SBS Software Update

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SBS weekly meeting

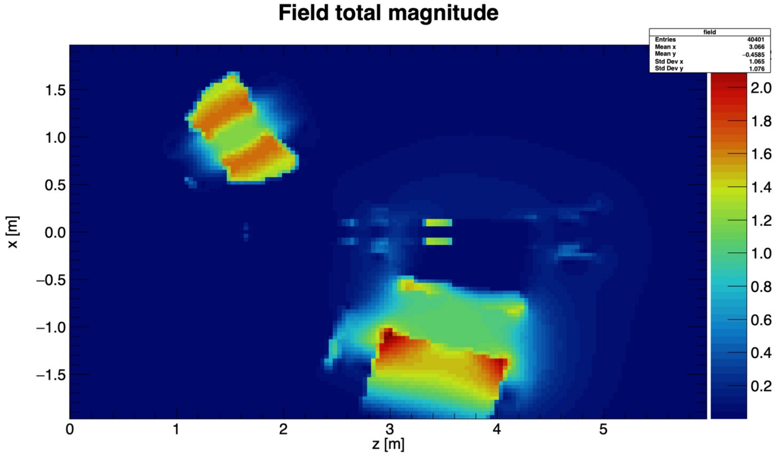
April 12, 2021

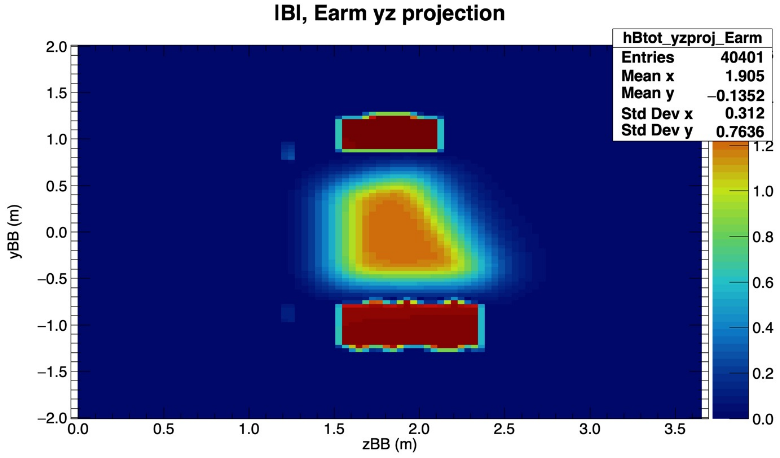
UCONN

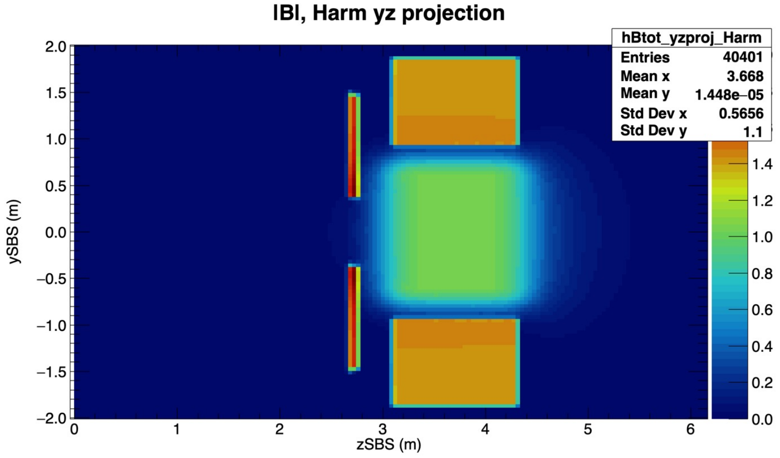
Outline

- Software status was presented at recent SBS review and collaboration meeting, see here: https://indico.jlab.org/event/430/contributions/7822/attachments/6476/8693/PuckettSBS_software_Feb2021.pdf
- Today I will highlight recent developments and progress since the collaboration meeting

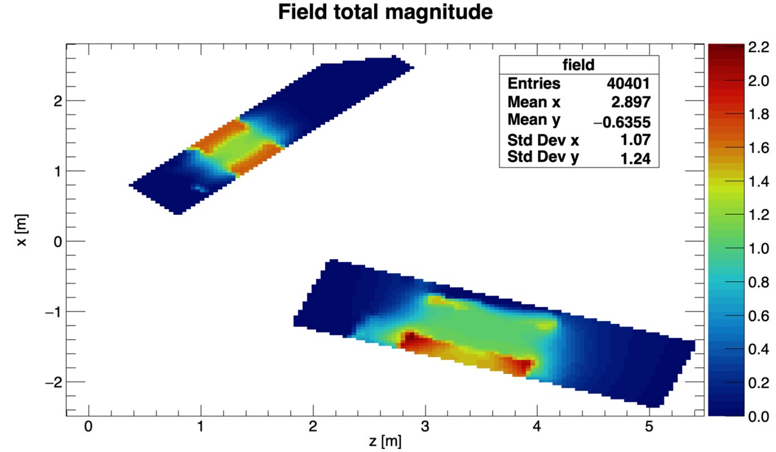
New "Portable" field maps for SBS and BigBite

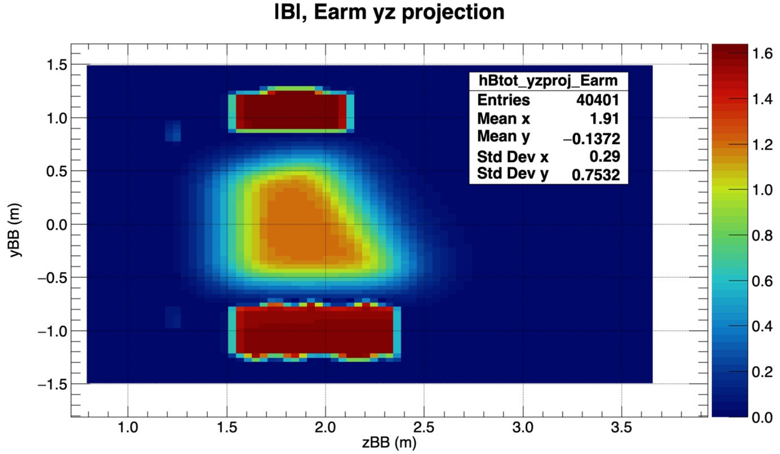


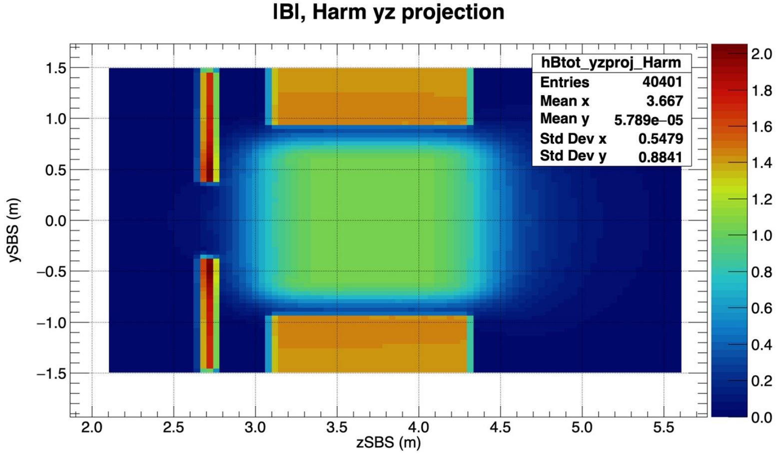




Motivation: generate accurate field maps for SBS and BB magnets that are rotatable, translatable, and scalable, and can be reused in any kinematic configuration



