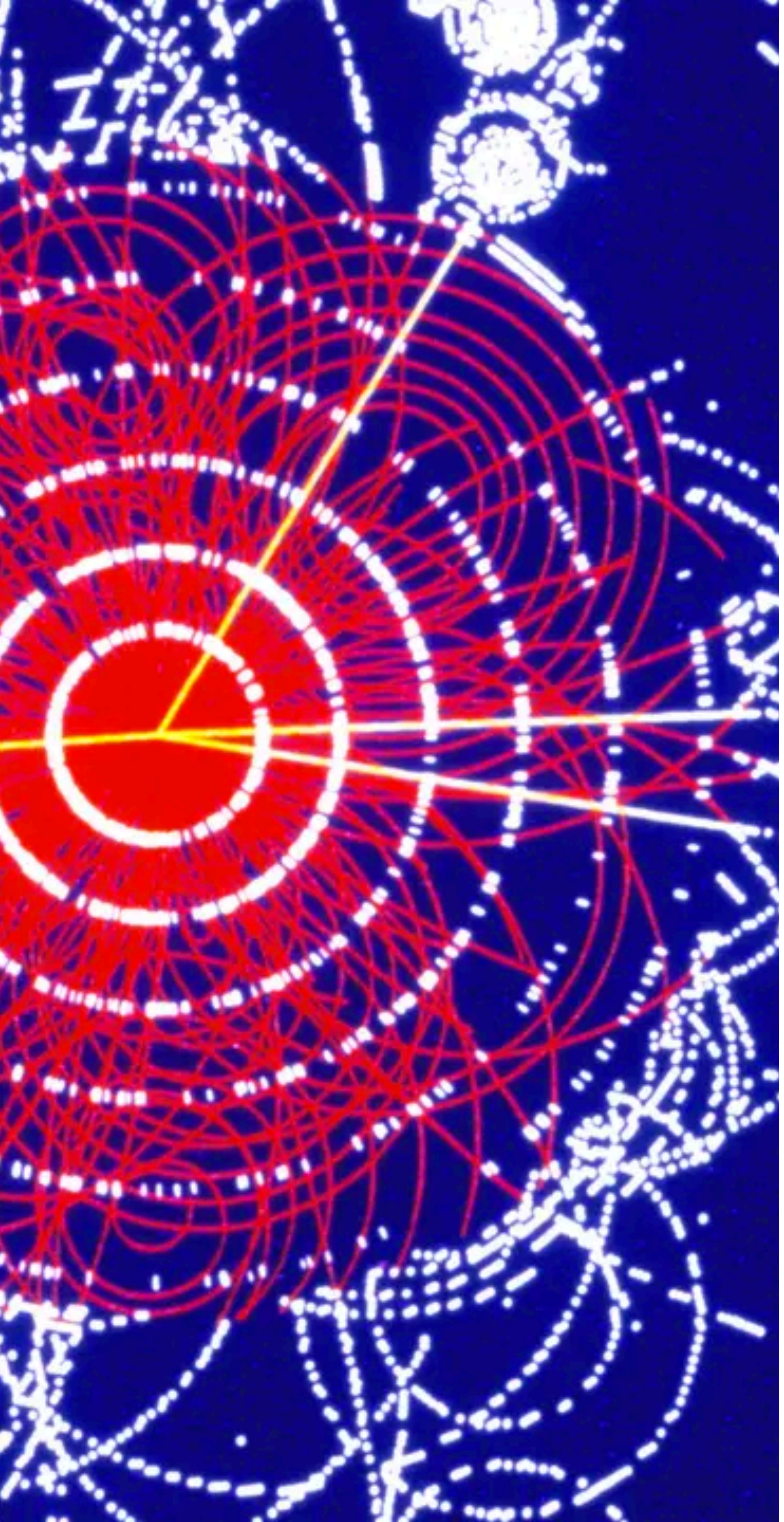


Searching for Dark Matter at the LHC with GNN

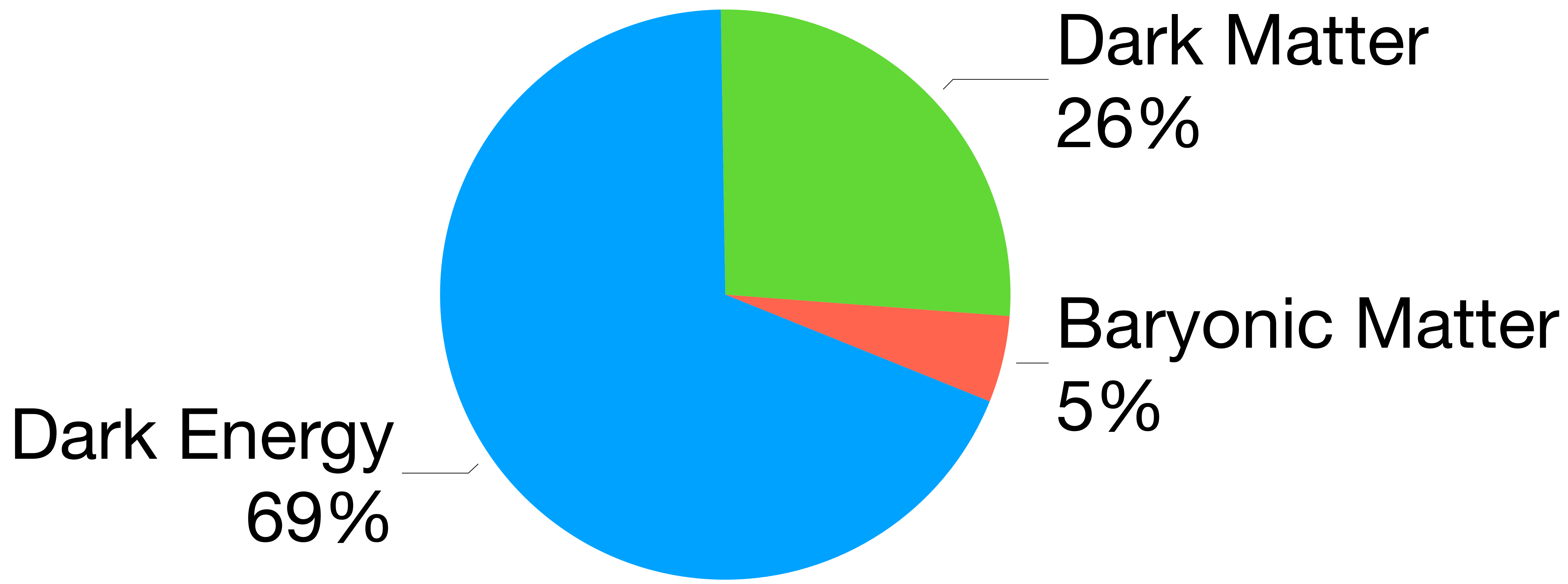
Rafał Masełek

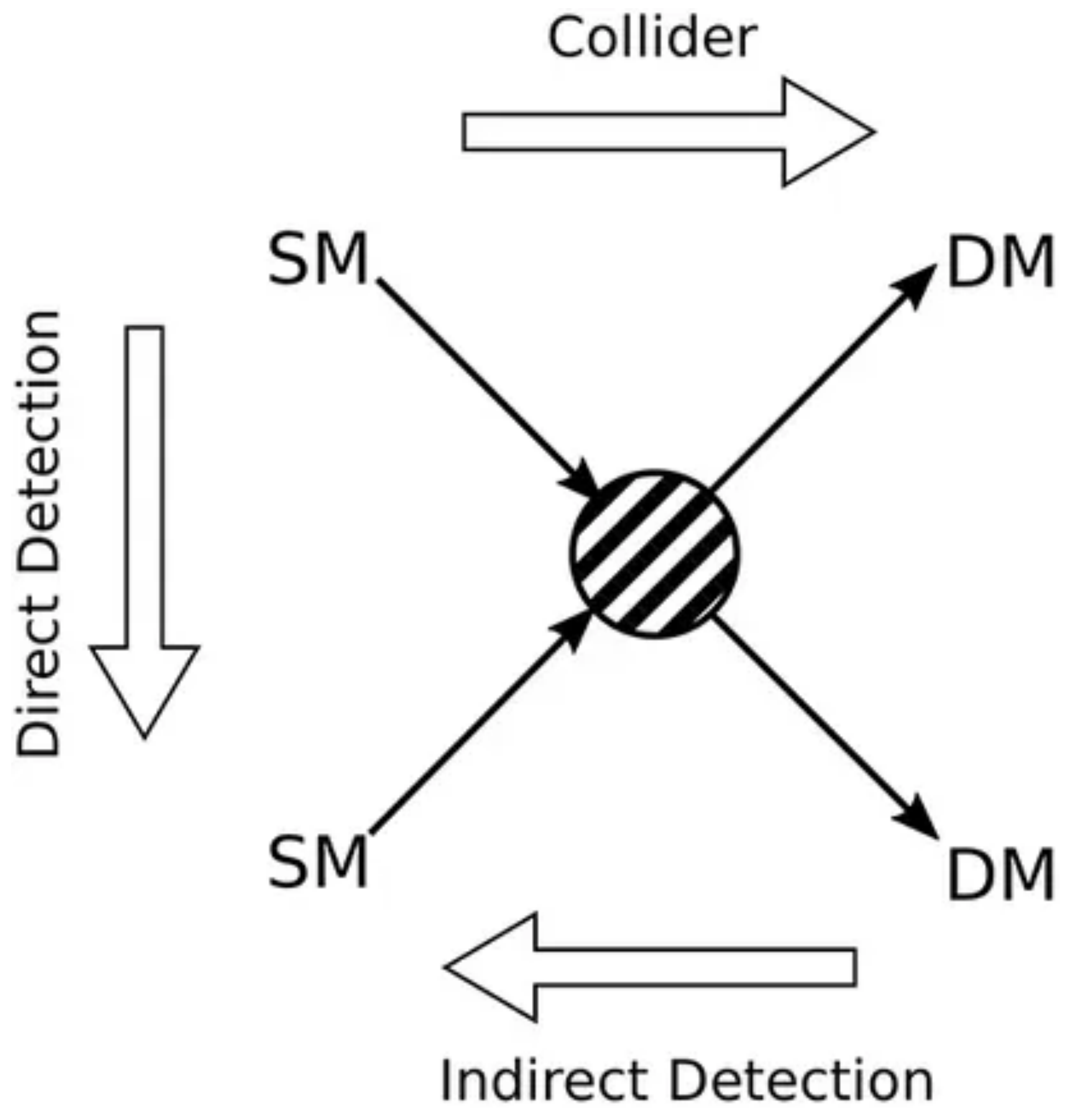
in collaboration with K. Sakurai and M. Nojiri

AISSAI Toulouse workshop 02-10-2024

RM is supported by IN2P3 theory master project DataMATTER; Polish National Science Centre grants: 2020/38/E/ST2/00243 and 2021/41/N/ST2/00972; Polish National Agency For Academic exchange grant BPN/BEK/2022/1/00253/DEC/1.

