2025 EIC User Group Early Career Workshop

Affinity potentiality in EIC data exploration

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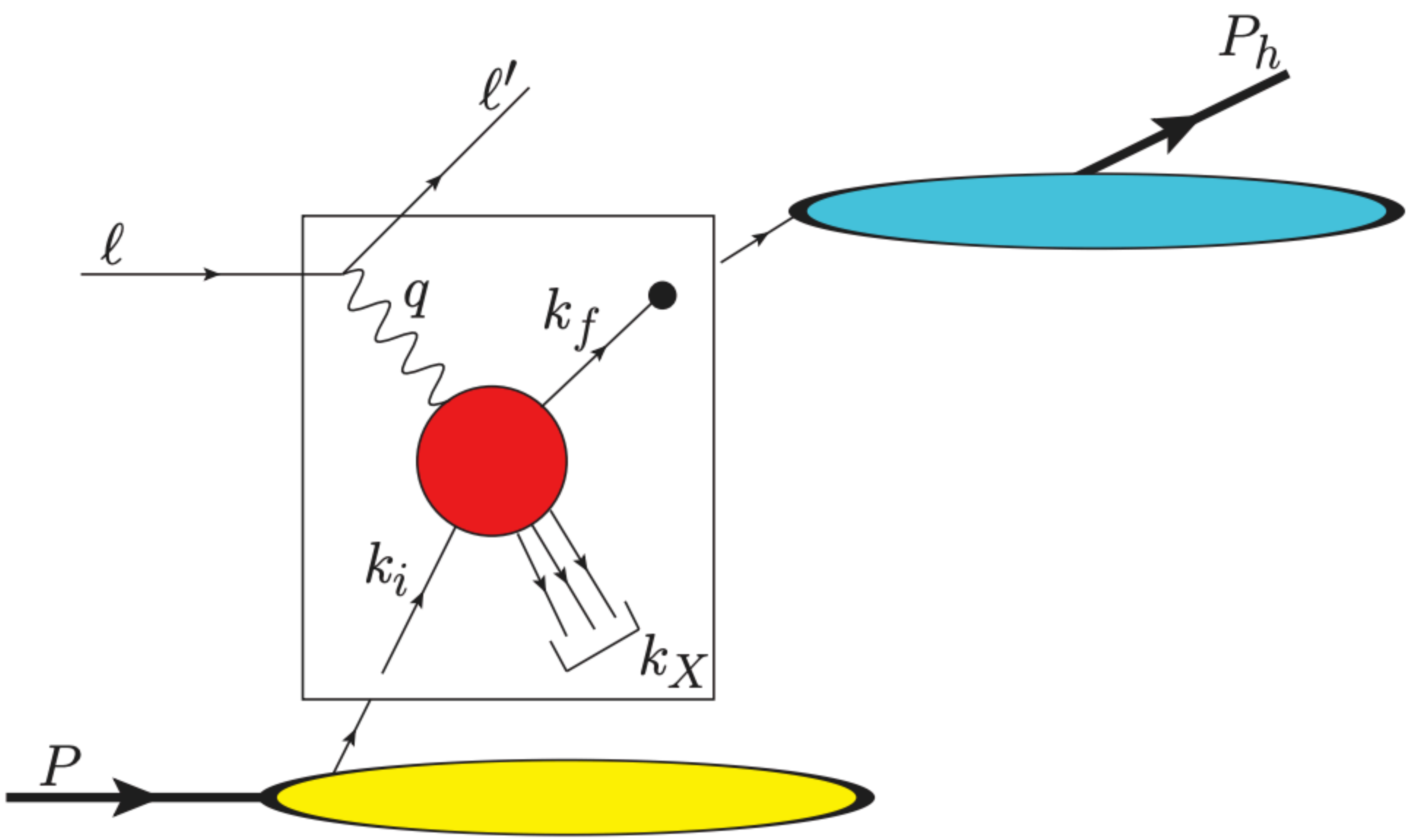
Sketch of SIDIS process



ℓ - incident lepton momentum

ℓ' - lepton momentum in final state

q - virtual photon

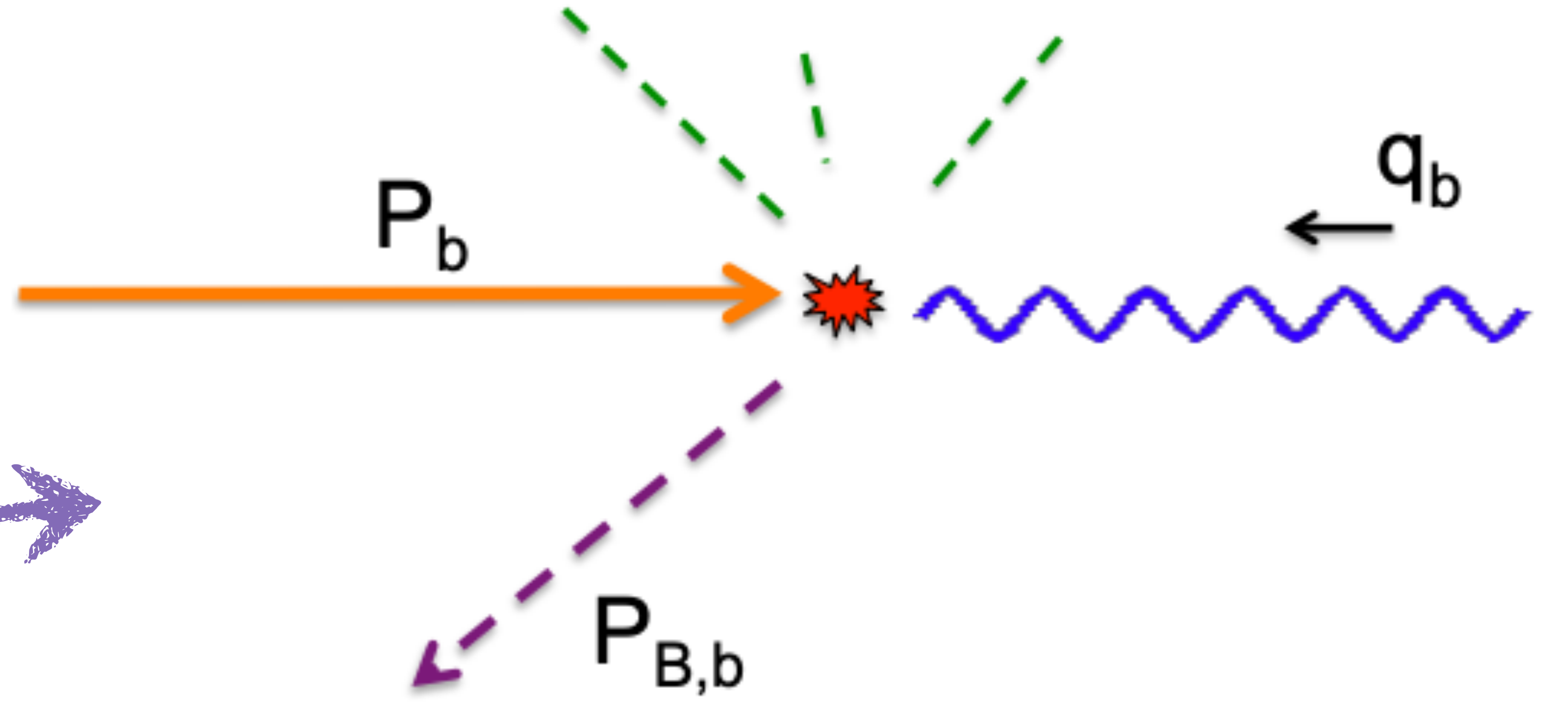
k_i - four-momentum of incoming quark

P - momenta of hadron in the initial state

k_f - four-momentum of outgoing quark

P_h - momenta of hadron in the final state

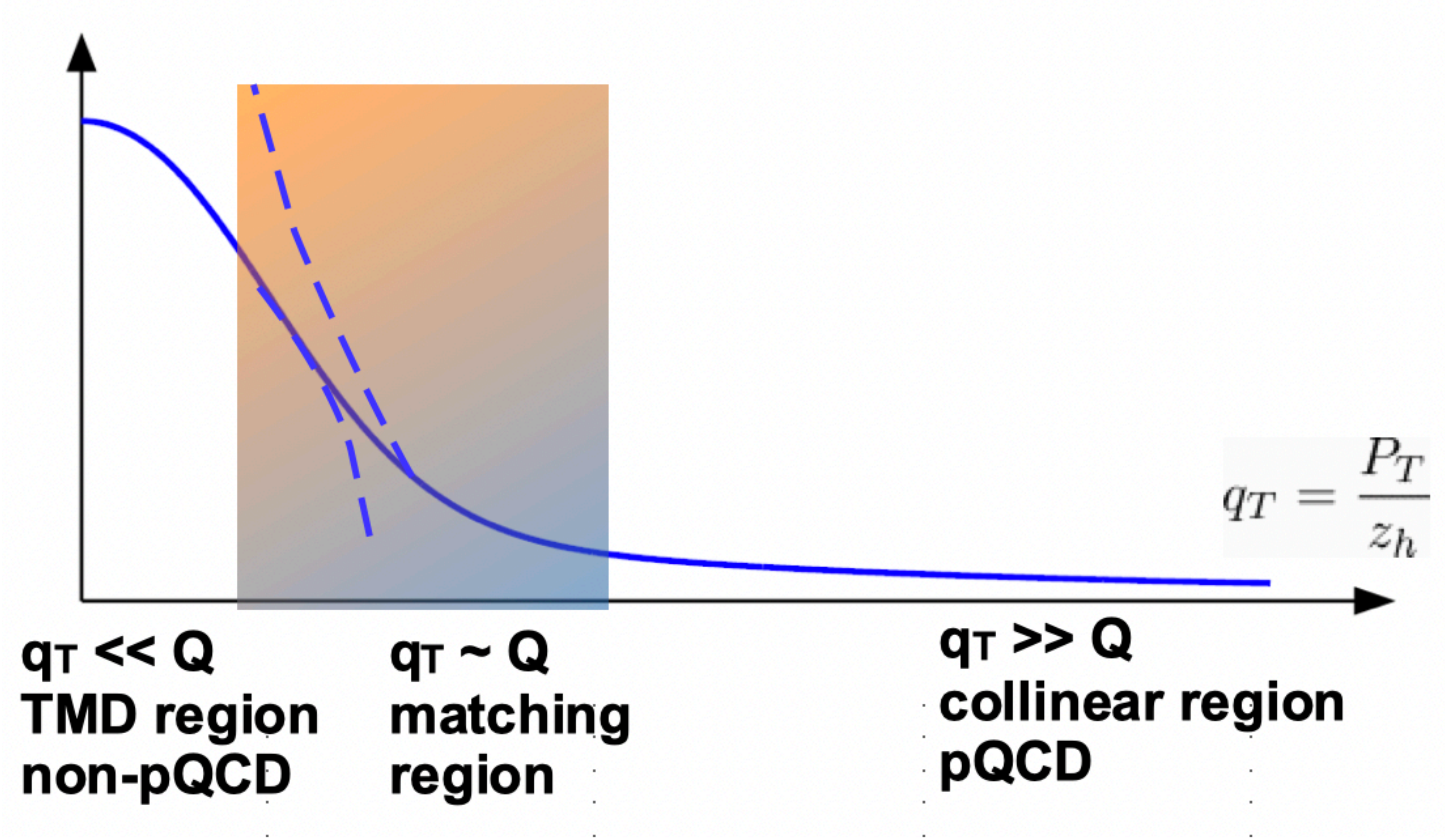
k_X - unmeasured hadronic debris



The configuration of the proton, photon, and outgoing hadron in the Breit photon frame

https://arxiv.org/pdf/1904.12882

Distribution of SIDIS cross section according to q_T values



Affinity

https://arxiv.org/pdf/2201.12197

$$\mathcal{A}(x_{\rm Bj}, z_h, Q^2, P_{hT}\,|\,\text{region}) = \int \mathrm{d}\{R_i\}\Theta(\{R_i\}\,|\,\text{region}) \int \mathrm{d}^4k_i \mathrm{d}^4k_f \mathrm{d}^4\delta k_T$$

$$\times\, \mathcal{P}(\{R_i\}\,|\,x_{Bj}, Q^2, z_h, P_{hT}; k_i, k_f, \delta k_T)\pi(k_i, k_f, \delta k_T)$$

Region indicators

$$R_0 \equiv \max\left(\left|\frac{k_i^2}{Q^2}\right|, \left|\frac{k_f^2}{Q^2}\right|, \left|\frac{\delta k_T^2}{Q^2}\right|\right)$$

$$R_1 \equiv \frac{P_h \cdot k_f}{P_h \cdot k_i}$$

$$R_2 \equiv \frac{|k^2|}{Q^2}$$

$(k_X = k_i + q - k_f)$

$$R_3 \equiv \frac{|k_X^2|}{Q^2}$$

$$R_4 \equiv \max\left(\left|\frac{k_i^2}{k^2}\right|, \left|\frac{k_f^2}{k^2}\right|, \left|\frac{\delta k_T^2}{k^2}\right|, \left|\frac{k_{iT}^2}{k^2}\right|\right)$$

https://arxiv.org/pdf/2201.12197

R_i definitions

$$R_0 = \max\left(\left|\frac{k_i^2}{Q^2}\right|, \left|\frac{k_f^2}{Q^2}\right|, \left|\frac{\delta k_T^2}{Q^2}\right|\right)$$

