

# 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

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# Recap: different cuts in JetFitter and SVF and effects in secondary vertexing

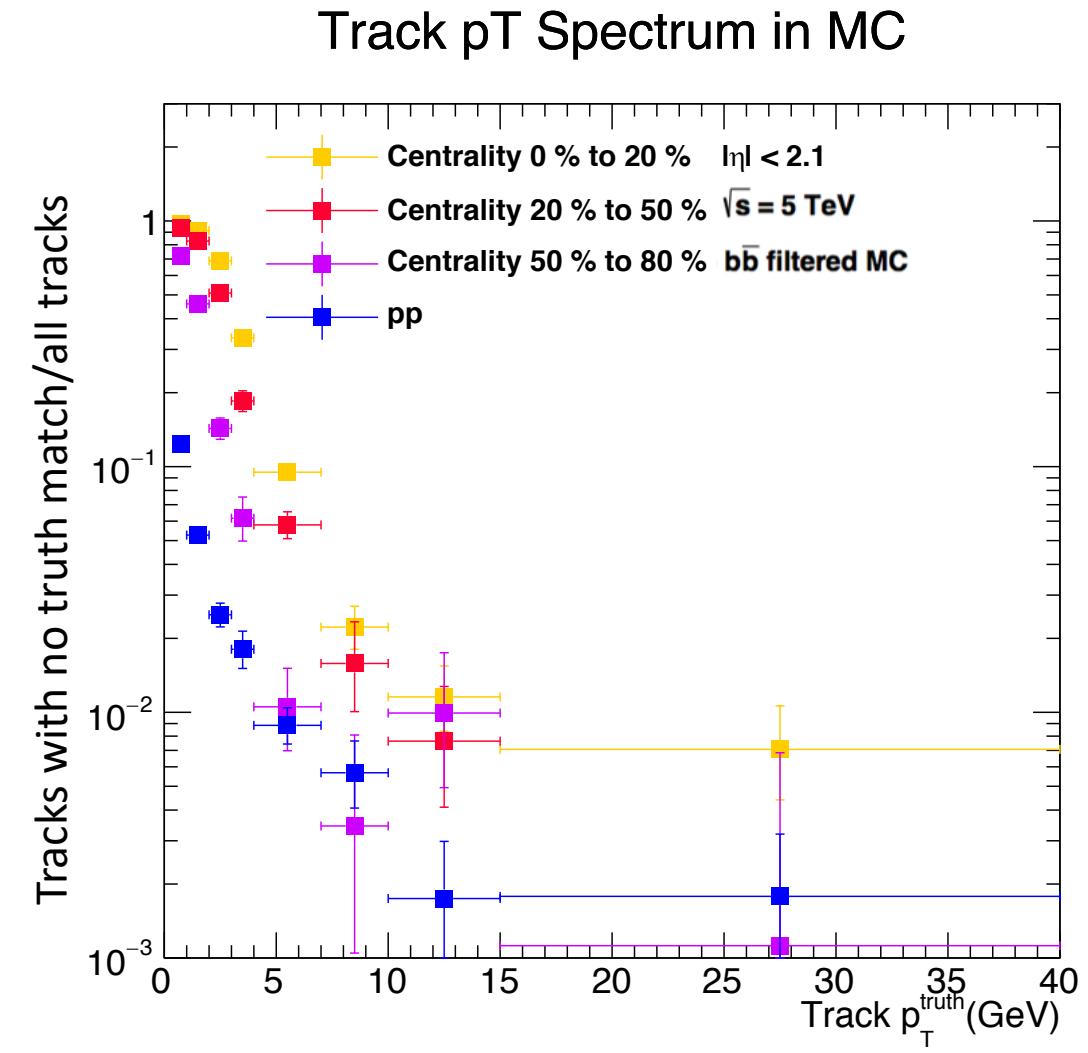
- Last time:

<https://indico.cern.ch/event/915738/contributions/3855987/attachments/2033959/3404942/QT16-20200507.pdf>

- JetFitter and SVF performances were evaluated in terms of secondary vertexing performance and loglikelihood-ratio with default templates.
  - Default templates outdated, looking at input variables.
- different cuts were experimented
- This time: performance of selected cuts for vertexing and input variables.
- This time: remaking of IP3D templates and their performances with inclusive dijet samples.

# Tracks reconstruction in Heavy Ion Collisions

- Reconstruction is different, designed to work with high occupancy data (order of 1000 tracks)
  - Occupancy has a centrality dependence
- Only one primary vertex per event. No pile-up effect.
- Many more underlying event tracks in comparison to pp collisions.
  - Especially at central events, and are mostly low energy.
- Different track recommendations for analysis from pp collisions
  - <https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/TrackingCPMoriond2017>

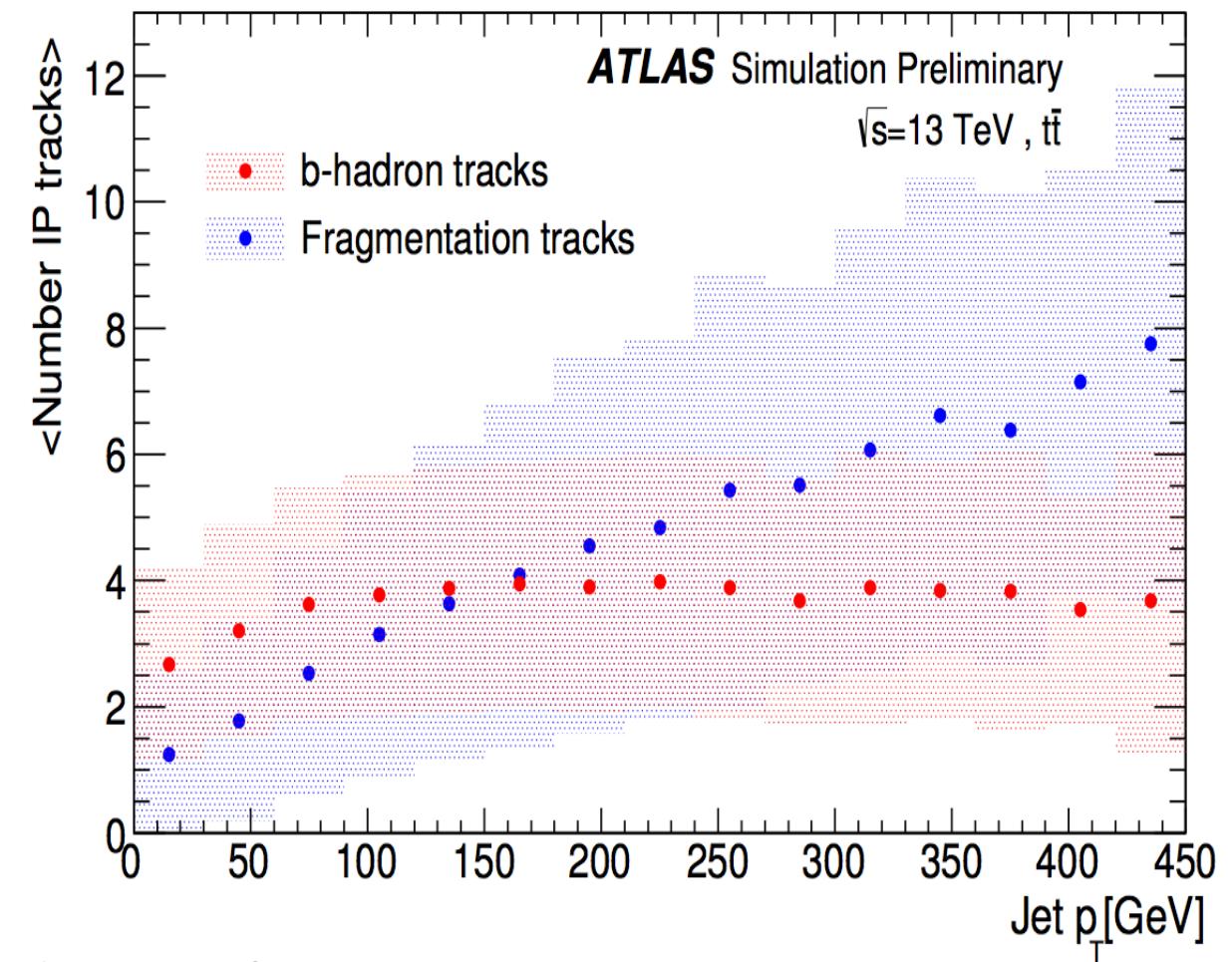
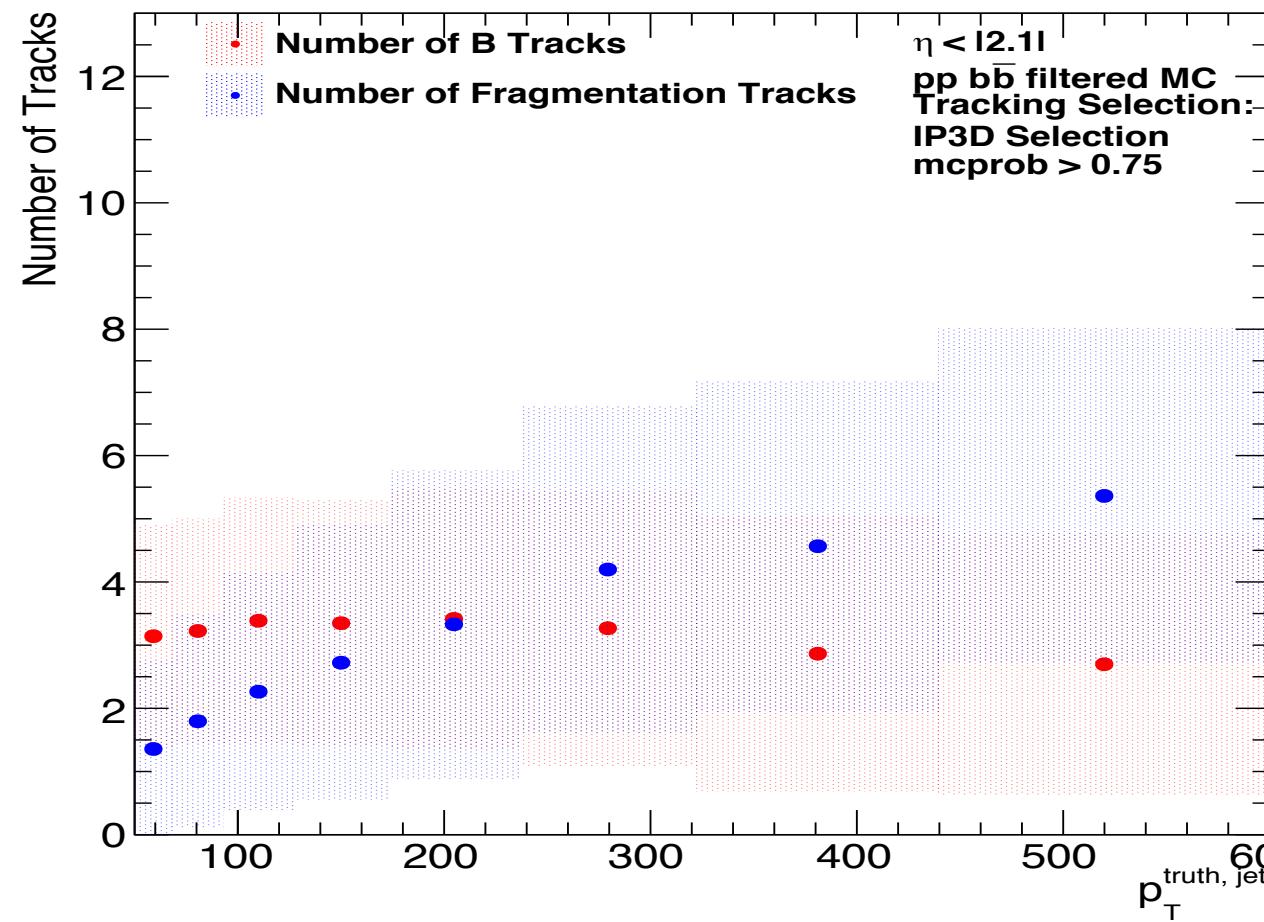


# MC Samples

- pp MC and MC overlay (**JetFitter and SV1 plots**):
  - pp MC: 50k events (12.5k each for JZ1-JZ4) of pythia dijets events at 5.02 TeV, applied with bbar filter Selection on Jets.
  - Configuration file: [https://gitlab.cern.ch/atlas-physics/pmg/infrastructure/mc15joboptions/blob/master/share/DSID420xxx/MC15.420271.Pythia8EvtGen\\_A14NNPDF23LO\\_jetet\\_JZ1\\_bbfilter.py](https://gitlab.cern.ch/atlas-physics/pmg/infrastructure/mc15joboptions/blob/master/share/DSID420xxx/MC15.420271.Pythia8EvtGen_A14NNPDF23LO_jetet_JZ1_bbfilter.py)
  - Overlay: pp MC + 2018 minBias data to simulate underlying events.
- pp Inclusive dijets samples (**IP3D plots**):
  - [https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/HIJetMCSamples#Pythia8\\_dijets\\_8M\\_per\\_sample\\_in](https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/HIJetMCSamples#Pythia8_dijets_8M_per_sample_in)
  - Pythia8 dijets - 8M per sample in 21.0.93
- Selection on Jets:
  - Reco jets with  $\Delta R(\text{truth-reco}) < 0.3$
  - $p_T^{\text{truth jet}} > 50 \text{ GeV or } 100 \text{ GeV (see plots)}$
- Disabled all anti-pile up tools( small  $R\phi$  and large Z or JFV scores)
- B-Jets: jets with a truth B hadron associated with it. Similarly for C-jets
  - $p_T^B > 5 \text{ GeV}$
  - $\Delta R(\text{jet-B}) < 0.3$
- Tool: <https://gitlab.cern.ch/atlas-flavor-tagging-tools/FlavourTagPerformanceFramework>
  - The most updated modified version is at [https://gitlab.cern.ch/xiaoning/hiretagging\\_framework](https://gitlab.cern.ch/xiaoning/hiretagging_framework)

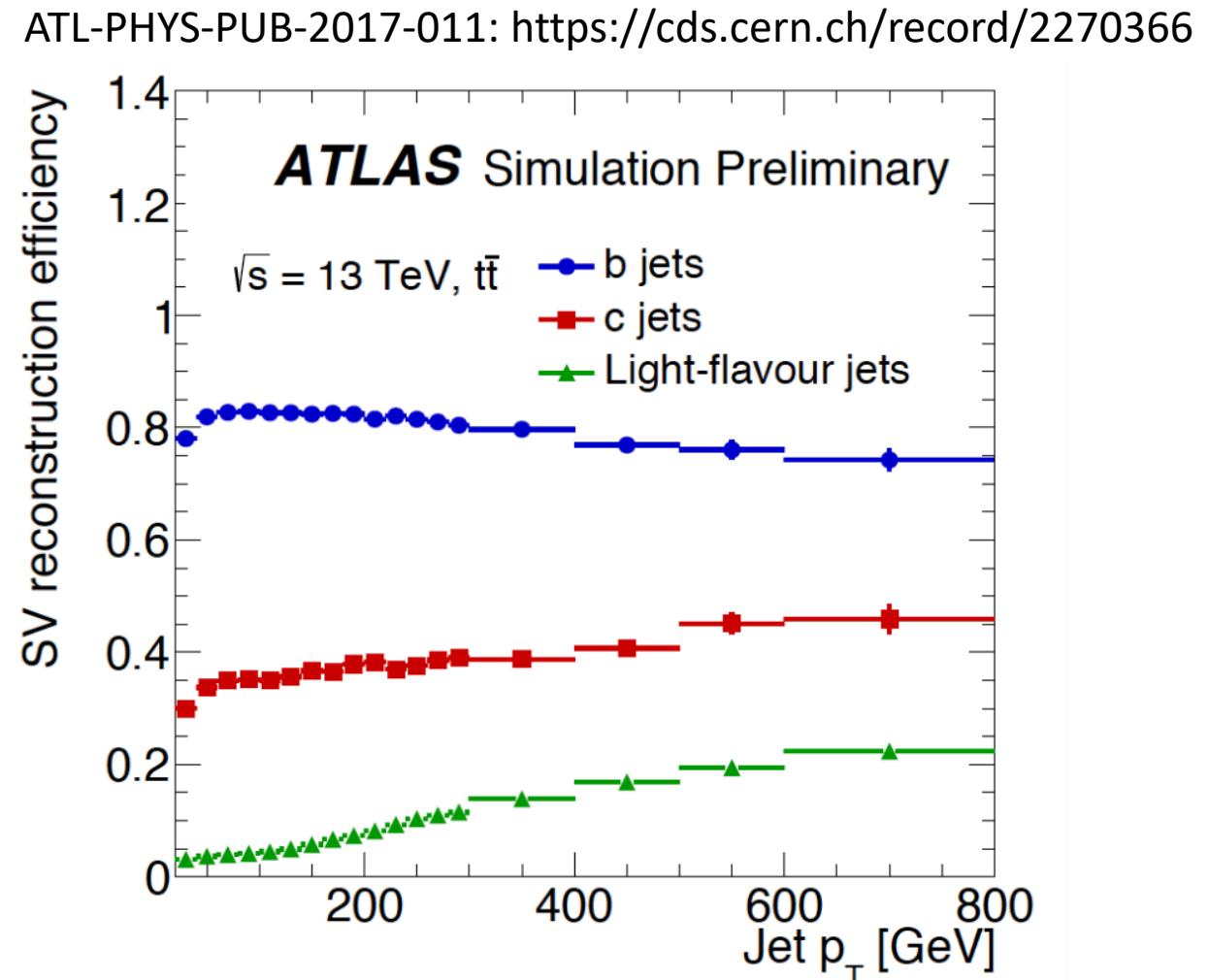
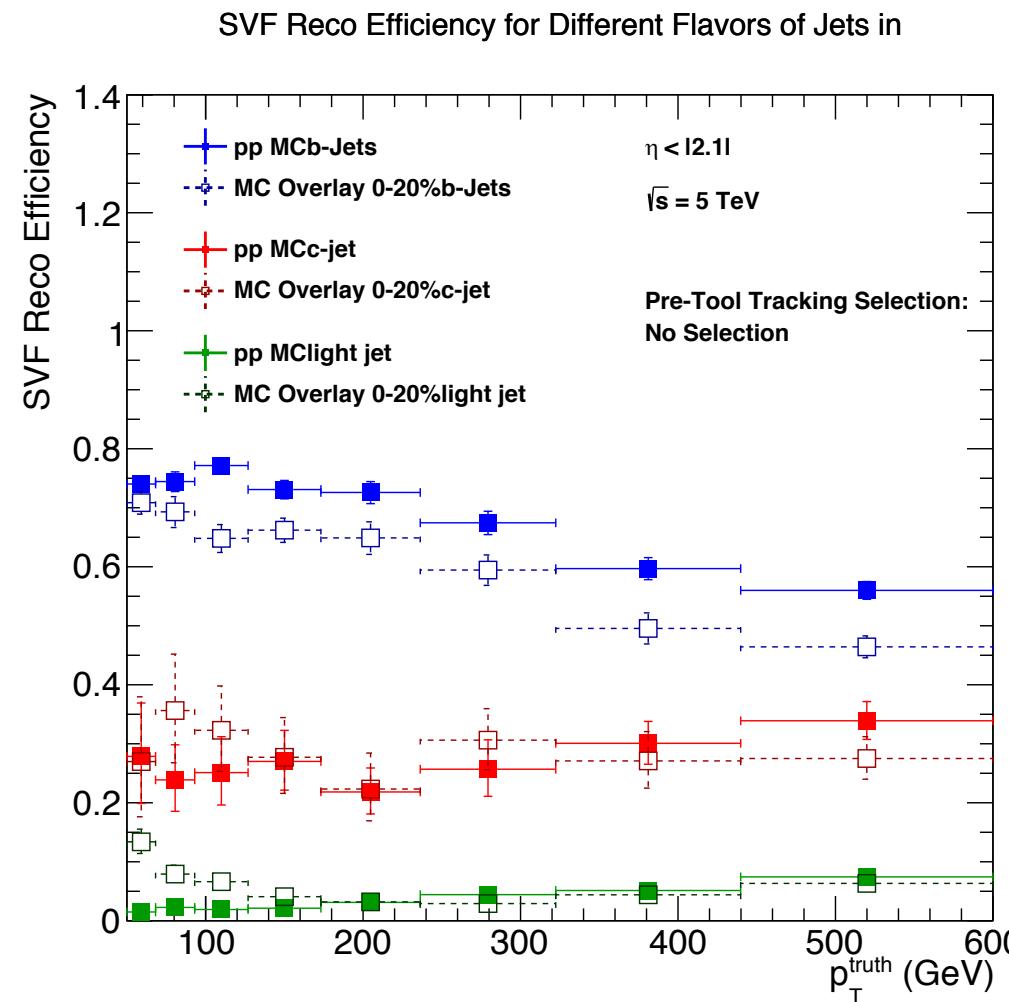
# Secondary Vertexing Performance for JetFitter and SVF

# Recap: 50k bbar filtered samples



- Less number of tracks reconstructed in each jet
- Lower efficiency of secondary vertex reconstruction with SVF.

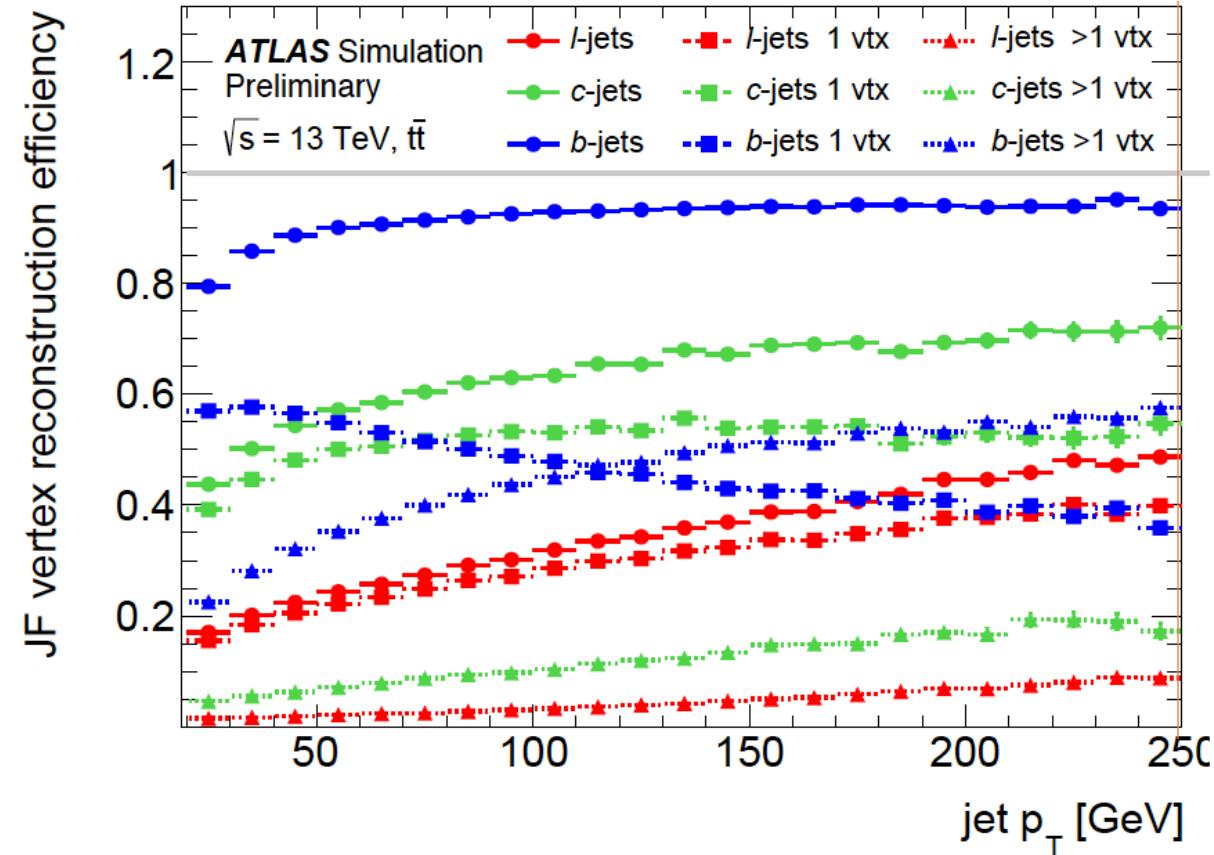
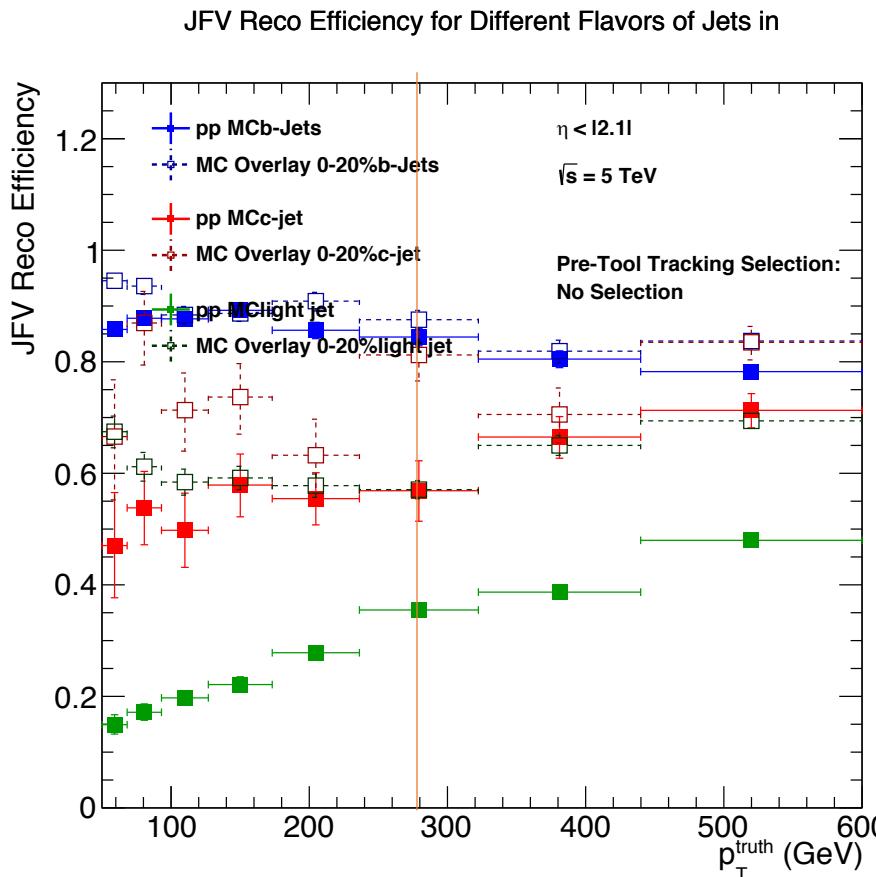
# Recap: Secondary Vertexing Performance with Default setup for SVF



Most central overlay MC has lower vertexing efficiency at high pT and higher fake rate at low pT.

- Need to reduce low pT UE tracks and include more tracks at high pT.

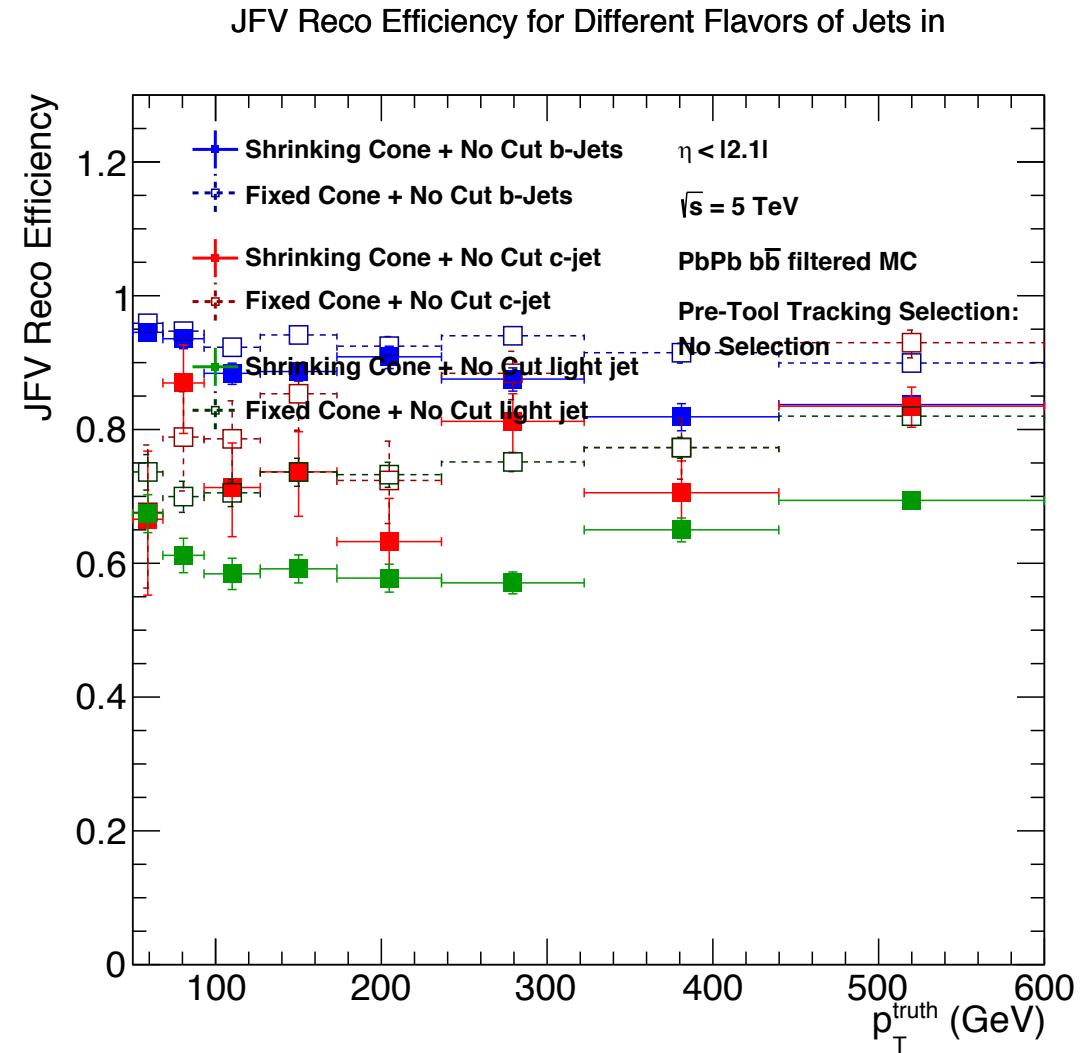
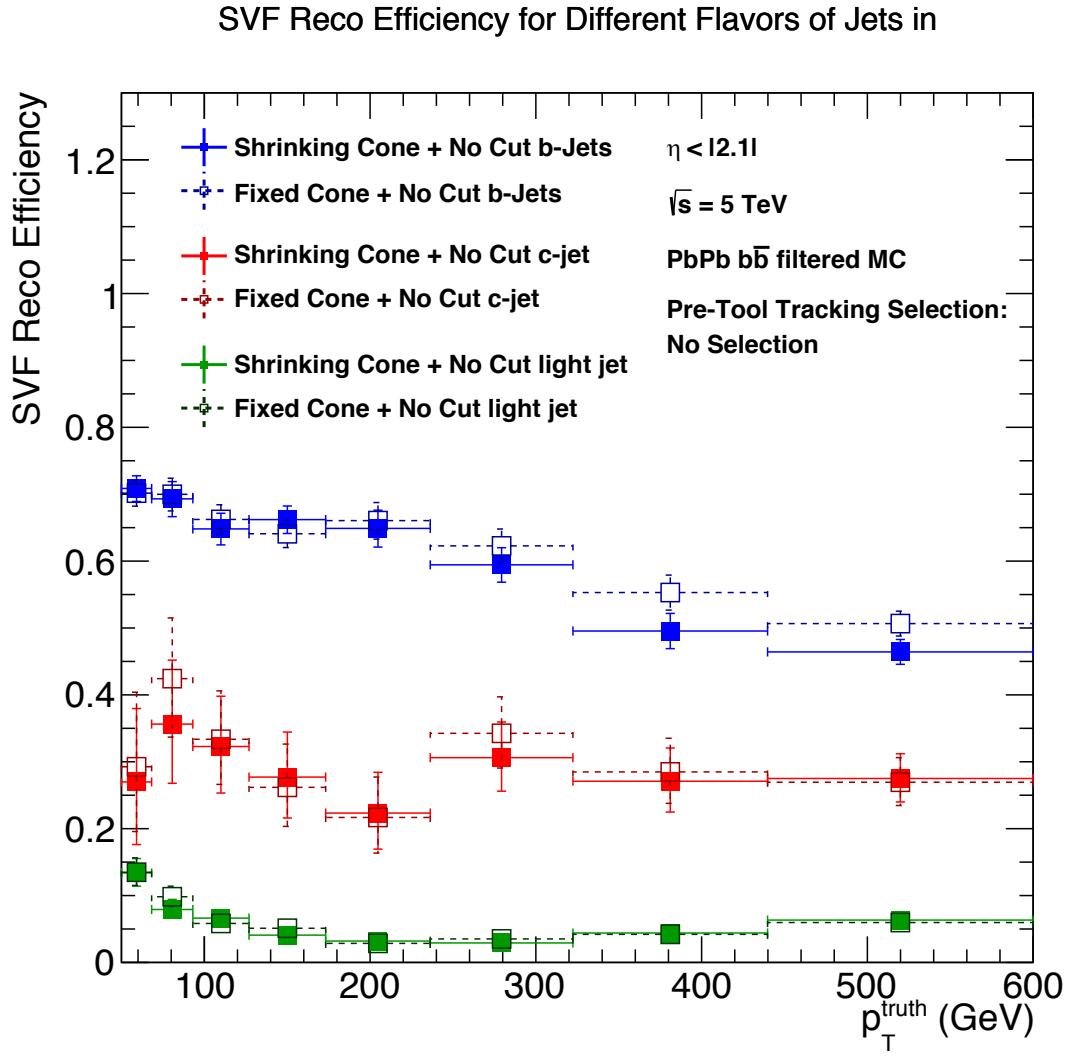
# Secondary Vertexing Performance with Default setup for JetFitter



- Inclusive fake rate is much higher in overlay MC central event. (comparing to solid line on the right)
  - Needs to reduce UE tracks' effect.

