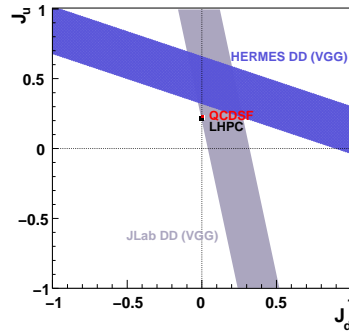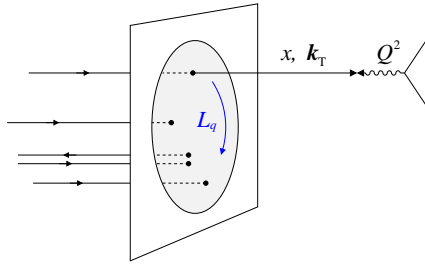# Orbital Angular Momentum in QCD

## INT Workshop INT-12-49W, 06-17 Feb 2012

L. Bland, Z.–E. Meziani, G. A. Miller, M. Vanderhaeghen, Ch. Weiss, Feng Yuan
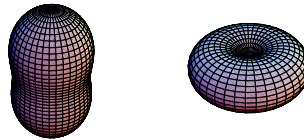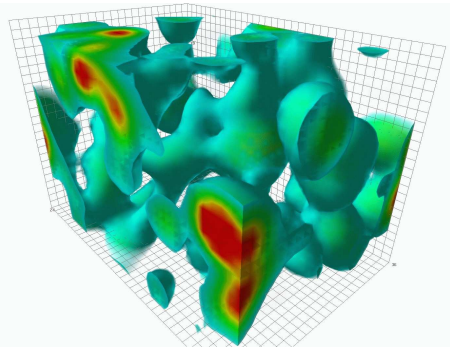
- Welcome

  Thanks to INT

- Orbital angular momentum in QCD

  More and more evidence
  Challenges
  Experimental programs

- Plan of meeting

# Orbital angular momentum: Evidence

- Nucleon spin decomposition

  Quark and gluon helicities most likely do not account for total $S_z = 1/2$

- Azimuthal asymmetries in semi–inclusive particle production

  $T$–odd: Spin–orbit interactions

  $T$–even: "Deformation"

- Hard processes probing nucleon's valence component $|qqq\rangle$

  Elastic form factors $F_2/F_1$ at high $|t|$

  Spin structure functions at $x \to 1$

- Non–perturbative dynamics

  Chiral symmetry breaking: Quark helicity flip amplitudes, pion cloud

# Orbital angular momentum: Challenges

- Operator definition of angular momentum

  Not unique: EM tensor forms, gauge dependence, quark–gluon separation

  Renormalization and scale dependence

  Partonic interpretation: Surface terms, $x = 0$ modes?

  Connection with operator product expansion for hard processes?

- OAM in nucleon structure

  Lattice: Singlets, gluonic structure

  Effective models: Beyond mean–field, correlations, $q\bar{q}$ pairs, gluons

- Relation to observables

  Semi–inclusive: Separating OAM in wave function $\leftrightarrow$ final–state interaction

  Exclusive: Finite–size/higher–twist effects? Sensitivity to Ji sum rule?

| | | |
|---|---|---|
| $\vec{e}\vec{N}/\vec{\mu}\vec{N}$ | JLab 6/12 GeV | Valence quark spin/flavor TMDs, GPDs, correlations |
| | COMPASS | Quark and gluon spin, TMDs |
| | EIC | Sea quarks and gluon spin/flavor TMDs, GPDs, correlations |
| $\vec{p}\vec{p}$ | RHIC Spin | Gluon spin, sea quarks with $W^{\pm}$, TMDs |
| $pp/\bar{p}p$ hadron | JPARC, GSI FAIR | Drell–Yan |
| | LHC | Spin–orbit in W/Z/Higgs, multiparton correlations |
| $e^{+}e^{-}$ | BELLE | Fragmentation |

# OAM: Week 1

Mon 06    **Longitudinal spin structure**
Status and perspectives of global fits, experiments
Lattice calculations of spin structure
Flavor separation with SIDIS

Tue 07    **QCD energy–momentum tensor**
Form factors and interpretation
Lattice calculations

**Angular momentum in gauge theories**
Quantization of gauge theories
Field-theoretical vs. partonic formulation

**OAM in light-front quantization / few–body systems**
Large–$t$ form factors
Structure functions at $x \to 1$

Wed 08    **Angular momentum in QCD**
Physical considerations and properties of different definitions
Relation beween different definitions

Thu 09    **OAM in nucleon structure**
Impact of different definitions
Composite models of nucleon
Light-front phenomenology, transverse denities, resonances

**Spin sum rules**
Spin–1 systems, transverse polarization

Fri 10    **OAM in semi-inclusive DIS**
QCD factorization – collinear and TMD
Experimental $p_T$ dependence
Azimuthal asymmetries in $ep, pp, e^+e^-$
Final–state interactions

# OAM: Week 2

**Mon 13**  **Exclusive processes: Deeply–virtual Compton scattering**
DVCS experiments and GPD analysis
Dispersion relations and information content
Sensitivity to angular momentum sum rule

**Tue 14**  **Exclusive processes: Vector mesons**
Reaction mechanism and GPD description
Polarization observables
Sensitivity to angular momentum sum rule

**Wed 15**  **Semi–inclusive DIS and Drell–Yan**
Lensing picture of single–spin asymmetries
$T$–even TMDs and nucleon deformation
Sea quarks with Drell–Yan

**Exclusive processes: Pseudoscalar mesons**
Pseudoscalars and transversity GPDs
Angular momentum in meson wave functions
Experiments

**Thu 16**  **Anguar momentum in QCD**
Digest and comments
Properties of different definitions
Impact on phenomenology

**Follow–up talks and discussions**
To be scheduled as needed

**Fri 17**  **Summary and outlook**
Priorities for experimental and theoretical studies
Role of dynamical models
Comprehensive approach to OAM                     **"open–ended"**