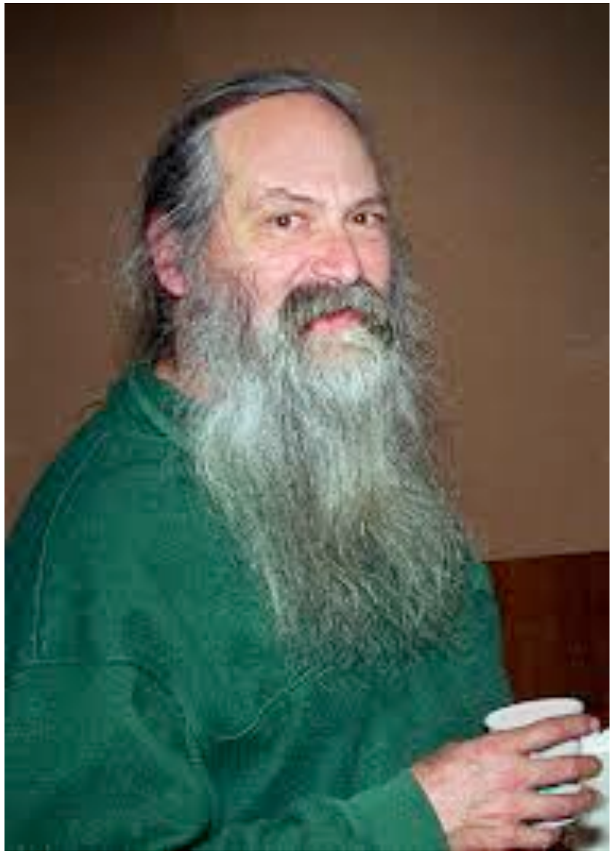
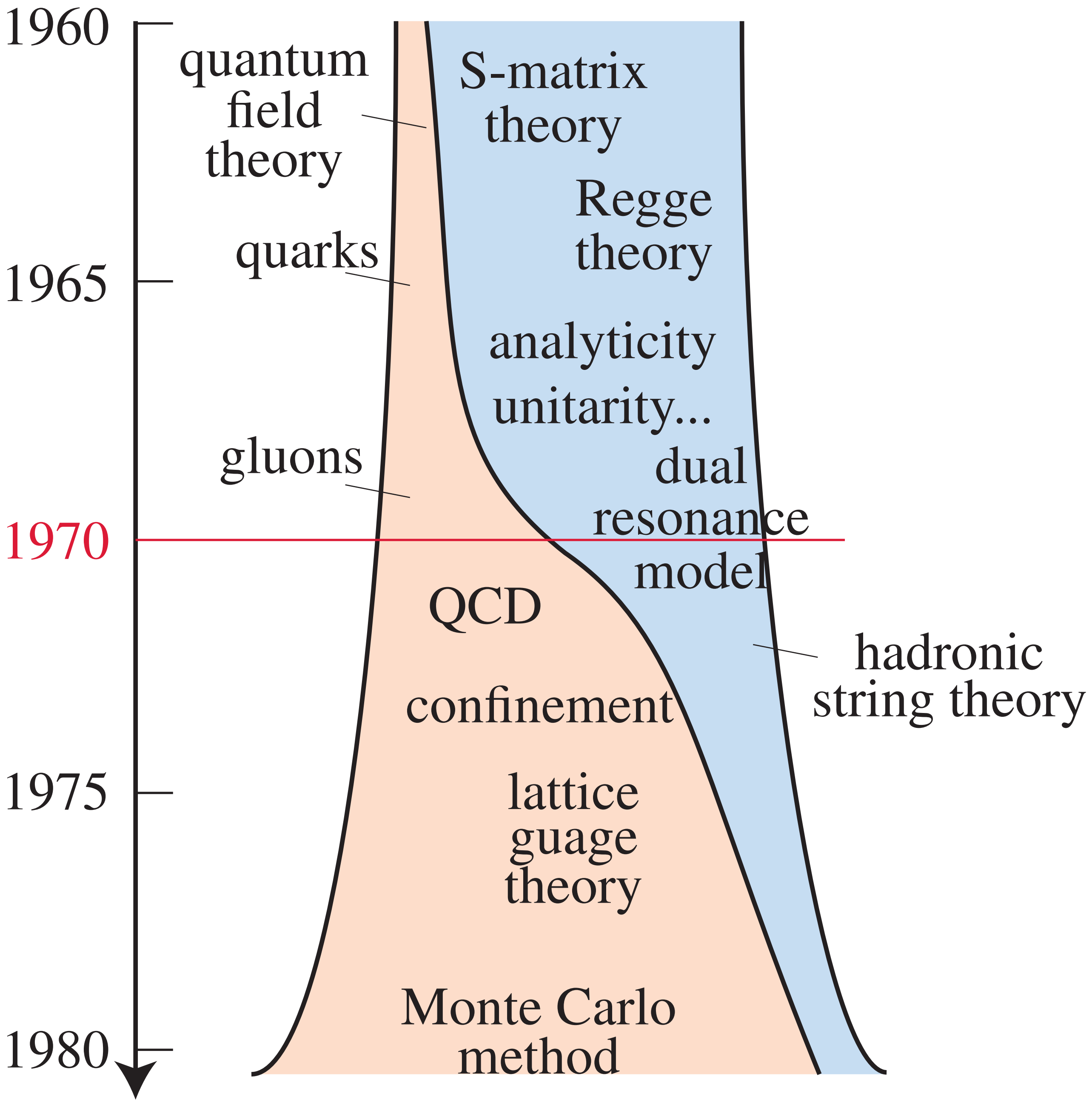
Mike at SLAC and other observations

(and a small challenge for lattice QCD)



