CLAS12/Hall-B Overview and Progress

(addresses charge items: 1a, b, c, and 2a, b, c)

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Jefferson Lab 12-GeV Experimental Computing Review

November 27-28, 2018

Outline

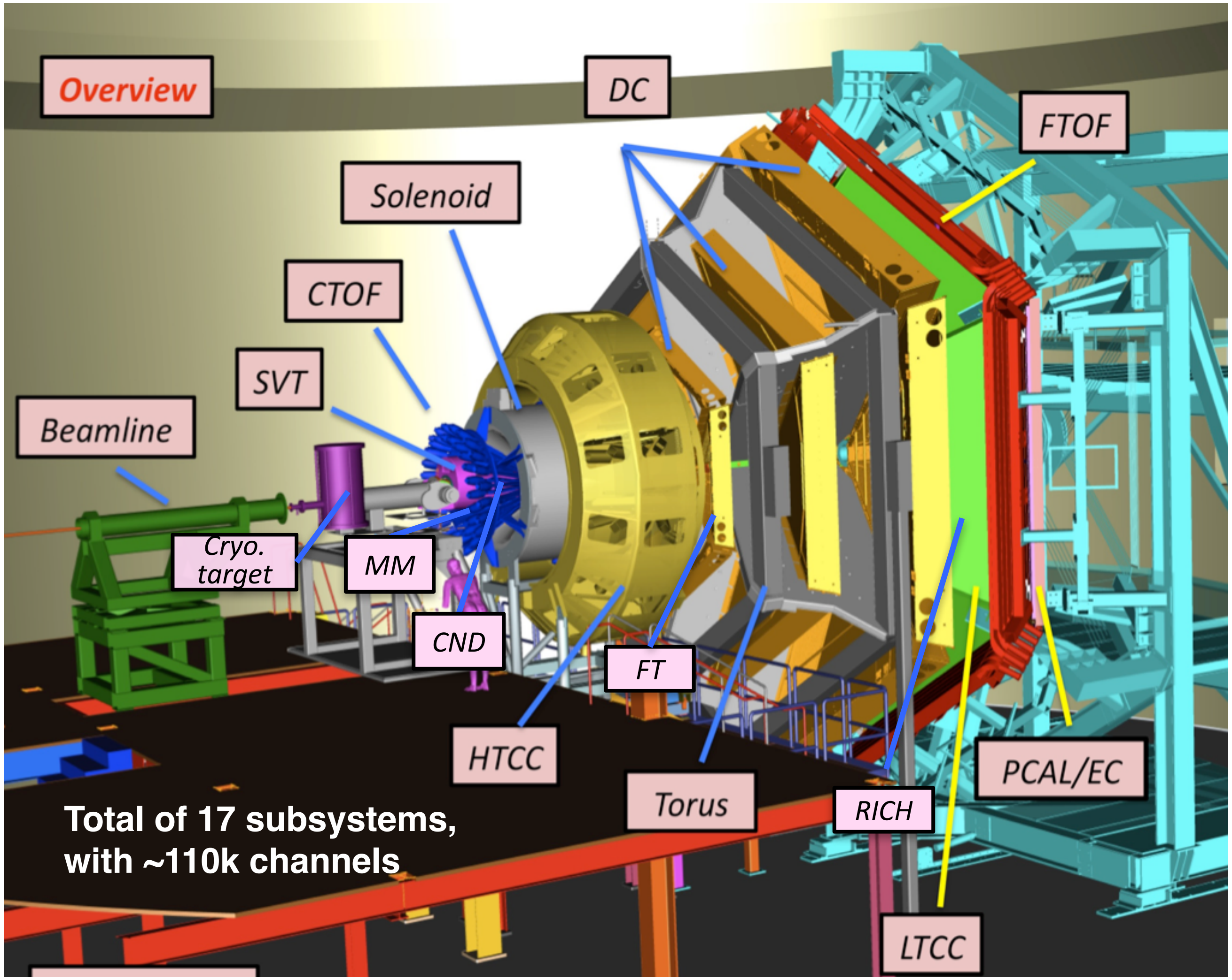
- Hall-B CLAS12 detector and the physics program
- Software support
- Experiment organization and Run Groups
- Data handling, current status
- CLAS12 performance
- Path forward to physics results
- Summary

CLAS12 Detector in Hall-B

Forward Detector (FD)
- TORUS magnet
- High Threshold Cherenkov Counter (HTCC)
- Drift chamber system (DC)
- Low Threshold Cherenkov Counter (LTCC)
- RICH detector
- Forward Time-of-Flight System (FTOF)
- Pre-shower calorimeter (PCAL)
- E.M. calorimeter (EC)

