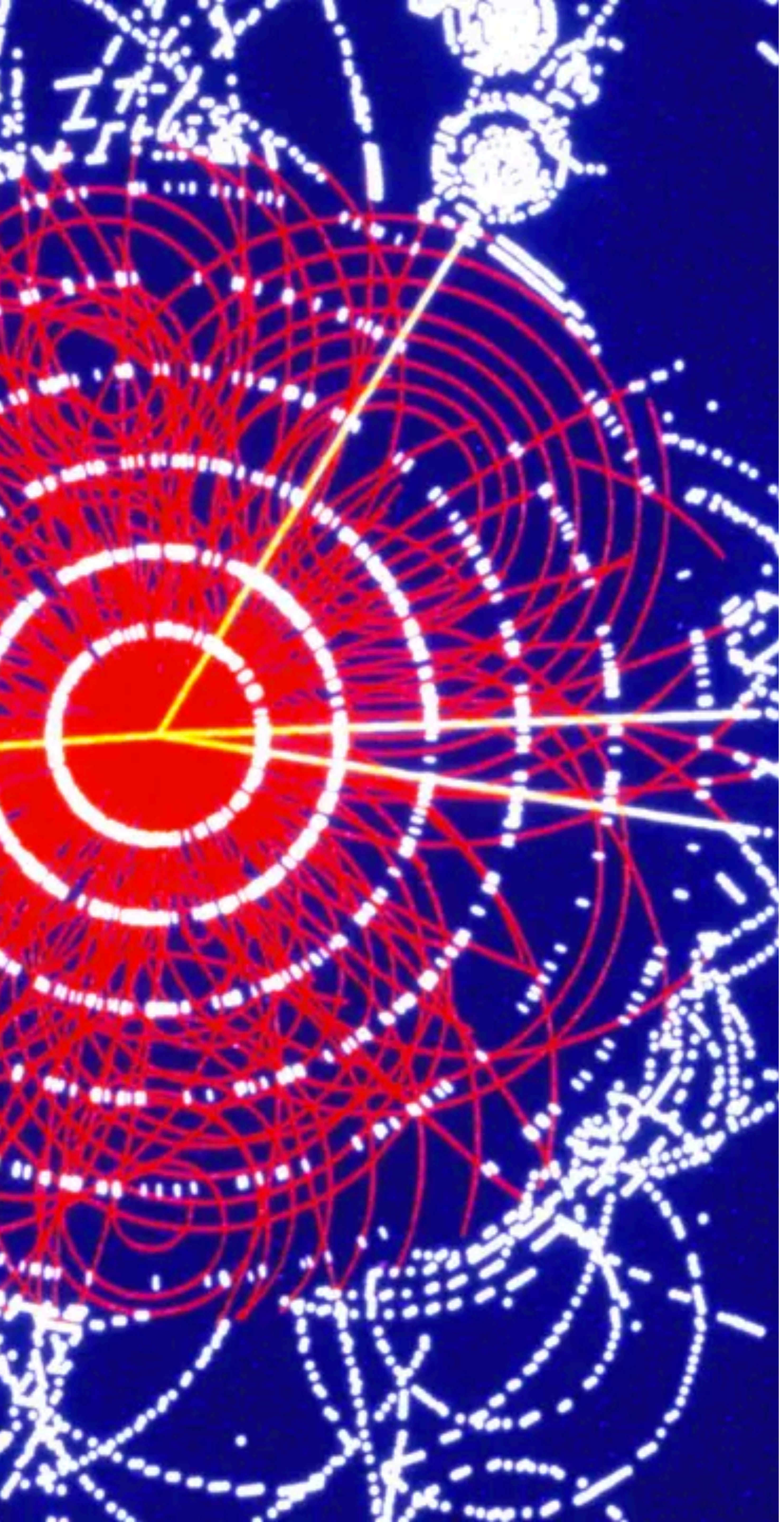

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Norway grants

FACULTY OF PHYSICS
UNIVERSITY OF WARSAW

Searching for Dark Matter in the LHC with the help of Machine Learning

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in collaboration with

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Corfu Summer Institute
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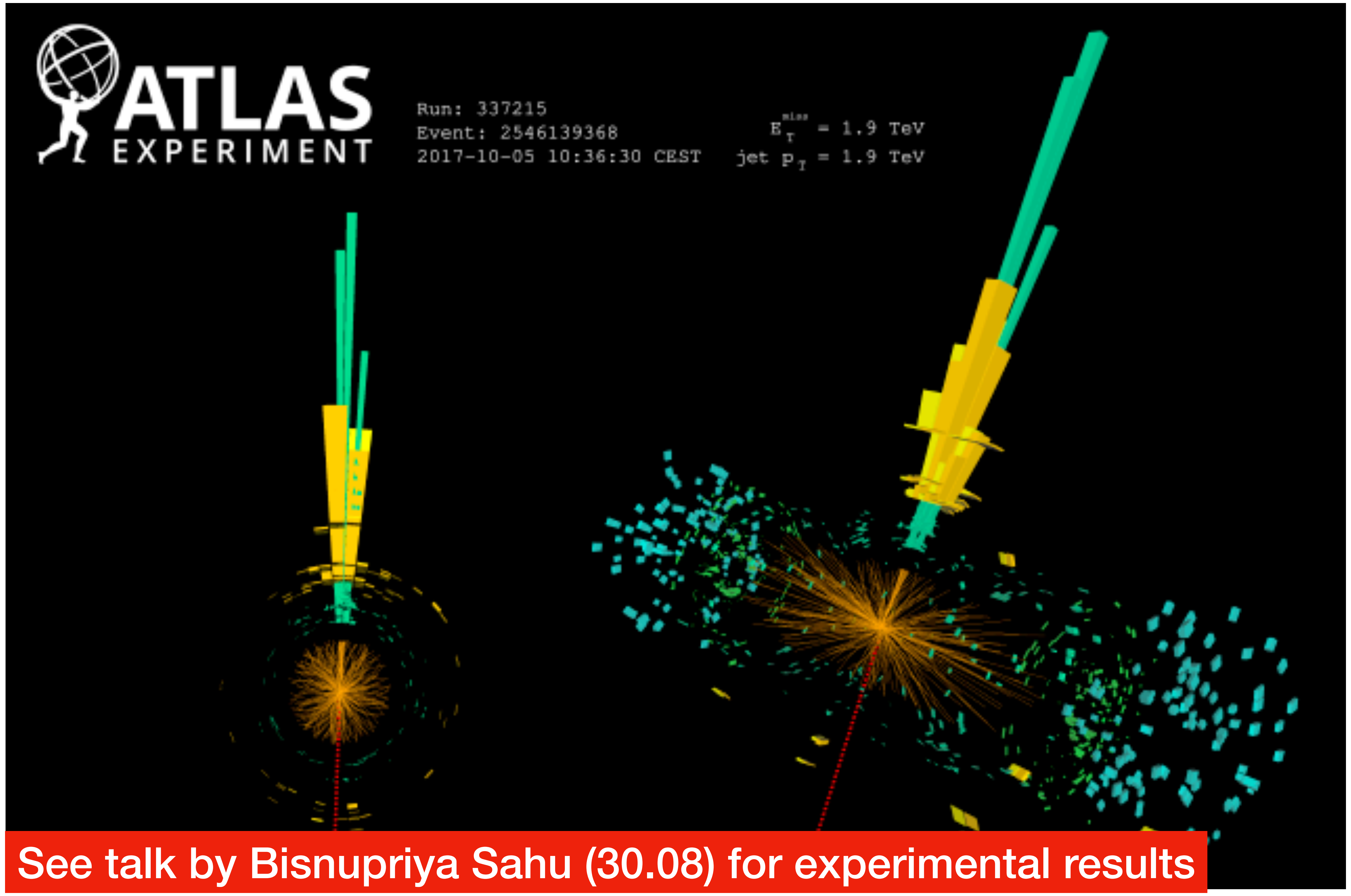
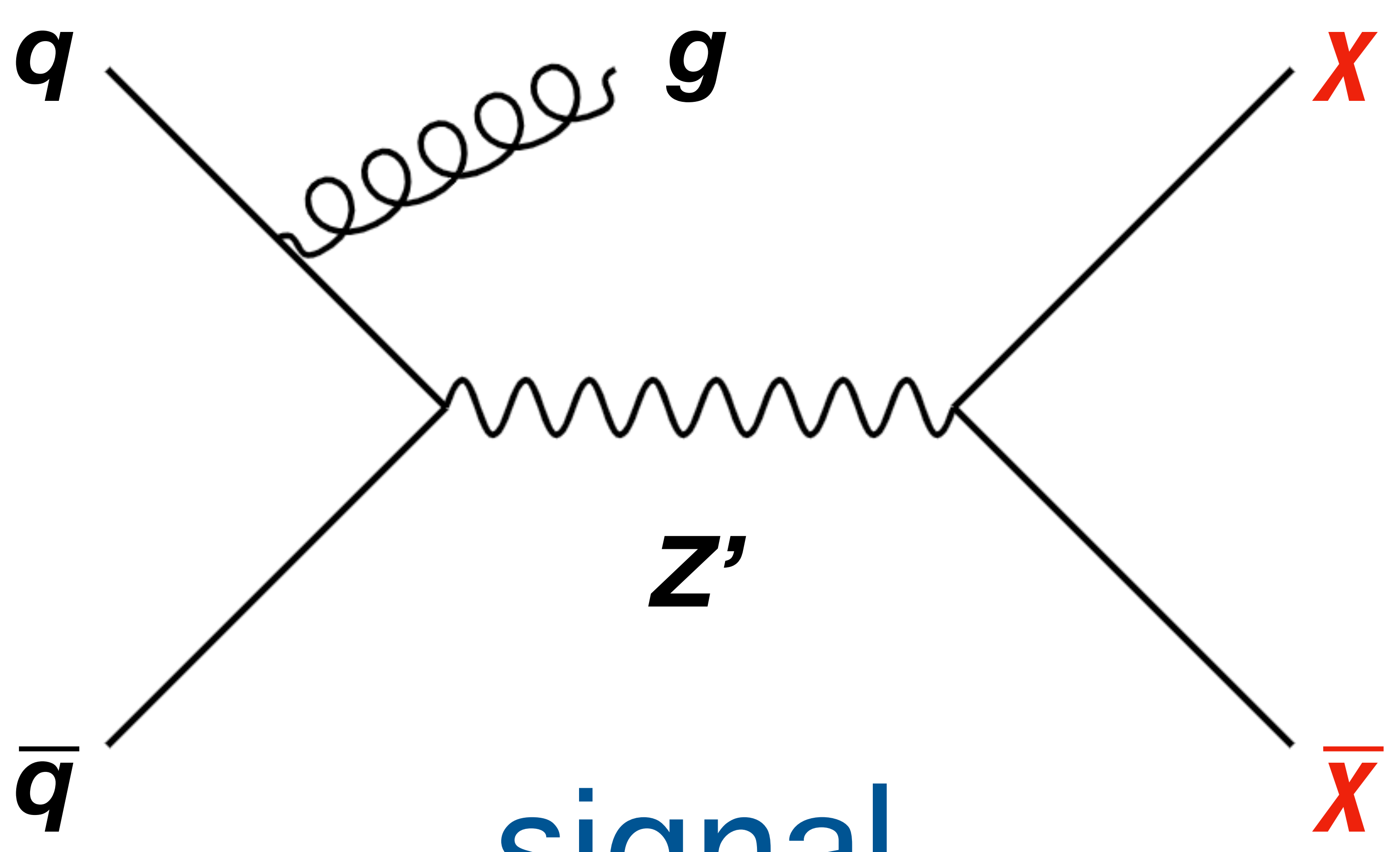
DM searches @ LHC — Monojet

Monojet channel = 1 or more hard jets
recoiling against a missing transverse momentum
and no isolated leptons

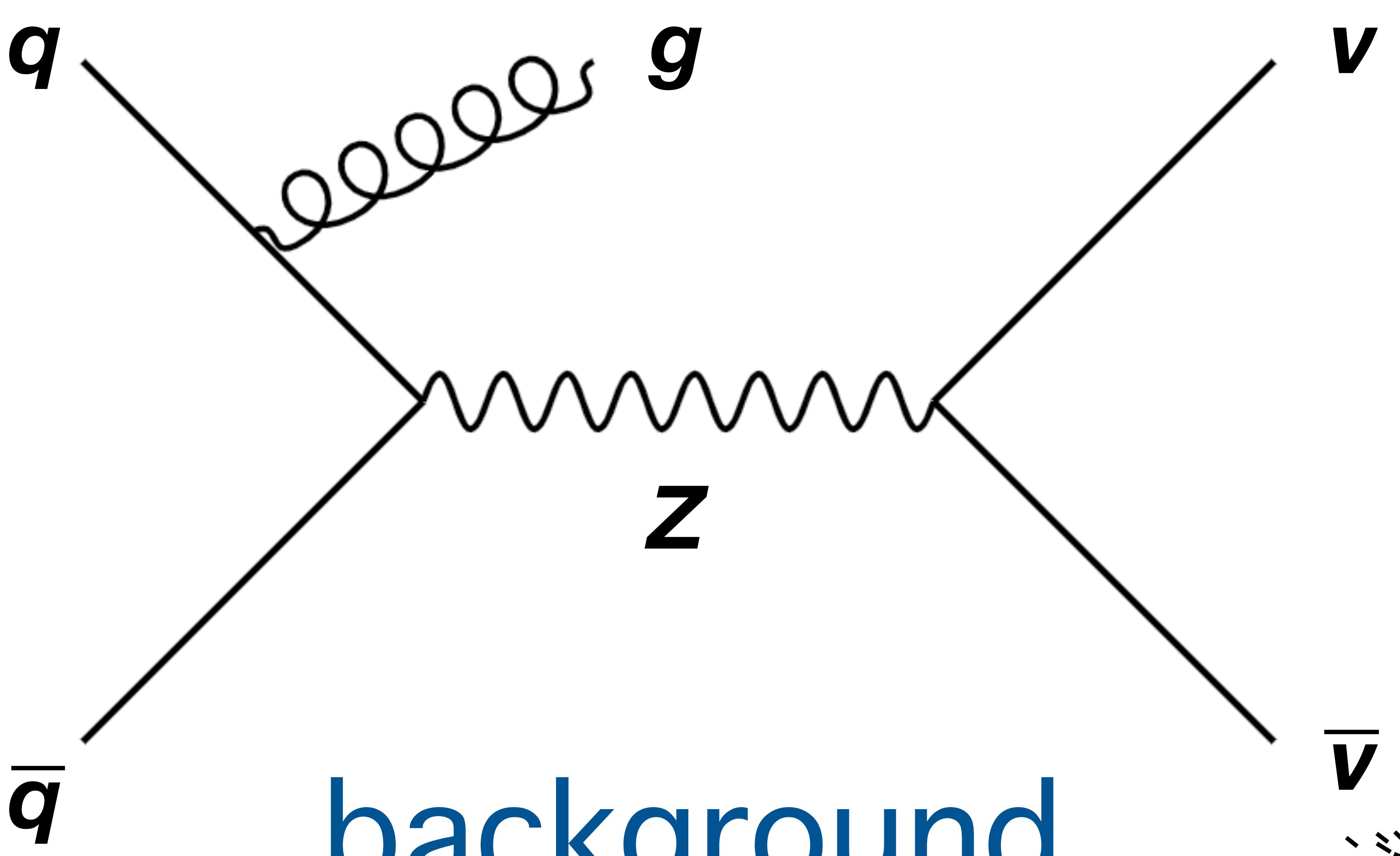


img source: https://cds.cern.ch/record/2725235

See talk by Bisnupriya Sahu (30.08) for experimental results



signal



background

The idea

- One of the challenges for the Monojet searches is that we observe very similar jets for both signal and background
- Analysis of jet substructure is needed
- With Machine Learning we can analyse low-level data
- ML can learn both local and global correlations
- GOAL: Design new analysis using ML

