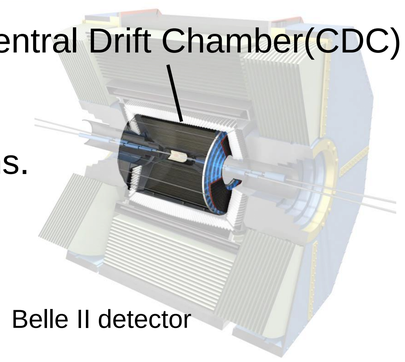
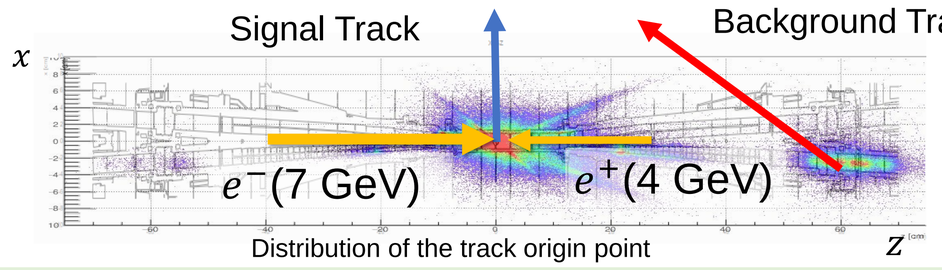
Development of the Belle II Hardware Track Trigger for High Luminosity

Hiroto Sudo
University of Tokyo Ushiroda lab. M2

1. Motivation

- The Belle II detector detects huge events from electron-positron collisions.
- Central Drift Chamber(CDC) is used mainly for particle tracking.



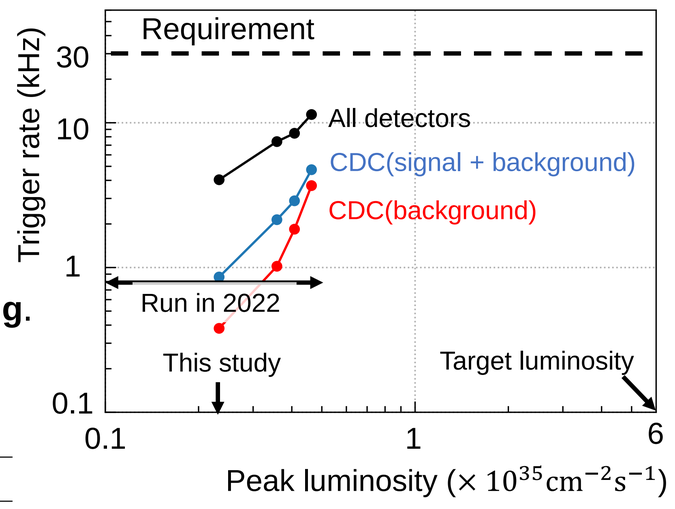


- Belle II uses the hardware trigger system to reduce the readout rate and data size.

Requirements of the trigger system
1. **Trigger rate < 30 kHz**
2. Latency < 4.5 μs
3. Trigger efficiency for the B physics~100%

- The current trigger system would exceed the limit of 30 kHz at the target luminosity.
- We can reject background tracks based on z_0 (z position of the track origin) obtained by **3D tracking**.
- The target performance of this study

	target	(cf. original)
efficiency	90%	~ 90%
background rejection rate	80%	~ 40%



2.Original 3D tracking algorithm

Track Segment Finder
Center hit information
- position
- timing
- left/right

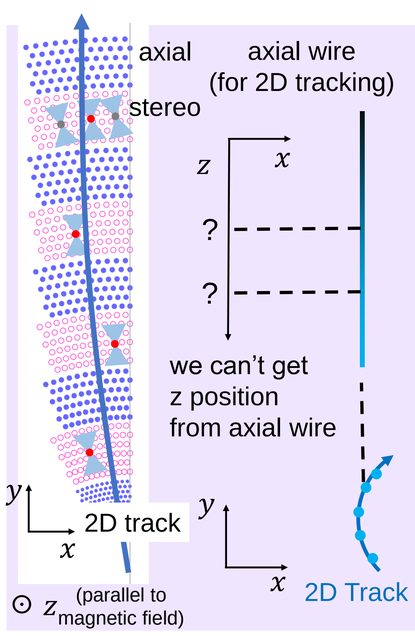
2D Track Finder
azimuth angle φ
track curvature ω

