MC (Mis-)Alignment Studies

Sarah, Cam, and PF
Stanford/SLAC
April 12, 2023

Stanford University

SLAC NATIONAL ACCELERATOR LABORATORY

Overview

SLAC

1. Motivation and data samples
2. Momentum distributions
3. Unbiased u-residuals
   - Step in ures vs u
   - Bump in ures vs v
   - V-shape in ures vs v distribution
4. Summary and outlook

Motivation

- 2019 and 2021 alignments making progress but still some leftover unknown misalignments
- 2019: p vs tan λ slope
- 2021: multiple artifacts in u-residual distributions
  - Step in ures vs u – L6
  - Bump in ures vs v – L6
  - V-shape in ures vs v – L2
- Use MC to experiment with translation along w

Data samples

- MC data: 2019 FEE, simulated with nominal detector (HPS_IDEAL_iter0); re-reconstruct with misaligned sensors

Data samples

- MC data: 2019 FEE, simulated with nominal detector (HPS_IDEAL_iter0); re-reconstruct with misaligned sensors
- MC data: 2019 tritrig+beam (ttb), simulated with HPS-PhysicsRun2019-v2-4pt5; re-reconstruct with misaligned sensors

Data samples

- MC data: 2019 FEE, simulated with nominal detector (HPS_IDEAL_iter0); re-reconstruct with misaligned sensors
- MC data: 2019 tritrig+beam (ttb), simulated with HPS-PhysicsRun2019-v2-4pt5; re-reconstruct with misaligned sensors
- 2021 physics data; reconstructed with
  - HPS_Run2021Pass0_v1 and
  - HPS_Run2021Pass1_v0 iter3

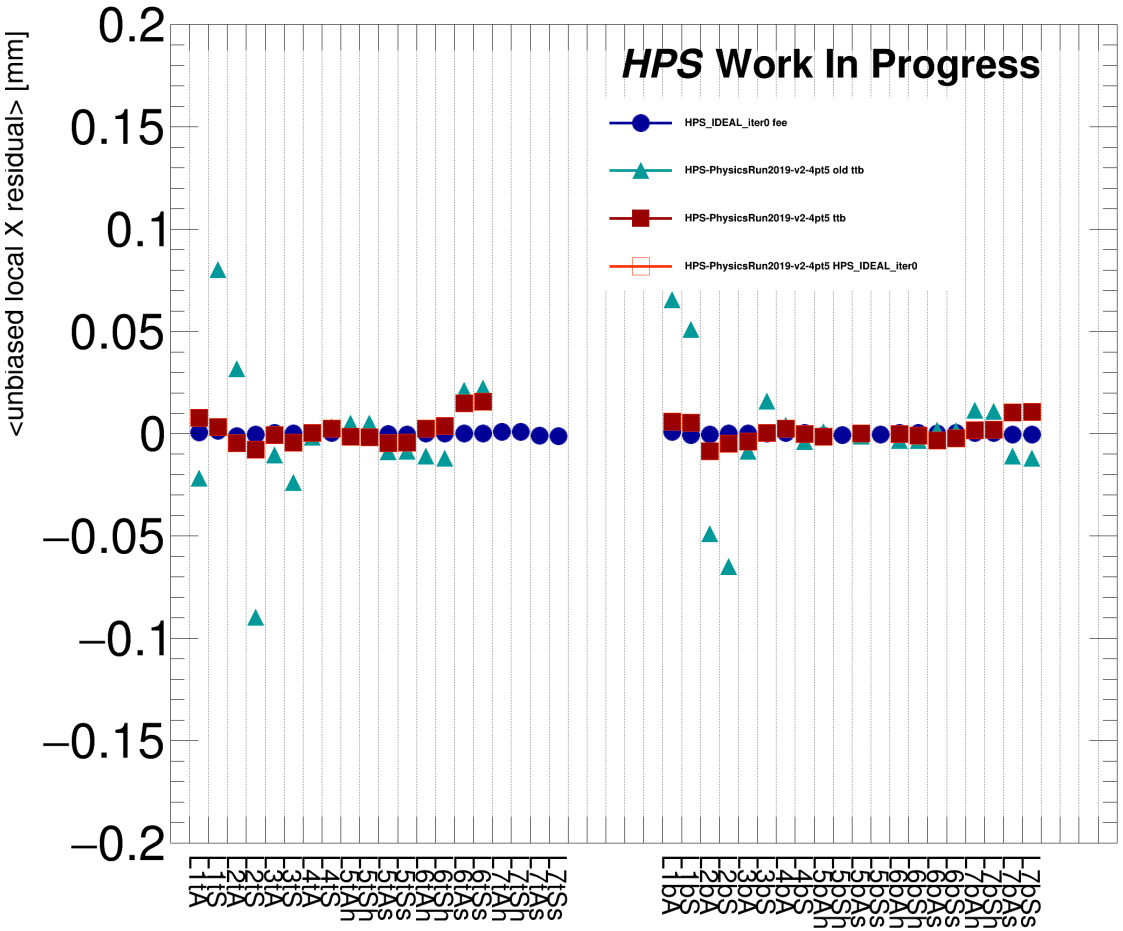
  detectors $\rightarrow$ plots and data from Cam

Data samples

- MC data: 2019 FEE, simulated with nominal detector (HPS_IDEAL_iter0); re-reconstruct with misaligned sensors
- MC data: 2019 tritrig+beam (ttb), simulated with HPS-PhysicsRun2019-v2-4pt5; re-reconstruct with misaligned sensors
- 2021 physics data; reconstructed with
  - HPS_Run2021Pass0_v1 and
  - HPS_Run2021Pass1_v0 iter3

  detectors $\rightarrow$ plots and data from Cam
- Other detectors as they come up

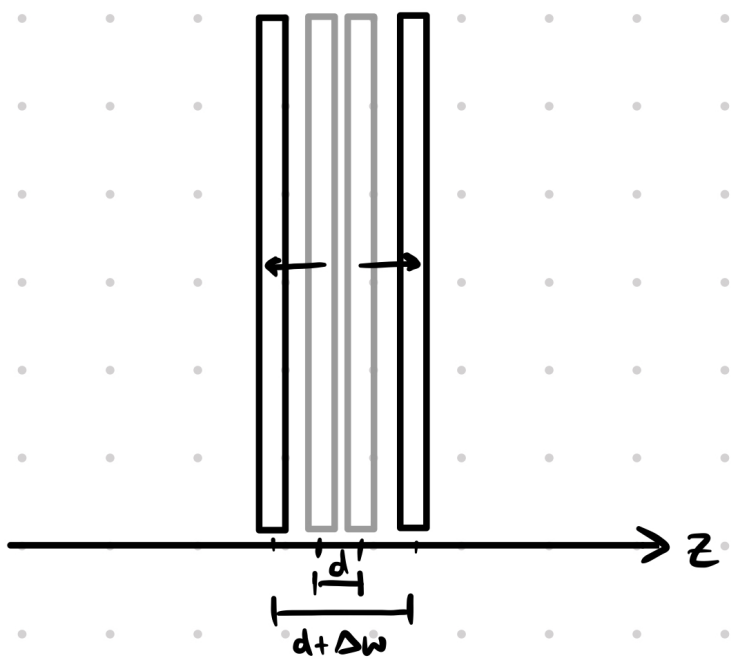
Tritrig+beam MC sample



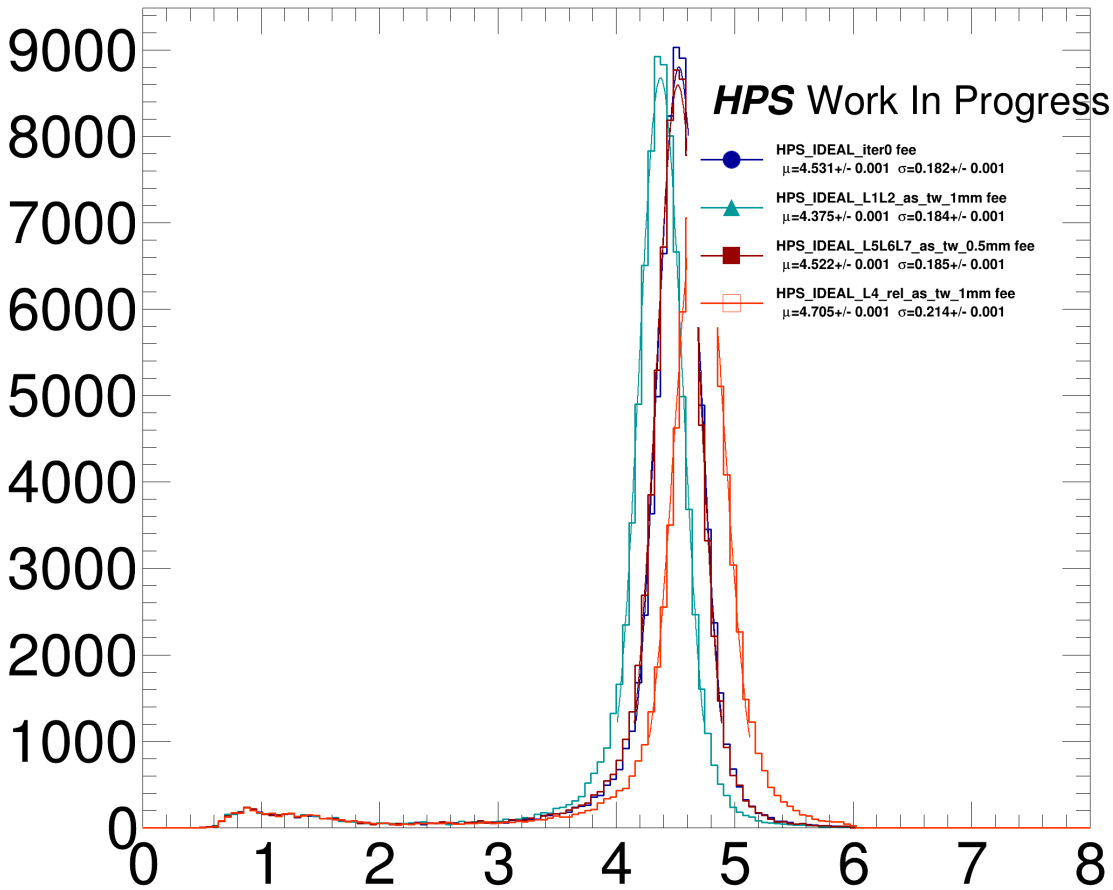
- Generation of ttb MC with HPS-PhysicsRun2019-v2-4pt5
- 'Fixed' version equivalent to HPS_IDEAL_iter0

Misalignments

- 'Aligned' sample: HPS_IDEAL_iter0
- Increased separation in w between axial and stereo sensors
  - HPS_IDEAL_L1L2_as_tw_1mm: +1 mm in L1 and L2
  - HPS_IDEAL_L5L6L7_as_tw_0.5mm: +0.5 mm in L5, L6, and L7
  - HPS_IDEAL_L4_as_tw_1mm: +1 mm in L4