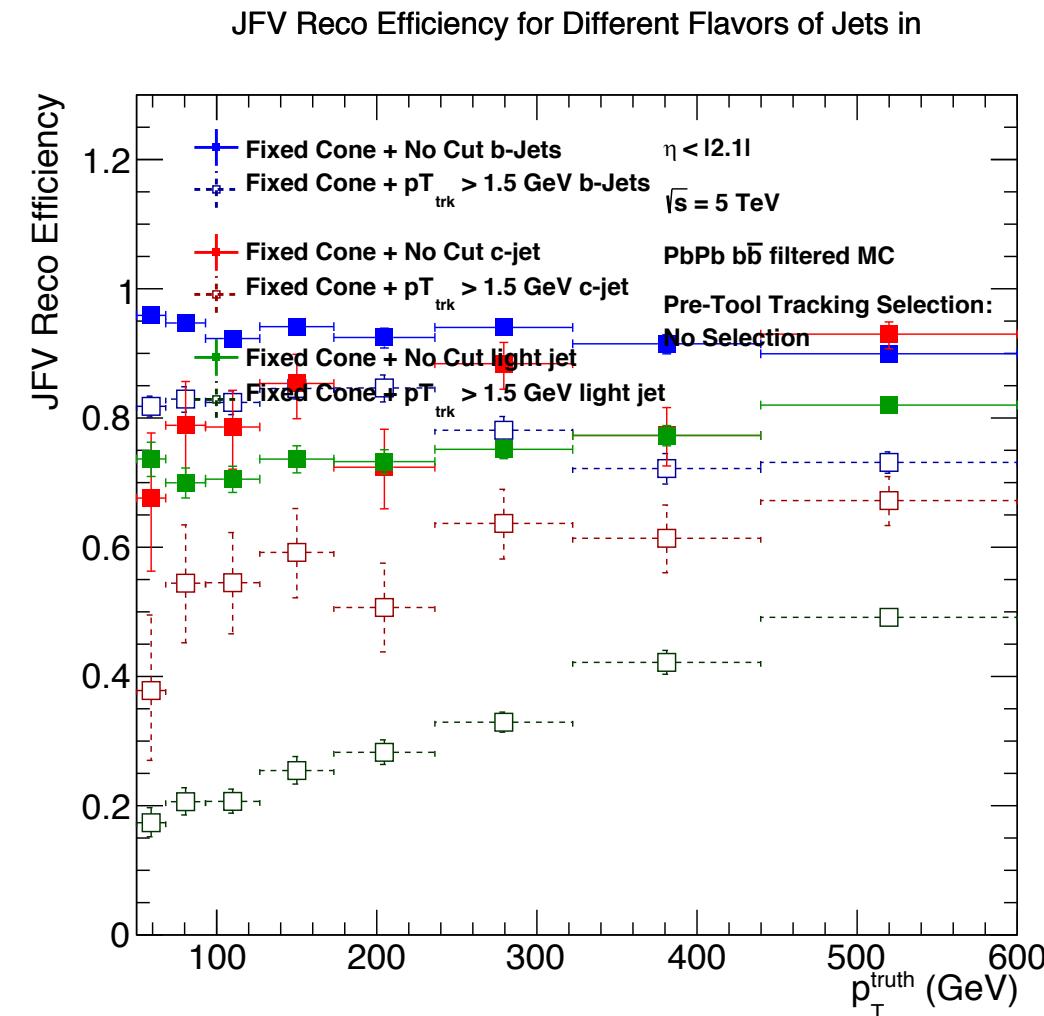
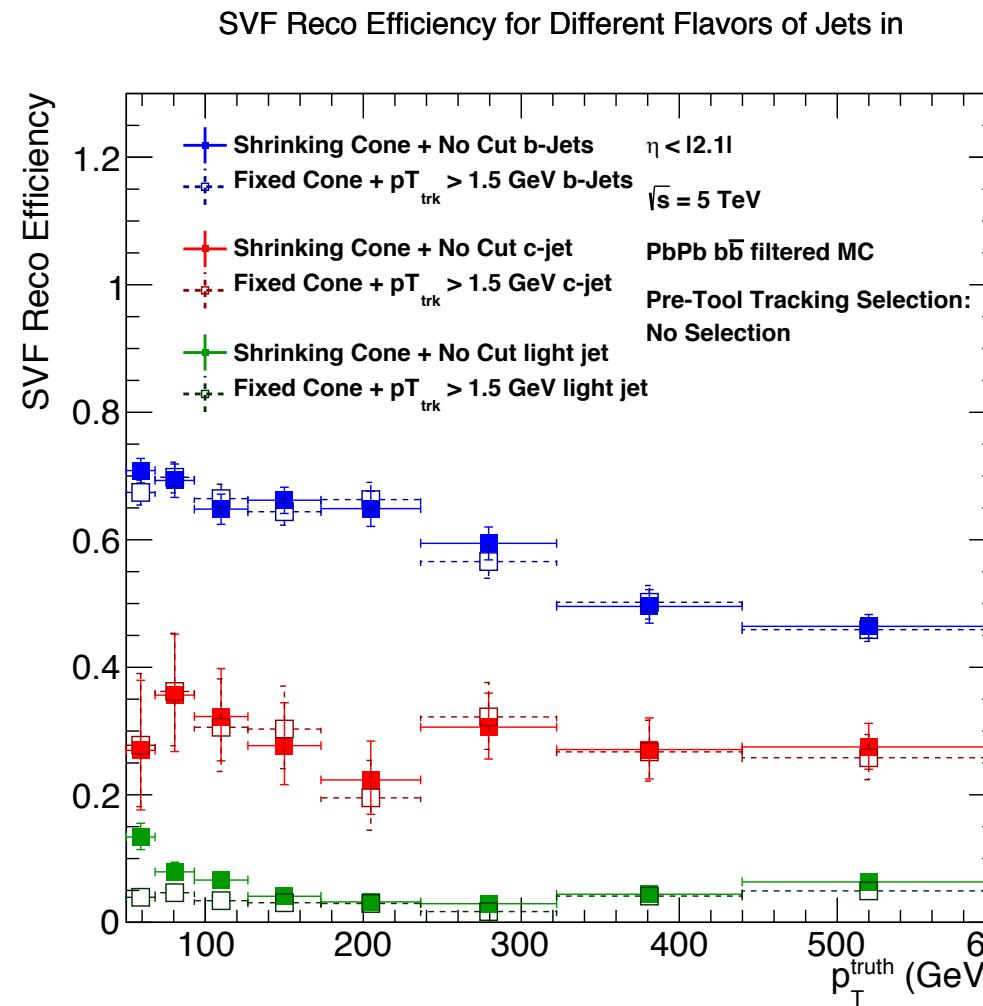
# Fixed Cone at R = 0.4

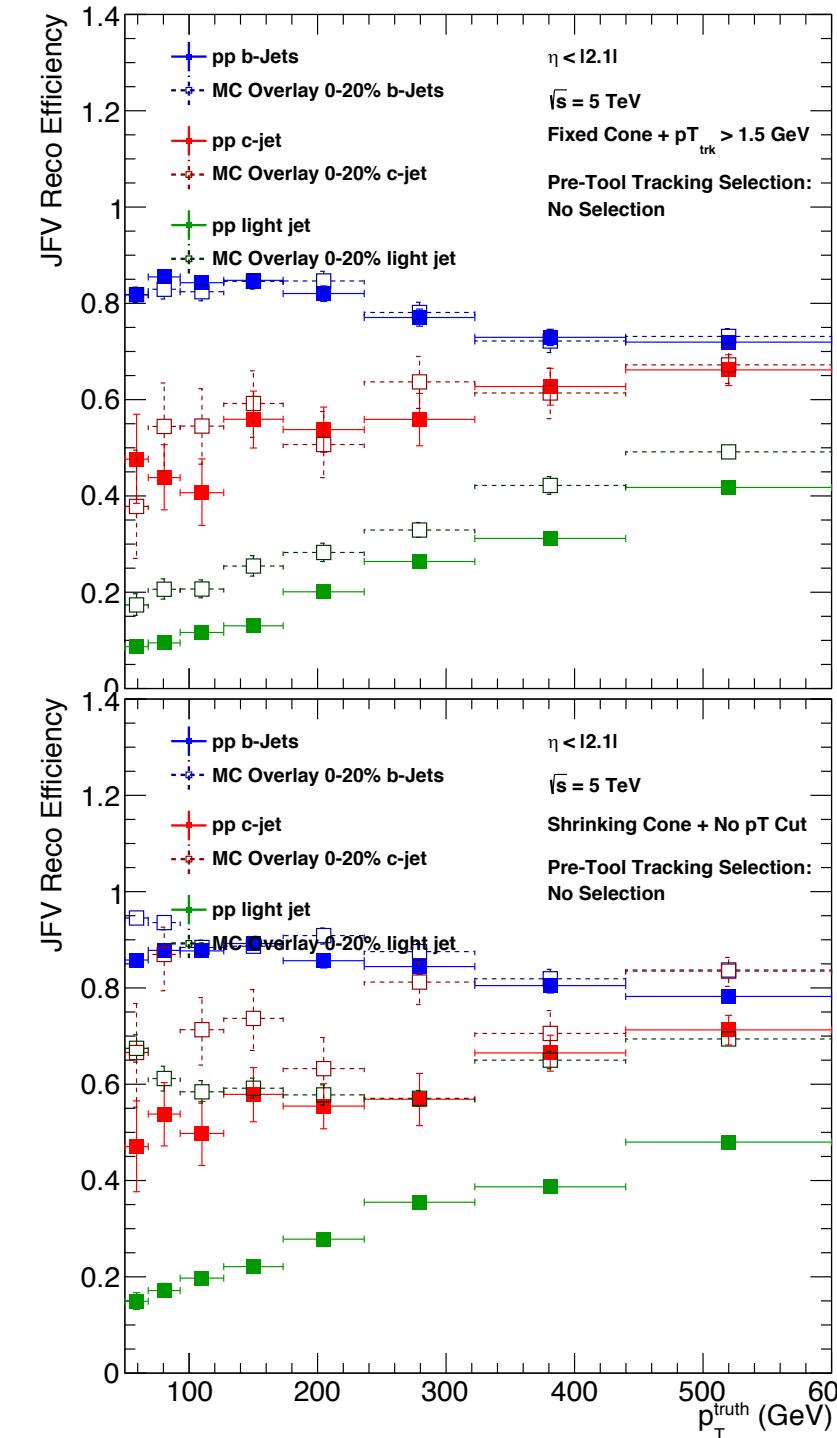
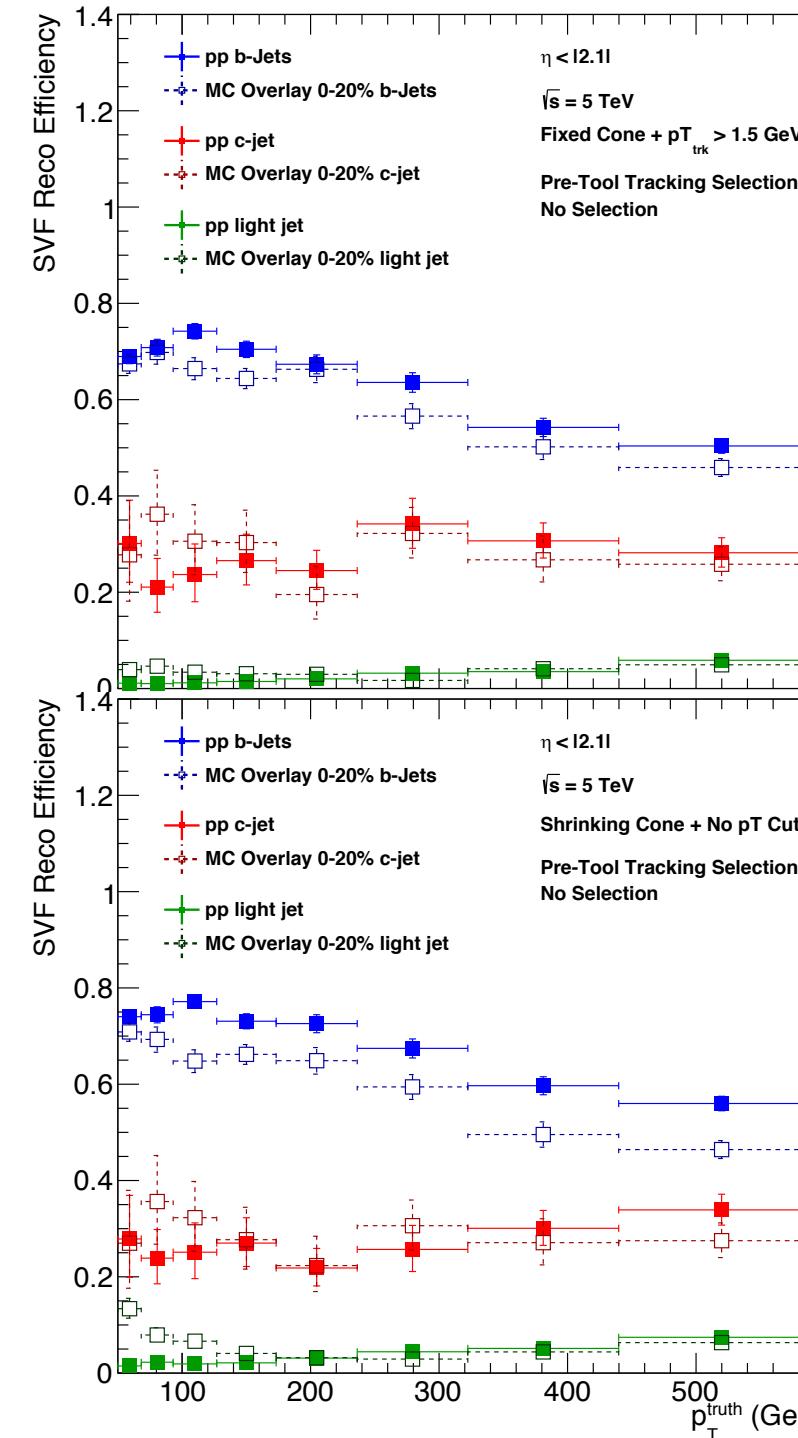
- Motivation: unknown track distributions for PbPb jets
- Improve high pT SVF performance but worsen JetFitter.



# Fixed Cone at $R = 0.4$ + Track pT cut at 1.5 GeV

- Significantly improved central overlay performance in JetFitter





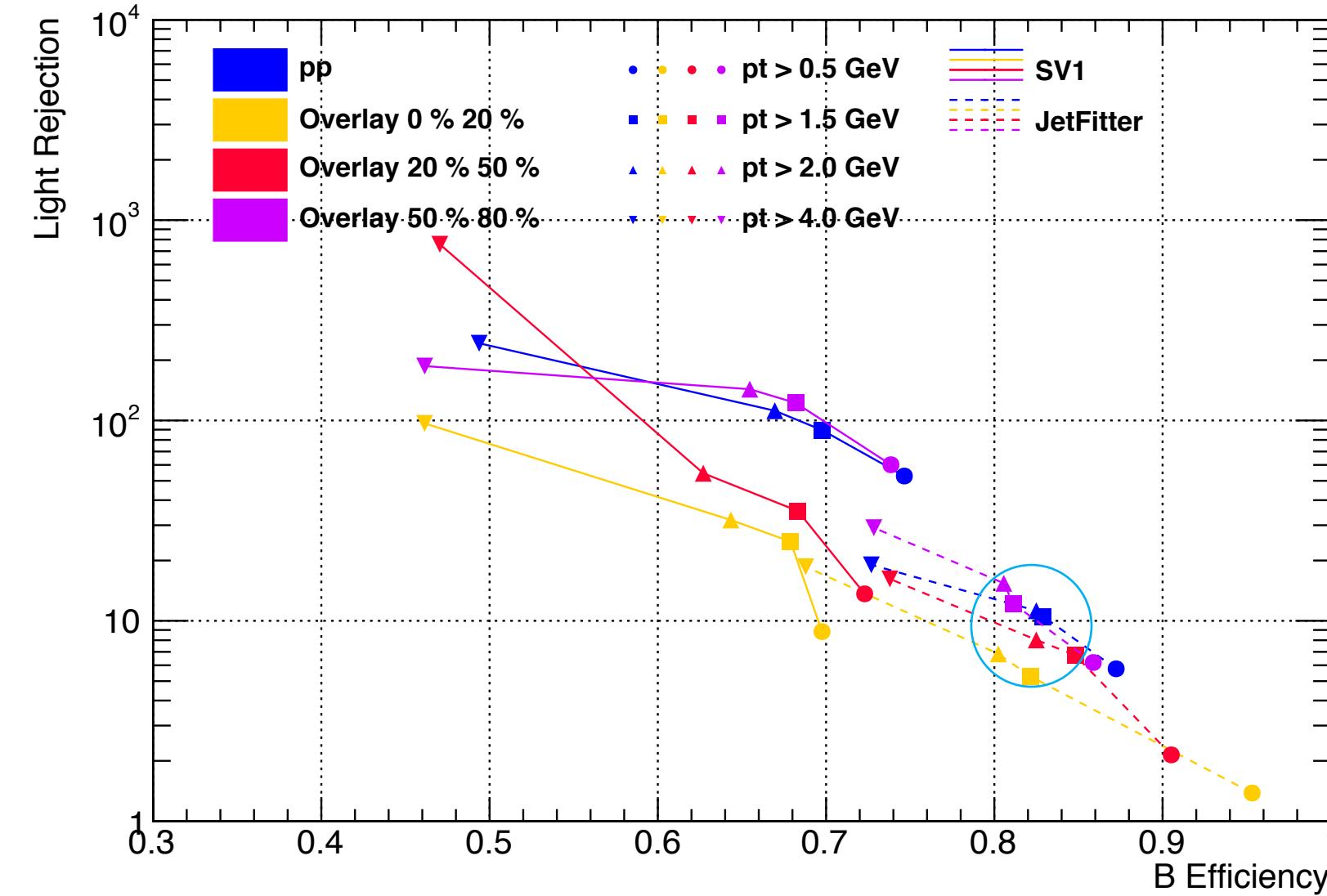
Left column: SVF  
Right column: JFV

Top row: Fixed Cone + 1.5 GeV  
Bottom row: Shrinking Cone + no pT cut

Centrality dependence is less with the two cuts.

# ROC curve for JF and SV1 Vertexing Efficiency

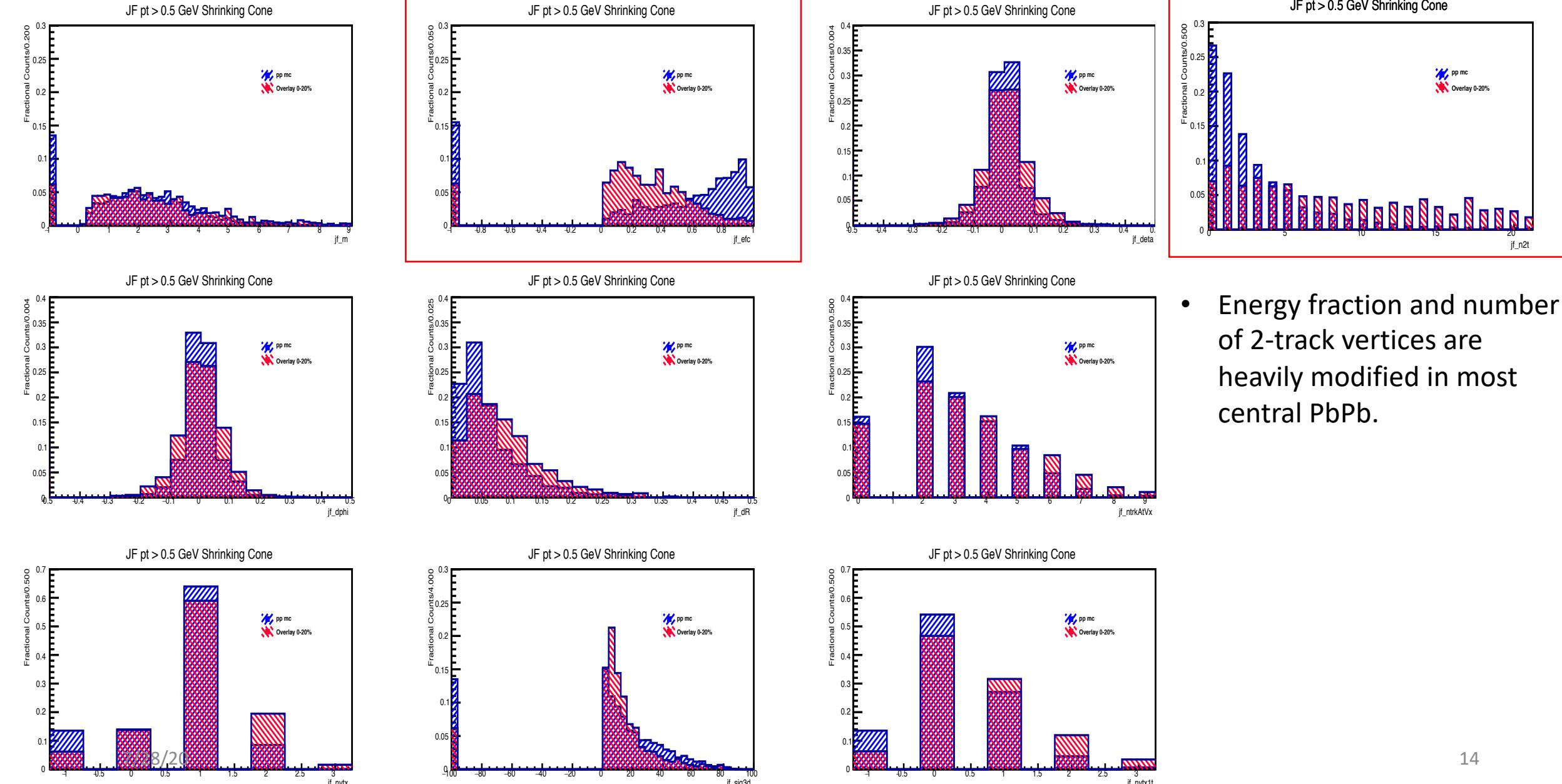
ROC Curve of Vertexing Efficiency with min Jet pt 50 GeV



- Blue circle: For JetFitter, cutting at  $pT = 1.5$  GeV or  $pT = 2.0$  GeV gives least centrality dependence.
- SV1: Centrality dependence similar for different cuts

# Flavour Tagging Input Variables JetFitter and SVF

# JF Variables at Default Setup

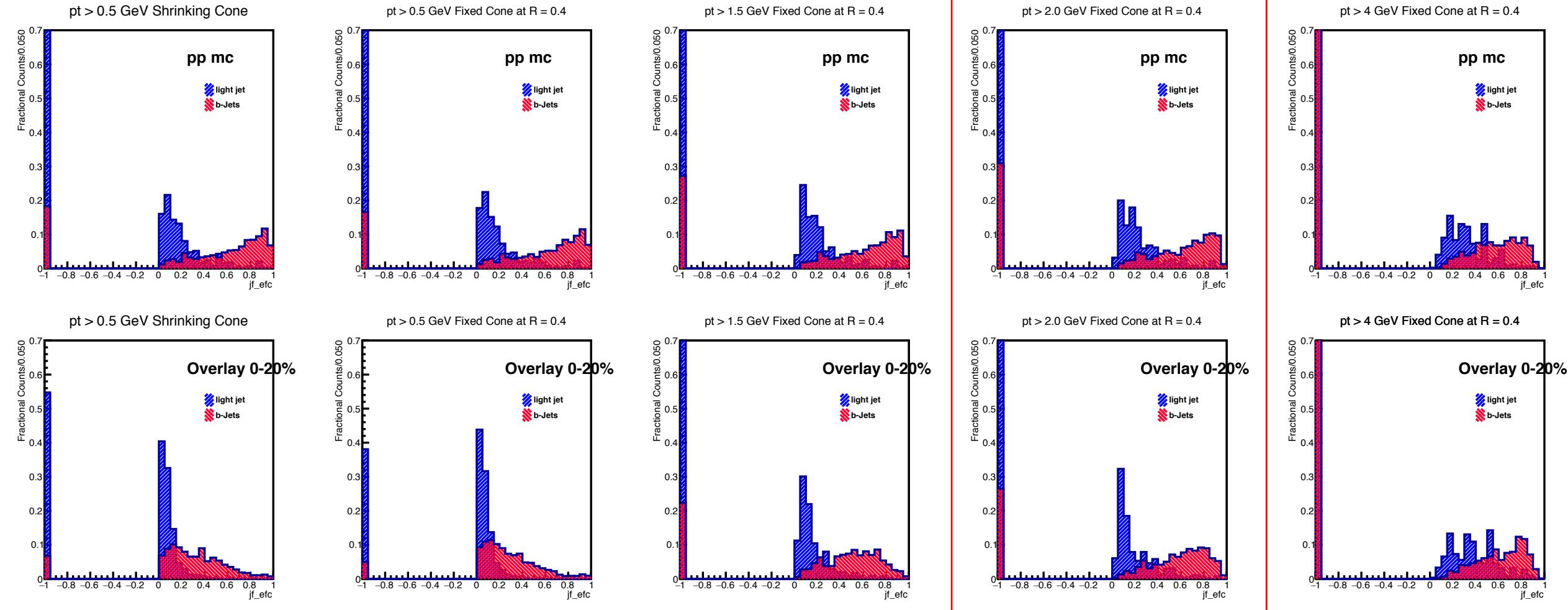


- Energy fraction and number of 2-track vertices are heavily modified in most central PbPb.

# JF Energy Fraction

↓ Visually the two distributions are the most distinct at 2 GeV

↓ over cutting causes light jet to right-shift as well



Top Row: pp mc

Bottom Row: Overlay 0-20%

From left to right:

1. No pT Shrinking Cone
2. No pT Fixed Cone
3. Min pt = 1.5 GeV Fixed Cone

4. Min pt = 2.0 GeV Fixed Cone

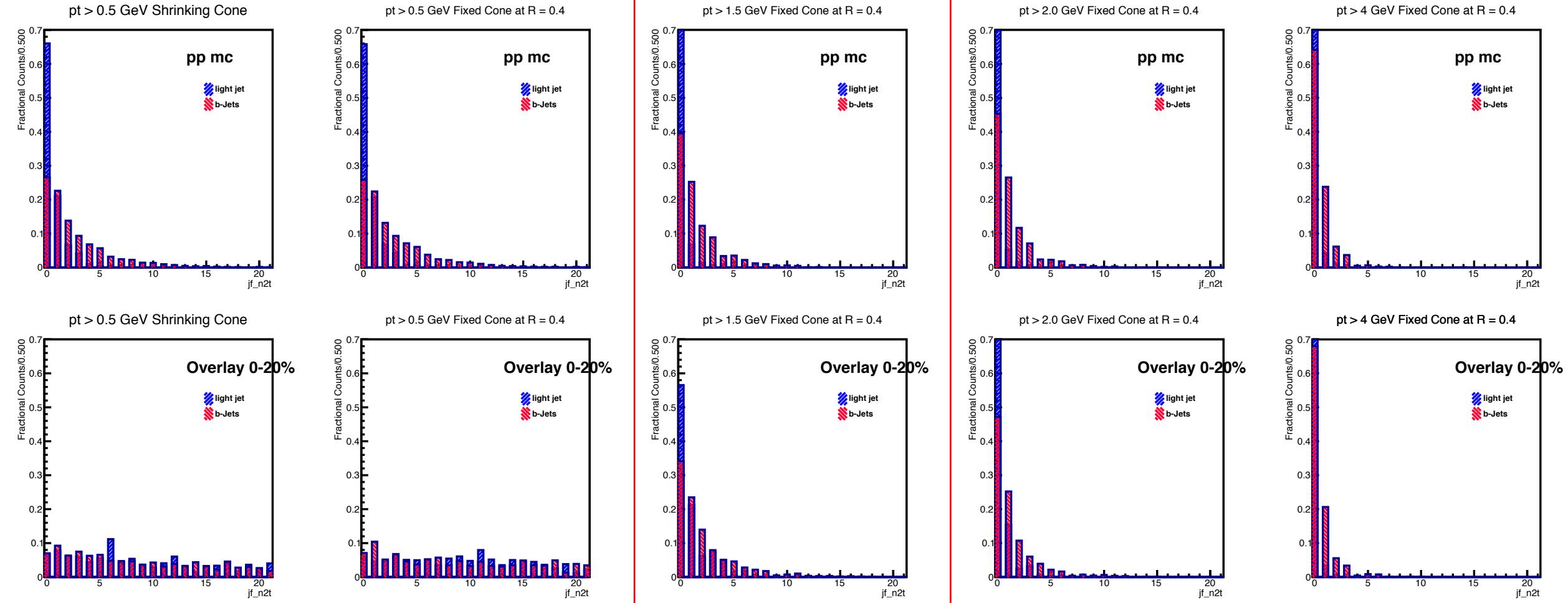
5. Min pt = 4.0 GeV Fixed Cone

Red: b-jet

Blue: light jet

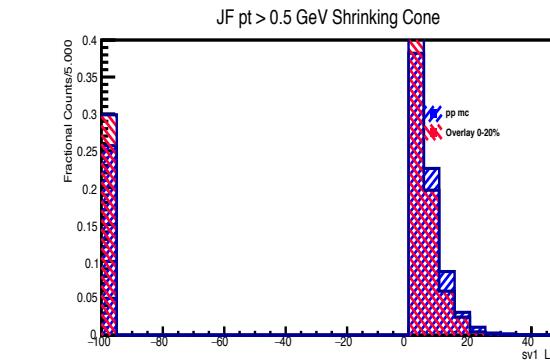
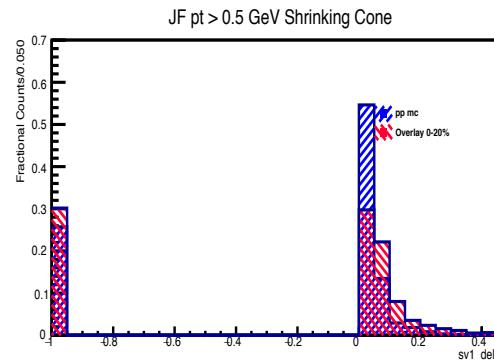
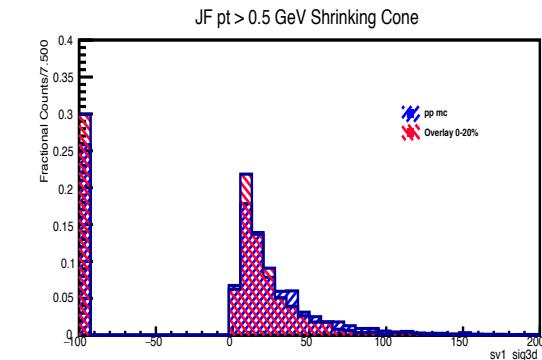
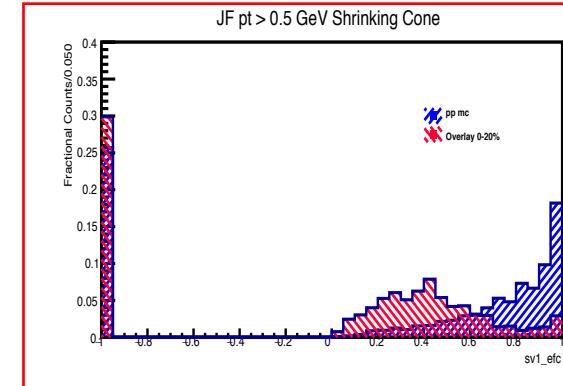
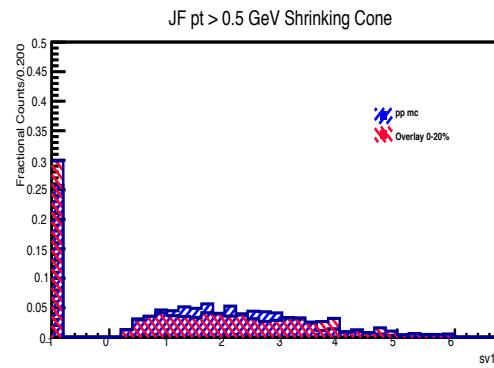
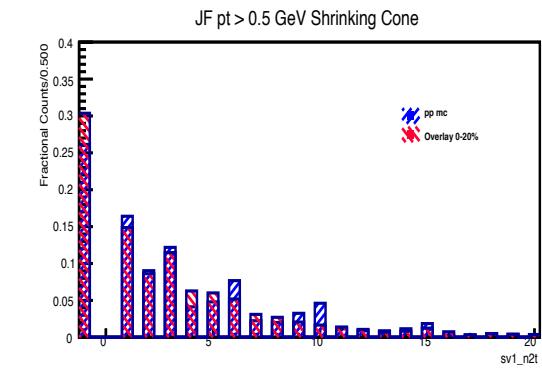
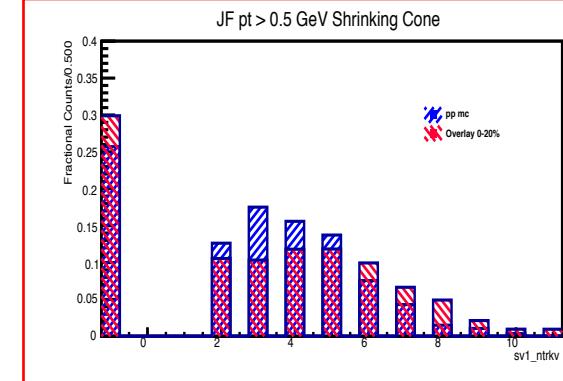
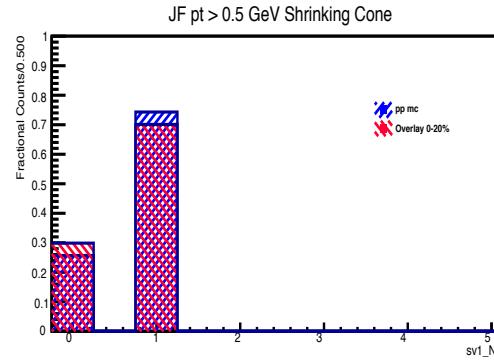
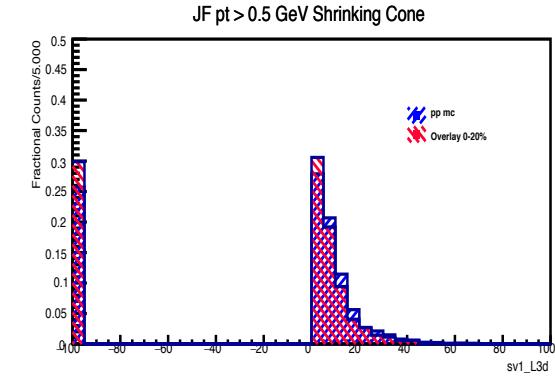
# JF n2t (2-trk vertices candidates)

↓ over cutting leaves too few bins



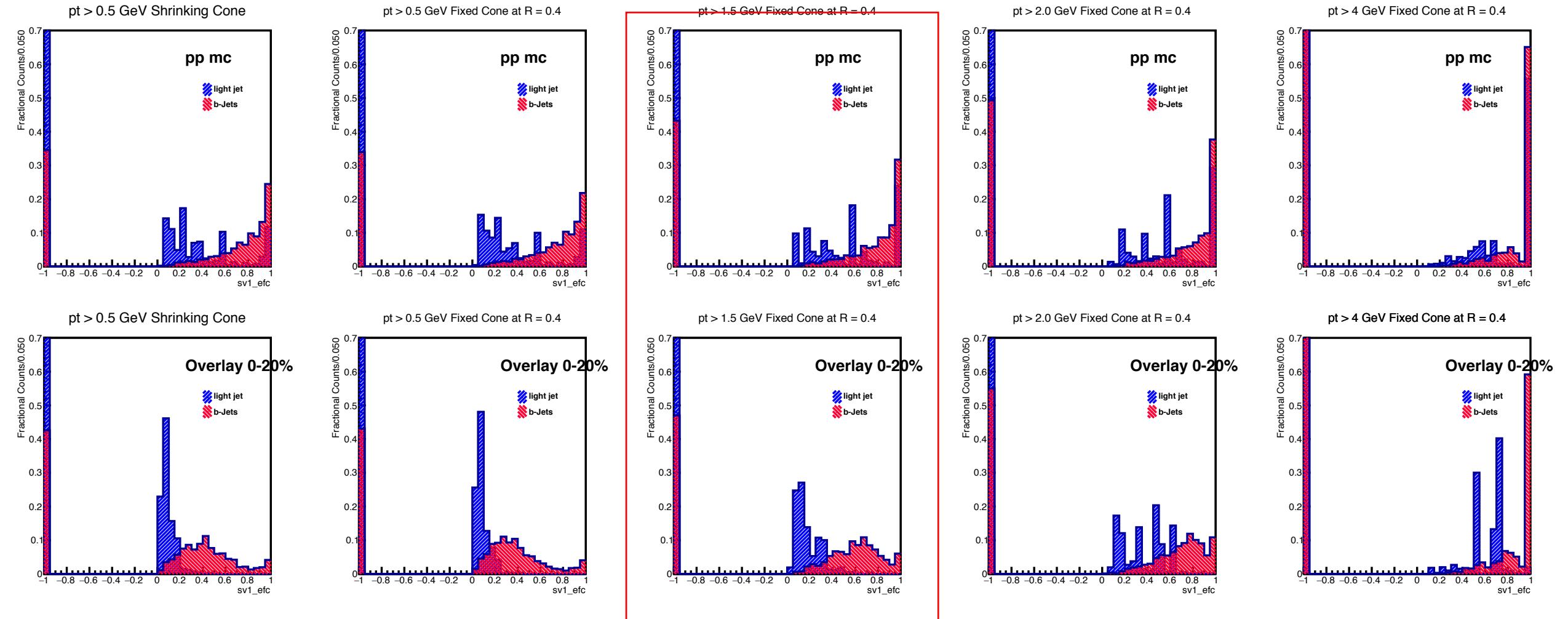
- Before applying cuts in  $p_T$ , distribution is even, possibly for combinatorics of UE tracks.
- Starting at 1.5 GeV or above, overlay have a similar distribution as pp.

# SV Variables at Default Setup



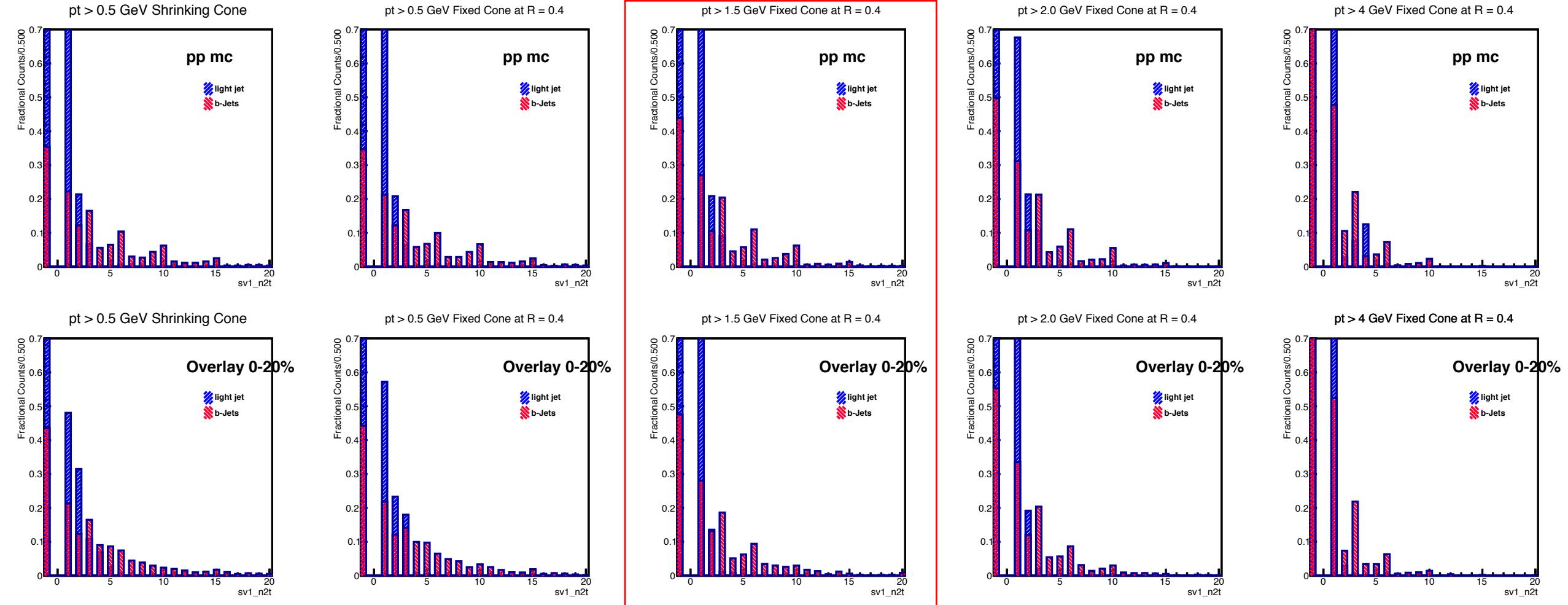
- Energy fraction and number of 2-track vertices are heavily modified.
- Peak at 1 is due to missing tracks. See back up slide 18.

# SV Energy Fraction



- Visually speaking, light and b-jets distributions are the most different/separated when cutting at 1.5 GeV
- Over cutting or under cutting right-shift/left-shift both distributions.