Bob Jaffe
BNL
September 2014

A great time to be a graduate student at SLAC 1966 – 1972



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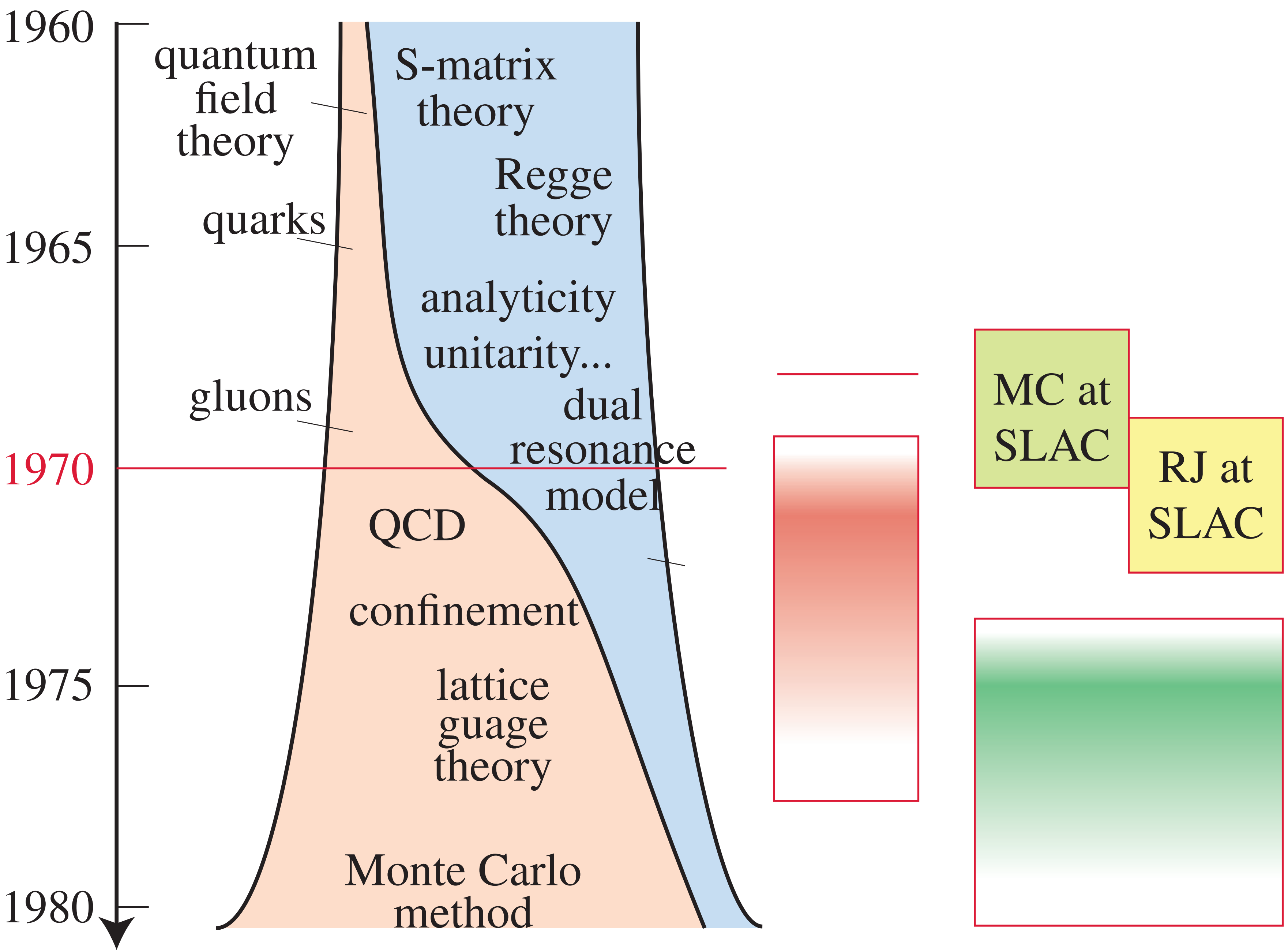

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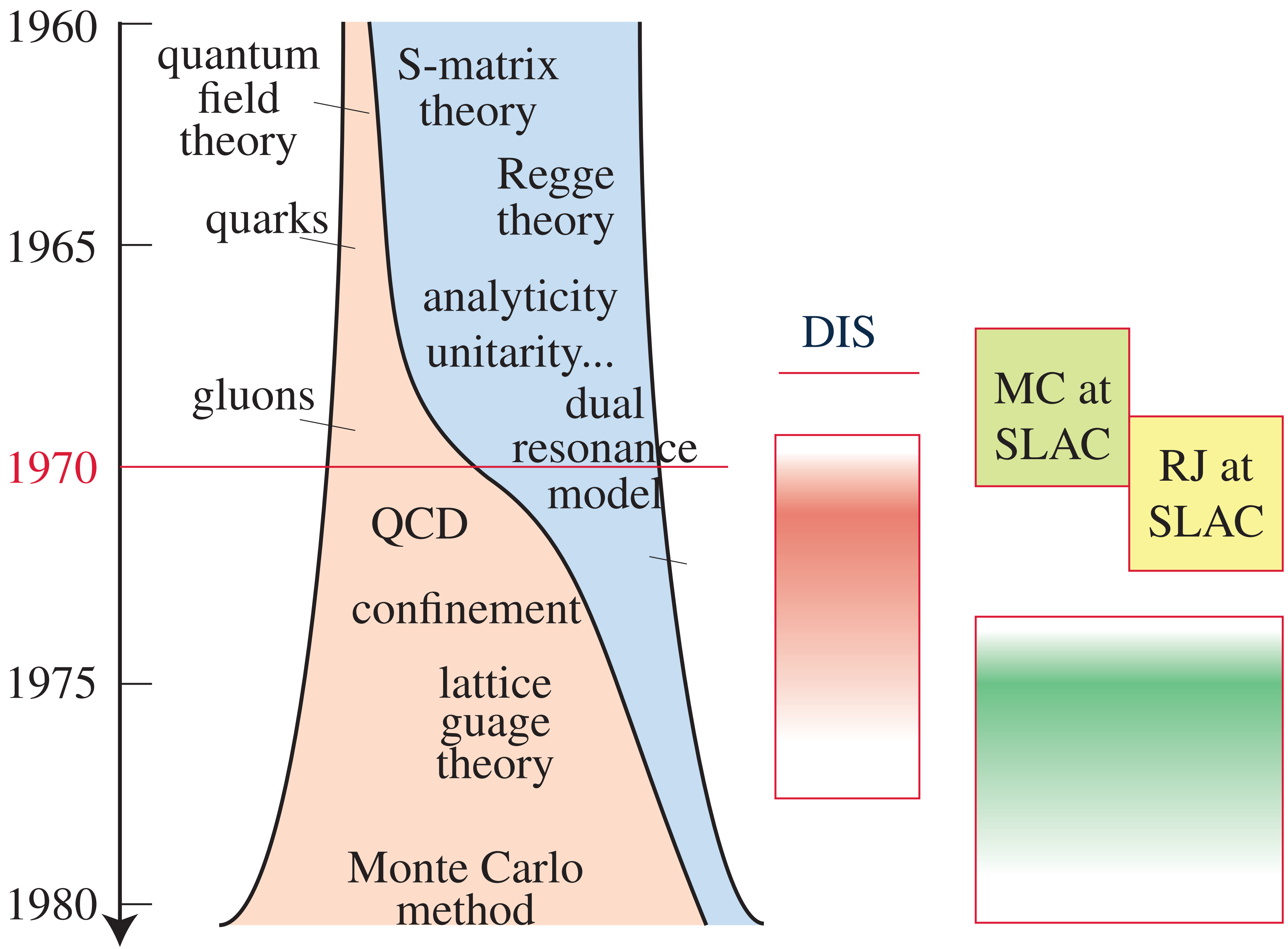

