

Muon Collider Reconstruction Performance

Karol Krizka
on behalf of many people

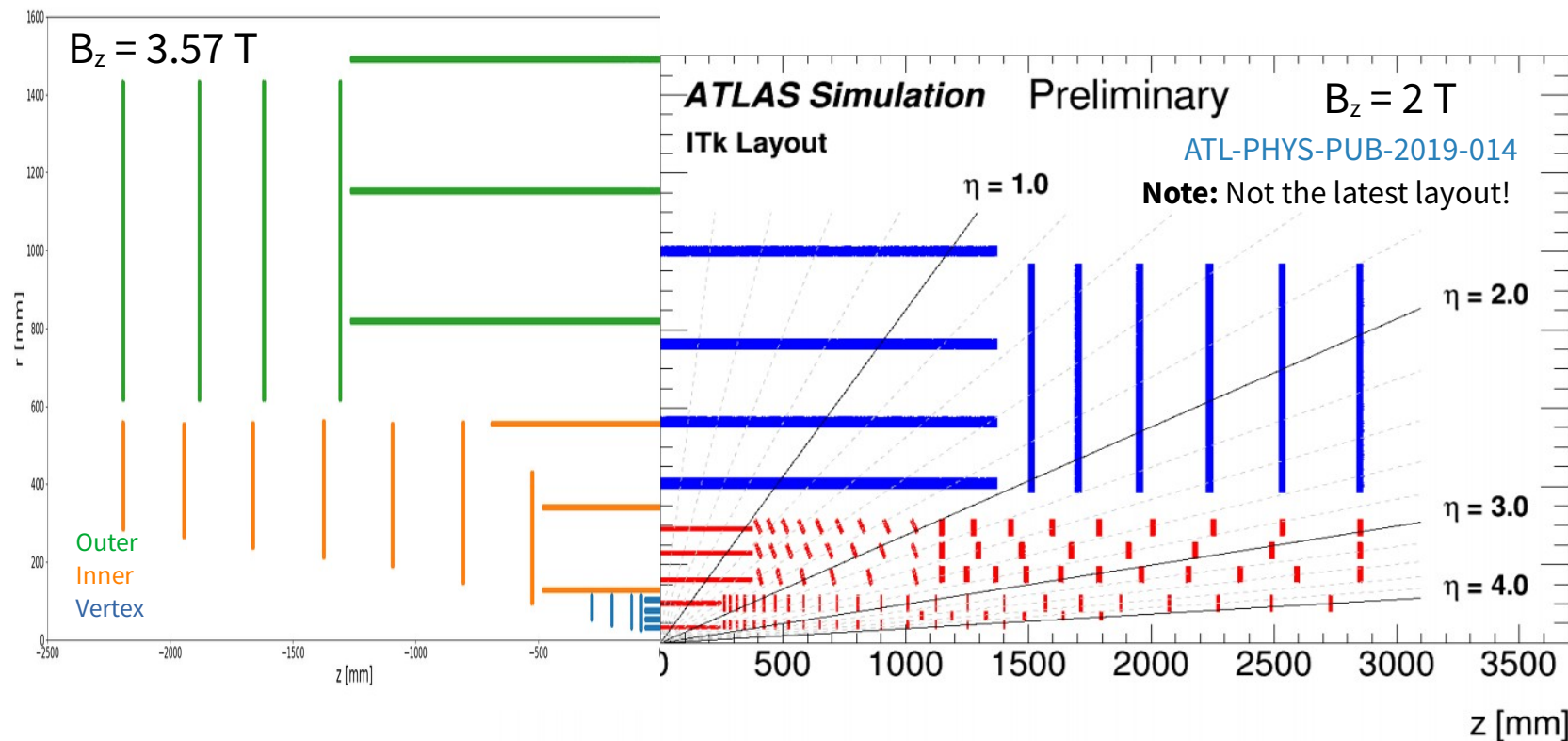
December 10, 2021

LBL Contribution: Tracking with ACTS

- Karol Krizka
- Simone Pagan Griso
- Richard Wu



The Scale of BIB



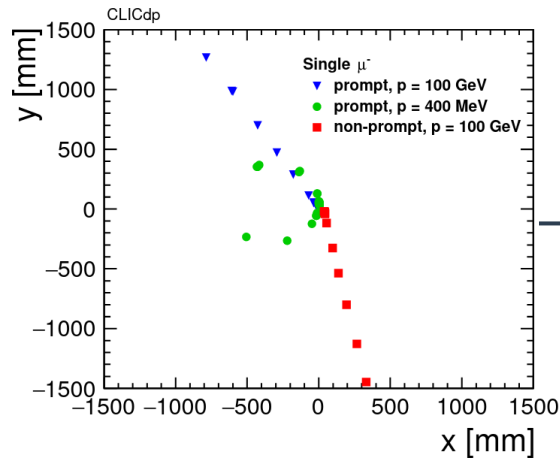
Hit density
after timing cuts
10x HL-LHC

