CLAS12 Computing Highlights

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for the CLAS12 Software Group

Computing Round Table

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CLAS12 Software at a Glance

Deployed in ClaRA platform

I/O package
- Evio I/O provider
- Raw event decoder
- ccdb access tools

Plotting package
- Histogramming & Fitting
- Ntuple Maker
- Event viewing & monitoring tools

Geometry package
- Geometry Objects and Methods
- Detector Geometry

Reconstruction packages
- CVT: central tracker
- DC: hit-based & time-based trk^{g}
- HTCC: e- ID
- FTOF: timing
- EC/PCAL: e- & neutrals ID
- FT-Cal, -Hodo: low angle e-, neutrals
- EB: detectors track matching & PID

Analysis package
- Kinematic Fitter
- Event Selector
- Fiducial Cuts provider
- Fast MC

Simulation (GEMC)
- Event simulation emulating detector responses and track propagation through CLAS12

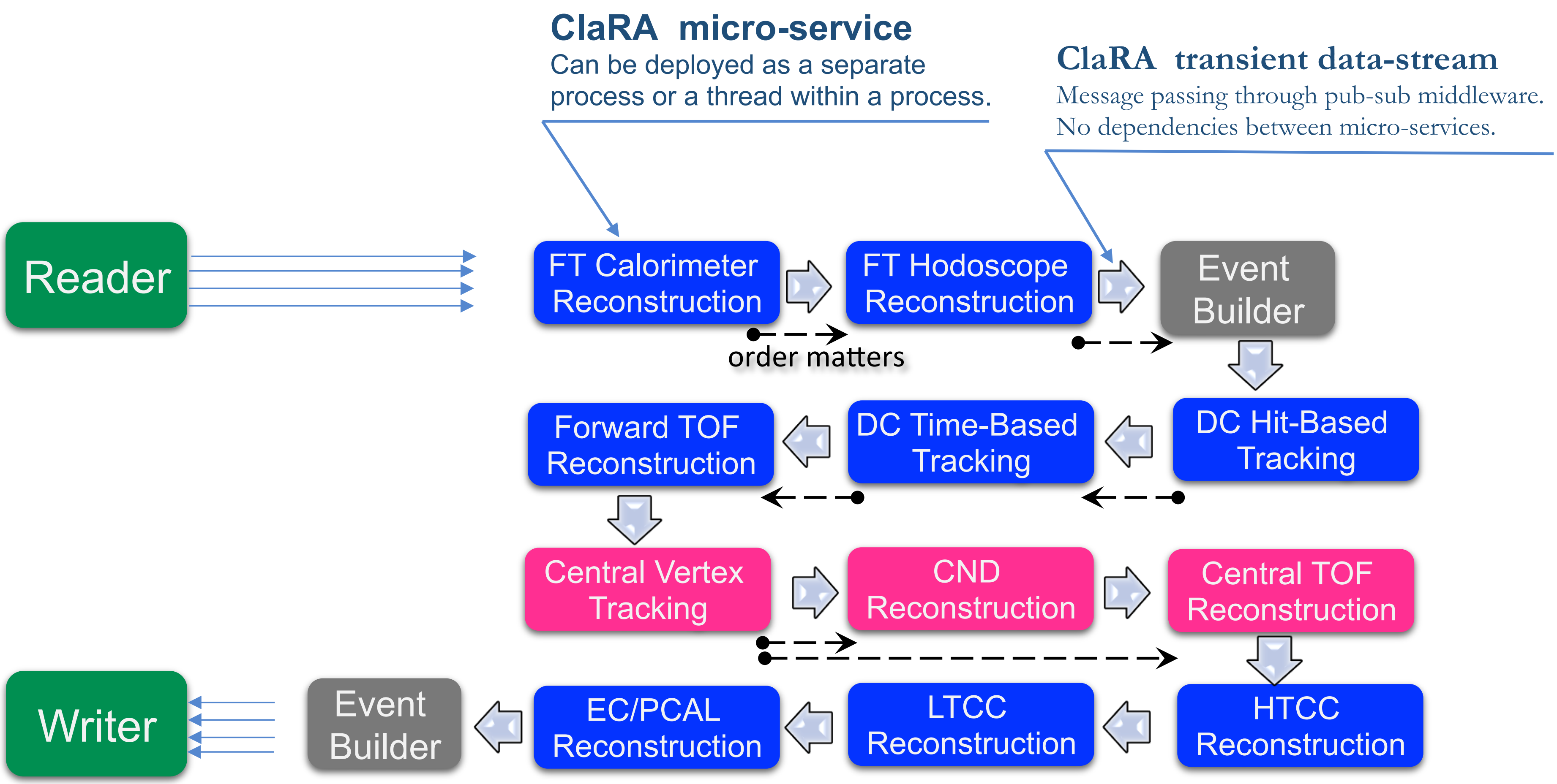
Event viewer
- cLAS eVEnt dISPLAY

Utilities
- DC noise finder
- MagField & Swimmer

Clas
Offline
Analysis
Tools

Event Reconstruction Service Composition

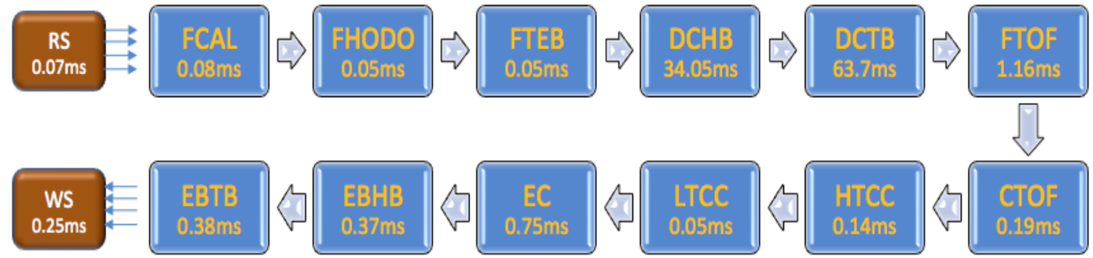
- Each detector reconstruction component is a **ClaRA** service.
- Event building services (EB) combines info from individual services output banks to reconstruct particle candidate.