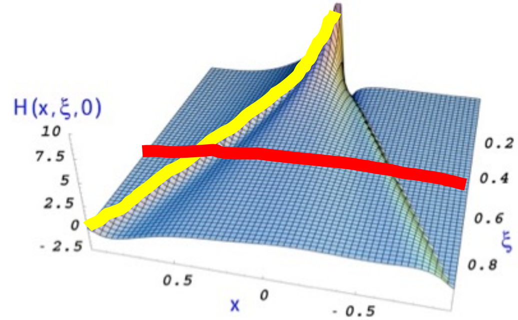
Central Detector (CD)
- SOLENOID magnet
- Silicon Vertex Tracker (SVT)
- MicroMegas (MM)
- Central Time-of-Flight (CTOF)
- Central Neutron Detector (CND)

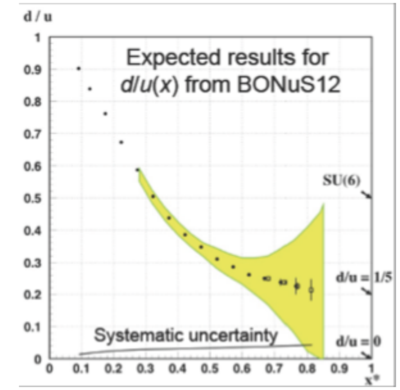
Others
- Forward Tagger (FT)
- Beamline
- Cryo Target
- Moller polarimeter

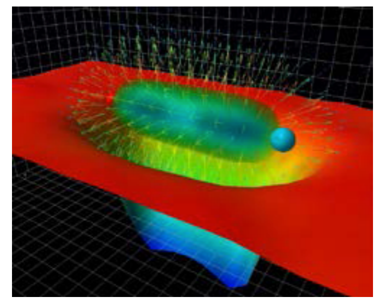


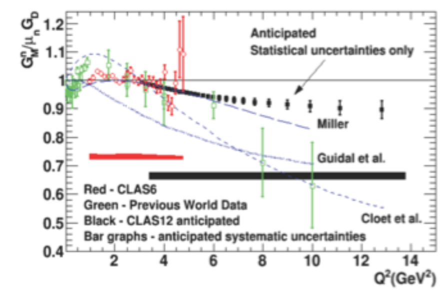
Hall-B Physics program

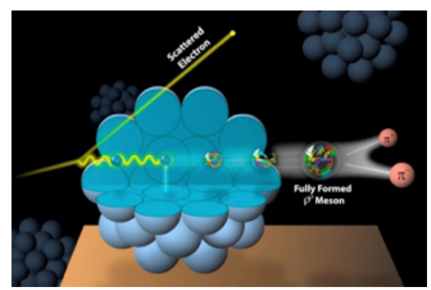
- The 3D structure of the hadrons (generalized parton distributions, GPDs, and transverse momentum distributions, TMDs)
- The transverse and longitudinal structure of hadrons (unpolarized and polarized parton distribution functions, elastic and transition FF)
- The Hadron spectra as probes of QCD (heavy baryon and meson spectroscopy, search for exotics)
- Hadrons and cold nuclear matter (Medium modification of the nucleons, quark hadronization, N-N correlations, few-body experiments)
- Search for physics beyond Standard Model (dark force carriers)

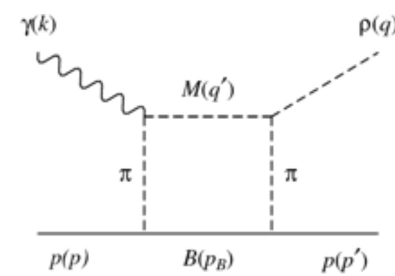








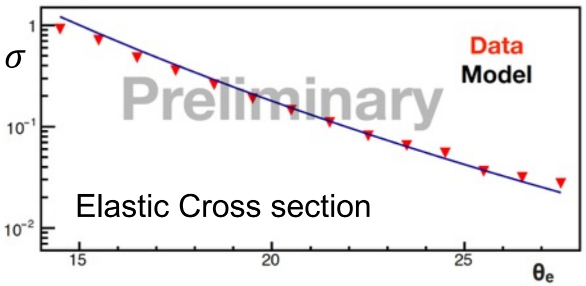




Physics observables

Detector efficiency and geometrical acceptance

Integrated luminosity (includes beam charge & target thickness)