→ R_0 - General Hardness Ratio

If R_0 is small, we can apply factorization theorems

$$R_1 = \frac{P_h \cdot k_f}{P_h \cdot k_i}$$

→ R_1 - Collinearity

If scattering is assumed to be in the current region, R_1 should be small

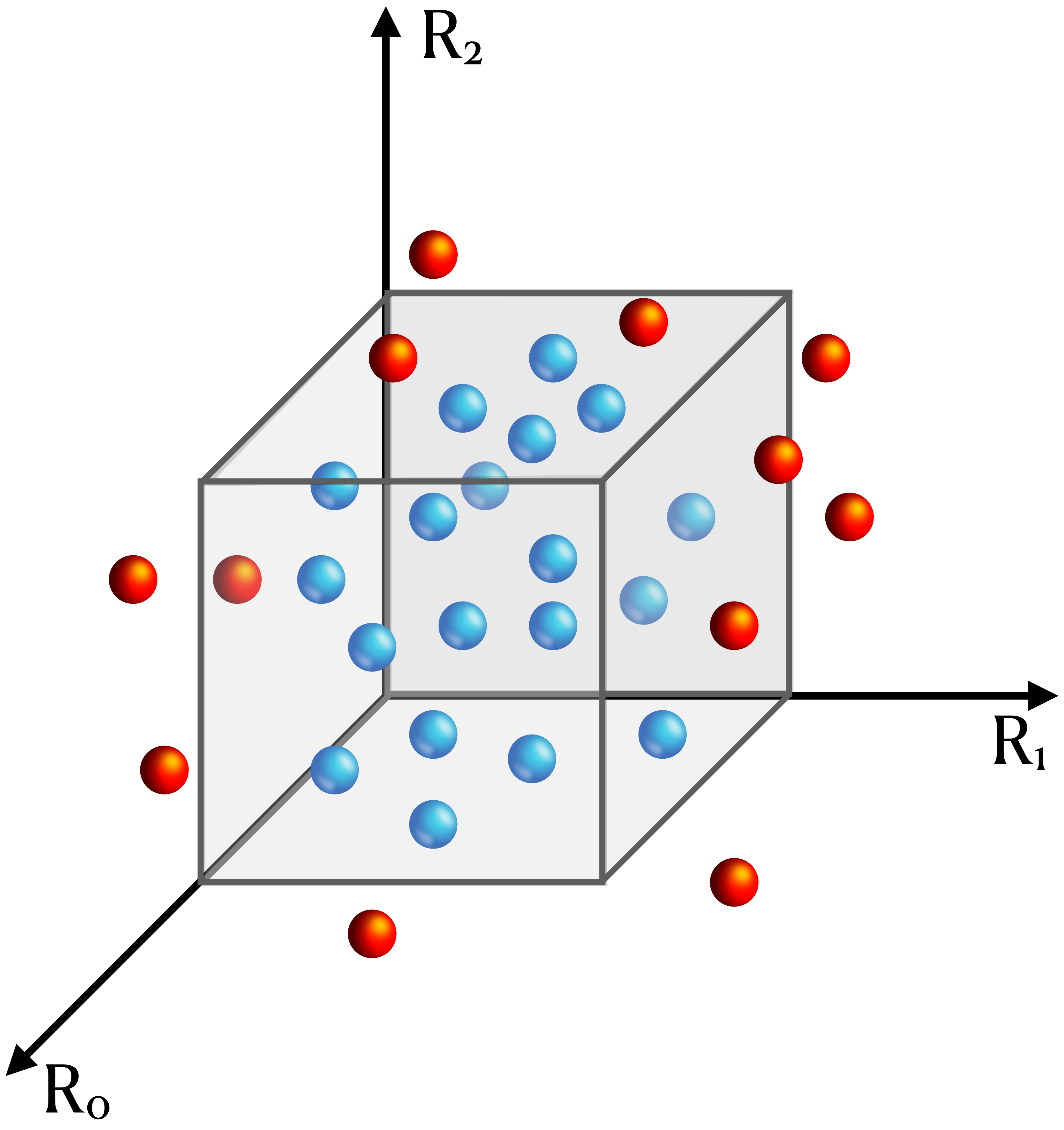
$$R_2 = \frac{|k^2|}{Q^2}$$

→ R_2 - Transverse Hardness Ratio

It shows us if we are in TMD region or not

$$k = k_f - q \qquad k_X = k_i + q - k_f$$

Affinity visualisation

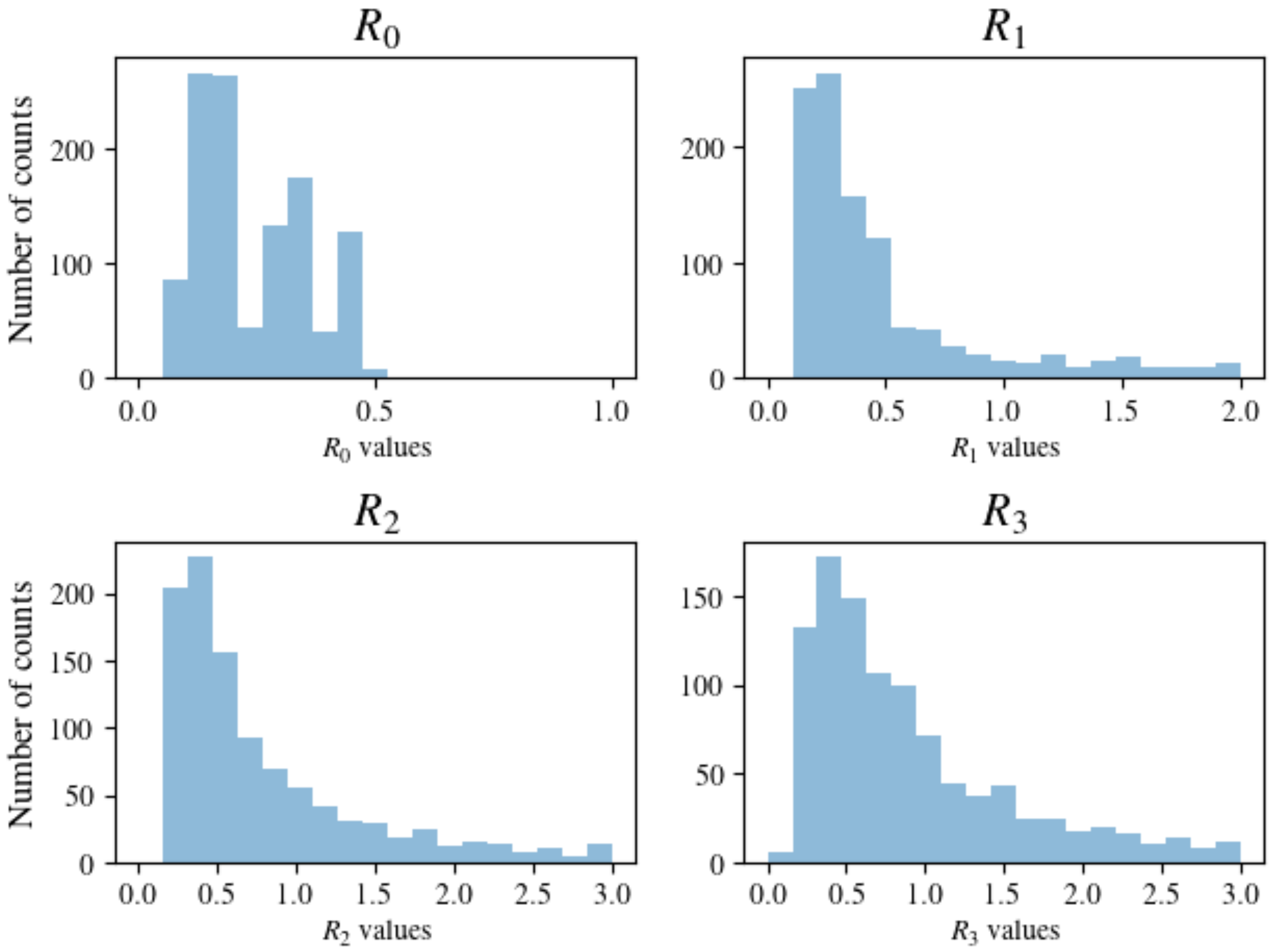


$$\text{Affinity} = \frac{\#\text{times in}}{\#\text{times in} + \#\text{times out}}$$

Affinity ranges from 0% to 100% *(or from 0 to 1)* and indicates affinity of a bin of a measurement to a particular kinematic region.

Region indicators value

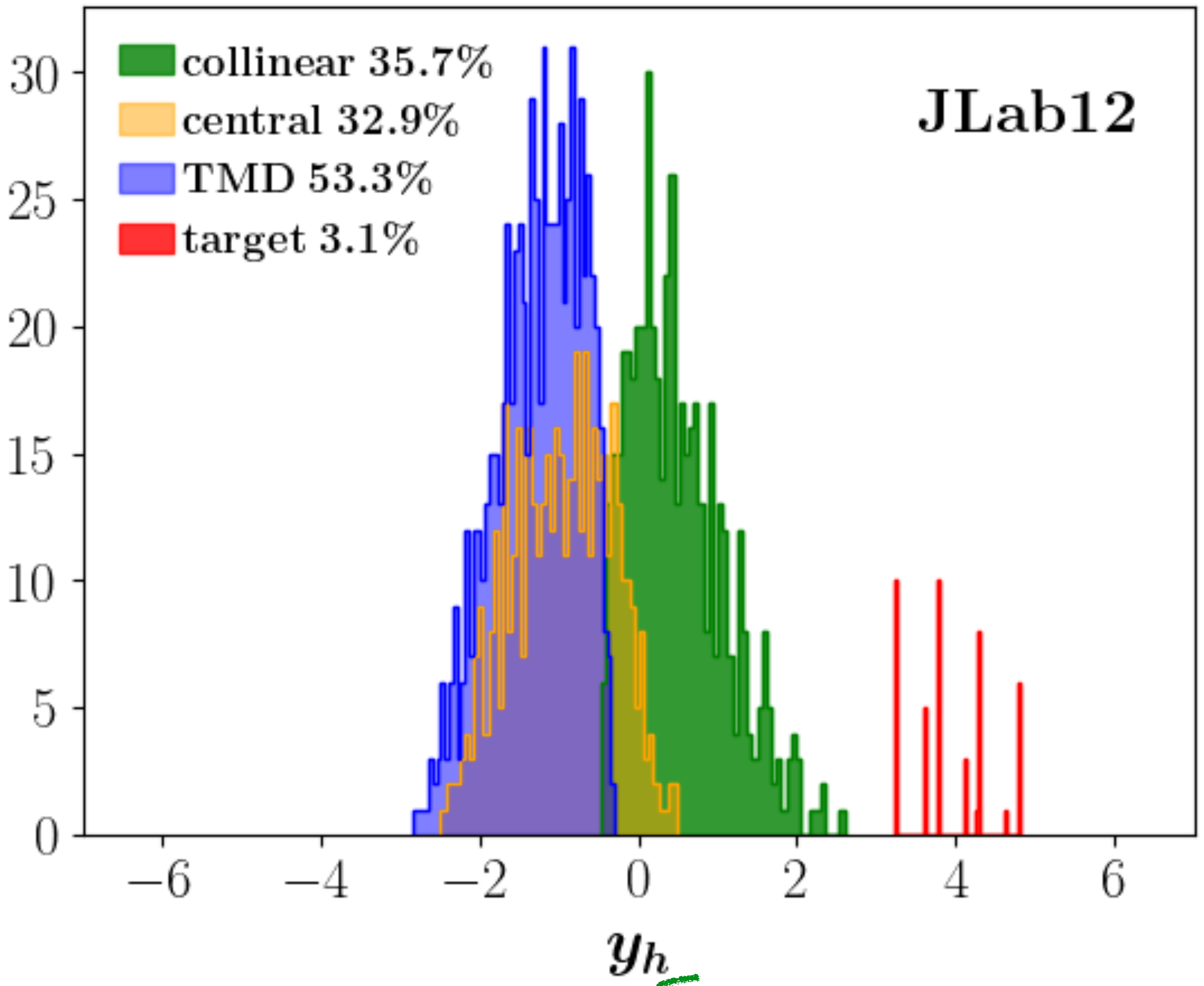
Region	R_0 *(General Hardness Ratio)*	R_1 *(Collinearity)*	R_2 *(Transverse Hardness Ratio)*
TMD	Small	Small	Small
Collinear	Small	Small	Large

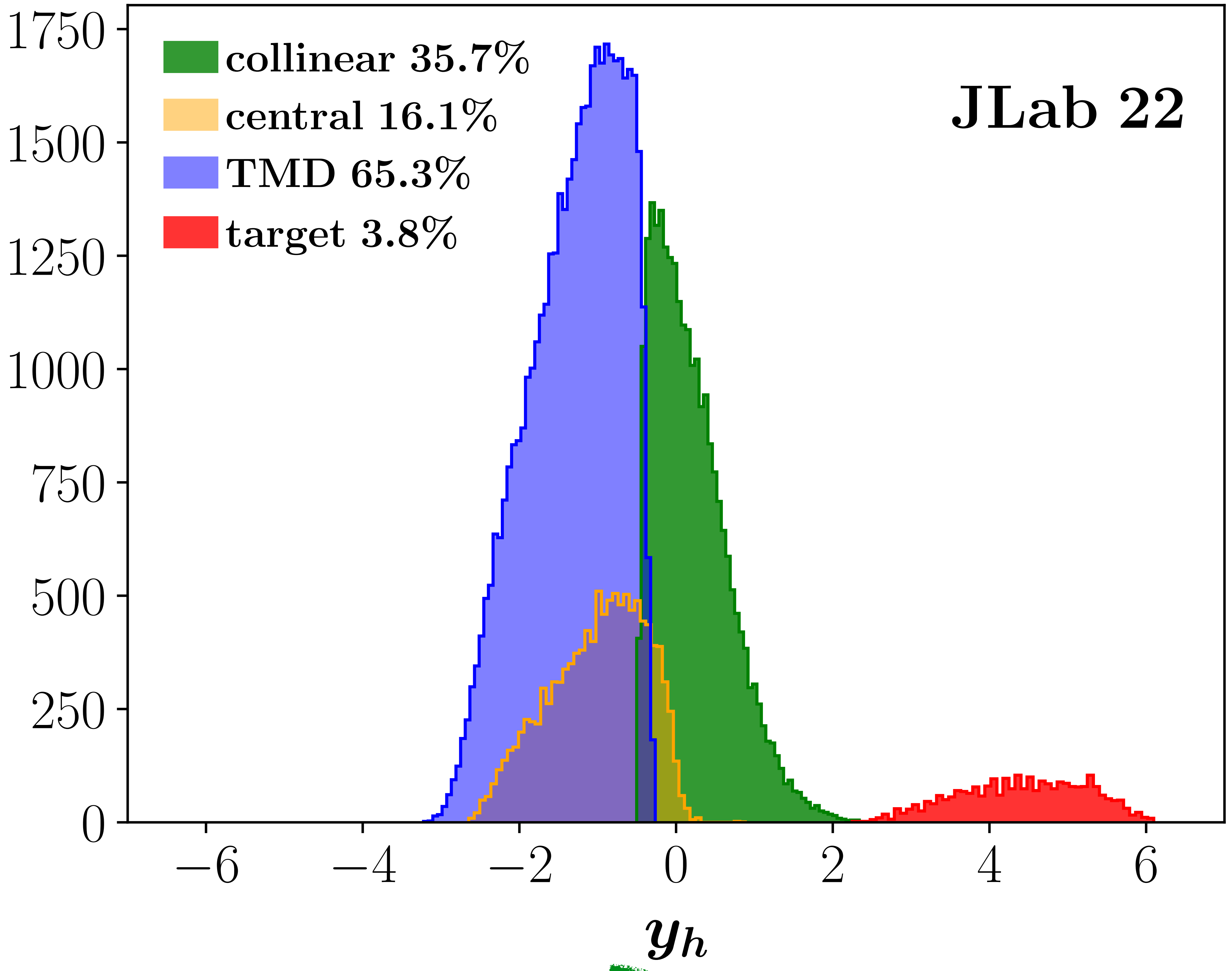


Kinematics

MC generated data were provided by Anselm Vossen, Rowan Keller and Matthew McEneaney