Data

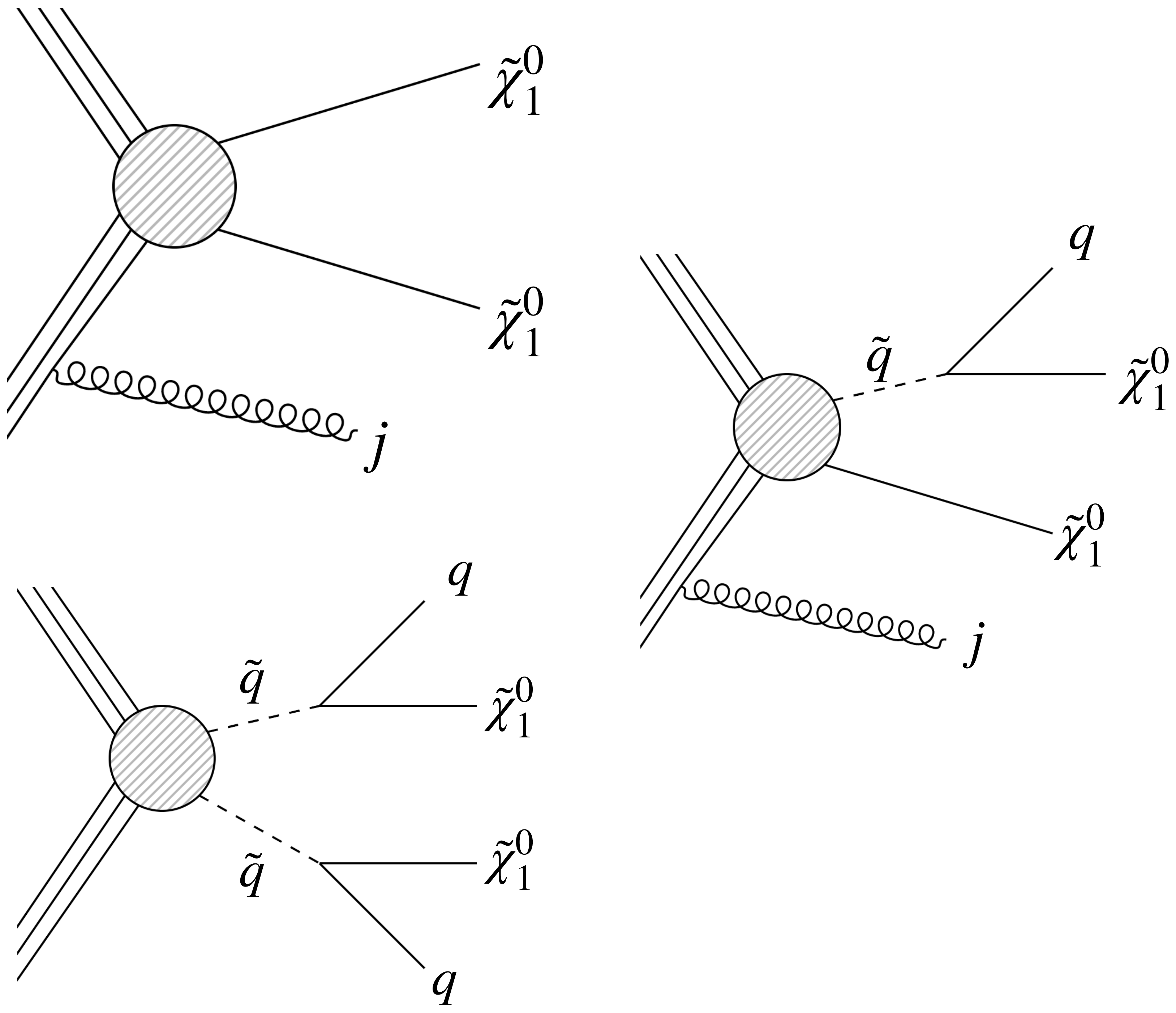
SM

$pp \to Z + \text{jets};\ (Z \to \nu\bar{\nu})$

BSM

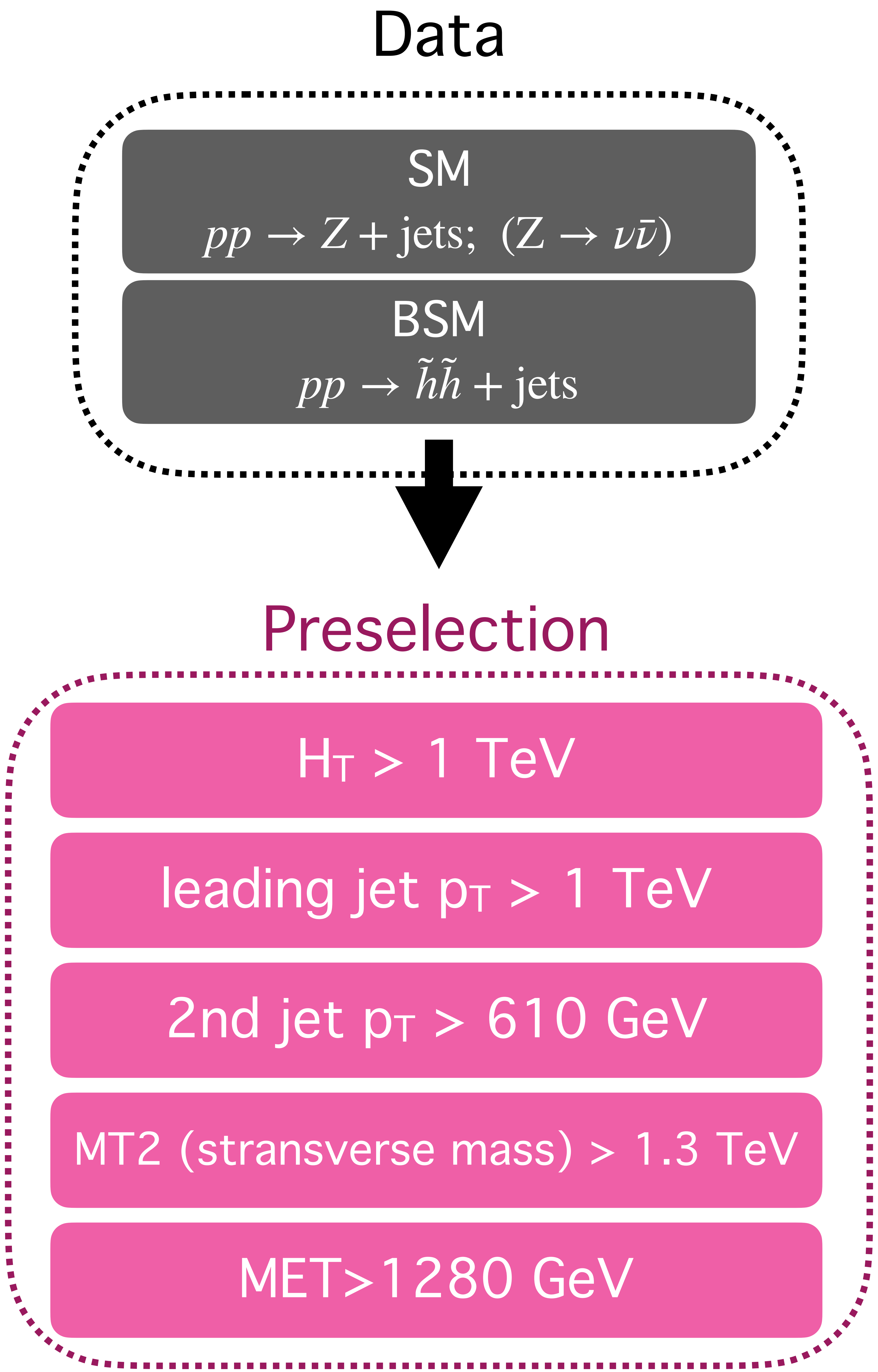
$pp \to \tilde{h}\tilde{h} + \text{jets}$

Benchmark model SUSY



neutralino flavour	neutralino mass [GeV]	squark mass [TeV]
higgsino	200	2.00
higgsino	300	2.00
higgsino	400	2.00
higgsino	500	2.00
higgsino	600	2.00
higgsino	300	2.25
higgsino	300	2.50
higgsino	300	2.75
higgsino	300	3.00
wino	200	2.00
wino	500	2.00

First start with the preselection



Then apply NN to hard-to-distinguish events

Data

- SM: $pp \to Z + \text{jets}; \;(Z \to \nu\bar{\nu})$
- BSM: $pp \to \tilde{h}\tilde{h} + \text{jets}$

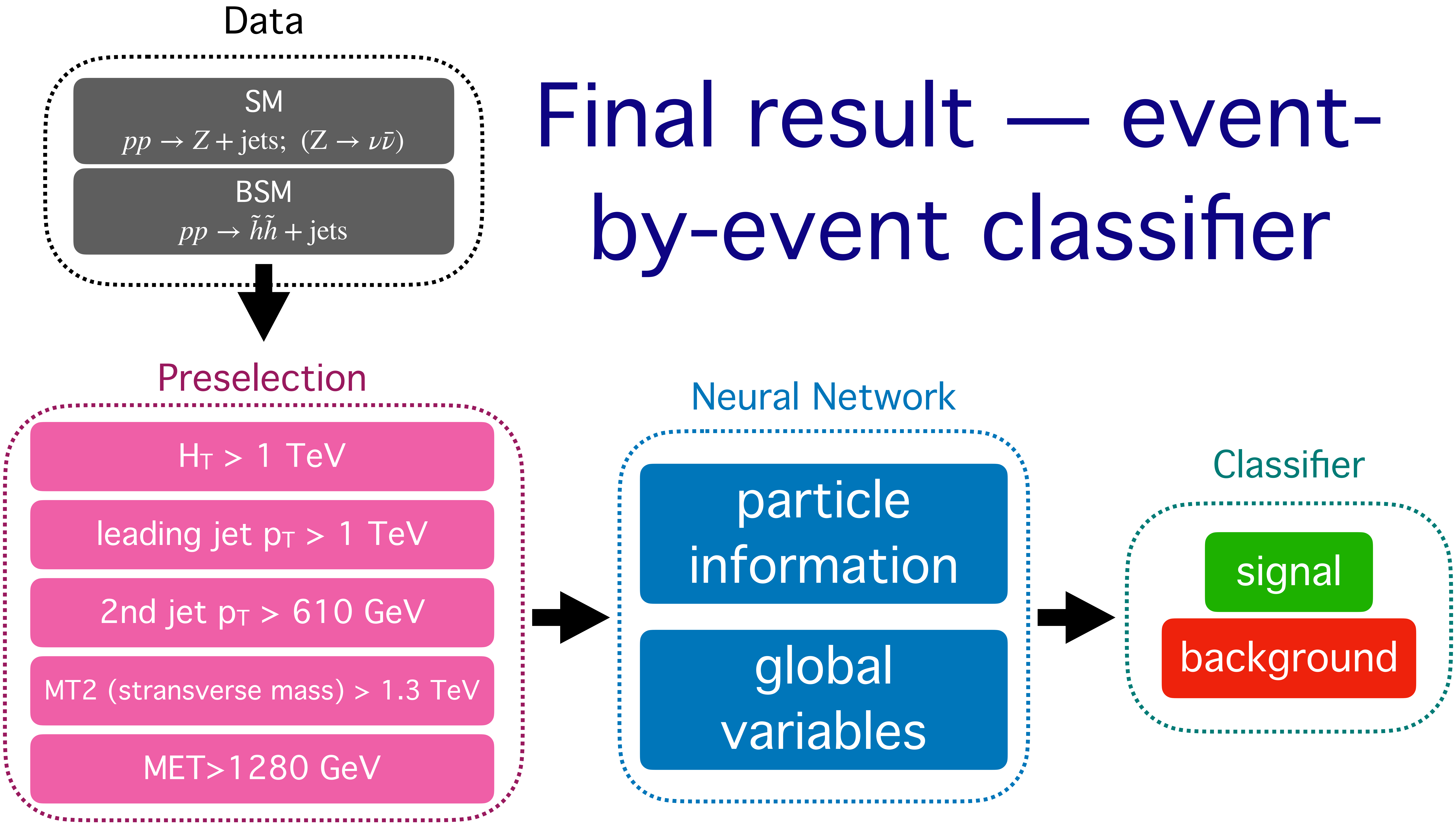
Preselection

- $H_T > 1$ TeV
- leading jet $p_T > 1$ TeV
- 2nd jet $p_T > 610$ GeV
- MT2 (stransverse mass) > 1.3 TeV
- MET>1280 GeV

Neural Network

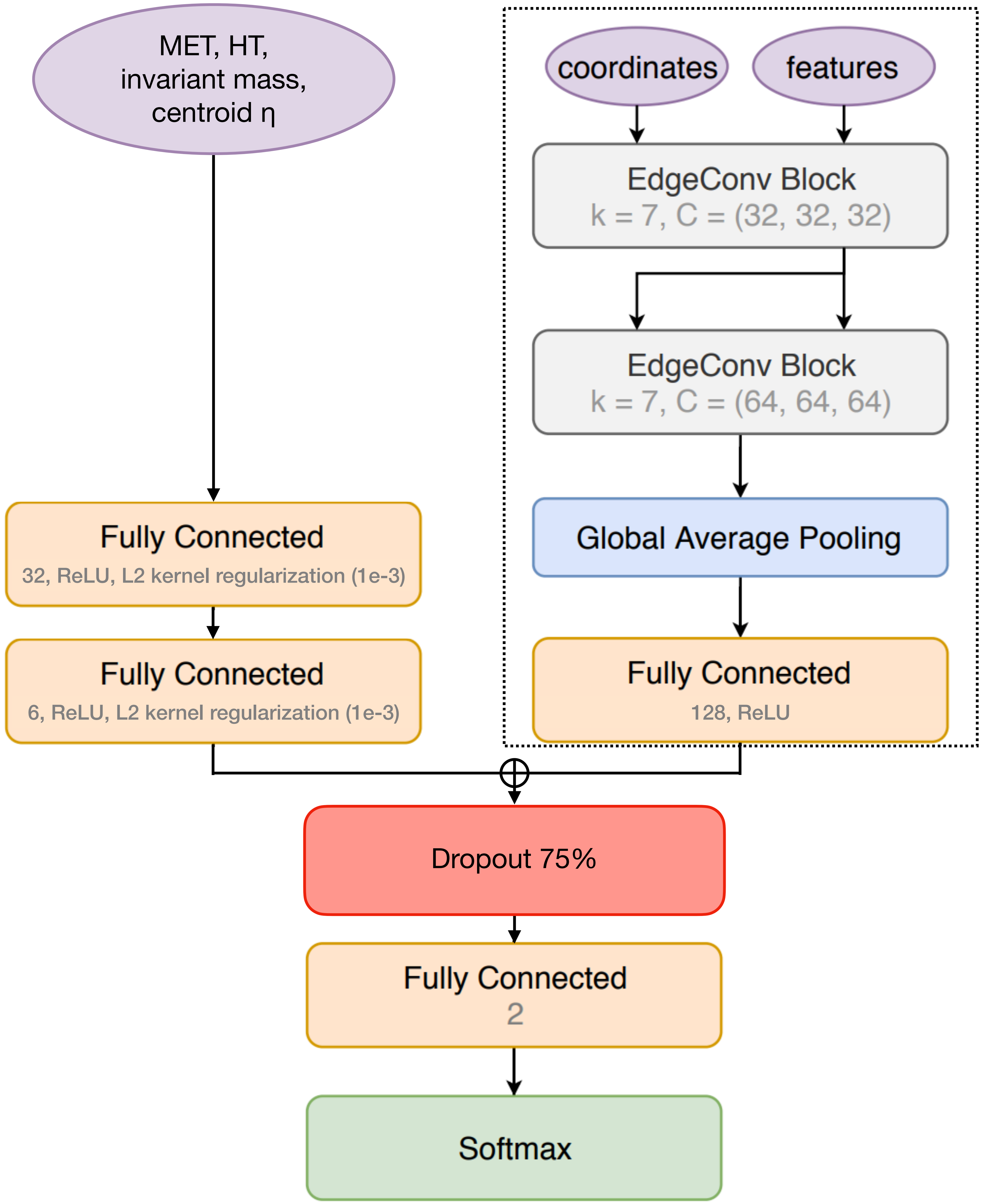
- particle information
- global variables

