GlueX Data Analysis

Paul Mattione (JSA)

Outline

- Offline data processing:
  - Calibration, monitoring, & reconstruction
- GlueX analysis software
- Coordinating collaboration analysis efforts

Offline Data Processing

Offline data processing team:
Paul Mattione (JSA), Sean Dobbs (NWU),
Alex Austregesilo (JSA), Thomas Britton (JSA)

Previous members:
Justin Stevens (W&M), Kei Moriya

Calibration Automation

- Batch farm calibration train (SWIF)
  - Run plugins & scripts to automatically calibrate data
  - Timing offsets, drift time-to-distance, tagger time-walk, SC, etc.
  - Multiple passes: Dependencies
  - Calibration constants published once human-verified

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    - Skims created to speed up calibrations

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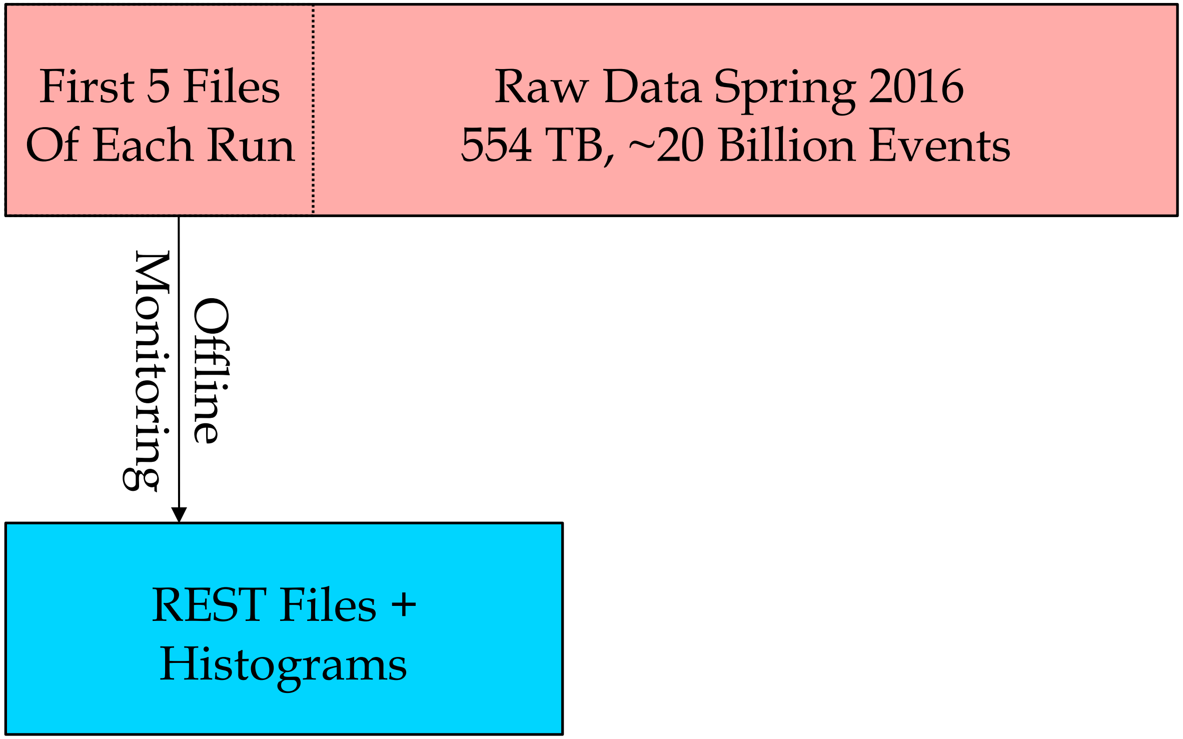
- Some (complex) procedures not finalized/automated yet
  - E.g. TOF, π^0, Tagger/PS calibrations
  - Skims created to speed up calibrations
- Prompt calibrations:
  - Spring 2016: ~Weekly calibration trains, 1st recon. ~3 weeks after start
  - Fall 2016: Calibrate as data hits the tape
  - Future: Run calibrations online

Production Overview (SWIF)



First 5 Files Of Each Run

Raw Data Spring 2016
554 TB, ~20 Billion Events

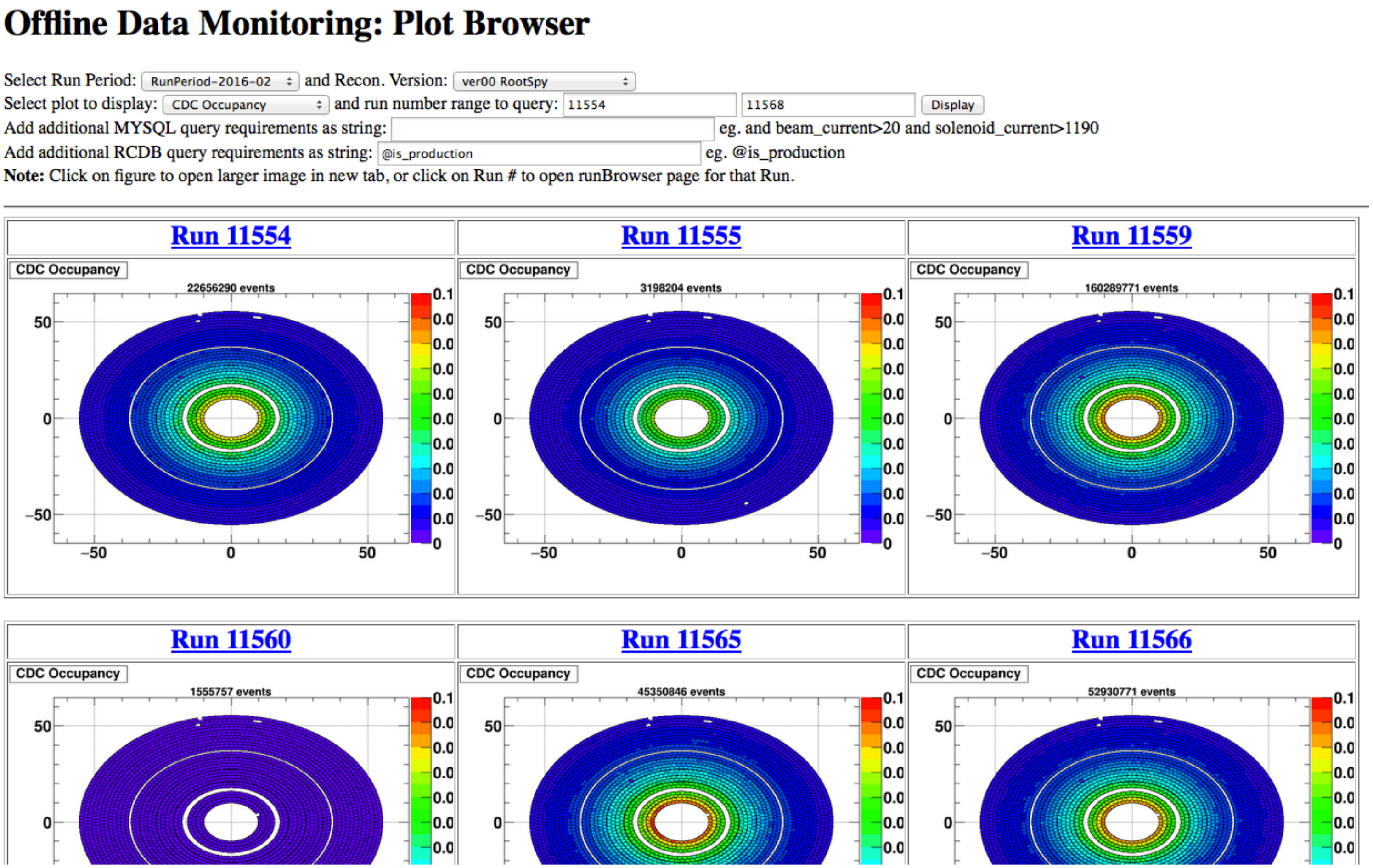
Offline Monitoring

REST Files + Histograms

REST: Reconstructed data (tracks, showers, etc.)

Offline Monitoring (SWIF)

- Run 40 JANA plugins: Occupancies, calibrations, reconstruction
  - Incoming data (cron), + every ~2 weeks (as changes come in)



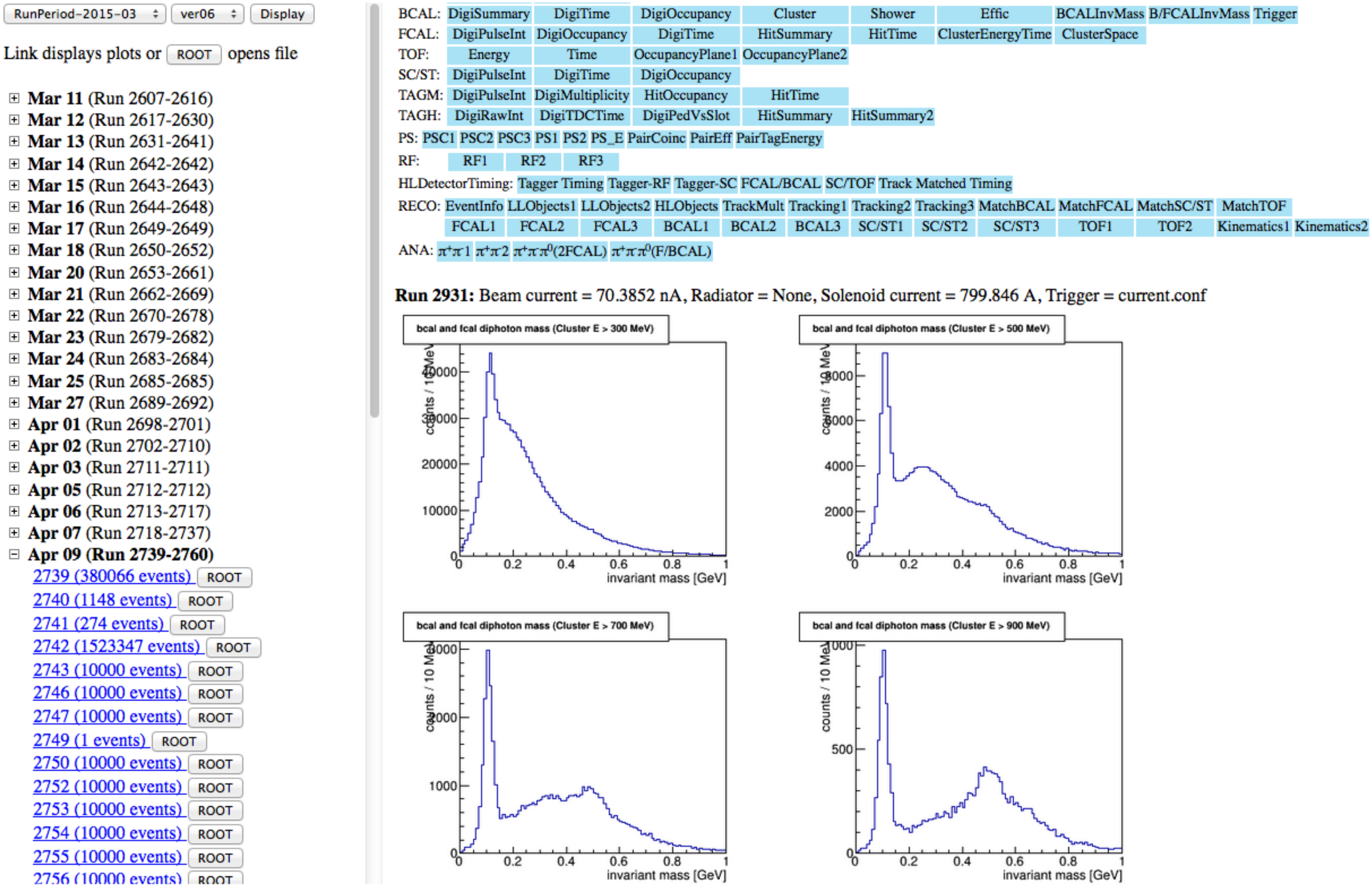
Offline Data Monitoring: Plot Browser

Select Run Period: RunPeriod-2016-02 and Recon. Version: ver00 RootSpy
Select plot to display: CDC Occupancy and run number range to query: 11554 11568 Display
Add additional MYSQL query requirements as string: eg. and beam_current>20 and solenoid_current>1190
Add additional RCDB query requirements as string: @is_production eg. @is_production
Note: Click on figure to open larger image in new tab, or click on Run # to open runBrowser page for that Run.

Run 11554	Run 11555	Run 11559
CDC Occupancy 22656290 events	CDC Occupancy 3198204 events	CDC Occupancy 160289771 events
Run 11560	Run 11565	Run 11566
CDC Occupancy 1555757 events	CDC Occupancy 45350846 events	CDC Occupancy 52930771 events

Offline Monitoring (SWIF)

- Web browse plots, can browse (& download) ROOT files



Link displays plots or ROOT opens file

⊞ **Mar 11** (Run 2607-2616)
⊞ **Mar 12** (Run 2617-2630)
⊞ **Mar 13** (Run 2631-2641)
⊞ **Mar 14** (Run 2642-2642)
⊞ **Mar 15** (Run 2643-2643)
⊞ **Mar 16** (Run 2644-2648)
⊞ **Mar 17** (Run 2649-2649)
⊞ **Mar 18** (Run 2650-2652)
⊞ **Mar 20** (Run 2653-2661)
⊞ **Mar 21** (Run 2662-2669)
⊞ **Mar 22** (Run 2670-2678)
⊞ **Mar 23** (Run 2679-2682)
⊞ **Mar 24** (Run 2683-2684)
⊞ **Mar 25** (Run 2685-2685)
⊞ **Mar 27** (Run 2689-2692)
⊞ **Apr 01** (Run 2698-2701)
⊞ **Apr 02** (Run 2702-2710)
⊞ **Apr 03** (Run 2711-2711)
⊞ **Apr 05** (Run 2712-2712)
⊞ **Apr 06** (Run 2713-2717)
⊞ **Apr 07** (Run 2718-2737)
⊟ **Apr 09 (Run 2739-2760)**

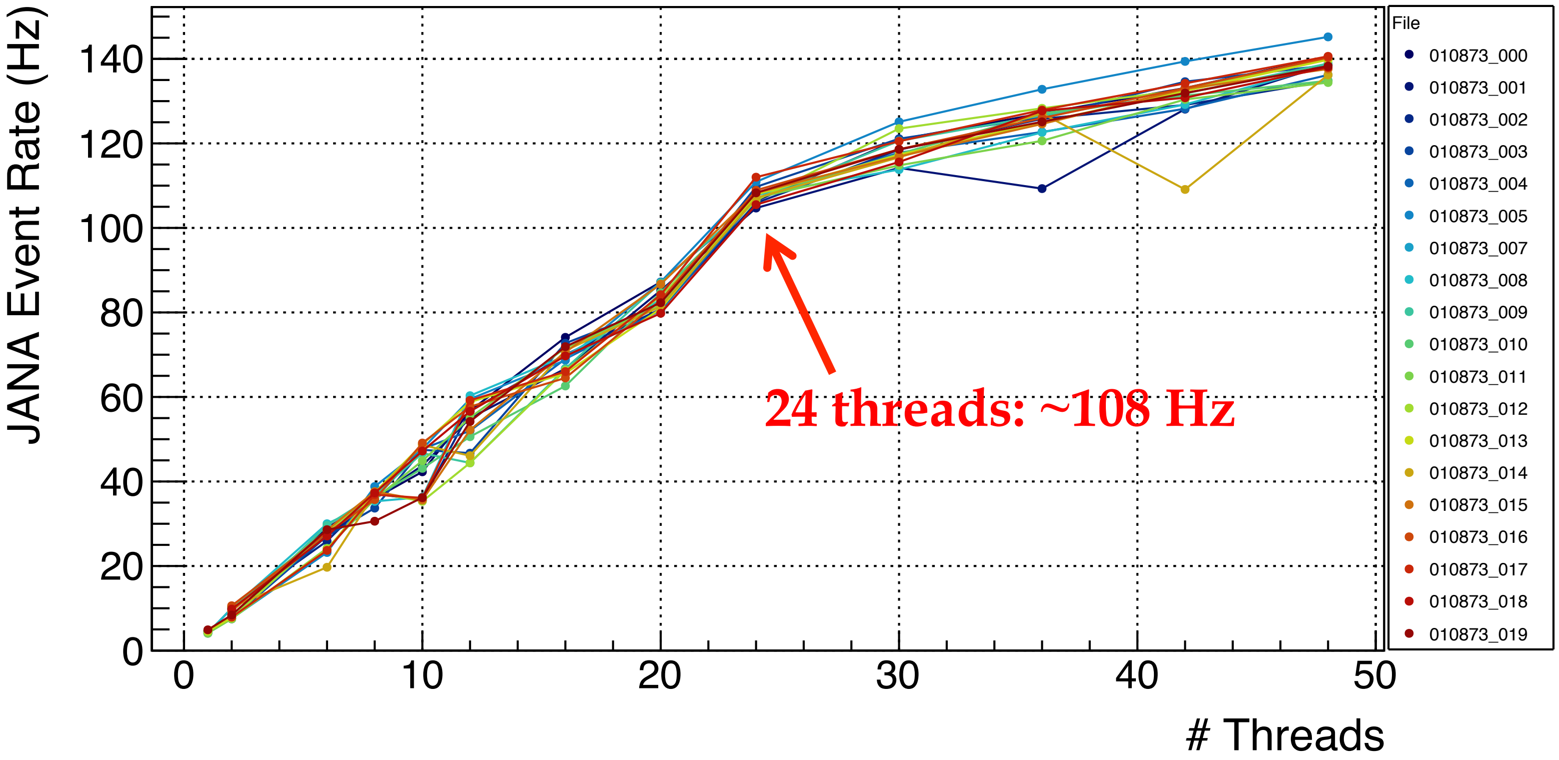
2739 (380066 events) ROOT
2740 (1148 events) ROOT
2741 (274 events) ROOT
2742 (1523347 events) ROOT
2743 (10000 events) ROOT
2746 (10000 events) ROOT
2747 (10000 events) ROOT
2749 (1 events) ROOT
2750 (10000 events) ROOT
2752 (10000 events) ROOT
2753 (10000 events) ROOT
2754 (10000 events) ROOT
2755 (10000 events) ROOT
2756 (10000 events) ROOT

BCAL: DigiSummary DigiTime DigiOccupancy Cluster Shower Effic BCALInvMass B/FCALInvMass Trigger
FCAL: DigiPulseInt DigiOccupancy DigiTime HitSummary HitTime ClusterEnergyTime ClusterSpace
TOF: Energy Time OccupancyPlane1 OccupancyPlane2
SC/ST: DigiPulseInt DigiTime DigiOccupancy
TAGM: DigiPulseInt DigiMultiplicity HitOccupancy HitTime
TAGH: DigiRawInt DigiTDCTime DigiPedVsSlot HitSummary HitSummary2
PS: PSC1 PSC2 PSC3 PS1 PS2 PS_E PairCoinc PairEff PairTagEnergy
RF: RF1 RF2 RF3
HLDetectorTiming: Tagger Timing Tagger-RF Tagger-SC FCAL/BCAL SC/TOF Track Matched Timing
RECO: EventInfo LLObjects1 LLObjects2 HLObjects TrackMult Tracking1 Tracking2 Tracking3 MatchBCAL MatchFCAL MatchSC/ST MatchTOF
FCAL1 FCAL2 FCAL3 BCAL1 BCAL2 BCAL3 SC/ST1 SC/ST2 SC/ST3 TOF1 TOF2 Kinematics1 Kinematics2
ANA: $\pi^+\pi^-1$ $\pi^+\pi^-2$ $\pi^+\pi^-\pi^0$(2FCAL) $\pi^+\pi^-\pi^0$(F/BCAL)

