ILD Tracking Performance Studies

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DESY

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

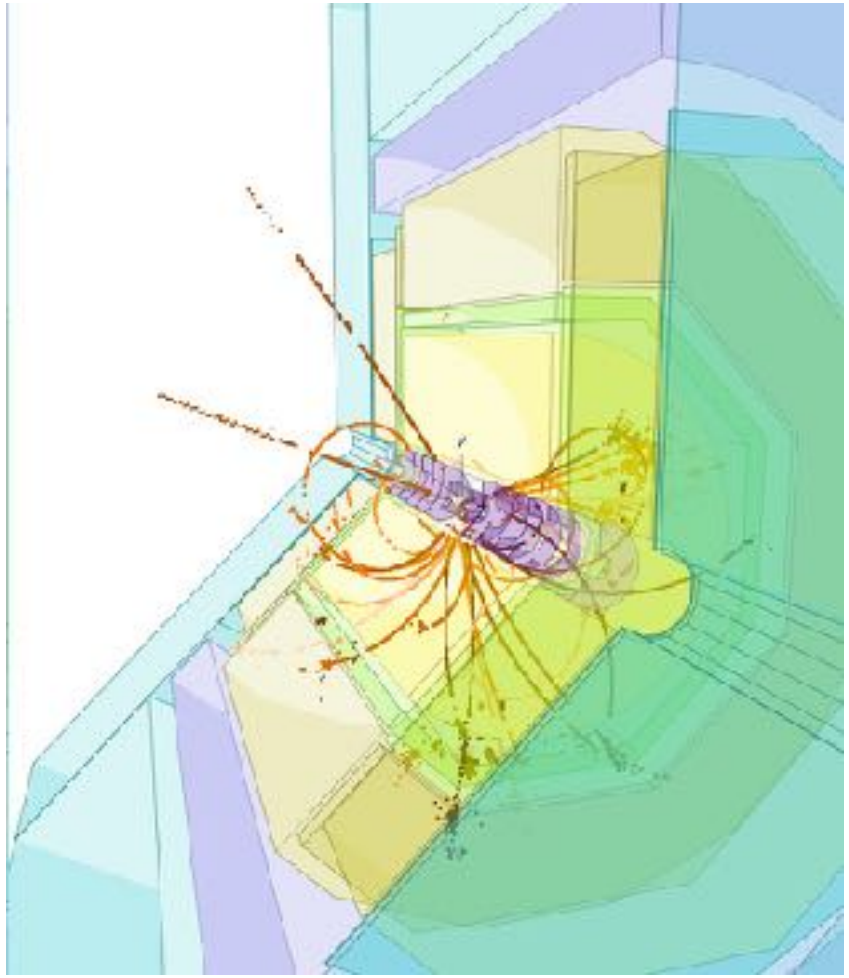
iLC SOft

AIDA 2020

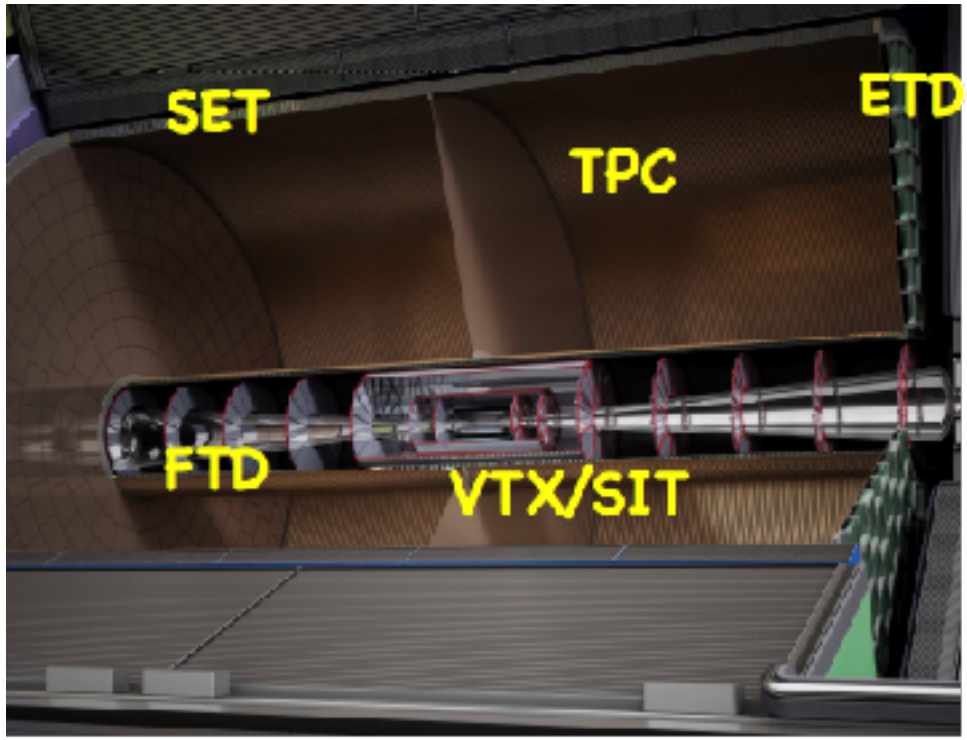
DESY.

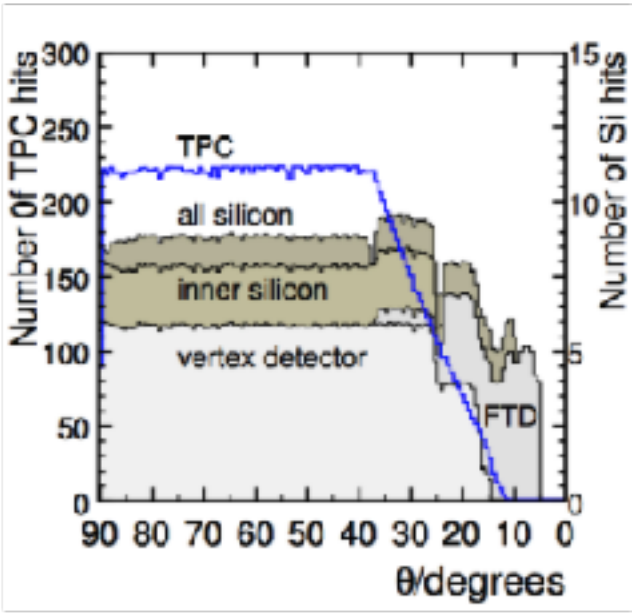
Overview

- ILD tracking System
- Track reconstruction Software
- ILD Tracking Performance
  - efficiency
  - resolution
  - large vs small ILD
- Alternative approaches
  - pixel FTD
  - Conformal Tracking
- Summary & Outlook



The ILD Tracking System

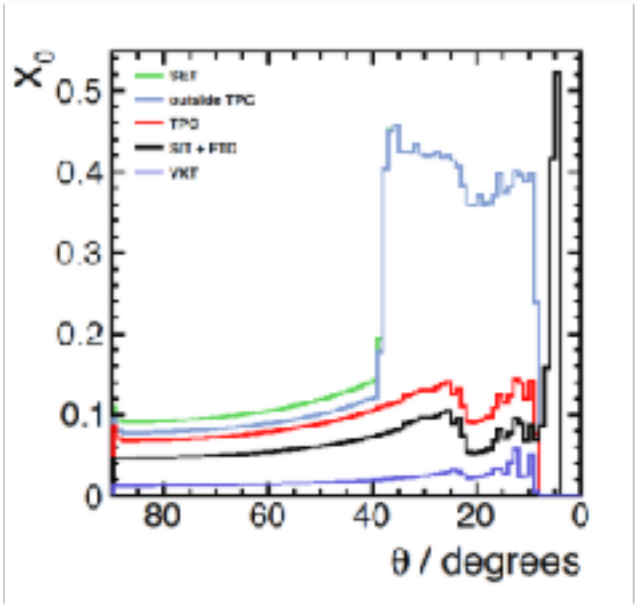




Detector	Point Resolution
VTX	$\sigma_{r\phi,1} = 2.8\mu$m (layer 1) $\sigma_{r\phi,2} = 6.0\mu$m (layer 2) $\sigma_{r\phi,3-6} = 4.0\mu$m (layers 3-6)
SIT	$\sigma_{u_r} = 7.0\mu$m $\alpha_z = \pm 7.0^\circ$ (angle with z-axis)
SET	$\sigma_{u_r} = 7.0\mu$m $\alpha_z = \pm 7.0^\circ$ (angle with z-axis)
FTD *Pixel*	$\sigma_r = 3.0\mu$m $\sigma_{r\perp} = 3.0\mu$m
FTD *Strip*	$\sigma_{u_r} = 7.0\mu$m $\alpha_r = \pm 5.0^\circ$ (angle with radial direction)
TPC	$\sigma^2_{r\phi} = (5\beta^2 + 900^2 \sin^2\phi + ((25^2/22) \times (4T/B)^2 \sin\theta)\,(z/\mathrm{cm})]\,\mu\mathrm{m}^2$ $\sigma^2_z = (400^2 + 80^2 \times (z/\mathrm{cm}))\,\mu\mathrm{m}^2$ where ϕ and θ are the azimuthal and polar angle of the track direction

now pixel (3 μm)

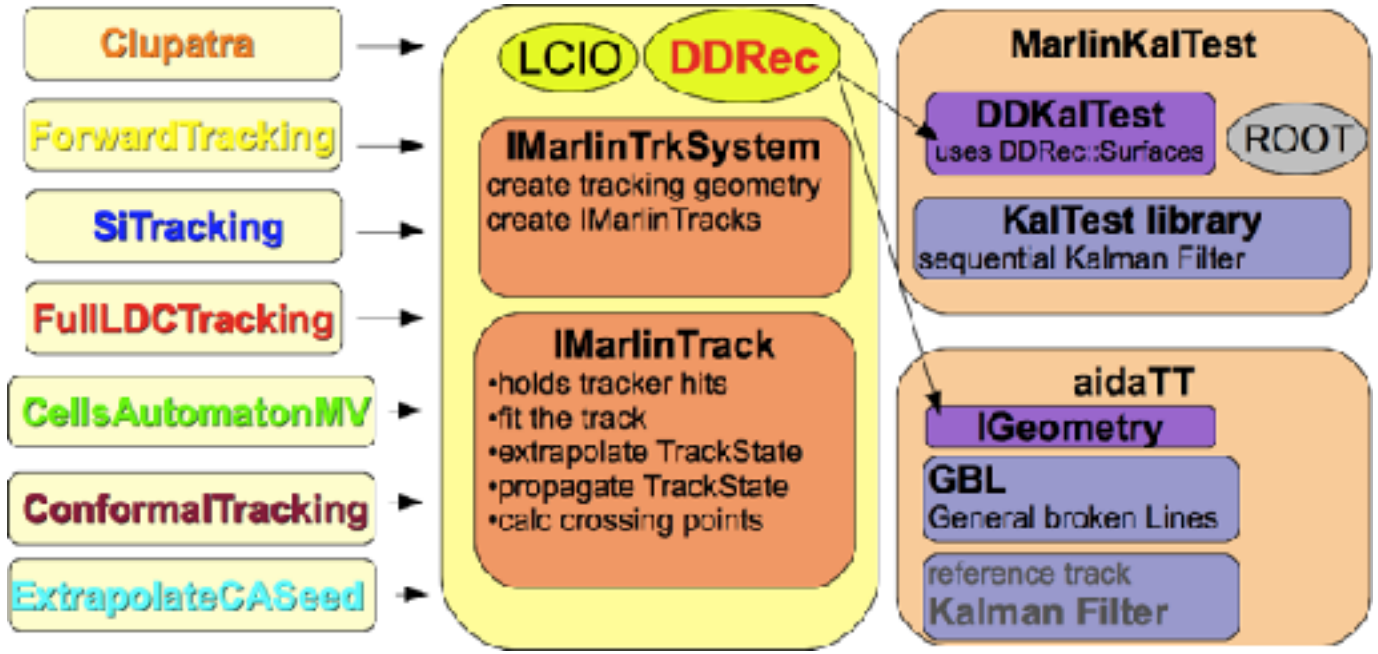
first two discs



ILD Tracking Software

MarlinTrk and DDRec

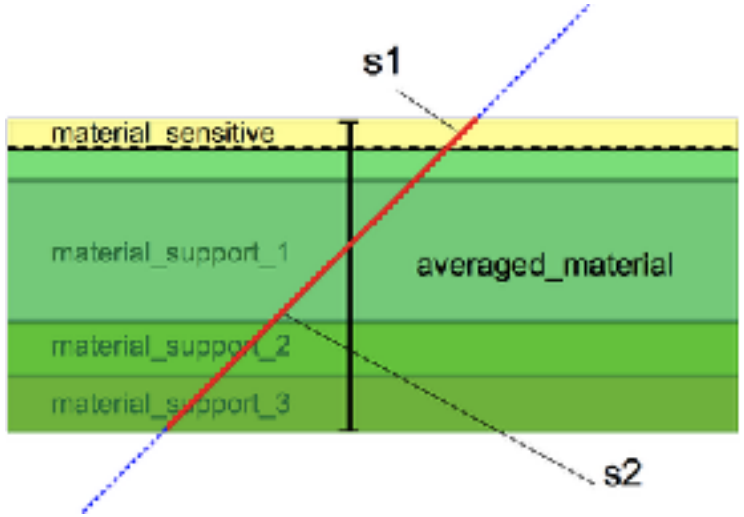
- **MarlinTrk**:
  - abstract interface for track reconstruction in iLCsoft
  - decouples pattern recognition from concrete fitter implementation
- **DDRec**
  - provide geometry for tracking
  - based on surfaces attached to sensitive volumes



DDRec tracking geometry

Based on Surfaces w/ material properties

- materials from detailed model are **automatically averaged** along surface normal (with given *thickness*)



- roughly equivalent to individual materials for Bethe-Bloch
- identical for multiple scattering

