Study of Tracking and Flavor Tagging with FPCCD Vertex Detector

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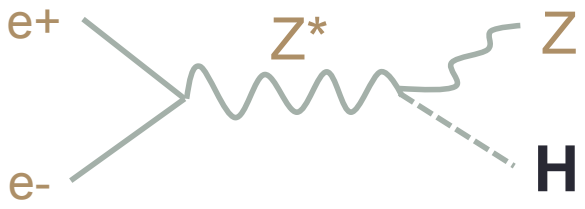
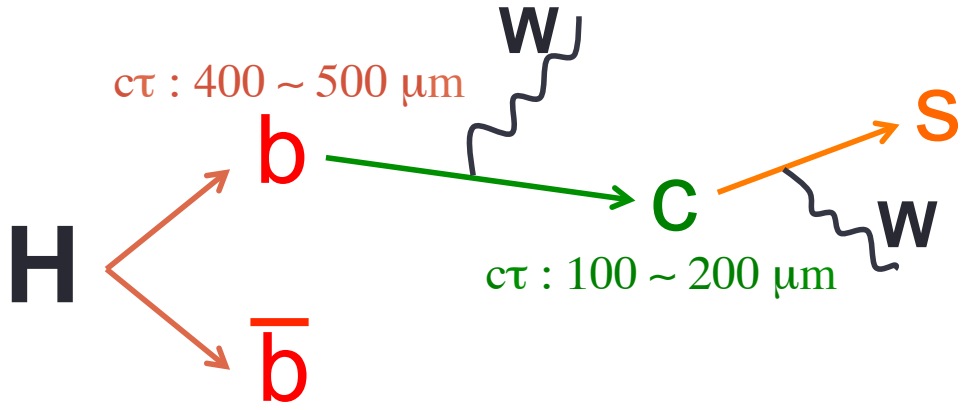
Introduction

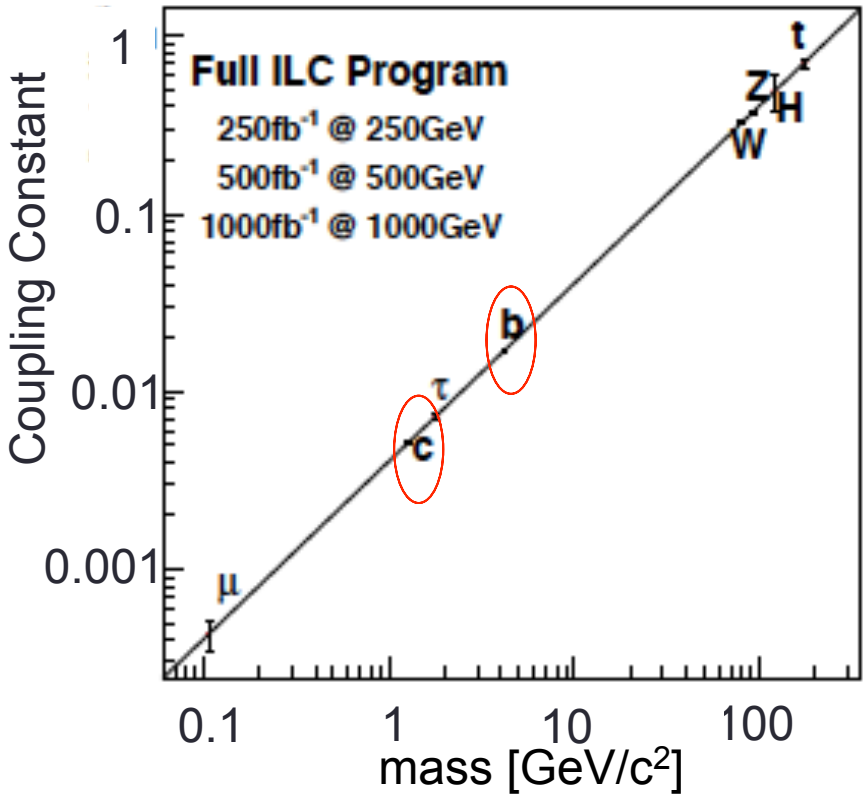
Road of Vertex Detector

one of the ILC physics goals :
Precise measurement of Higgs coupling constant to “c, b-quark, gluon”



Precise identification of H→bb, cc, gg is required





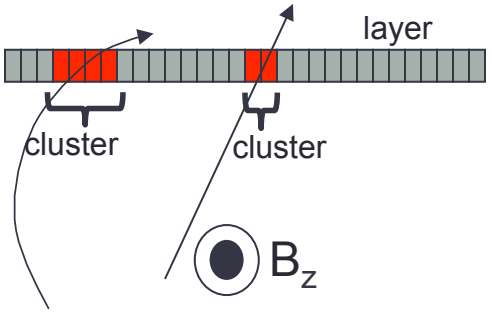
We need VXD with high performance → FPCCD

FPCCD Vertex Detector

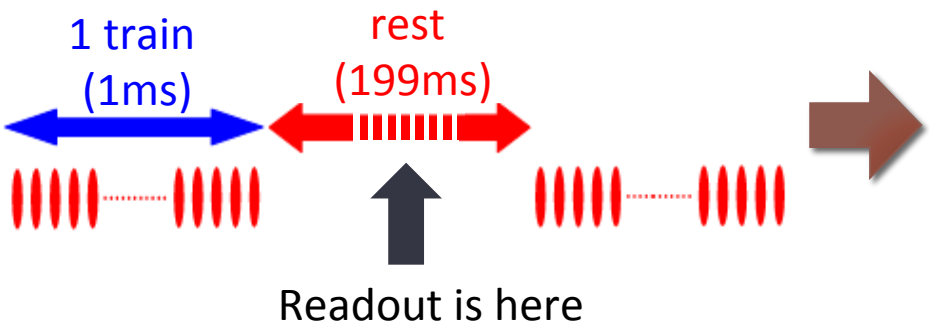
- **FPCCD (Fine Pixel CCD) Features**
- sensitive thickness: 15 μm
- total thickness: 50 μm
- # of pixels : ~ 0.4 x 10^9
- Cluster of hit pixels
  - ✓ Extrapolation of tracks
  - ✓ Position resolution
  - ✓ Discrimination : BG cluster & signal cluster

Geometry

layer	length from I.P. (mm)	pixel size (μm^2)
0, 1	16 , 18	5 × 5
2, 3	37 , 39	10 × 10
4, 5	58 , 60	10 × 10



- Readout: per 1 train

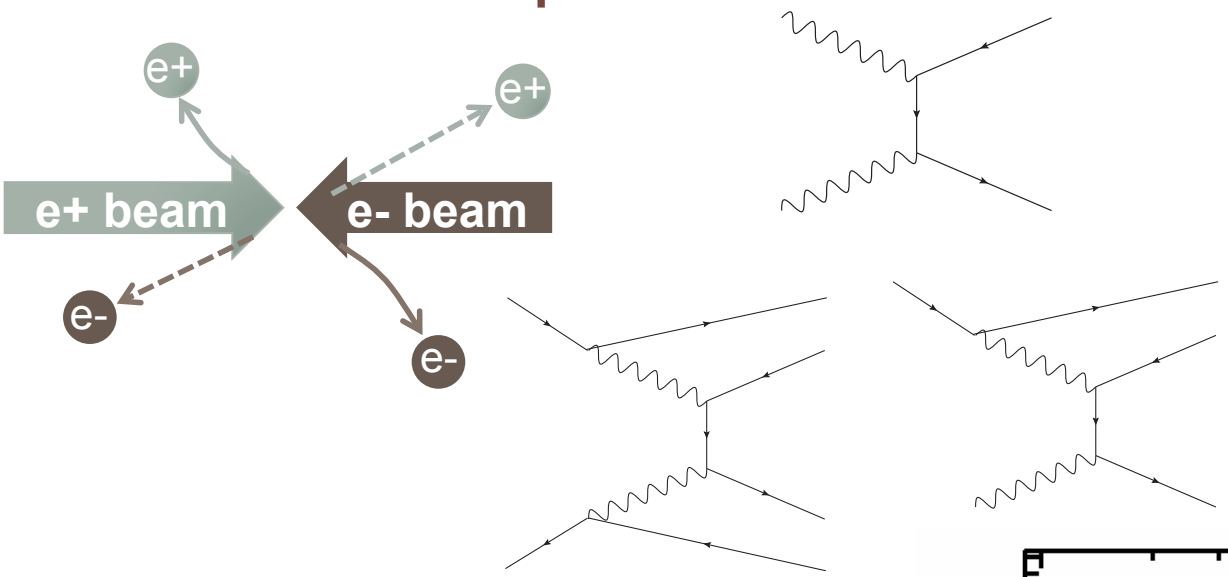


Merit:
Noise from Electromagnetic Interference (EMI) can be ignored

Demerit:
Tracking is challenging due to so many hits

Occupancy and Impact Parameter Resolution

- Dominant BG : **e+e- pair BG**



(reported in ECFA 2013)

