Qualification Task AFT 455:
Optimization of Inputs for High Level Discriminants (DL1 and MV2) to Improve Performance of B-Tagging in Heavy Ion Collisions

Xiaoning Wang

University of Illinois-Urbana Champaign

May 4, 2020

Jet Fitter Performances and Cuts

- Tested cuts:
  - Min pT on track selection (0.5 GeV, 1.0 GeV, 1.5 GeV, 2.0 GeV, 4.0 GeV)
  - Fixed cone track association
  - Removal of cuts associated with pile up tracks (graphs not shown here)
- Performance measurements
  - Efficiency vs Pt plots
  - Integrated efficiency vs fake rate
  - Integrated efficiency vs purity
    - Purity: fraction of tracks associated with JetFitter vertices that originate from B or D decay.
  - Source of tracks plots
    - Found differences between what Dominik saw in his study.. looking for the cause.
- Missing: cuts applied to jets used and track used
  - There's a difference between what I used and Domink had, looking at why.

Default JetFitter Results and Fixed Cone Results

Default Cuts

Integrated Efficiency (pT >20 GeV)	0-20%	20-50%	50-80%	pp
B-jet	0.939	0.901	0.844	0.865
C-jet	0.708	0.553	0.519	0.496
Light-jet (fake)	0.645	0.409	0.152	0.165

Fixed Cone at 0.4

Integrated Efficiency (pT >20 GeV)	0-20%	20-50%	50-80%	pp
B-jet	0.954	0.907	0.860	0.872
C-jet	0.716	0.579	0.507	0.507
Light-jet (fake)	0.723	0.468	0.160	0.174

Performance Paper results:

|	JF Vertices All
b-jets	0.893
c-jets	0.556
light jets	0.234

Effects of Min pT Cuts using Fixed Cone

Fraction vs Fake Rate for JF Vertexing
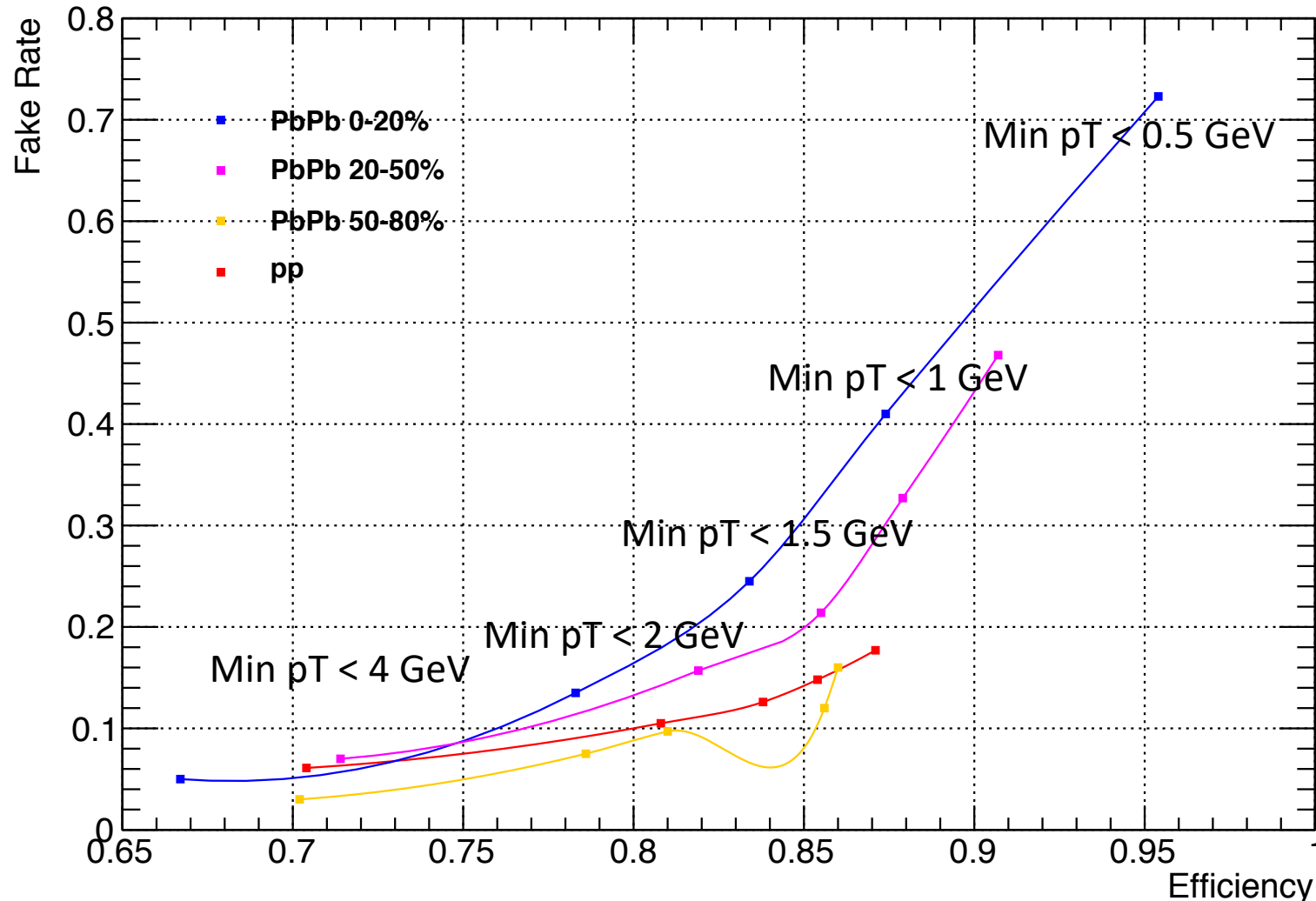
- Shown curve is not fitted, just to show general trend.
  - Fluctuation in 50~80% is probably due to statistics. (see back up efficiency vs pT plots)
- Central events' fake rate is greatly affected by minimum pT cut in selecting first set of tracks.
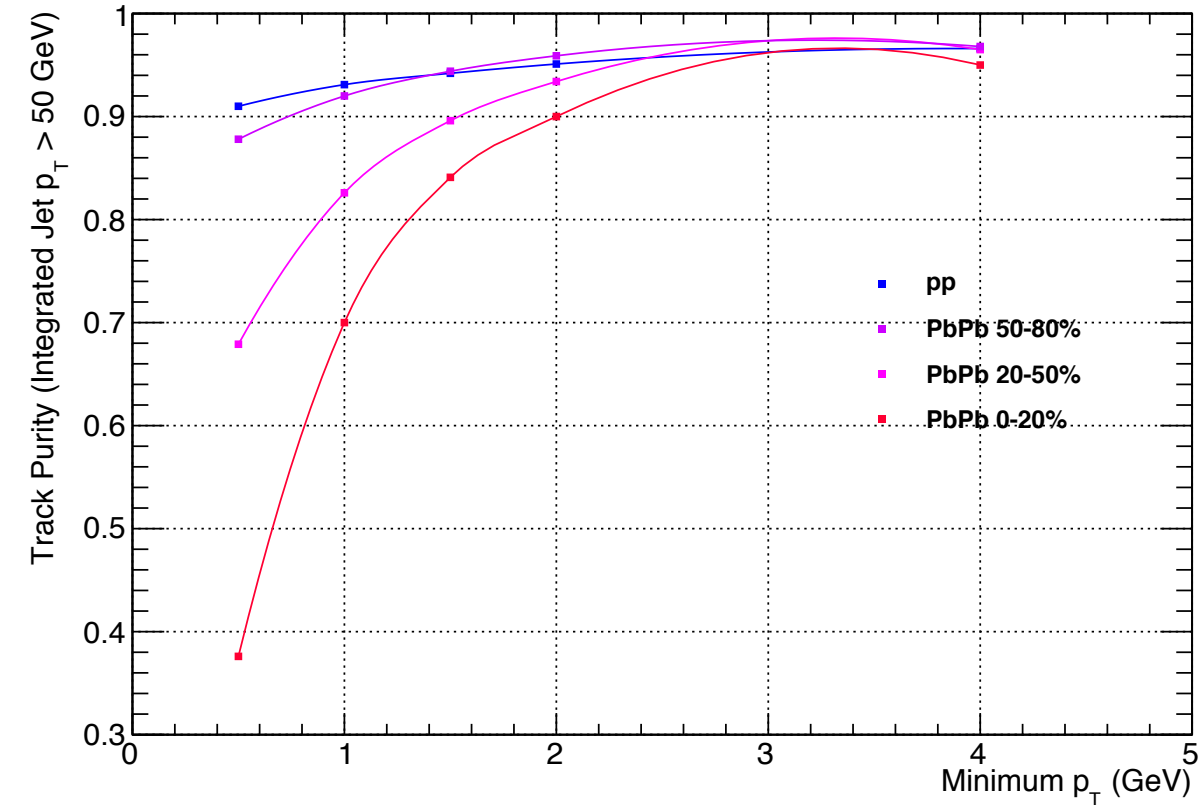- Central events start to have closer performance with peripheral and pp at ~ 1.5 to 2.0 GeV
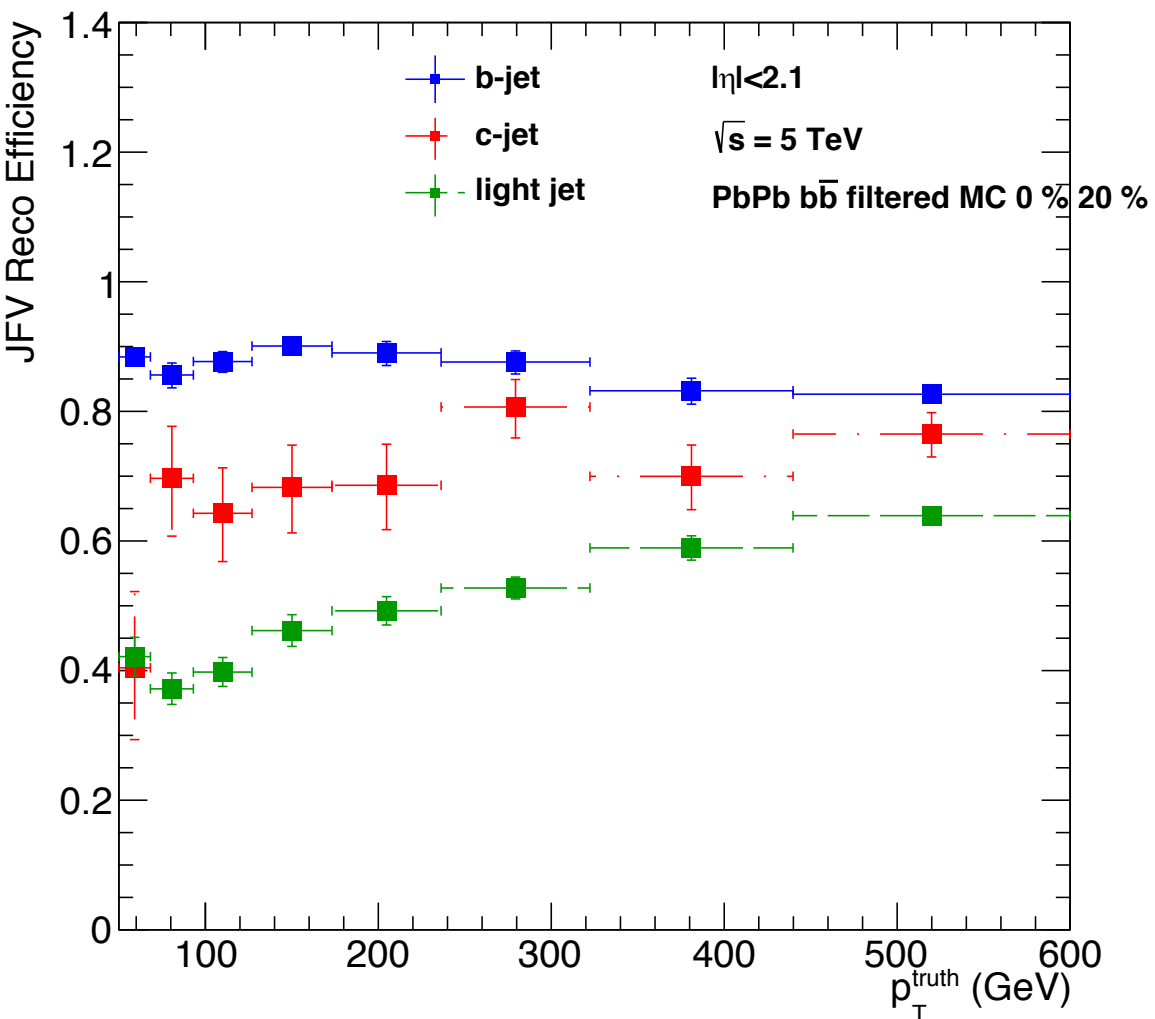
0.5 GeV   4.0 GeV
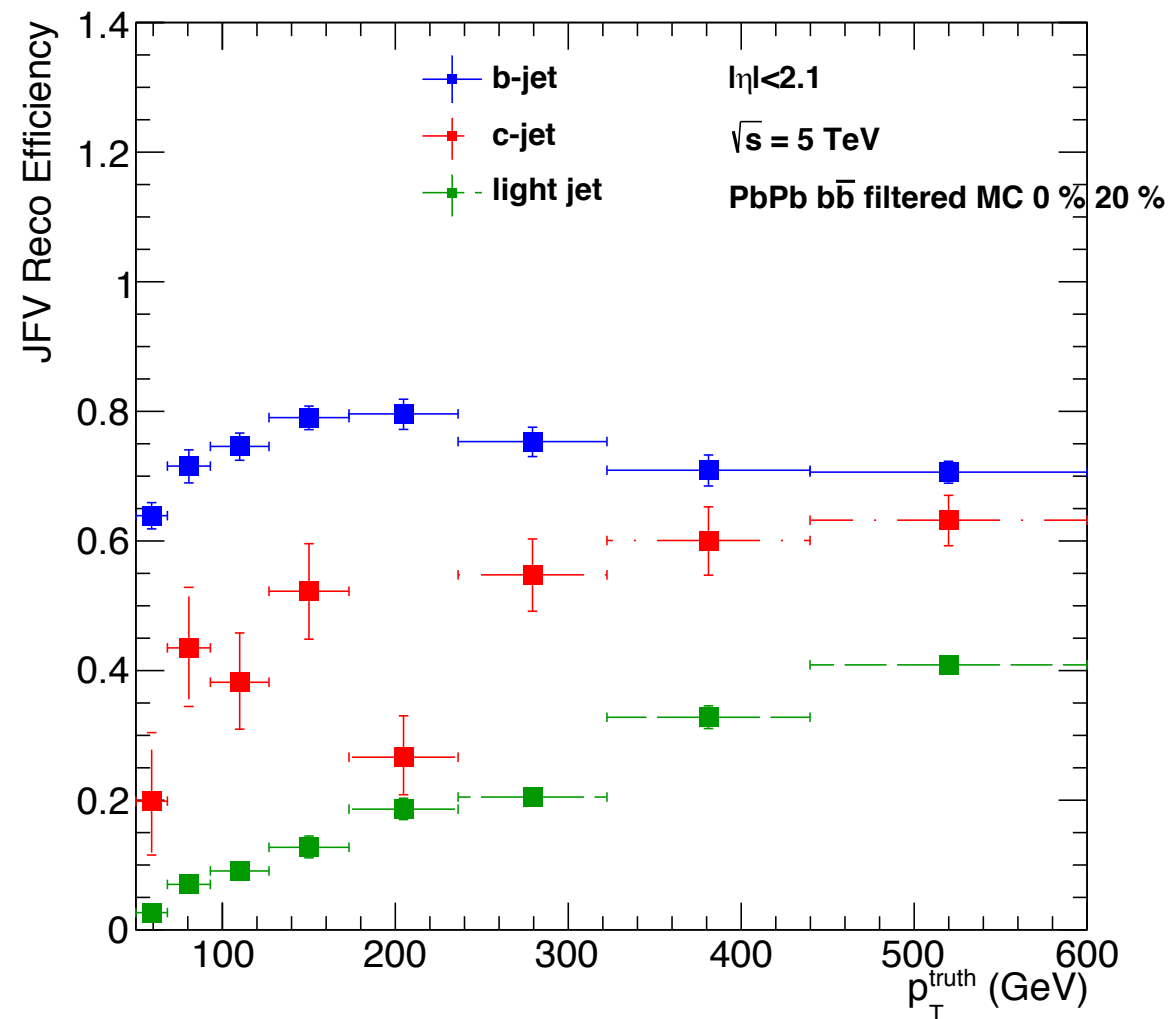
- Effect of minimum pT cut is more obvious in low pT jets (50-100 GeV)
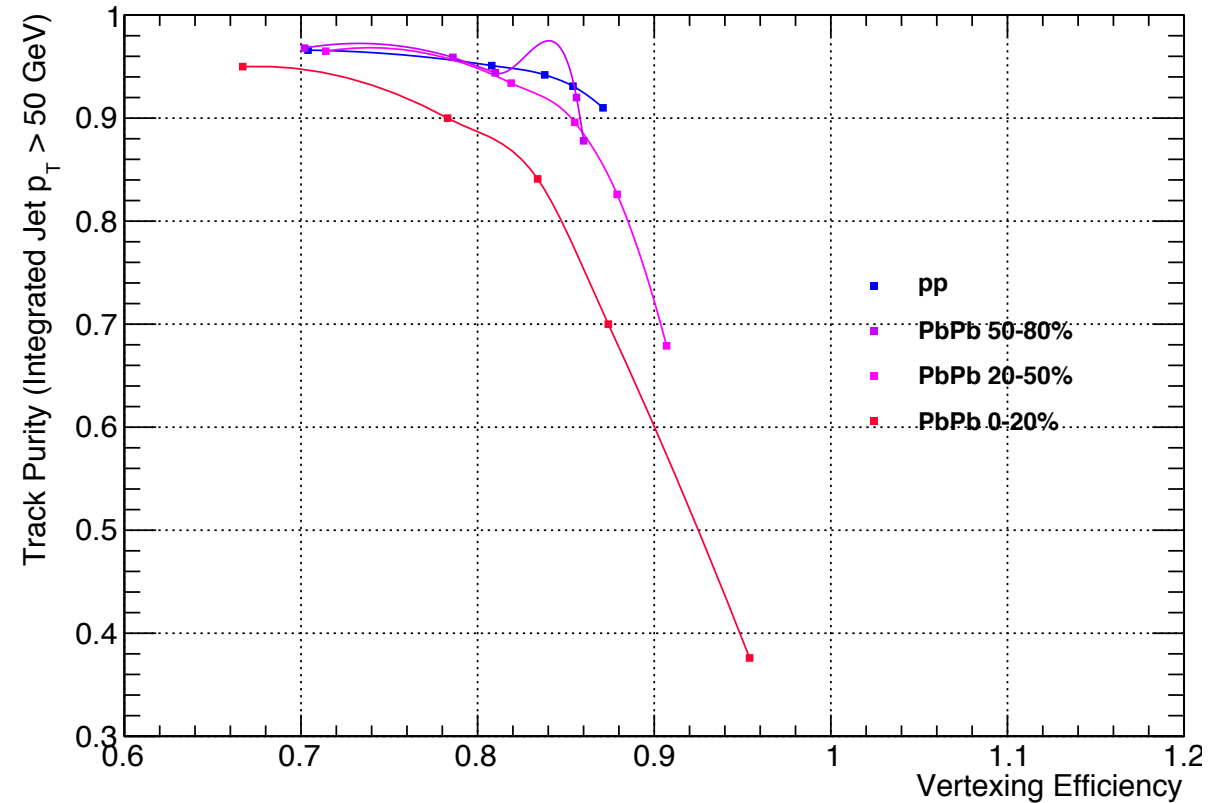- Other parts of curve shape does not change.