	ITk Hit Density [mm ⁻²]	MCC Equiv. Hit Density [mm ⁻²]
Pix Lay 0	0.643	3.68
Pix Lay 1	0.022	0.51
Str Lay 1	0.003	0.03

ITk Pixels TDR, ITk Strips TDR

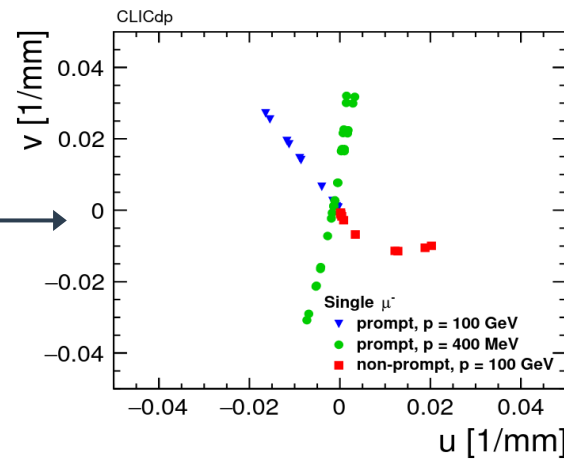
Global Hit Selection

ie: timing or double layers



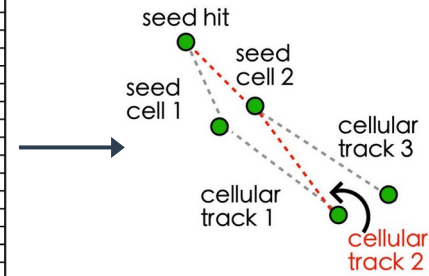
Conformal Transform

