# SoLID Track Reconstruction

Ole Hansen

Jefferson Lab

with Seamus Riordan & Rich Holmes

SoLID Collaboration Meeting
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# SoLID Tracking Considerations

Challenges:

- High rates: $\mathcal{O}(1\ \text{MHz/cm}^2) \rightarrow$ high expected occupancies
- Real-time processing required for level-3 trigger
- Parity experiment: pay attention to possible helicity-dependent systematics

Approach:

- Use GEMs
- Learn from SBS
- Thoroughly simulate tracking

# Track Reconstruction Algorithm Candidates

- Xin's Progressive Algorithm (Kalman filter)
  - Pros
    - ⋆ Allows for arbitrary track curvature (if parameterization available)
    - ⋆ Already shown to be feasible for PVDIS/SIDIS rates
  - Cons
    - ⋆ Needs seed (*e.g.* calorimeter hit)
    - ⋆ Slow: $\approx \mathcal{O}(Nk^2)$
    - ⋆ Not yet implemented in Hall A analyzer
- TreeSearch (global recursive template matching)
  - Pros
    - ⋆ Efficient. High speed: $\mathcal{O}(\log N)$. Small memory footprint: $\mathcal{O}(10\text{ MB})$
    - ⋆ No seed needed
    - ⋆ Available in Hall A analyzer
    - ⋆ Successfully used with BigBite and SBS simulations
  - Cons
    - ⋆ May not fully solve the problem: requires (nearly) straight tracks
    - ⋆ Allowing for small track curvature adds complexity
    - ⋆ Code must be adapted to SoLID geometry

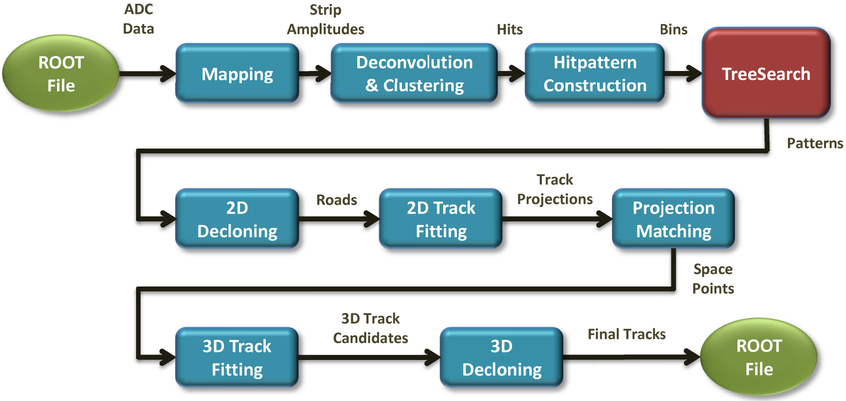
# SoLID Track Reconstruction: 1$^{st}$ attempt

Decided to investigate TreeSearch approach first

## Key advantages

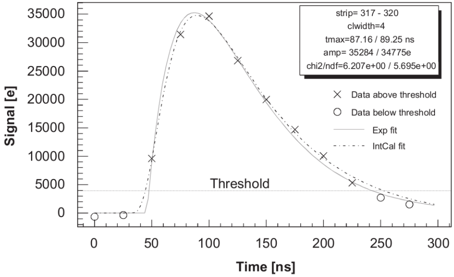
- High speed, essential for level-3 trigger processing
- Code is largely written, well understood & debugged
- Could serve as preprocessor for a subsequent Kalman filter

# Full TreeSearch GEM Track Reconstruction Chain



# APV25 Pulse Shape Deconvolution & Noise Filtering

S. Gadomski *et al.*, NIM A 320, 217 (1992)




- For first-order RC circuit, signal amplitudes $s_k$ can be deconvoluted using three measured values $v_k$:

