CLAS12 Event Reconstruction

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CLAS12 Collaboration Meeting
Jefferson Lab
July 10, 2018

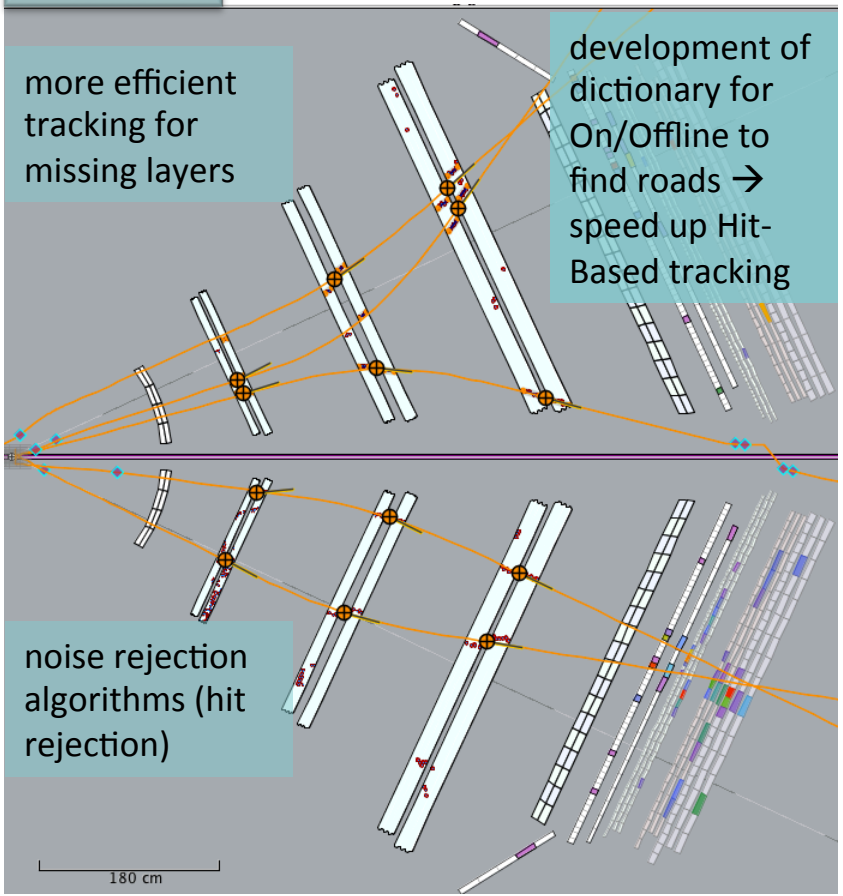
Code & Data Processing Improvements

- Algorithmic
  - Track pathologies analysis
    - Segment finding/fitting
  - Tracking failures due to beam background
    - Noise rejection algorithm tuning & improvements (implementation of cellular automaton with Central Tracking pattern recognition)
    - More robust DC Hit-based recognition and improvements to tracking with missing layers and 5-out-of-6 superlayers on-track

- Event Processing Speed
  - Roads (track hits dictionaries) in hit-based tracking → Speed up pattern recognition (in development)
  - Swimming in B-field: grid cells caching
  - Memory usage analysis
  - Profiling to find hot spots

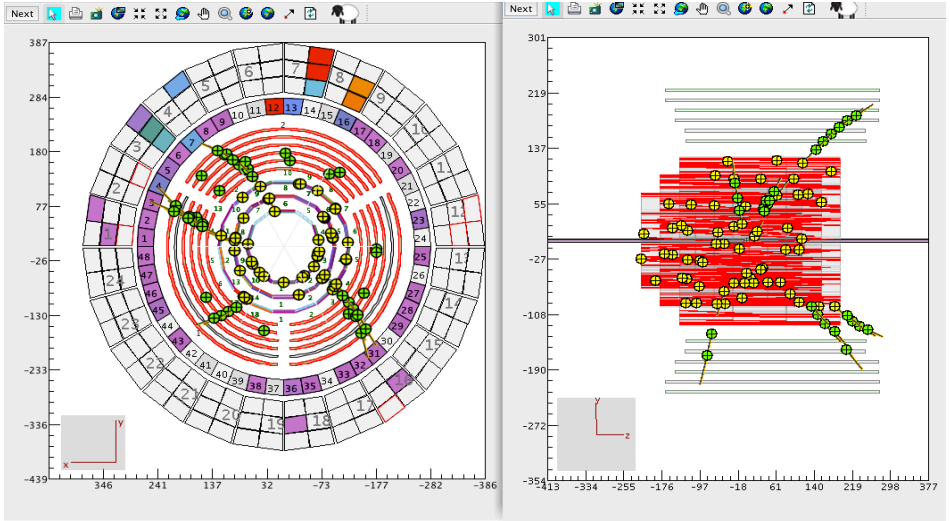
Algorithmic Code Optimization

30 nA data



implementation of Cellular Automaton to find track seeds

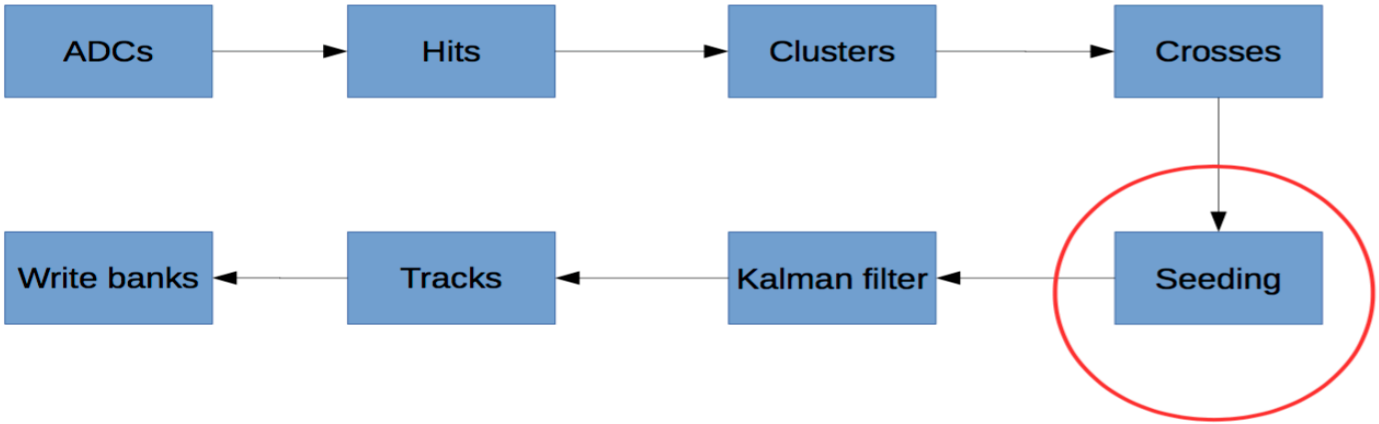
75 nA data



Central Tracking Updates (F. Bossu)

Track seeding

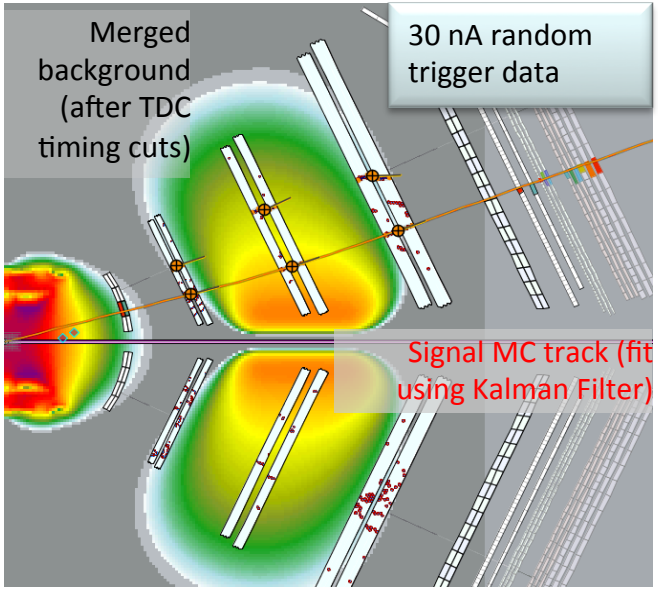
- New track seeding algorithm based on cellular automata
- Inspired to the Hera-B CATS algorithm (NIM A 498 (2002))
- Minimal impact on existing CVT code and fully retro-compatible: **no modifications to the CVT banks** and to the track fitting

