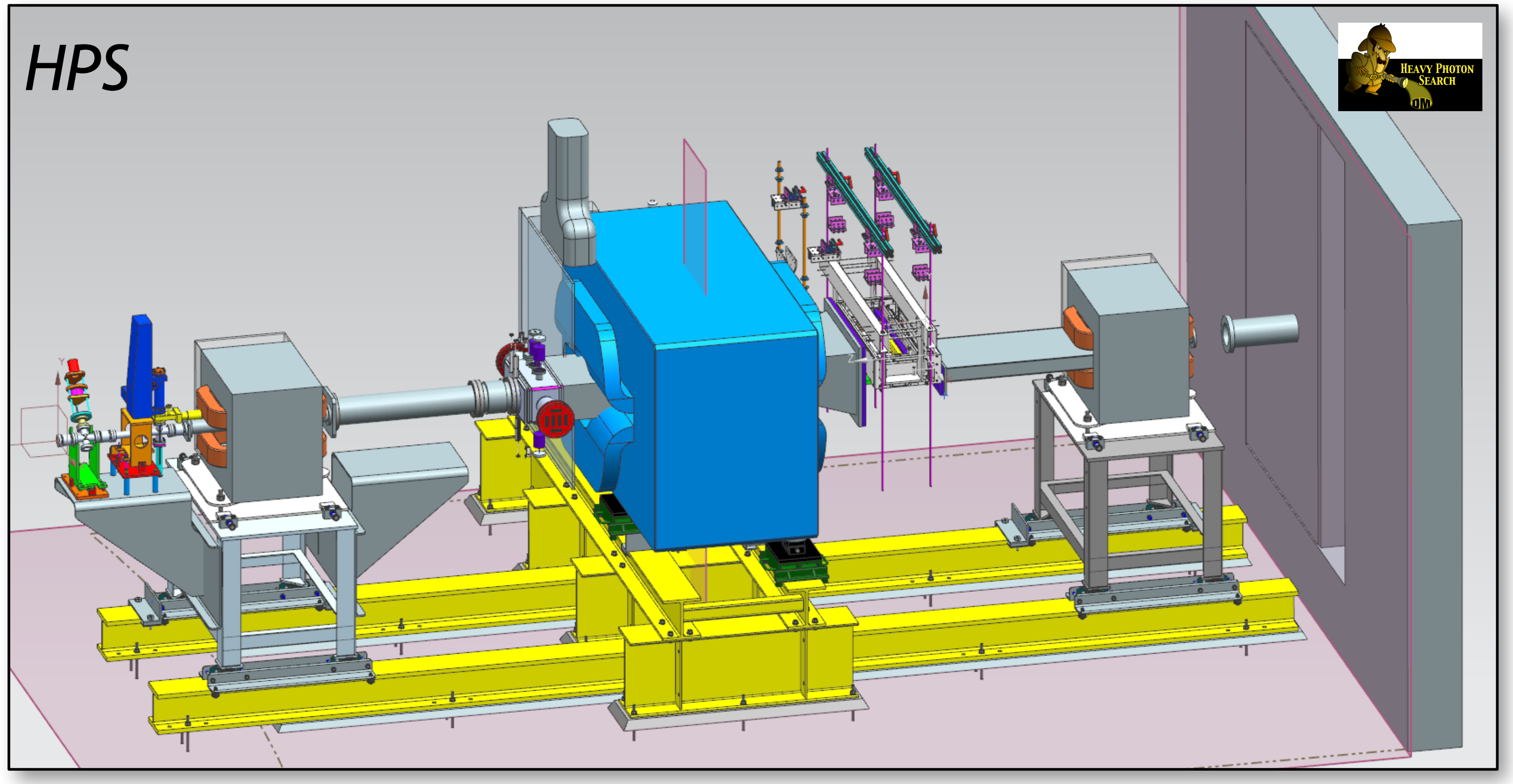
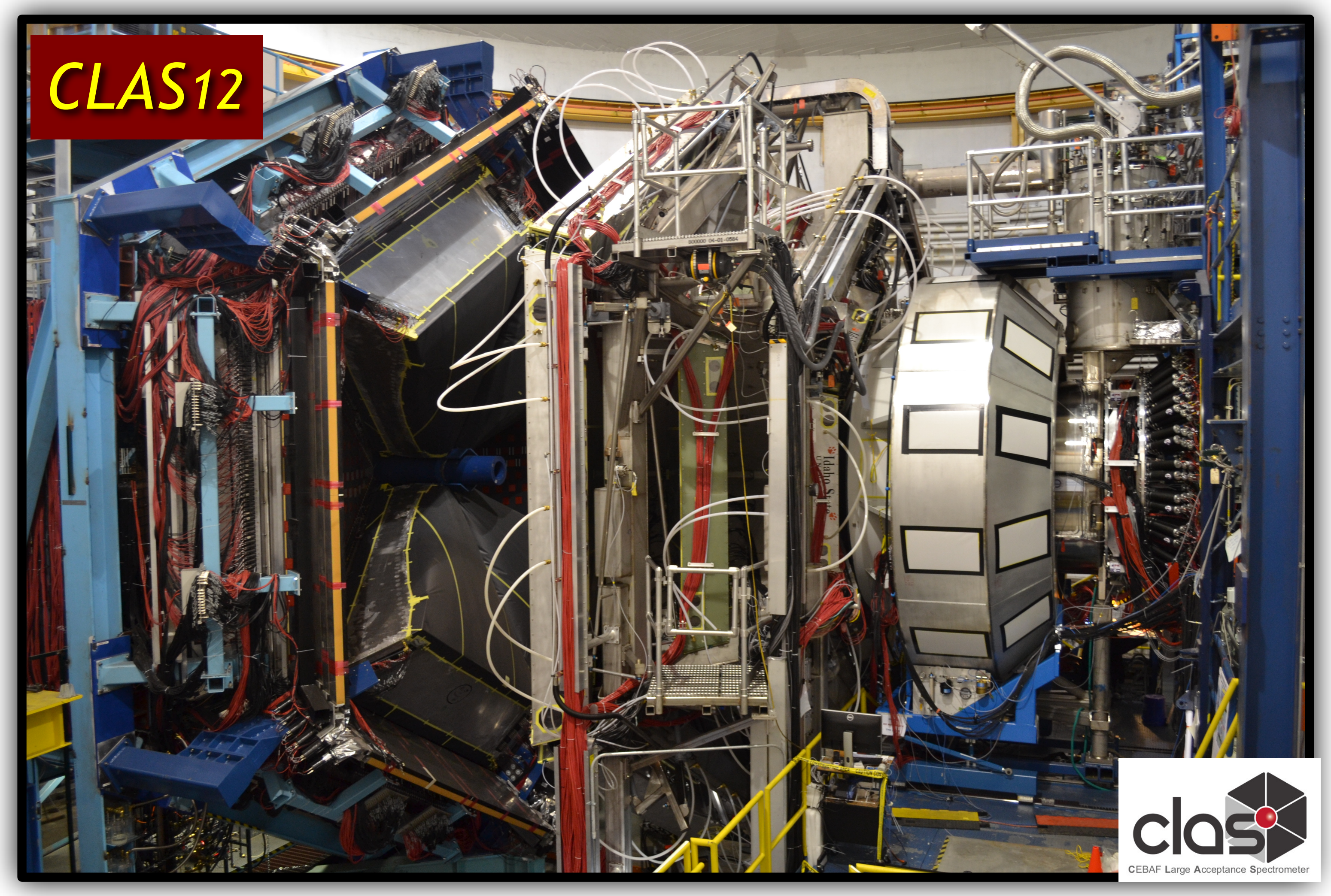
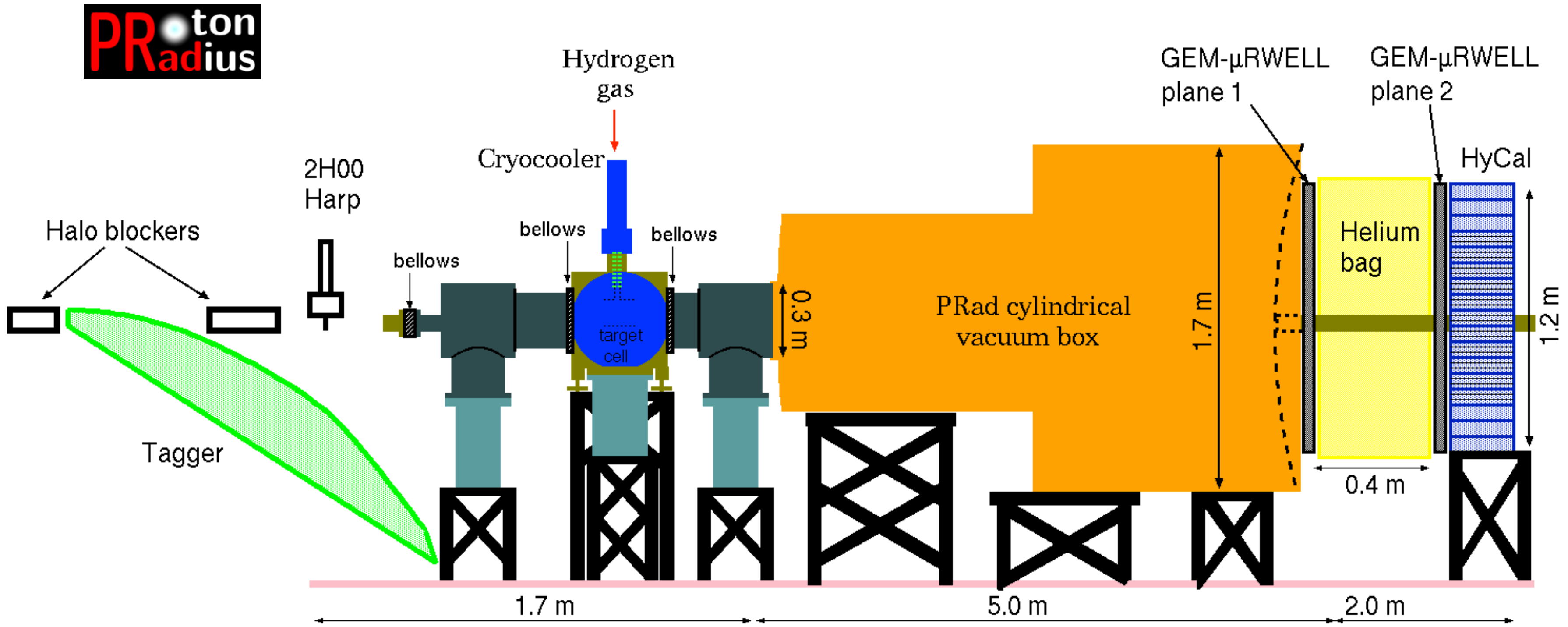






CLAS Collaboration Meeting
Mar 2-5, 2021

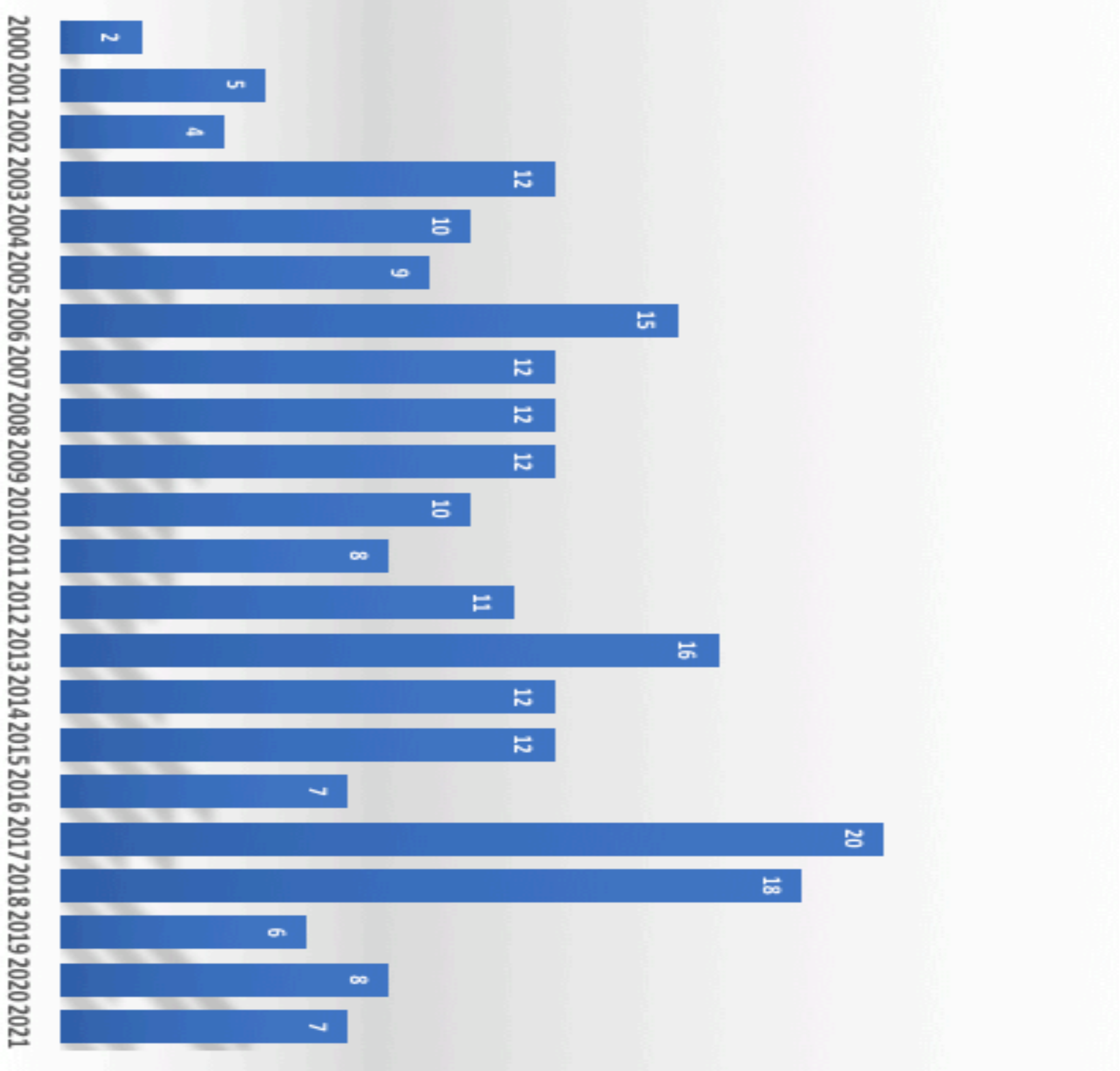
Status of Hall B

Marco Battaglieri
Jefferson Lab

Refereed Physics Publications

Hall B

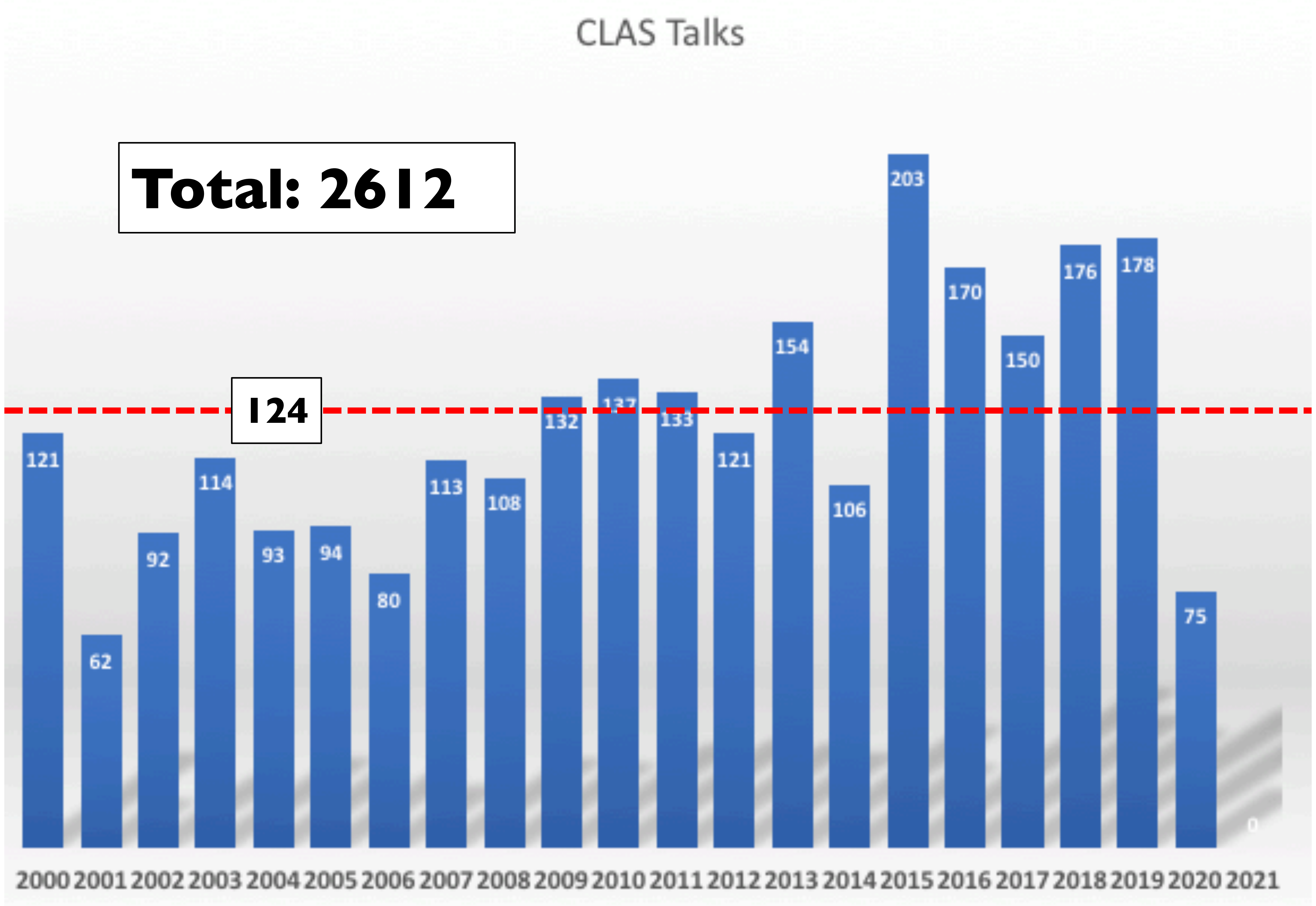
	Spectroscopy	Hard Scattering	Nuclear	ALL
2000		1	1	2
2001	2	3		5
2002	3		1	4
2003	7	4	1	12
2004	3	3	4	10
2005	7	3	2	9
2006	8	4	3	15
2007	7	2	3	12
2008	4	6	2	12
2009	8	7	4	12
2010	4	2	4	10
2011	3	1	4	8
2012	6	3	2	11
2013	8	6	2	16
2014	5	6	1	12
2015	4	5	3	12
2016	7			7
2017	12	7	1	20
2018	10	6	2	18
2019	1	2	3	6
2020	5	1	2	8
2021	2	4	1	7
SUM	116	66	46	228