Dark Matter



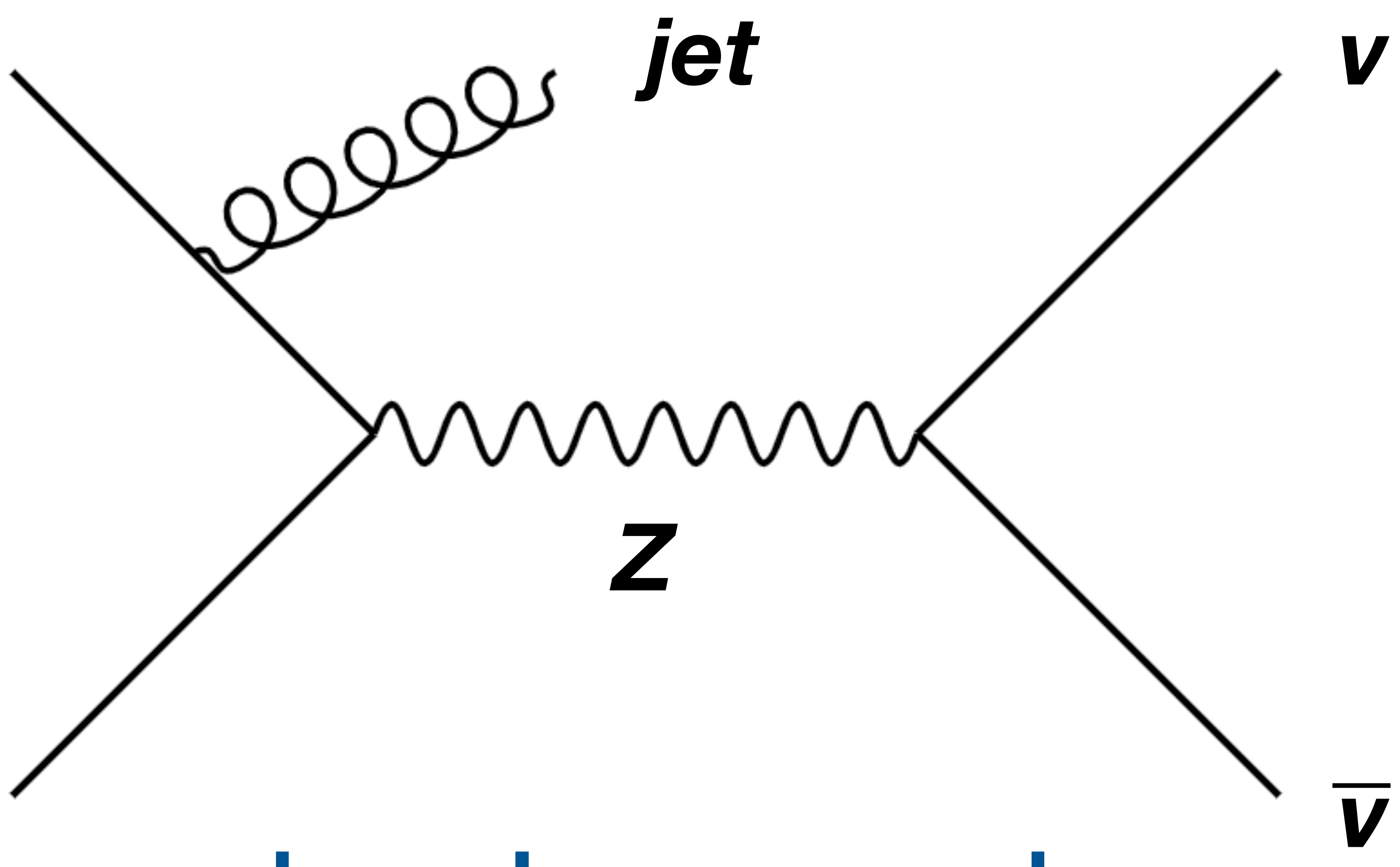


- long-lived over the age of the Universe
- feebly-interacting with photons and baryons
- not too hot

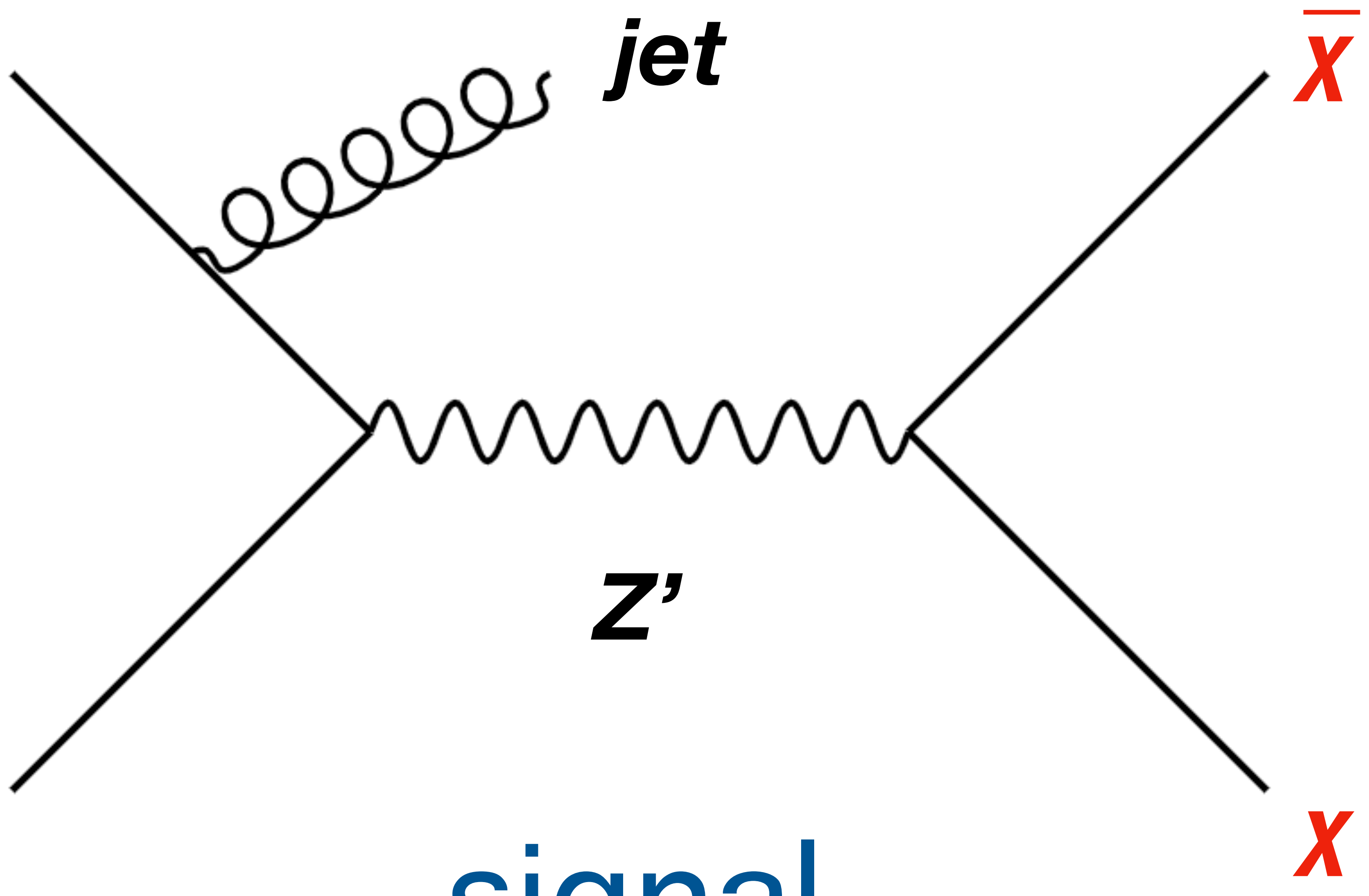
img source: https://doi.org/10.3389/fphy.2019.00075

DM searches @ LHC — Monojet

Monojet channel = one (or more but few) high-momentum jet recoiling against a missing transverse momentum and no isolated leptons