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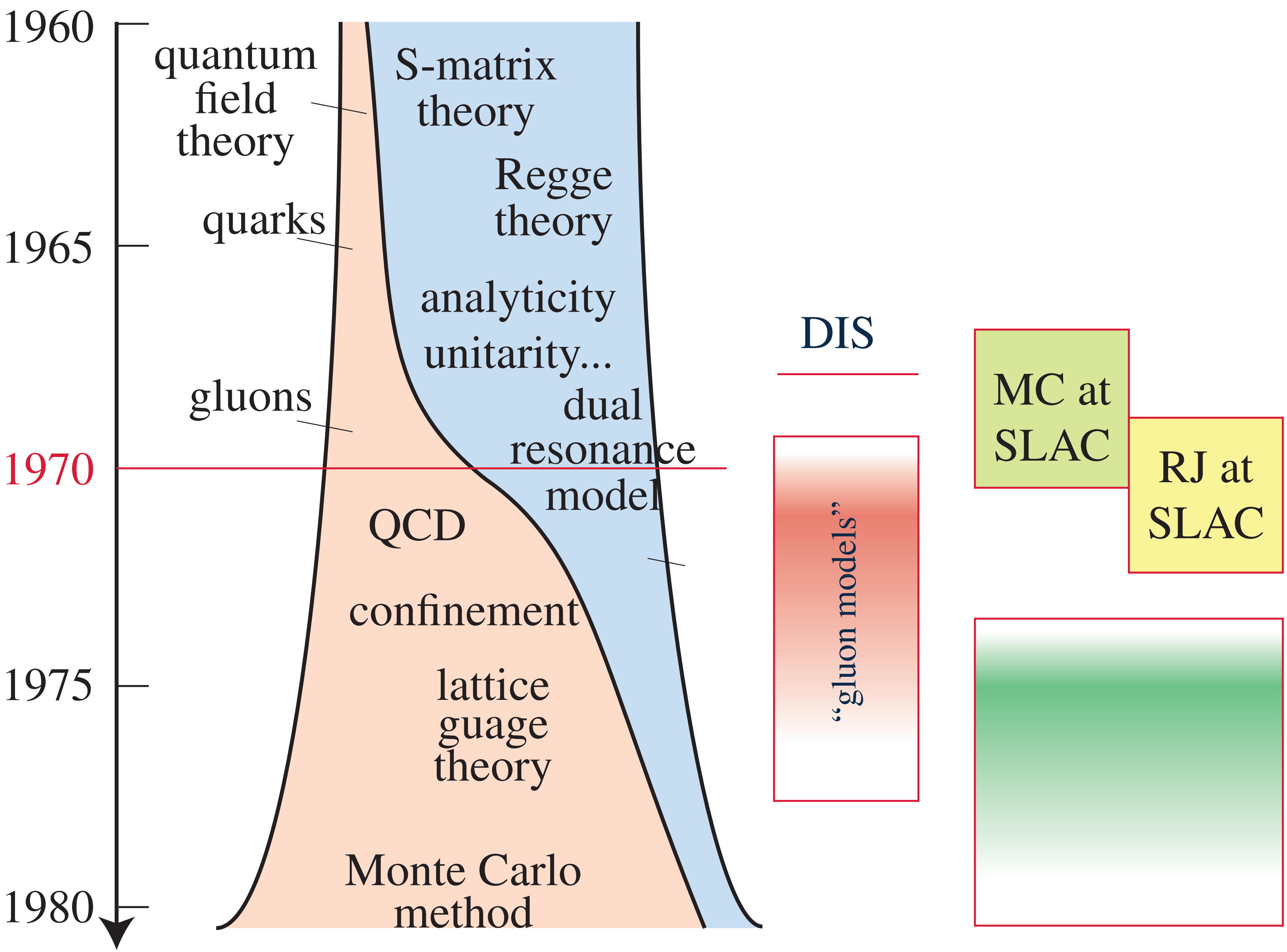

