Tracking Efficiency for $H \rightarrow b\bar{b}$ & calorimeter Seed tracking for the CLIC SiD

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Outline

- SiD Detector
- Track Reconstruction Efficiency

  Samples Used

  - $e^+e^- \rightarrow H\nu\bar{\nu} \rightarrow b\bar{b}\,\nu\bar{\nu}$ @3TeV, Higgs search
  - $e^+e^- \rightarrow Z^0/\gamma \rightarrow b\bar{b}$ @3TeV

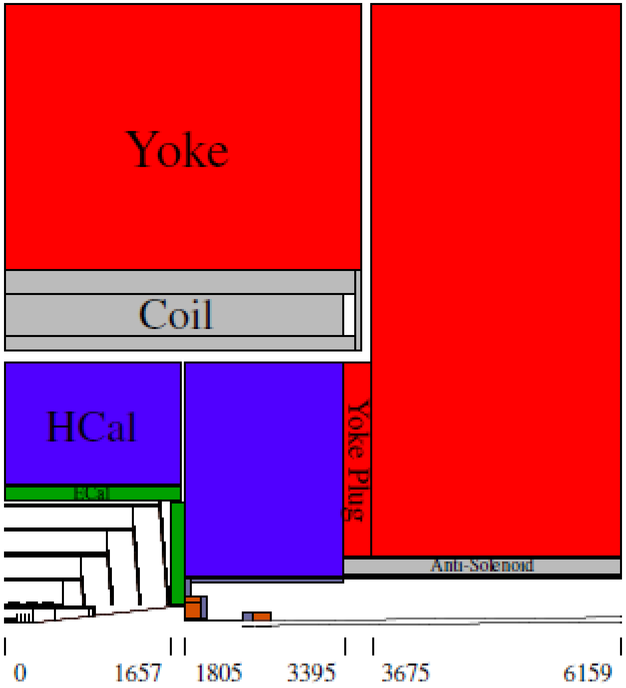
  Tracking Algorithm

  Results
- Calorimeter Seed Tracking (ongoing)
- Summary & Future Outlook

SiD Overview

The CLIC SiD detector model is a concept for a 4π multi purpose detector for a future linear lepton collider

- ➢All silicon tracking system is designed to provide excellent point resolution.
- ➢Pixel detectors in vertex and forward region
- ➢ Compact finely segmented EM calorimeter (silicon-tungsten) & hadronic calorimeter.
- ➢ 5T solenoid field is provided by superconducting coil outside of the calorimeter.



One quadrant of the CLIC SiD CDR detector model in the zx-plane

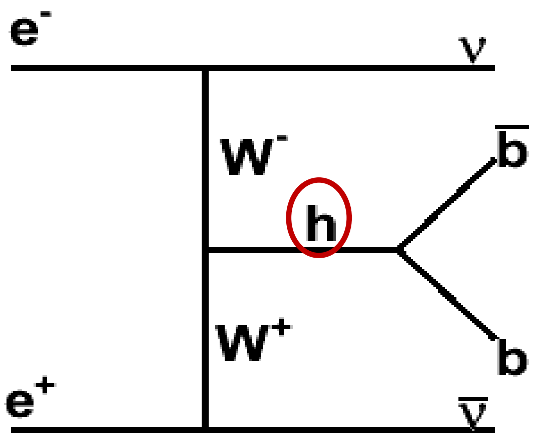
Task01 :

Track reconstruction efficiency study

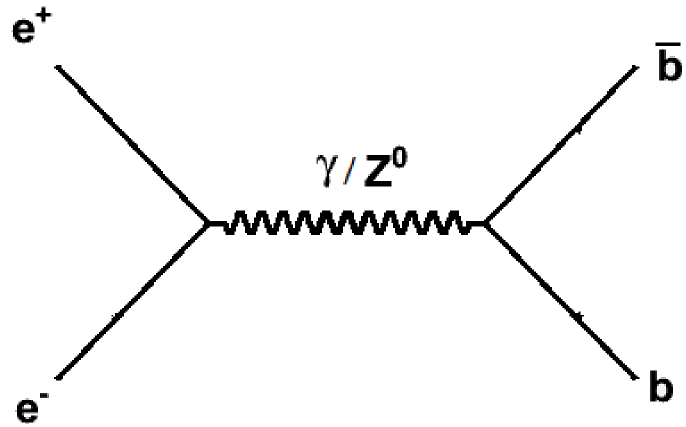
Samples Used@3TeV, 9k events

$$e^+e^- \rightarrow H\nu\bar{\nu} \rightarrow b\bar{b}\,\nu\bar{\nu}$$

$$e^+e^- \rightarrow Z^0/\gamma \rightarrow b\bar{b}$$



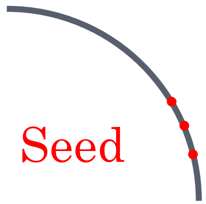
WW Fusion



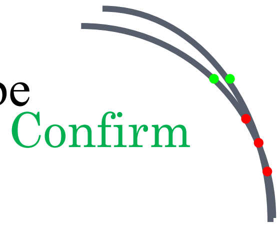
- At 3TeV CM energy, diboson fusion is the dominant mode of Higgs production
- Samples are generated using Whizard & pythia
- The tracking system is tasked with finding and reconstructing the trajectories of charged particles with high efficiency and precision.

SEED TRACKER ALGORITHM

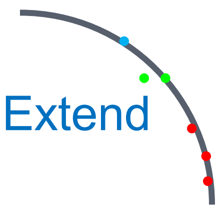
- Track finding begins by forming all possible 3 hit track seeds in the three "Seed Layers"
  - Brute force approach to finding all possible track seeds



- Require the presence of a hit in a "Confirmation Layer"
  - Significantly reduces the number of candidate tracks to be investigated



- Add hits to the track candidate using hits on the "Extension Layers"
  - Discard track candidates with fewer than 7 hits (6 hits for barrel only tracks)
  - If two track candidates share more than one hit, best candidate is selected



- Upon each attempt to add a hit to a track candidate, **a helix fit** is performed and a **global** χ^2 is used to determine if the new track candidate is viable

Seed Tracker Algorithm

- Track finding is controlled by a set of strategies.
- Use automated Strategy Builder

  Set required

  - SeedHits, ConfirmHits, ExtendHits
  - P_t, d0, z0 and χ^2 cuts

    d0 – distance of closest approach (DCA) in xy plane

    z0- z coordinate of DCA
  - requirements in the number of hits

Tracking algorithm & Selection cut

$$\text{Tracking Efficiency} = \frac{reco\ MC\ particles}{findable\ MC\ particles}$$

where,

- findable MC particles: All MC particles that pass the cuts described below
- reco MC particles : fraction of findable MC particles found by the tracking algorithm

Selection criteria :