Track Purity as a function of min pT

Track Purity vs min pT for JF Vertexing
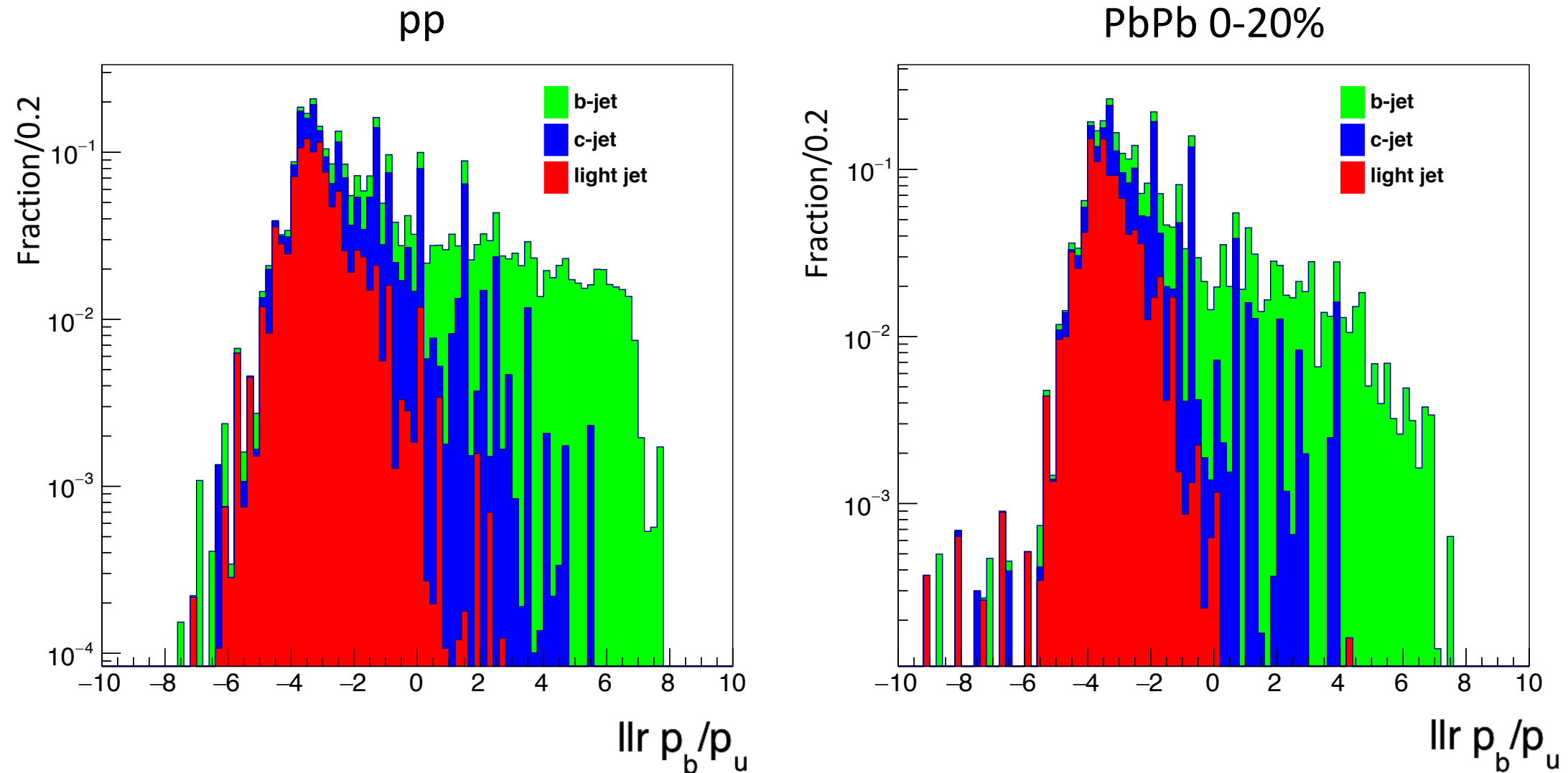

Track Purity vs Efficiency for JF Vertexing

Centrality dependence decreases as min pT is increased, as expected.

