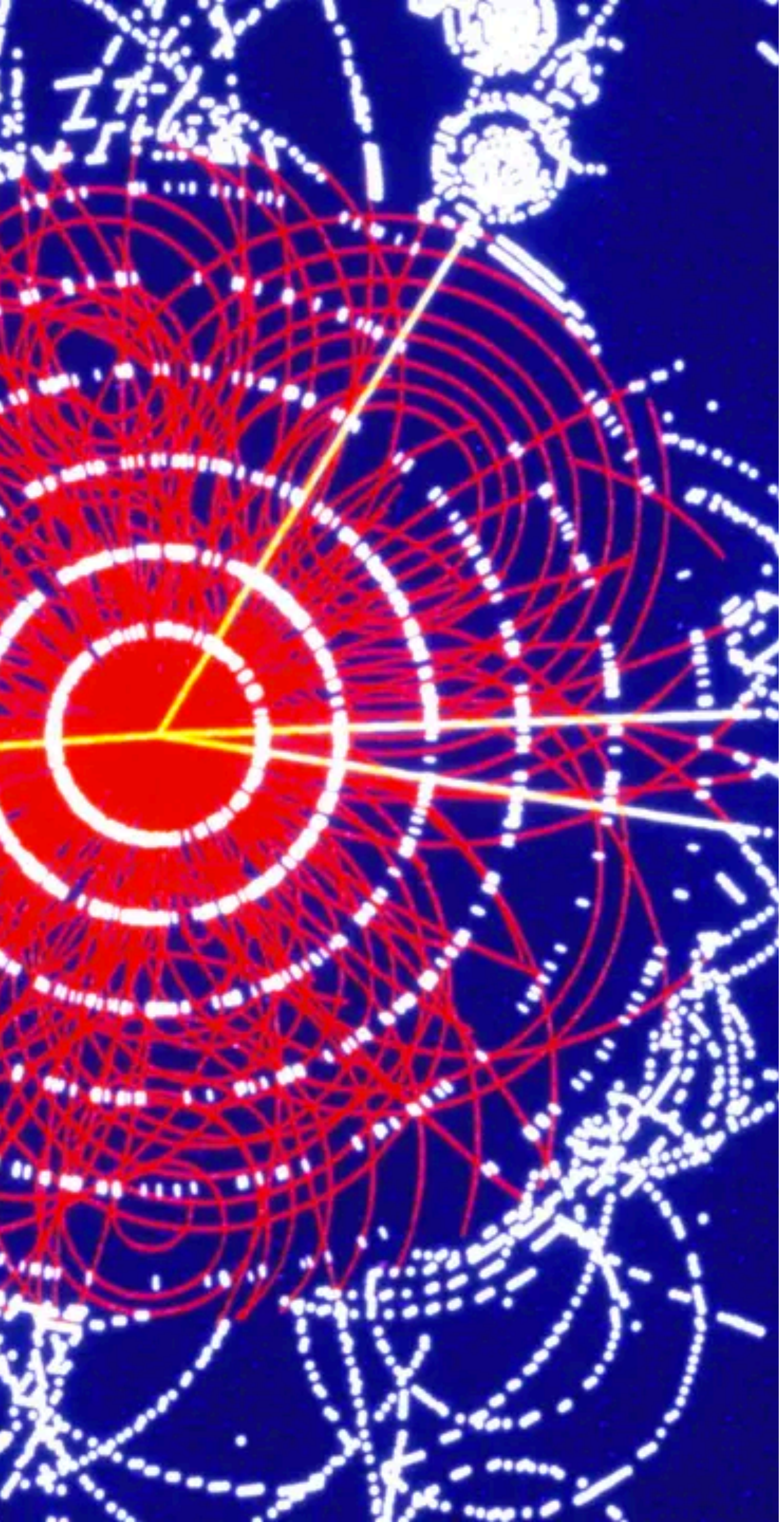

NATIONAL SCIENCE CENTRE POLAND

NAWA POLISH NATIONAL AGENCY FOR ACADEMIC EXCHANGE

FACULTY OF PHYSICS UNIVERSITY OF WARSAW

Enhancing LHC searches for Dark Matter with Machine Learning

Rafał Masełek

in collaboration with
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Rencontres du Vietnam
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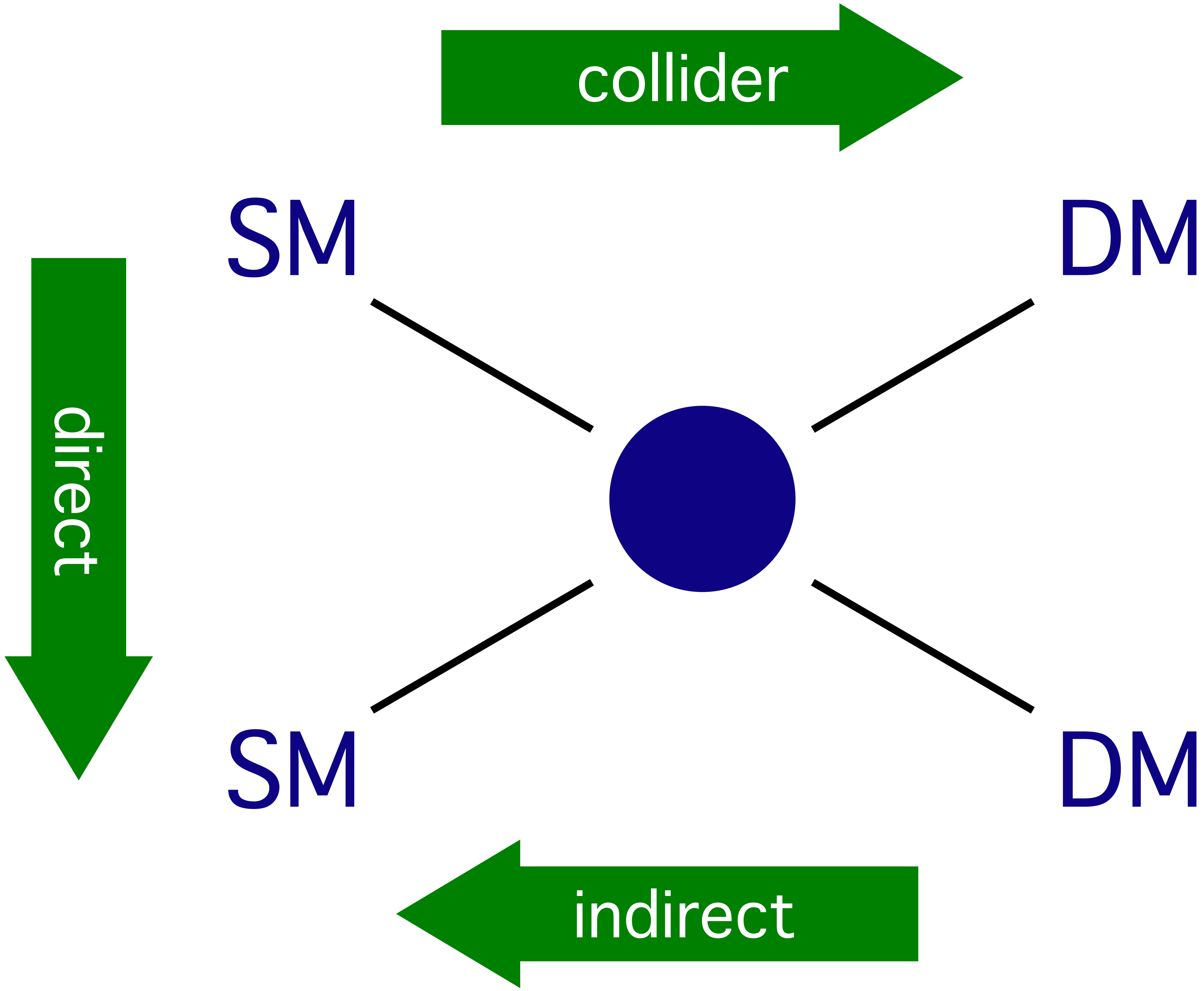
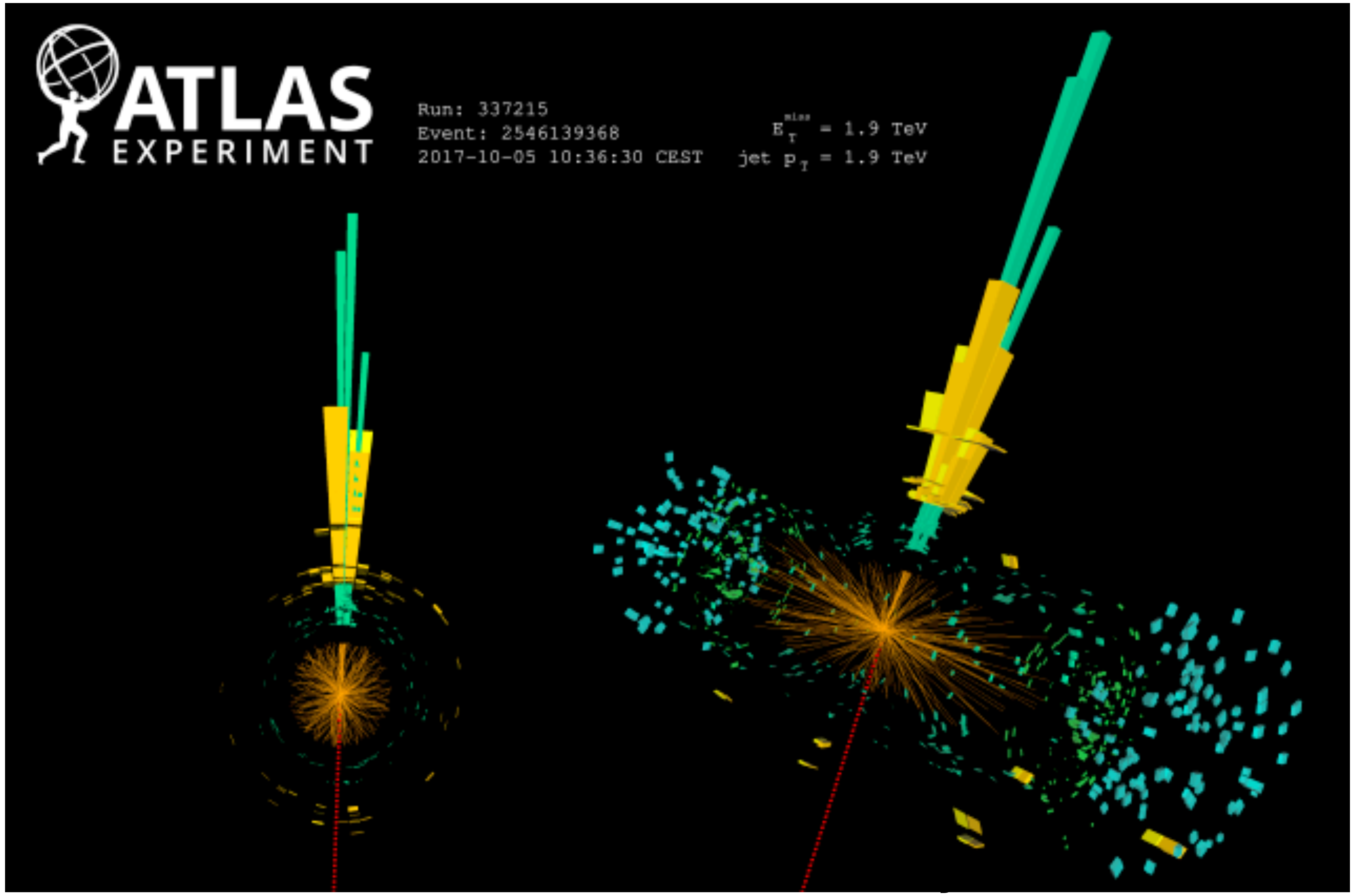
Dark Matter searches

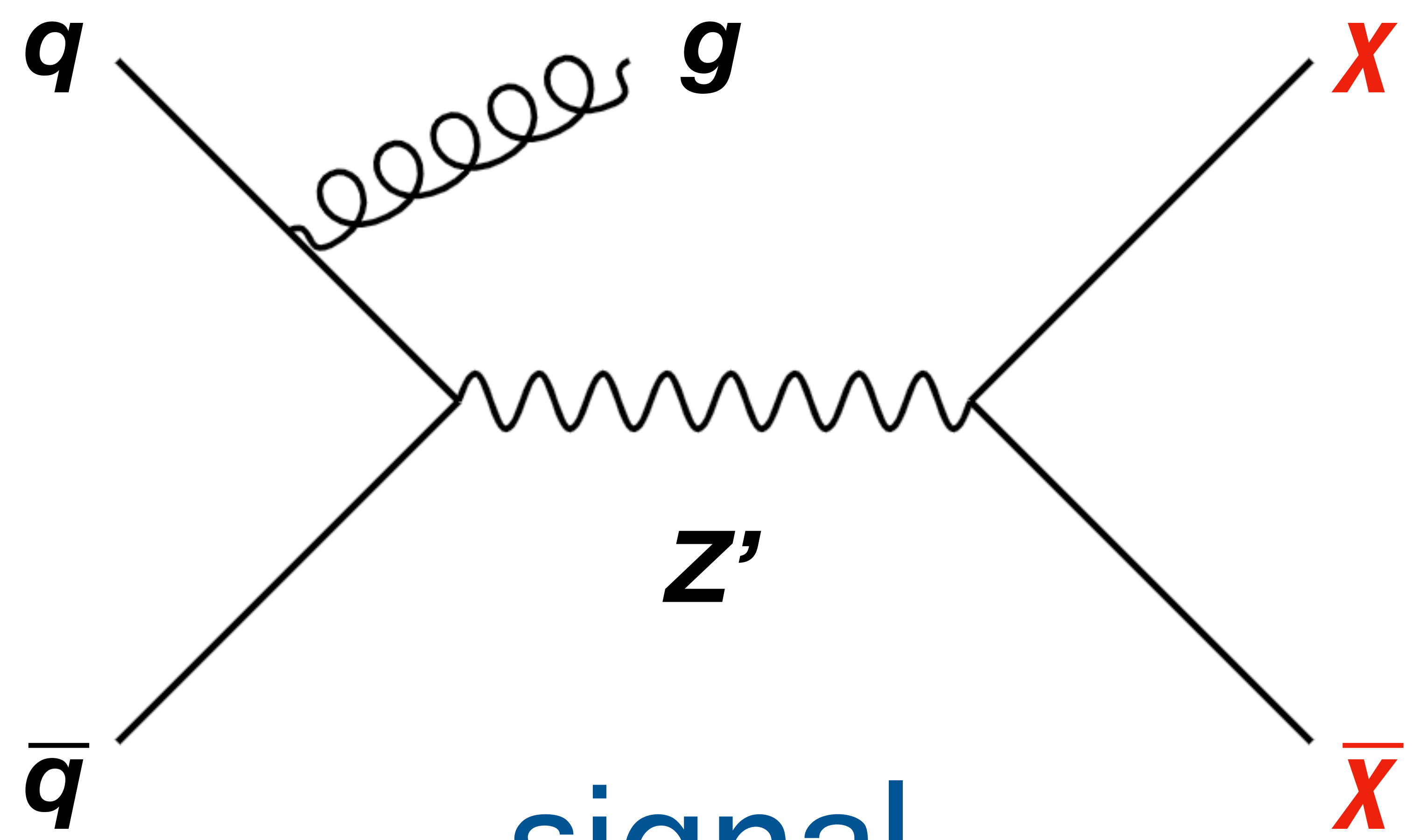


DM searches @ LHC — Monojet

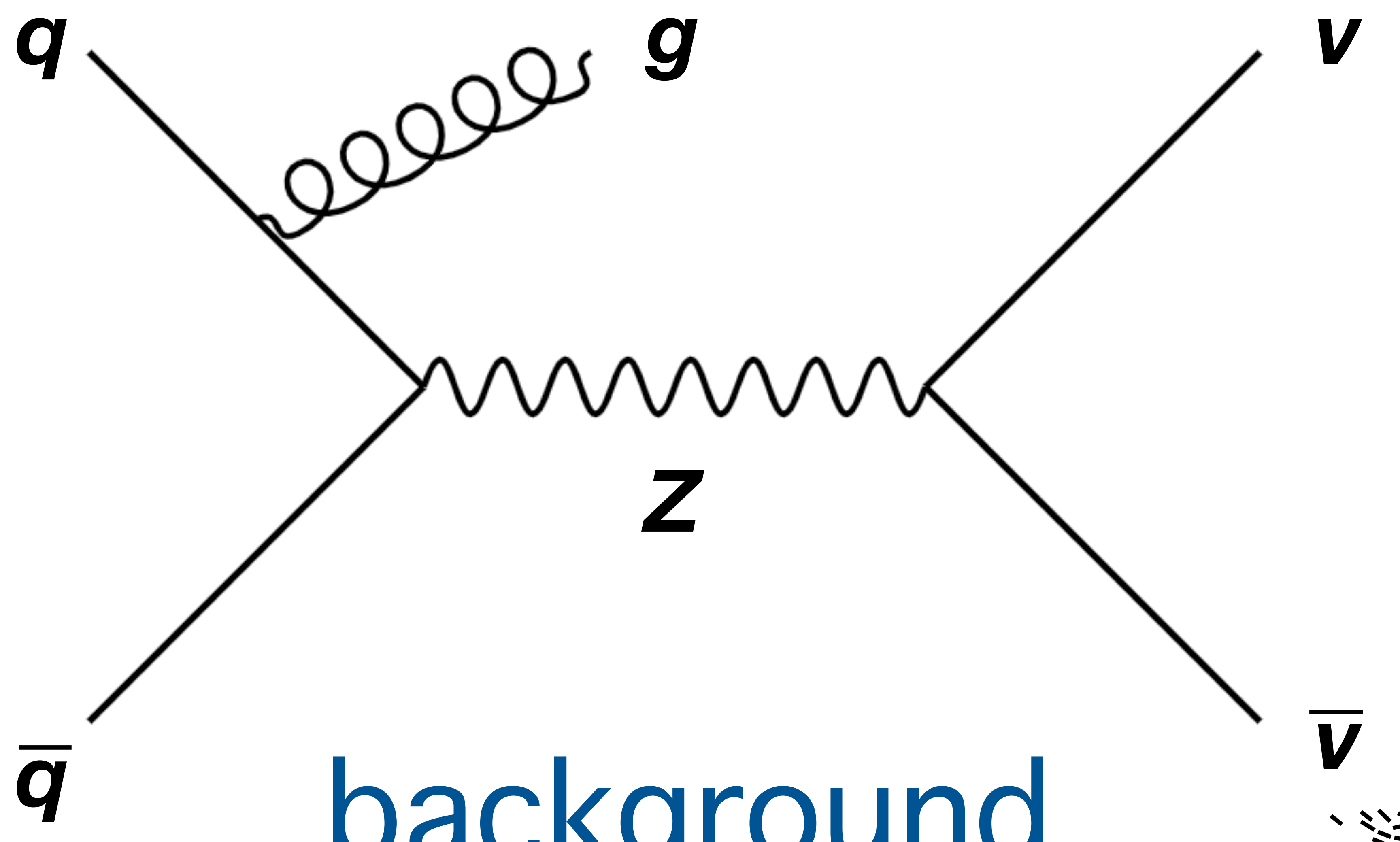
Monojet channel = 1 or more hard jets recoiling against a missing transverse momentum and no isolated leptons



