

A Problem With Isobar Lambda and Hypernuclei Embeddings

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My previous study on multiplicity dependence of H3L yield in isobar collisions:

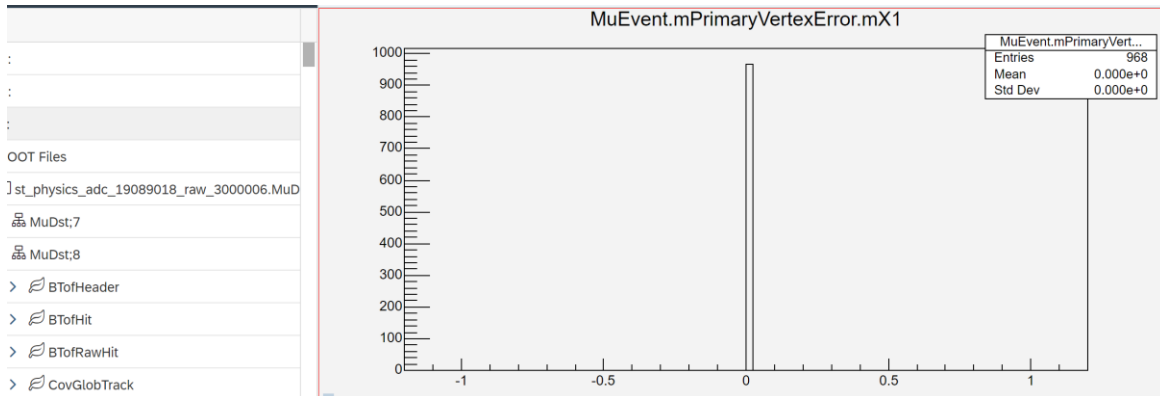
https://drupal.star.bnl.gov/STAR/system/files/STAR_Collaboration_meeting_Dongsheng_Li_0.pdf

Outline

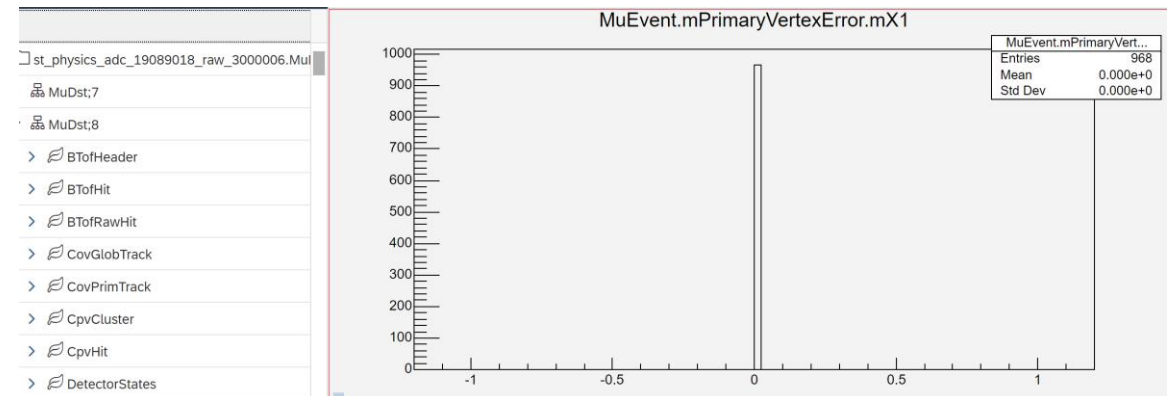
- Related Embedding and the Problem
- Consequences
 - Strange Behavior of Chi2topo with Lambda Embedding
 - Data-MC Inconsistency
 - Lambda
 - H3L
 - Impacts on Lambda and H3L Yields

Related Embedding and The Problem

- Related Embeddings:
 - (Anti-)H3L: <https://drupal.star.bnl.gov/STAR/starsimrequests/2021/sep/10/anti-h3l-isobar-2018>
 - (Anti-)Lambda and Xi: <https://drupal.star.bnl.gov/STAR/starsimrequests/2023/Mar/03/Lambda-anti-Lambda-Xi-anti-Xi-Run-18-200-GeV-isobar-collisions>
- The Problem with the MuDst Files when running the KFParticle Package:
 - Errors on primary vertex are necessary for the calculations of chi2topo/chi2primary/LdL in KFParticle Package (see definitions in backup)
 - We checked that **all entries for MuEvent.mPrimaryVertexError.mX1/mX2/mX3 are 0**
(see a proper case in backup)



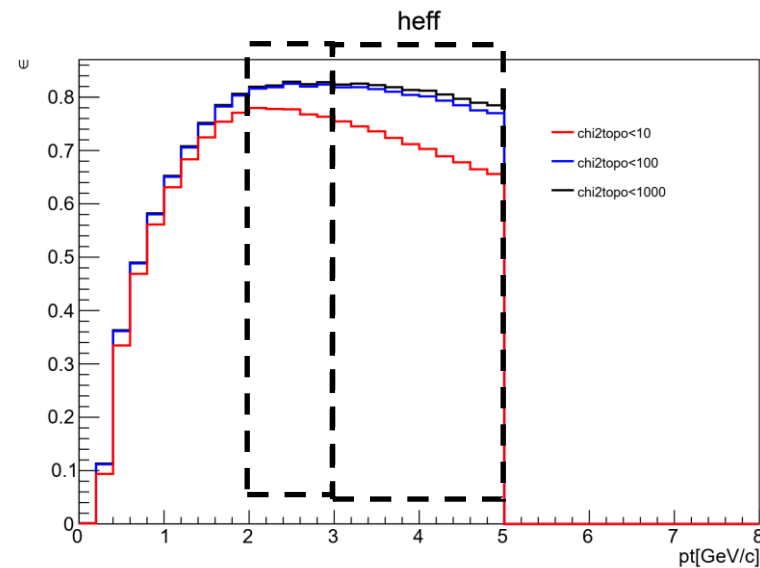
From H3L embedding file, drawn with TBrower
st_physics_adc_19089018_raw_3000006.MuDst.root



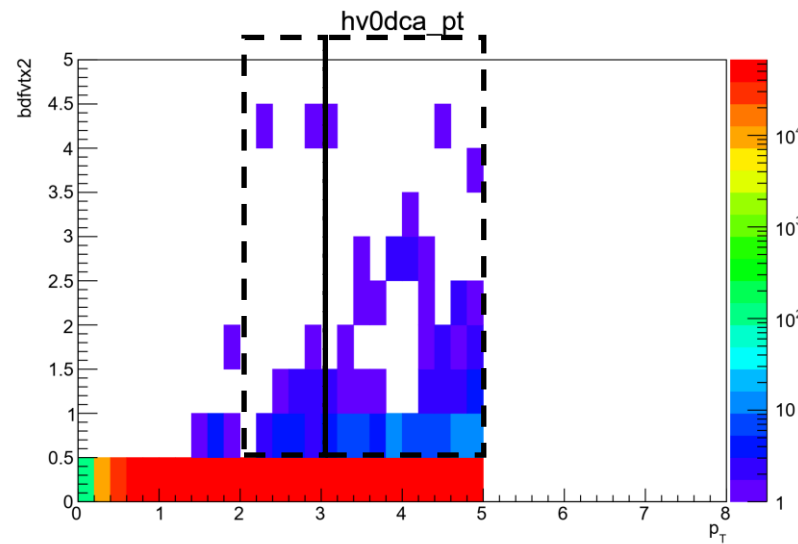
From Lambda embedding file, drawn with TBrower
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Consequences

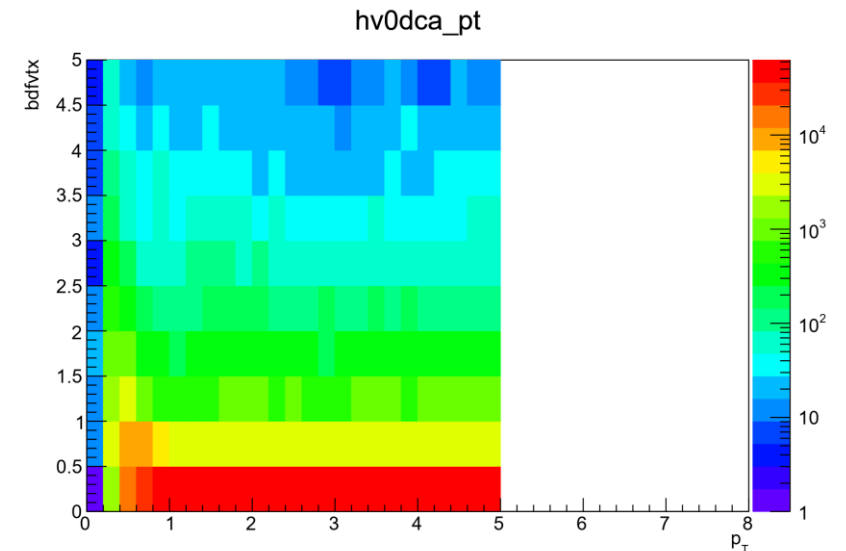
- Strange behaviors for χ^2_{topo} with Lambda embedding
 - In KFParticle, $\chi^2_{\text{topo}} = V0dca / \text{Error}$.
 - The V0dca and its error are calculated with assumption that the V0 comes from the primary vertex
 - **With zero primary vertex errors as inputs, it is likely to give wrong predictions on V0dca with small errors**
 - Calculations for $\chi^2_{\text{primary/LdL}}$ are similar
 - **A loose cut on $\chi^2_{\text{topo}} < 10$, will result in large efficiency loss at high p_T**