# SV n2t (2-trk vertices candidates)



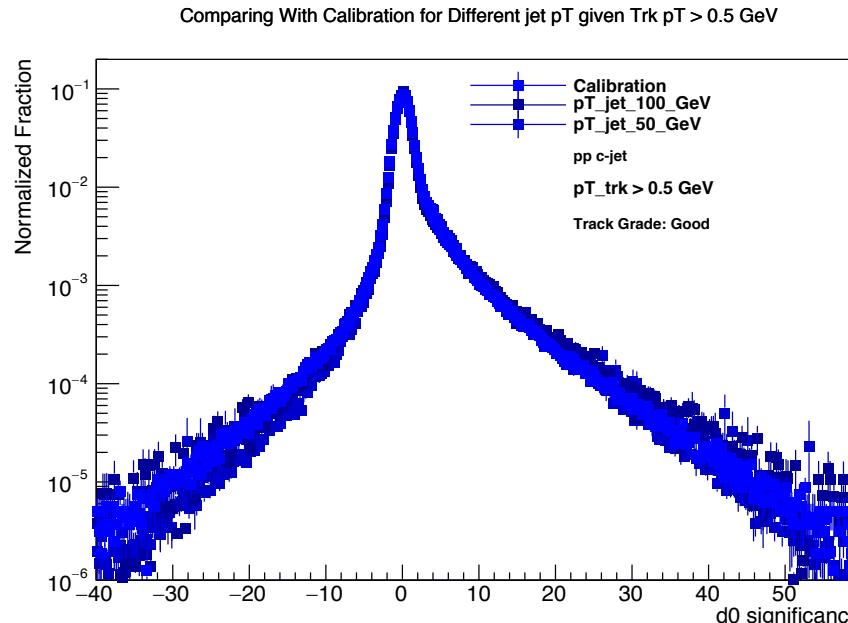
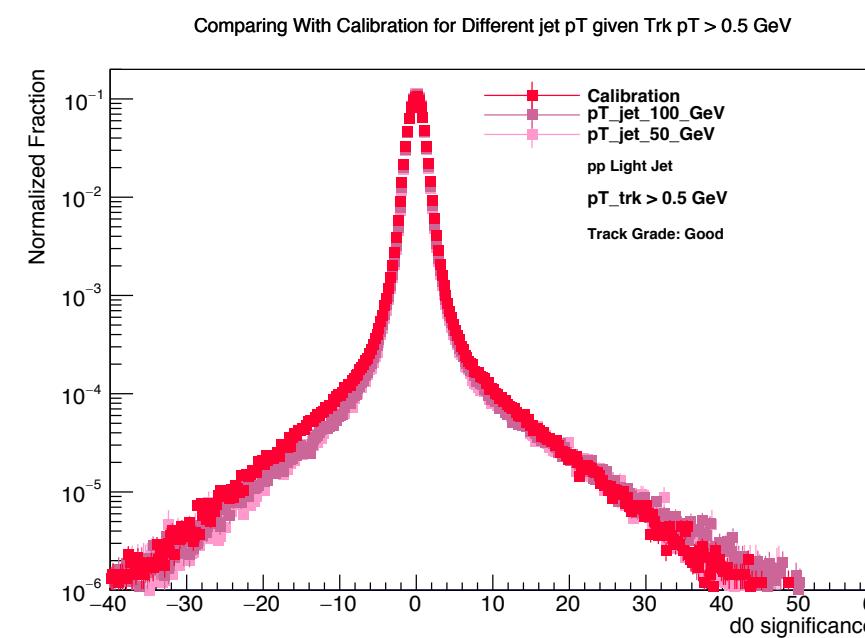
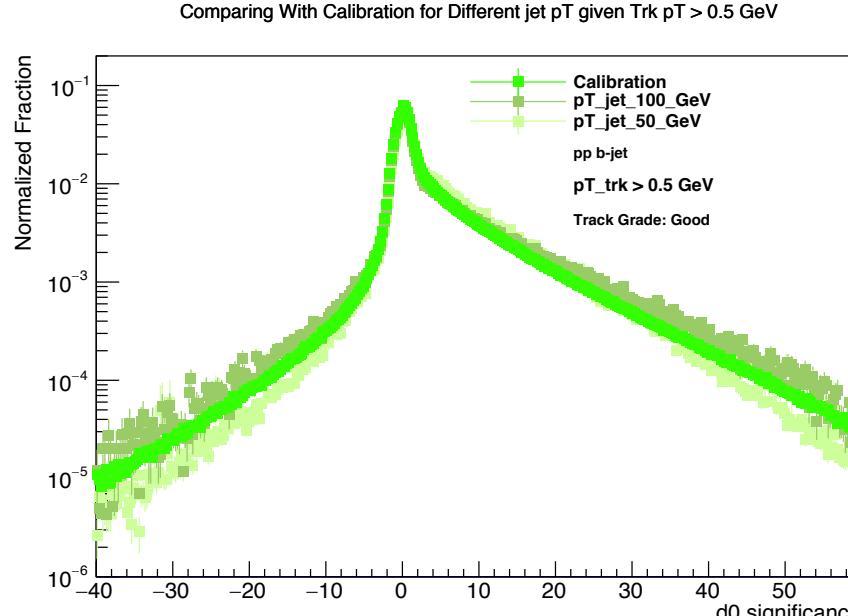
- 1.5 GeV or above cuts reduces light jet candidates in overlay to 1 or 0

↑ overcutting  
removes too many b-jets candidates as well

# IP3D Templates Remaking

- Made templates with 8M inclusive dijet samples
- Jets selection:
  - $pT > 50 \text{ GeV}$ ;  $100 \text{ GeV}$
  - Truth matched
  - Rapidity  $< 2.1$
  - JVT (Jet Vertex Tagger)\* score related requirements disabled (pile up is irrelevant)
- Flavour Labelling in templates:
  - `jet_LabDr_HadF` branch in the ntuple
  - based on  $dR < 0.3$ , requiring min hadron  $pT > 5 \text{ GeV}$ , implemented in ParticleJetTools.
- Retraining: make new templates with 8M sample and use these templates for evaluating the same MC.

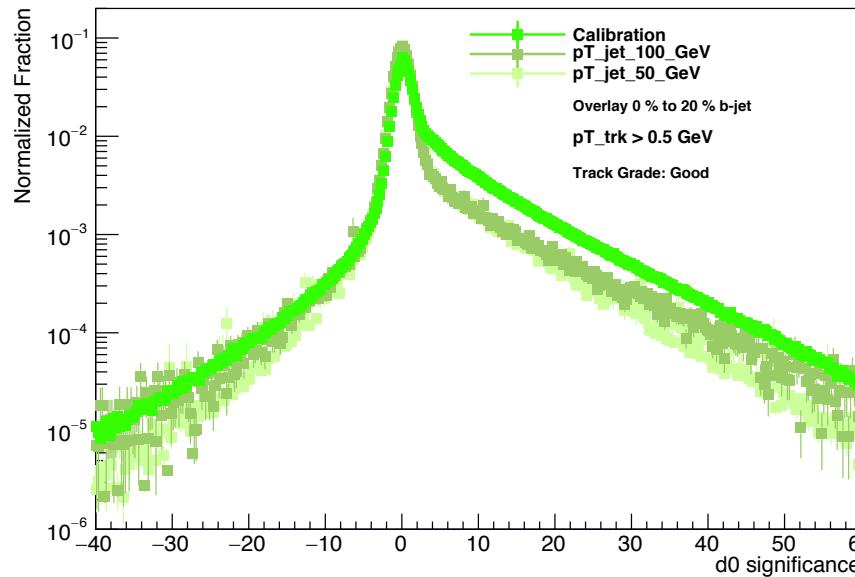
# pp comparison to calibration templates d0 sig



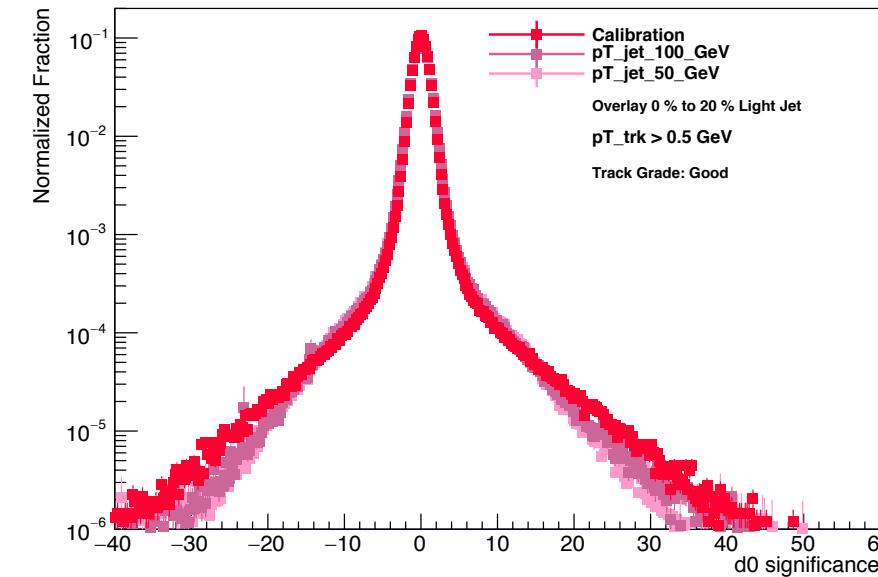
To do: ratio plots

# PbPb comparison to calibration templates d0 sig

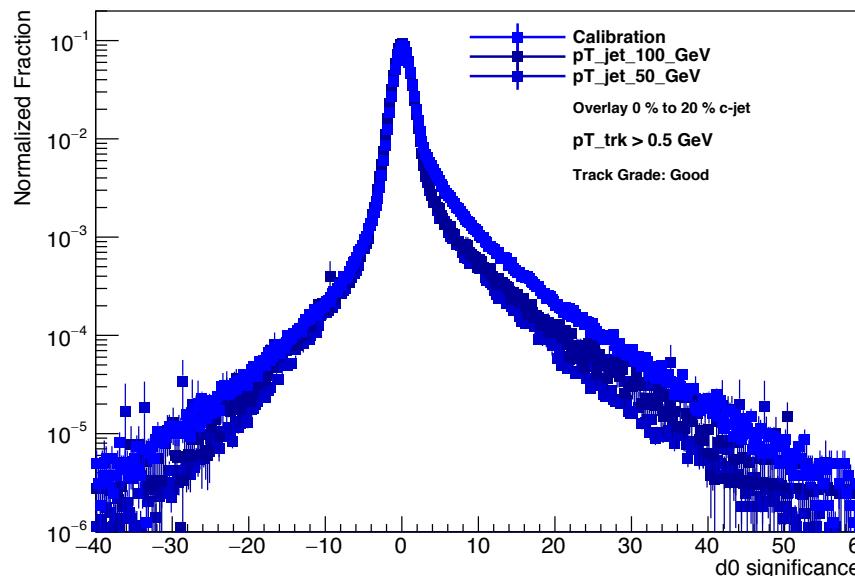
Comparing With Calibration for Different jet pT given Trk pT > 0.5 GeV



Comparing With Calibration for Different jet pT given Trk pT > 0.5 GeV



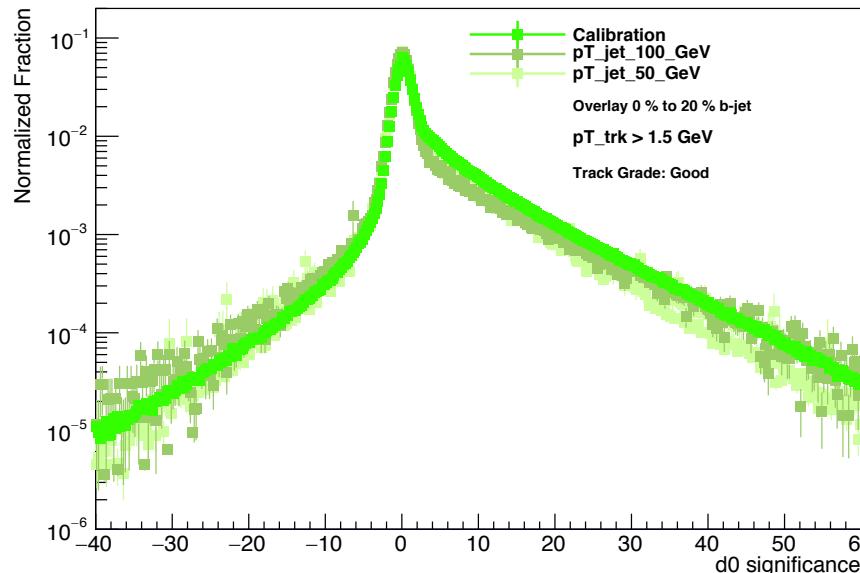
Comparing With Calibration for Different jet pT given Trk pT > 0.5 GeV



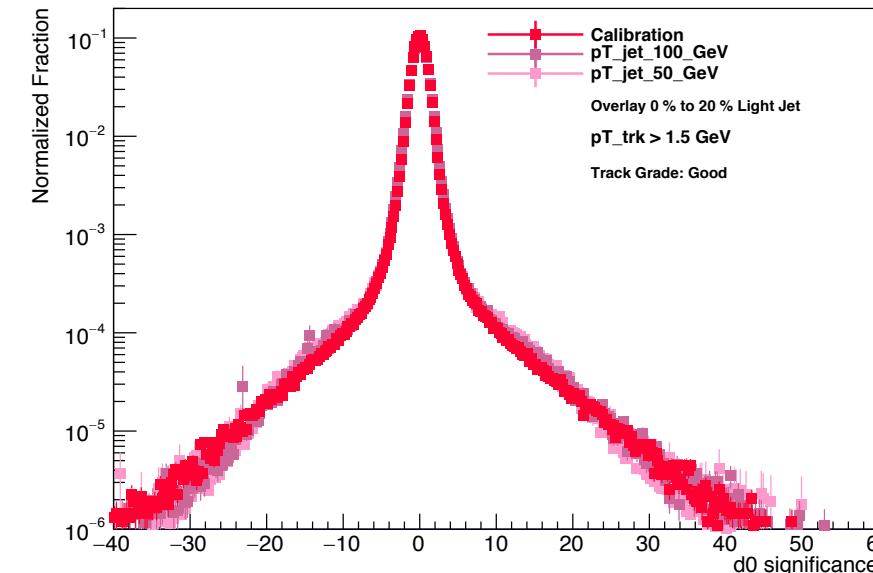
PbPb have a sharper peak in comparison.  
These plots have no cuts applied.  
To do: ratio plots

# PbPb comparison to calibration templates d0 sig

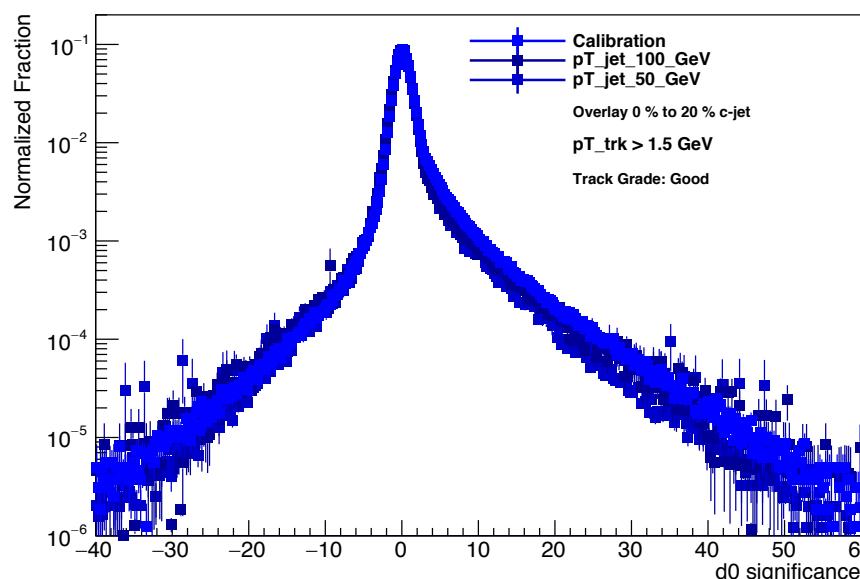
Comparing With Calibration for Different jet pT given Trk pT > 1.5 GeV



Comparing With Calibration for Different jet pT given Trk pT > 1.5 GeV



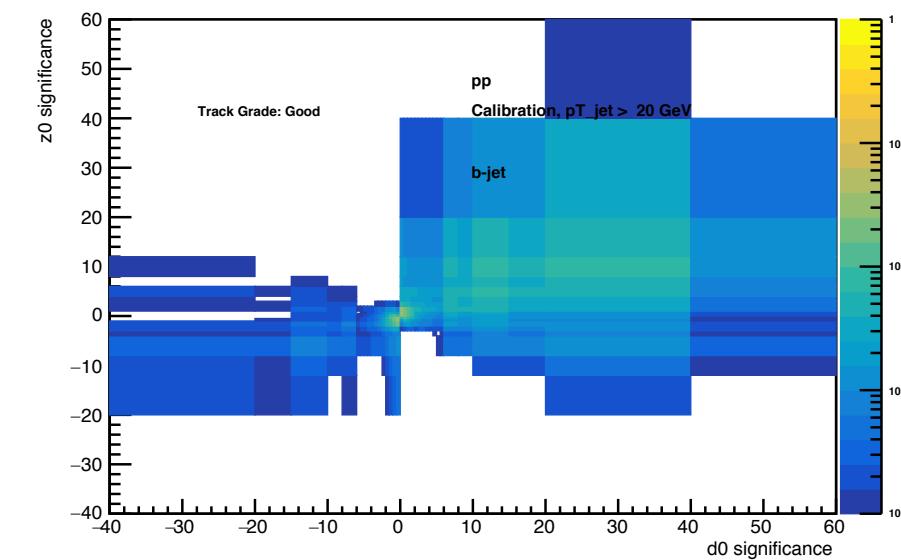
Comparing With Calibration for Different jet pT given Trk pT > 1.5 GeV



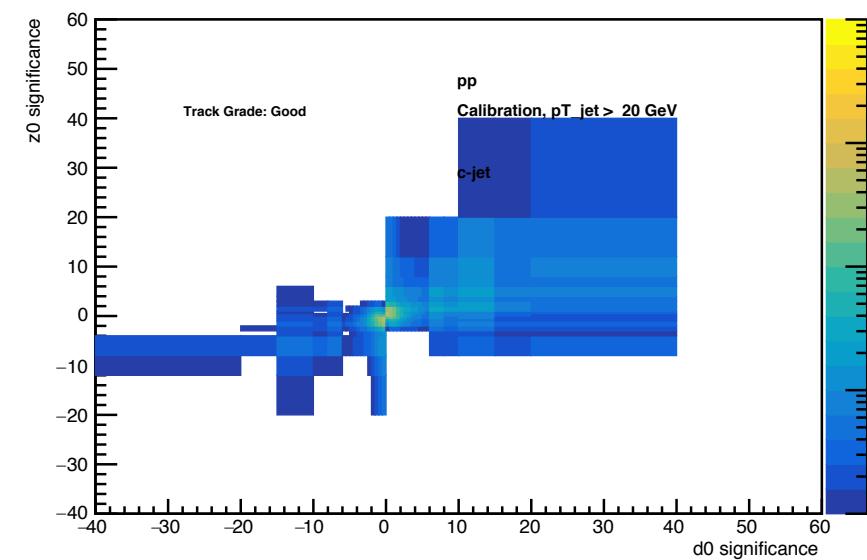
To do: ratio plots

# Comparison to calibration templates 3D: calibration

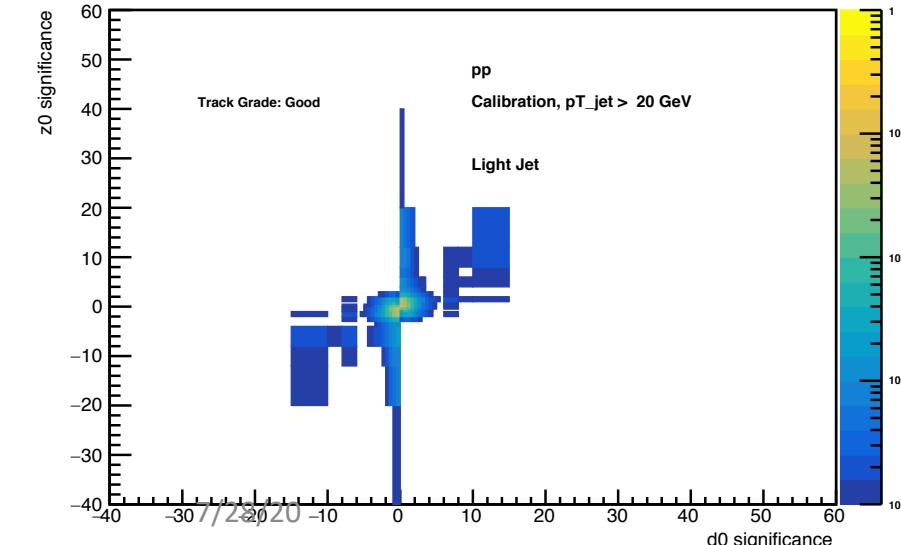
Z0 and d0 Significance Templates of pp Calibration,  $pT_{jet} > 20 \text{ GeV}$



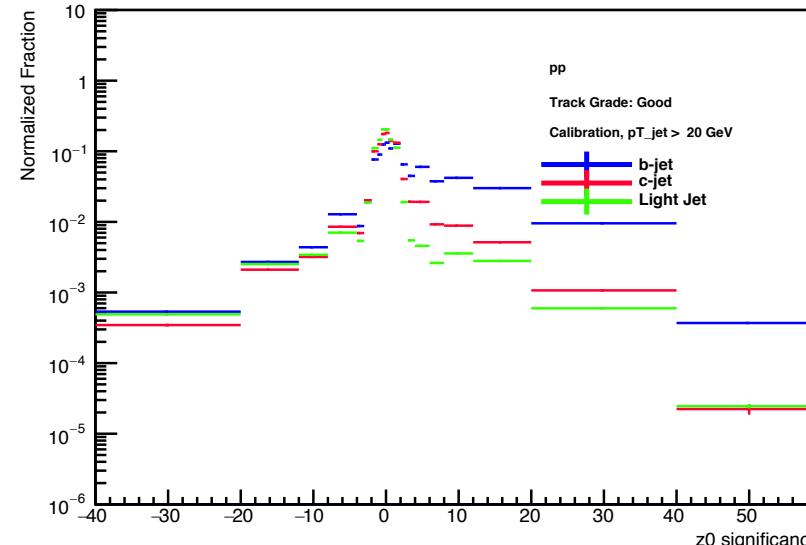
Z0 and d0 Significance Templates of pp Calibration,  $pT_{jet} > 20 \text{ GeV}$



Z0 and d0 Significance Templates of pp Calibration,  $pT_{jet} > 20 \text{ GeV}$

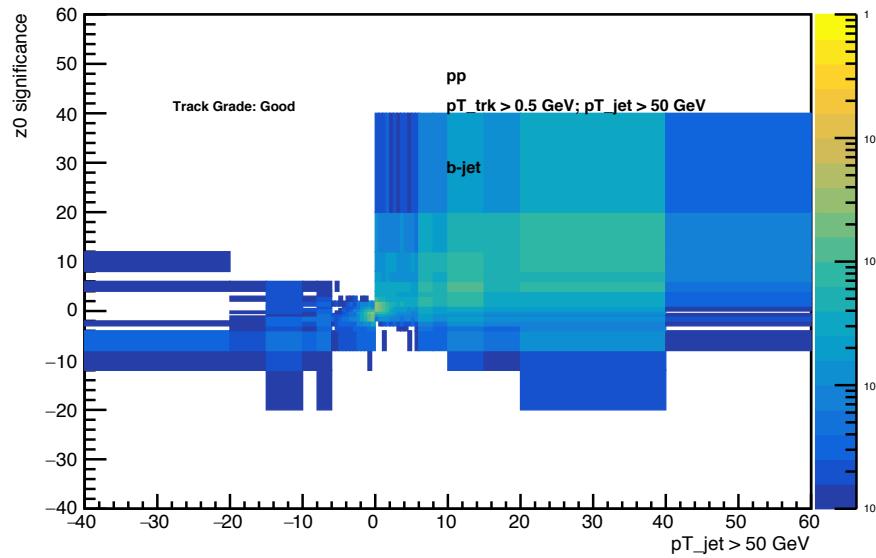


Z0 Significance Templates pp Calibration,  $pT_{jet} > 20 \text{ GeV}$

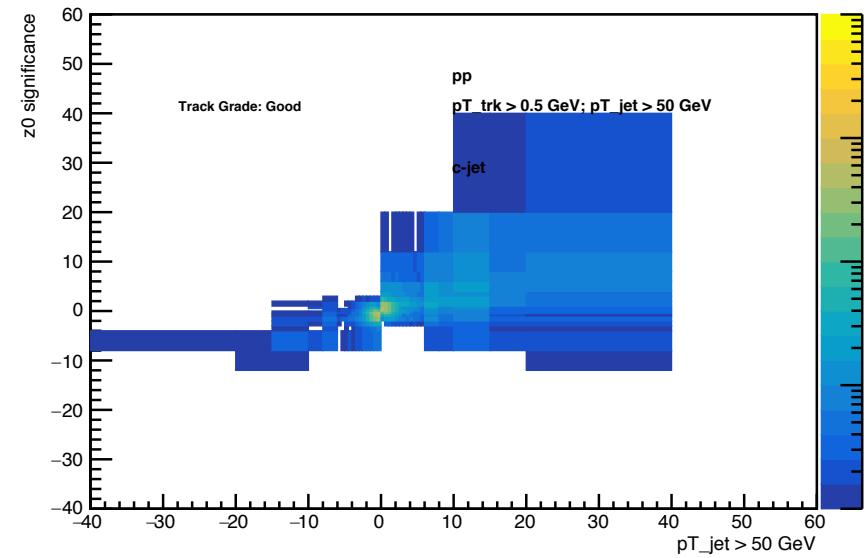


# Comparison to calibration templates 3D: inclusive pp

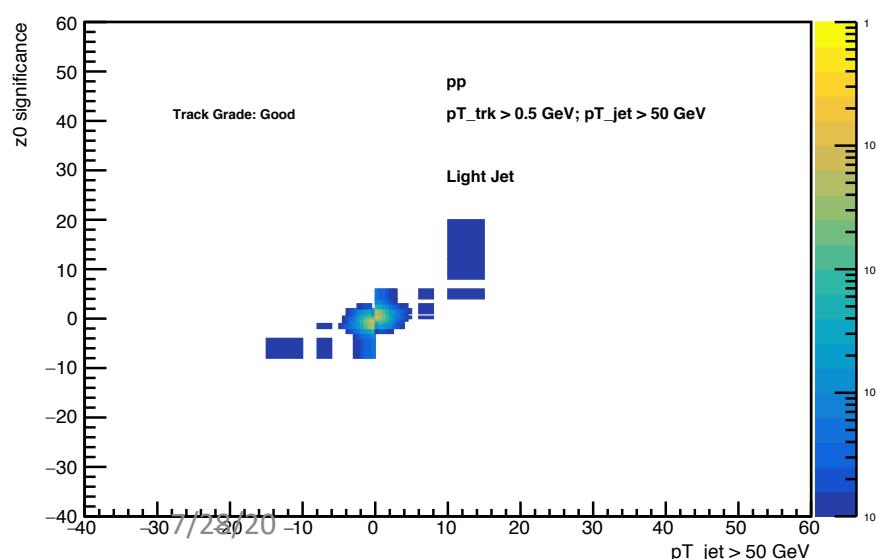
Z0 and d0 Significance Templates of pp  $pT_{trk} > 0.5$  GeV



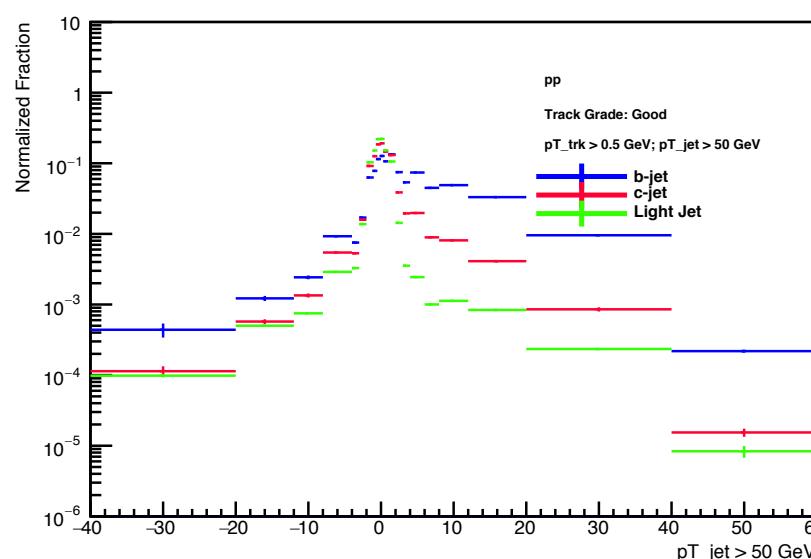
Z0 and d0 Significance Templates of pp  $pT_{trk} > 0.5$  GeV



Z0 and d0 Significance Templates of pp  $pT_{trk} > 0.5$  GeV



Z0 Significance Templates pp  $pT_{trk} > 0.5$  GeV

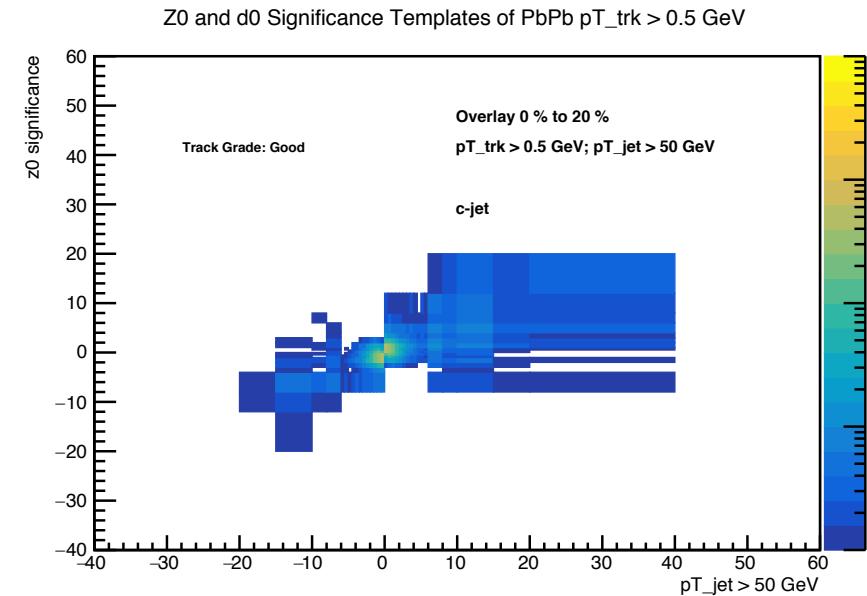
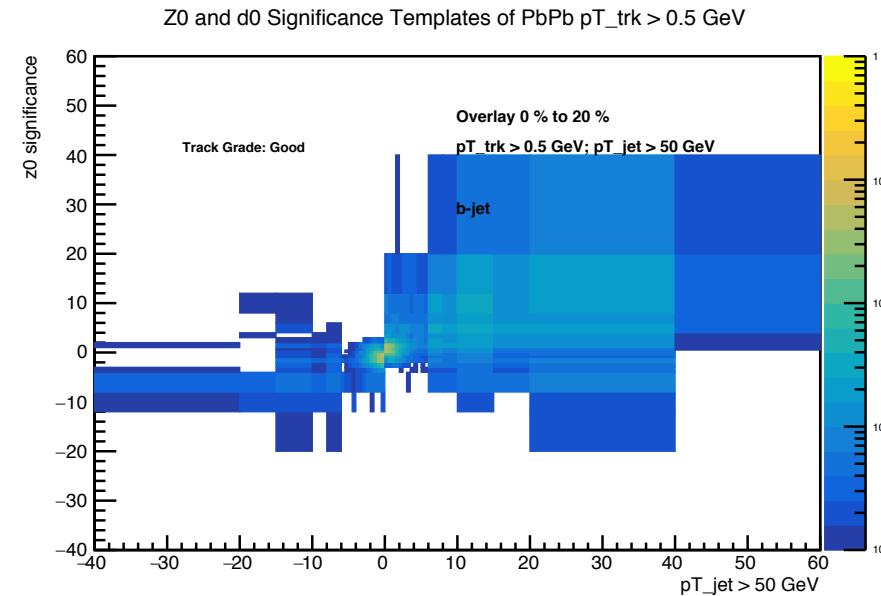


Less well populated in high Z0 bins, for all three flavors.

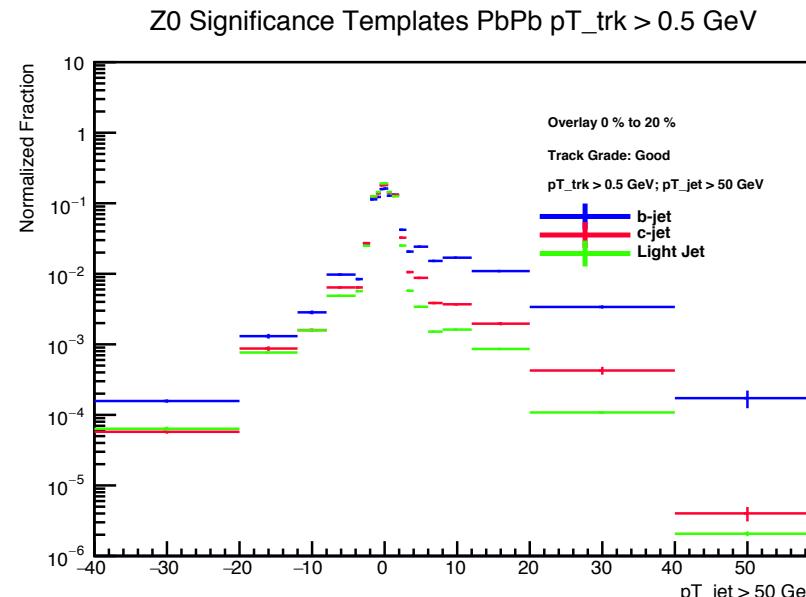
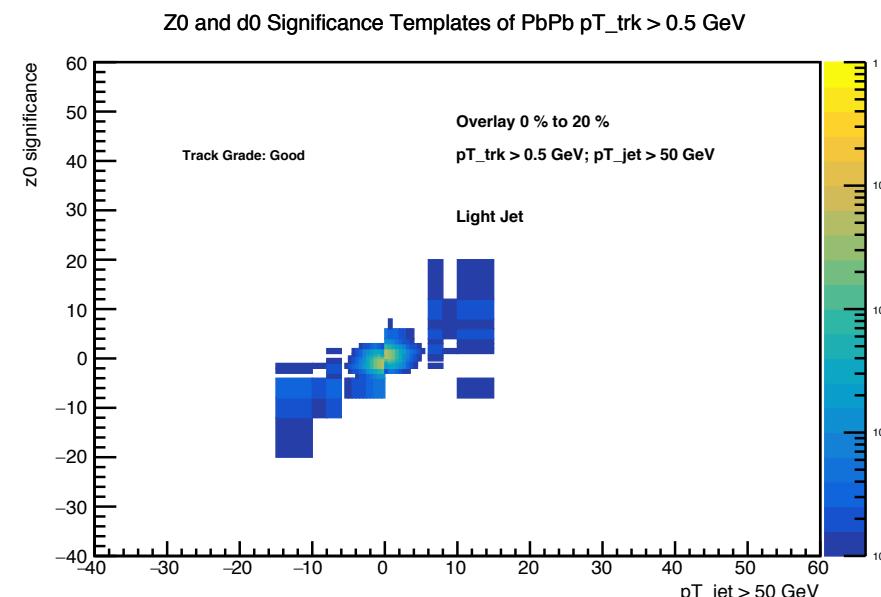
Plots are normalized to 1 since calibration was made with data.

- What data? (tag just says "run2")

# Comparison to calibration templates 3D: central PbPb

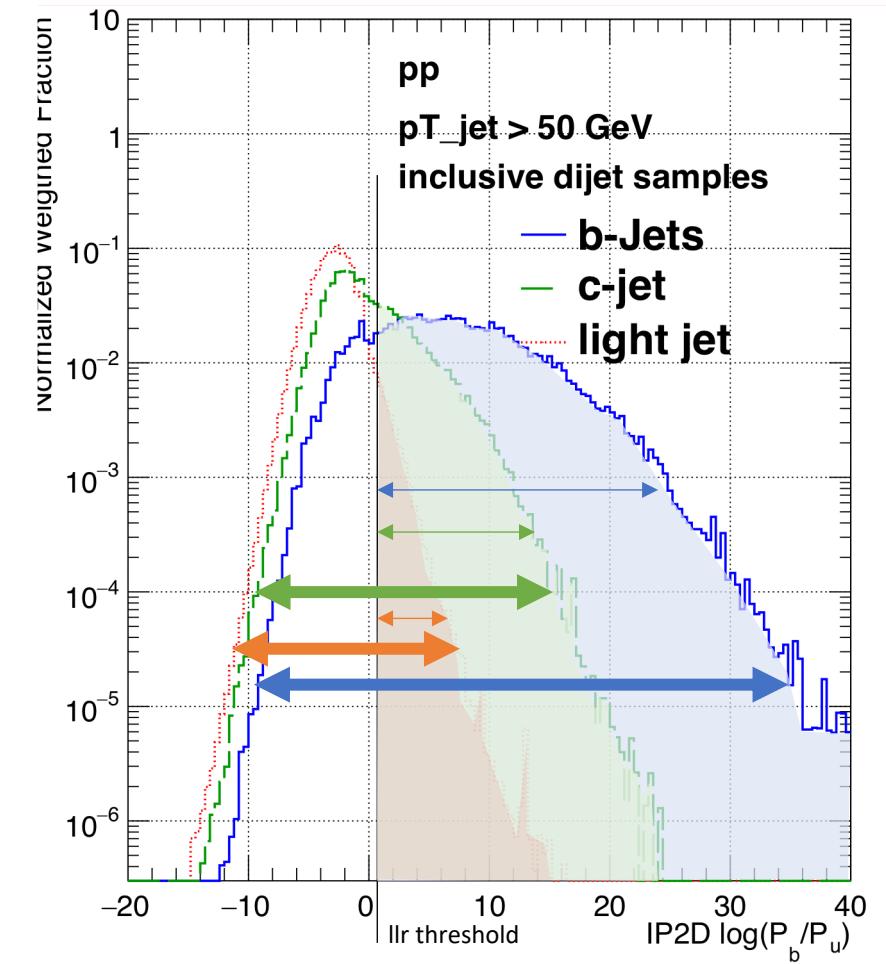


Better populated in light  
than pp, less well in b and  
c.