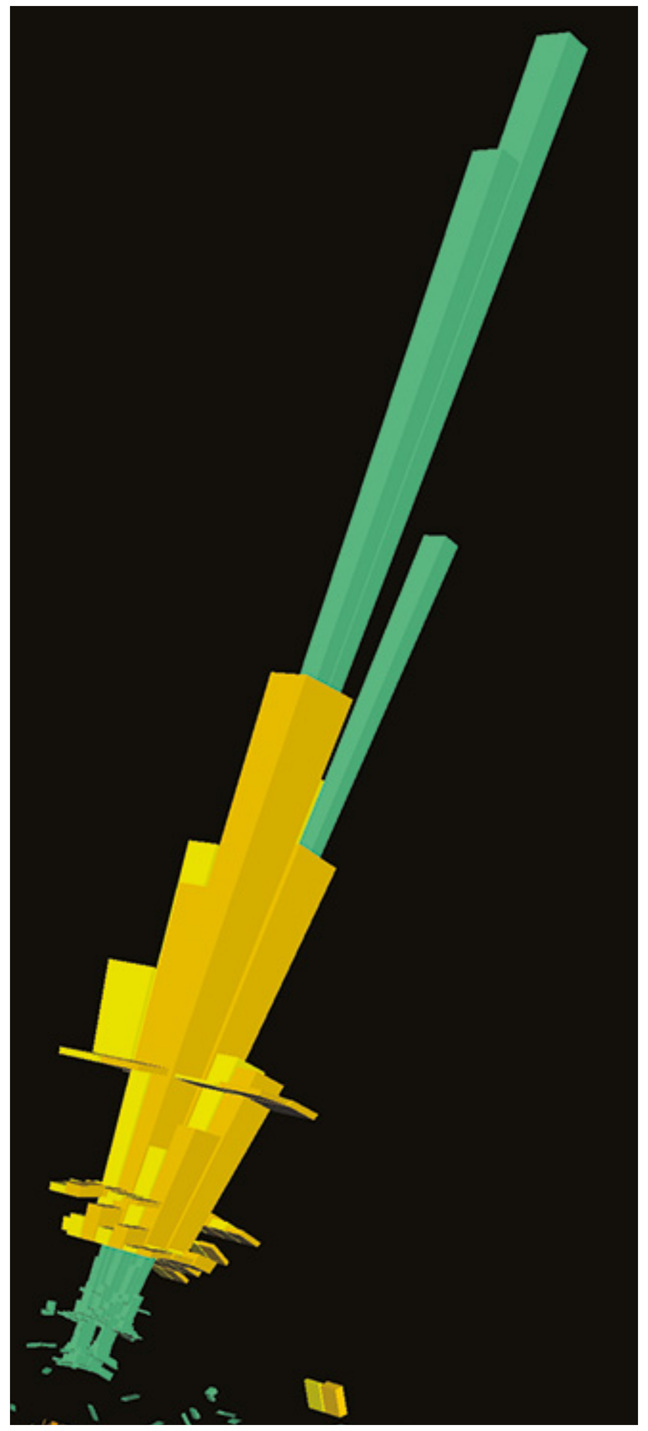
background



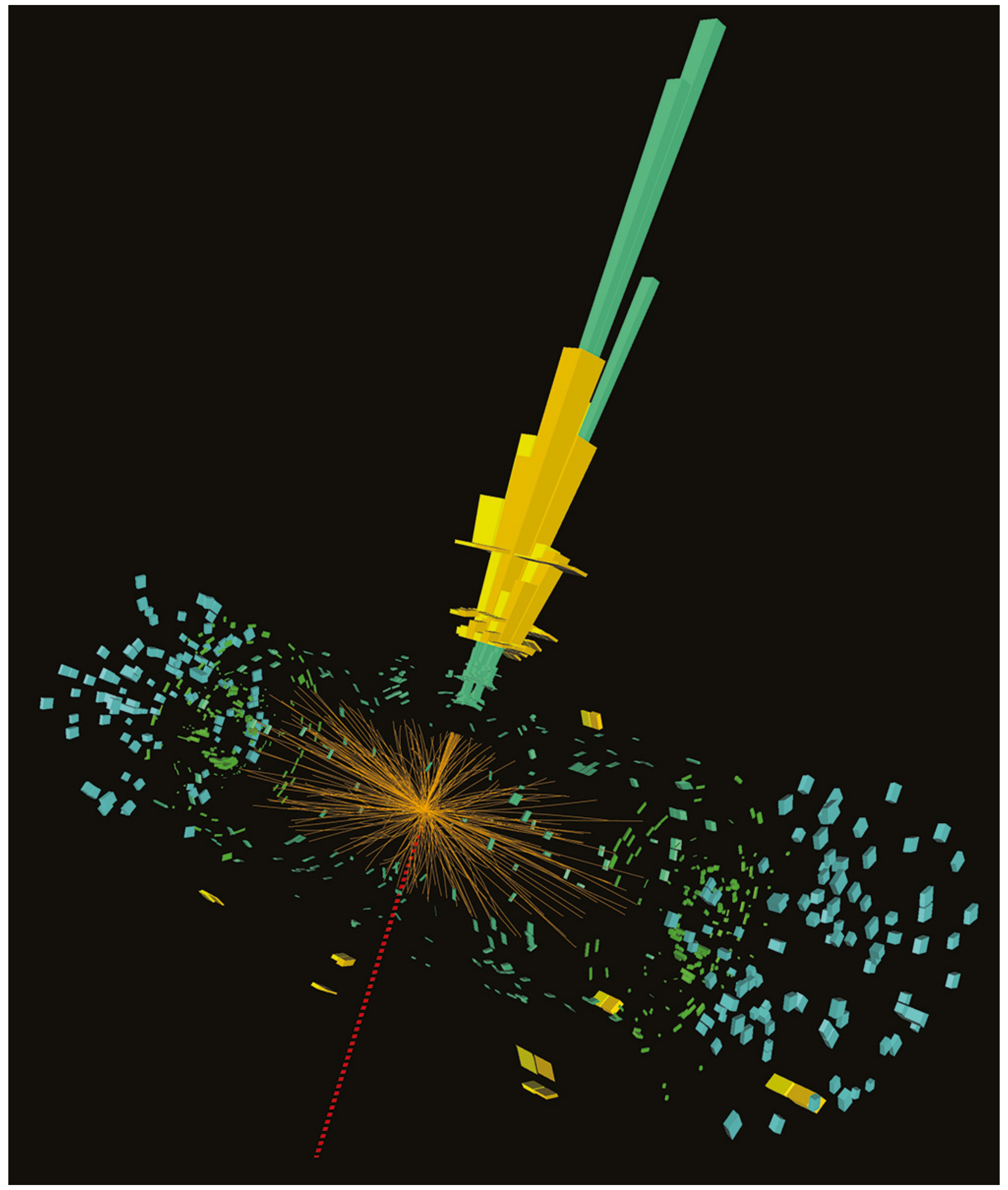
signal

Heterogenous data

particle



jet



events

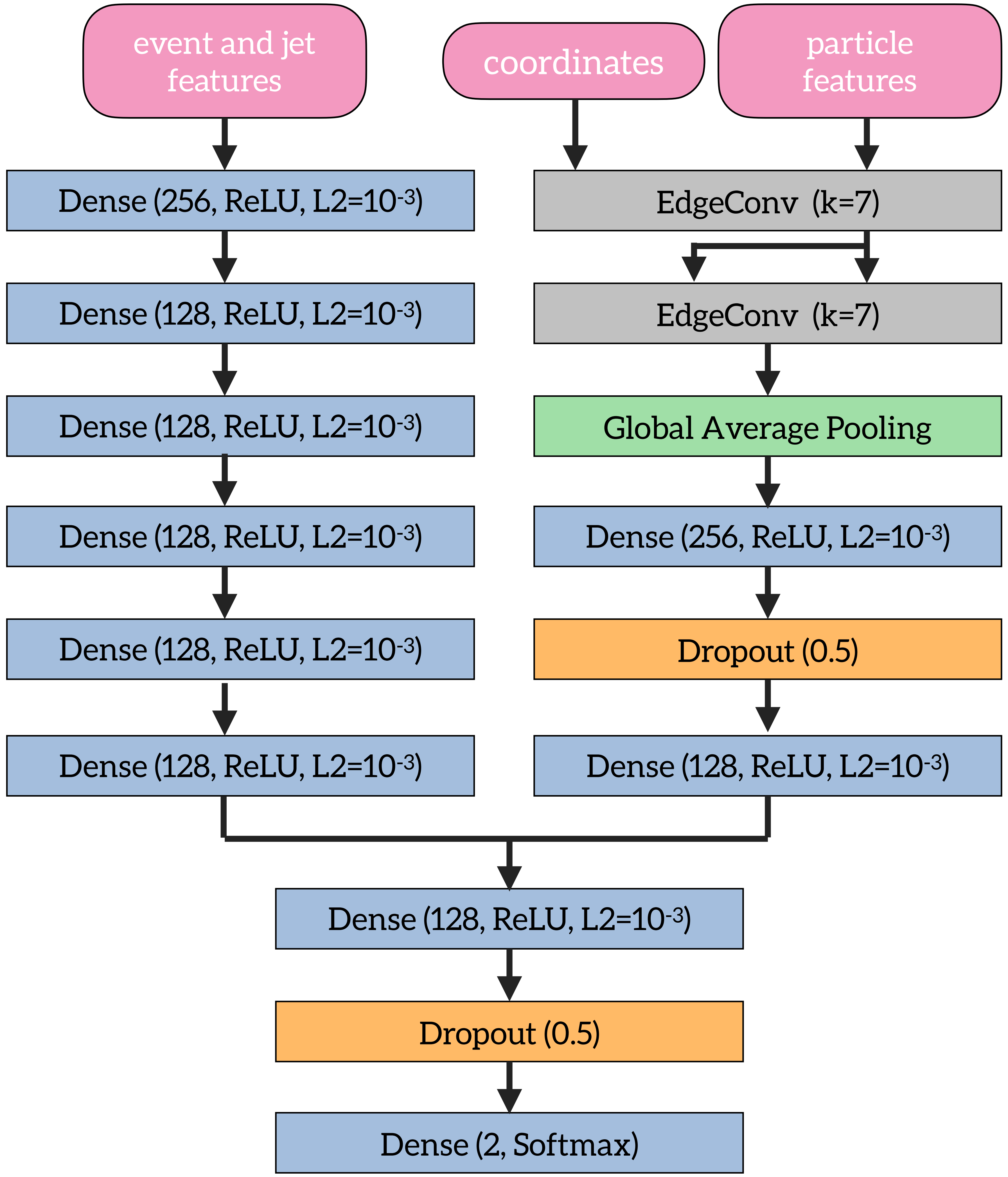
low level → high level

Analysis

Preanalysis

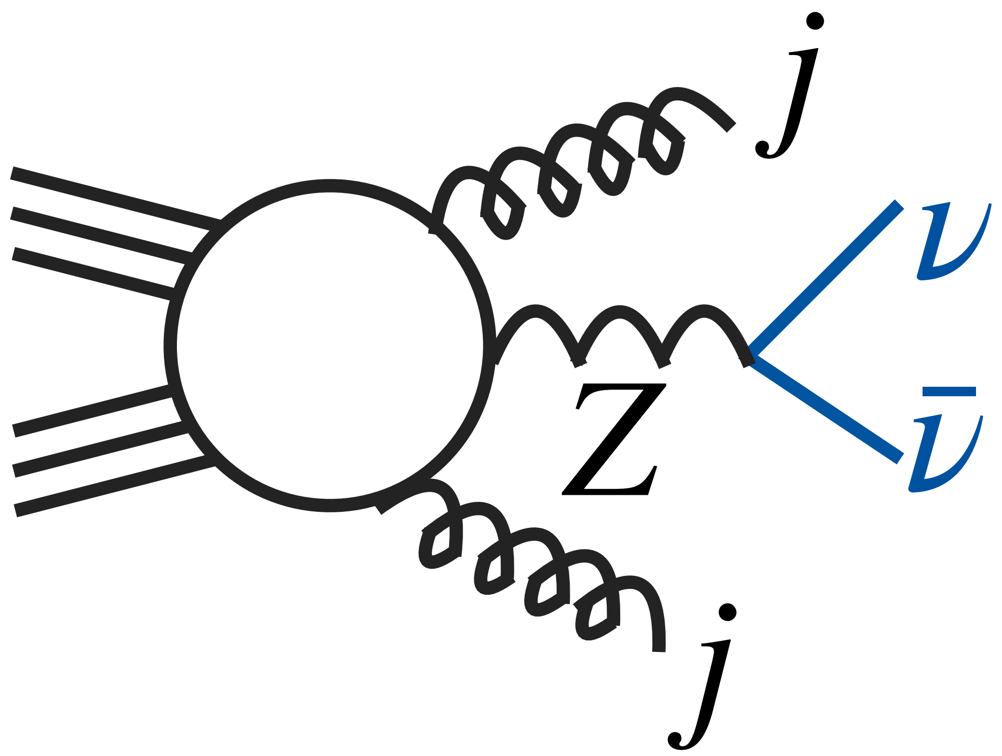
- $4 \geq \#\text{jets} \geq 2$
- $p_T^{1j} > 520$ GeV
- $\eta^{1j} < 2.0$
- $p_T^{2j} > 320$ GeV
- $\eta^{2j} < 2.0$
- MET > 820 GeV
- lepton veto
- $\Delta\phi\left(j^{1,2,3}, p_T^{miss}\right) > 0.8$
- $\Delta\phi\left(j^{4}, p_T^{miss}\right) > 0.4$
- $\text{MET}/\sqrt{H_T} > 16\ \sqrt{\text{GeV}}$
- $M_{eff} > 1600$ GeV
- particle $p_T > 1/5/10$ GeV

