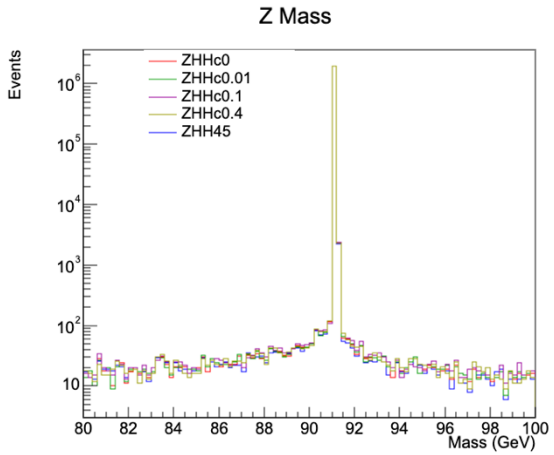
Di-Higgs All-Hadronic Channel Analysis

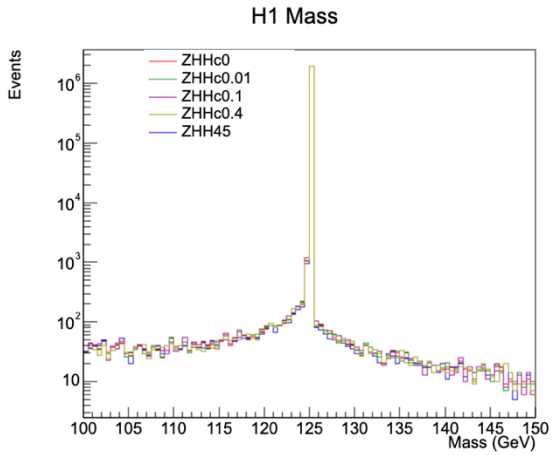
TAN MAN HONG

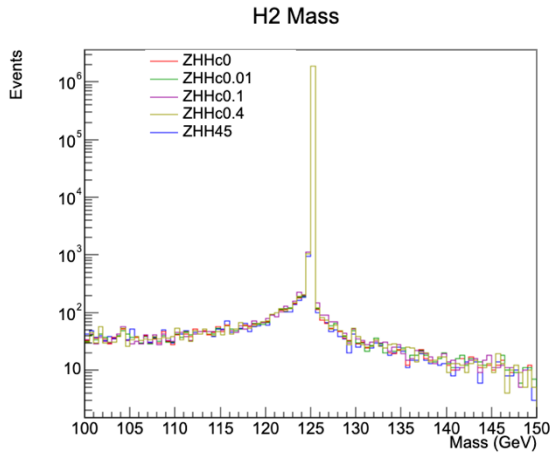
Work Progress Update on 27th May 2026

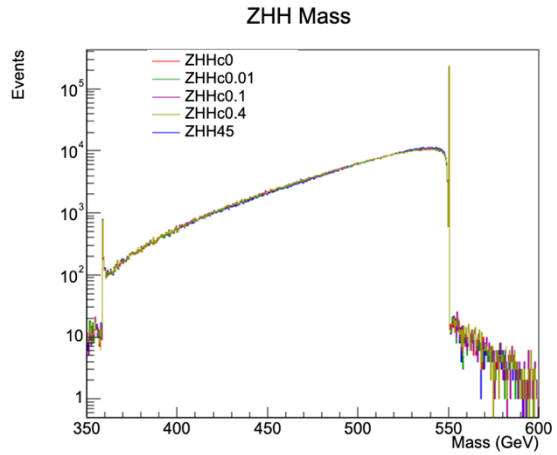
Current issues

- **LAW run creates faulty events (fiterrorcode=0, but not achieving hard mass constraint postfit mass, high chi2)**









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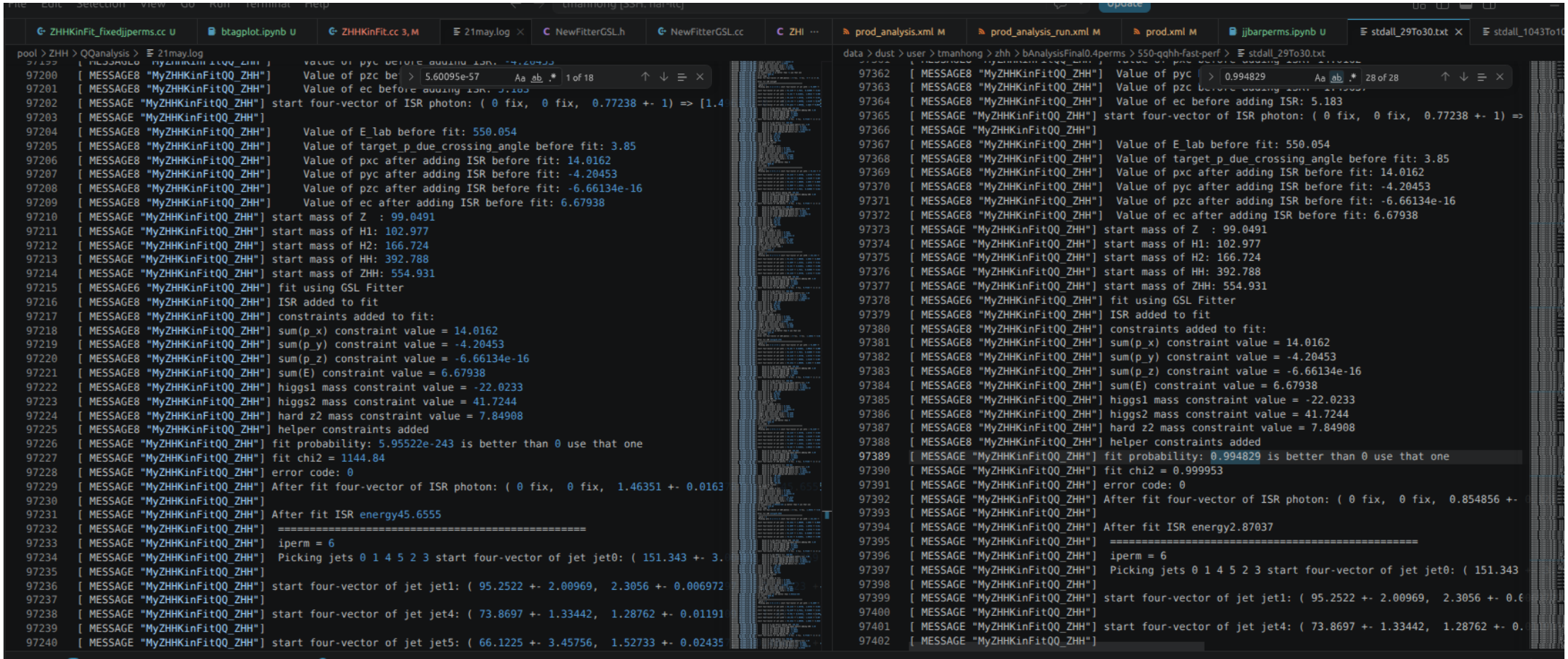
- **The issue don’t appear when rerunning the same event**



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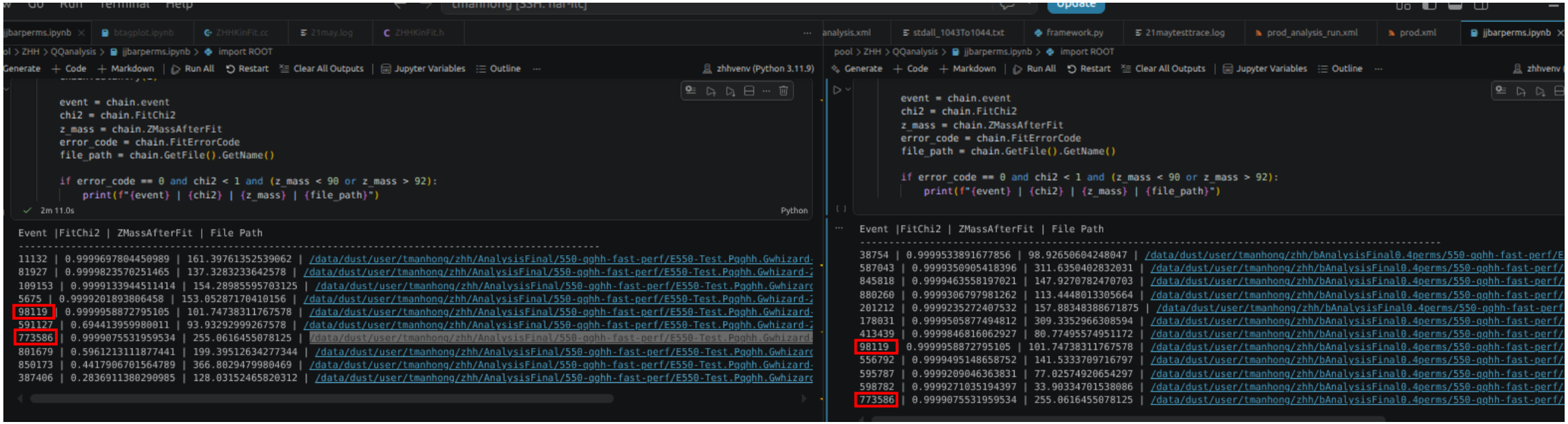

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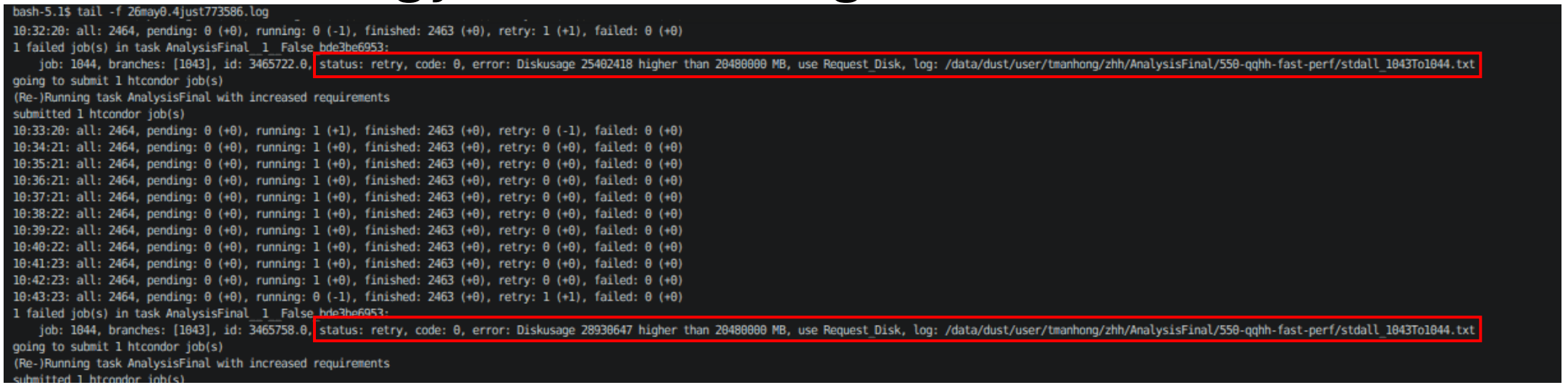

