SoLID Tracking Simulations

Ole Hansen

Jefferson Lab

with Seamus Riordan, Rich Holmes

SoLID Collaboration Meeting
April 13, 2012

SoLID Tracking Considerations (from Seamus)

Challenges:

- High rates: $\mathcal{O}(10 \text{ kHz/mm}^2)$
- 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

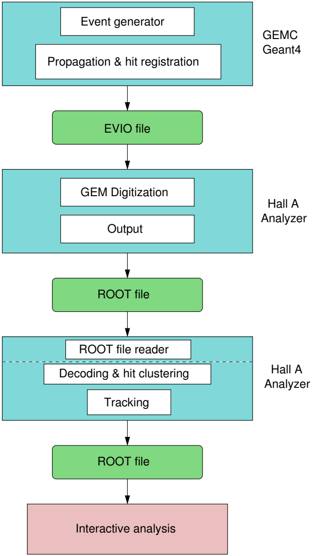
Tracking Simulation Goals (from Seamus's ideas)

- GEM occupancies at proposed luminosities
- Particle types associated with GEM hits (signal/noise)
- Noise rate from induced photons (correlated noise)
- Track rates: physics, background, ghosts
- Tracking efficiency
- Reconstruction accuracy
- Rate dependencies (background, helicity effects)
- Optimal GEM hit clustering algorithm (noise tolerance)
- Optimal readout strip configuration (x/y vs. r/ϕ)
- Optimal track finding algorithm (speed, accuracy, efficiency)

Not necessarily a complete list ...

Tracking Simulation Flowchart

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



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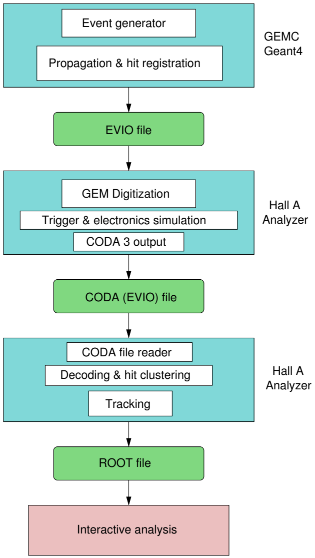
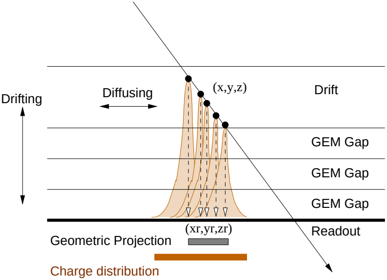
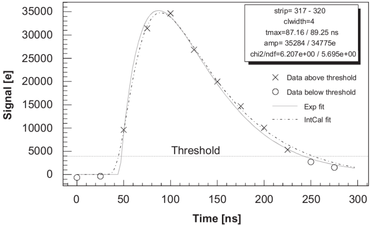
- Should eventually use actual DAQ format (CODA 3) for analyzer input



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

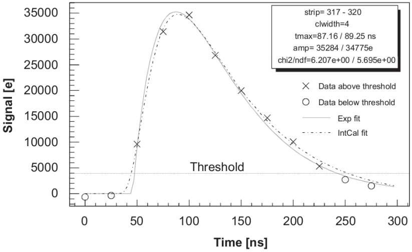
- GEMC outputs raw hits (energy deposition ΔE) in GEM layers
- GEM response tuned to match COMPASS observations
- Avalanche simulation:
  - Poisson-distributed number of ion pairs calculated from ΔE
  - Use geometric distribution for ionization probability along path
  - Assume constant-velocity diffusion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





APV25 Pulse Shape Deconvolution

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



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

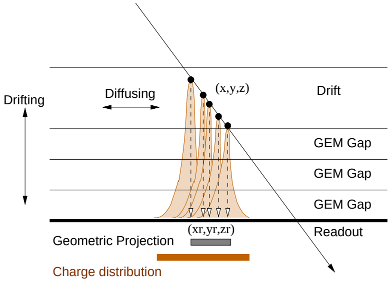
$$s_k = w_1 v_k + w_2 v_{k-1} + w_3 v_{k-2}$$