- +1 CLAS paper submitted to Nature
- **2 CLAS12 papers submitted to PRL**

updated 03/01/2021

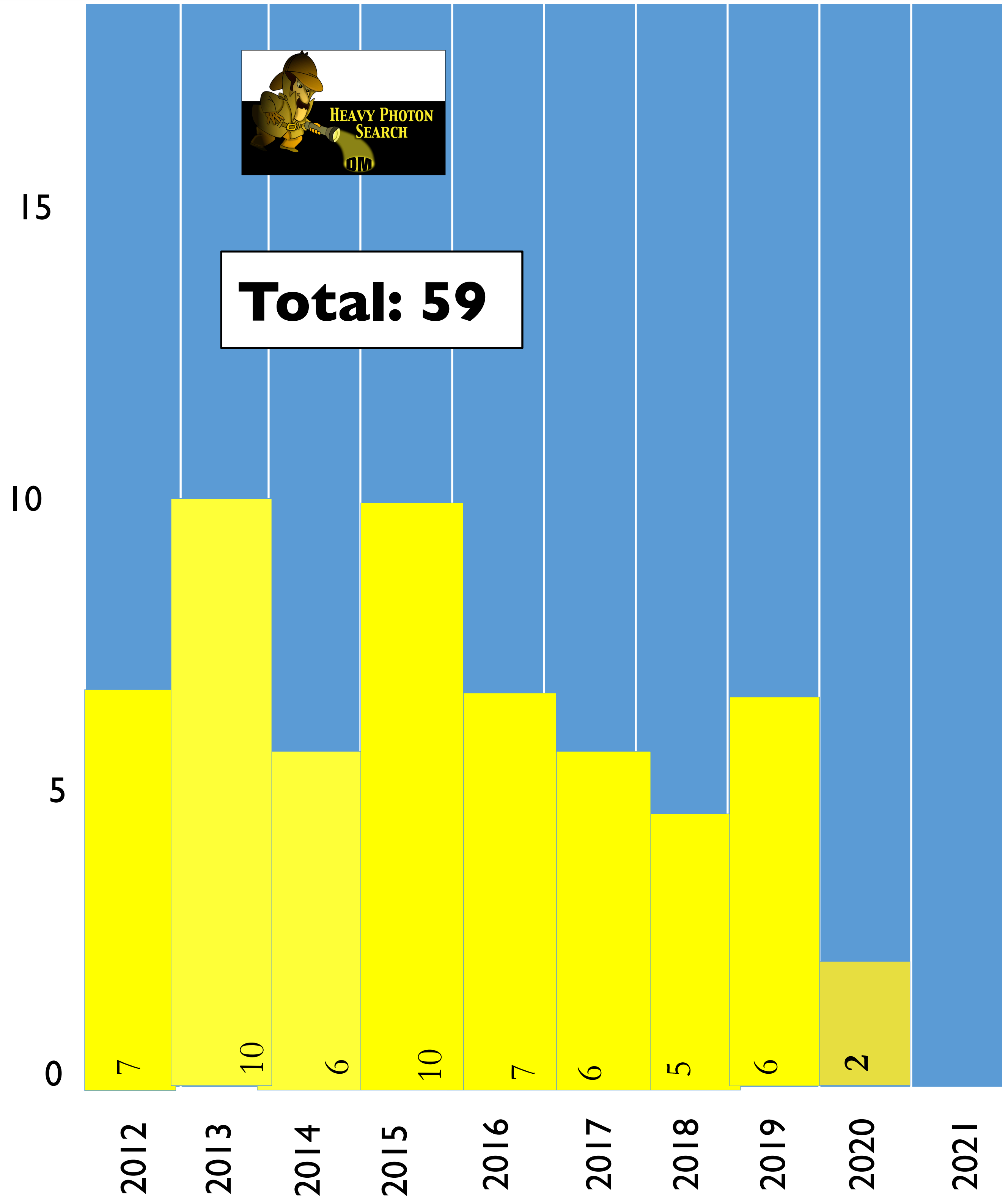
Conference Presentations

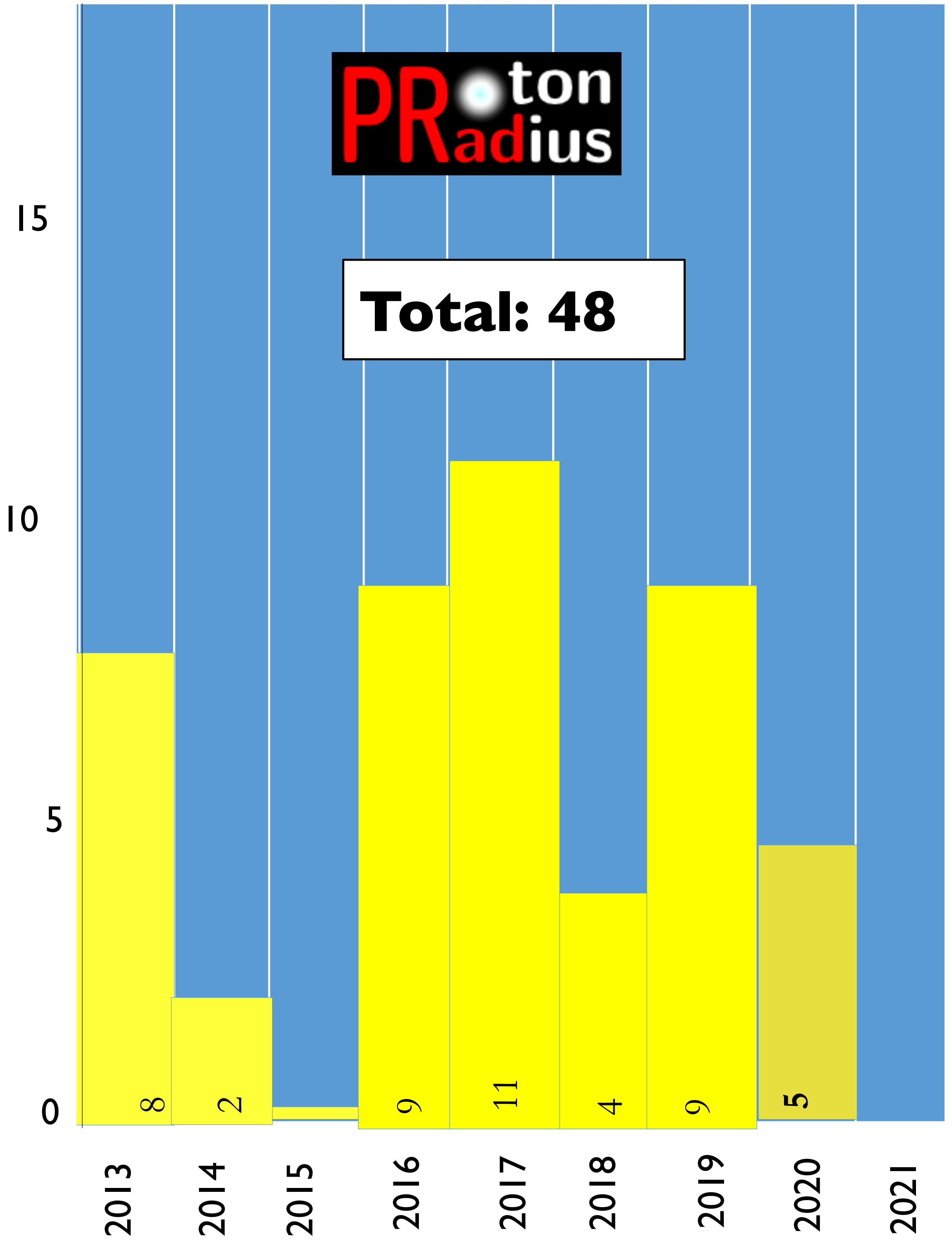


Source: CSC
updated March 1 2021

Conference Presentations

Hall B





Source: HPS & PRAD wiki

updated March 1 2021

Hall B highlights

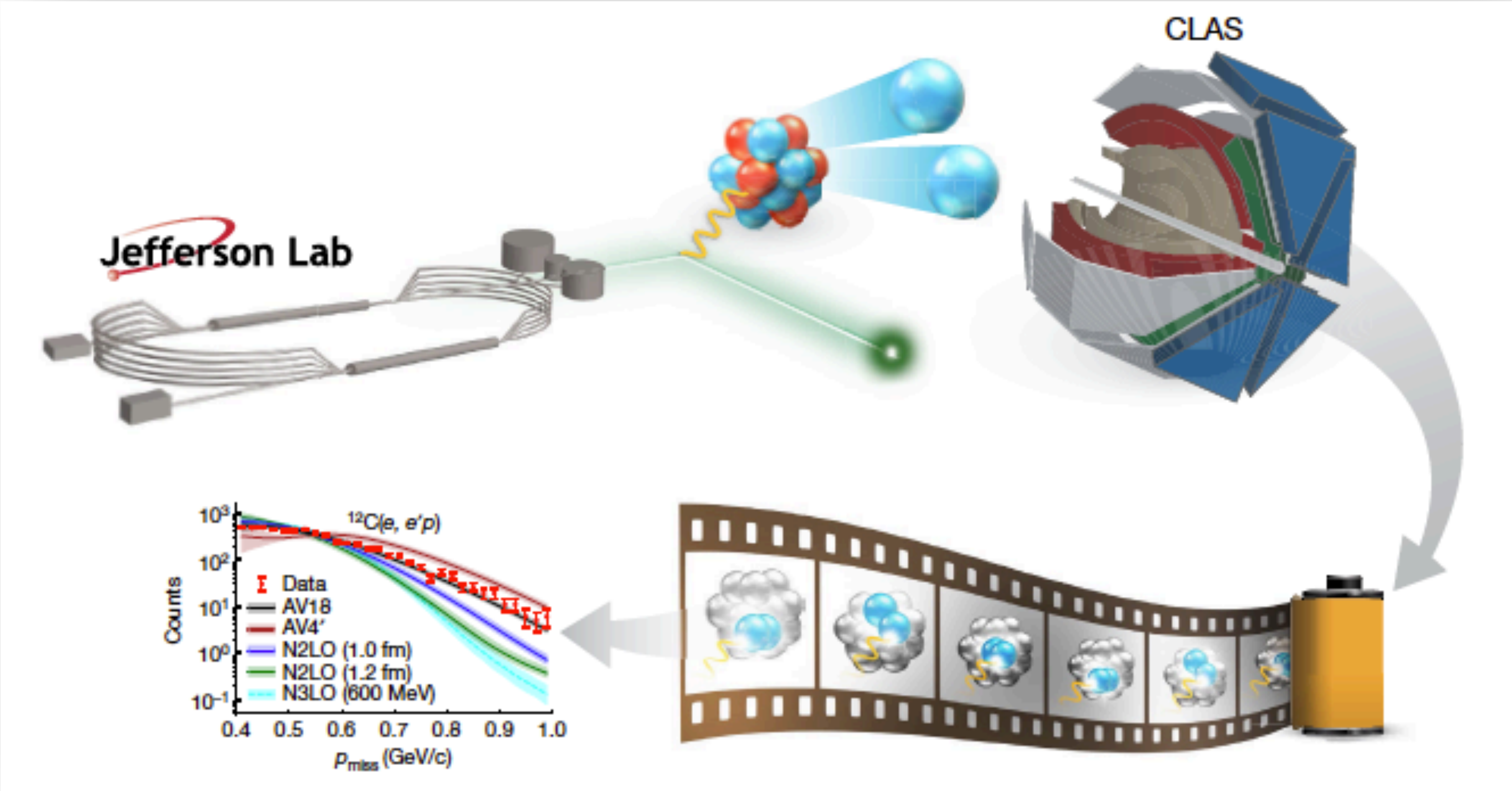
- **CLAS12 physics runs:**
  - RG-A (13 proposals,139 PAC days) - partial -
  - RG-K (3 proposals, 100 PAC days) - partial -
  - RG-B (7 proposals, 90 PAC days) - partial -
  - RG-F (BONUS, 42 PAC days) - concluded -

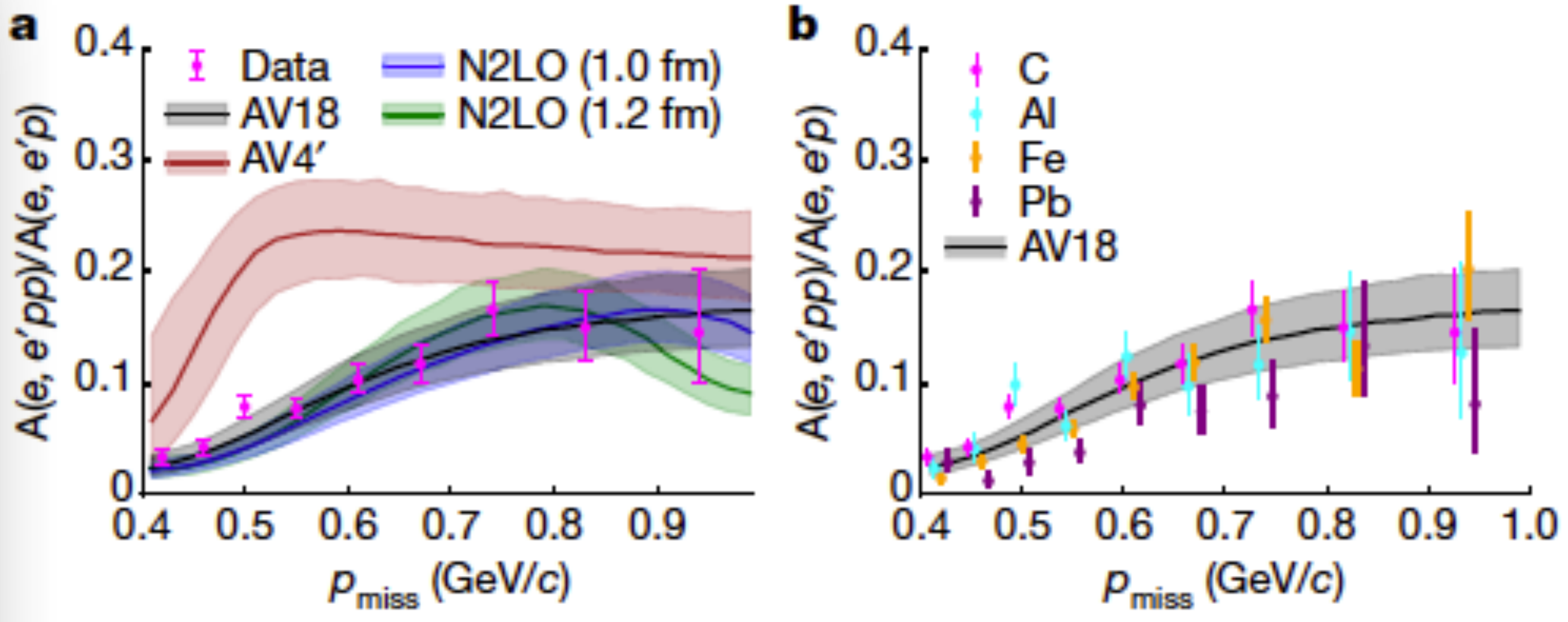
- **Continued flow of results from Hall B (CLAS+PRAD+HPS+PRIMEX..)**
  - ~ 230 physics papers in peer reviewed journals (> 14,000 citations)
  - 4 papers in **Nature** (+1 Nature Phys.), 1 paper in **Science**
  - >2,600 conference talks (~1,660 invited)

- **Specialized Hall B experiments**
  - PRAD experiment – results published in **Nature**
  - PRIMEX - results published in **Science**
  - Heavy Photon Search

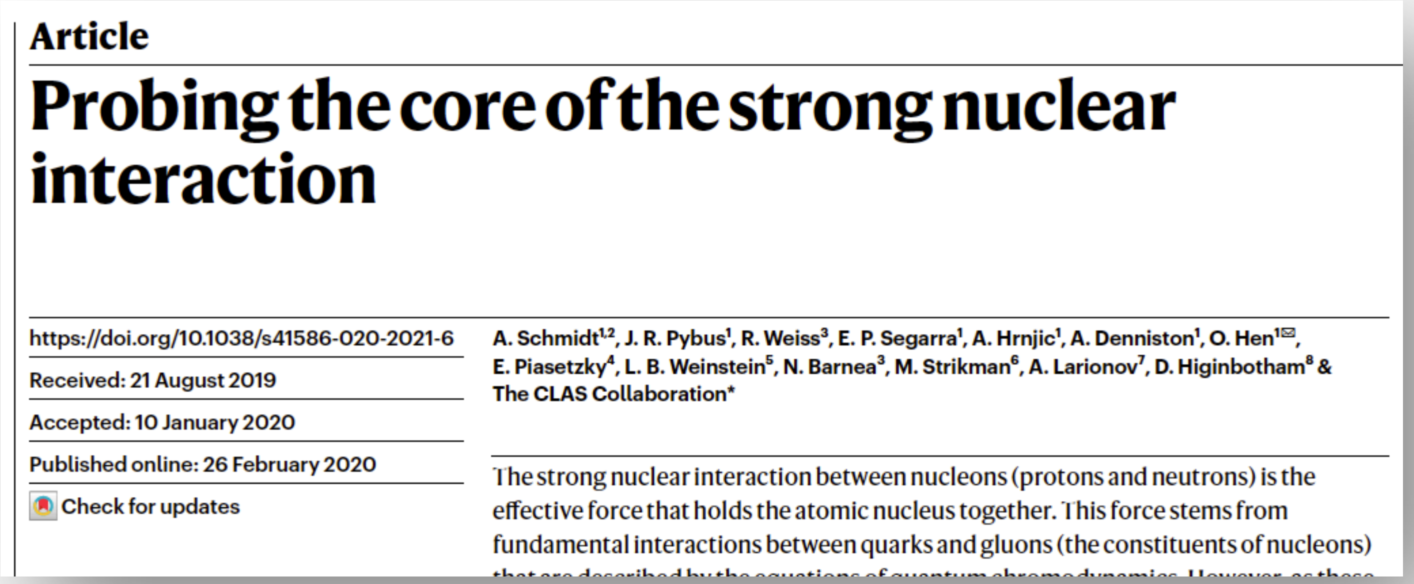
Nuclear interaction via e-scattering

Hall B





Nature **volume 578**, pages 540-544 (2020)



Article

Probing the core of the strong nuclear interaction

https://doi.org/10.1038/s41586-020-2021-6

Received: 21 August 2019

Accepted: 10 January 2020

Published online: 26 February 2020

Check for updates

A. Schmidt[1,2], J. R. Pybus[1], R. Weiss[3], E. P. Segarra[1], A. Hrnjic[1], A. Denniston[1], O. Hen[1✉], E. Piasetzky[4], L. B. Weinstein[5], N. Barnea[3], M. Strikman[6], A. Larionov[7], D. Higinbotham[8] & The CLAS Collaboration*

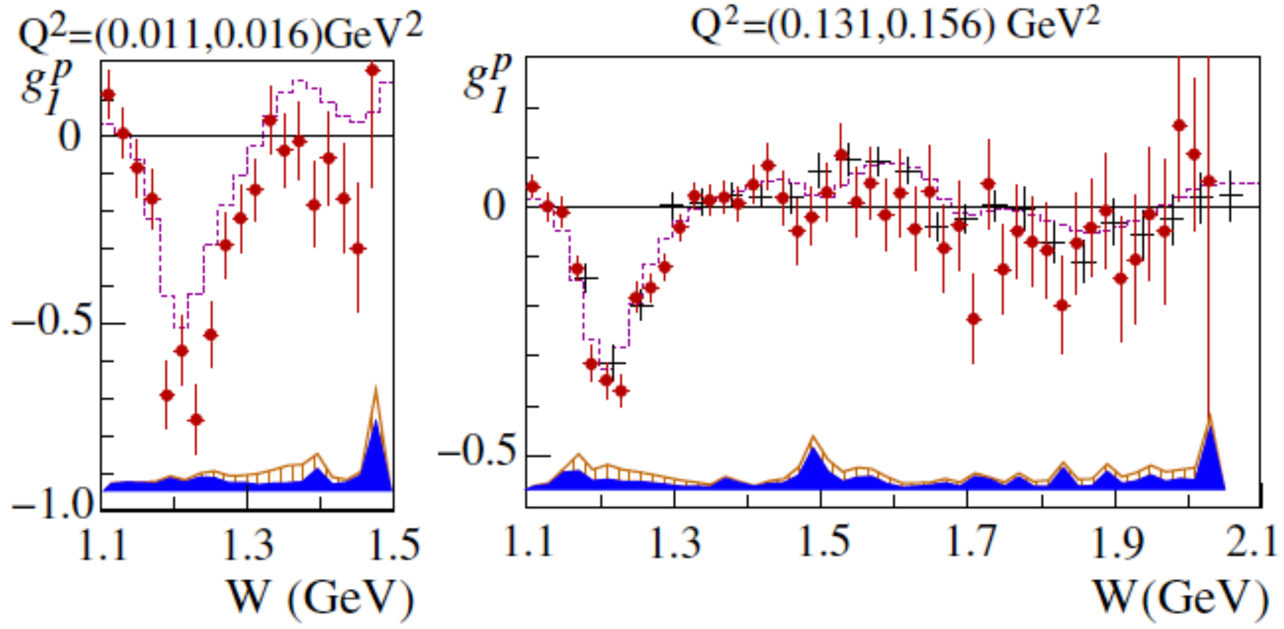
The strong nuclear interaction between nucleons (protons and neutrons) is the effective force that holds the atomic nucleus together. This force stems from fundamental interactions between quarks and gluons (the constituents of nucleons)

- CLAS6 data mining activity
- Electron-nucleus scattering to test nuclear interaction
- Short range correlations up to 400 MeV/c (relative p)
- Transition from spin-dependent tensor force to spin-independent scalar force
- Access to nuclear force in extreme conditions (neutron stars)