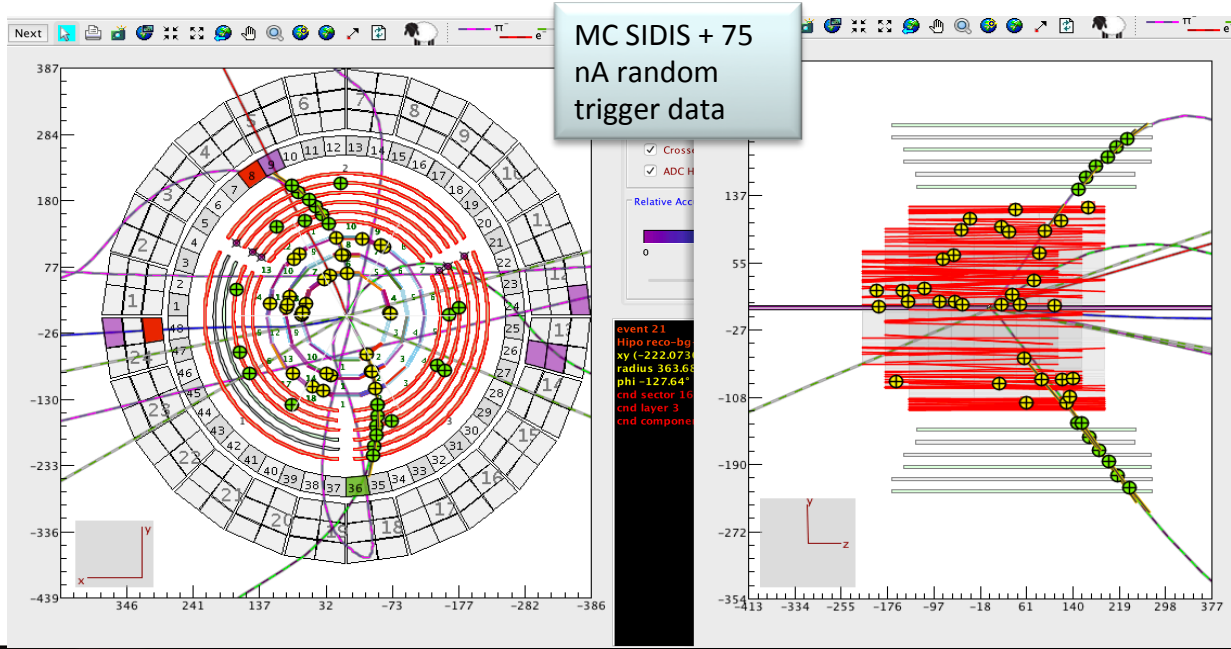


Analysis of Efficiency as a function of Beam Backgrounds

- Background merging ready for C(F)VT and DC → realistic measure of tracking efficiency as a function of beam current & tool to analyze tracking performance and validation algorithm improvements (c.f. Josh's presentation)

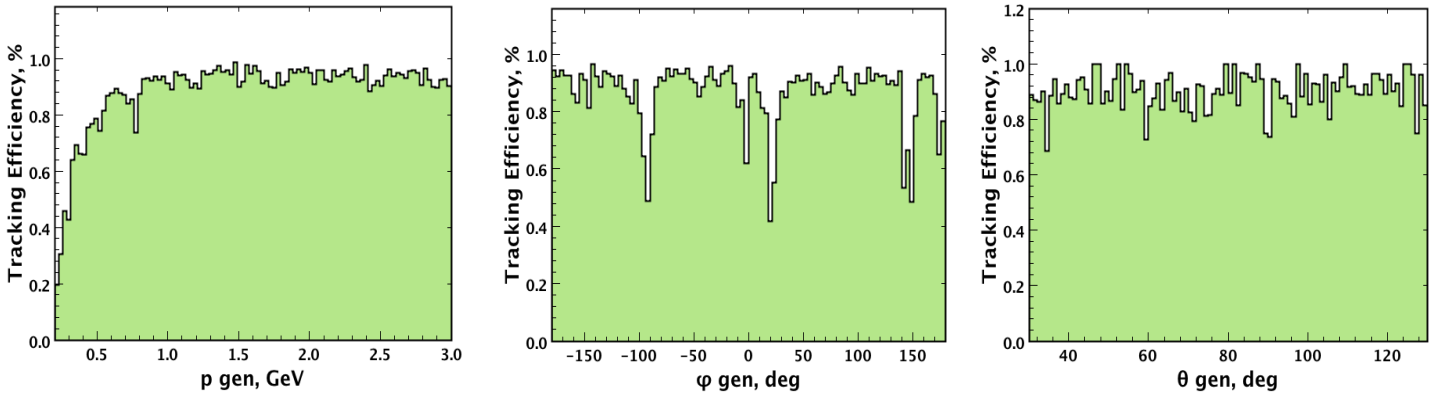
  – Signal MC track (parametrized wire intrinsic inefficiency) merged with random trigger data.
  – ADC and TDC raw lists from data and MC combined.



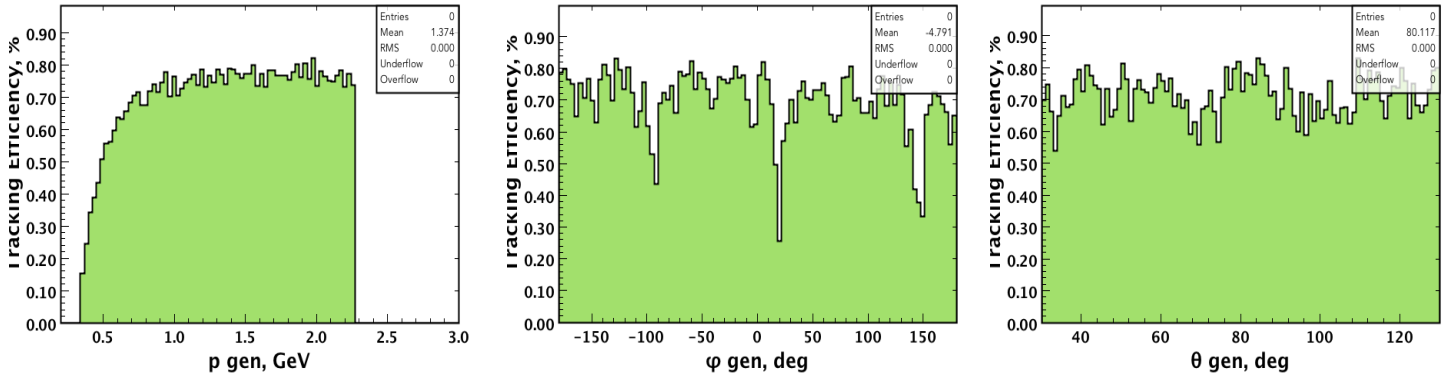


CVT Track reconstruction efficiency

Y. Gotra



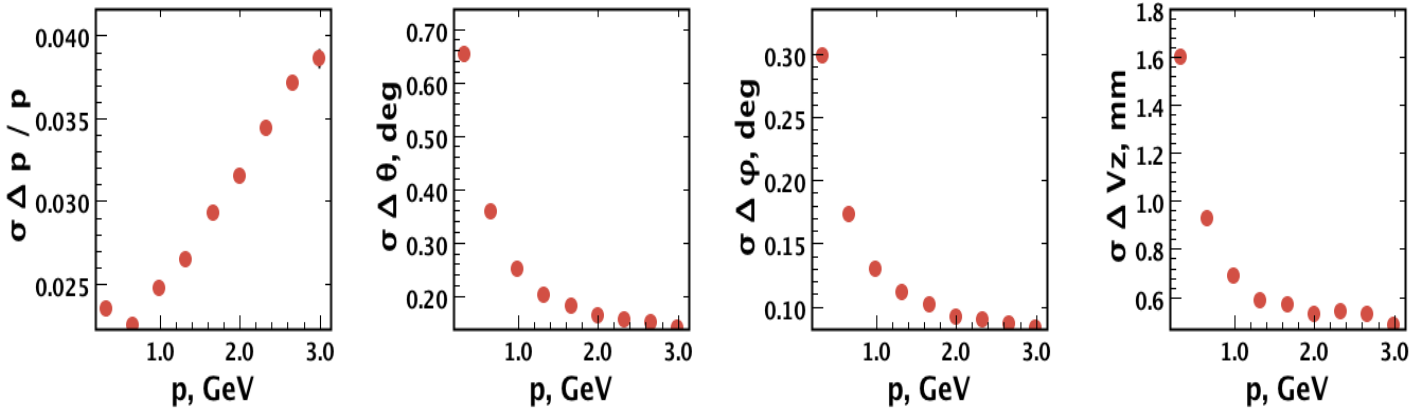
Muon, no background



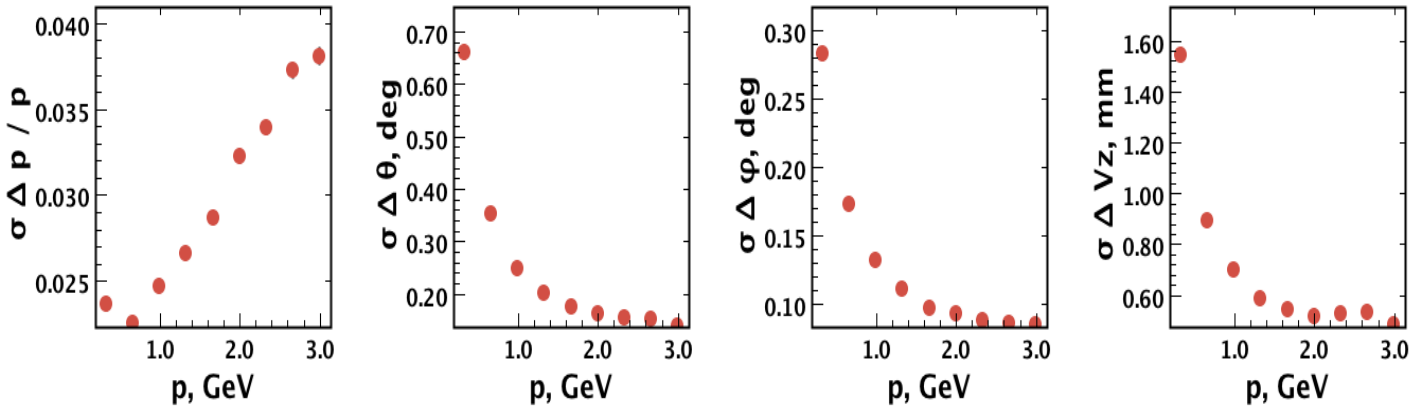
Proton with 50 nA background

Simulation, positive muon, no background

Y. Gotra



shim, GEMC 4a.2.3



no shim, GEMC 4a.2.4

Forward Tracking Updates

Use of start Time in Time-based Tracking
- Use start time from Hit-based event builder information, trigger jitter, cable delays, flight and beta-dependent time corrections to compute the doca to the wires.
- Validated procedure. Improves time to distance parameters calibrations.