Run 2931: Beam current = 70.3852 nA, Radiator = None, Solenoid current = 799.846 A, Trigger = current.conf

Monitoring Rate (April)

- Issues with multi-threaded scaling: 24 threads: 5x scaling 24 Hz
- Fixed how locking was handled: 24 threads: 108 Hz, 23x scaling



24 core node + hyperthreads

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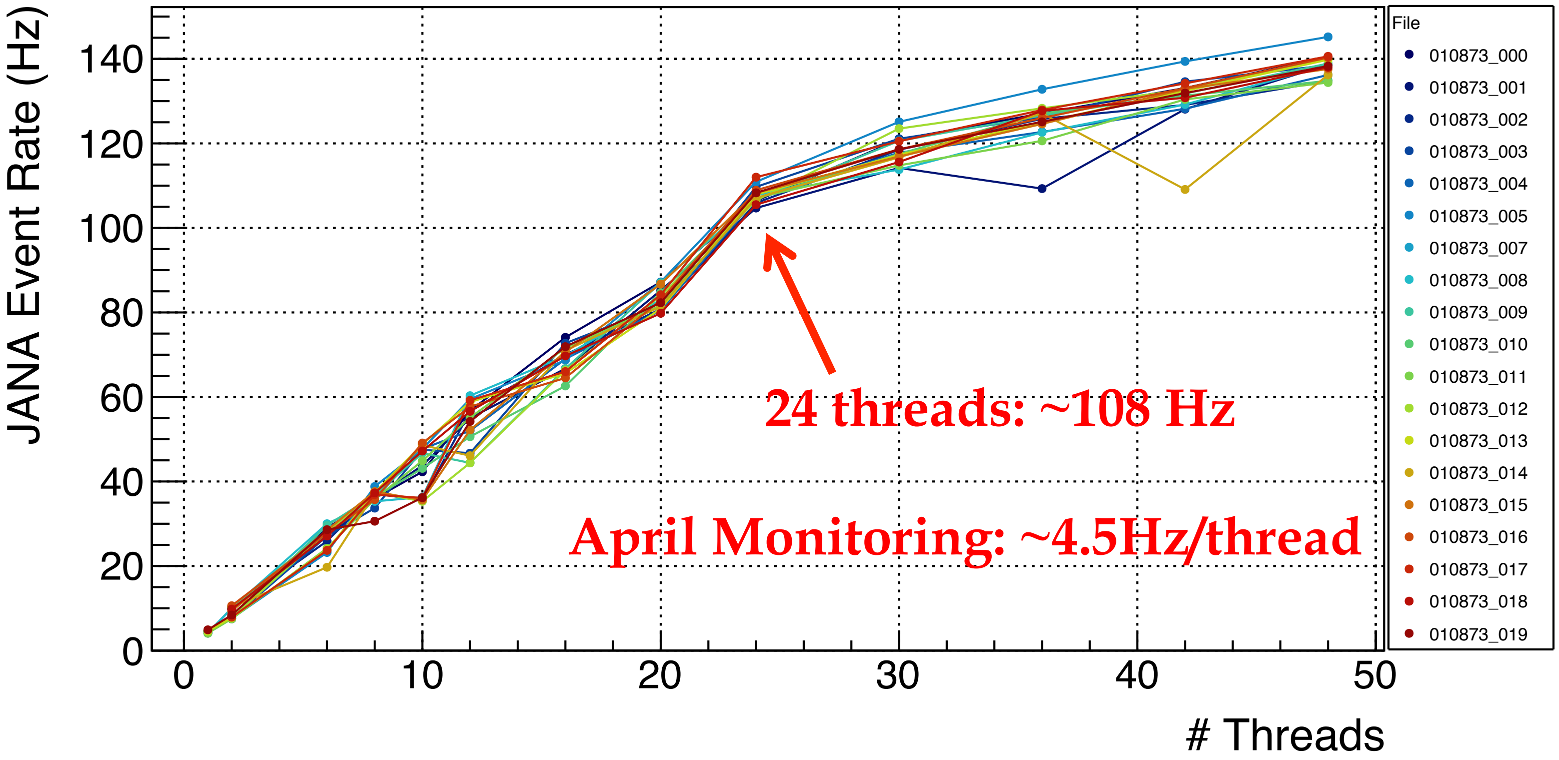

24 threads: ~108 Hz

April Monitoring: ~4.5Hz/thread

24 core node + hyperthreads

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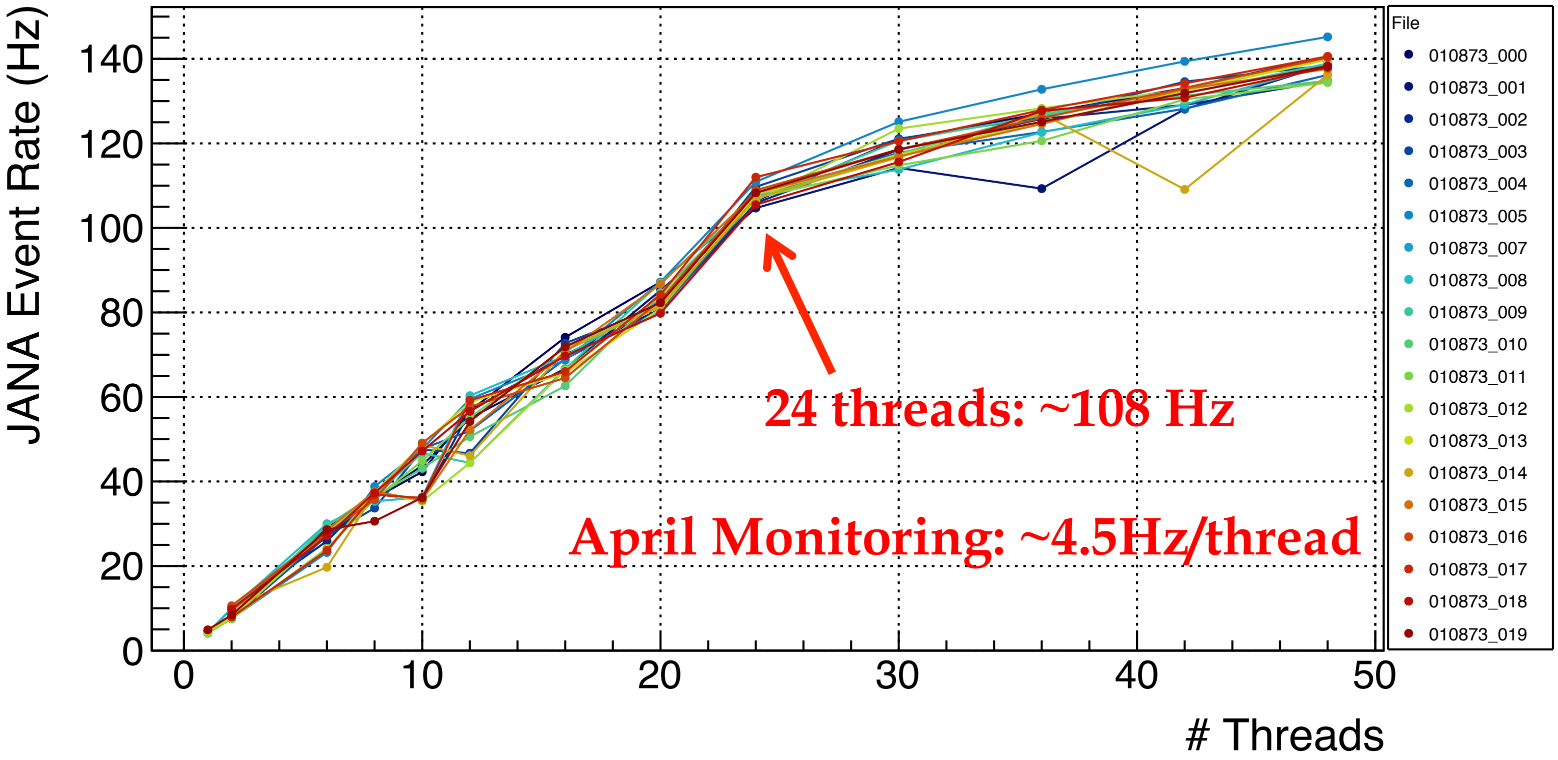
- Current reconstruction: **~10Hz**/ thread



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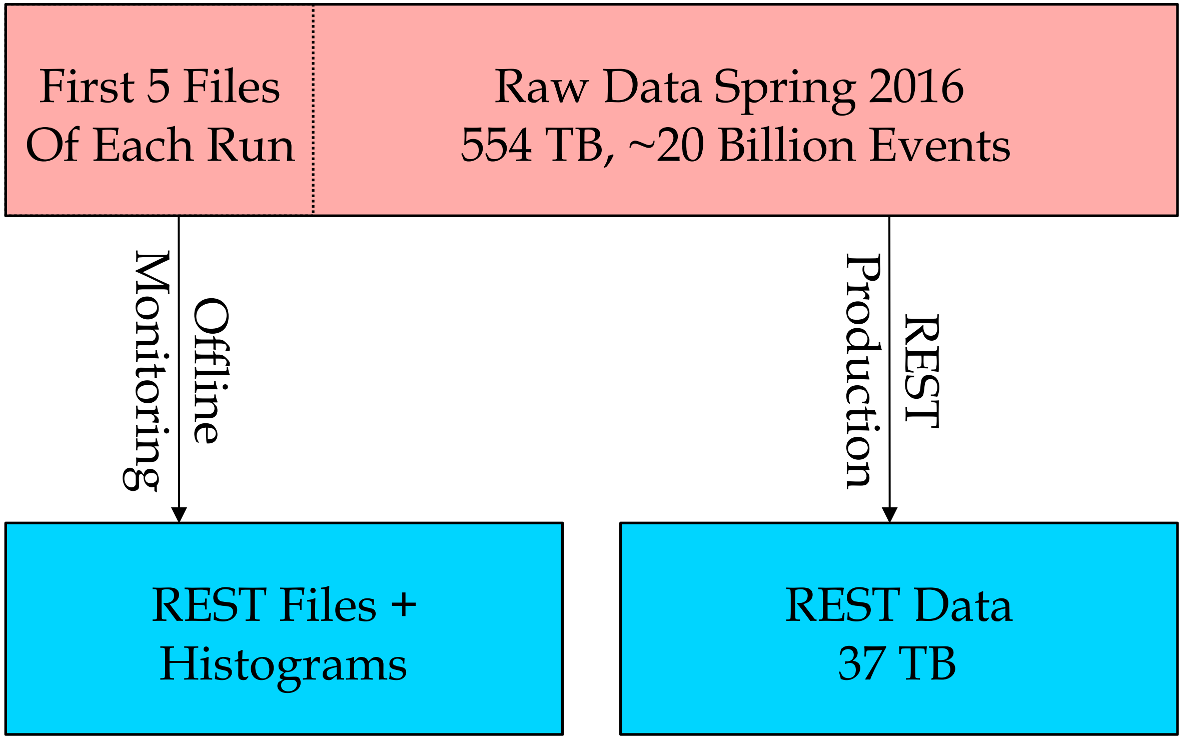
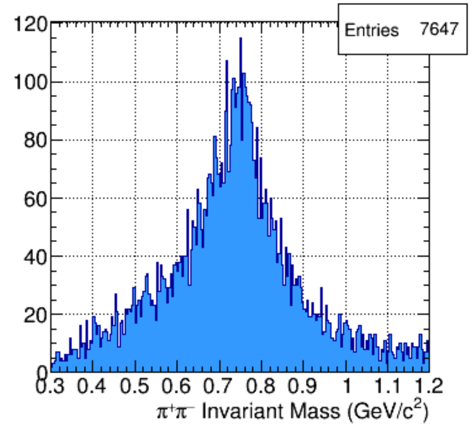
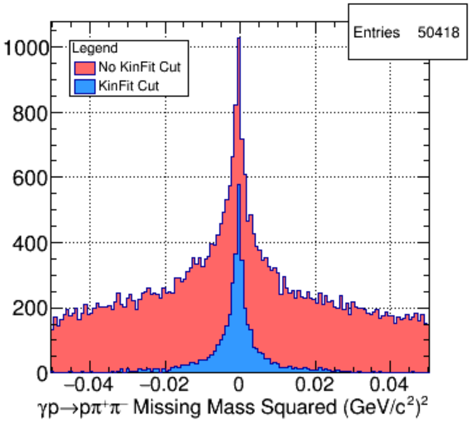


REST: Reconstructed data (tracks, showers, etc.)

REST Production (SWIF)

- Full reconstruction (tracks, showers, etc.)

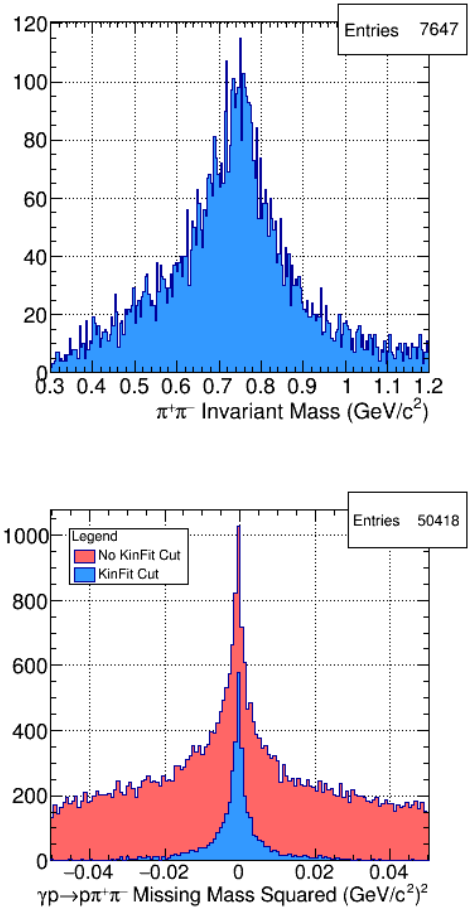




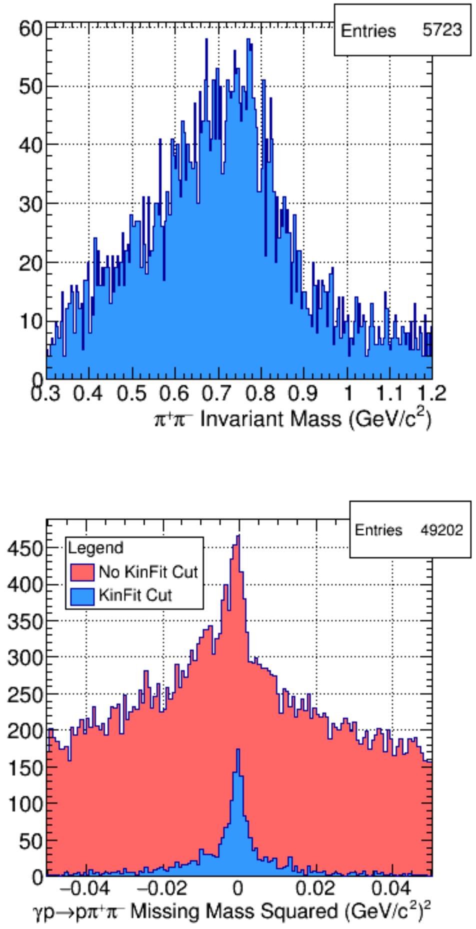
Reconstruction ver01

REST Production (SWIF)

- Full reconstruction (tracks, showers, etc.)



Reconstruction ver01



Reconstruction ver02

Ver02 problem:

- Track timing overhauled
- Lingering issues

Didn't notice before launch

- Not in existing monitoring
- Noticed after ~ 1 week

REST Production (SWIF)

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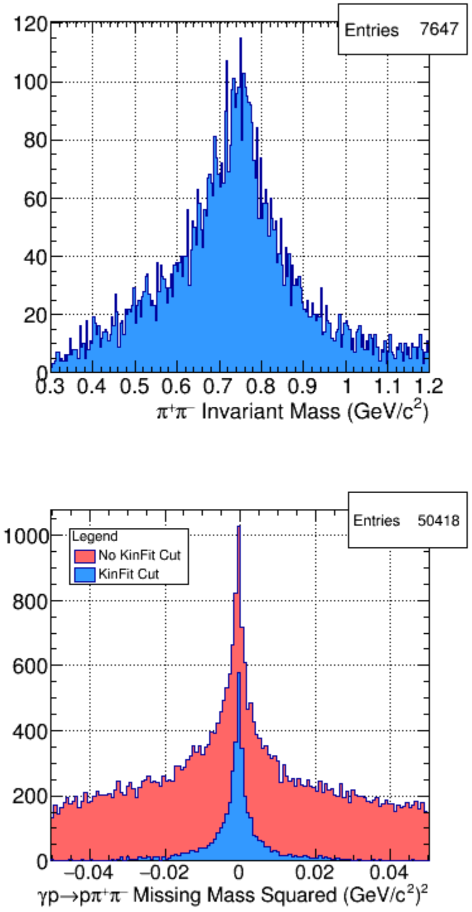
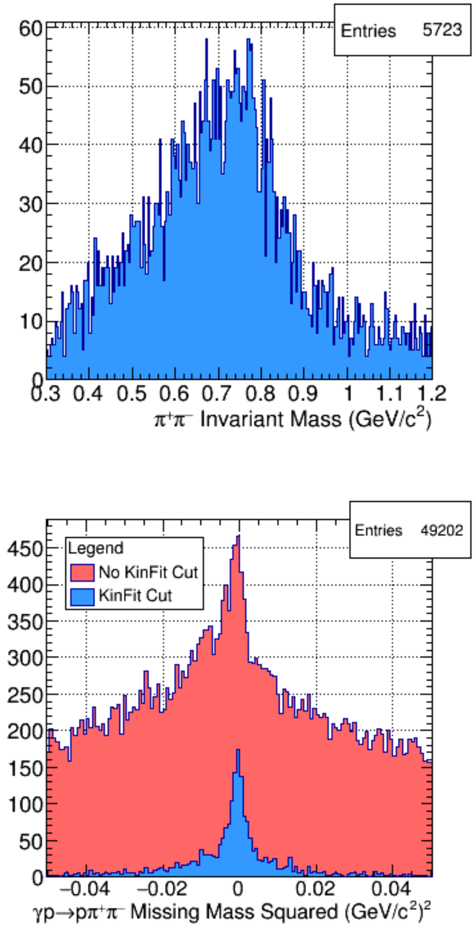


Reconstruction ver01



Reconstruction ver02

Ver02 problem:

- Track timing overhauled
- Lingering issues

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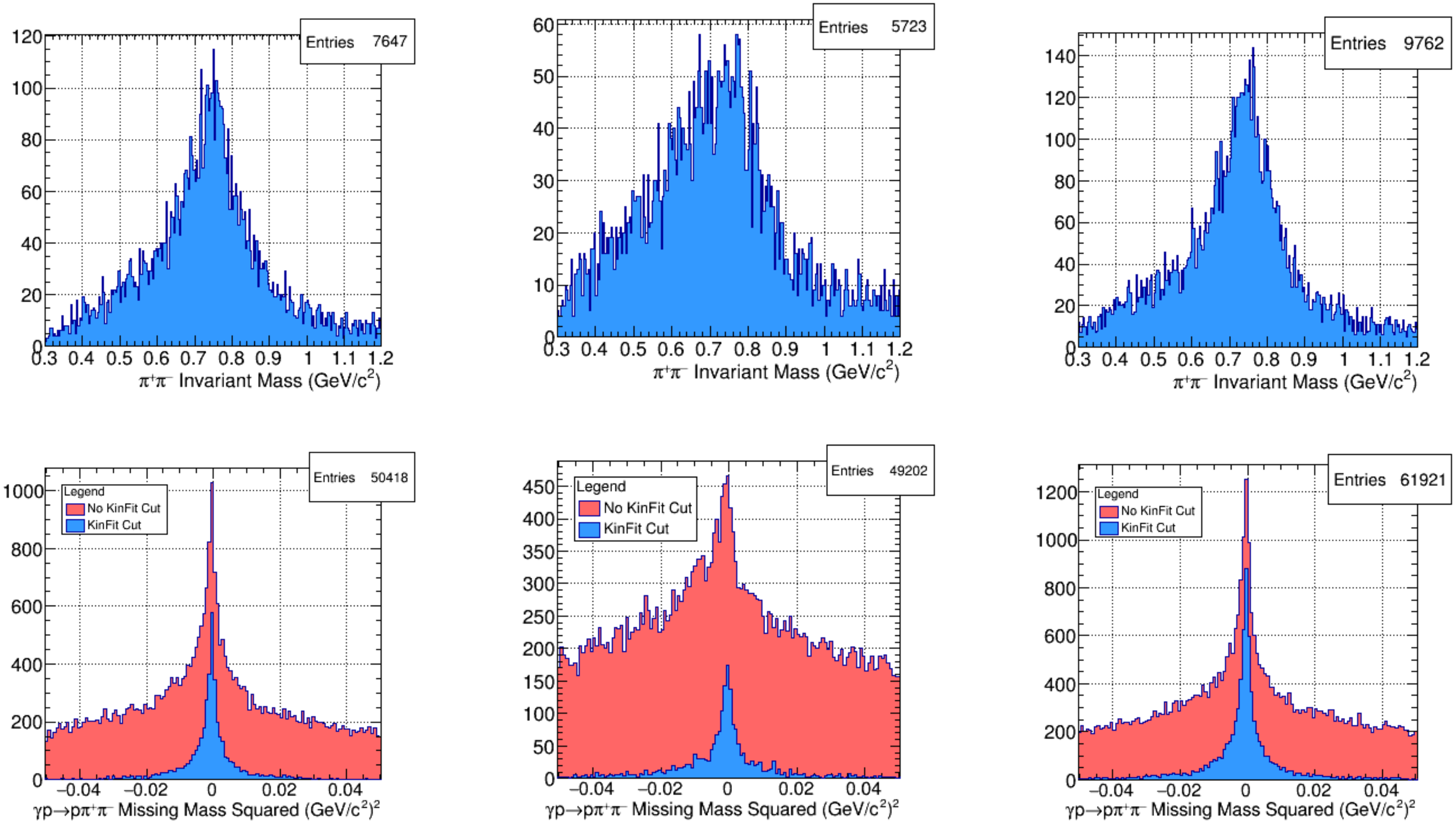
Remedy:

- New ρ, ω monitoring
- New reconstruction tests:
  - Cron every 3 days
  - 1–to–1 comparison

REST Production (SWIF)

- ⋆ Full reconstruction (tracks, showers, etc.)



Reconstruction ver01 Reconstruction ver02 Current

Reconstruction now better than ever!

GlueX Analysis Software

JANA Analysis Library (C++)

- Library overview (30+ active users):
  - Provide: Best-practices, efficient, validated, user-friendly code
  - GlueX program: > 100 channels to study: Must be easy, scalable
  - Built on JANA: Multi-threaded, factory-based, EVIO or REST

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  - Run perl script: Generates user plugin with example code
  - In plugin, user specifies their reaction, sets control settings
  - Optionally apply built-in/custom cuts, histogram

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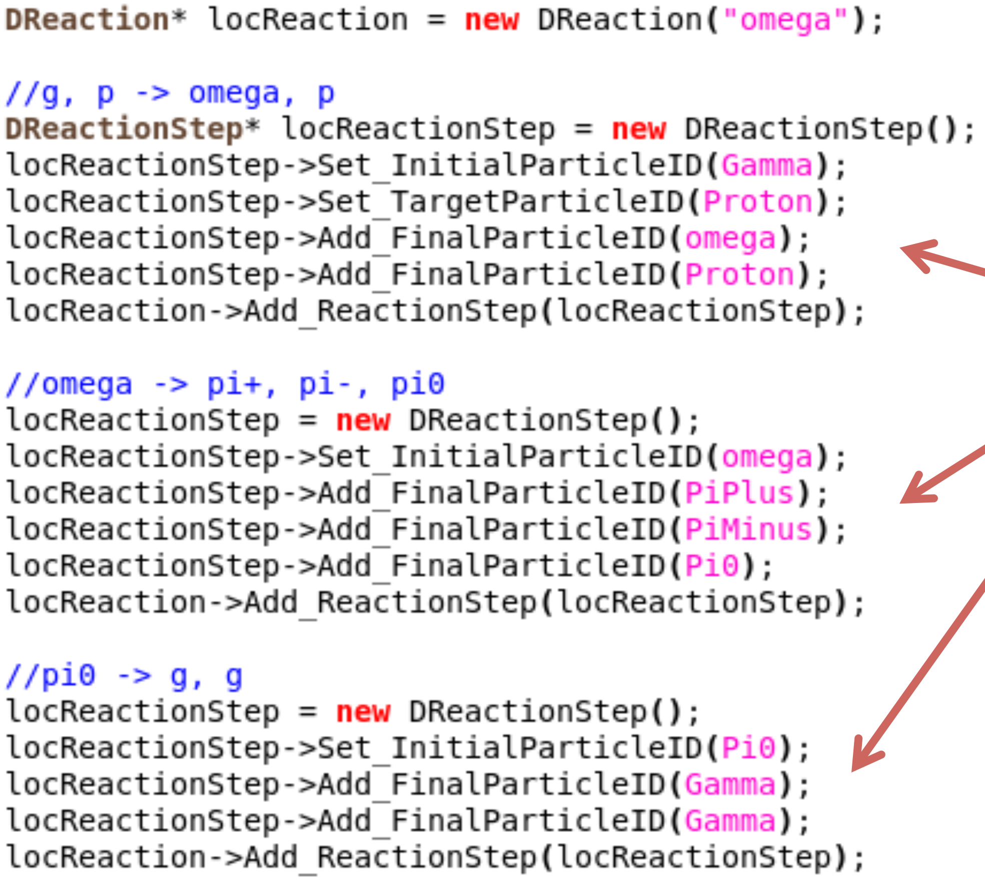
  - Optionally apply built-in/custom cuts, histogram
- Run with plugin: Automatically:
  - Find all combos of reconstructed particles match the reaction
  - Kinematic fit the reaction: Hypothesis test
  - Runs user-selected cuts, histograms
  - Save analysis data to ROOT trees for further analysis

$\gamma p \rightarrow \omega p$: Setup Reaction

- **DReaction**: Collection of **DReactionSteps**
  - Example code is auto-generated: Uncomment, modify



```
DReaction* locReaction = new DReaction("omega");

//g, p -> omega, p
DReactionStep* locReactionStep = new DReactionStep();
locReactionStep->Set_InitialParticleID(Gamma);
locReactionStep->Set_TargetParticleID(Proton);
locReactionStep->Add_FinalParticleID(omega);
locReactionStep->Add_FinalParticleID(Proton);
locReaction->Add_ReactionStep(locReactionStep);

//omega -> pi+, pi-, pi0
locReactionStep = new DReactionStep();
locReactionStep->Set_InitialParticleID(omega);
locReactionStep->Add_FinalParticleID(PiPlus);
locReactionStep->Add_FinalParticleID(PiMinus);
locReactionStep->Add_FinalParticleID(Pi0);
locReaction->Add_ReactionStep(locReactionStep);

//pi0 -> g, g
locReactionStep = new DReactionStep();
locReactionStep->Set_InitialParticleID(Pi0);
locReactionStep->Add_FinalParticleID(Gamma);
locReactionStep->Add_FinalParticleID(Gamma);
locReaction->Add_ReactionStep(locReactionStep);
```

DReactionSteps

$$\gamma p \rightarrow \omega p$$
$$\omega \rightarrow \pi^+ \pi^- \pi^0$$
$$\pi^0 \rightarrow \gamma \gamma$$

Particle Combinations

$$\boxed{\begin{aligned} &\gamma p \rightarrow \omega p \\ &\quad \omega \rightarrow \pi^+\pi^-\pi^0 \\ &\qquad \pi^0 \rightarrow \gamma\gamma \end{aligned}}$$

- Want to isolate a channel:
  - GlueX detects: Beam-γ, final-state: $p\pi^+\pi^-\gamma\gamma$
- Build combinations of detected particles that match our channel

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For example:
Need: **2 q^+, 1 q^-, 2 q^0**
Measure: **2 q+, 1 q^-, 4 q^0**
Beam: **3** in-time γ's

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Test each q^+ as p (**2x**), π^+ (**1x**)
Test each q^- as π^-: **1x**
Test each neutral as γ: **6x**
Beam: **3x**
Total: **36**

Particle Combinations

$\gamma p \rightarrow \omega p$

$\omega \rightarrow \pi^+ \pi^- \pi^0$

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Test each q^- as π^-: **1x**
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Total: **36**

- Cuts reduce #-combos: Particle ID, missing mass, kinematic fit, etc.

Histogram, Cut Actions

- Analysis actions: Particle ID, invariant mass histograms, etc.
  - Share common base class
- Are executed in order on particle combos
  - If a combo fails a cut, it will stop executing actions on it

Histogram, Cut Actions

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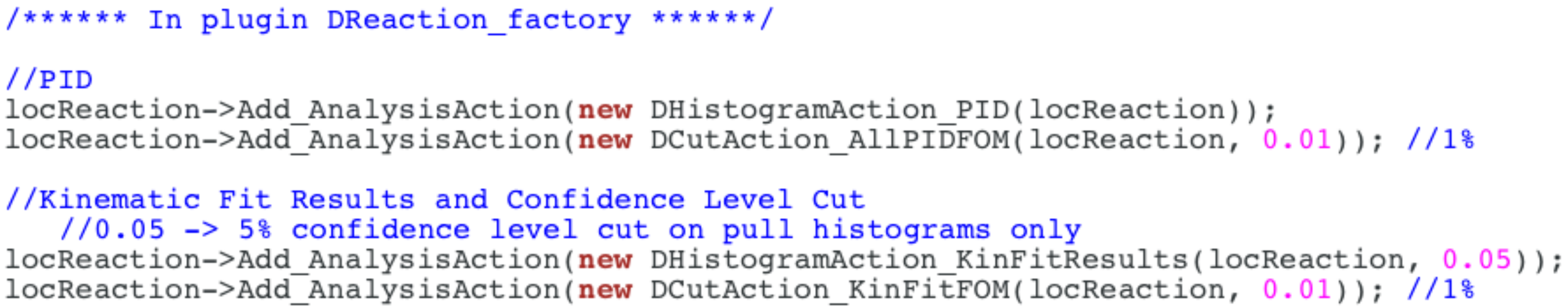
  - Share common base class
- Are executed in order on particle combos
  - If a combo fails a cut, it will stop executing actions on it
- Below: PID section performed before kinematic fit
  - Fit not performed until needed (when results are requested)
  - Can reject background before fitting



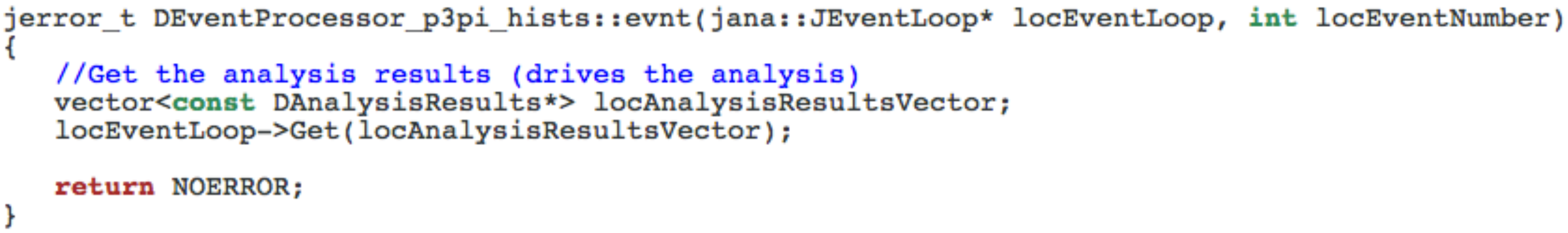
```
/****** In plugin DReaction_factory ******/

//PID
locReaction->Add_AnalysisAction(new DHistogramAction_PID(locReaction));
locReaction->Add_AnalysisAction(new DCutAction_AllPIDFOM(locReaction, 0.01)); //1%

//Kinematic Fit Results and Confidence Level Cut
   //0.05 -> 5% confidence level cut on pull histograms only
locReaction->Add_AnalysisAction(new DHistogramAction_KinFitResults(locReaction, 0.05));
locReaction->Add_AnalysisAction(new DCutAction_KinFitFOM(locReaction, 0.01)); //1%
```

Run the Analyses

- Tell JANA to run the analyses:



```
jerror_t DEventProcessor_p3pi_hists::evnt(jana::JEventLoop* locEventLoop, int locEventNumber)
{
	//Get the analysis results (drives the analysis)
	vector<const DAnalysisResults*> locAnalysisResultsVector;
	locEventLoop->Get(locAnalysisResultsVector);

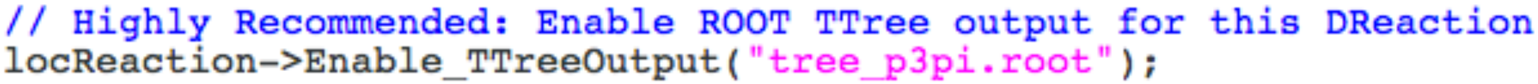
	return NOERROR;
}
```

- Code is pre-generated for you: Just uncomment

OR: Run, Save to ROOT

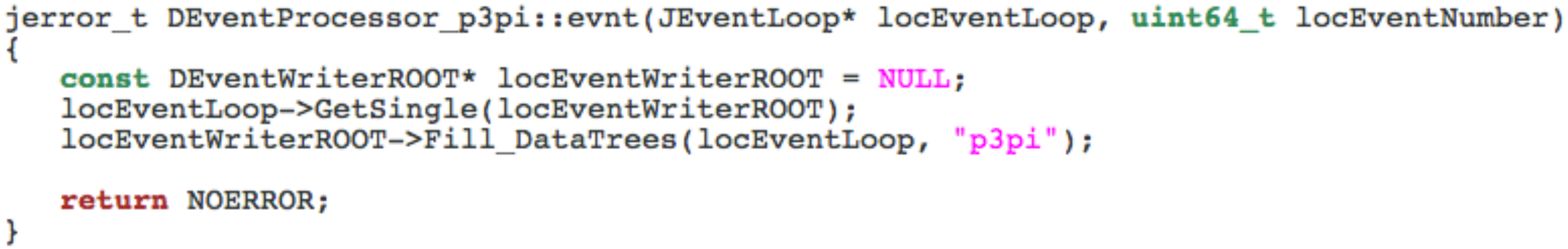
- Or: Tell JANA to run the analyses, AND save to ROOT TTree:

DReaction:



```
// Highly Recommended: Enable ROOT TTree output for this DReaction
locReaction->Enable_TTreeOutput("tree_p3pi.root");
```

DEventProcessor:



```
jerror_t DEventProcessor_p3pi::evnt(JEventLoop* locEventLoop, uint64_t locEventNumber)
{
    const DEventWriterROOT* locEventWriterROOT = NULL;
    locEventLoop->GetSingle(locEventWriterROOT);
    locEventWriterROOT->Fill_DataTrees(locEventLoop, "p3pi");

    return NOERROR;
}
```

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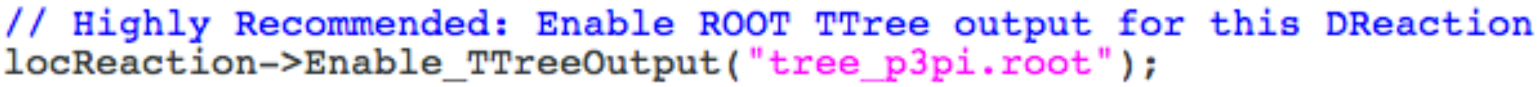

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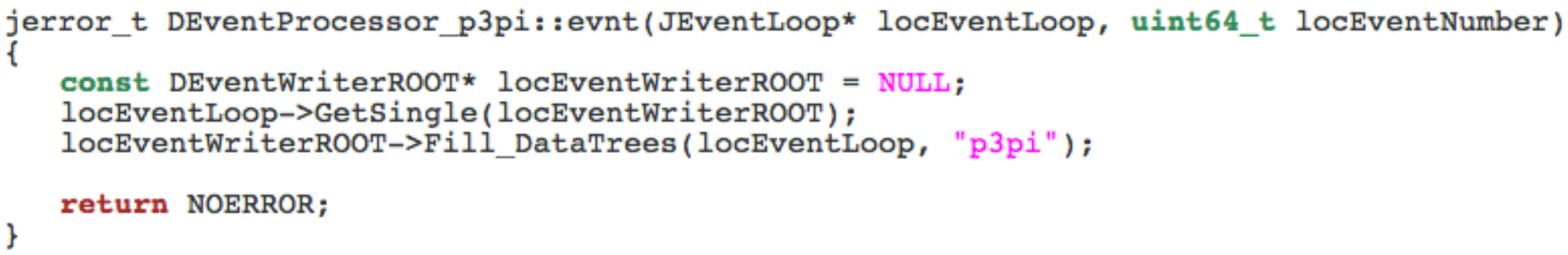

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    return NOERROR;
}
```

- TTree contents (PART format):
  - Event info (Run #, event #, etc.) & metadata (your channel)
  - Particles (beam, charged, neutral, MC thrown)
  - Surviving combos for your channel

Code is auto-generated: Just uncomment

DSelector

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  - Can generate code (TSelector) to read TTree, analyze data
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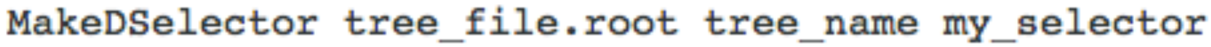
- DSelector (GlueX):
  - Inherits from TSelector: Can use in same way
  - Provides C++ interface classes to TTree data (for particles, combos)
- DSelector has knowledge of your analysis:
  - Generates starting, example code for analyzing your channel
  - Analysis actions: Similar to JANA
    - Cut PID, histogram masses, cut kinematic fit, etc.

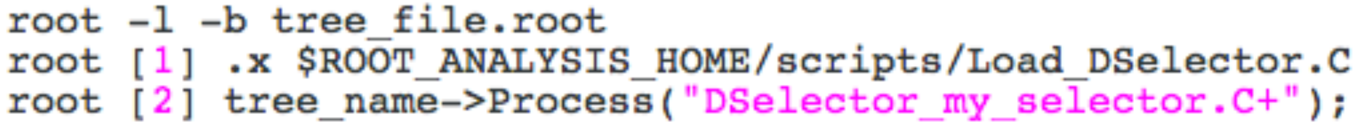
DSelector Usage

- Make a custom DSelector with:



```
MakeDSelector tree_file.root tree_name my_selector
```

- Run with:



```
root -l -b tree_file.root
root [1] .x $ROOT_ANALYSIS_HOME/scripts/Load_DSelector.C
root [2] tree_name->Process("DSelector_my_selector.C+");
```

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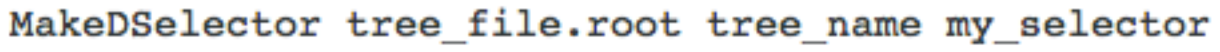

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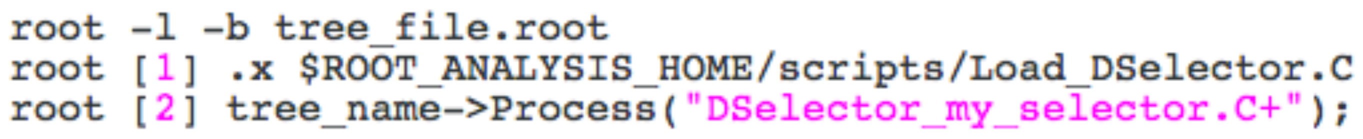

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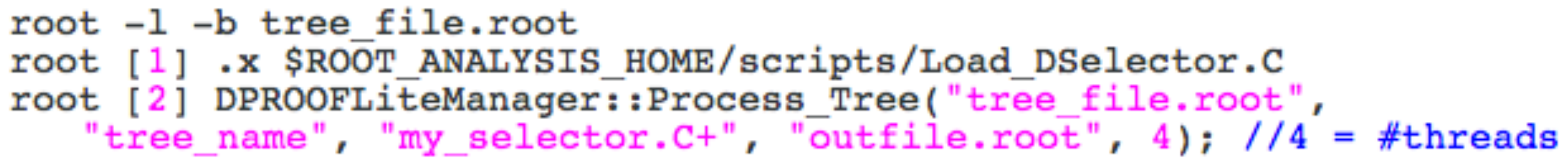
- PROOF-Lite: Run multi-threaded over TChain on a node
  - No change to DSelector code needed
  - Already setup for users
  - Run with:



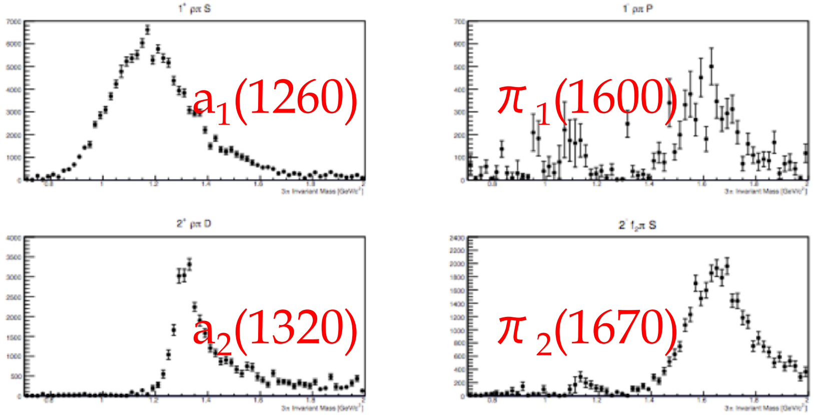
```
root -l -b tree_file.root
root [1] .x $ROOT_ANALYSIS_HOME/scripts/Load_DSelector.C
root [2] DPROOFLiteManager::Process_Tree("tree_file.root",
    "tree_name", "my_selector.C+", "outfile.root", 4); //4 = #threads
```

Coordinating Collaboration Efforts

Analysis Coordinators:
Paul Mattione (JSA), Justin Stevens (W&M)

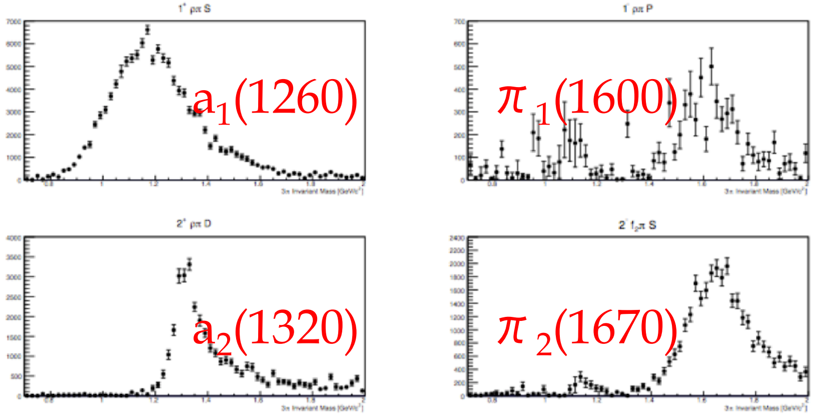
Physics & Analysis Workshops

- 2013: 35 registered participants, ~25 on-site
  - Talks & exercises: Extracting $\pi_1(1600)$ hybrid in $\gamma p \rightarrow \pi^+\pi^+\pi^-(n)$
- 2016: 57 registered participants, ~45 on-site
  - Talks & exercises: Measuring $\gamma p \rightarrow \omega p$ polarization observables

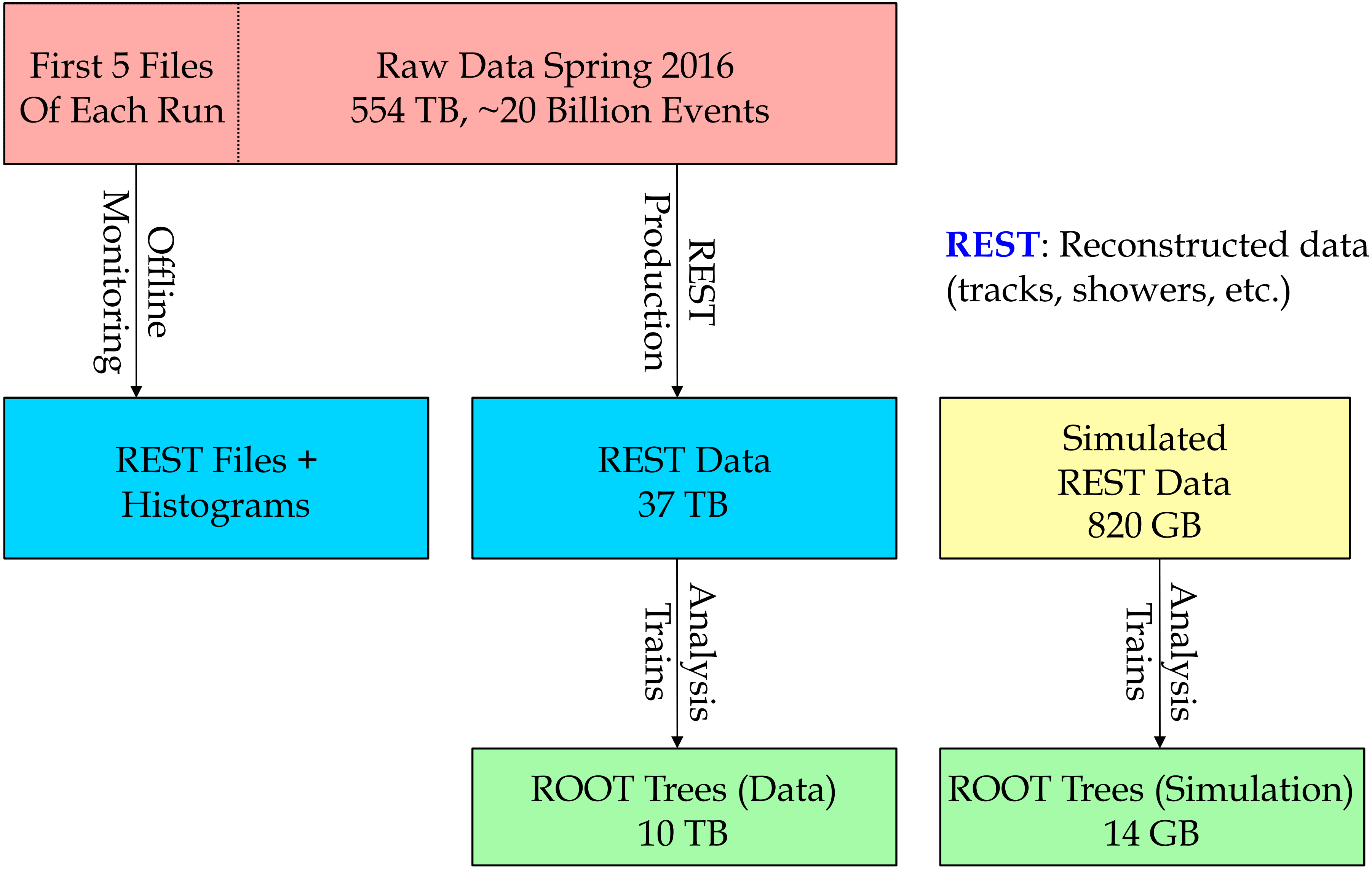


Physics & Analysis Workshops

- 2013: 35 registered participants, ~25 on-site
  - Talks & exercises: Extracting $\pi_1(1600)$ hybrid in $\gamma p \rightarrow \pi^+\pi^+\pi^-(n)$
- 2016: 57 registered participants, ~45 on-site
  - Talks & exercises: Measuring $\gamma p \rightarrow \omega p$ polarization observables
- Some software topics covered:
  - Simulation, analysis library, ROOT analysis, batch farm, etc.
- All sessions recorded (audio + screen): New user startup



Production Overview (SWIF)



First 5 Files
Of Each Run

Raw Data Spring 2016
554 TB, ~20 Billion Events

Offline Monitoring

REST Production

REST: Reconstructed data (tracks, showers, etc.)

REST Files +
Histograms

REST Data
37 TB

Simulated
REST Data
820 GB

Analysis Trains

Analysis Trains

ROOT Trees (Data)
10 TB

ROOT Trees (Simulation)
14 GB

Analysis Trains (SWIF)

- Analysis train: Run user JANA analysis plugins on REST data
