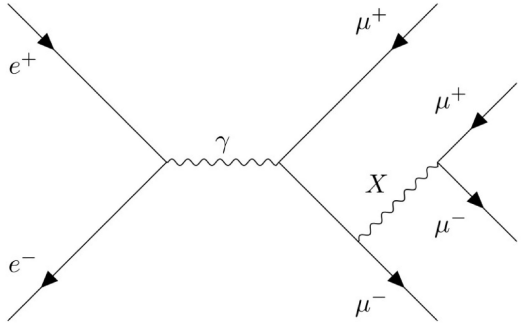
Dark Sector Challenge
ee →μμZ’(→μμ)



Leader: Martina Laurenza
Participants: Jonas Epplet, Tommy Lam

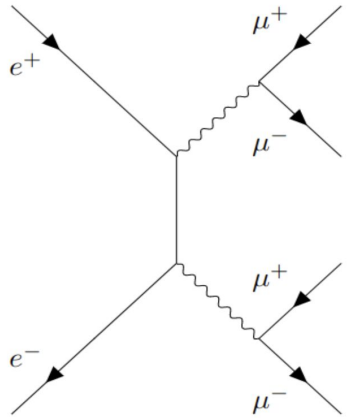
Reminder of Challenge

Reminder of Challenge: Background Reduction

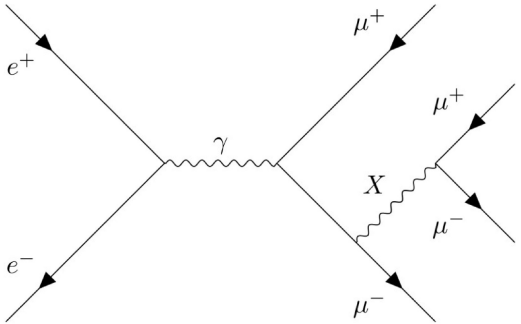
Muonic Dark Force Searches at Belle 2 has one dominate background:

- ee→ɣɣ, where both ɣ→μμ

Reducing this background would help set competitive limits for coupling constant g’



(b) Double photon conversion.



XGBoost

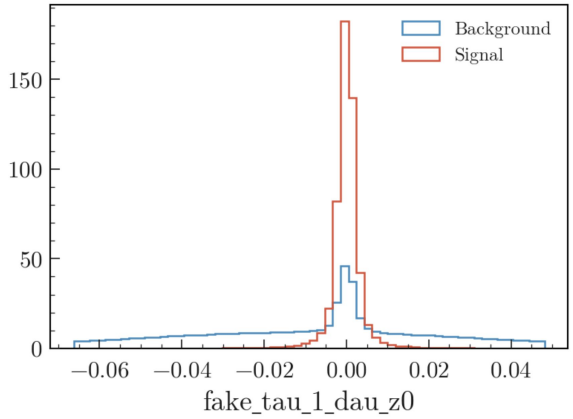
Configuration of XGBoost

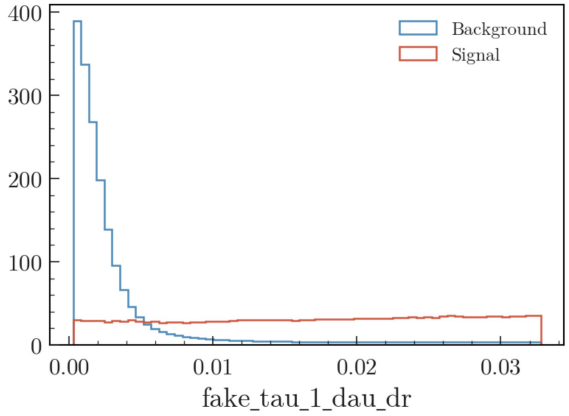
Input Features (in order of importance):

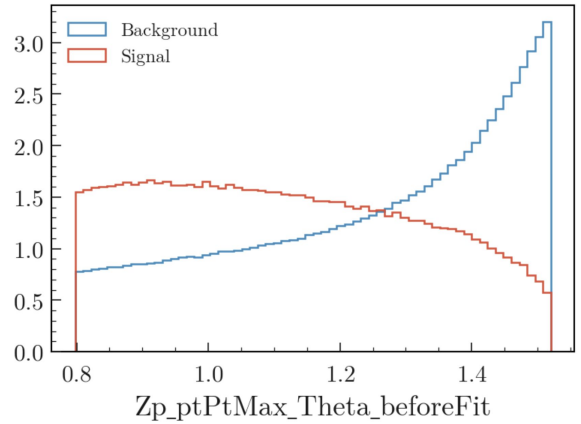
- dr, d0, and z0 of the vertexed muons
- CM energy of non Z’ vertex
- Z’ transverse projected momentum w.r.t. recoil muon w/ minimal/maximal (w/ some coordinate transformations)