Points from right to left corresponds to small min pT requirement to larger min pT requirement.

JetFitter Tagging Performance

pp

PbPb 0-20%

- B-jet distribution are more toward left in central events in comparison to pp, which would hurt tagging efficiency/fake rate.
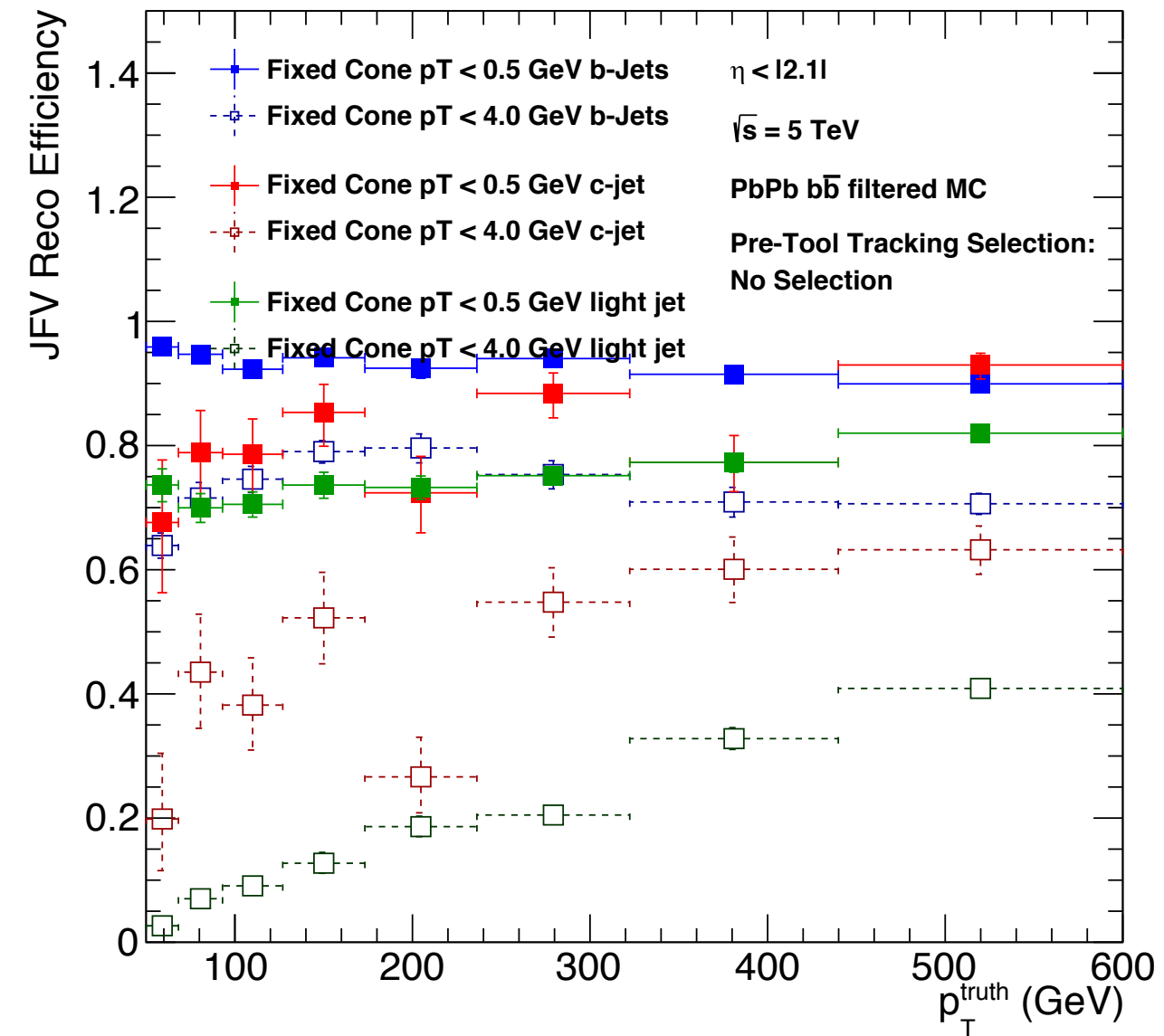- How should we quantitatively make use of these?

Summary

- Modifications to the tracking selections in JetFitter Alogrithms are looked at to see the effect of performance on secondary vertexing.
    - Remove anti-pile up tool doesn't create much difference.
    - Applying fixed cone method introduced fake rate into central events, but with increased minimum pT cut, central events can reach a good efficiency/fake rate.
- Tagging performance are qualitatively looked at
    - Will look into quantitative comparison.
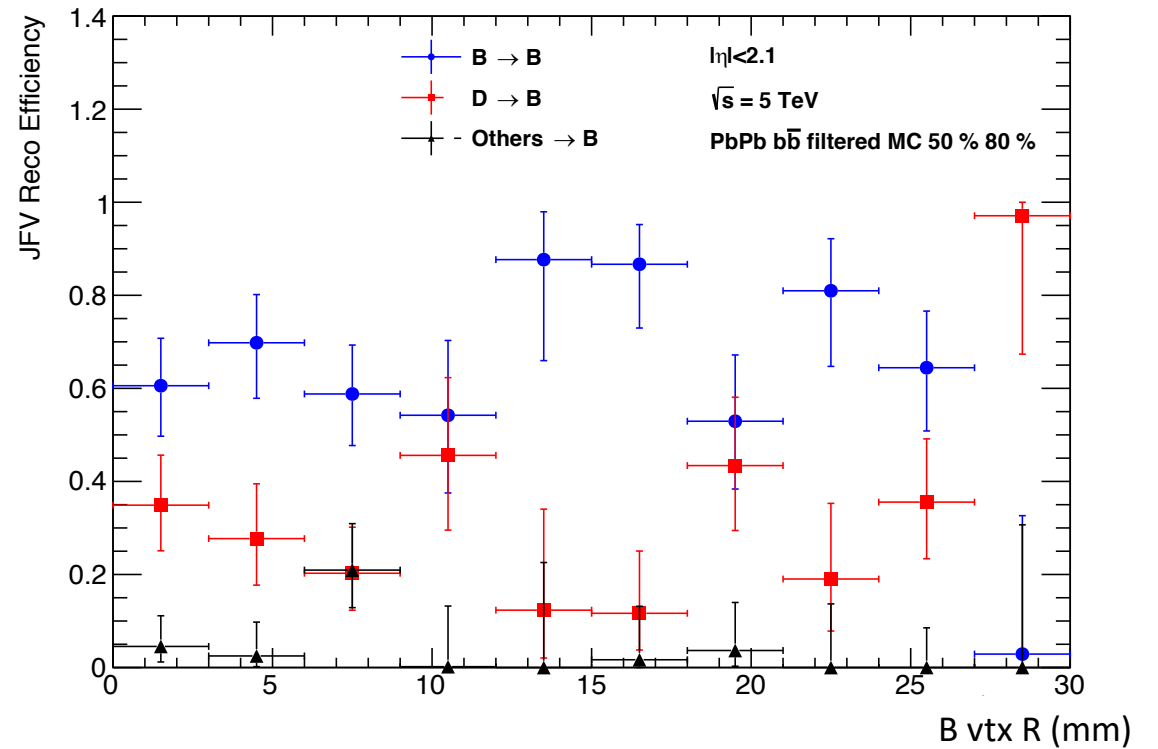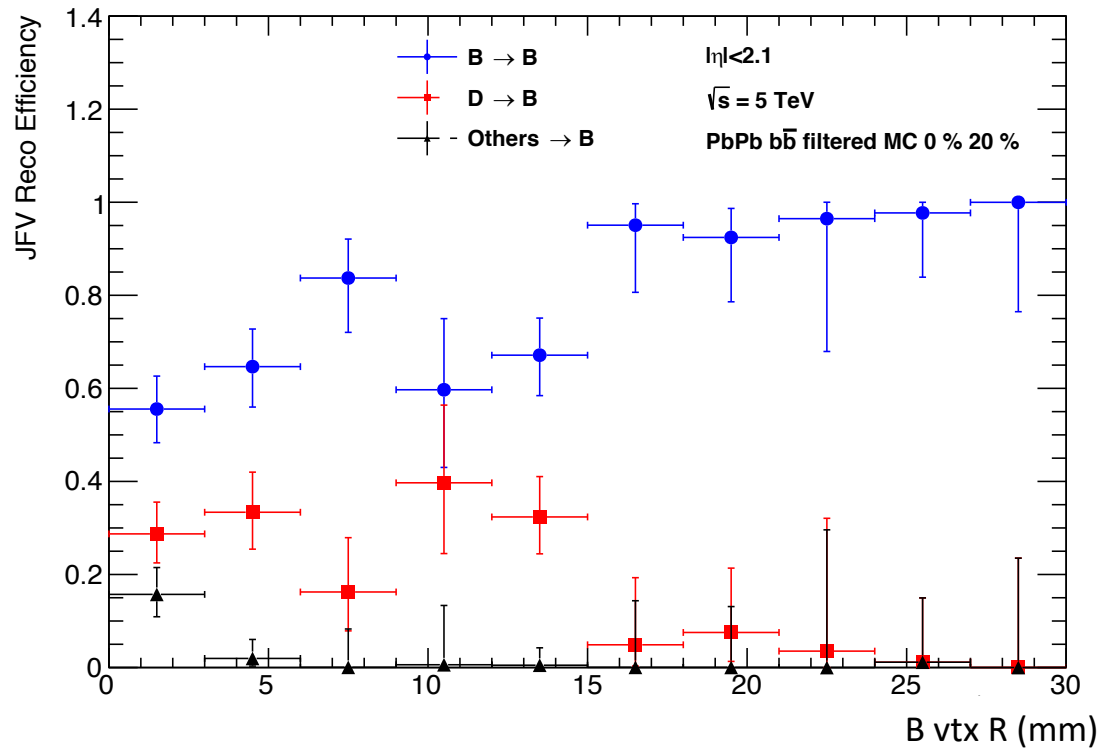- Migrate to use inclusive dijet samples.