Final result — event-by-event classifier



Neural Network architecture

Global variables



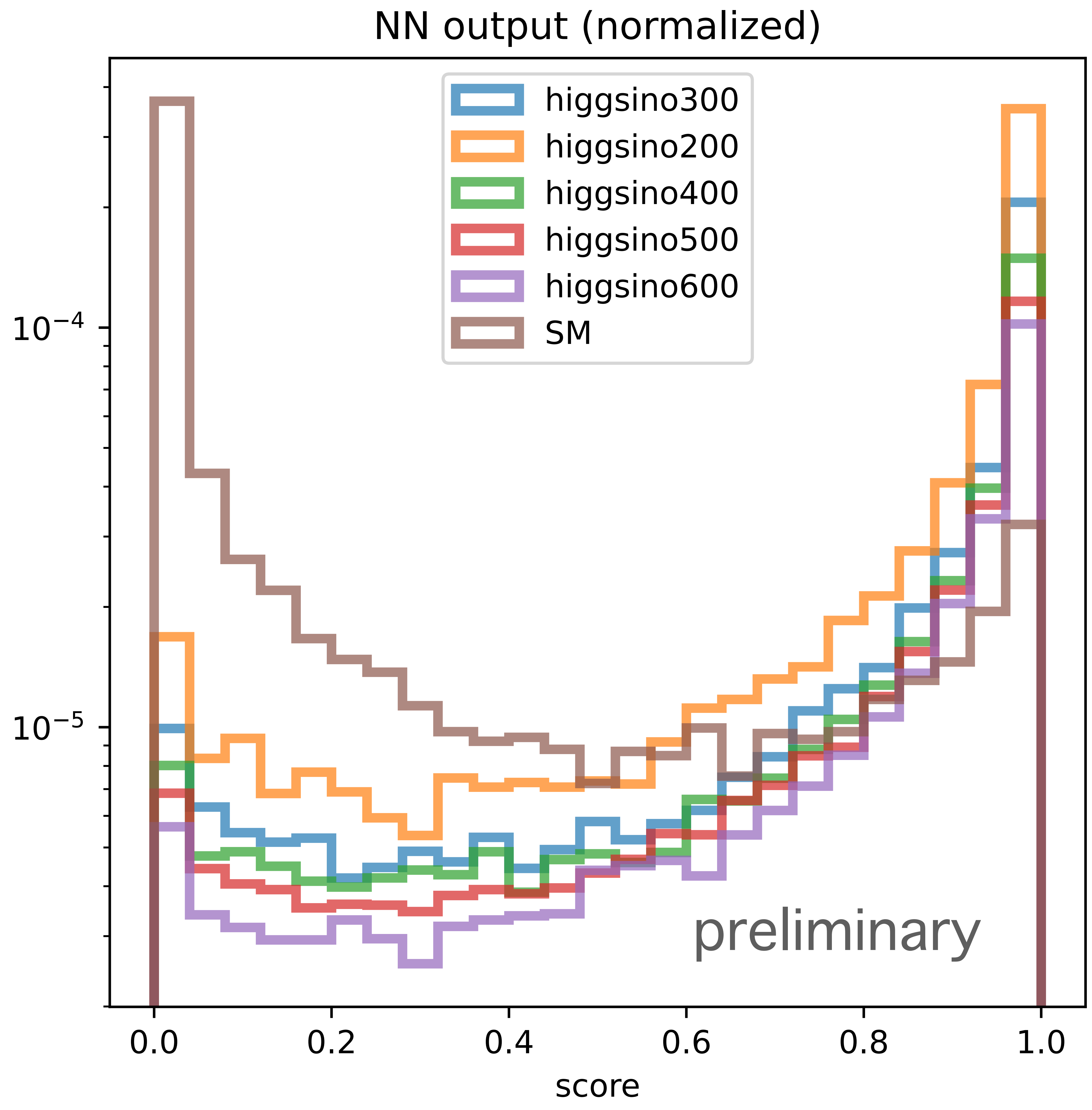
Local variables

Based on ParticleNet Lite

Evaluation

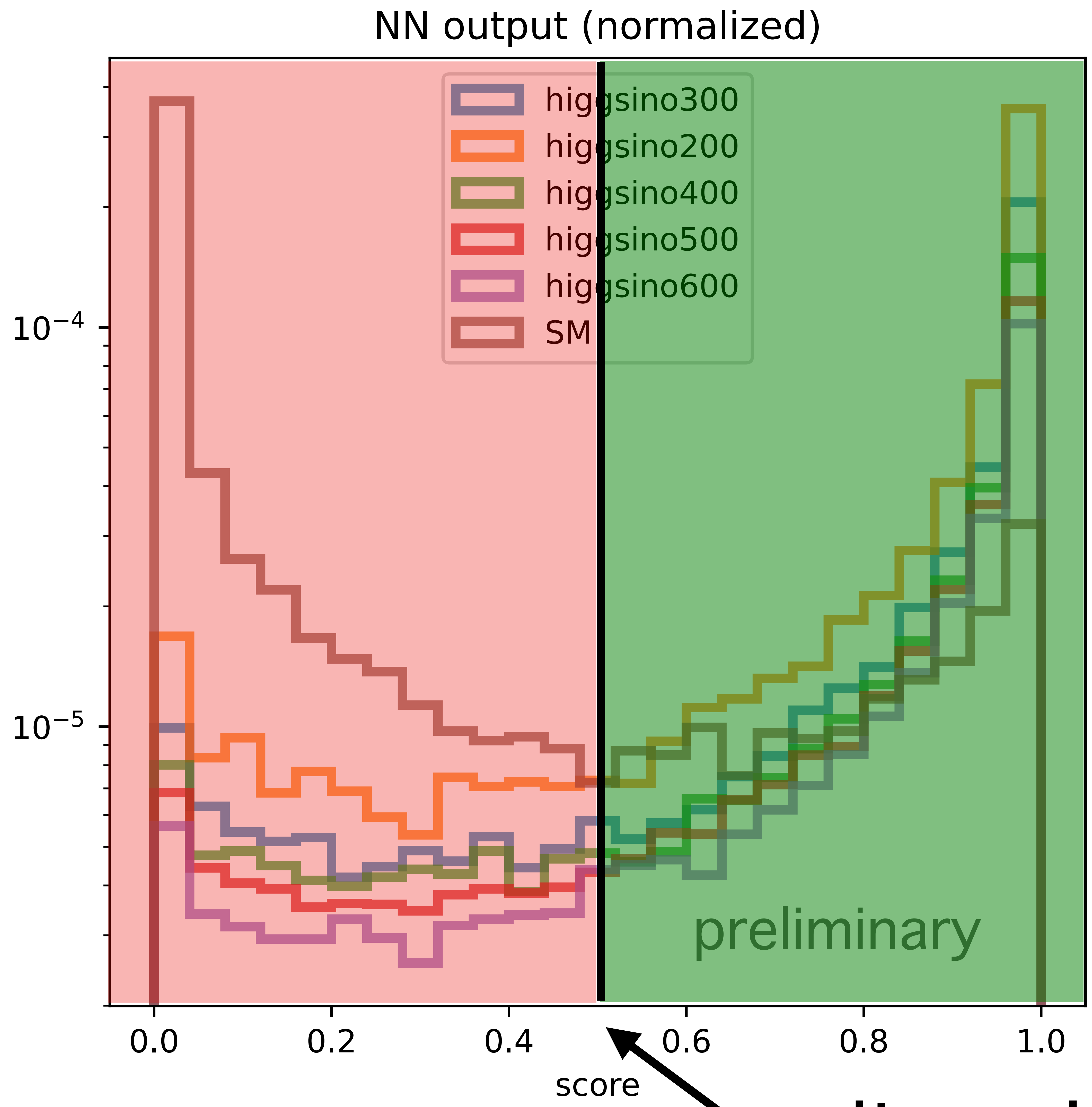
Malbork Castle, Poland
photo from museum’s FB page