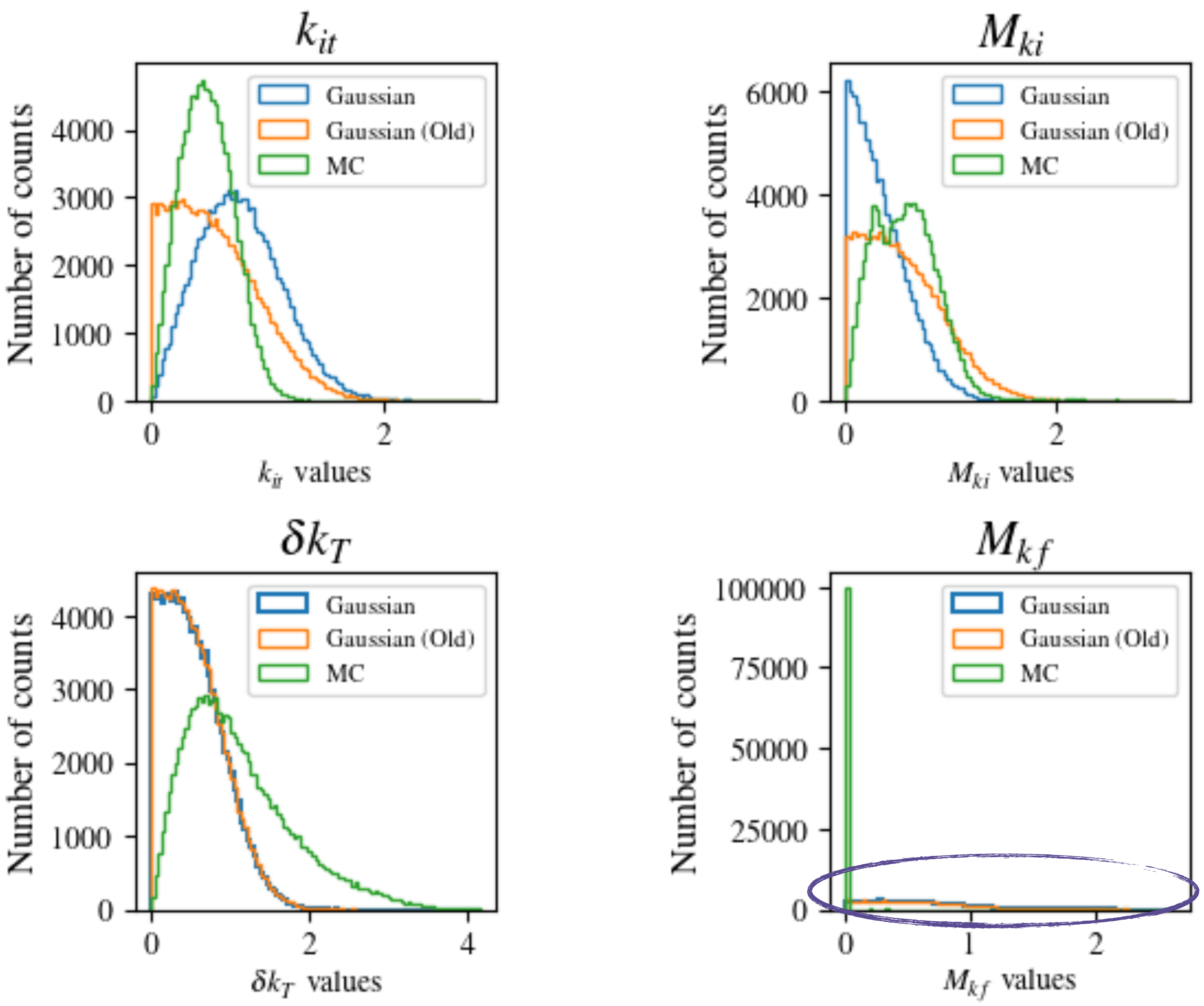
Phase space of produced hadrons





$$y_h = \frac{1}{2} \log \left(\frac{P_h^+}{P_h^-} \right)$$

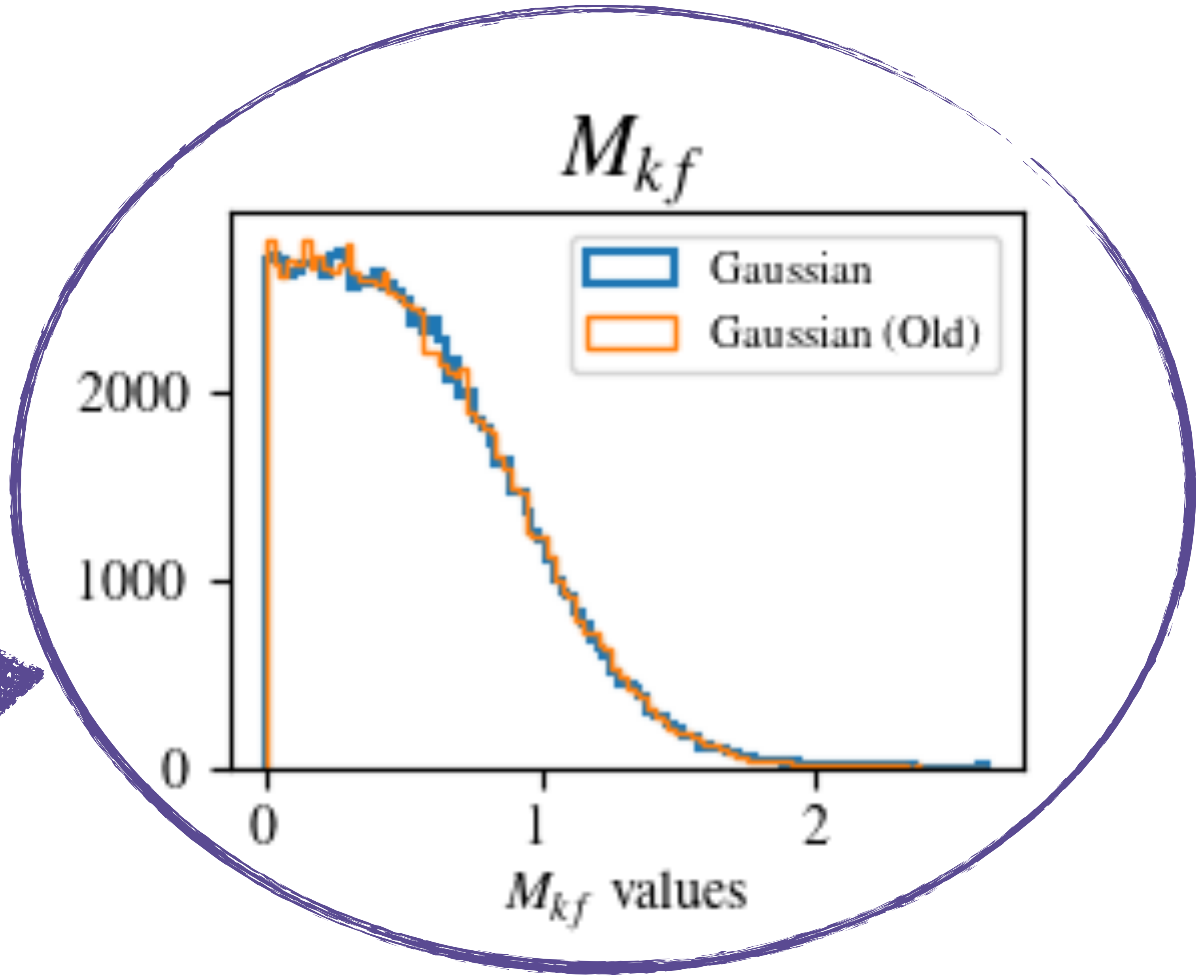
Changing of methodology



Non-perturbative variables:

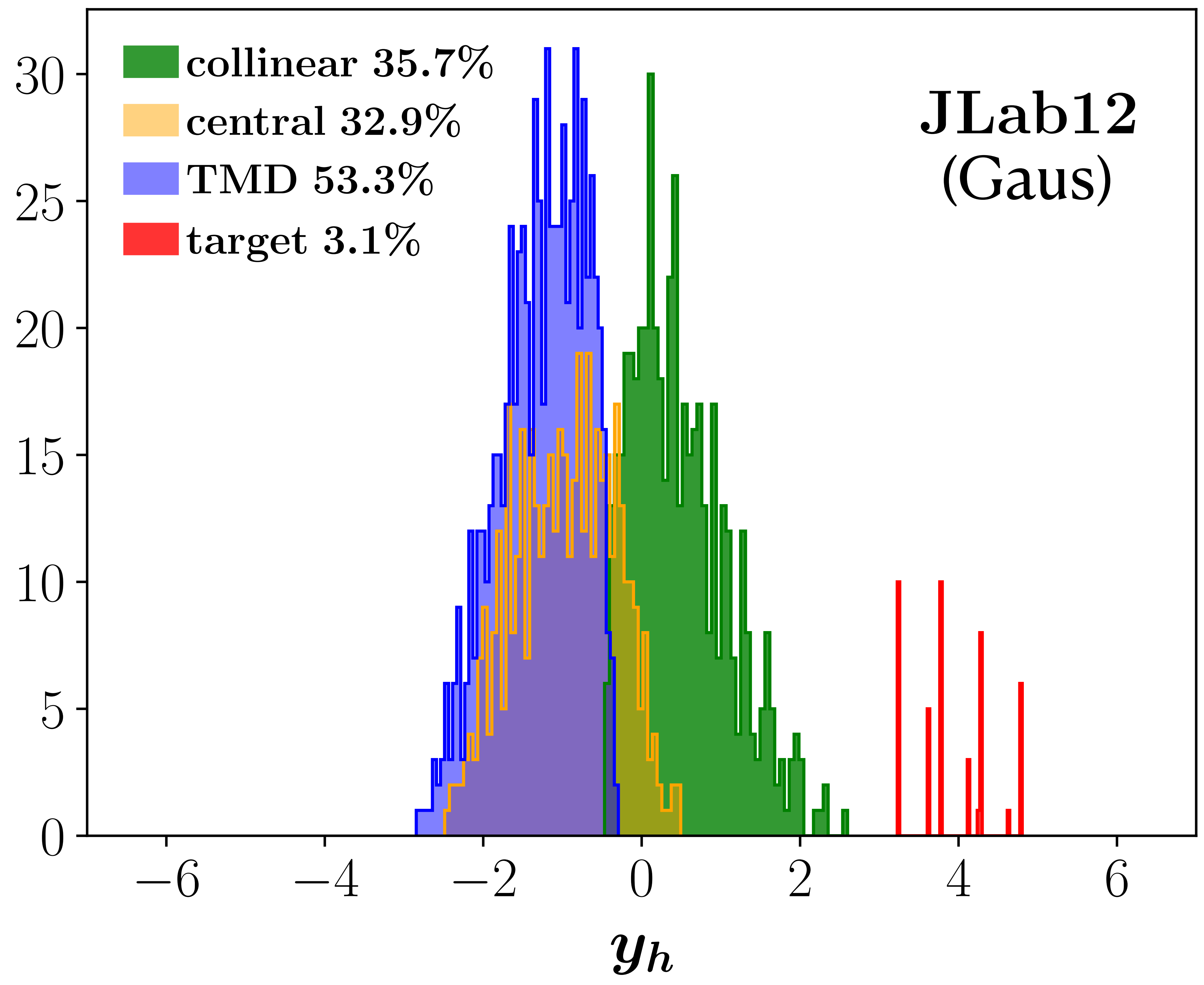
blue and orange - follow Gaussian distributions;