Backups

Current issues

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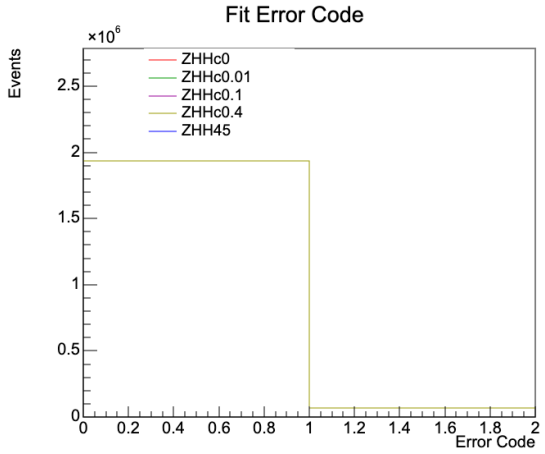
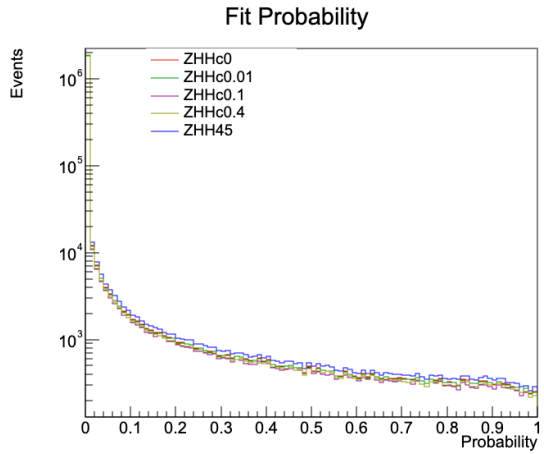
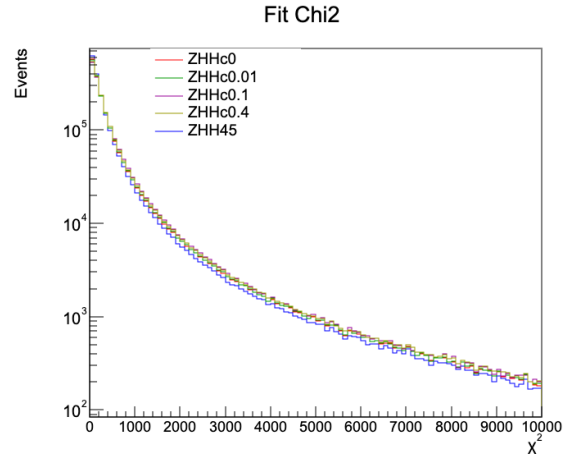
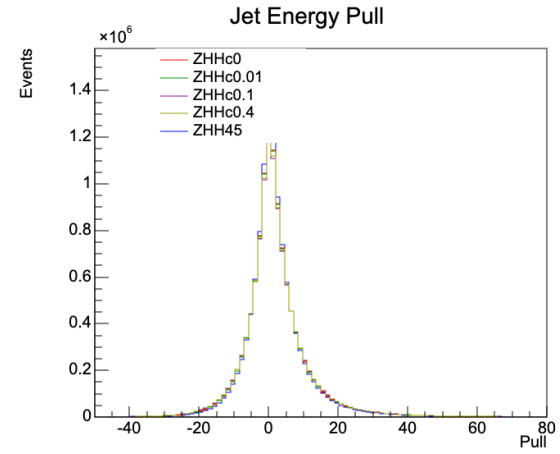
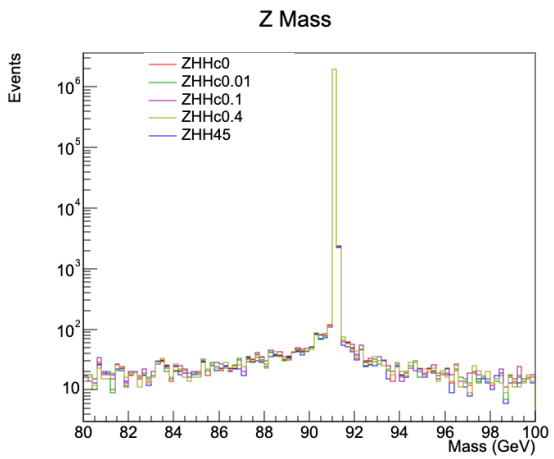
- Faulty events are random for each LAW run, although some appears in both
- Tried rerunning just 1 event using LAW with trace but job: 1044, branches: [1043], id: 3465610.0, status: retry, code: 0, error: Diskusage 35164764 higher than 20480000 MB, use Request_Disk

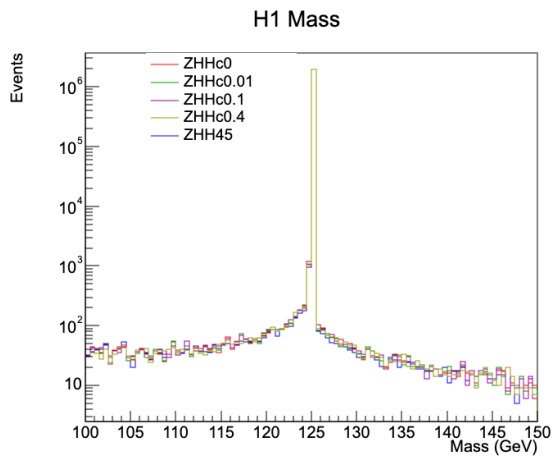


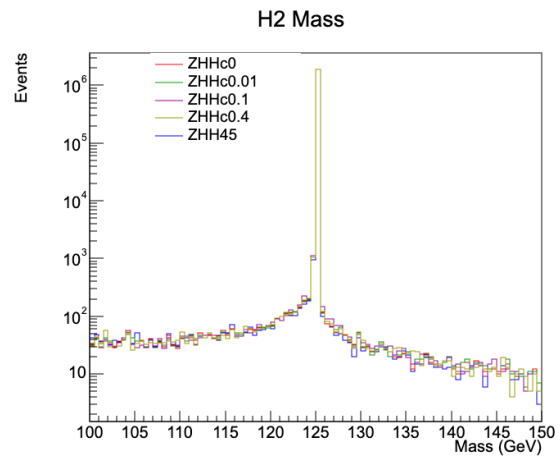


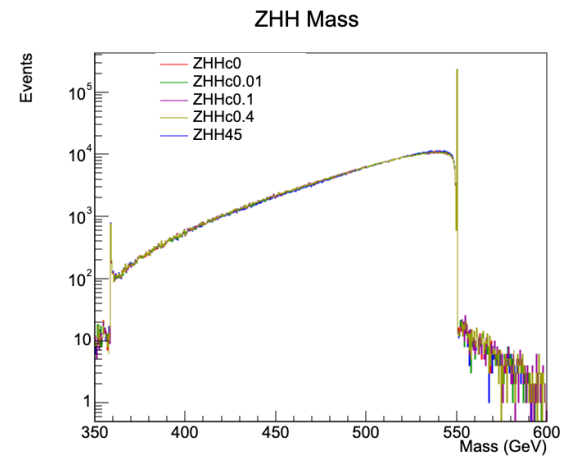












- Only events with FitErrorCode == 0 is plotted
- Hard mass constraint on individual masses

*	140 *	0 *	125 *
*	141 *	0 *	125 *
*	142 *	0 *	125 *
*	143 *	0 *	139.08805 *
*	144 *	0 *	125 *
*	145 *	0 *	125 *
*	146 *	0 *	125 *

*	862 *	0 *	125 *
*	863 *	0 *	125 *
*	864 *	0 *	125 *
*	865 *	0 *	125 *
*	866 *	0 *	97.719528 *
*	867 *	0 *	125 *
*	868 *	1 *	0 *
*	869 *	0 *	125 *

Some events with FitErrorCode = 0 did not fit to hard constraint value

```
bool converged = 0;
ierr = 0;
double chi2new = calcChi2();
nit = 0;
do {
#ifndef FIT_TRACEOFF
if (tracer) tracer->step (*this);
#endif
// Store old x values in xold
gsl_blas_dcopy (x, xold);
// Fill errors into perr
fillperr(perr);


// Now, calculate the result vector y with the values of the derivatives
// d chi^2/d x
int ifail = calcNewtonDx(dx, dxscal, x, perr, M, Mscal, y, yscal, W, W2, permW, v1);
if (ifail) {
ierr = 99;
if (debug > 0) {
std::cout << "NewFitterGSL::fit: calcNewtonDx error " << ifail << std::endl;
}
break;
}
// test convergence:
if (gsl_blas_dasum (dxscal) < 1E-6*idim) {
converged = true;
break;
}
double alpha = 1;
double mu = 0;
int imode = 2;
calcLimitedDx (alpha, mu, xnew, imode, x, v2, dx, dxscal, perr, M, Mscal, W, v1);

gsl_blas_dcopy (xnew, x);
```

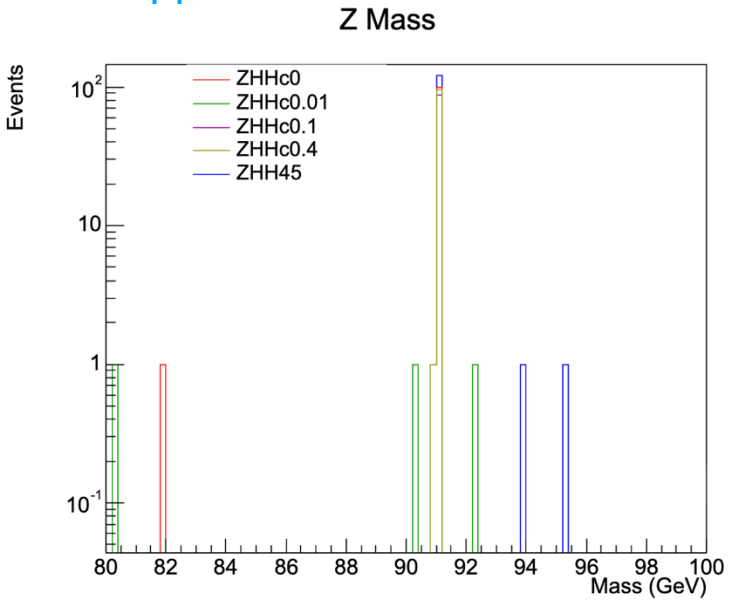
FitErrorCode = 0 criteria:

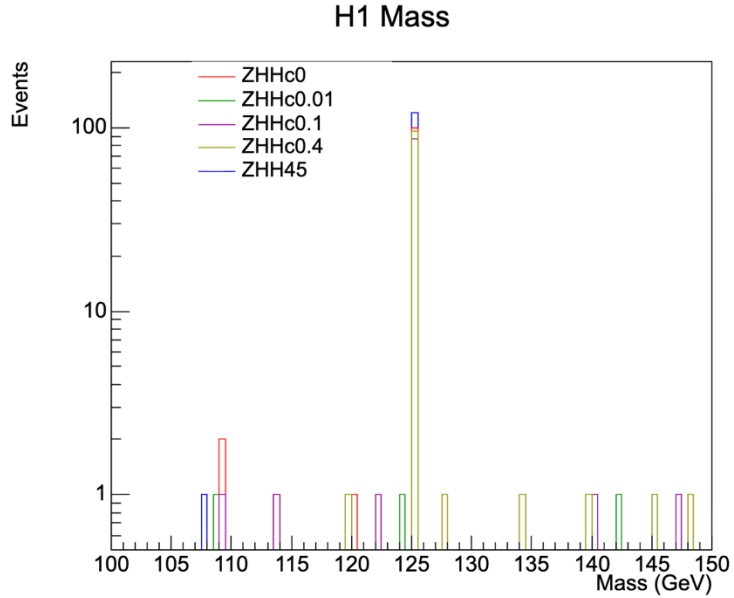
1. calcNewtonDx
2. dxscal
3. nit

```
chi2new = calcChi2();
//cout << "chi2: " << chi2old << " -> " << chi2new << endl;
// *-- Convergence criteria

++nit;
if (nit > 200) ierr = 1;
converged = (abs (chi2new - chi2old) < 0.0001);
// if (abs (chi2new - chi2old) >= 0.001)
// cout << "abs (chi2new - chi2old)=" << abs (chi2new - chi2old) << " -> try again\n";
// if (fvalbest >= 1E-3)
// cout << "fvalbest=" << fvalbest << " -> try again\n";
// if (fvalbest >= 1E-6 && abs(fvals[0]-fvalbest) >= 0.2*fvalbest )
// cout << "fvalbest=" << fvalbest
// << ", abs(fvals[0]-fvalbest)=" << abs(fvals[0]-fvalbest)<< " -> try again\n";
// if (stepbest >= 1E-3)
// cout << "stepbest=" << stepbest << " -> try again\n";
// cout << "converged=" << converged << endl;
if (debug > 2 && converged) {
cout << "abs (chi2new - chi2old)=" << abs (chi2new - chi2old) << "\n"
<< "fvalbest=" << fvalbest << "\n"
<< "abs(fvals[0]-fvalbest)=" << abs(fvals[0]-fvalbest)<< "\n";
}
} while (!(converged || ierr));
```

After applied :FitErrorCode == 0 && FitChi2 < 1



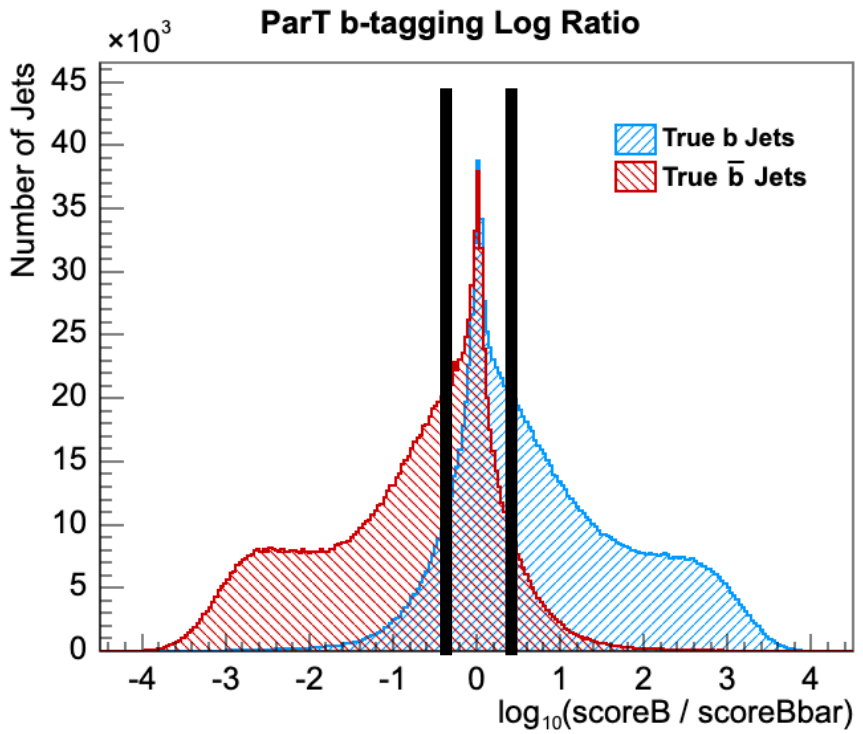


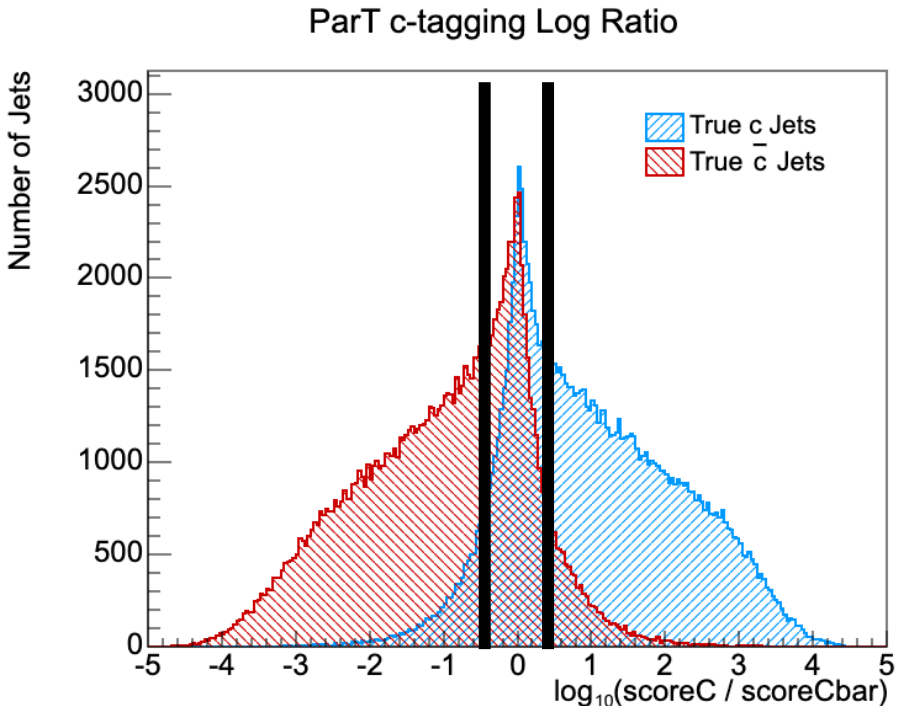
Why event info do not match up?

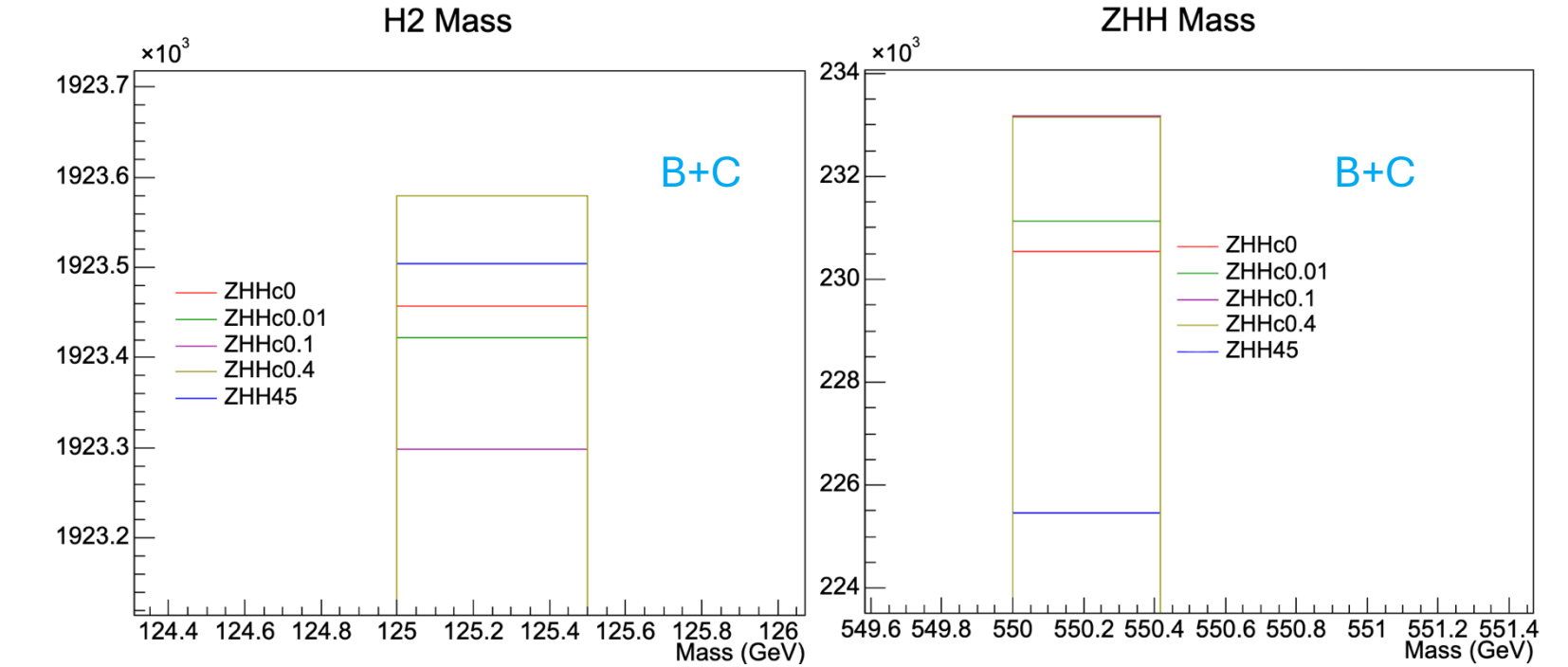
Event	FitChi2	ZMassAfterFit	File Path
109153	0.9999133944511414	154.28985595703125	/data/dust/user/tmanhong/zhh/An
504583	0.9999009370803833	108.69320678710938	/data/dust/user/tmanhong/zhh/An
608884	0.9999759197235107	70.12799072265625	/data/dust/user/tmanhong/zhh/Ana
640733	0.9999035596847534	129.66354370117188	/data/dust/user/tmanhong/zhh/An
851834	0.4476035535335541	95.34463500976562	/data/dust/user/tmanhong/zhh/Ana
940888	0.9999696016311646	170.2714080810547	/data/dust/user/tmanhong/zhh/Ana
145878	0.9999136924743652	100.0264663696289	/data/dust/user/tmanhong/zhh/Ana
146066	0.8469420075416565	36.472023010253906	/data/dust/user/tmanhong/zhh/An
171377	0.9999967813491821	210.94873046875	/data/dust/user/tmanhong/zhh/Analy
284938	0.9999436140060425	78.99983978271484	/data/dust/user/tmanhong/zhh/Ana
477873	0.9999906420707703	257.6137390136719	/data/dust/user/tmanhong/zhh/Ana
591127	0.694413959980011	93.93292999267578	/data/dust/user/tmanhong/zhh/Anal
773586	0.9999075531959534	255.0616455078125	/data/dust/user/tmanhong/zhh/Ana
911112	0.819556474685669	79.32839965820312	/data/dust/user/tmanhong/zhh/Anal
167506	0.9999611973762512	107.99821472167969	/data/dust/user/tmanhong/zhh/An
203990	0.9999852180480957	76.4360580444336	/data/dust/user/tmanhong/zhh/Anal
283850	0.9999371767044067	123.97274780273438	/data/dust/user/tmanhong/zhh/An
360881	0.7926355004310608	141.50051879882812	/data/dust/user/tmanhong/zhh/An