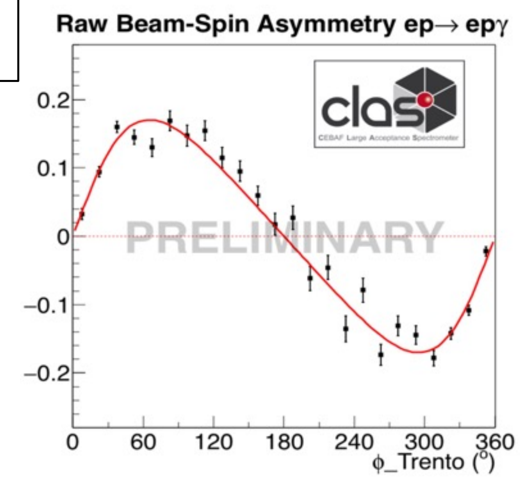
$$\sigma \sim N/(\epsilon\mathcal{L})$$

Cross sections

Number of identified physics events at each B/T spin state

Spin (beam and/or target) asymmetries

$$A_{B(T)} \sim \frac{1}{P_{B(T)}} \frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}}$$

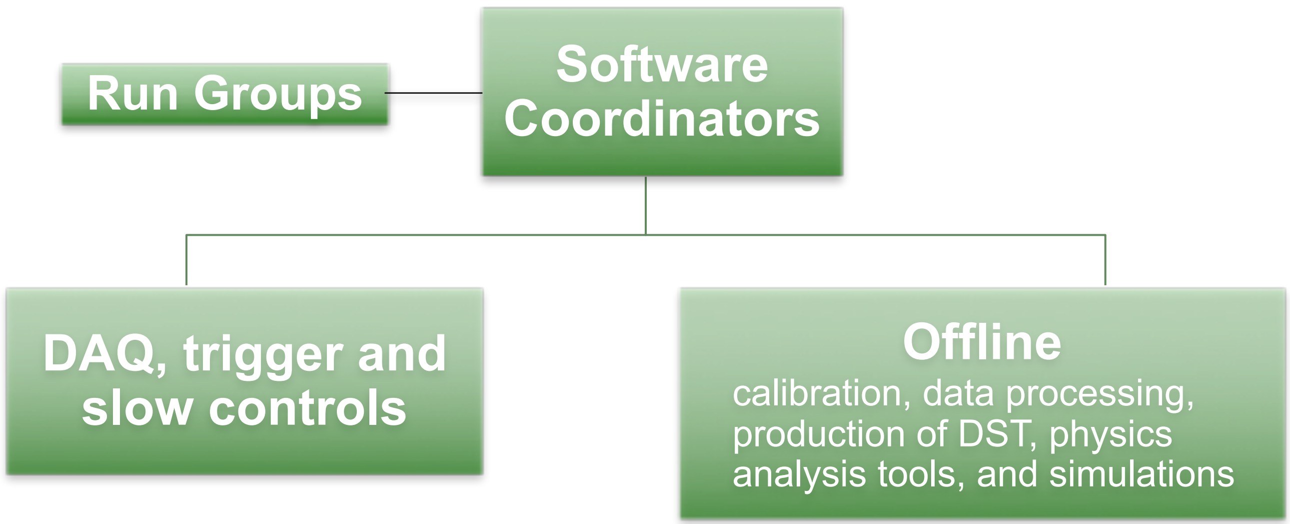


Beam (target) polarization

Need a software to extract quantities needed for calculation of these observables.

Goal for the software support

- efficient acquisition of data and data quality monitoring during the experiment
- control and monitoring of hardware performance and stability
- build and maintain software tools for detector calibration, data processing and production of DSTs, and for physics analysis
- provide GEANT-4 based simulation package for the detector response



The CLAS collaboration contributes in all areas, with significant efforts directed towards detector calibrations

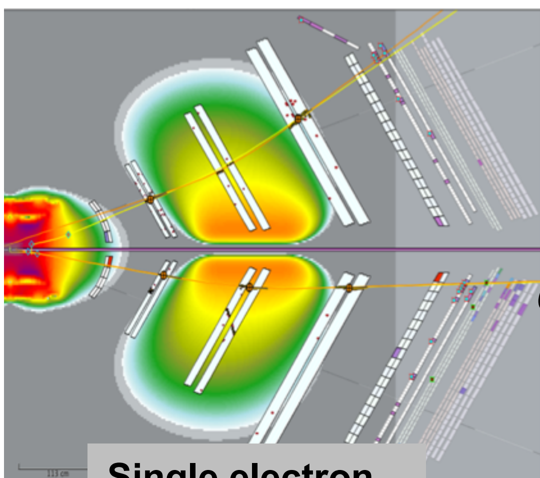
Details in R. De Vita's talk

Experiment organization

- Experiments in Hall-B, total of 42, organized into 12 Run Groups based on beam conditions and the targets. Most of the Run Groups consist of more than 3 experiments, approved either by PAC or by the CLAS collaboration
- A run group can have multiple different trigger requirements for data acquisition based on the physics reactions under the study

