TMDPDF Evolution from Lattice QCD

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work in progress with

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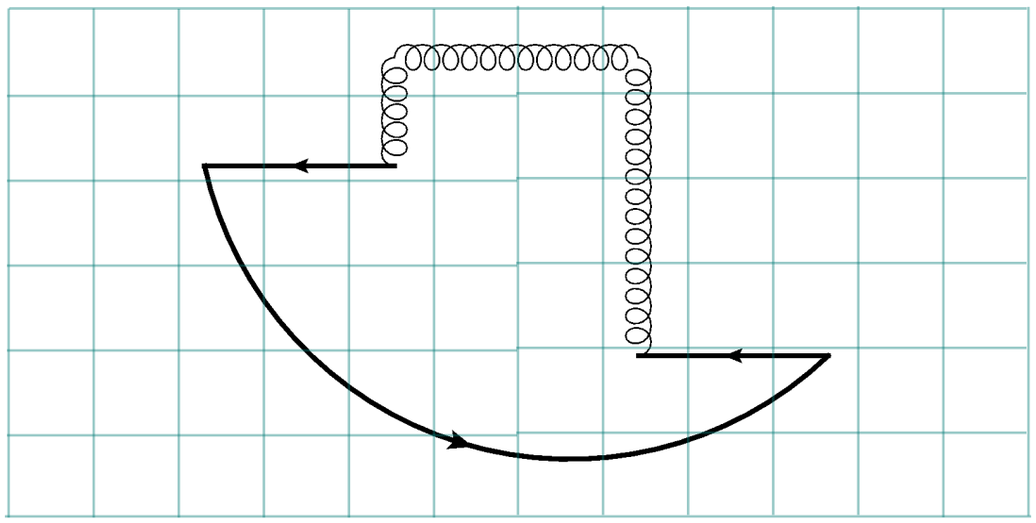
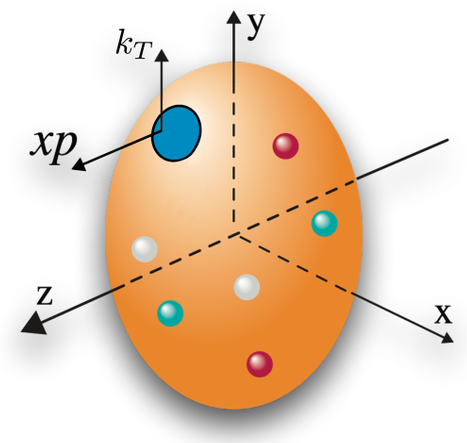