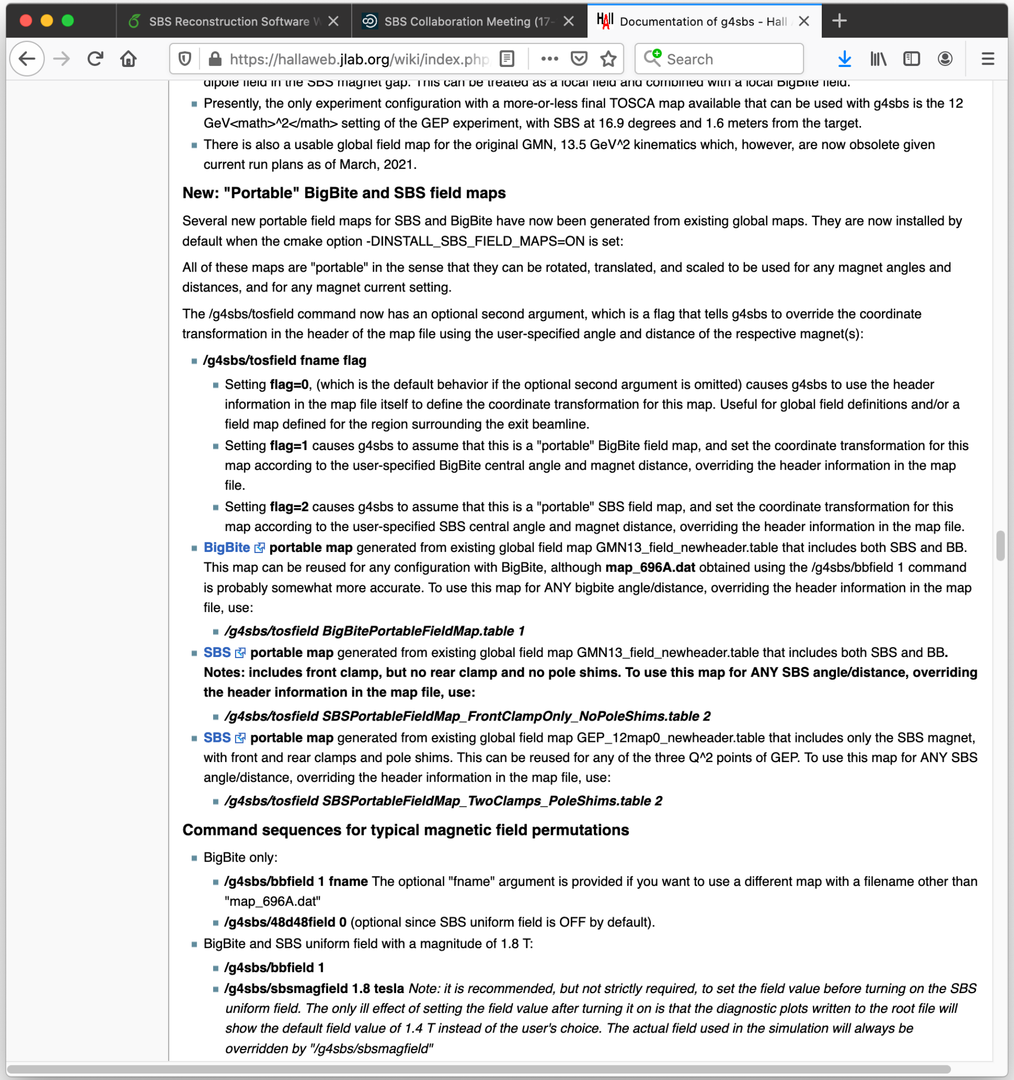




Example: portable maps generated from existing global map, rotated from 33-45 deg (BB) and 14.8-20 deg (SBS)

How to use portable field maps

- G4sbs documentation updated at:
- https://hallaweb.jlab.org/wiki/index.php/Documentation_of_g4sbs#New:_.22Portable.22_BigBite_and_SBS_field_maps
- Optional flag added to "/g4sbs/tosfield" command, which tells g4sbs to override map header information with user-specified BigBite/SBS angle and magnet distance when calculating the global coordinate transformation from map-local to g4sbs coordinates.



- Presently, the only experiment configuration with a more-or-less final TOSCA map available that can be used with g4sbs is the 12 GeV^2 setting of the GEP experiment, with SBS at 16.9 degrees and 1.6 meters from the target.
- There is also a usable global field map for the original GMN, 13.5 GeV^2 kinematics which, however, are now obsolete given current run plans as of March, 2021.

New: "Portable" BigBite and SBS field maps

Several new portable field maps for SBS and BigBite have now been generated from existing global maps. They are now installed by default when the cmake option -DINSTALL_SBS_FIELD_MAPS=ON is set:

All of these maps are "portable" in the sense that they can be rotated, translated, and scaled to be used for any magnet angles and distances, and for any magnet current setting.