  - Produce ROOT trees for further analysis
- Run every ~month on reconstructed data
- Large collaboration participation: ~15 Users, ~50 Plugins

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  - Single meson: π^0, π^+, η, ρ, ω, η', ϕ
  - Multi-meson: 2π, 3π, 4π, 2η, $\eta\eta'$, $\pi\omega$, $\phi\eta$, KK, KK$\pi\pi$
  - Strangeness studies: K*'s, Λ, Σ's, Σ*'s, Λ*'s, Ξ^-
  - Charm physics: J/ψ, $D^0\Lambda_c$
  - Other: Antiproton, B-boson, multi-γ

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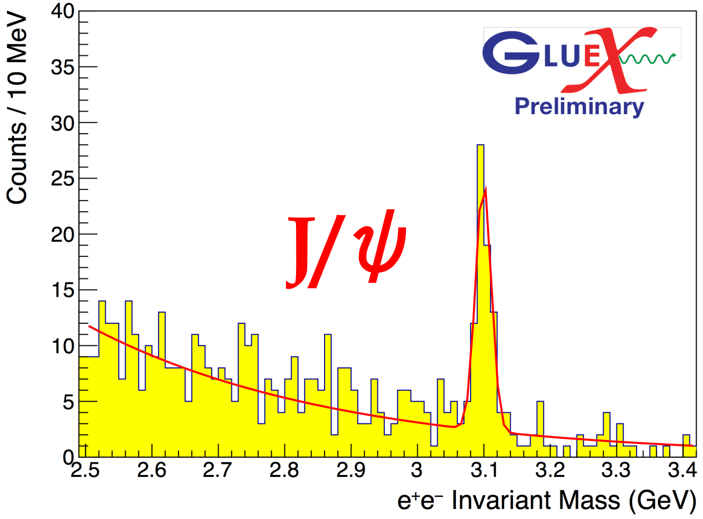
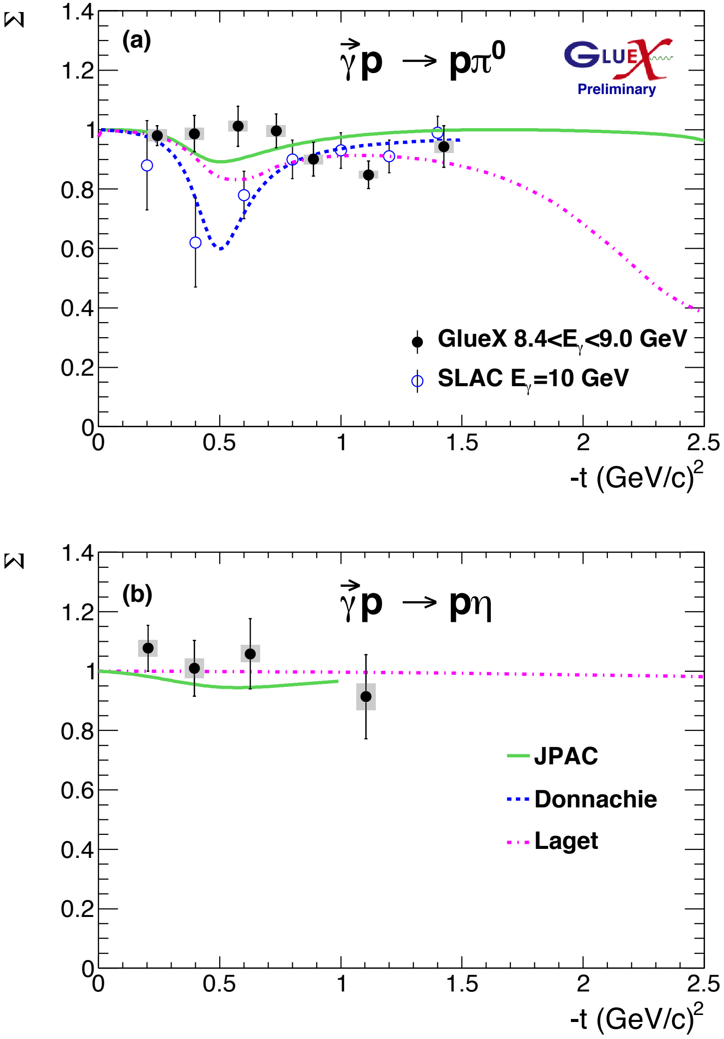
  - Other: Antiproton, B-boson, multi-γ
- ROOT trees saved to cache/tape: Available for everyone's use

Early GlueX Physics: DNP

- DNP Physics:
  - Asymmetries: π^0, η, ρ, ω, η'
  - Peaks: $a_0(980)$, $b_1(1235)$, J/ψ,…
  - 4 months after end of run
- Analysis software: Success!
  - Many users, channels studied





Blue: Preparing for publication

Documentation

- Extensive documentation:
  - Monitoring: https://halldweb.jlab.org/wiki/index.php/Data_Monitoring_Procedures
  - Analysis: https://halldweb.jlab.org/wiki/index.php/GlueX_Analysis_Software
  - How-To's: https://halldweb.jlab.org/wiki/index.php/Offline_HOWTO_List
  - Etc. etc.
- Tracking collaboration analysis activities:
  - https://halldweb.jlab.org/wiki-private/index.php/GlueX_Physics_Analyses
- Workshops:
  - 2016: https://halldweb.jlab.org/wiki/index.php/GlueX_Physics_Workshop_2016
  - 2013: https://halldweb.jlab.org/wiki/index.php/GlueX_Analysis_Workshop_2013
- YouTube channel (2016 Workshop): "Jefferson Lab Hall-D"
  - https://www.youtube.com/channel/UCjI87hRy7U60CdkGpMSk2Fw

Summary

Summary

- Offline data processing
  - Many calibrations automated (SWIF, still improving)
  - Monitoring, reconstruction, & analysis: SWIF
  - Software tests: Simulation, experiment, nightly build, etc.

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  - Built-in actions for common tasks: No re-inventing the wheel
  - Mature: Library since 2012, 30+ active users

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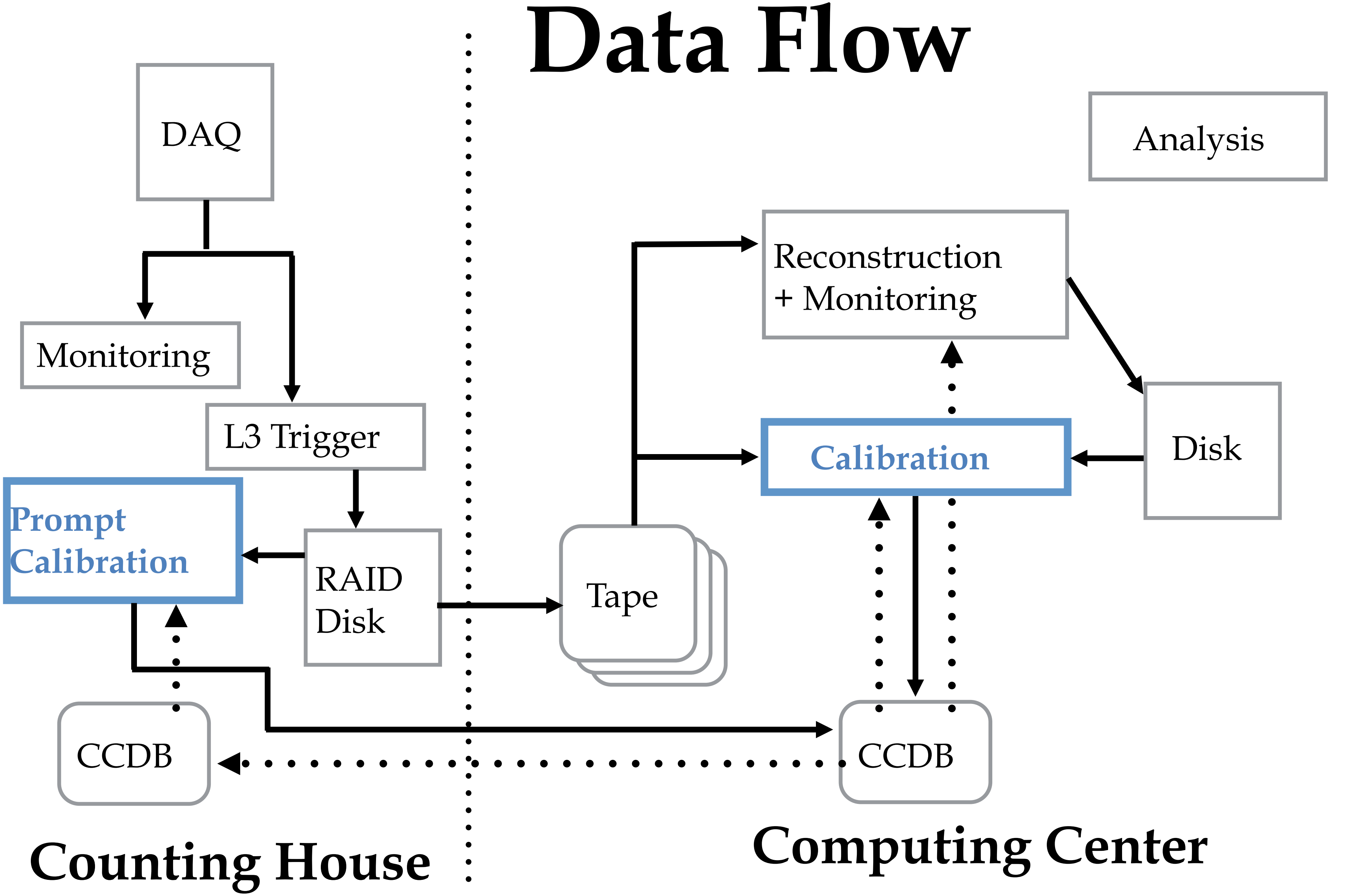
  - Mature: Library since 2012, 30+ active users
- Collaboration
  - 2013, 2016 Workshops: Software, physics, & analysis
  - Many early results shown at DNP
  - First publication under collaboration review

