

Status of Hall B

Volker D. Burkert
Jefferson Lab

PAC46 Meeting 07/16/2018

- Hall B Publications & impact
- CLAS12 status
 - Spring 2018 run
 - Preliminary data
- Future run groups
- Summary

Evidence for Nucleon & Delta States

Multiple nucleon resonances now confirmed; highlighted in Particle Data Group (PDG) tables.

State N((mass)J ^P)	RPP 2008	RPP 2018
N(1710)1/2 ⁺	***	****
N(1880)1/2 ⁺		***
N(2100)1/2 ⁺	*	***
N(1895)1/2 ⁻		****
N(1900)3/2 ⁺	**	****
N(1875)3/2 ⁻		***
N(2120)3/2 ⁻		***
N(2060)5/2 ⁻		***
Δ(1900)1/2 ⁻	**	***
Δ(2200)7/2 ⁻	*	***

Obtaining an accurate account of the nucleon resonance spectrum is essential for connecting QCD to the light quark sector.

Tremendous progress in solving the “Missing Resonances” problem in employing PWA to high precision data

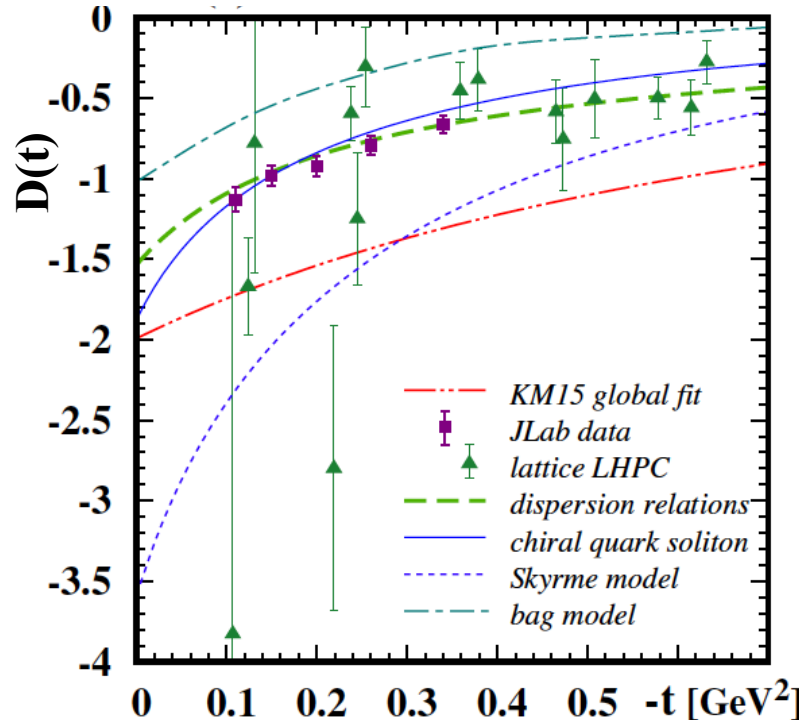
Also electroproduction transition form factors included in N* & Δ review.

<http://pdg.lbl.gov/2018/reviews/rpp2018-rev-n-delta-resonances.pdf>

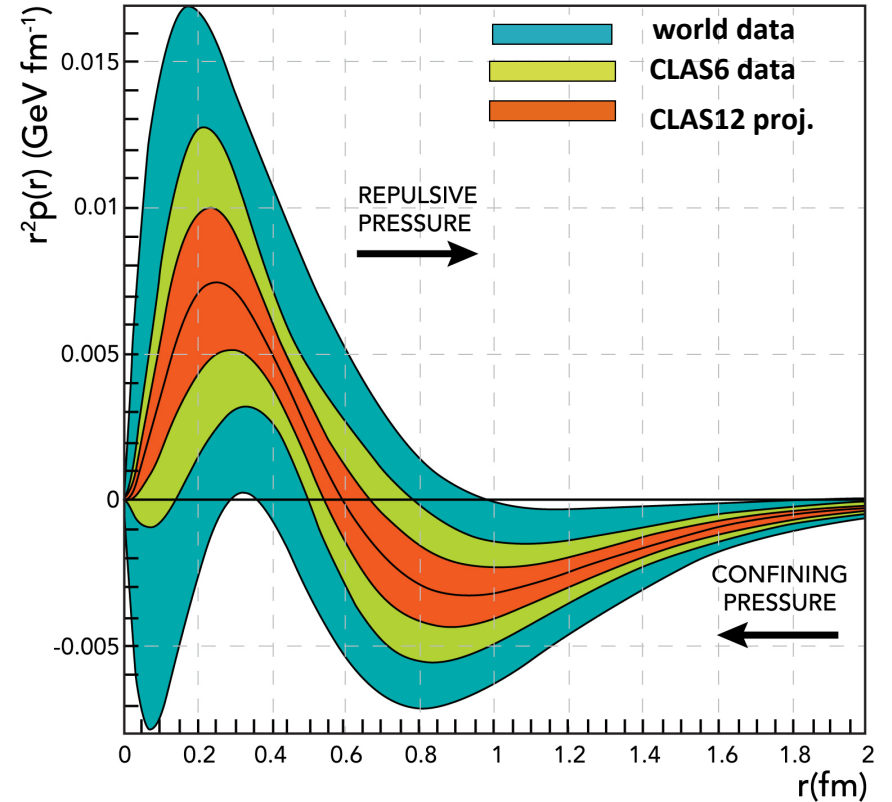
**** Existence is certain
 *** Existence is very likely
 ** Evidence of existence is fair
 * Evidence of existence is poor

First gravitational FF of the proton

From CLAS DVCS-BH beam spin asymmetry.
First determination of basic proton property.



$$d_1(t) \propto \int d^3r \frac{j_0(r\sqrt{-t})}{2t} p(r)$$



V.B., L. Elouadrhiri, F.X. Girod,
Nature 557 (2018) 7705, 396

**PAC44 approved 12 GeV program
E12-16-10B**

The beginning of a new direction in nuclear and hadronic physics.

In the News May/June 2018

The Virginian-Pilot

"The great newspaper will, by honest and intelligent journalism, inspire people to do better."
FRANK BATTEN
JANUARY 1954 EDITION

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Page 21 | THE VIRGINIAN-PILOT | 05.29.18 | Tuesday

Study: Protons pack more pressure than neutron stars

By Katherine Hubner
The Virginian-Pilot

"Think you're under pressure?" Consider the proton. The inside of the subatomic particle withstands 100 quadrillion times the pressure of the 33 zettas - Pascal, a unit of pressure, according to new research out of the Thomas Jefferson National Accelerator Facility.



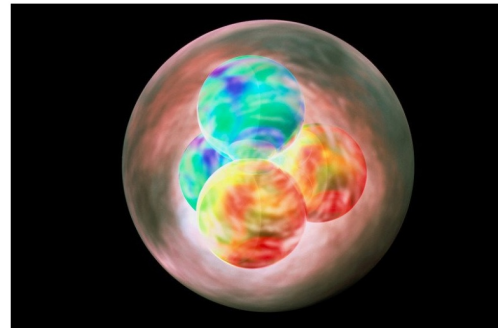
New Scientist

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DAILY NEWS 16 May 2018

We've measured the pressure inside a proton and it's extreme



A helium nucleus, with two protons and two neutrons

Физики нашли внутри протонов самую плотную форму материи во Вселенной

16.05.2018 (обновлено: 20:01 16.05.2018)



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LES FIGARO

Les pressions les plus infernales de l'Univers découvertes au cœur des atomes

Un accélérateur de particules américain a permis de déterminer les forces colossales qu'exercent à l'intérieur du proton.



Le proton est constitué de quarks et de gluons. Les chercheurs ont mesuré la pression à l'intérieur de ce petit volume.

10 étoiles dans un proton

Cette recherche de la distribution de la pression à l'intérieur du proton a permis de découvrir que la pression à l'intérieur est 100 fois plus élevée que celle que nous connaissons sur Terre.

Ne passez pas à côté de l'Audi de vos rêves.

Du 8 au 17 juin Journées Audi Offres de financements exceptionnelles avec extension.

Forbes Science

@SciForbes

Follow

Researchers have measured the distribution of pressure inside a proton: on.forbes.com/6015D9ehL

The inside of a proton even more pressure than anything else we've seen

For the first time, scientists used a particle accelerator to measure the pressure inside a proton. The pressure is 100 times greater than anything we've ever seen on Earth.

