CLAS12 reconstruction: latest improvements and plans

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CLAS12 Collaboration meeting

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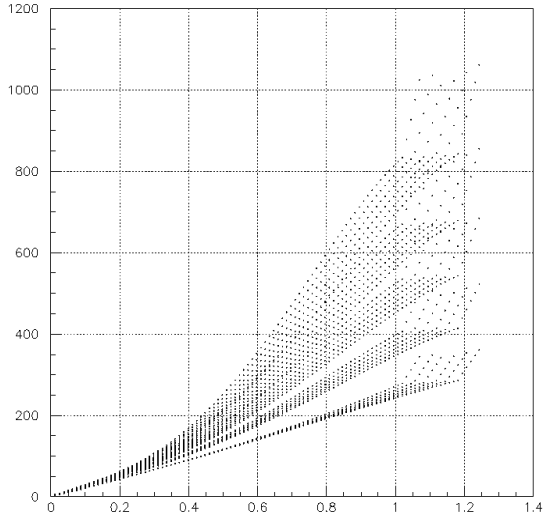
Forward Tracking Developments Overview

- Time-to-Distance function interpolation method as a function of B-field: fixes and improvements for interpolating between different-size tables→ improved track doca estimate affects segment reconstruction.
- Tracking Efficiency analysis
  - Tool available to merge events (e.g. 2 nA data) with random trigger events → use samples produced to understand and fix inefficiencies.
    - Detailed analysis of track failure pathologies (background hits overlapping with the track segments causing the pattern recognition and/or fit to fail; ghost tracks causing PID failures; etc.)
    - Noise rejection algorithms improvements ongoing.
    - Analysis of 5-out-of-6 superlayer tracking robustness ongoing.
  - Modification of Event Builder to allow matching of hits to more than one track → allow for ghost tracks at Hit-Based level to avoid prematurely rejecting the track.
  - Track swimming failures analysis and fix using state propagation method.
- DC Geometry
  - Fix to use wire distortions (wire sag and end-plate distortion) in tracking
  - DC alignment parameters used in tracking.
- Beam offset parameters used in recalculation of track at doca to plane containing the beam line (in validation).
- Speed Optimization: sub-level event parallelization by fitting each track on multiple threads (Bruno Benkel UC Santa Maria)→in testing.

Forward Tracking *features* fixes and Track failure *recoveries*

- Hits reconstruction
  - Time to Distance Interpolation: Different arrays tables.
  - Interpolate as a function of: track segment local angle, B-field value, and time.
  - Functional form for time vs distance. Dmax depends on B field (different isochrones shape in B-field; i.e. twist), and local angle. ➔ different array size as a function of local angle bin and B field bin.
  - Create table in bins of B^2 ➔ more uniform distribution. Fill empty portion of array to resolve interpolation issue. Ensure that there are no empty bins.

Time (ns)



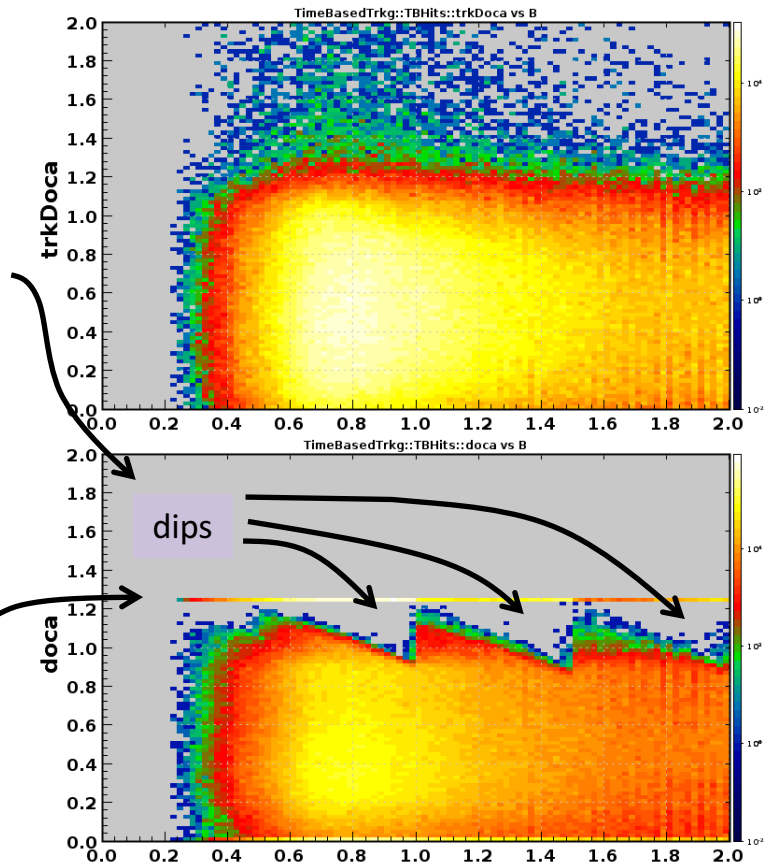
Distance to Wire (cm)

Set of Curves for different B-field intensities (⬆)