circular tracks \rightarrow straight lines



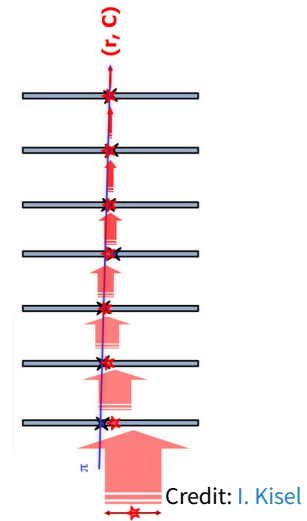
Cellular Automaton

straight "lines" \rightarrow tracks



Kalman filter

Track fit



Remove BIB hits

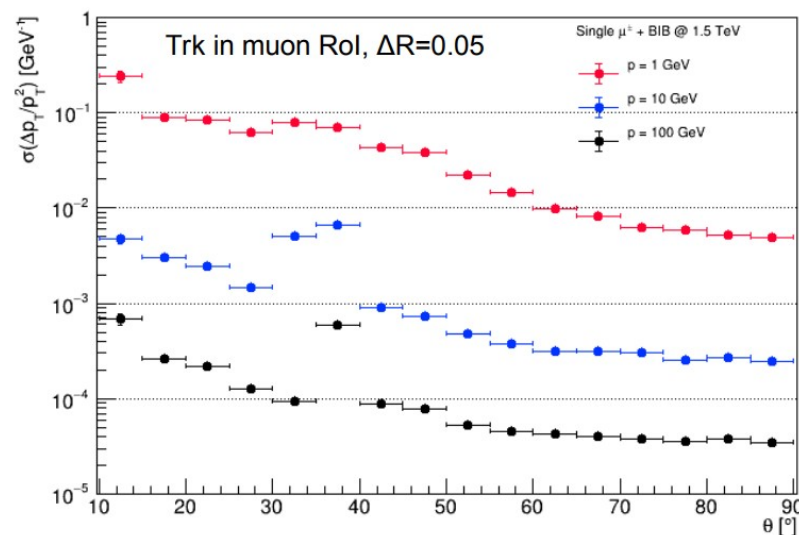
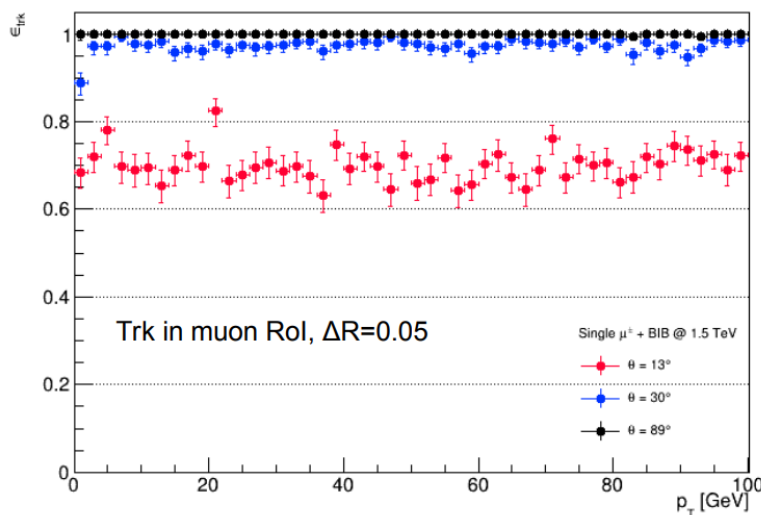
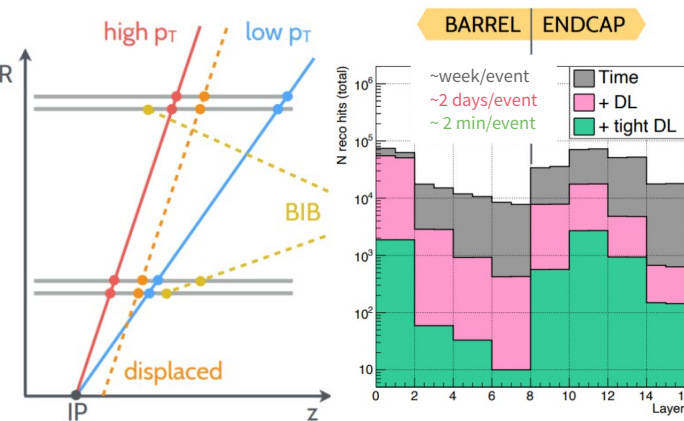
Pattern Recognition