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



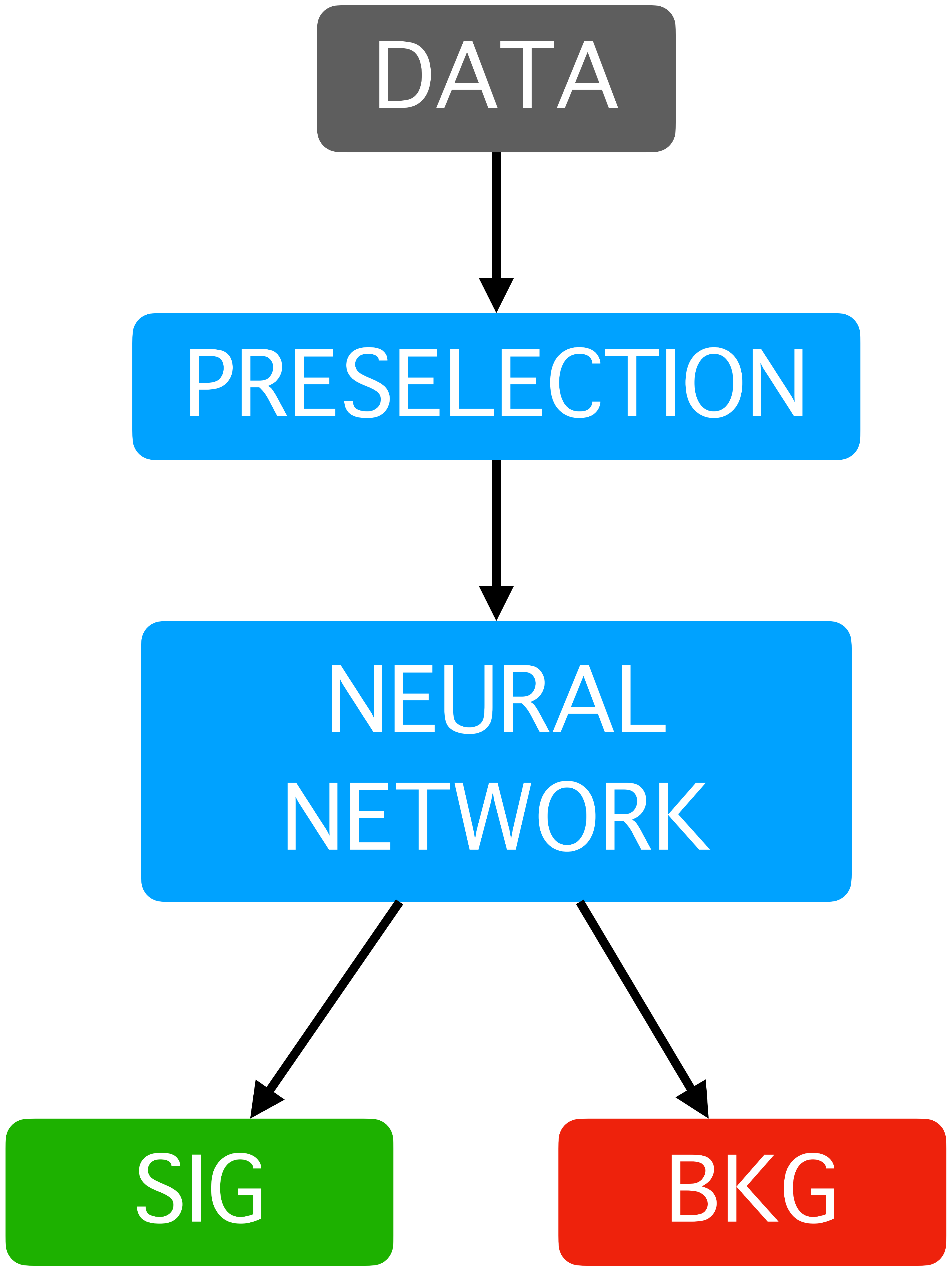
signal



background

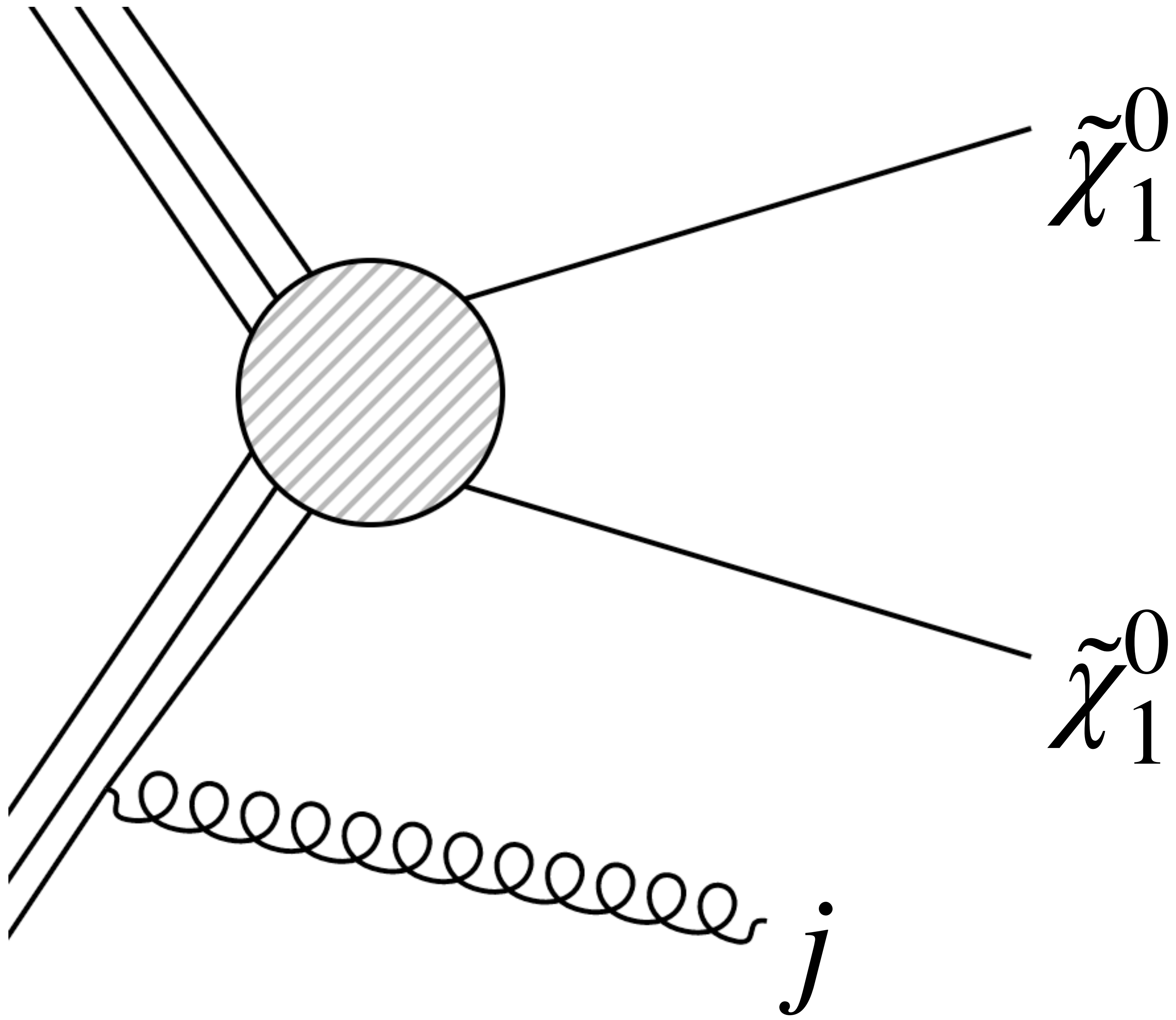
The idea

- Monojet channel is challenging because 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

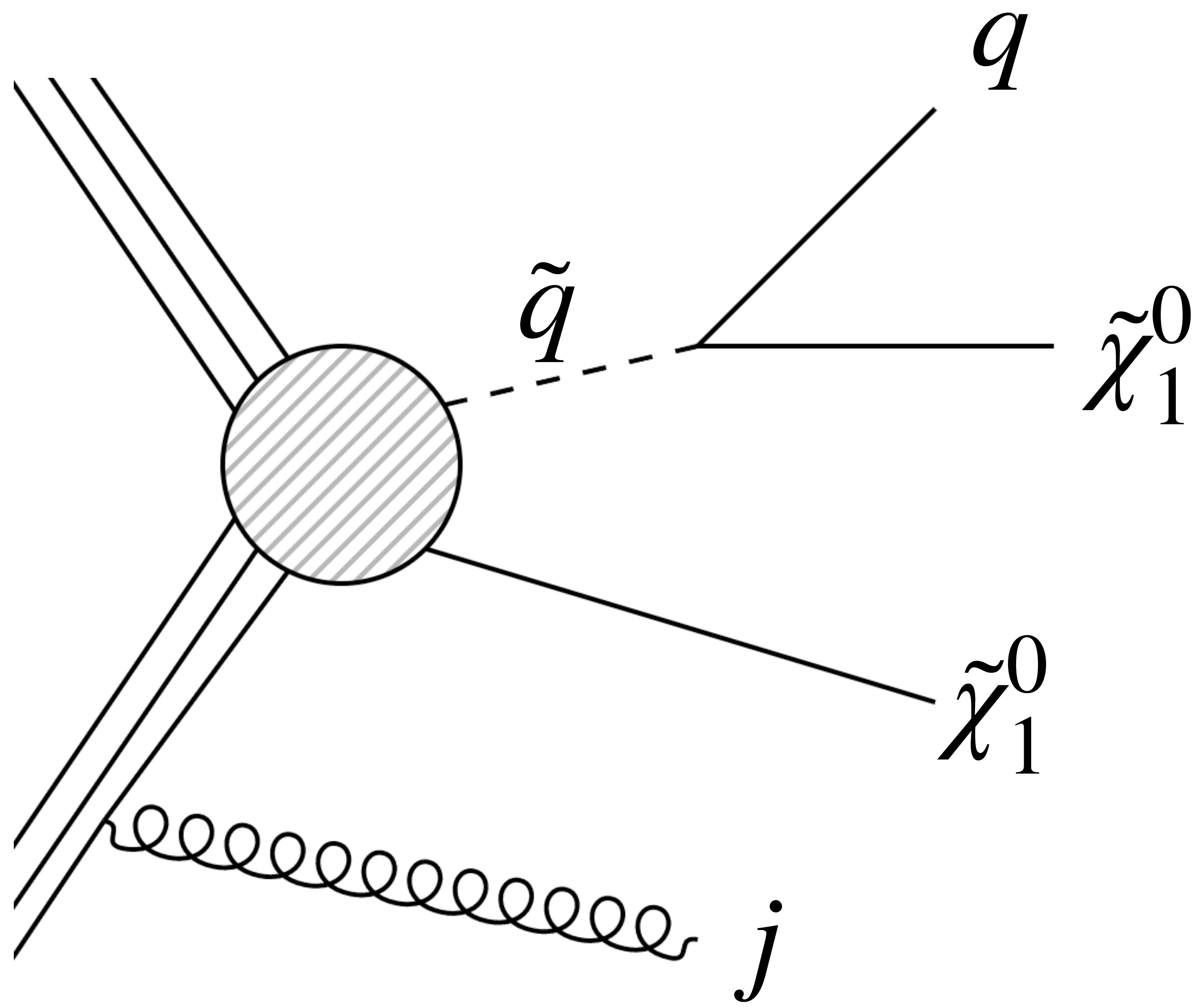


Model choice — simplified SUSY scenario

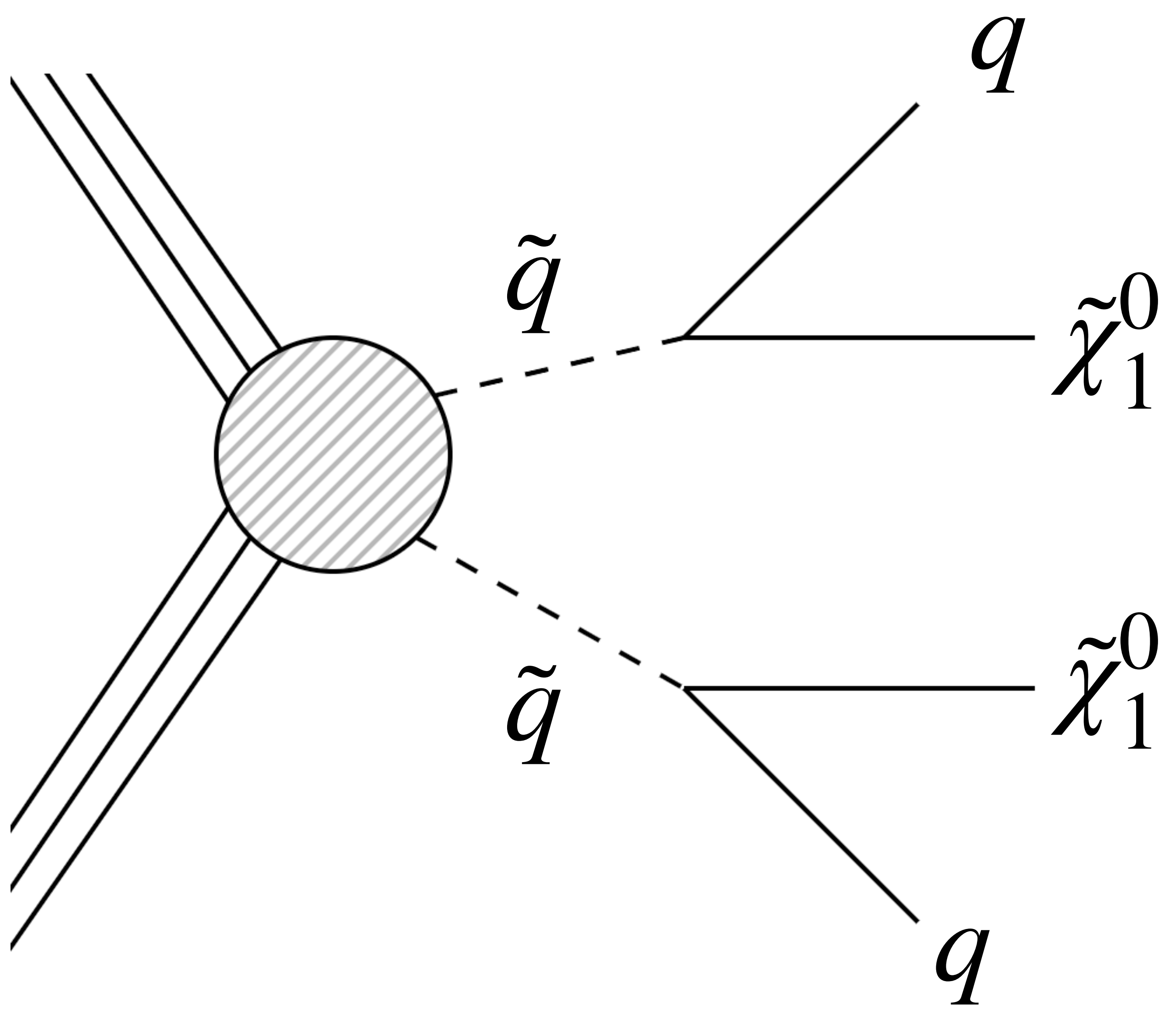
We generate a pair of neutralinos (higgsino or wino) and allow for 1-2 extra partons in the final state...



... it is possible to have intermediate on-shell squarks produced...



... which led us to aim at constraining SUSY in squark vs neutralino mass plane.