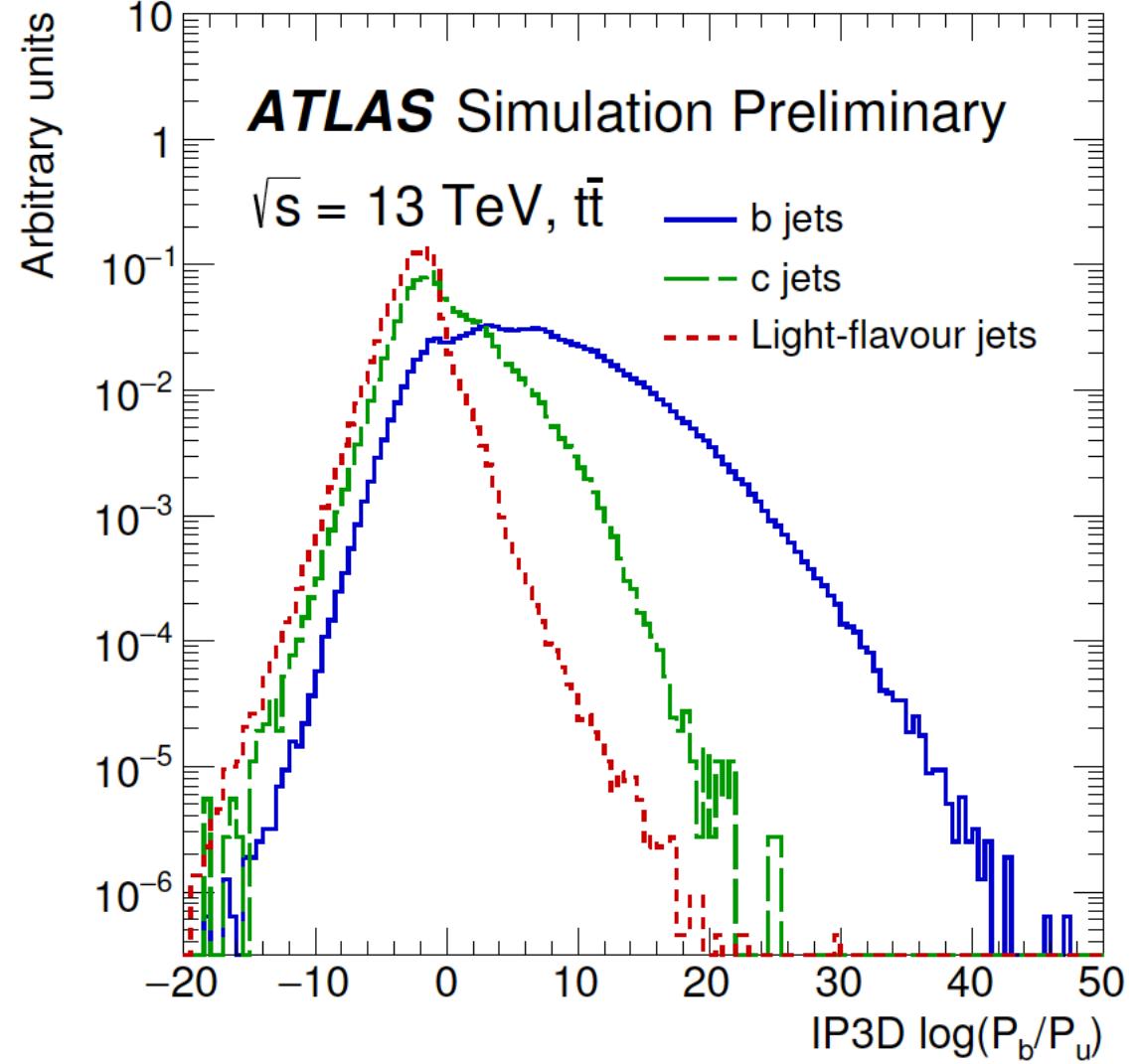
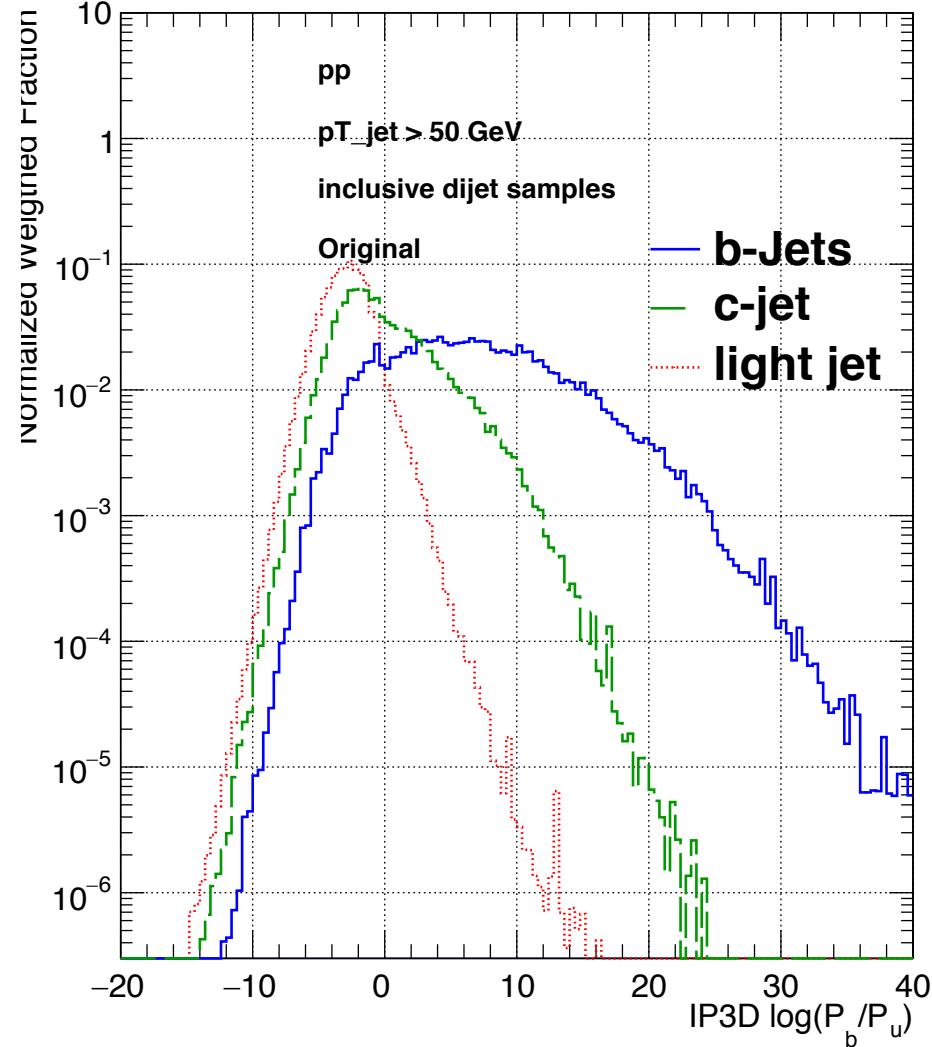


# LogLikelihood Plot for $(p_b/p_u)$

- $\log_{(\frac{P_b}{P_u})}^{jet} = \sum \log_{(\frac{P_b}{P_u})}^{trk}$  for qualified tracks,  $P_b$  and  $P_u$  are extracted from corresponding 3D templates based on track quality.
- $P_{flav}$  = template bin content/template integral.
- To make each point of the ROC curve:
  - Set a threshold, integrate from threshold rightward.
  - Divide the integral/total integration for each flavor
  - Efficiency = ratio of b-jet
  - Purity = 1/ratio of light-jet



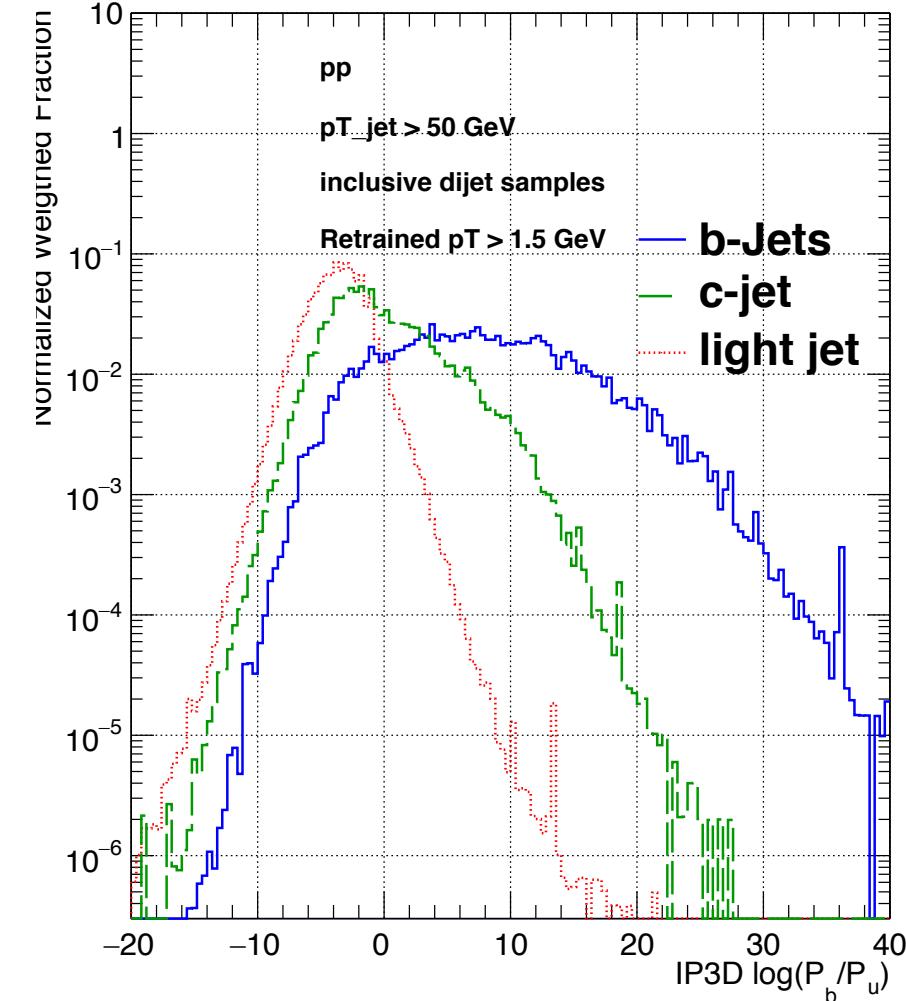
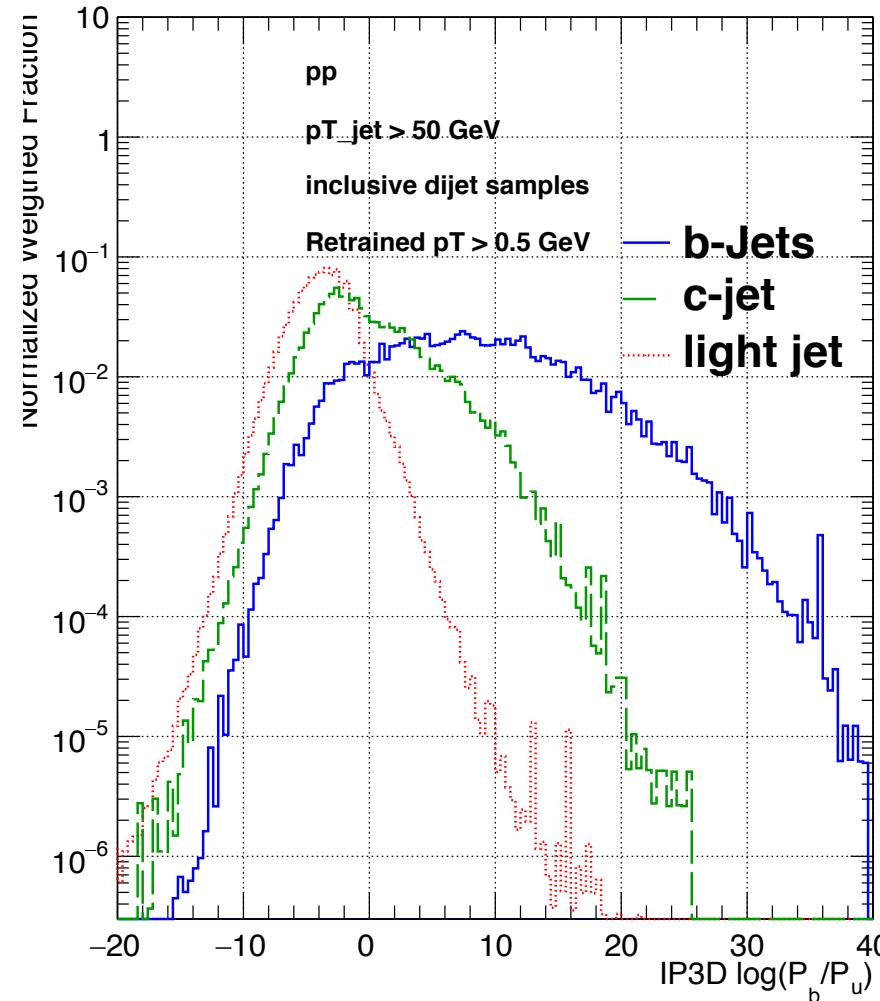
# Comparison with ttbar samples



Qualitatively similar.

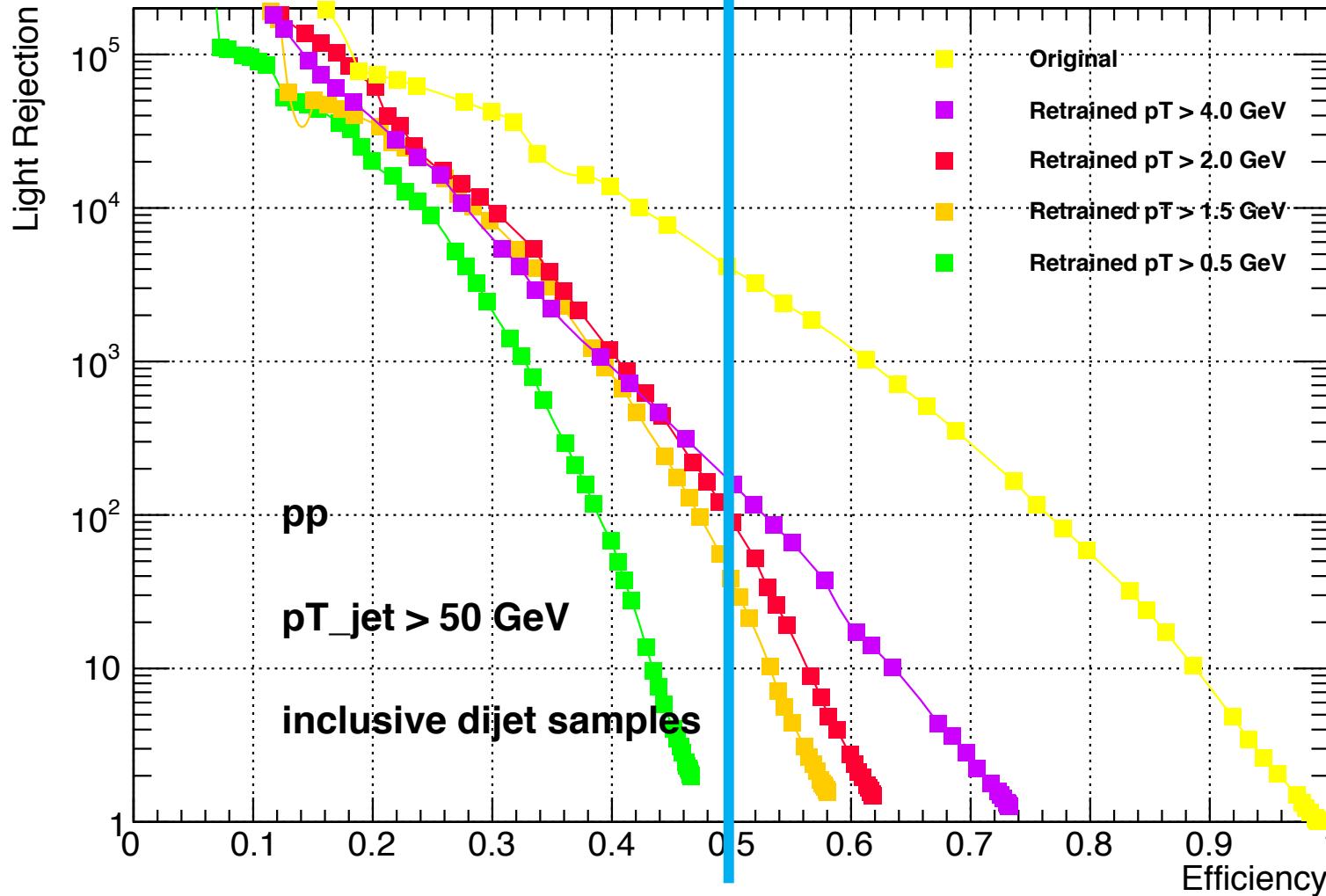
Peaks are slightly more smeared.

# Retrained IIR plots

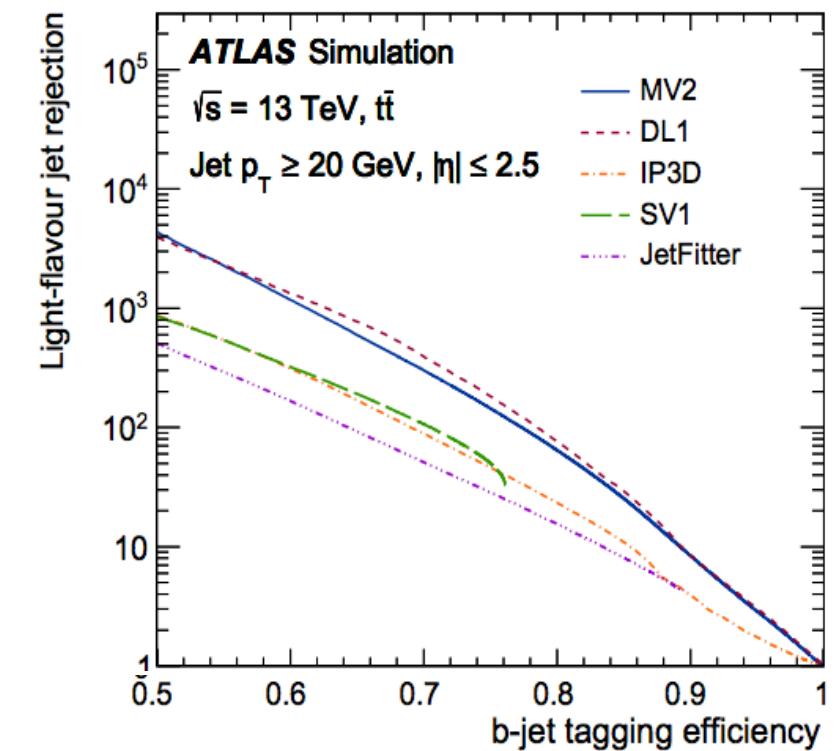


- Distribution even more smeared than using original templates.

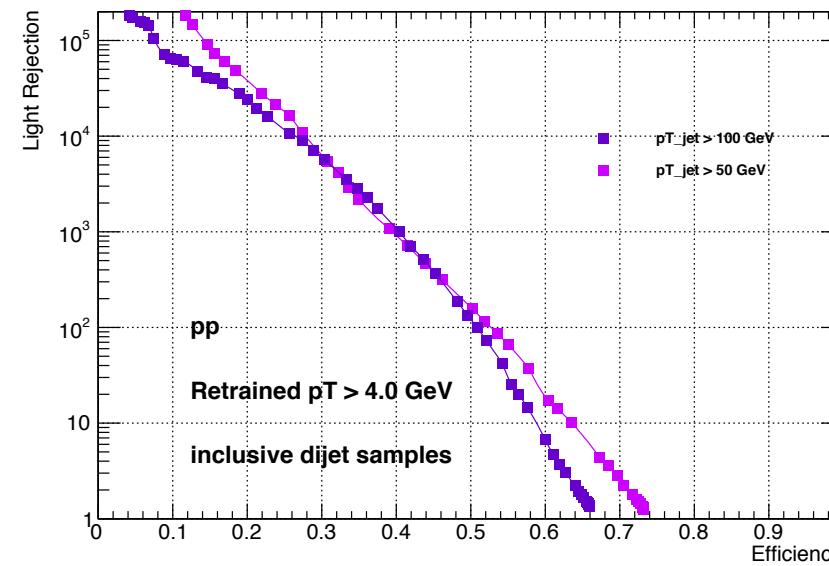
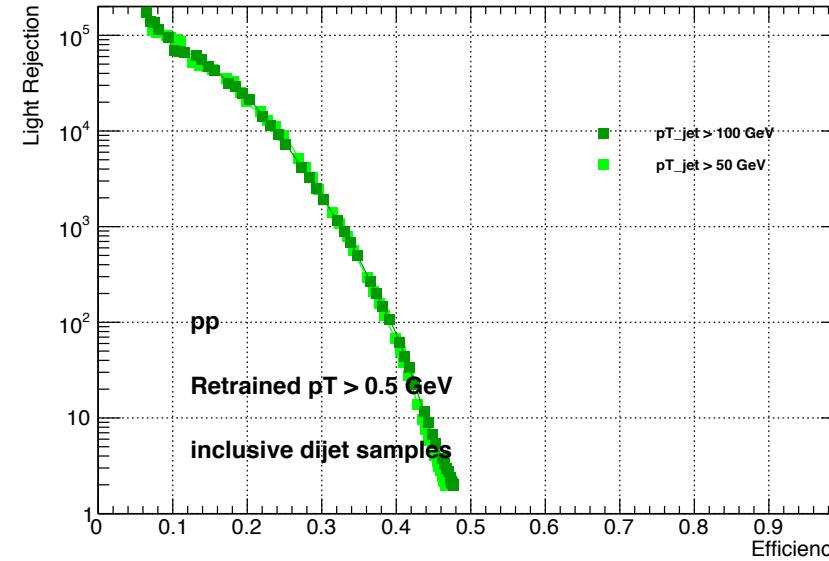
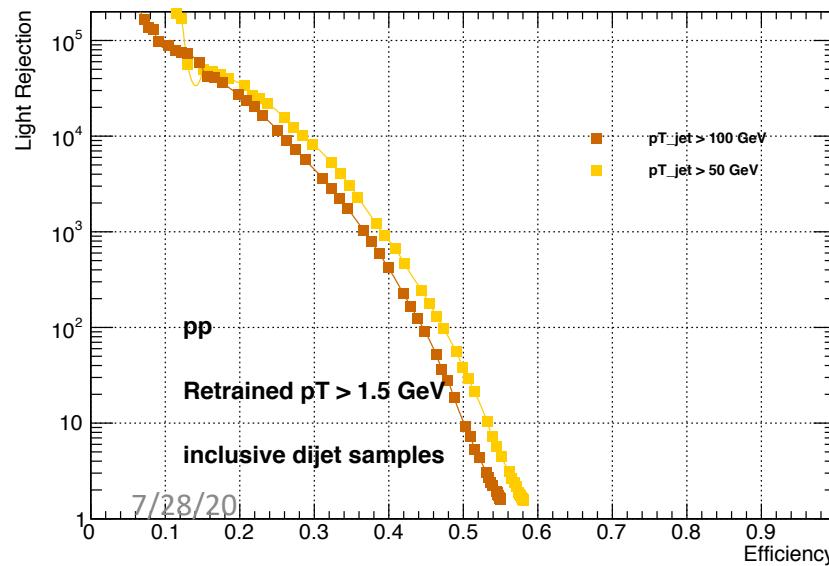
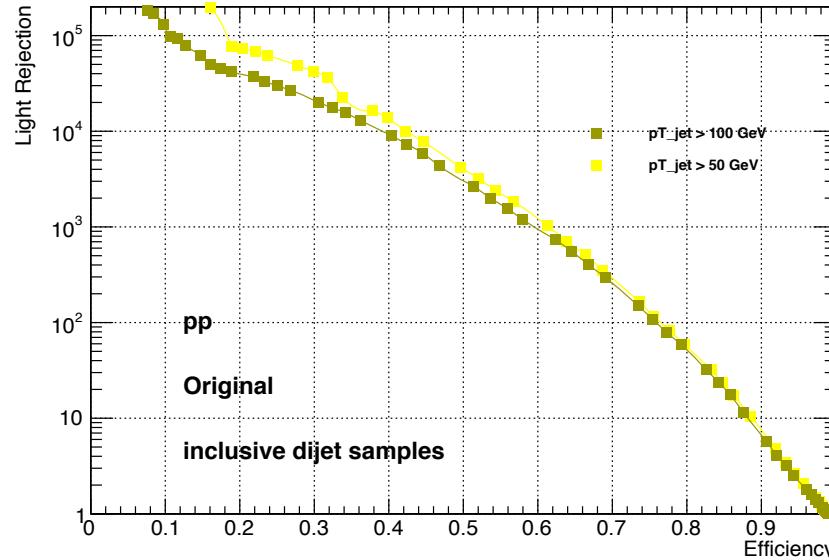
# IP3D ROC curve with pp



- Original templates have the best performance.
  - Potentially due to not well populated templates.
- With increased cuts on pT track, the performance is improved.



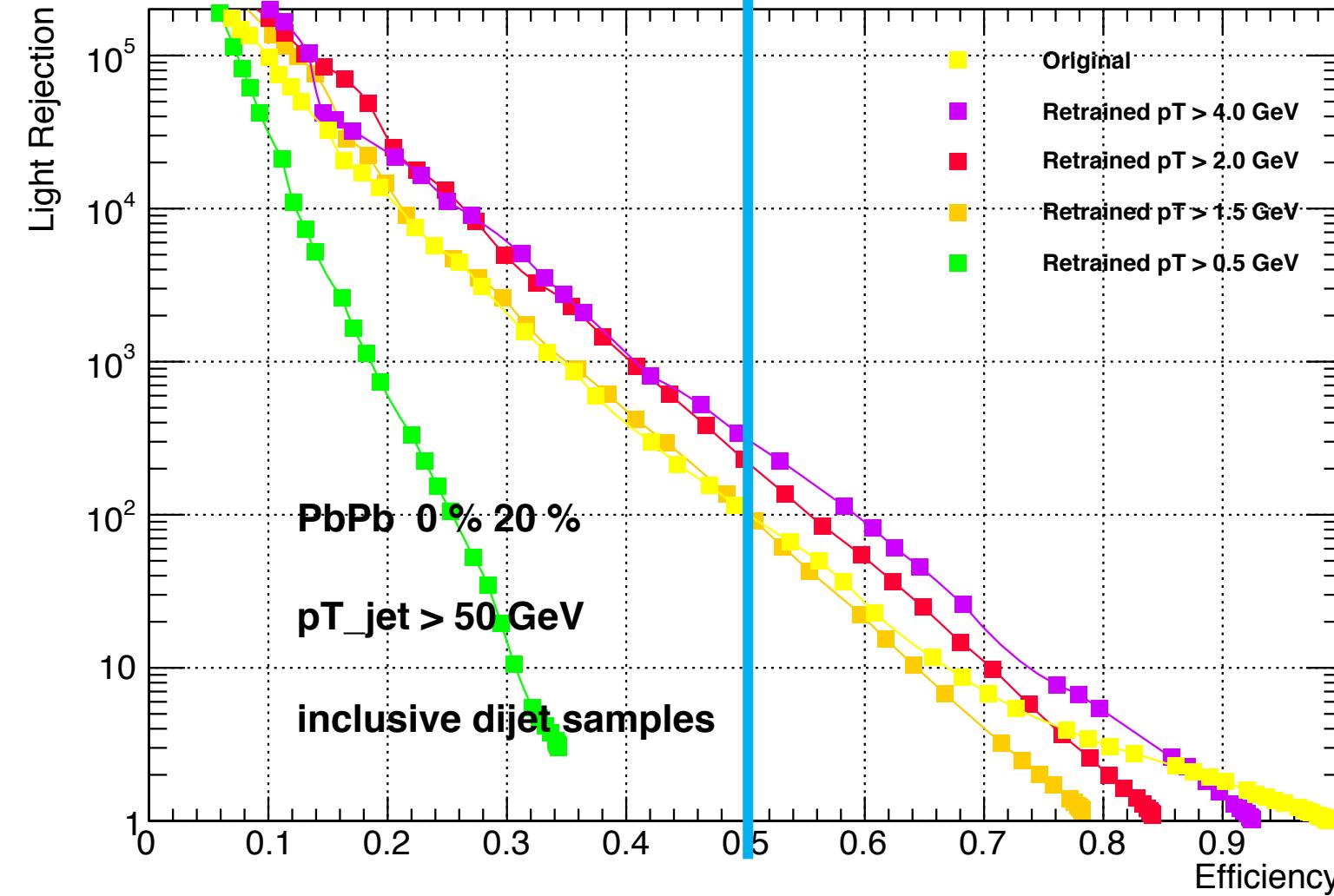
# Effects of low pT jets



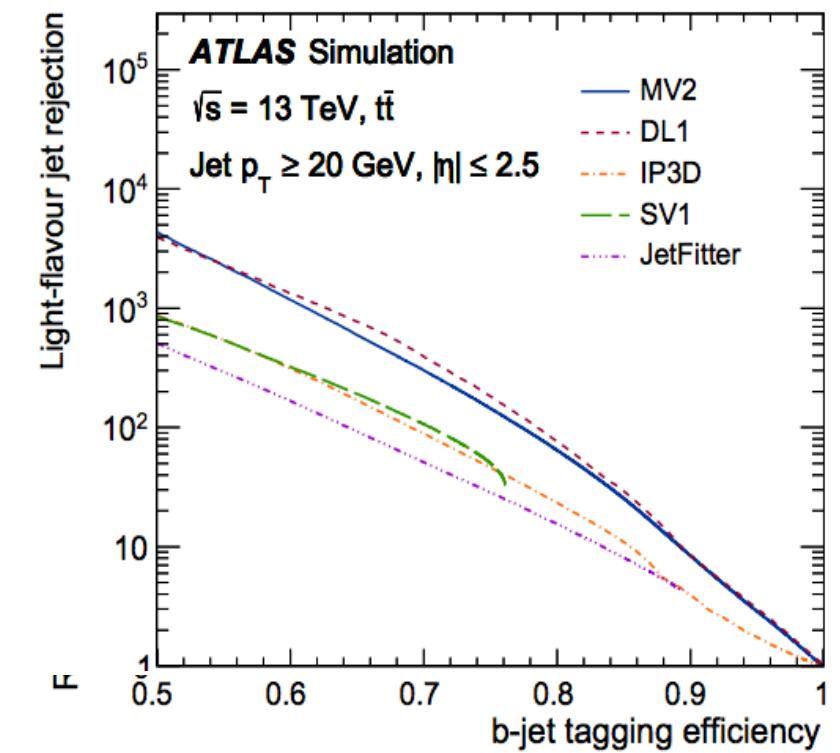
For the pp samples concerned,

- Without cuts on track pT, cutting jet pT at 100 GeV is performing marginally better
  - Possibly due to underlying effects in low pT jets
- With cuts on track pT, cutting at jet pT 50 GeV is performing slightly better than cutting at jet pT 100 GeV.

# IP3D ROC curve with PbPb



- Light rejection worse than pp
- Performance is better than original templates when using min pT cuts.



# Summary

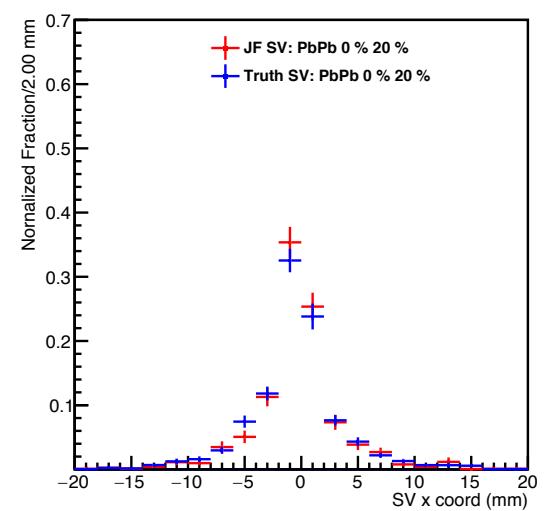
- Evaluated secondary vertexing performances of JetFitter and SVF
  - Motivated by unknown track-in-jet distribution, used fixed cone at  $R = 0.4$
  - Requiring minimum  $pT$  reduces centrality dependence.
- Comparing heavily modified physics variables, cutting  $pT$  at  $1.5 \text{ GeV}/2.0 \text{ GeV}$  starts to assimilates overlay to pp MC.
  - Question: how to choose the right cut combining everything?
- IP3D for pp shows worse performance with re-training, and improved performance with retraining for PbPb.
  - Templates are less well populated than calibration plots.
    - Are there better templates?
  - PbPb performance improves when  $pT$  cuts are applied.
- Plan:
  - review JetFitter and SVF performance with inclusive dijet MC.
  - Write-up for what has been done.

# Back up

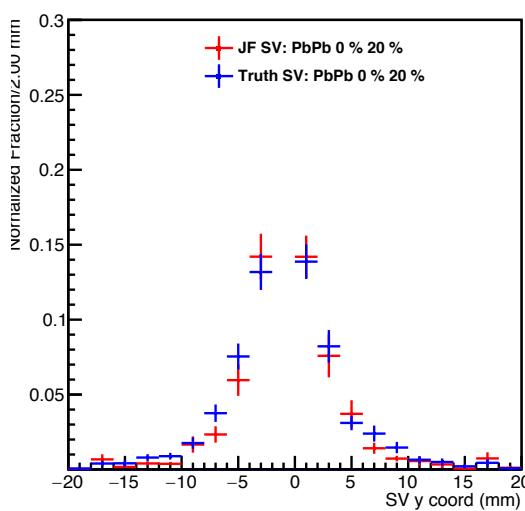
# Secondary Vertexing Resolution with JetFitter

Default JF Setup; No Selection on Input Tracks; Shrinking Cone

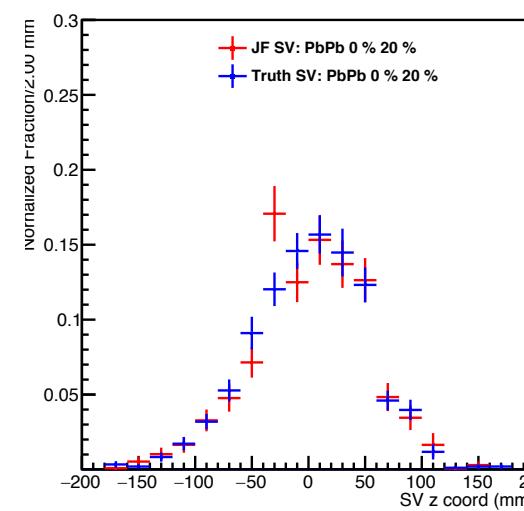
x Coordinate of JF Secondary Vertex



y Coordinate of JF Secondary Vertex



z Coordinate of JF Secondary Vertex

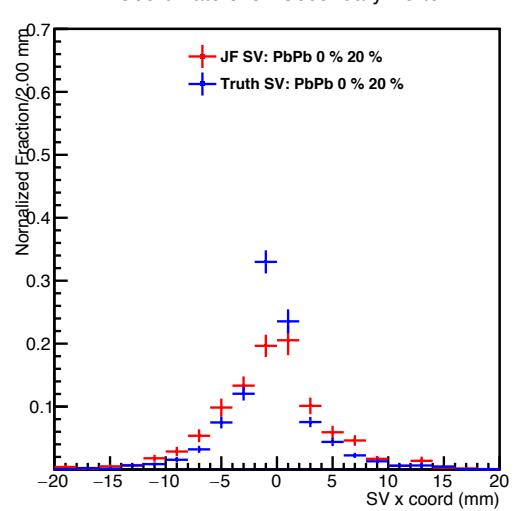


No big change in secondary vertex resolution, reconstructed SV coordinates have similar distribution with truth SV.