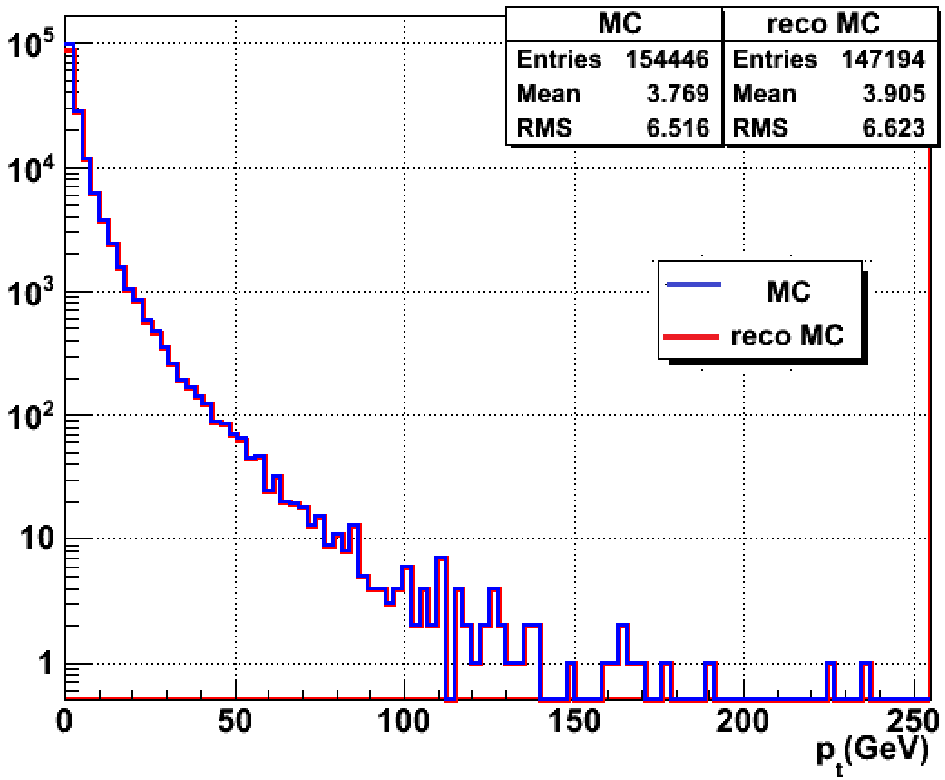
Theta > 10 degrees
Pt > 250 MeV
Charge different from 0
Distance from IP (originating from the IP) < 50 mm
Flight distance (path length) > 50 mm
Stable MC Particles

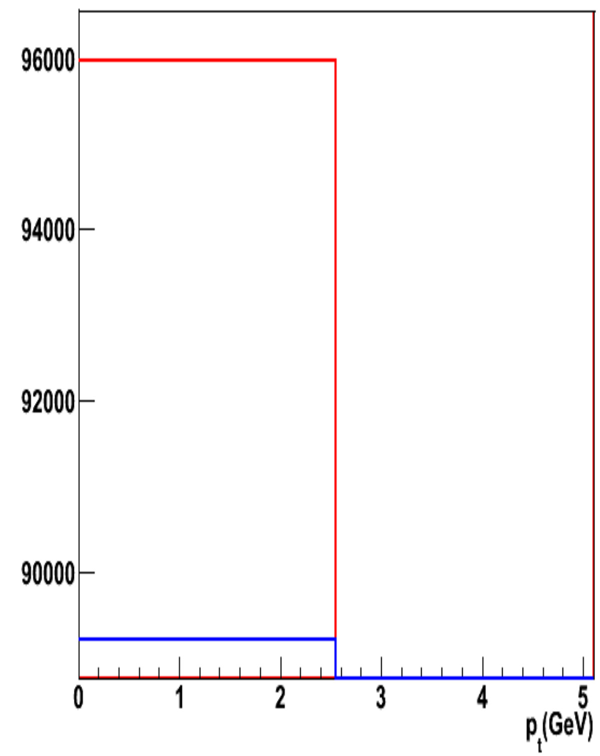
- Studied variation of all selection cuts used

Results:

$e^+e^- \to H\nu\bar{\nu} \to b\bar{b}\,\nu\bar{\nu}$ *@ 3 TeV ~9k events*

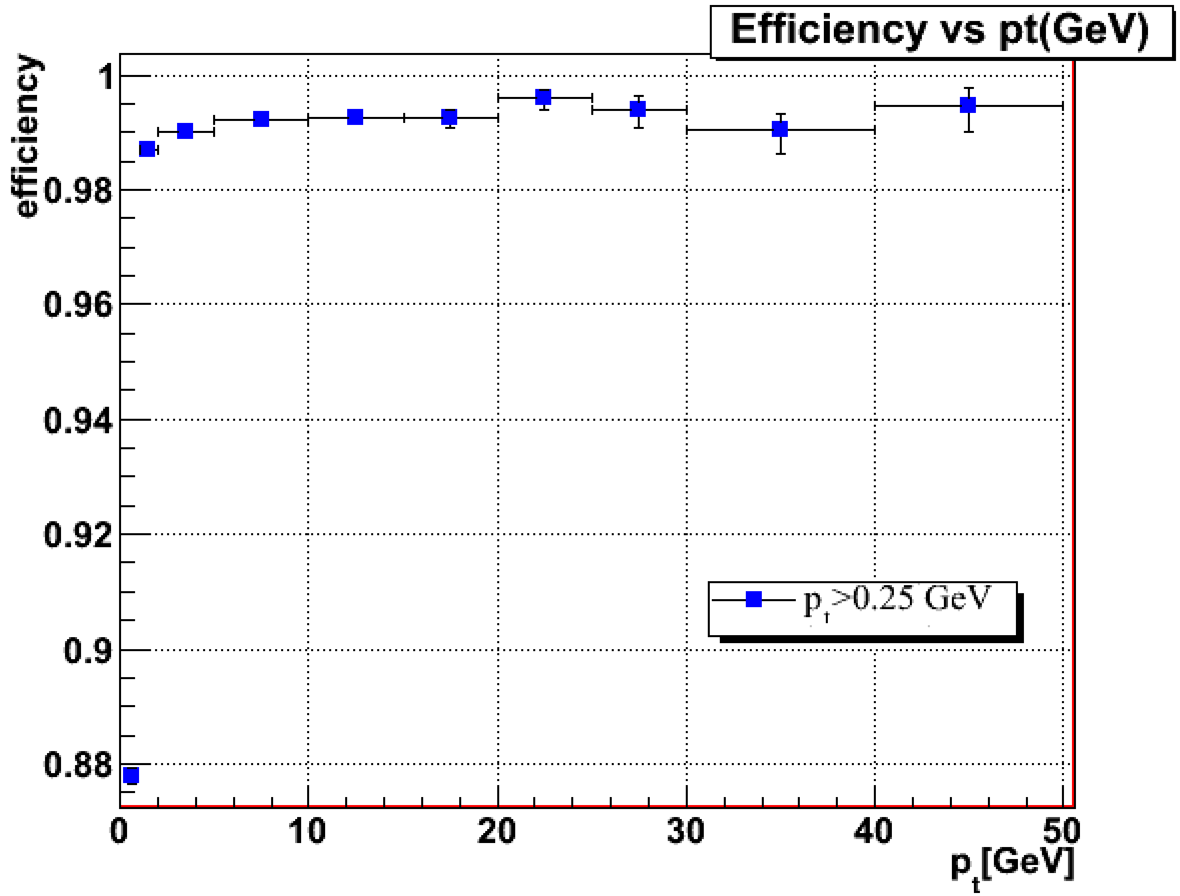
- MC – findable MC





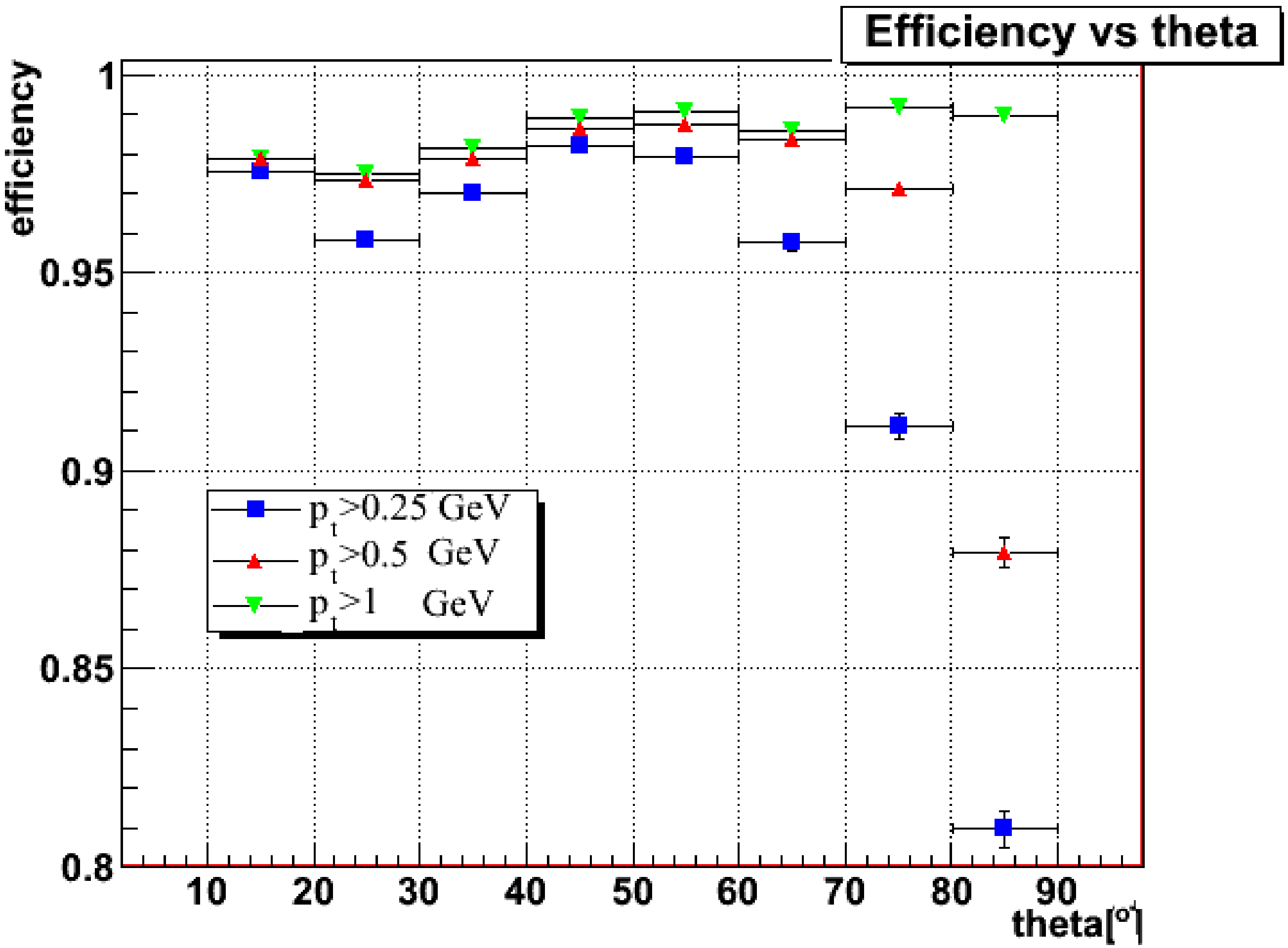
➢Average 95.3% of findable MC's are effectively reconstructed

Efficiency plots: (P_T)



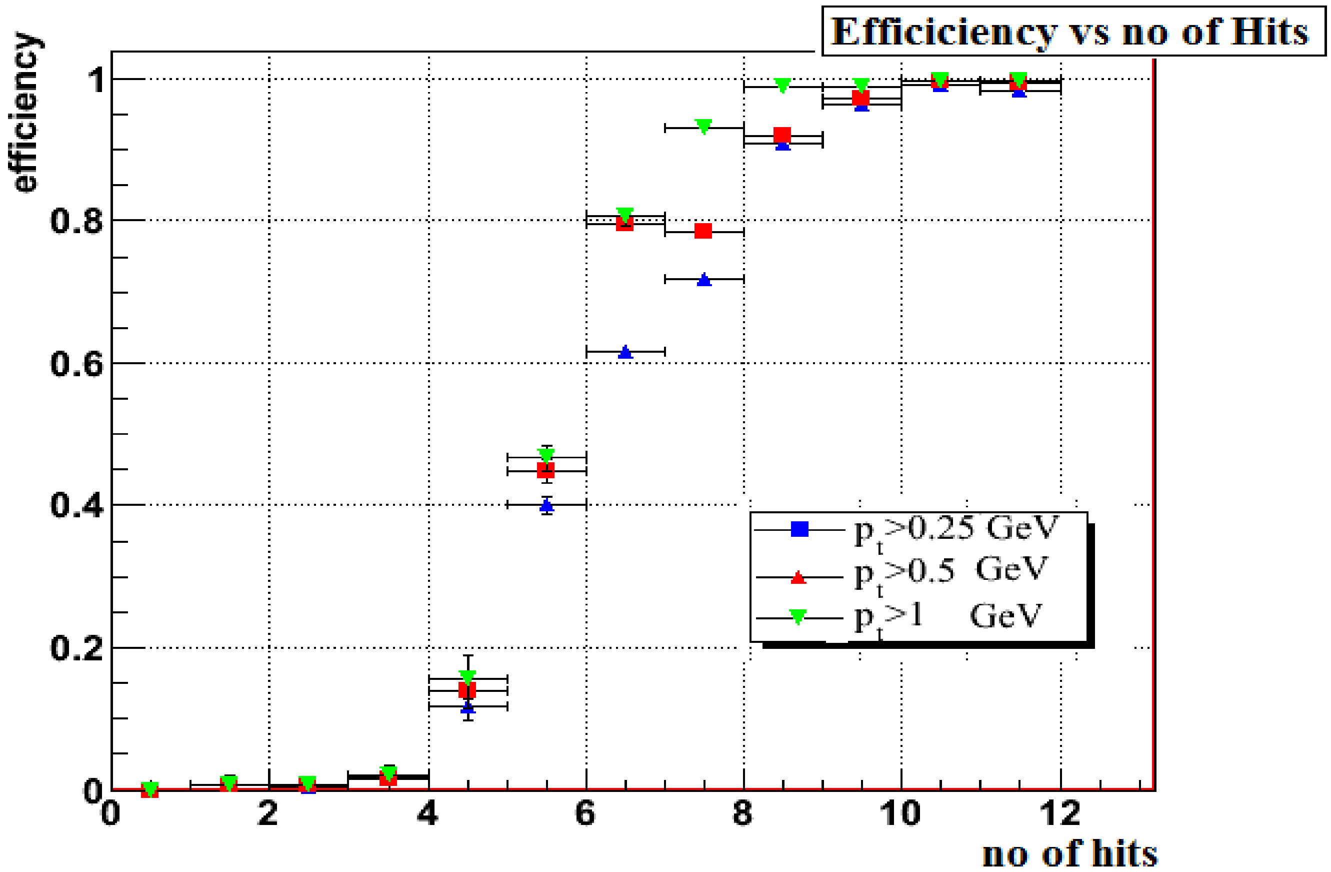
➢ efficiency is ~99% for pt> 1GeV & drops to 88% for 0.25-1 GeV pt particles.

