RANSAC Track Finding for COMET Drift Chamber

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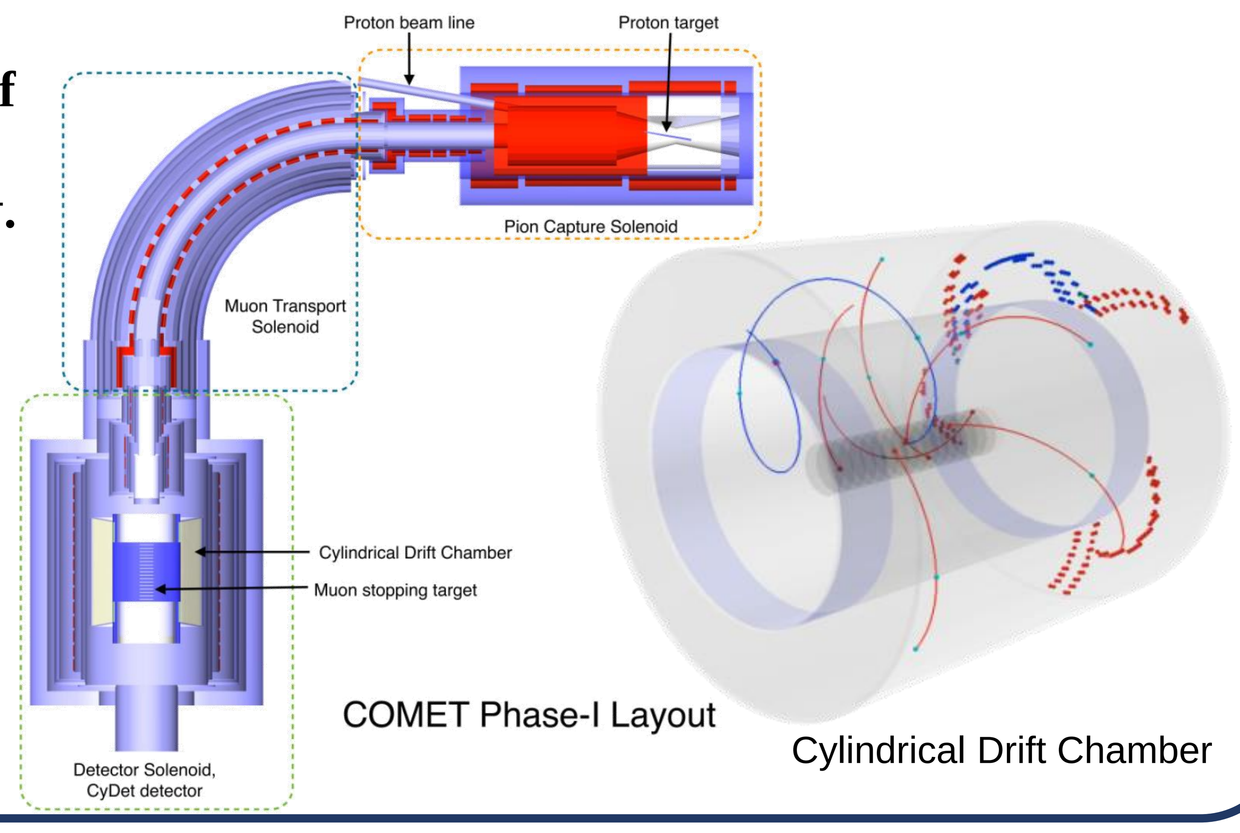
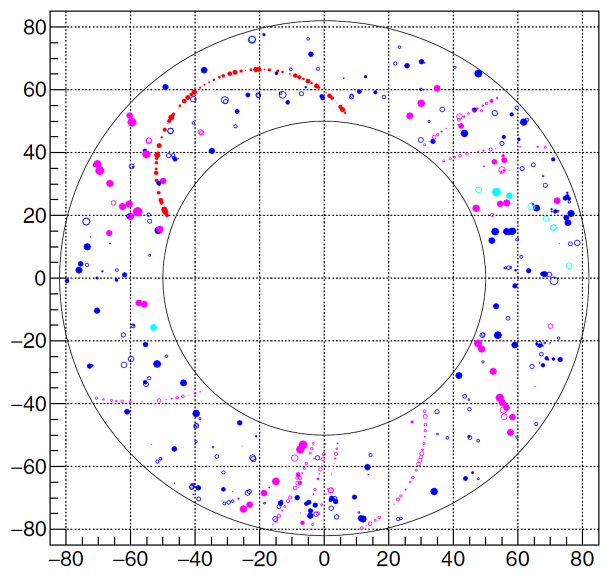
COMET Experiment and Cylindrical Drift Chamber