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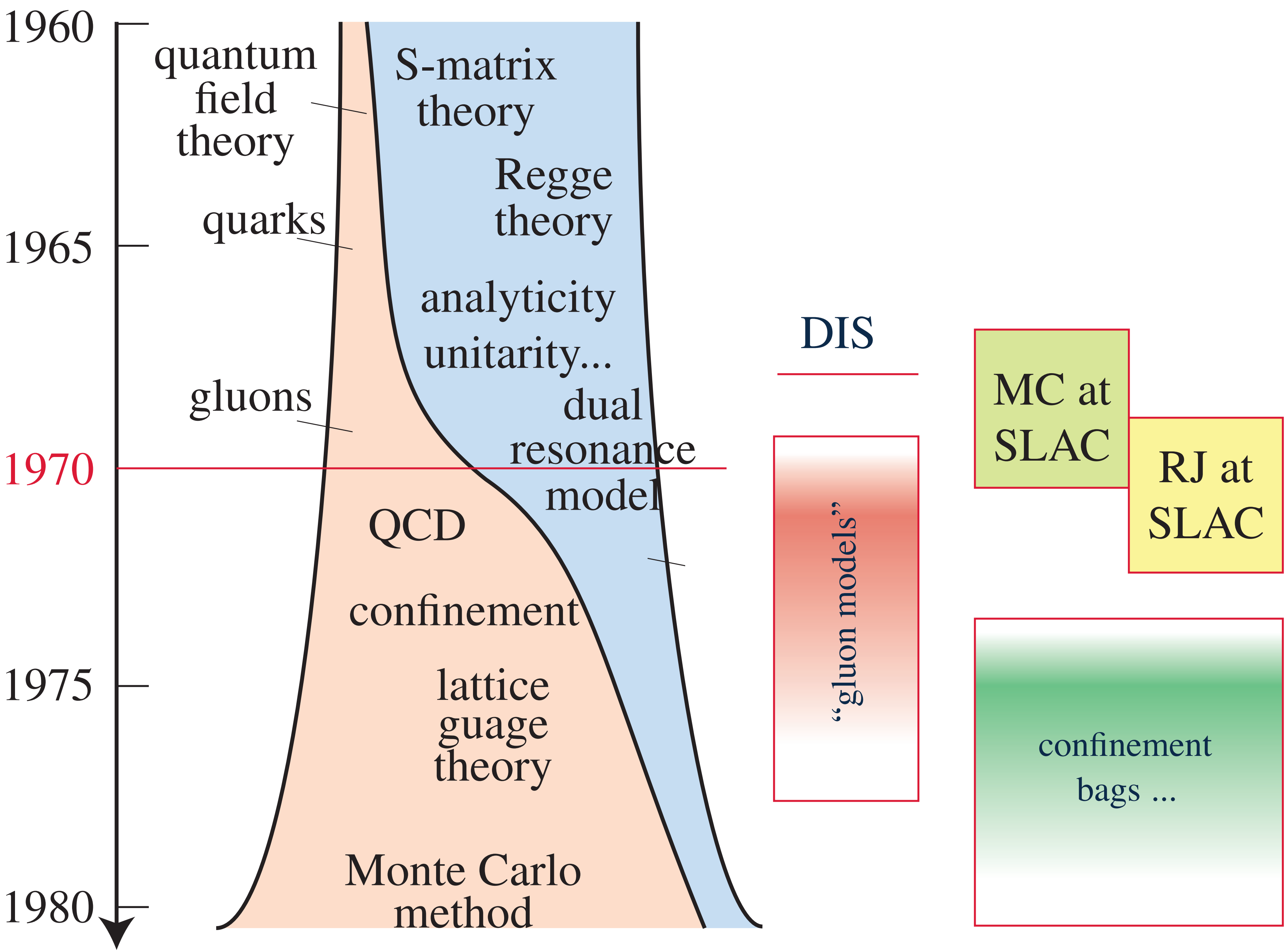

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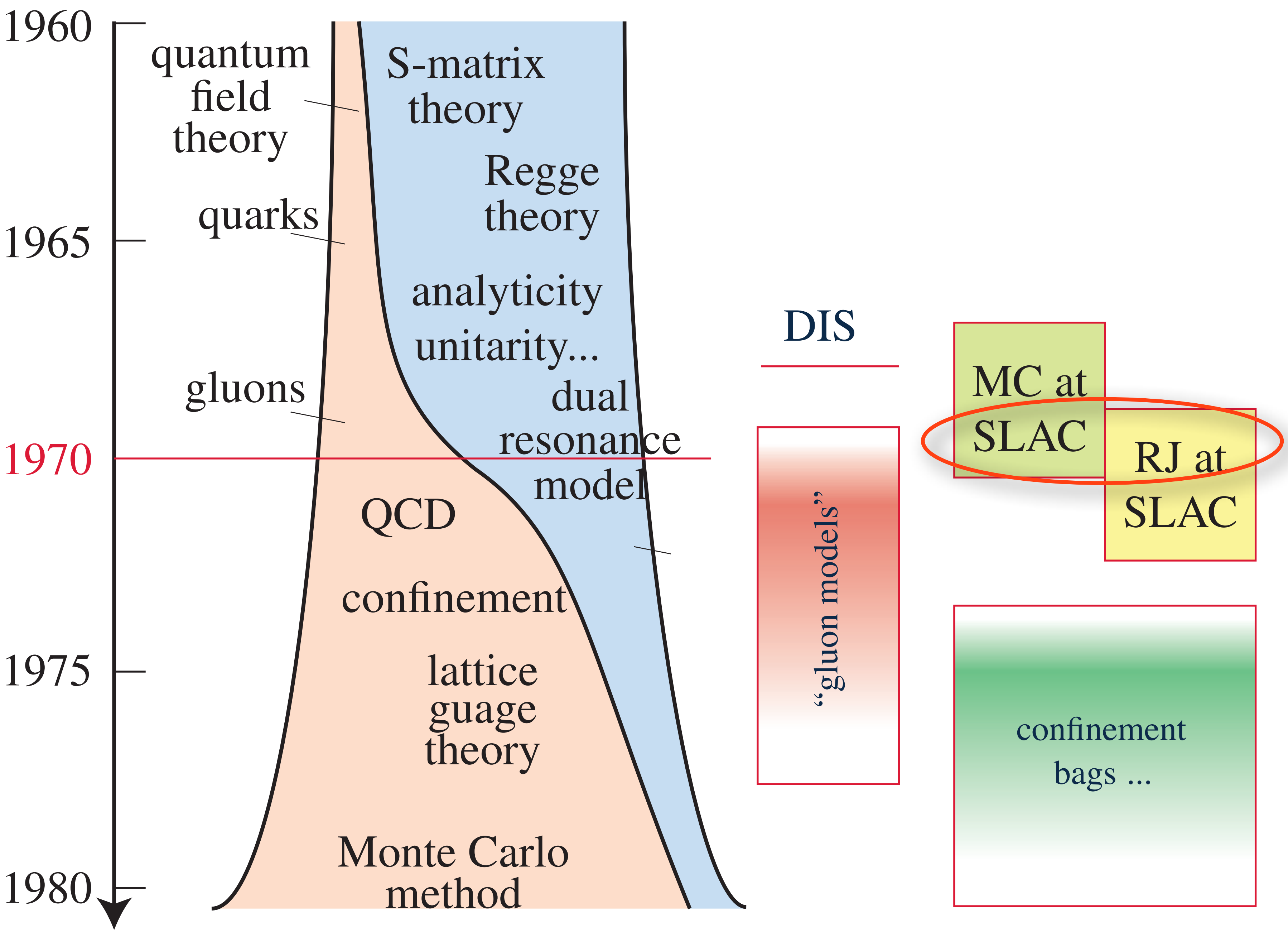


