

SPIN

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Some Questions about Hadronic Matter:

- What is the *structure* of hadrons in terms of their quark and gluon constituents?
- How do quarks and gluons *evolve* into hadrons through the dynamics of confinement?
- How do the *quarks* and *gluons* manifest themselves in the properties of *nuclei*?

More Questions about Hadronic Matter:

- Does partonic matter *saturate* in a universal high-density state?
- Are there any *long range correlations* between produced partons?
- To what degree can QCD be *demonstrated* as an exact theory of the strong interaction?

20 minutes, in the Lab frame...

Focus on SPIN:

- What is the *helicity sub-structure* of the nucleon?
- Which *symmetries* are at play?
- Precision tests of QCD?

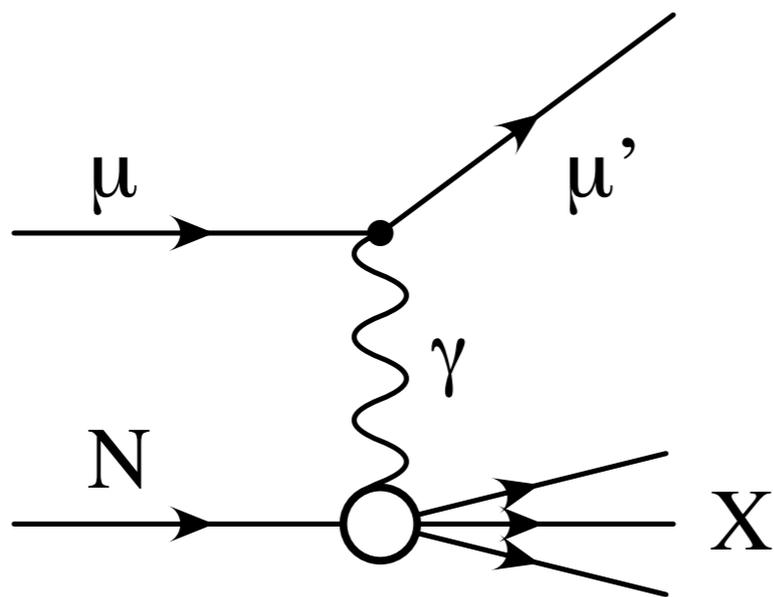
Other cherries certainly exist, as do other talks...

Transversity - M. Grosse Perdekamp, January 27, 2004

Recent talks - R. Ent, W. Vogelsang, S. Kretzer, B. Fleming

What do we (*not*) know?

- So far, most knowledge comes from inclusive DIS:



Direct sensitivity to charge squared (only).

The (longitudinal spin) cross-section has one structure function, $g_1(x, Q^2)$

$$g_1 \propto e^2 \Delta q$$

Decomposition(s):

