Qualification Task AFT 455:

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

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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    - Default templates outdated, looking at input variables.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 secondary vertexing and input variables.
- This time: remaking of IP3D templates and their performances with inclusive dijet samples.

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_jetjet_JZ1_bbfilter.py
  - Overlay: pp MC + 2018 minBias data to simulate underlying events.

- pp Inclusive dijets samples (IP2D/3D plots) and Overlay:
  - https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/HIJetMCSamples#Pythia8_dijets_8M_per_sample_in
  - Pythia8 dijets - 8M per sample in 21.0.93
  - Overlay: pp MC + 2018 minBias data to simulate underlying events.
- Selection on Jets:
  - Reco jets with ΔR(truth-reco) < 0.3
  - $p_T^{truth\ jet} > 50$ GeV or 100 GeV (see plots)

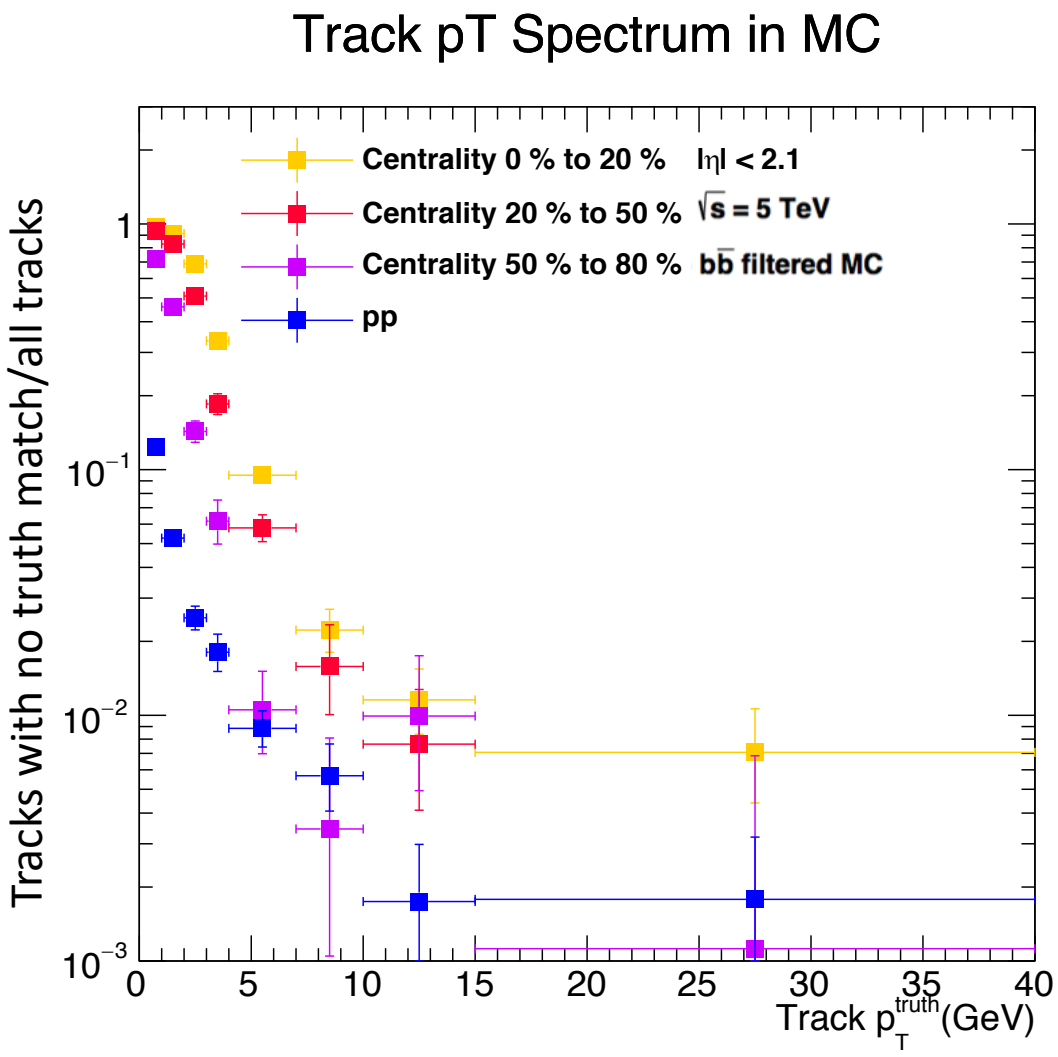
- Disabled all anti-pile up tools(small Rϕ and large Z or JFV scores)

- B-Jets: jets with a truth B hadron associated with it. Similarly for C-jets
  - $p_T^B > 5$ GeV
  - ΔR(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

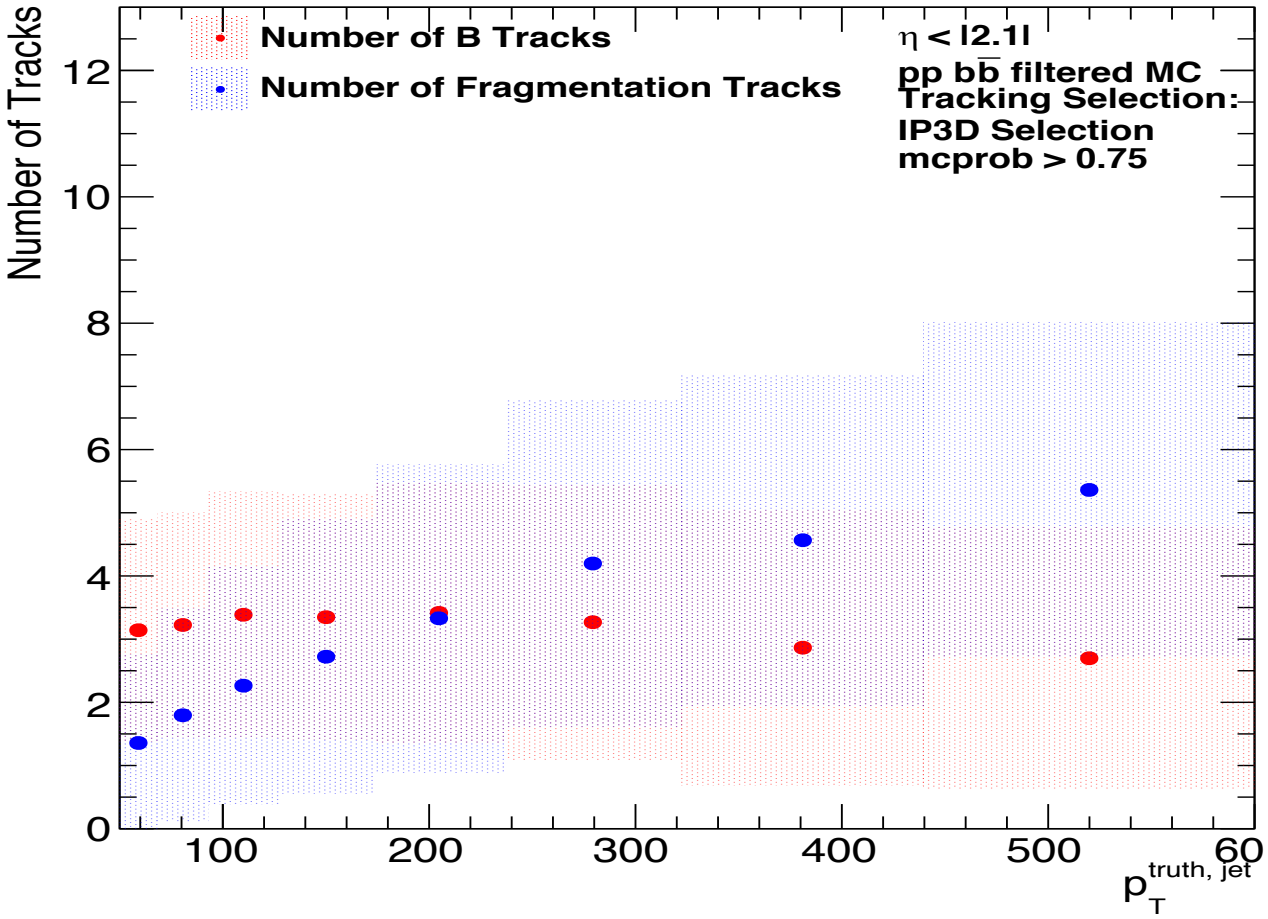
Tracks reconstruction in Heavy Ion Collisions

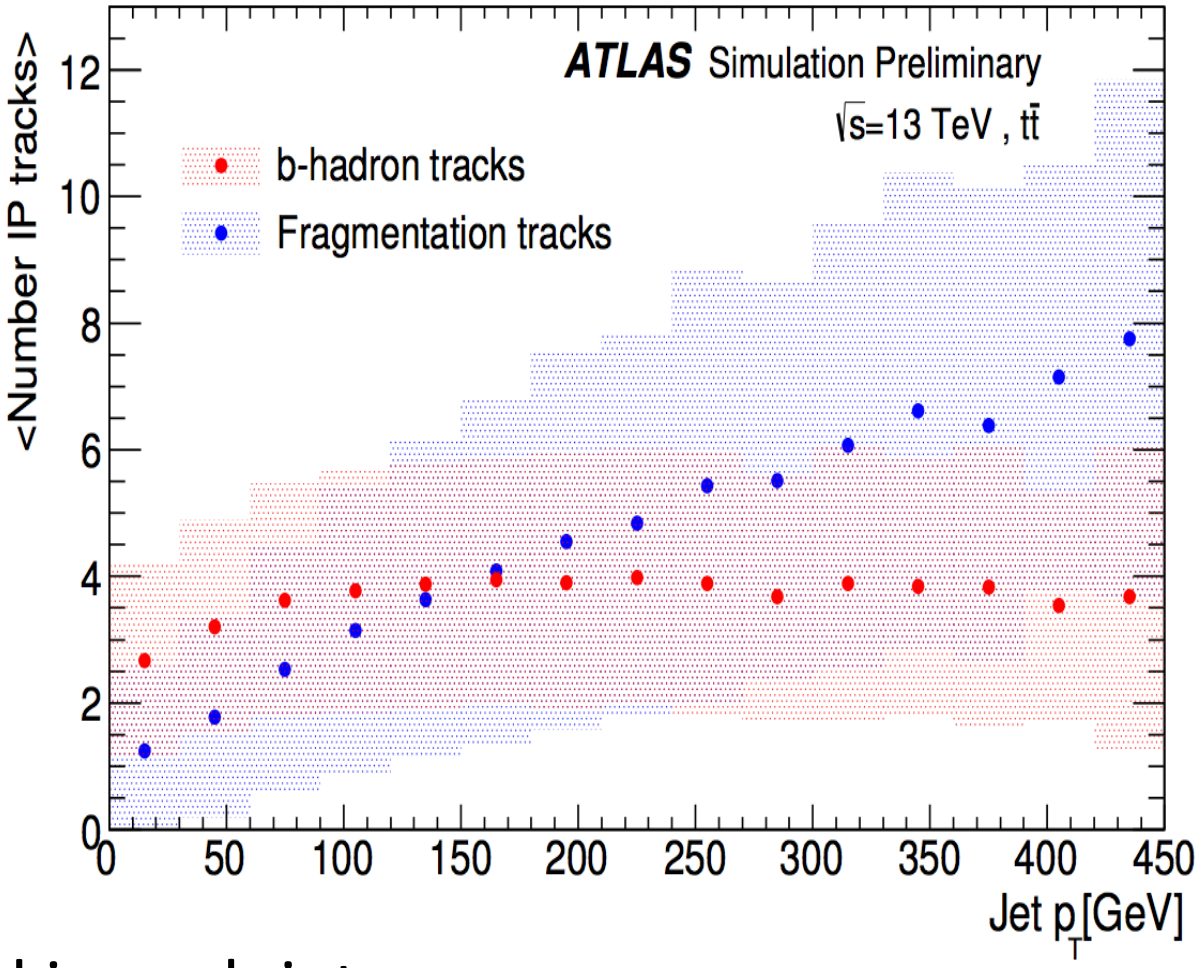
- Reconstruction is different, designed to work with high occupancy data (order of 1000 tracks)
  - Occupancy has a centrality dependence
- Only one primary vertex per event. No pile-up effect.
- Lower collision energy.
- Many more underlying event tracks in comparison to pp collisions.
  - Especially 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



Secondary Vertexing Performance for JetFitter and SVF

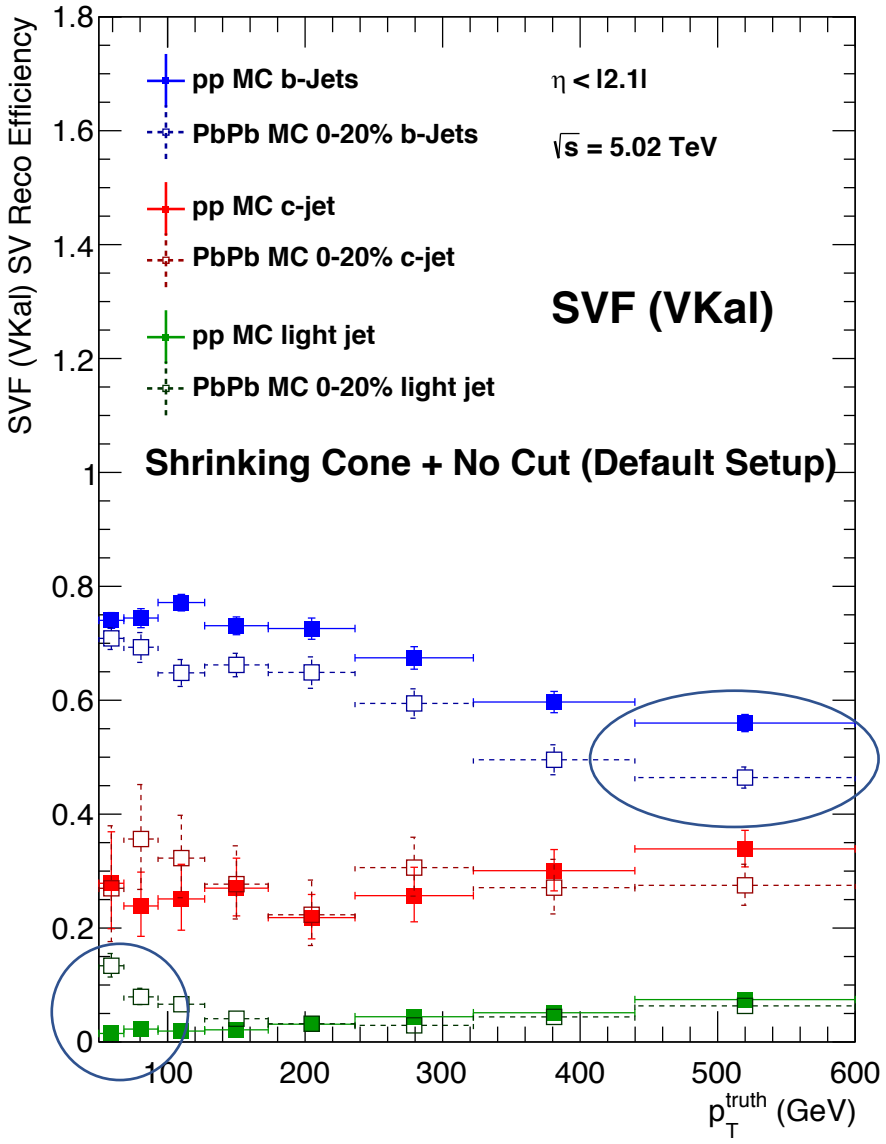
Recap: 50k bbar filtered samples



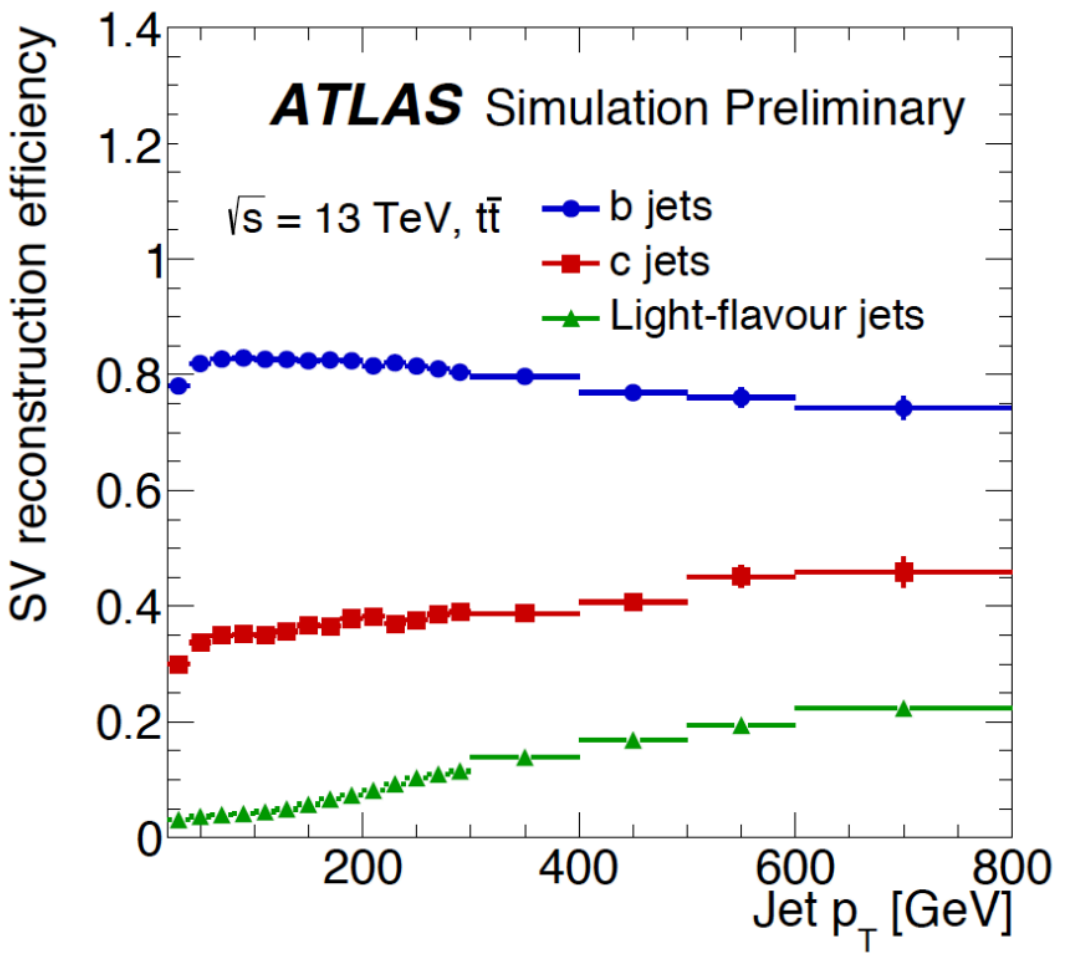


- Less number of tracks reconstructed in each jet
- Lower efficiency of secondary vertex reconstruction in VKal.

Recap: Secondary Vertexing Performance with Default setup for SVF



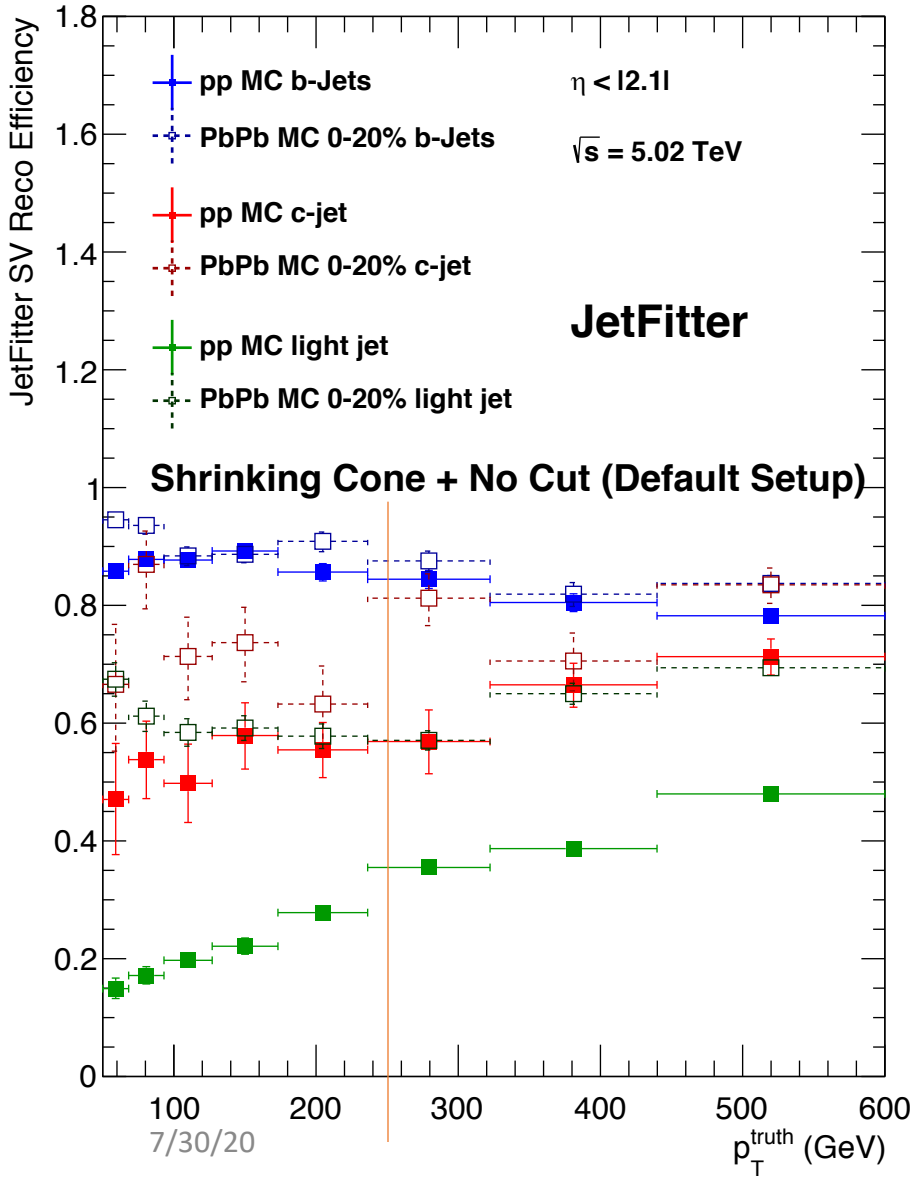
ATL-PHYS-PUB-2017-011: https://cds.cern.ch/record/2270366



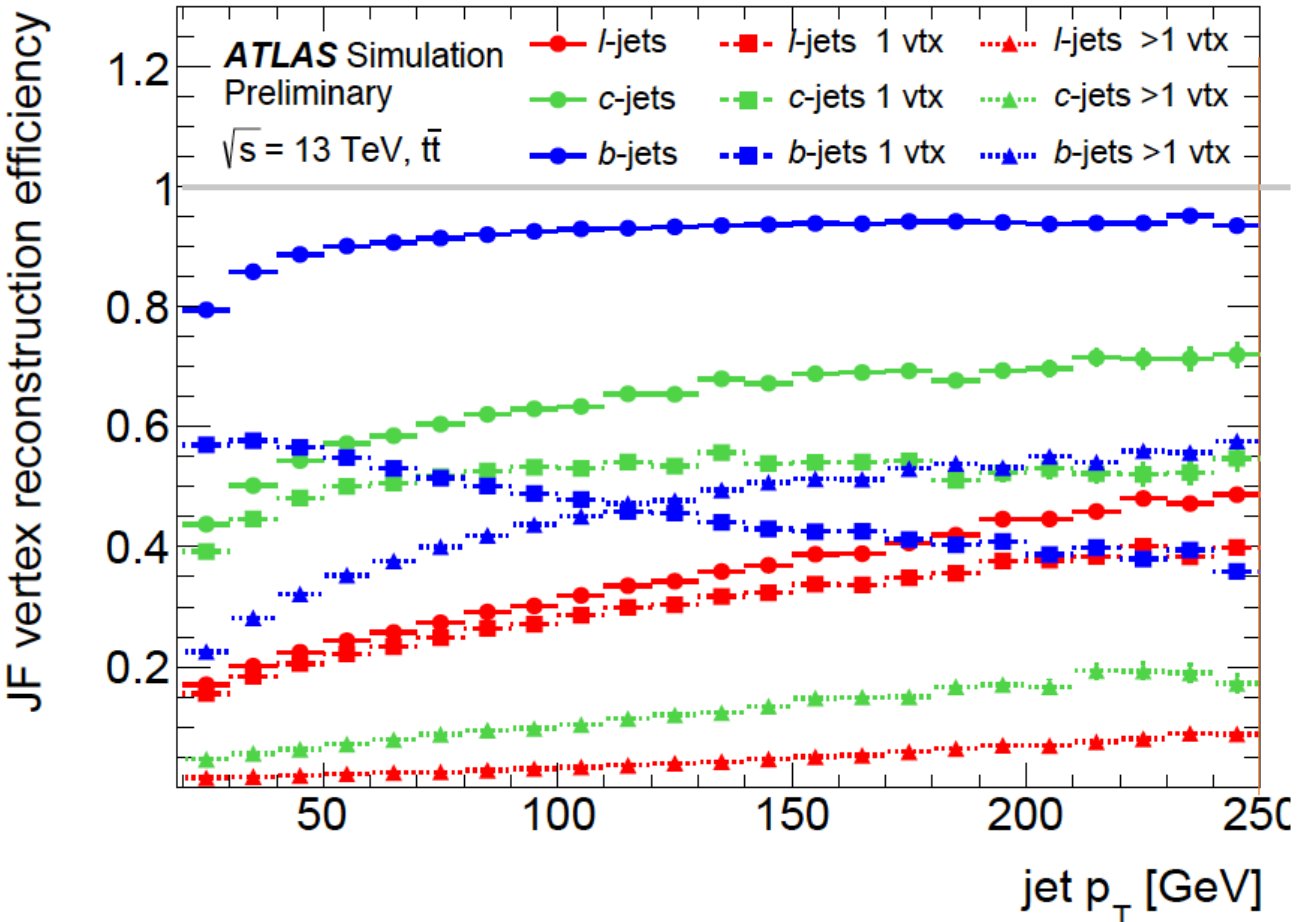
Most central overlay MC has lower vertexing efficiency at high pT and higher fake rate at low pT.

- Need to reduce low pT UE tracks.
- Inefficiency caused by missing tracks, need to include more tracks for PbPb.

Secondary Vertexing Performance with Default setup for JetFitter

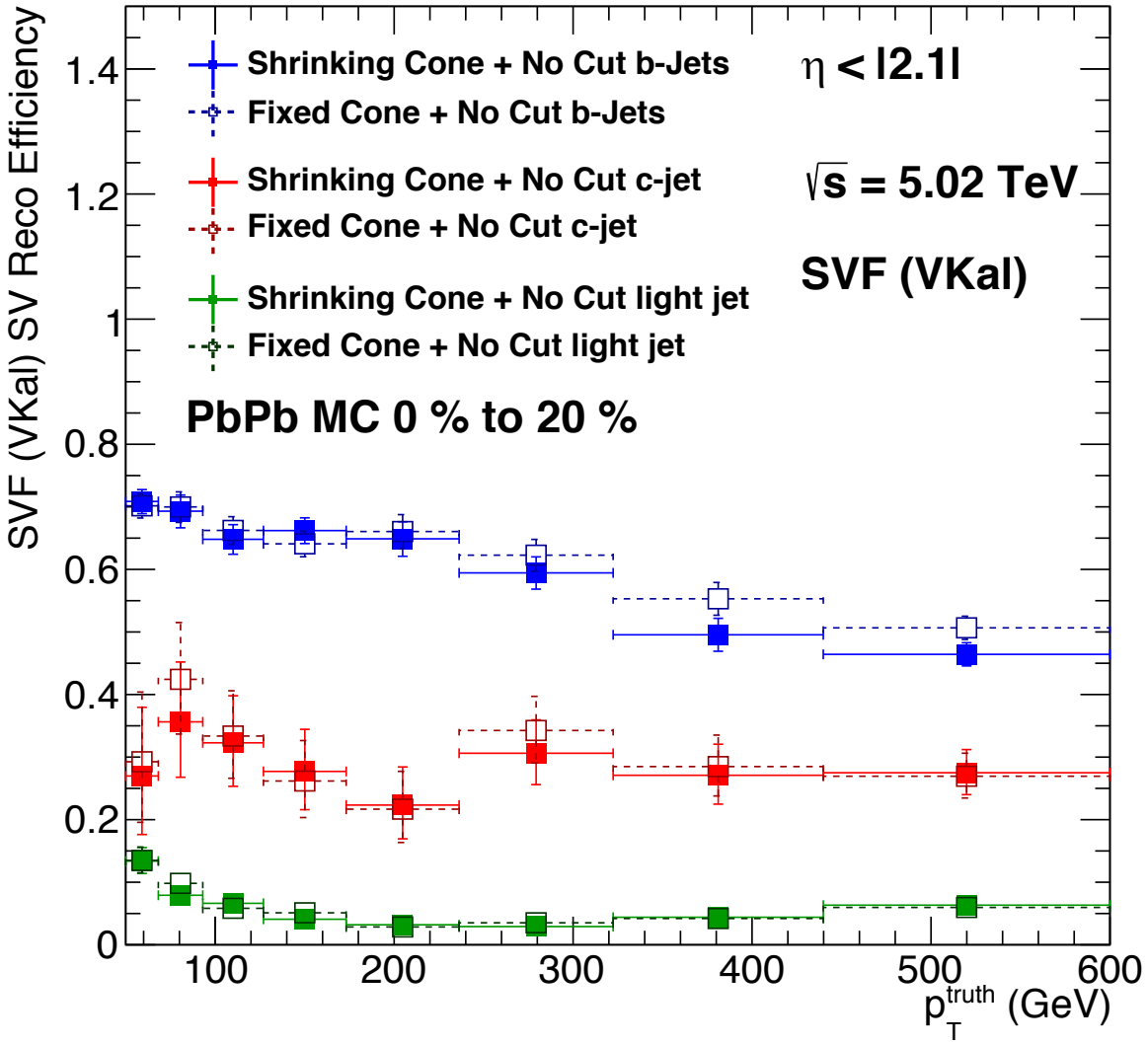


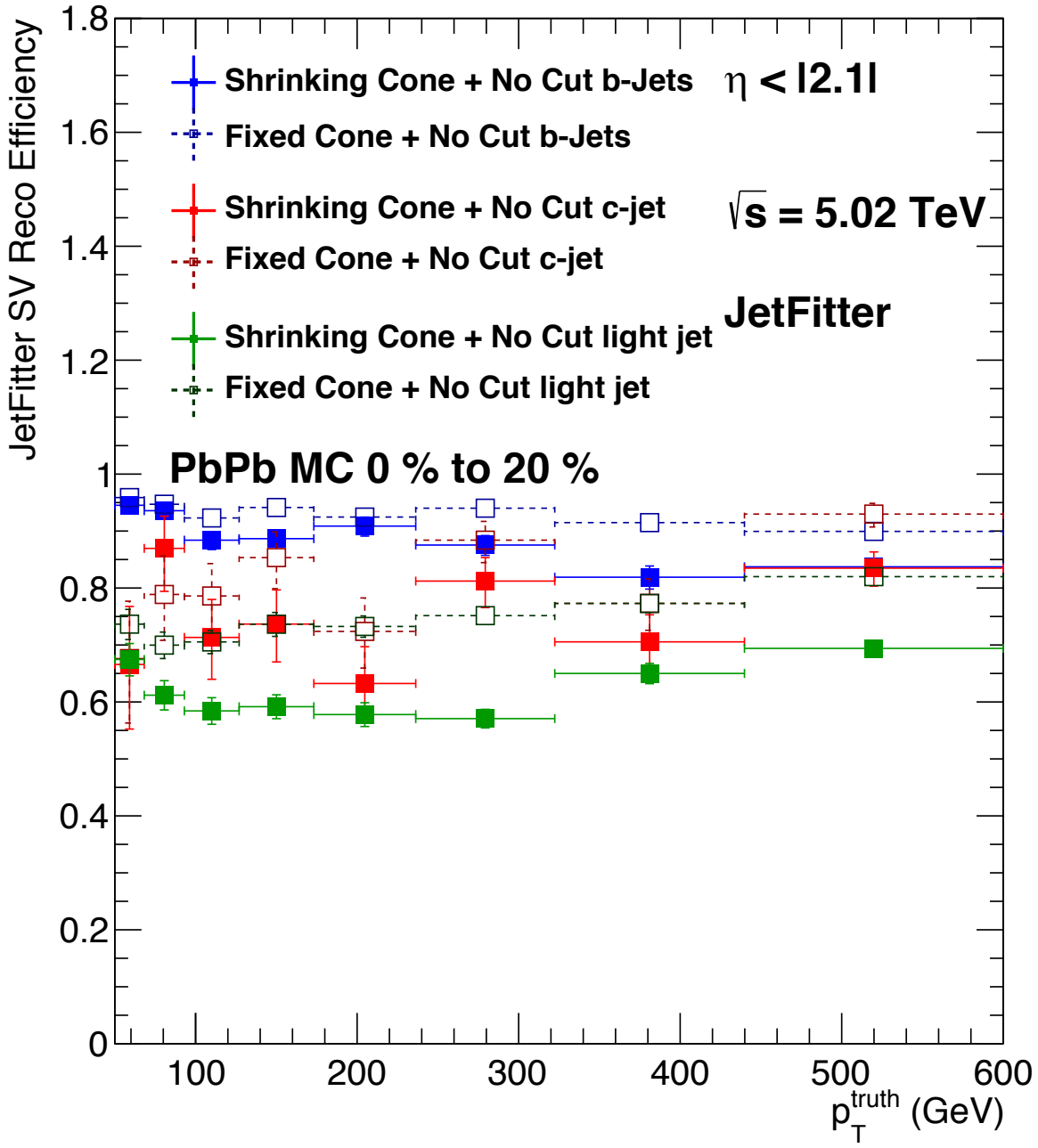
- Inclusive fake rate is much higher in overlay MC central event. (comparing to solid line on the right)
  - Needs to reduce UE tracks' effect.



Fixed Cone at R = 0.4 in Central PbPb (0-20%)

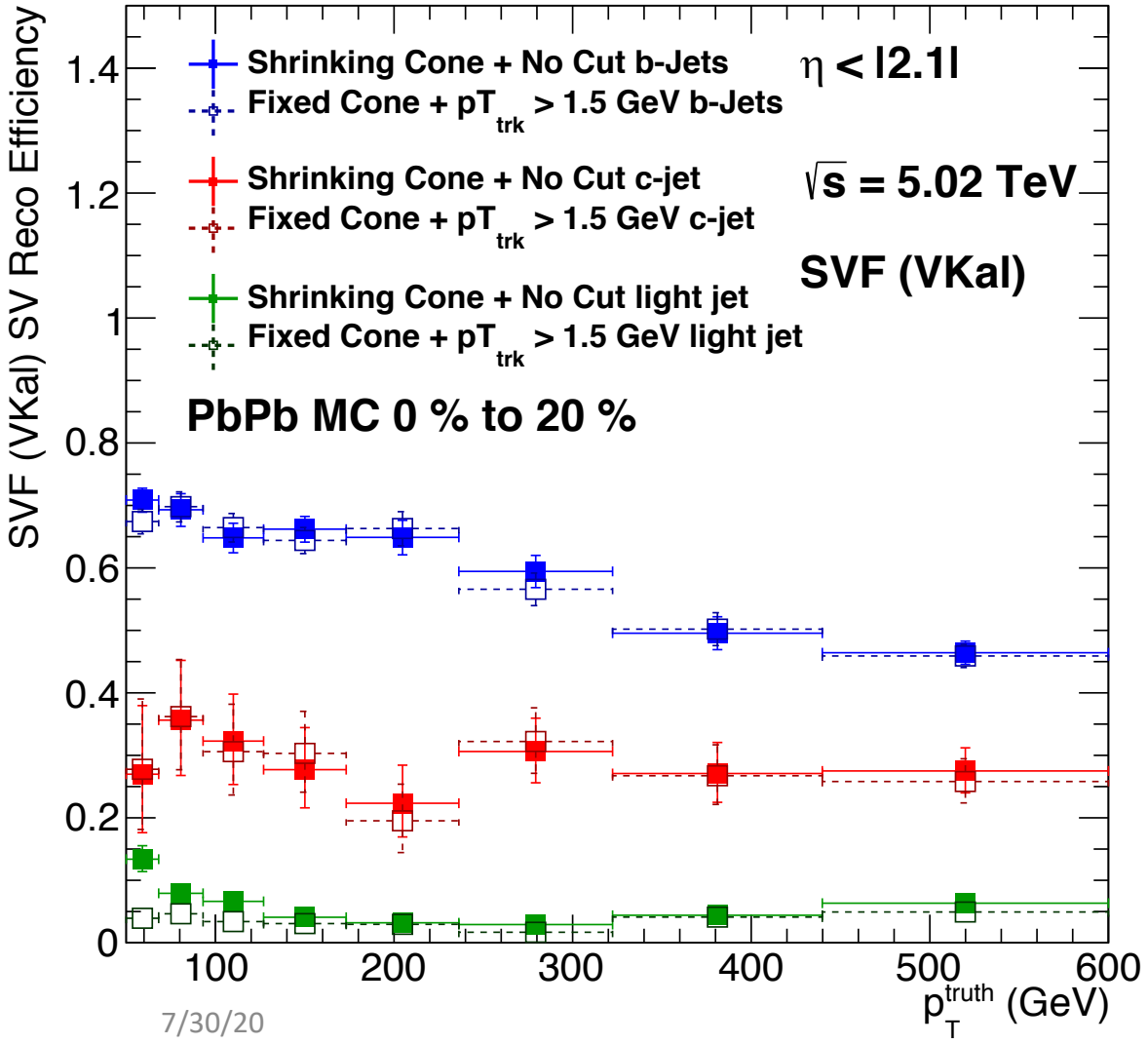
- Motivation: unknown track distributions for PbPb jets
- Improve high pT SVF performance but worsen JetFitter.