Some photographs...

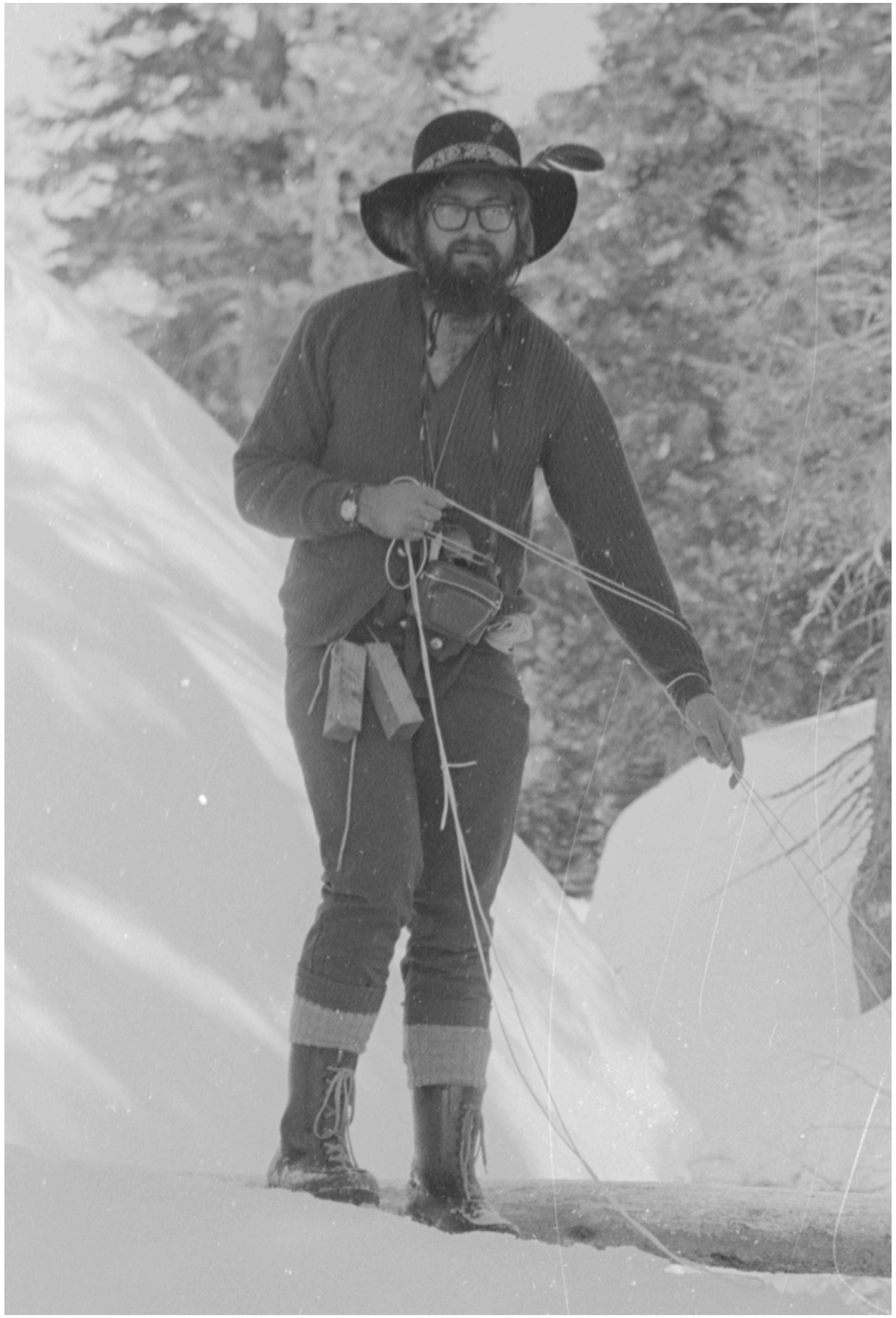
Some photographs...