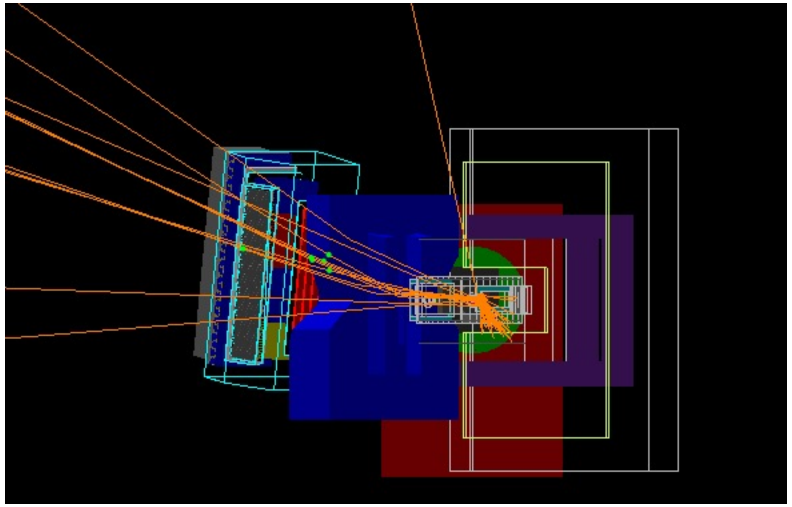
The /g4sbs/tosfield command now has an optional second argument, which is a flag that tells g4sbs to override the coordinate transformation in the header of the map file using the user-specified angle and distance of the respective magnet(s):

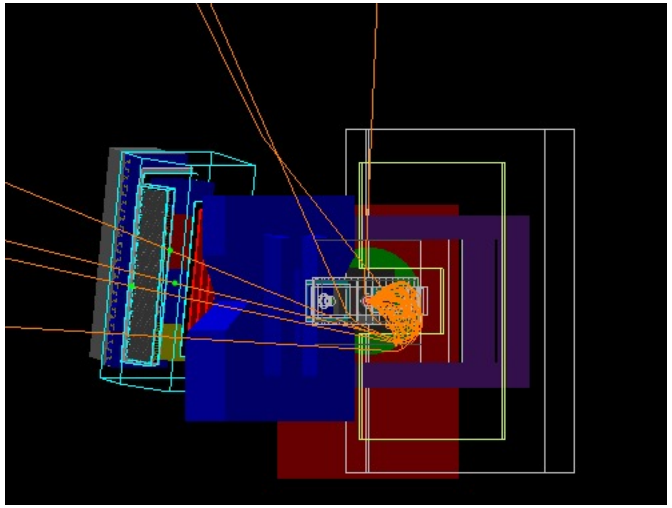
- **/g4sbs/tosfield fname flag**
  - Setting **flag=0**, (which is the default behavior if the optional second argument is omitted) causes g4sbs to use the header information in the map file itself to define the coordinate transformation for this map. Useful for global field definitions and/or a field map defined for the region surrounding the exit beamline.
  - Setting **flag=1** causes g4sbs to assume that this is a "portable" BigBite field map, and set the coordinate transformation for this map according to the user-specified BigBite central angle and magnet distance, overriding the header information in the map file.
  - Setting **flag=2** causes g4sbs to assume that this is a "portable" SBS field map, and set the coordinate transformation for this map according to the user-specified SBS central angle and magnet distance, overriding the header information in the map file.
- **BigBite portable map** generated from existing global field map GMN13_field_newheader.table that includes both SBS and BB. This map can be reused for any configuration with BigBite, although **map_696A.dat** obtained using the /g4sbs/bbfield 1 command is probably somewhat more accurate. To use this map for ANY bigbite angle/distance, overriding the header information in the map file, use:
  - ***/g4sbs/tosfield BigBitePortableFieldMap.table 1***
- **SBS portable map** generated from existing global field map GMN13_field_newheader.table that includes both SBS and BB. **Notes: includes front clamp, but no rear clamp and no pole shims. To use this map for ANY SBS angle/distance, overriding the header information in the map file, use:**
  - ***/g4sbs/tosfield SBSPortableFieldMap_FrontClampOnly_NoPoleShims.table 2***
- **SBS portable map** generated from existing global field map GEP_12map0_newheader.table that includes only the SBS magnet, with front and rear clamps and pole shims. This can be reused for any of the three Q^2 points of GEP. To use this map for ANY SBS angle/distance, overriding the header information in the map file, use:
  - ***/g4sbs/tosfield SBSPortableFieldMap_TwoClamps_PoleShims.table 2***

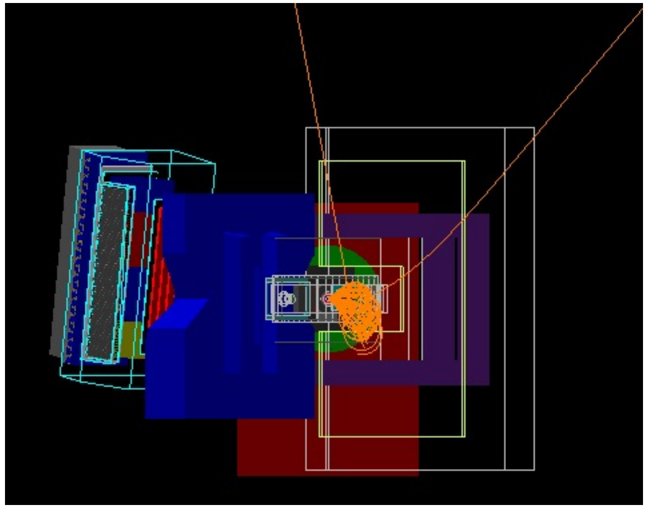
Command sequences for typical magnetic field permutations

- BigBite only:
  - **/g4sbs/bbfield 1 fname** The optional "fname" argument is provided if you want to use a different map with a filename other than "map_696A.dat"
  - **/g4sbs/48d48field 0** (optional since SBS uniform field is OFF by default).
- BigBite and SBS uniform field with a magnitude of 1.8 T:
  - **/g4sbs/bbfield 1**
  - **/g4sbs/sbsmagfield 1.8 tesla** *Note: it is recommended, but not strictly required, to set the field value before turning on the SBS uniform field. The only ill effect of setting the field value after turning it on is that the diagnostic plots written to the root file will show the default field value of 1.4 T instead of the user's choice. The actual field used in the simulation will always be overridden by "/g4sbs/sbsmagfield"*