Back-Up

Track Purity Plot

JFV Reco Efficiency for Different Flavors of Jets in

- Fixed Cone pT < 0.5 GeV b-Jets
- Fixed Cone pT < 4.0 GeV b-Jets
- Fixed Cone pT < 0.5 GeV c-jet
- Fixed Cone pT < 4.0 GeV c-jet
- Fixed Cone pT < 0.5 GeV light jet
- Fixed Cone pT < 4.0 GeV light jet

$\eta < |2.1|$

$\sqrt{s} = 5$ TeV

PbPb $b\bar{b}$ filtered MC

Pre-Tool Tracking Selection:
No Selection

JFV Reco Efficiency

p_T^{truth} (GeV)

Track purity Plots

Pp integrated purity: 0.903
PbPb 0-20%: ~0.371 (seems really wrong...)

- B-Tagging Optimization
  - Running data on changing min pT Cuts (for both "high quality first selection" and "low quality second selection")
  - Implementing number of tracks from B/D/Fragmentation plots.
- Overlay Geometry
  - Made histograms of x, y, z shifts from different parts of inner detector.
  - Plot for other parts? Plot angles?

Effect of Anti Pile-up Track Selection Removal
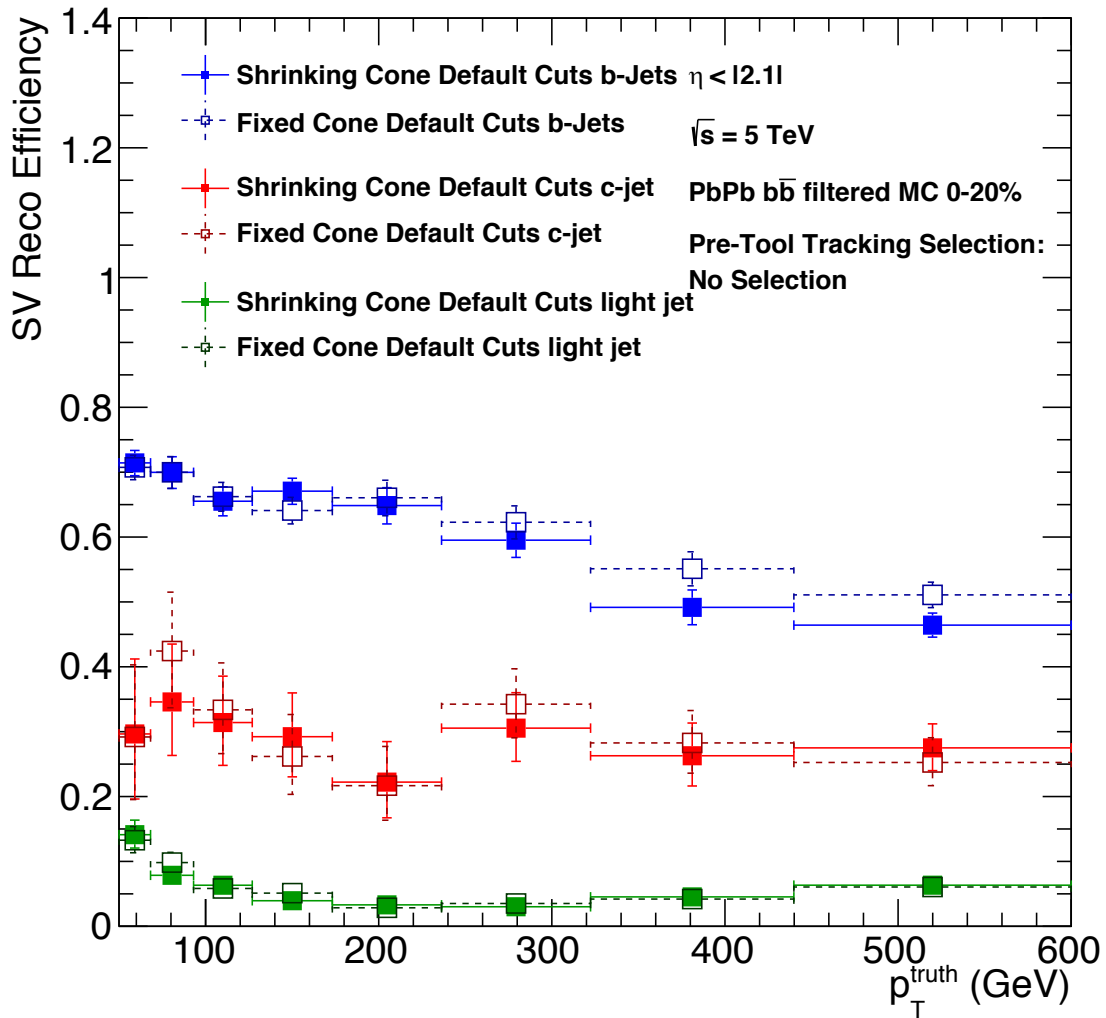
Effects of Cuts on Overlay

- Cuts those are effective in improving efficiency at pp MC were used in overlay.

- Fixed Cone: Using Fixed cone at 0.4 for tracks to jet association in contrast to shrinking cone algorithm optimized for pp.

- Minimum pT fraction: (wrong understanding previously)
  - 2-trk vertices candidates are created.
  - For tracks those are not in the candidates' tracks, if they pass minfraction*jet_Pt, then the common fitting algorithm will also use them.
  - Correction: minimum fraction of Pt used to select tracks used to form 2-trk vertices; misunderstood one of the selections last time (see back-up).

- Anti Pile Up tool:
  - Remove tracks with small xy impact parameter and big z impact parameter those are presumably from pileup.

- IP Selection:
  - Maximum xy-plane and z-plane impact parameter selections.

- This week:
  - looked at comparison with pp with SVF
  - A first look at JetFitter efficiency

- Things to look at :
  - Min number of shared hits. (the algorithm seems to not be using it? But there is an effect…)
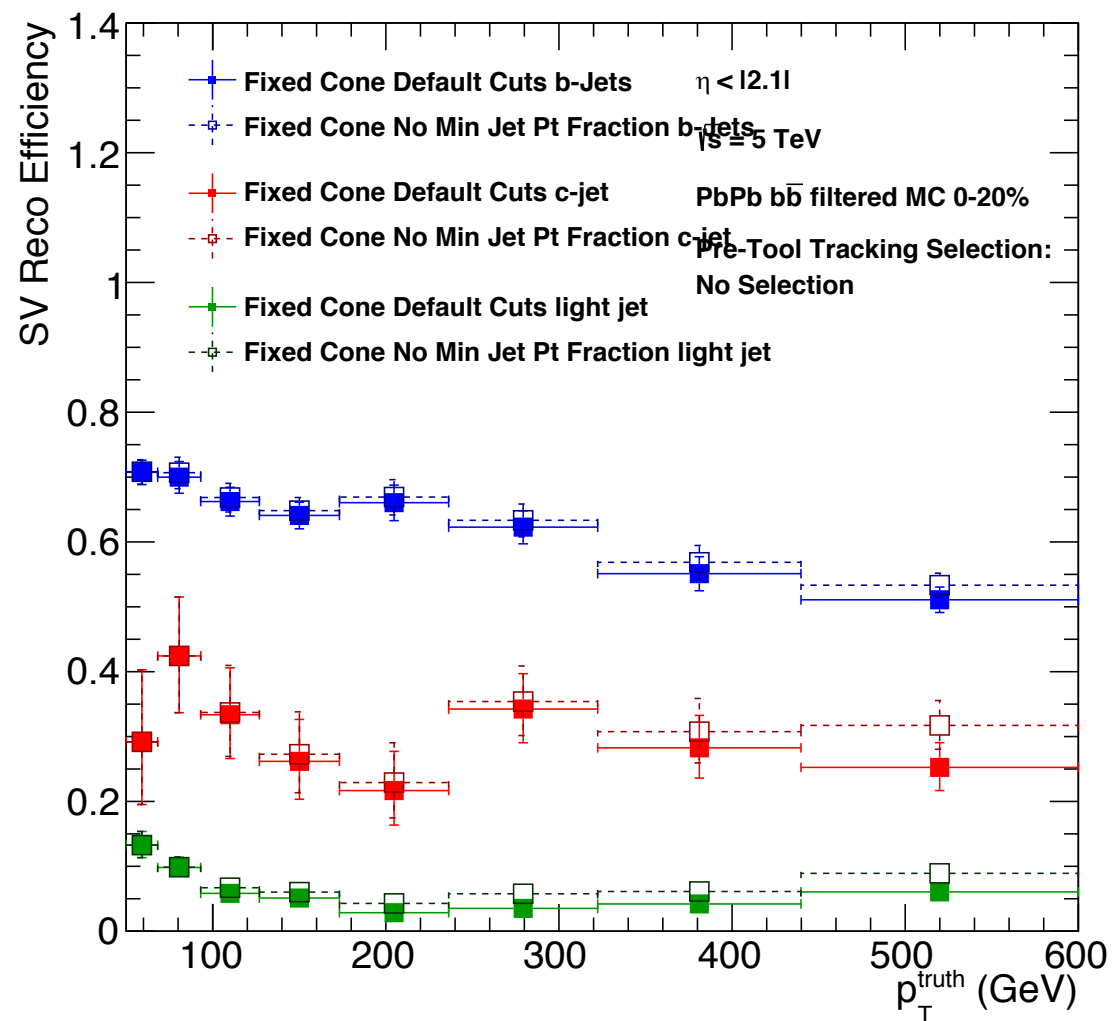
Summary of Effects of Cuts on Overlay (0-20%)