Efficiencies for different χ^2_{topo} cuts (here we have one pre-cut “ $\chi^2_{\text{ndf}} < 10$ ”, when producing the mini-tree)



V0dca when set primary vertex as the production point

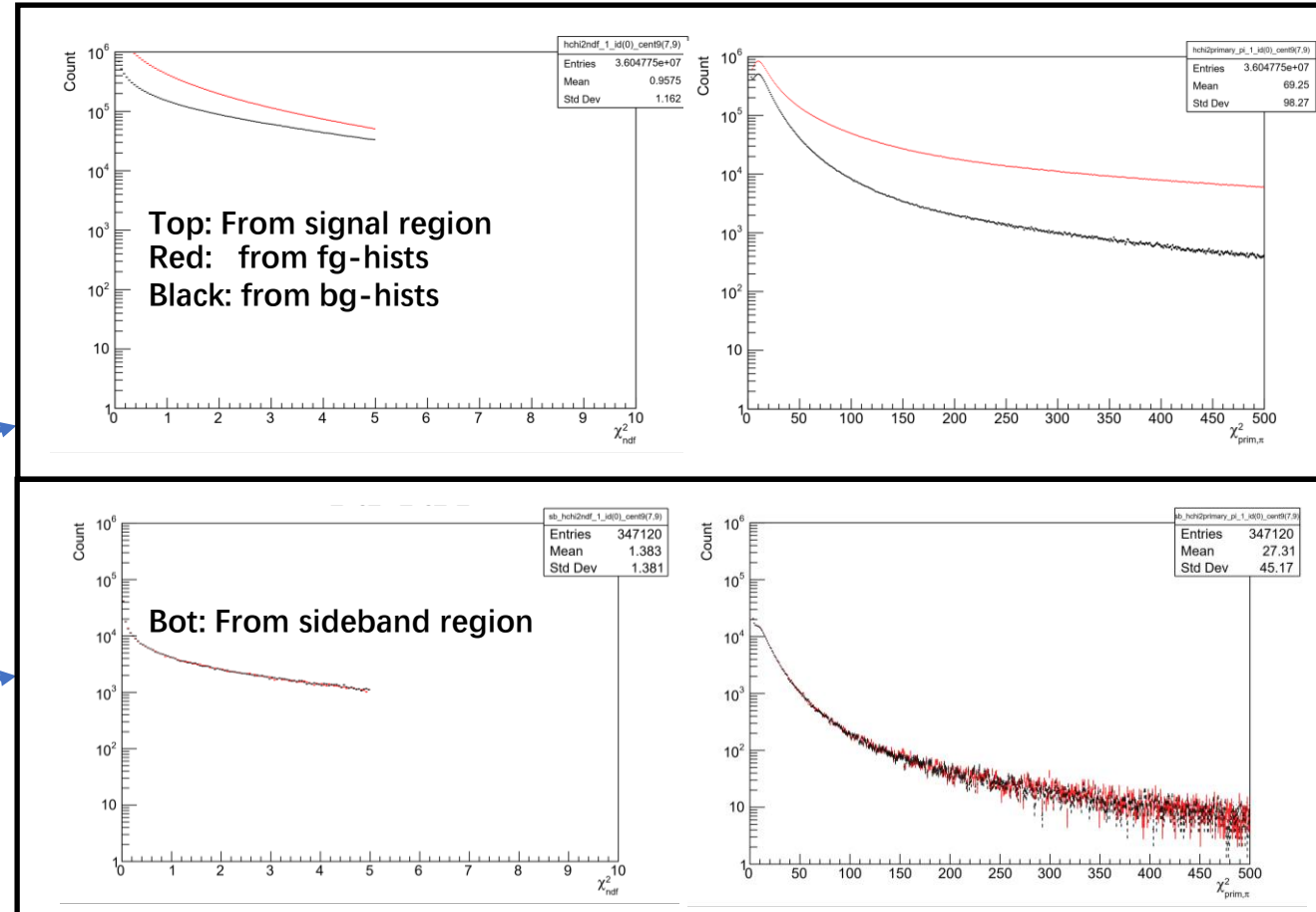
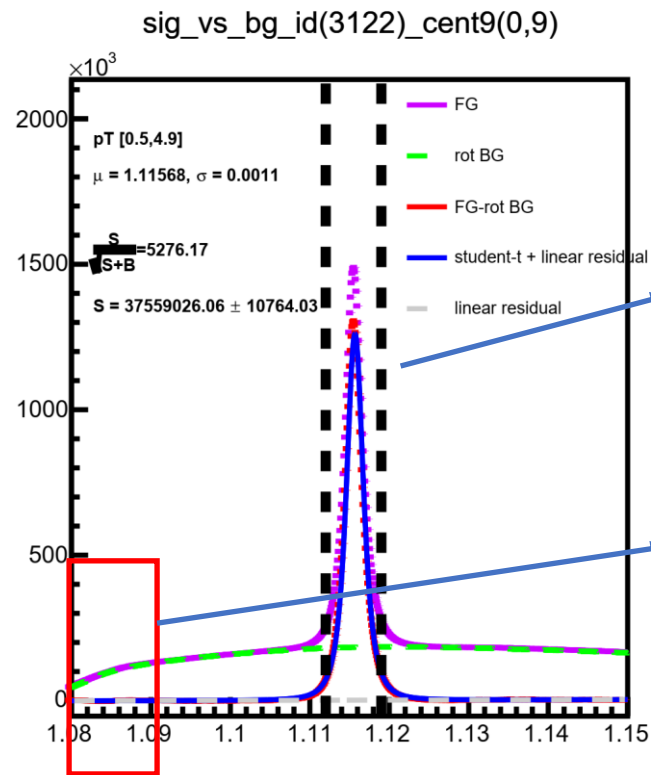


V0dca when we don't set primary vertex as the production point

Consequences

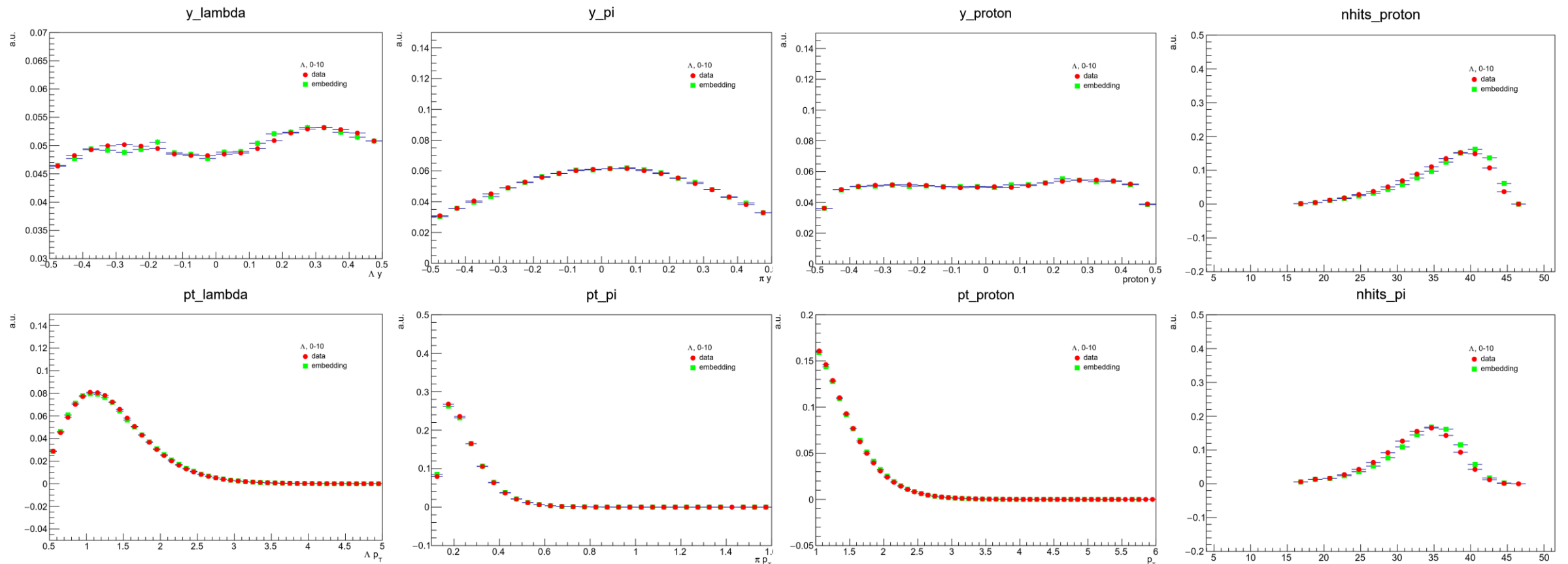
- Reconstruct Lambda and compare with MC using the same topological cuts
 - To get the distributions for the topological variables, we use fg-bg within the 3-sigma signal region
 - We also checked the sideband [1.08,1.09], and fg-bg gives zero here