Geometry
- Core parameters from surveyed data: significant impact on vertex reconstruction
- Correct MM geometry parameters in ccdb (read in reconstruction)

Field Maps
- Specified in Yaml file (full or symmetric torus maps available)→ effect on reconstruction being studied
- New solenoid field map available in ascii and binary format

Swimming algorithm (ongoing validation)
- Faster, more robust algorithm in swimmer package
- Correct handling of solenoid/torus overlaps & sector-dependence for full torus map

DC Tracking algorithm improvements
- Hit pruning
- Pattern recognition: fitting with missing layers, and superlayers.

Under validation
- Road finder for fast pattern recognition
- Vertex reconstruction using FMT

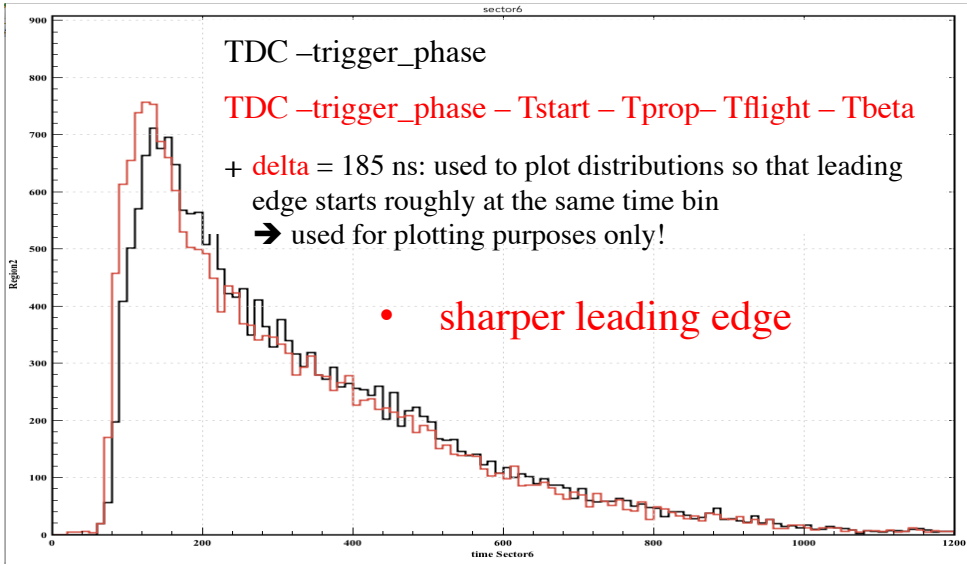
Use of start Time in Time-based Tracking

Time-Based Tracking:

- TDC: selected Hit on Track
- T0: Calibration of quantity TDC-TFlight-TProp-Tstart-Tbeta
- Tstart: Event start time from HB Event builder information
- TFlight: HB time of flight of track from reconstructed vertex to the wire from HBT
- TProp: HB propagation time of the signal along the wire from HBT
- Time = TDC-TFlight-Tprop-TStart-T0-TBeta
- TFlight: fitted track TOF
- TProp: fitted track Tprop
- TBeta: beta from EB using HB rec
- T0 used in tracking
- TStart used in tracking

- input
- output

- calibration quantity to extract T0:



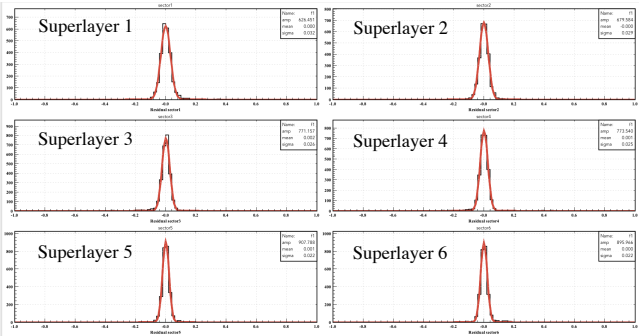
c.f. Latif's Presentation for details of the calibration results

DC Geometry Updates

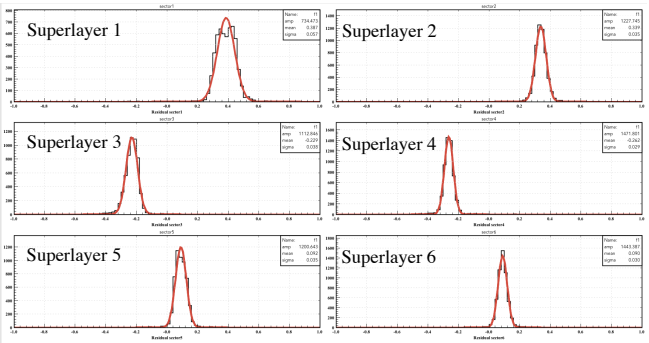
- End plate bowing and wire sag take into account in reconstruction (sector-dependent effects).
- Core parameters updated to 2018 numbers from engineers: largest deviation from previous DB numbers for Region 2.

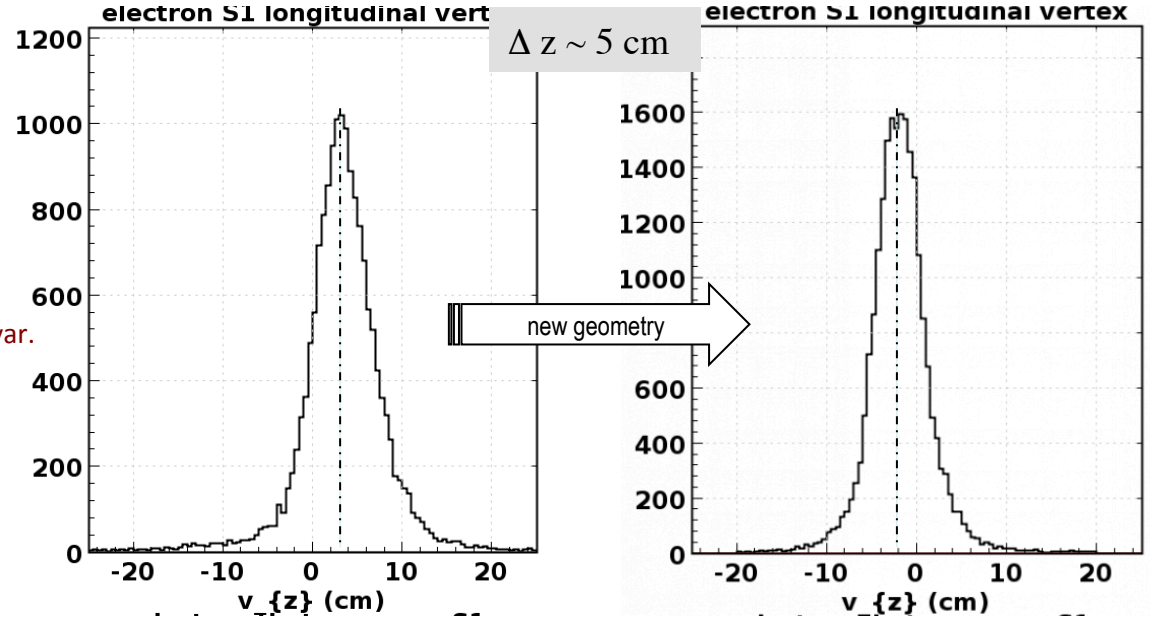
MC sample simulated with 2017 geometry variation:

Fit residuals of events reconstructed with 2017 geometry var.



Fit residuals of events reconstructed with 2018 geometry var.

