Joint Hall A&C Data Analysis Workshop

Overview & Update of the Hall-C Analyzer

Eric Pooser

Jefferson Lab

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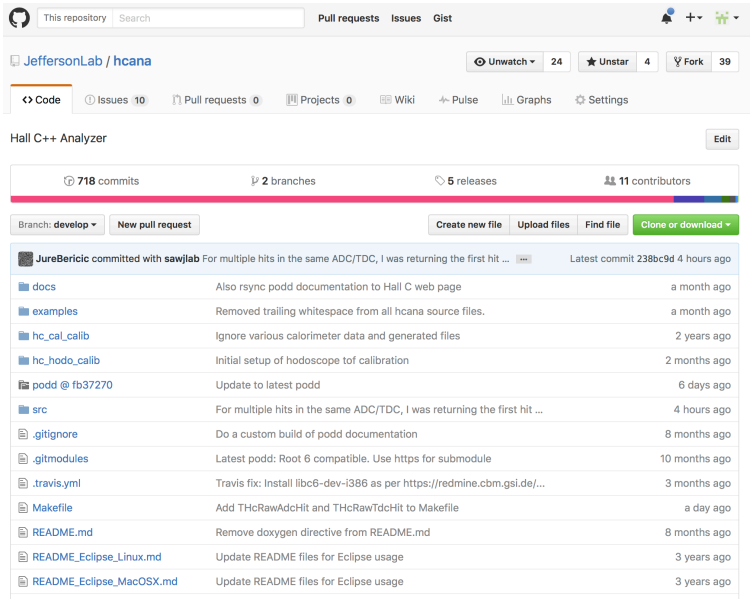
Hall-C Analyzer Overview

- Hall-C ROOT Analysis framework (HCANA) is written in C++ and is an extension of the Hall A analyzer “podd”
  - Based on previous Fortran Analyzer ENGINE infrastructure
  - Hall C ROOT Analyzer Wiki
- Maintained on GitHub
- Users fork off of “develop” branch
- Contributions are made in local/remote personal repository of HCANA
- Changes are pushed back onto the development branch which (may) get merged into the development branch
- Detailed "How-To" wiki: instructions how to “Git” started with HCANA and GitHub



Contents [hide]

Steps to Install HCANA

1. Download and install ROOT (> 5.32)
2. Setup ROOT environment
   - source /path/to/rootbuild/bin/thisroot.(c)sh
3. Fork hcana repository (if you have not already done so)
4. Clone personal remote repository on local machine
   - git clone https://github.com/username/hcana
5. cd into “hcana” directory and setup the environment
   - source setup.(c)sh
6. Obtain the podd submodule which hcana points too
   - git submodule init
   - git submodule update
7. Create new branch and switch to it
   - git checkout -b branch-name
8. Build HCANA
   - scons -j4

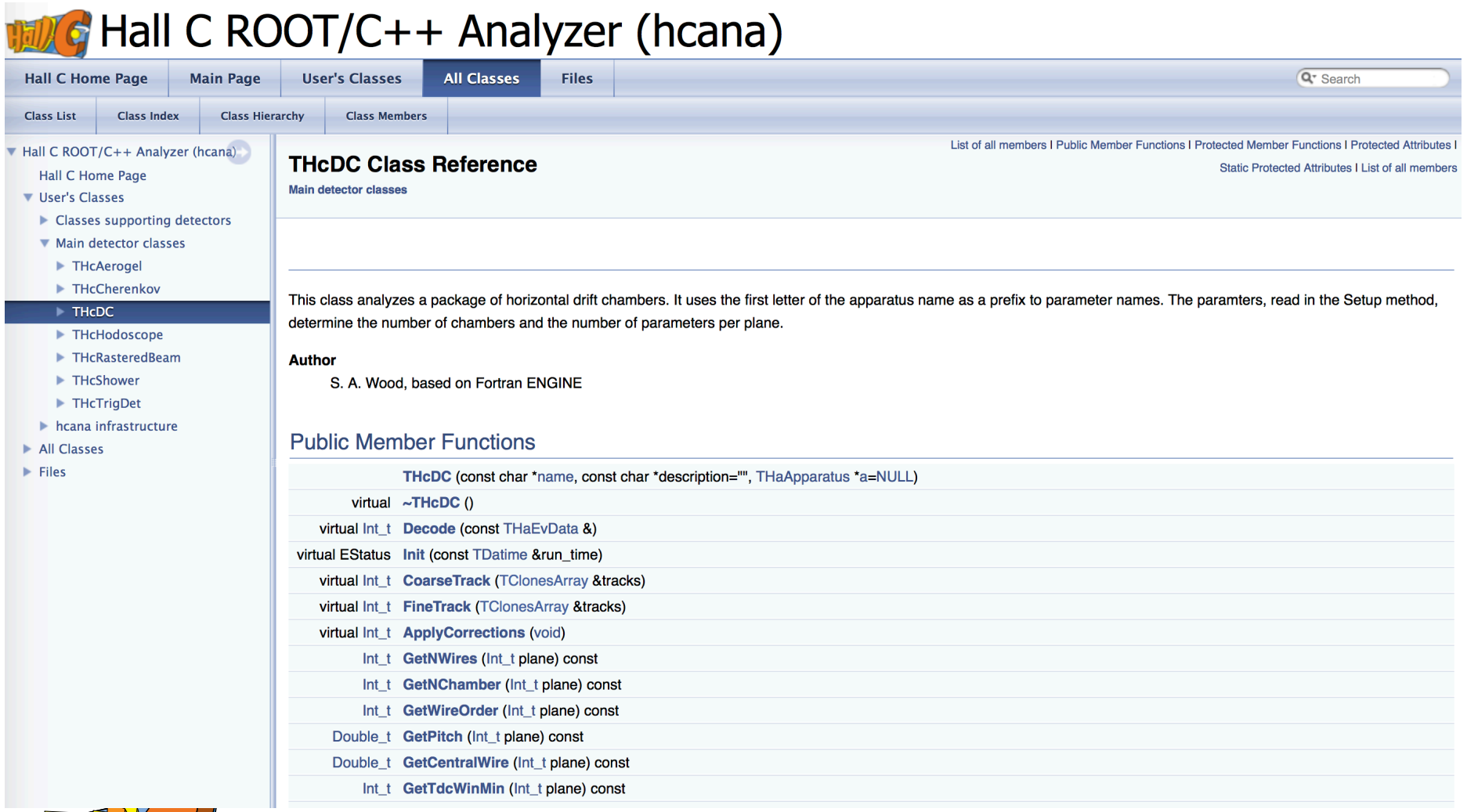
"How-To" wiki

ROOT Analyzer/Compiling Wiki

ROOT Analyzer/Running Wiki

Hall-C Analyzer Overview

- Doxygen page documents HCANA source code



Work Flow of HCANA

- HCANA utilizes the Hall-A podd decoder to unpack raw EVIO data into THaEvData objects
  - Each readout module (F250, 1190, …) has its own decoder class ➛ podd/hana_decode
- THcHitList utilizes the detector maps to associate the ROC, slot, & channel number with a specific detector
  - `THcHitList::DecodeToHitList(&THaEvData)`
- THcDetectorMap builds an array (fTable) with one structure element per readout channel
  - `THcDetectorMap::Load(const char *fName)`
- Each element holds the roc, slot, channel number and module type for a given channel
- In addition, the element holds the id number of the detector, the plane, the counter (or wire number), and the signal number (ADC/TDC, +/-)

Work Flow of HCANA

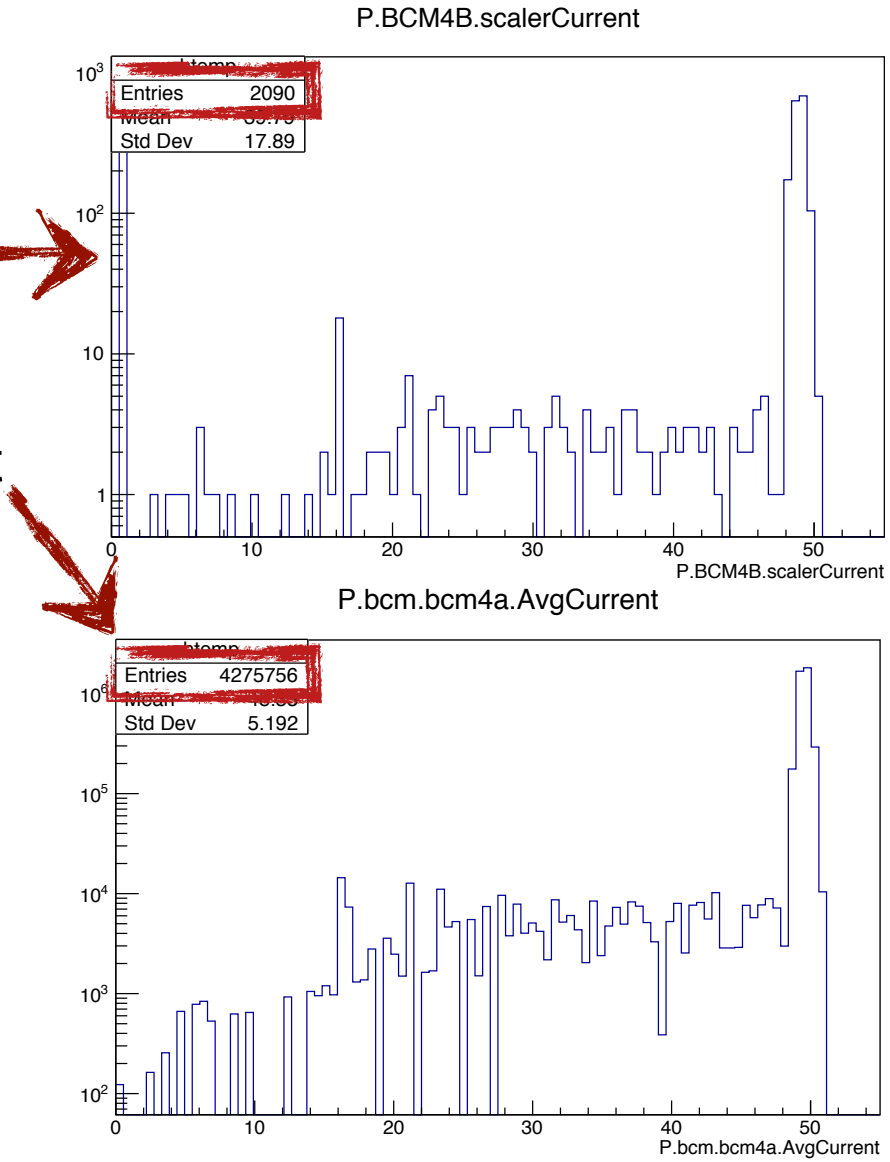
- At initialization each detector class has its detector map populated with the list of readout channels belonging it
  - `gHcDetectorMap->FillMap(fDetMap, idstring)`
- In addition, a hit list is created to hold the raw hits for each respective detector
  - `THcHitList::InitHitList(fDetMap, rawhitclassname, maxhits)`
- Detector classes then decode the THcHitList data into raw hit data associated with a specific detector's readout channel
  - `THcDetector::Decode(&THaEvData)`
- Raw hit information is stored as TClonesArray objects which are accessible *via* THcAnalyzer
  - `adcPulseAmpRaw, adcPulseAmp, …`

