

QUARKONIUM PRODUCTION AS A PROBE OF THE GLUON CONTENT OF THE PROTON

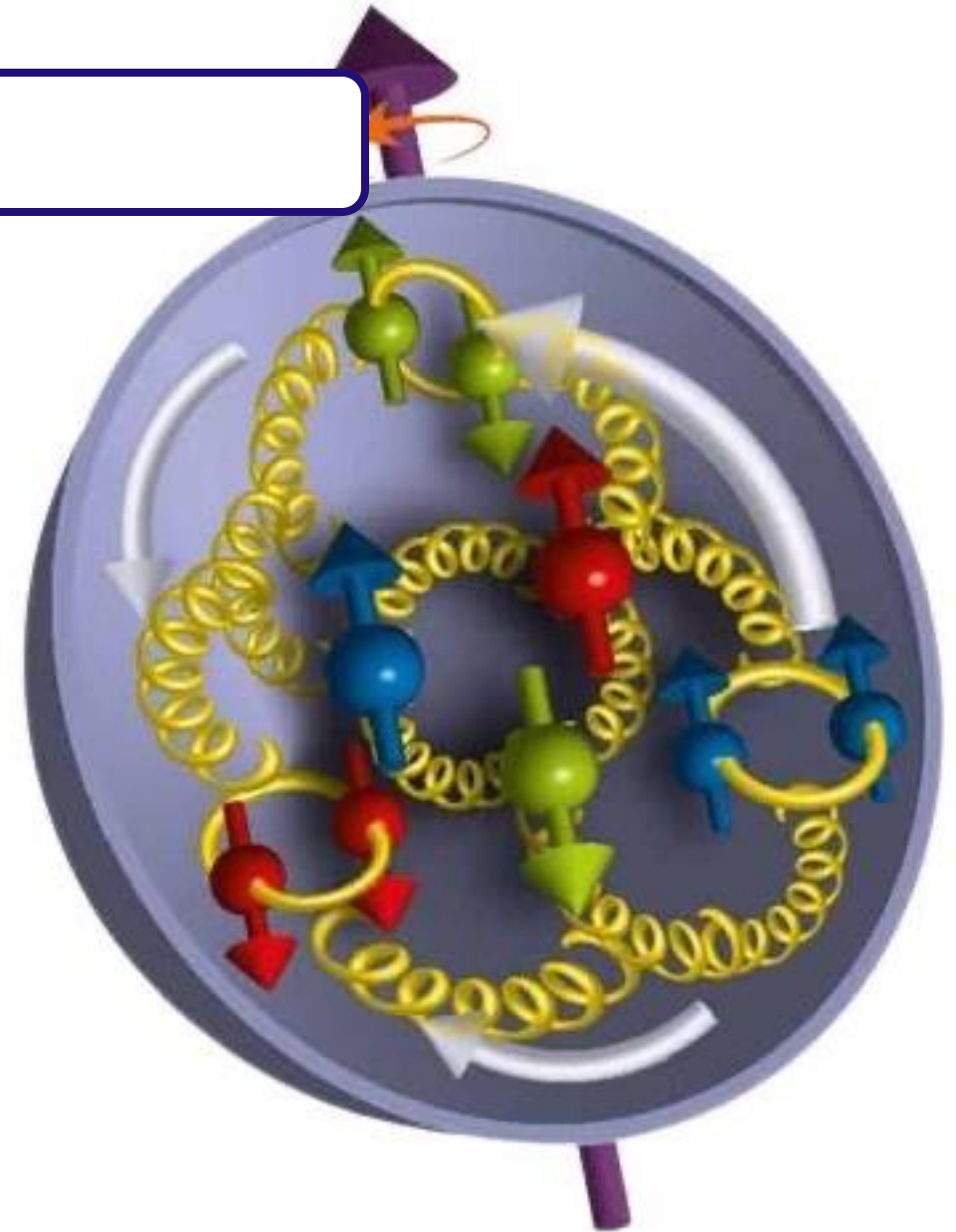
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Women in Theoretical Physics
National Award Milla Baldo Ceolin 2023
Galileo Galilei Institute, Firenze
8th October 2024