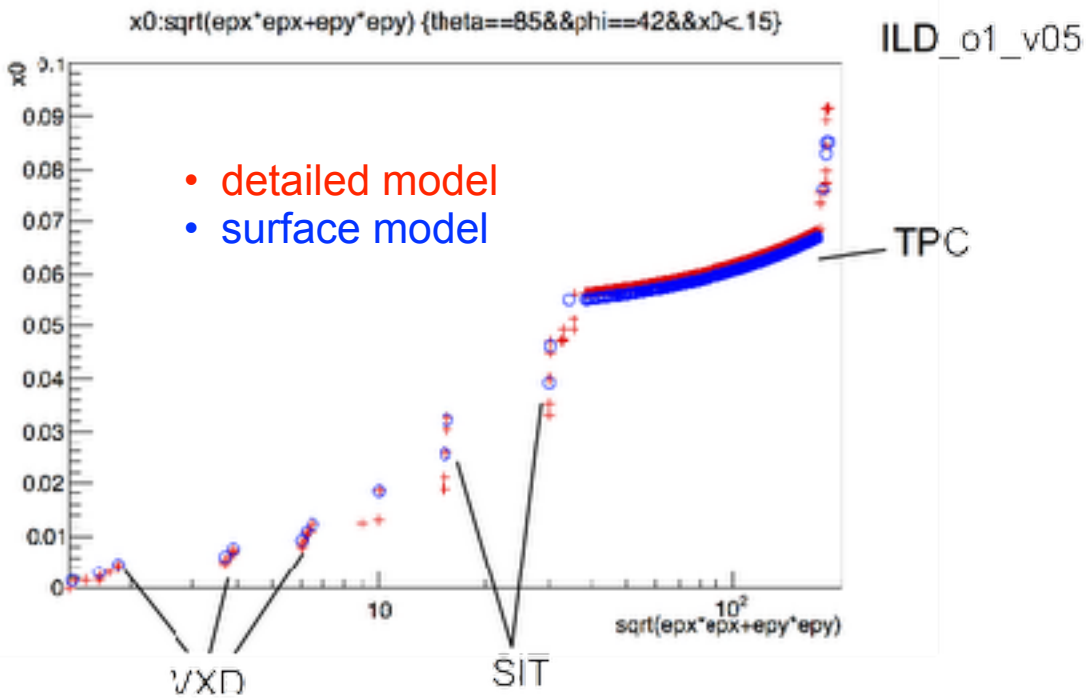
$$\langle A \rangle = \left(\sum_i^N \rho_i t_i\right) / \left(\sum_i^N \rho_i \frac{t_i}{A_i}\right)$$

$$\langle Z \rangle = \left(\sum_i^N \rho_i \frac{t_i Z_i}{A_i}\right) / \left(\sum_i^N \rho_i \frac{t_i}{A_i}\right)$$

$$\langle \rho \rangle = \left(\sum_i^N \rho_i t_i\right) / \left(\sum_i^N t_i\right)$$

$$\langle X_0 \rangle = \left(\sum_i^N t_i\right) / \left(\sum_i^N \frac{t_i}{X_{0i}}\right)$$

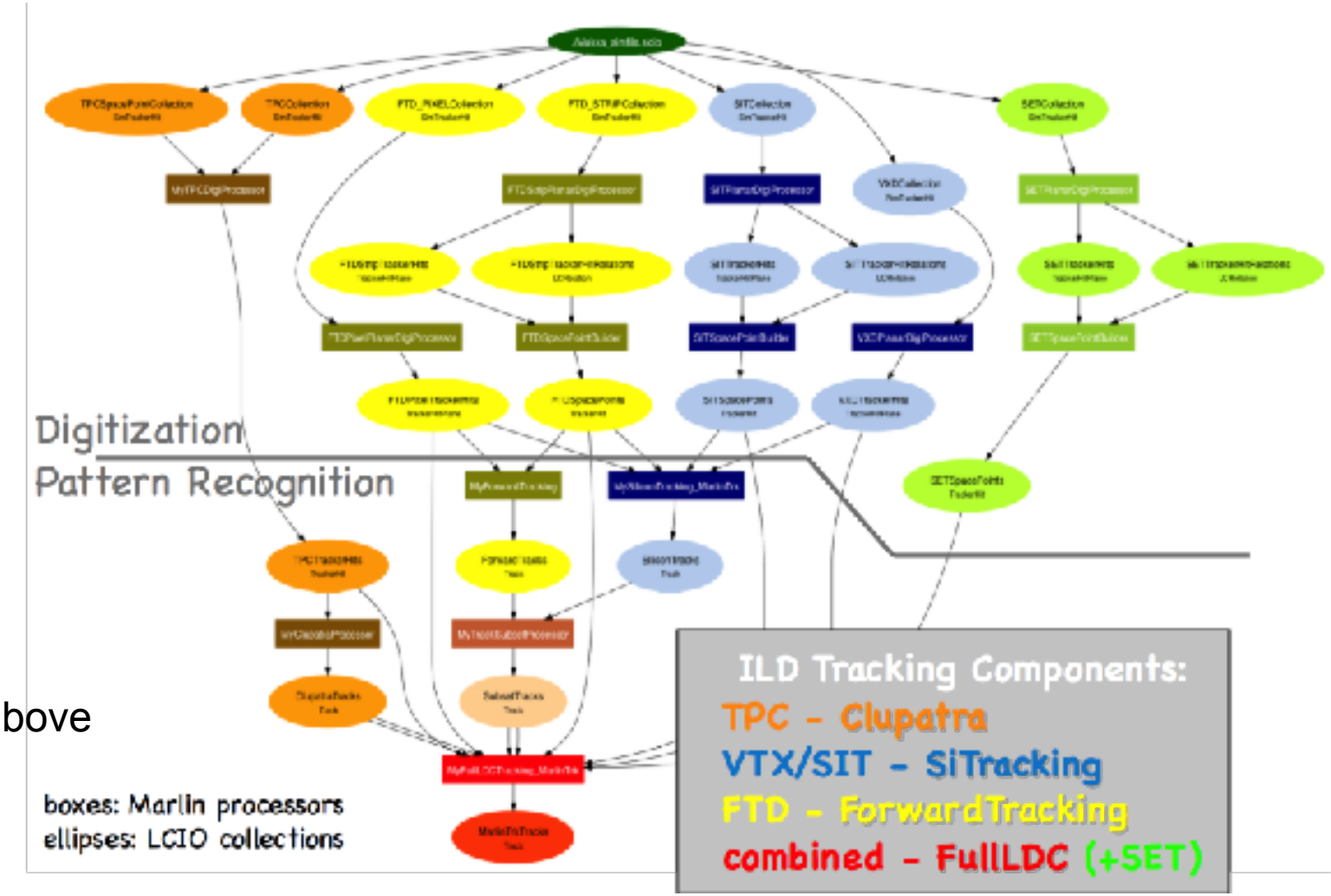
$$\langle \lambda \rangle = \left(\sum_i^N t_i\right) / \left(\sum_i^N \frac{t_i}{\lambda}\right)$$



Pattern recognition

Track Finding Algorithms

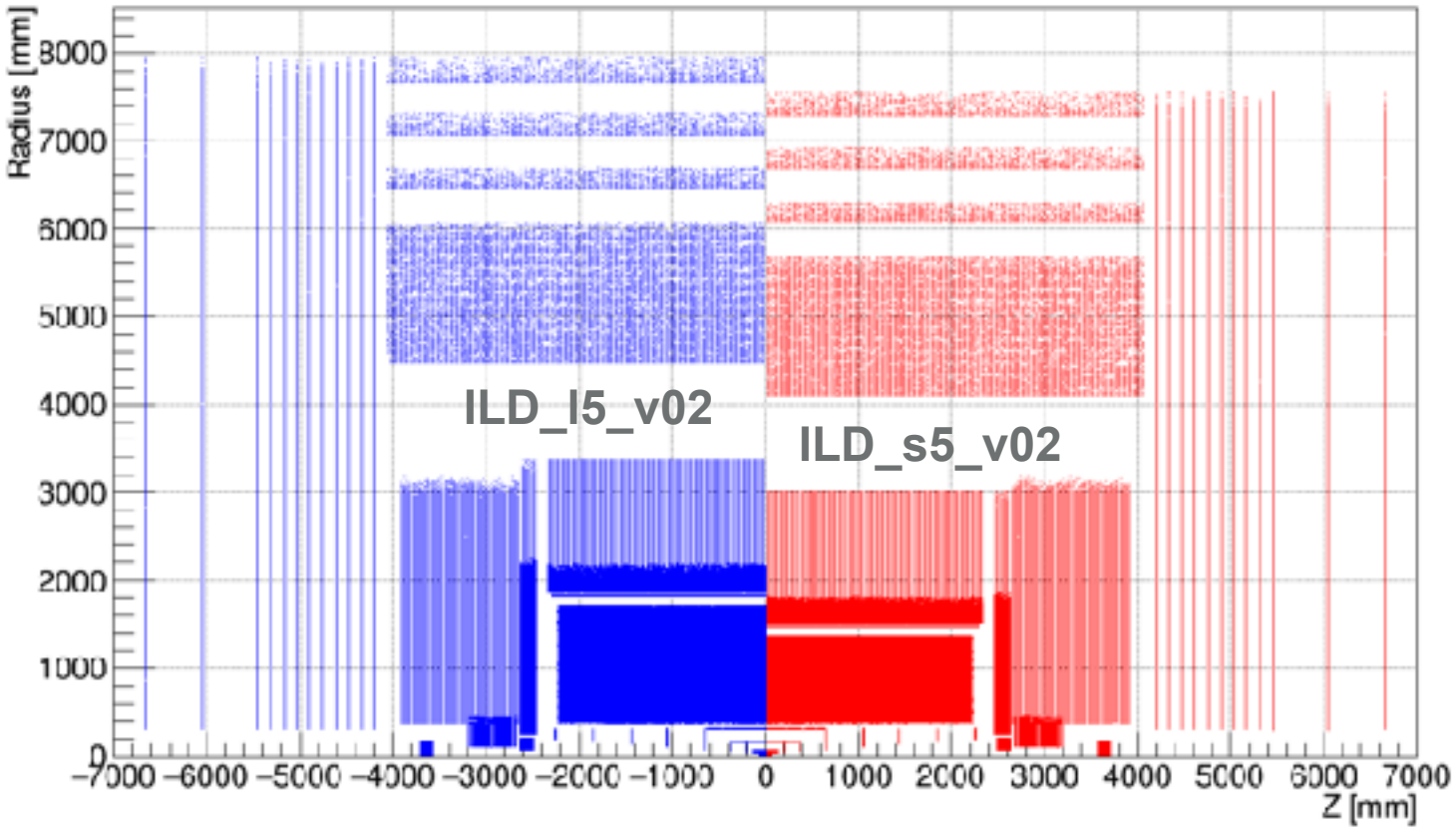
- **SiTracking** (VXD, SIT, FTD)
  - hit search based on seed triplets
- **Clupatra** (TPC)
  - topological clustering
  - followed by road search
- **ForwardTracking** (FTD)
  - Cellular Automaton
- **FullLDCTracking**
  - combine all Tracks(egments) from above algorithms



ILD detetor models

Large vs Small

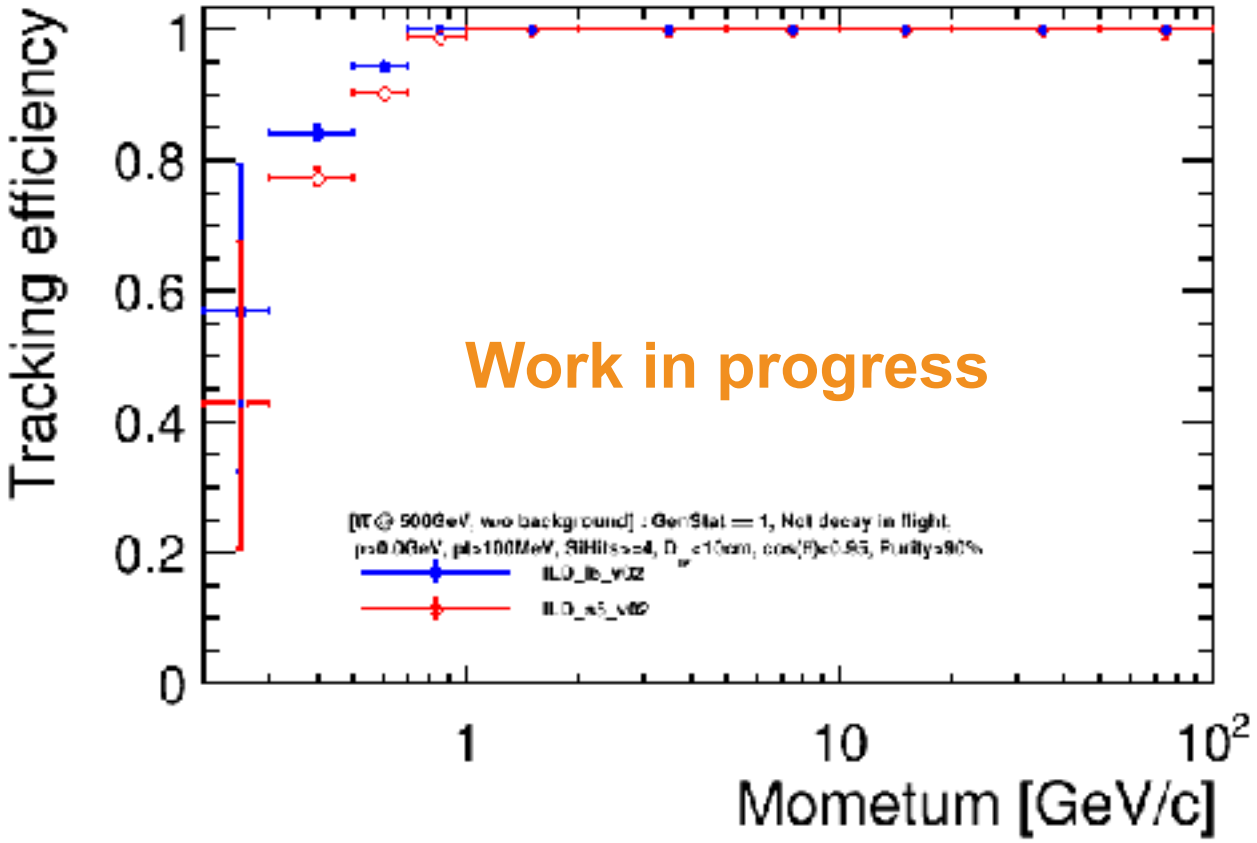
- recently created new ILD simulation models in DD4hep:
  - two different sizes
  - various technology options
    - Ecal, Hcal technology
- started a large scale Monte Carlo production
  - 500 fb^-1 @ 500 GeV
- Goal: compare detector performance:
  - detector benchmarks
  - selected *physics signals*
  - full physics analysis