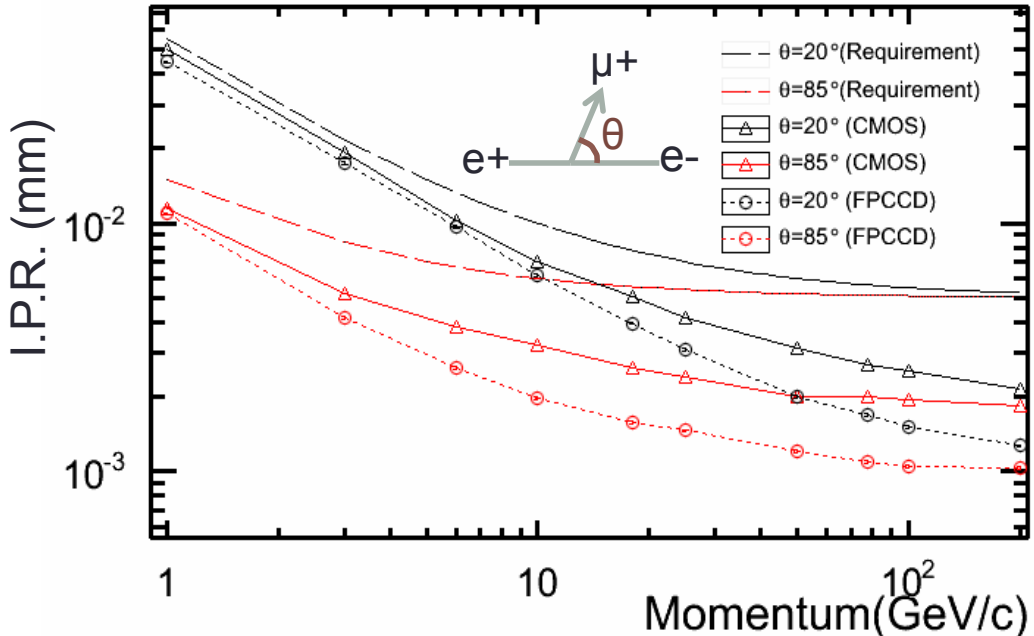
E_{CM} (GeV)	occupancy in 0th layer (%)
250	0.8
350	0.9
500	2.8
1000	19.6

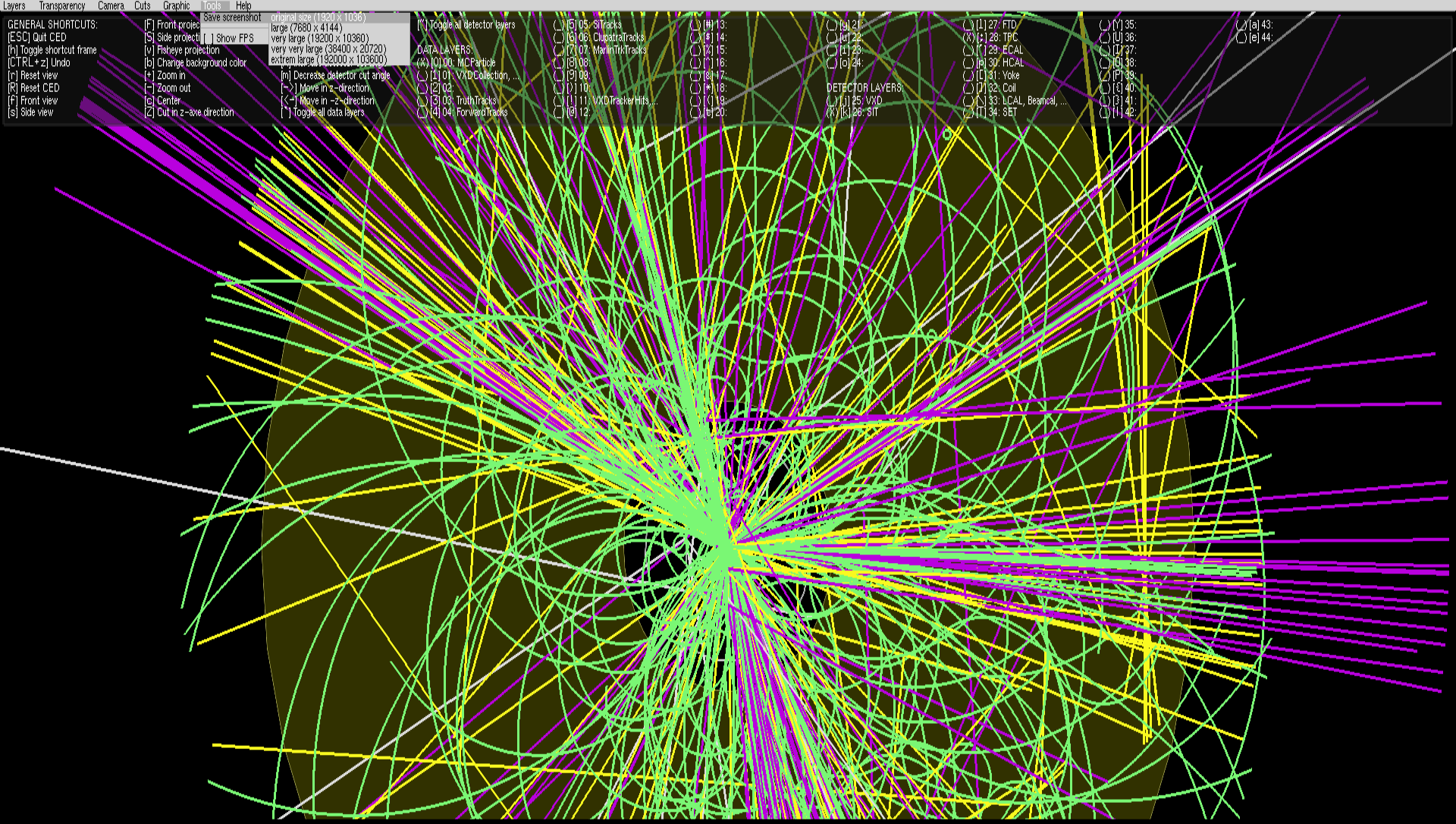
- Impact Parameter Resolution (I.P.R.)

$$\sigma_{r\phi} = 5\mu\mathrm{m} \oplus \frac{10\mathrm{GeV/c}}{\mathrm{p}\cdot\sin^{3/2}\theta}\mu\mathrm{m}$$

→**Satisfied** and
I.P.R. ~ **1 μm** in high P region

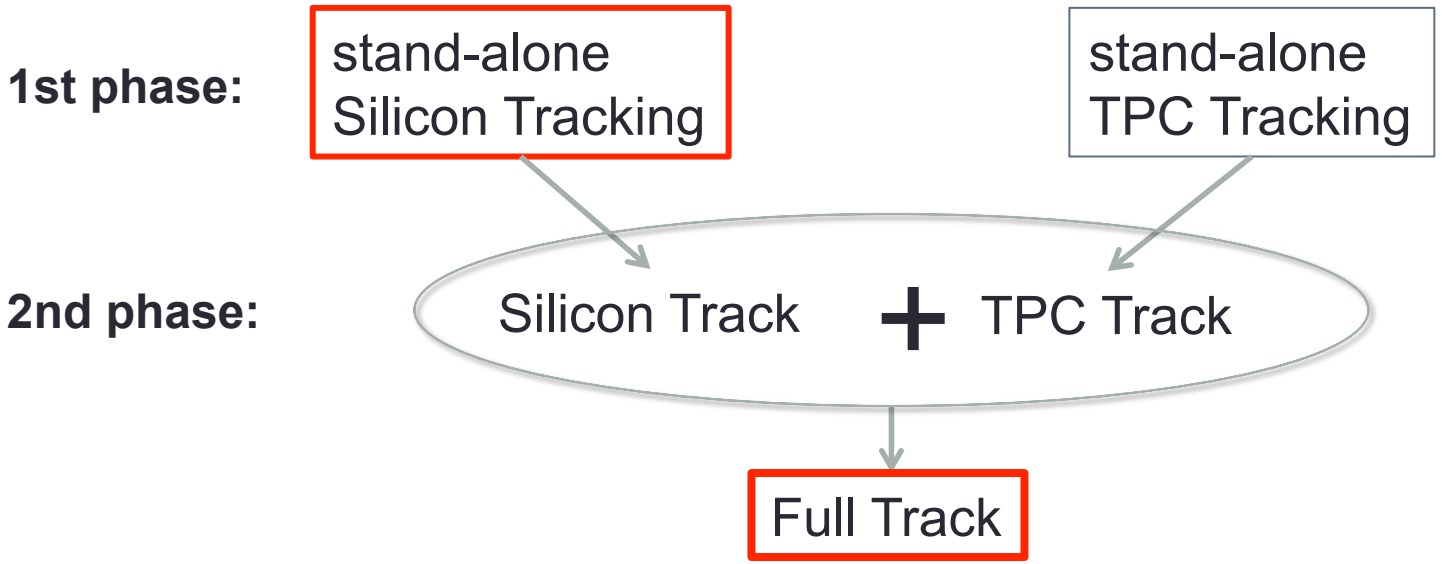
(reported in ECFA 2013)





