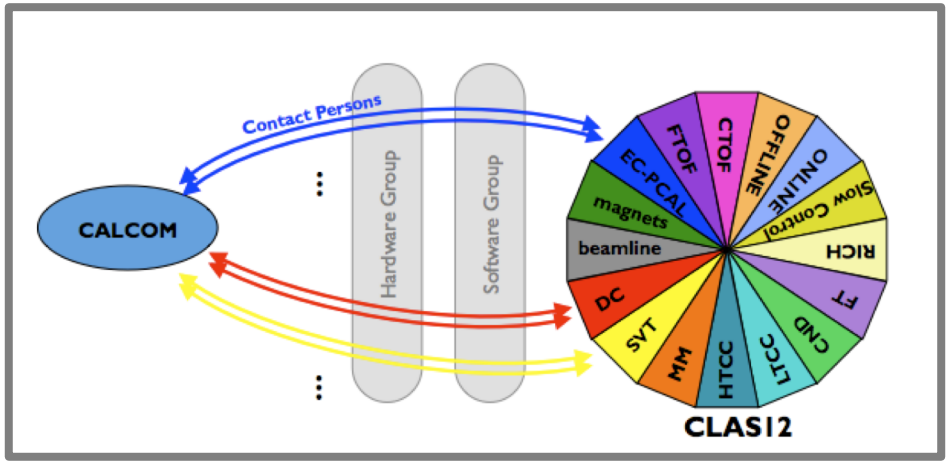
ACTIVITIES OF THE CLAS12 CALIBRATION AND COMMISSIONING GROUP (CALCOM)

Daniel S. Carman – CLAS Collaboration Meeting - July 21, 2020

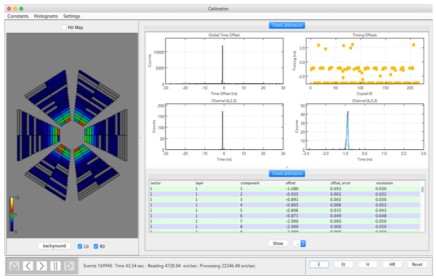
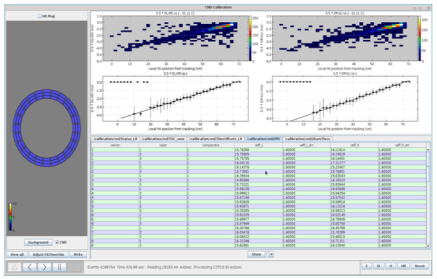
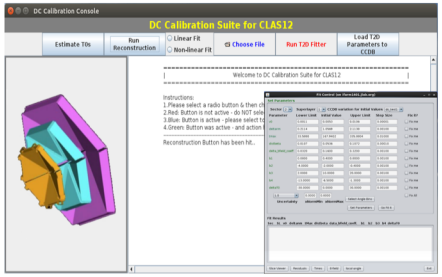


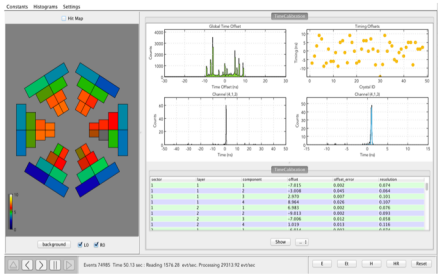
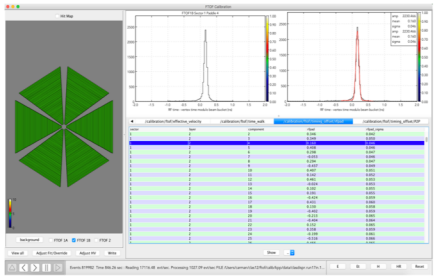
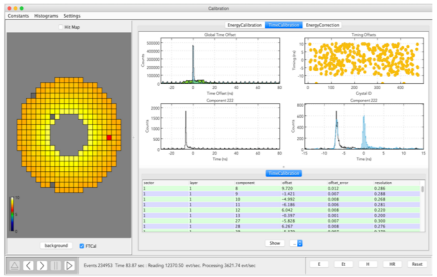
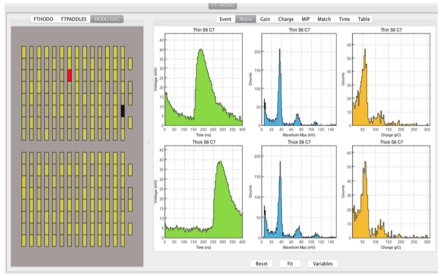
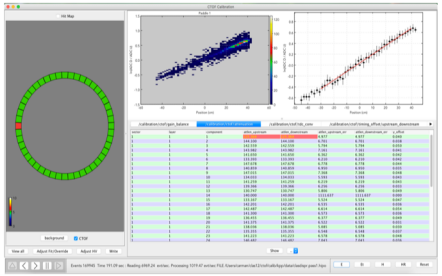
CALCOM Roles and Responsibilities

Responsible for directing CLAS12 **CAL**ibration and **COM**missioning for baseline and non-baseline detectors

- Provide oversight to the development of subsystem *calibration* suites
  - With the Software Group, provide software templates for detector groups and common I/O tools
  - Work with subsystem groups to develop documentation, tutorials for calibration suites, and calibration tools
  - Help to find manpower and to ensure efficient use of resources by setting priorities for different work tasks
  - Help to define standards for subsystem calibration metrics (e.g. energy, time, position resolution)
- Develop detailed plans for *commissioning* with beam activities
  - CWB to verify Key Performance Parameters (KPP)
  - Commissioning/engineering run before start of RG-A production run

CALCOM "Deliverables"

KPP run

Commissioning With Beam of the CLAS12 Spectrometer
to Demonstrate the JLab 12 GeV Project
Key Performance Parameter
Version 8.0

December 13, 2016

Abstract

This document describes the procedures that will be followed for the commissioning of the CLAS12 spectrometer using electron-beam-induced reactions in order to demonstrate that the system meets the Key Performance Parameter (KPP) as defined by the JLab 12 GeV Upgrade Project. The commissioning will consist of different phases, starting from low luminosity operation for the initial detector turn-on and functionality checks, then optimizing the detector settings, and then performing data acquisition studies of the basic system response to charged and neutral particles coming from beam-target interactions.

