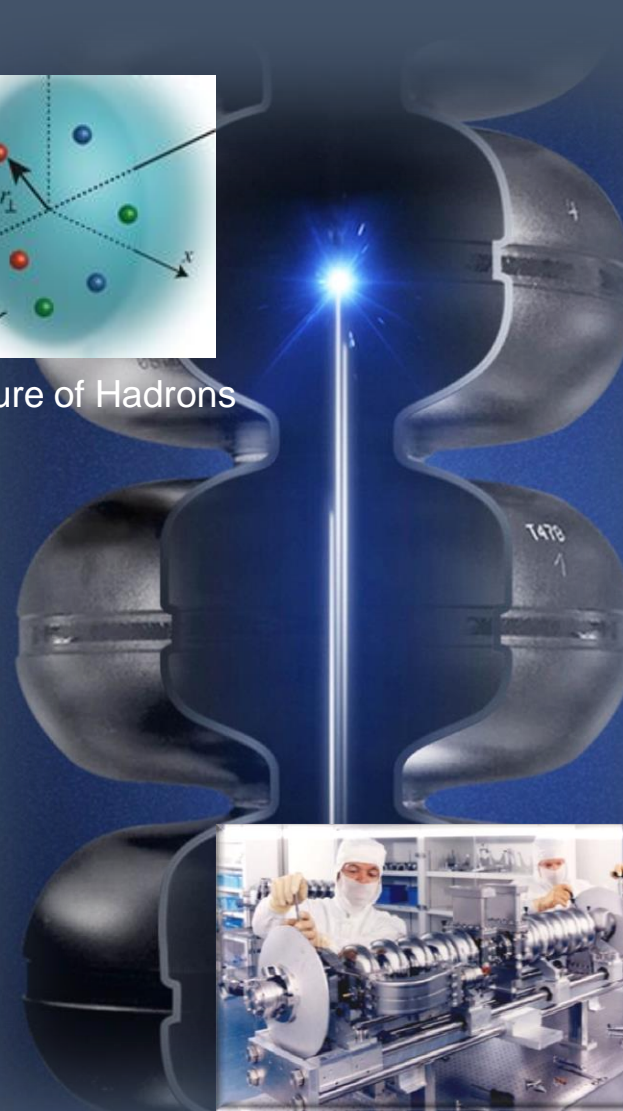
Medical Imaging



Cryogenics



Structure of Hadrons



Accelerator S&T



Fundamental Forces & Symmetries



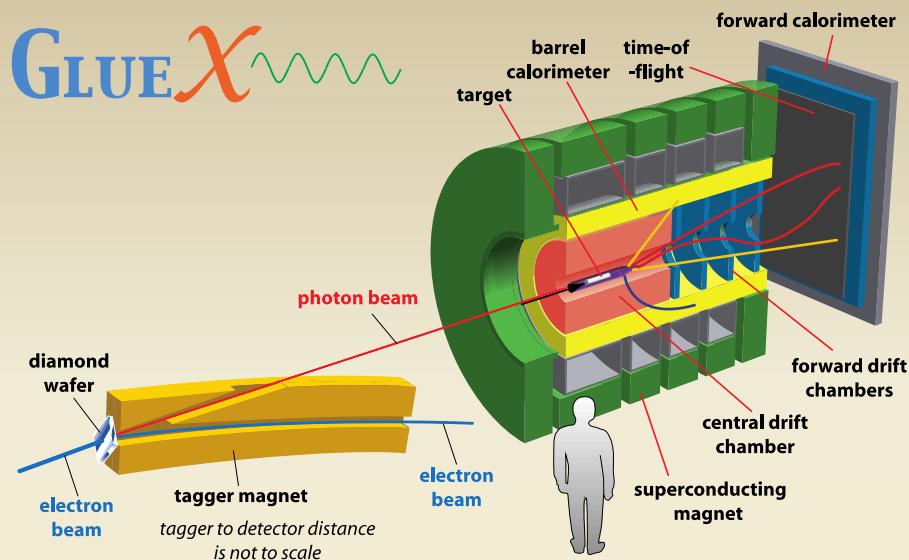
Nuclear Astrophysics



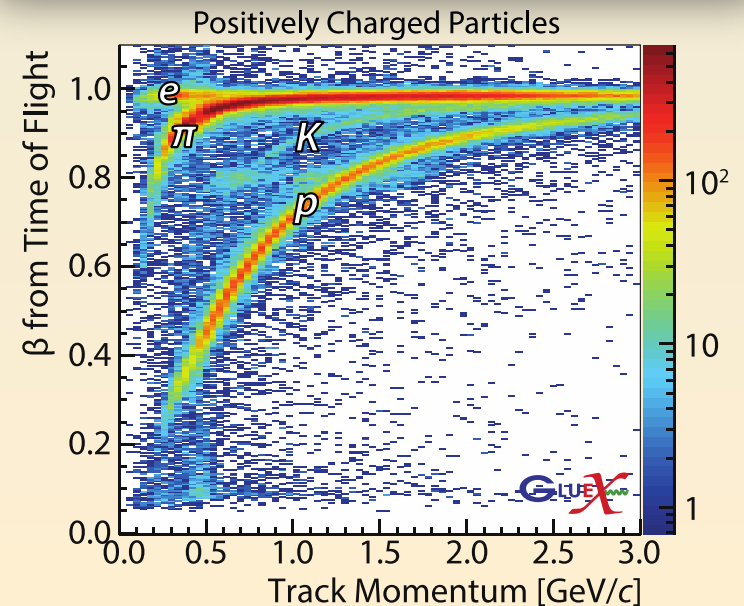
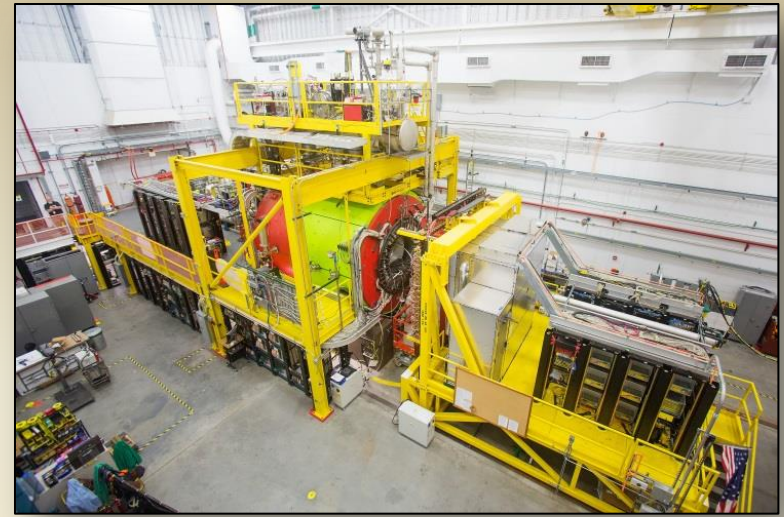
Theory & Computation

BACK-UP

GlueX in Hall D



- New experiment to study quark confinement
- Commissioning complete
- Detector functioning well
- Production data-taking started
- Poised to discover exotic hybrid mesons



All presentations are part of a GlueX-related minisymposium spanning several sessions and including both theory and experiment talks. GlueX collaborators will present:

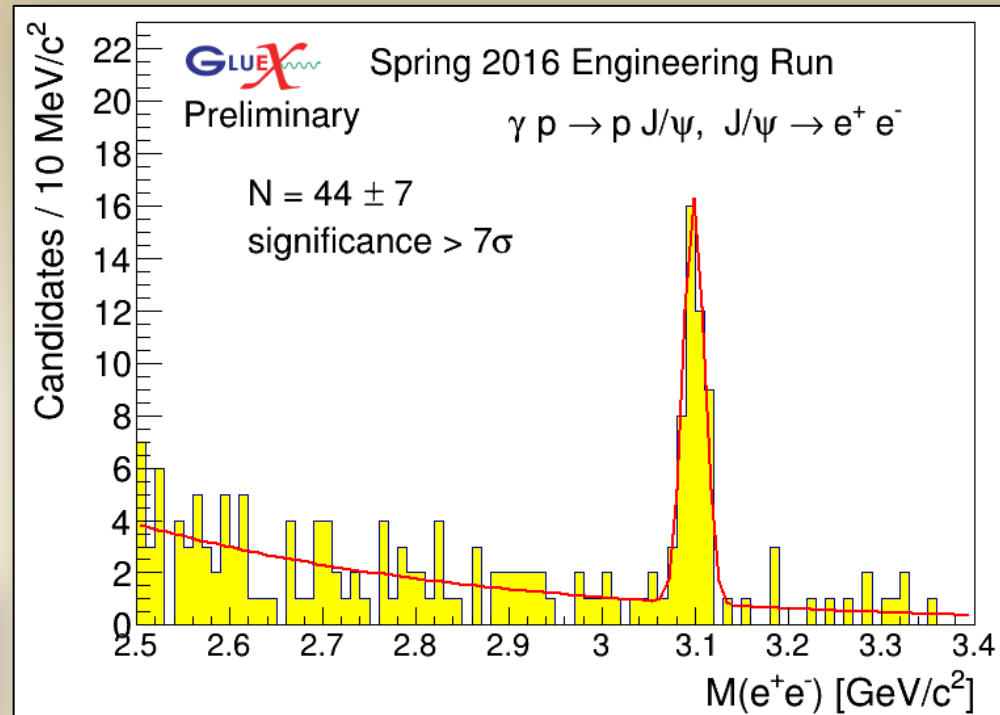
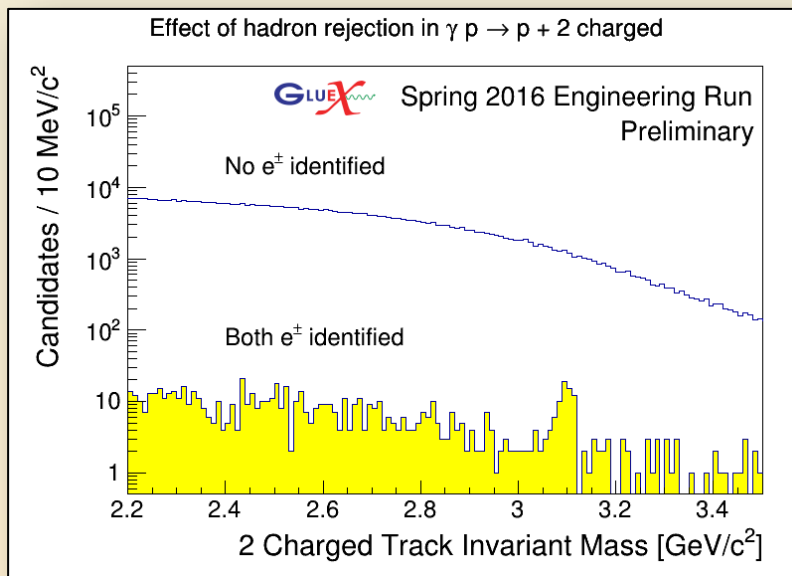
- Σ beam asymmetry of the π^0 and η in GlueX. (PRL in preparation)
- Photoproduction of the ρ (770) with GlueX.
- Photoproduction of the η' (958) with GlueX.
- Photoproduction of the ω (782) with GlueX.
- A survey of multi-photon final states in GlueX.
- Measurement of the η' transition form factor in GlueX.
- A Leptophobic Boson search in GlueX.
- Excited ρ mesons in GlueX.
- Photoproduction of J/ψ in GlueX.