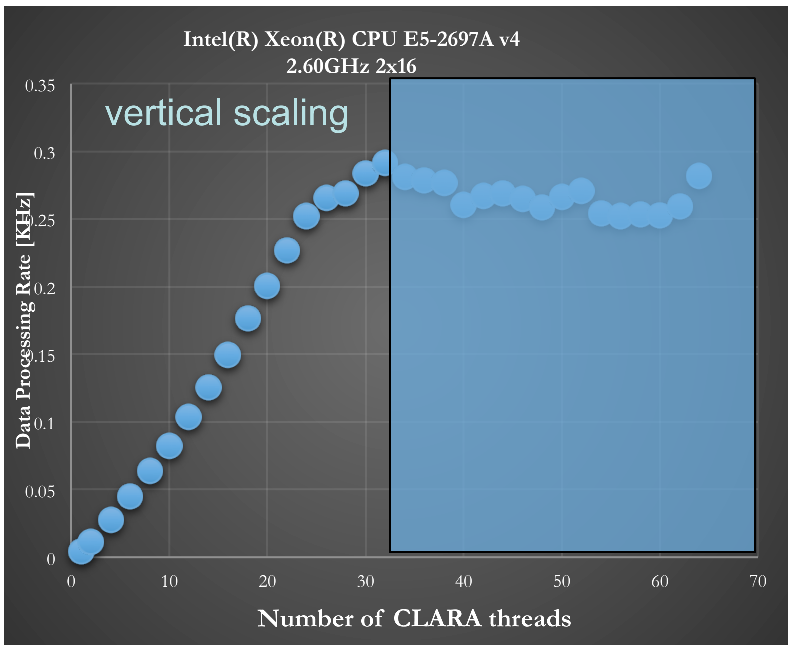


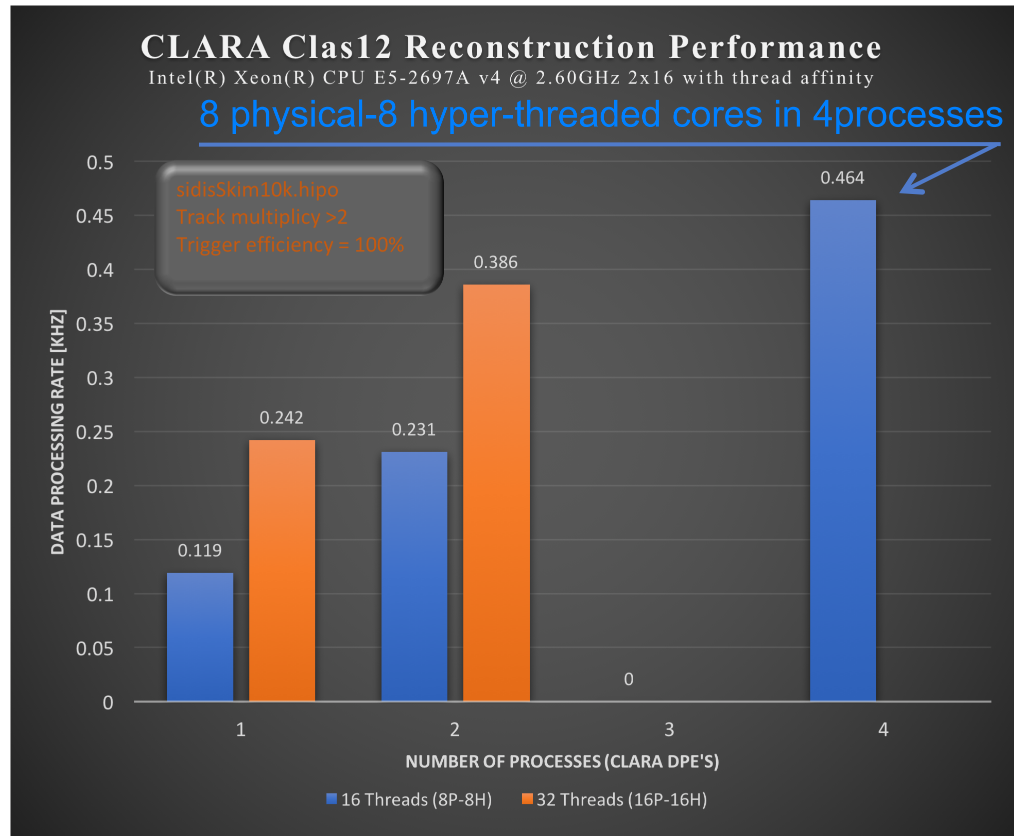
Reconstruction Readiness

Reconstruction framework stable.
Framework performance studies:

- Scaling studies using MC data*
  - Vertical scaling (multi-threading within the same node) ✔
  - Horizontal scaling (across nodes) ✔
- Ongoing optimization (reco. rates)







* Trigger efficiency = 100%
Sidis events, Track multiplicity >=2, No background
Node = Intel(R) Xeon(R) CPU E5-2697A v4 @ 2.60GHz 2x16

ClaRA Framework Usability

Running in shell environment

```
gurjyan@clara1601:~$ $CLARA_HOME/bin/clara-shell

 CLARA 4.3.0

 Run 'help' to show available commands.

clara> help
Commands:

  run        Start CLARA data processing
  edit       Edit data processing conditions
  set        Parameter settings
  show       Show values
  save       Export configuration to file
  source     Read and execute commands from file

Use help <command> for details about each command.

clara> help run

  run local
    Run CLARA data processing on the local node.

  run farm
    Run CLARA data processing on the farm.

clara>
```