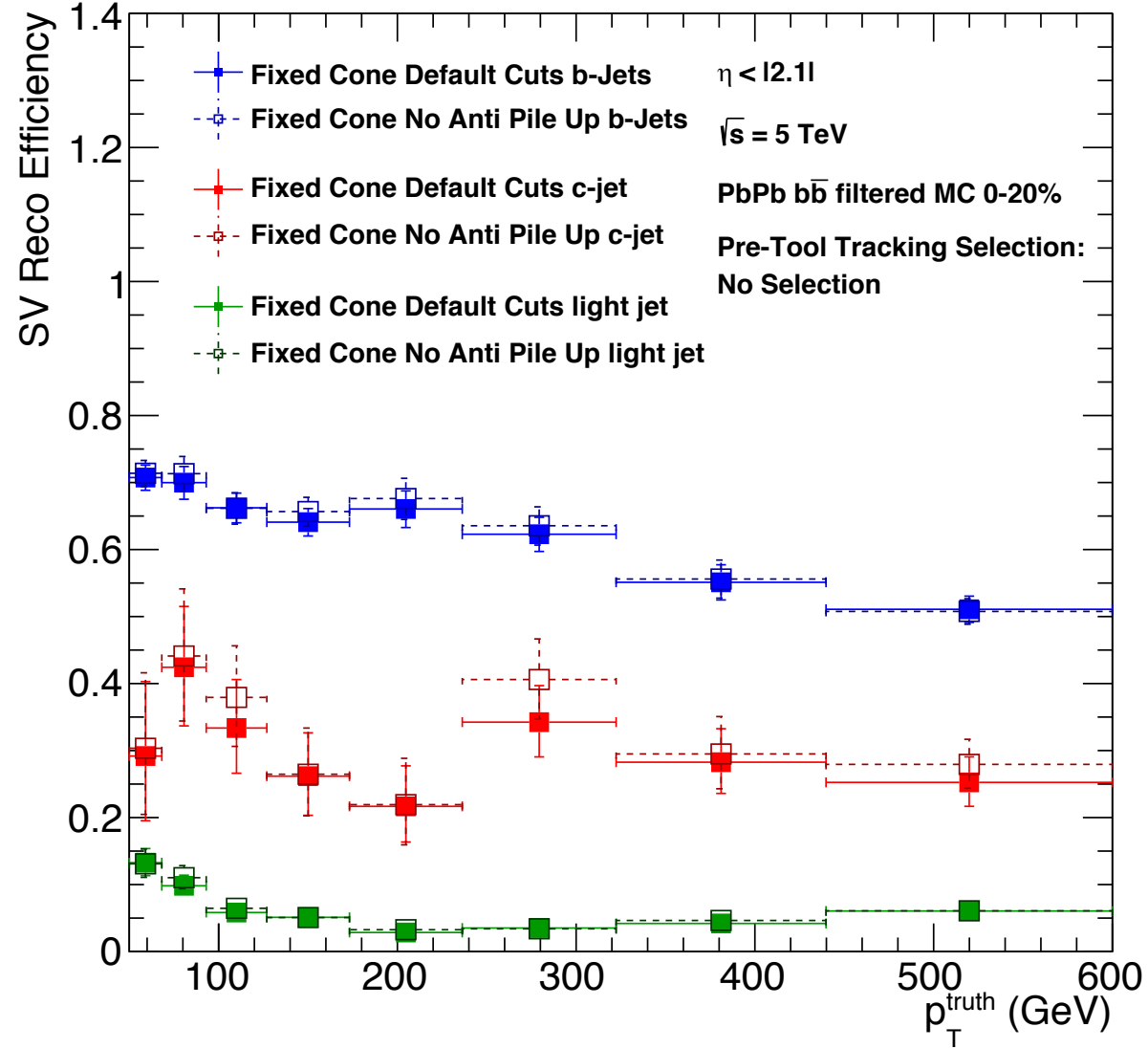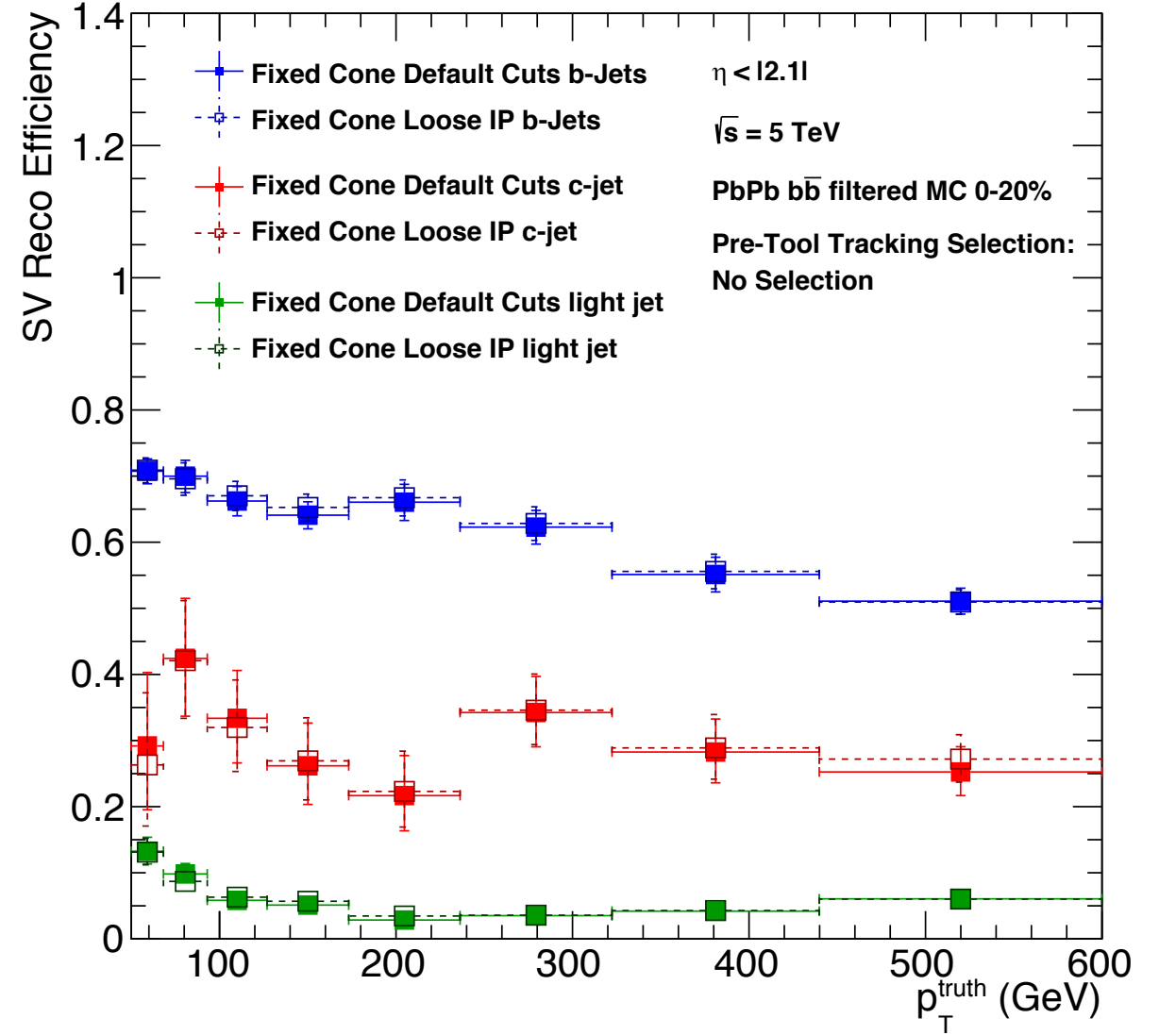| Cuts (original) (New)	Efficiency	Purity	Comment	Action
Fixed Cone (0.4)	+(~5%) at high pT	No change	Safer to use for HI jets	Keep using
Min pT Fraction(0.01) (0.00)	+(~2%) at high pT b +(~3%) at high pT c	+(~3%) fake ☹		Do not change
Anti Pile Up tool (On) (Off)	+(~2%) at high pT c	No change	Does it make sense to use in HI?	Keep using
IP Selection(On) (Off)	No significant Effect	No change		Do not change

SV Reco Efficiency for Different Flavors of Jets in PbPb 0-20%

SV Reco Efficiency for Different Flavors of Jets in PbPb 0-20%

Left plot legend:
- Shrinking Cone Default Cuts b-Jets
- Fixed Cone Default Cuts b-Jets
- Shrinking Cone Default Cuts c-jet
- Fixed Cone Default Cuts c-jet
- Shrinking Cone Default Cuts light jet
- Fixed Cone Default Cuts light jet

$\eta < |2.1|$

$\sqrt{s} = 5$ TeV

PbPb $b\bar{b}$ filtered MC 0-20%

Pre-Tool Tracking Selection:
No Selection

Right plot legend:
- Fixed Cone Default Cuts b-Jets
- Fixed Cone No Min Jet Pt Fraction b-jets
- Fixed Cone Default Cuts c-jet
- Fixed Cone No Min Jet Pt Fraction c-jet
- Fixed Cone Default Cuts light jet
- Fixed Cone No Min Jet Pt Fraction light jet

$\eta < |2.1|$

$\sqrt{s} = 5$ TeV

PbPb $b\bar{b}$ filtered MC 0-20%

Pre-Tool Tracking Selection:
No Selection

Axis labels: SV Reco Efficiency; p_T^{truth} (GeV)

SV Reco Efficiency for Different Flavors of Jets in PbPb 0-20%

SV Reco Efficiency for Different Flavors of Jets in PbPb 0-20%

18

Comparison to pp

- Most of the points follow the trend (worse in central, similar to pp in peripheral)
- Due to limit in statistics, not clear.
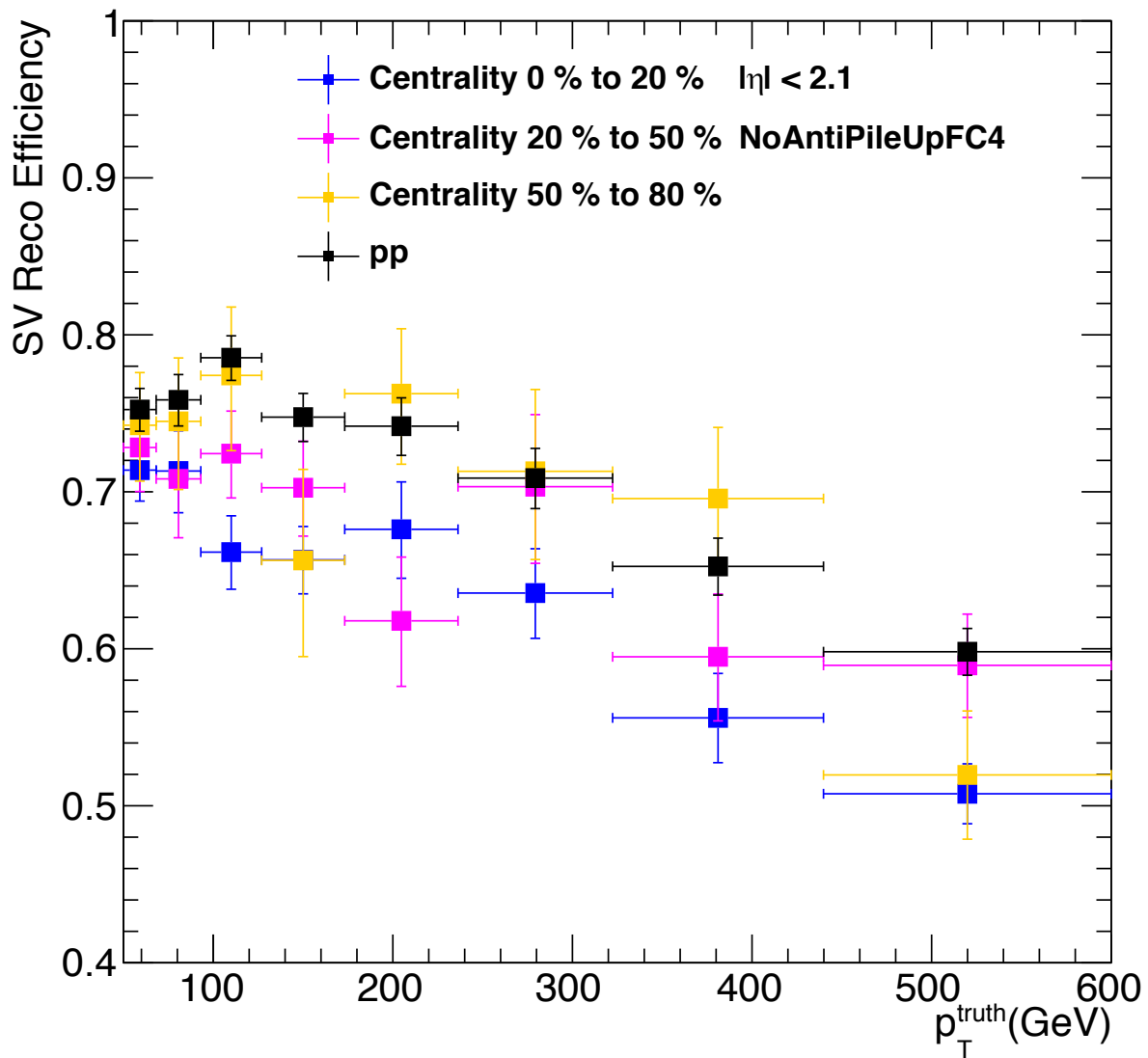- Will try change binning so lower pT range is clear.