Work Flow of HCANA

- Raw hit data is further processed into higher level hit data objects *via* fiducial ADC & TDC cuts
  - `THcDetector::CoarseProcess(&TClonesArray)`
  - `goodAdcPed, goodAdcPulseInt, …`
- Hit data can then be further processed into higher level physics data
  - `THcDetector::FineProcess(&TClonesArray)`
  - Fiducial tracking cuts e.g. χ_2/ndf, β, E/p
  - Track matching, efficiencies, …
- Raw, hit, & physics data is then processed by THcAnalyzer which makes the data available *via* ROOT histograms and TTrees

Recent Updates to HCANA: e9d8699

- BCM Module: **THcBCMCurrent**
  - Sanghwa's Slides
- Reads average BCM current values from scaler parameter file
- Writes values into bcm#.AvgCurrent event by event
- Compares the current readout values with the threshold and sets event flags (0, 1)
- The threshold current can be configured in two ways
  - SetCurrentCut()
  - gBCM_Current_threshold



Recent Updates to HCANA: 4cb3bfb

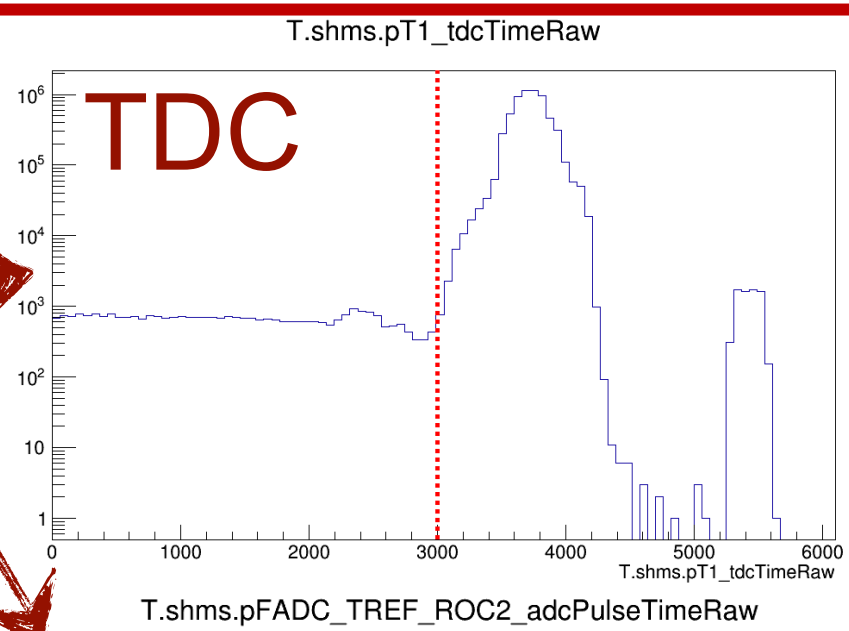
- Missing reference times are now printed in the analyzer summary
  - `End(THaRunBase *run)` added to each detector class
  - `THcHitList::MissReport(const char *name)`

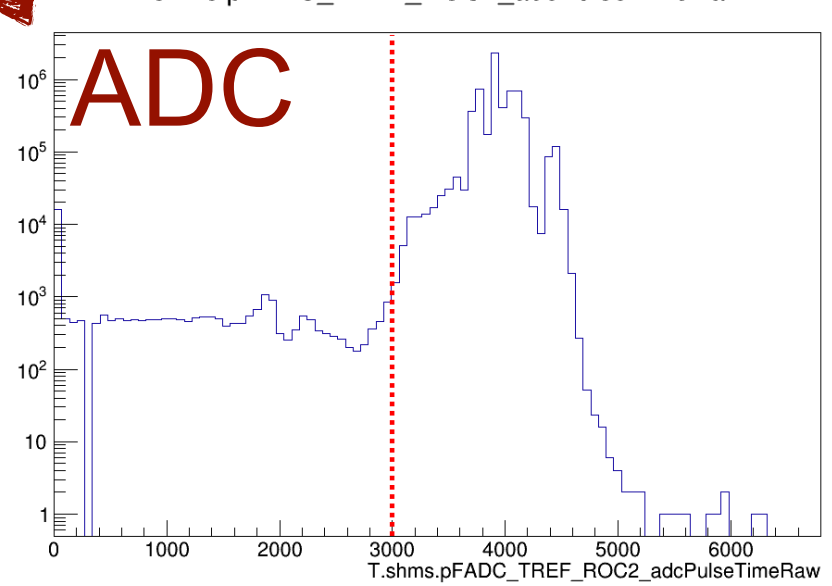
```
Normal end of file ./raw/shms_all_02484.dat encountered
Missing Ref times:                T.shms        0      4152
Missing Ref times:              P.ngcer         0      3484
Missing Ref times:                P.dc          0         0
Missing Ref times:               P.hod          0      4166
Missing Ref times:              P.hgcer         0      1519
Missing Ref times:               P.aero         0      2161
Missing Ref times:                P.cal         0      3021
THcScalerEvtHandler::End Analyzing 3 delayed scaler events
End of file
```

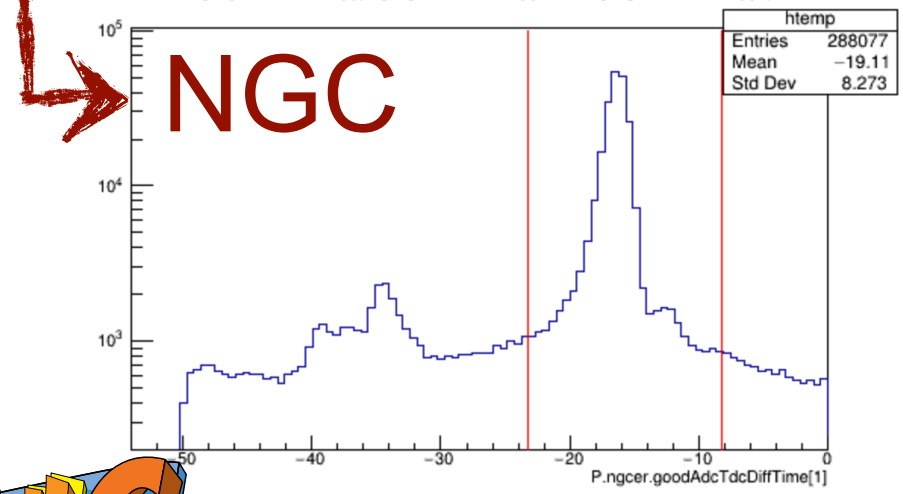
TDC ADC

Recent Updates to HCANA

- Reference time selection is dependent on the first TDC/FADC hit in the window which is greater than the associated cut
  - **`X_t(a)dcrefcut`**
- "Good" FADC hits are determined via. time difference cuts for every FADC readout channel
  - **`X_adcTimeWindowMin(Max)`**

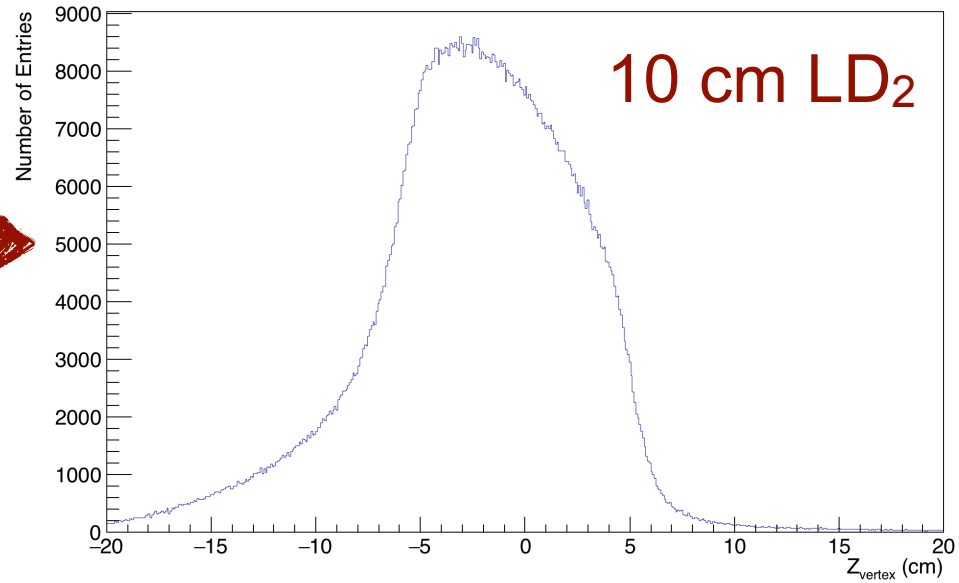


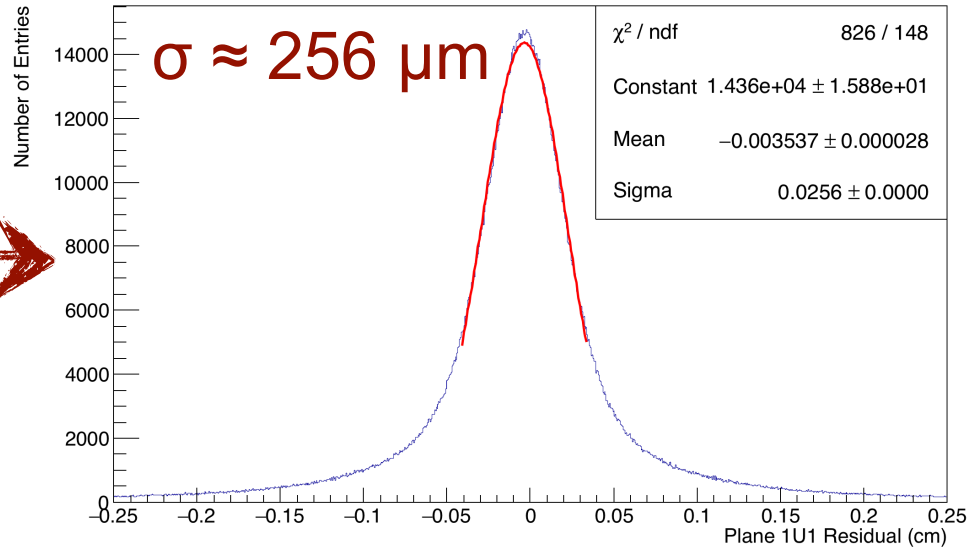




Recent Updates to HCANA

- Creation of **`THcReactionPoint`**
  - Calculates the z-vertex at the target in the transport coordinate system
  - The x & y vertex are defined via. **`gbeam_x(y)`** offsets and the raster position
- Modification to **`THcDC`** & **`ThcDCTrack`** now provides per plane residual calculations excluding the plane for which the residual is being calculated
  - **`X.dc.residualExclPlane`**
  - **`vector <Double_t>`**