Development of FPCCD Track Finder

DBD Track Finder



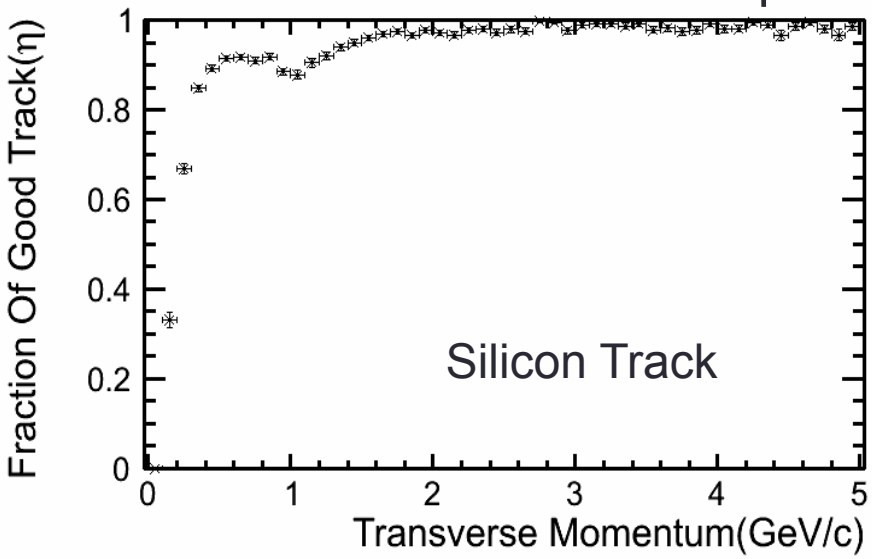
Performance of DBD Track Finder + FPCCD

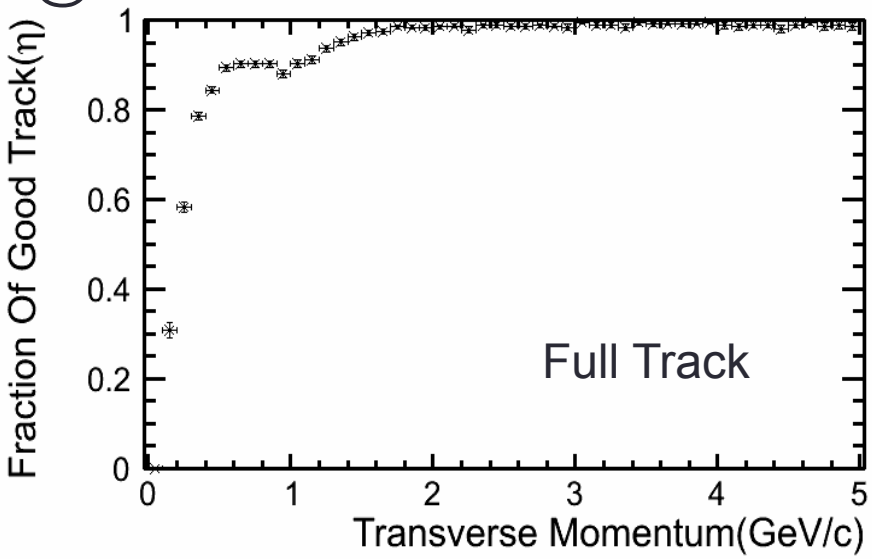
Fraction of Good Track : η ≡

$$\frac{\text{\# of tracks with VXD hits >= 5 \&\& track purity > 75\%}}{\text{\# of MCParticles creating VXD sim-hits >= 6 \&\& SIT sim-hits >= 4}}$$

Tips : required P_T
R_{in} of TPC : > 0.4 GeV/c
R_{out} of TPC : > 1.8 GeV/c

Sample: ttbar @ 350 GeV





Fraction : bad under P_T = 1.7GeV/c → **FPCCD Track Finder**

FPCCD Track Finder

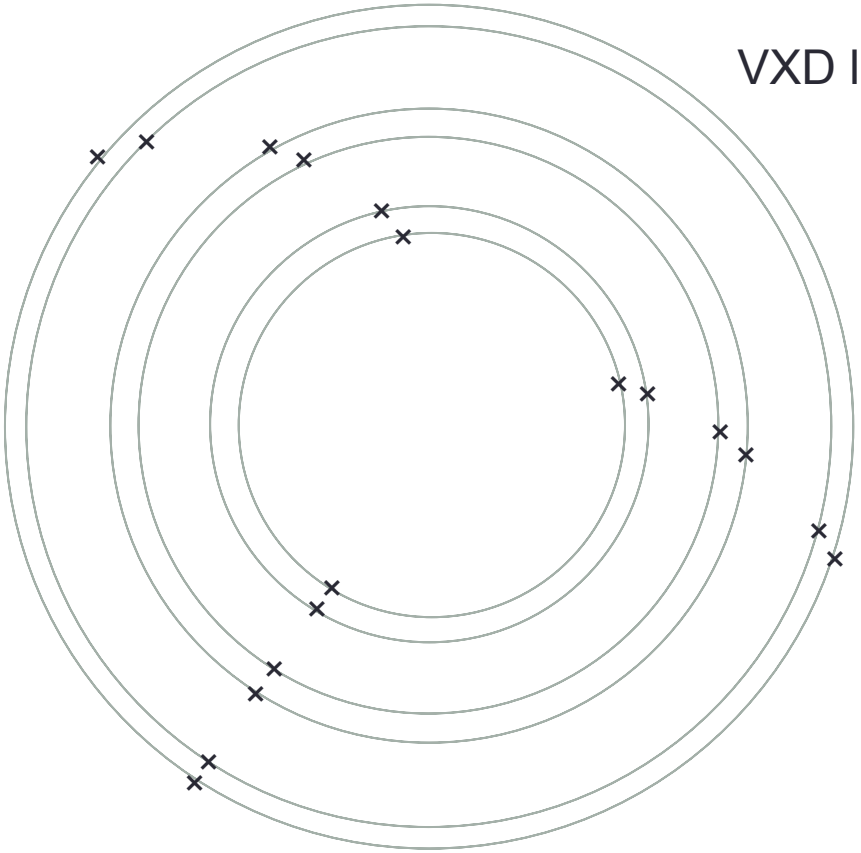
Goal :
Improvement of the fraction under $P_T = 1.7\text{GeV/c}$

Development Policy :
Silicon Track : already BAD → Full Track : BAD

→ **I concentrated on Silicon Tracking**

DBD Silicon Tracking

For ease,
We don't consider SIT and FTD

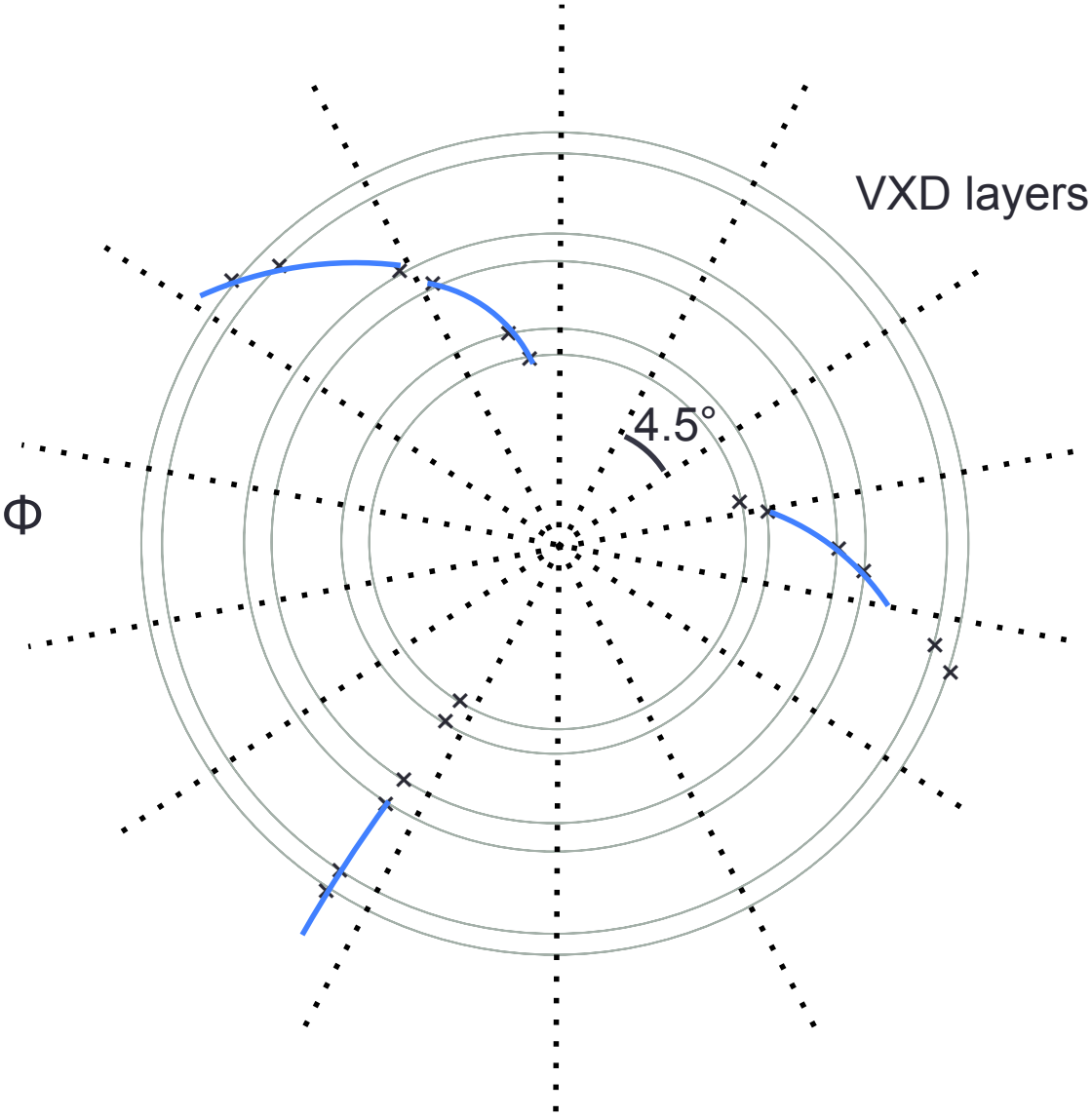


We approximate VXD shape by cylinder

DBD Silicon Tracking

Track Seed

Track seeds are generated
by combining 3 hits on each of
the 3 layers in each area
divided by 4.5° in the direction of Φ