Preanalysis

Preselection

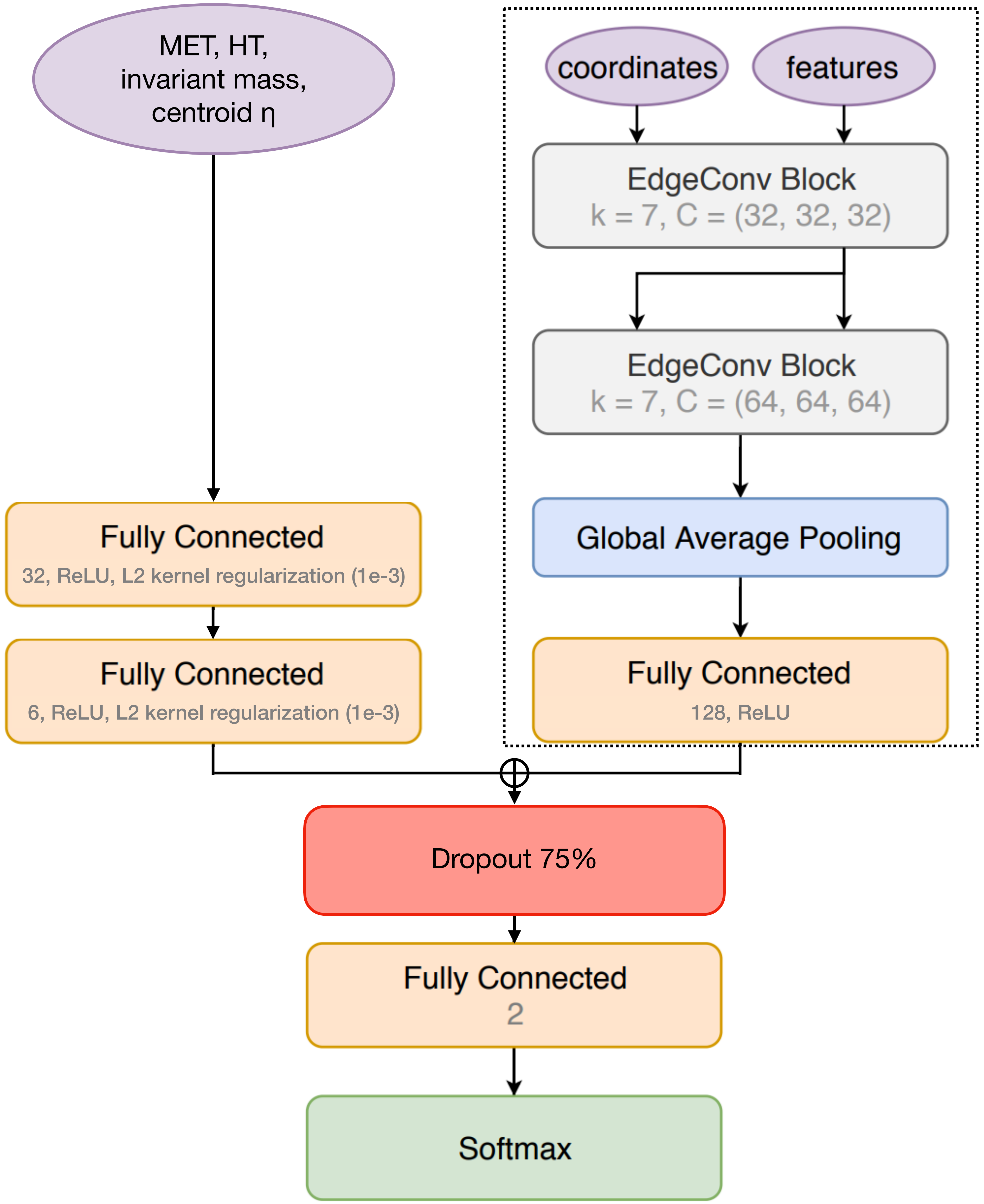
- $H_T > 1$ TeV
- p_T of the leading jet > 1 TeV
- p_T of the second jet > 610 GeV
- MT2 (stransverse mass) > 1300 GeV [arXiv:hep-ph/9906349]
- MET>1280 GeV

signal samples

neutralino flavour	neutralino mass [GeV]	squark mass [TeV]	S (L=300 fb^{-1})	S/B	S/√(S+B)
higgsino	200	2.00	211	0.98	10.23
higgsino	300	2.00	132	0.61	7.07
higgsino	400	2.00	106	0.49	5.89
higgsino	500	2.00	90	0.42	5.18
higgsino	600	2.00	80	0.37	4.64
higgsino	300	2.25	160	0.75	8.28
higgsino	300	2.50	182	0.85	9.16
higgsino	300	2.75	184	0.86	9.22
higgsino	300	3.00	63	0.29	3.75
wino	200	2.00	208	0.97	10.11
wino	500	2.00	64	0.30	3.83

Neural Network architecture

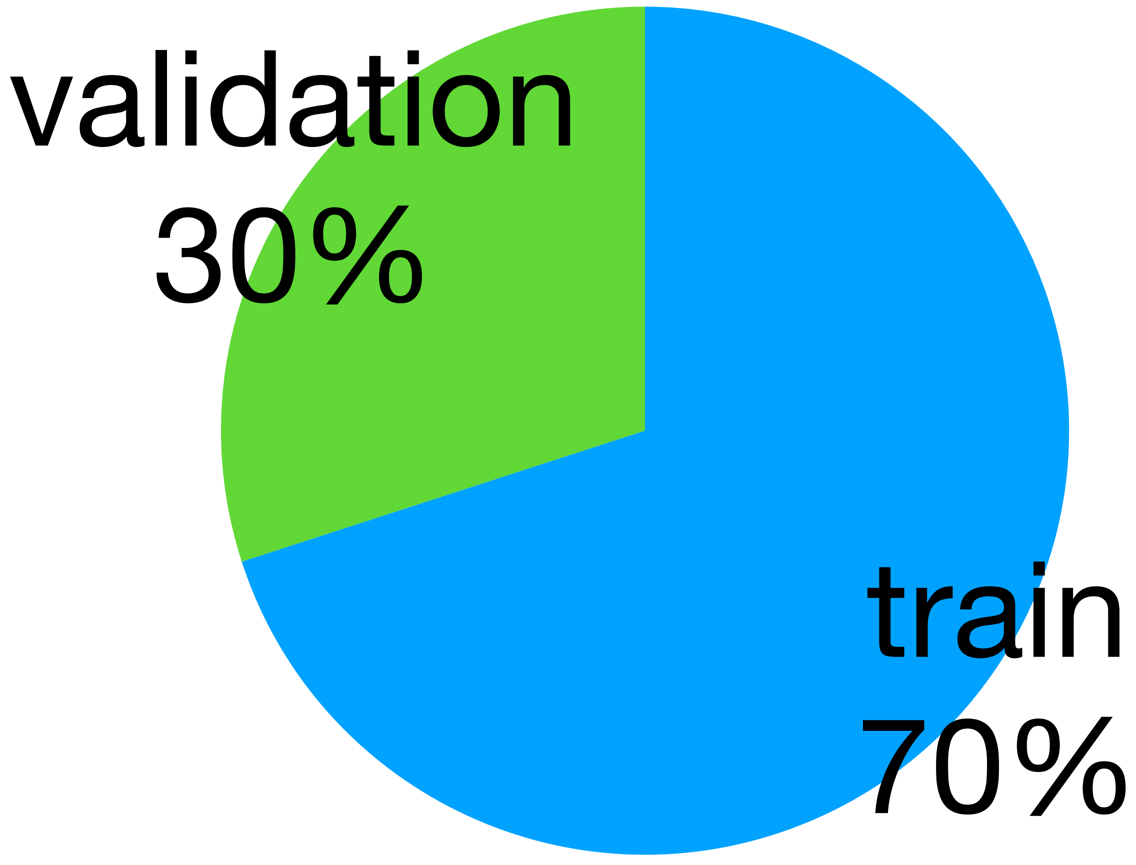
Global variables



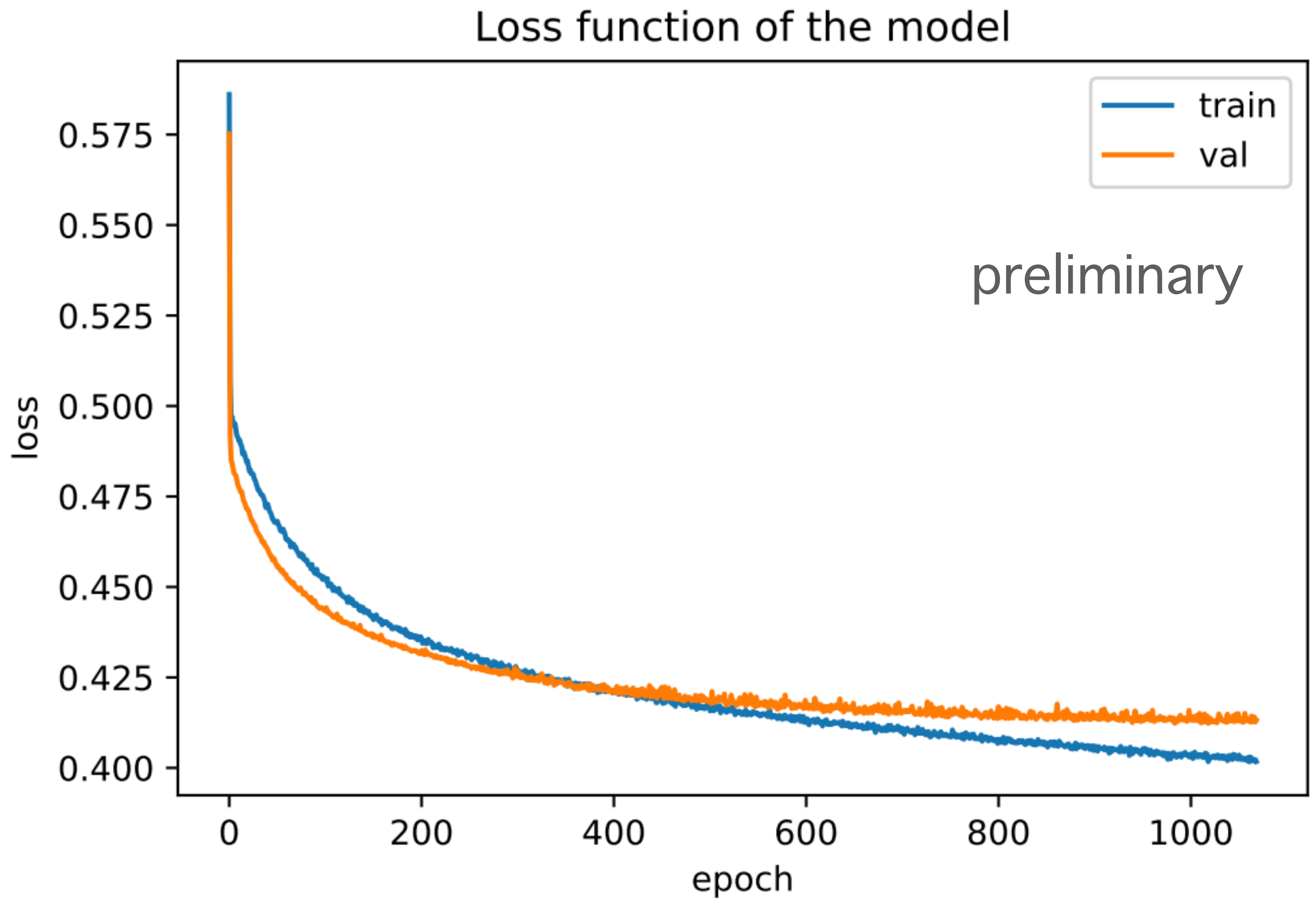
Local variables

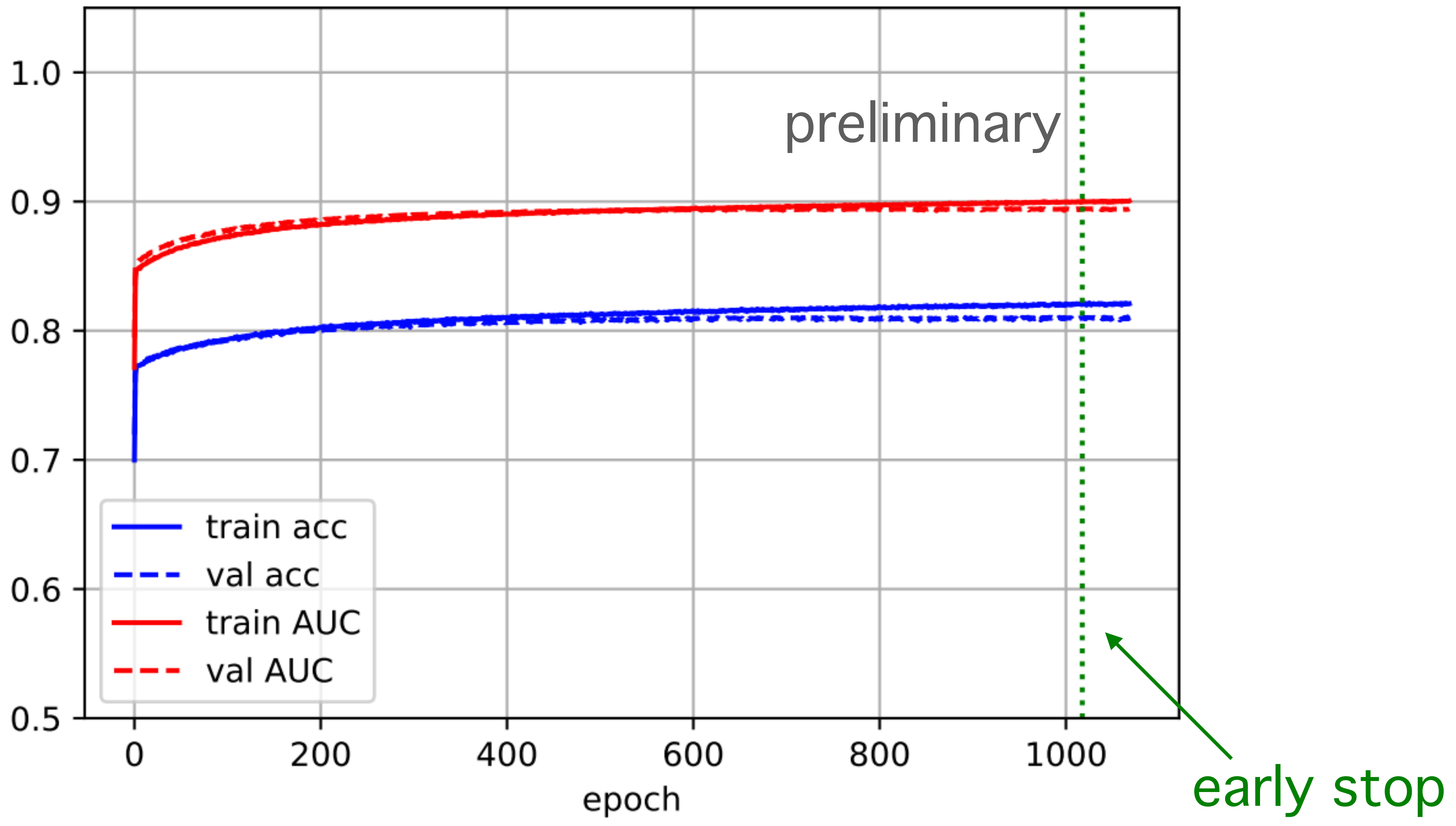
Based on ParticleNet Lite

Training



- particle p_T > 1 GeV cut on eflow objects
- fully supervised training for up to 1500 epochs
- early stopping after 50 epochs of validation loss not changing
- cosine decay learning scheduler (initial_learning_rate=0.001)