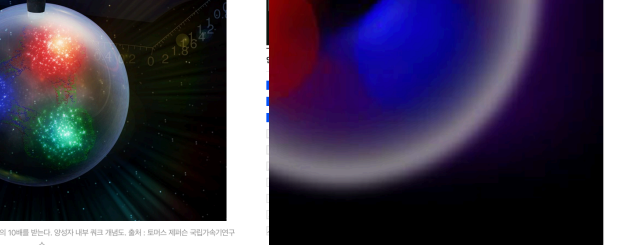


Illustration of a proton, showing the internal pressure distribution. The pressure is 100 times greater than anything we've ever seen on Earth.

미국 물리학회에서 새로 발표된 연구 결과가 '미국 물리학회 저널'에 실렸다. 이 연구는 양성자 내부의 압력을 측정하는 데 성공했다. 양성자 내부의 압력은 우리가 지금까지 측정했던 것보다 100배 더 높았다. 이 연구는 양성자 내부의 압력을 측정하는 데 성공했다. 양성자 내부의 압력은 우리가 지금까지 측정했던 것보다 100배 더 높았다.

Podcast: Probing the proton, research misconduct, and making sense of mystery genes

Listen to Shamini Bundell and Benjamin Thompson present the latest in science news.

LISTEN

This week, peering inside the proton, identifying research misconduct and making sense of mystery genes.

Download this episode

توزيع الضغط داخل البروتون

V. Burkert et al.

Published online: 17 May 2018

Nature (2018) doi:10.1038/s41586-018-0090-z

English article

بشكل البروتون، وهو أحد مكونات ذرة الأتوم، من حيثيات أولية تسمى كواركات، وجولونات الجولونات هي حاملات القوة، التي تربط الكواركات ببعضها البعض، والكواركات العرة لا توجد أبداً منفصلة أي أنها محصورة داخل الجسيمات العرة التي تكمن فيها. ويُعد أحد أخصاص الكوارك أحد أهم الأبحاث في فيزياء الجسيمات، والفرز بين البروتون والنيوترون، لأنه محوري في كون البروتون جسيماً مستقرًا، وبالتالي يفر استقرار الكون، وتختلف بنية الكوارك الداخلية للبروتون، بغض النظر عن كونها البروتون العصب، أو من عملية تمت فيها الاكثارونات، التي تشكلت من الكواركات داخل البروتون، فإحداثيات الخلفية، يُكف عن التزاوج مع الاكثارونات المشحونة والبروتونات العرة.

يقدم البروتون، في الجسيمات المشحونة، توزيع الضغط الذي تعرض له البروتون، وقد وجد الباحثون ضغطًا متزايدًا بالقرب من مركز البروتون (في نطاق يصل إلى 0.6 فيمتومتر)، وضغطًا أيضًا عند مسافات أكبر، ويبلغ متوسط ذروة الضغط بالقرب من المركز حوالي 10 بلاغات، وهو ما يتجاوز الضغط المقترح لأعلى الأحمال المعروفة لكافة في الكون، وهي النجوم النيوترونية.

Feeling the Pressure: Extreme pressures at quarks (illustrated) as well as gluons, which hold

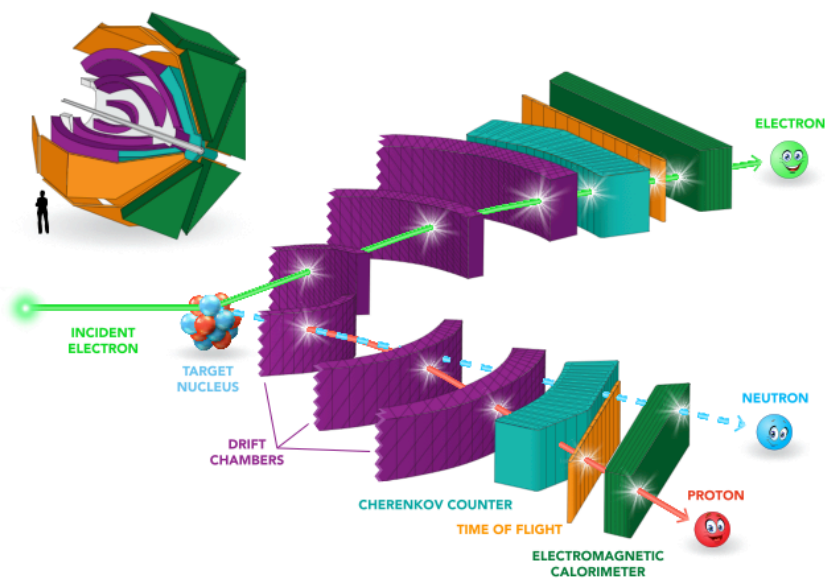
미국 물리학회에서 새로 발표된 연구 결과가 '미국 물리학회 저널'에 실렸다. 이 연구는 양성자 내부의 압력을 측정하는 데 성공했다. 양성자 내부의 압력은 우리가 지금까지 측정했던 것보다 100배 더 높았다. 이 연구는 양성자 내부의 압력을 측정하는 데 성공했다. 양성자 내부의 압력은 우리가 지금까지 측정했던 것보다 100배 더 높았다.



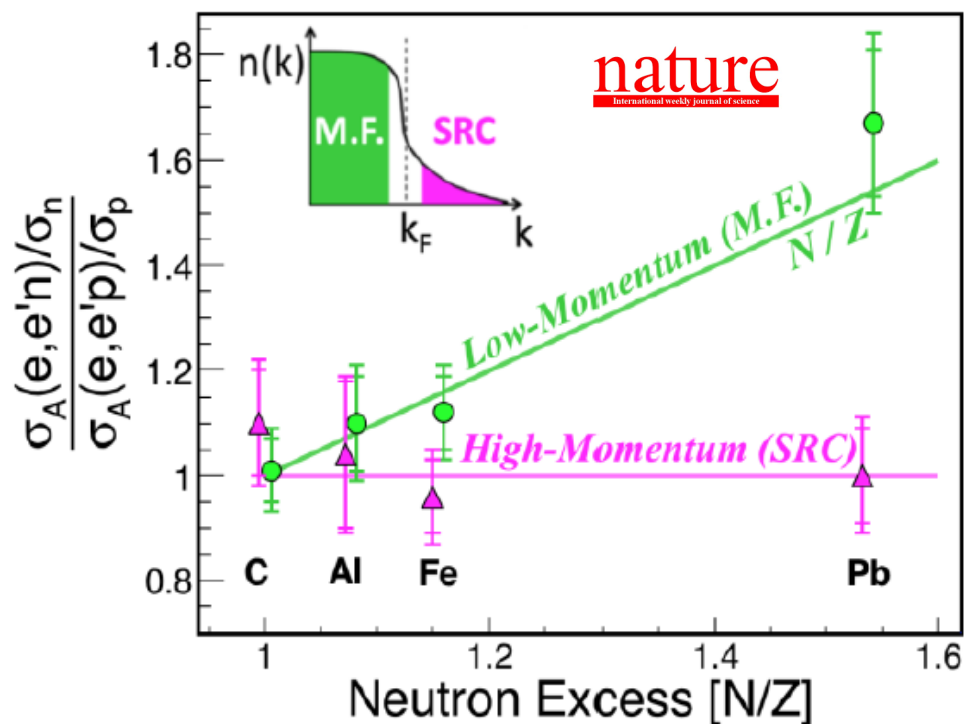
Abundance of hi/lo momentum protons/neutrons



EG2/Data Mining

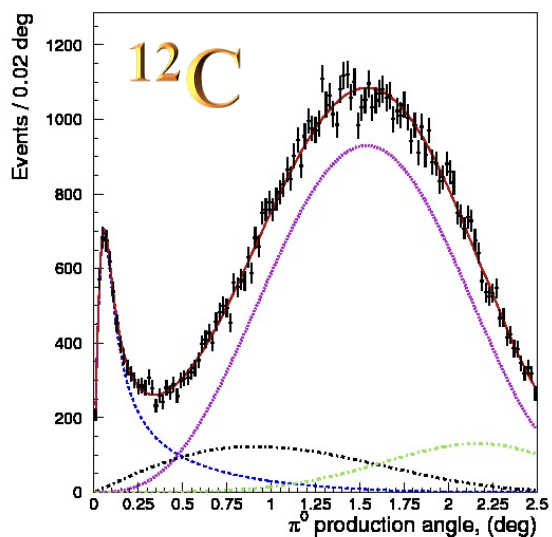
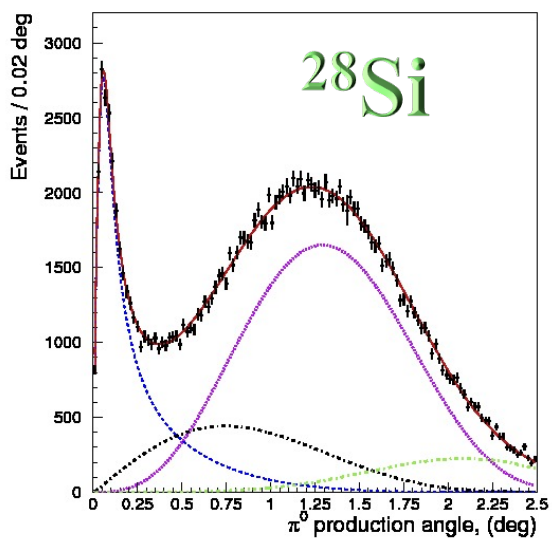