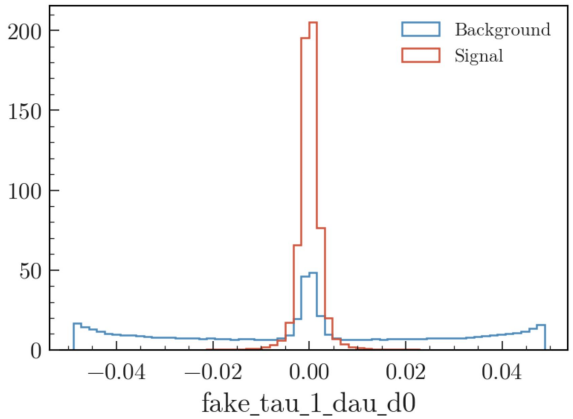
GridSearch parameters for cross validation:

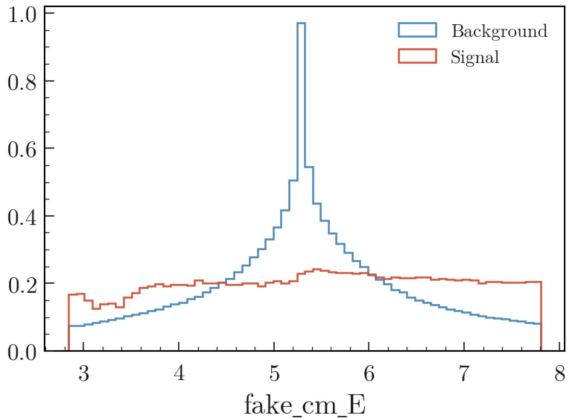
- # of estimators = [4, 6]
- Depth = 5-9
- Learning rate = 0.1
- Subsample = 0.7