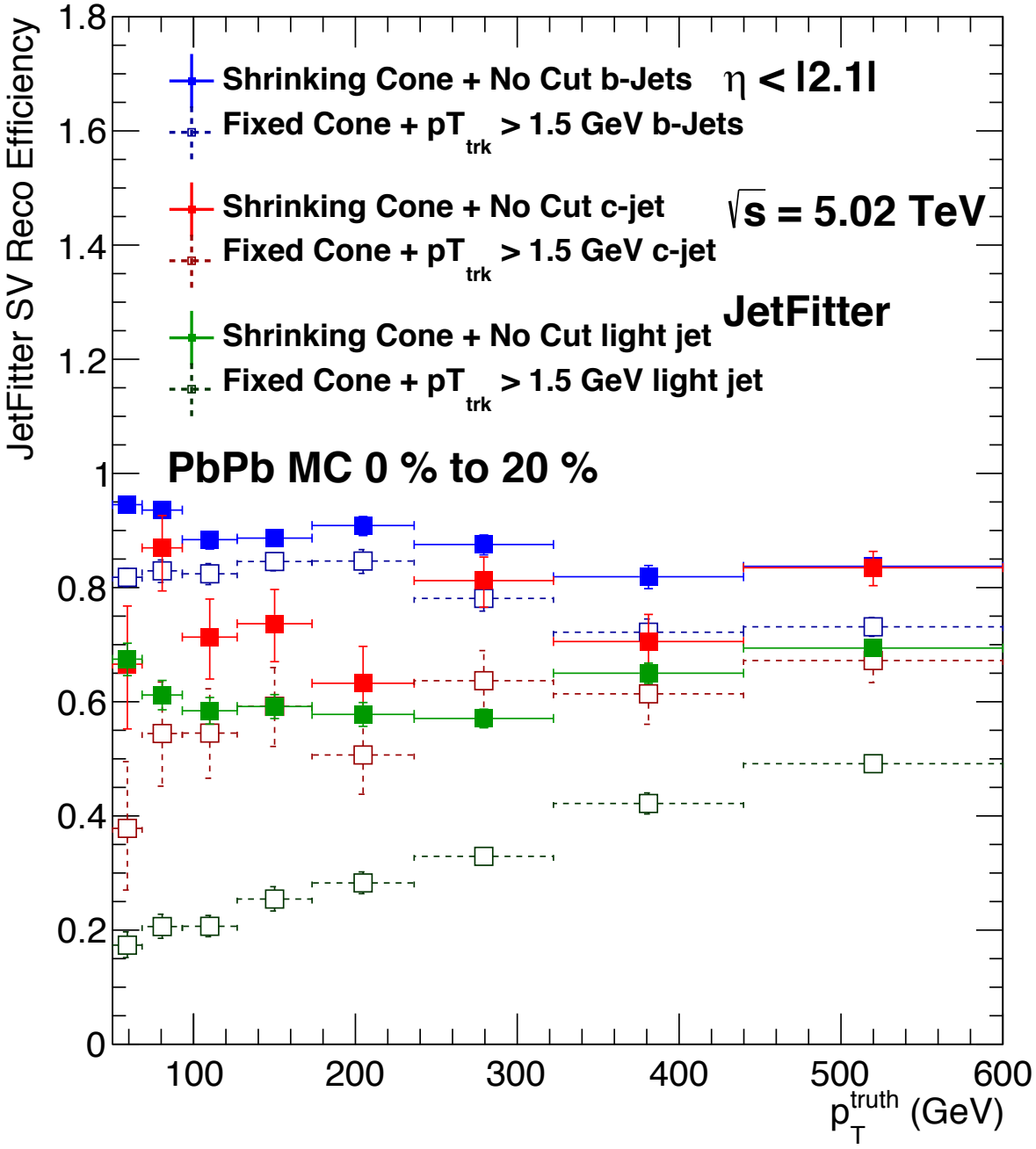


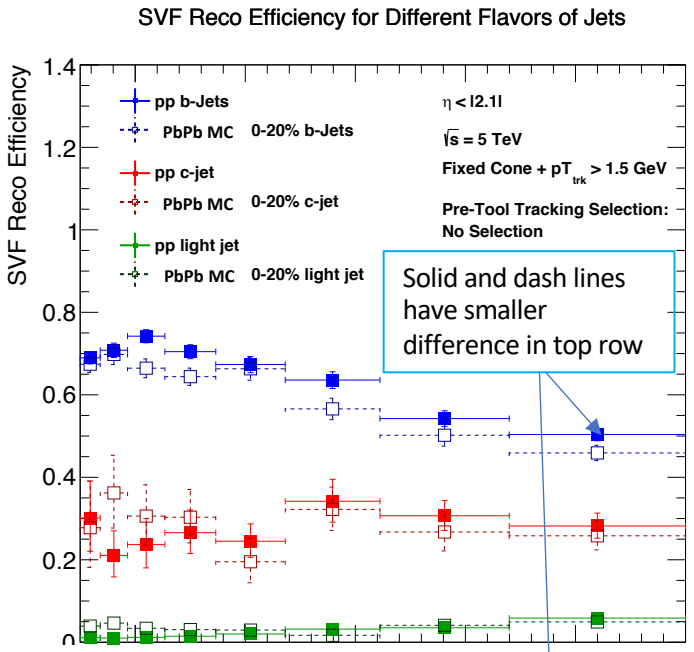


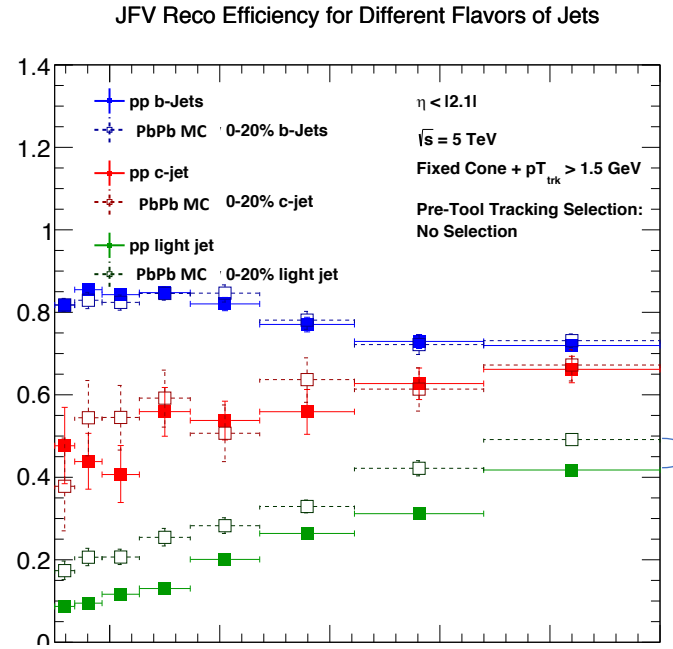
Fixed Cone at R = 0.4 + Track pT cut at 1.5 GeV in PbPb (0-20%)

- Shown are the most central (0-20%) PbPb MC
- Performance improved for JetFitter

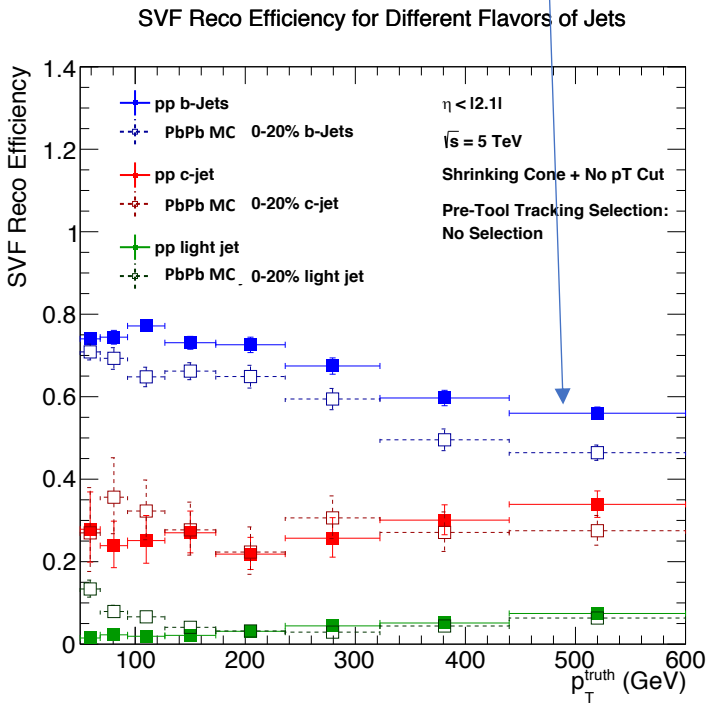


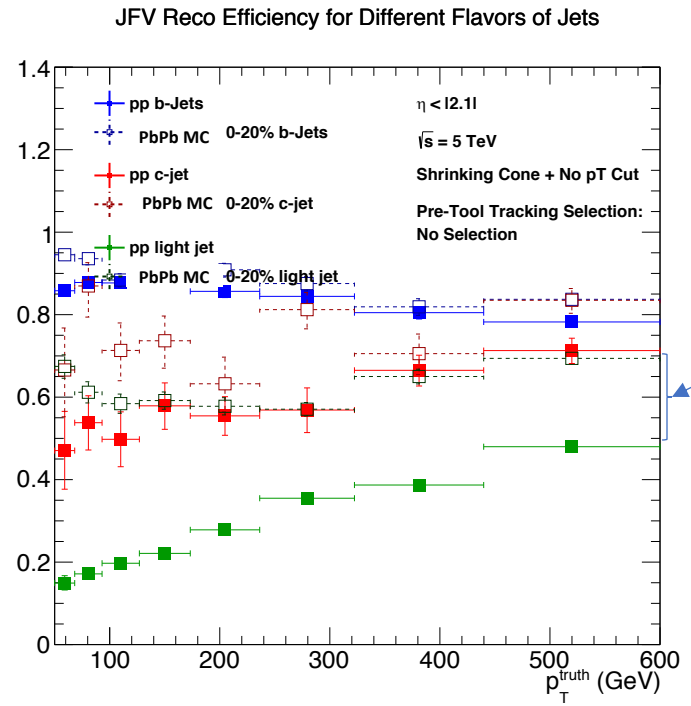






Solid and dash lines have smaller difference in top row





Reduced Centrality Dependence for Fixed Cone + Track pT Cut

Left column: SVF Efficiency
Right column: JetFitter Efficiency

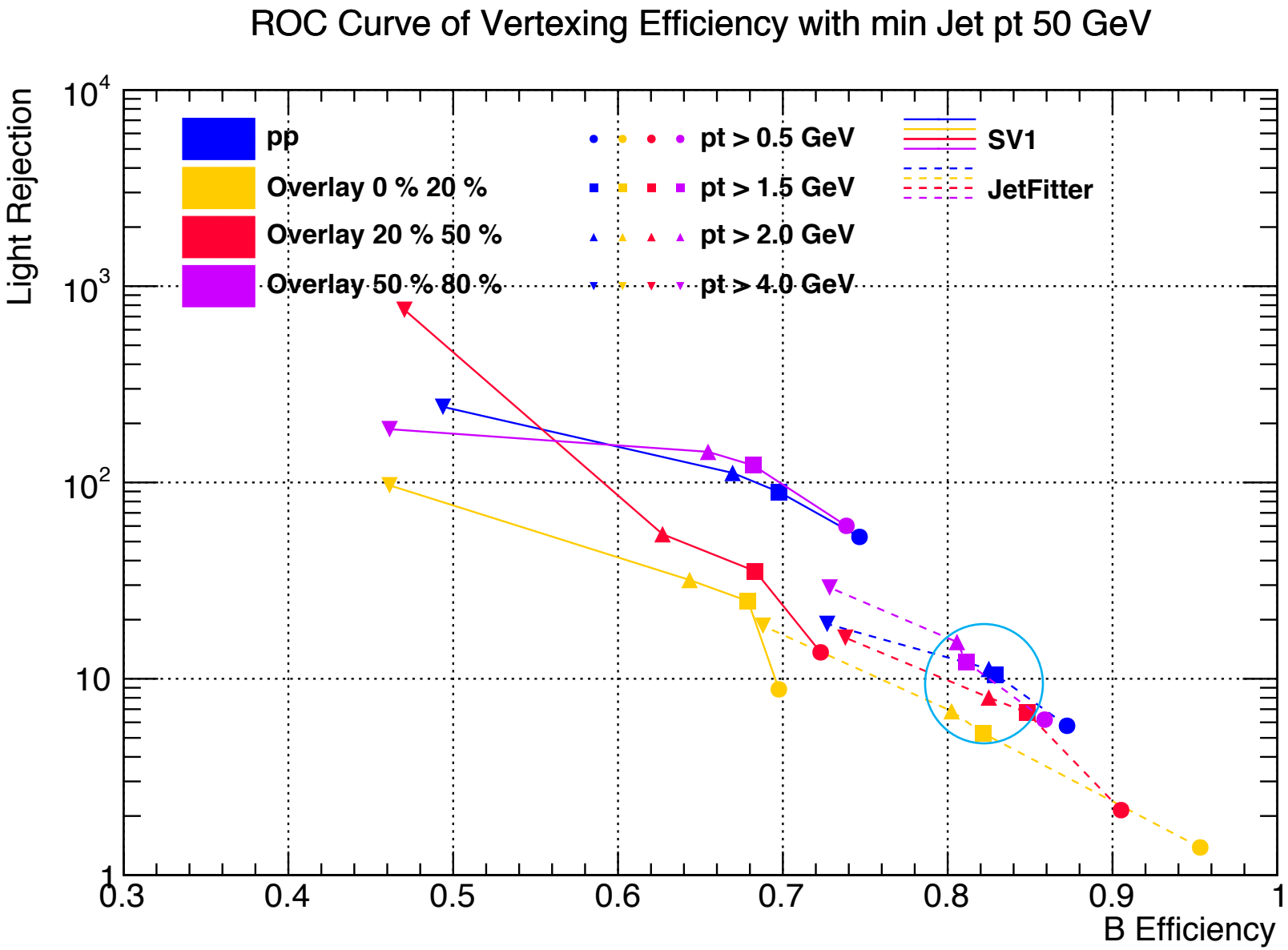
Top row: Fixed Cone + 1.5 GeV
Bottom row: Shrinking Cone + no pT cut

Centrality dependence is less in top row.

- Good since we want a less centrality dependent btagging tool that works in central collisions.

Again solid (pp) and dash (central PbPb) lines are closer in top row plots

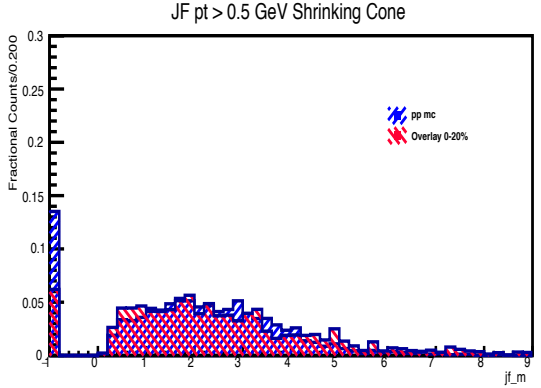
ROC curve for JF and SV1 Vertexing Efficiency

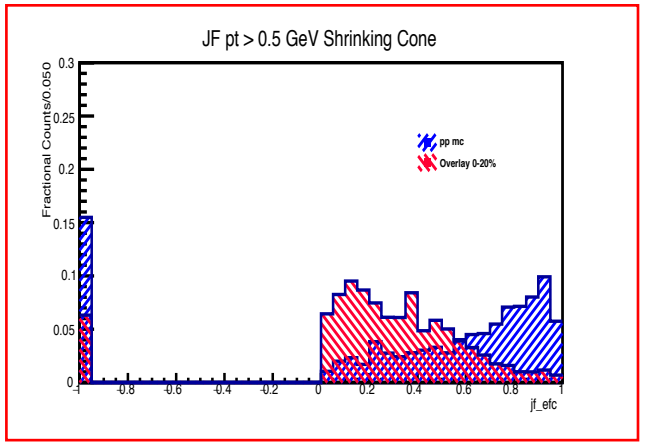


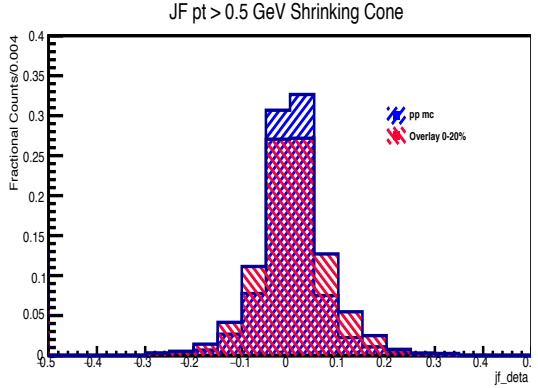
- Blue circle: For JetFitter, cutting at pT = 1.5 GeV or pT = 2.0 GeV gives least centrality dependence.
- SV1: Centrality dependence similar for different cuts

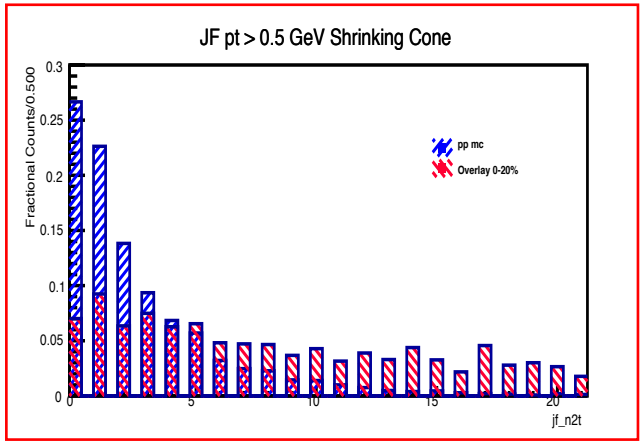
Flavour Tagging Input Variables from JetFitter and SVF

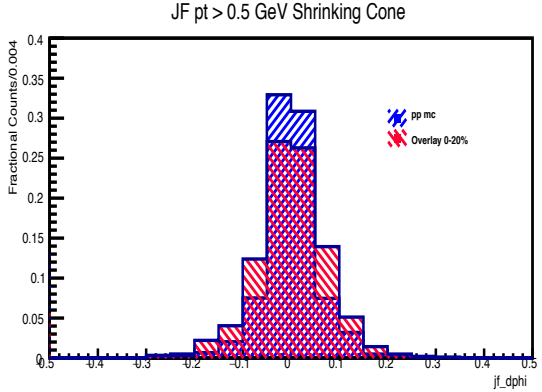
JF Variables at Default Setup

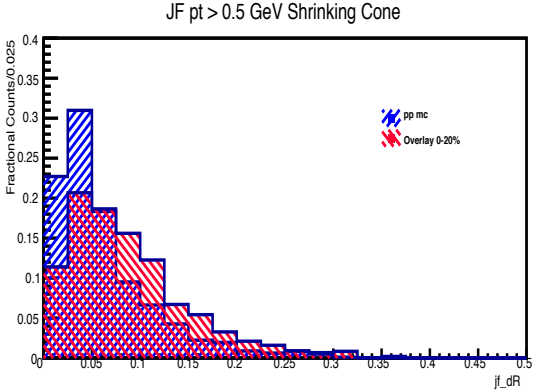


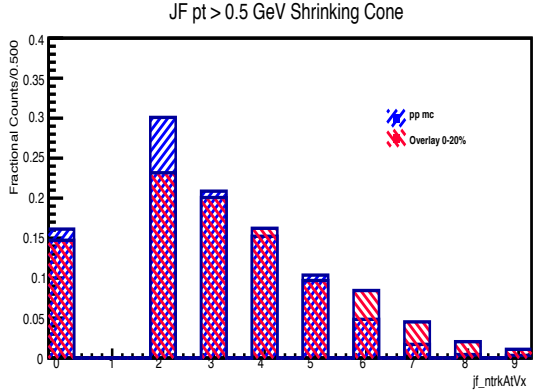




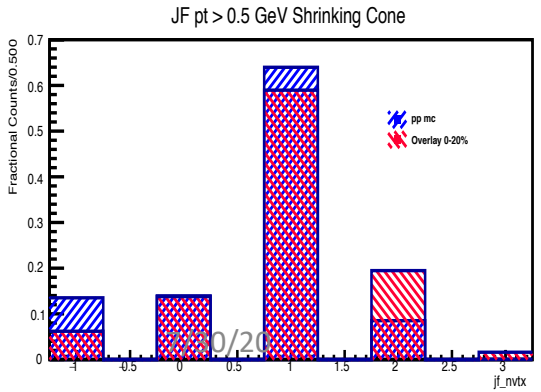


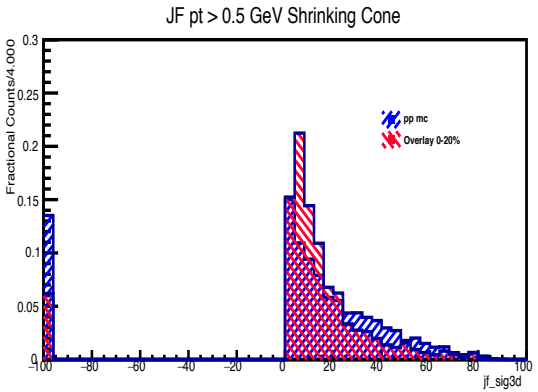


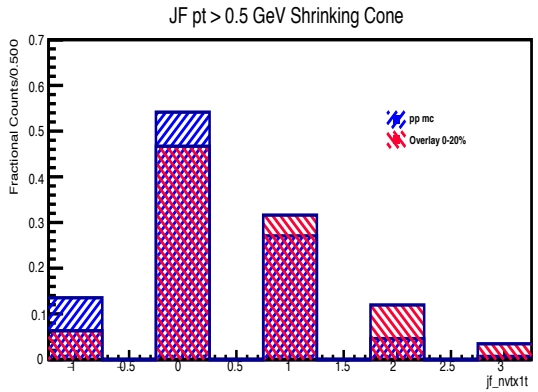




- Energy fraction and number of 2-track vertices are heavily modified in most central PbPb.



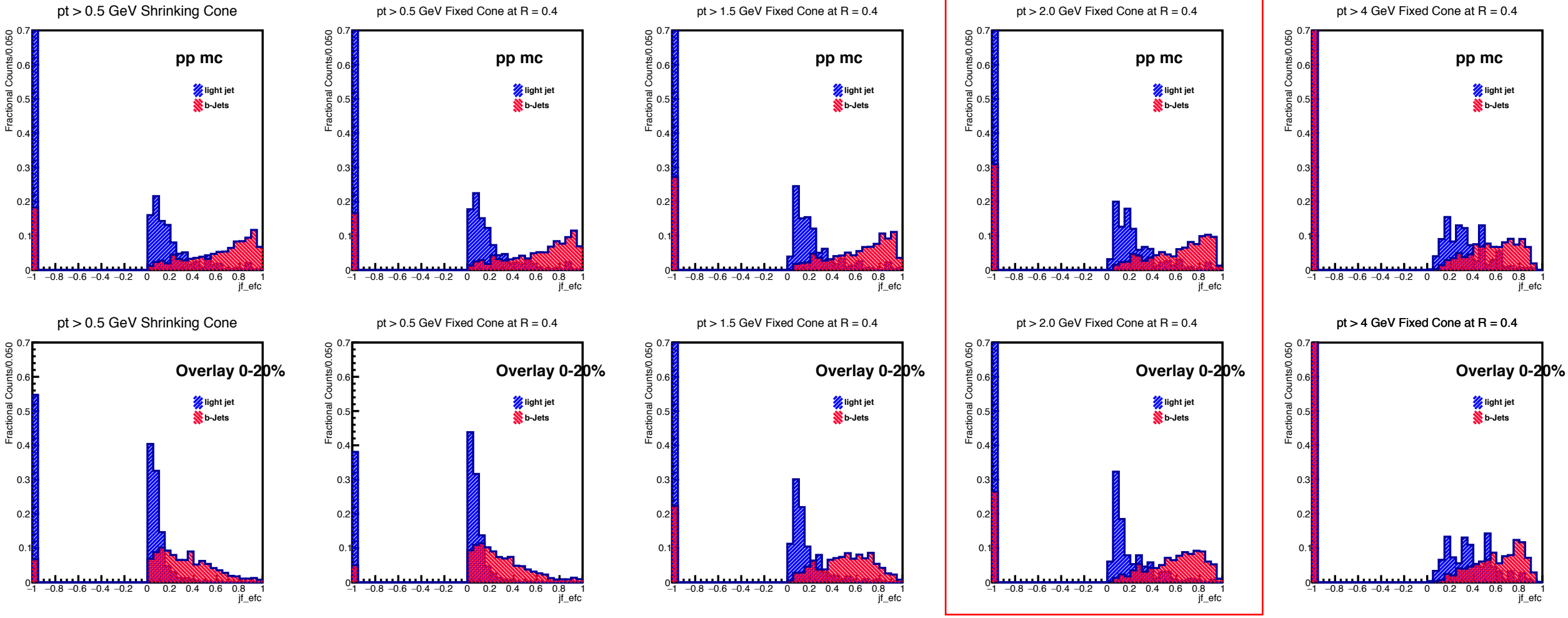




JF Energy Fraction

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

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



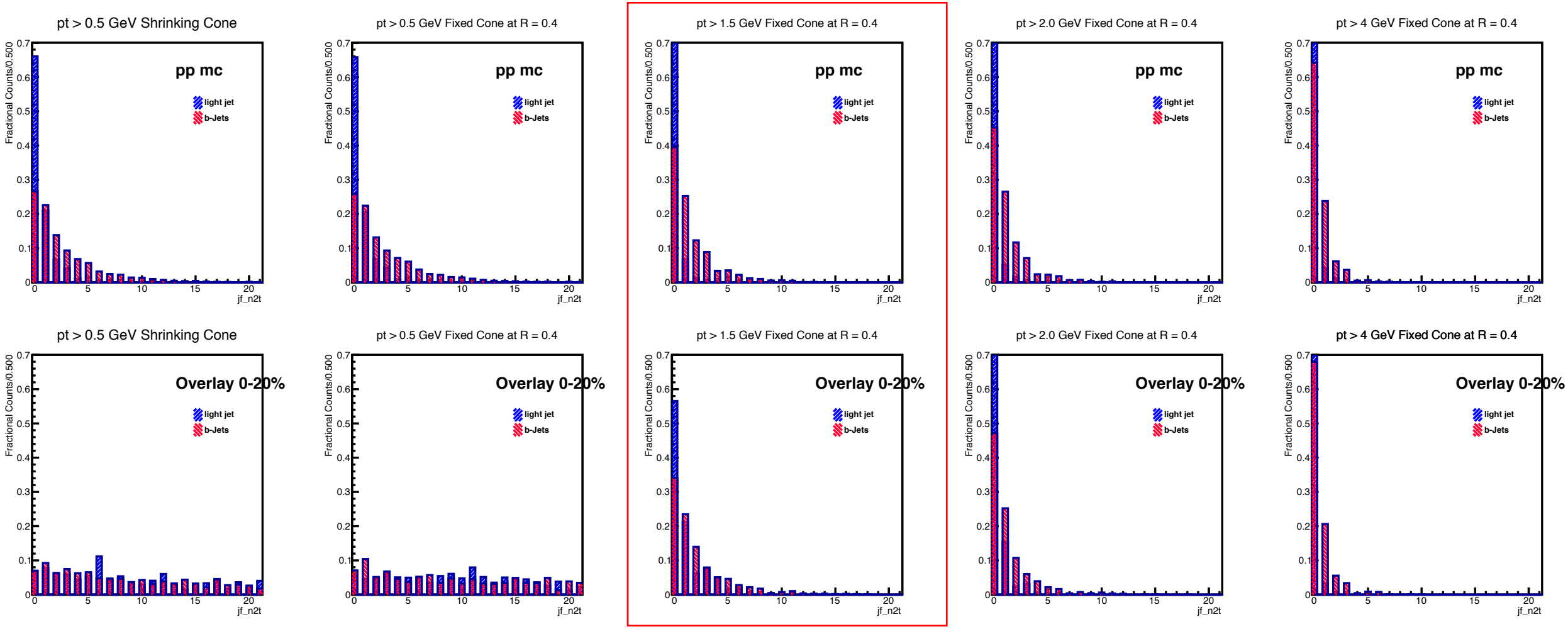
Top Row: pp mc
Bottom Row: Overlay 0-20%

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

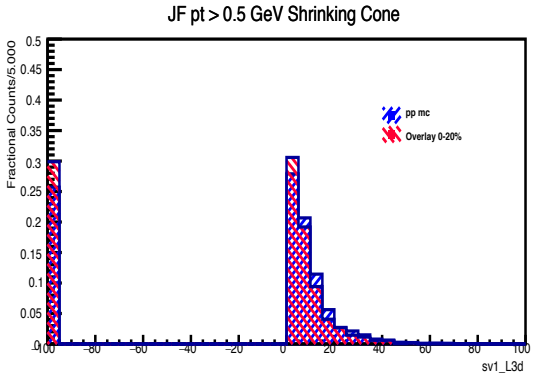
JF n2t (2-trk vertices candidates)

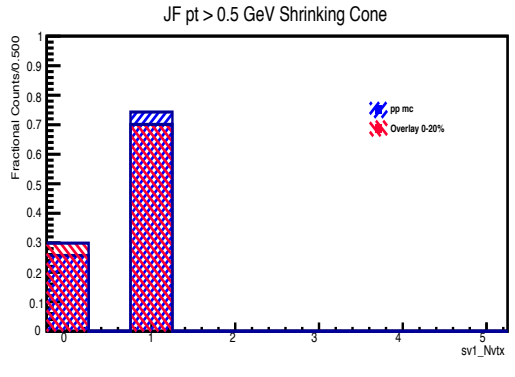
↓ over cutting leaves too few bins

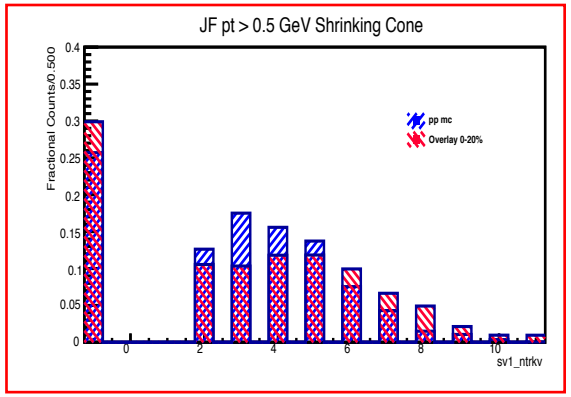


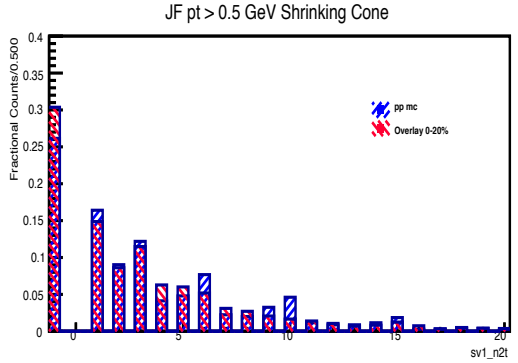
- Before applying cuts in pt, distribution is even, possibly for combinatorics of UE tracks.
- Starting at 1.5 GeV or above, overlay have a similar distribution as pp.

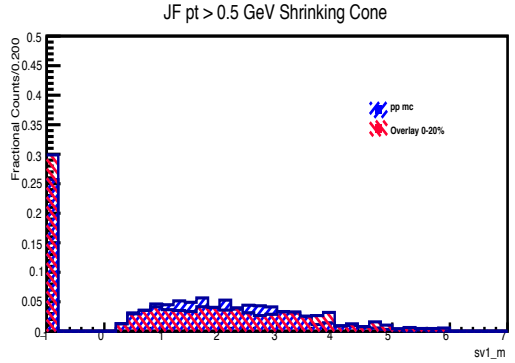
SV Variables at Default Setup

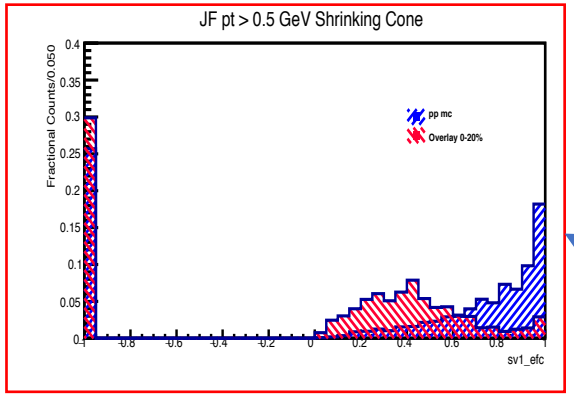


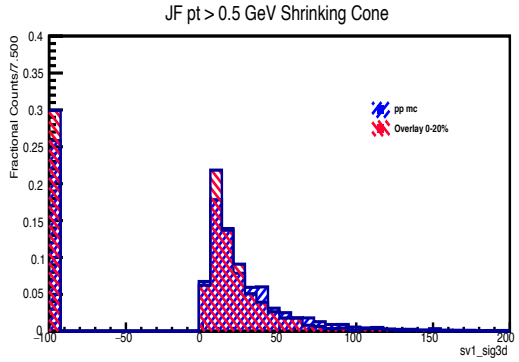


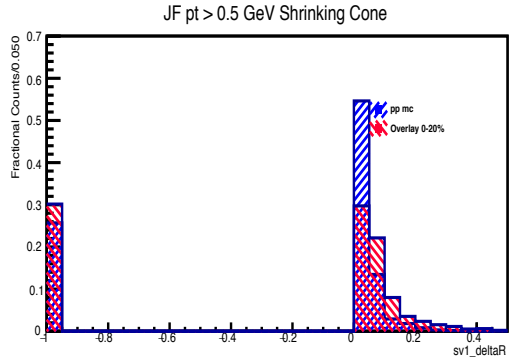


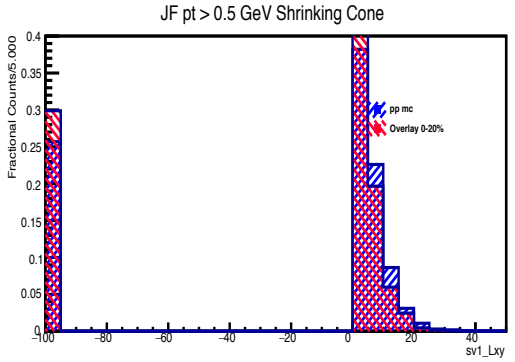






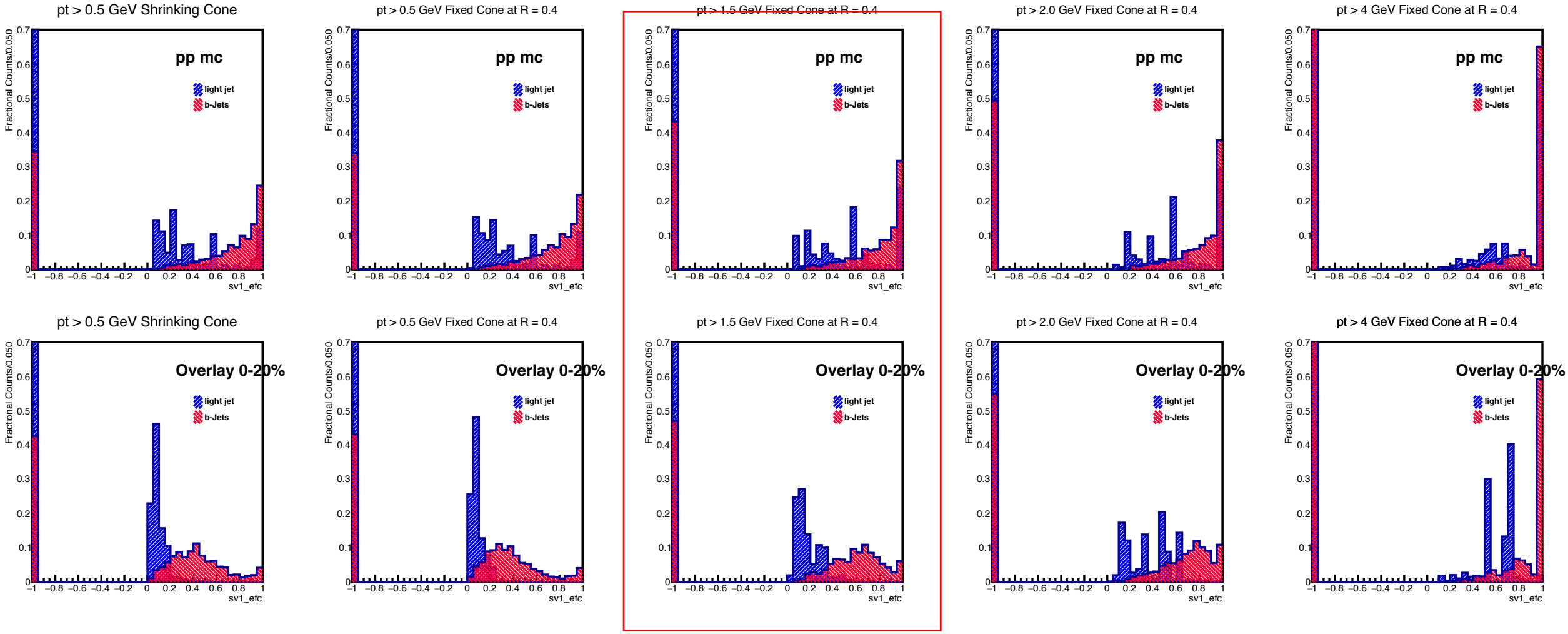






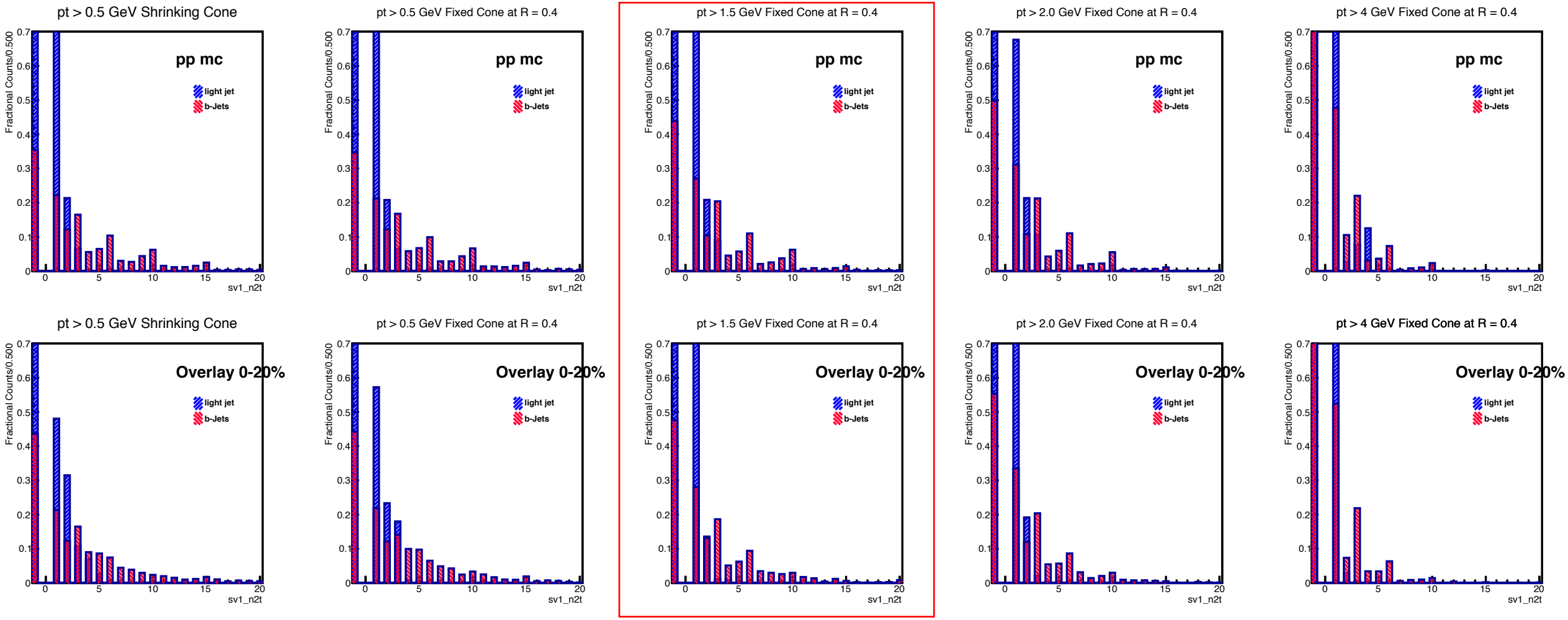
- Energy fraction and number of 2-track vertices are heavily modified.
- Peak at 1 is due to missing tracks. See back up slide 18.