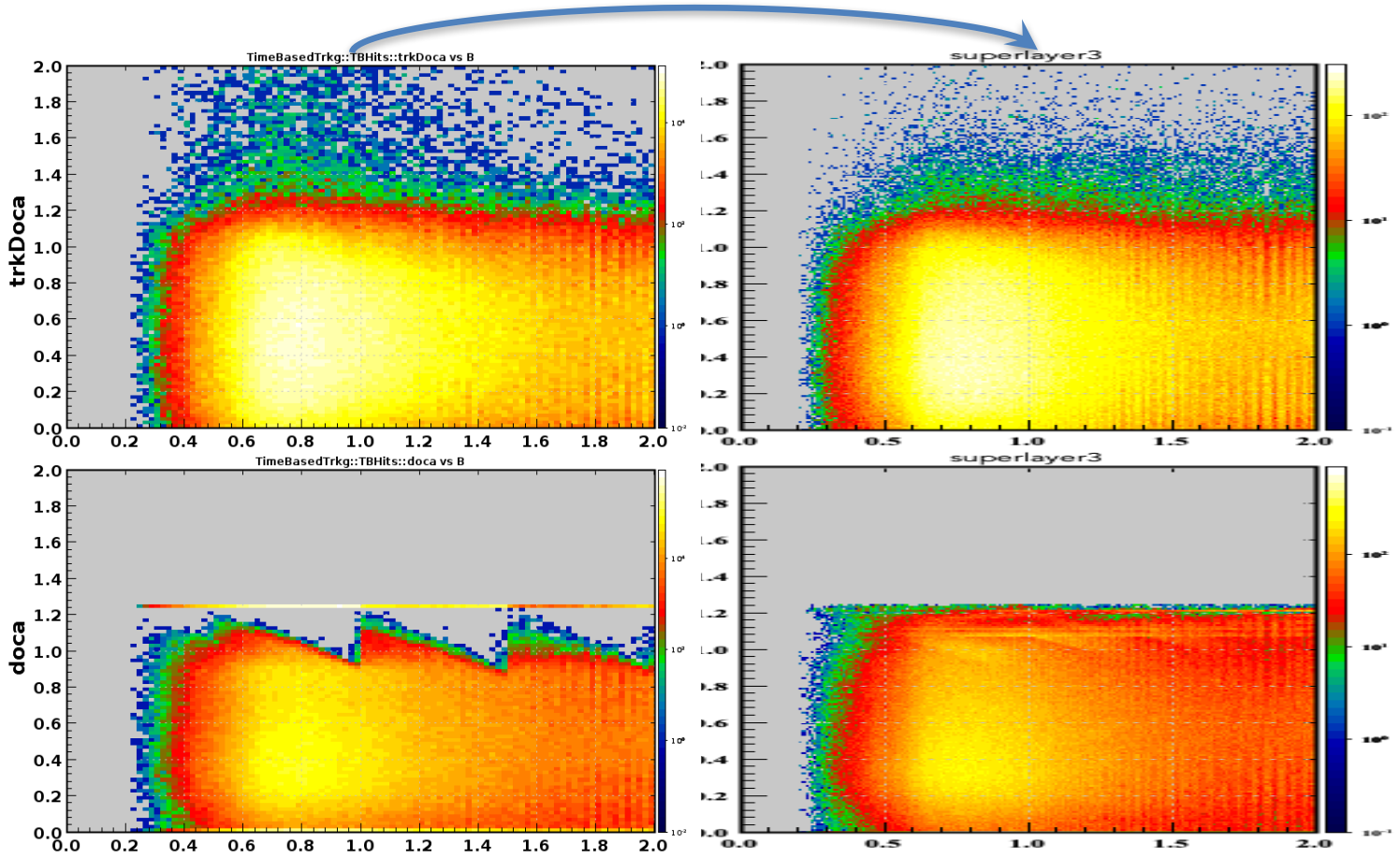
Collection of Tracking Anomalies

Name	Calculation of DOCA as a function of B-field		
Date 11/26/2018	Run 5036	Detector DC: SL3	Plot: Doca vs. Bfield Trkdoca vs. Bfield
Symptom	Dips in doca vs. Bfield (not present in trkdoca vs. Bfield)		
Problem cause?	There may be a problem with the interpolation between (time vs. doca) tables for different B-field values		

Name	Handling of hits seemingly beyond cell boundary		
Date 11/26/2018	Run 5036	Detector DC: SL3	Plot: Doca vs. Bfield Trkdoca vs. Bfield
Symptom	Single line at global Dmax; instead of angle-dependent Dmax		
Problem cause? (guess)	Not considering (or implementing) angle-dependence of Dmax		

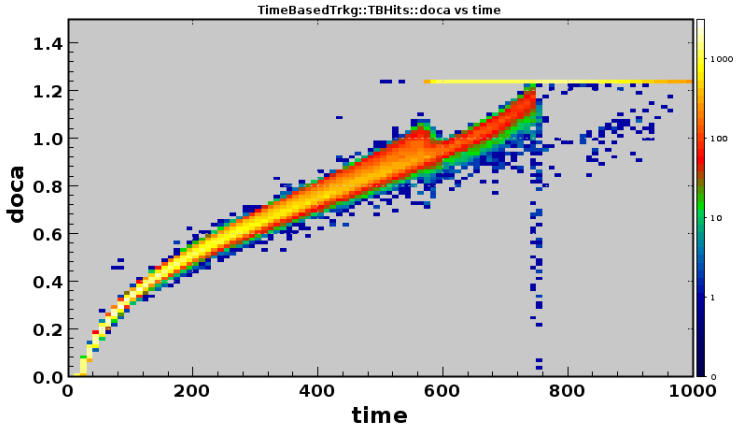


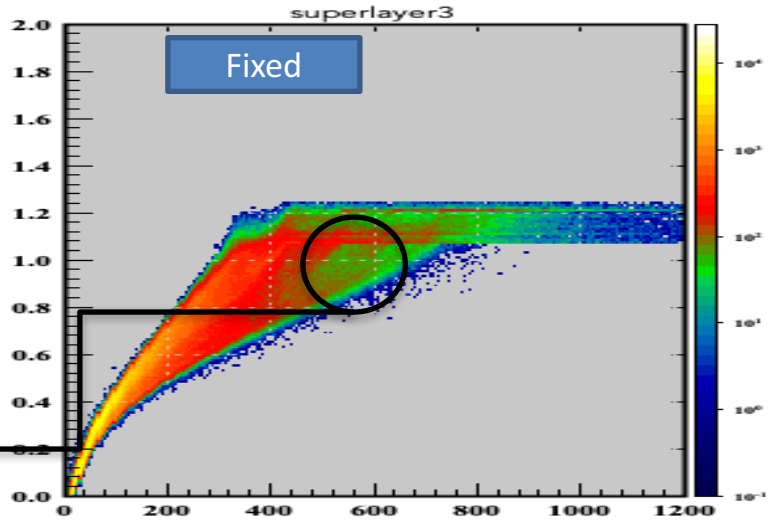
After Fixes


TimeBasedTrkg::TBHits::trkDoca vs B
trkDoca
superlayer3
TimeBasedTrkg::TBHits::doca vs B
doca
superlayer3

Collection of Tracking Anomalies (continued)

Name	A ‘bite’ out of the hit distribution		
Date ?	Run 4013	Detector SL3	Plot: doca vs. time
Symptom	A big ‘chunk’ of hits is missing		
Problem cause? (empty bins near Dmax)	???? on the FBI list of unsolved tracking anomalies ????		

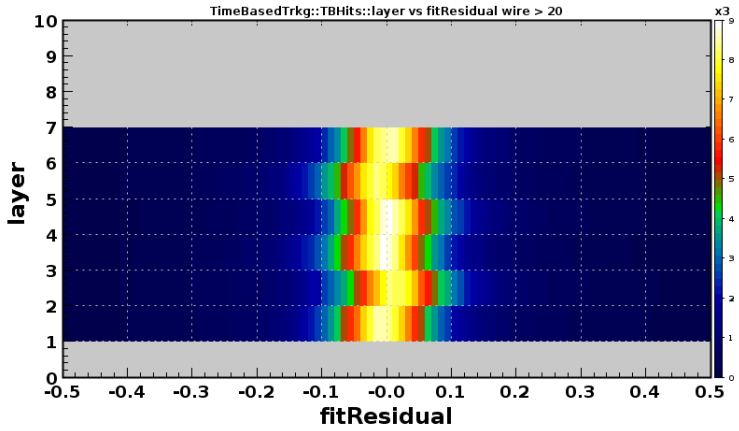




Curvature not modelled well enough ➔
Plan to use polynomial functional form for distance to time function

Collection of Tracking Anomalies (continued)

Name	Remnant “mini-stagger”		
Date 11/26/2018	Run 5036	Detector DC: SL5	Plot: Layer vs. fitresidual
Symptom	Layer to layer mini-stagger of ~ +/- 100 μm		
Problem cause? (guess)	The electric field is stronger on the side to which the wire is offset which changes the time to distance function; creating an “effective ministagger”		



