

# Run 2 MC Tracker Only Validation: $D^*$ Normalization

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May 4, 2021



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# Cuts/Selection

- Filtering- see “Run 2 proposed” on slide 3 [here](#)
- HLT2 (for FullSim)- Hlt2XcMuXForTauB2XcMu, see slide 5 of [same presentation](#)
- Stripping line 28r2 b2D0MuXB2DMuForTauMuLine not applied, but all cuts **except PID** are applied in reco script (again, see slide 5 of [same presentation](#))
- Additional cuts from reco script: see third column of table in slide 10 in [this \(other\) presentation](#)
  - Notably: upstream slow pions are cut
- **Multiple Candidates kept**
- *Some* truth matching done, as well as other cuts Phoebe uses in [redoHistos\\_Dst.C](#) (variables from [AddB.C](#)) and [redoHistos\\_D0.C](#) (variables from [AddD0B\\_temp.C](#))) to select individual decays. Individual slides contain more info.
  - Overall cuts for TupleB0:  $D^{*+}$  bkgcat=0 (or =50 and  $D^0$  bkgcat=50),  $D^{*+}$  mom or gdmom or gdgdmom= $B^0$ ,  $\mu$  trueID= $\mu$
  - Overall cuts for TupleBminus:  $|m_{D^0} - \langle m_{D^0} \rangle| < 23.4\text{MeV}$ ,  $\mu$  trueID= $\mu$
  - Efficiency of these truth matching selections will be manually noted where relevant

# ISO Fit Sample Selections

```
return (b.iso_BDT() < 0.15);
```

- This is equivalent to what is listed in the [ANA note](#) in table 16.
- However, [Phoebe's code \(line 1284\)](#) for this fit sample is slightly more complicated. It references the higher  $D^{**}$  states for some reason. Since this is not listed in the ANA note, I assume this was a temporary thing that Phoebe did (maybe to investigate something), and I don't implement it.

# DD Fit Sample Selections

```
if (iso_BDT <= -1.1) iso_NNk = 0.;  
if (iso_BDT2 <= -1.1) iso_NNk2 = 0.;  
if (iso_BDT3 <= -1.1) iso_NNk3 = 0.;  
  
return (b.iso_BDT() > 0.15 && (iso_NNk > 0.2 || iso_NNk2 > 0.2 || iso_NNk3 > 0.2)  
        && TMath::Max(iso_P*(iso_PT > 150), TMath::Max(iso_P2*(iso_PT2 > 150)*(iso_BDT2 > -1.1),  
        iso_P3*(iso_PT3 > 150)*(iso_BDT3 > -1.1))) > 5e3);
```

- Sample is defined to look at an enhanced fraction of decays like  $B \rightarrow D^{(*)}DX$  (by requiring a  $K$  among the tracks selected by the isolation algorithm, noting that submodes of these DD decays have  $D \rightarrow K\mu X$ )
- This is more complicated than what is listed in the [ANA note](#) in table 16.
- I am not sure why Phoebe recalculates the `iso_NNk` variables as above, but I blindly follow her implementation here.
- The complicated cut involving `iso_P`, `iso_PT`, and `iso_BDT` is also not referenced in the ANA note, but again I blindly follow Phoebe's code.
- [Phoebe's code \(line 1303\)](#) references a variable `iso_NNkw`. I do not know what this variable is, but as far as I can tell, we do not have a branch for it in our ntuples. Therefore, I ignore her use of this variable (which is also not listed in the ANA note).

# 10S Fit Sample Selections

```
return (iso_BDT > 0.15 && iso_BDT2 < 0.15 && iso_CHARGE*Dst_ID < 0 && iso_P > 5e3  
        && iso_PT > 150 && iso_NNk < 0.2);
```

- Sample is defined to look at an enhanced fraction of decays  $D^{**} \rightarrow D^{(*)}\pi^+$  (chosen to be orthogonal to the DD fit sample)
- This is more complicated than what is listed in the [ANA note](#) in table 16. The cut on the charge variable multiplied by the  $D^*$  MC ID is requiring that these particles have opposite charge; this is mentioned in the ANA note text. Besides this cut, my implementation here is equivalent to that table in the ANA note.
- [Phoebe's code \(line 1354\)](#) again references `iso_NNkw` for this fit sample selection. I again ignore the use of this variable in her code.