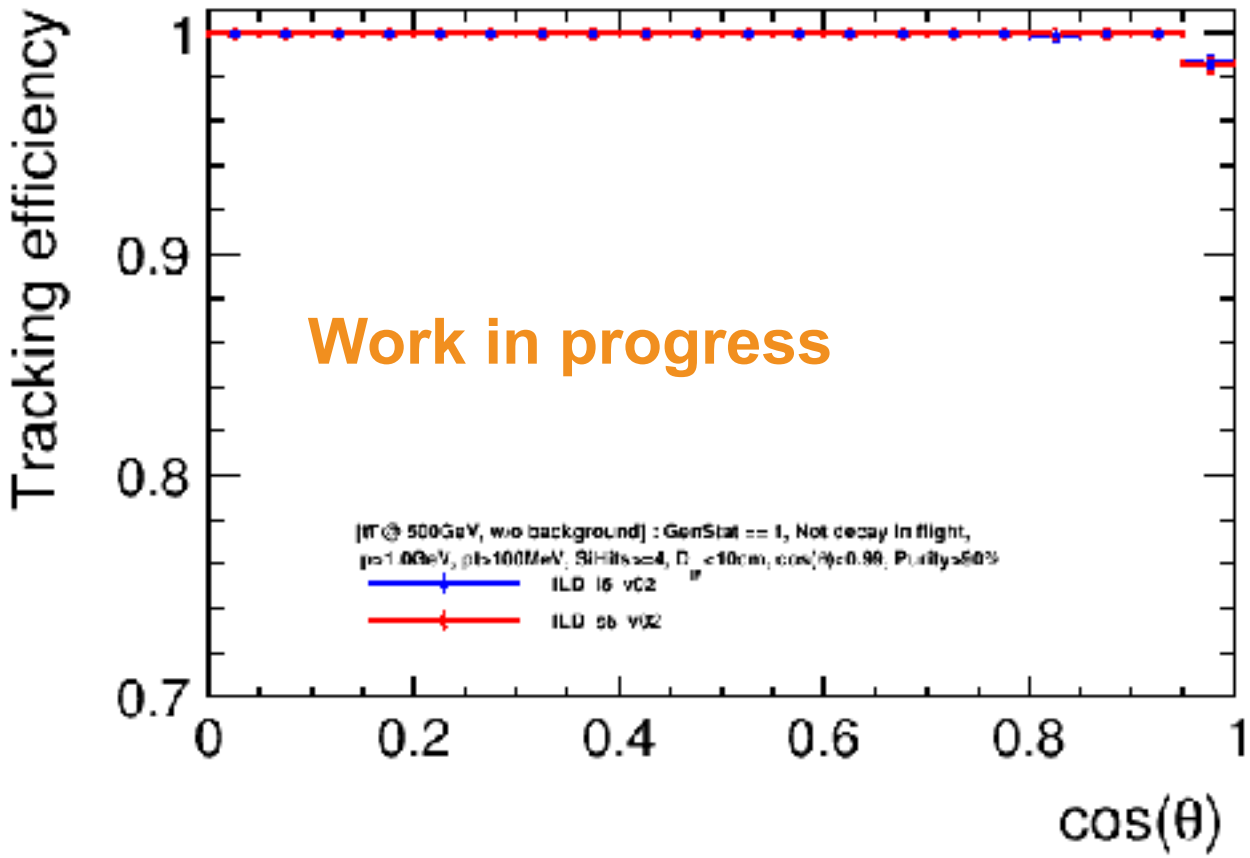


- TPC radius changed from 177cm to 143cm
- B-field changed from **3.5 T** to **4 T**
- all other dimensions kept the same

ILD tracking efficiency (v02-00-01)

Large vs Small



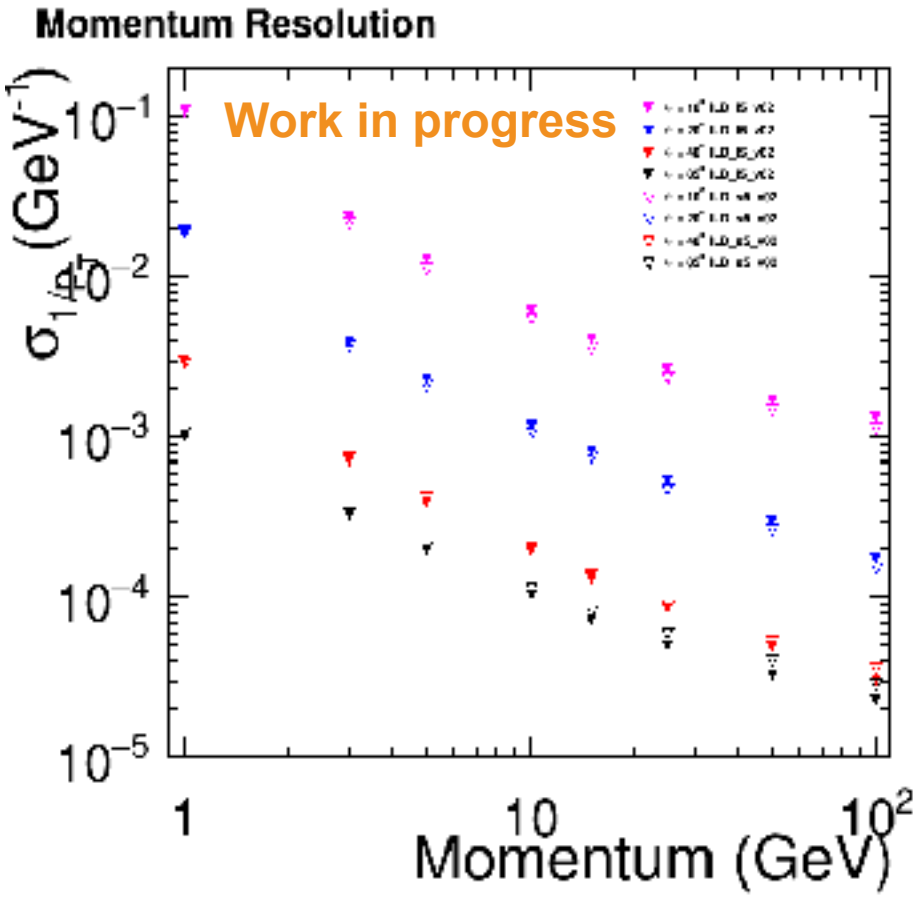


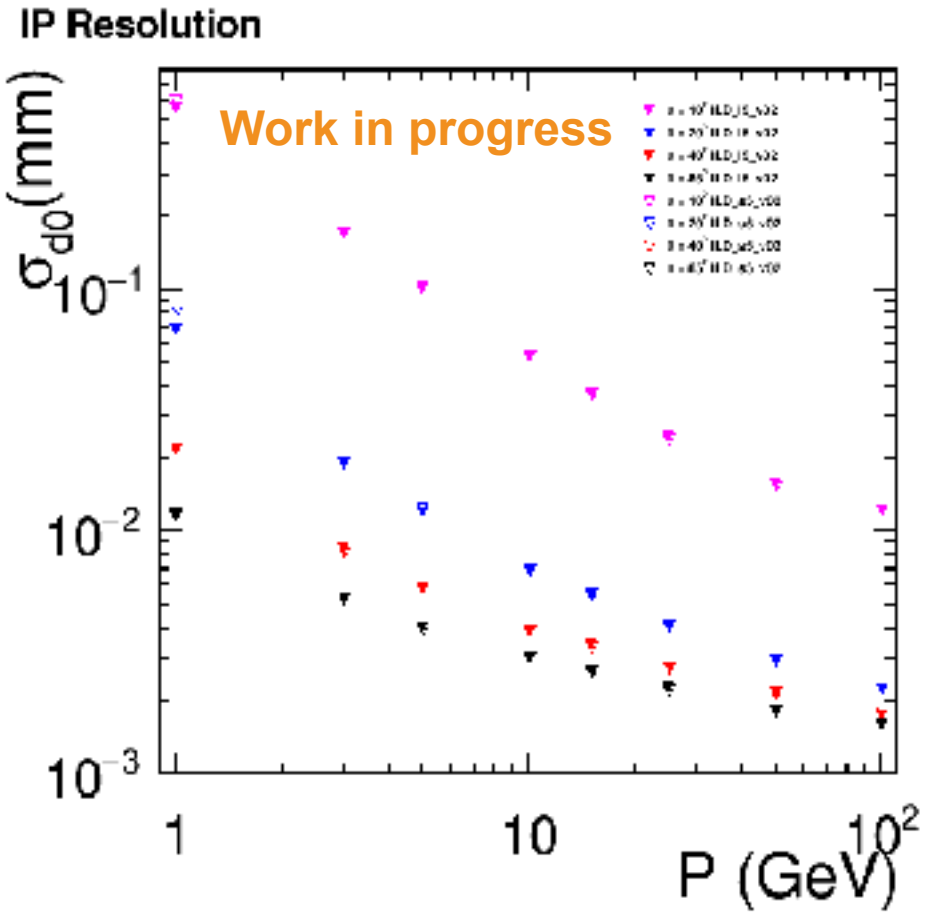
- observe good tracking efficiency - compatible w/ previous results (DBD)
- slightly worse for small detector at **low p_t** (higher field)

NB: all performance plots done w/o background overlay so far …

ILD tracking resolution (v02-00-01)

Large vs Small





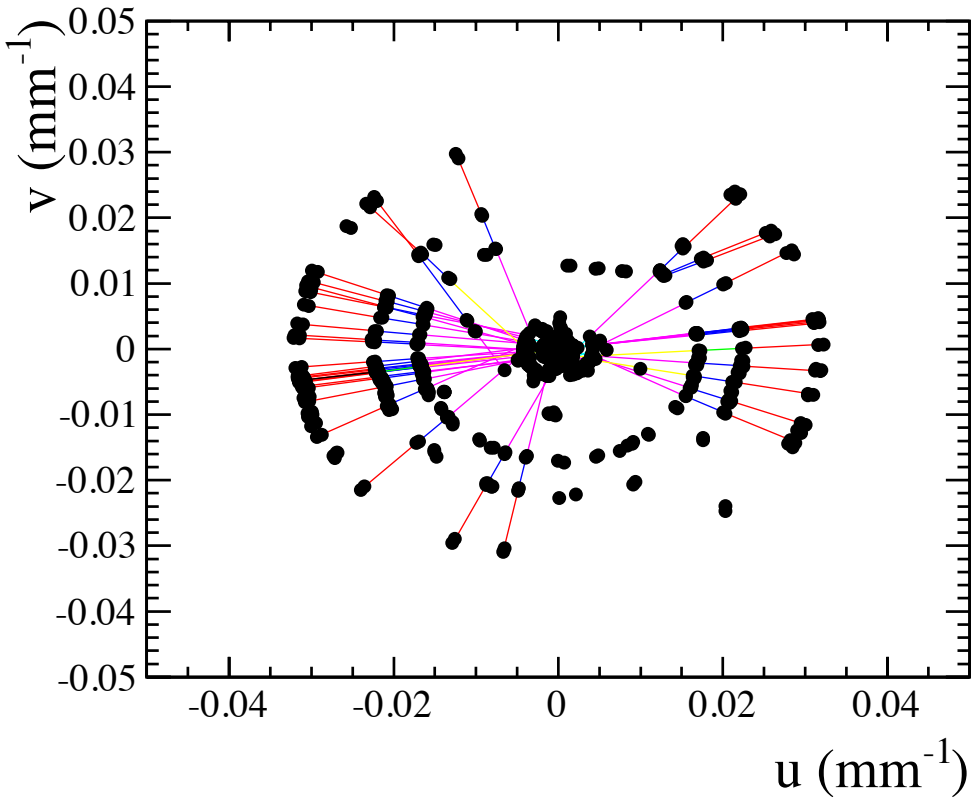
- reach ILD design goals vor resolution - compatible w/ previous results (DBD)
- slightly worse (better) for small detector in central (fwd) region