Reference Slides

Data Flow

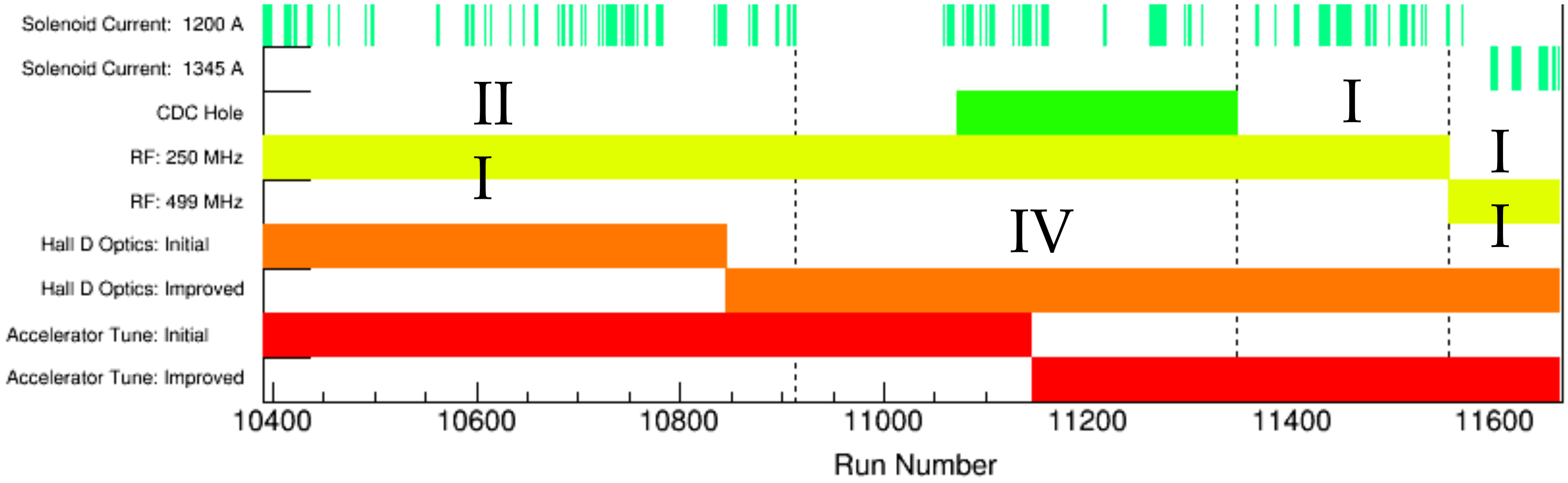


Counting House

Computing Center

REST Production (ver01)

- Planned for May 31th, started June 8th
- Included number of plugins for performance studies (detector efficiency, track reconstruction)
- Split the Data into 4 priority periods

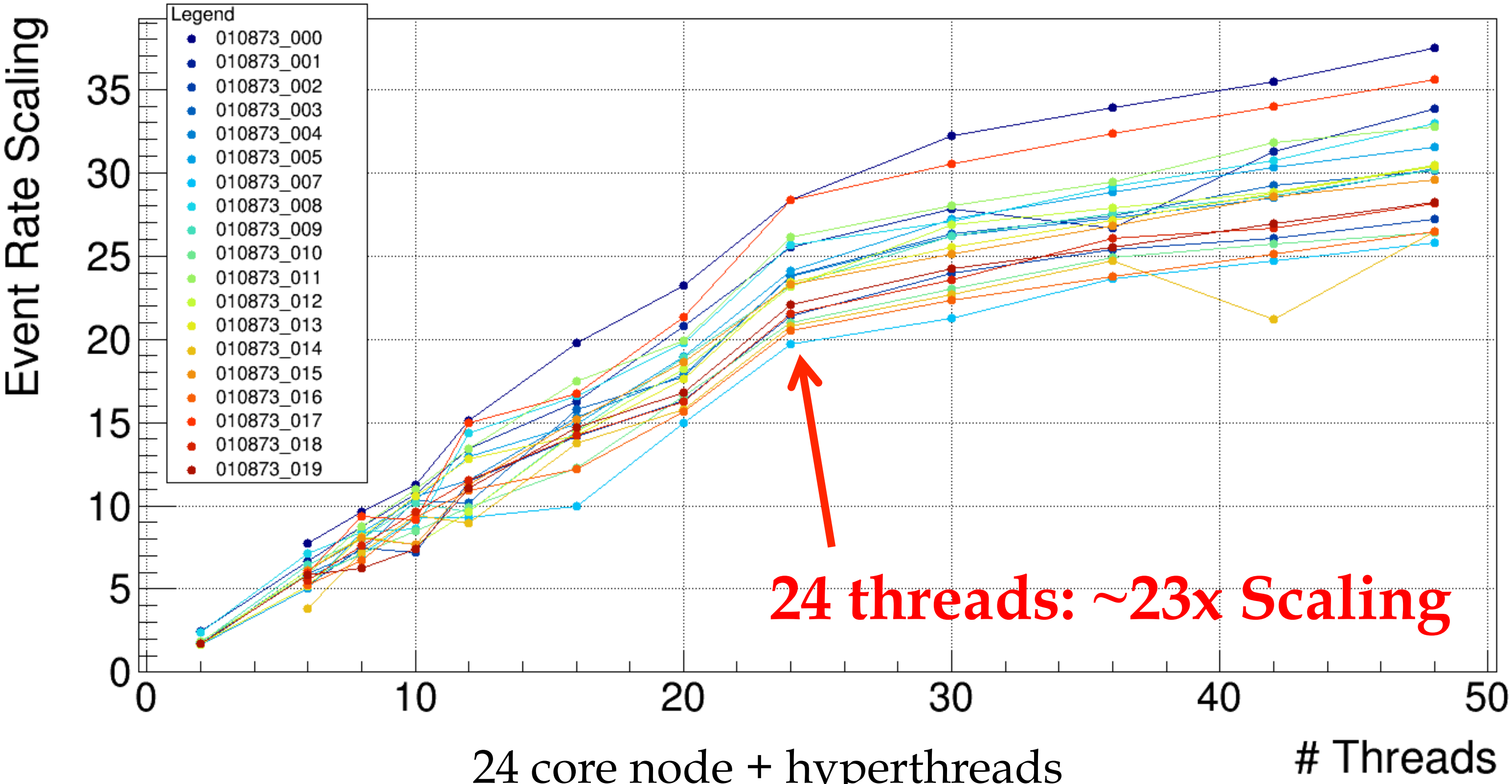


Slide courtesy
Alex Austregesilo

- Intermittent with periods waiting for detector calibration
- Successfully completed July 10th, 21d net processing time
- Failure rate after resubmissions: ~0.1%

Multi-threaded Scaling: April

- Compartmentalized histogram locks
- At 24 threads, **~23x** scaling: 450% improvement, within 5% of max

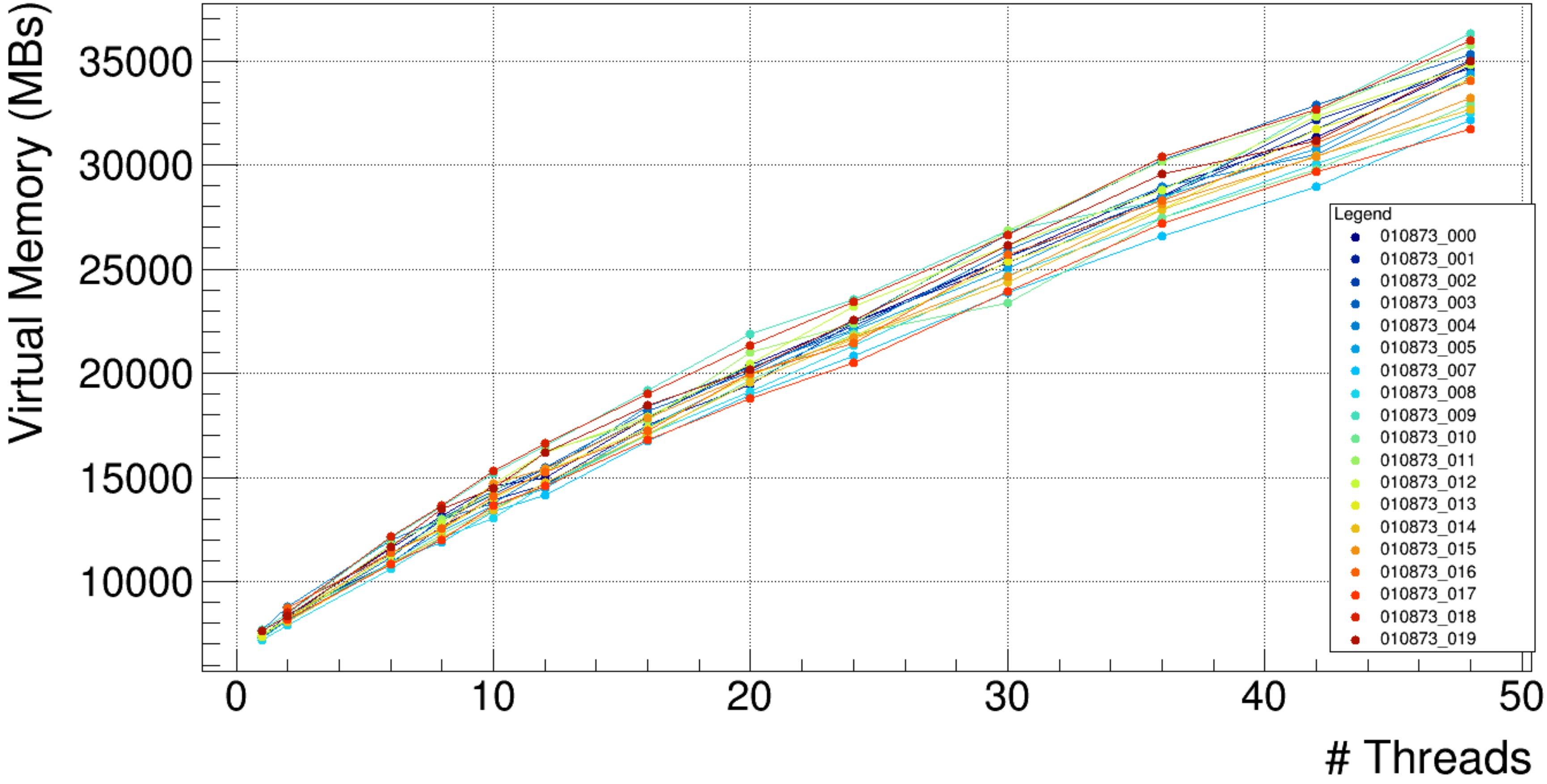


24 threads: ~23x Scaling

24 core node + hyperthreads

Virtual Memory

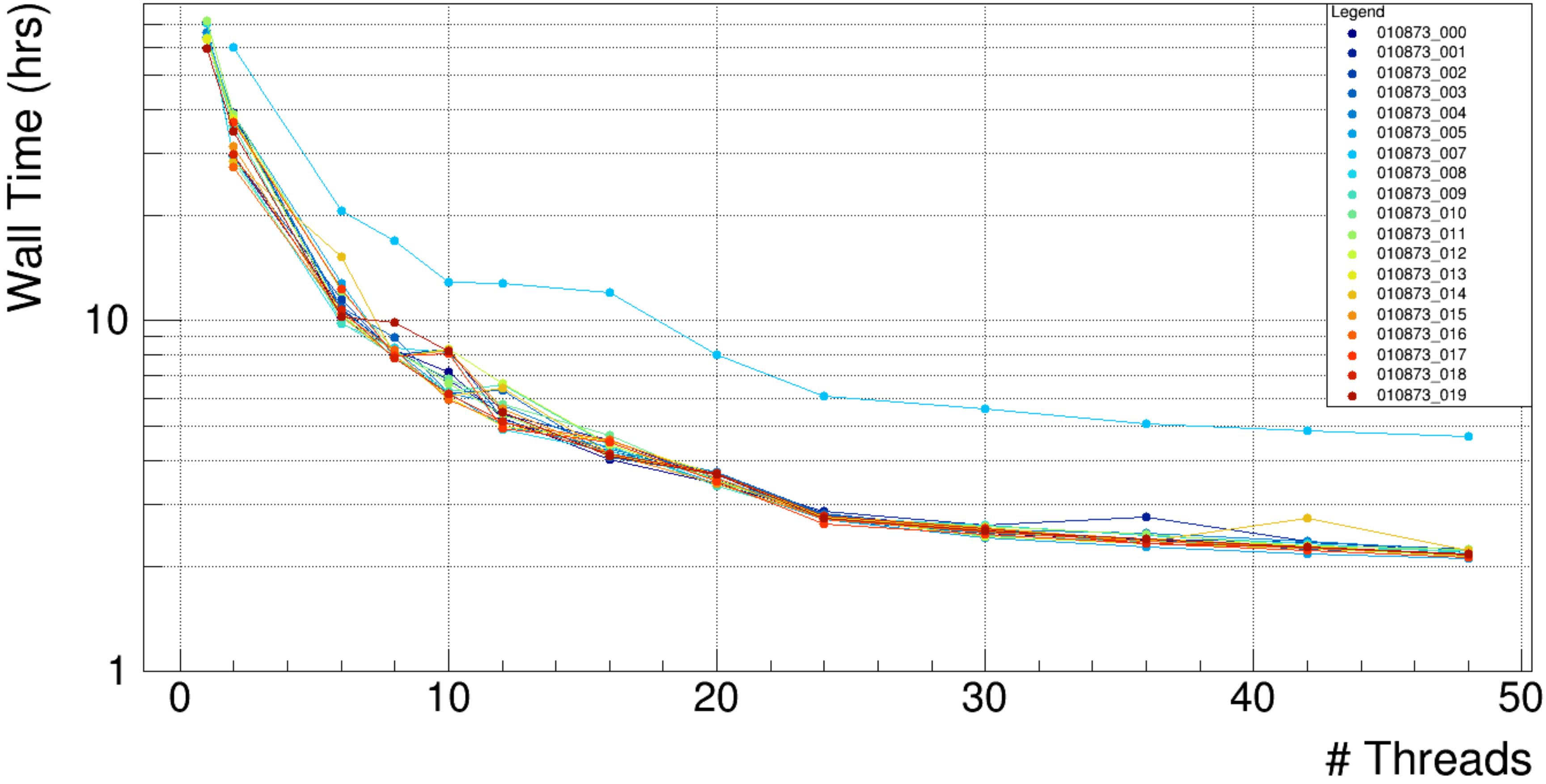
- Virtual memory: Max allowed is node-RAM / 0.7



Scaling: ~612 MB / thread

Wall Time

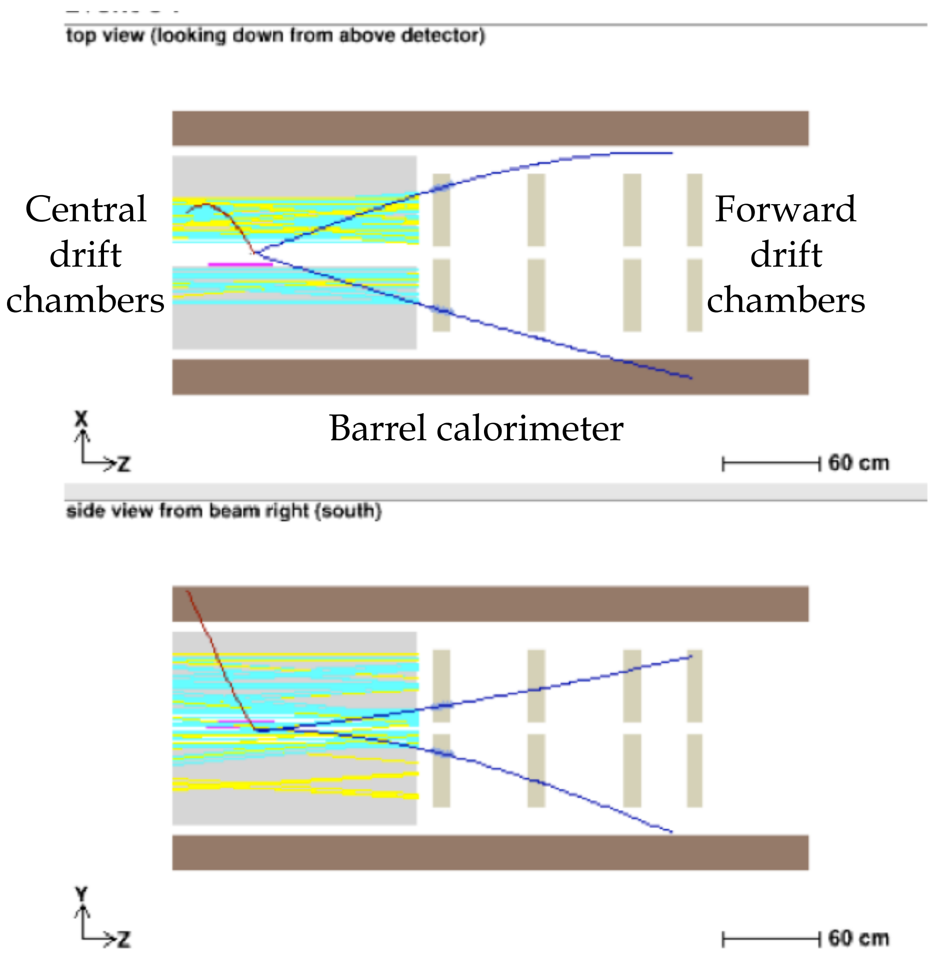
- At 24 threads, takes < 3 hrs



At 1 thread, many jobs timeout!!

Example Reconstructed Event

- Tracks, calorimeter showers reconstructed, correlated

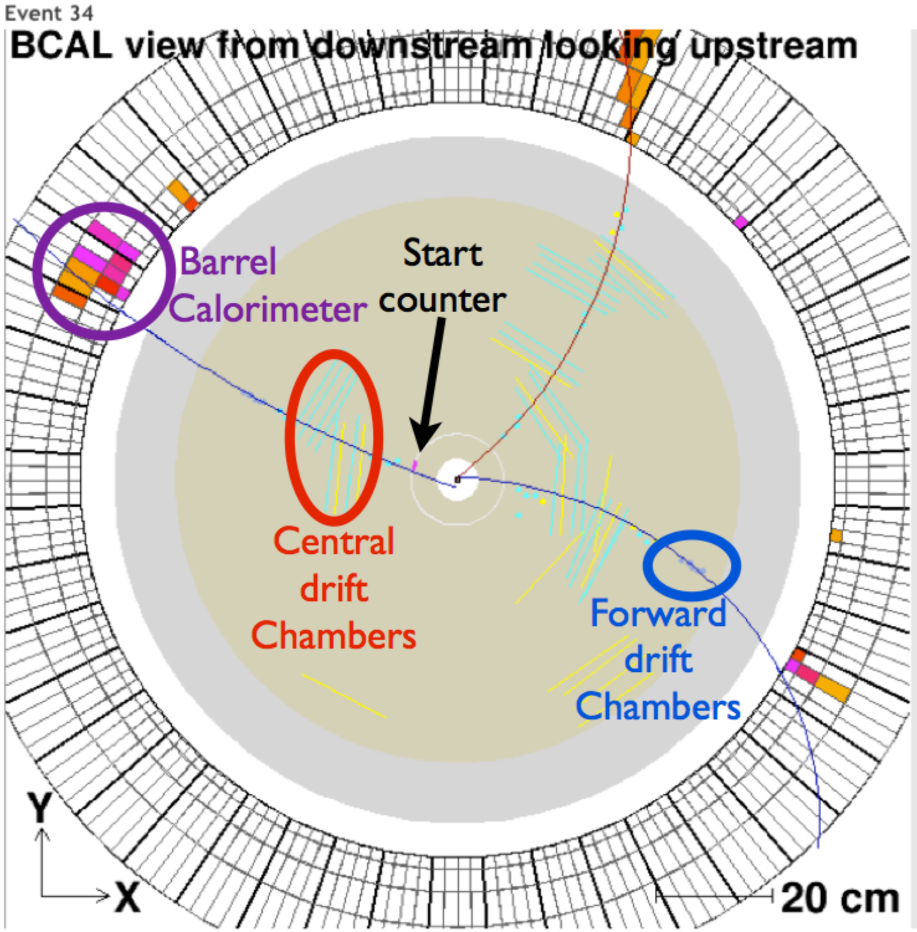


Central drift chambers

Forward drift chambers

Barrel calorimeter

top view (looking down from above detector)
X
Z
60 cm
side view from beam right (south)
Y
Z
60 cm



Barrel Calorimeter

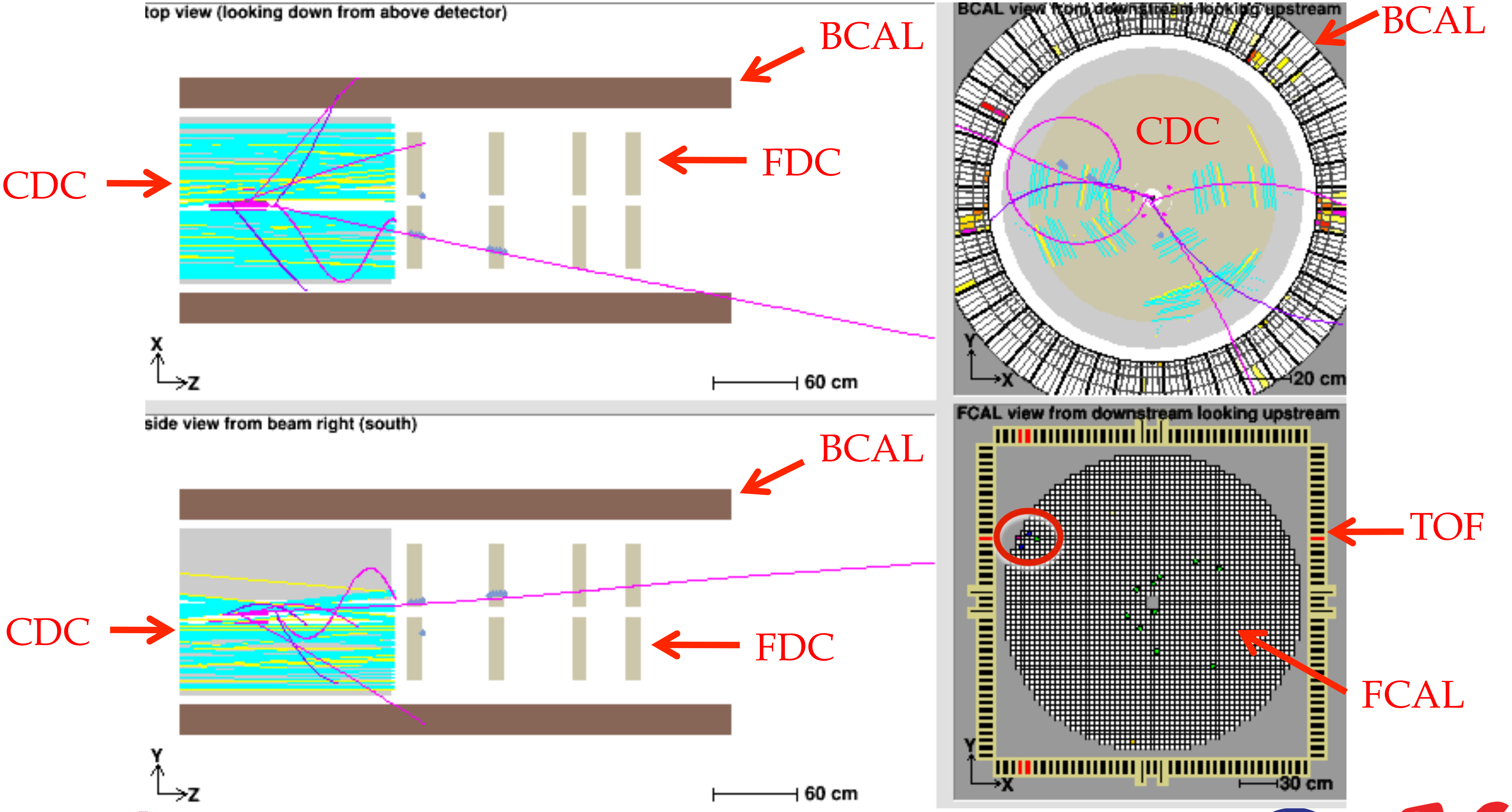
Start counter

Central drift Chambers

Forward drift Chambers

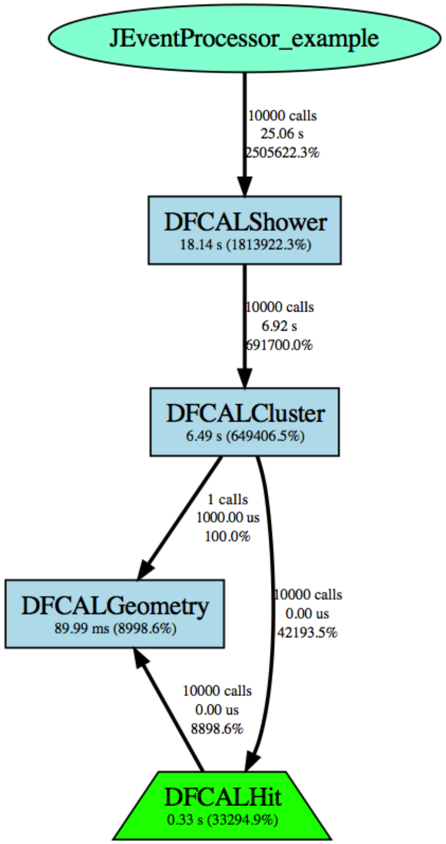
Reconstructed Events

- Detector correlation: Tracks, calorimeter showers reconstructed
  - From online reconstruction, first few days of beam

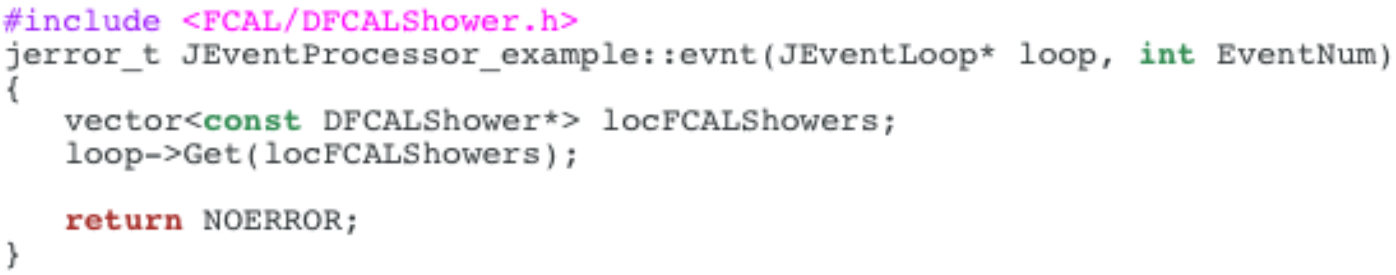

top view (looking down from above detector)
BCAL
FDC
CDC
X
Z
60 cm
BCAL view from downstream looking upstream
BCAL
CDC
Y
X
20 cm
side view from beam right (south)
BCAL
CDC
FDC
Y
Z
60 cm
FCAL view from downstream looking upstream
TOF
FCAL
Y
X
30 cm

JANA

- JANA: Multithreaded, factory-based, plugin-driven
  - Factory: Dedicated code for creating objects of that type
- User writes plugin to drive reconstruction/analysis
  - Perl script generates template code



E.g. Plugin for FCAL reconstruction (called every event)
- Factory calls on right (**DFCALHit** from file)

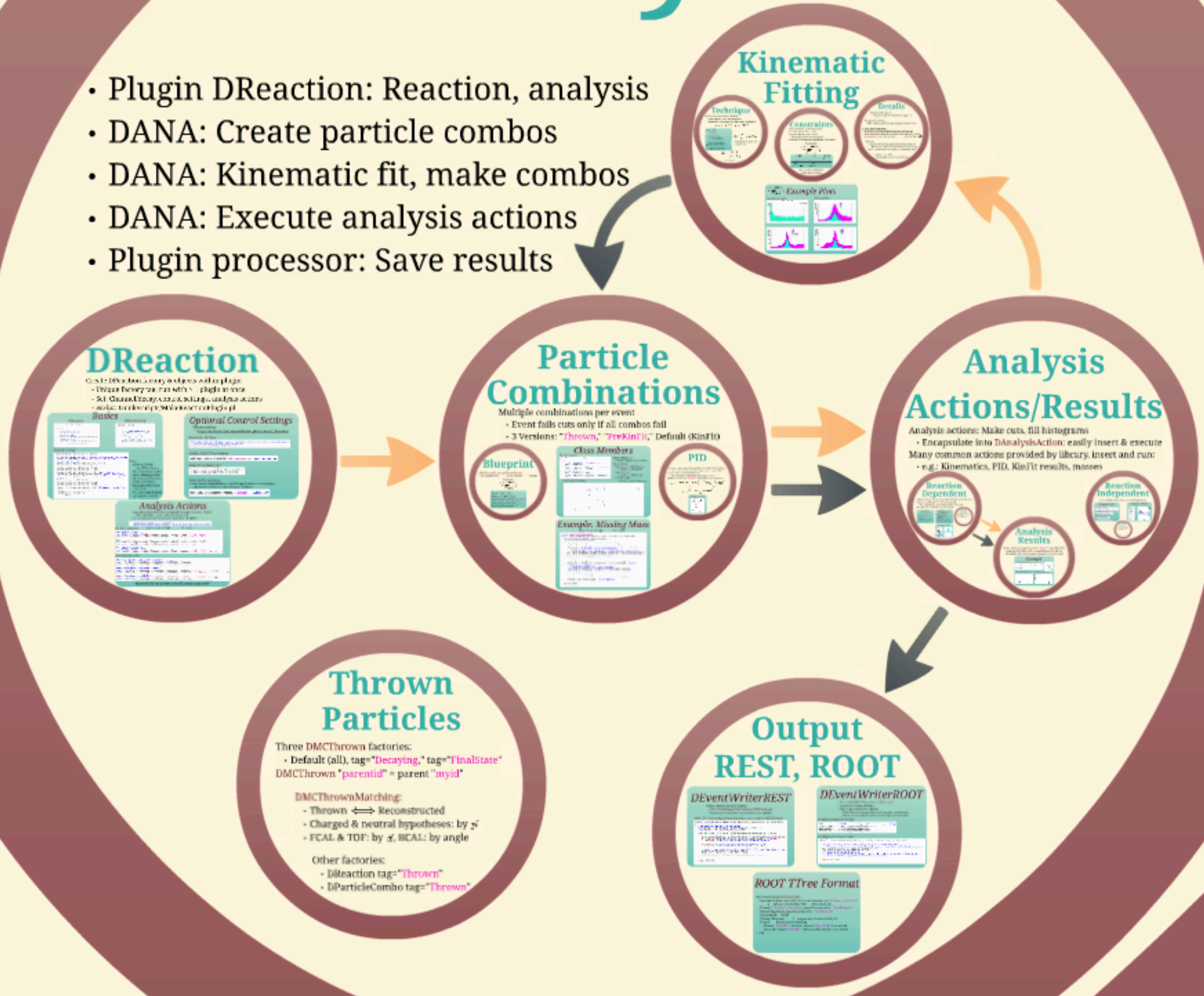