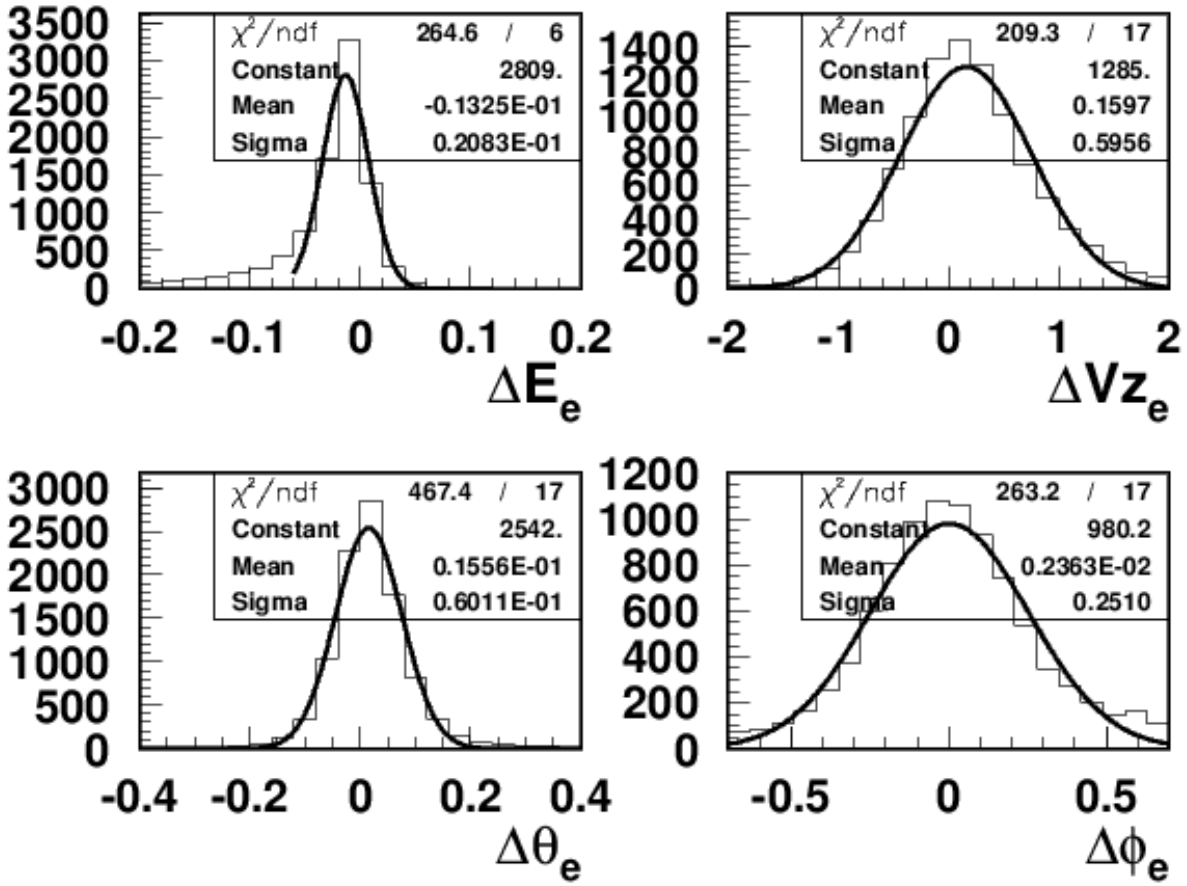




tag 5b.2.1 + 2017 geometry

tag 5b.5.0 + geometry: may_2018

Tracking Validations with SIDIS MC (H. Avakian)



Current Release Used for Calibration & MC Studies

Pre-release

5b.5.0

283de3b

Verified

COATJAVA (pre)release 5b.5.0

fxgirod released this 8 days ago · 53 commits to development since this release

Assets

Source code (zip)

Source code (tar.gz)

Compatible with gemc 4a.2.4

- DC
  - start time implemented
    - requires running FTOF after HBT and EBHB after HBT
    - requires STT and overwriting TBT at second TOF pass
  - added fit residual to TB hits banks
  - reading status table from CCDB
  - reading HB bank when TB is not yet available
  - timing cuts from TDC timing cut table, loading var table as env var
  - added tBeta to TBHits
  - variations, DC geometry, and STT flag from yaml
- MVT
  - no shim geometry for BMT and FTM
  - standalone FMT reconstruction with updated geometry from ccdb
- EC
  - fixed moments calculation
  - FADC time for MC
  - PMT Gain Offset Table used to globally shift PMT gains at the sector,layer level
    - Added /calibration/ec/global_gain_shift table to CCDB
  - TOFFSET moved to CCDB, set to zero for MC runs
- TOF
  - improved adc-tdc matching for CTOF
  - CTOF::hits - removed duplicated and added pointers to tdc/adc hits
  - removed FTOF printouts
- CND
  - added clustering in CND::clusters bank
- FT
  - modified position units in output banks from mm to cm
    - added units to JSON file
  - corrected definition of calID in FT::particles bank
  - fixed calculation of cluster widths to remove NAN values
- EB
  - turn on 3 EB tests in Travis
  - use FTOF paddle-dependent timing resolution in REC::Particle.chi2pid
  - fill REC::Traj and REC::CovMat for CVT
  - add units to EVENT.json
- Misc
  - FastMC particle swimmer now prefers env vars for field maps
  - DatabaseConstantProvider's timestamp support now works
  - build script now only downloads the default field maps

Pre-release

5b.5.1

2efb652

Verified

COATJAVA (pre)release 5b.5.1

fxgirod released this 3 days ago

Assets

Source code (zip)

Source code (tar.gz)

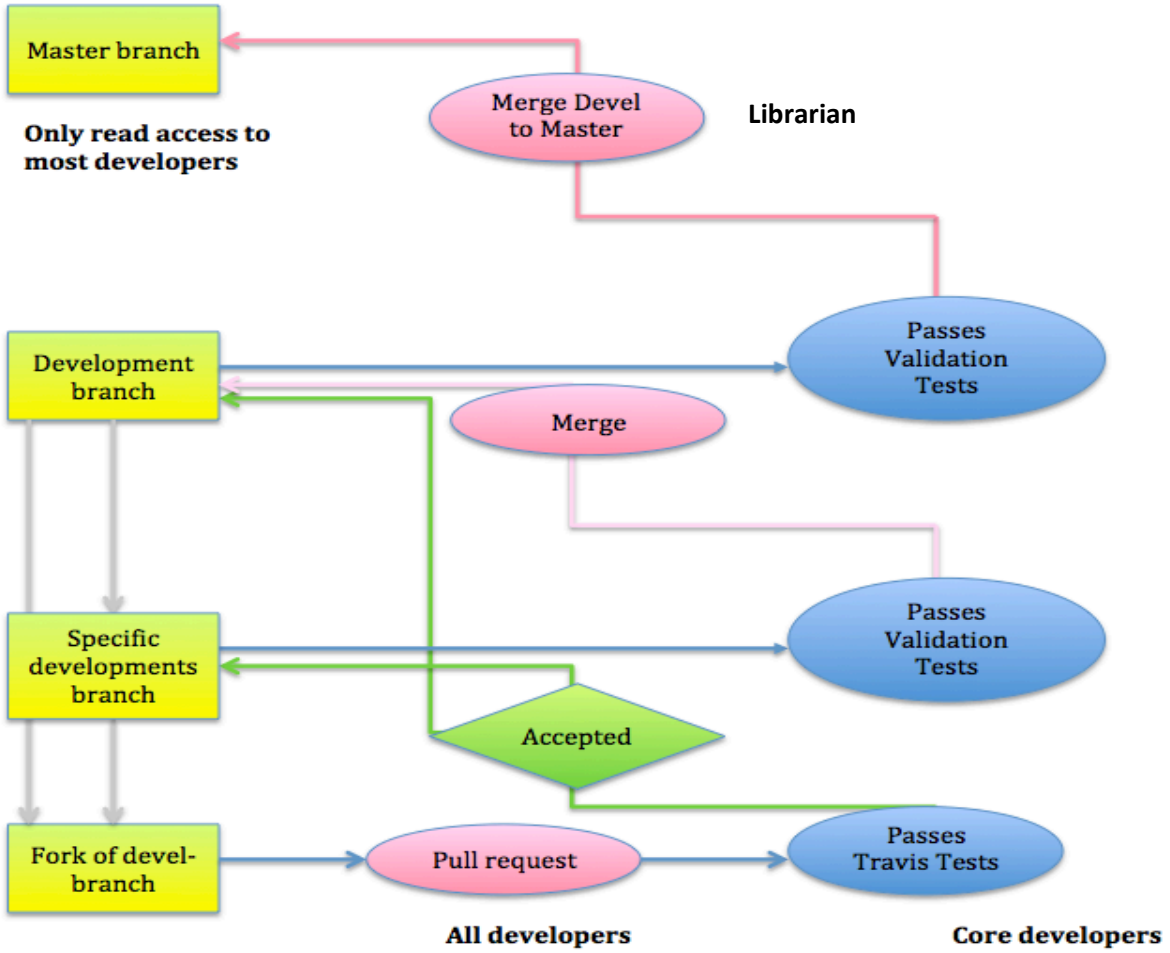
Compatible with gemc 4a.2.4

- CND
  - Take into account the effective velocity in the determination of the hit paddle
- EB:
  - CD matching now in EB instead of imported (to accommodate CTOF+CND)
  - PID for CD neutrals from Rong
  - analyze RAW::Scaler and fill REC::Event.BCG/LT
  - Bugfixes
    - missing (5,5) element in REC::CovMat
    - missing cluster width in REC::ForwardTagger
  - mark REC::Cherenkov.theta/phi as deprecated
  - code cleanup and deprecation
- EC
  - Add debug flag to diagnostic histos to avoid thread safe issues
- FMT
  - Added FMT dependency for geometry
  - FMT geometry fix for trajectory at FMT faces
  - Load FMT constants if FMT service not called
- FT
  - fixed unit error in vertex time calculation
  - changed response-particle association to improve code readability

http://clasweb.jlab.org/clas12offline/distribution/coatjava/coatjava-5b.5.1.tar.gz

Software Development Management

- clas12-offline software kept under github repository
- Code validation (validation suites, bug finding tool spotBugs) included in Travis build system
- Code development and release tagging scheme
  - release notes
  - issue reporting