green - are event-by-event from MC generation

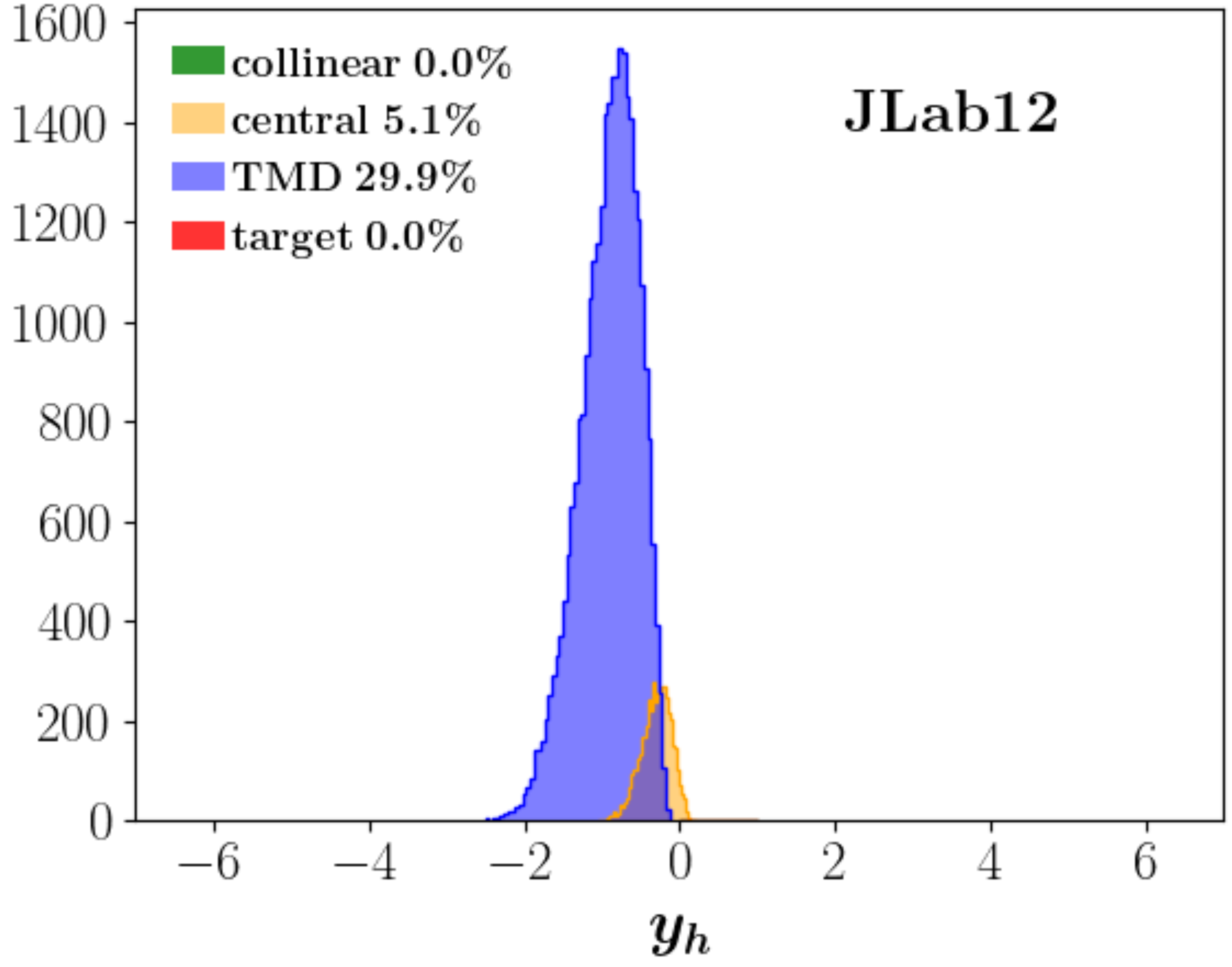


JLab12

Rapidity phase space for different methods

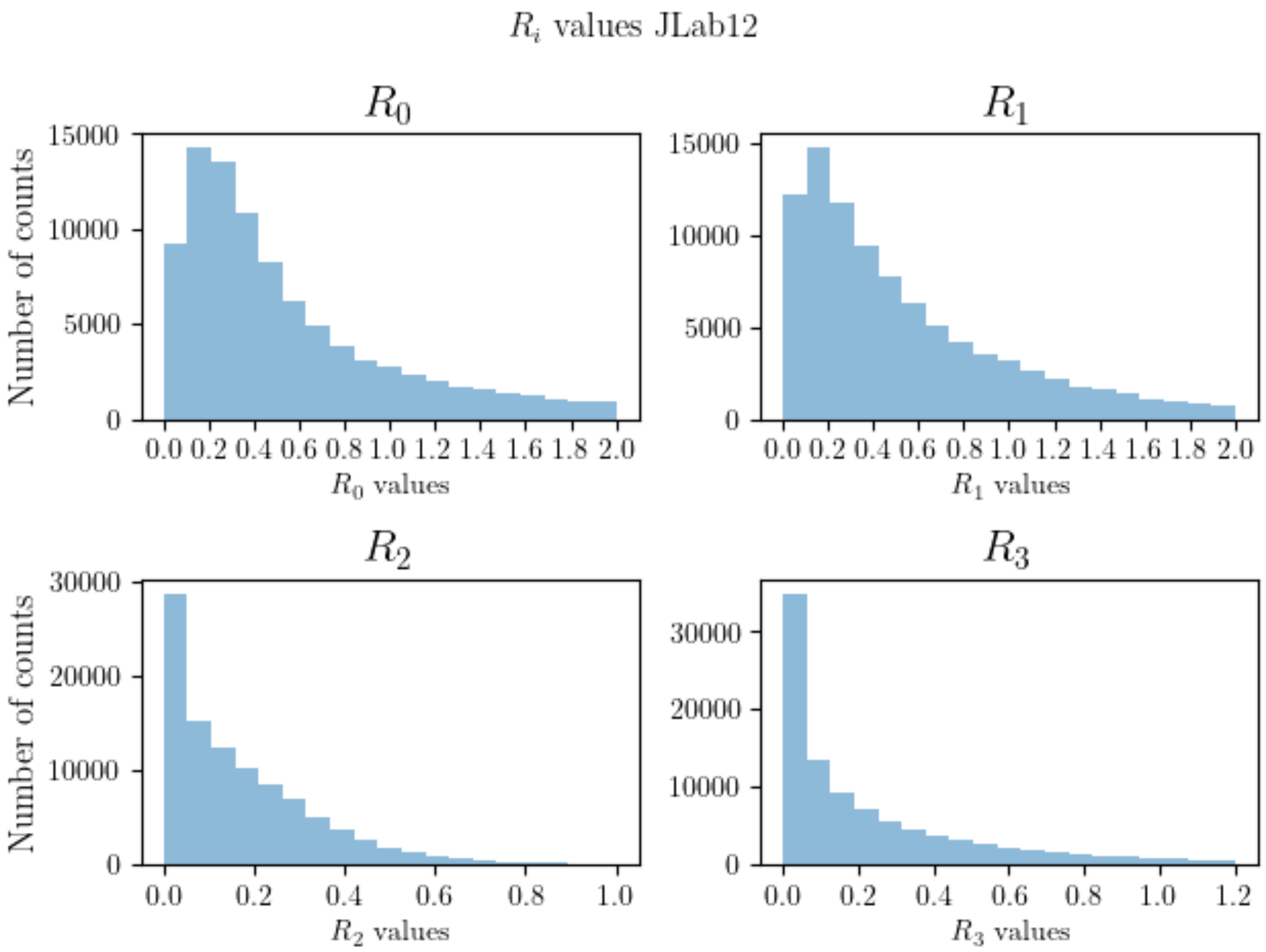


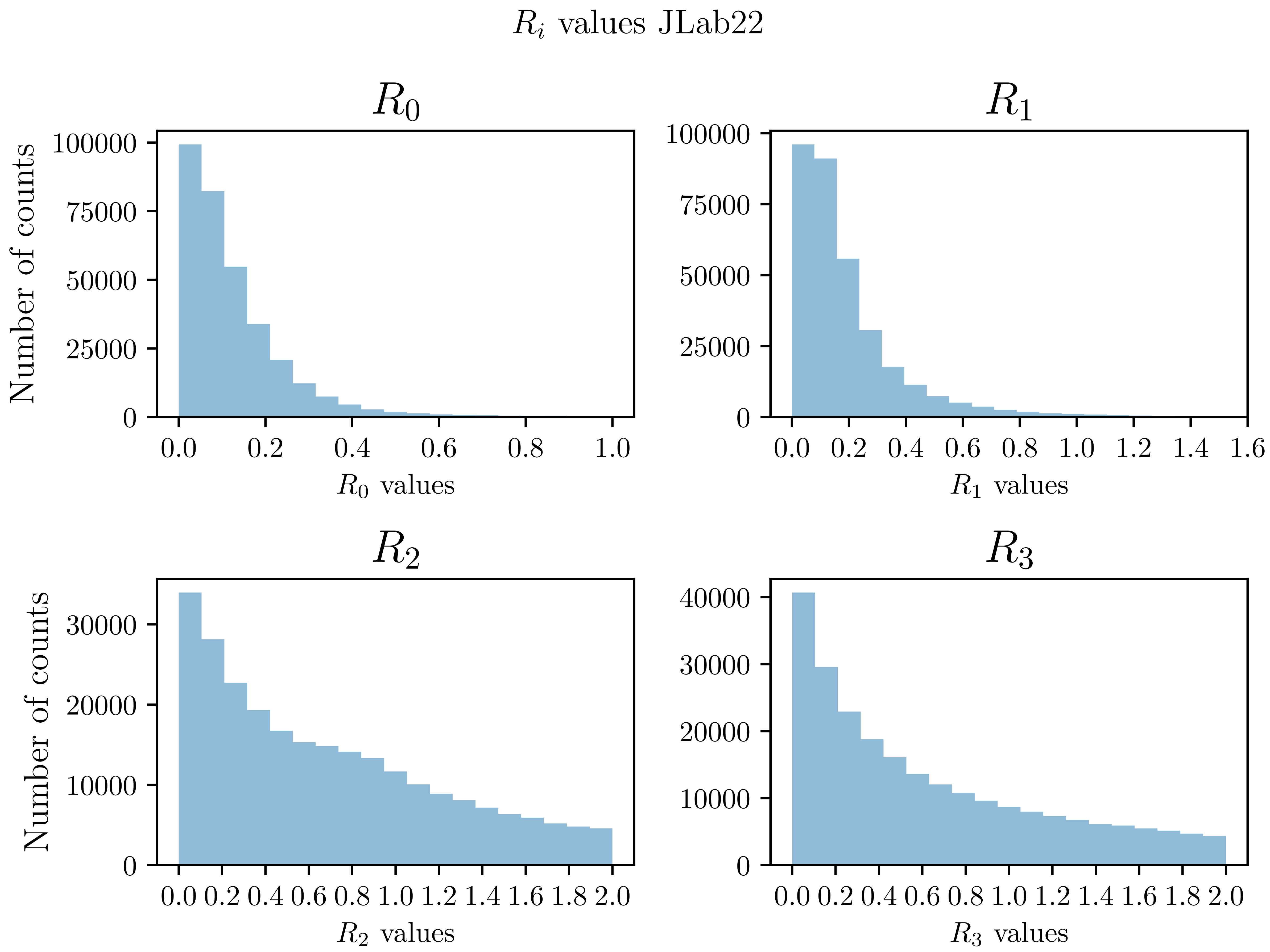
Based on Gaussian distributions



Based on MC generation

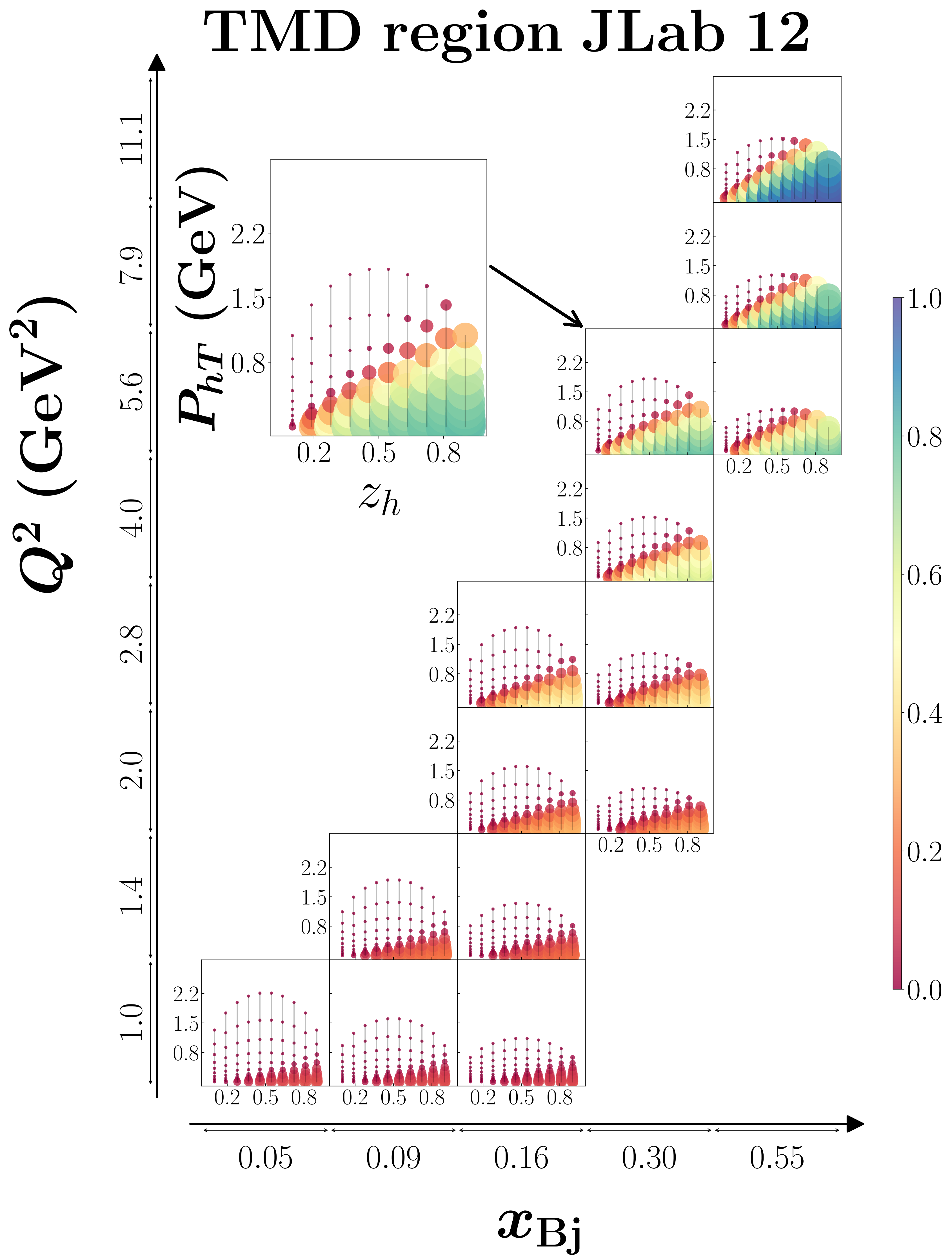
Event-by-event calculation

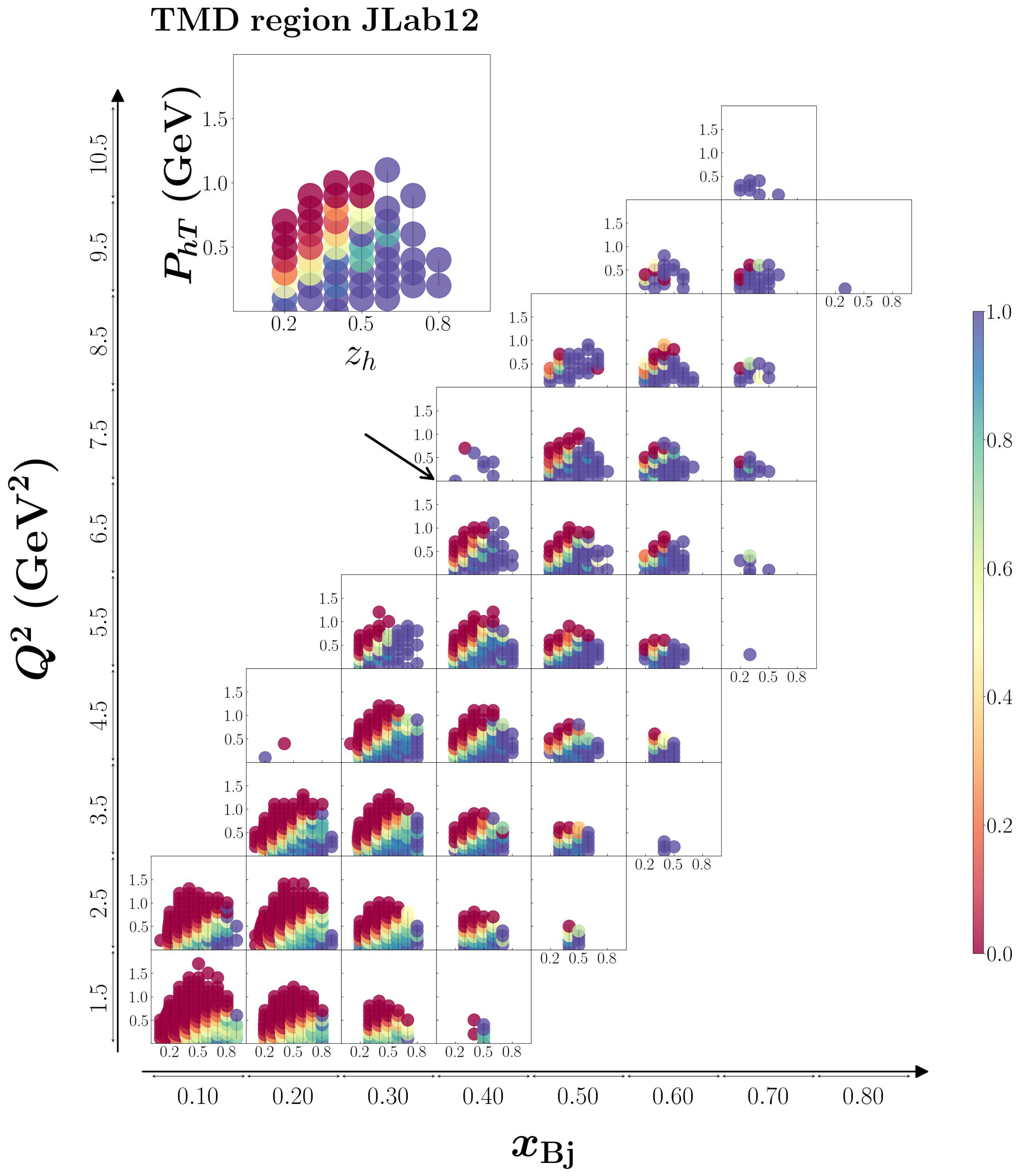