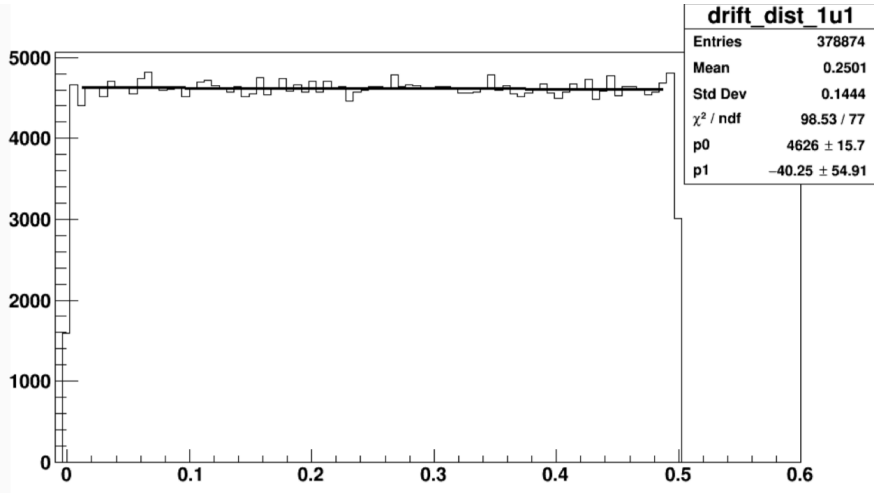


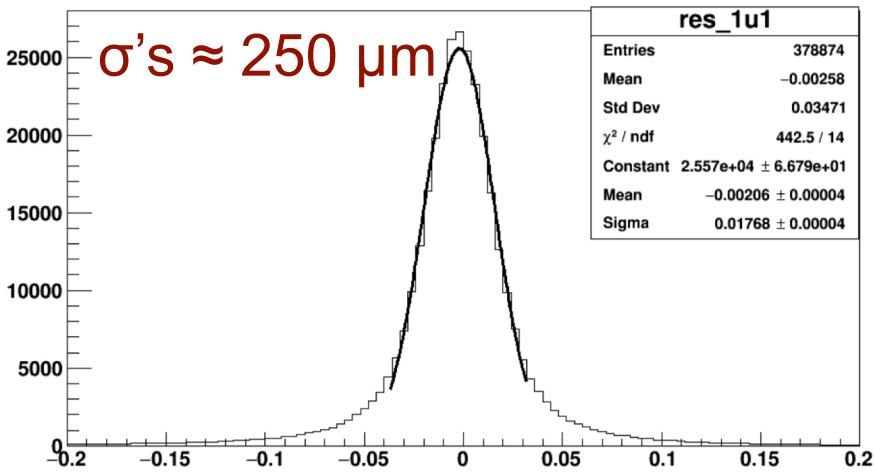


Recent Updates to HCANA: e06d50f

- Bug fix in `THcHodoscope`
- `fFPTimeAll` is the average FPT as calculated by all scintillator times
- `fFPTimeAll` was calculated in `EstimatedFocalPlaneTime()`, where it was set to the `starttime` defined to be the average FPT calculated without using a DC track
- For tracks, a FPT was calculated for each track by utilizing the track information in order to improve the FPT calculation and was saved for each track
- `fFPTimeAll` was being filled for each track, and thus the last track
- `fFPTimeAll` was moved to `THcHodoscope::FineProcess` and is now set to the average FPT of the golden track

- Data calibrated with run 2540
- Data shown with the same kinematics is for run 2525

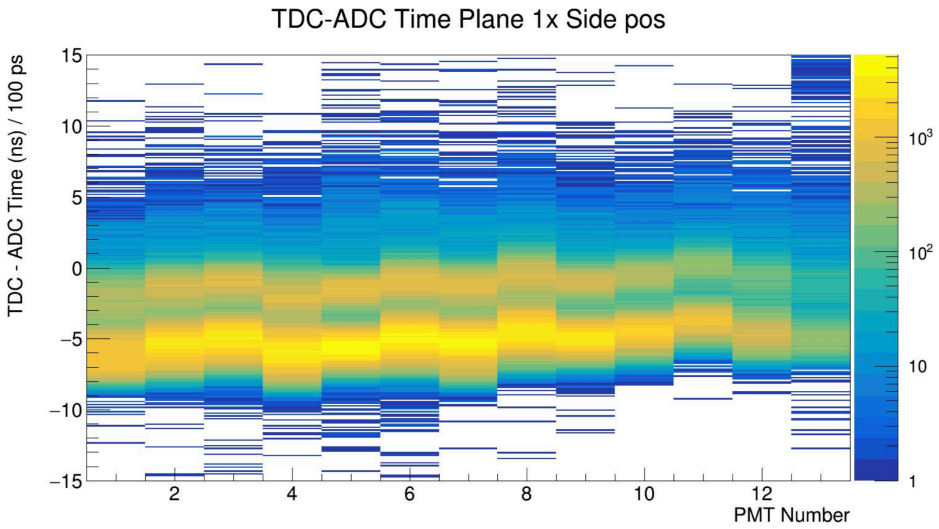




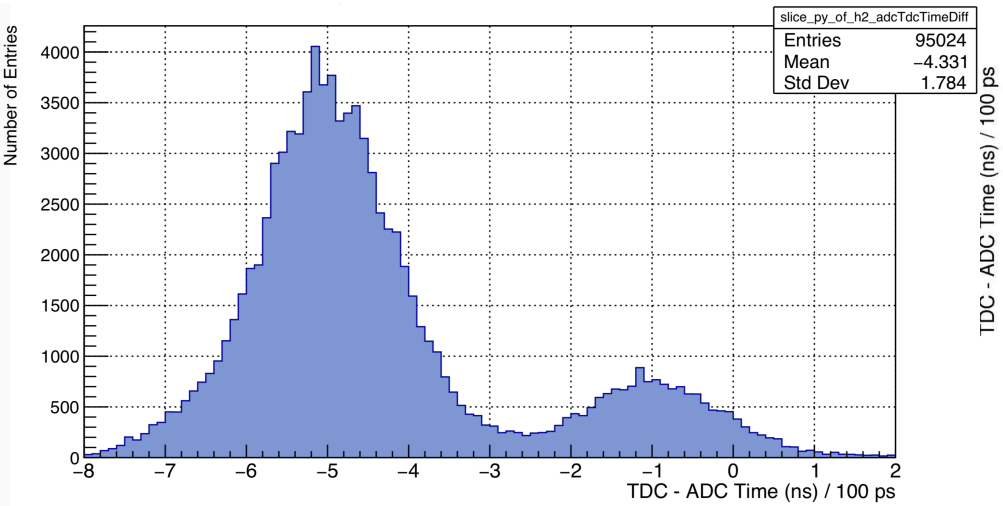
Recent Updates to HCANA: 8a26c04

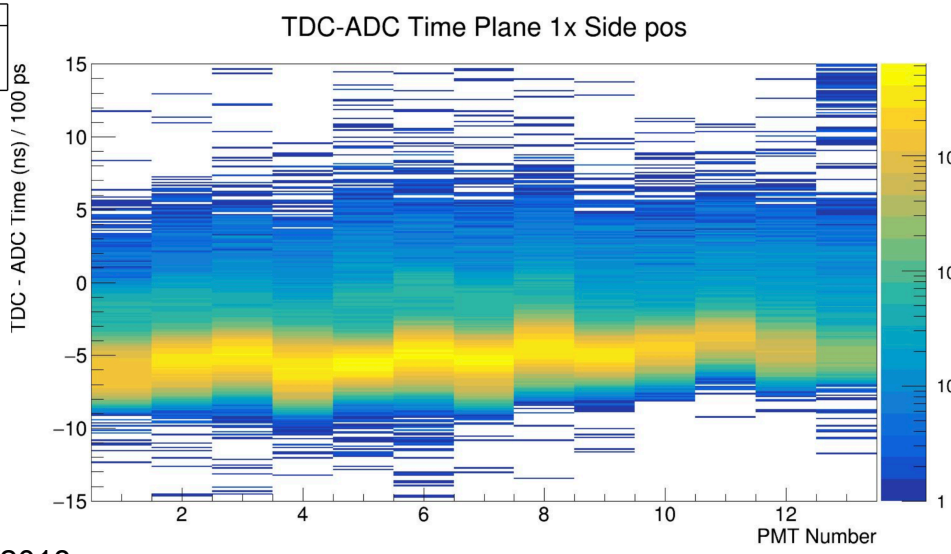
- FADC's modules found to have their trigger times (internal 250 MHz clock) slip randomly by 4 ns with firmware present during fall 2017 and spring 2018 run
- Correction applied in `THcHitList::DecodeToHitList()` via of comparing trigger time provided by the TI module to the trigger time in each FADC module

SHMS Defocused Run 1791 With No FADC Timing Corrections (Slot 3)



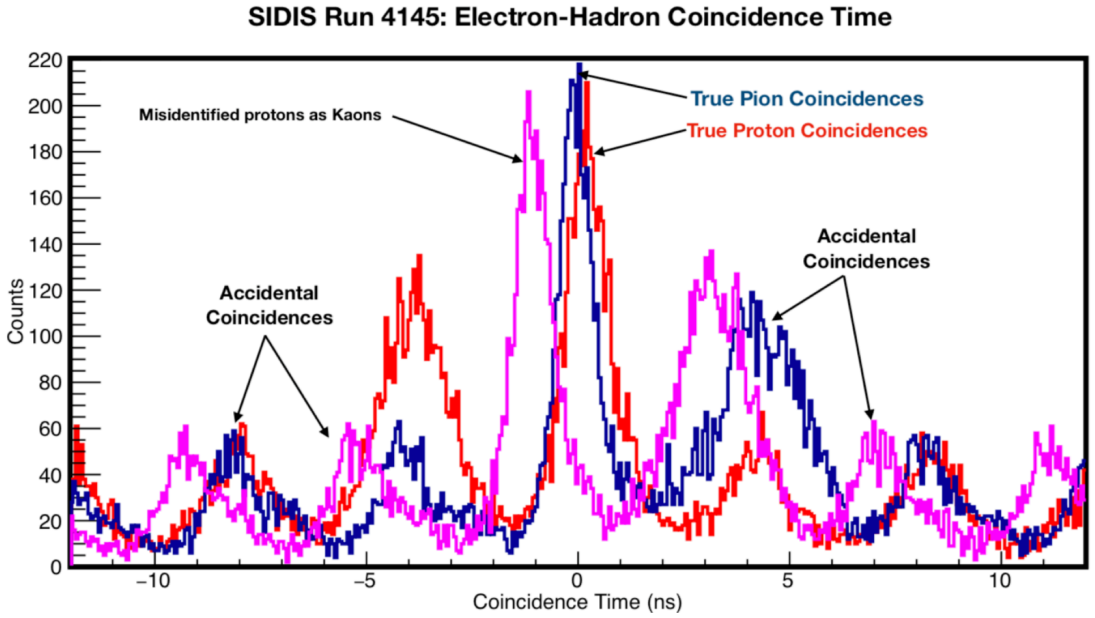
SHMS Defocused Run 1791 With FADC Timing Corrections (Slot 3)