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

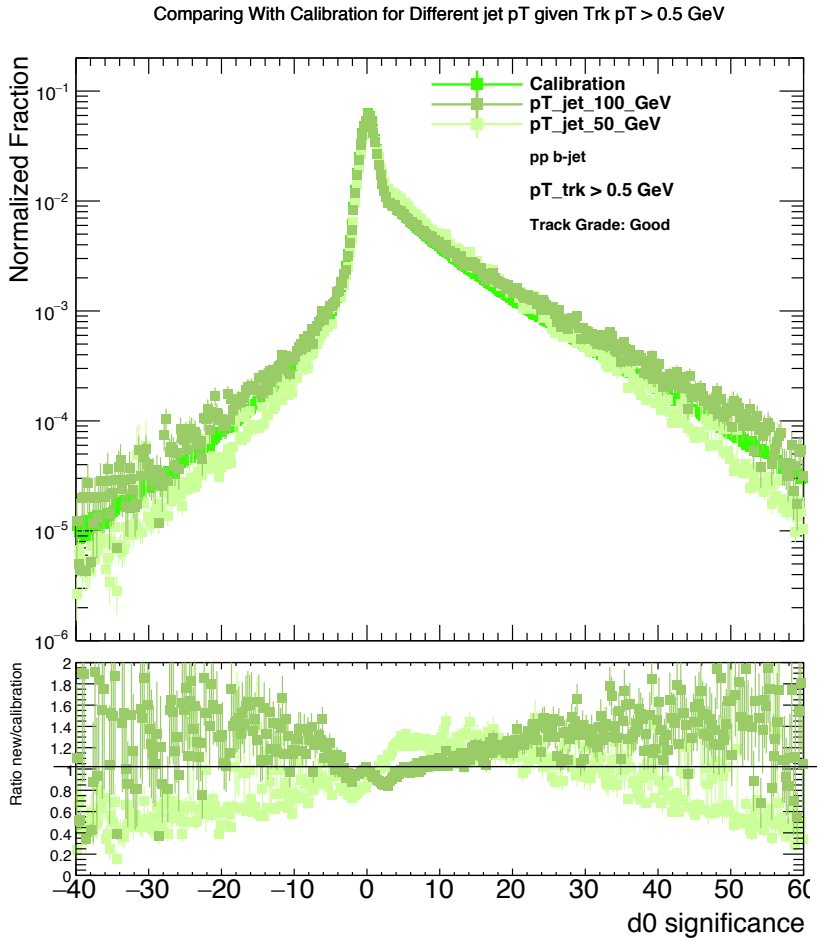
Summary for JetFitter and SVF

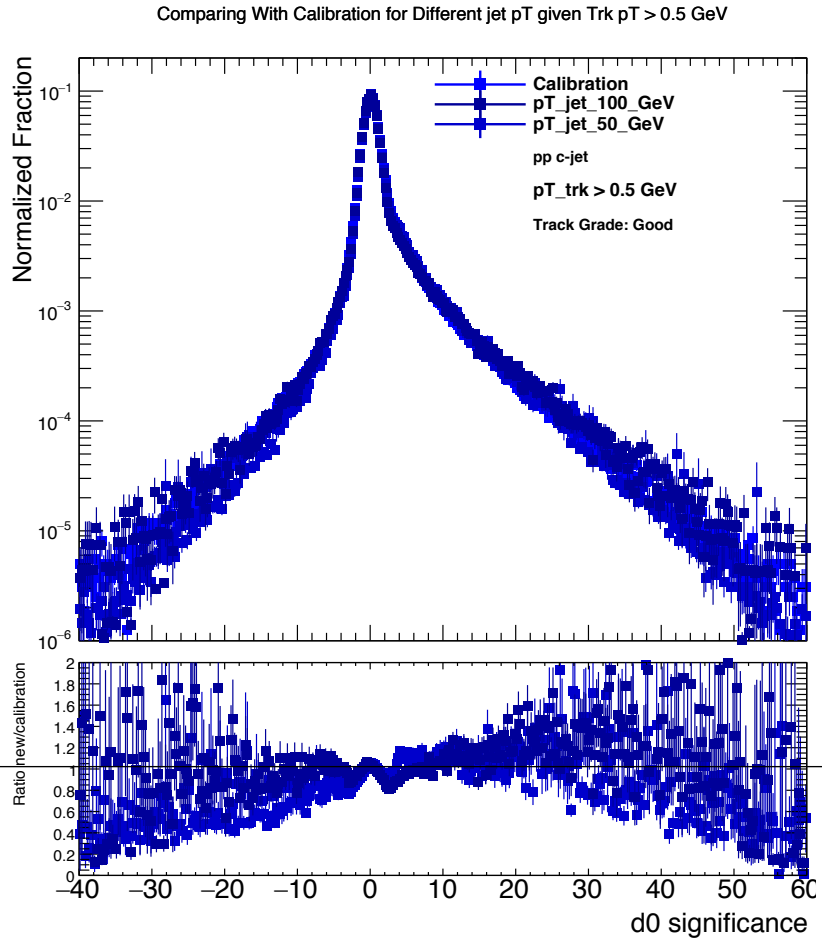
- Fixed Cone and track pT cut at 1.5 GeV/2 GeV improve both performances of secondary vertexing performance and some heavily modified physics variables.
- Next step:
  - Evaluate the taggers' performance as a whole
    - With higher level tagger's tagging performance
    - Or write custom classifier for each tagger with these variables

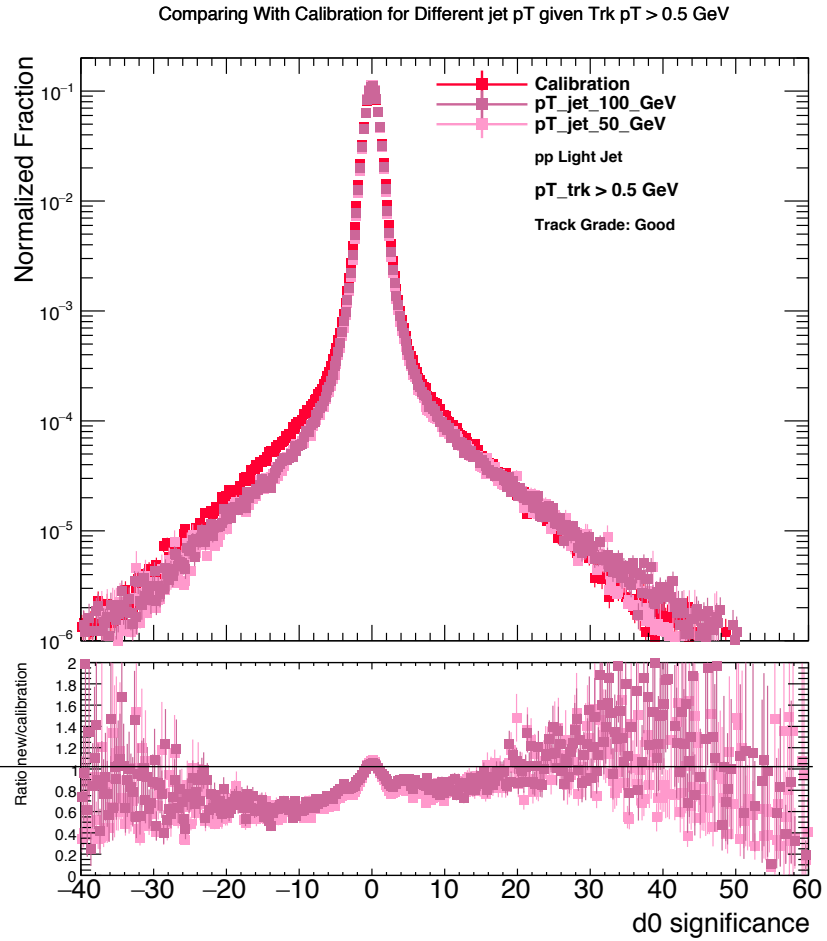
IP3D Templates Remaking

- Made templates with 8M inclusive dijet samples
- Jets selection:
  - pT > 50 GeV; 100 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 GeV, implemented in ParticleJetTools.
- Retraining: make new templates with 8M sample and use these templates for evaluating the same MC.
- Calibration templates used by default in Retagging: BTagCalibRUN2Onl-08-40.root
- Retrieved from /eos/atlas/atlascerngroupdisk/perf-flavtag/ReferenceHistograms

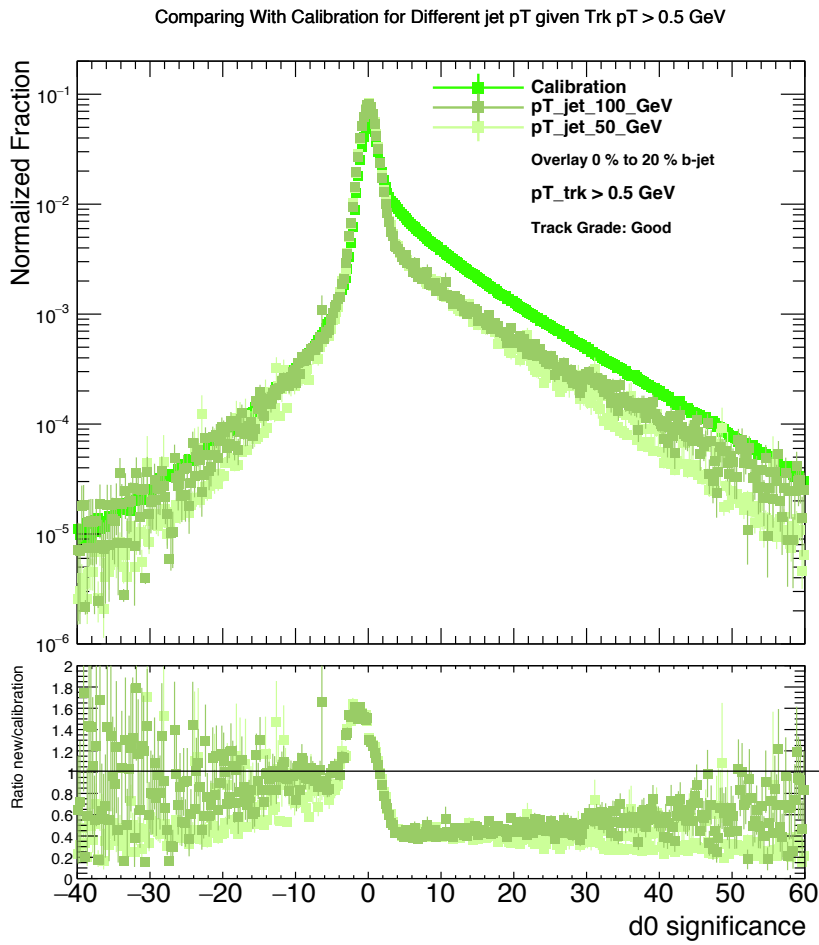
pp comparison to calibration templates d0 sig

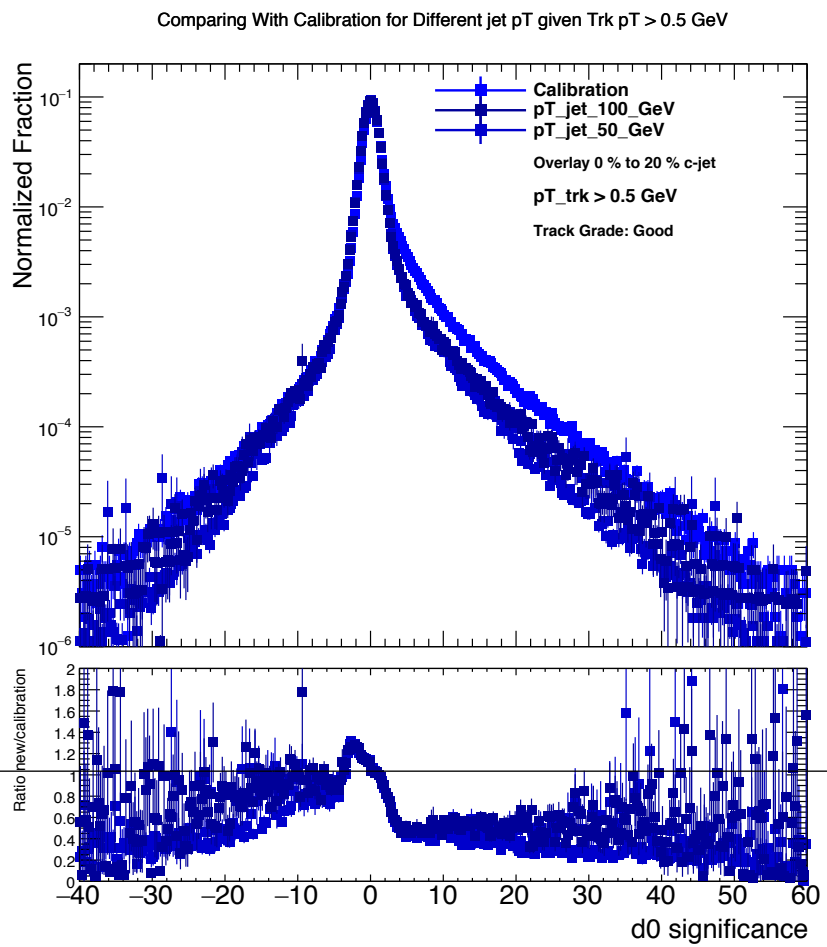


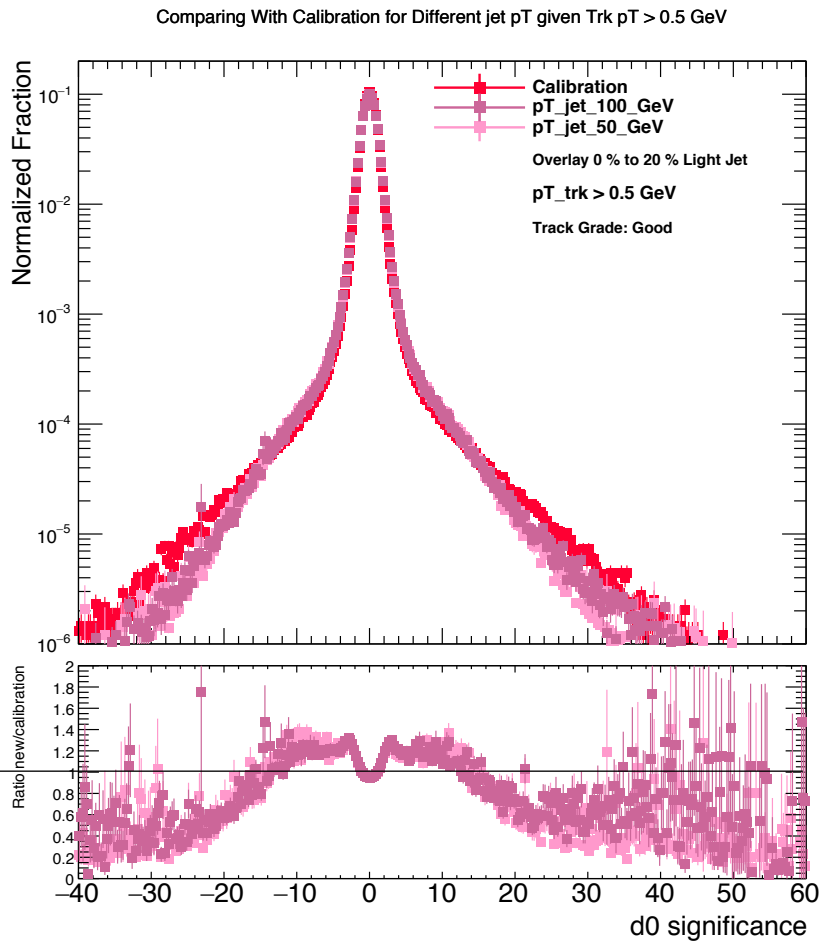




Central PbPb comparison to calibration templates d0 sig

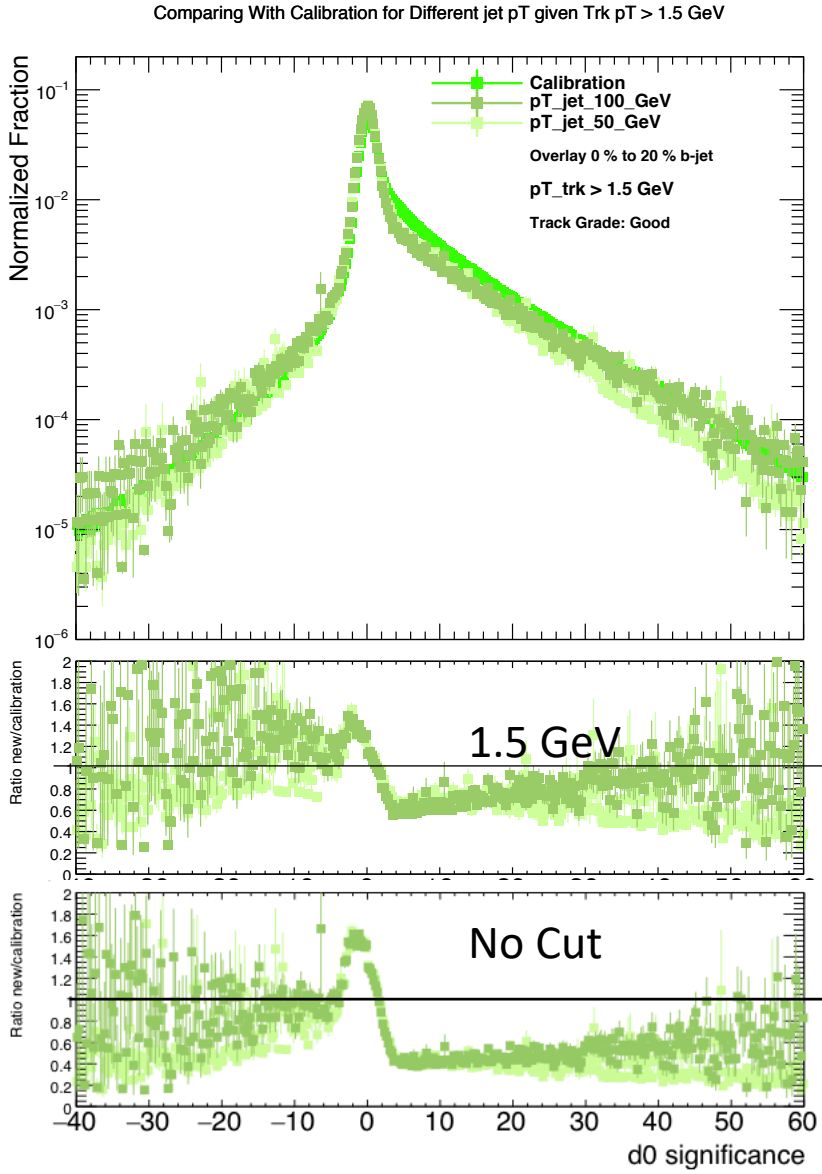


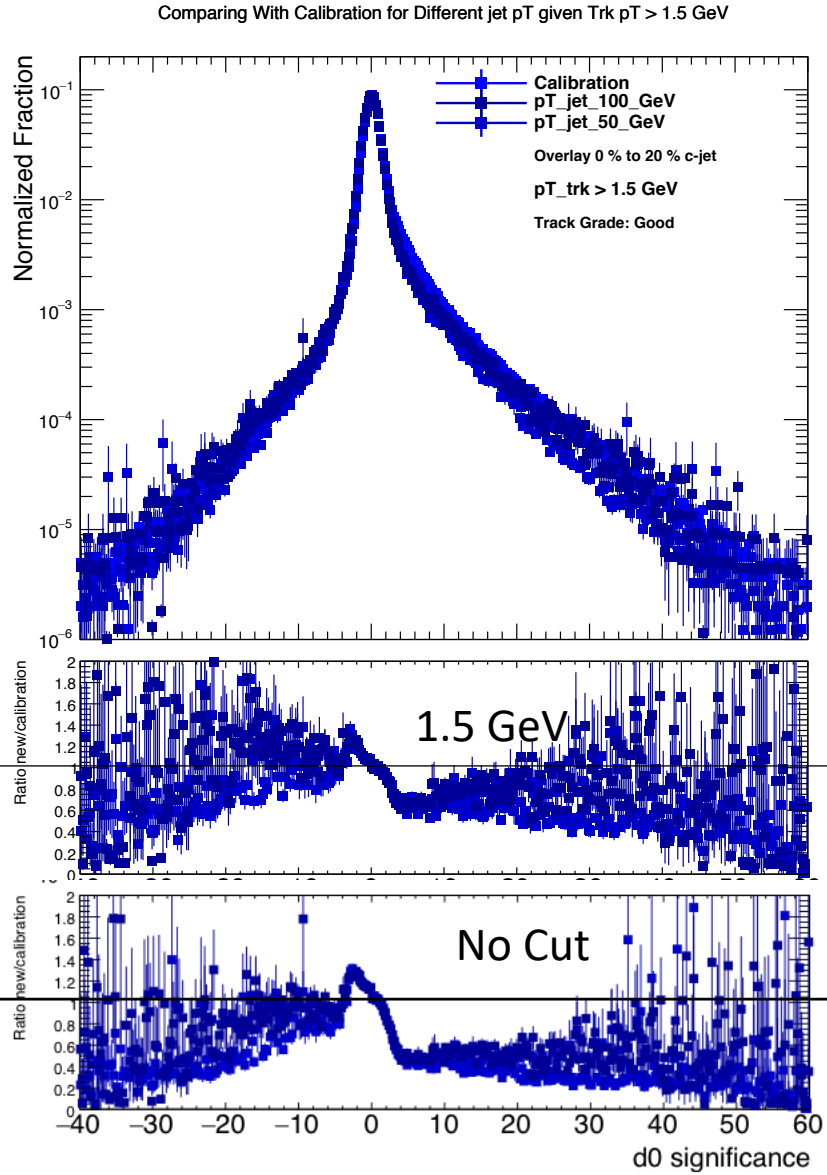


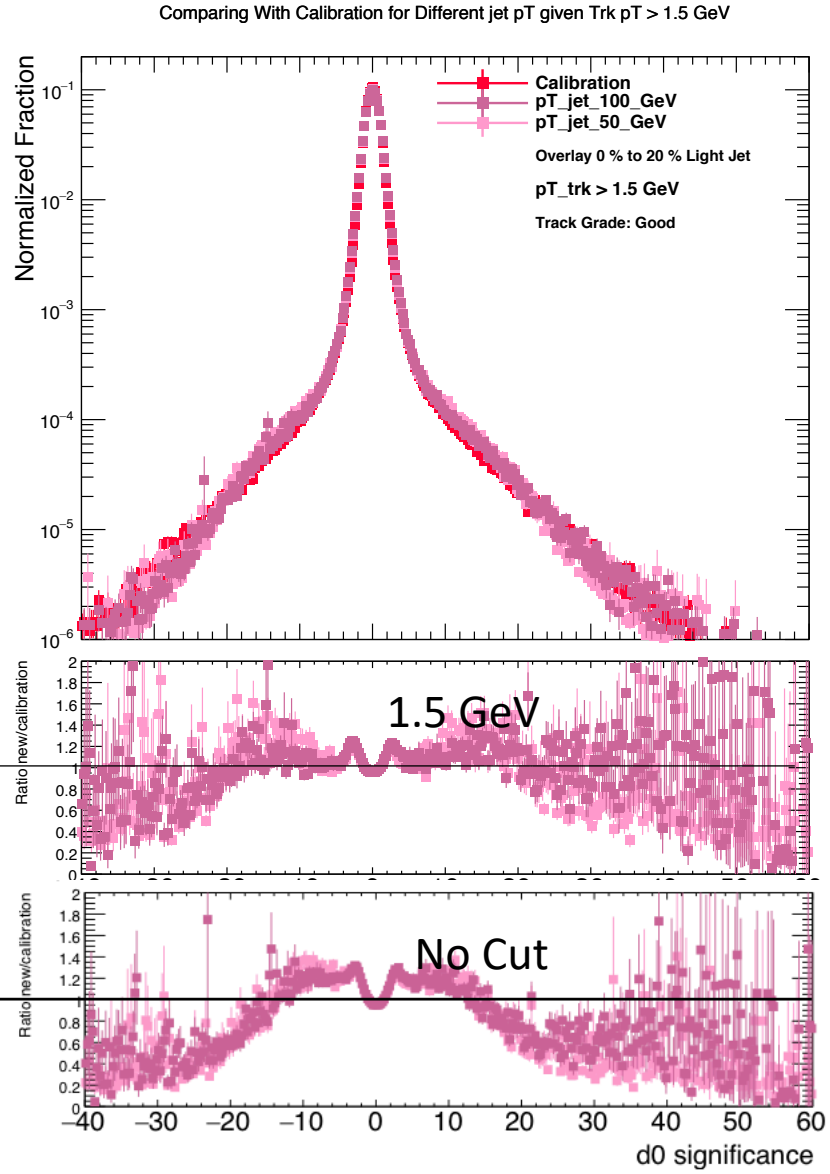


Clear drop in PbPb templates in d0 significance between 0 to 10

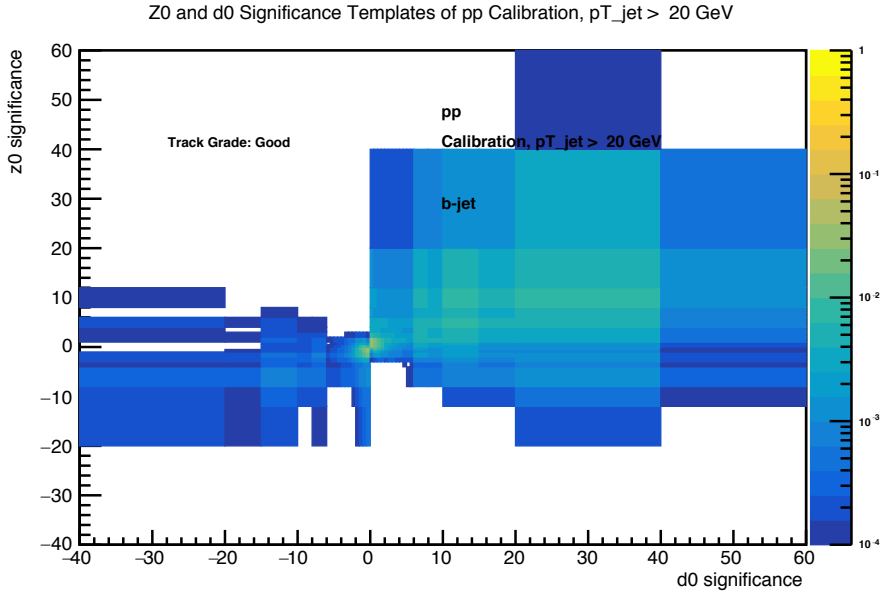
Central PbPb templates with track pT cut

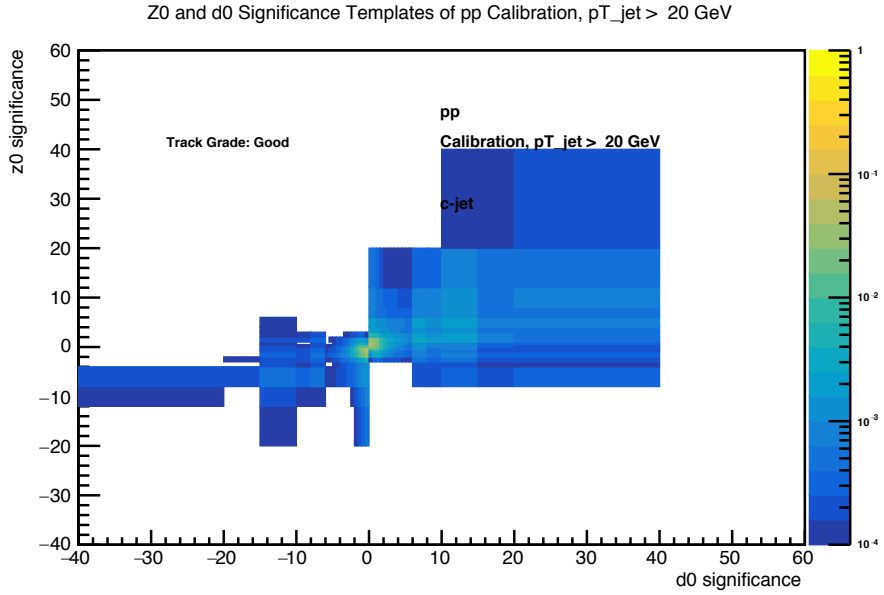


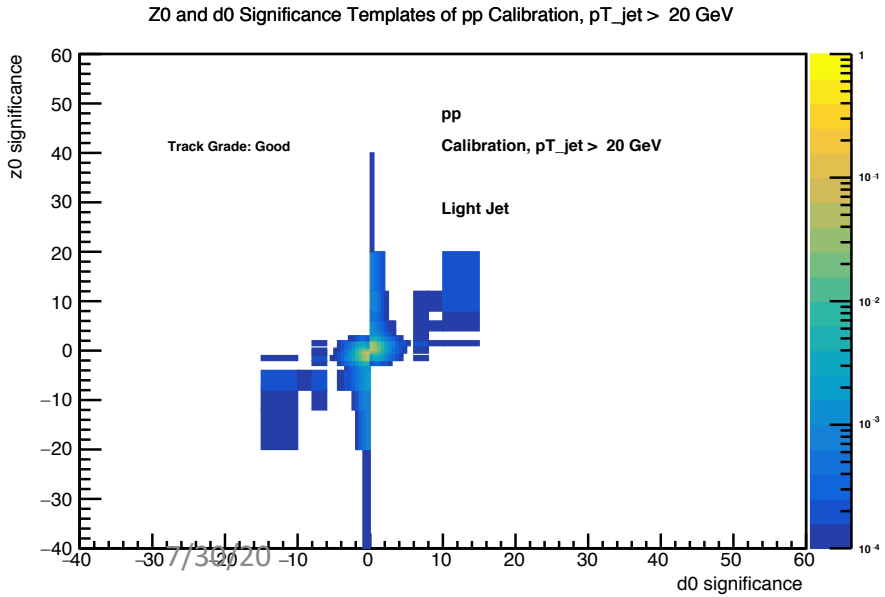


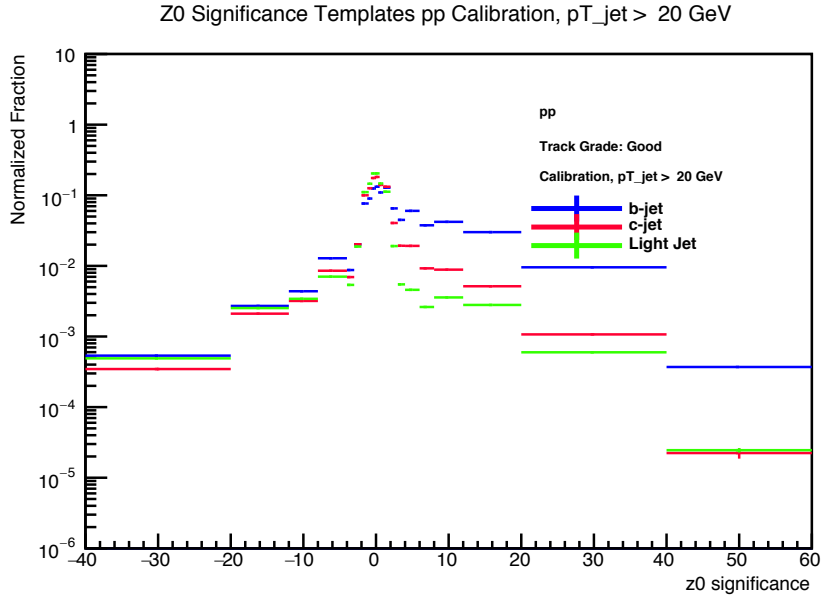


Comparison to calibration templates 3D: calibration

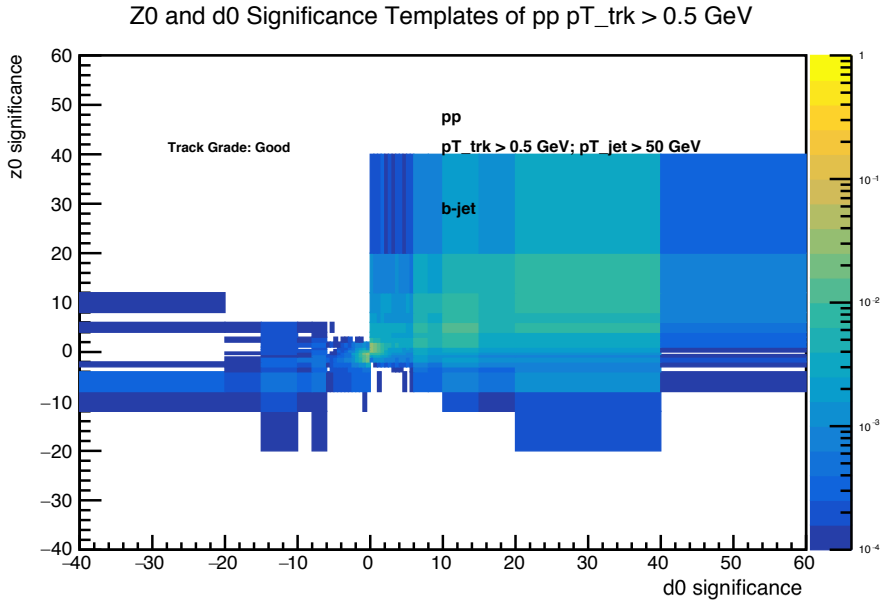


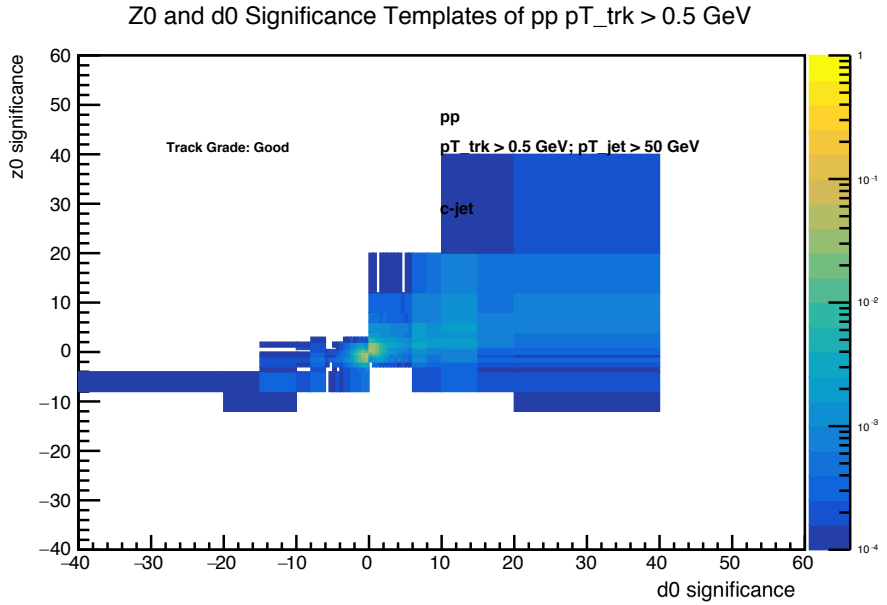


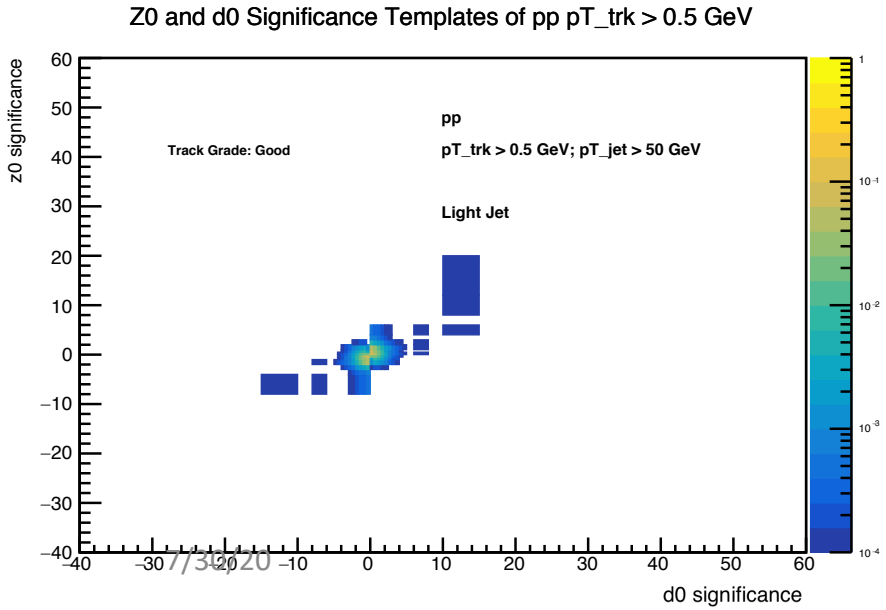


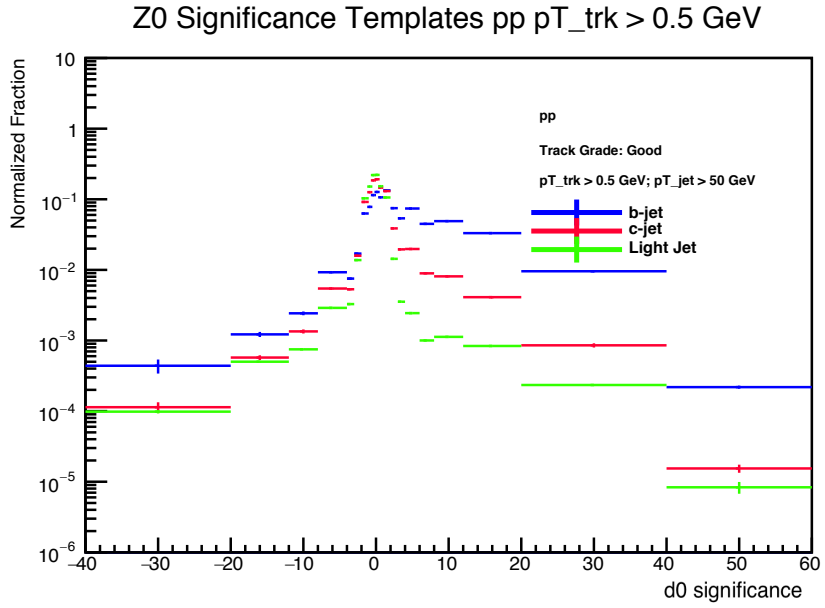


Comparison to calibration templates 3D: inclusive pp







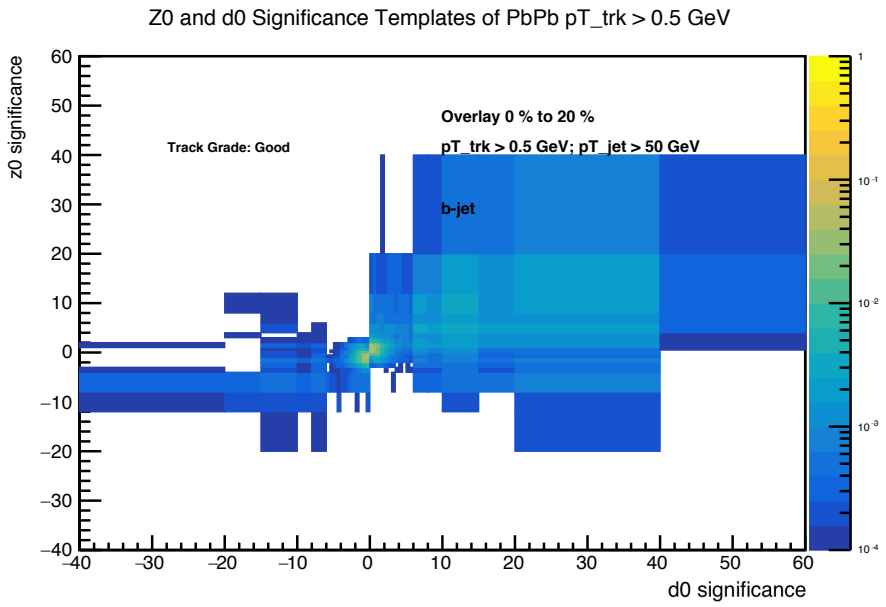


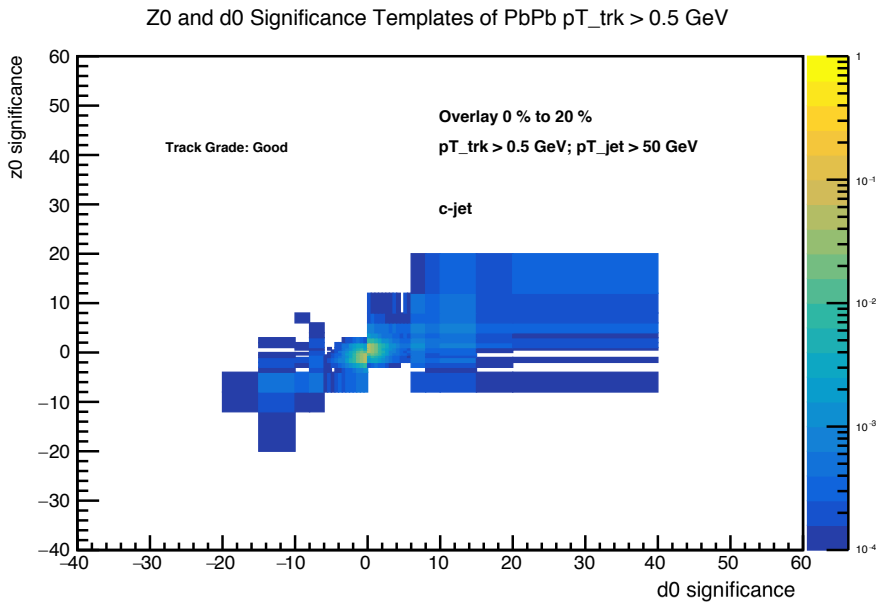
Less well populated in high Z0 bins, for all three flavors.

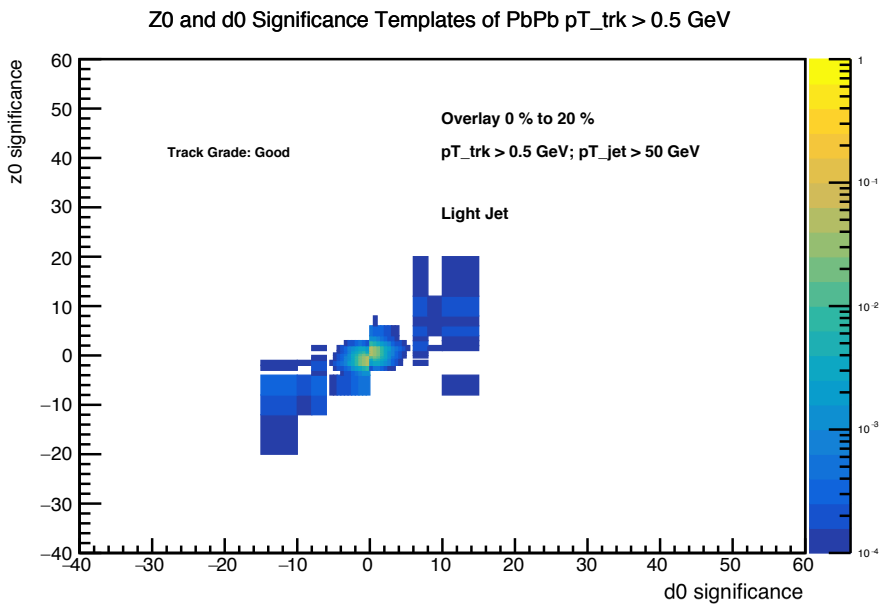
Plots are normalized to 1 since calibration was made with data.