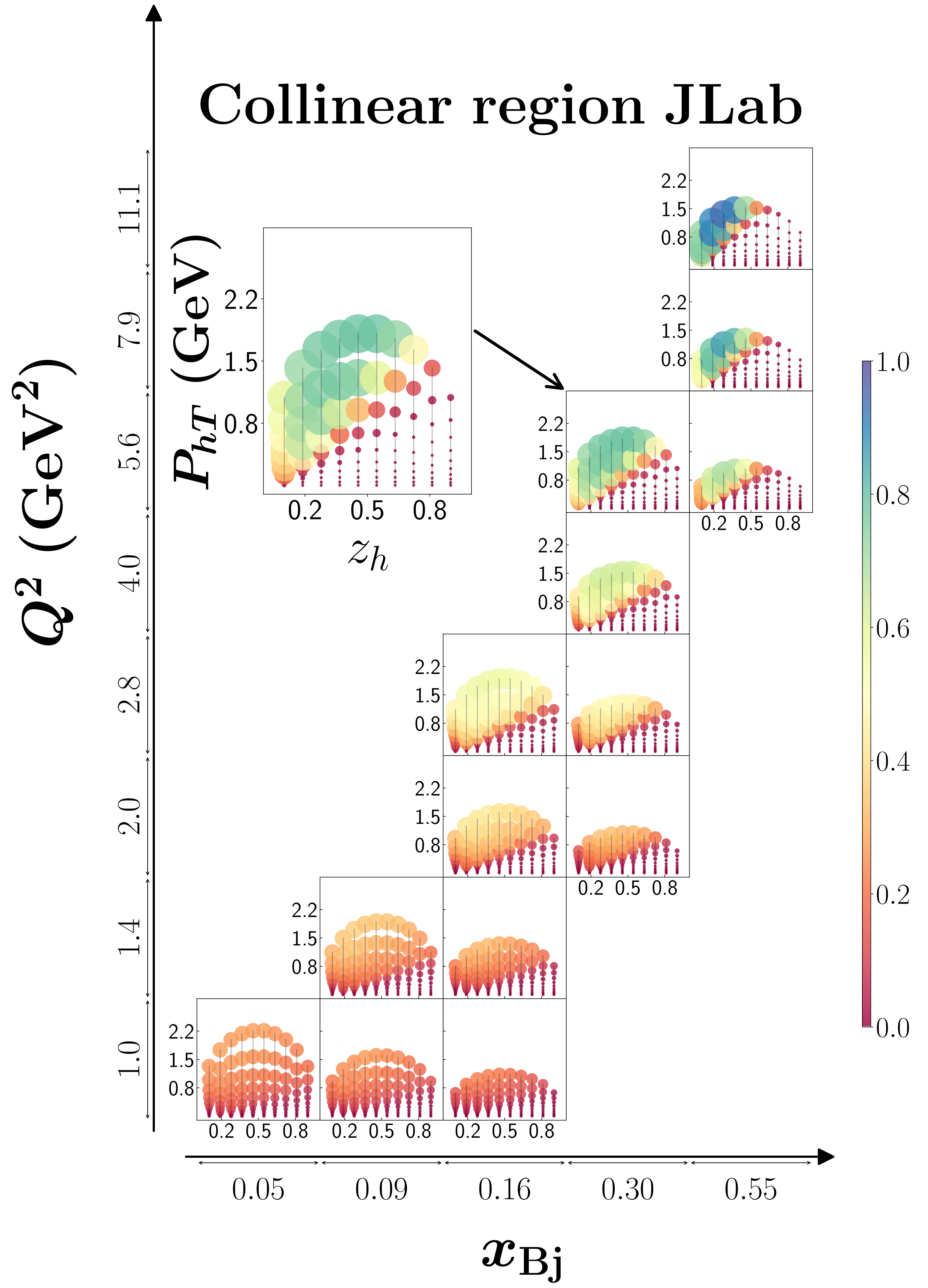


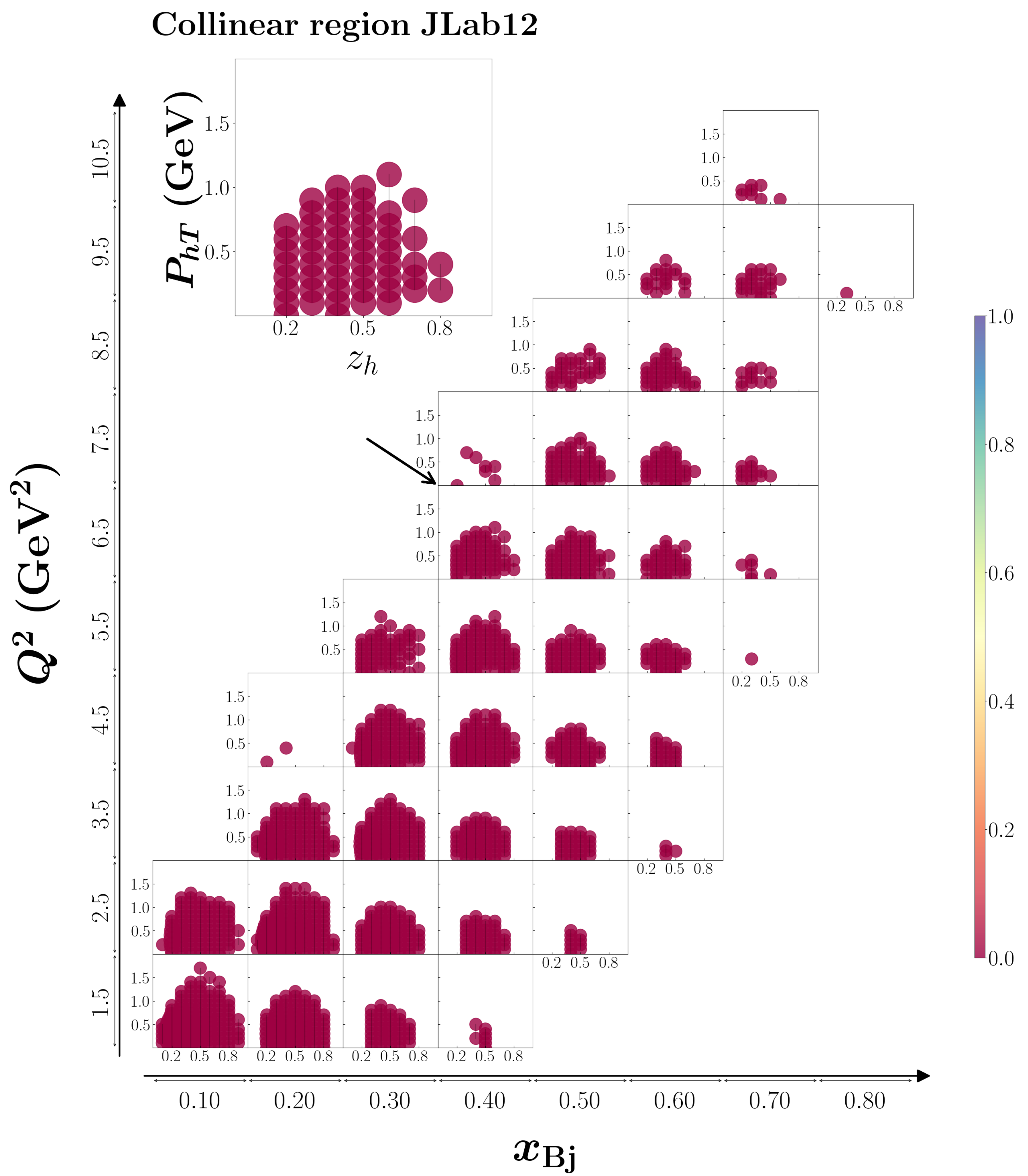
Affinity plots

Color represents the affinity value: blue - affinity = 1, red - affinity = 0.
Size of “blobs” consistent with number of events that fall inside of a kinematic bin



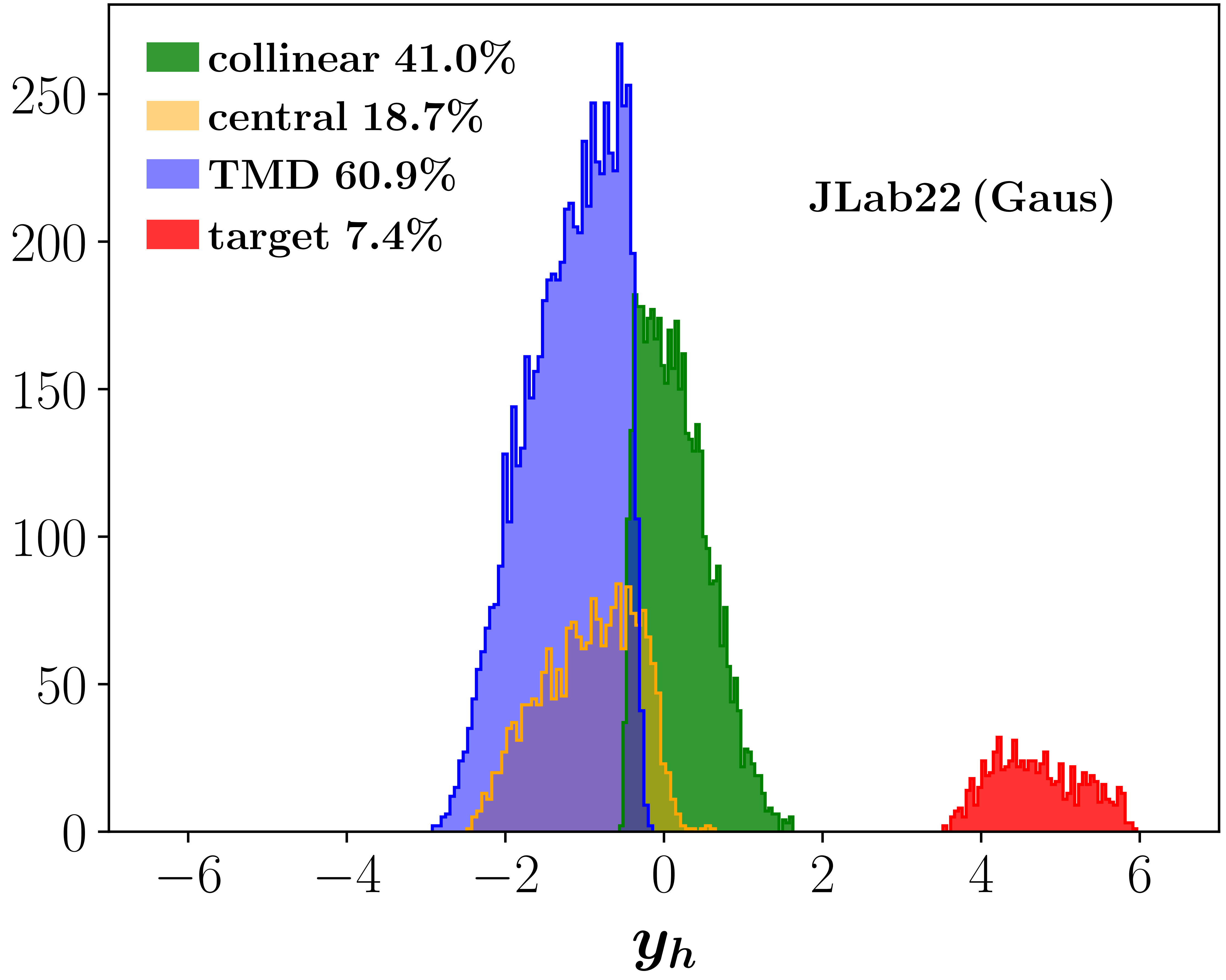



Collinear region JLab
Q^2 (GeV^2)
P_{hT} (GeV)
z_h
$x_{\rm Bj}$
0.05
0.09
0.16
0.30
0.55
1.0
1.4
2.0
2.8
4.0
5.6
7.9
11.1