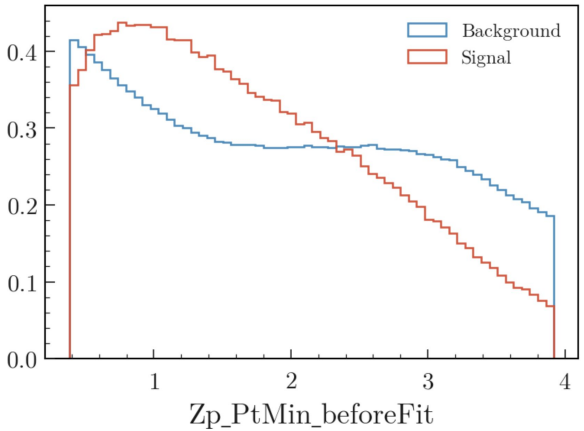










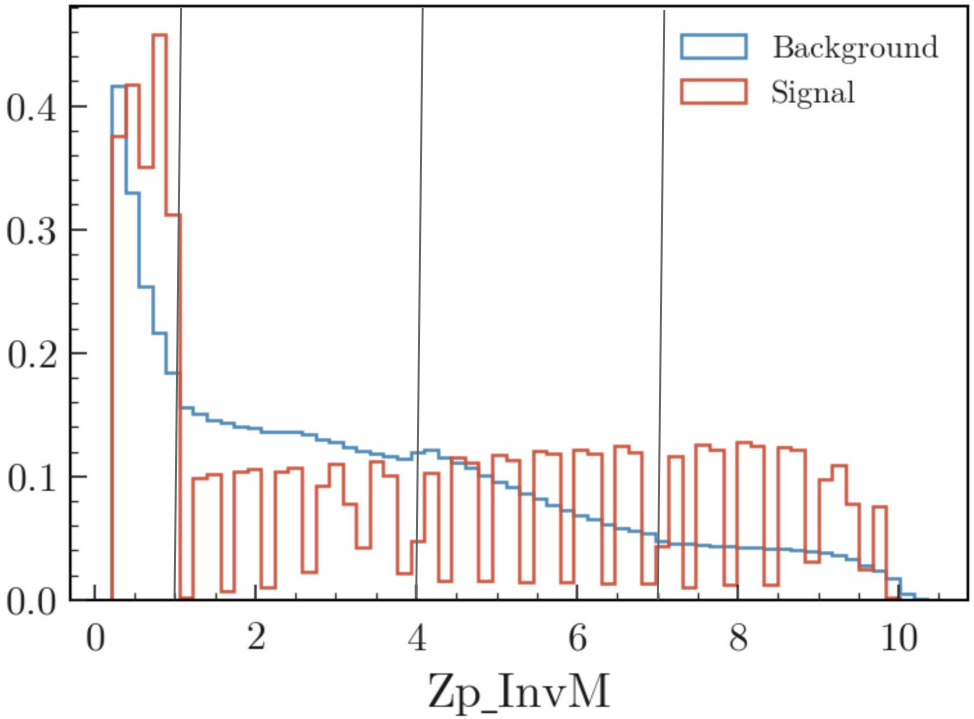


Normalized so area = 1

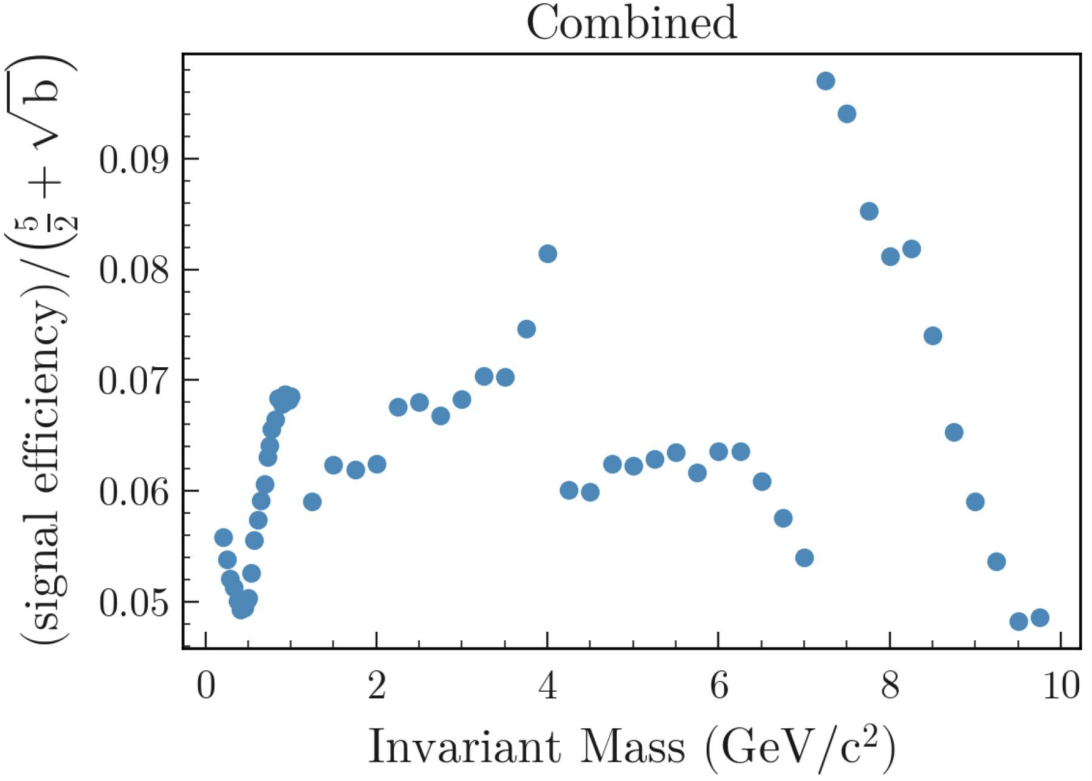
Configuration of XGBoost

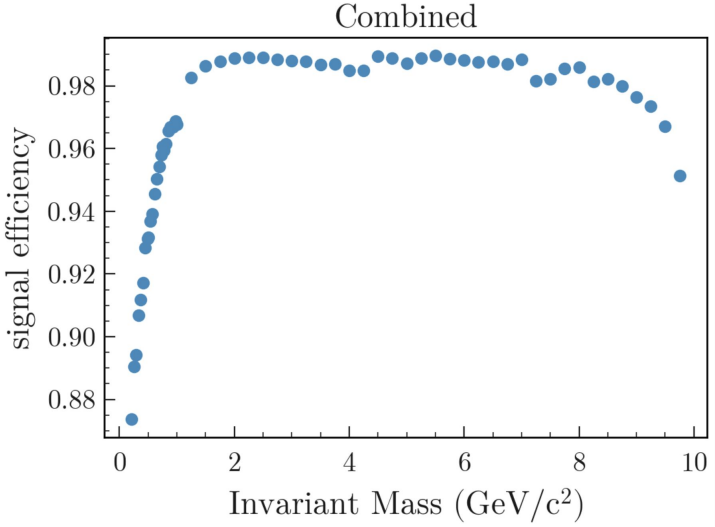
Training Regions:

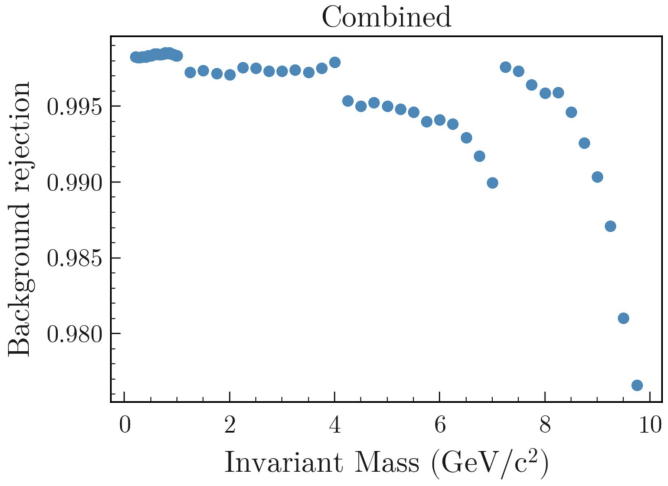
- < 1 GeV
- 1 - 4 GeV
- 4 - 7 GeV
- > 7 GeV



