Hall A Software Overview and Progress

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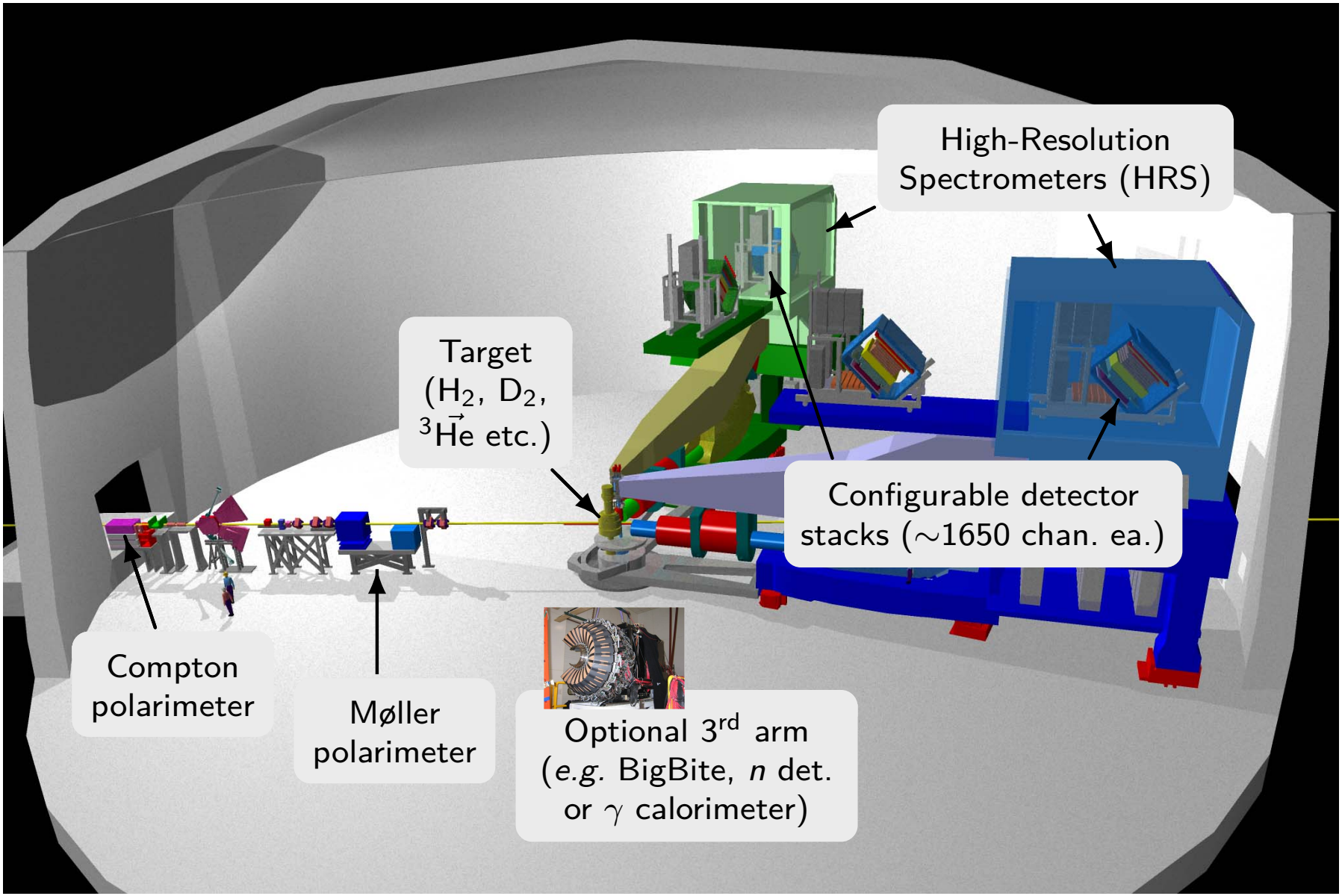
Jefferson Lab