NB: all performance plots done w/o background overlay so far …

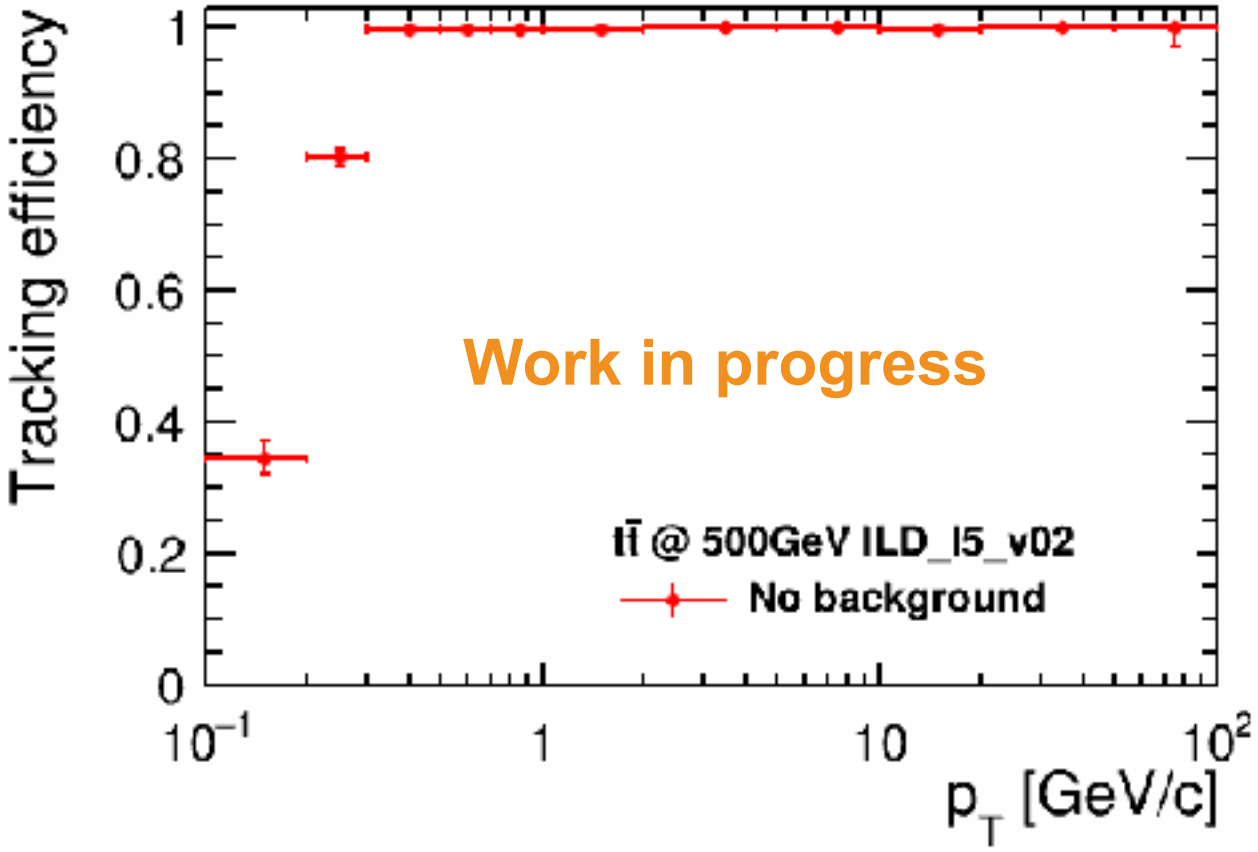
Next Steps

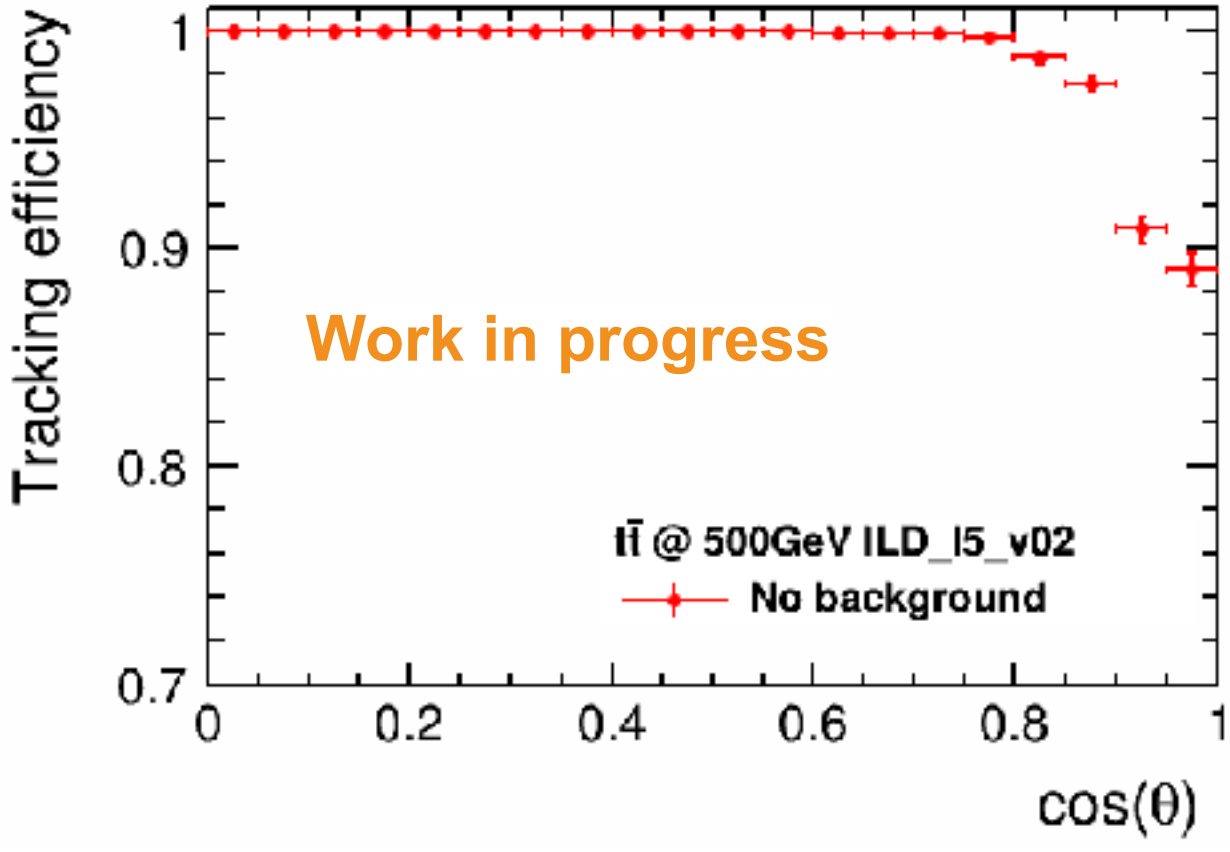
There's always room for improvement

- looked at tracking performance for large and small ILD detector:
  - reach ILC design goals for resolution
  - with good efficiency ground
- investigate possible improvements:
  - **software**:
    - evaluate alternative pattern recognition ConformalTracking
  - **hardware**:
    - replace FTD strip detectors w/ pixel readout
- include pair-background and non-homogeneous B-fields in performance



ILD reference (v02-00)

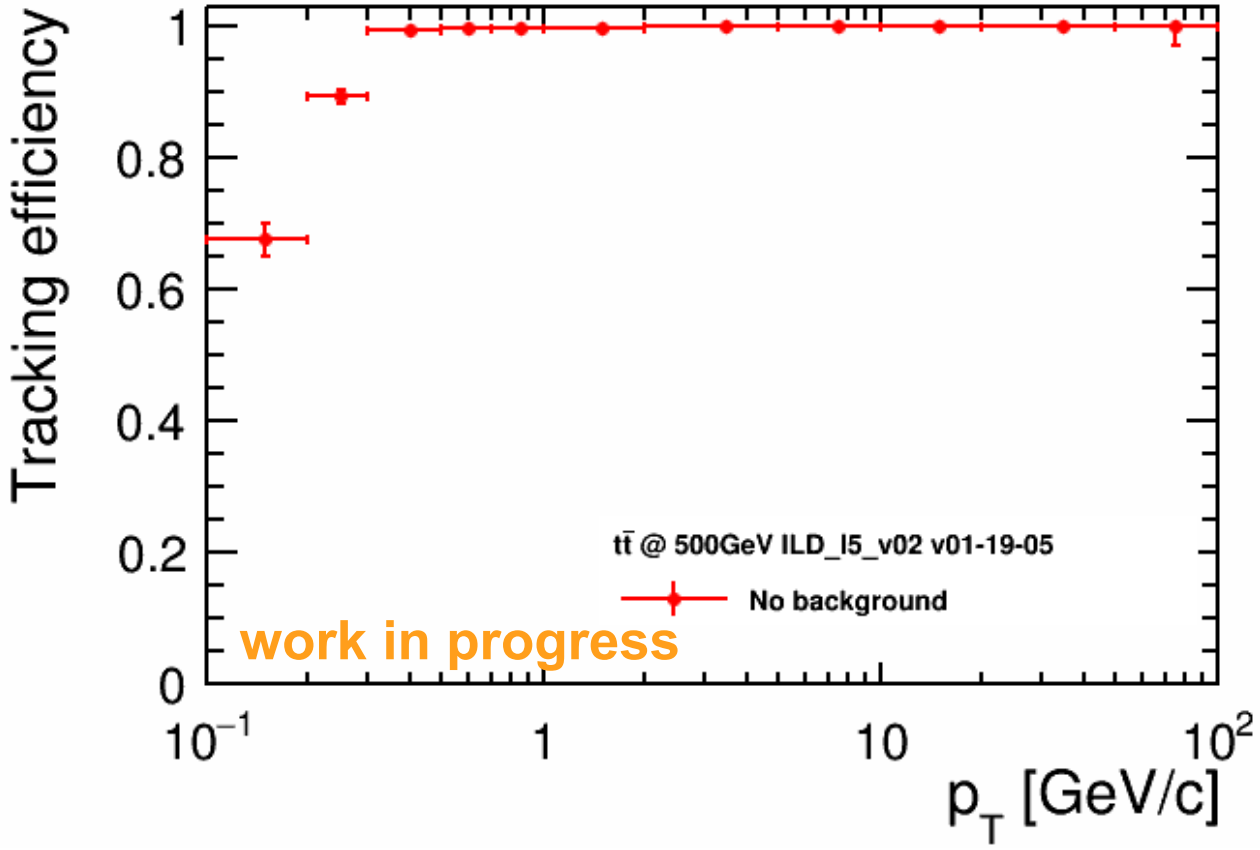


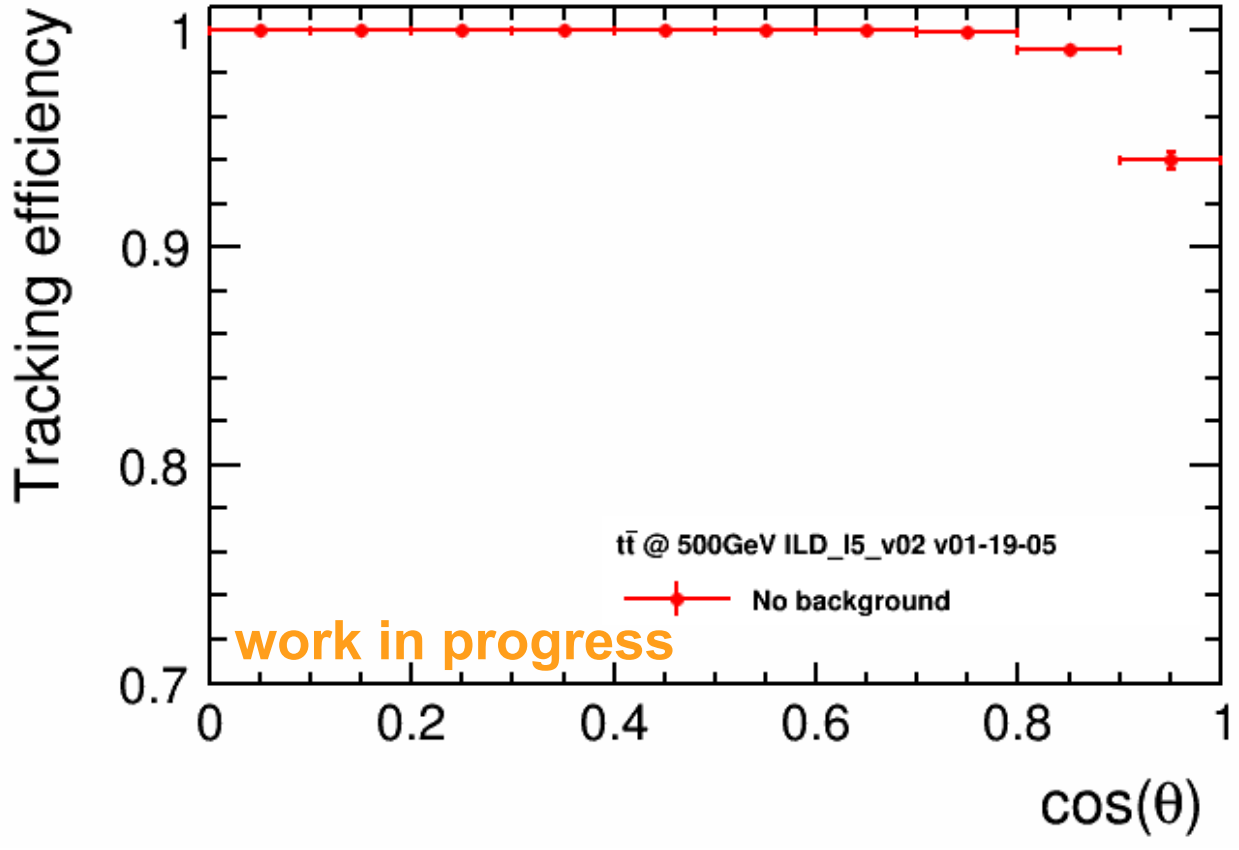


MCP nominator: stable charge particles with GeneratorStatus == 1 && !IsDecayedInTracker && maximum distance from IP< 10 mm && cosTheta<0.99