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

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

- 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

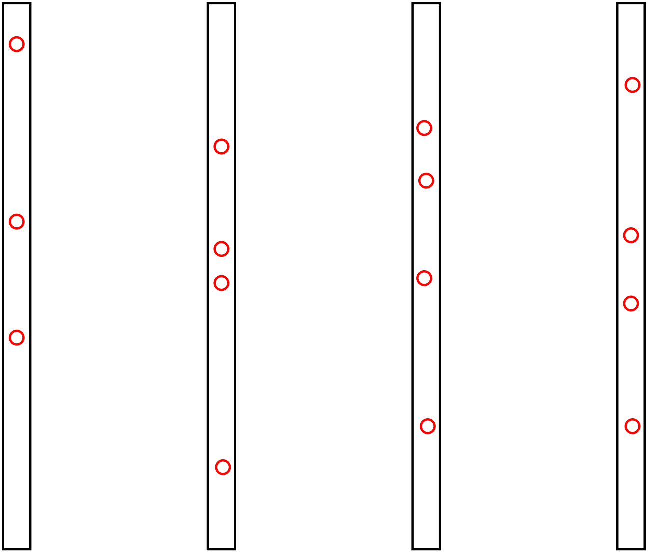


- Signals on adjacent readout strips typically belong to a single track crossing
- Sum signals to get
  - Total hit amplitude
  - Charge-weighted position centroid
- Currently use simple algorithm:
  - Look for local peak
  - When sequence "peak-valley-peak" is seen, split cluster at "valley"
  - Regardless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

Track Reconstruction Algorithm Candidates

- Xin's Progressive Algorithm
  - Kalman filter
  - Needs seed (e.g calorimeter hit)
  - Allows arbitrary track curvature
  - Already shown to be feasible for PVDIS/SIDIS rates
  - Slow, $\approx \mathcal{O}(Nk^2)$
  - Not yet implemented in Hall A analyzer
- TreeSearch
  - Global algorithm (recursive template matching)
  - Very fast, $\mathcal{O}(\log N)$
  - Available in Hall A analyzer
  - Successfully used with BigBite and SBS simulations
  - Requires straight tracks, but may still work for small curvature

TreeSearch Illustration



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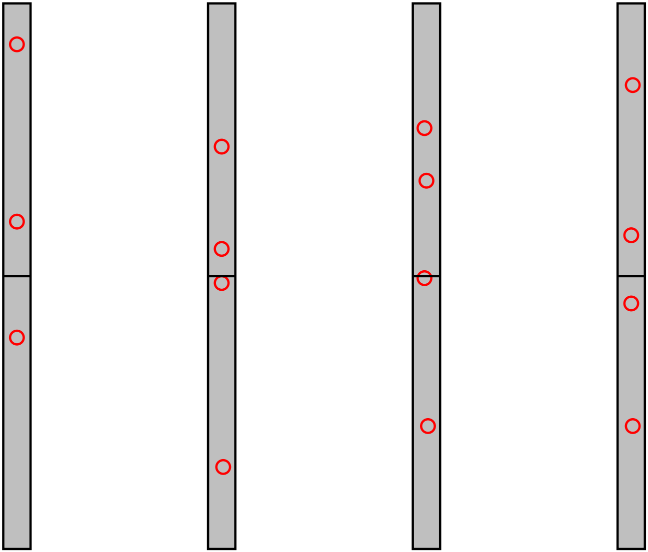

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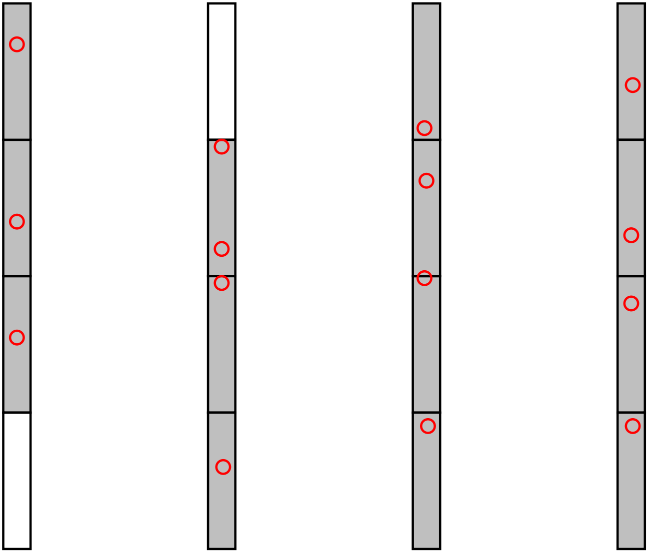