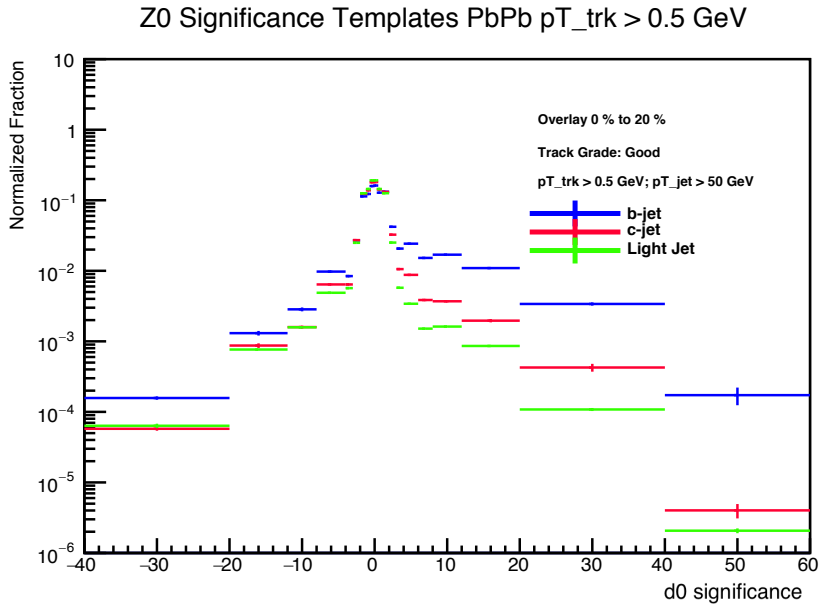
- What data? (tag just says “run2”)

Comparison to calibration templates 3D: central PbPb







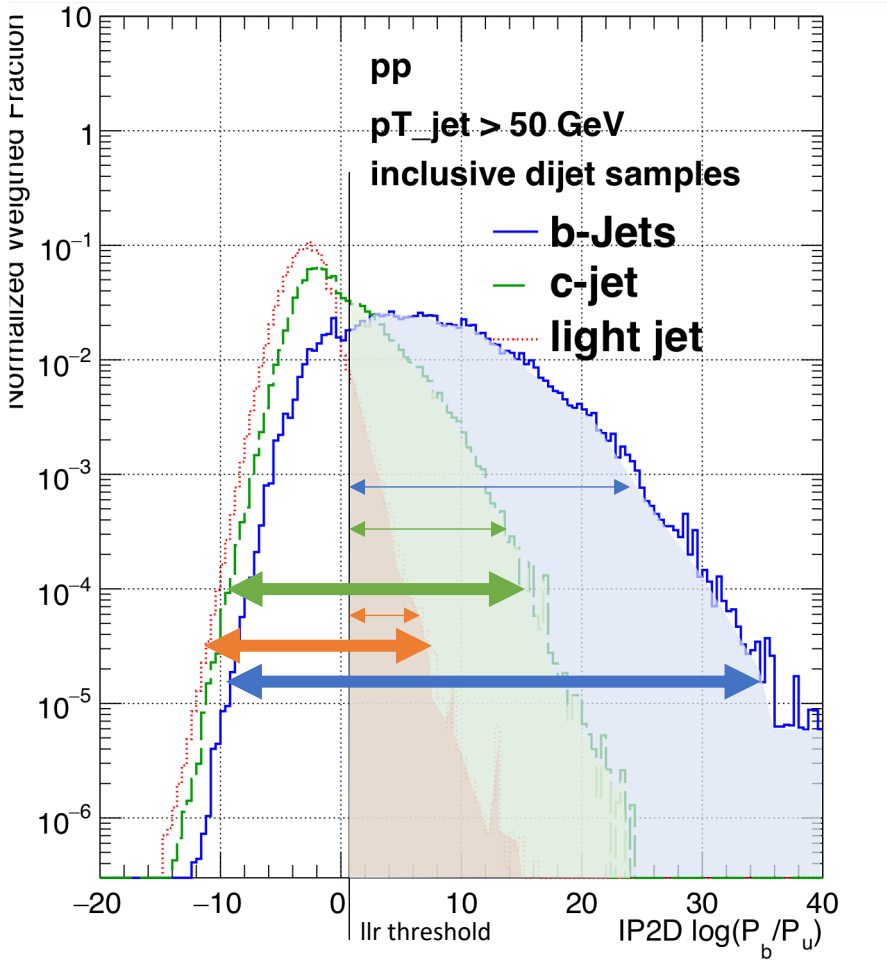


Better populated in light than pp, less well in b and c.

Less well populated than calibration templates.

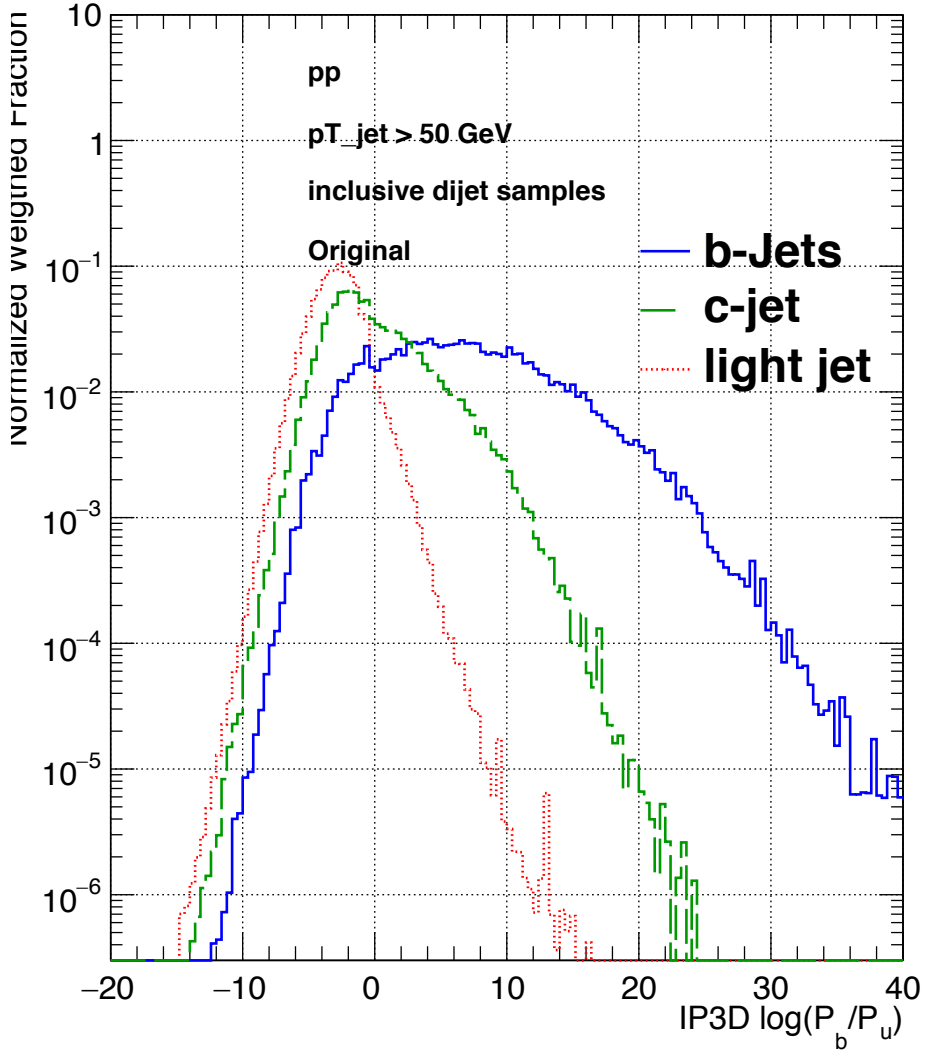
LogLikelihood Plot for (p_b/p_u)

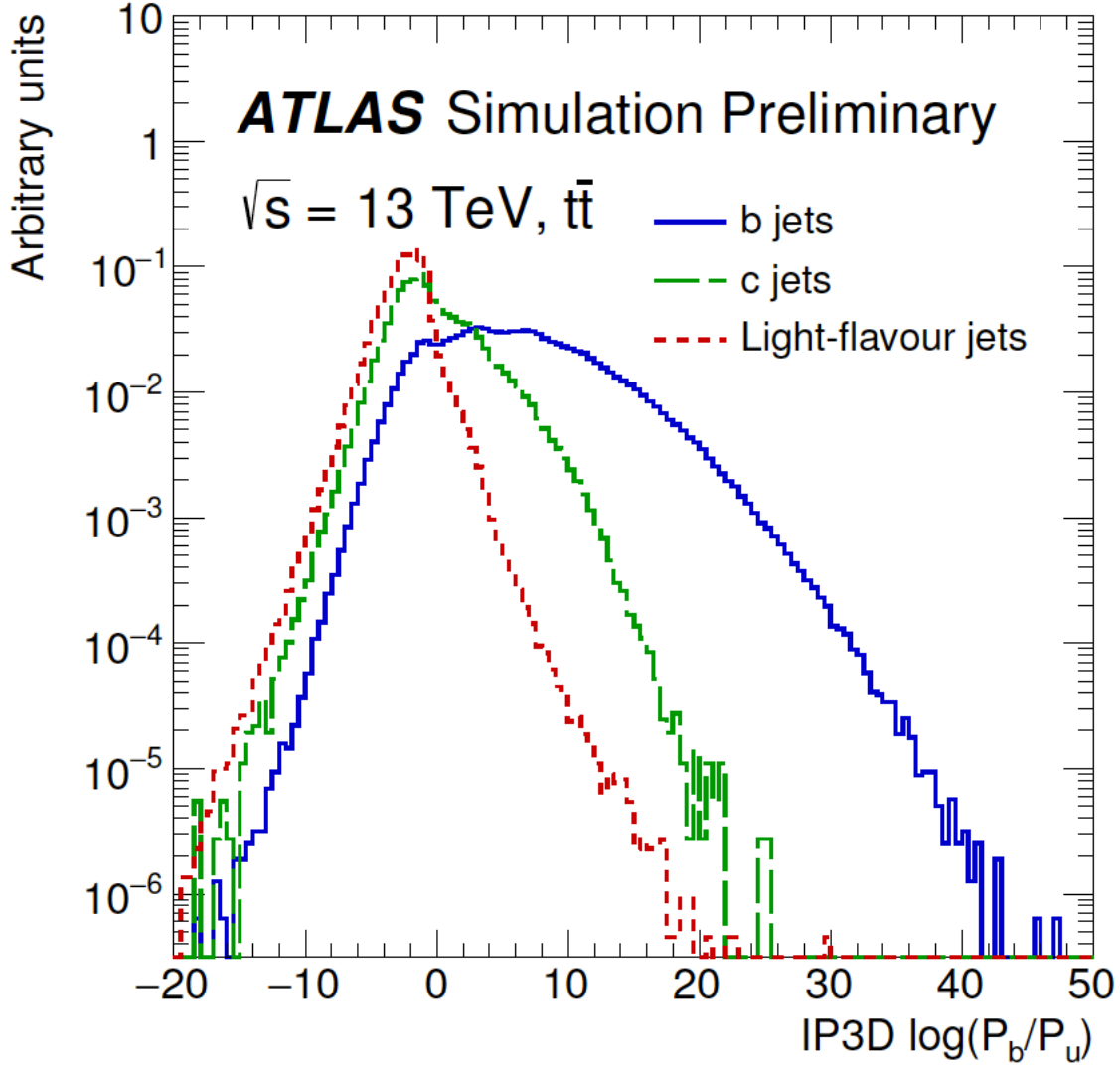
- $log^{jet}_{(\frac{P_b}{P_u})} = \sum log^{trk}_{(\frac{P_b}{P_u})}$ for qualified tracks, P_b and P_u are extracted from corresponding 3D templates based on track quality.
- P_{flav} = template bin content/template integral.
- To make each point of the ROC curve:
  - Set a threshold, integrate from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



Ratio = thin arrow integral/thick arrow integral

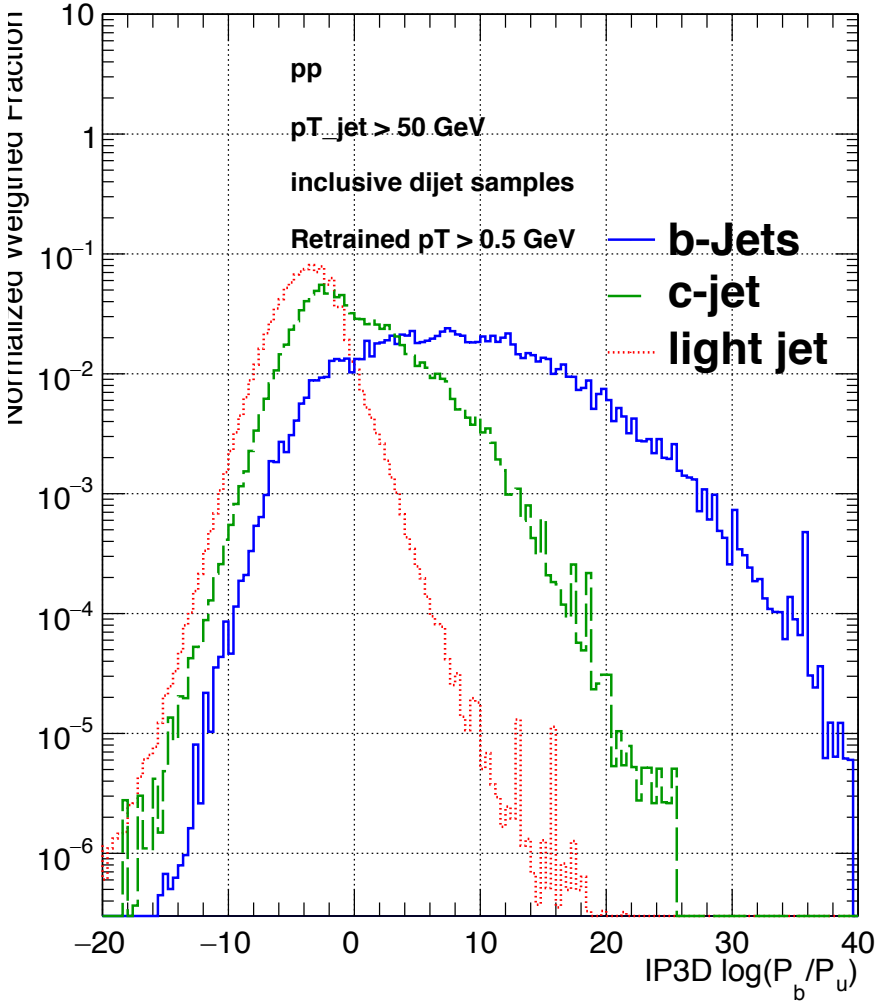
Comparison with ttbar samples

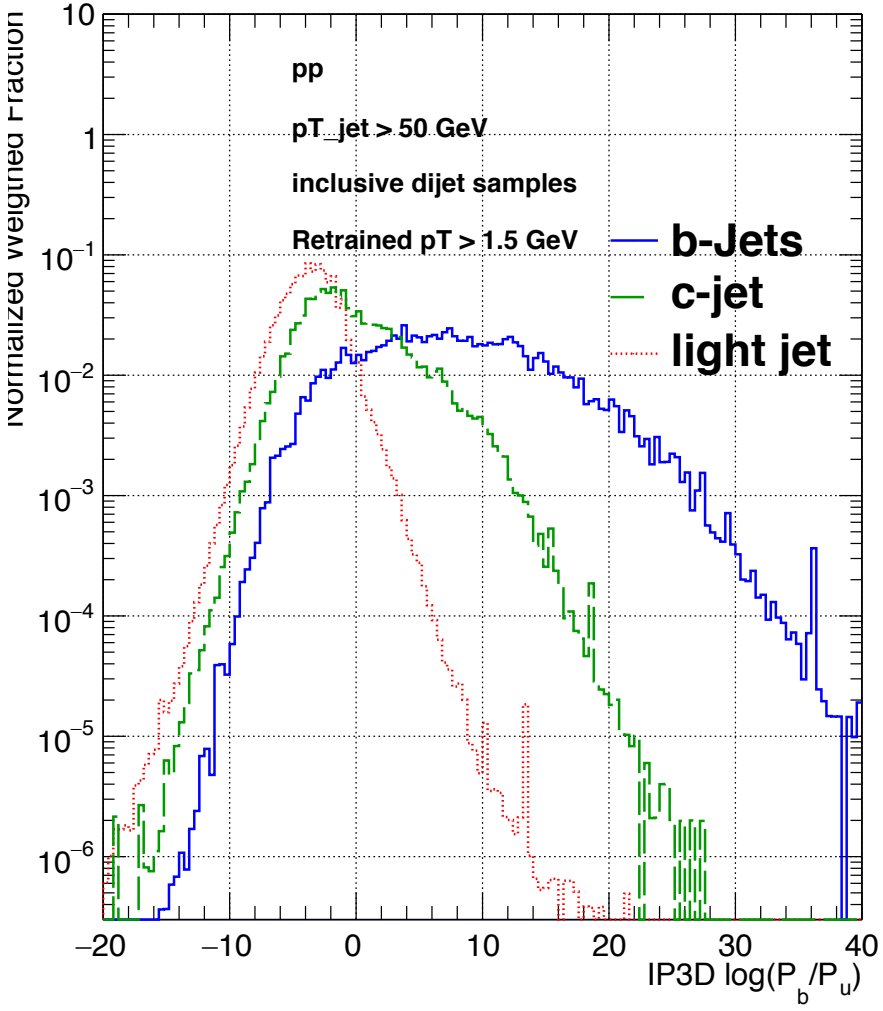




Qualitatively similar.
Peaks are slightly more smeared.

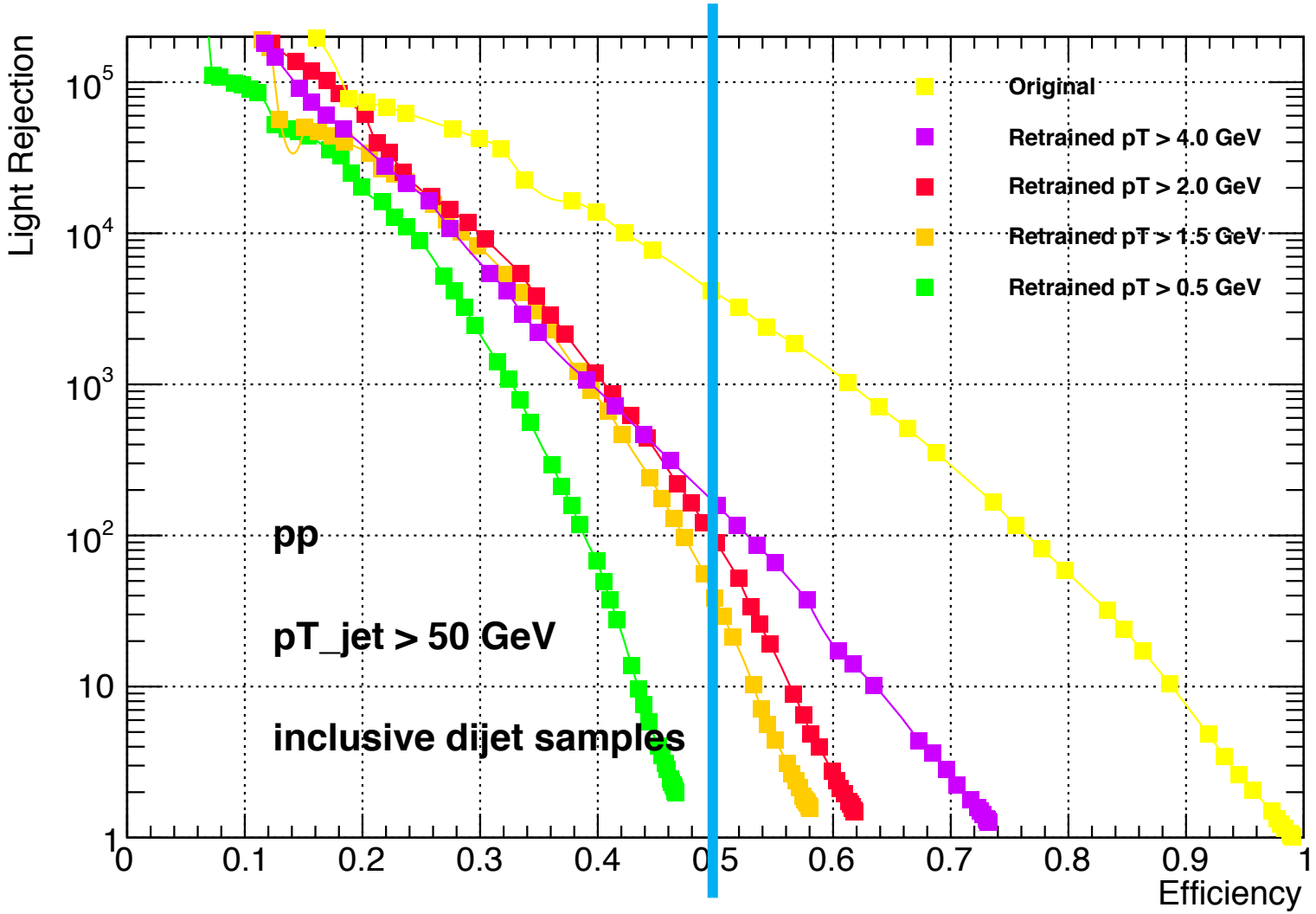
Retrained llr plots



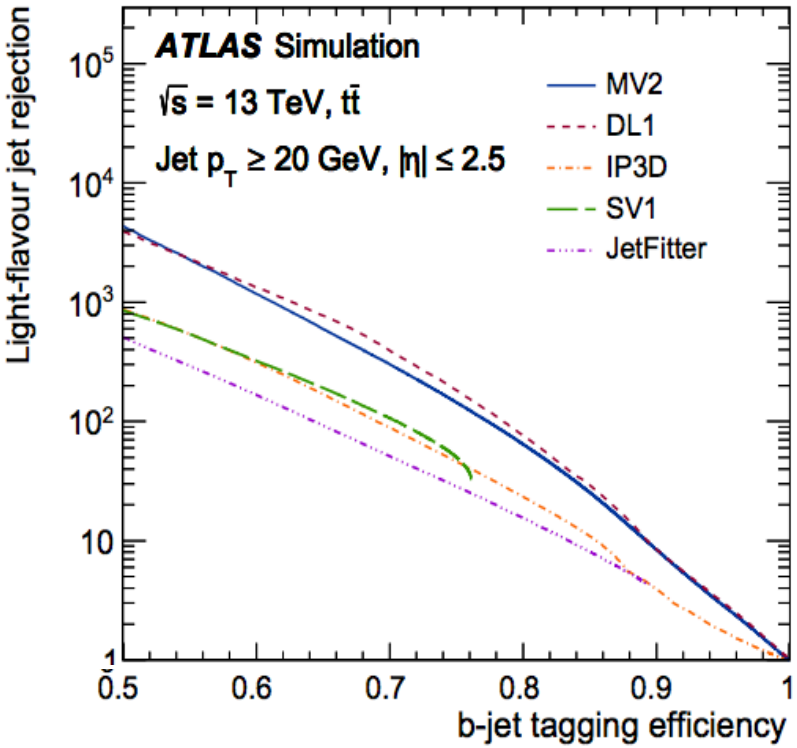


- Distribution even more smeared than using original templates.

IP3D ROC curve with pp

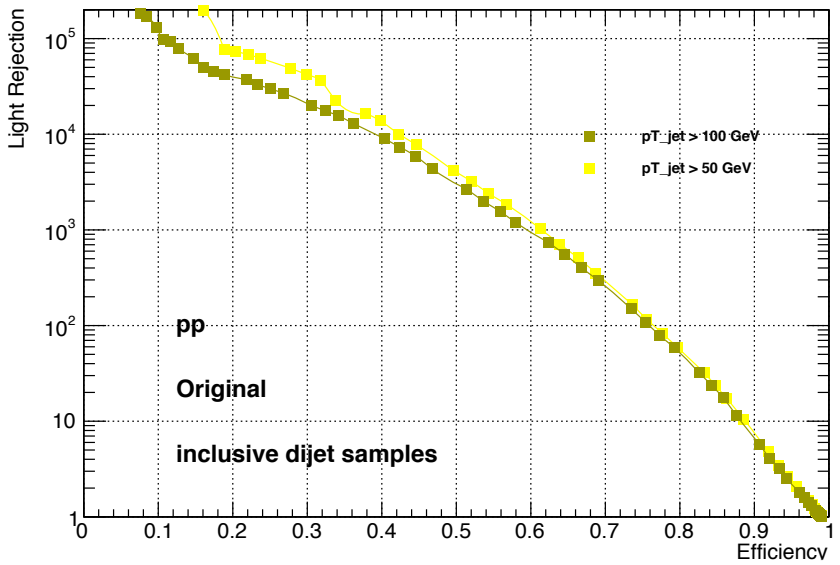


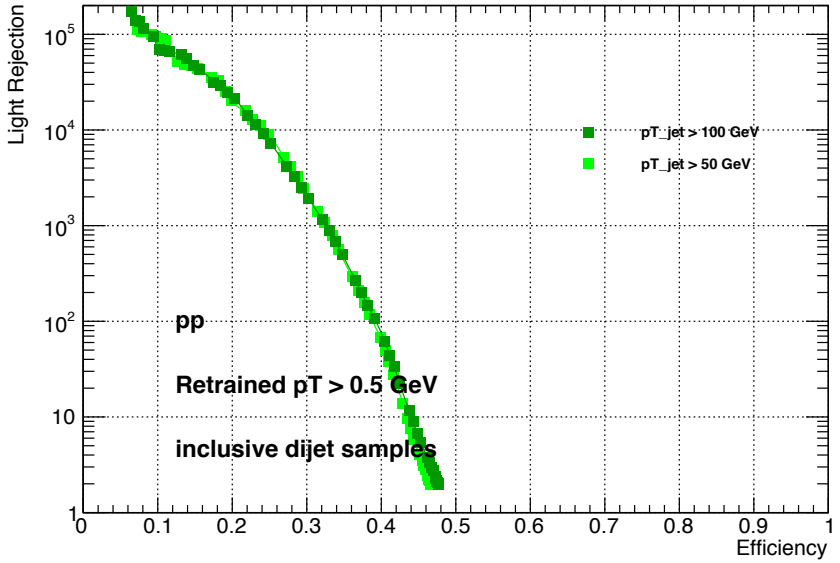
- Original templates have the best performance.
  - Potentially due to not well populated templates.
- With increased cuts on pT track, the performance is improved.

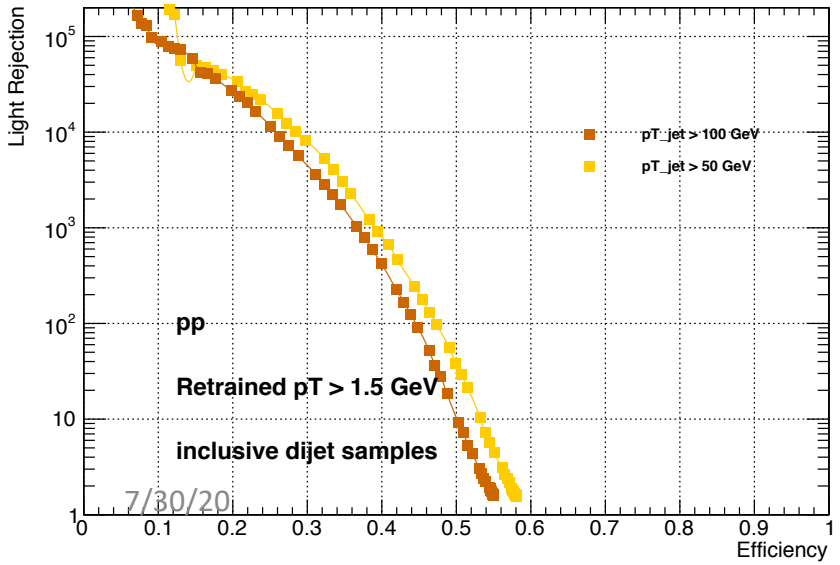


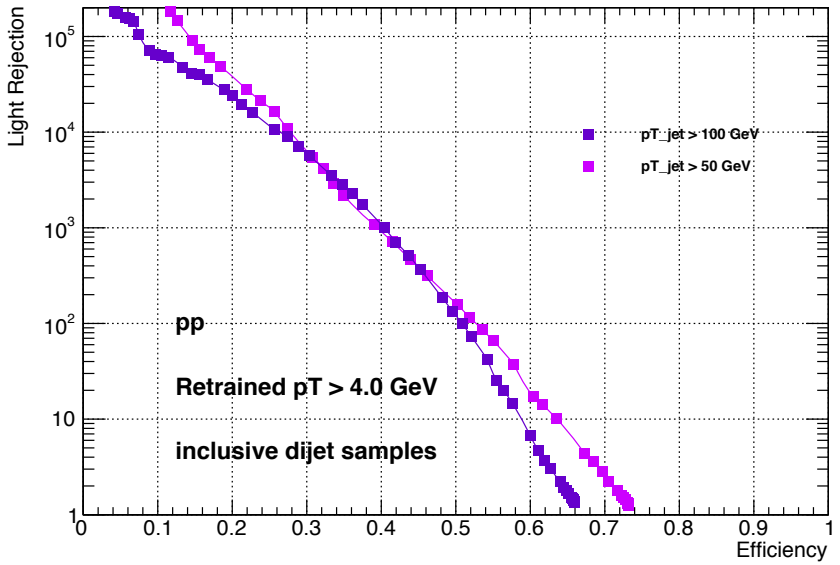
https://arxiv.org/pdf/1907.05120.pdf

Effects of low pT jets







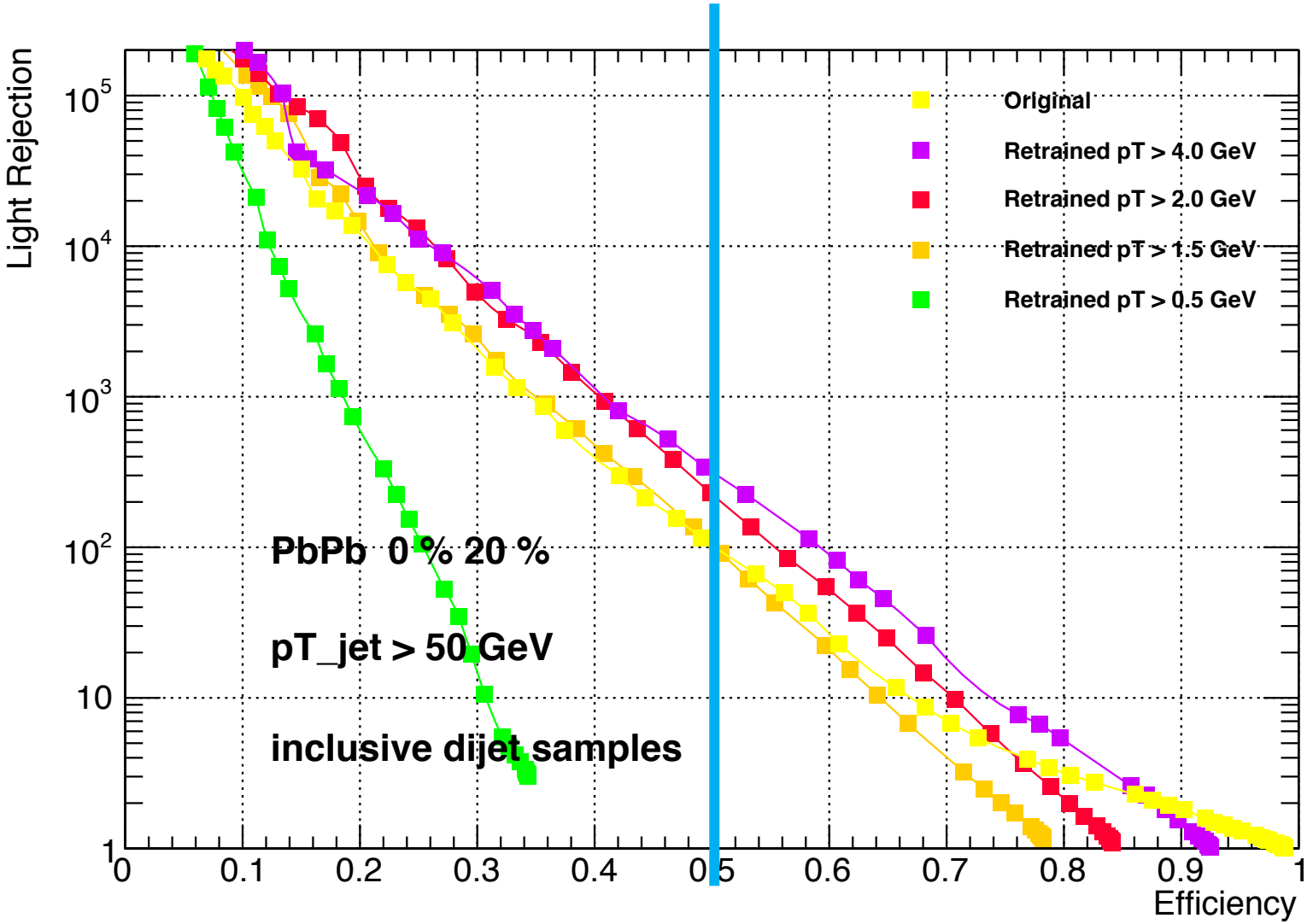


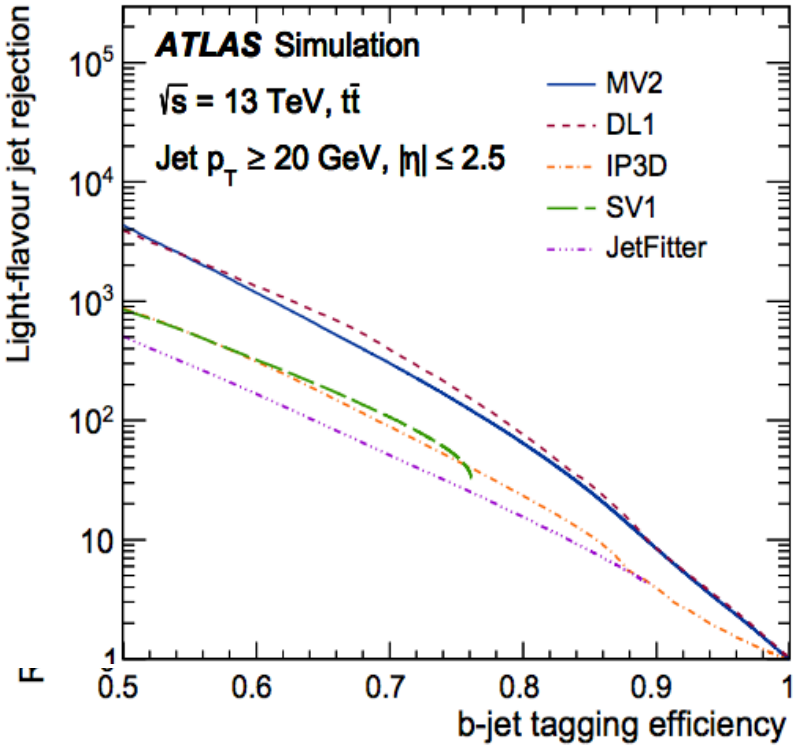
For the pp samples concerned,

- 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.





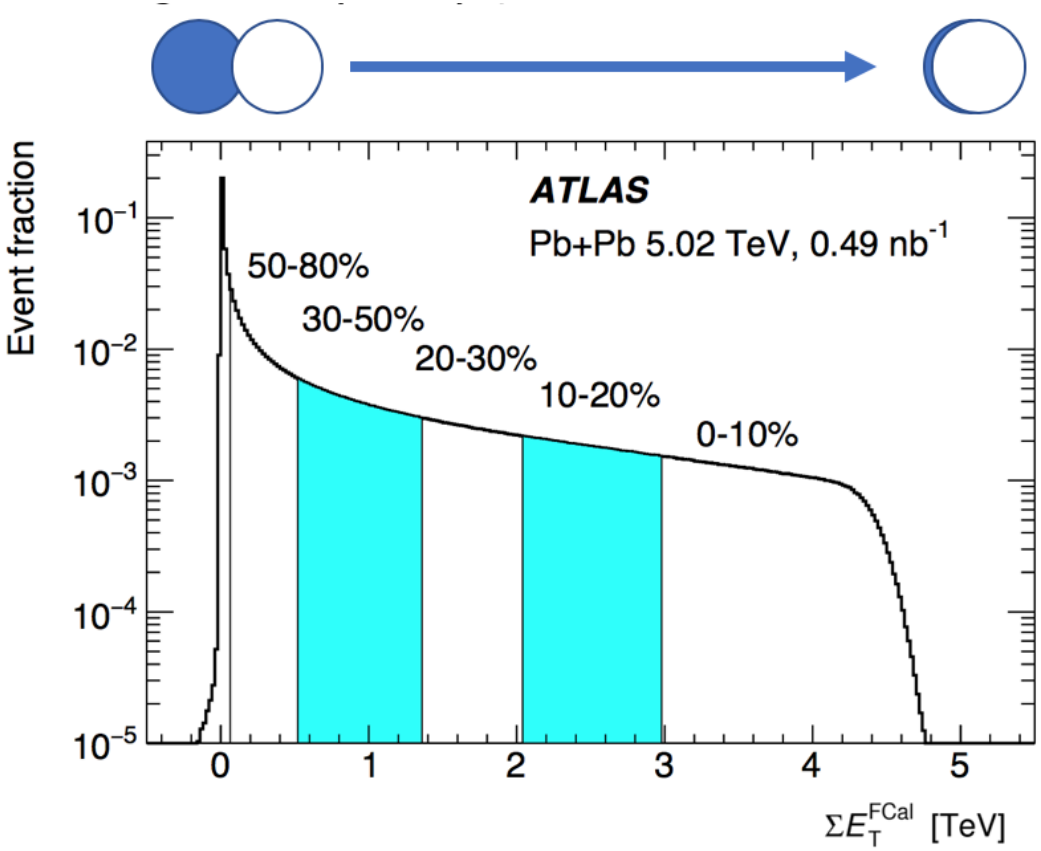
Summary

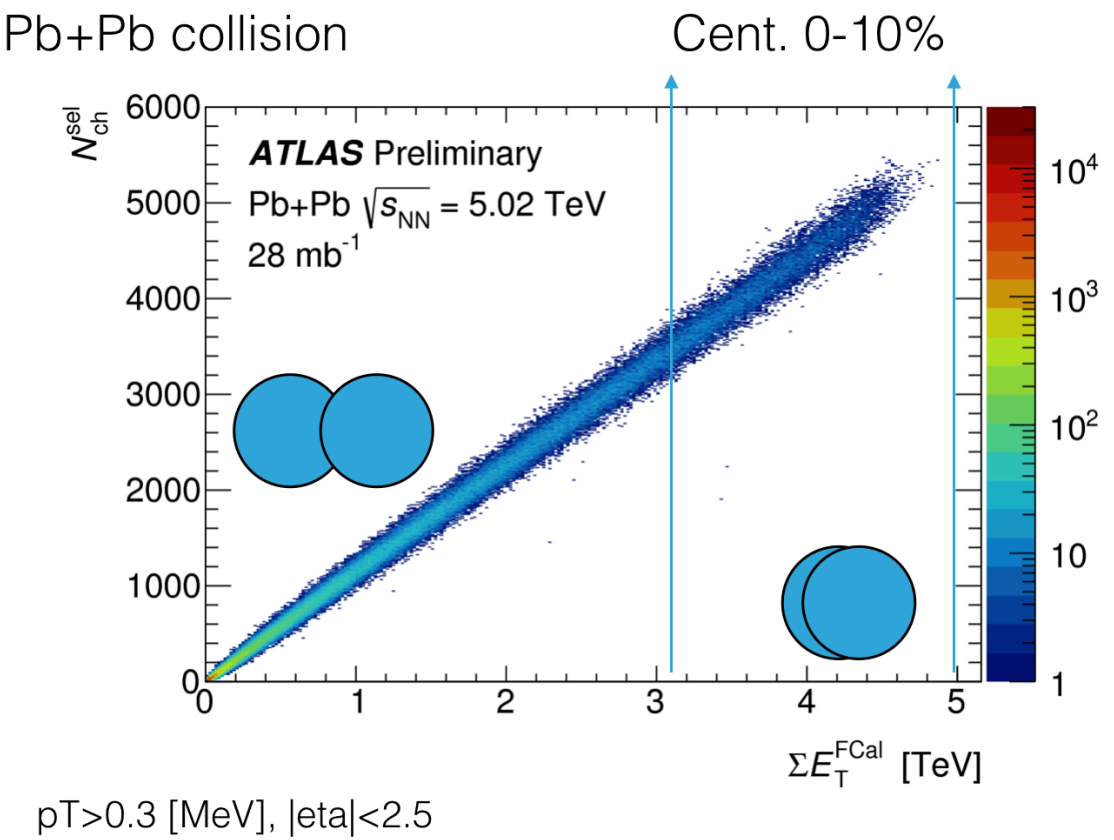
- Evaluated secondary vertexing performances of JetFitter and SVF
  - Motivated by unknown track-in-jet distribution, used fixed cone at R = 0.4
  - Requiring minimum pT reduces centrality dependence.
- Comparing heavily modified physics variables, cutting pT at 1.5 GeV/2.0 GeV starts to assimilates 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

Centrality

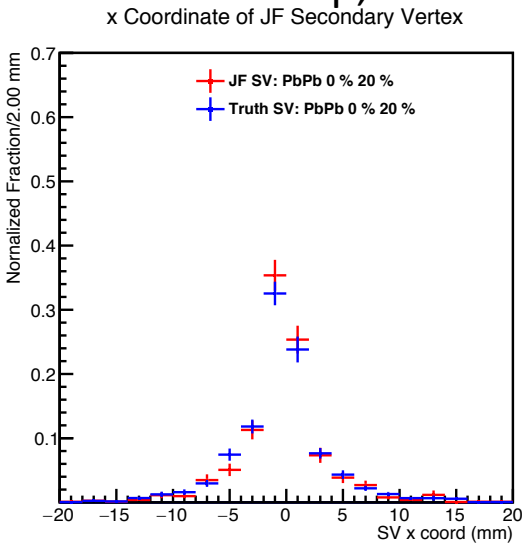
- Centrality:
  - Whether the collision is central (“head-on”) or peripheral (“glancing”)
  - Estimated using the total transverse energy measured in the ATLAS Forward Calorimeter (ΣE_T)
- Central collisions have high occupancy (thousands of tracks per event)

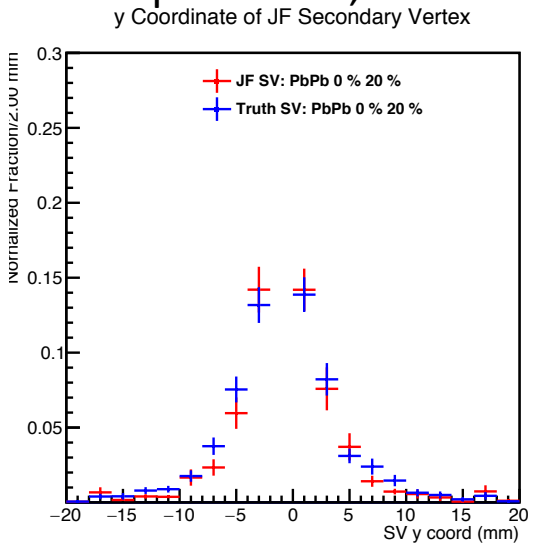


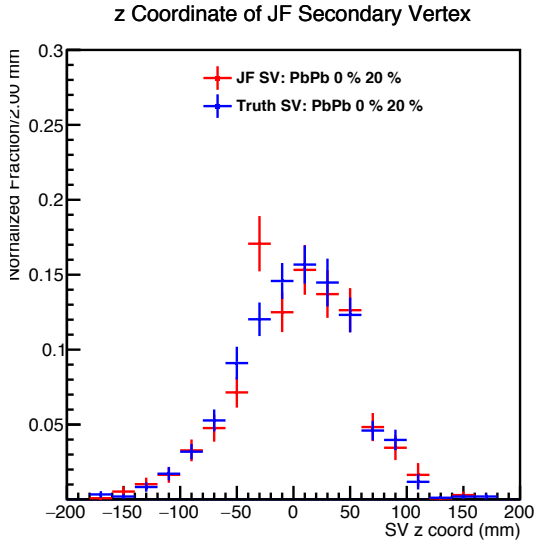


Secondary Vertexing Resolution with JetFitter

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



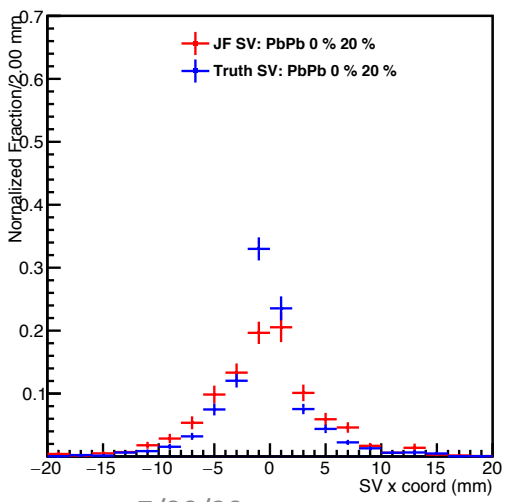


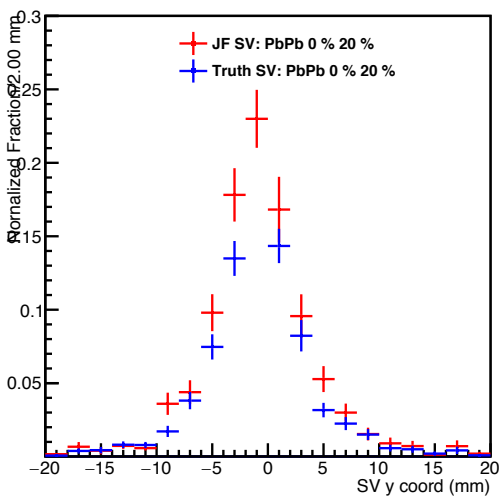


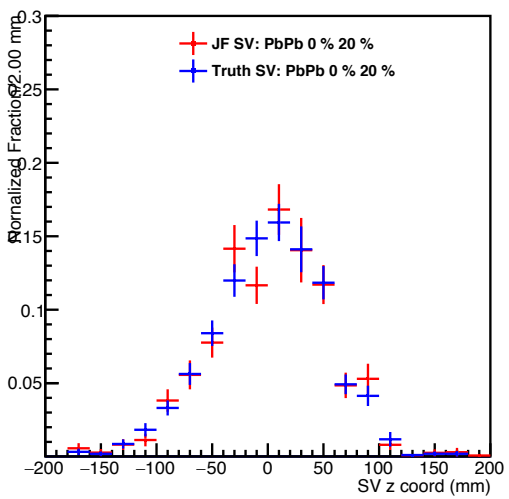
No big change in secondary vertex resolution, reconstructed SV coordinates have similar distribution with truth SV.