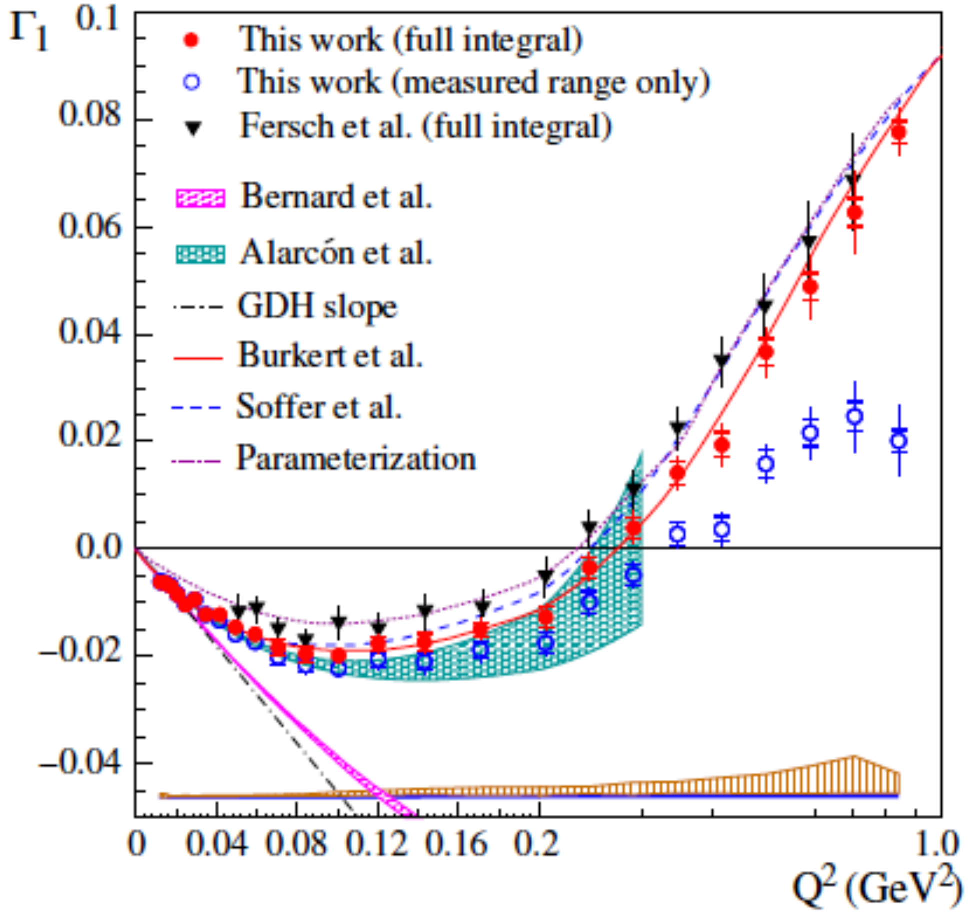
EG4 results

Measurement of the proton spin structure at long distances

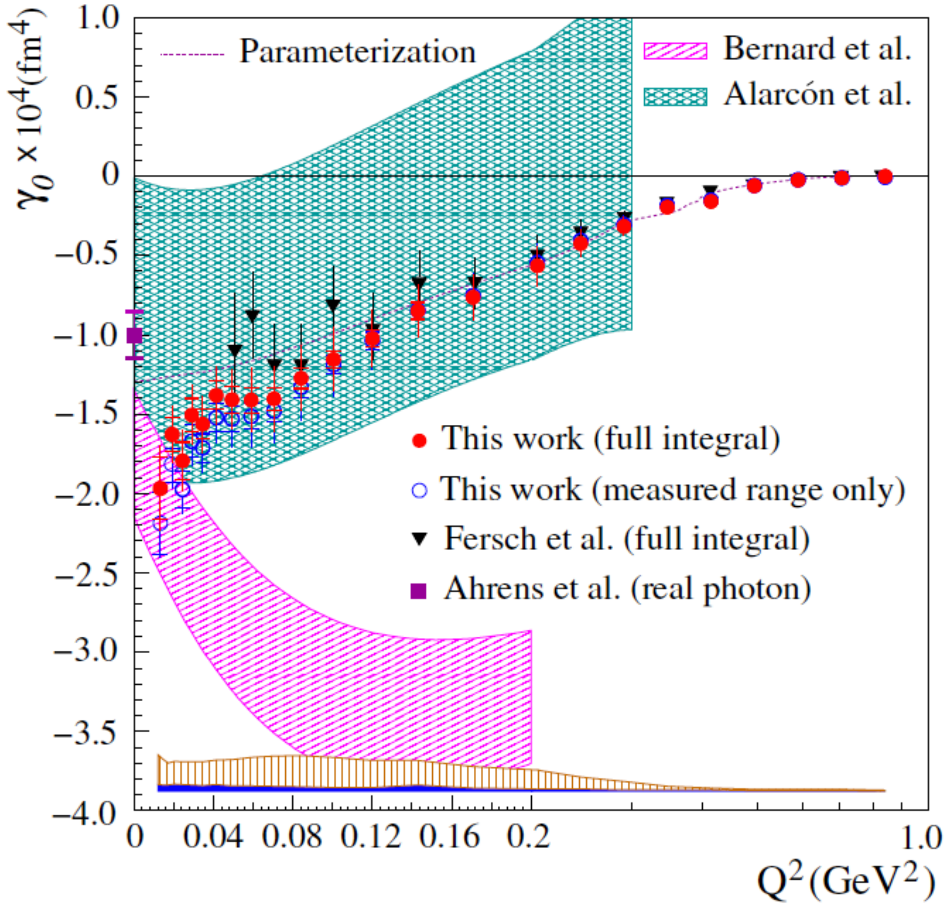
- Lattice or EFT to describe QCD at long distances (non-perturbative). Spin observables can challenge XEFT, widely used to describe other observables
- Spin-dependent xsection in nucleon resonance region at very low Q2: E=1.1GeV - 3.0 GeV, NH3 DNP (longitudinal) target PT~75%-90% + P_{Beam}~85% + e' in CLAS



$$I(Q^2) = \frac{2M^2}{Q^2}\int_0^{x_0}\left[A_1(x,Q^2)F_1(x,Q^2)\right]dx,$$



$$\gamma_0(Q^2) = \frac{16\alpha M^2}{Q^6}\int_0^{x_0} x^2 A_1(x,Q^2)F_1(x,Q^2)dx.$$



To be published in Nature Physics

- Good agreement with phenomenological model
- XEFT are reasonably in agreement but room to improve the theory with new CLAS data
- Theory fails to reproduce the generalised longitudinal spin polarisability γ_0(Q2) (interpreted as nucleon spin-dependent response to virtual photon)
- In XPT the main contributions are: p-π cloud and Δ excitation (opposite sign). Data indicate Δ dominance at low Q2 while the π cloud gets suppressed by Q2

Physics Analyses

- Finishing the analysis of 2016 data:
  - the resonance search analyses are reviewed and approved
  - the review of the vertexing analysis will be concluded soon
- Most of the calibrations and alignment work for 2019 data are done
- Getting ready for a "pass-0" production
- While no publications, in 2020 three theses completed

2020 Summer run preparation

- Scheduled for 54 days (27 PAC days), starting in mid August
- Mostly the previous detector with few changes:
  - new FEBs
  - new L0 and L1 sensors
  - replacing the collimator

  and repairs (SVT, ECal and hodoscope) and upgrades (DAQ and DQM)

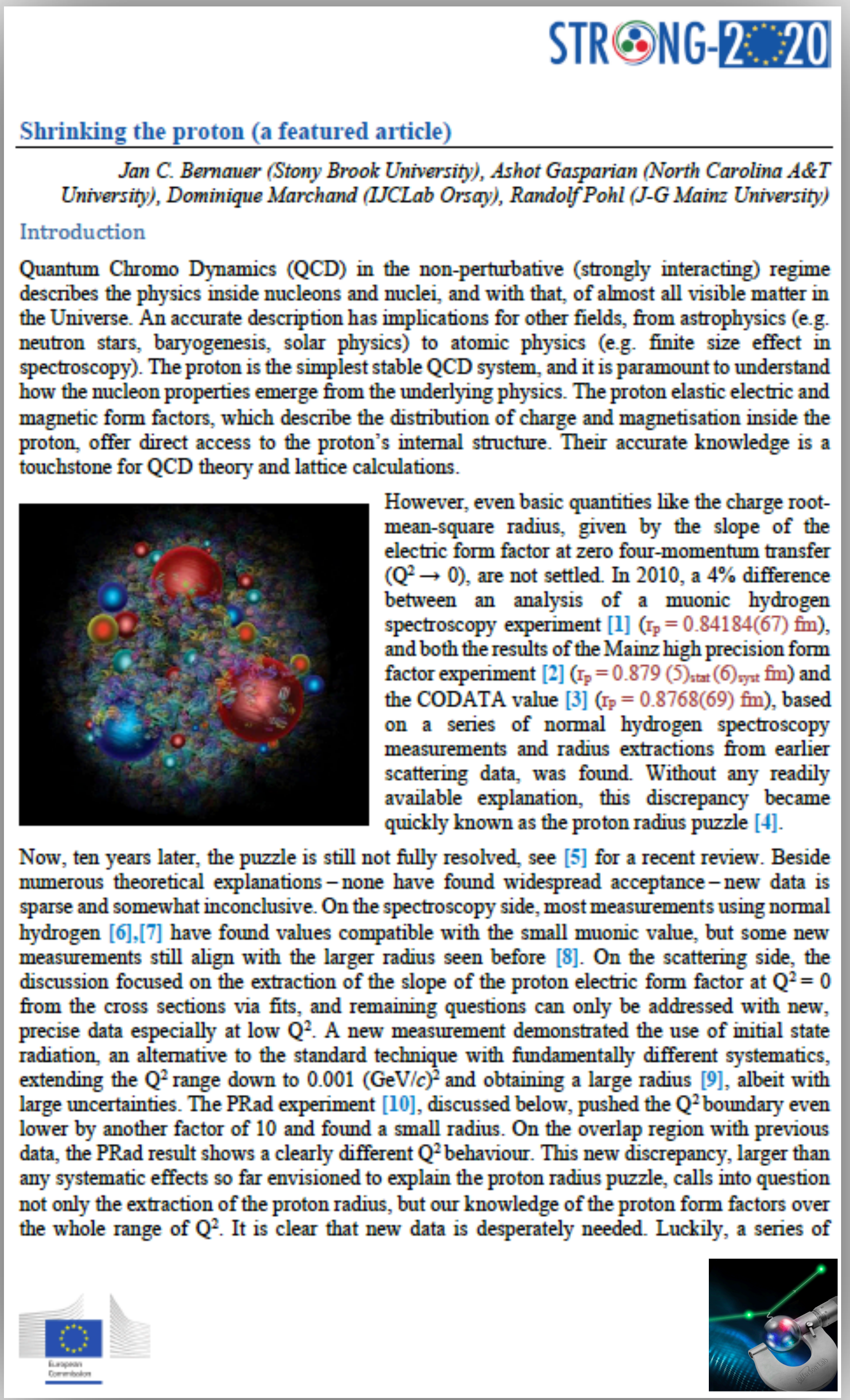
- SVT to be moved to the clean room for repairs, the schedule depends on the travel restrictions due to the pandemic
- Similarly, shifts scheduling will depend on the allowed travels (a large number of oversees collaborators), looking into remotes shift taking (have some experience from the past run for running SVT)

Credit: S.Stepanyan

Proton Charge Radius

Hall B

PRad-II: a new and upgraded version of PRad-I. Awarded by PAC48 with A scientific rating (40 PAC days) with C-1 condition to remeasure the Proton Radius with a factor of 4 times better than PRad



STRONG-2020

Shrinking the proton (a featured article)

Jan C. Bernauer (Stony Brook University), Ashot Gasparian (North Carolina A&T University), Dominique Marchand (IJCLab Orsay), Randolf Pohl (J-G Mainz University)

Introduction

Quantum Chromo Dynamics (QCD) in the non-perturbative (strongly interacting) regime describes the physics inside nucleons and nuclei, and with that, of almost all visible matter in the Universe. An accurate description has implications for other fields, from astrophysics (e.g. neutron stars, baryogenesis, solar physics) to atomic physics (e.g. finite size effect in spectroscopy). The proton is the simplest stable QCD system, and it is paramount to understand how the nucleon properties emerge from the underlying physics. The proton elastic electric and magnetic form factors, which describe the distribution of charge and magnetisation inside the proton, offer direct access to the proton's internal structure. Their accurate knowledge is a touchstone for QCD theory and lattice calculations.

However, even basic quantities like the charge root-mean-square radius, given by the slope of the electric form factor at zero four-momentum transfer ($Q^2 \rightarrow 0$), are not settled. In 2010, a 4% difference between an analysis of a muonic hydrogen spectroscopy experiment [1] ($r_p = 0.84184(67)$ fm), and both the results of the Mainz high precision form factor experiment [2] ($r_p = 0.879\,(5)_{stat}\,(6)_{syst}$ fm) and the CODATA value [3] ($r_p = 0.8768(69)$ fm), based on a series of normal hydrogen spectroscopy measurements and radius extractions from earlier scattering data, was found. Without any readily available explanation, this discrepancy became quickly known as the proton radius puzzle [4].

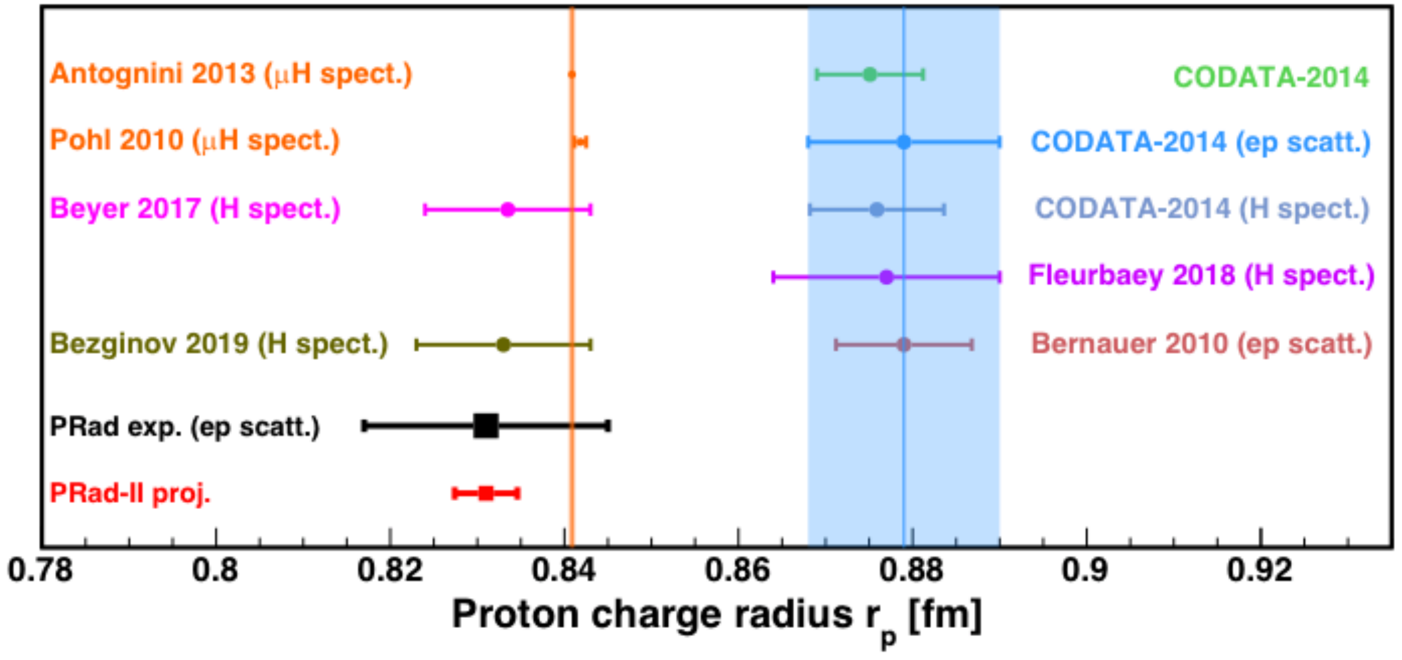
Now, ten years later, the puzzle is still not fully resolved, see [5] for a recent review. Beside numerous theoretical explanations – none have found widespread acceptance – new data is sparse and somewhat inconclusive. On the spectroscopy side, most measurements using normal hydrogen [6],[7] have found values compatible with the small muonic value, but some new measurements still align with the larger radius seen before [8]. On the scattering side, the discussion focused on the extraction of the slope of the proton electric form factor at $Q^2 = 0$ from the cross sections via fits, and remaining questions can only be addressed with new, precise data especially at low Q^2. A new measurement demonstrated the use of initial state radiation, an alternative to the standard technique with fundamentally different systematics, extending the Q^2 range down to 0.001 $(GeV/c)^2$ and obtaining a large radius [9], albeit with large uncertainties. The PRad experiment [10], discussed below, pushed the Q^2 boundary even lower by another factor of 10 and found a small radius. On the overlap region with previous data, the PRad result shows a clearly different Q^2 behaviour. This new discrepancy, larger than any systematic effects so far envisioned to explain the proton radius puzzle, calls into question not only the extraction of the proton radius, but our knowledge of the proton form factors over the whole range of Q^2. It is clear that new data is desperately needed. Luckily, a series of

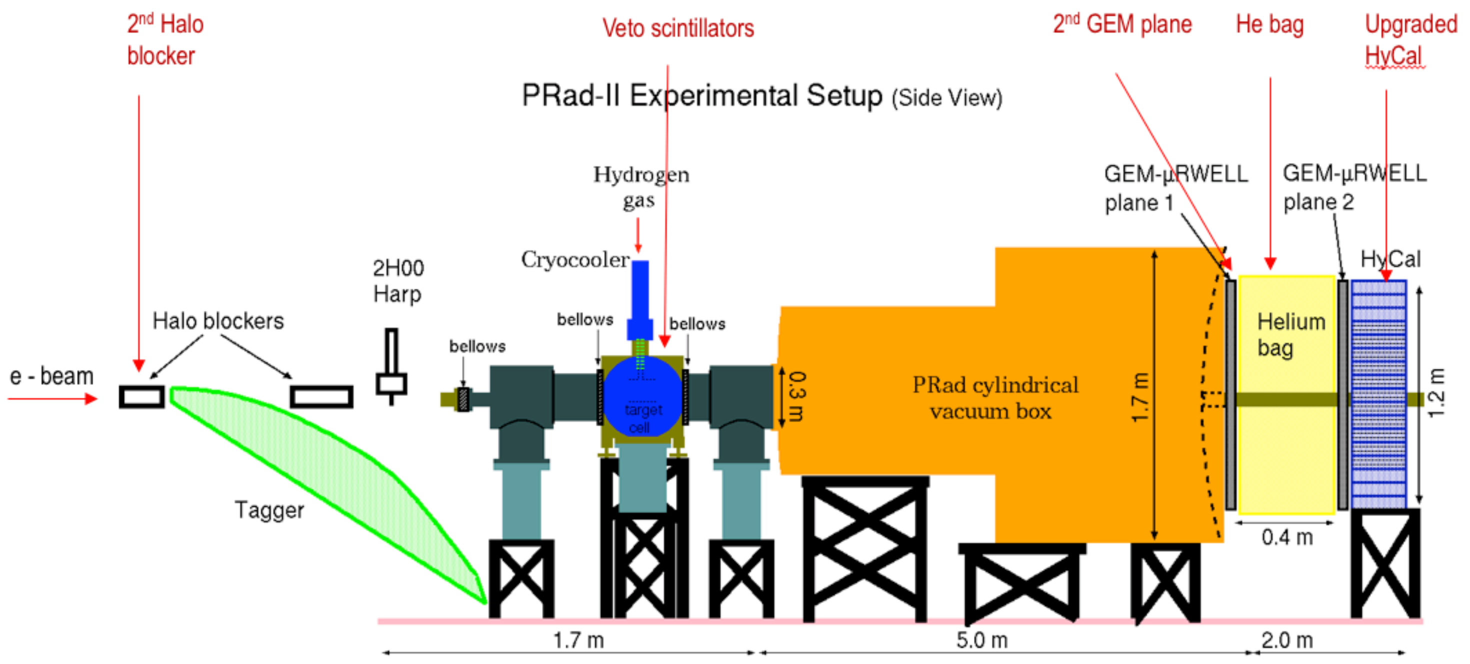
PRad-II

- A factor of 16 times more statistics;
- additional beam halo blocker before the Tagger magnet;
- small-size veto scintillators to reject the Moller events at very small scattering angles;
- 2 GEM planes for better tracking capabilities;
- upgrade HyCal to all $PbWO_4$ crystal based calorimeter for better subtraction of ep-inelastic contribution