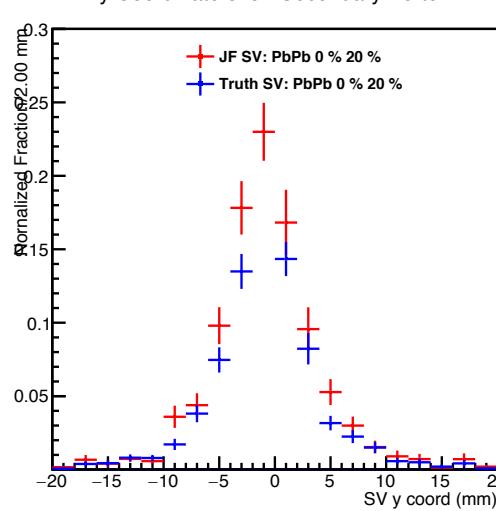
*Plan: plot coordinate difference and fit for quantitative comparison.*

Default JF Setup (anti PU off); Loose Selection on TrackAssociation; Min pT = 1.5 GeV; Fixed Cone at 0.4

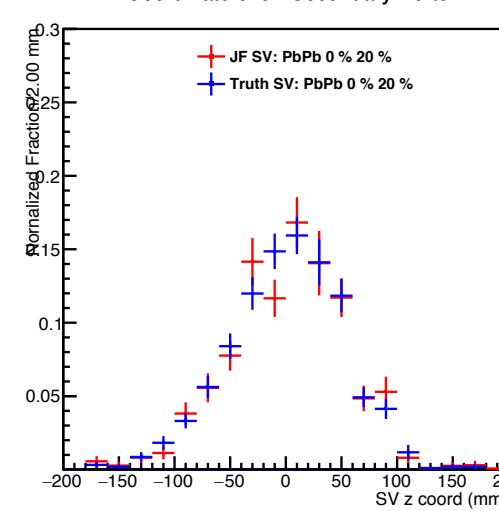
x Coordinate of JF Secondary Vertex



y Coordinate of JF Secondary Vertex

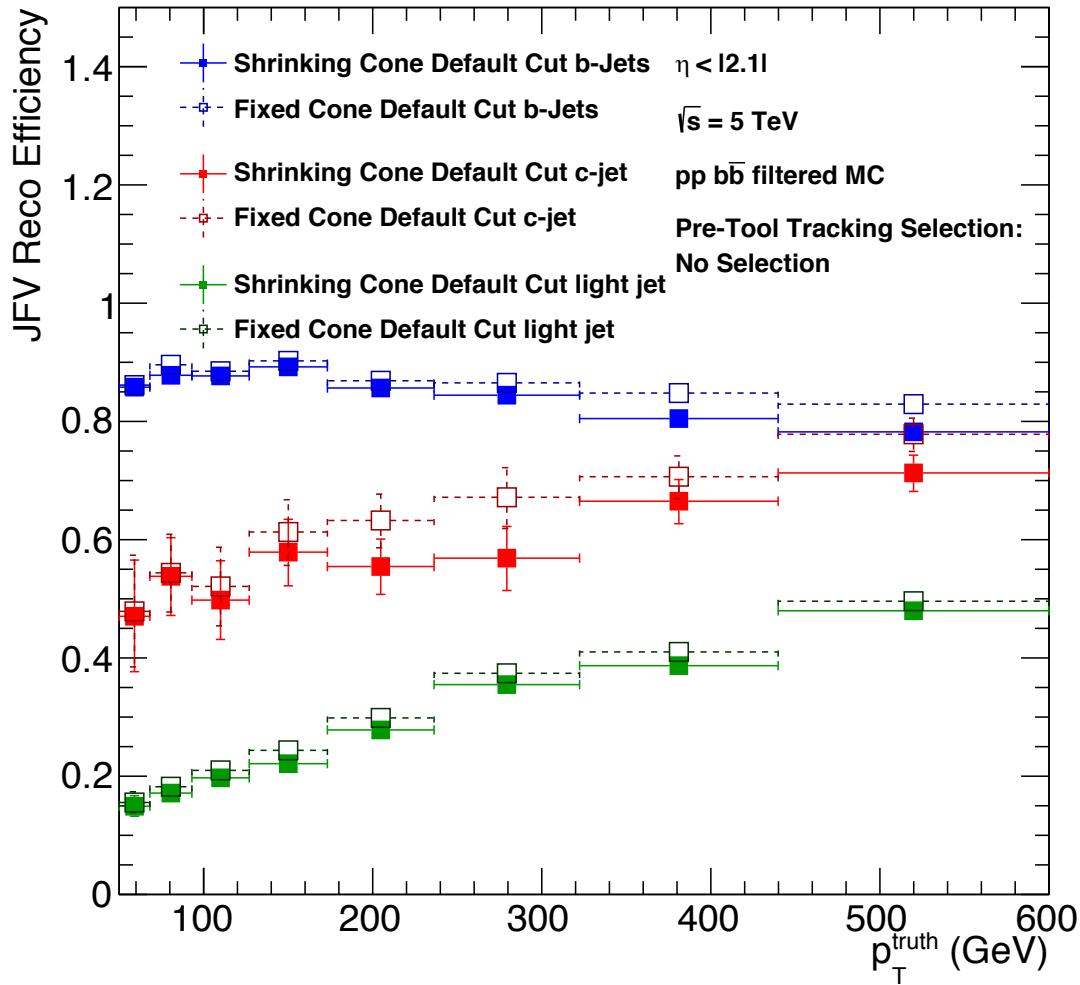


z Coordinate of JF Secondary Vertex



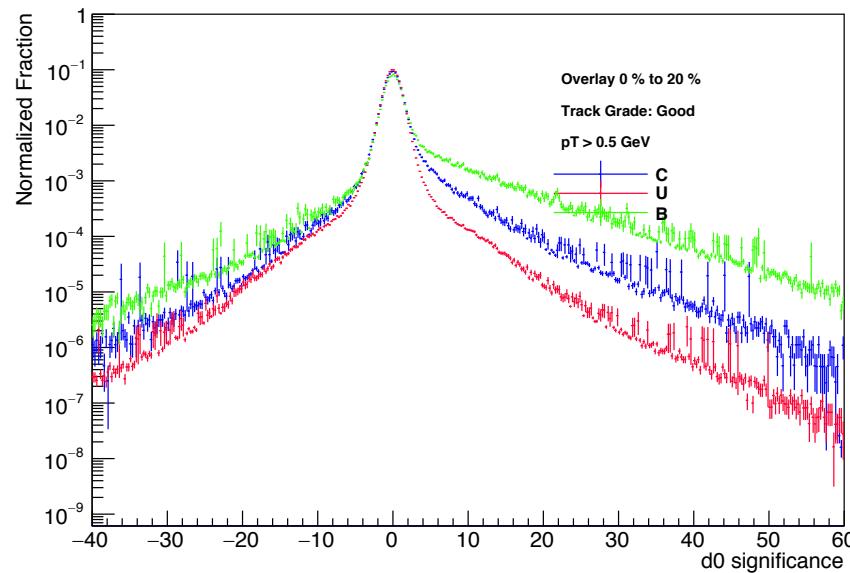
# Only Fixed Cone's effects

JFV Reco Efficiency for Different Flavors of Jets in pp MC

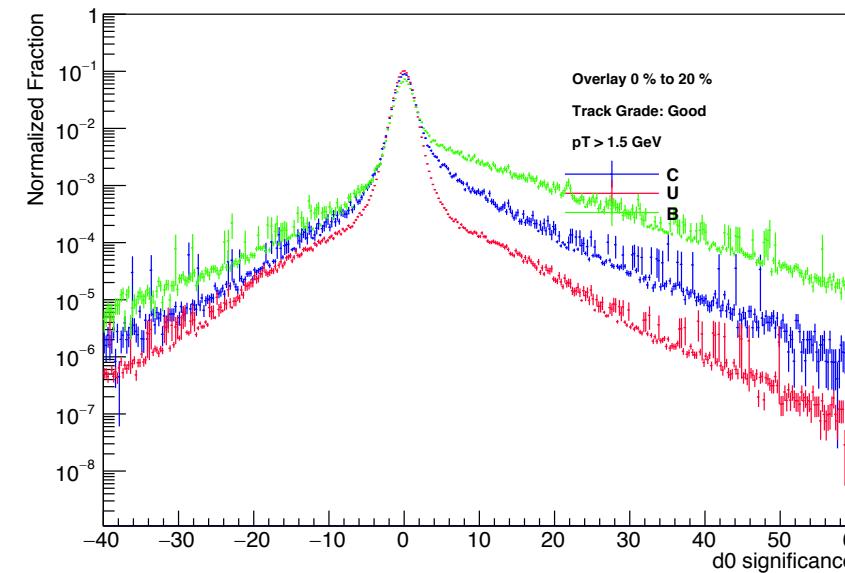


# New Templates Making

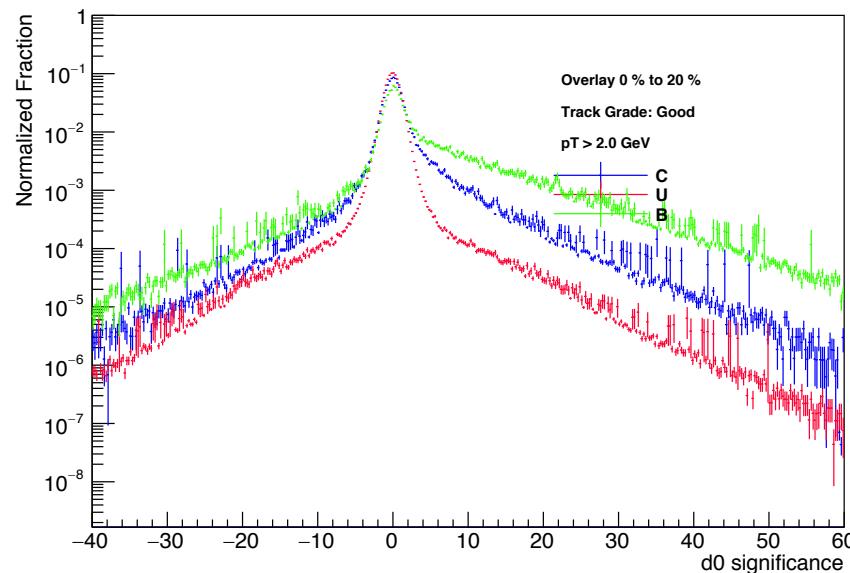
D0 Significance Templates PbPb pT > 0.5 GeV



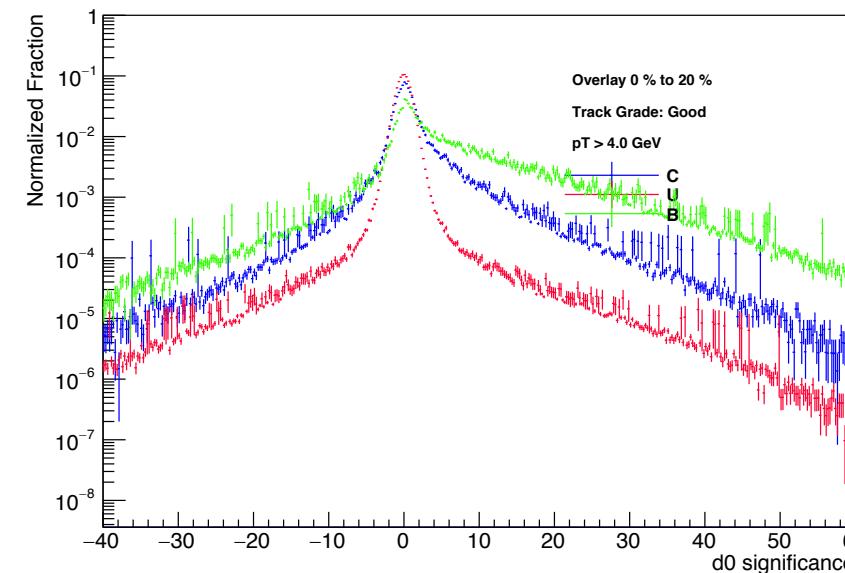
D0 Significance Templates PbPb pT > 1.5 GeV



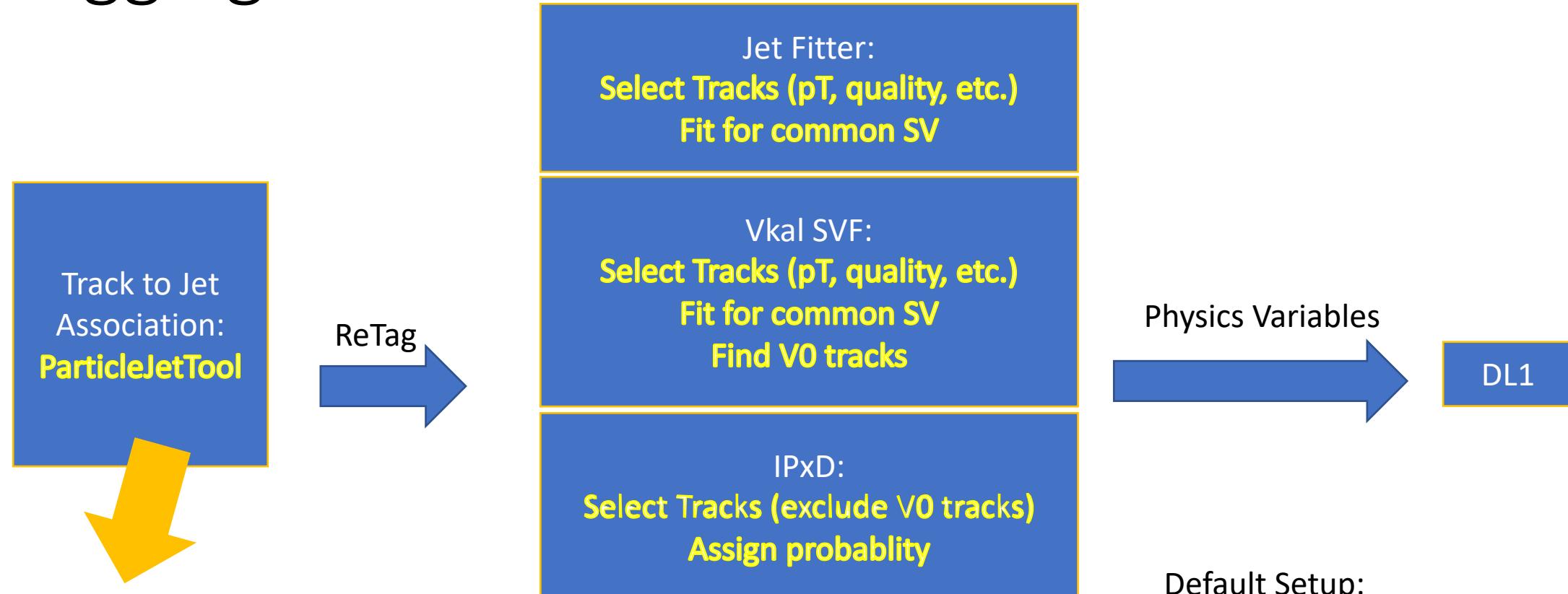
D0 Significance Templates PbPb pT > 2.0 GeV



D0 Significance Templates PbPb pT > 4.0 GeV



# B-Tagging Workflow



-track pass **TrkSelectionTool**

-associate each track to closest jet

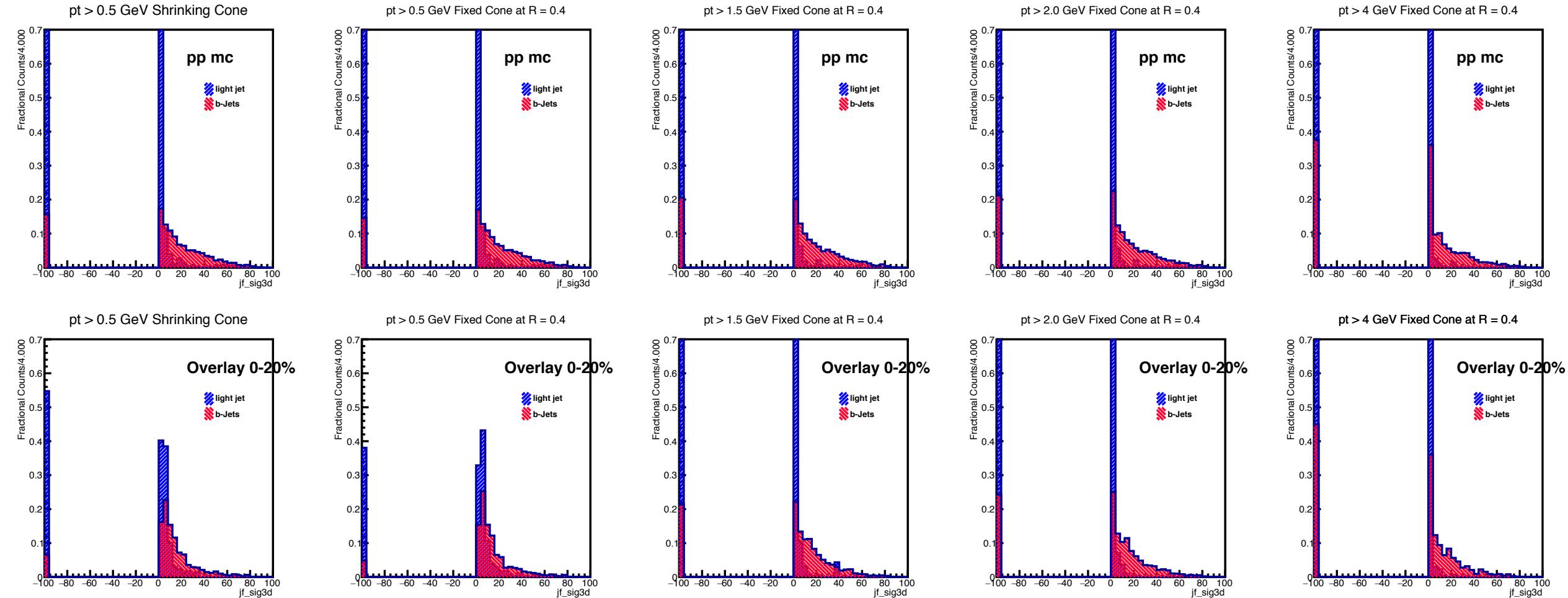
-if  $dR <$  threshold, track is associated

**Shrinking Cone:** higher jet pT, smaller the threshold  $dR$

**Fixed Cone:** threshold  $dR = 0.4$  for all jet pR

SV1

# JF sig3d (decay length significance)



Top Row: pp mc

Bottom Row: Overlay 0-20%

From left to right:

1. No pT Shrinking Cone
2. No pT Fixed Cone
3. Min pt = 1.5 GeV Fixed Cone

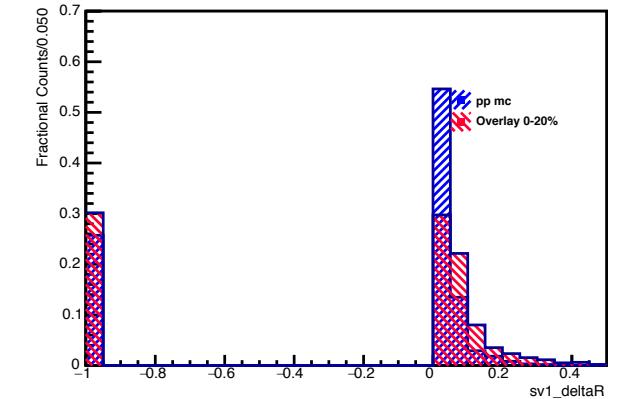
4. Min pt = 2.0 GeV Fixed Cone

5. Min pt = 4.0 GeV Fixed Cone

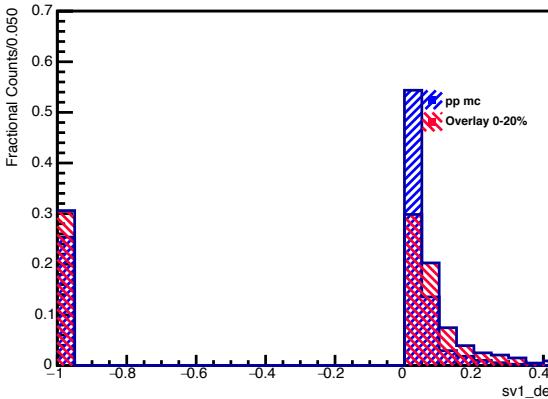
Red: b-jet

Blue: light jet

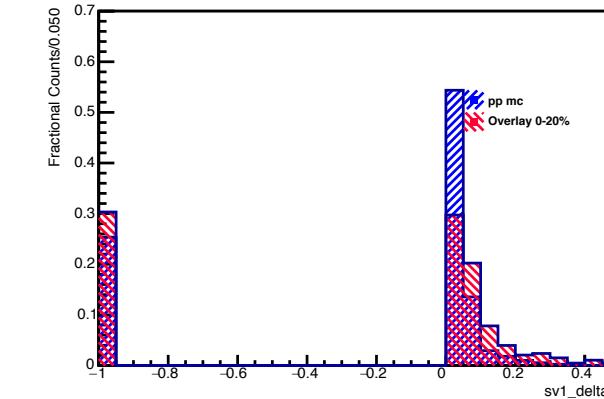
JF pt &gt; 0.5 GeV Shrinking Cone



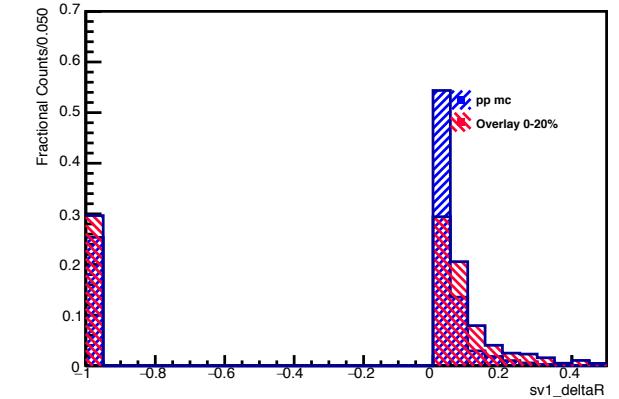
JF pt &gt; 0.5 GeV Fixed Cone at R = 0.4



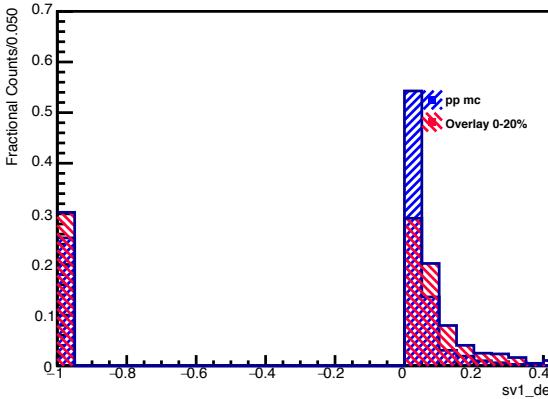
JF pt &gt; 1.0 GeV Fixed Cone at R = 0.4



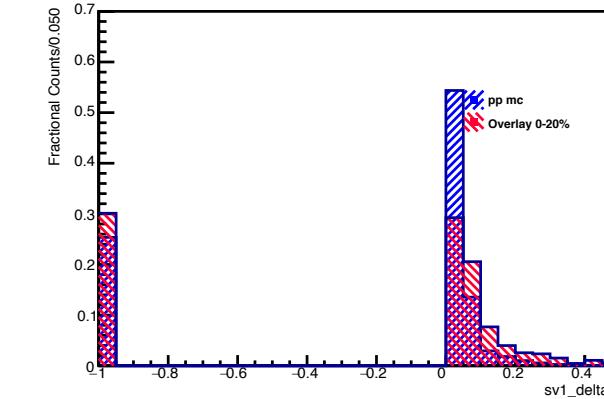
JF pt &gt; 1.5 GeV Fixed Cone at R = 0.4



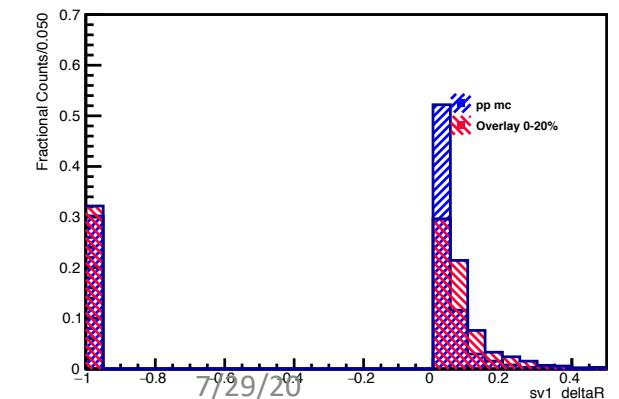
JF pt &gt; 2.0 GeV Fixed Cone at R = 0.4



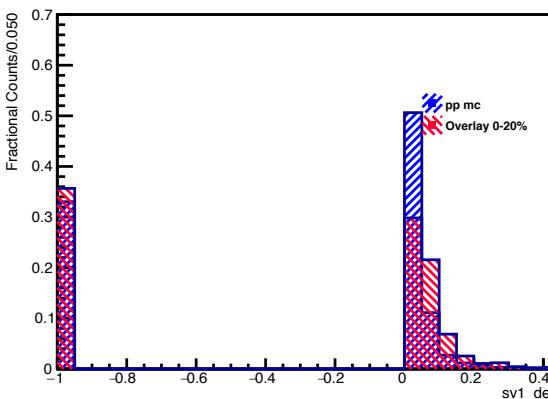
JF pt &gt; 4 GeV Fixed Cone at R = 0.4



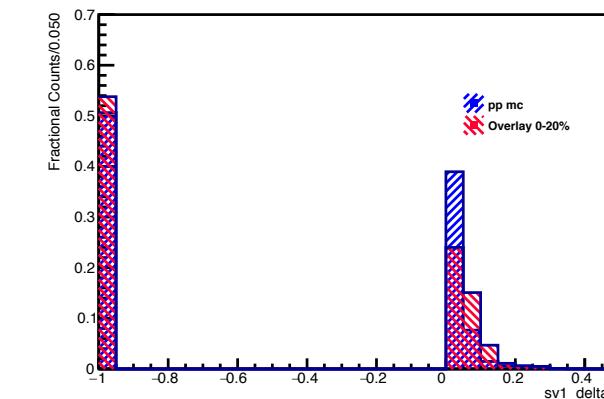
pre-tagging pt &gt; 1.5 GeV Fixed Cone at R = 0.4



pre-tagging pt &gt; 2.0 GeV Fixed Cone at R = 0.4

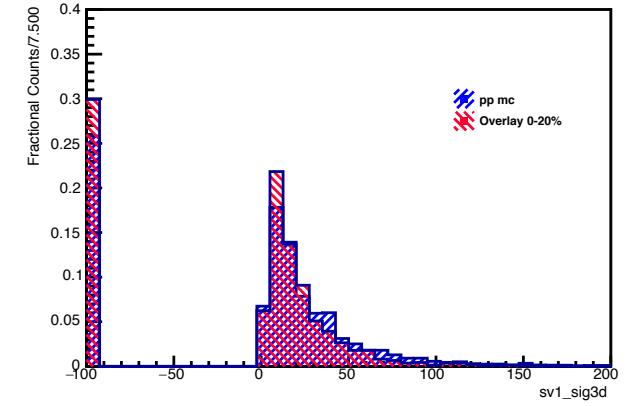


pre-tagging pt &gt; 4.0 GeV Fixed Cone at R = 0.4

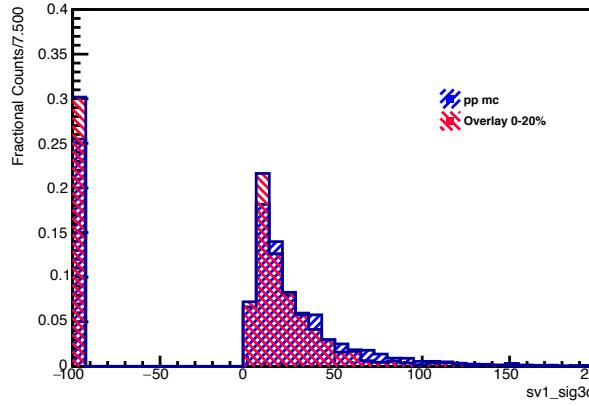


7/29/20

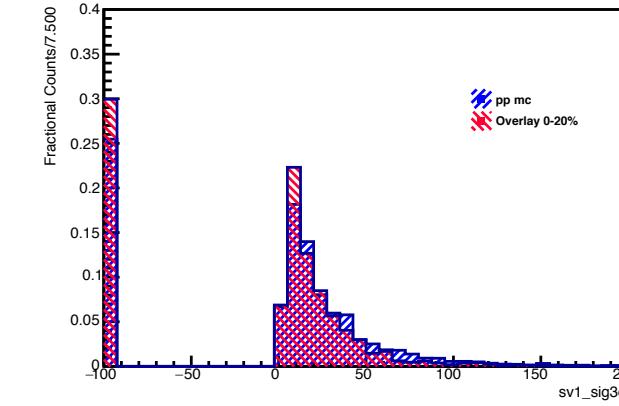
JF pt &gt; 0.5 GeV Shrinking Cone



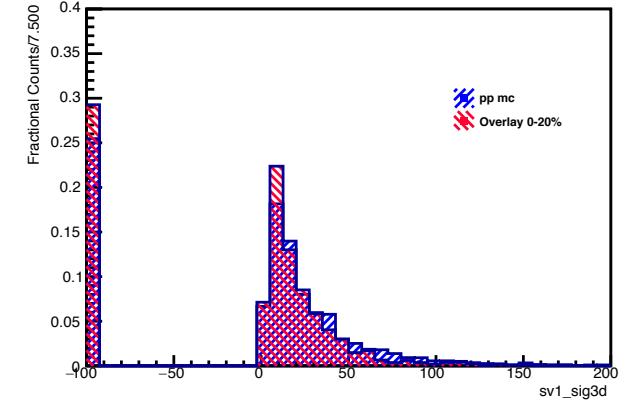
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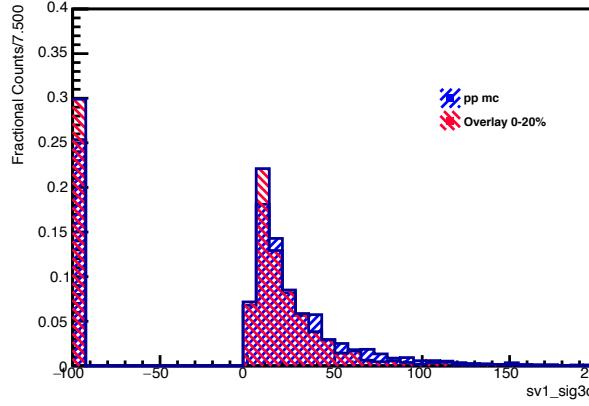
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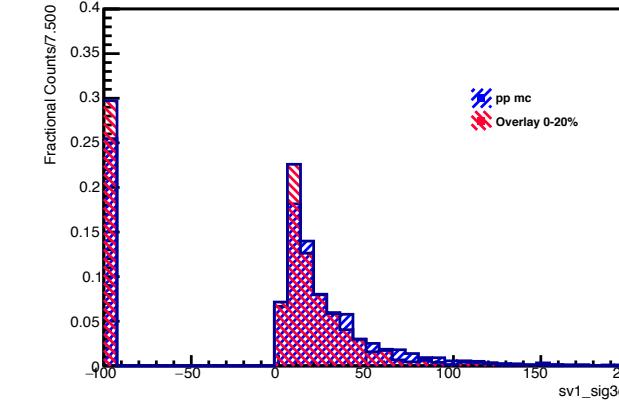
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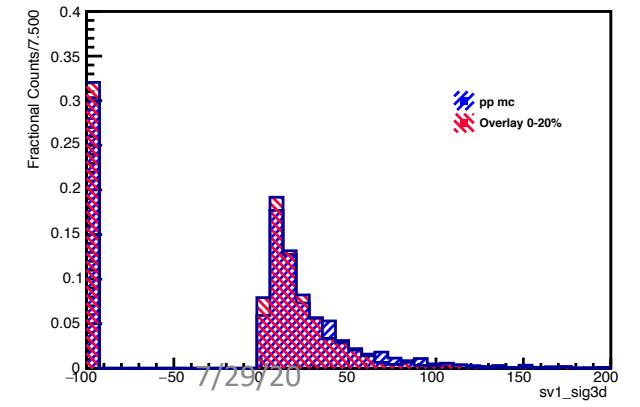
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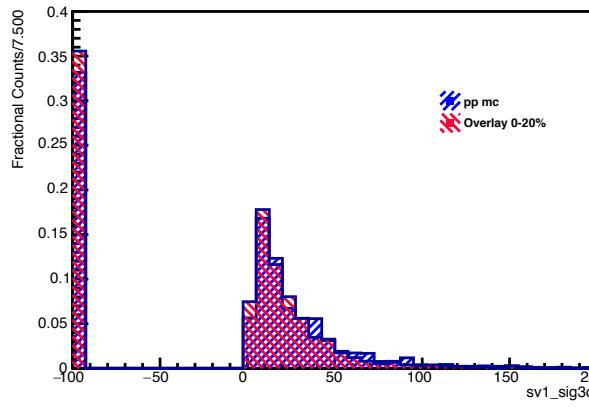
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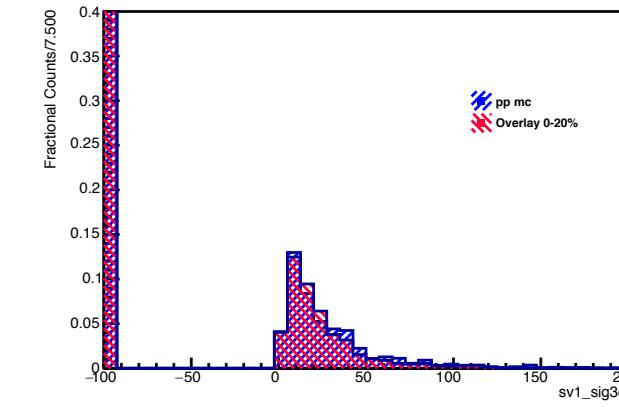
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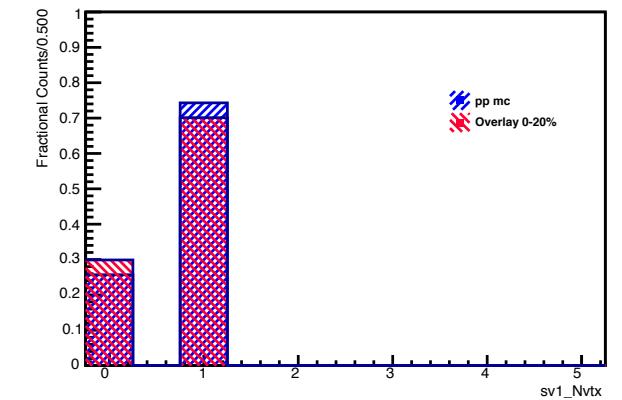
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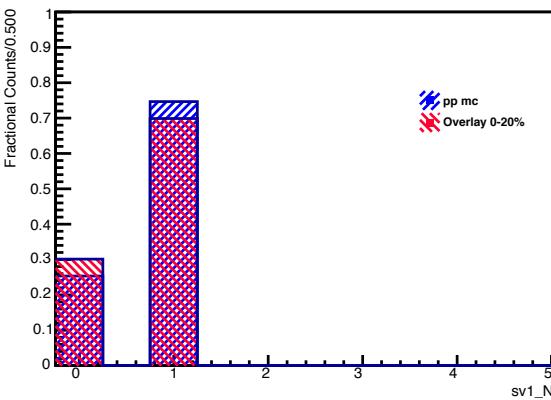
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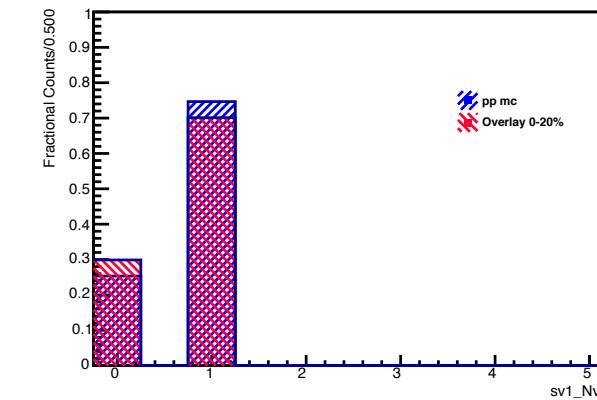
JF pt &gt; 0.5 GeV Shrinking Cone



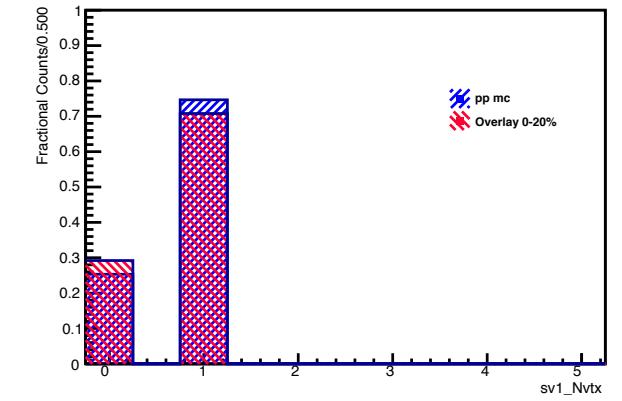
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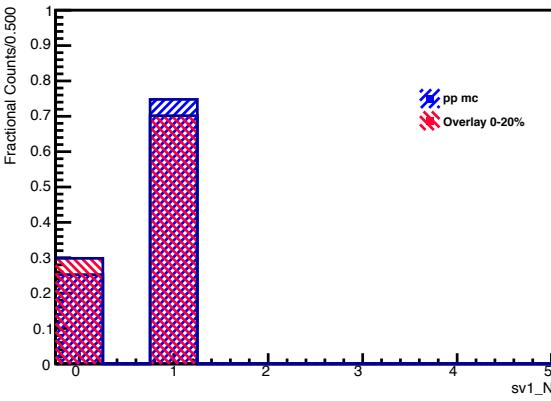
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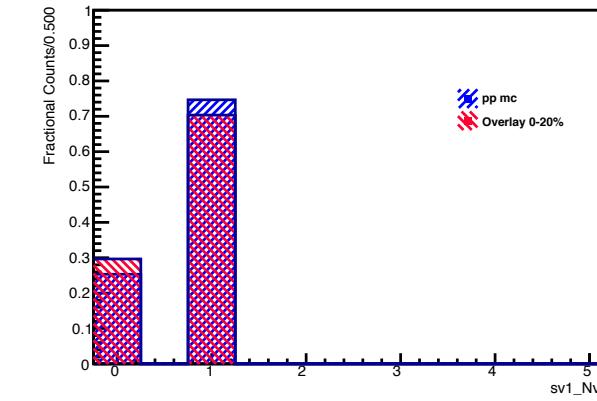
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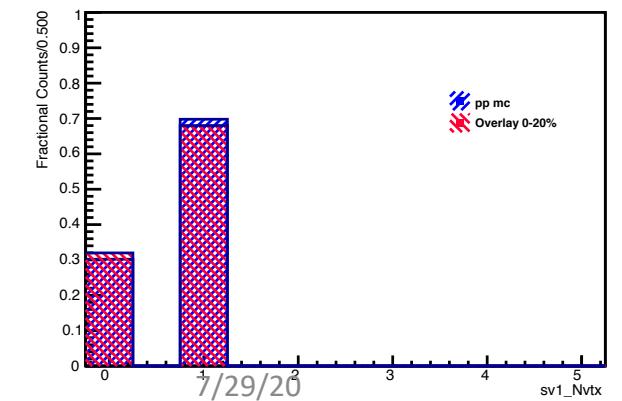
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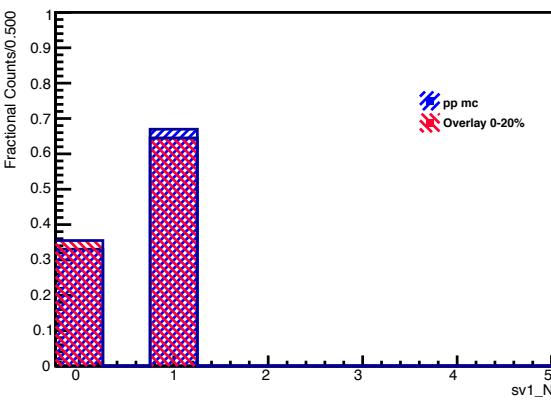
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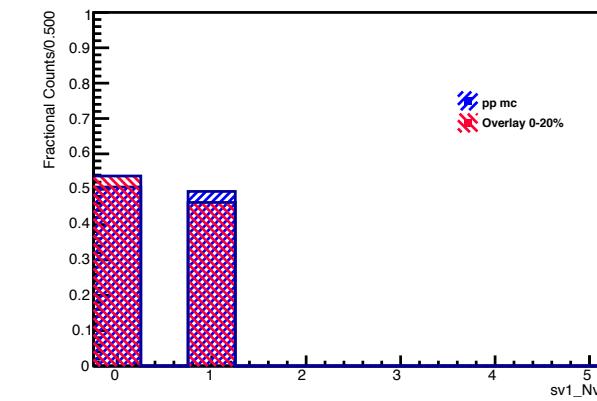
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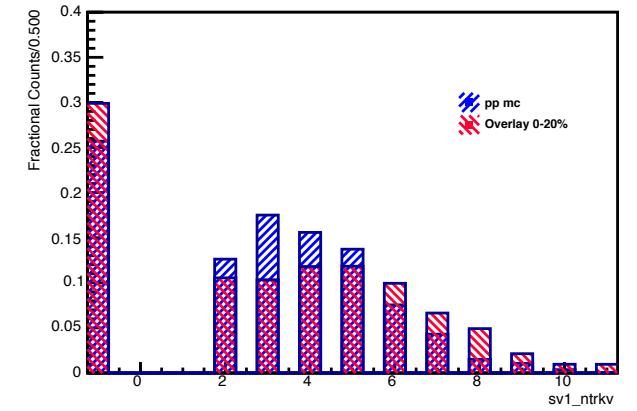
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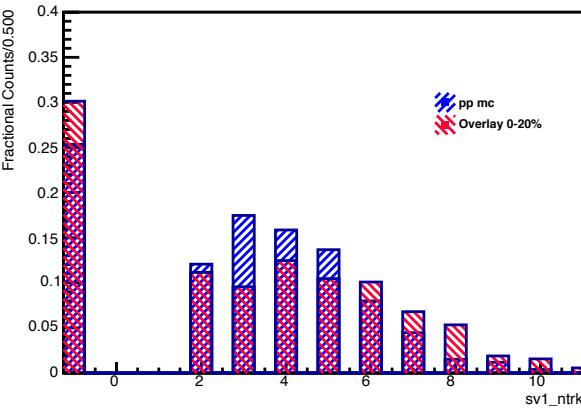
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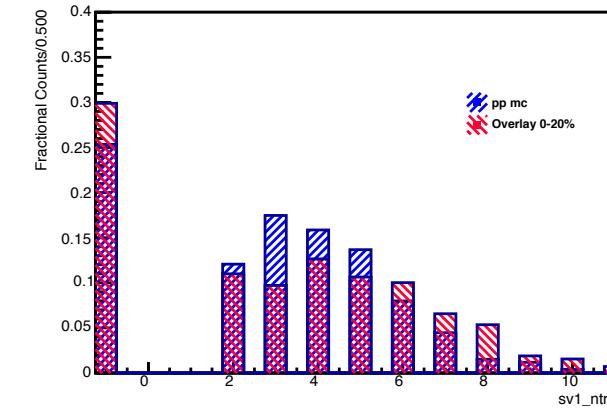
JF pt &gt; 0.5 GeV Shrinking Cone