Recent Updates to HCANA: d6e15d1

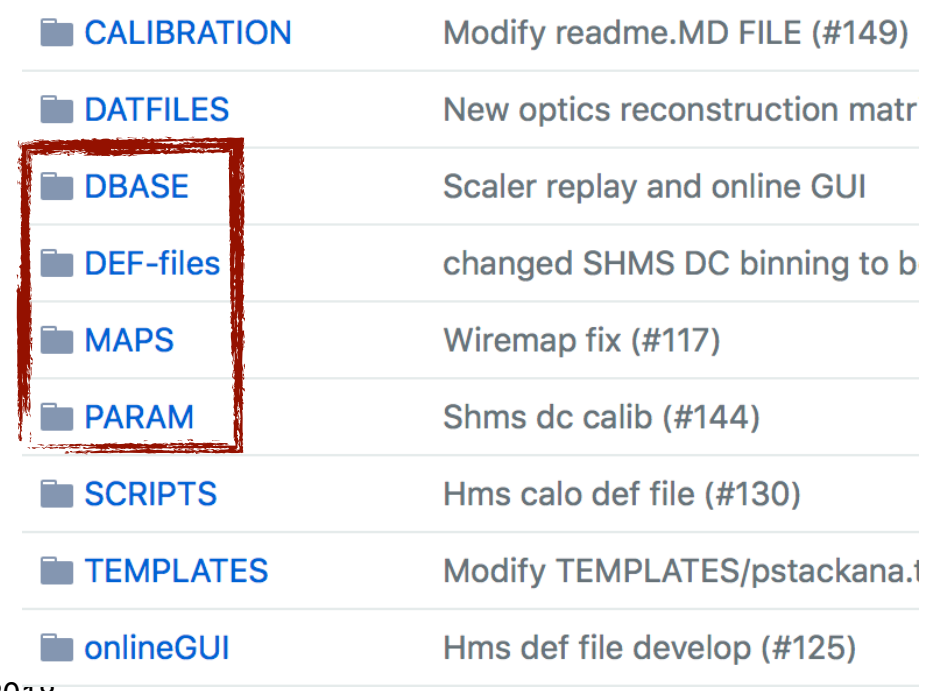
- Creation of coincidence time module **`THcCoinTime`**
- Documentation
- Facilitates the analysis of coincidence time data
- Derived from THaPhysicsModule
- The spectrometers central path length and coincidence time offset are parameters in hallc-replay
- Coincidence times for various particle species are supported



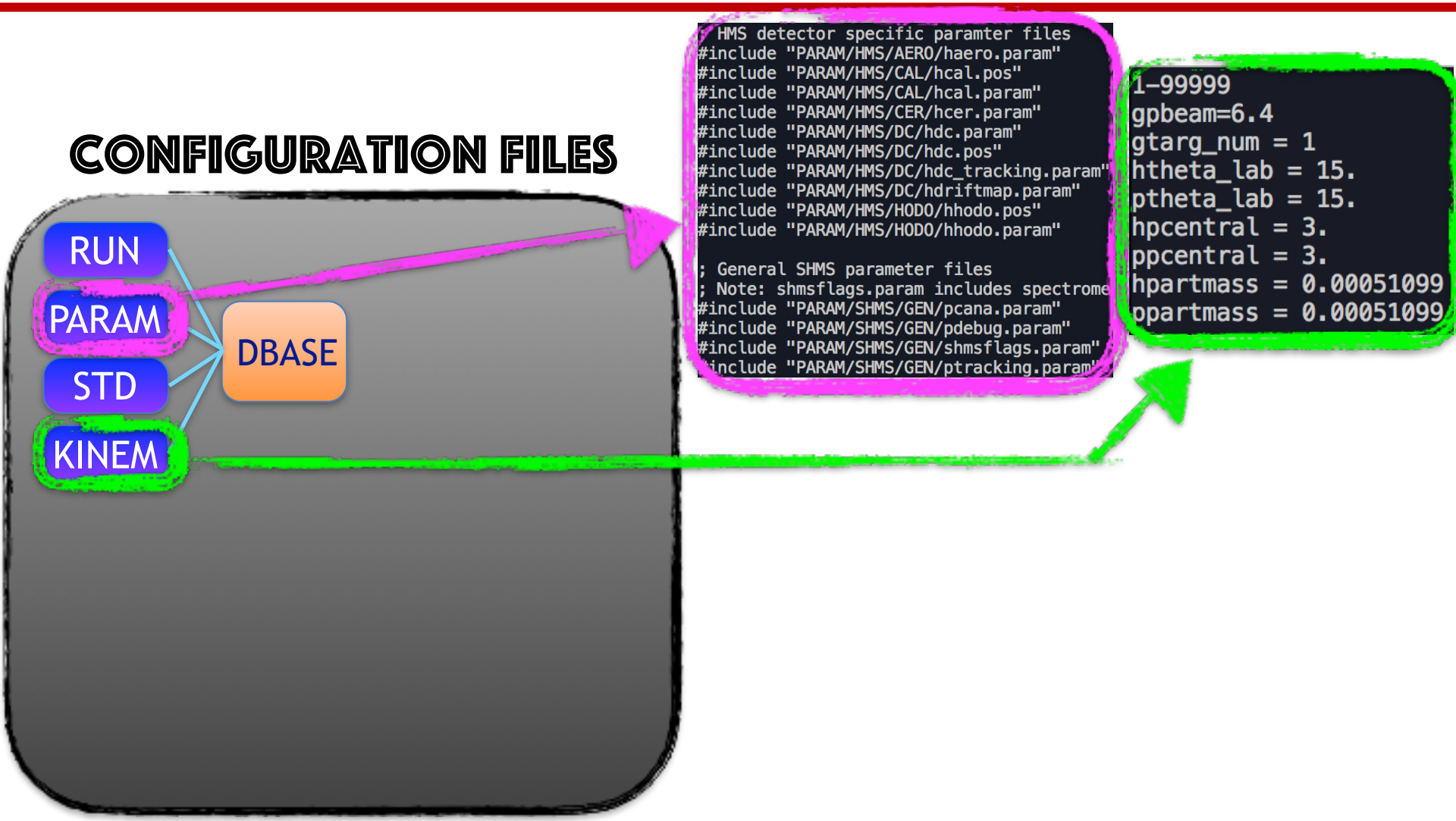
Hall-C Replay

- Framework designed to facilitate the reconstruction of events in the Hall-C spectrometers
- The Hall-C Replay Strucutre Wiki provides general information regarding the infrastructure
- The Hall-C replay code is maintained in the JeffersonLab/hallc_replay GitHub repository

- Interfaces with THcAnalyzer to process and obtain the data
  - Raw, hit, & tracking data
  - Physics data

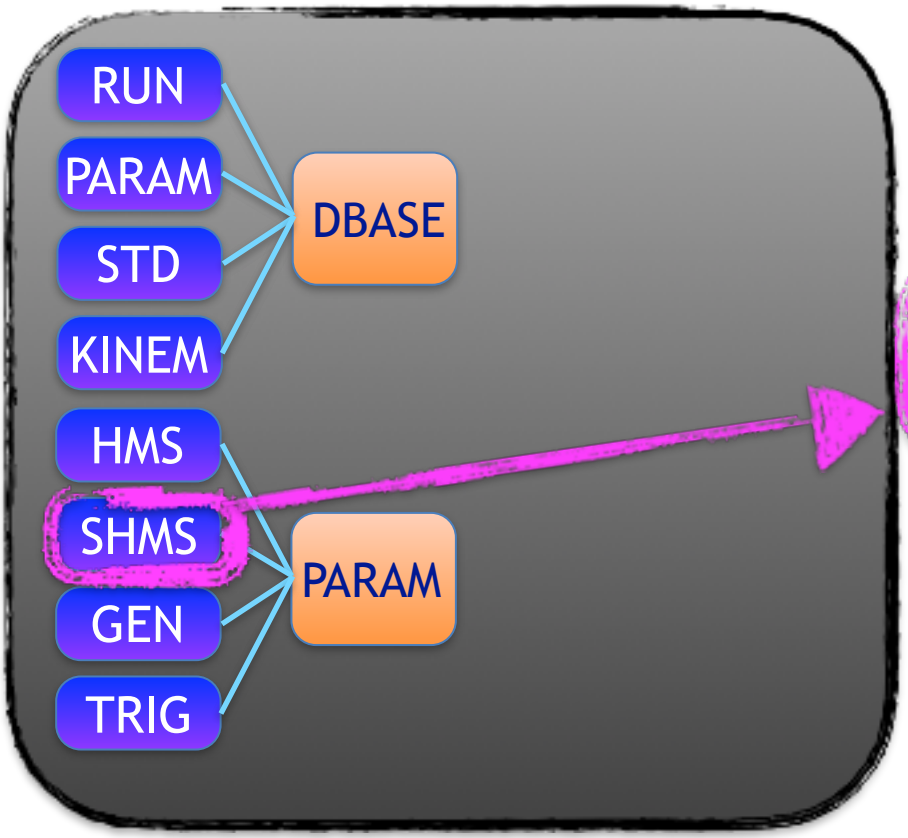


Hall-C Replay Framework: DBASE



Hall-C Replay Framework: PARAM

CONFIGURATION FILES




```
; HMS detector specific paramter files
#include "PARAM/HMS/AERO/haero.param"
#include "PARAM/HMS/CAL/hcal.pos"
#include "PARAM/HMS/CAL/hcal.param"
#include "PARAM/HMS/CER/hcer.param"
#include "PARAM/HMS/DC/hdc.param"
#include "PARAM/HMS/DC/hdc.pos"
#include "PARAM/HMS/DC/hdc_tracking.param"
#include "PARAM/HMS/DC/hdriftmap.param"
#include "PARAM/HMS/HODO/hhodo.pos"
#include "PARAM/HMS/HODO/hhodo.param"

; General SHMS parameter files
; Note: shmsflags.param includes spectrome
#include "PARAM/SHMS/GEN/pcana.param"
#include "PARAM/SHMS/GEN/pdebug.param"
#include "PARAM/SHMS/GEN/shmsflags.param"
#include "PARAM/SHMS/GEN/ptracking.param"
```