Punzi F.O.M of XGBoost







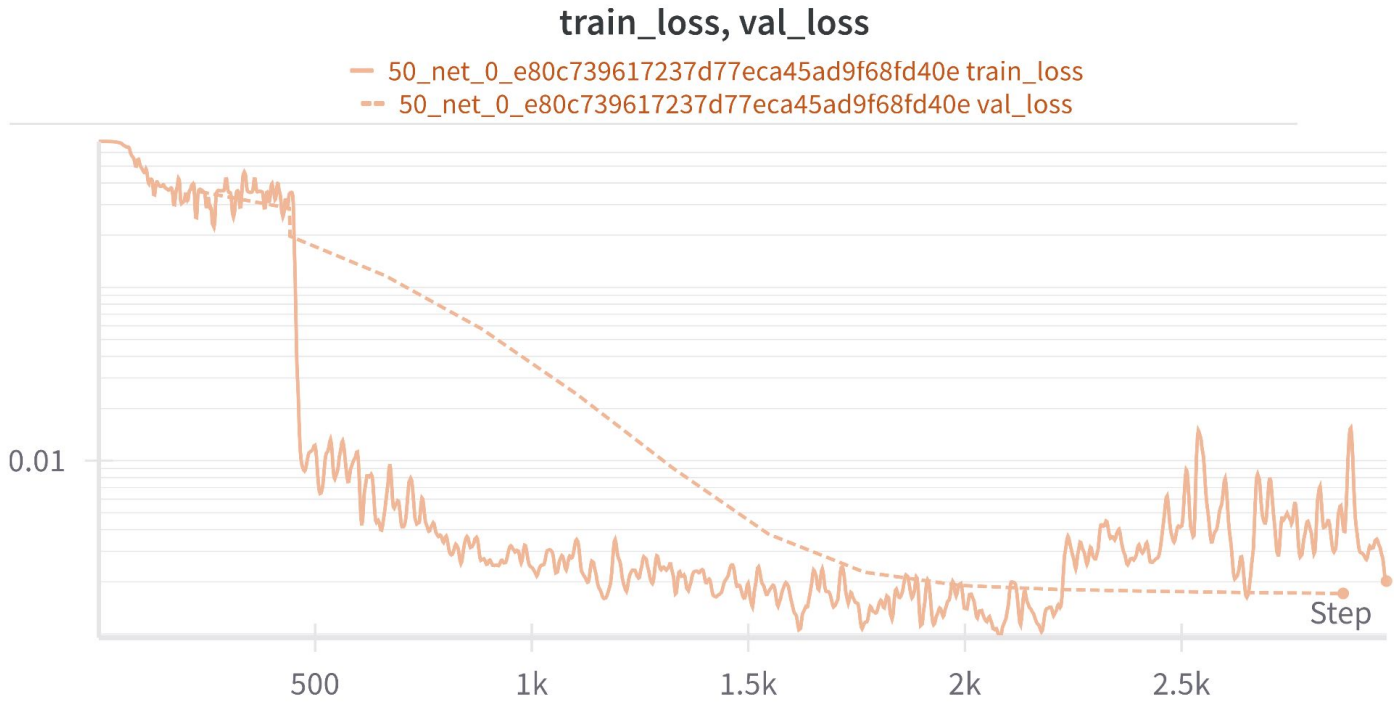
One-shot-net

Strategy

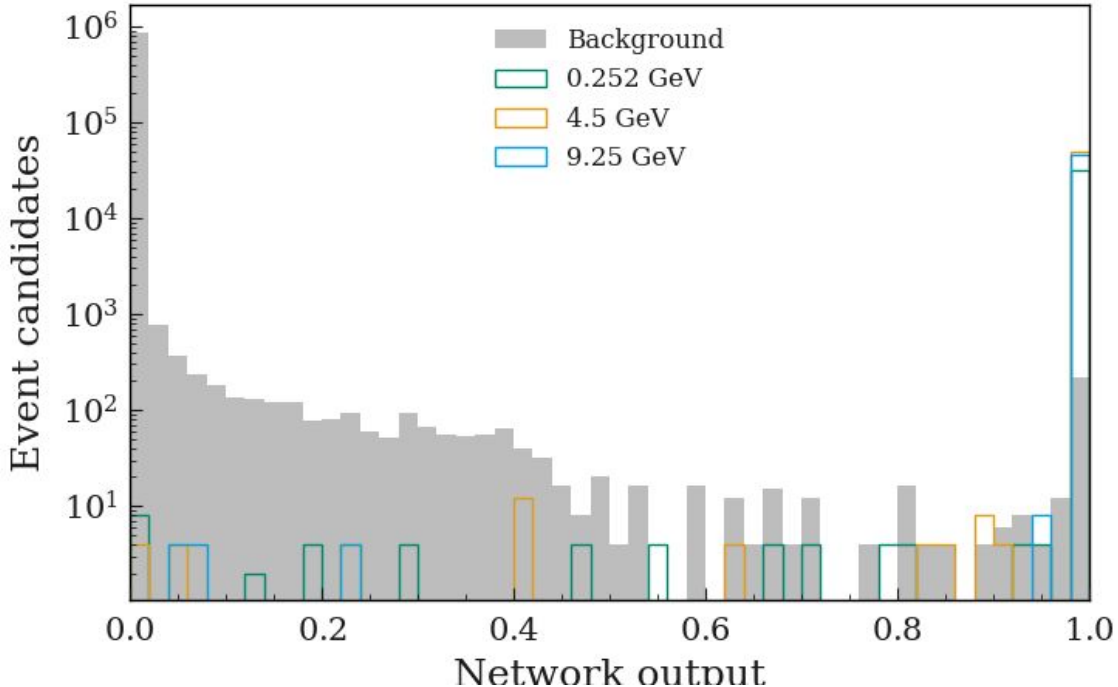
- Order FSP particles, such that the first is the highest energetic positively charged muon and the second is the highest energetic negatively charged muon.
- Using FSP kinematics and vertex information as inputs.
- Train for all mass points simultaneously.
    - Some mass points are omitted for generaliation tests later