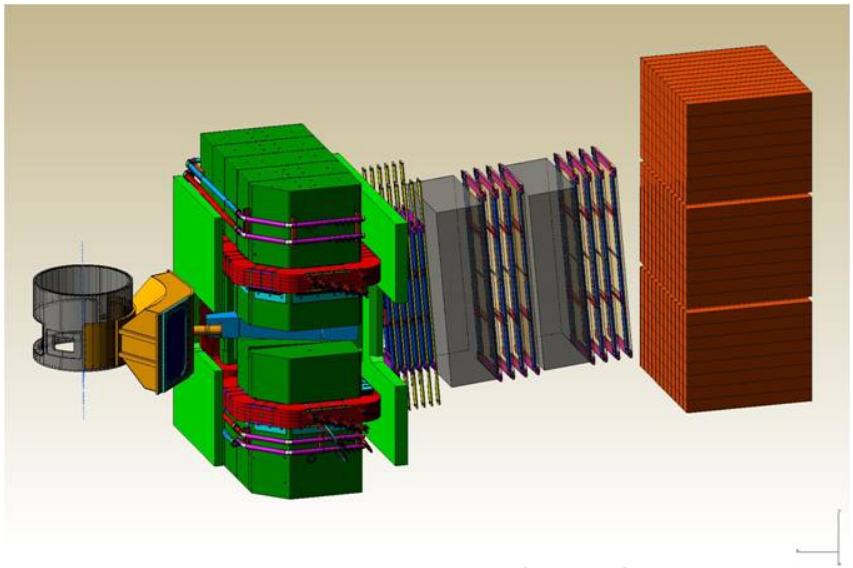
JLab 12 GeV Computing Review
November 27–28, 2018

Jefferson Lab
Thomas Jefferson National Accelerator Facility

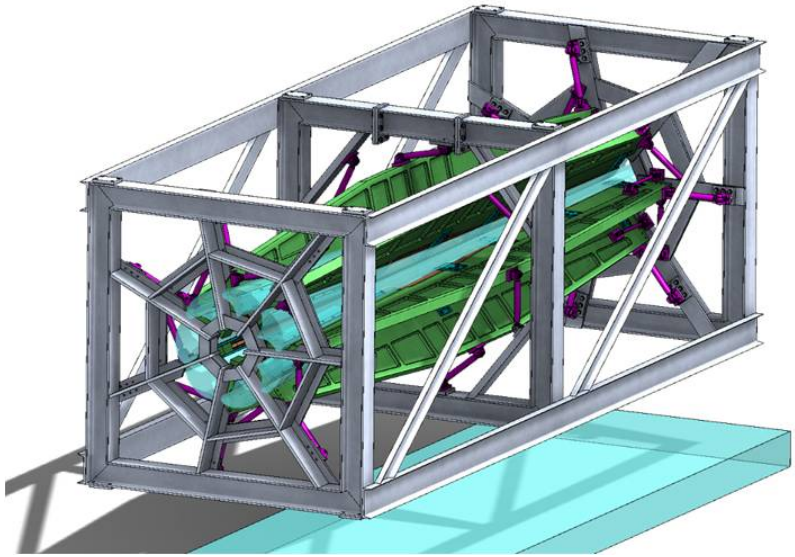
Hall A Core Experimental Equipment



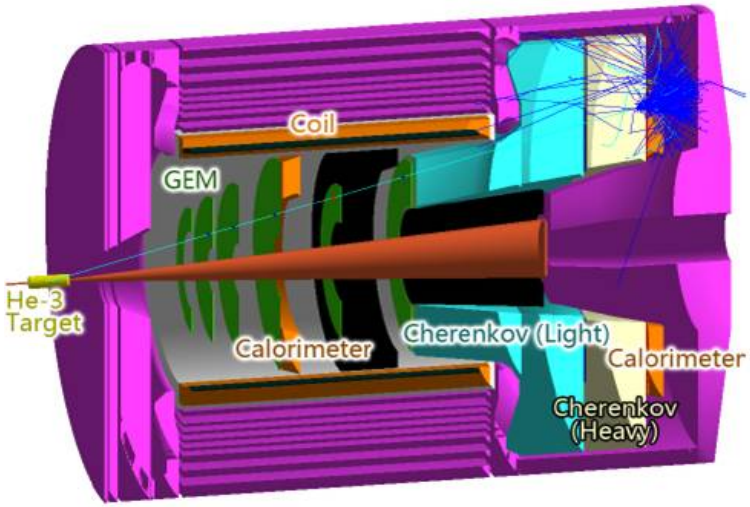
Future Hall A Projects



SuperBigBite (SBS)