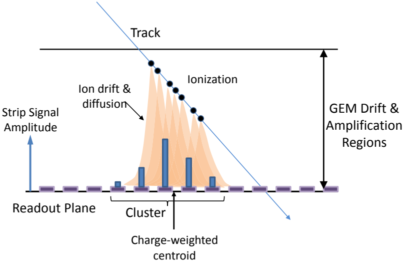
$$s_k = w_1 v_k + w_2 v_{k-1} + w_3 v_{k-2}$$

$$w_1 = e^{x-1}/x, w_2 = -2e^{-1}/x, w_3 = e^{-x-1}/x, \text{ where } x = \Delta t/T_p$$

$$A \approx \sum_{k=1}^{3} s_k$$

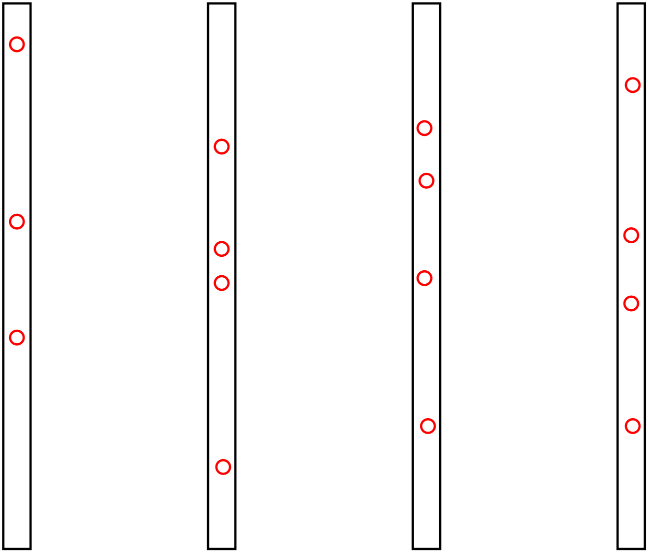
- Reject noise by cutting on ratios, $r_1 = v_3/v_1$ and $r_2 = v_2/v_1$, requiring rising slope

# GEM Hit Clustering

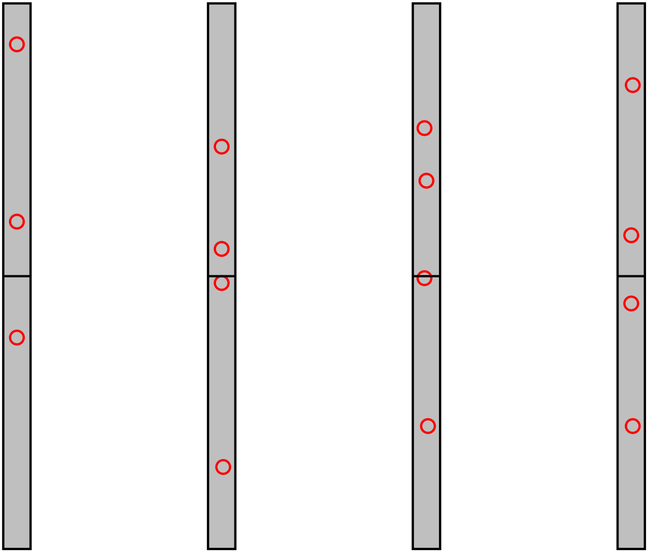



- Signals on adjacent readout strips typically belong to a single track crossing
- Sum signals to get
  - Total hit amplitude
  - Charge-weighted position centroid
- Currently use simple algorithm:
  - Look for local peak
  - When sequence "peak-valley-peak" is seen, split cluster at "valley"
  - Regardless of shape, limit clusters to a maximum size
- Improvements
  - Match hits by their pulse shape, *i.e.* timing centroid
  - Redo clustering after preliminary tracking (*e.g.* better cluster splitting)
  - . . . possibly more
- *NB:* Clustering does not necessarily have to be separate from tracking, could be integrated into a progressive tracking algorithm