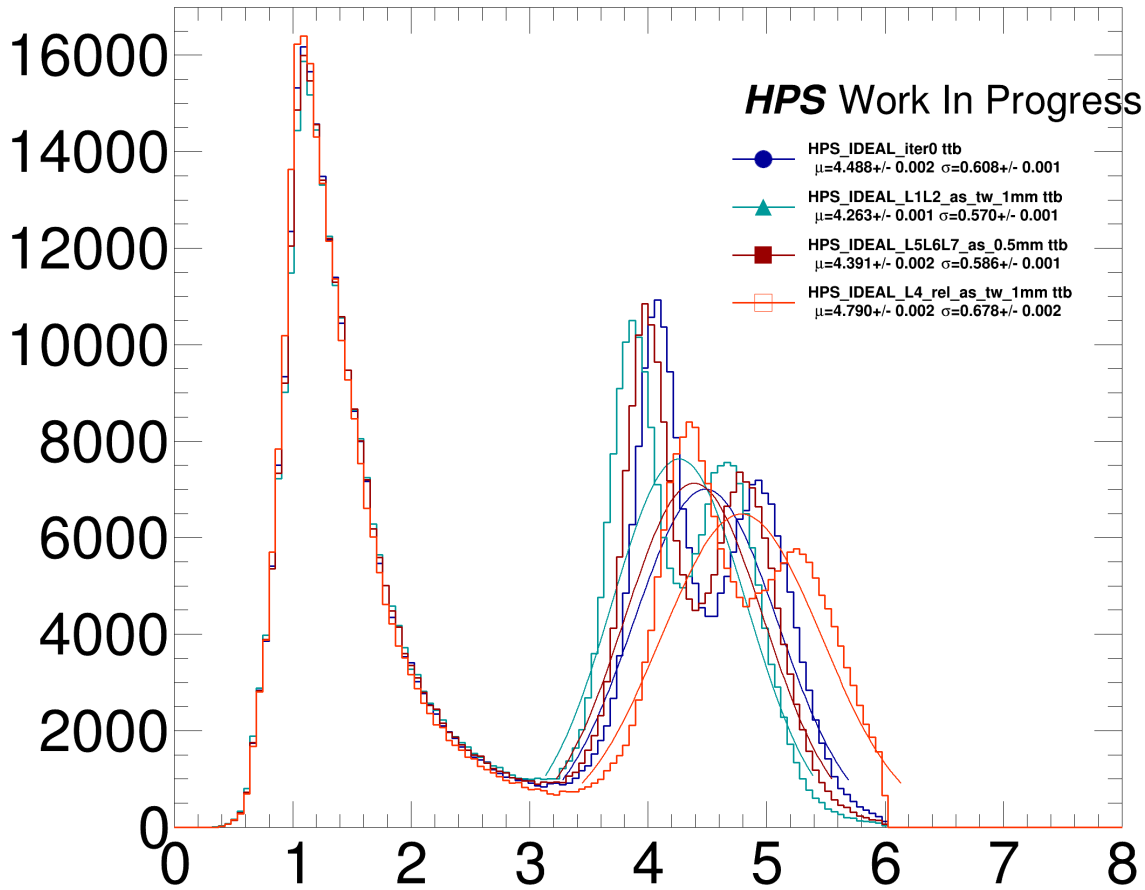


Momentum distributions – fee MC, top



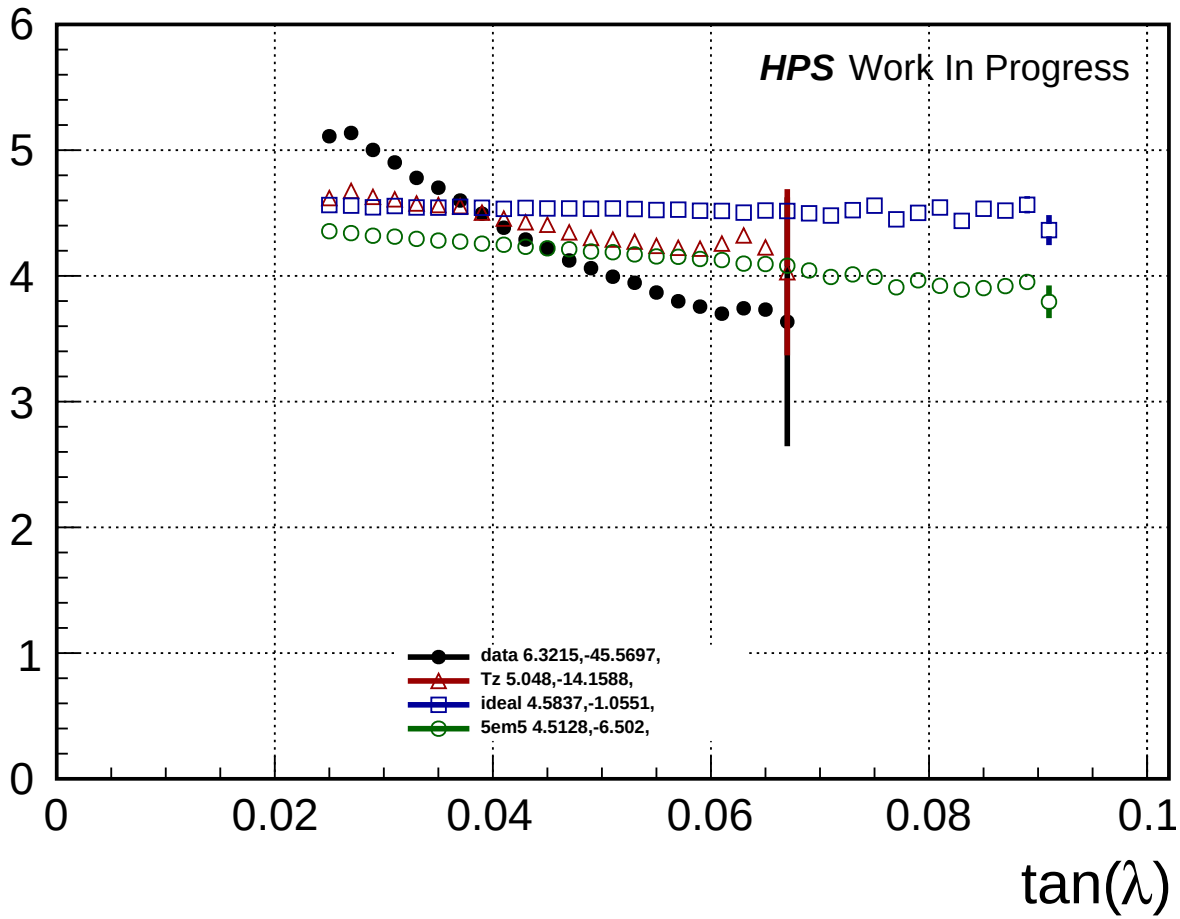
- Misalignments have more effect on high momentum tracks

Momentum distributions – ttb MC, top



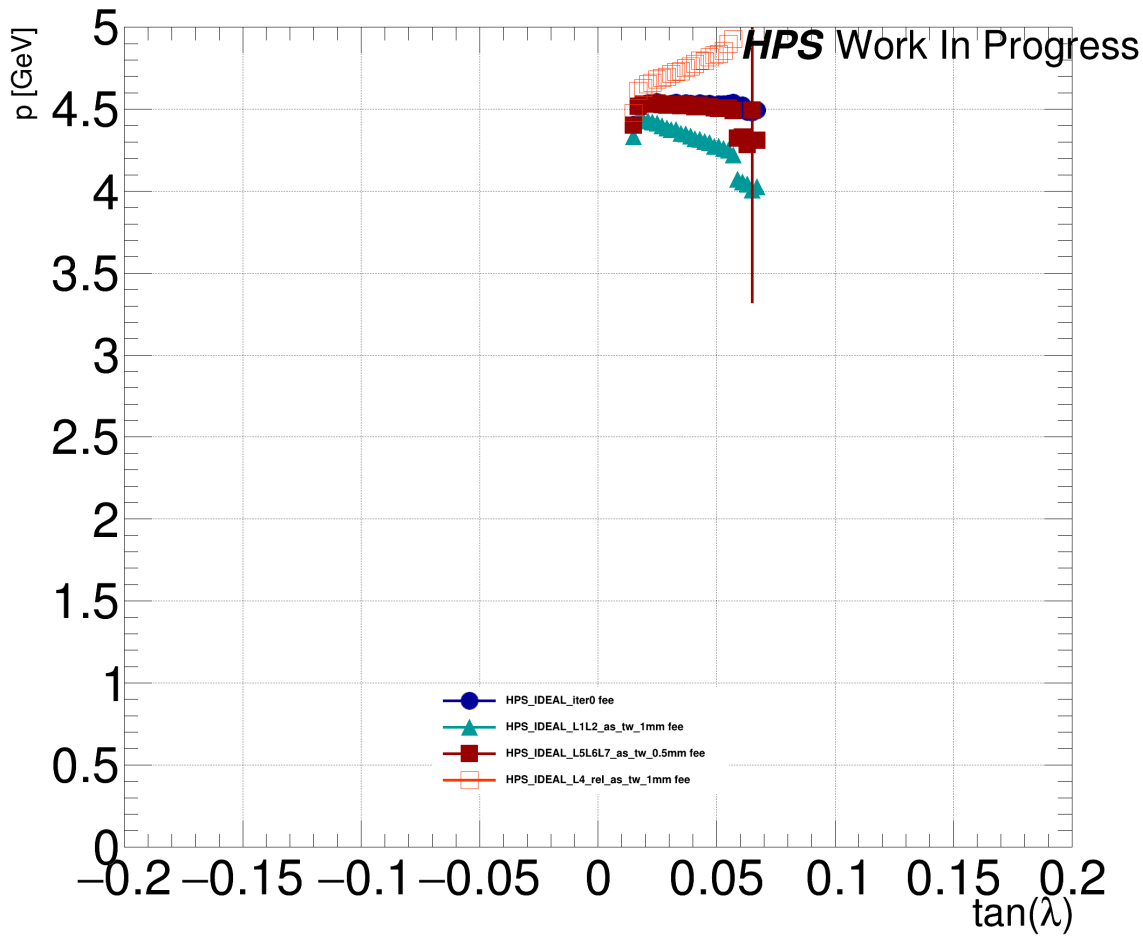
- Misalignments have more effect on high momentum tracks

Momentum vs tanL – fee data 2019, top



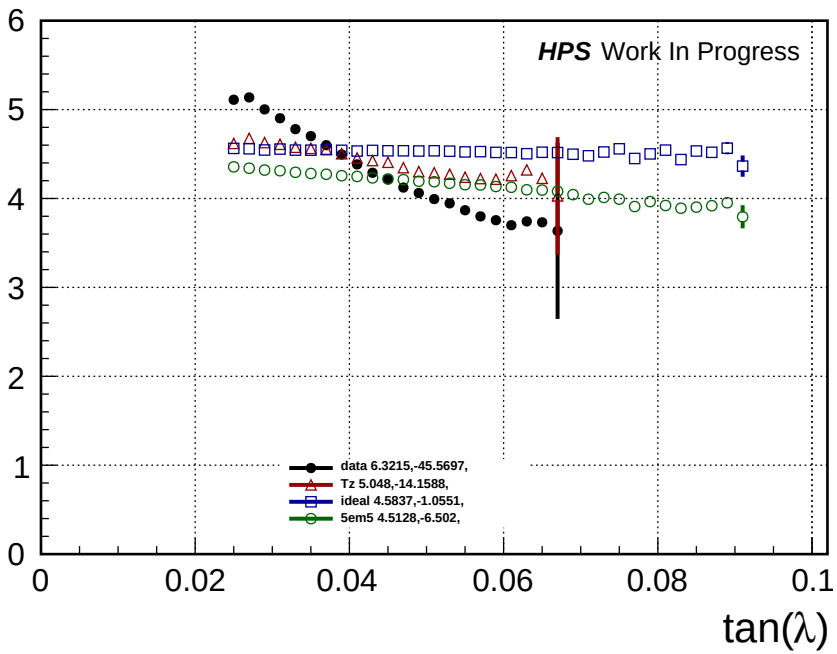
- Slope in p vs tan λ as seen in 2021 data by PF