## $D^{**}$ Fit Sample Selections

```
return (iso_BDT > 0.15 && iso_BDT2 < 0.15 && iso_CHARGE*Dst_ID < 0 && (iso_DeltaM > 390  
      && iso_DeltaM < 510) && iso_P > 5e3 && iso_PT > 150 && iso_NNk < 0.2);
```

- This is the same as the 1OS fit sample, but with a mass cut on the  $D^{*+}\pi^{-}$  combination around the relatively narrow  $D_1$  and  $D_2^*$  states.
- [Phoebe's code](#) actually doesn't reference this sample, and her 1OS sample actually has a mass cut that I don't implement – under the assumption that the  $D^{**}$  sample was created at a later time than the code was written – and using the mass cut listed in the ANA note rather than line 1349 of her code.
- `iso_DeltaM` is defined as  $\sqrt{(p_{B \text{ isolation track}} + p_{D^*})^2 - m_{D^*}^2}$

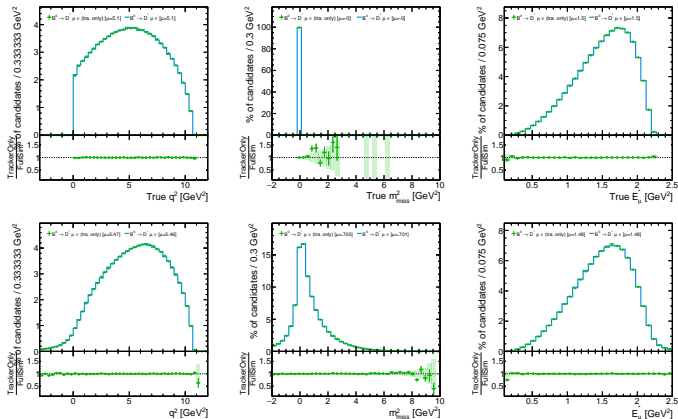
## 2OS Fit Sample Selections

```
return (iso_BDT > 0.15 && iso_BDT2 > 0.15 && iso_BDT3 < 0.15 && iso_CHARGE != iso_CHARGE2  
    && iso_CHARGE != 0 && iso_CHARGE2 != 0 && iso_CHARGE < 100  
    && TMath::Max(iso_P*(iso_PT > 150), iso_P2*(iso_PT2 > 150)) > 5e3  
    && iso_NNk < 0.2 && iso_NNk2 < 0.2);
```

- Sample is defined to look at an enhanced fraction of the higher excited charm states, decaying as  $D_H^{**} \rightarrow D^{(*)}\pi\pi$  (by requiring the isolation to find two tracks). Sample is chosen to be orthogonal to the DD and 1OS fit samples.
- This is more complicated than what is listed in the [ANA note](#) in table 16.
- I'm not sure why the charge < 100 selection is there, but I just copied Phoebe's code for this.
- The complicated cut involving the `iso_P`, `iso_PT` are also not listed in that table, but again I blindly follow Phoebe's code.

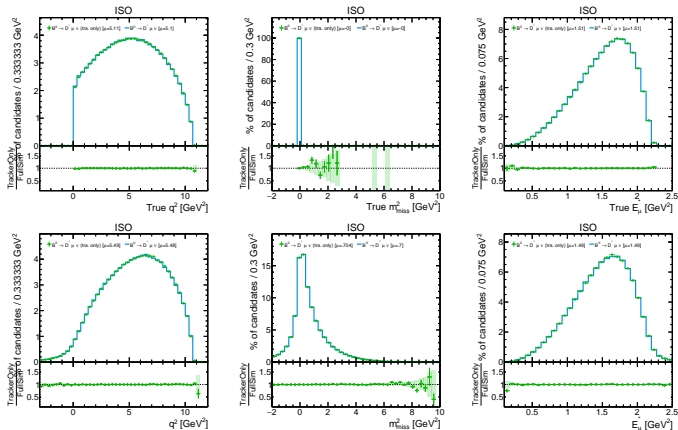


All  $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ :  $q^2$ ,  $m_{miss}^2$ ,  $E_\mu^*$