Motivation

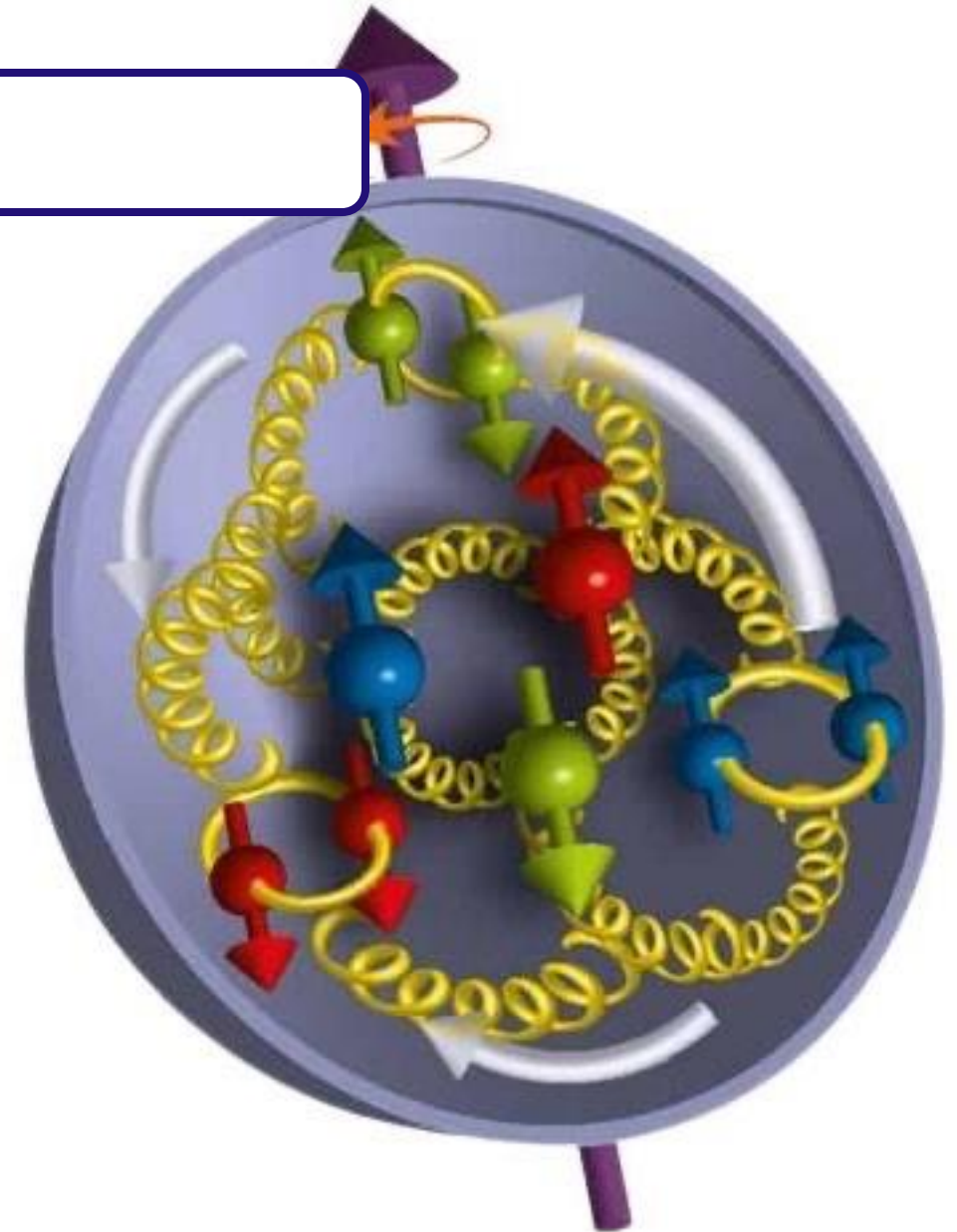
Our purpose:
investigate the internal
structure of the proton