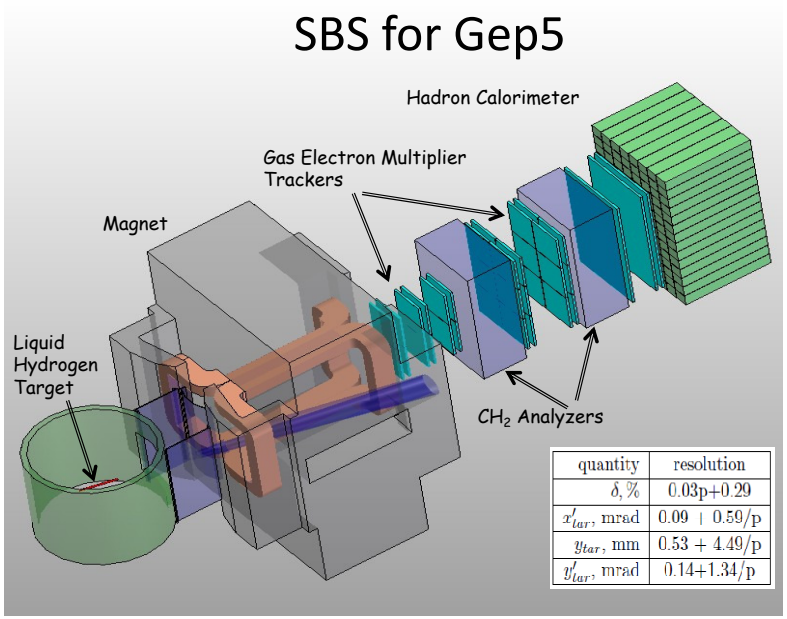
Møller (standard model test)

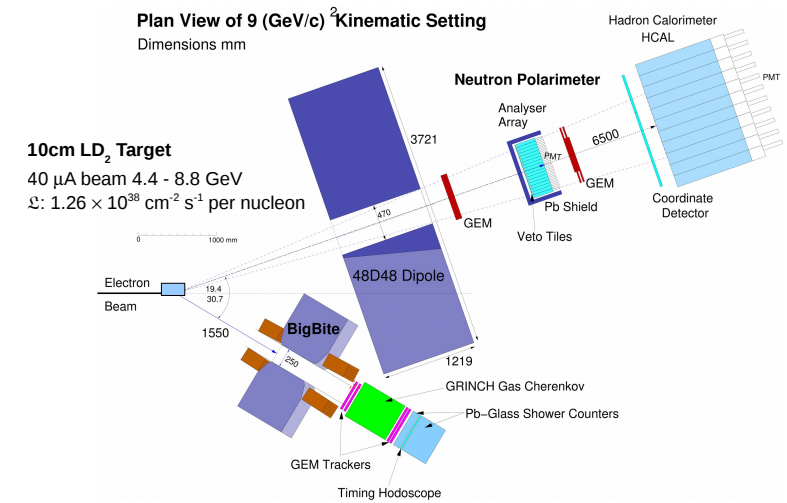


SoLID (SIDIS, PVDIS, J/ψ, . . .)