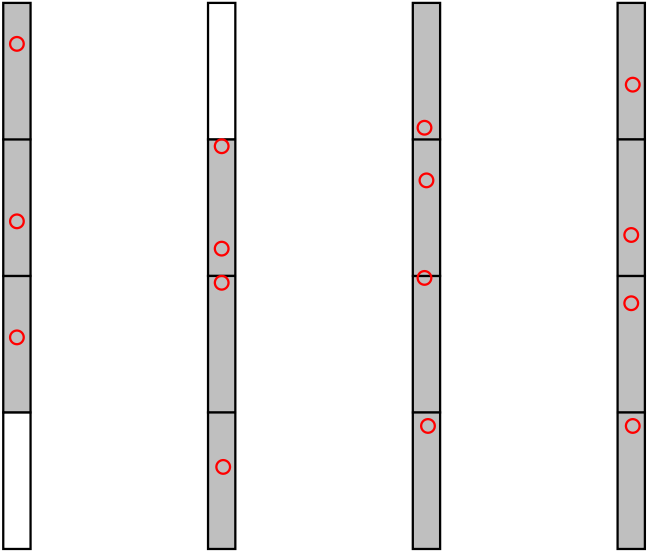
# TreeSearch Illustration: Hits in One Coordinate



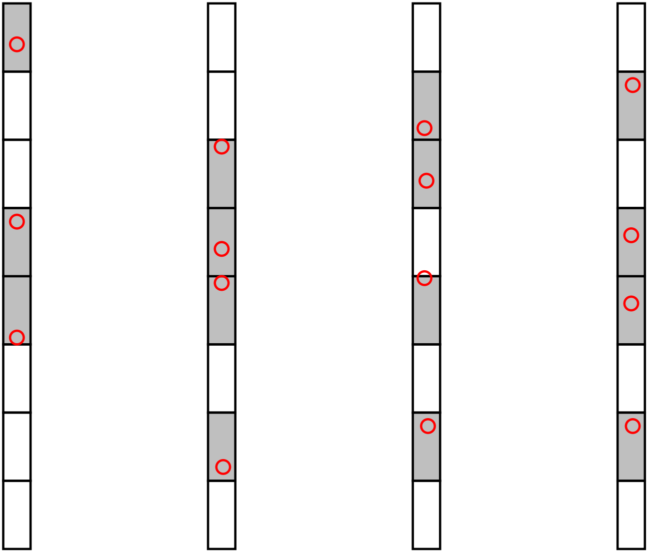
# TreeSearch Illustration: Level 1 Hitpattern



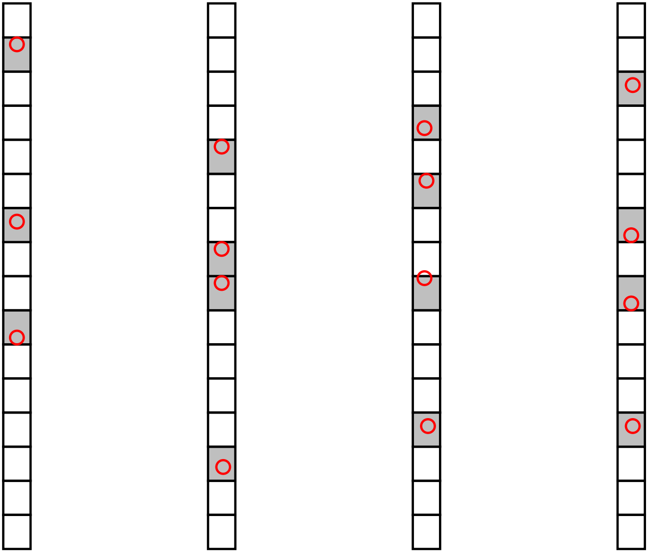
# TreeSearch Illustration: Level 2 Hitpattern



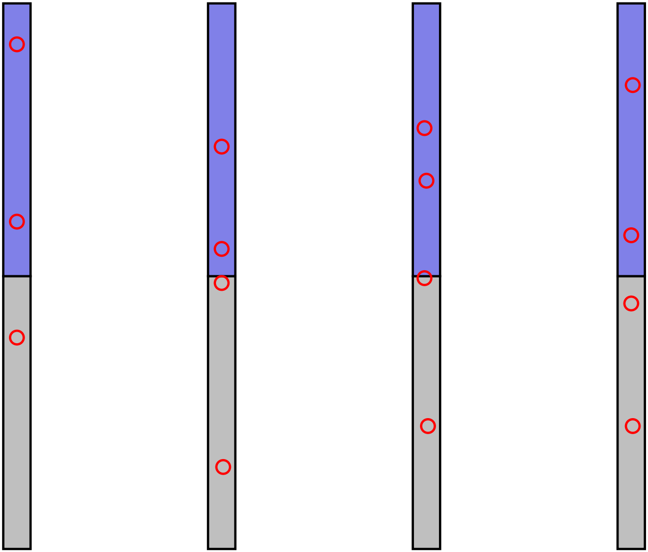
# TreeSearch Illustration: Level 3 Hitpattern