TO DO: put ministagger value in ccdb and modify the value to ~400 μm

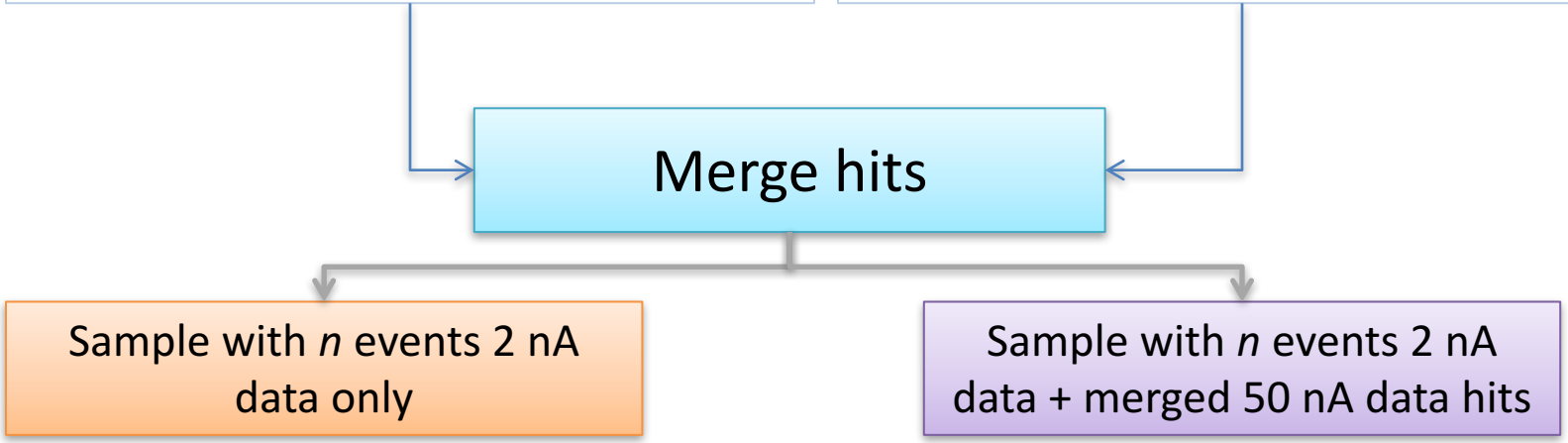
Forward Tracking *features* fixes and Track failure *recoveries*

- Tracking pathologies
  - Analysis of track failures done using *data-to-data* merging technique (next slide)
  - Development done in branch
  - Categories of pathologies
    - Background on top of cluster → noise rejection algorithm tuning
    - Failures due to ghost tracks
    - Wrong HB candidate (wrong hits on track) → subsequent TB tracking failure
    - Swimming failures (fixed using RK4 track propagator [same as KF state propagator method] using HB state vector as input)
    - Remaining fit failures
- Analysis of tracking efficiencies (see Stepan's presentation)

Background merging strategy

- 2 nA data sample
  - Filter for events with at least one TB track
  - Create sample with raw banks
    - DC TDC
    - FTOF ADC, TDC
    - …. All decoded banks

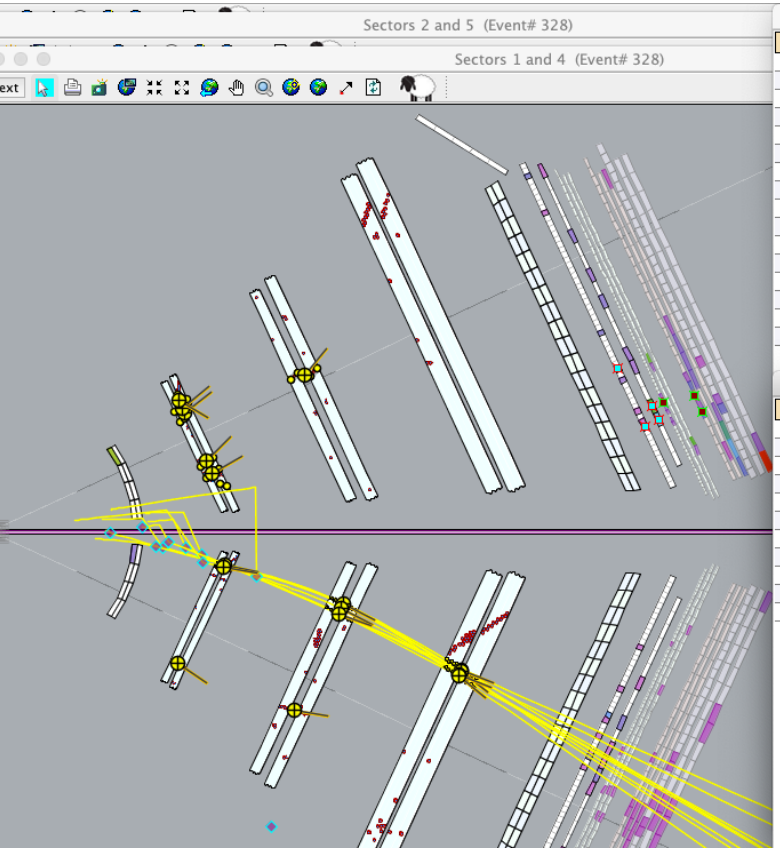
- 50 nA random trigger data
  - Filter for existing raw banks
    - DC TDC
    - FTOF ADC, TDC
    - …. All decoded banks



Efficiency losses due to wrong track selection when there are *ghost* tracks

RECOVERED

- Overlaps removal turned off.
- Failures of beta assignment from EB → recovered by using pion assumption.
- EB allowing many-to-one track to outer detector hit matching.