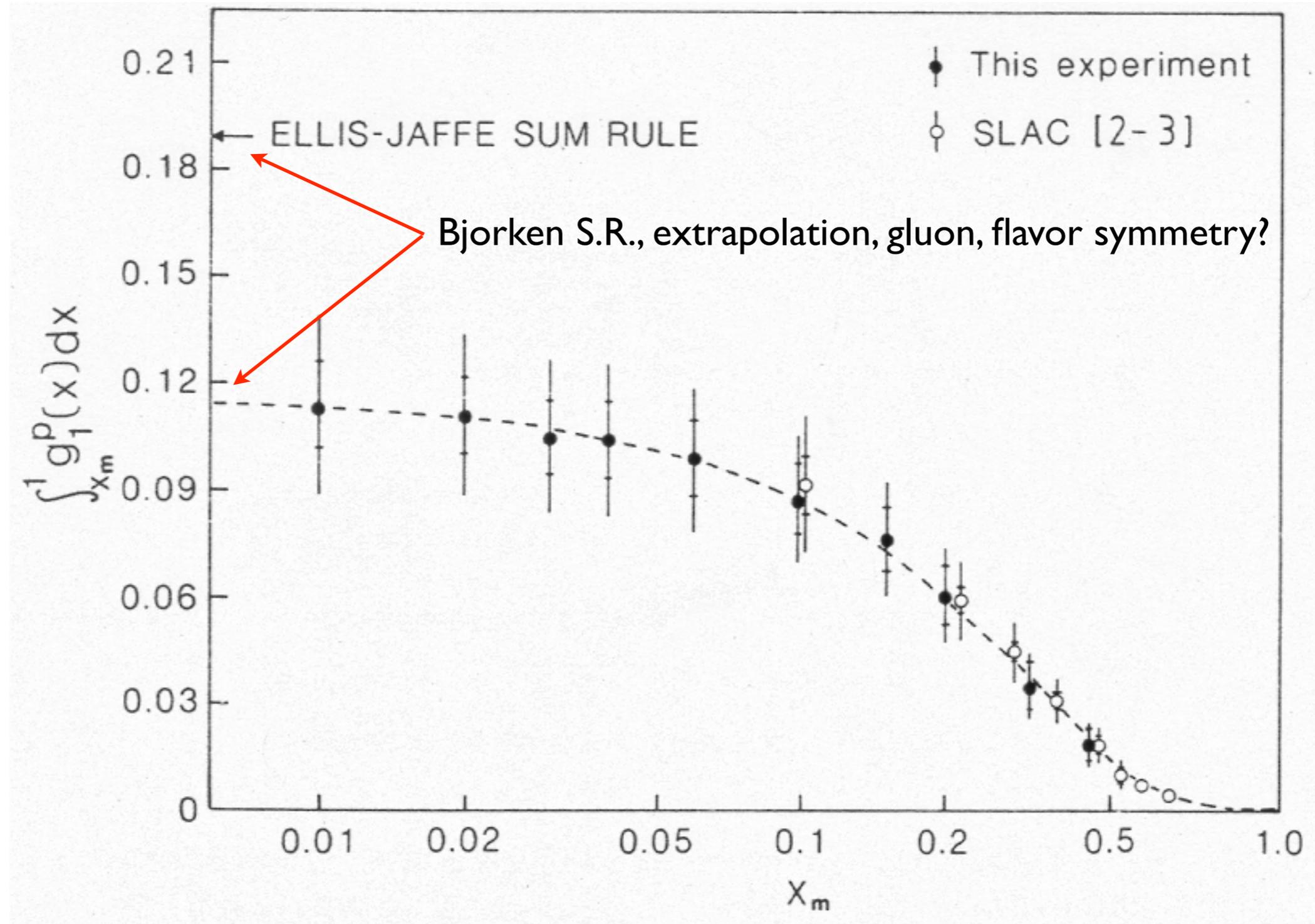
$$a_3 = \Delta u - \Delta d, \quad a_8 = \Delta u + \Delta d - 2\Delta s, \quad \text{and} \quad a_0 = \Delta u + \Delta d + \Delta s$$

take input from hyperon decay measurements.

Scale dependence gives *indirect* access to gluons (and even some flavor cmb).

- *Paths* are about *numbers*, the natural scale being 1/2

What do we (*not*) know?



Progress since, and

- **polarized-DIS** with *complementary targets* brought the Bjorken Sum, nowadays to within $\sim 5\%$ uncertainty (precision QCD),
- **polarized-DIS** over a *wider kinematic region* brought scaling violations, i.e. some sensitivity to gluon helicity. *Even nowadays extrapolation to low- x is the leading uncertainty,*
- **polarized proton-proton collisions** will have the potential to measure gluon helicity and measure the helicities of the up and down quark and anti-quark.
- **near non-existent on strange quarks**; semi-inclusive fixed target DIS is limited by scale, new hyperon decay measurements lack precision.

in the Future

Needs polarimetry breakthroughs, wider kinematics, and/or *perhaps* neutrino fixed target DIS,