This document is structured as follows: In Sections 1 and 2 the specific KPP requirements are detailed and the objectives of the CLAS12 KPP commissioning beam period are discussed. In Sections 3 and 4 the specific assumptions regarding which elements of Hall B and CLAS12 will have been commissioned and tested prior to the start of the KPP beam time are discussed along with the beamline and detector configurations. Section 5 provides an overview of the expected rates in the detectors for the KPP conditions based on Monte Carlo simulation studies. Sections 6 and 7 describe the different phases of the KPP run and the specific commissioning tasks to be completed along with the associated task timelines. Finally, Section 8 details the CLAS12 subsystem contacts, as well as the management and organization details for Hall B during the KPP beam commissioning period.

engineering run

Commissioning of the CLAS12 Spectrometer
Engineering Run
Version 2.5

December 1, 2017

Abstract

This document details the run plan for the commissioning of the CLAS12 spectrometer during the Dec. 2017/Jan. 2018 Engineering Run using the CEBAF electron beam at 5-pass and 3-pass energies. The commissioning run will consist of four different phases: i) beamline commissioning at 10.6 GeV, ii) CLAS12 commissioning at 10.6 GeV (Part 1) iii) CLAS12 commissioning at 10.6 GeV (Part 2), and iv) CLAS12 commissioning at 6.4 GeV. The commissioning of the CLAS12 detector subsystems and spectrometer will include low luminosity operation for the initial detector turn-on, functionality checks, and optimization of the detector settings, studies of the DAQ and trigger systems, and calibration and commissioning studies at different luminosities and torus/solenoid field settings. In addition, the Hall B Møller polarimeter system will be commissioned and used to measure the polarization of the electron beam, and zero field runs will be taken for detector alignment studies in both the CLAS12 forward and central detectors.

This document is structured as follows: In Section 1 the specific objectives of the CLAS12 Engineering Run period are introduced. In Section 2 the configuration of the Hall B beamline and detector subsystems for the run are defined. Section 3 provides a high-level overview of the different operational phases of the run period and the daily schedule and Section 4 provides details on the specific commissioning tasks to be completed in each phase, along with the associated task durations, required personnel, and offline analysis goals.

CALCOM led development of:

- Subsystem calibration suites
- CLAS12 commissioning plans

CLAS12 Calibration and Commissioning

Contents [hide]

1 CALCOM Committee
2 CLAS12 Subsystem Contact Persons
3 Commissioning Plans
4 CLAS12 Calibration
5 Meetings and Minutes

CALCOM Committee

The role of the CALCOM (Calibration and Commissioning) Group is to be responsible for the development of the tools/algorithms to calibrate the CLAS12 detector and to help ensure that the design performance specifications are met. In addition the CALCOM group is responsible for developing the CLAS12 commissioning plan and overseeing its execution.

The committee is composed by:

- Daniel Carman (chair / hardware)
- Raffaella De Vita (software / hardware)
- Gagik Gavalian (common tools)
- Maurizio Ungaro (simulation)
- Veronique Ziegler (reconstruction)

CLAS12 Subsystem Contact Persons

System	Subsystem	Contact Person(s)	Software Contact Person
Calorimeters	ECAL	*C. Smith*	*C. Smith*
Central Tracker	SVT	*Y. Gotra*	*V. Ziegler*
	MM	*M. Defurne*	*F. Bossu, M. Defurne*
	RTPC	*M. Hattawy*	*D. Payette*
Cerenkov Counters	HTCC	*Y. Sharabian*	*N. Markov, W. Phelps*
	LTCC	*M. Ungaro*	*M. Ungaro*
	RICH	*M. Contalbrigo*	*M. Mirazita*
Forward Tagger	FT-Cal	*R. De Vita*	*R. De Vita*
	FT-Hodo	*N. Zachariou*	*R. De Vita*
	FT-Trk	*R. De Vita*	*V. Ziegler*
Forward Tracker	DC	*M.D. Mestayer*	*V. Ziegler*
	FMT	*M. Defurne*	*V. Ziegler*
RF		*R. De Vita*	*R. De Vita*
Scintillation Counters	FTOF	*D.S. Carman*	*D.S. Carman*
	CTOF	*D.S. Carman*	*D.S. Carman*
	CND	*S. Niccolai*	*P. Chatagnon*
	BAND	*F. Hauenstein*	*F. Hauenstein*

Commissioning Plans

- KPP Commissioning Plan
  - CLAS12 KPP Demonstration Slides
- Engineering Run Commissioning Plan
  - Analysis of electron and hadron rates for CLAS12 calibration and commissioning
- Calibration Challenges: Dec. 2016, Aug. 2017

CLAS12 Calibration

Information for Analysis Coordinators:

- How to calibrate? What are the standards for CLAS12? [1]
- Calibration and Software Development and Calibration Teams:
  - Development Team
  - Calibration Team
- Run-Based Monitoring
- CCDB Tables and Usage Policies
- CLAS12 Hardware Status Word Definitions

Calibration Suite Documentation:

- BAND:
- Cherenkov:
  - HTCC:
  - LTCC: suite
  - RICH: suite, manual
- CND: suite, tutorial, algorithms
- CTOF: suite, tutorial, algorithms, ccdb, geometry
- CVT:
  - MM:
  - SVT: suite
- DC: suite, tutorial, calibration wikipage
- ECAL: suite
- FT:
  - FT-CAL: suite, tutorial
  - FT-HODO: suite, tutorial
- FTOF: suite, tutorial, algorithms, ccdb, geometry
- RF: suite, tutorial
- RTPC: geom, ccdb

Meetings and Minutes

- Bluejeans meeting connection: [2]
- 2011 Meetings
- 2012 Meetings
- 2013 Meetings
- 2014 Meetings
- 2015 Meetings
- 2016 Meetings
- 2017 Meetings
- 2018 Meetings
- 2019 Meetings
- 2020 Meetings

https://clasweb.jlab.org/wiki/index.php/CLAS12_Calibration_and_Commissioning

CLAS12 CALCOM Group

A ***new role*** has been assigned to CALCOM (in addition to the existing roles):

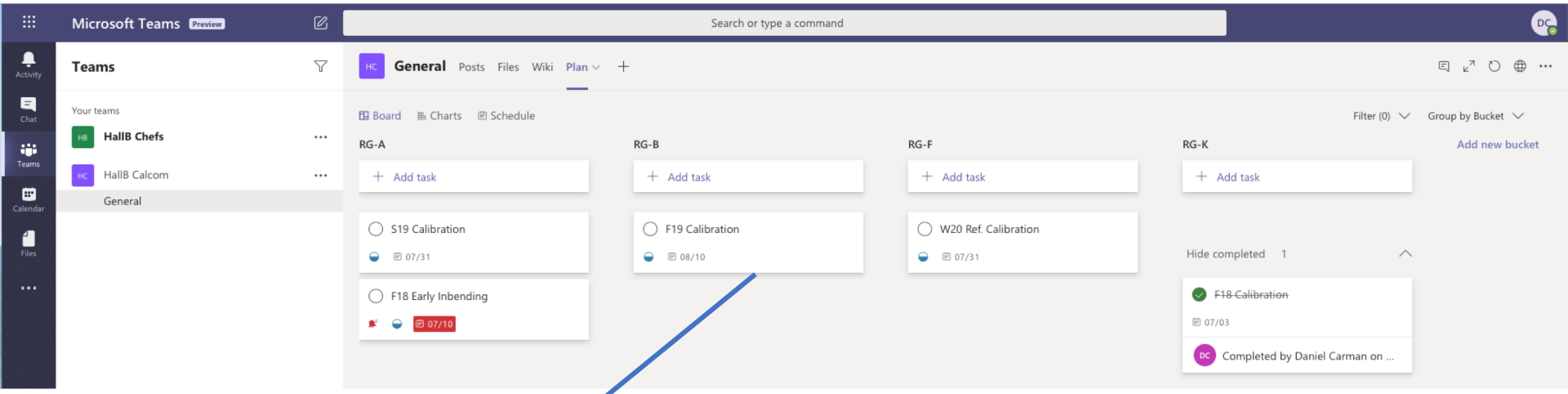
- With multiple Run Groups calibrating data sets simultaneously, there needs to be coordination among:
  1. the CCC that sets the priorities for cooking
  2. the Analysis Coordinators that oversee the calibration efforts and determine the priorities within the Run Groups
  3. the team of subsystem calibrators that are doing the calibrations
- The CALCOM Group will provide this coordination to ensure that the requests for calibrations are carried out in a manner that:
  1. takes into account the priorities set by the CCC
  2. ensures that the calibrators are not beset with tasks without clear priorities and defined/reasonable deadlines
  3. ensure that the calibrators are not overwhelmed with work requests

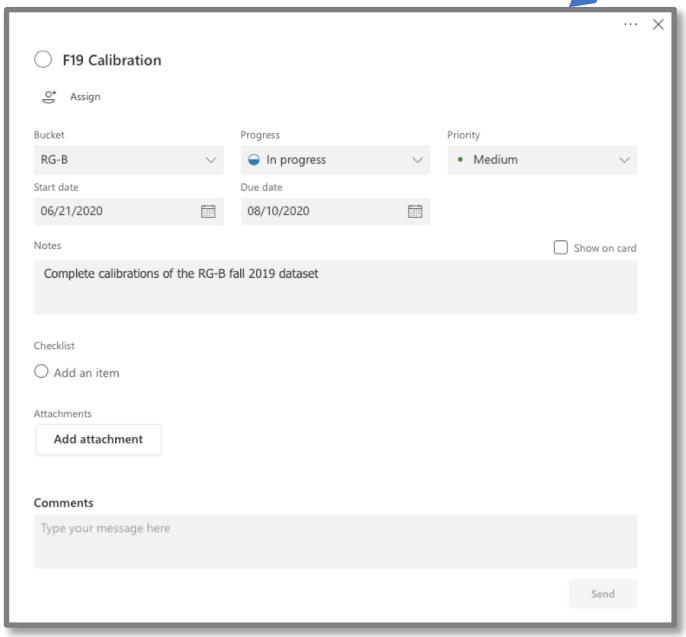
CLAS12 Calibration Requests

To begin calibrations the following sequence should be followed:

1. The Analysis Coordinator should prepare a *specific* work request with associated priorities to present at a weekly CALCOM meeting
    - Low, medium, high, urgent
2. The CALCOM chair will then provide feedback to the Analysis Coordinator based on other ongoing work to provide an expected completion date for the request
3. The Analysis Coordinator will interact with the assigned Run Group chef to cook the data and produce the calibration skims
4. The Analysis Coordinator will interact with the assigned calibrators with the calibration request and completion deadline
5. All calibration work requests, priorities, and status will be maintained on a documentation page updated regularly the CALCOM chair

