Cherenkov Detector in BDT Analysis

Justin Stevens

PID Upgrade Meeting: 3.22.13

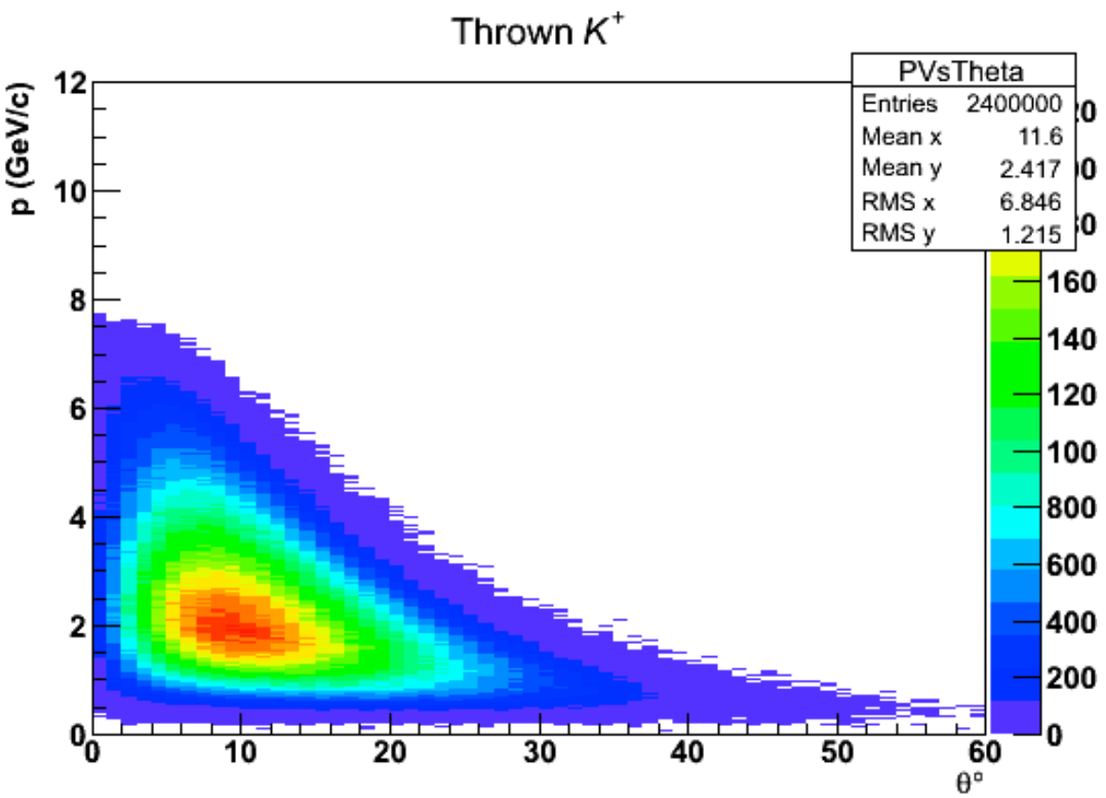
Outline

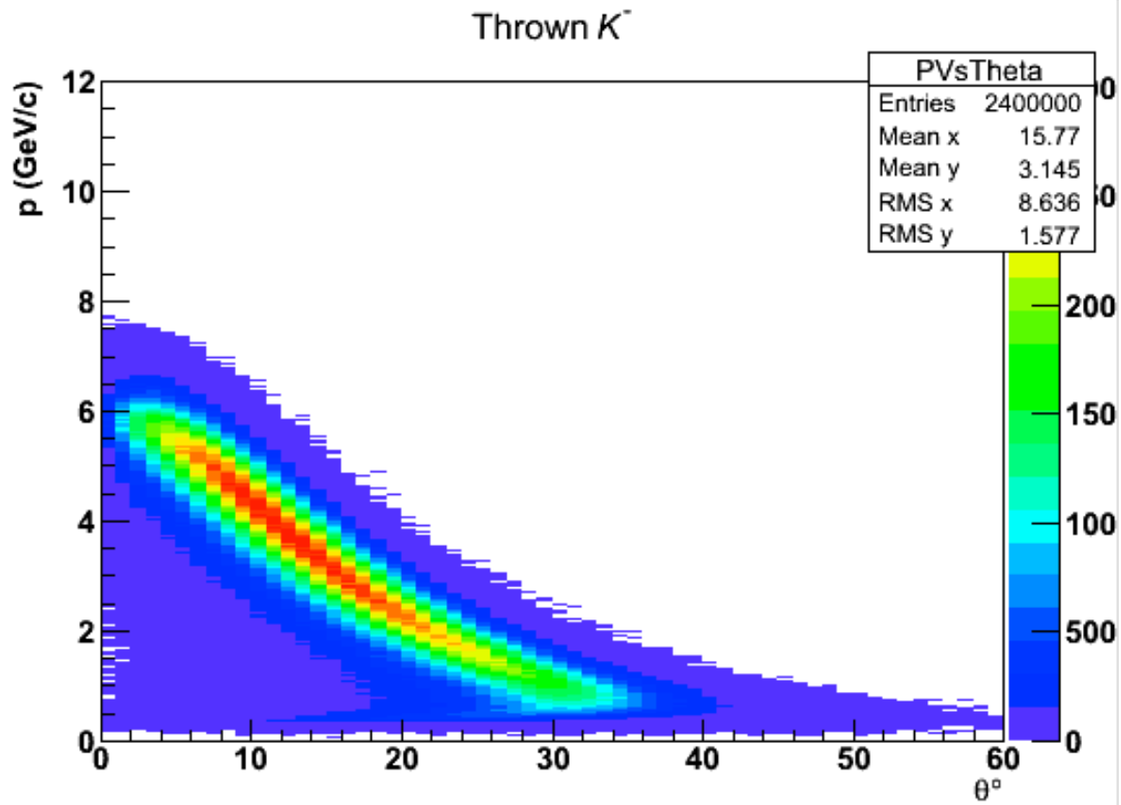
- Study four channels from PAC proposal

$$\eta_1'(2300), h_2'(2600), Y(2175), \text{and } \phi_3(1850)$$

  - Only considered reconstructed proton
  - Choose BDT cut to give purity of 90% for all channels for simple comparison
  - Improvements with BDT should be better for higher purity

h’(2600)





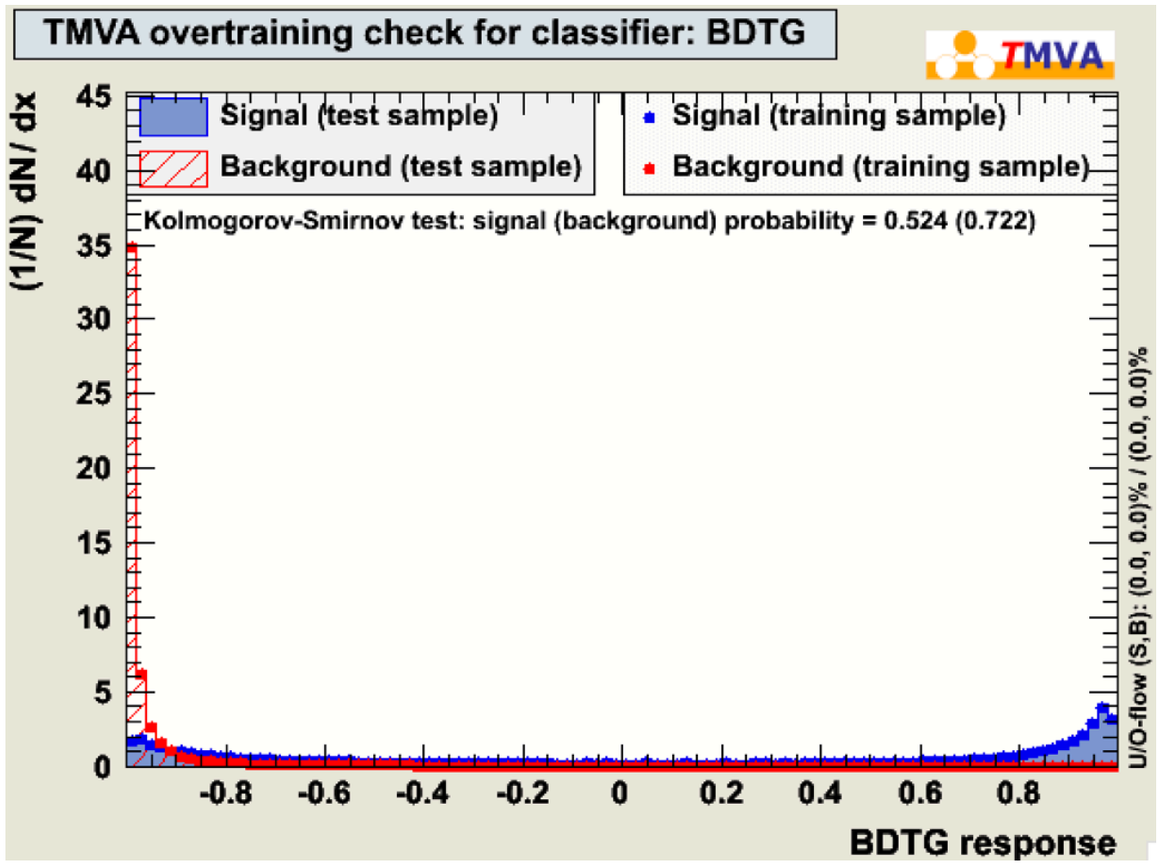
- Data samples (data challenge bggen with 8.4<E_γ<9 GeV):
  - Signal: Exclusive requirement on final state p, K+, K-, π+, π-
  - Background: All bggen not satisfying signal requirement
- All particle combinations are considered with **no cuts** applied before the decision tree
- Only reconstructed proton considered

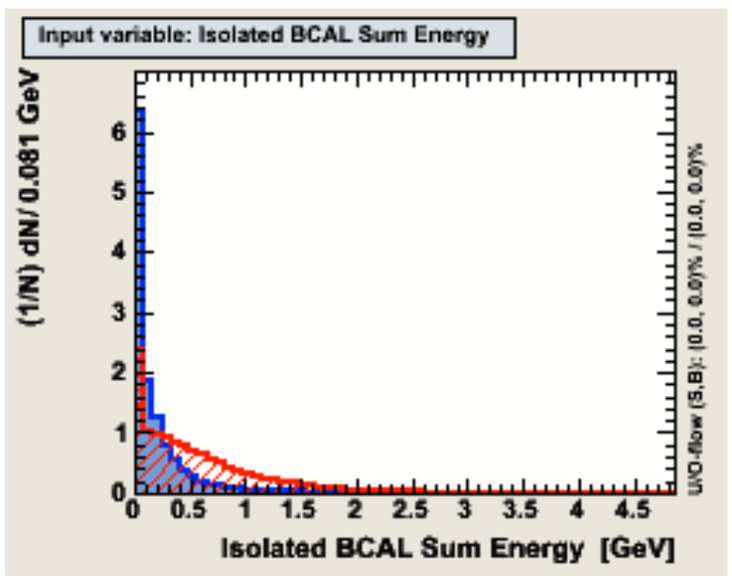
$$\gamma p \to h_2'(2600)p$$
$$h_2'(2600) \to K_1(1400)^+ K^-$$
$$K_1(1400)^+ \to K^*(892)^0 \pi^+$$
$$K^*(892)^0 \to K^+ \pi^-$$

Selection Efficiency

- My signal condition for PYTHIA events only requires final state particles to be correctly identified but not intermediate resonance (eg. $K^* \rightarrow K\pi$)
- Place cuts on intermediate resonance masses separate from BDT cut
- Previous presentations:
  - Selection efficiency was the fraction of reconstructed signal events which passed the invariant mass cuts and the BDT cut
  - Not real signal efficiency because some events removed by invariant mass cuts, which made these too low
- This presentation (and future):
  - Selection efficiency is for the BDT cut only
  - No impact to purity numbers or expected yields

h'(2600) w/o CKOV





Particle codes:

p1 = π+

p2 = π-

p3 = K+

p4 = K-

p5 = proton

```
--- Factory             : Begin ranking of input variables...
--- BDTG                : Ranking result (top variable is best ranked)
--- BDTG                : ----------------------------------------------
--- BDTG                : Rank :Variable         :Variable Importance
--- BDTG                : ----------------------------------------------
--- BDTG                :    1 : kinFitCL        : 1.932e-01
--- BDTG                :    2 : isolatedBCALSumE : 1.288e-01
--- BDTG                :    3 : p5_dEdxFOM      : 7.343e-02
--- BDTG                :    4 : p3_timeFOM      : 7.225e-02
--- BDTG                :    5 : p3_dEdxFOM      : 6.985e-02
--- BDTG                :    6 : p4_dEdxFOM      : 4.605e-02
--- BDTG                :    7 : p1_ChiSqIP      : 4.072e-02
--- BDTG                :    8 : PV_r            : 3.796e-02
--- BDTG                :    9 : PV_ChiSq        : 3.460e-02
--- BDTG                :   10 : p4_ChiSqIP      : 3.286e-02
--- BDTG                :   11 : p2_dEdxFOM      : 3.186e-02
--- BDTG                :   12 : p5_ChiSqIP      : 3.173e-02
--- BDTG                :   13 : p3_ChiSqIP      : 2.789e-02
--- BDTG                :   14 : p5_timeFOM      : 2.280e-02
--- BDTG                :   15 : p4_timeFOM      : 2.276e-02
--- BDTG                :   16 : isolatedFCALSumE : 2.096e-02
--- BDTG                :   17 : p2_ChiSqIP      : 2.080e-02
--- BDTG                :   18 : p1_dEdxFOM      : 1.839e-02
--- BDTG                :   19 : isolatedTrackSumP : 1.737e-02
--- BDTG                :   20 : p1_timeFOM      : 1.485e-02
--- BDTG                :   21 : p1_ChiSq        : 1.422e-02
--- BDTG                :   22 : p2_ChiSq        : 9.084e-03
--- BDTG                :   23 : p3_ChiSq        : 7.893e-03
--- BDTG                :   24 : p4_ChiSq        : 7.377e-03
--- BDTG                :   25 : p2_timeFOM      : 2.292e-03
--- BDTG                :   26 : p5_ChiSq        : 0.000e+00
--- BDTG                : ----------------------------------------------
```