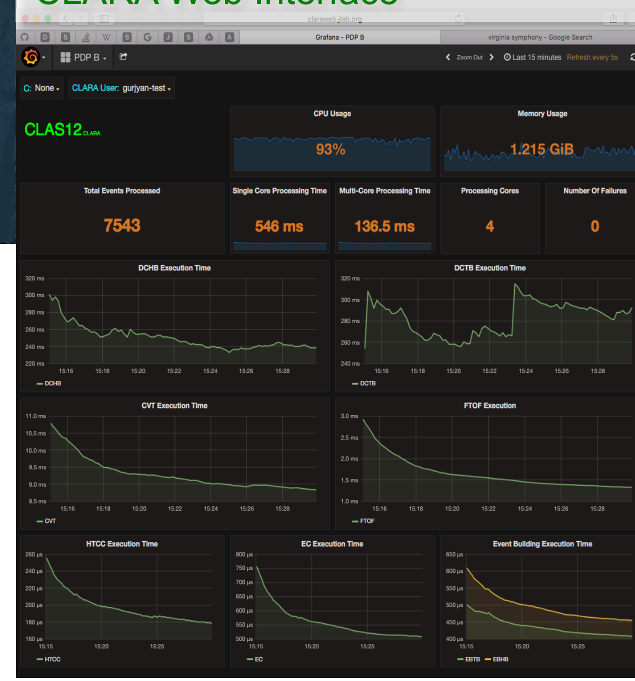
Setting configuration

```
clara> set farm.cpu 16

clara> set farm.scaling 5

clara> show config
servicesFile:     "/group/da/vhg/testbed/clara/myClara/plugins/clas12/config/services.yaml"
fileList:         "/group/da/vhg/testbed/clara/myClara/plugins/clas12/config/files.list"
inputDir:         "/group/da/vhg/testbed/clara/myClara/data/input"
outputDir:        "/group/da/vhg/testbed/clara/myClara/data/output"
threads:          NO VALUE
reportEvents:     NO VALUE
skipEvents:       NO VALUE
maxEvents:        NO VALUE
logDir:           "/group/da/vhg/testbed/clara/myClara/log"
feHost:           NO VALUE
fePort:           NO VALUE
author:           "gurjyan"
description:      "clara"
useFE:            true
javaMemory:       NO VALUE
javaOptions:      NO VALUE
monHost:          NO VALUE
farm.cpu:         16
farm.memory:      40
farm.disk:        5
farm.time:        1440
farm.os:          "centos7"
farm.stage:       NO VALUE
farm.track:       "debug"
farm.scaling:     5
farm.system:      "jlab"

clara>
```

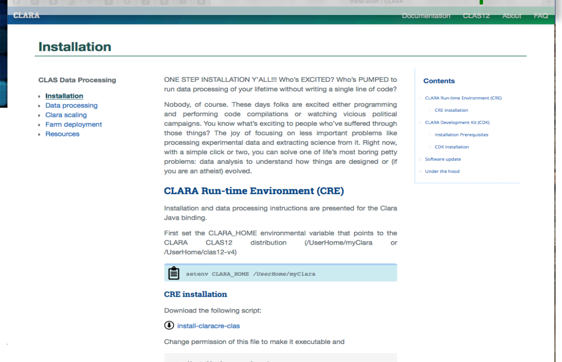
Checking jobs status

```
clara> show farmStatus
JOB_ID   USER    STAT  QUEUE     EXEC_HOST  JOB_NAME         SUBMIT_TIME   CPU_TIME  WALLTIME  ACCOUNT
43981885 gurjyan  R    priority  farm160143 ...an-clara_000  Sep 21 13:52  --        --        clas12
43981886 gurjyan  R    priority  farm160135 ...an-clara_001  Sep 21 13:52  --        --        clas12
43981887 gurjyan  R    priority  farm160134 ...an-clara_002  Sep 21 13:52  --        --        clas12
43981888 gurjyan  R    priority  farm160131 ...an-clara_003  Sep 21 13:52  --        --        clas12
43981889 gurjyan  R    priority  farm160130 ...an-clara_004  Sep 21 13:52  --        --        clas12
43981890 gurjyan  R    priority  farm160129 ...an-clara_005  Sep 21 13:52  --        --        clas12
43981891 gurjyan  R    priority  farm160128 ...an-clara_006  Sep 21 13:52  --        --        clas12
43981892 gurjyan  R    priority  farm160127 ...an-clara_007  Sep 21 13:52  --        --        clas12
43981893 gurjyan  A    priority  --         ...an-clara_008  Sep 21 13:49  --        --        clas12
43981894 gurjyan  A    priority  --         ...an-clara_009  Sep 21 13:49  --        --        clas12
43981895 gurjyan  A    priority  --         ...an-clara_010  Sep 21 13:49  --        --        clas12
43981896 gurjyan  A    priority  --         ...an-clara_011  Sep 21 13:49  --        --        clas12
43981897 gurjyan  A    priority  --         ...an-clara_012  Sep 21 13:49  --        --        clas12
43981898 gurjyan  A    priority  --         ...an-clara_013  Sep 21 13:50  --        --        clas12

clara>
```