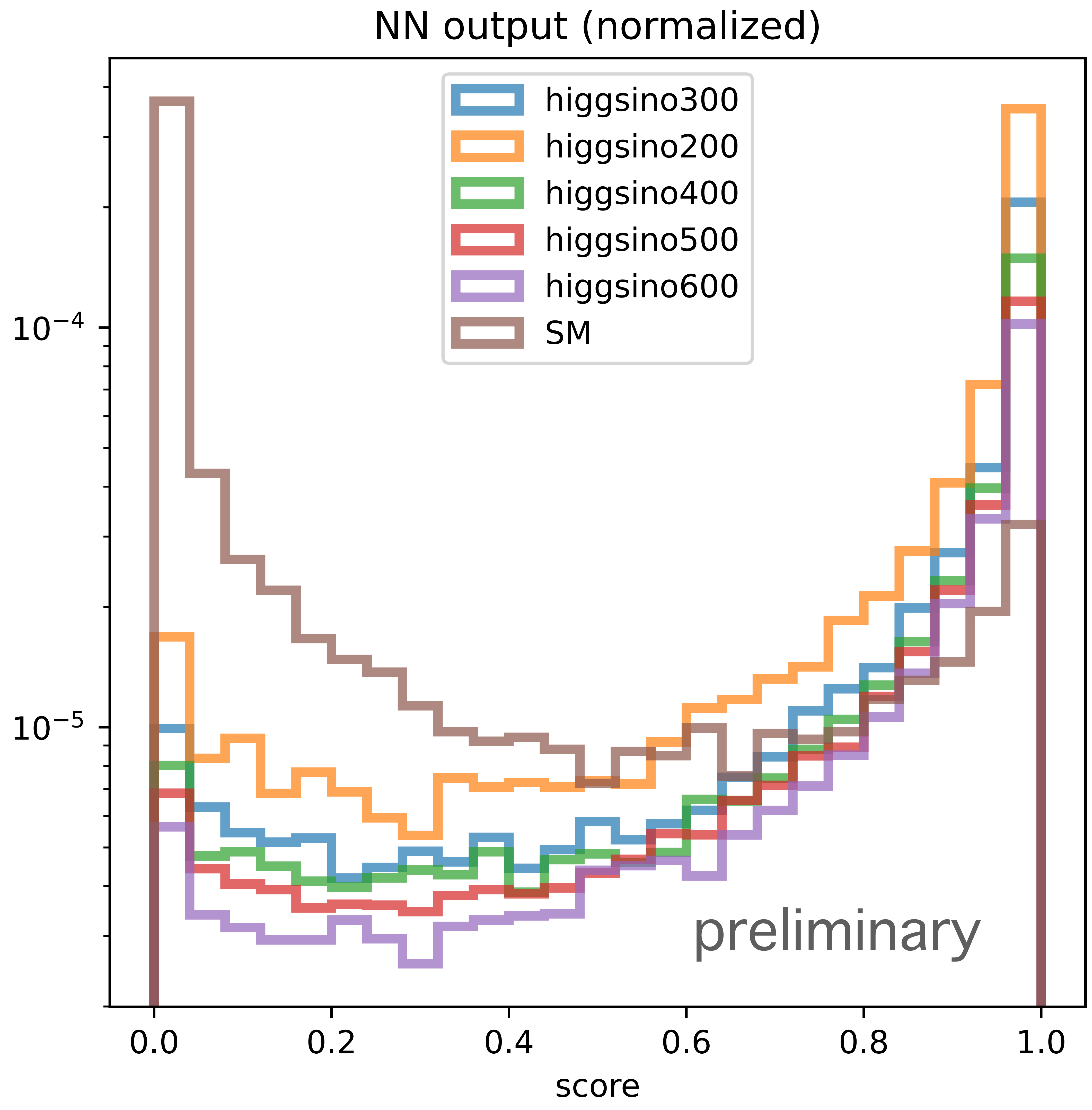




Evaluation

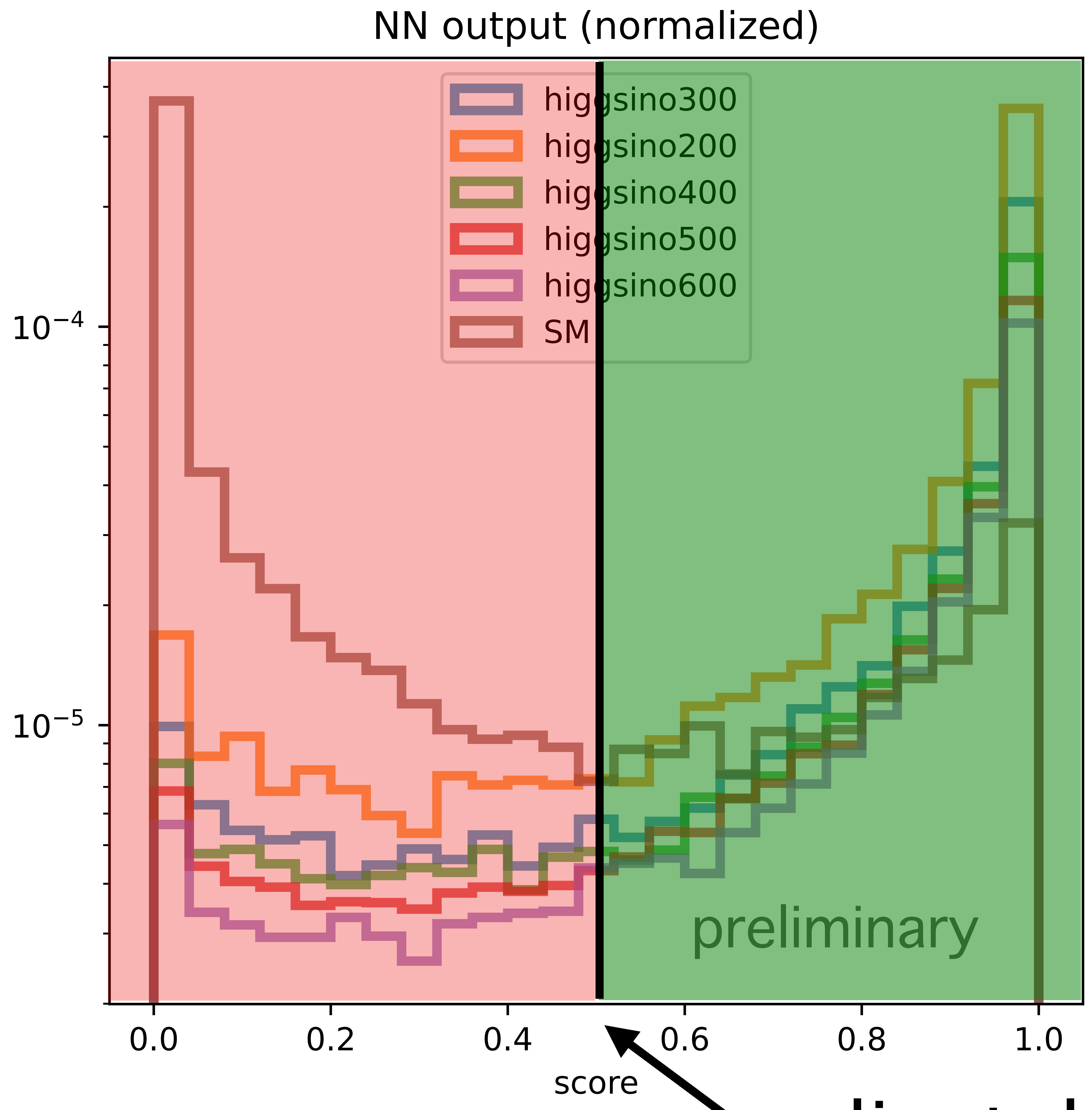
Malbork Castle, Poland
photo from museum’s FB page