Topo cuts
$\text{Chi2topo} \leq 5$
$\text{Chi2ndf} \leq 5$
$\text{Chi2primary_pi} \geq 5$
$\text{Ldl} \geq 2.5$
$\text{L} \geq 2.5$
$\text{Lifetime} \geq 0$



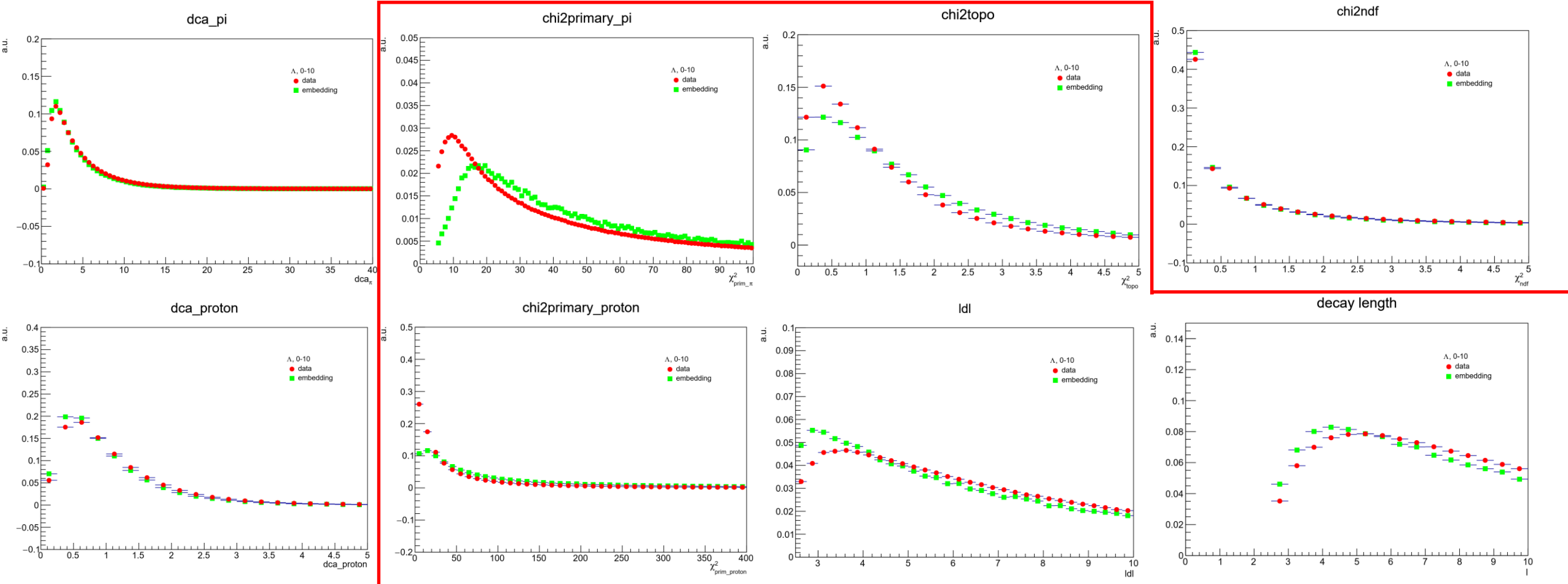
Consequences

- Reconstruct Lambda and compare with MC using the same topological cuts
 - pT&y weighted MC
 - most kinematics are matched, **except for chi2topo/chi2primary/decay length**



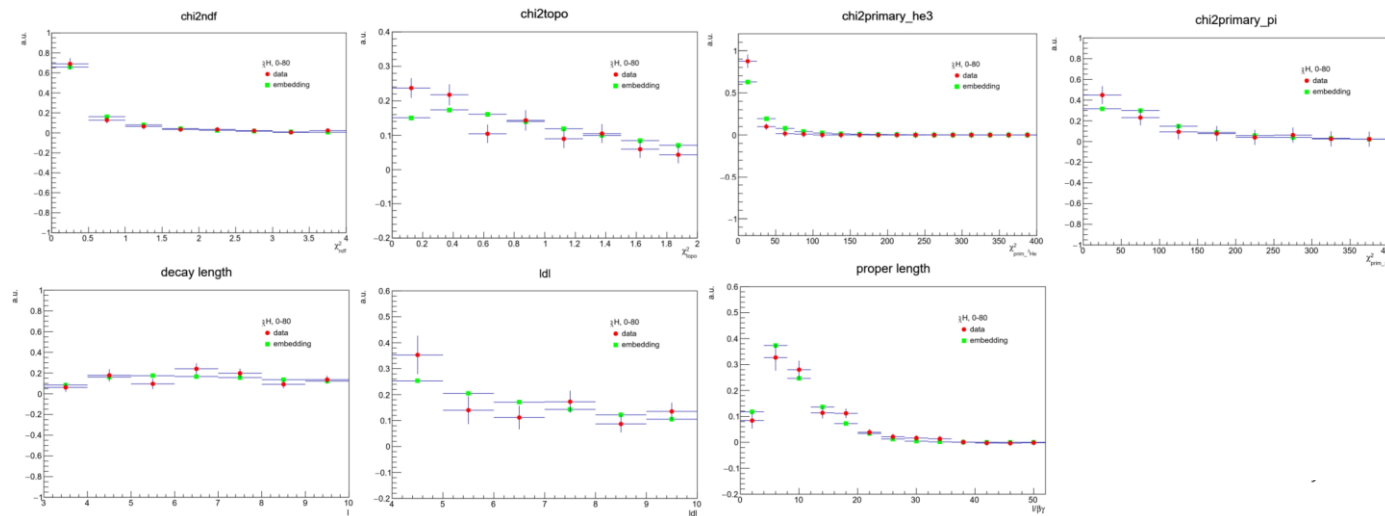
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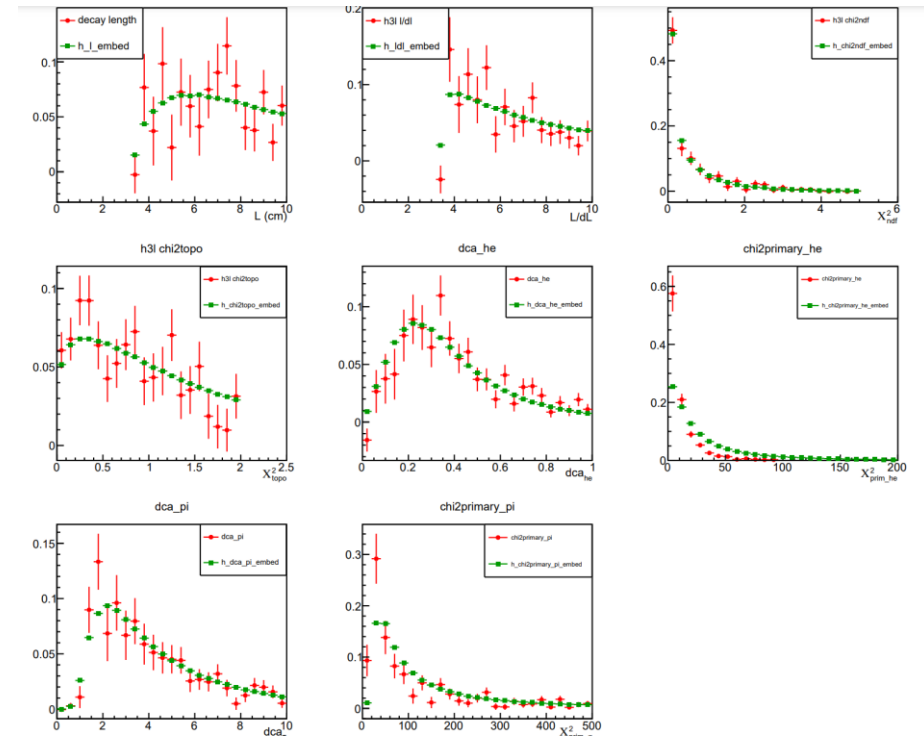
Consequences