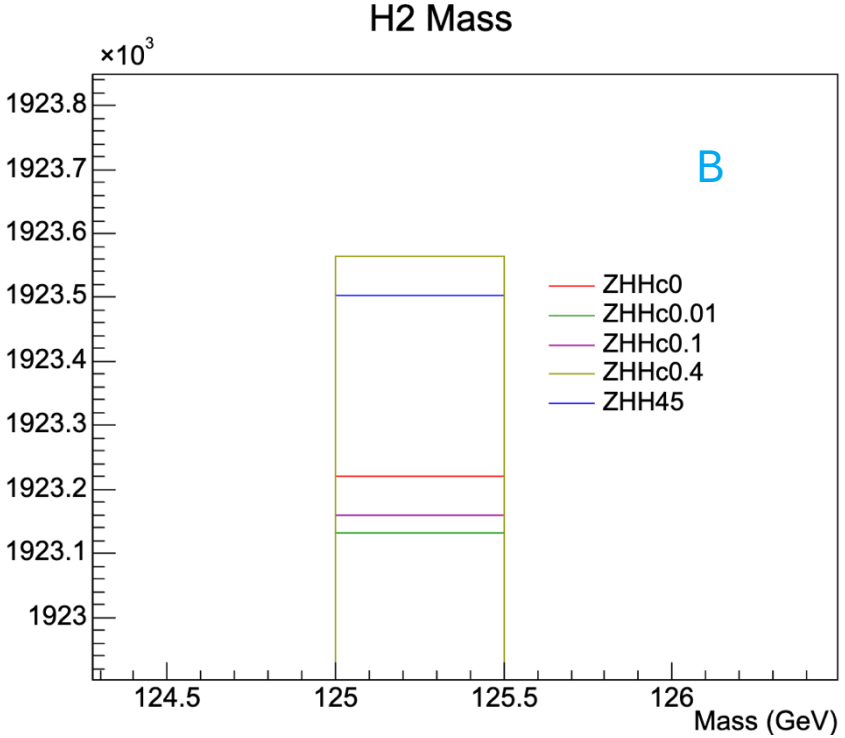
```
[ MESSAGE1 "MyZHHKinFitQQ_ZHH"] Z mass prefit = 99.9817
[ MESSAGE1 "MyZHHKinFitQQ_ZHH"] H1 mass prefit = 127.851
[ MESSAGE1 "MyZHHKinFitQQ_ZHH"] H2 mass prefit = 152.68
[ MESSAGE1 "MyZHHKinFitQQ_ZHH"] HH mass prefit = 346.291
[ MESSAGE1 "MyZHHKinFitQQ_ZHH"] ZHH mass prefit = 549.714
[ MESSAGE "MyZHHKinFitQQ_ZHH"] Z mass postfit = 91.2
[ MESSAGE "MyZHHKinFitQQ_ZHH"] H1 mass postfit = 125
[ MESSAGE "MyZHHKinFitQQ_ZHH"] H2 mass postfit = 125
[ MESSAGE "MyZHHKinFitQQ_ZHH"] HH mass postfit = 312.696
[ MESSAGE "MyZHHKinFitQQ_ZHH"] ZHH mass postfit = 505.877
[ MESSAGE "MyZHHKinFitQQ_ZHH"] ISR energy true    = 1.09563e-05
[ MESSAGE "MyZHHKinFitQQ_ZHH"] ISR energy postfit = 42.3891
[ MESSAGE "MyZHHKinFitQQ_ZHH"] pulls jet0: -4.11888, 8.52584, -4.7647
[ MESSAGE "MyZHHKinFitQQ_ZHH"] pulls jet1: 2.03751, 7.46853, -5.74896
[ MESSAGE "MyZHHKinFitQQ_ZHH"] pulls jet2: -8.36573, 1.93551, -10.7941
[ MESSAGE "MyZHHKinFitQQ_ZHH"] pulls jet3: -0.528419, 4.96093, 11.7205
[ MESSAGE "MyZHHKinFitQQ_ZHH"] pulls jet4: -13.4661, 15.8359, -12.8261
[ MESSAGE "MyZHHKinFitQQ_ZHH"] pulls jet5: -17.4563, 13.7738, 17.3617
[ MESSAGE "MyStatusmonitor"]  ===== Run  :       0  Event:     871
[ MESSAGE1 "MyZHHKinFitQQ_ZHH"]     ////////////////////////////////////////////////////////////////////////////////
[ WARNING "MyZHHKinFitQQ_ZHH"]  ////////////////////////////////// processing event 109154 in run 404009 /
```

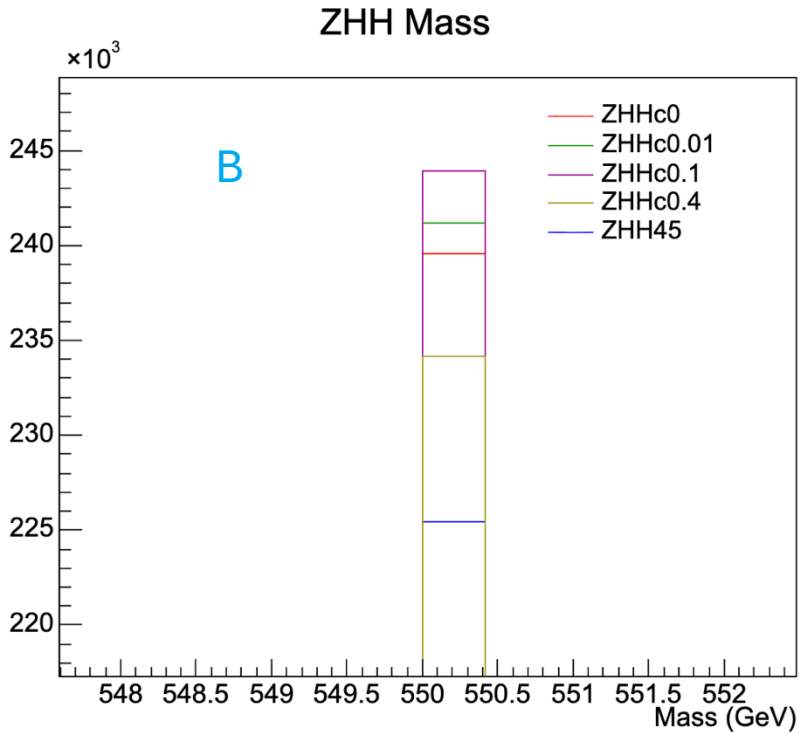
- The $j\bar{j}$ informed permutations for 6 jets event.
  - jets passed the cut → well defined charge
  - 4 event cases based on no. of passed cut jets:
    - $3q \,||\, 3\bar{q}$ → 18 perms
    - $2q \,\&\&\, 2\bar{q}$ → 30 perms
    - $2q \,||\, 2\bar{q} \,||\, 4q \,||\, 4\bar{q}$ → 36 perms
    - $1q \,||\, 1\bar{q} \,||$ else → 45 perms