```
#include <FCAL/DFCALShower.h>
jerror_t JEventProcessor_example::evnt(JEventLoop* loop, int EventNum)
{
   vector<const DFCALShower*> locFCALShowers;
   loop->Get(locFCALShowers);

   return NOERROR;
}
```

Analysis

- Plugin DReaction: Reaction, analysis
- DANA: Create particle combos
- DANA: Kinematic fit, make combos
- DANA: Execute analysis actions
- Plugin processor: Save results



Kinematic Fitting

DReaction

Create DReaction factory & objects within plugin
- Unique factory tag: run with > 1 plugin at once
- Set: Channel/decay, control settings, analysis actions
- Script: [illegible] MakeReactionPlugin.pl

Particle Combinations

Multiple combinations per event
- Event fails cuts only if all combos fail
- 3 Versions: "Thrown," "PreKinFit," Default (KinFit)

Analysis Actions/Results

Analysis actions: Make cuts, fill histograms
- Encapsulate into DAnalysisAction: easily insert & execute

Many common actions provided by library, insert and run:
- e.g.: Kinematics, PID, KinFit results, masses

Thrown Particles

Three DMCThrown factories:
- Default (all), tag="Decaying," tag="FinalState"

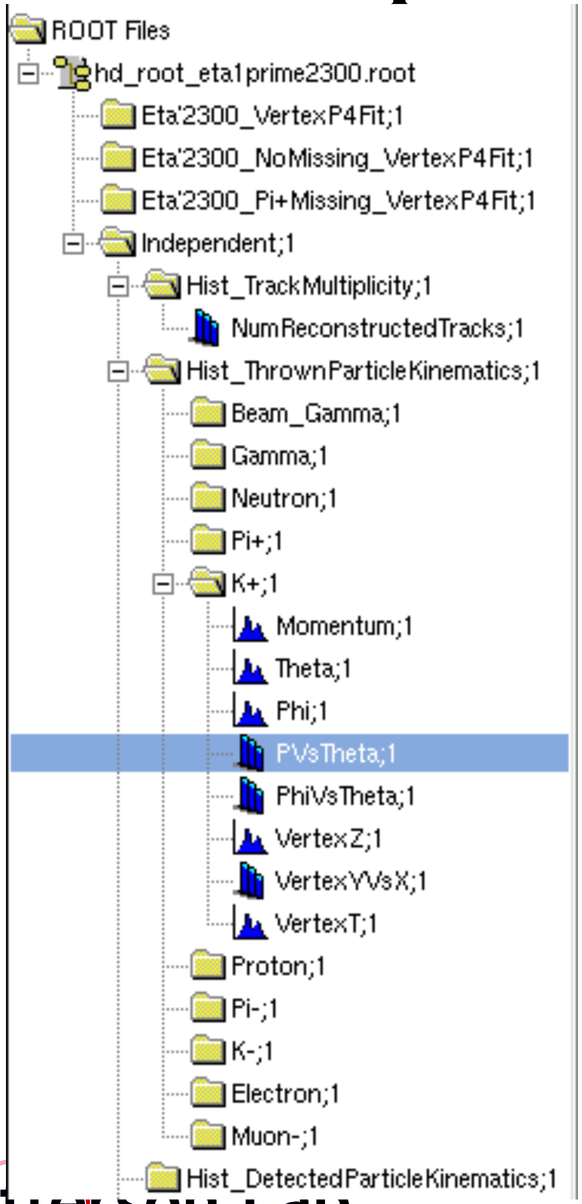
DMCThrown "parentid" = parent "myid"

DMCThrownMatching:
- Thrown ⟺ Reconstructed
- Charged & neutral hypotheses: by χ^2
- FCAL & TOF: by χ^2, BCAL: by angle

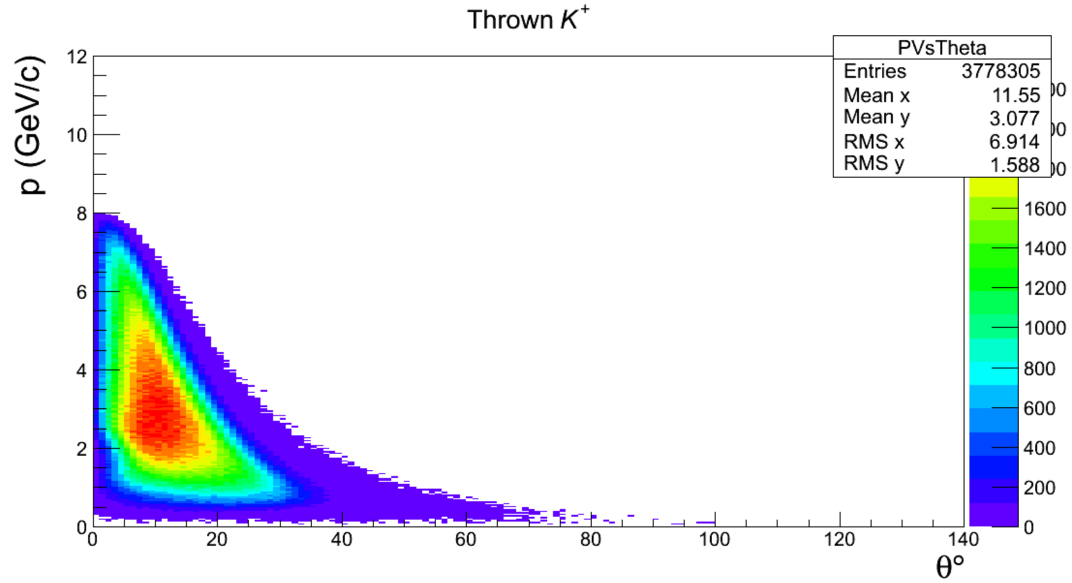
Other factories:
- DReaction tag="Thrown"
- DParticleCombo tag="Thrown"

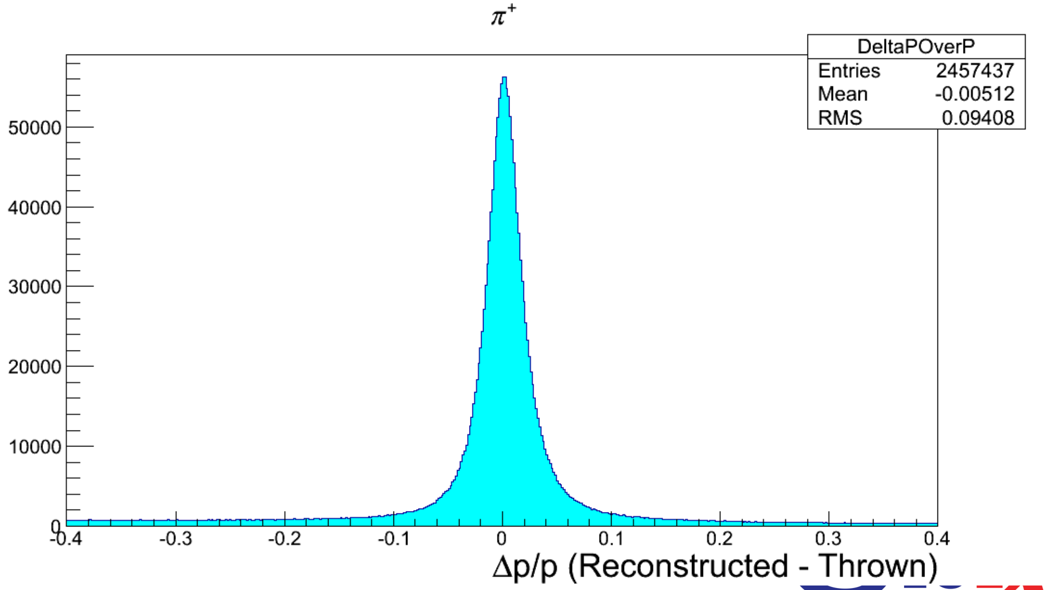
Output REST, ROOT

Example Histogram Actions



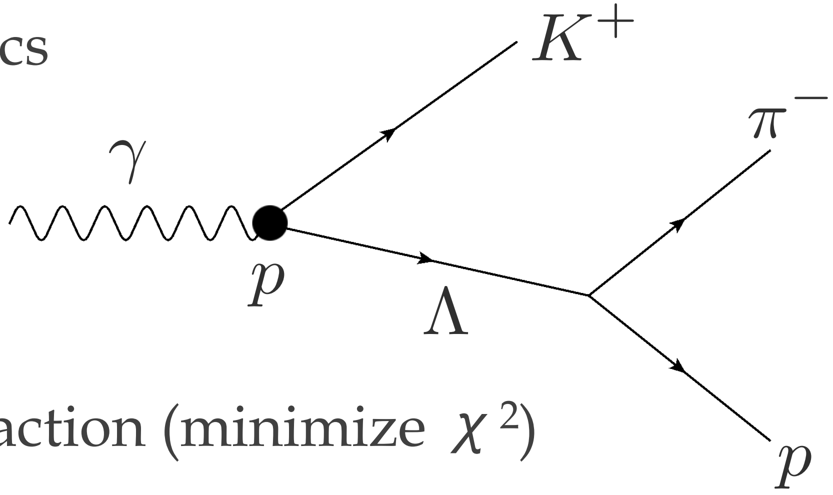
- ROOT Files
  - hd_root_eta1prime2300.root
    - Eta'2300_VertexP4Fit;1
    - Eta'2300_NoMissing_VertexP4Fit;1
    - Eta'2300_Pi+Missing_VertexP4Fit;1
    - Independent;1
      - Hist_TrackMultiplicity;1
        - NumReconstructedTracks;1
      - Hist_ThrownParticleKinematics;1
        - Beam_Gamma;1
        - Gamma;1
        - Neutron;1
        - Pi+;1
        - K+;1
          - Momentum;1
          - Theta;1
          - Phi;1
          - PVsTheta;1
          - PhiVsTheta;1
          - VertexZ;1
          - VertexYVsX;1
          - VertexT;1
        - Proton;1
        - Pi-;1
        - K-;1
        - Electron;1
        - Muon-;1
      - Hist_DetectedParticleKinematics;1

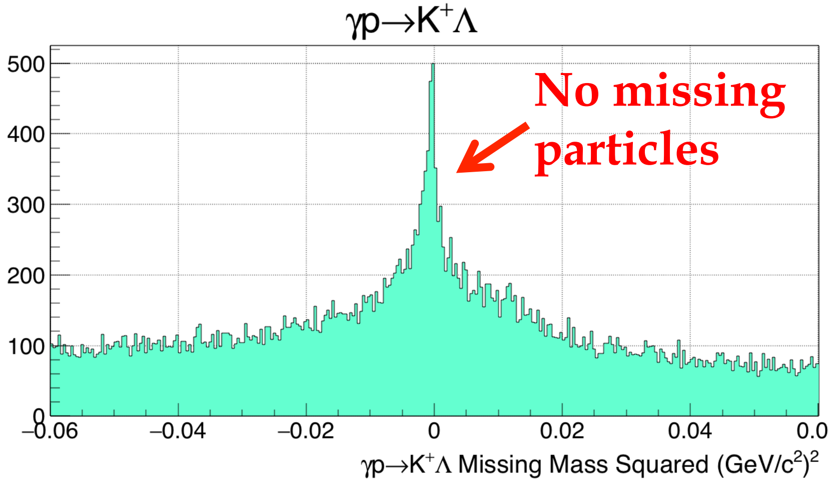


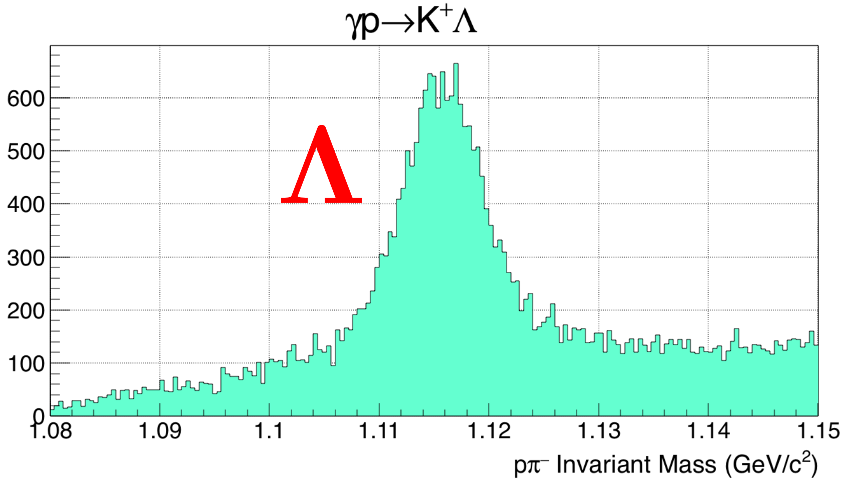


Kinematic Fitting (C++)

- Want to do strange-quark (Λ) physics
  - Backgrounds, e.g. $\gamma p \rightarrow p \pi^+ \pi^-$
- Hypothesis test: Fit the data
  - Was this event the reaction I want?
- Constrain the data to match your reaction (minimize χ^2)
- Powerful: Apply many constraints simultaneously

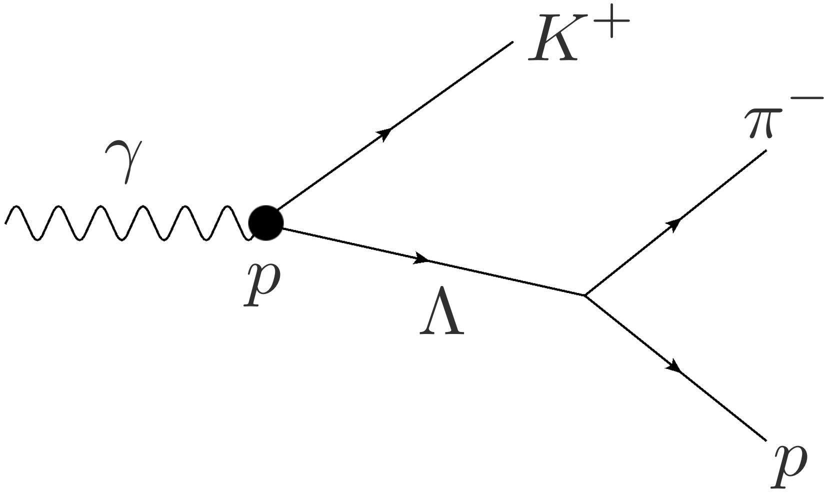


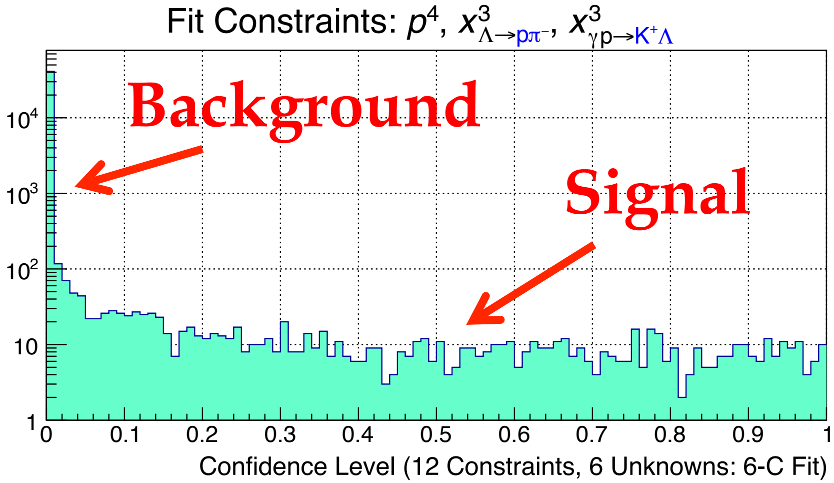




Λ Reconstruction

- Constraints:
  - E & p conservation
  - Production vertex, decay vertex
  - Over-constrained: 6 DF
- Confidence level: Cut near zero
- Clean Λ peak (mass not constrained)





Very low background: Clean Λ selection!!

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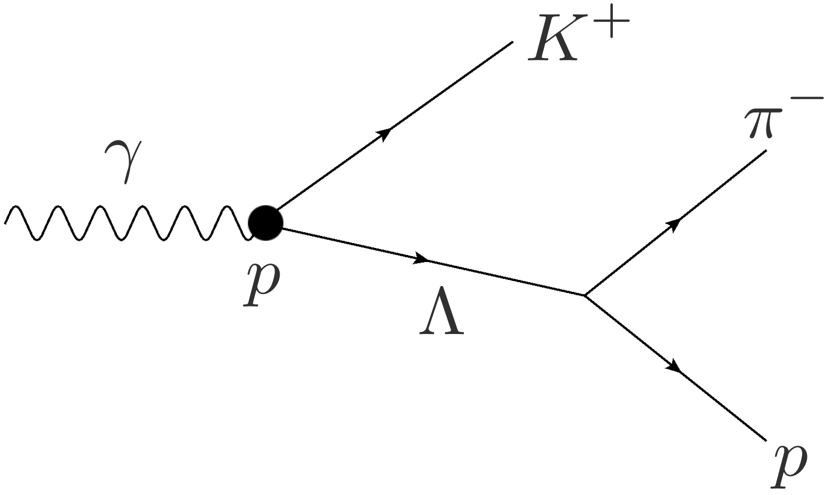
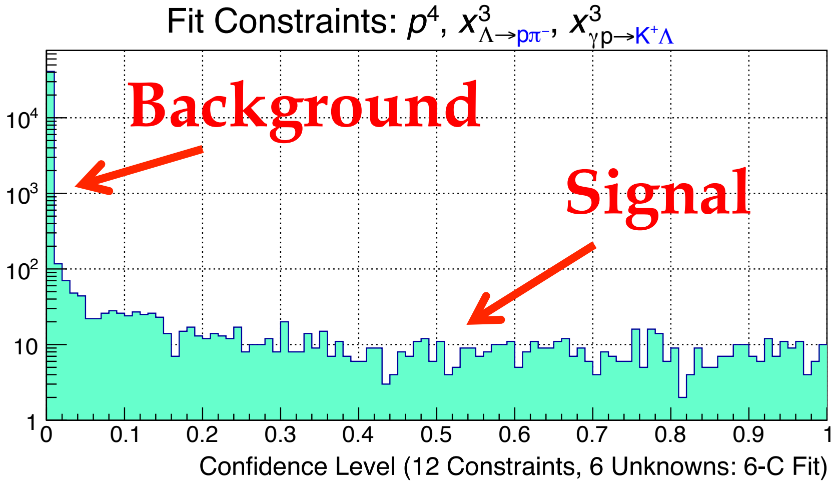
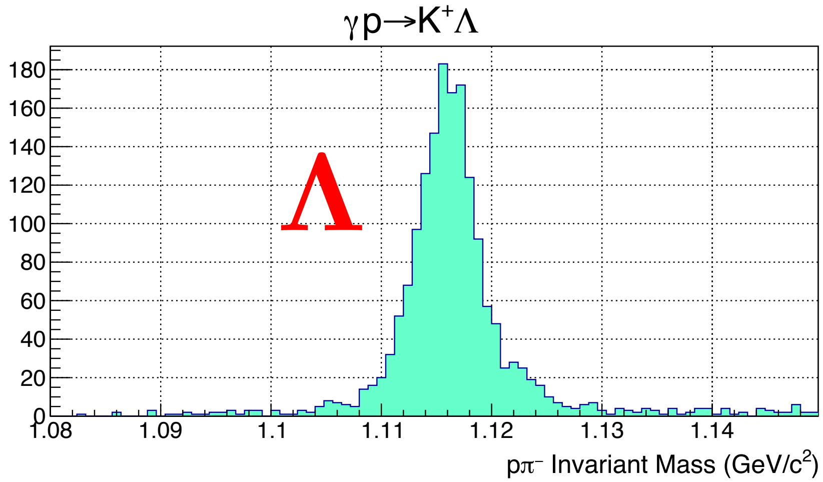


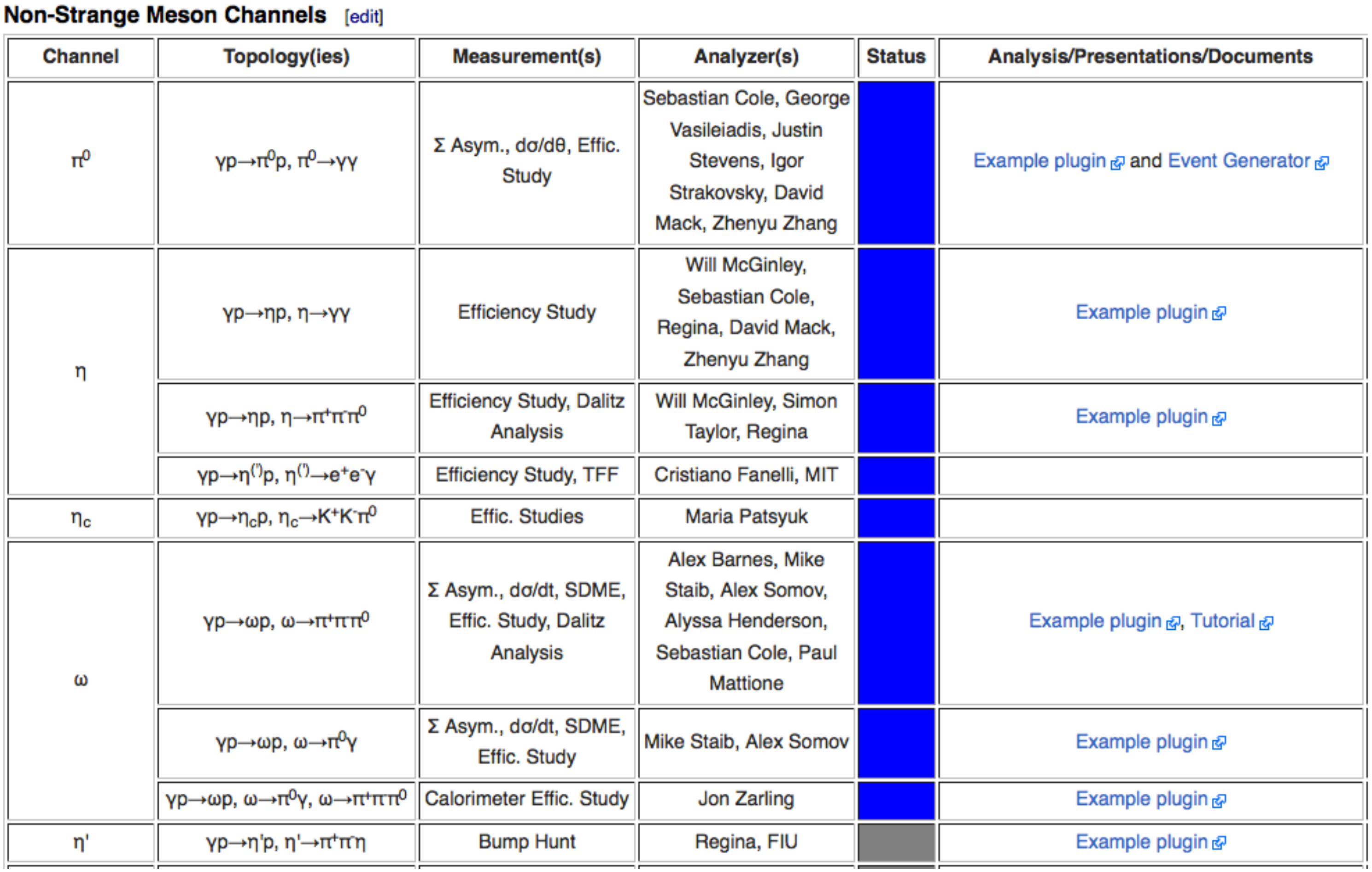




Very low background: Clean Λ selection!!

Analysis Tracking

- Coordinate collaboration efforts for understanding data