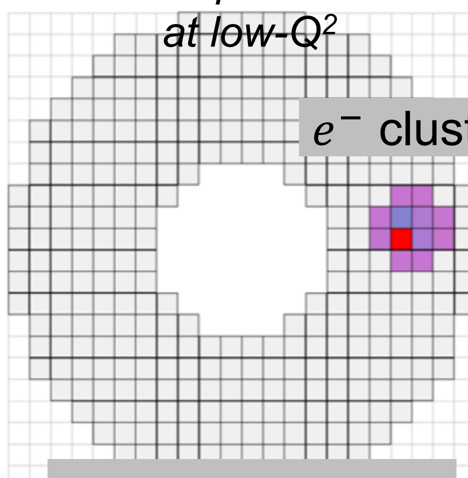
RG-A triggers

Electroproduction



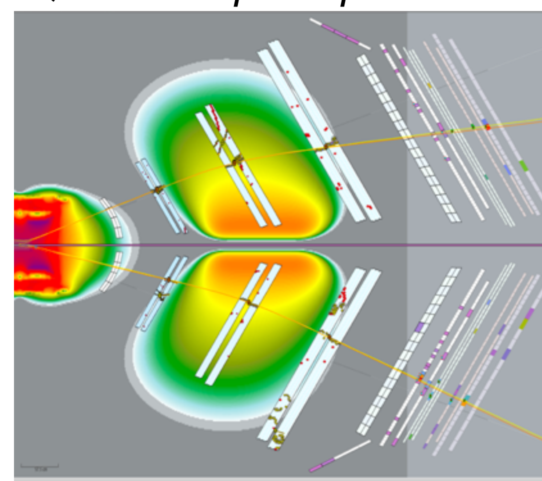
Single electron, HTCC&Ecal 30%

Electroproduction at low-Q^2



Electron in FT and 2-hadrons in FD, 45%

Quasi-real photoproduction



2μ-opposite sector, 23%

Hall-B Run Groups Summary

Run Groups	Number of experiments	Beam time (PAC-days)	Luminosity (per nucleon)	Triggers
A	13	139 (100)	$10^{35} cm^{-2} s^{-1}$	$e^-, 2\mu, e^-_{FT} 2H$
B	7	90	$10^{35} cm^{-2} s^{-1}$	$e^-, 2\mu$
C	6	180	$2\times10^{35} cm^{-2} s^{-1}$	e^-
D	1	60	$2\times10^{35} cm^{-2} s^{-1}$	e^-
E	1	60	$2\times10^{35} cm^{-2} s^{-1}$	e^-
F	1	42	$4\times10^{34} cm^{-2} s^{-1}$	e^-
G	1	55	$2\times10^{35} cm^{-2} s^{-1}$	e^-
H	3	110	$10^{34} cm^{-2} s^{-1}$	e^-
I¶	1	180	$10^{34} cm^{-2} s^{-1}$	$e^+ e^-$
K	3	100	$10^{35} cm^{-2} s^{-1}$	e^-
L	4	55	$10^{35} cm^{-2} s^{-1}$	e^-
M	2	45	$2\times10^{34} cm^{-2} s^{-1}$	e^-

¶ - Heavy Photon Search, non-CLAS12 experiment

- The experiment in RG-J (PRad) has been completed

Data Handling – from DAQ to Physics

- Beam run (data taking) is managed by the collaboration – organization of shifts and providing experts for 24/7 on-call support
- During the run Run Group is responsible for the run plan and provides an additional support for data quality monitoring (both online and offline)
- Offline group provides software tools for data calibration and processing. Organizes training sessions for collaborators (usually during the collaboration meetings), and oversees calibration process
- The Run Groups provide manpower for the data calibration, data processing and production of skimmed DSTs for physics analyses
- Different experiments in a run group will have common tools for analysis with:
  - some overlap in requirements for PID, kinematic fits, and corrections (inclusive vs. exclusive channels), and
  - limited overlap in the physics analysis (radiative corrections, PWA, spin asymmetries, …)