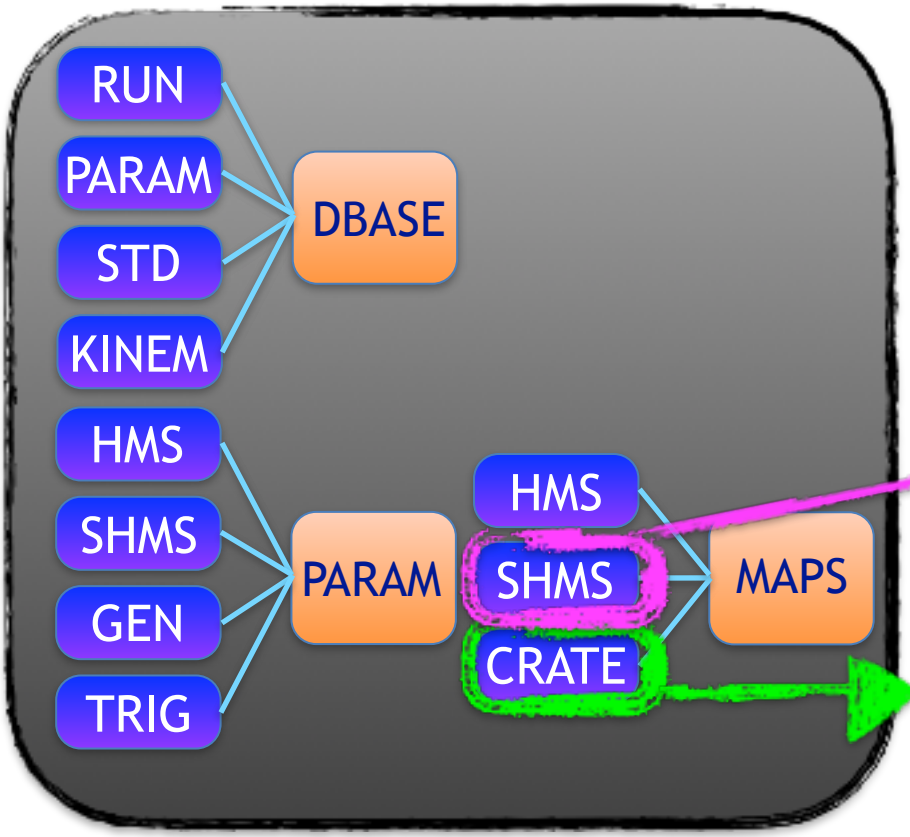
```
1-99999
gpbeam=6.4
gtarg_num = 1
htheta_lab = 15.
ptheta_lab = 15.
hpcentral = 3.
ppcentral = 3.
hpartmass = 0.00051099
ppartmass = 0.00051099
```

```
; Number of heavy gas Cherenkov PMT's
phgcer_tot_pmts = 4

; Garth H. gain calibration from run 486, March 9 2017
phgcer_adc_to_npe = 1/436., 1/393., 1/364., 1/372.
```

Hall-C Replay Framework: MAPS

CONFIGURATION FILES




```
; HMS detector specific paramter files
#include "PARAM/HMS/AERO/haero.param"
#include "PARAM/HMS/CAL/hcal.pos"
#include "PARAM/HMS/CAL/hcal.param"
#include "PARAM/HMS/CER/hcer.param"
#include "PARAM/HMS/DC/hdc.param"
#include "PARAM/HMS/DC/hdc.pos"
#include "PARAM/HMS/DC/hdc_tracking.param"
#include "PARAM/HMS/DC/hdriftmap.param"
#include "PARAM/HMS/HODO/hhodo.pos"
#include "PARAM/HMS/HODO/hhodo.param"

; General SHMS parameter files
; Note: shmsflags.param includes spectrome
#include "PARAM/SHMS/GEN/pcana.param"
#include "PARAM/SHMS/GEN/pdebug.param"
#include "PARAM/SHMS/GEN/shmsflags.param"
#include "PARAM/SHMS/GEN/ptracking.param"
```

```
1-99999
gpbeam=6.4
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htheta_lab = 15.
ptheta_lab = 15.
hpcentral = 3.
ppcentral = 3.
hpartmass = 0.00051099
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```
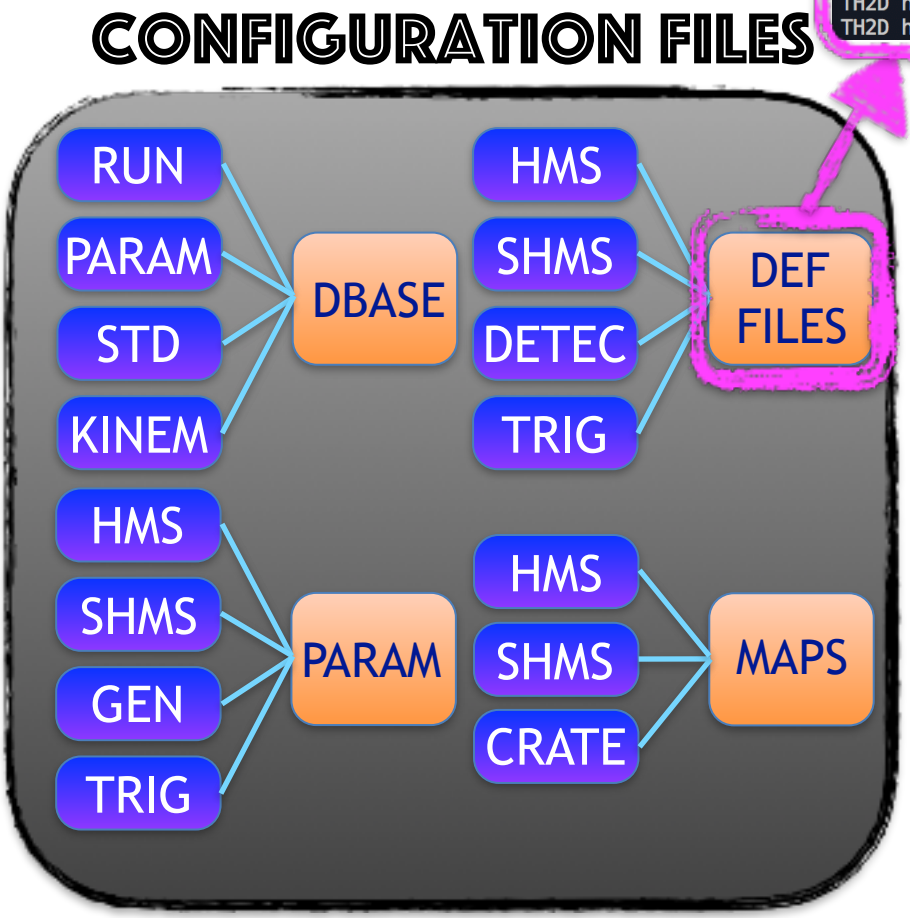

```
; Number of heavy gas Cherenkov PMT's
phgcer_tot_pmts = 4

; Garth H. gain calibration from run 486, Ma  9 2017
phgcer_adc_to_npe = 1/436., 1/393., 1/364., 1/372.
```

```
==== Crate 2 type vme Bank Decoding
# slot  model   bank
  3     250     250
  4     250     250
  5     250     250
  6     250     250
  7     250     250
  8     250     250
  9     250     250
  10    250     250
  13    250     250
  14    250     250
  18    1190    1190
  19    1190    1190
  20    1190    1190
```

```
! SAERO_ID=25        ::  ::,ADC+,ADC-

DETECTOR=25

ROC=2

SLOT=10
  10,   1,   1,   0  ! sAER01+
  11,   1,   2,   0  ! sAER02+
  12,   1,   3,   0  ! sAER03+
  13,   1,   4,   0  ! sAER04+
  14,   1,   5,   0  ! sAER05+
  15,   1,   6,   0  ! sAER06+

SLOT=11
   0,   1,   7,   0  ! sAER07+
   1,   1,   1,   1  ! sAER01-
   2,   1,   2,   1  ! sAER02-
   3,   1,   3,   1  ! sAER03-
   4,   1,   4,   1  ! sAER04-
   5,   1,   5,   1  ! sAER05-
   6,   1,   6,   1  ! sAER06-
   7,   1,   7,   1  ! sAER07-
```

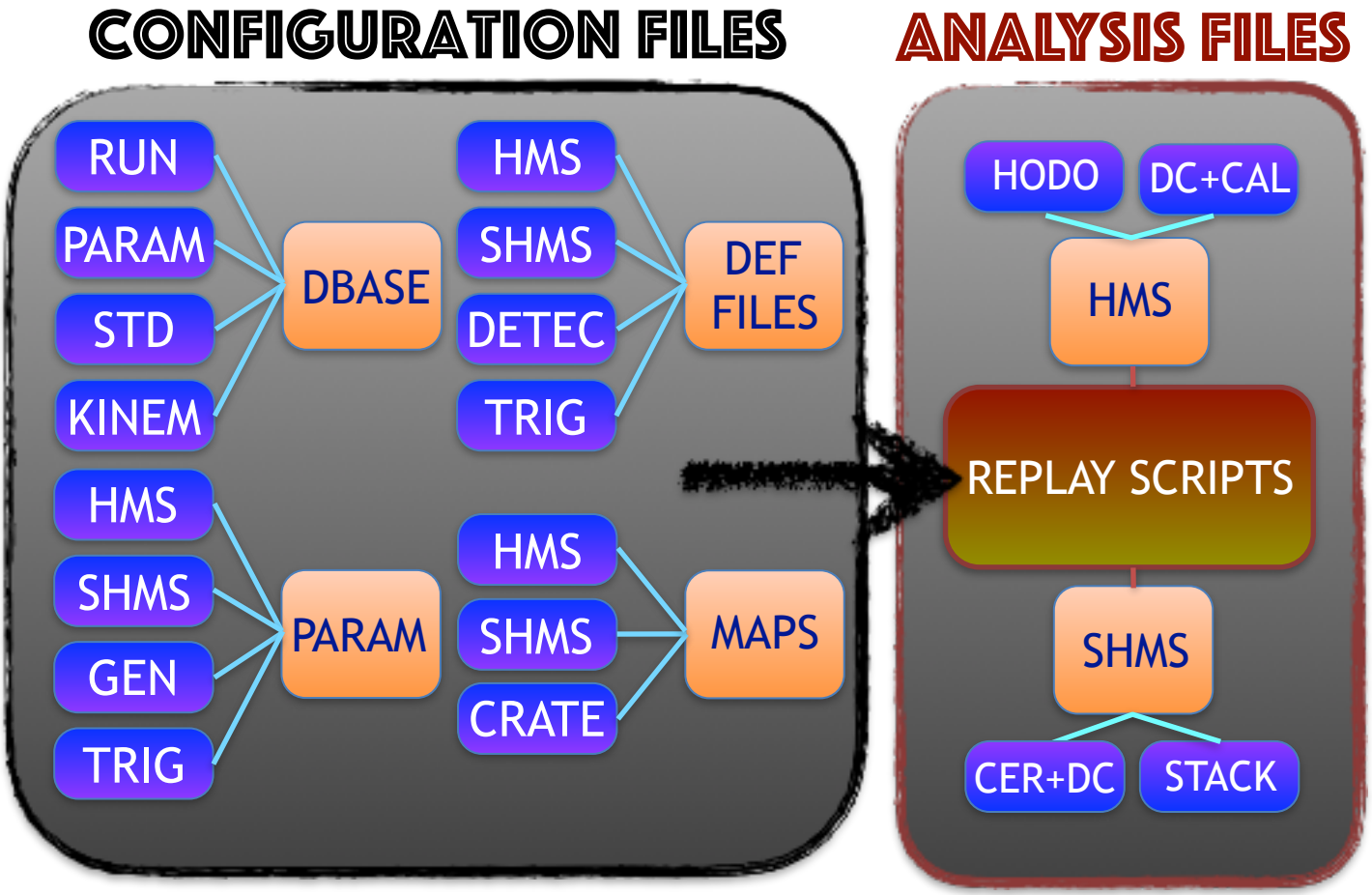
Hall-C Replay: DEF-files