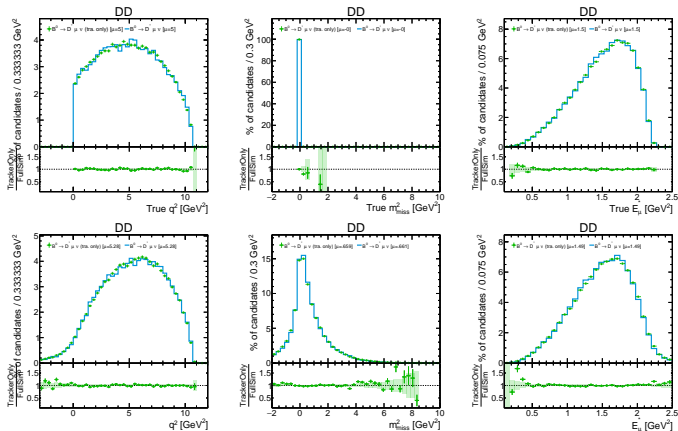
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Truth matching selection efficiency (trackeronly, fullsim): 0.913, 0.912
- $q^2 = (p_B - p_{D^*})^2$ ,  $m_{miss}^2 = (p_B - p_{D^*} - p_\mu)^2$ ,  $E_\mu^* = E_\mu$  boosted to B rest
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# ISO $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : $q^2$ , $m_{miss}^2$ , $E_\mu^*$



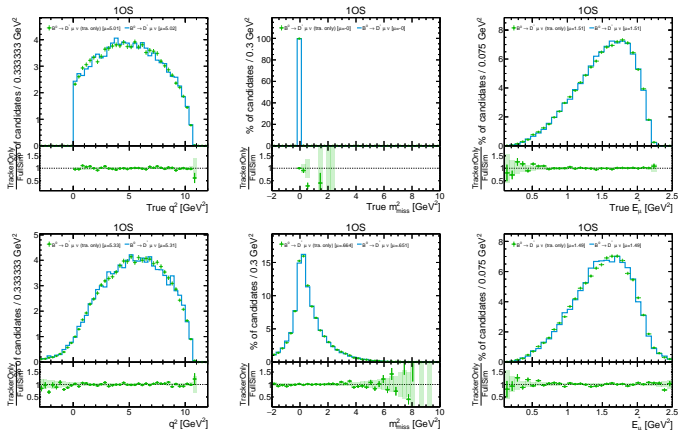
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- ISO fit sample selec. efficiency, after truth-match (trackeronly, fullsim): 0.774, 0.773
- $q^2 = (p_B - p_{D^*})^2$ ,  $m_{miss}^2 = (p_B - p_{D^*} - p_\mu)^2$ ,  $E_\mu^* = E_\mu$  boosted to B rest
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

$$DD \ B^0 \rightarrow D^{*+} \mu \bar{\nu}: q^2, m_{miss}^2, E_{\mu}^*$$



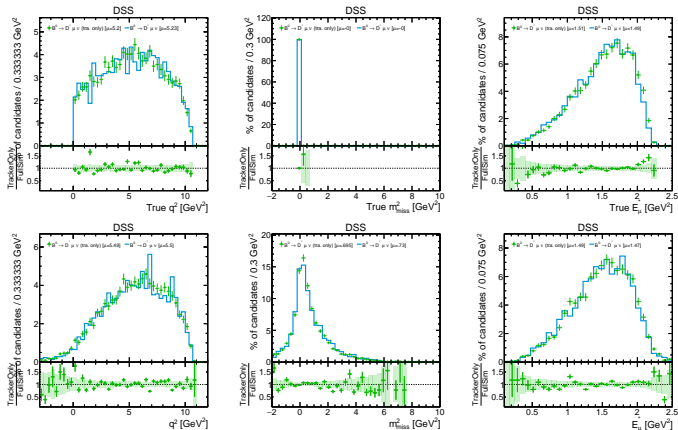
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- DD fit sample selec. efficiency, after truth-match (trackeronly, fullsim): 0.046, 0.045
- $q^2 = (p_B - p_{D^*})^2$ ,  $m_{miss}^2 = (p_B - p_{D^*} - p_{\mu})^2$ ,  $E_{\mu}^* = E_{\mu}$  boosted to B rest
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# 1OS $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : $q^2$ , $m_{miss}^2$ , $E_\mu^*$