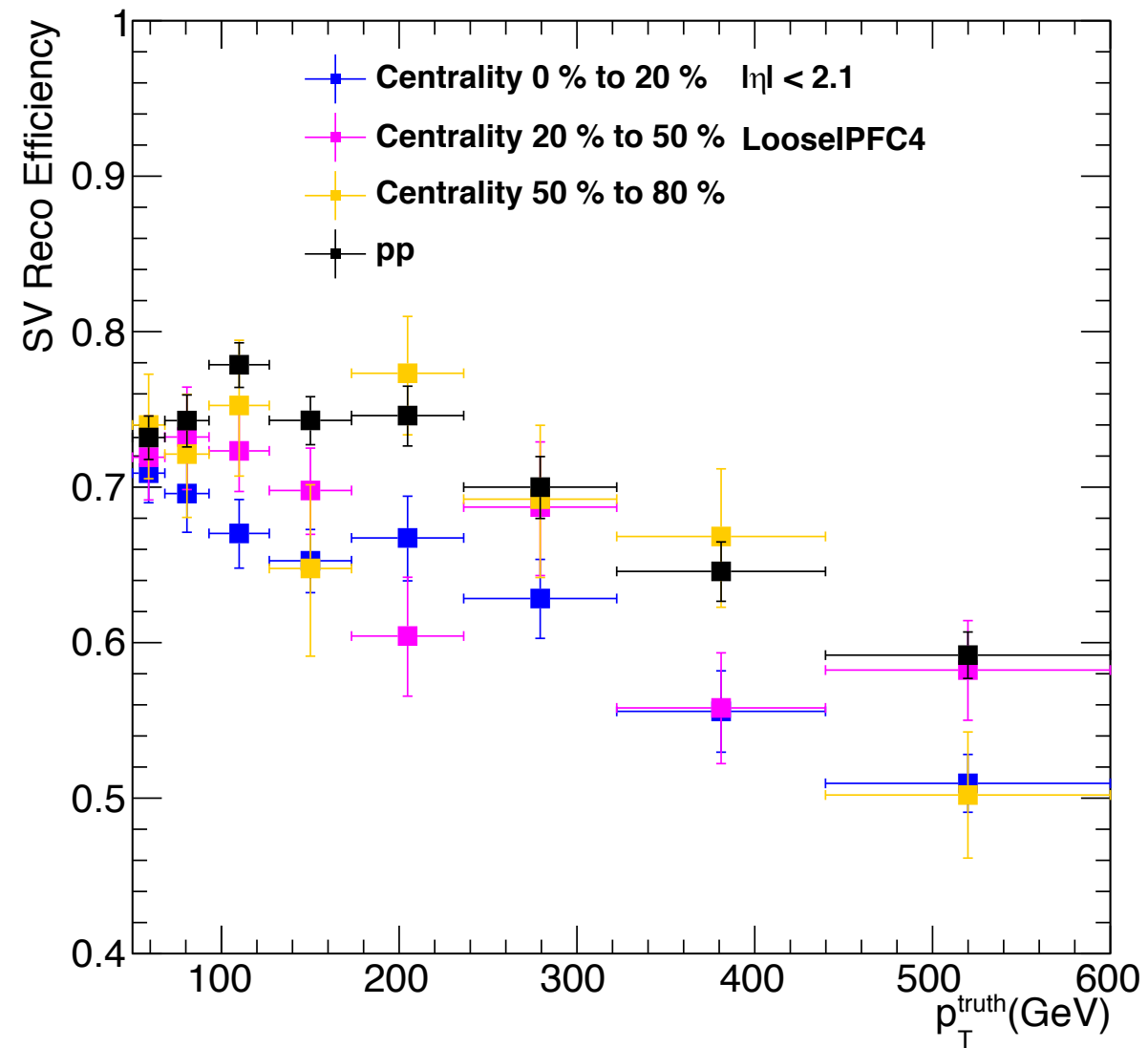SV Reconstruction Efficiency in b-jet with SV1 Tagger in MC
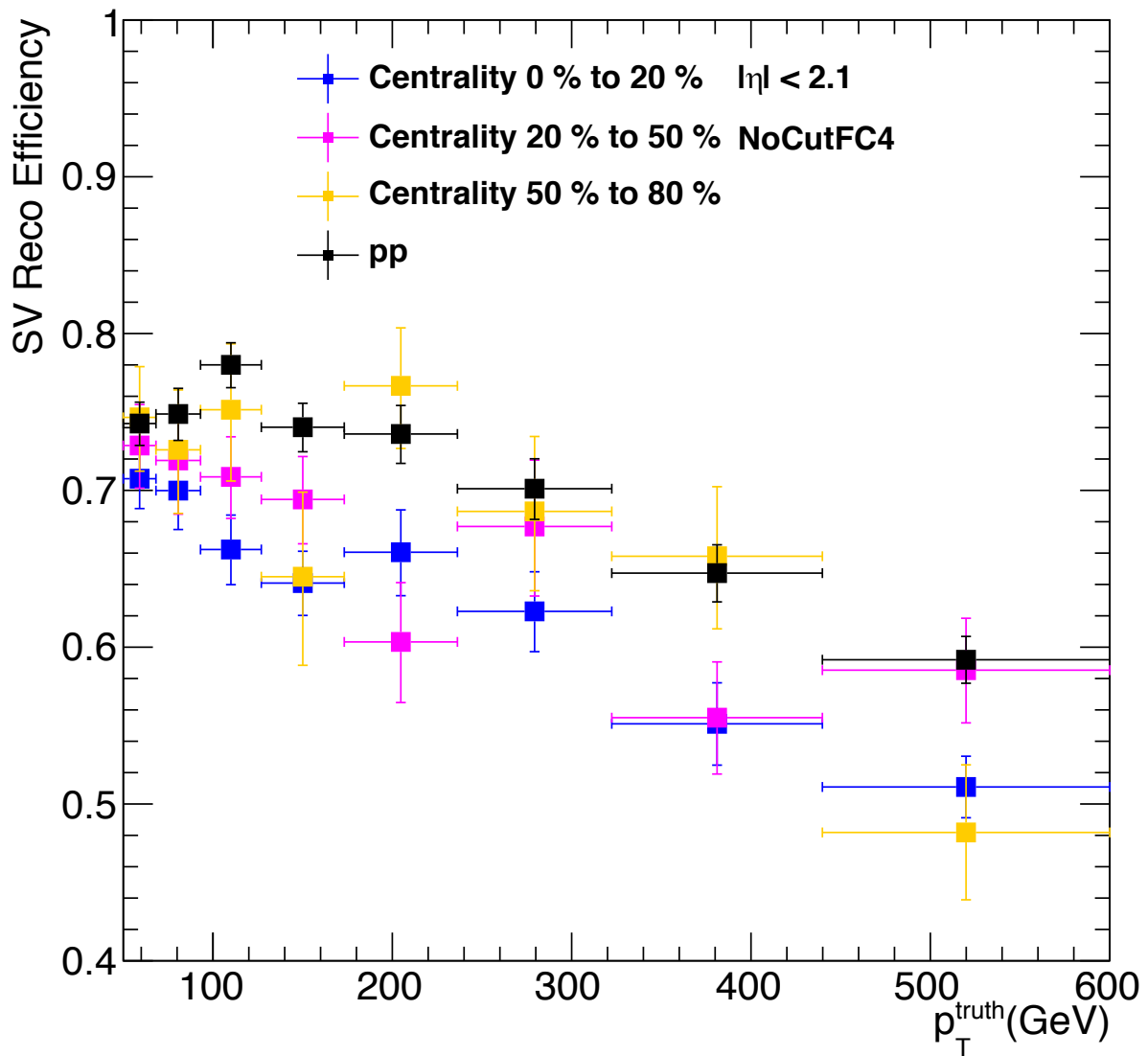
SV Reconstruction Efficiency in b-jet with SV1 Tagger in MC

20
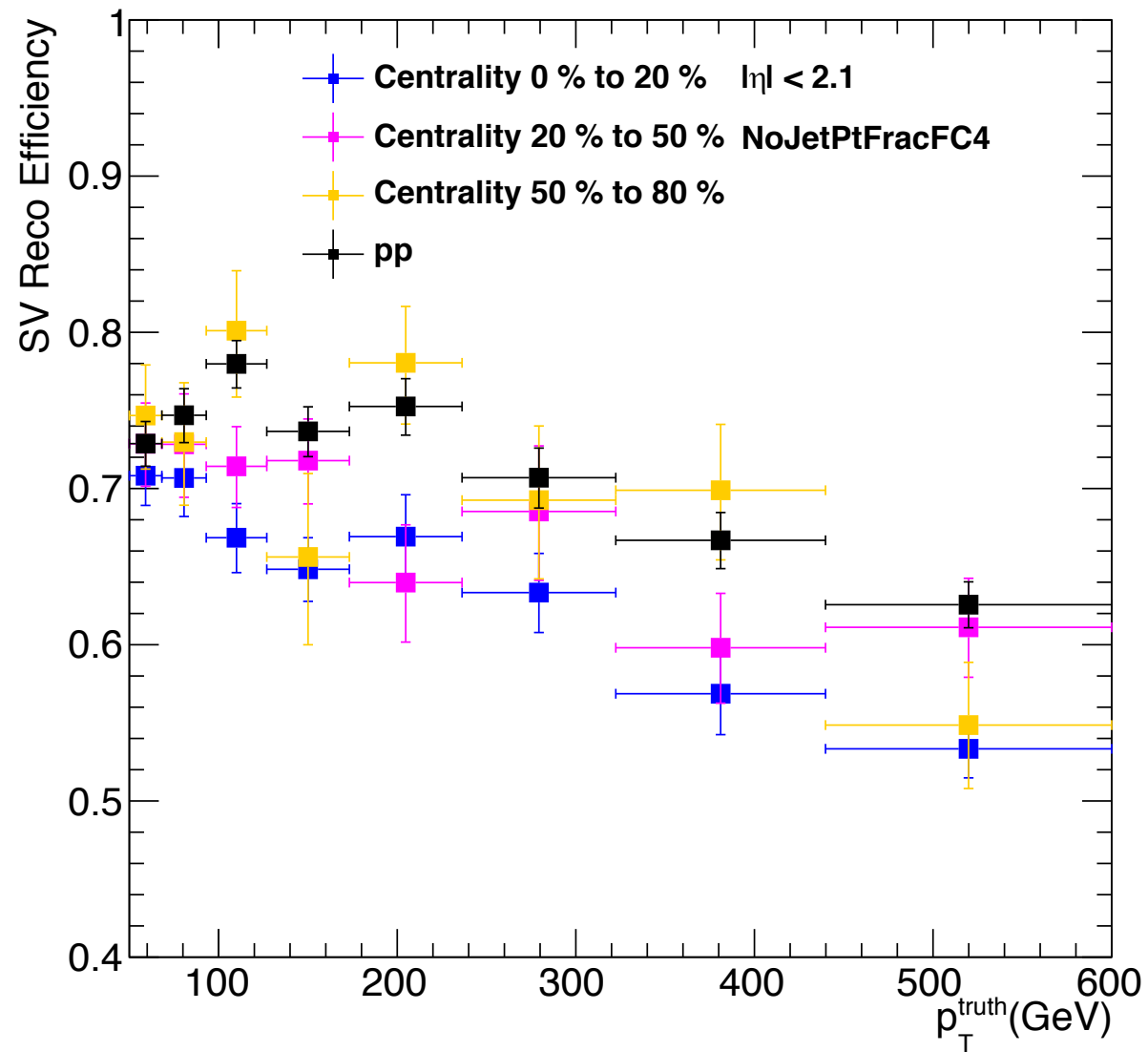
SV Reconstruction Efficiency in b-jet with SV1 Tagger in MC