```
block App.det.*
block App.det.var*

TH1F h1Name 'Title; X-Title; Y-Title' var nBins xLow xHigh
TH1I h2Name 'Title; X-Title; Y-Title' var nBins xLow xHigh cut1&&cut2||cut3
TH2D h3Name 'Title; X-Title; Y-Title' var1 var2 nBins xLow xHigh nBins yLow yHigh
TH2D h3Name 'Title; X-Title; Y-Title' [I+1] var2 nBins xLow xHigh nBins yLow yHigh cut4
```



- THaOutput Analysis Output (DEF-files)
- Interfaces with THcAnalyzer to output user defined histograms and ROOT TTrees
- Variables are created in detector classes in the DefineVariables() method and can be written to the TTree output and histogrammed *via* DEF-files
  - `P.hodo.goodAdcPulseAmp`
- Block variables write multiple variables to the TTree with a single call
  - `block P.gtr.*`
- Histograms can be defined for specific variables with and without cuts (1, 2, & 3D supported)
  - `TH1F h1Name 'Title; X-Title; Y-Title' var nBins xLow xHigh`
  - `TH1F h1Name 'Title; X-Title; Y-Title' var nBins xLow xHigh cut1&&cut2||cut3`
- DEF-files defining cuts create global cut objects for histograms and interactive analysis
  - `time_cut1 P.dc.1u1.time>0&&P.dc.1u1.time<250`

Hall-C Replay Framework: Analysis Files

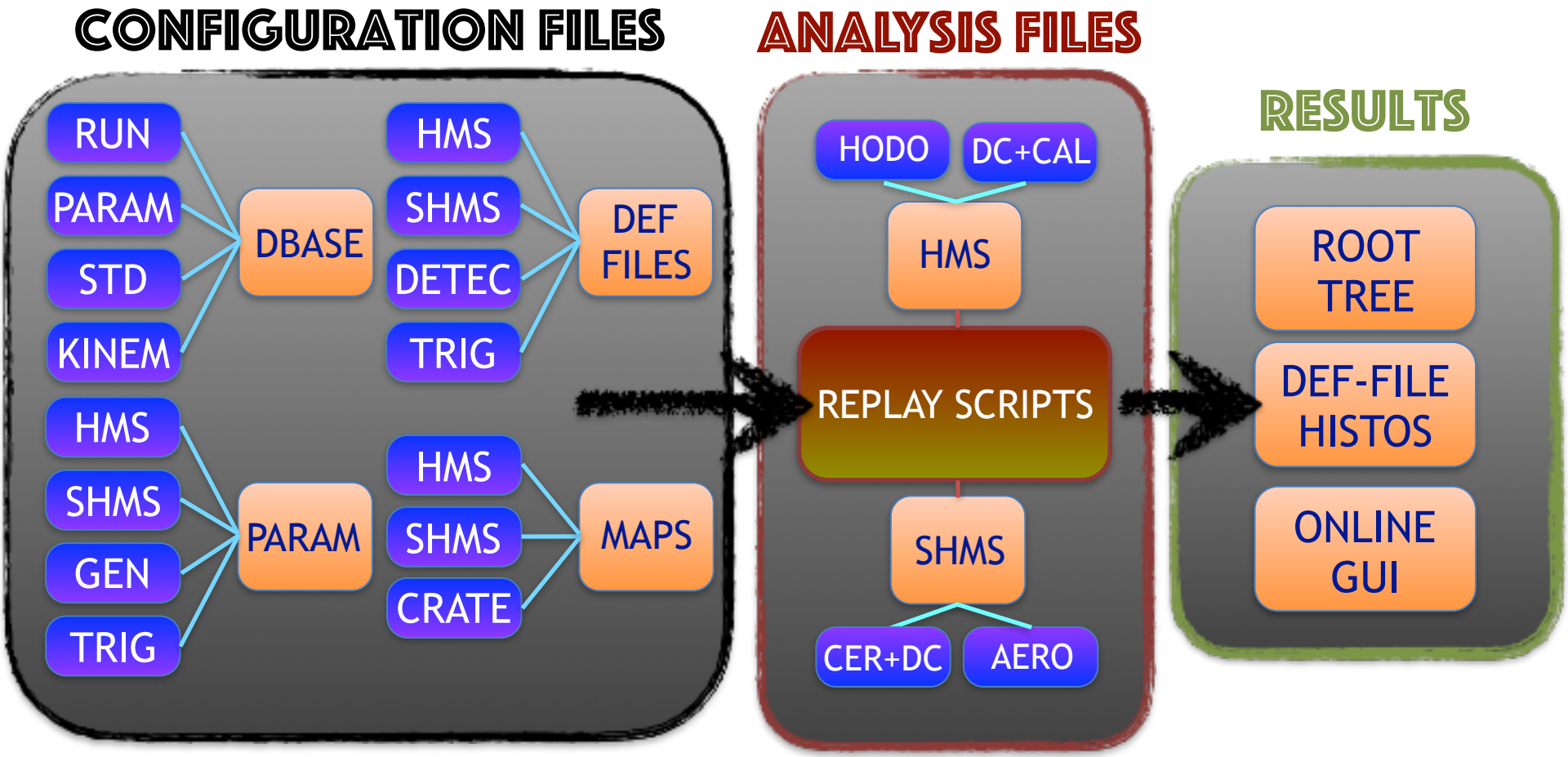


Hall-C Replay Scripts: Report Files

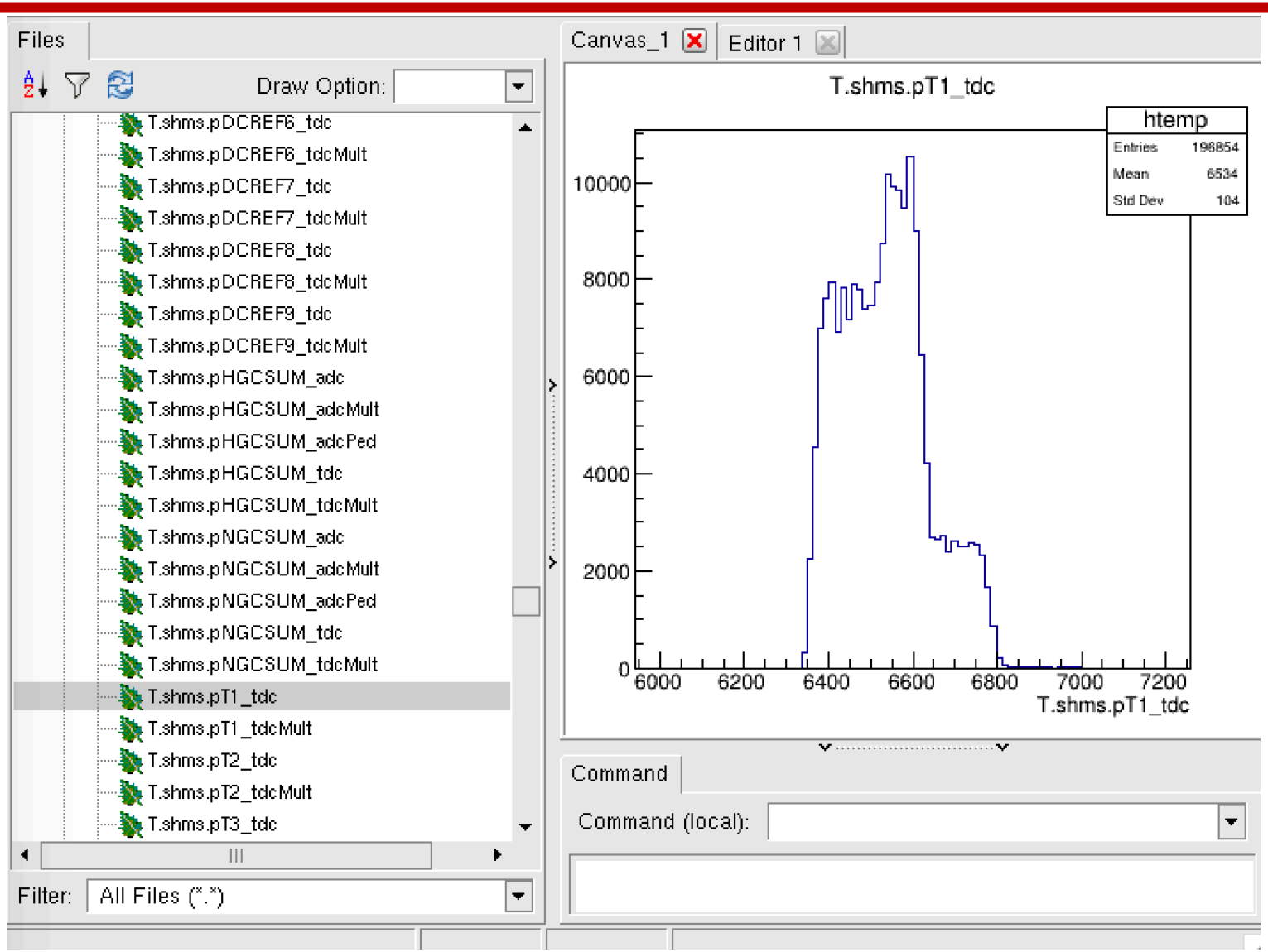
```
void replay_workshop_example(Int_t RunNumber=0, Int_t MaxEvent=0) {