- For H3L, similar procedures are done (Junlin also reconstructed H3L in Anti-H4L analysis)
- There are discrepancies for **chi2primary** and **chi2topo** between data and MC
- However, due to limited statistics, we both ignored the discrepancy



My Analysis:

https://drupal.star.bnl.gov/STAR/system/files/STAR_Collaboration_meeting_Dongsheng_Li_0.pdf

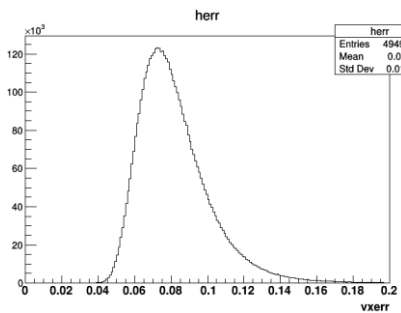


Junlin's analysis:

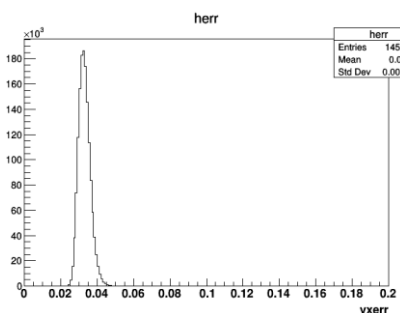
https://drupal.star.bnl.gov/STAR/system/files/Analysis_note_for_anti_HyperH4_ver7.pdf

Impacts on Lambda and H3L Yields

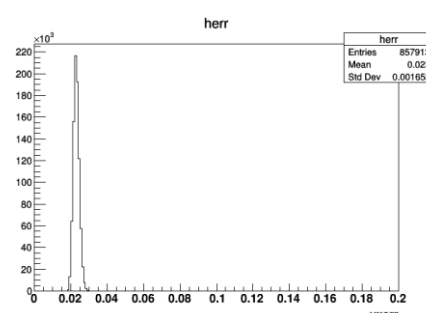
- The impacts of using incomplete embeddings are estimated, by manually inserting vertex errors when running the KFParticle Package
- How to manually insert vertex errors
 - Get 2D-hists for vtxerr_x/y/z v.s. refmult from real data
 - When reading embeddings with KFParticle,
 - For each event, we project the 2D-hist to a vtxerr hist within the corresponding refmult bin
 - We sample from the vtxerr hists by `TH1::GetRandom()`, and set errors



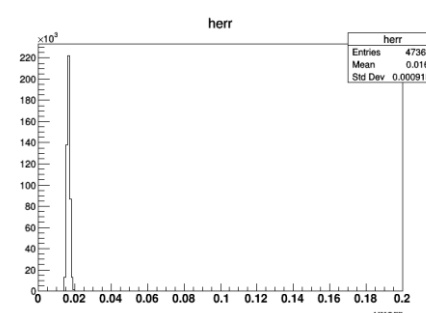
refmult=10,



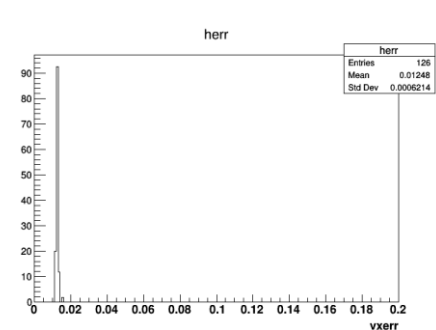
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100,



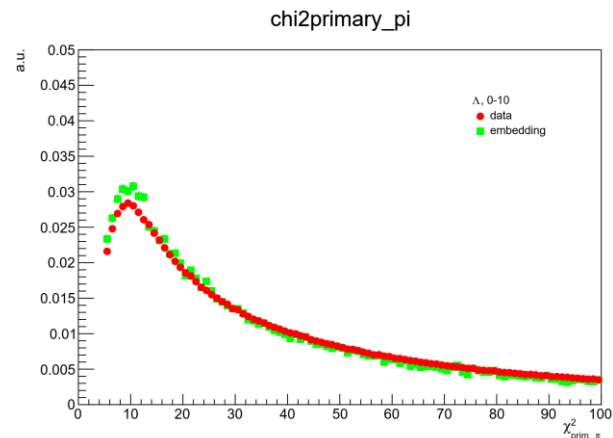
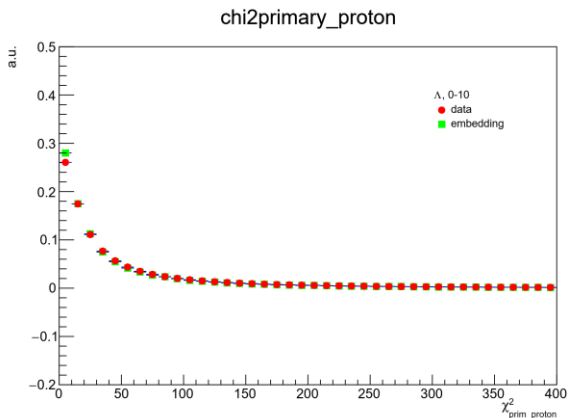
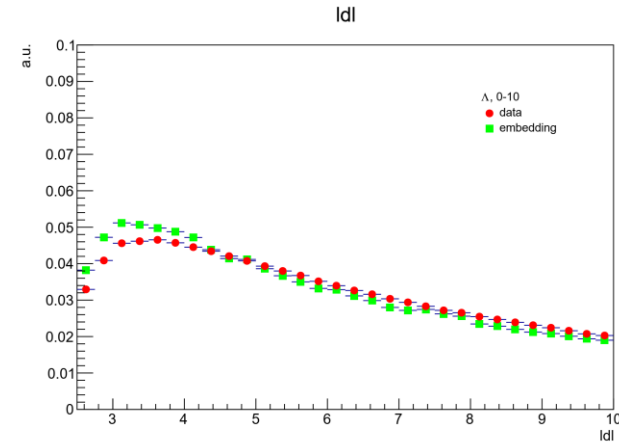
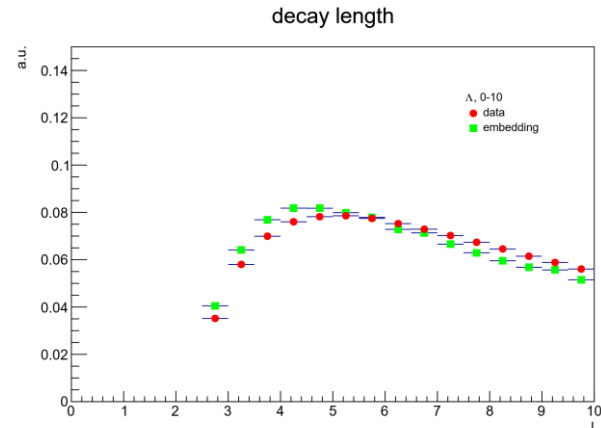
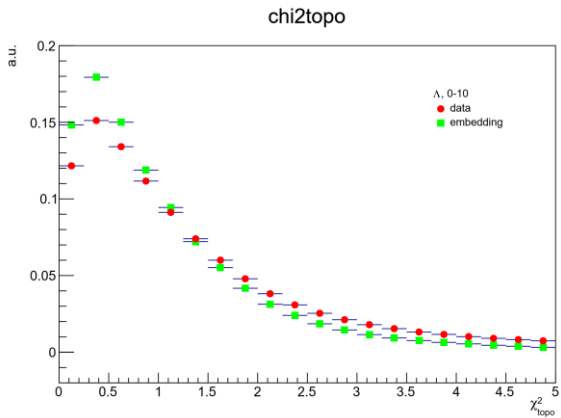
200,