SV Reconstruction Efficiency in b-jet with SV1 Tagger in MC

JetFitter Algorithm—i.e., not only one vertex but also decay chain

- 1. Select Tracks
  - Form all possible 2-track vertices, and exclude tracks compatible with primary vertex, and hadronic material interactions.
- 2. Fitting and Merging
  - Initialize B-hadron flight direction as jet direction.
  - Initialize vertices candidates as closest approach position of each of the selected tracks to this direction.
  - Iteratively merge vertices and reject tracks with χ^2 cut.
  - Meanwhile iteratively align vertices with a common B-hadron flight direction and reject vertices with χ^2 cut.
  - Output a list of vertices aligned at common B-hadron flight axis
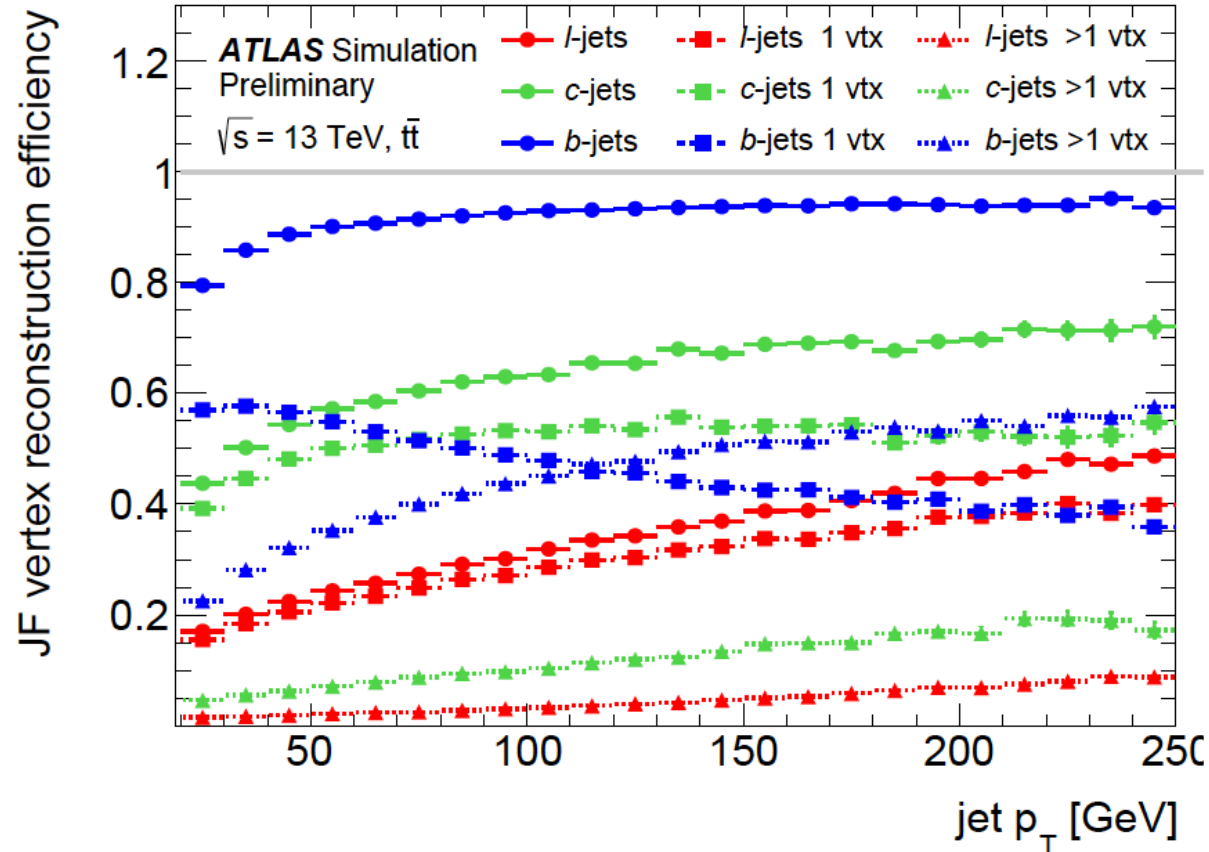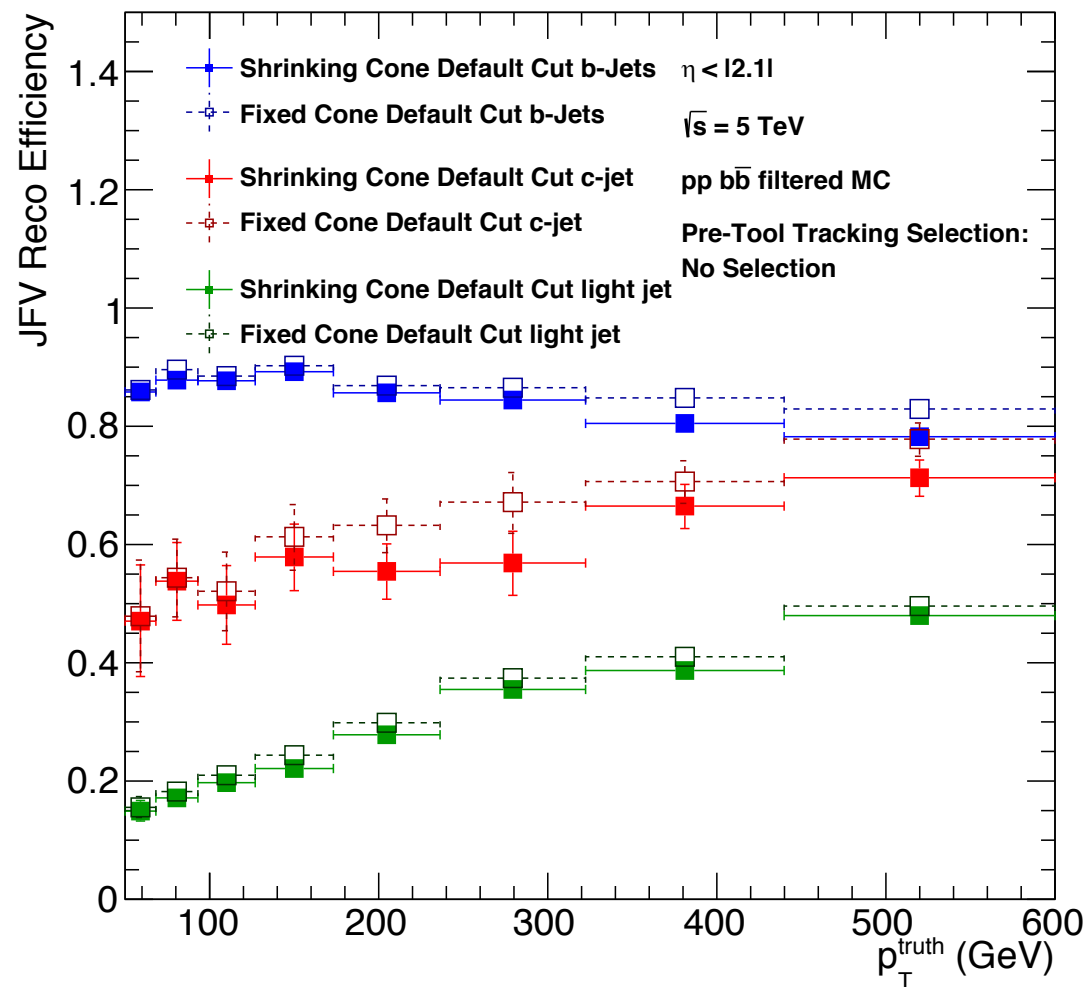- Performance Paper: https://cds.cern.ch/record/2645405/files/ATL-PHYS-PUB-2018-025.pdf

Efficiency Comparison to pp at 13 TeV
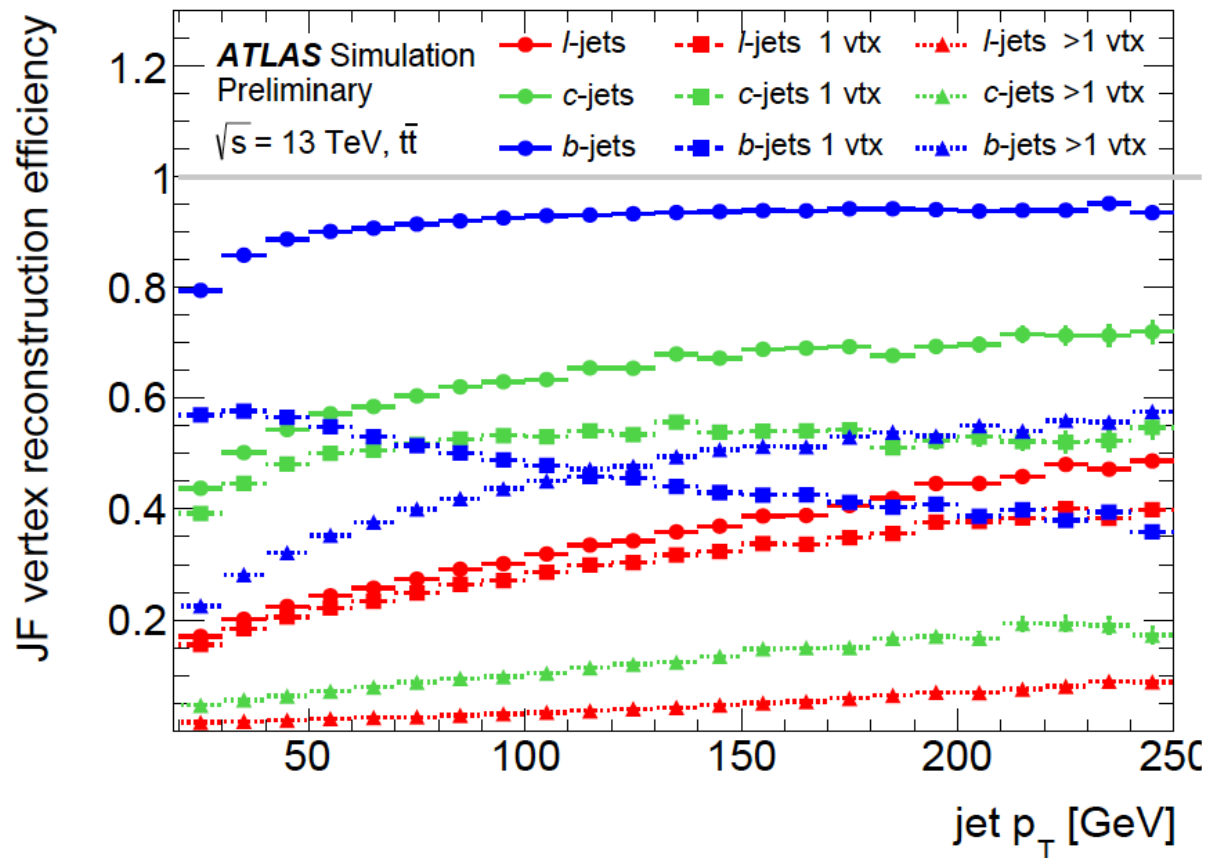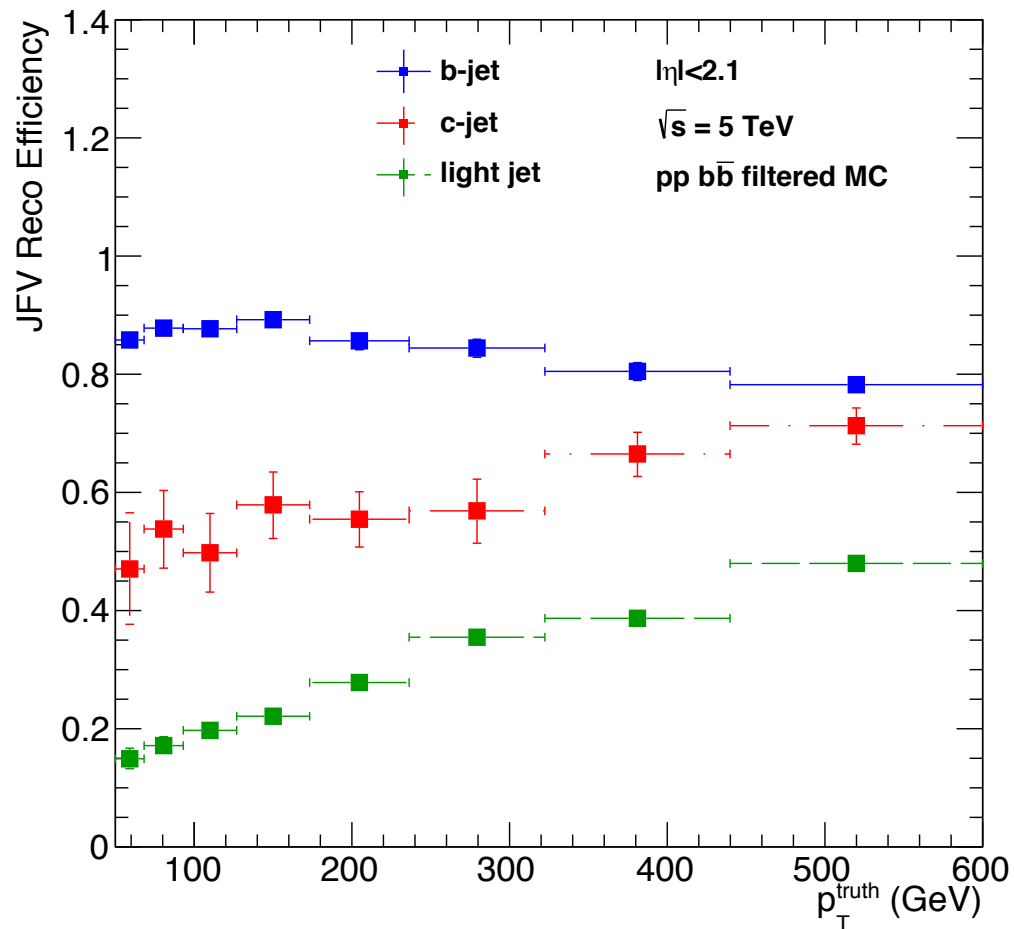
- Observed a minor decrease in efficiency at higher pT
- Higher than 250 GeV results are not shown in the performance paper
- 50-250 range is relatively flat.