RECHB::Particle

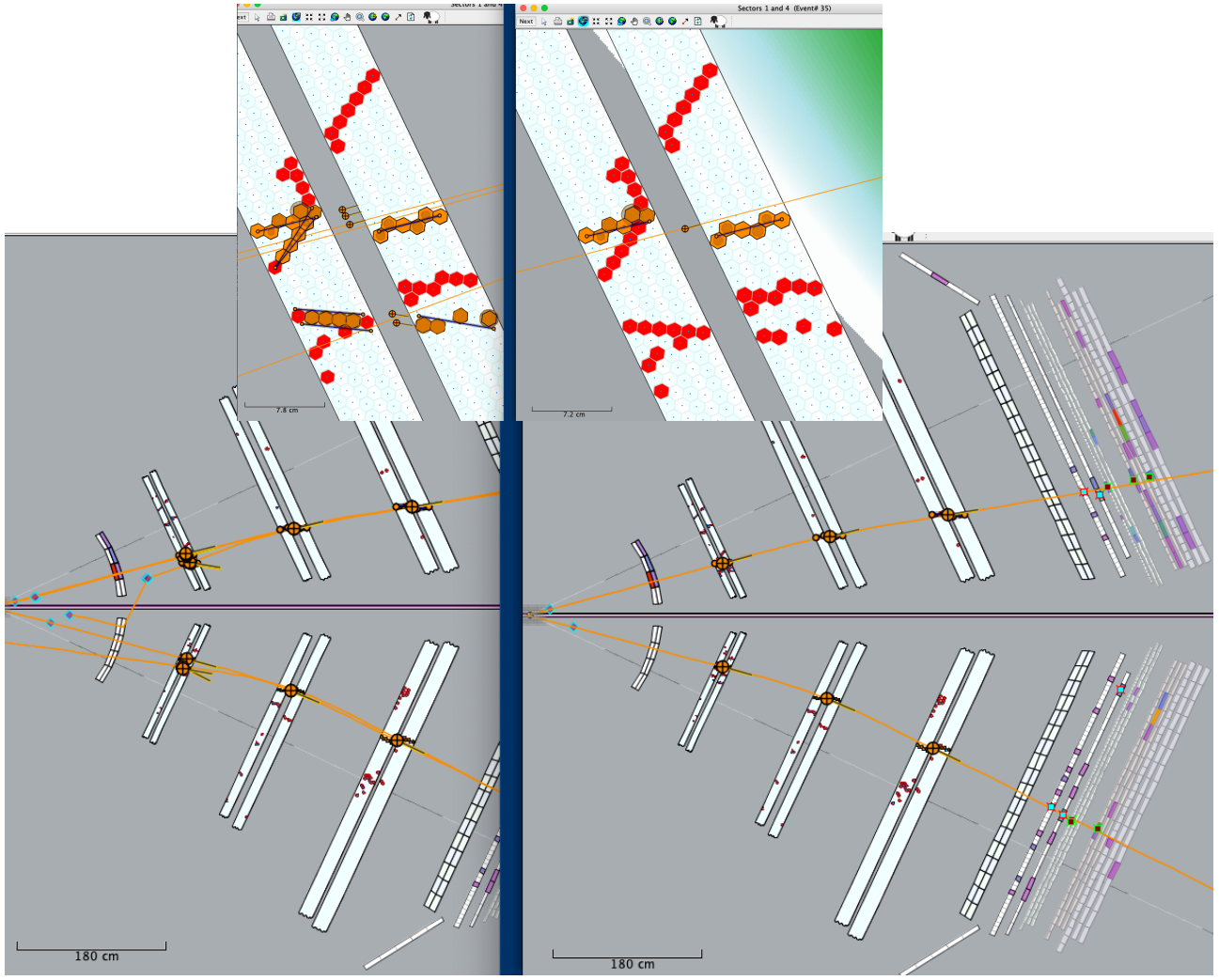
	pid	px	py	pz	vx	vy	vz	charge	beta	chi2pid	status
1	211	-0.29081	-0.17172	1.50750	1.54823	-0.89612	-5.82158	1	0.99594	-1.19794	2230
2	0	-0.66903	-0.06009	2.44199	-0.00168	0.66542	120.77356	1	-9999.00000	9999.00000	2000
3	0	-0.58295	-0.23259	2.16249	-9.27010E-4	14.61809	117.88097	1	-9999.00000	9999.00000	2000
4	0	-0.46689	0.05714	1.86689	-6.71190E-4	-8.08605	110.27516	1	-9999.00000	9999.00000	2000
5	0	-10.12515	-2.67602	23.75494	-1.79119E-4	11.96350	165.68150	1	-9999.00000	9999.00000	2000
6	0	-3.63516	-1.85177	8.76469	-0.00193	22.81193	163.32819	1	-9999.00000	9999.00000	2000
7	0	-1.91993	-0.24145	4.79342	2.62810E-4	5.62104	160.09332	1	-9999.00000	9999.00000	2000
8	0	-0.47445	-0.00107	1.92158	-0.00167	13.98806	89.20173	1	-9999.00000	9999.00000	2000
9	0	-0.80122	0.00764	2.55285	-0.00144	26.99935	126.72308	1	-9999.00000	9999.00000	2000
10	0	-0.51633	0.85475	2.23905	-6.95379	-4.01246	133.11261	1	-9999.00000	9999.00000	2010
11	45	-1.11031	-0.09341	0.71432	-0.92275	-0.07763	12.37988	1	0.65505	-3.26179	4100
12	22	0.46909	0.09021	2.48463	1.54823	-0.89612	-5.82158	0	0.99149	9999.00000	2120
13	22	-0.19556	0.24919	0.65507	1.54823	-0.89612	-5.82158	0	1.10293	9999.00000	2220
14	22	0.02523	-0.09006	0.35101	1.54823	-0.89612	-5.82158	0	1.05596	9999.00000	2010
15	22	0.05920	0.01329	0.35646	1.54823	-0.89612	-5.82158	0	1.07807	9999.00000	2110
16	11	-0.10731	-0.00792	1.37465	0.0	0.0	0.0	-1	0.0	9999.00000	1000

RECHB::Track

	index	pindex	detector	sector	status	q	chi2	NDF	px_nomm	py_nomm	pz_nomm	vx_nomm	vy_nomm	vz_nomm	chi2_nomn	NDF_nom
1	8	0	6	5	0	1	20.20510	30	-0.29081	-0.17172	1.50750	1.54823	-0.89612	-5.82158	0.0	0
2	0	1	6	4	0	1	30.68872	30	-0.66903	-0.06009	2.44199	-0.00168	0.66542	120.77356	0.0	0
3	1	2	6	4	0	1	270.32928	29	-0.58295	-0.23259	2.16249	-9.27010E-	14.61809	117.88097	0.0	0
4	2	3	6	4	0	1	11.70216	27	-0.46689	0.05714	1.86689	-6.71190E-	-8.08605	110.27516	0.0	0
5	3	4	6	4	0	1	34.13667	27	-10.12515	-2.67602	23.75494	-1.79119E-	11.96350	165.68150	0.0	0
6	4	5	6	4	0	1	163.66280	26	-3.63516	-1.85177	8.76469	-0.00193	22.81193	163.32819	0.0	0
7	5	6	6	4	0	1	64.65248	24	-1.91993	-0.24145	4.79342	2.62810E-4	5.62104	160.09332	0.0	0
8	6	7	6	4	0	1	403.09763	30	-0.47445	-0.00107	1.92158	-0.00167	13.98806	89.20173	0.0	0
9	7	8	6	4	0	1	477.45248	29	-0.80122	0.00764	2.55285	-0.00144	26.99935	126.72308	0.0	0
10	9	9	6	3	0	1	398.27798	29	-0.51633	0.85475	2.23905	-6.95379	-4.01246	133.11261	0.0	0
11	0	10	5	0	0	1	1082.95300	1	-1.11031	-0.09341	0.71432	-0.92275	-0.07763	12.37988	0.0	0

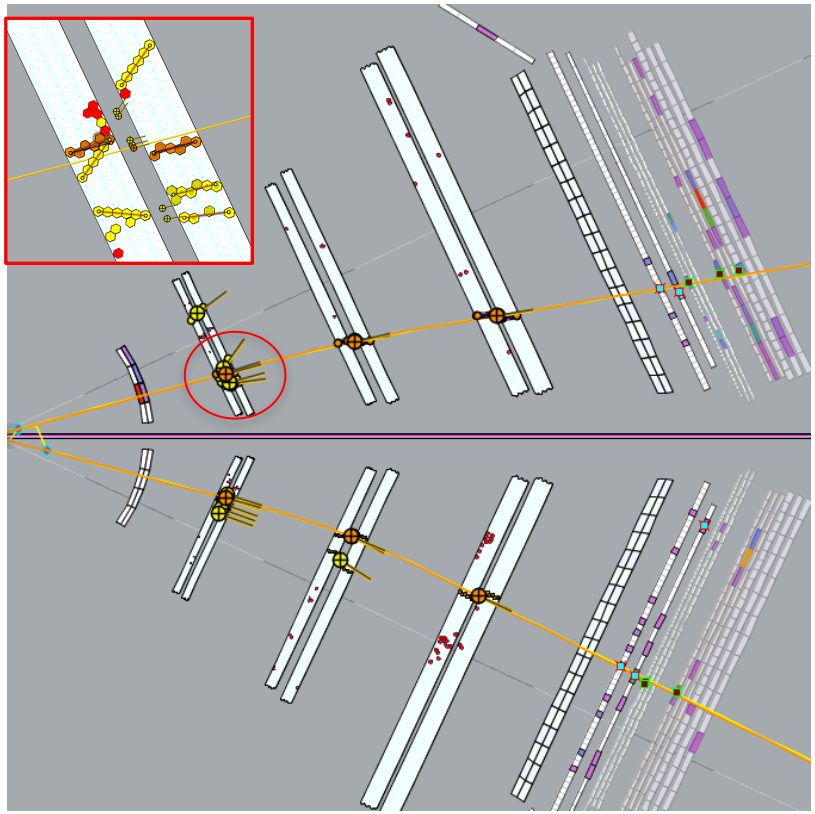
Forward Tracking *features* fixes and Track failure *recoveries*