CLARA Web Interface

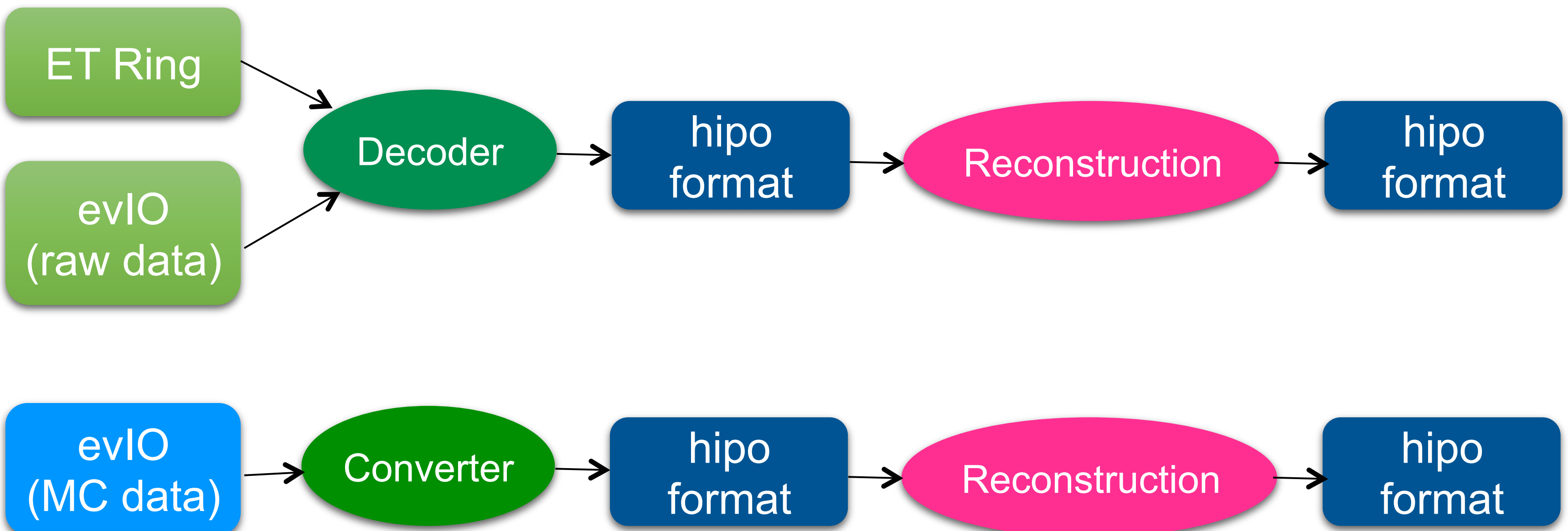


Installation from a shell script



Data Formats

- Raw bank decoders implemented for all detectors.
  - Translation tables in ccdb
  - ADC pulse parameters read from ccdb
- Data structures implemented (High Performance Output – hipo format) for data compression. Bank structures optimized to save space.
  - Bank filtering, compression → suitable for DSTs



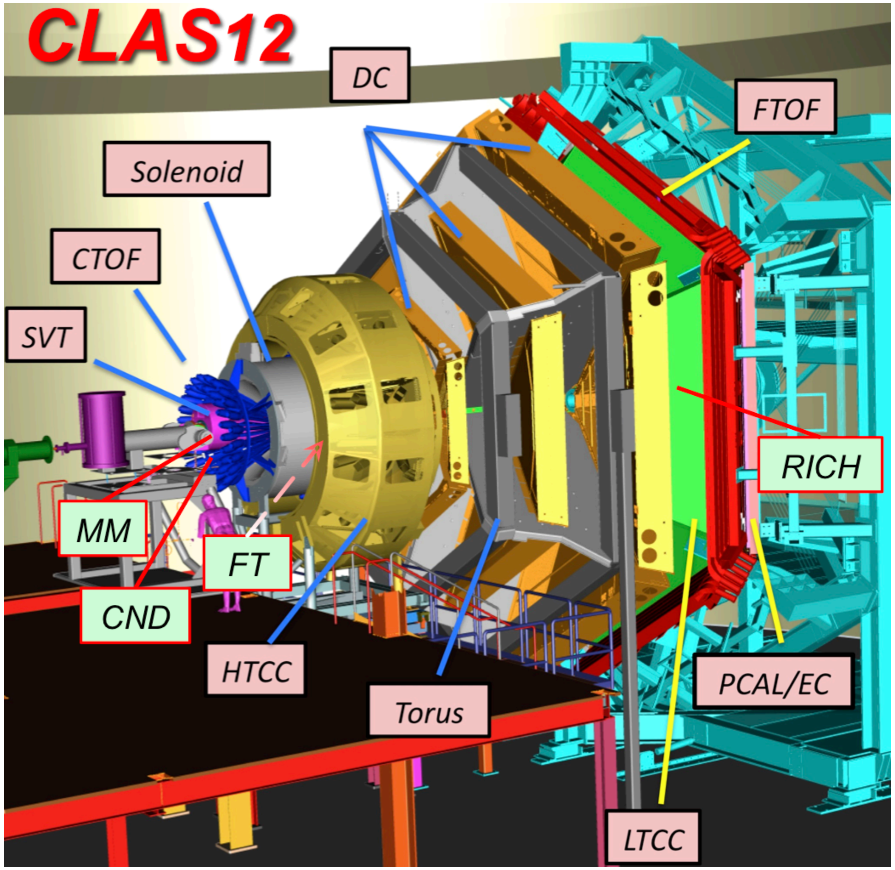
Event Reconstruction

Central Detector

- Silicon Vertex Tracker+Central Micromegas Tracker → tracking uses Kalman Filter fitting method
- Central Time Of Flight → β (from path length) for PID
- Central Neutron Detector →track β for neutron ID

Forward Detector

- Drift Chambers *Hit-Based & Time-Based* Tracking → Kalman Filter fitting method to reconstruct tracks
  - Forward Micromegas Tracker → refit DC tracks with FMT hits (resolution improvement)
- Forward Time Of Flight → β (track path length)
- Forward Tagger calorimeter and hodoscope →id low angle electrons and reconstruct π^0's
- Electromagnetic Calorimeter/Preshower CALorimeter → detector responses for PID, reconstruction of neutrals
- High/Low Threshold Cherenkov Counter→ detector responses for PID, e- tagging using HTCC
- RICH detector → detector response for PID



Event Builder

- Matches track to outer detectors, uses TOF, Calorimeters and Cherenkov detector responses for PID

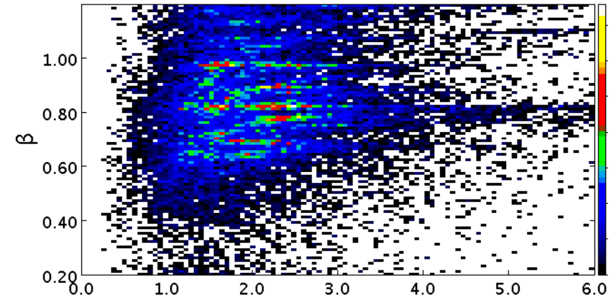
Calibration & Monitoring Suites

Test of the full calibration procedure:

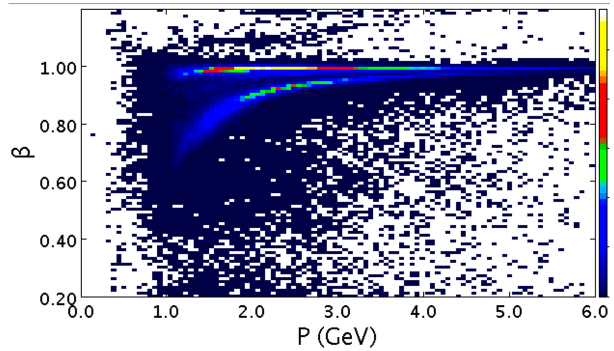
1. Calibration procedures in place:
   - Validated using pseudo-data with "wrong" calibration constants (CLAS12-Note 2017-002).
2. Feb. 2017 Commissioning Run (KPP) data calibration for all detectors:
   - Procedure and algorithms tested on all forward detectors.
   - While the KPP data has limited statistics, it has allowed for important verification of the calibration procedures.

PID from FTOF (MC events):
β vs p (positively charged tracks)

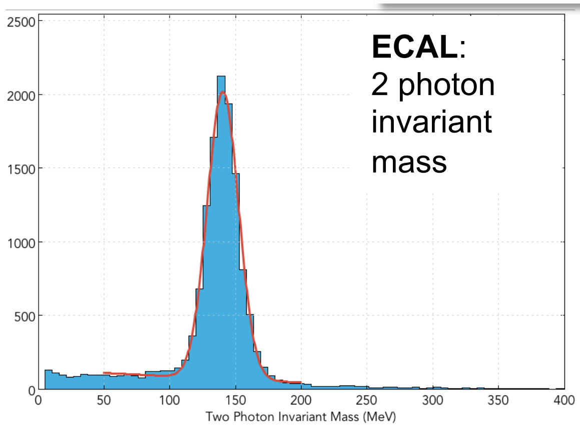
Before calibration

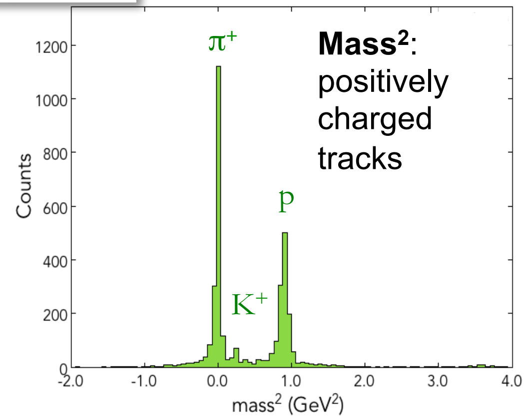


After calibration



KPP data analysis



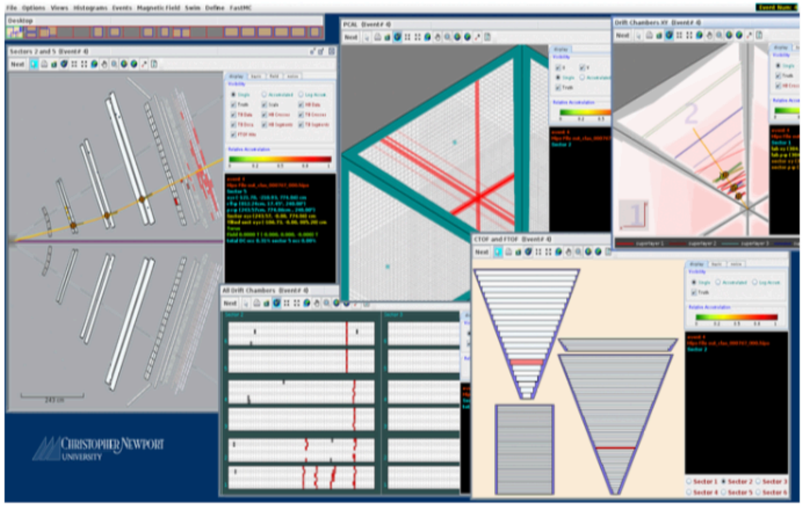


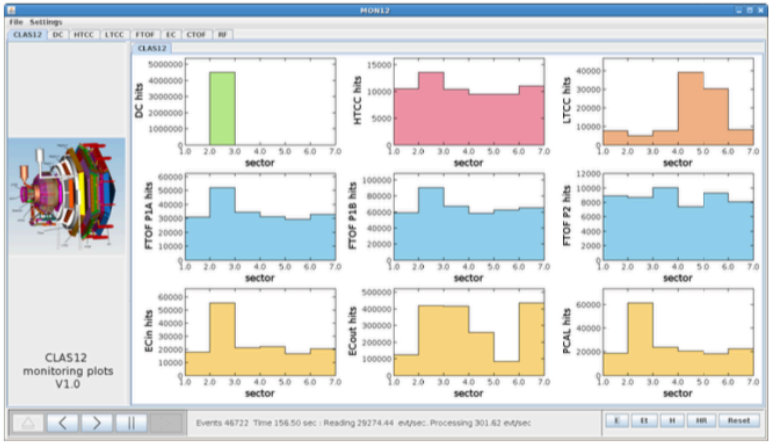
Event Monitoring

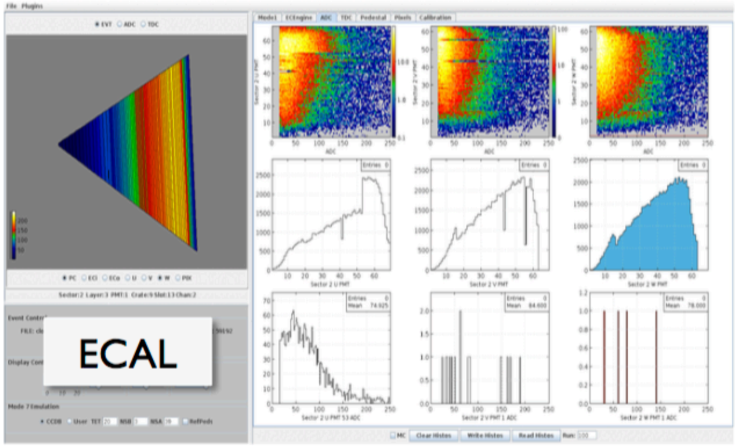
CLAS12 monitoring GUIs

Expert and Shift Taker GUIs developed in COATJAVA

- CED: CLAS12 event display (D. Heddle)
- MON12: shift taker GUI showing occupancies and raw data distributions for CLAS12 systems (RDV)
- Detector specific expert GUIs for detailed monitoring from pulse views to reconstructed information (C. Smith)