M. Duer et al. (accepted in Nature)

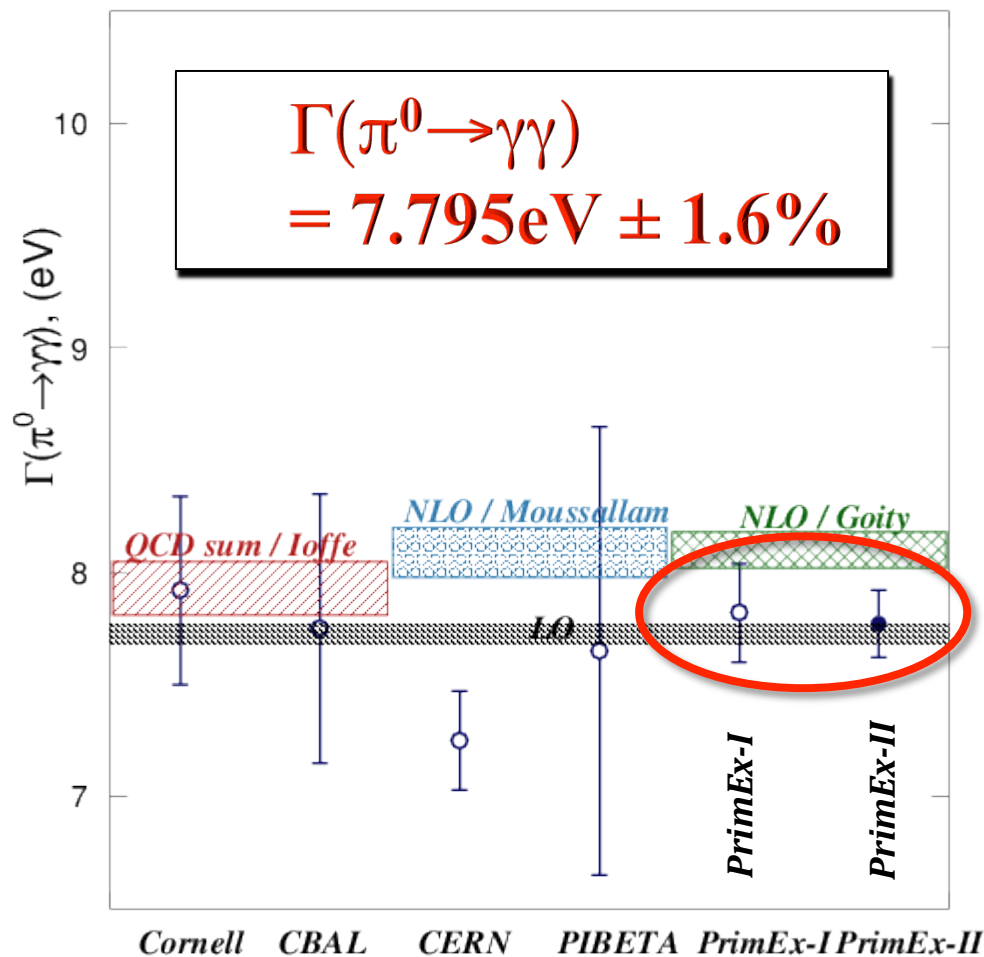


Ratio of neutron/proton abundances ~ independent of neutron excess in SRC
~ linearly rising for M.F. nucleons.

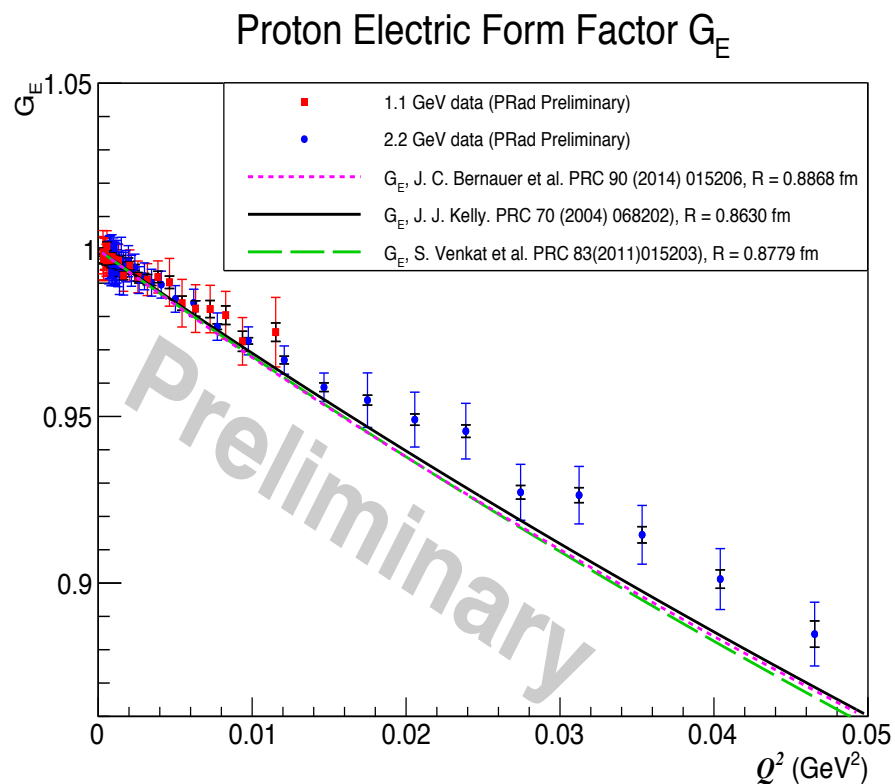
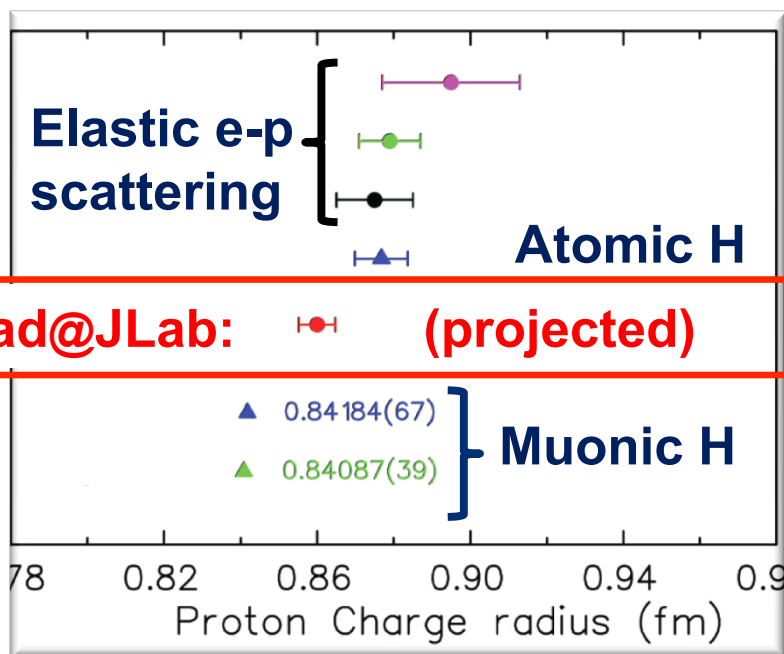
PrimEx-II results



Primakoff measurements of $\Gamma(\pi^0 \rightarrow \gamma\gamma)$



Experiment ran in 2016

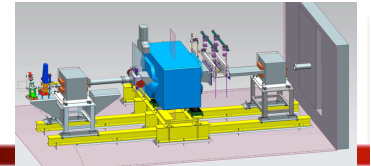


Goal: Resolve the discrepancy with non-magnetic detection system, higher precision and lowest min. Q^2

Preliminary G_E slope seems to favor smaller radius

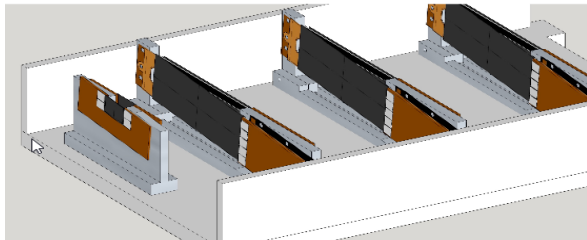


Heavy Photon Search (A')

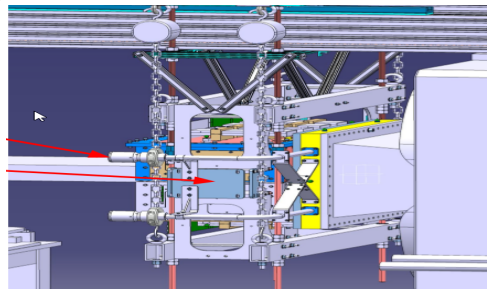
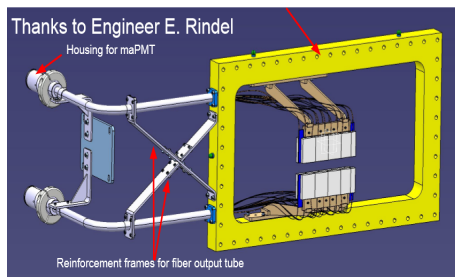


The final bump hunt results from 2015 are close to publication. 2016 Bump hunt and vertex search analyses are under way.