Track Fit

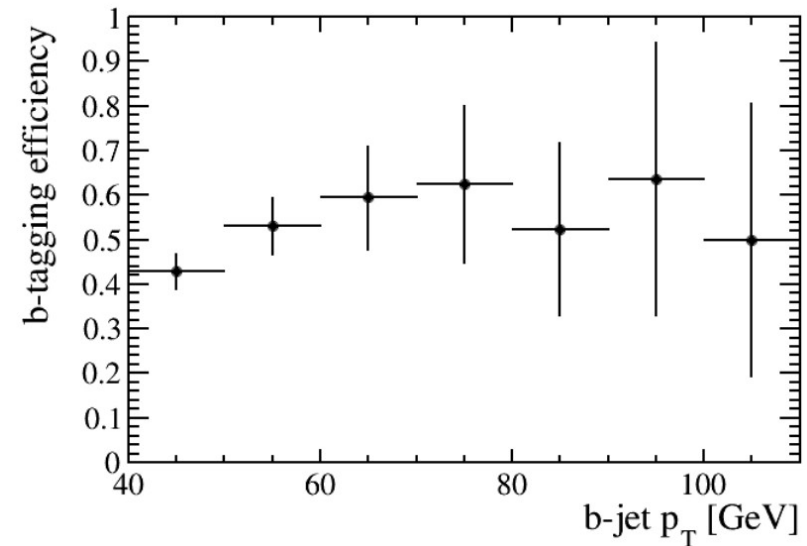
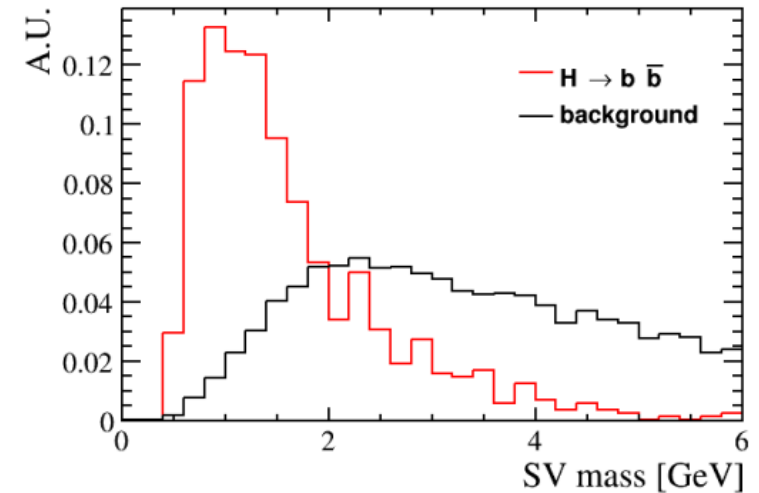
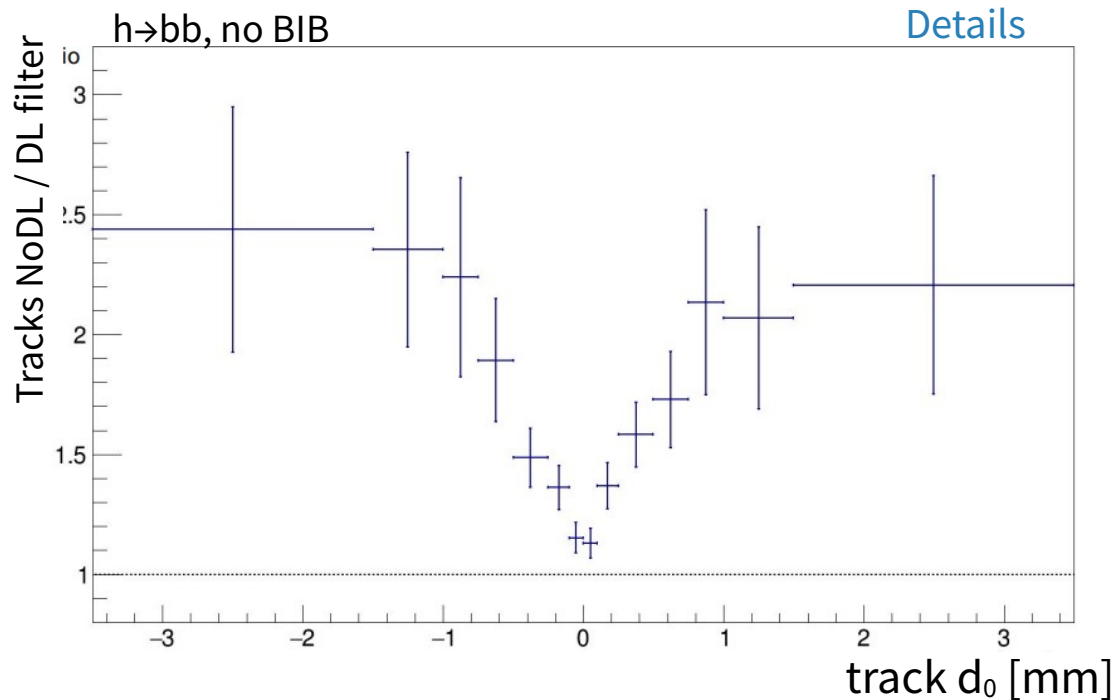
Algorithm + code inherited from CLIC software.

aka optimized for clean e^+e^- environment

- Employ hit multiplicity **reduction strategies**
 - Region of Interest seeded tracking
 - Directional information from double layers
- Require **tight filtering** for practical tracking
- **Good track reconstruction** once algorithm completes



- Secondary vertex reconstruction possible with BIB
 - Caveat: using a very loose hit filter
- Work ongoing on multivariate tagger
- Double layer filtering \rightarrow possible bias



- **ACTS is a standalone library for tracking algorithms**
- **Dedicated team working on advancing tracking algorithms**
 - Tracking is hard!
- **Allows us explore alternate algorithms**
 - Triplet-based seeding optimized for high multiplicity environments
 - Ongoing work to incorporate ML-based algorithms
- **Code optimization come for free**
 - Good software is even harder than tracking!
 - Also explores modern computing architectures (ie: GPU's)