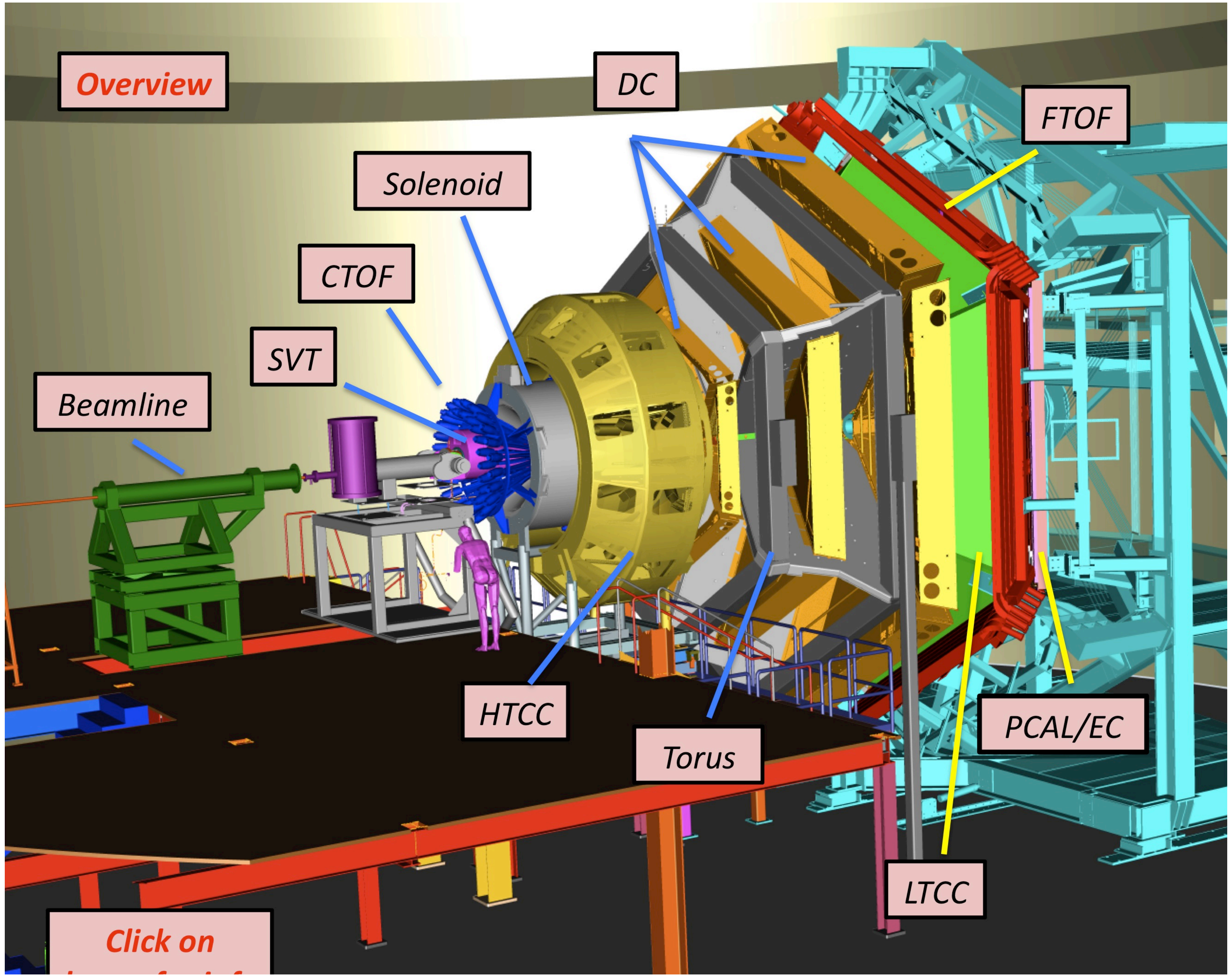
Status

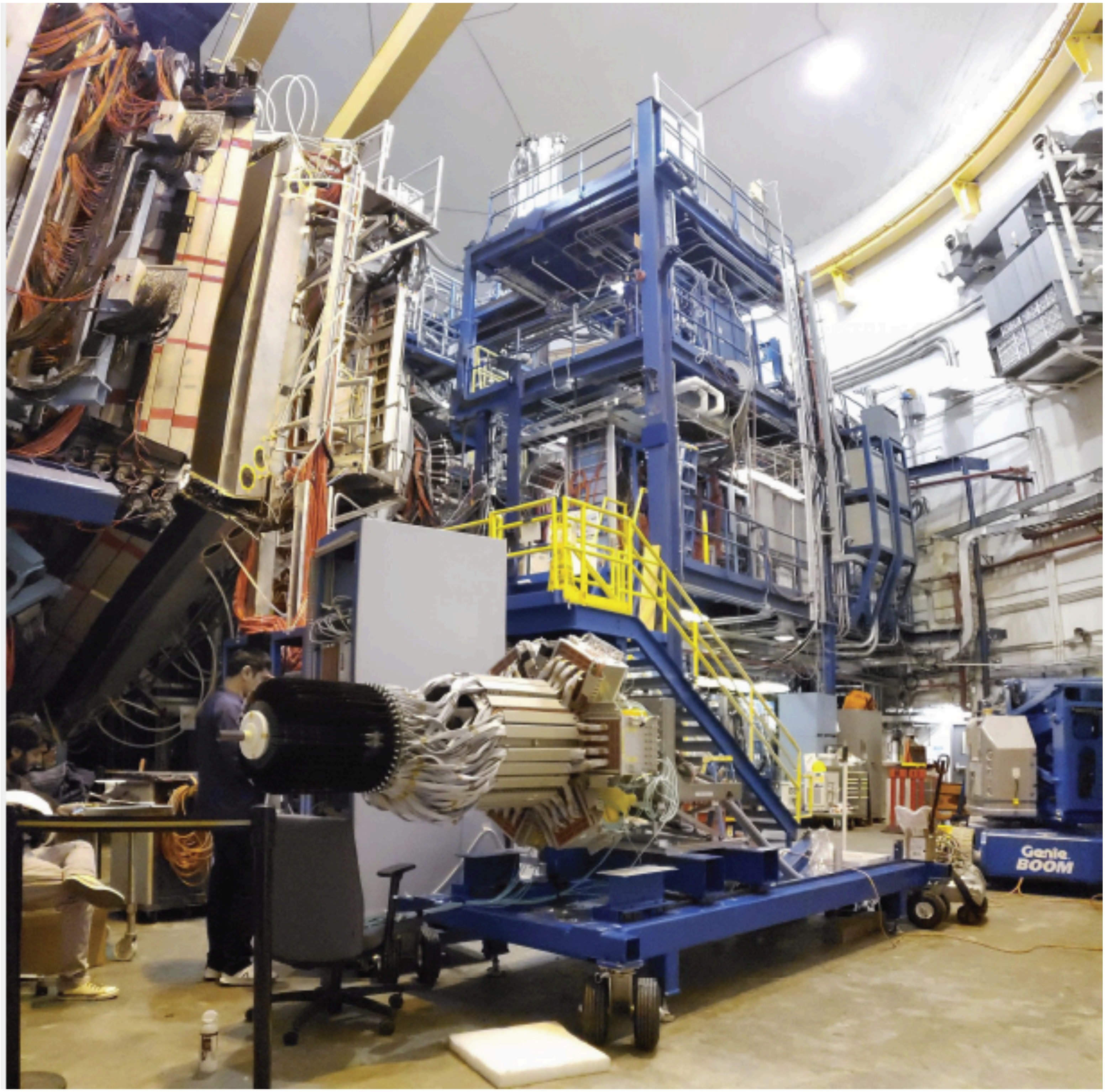
- PhysDiv C-1 Review is scheduled for March 12
- PRad Collaboration submitted NSF RI-1 pre-proposal to support the experimental setup upgrade
- Appointed a Hall-B Task Force (PI: S.Stepanyan) to support the C-1 Review preparation





Credit: A.Gasparyan


Overview
DC
FTOF
Solenoid
CTOF
SVT
Beamline
HTCC
Torus
PCAL/EC
LTCC
Click on


Genie BOOM

CLAS12 data taking

- from Feb 2017 (KPP) to Summer 2020 (physics runs)

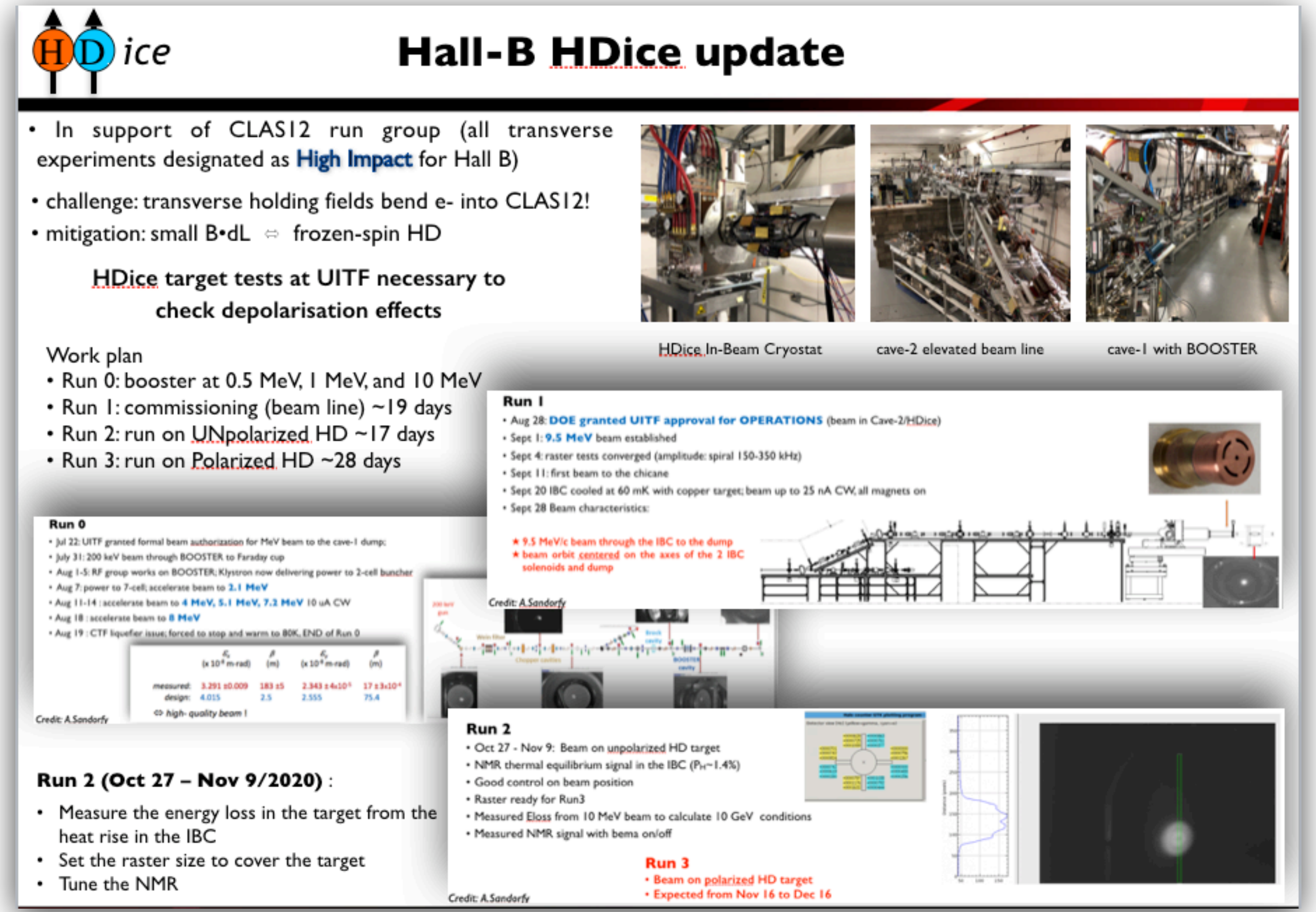
– **Run Group A**:
- 13 experiments
- 10.2-10.6 GeV polarized electrons
- Liquid-hydrogen target
- ~300 mC, ~50% of approved beam time

– **Run Group K**:
- 3 experiments
- 6.5, 7.5 GeV polarized electrons
- Liquid-hydrogen target
- ~45 mC, ~12% of approved beam time

– **Run Group B**:
- 7 experiments
- 10.2-10.5 GeV polarized electrons
- Liquid-deuterium target
- ~155 mC, ~43% of approved beam time

– **Run Group F (BONUS)**:
- 1 experiment
- 10.2 GeV polarized electrons (+2.2 GeV for calibration)
- Gas-deuterium target +RTPC
- ~92% of approved beam time (Run concluded!)

– **Nuclear targets test (special run)**:
- 10.2 GeV electrons
- LD2, LHe and Pb targets
- 100% of scheduled time



Data processing

– **Run Group A**:
- 13 experiments
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- 3 experiments
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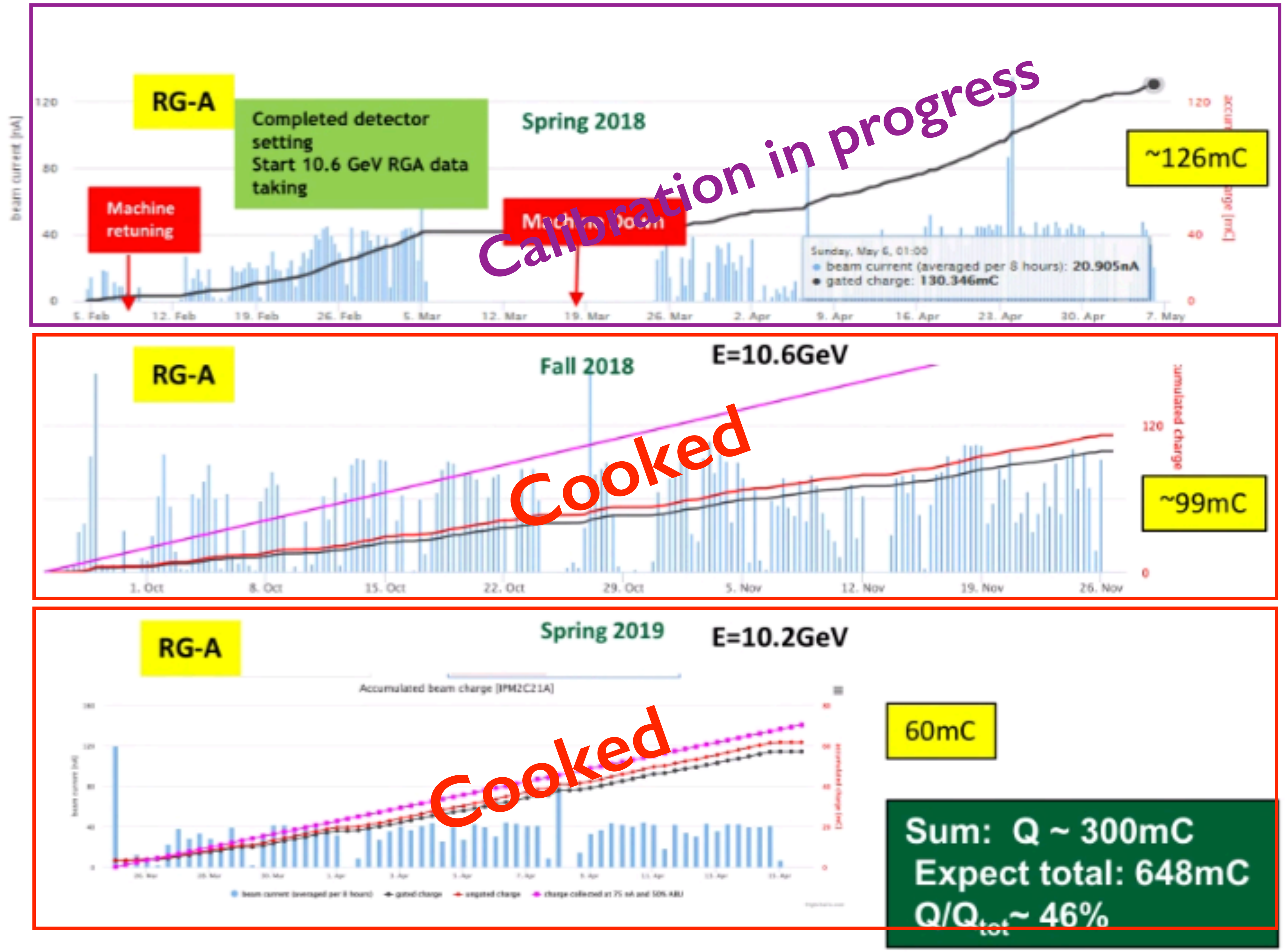

CLAS12 Data processing Hall B

– **Run Group A**:
- 13 experiments
- 10.2-10.6 GeV polarized electrons
- Liquid-hydrogen target
- ~300 mC, ~50% of approved beam time

– **Run Group K**:
- 3 experiments
- 6.5, 7.5 GeV polarized electrons
- Liquid-hydrogen target
- ~45 mC, ~12% of approved beam time

– **Run Group B**:
- 7 experiments
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– **Run Group F (BONUS)**:
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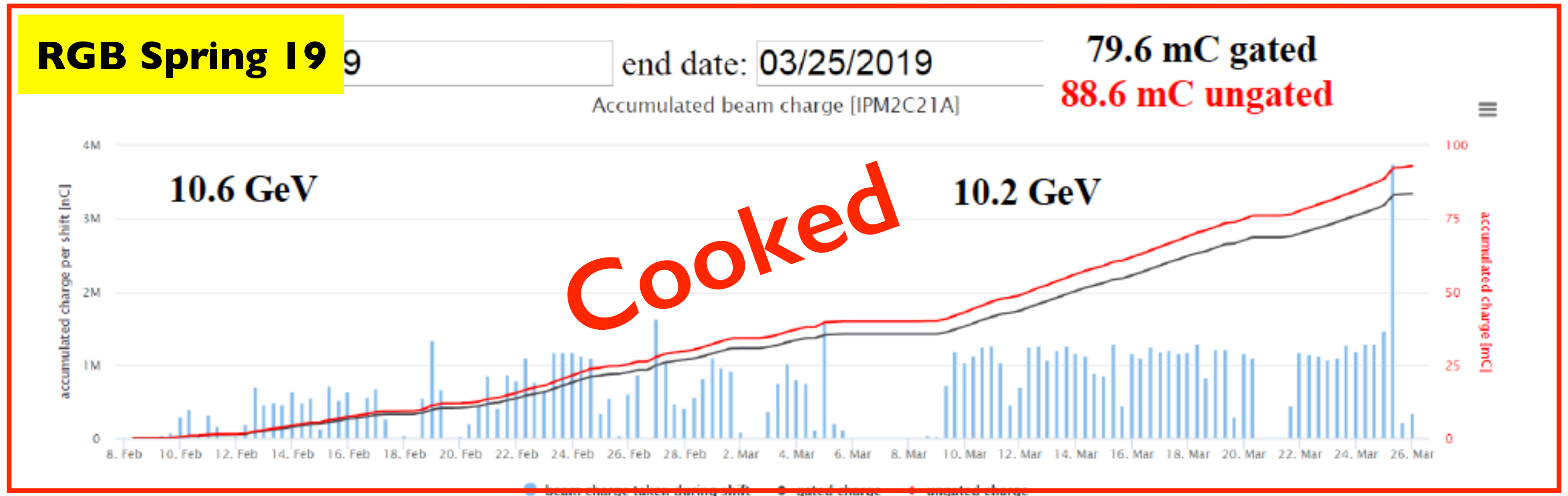
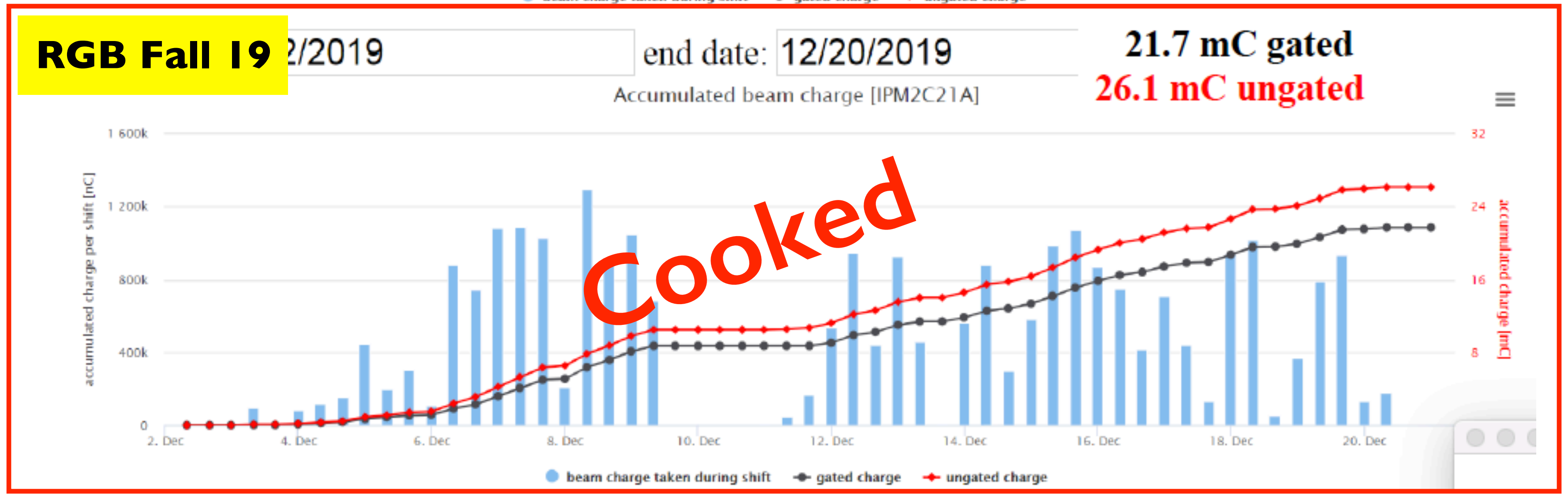
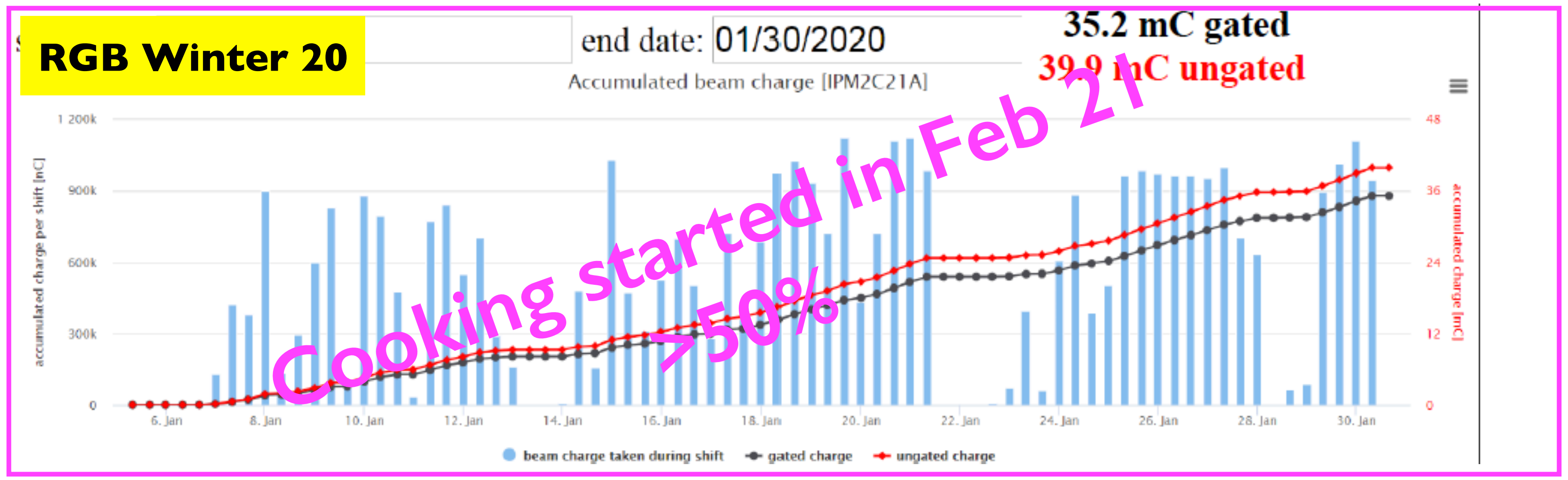
- Gas-deuterium target +RTPC
- ~92% of approved beam time