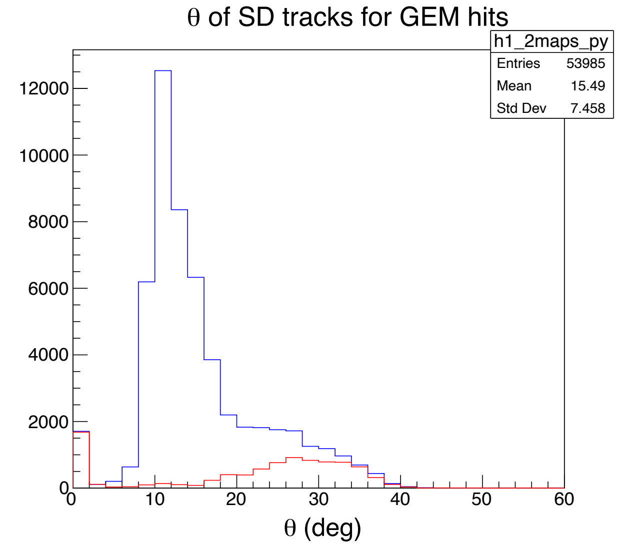
Limitations of "portable" field maps

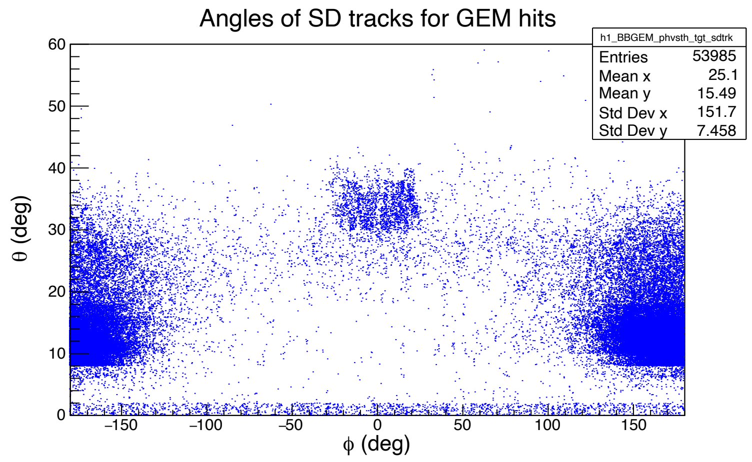


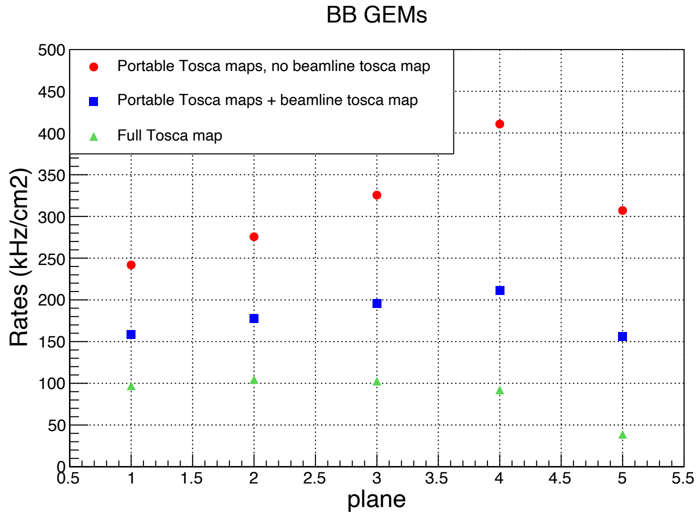




Incomplete description of fringe field and beamline field leads to spurious effects on low-energy particles → for now, portable maps should ONLY be used/trusted for physics simulations, not beam background simulations!