<https://github.com/acts-project/acts>

Truth Tracking

Pattern Recognition

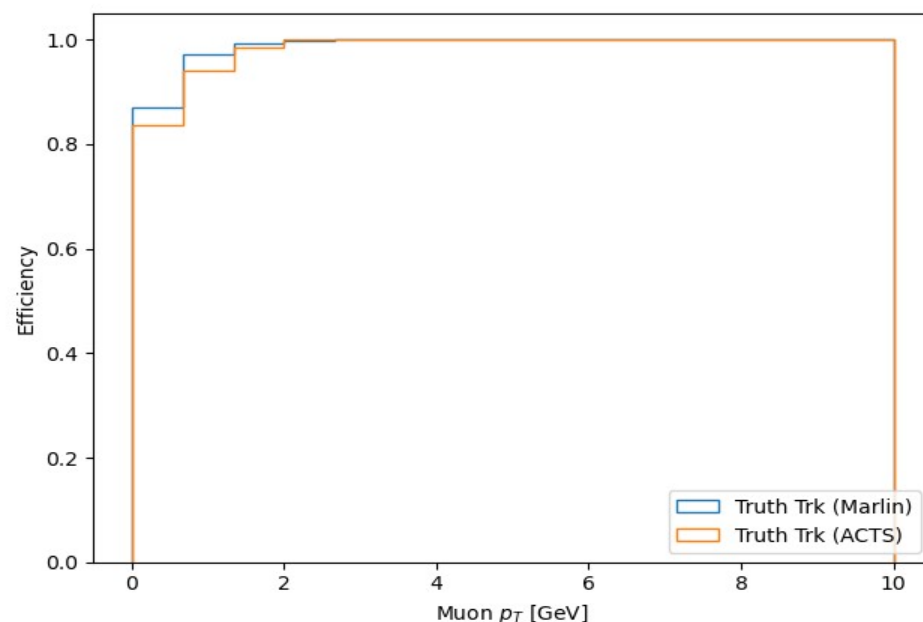
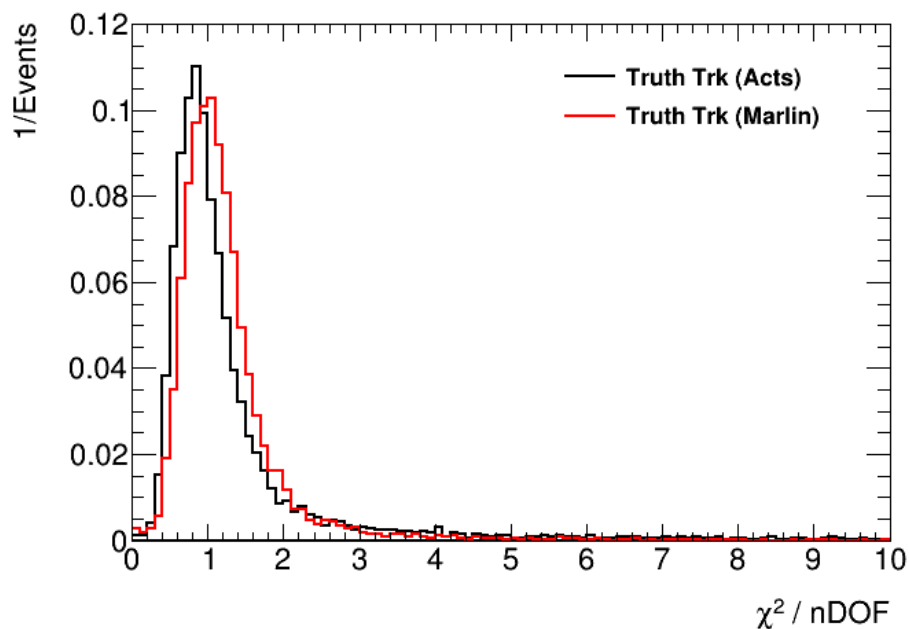
- Use hits associated to MC particle (100% efficiency)
- Same code for Marlin and ACTS

Same inputs, same algorithm,
but different programmer.

Fit Library	Execution Time
ACTS	0.5 ms / evt
iLCsoft	100 ms / evt

Track Fit

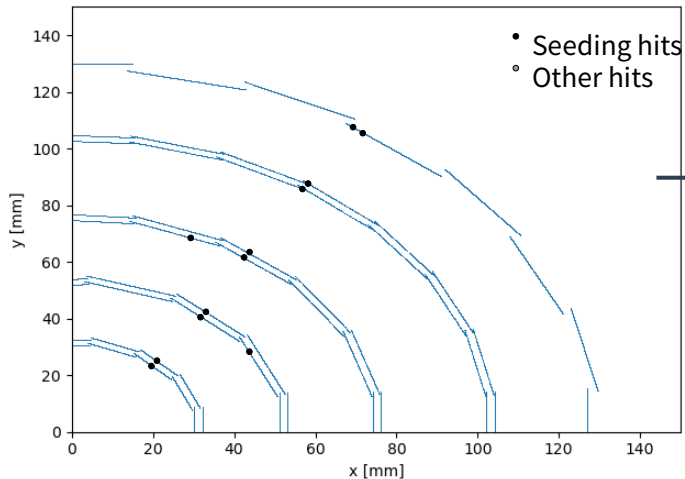
- Kalman Filter, but ACTS vs Marlin implementation