CLAS12 Data processing Hall B

– **Run Group A**:
- 13 experiments
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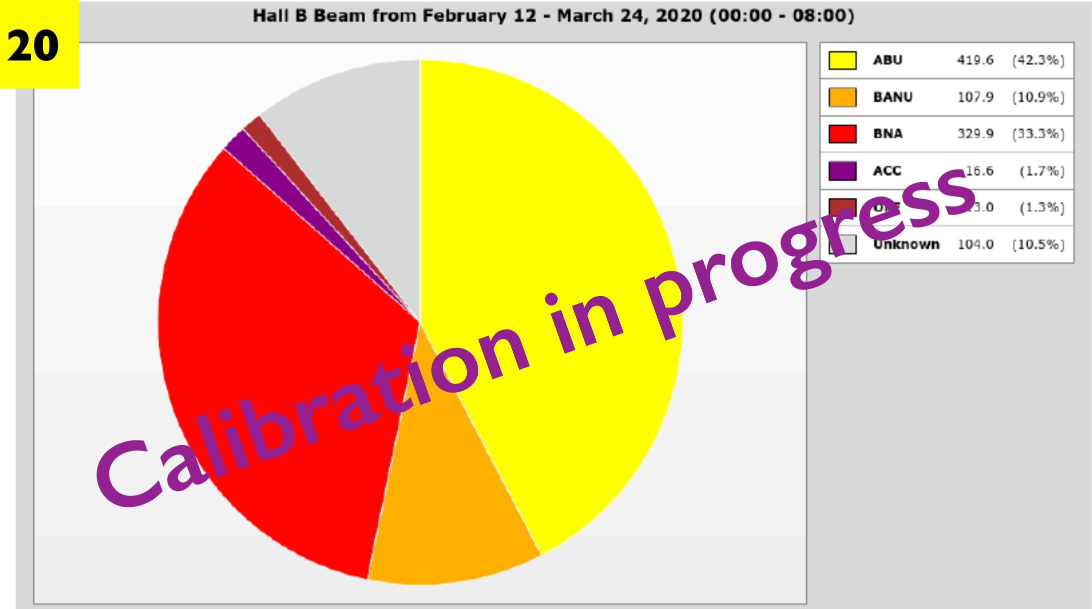
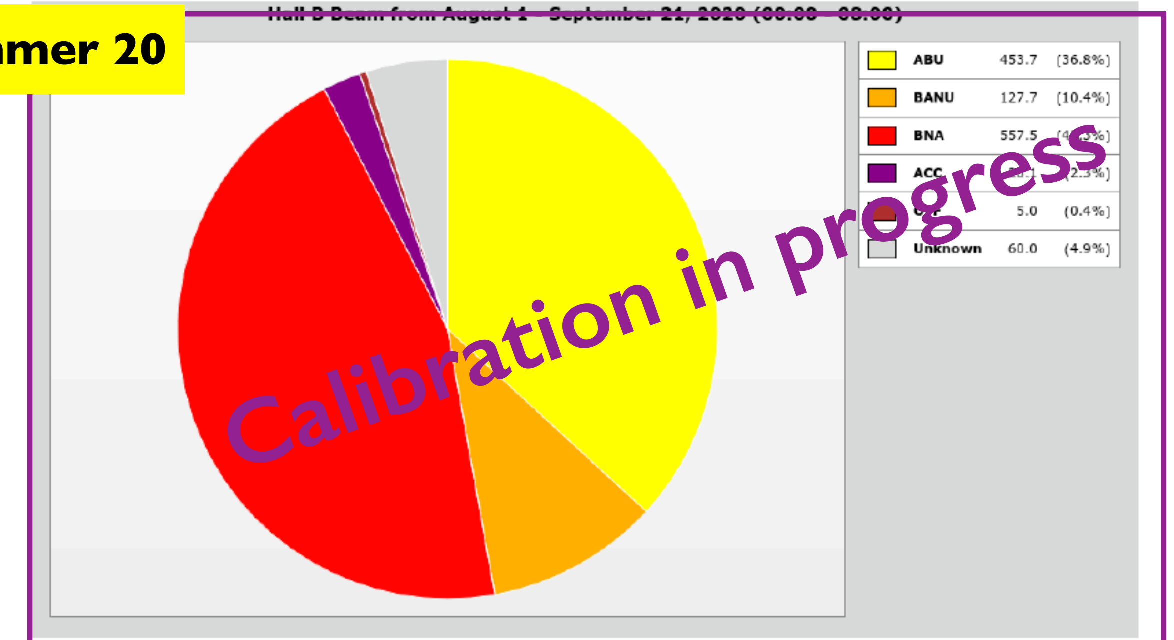
RGF Spring 20



- ABU: 17.5 PAC days (1 @ 1 pass, 16.5 @ 5 pass)
- BANU: RTPC1->RTPC3 Swap, Target gas changing and purging.
- 6 Moller runs (Avg. Beam Pol. = 84.3 ±1.5)

RGF Summer 20



- ABU: 19 PAC days (3 @ 1 pass, 16 @ 5 pass)
- BANU: Beamline exit window replacement, Target gas changing and purging.
- 8 Moller runs (Avg. Beam Pol. (%) = 83.1 ±1.5)

Data processing

	Calibration status	Cooking status	Timeline for completion
Run Group A: • 13 experiments • 10.2-10.6 GeV polarized electrons • Liquid-hydrogen target • ~300 mC, ~50% of approved beam time	In progress	60% done	Spring 18 calibration in progress
Run Group K: • 3 experiments • 6.5, 7.5 GeV polarized electrons • Liquid-hydrogen target • ~45 mC, ~12% of approved beam time	Completed	Fully cooked	-
Run Group B: • 7 experiments • 10.2-10.5 GeV polarized electrons • Liquid-deuterium target • ~155 mC, ~43% of approved beam time	Almost completed	90% cooked	-
Run Group F (BONUS): • 1 experiment • 10.2 GeV polarized electrons (+2.2 GeV for calibration) • Gas-deuterium target +RTPC • ~92% of approved beam time	In progress	-	Start cooking in as soon as calibrations are ready

Goal: complete the Pass1 reconstruction of the whole RGA/B(/F) data sets in the next couple of months to analyse the entire statistics available

Pass2 data rec preparation

- **Reprocessing of proton and deuteron target data with improved reconstruction, calibration, alignment and field map (including AI-supported algorithms)**
- **Involves already processed RGA, RGB and RGK data**
- **Provides improved data quality to enable maximum physics output**

Reconstruction:

Tracking (New CD tracking, covariance matrix tuning, AI-assisted tracking in FD, …)
Improvements to PID (e/pi separation, matching criteria, neutrals in CD, …)
Finalized RICH reconstruction
Updates of other packages

Calibration:

Improvements to detector calibrations (DC corrections to pressure dependence, …)

Alignment:

Central tracker alignment
RICH alignment
Explore improvements to FD alignment

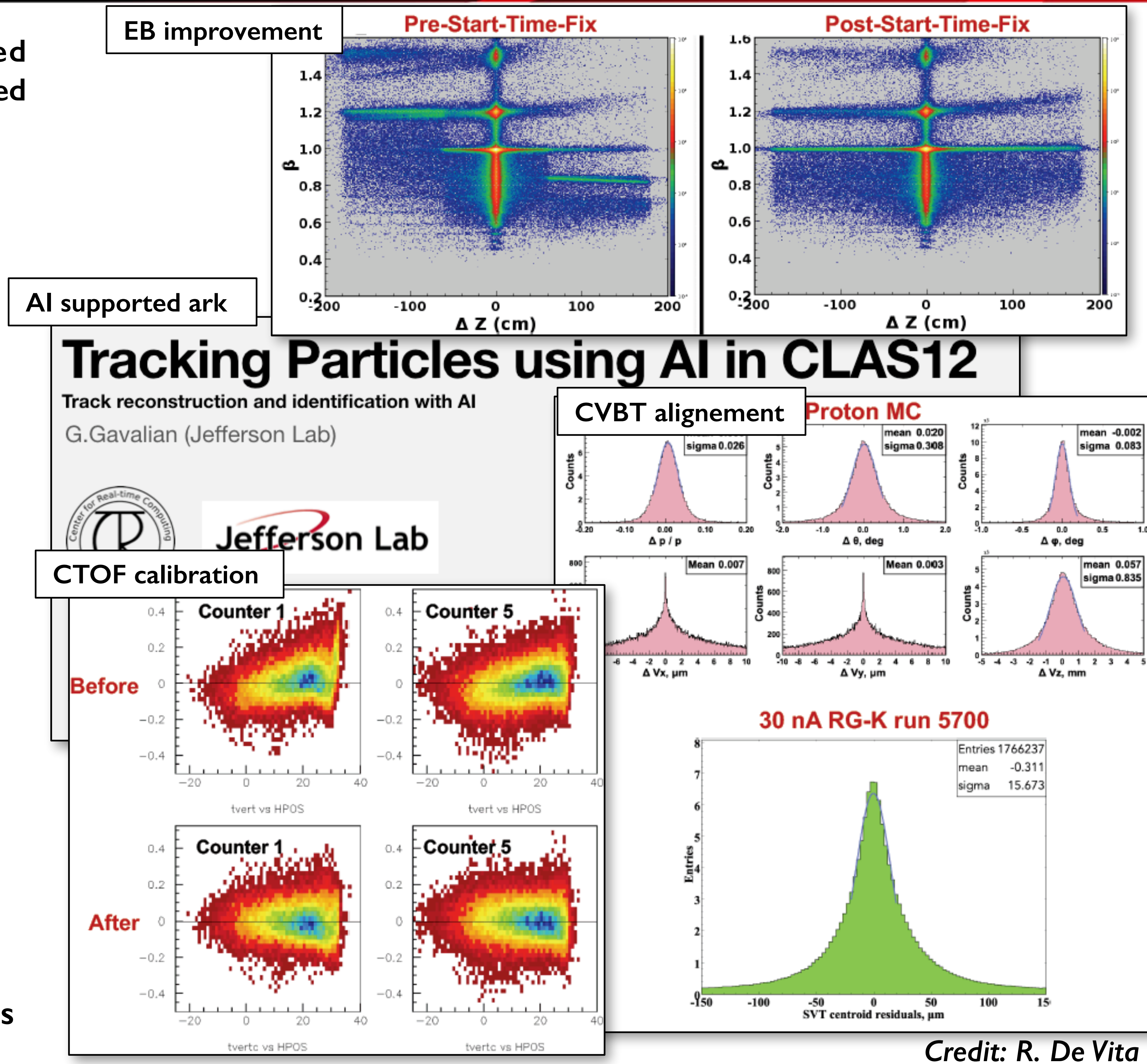
Field map:

Updated torus map based on coil full survey and field measurements

Significant progress toward pass2

- Several task already completed or close to completion
- Many in progress
- Good response to service work task offer

As soon as the new sw and calib release ready, work plan with RGs analysis coordinators, Pass1-2RR committee and CCC to discuss requests and priorities



Credit: R. De Vita

Data analysis

First multidimensional, high precision measurements of semi-inclusive π⁺ beam single spin asymmetries from the proton over a wide range of kinematics

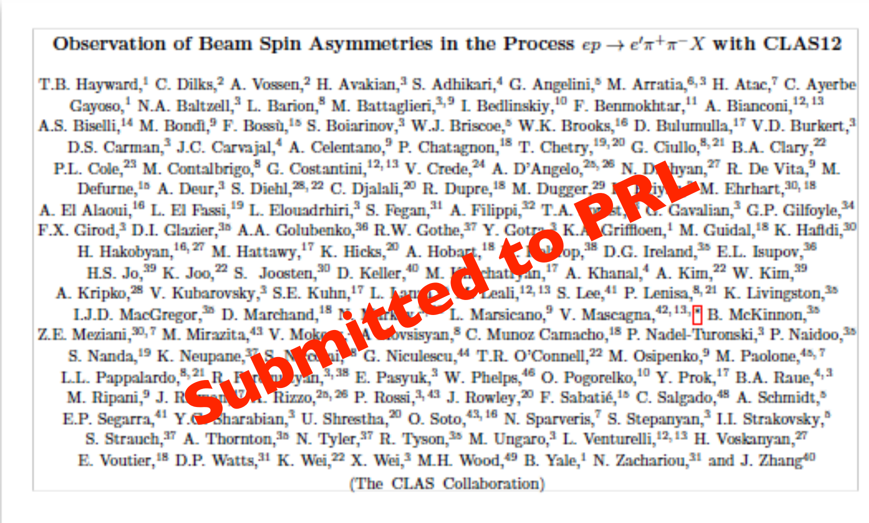
- So far, good mapping of 1D PDF (longitudinal momentum dependence)
- Are the q carrying an orbital angular momentum? how is it connected to the spin of the nucleon? q correlations?
- 3-D structure accessed trough Transverse Momentum dep. Distributions (TMDs)
- Semi Inclusive DIS (SIDIS) to study the transverse structure of the nucleon
- Single Spin Asymmetries (SSA) sensitive to TMDs and Fragmentation Functions (FF)
- Beam SSA: twist-3, subleading, O(M/Q), accessible in fixed target, medium energy (~10 GeV) experiments

★ First multi-D measurement over a wide kinematic range
★ Extraction of Collins and TMD functions

First Observation of Beam Spin Asymmetries in the Process e p → e' π⁺ π⁻ X with CLAS12

- SIDIS ingredients: q in the nucleon (PDF), hadronization (Fragmentation Functions)
- Fragmentation in 2h is sensitive to *several* TMDs and Dihadron Fragmentation Functions (DiFFs)
- Spin-momentum correlations in hadronization
- Access to PDF e(x) (transv polarized q in a unp nucleon, tw-3) and Dihadron FF G1-perp (helicity of fragmenting q)
- Complement single-hadron SIDIS, with the advantage of another degree of freedom

★ First measurement of BSA in di-h production
★ Sub-leading PDF e(x) different from 0
★ First helicity-deg FF $G_1^{\perp}$ observation



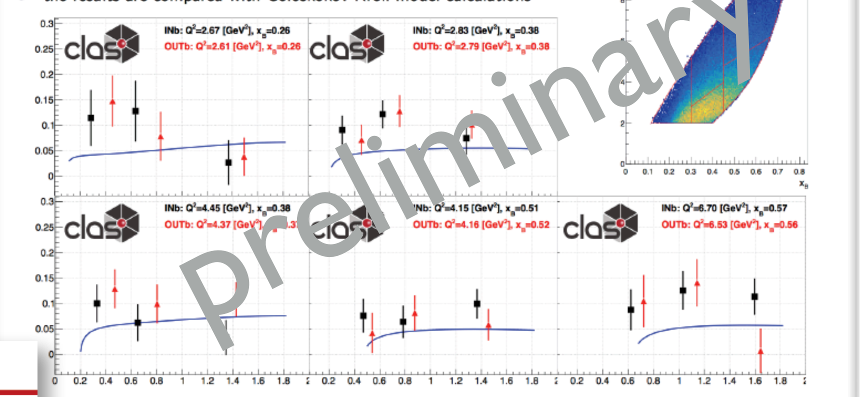
Credit: S.Diehl, T.Hayward, Latifa E.

CLAS12 preliminary results

EXCLUSIVE PI0 ANALYSIS - RGA

Preliminary $\frac{\sigma_{LT'}}{\sigma_0}$ for Deeply Virtual π^0 Production from CLAS12 first experimen

- beam spin asymmetry (BSA) extracted for 5 Q^2, x_B bins with FD proton
- the ratio $\frac{\sigma_{LT'}}{\sigma_0}$ can be extracted from BSA by dividing on $\sqrt{2\epsilon(1-\epsilon)}$
- the results are compared with Goloskokov-Kroll model calculations

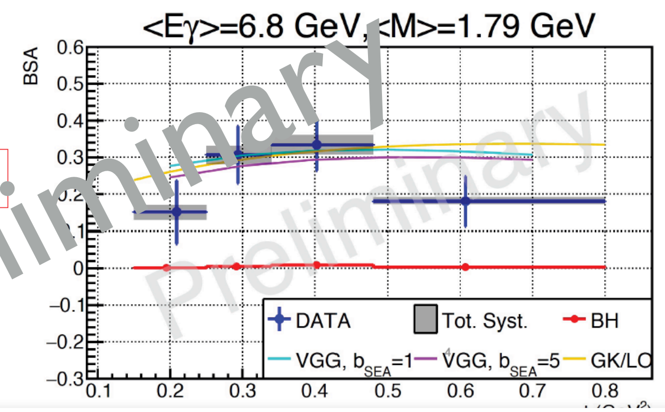


TODO:

- Remaining systematics studies: acceptance effects from Monte-Carlo studies
- Finalize electron and proton momentum corrections
- Cross check
- Finish analysis note

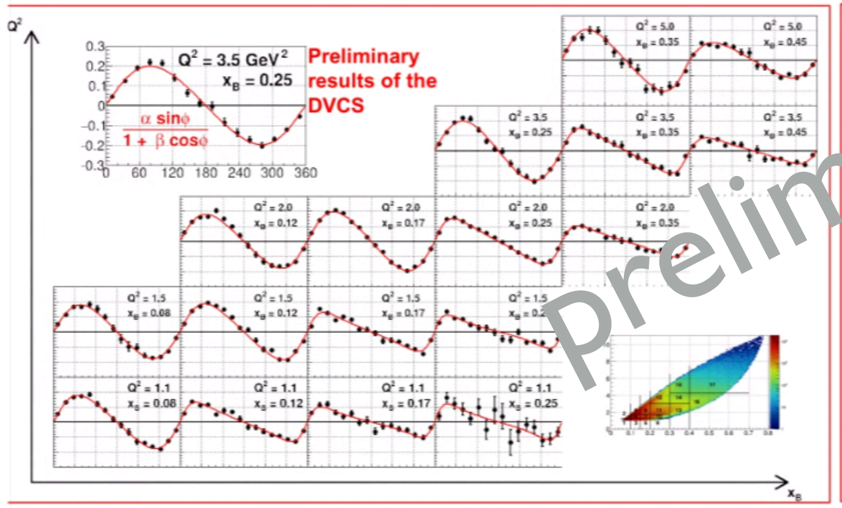
TCS - ANALYSIS REVIEW - STATUS

First round of comments received and Lead authors submitted responses

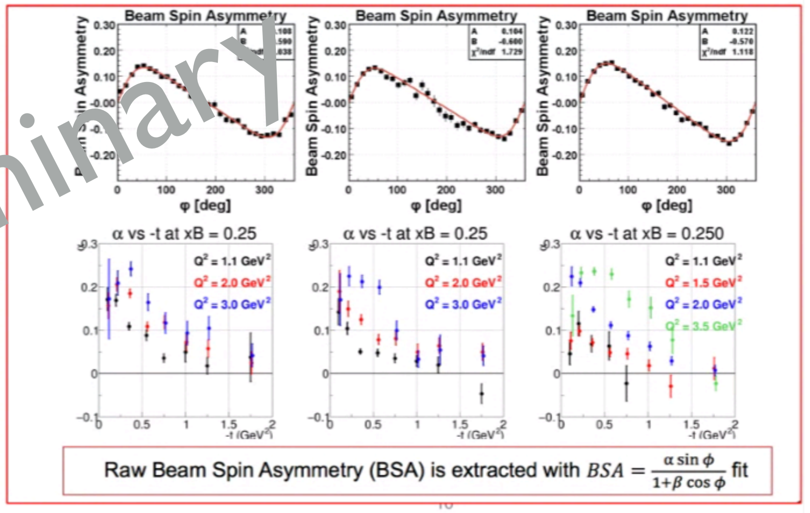


DEEPLY VIRTUAL COMPTON SCATTERING

RG-A



RG-K



Requires understanding of the tracking/PID in Central tracking
Requires understanding the photon/pi0 reconstruction in the calorimeter
Requires understanding physics background in particular the pi0