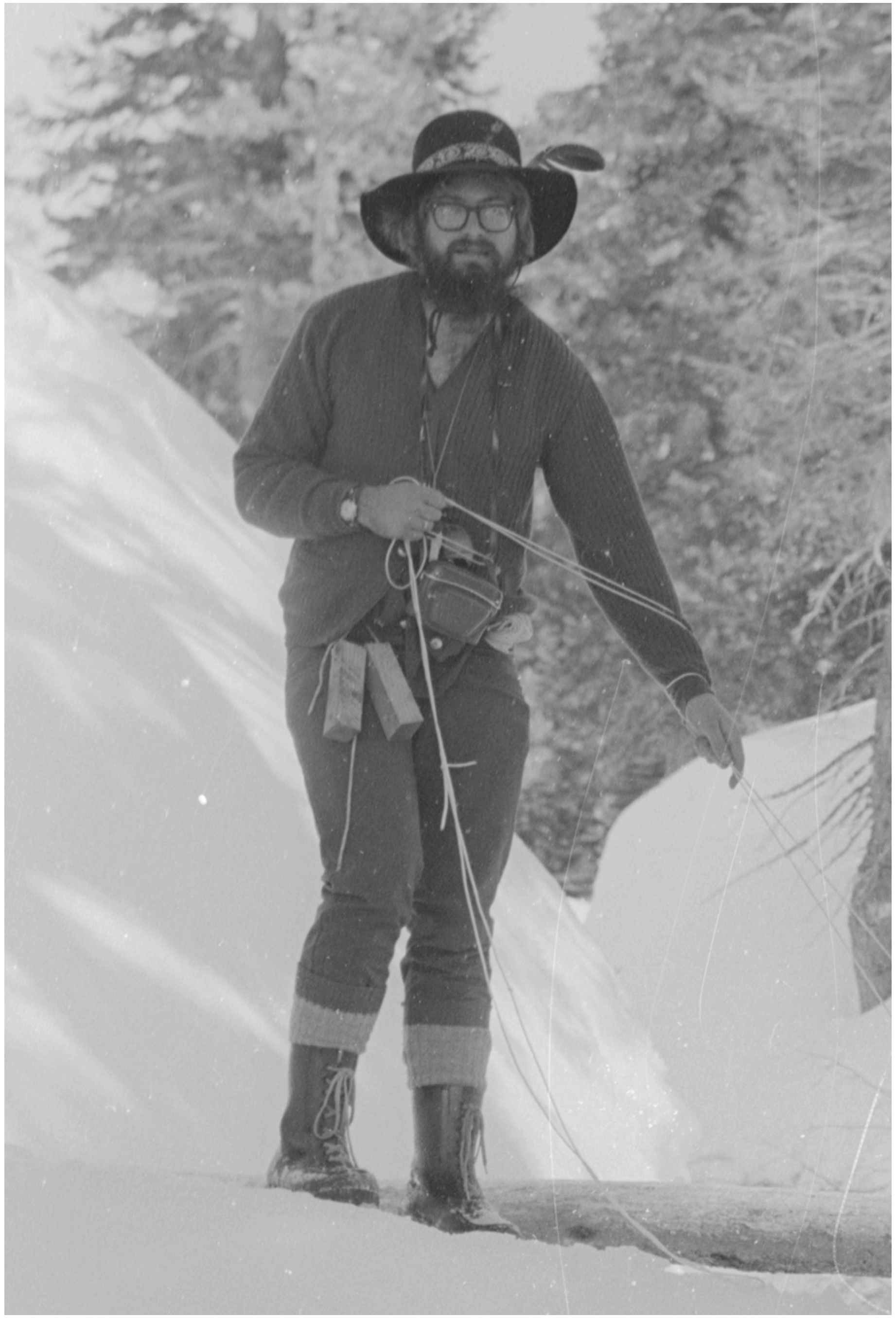
Winter 1969-70 Desolation Valley, Pyramid Peak Wilderness, Sierra Nevada, snowshoe, ski trip...