# TreeSearch Illustration: Level 4 Hitpattern



# TreeSearch Illustration: Level 1 Pattern Match



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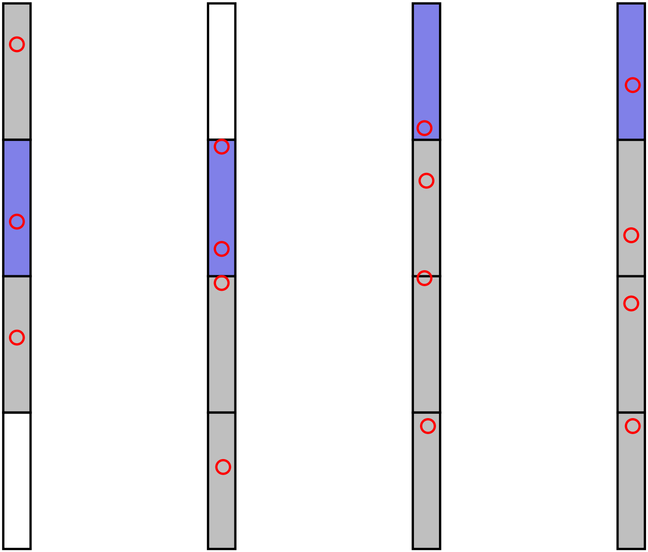

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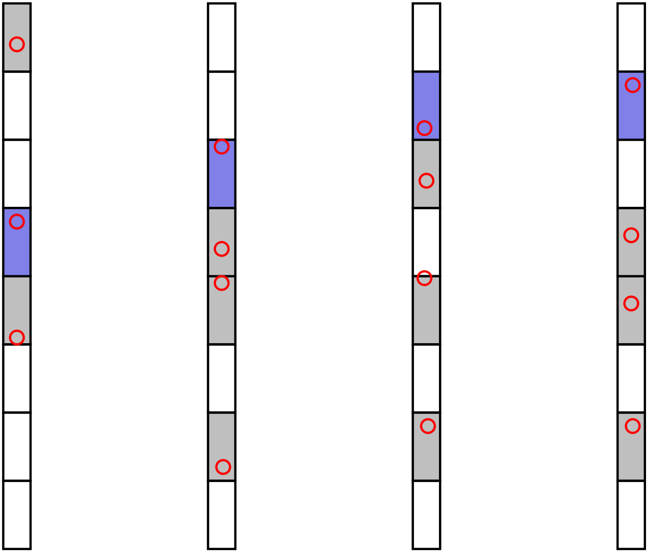
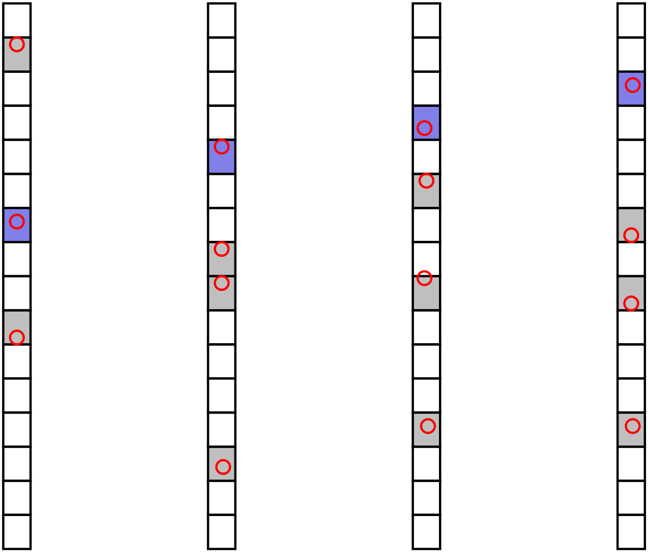
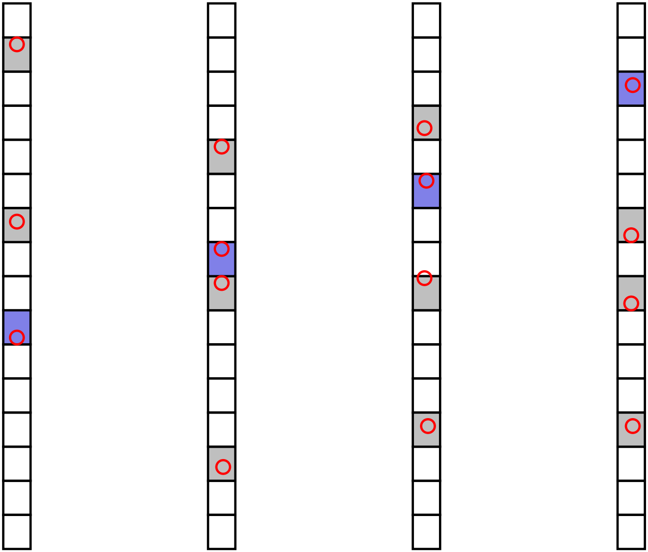