Motivation

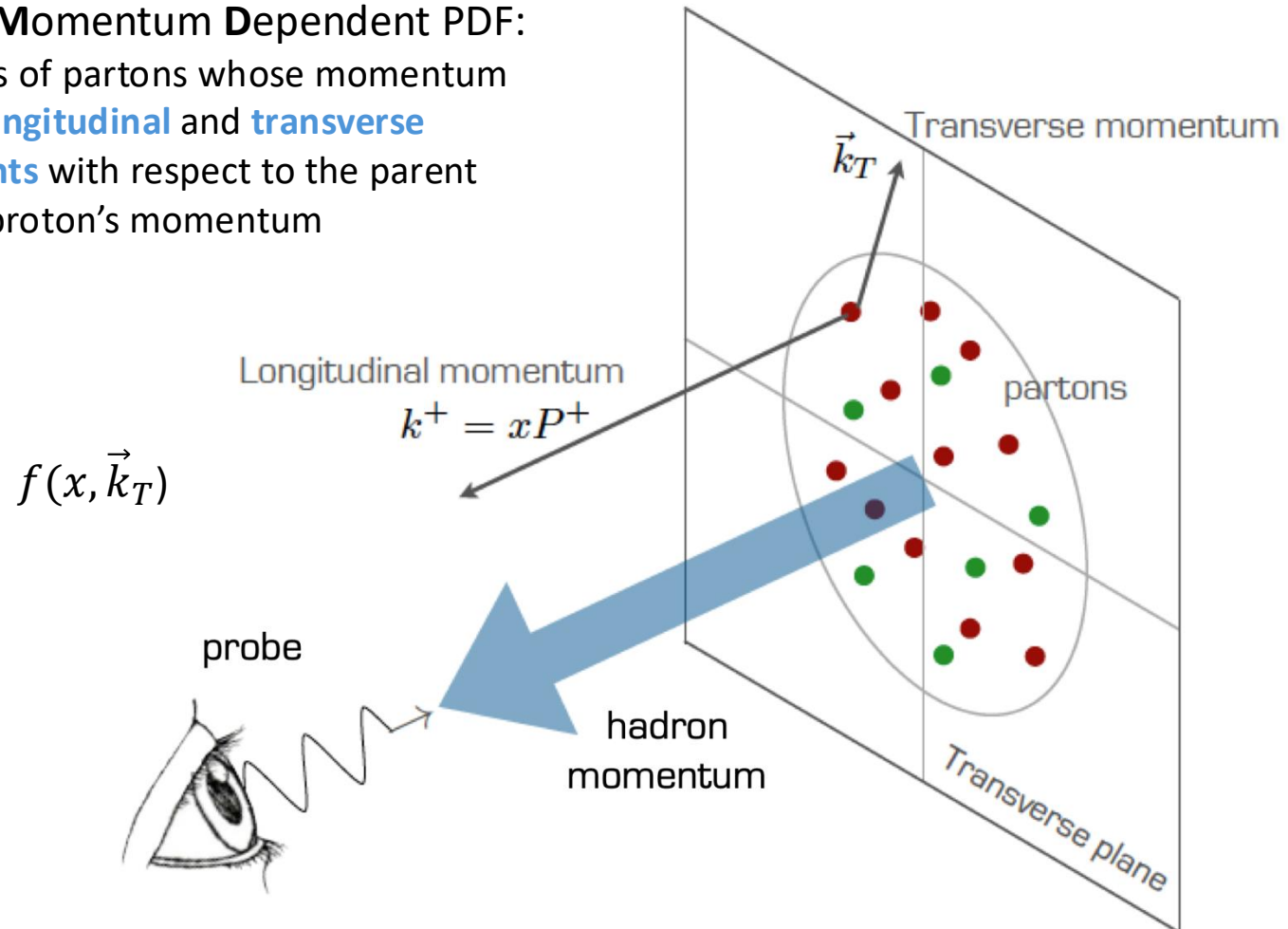
Our purpose:
investigate the internal
structure of the proton

- How are quarks and gluons **distributed**?
- What's the contribution from quarks and gluons to the **mass** of the proton?
- Where does the proton's **spin** come from?
- ... and many more



Gluon TMDs

Transverse Momentum Dependent PDF:
Distributions of partons whose momentum have **longitudinal** and **transverse components** with respect to the parent proton's momentum



3D

TMD PDFs:

- encode all the possible **spin-spin** and **spin-momentum** correlations between the proton and its constituents
- depend on x and $\vec{k}_T$

Transverse Momentum Dependent Parton Distribution Functions (TMD PDFs)

GLUONS	unpolarized	circular	linear
U	$\textcircled{f_1^g}$		$h_1^{\perp g}$
L		$\textcircled{g_{1L}^g}$	$h_{1L}^{\perp g}$
T	$f_{1T}^{\perp g}$	g_{1T}^g	$h_{1T}^g, h_{1T}^{\perp g}$

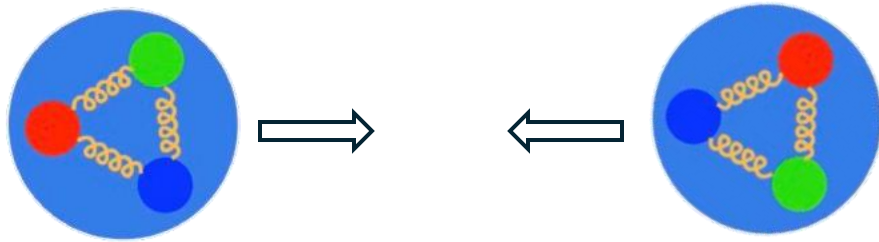
← Gluon pol.