- Improved noise rejection and cluster finder

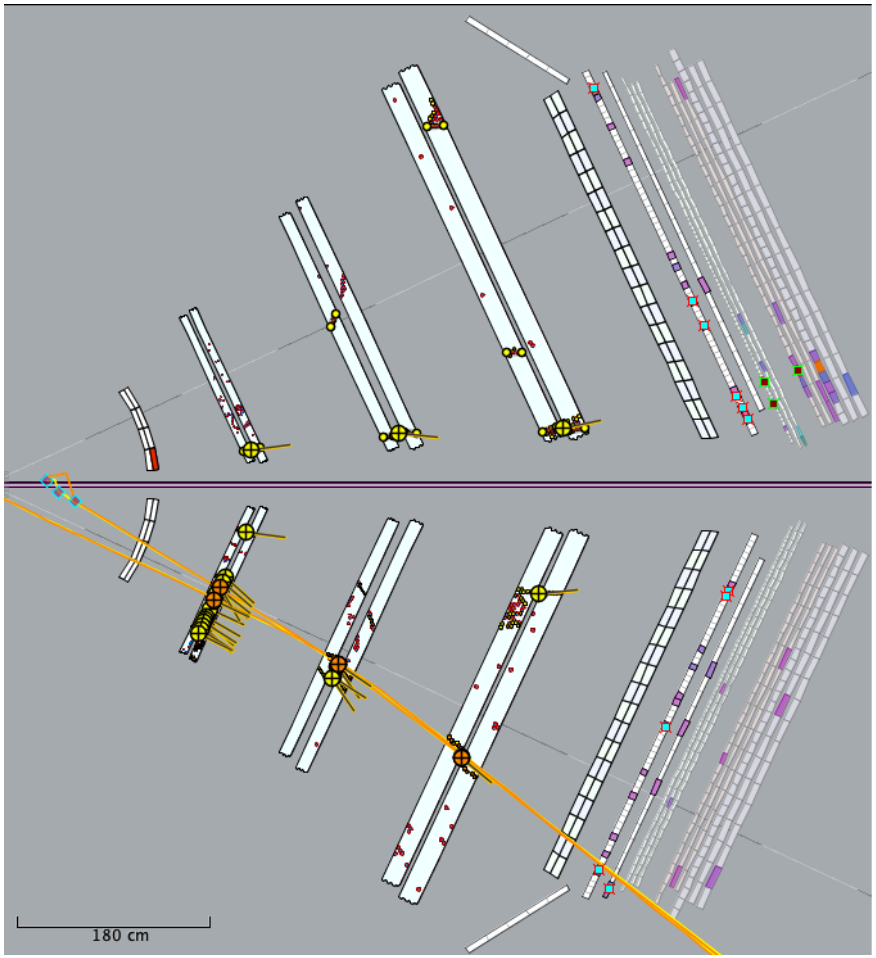


Forward Tracking *features* fixes and Track failure *recoveries*

- Use 5-OfOut-6-superlayer tracking when the track χ^2 is below cutoff value (tight cut at 50). Ensures that track not poorly reconstructed at Hit-Based level using a wrong cross. Subsequent match to crosses to find hits on track for fitting.



Investigating Remaining Failures…



- Seeding failures
  - Segments yield cross directions and position that are wrong ➔ first stage PR fails)
  - Seed parameters too far for KF to converge
- Tracking failures
  - HOTS rejected at TimeBased level → investigate time corrections
  - HB passes, TB fails
- No start time…

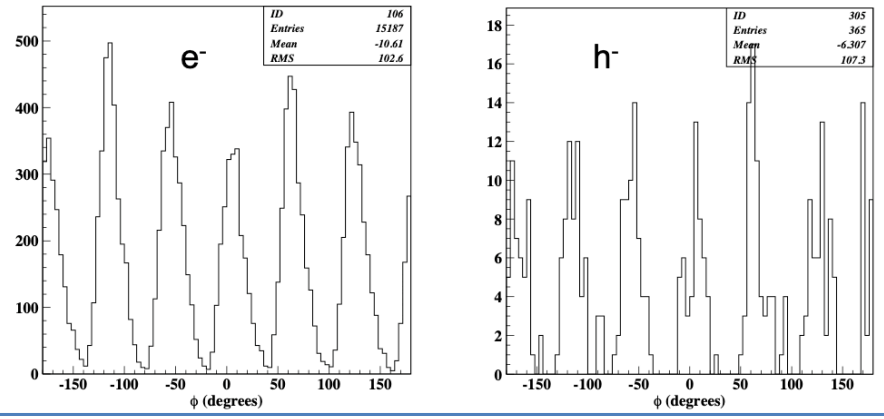
Results and Plans

~ 4% increase in e- reconstruction efficiency after selection observed in 2nA to 2+50nA merged data samples:

e-'s form the 2 nA sample as a h- or e- in the merged sample (Stepan's analysis)

Total of 15523 electrons + negative tracks, or 73% (before the last changes this number was 69%) of the original electrons were reconstructed within:

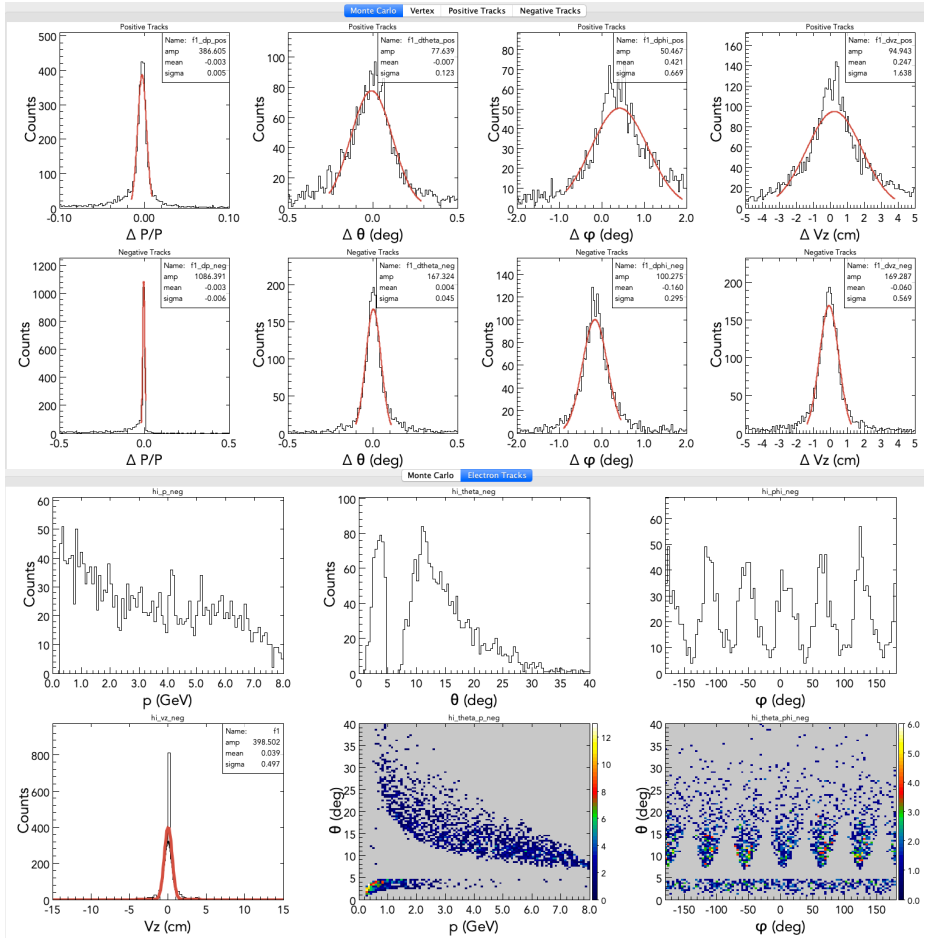
$$|\Delta p/p| < 0.5\%,\ |\Delta\vartheta| < 0.5^o \text{ and } |\Delta\varphi| < 1^o$$