Since the Last Review

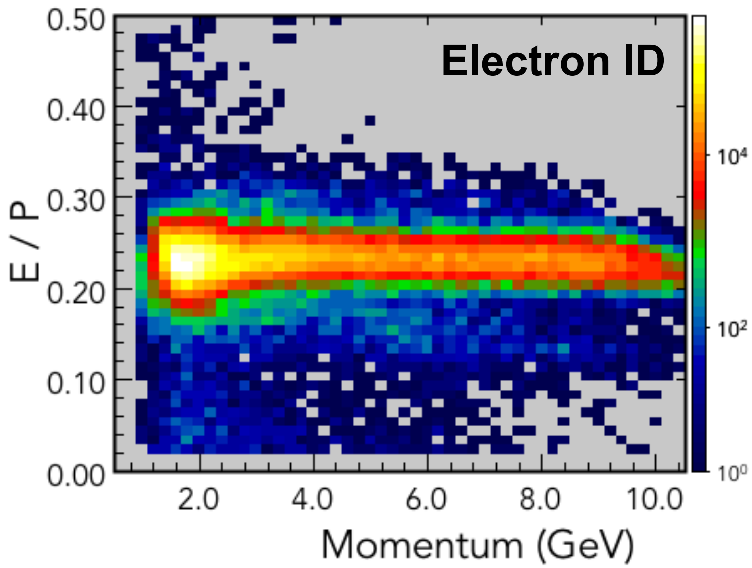
- The Hall-B/CLAS12 successfully completed demonstration of KPP and the commissioning run, and started execution of the CLAS12 physics program
- Currently, about the third of data for RG-A, the largest and the most diverse run group, are on tapes, and the data taking for RG-K will start shortly
- Following the recommendation of the November 2016 review: *"Continue to carefully track software milestones, and maintain an achievable plan, leading up to the commissioning/physics run in 2017",* the CLAS12 software group prepared and executed a plan to have the online and offline software fully ready for beam runs
- Overall performance of the software at the start of the beam runs was reasonably good, but not necessarily with optimum conditions and speed
- There was some learning involved (and continues) with high luminosity running to understand the detector performance, backgrounds, data handling, monitoring …

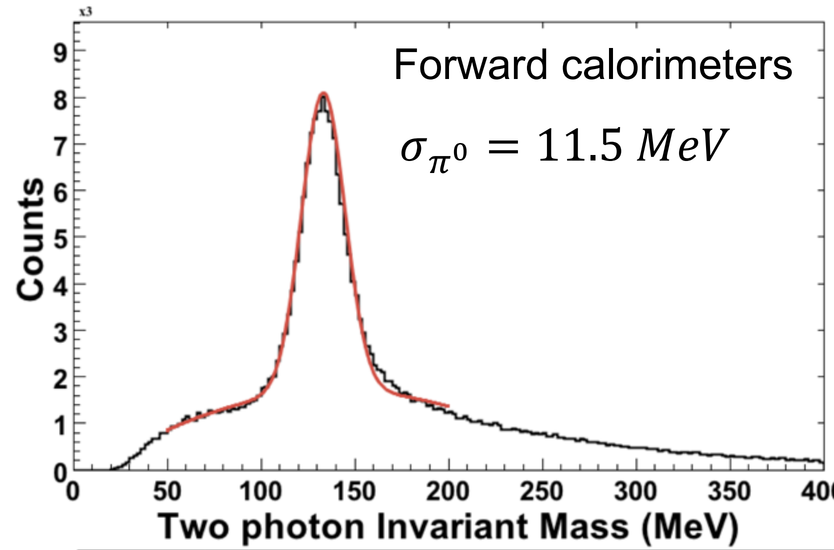
Current State of the Software

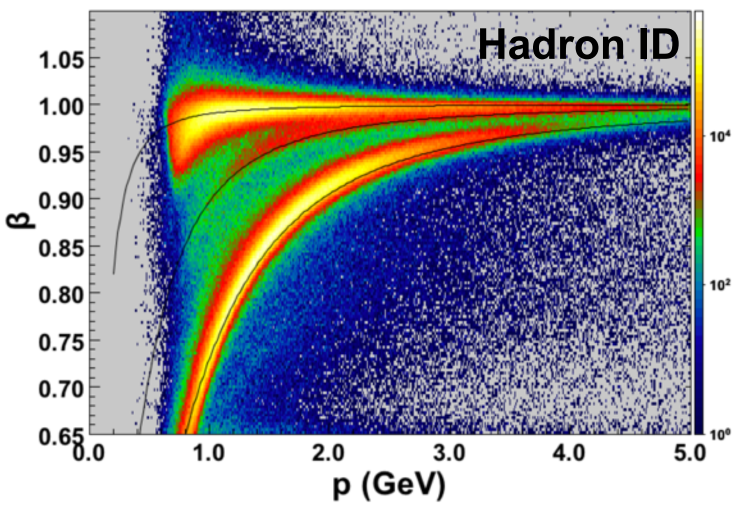
- May-2018 software review acknowledged the progress, but had several recommendations for improving the data collection and the offline analysis – *all recommendations have been addressed within four months time*
- Working together with the support groups, we were able within few months make significant improvements in data handling:
  - DAQ event size was reduced from 42 kB/event to **25 kB/event**
  - improved trigger purity by about **20%** using tracking trigger
  - built better/reliable monitoring system, and
  - reduce offline data processing time by more than **x3**
- Within three months after the first part of the RG-A run, collaboration was able to calibrate and process 10% of the data, and produce DST skims for physics analyses
- Very preliminary results from the multiple physics analyses of the 10% of RG-A spring run were presented at the fall DNP meeting