Plan: plot coordinate difference and fit for quantitative comparison.

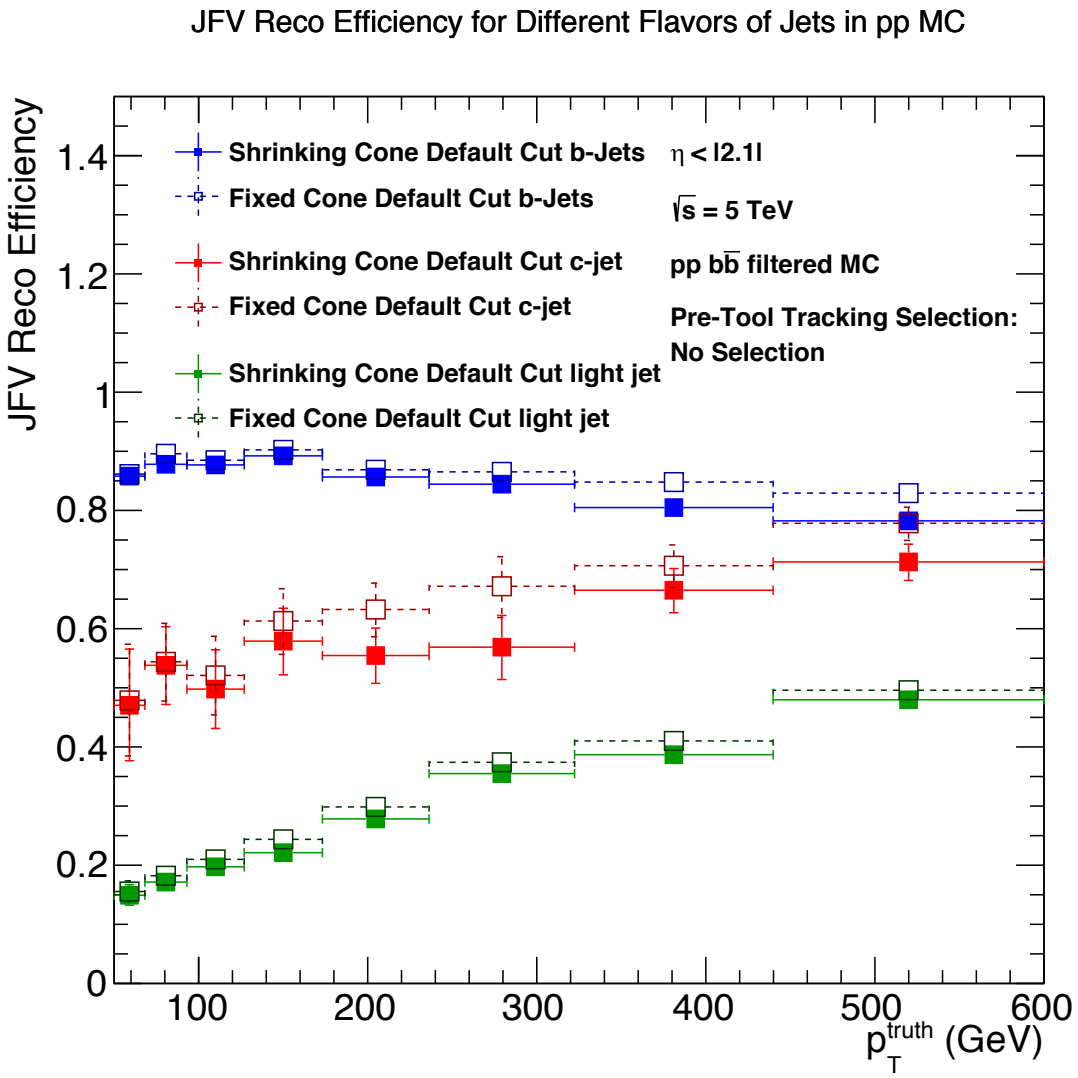
Default JF Setup (anti PU off); Loose Selection on TrackAssociation; Min pT = 1.5 GeV; Fixed Cone at 0.4



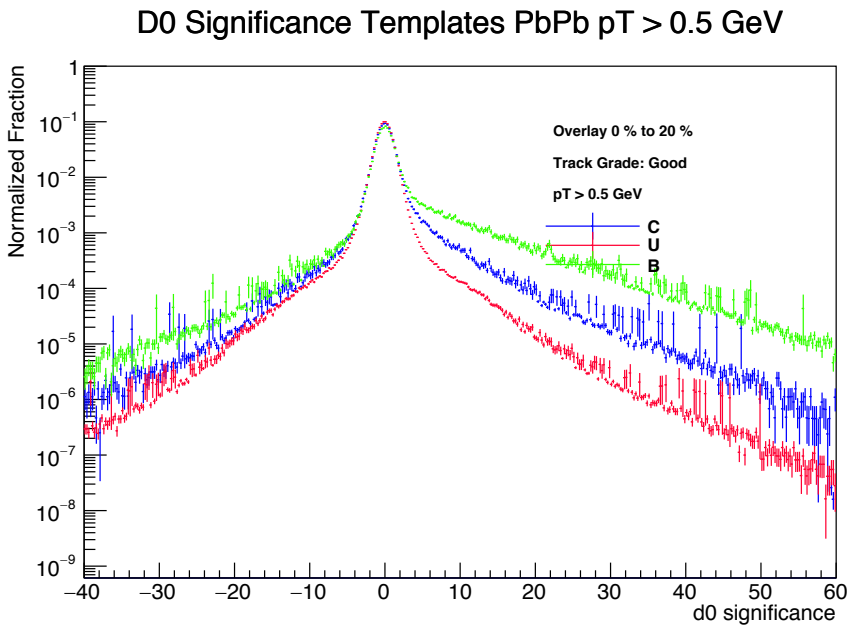


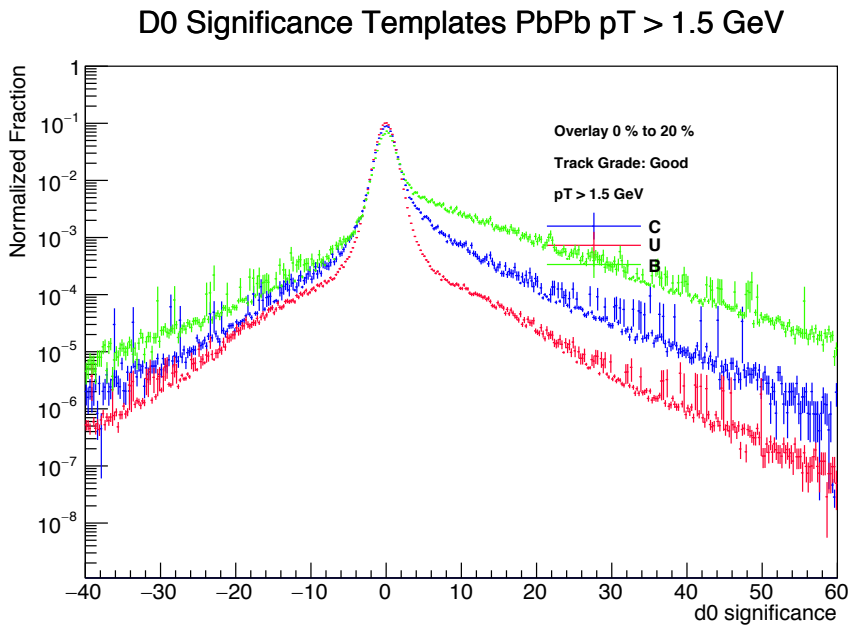


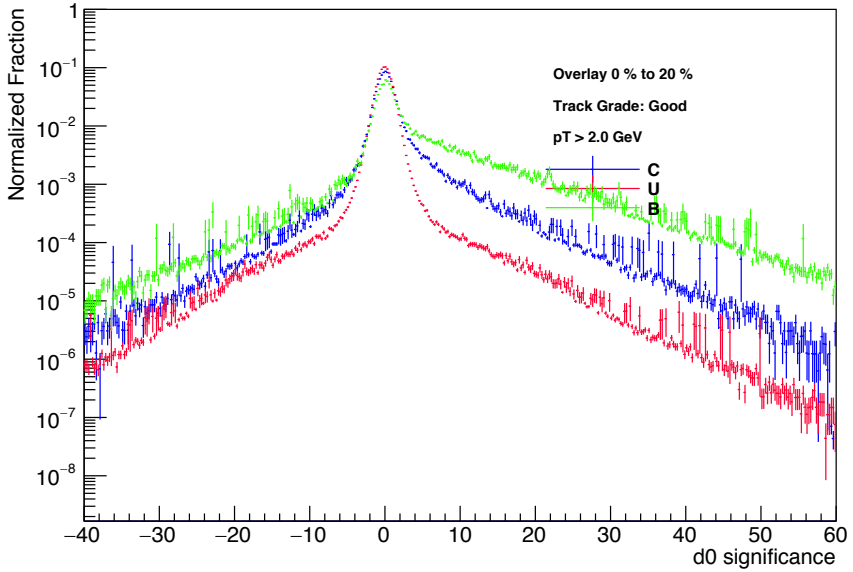
Only Fixed Cone's effects

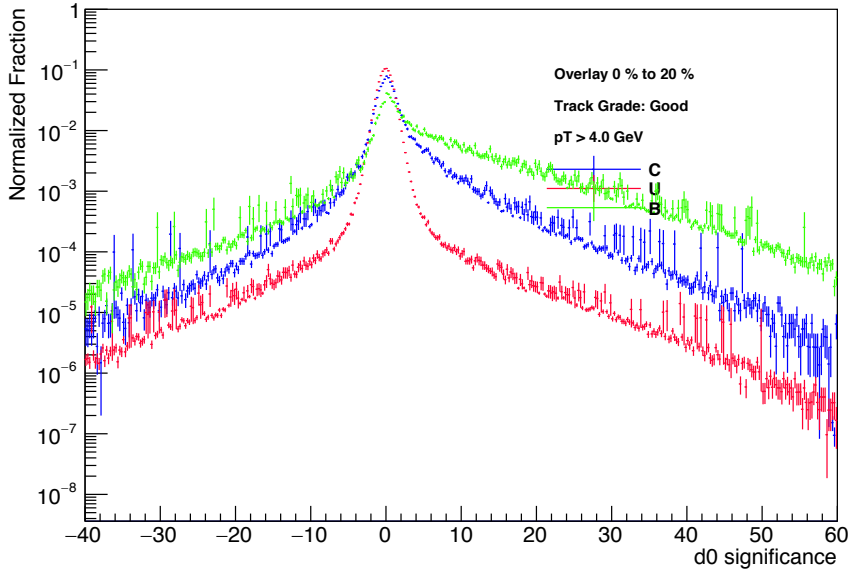


New Templates Making

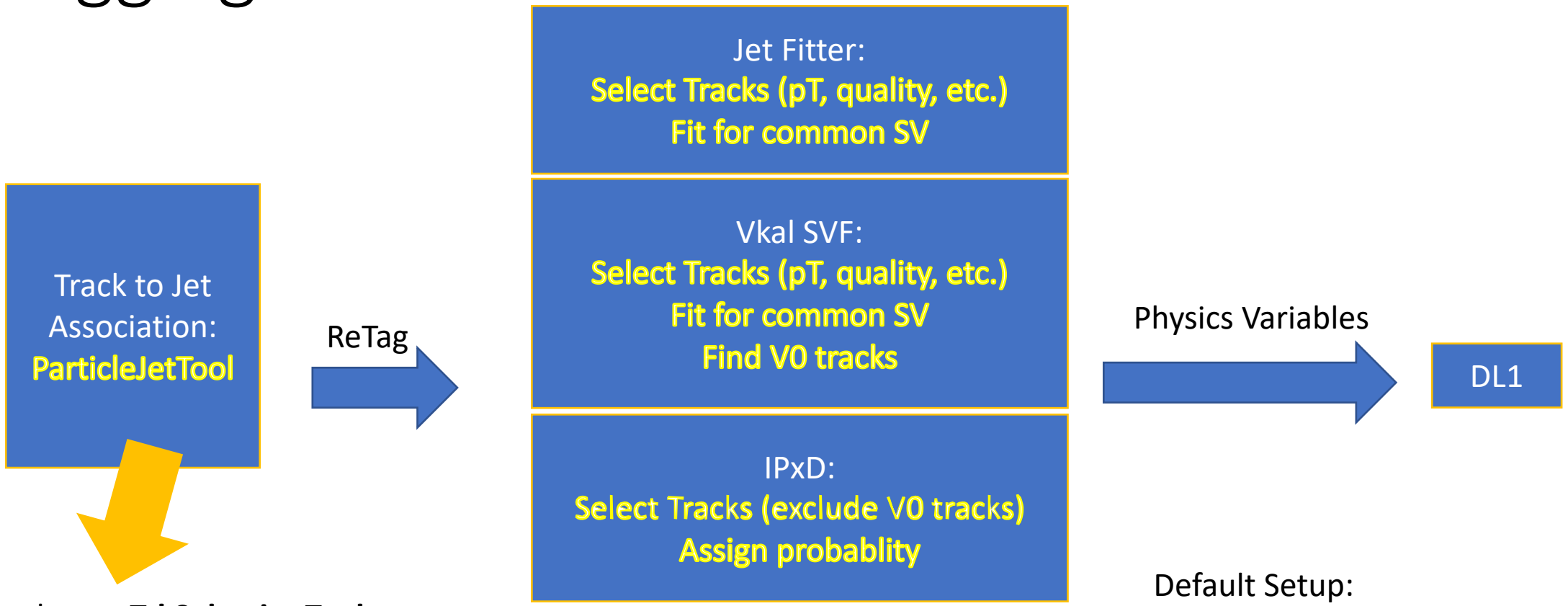








B-Tagging Workflow



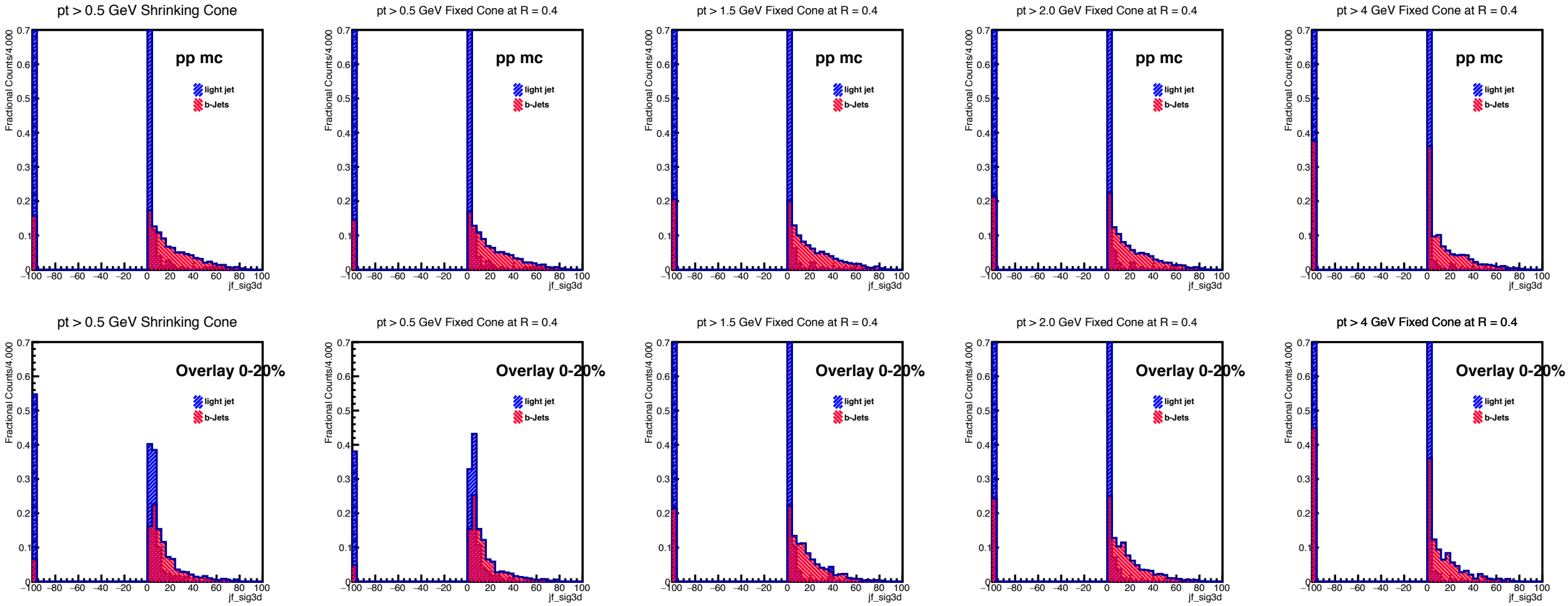
-track pass **TrkSelectionTool**
-associate each track to closest jet
-if dR < threshold, track is associated
Shrinking Cone: higher jet pT, smaller the threshold dR
Fixed Cone: threshold dR = 0.4 for all jet pR

Pre-Tagging Selection

Default Setup:
Shrinking Cone, min track pT > 0.5 GeV

SV1

JF sig3d (decay length significance)

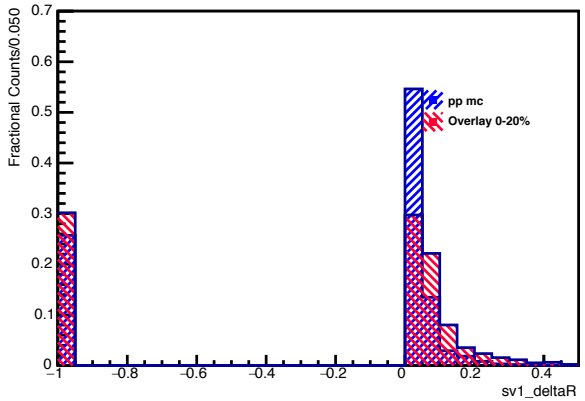


Top Row: pp mc
Bottom Row: Overlay 0-20%

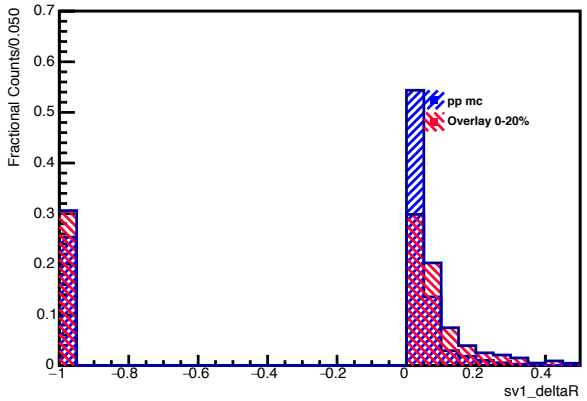
From left to right:
1. No pT Shrinking Cone
2. No pT Fixed Cone
3. Min pt = 1.5 GeV Fixed Cone
4. Min pt = 2.0 GeV Fixed Cone
5. Min pT = 4.0 GeV Fixed Cone

Red: b-jet
Blue: light jet

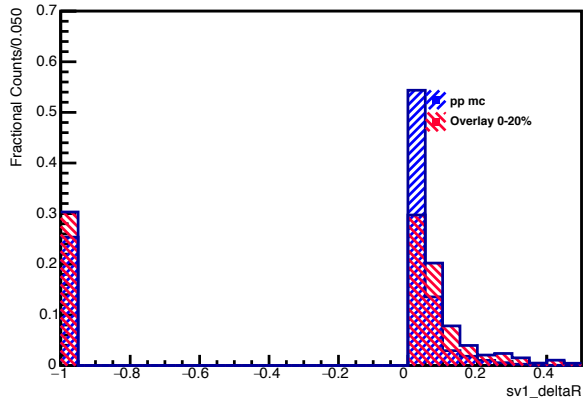
JF pt > 0.5 GeV Shrinking Cone



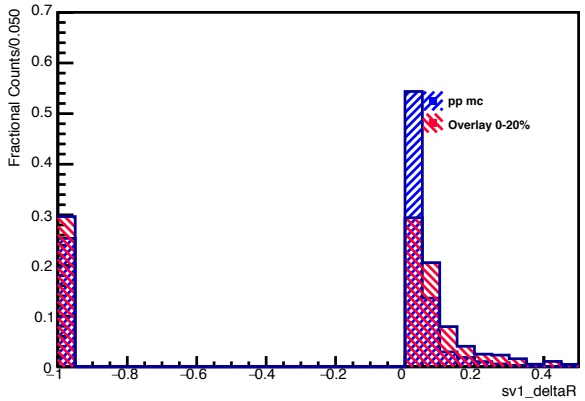
JF pt > 0.5 GeV Fixed Cone at R = 0.4



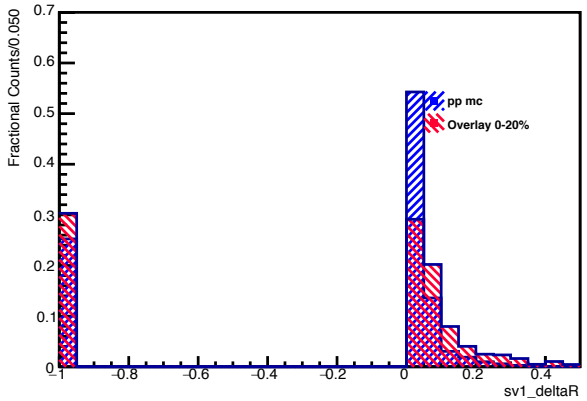
JF pt > 1.0 GeV Fixed Cone at R = 0.4



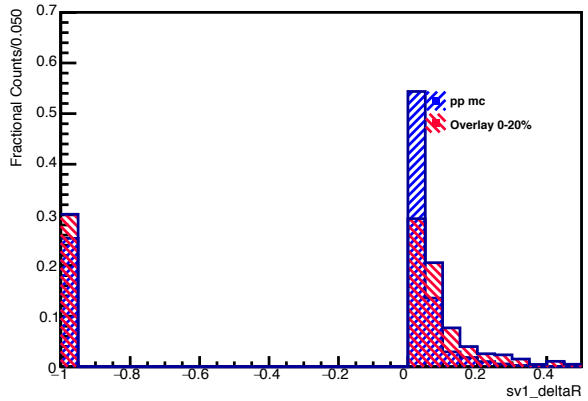
JF pt > 1.5 GeV Fixed Cone at R = 0.4



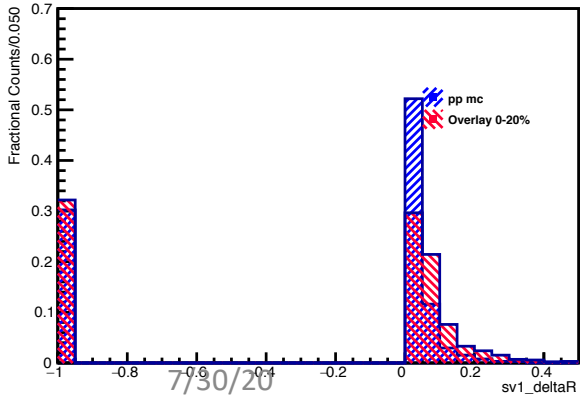
JF pt > 2.0 GeV Fixed Cone at R = 0.4



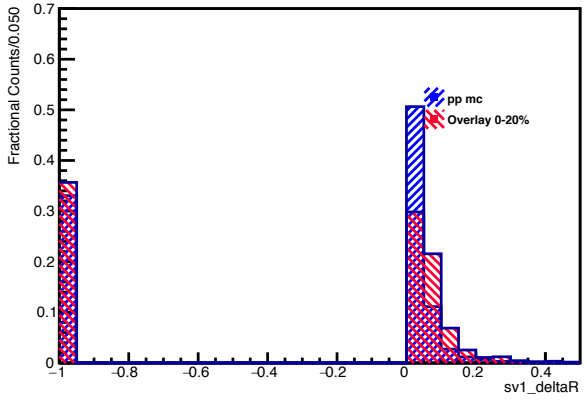
JF pt > 4 GeV Fixed Cone at R = 0.4



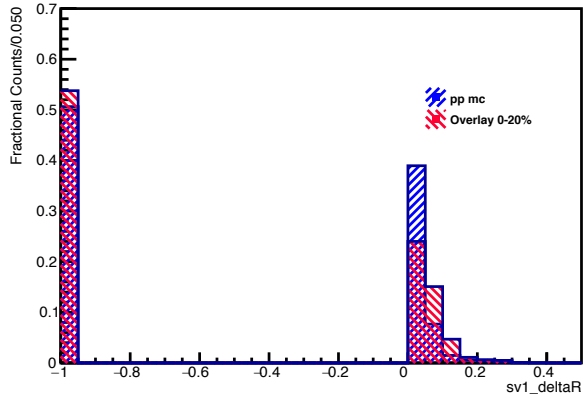
pre-tagging pt > 1.5 GeV Fixed Cone at R = 0.4



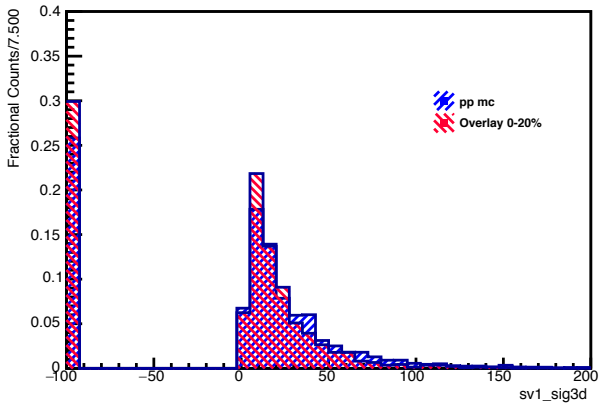
pre-tagging pt > 2.0 GeV Fixed Cone at R = 0.4



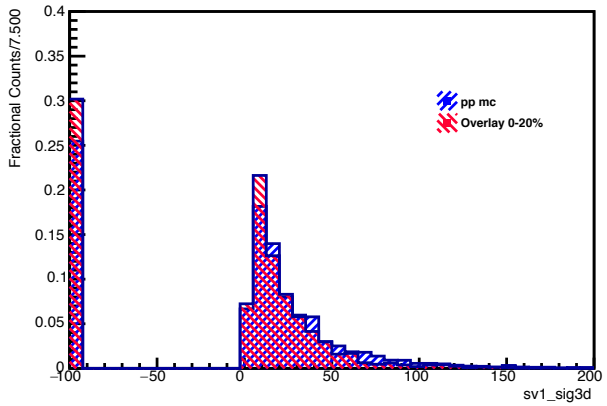
pre-tagging pt > 4.0 GeV Fixed Cone at R = 0.4



JF pt > 0.5 GeV Shrinking Cone



JF pt > 0.5 GeV Fixed Cone at R = 0.4



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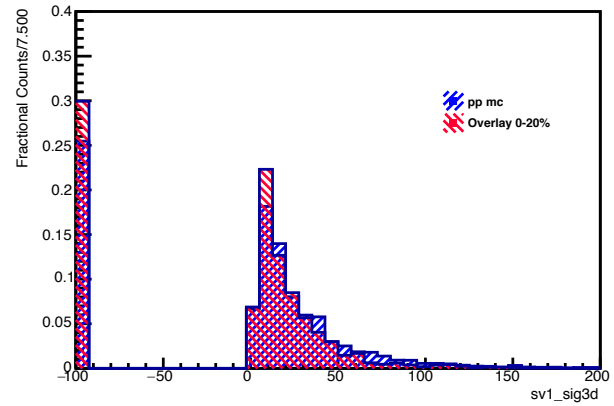

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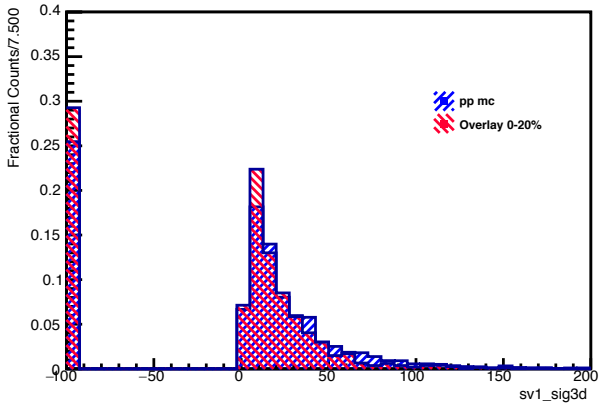

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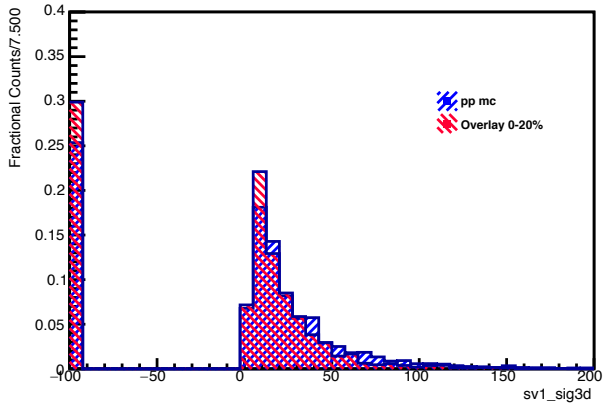

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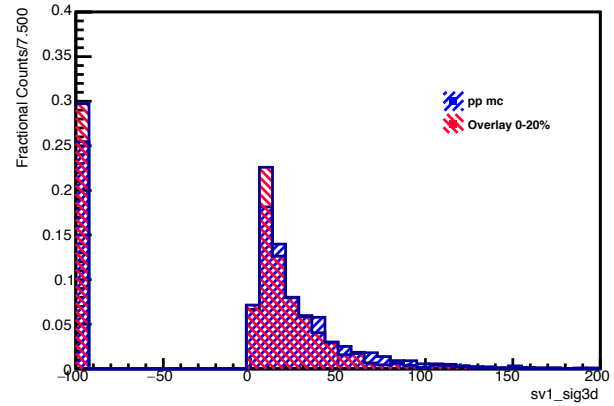

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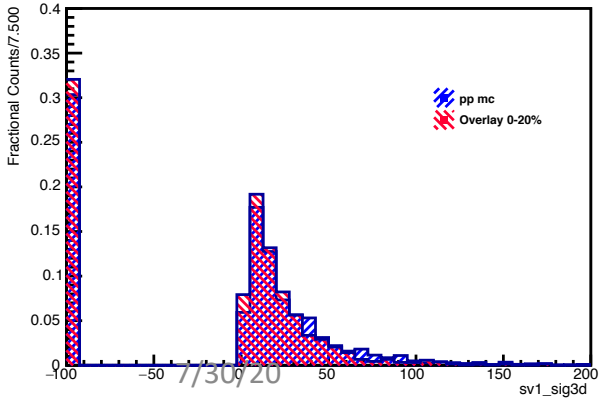

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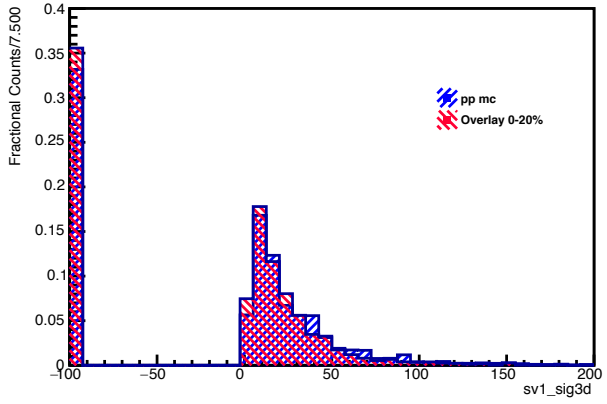

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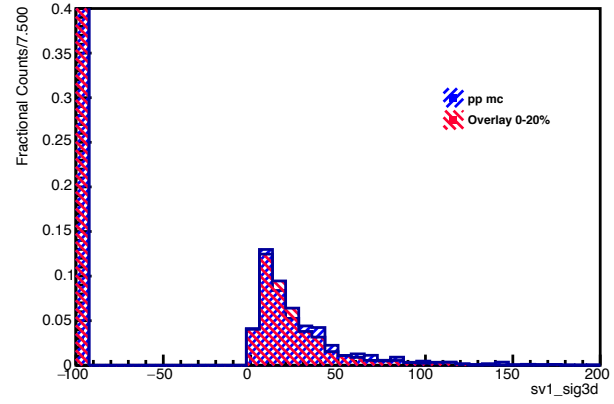

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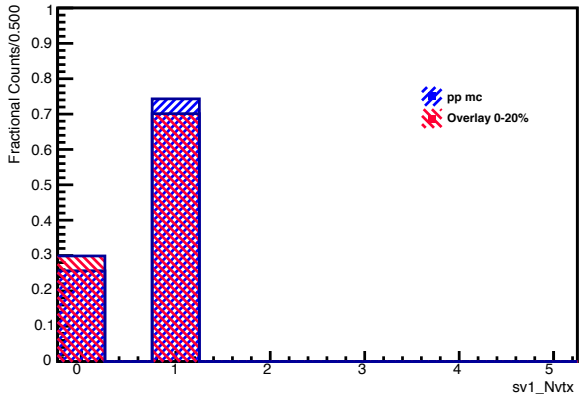

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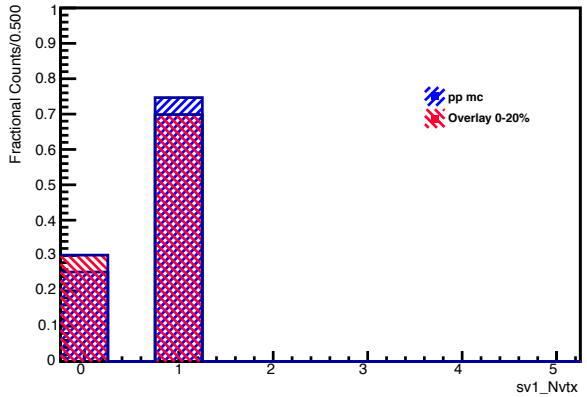

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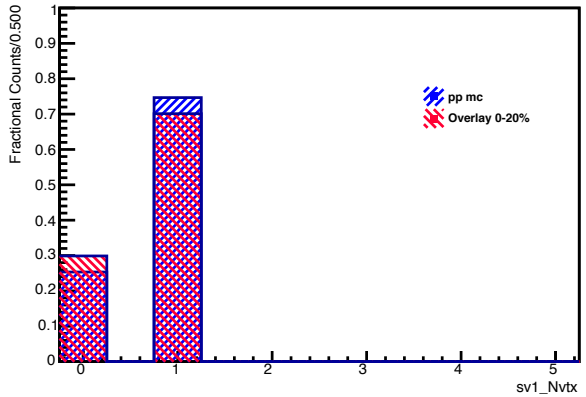

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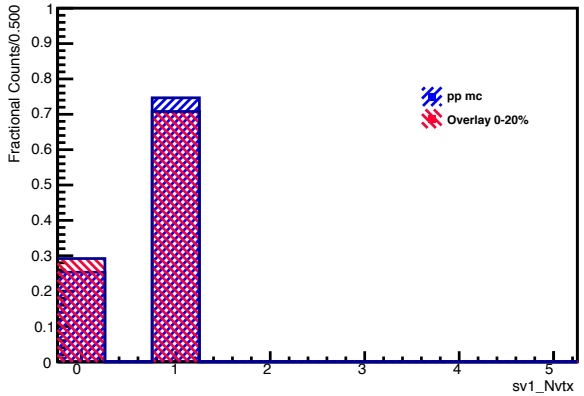

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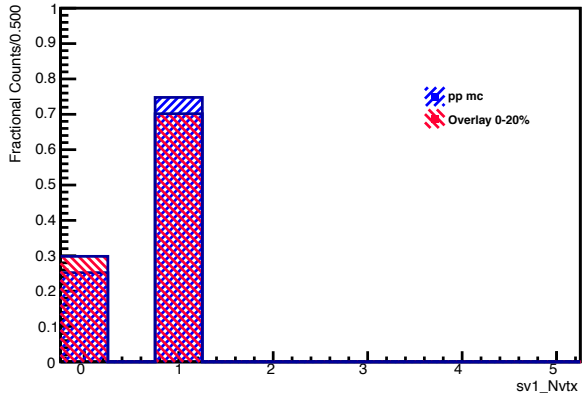