ILD w/ ConformalTracking and two FTD pixel disks

ILD VXD and two FTD pixel disks, ConformalTracking

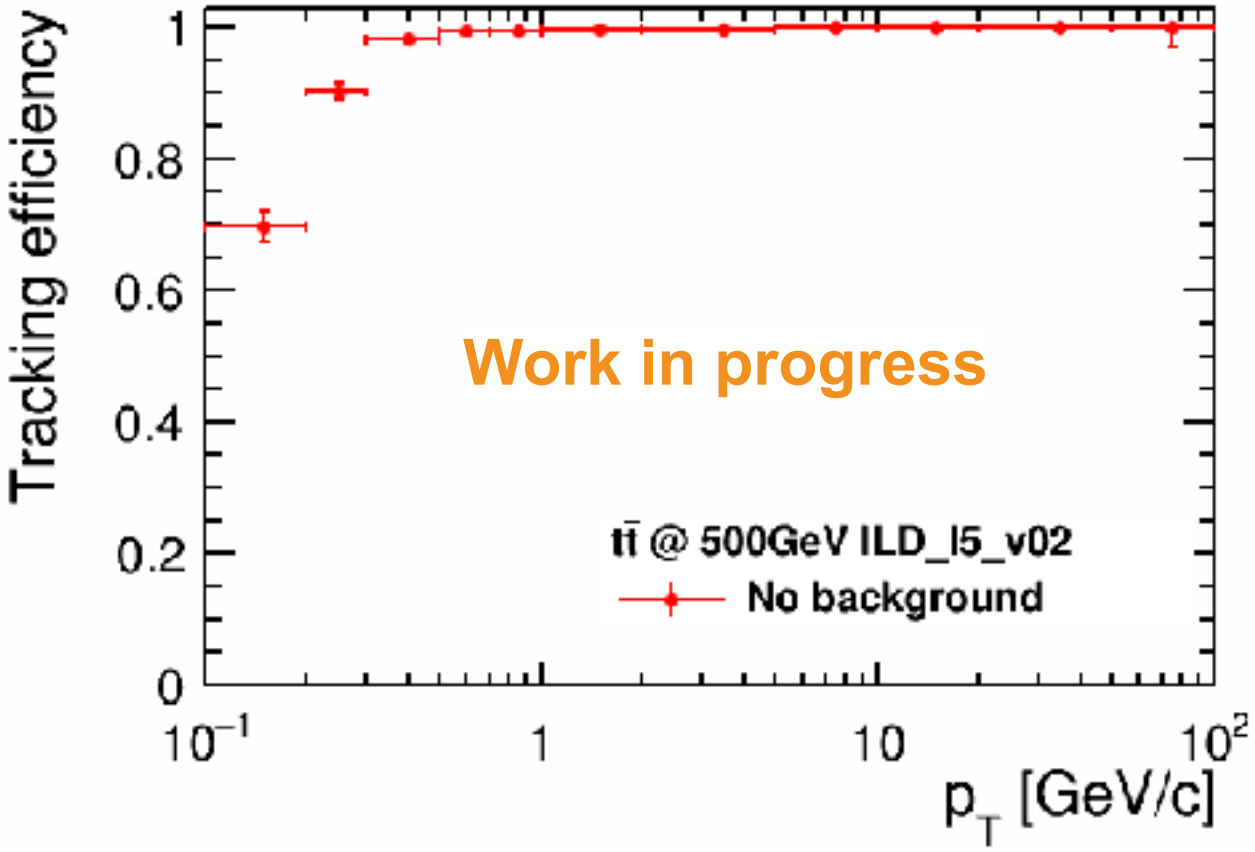


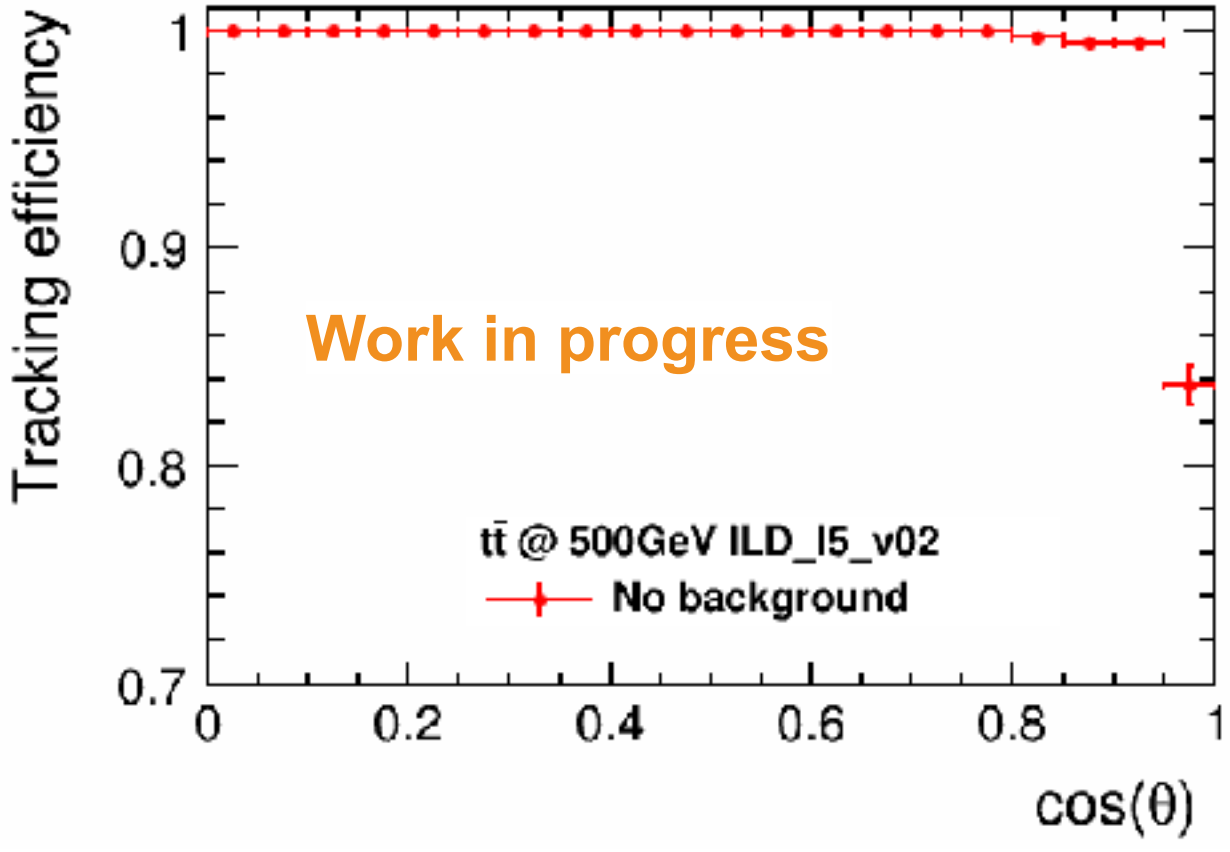


MCP nominator: stable charge particles with GeneratorStatus == 1 && !IsDecayedInTracker && maximum distance from IP< 10 mm && cosTheta<0.99

ILD concept with FTD all pixel disks

ILD VXD and FTD all pixel disks, ConformalTracking

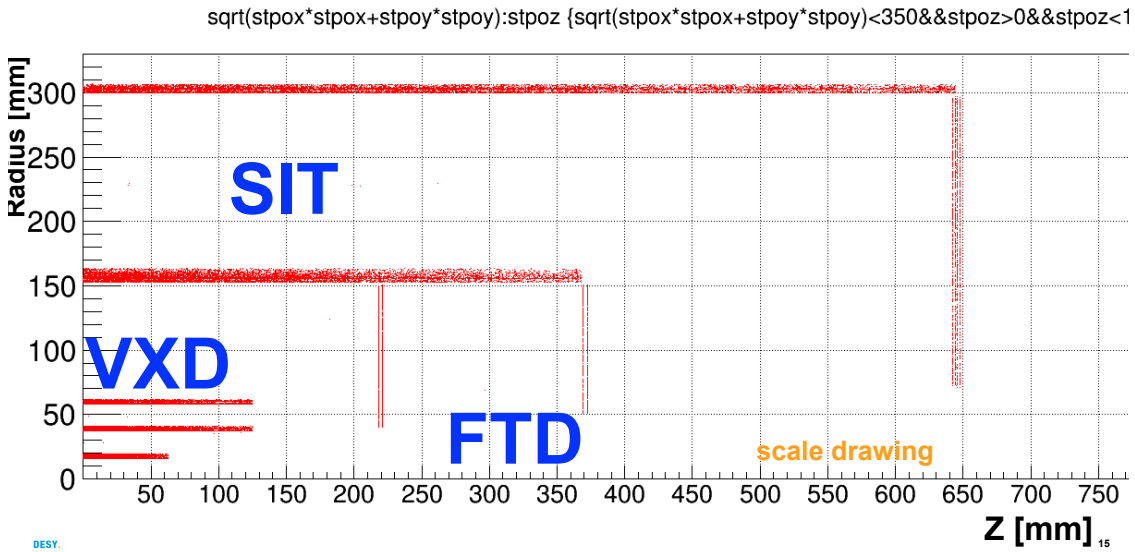


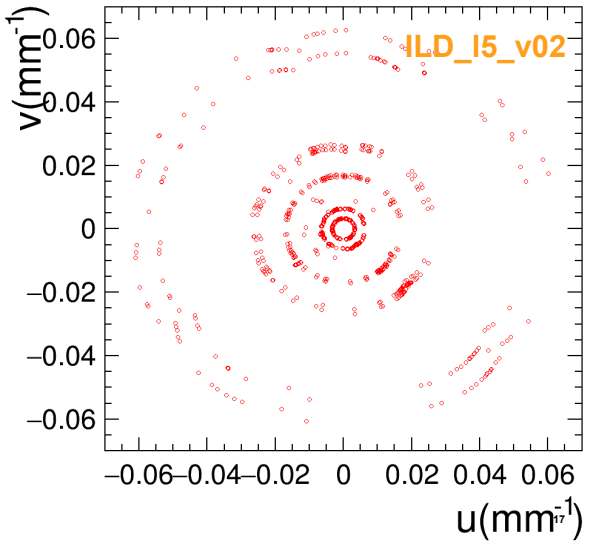


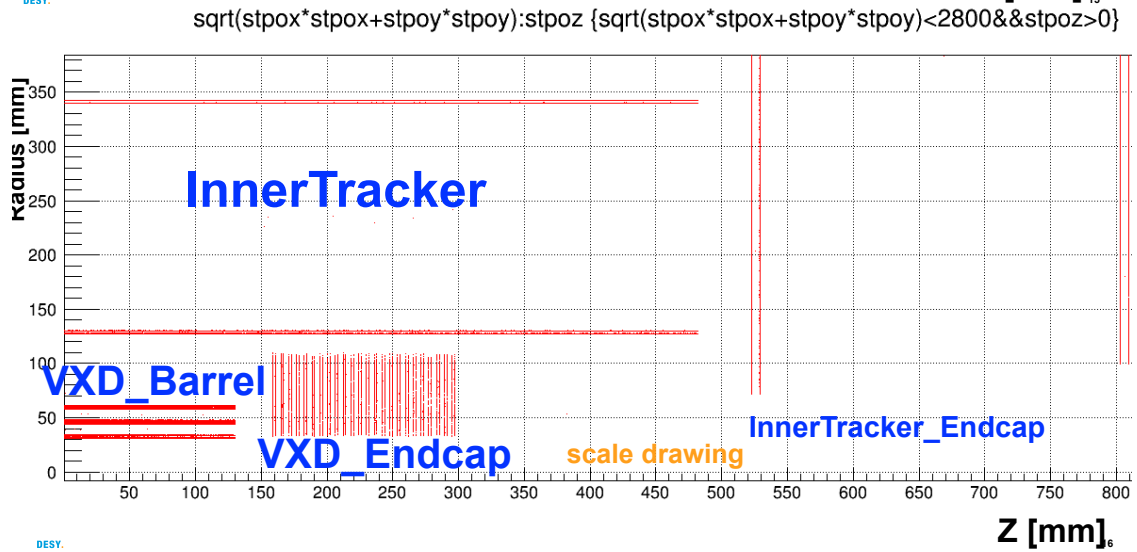
MCP nominator: stable charge particles with GeneratorStatus == 1 && !IsDecayedInTracker && maximum distance from IP< 10 mm && cosTheta<0.99

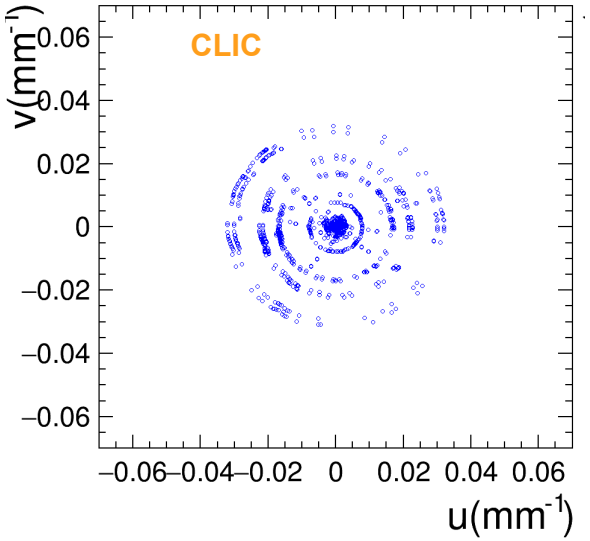
Different inner tracker layouts: ILD and CLICdp

In real and conformal space









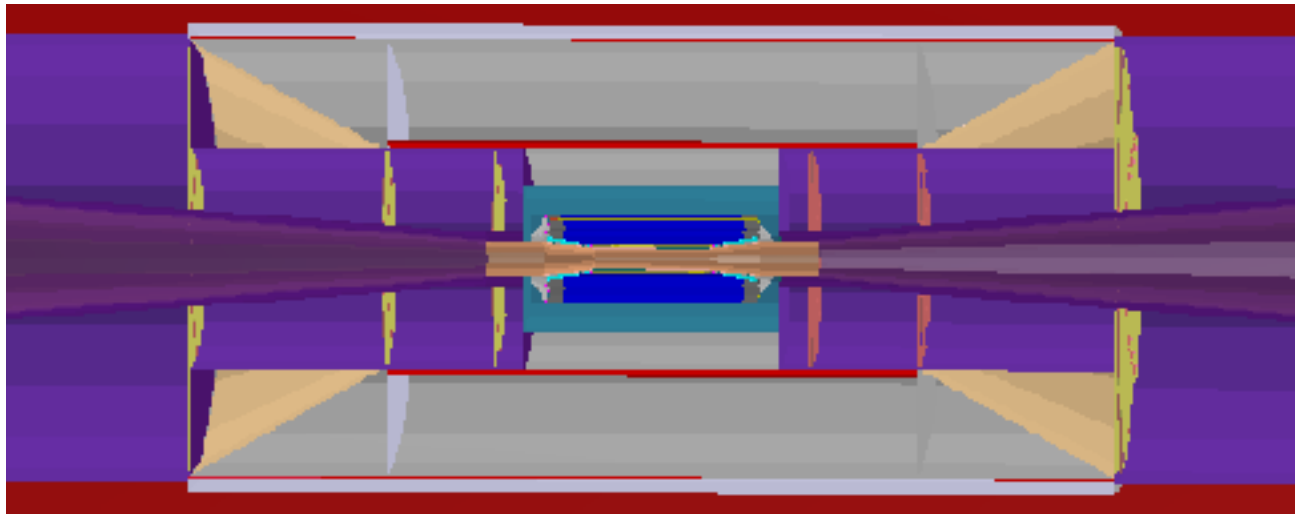
ILD concept with CLICdp style vertex detectors