- Network architecture:
    - 6 Layers, 64 neurons each
    - 34.5 K Parameters

Training


train_loss, val_loss
50_net_0_e80c739617237d77eca45ad9f68fd40e train_loss
50_net_0_e80c739617237d77eca45ad9f68fd40e val_loss
0.01
Step
500
1k
1.5k
2k
2.5k

Network output

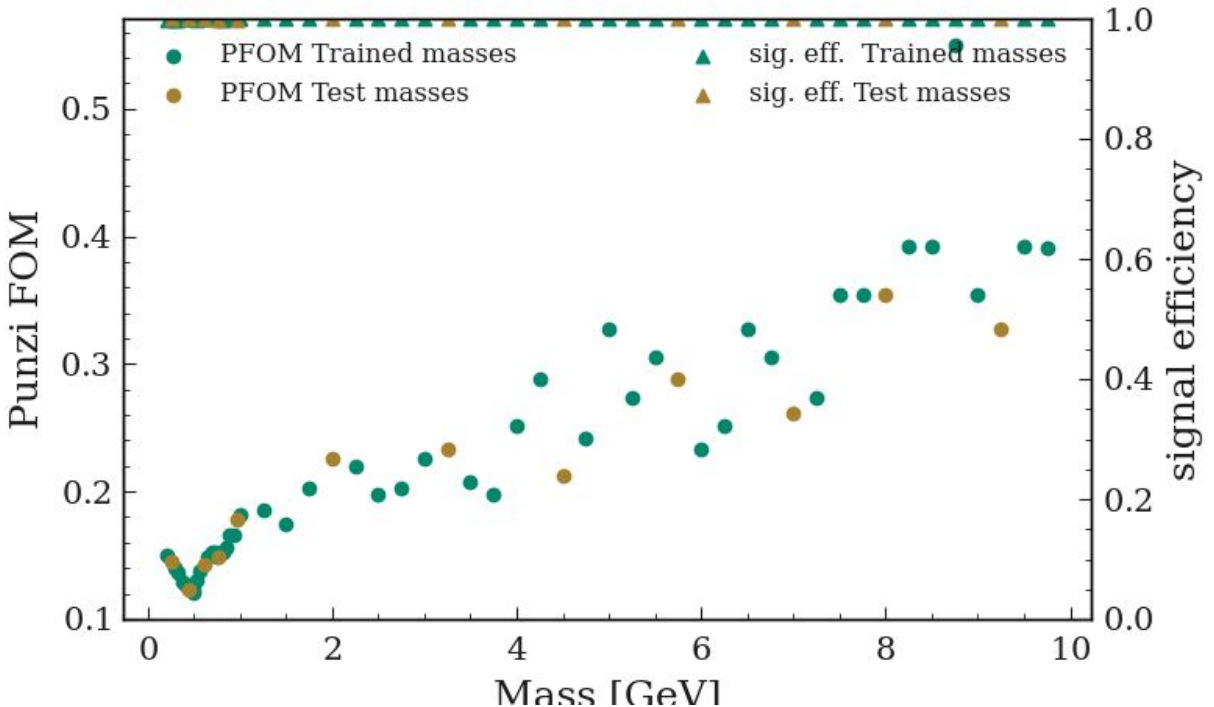


Punzi F.O.M

Punzi FOM = eff / (1.64 + sqrt(b))

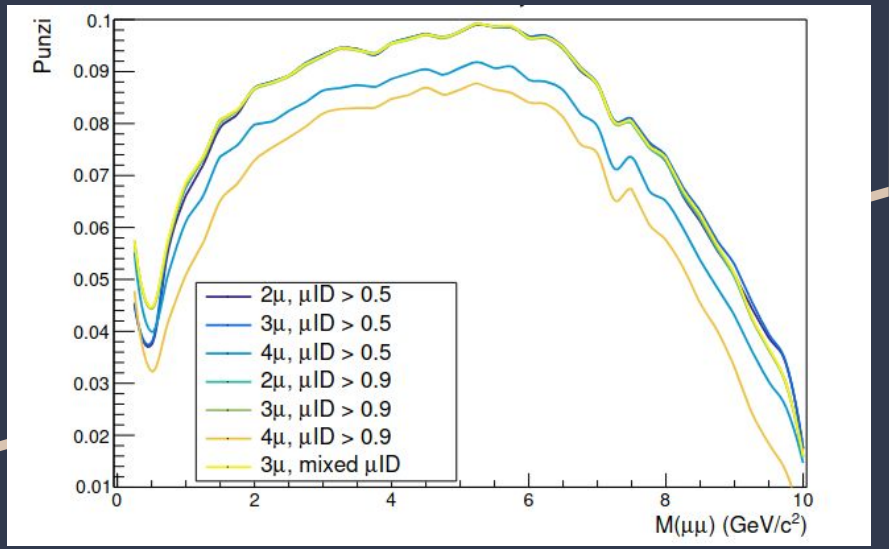
- Eff: Signal efficiency
- B: number of background events