Efficiency plots: (THETA)



- non reconstructed low pt MC are lying in the central barrel region
- efficiency is improving with the pt cut

Efficiency plots: (NO OF HITS)

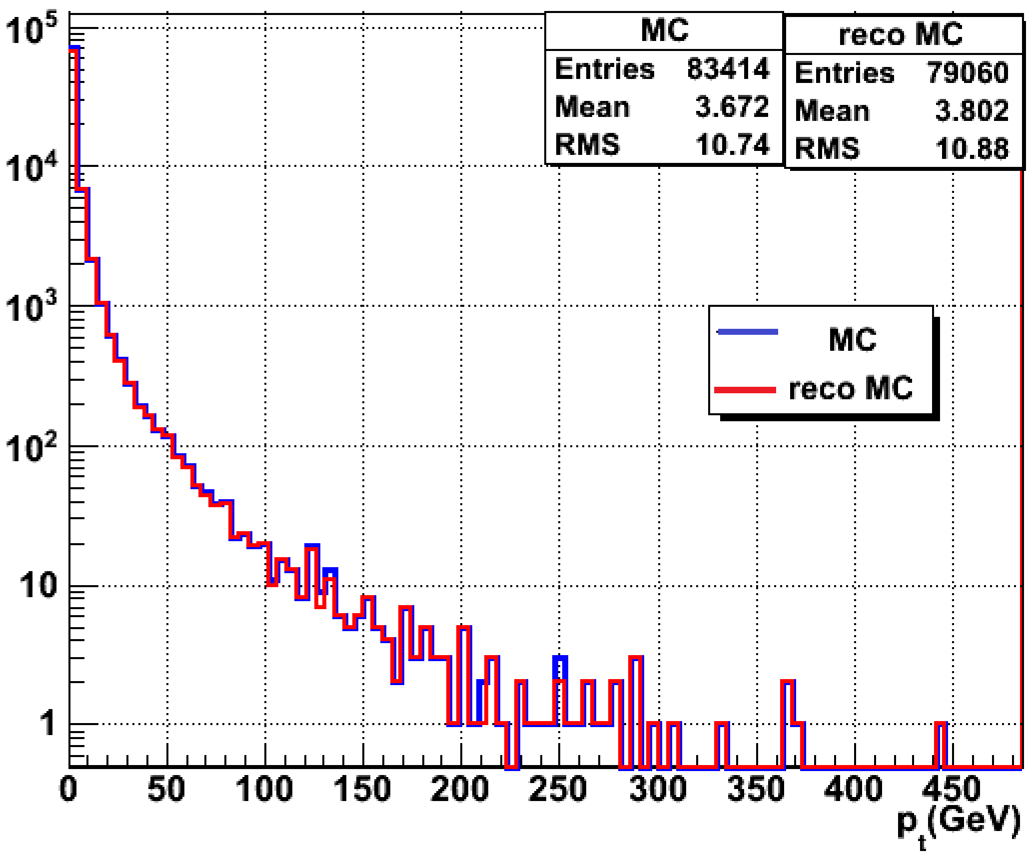


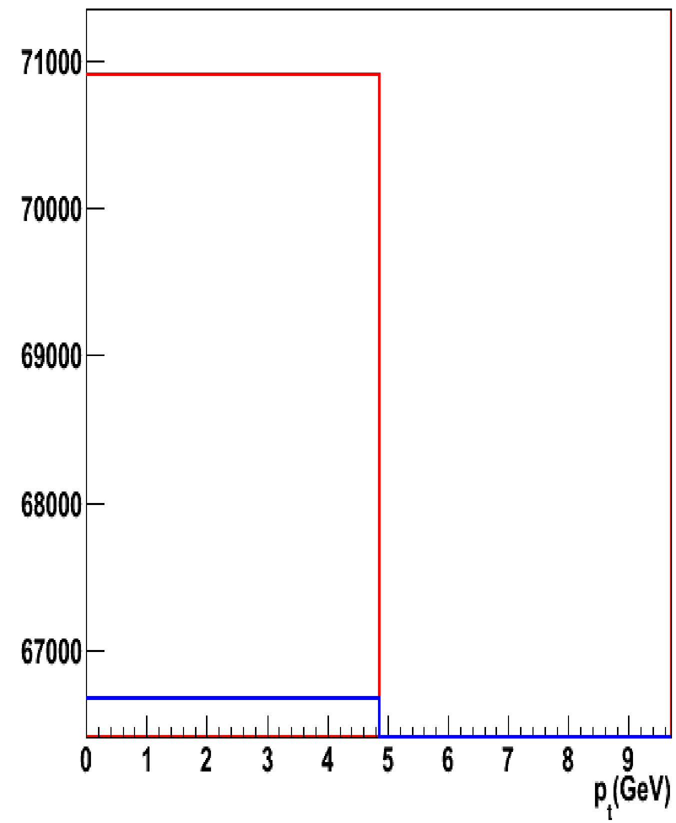
For no of hits= 7

Pt (GeV)	efficiency
0.25	73
0.5	79
1.0	94

Results:

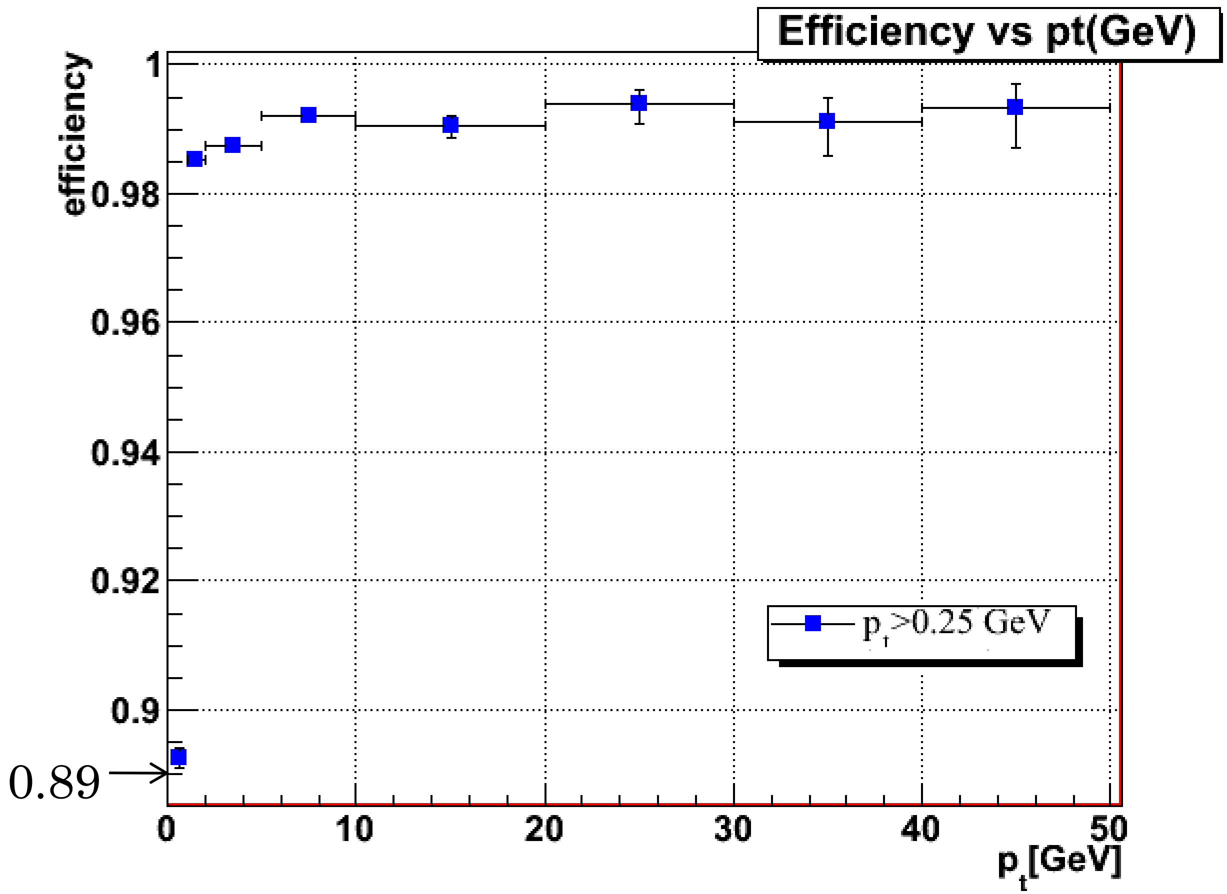
$e^+e^- \rightarrow Z^0/\gamma \rightarrow b\bar{b}$ *@3 TeV, 9k event*