SuperBigbite Spectrometer (SBS)

B. Wojtsekhowski, G. Cates, *et al.*





- Set of components for flexible medium-acceptance spectrometer configurations
  - Magnet
  - GEM trackers ($\approx$ 100k channels) in high-rate environment (700 kHz/cm^2)
  - Hadron and electron calorimeters
  - Segmented scintillator coordinate det.
  - Timing hodoscope & veto plane
  - Gas Cherenkov
  - Dual-radiator RICH
- To be used in conjunction with existing BigBite magnet for building electron arm
- Proposals approved for
  - High-luminosity (10^{38}) EM form factor measurements up to $Q^2 \approx 10$ GeV^2
  - SIDIS/Transversity
  - At least four different experimental configurations
- Additional proposals submitted
- Under construction
- Earliest run likely Spring 2021

Projected Hall A Schedule & Experiment Requirements

as of 10/2018 (somewhat tentative, as always)

Run Period	2019 Spring	2019 Fall	2020* Spring	2021 Spring	2021 Fall	2022* Fall	2023* Fall
Main Experiment(s)	*APEX*	*PREX* *CREX*	*CREX*	----------	----------	*SBS*	----------
				GMn	*GEn*	*GEp*	*SIDIS*
Detector Systems	HRS	HRS	HRS	BB SBS as n det		ECAL SBS as $\vec{p}$ det	BB SBS+RICH
Trigger Rate (kHz)†	10	0.24	0.03	2.5	2.5	2.5	5
Event Size (kB)†	5	8	8	50	60	170	64
Data Rate (MB/s)	50	2	0.25	125	150	425	320
Total Tape Volume (PB)‡	0.49	0.12	0.01	0.63	1.2	3.3	2.5
Total CPU (M-core-hrs)‡	0.04	0.003	$<$0.001	1.0	1.5	3.8	3.3
Software Framework	----------	----------	C++ Analyzer ("Podd") ✔	----------	----------	----------	----------
Extensions	High-rate VDC ✔	Parity analyzer (JA◐)PAN ✔	GEM Tracking ◐, Calorimeter analysis ◐, multi-threading ◐, new decoders ◐, Calibrations ✗, ToF ✗, PID ✗				

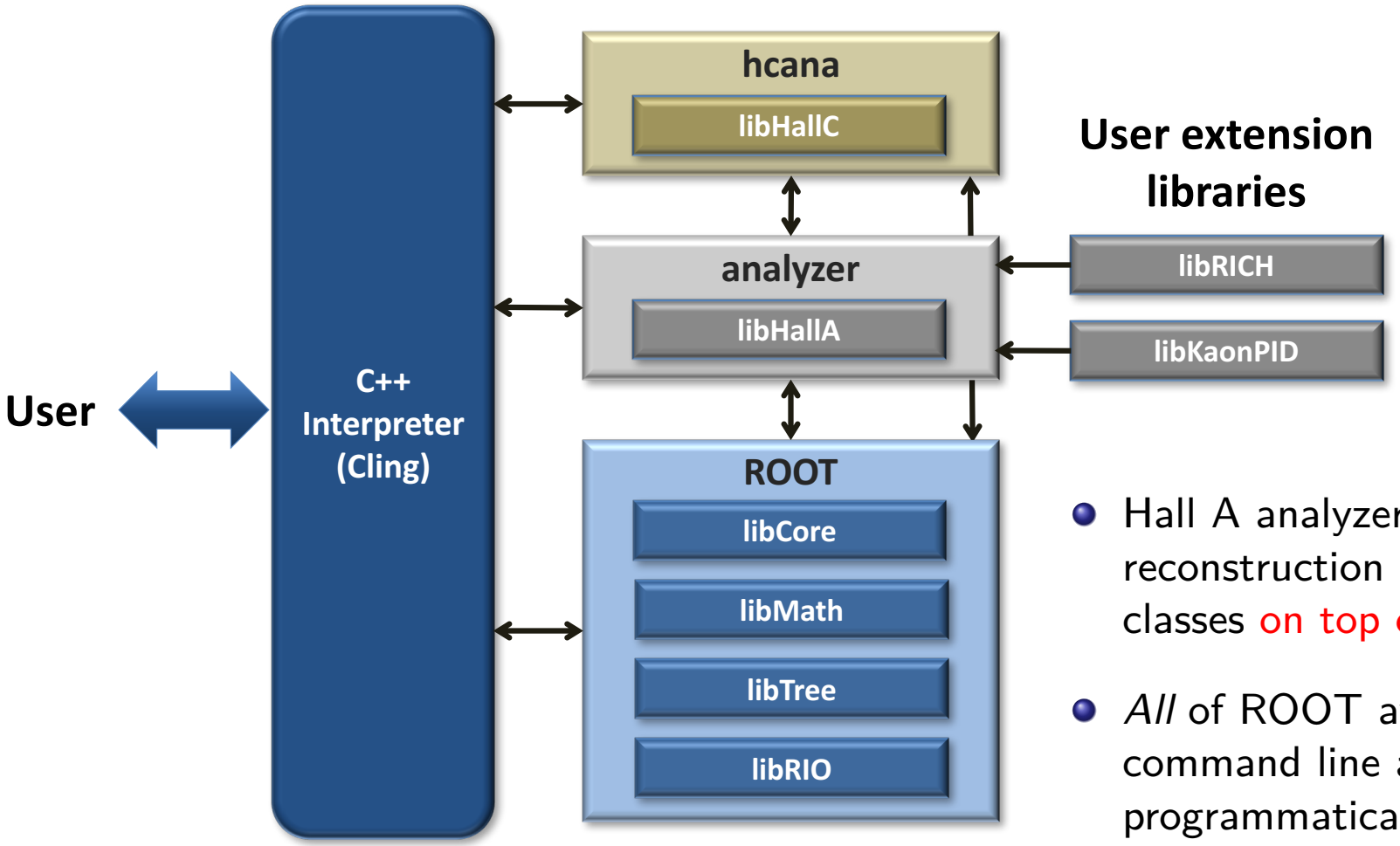
*Installation period during part of year; †Averages; ‡Includes simulations and three full production passes