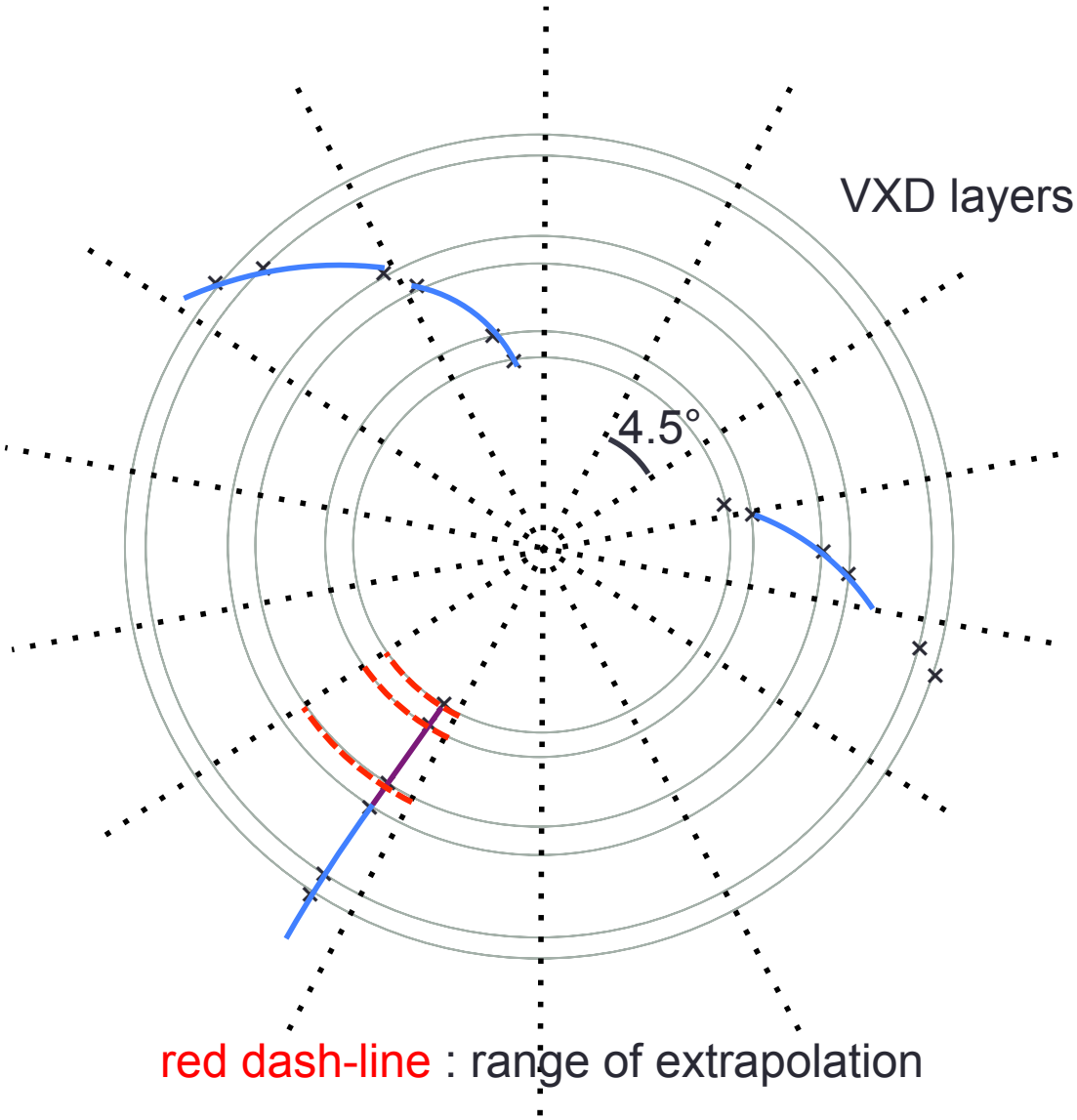


DBD Silicon Tracking

Track Seed

↓

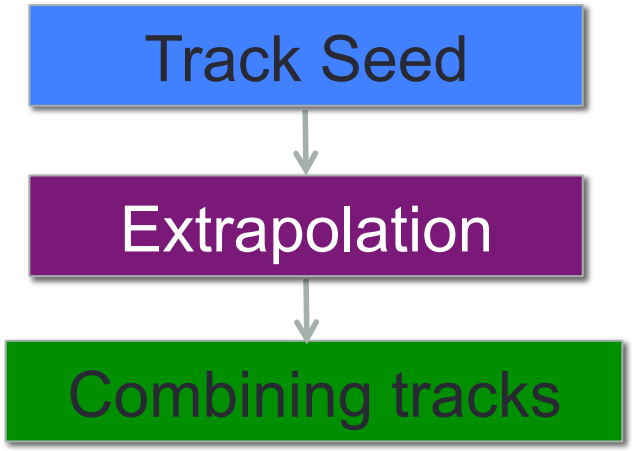
Extrapolation

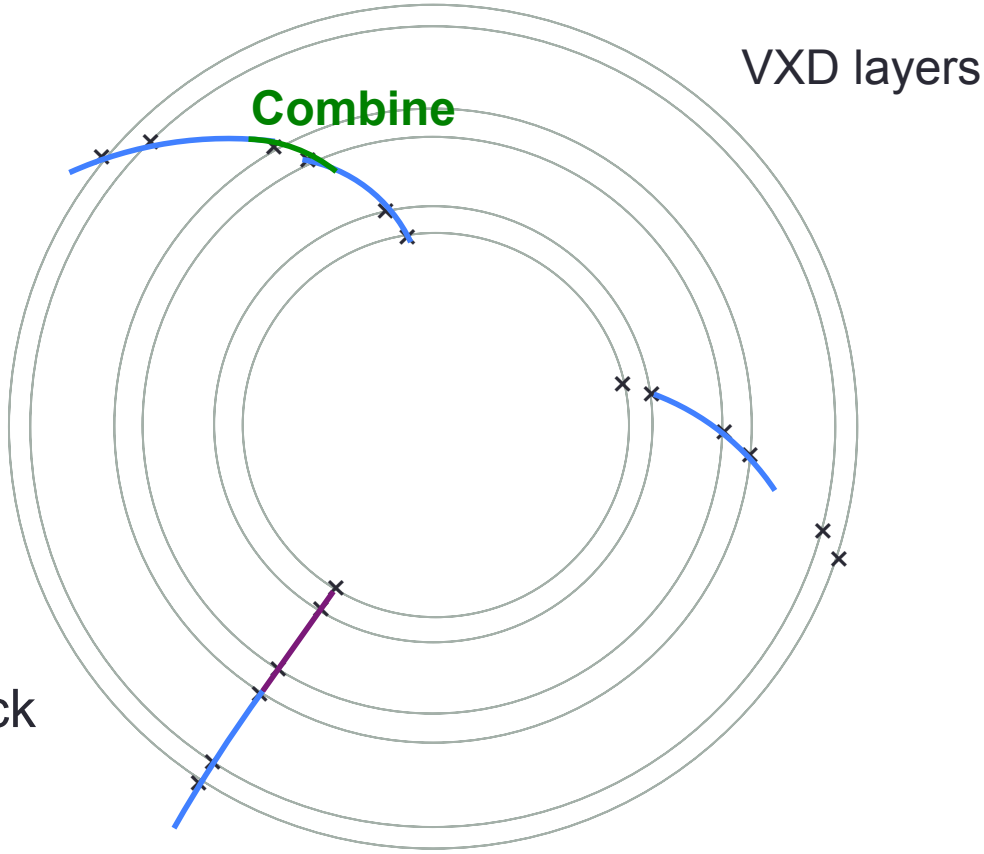


Area for extrapolation:
divided by 4.5°
in the direction of Φ

Fitter:
Simple Helix Fit

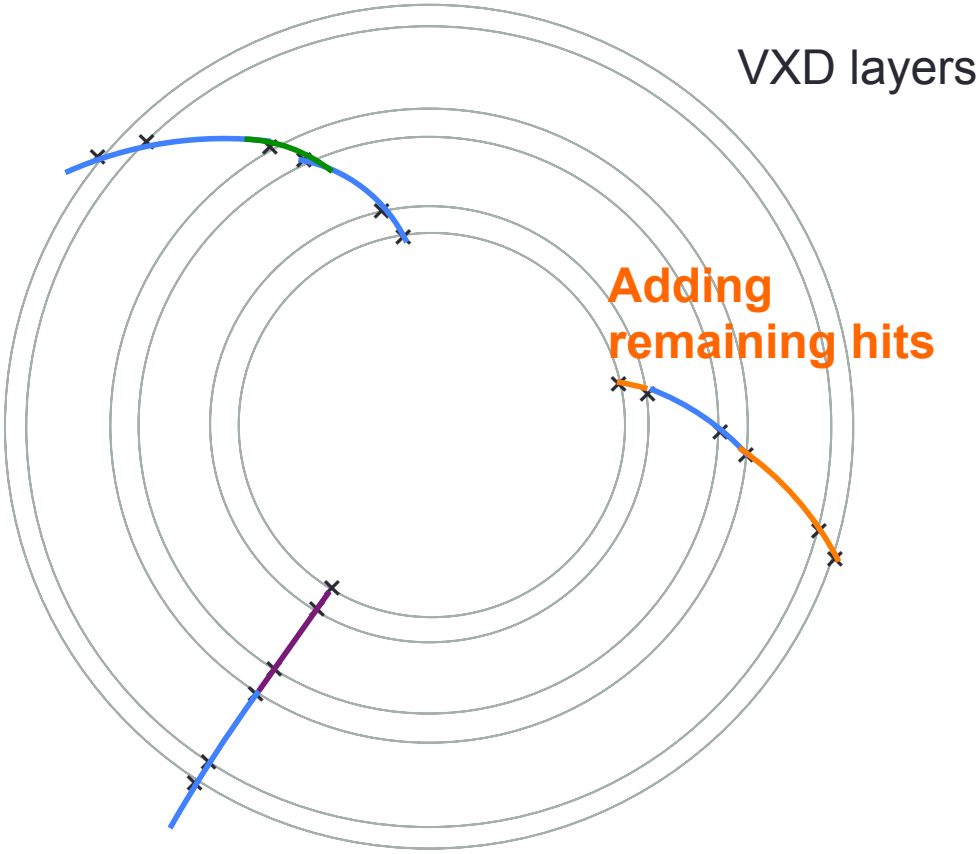
DBD Silicon Tracking





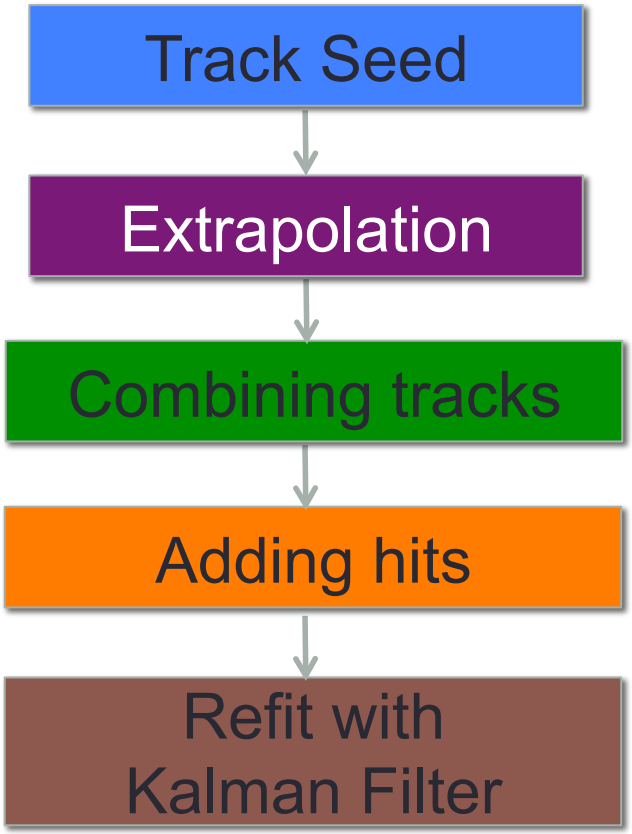
If possible,
we combine a track and another track