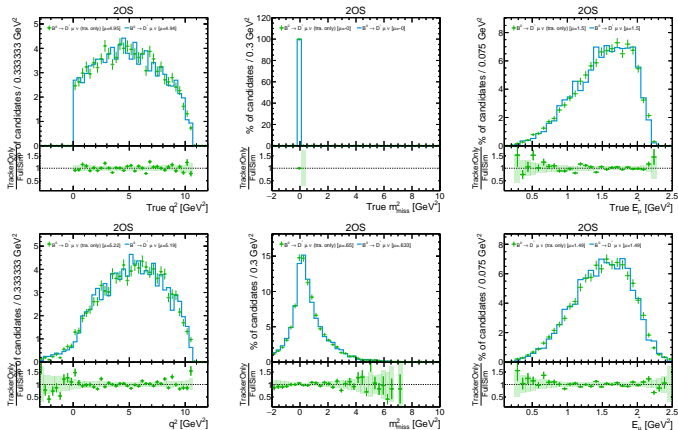
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- 1OS fit sample selec. efficiency, after truth-match (trackeronly, fullsim): 0.022, 0.022
- $q^2 = (p_B - p_{D^*})^2$ ,  $m_{miss}^2 = (p_B - p_{D^*} - p_\mu)^2$ ,  $E_\mu^* = E_\mu$  boosted to B rest
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

$$D^{**} B^0 \rightarrow D^{*+} \mu \bar{\nu}: q^2, m_{miss}^2, E_{\mu}^*$$



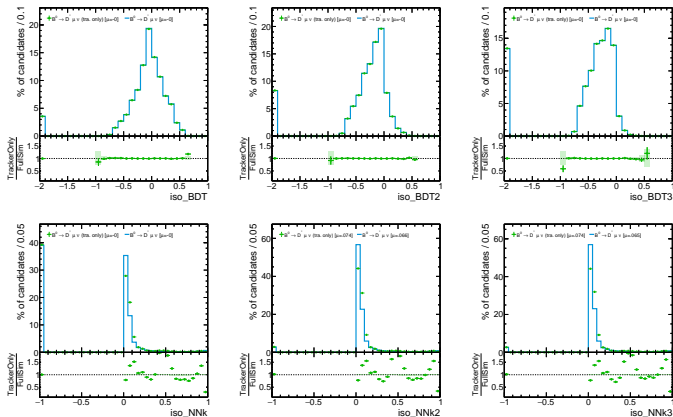
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- $D^{**}$  fit sample selec. efficiency, after truth-match (trackeronly, fullsim): 0.0025, 0.0024
- $q^2 = (p_B - p_{D^*})^2$ ,  $m_{miss}^2 = (p_B - p_{D^*} - p_{\mu})^2$ ,  $E_{\mu}^* = E_{\mu}$  boosted to B rest
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# 2OS $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : $q^2$ , $m_{miss}^2$ , $E_\mu^*$



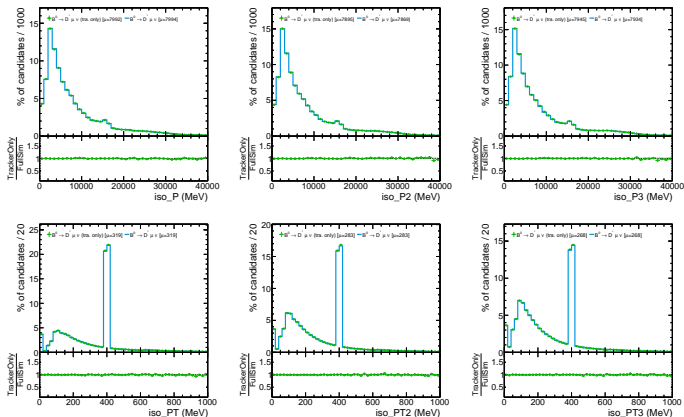
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- 2OS fit sample selec. efficiency, after truth-match (trackeronly, fullsim): 0.0031, 0.0032
- $q^2 = (p_B - p_{D^*})^2$ ,  $m_{miss}^2 = (p_B - p_{D^*} - p_\mu)^2$ ,  $E_\mu^* = E_\mu$  boosted to B rest
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : Iso BDT, Iso NNk



- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+}[\rightarrow D^0[\rightarrow K^- \pi^+]\pi_s^+]\mu$

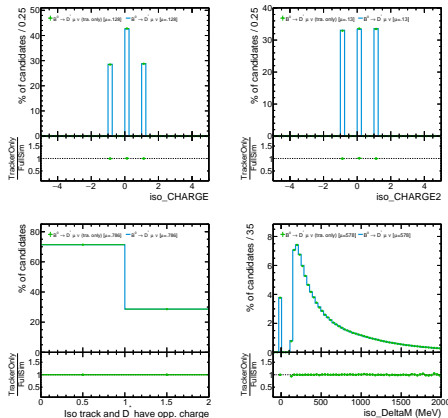
# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : Iso $p$ , Iso $p_T$



- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+}[\rightarrow D^0[\rightarrow K^- \pi^+]\pi_s^+]\mu$

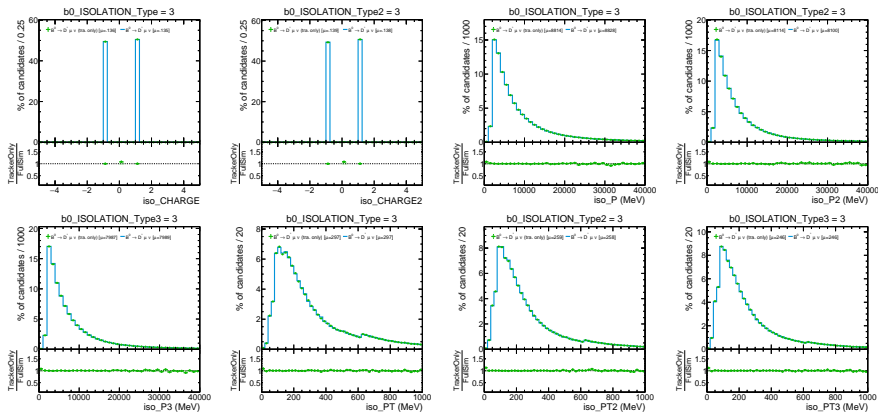


# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : Other Variables for Fit Samples



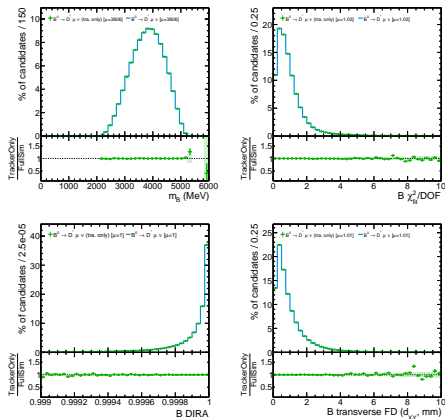
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : Investigation Requiring $B^0$ Isolation Track Type = 3



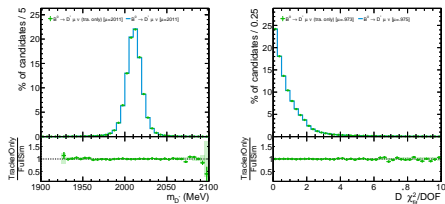
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : $B$ Selection Variables



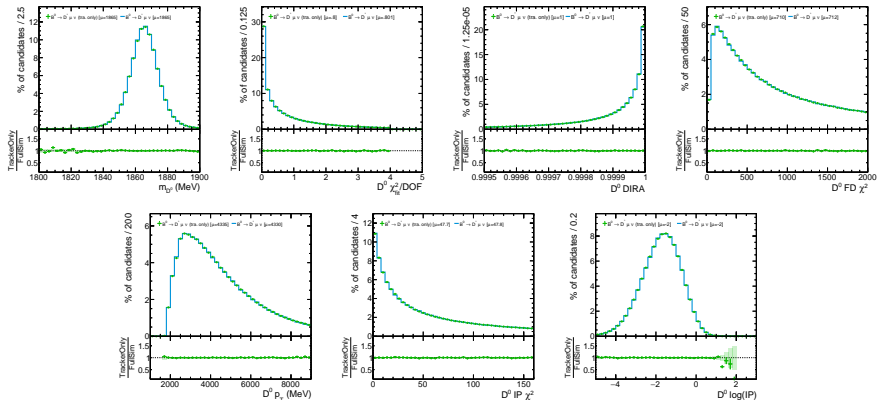
- Selection:  $\mu \text{ mom} = B^0$ ,  $D^{*+} \text{ mom} = B^0$ ,  $B^0 \text{ bkgcat} = 0$
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : $D^*$ Selection Variables



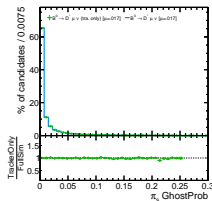
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : $D^0$ Selection Variables