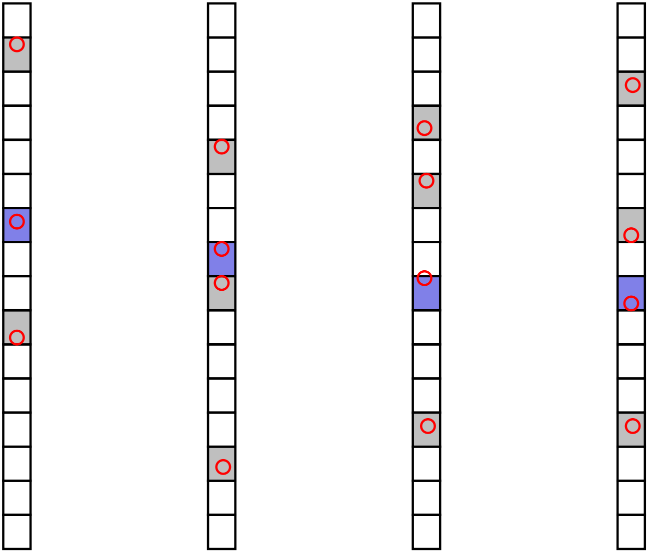
# TreeSearch Illustration: Level 4 Pattern Match → Road 1



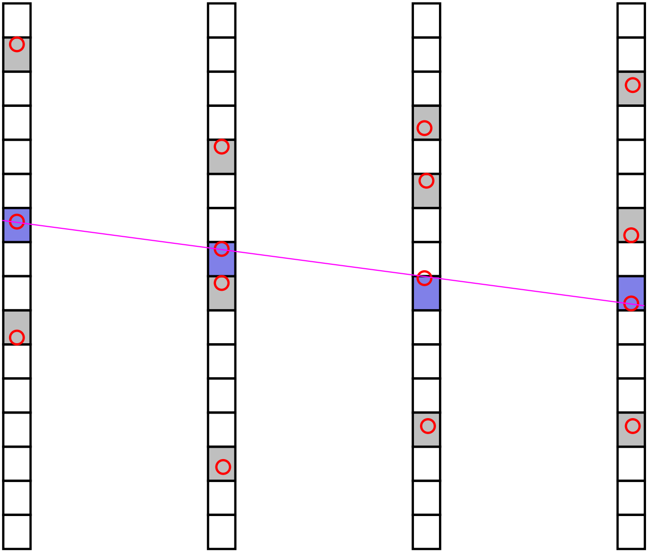
# TreeSearch Illustration: Level 4 Pattern Match → Road 2