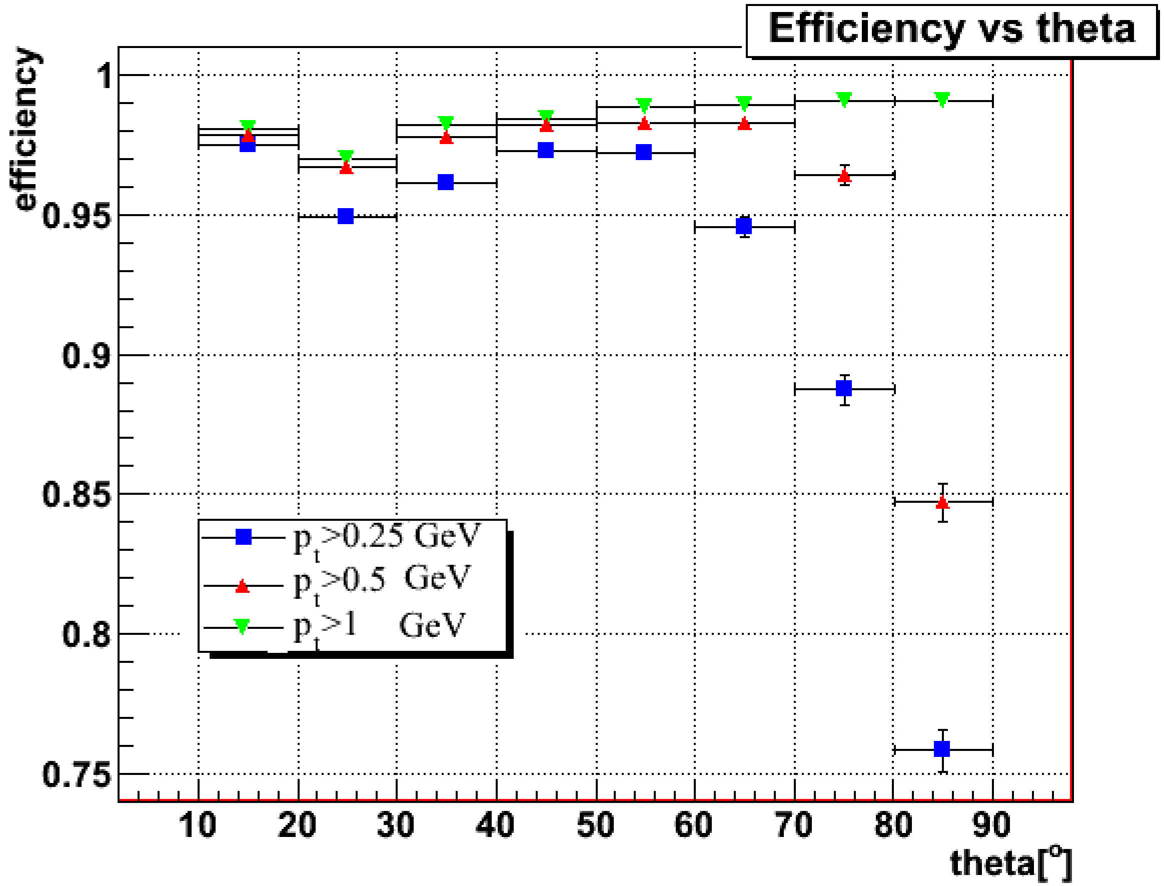
- Average 94.7% of findable MC's are effectively reconstructed

Efficiency plots: (PT)



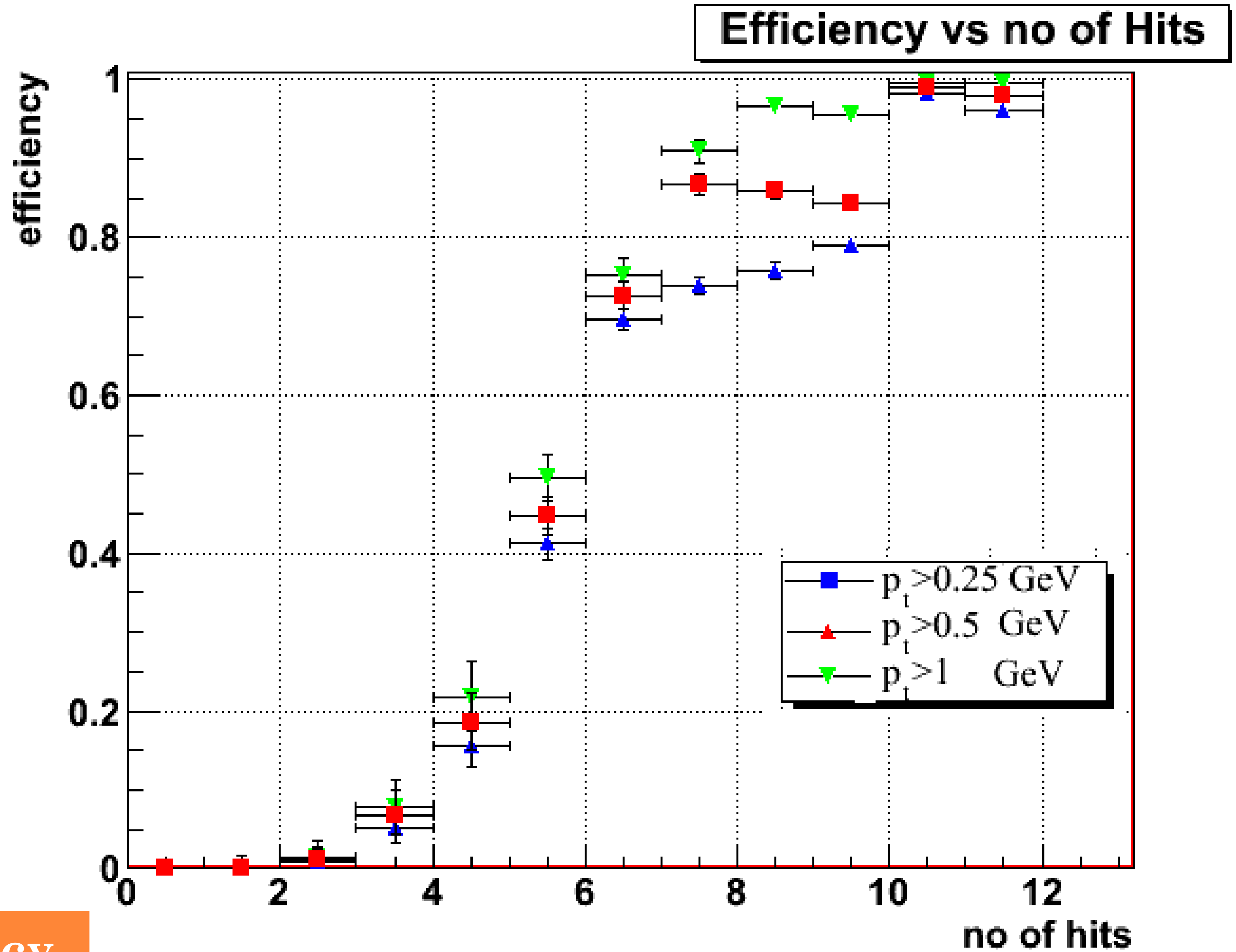
➢ efficiency is ~99% for pt> 1GeV & drops to 89% for 0.25-1.0 GeV pt particles