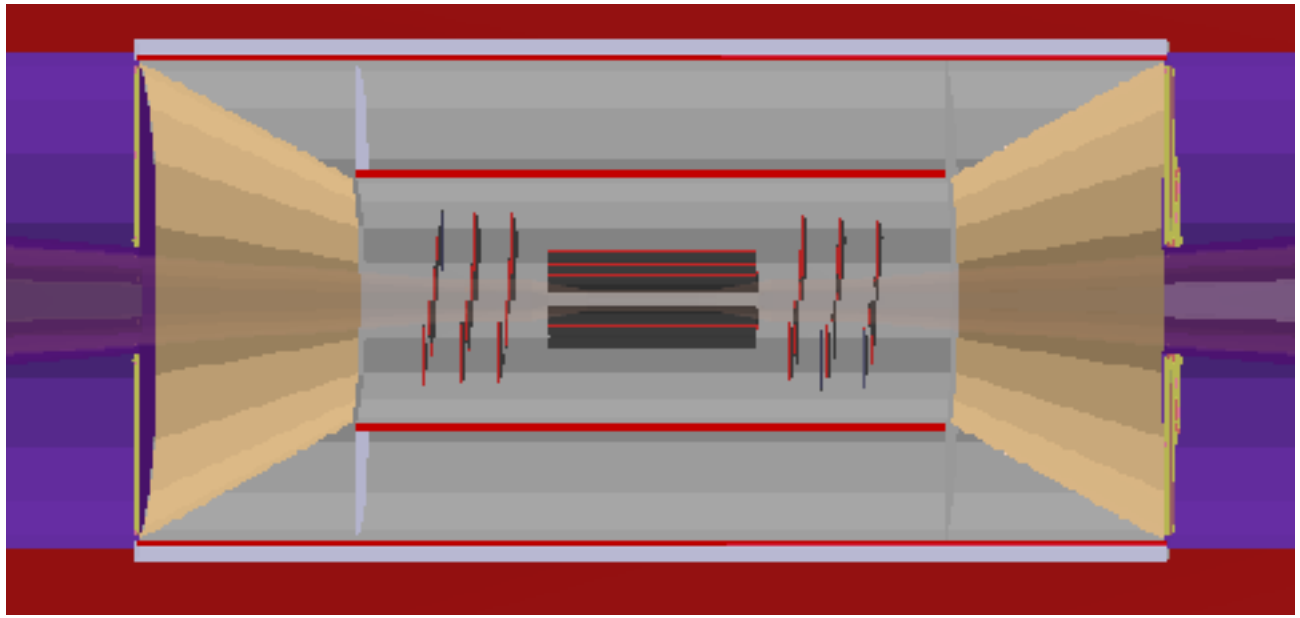
The difference of ILD VXD and CILCdp vertex barrel

- In total 6 layers for both
- Point resolution 3um
- Outer layer r2 is same
- Inner layer r1 is smaller in ILD VXD

$$\sigma^2 = (\frac{\sigma_1 r_2}{r_2 - r_1})^2 + (\frac{\sigma_2 r_1}{r_2 - r_1})^2$$

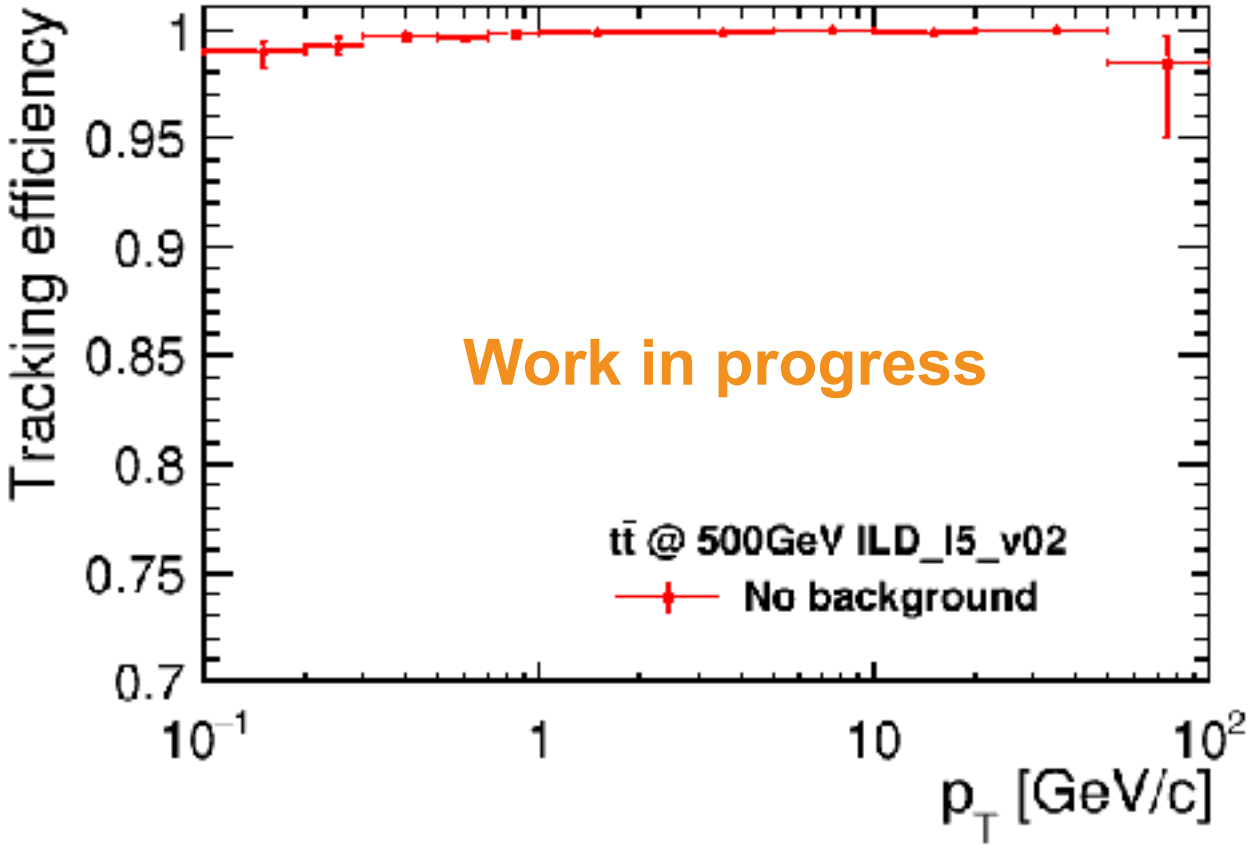
- ILD VXD should have better resolution just simplify take account the inner and outer radius.

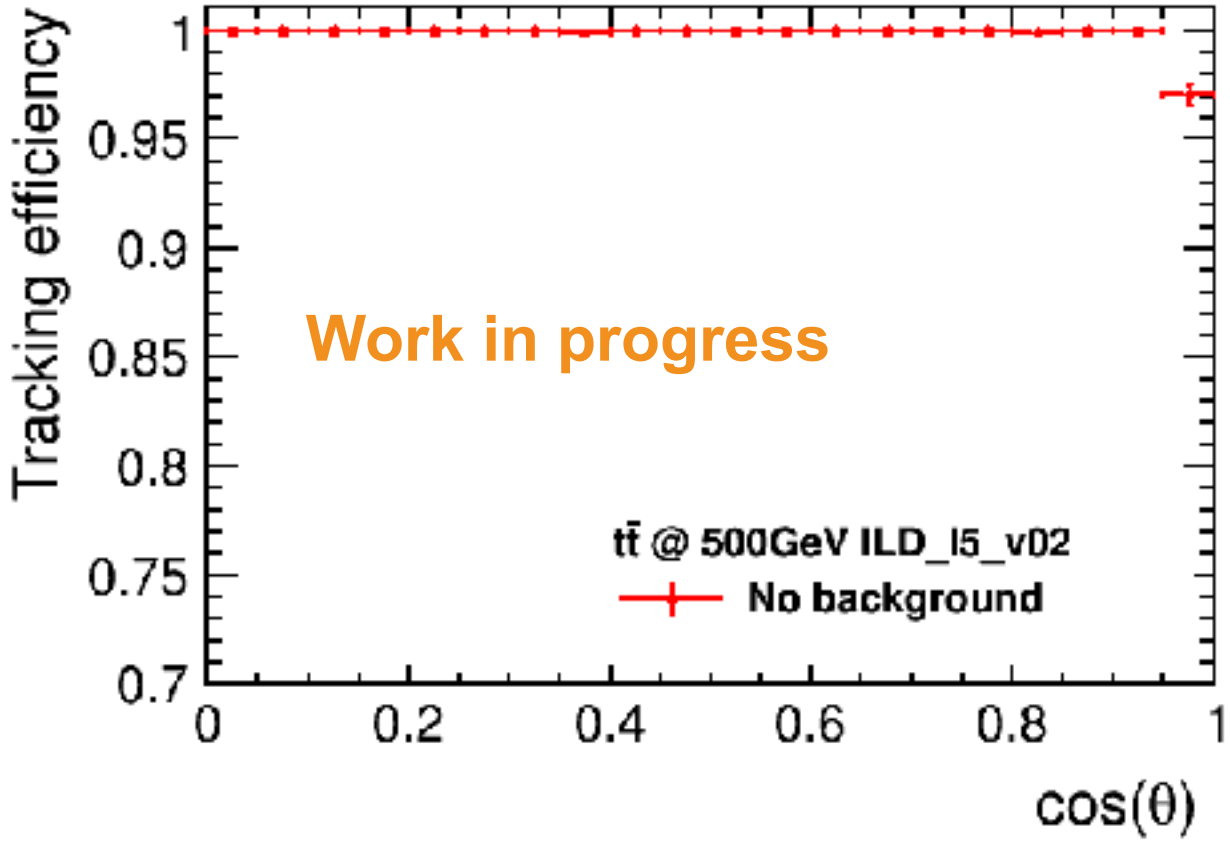




ILD concept with CLICdp style vertex detectors

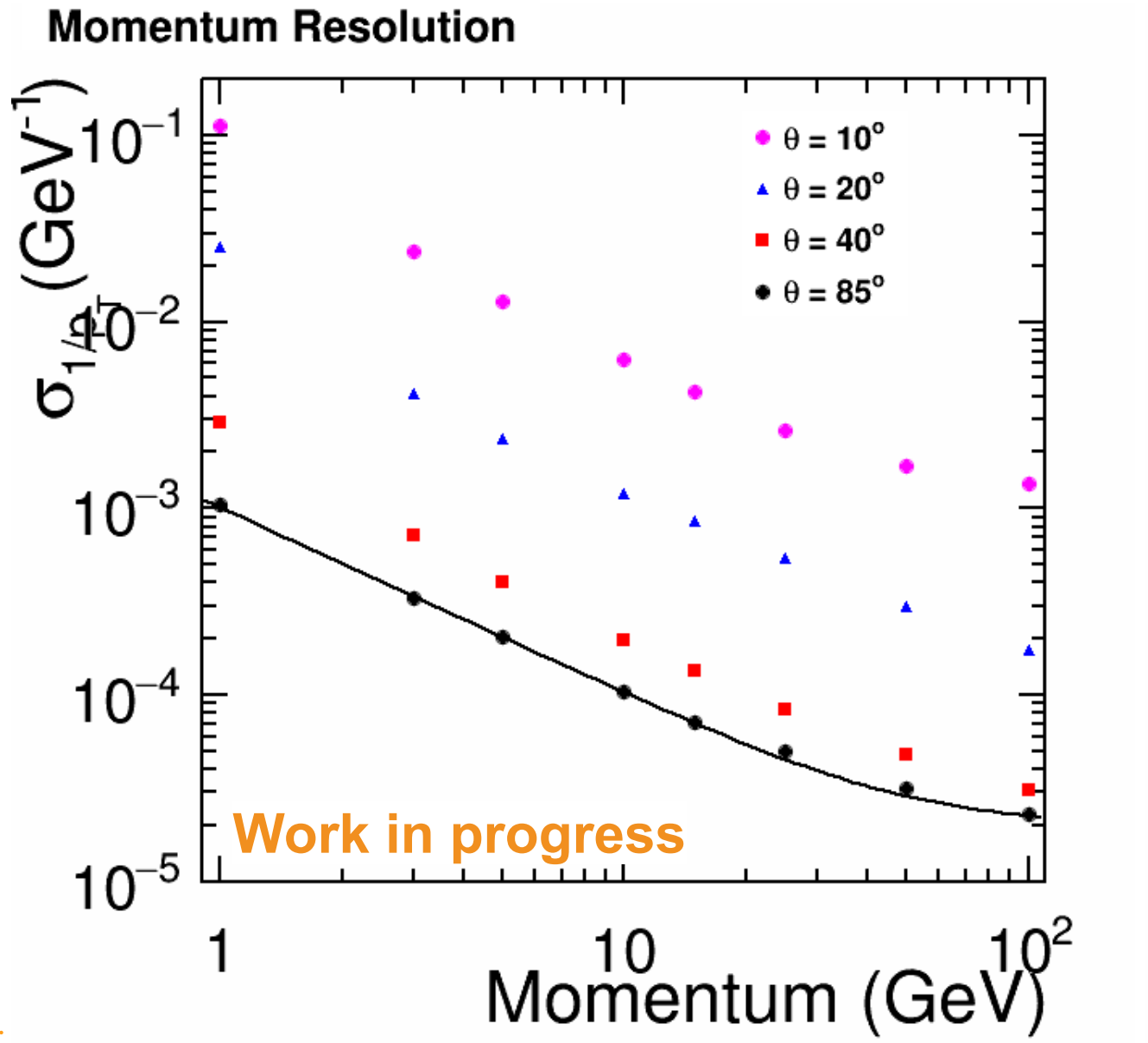
Replace ILD VXD and FTD pixel with CILCdp vertex detector, ConformalTracking