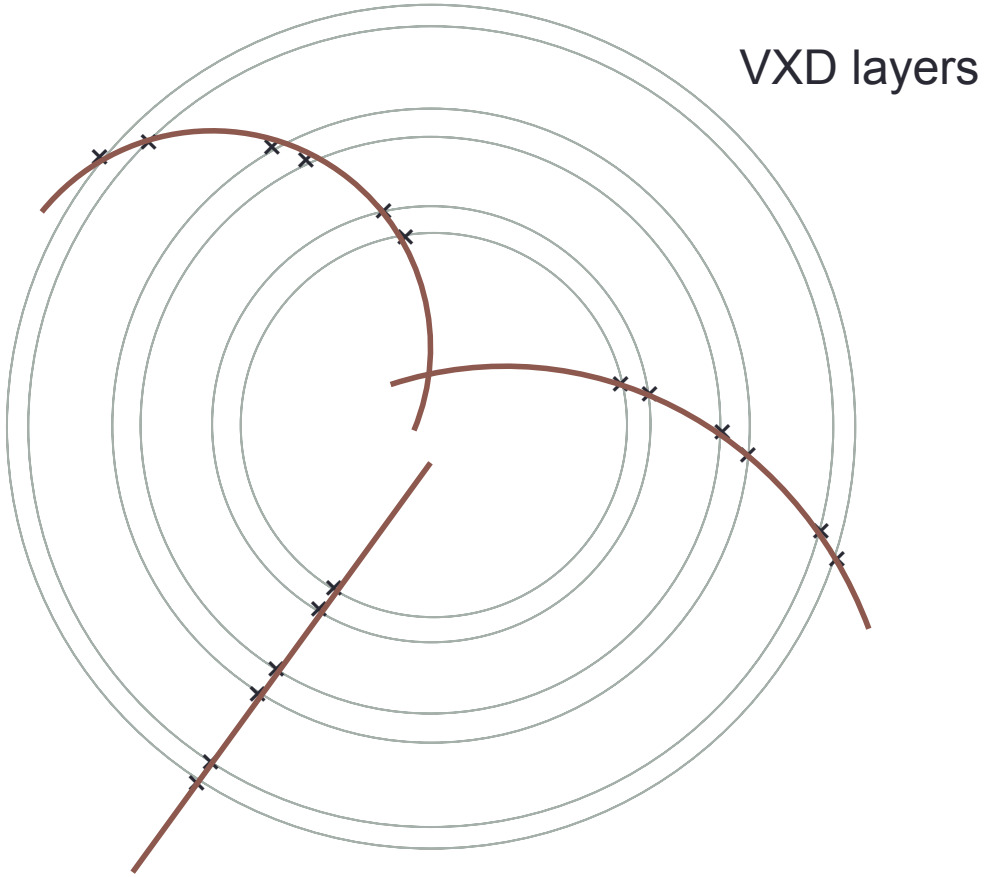
DBD Silicon Tracking



If possible,
we add remaining hits to tracks

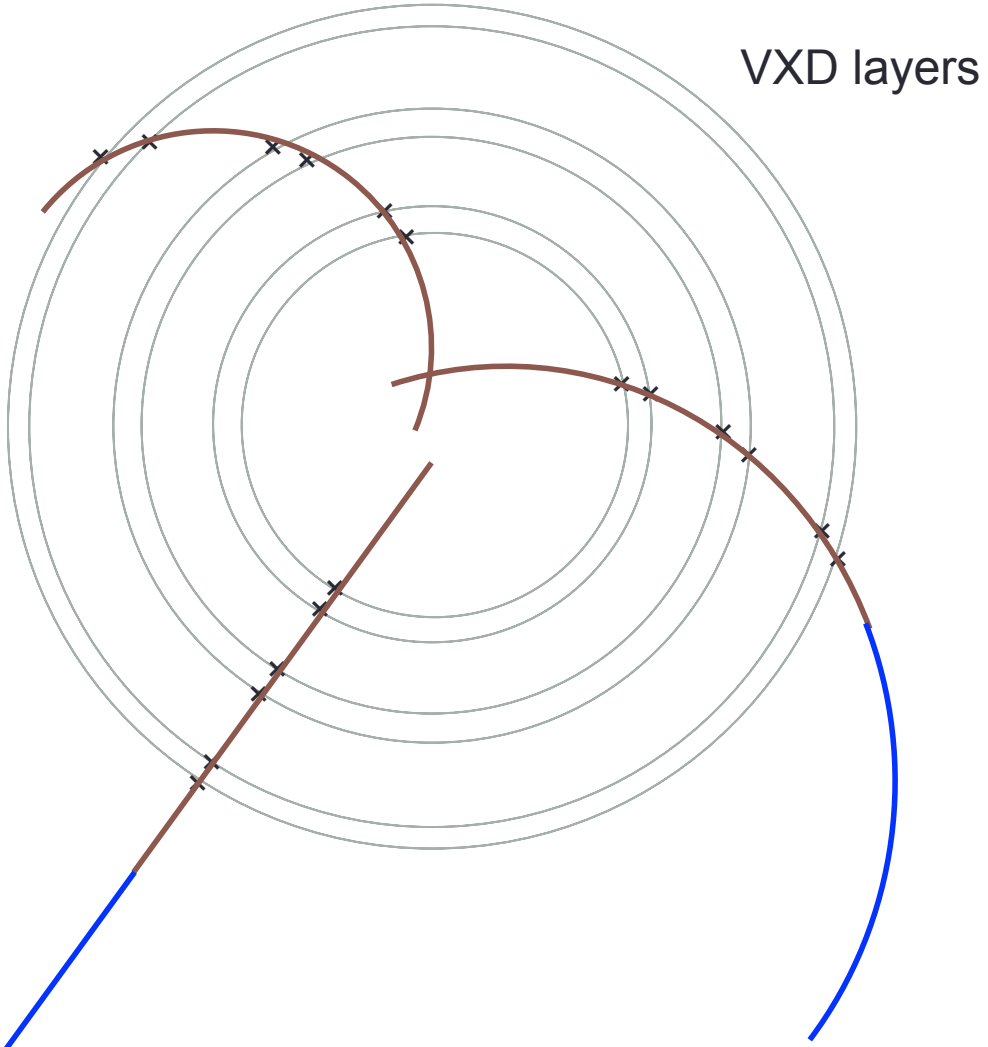
DBD Silicon Tracking



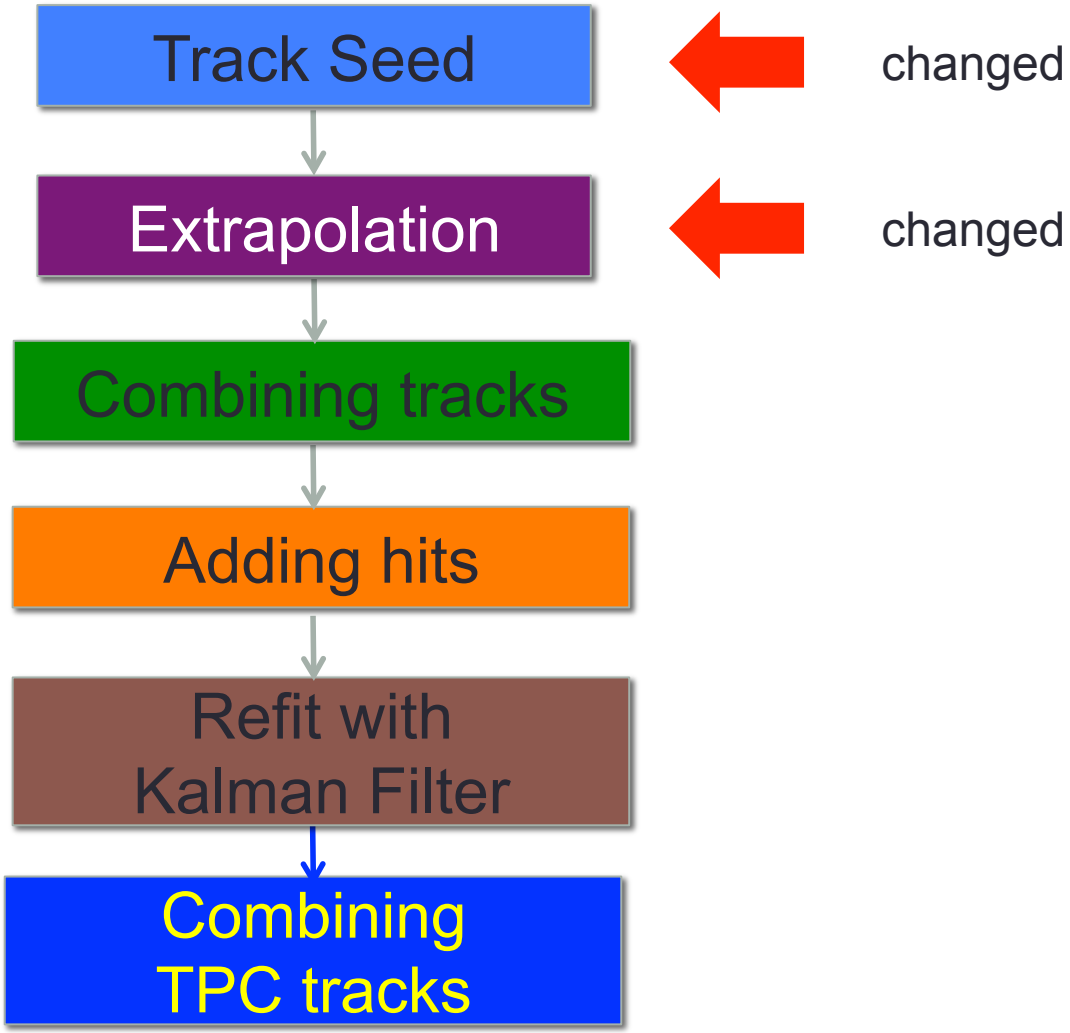


Full Track

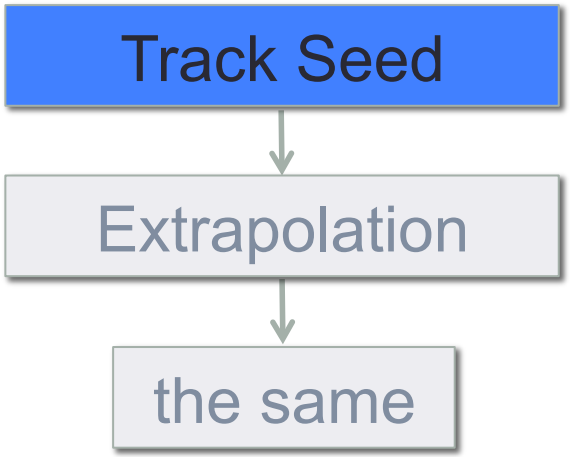
If possible, we combine TPC tracks with silicon tracks, and then refit tracks with Kalman Filter