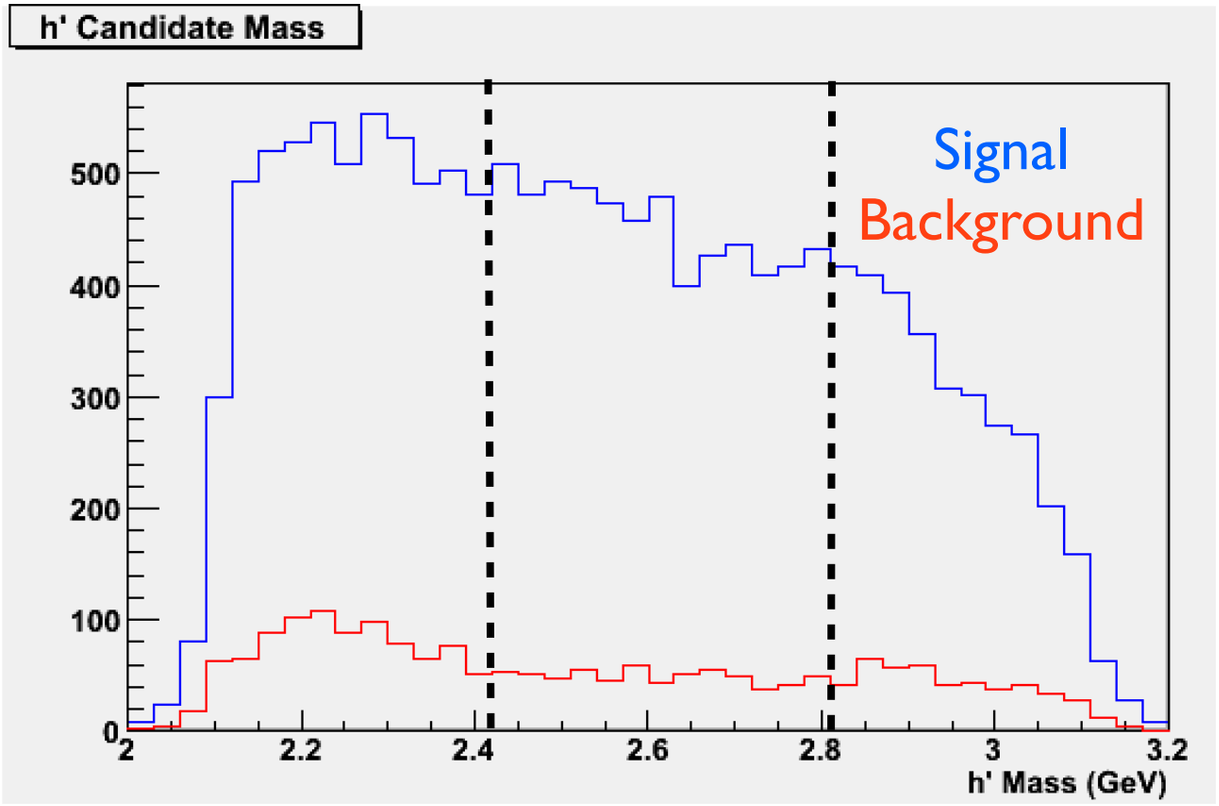
Highest ranked variables:

Kinematic Fit

PID information

χ^2 variables

h’(2600) w/o CKOV



BDT Cut and
±1.5 Γ cut on K_1, K* and h’ masses

For cuts-based adjusted KinFit CL cut to achieve purity = 0.9

Analysis	Selection Efficiency	Purity
Cuts (w/o CKOV)	0.06	0.90
BDT (w/o CKOV)	0.30	0.90

CKOV FOM

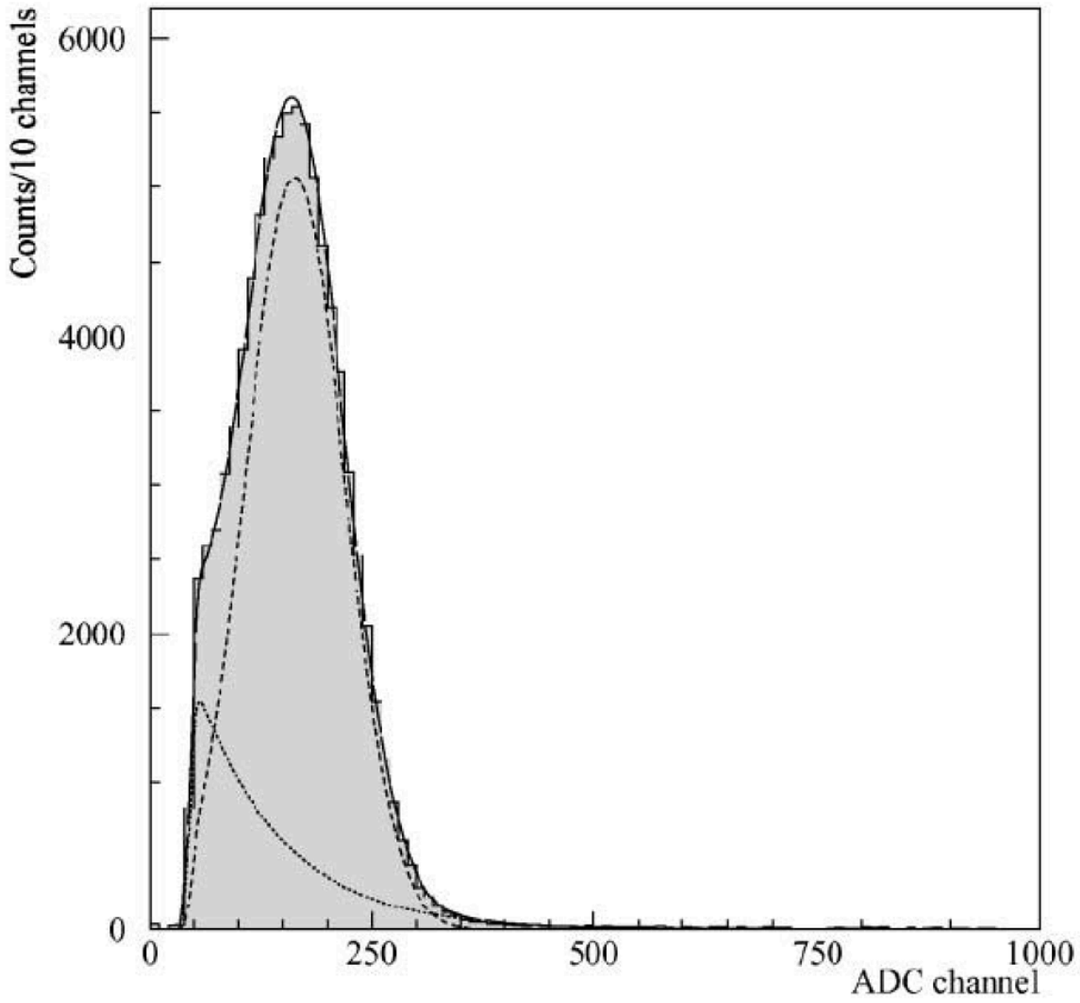
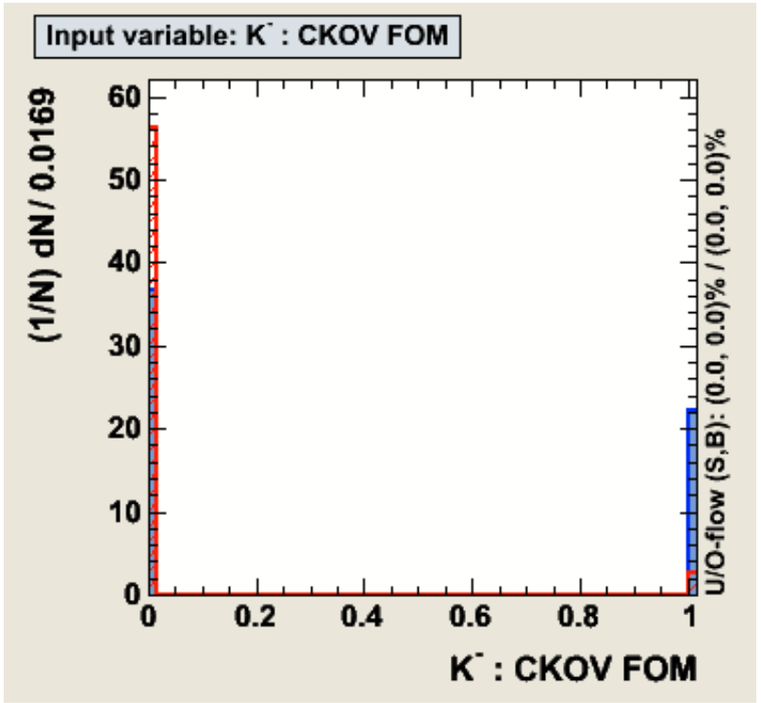
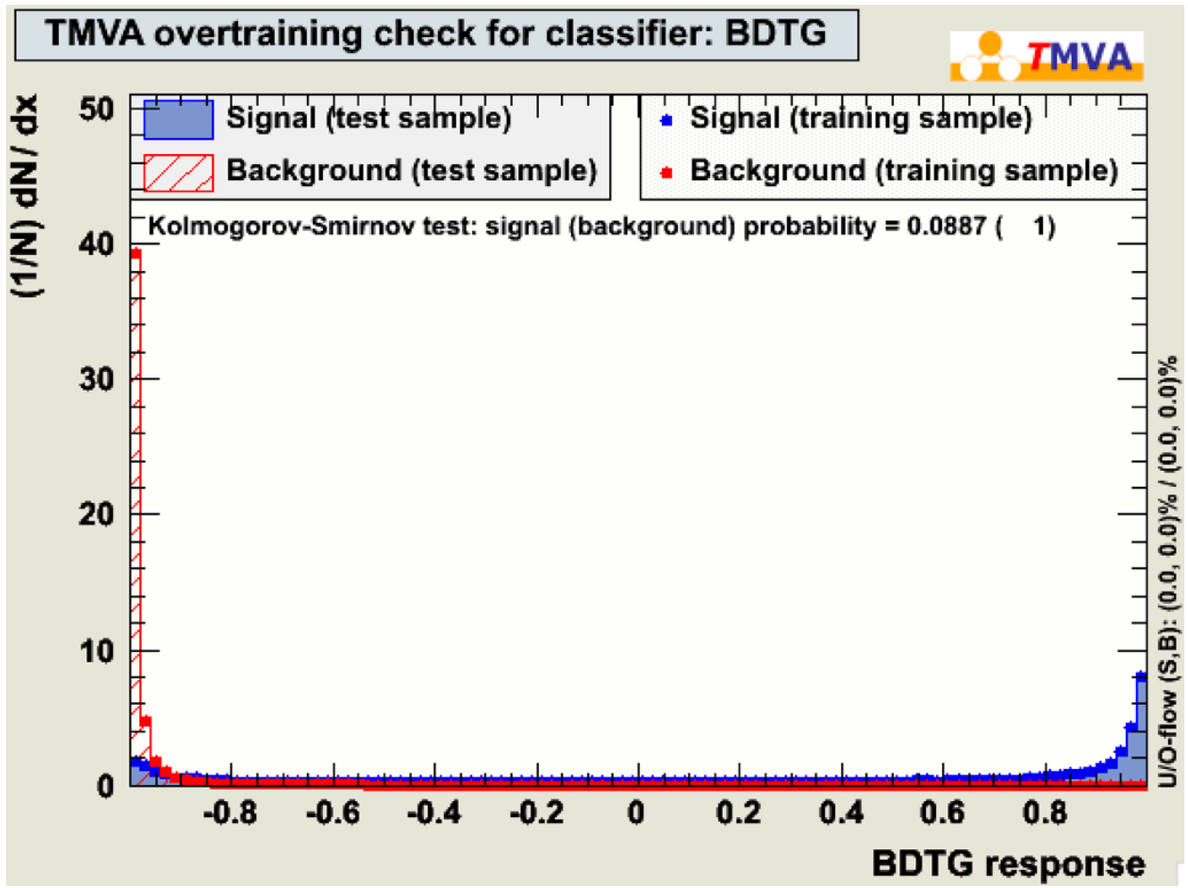


Fig. 13. A typical ADC spectrum showing the single photo-electron peak (dashed line) and the electronic noise (dotted line). The solid curve shows the sum of the two separate components. The PMT threshold is typically approximately 1/4 of the single photoelectron peak position.