Evaluation — varying Higgsino mass



Evaluation — varying Higgsino mass

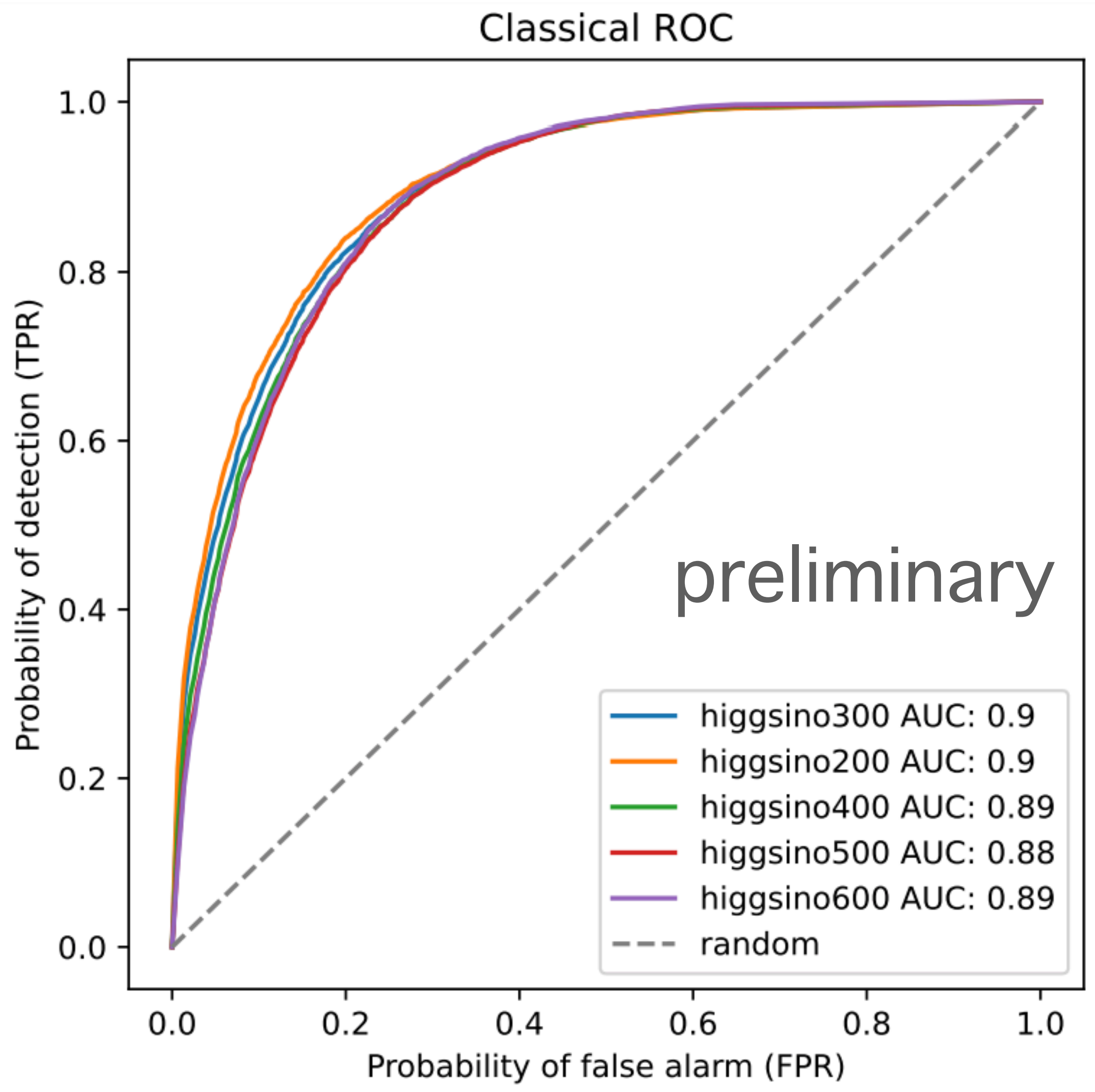
background

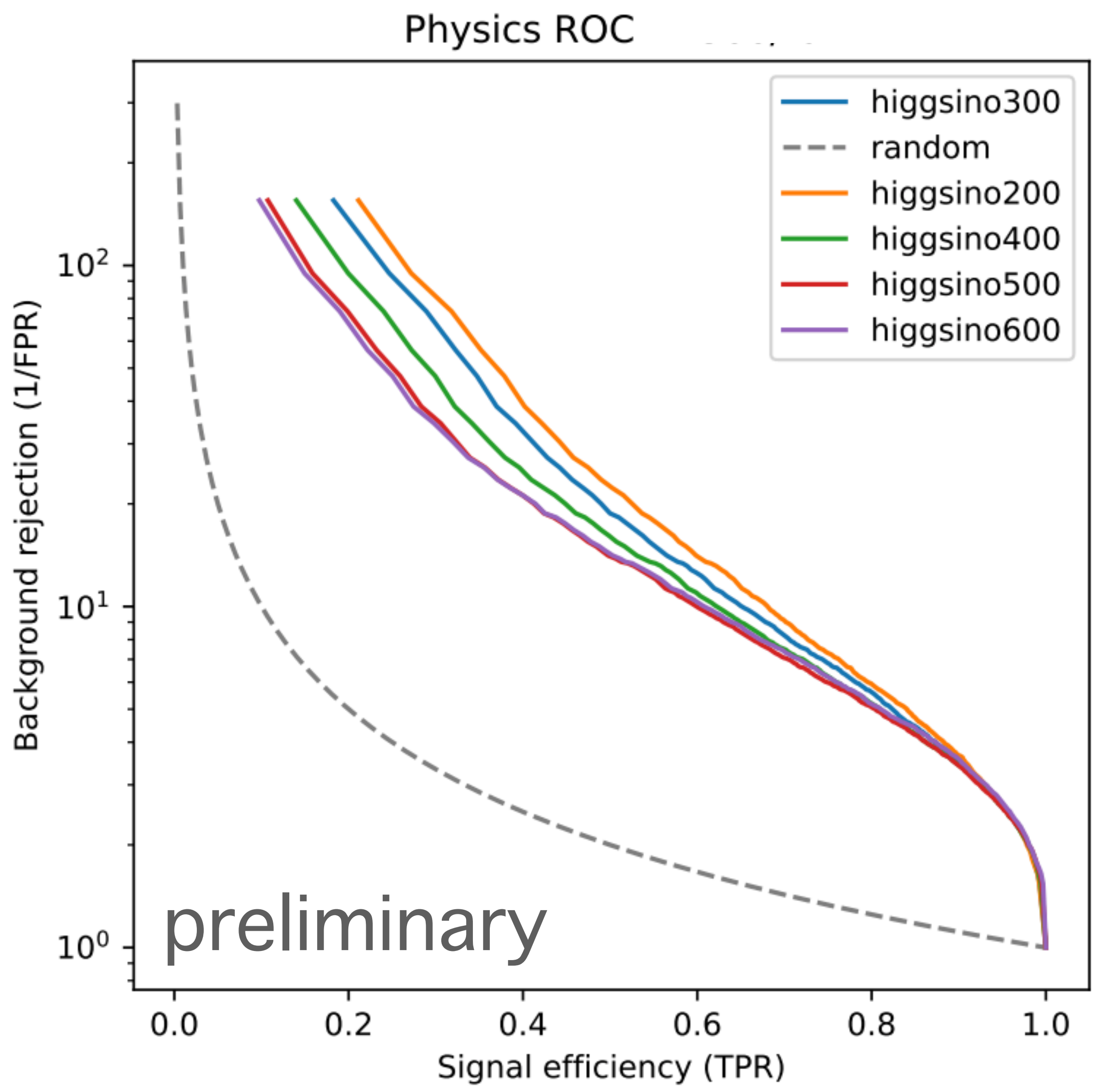


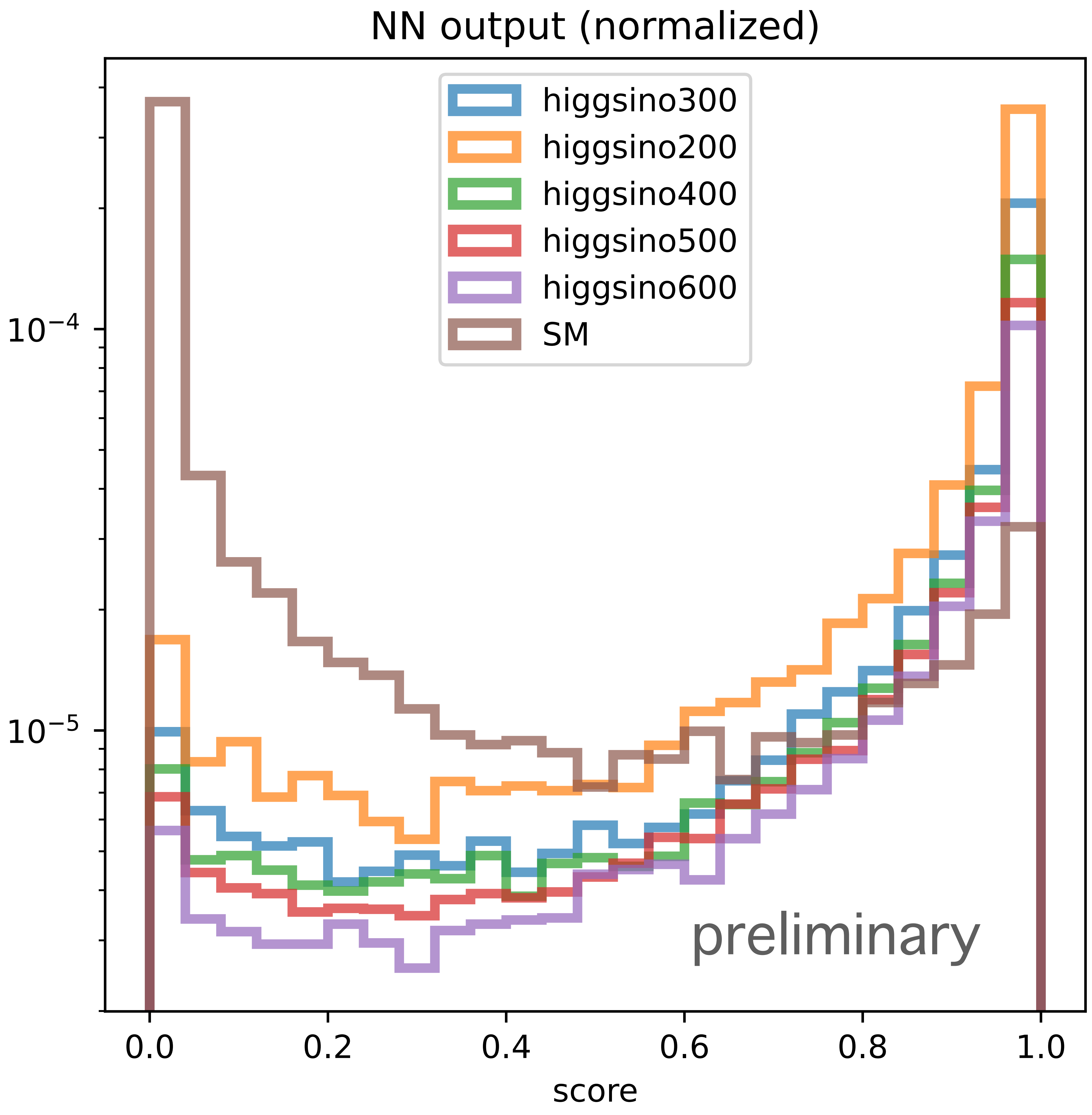
signal

adjustable threshold

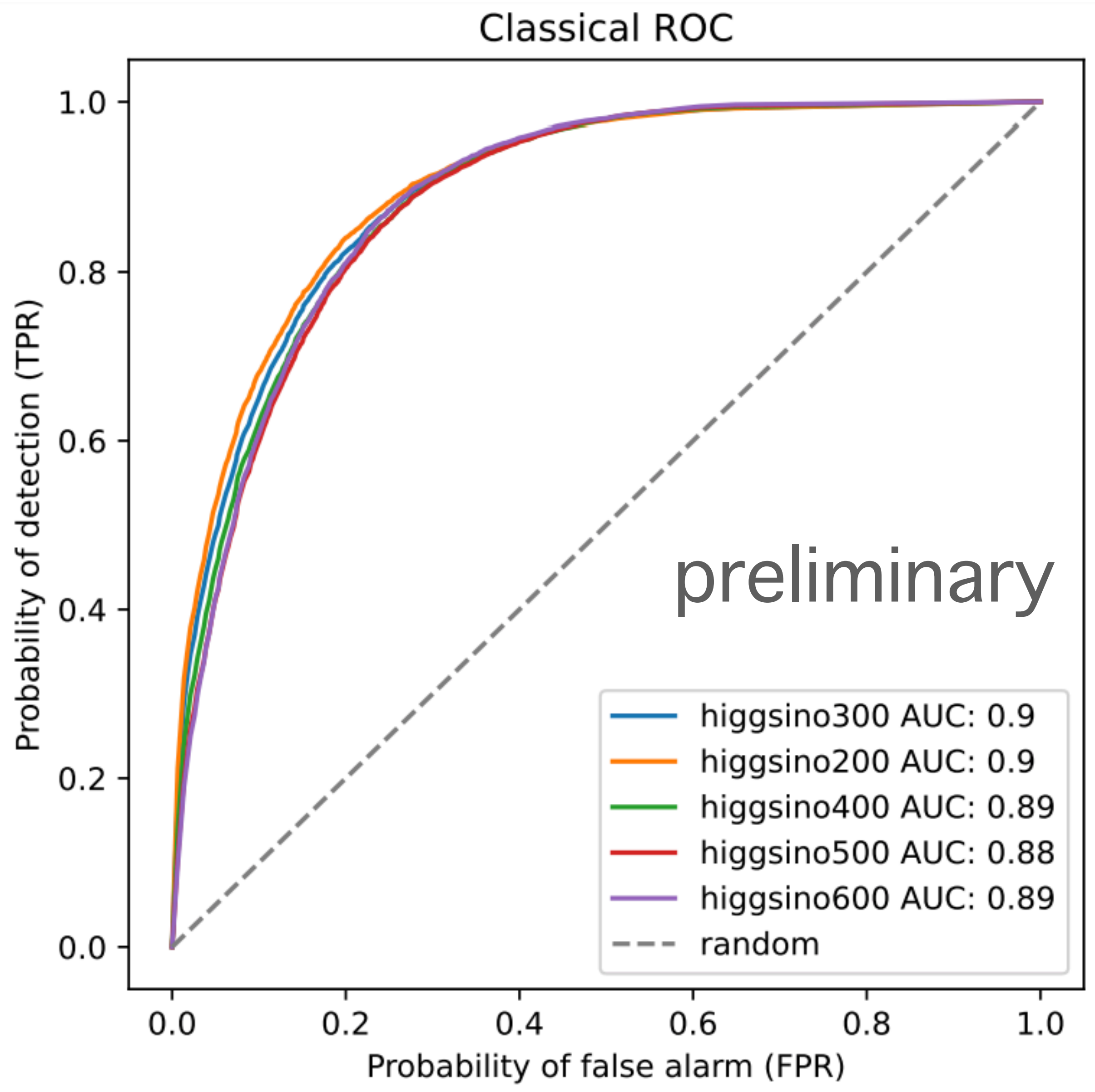
Evaluation — varying Higgsino mass

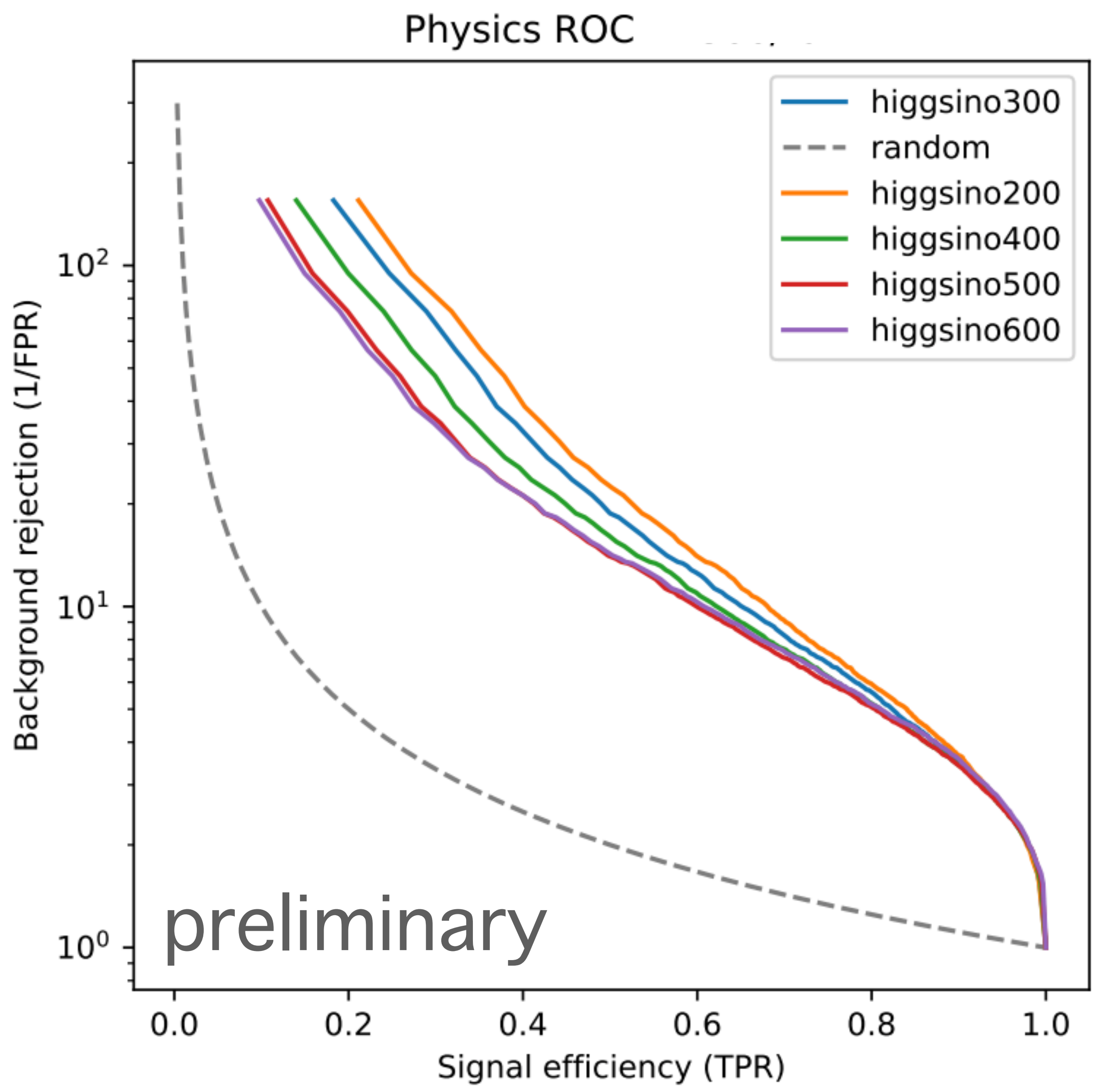


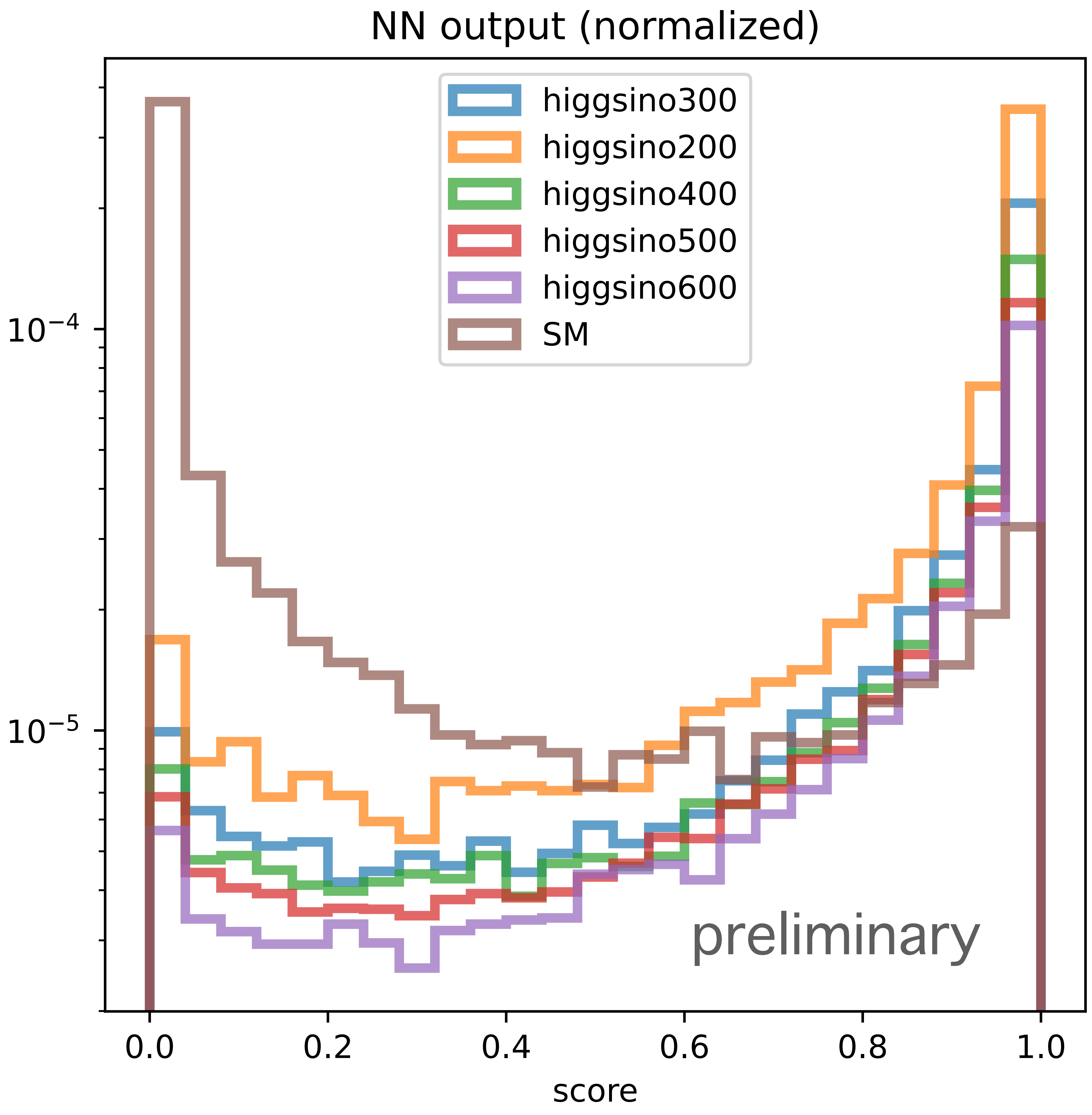


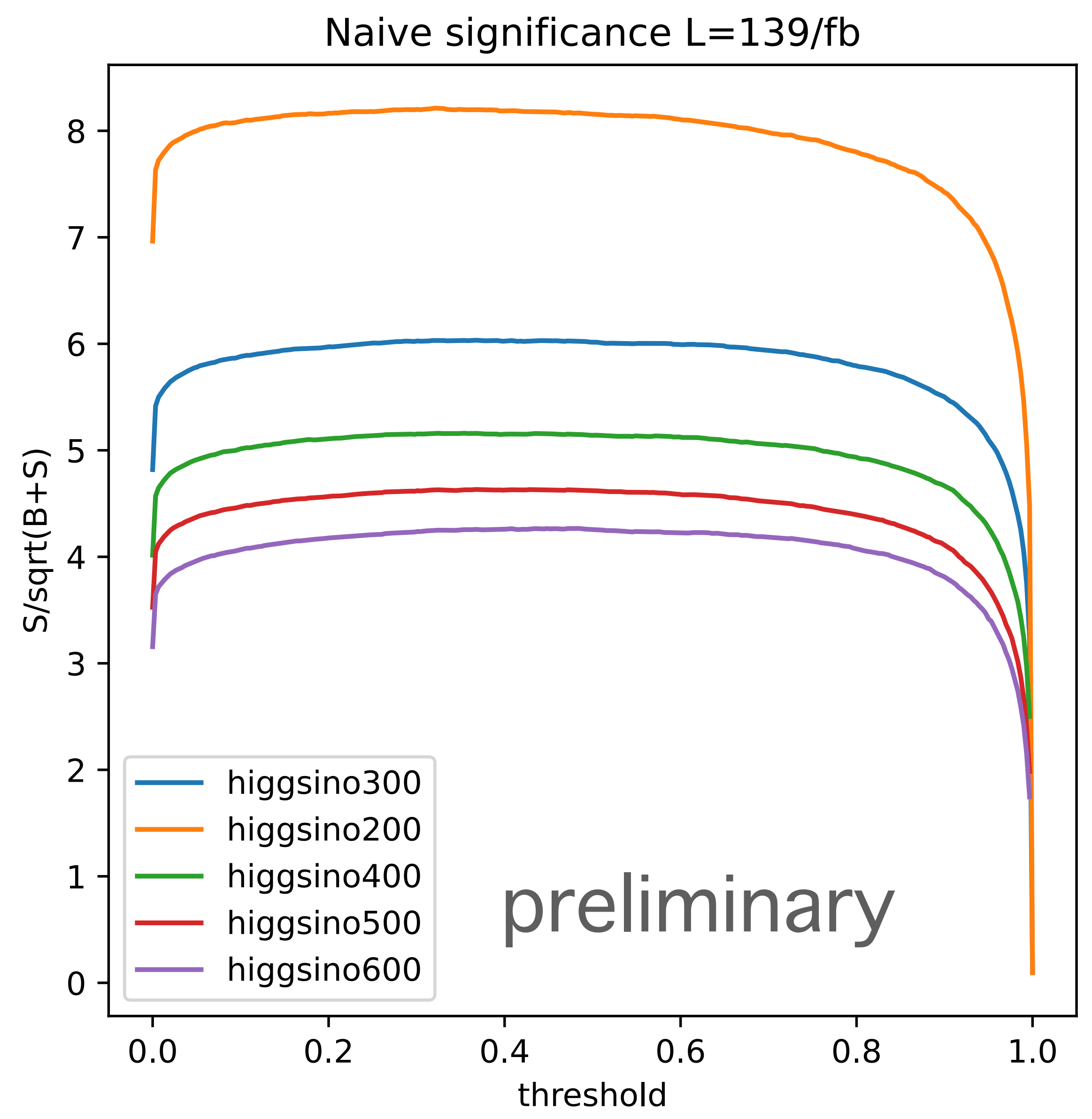


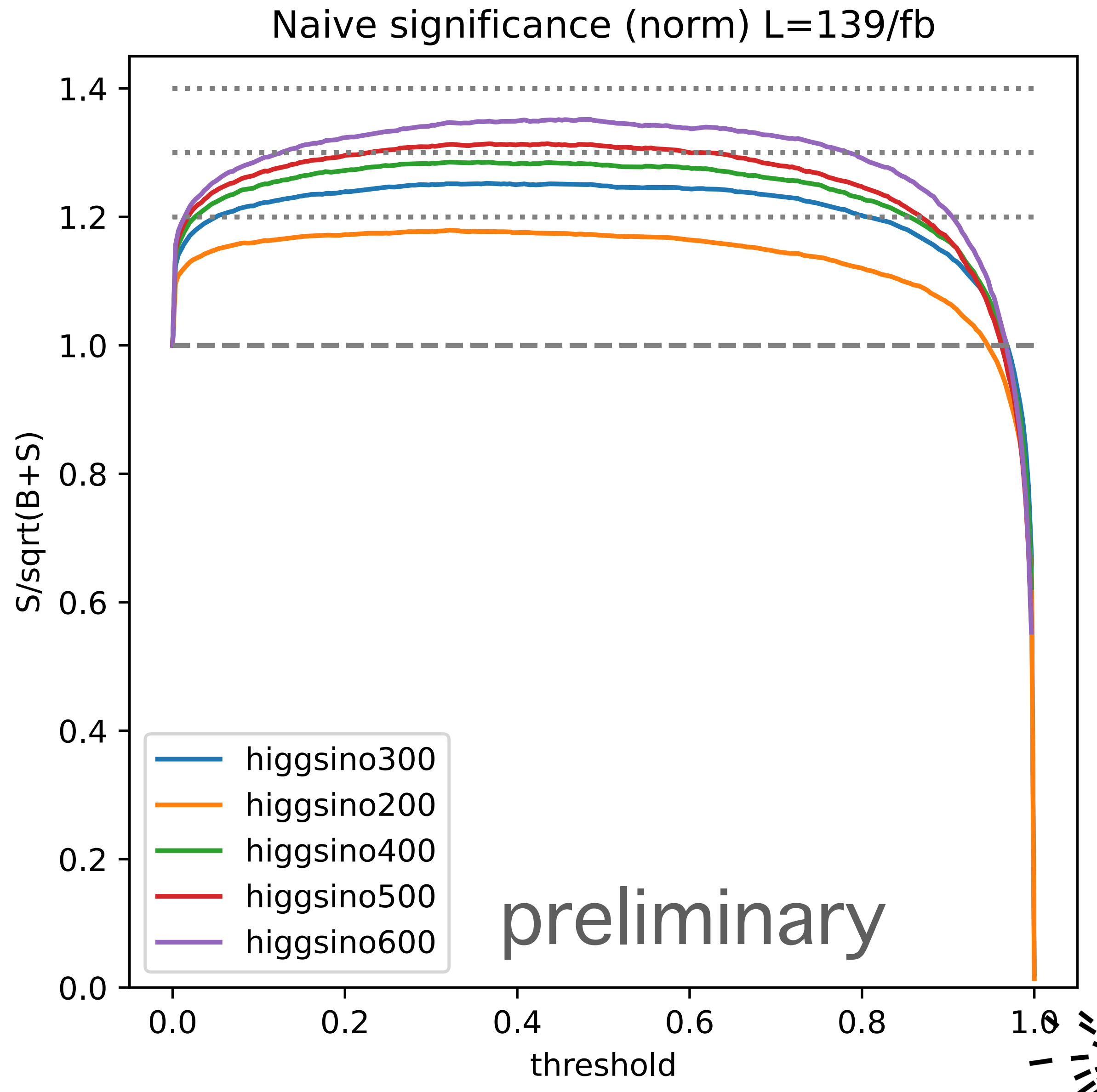