  // Get RunNumber and MaxEvent if not provided.
  if(RunNumber == 0) {
    cout << "Enter a Run Number (-1 to exit): ";
    cin >> RunNumber;
    if( RunNumber<=0 ) return;
  }
  if(MaxEvent == 0) {
    cout << "\nNumber of Events to analyze: ";
    cin >> MaxEvent;
    if(MaxEvent == 0) {
      cerr << "...Invalid entry\n";
      exit;
    }
  }
  // Create file name patterns.
  const char* RunFileNamePattern = "raw/shms_all_%05d.dat";
  const char* ROOTFileNamePattern = "ROOTfiles/shms_replay_%d_%d.root";
  // Add variables to global list.
  gHcParms->Define("gen_run_number", "Run Number", RunNumber);
  gHcParms->AddString("g_ctp_database_filename", "DBASE/standard.database");
  // Load varibles from files to global list.
  gHcParms->Load(gHcParms->GetString("g_ctp_database_filename"), RunNumber);
  // g_ctp_parm_filename and g_decode_map_filename should now be defined.
  gHcParms->Load(gHcParms->GetString("g_ctp_kinematics_filename"), RunNumber);
  gHcParms->Load(gHcParms->GetString("g_ctp_parm_filename"));
  // Load params for SHMS trigger configuration
  gHcParms->Load("PARAM/TRIG/tshms.param");

  // Load the Hall C style detector map
  gHcDetectorMap = new THcDetectorMap();
  gHcDetectorMap->Load("MAPS/SHMS/DETEC/shms_stack.map");

  // Add trigger apparatus
  THaApparatus* TRG = new THcTrigApp("T", "TRG");
  gHaApps->Add(TRG);
  // Add trigger detector to trigger apparatus
  THcTrigDet* shms = new THcTrigDet("shms", "SHMS Trigger Information");
  TRG->AddDetector(shms);
  // Set up the equipment to be analyzed.
  THaApparatus* SHMS = new THcHallCSpectrometer("P", "SHMS");
  gHaApps->Add(SHMS);
  // Add drift chambers to SHMS apparatus
  THcDC* dc = new THcDC("dc", "Drift Chambers");
  SHMS->AddDetector(dc);
  // Add hodoscope to SHMS apparatus
  THcHodoscope* hod = new THcHodoscope("hod", "Hodoscope");
  SHMS->AddDetector(hod);
  // Add Heavy Gas Cherenkov to SHMS apparatus
  THcCherenkov* hgcer = new THcCherenkov("hgcer", "Heavy Gas Cherenkov");
  SHMS->AddDetector(hgcer);
  // Include golden track information
  THaGoldenTrack* gtr = new THaGoldenTrack("P.gtr", "SHMS Golden Track", "P");
  gHaPhysics->Add(gtr);
```

```
// Add handler for prestart event 125.
THcConfigEvtHandler* ev125 = new THcConfigEvtHandler("HC", "Config Event type 125");
gHaEvtHandlers->Add(ev125);

// Set up the analyzer - we use the standard one,
// but this could be an experiment-specific one as well.
// The Analyzer controls the reading of the data, executes
// tests/cuts, loops over Acpparatus's and PhysicsModules,
// and executes the output routines.
THcAnalyzer* analyzer = new THcAnalyzer;

// A simple event class to be output to the resulting tree.
// Creating your own descendant of THaEvent is one way of
// defining and controlling the output.
THaEvent* event = new THaEvent;

// Define the run(s) that we want to analyze.
// We just set up one, but this could be many.
char RunFileName[100];
sprintf(RunFileName, RunFileNamePattern, RunNumber);
THaRun* run = new THaRun(RunFileName);

// Eventually need to learn to skip over, or properly analyze
// the pedestal events
run->SetEventRange(1, MaxEvent);    // Physics Event number, does not
                                    // include scaler or control events.
run->SetNscan(1);
run->SetDataRequired(0x7);
run->Print();

// Define the analysis parameters
TString ROOTFileName = Form(ROOTFileNamePattern, RunNumber, MaxEvent);
analyzer->SetCountMode(2);    // 0 = counter is # of physics triggers
                              // 1 = counter is # of all decode reads
                              // 2 = counter is event number
analyzer->SetEvent(event);
analyzer->SetCrateMapFileName("MAPS/db_cratemap.dat");
analyzer->SetOutFile(ROOTFileName.Data());
analyzer->SetOdefFile("DEF-files/SHMS/GEN/workshop_example.def");
analyzer->SetCutFile("DEF-files/SHMS/GEN/pstackana_cuts.def");    // optional

// File to record cuts accounting information
//analyzer->SetSummaryFile("summary_example.log");    // optional