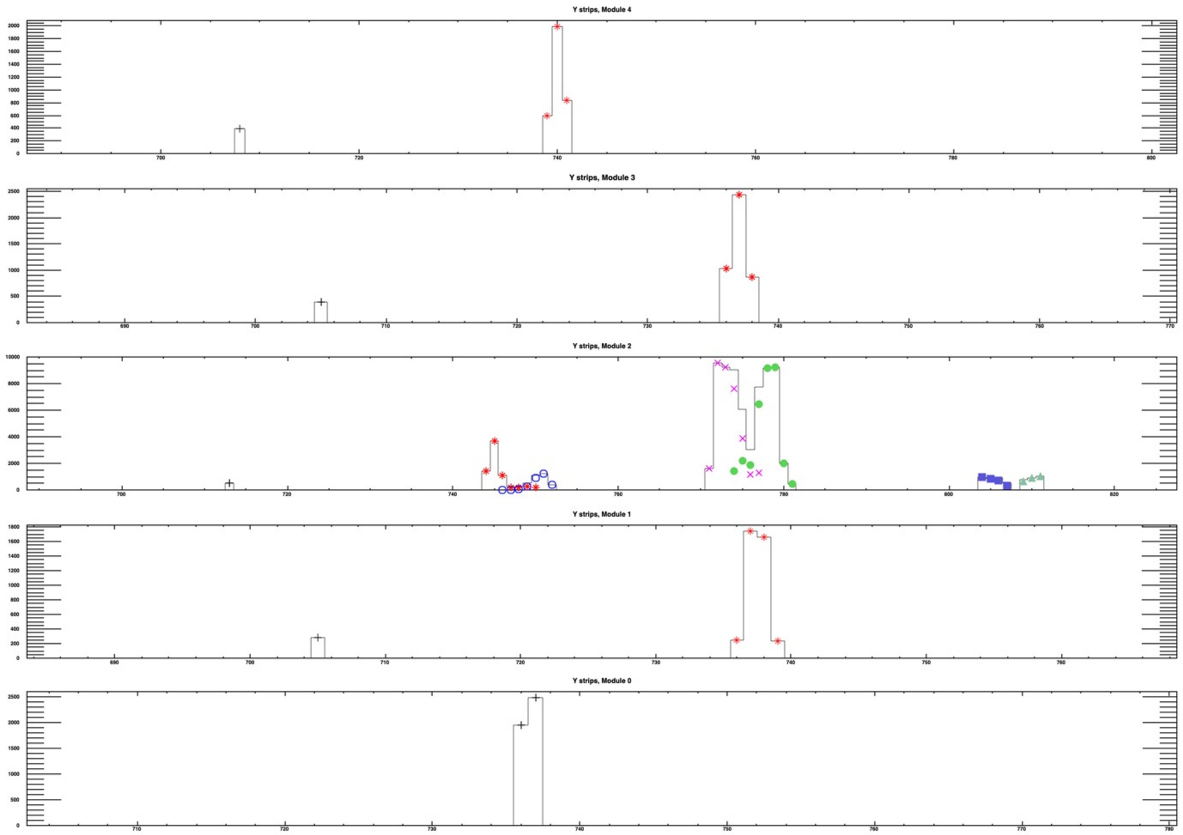


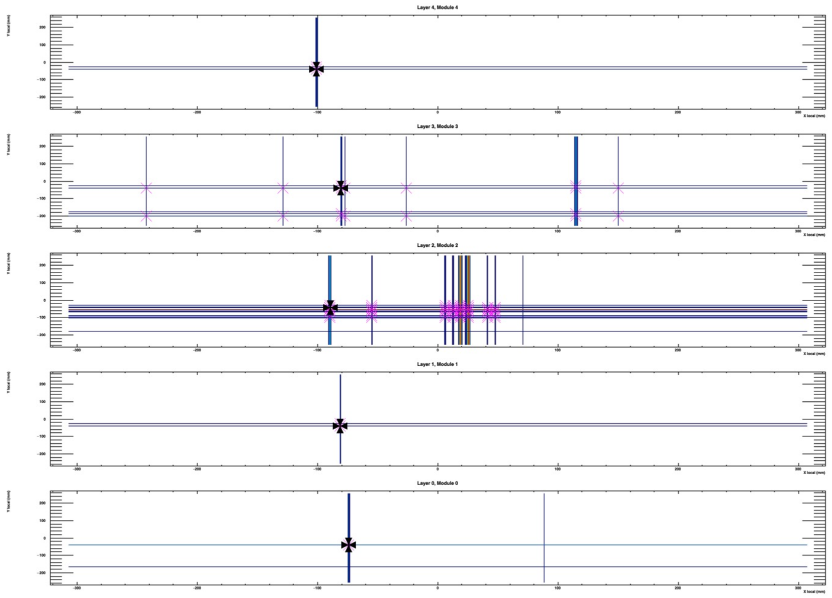


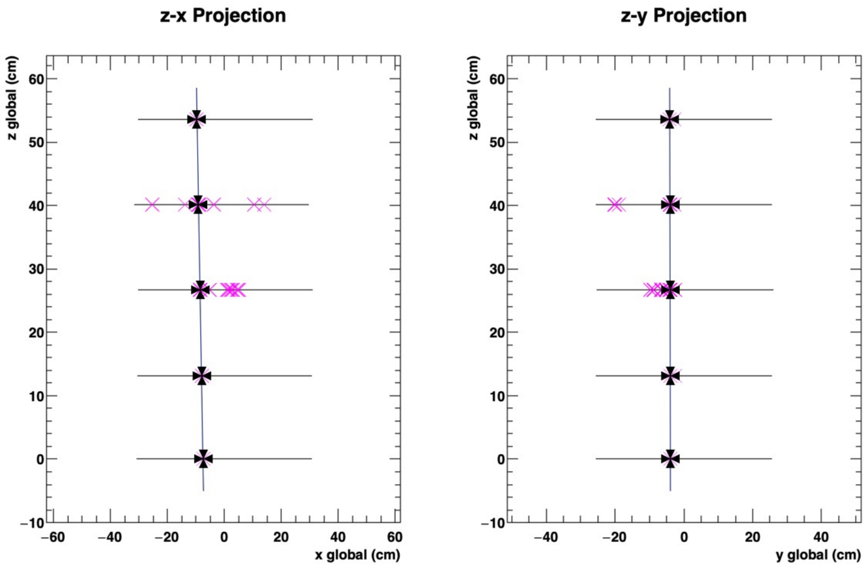
Improvements in GEM clustering

- Clustering algorithm:
  - OLD (simplified): build clusters around ALL local maxima of ADCX*ADCY, pass all possible X, Y combinations to track finding after filtering based on certain criteria (cluster size, ADC X/Y asymmetry, time correlation)
  - NEW (simplified):
    - Perform 1D clustering separately in X and Y directions (or U and V), split overlapping clusters, reject local maxima that are insufficiently "prominent" when they overlap with a nearby higher peak: peak prominence $> 5\sigma$, and $> 0.20 \times$ peak height.
    - Combine all possible X and Y clusters passing "prominence" criteria, optionally filter based on ADC X/Y asymmetry, time correlation, cluster size, etc.
  - Advantage of new clustering algorithm over old: new finds fewer clusters overall, and improves spatial resolution for overlapping clusters. Eases analysis of noisy events. Currently being tested with simulated high-rate data.