- Take PMT noise shape from CLAS Cherenkov
- Assume conservative noise rate of 10^4 Hz and a 200 ns window
- Smear PMT response to each PE with a Gaussian
- Poisson probability of number of "detected" PE with the number of expected PE (based on momentum and amount of gas)



h'(2600) w/ CKOV



Highest ranked variables:

Kinematic Fit

PID information

χ^2 variables

Particle codes:

p1 = π+

p2 = π-

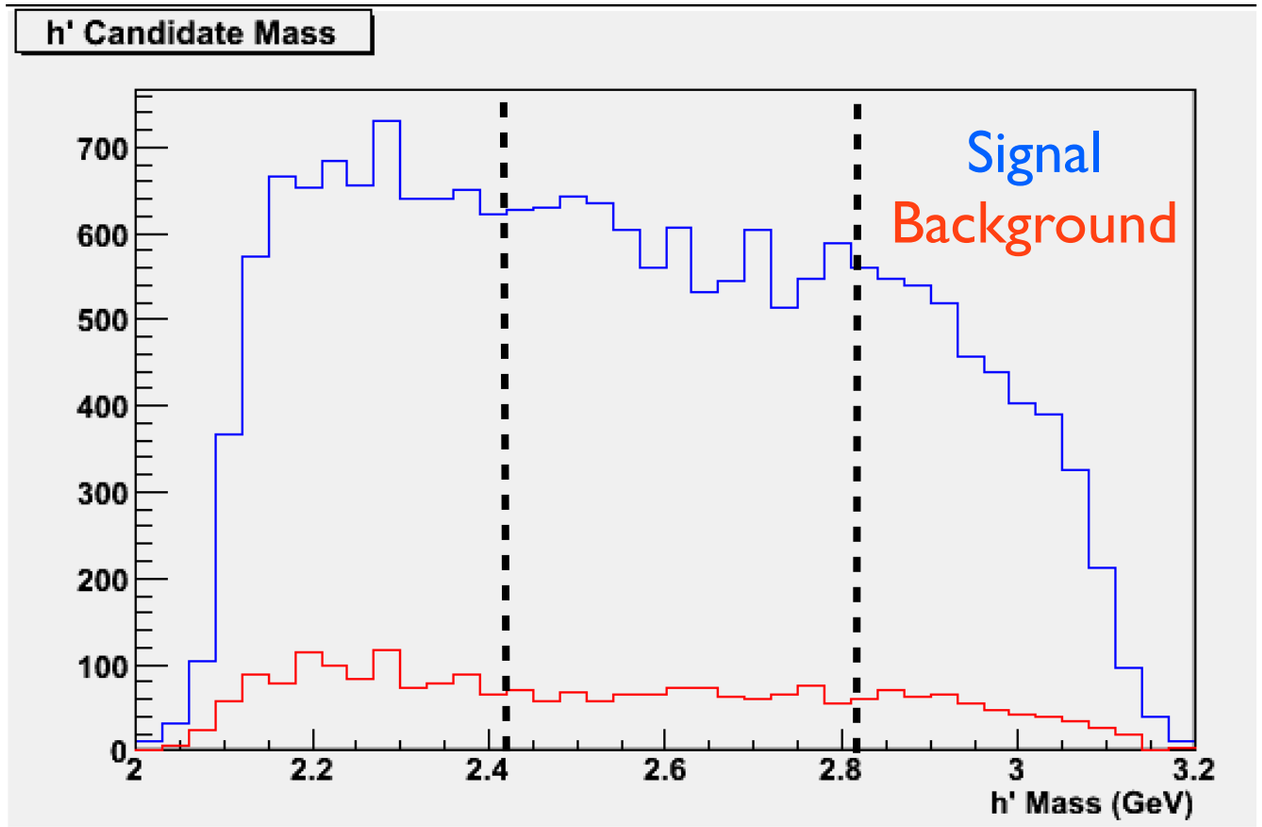
p3 = K+

p4 = K-

p5 = proton

```
--- Factory             : Begin ranking of input variables...
--- BDTG                : Ranking result (top variable is best ranked)
--- BDTG                : ----------------------------------------------
--- BDTG                : Rank :Variable         :Variable Importance
--- BDTG                : ----------------------------------------------
--- BDTG                :    1 : kinFitCL        : 1.756e-01
--- BDTG                :    2 : p4_ckovFOM      : 1.492e-01
--- BDTG                :    3 : isolatedBCALSumE : 1.085e-01
--- BDTG                :    4 : p3_ckovFOM      : 7.703e-02
--- BDTG                :    5 : isolatedTrackSumP : 5.369e-02
--- BDTG                :    6 : p5_dEdxFOM      : 5.218e-02
--- BDTG                :    7 : p3_timeFOM      : 5.007e-02
--- BDTG                :    8 : PV_r            : 3.238e-02
--- BDTG                :    9 : p3_dEdxFOM      : 2.974e-02
--- BDTG                :   10 : isolatedFCALSumE : 2.428e-02
--- BDTG                :   11 : p1_ckovFOM      : 2.217e-02
--- BDTG                :   12 : p5_timeFOM      : 1.930e-02
--- BDTG                :   13 : p1_timeFOM      : 1.851e-02
--- BDTG                :   14 : p1_ChiSqIP      : 1.742e-02
--- BDTG                :   15 : p5_ChiSqIP      : 1.639e-02
--- BDTG                :   16 : p2_dEdxFOM      : 1.591e-02
--- BDTG                :   17 : p3_ChiSq        : 1.474e-02
--- BDTG                :   18 : p1_dEdxFOM      : 1.396e-02
--- BDTG                :   19 : p5_ckovFOM      : 1.395e-02
--- BDTG                :   20 : PV_ChiSq        : 1.232e-02
--- BDTG                :   21 : p3_ChiSqIP      : 1.191e-02
--- BDTG                :   22 : p4_timeFOM      : 1.131e-02
--- BDTG                :   23 : p2_timeFOM      : 1.039e-02
--- BDTG                :   24 : p2_ChiSqIP      : 9.172e-03
--- BDTG                :   25 : p4_dEdxFOM      : 8.990e-03
--- BDTG                :   26 : p2_ckovFOM      : 8.897e-03
--- BDTG                :   27 : p1_ChiSq        : 8.473e-03
--- BDTG                :   28 : p2_ChiSq        : 8.209e-03
--- BDTG                :   29 : p4_ChiSqIP      : 3.481e-03
--- BDTG                :   30 : p4_ChiSq        : 1.853e-03
--- BDTG                :   31 : p5_ChiSq        : 0.000e+00
--- BDTG                : ----------------------------------------------
```

h’(2600) w/ CKOV

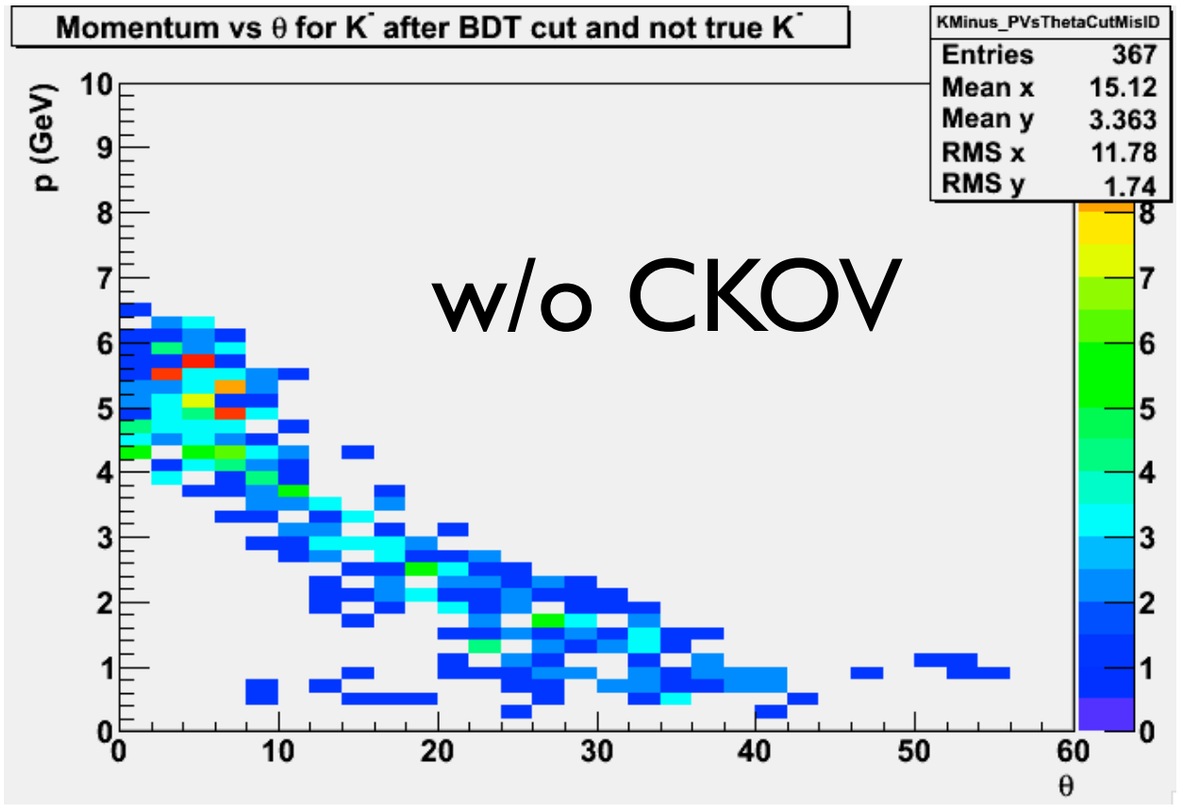


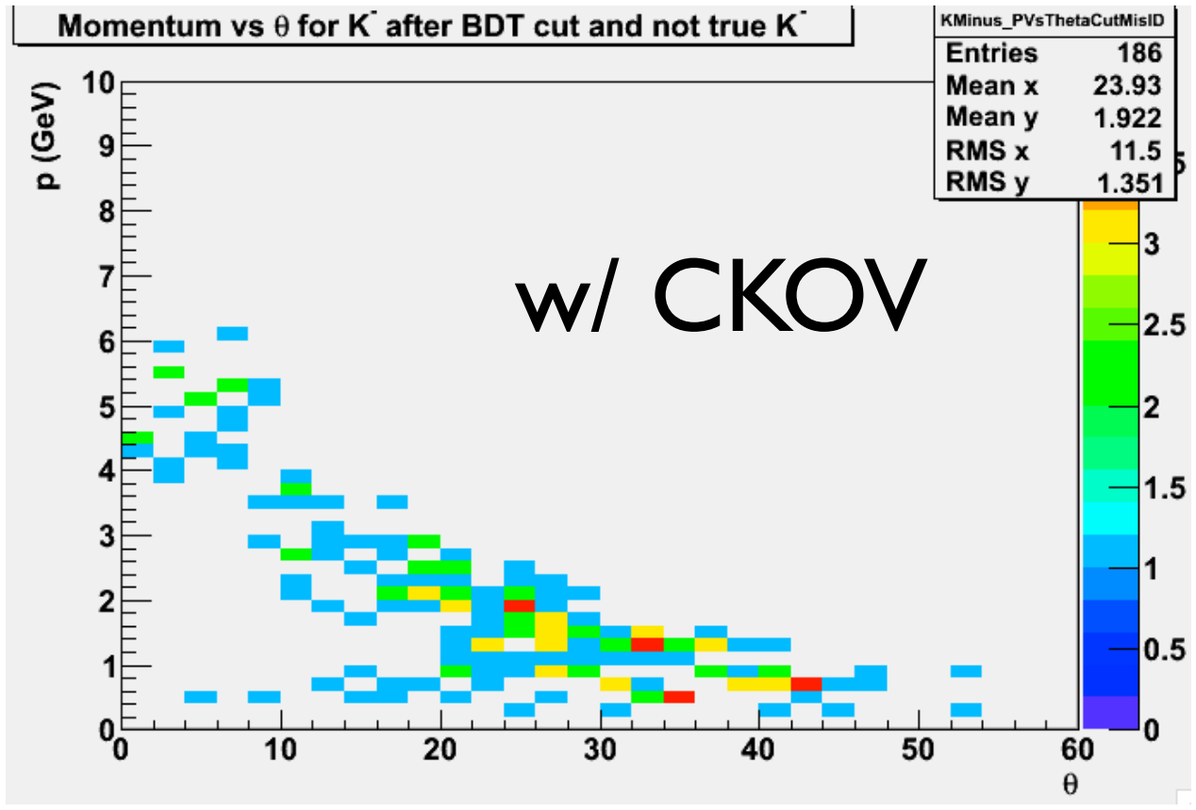
BDT Cut and
±1.5 Γ cut on K_1, K* and h’ masses

Remaining background:
5% True PID but not exclusive
10% Correct topology but Proton ↔ K+
50% Correct topology but π+ ↔ K+
15% Correct topology but π- ↔ K-

Analysis	Selection Efficiency	Purity
Cuts (w/o CKOV)	0.06	0.90
BDT (w/o CKOV)	0.30	0.90
BDT (w/ CKOV)	0.37	0.90

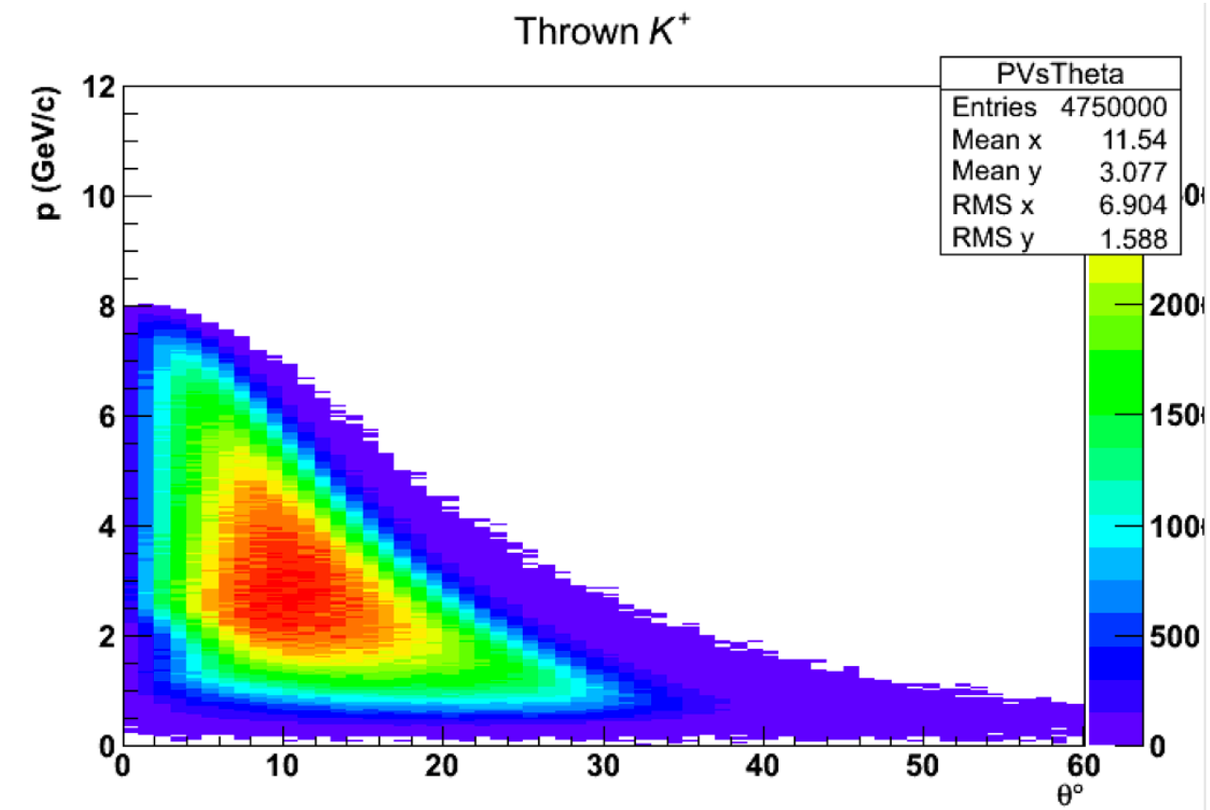
Remaining Backgrounds





- Most of background with mis-ID K- in the CKOV acceptance are removed

η‘(2300)