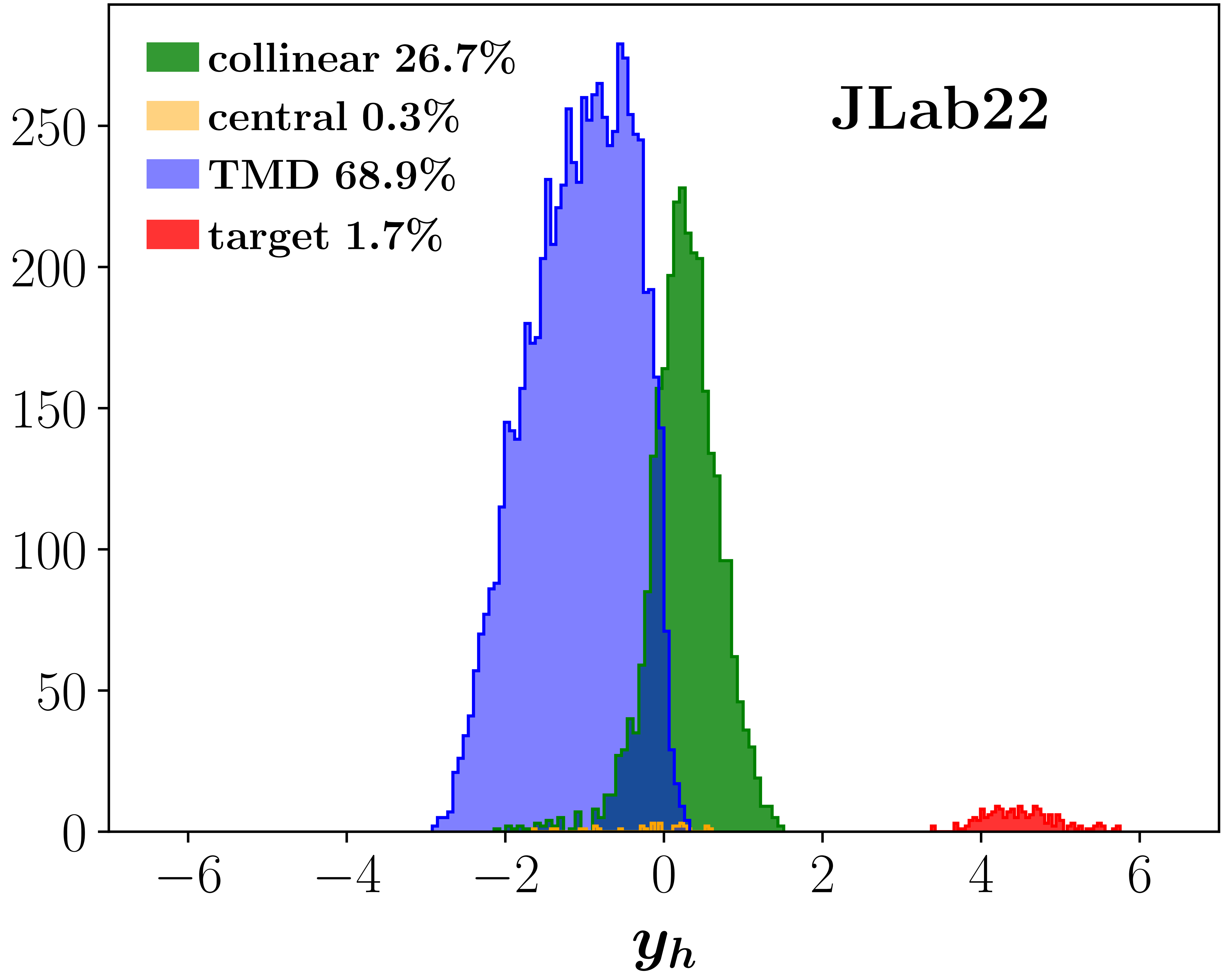

Collinear region JLab12
Q^2 (GeV^2)
P_{hT} (GeV)
z_h
$x_{\rm Bj}$
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
1.5
2.5
3.5
4.5
5.5
6.5
7.5
8.5
9.5
10.5

JLab22

Rapidity phase space (π^+)