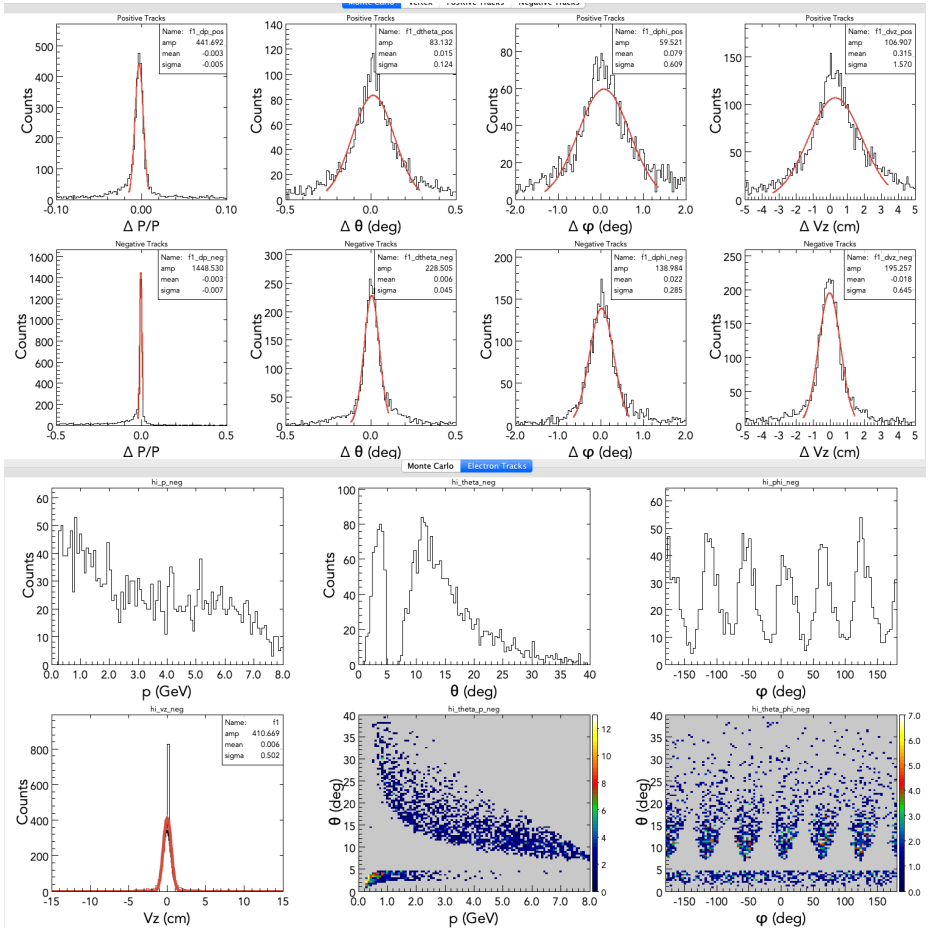
- Use tag of branch used for the developments described in this talk to recook lumi. scan.
- Continue to investigate track failure pathologies.
- Rerun efficiency studies and resolution validations at each stage of the development.

Validations & Comparison with Previous Tag

- Sidis: 5b.7.4 resolutions



- Sidis: dc-trackingEff resolutions
  - Similar resolutions
  - Much higher charged tracks tracking efficiency (study angular dependence
  - About 2% higher e- efficiency



Benchmarking Results

Sidis: 5b.7.4

```
2019-03-04 16:17:06.104: Benchmark results:
2019-03-04 16:17:06.105:   READER        10000 events    total time =    0.47 s    average event time =    0.05 ms
2019-03-04 16:17:06.105:   MAGFIELDS     10000 events    total time =    0.11 s    average event time =    0.01 ms
2019-03-04 16:17:06.105:   FTCAL         10000 events    total time =    4.76 s    average event time =    0.48 ms
2019-03-04 16:17:06.105:   FTHODO        10000 events    total time =    3.29 s    average event time =    0.33 ms
2019-03-04 16:17:06.106:   FTEB          10000 events    total time =    2.76 s    average event time =    0.28 ms
2019-03-04 16:17:06.106:   DCHB          10000 events    total time = 2125.98 s    average event time =  212.60 ms
2019-03-04 16:17:06.106:   FTOFHB        10000 events    total time =   16.01 s    average event time =    1.60 ms
2019-03-04 16:17:06.107:   EC            10000 events    total time =   11.08 s    average event time =    1.11 ms
2019-03-04 16:17:06.107:   CVT           10000 events    total time =  126.86 s    average event time =   12.69 ms
2019-03-04 16:17:06.107:   CTOF          10000 events    total time =    8.27 s    average event time =    0.83 ms
2019-03-04 16:17:06.107:   CND           10000 events    total time =   13.47 s    average event time =    1.35 ms
2019-03-04 16:17:06.108:   HTCC          10000 events    total time =    1.64 s    average event time =    0.16 ms
2019-03-04 16:17:06.108:   LTCC          10000 events    total time =    0.66 s    average event time =    0.07 ms
2019-03-04 16:17:06.108:   RICH          10000 events    total time =    0.07 s    average event time =    0.01 ms
2019-03-04 16:17:06.109:   EBHB          10000 events    total time =   11.05 s    average event time =    1.10 ms
2019-03-04 16:17:06.109:   DCTB          10000 events    total time = 1346.04 s    average event time =  134.60 ms
2019-03-04 16:17:06.109:   FTOFTB        10000 events    total time =   18.06 s    average event time =    1.81 ms
2019-03-04 16:17:06.109:   EBTB          10000 events    total time =   18.86 s    average event time =    1.89 ms
2019-03-04 16:17:06.110:   WRITER        10000 events    total time =   21.76 s    average event time =    2.18 ms
2019-03-04 16:17:06.110:   TOTAL         10000 events    total time = 3731.20 s    average event time =  373.12 ms
2019-03-04 16:17:06.110: Average processing time  =  32.26 ms
2019-03-04 16:17:06.110: Total processing time    =  322.57 s
2019-03-04 16:17:06.111: Total orchestrator time  =  333.41 s
```