Note: Common problems to all run groups (A, B and K) and the groups are working together

INCLUSIVE CROSS SECTION - RGA

Required absolute normalization:

- Acceptances
- Detector efficiencies
- Reconstruction efficiencies
- PID
- Radiative corrections
- others

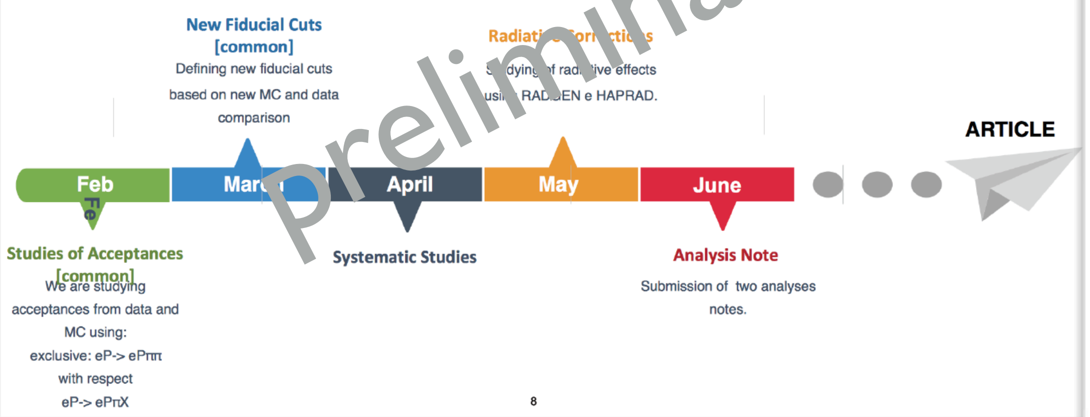
Led by Hall-B TF (N. Markov)

Task	Efficiency estimation and match	Data/ simulation match	Normalization checks	Analysis details	Note writing	Systematics analysis	Running simulation	Analysis procedure and note finalization
February	X	X	X	X	X			
March	X	X	X	X	X			
April	X	X		X	X			
May					X	X	X	
June					X	X	X	

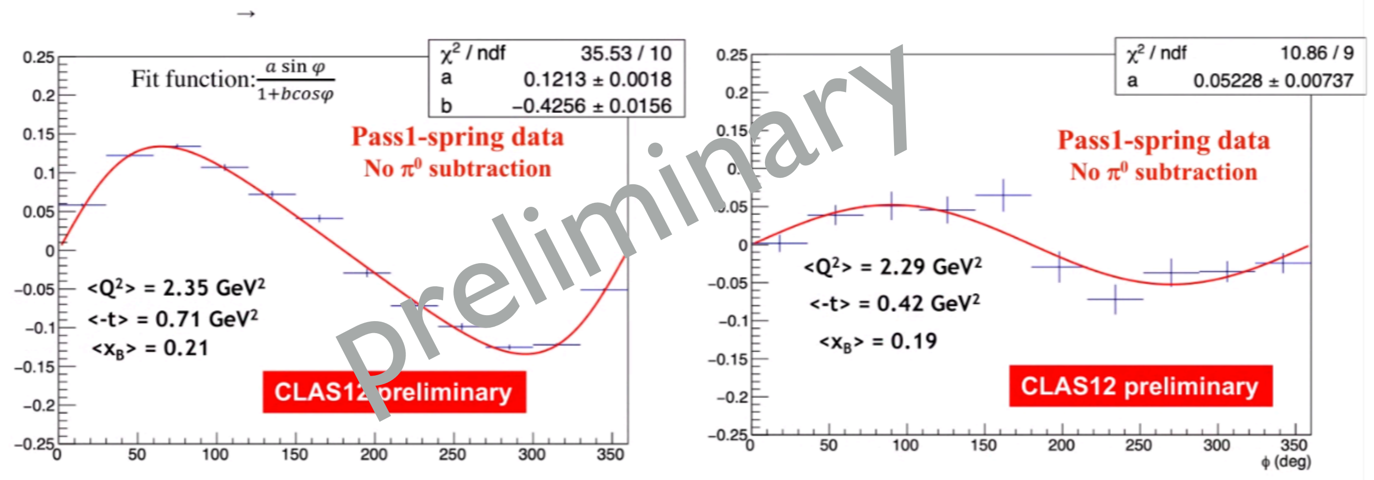
Single & Di Hadron Multiplicities TIMELINE

Data: Fall 2018 inbending [using semi inclusive charged pions]

MC : CLASDIS on OSG. Production will end on March 1st.



DVCS ANALYSIS RG-B



Incoherent pDVCS on deuterium

nDVCS with RGB data

Several talks with details of CLAS12 analyses at the meeting!

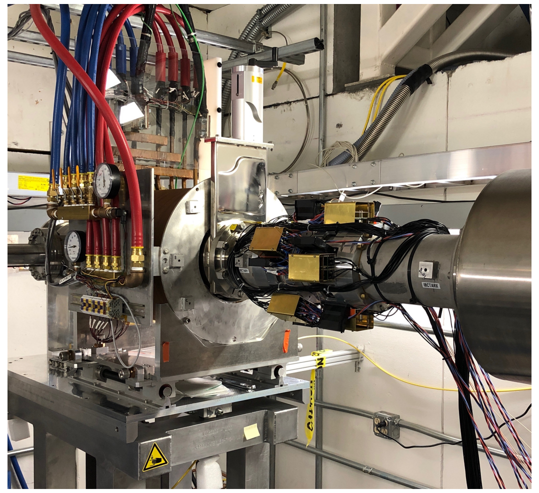
Credit: Latifa E., G.Angelini, N.Markov, P.Chatagnon, A.Kim, F.Bossu, M.Defurne, F.X. Girod, S.Niccolai

CLAS12 — HDice @UITF — Hall B

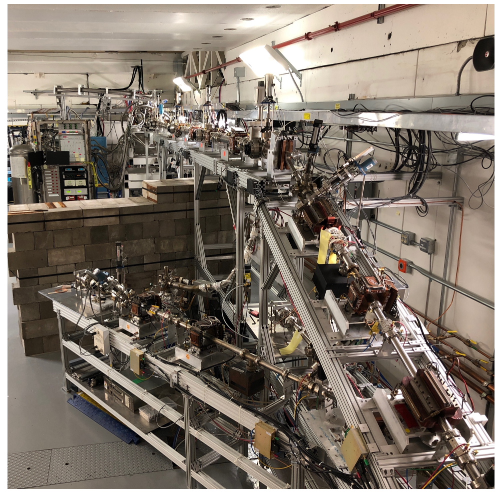
- In support of CLAS12 run group (all transverse experiments designated as **High Impact** for Hall B)
- challenge: trans. holding fields bend electrons into the detector !
- mitigation: small B•dL ⇔ frozen-spin HD

HDice target tests at UITF necessary to check depolarisation effects

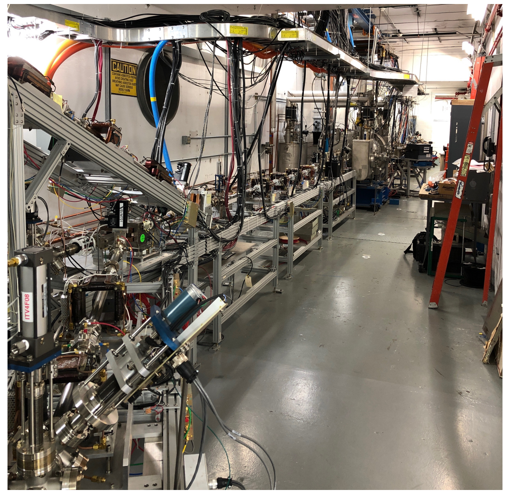
Work plan
- Run 0: booster at 0.5 MeV, 1 MeV, and 10 MeV
- Run 1: commissioning (beam line) ~19 days
- Run 2: run on UNpolarized HD ~17 days
- Run 3: run on Polarized HD ~28 days
- [Run 2b: calibration purpose currently running]



HDice In-Beam Cryostat



cave-2 elevated beam line



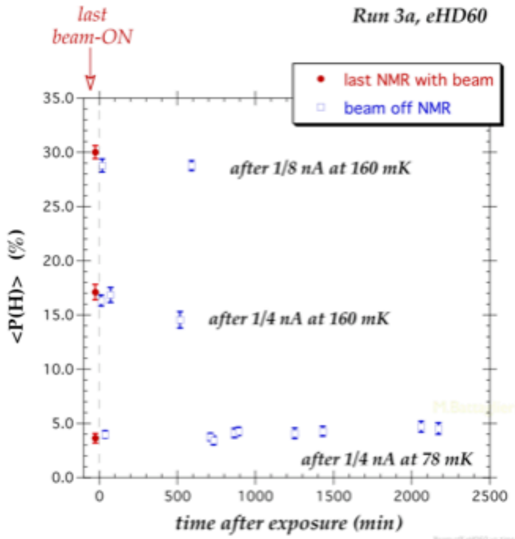
cave-1 with BOOSTER

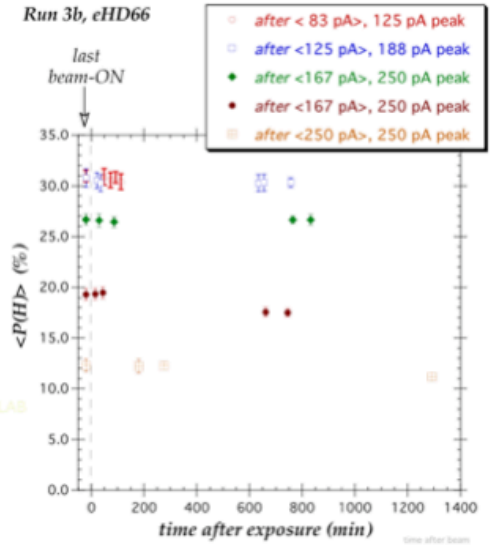
Run 3 (Nov 23 - Dec 17/2020):
- 2 frozen-spin HD targets, *eHD60 & eHD66*, both starting with P(H) ~ 30 %
- H-spins *flipped* with AFP to eliminate hyperfine dilution

Expectations going into Run 3 (from brief 2012 tests):
- Moller electrons would create a partial screening of the NMR response
  - Run 2 reduction in NMR is either due to *screening*, or to higher HD temperatures
- chemical changes following ionization might break the frozen-spin state
- provided the beam was rastered at > 10 KHz, heat should not be the dominant issue

⇔ No evidence for screening of the NMR response

⇔ No evidence for permanent loss of the frozen-spin state following irradiation



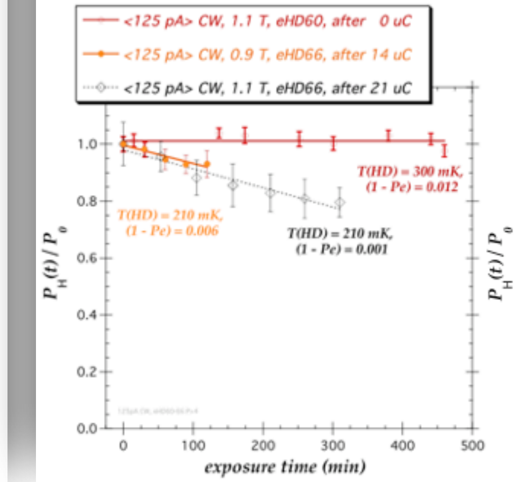


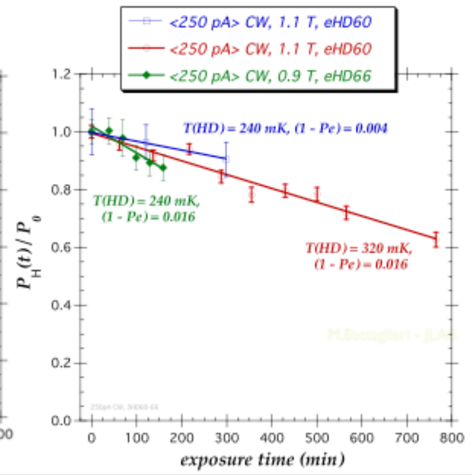
⇔ **reduced NMR signals in run 2** must reflect higher HD temperatures

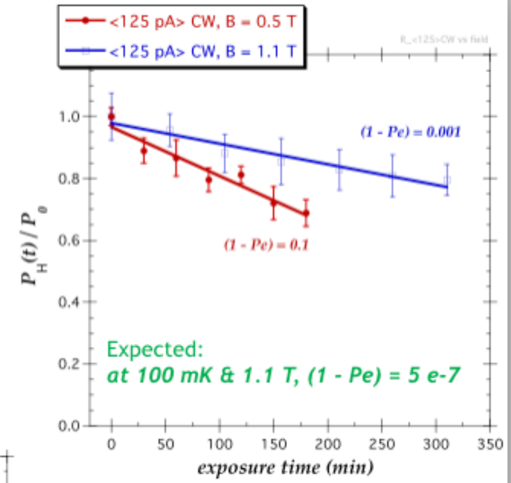
using Thermal equilibrium NMR signals **to deduce HD temperatures**

⇔ T(IBC) < 80 mK, but **T(HD) > 200 mK** heat is certainly an issue !

consequence of higher temperatures:
- dP/dt under different holding fields: same current ⇔ same temperature ⇔ different atomic el pol
- **High HD temperatures (> 200 mK)** result in only partial atomic electron polarization ⇔ flipping electron spins have Fourier components at the H-Larmor frequencies ⇔ significant dP/dt







- *initial* dP/dt slope is flat, but develops with dose
- but, there is no long-term effect on the frozen-spin state (P_H is steady with no beam) ⇔ charge build-up ?

HDice UITF tests summary

- the present state of HDice is not able to support the required RG-H luminosity. If there is another viable target technology that can provide most of the Physics reach, it should be pursue
- if alternative options are limited, there are avenues worth investigating that may extend the viability of HDice targets, although these are R&D projects

HDice report at summer CLAS Coll meeting

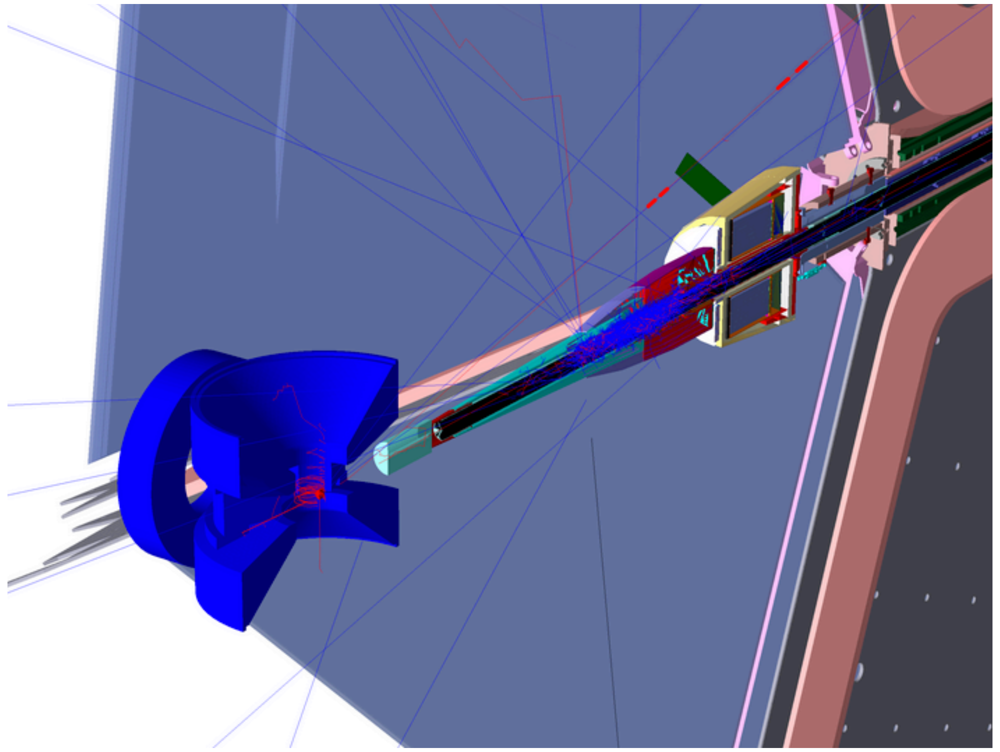
Credit: A.Sandorfy, X.Wei, C.Hanretty, T.Kageya, M.Lawry

Transvere Polarized target alternatives

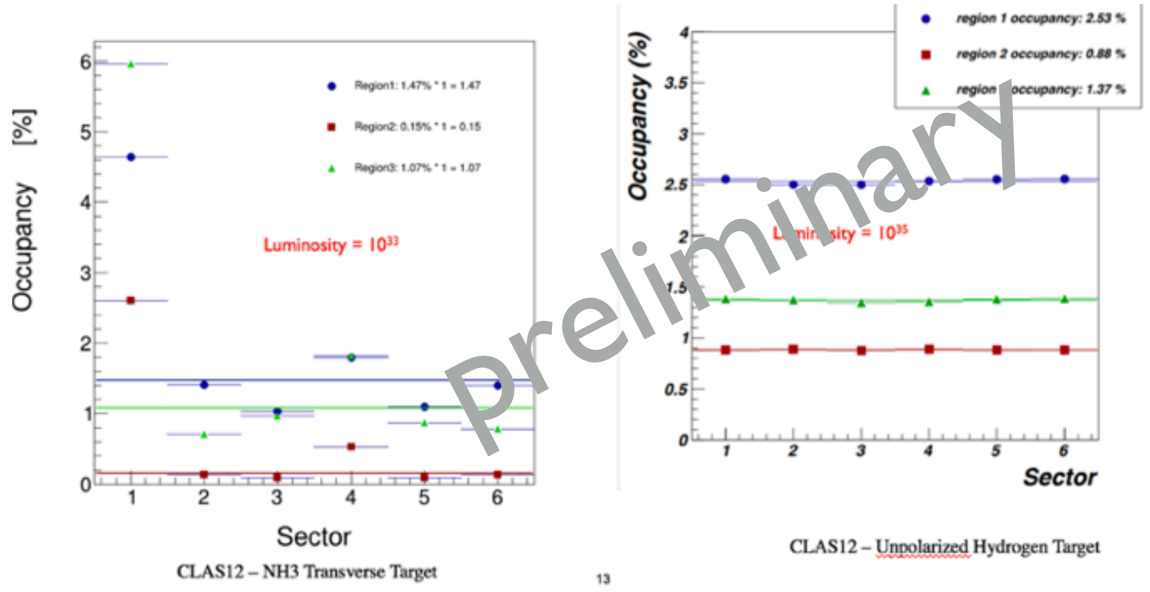
- Hall-B Task Force appointed (E.Pasyuk)
- Identified NH3/ND3 DNP target as an alternative
- currently studying the impact on CLAS12, impact on approved physics program

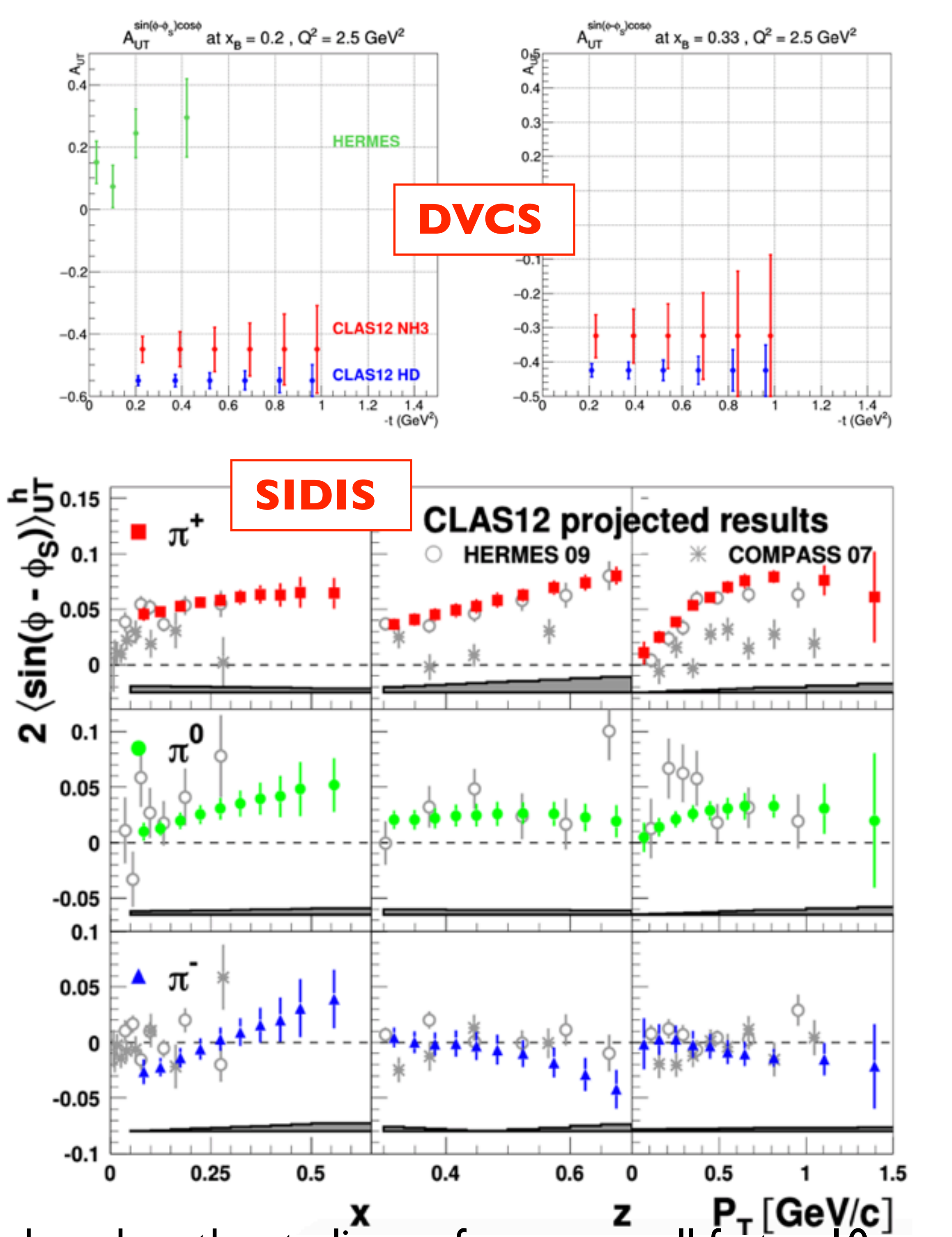
Physics impact

- A Reduction in luminosity from 5×10^{33} $cm^{-2}s^{-1}$ to 1×10^{33} $cm^{-2}s^{-1}$;
- Increase in polarization from 60% to 80%;
- Change in the dilution factor from 1/3 to 3/17;
- Operating 5 sectors (instead of 6) of CLAS12 Forward Detector due to electromagnetic background;
- Removing the Forward Tagger covering small angle photons (this only affects the DVCS program);
- Removing the CLAS12 Central Detector (this only affects the DVCS program).