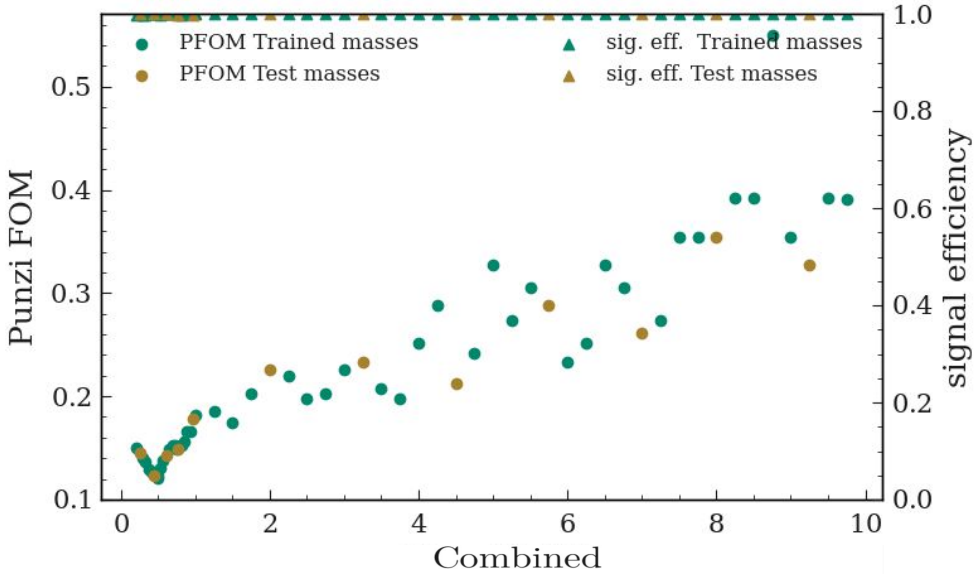
Evaluated in a +/- 250MeV window around the mass