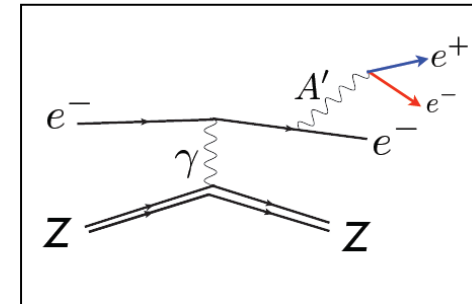
- HPS upgrades ready for 2019 running.



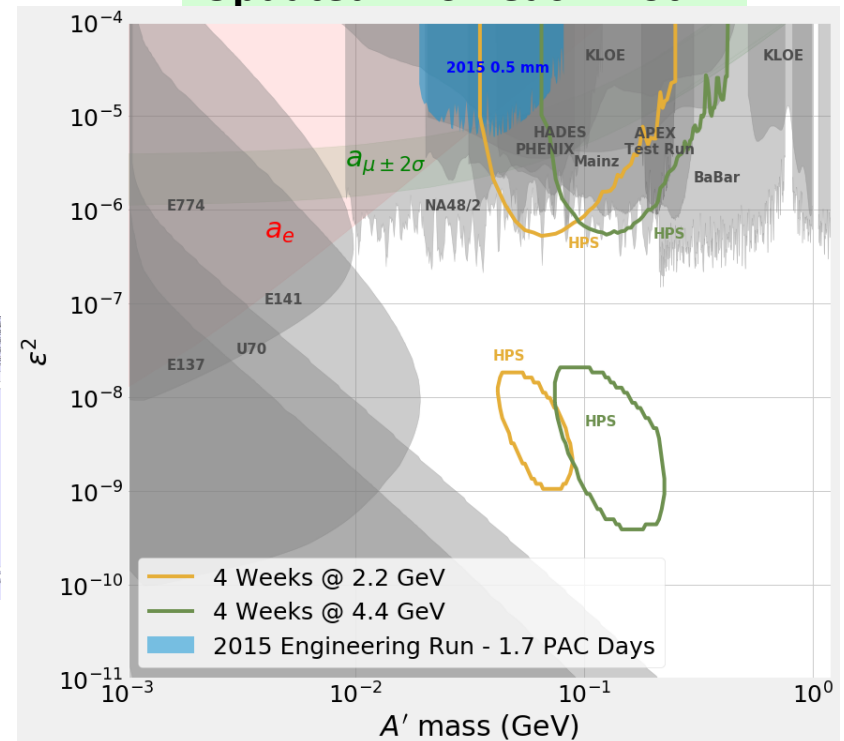
- New Positron Trigger will double e^+e^- pairs yield and reduce backgrounds.



- HPS will resume A' search in well-motivated, unexplored parameter space in 2019



Updated HPS Reach Plot



Forward Detector (FD)

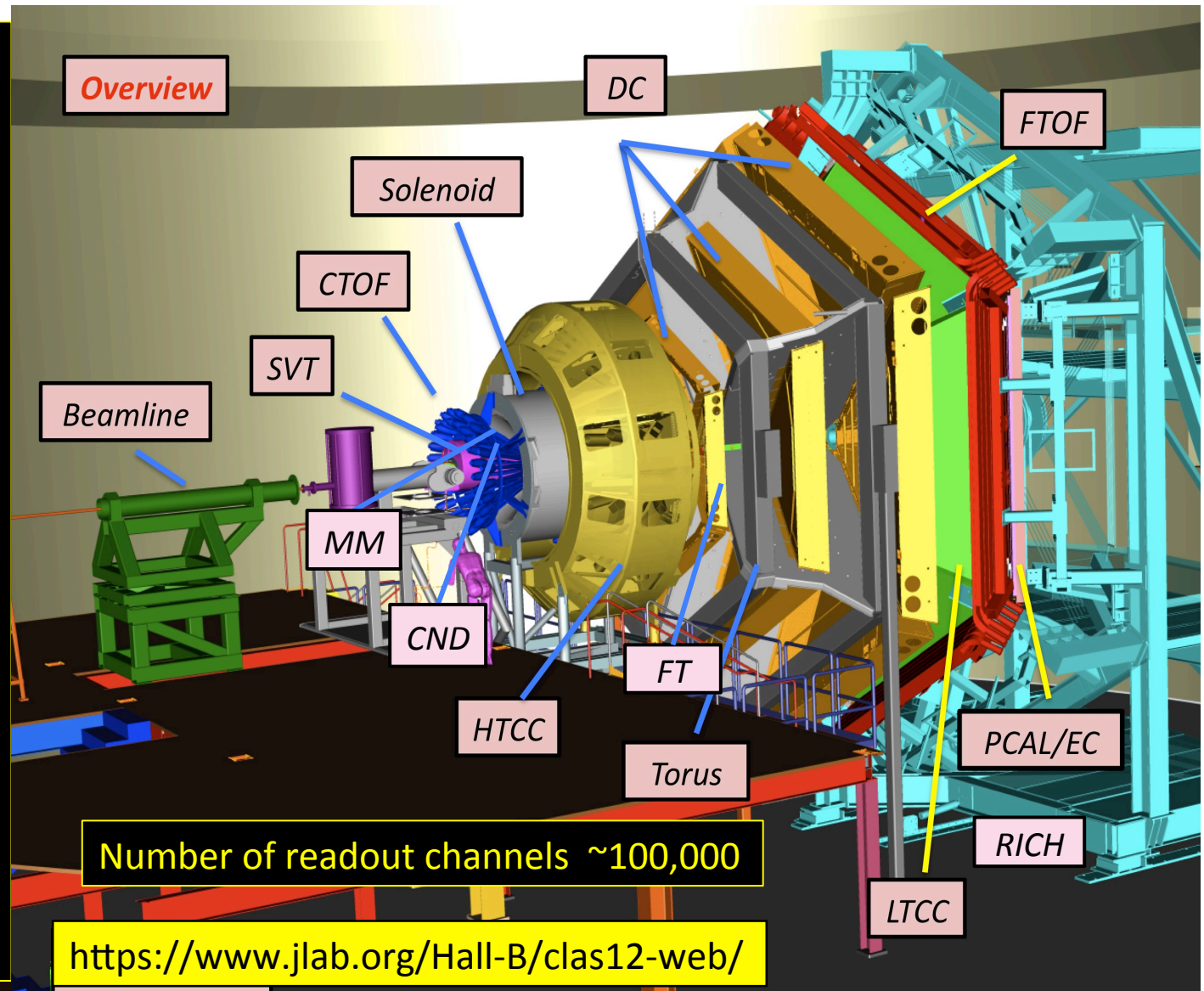
- TORUS magnet
- HT Cherenkov Counter
- Drift chamber system
- LT Cherenkov Counter
- Forward ToF System
- Pre-shower calorimeter
- E.M. calorimeter
- Forward Tagger
- RICH detector

Central Detector (CD)

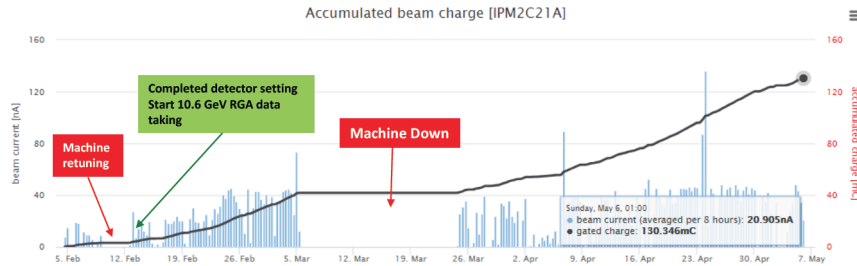
- Solenoid magnet
- Silicon Vertex Tracker
- Central Time-of-Flight
- Central Neutron Detector
- MicroMegas