Momentum vs tanL – fee MC, top

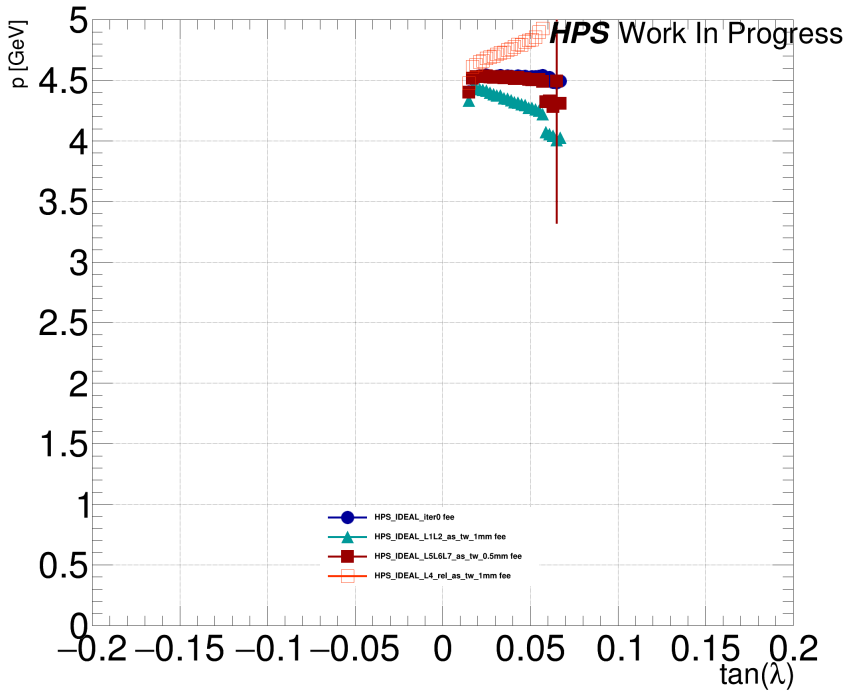


- +1 mm axial-stereo separation in L1 and L2 reproduces slope

Momentum vs tanL – fee, top



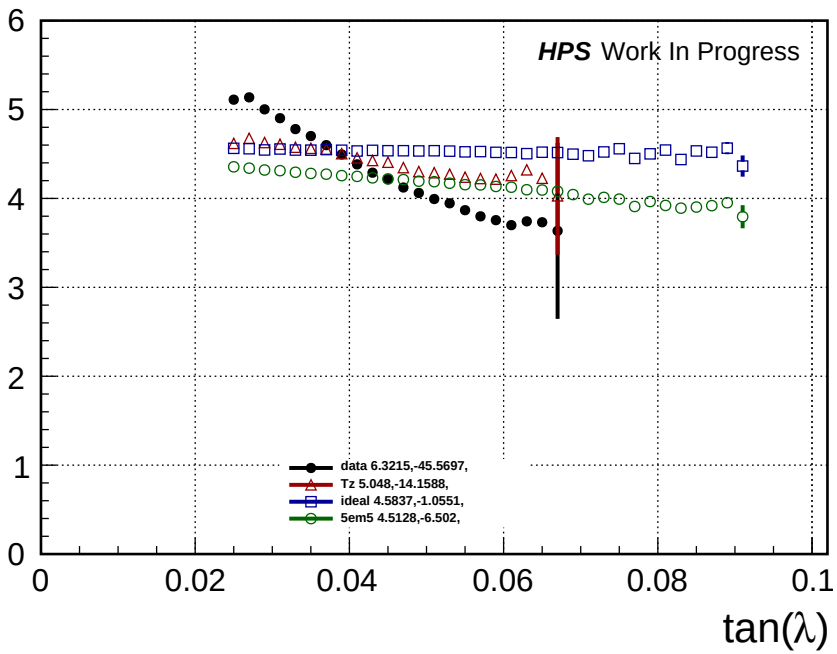
2019 fee data



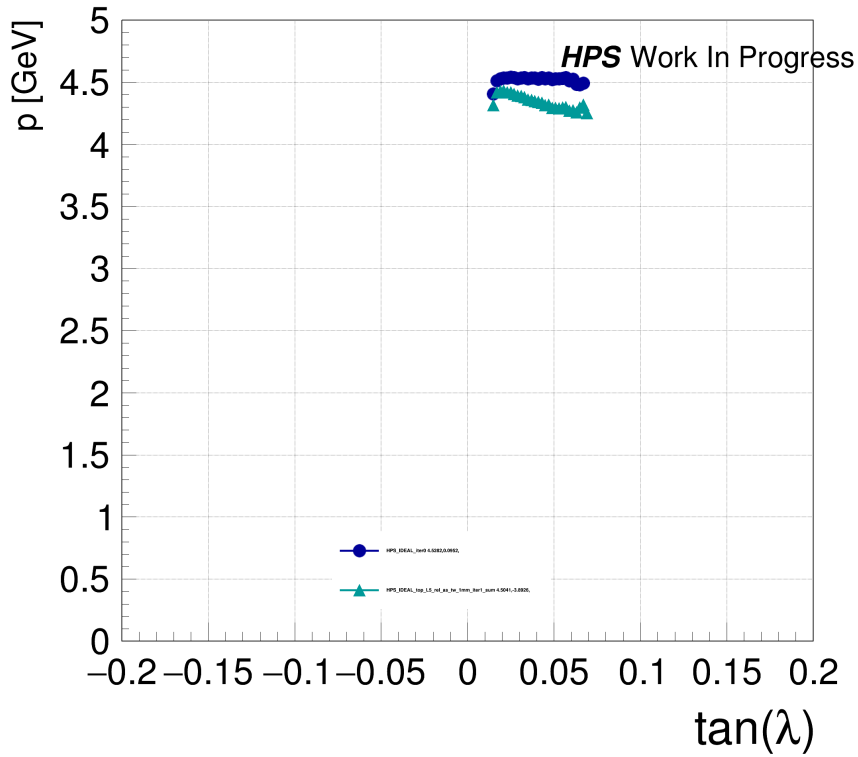
fee MC

- +1 mm axial-stereo separation in L1 and L2 reproduces slope

Momentum vs tanL – fee, top



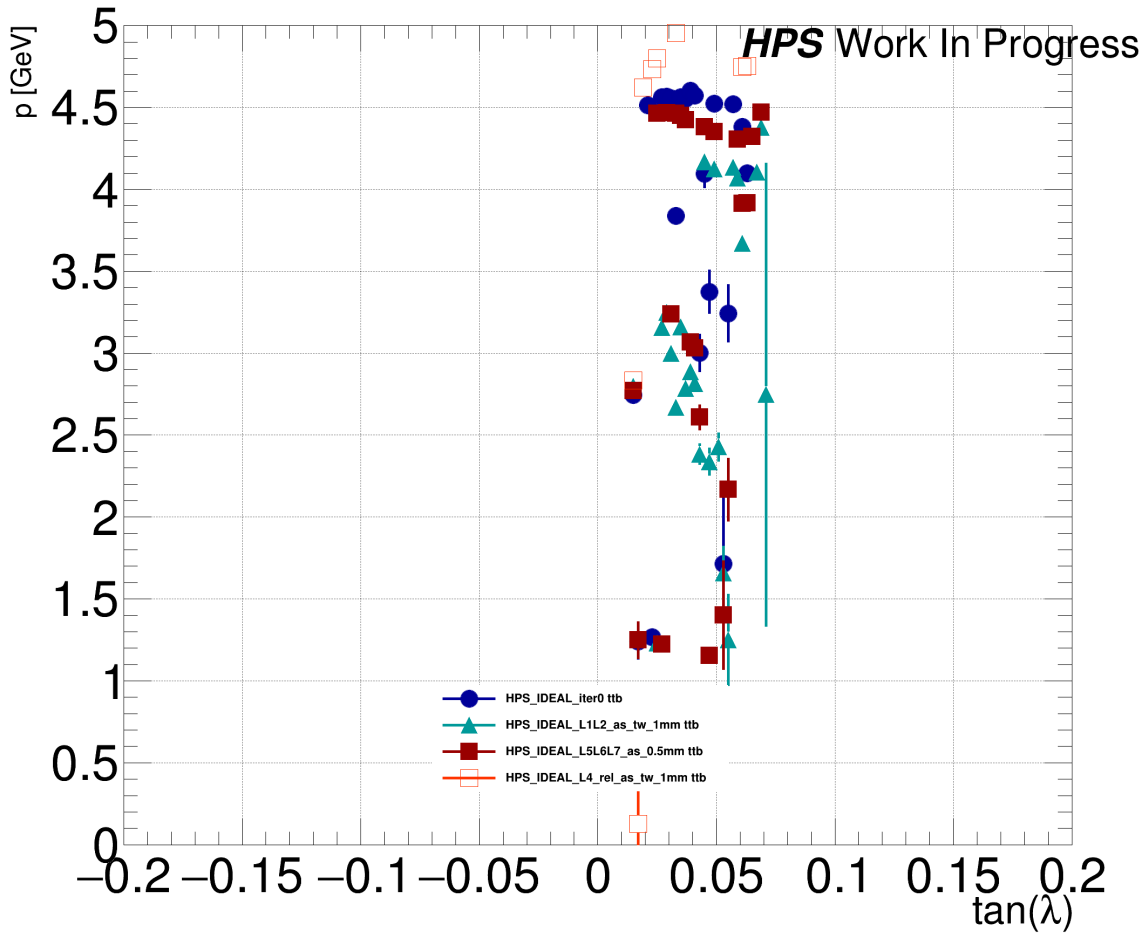
2019 fee data



fee MC +1 mm ax-st L5

- +1 mm axial-stereo separation in L5 also generates slope

Momentum vs tanL – ttb MC, top



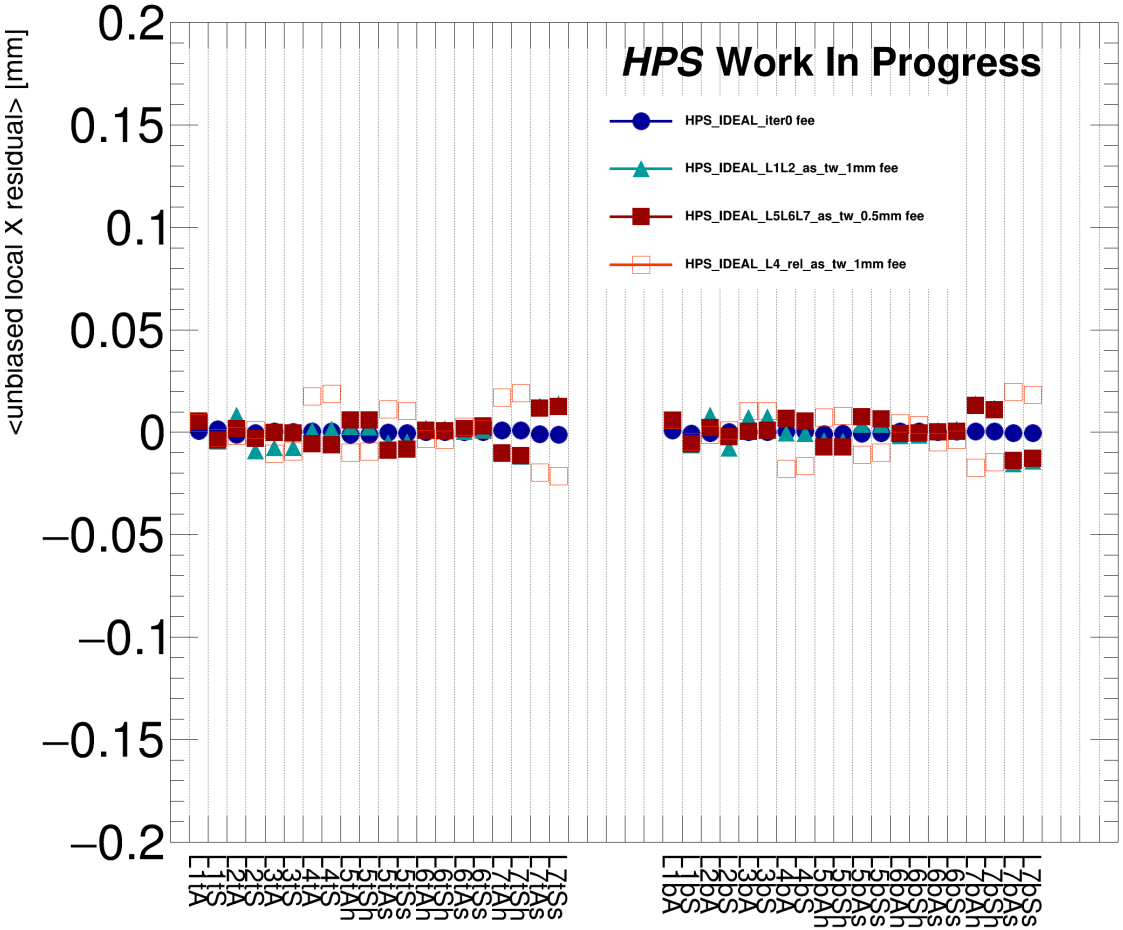
- p vs tan λ for ttb sample
- Range of momenta $\rightarrow$ smeared distribution

Momentum vs tanL – Summary

SLAC

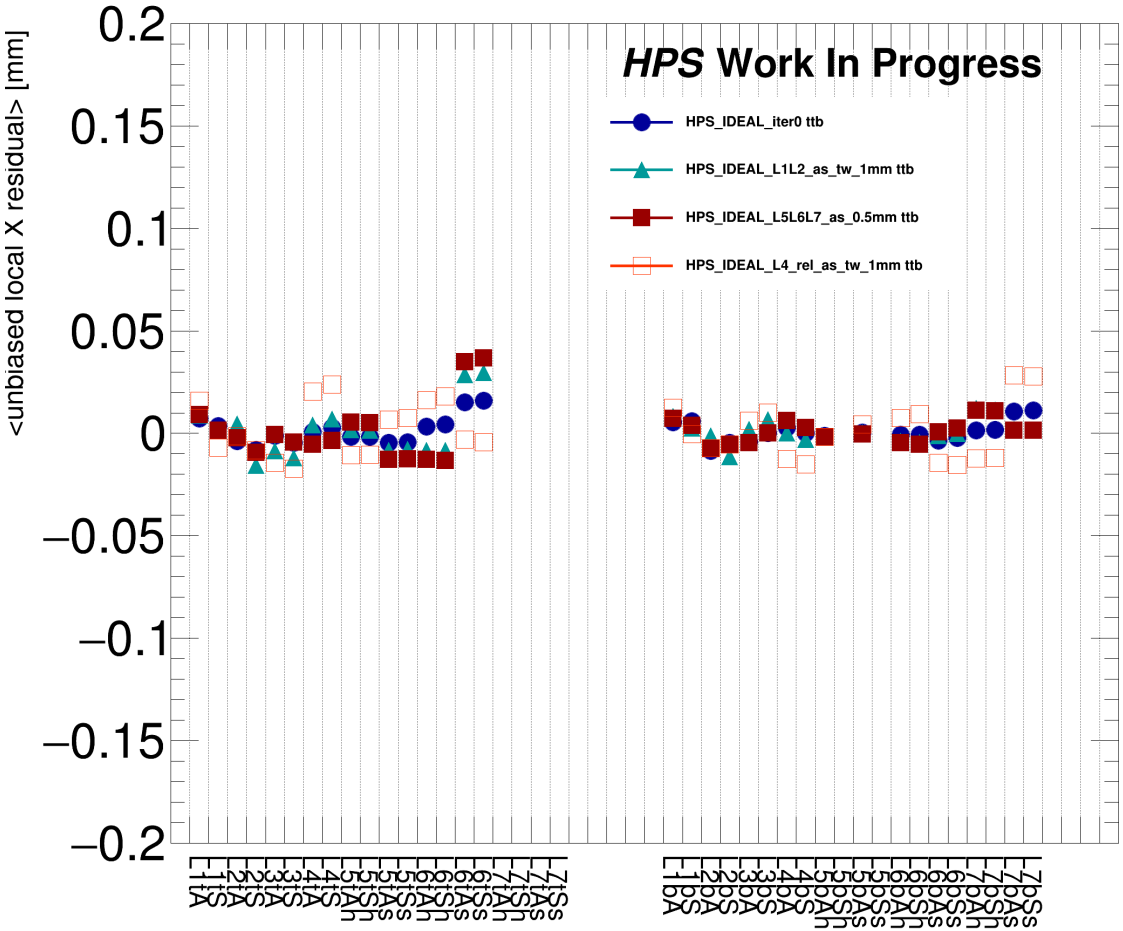
- Slope in p vs tan λ reproducible by $+1$ mm axial-stereo separation
  - in L1 and L2
  - in L5
- Other w movements yield different p vs tan λ trends
- Full tritrig+beam sample: no clear dependence of momentum on tan λ