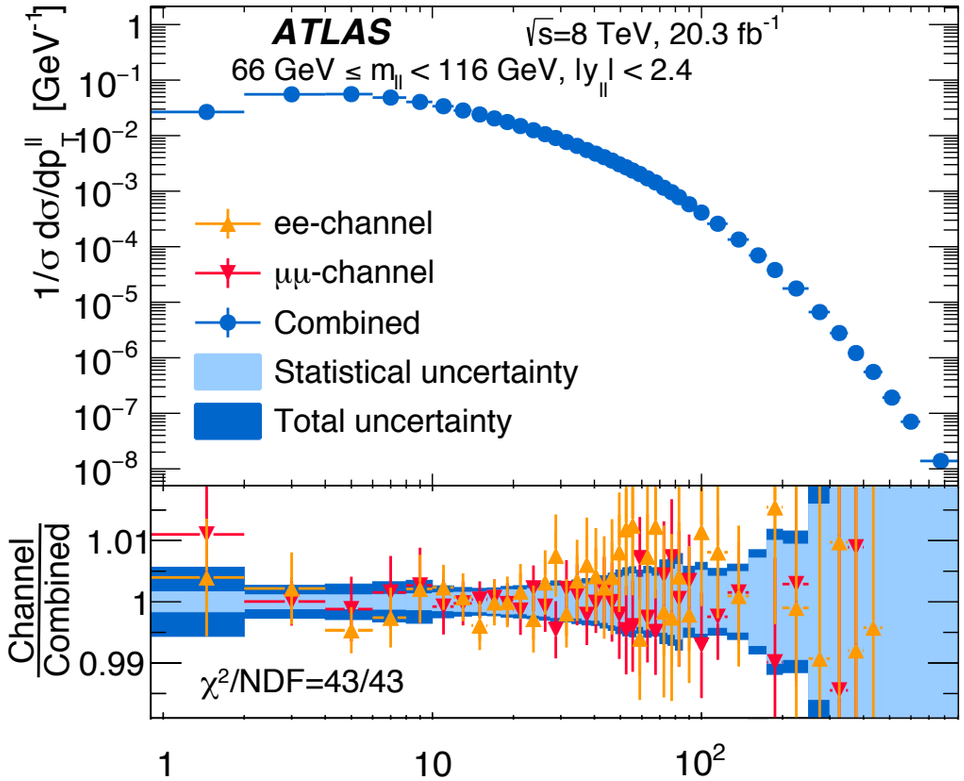
Sante Fe

August 29, 2019

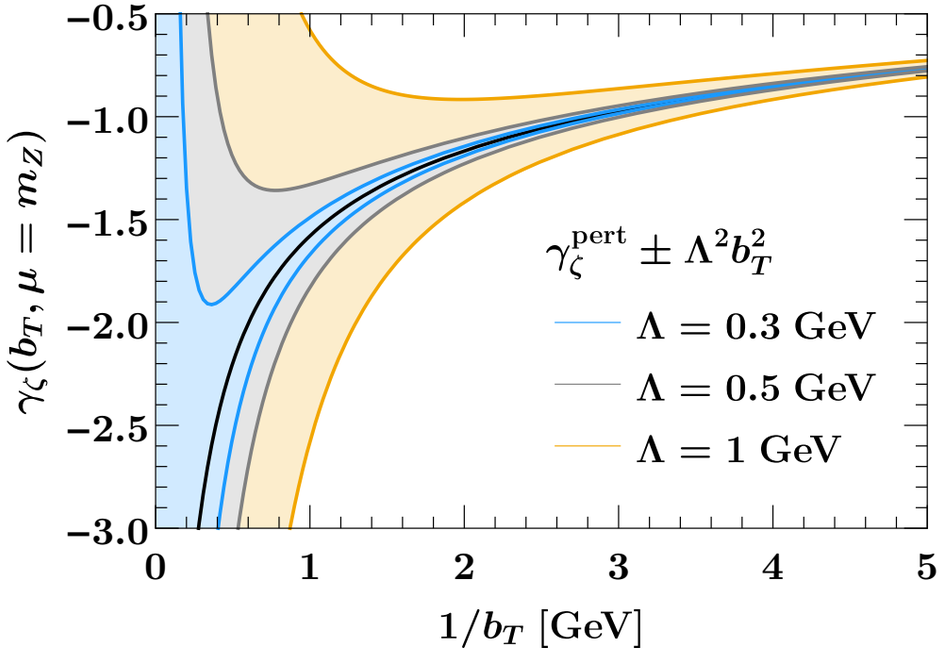
TMD evolution

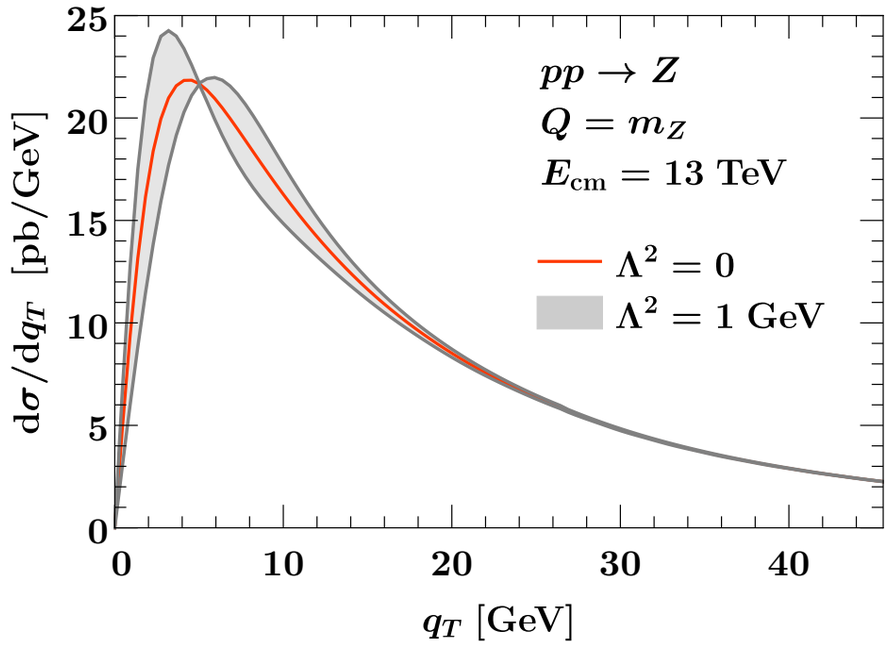
TMDPDFs needed to compute transverse-momentum-dependent cross-sections