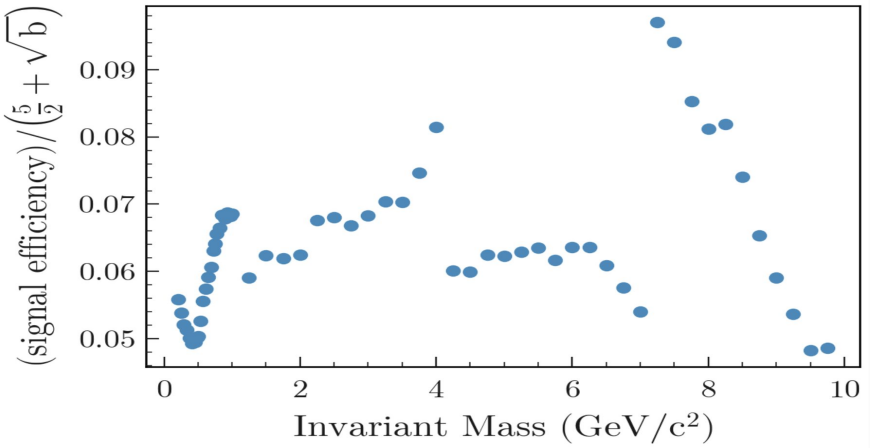


Concluding Remarks

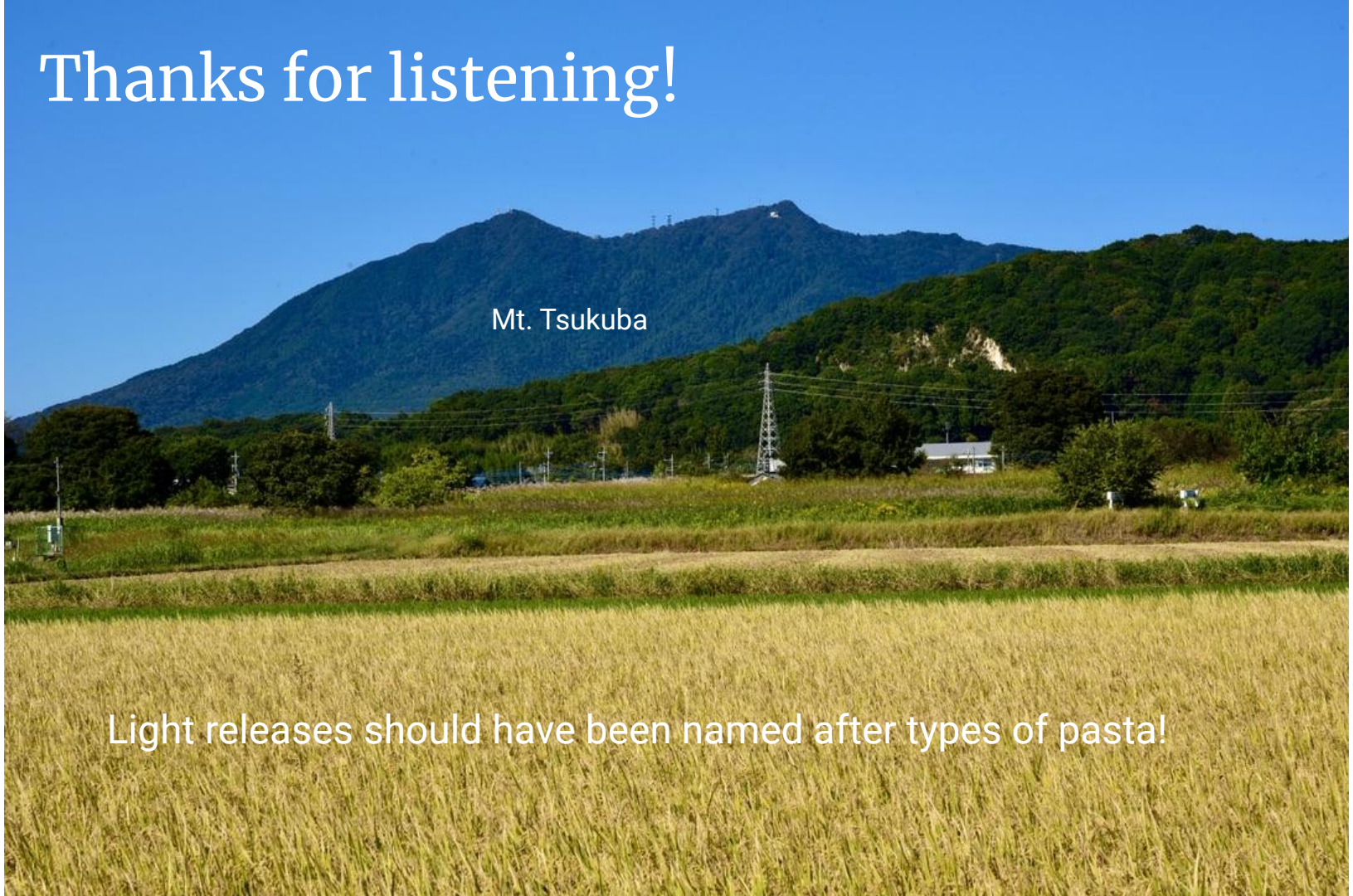
Final Comparison w/ benchmark plot from Martina







Thanks for listening!



Light releases should have been named after types of pasta!

Back up

Signal Efficiency Definition

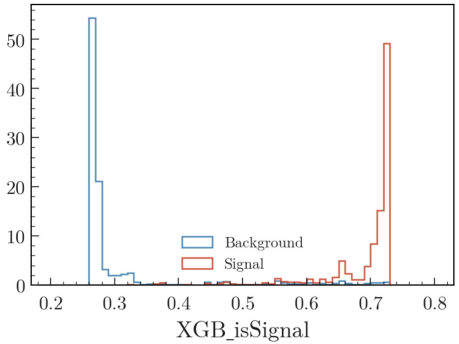
For a given model we want to test with mass M

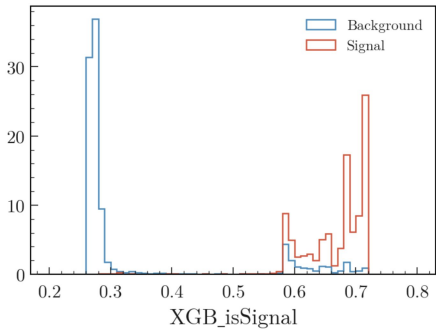
- Signal = number of reconstructed events from ee $\rightarrow \mu\mu Z'(\rightarrow \mu\mu)$
- Truth Label/Signal = events with muons' mother is Z' (MC info)
- Invariant Mass Region is ±250 MeV around mass M

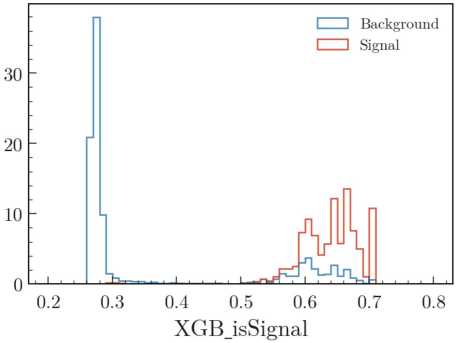
Efficiency = total number of signal events after MVA / total number of signal events before MVA

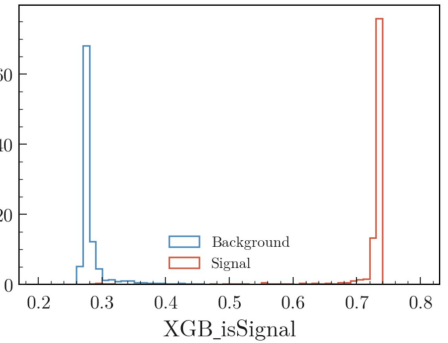
- Combinatorics included in signal events

Similar mass range cuts was made for counting number of background events for Punzi F.O.M.