CALCOM Calibration Tracking





Ongoing calibration tracking done on CALCOM Microsoft Teams platform

- List ongoing calibrations across all active Run Groups
- List completed tasks
- Track work against assigned deadlines
- Reviewed at CALCOM weekly meetings

CLAS12 Calibration Sequence

1) DC and Beam-Offset Calibrations:
   - time → distance calibration for reference runs
     - relies only on crude ST calibration from FTOF
   - complete beam (x,y) offset calibration

recook

2) FTOF Calibration:
   - energy and timing calibration for reference runs
     - calibrate offset between CTOF FADC and TDC time

recook

3) RF Calibration:
   - run-by-run calibration after FTOF calibrations – pass-0 files

recook

4) CLAS12 Subsystem Calibration:
   - CND, CTOF, DC, ECAL, FT (Hodo, Cal), HTCC, LTCC, RICH
     - complete for reference runs
     - calibration uses event ST from FTOF and EB PID
   - Check EB constants and ECAL e/γ sampling fraction

CLAS12 "Global" Performance Specs

System	Spec	Achieved	Spec	Achieved
CND	$\langle eff_n \rangle$ = 10%	~10%	δt = 150 ps	185 ps
CTOF	δt = 80 ps	85 ps		
DC	δx = 250 – 400 μm	330 – 400 μm		
ECAL	$\sigma_E/E = 10\%/\sqrt{E}$	$10\%/\sqrt{E}$	$\langle \delta t_\gamma \rangle$ < 500 ps	~500 ps
FT	$\sigma_E/E < 2\%/\sqrt{E} + 1\%$	$3.3\%/\sqrt{E}$	δt < 300 ps	< 150 ps
FTOF	60 – 110 ps (p1b)	60 – 120 ps (p1b)	90 – 180 ps (p1a)	70 – 250 ps (p1a)
HTCC	eff_π < 1%	< 1%	<nphe> = 16	12
RICH	δt < 1 ns	0.5 ns	π/K rej > 500	TBD
SVT	S/N > 10	~14	δx = 50 – 65 μm	TBD

**Entries highlighted in red have not yet met specs*

Subsystem Calibration Variance

	RF μ	RF σ	FTOF1B μ	FTOF1B σ	FTOF1A μ	FTOF1A σ
specification				60 ps		90 ps
RGA IN	$<$ 10 ps	55 - 65 ps	$<$ 5 ps	50 - 62 ps	$<$ 15 ps	85 - 105 ps
RGA OUT	$<$ 5 ps	60 - 65 ps	$<$ 3 ps	62 - 65 ps	$<$ 10 ps	105 - 125 ps

	DC res μ	DC res σ	vz μ	χ^2
specification		250 to 400 μm		
RGA IN	-120 to 50 μm	300 to 375 μm	-3.5 to -2.5 cm	110 to 150
RGA OUT	-100 to 50 μm	225 to 350 μm	-4.75 to -3.75 cm	90 to 120

	HTCC nphe	FTCal $\pi^0\mu$	FTCal $\pi^0\sigma$	ECal $\pi^0\mu$	ECal $\pi^0\sigma$
specification	16				
RGA IN	11 to 13	134 to 136 MeV	3.5 to 4.5 MeV	131 to 134 MeV	15 to 22 MeV
RGA OUT	12 to 13	134 to 136 MeV	3.5 to 4.5 MeV	131 to 133 MeV	10 to 15 MeV

	e rate/trig	prot rate / trig	π^+ rate / trig	K^+ rate / trig
RGA IN	0.25 to 0.37	0.4 to 0.6	2.5 to 3.5	0.07 to 0.1
RGA OUT	0.65 to 0.75	0.17 to 0.25	0.9 to 1.1	0.03 to 0.037

Develop tools to analyze timeline data to flag runs that do not meet specs

Subsystem Recalibration Criteria

Subsystem	Recalibration Criteria
CND	Timing: $\langle\delta t\rangle$ > 190 ps
	Gains: <gain shift> > 10%
DC	T_{max} > ±5 ns / ±20 ns (partial /full)
ECAL	Timing: var(δt) > 300 ps
	Gain: <gain shift> > 5%, var(G) < 5%
FT	CAL energy: $\sigma(\pi^0$ mass) > 20% or 2-3 MeV shift
	CAL timing: $\langle\delta t\rangle$ worsens by 10%
	HODO energy: MIP peak position shifts by > 0.2 MeV
	HODO timing: $\langle\delta t\rangle$ worsens by 10%
TOF	Gains: <gain shift> > 10%
	Timing: $\langle\delta t\rangle$ > 150 ps (p1a), > 80 ps (p1b), > 90 ps (CTOF)
RF	Run by run

IN PROGRESS

Prevent "creep" of accepted shifts to ensure consistent calibration performance

Detector Status Words

- Detector status words capture the status of the CLAS12 subsystem hardware

Status	Definition
0	Fully functioning (PMT)
1	No ADC
2	No TDC
3	No ADC and no TDC (PMT is dead)
5	Any other hardware problem

example for PMT-based detectors

https://clasweb.jlab.org/wiki/images/b/b9/Clas12-hardware-status-words.pdf

- Status words determined for most systems during calibration procedure
- Status tables exist in ccdb (and are being filled)
- It is crucial that tables are accurate so MC and data will match
- Also reconstruction has dependencies on hardware status
- Need to develop tools:
  - to accurately determine status tables during run sequence
  - for trackers to identify cable swaps and flips before data decoding (or massive data processing)