Sub-percent precision achieved in measurements of e.g. Drell-Yan differential cross-sections at LHC



Nonperturbative contributions to TMDPDF evolution (Collins-Soper kernel / rapidity anomalous dimensions) limits QCD theory predictions to much lower precision



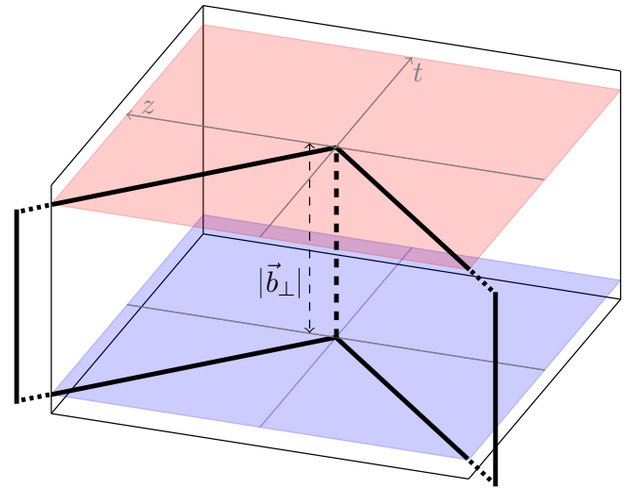


TMD evolution from LQCD

TMDPDFs inaccessible to LQCD with LaMET

— soft factor includes two light-light directions

Ebert, Stewart, Zhao, arXiv:1901.03685



Ratios of TMDPDFs free from soft factors, can be calculated with LQCD

Musch et al, PRD 85 (2012) Engelhardt et al, PRD 93 (2016) Yoon et al, PRD 96 (2017)

TMDPDF rapidity anomalous dimensions (Collins-Soper kernel) calculable from ratios of quasi-TMDPDFs

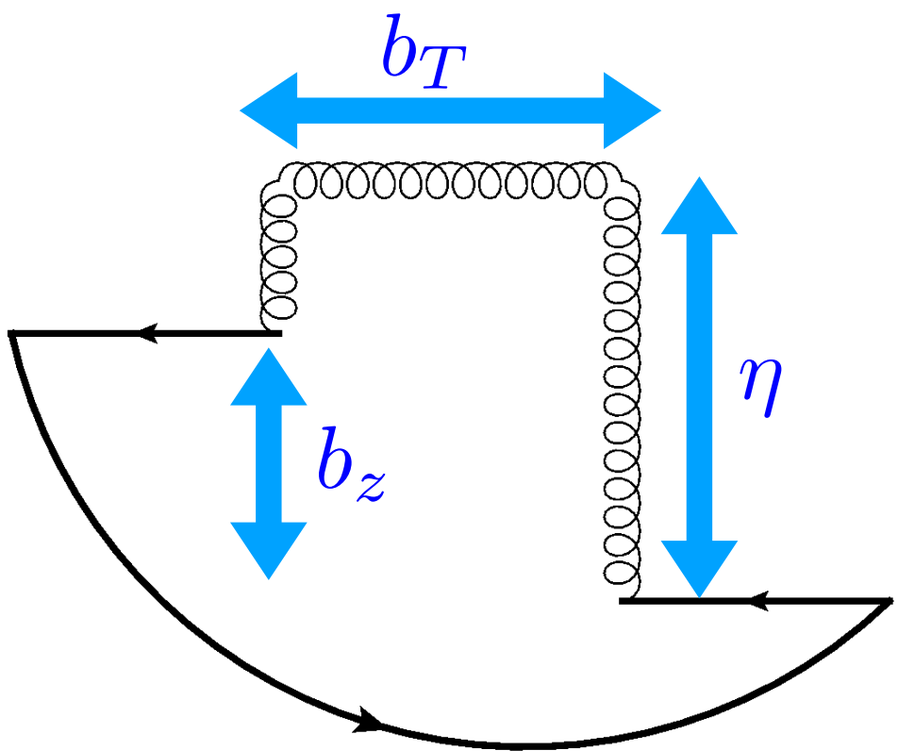
Ebert, Stewart, Zhao, PRD 99 (2019)

$$\gamma_\zeta^{q,\overline{\rm MS}}(b_T,\mu) = \zeta\frac{d}{d\zeta} f_q^{\overline{\rm MS}}(x,b_T,\mu,\zeta)$$