Unbiased u-residuals – fee MC



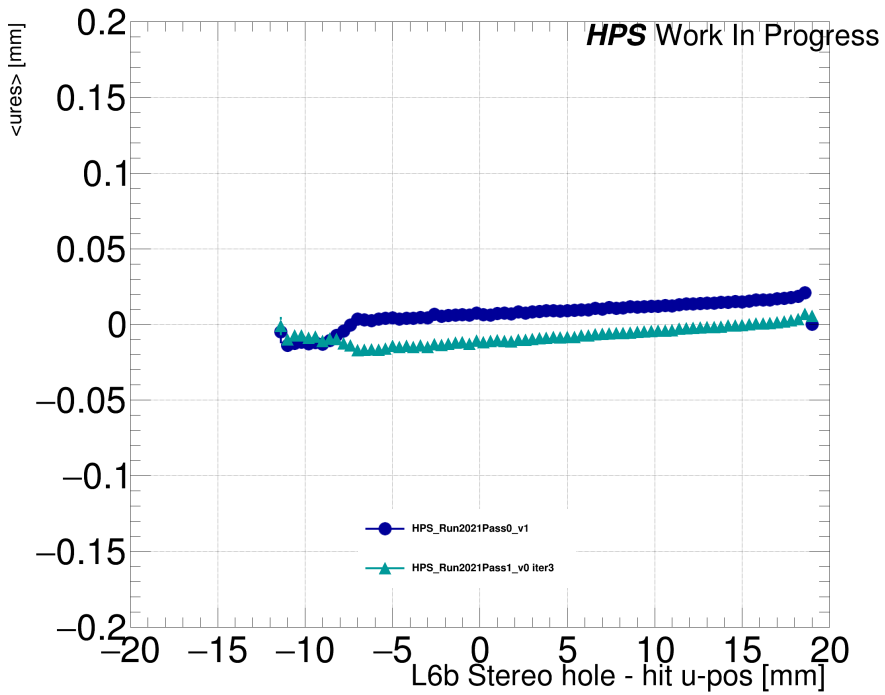
- ures in all layers for fee sample – comparison of misalignments

Unbiased u-residuals – ttb MC

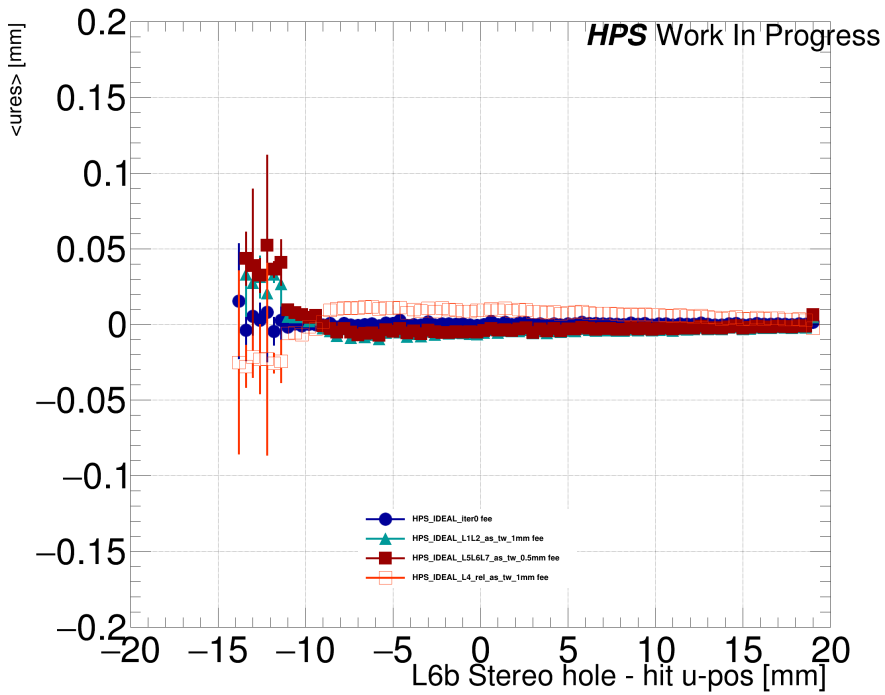


- ures in all layers for ttb sample – comparison of misalignments

Step in ures vs u distribution – data vs fee



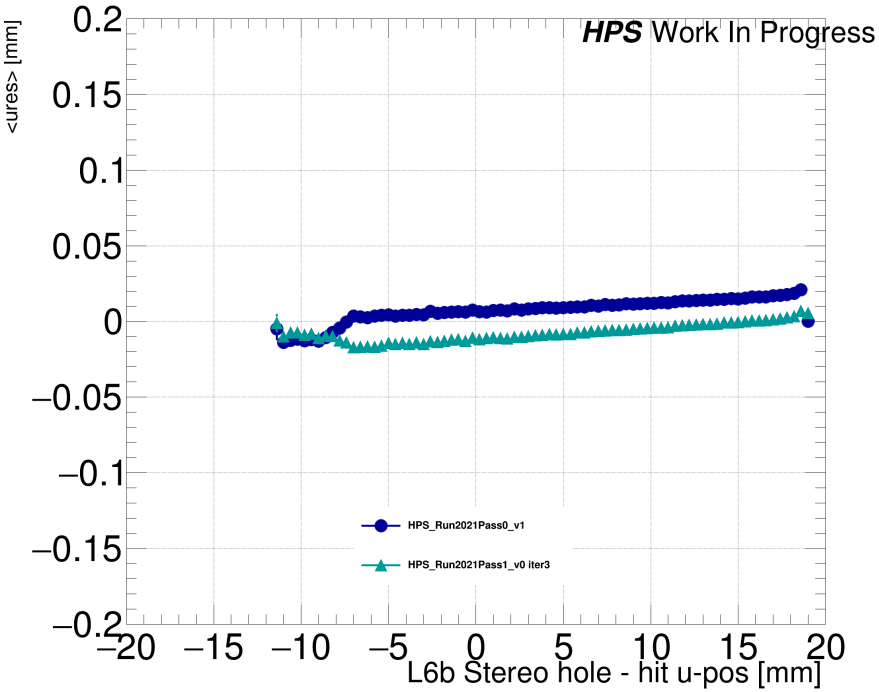
2021 data



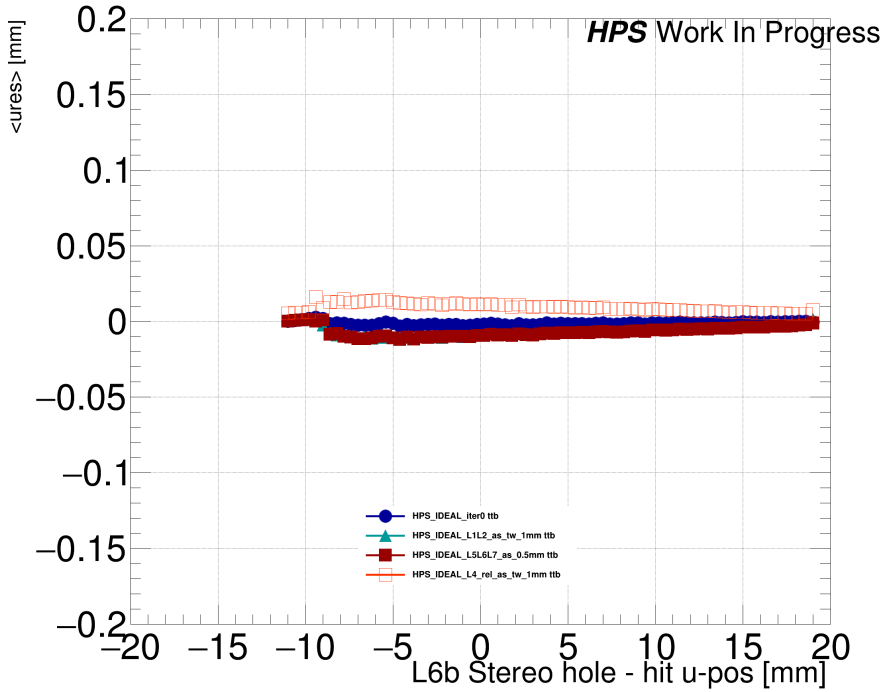
fee MC

- Step in distribution reproducible by +1 mm ax-st in L1+L2 or +0.5 mm ax-st in L5+L6+L7