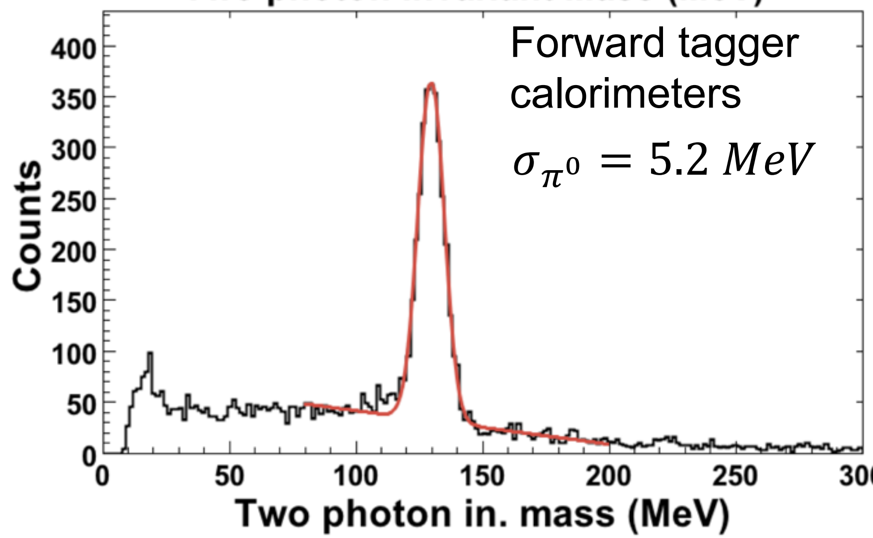
Details in R. De Vita's and G. Heyes's talks

CLAS12 performance, RG-A data (PID)