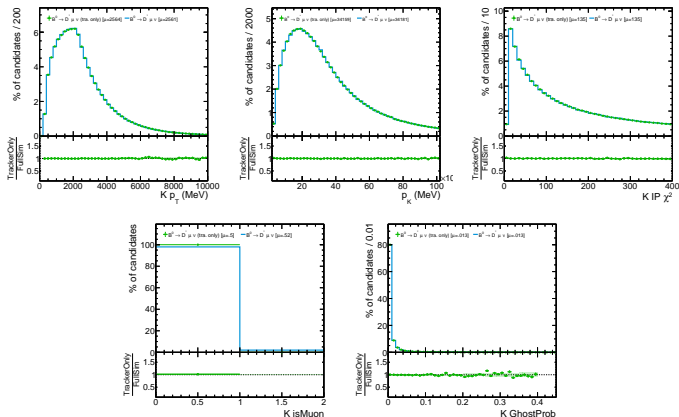
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : $\pi_s$ Selection Variables



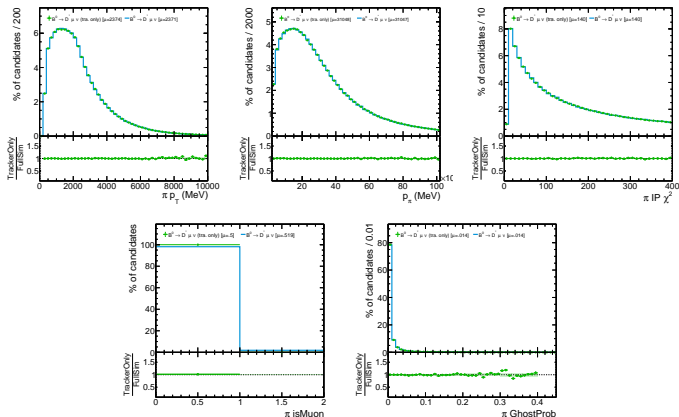
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : $K$ Selection Variables



- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

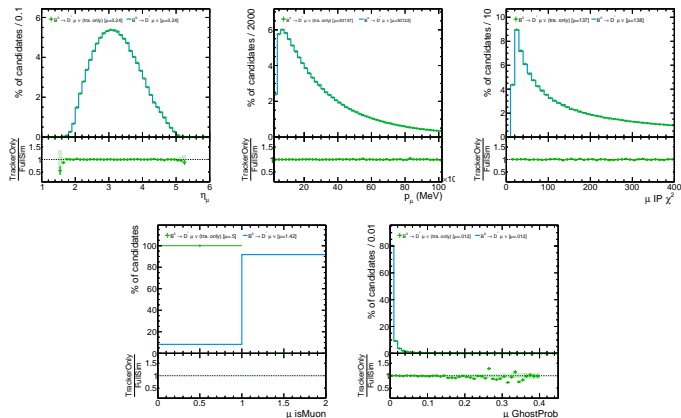
# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : $\pi$ Selection Variables



- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

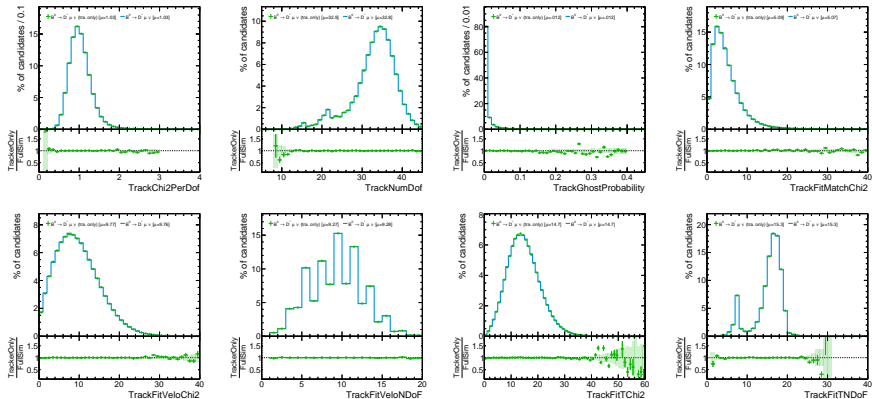


# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : $\mu$ Selection Variables