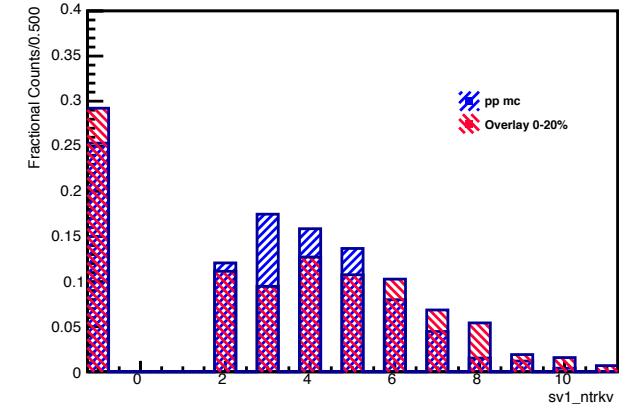
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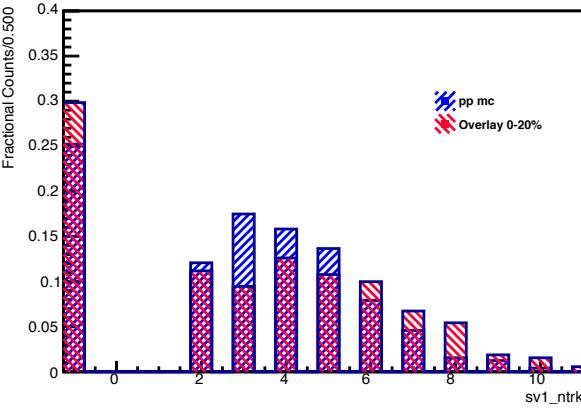
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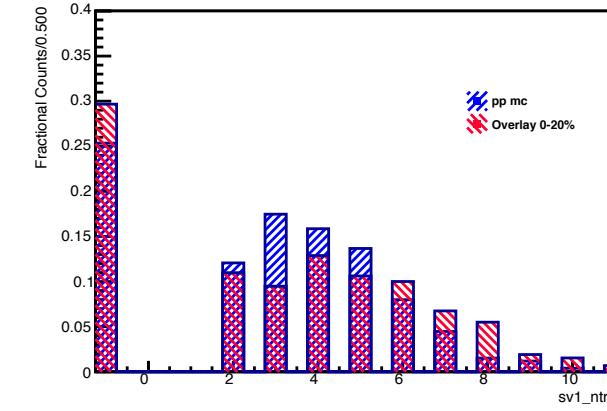
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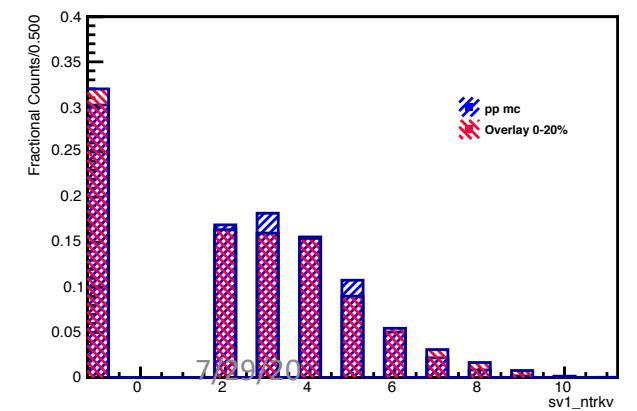
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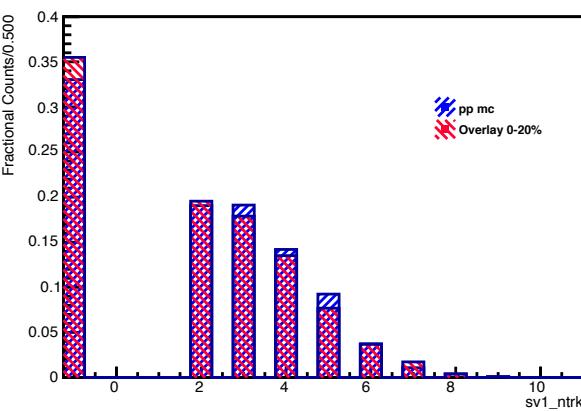
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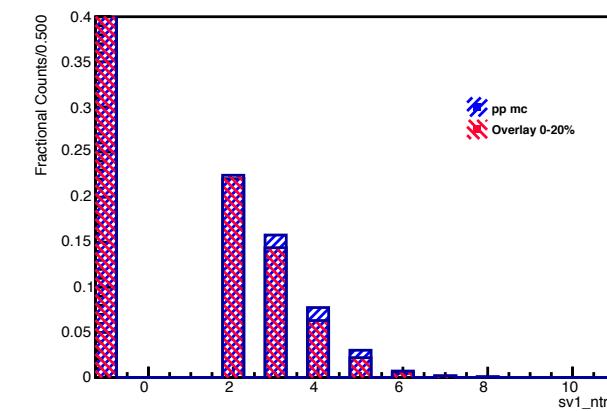
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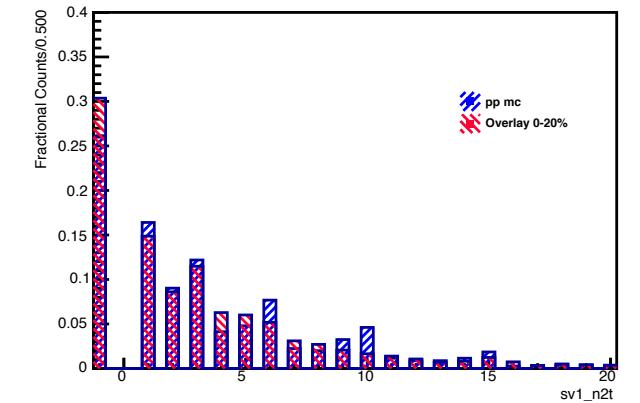
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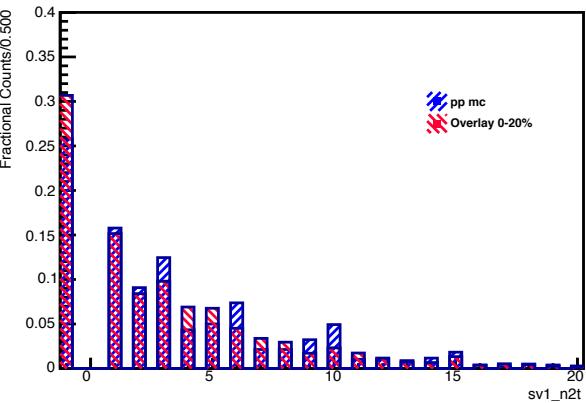
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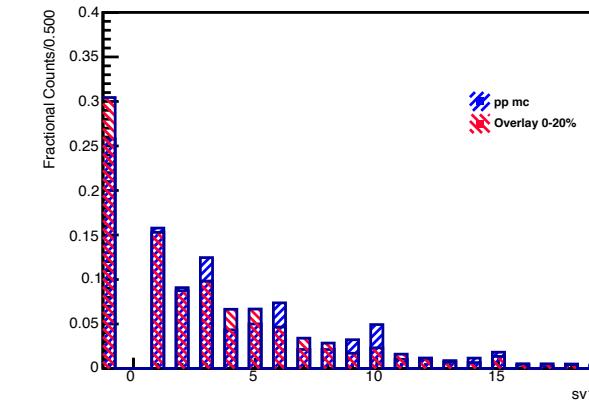
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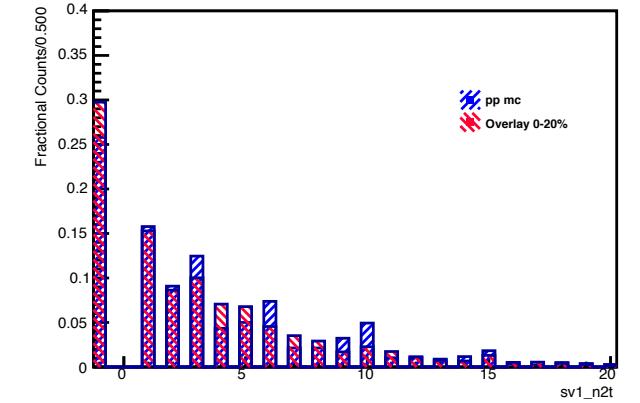
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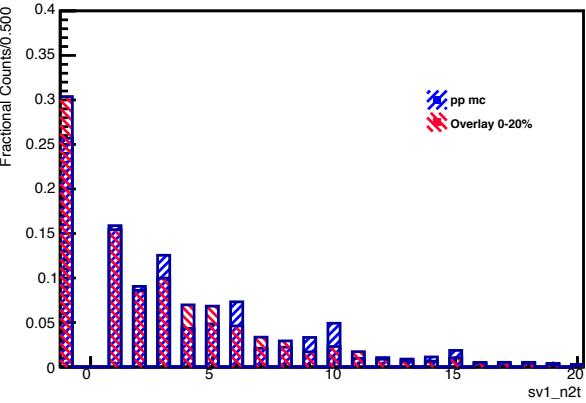
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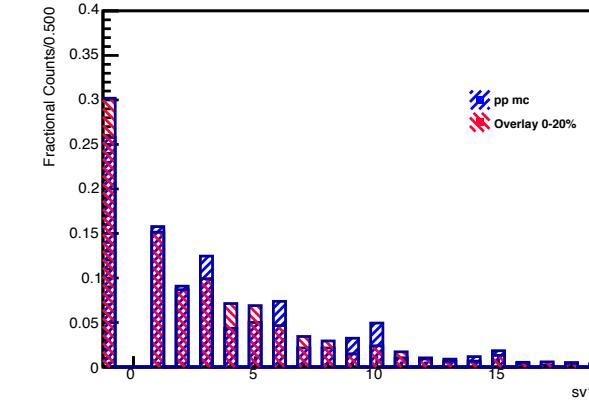
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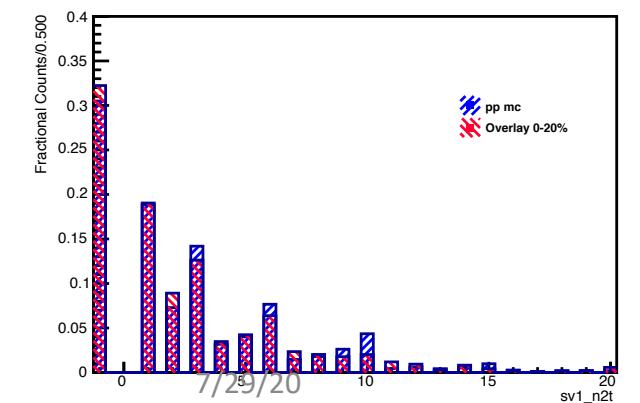
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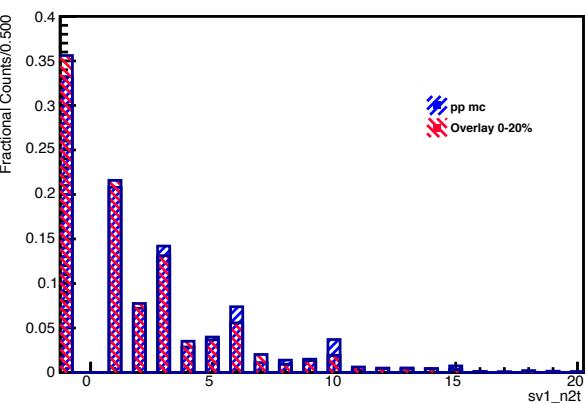
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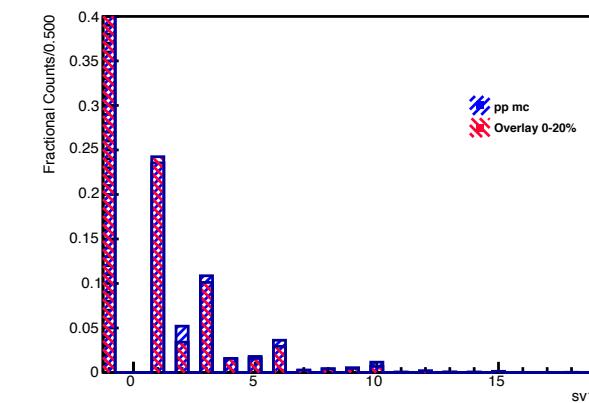
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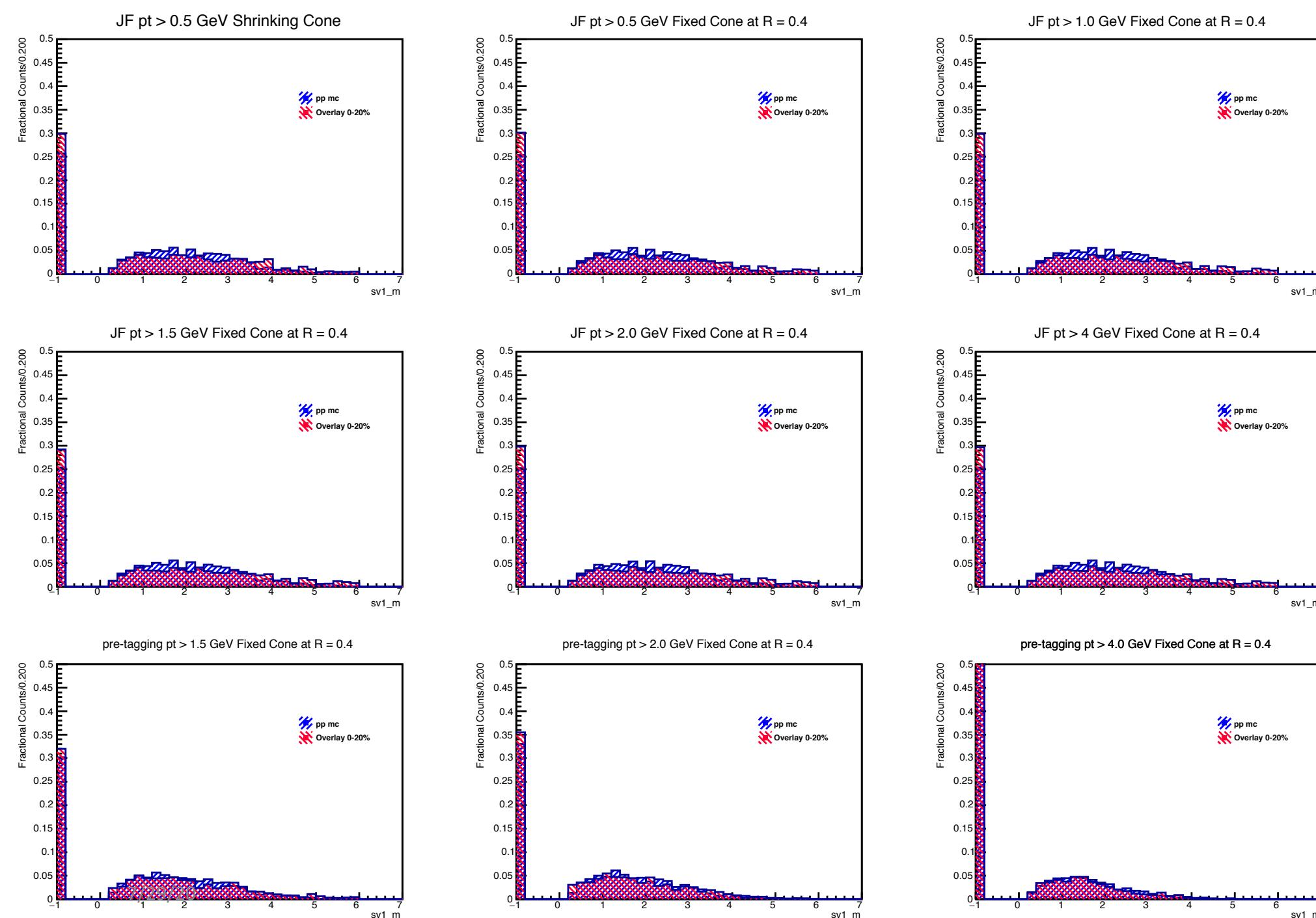


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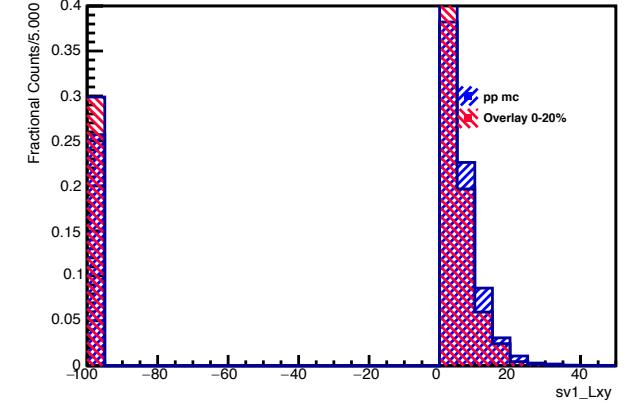


pre-tagging pt &gt; 4.0 GeV Fixed Cone at R = 0.4

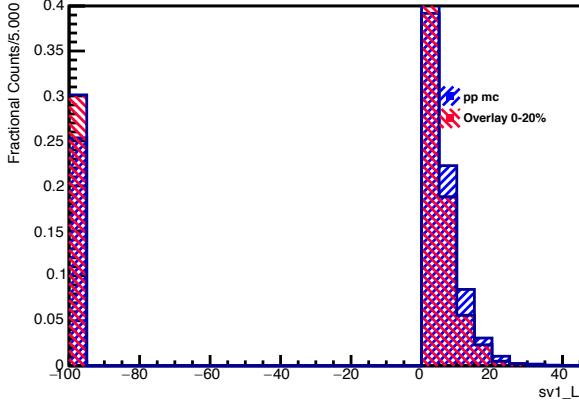




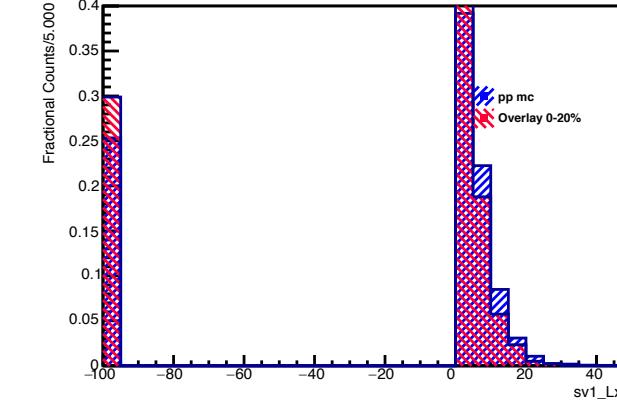
JF pt &gt; 0.5 GeV Shrinking Cone



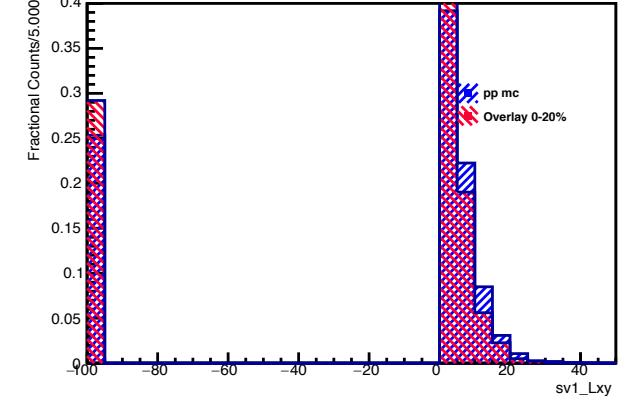
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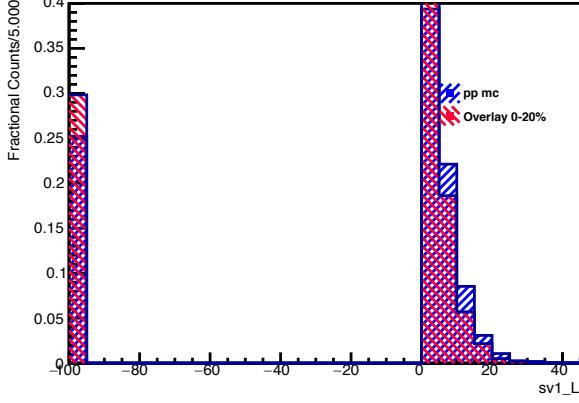
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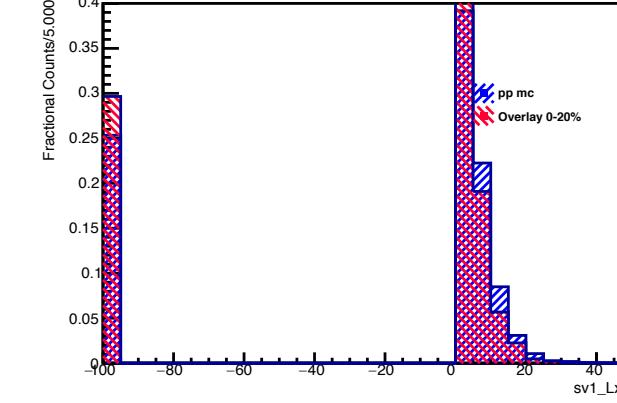
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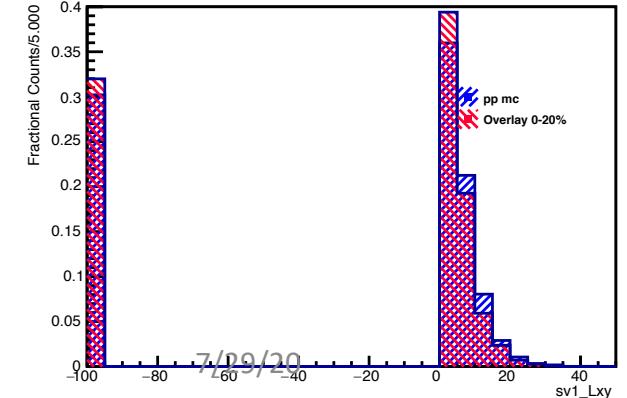
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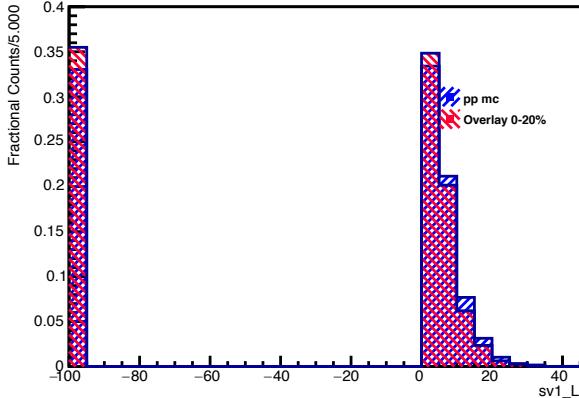
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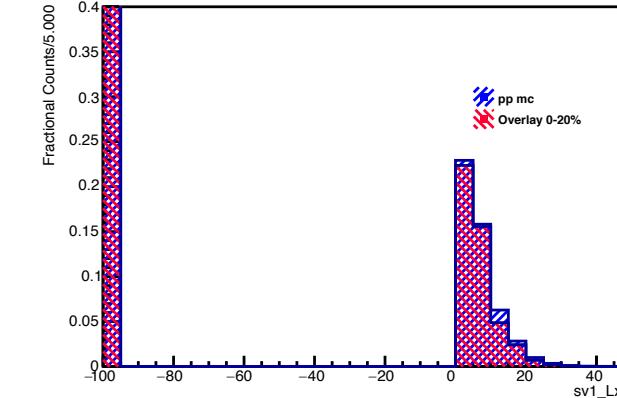
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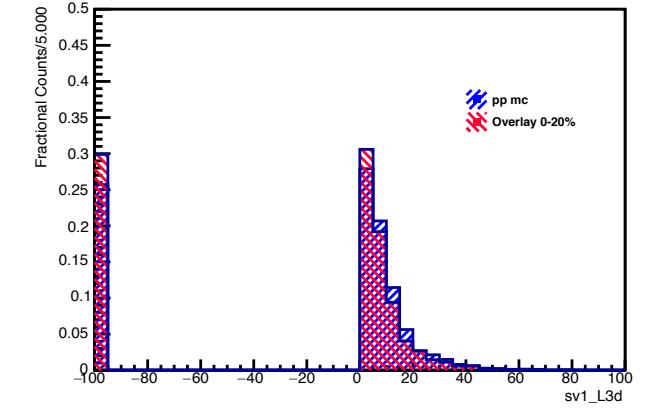
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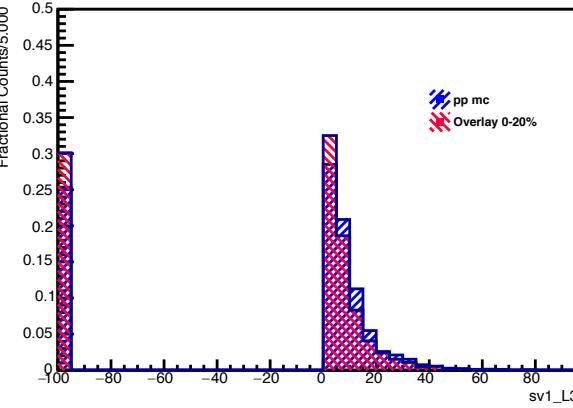
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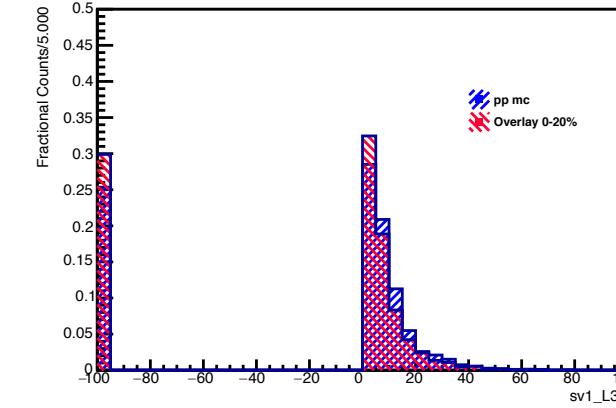
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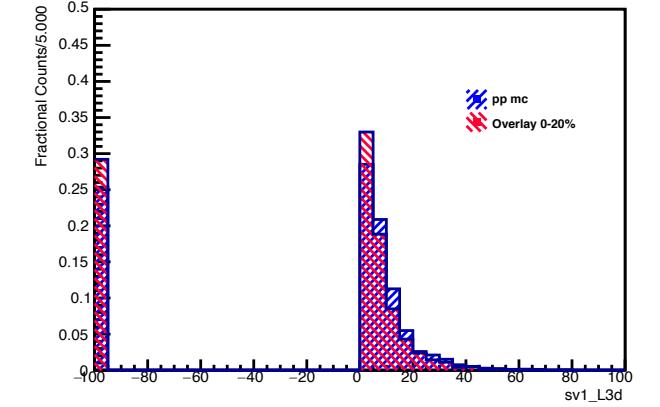
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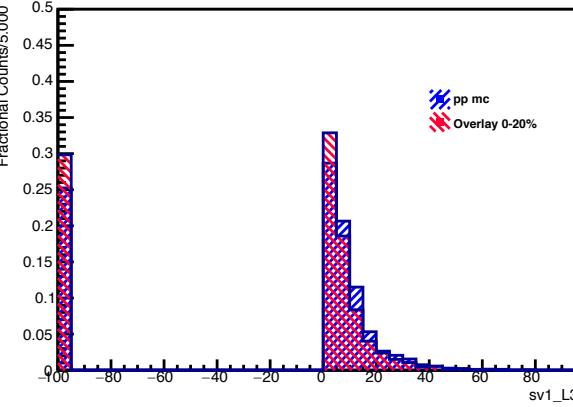
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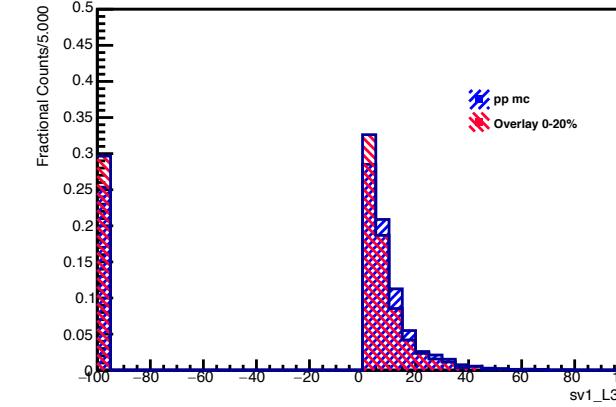
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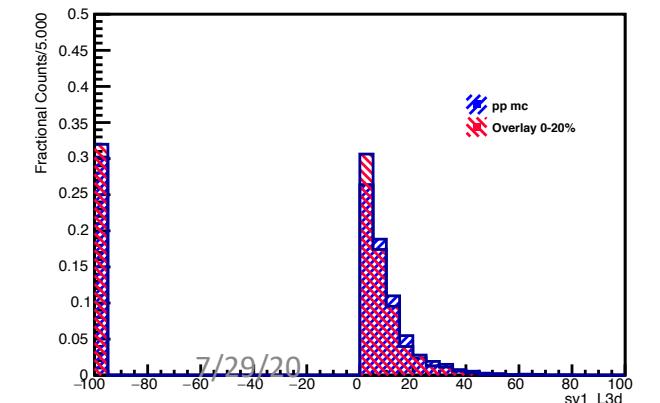
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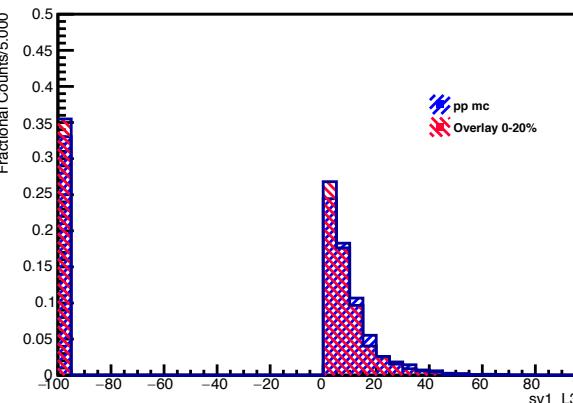
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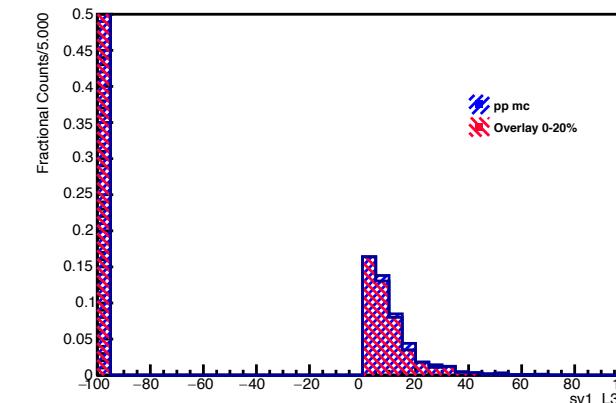
pre-tagging pt &gt; 1.5 GeV Fixed Cone at R = 0.4



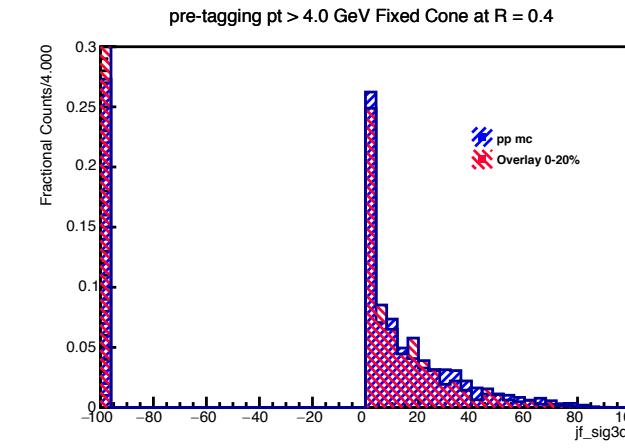
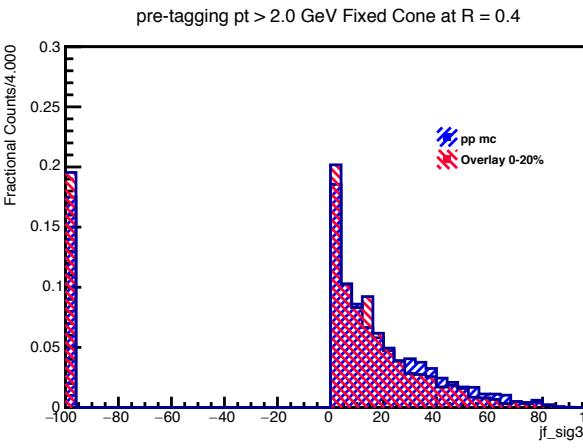
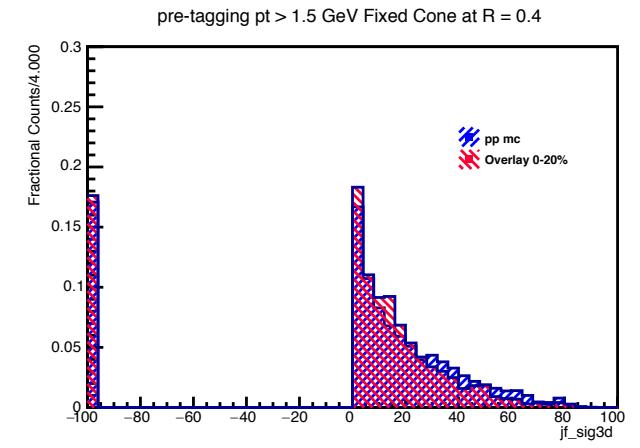
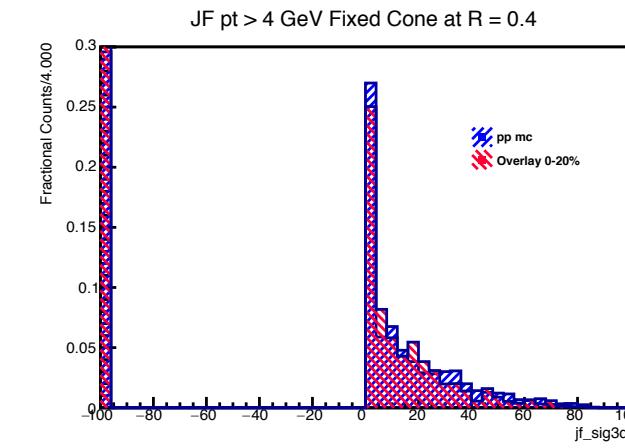
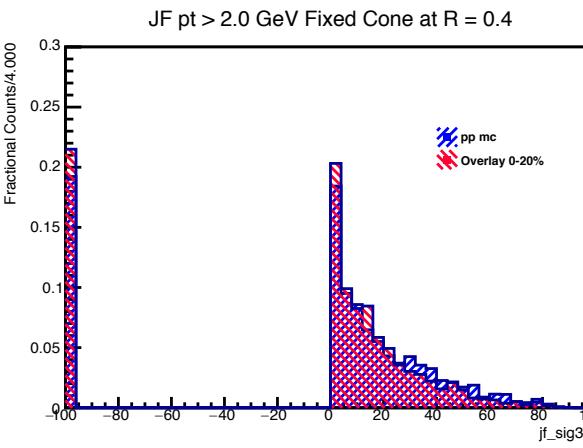
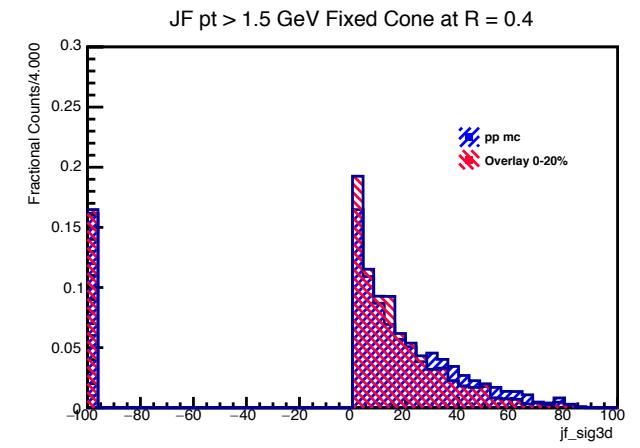
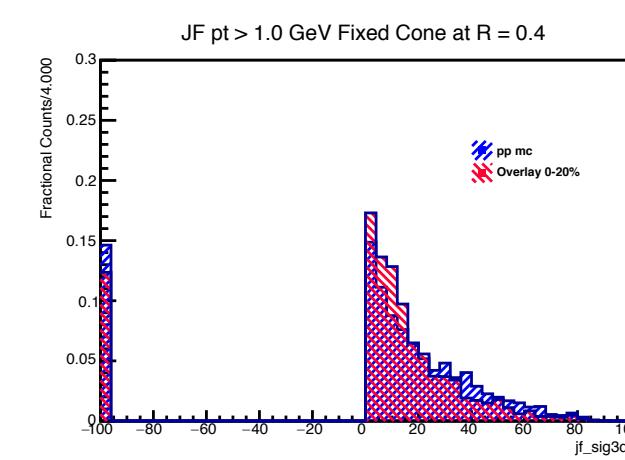
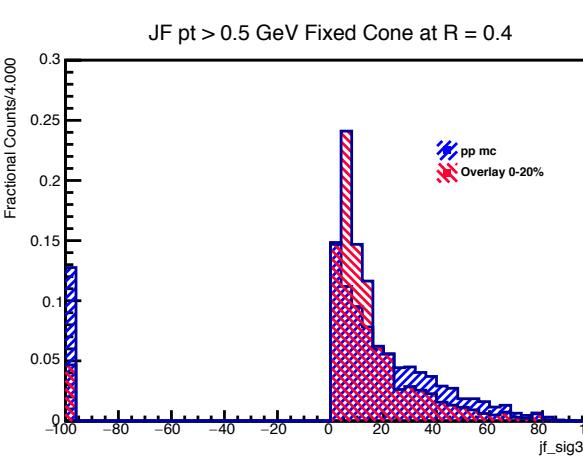
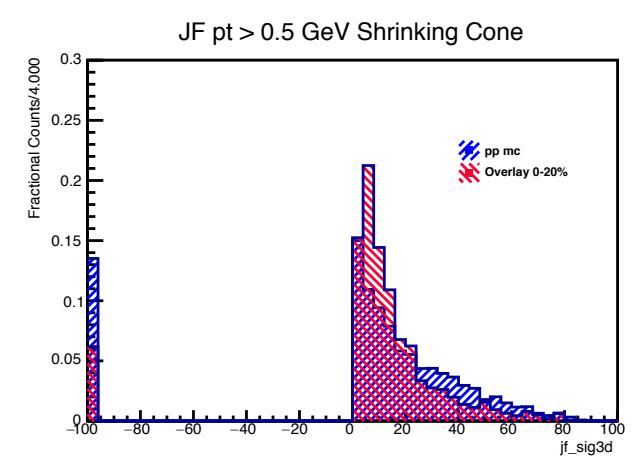
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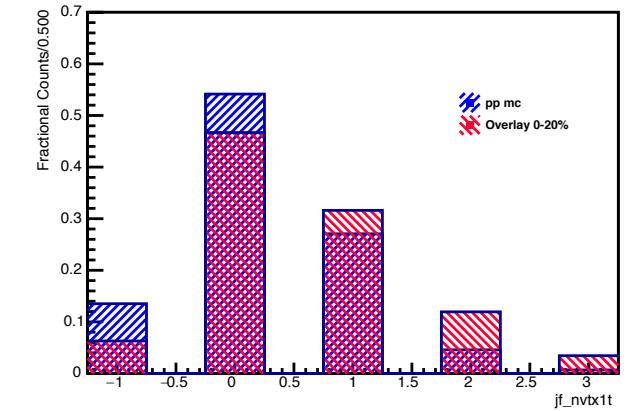
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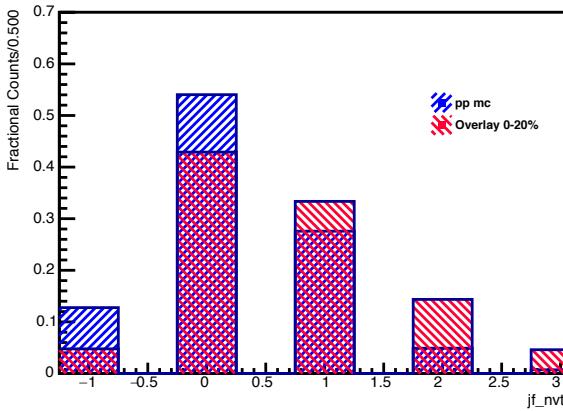
# JetFitter