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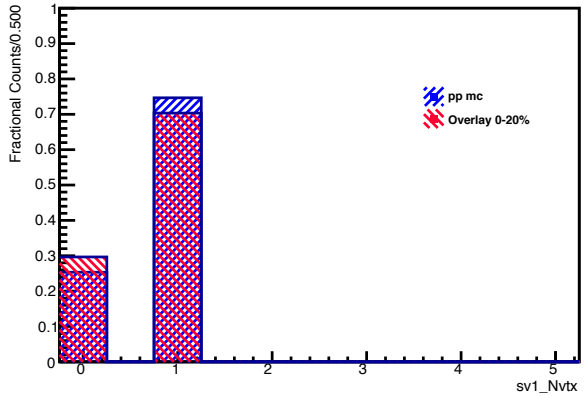

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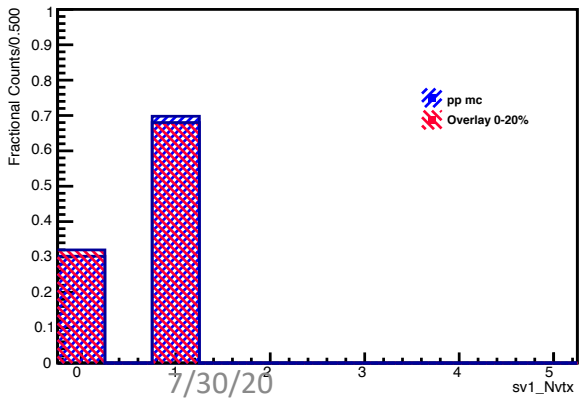

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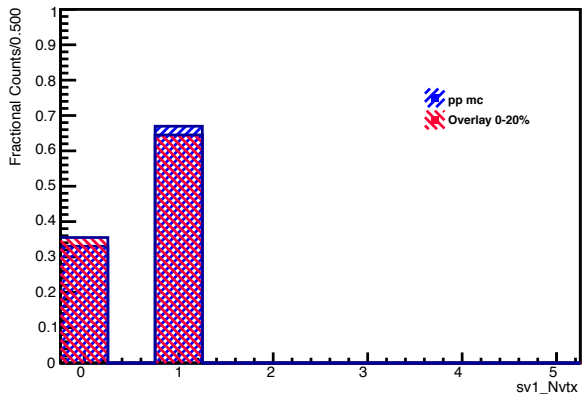

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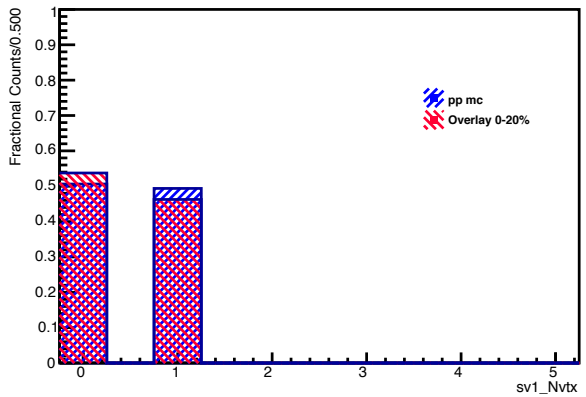

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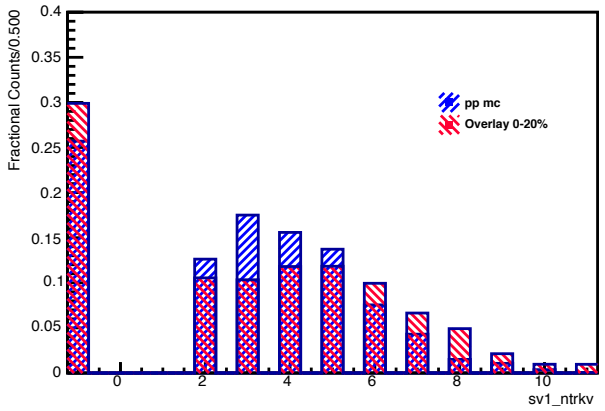

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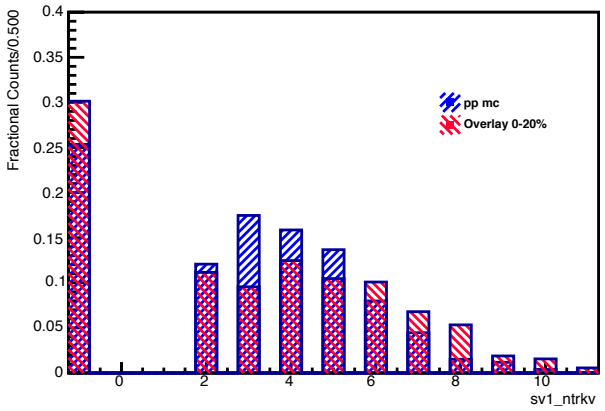

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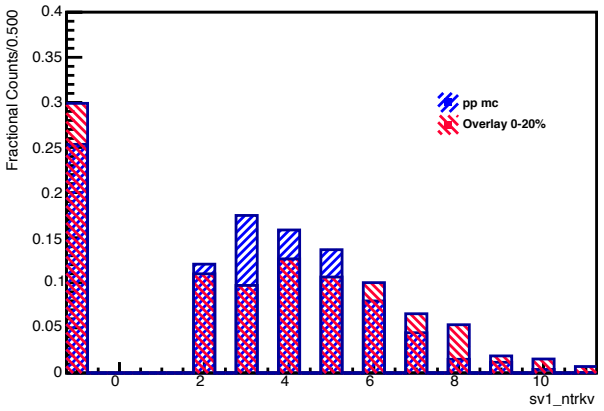

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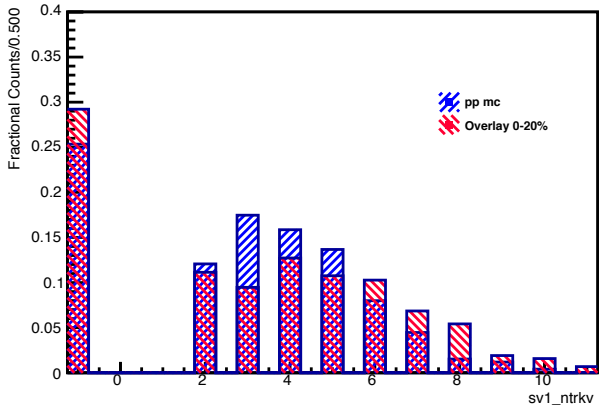

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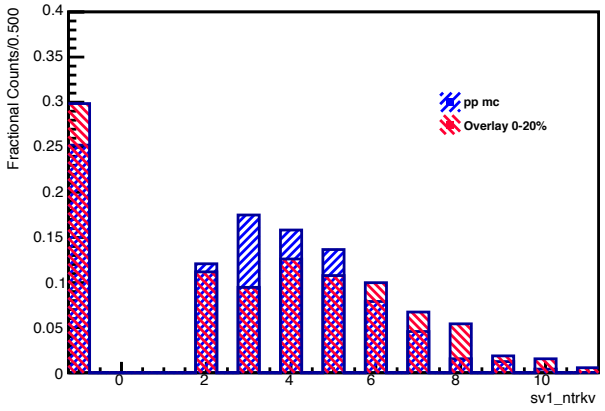

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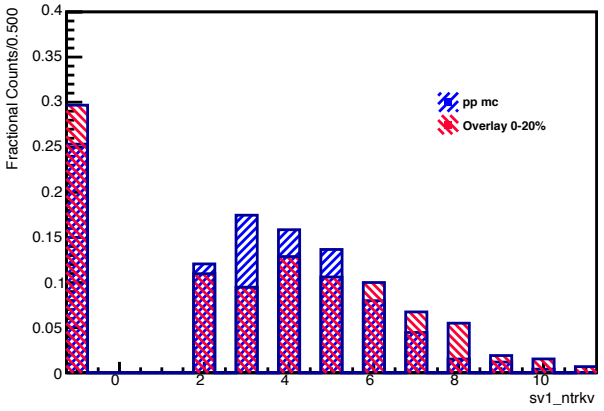

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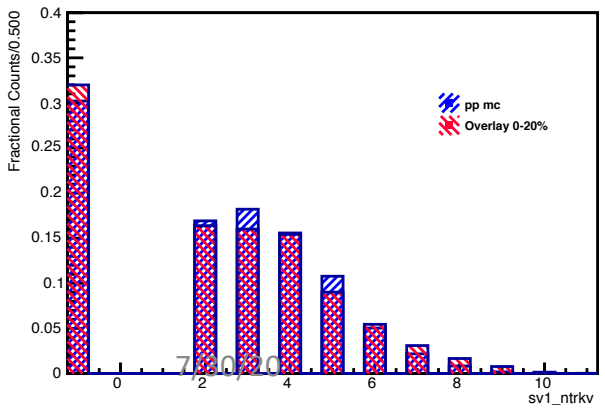

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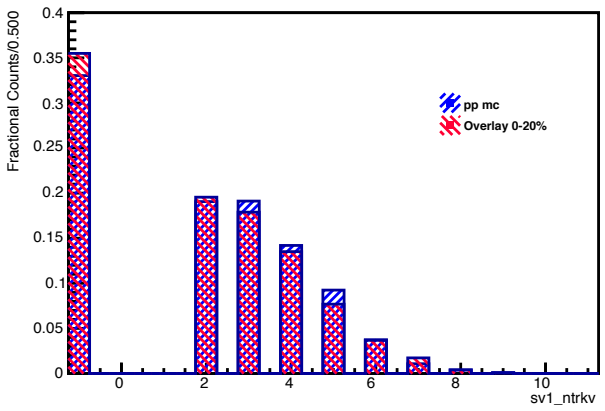

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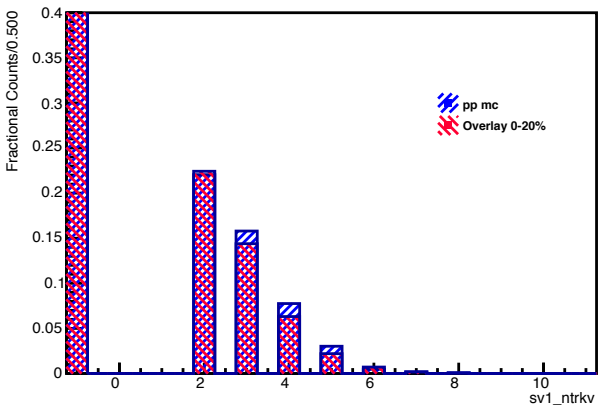

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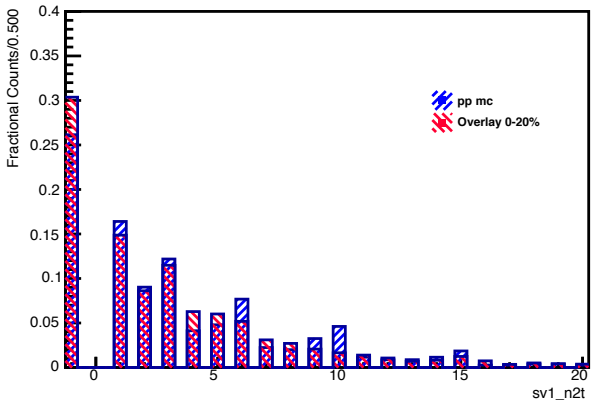

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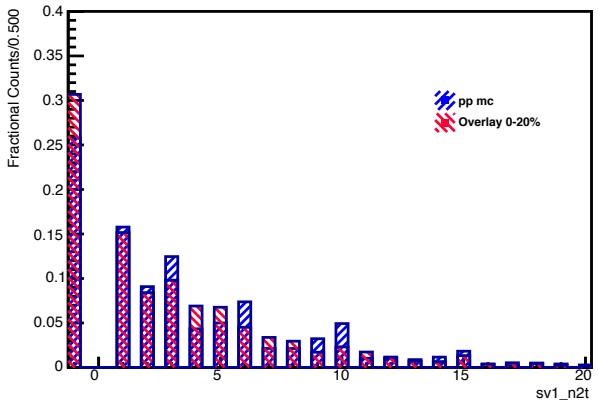

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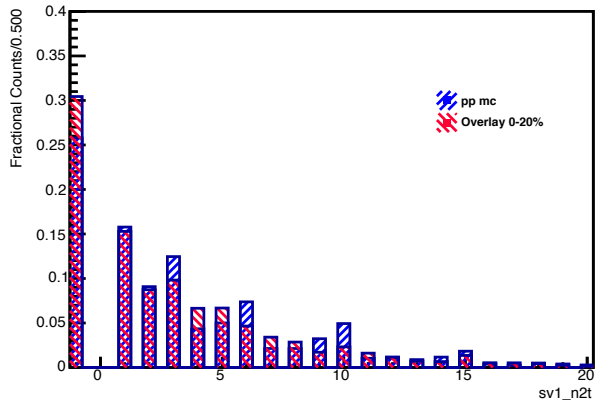

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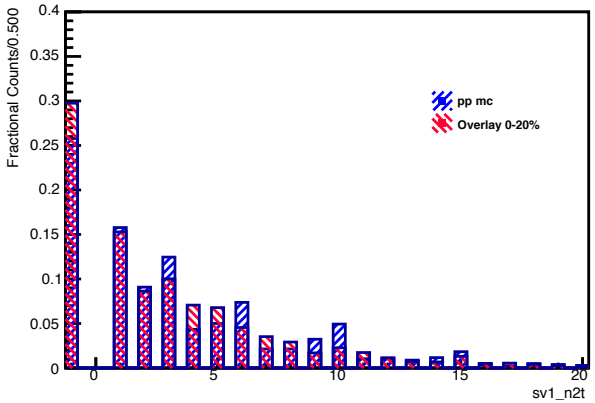

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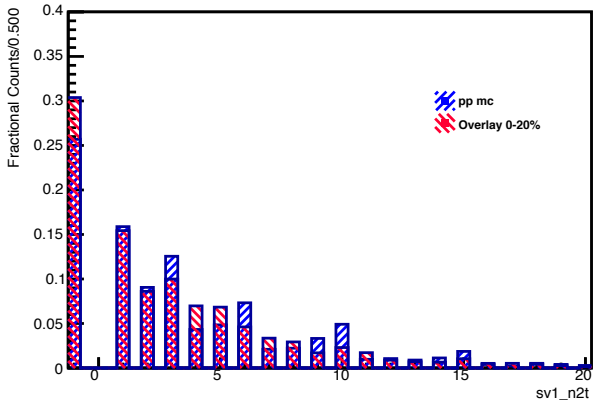

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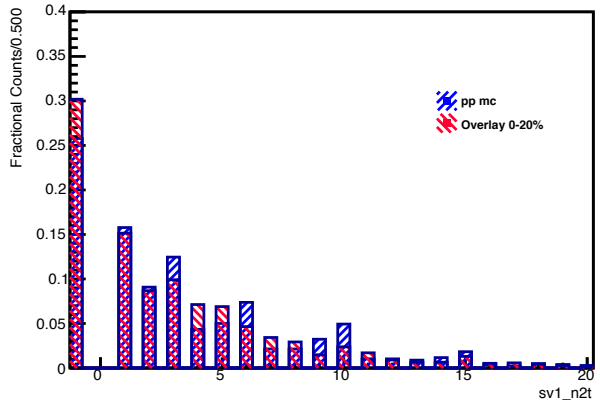

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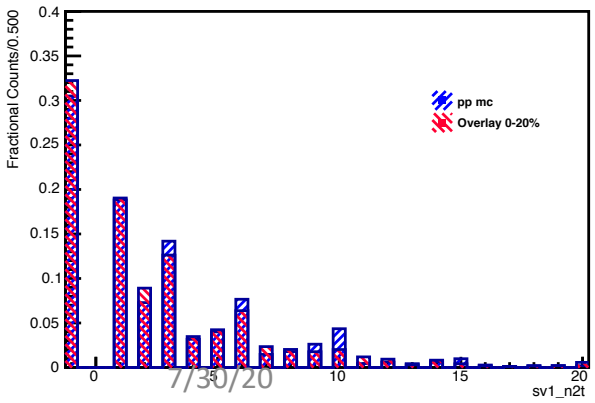

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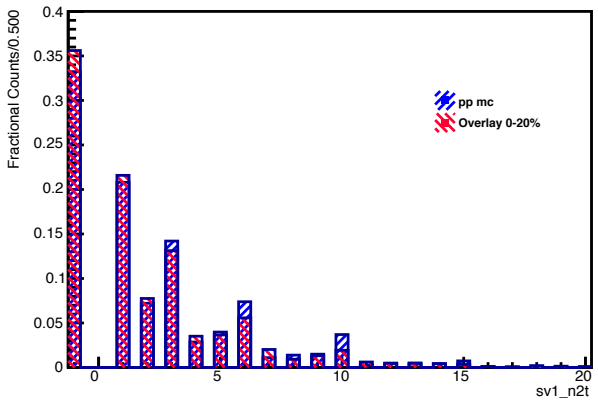

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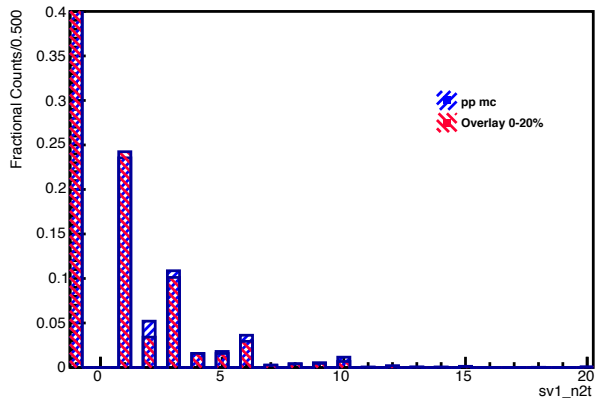

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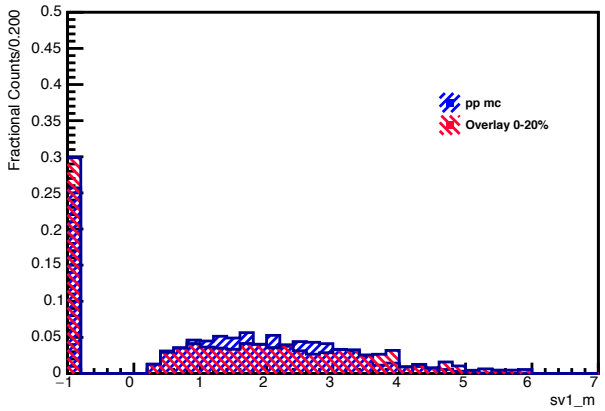

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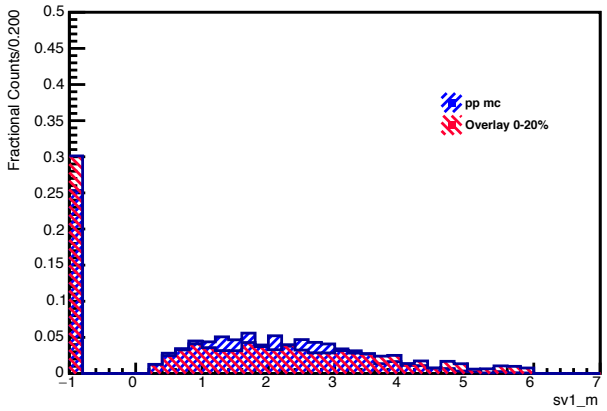

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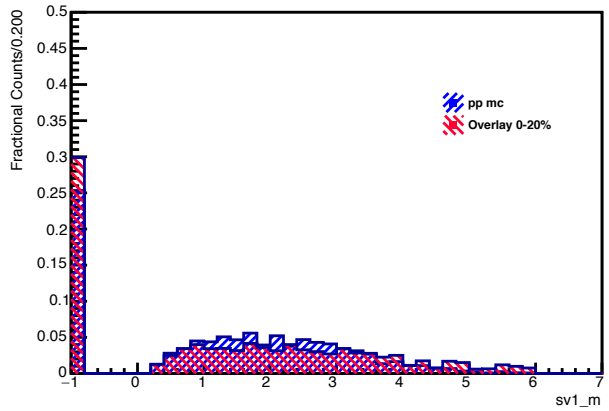

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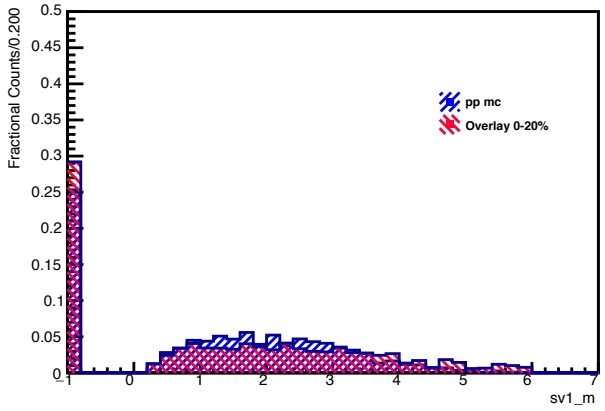

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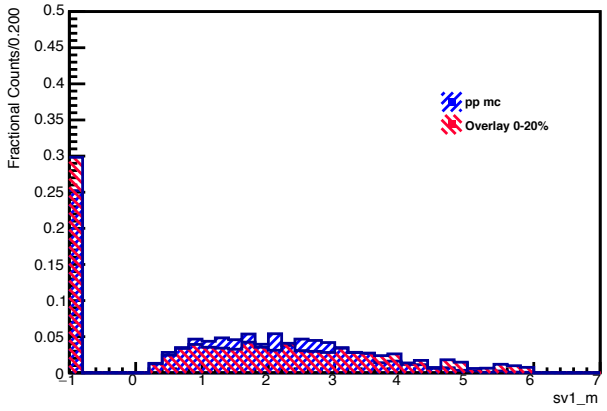

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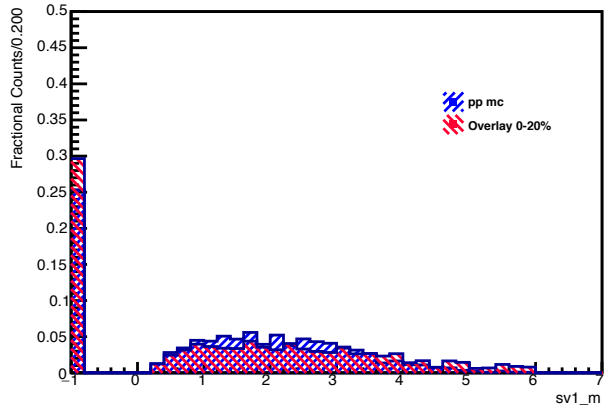

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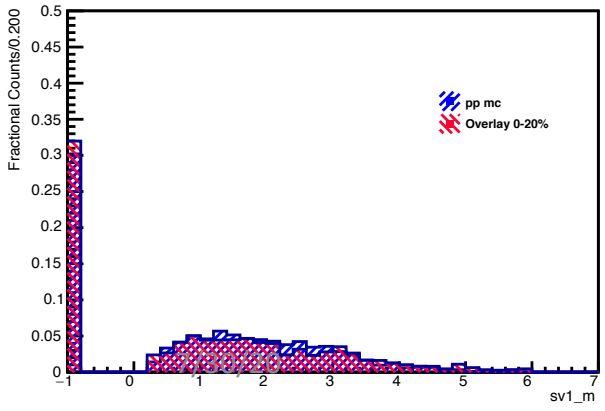

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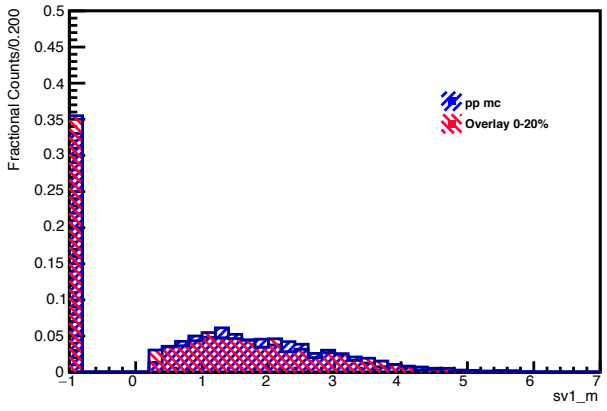

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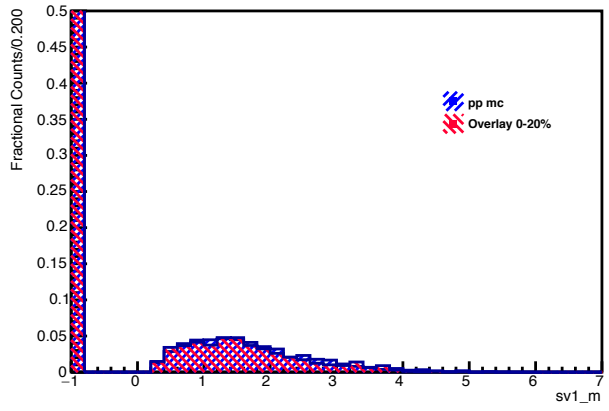

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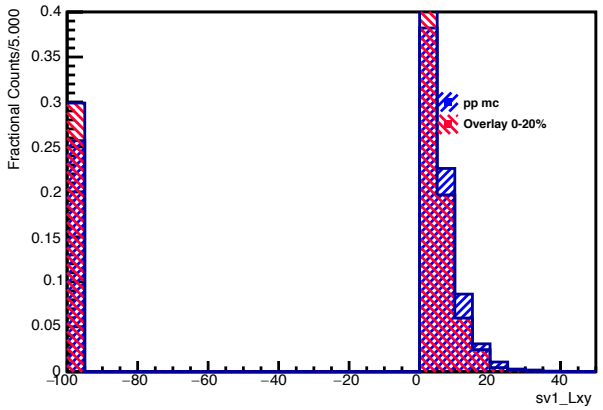

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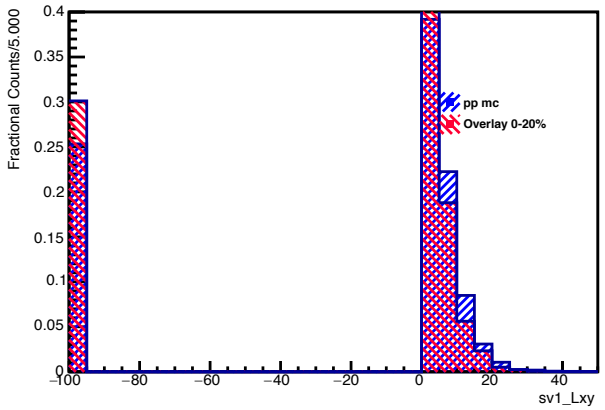

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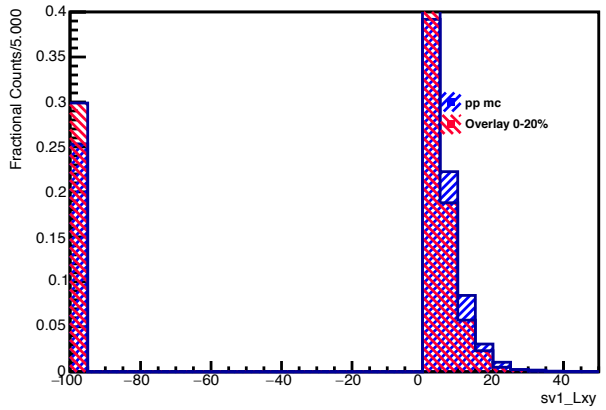

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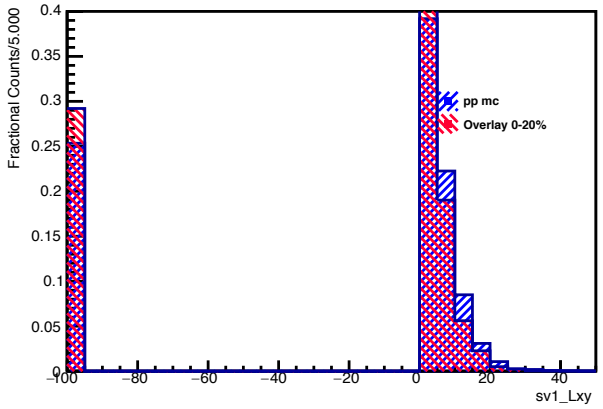

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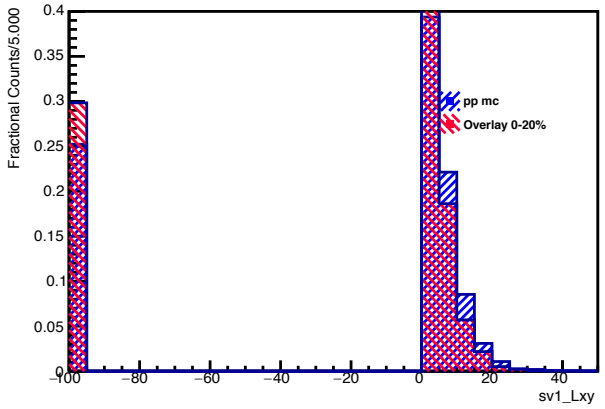

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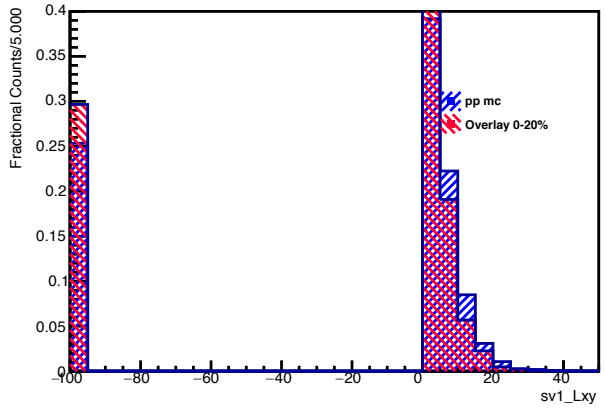

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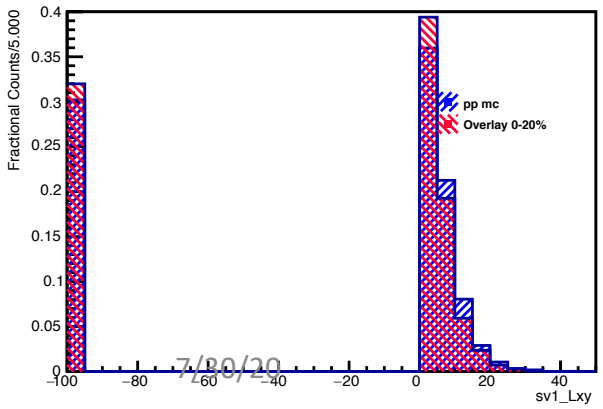

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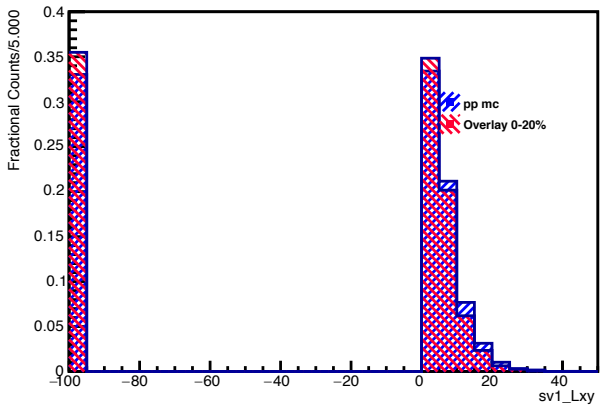

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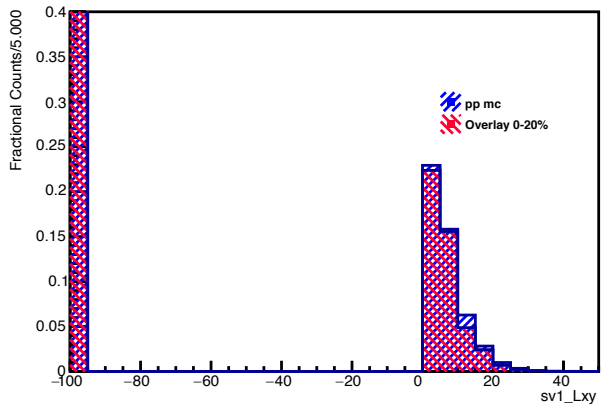

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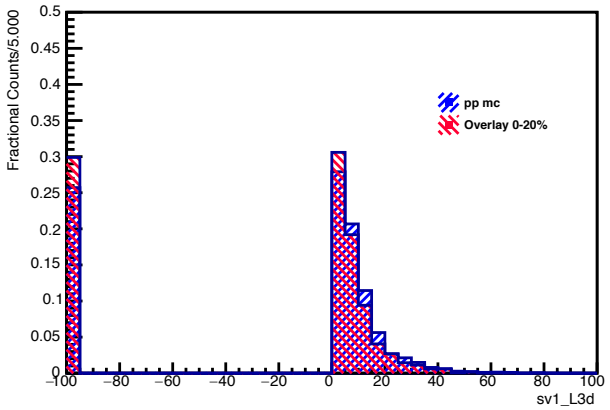

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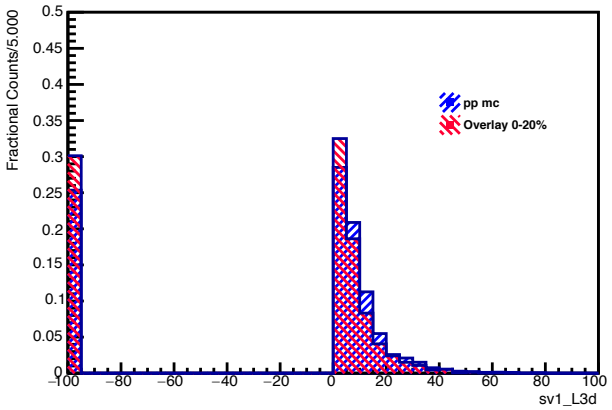

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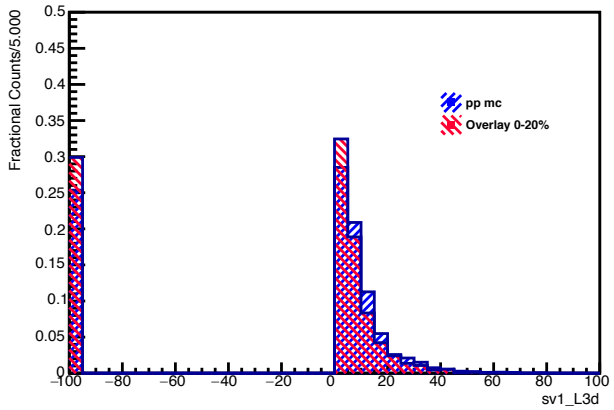

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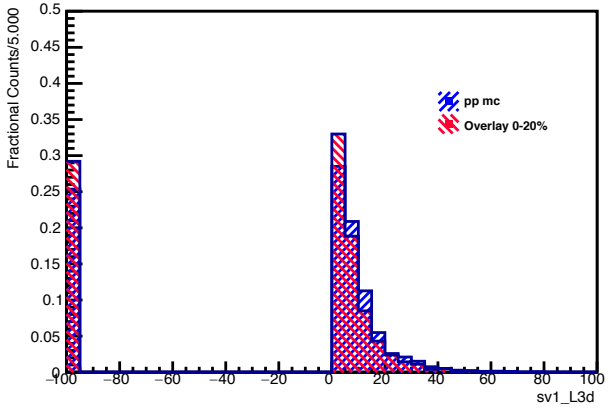

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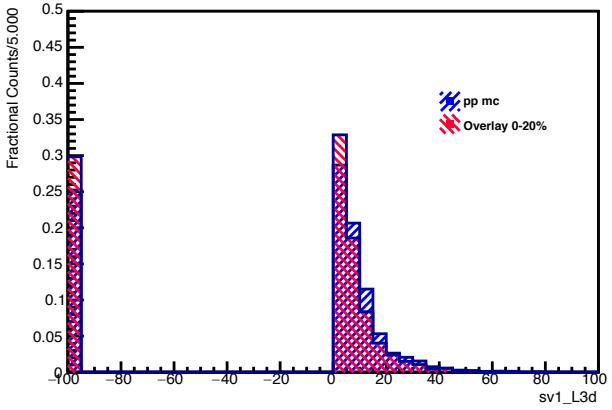

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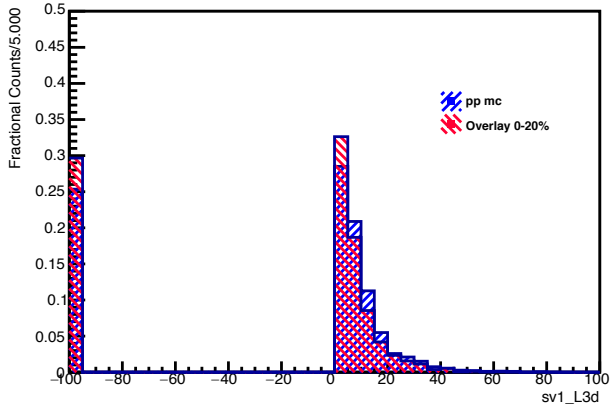

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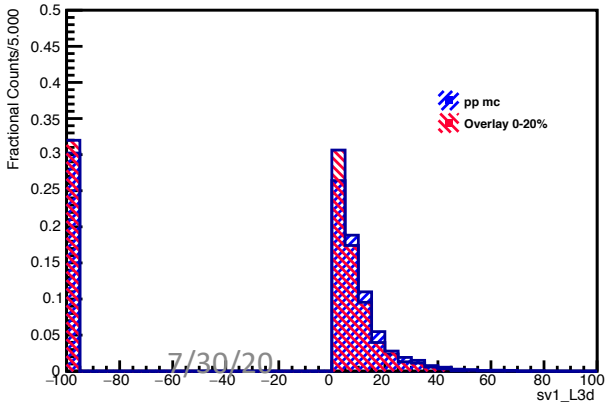

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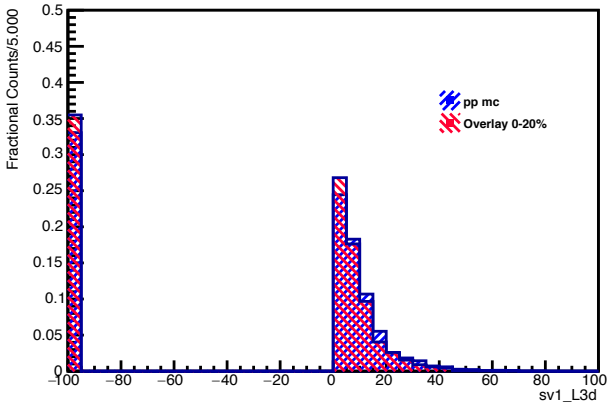

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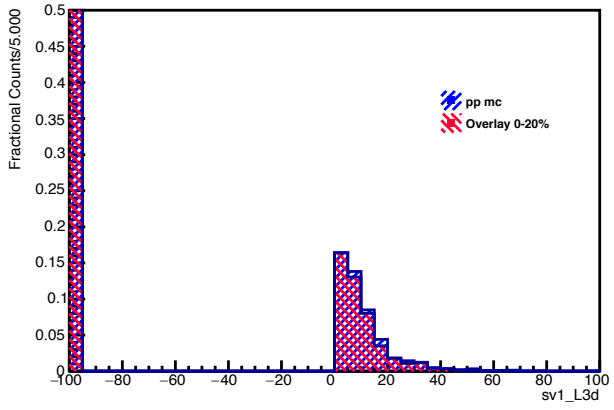

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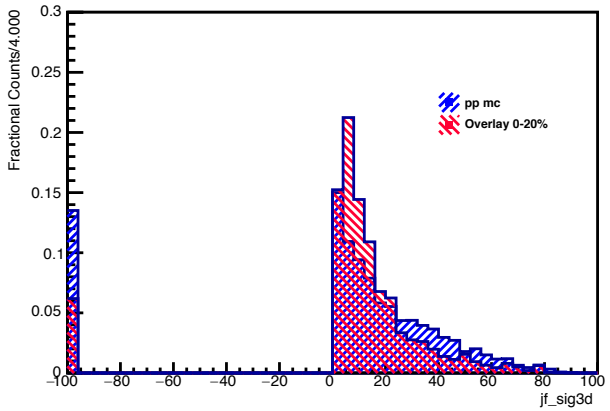

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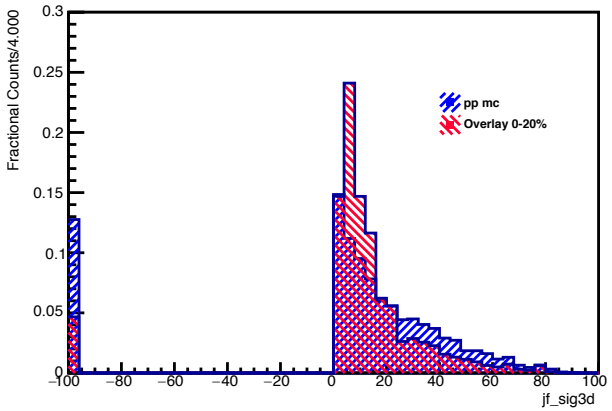

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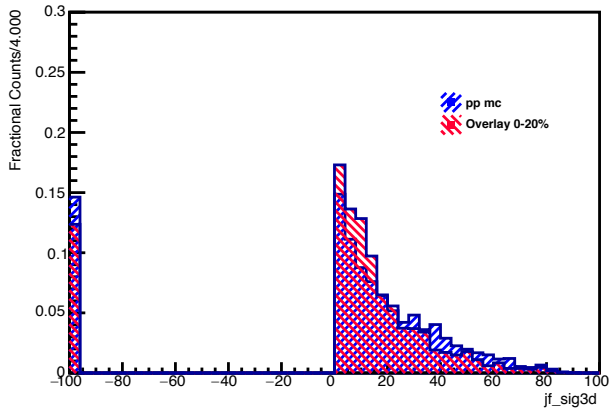