Does Fixed Cone still work wit JetFitter?

JFV Reco Efficiency for Different Flavors of Jets in pp MC

Shrinking Cone Default Cut b-Jets $\eta < |2.1|$

Fixed Cone Default Cut b-Jets

$\sqrt{s} = 5$ TeV

Shrinking Cone Default Cut c-jet   pp $b\bar{b}$ filtered MC

Fixed Cone Default Cut c-jet

Pre-Tool Tracking Selection: No Selection

Shrinking Cone Default Cut light jet

Fixed Cone Default Cut light jet

Default JetFitter Results and Fixed Cone Results

Default Cuts

Integrated Efficiency (pT >20 GeV)	0-20%	20-50%	50-80%	pp
B-jet	0.939	0.901	0.844	0.865
C-jet	0.708	0.553	0.519	0.496
Light-jet (fake)	0.645	0.409	0.152	0.165

Fixed Cone at 0.4

Integrated Efficiency (pT >20 GeV)	0-20%	20-50%	50-80%	pp
B-jet	0.954	0.907	0.860	0.872
C-jet	0.716	0.579	0.507	0.507
Light-jet (fake)	0.723	0.468	0.160	0.174

Performance Paper results:

	JF Vertices All
b-jets	0.893
c-jets	0.556
light jets	0.234

Back-up

Back-up: compare to SV
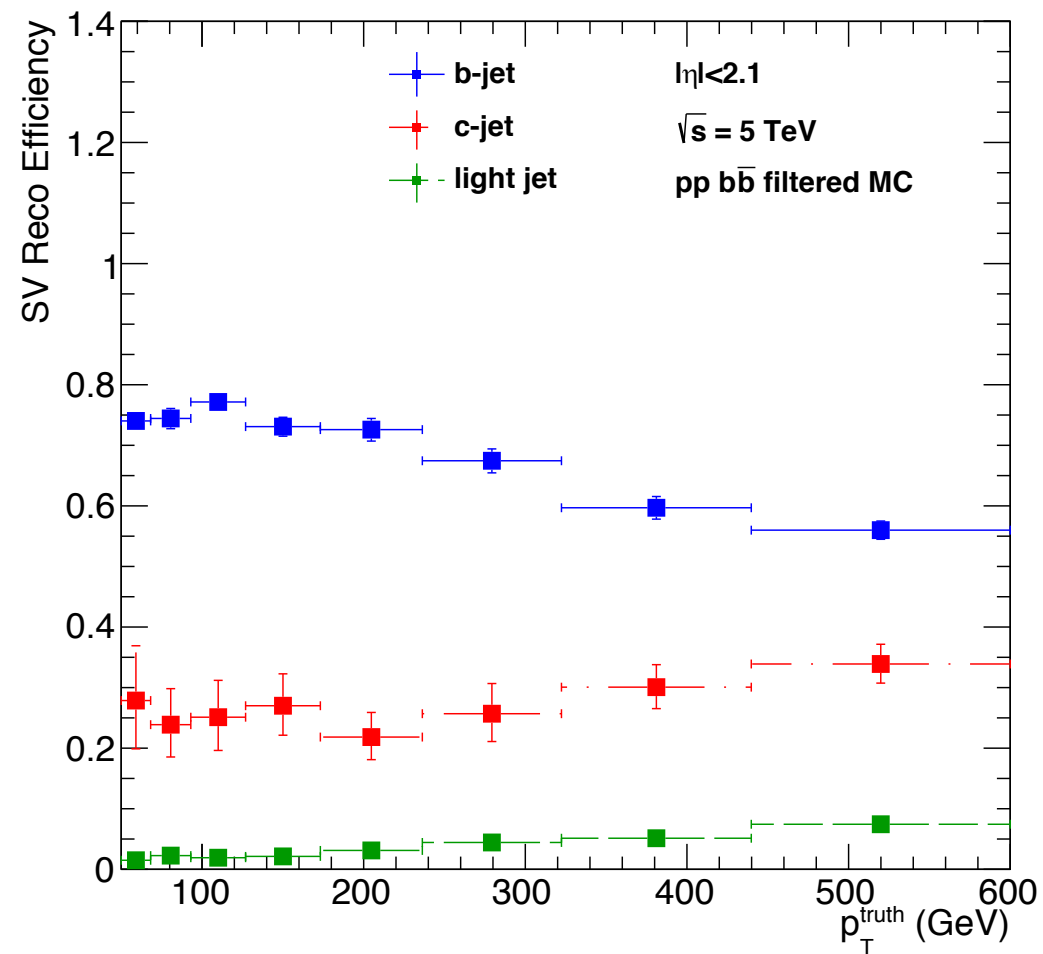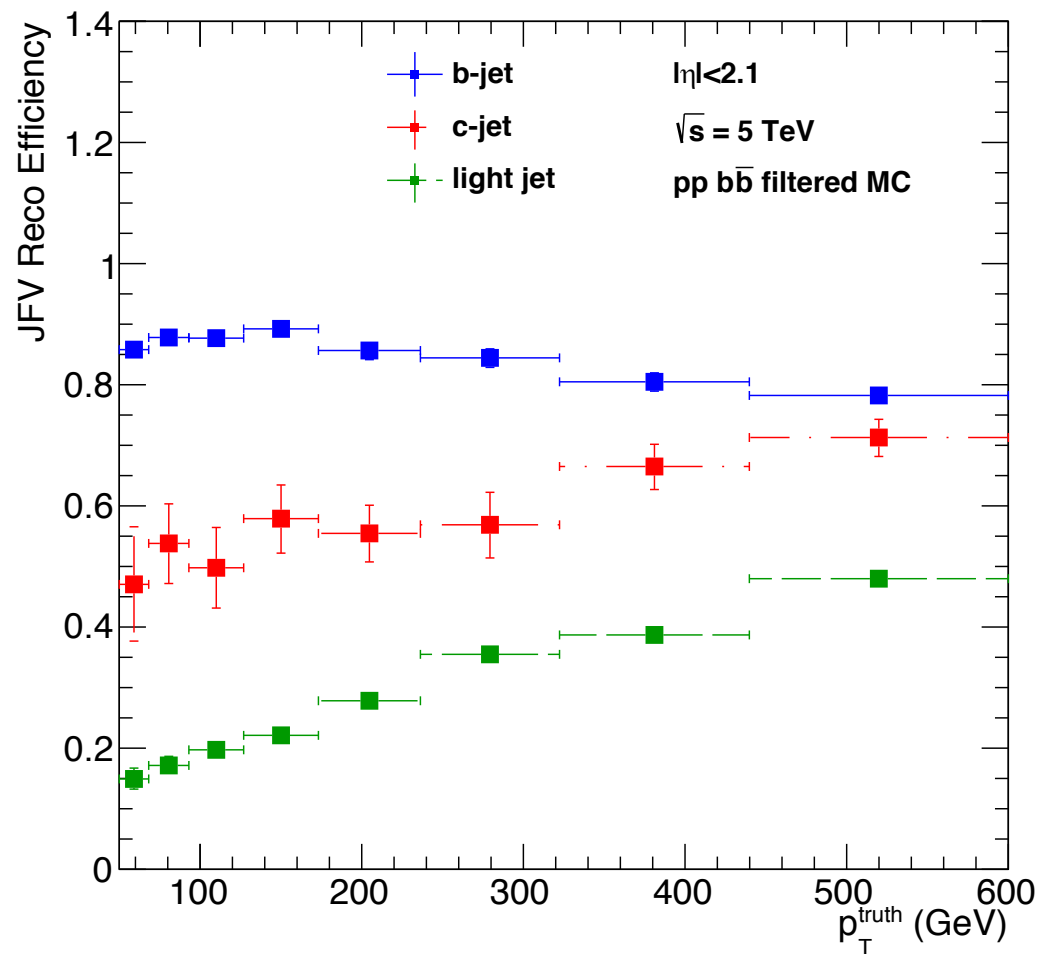
Minimum Jet Pt Fraction

- Algorithm overview:
  - 1. Select list of good particles
    - A0 Z0 track error cuts (Perigee quality)
    - For tracks with p > 10 GeV, stdev < 50%
    - Min Pixel hits, SCT hits and IBL hits requirement should be met
    - within 0.4 of JetDir
  - 2. Select list of two track vertices using selected good particles
    - Vertices are not in material layer and invariant mass is not a V^0 decay
    - Both track passes Jet Pt Fraction and vertex fitting quality

Other to-do

- Reproduce plots from JetFitter performance with our MC.
- Plan on summary of progress for flavour tagging group.