Evaluation — varying Higgsino mass



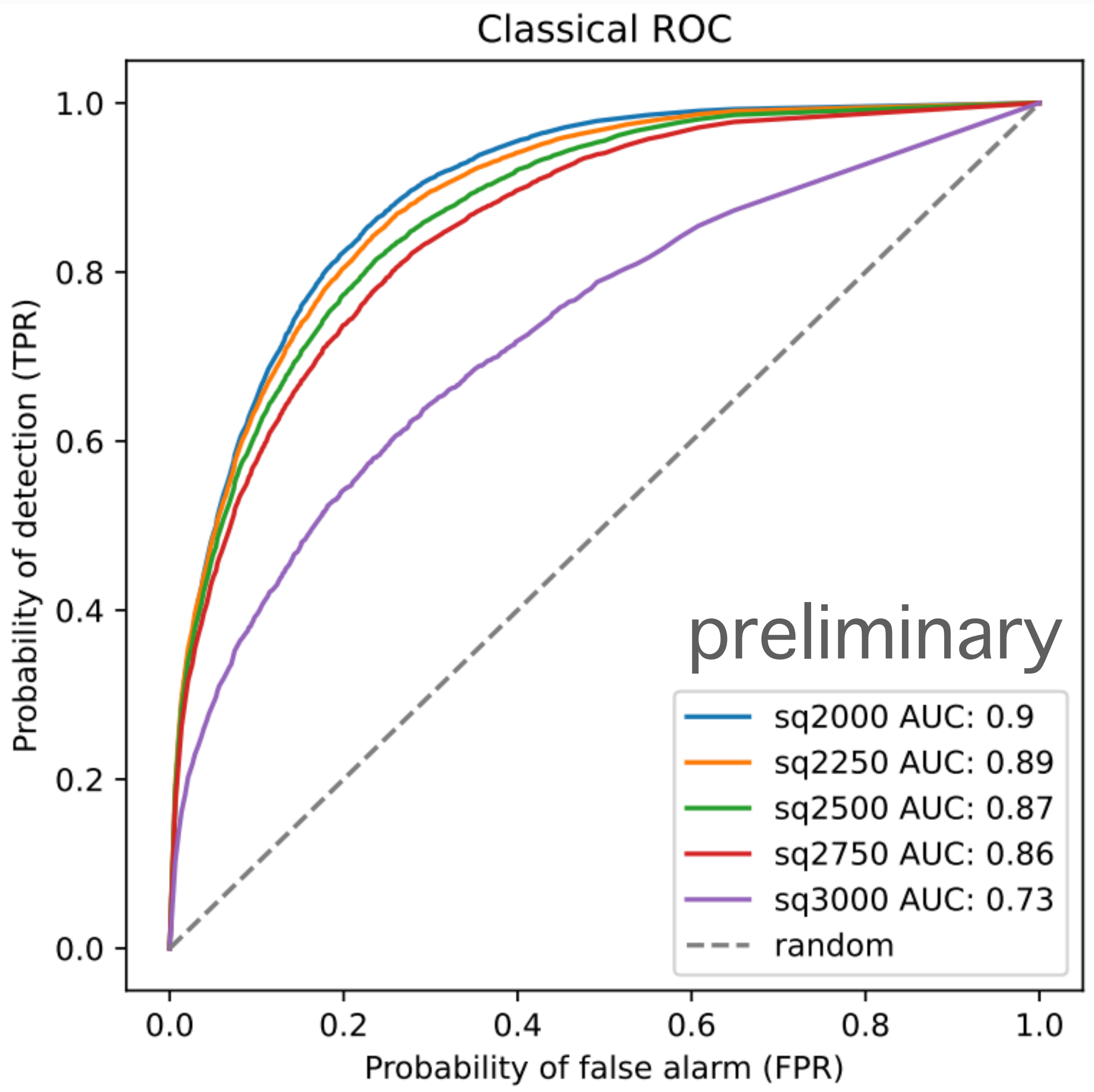


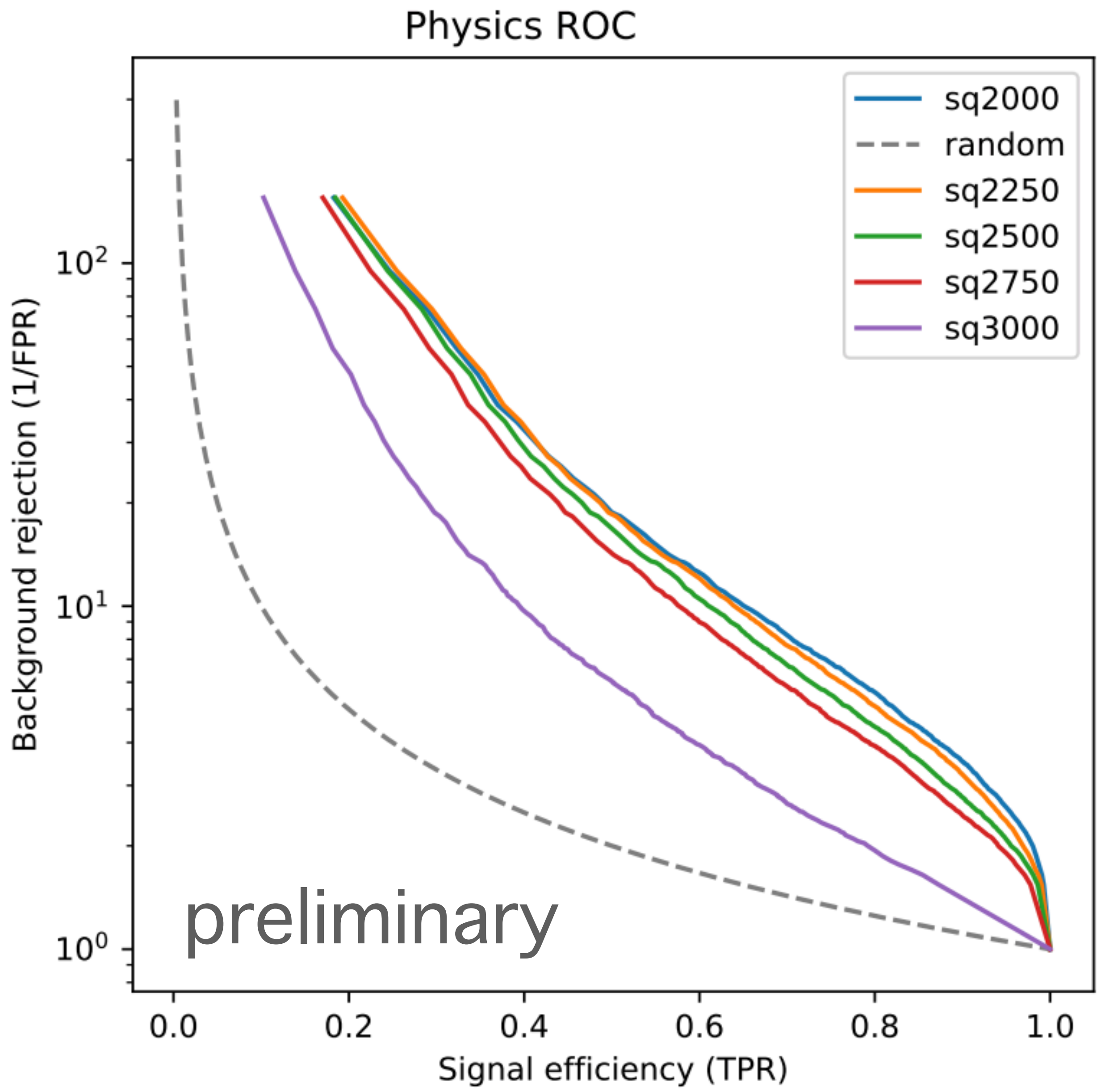


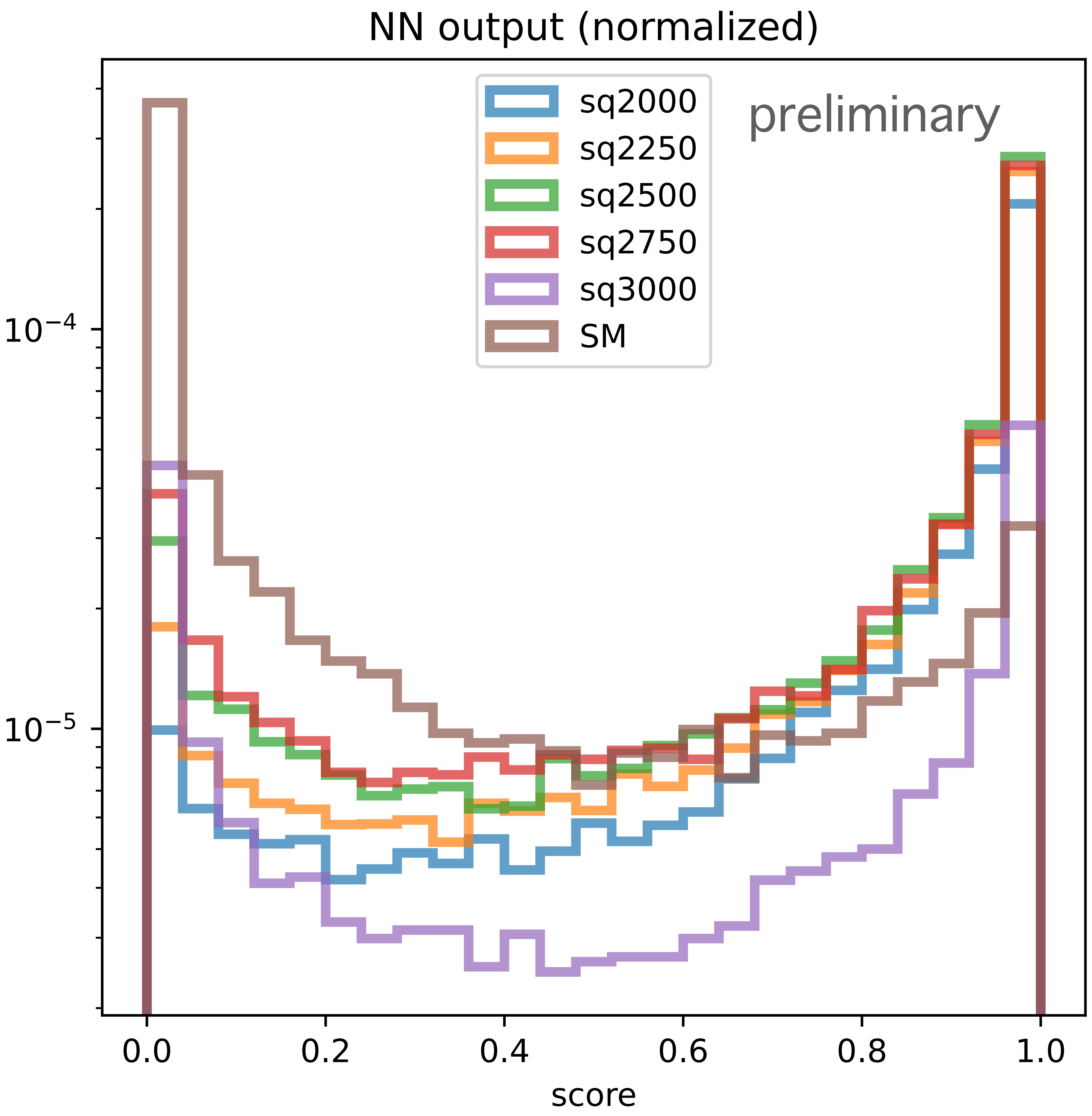


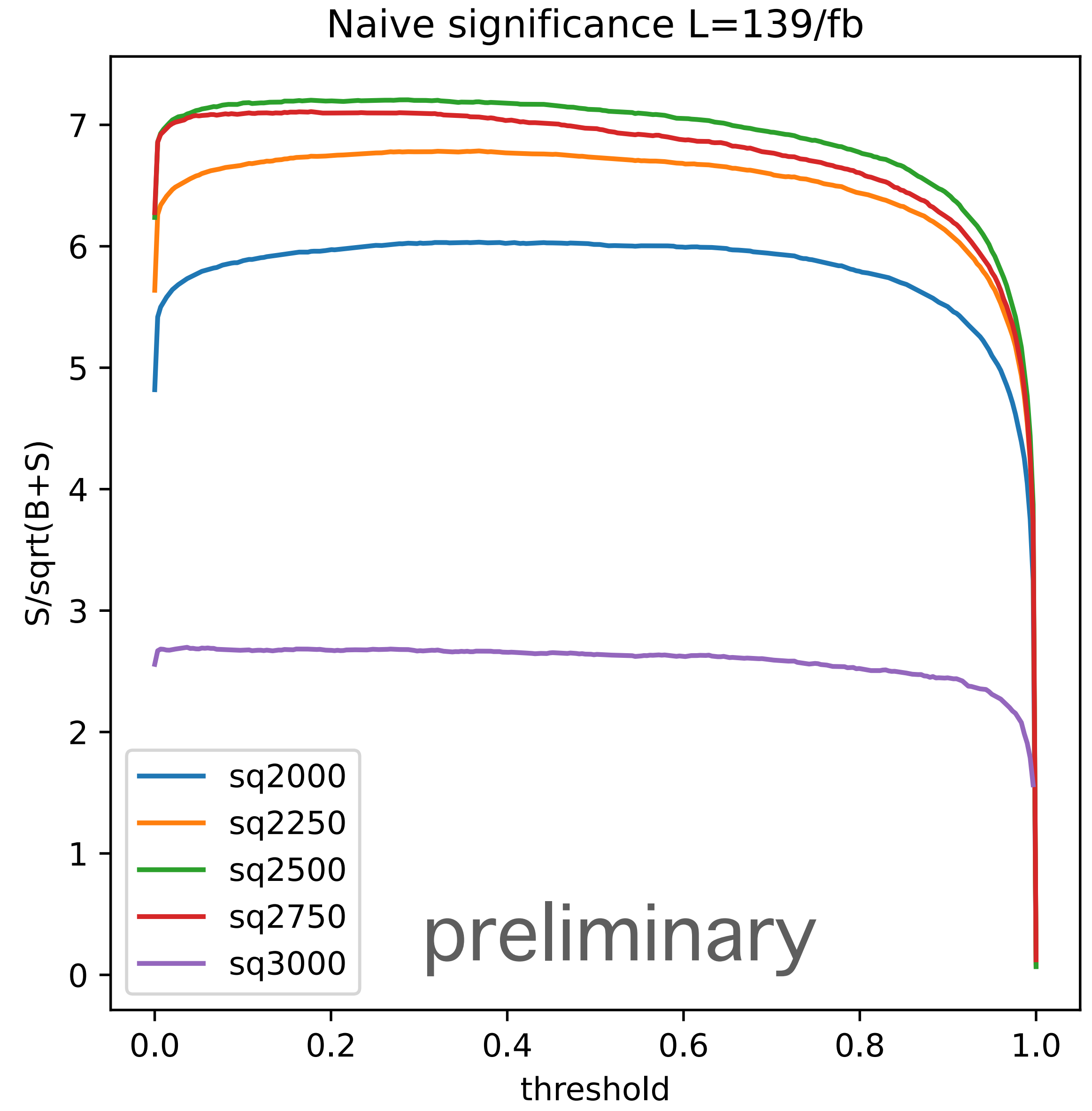


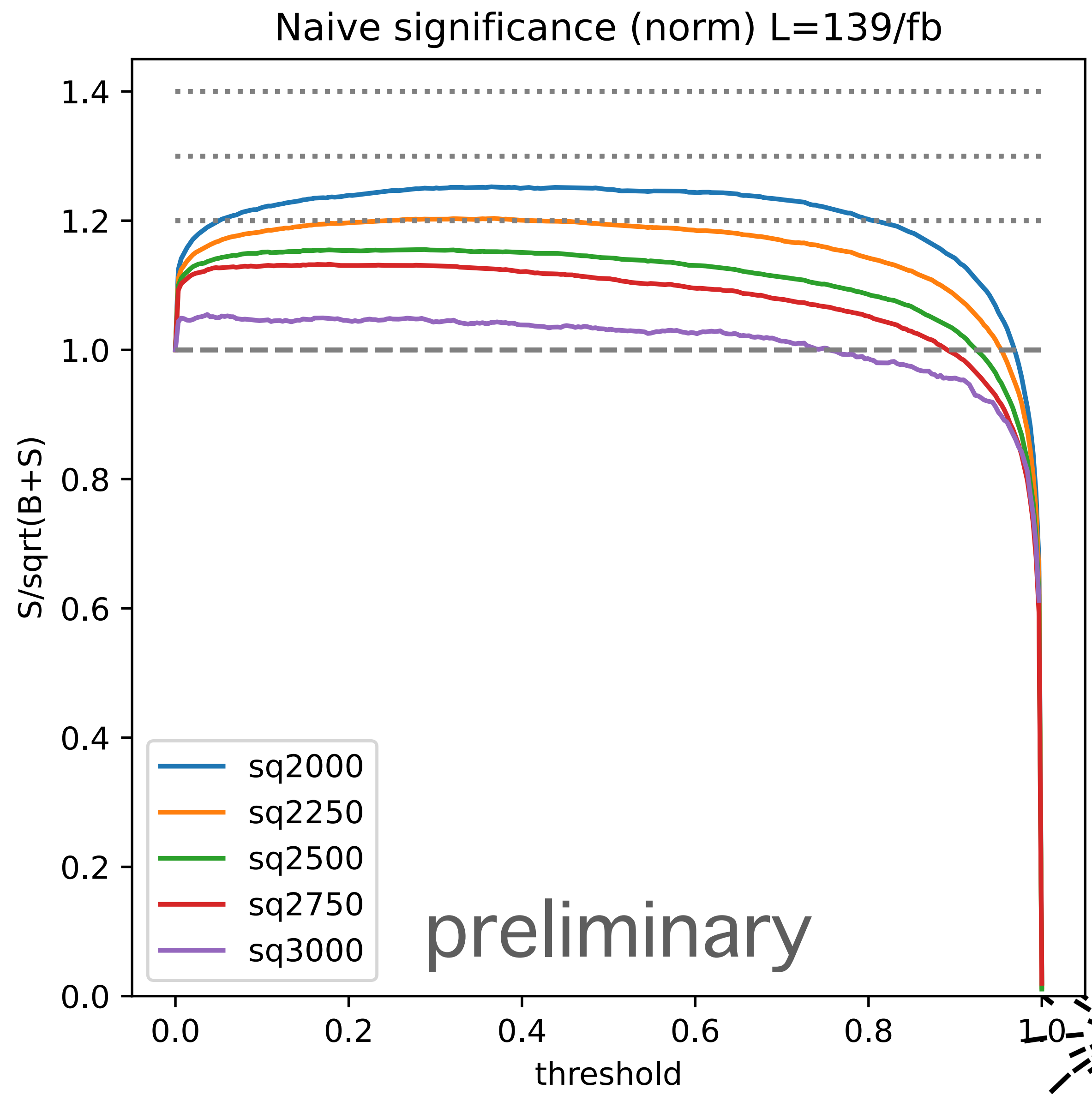
Evaluation — varying squark mass



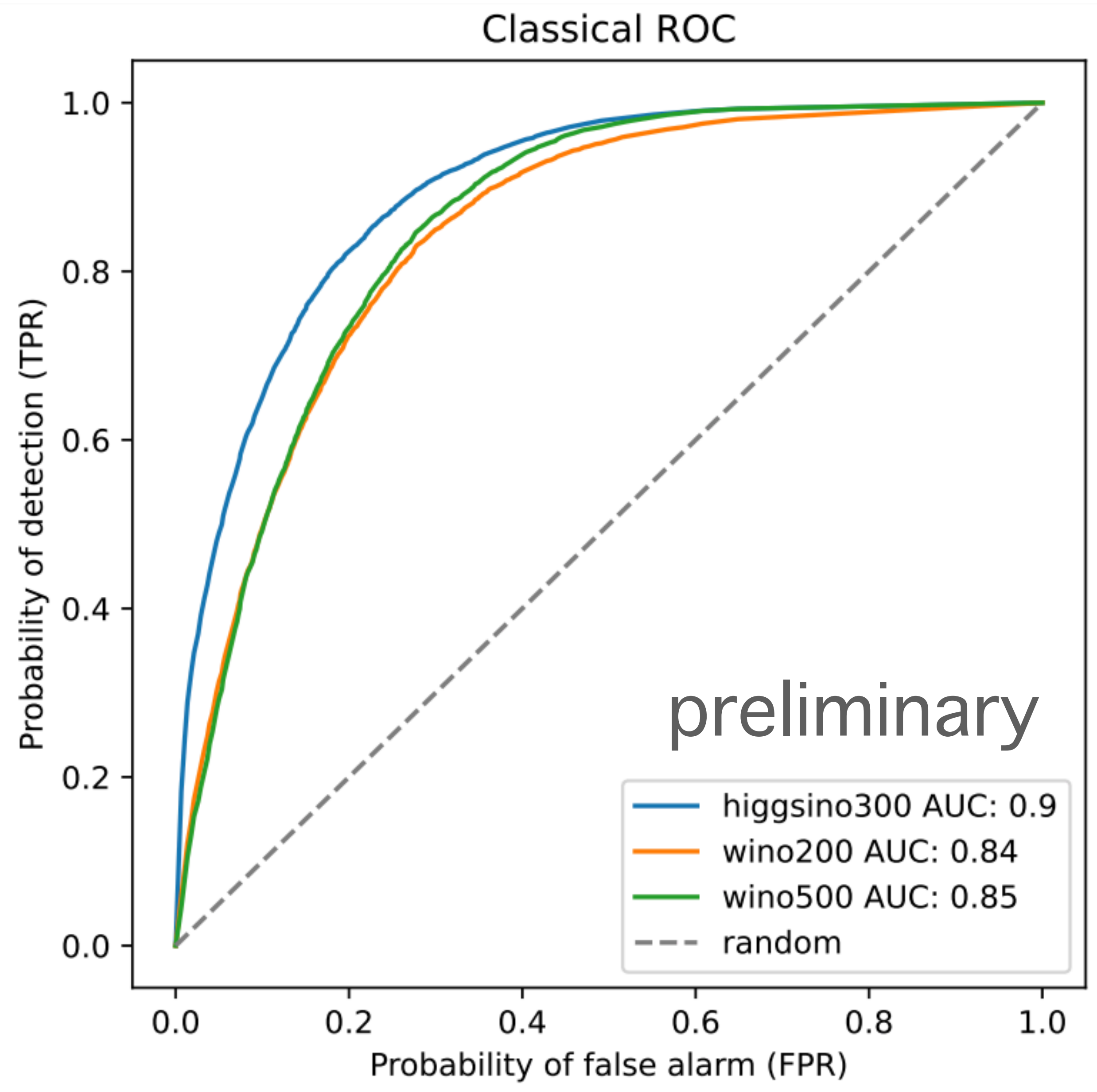


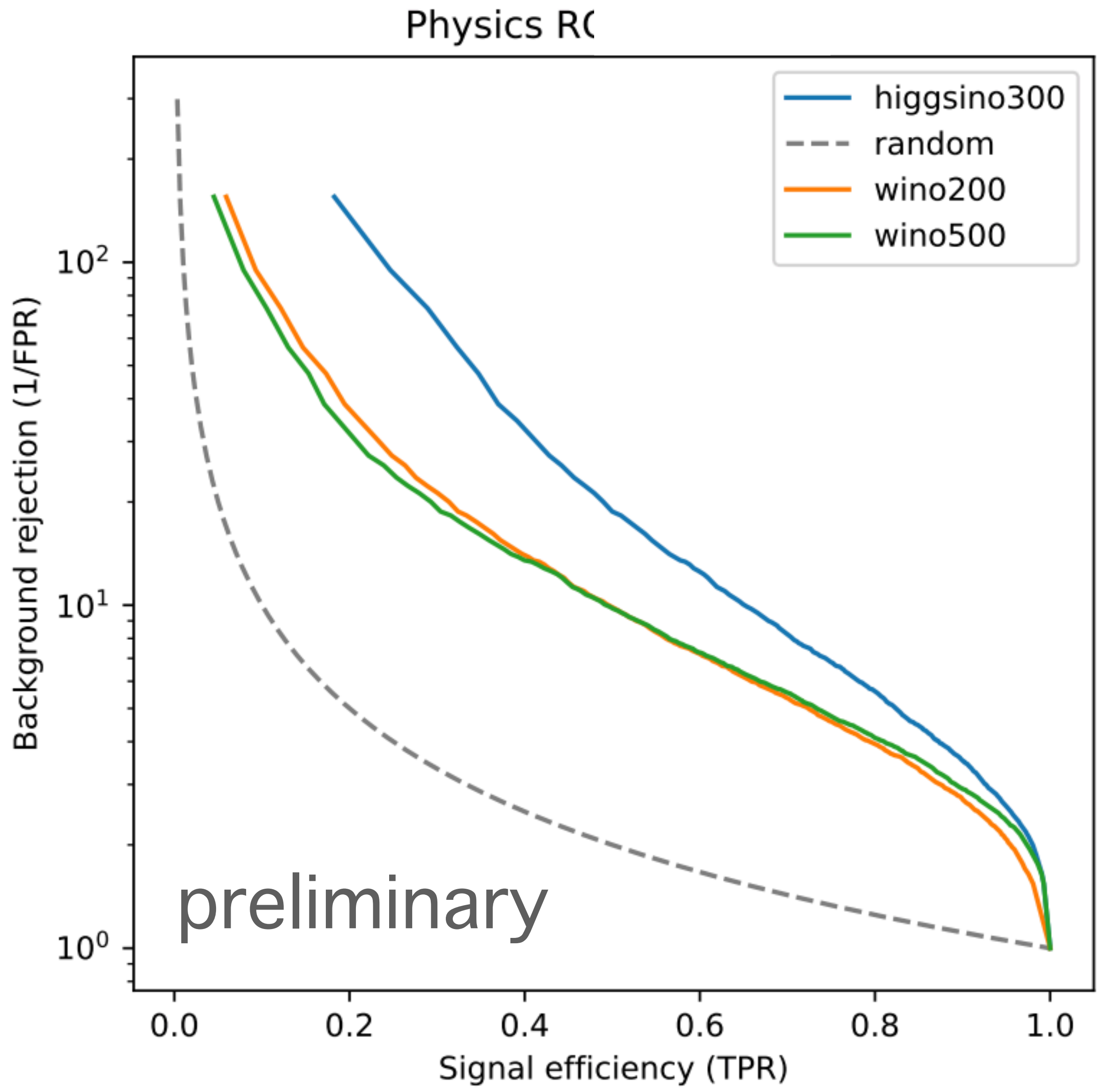


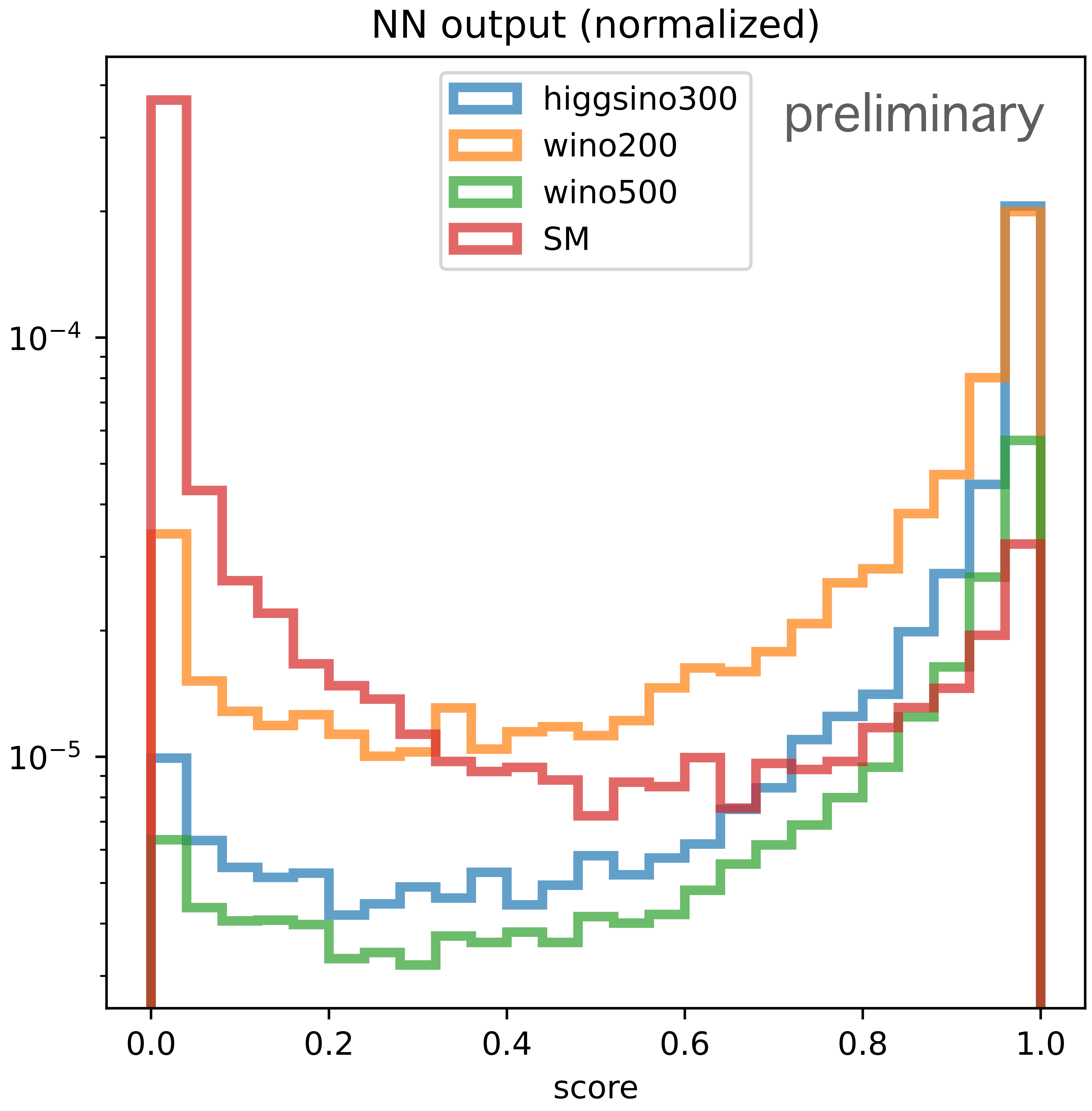


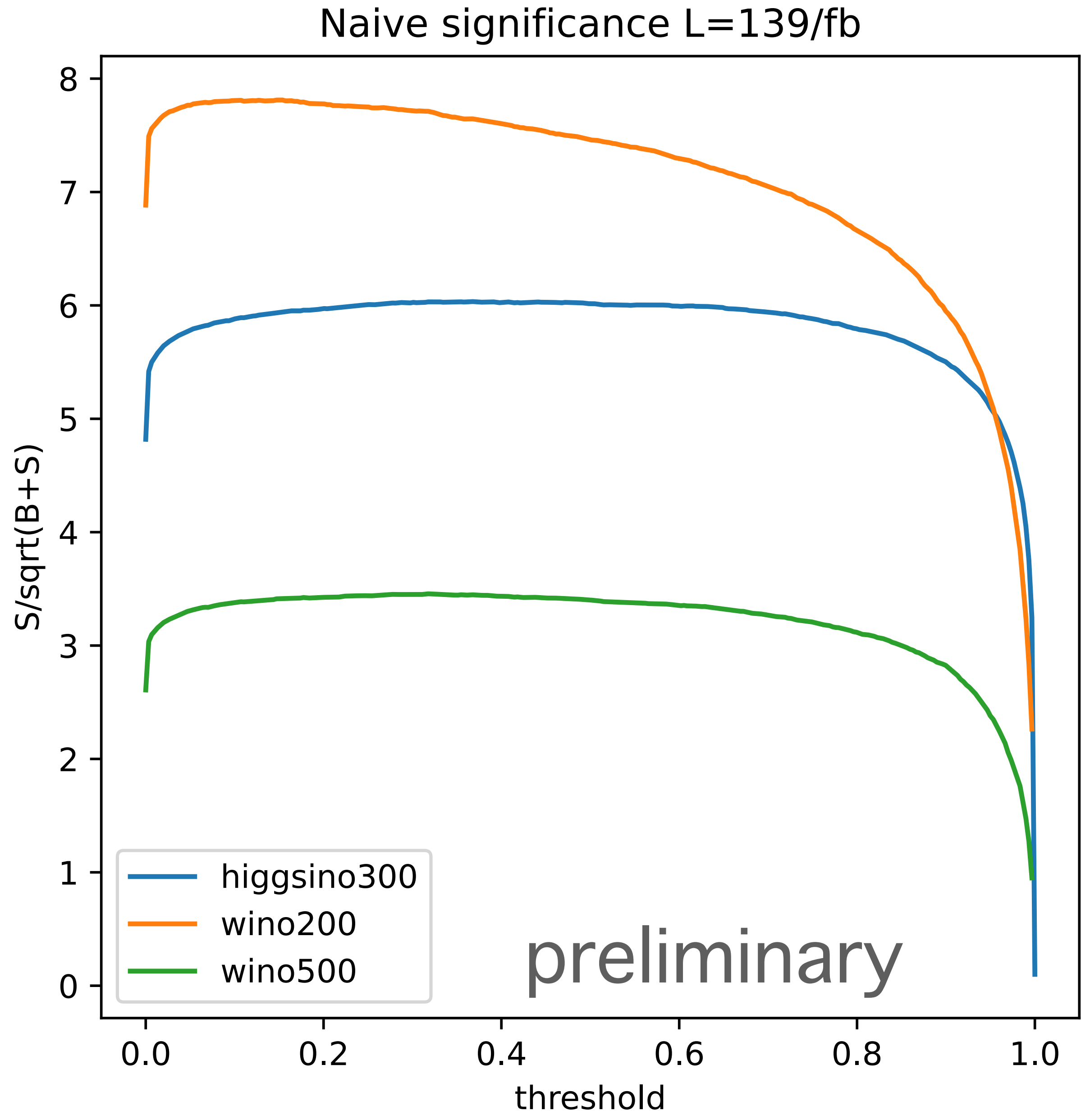


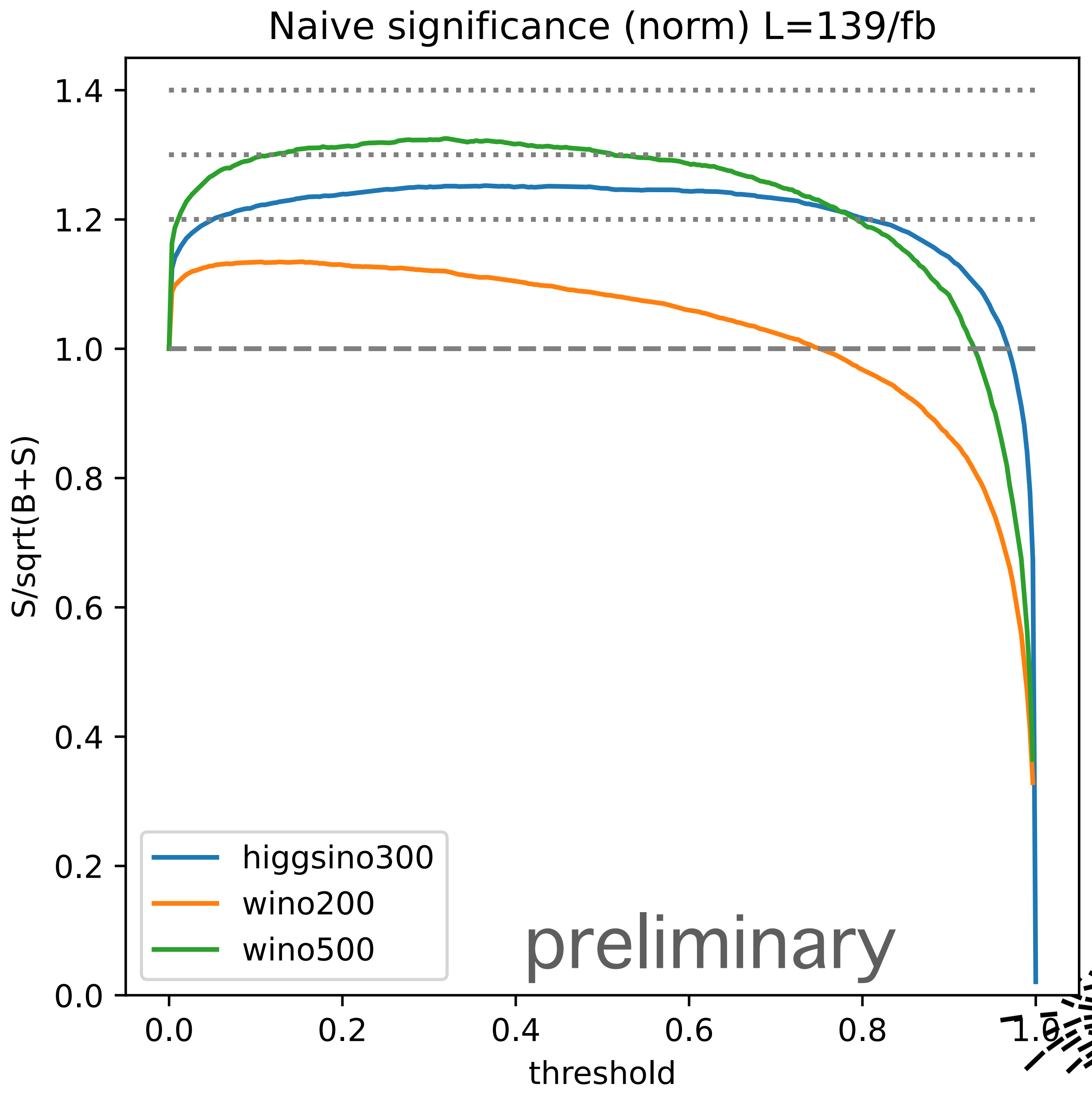