Beamline

- Photon Tagger Dump
- Shielding
- Targets
- Moller Polarimeter
- Faraday Cup



start date: end date:

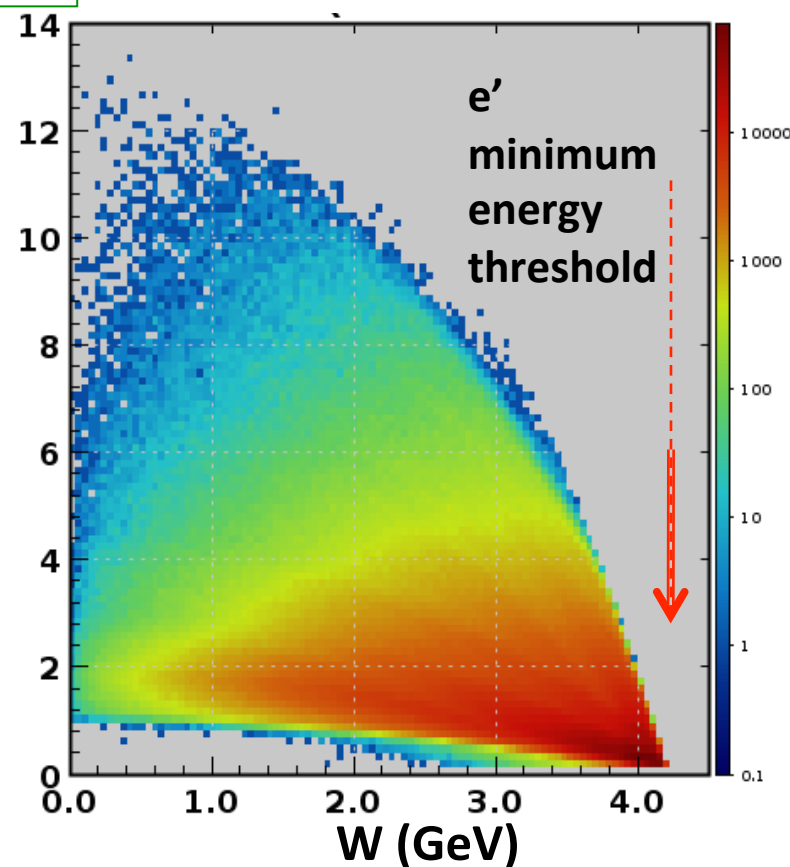
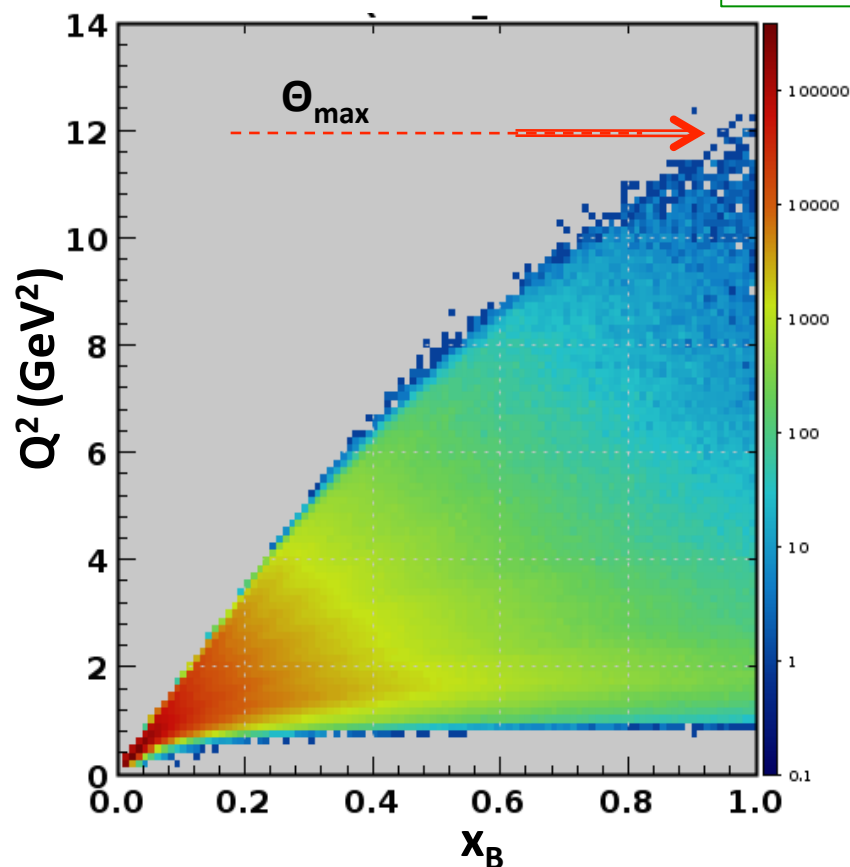


118mCb collected charge of high luminosity
 At $L = 10^{35} \text{cm}^{-2}\text{s}^{-1}$ this corresponds to: 18.2 PAC days
 Low luminosity for 7 scheduled days: 3.5 PAC days
Total: 21.7 PAC days

Proposal	Physics	Contact	Rating	Days	% complete	comment
E12-06-108	Hard exclusive electro-production of π^0, η	Stoler	B	80	24	
E12-06-108A	Exclusive $N^* \rightarrow KY$ Studies with CLAS12	Carman	NR	(60)	35	
E12-06-108B	Transition Form Factor of the η' Meson with CLAS12	Kunkel	NR	(80)	24	
E12-06-112	Proton's quark dynamics in SIDIS pion production	Avakian	A	60	11	1 LTCC, 1 RICH
E12-06-112A	SIDIS Λ production in target fragmentation region	Mirazita	NR	(60)	11	1 LTCC, 1 RICH
E12-06-112B	Collinear nucleon structure at twist-3	Pisano	NR	(60)	11	1 LTCC, 1 RICH
E12-06-119(a)	Deeply Virtual Compton Scattering	Sabatie	A	80	24	
E12-09-003	Excitation of nucleon resonances at high Q^2	Gothe	B+	40	48	
E12-11-005	Hadron spectroscopy with forward tagger	Battaglieri	A-	119	19	
E12-11-005A	Photoproduction of the very strangest baryon	Guo	NR	(120)	19	
E12-12-001	Timelike Compton Scatt. & J/ψ production in $e+e$	Nadel-Turonski	A-	120	19	
E12-12-001A	J/ψ Photoproduction & study of LHCb pentaquarks	Stepanyan	NR	(120)	19	
E12-12-007	Exclusive ϕ meson electroproduction with CLAS12	Girod	B+	60	31	
Average completion (%)					22.7	

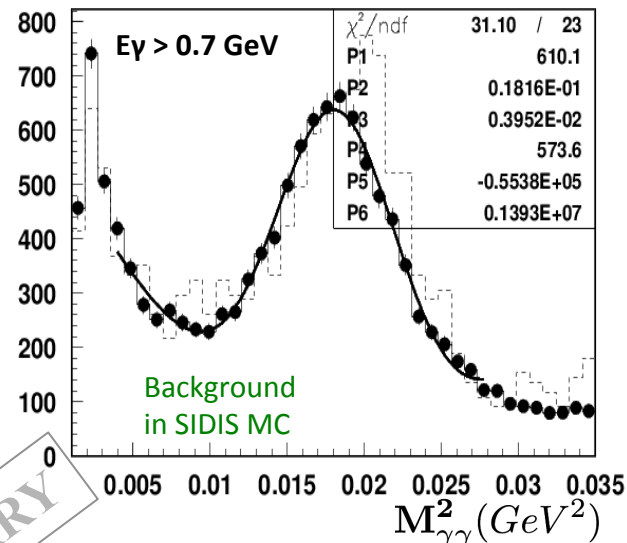
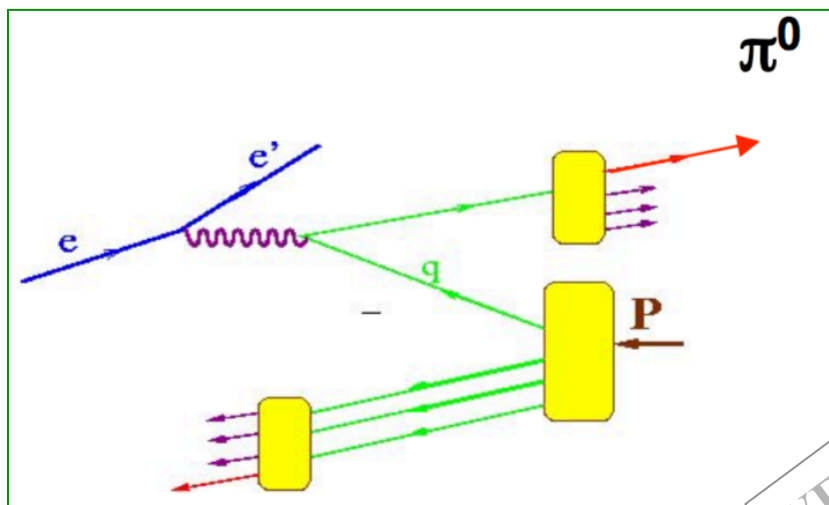
Beam energy at 10.6 GeV Torus current 3770 A, electrons out-bending,
Solenoid magnet at 2416 A.