Active Branches

- Speed-opt → Branch to test algorithms and code rewrites aimed at improving reconstruction speed
- SwimFMT-devel → Branch to develop tracking code including FMT clusters
- swim-devel → Branch to develop and test new swimmer and magfield algorithms
  - Removes solenoid + torus overlap computation→ creates composite map loaded in memory & non-overlapping solenoid map
  - Sector dependence to obtain the value of the field in the tilted sector coordinate system for the full map
- ctof-debug→ Branch to test the ADC/TDC matching in TOF
- development → active branch used to tag (b-type) to validate the reconstruction, simulation and for calibration cooking. Stable version of the code.
- master → updates when all validations from development tag pass (i.e. large data samples output analyzed, no bugs found)

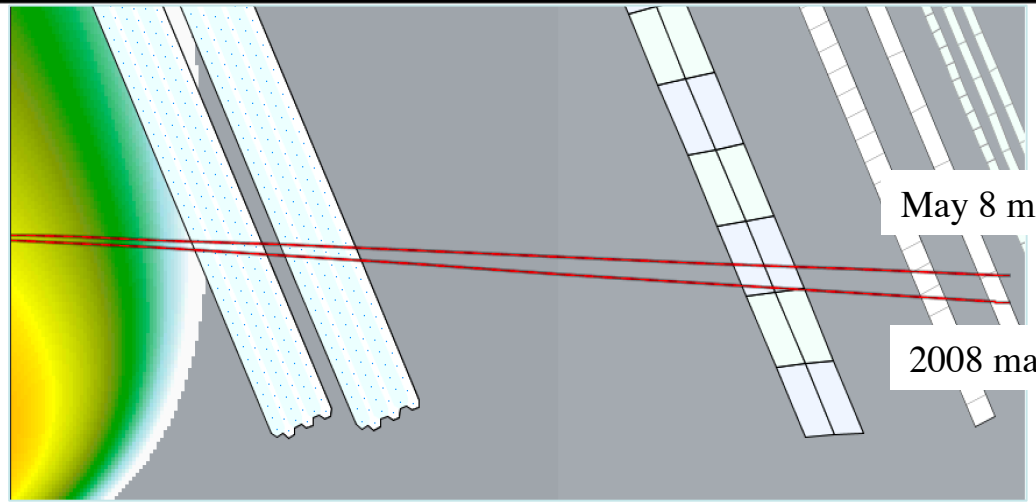
MagField/ Swimmer Summary of Changes

- Using ‘realistic” non-symmetric maps
  - Latest map Full_torus_r251_phi181_z251_08May2018.dat
  - Note: latest map rewritten in GEMC ASCII format: Symm_torus_r2501_phi16_z251_24Apr2018.dat

- Speed Enhancements (in a development branch)
  - Faster math library (especially for atan2)
  - Additional caching via field “probes”
  - In-situ solenoid-torus overlap removal

- Added sector coordinate system versions of the magfield and swimmer methods (in a development branch)

Effects of new Field Map on Track Swimming (D. Heddle)



Particle Energy

Mass	0.000511	GeV/c²
Relativistic γ	3913.90280	
Relativistic β	0.999999967	
Total Energy	2.00000	GeV

Initial Momentum and Direction

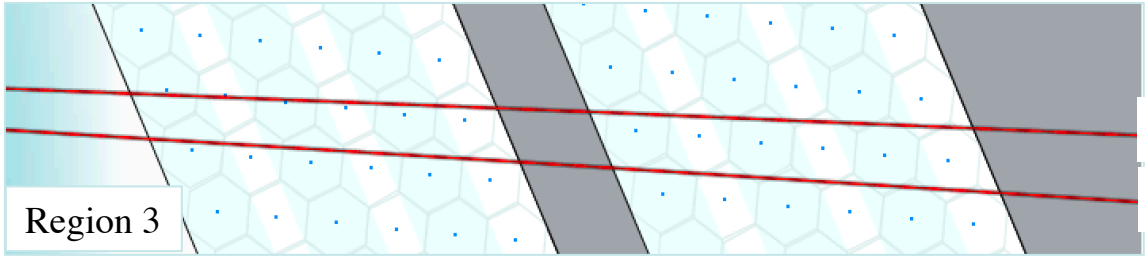
Momentum	2.00000	GeV/c
θ	15.0	deg
φ	0.0	deg

```
R = [ 0.768385,  0.000000,  7.249994] |R| =  7.290599 m
P = [-1.168606e-01, 1.021628e-08, 1.996583e+00] |P| =  2.000000e+00 GeV/c
```

2008 map end point

```
R = [ 0.835999, -0.000386,  7.249993] |R| =  7.298034 m
P = [-7.626327e-02, -2.402224e-04, 1.998545e+00] |P| =  2.000000e+00 GeV/c
```

May 8 map end point



FMT Matching and Track Fitting Algorithm Development

- Find FMT Matches within ~1 cm of DC track trajectory (resolution at FMT face from MC ~1 cm → 20 strips)
- Use FMT centroid positions as KF Measurements
- Use same KF formalism as for DC except the coordinate system is now the lab frame. Same principle of fixed z measurement planes (FMT disks).

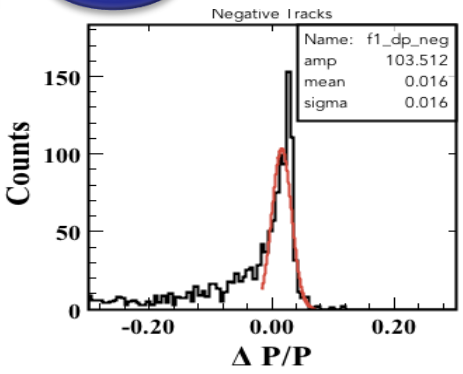
- Multiple hits on track lists from matches → multiple candidates
  - clones of DC track → refit all clones → select the best clone (selection to be done)

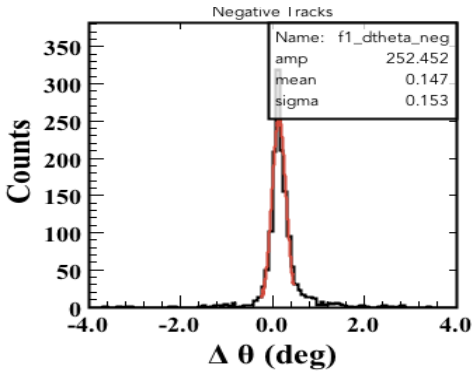
FVT state vector:

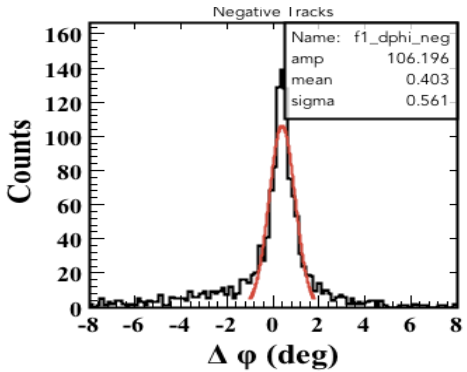
$$\tilde{x}(z) = \begin{pmatrix} x \\ y \\ t_x \\ t_y \\ q \end{pmatrix}, \quad \begin{aligned} t_x &= p_x/p_z \\ t_y &= p_y/p_z \\ q &= Q_e/|\vec{p}| \end{aligned}$$