Step in ures vs u distribution – data vs ttb



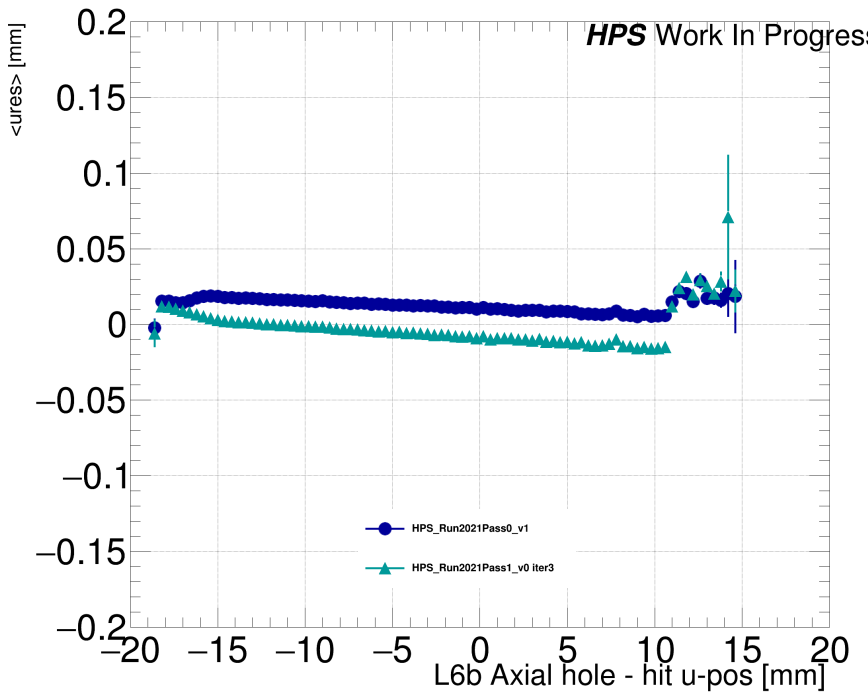
2021 data



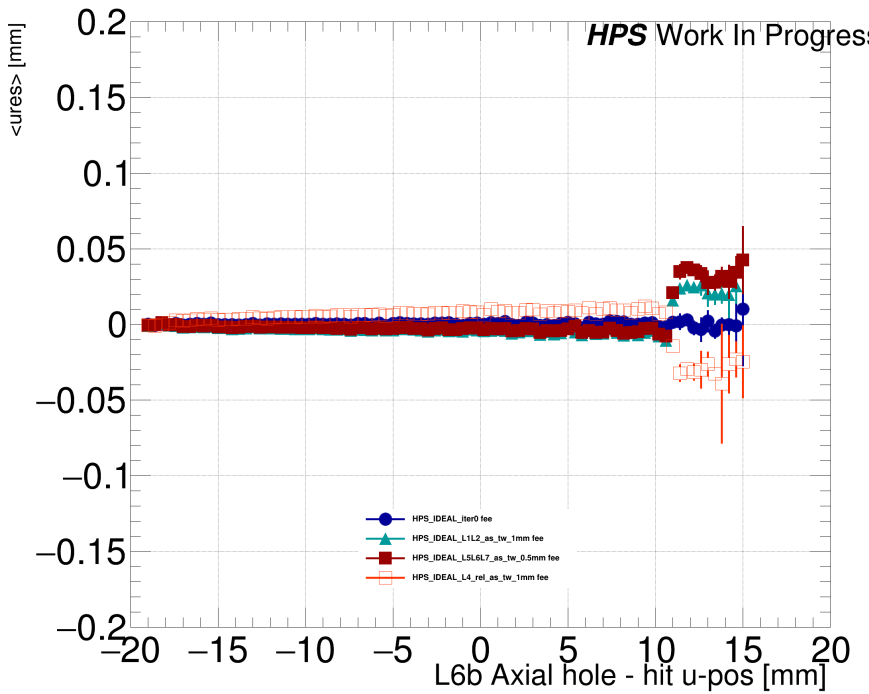
ttb MC

- Smaller effect using ttb MC → matches shape from 2021 data sample

Step in ures vs u distribution – data vs fee



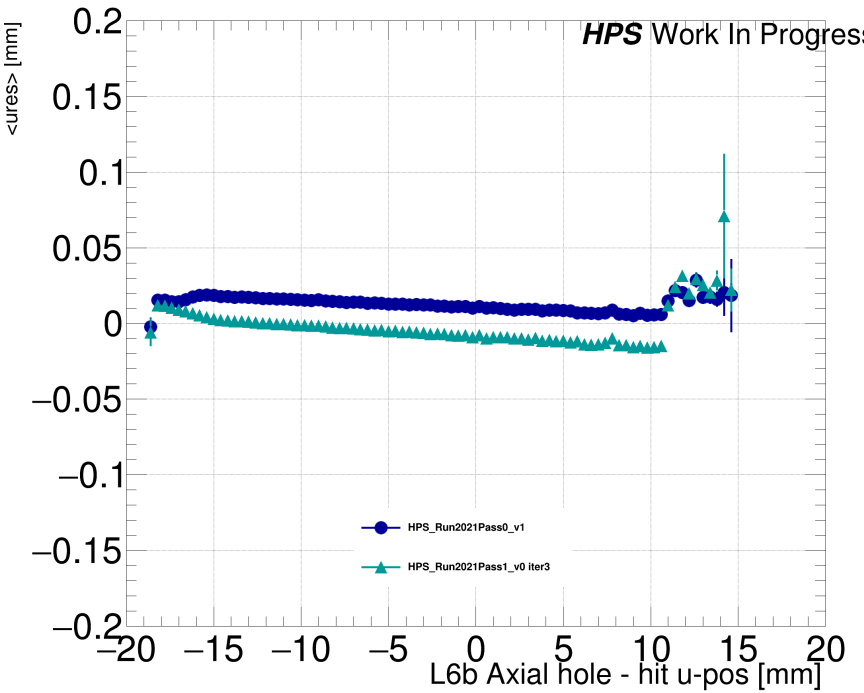
2021 data



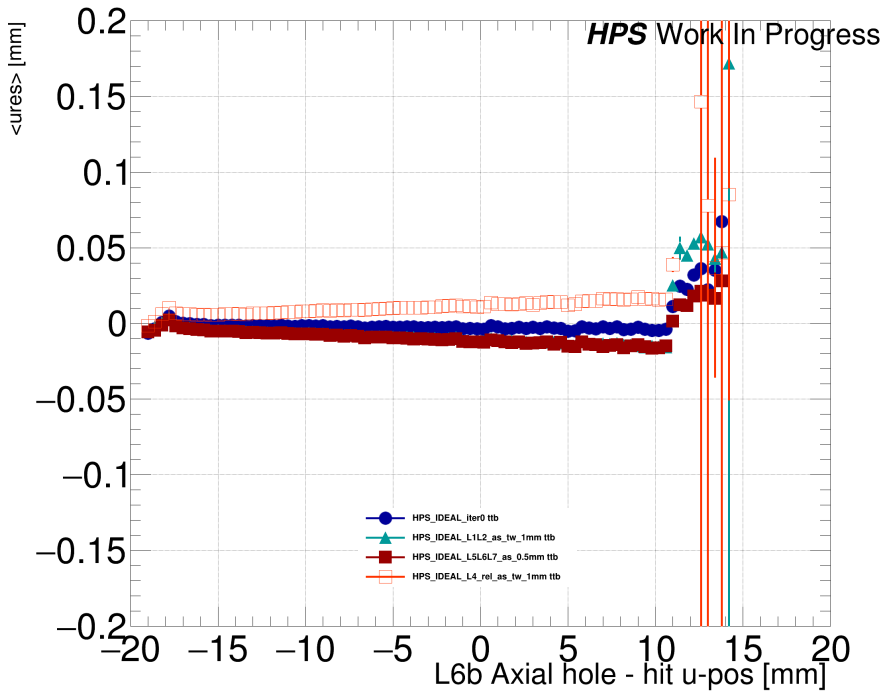
fee MC

- Step in distribution reproducible by +1 mm ax-st in L1+L2 or +0.5 mm ax-st in L5+L6+L7

Step in ures vs u distribution – data vs ttb



2021 data



ttb MC

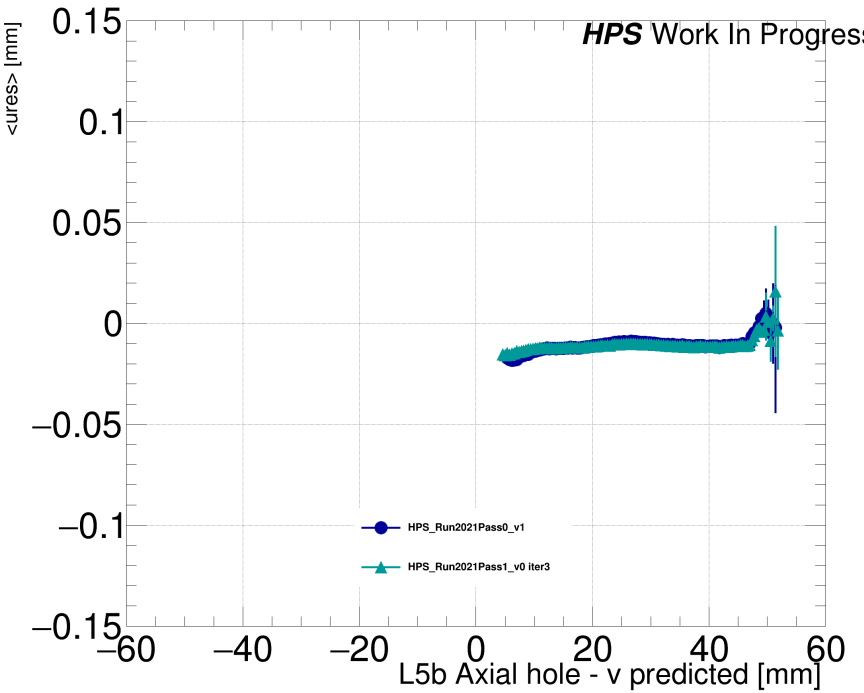
- Additional slope for data sample matched by ttb MC sample

Step in ures vs u distribution – Summary

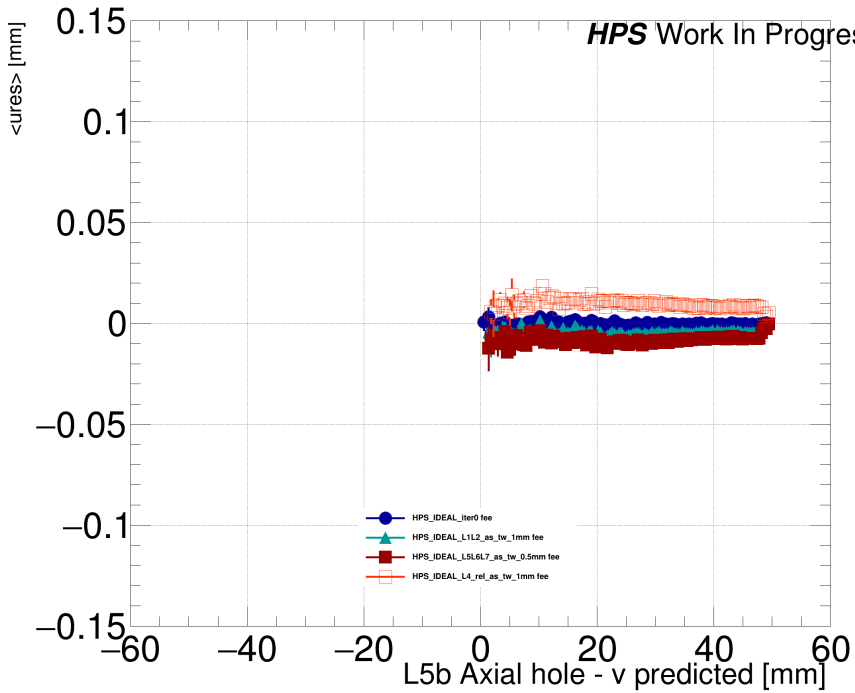
SLAC

- Step in ures vs u in L6b in data can be reproduced by increasing axial-stereo separation by
  - 1 mm in L1 and L2, or
  - 0.5 mm in L5, L6, and L7
- fee MC samples: structures more distinct, 'cleaner'
- ttb MC samples: misaligned detectors create ures vs u distribution that matches data