Legend: **APEX**: Dark photon search; **PREX**: Neutron skin of ^{208}Pb; **CREX**: Weak charge of ^{48}Ca; **HRS**: High-resolution spectrometer; **BB**: BigBite; **SBS**: SuperBigBite; **VDC**: Vertical drift chamber; **GEM**: Gas Electron Multiplier tracker; **PAN**: Parity Analyzer; **Core**: Xeon W-2145 3.7 GHz (Skylake); ✔ ready; ◐ in progress; ✗ to do

Hall A C++ Analyzer ("Podd") Framework

- Design goals:
  - Highly modular to accommodate frequently changing experimental setups
  - Run-time configurable
- C++ class library built on top of ROOT. Steering via ROOT interpreter
- Developed in-house. Standard choice for Hall A analysis since 2003
- Shared development with Hall C since 2012
- Strengths
  - Light-weight: minimal dependencies, small memory footprint
  - Apparently quite user-friendly: students learn easily
  - Output & cuts configurable (at run-time) via text files. Flat text file database
  - Works with ROOT 5 & 6, on current and older Linux and macOS
  - Adequate for Hall A & C-style spectrometer analyses
- Limitations
  - Single-threaded & not distributed
  - Designed for one-pass analysis only:
    EVIO raw data $\rightarrow$ ROOT ntuple-style trees + histograms