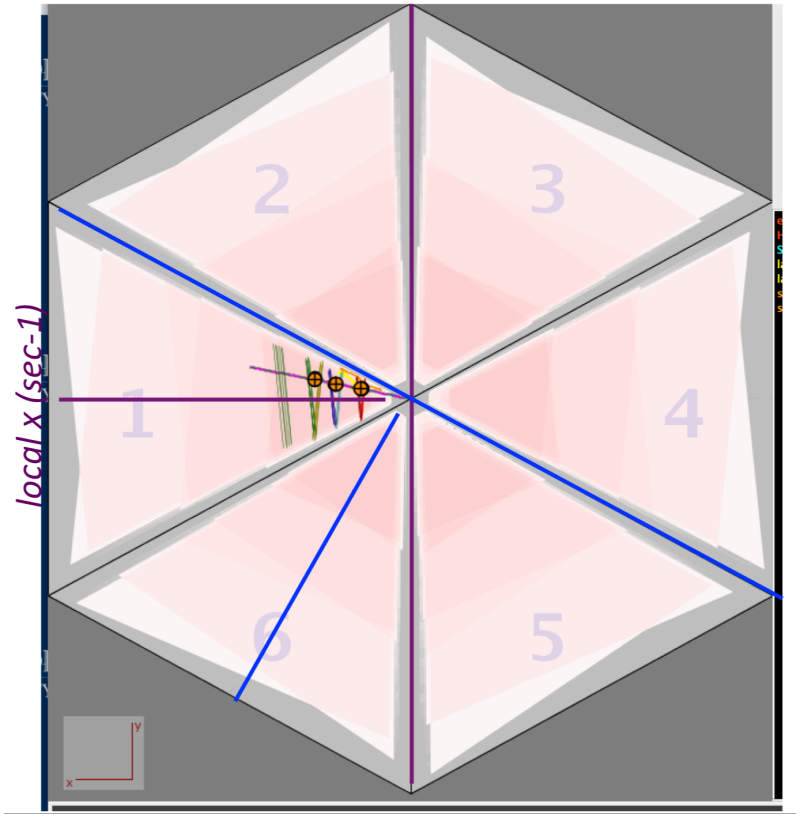
Sidis: dc-trackingEff

- Reconstruction time increase in DC tracking
- Tracking reconstruction time correlated with higher tracking efficiency

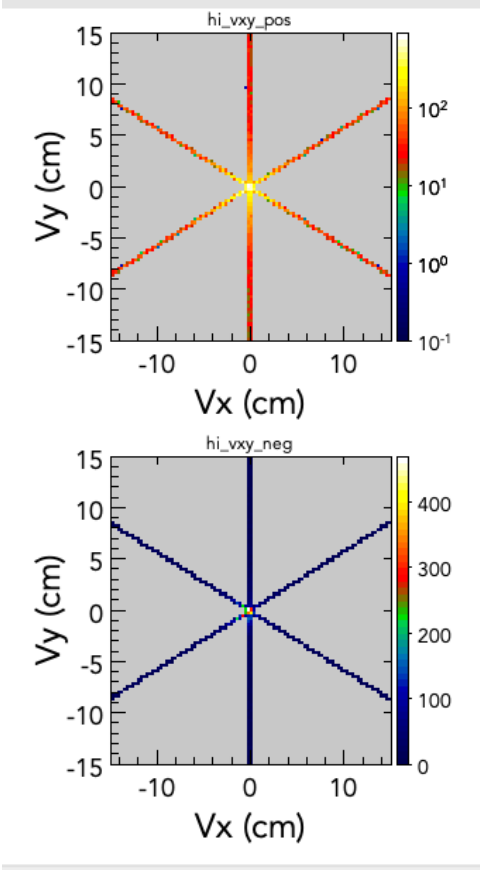
```
2019-03-04 15:29:24.224: Benchmark results:
2019-03-04 15:29:24.224:   READER        10000 events    total time =    0.45 s    average event time =    0.04 ms
2019-03-04 15:29:24.224:   MAGFIELDS     10000 events    total time =    0.11 s    average event time =    0.01 ms
2019-03-04 15:29:24.225:   FTCAL         10000 events    total time =    3.12 s    average event time =    0.31 ms
2019-03-04 15:29:24.225:   FTHODO        10000 events    total time =    2.37 s    average event time =    0.24 ms
2019-03-04 15:29:24.225:   FTEB          10000 events    total time =    1.99 s    average event time =    0.20 ms
2019-03-04 15:29:24.225:   DCHB          10000 events    total time = 2576.35 s    average event time =  257.63 ms
2019-03-04 15:29:24.226:   FTOFHB        10000 events    total time =   15.81 s    average event time =    1.58 ms
2019-03-04 15:29:24.226:   EC            10000 events    total time =   10.55 s    average event time =    1.06 ms
2019-03-04 15:29:24.226:   CVT           10000 events    total time =  111.48 s    average event time =   11.15 ms
2019-03-04 15:29:24.226:   CTOF          10000 events    total time =    7.10 s    average event time =    0.71 ms
2019-03-04 15:29:24.227:   CND           10000 events    total time =    9.69 s    average event time =    0.97 ms
2019-03-04 15:29:24.227:   HTCC          10000 events    total time =    1.49 s    average event time =    0.15 ms
2019-03-04 15:29:24.228:   LTCC          10000 events    total time =    0.63 s    average event time =    0.06 ms
2019-03-04 15:29:24.228:   RICH          10000 events    total time =    0.06 s    average event time =    0.01 ms
2019-03-04 15:29:24.228:   EBHB          10000 events    total time =   10.81 s    average event time =    1.08 ms
2019-03-04 15:29:24.228:   DCTB          10000 events    total time = 1486.81 s    average event time =  148.68 ms
2019-03-04 15:29:24.229:   FTOFTB        10000 events    total time =   17.33 s    average event time =    1.73 ms
2019-03-04 15:29:24.229:   EBTB          10000 events    total time =   18.83 s    average event time =    1.88 ms
2019-03-04 15:29:24.229:   WRITER        10000 events    total time =   23.10 s    average event time =    2.31 ms
2019-03-04 15:29:24.229:   TOTAL         10000 events    total time = 4298.06 s    average event time =  429.81 ms
2019-03-04 15:29:24.230: Average processing time  =  36.86 ms
2019-03-04 15:29:24.230: Total processing time    =  368.61 s
2019-03-04 15:29:24.230: Total orchestrator time  =  377.97 s
```

Beam Offset Parameters in Forward Tracking

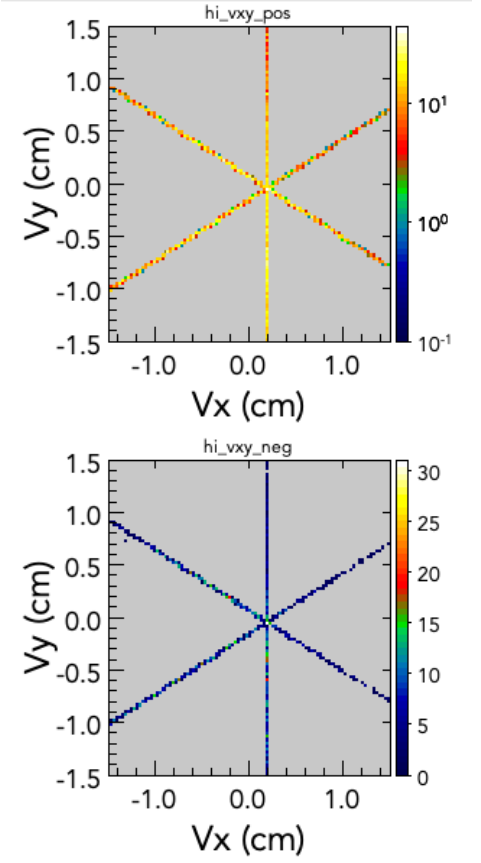
- Swim to plane perpendicular to the sector local x axis
- Move plane to contain beam axis moved by *Offset*
- Save track parameters at that plane