GNN model



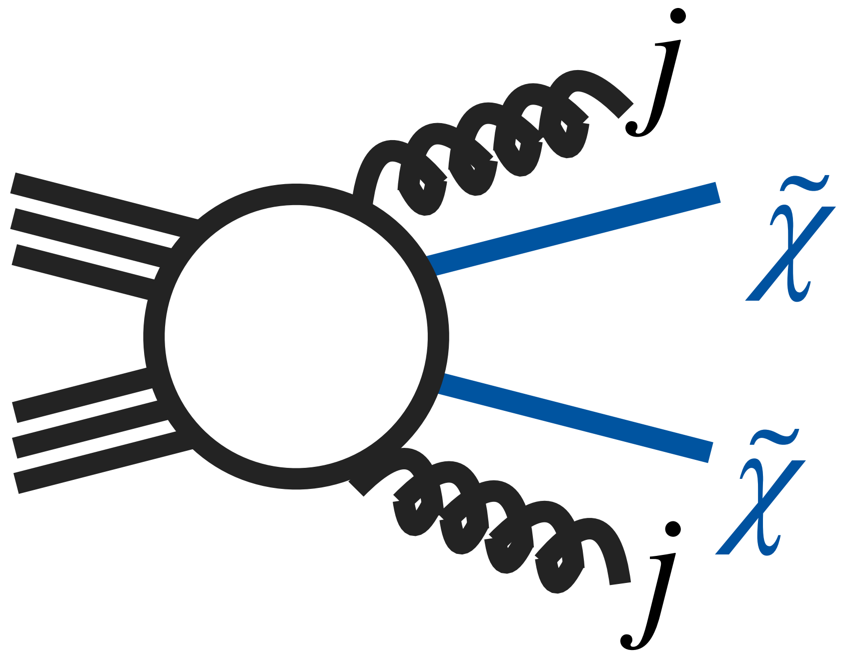
supersymmetric benchmark model

SM background

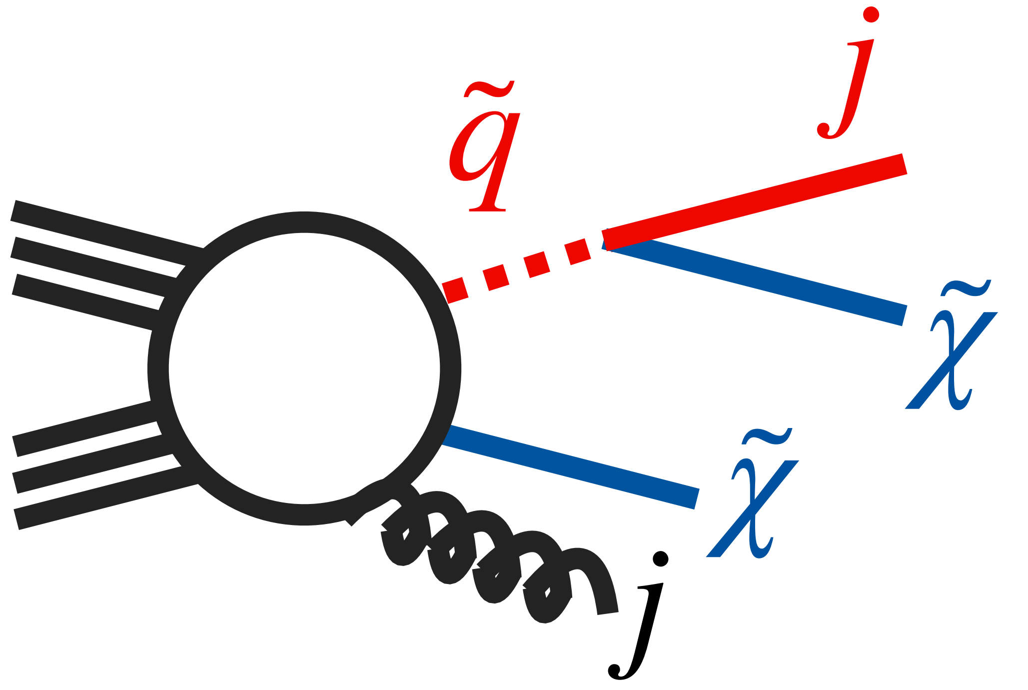


$(Z \to \nu\bar{\nu}) + \text{jets}$

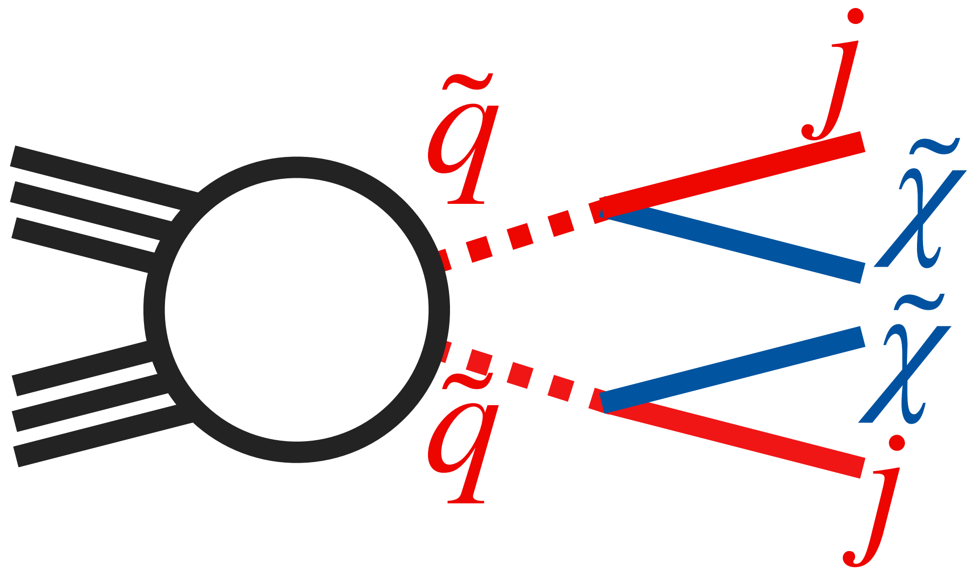
Contributing signal processes



neutralino-neutralino



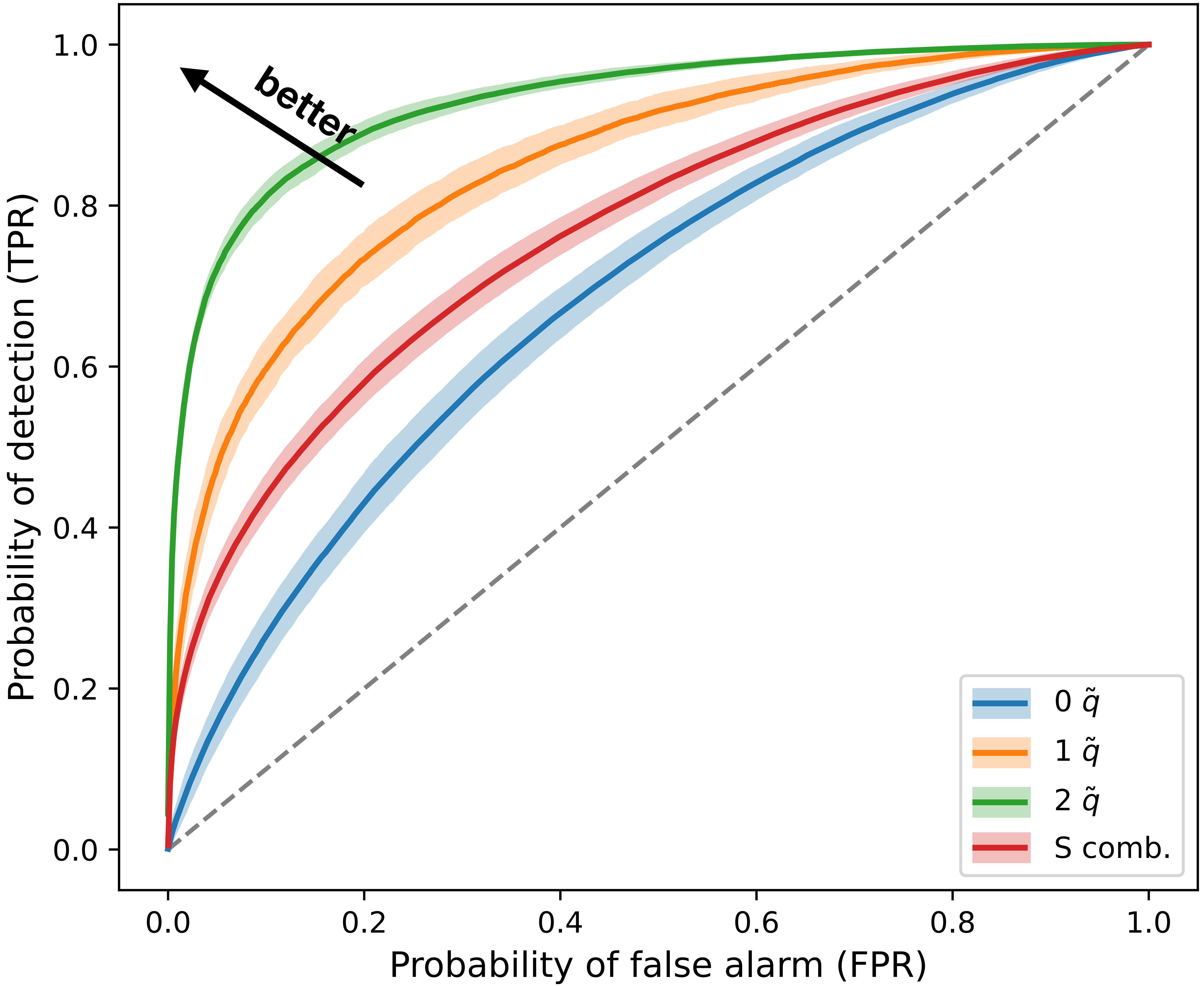
neutralino-squark



squark-squark

neutralino = ☑ wino
☑ higgsino
☐ bino

Evaluation (winos)