Plug-In Architecture

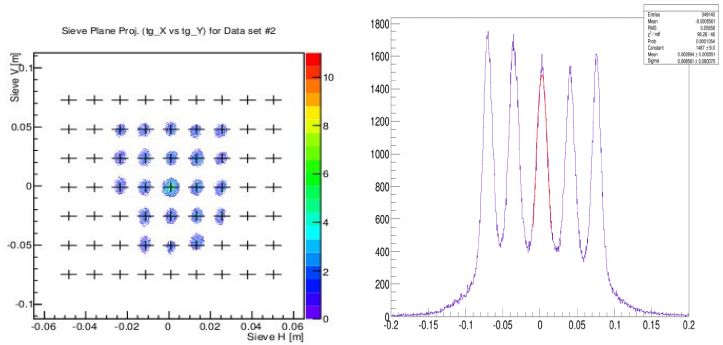


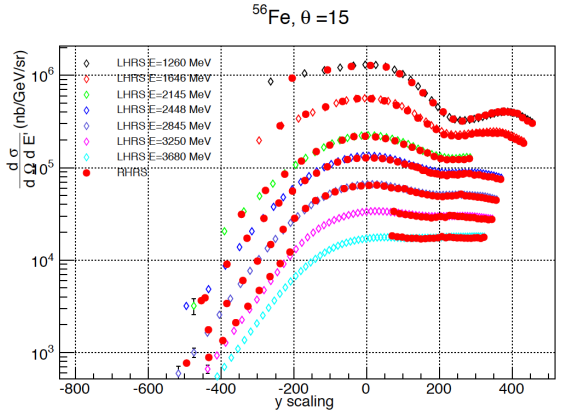
- Hall A analyzer = Library of reconstruction & analysis classes on top of ROOT
- *All* of ROOT available at command line and programmatically

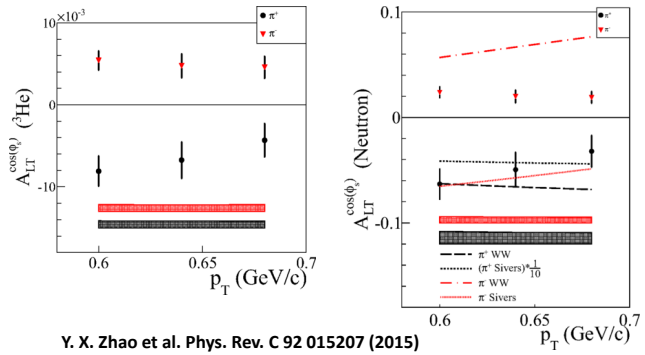
Extensive Repository of Application Libraries

- **Hardware decoders**
  - ✔ Various common Fastbus and VME modules
  - ✔ JLab 12 GeV pipelined electronics (FADC250, F1TDC)
  - INFN "MPD" GEM tracker readout
- **Hall A Reconstruction**
  - ✔ HRS w/standard trackers & detectors
  - ✔ HRS focal-plane polarimeter (FPP)
  - BigBite drift chamber track reconstruction (TreeSearch)
  - DVCS calorimeter waveform analysis
  - Tritium experiments custom detector classes
  - ✔ Calibration scripts & tools
- **Hall C Reconstruction**
  - ✔ HMS & SHMS w/standard trackers & detectors
  - ✔ Calibration scripts & tools
- **SBS**
  - Digitization algorithms
  - Prototype GEM track reconstruction
- **Physics/Analysis**
  - ✔ Standard kinematics calculations, *e.g.* (e, e'), $(e, e'p)$
  - ✔ Frequently-used correction algorithms, *e.g.* energy loss, beam position, extended target

✔ = included in standard Hall A distribution (✔=Hall C)