↑
Proton pol.

Angeles-Martinez et al., Acta Phys., Pol B46 (2015)

Quarkonium Production

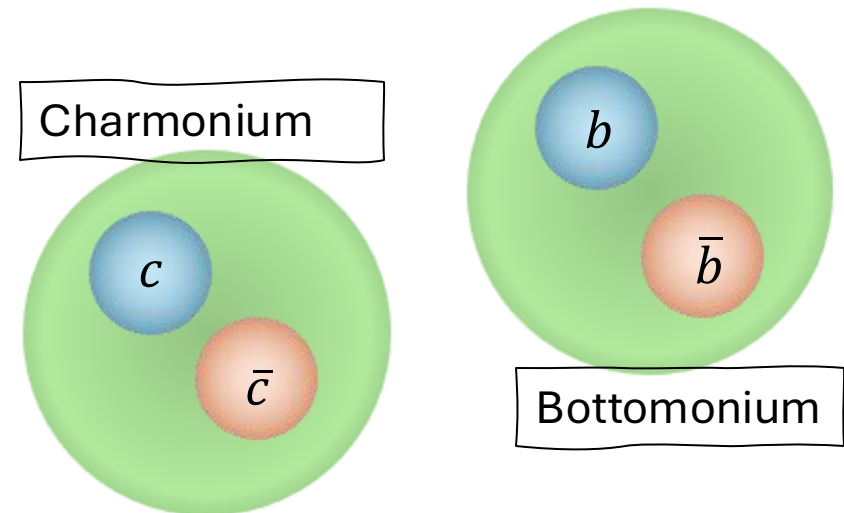
$$p(P_A, S_A) + p(P_B, S_B) \rightarrow Q\bar{Q}[{}^{2S+1}L_J^{(1)}](q) + X$$



Quarkonium is a quark-antiquark bound state that can be produced in proton-proton collisions

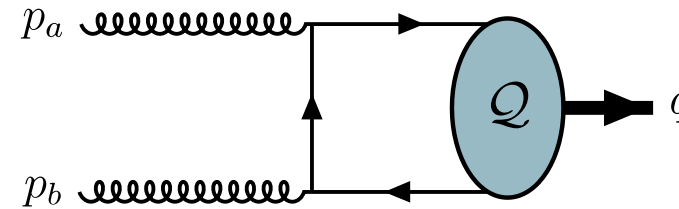
Model: Non-Relativistic QCD (NRQCD)

- Double power series expansion in α_s and v
- Partonic subprocess $gg \rightarrow Q\bar{Q}$ calculated perturbatively
- Non-perturbative quarkonium formation from the $Q\bar{Q}$ -pair encoded in the LDMEs



Quarkonium Production

$$g(p_a) + g(p_b) \rightarrow Q\bar{Q}[{}^{2S+1}L_J^{(1)}](q)$$



We calculated the single-polarized
cross sections

UU, UL, UT

$$d\sigma^{pp \rightarrow Q\bar{Q}} = \sum_n \underbrace{d\hat{\sigma}[gg \rightarrow Q\bar{Q}]}_{\text{Perturbative short-distance coefficients}} \underbrace{\langle 0 | \mathcal{O}_n({}^{2S+1}L_J^{(1)}) | 0 \rangle}_{\text{Non-perturbative LDME}}$$

Perturbative short-distance coefficients

Non-perturbative LDME

Current work

Currently doing my PhD at the University of Cagliari under the supervision of Prof. Cristian Pisano and Dr. Simone Rodini

- We also studied the double-polarized cross sections (LL, LT, TT) and *single spin asymmetries* for the process $pp \rightarrow \eta_c X$ in [Phys. Rev. D **110**, 034038](#)
- More study on gluon TMDs through *matching relations* with collinear PDFs
- Predictions for LHCSpin and EIC





THANKS FOR YOUR ATTENTION!