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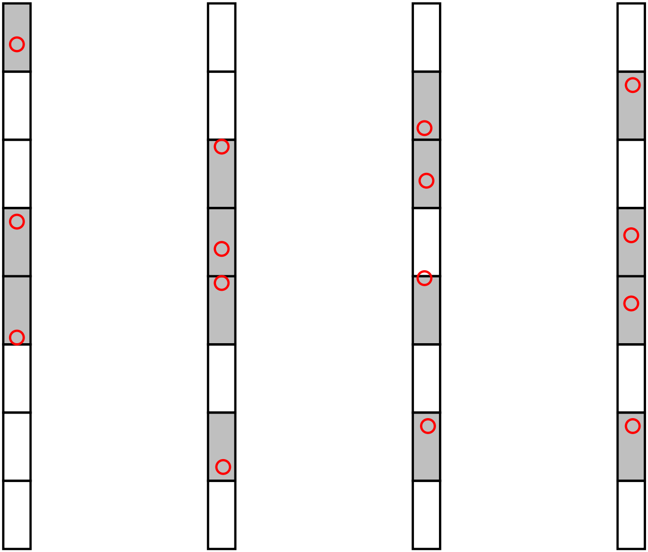

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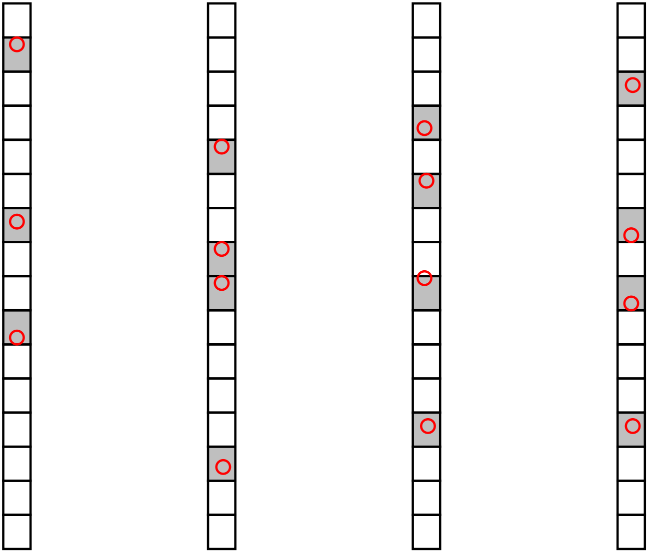

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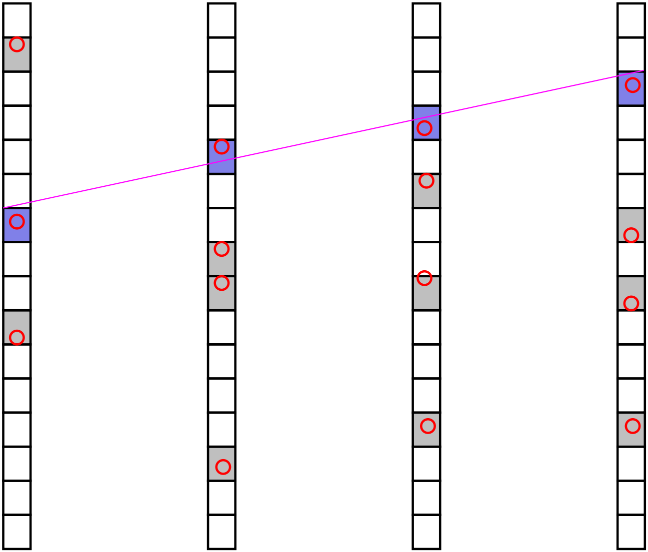