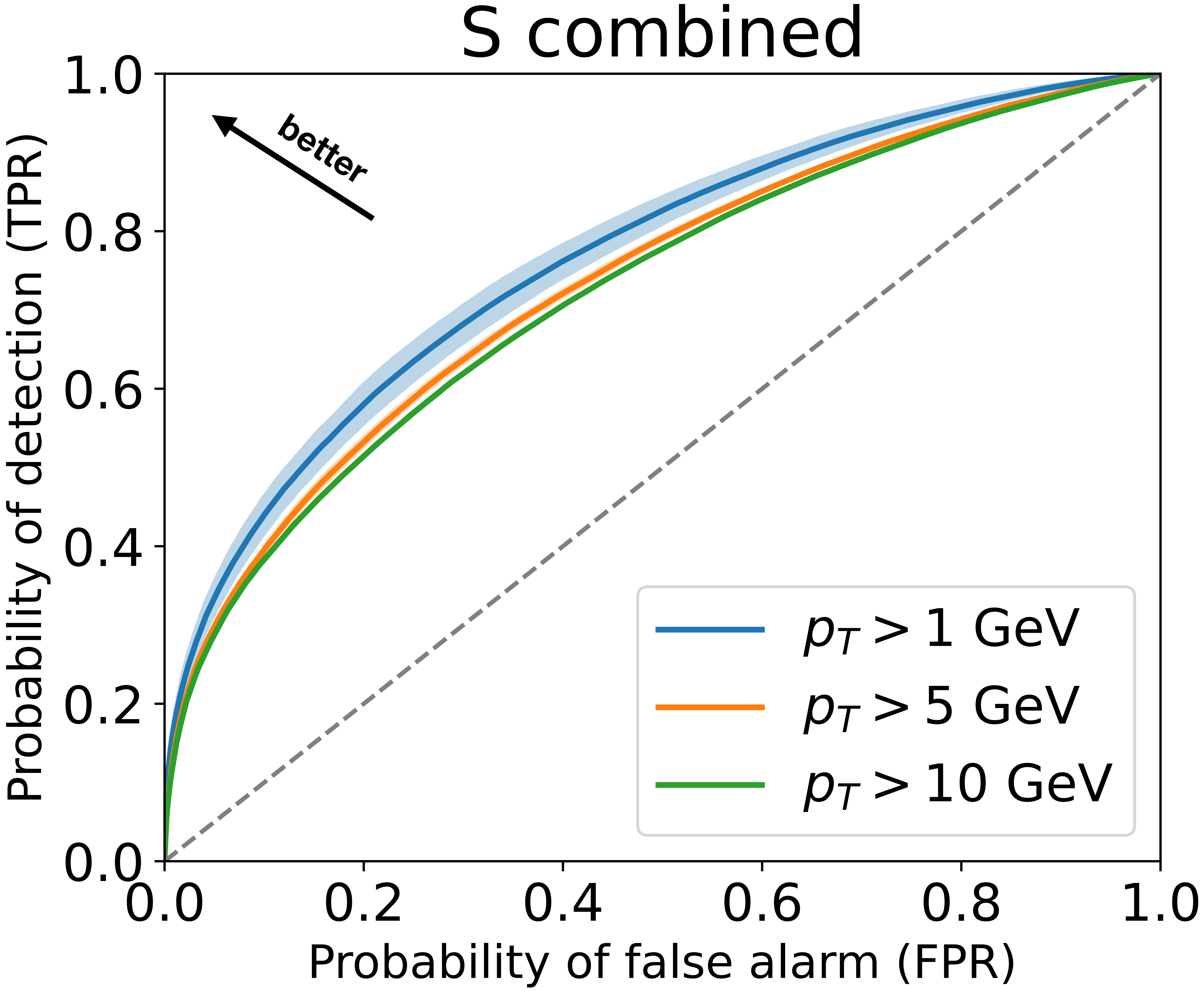
$m_{\tilde{W}} = 300$ GeV, $m_{\tilde{q}} = 2200$ GeV

More decaying squarks

=>

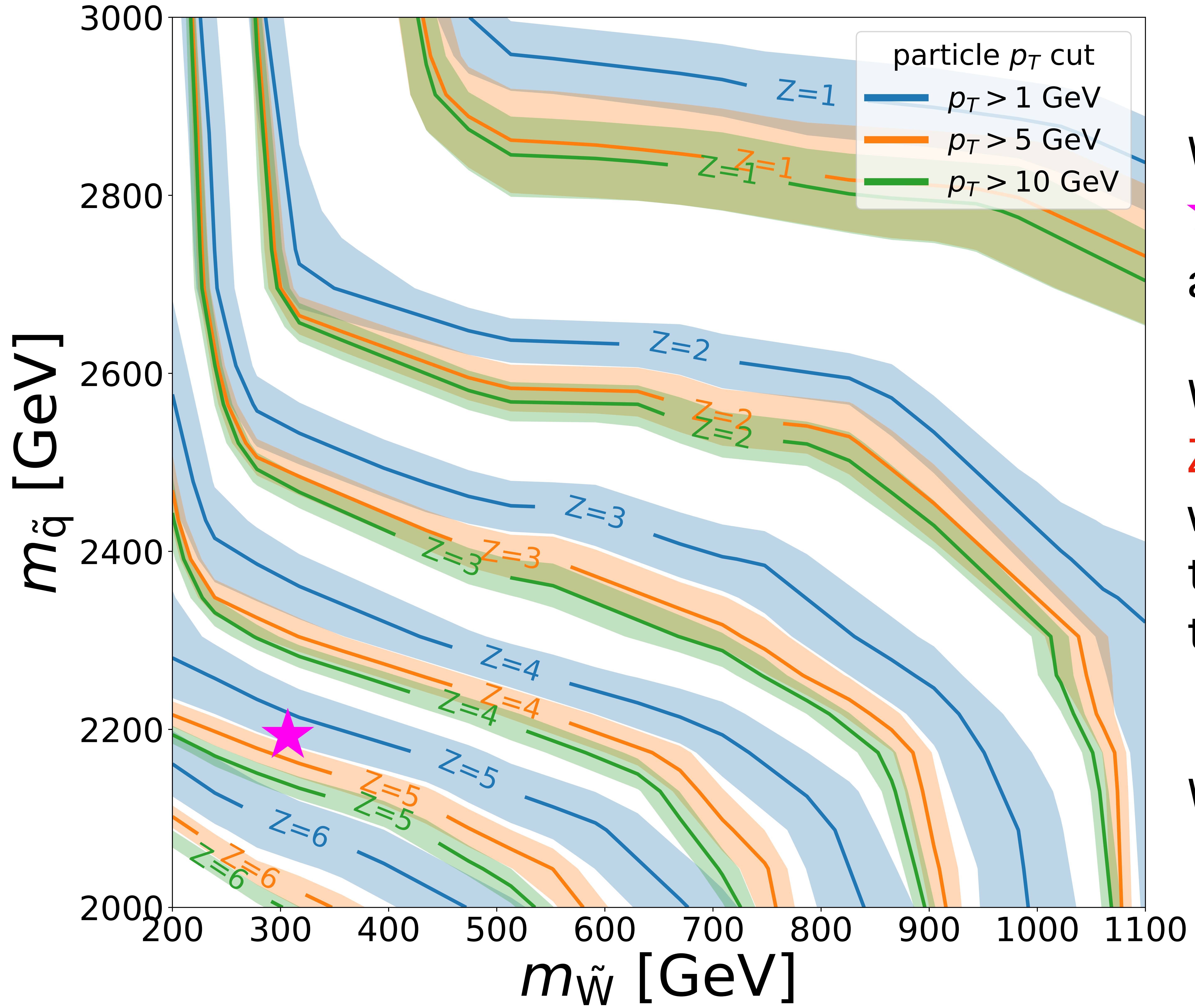
easier classification

particles' pT cut



Lower p_T cut
=>
better result but
larger uncertainty

HL-LHC limit for winos



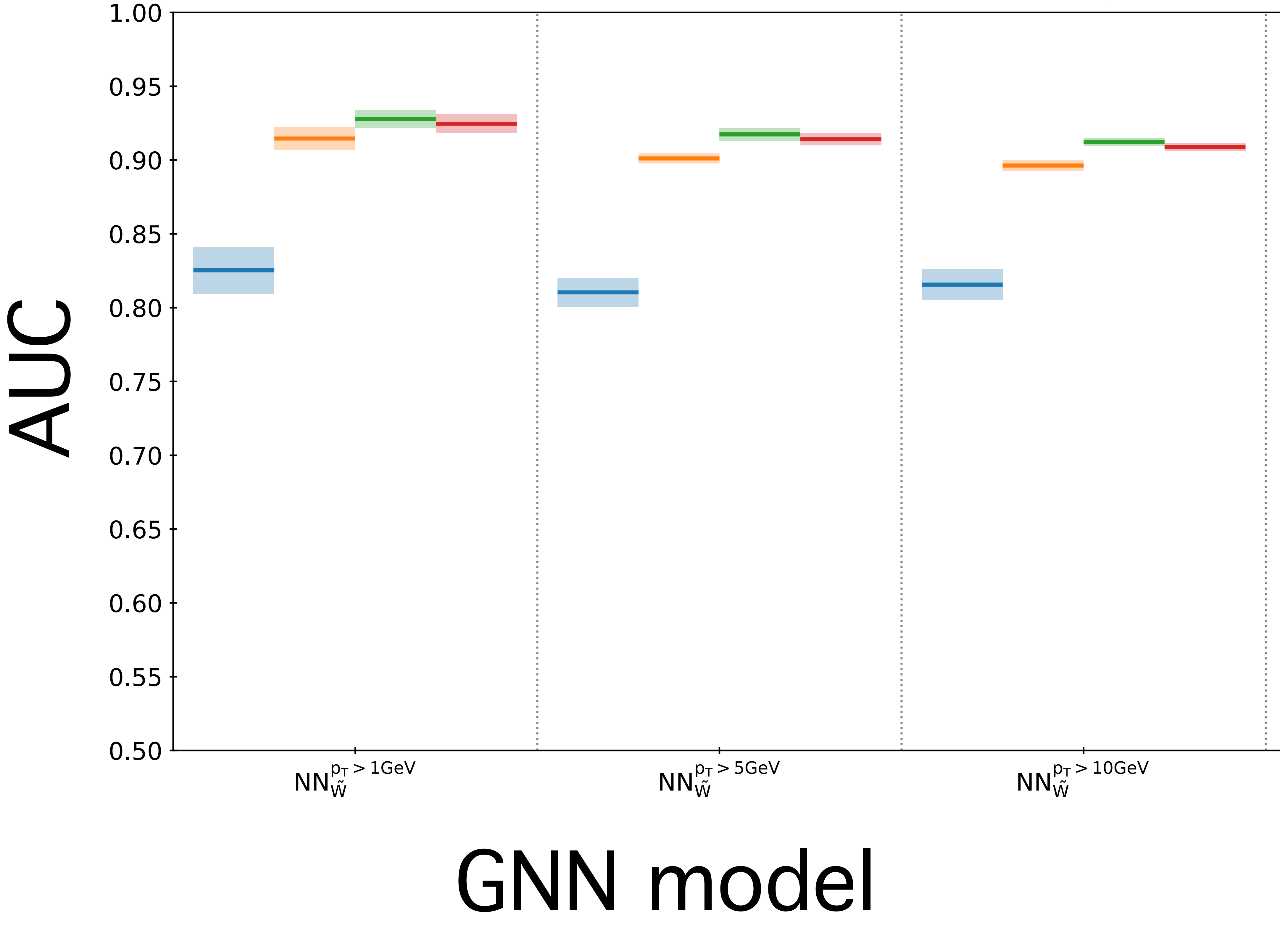
We train model on wino-like neutralino with ★ $m_{\tilde{W}} = 300$ GeV, $m_{\tilde{q}} = 2200$ GeV and evaluate it on multiple mass points.