- **COMET is an experiment at J-PARC, Japan, which will search for neutrino-less conversion of muons into electrons in the field of an aluminum nucleus (μ–e conversion, $\mu^- N \rightarrow e^- N$); a lepton flavor violating process, with signal of 105 MeV monoenergetic e^-.**
- **Track reconstruction in the Cylindrical Drift Chamber (CDC), which is the main detector at COMET, is critical for high-precision physics.**
- **Challenges of tracking algorithm of CDC:**
  1. **All stereo layers which can't provide z position directly**
  2. **No vertex constraint**
  3. **No seed from sub-detector could be used**
  4. **Tracks with low transverse momentum is circle inside detector**
  5. **Overlapping between tracks from different turns**



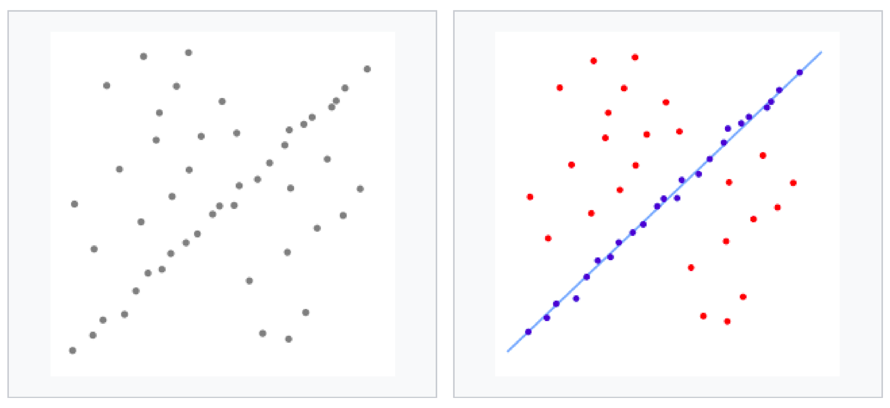
Simulation

- **Full simulation of signal electron with energy of 105 MeV is used in this study. Following is CDC event display of signal with background.**



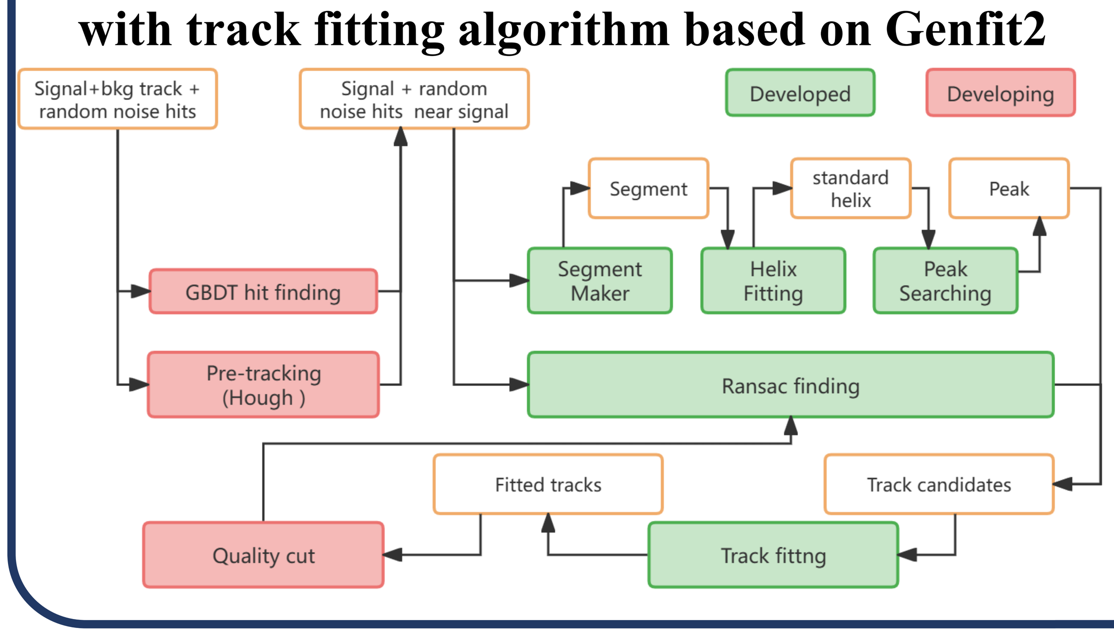
Track Finding Algorithm

- **A track finding algorithm is developed based on Random Sample Consensus (RANSAC):**
  - **An iterative method to estimate parameters of a mathematical model from a set of observed data that contains outliers**