Triplet Seeded CKF

Global Hit Selection

ie: timing, *

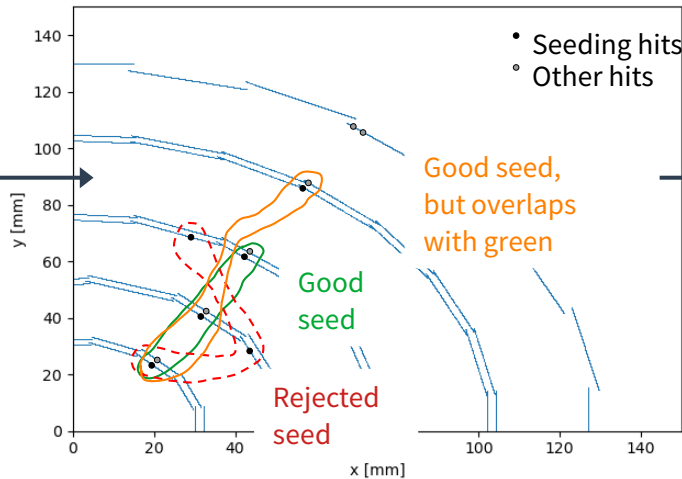


* Currently not leveraging double layers.

Remove BIB hits

Seed Finding

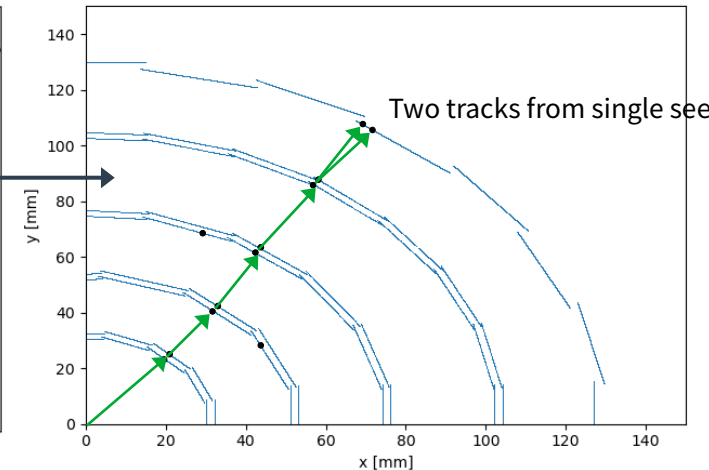
Initial parameters for CKF



Pattern Recognition

Combinatorial Kalman filter

Track fit

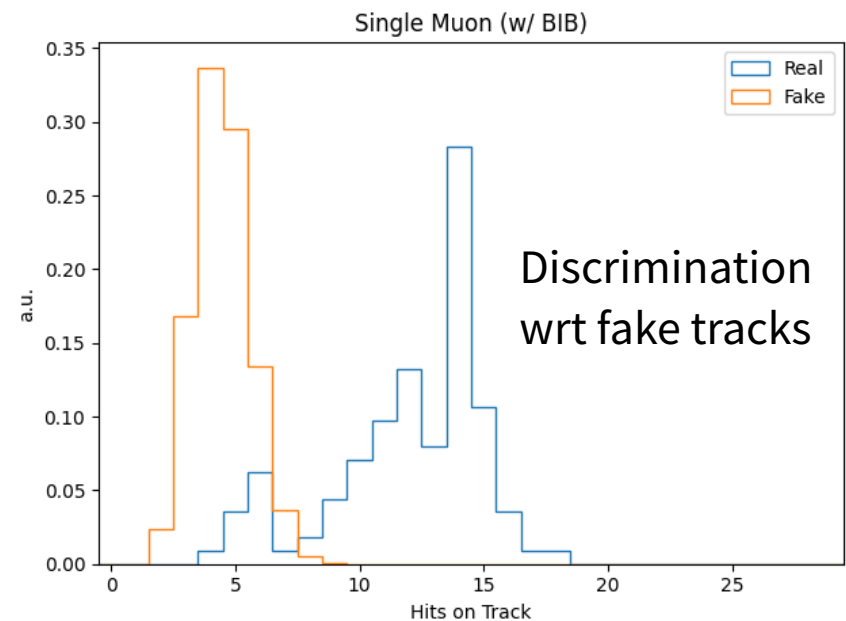
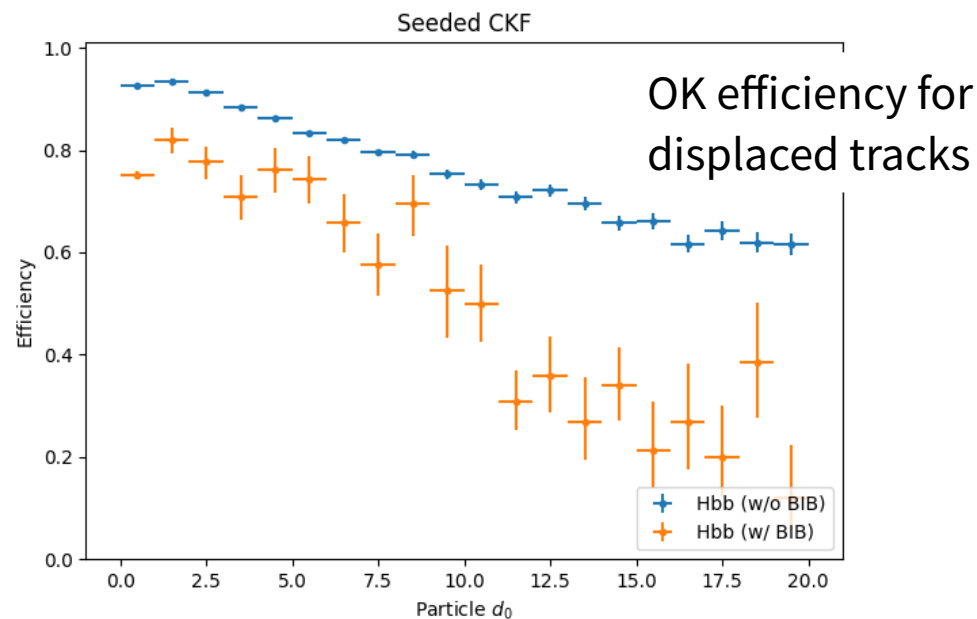
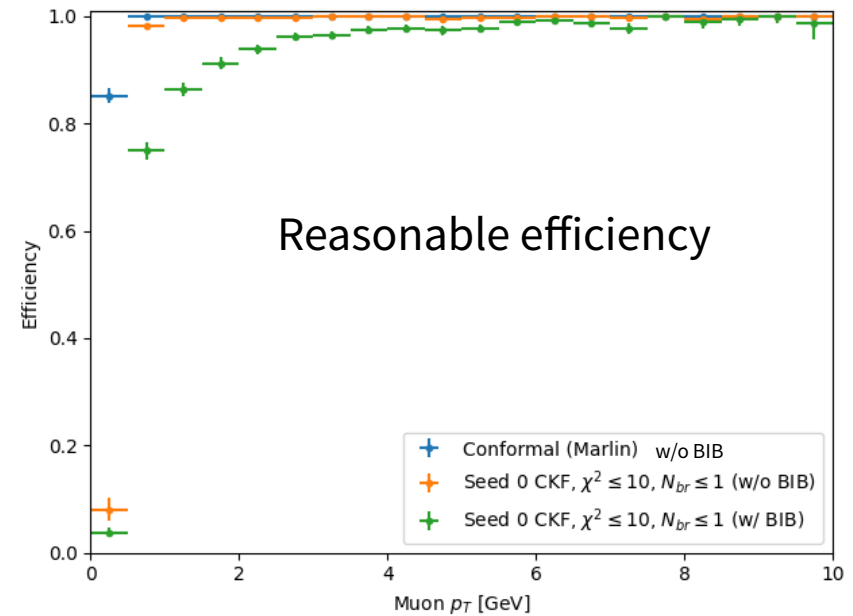


Track Fit

Similar algorithm used by ATLAS.

aka optimized for high hit multiplicity

- Seeded CKF runs in **~4 min / event**.
- Parameters need to be optimized.
 - Seeding: very narrow collision region
 - CKF: No branching allowed



ACTS Next Steps

Very promising direction for track reconstruction at Muon Collider!

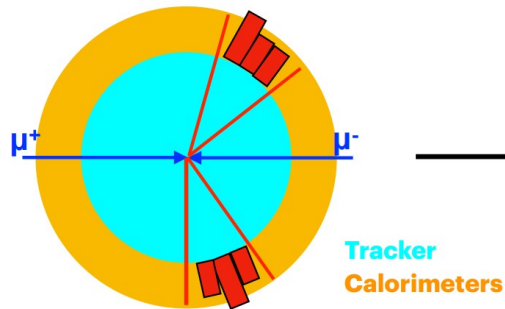
- More validation
- Optimize seeding + CKF parameters
 - Richard Wu's URAP project: automated optimization using evo algorithms
- Need selection for fake track rejection
- Study (secondary) vertex reconstruction
- Extrapolation to calorimeter for p-flow