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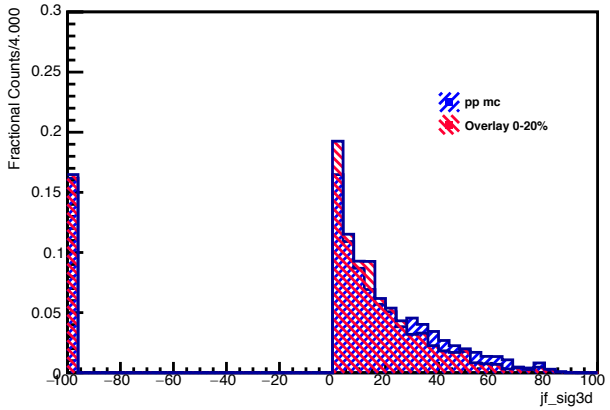

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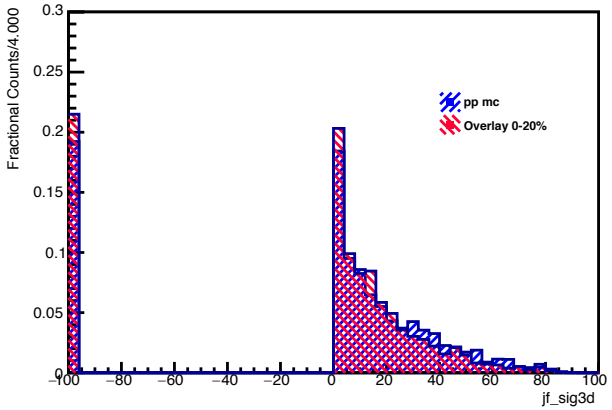

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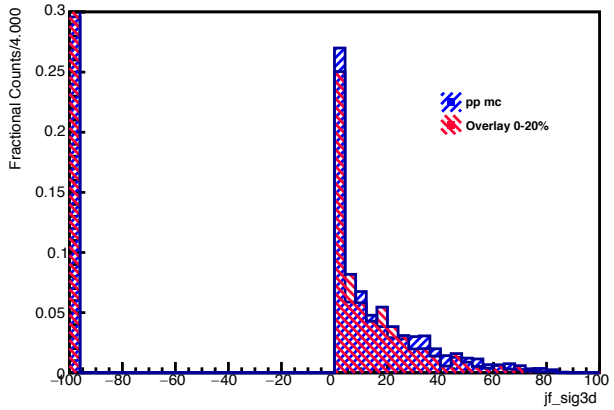

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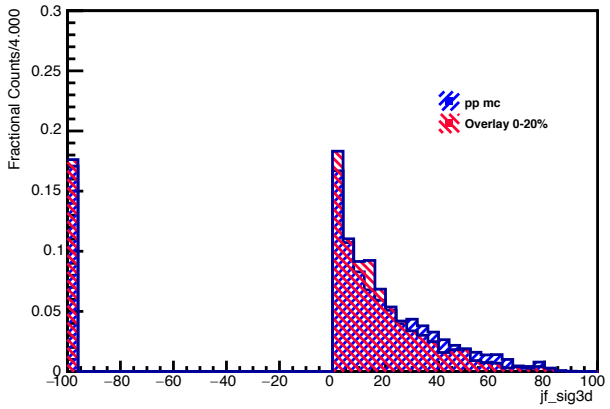

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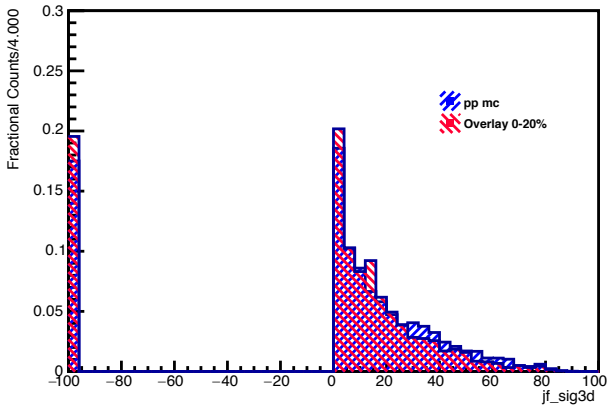

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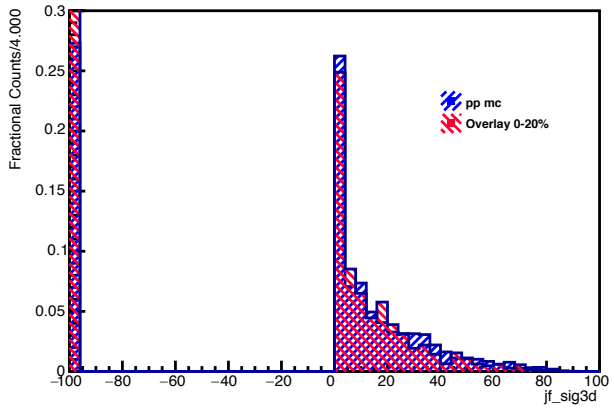

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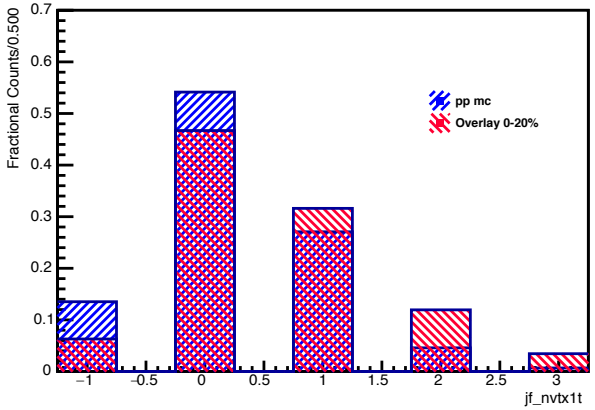

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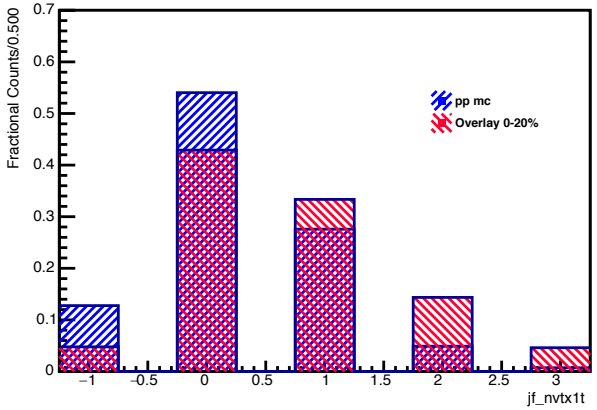

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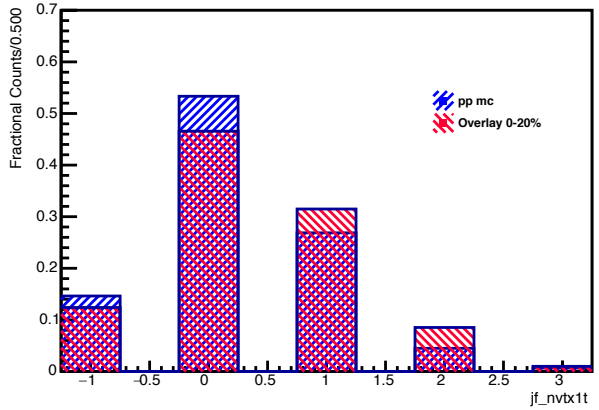

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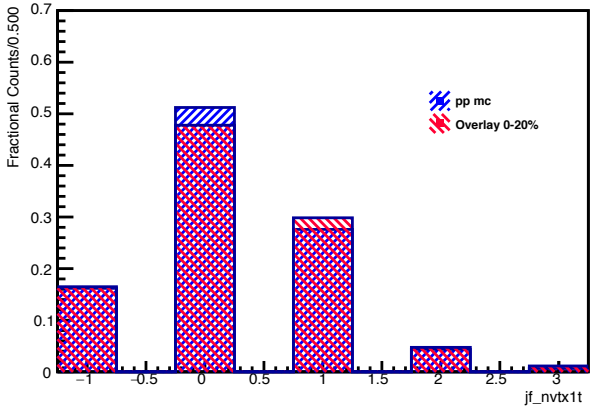

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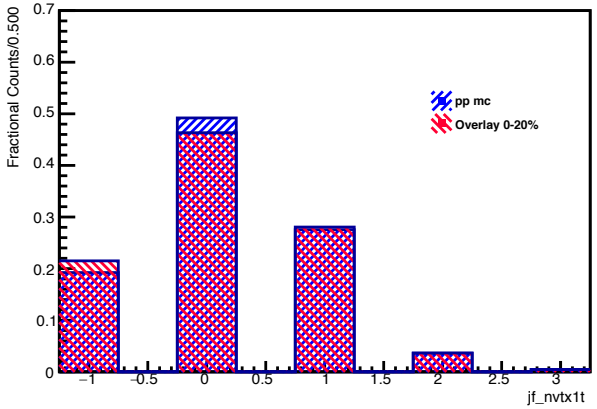

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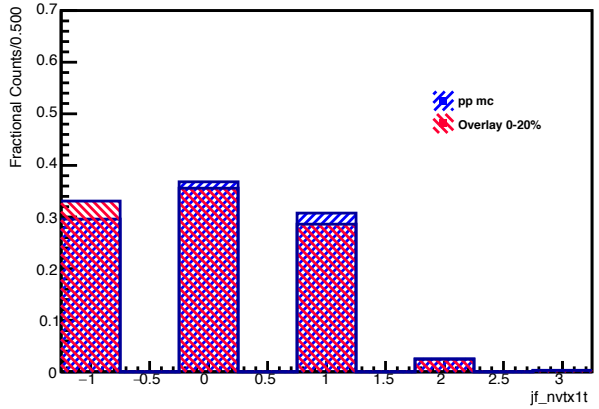

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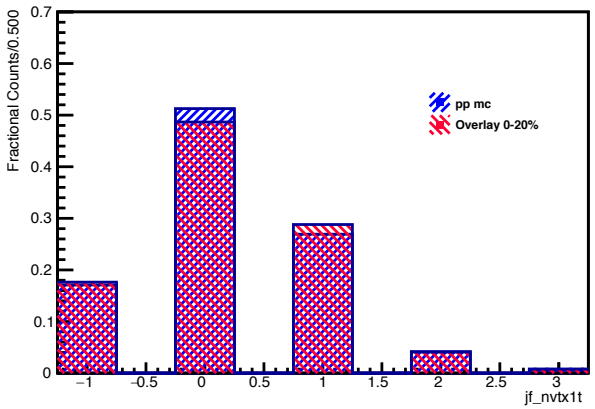

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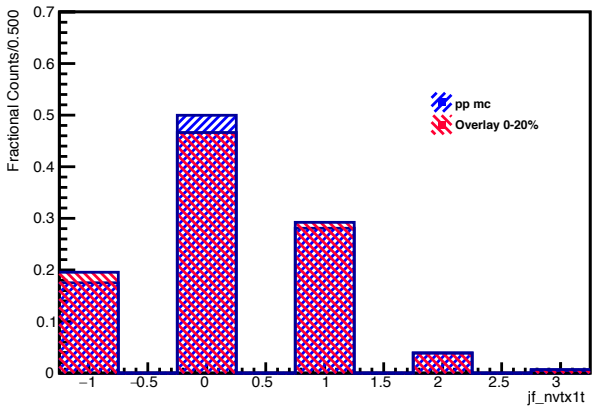

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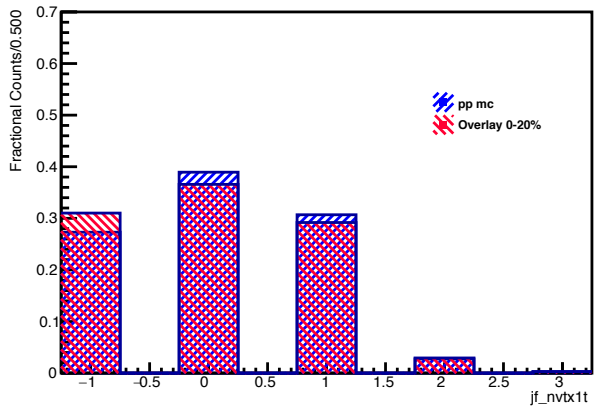

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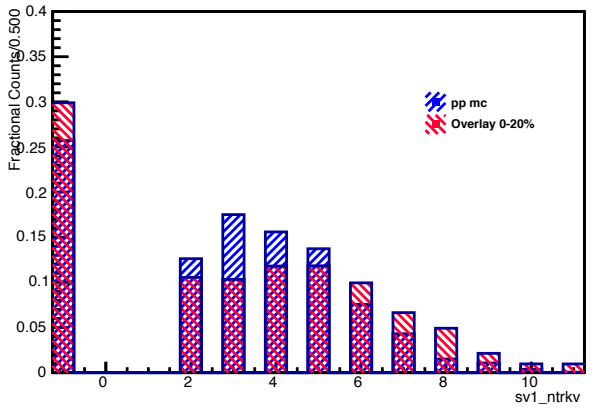

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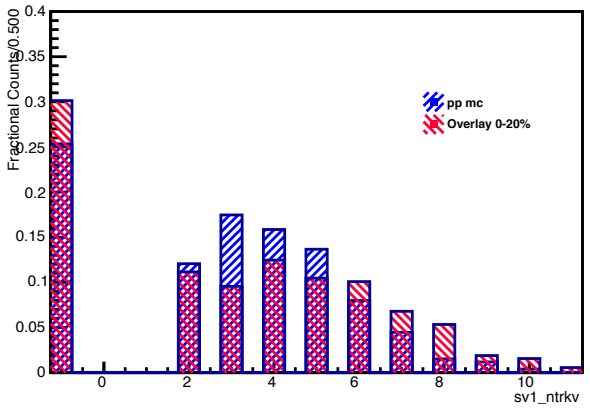

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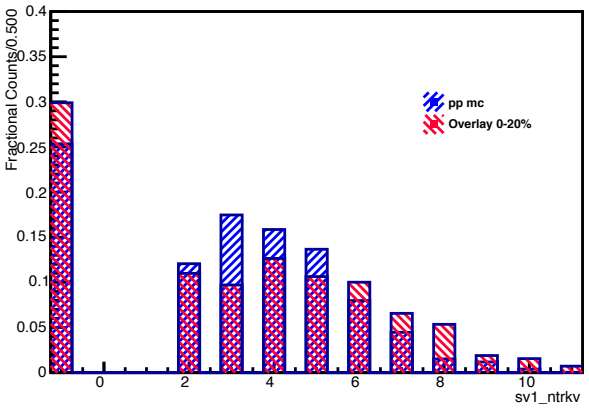

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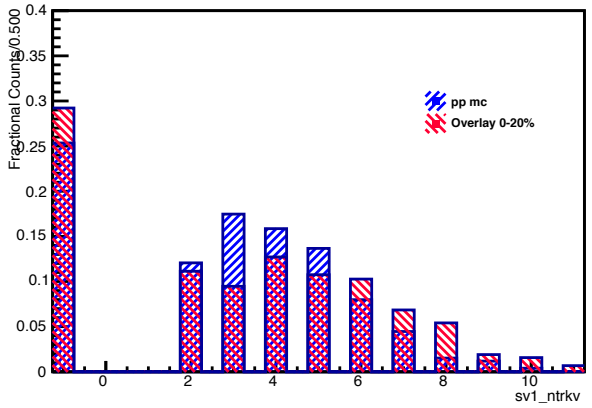

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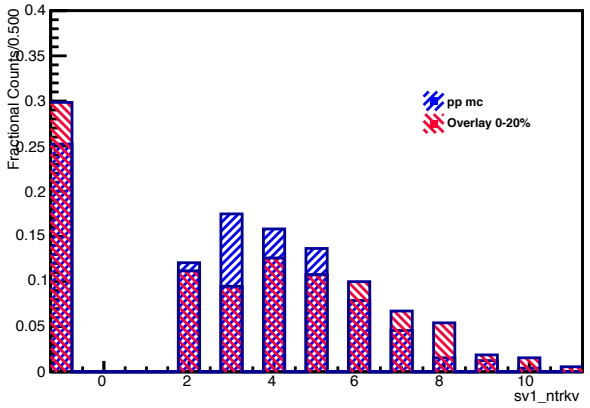

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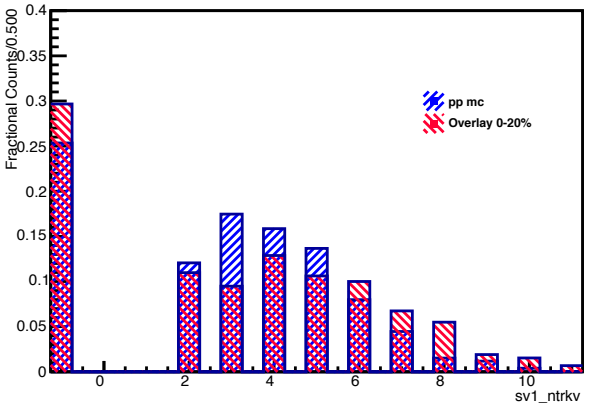

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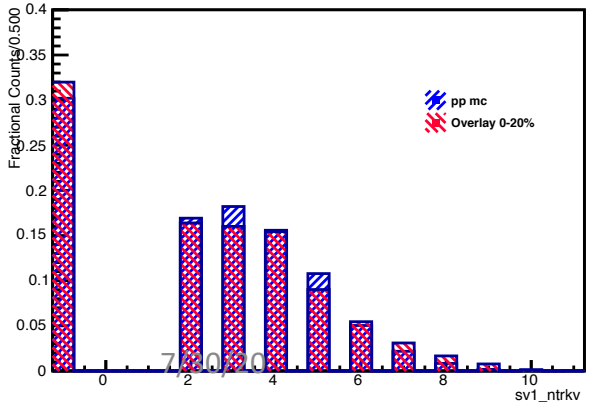

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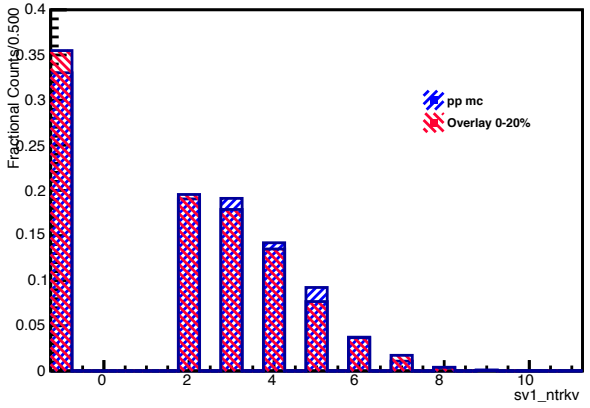

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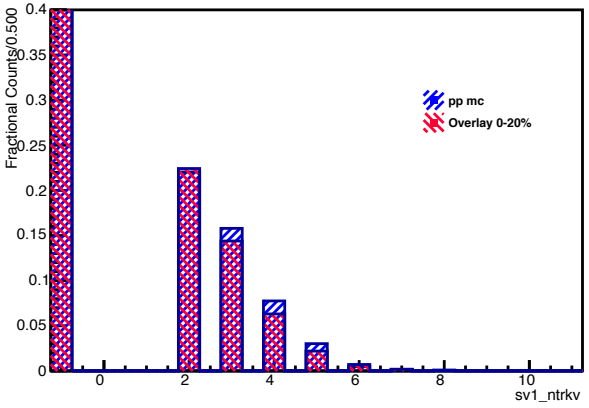

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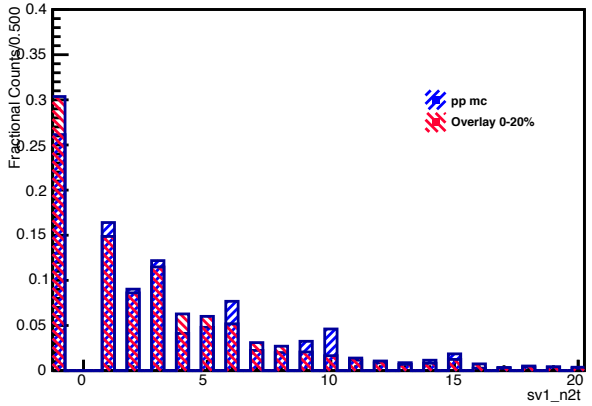

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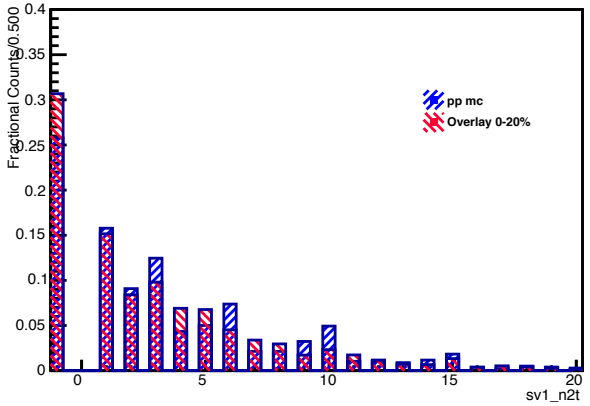

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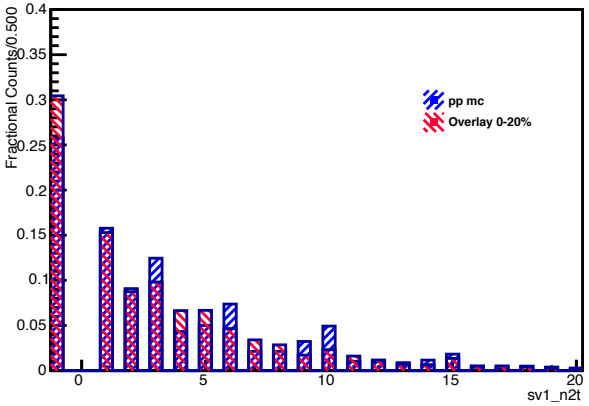

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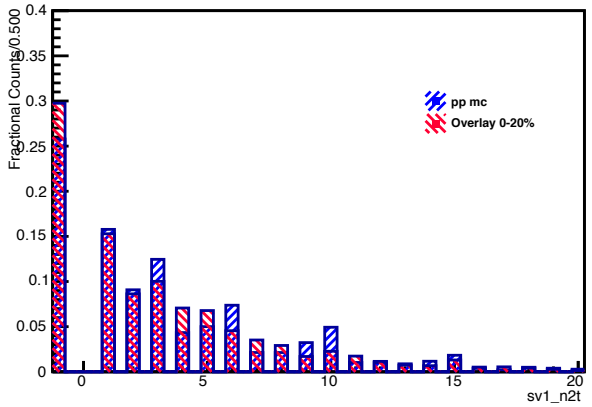

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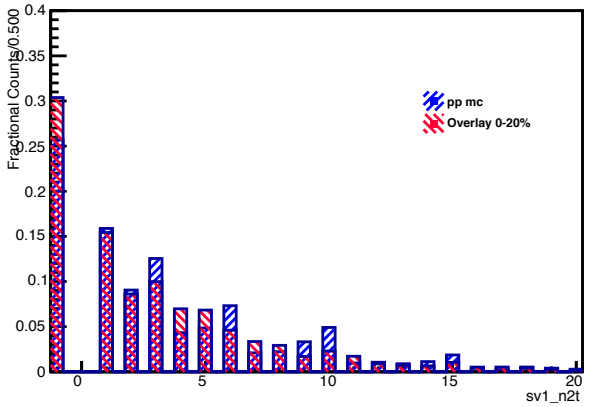

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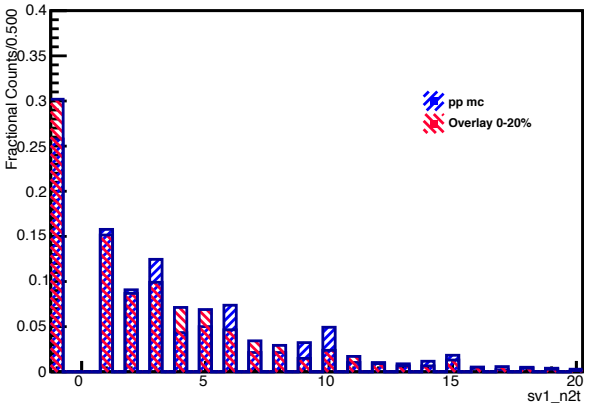

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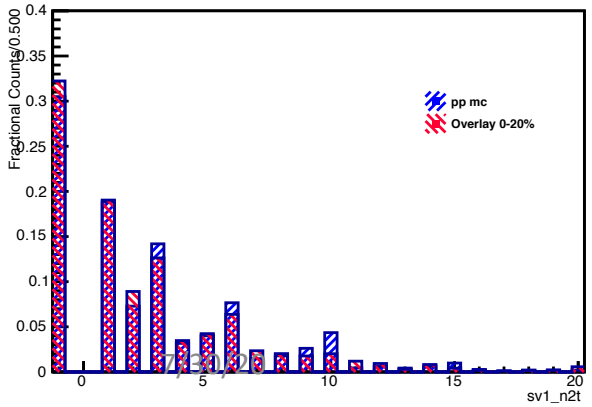

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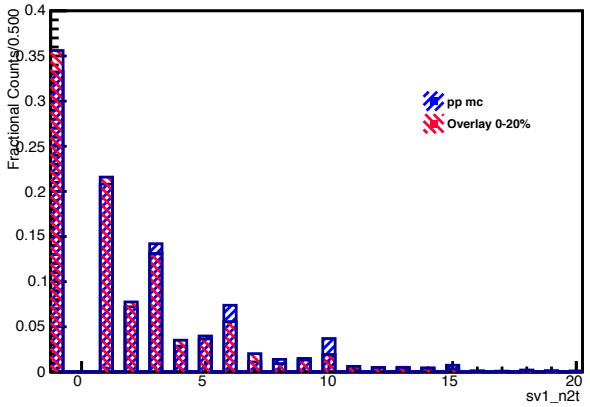

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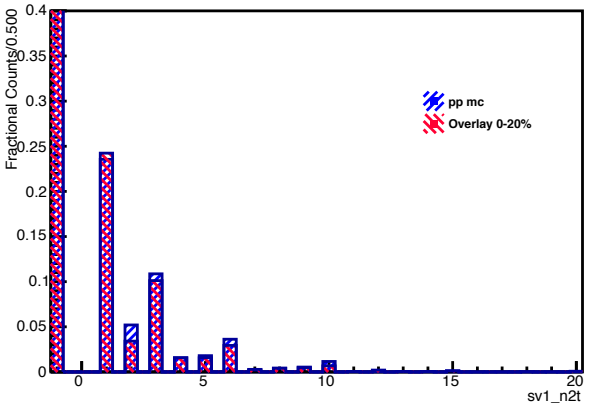

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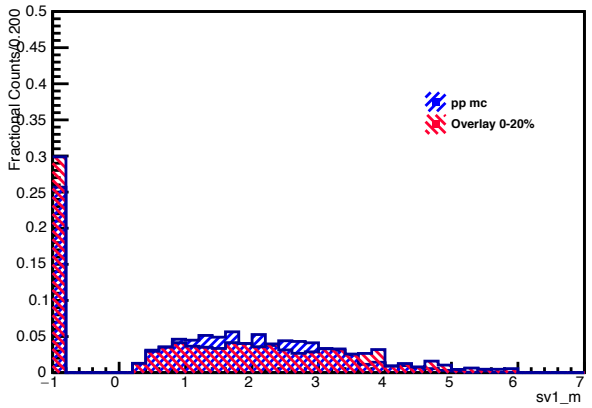

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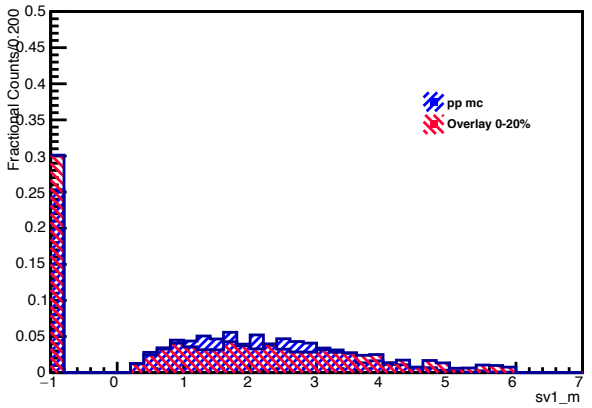

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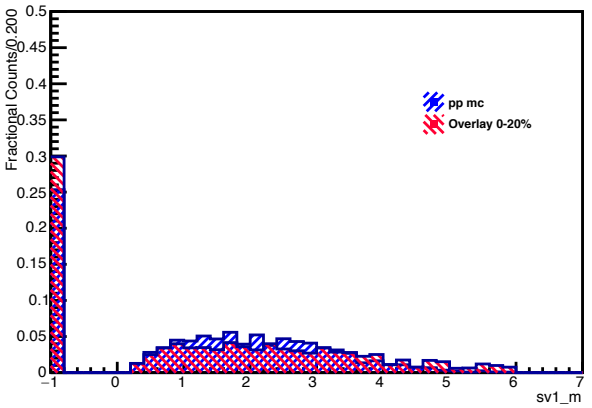

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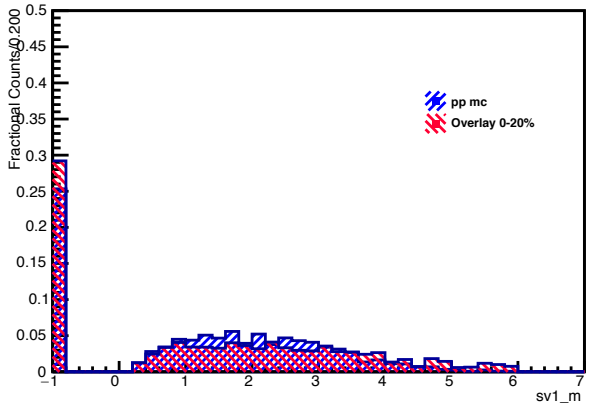

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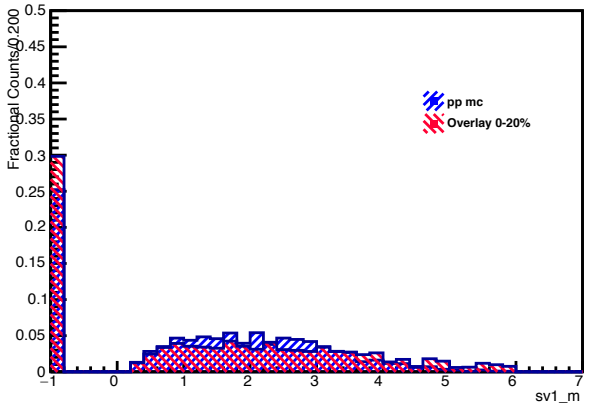

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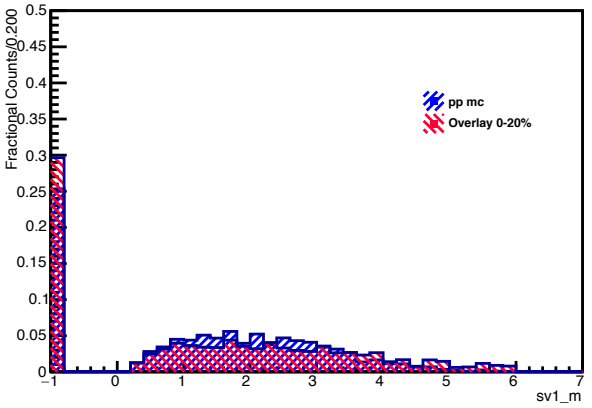

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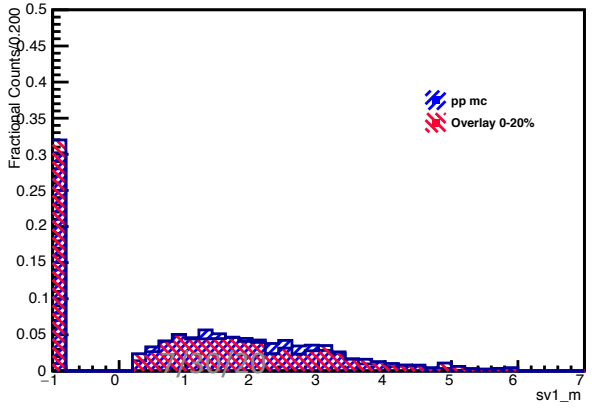

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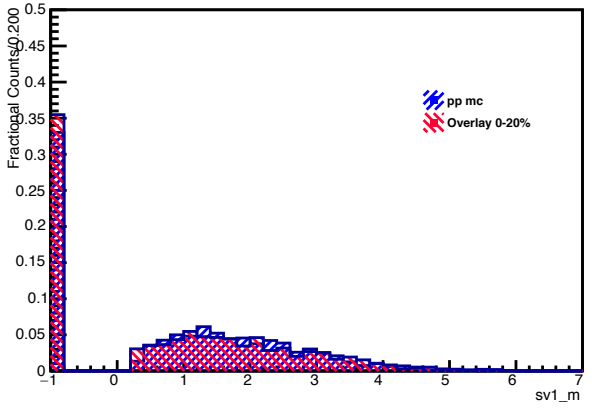

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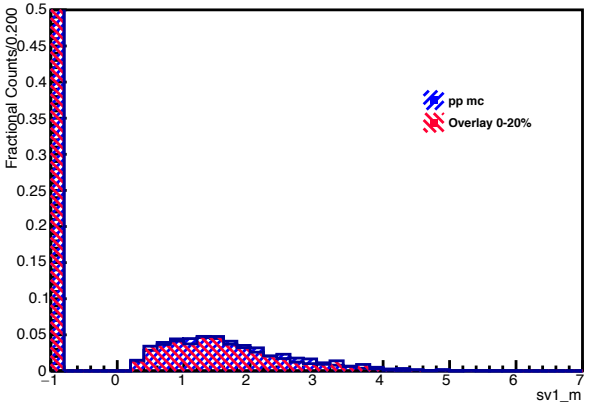

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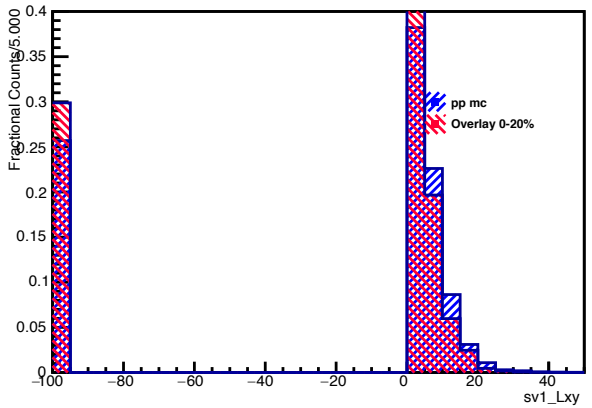

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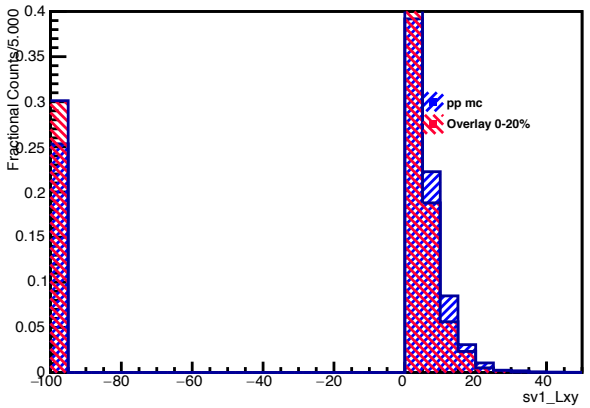

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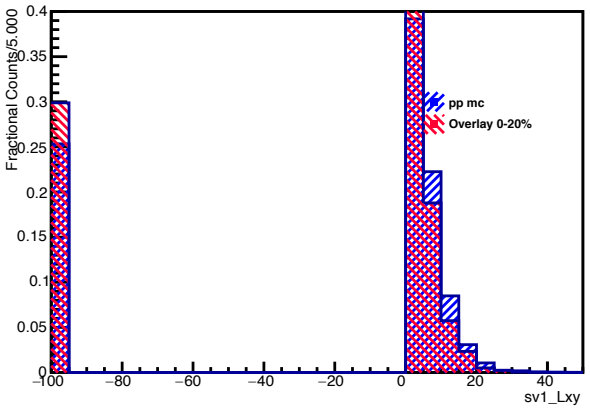

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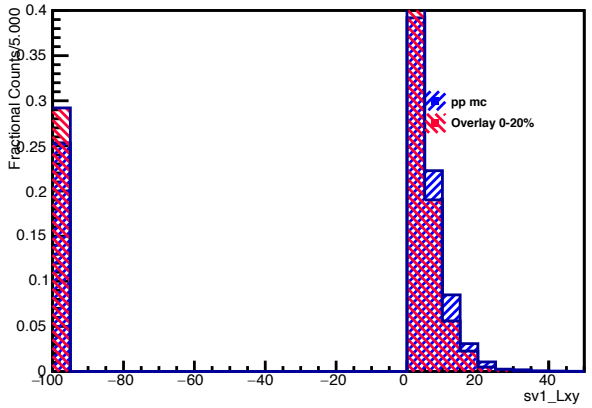

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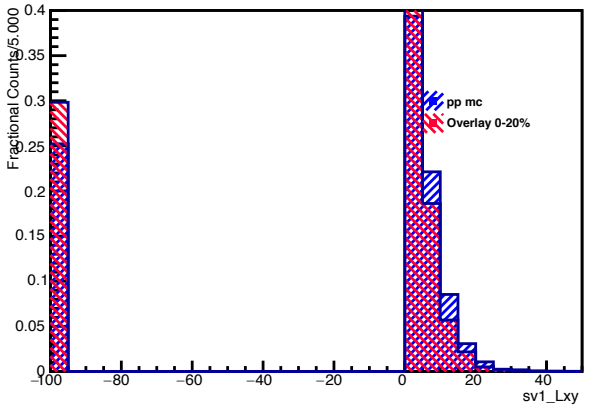

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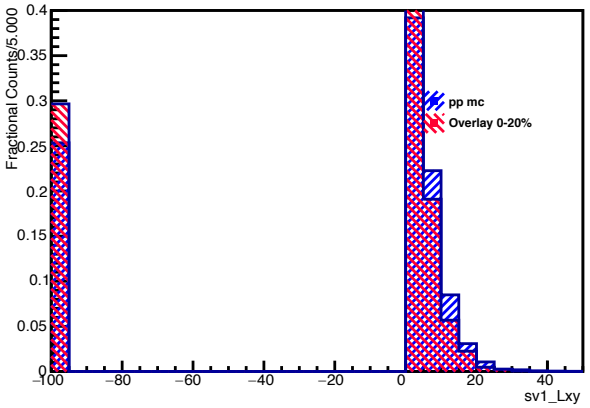

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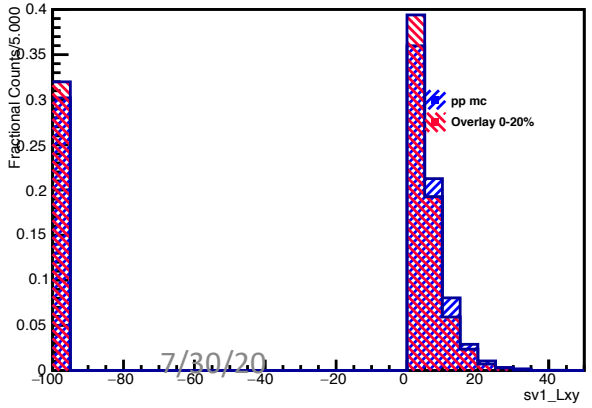

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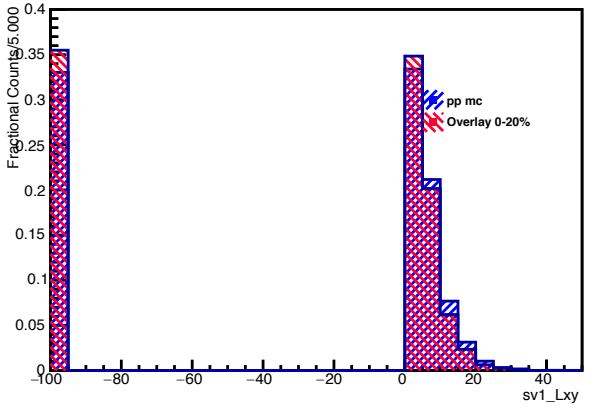

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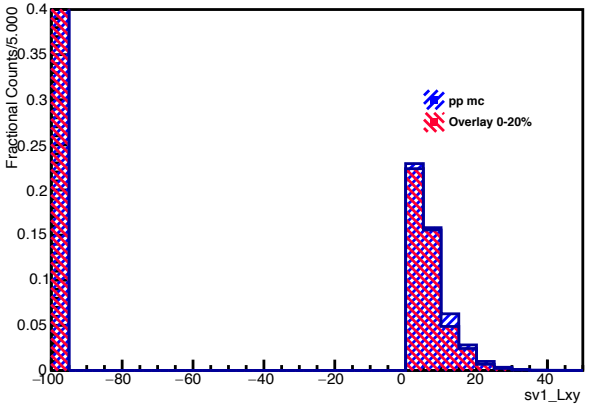