Particle background in CLAS12





based on the studies so far an overall factor 10 less in statistics

A significant contribution to these studies is expected from RG-H

C.Keith, E.Pasyuk, S.Stepanyan, Latifa E., F.X.Girod, M.Ungaro, H.Avagyan

TJNAF biennial Science and Technology (S&T) Review, July 7-9, 2020

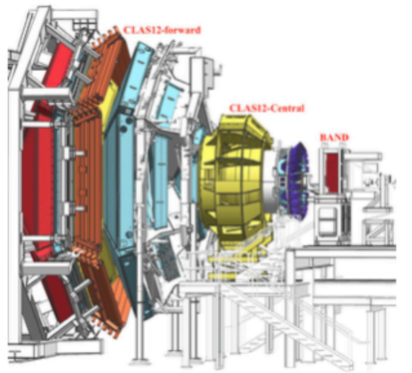
CLAS12
- demonstrated to exceed the expected performance
- Room for improvement for alignment, calibrations and efficiency

Data reconstruction
- Started massive cooking of 2y of data
- So far:
  - 13.5B triggers
  - 0.3PB raw →40TB DST →25TB skimmed
  - 4M core/hrs processing time
  - 600k jobs processed by JLab farm (SWIF) with 6 corrupted files …

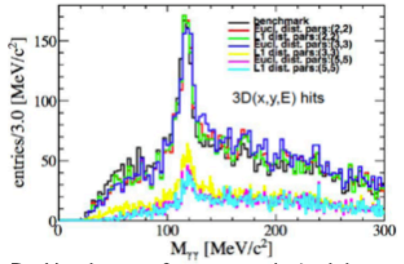
IT resources
- Docker containers for RecSW distribution
- Off-site resources: OSG + INFN + UK for CLAS12 simulations

Machine Learning for CLAS12
- Tracking: speed (6x)
- Clustering
- RecSW handles both conventional and AI algorithms (validation)
- Expected improvement in efficiency and resolution
- Future: on-line reconstruction

Review outcome
- Status of HDIce tests (mid October 2020)
- Alternative options for a transverse pol target (Mid Jan 2021)



Future plans
- **High Luminosity upgrade**: staged approach (TF), requires higher granularity tracker (GEM?)
- **Streaming RO**: first test in Feb performed using the FT-Cal, application of AI algorithms



Double cluster π0 mass as obtained by an unsupervised hierarchical clustering algorithm implemented in JANA framework by C.Fanelli

Credit: V.Ziegler

Two recommendations:

1. *Carry out the UITF tests of the HDIce target as soon as possible. Report to DOE-NP no later than October 15, 2020*
2. *Develop a definite plan for moving forward the transverse polarized 3D imaging measurements in parallel with HDIce testing. The plan should consider options for alternate targets with an analysis of the scientific impact and the timeline for carrying out the PAC approved experiments. Submit to DOE-NP by January 15, 2021*

HD-ice/UITF tests status (PART-2)

V2.7 Feb 4 2021

Summary

This document is the follow-on of the 'HD-ice/UITF tests status' document provided in response to a recommendation from the 2020 TJNAF biennial Science and Technology Review to "Carry out the UITF tests of the HDIce target as soon as possible. Report to DOE-NP no later than October 15,

HD-ice/UITF tests status

V4.2 Oct 14 2020

Summary

This document is in response to a recommendation from the 2020 TJNAF biennial Science and Technology Review to "Carry out the UITF tests of the HDIce target as soon as possible. Report to DOE-NP no later than October 15, 2020." The document describes the status of the frozen-spin HD target (HD-ice) tests at the new JLab Upgraded Injector Test Facility (UITF) and plans to validate the proposed technology.

BACKGROUND:

The JLab physics program requiring a transverse polarized target (Hall-B Run Group H or RG-H), proposed the HD-ice target as the leading technical option. Experiments in RG-H received the maximum scientific rating (A) by JLab PAC 38 and 39, and were designated as *high scientific impact* for Hall-B, but were conditionally-approved (C1), subject to the '*successful demonstration of viable performance of an eHD test*'.

The proposed HD-ice target makes use of an intense magnetic field (15 T) and low temperature (T ~ 10 mK) to polarize the proton and neutron in HD up to P_H~60% and P_n~20% vector polarization; (subsequent RF manipulations can be used to adjust the spin populations to produce P_H~20% and P_n~40%.). Other than the material of the containment cell and Al cooling wires, the target contains no unpolarized nucleons that would dilute the polarization asymmetry. The sample is brought to high polarization in a lab separate from the experimental hall. The advantage of this technique is that once a frozen-spin state has been reached, to maintain the polarization during beam-on operations requires only a small B dL (of the order of ¼ Tm). This is particularly useful for an electron beam run since the transverse holding field necessary to hold the polarization, bends electrons into the detector producing background and impacts the achievable luminosity of the experiment. When exposed to a charged particle beam, the HD-ice target can undergo depolarization related to beam particle energy loss as well as by mechanisms different from conventional targets. The polarization lifetime determines the applicability of this technique to run an experiment and quantifies the overhead required for target replacement and re-polarization in the external cryostat/field.

An assessment of the HD-ice target lifetime with a multi-GeV photon beam was determined during the last CLAS run in the 6 GeV era (the g14 run) in 2011-12, resulting in a value (~2 years) compatible with operations with neutral particle beams. Some preliminary tests performed during g14 exposing the target to a 6 GeV electron beam, were not conclusive and called for a new set of tests to validate the use of the HD-ice target with an 11 GeV electron beam.

Due to the complication in running these tests in the experimental hall related to the installation of the HD-ice apparatus and the interference with the approved physics program, Jefferson Lab decided to conduct the tests at the Upgraded Injector Test Facility, which provides up to a 10 MeV CW electron beam. While the energy lost by the beam in the target is dominated by bremsstrahlung, which rises rapidly with incident energy, the resulting photons have no effect on polarization. However, potential depolarization effects can result from the ionization and energy deposition following Moeller scattering from the molecular electrons of HD (~2 MeV deposited/electron in 5 cm of HD); but this is almost independent of the incident beam energy in

1

1. Results of Run0 and Run1 reported to DOE in October. Run2 and Run4 at the end of January

Transversely polarized target options for CLAS12

V2.9 Jan 15, 2021

Summary

This document is in response to a recommendation from the 2020 TJNAF biennial Science and Technology Review to *"Develop a definite plan for moving forward the transverse polarized 3D imaging measurements in parallel with HDIce testing. The plan should consider options for alternate targets with an analysis of the scientific impact and the timeline for carrying out the PAC approved experiments. Submit to DOE-NP by January 15, 2021"*. The document reports status and preliminary results of a study to assess possible transversely polarized target options for CLAS12, the envisaged timeline and the impact on the planned physics program. Three configurations of dynamically polarized solid ammonia, NH3, are considered. The third configuration is preferred based on risk, cost, and schedule. In this configuration the NH3 target figure-of-merit is similar as HDice, and the main limitation comes from the maximum operational luminosity due to the background generated in CLAS12 with a 5 T transverse field. More detailed studies will be available in approximately 6 months.

The Hall-B polarized transverse target physics program

The JLab Hall-B physics program requiring a transverse polarized target (Hall-B Run Group H or RG-H), includes three sets of measurements:
- Deeply Virtual Compton Scattering (DVCS): JLab experiment C12-12-010 '*Studies of the spin azimuthal asymmetries in Deep Virtual Compton Scattering (DVCS) using the CEBAF 11 GeV polarized electron beam and transversely polarized target*' providing access to different combinations of Generalized Parton Distributions (GPDs) and in particular, to the elusive GPD-E and the contributions of *u* and d quarks to the total orbital angular momentum of the nucleon.
- Inclusive hadron production in Semi-Inclusive Deep Inelastic Scattering (SIDIS): JLab experiment C12-11-111 '*Studies of azimuthal distributions of measured final state hadrons in coincidence with the scattered electron for the transversely polarized target*' provide access to the Sivers function describing the unpolarized quarks, and "transversity" and "pretzelosity" distributions describing transversely polarized quarks in the transversely polarized nucleon.
- Di-hadron production in SIDIS: JLab experiment C12-12-009 '*Studies of azimuthal distributions of measured final state hadron pairs*' provide complementary access to quarks transversity distributions within the collinear theory, as well as enable studies of correlations of hadrons in hadronization process, crucial for interpretation of single-hadron measurements

All these experiments, grouped in Hall-B Run Group H or RG-H, received the maximum scientific rating (A) by the Jefferson Lab Program Advisory Committee PAC-38 and -39 and were designated as *high scientific impact* for Hall-B.

The experiments require to operate a transverse polarized target within the CLAS12 detector. The HDIce target was considered as the primary option, but preliminary results of recent tests performed at the JLab-UITF indicate that **HDIce remains an R&D project that is not, at this time, ready to support RG-H**.

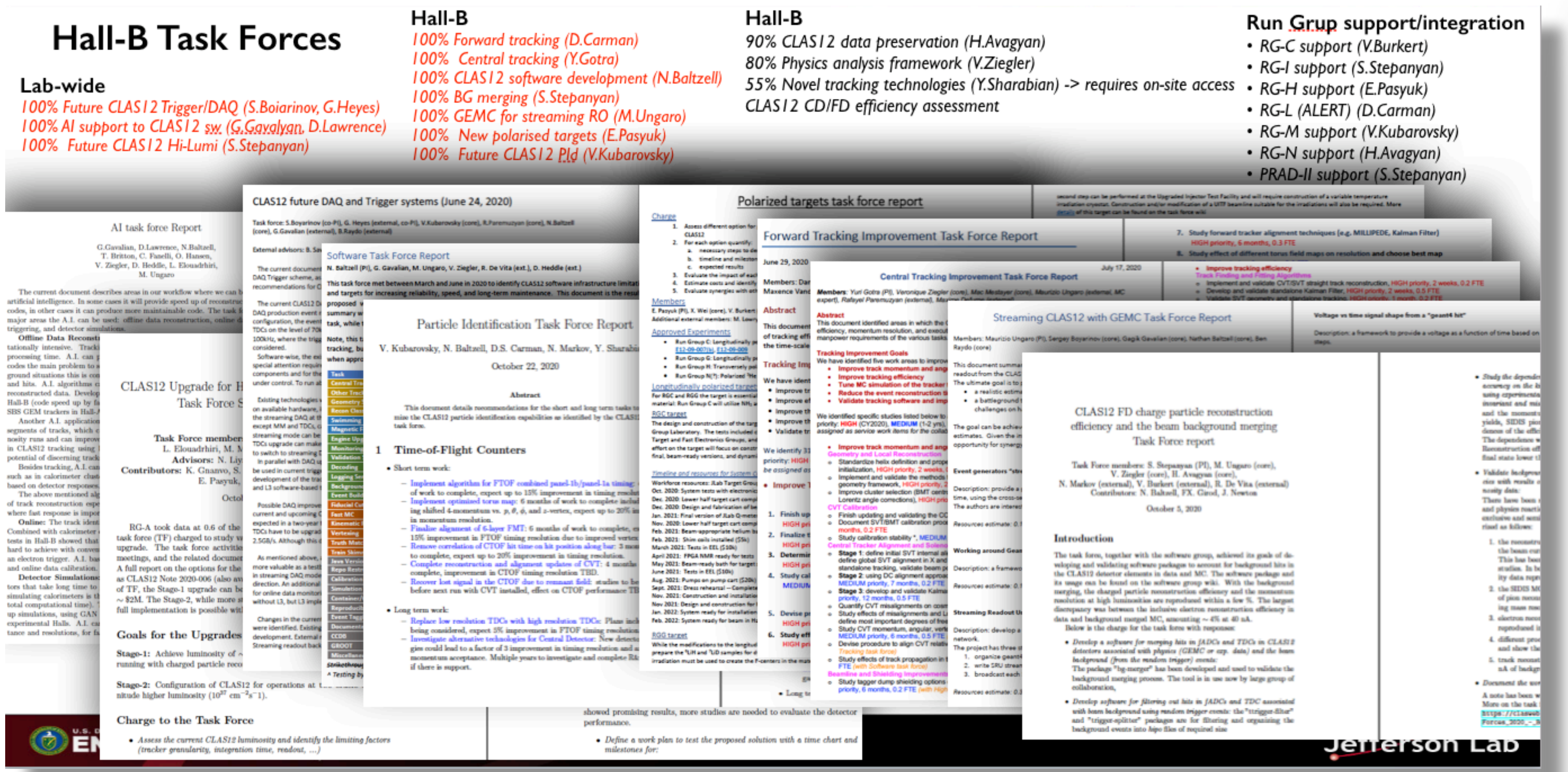
Due to the challenges posed by the HDice target technology, these proposals are *conditionally approved* with specific conditions from the JLab PAC to be met for approval:

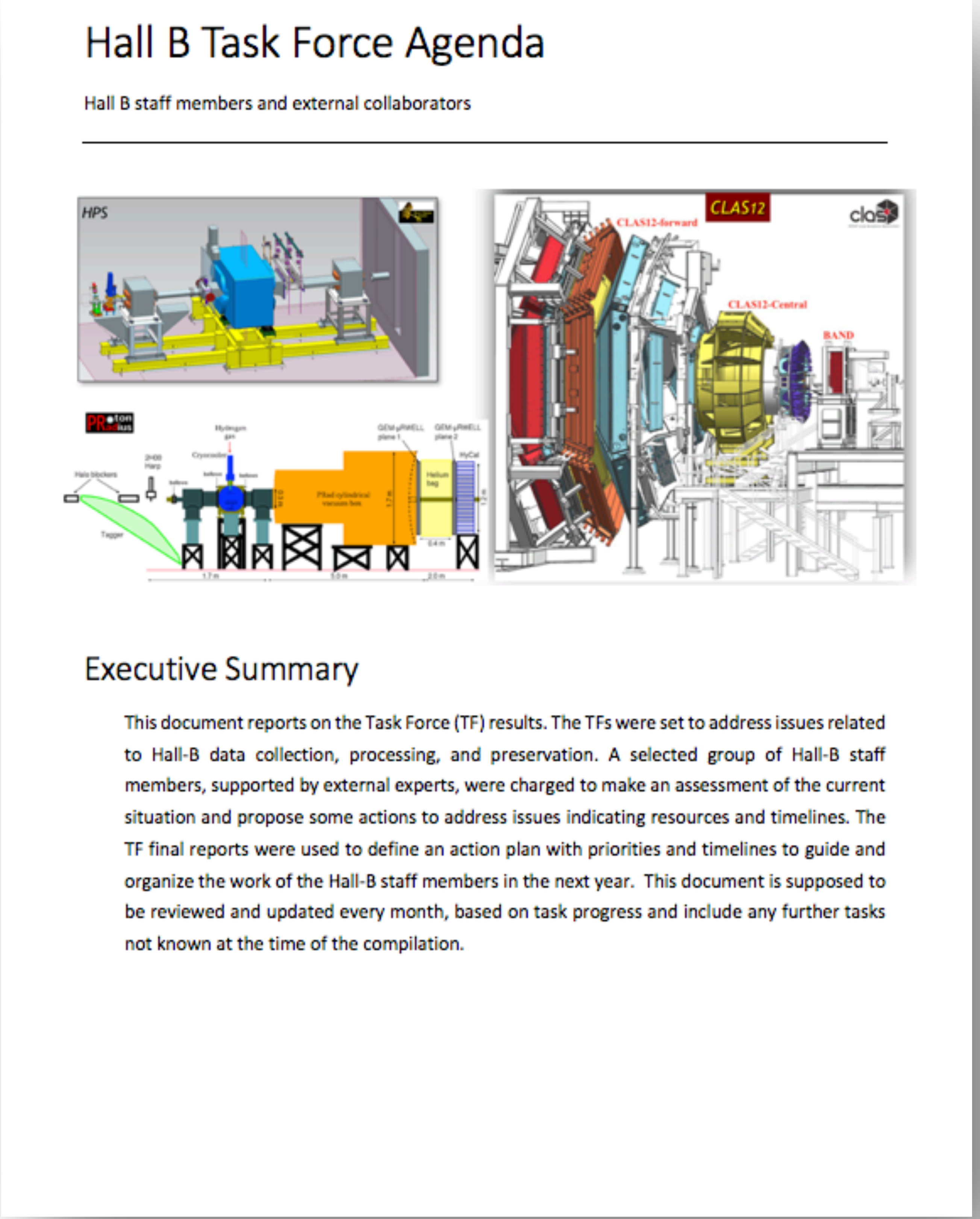
2. Alternative options for RG-H sent to DOE by mid January. A new report with impact expected for June.

Hall B

Hall-B Agenda

PRoton Radius PrimEx CLAS12 Heavy Photon Search



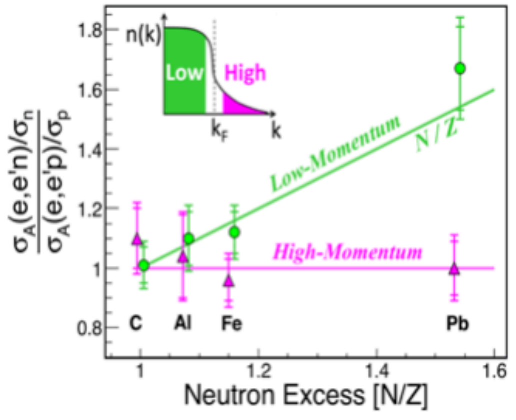


- Almost all TF concluded the assessment phase
- Some moved to the execution
- New RGs support TFs
- Compiled a Hall-B TF Agenda for 2021
- Priorities, timelines, milestones, resources, …
- Updated every ~3 months

Near future: RG-M

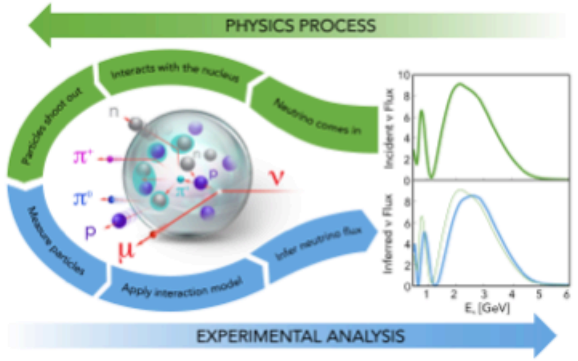
Short Range Correlations

- Build on the tremendous success of the CLAS6 data mining SRC program (Science, several Nature, …)
- Take far more (e,e'pN) and (e,e'pNN) data on a wider range of nuclei
  - Three nucleon SRCs?
  - Constraining the NN interaction at short distances
  - Understanding factorized effective theories
  - SRC formation mechanisms
  - SRCs and the EMC Effec



Electrons for neutrinos

- Take (e,e'X) data to test vector-current part of neutrino-nucleus event generators
  - Energy reconstruction techniques
  - Event generators key to reconstructing oscillation parameters



- Scheduled for 30 PAC days: fall 2021
- D, 4He, C, [O,] 40Ar, 40Ca, 48Ca, Sn
  - Targets designed and under development
  - Standard liquid target cell
  - Short 0.5-cm Ar liquid target cell
  - Solid target C, Sn insertion mechanism
  - Special Ca target holders

Credit: V.Kubarovsky

- RG-M support Task force (PI: V.Kubarovsky)
- CLAS12 configuration completed: No FT, no LTCC, TORUS in-bending and out-bending
- Target
- Mechanical design completed, target foils production in progress
- Mechanical support production – March 2021
- Target test together with slow motor control– April 2021
- MC (target geometry, trigger parameters, DC roads) - started
- Target slow control – April 2021
- Detailed draft of run plan is ready (lumi scan, empty target, trigger validation, beam energy, targets, torus etc)

- Off-line analysis and trigger validation software – ongoing
- Analysis coordinator and chef identified
- Data calibration during run – discussed with CALCOM, D. Carman made report on the RG-M meeting. Engineering runs will be cooked soon and sent to Daniel for calibration to practice

"Online" Detector Calibrations

There is a push to reduce the time period from completion of data-taking to readiness for pass-1 cooking

⇒ the quicker the detector calibrations, the sooner the data can be processed, and the sooner data analysis can begin

The *ideal* would be doing calibrations online – *i.e. during data taking*

For some systems, in principle, calibrations can be done very close to online, e.g. beam offsets, RF, BMT, FMT, SVT

For the bulk of the detailed timing calibrations, i.e. FTOF, ECAL, CTOF, HTCC, FT, LTCC, RICH, a complete picture is needed based on the full set of timelines to properly apply the calibration constants over the appropriate run ranges

Where do the delays come from between collecting the data and being ready for pass-1 data processing?