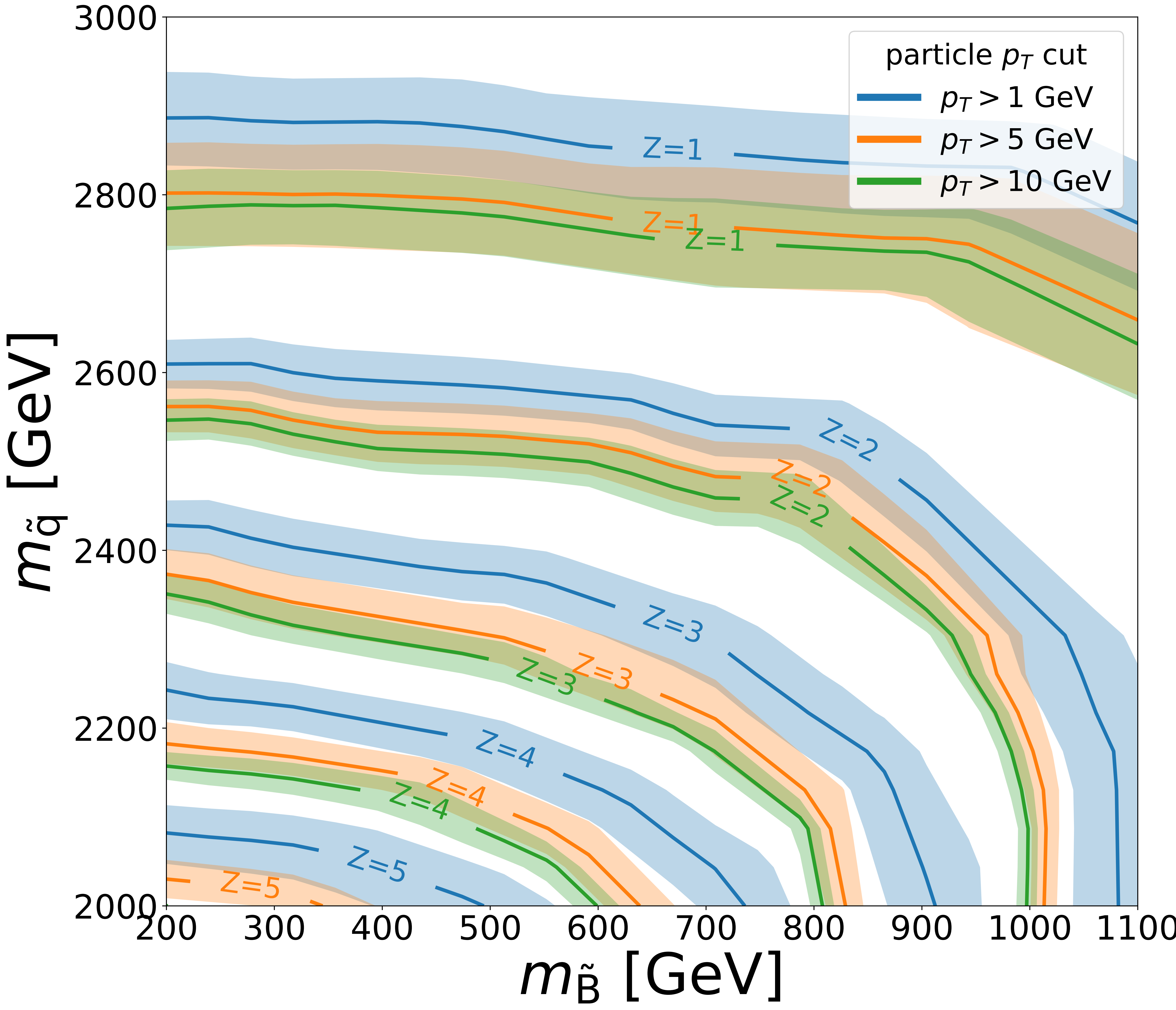
We calculate naive significance
Z=S/√(S+B),
which estimates statistical significance that we could get if GNN model was used to experimental data.

We do the same for higgsinos.

What about binos?

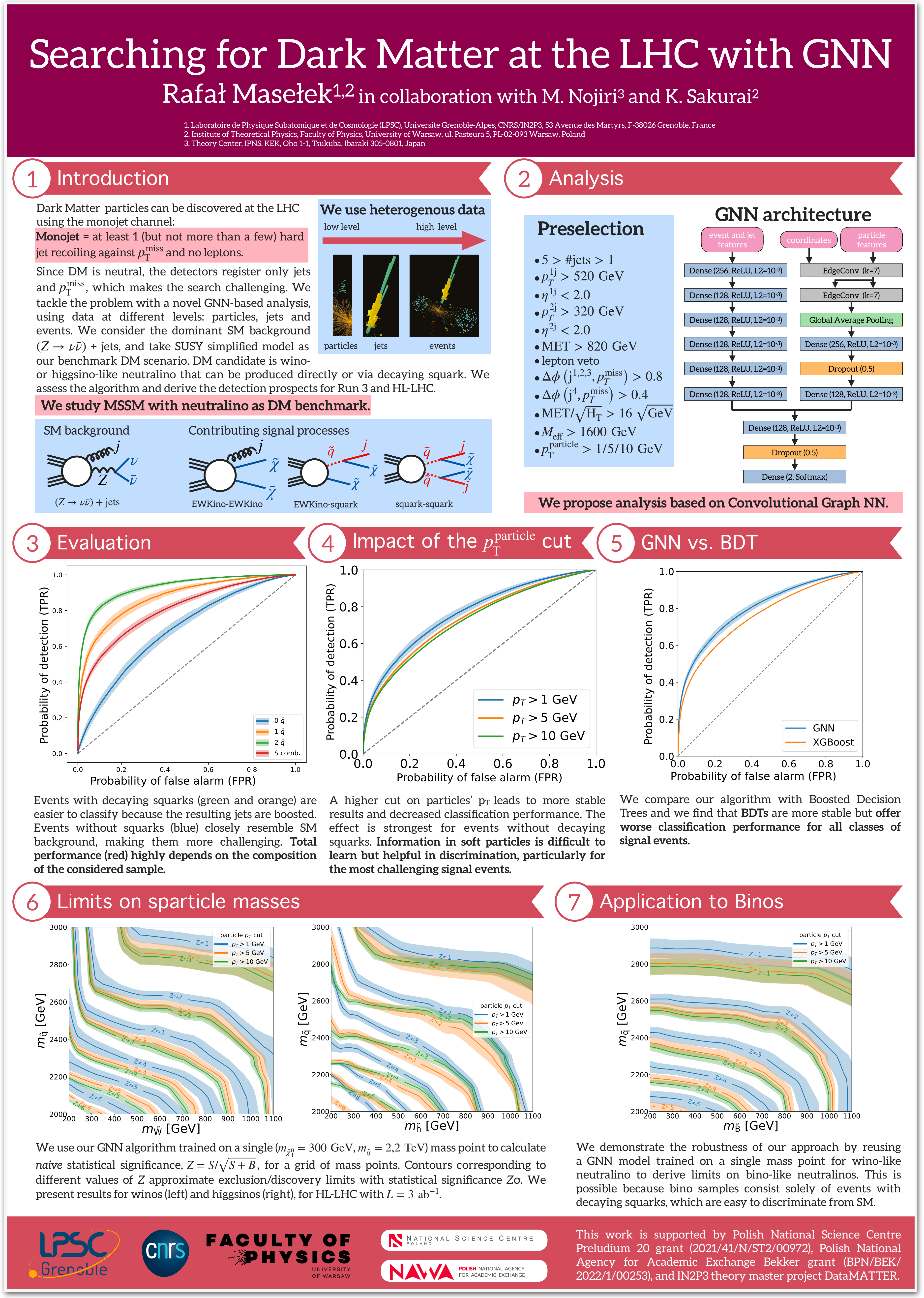
evaluated on $m_{\tilde{B}} = 300$ GeV, $m_{\tilde{q}} = 2200$ GeV





Summary

- Dark Matter can be searched @ LHC
- We introduce new analysis based on GNN
- SUSY as a benchmark model:
  - neutralino pair production
  - neutralino-squark associated production
  - squark-pair production
- We evaluate our model:
  - sample composition is crucial: the more squarks the easier classification
  - high robustness against a change of the neutralino type
  - high robustness against change of the masses of sparticles
- We derive limits on masses of new particles:
  - we train models for winos and higgsino
  - we derive limits on binos using model trained on winos
  - we derive Z=S/√(S+B) for Run-3 and HL-LHC



Thank you for attention!