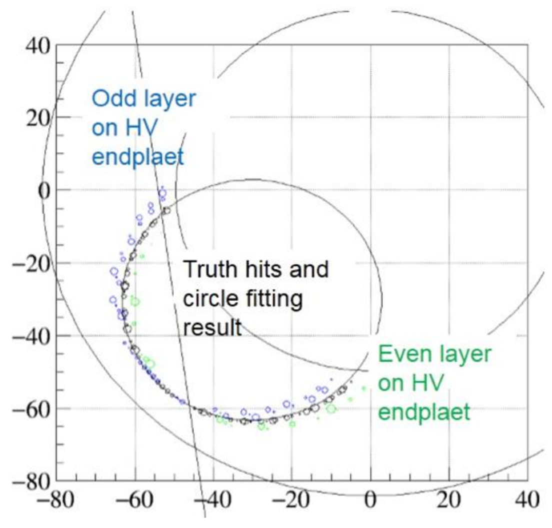
A data set with many outliers for which a line has to be fitted. Fitted line with RANSAC; outliers have no influence on the result.

- **This algorithm is implemented in the framework for COMET and tested combining with track fitting algorithm based on Genfit2**



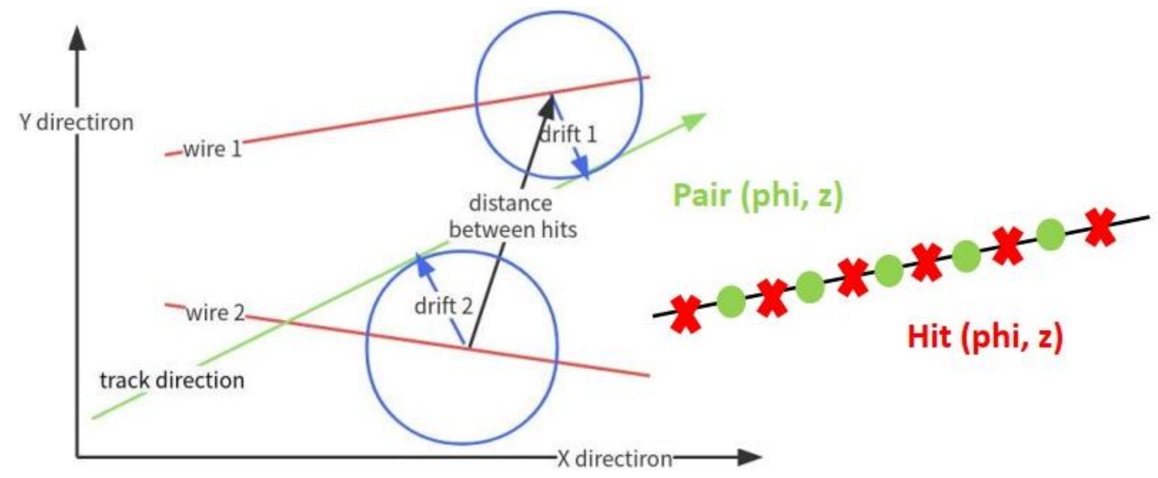
Circle Fitting

- **Circle fitting is performed on odd/even layers respectively as initial parameters, using wire position on endplate.**
- **For a circular track projection with a radius of about 30 cm to be fitted, the resolutions center position and radius are 3.7 mm and 2.5 mm, respectively.**