LQCD-friendly quasi-beam function

$$= \frac{1}{\ln(p_1^z/p_2^z)} \ln \frac{C_{\rm TMD}^{\overline{\rm MS}}(\mu,xP_2^z)\int db^z e^{ib^z x p_1^z}\widetilde{B}_q^{\overline{\rm MS}}(b^z,b_T,\eta,\mu,p_1^z)}{C_{\rm TMD}^{\overline{\rm MS}}(\mu,xp_1^z)\int db^z e^{ib^z x p_2^z}\widetilde{B}_q^{\overline{\rm MS}}(b^z,b_T,\eta,\mu,p_2^z)}$$

LQCD Setup



Quasi-beam function calculable from staple-shaped Wilson line matrix elements

Independent of hadron state, choice of momenta, choice of longitudinal Fourier transform scale x up to power corrections b_T/η , $1/(p^z b_T)$, M/p^z

LQCD plan:

Exploit hadron state independence, use heavy pseudoscalar meson $m \sim 1.2$ GeV starting with quenched ensembles for exploratory study

Use three lattice spacings $a = 0.04,\ 0.06,\ 0.08$ fm to study continuum limit

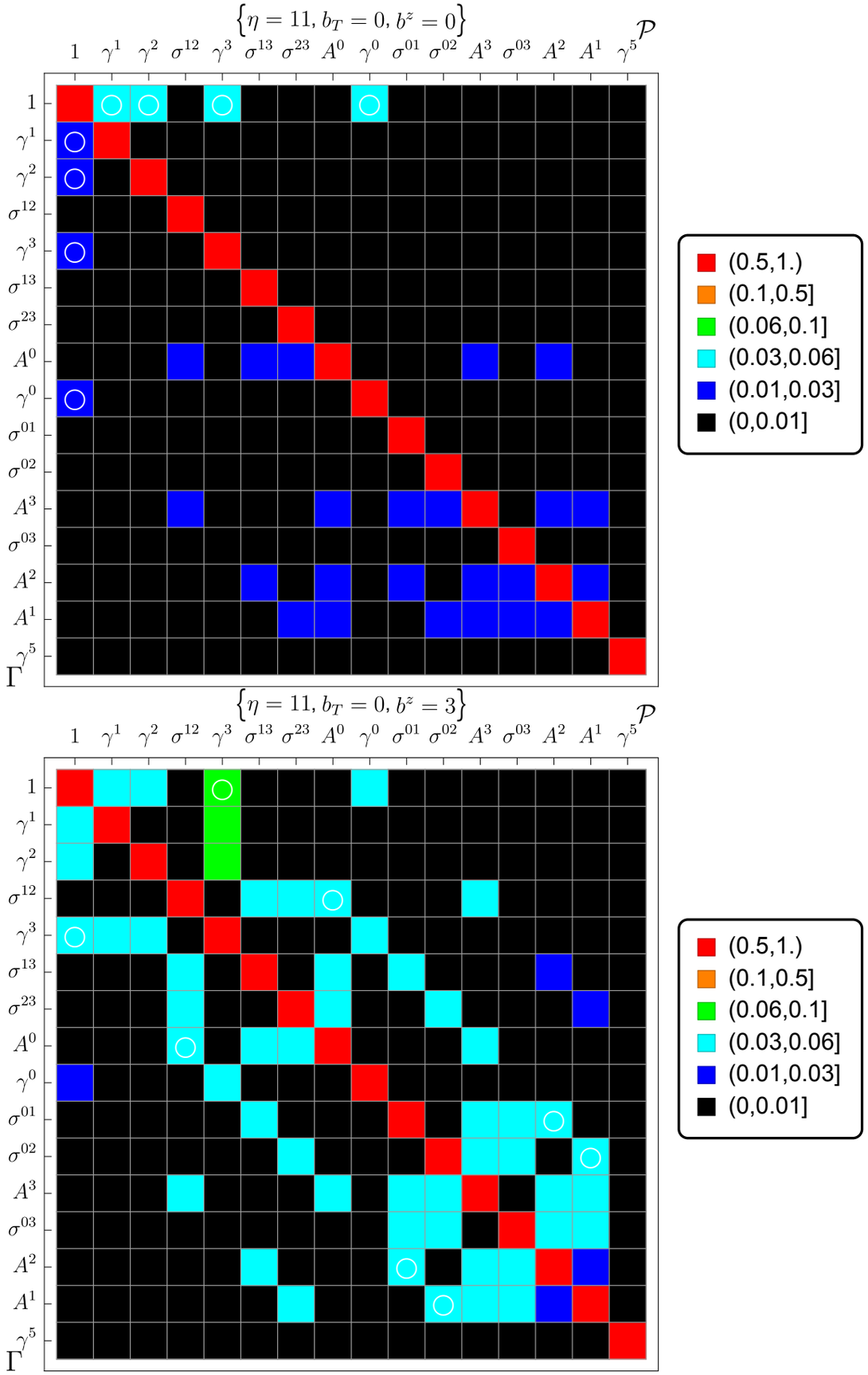
Vary momentum to explore size of power corrections