Bump in ures vs v distribution – fee MC



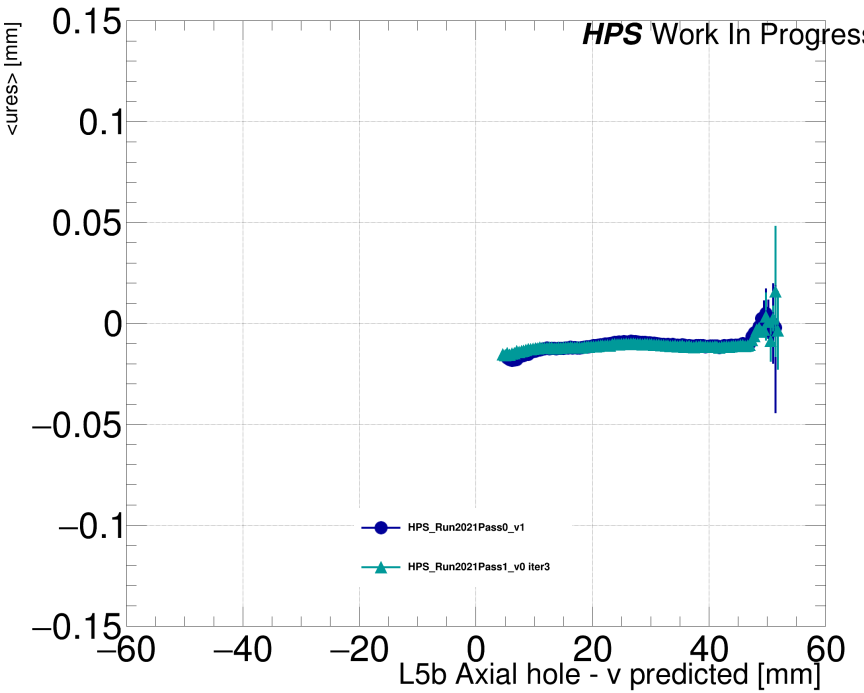
2021 data



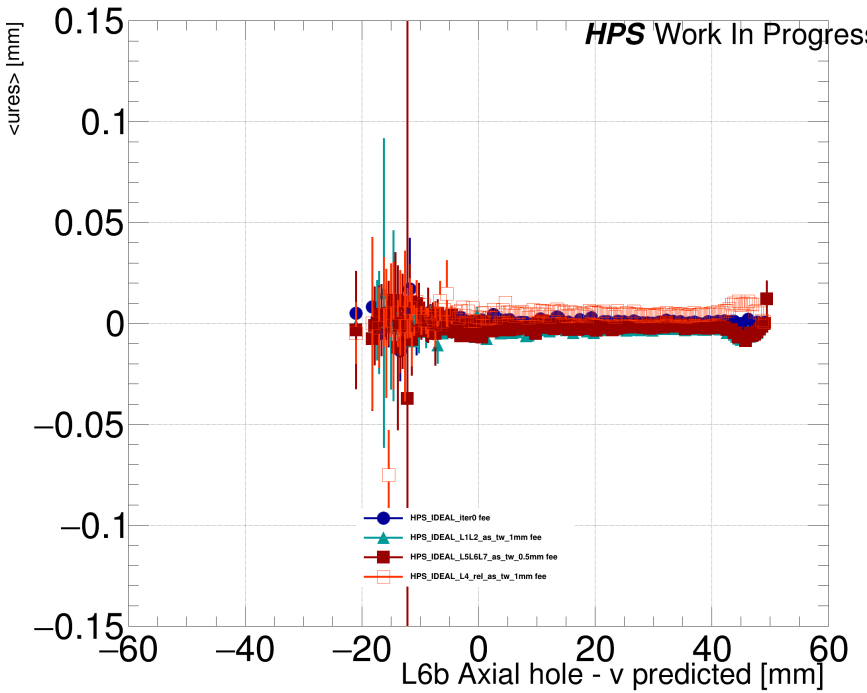
fee MC

- No bump in fee MC L5b axial hole

Bump in ures vs v distribution – fee MC



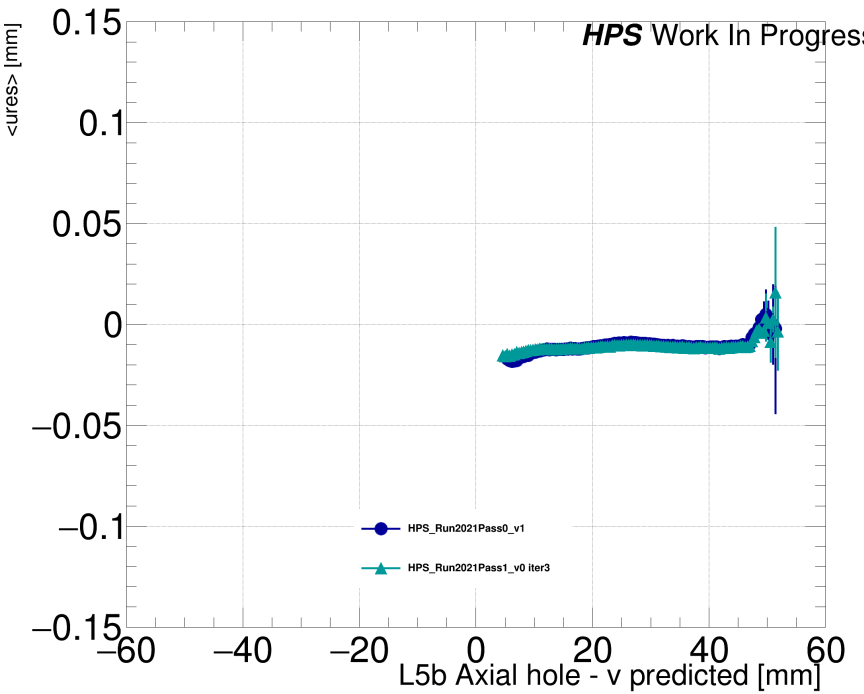
2021 data



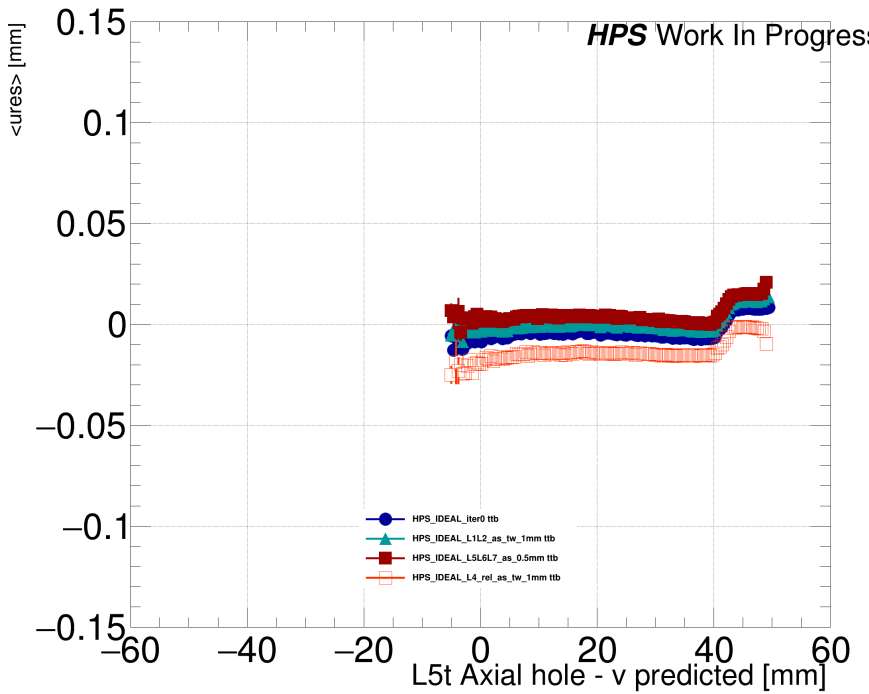
fee MC

- Bump shape in L6b axial hole for fee MC

Bump in ures vs v distribution – ttb MC



2021 data



ttb

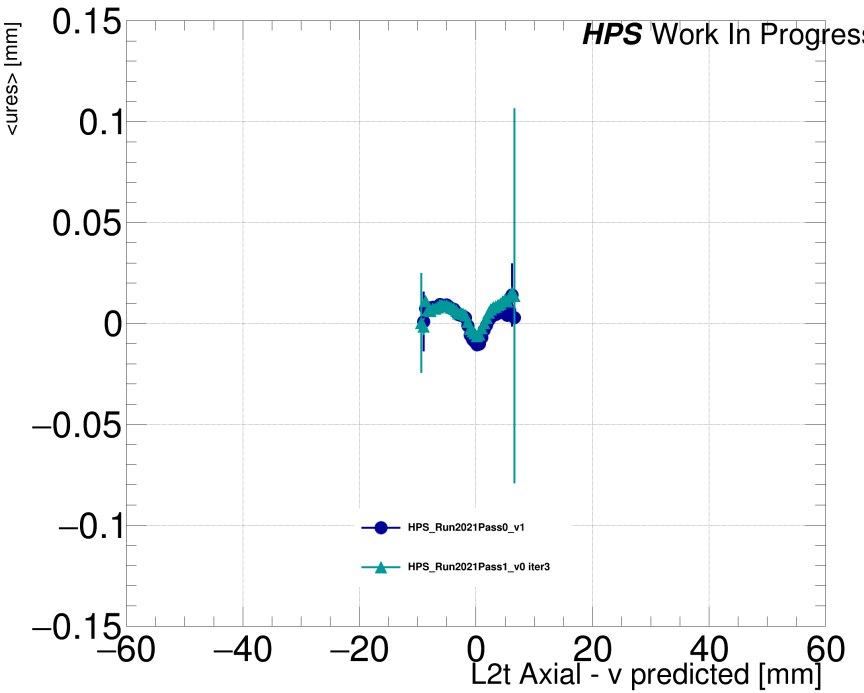
- Step/bump-like structure for ttb MC sample for all misalignments

Bump in ures vs v distribution – Summary

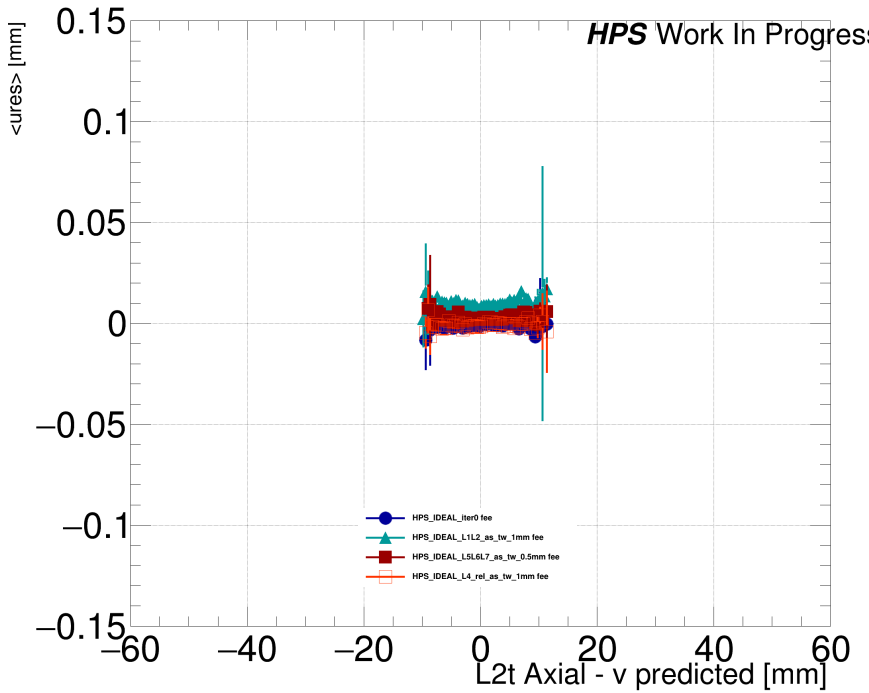
SLAC

- Hypothesis: step in ures vs u and bump in ures vs v originate from same misalignment
  - Increasing axial-stereo separation in front or back does not reproduce both shapes
  - Could be several misalignments interacting
  - Hard to test but maybe just play around with mixed misalignments?
- Hypothesis: Bump is inherent to tritrig+beam/physics samples
  - Generate 2021 ttb MC sample with 'correct' detectors and repeat study