Example results of cluster-splitting algorithm, 2016 Hall A data

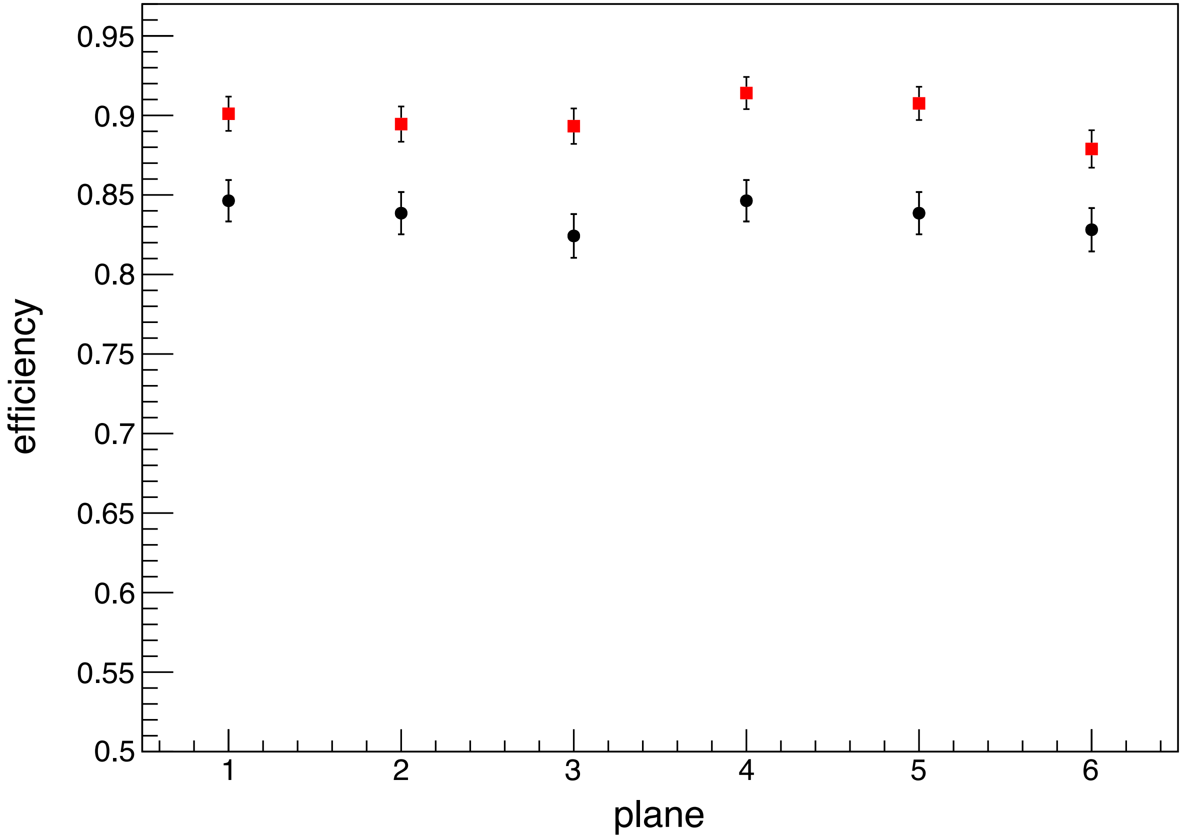


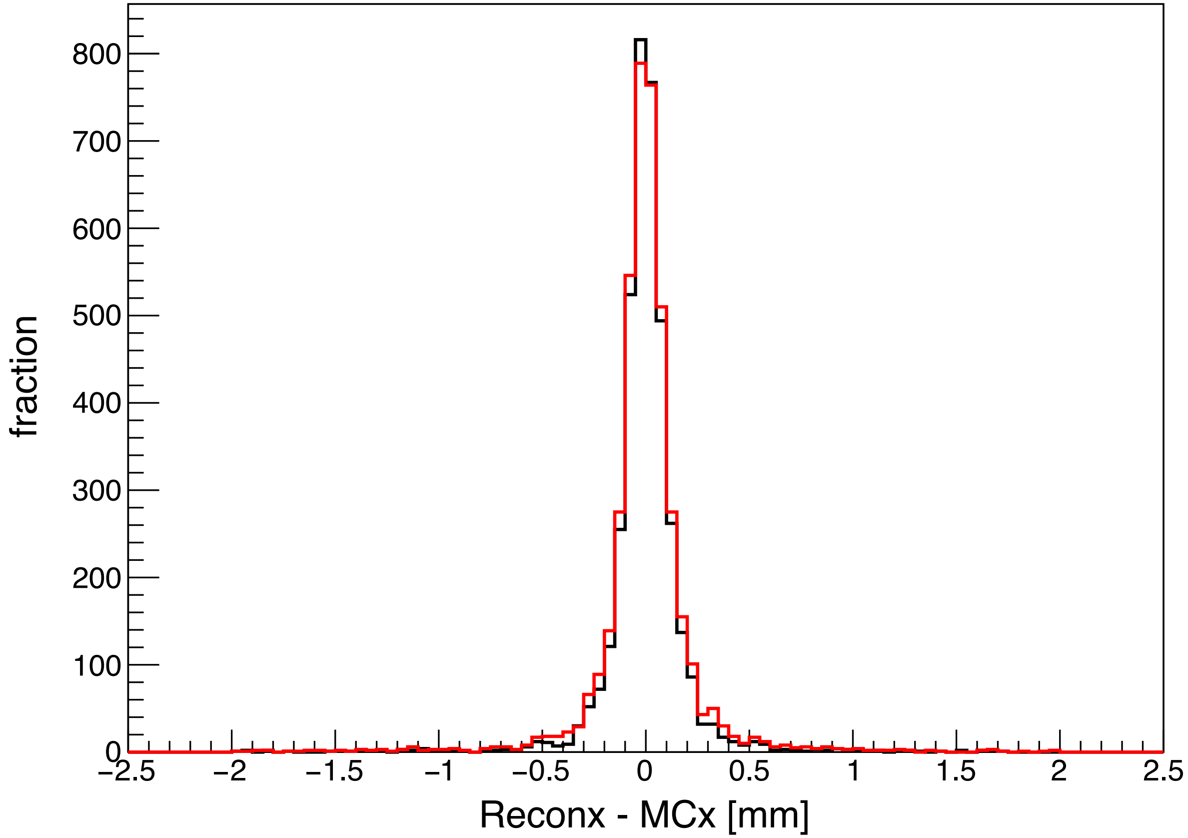




- Above: new event display component—ADC X and Y vs. strip by module. Histogram – strip ADC, colored markers = fraction of strip ADC attributed to nearby clusters (parameters for splitting algorithm need fine-tuning)

Improved hit reconstruction efficiency at high rate:





- At 20% of full luminosity of GEP (approximately 100% of GMN worst-case), new clustering improves hit reconstruction efficiency from 85% to 90% (exact reason still under investigation), without significantly changing spatial resolution (perhaps surprising)

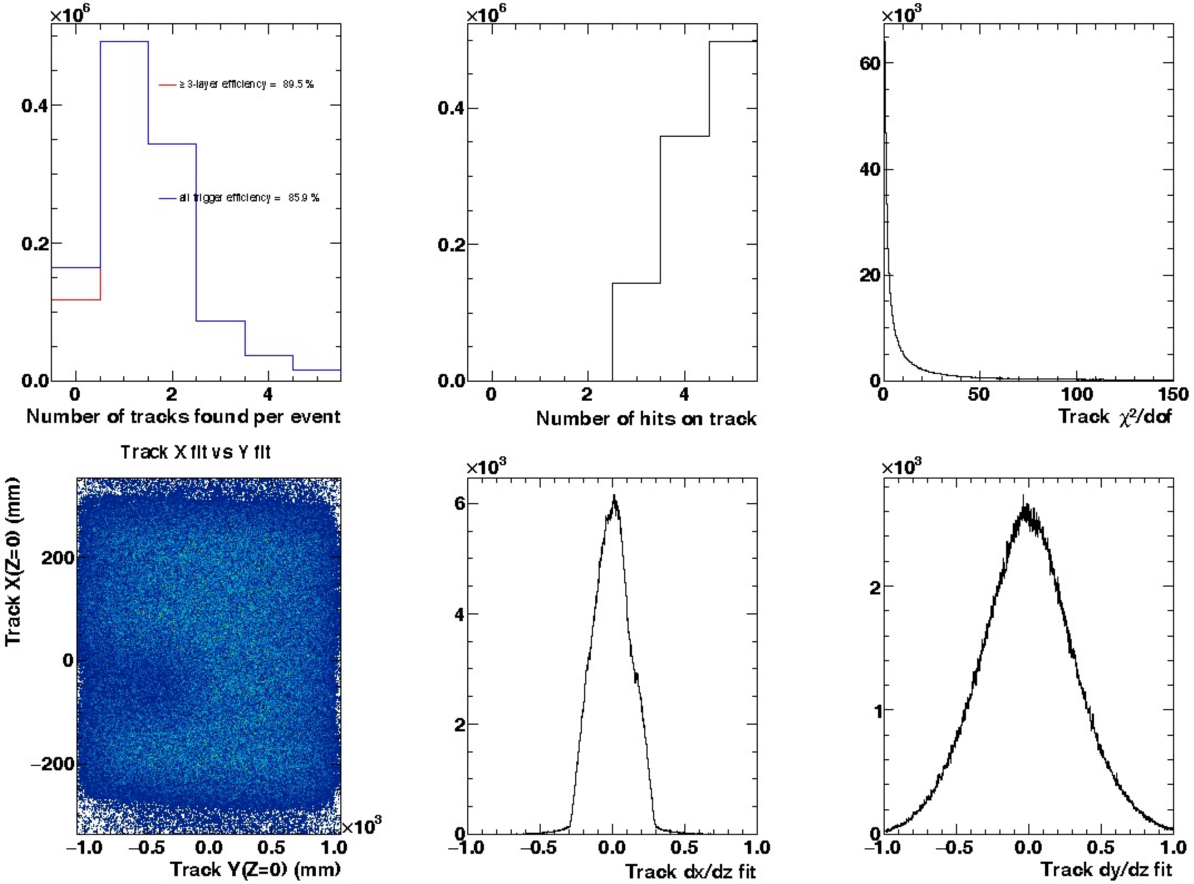
Improvements in track-finding algorithm, I