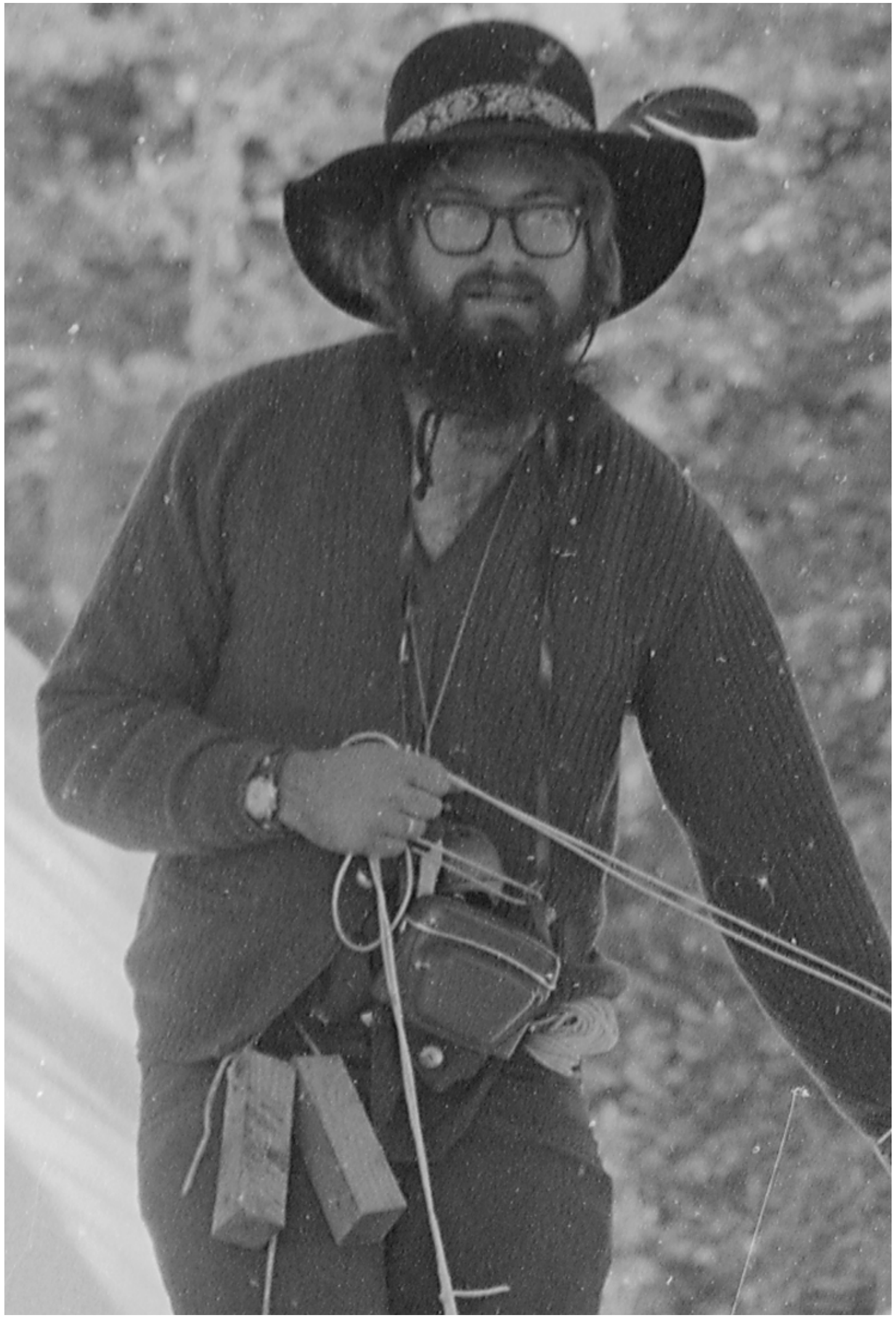
Some photographs…

Some photographs...

Some photographs...







Summer 1970 – Minarets Wilderness Sierra Nevada...

Mike and George Gaffney(?) going north while three of us were going south...

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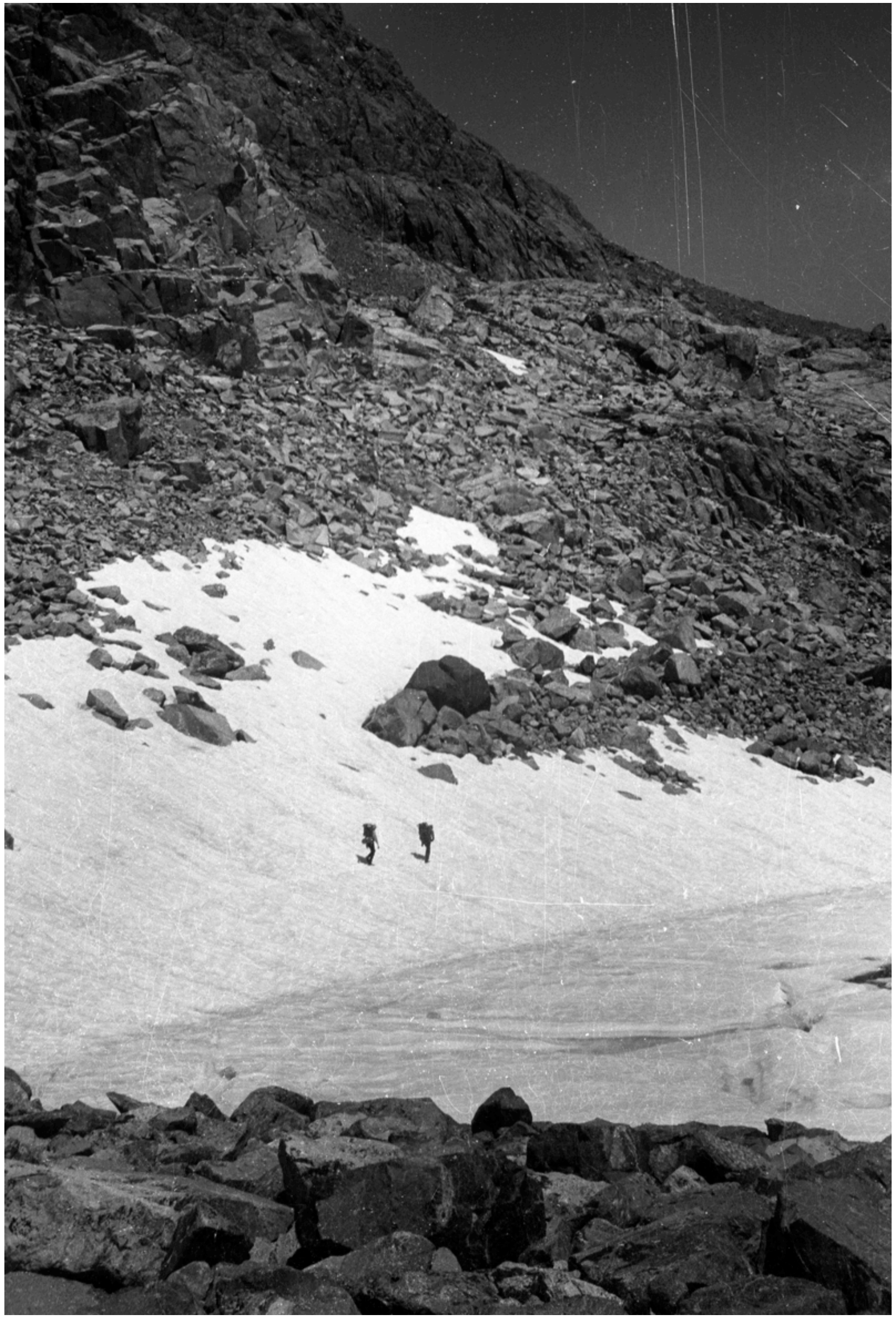