Efficiency plots: (THETA)



- non reconstructed MC of pt , 0.25-1 GeV are lying in the central region
- theta efficiency is improving with the pt cut

Efficiency plots: (NO OF HITS)



For no of hits= 7

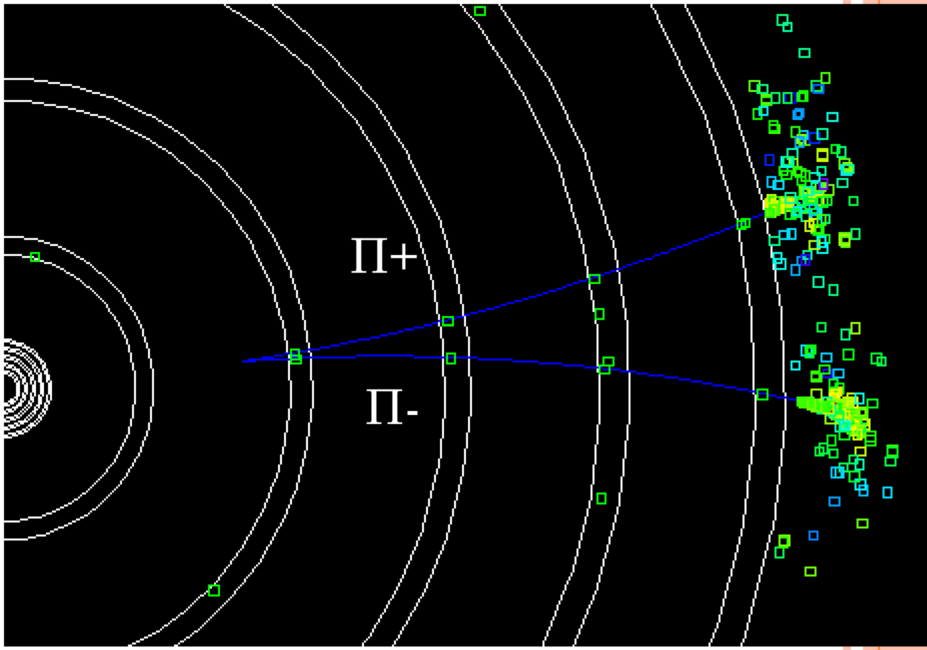
Pt (GeV)	efficiency
0.25	75
0.5	86
1.0	92

Task02 :
Calorimeter Seed Tracking Study

Calorimeter seed Tracking

- Tracking code is not meant for the long lived particles like (KS0 , Λ) decaying outside vertex region due to the vertex constraint in the helix fitting

- But with the finely segmented ECAL, outside-to-Inside Tracking starting from Calorimeter Clusters is effective



JAS3 view, $K^0 \rightarrow \pi^+\pi^-$

- Particle-Flow algorithms will benefit from calorimeter-seed tracking through
  - -better tracking,
  - -better track-cluster matching

"In addition, The algorithm is also able to find calorimeter backscatters"

CALORIMETER SEED TRACKING

- Some basic code (Garfield) exist (written in 2005) for cal seed tracking,

  - It uses simulated hit (Garfield hit), whereas we have properly **digitized hit (helical hit)** which encapsulates all the information needed by the standard pattern recognition algorithm

  -It uses its own helix (GarfieldHelix) with different definition of helix parameters, want to interface to current version of Helix with proper parameter dependence (**HelixSwimmer**, written by Jan Strube)

- Need to rewrite the code for track finding with the current version of Helix.

Calorimeter seed Tracking

Initial Implementation:

- Every ECAL cluster is considered to be a seed

- Identify such seeds using simple nearest neighbour clustering & calculate position, direction, and curvature radius for each of them.

- Extrapolate tracks from seed towards the centre of the detector, picking up tracker hits as we go.

- After each new added hit, recalculate track parameters (χ^2-Fit). If there are multiple hit candidates in the same layer, branch and create new tracks.

- Apply quality cuts & discard duplicate

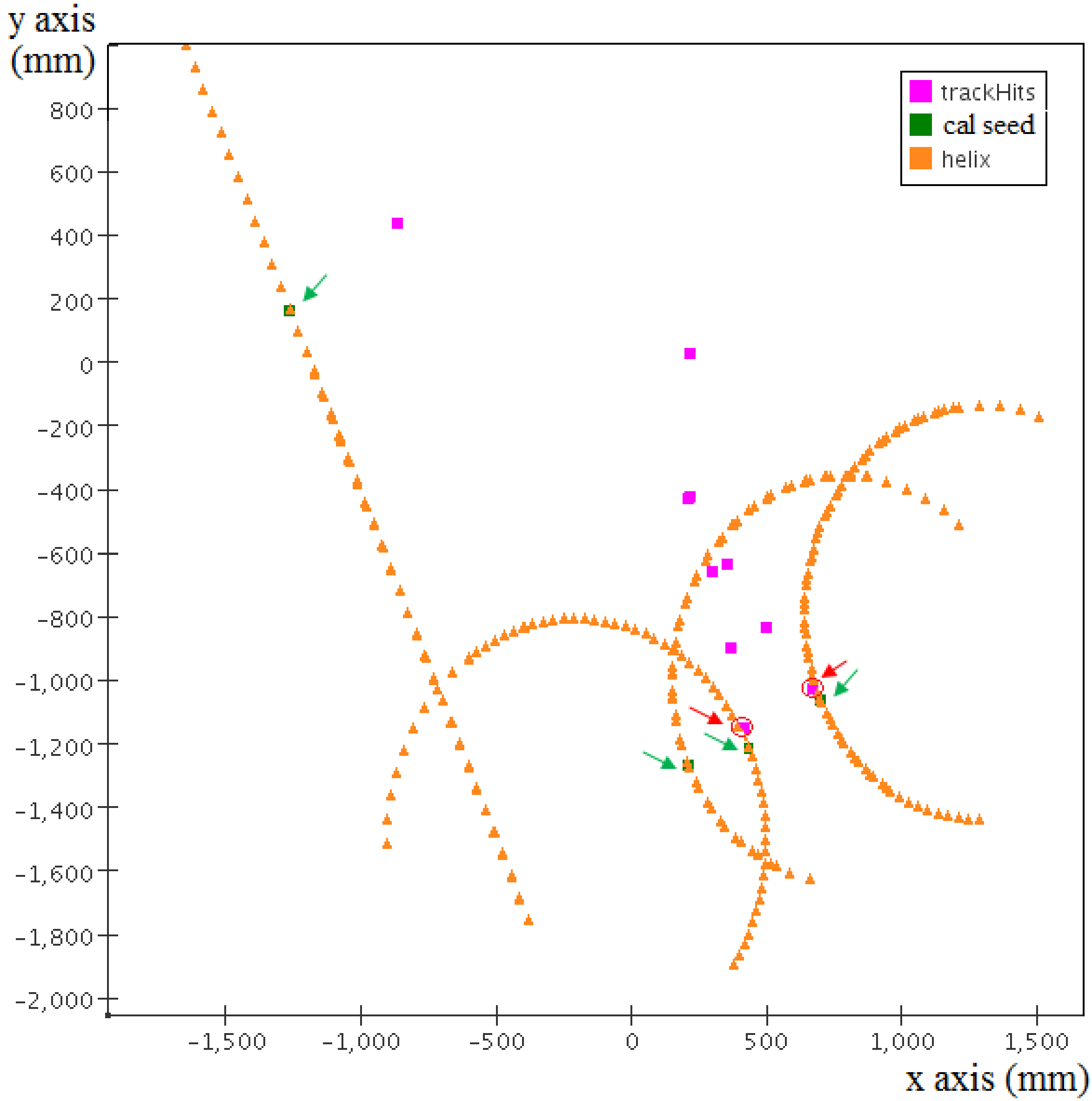
- Find track intersection

- Identify particle by reconstructing the invariant mass

Calorimeter seed Tracking

Progress so far :