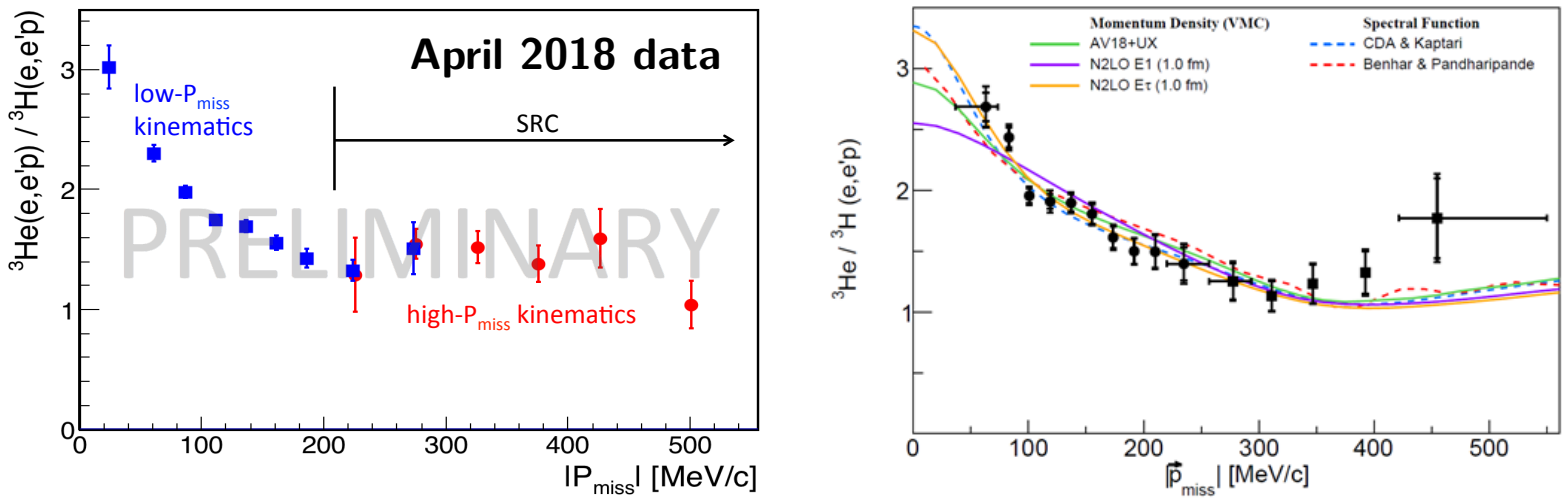


Y. X. Zhao et al. Phys. Rev. C 92 015207 (2015)

Experience with Hall A Analyzer

- Used by (nearly) all experiments since 2003 without significant issues
- Close ROOT integration seen as advantage (by both users and developers)
- Readily accepted by students
- Modularity very helpful
- Early 12 GeV experiments (2014–2018): again, no significant issues (unsurprising since no new spectrometers)
- Fast time to publication is possible if calibration demands are low:

"online" May/June 2018 $\longrightarrow$ **draft publication Oct 2018**



User Education & Resources

- (Bi-)Annual Analysis Workshop
  - Hands-on tutorials & worked-out analysis examples
  - New this year:
    - ★ Analysis with Python
    - ★ Hands-on introduction to computing on the JLab farm
  - Materials archived on web
  - AV recordings of presentations
  - Well attended (50-some participants). May expand next year
- New: Redmine project management, issue tracker, documentation wiki
  `https://redmine.jlab.org/projects/podd`
- Software development kit (SDK)
- GitHub code repository: `https://github.com/JeffersonLab/analyzer`
  - Automated Travis CI builds
  - $\sim$ Monthly Coverity Scan defect analysis

Recent Progress

- Support for new DAQ modules and modes (mainly for SBS *et seq.*)
  - JLab 12 GeV pipelined frontends (FADC250, F1TDC)
  - INFN "MPD" readout for GEM trackers
  - Multiblock readout mode (multiple events per buffer) for pipelined modules
  - CODA 3 data format
- Official Analyzer Release 1.6 (14-Mar-2018)
  - Stable environment, used by current ^{3}H/^{3}He experiments
- Universal database API (beta)
  - Important as Hall A and Hall C use different database backends
- Under-the-hood improvements
  - `CMake` build system (alternative to aging `SCons`)
  - Extensive code cleanup, guided by static code analysis

New Development Required for 2021 and Beyond

- SBS
  - GEM track reconstruction for BigBite and SBS configurations (partly done)
  - New detector reconstruction algorithms
    - ★ Hadron and electron calorimeters (cluster finding)
    - ★ RICH (for SBS-SIDIS, re-use existing HERMES algorithm)
  - Calibration & analysis
    - ★ Elastic e-p kinematic correlation analysis for SBS-GEp
    - ★ SBS-GEp $\vec{p}$ polarimetry
    - ★ Time-of-flight and PID
    - ★ GEM tracker alignment, calibrations
    - ★ Event display and online monitoring

See S. Riordan's talk (next) for details

- Large data volume handling
  - Efficient workflow tools, already developed by SciComp group (SWIF), can learn from Hall B & D's experience
  - Multi-threading (may benefit SBS — better I/O and memory usage)

Summary

- Hall A analysis framework and HRS reconstruction software has been in production use for 15 years. Stable and well debugged
- Sufficient for 12 GeV experiments through 2020
- Shared development with Hall C ongoing, proven very helpful
- Experiments from 2021 onwards, in particular the SBS project, require development of new reconstruction routines, which is underway