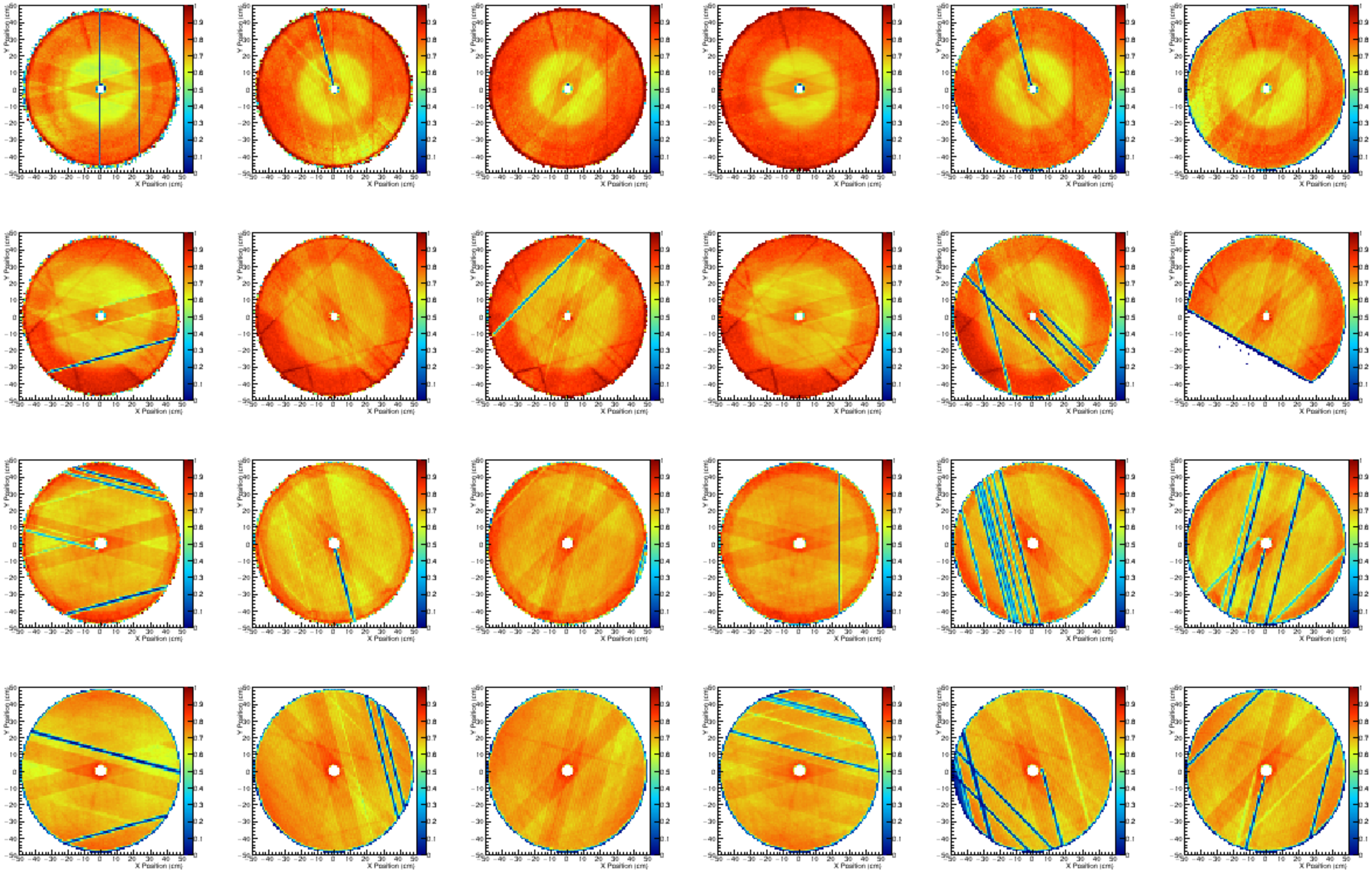
Non-Strange Meson Channels [edit]

Channel	Topology(ies)	Measurement(s)	Analyzer(s)	Status	Analysis/Presentations/Documents
π^0	$\gamma p \to \pi^0 p,\ \pi^0 \to \gamma\gamma$	Σ Asym., dσ/dθ, Effic. Study	Sebastian Cole, George Vasileiadis, Justin Stevens, Igor Strakovsky, David Mack, Zhenyu Zhang	🟦	Example plugin and Event Generator
η	$\gamma p \to \eta p,\ \eta \to \gamma\gamma$	Efficiency Study	Will McGinley, Sebastian Cole, Regina, David Mack, Zhenyu Zhang	🟦	Example plugin
	$\gamma p \to \eta p,\ \eta \to \pi^+\pi^-\pi^0$	Efficiency Study, Dalitz Analysis	Will McGinley, Simon Taylor, Regina	🟦	Example plugin
	$\gamma p \to \eta^{(')} p,\ \eta^{(')} \to e^+e^-\gamma$	Efficiency Study, TFF	Cristiano Fanelli, MIT	🟦	
η_c	$\gamma p \to \eta_c p,\ \eta_c \to K^+K^-\pi^0$	Effic. Studies	Maria Patsyuk	🟦	
ω	$\gamma p \to \omega p,\ \omega \to \pi^+\pi^-\pi^0$	Σ Asym., dσ/dt, SDME, Effic. Study, Dalitz Analysis	Alex Barnes, Mike Staib, Alex Somov, Alyssa Henderson, Sebastian Cole, Paul Mattione	🟦	Example plugin, Tutorial
	$\gamma p \to \omega p,\ \omega \to \pi^0\gamma$	Σ Asym., dσ/dt, SDME, Effic. Study	Mike Staib, Alex Somov	🟦	Example plugin
	$\gamma p \to \omega p,\ \omega \to \pi^0\gamma,\ \omega \to \pi^+\pi^-\pi^0$	Calorimeter Effic. Study	Jon Zarling	🟦	Example plugin
η'	$\gamma p \to \eta' p,\ \eta' \to \pi^+\pi^-\eta$	Bump Hunt	Regina, FIU	▨	Example plugin

FDC Hit Efficiencies (Alex A.)

Pseudo hit = wire position + clusters in both cathodes (position along wire)

- Requires matching position perpendicular to wire and timing



Efficiency ≈70%

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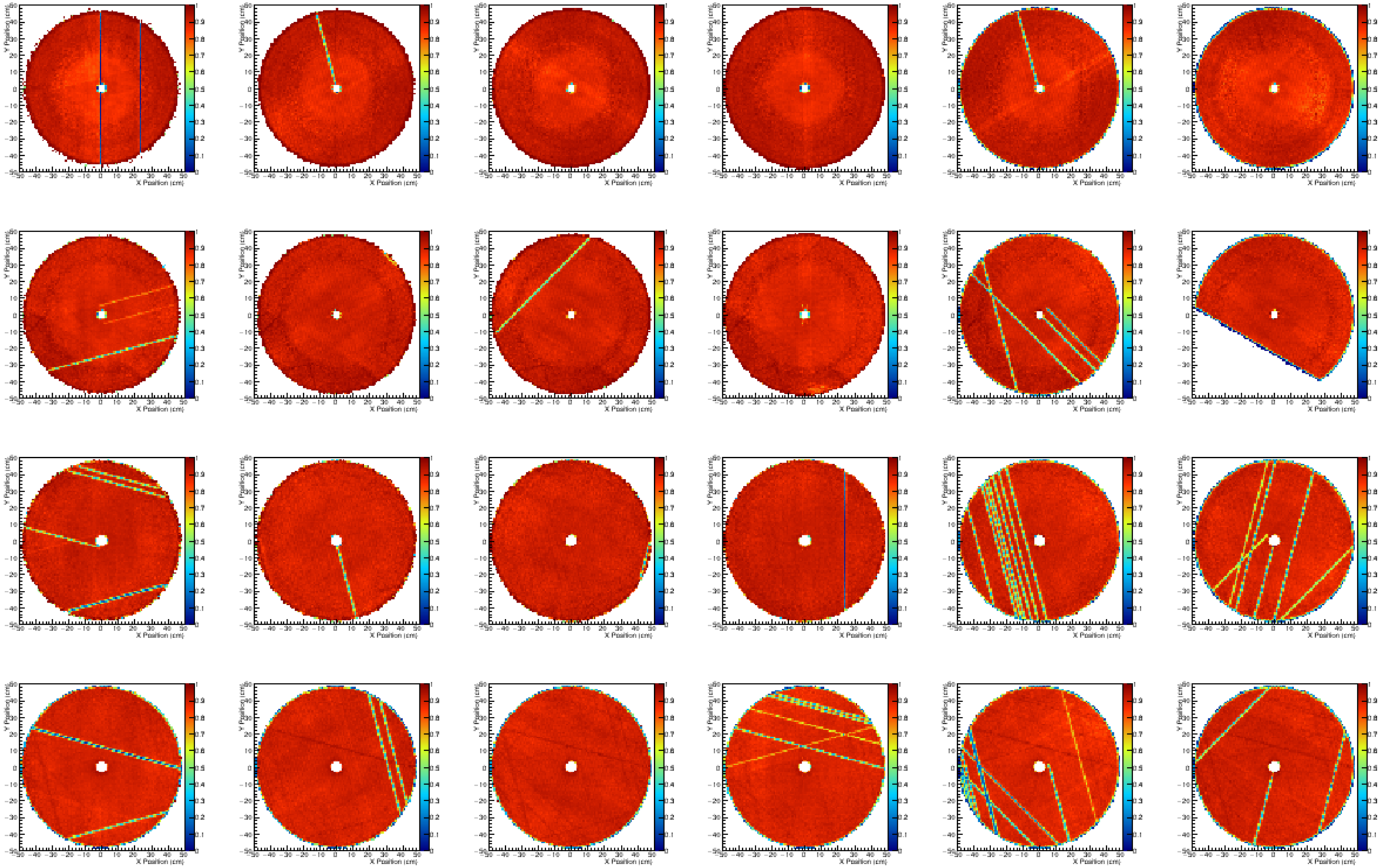


Efficiency ≈90%
+10% reconstructed tracks

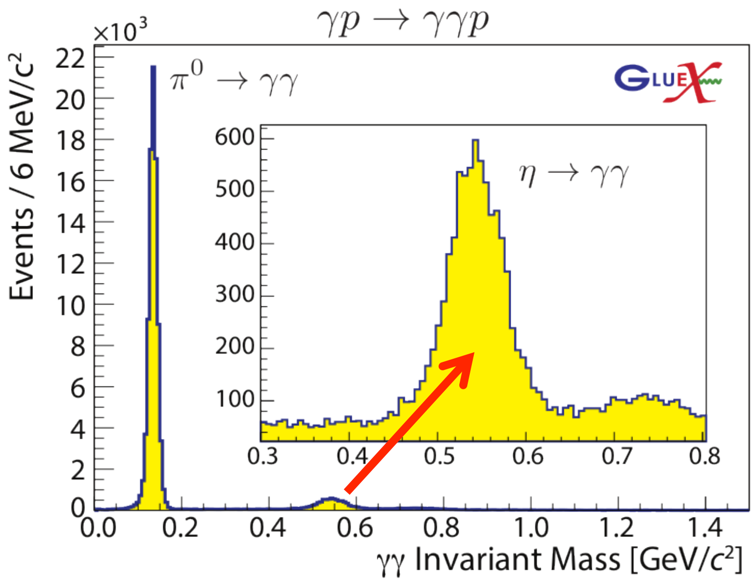
Detector/Reconstruction Studies

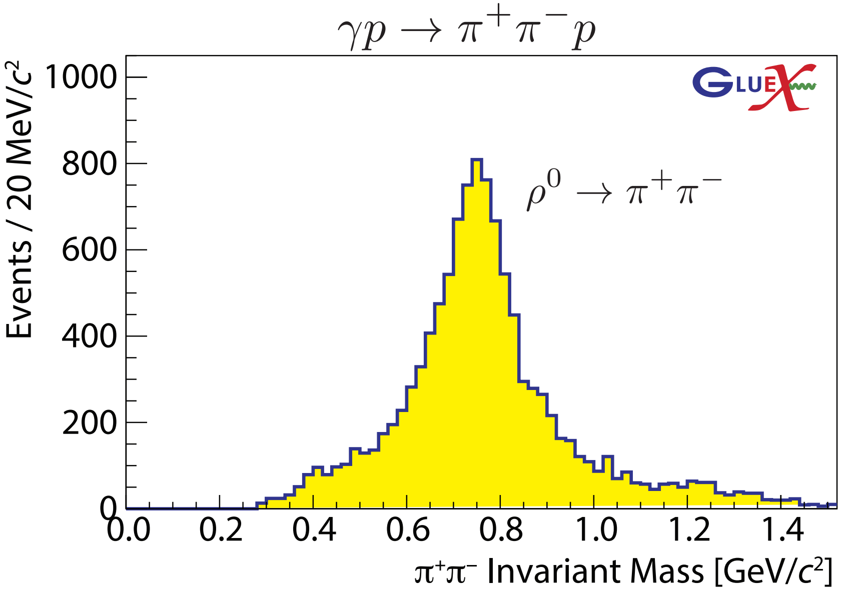
- Beam:
  - Beam Polarization (Talks by Justin & Mike D.)
  - Beam Energy (Talk by Alex D.)
  - Beam Flux (Talk by Justin)
- Tracking
  - CDC Hit Efficiency (Mike S.)
  - FDC Hit Efficiency (Alex A.)
  - Track Reconstruction (Talk by Simon)
  - Track Resolution & Efficiency (Paul M.)
- TOF/SC:
  - TOF Efficiency (Beni)
  - SC Efficiency (Mahmoud)

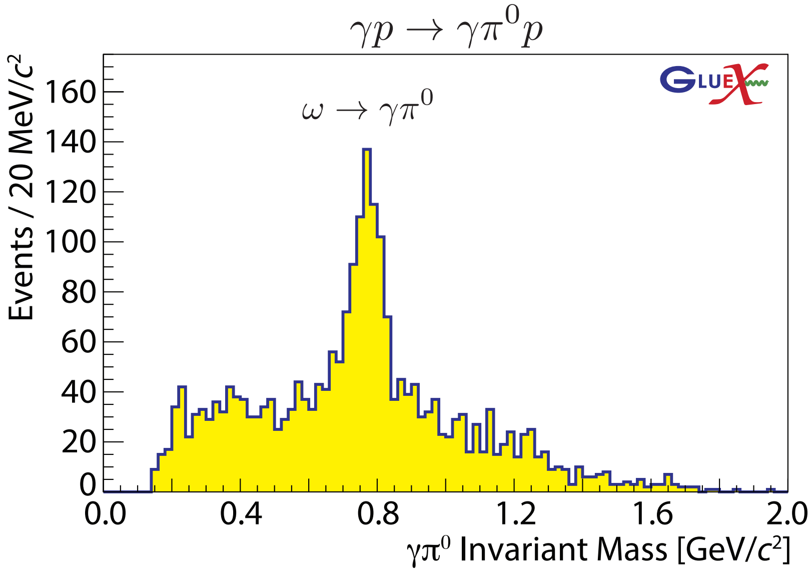
Detector/Reconstruction Studies

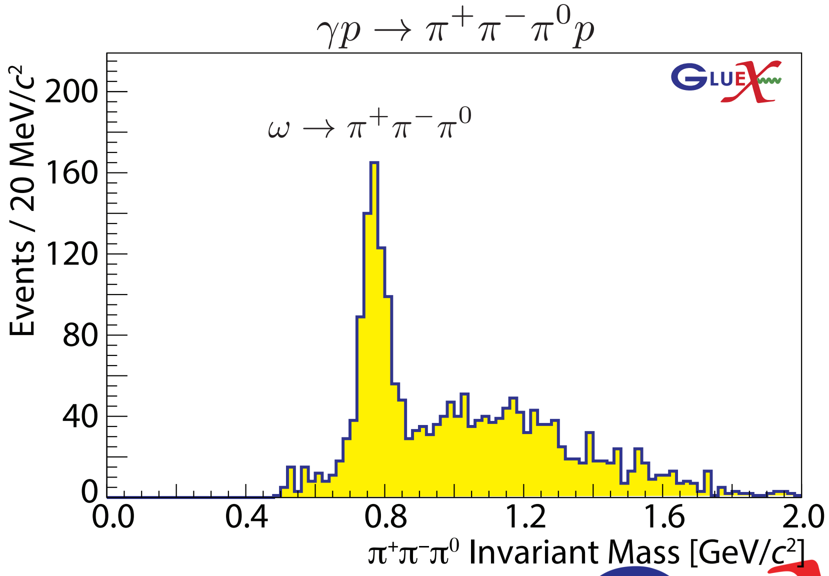
- BCAL:
  - Neutral Energy & Efficiency
  - Hadronic Energy & Efficiency (Elton)
  - Covariance Matrix (Mark D., testing soon)
- FCAL:
  - Neutral Energy & Efficiency (Jon Z.)
  - Hadronic Energy & Efficiency
  - Covariance Matrix (Mark D., testing soon)
- Channel reconstruction, triggering, & acceptance:
  - Triggering (Talk by Alex S.)
  - Magnetic field comparison
    - ρ (Alex A.), 4π (Alex A.), ω (Mike S.), ϕ (Alex B., see his talk)

Reconstructed Meson Peaks



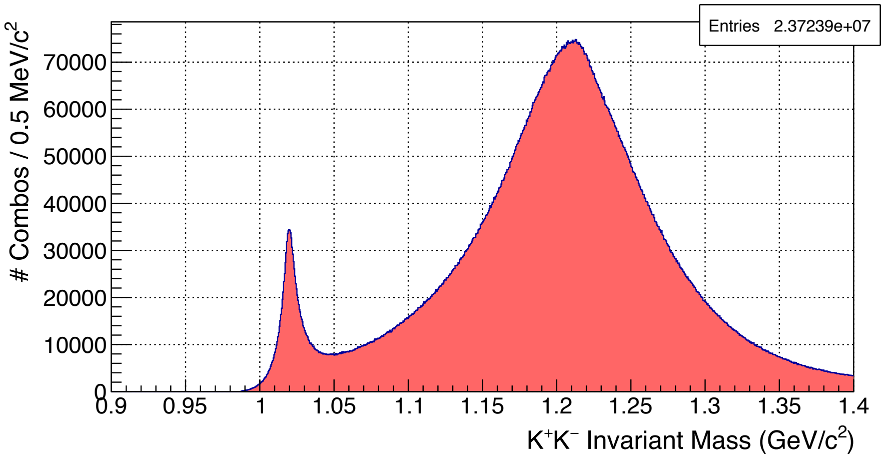


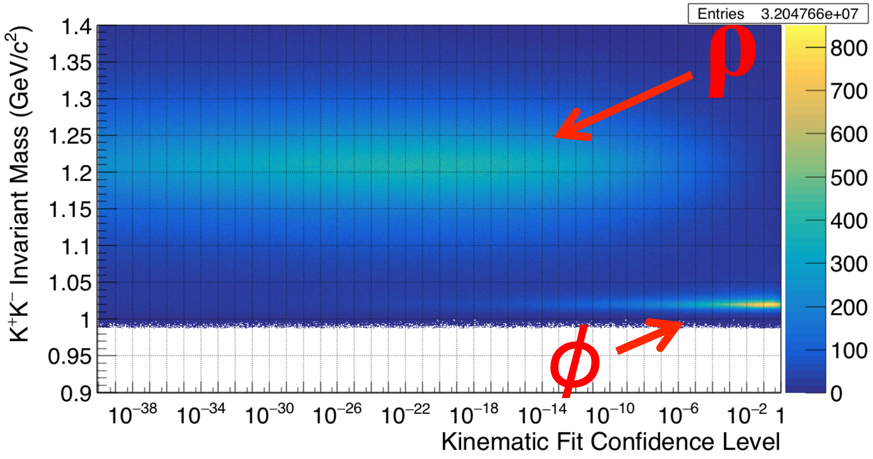


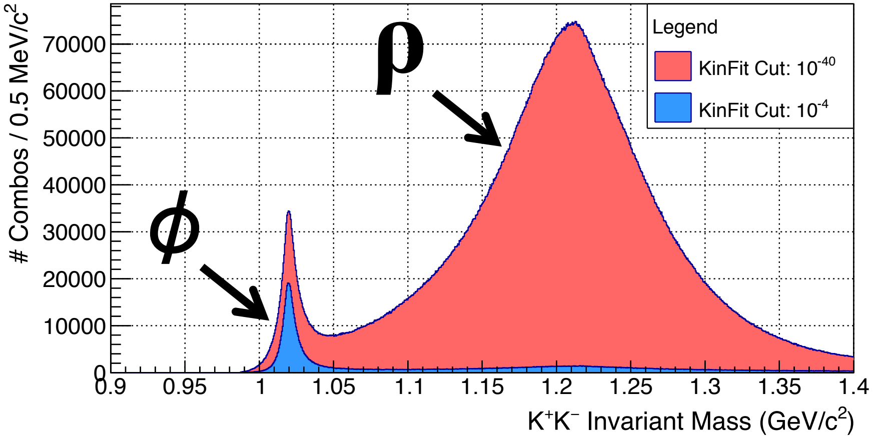


$\gamma\, p \rightarrow pK^+K^-$

- Use KinFit cut to ~remove ρ


Entries 2.37239e+07
# Combos / 0.5 MeV/c²
K⁺K⁻ Invariant Mass (GeV/c²)


Entries 3.204766e+07
ρ
ϕ
K⁺K⁻ Invariant Mass (GeV/c²)
10⁻³⁸
10⁻³⁴
10⁻³⁰
10⁻²⁶
10⁻²²
10⁻¹⁸
10⁻¹⁴
10⁻¹⁰
10⁻⁶
10⁻²
Kinematic Fit Confidence Level


ρ
ϕ
Legend
KinFit Cut: 10⁻⁴⁰
KinFit Cut: 10⁻⁴
# Combos / 0.5 MeV/c²
K⁺K⁻ Invariant Mass (GeV/c²)