Reconstruction Readiness

Test of the full reconstruction chain:

2. Validations on MC:
   - Use calibration challenge data sample and kinematic-specific samples.
   - Verify reconstruction resolutions and efficiencies.

Single track resolution and multi-track event reconstruction well within specs

Average Specs:
- $\sigma(\Delta p/p) < 1\%$
- $\sigma(\theta) < 1$ mrad
- $\sigma(\phi) < 3$ mrad

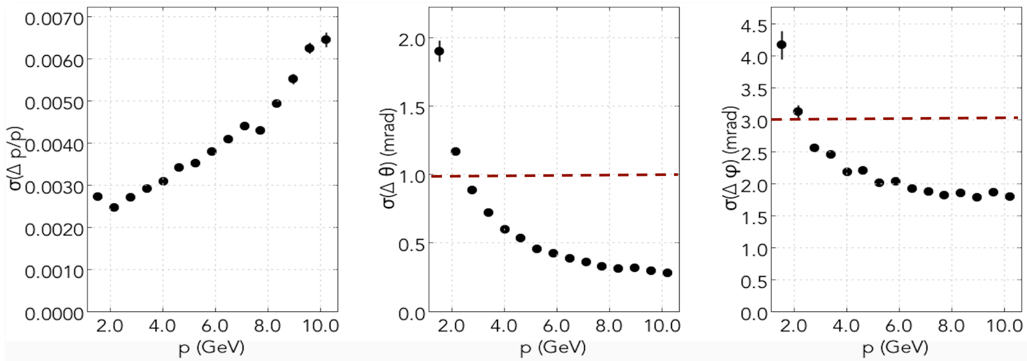
Tracking Efficiency:

$10^o<\theta<35^o$, p>1 GeV/c — DC

$\varepsilon > 97\ \%$

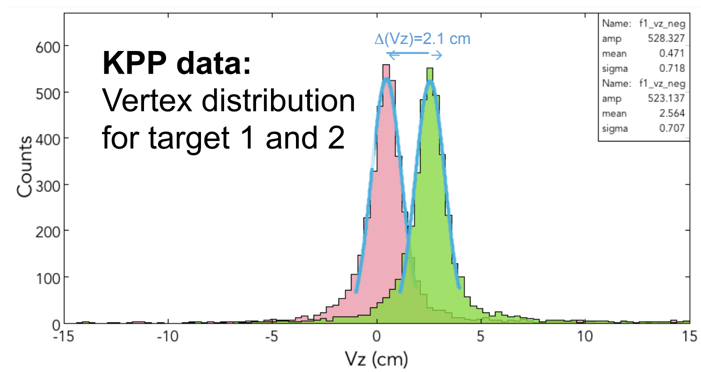
$45^o<\theta<110^o$, 0.5<p<2 GeV/c — SVT

$\varepsilon > 96\ \%$



3. Feb. 2017 Commissioning Run data:
   - Feb. 3 (evening): begin KPP run*
   - Feb. 6 (morning): end run
   - Feb. 6 (noon): Key Performance Parameter (KPP) results presented to Project Management
   - Feb. 7 (afternoon): concurrence obtained

Targets: two 0.5 mm ^{12}C wires mounted 2.1 cm apart along the beamline (Vz)



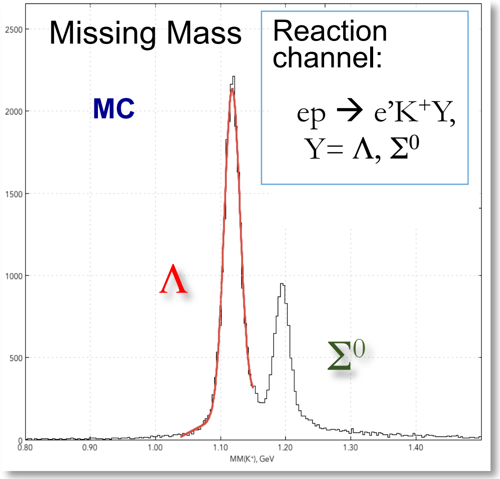
*KPP runs 804—810 (used for TOF calibrations) contain ~3M event with at least one track in sector2.

Event Selection

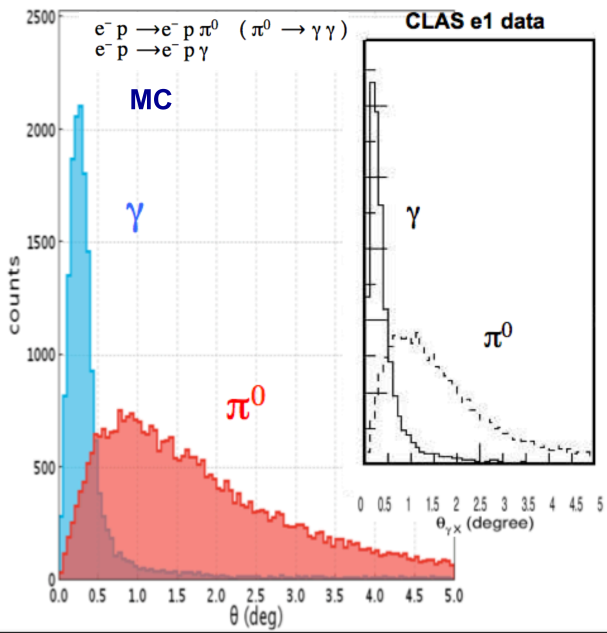
Various analyses techniques to select events in place