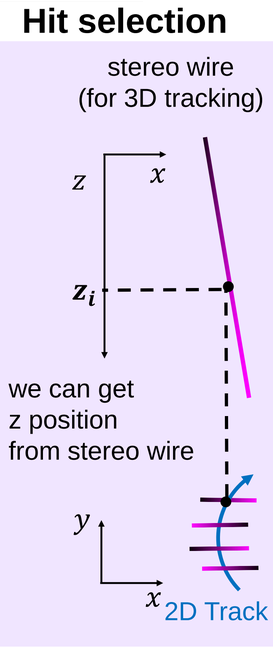
Event Time Finder
event time T0

input

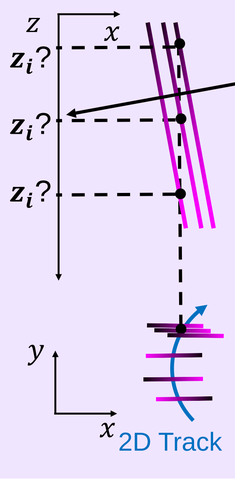
3D Fitter
track origin z_0
polar angle $\cot\theta$

Hit selection



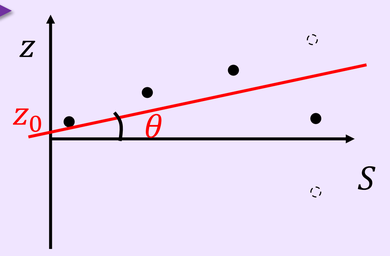


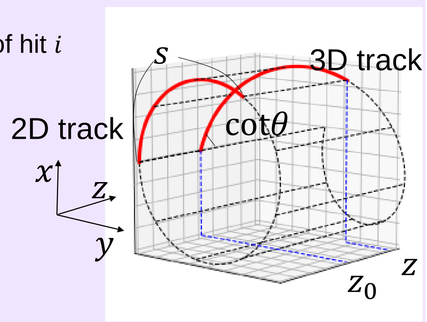
- If several hits intersect with 2D track, the middle one is selected.



Fitting

- 3D fitter gets z_0 and $\cot\theta$ by fitting the equation
$$z(s) = \boldsymbol{\cot\theta} \cdot s + \boldsymbol{z_0}$$
- 3D fitter minimizes $\chi^2 = \sum_{i=1}^{4} \frac{(z_i - z(s_i))^2}{\sigma_i^2}$
  - z_i: z position of hit i
  - s_i: arc length on 2D track of hit i
  - σ_i: constant of wire i





$$z_{hit} = +\cot\theta \cdot S_{hit} + z_0$$

track origin z_0
polar angle $\cot\theta$

3. New 3D tracking algorithm

Track Segment Finder
Full hit information
- position
- timing
- left/right

2D Track Finder
azimuth angle φ
track curvature ω

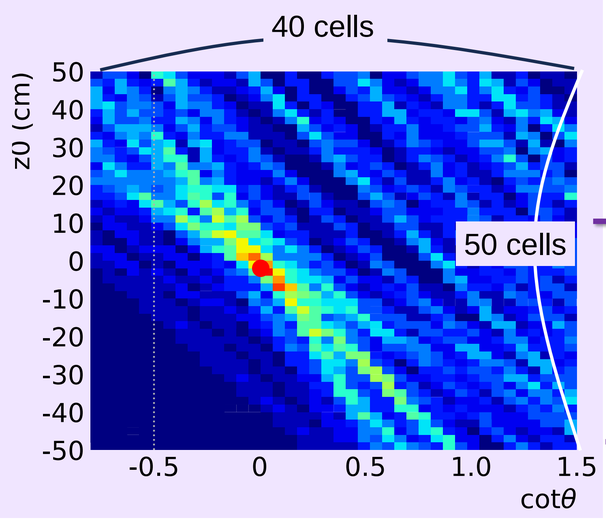
Event Time Finder
event time T0

input

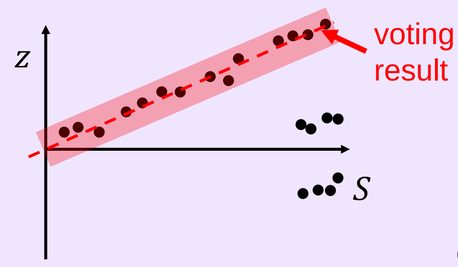
3D Fitter
track origin z_0
polar angle $\cot\theta$

Voting

- The $z_0 - \cot\theta$ parameter space is divided into cells.
- Each hit corresponds to each line.
$$z_0 = -S_{hit} \cdot \cot\theta + z_{hit}$$
- The most voted cell is the result.
- The voting method is **noise-robust.**

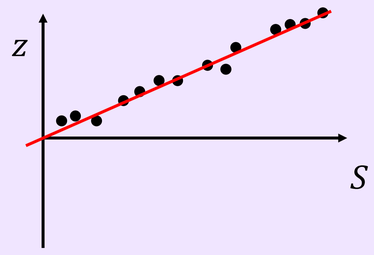


Hit selection



- The nearest hits within 20 cm from the voting result will be selected.