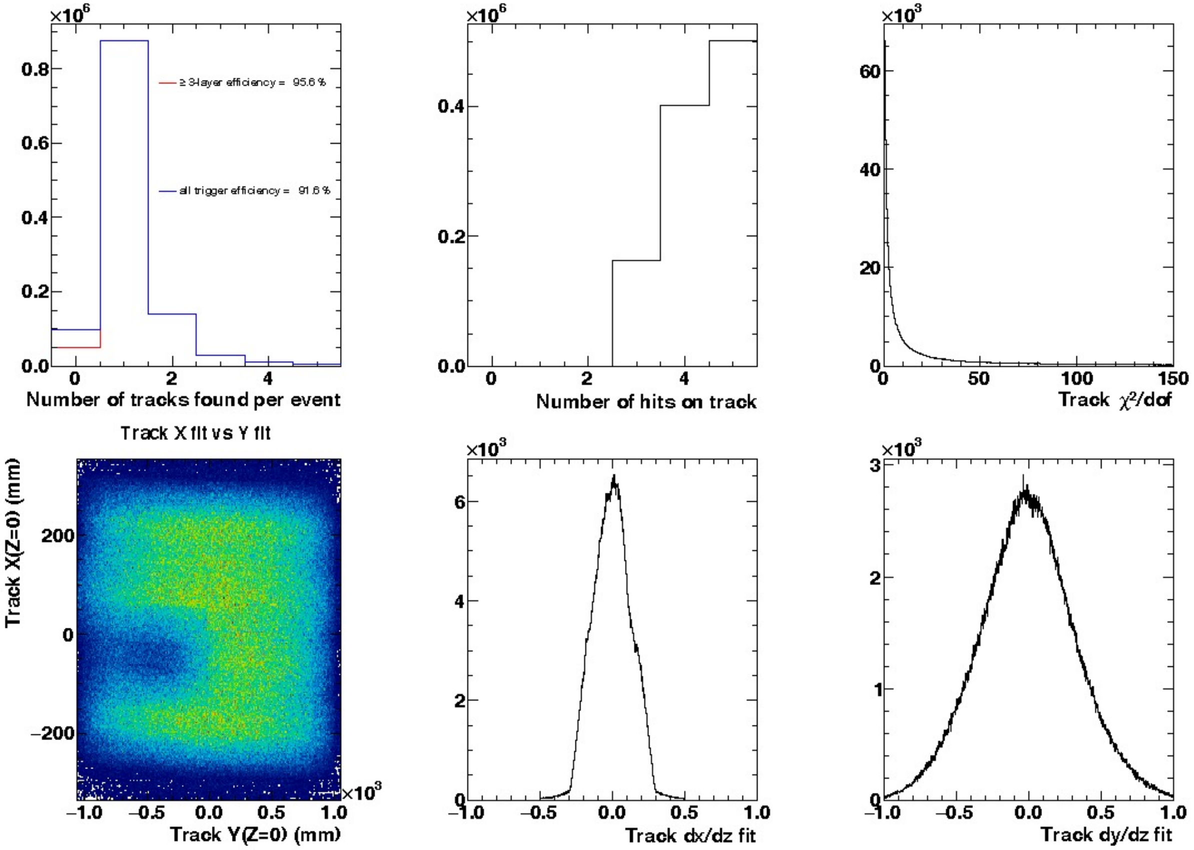
- Until recently, cosmic data were being analyzed by “brute force” track-finding algorithm which essentially considers all possible combinations of one hit per layer in any given event
- In large tracking assemblies such as the UVA 5-layer setup in the EEL clean-room, which includes 20 X/Y GEM modules, when the data are “noisy”, the combinatorics for “brute force” track finding quickly become unmanageable.
- Brute force tracking was skipping ~5-6% of events in typical cosmic runs using this setup, due to an upper limit on the number of hit combinations imposed to avoid spending an excessive amount of time processing noisy events.

Improvements in Track-finding algorithm, II

1. New track-finding algorithm starts by dividing each tracking layer into a 2D grid with bin size of 10 mm x 10 mm, and collecting a list of hits in each 2D bin.
2. Loops over all possible combinations of one hit from each of the two outermost layers—calculates a straight line passing through these two hits.
   a) Can also use other combinations of two layers if the number of hit combinations from two outermost layers is excessive
3. Projects candidate track to intermediate layers, calculates the bin within the 2D grid where the projected track falls.
   a) If the track projection is close to the edge of the bin, it also considers hits in neighboring bins.
4. Loop over all the hits in the relevant 2D bins at each layer, find the hit closest to the projected track
5. On first track-finding iteration, require N layers, if no good tracks found at N hit requirement, repeat with hit requirement N-1, as long as the hit requirement is 3 or more.
6. When good tracks are found, mark all hits as used, and additionally mark all other 2D clusters formed from the 1D X and Y clusters on the track as used, to avoid reusing the same 1D X and Y hits in multiple tracks.
   a) This is very useful in avoiding spurious “multi-track” events where the code is finding several tracks that aren’t really unique, and are really the same track
7. Non-brute force method allows us to analyze noisier events from 5-layer UVA GEM cosmic stand, without skipping any events due to prohibitive combinatorics, recovering ~5-6% of events that were simply skipped by the brute-force methods.