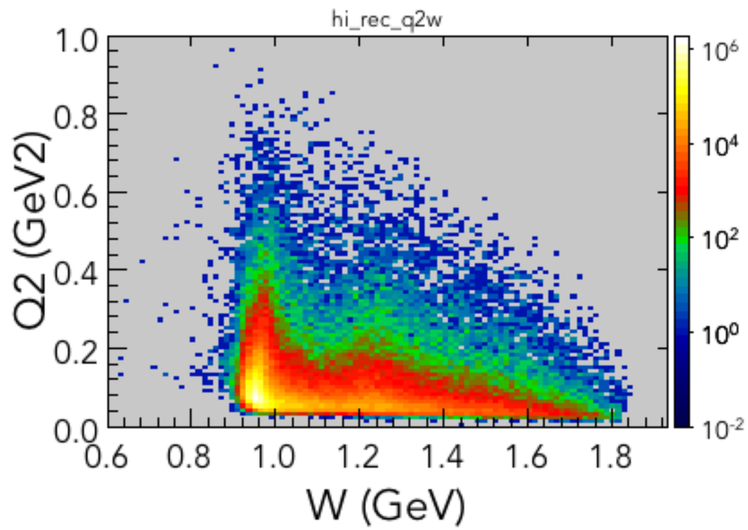


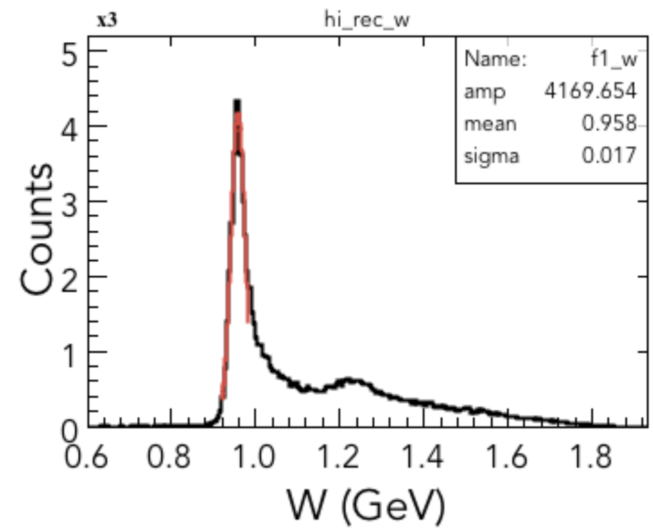




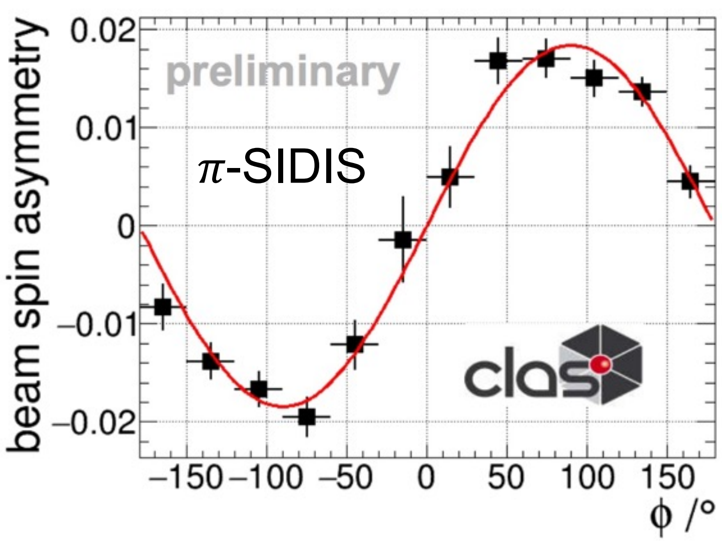
CLAS12 performance (physics observables)

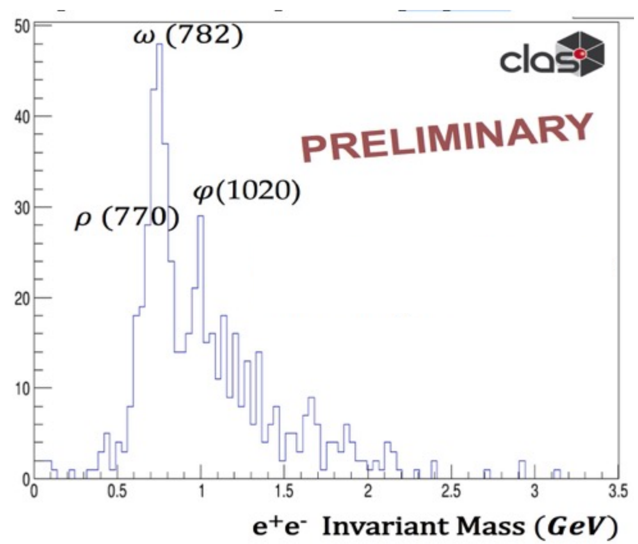
2.2 GeV





10.6 GeV





Expectations for 5 years of running

- Sequence of runs for the next 2 years is defined, run conditions are known
- Expected event and data rates are scalable from RG-A and well within expected range of available resources