Lepton-proton (nucleon) collider,

500 GeV program *essential*, in particular also for the RHIC gluon measurements, and for EIC / eRHIC.

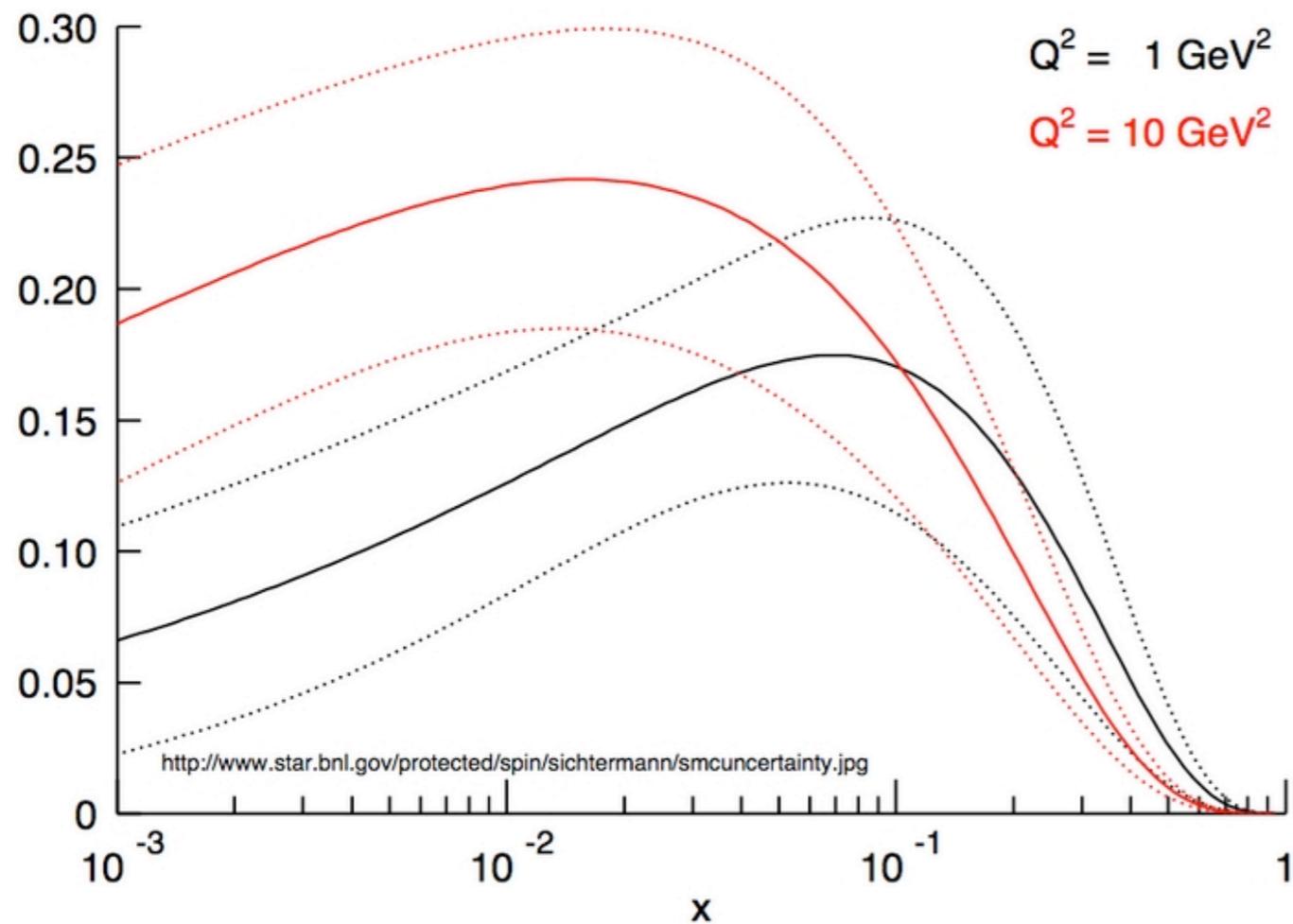
neutrino probes (FINeSSE), semi-inclusive collider DIS, charm-associated W in pp, ~~scale dep. in collider DIS,~~ ~~hyperon decay measurements~~

A comment on gluon polarization:

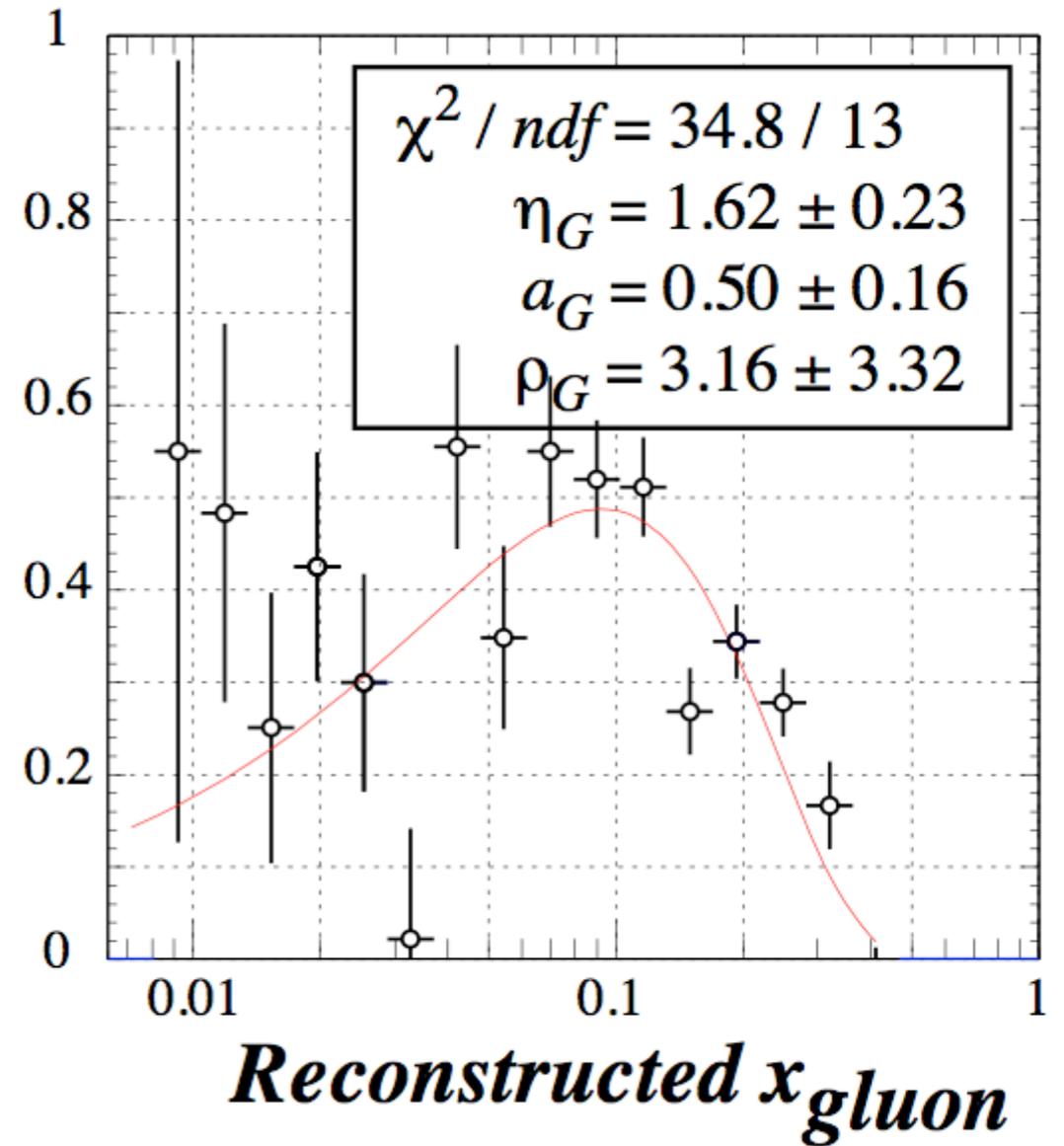
present DIS
| +/- |

to

STAR
+/- ~0.4



Reconstructed $x\Delta G(x)$



Gluon helicity will remain less well-known than e.g. the quark helicity sum.

Comments on: $g_1 \propto e^2 \Delta q$ and flavor decomposition,

$$a_3 = \Delta u - \Delta d, \quad a_8 = \Delta u + \Delta d - 2\Delta s, \quad \text{and} \quad a_0 = \Delta u + \Delta d + \Delta s$$

Current solution(s):

Axial charge	value		correlation coefficient						
			a_u	a_d	a_s	a_0	a_3	a_8	
a_u	0.77	± 0.03	1						
a_d	-0.49	± 0.03	0.99	1					
a_s	-0.15	± 0.04	0.87	0.87	1				
a_0	0.13	± 0.10	0.98	0.98	0.95	1			
a_3	1.2670 ± 0.0035 [59]		-0.04	0.07	0.03	0.02	1		
a_8	0.59 ± 0.03 [59, 133]		0.11	0.10	-0.39	-0.07	-0.04	1	

Two features:

a shift in a_0 , which could result if extrapolation uncertainties are underestimated, affects all the quark helicities equally,

a shift in a_8 , which could result from flavor symmetry breaking, affects the strange quark helicity most (and keeps the sum equal).

Possible Future Progress:

Spin:

- Bjorken Sum - a modest factor
- Gluon polarization - needs second generation measurement,
- strange quark situation - unsatisfactory
- transverse structure

Probes:

- role for EIC
- role for neutrino's?
- anti protons?