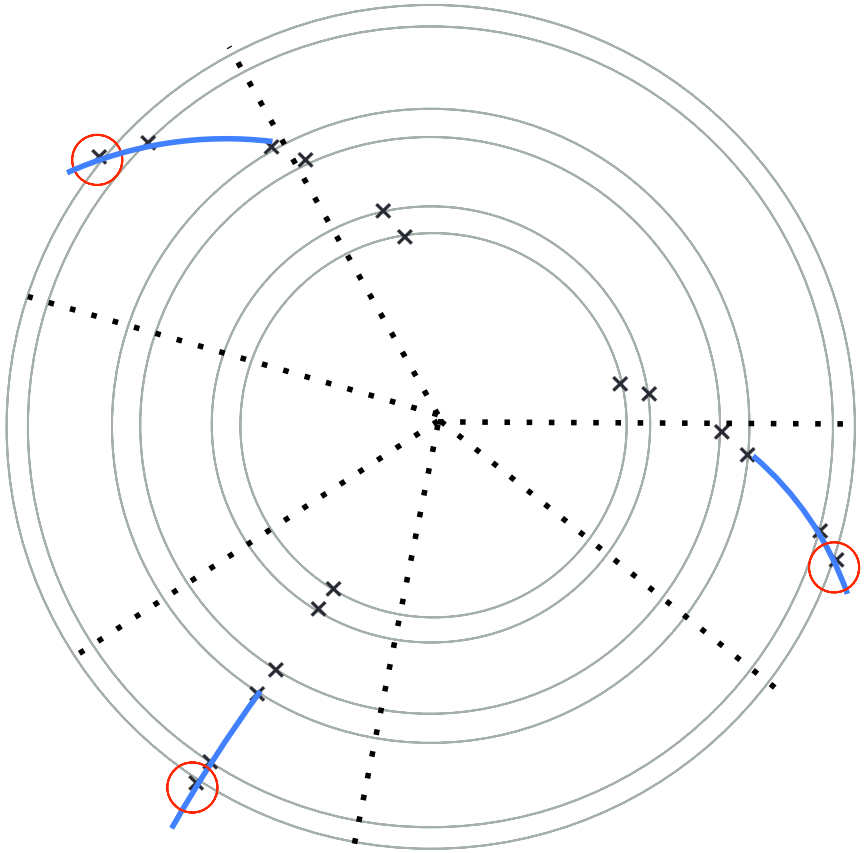


Differences between DBD ver. and FPCCD ver.



FPCCD Track Finder

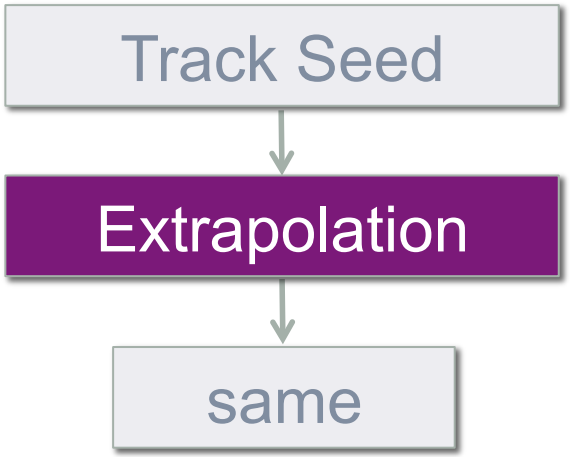


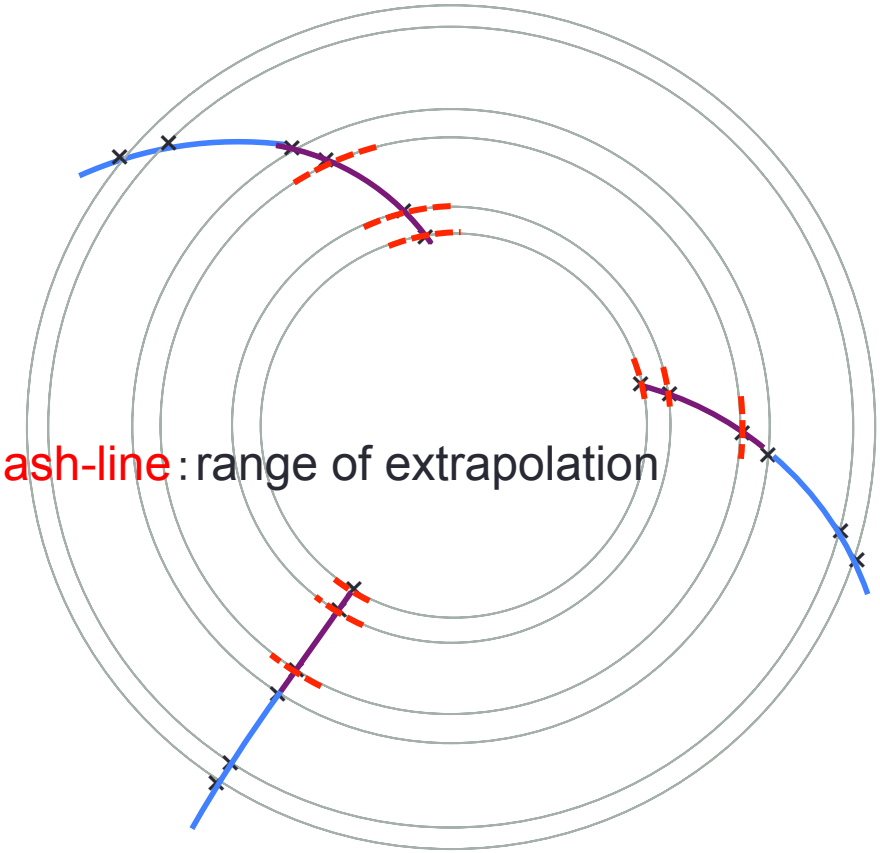


(FPCCD version)
We calculate Φ width enough to generate track seeds with P_T > 0.18 GeV/c on the basis of a hit on the outer layer