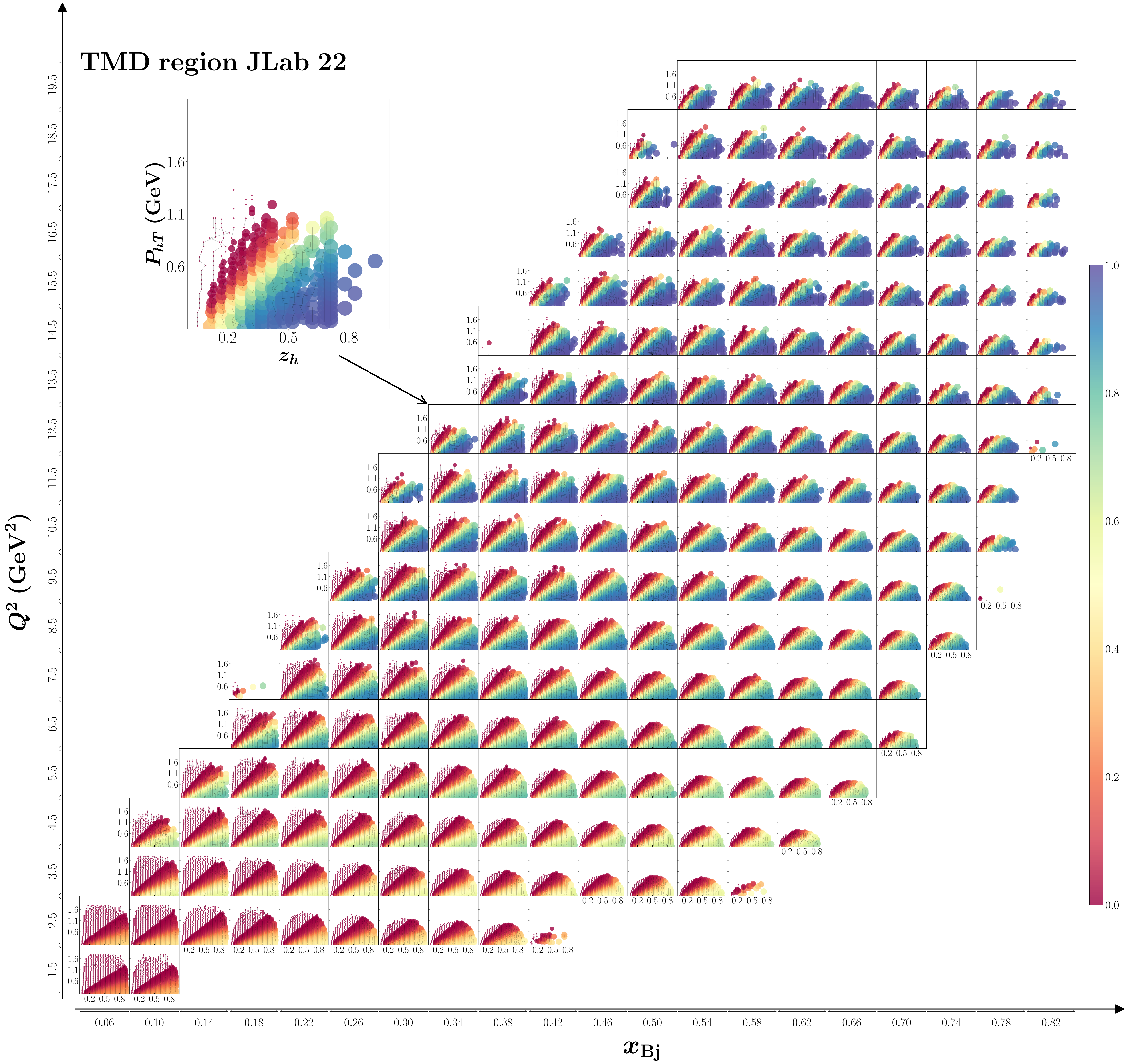


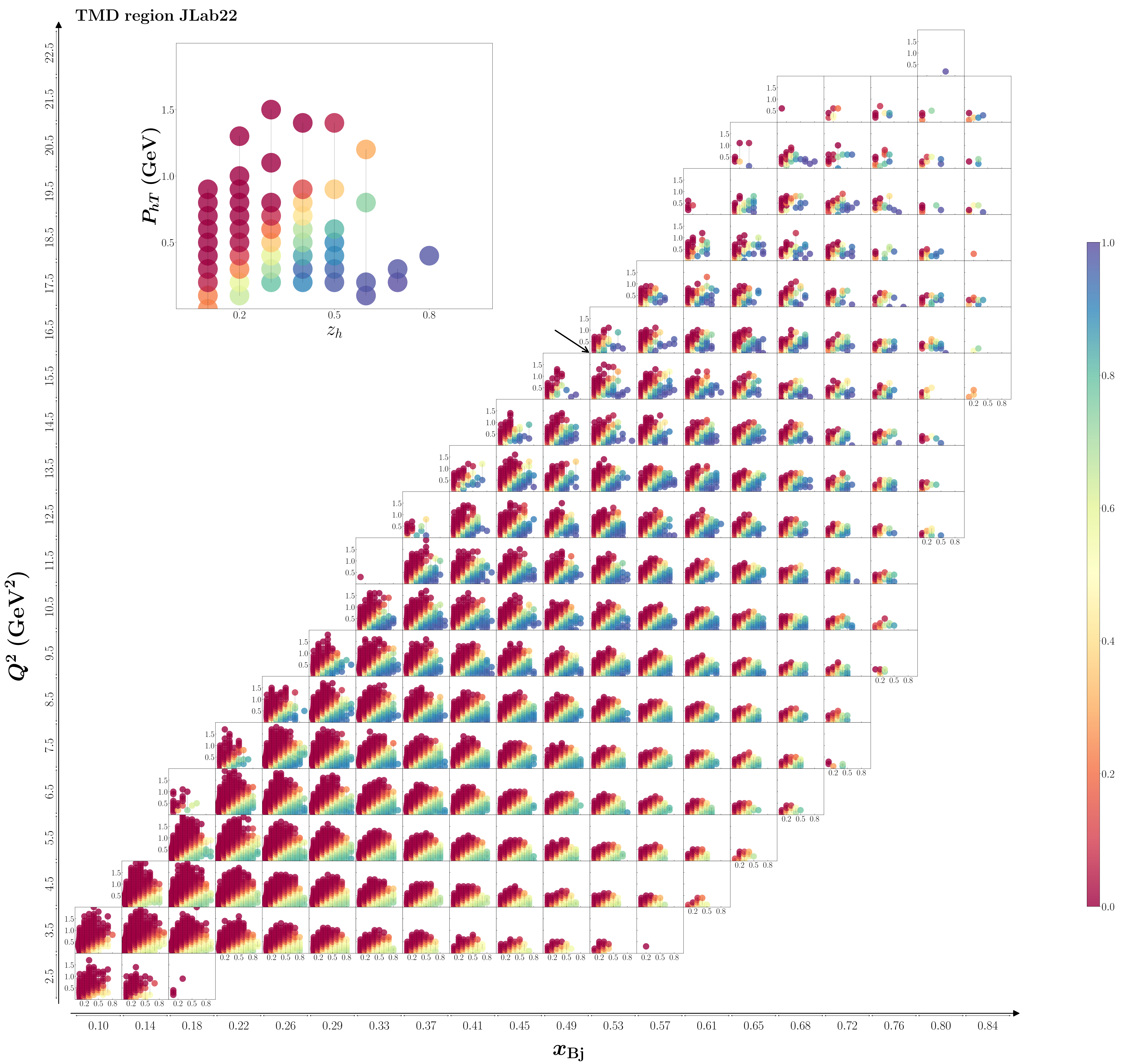
Based on Gaussian distributions



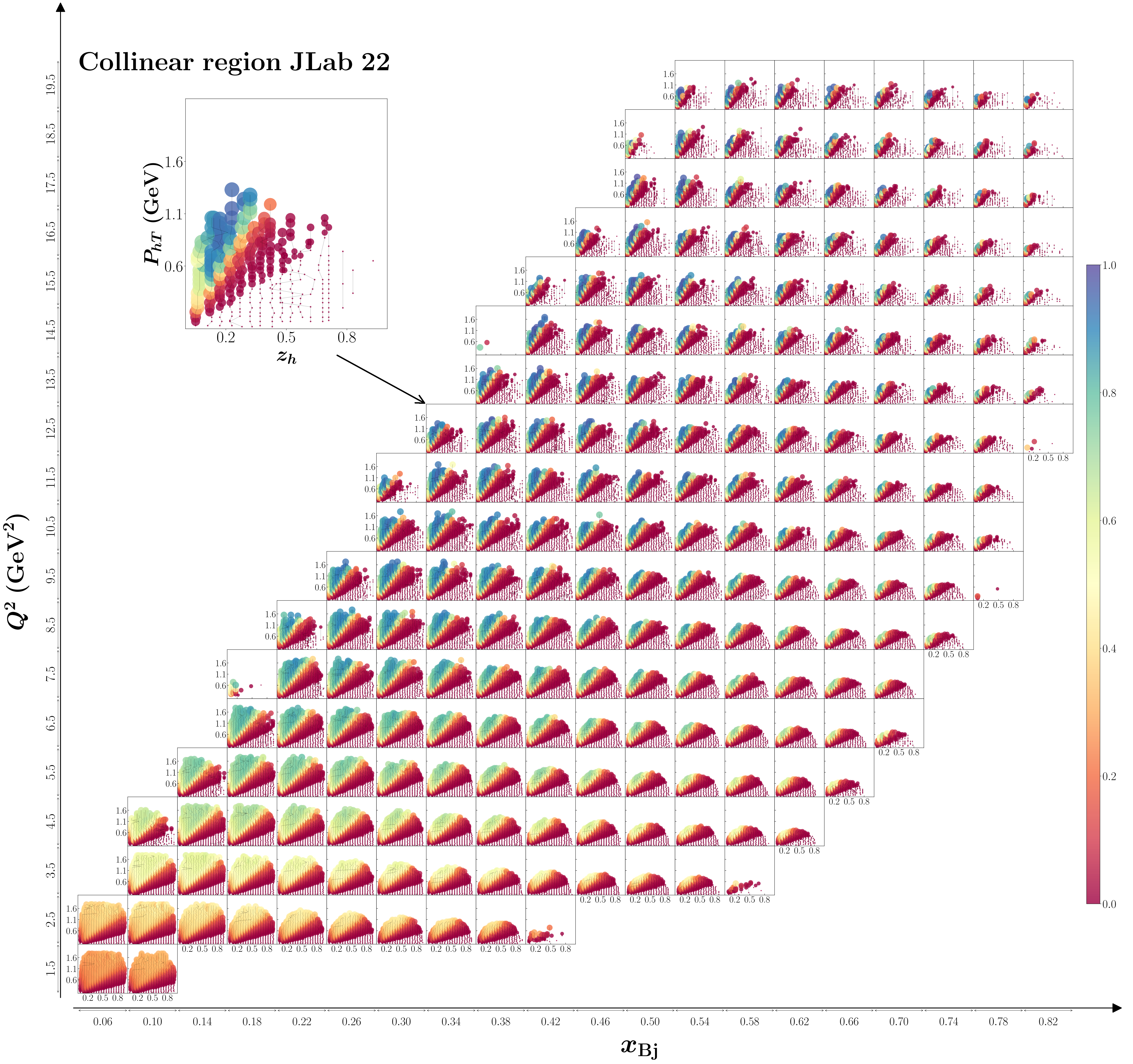
Based on MC generation

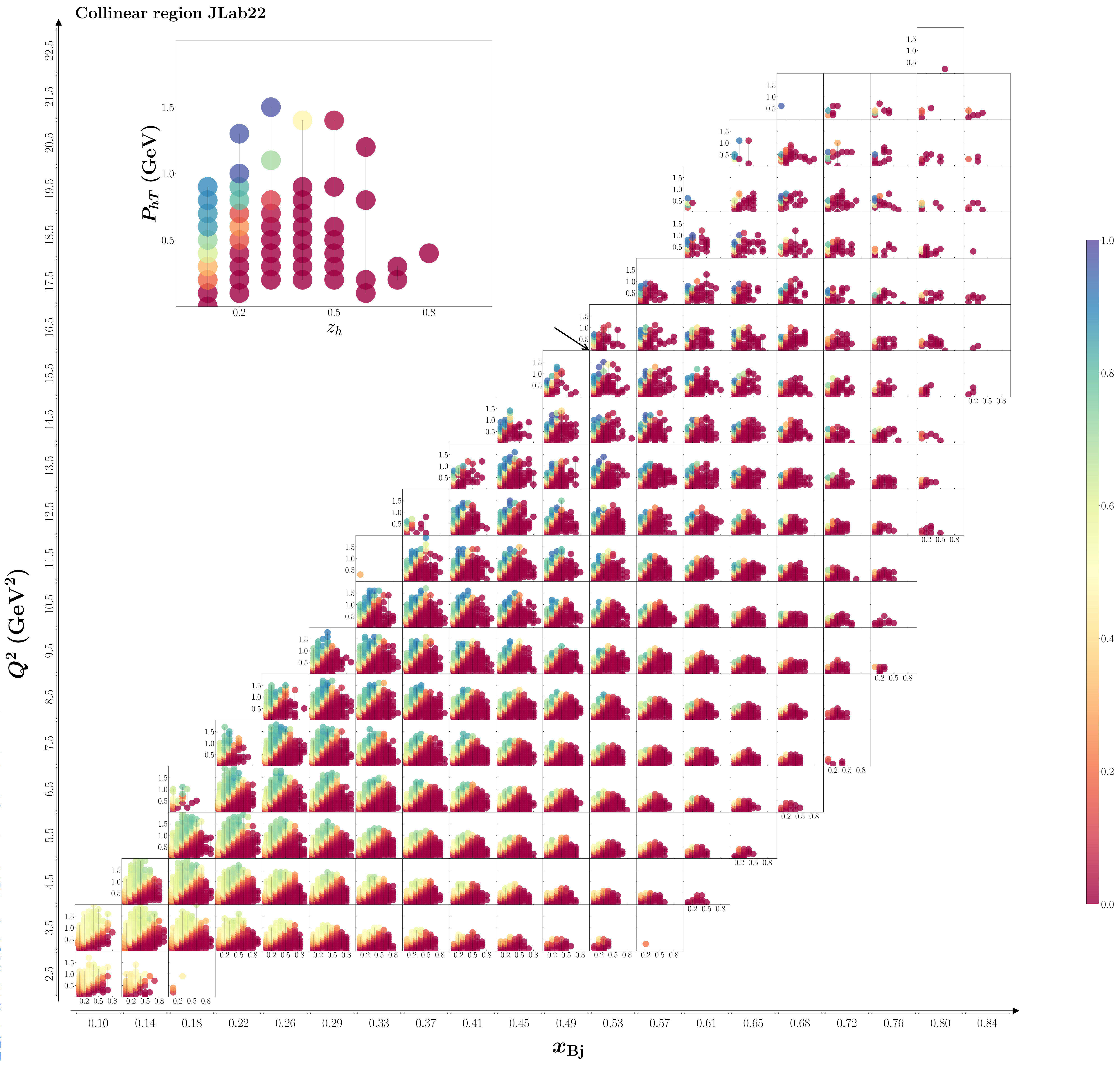
Affinity plots



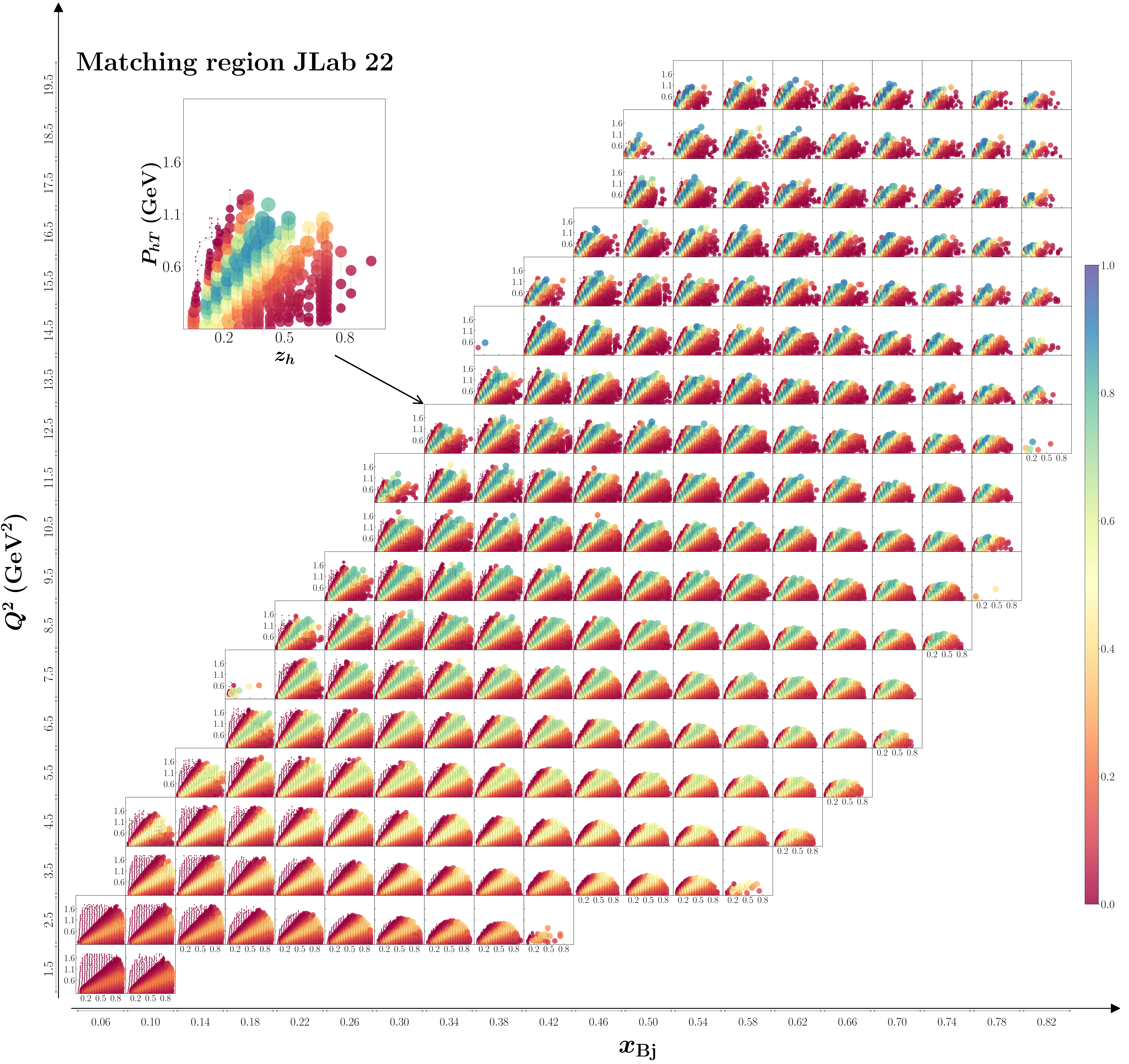


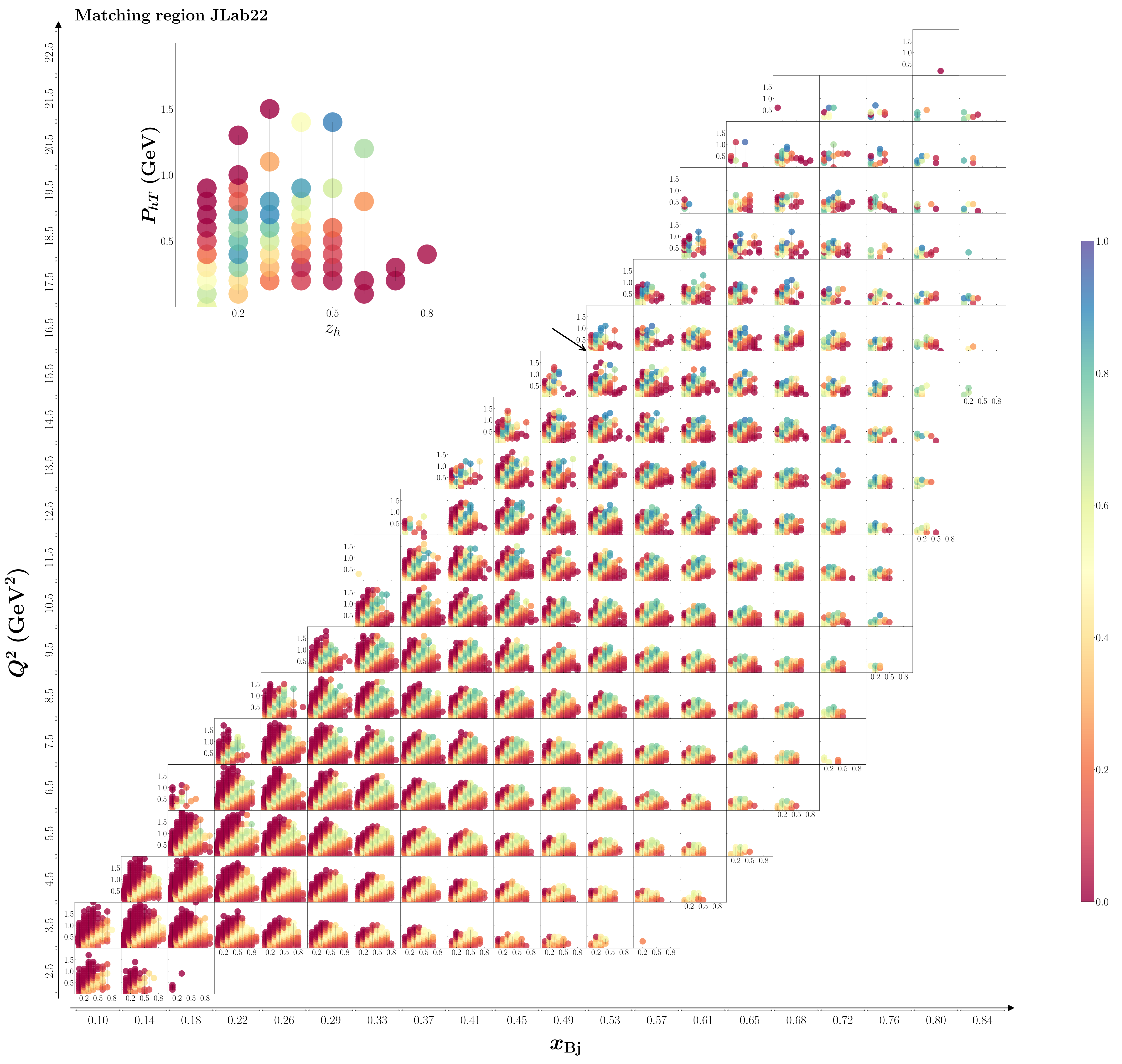
Affinity plots





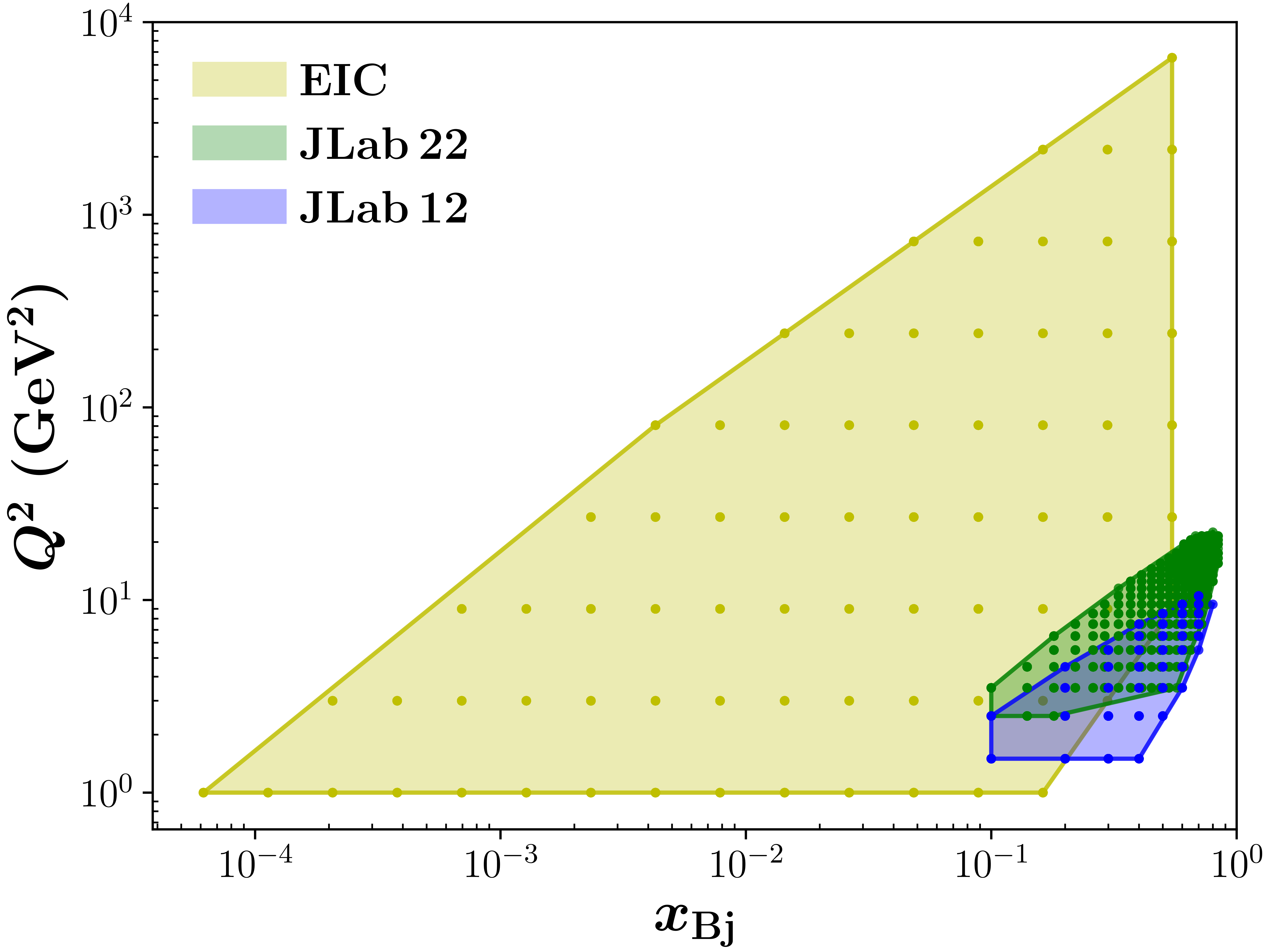
Affinity plots



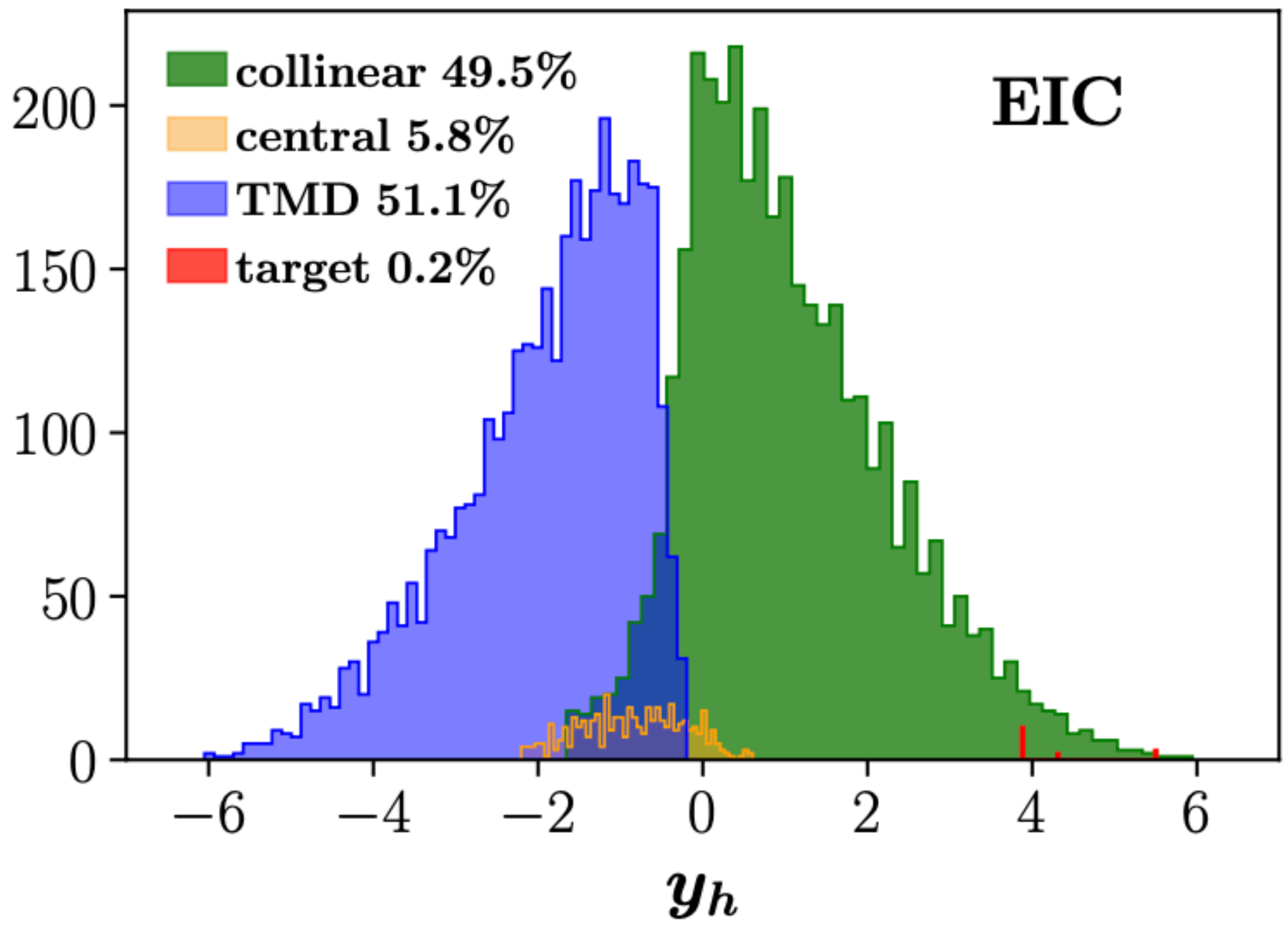


EIC

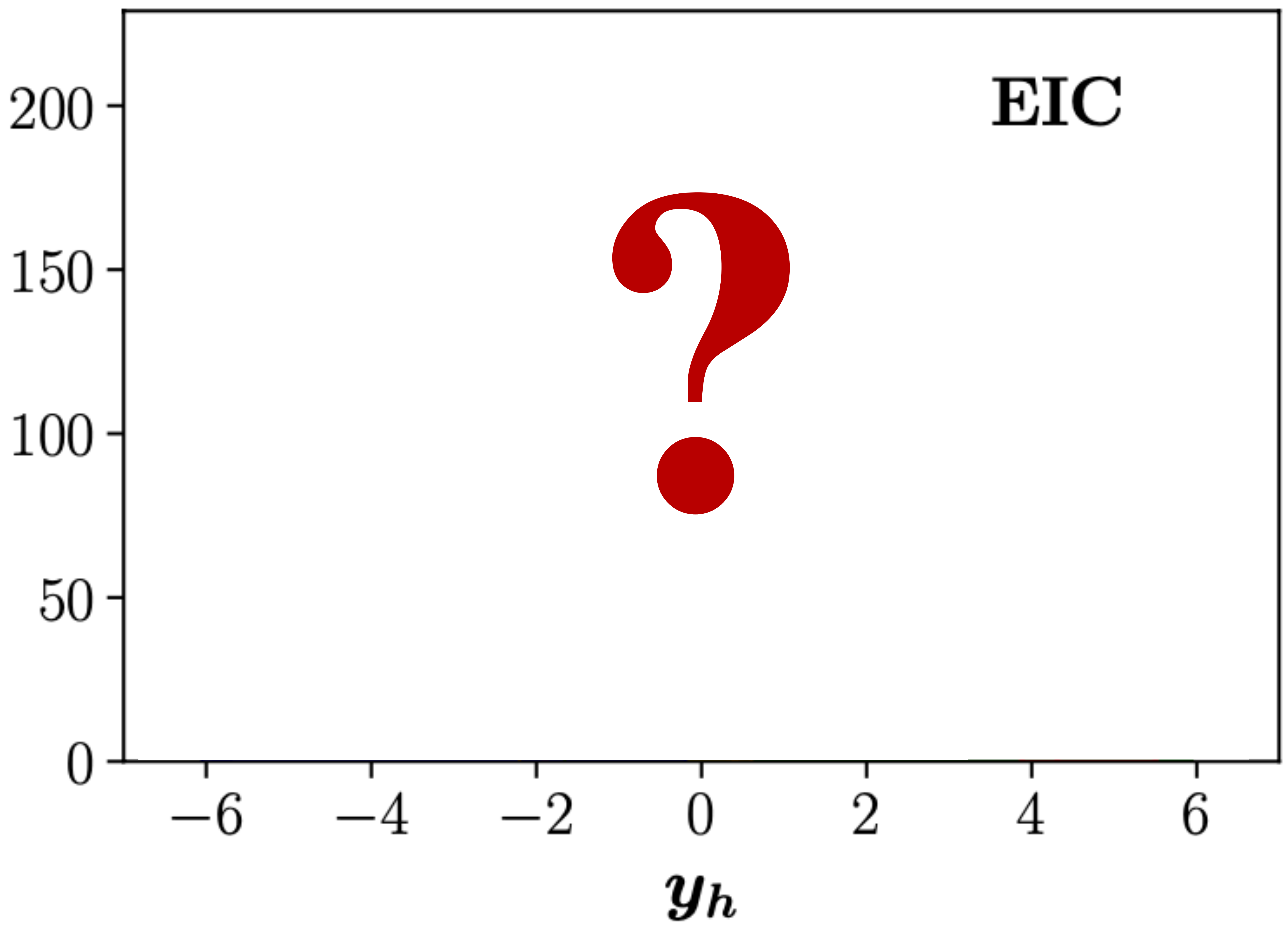
Phase space



EIC
JLab 22
JLab 12
Q^2 (GeV^2)
10^0
10^1
10^2
10^3
10^4
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^0
x_{Bj}