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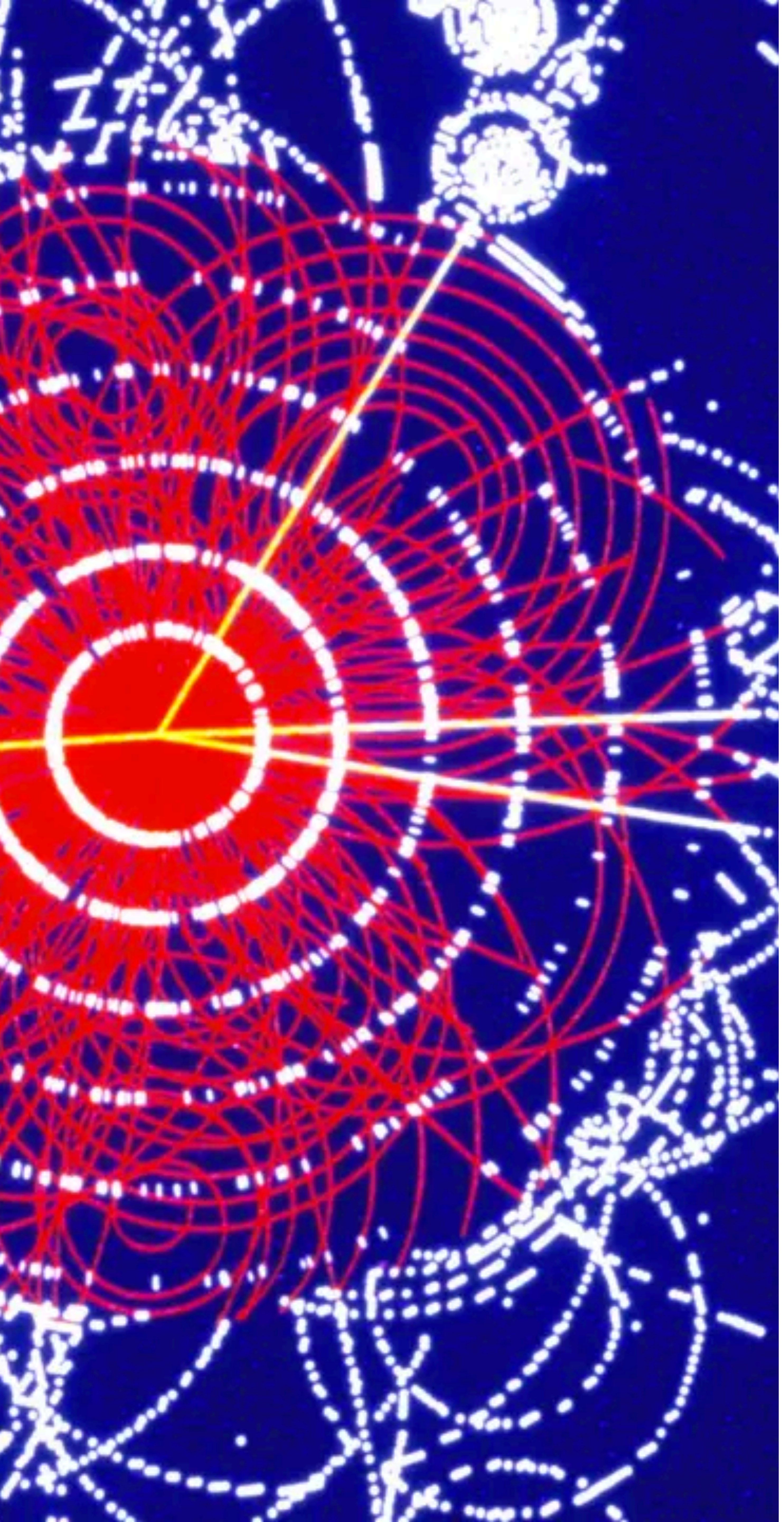
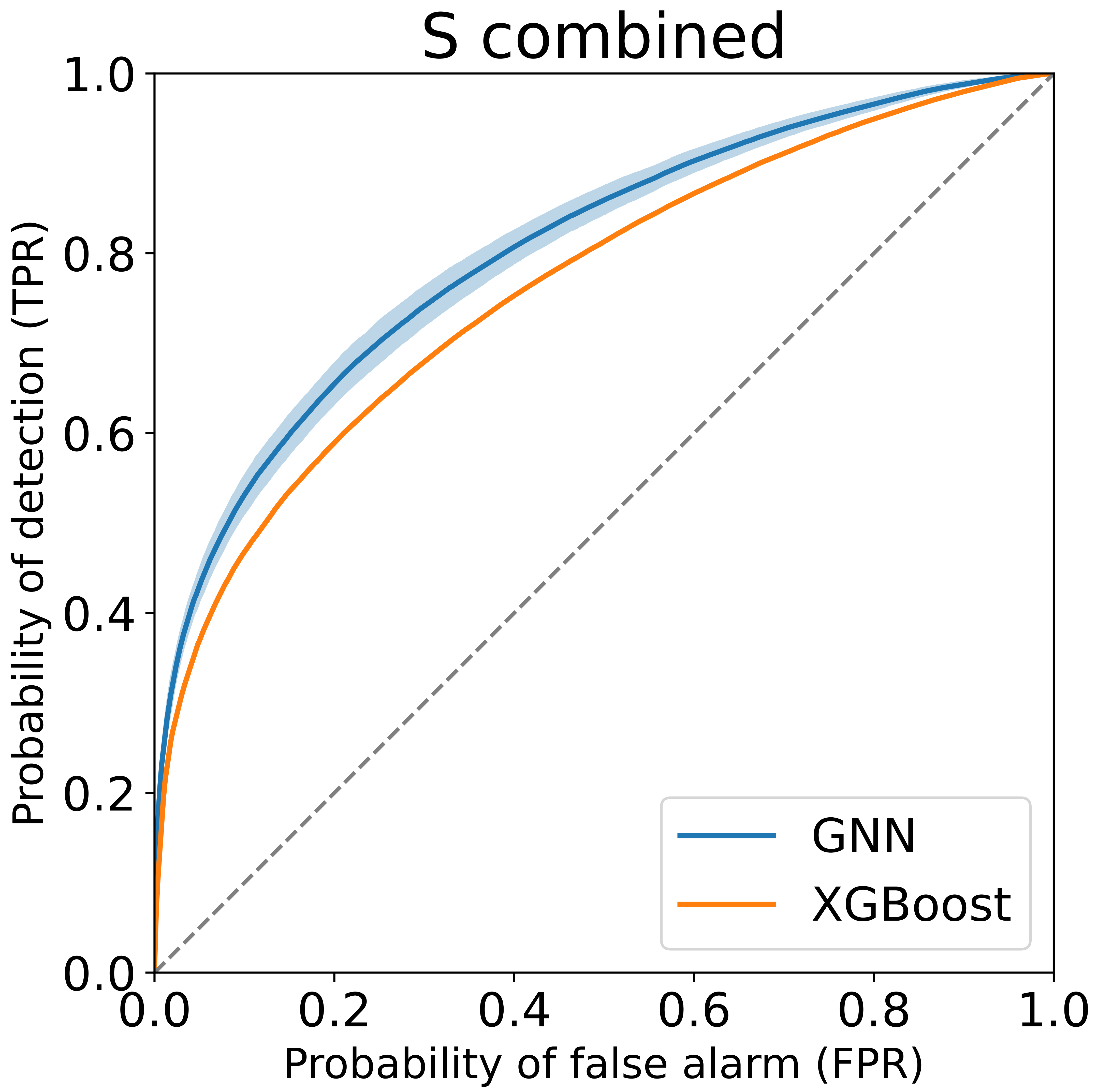
Dolina Chochołowska, Poland
photo by Piotr Kałuża