$p(e,e')X$



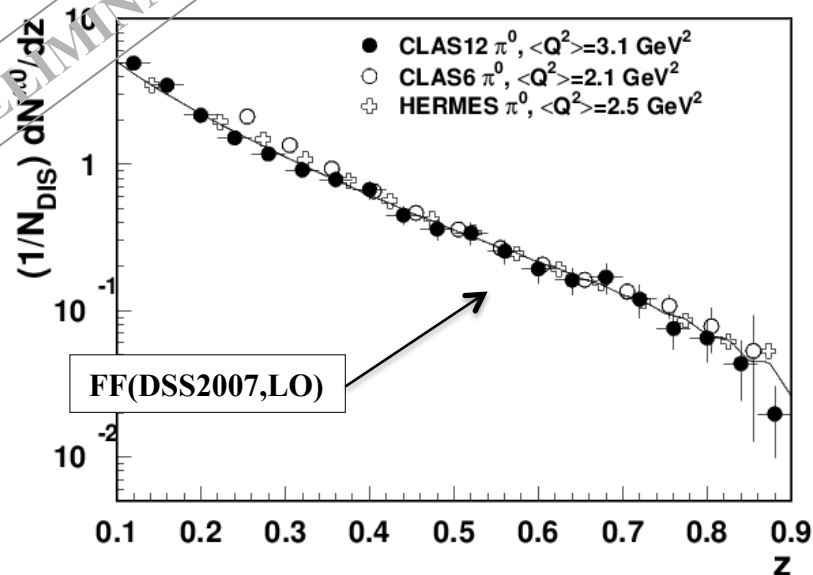
Extraction of $e'\pi^0X / e'X$ ratio (ratio of semi-inclusive π^0 to inclusive electron) requires good control over the acceptance of photons.

$\sim 0.5\%$ of spring 10.6 GeV data.



At large x , when sea contribution can be neglected $e'\pi^0X / e'X$ should follow the z -dependence of the fragmentation function (after integration over P_T)

VERY PRELIMINARY



Hall B 12 GeV Publication Schedule

- Heavy Photon Search (HPS) 2015 data - expect in one month
2016 data - end of 2019
- Proton Radius (PRAD) End of 2018
- RG-A (13 proposals) Release first results at DNP 2019
First publication after that.

Future Run Groups

- **RG-A (RG-K)** - to continue this fall until end of 2018
- **RG-B** - scheduled to run during the spring and the fall of 2019
 - Liquid deuterium target
 - BAND detector for backward angle neutron detection
- **HPS** - scheduled to run summer of 2019 with upgraded detector and trigger system
- **BONuS12** - projected to run spring/fall of 2020
 - A new low energy recoil detector based on GEM technology, to replace SVT
- **RG-C** - Polarized target for CLAS12 - on track for installation to support spin program in 2020/21

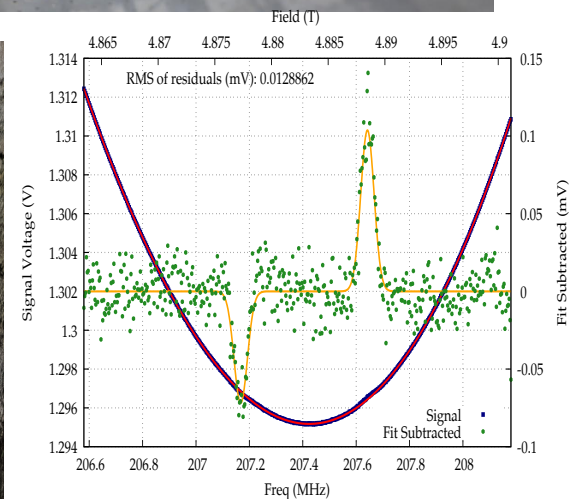
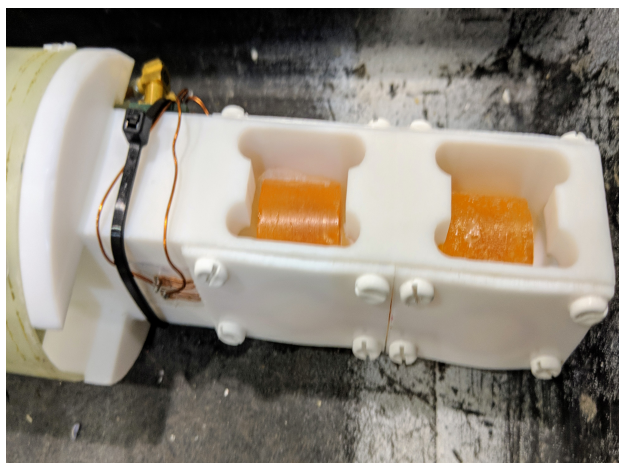
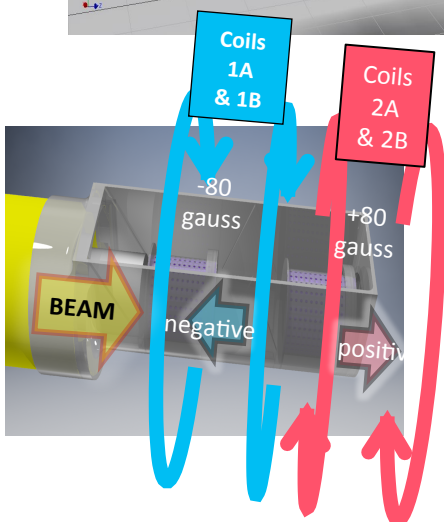
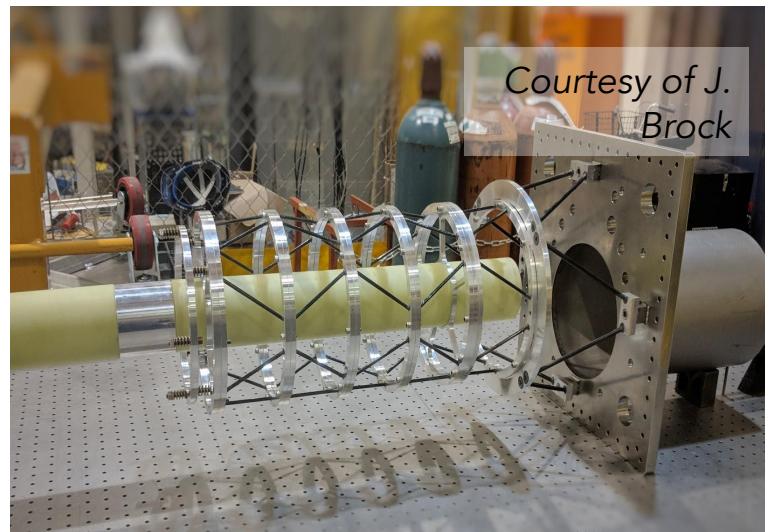
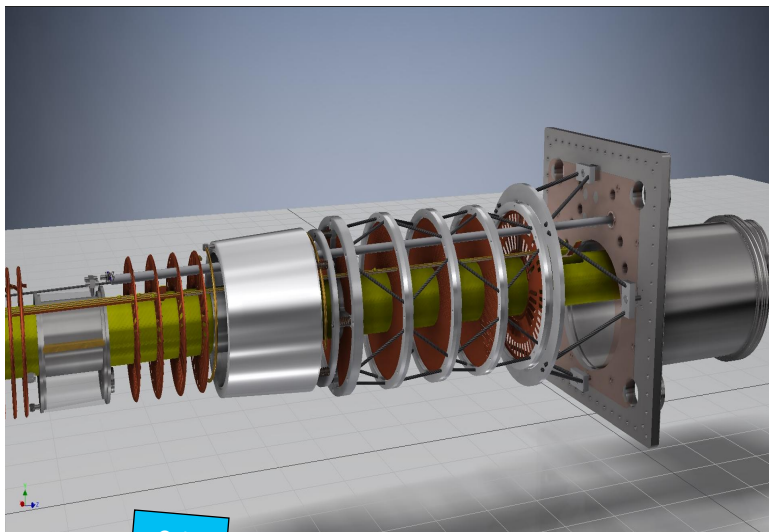
Summary

- Continuous flow of data from CLAS lead to discovery of new baryon states and first insight into the nucleon gravitational properties.
- The data mining initiative has been very successful leading to several publications, including publication in Science and Nature Journals.
- Several dedicated experiments addressing fundamental properties of hadrons (π^0 LT, proton charge radius) and search for the messengers of dark matter.
- CLAS12 had successful first production run achieving projected luminosity and providing data for 13 individual proposals.
- Data runs after 2018 focus of neutron structure properties RG-B (7 experiments), HPS, BoNuS12, and spin physics with RG-C (6 experiments).