- ➢ have set helix for cal seed
- ➢ have added hits lying on the last tracker layer
- ➢ Need to get the modified parameters for the newly added hit
- ➢ Further hits following χ^2 cut and helix fit will be added



Summary & Future Plan

TASK 01

- Tracking efficiency for H->bb MC's were studied at 3TeV Center of Mass energy with 9k events.
- Tracking efficiency is studied for various selection parameters variation.
- Tracking reconstruction efficiency is 88% for pt> 0.25-1.0 GeV MC particle lying in the central region for H-> bb
- ~ 99% tracking efficiency of both samples for pt > 1GeV & theta ~10 deg

TASK 02

- Presently understanding the cal assisted tracking code & trying to modify the code.
- Could run the example driver of Garfield track finder & found the K0 for some samples.
- Ongoing cal seed tracking study.

ACKNOWLEDGEMENT

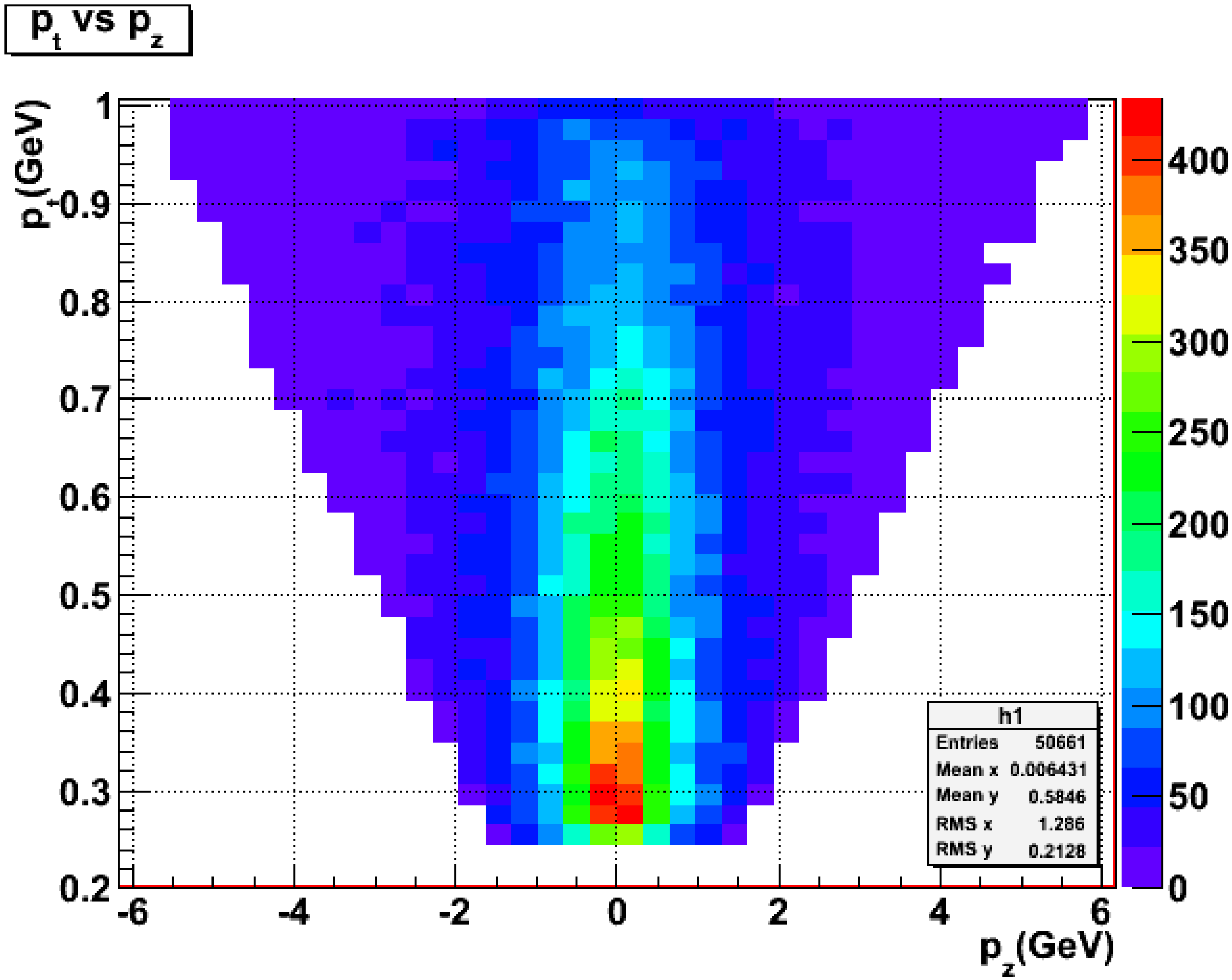
Thanks to

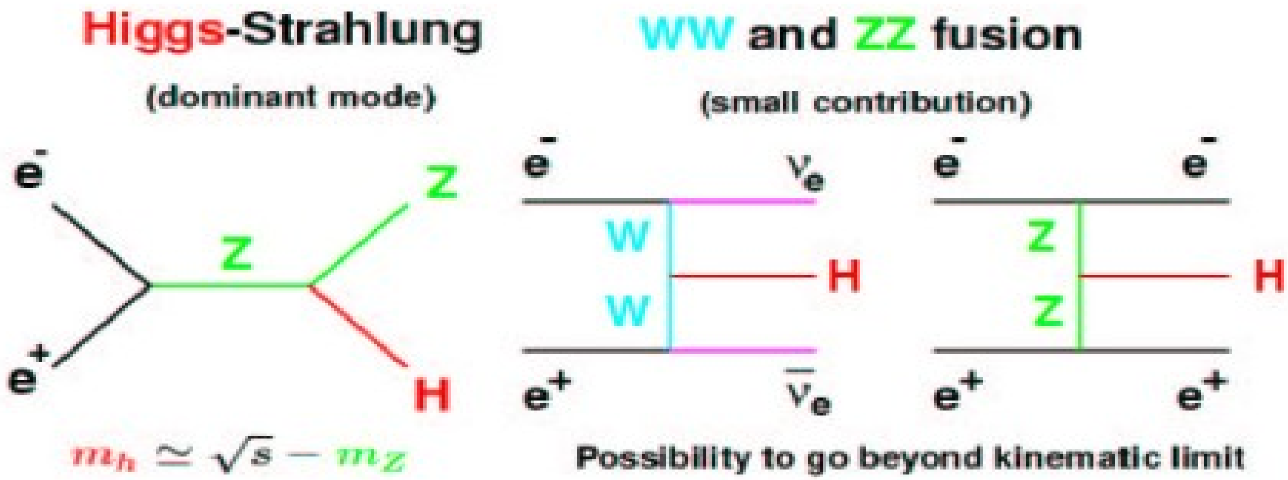
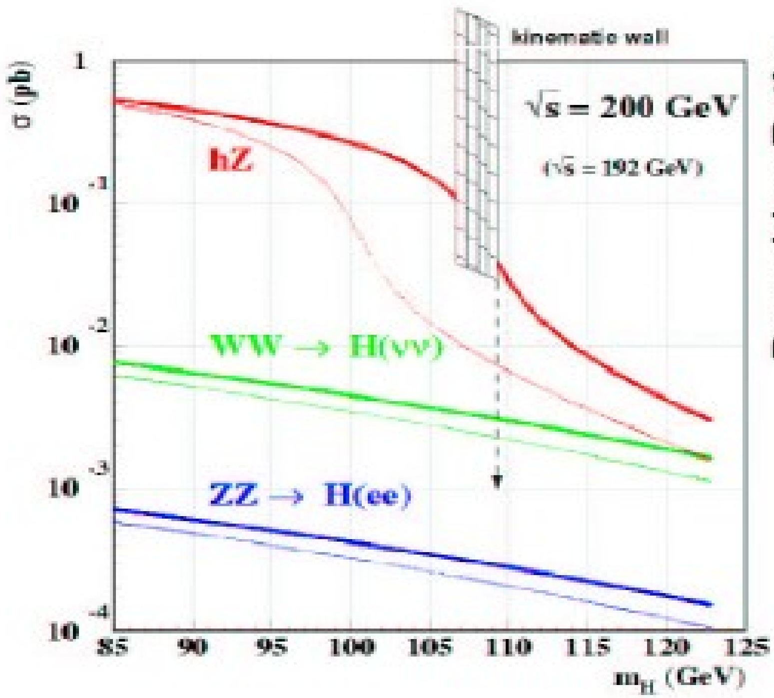
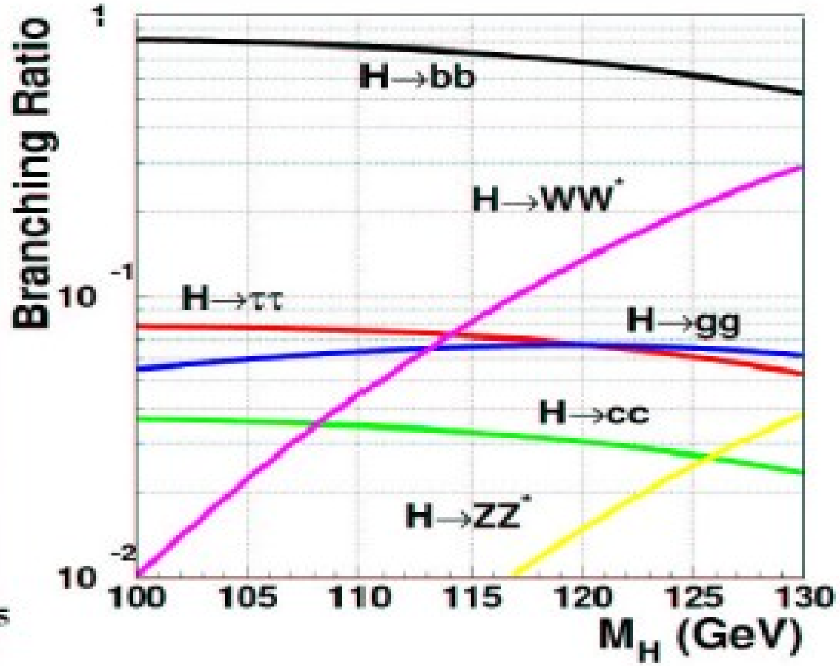
- Christian Grefe for helping me with the understanding of the code & for the discussions.
- Stephane Poss & Jan Fridolf Strube for discussions

Backup