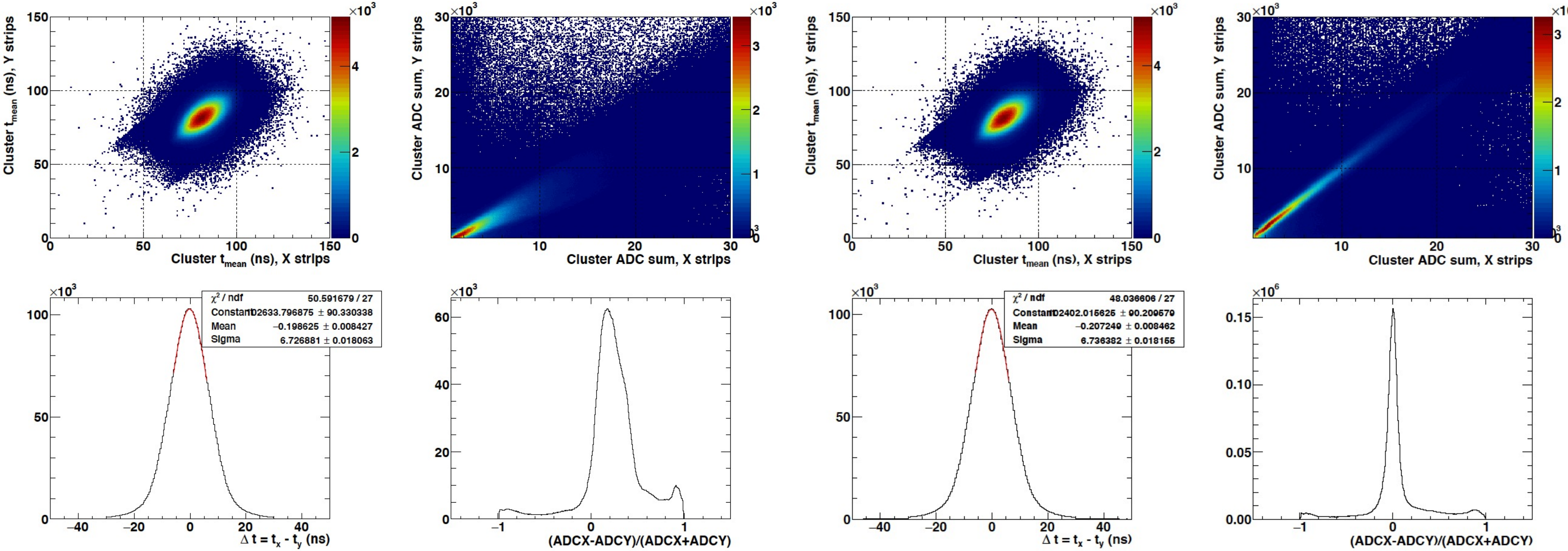
Improved tracking performance





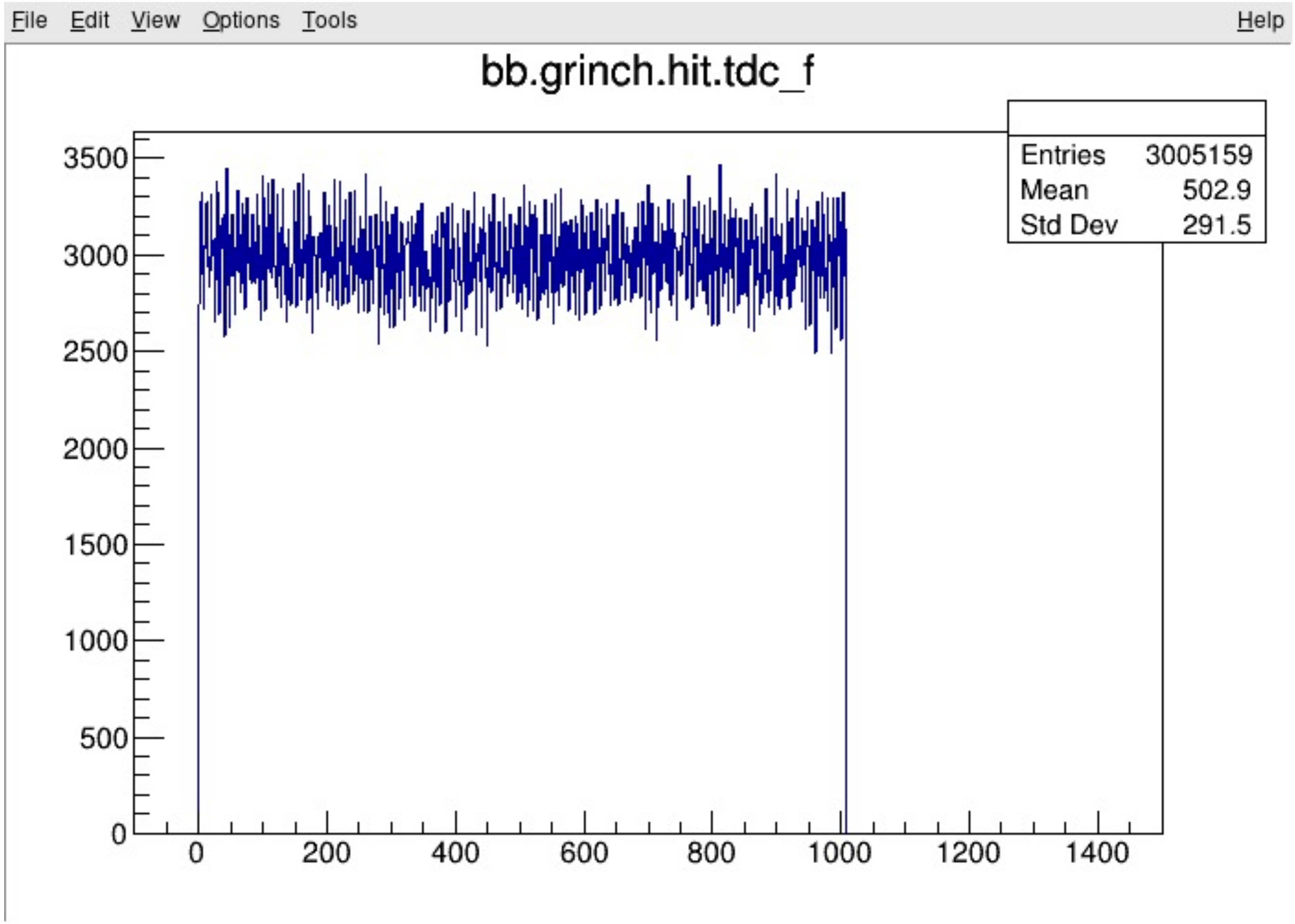
- Unfortunately this is not a perfectly "apples-to-apples" comparison, but typical improvement in "tracks/triggers" ratio and "tracks/events with at least 3 layers fired" efficiencies with new tracking algorithm is ~4-6%, depending on noise conditions, etc.
- Dramatic reduction of average track multiplicity, spurious "multi-track" events

Software “gain match” of GEMs



- Developed machinery to fit “relative gain” coefficients by individual APV cards based on ADC asymmetry, to allow better filtering by ADC X/Y asymmetry, etc.
- Preliminary results encouraging.

GRINCH VETROC decoder working in SBS-offline



Thanks to efforts of Bradley Yale and Juan-Carlos Cornejo

Other progress/ongoing efforts

- Juan Carlos Cornejo: “SBS generic detector” class, abstract base class for all PMT-based detectors, in principle takes care of decoding of raw ADC/TDC data (and ROOT output for such) for every detector, saves work for subsystem developers
- E. Fuchey/Weizhi Xiong: improving speed of GEM digitization by using less computationally expensive algorithm
- P. Datta: Adding “pulse shape” information for ”calorimeter” and “PMT” sensitive detector types in g4sbs