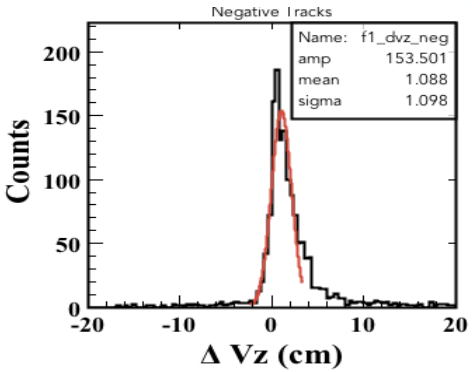
e-

DC Stand-alone reconstruction

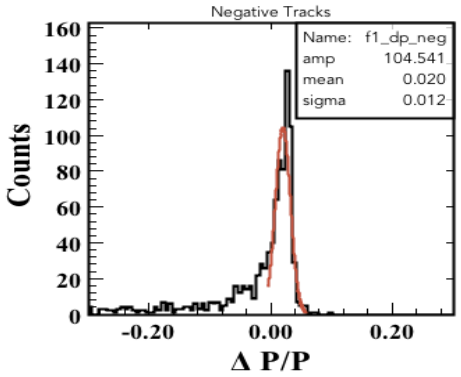


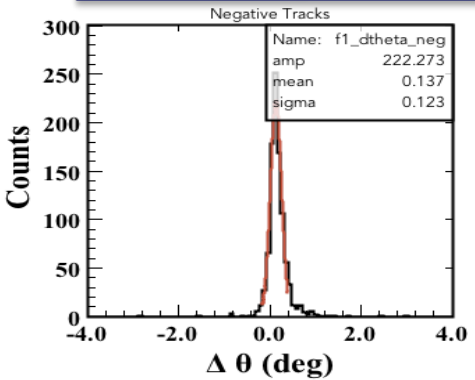


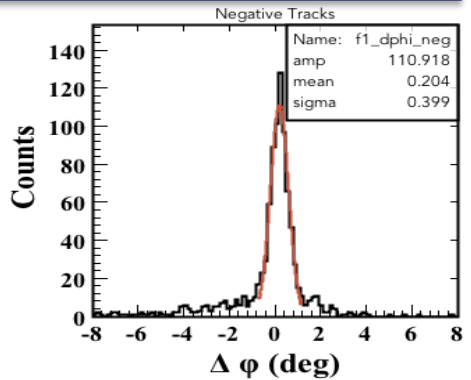


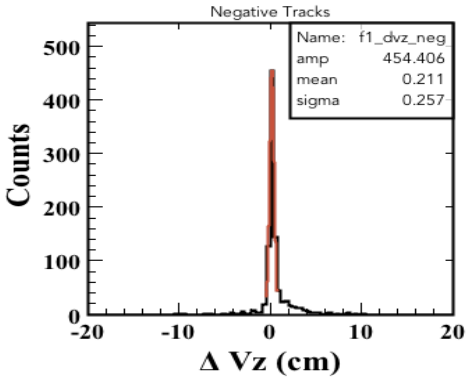


Using FMT clusters in reconstruction





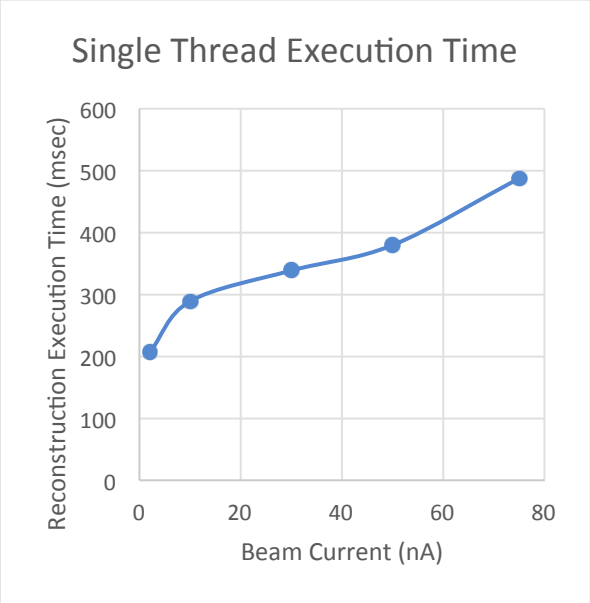




- CAVEAT : The *with-FMT-reconstruction sample* has ghosts. This validation picks 1st track.
- Code not yet ready for data

Ongoing Code Speed Optimization

Development not yet validated for physics resolution goals



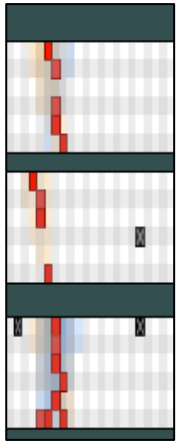
- No CVT optimization yet
- service initialization factored out

- Ongoing optimizations
  - Tracking engine optimizations
    - new Swimmer methods, Engine Design, Code improvements (memory & CPU usage)→ involvement from Chili group.
  - Remaining thread contentions
    - un-necessary synchronizations slowing down the code.
  - Verification of engines thread safety from analyses.

- Continued optimizations and validations
  - Validation tools in place → start optimizing code without jeopardizing parameters of the physics.

DC Fast Pattern Recognition With Dictionaries (D. Heddle)

- SNR finds DC noise. As a byproduct it **already** produces, per superlayer, a 112 bit word indicating the possible start of a segment

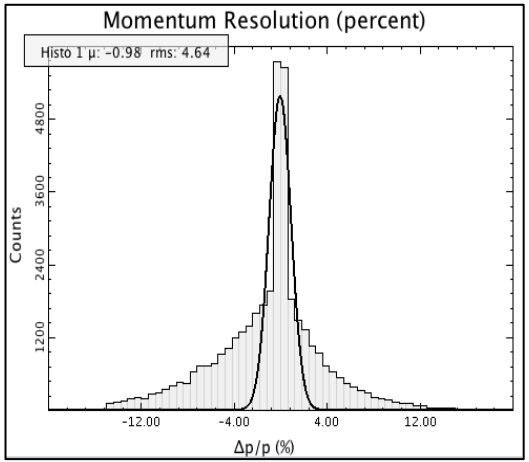


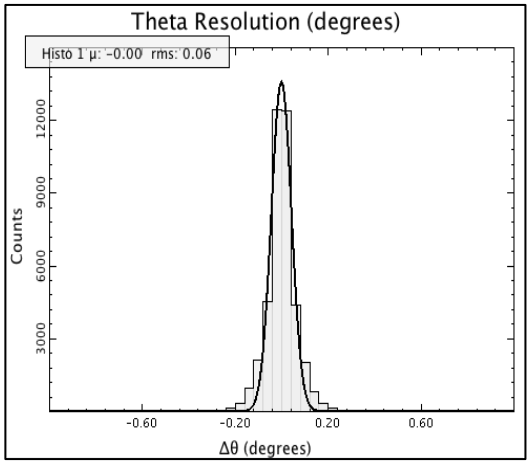
112 bits

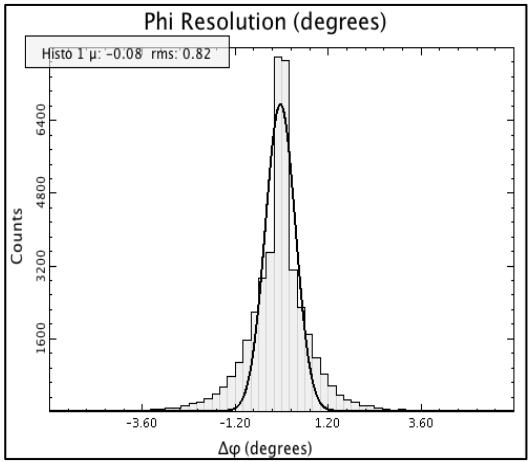
Presently this information is **not used**.

Took all 6 superlayers, combined into one massive 672 bit word. Encoded in base 36. That became the *key*. Multiplied track parameters (x, y, z, p, θ, ϕ) by 100, rounded them, included charge and encoded in base 36. That became the *value.* Trained (with FastMC) dictionary → 381k *key-value* pairs; Dictionary size = 32 MB.

Dictionary retrieval time (including encoding key and decoding value back to track parameters) ~**2 microsec** (if found.) Working on fast "nearest key" if not found. Current dictionary finds ~80%. **Resolutions:**





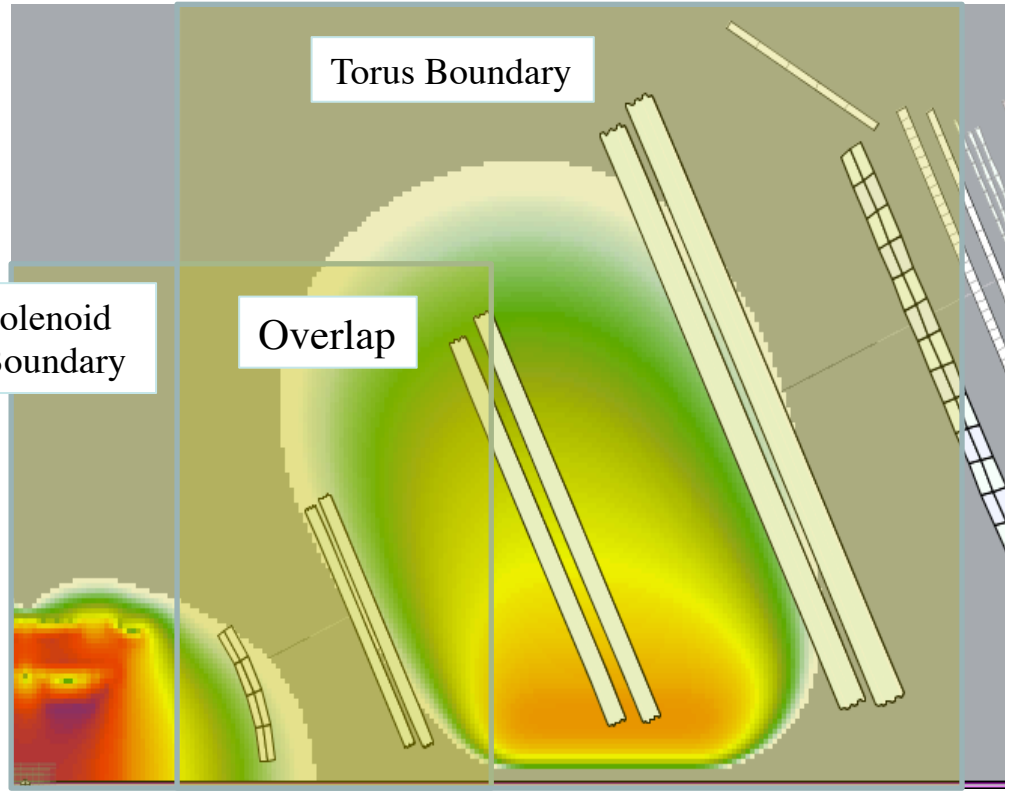


Outlook

- Validation of current tag (5b.5.1) ongoing. Cooking of 10.6, 6 and 2 GeV data ongoing. After completion of an overall analysis (basics: residuals, vertex, masses) of these data this tag will be a production tag (i.e. official release by July 16).
- Completion of Magnetic Field and Swimmer packages and use of their respective APIs in tracking done by the end of July.
- Completion of tracking code using FMT clusters done by the start of the Fall run.
- Tracking code speed improvements will be ongoing. Aim to achieve 500 ms/ev without resolution degradation by mid-August.