Observation of J/ψ Photoproduction in **GLUEX**

$$\gamma p \rightarrow p J/\psi$$

$$J/\psi \rightarrow e^+ e^-$$

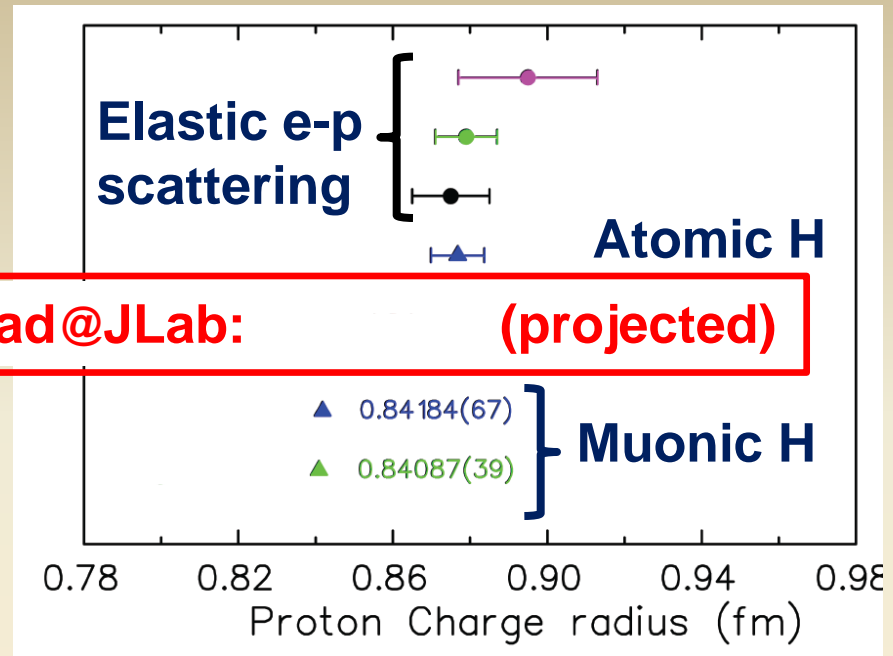
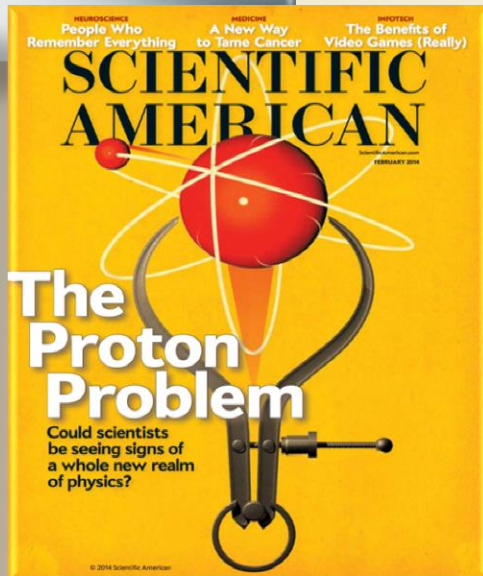
Reconstruct **exclusive** final state:
Identify the p using **timing** and the
 e^+ and e^- through **p/E** in the
calorimeters.



By identifying both e^+ and e^- , we get
over a factor of 100 in rejection power
and a very clean signal.

First observation of
charmonium at JLab!

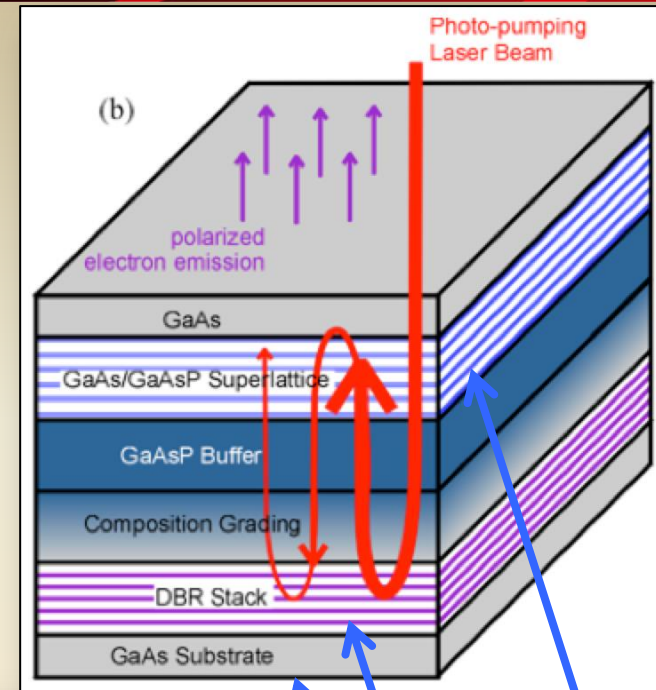
Solving the Proton Radius Puzzle



- PRad: new experiment to address proton radius @ JLab
- NSF MRI: H₂ gas target
- DOE GEM tracking detectors
- Successful run in summer 2016!