# TreeSearch Illustration: Level 4 Pattern Match → Road 3

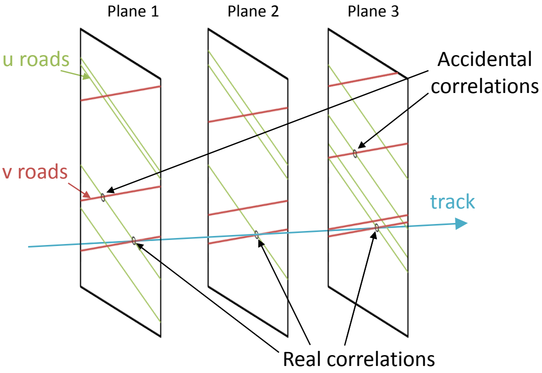


# TreeSearch Illustration: 2D Line Fit in Road 3



# 3D Matching

- Correlate roads from different projections via hit amplitude in shared readout planes (2 projections)
- Could use hit timing information as well to improve correlations (not yet implemented)
- Repeat for each readout plane along *z*
- Pair roads with the best overall correlation to get space points for 3D track fits

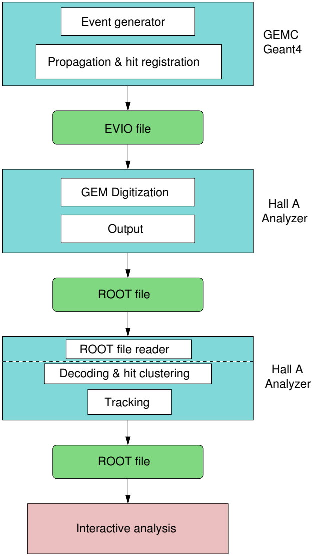


# Code & Algorithm Modifications (To Be) Made for SoLID

- Support SoLID geometry
  - Allow downstream tracker planes to be asymmetric w.r.t. first plane
  - Support detector positioning in cylindrical coordinates
  - Cut on non-rectangular active detector area
- Allow for (small) track curvature in 2D and 3D fits
  - Need efficient algorithm
  - Implement parameter range limits
  - Stability?
- Make all sectors appear as one spectrometer, not 30 separate ones ;)

# Track Reconstruction Simulation

- `solgemc` EVIO files as digitization input
- GEM digitization based on SBS work (E. Cisbani, INFN)
  - APV25 pulse shape: done
  - Background added
  - No other detectors digitized yet
  - Partial passthrough of generated data (tracks, vertices)
- ROOT file interface: done
- Tracking: under development



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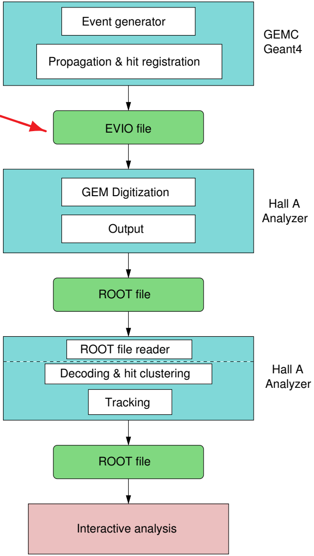

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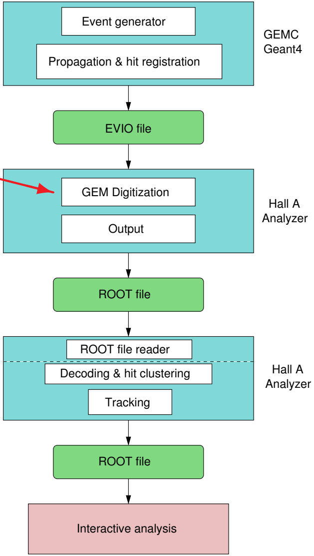

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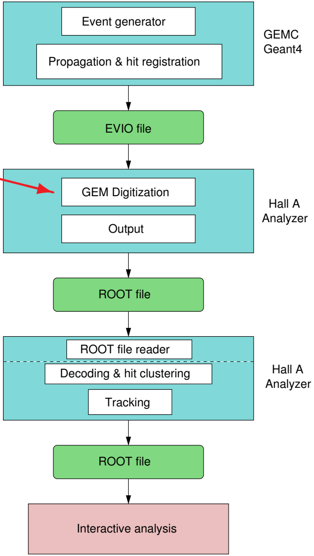