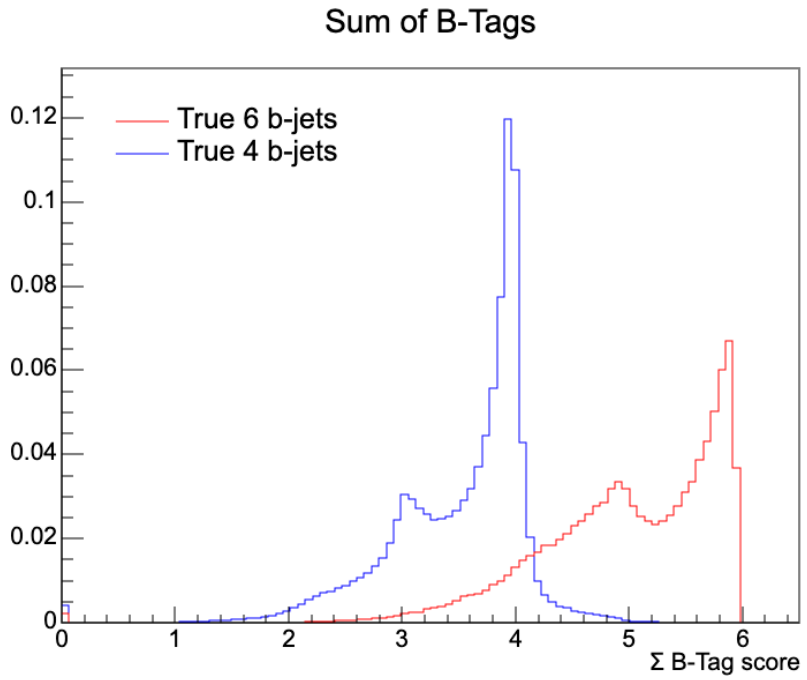


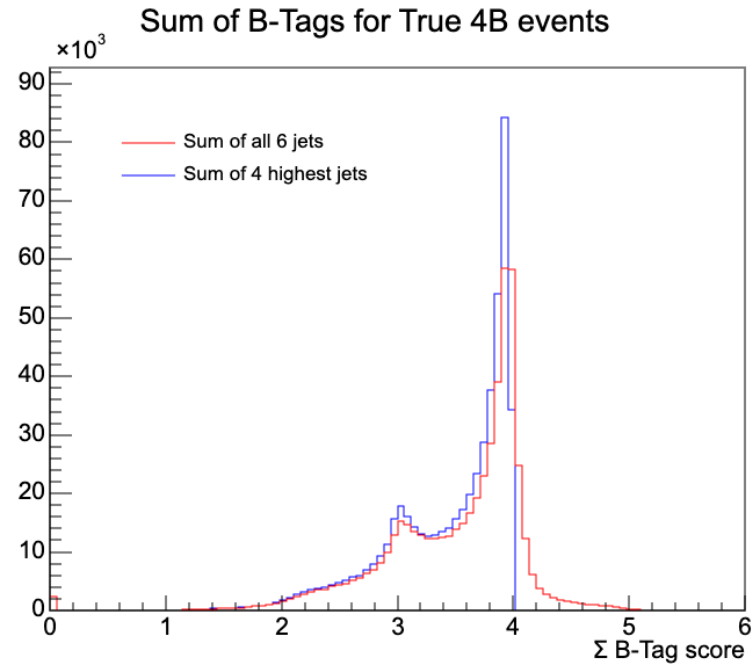


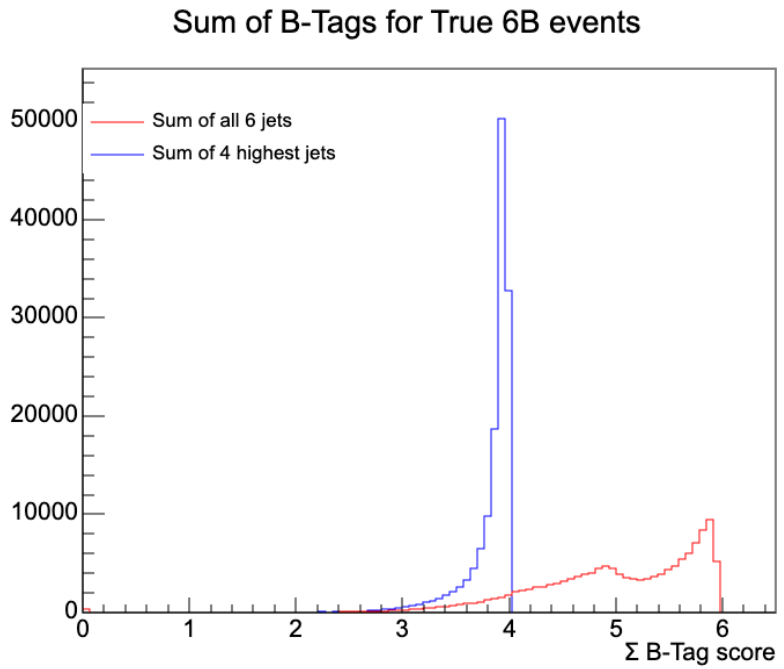




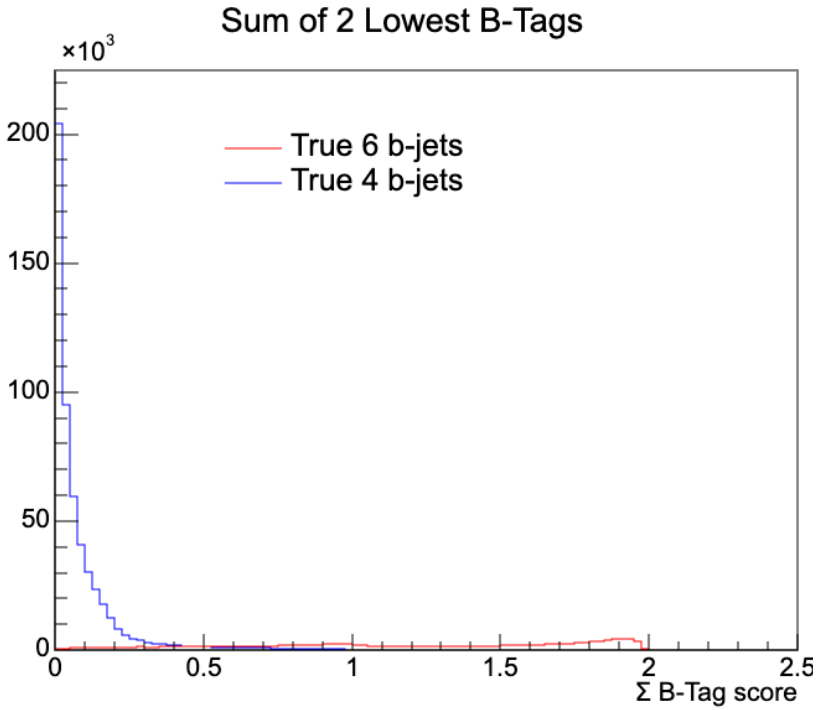
- Similar performance in individual mass reconstruction
- Just B tag cut ~10k more events in ZHH 550 bin
- Just B tag cut is sufficient