400

Impacts on Lambda and H3L Yields

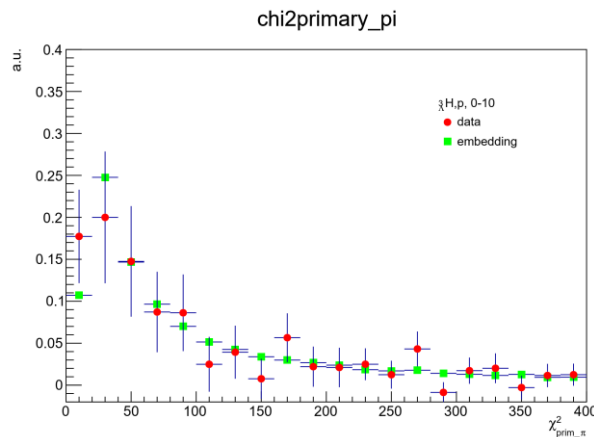
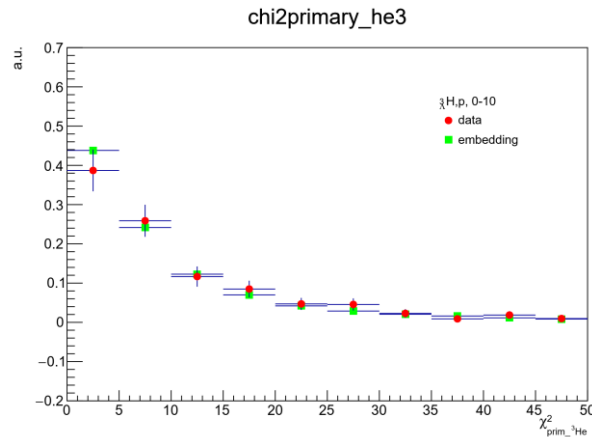
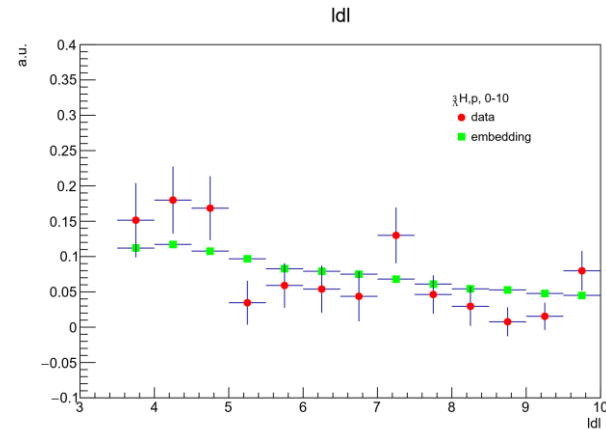
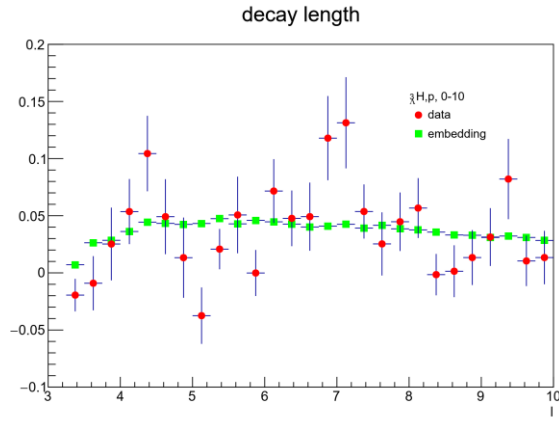
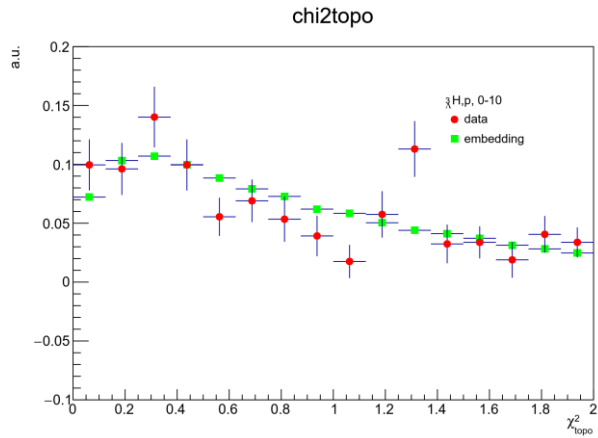
- Now we get more consistent kinematics for data and MC
 - Lambda



- Apparent improvements for chi2primary

Impacts on Lambda and H3L Yields

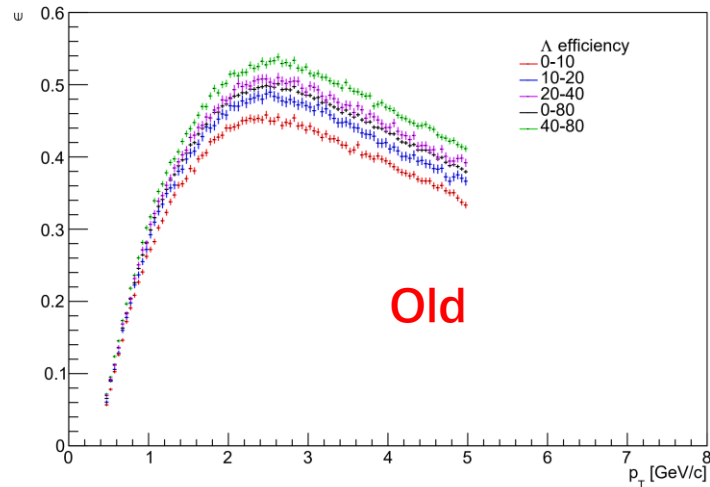
- Now we get more consistent kinematics for data and MC
 - H3L



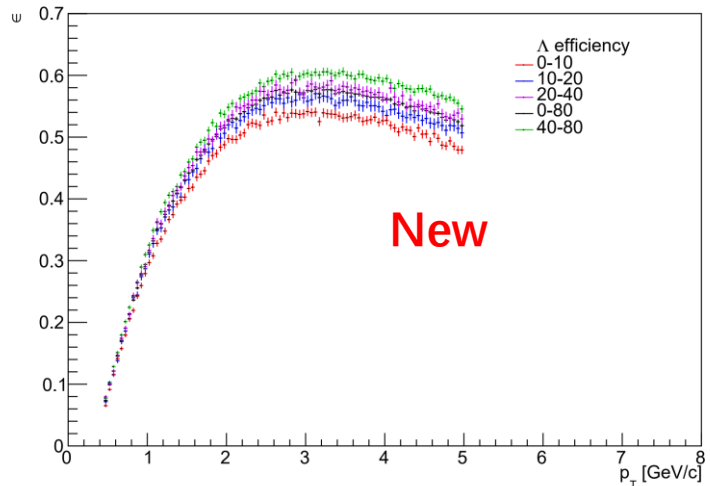
- Apparent improvements for chi2primary

Impacts on Lambda and H3L Yields

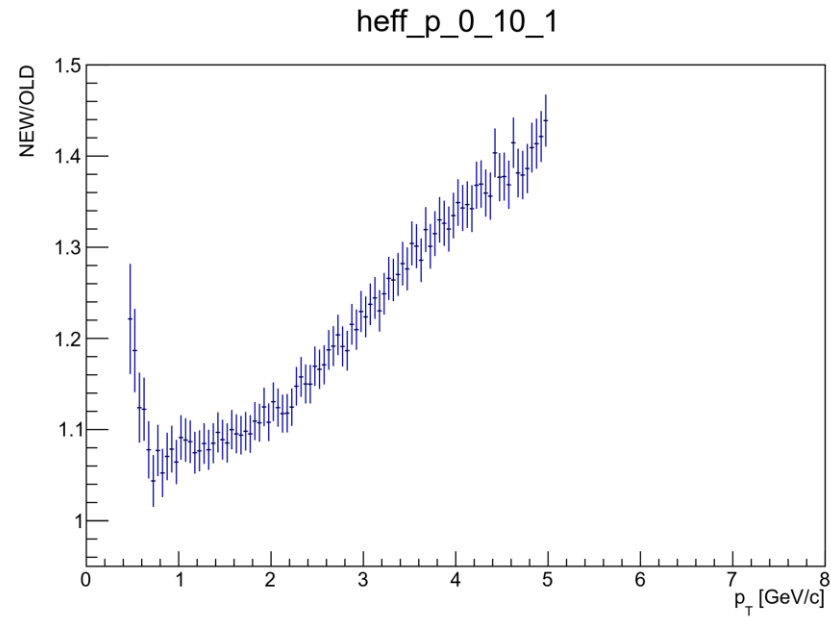
- Impacts on Lambda yield:
 - The pT spectra will vary by 5-40% within different pT bins



Old

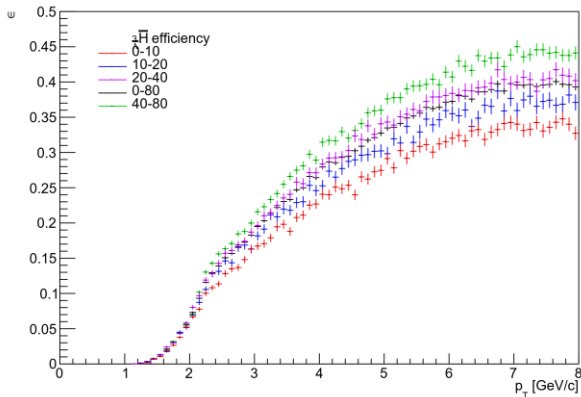
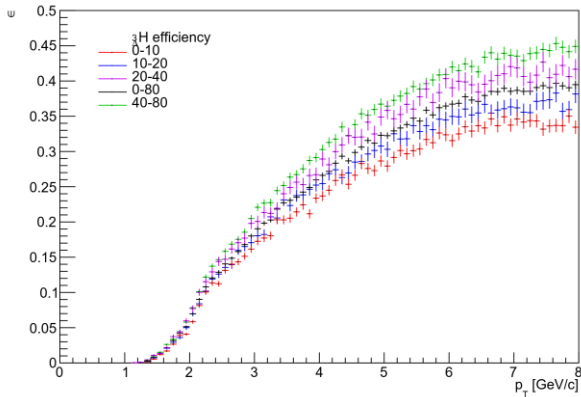