Detector Status Words – The Details

- The standards for definition of the status words has been set
- The reconstruction code is not yet set up to handle subsystem status lists
  - When the code is ready we will complete a validation procedure
  - For now the plan is for reconstruction to only deal with status of "good" or "bad" - no "partial" efficiencies

Discussion needed to finalize plan, but it seems desirable for:

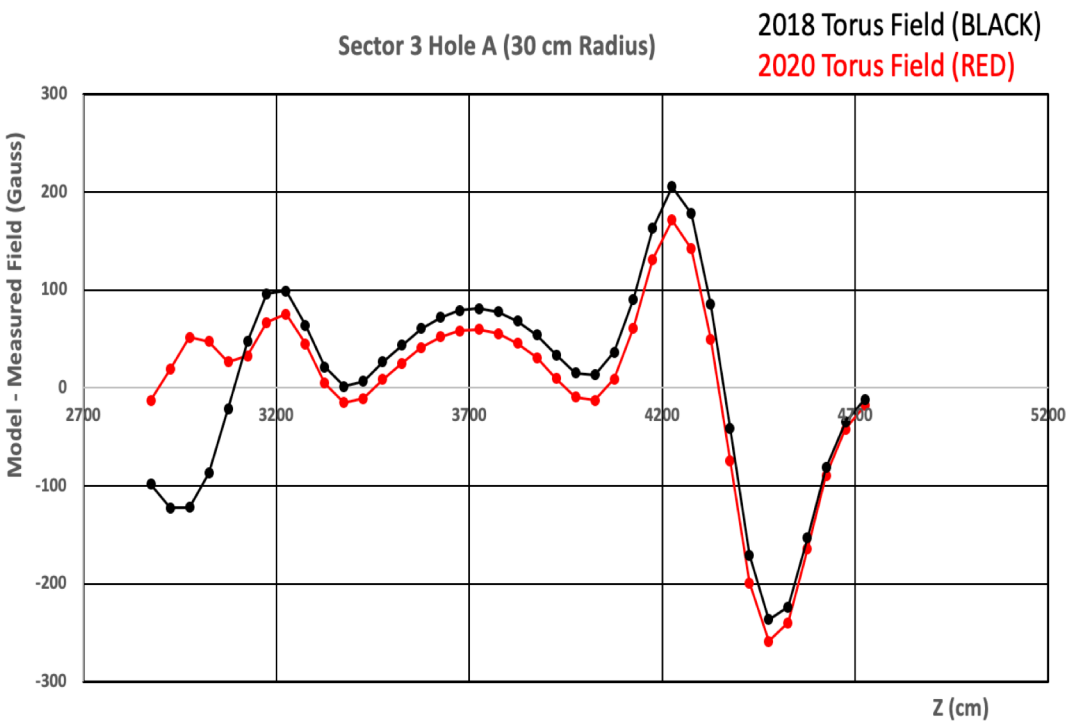
- The simulation should be done with perfect detector status for all channels and the knockout of channels should be done in reconstruction
- Presently the simulation code does channel knockout; we might want to have the ability to turn this on or off
- As the hardware status is defined in ccdb by run number, the simulation jobs should handle this by reading in a good run list file and the run weighting factor
  - This file should be part of the configuration file when selecting the run period
  - Bad run files should be removed by the tools that have been developed

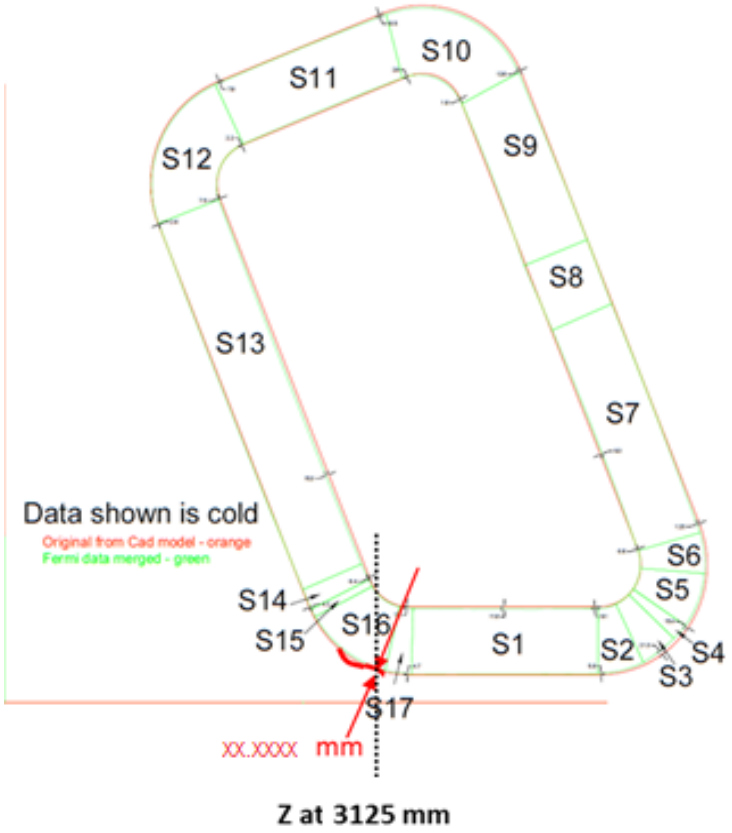
Stay tuned – some additional discussion and development is needed here

