Kalman Filter Tracking Finding and Fitting for SoLID

- Kalman Filter (KF) is a recursive fitting algorithm
- Developed into concurrent tracking finder and fitter for SoLID, works for both PVIDS and SIDIS configurations
- The same set of track parameters (state vector) for both configurations: $(x, y, t_x, t_y, q/p)$
  1. x, y are the transverse position of the track at a given z location
  2. t_x, t_y are the slope of the track in the x-z and y-z planes at a given z location
  3. q/p is the charge over momentum at a given z location
- The basic steps are the same for both configurations, some details are different:
  1. Initializing KF: use short track segment from downstream chambers (seed) to calculate initial track parameters. Assist from other detectors (calorimeter for instance) may be needed
  2. Tracking following: propagating the track parameters towards upstream GEMs and collect hits that satisfy selection cuts, use the selected hits to improve track parameters
  3. Vertex reconstruction: after selecting all hits from GEMs, propagate the track back to target, add BPM measurement to obtain final vertex variables

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- Initializing KF:
  - ➢Same part: Both configuration use the last three GEMs from downstream to select the track segment for initialization (at least 2 out of 3 GEMs have hits)
  - ➢Different part:
    - PVDIS uses the calorimeter measurement to initialize the fifth parameter, the first four can be obtained easily assuming the track is straight
    - SIDIS uses parameterization functions to calculate all 5 parameters from 2 hits, these functions can be extracted from MC
- Track following: same for both configurations, works like a loop

Propagating the track parameter and its covariance matrix to the next GEM: solving Lorentz equation using Runge-Kutta method

If a hit satisfy the selection cuts, use it to improve track parameters using the KF method

Based on the projected hit on the next GEM, look for potential hits for the track:

1. Using the covariance matrix elements for x and y to open a selection window, GEM reconstructed hit must fall inside the window
2. Cut on the χ^2 increment of adding this hit, reject the hit if χ^2 is too large

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- The track following loop is terminated if more than 1 hit (1 missing hit is allowed but not 2) is missing from any of the GEMs
- Once the loop reaches the most upstream GEM, the survived tracks are ready to be propagated back to the target and reconstruct the final vertex variable by adding the BPM measurement (x_B, y_B), assuming the resolution is 300um
- Vertex reconstruction: also same for both configurations
    1. Propagate the track parameter on the most upstream GEM back to the target (again just solving Lorentz equation using Runge-Kutta method)
    2. Find the closest approach between the track and the electron beam (position at x_B, y_B and parallel to z-axis)
    3. The closest approach can be used to determine vertex z z_v
    4. Finally, assuming the interaction happens at (x_B, y_B, z_v), add this hit to the track and improve track parameter using KF method (this is similar to GEM hits)
    5. Improvement from BPM rather limited for SIDIS but important for PVDIS momentum