- e.g. K Y production analysis from simulation

Particle identification from TOF systems, Calorimeters and Cherenkov counters



reconstructed e-p→e'p'γ MC events



- e.g. Deeply Virtual Compton Scattering (DVCS*) Studies:

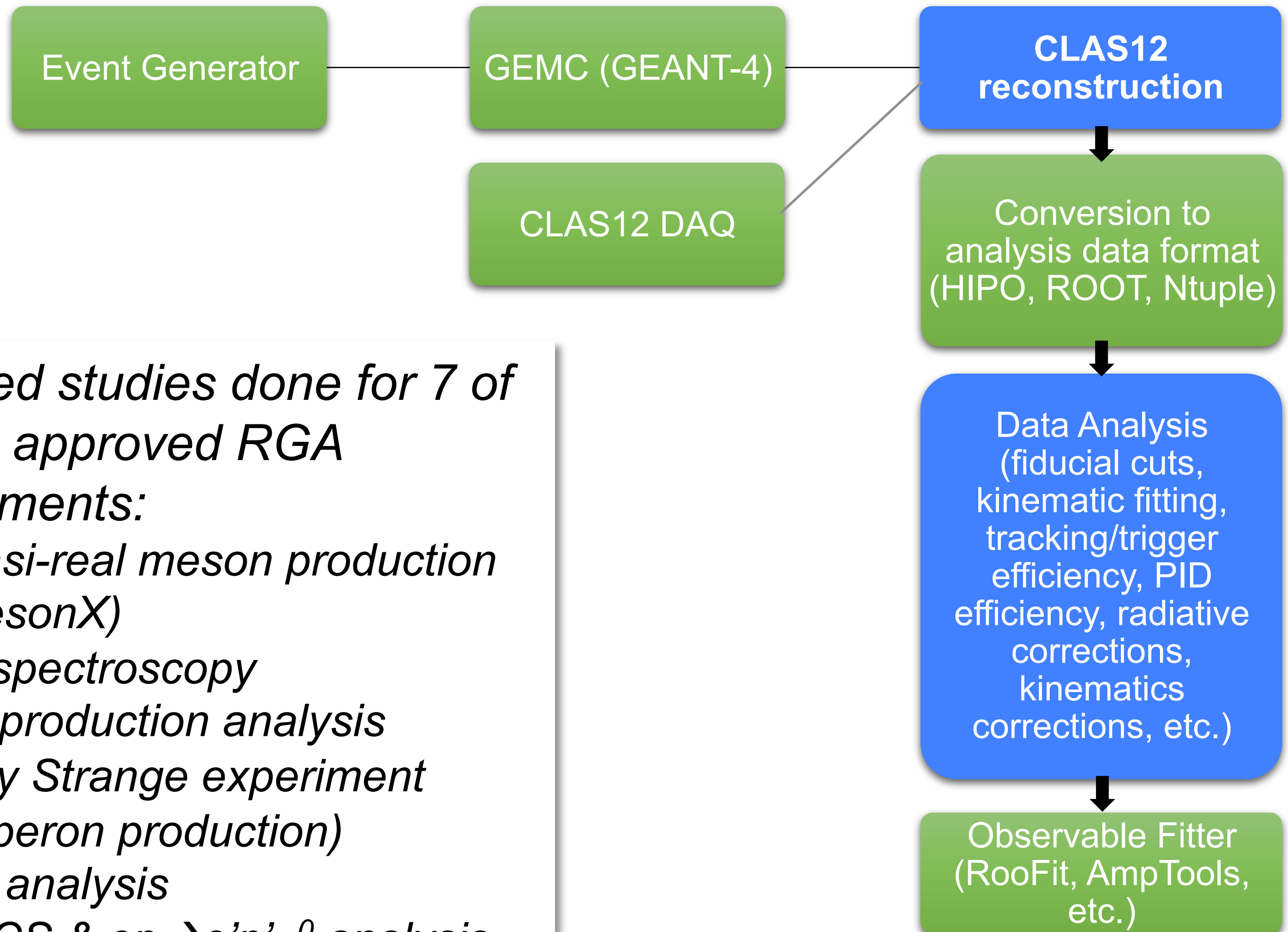
  $ep \rightarrow e' p' \gamma$

Compare kinematic variable spectra with CLAS (6 GeV) data

* key reaction for CLAS12 physics program

Physics Analysis Scheme

- done & tested
- optimizing



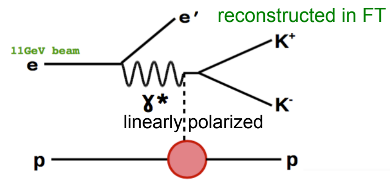
Detailed studies done for 7 of the 12 approved RGA experiments:

- *quasi-real meson production (mesonX)*
- *N* spectroscopy*
- *KY production analysis*
- *Very Strange experiment (hyperon production)*
- *J/ψ analysis*
- *DVCS & ep→e'p'π^0 analysis*
- *SIDIS analysis (π production)*