ACTSTracking package part of MCC software release

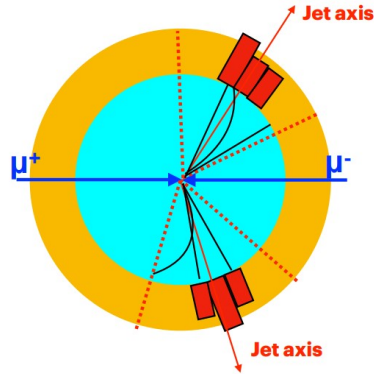
aka drop in replacement for current track reconstruction

Jet Reconstruction

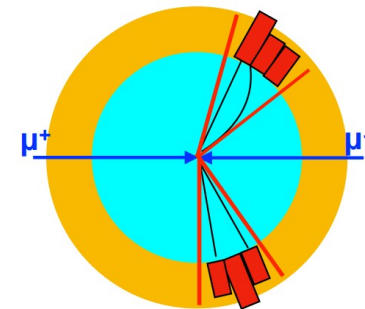
Step 1: calorimeter jet reconstruction with PandoraPFA and kt ($R=0.5$)



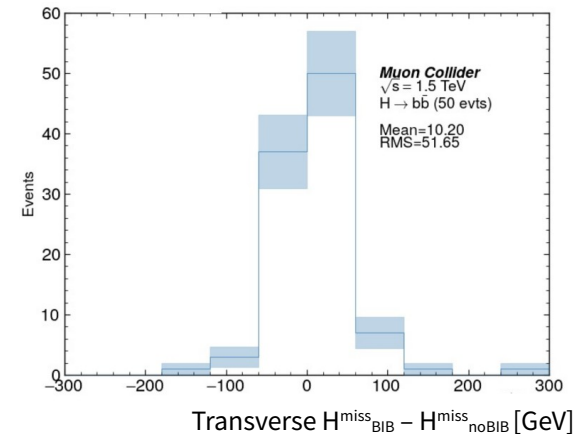
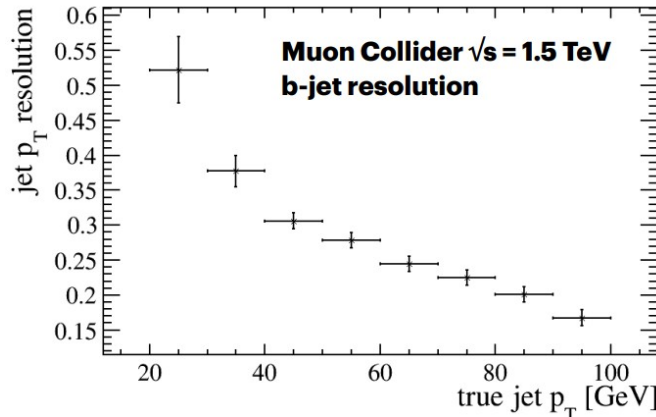
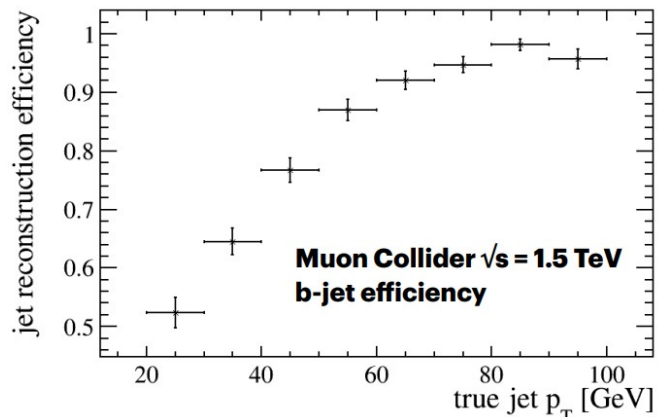
Step 2: regional tracking in cones ($R=0.7$) defined by the calorimeter jet directions



Step 3: final jet clustering using calorimeter clusters and tracks with PandoraPFA and kt ($R=0.5$)



Fully efficient for $p_T > 80$ GeV with $\sim 20\%$ resolution



Plenty of room to *optimize* and *innovate*!

Conclusions

- **Tracking: biggest challenge is pattern recognition**

- Significant contribution from LBL: Modern algorithms via ACTS

- **Calorimeter: huge diffuse background**

- Plenty of room for new ideas

- **Muons: No major problems seen**

SUBJECT TO CHANGE!

Expect plenty of innovation

in years to come.

My next steps:

- Understand impact of BIB on physics results.
- Target $H \rightarrow b\bar{b}$ final state (H and HH)