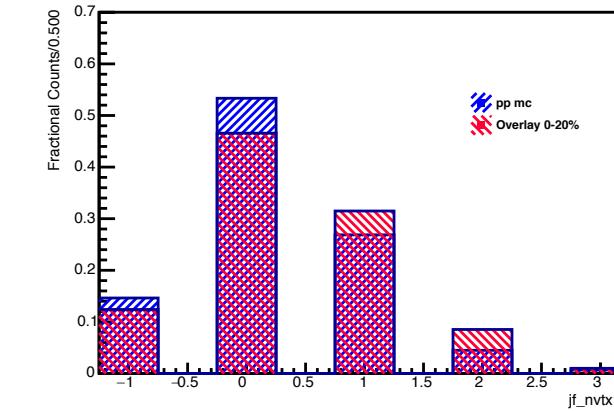
JF pt &gt; 0.5 GeV Shrinking Cone



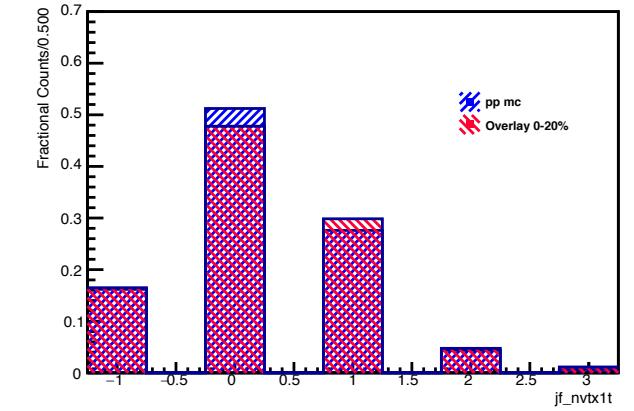
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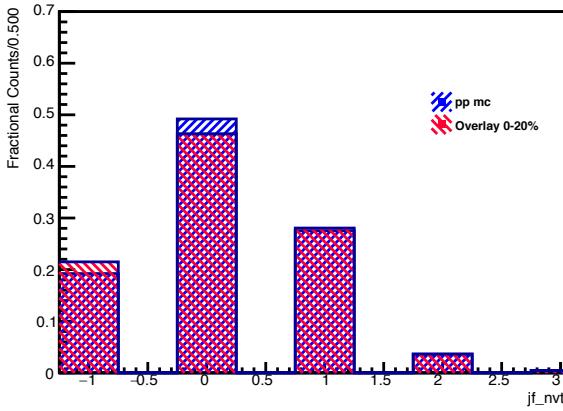
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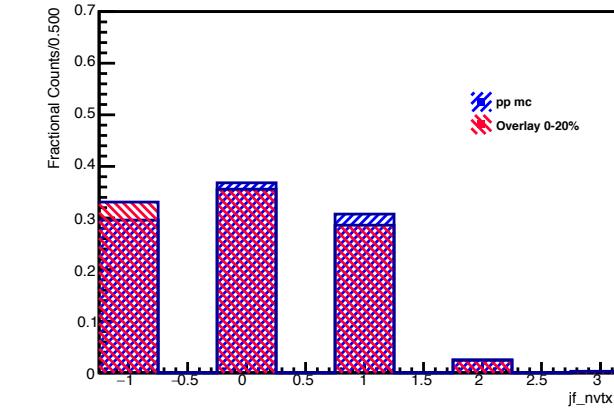
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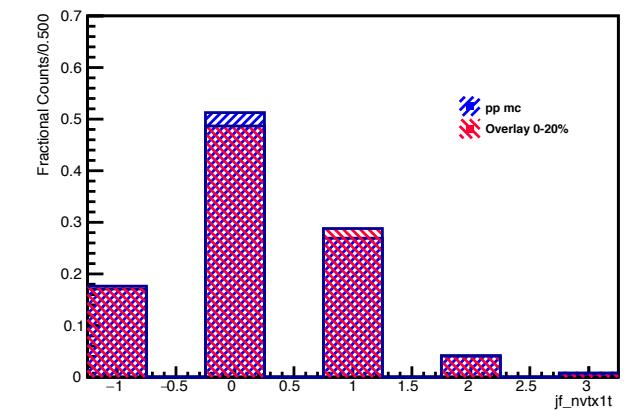
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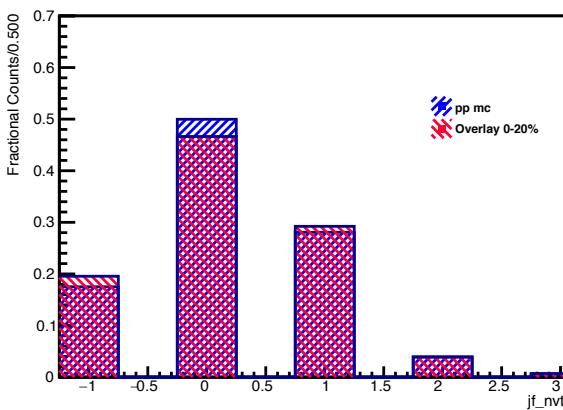
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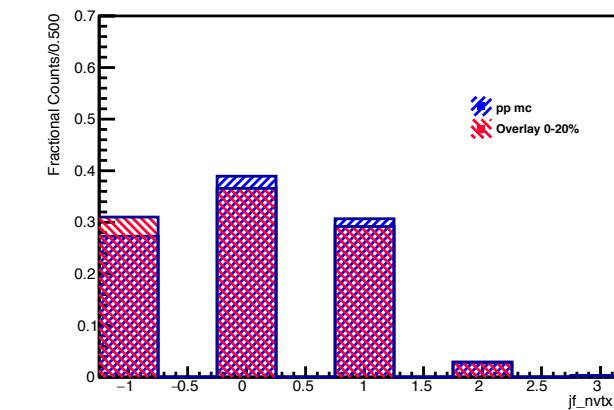
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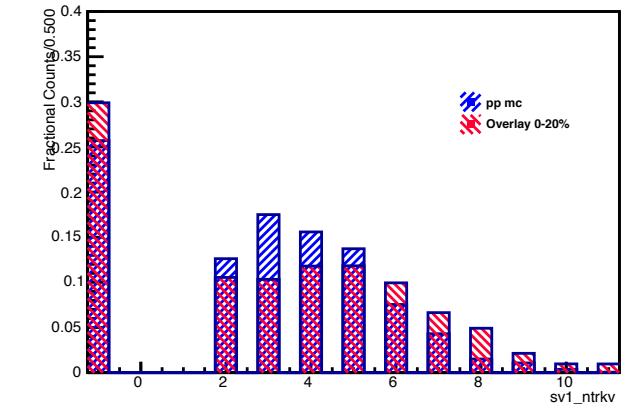
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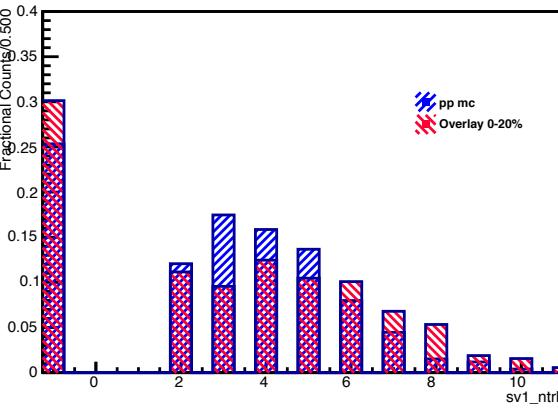
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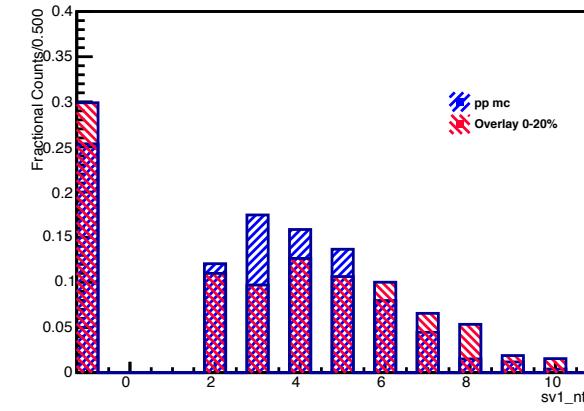
JF pt &gt; 0.5 GeV Shrinking Cone



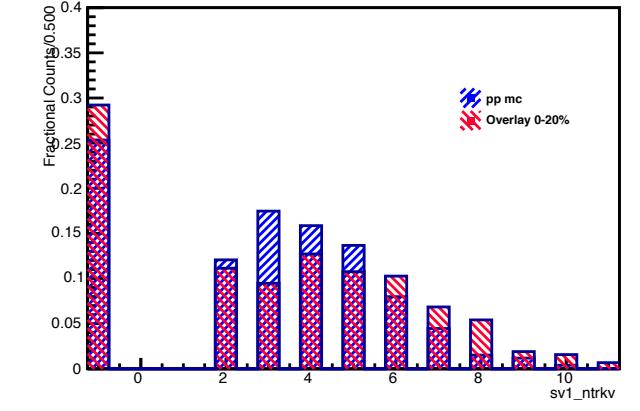
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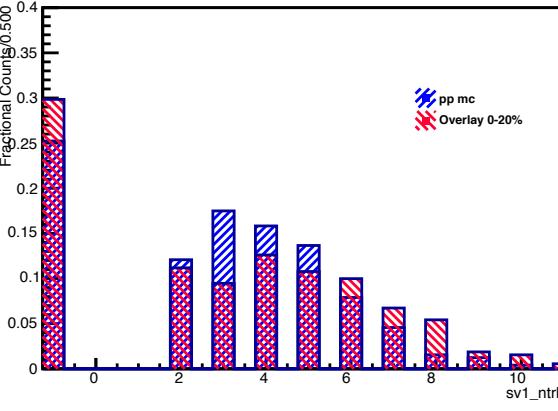
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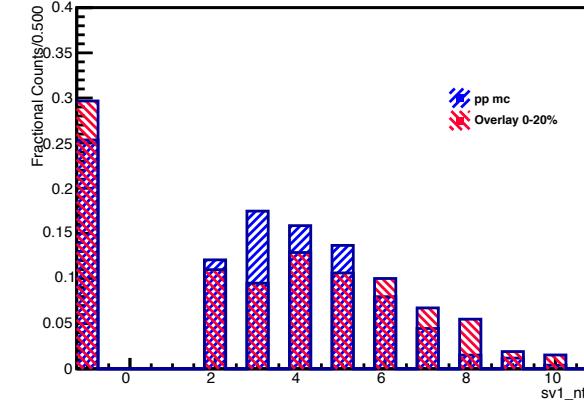
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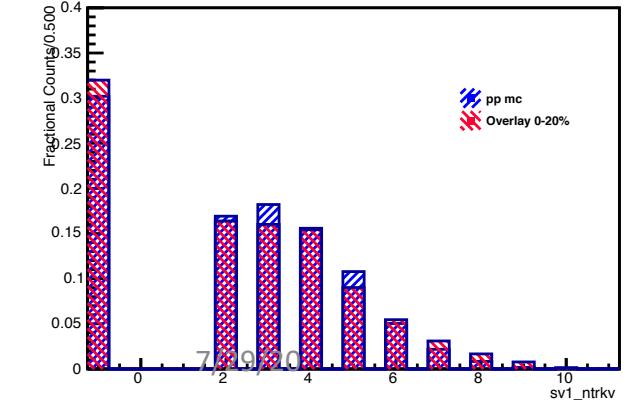
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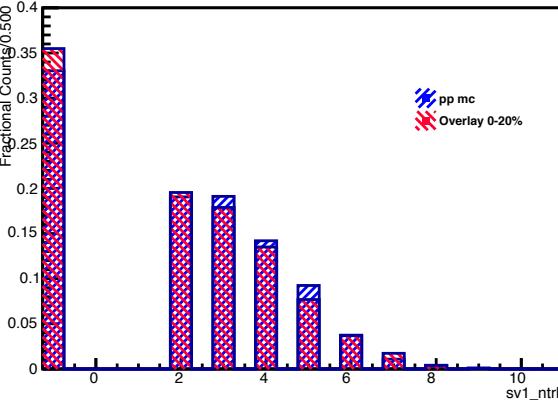
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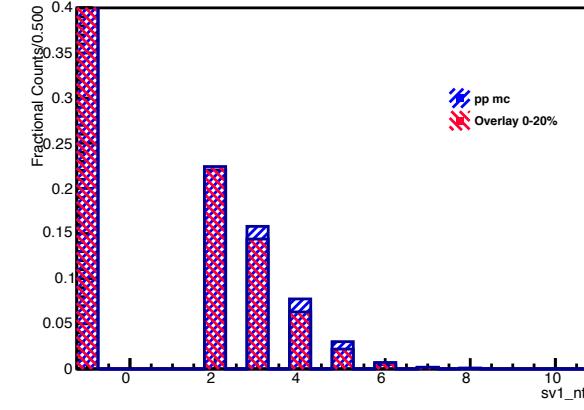
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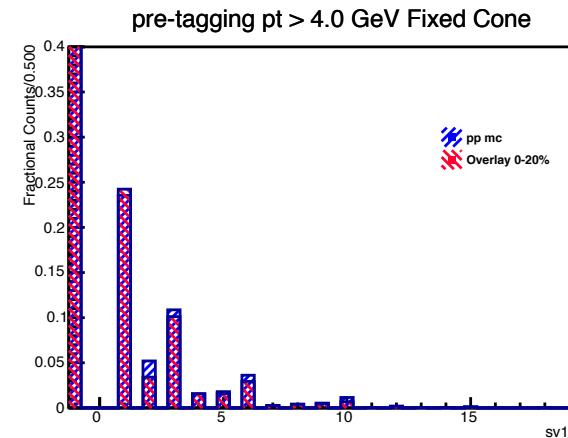
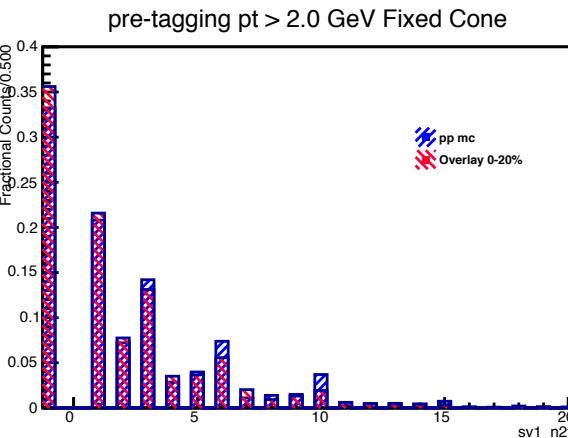
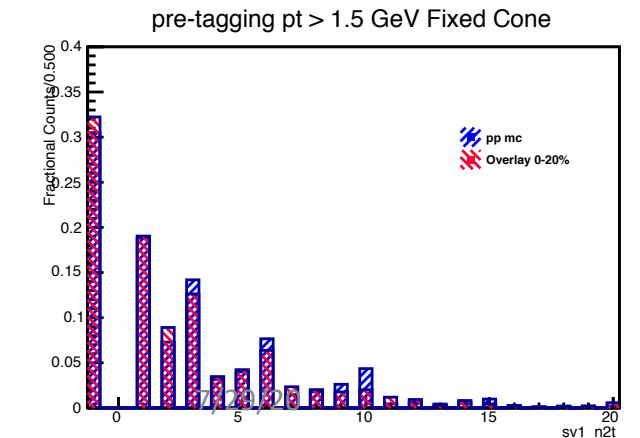
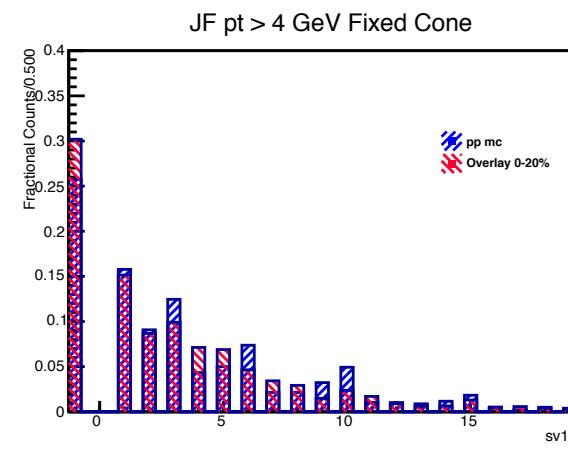
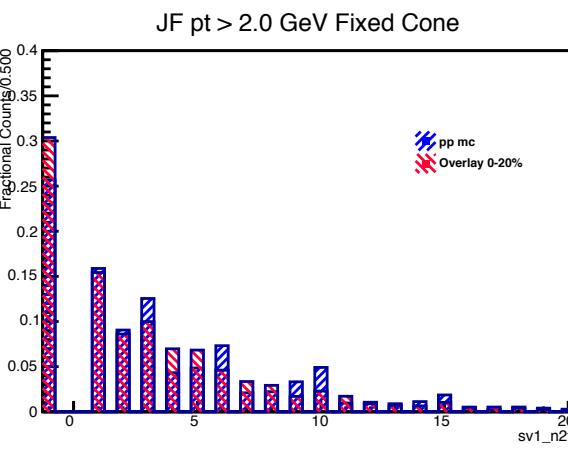
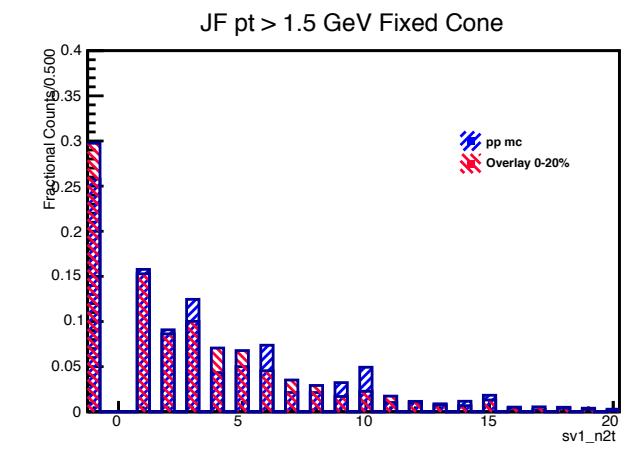
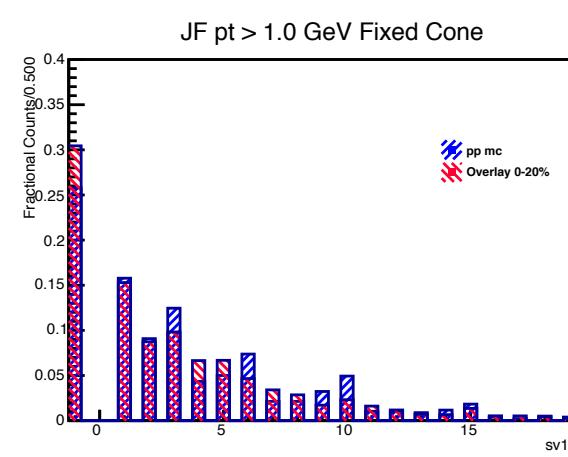
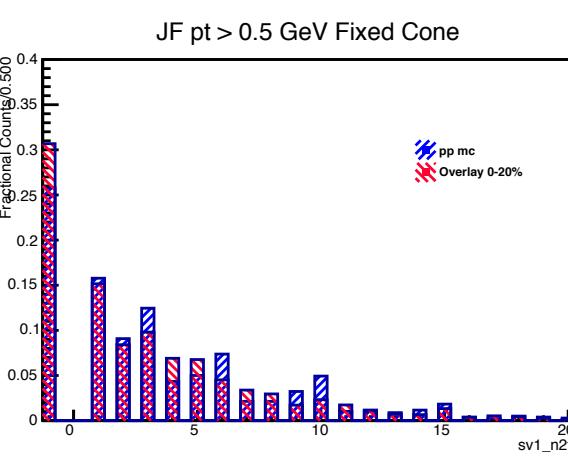
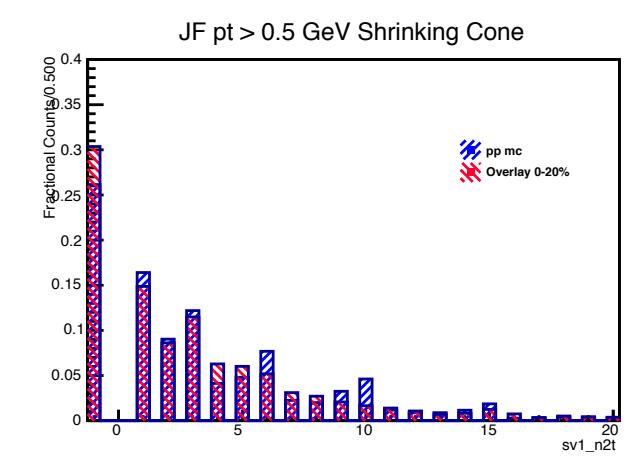


pre-tagging pt &gt; 2.0 GeV Fixed Cone

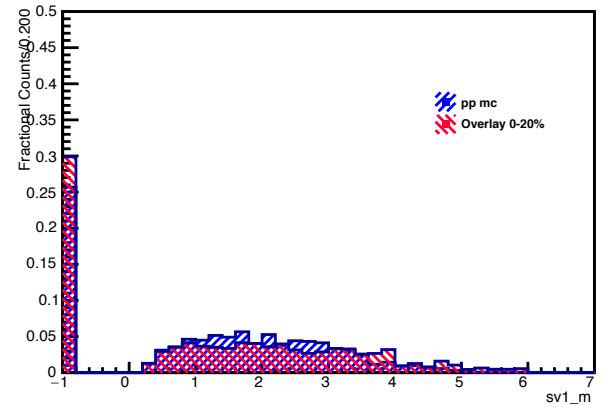


pre-tagging pt &gt; 4.0 GeV Fixed Cone

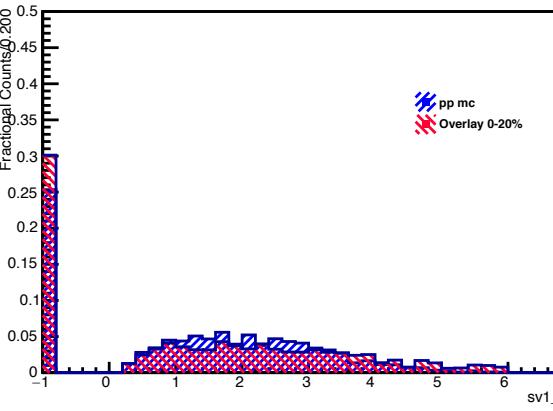




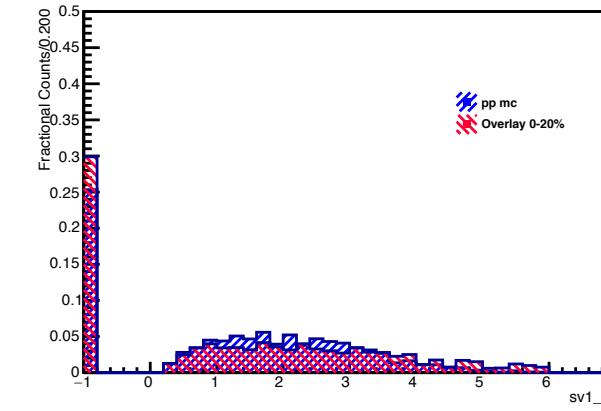
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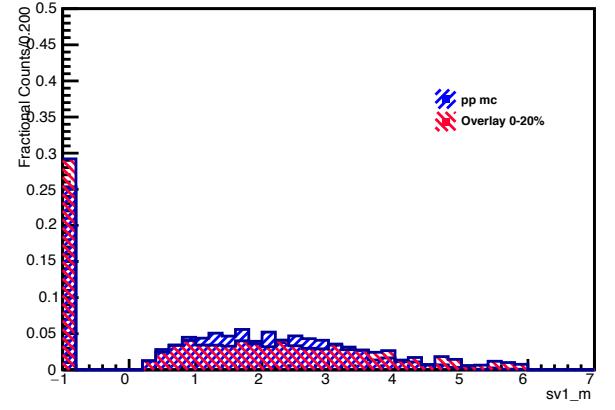
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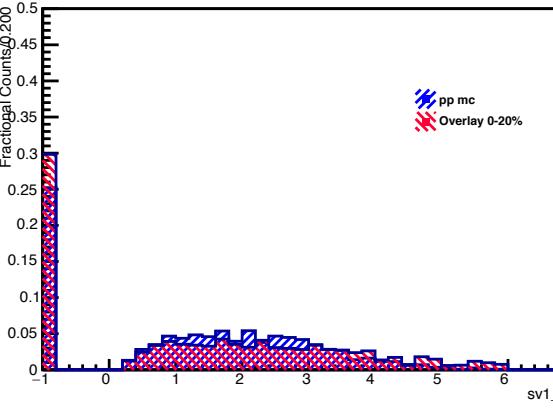
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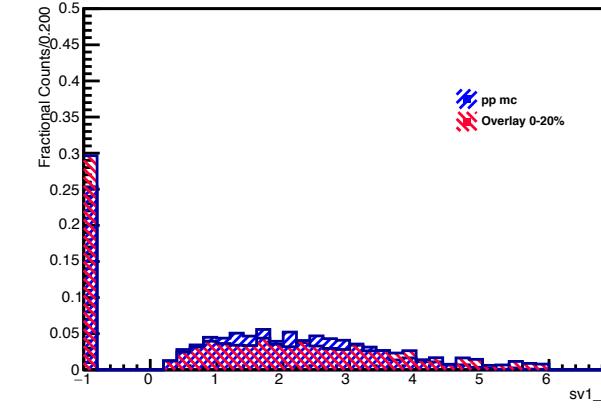
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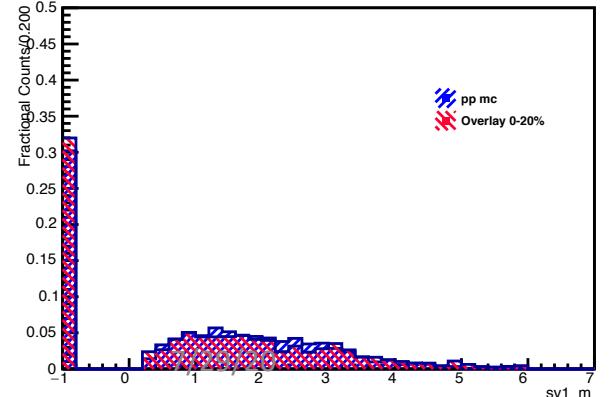
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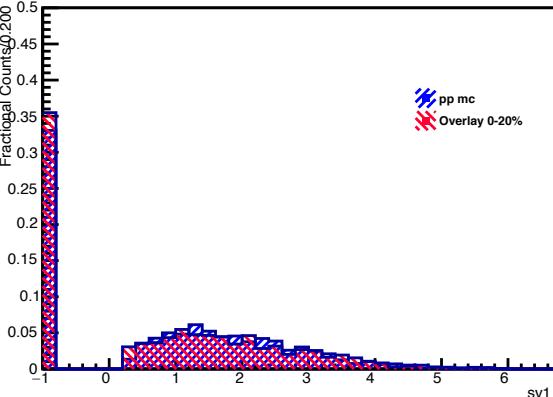
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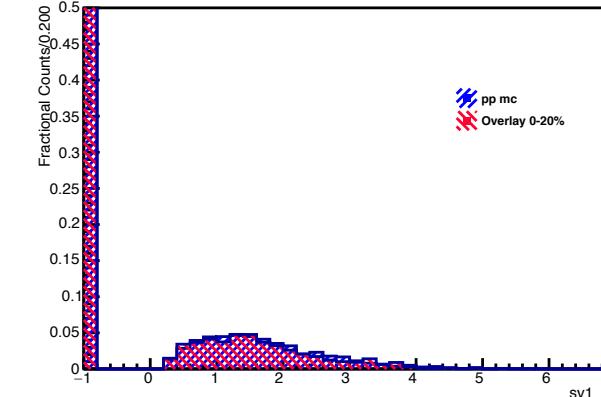
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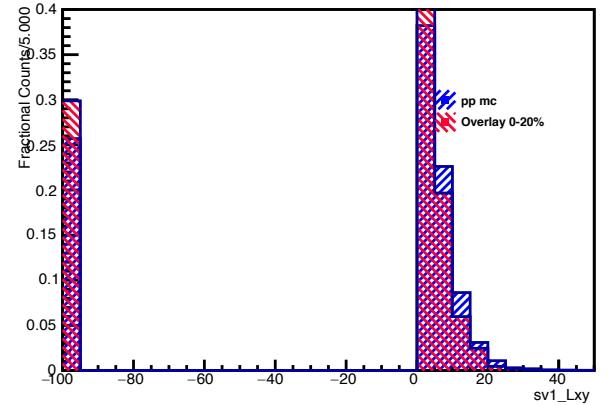
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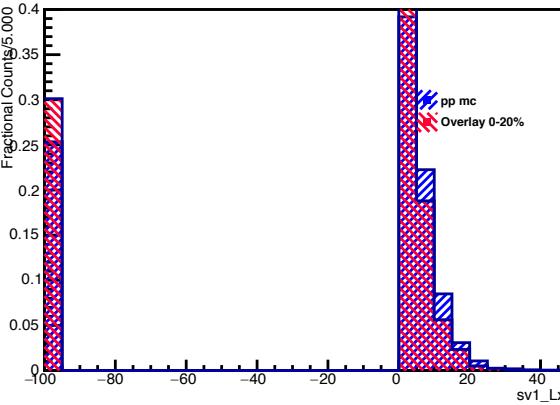
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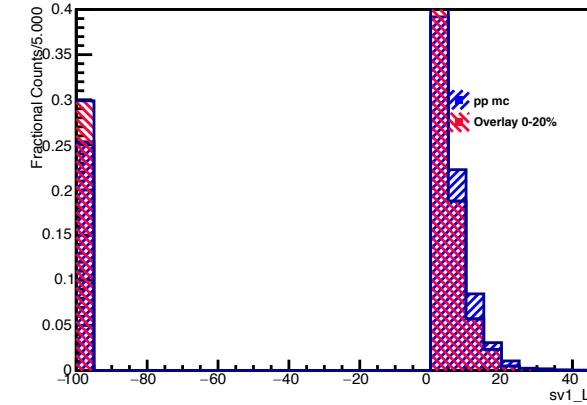
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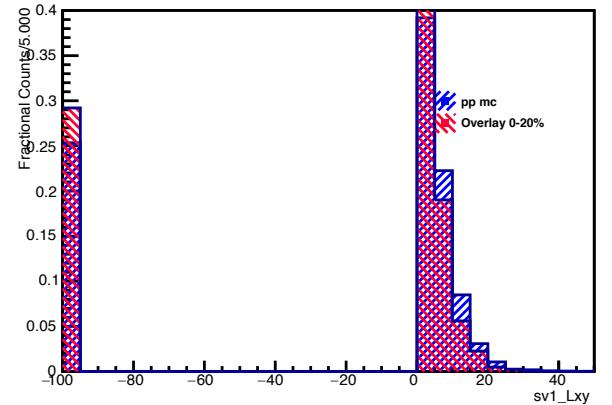
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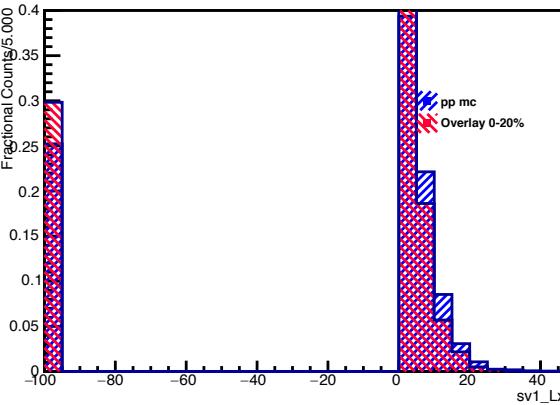
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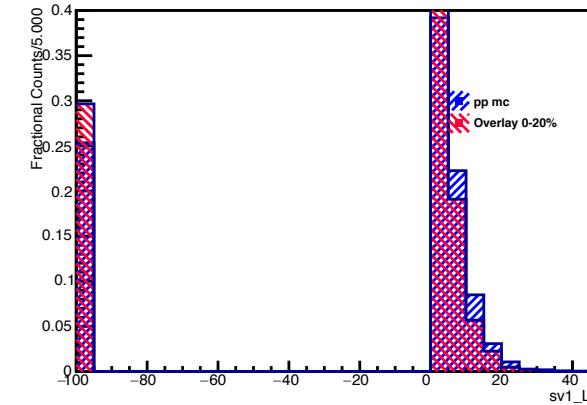
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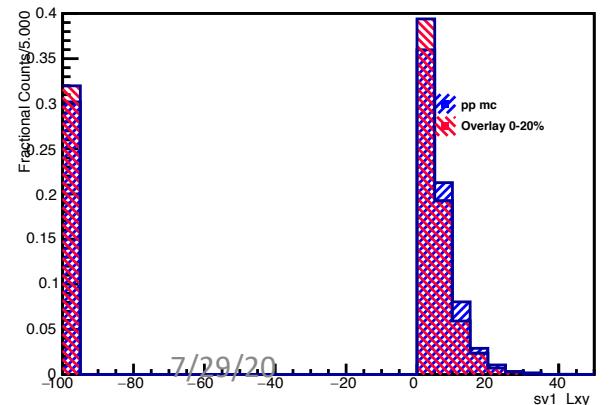
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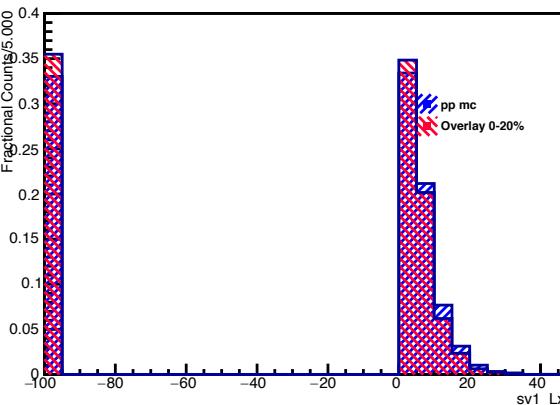
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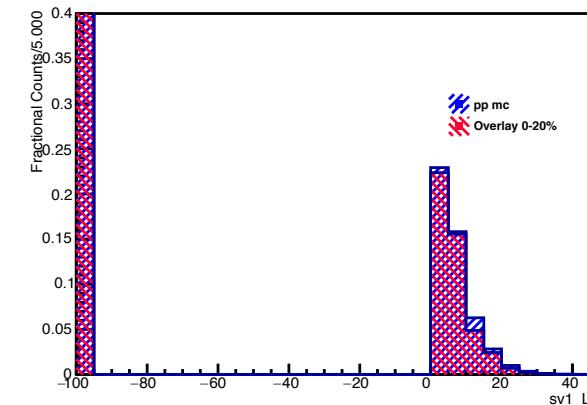
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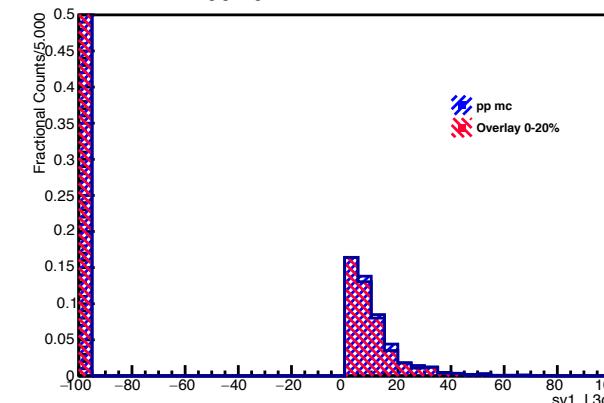
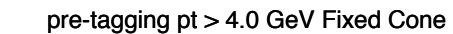
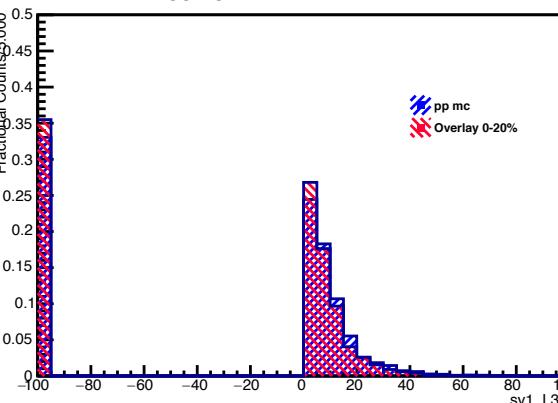
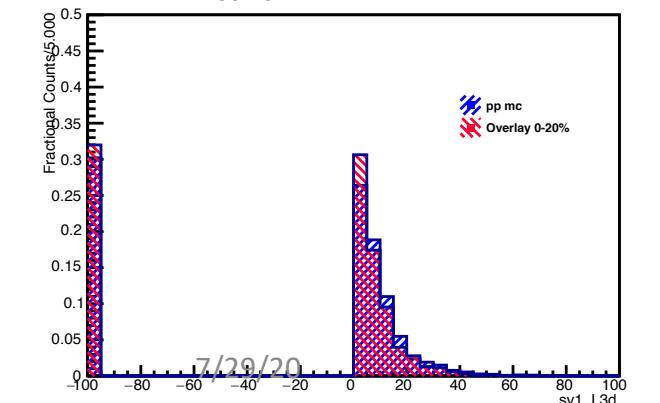
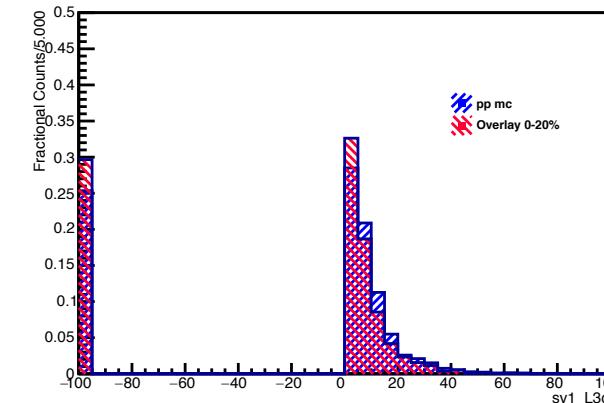
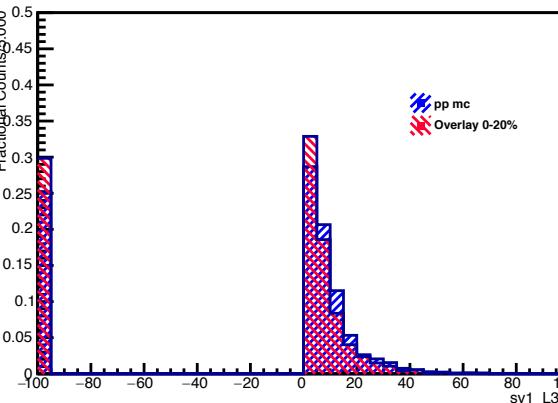
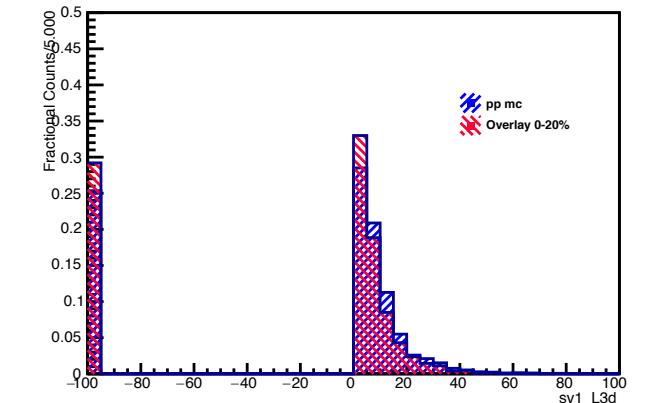
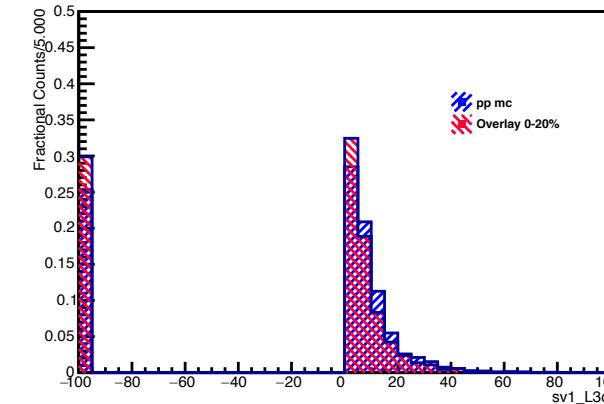
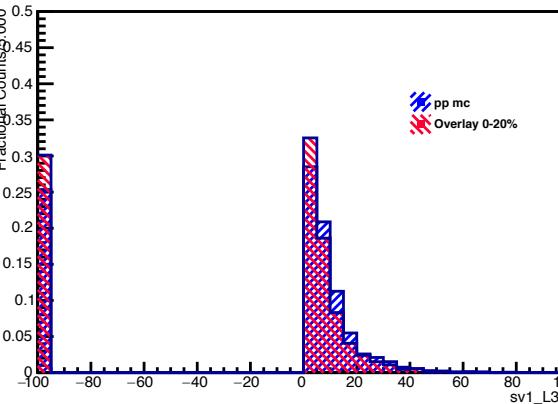
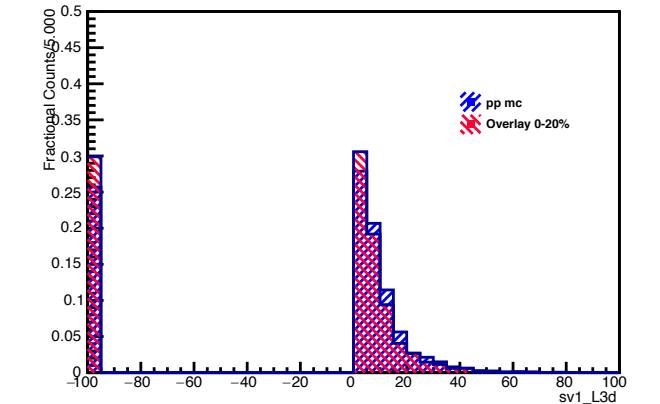