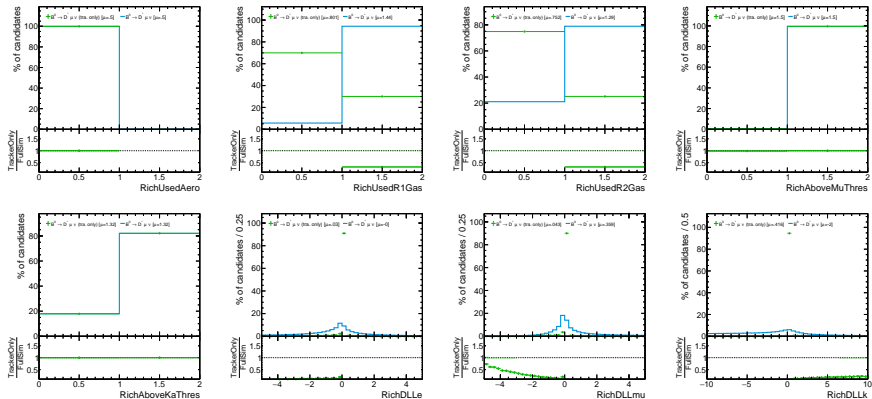
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+}[\rightarrow D^0[\rightarrow K^- \pi^+]\pi_s^+]\mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : BDT $\mu$ Variables (1)



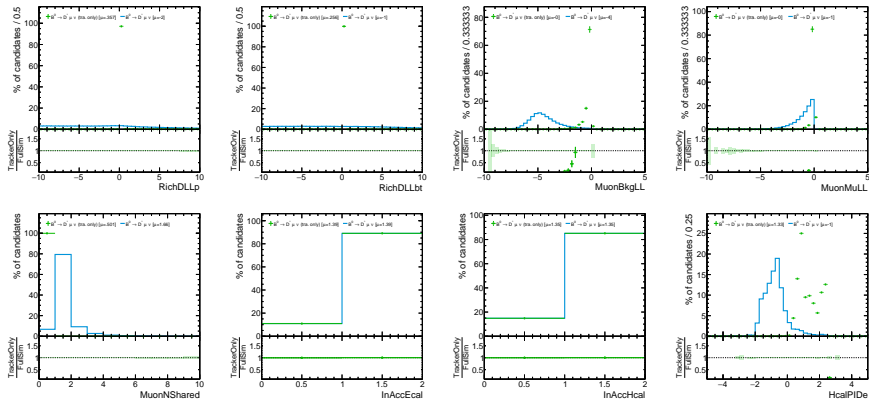
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : BDT $\mu$ Variables (2)



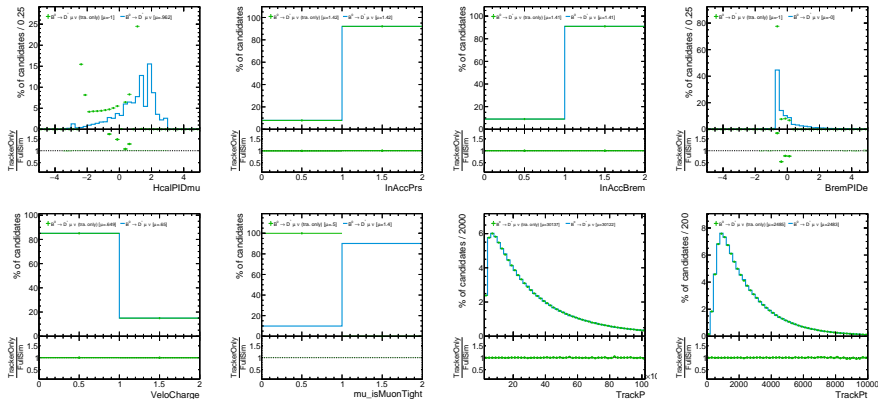
- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : BDT $\mu$ Variables (3)



- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# All $B^0 \rightarrow D^{*+} \mu \bar{\nu}$ : BDT $\mu$ Variables (4)



- Selection:  $\mu$  mom= $B^0$ ,  $D^{*+}$  mom= $B^0$ ,  $B^0$  bkgcat=0
- Plotted using TupleB0: reconstructed as  $B^0 \rightarrow D^{*+} [\rightarrow D^0 [\rightarrow K^- \pi^+] \pi_s^+] \mu$

# Questions

- See the slides where I define and make observations about the implementation of the cuts for defining the fit samples.

# Observations

• ...

# TODO





# Backup Slides