Nontrivial O(a) operator mixing pattern predicted by lattice perturbation theory

Constantinou, Panagopoulos, PRD 96 (2017) Constantinou, Panagopoulos, Spanoudes, PRD 99 (2019)

— Investigate mixing pattern with NPR studies

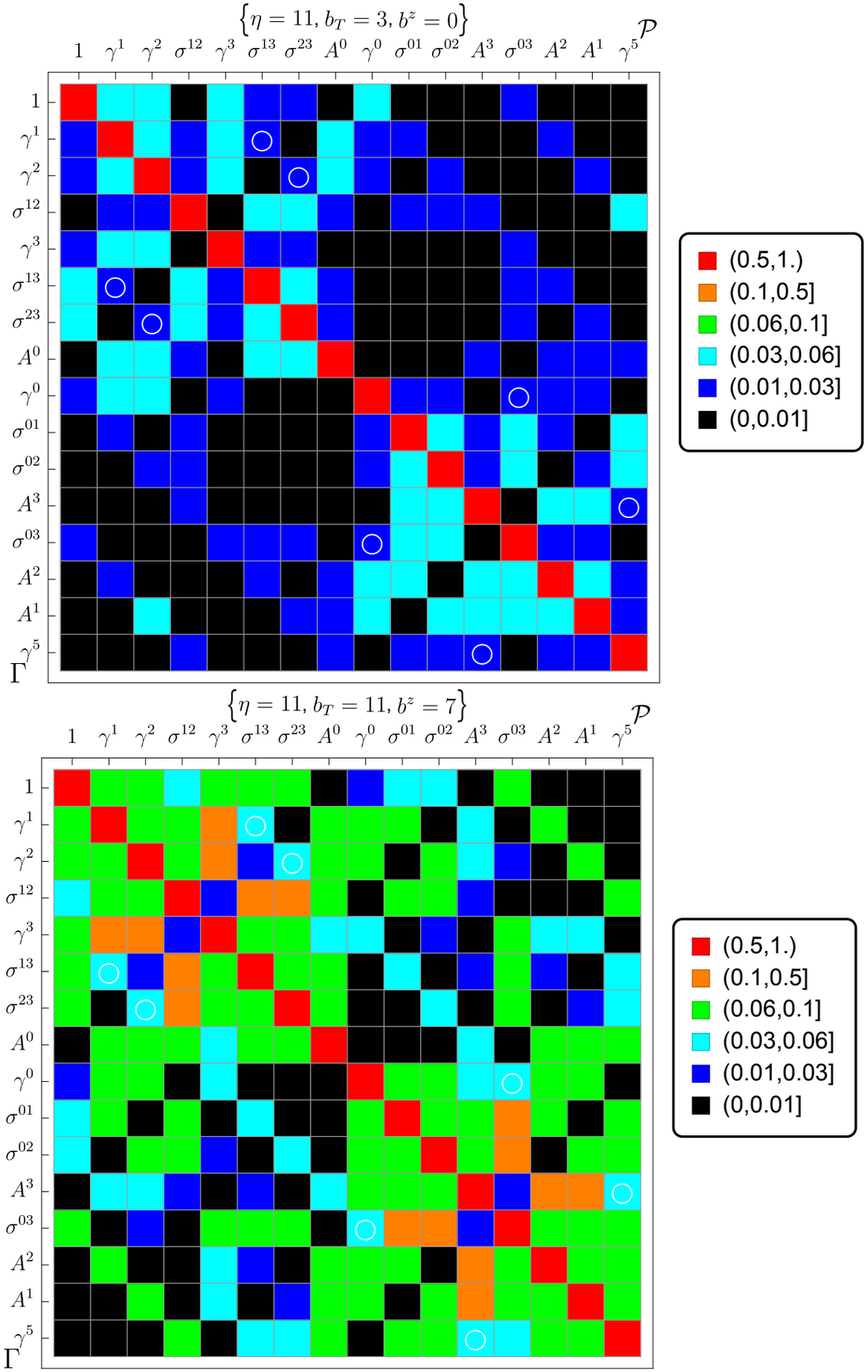