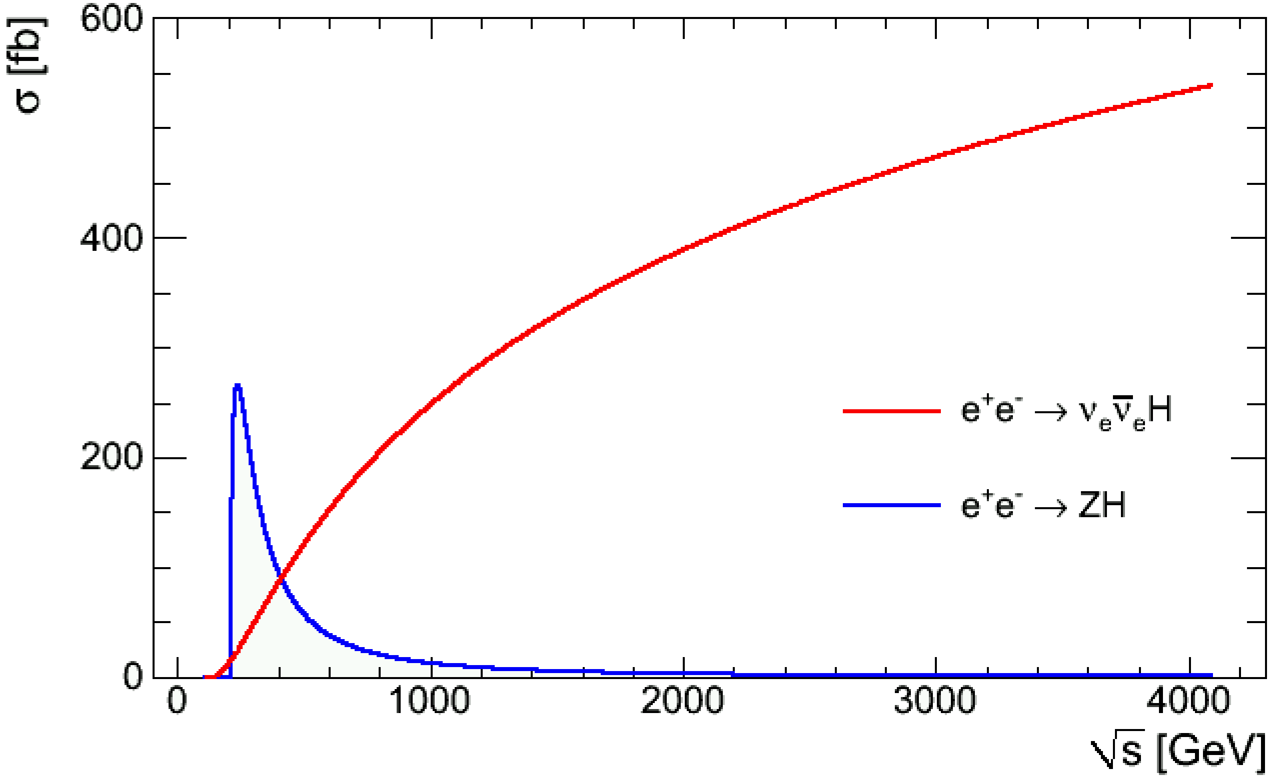
SLIDES

Pt vs Pz for H->bb




Higgs-Strahlung
(dominant mode)
WW and ZZ fusion
(small contribution)
e-
e+
Z
Z
H
W
W
H
ν_e
$\bar{\nu}_e$
Z
Z
H
$m_h \simeq \sqrt{s} - m_Z$
Possibility to go beyond kinematic limit

kinematic wall
σ (pb)
√s = 200 GeV
(√s = 192 GeV)
hZ
WW → H(νν)
ZZ → H(ee)
m_H (GeV)

Branching Ratio
H→bb
H→WW*
H→ττ
H→gg
H→cc
H→ZZ*
M_H (GeV)

HIGGS CROSS SECTION VS CM ENERGY



➢without beam effects
➢tree-level diagrams

Tracking algorithm & Selection cut

- Convert the digitized hits into a common hit format.
- Typically, 6-7 hits are sufficient for finding a track, which allows the standard pattern recognition algorithm to efficiently track particles originating near the interaction point with $pT > 200$ *MeV.*
- Three types of hits are supported: pixel hits, strip hits & stereo hits
- Track finding is controlled by a set of strategies. A strategy consists of the list of detector layers to be used, the role of each layer (seed, confirm, or extend), kinematic constraints (*Pt , impact parameters), requirements in the number of hits, and the* χ^2 *cut.*

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