CLAS12 Analysis Example

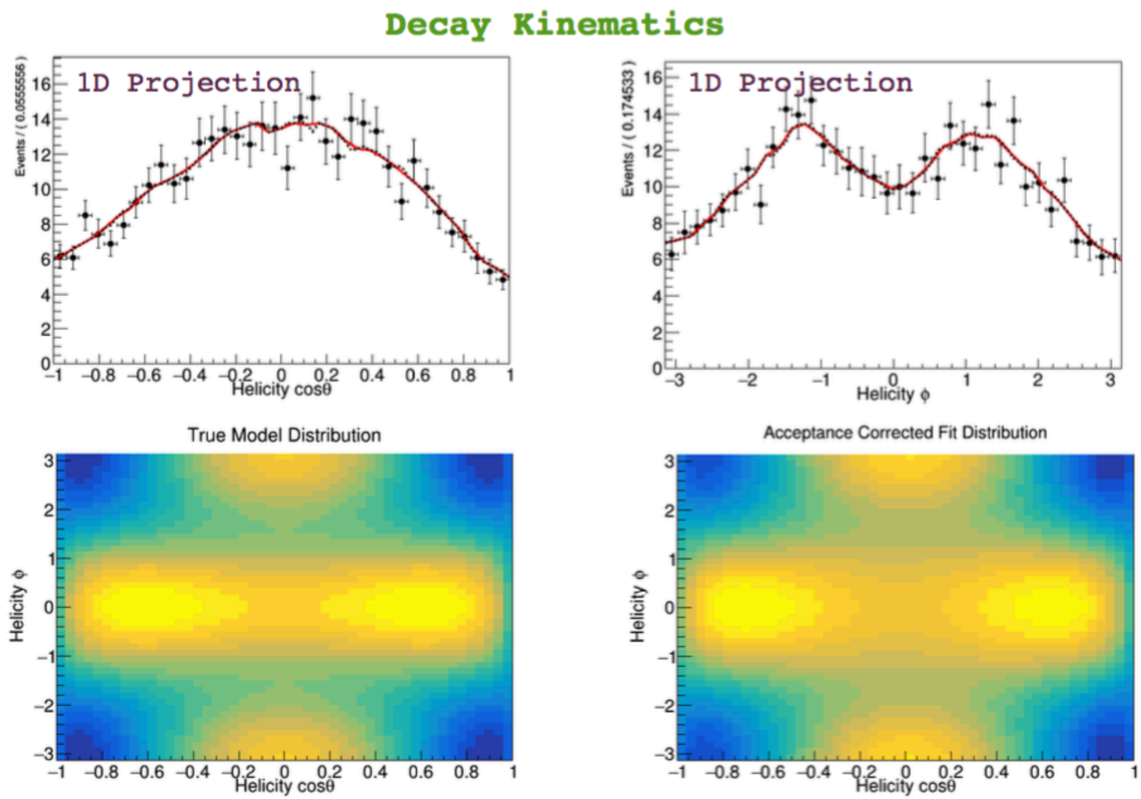
Reaction channel :

ep → e' p' K^+ K^-



- **Analysis**:
  - Data generated as phase space and weighted according to model (t-slope=1 GeV^{-2}, photon asymmetry=0.8, non-zero Y_{LM} moments).
  - Reconstruct & filter events for each topology (exclusive or missing hadron).
  - Convert to *analysis* data format and calculate fit variables.

Extended Maximum Likelihood fits to reconstructed simulated data after acceptance correction



CLAS12 Analysis Example

Reaction channel* :

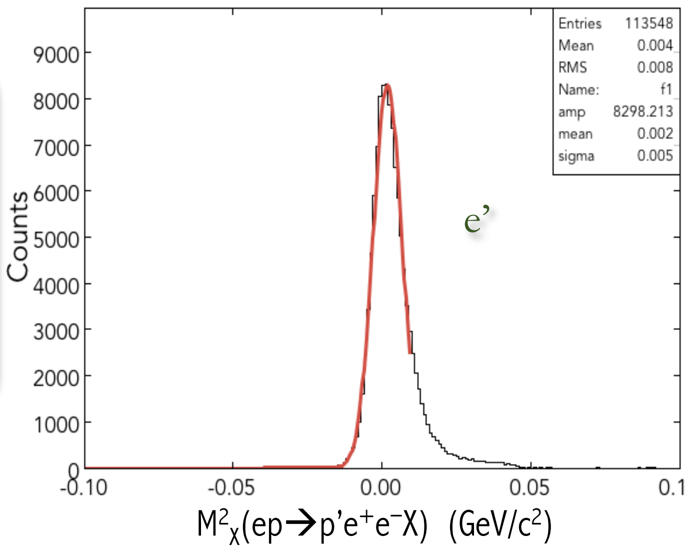
ep → e' J/ψ p; J/ψ → e^+ e^-

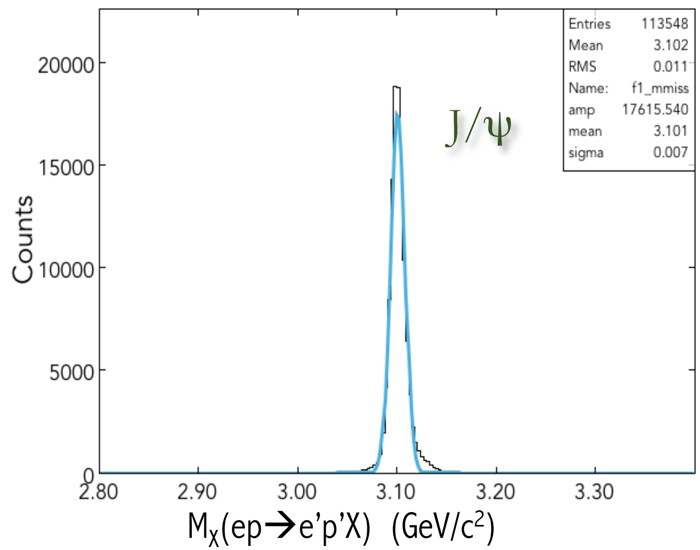
*Search for Hidden-Charm Pentaquark ep → e' Pc → e' J/ψ p

Reconstructed Masses by Missing Mass Technique

Forward going e- in Forward Tagger

e' M_X resolution important for pentaquark search in ep→ e'Pc reaction





Summary

- Calibration tools developed with real and pseudo data.
  - Successful Feb. 2017 commissioning run.
  - Ready for Fall 2017 engineering run.
- Reconstruction code stable. Validated on commissioning and simulated data.
- Simulations ready to generate realistic pseudo data.
- Analysis tools well underway:
  - Event generators
  - Event selection and data handling tools
  - High level physics analysis tools
  - Full analysis of physics reactions tested
- Analysis organization and management defined.
- Ready for physics.