// Start the actual analysis.
analyzer->Process(run);
// Create report file from template.
//analyzer->PrintReport(    // optional
//  "TEMPLATES/dcana.template",
//  Form("REPORT_OUTPUT/replay_shms_%05d.report", RunNumber)
//);
```

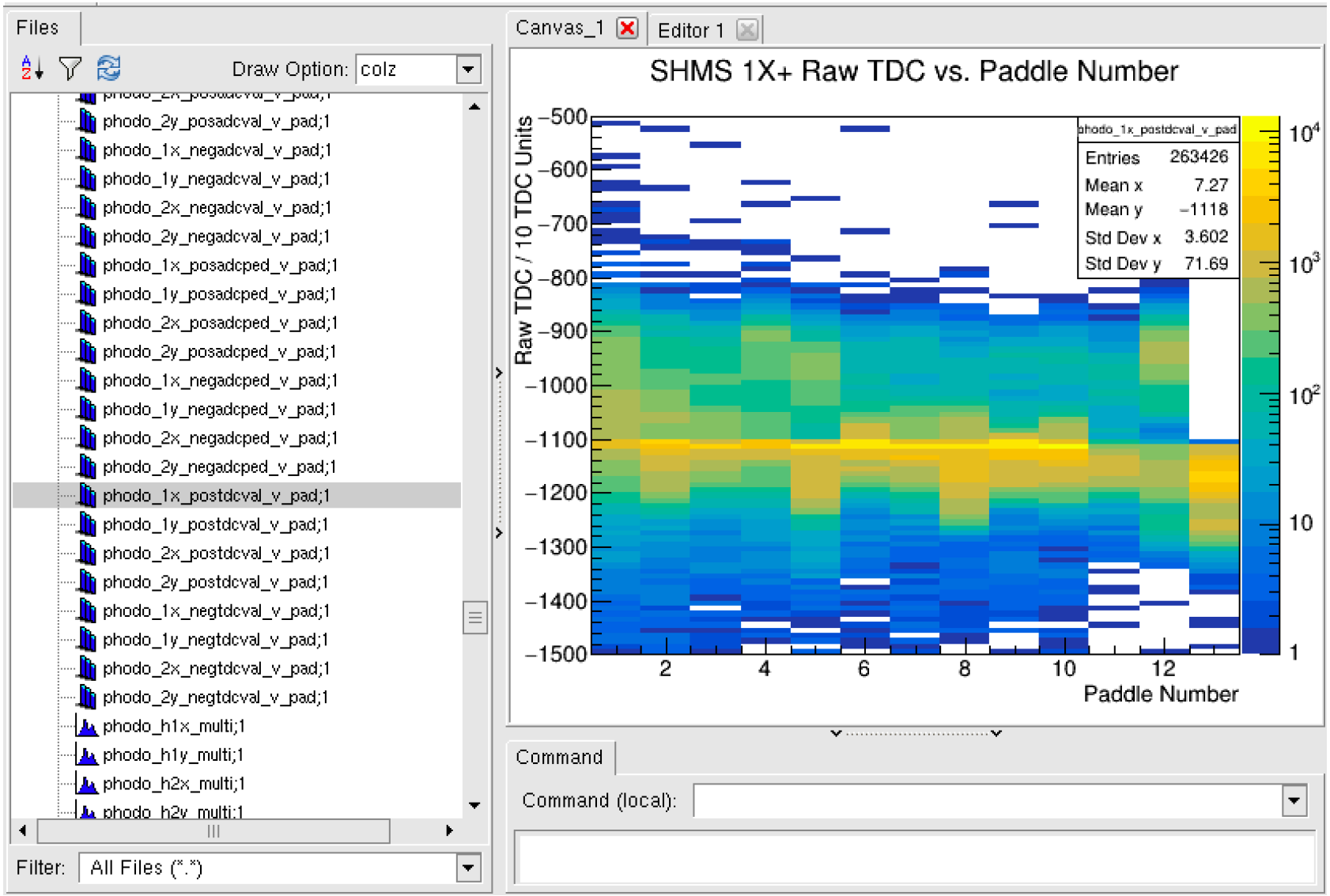
Hall-C Replay: Results



Hall-C Replay: ROOT TTree

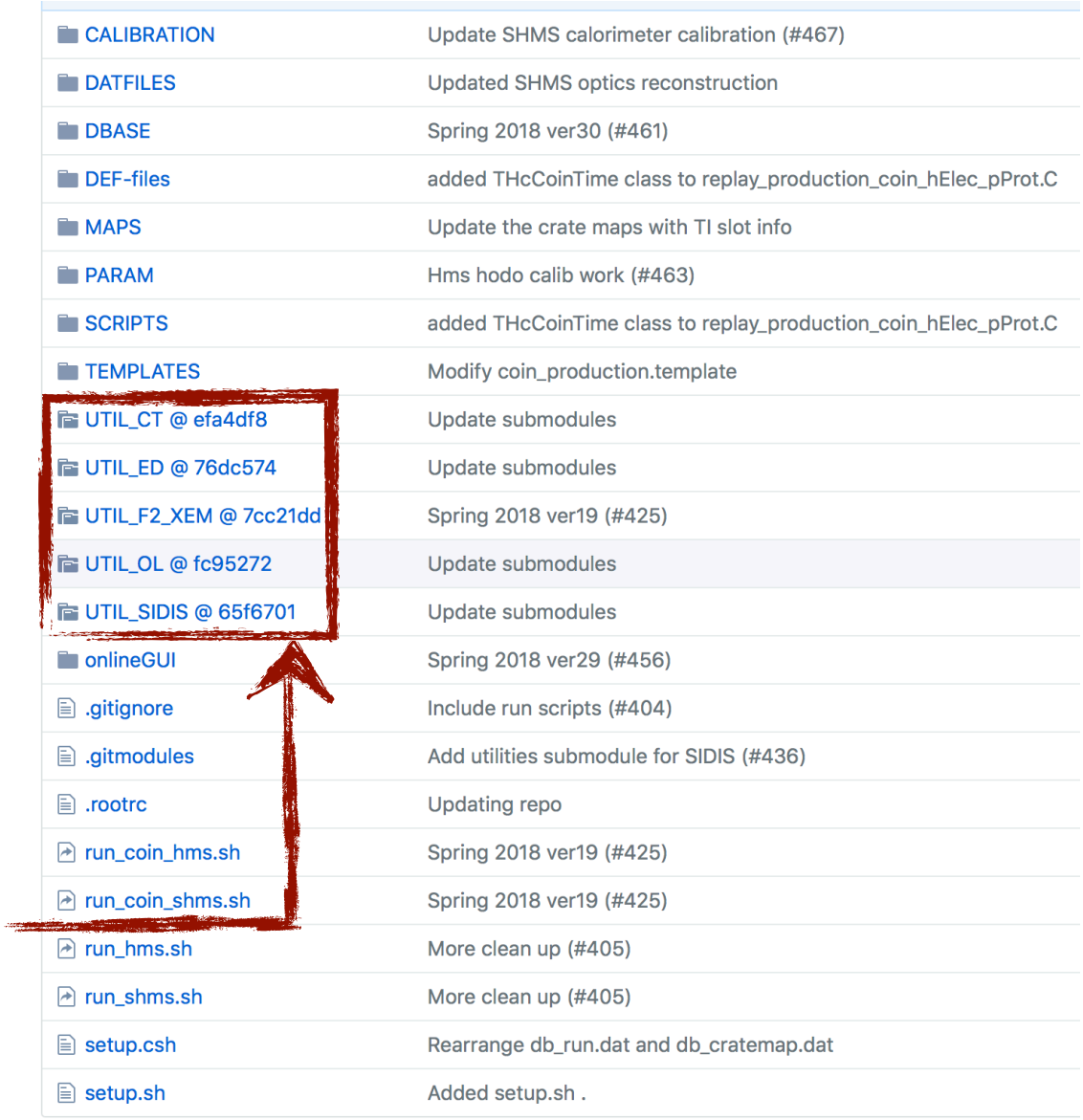


Hall-C Replay: DEF-Files Histograms



Recent Updates to Hall-C Replay

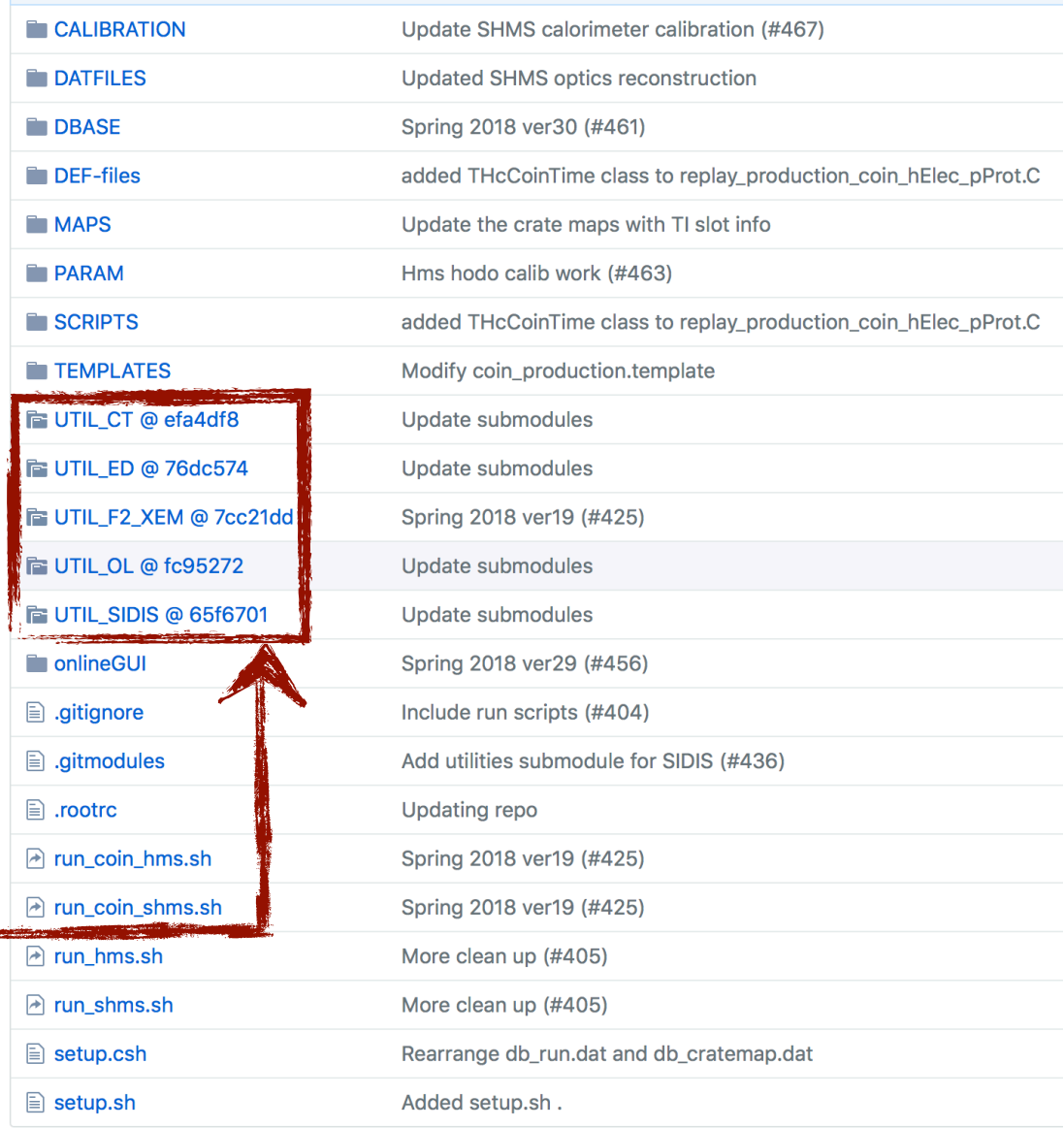
- Hall-C replay reconfigured to specifically support online analysis: #403
- Run specific calibrations and parameter configuration removed so that the replay is specific to experiment which is currently on the floor
- The previous run specific configuration is preserved with the tagged release 1.0
- Submodules configured for specific run groups so they have complete control of the online & offline replays



CALIBRATION	Update SHMS calorimeter calibration (#467)
DATFILES	Updated SHMS optics reconstruction
DBASE	Spring 2018 ver30 (#461)
DEF-files	added THcCoinTime class to replay_production_coin_hElec_pProt.C
MAPS	Update the crate maps with TI slot info
PARAM	Hms hodo calib work (#463)
SCRIPTS	added THcCoinTime class to replay_production_coin_hElec_pProt.C
TEMPLATES	Modify coin_production.template
UTIL_CT @ efa4df8	Update submodules
UTIL_ED @ 76dc574	Update submodules
UTIL_F2_XEM @ 7cc21dd	Spring 2018 ver19 (#425)
UTIL_OL @ fc95272	Update submodules
UTIL_SIDIS @ 65f6701	Update submodules
onlineGUI	Spring 2018 ver29 (#456)
.gitignore	Include run scripts (#404)
.gitmodules	Add utilities submodule for SIDIS (#436)
.rootrc	Updating repo
run_coin_hms.sh	Spring 2018 ver19 (#425)
run_coin_shms.sh	Spring 2018 ver19 (#425)
run_hms.sh	More clean up (#405)
run_shms.sh	More clean up (#405)
setup.csh	Rearrange db_run.dat and db_cratemap.dat
setup.sh	Added setup.sh .

Recent Updates to Hall-C Replay

- The experiment specific submodules is where the following should reside:
  - Shell scripts
  - Custom replay scripts
  - DEF-files
  - Monitoring scripts
  - Macros
  - Symbolic links to data files stored in the experiments directory on the RAID disk
  - Parameter files, etc.
- UTIL_OL is general utility submodule for online operations
  - Pedestal monitoring, report file monitoring, …



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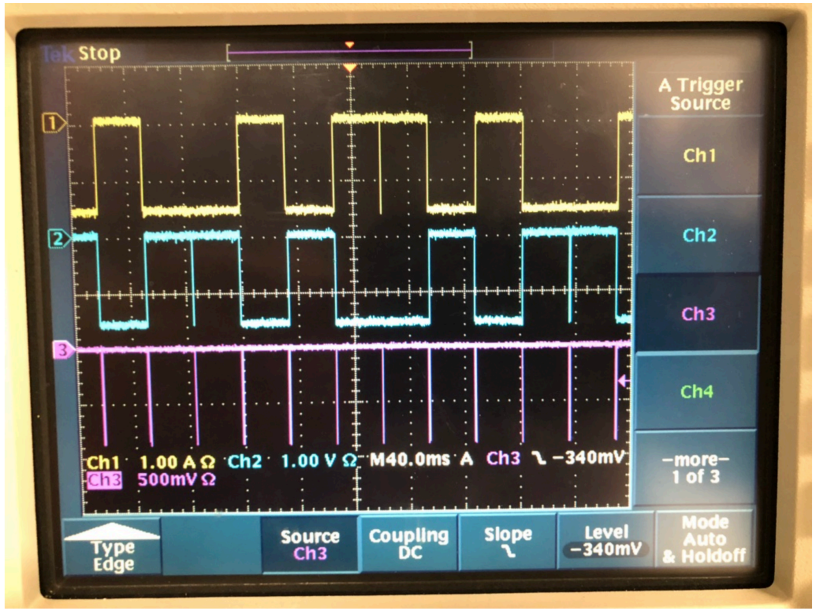
Recent Updates to Hall-C Replay

- New calibration code exists for the calorimeter, drift chambers, and hodoscope's
  - See various talks during Tuesday morning (10:45 - 12:15) session
- Helicity gated scalers and FADC channels included in ROOT tree

```
SLOT=14
REFINDEX=3
  11,1000,    0,    3  ! pFADC_TREF_ROC2
   0,    1,    1,    0  ! pAER
   1,    1,    2,    0  ! pHGCER
   2,    1,    3,    0  ! pNGCER
   3,    1,    4,    0  ! pPSHWR
   4,    1,    6,    0  ! pHGCER_MOD
   5,    1,    7,    0  ! pNGCER_MOD
   8,    1,    8,    0  ! pHEL_NEG
   9,    1,    9,    0  ! pHEL_POS
  10,    1,   10,    0  ! pHEL_MPS
  11,    1,    5,    0  ! pFADC_TREF_ROC2
```



+# desc	hel	crate	slot	start	nchan	page	long-description
+pBCM1_posHel	0	5	8	0	1	-1	SHMS BCM1 Hel+
+14/01	0	5	8	1	1	-1	Empty
+pBCM2_posHel	0	5	8	2	1	-1	SHMS BCM2 Hel+
+14/03	0	5	8	3	1	-1	Empty
+pBCM17_posHel	0	5	8	4	1	-1	SHMS BCM17 Hel+
+14/05	0	5	8	5	1	-1	Empty
+pUnser_posHel	0	5	8	6	1	-1	SHMS Unser Hel+
+14/07	0	5	8	7	1	-1	Empty
+p1MHz_posHel	0	5	8	8	1	-1	SHMS 1MHz Hel+
+14/09	0	5	8	9	1	-1	Empty
+pBCM4A_posHel	0	5	8	10	1	-1	SHMS BCM4A Hel+
+14/11	0	5	8	11	1	-1	Empty
+pBCM4B_posHel	0	5	8	12	1	-1	SHMS BCM4B Hel+
+14/13	0	5	8	13	1	-1	Empty
+pTRIG6_posHel	0	5	8	14	1	-1	SHMS TRIG6 Hel+
+pL1ACCP_posHel	0	5	8	15	1	-1	SHMS L1 Accept Hel+

Joint Hall A&C Data Analysis Workshop

Backup Slides

Slide Title