Before using beam offset parameters



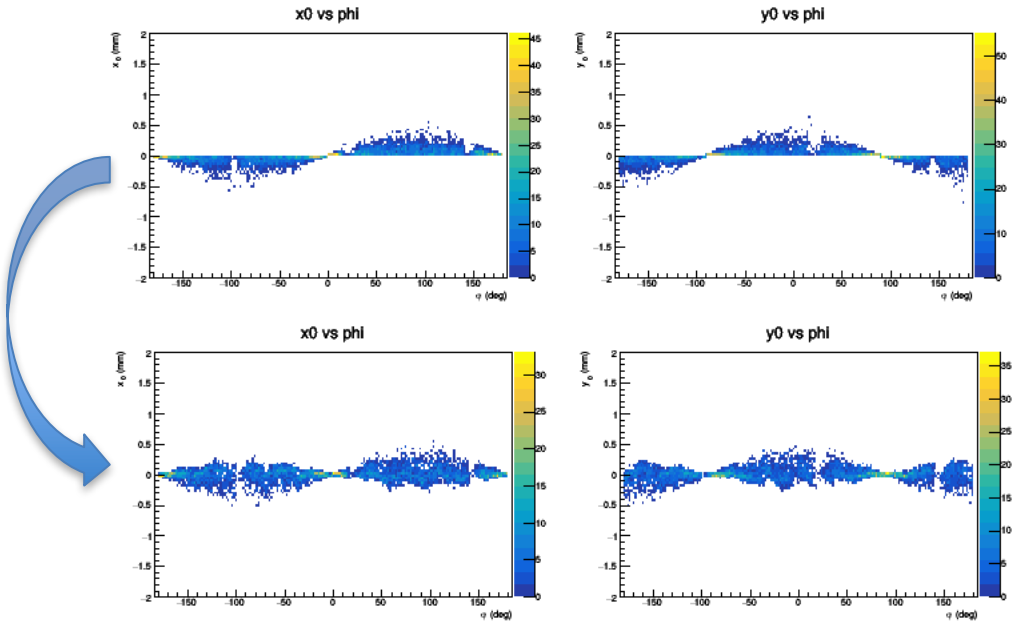
After using beam offset parameters



(Using Stepan's analysis →xb =0.202 cm, yb=-0.038 cm)

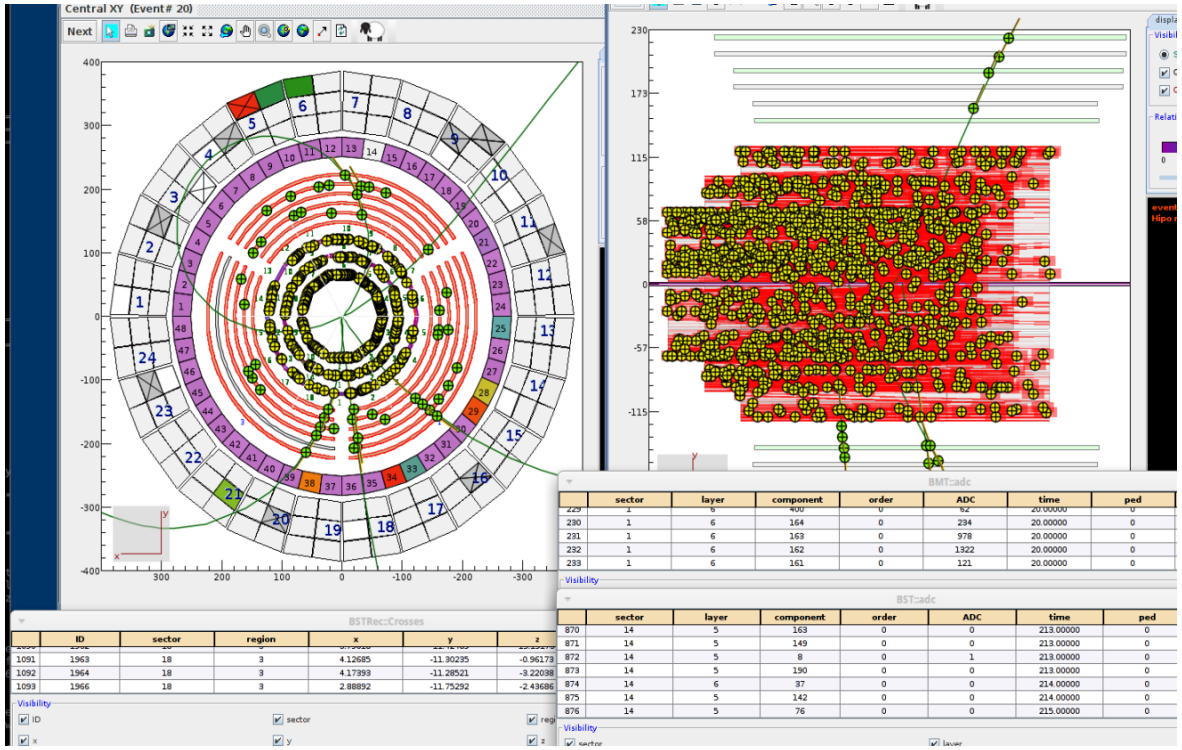
Central Tracking *features* fixes and Track failure *recoveries*

- Fixes (Francesco)
  - Last fit iteration outputting the correct χ^2
  - DOCA signed



- Cut on # hits for high background data

High Occupancy Data Analysis (Francesco)



- With cut at #hit In SVT < 1000
- Still more than 1000 crosses created (side issue, overlap of ID with BMT)
- Many events skipped, though on average ~25s/ev
- Tighter cut:
  - #svt hits < 700
  - #svt cross < 1000

New Detector Reconstruction Packages

- Central Neutron Detector completed
- FT Tracker Detector Java implementation nearly done
- Ring Imaging Detector advanced
- Backward Angle Neutron Detector (scintillator half-ring) part of service chain
- Radial Time Projection Chamber (BONuS detector for bound nucleus experiment)

Reconstruction Options

- Configuration options
  - Field Maps
  - Start time
  - DC wire distortions (being tested)
  - Different YAML files for running data or MC
  - Solenoid can be shifted in z, torus can be shifted in x,y,z; symmetric or non-symmetric torus map selection in YAML.
  - Variations
- Additional Tools
  - DC layer efficiency analysis
  - Data bg merger for tracking efficiency studies (used for forward and central tracking efficiency analysis)
  - Tracking Trigger Roads maker

    * for online, has duplicate roads counter, dictionary validation code

Outlook

- Finalize debugging of remaining reconstruction issues (TOF position-dependent corrections, vertex correction to RF, track to hit matching, trajectory bank updates, systematic tracking failures).
- Tag the current tracking development branch and recook the luminosity scan.
- Additional tracking efficiency improvements will be ongoing.