BACK-UPS

Removing Overlap



In overlap region, two interpolations are required in the standard approach

The overlap is removed by adding the (interpolated) solenoid field to every point on the torus grid in the overlap region, and reducing the solenoid boundary to remove the overlap.

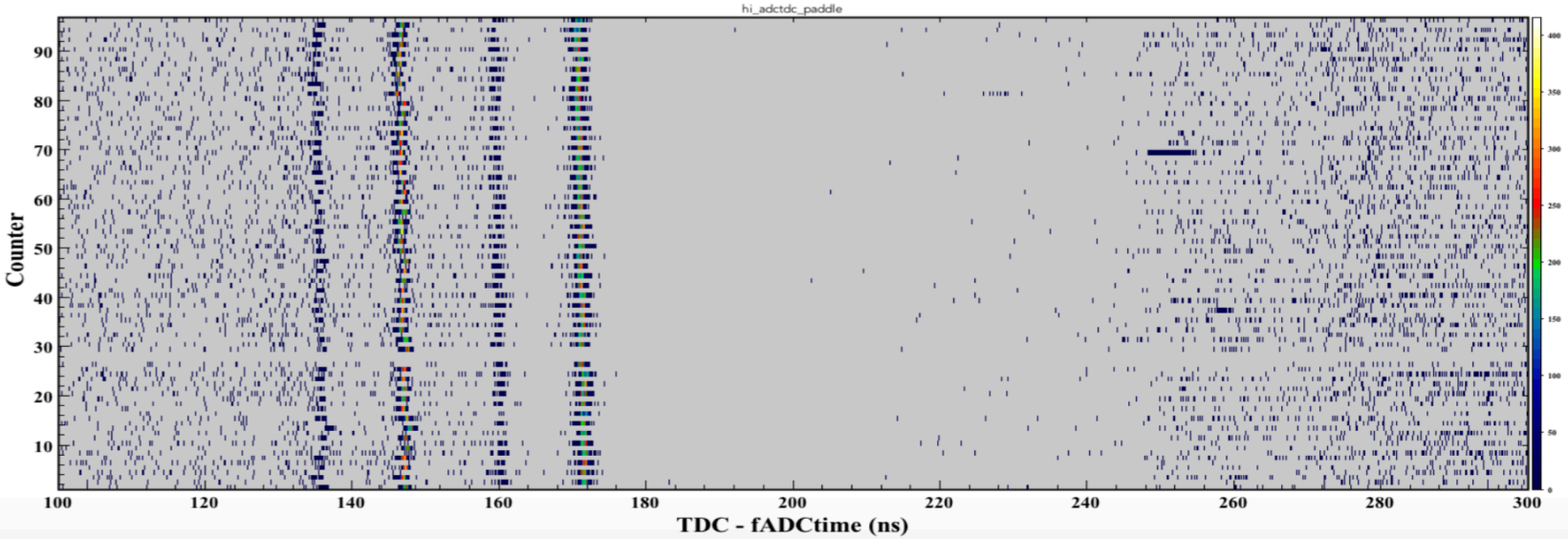
After processing: only one interpolation is needed at any point.

ADC-TDC matching in TOF

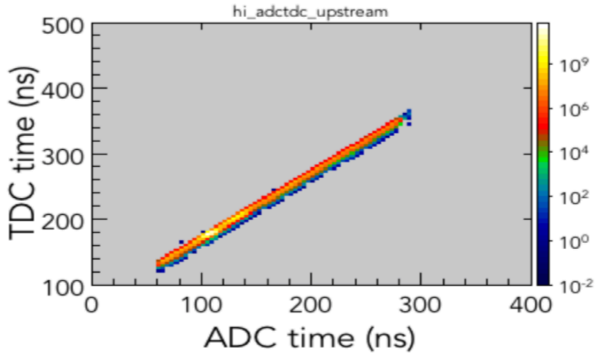
R. DeVita

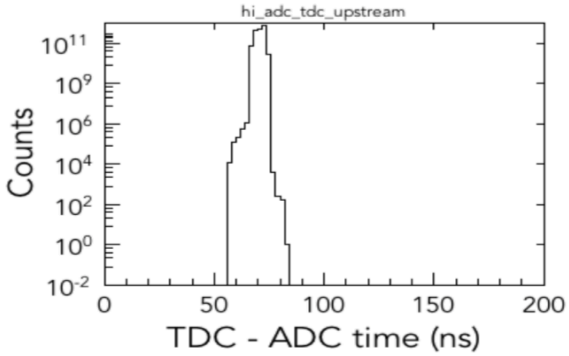
- Current version of the reconstruction matches ADC and TDC hits only based on the counter, selecting the first hit in time in case TDC hits are more then one
- Better matching can be done using the fADC time information:
  - Pro: reject out-of-time TDC hits, ensure correct matching of charge and time information
  - Con: fADC pulse is required to have a reconstructed hit, fADC-to-TDC time offsets have to be determined as part of the calibration