Evaluation — winos









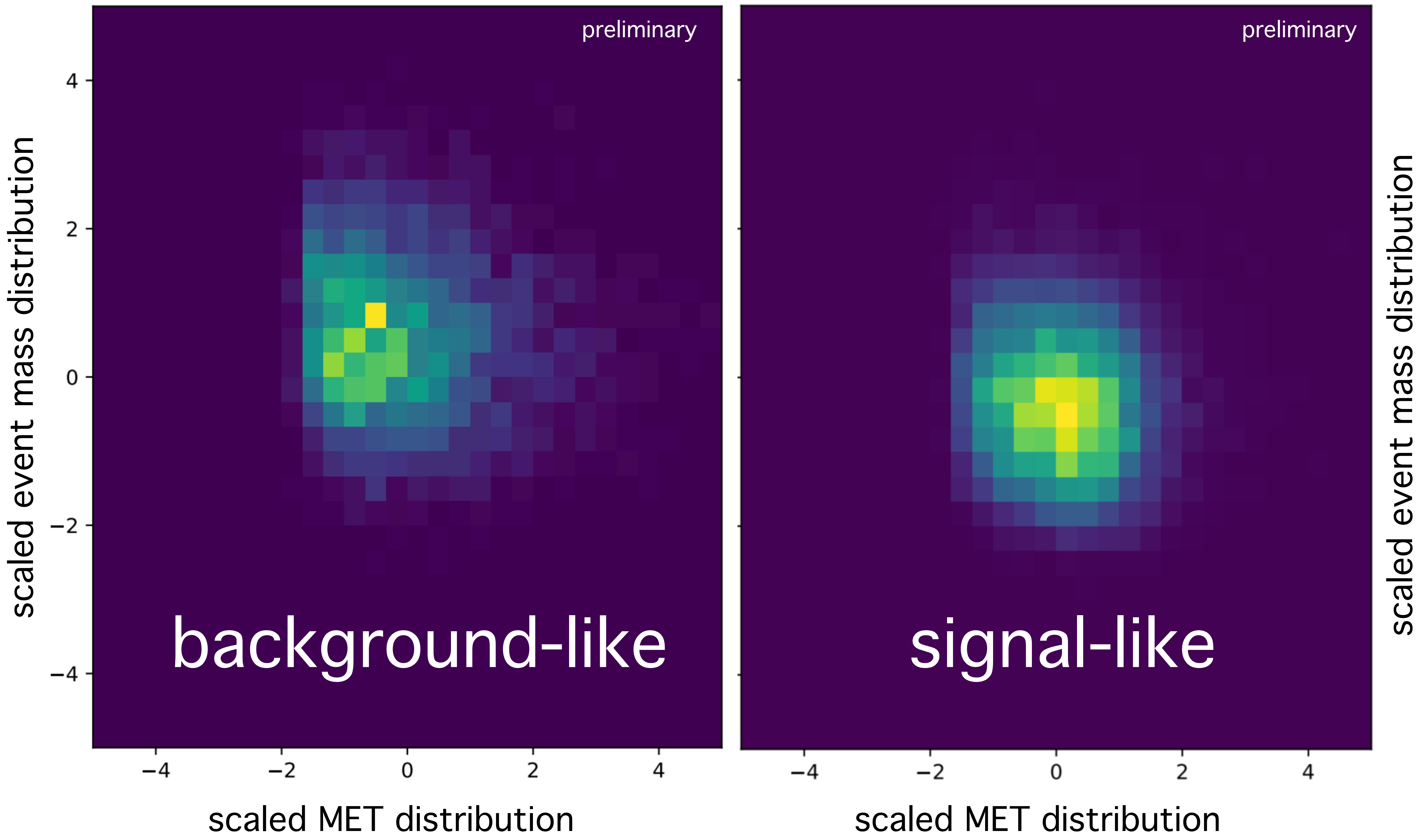


Corfu 31-08-2023

Interpretation

Morskie Oko, Tatra, Poland

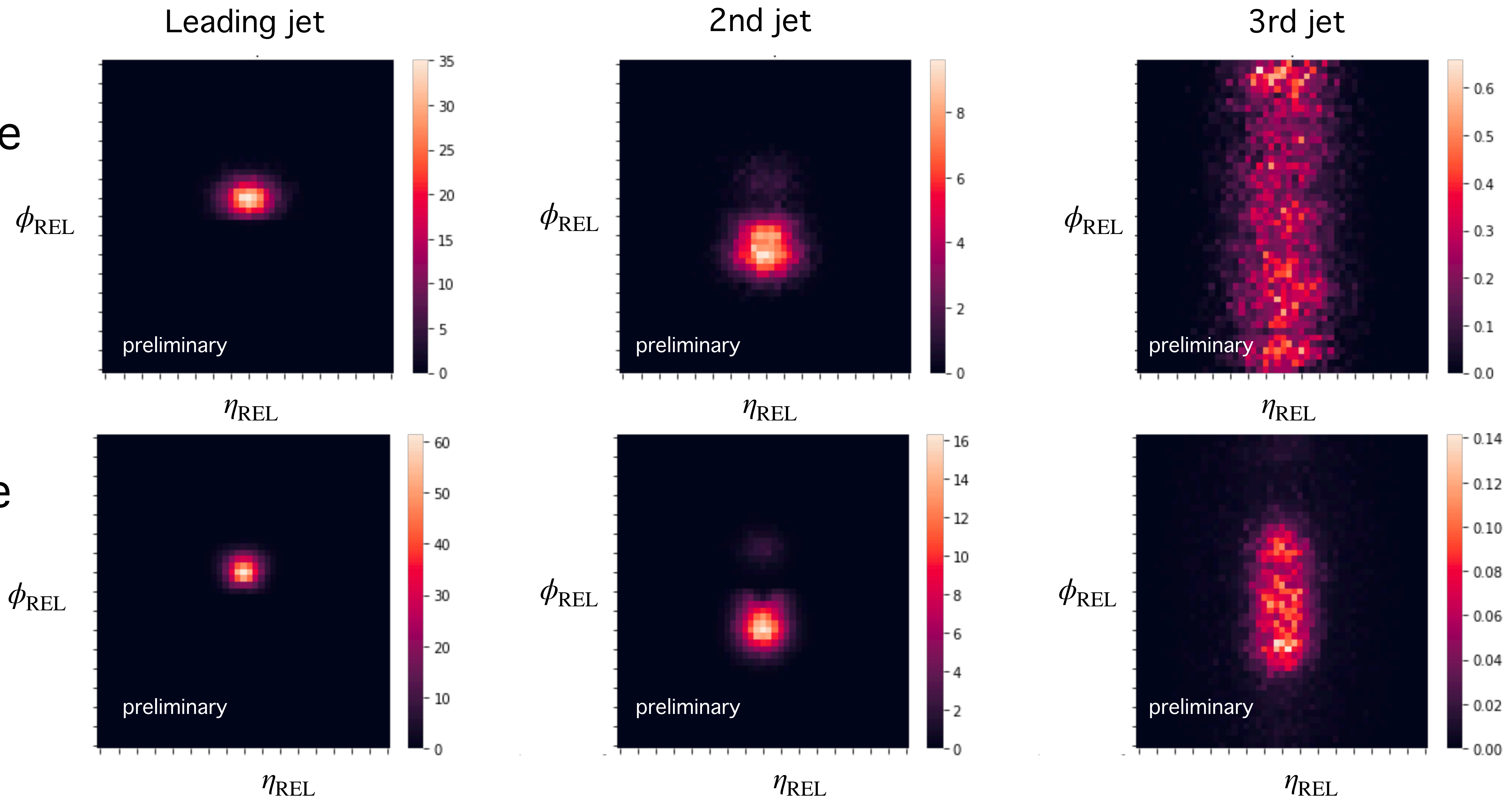
Interpretation — event-level distributions



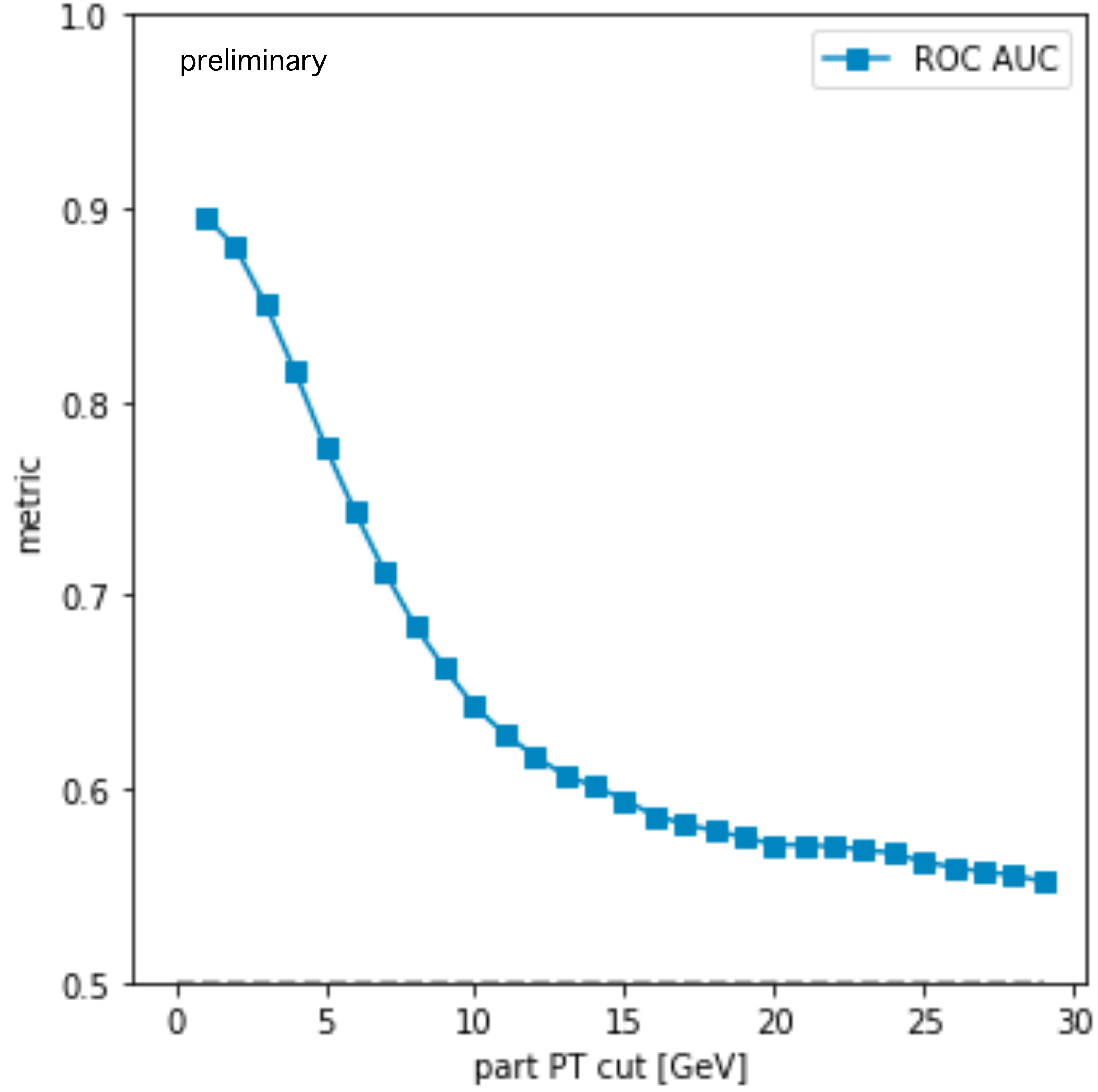
Interpretation — calorimeter image

BKG-like

SIG-like



Interpretation — sensitivity to soft particles



Outlook

- Understand better what allows the network to distinguish between the signal and the background.

- Generate samples for heavier sparticles.

- Estimate how much the current limits on sparticles can be improved.

Summary

- Dark Matter can be searched at colliders, e.g. in the monojet channel.
- One of the DM candidates is neutralino in SUSY.
- Searches in the monojet channel can be improved if ML techniques are used.
- We used preselection and Neural Network based on ParticleNet applied to whole-event information.
- We are able to get 10-35% improvement over just preselection in terms of $S/\sqrt{(S+B)}$, depending on the sample.
- We are trying to interpret the model:
  Network learns distributions of global variables; correlations between jets and jets' constituents; it uses information about soft particles
- Final goal is to estimate how the limits on sparticles' masses will improve.
- The method can be used also for other models contributing to the monojet channel

Thank you for attention!

r.maselek@uw.edu.pl

Dolina Chochołowska, Poland
photo by Piotr Kałuża