New

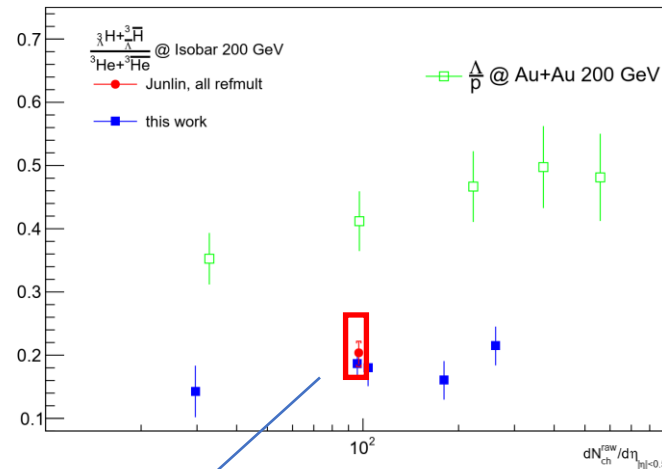


Impacts on Lambda and H3L Yields

- Impacts on H3L yield:
 - The pT integrated yield (pT [2.2,3.4]) will vary by 10% in 0-80% (I apply same topological cuts for H3L and Anti-H3L, those cuts are same as Junlin's cuts on H3L) (My previous 0-80% result was very close to Junlin's all refmult result)



He3 from Yun Huang CCNU



My previous result in 0-80%: 0.21
 Now I get ~10% lower result: 0.186

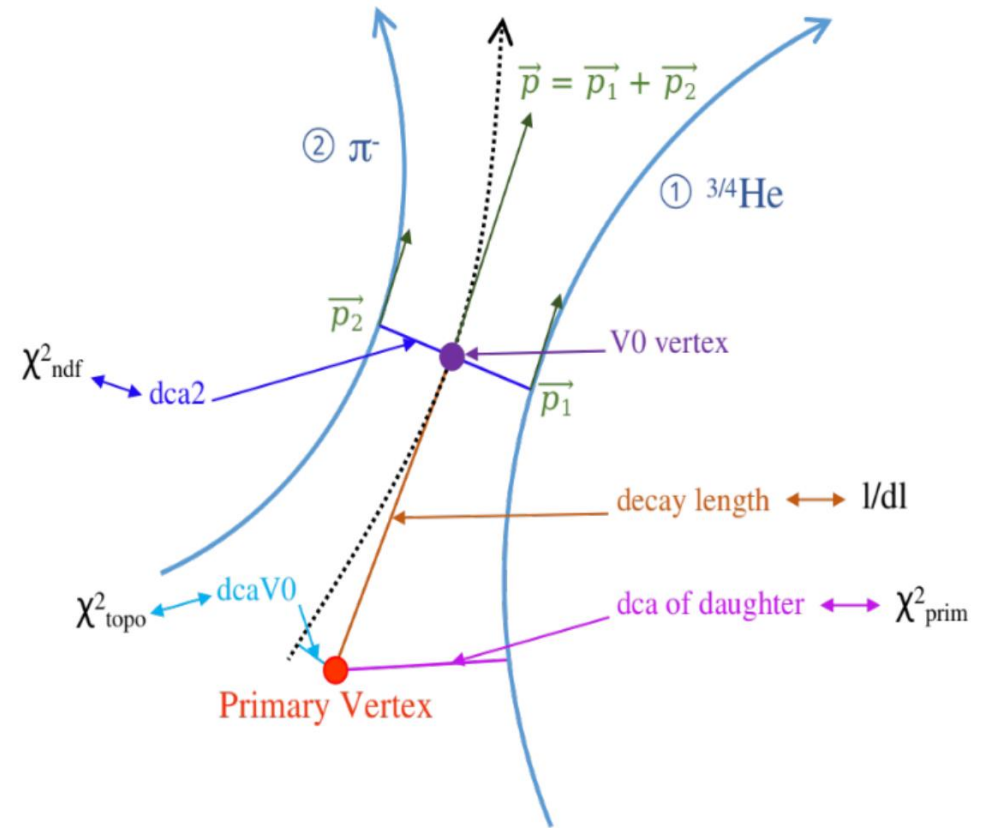
Topo cuts
Chi2topo < 2
Chi2ndf < 5
Chi2primary_pi > 10
LdL > 3.5
L > 3.4
He3 dca < 1
He3 p > 2

Summary

- In Isobar H3L and Lambda embeddings, vertex errors are not recorded
 - Several quantities in KFParticle are skewed
 - Strange behavior of Lambda χ^2_{topo}
 - Inconsistency between data and MC kinematics
- Manually inserting vertex errors gives more reasonable MC kinematics
 - The impacts of using an incomplete embedding is estimated
 - For Lambda, the pT spectra show 5-40% difference varying with pT
 - For H3L, the pT-integrated yield in 0-80% varies $\sim 10\%$
- New embedding samples with vertex errors are needed

Backup

KF Particle variable	Related helix method variable	Description
$\chi_{prim^{3/4He}}^2$	DCA of Helium	DCA of Helium over its error
$\chi_{prim\pi}^2$	DCA of π^\pm	DCA of π^\pm over its error
χ_{ndf}^2	DCA 1 to 2	DCA between 2 daughter particle tracks over its error
χ_{topo}^2	DCA V0	DCA from mother particle to primary vertex over its error
l	-	decay length
ldl	-	decay length over its error



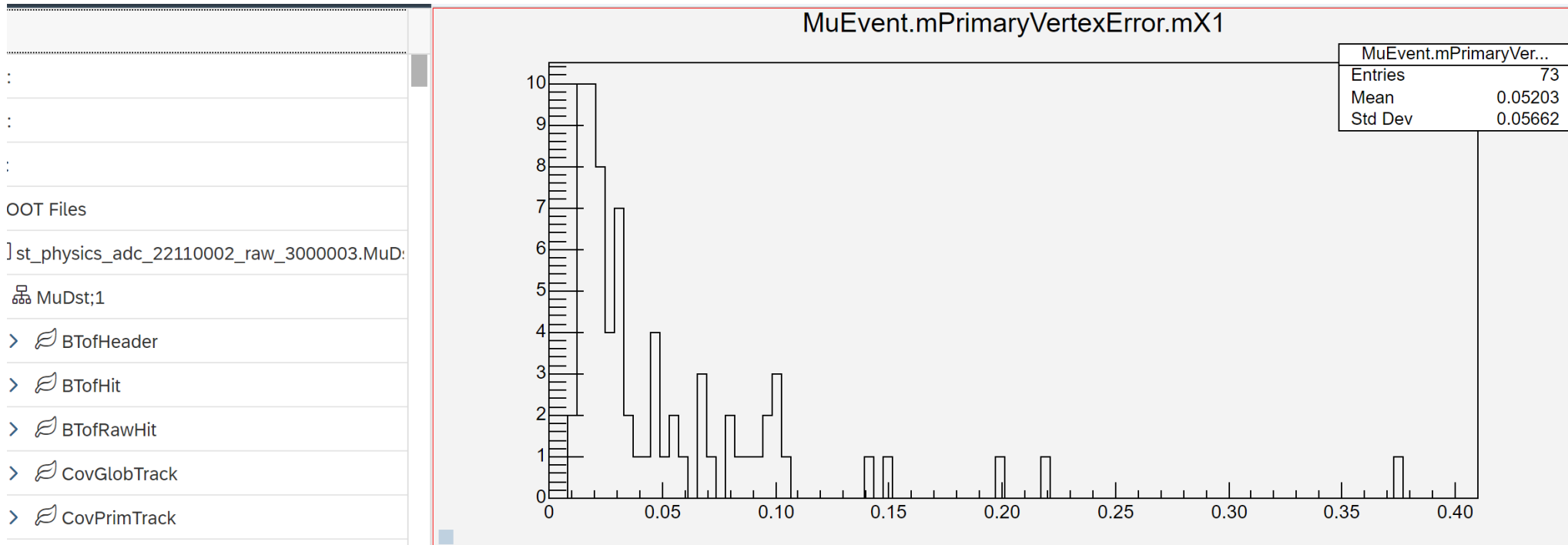
Backup

A proper case for MuEvent.mPrimaryVertexError.mX1:

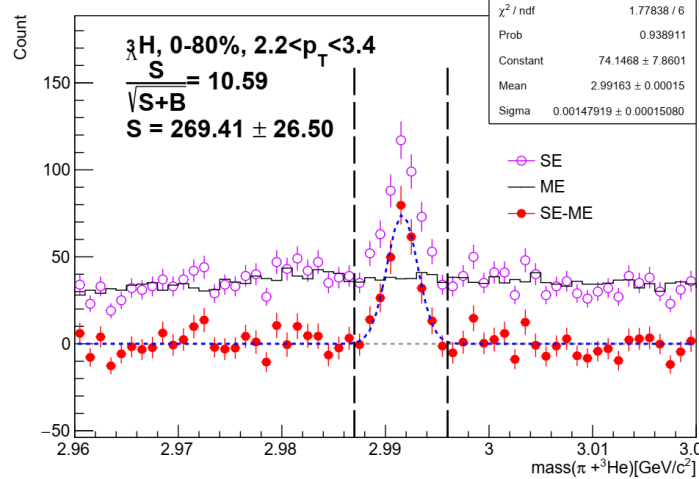
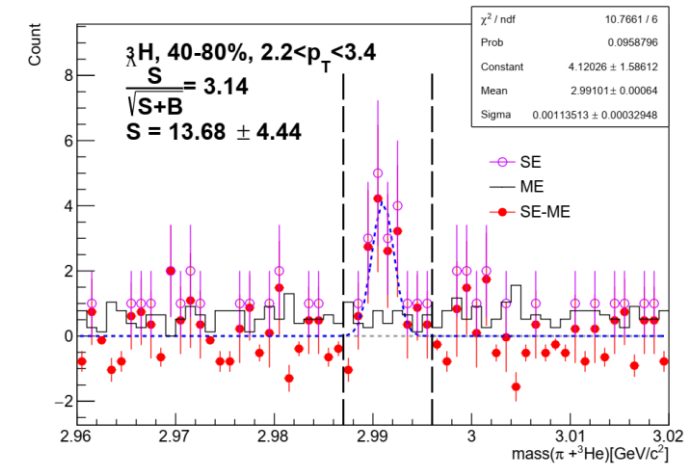
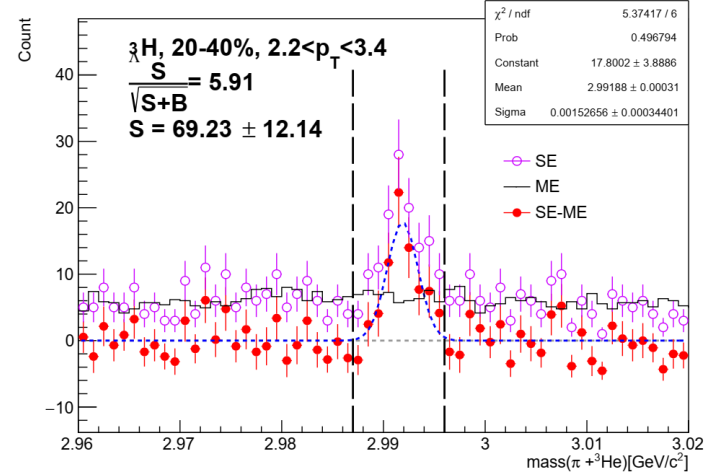
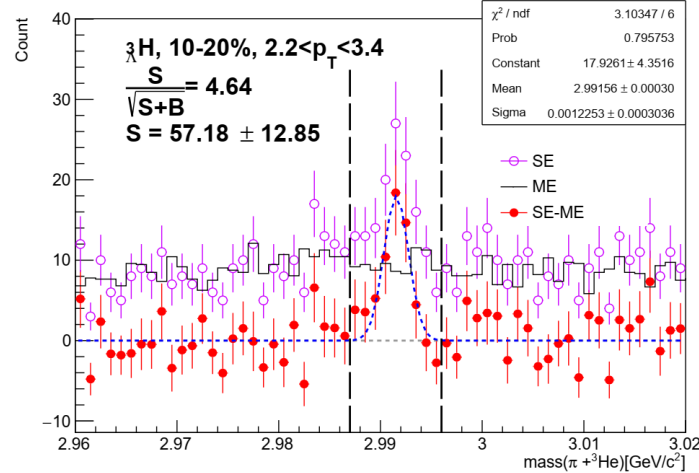
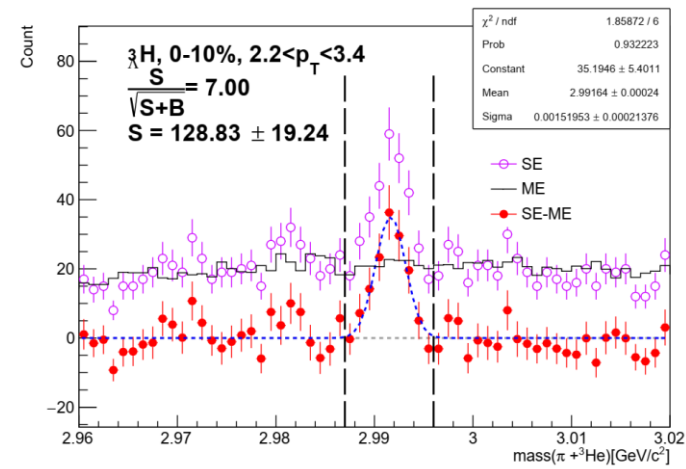
<https://drupal.star.bnl.gov/STAR/starsimrequests/2023/Jan/25/Hypernuclei-and-Lambda-Run-21-AuAu-77-GeV-COL>

From H3L embedding file, drawn with TBrowser

st_physics_adc_22110002_raw_3000003.MuDst.root (Entries are not 0)

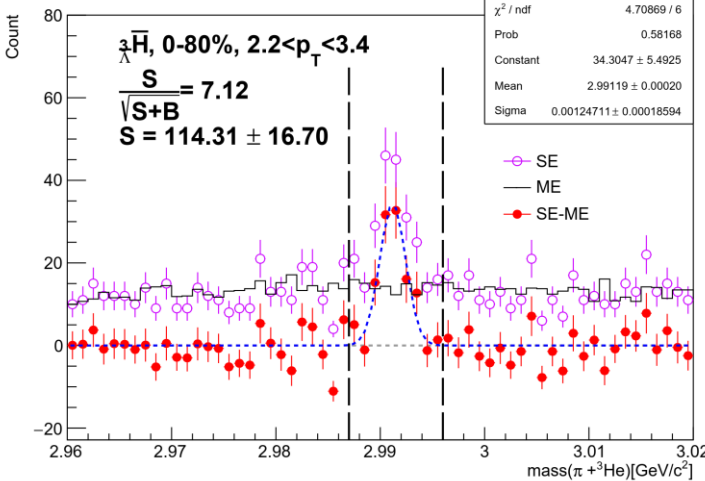
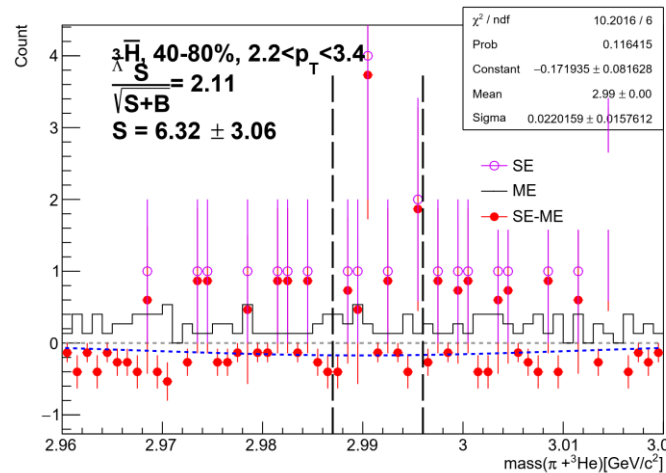
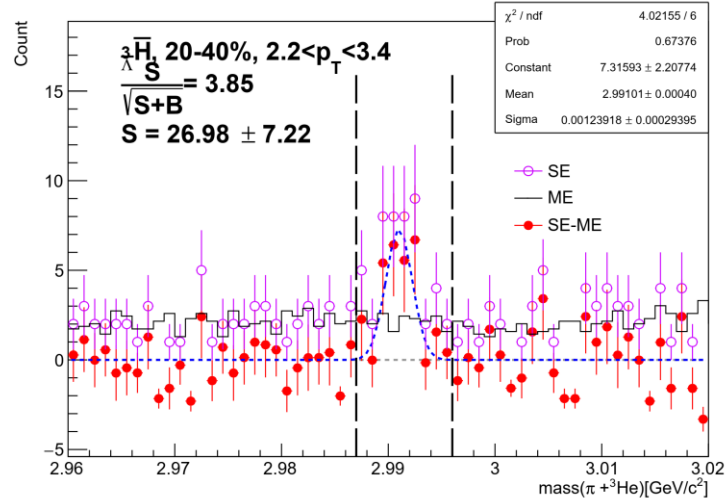
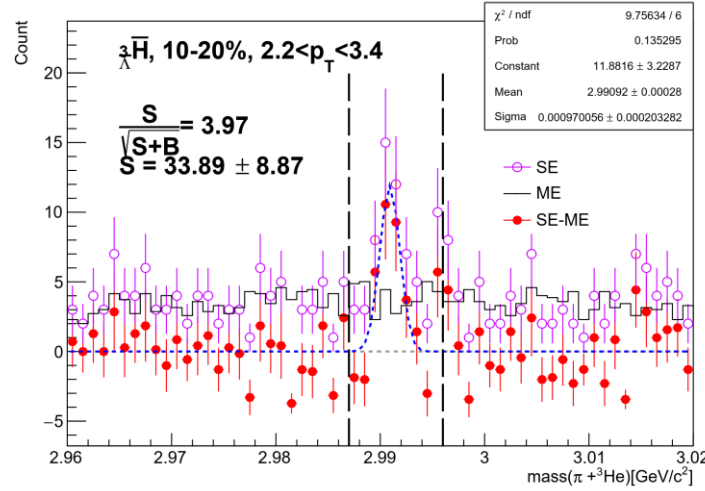
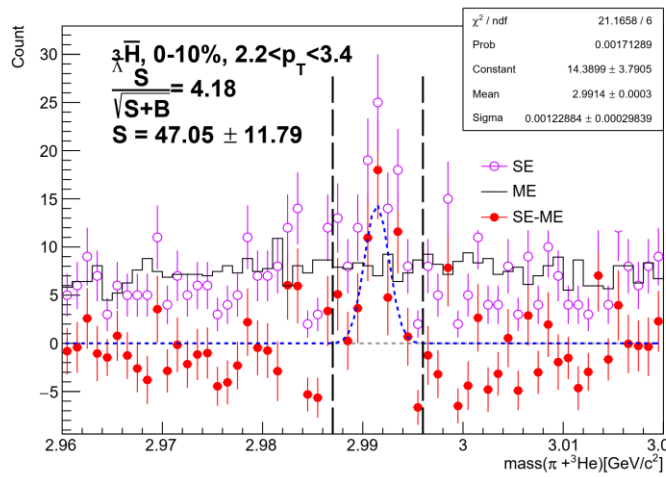