Magnet Field Map Studies

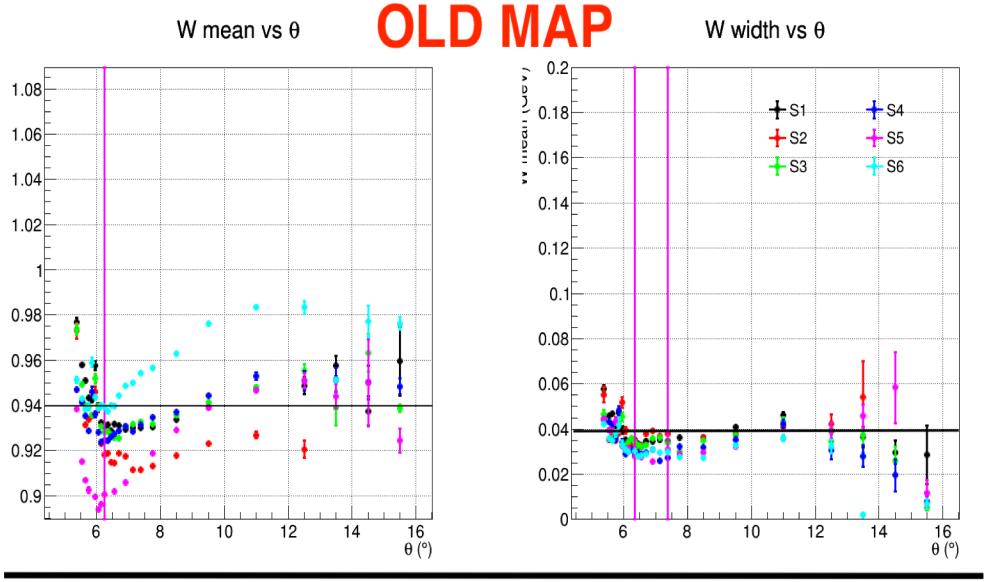
An updated torus field map exists:

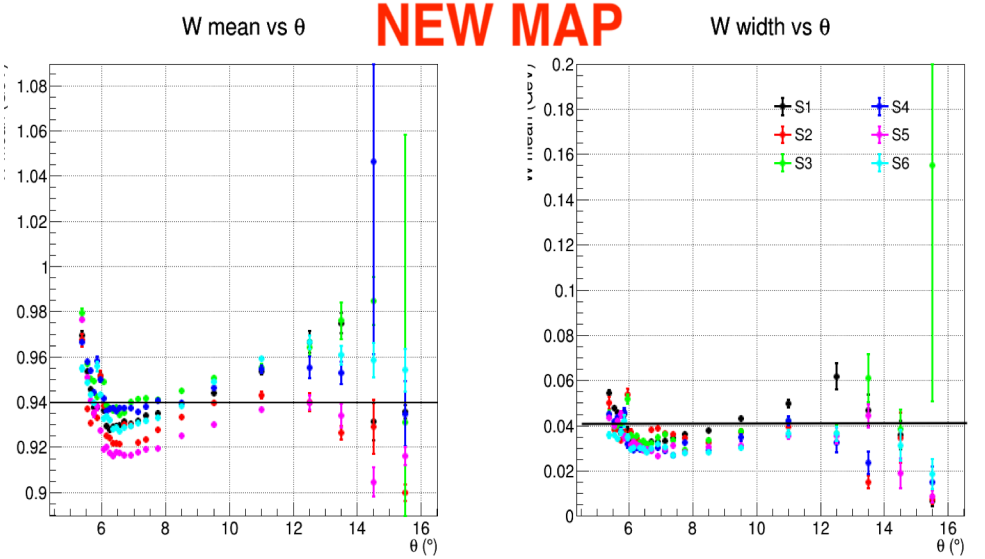
The key new feature of the new map is the additional degree of freedom in the fit – amounting to an "s-wave" corner adjustment





Magnet Field Map Studies



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Magnetic Field Reconstruction Studies
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1) Evaluate needs for additional data cooking with updated torus map:
 - Consider RG-A (inbending, outbending settings), RG-K
   - Who: Francois
 - Make request to Nick for data cooking
   - Who: Daniel

2) Study RG-K 6.5 GeV cooked data with new torus field:
 - Plot Wmean, sigmaW for elastics vs. p, theta, phi for all 6 sectors
   - Who: Francois

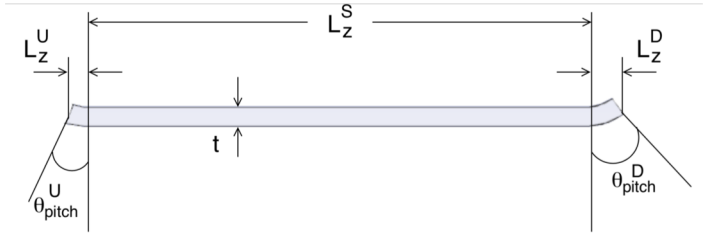
3) Study reconstruction with the new solenoid field map produced by Victoria:
 - Who: Raffaella and Nick to cook the data, Francois to generate his standard
   plots (as in item 2 above)

4) Follow up on ability to reconstruct with shifted solenoid field:
 - Get feedback on functionality of reconstruction with a z-shifted field
   map
   - Who: Veronique
 - Prepare necessary yaml file for cooking
   - Who: Raffaella