We generate track seeds from 3 hits on each of the 3 layers in the calculated Φ width

FPCCD Track Finder





(FPCCD version)
Fitter : **Kalman Filter**

Φ width for extrapolation : determined from track parameters from the fitter

Algorithm for matching hit clusters : **optionally available** : **purity** ↑

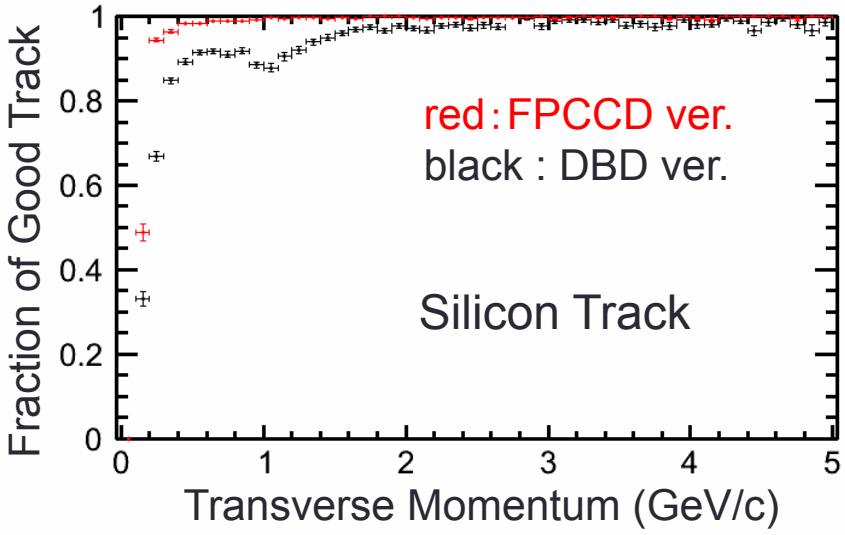
Performance of FPCCD Track Finder

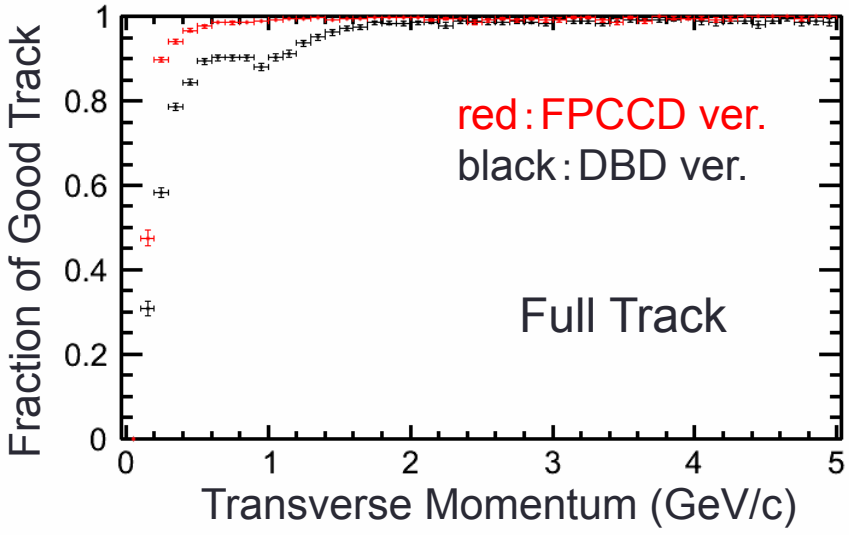
Fraction of Good Track : η ≡

$$\eta \equiv \frac{\#\text{ of tracks with VXD hits >= 5 \&\& track purity > 75\%}}{\#\text{ of MCParticles creating VXD sim-hits >= 6 \&\& SIT sim-hits >= 4}}$$

Tips : required P_T
R_{in} of TPC : > 0.4 GeV/c
R_{out} of TPC : > 1.8 GeV/c

Sample: ttbar @ 350 GeV (without BG)





Fraction : ~ 99% until P_T = 0.6 GeV/c

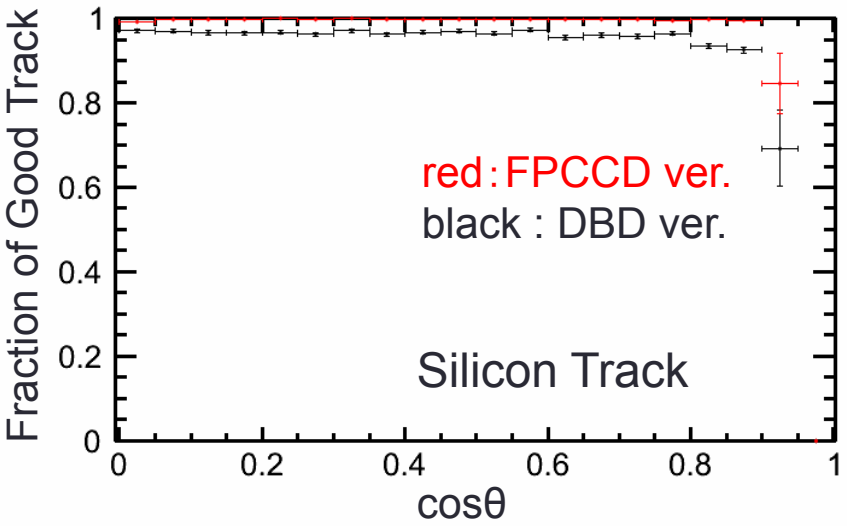
Performance of FPCCD Track Finder

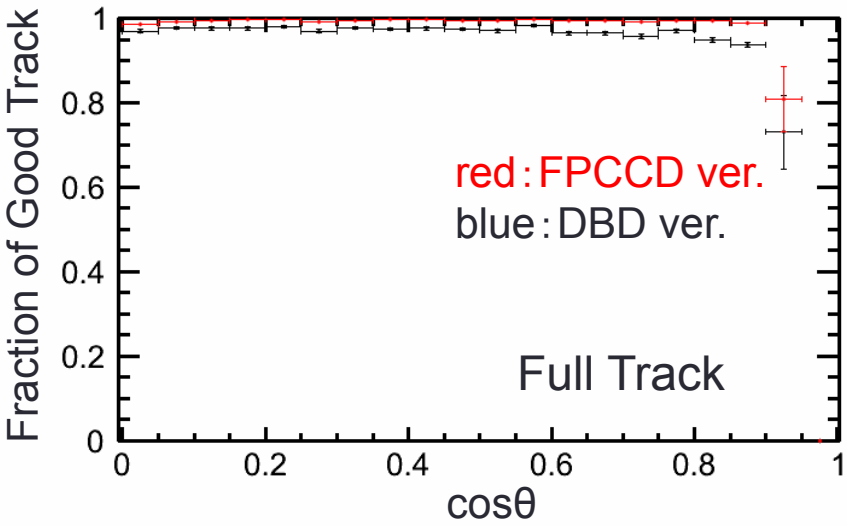
Fraction of Good Track : η ≡

$$\frac{\text{\# of tracks with VXD hits >= 5 \&\& track purity > 75\%}}{\text{\# of MCParticles creating VXD sim-hits >= 6 \&\& SIT sim-hits >= 4}}$$

Sample: ttbar @ 350 GeV (without BG)
|P| > 1 GeV/c

Tips : SIT coverage
cosθ < 0.9





Fraction : ~ 99 % within cosθ = 0.9

Performance of FPCCD Track Finder

Fraction of Good Track : η ≡

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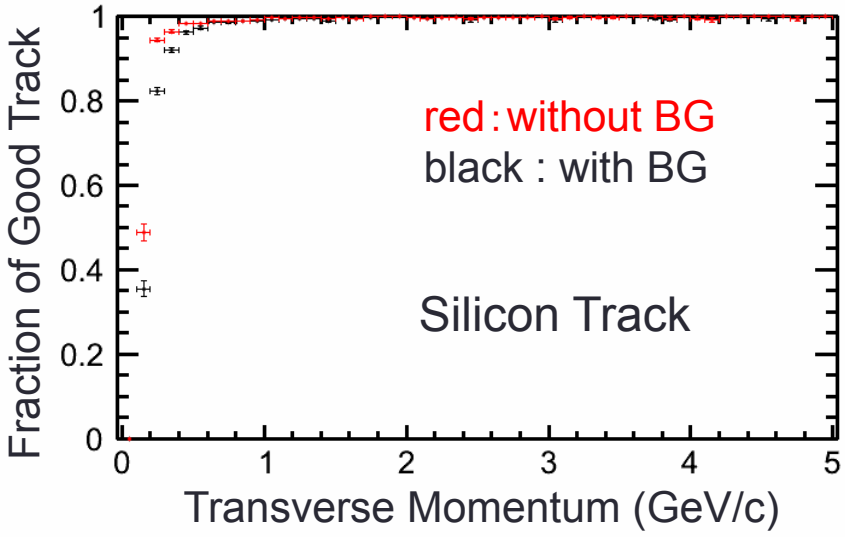