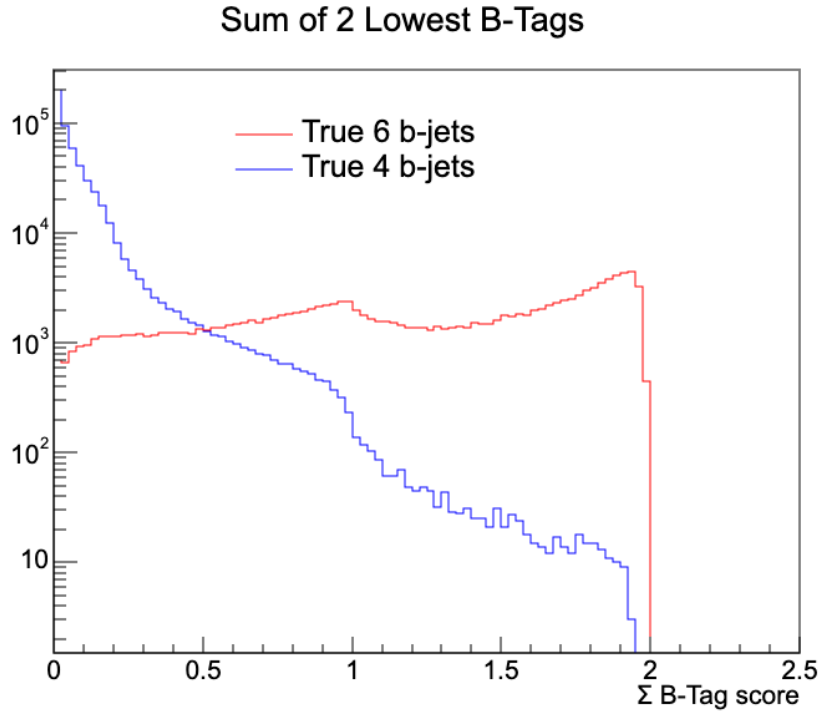




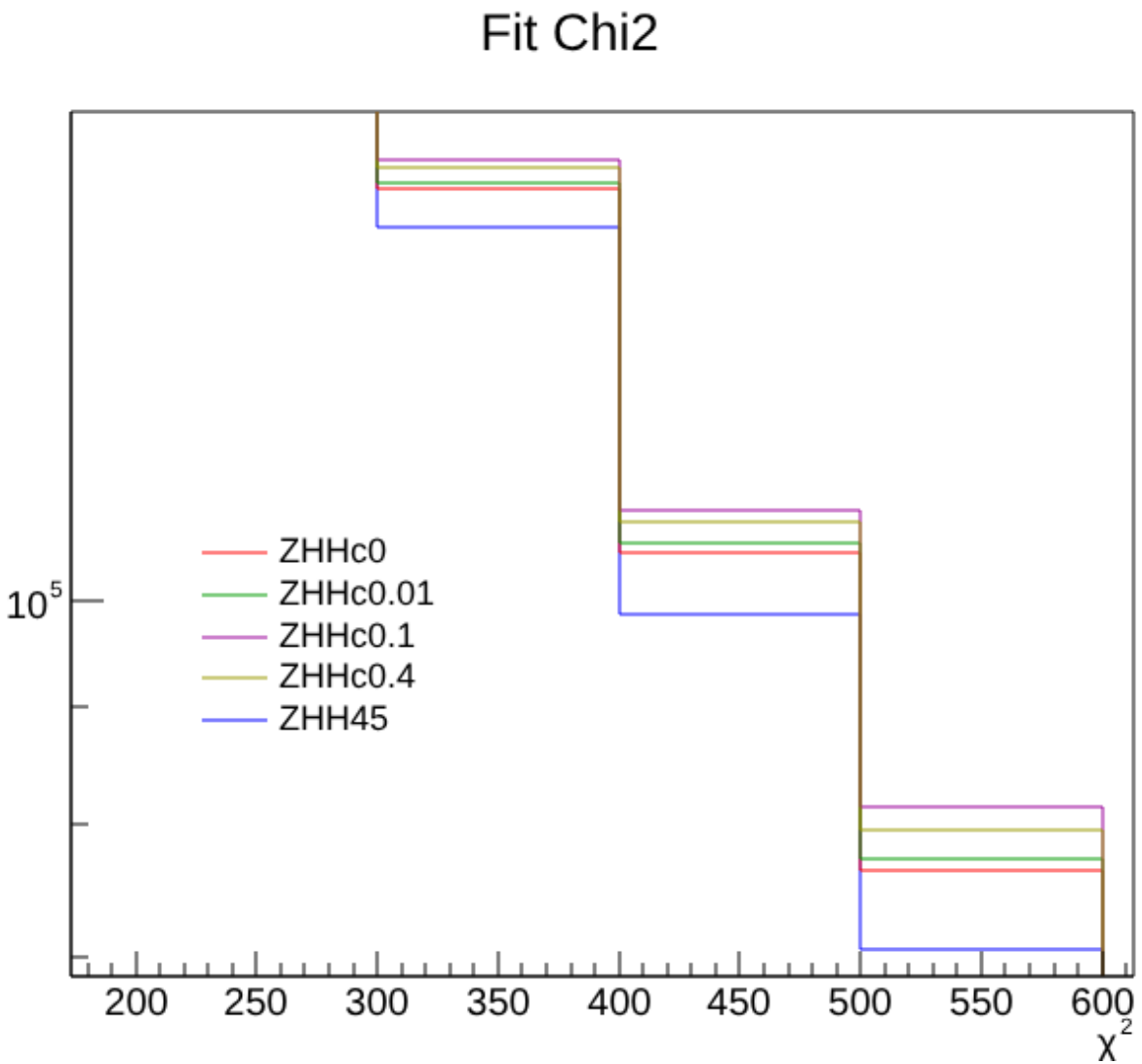


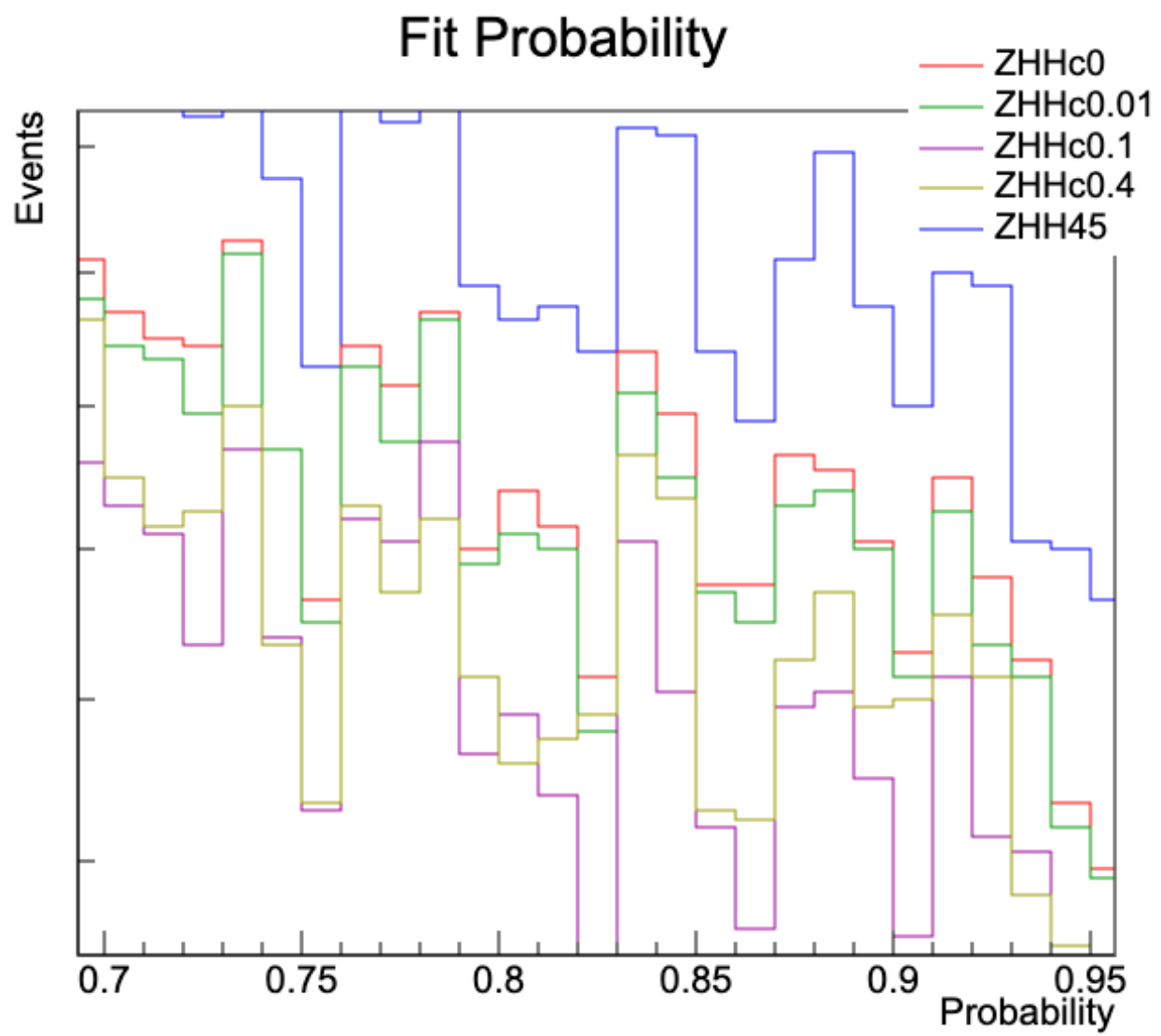
- Exploring to separate 4b-jets/6b-jets
- If ∑btag < 4,
  - If hypo = zhh(soft)/EQM
    - bmax1-4 → HH
    - bmax5,6 → Z
    - 3 perms
  - if hypo = zzh(soft)/MH
    - bmax5,6 not higgs
    - bmax1-4 →Z&H
    - 6 perms

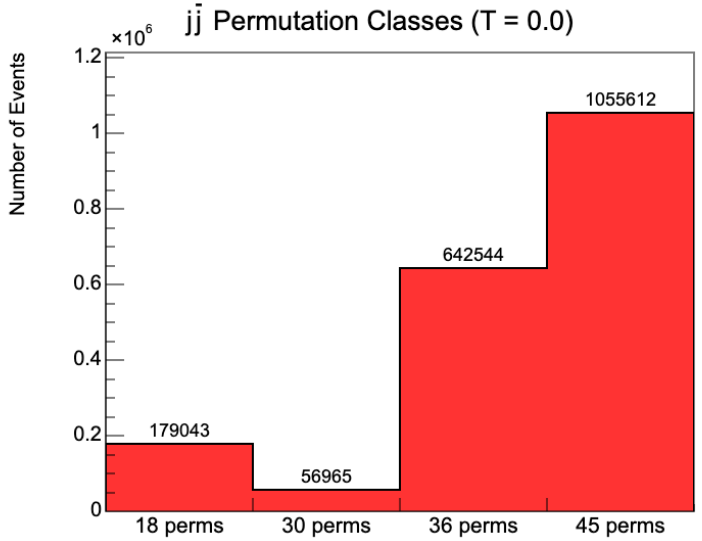


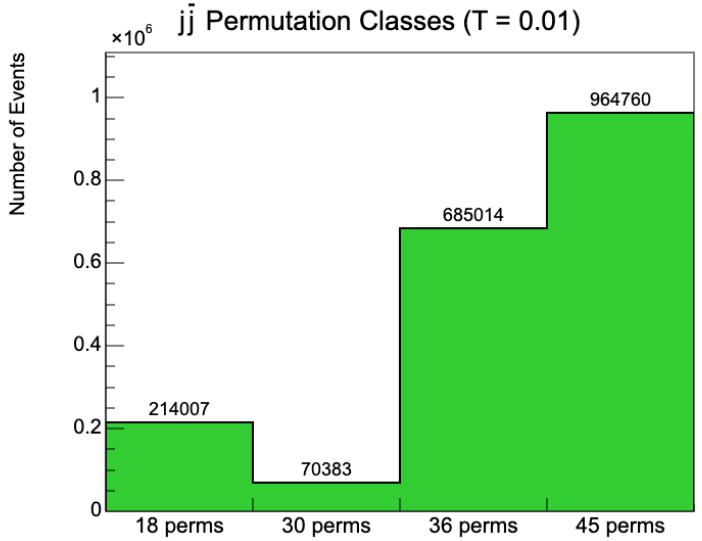


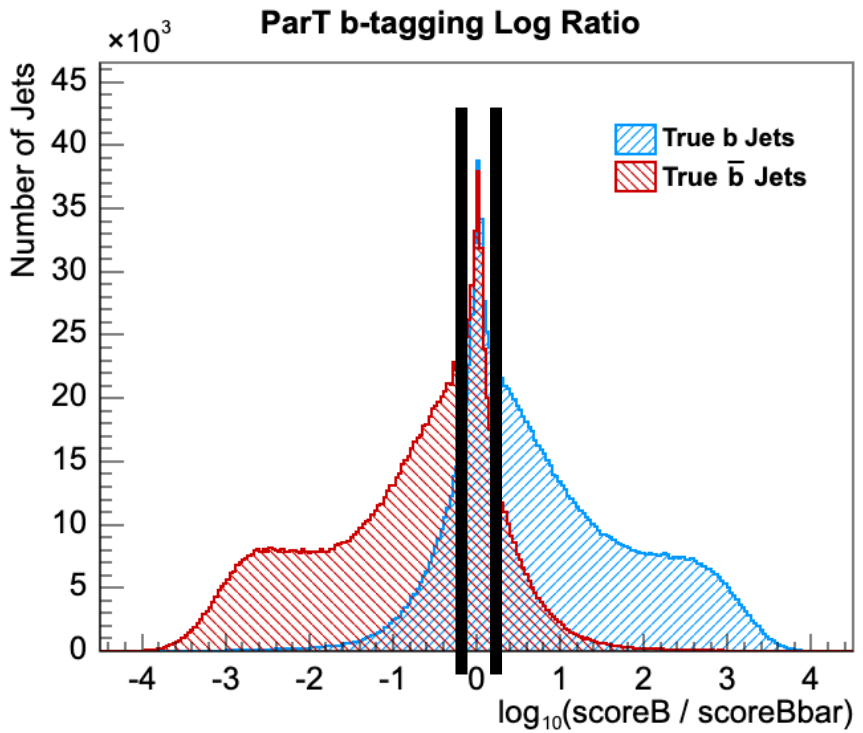
- More events in 97-98 fitprob in b/ctag(0) than just b tag(0.4) for best cut
- But other cuts perform much worse for b/c tag than b tag at 97-98
- Fit performance(based on fitprob) still follows no of events in 45