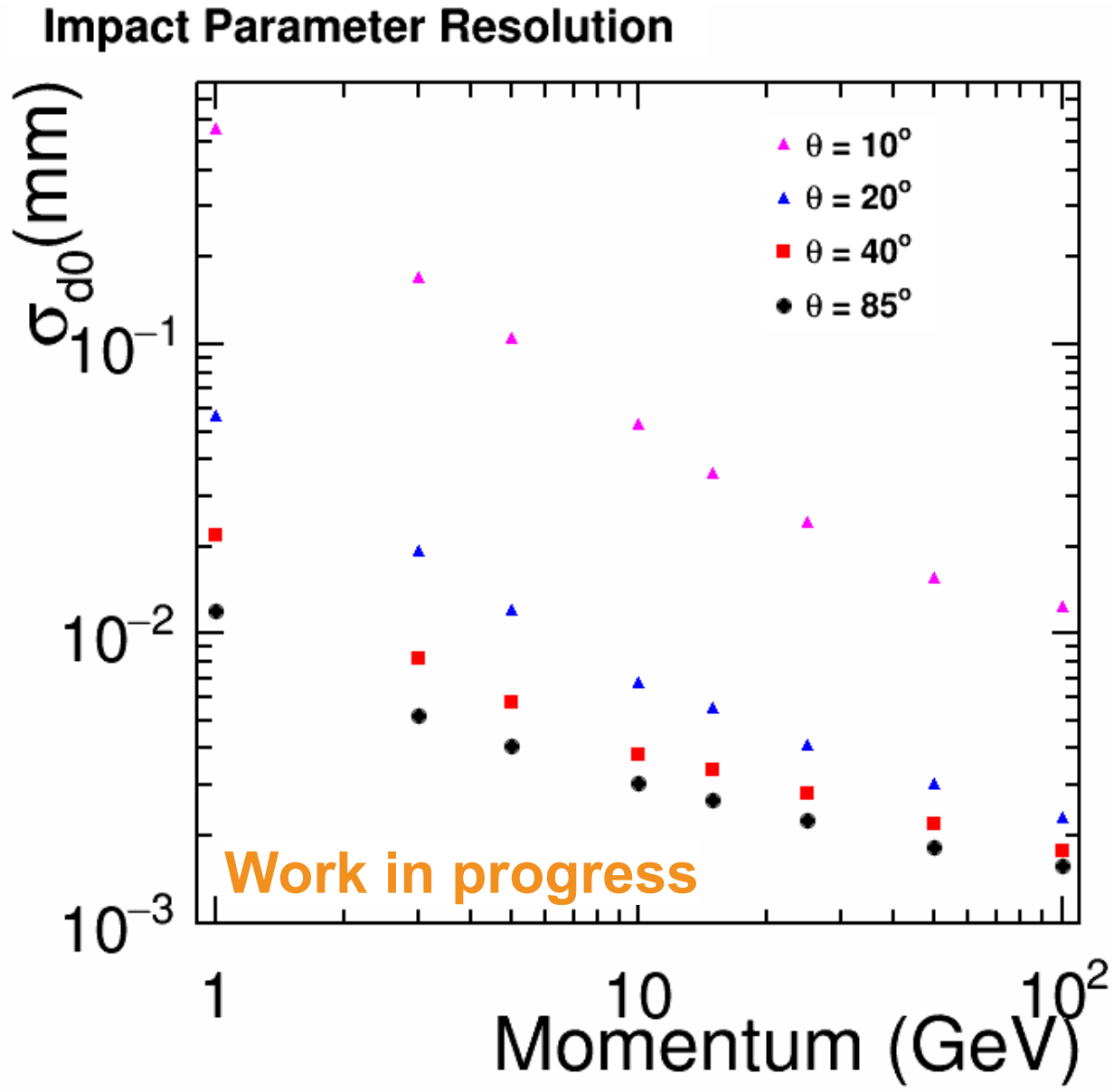




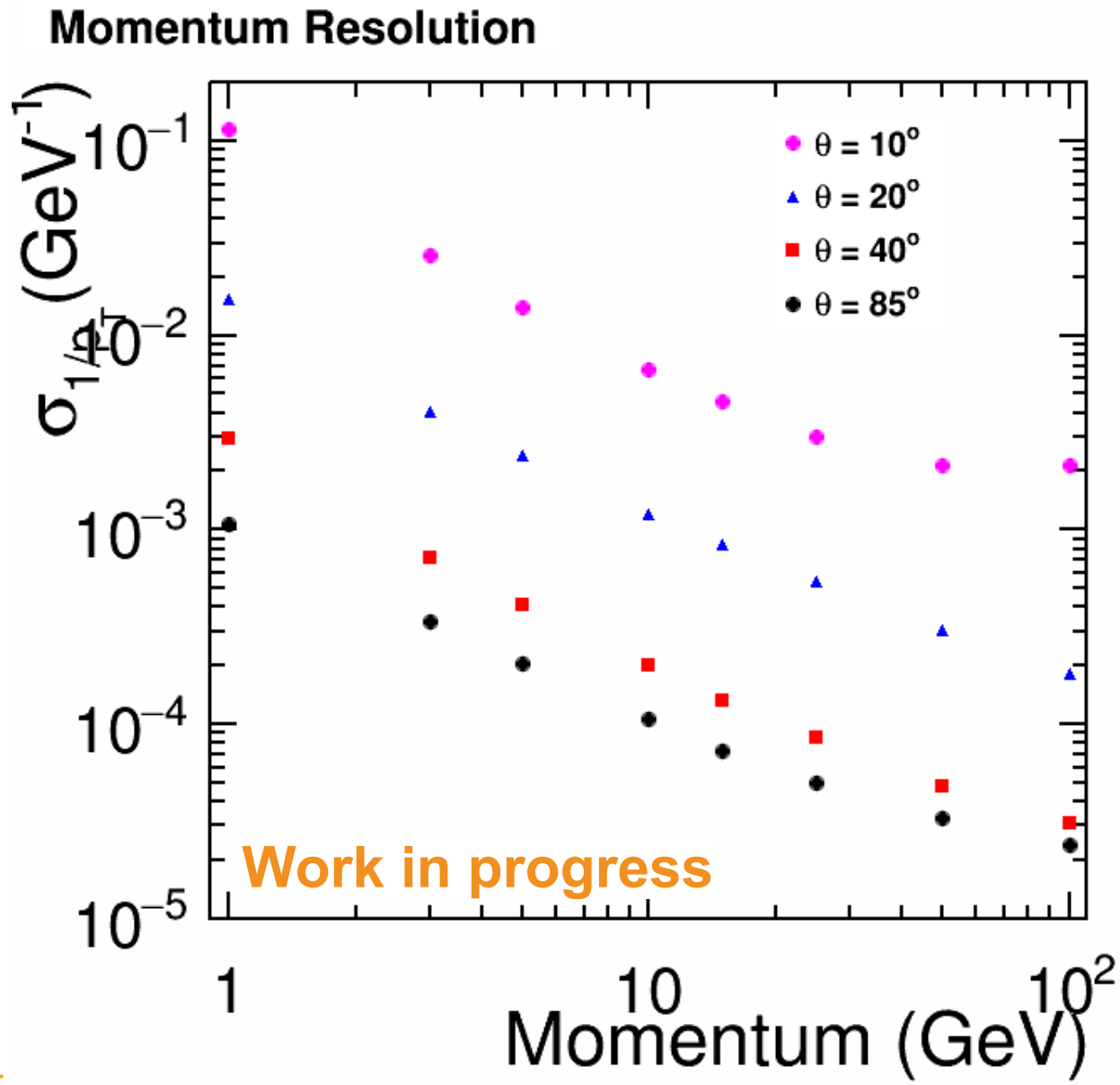
MCP nominator: stable charge particles with GeneratorStatus == 1 && !IsDecayedInTracker && maximum distance from IP< 10 mm && cosTheta<0.99

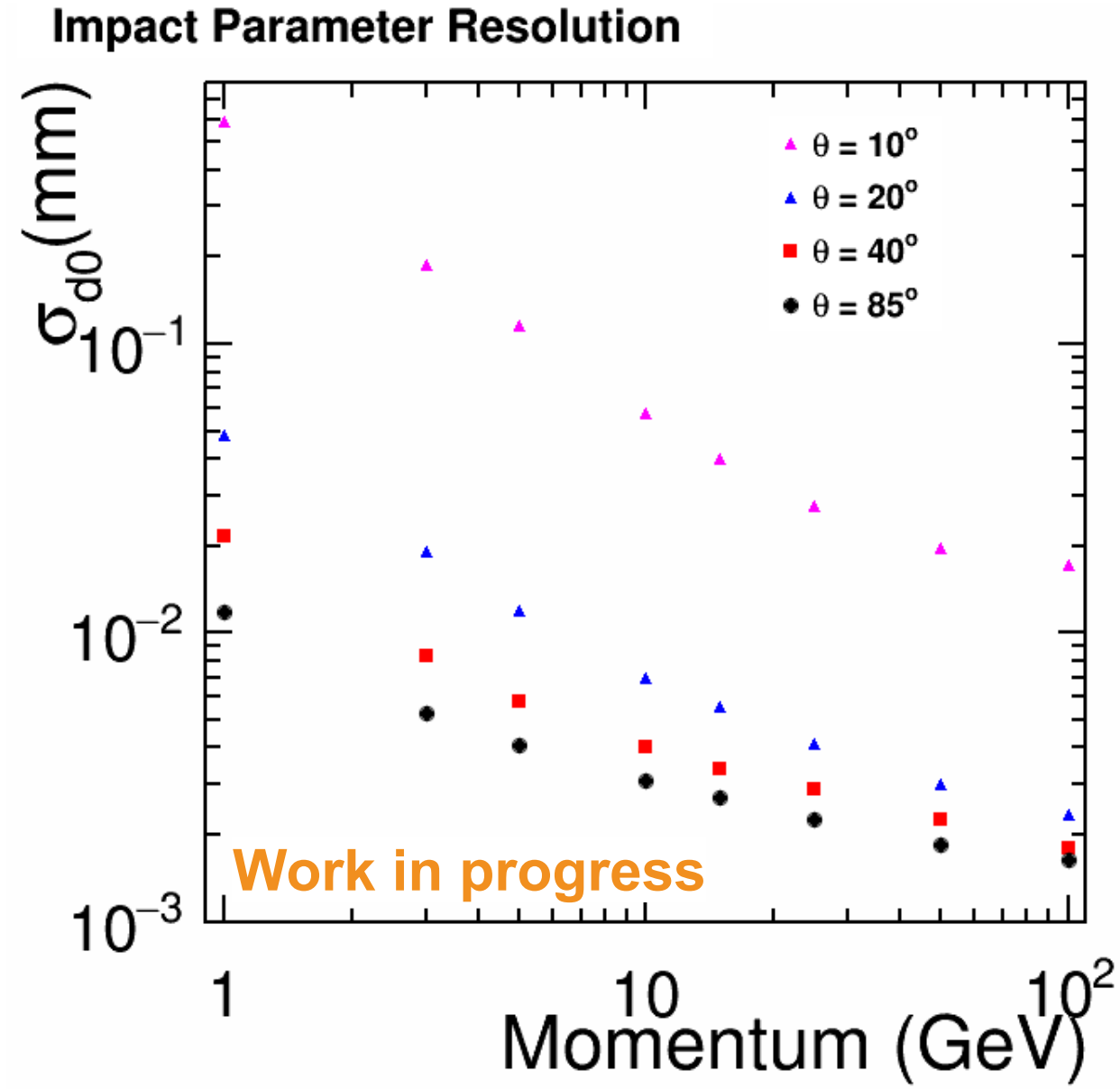
ILD reference (v02-00)