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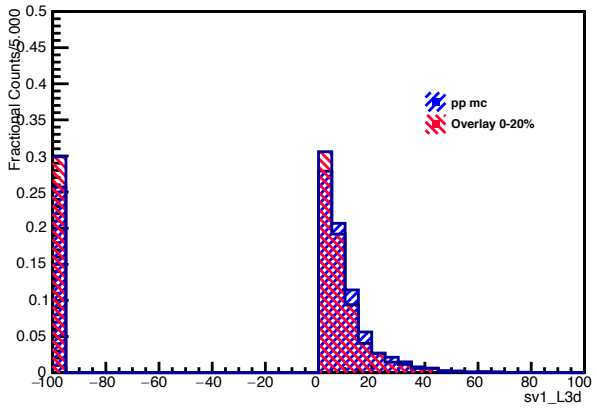

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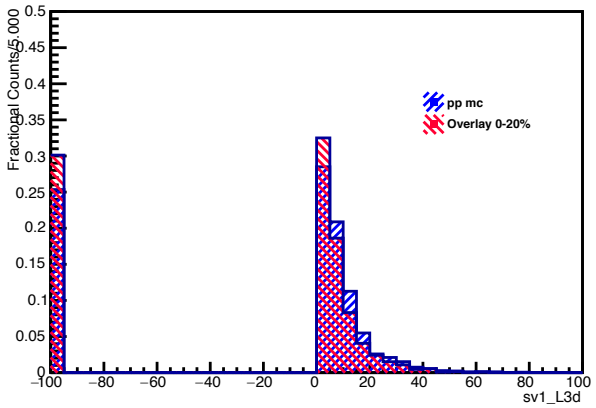

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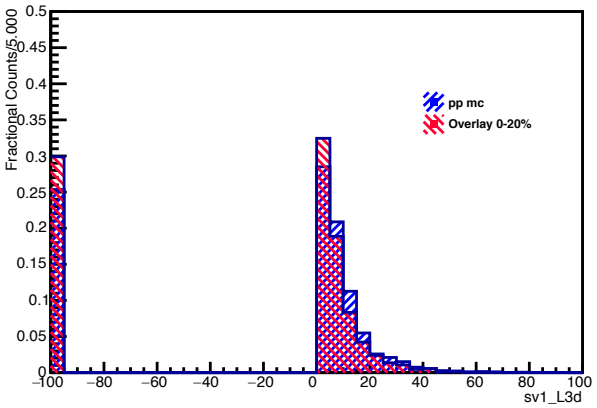

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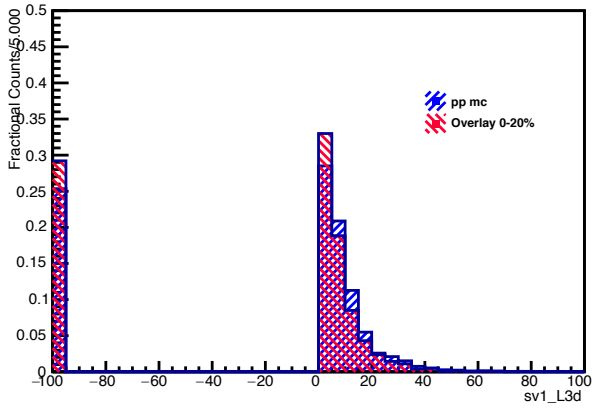

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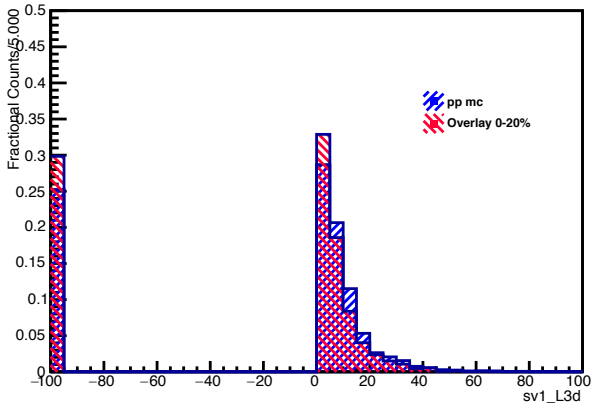

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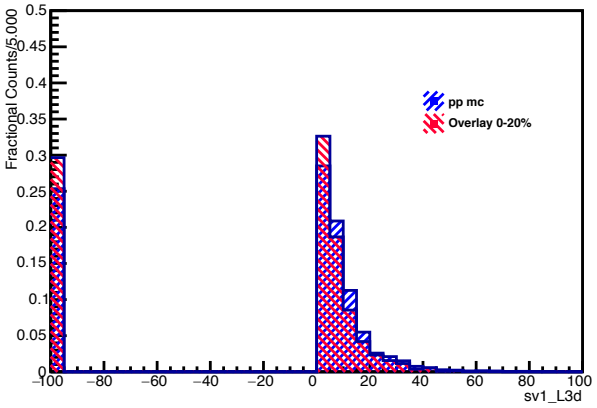

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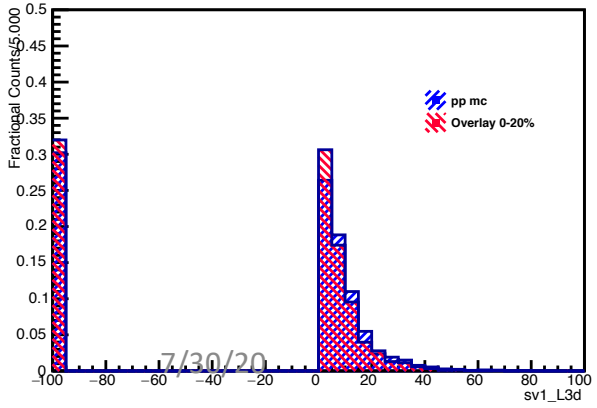

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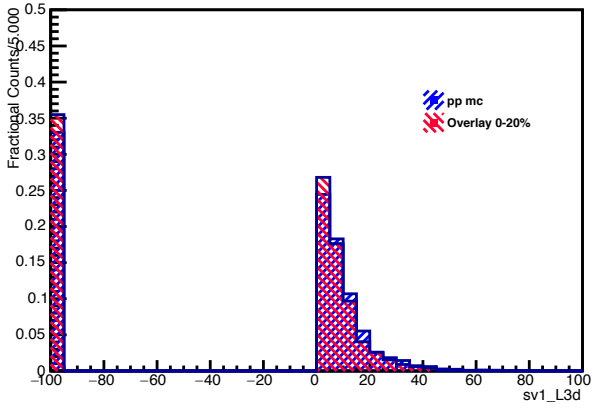

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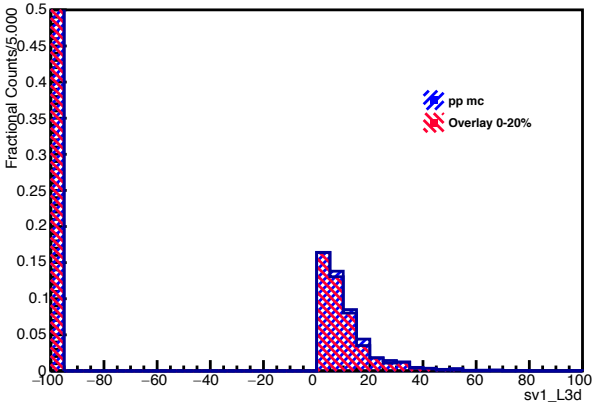

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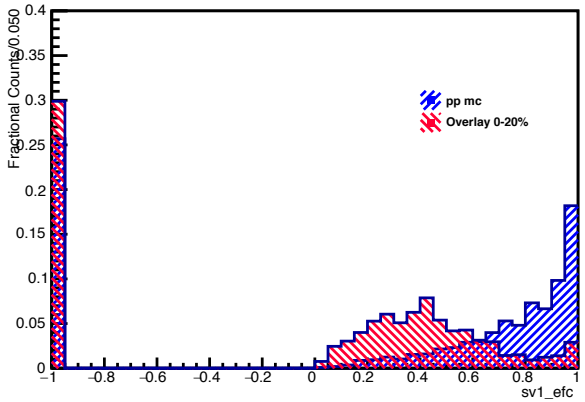

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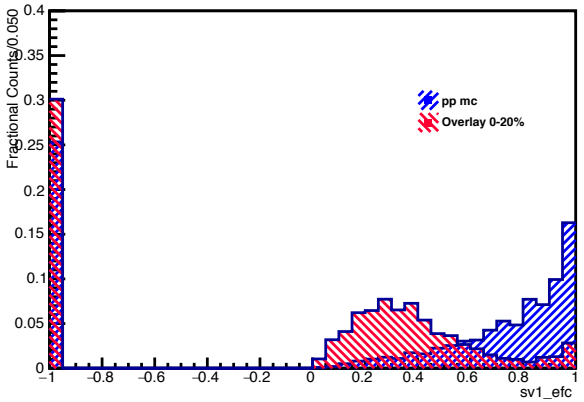

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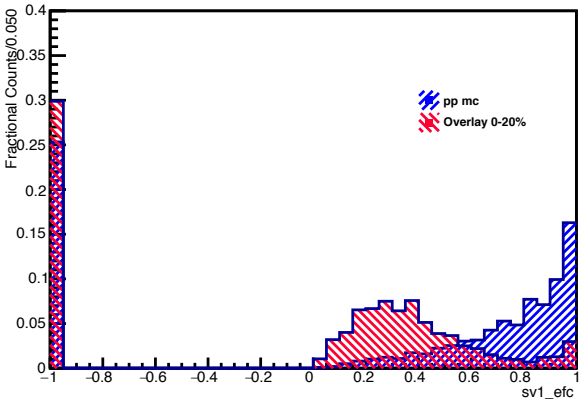

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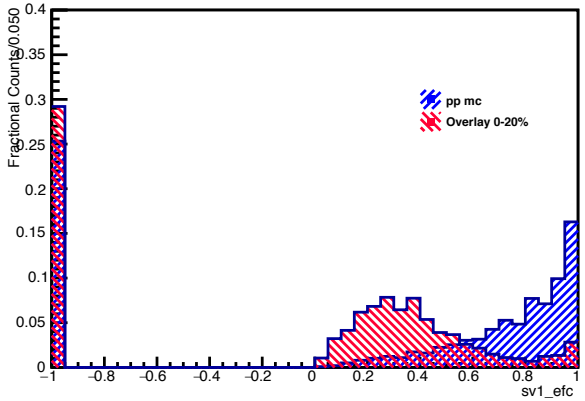

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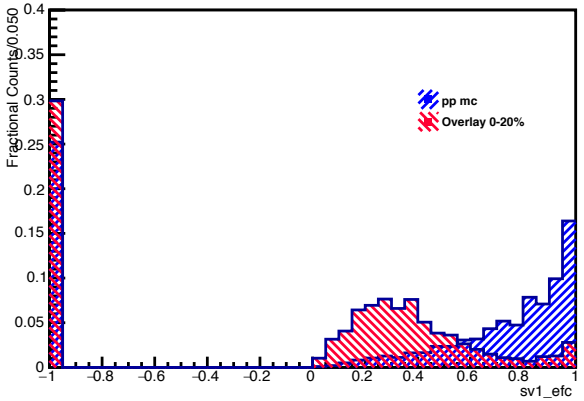

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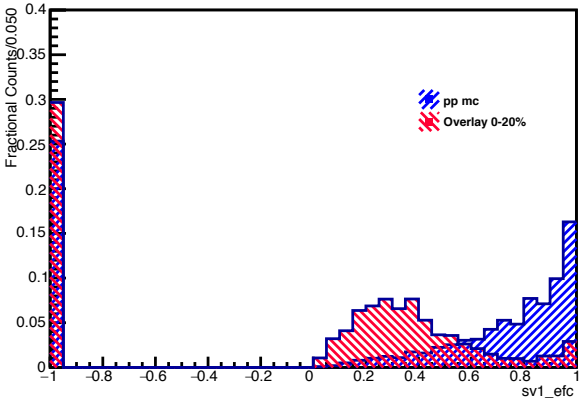

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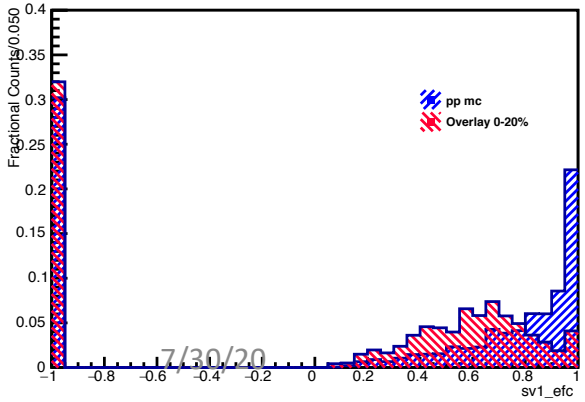

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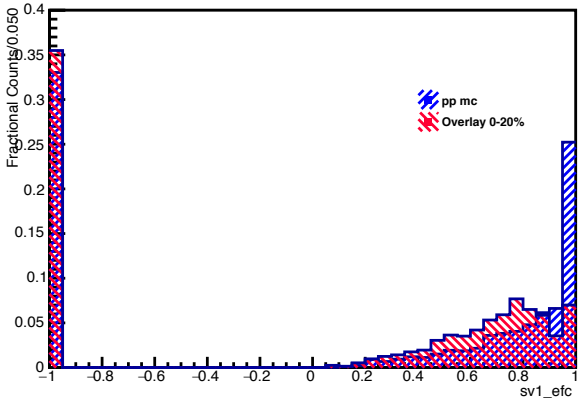

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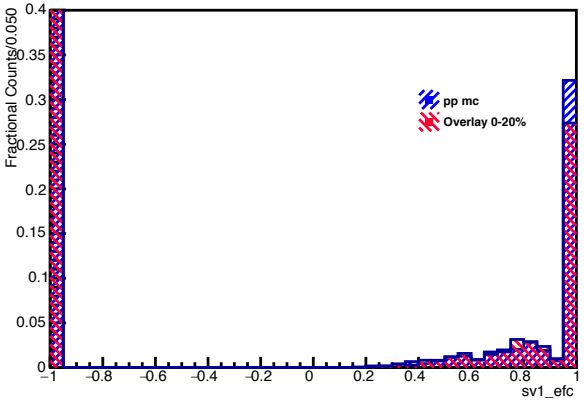

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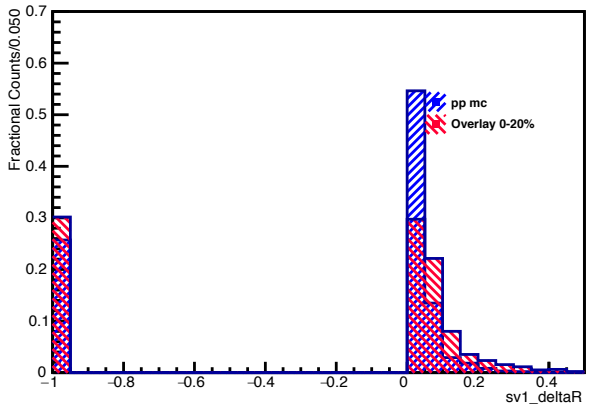

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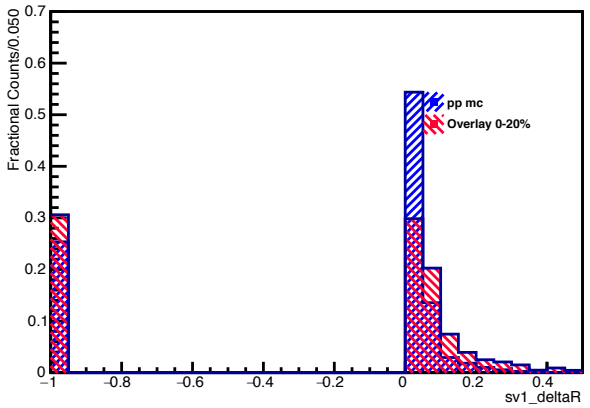

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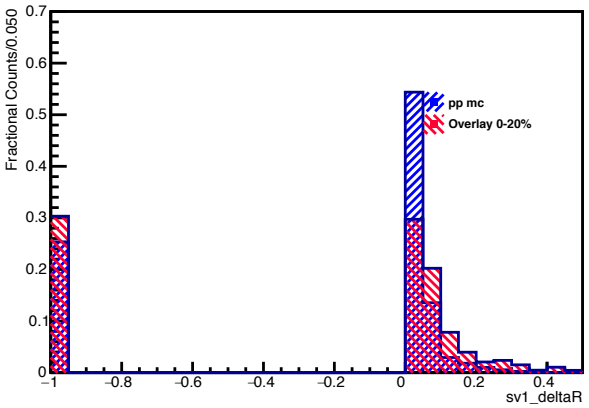

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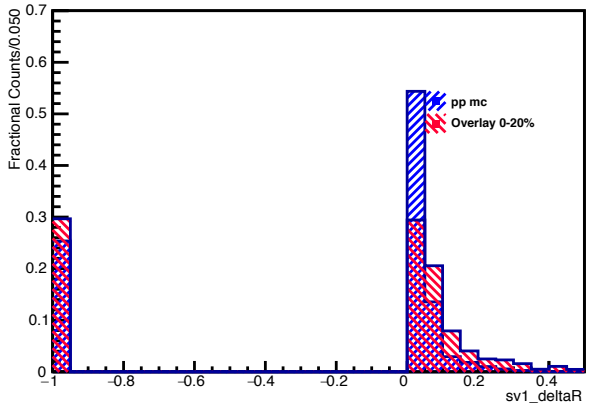

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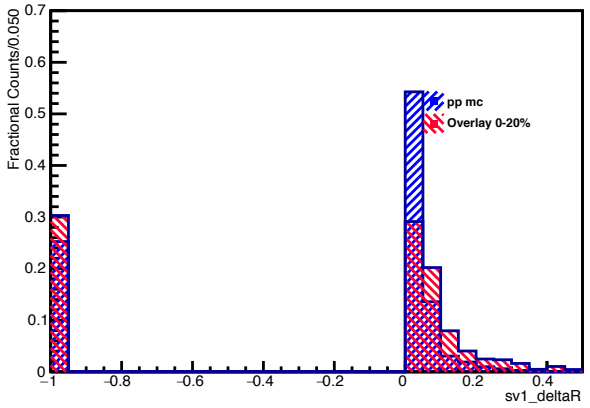

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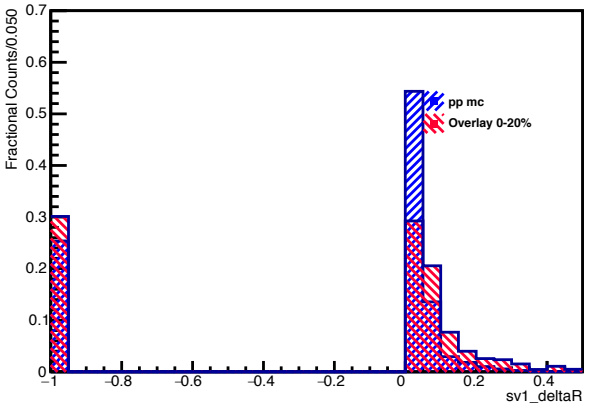

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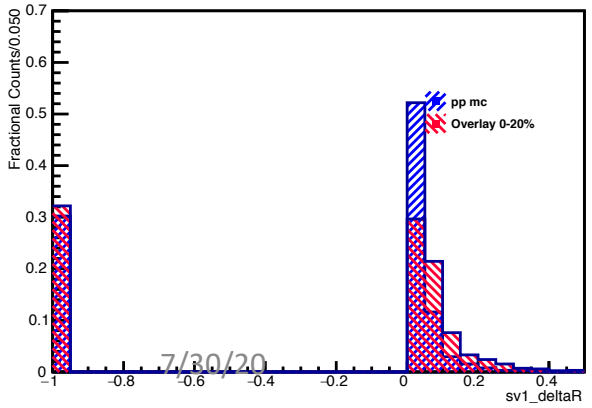

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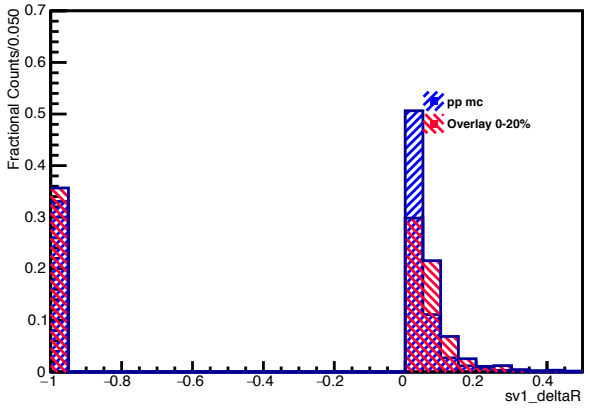

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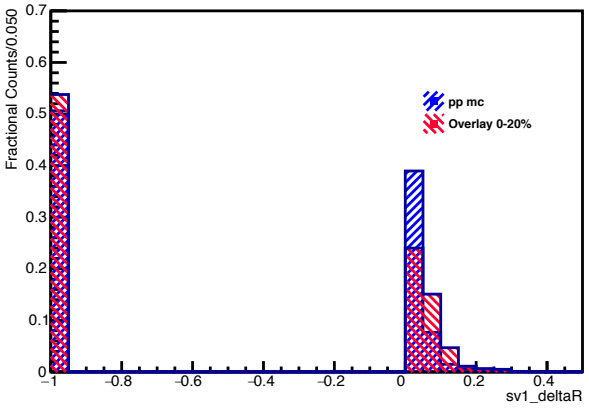
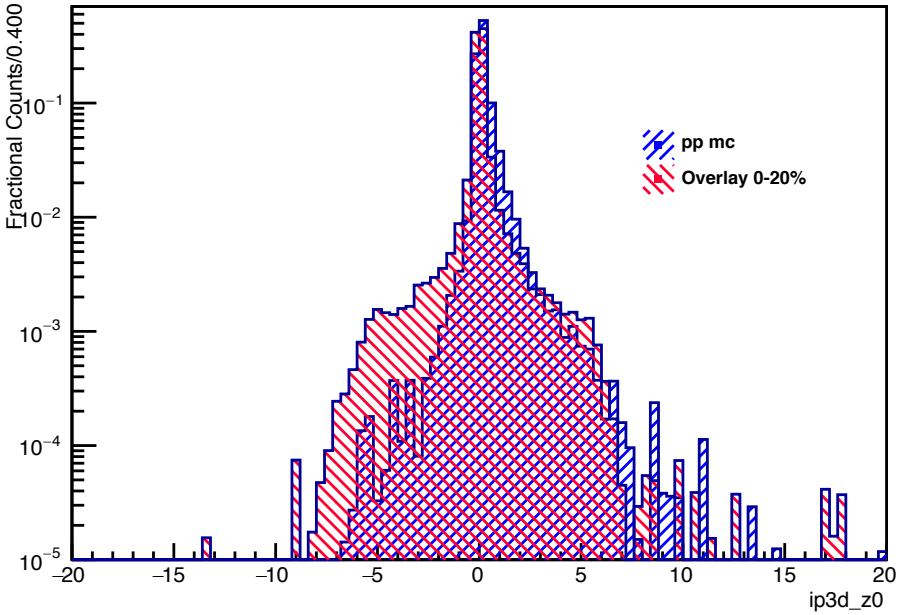


IPxD

Default Cuts Shrinking Cone



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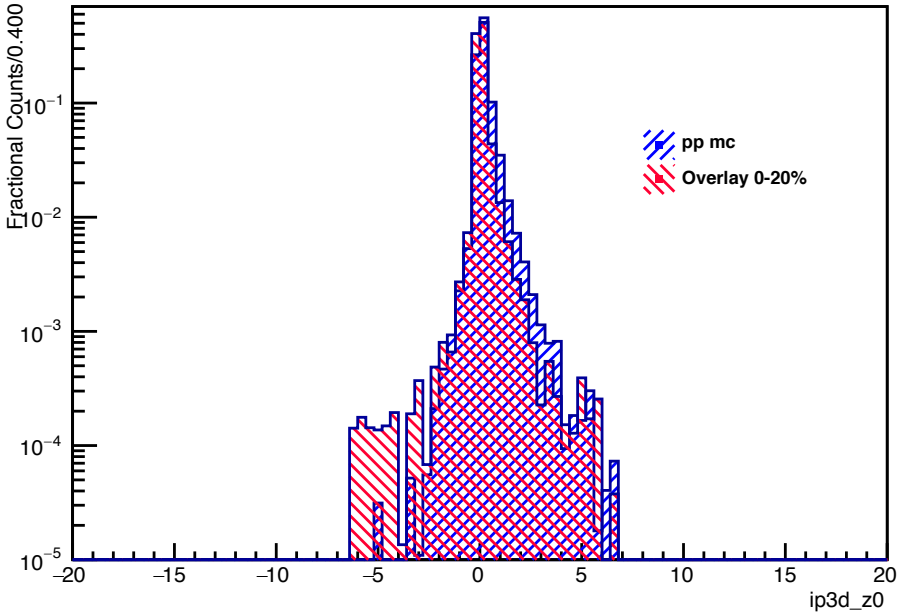

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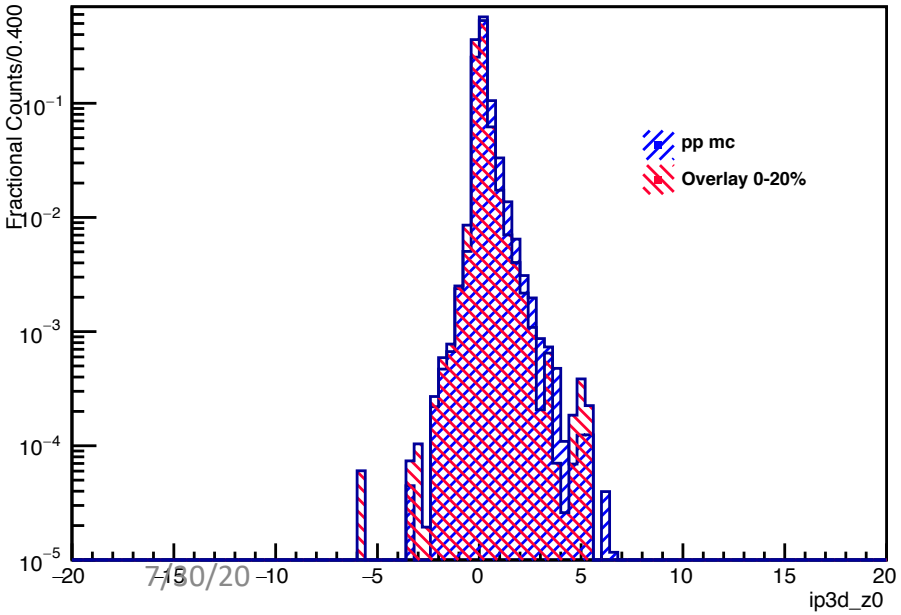

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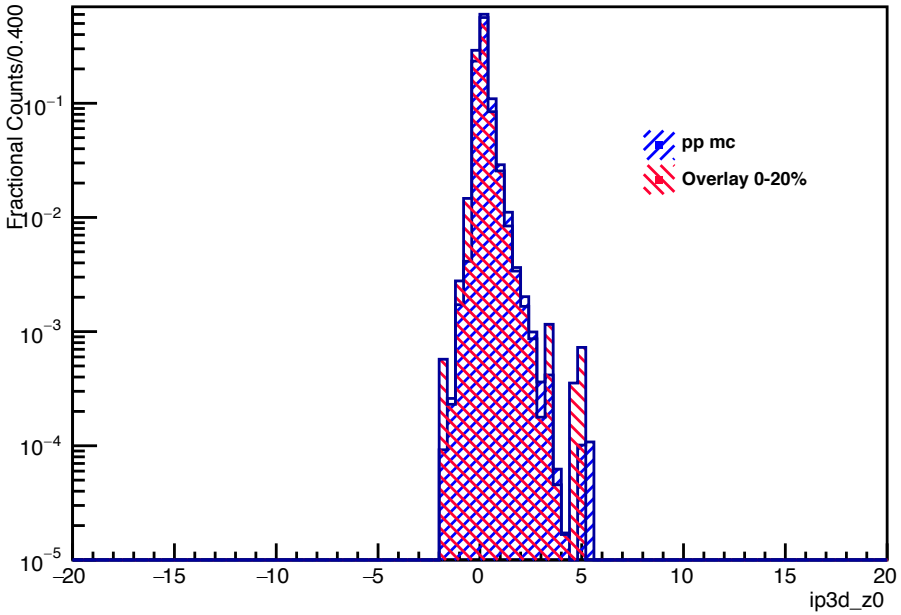

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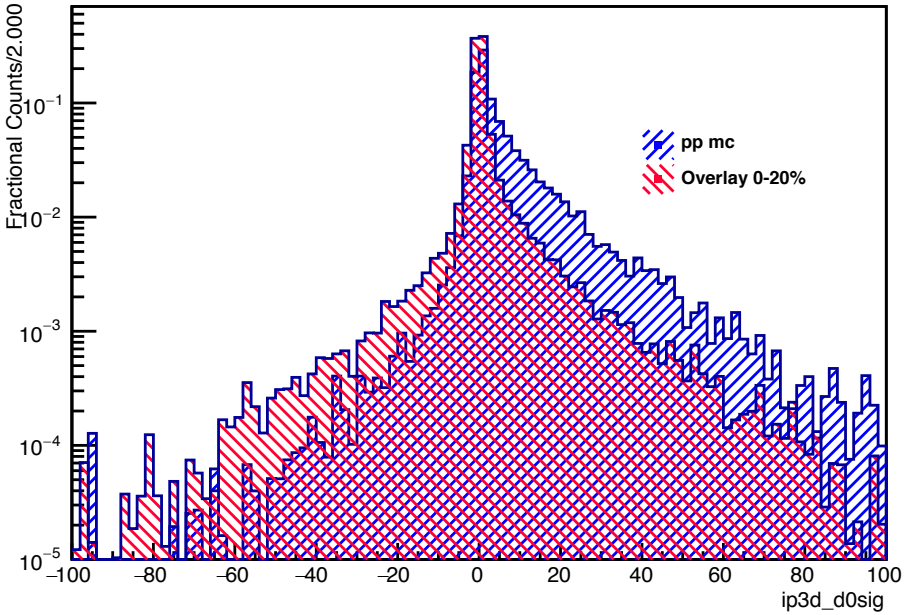

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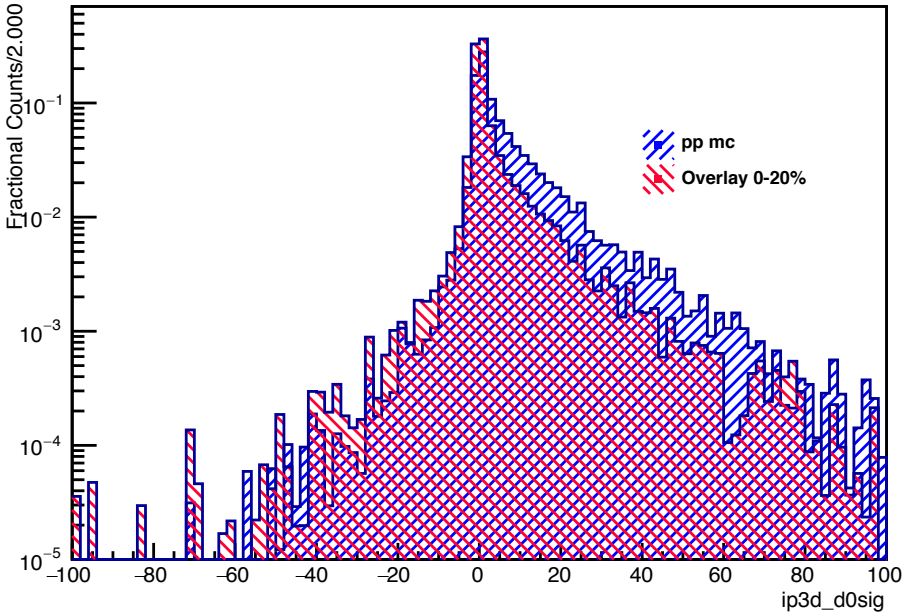

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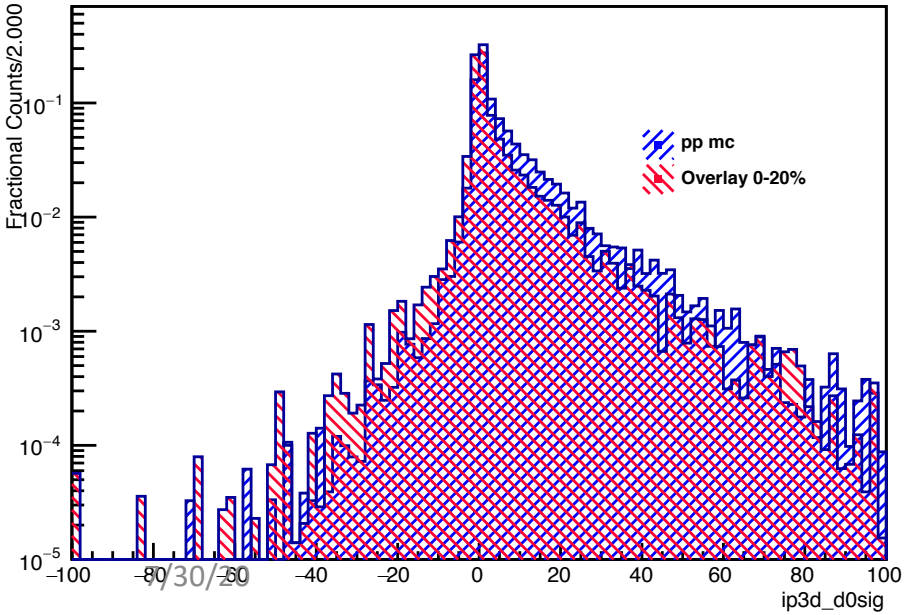

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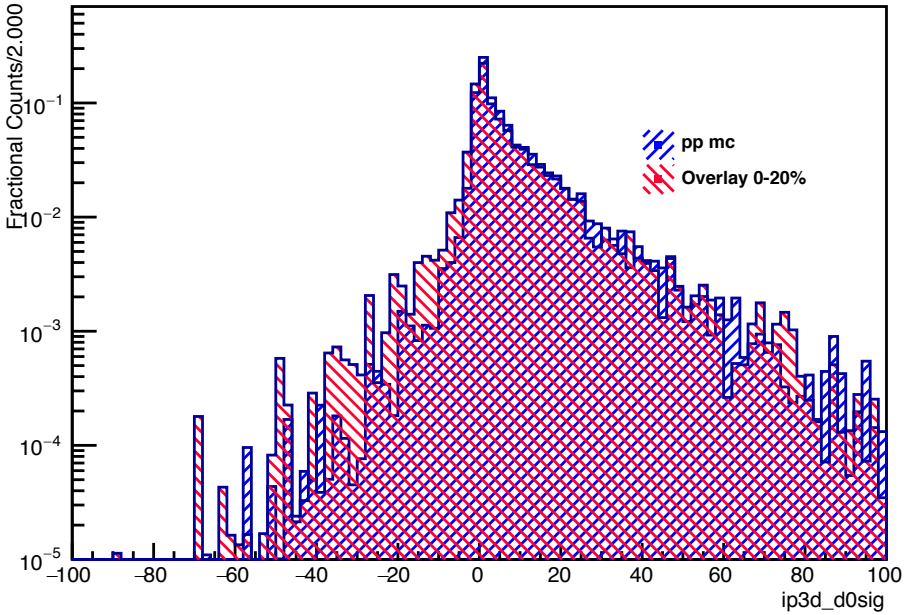

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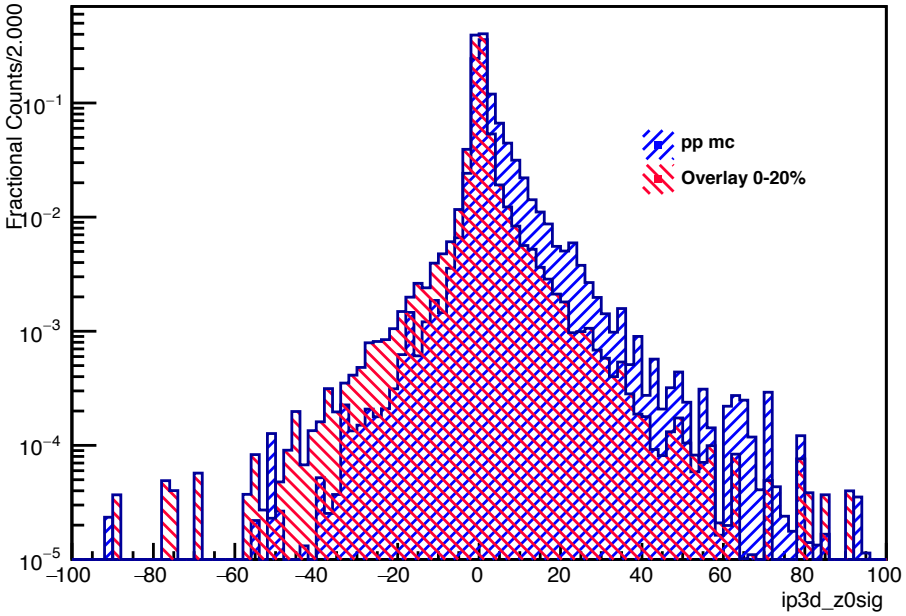

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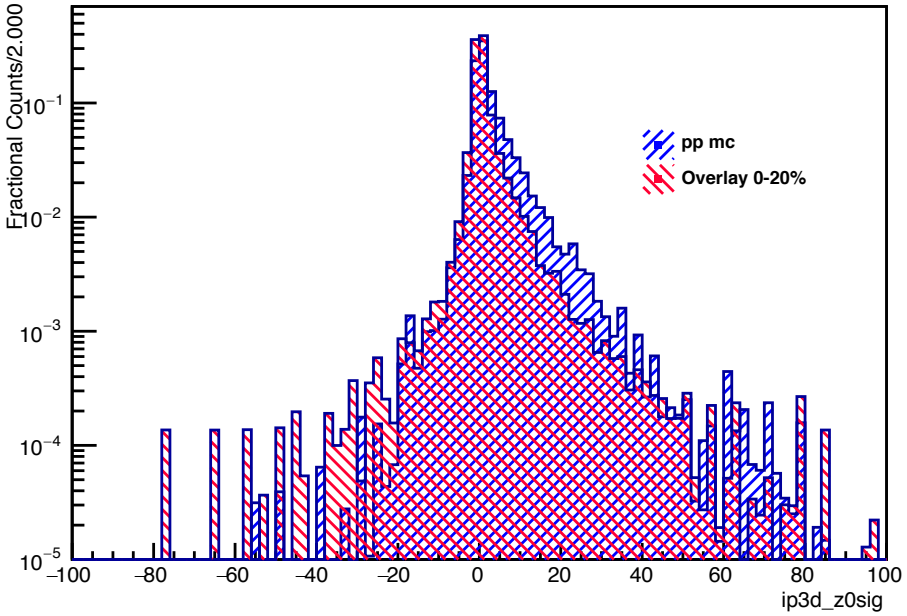

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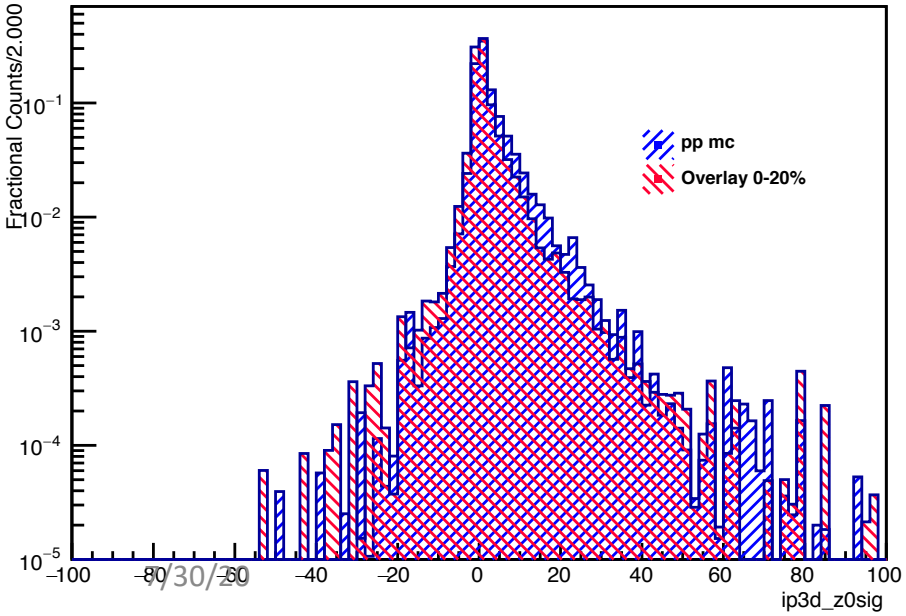

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