Evaluation — varying Higgsino mass



Evaluation — varying Higgsino mass

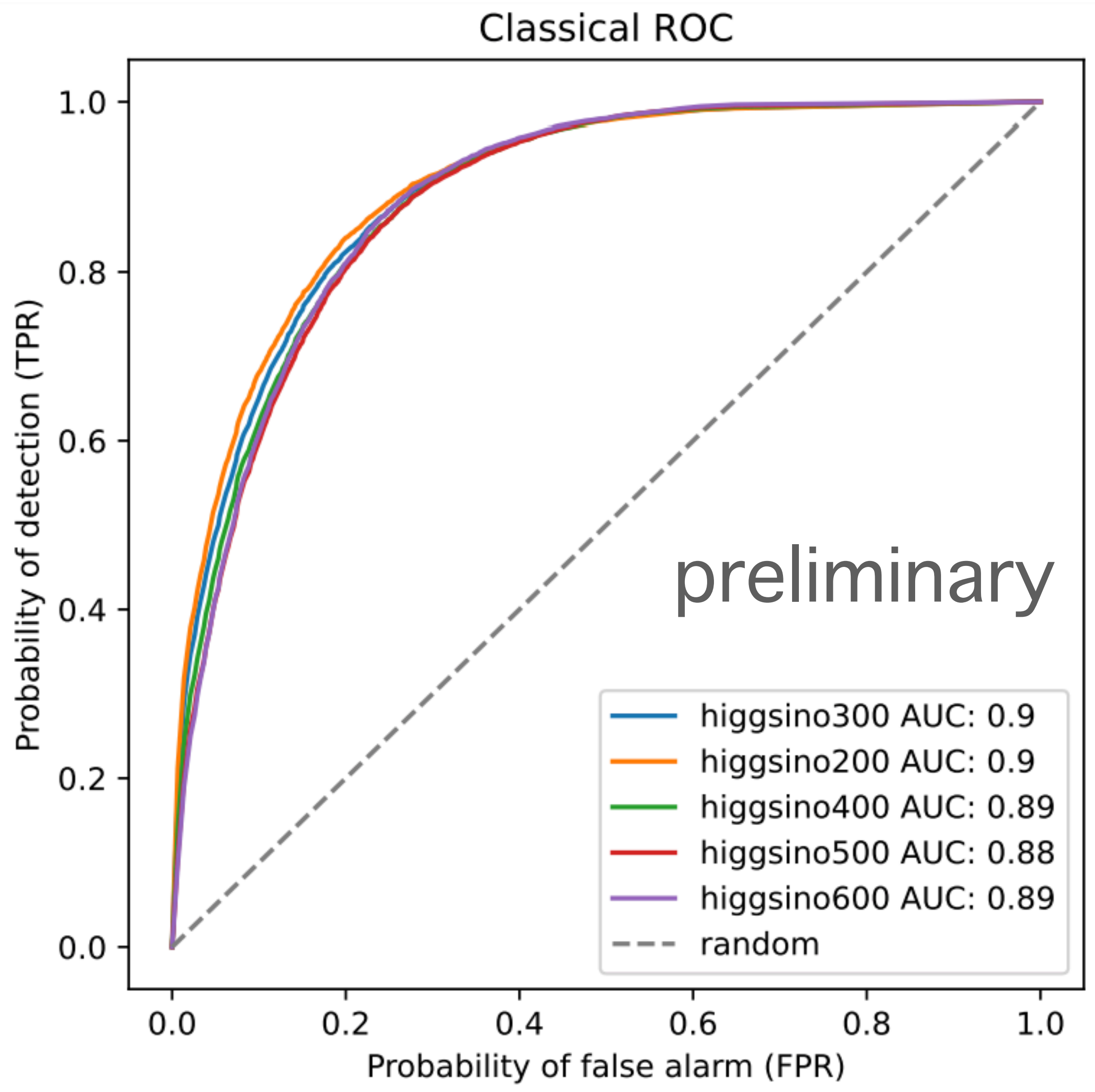
background

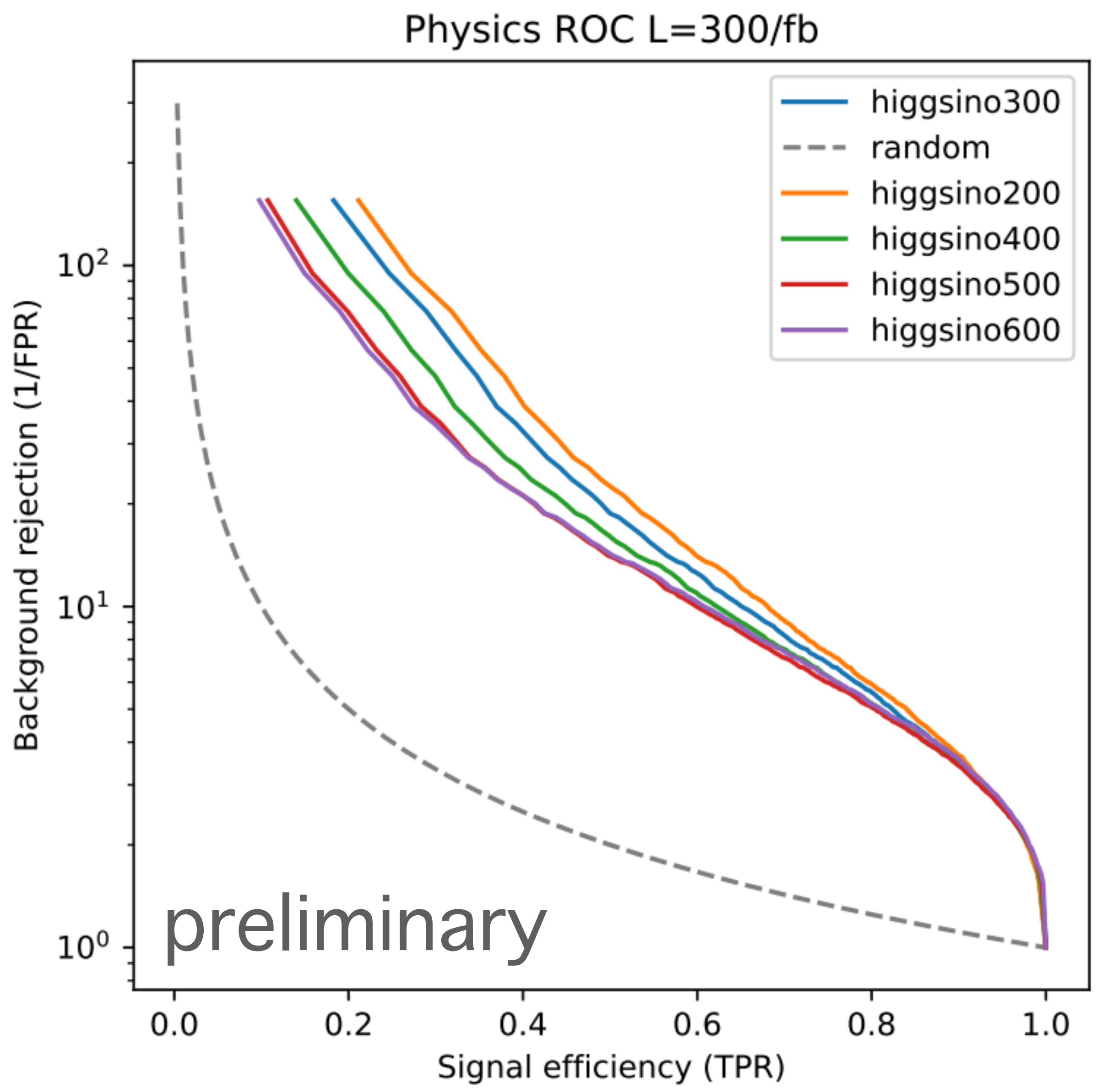


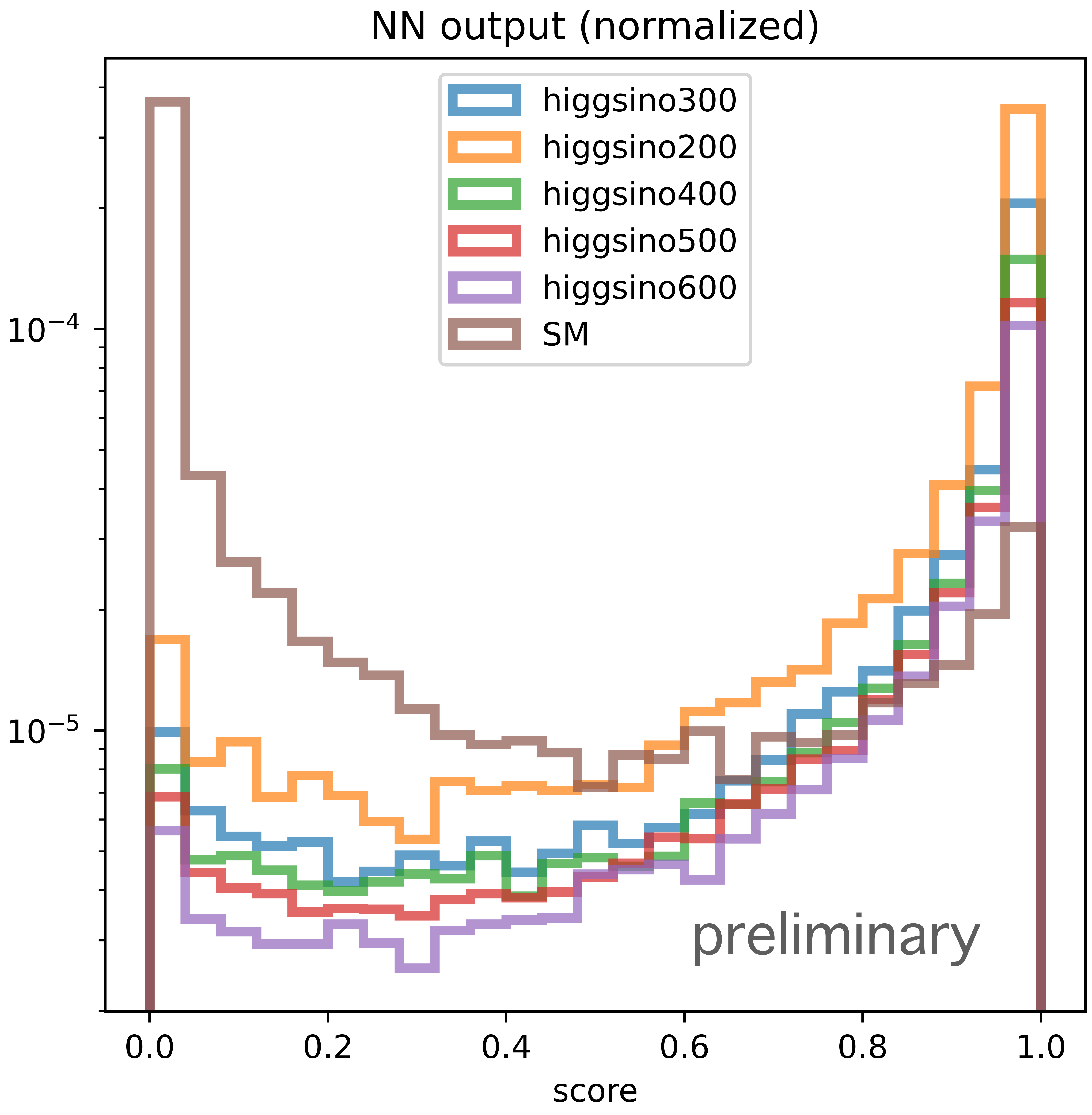
signal

adjustable threshold

Evaluation — varying Higgsino mass







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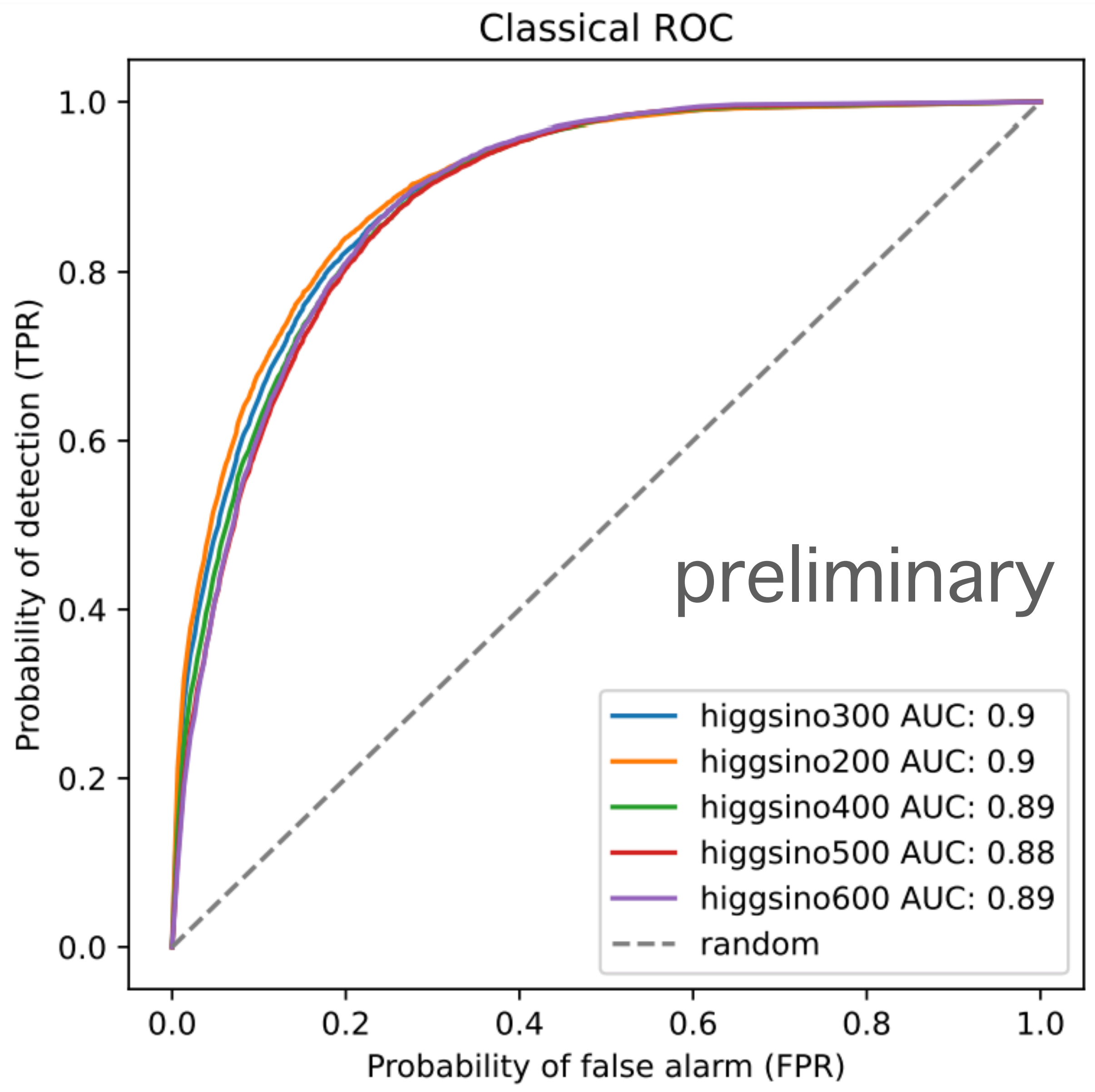
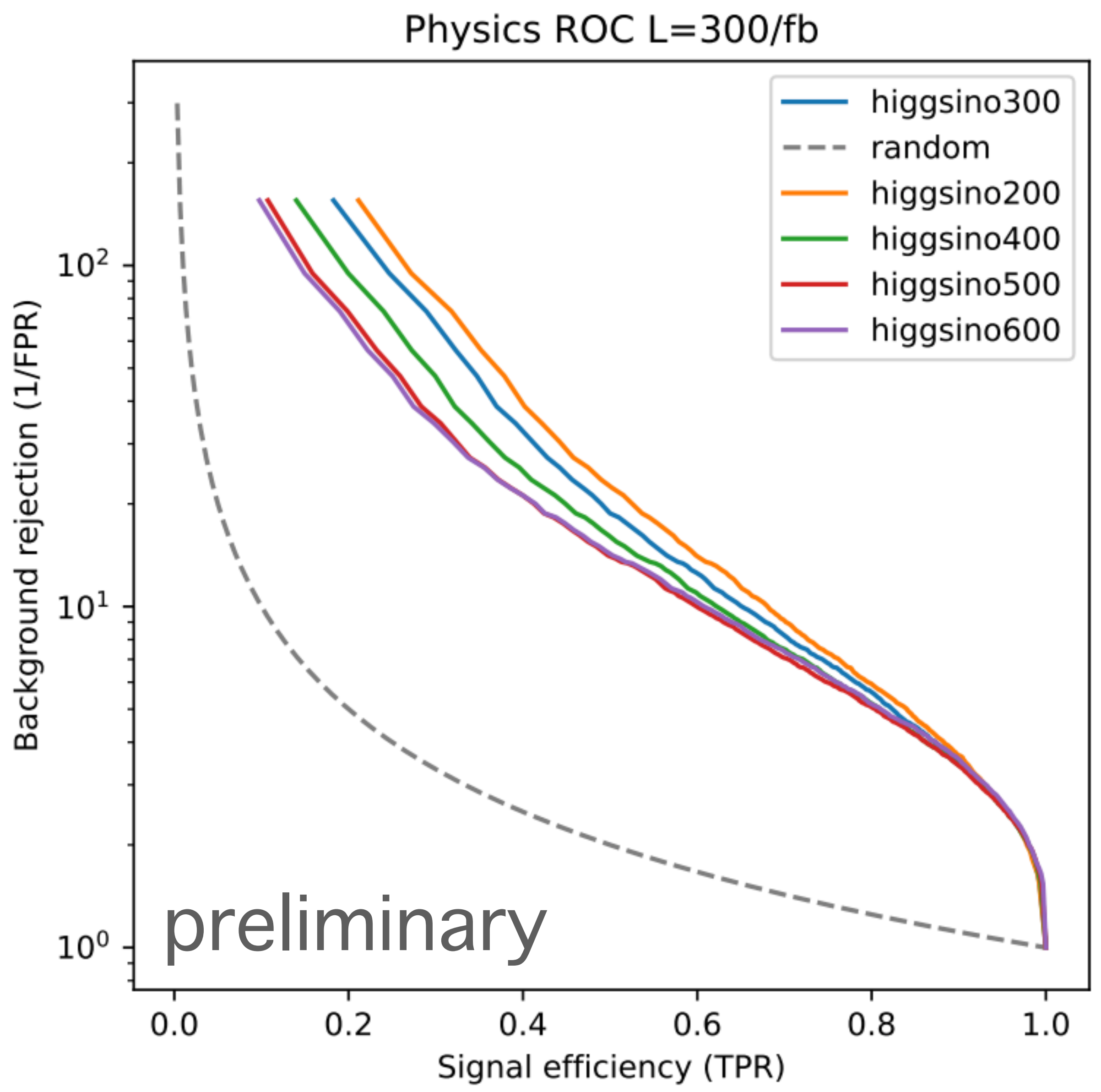
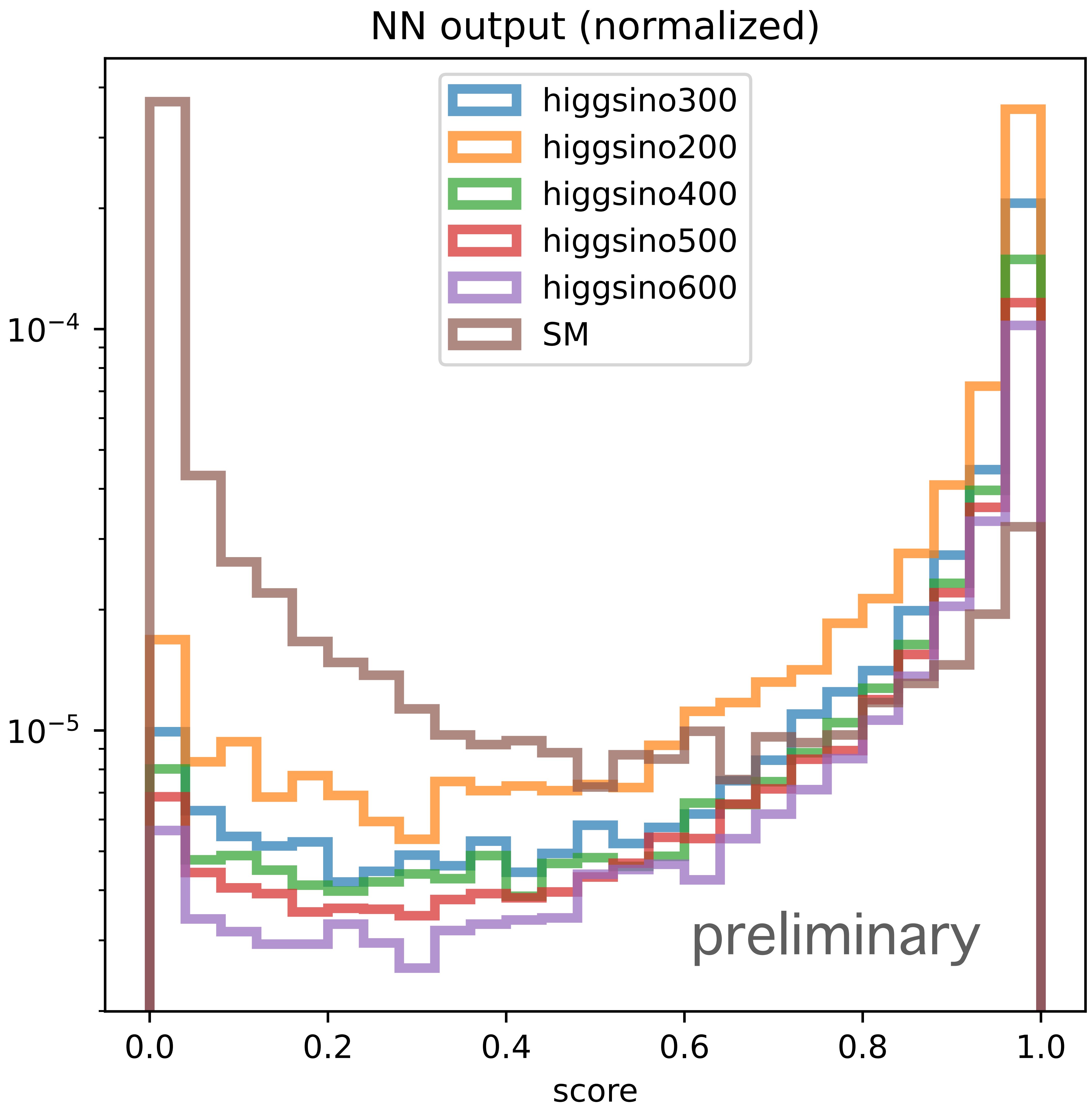
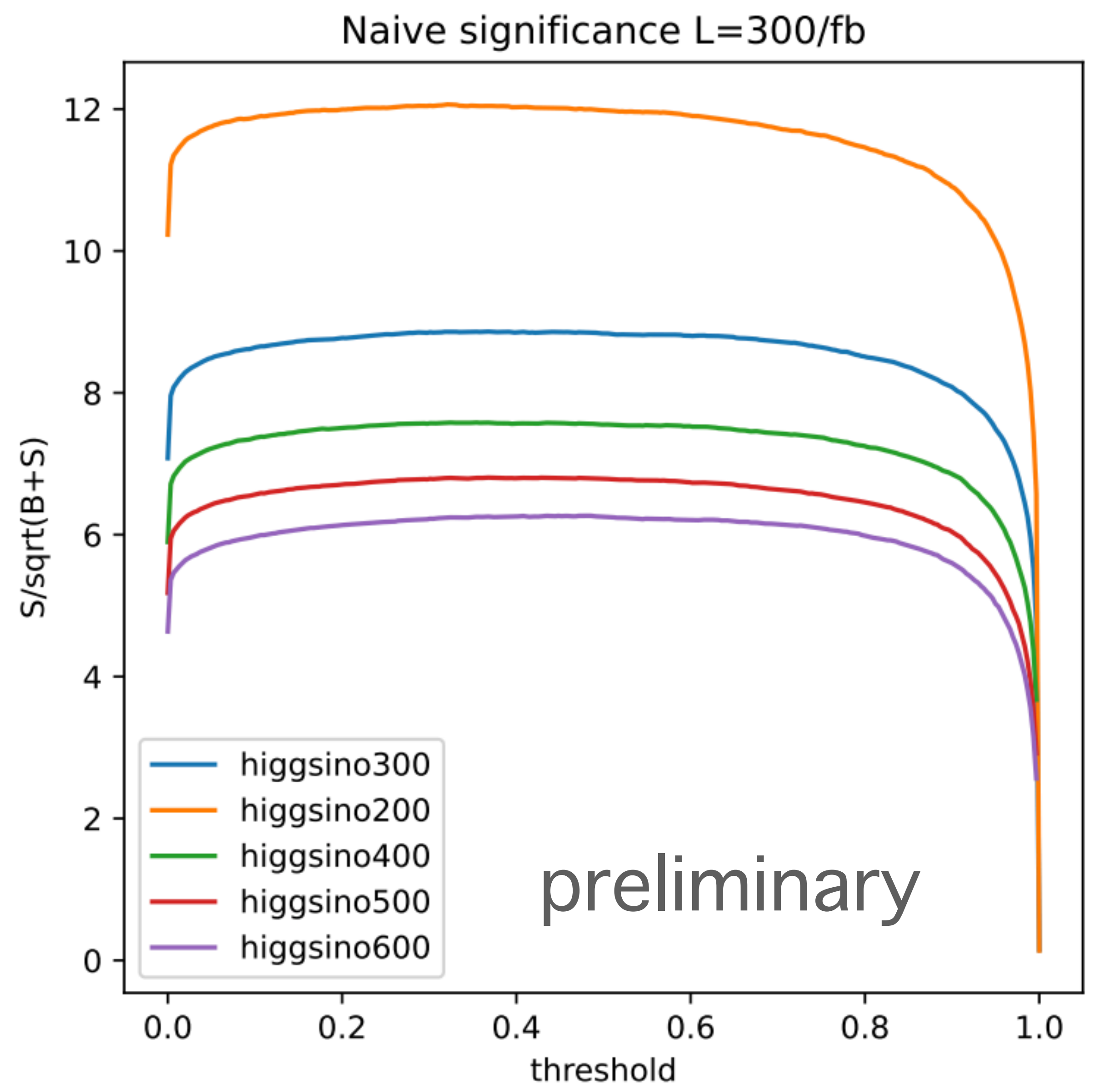
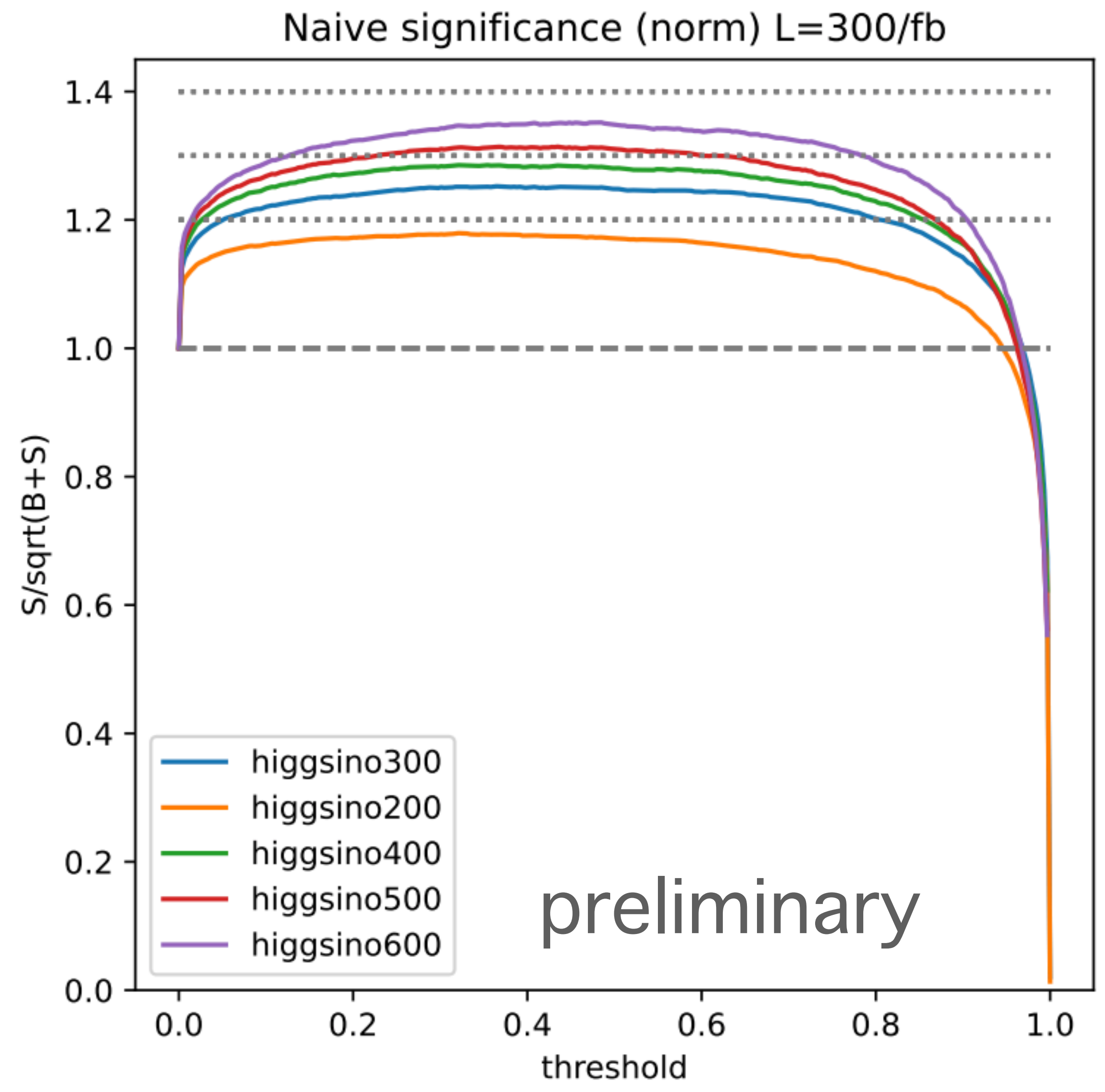
Evaluation — varying Higgsino mass