Backup



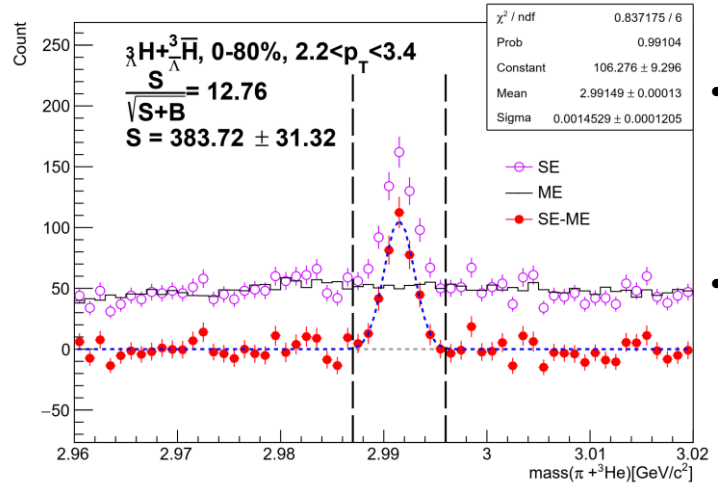
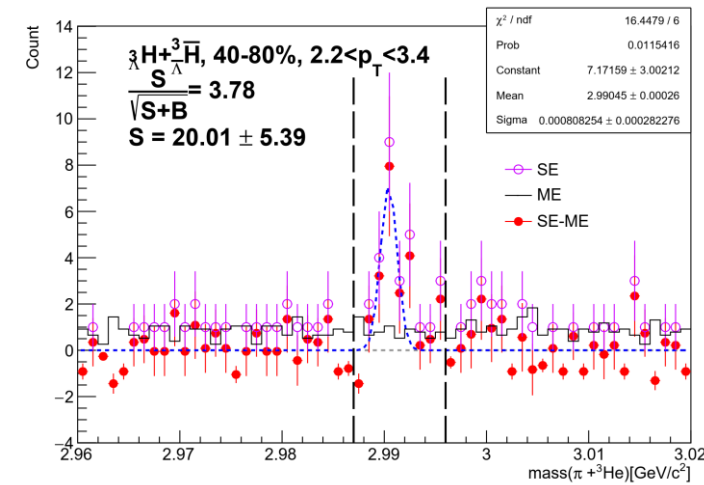
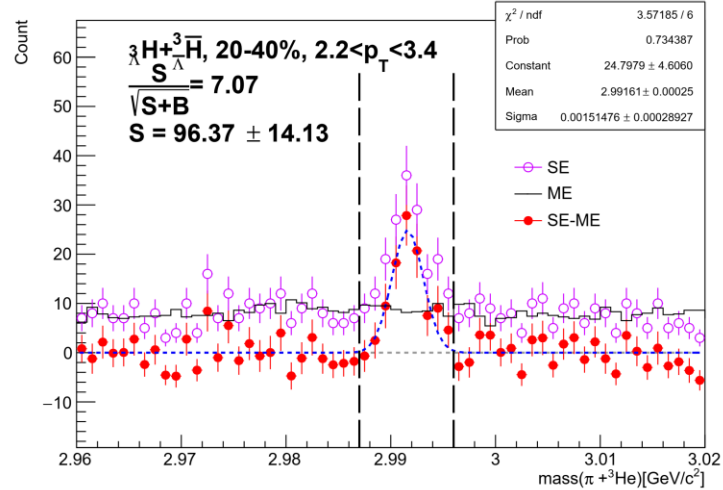
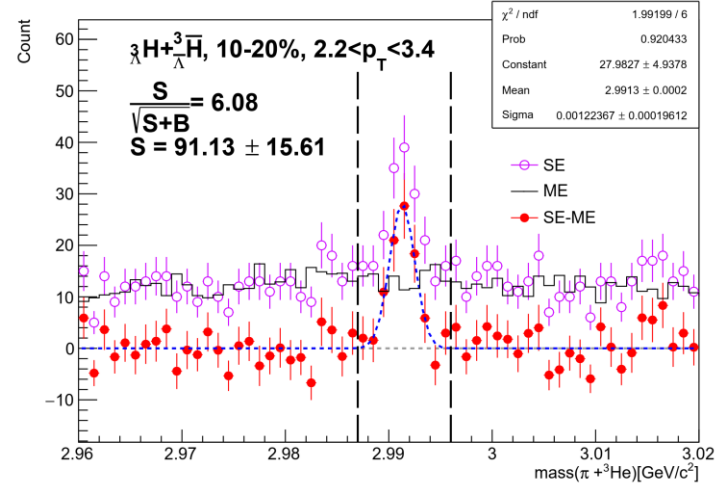
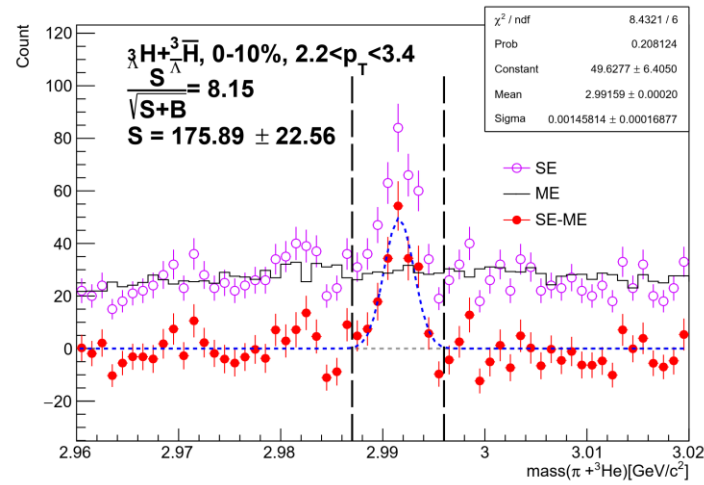
- ROI: $2.2 < p_T < 3.4$ (GeV/c)
 - later compare with analysis on He3 by Yun Huang (CCNU) and calculate a ratio
 - Mass window (3-sigma): 2.987~2.996 (GeV/c²)
- Significance in peripheral collisions (40-80%)
 - ~3-sigma for H3L

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