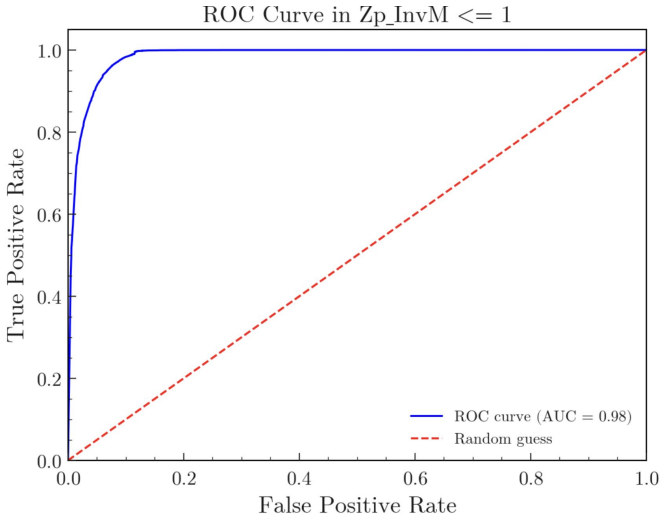


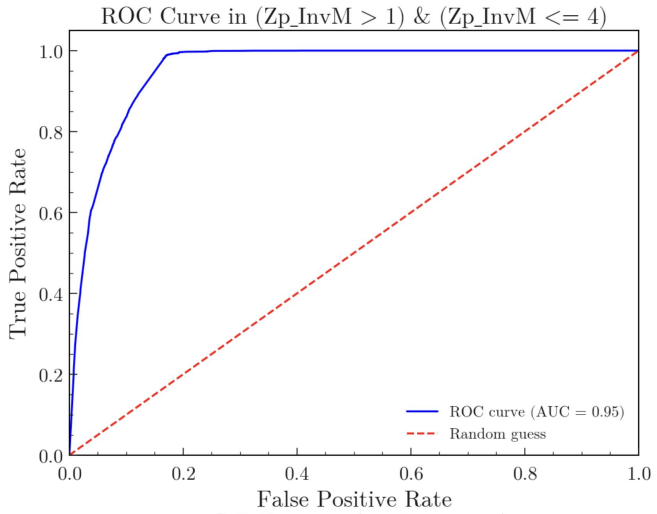


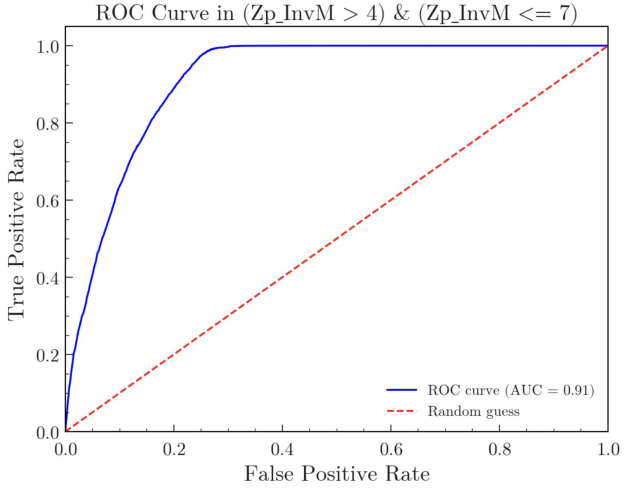


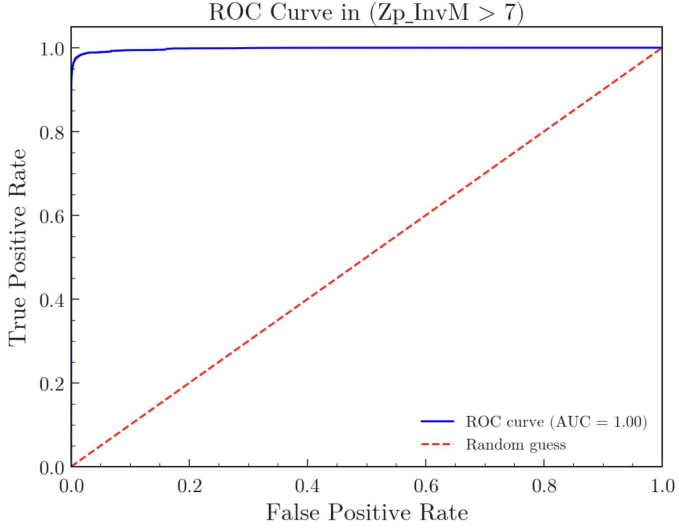


- Currently, cut on BDT was made at 0.5
- Maybe some marginal improvement by better optimizing this threshold cut for each region but not enough time


ROC Curve in Zp_InvM <= 1
True Positive Rate
False Positive Rate
ROC curve (AUC = 0.98)
Random guess


ROC Curve in (Zp_InvM > 1) & (Zp_InvM <= 4)
True Positive Rate
False Positive Rate
ROC curve (AUC = 0.95)
Random guess


ROC Curve in (Zp_InvM > 4) & (Zp_InvM <= 7)
True Positive Rate
False Positive Rate
ROC curve (AUC = 0.91)
Random guess


ROC Curve in (Zp_InvM > 7)
True Positive Rate
False Positive Rate
ROC curve (AUC = 1.00)
Random guess