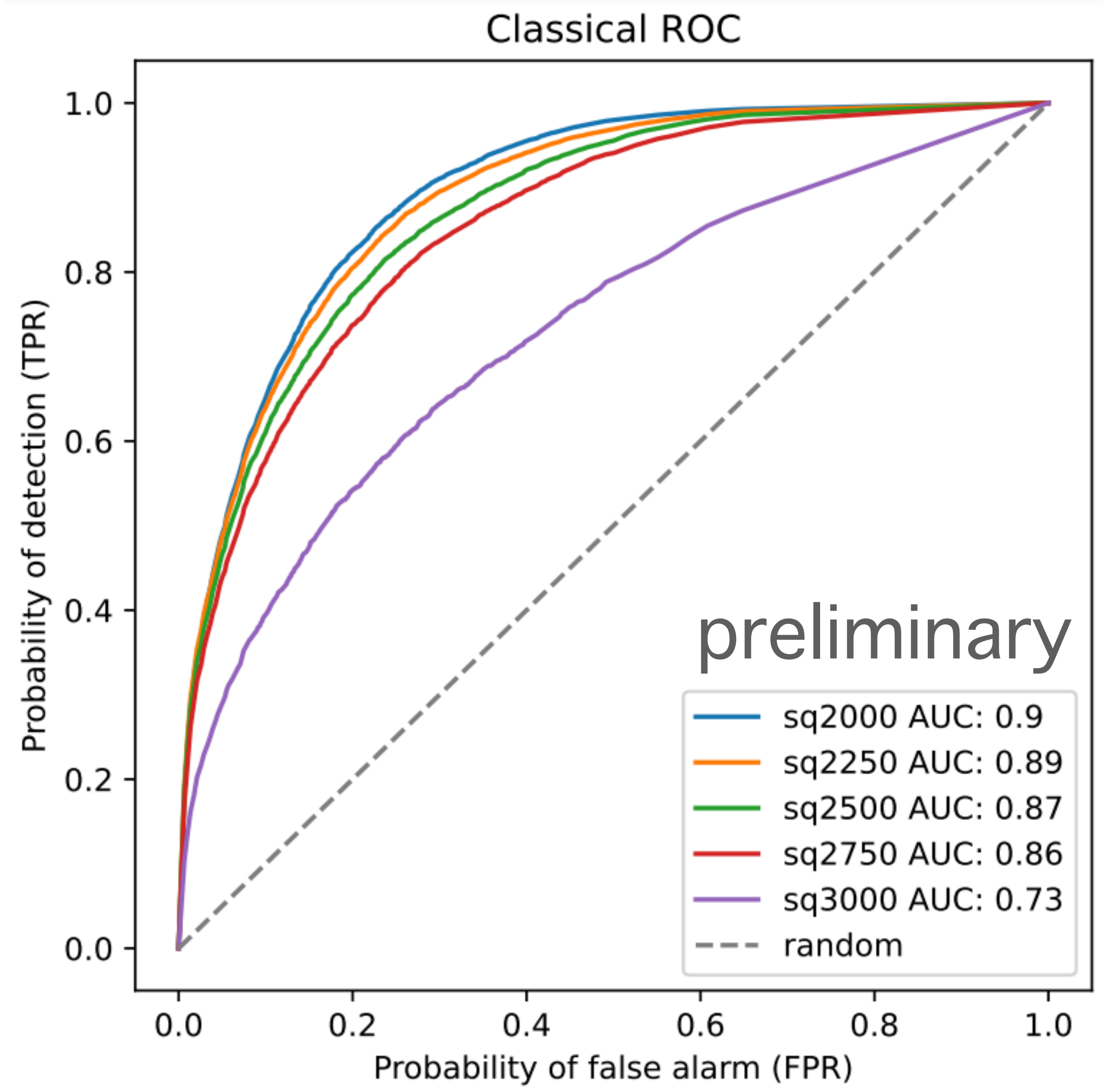


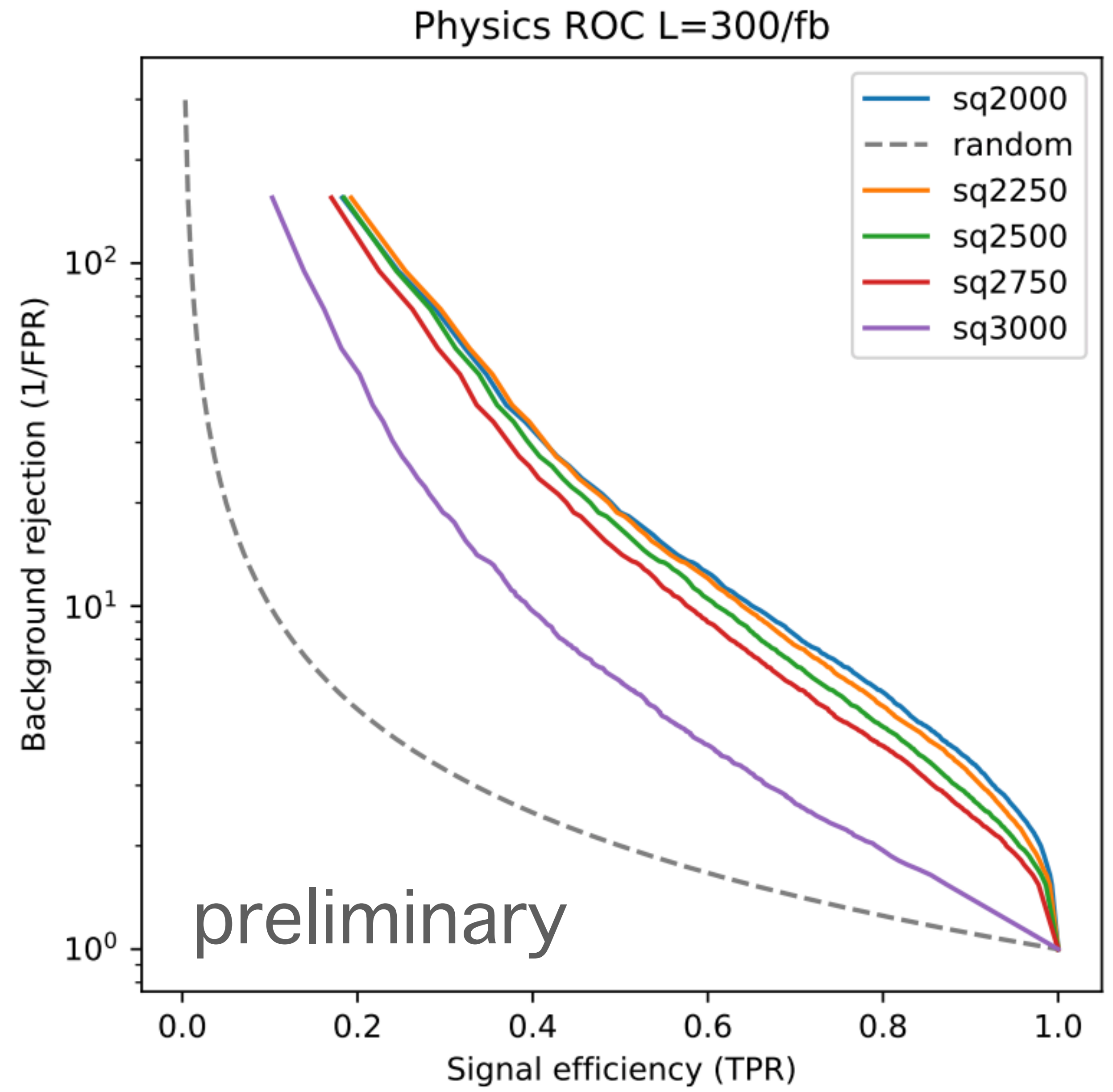


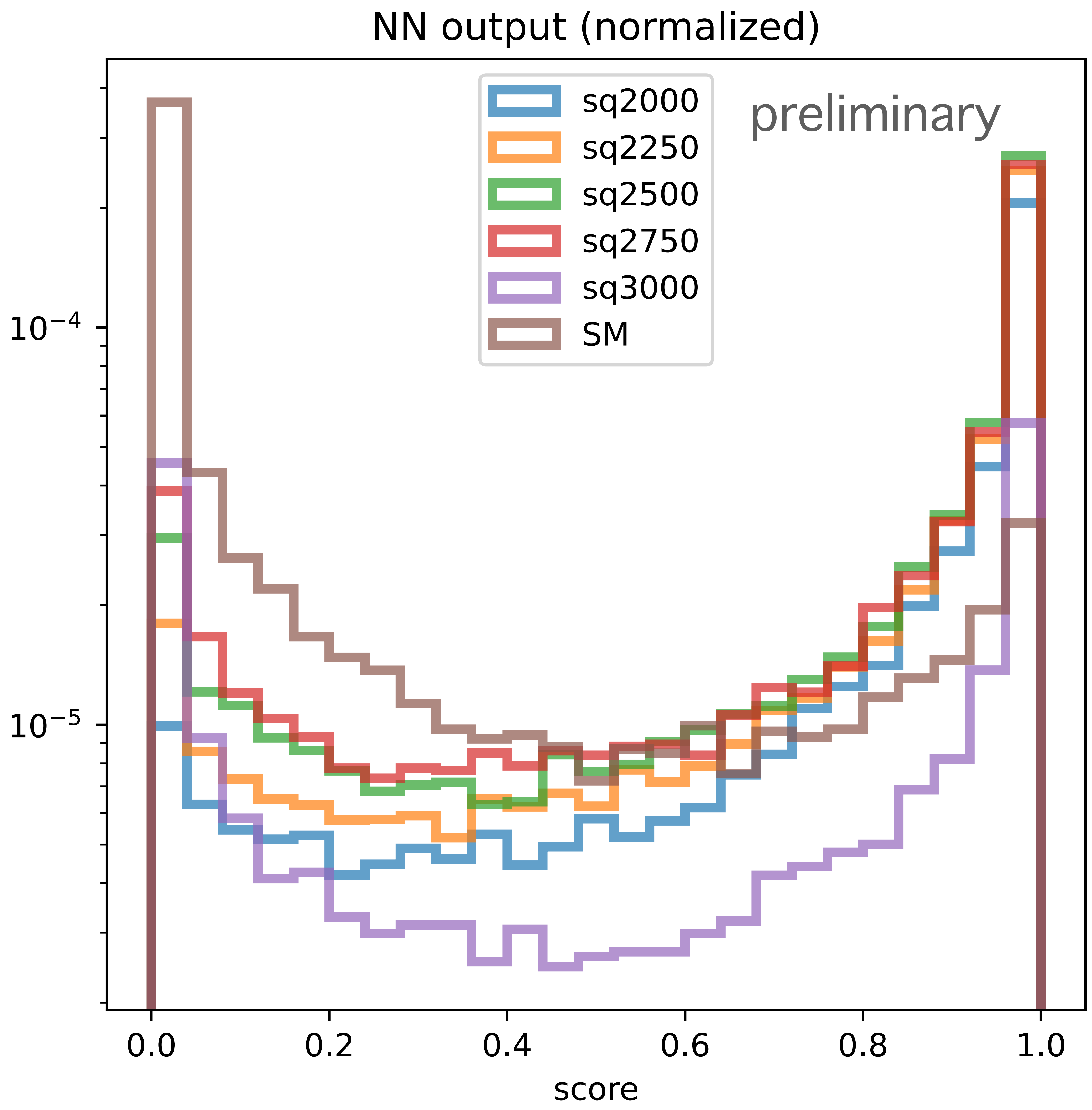


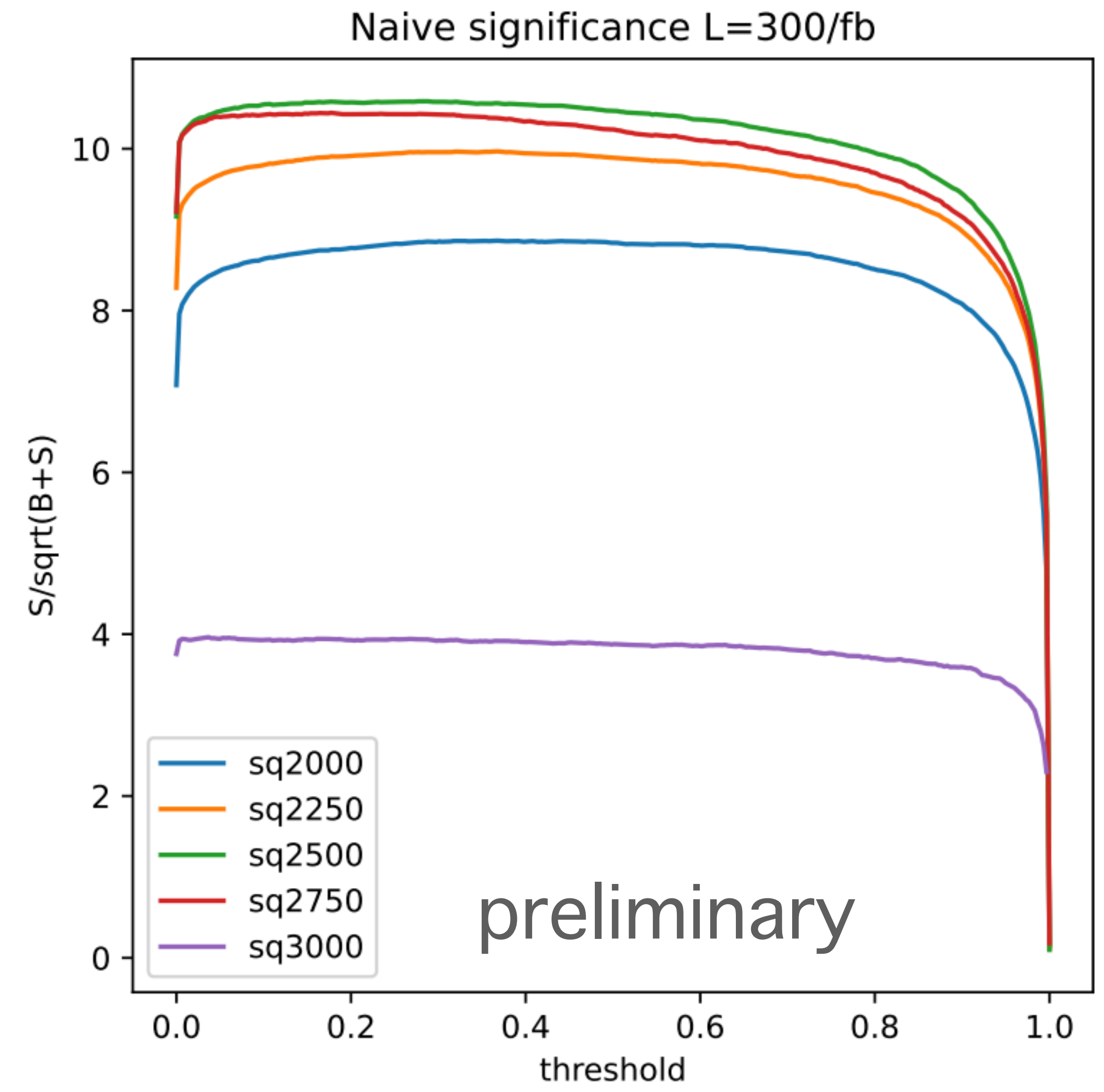


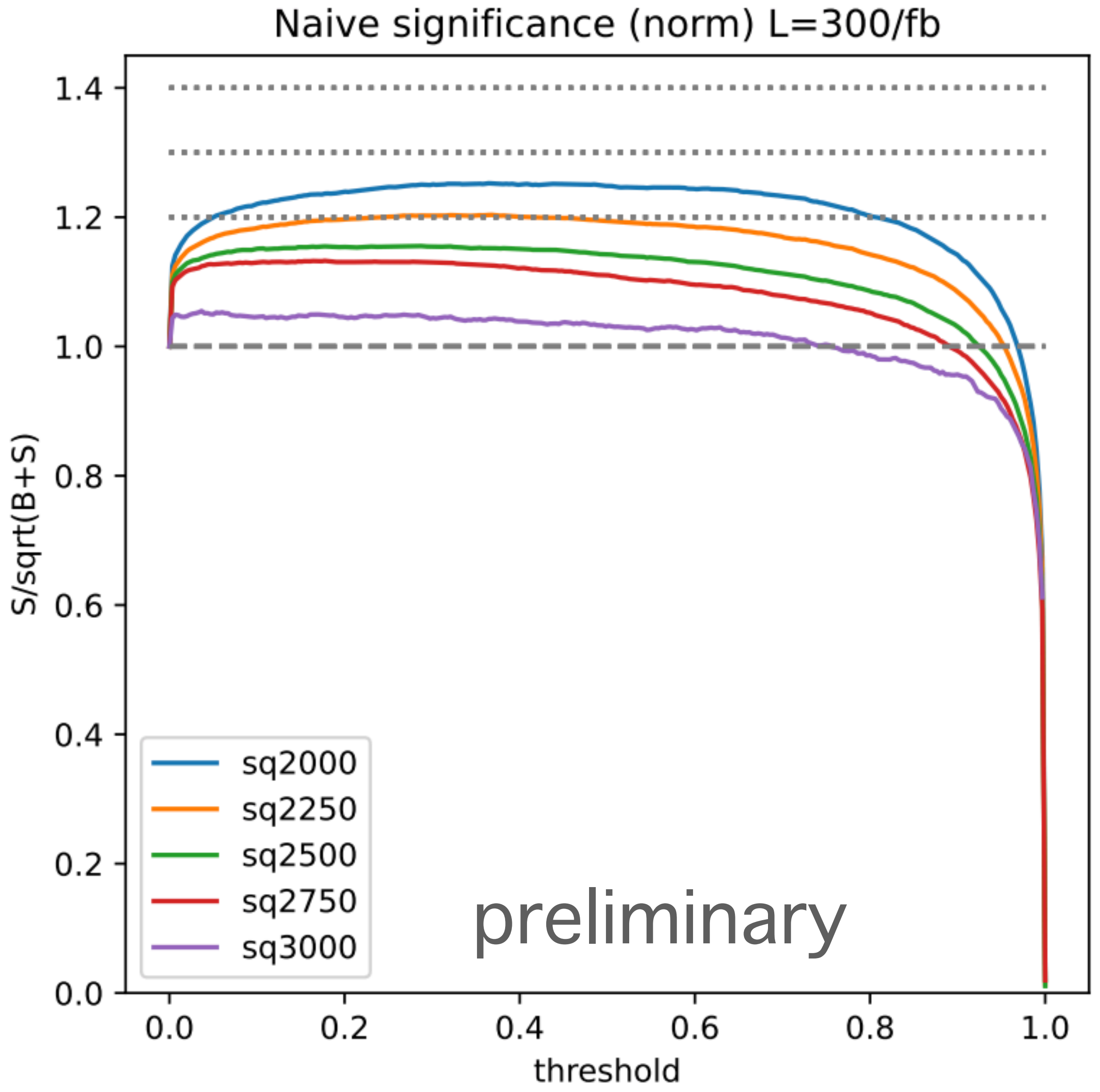
Evaluation — varying squark mass