Fitting



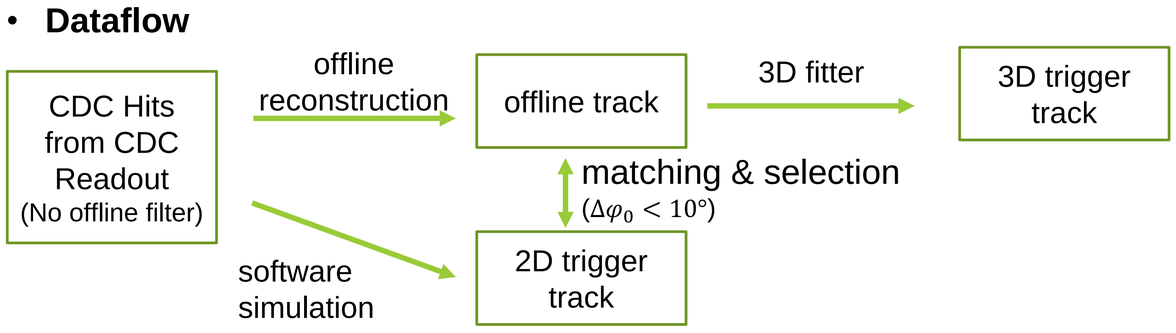
- The fitting algorithm is the same as before.

get z_0 and $\cot\theta$ directly

track origin z_0
polar angle $\cot\theta$

4. Performance evaluation

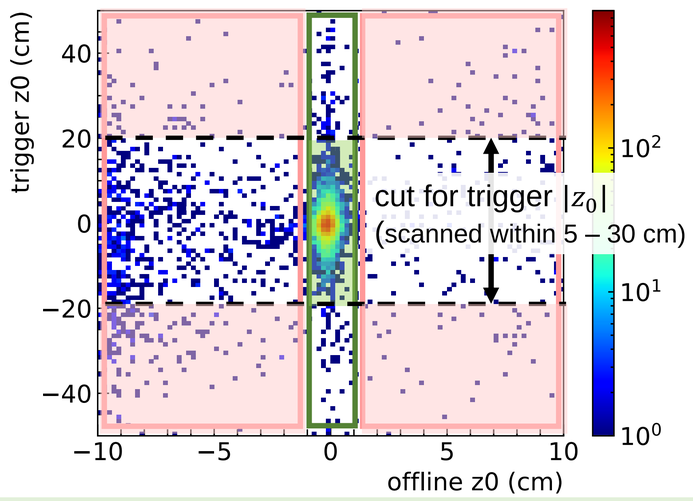
- **Dataflow**



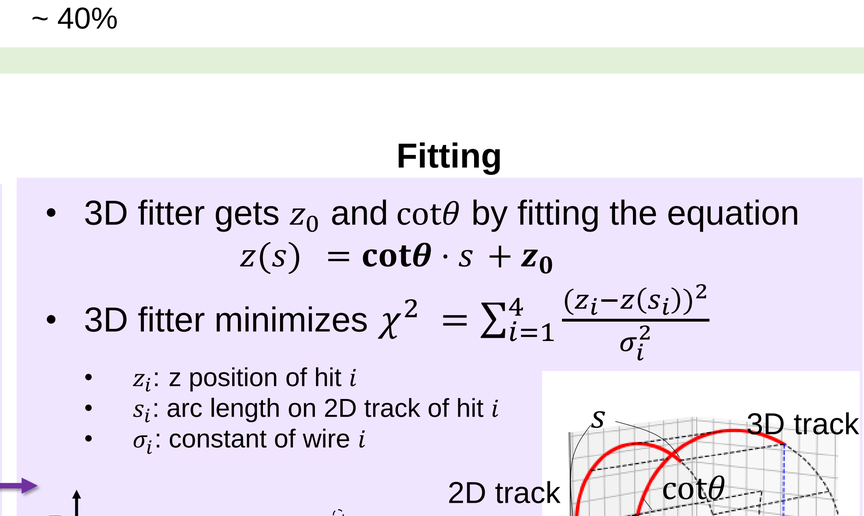
- **Performance indices**

3D efficiency
$$:= \frac{\#(\text{triggered signal track})}{\#(\text{signal track})}$$

BG rejection rate
$$:= \frac{\#(\text{rejected BG track})}{\#(\text{BG track})}$$



5. Result



- Cut for trigger $|z_0|$ was scanned within 5-30cm

6. Summary & Future

- **To reduce the trigger rate**, I developed new algorithms for the hardware track trigger.
- The **voting + fitting** method achieved the target performance(efficiency ~ 90% and BG rejection rate ~ 80%).
- Implementation of this method to the FPGA is ongoing.