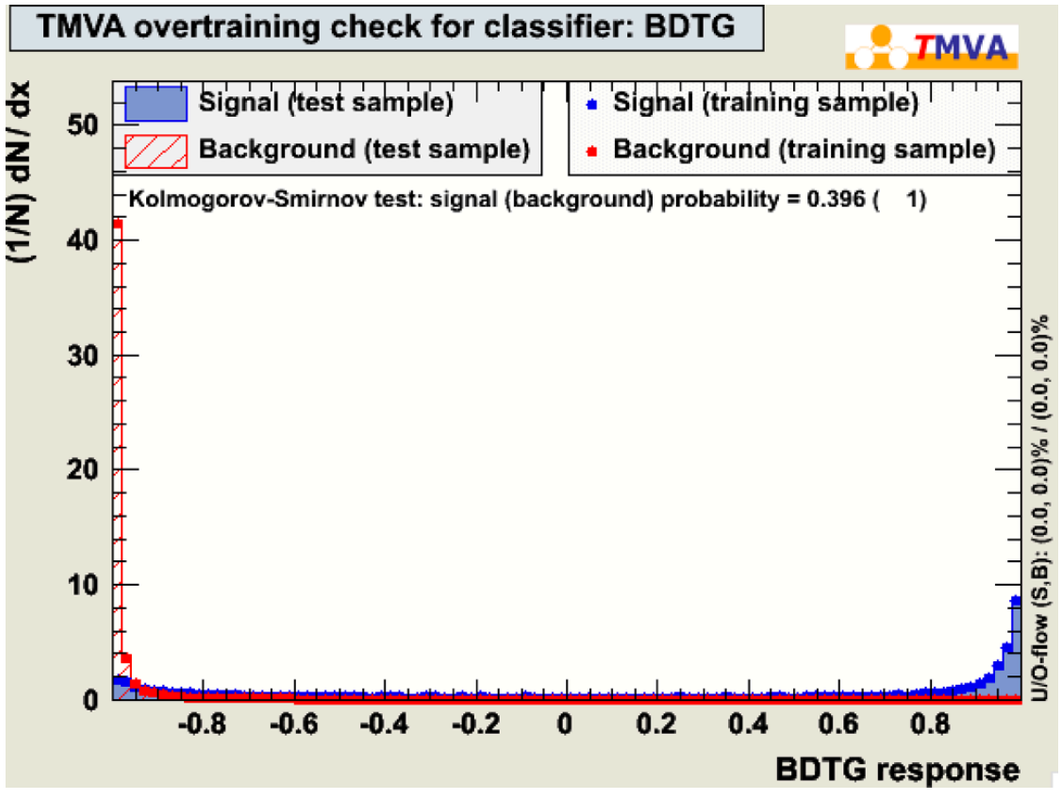


$$\gamma p \to \eta_1'(2300) p$$
$$\eta_1'(2300) \to K^*(892)^0 K_s^0$$
$$K^*(892)^0 \to K^+ \pi^-$$
$$K_s^0 \to \pi^+ \pi^-$$

- Data samples (data challenge bggen with $8.4<E_\gamma<9$ GeV):
  - Signal: Exclusive requirement on final state p, K+, π-, $K_s \to$ π+ π-
  - Background: All bggen not satisfying signal requirement
- All particle combinations are considered with **no cuts** applied before the decision tree
- Only reconstructed proton considered

Note: Displaced vertex!

η'(2300) w/o CKOV



Highest ranked variables:

Kinematic Fit

Secondary vertex displacement

PID information

χ^2 variables

Particle codes:

p1 = π+ (Ks)

p2 = π- (Ks)

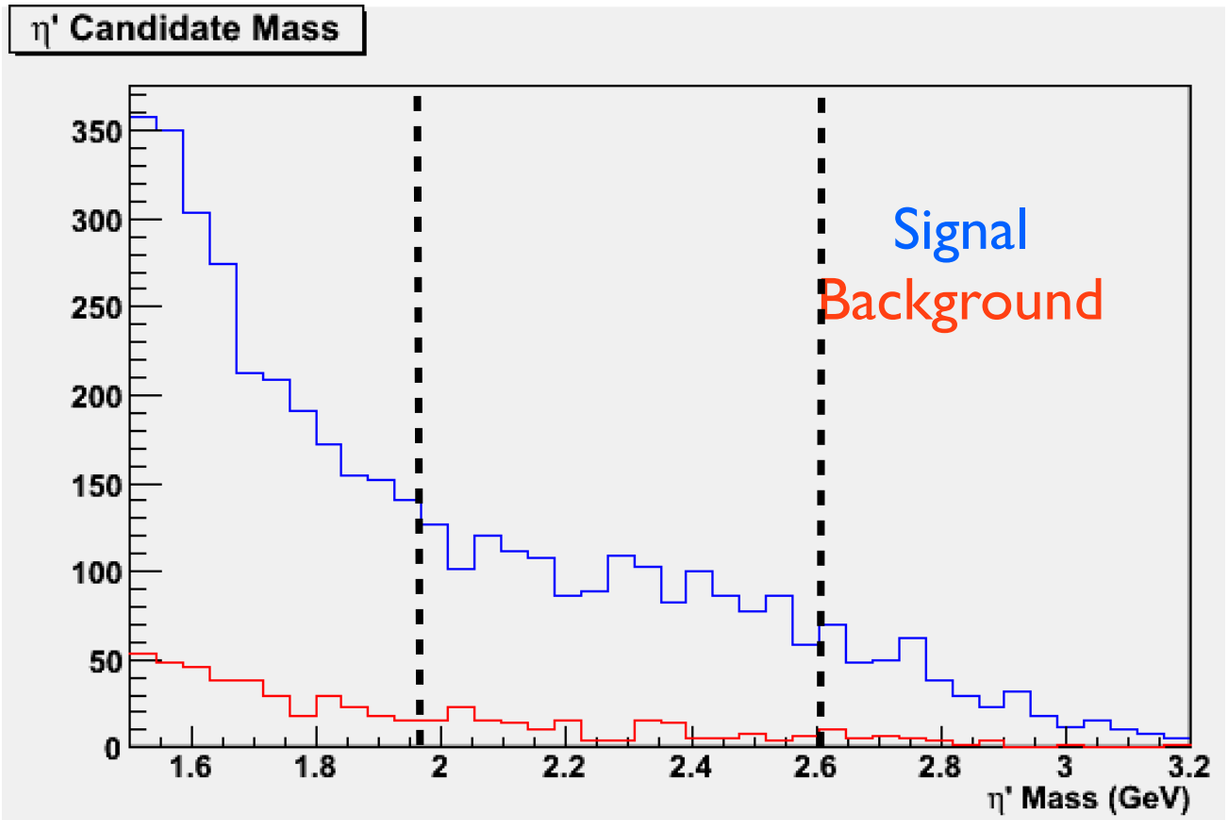
p3 = K+ (K*)

p4 = π- (K*)

p5 = proton

```
--- Factory             : Begin ranking of input variables...
--- BDTG                : Ranking result (top variable is best ranked)
--- BDTG                : ----------------------------------------------------------
--- BDTG                : Rank : Variable                 : Variable Importance
--- BDTG                : ----------------------------------------------------------
--- BDTG                :    1 : SV_flightSignificanceDelZ : 2.853e-01
--- BDTG                :    2 : isolatedBCALSumE          : 1.208e-01
--- BDTG                :    3 : kinFitCL                  : 1.176e-01
--- BDTG                :    4 : SV_ChiSq                  : 7.346e-02
--- BDTG                :    5 : p3_timeFOM                : 5.381e-02
--- BDTG                :    6 : p5_dEdxFOM                : 4.984e-02
--- BDTG                :    7 : SV_flightSignificanceDelR : 4.771e-02
--- BDTG                :    8 : p5_ChiSq                  : 3.124e-02
--- BDTG                :    9 : PV_r                      : 3.062e-02
--- BDTG                :   10 : p4_timeFOM                : 2.355e-02
--- BDTG                :   11 : p5_timeFOM                : 2.122e-02
--- BDTG                :   12 : p4_dEdxFOM                : 1.854e-02
--- BDTG                :   13 : p3_dEdxFOM                : 1.670e-02
--- BDTG                :   14 : p1_timeFOM                : 1.440e-02
--- BDTG                :   15 : p2_timeFOM                : 1.432e-02
--- BDTG                :   16 : SV_ChiSqIP                : 1.392e-02
--- BDTG                :   17 : isolatedFCALSumE          : 1.269e-02
--- BDTG                :   18 : p2_dEdxFOM                : 9.421e-03
--- BDTG                :   19 : p5_ChiSqIP                : 8.220e-03
--- BDTG                :   20 : p2_ChiSq                  : 7.217e-03
--- BDTG                :   21 : p1_dEdxFOM                : 6.540e-03
--- BDTG                :   22 : p4_ChiSqIP                : 6.205e-03
--- BDTG                :   23 : isolatedTrackSumP         : 5.282e-03
--- BDTG                :   24 : p3_ChiSq                  : 5.192e-03
--- BDTG                :   25 : PV_ChiSq                  : 3.040e-03
--- BDTG                :   26 : p3_ChiSqIP                : 1.764e-03
--- BDTG                :   27 : p4_ChiSq                  : 1.008e-03
--- BDTG                :   28 : p1_ChiSq                  : 3.971e-04
--- BDTG                : ----------------------------------------------------------
```

η’(2300) w/o CKOV

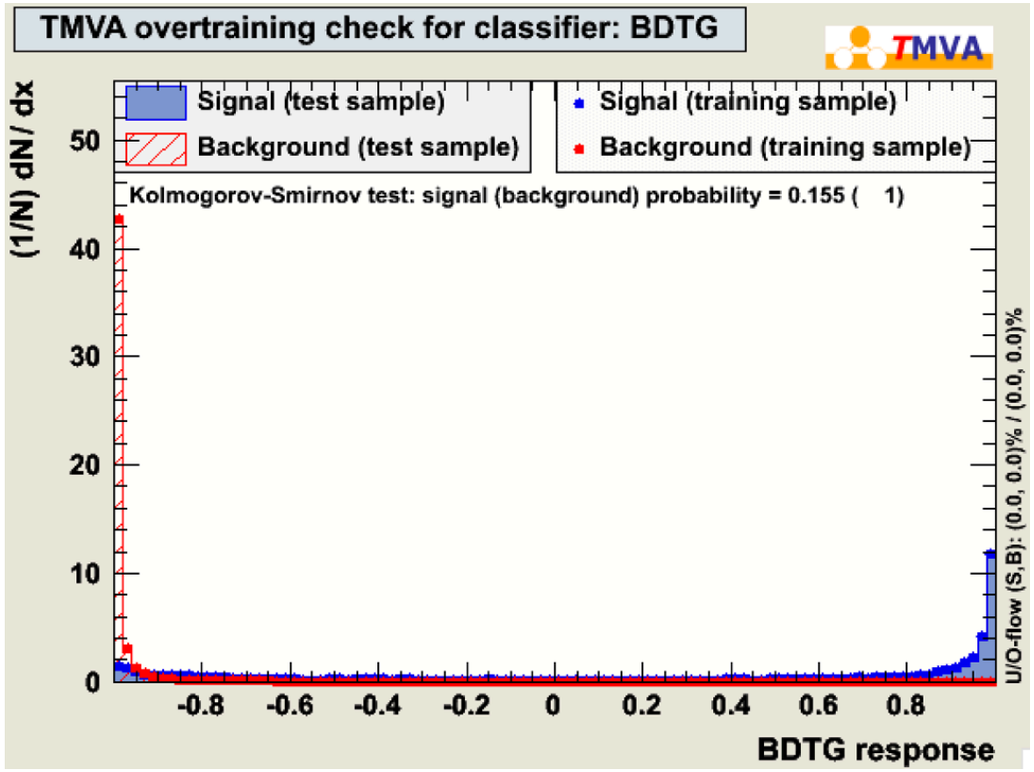


BDT Cut and
±1.5 Γ cut on K* and η’ masses

For cuts-based adjusted KinFit CL
cut to achieve purity = 0.9

Analysis	Selection Efficiency	Purity
Cuts (w/o CKOV)	0.08	0.90
BDT (w/o CKOV)	0.33	0.90

η'(2300) w/ CKOV



Highest ranked variables:

Kinematic Fit

Secondary vertex displacement

PID information

χ^2 variables

Particle codes:

p1 = π+ (Ks)

p2 = π- (Ks)