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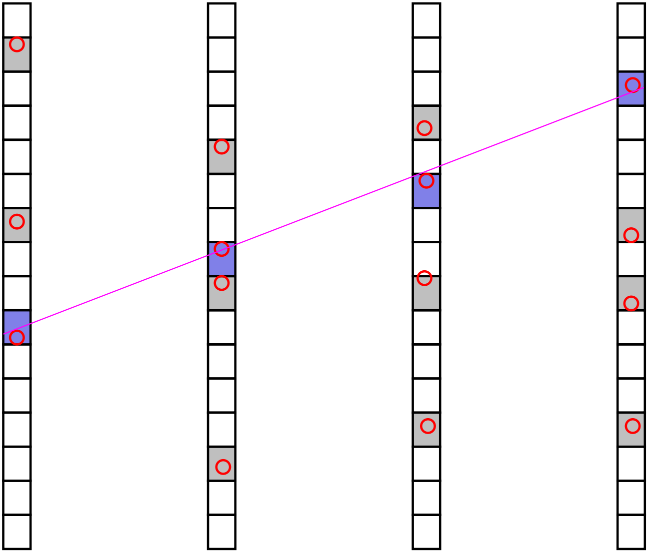

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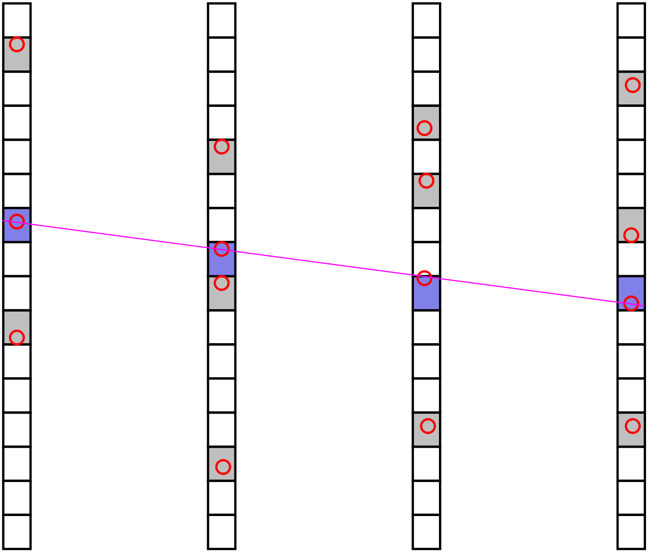
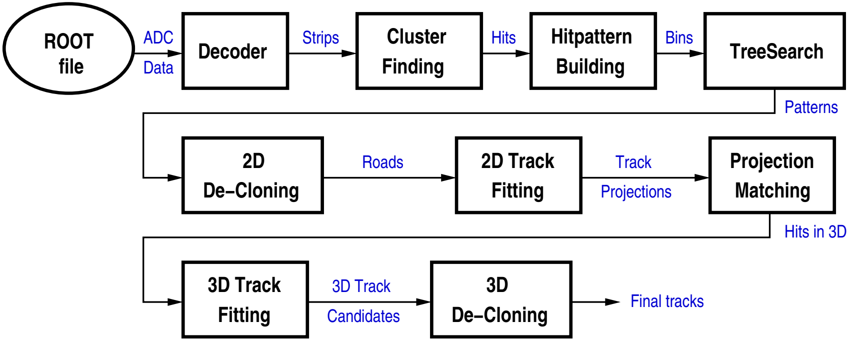


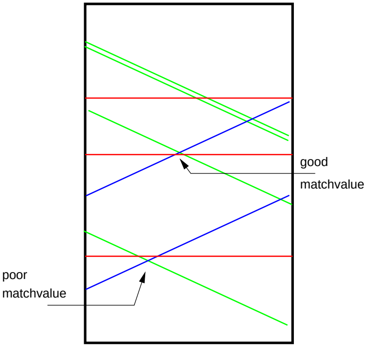
TreeSearch Reconstruction Flow



3D Matching

- Correlation of roads from different projections, either
  - geometrically (3+ projections); or
  - via hit amplitude & timing in shared readout planes (2 projections)
- Repeat for each chamber group along z

Chamber front view



TreeSearch for SoLID: Status

- Code exists from SBS simulations
- In principle, all components implemented
- To do
  - Adapt database and code to SoLID geometry
  - Generate pattern lookup tables
  - Tune parameters
  - Find tracks for field-free case
  - Investigate effect of field, track curvature
  - Handle possible curved tracks in final fitting step

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- ⇒ "basic tracking demonstration"
- ETA: June meeting

Outlook

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- Include other tracking-relevant detectors in digitization & analysis
- Run through full program of tracking studies outlined earlier

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- $\Rightarrow$ "full tracking evaluation"