Run Groups

HALL B

Proposal	Physics	Contact	Rating	Days	Group	Equipment	Energy	Run Group	Target
E12-06-108	Hard exclusive electro-production of π^0, η	Stoler	B	80	139	RICH (1 sector) Forward tagger	11	A F. Sabatié	liquid H ₂
E12-06-108A	Exclusive N*->KY Studies with CLAS12	Carman		(60)					
E12-06-108B	Transition Form Factor of the η' Meson with CLAS12	Kunkel		(80)					
E12-06-112	Proton's quark dynamics in SIDIS pion production	Avakian	A	60					
E12-06-112A	SIDIS Λ production in target fragmentation region	Mirazita		(60)					
E12-06-112B	Colinear nucleon structure at twist-3	Pisano		(60)					
E12-06-119(a)	Deeply Virtual Compton Scattering	Sabatie	A	80					
E12-09-003	Excitation of nucleon resonances at high Q ²	Gothe	B+	40					
E12-11-005	Hadron spectroscopy with forward tagger	Battaglieri	A-	119					
E12-11-005A	Photoproduction of the very strangest baryon	Guo		(120)					
E12-12-001	Timelike Compton Scatt. & J/ ψ production in e+e	Nadel-Turonski	A-	120					
E12-12-001A	J/ ψ Photoproduction & study of LHCb pentaquarks	Stepanyan		(120)					
E12-12-007	Exclusive ϕ meson electroproduction with CLAS12	Girod	B+	60					
E12-07-104	Neutron magnetic form factor	Gilfoyle	A-	30	90	Neutron detector RICH (1 sector) Forward tagger	11	B S. Niccolai	liquid D ₂ target
E12-09-007(a)	Study of partonic distributions in SIDIS kaon production	Hafidi	A-	30					
E12-09-008	Boer-Mulders asymmetry in K SIDIS w/ H and D targets	Contalbrigo	A-	56					
E12-09-008A	Hadron production in target fragmentation region	Mirazita		(60)					
E12-09-008B	Colinear nucleon structure at twist-3	Pisano		(60)					
E12-11-003	DVCS on neutron target	Niccolai	A	90					
E12-11-003A	In medium structure functions, SRC, and the EMC effect	Hen		(90)					
E12-11-003B	J/Psi Photoproduction off the Deuteron	Ilieva		(80)					
Beam time partial sum				765 (1475)					



Construction of the 1K refrigerator anticipated completion date: Sept. 30, 2018

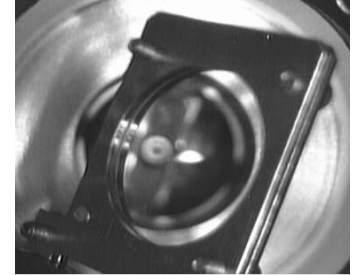


$e+HD$ studies at the UITF – a prelude to $e+H_{\text{transverse}}$



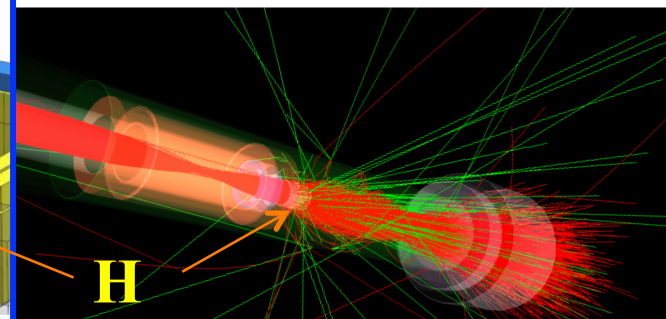
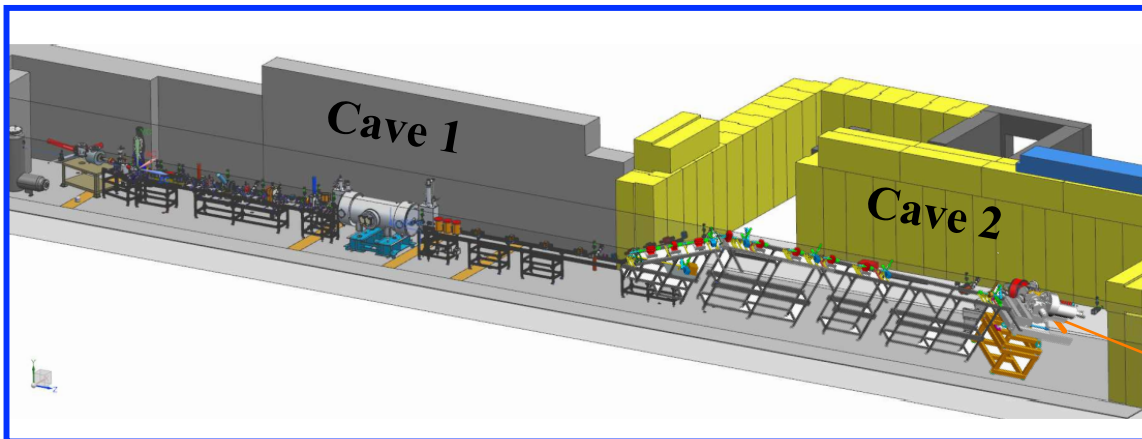
UITF \Leftrightarrow 10 MeV accelerator in the TestLab

- energy deposition in HD \sim as with 10 GeV \Leftrightarrow testbed for transverse $e+HD$
- keV beams in cave 1 in Dec/17 ✓
- $\frac{1}{4}$ CM cooled in Apr/18 ✓
- PSS-RadCon under construction



Next Steps:

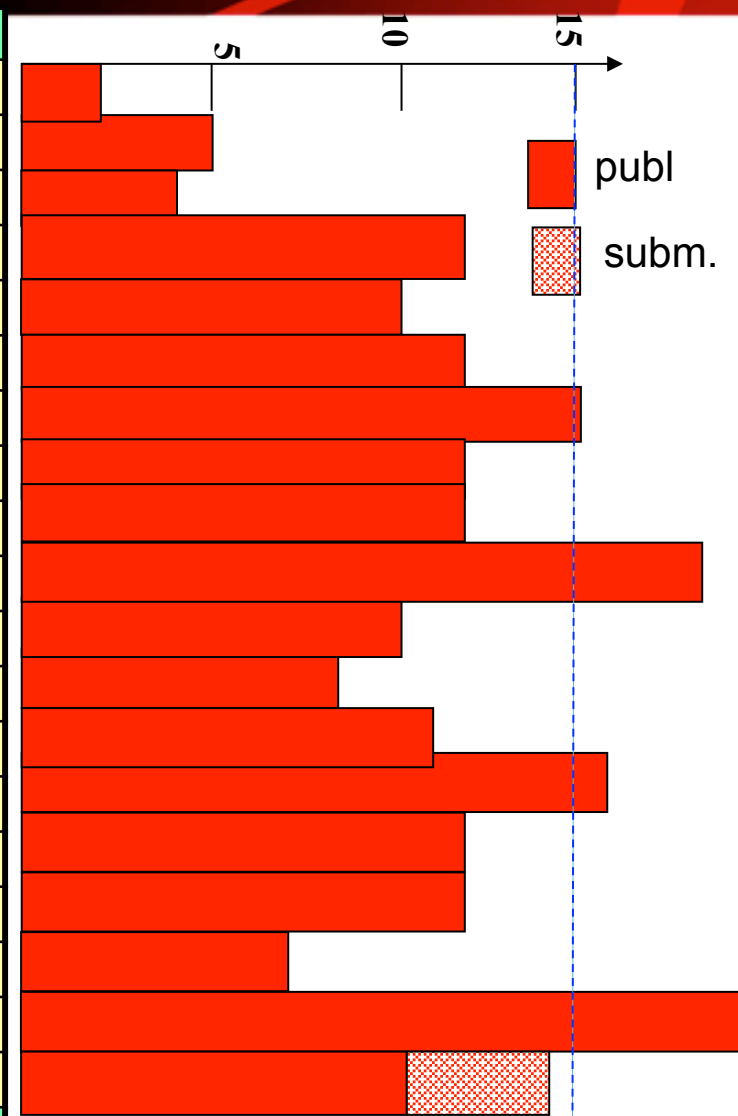
- Klystron installation & commissioning \sim Fall/18
- beamline to HDice under construction; 1st beam studies in cave-2 \sim Spring/19
- 1st eHD test with polarized targets \sim Summer/19