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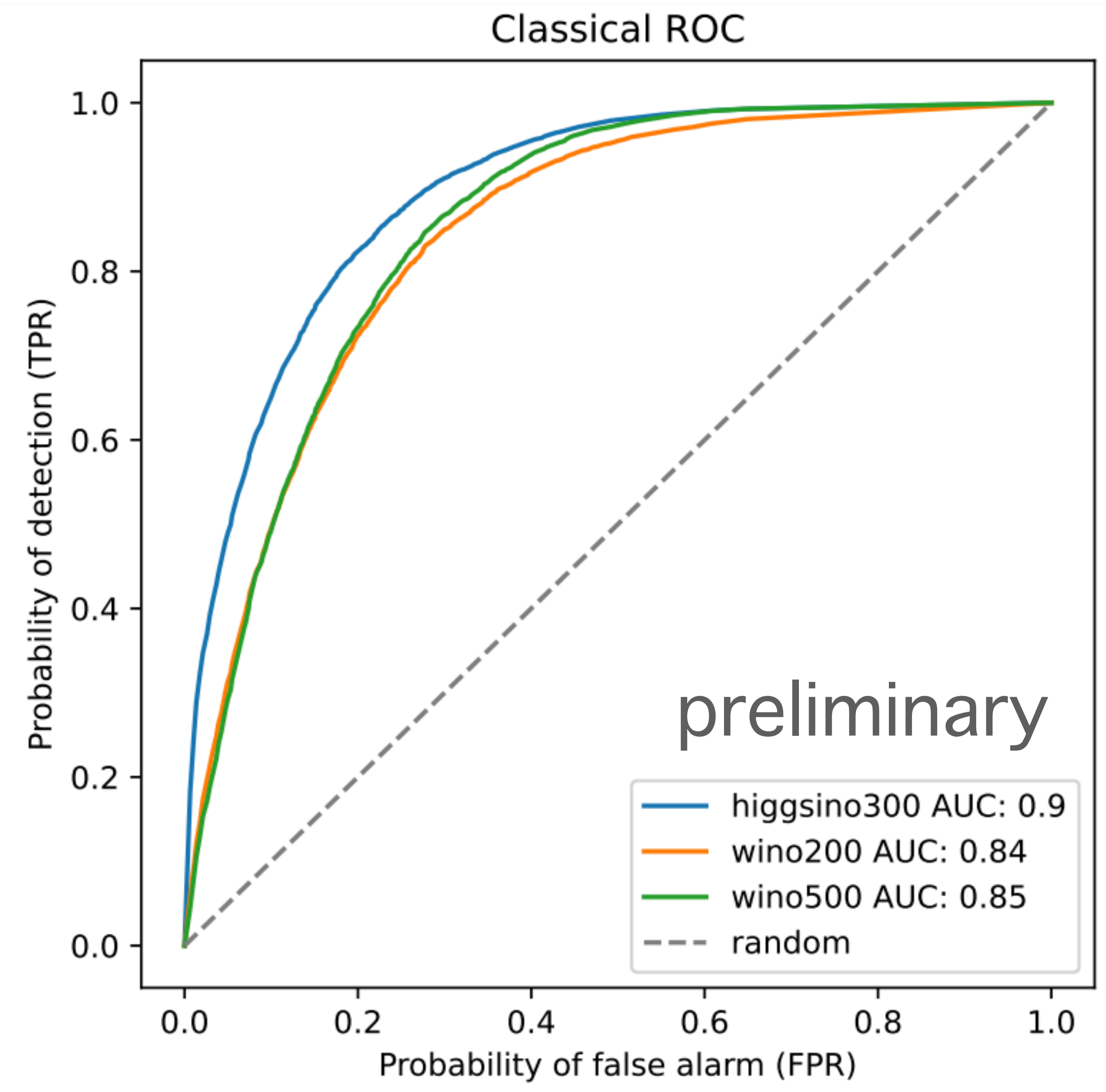
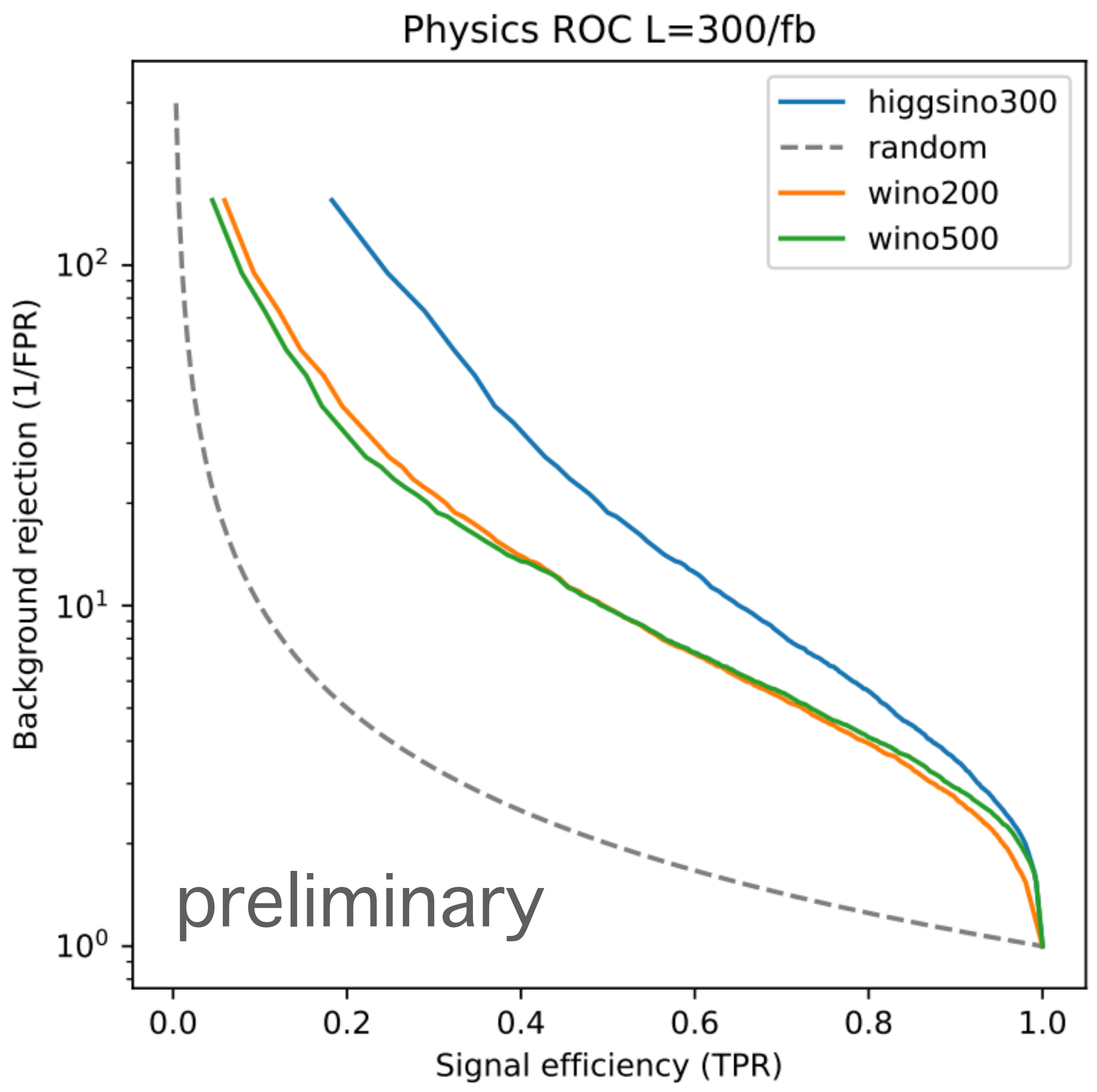
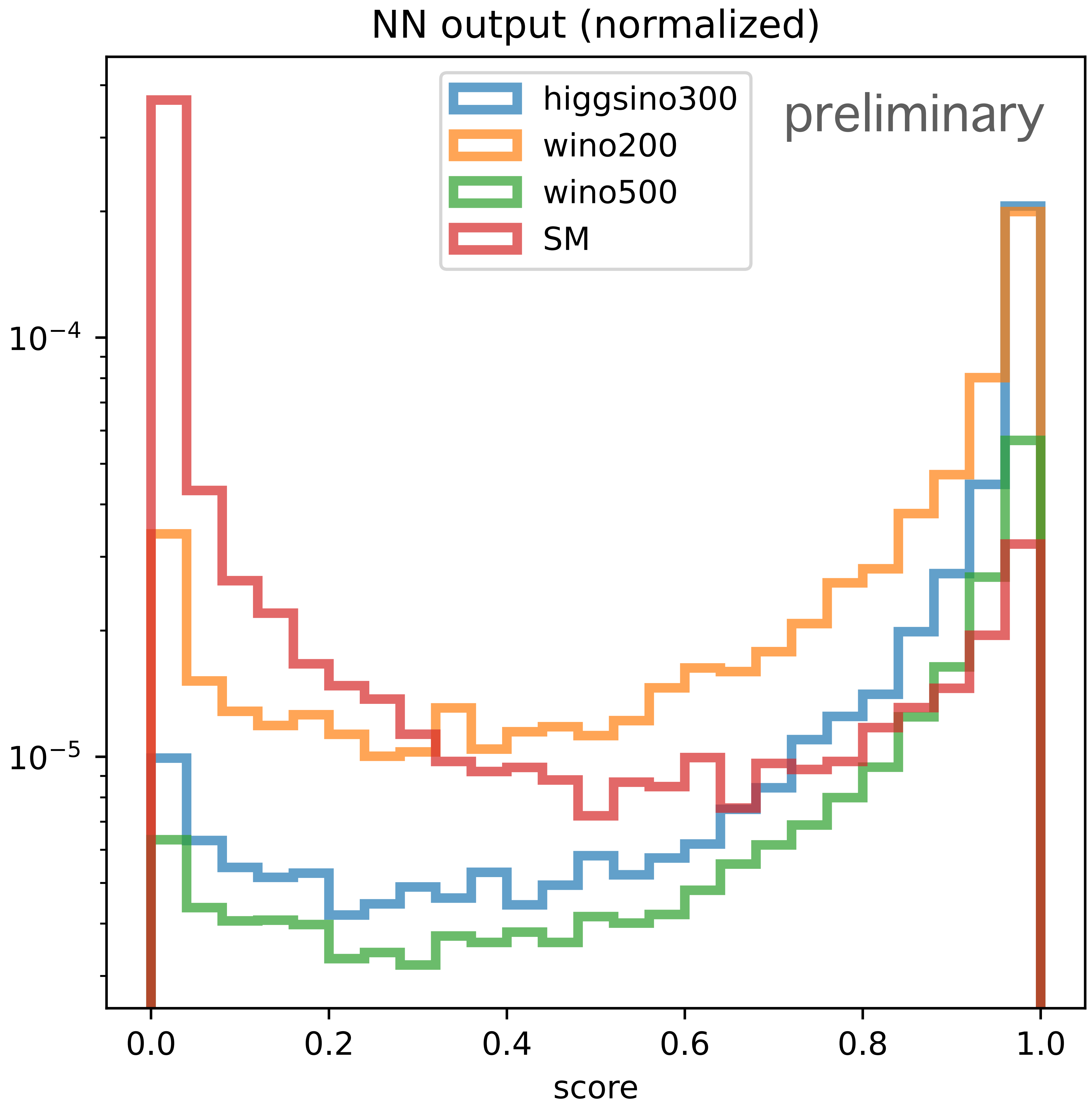
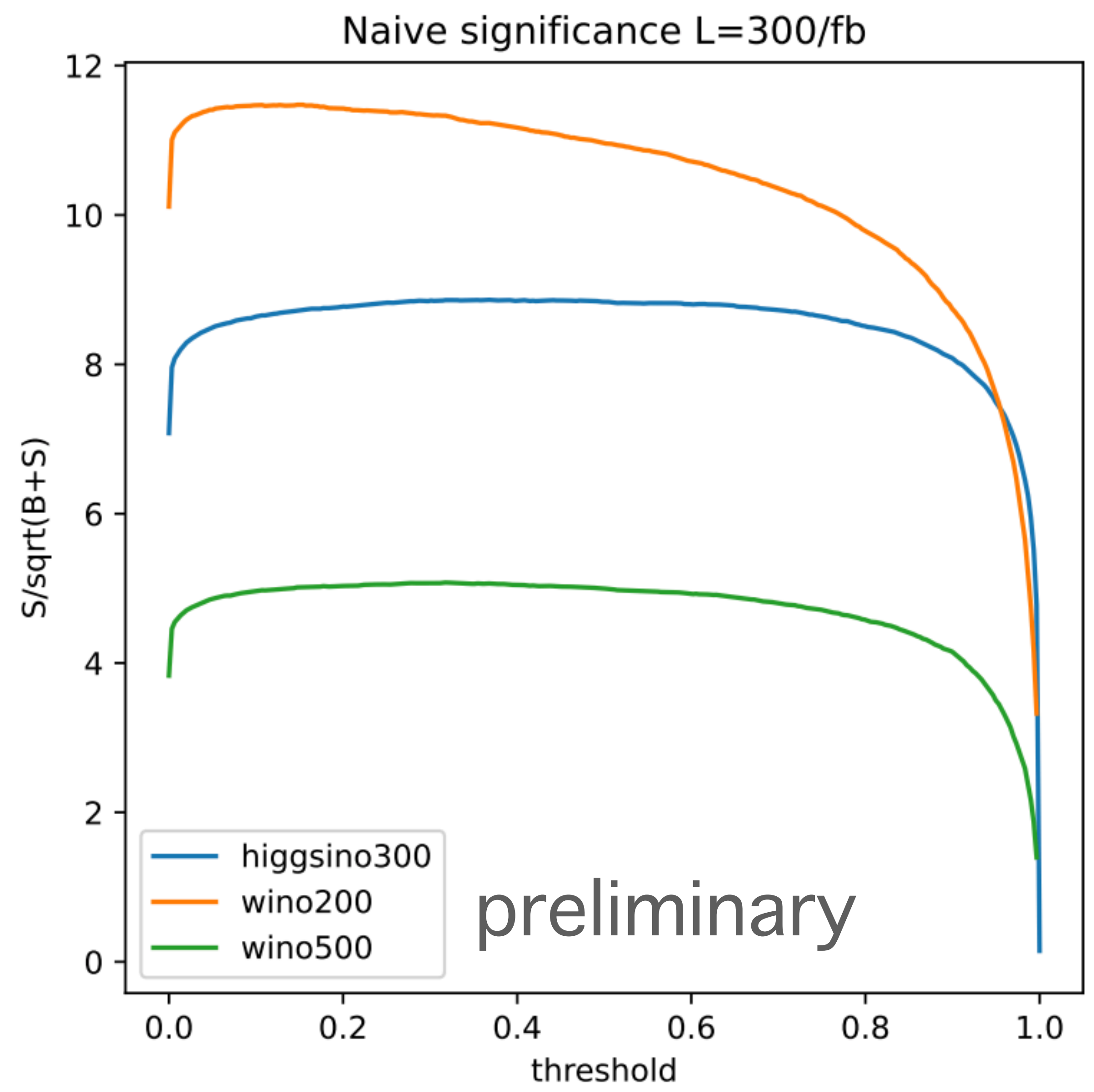
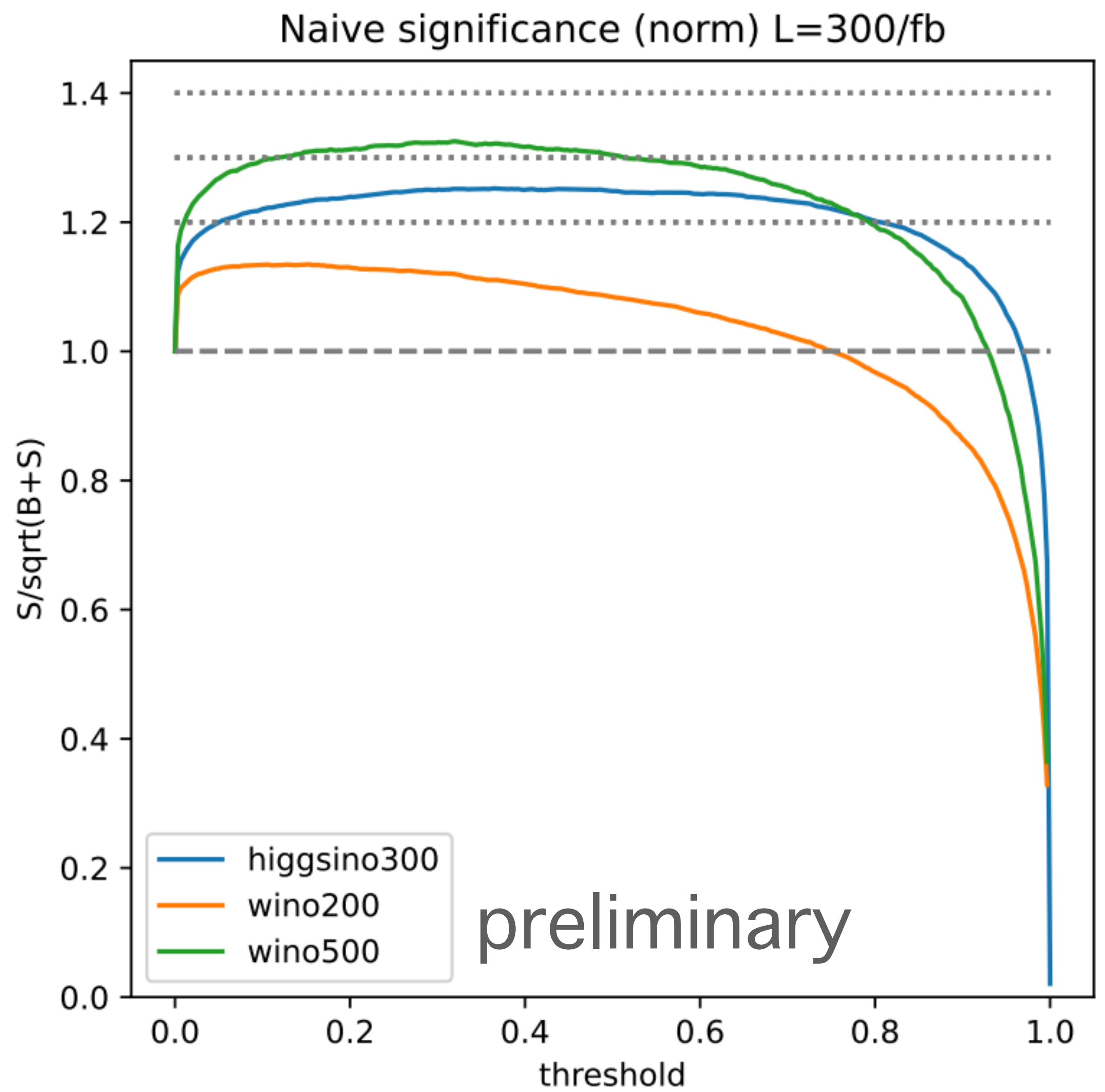
Evaluation — winos