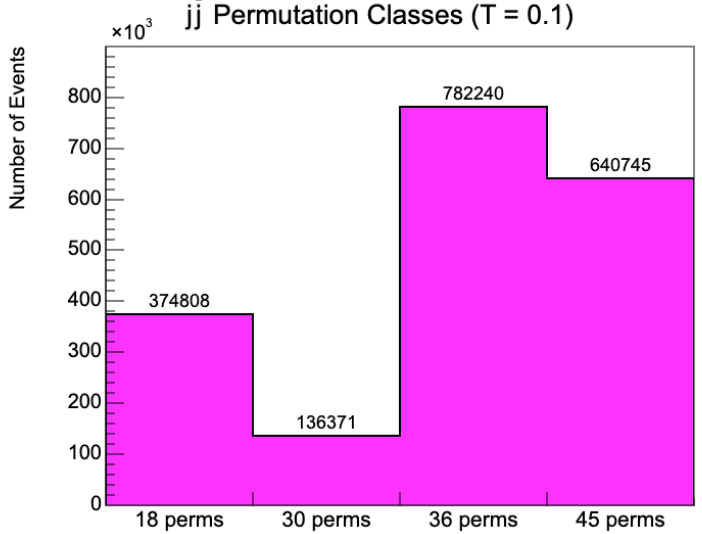


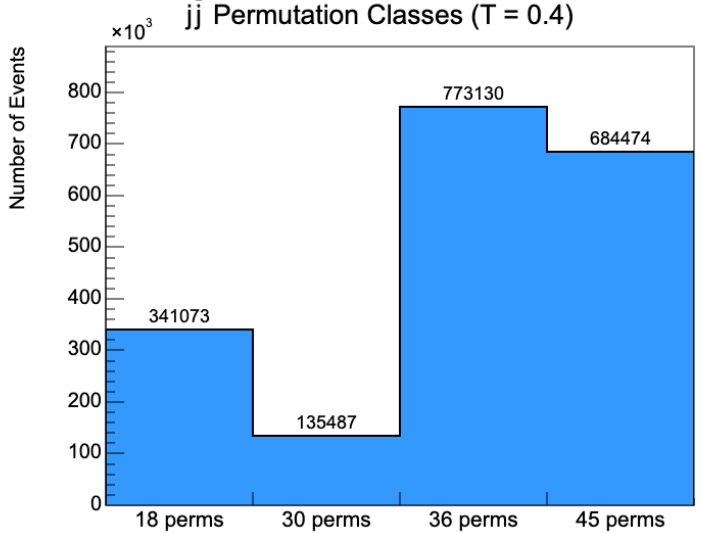


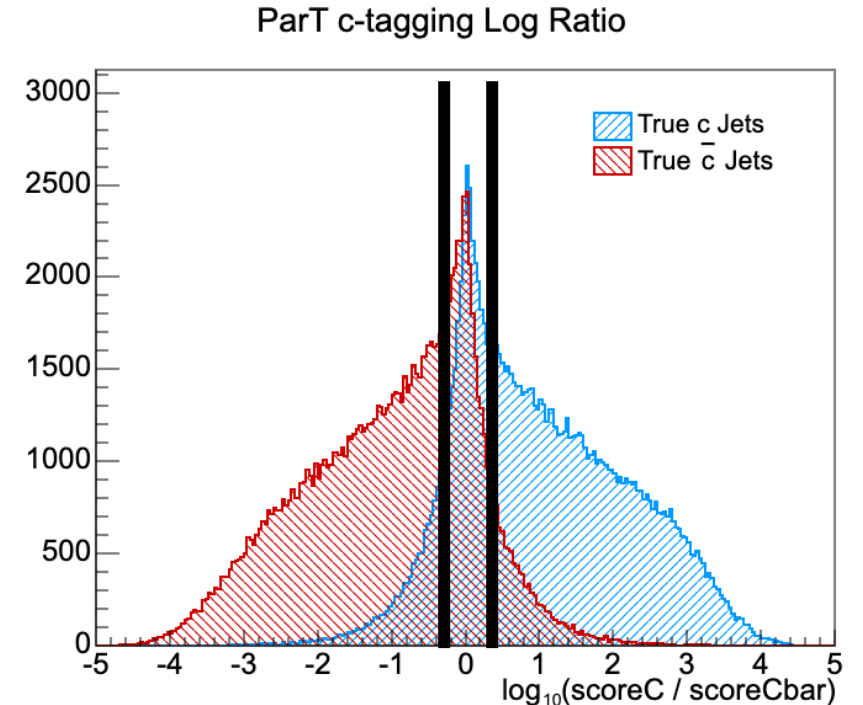

jj̄ Permutation Classes (T = 0.0)
×10^6
Number of Events
179043
56965
642544
1055612
18 perms
30 perms
36 perms
45 perms

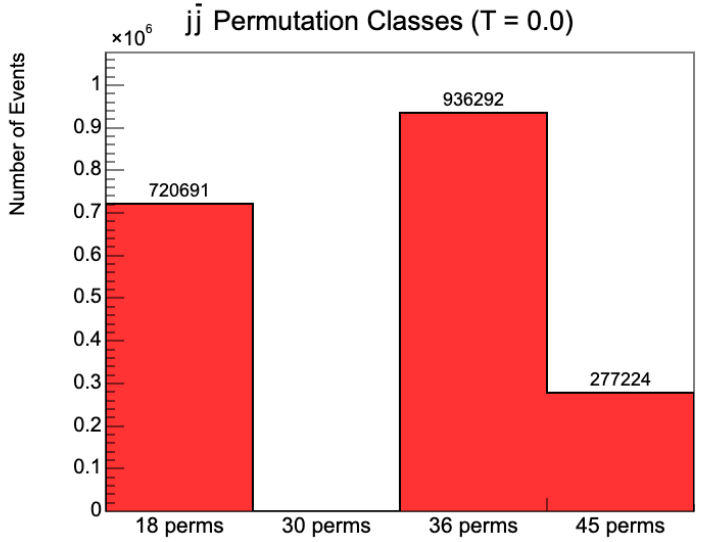

jj̄ Permutation Classes (T = 0.01)
×10^6
Number of Events
214007
70383
685014
964760
18 perms
30 perms
36 perms
45 perms

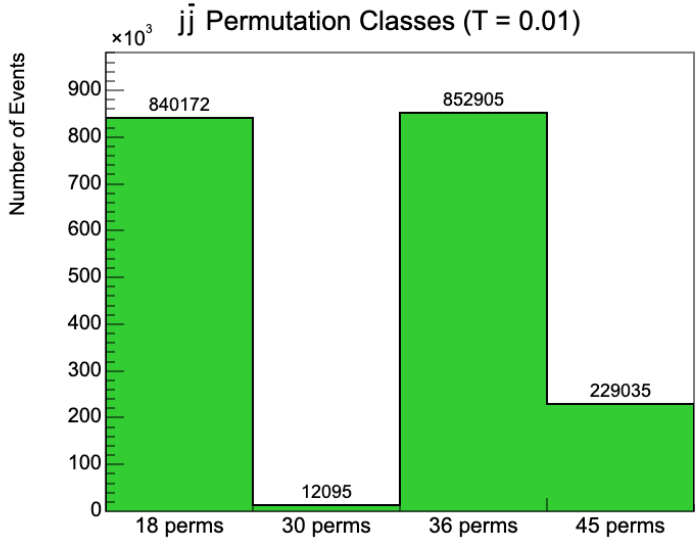

ParT b-tagging Log Ratio
×10^3
Number of Jets
True b Jets
True b̄ Jets
log10(scoreB / scoreBbar)

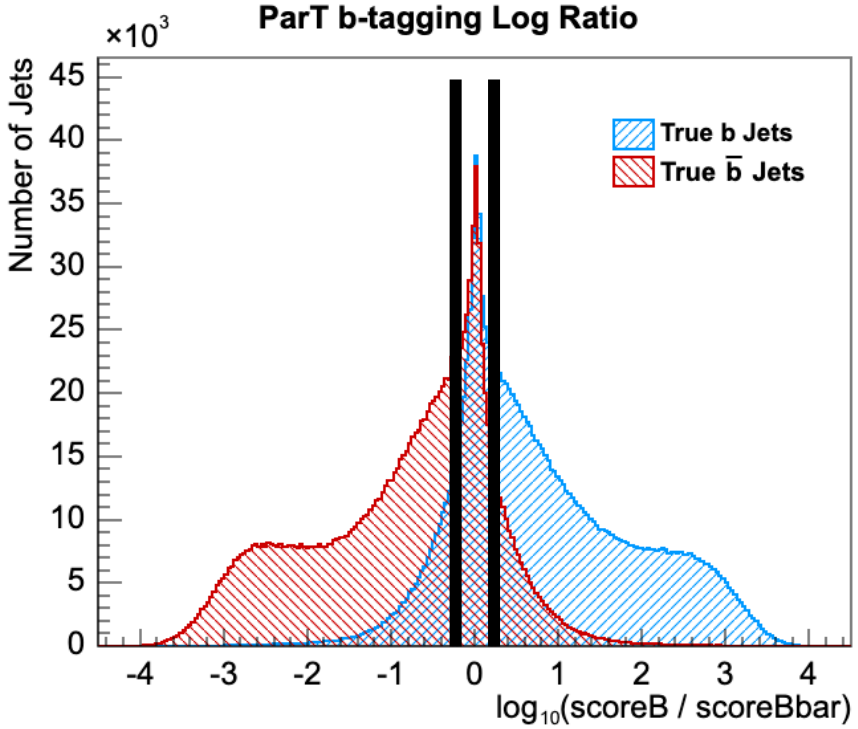

jj̄ Permutation Classes (T = 0.1)
×10^3
Number of Events
374808
136371
782240
640745
18 perms
30 perms
36 perms
45 perms

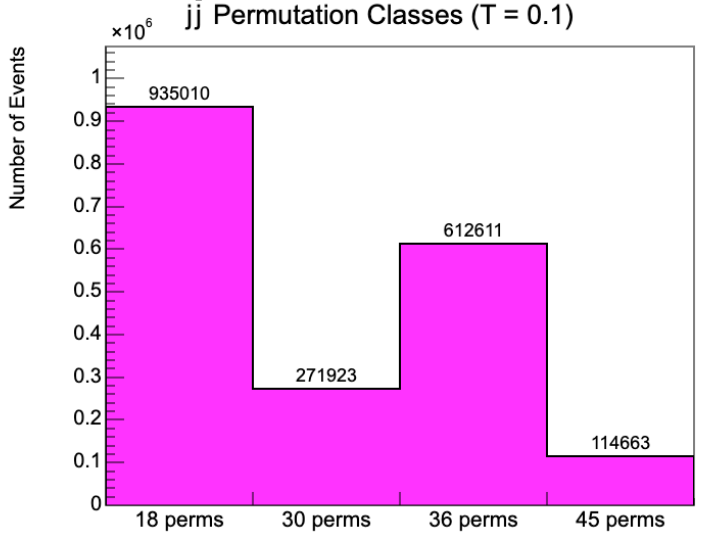

jj̄ Permutation Classes (T = 0.4)
×10^3
Number of Events
341073
135487
773130
684474
18 perms
30 perms
36 perms
45 perms

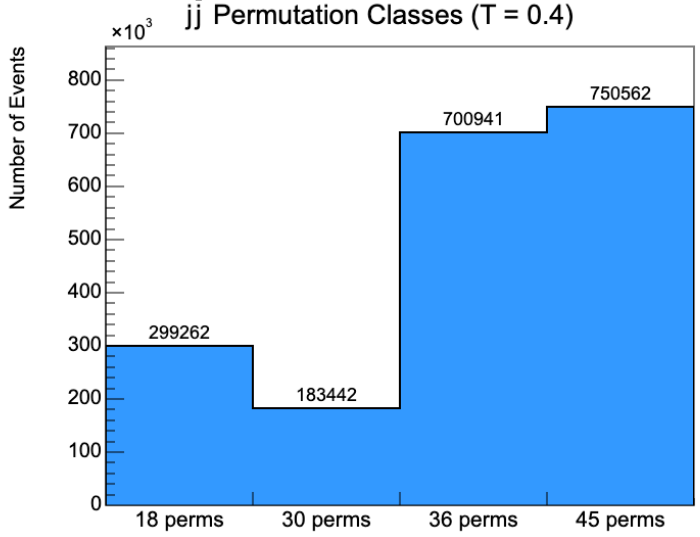

ParT c-tagging Log Ratio
True c Jets
True c̄ Jets
log10(scoreC / scoreCbar)


jj̄ Permutation Classes (T = 0.0)
×10^6
Number of Events
720691
936292
277224
18 perms
30 perms
36 perms
45 perms