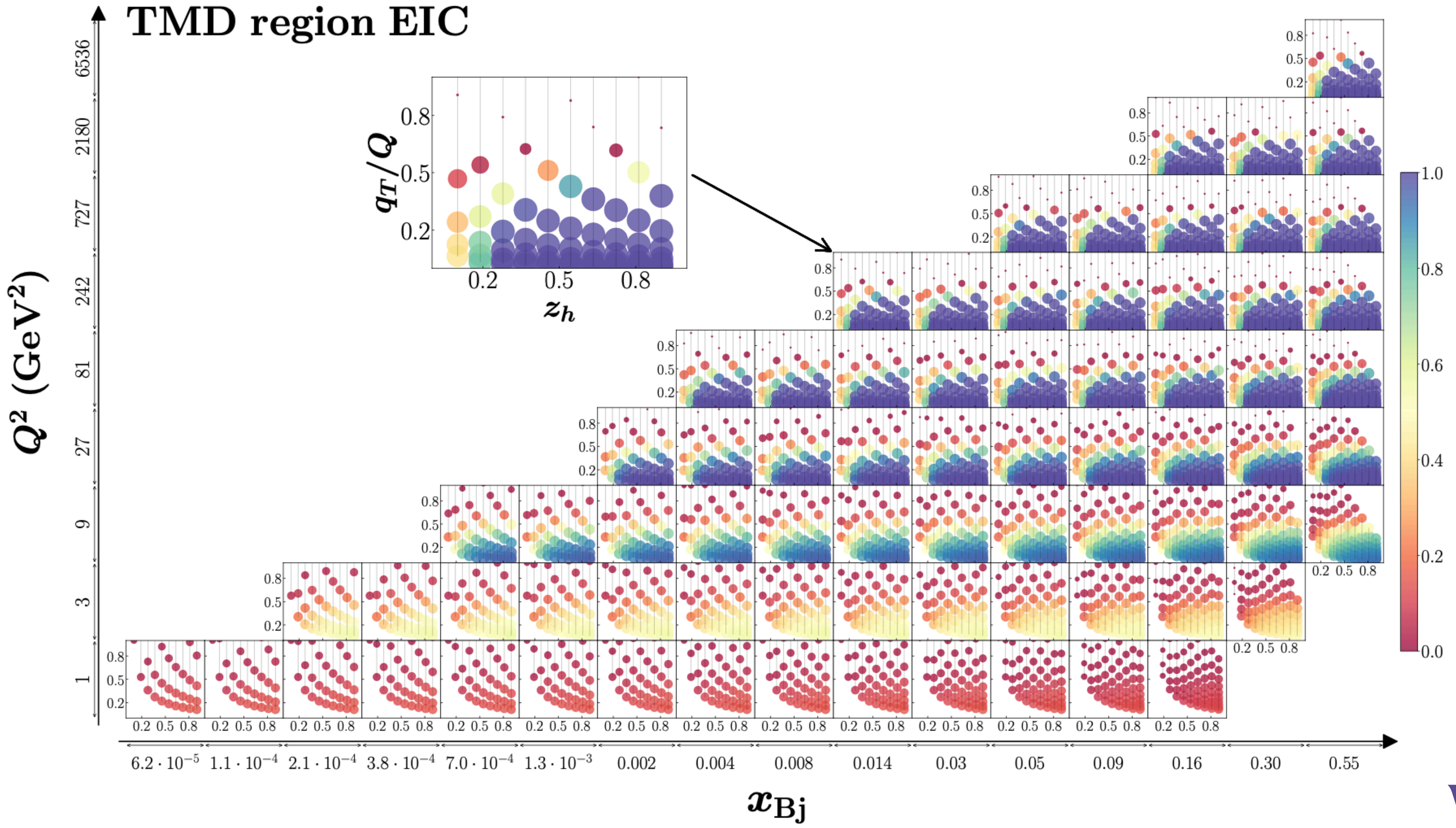


Based on Gaussian distributions



Based on MC generation

https://arxiv.org/pdf/2201.12197



How will it change if we apply event-by-event method?

Will it give us more information about TMD and Matching regions?

Thank you!

Useful articles:

1. Mapping the Kinematical Regimes of Semi-Inclusive Deep Inelastic Scattering
2. New tool for kinematic regime estimation in semi-inclusive deep-inelastic scattering
3. Kinematics of Current Region Fragmentation in Semi-Inclusive Deeply Inelastic Scattering
4. Unpolarised transverse momentum dependent distribution and fragmentation functions from SIDIS multiplicities