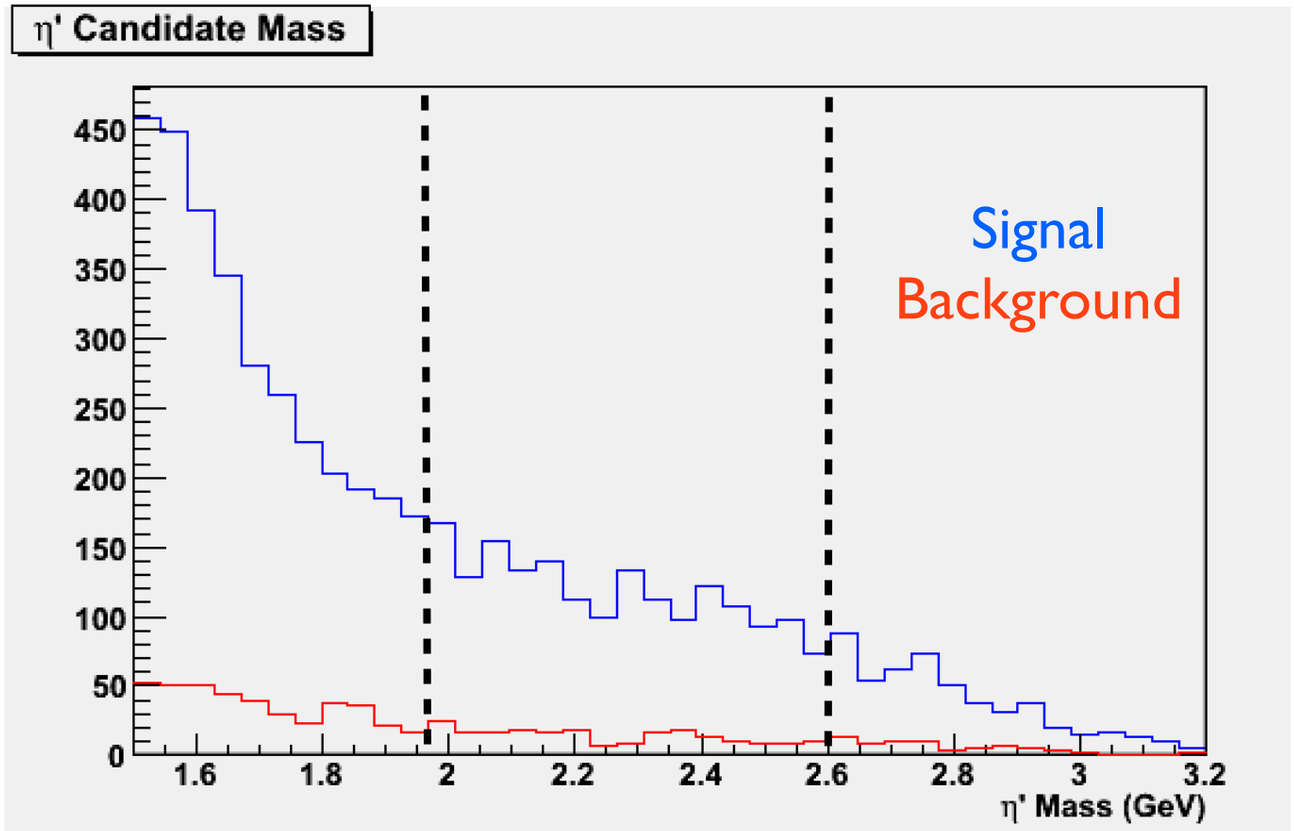
p3 = K+ (K*)

p4 = π- (K*)

p5 = proton

```
--- Factory             : Begin ranking of input variables...
--- BDTG                : Ranking result (top variable is best ranked)
--- BDTG                : ----------------------------------------------------------
--- BDTG                : Rank :Variable                 :Variable Importance
--- BDTG                : ----------------------------------------------------------
--- BDTG                :    1 : SV_flightSignificanceDelZ : 2.475e-01
--- BDTG                :    2 : isolatedBCALSumE          : 1.201e-01
--- BDTG                :    3 : kinFitCL                  : 1.052e-01
--- BDTG                :    4 : p3_ckovFOM                : 6.740e-02
--- BDTG                :    5 : SV_ChiSq                  : 4.182e-02
--- BDTG                :    6 : p2_ckovFOM                : 4.144e-02
--- BDTG                :    7 : p3_timeFOM                : 3.915e-02
--- BDTG                :    8 : PV_r                      : 3.861e-02
--- BDTG                :    9 : p1_ckovFOM                : 3.348e-02
--- BDTG                :   10 : SV_flightSignificanceDelR : 2.977e-02
--- BDTG                :   11 : p5_ChiSq                  : 2.854e-02
--- BDTG                :   12 : p4_dEdxFOM                : 2.714e-02
--- BDTG                :   13 : p1_timeFOM                : 2.209e-02
--- BDTG                :   14 : p3_dEdxFOM                : 1.713e-02
--- BDTG                :   15 : p5_dEdxFOM                : 1.604e-02
--- BDTG                :   16 : p4_timeFOM                : 1.601e-02
--- BDTG                :   17 : SV_ChiSqIP                : 1.339e-02
--- BDTG                :   18 : p2_dEdxFOM                : 1.323e-02
--- BDTG                :   19 : p1_dEdxFOM                : 1.229e-02
--- BDTG                :   20 : p5_timeFOM                : 1.143e-02
--- BDTG                :   21 : p4_ckovFOM                : 9.079e-03
--- BDTG                :   22 : p4_ChiSq                  : 8.729e-03
--- BDTG                :   23 : isolatedFCALSumE          : 8.360e-03
--- BDTG                :   24 : p2_timeFOM                : 7.071e-03
--- BDTG                :   25 : PV_ChiSq                  : 6.105e-03
--- BDTG                :   26 : p3_ChiSq                  : 6.055e-03
--- BDTG                :   27 : isolatedTrackSumP         : 5.687e-03
--- BDTG                :   28 : p2_ChiSq                  : 4.487e-03
--- BDTG                :   29 : p4_ChiSqIP                : 2.574e-03
--- BDTG                :   30 : p1_ChiSq                  : 0.000e+00
--- BDTG                :   31 : p3_ChiSqIP                : 0.000e+00
--- BDTG                :   32 : p5_ChiSqIP                : 0.000e+00
--- BDTG                :   33 : p5_ckovFOM                : 0.000e+00
--- BDTG                : ----------------------------------------------------------
```

η'(2300) w/ CKOV

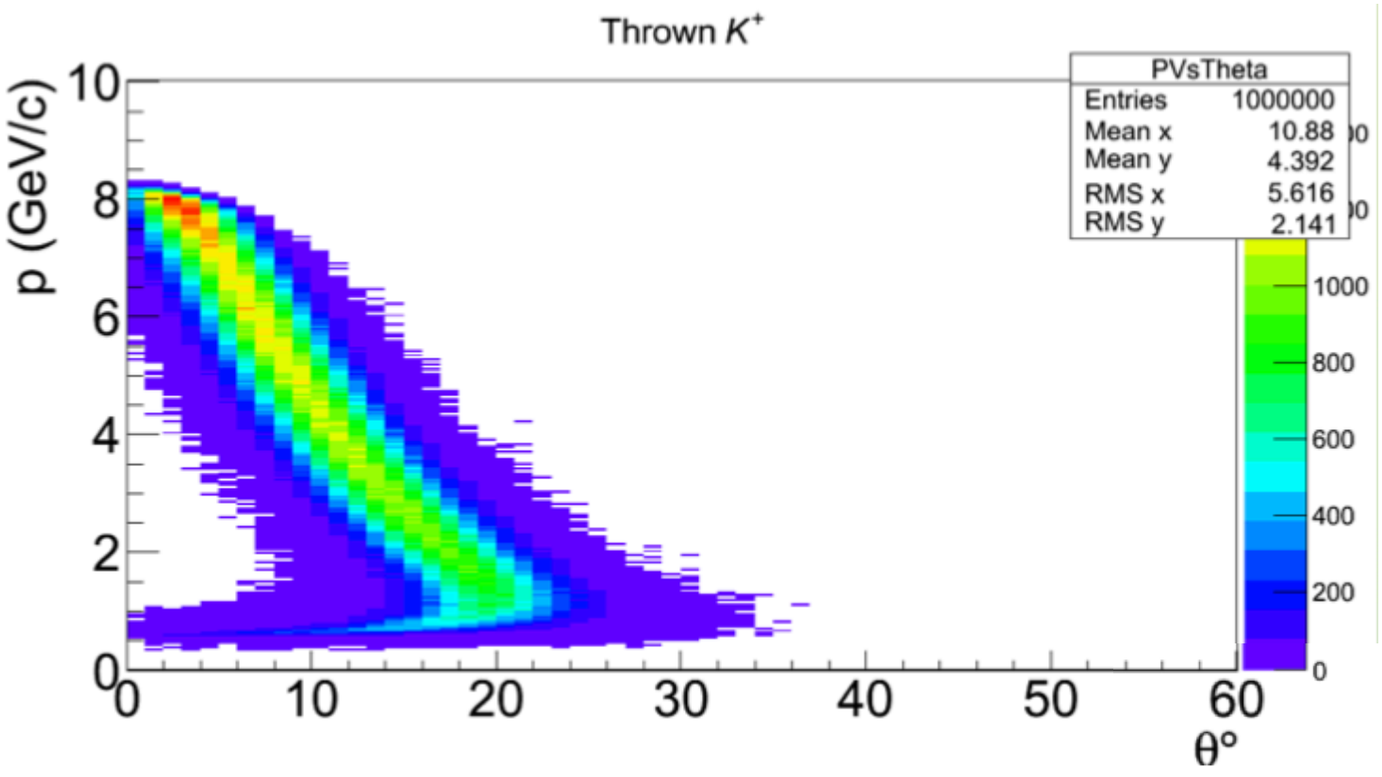


BDT Cut and
±1.5 Γ cut on K* and η' masses

Remaining background:
10% True PID but not exclusive
10% Correct topology but Proton ⟷ K+
80% K- π+ K_s (really signal with $\overline{K}$*)

Analysis	Selection Efficiency	Purity
Cuts (w/o CKOV)	0.08	0.90
BDT (w/o CKOV)	0.33	0.90
BDT (w/ CKOV)	0.41	0.90

ϕ(1850)

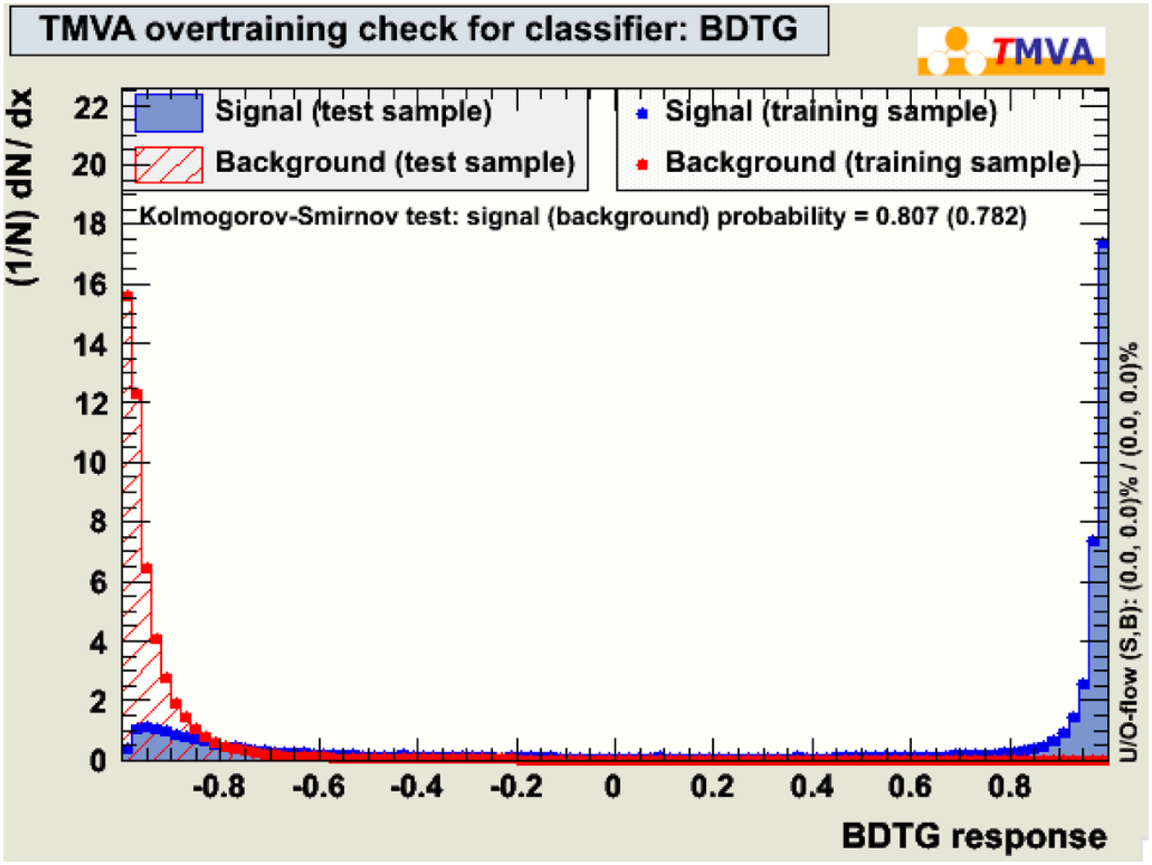


$$\gamma p \to \phi(1850) p$$

$$\phi(1850) \to K^+ K^-$$

- Data samples (data challenge bggen with $8.4<E_\gamma<9$ GeV):
  - Signal: Exclusive requirement on final state p, K+, K-
  - Background: All bggen not satisfying signal requirement
- All particle combinations are considered with **no cuts** applied before the decision tree
- Only reconstructed proton considered

ϕ(1850) w/o CKOV




```
--- Factory             : Begin ranking of input variables...
--- BDTG                : Ranking result (top variable is best ranked)
--- BDTG                : ----------------------------------------------
--- BDTG                : Rank :Variable         :Variable Importance
--- BDTG                : ----------------------------------------------
--- BDTG                :    1 : kinFitCL        : 1.250e-01
--- BDTG                :    2 : p5_dEdxFOM      : 1.249e-01
--- BDTG                :    3 : p5_ChiSq        : 9.285e-02
--- BDTG                :    4 : p3_dEdxFOM      : 8.806e-02
--- BDTG                :    5 : isolatedBCALSumE : 7.638e-02
--- BDTG                :    6 : p5_ChiSqIP      : 6.871e-02
--- BDTG                :    7 : p3_ChiSq        : 6.762e-02
--- BDTG                :    8 : p3_timeFOM      : 6.480e-02
--- BDTG                :    9 : p4_ChiSq        : 5.686e-02
--- BDTG                :   10 : p4_timeFOM      : 5.345e-02
--- BDTG                :   11 : isolatedTrackSumP : 3.423e-02
--- BDTG                :   12 : isolatedFCALSumE : 2.992e-02
--- BDTG                :   13 : PV_r            : 2.810e-02
--- BDTG                :   14 : PV_ChiSq        : 2.741e-02
--- BDTG                :   15 : p5_timeFOM      : 2.591e-02
--- BDTG                :   16 : p4_dEdxFOM      : 2.215e-02
--- BDTG                :   17 : p3_ChiSqIP      : 8.943e-03
--- BDTG                :   18 : p4_ChiSqIP      : 4.709e-03
--- BDTG                : ----------------------------------------------
```