V-shape in ures vs v distribution – data vs fee



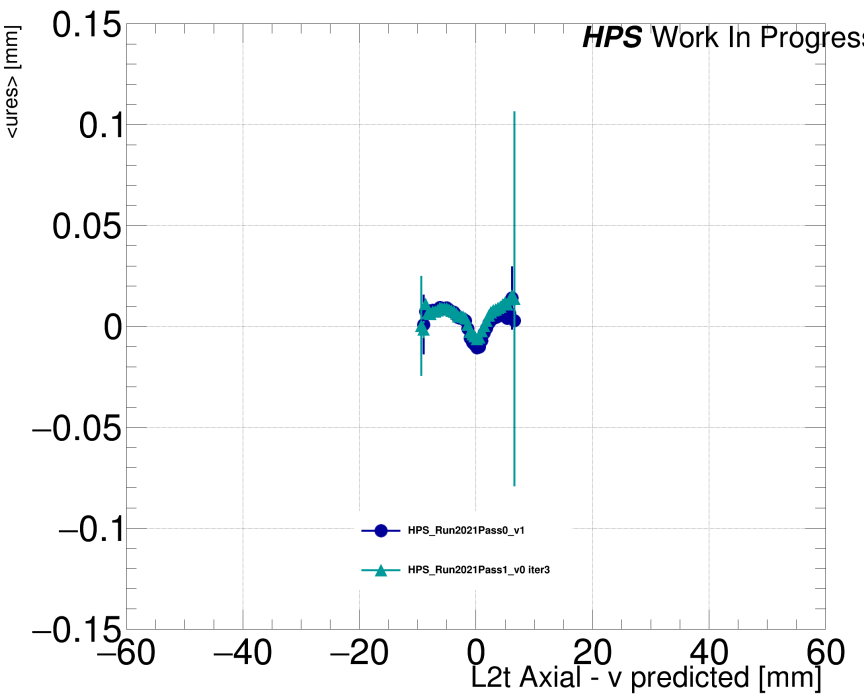
2021 data



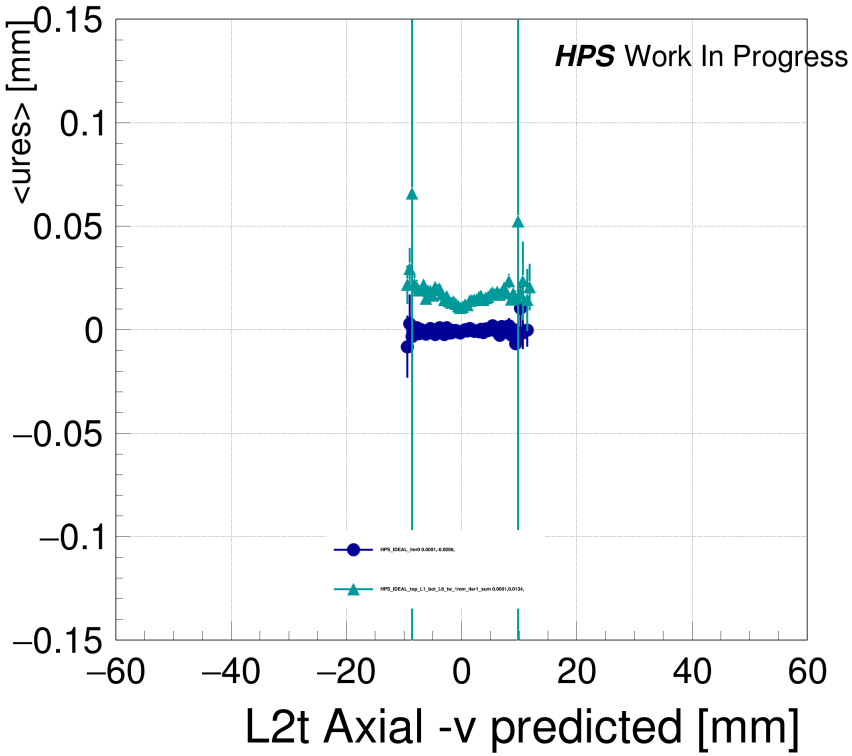
fee MC

- Very slight v-shape for +1 mm ax-st in L1+L2

V-shape in ures vs v distribution – data vs fee



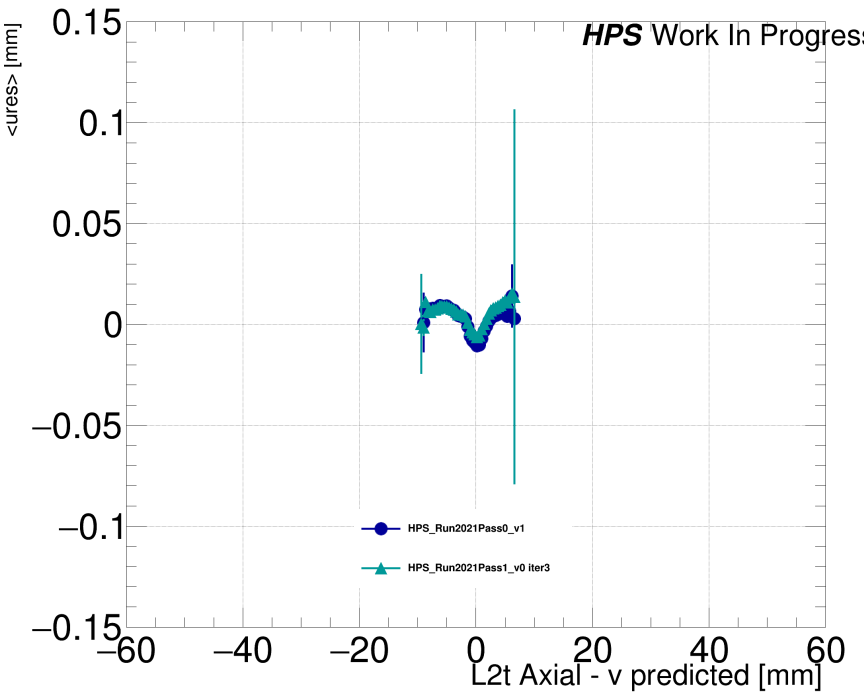
2021 data



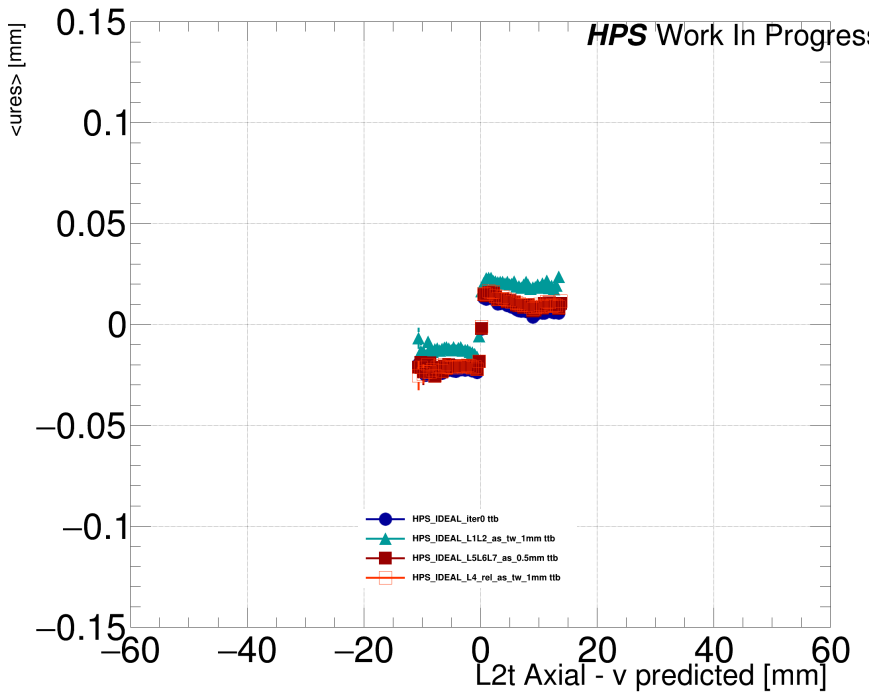
fee MC

- New sample: L1 tw by 1 mm $\rightarrow$ V-shape more visible

V-shape in ures vs v distribution – data vs ttb



2021 data



ttb MC

- Strange step in distribution → need to investigate ttb MC sample

Summary and outlook

SLAC

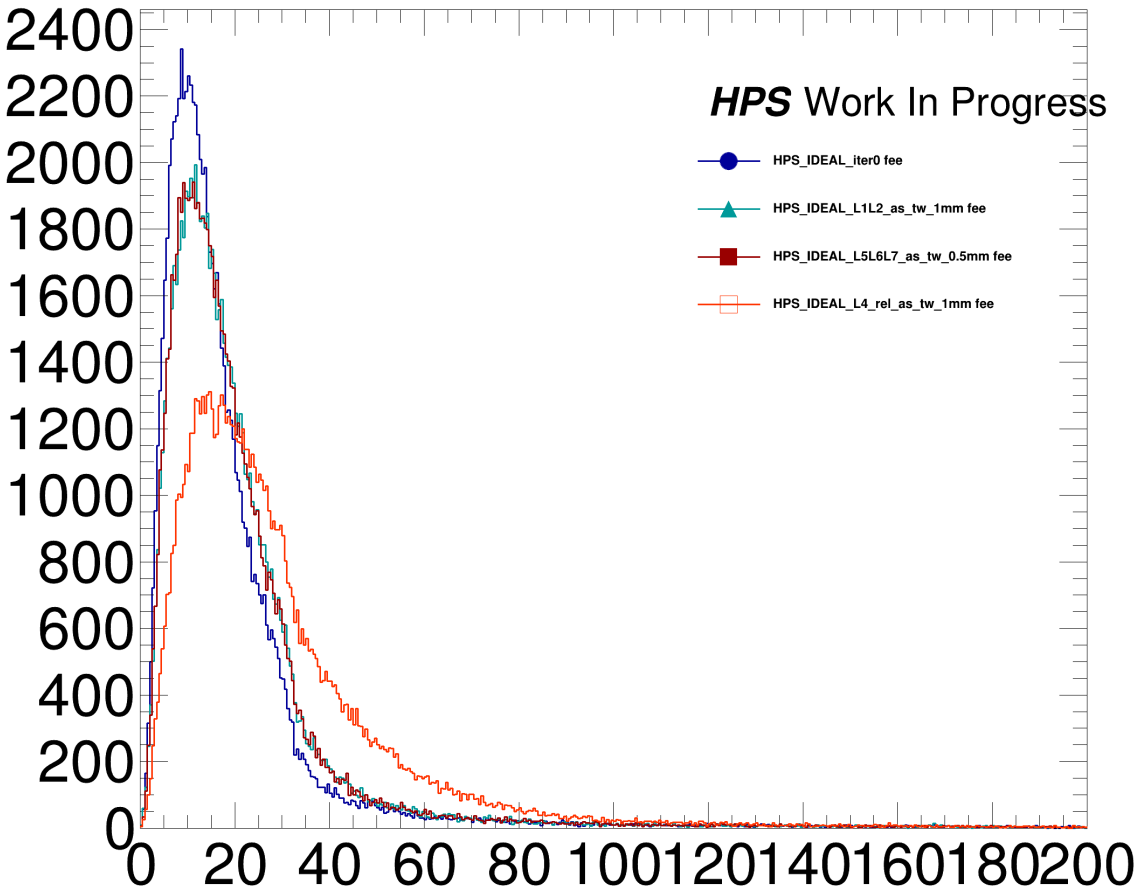
- Slope in fee p vs tan λ reproducable by $+1$ mm axial-stereo separation
  - in L1 and L2
  - in L5
- Step in ures vs u in L6b in data can be reproduced by increasing axial-stereo separation by
  - 1 mm in L1 and L2, or
  - 0.5 mm in L5, L6, and L7
  - ttb MC samples match data
- Origin of bump in L5b ures vs v 2021 data not clear yet $\rightarrow$ more tests necessary
- V-shape in ures vs v seen for
  - $+1$ mm axial-stereo separation in L1+L2
  - 1 mm tw of L1

Summary and outlook

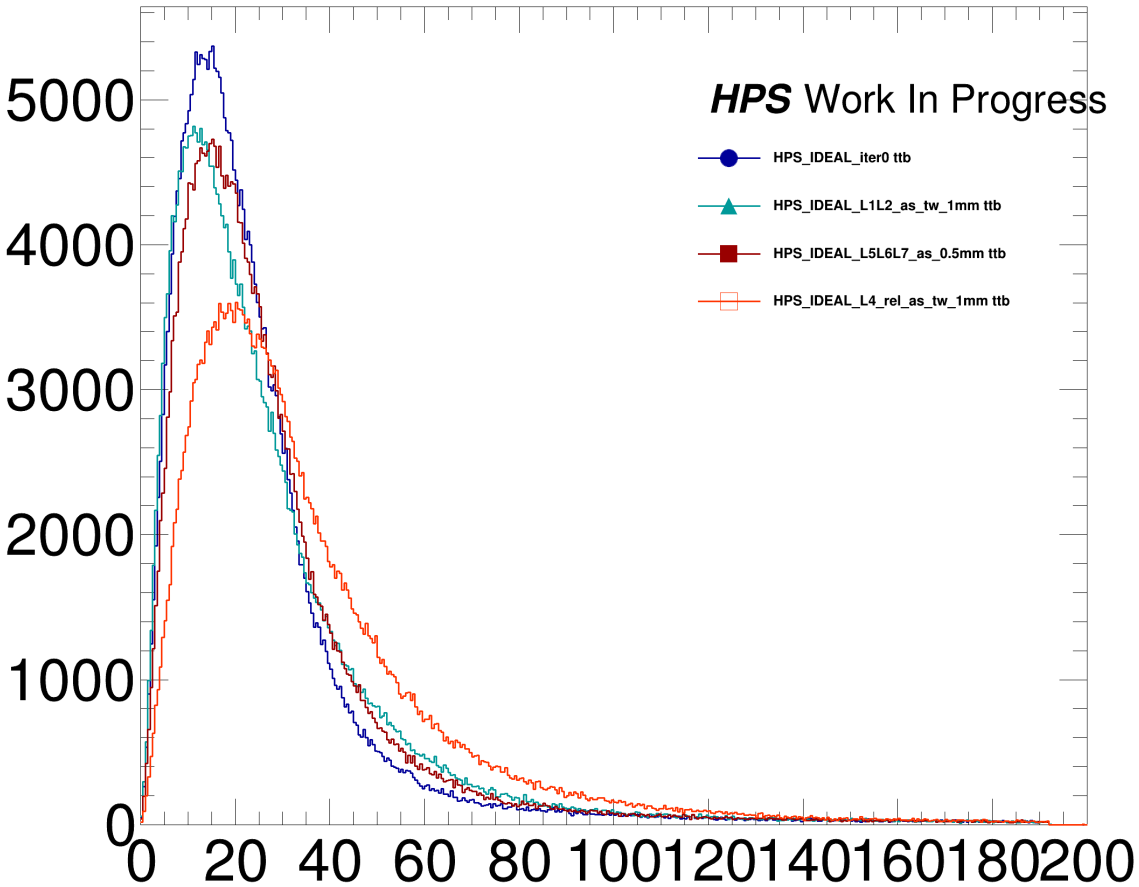
SLAC

- Need to repeat MC tritrig+beam studies
  - Fix mismatch between detector used to generate and detector used in my analysis
  - Use new sample?
  - Understand old sample?
- Possible physical reason between changed axial-stereo separation in back layers
  - Bowing of sensors away (towards) each other?
  - Mentioned by Tim/PF on Monday