- Waiting for necessary reconstruction software developments
- Waiting for calibration procedures of new detector systems implemented for a given physics run
- Waiting for detector alignment work
- Performing the detector calibrations over multiple iterations
- Cooking the data, performing pass-0, generating the timelines
- However, another contribution to the time delay (and perhaps the most important) is not beginning the work
  - The Analysis Coordinator has to aggressively push the effort and maintain daily oversight to reduce the delays
  - We are getting better with the new oversight role of CALCOM (e.g. RG-B F19/W20, RG-A Spr19, RG-F Sum20/W20)
  - How can we do better??

A goal would be to have all calibrations done and ready for pass-1 cooking no more than 6 months after the run ends

D.Carman

Medium future: RG-C

Experiments will use longitudinally polarized NH3/ND3 target

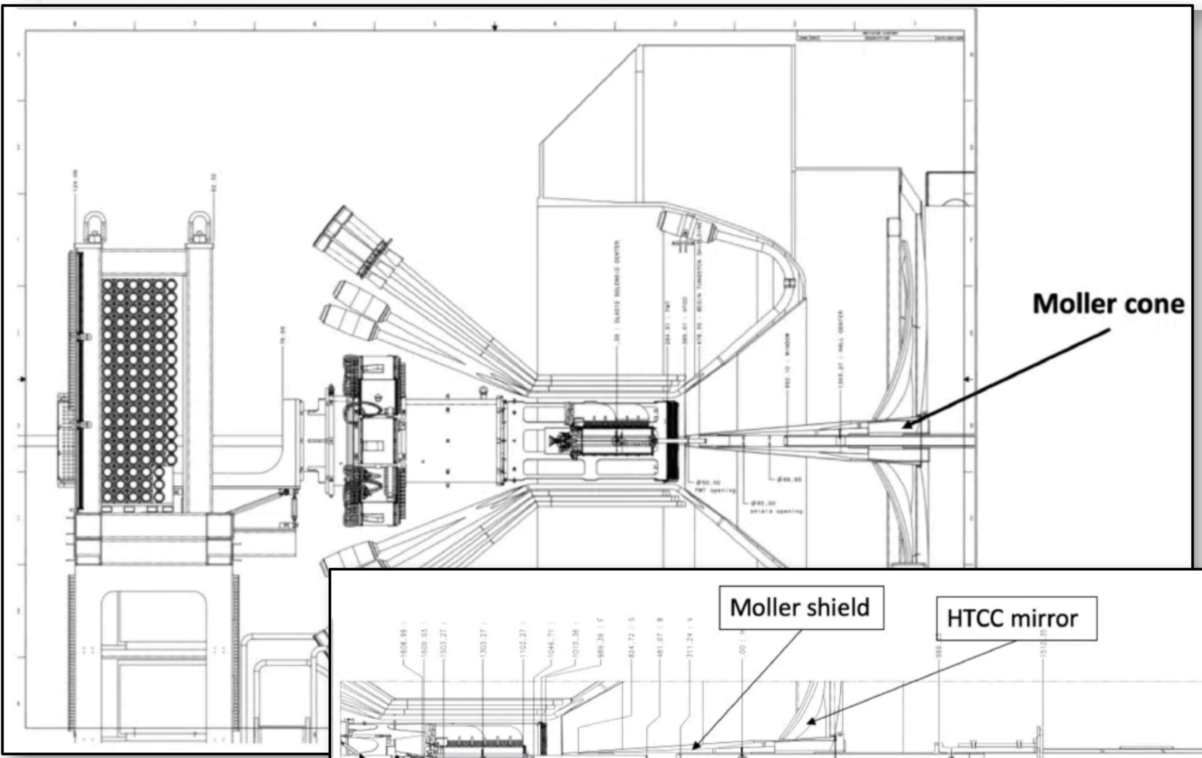
E12-06-109	Longitudinal Spin Structure of the Nucleon	Kuhn	A	80	185	Polarized target RICH (1 sector) Forward tagger	11	C S. Kuhn	NH_3 ND_3
E12-06-109A	DVCS on the neutron with polarized deuterium target	Niccolai		(60)					
E12-06- 119(b)	DVCS on longitudinally polarized proton target	Sabatie	A	120					
E12-07-107	Spin-Orbit Correl. with Longitudinally polarized target	Avakian	A-	103					
E12-09-007(b)	Study of partonic distributions using SIDIS K production	Hafidi	A-	80					
E12-09-009	Spin-Orbit correlations in K production w/ pol. targets	Avakian	B+	103					

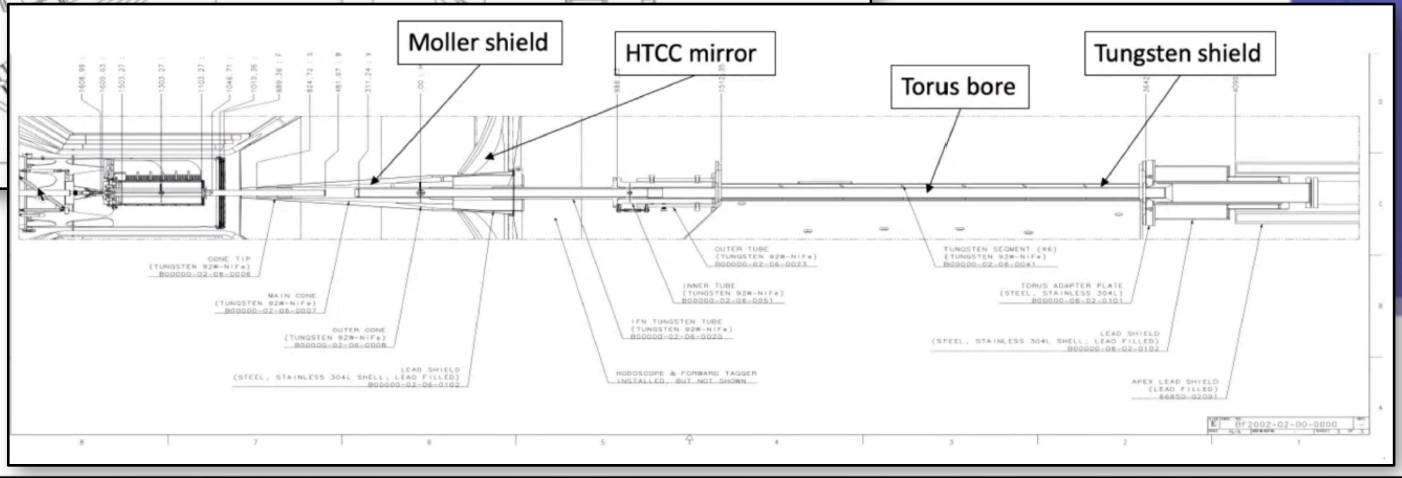
<u>RGC:</u> - Originally approved for 185 days of beam time

<u>PAC48-Jeopardy:</u> - Reduced beam time to 120 days w/ focus on DVCS (proton, neutron)
- For remaining beam time return to PAC with new impact study
- Emphasizes availability of Forward Tagger

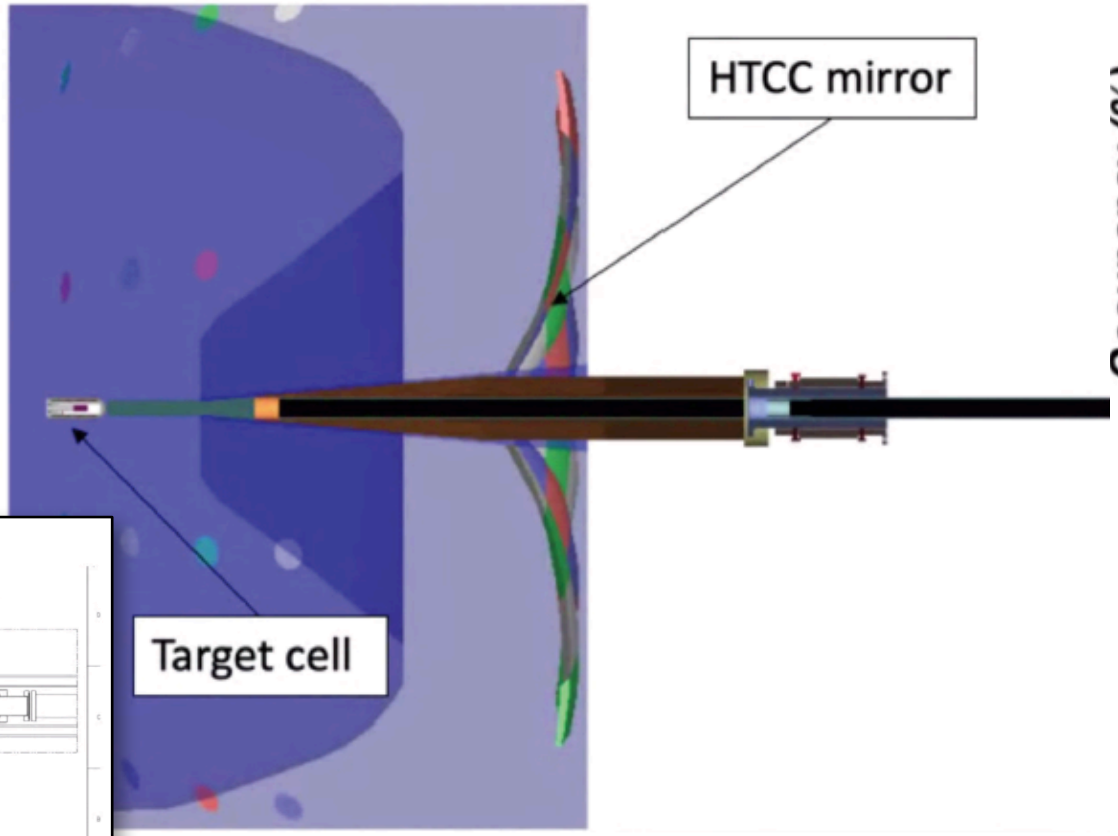
Experiment expected to run in early 2022 (CY)

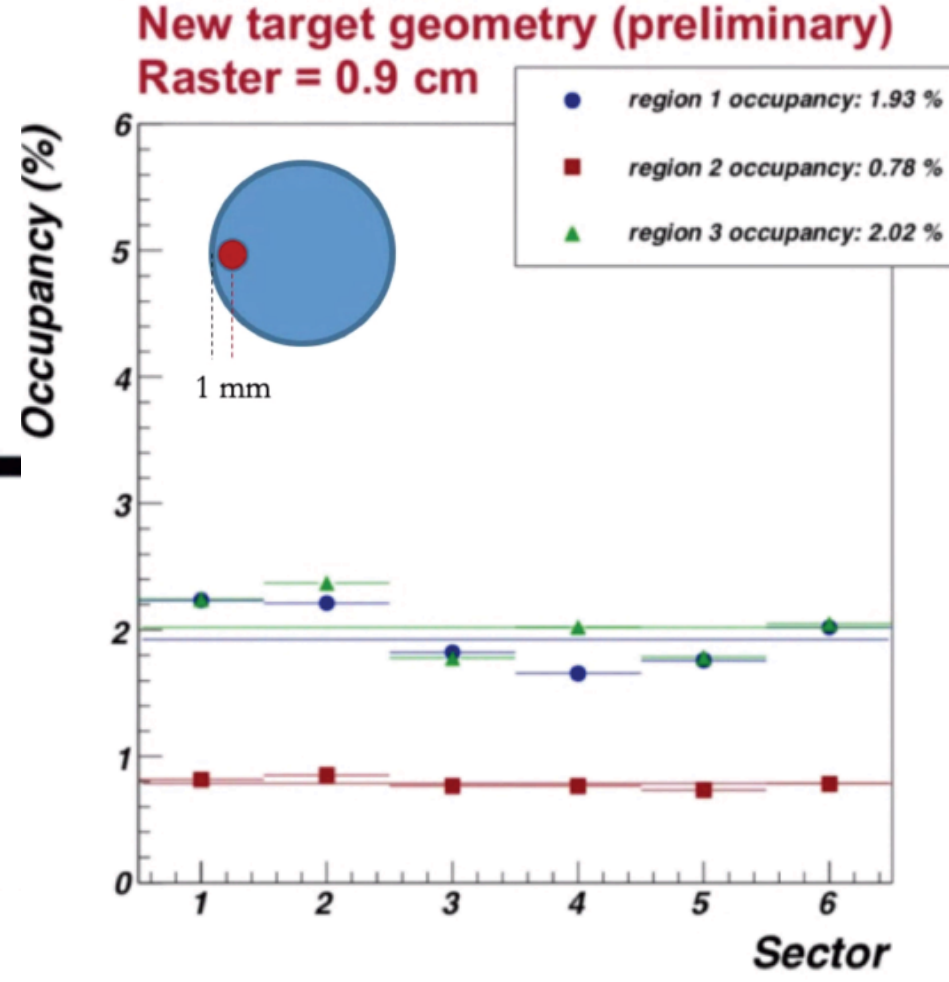
- RG-C support Task Force (PI:V.Burkert): polarized target, design of the beamline (raster magnets, Moller cone), simulations
- Current run plan: 90/120 PAC days FT-Off configuration; 30/120 PAC days FT-On configuration
- So far optimised the FT-off configuration: next step FT-on
- Installation/preparation plan defined (+2 months for DNP target)
- New tungsten Moller cone, optimized raster size and target geometry: DC occupancies comparable to the simulations for RG-A
- Still working on DC3 background
- Slow controls integration





Credit: V.Burkert





Foreseable future: Hi-Luminosity

CLAS12 at Hi-Lumi Task Force (PI: S.Stepanyan)

- Two-stages work-plan: I) Lx2, II) Lx100
- new tracker (GEM, uRwell) to replace DC (+improved FE electronics)

CLAS12 Upgrade to High luminosity Operations

Sect.1: timeline, milestones, dependences, resources, funds

Review 0.0 December 2020

Goals

Stage-1: Achieve luminosity of ~ 2×10^{35} $cm^{-2}s^{-1}$ for normal CLAS12 running with charged particle reconstruction efficiency of > 85%.
Stage-2: Configuration of CLAS12 for operations at two orders of magnitude higher luminosity (10^{37} $cm^{-2}s^{-1}$).

Task Force	**CLAS12 High Luminosity Operations**
PI	**S. Stepanyan**
Members	V. Burkert, L. Elouadrhiri, M. Mestayer, M. Ungaro, V. Ziegler
Advisors	N. Liyanage, E. Cisbani, E. Fuchey
Contributors	K. Gnanvo, S. Boyarinov, D.S. Carman, V. Kubarovsky, E. Pasyuk, R. De Vita, M. Bondi

Tasks/Subtasks	2020	2021				2022				2023	2024
	IV	I	II	III	IV	I	II	III	IV		
1. Improve existing FD tracking system (S1):											
1.1 Test DC time-over-threshold readout				M1.1							
1.2 Develop software for analysis of time-over-threshold readout				M1.2							
2. New tracking solutions (S1):											
2.1 Define MPGD configuration for the CLAS12 FD			M2.1								
2.2 Define readout configuration for MPGD					M2.2						
2.3 Fabricate large GEM and µRWELL prototypes				D3.1/2	D2.1/2			M2.3			
2.4 Test prototypes and readout systems						D2.3			M2.4		
3. MPGD simulation and reconstruction (S1):											
3.1 Full GEMC development of the MPGD tracker				M3.1							
3.2 Tracking with FPGD R1 detectors				M3.2							
4. Full implementation of the MPGD tracker (S1):											
4.1 Final design of the tracker								D2.4	M4.1		
4.2 Procurement of components									D4.1	M4.2	
4.3 Fabrication of detectors										D4.2	M4.3
5. MC studies of rates, occupancies and BG for S2:											
5.1 GEMC studies of CLAS12 at x10L									M5.1		
5.2 Studies of µCLAS12									M5.2		

Credit: S.Stepanyan

Hall-B project

- Focus on Stage I: Achieve luminosity of ~ 2×10^{35} $cm^{-2}s^{-1}$ for normal running conditions of CLAS12 with charged particle reconstruction efficiency of > 85%.
- Hall-B staff: previous TF + new members
- UVA, INFN expressed interest for building a prototype and develop a new FE electronics
- Preliminary work plan aiming to develop a detector in ~1y time and test it on-beam in CLAS12
- Bi-weekly meeting to discuss design and progres

Plan for the first year FD tracking

1. **improve existing DC readout - time-over-threshold**
   a. test with cosmics (ongoing)
   b. test with beam, parasitically with HPS and then with RG-M (Mac, Sergey, Ben, ?)
   c. develop offline software to use time-over-threshold information to improve BG reduction (Veronique, ?)
2. **develop MPGD detectors for R1 DC**
   a. build and test large area µRWELL, test in Hall-B (Kondo, ...)
   b. study options for light weight detector, test solutions (Kondo, Rui?, ...)
   c. study options for the readout (Kondo, INFN, Stepan, FE group)
3. **develop software for R1 MPGD**
   a. implementation of a µRWELL plane in GEMC (Maury)
   b. development of FD tracking with µRWELL plane (Veronique)
   c. study track reconstruction efficiency with the new detector using BG merging (?)

The next two years

1. **Study design parameters of a MPGD detector for R1 (2022)**
   a. number of layers
   b. readout granularity
   c. FD tracking performance with the final design option
2. **MPGD detectors for R1 (2023)**
   a. build a full scale prototype
   b. develop readout electronics
   c. test the prototype with the final readout with beam
3. **Final design of the MPGD planes for R1**
4. **Prepare procurements for six sector detector**
5. **start fabrication (2024?)**

Hall B Long range - FY21 schedule

PRoton Radius PrimEx CLAS12 Heavy Photon Search

▪ Plans

- No solid plans are possible due to the COVID-19 uncertainty
- FY21: SAD is progressing with the scheduled maintenance
- The ACC schedule will be published soon
- HPS and RG-M in CY21 and RG-C in CY22
- Working to support RG-L (ALERT) ERR
- Staffing CLAS shifts for next run can be an issue

from November 2020 CLAS Collaboration meeting

▪ **Schedule**

▪ FY21: long CEBAF shutdown for CHL Cold Box repair (Scheduled Accelerator Down - SAD)

- Decommissioning of installed components: BONUS
- Maintenance of several detectors
- Installation of the next experiments (HPS, RG-M requires nuclear targets)
- Weekly meeting to plan the activity
- Regular report at Monday meeting
- Update on a dedicated wiki page: https://www.jlab.org/Hall-B/clas12-web/sad-2021-update.html

▪ FY21: 20 weeks (Jun-Oct), 10.9 max E_b, only two RGs that requires low beam energy will be able to run (HPS and RGM)

▪ FY22 (tentative): polarized longitudinal target

▪ … : nuclear targets, transverse polarized target, completion of RGA, RGB, RGK, HPS, …

▪ … : new proposals (PRAD-II, polarized 3He, tritium target, …)

▪ Lesson learned: CLAS12 remote shifts went pretty well

Remote shifts for monitoring and support onsite personnel
- only monitoring (no DAQ or control detectors)
- home-like network connection + BJ to communicate with the Counting House

Should we extend the remote shifts to regular CLAS12 operations?

Credit: S.Stepanyan, N.Balzell

In summary:

… difficult time but:

▪ Difficult times but JLab was able to complete the experimental program planned for FY20

▪ Hall-B staff members and collaborators are doing their best to provide data ready for physics analysis

In summary:

▪ Progressing in CLAS12 data preparation for physics analysis (first two letters submitted): strong support from HAll-B SW and CALCOM for new reconstruction sw release, calibration suites, MC simulations on OSG

▪ PassI data reconstruction almost concluded for the all data sets (RGA/B/K and soon RGF) and preparation for a Pass2

▪ Preparing the near- (HPS, RG-M, RG-C and RICH-II), medium- (RG-L, RG-H, PRAD-II) as well as the far-future (RG-N, CLAS12@hi-lumy) of CLAS12