pre-tagging pt &gt; 2.0 GeV Fixed Cone

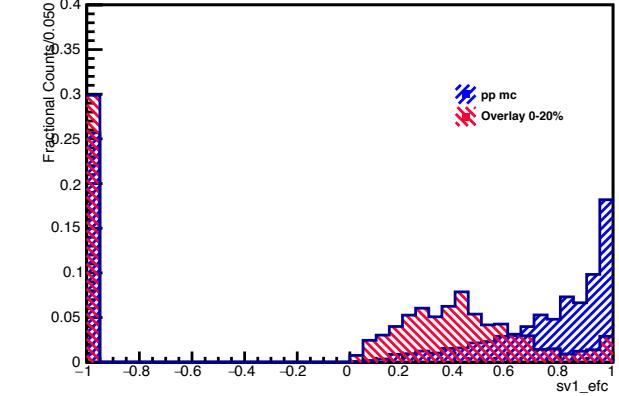


pre-tagging pt &gt; 4.0 GeV Fixed Cone

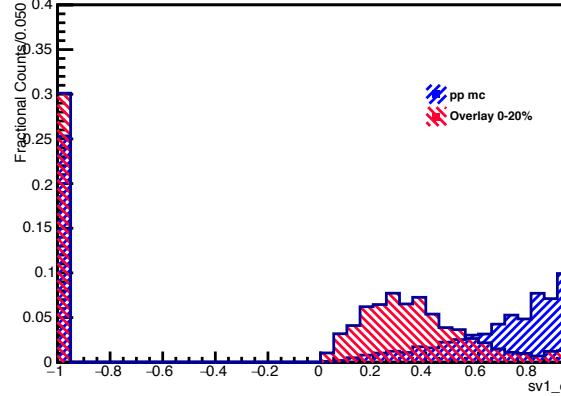




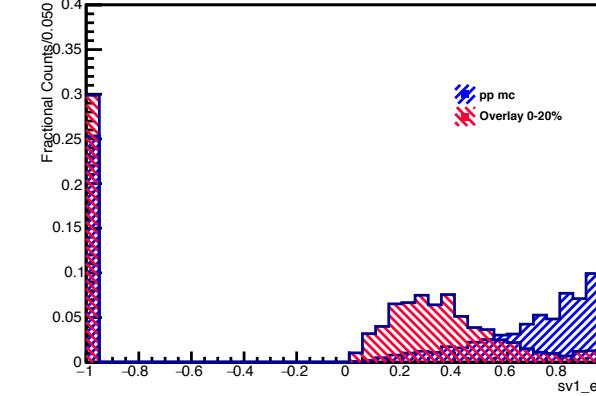
JF pt &gt; 0.5 GeV Shrinking Cone



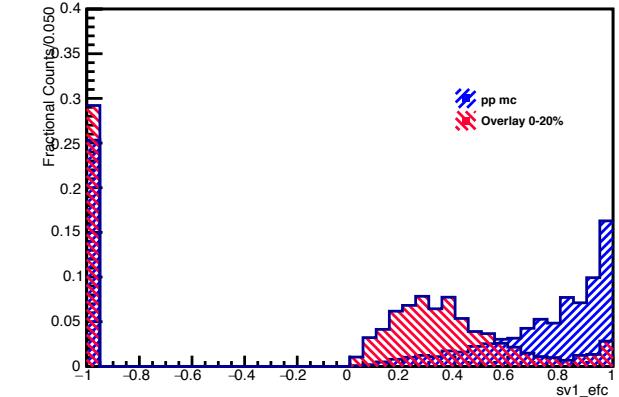
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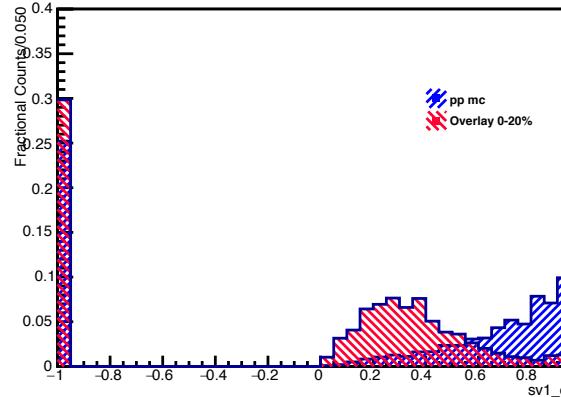
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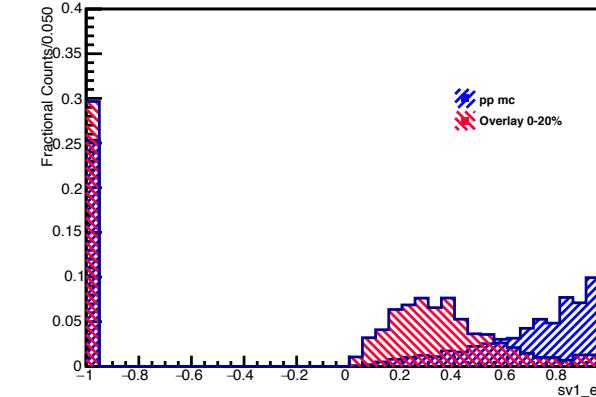
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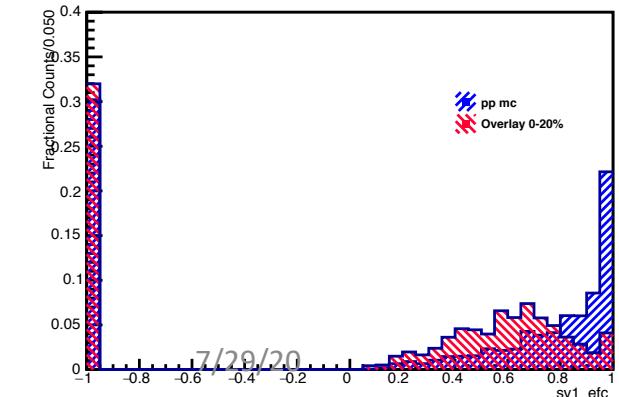
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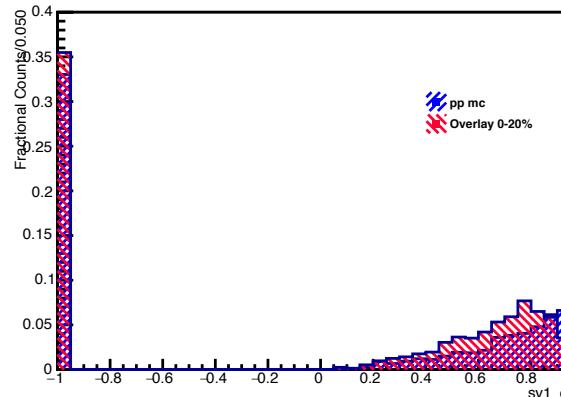
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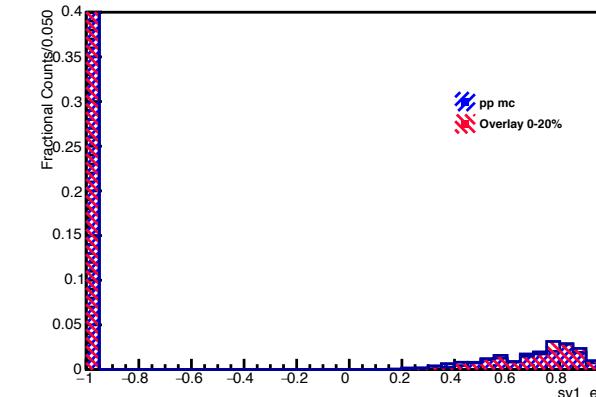
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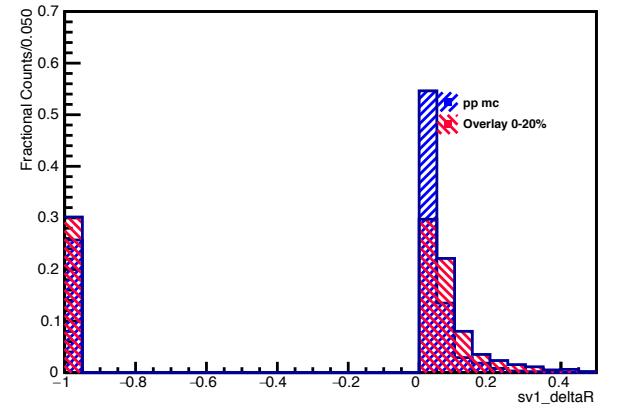
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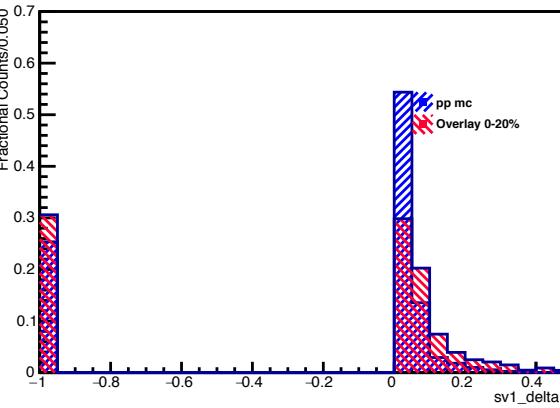
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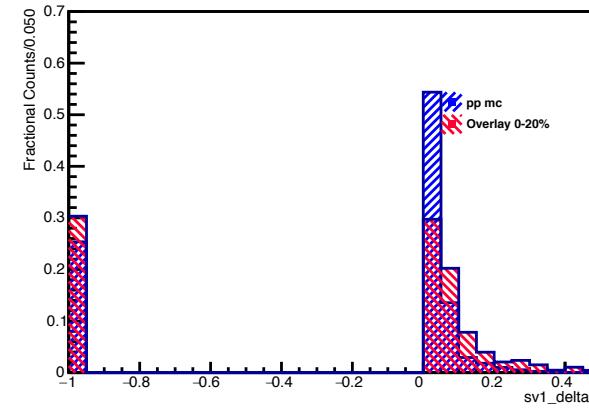
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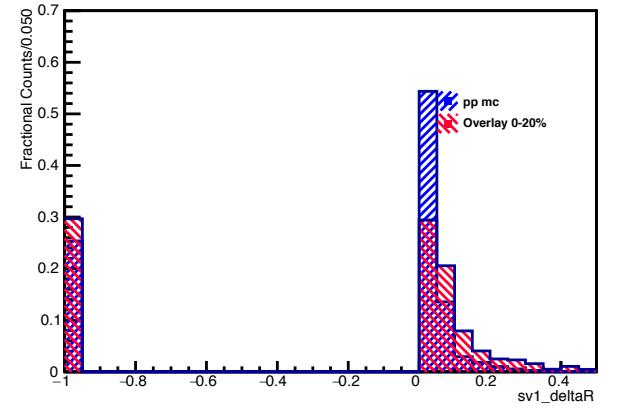
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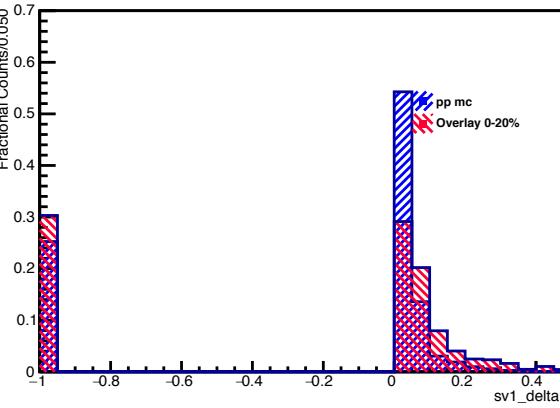
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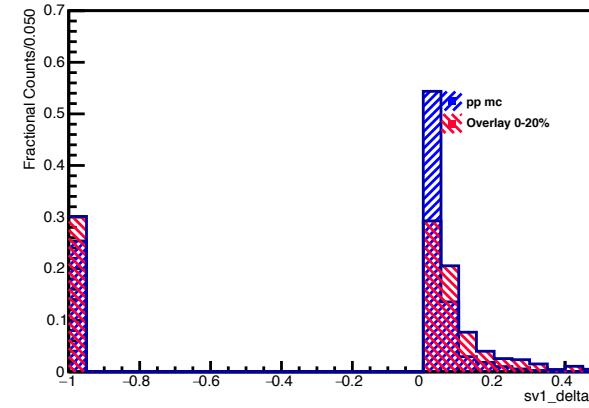
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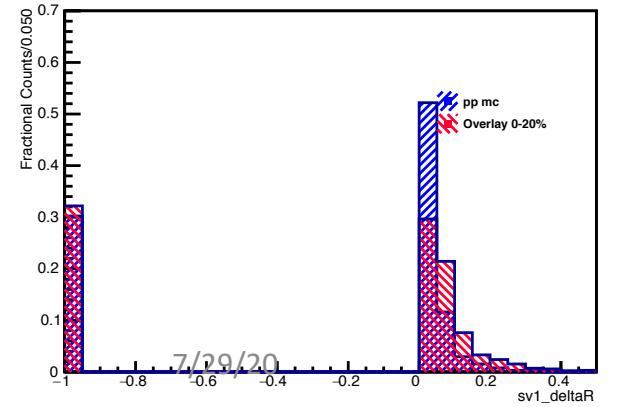
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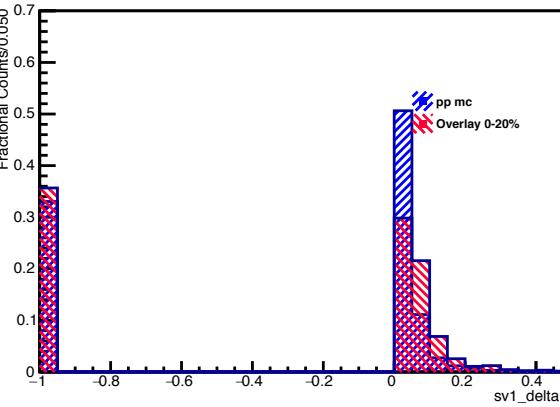
JF pt &gt; 4 GeV Fixed Cone



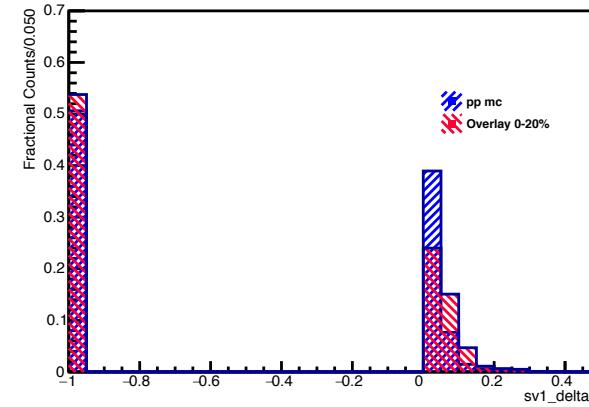
pre-tagging pt &gt; 1.5 GeV Fixed Cone



pre-tagging pt &gt; 2.0 GeV Fixed Cone

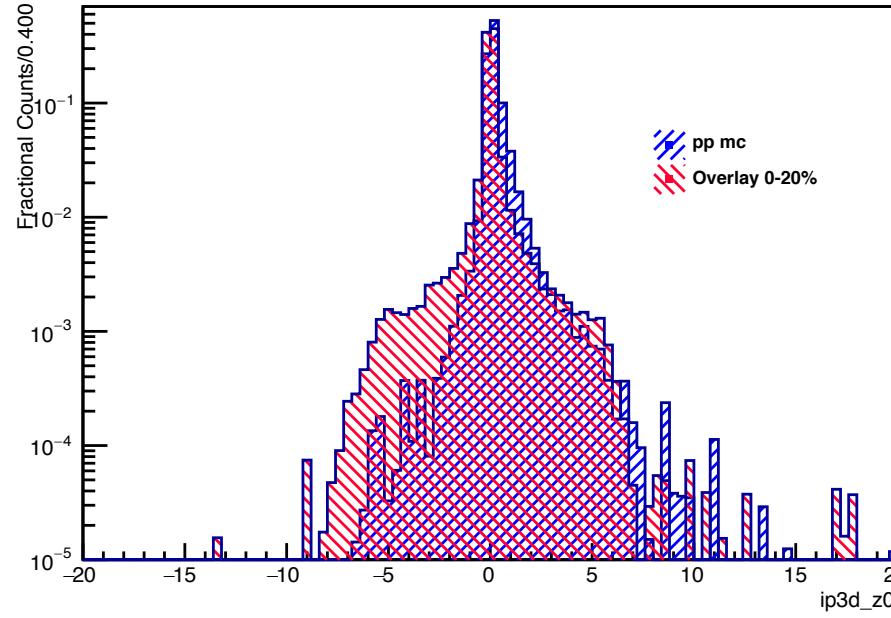


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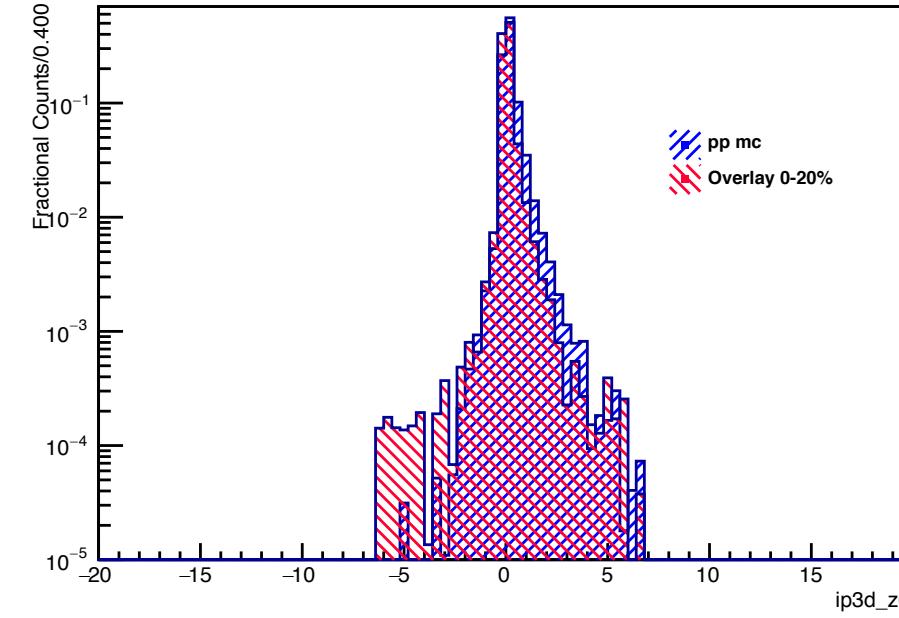


|PxD

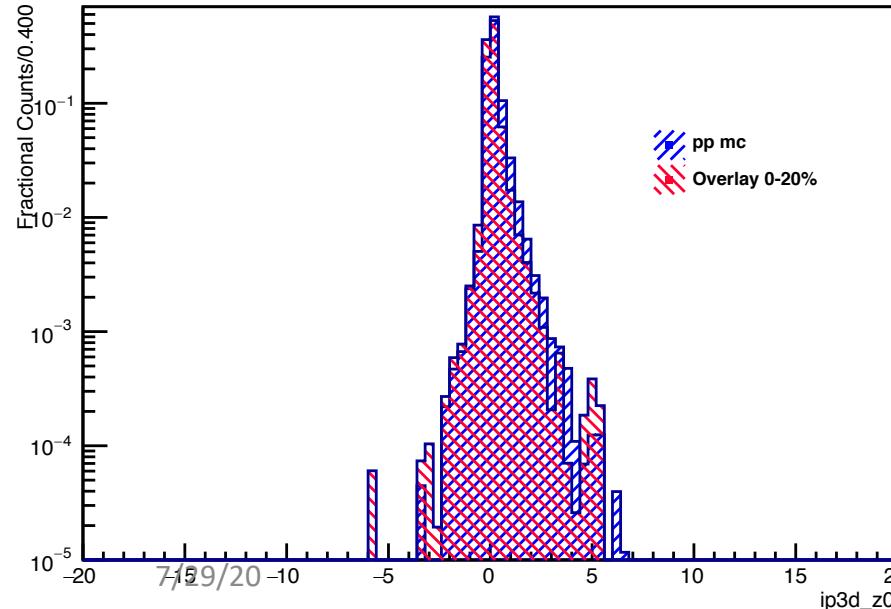
Default Cuts Shrinking Cone



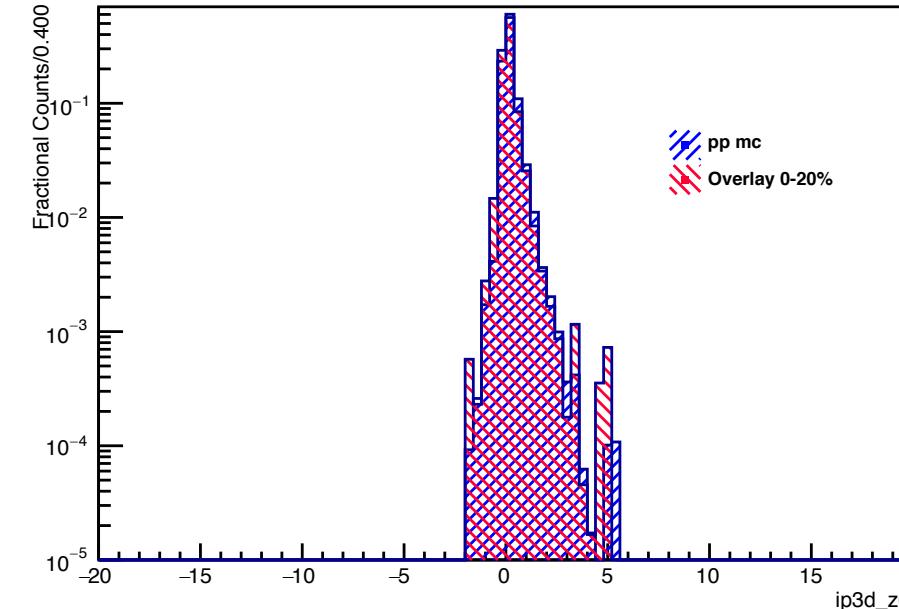
Pre-tagging min pT 1.5 GeV FC4



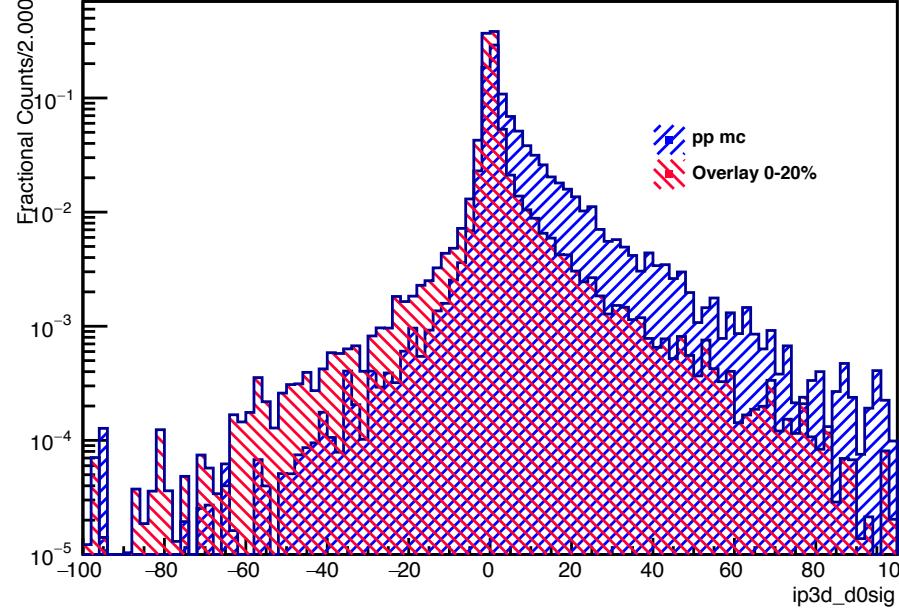
Pre-tagging min pT 2 GeV FC4



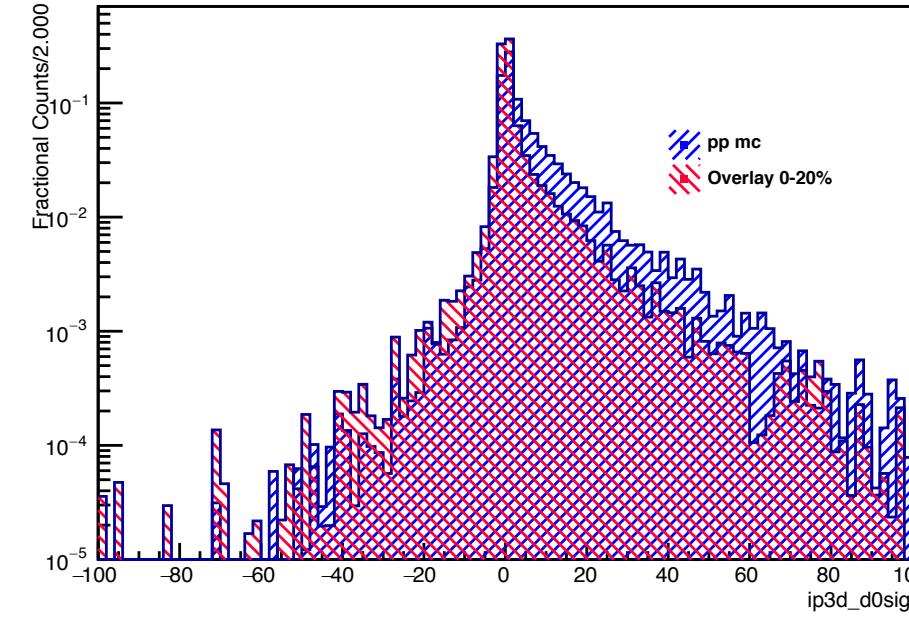
Pre-tagging min pT 4 GeV FC4



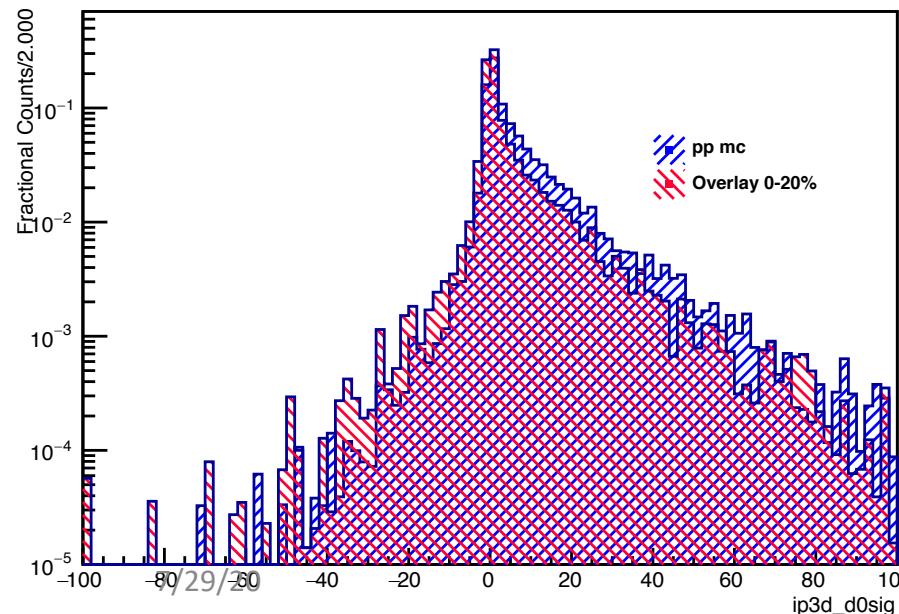
Default Cuts Shrinking Cone



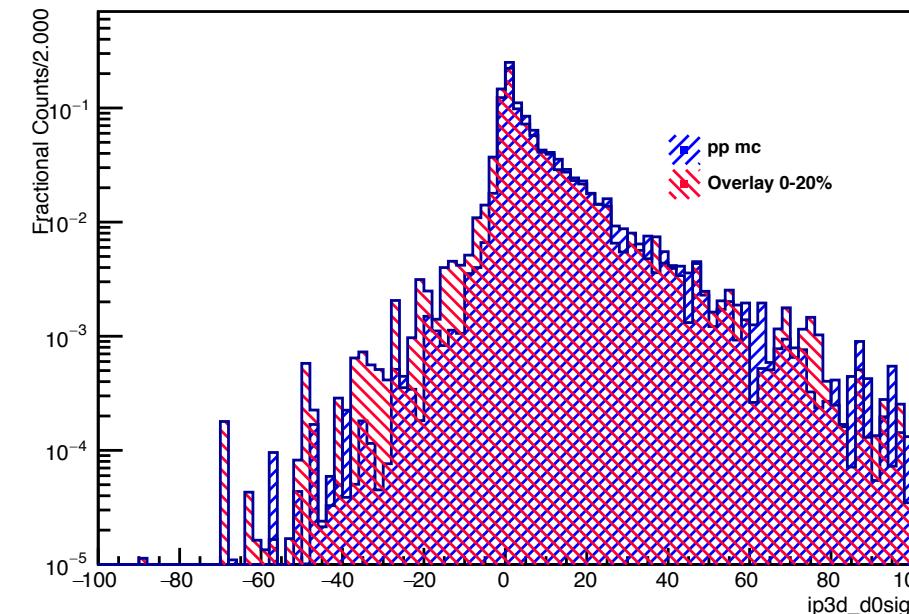
Pre-tagging min pT 1.5 GeV FC4



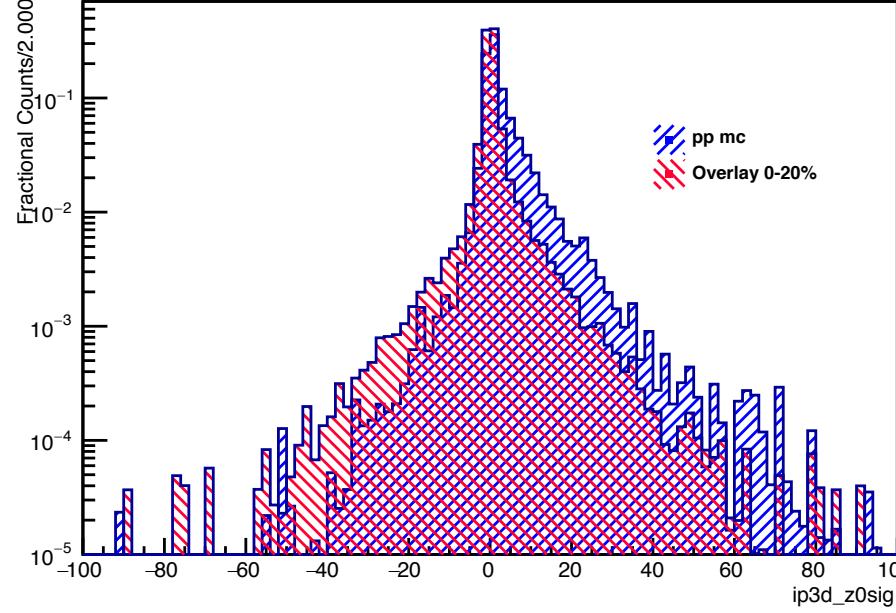
Pre-tagging min pT 2 GeV FC4



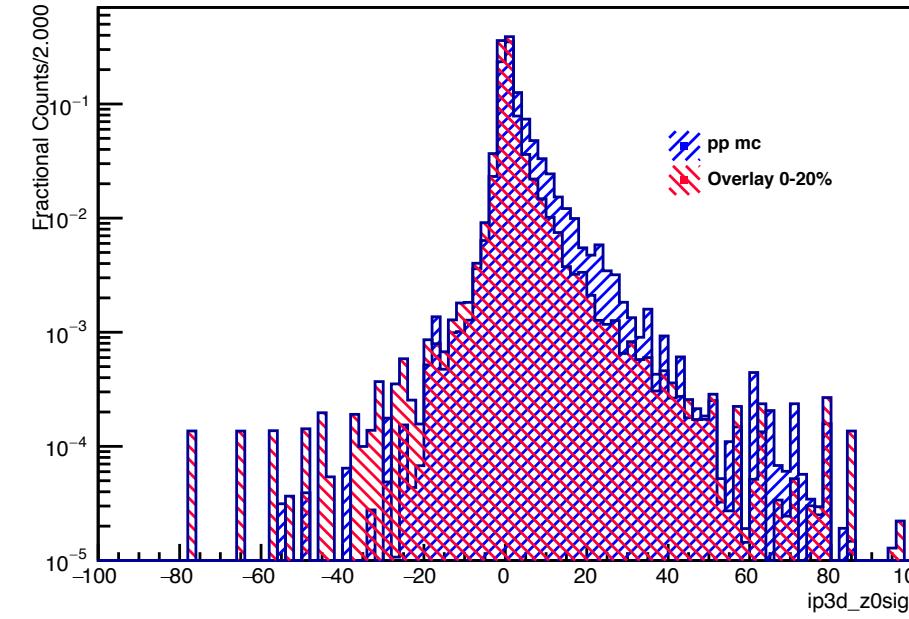
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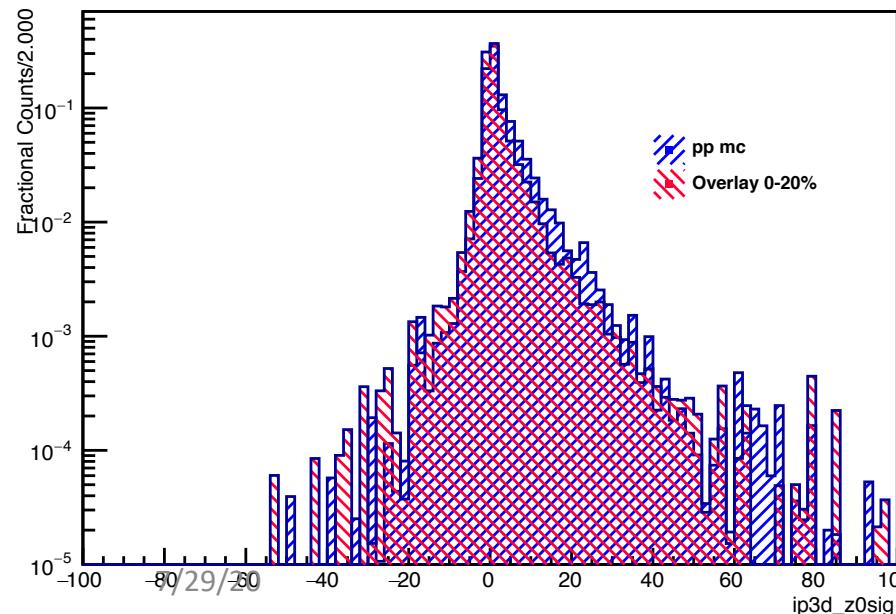
Default Cuts Shrinking Cone



Pre-tagging min pT 1.5 GeV FC4



Pre-tagging min pT 2 GeV FC4



Pre-tagging min pT 4 GeV FC4