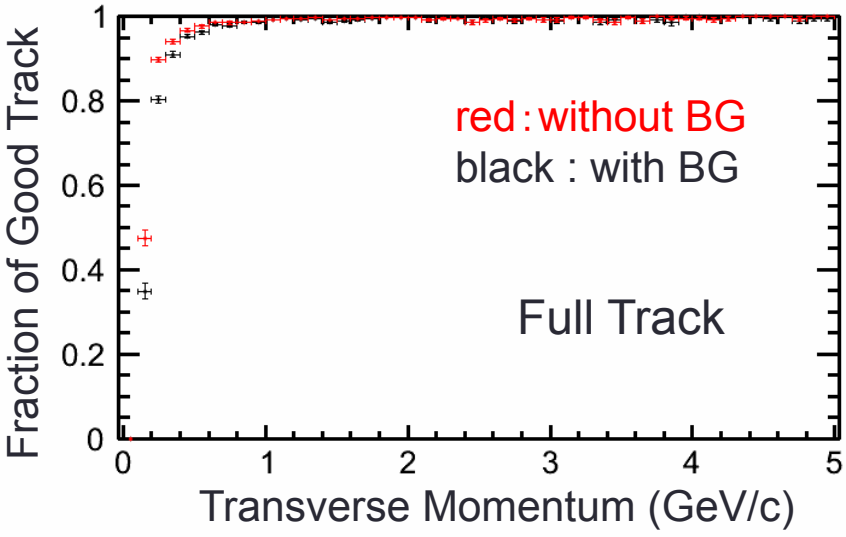

There is little deterioration until 0.6 GeV/c

Performance of FPCCD Track Finder

Fraction of Good Track : η ≡

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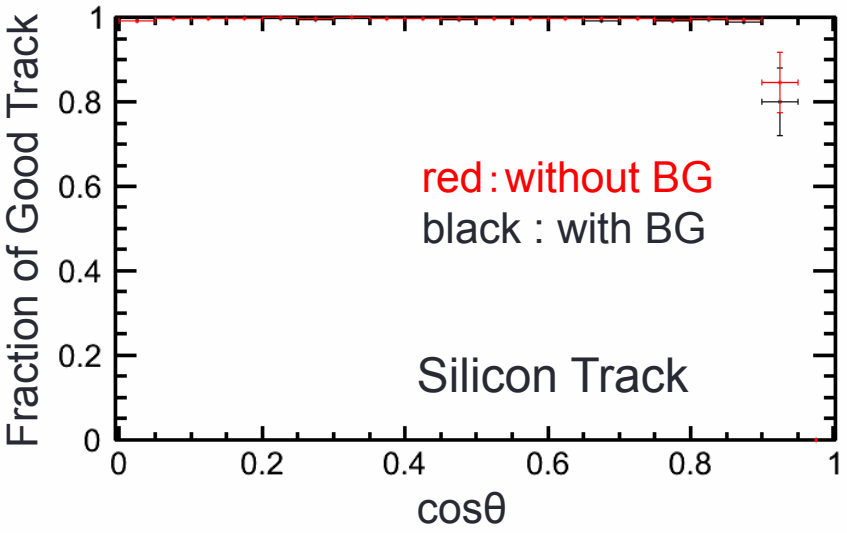
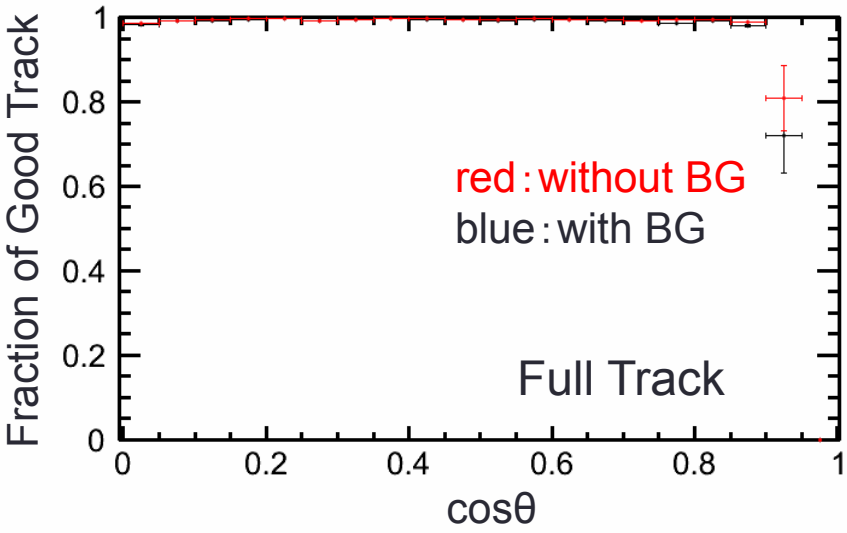
Sample: ttbar @ 350 GeV
|P| > 1 GeV/c

Tips : SIT coverage
cosθ < 0.9





There is little deterioration

Performance Evaluation of Flavor Tagging

Setup

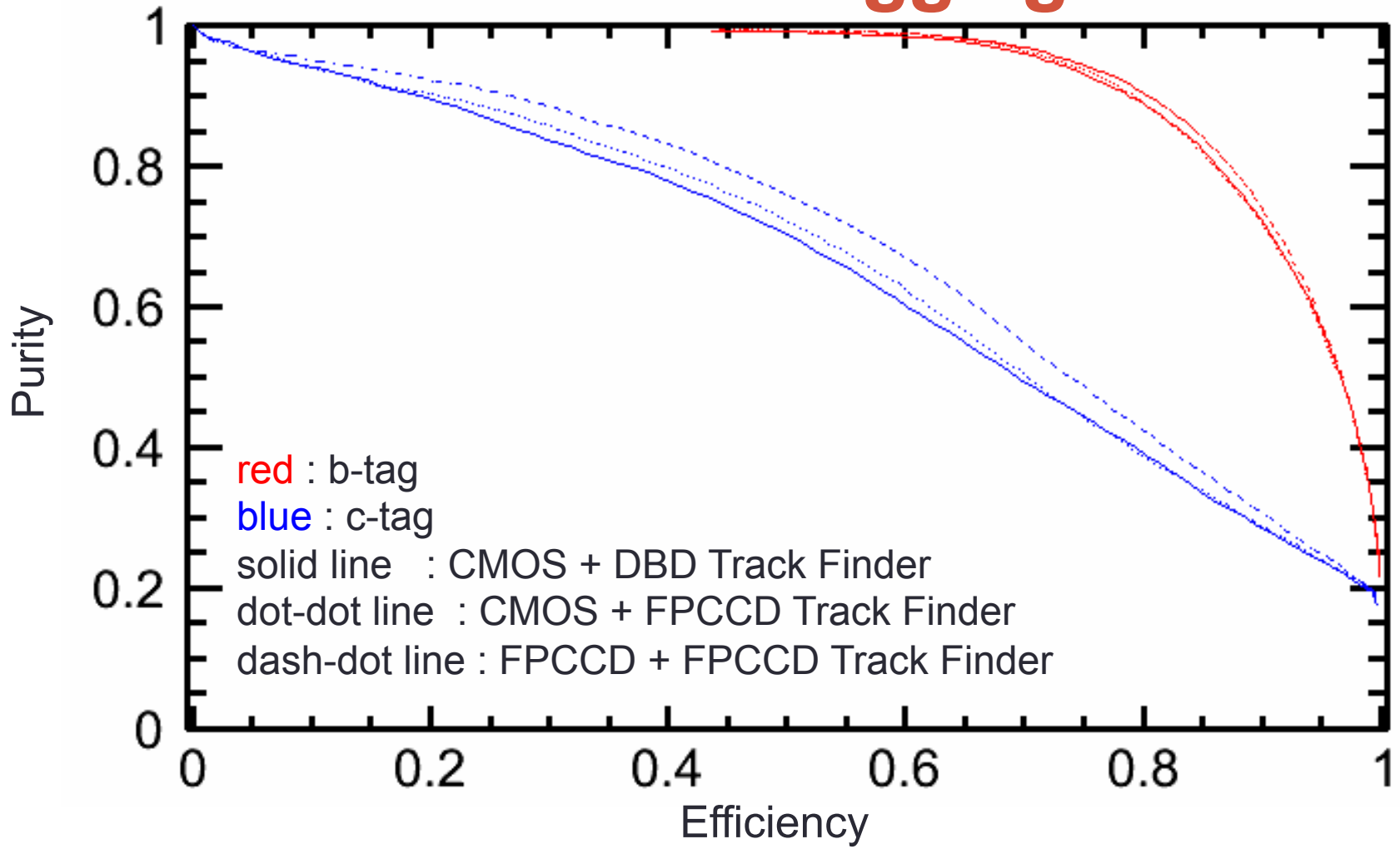
MC sample : Z→bb, cc, qq (q : u, d, s) @ 91.2GeV
(# of each events of them : 25000 events)

Efficiency : $\frac{\text{\# of signal jets}}{\text{\# of true jets}}$

Purity : $\frac{\text{\# of signal jets}}{\text{\# of signal jets \& noise jets}}$

Assumption of Branching Fraction : → for calculating purity
BF(Z→bb) = 0.1512
BF(Z→cc) = 0.1203
BF(Z→qq) = 0.428

Performance of Flavor Tagging



FPCCD +
FPCCD Track Finder

b-tag : efficiency 2% Up @ purity 90%
c-tag : efficiency 4% Up @ purity 70%

Summary and Plan

◆Summary

- FPCCD Track Finder has been developed
  - Fraction of Good Track & Performance of Flavor Tagging
    - ➢more improvement can be seen than using DBD tracking

◆Plan

- Evaluation of flavor tag in the presence of pair BGs
- Evaluation of measurement precision of Higgs coupling to b, c, and g by using FPCCD and analyzing e+e-→ZH @ 250 GeV