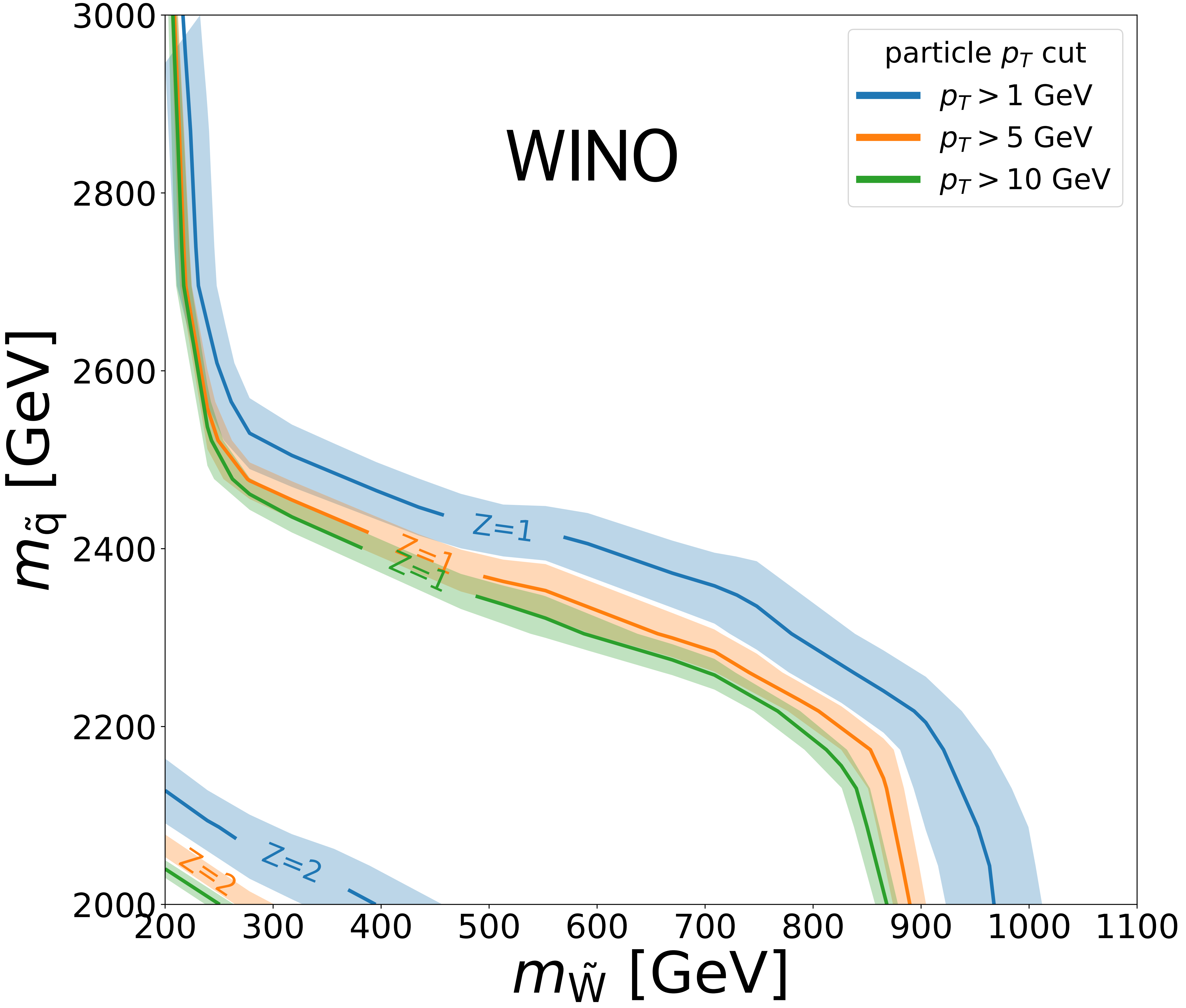
Backup slides

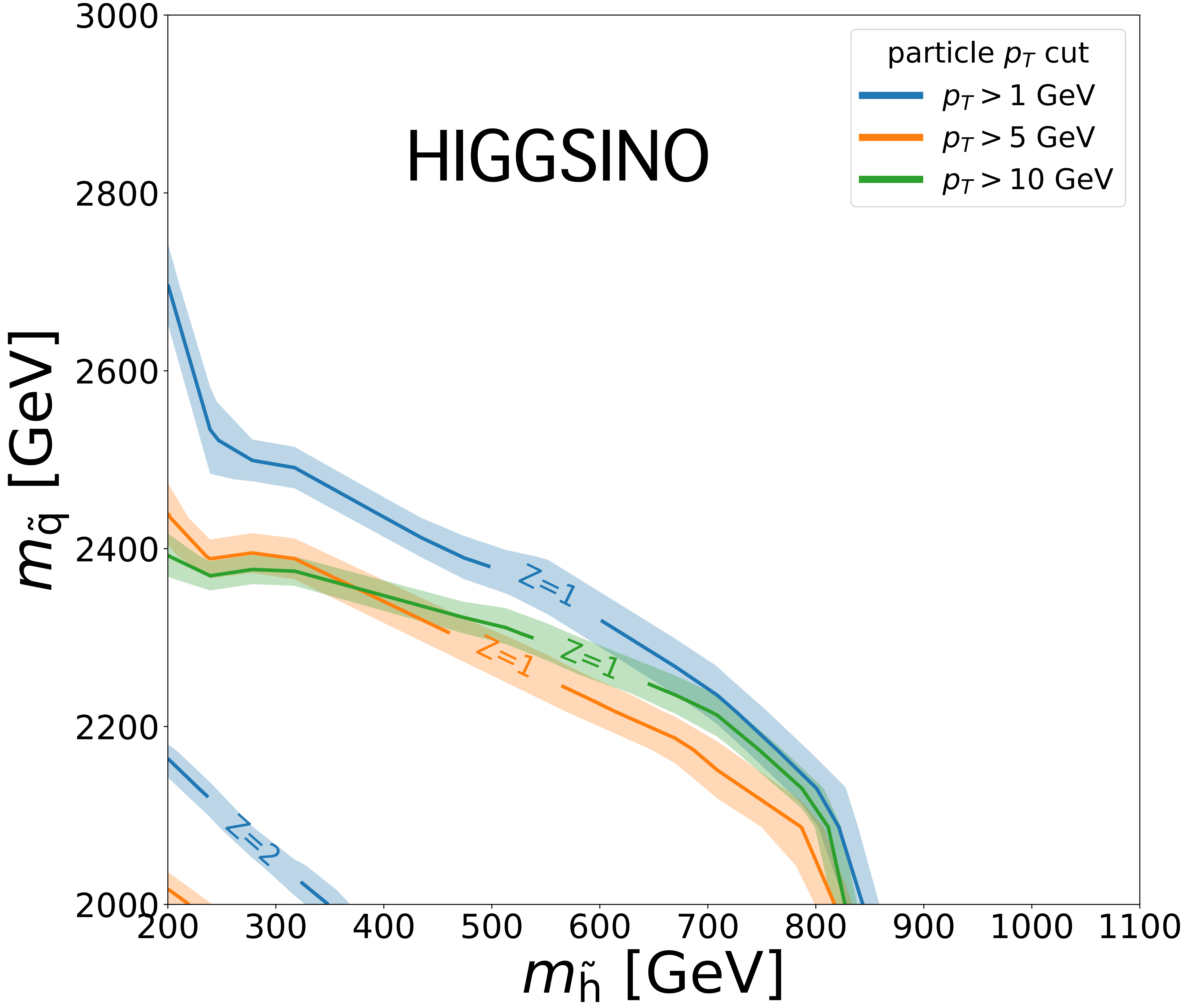
Rafał Masełek

GNN vs. BDT

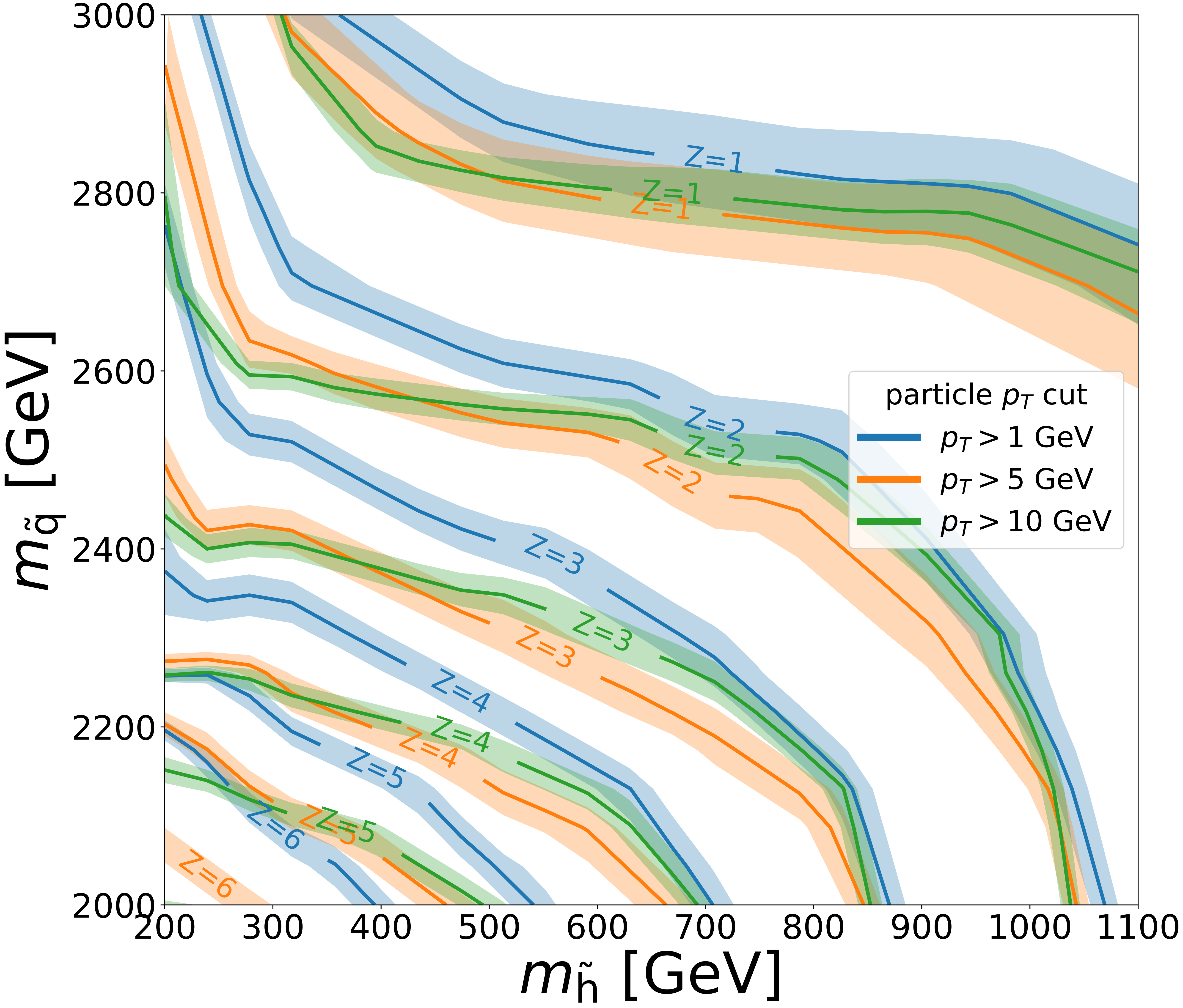

S combined
1.0
0.8
0.6
0.4
0.2
0.0
Probability of detection (TPR)
0.0
0.2
0.4
0.6
0.8
1.0
Probability of false alarm (FPR)
GNN
XGBoost

Limits for Run-3 LHC





Higgsino limits for HL-LHC



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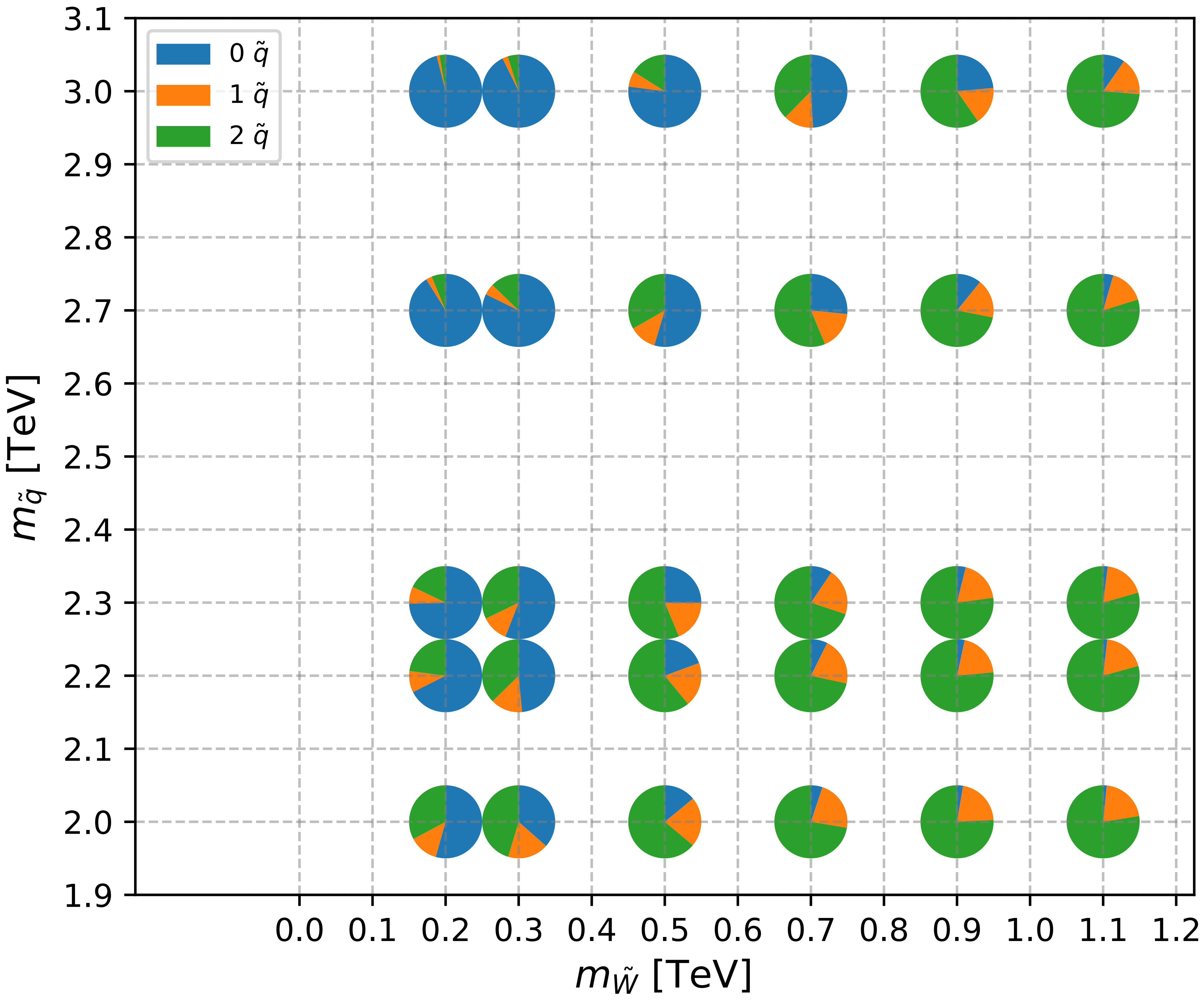
Sample composition

WINO



HIGGSINO