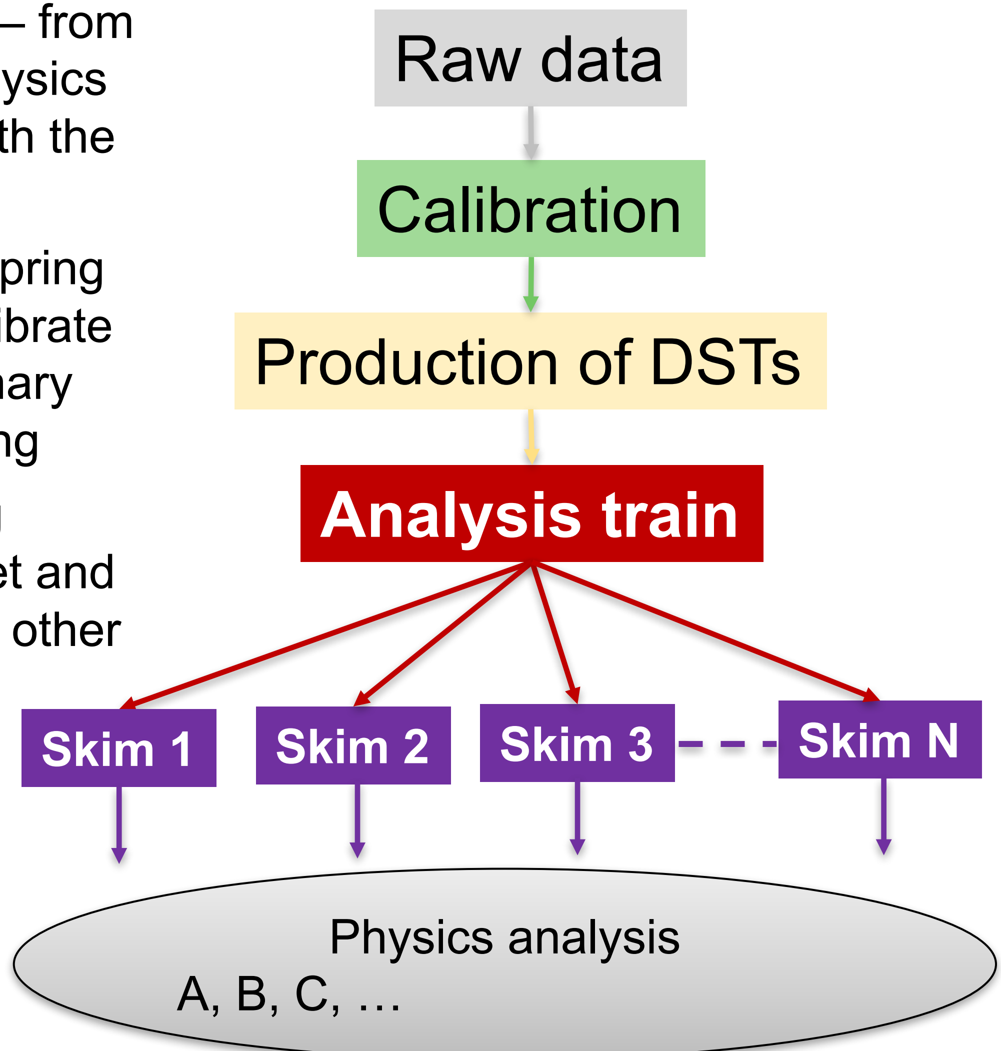
Run Group	Event rate (kHz)	Data rate (MB/s)	Beam time (days)	Total events (1E+9)	Total data (TB)	Comments	
RG-A	**13**	**360**	**62**	**72**	**1918**	**spring-fall 2018, spring 2019**	Scheduled
RG-B	**15**	**350**	**49**	**64**	**1482**	**spring-fall 2019**	
RG-K	**13**	**300**	**9**	**10**	**233**	**fall 2018**	
RG-I (HPS)	**15**	**150**	**28**	**36**	**363**	**summer 2019**	
RG-F	**2**	**54**	**42**	**8**	**195**	**full beam time, spring 2020**	
Total for 3-years				**190**	**4191**		
RG-C	12	269	112	113	2605	32 weeks on the floor	Tentative, assumes 32 weeks/year
RG-D/E	12	269	15	15	349		
RG-L	6	135	55	28	640	full beam time	
RG-M (low energy)	20	400	42	73	1452	full beam time	
Total for next 2-years				228	5045		
Total for 5 years				**419**	**9237**	Events and TBytes	

- With 45% fair share of JLAB farm, assuming x2 overhead for calibration and pass0, processing of data from 5 years of running will take ~2 years

Details in R. De Vita's and G. Heyes's talks

Path Forward to Physics Results

- The full chain of data processing – from raw data to skimmed DSTs for physics analysis – has been exercised with the 10% of RG-A data
- Within 3-months after the RG-A spring run, collaboration was able to calibrate data and present the first preliminary physics results at the DNP meeting
- The whole process is now getting repeated for the full RG-A data set and expect to be exactly the same for other Run Groups
- Our aim is to have the first significant physics results from RG-A in fall of 2019, and expect to have a similar time scale for all Run Groups



Summary

- Hall B started execution of a diverse physics program using one of the most sophisticated detectors at JLAB, CLAS12
- Software for the control and monitoring of hardware performance, acquisition, calibration, and processing of data, and simulation of the detector response are in place and performing as expected
- Present performance of the whole software framework is adequate for successful completion of the upcoming experiments for years to come
- Plans are in place to continue further improvements of DAQ/trigger efficiency, hardware control and monitoring, and offline analysis
- The next few years we expect to integrate new detectors: *BAND, Bonus12, ALERT, polarized target (operations with rastered beam), …* and provide a support for any new physics requirements that will come

In the following talks by R. De Vita and G. Heyes, more details of the software organization, offline data processing, plans for simulations and physics analysis will be discussed.