Physics Publications

Hall B

	HSWG	DPWG	NPWG	ALL
2000	-	1	1	2
2001	2	3	-	5
2002	3	-	1	4
2003	7	4	1	12
2004	3	3	4	10
2005	7	3	2	12
2006	8	4	3	15
2007	7	2	3	12
2008	4	6	2	12
2009	8	7	4	19
2010	4	2	4	10
2011	3	1	4	8
2012	6	3	2	11
2013	8	6	2	16
2014	5	6	1	12
2015	4	5	3	12
2016	7			7
2017	12	7	1	20
2018	5	4	1	10 + 4
SUM	103	67	39	209+4



updated 07 July 2018

JLab $\Delta(1232)$ transition FF in RPP 2018

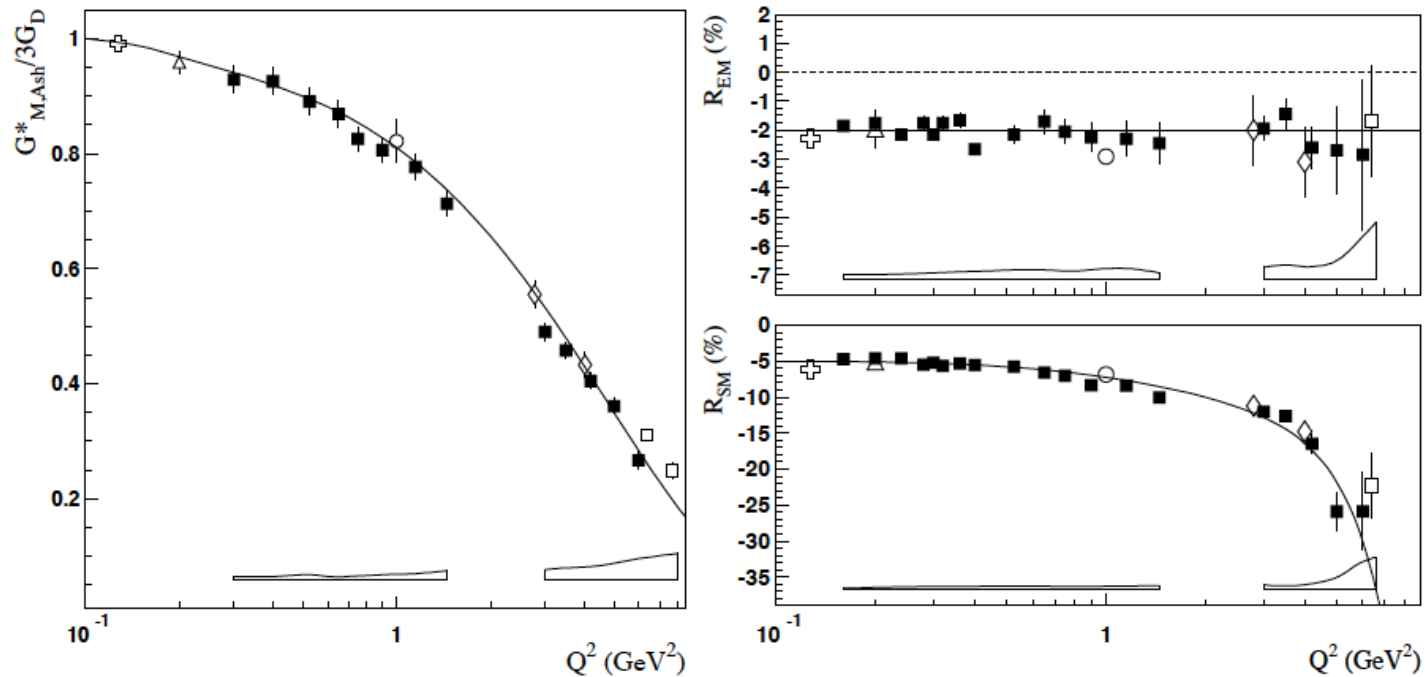
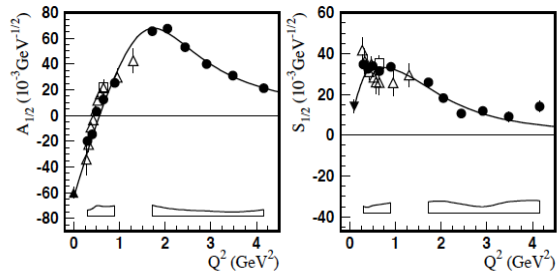
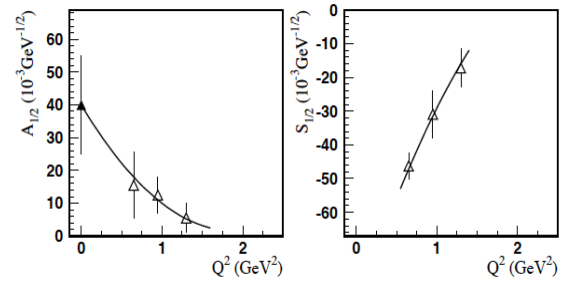


Figure 97.1: Left: The magnetic transition form factor for the $\gamma^*p \rightarrow \Delta^+(1232)$ transition versus the photon virtuality Q^2 . Right: The electric and scalar quadrupole ratios R_{EM} and R_{SM} . The different symbols are results from different experiments at JLab (squares, diamonds, circle) and MAMI (triangle, cross). The boxes near the horizontal axis indicate model uncertainties of the squares. Curves to guide the eyes.

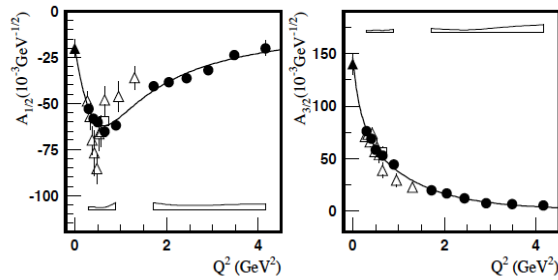
JLab N* transition FF in RPP 2018



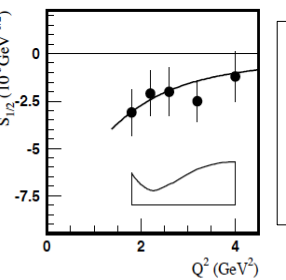
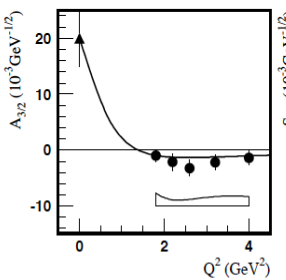
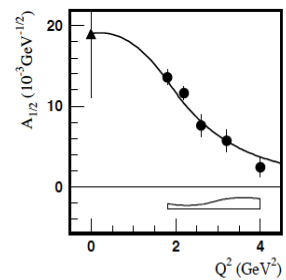
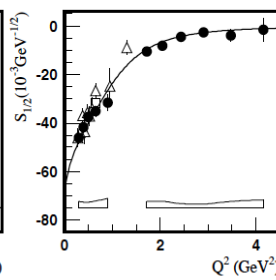
N(1440)
“Roper”



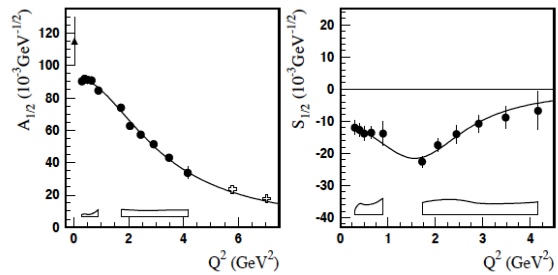
$\Delta(1620)$



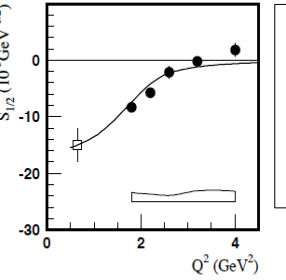
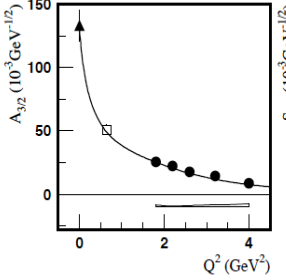
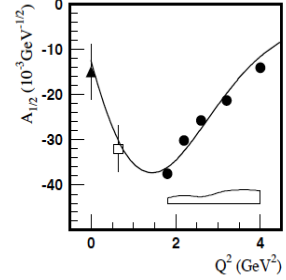
N(1520)



N(1675)



N(1535)



N(1680)