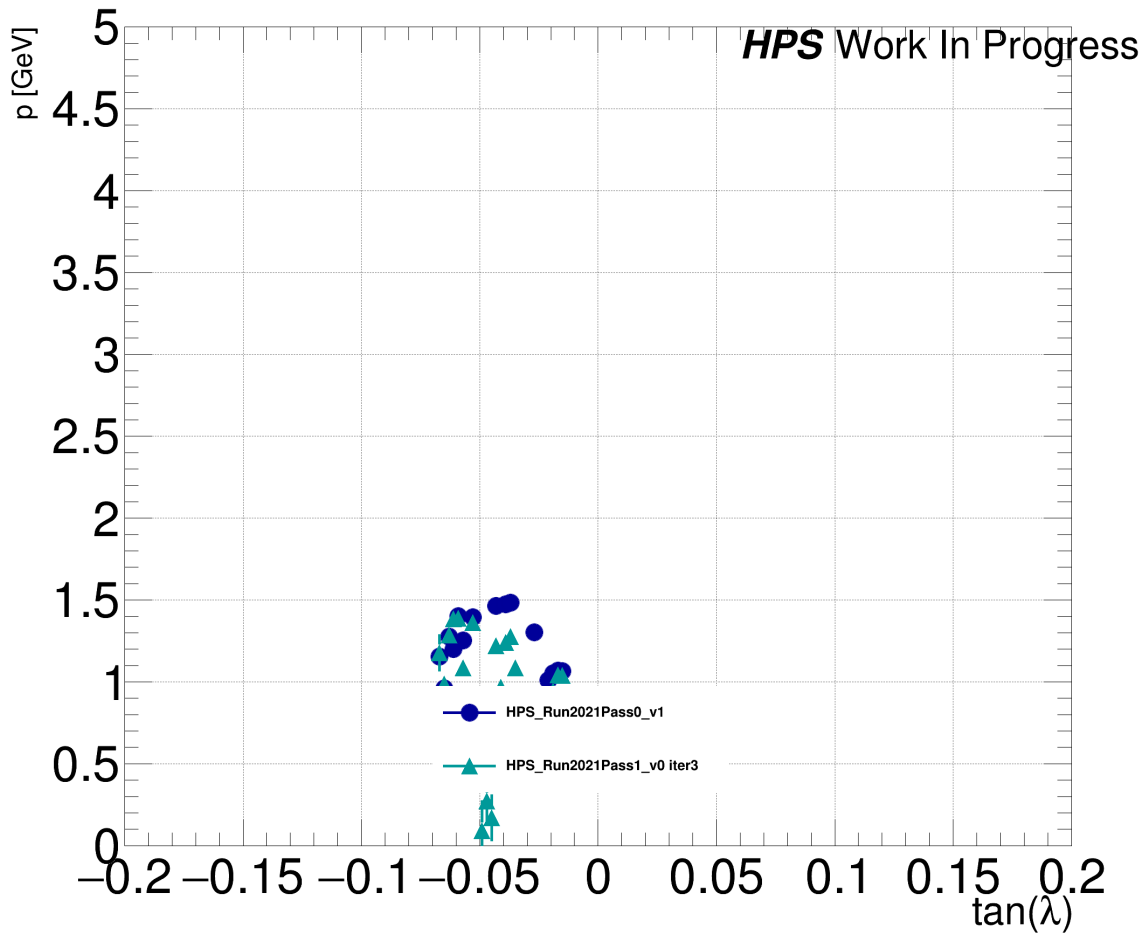
Chi2 – fee MC, top



Chi2 – ttb MC, top

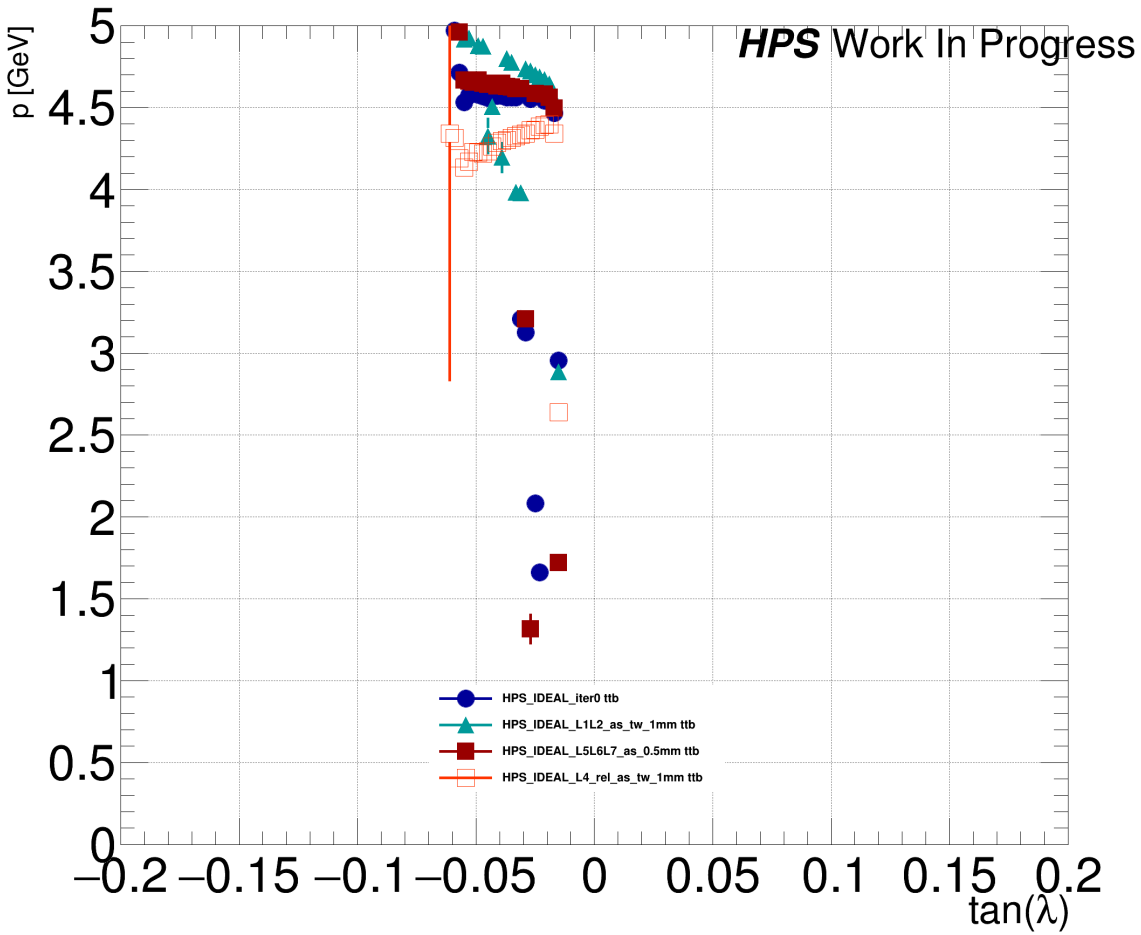


Momentum vs tanL – ttb data 2021, bottom



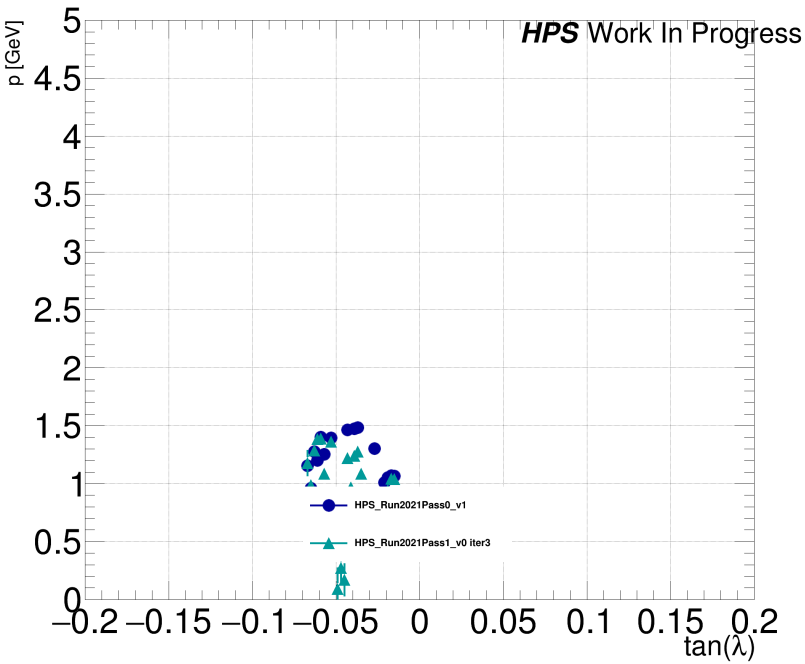
- comment

Momentum vs tanL – ttb MC, bottom

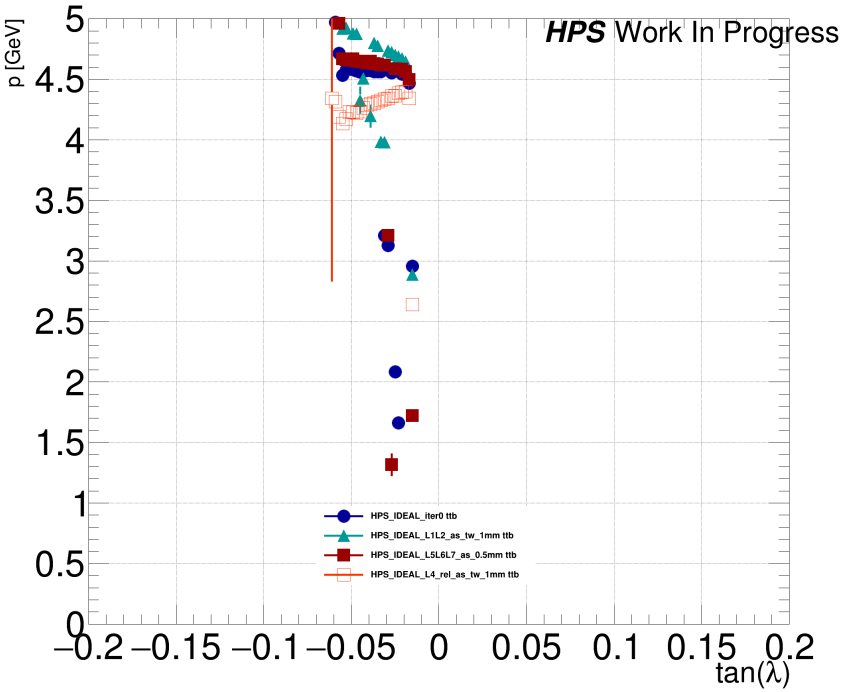


- comment

Momentum vs tanL – ttb, bottom

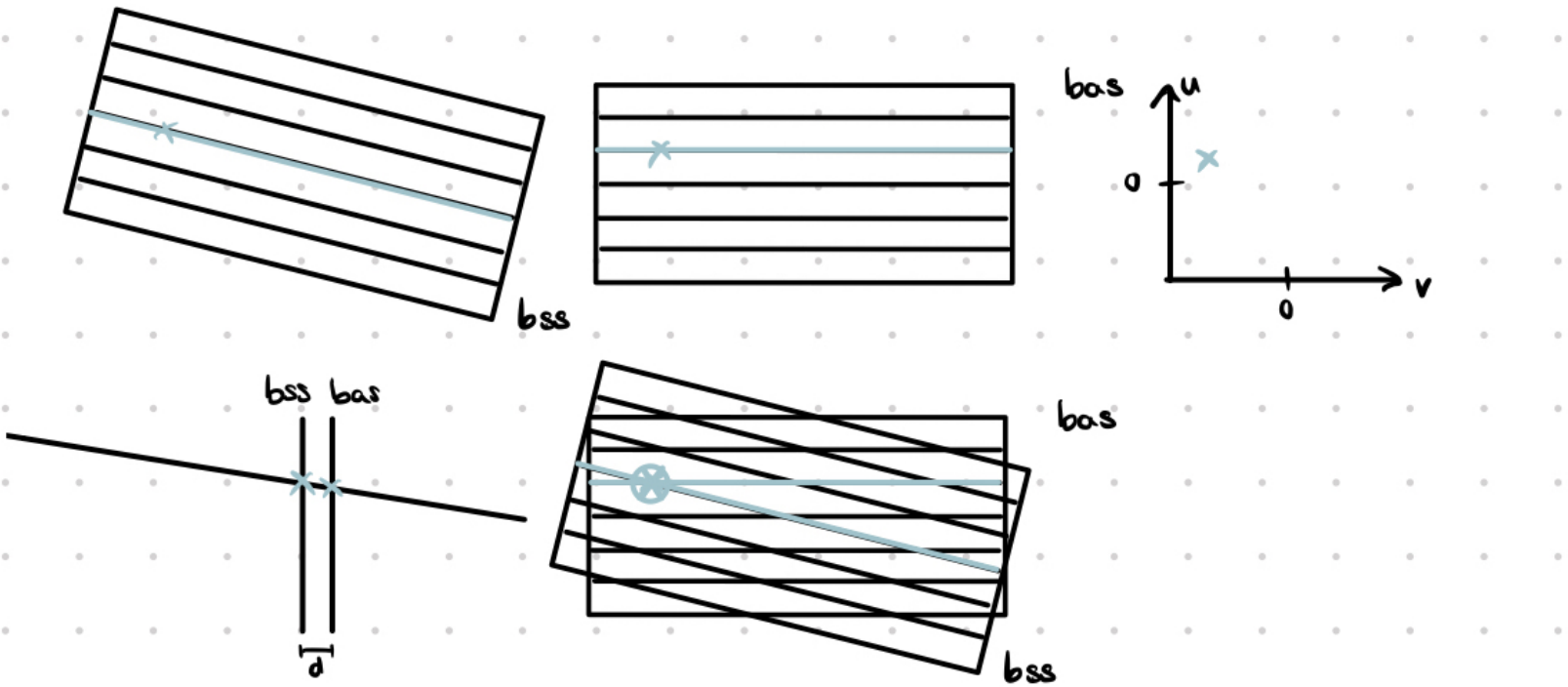


2019 ttb data



ttb MC

Geometric considerations



Geometric considerations