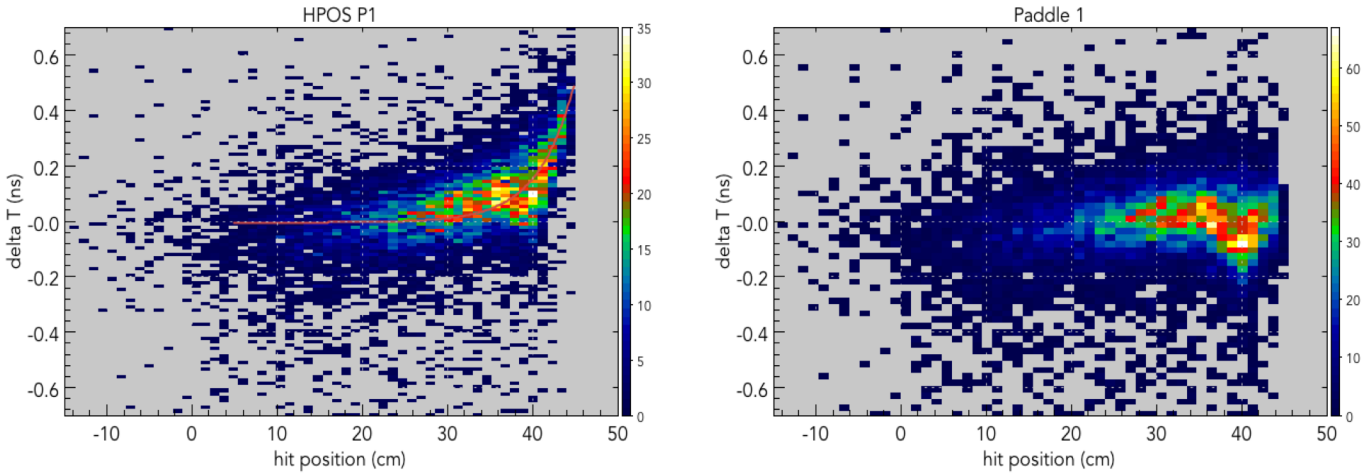
5) Study reconstruction with shifted solenoid map:
 - Decide on the step size and number of points for reconstruction study.
   - Who: Francois
 - Study elastic data to compare against nominal and new torus maps
   - Who: Nick to cook the data, Francois to generate his standard plots
 - Study reconstruction for various exclusive final states (e'K+), (e'pi+)
   - Who: Francois, Daniel
 - Study sensitivity to FTOF timing calibrations on solenoid z-shift
   - Who: Daniel
```

CALCOM Ongoing Studies

- Forward Tagger:
  - Reduce resolution smearing in energy calibration using π^0s by incorporating known reaction vertex
- Central Time-of-Flight:
  - Reduce correlation of vertex time with hit position along bar



before



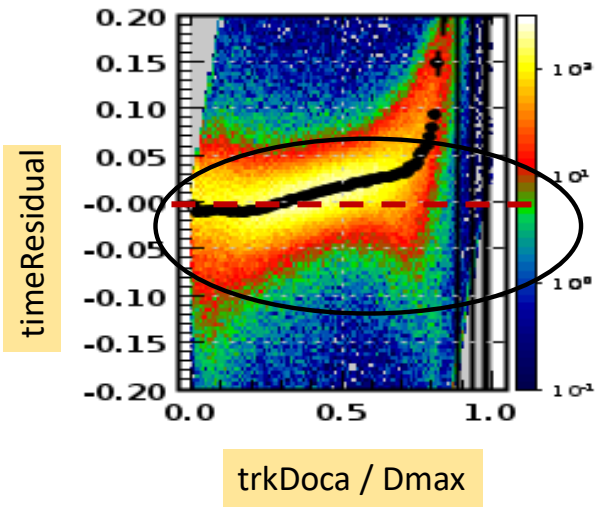
after

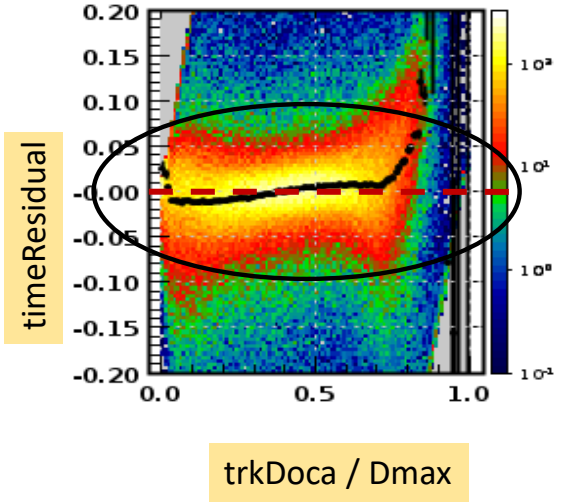
CALCOM Ongoing Studies

- Drift Chambers:

reducing biases in reconstruction

before



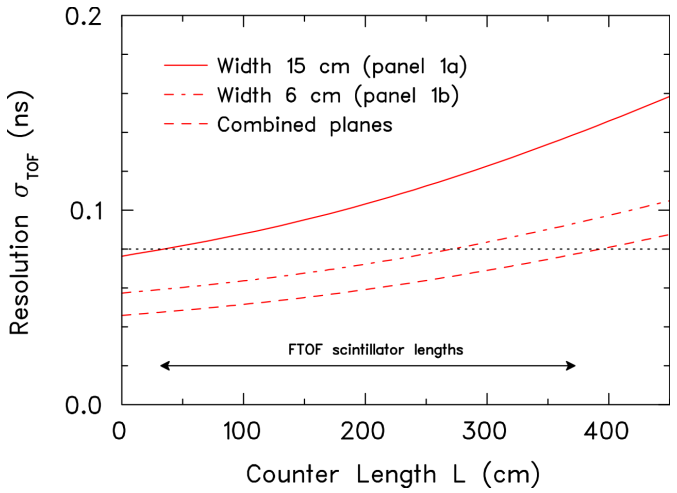


after

- Forward Time-of-Flight:

$$t_{corr} = \frac{\dfrac{t_{1b}^{cluster}}{\delta_{1b}} + \dfrac{(t_{1a}^{cluster} - \Delta r/\beta)}{\delta_{1a}}}{\left(\dfrac{1}{\delta_{1b}} + \dfrac{1}{\delta_{1a}}\right)}$$

Hit clustering and combined timing in p1b & p1a



CALCOM Ongoing Studies

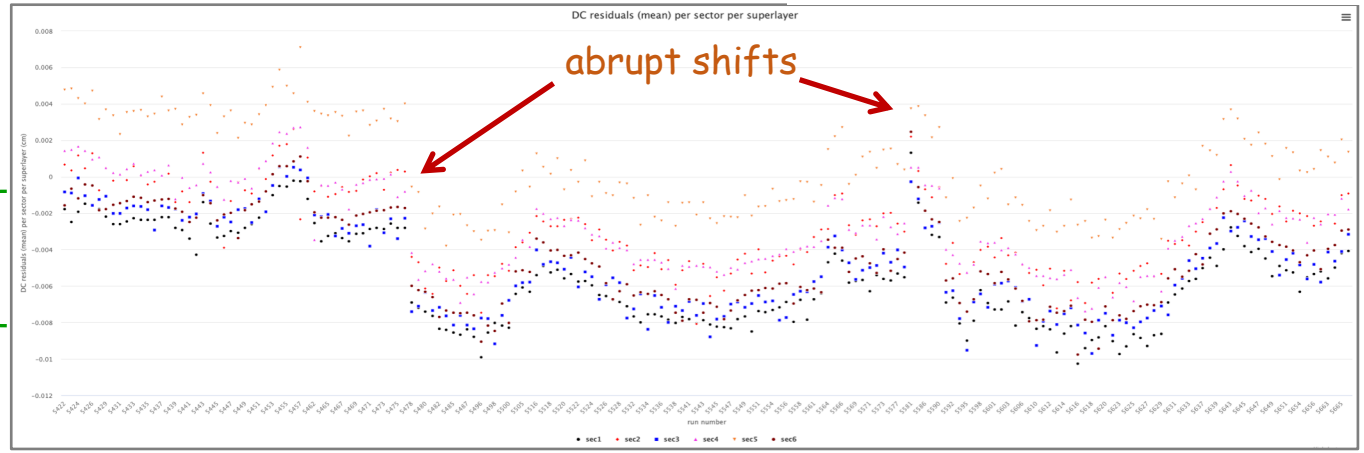
- Drift Chambers:

1) Improve stability using correlations with P_{atm}

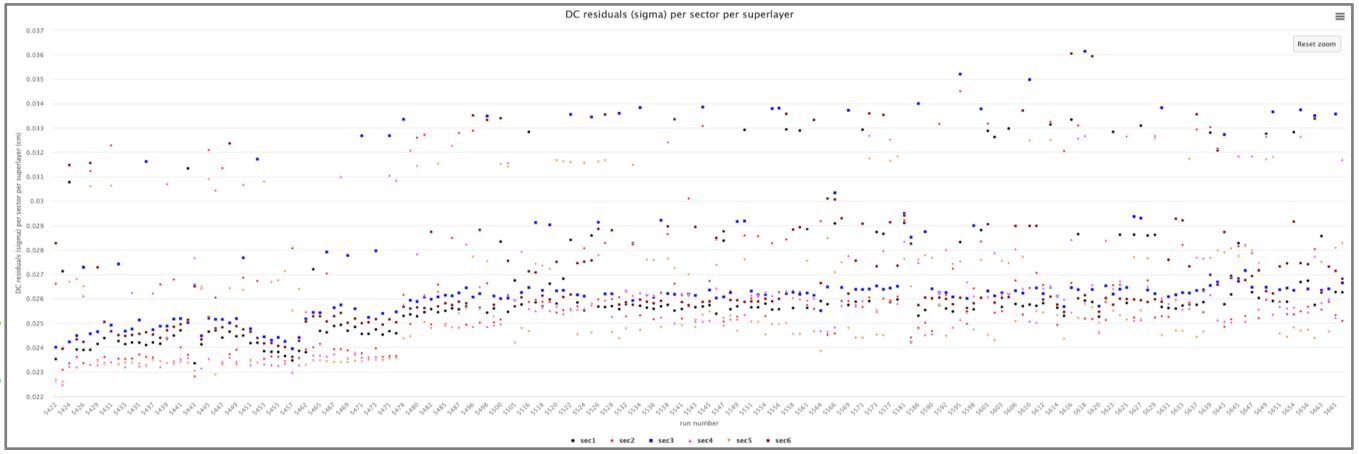
2) Remove abrupt shifts with global time offset

DC residuals (mean) per sector

RG-A fall 2018 outbending timelines



DC residuals (σ) per sector



Summary

- The CLAS12 CALCOM group has been meeting weekly since 2011
  - Develop calibration tools and procedures
  - Incorporate new subsystems are they become part of CLAS12
  - Establish and optimize calibration procedures
  - Discuss calibration anomalies and issues
  - Study calibration stability and performance drifts with time
- The role of the CALCOM group has recently expanded to coordinate the ongoing parallel calibrations of the Run Group
  - Calibrators sign-up as part of yearly service work commitment
  - Calibrators are assigned to a particular subsystem, not a specific Run Group
  - CALCOM oversight will serve to ensure reduced tensions among the requests from different Run Groups
- CALCOM is active on a number of fronts:
  - Working to identify calibration limitations due to algorithms
  - Working to optimize calibrations and reduce variance vs. run number
  - Ensure that calibration standards are maintained vs. time
  - Working on performance studies
  - Capturing hardware status (necessary to match MC to data, reconstruction dependencies on hardware)