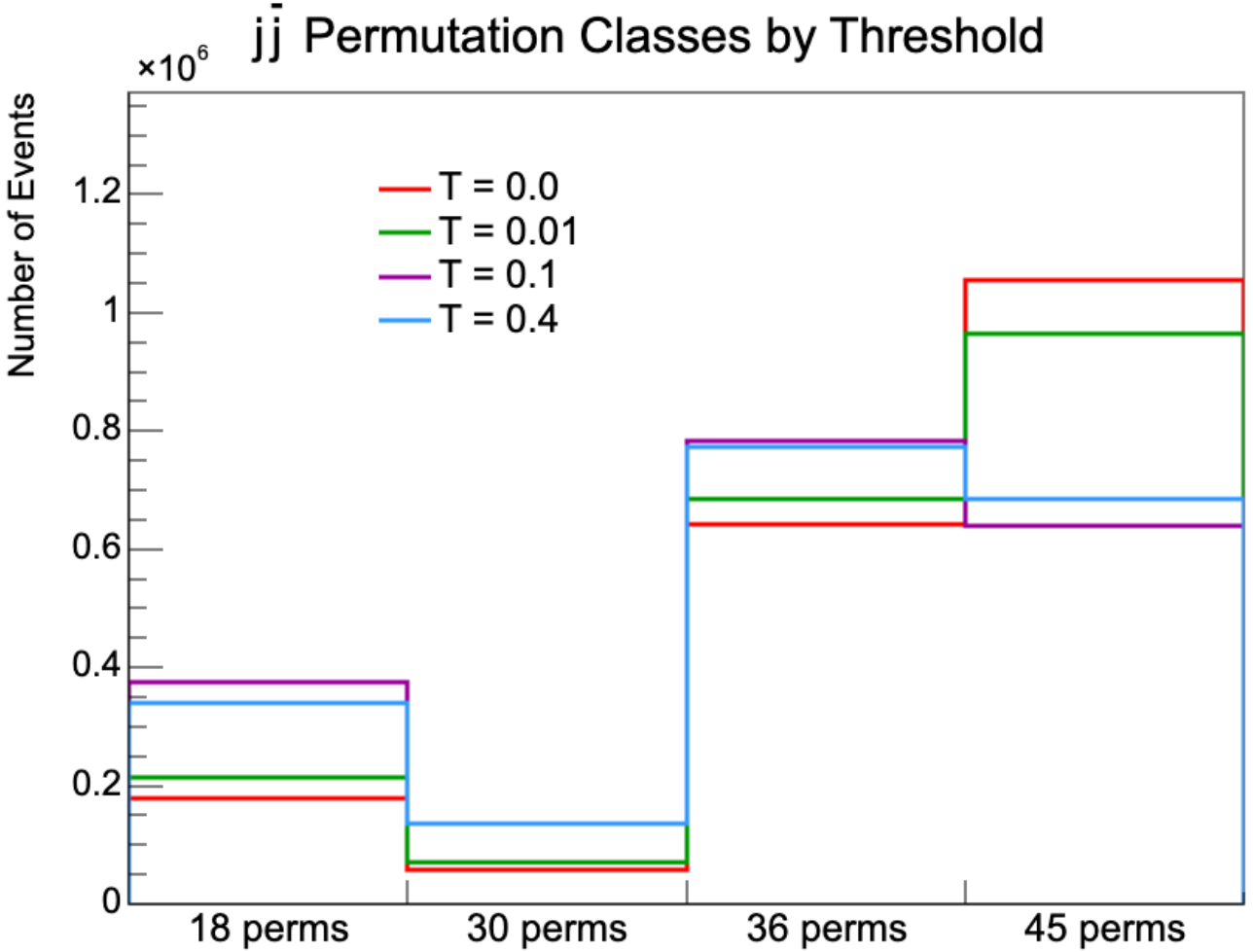

jj̄ Permutation Classes (T = 0.01)
×10^3
Number of Events
840172
12095
852905
229035
18 perms
30 perms
36 perms
45 perms


ParT b-tagging Log Ratio
×10^3
Number of Jets
True b Jets
True b̄ Jets
log10(scoreB / scoreBbar)


jj̄ Permutation Classes (T = 0.1)
×10^6
Number of Events
935010
271923
612611
114663
18 perms
30 perms
36 perms
45 perms

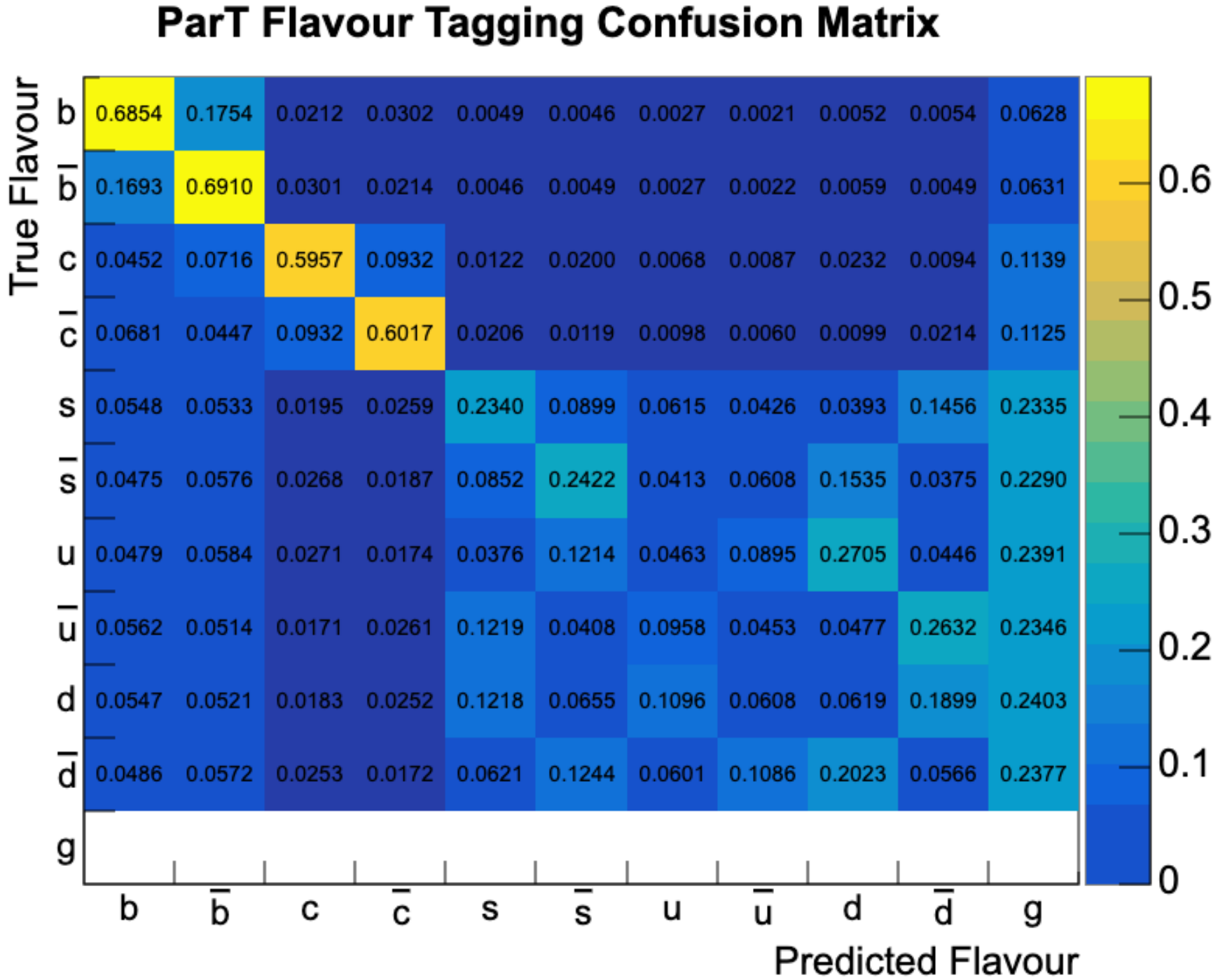

jj̄ Permutation Classes (T = 0.4)
×10^3
Number of Events
299262
183442
700941
750562
18 perms
30 perms
36 perms
45 perms

- Counter-expectation from class:
  - > 2 jets passed cut → non-45perms
  - Lower T, more jets pass cut, more > 2 events, less events in 45 perm
- Could be for extreme low cut 0.0 and 0.01:
  - If conflicting sign from logB and logC → Ambiguous
  - Low cut T, more conflicting cases, more < 2 events in 45 perms
- For 0.1 and 0.4 back to expectation:
  - 0.4 is more strict, more ambiguous



perms = bmax1,bmax2,bmax3,bmax4
bmax1,bmax3,bmax2,bmax4
bmax1,bmax4,bmax2,bmax3

perms = bmax1,bmax2,bmax3,bmax4
bmax3,bmax4,bmax1,bmax2
bmax1,bmax3,bmax2,bmax4
bmax2,bmax4,bmax1,bmax3
bmax1,bmax4,bmax2,bmax3
bmax2,bmax3,bmax1,bmax4


ParT Flavour Tagging Confusion Matrix
True Flavour
b 0.6854 0.1754 0.0212 0.0302 0.0049 0.0046 0.0027 0.0021 0.0052 0.0054 0.0628
b̄ 0.1693 0.6910 0.0301 0.0214 0.0046 0.0049 0.0027 0.0022 0.0059 0.0049 0.0631
c 0.0452 0.0716 0.5957 0.0932 0.0122 0.0200 0.0068 0.0087 0.0232 0.0094 0.1139
c̄ 0.0681 0.0447 0.0932 0.6017 0.0206 0.0119 0.0098 0.0060 0.0099 0.0214 0.1125
s 0.0548 0.0533 0.0195 0.0259 0.2340 0.0899 0.0615 0.0426 0.0393 0.1456 0.2335
s̄ 0.0475 0.0576 0.0268 0.0187 0.0852 0.2422 0.0413 0.0608 0.1535 0.0375 0.2290
u 0.0479 0.0584 0.0271 0.0174 0.0376 0.1214 0.0463 0.0895 0.2705 0.0446 0.2391
ū 0.0562 0.0514 0.0171 0.0261 0.1219 0.0408 0.0958 0.0453 0.0477 0.2632 0.2346
d 0.0547 0.0521 0.0183 0.0252 0.1218 0.0655 0.1096 0.0608 0.0619 0.1899 0.2403
d̄ 0.0486 0.0572 0.0253 0.0172 0.0621 0.1244 0.0601 0.1086 0.2023 0.0566 0.2377
g
b b̄ c c̄ s s̄ u ū d d̄ g
Predicted Flavour
0.6
0.5
0.4
0.3
0.2
0.1
0