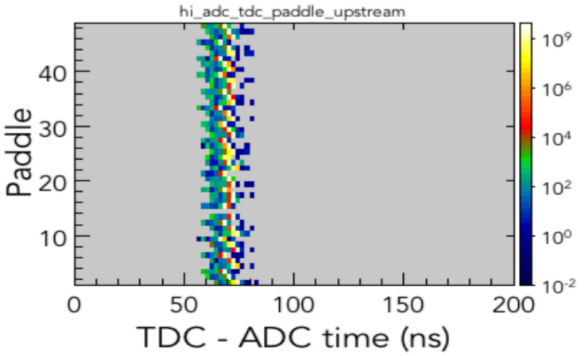
Run 4013

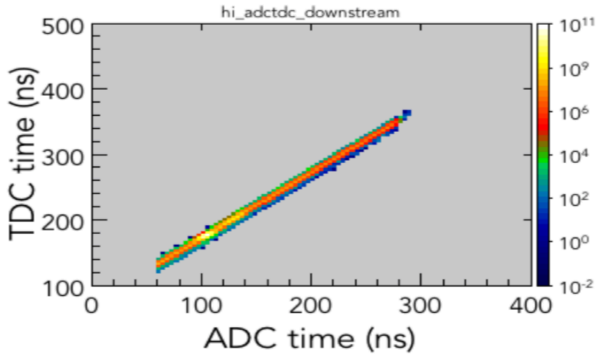


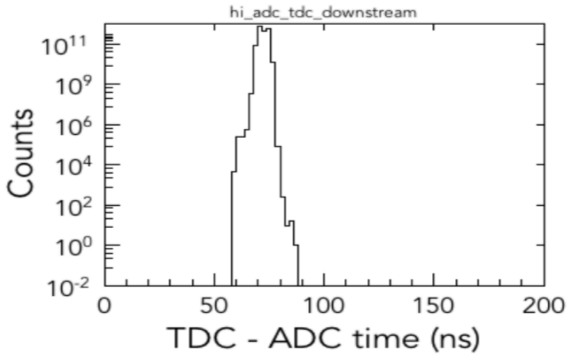
CTOF adc-tdc matching in ctof-debug

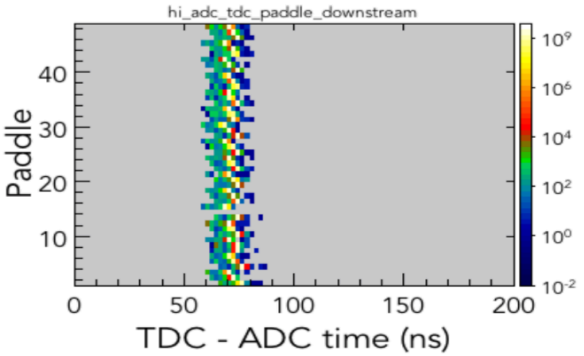






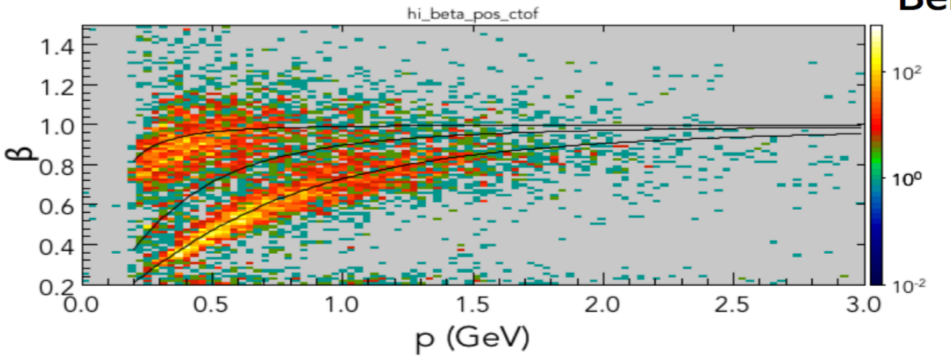


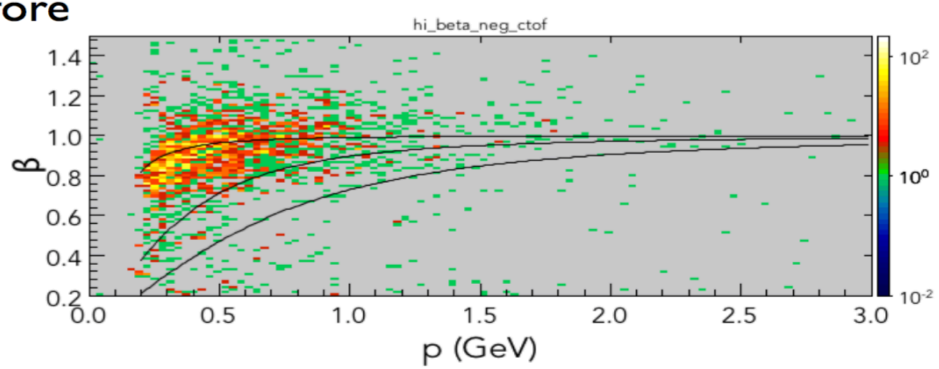




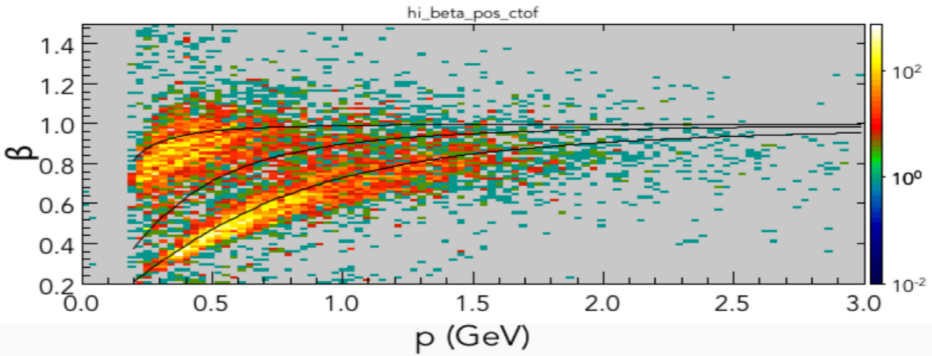
EB results

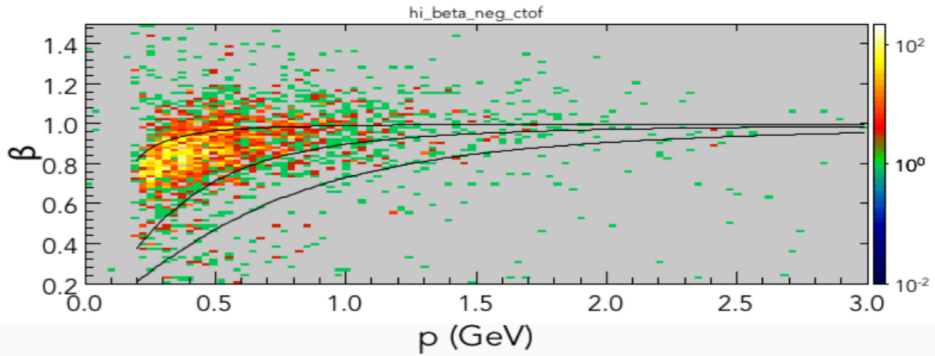
Before





After





Software Versioning Scheme

- The versioning of CLAS12 software releases is based on the following version numbering scheme MAJOR.MINOR.PATCH, where:

  1. MAJOR increments when the code is modified in a non-backwards- compatible way (e.g. banks change), there are major changes to the reconstruction algorithms, or the simulation digitization routines have changed.

  2. MINOR increments when functionality is added in a backwards-compatible manner, and additions have been made that do not constitute significant changes to the algorithms (e.g. adding capability to read RF constants).

  3. PATCH increments when backwards-compatible bug fixes are made.

- For pre-release versioning, MAJOR is the number of the next intended stable release number. Now MAJOR = 5a. The letter indicates that this is pre-release.
  - ”**a**“ represents a stable version that can be used for general analysis purposes.
  - ”**b**“ represents a tag corresponds to the main development branch.
  - ”**c**“ represents a tag used for dedicated studies (i.e. lumi studies with special cuts).

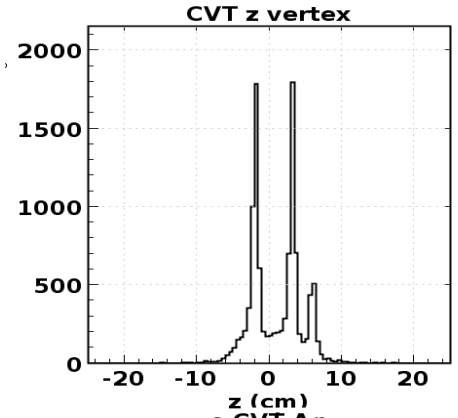
Offline monitoring: detector plots: CVT

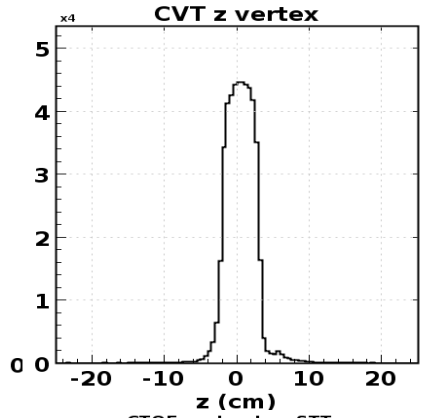
CVT Resolutions

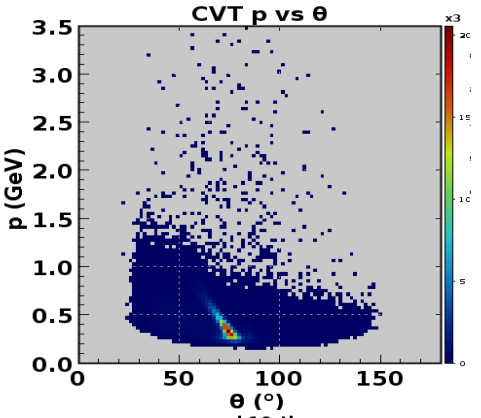
- Empty target
- Full Target
- Elastic peak in θ vs p

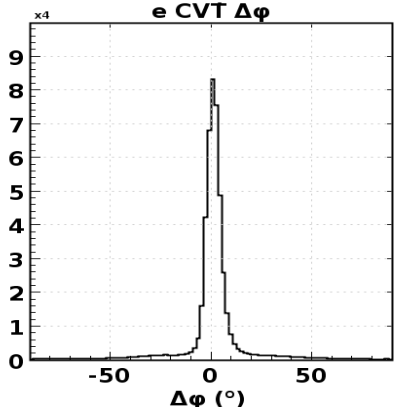
Correlations with FD

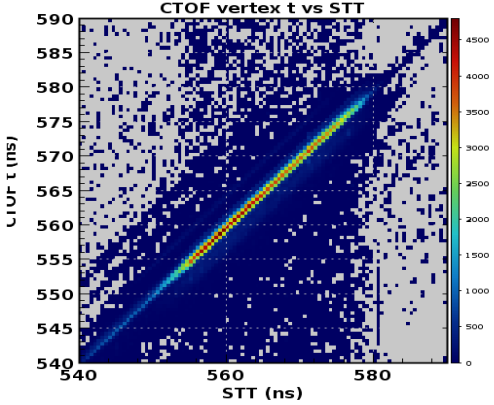
- DC – CVT ϕ
- CTOF vs STT
- CTOF pad time

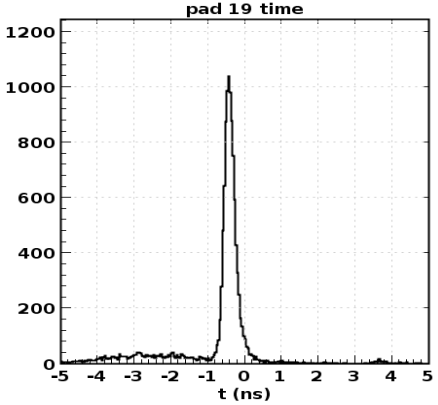












Specifications

Drift Chamber and Tracking Specifications			
	Specification	Achieved So Far	Future Improvements
Operating Luminosity	10^{35} (75 nA)	HV supply current limits beam to ~ 80 nA	• Turn reg.2 voltage down if less noise • More HV segmentation
		Track efficiency ~ 95% at 50 nA ?? ~ 93% at75 nA ??	• Results await verification • Better noise rejection algorithms possible
Angular Coverage	5^0 to 40^0 scattering angle	~ 5.5^0 for outbenders ~ 6^0 for inbenders	
Spatial Resolution	250 to 350 mm	450 to 500 mm	Better time delay calibrations
Track Resolution	dp/p < 1%; dΘ < 1 mrad	dp/p < 2%; dΘ < 4 mrad	• DC alignment • Better B-field map
B-field accuracy	< 0.1 – 0.2%	< 0.5%	• Use coil fabrication surveys to improve coil shape

Drift/Tracking Software Status: July, 2018

Project	Description	Status
Time to Distance Calibration	• Include Tstart event-by-event	Written; being tested
	• Merge calibration, reconstruction & simulation methods into one source	Underway
Simulation	• Find malfunctions; fill status table	faultFinder done; status table defined, being filled
	• Simulate distance → time; time smearing, inefficiency	Done; being documented and compared to data
Monitoring	• Monitor occupancy, time, hit distributions	Done
Alignment & Distortions	• End-plate bowing; wire sagging	Done
	• Adjust for displacements, rotations	Table built; 'mover' service being written; studies begun
Magnetic Field	• Model field to ~ 0.1% accuracy	2nd Order Model done with adjusted coil shape