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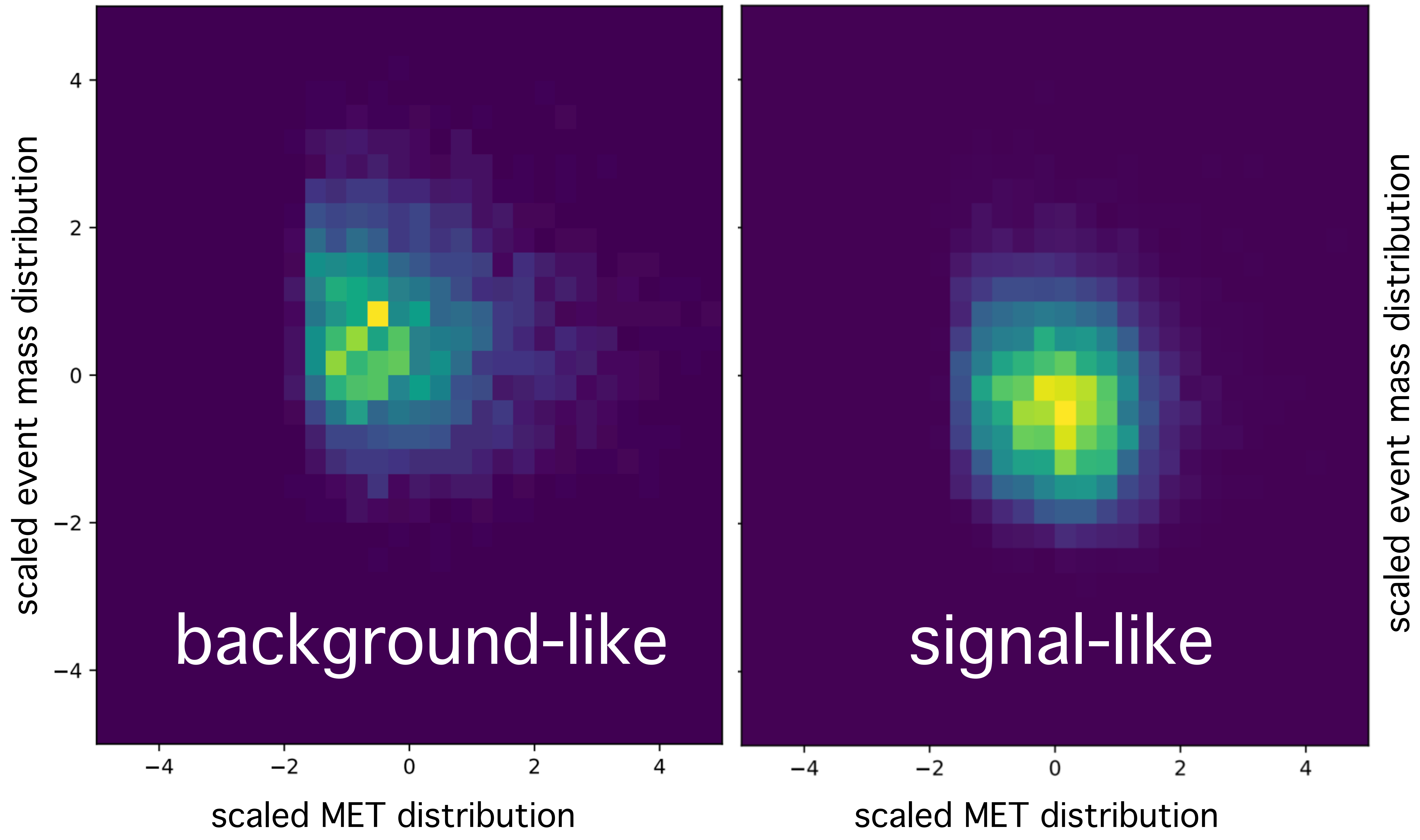
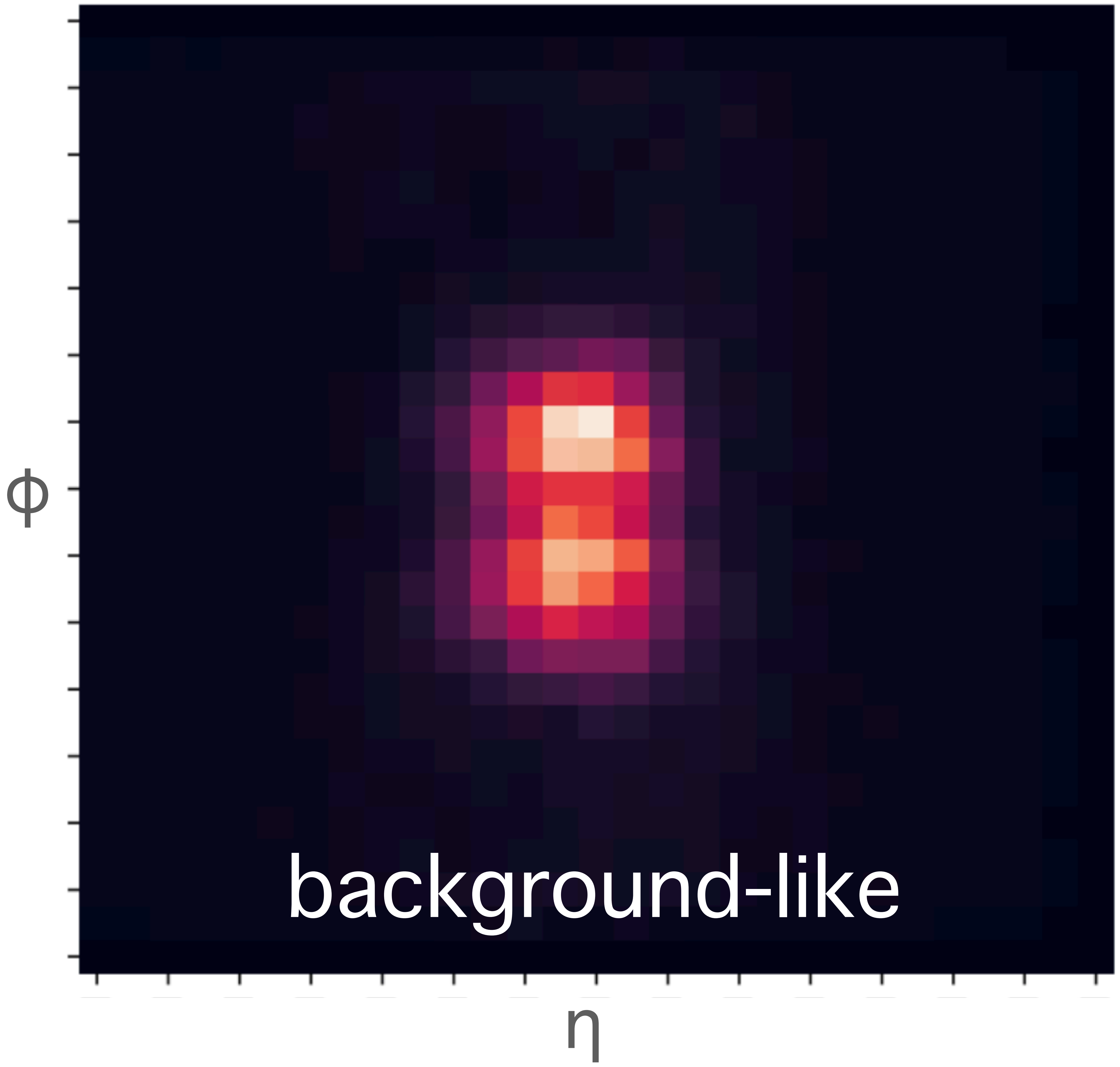
Interpretation

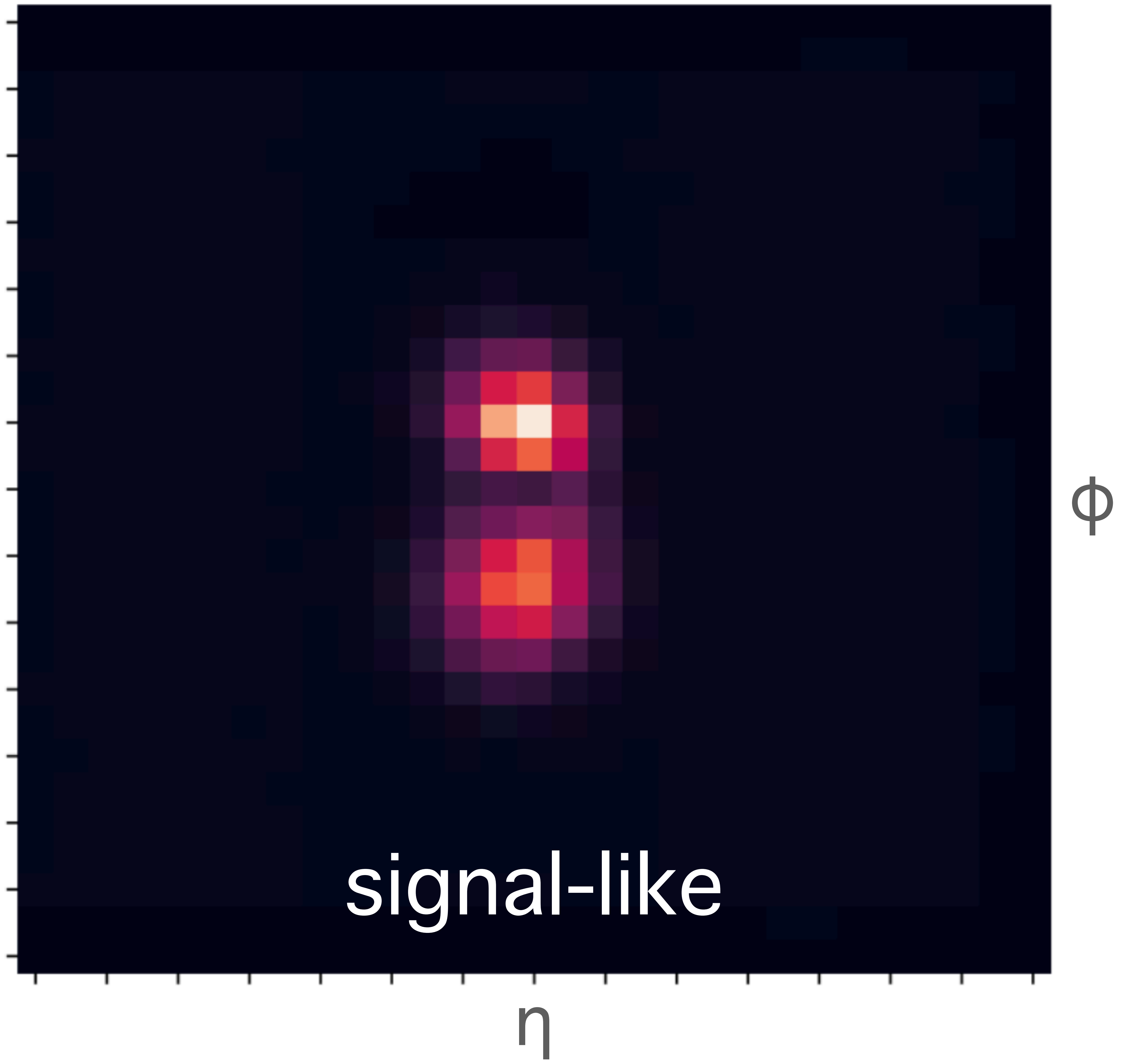
Morskie Oko, Tatra, Poland

Interpretation — event-level distributions

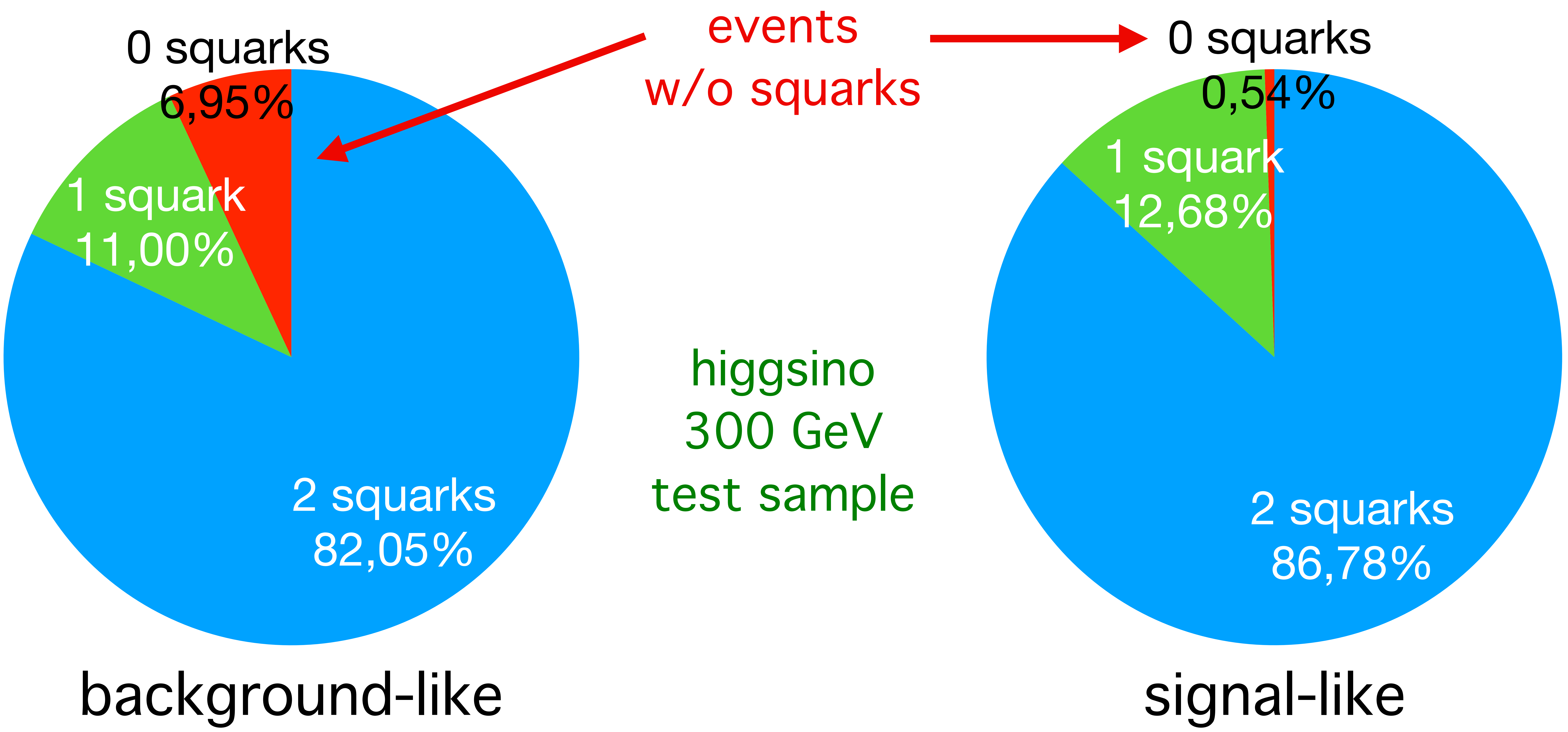


Interpretation — calorimeter image

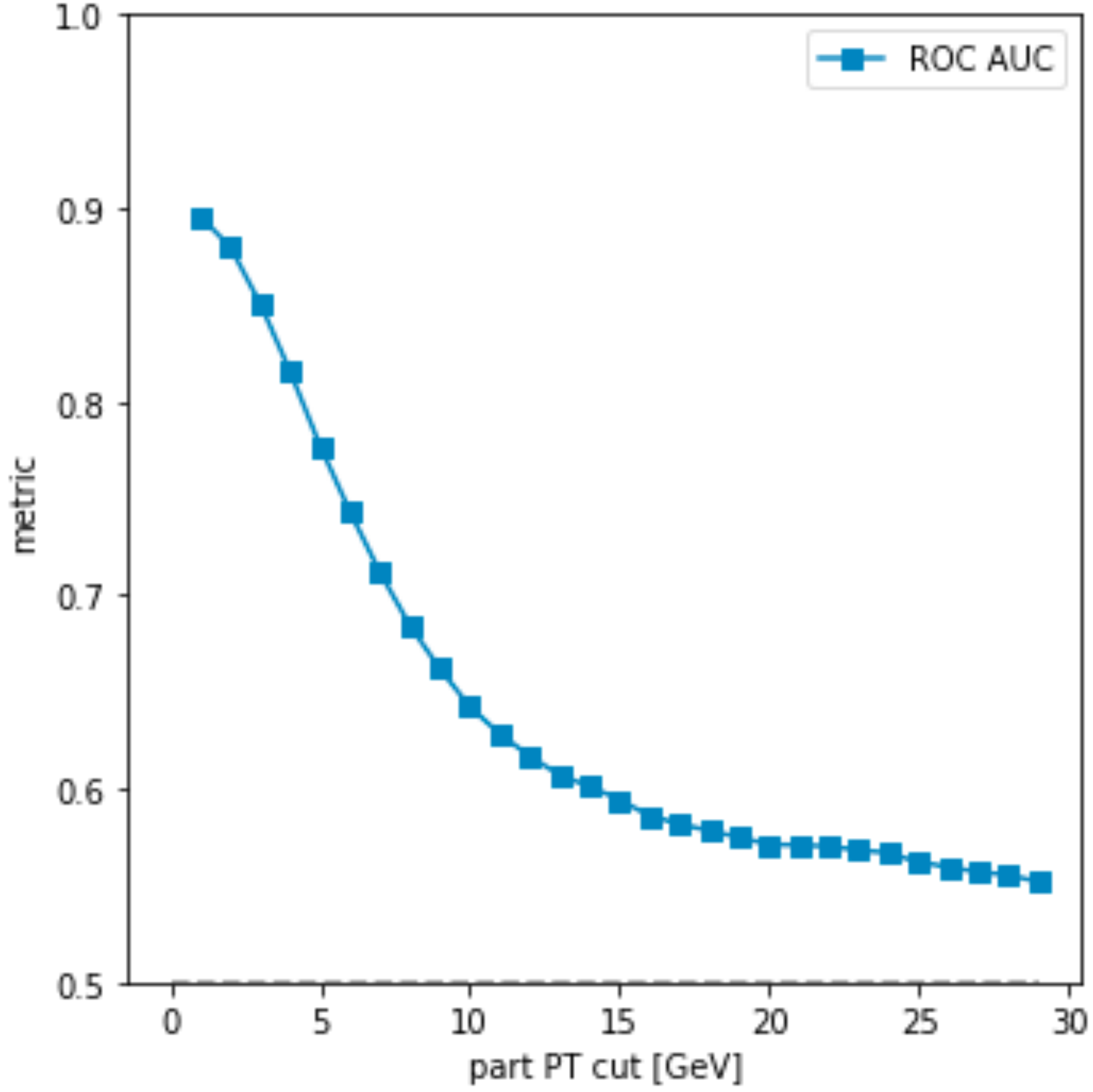




Interpretation — squark vs QCD jets



Interpretation — sensitivity to soft particles



Outlook

- Understand better what allows the network to distinguish between the signal and the background.
- Estimate how much the current limits on neutralino and squark masses 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 seems to be able to recognize the number of jets, knows the characteristics of QCD jets, and uses both event-level and soft-particle information.
- 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