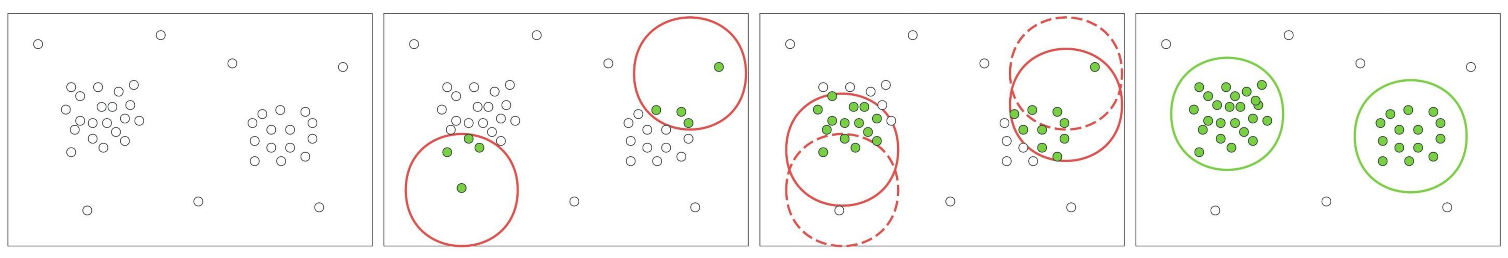
Helix Fitting

- **6 hits from 6 consecutive layers are randomly selected to form a track segment.**
- **For two hits from adjacent layers:**
  - $F(\overrightarrow{w_1}, \overrightarrow{w_1}, d_1, d_2, \varphi_{track}, Zpai_r, \Delta Z, LR)$,
  - $Zpa_{ir} = \frac{Z_1+Z_2}{2}, \Delta Z = Z_1 - Z_2$
- **The resolution of hit Z calculation is 9.9 mm.**



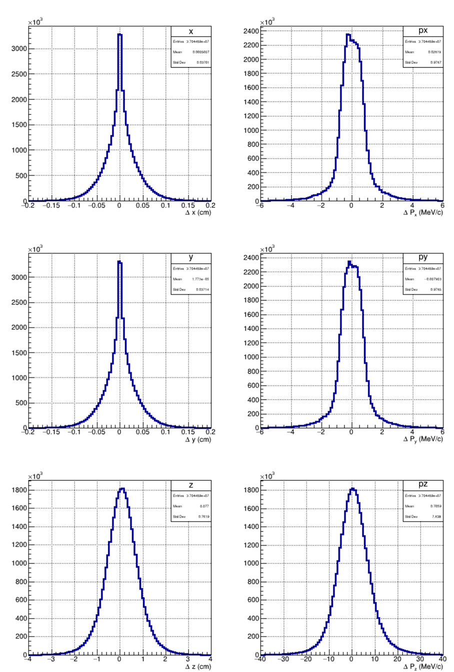
Peak Searching

- **Helices fitted from signal segments are expected to be close to the truth value**
- **A naive peak searching algorithm is developed to find peak in track parameter space**
- **Efficiency of peak searching:**
  - **Single turn tracks: 98.9%**
  - **Double turn tracks: 89.0%**



Tracking Performance

- **Helix fitting is performed with seed track obtained from the previous steps.**
- **The resolution of helix fitting with signal segment (signal hits only) is tested:**
  - **Single turn tracks:**
    - $\sigma_x = 0.33\ mm, \sigma_y = 0.33mm, \sigma_z = 7.0mm$
    - $\sigma_{px} = 0.7\text{MeV}, \sigma_{py} = 0.7\text{MeV}, \sigma_{pz} = 6.9\text{ MeV}$
  - **Double turn tracks:**
    - $\sigma_x = 0.31\ mm, \sigma_y = 0.31mm, \sigma_x = 6.2mm$
    - $\sigma_{px} = 2.6\text{ MeV}, \sigma_{py} = 2.5\text{ MeV}, \sigma_{pz} = 8.7\text{ MeV}$



- **Track candidates are passed to the track fitting algorithm**
- **Results of track reconstruction are shown:**

	Geometrical Acceptance	Tracking		Totally	Tail	Mom resolution (body/tail)
		finding	fitting			
Single Turn	14.0%	95.1%	97.8%	13.0%	0.13%	192keV/309keV
		93.0%				
Double Turn	4.3%	88.5%	47.6%	1.81%	10%	262keV/1.2MeV
		42.1%				

Conclusion

- The RANSAC track finding algorithm has been basically developed and tested.
- The efficiency and resolution of tracking is good after preliminary optimization
- Many optimizations are on-going

References:
[1] Abramishvili R, et al. COMET Phase-I Technical Design Report [J/OL]. PTEP, 2020, 2020 (3): 033C01. DOI: 10.1093/ptep/ptz125
[2] Fischler M A, Bolles R C. Random sample consensus: A paradigm for model fitting with applications to image analysis and automated cartography [J]. 1981, 24(6)
[3] Zamora J C, Fortino G F. Tracking algorithms for TPCs using consensus-based robust estimators [J/OL]. Nucl. Instrum. Meth. A, 2021, 988: 164899

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