Highest ranked variables:

Kinematic Fit

PID information

χ^2 variables

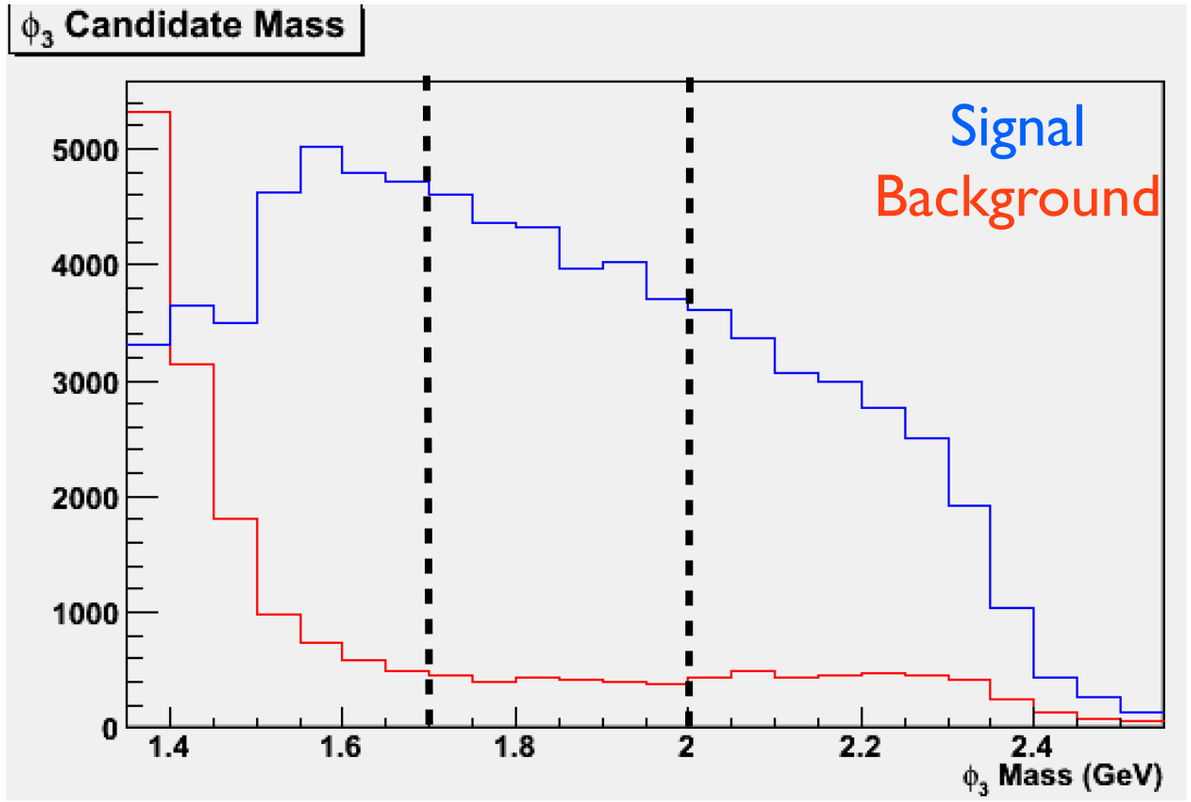
Particle codes:

p3 = K+

p4 = K-

p5 = proton

ϕ(1850) w/o CKOV



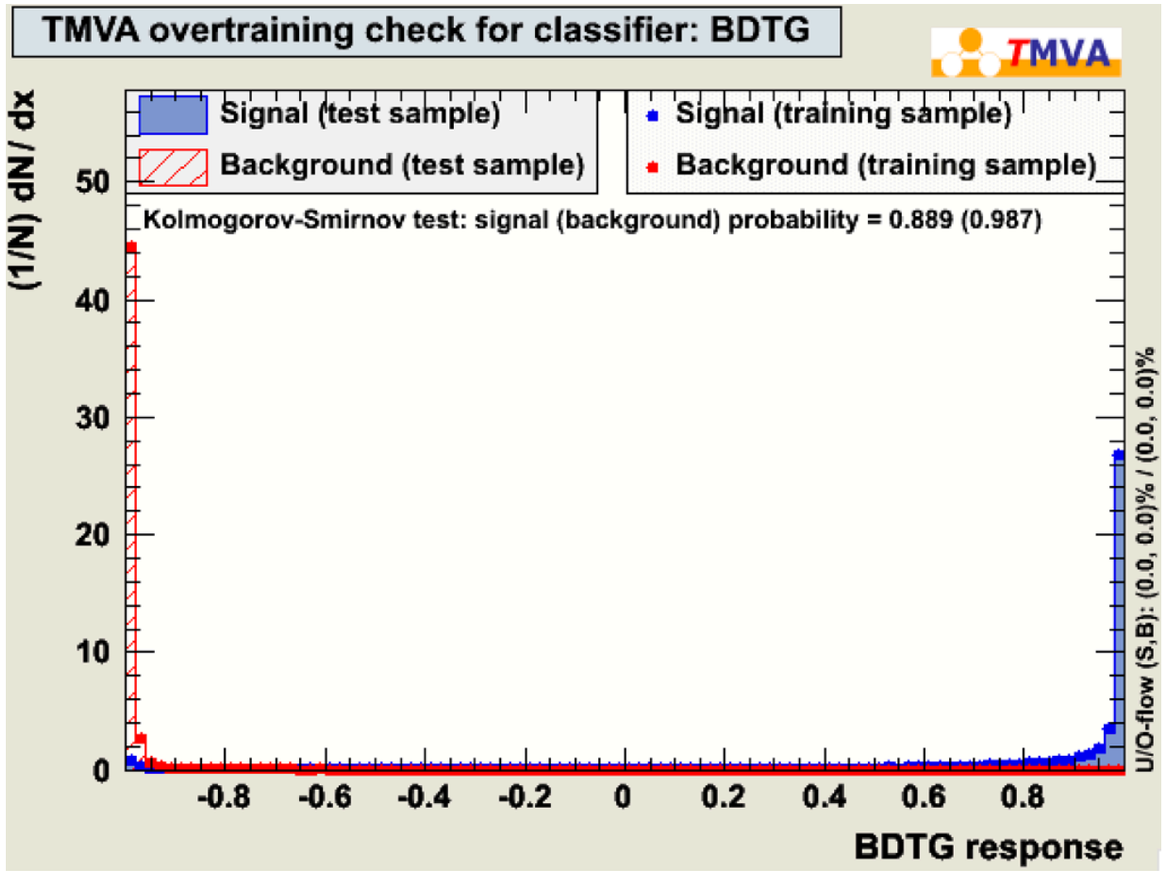
BDT Cut and
±1.5 Γ cut on ϕ mass

For cuts-based adjusted KinFit CL cut
to achieve purity = 0.9

Background at low mass is a πππ
resonance at ~1250 MeV

Analysis	Selection Efficiency	Purity
Cuts (w/o CKOV)	0.25	0.90
BDT (w/o CKOV)	0.69	0.90

ϕ(1850) w/ CKOV




```
--- Factory             : Begin ranking of input variables...
--- BDTG                : Ranking result (top variable is best ranked)
--- BDTG                : ----------------------------------------------
--- BDTG                : Rank :Variable          :Variable Importance
--- BDTG                : ----------------------------------------------
--- BDTG                :    1 : p4_ckovFOM       : 2.204e-01
--- BDTG                :    2 : kinFitCL         : 1.337e-01
--- BDTG                :    3 : p3_ckovFOM       : 1.305e-01
--- BDTG                :    4 : isolatedTrackSumP : 8.888e-02
--- BDTG                :    5 : isolatedBCALSumE  : 7.644e-02
--- BDTG                :    6 : p4_timeFOM       : 5.269e-02
--- BDTG                :    7 : p5_dEdxFOM       : 3.937e-02
--- BDTG                :    8 : p3_dEdxFOM       : 3.722e-02
--- BDTG                :    9 : p3_ChiSqIP       : 3.561e-02
--- BDTG                :   10 : p5_ChiSq         : 3.074e-02
--- BDTG                :   11 : p3_timeFOM       : 2.705e-02
--- BDTG                :   12 : p4_ChiSqIP       : 1.981e-02
--- BDTG                :   13 : PV_r             : 1.930e-02
--- BDTG                :   14 : isolatedFCALSumE  : 1.930e-02
--- BDTG                :   15 : p4_dEdxFOM       : 1.521e-02
--- BDTG                :   16 : p5_ChiSqIP       : 1.384e-02
--- BDTG                :   17 : p4_ChiSq         : 1.358e-02
--- BDTG                :   18 : p5_timeFOM       : 1.099e-02
--- BDTG                :   19 : p3_ChiSq         : 8.201e-03
--- BDTG                :   20 : PV_ChiSq         : 3.835e-03
--- BDTG                :   21 : p5_ckovFOM       : 3.301e-03
--- BDTG                : ----------------------------------------------
```

Highest ranked variables:

Kinematic Fit

PID information

χ^2 variables

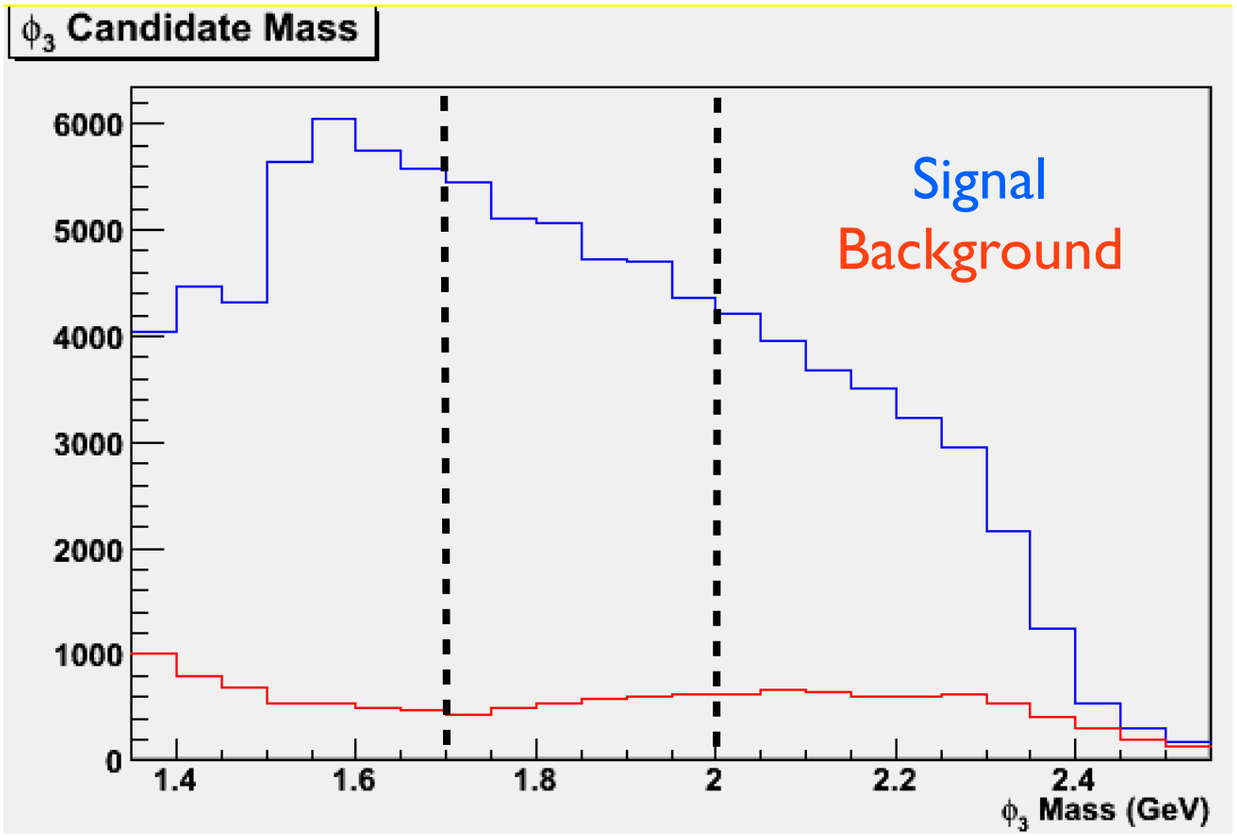
Particle codes:

p3 = K+

p4 = K-

p5 = proton

ϕ(1850) w/ CKOV



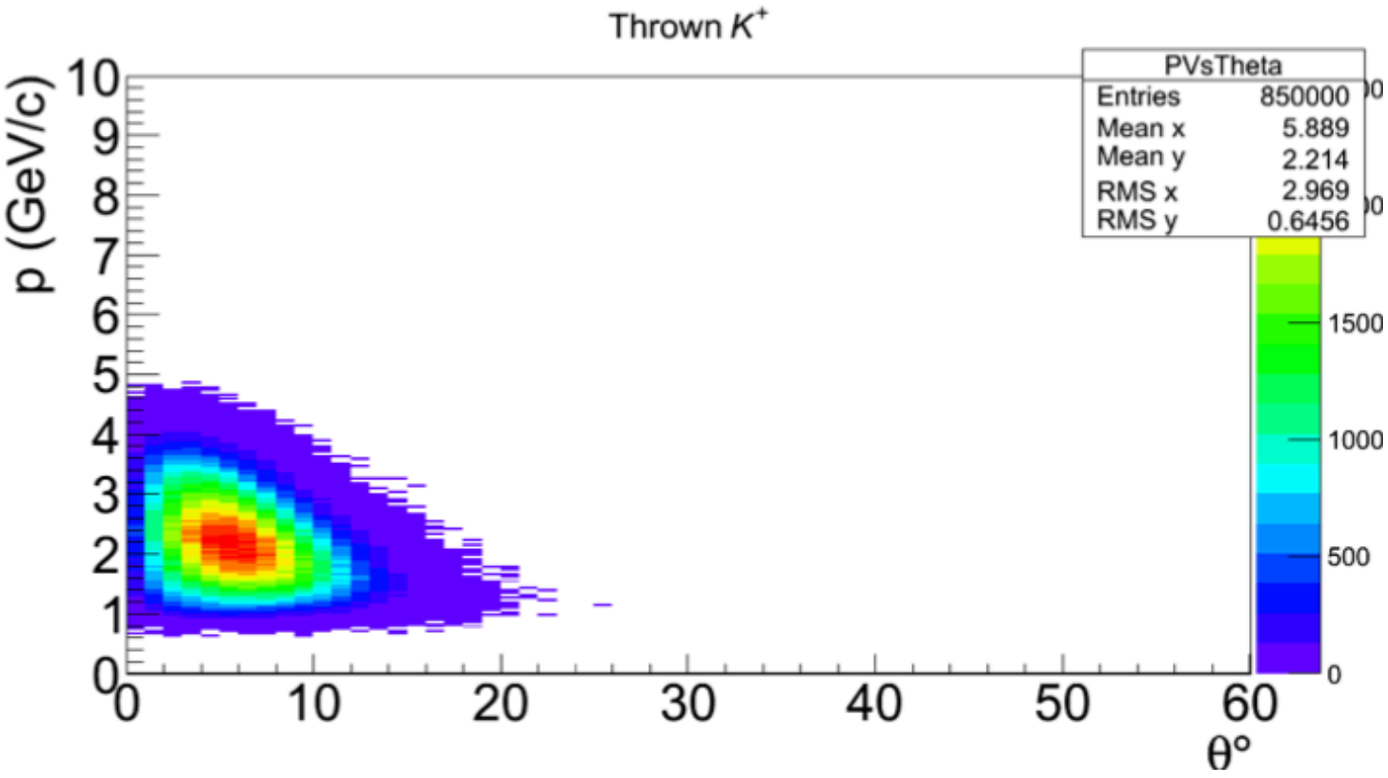
BDT Cut and
±1.5 Γ cut on ϕ mass

Remaining background:
25% True PID but not exclusive
25% Correct topology but Proton ⟷ K+
10% True track PID: pi+ pi- p
15% True track PID: K+ pi- p
15% True track PID: K- pi+ p

Missing tracks (to be studied)

Analysis	Selection Efficiency	Purity
Cuts (w/o CKOV)	0.25	0.90
BDT (w/o CKOV)	0.69	0.90
BDT (w/ CKOV)	0.82	0.90

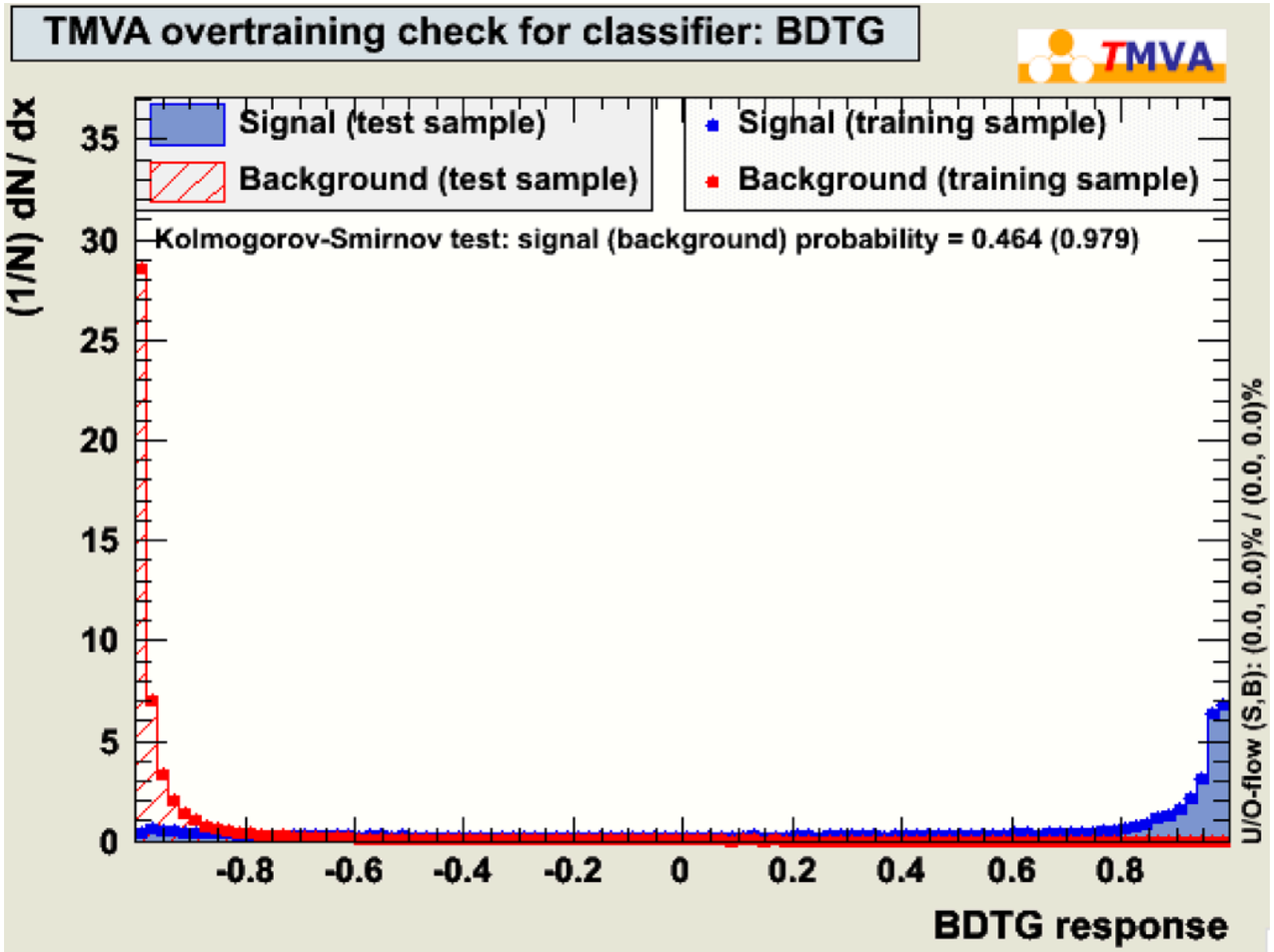
Y(2175)



$$\gamma p \to Y(2175)p$$
$$Y(2175) \to \phi\ f_0(980)$$
$$\phi \to K^+K^-$$
$$f_0(980) \to \pi^+\pi^-$$

- Data samples (data challenge bggen with $8.4<E_\gamma<9$ GeV):
  - Signal: Exclusive requirement on final state p, K+, K-, π+, π-
  - Background: All bggen not satisfying signal requirement
- All particle combinations are considered with **no cuts** applied before the decision tree
- Only reconstructed proton considered

Y(2175) w/o CKOV




```
--- Factory             : Begin ranking of input variables...
--- BDTG                : Ranking result (top variable is best ranked)
--- BDTG                : ----------------------------------------------
--- BDTG                : Rank :Variable          :Variable Importance
--- BDTG                : ----------------------------------------------
--- BDTG                :    1 : p3_timeFOM       : 1.208e-01
--- BDTG                :    2 : kinFitCL         : 1.131e-01
--- BDTG                :    3 : isolatedBCALSumE : 8.879e-02
--- BDTG                :    4 : p4_timeFOM       : 7.968e-02
--- BDTG                :    5 : p5_dEdxFOM       : 7.414e-02
--- BDTG                :    6 : p5_ChiSq         : 7.411e-02
--- BDTG                :    7 : PV_r             : 3.636e-02
--- BDTG                :    8 : p1_timeFOM       : 3.443e-02
--- BDTG                :    9 : PV_ChiSq         : 3.310e-02
--- BDTG                :   10 : p3_dEdxFOM       : 3.188e-02
--- BDTG                :   11 : p4_ChiSqIP       : 2.896e-02
--- BDTG                :   12 : p5_ChiSqIP       : 2.873e-02
--- BDTG                :   13 : p2_timeFOM       : 2.706e-02
--- BDTG                :   14 : p5_timeFOM       : 2.480e-02
--- BDTG                :   15 : p3_ChiSqIP       : 2.434e-02
--- BDTG                :   16 : p2_ChiSqIP       : 2.373e-02
--- BDTG                :   17 : p1_ChiSqIP       : 2.372e-02
--- BDTG                :   18 : p1_ChiSq         : 2.171e-02
--- BDTG                :   19 : isolatedTrackSumP : 2.125e-02
--- BDTG                :   20 : p1_dEdxFOM       : 2.116e-02
--- BDTG                :   21 : p2_dEdxFOM       : 1.838e-02
--- BDTG                :   22 : p2_ChiSq         : 1.528e-02
--- BDTG                :   23 : isolatedFCALSumE  : 1.358e-02
--- BDTG                :   24 : p3_ChiSq         : 9.185e-03
--- BDTG                :   25 : p4_dEdxFOM       : 8.711e-03
--- BDTG                :   26 : p4_ChiSq         : 3.033e-03
--- BDTG                : ----------------------------------------------
```

Highest ranked variables:

Kinematic Fit

PID information

χ^2 variables

Particle codes:

p1 = π+

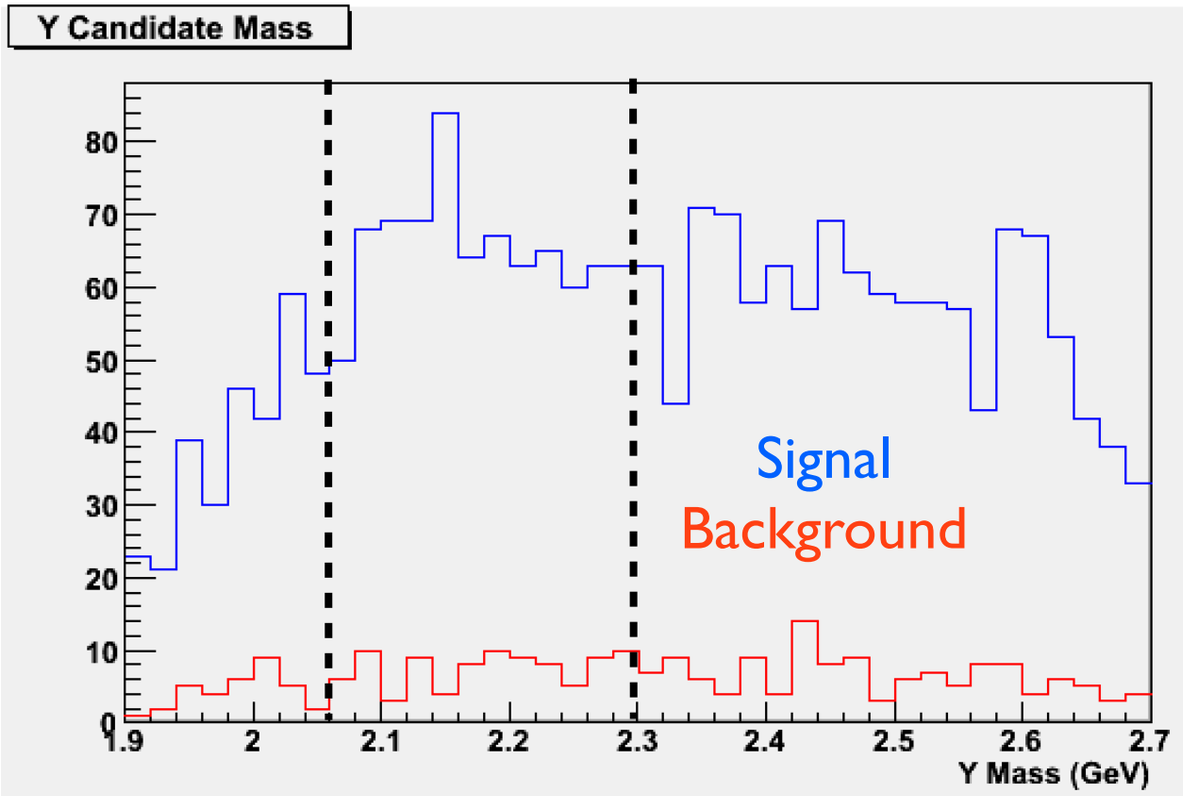
p2 = π-

p3 = K+

p4 = K-

p5 = proton

Y(2175) w/o CKOV

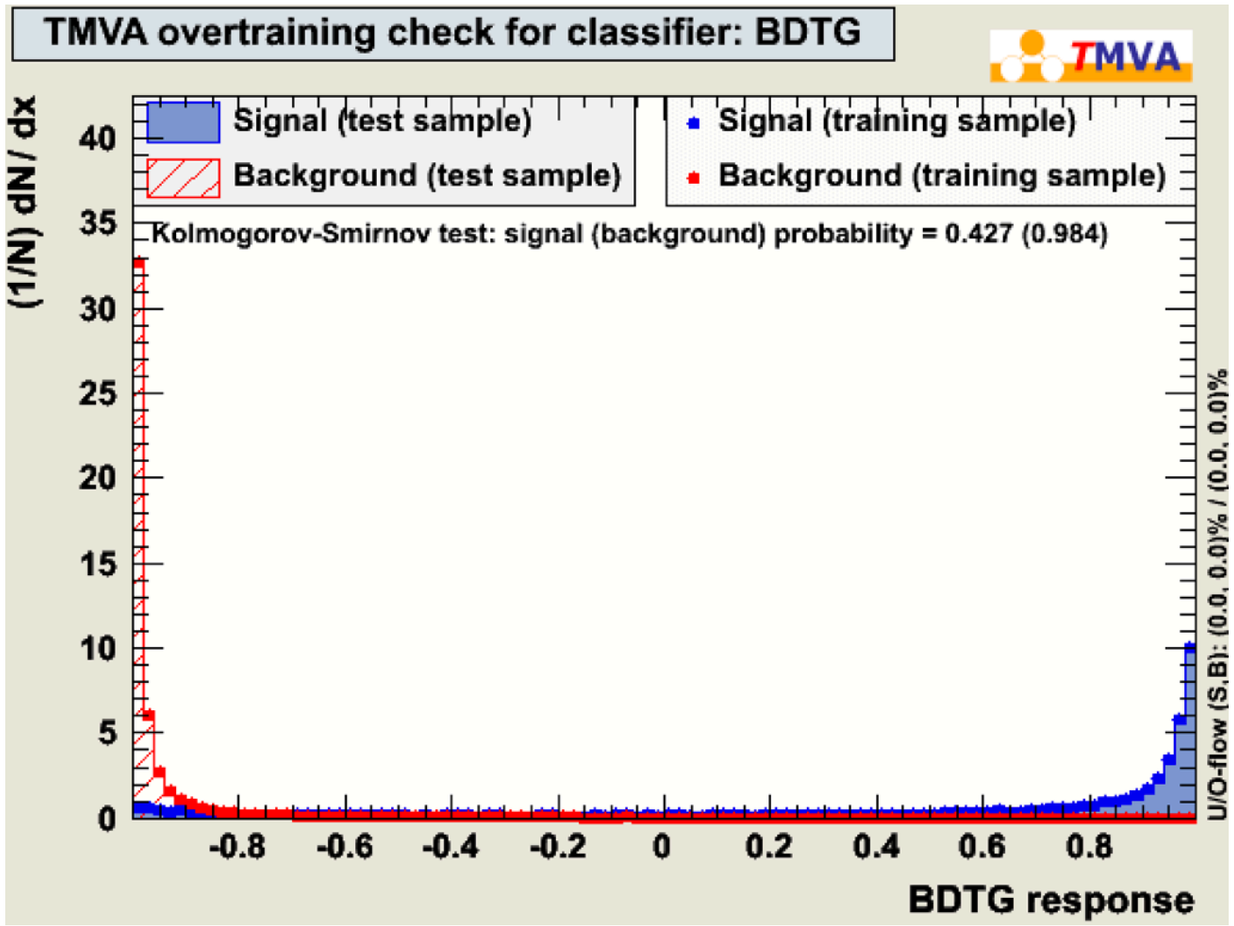


BDT Cut and
±1.5 Γ cut on ϕ, f_0, and Y masses

For cuts-based adjusted KinFit CL cut to achieve purity = 0.9

Analysis	Selection Efficiency	Purity
Cuts (w/o CKOV)	0.12	0.90
BDT (w/o CKOV)	0.52	0.90

Y(2175) w/ CKOV




```
--- Factory              : Begin ranking of input variables...
--- BDTG                 : Ranking result (top variable is best ranked)
--- BDTG                 : ----------------------------------------------
--- BDTG                 : Rank :Variable          :Variable Importance
--- BDTG                 : ----------------------------------------------
--- BDTG                 :    1 : kinFitCL         : 1.337e-01
--- BDTG                 :    2 : p3_timeFOM       : 9.808e-02
--- BDTG                 :    3 : p4_ckovFOM       : 6.798e-02
--- BDTG                 :    4 : p5_ChiSq         : 6.737e-02
--- BDTG                 :    5 : p5_dEdxFOM       : 6.687e-02
--- BDTG                 :    6 : isolatedBCALSumE : 6.068e-02
--- BDTG                 :    7 : p3_ckovFOM       : 5.752e-02
--- BDTG                 :    8 : p4_timeFOM       : 5.340e-02
--- BDTG                 :    9 : p1_timeFOM       : 3.304e-02
--- BDTG                 :   10 : p5_timeFOM       : 3.255e-02
--- BDTG                 :   11 : p1_dEdxFOM       : 3.008e-02
--- BDTG                 :   12 : isolatedTrackSumP : 2.913e-02
--- BDTG                 :   13 : p2_ckovFOM       : 2.911e-02
--- BDTG                 :   14 : PV_r             : 2.634e-02
--- BDTG                 :   15 : p1_ckovFOM       : 2.388e-02
--- BDTG                 :   16 : p1_ChiSqIP       : 1.843e-02
--- BDTG                 :   17 : p5_ckovFOM       : 1.687e-02
--- BDTG                 :   18 : p3_ChiSqIP       : 1.571e-02
--- BDTG                 :   19 : p3_dEdxFOM       : 1.566e-02
--- BDTG                 :   20 : p4_dEdxFOM       : 1.417e-02
--- BDTG                 :   21 : p1_ChiSq         : 1.357e-02
--- BDTG                 :   22 : p2_ChiSqIP       : 1.279e-02
--- BDTG                 :   23 : p2_ChiSq         : 1.244e-02
--- BDTG                 :   24 : p5_ChiSqIP       : 1.215e-02
--- BDTG                 :   25 : isolatedFCALSumE : 1.195e-02
--- BDTG                 :   26 : p4_ChiSqIP       : 1.121e-02
--- BDTG                 :   27 : p2_dEdxFOM       : 9.486e-03
--- BDTG                 :   28 : p2_timeFOM       : 8.139e-03
--- BDTG                 :   29 : PV_ChiSq         : 8.073e-03
--- BDTG                 :   30 : p4_ChiSq         : 6.412e-03
--- BDTG                 :   31 : p3_ChiSq         : 3.251e-03
--- BDTG                 : ----------------------------------------------
```

Highest ranked variables:

Kinematic Fit

PID information

χ^2 variables

Particle codes:

p1 = π+

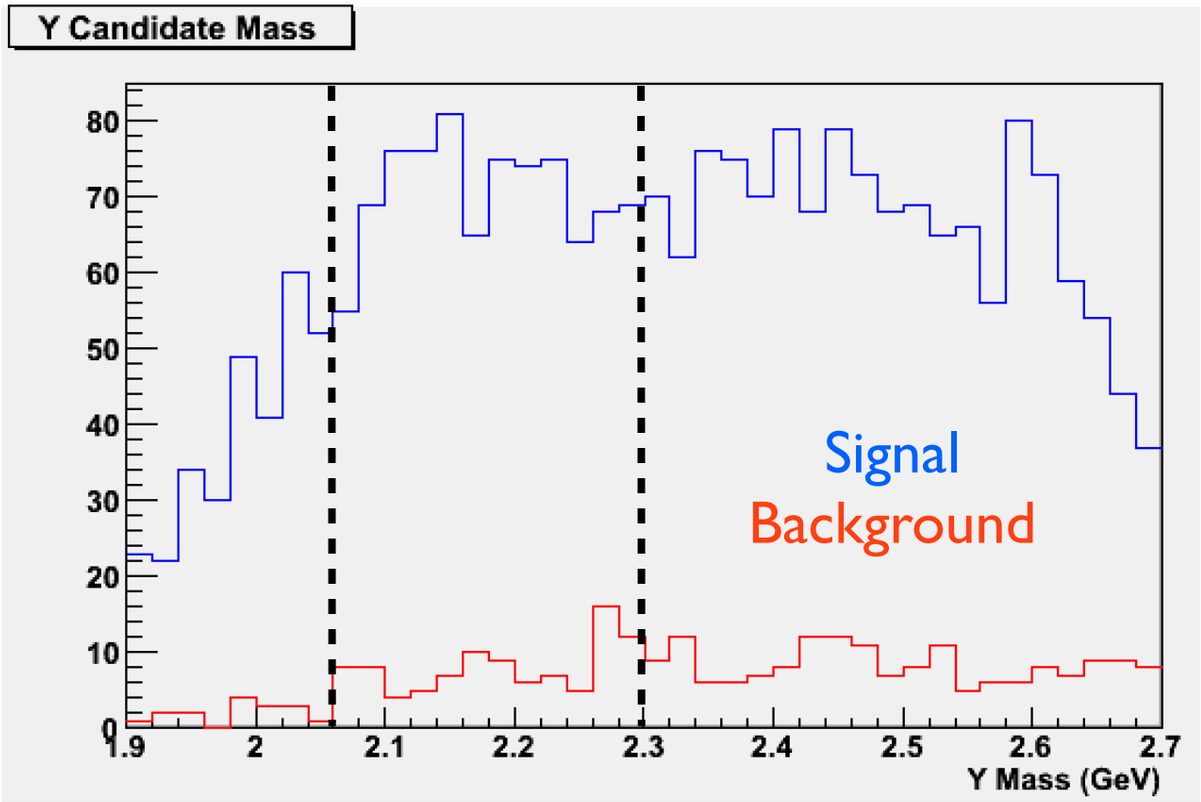
p2 = π-

p3 = K+

p4 = K-

p5 = proton

Y(2175) w/ CKOV



BDT Cut and
±1.5 Γ cut on ϕ, f_0, and Y masses

Remaining background:
~15% True PID but not exclusive
~10% Correct topology but π+ ⟷ K+
~40% Correct topology but π- ⟷ K-

Analysis	Selection Efficiency	Purity
Cuts (w/o CKOV)	0.12	0.90
BDT (w/o CKOV)	0.52	0.90
BDT (w/ CKOV)	0.59	0.90

Summary

	Selection efficiency		Expected Yield (x10^6)	
	w/o CKOV	w/ CKOV	w/o CKOV	w/ CKOV
h'(2600)	0.30	0.37	2.97	3.84
η'(2300)	0.33	0.41	0.88	0.97
Y(2175)	0.52	0.59	0.21	0.23
ϕ(1850)	0.69	0.82	6.65	7.82

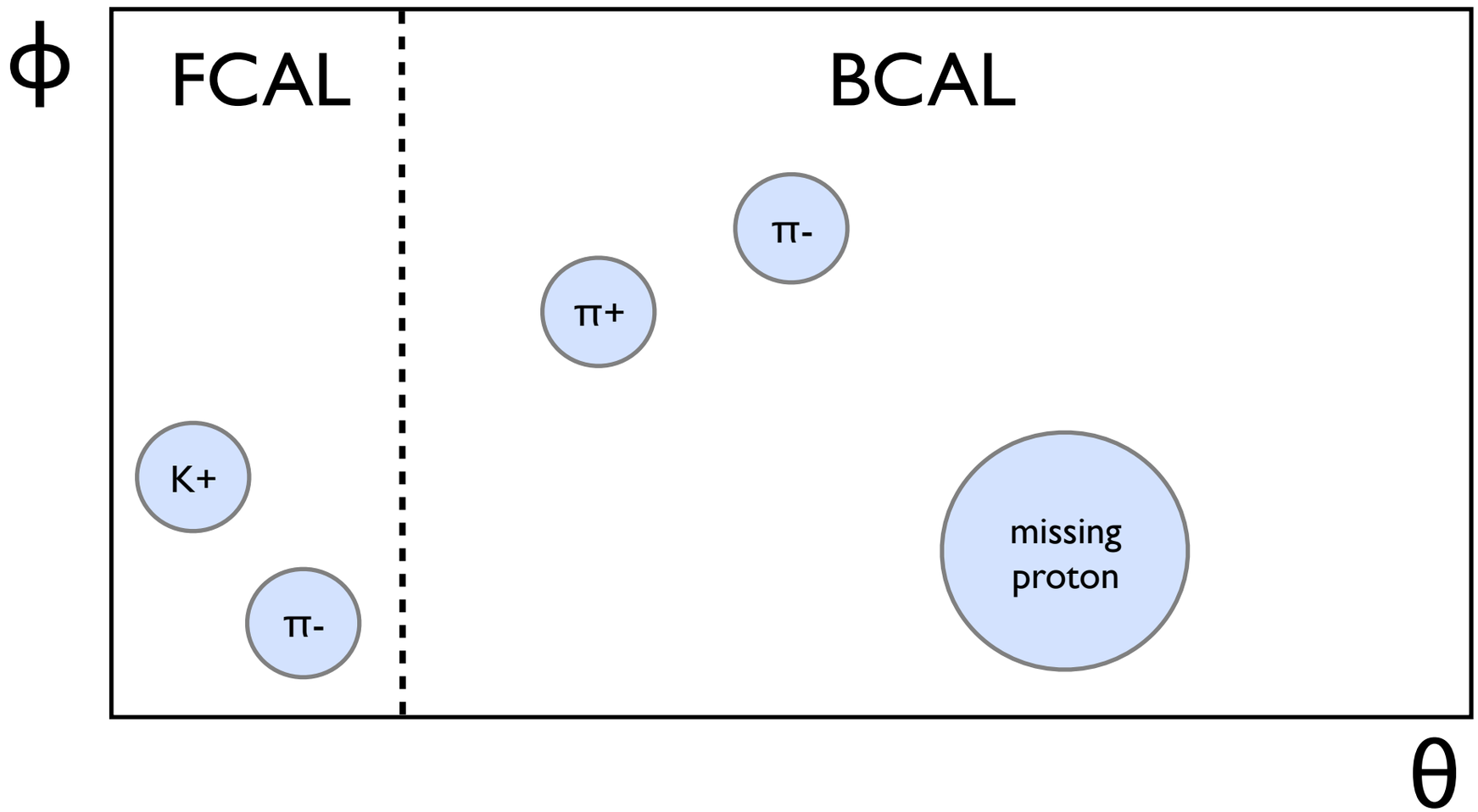
- BDT cut selected to give purity of 0.9 for all channels for comparison
- Integrate signal yields in the expected hybrid mass ranges
- Scale signal yields from this sample to 200 PAC days with 70% uptime at 10^8 γ/s to obtain expected yield

Backup

Reminder of variables included in the BDT

- Kinematic Fit CL
- Primary vertex χ^2 : Quality of K_s K^+ π^- from a single point
- Secondary vertex χ^2 : Quality of π^+ π^- from a single point
- K_s flight distance significance in R and Z (separately)
- K_s impact parameter χ^2 : Change in PV χ^2 when particle removed from PV
- Isolation sums for track momenta, BCAL and FCAL energy
- For each track use:
  - χ^2 from track fit
  - Time of flight CL
  - Track energy loss dE/dx CL
  - Impact parameter χ^2 : Change in PV χ^2 when particle removed from PV

Isolation Variables



- Motivation: identify backgrounds with extra charged track or neutral outside of the desired topology
- Use covariance matrices for reconstructed tracks to identify a "cone" around each track which we exclude ECAL showers within