World Record High Polarization Photocathode

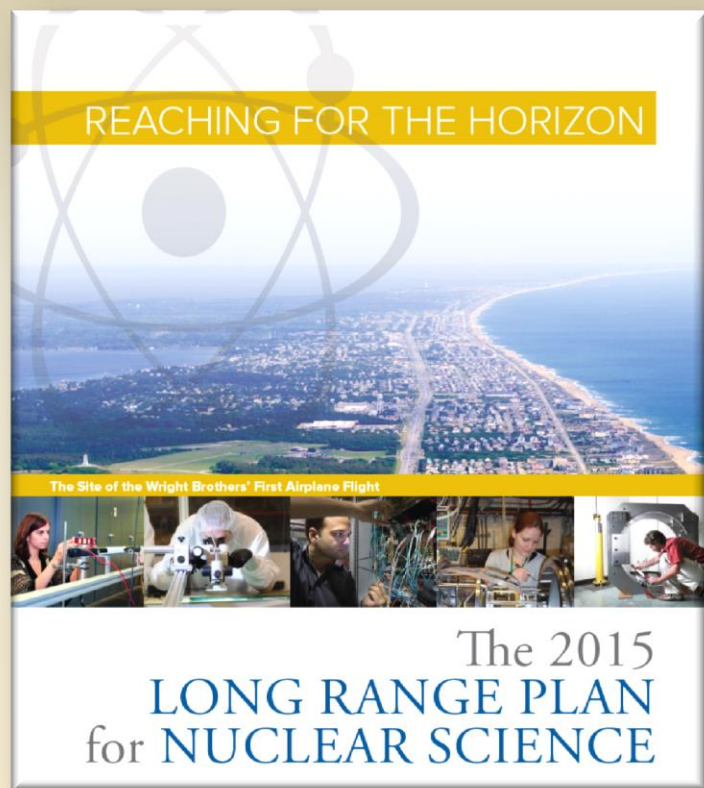
- 6.4% QE & 84% polarization at 776 nm from strained GaAs/GaAsP superlattice photocathode with GaAsP/AlAsP **Distributed Bragg Reflector** (DBR)
- The highest QE & FOM of any reported high polarization photocathode
- Possible to improve both QE & Pol
- SBIR partnership



Cathode	Lab	P(%)	QE (%)	FOM (P^2QE)
GaAs-GaAsP	SLAC/SVT	86	1.2	0.89
AlInGaAs-AlGaAs	St. Petersburg	92	0.85	0.72
GaAs-GaAsP	Nagoya	92	1.6	1.35
GaAs-GaAsP/DBR	JLab/SVT	84	6.4	4.52

Paper ready for SPIN and APL submission: W. Liu, S. Zhang, M. Stutzman, M. Poelker, Y. Chen, W. Lu, and A. Moy

2015 NSAC Long Range Plan



RECOMMENDATION I

The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. The highest priority in this 2015 Plan is to capitalize on the investments made.

→ **Operate 12 GeV CEBAF**

RECOMMENDATION II

We recommend the timely development and deployment of a U.S.-led ton-scale neutrinoless double beta decay experiment.

RECOMMENDATION III

We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.

→ **Jefferson Lab EIC (JLEIC) development**

RECOMMENDATION IV

We recommend increasing investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.

→ **MOLLER, SoLID**

Bunched Ion Beam Cooling – Preliminary Results

- A collaboration of **JLAB** and Institute of Modern Physics (**IMP**), China
- The 1st experiment was carried out on **May 17-22**, 2016, at Lanzhou, China
- A 7MeV/u **$^{12}\text{C}^{6+}$ ion beam** stored in the IMP CSRm ring, either coasting or captured by 450kHz RF system (two long bunches)
- **Cooling of both coasting and bunched ion by a pulsed electron beam** are observed: first successful step of experimental demonstration of bunched beam cooling
- **Data analysis** both at IMP and JLAB is in progress
- Initial 1D **modeling** with RF capture and bunching shows the ion cooling and synchrotron sideband effects, agree with experimental observations