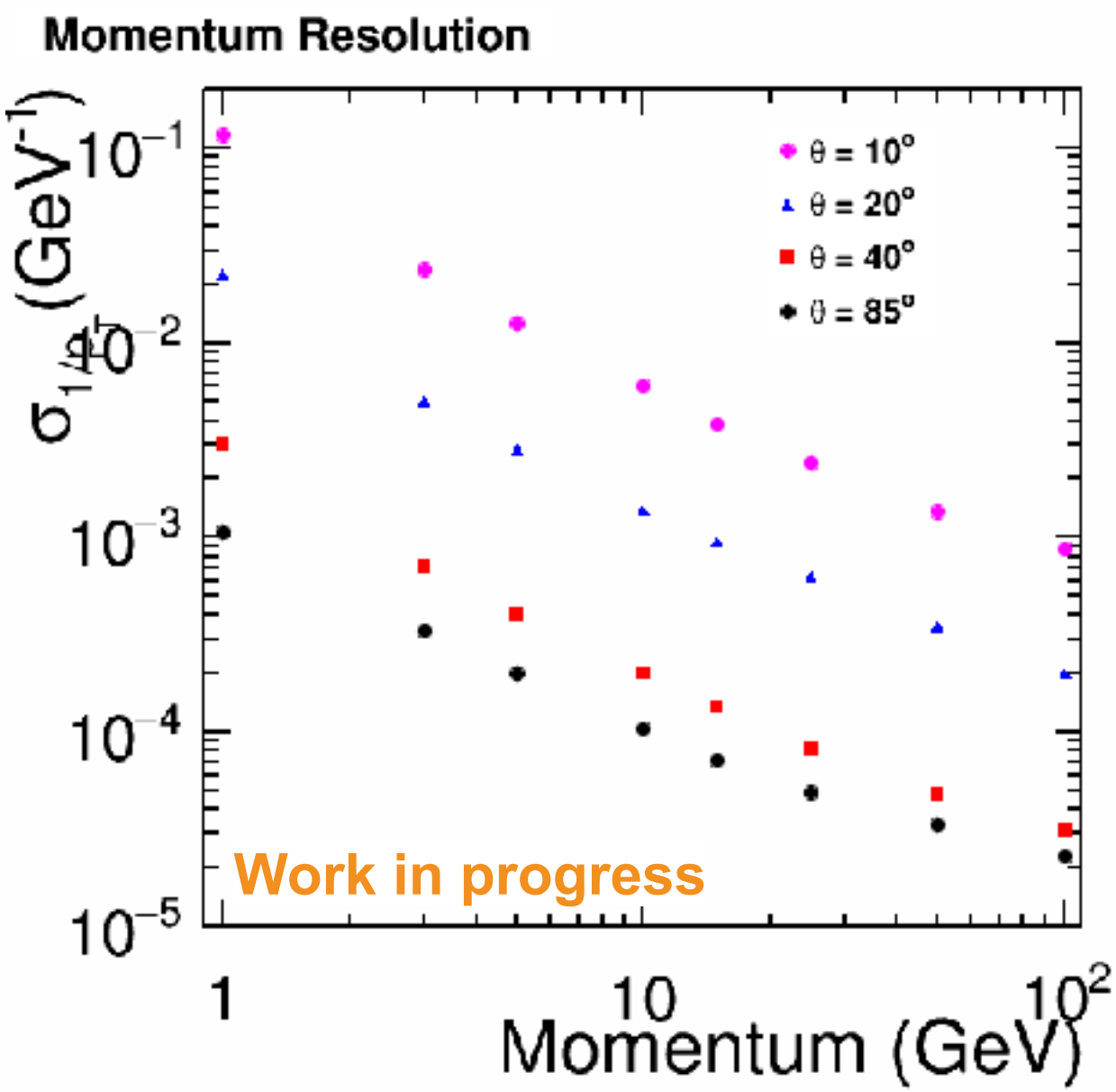


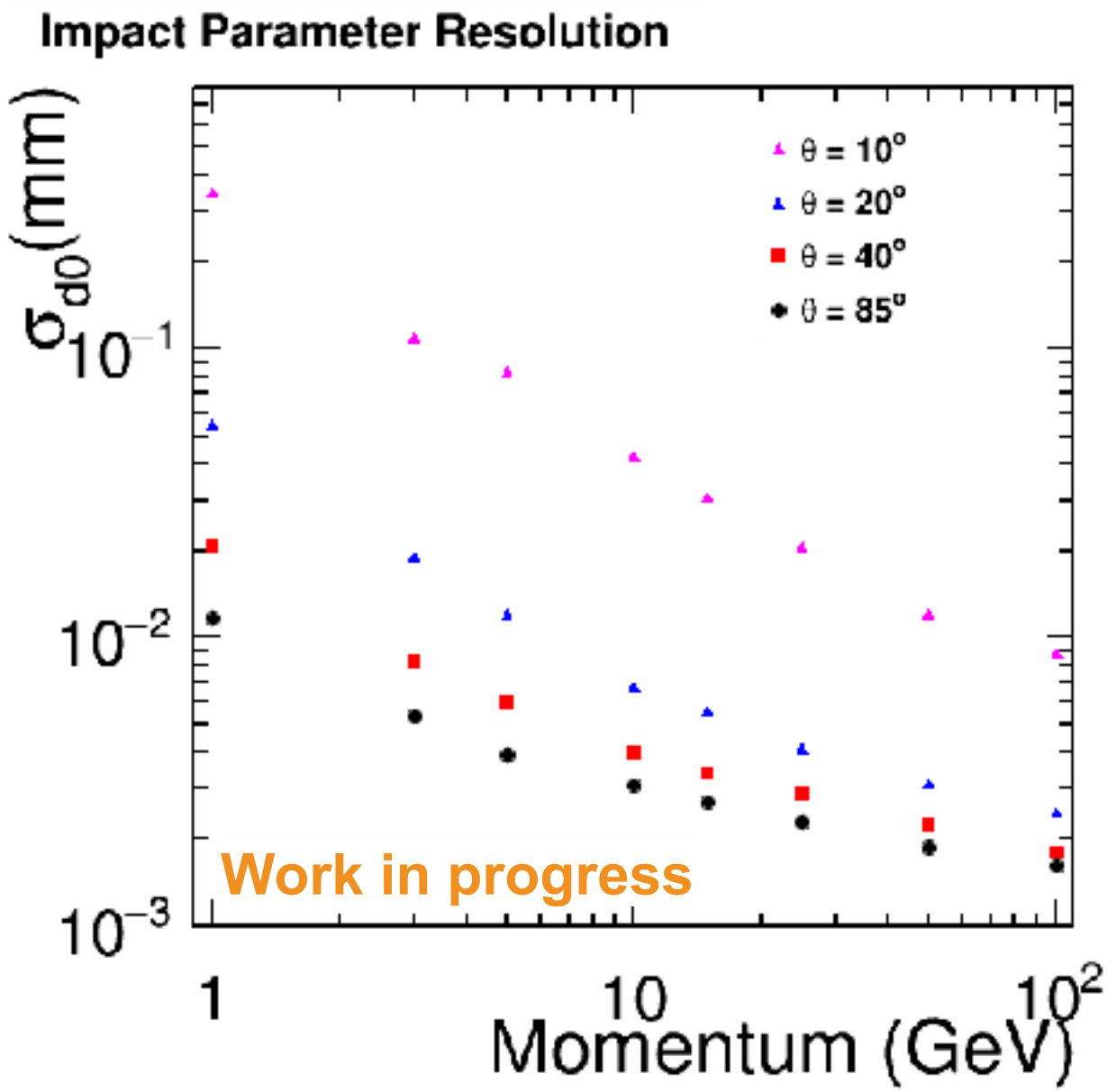
ILD w/ ConformalTracking and two FTD pixel disks



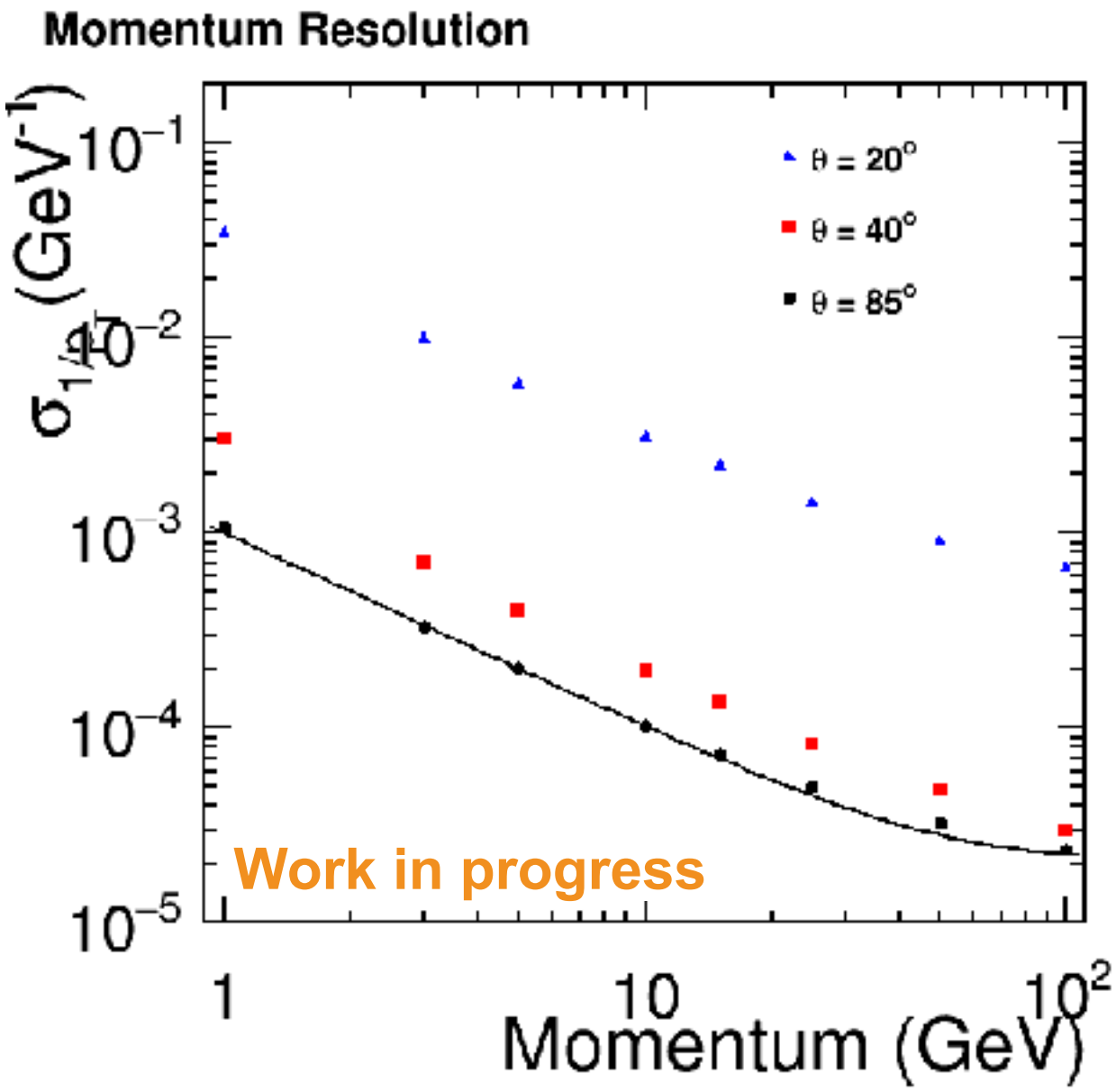


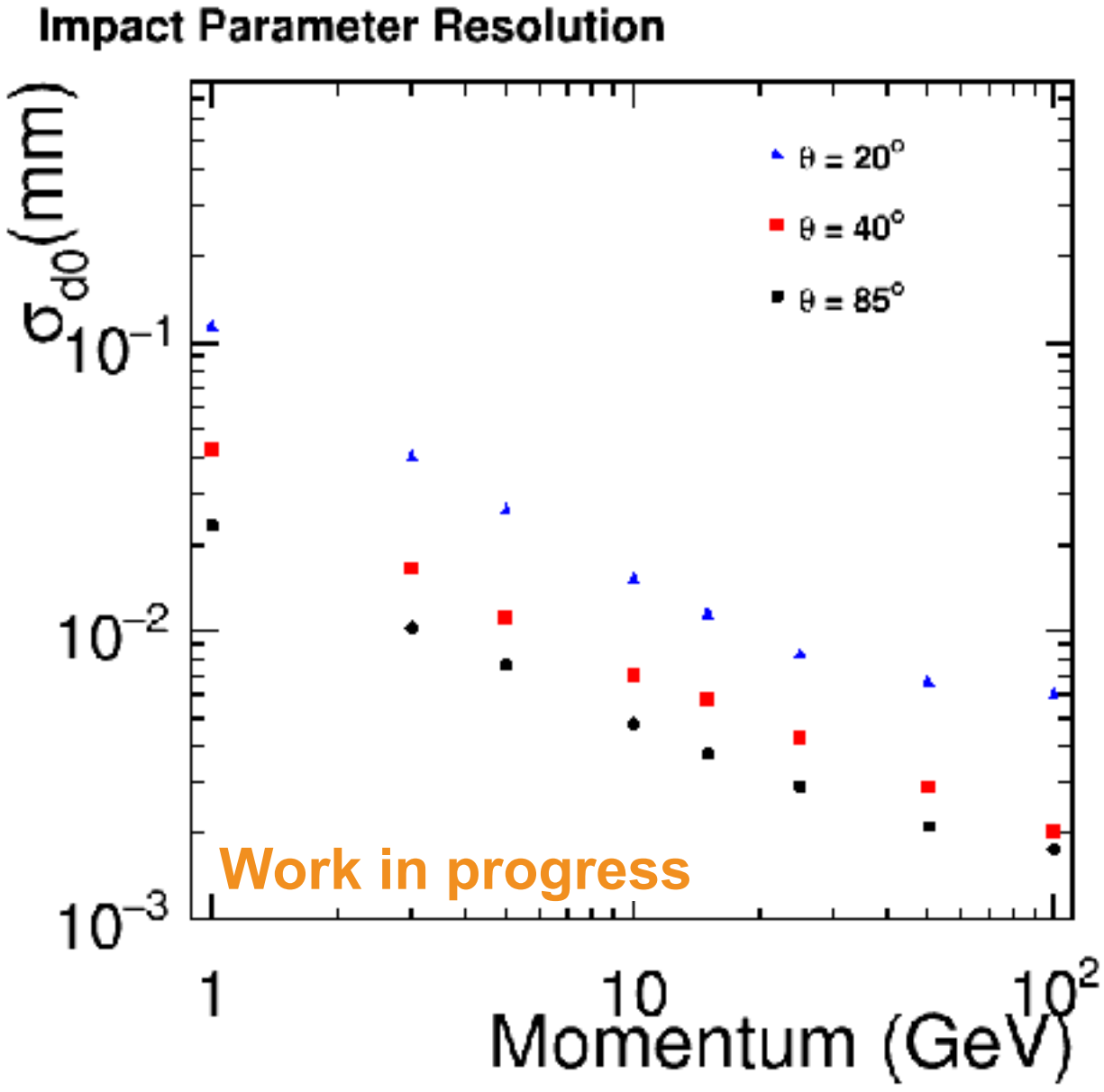
ILD concept with FTD all pixel disks





ILD concept with CLICdp style vertex detectors





Summary and Outlook

- started to study ILD tracking performance (large and small detector)
  - both fulfil the ILC design goals
  - ‘room for improvement’ in pattern recognition

- ConformalTracking algorithm shows better tracking efficiency than ILD standard reconstruction
  - not quite as good as with the CLICdp detector -> different geometrical layout

- Replacing the ILD FTD strip disks with pixel readout we observe
  - slight improvement in impact parameter resolution in fwd direction
- Next steps:
  - continue investigation of integrating ConformalTracking into ILD tracking chain
  - repeat performance studies with full background and realistic B-fields