Straight-Line Operator NPR

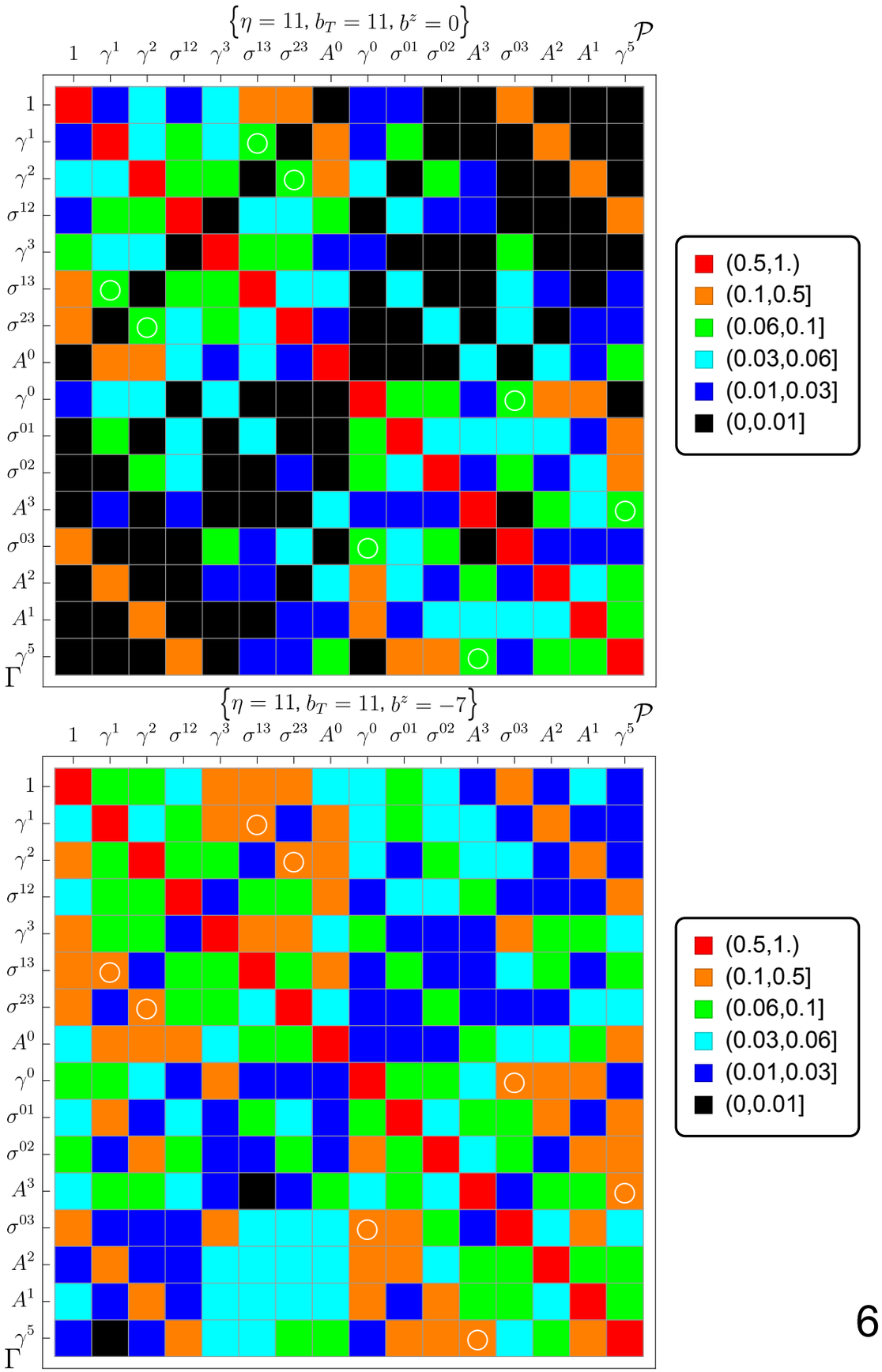


Operator mixings predicted by lattice perturbation theory present, but other mixings also present

Mixings grow to O(10%) for Wilson lines of length ~1 fm

Staple-Shaped Operator NPR





Staple-Shaped Operator NPR