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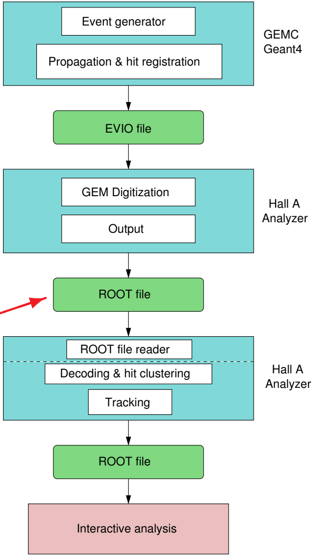

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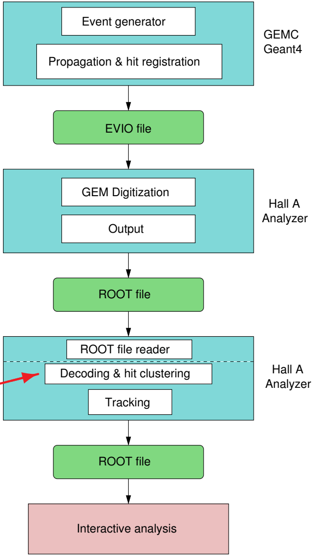

# Track Reconstruction Simulation (“data challenge” ready)

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  - Background added
  - No other detectors digitized yet
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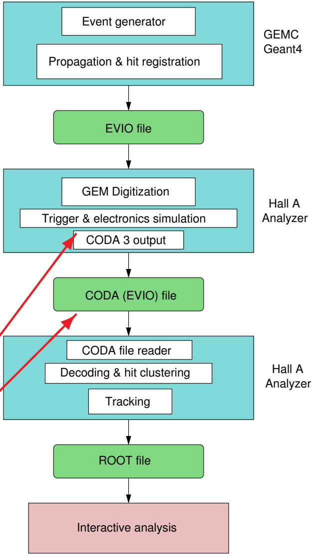
- ROOT file interface: done
- Tracking: under development
- Should eventually use actual DAQ format (CODA 3) for analyzer input



# TreeSearch for SoLID: Priority To Do List (in lieu of results)

- Make code modifications outlined earlier
- Find tracks for field-free and background-free case
- Investigate effect of field, track curvature
- Optimize parameters, esp. road width
- Turn on background
- Get rough numbers for
  - tracking efficiency
  - ghost track rate
  - performance
- Conclude if algorithm suitable

# Outlook: Desired Tracking Simulation Results

- GEM occupancies at proposed luminosities
- Particle types associated with GEM hits (signal/noise)
- Correlated noise from induced photons
- Track rates: physics, background, ghosts
- Tracking efficiency
- Reconstruction accuracy
- Rate dependencies (background, helicity effects)
- Optimizations
  - GEM hit clustering algorithm (noise tolerance)
  - Readout strip configuration (x/y vs. r/$\phi$) [?]
  - Reconstruction algorithm (speed, accuracy, efficiency)

# Outlook: Program for Next 12–18 Months

- Adapt Xin's progressive tracking to Hall A analyzer & optimize performance
- Include other tracking-relevant detectors in digitization & analysis
- Include full realistic background conditions in simulation
- Run through full program of tracking studies from previous slide

# Backup Slides

# GEM & APV25 Digitization (adapted from SBS by Rich Holmes)

- GEMC outputs raw hits (energy deposition $\Delta E$) in GEM layers
- GEM response tuned to match COMPASS observations
- Avalanche simulation:
  - Poisson-distributed number of ion pairs calculated from $\Delta E$
  - Use geometric distribution for ionization probability along path
  - Assume constant-velocity diffusion and drift
  - Gaussian distribution of charge deposited on strips
- Shape output amplitude: $v = A\tau \exp(-\tau)$, record 3 samples in 25ns intervals