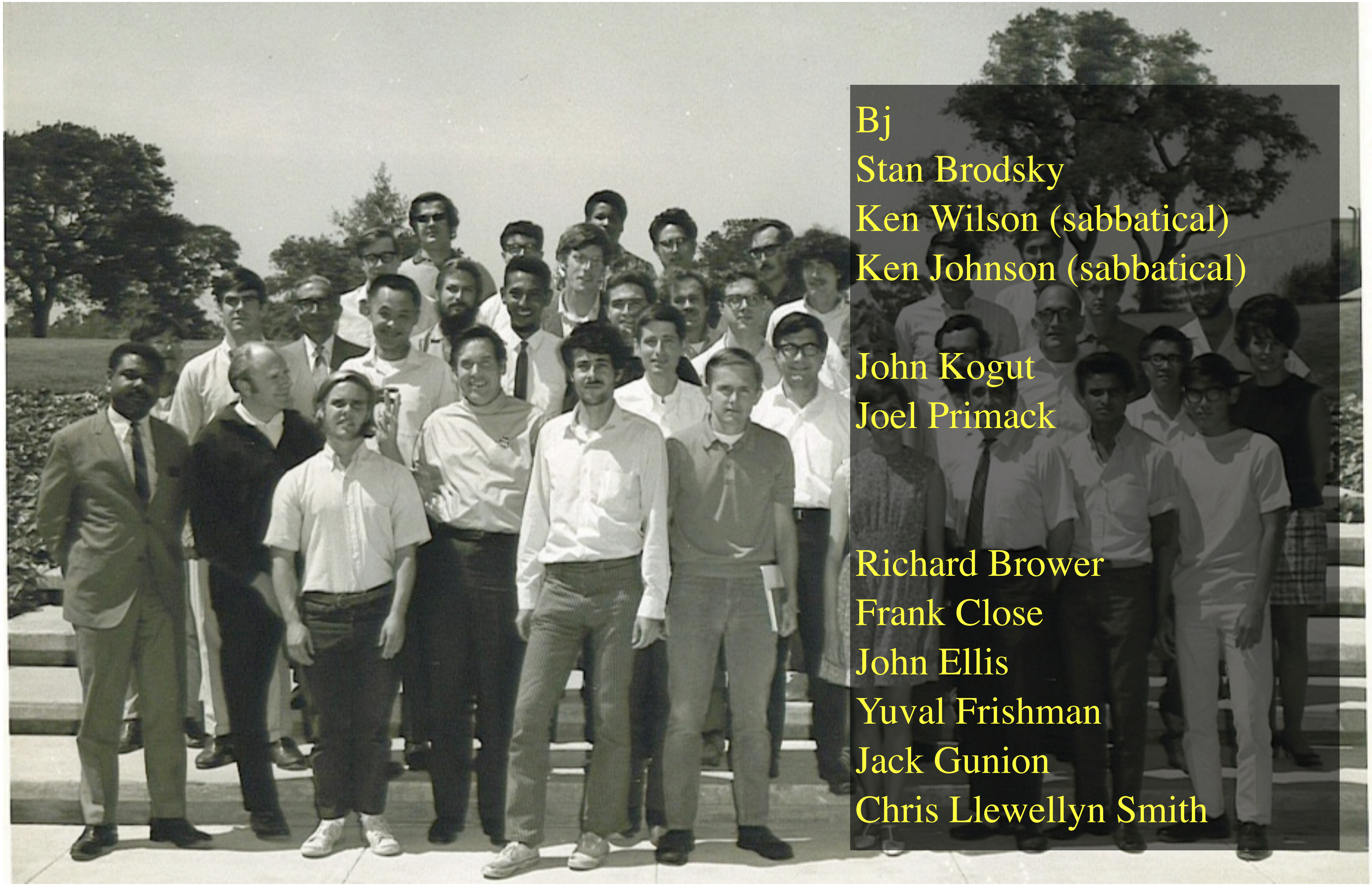
Bj
Stan Brodsky
Ken Wilson (sabbatical)
Ken Johnson (sabbatical)
John Kogut
Joel Primack
Richard Brower
Frank Close
John Ellis
Yuval Frishman
Jack Gunion
Chris Llewellyn Smith

Causality?

PHYSICAL REVIEW VOLUME 181, NUMBER 5 25 MAY 1969

Experimental Test of the Pion-Nucleon Forward Dispersion Relations at High Energies*

K. J. Foley, R. S. Jones,† S. J. Lindenbaum, W. A. Love, S. Ozaki, E. D. Platner, C. A. Quarles,‡ and E. H. Willen

Brookhaven National Laboratory, Upton, New York 11973

(Received 2 December 1968)

interference with the known Coulomb amplitude. Combining these results with precision measurements of pion-proton total cross sections over this energy range provided a critical test of the predictions of the forward dispersion relations. The results demonstrate the validity of the dispersion relations up to at least 20 GeV/c laboratory momentum. The predictions of charge independence are also verified by comparing these experimental measurements with forward charge-exchange scattering cross sections. Furthermore, if microscopic causality is violated, this occurs at "distances" less than 10^{-15} cm.

Causality, unitarity, bounded cross sections ⇒ forward dispersion relations

Real part of forward πN scattering amplitude is determined by cross section and coupling constants.

$$D_l^+(\omega)=D_l^+(1)+\frac{f^2k^2}{M[1-(1/2M)^2][\omega^2-(1/2M)^2]}+\frac{k^2}{4\pi^2}P\int_1^\infty\frac{\omega'}{k'}\frac{(\sigma_-+\sigma_+)}{(\omega'^2-\omega^2)}d\omega',$$

$$D_l^-(\omega)=\frac{2f^2\omega}{\omega^2-(1/2M)^2}+\frac{\omega}{4\pi^2}P\int_1^\infty\frac{k'}{\omega'^2-\omega^2}\times(\sigma_--\sigma_+)d\omega',$$

PHYSICAL REVIEW D VOLUME 2, NUMBER 10 15 NOVEMBER 1970

Noncausal Dispersion Relations and a Fundamental Length*

MICHAEL CREUTZ† AND ROBERT JAFFE‡
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305
(Received 27 July 1970)

We study the use of dispersion relations, modified to violate causality, as a tool to limit a fundamental noncausal length. We find that unless the usual dispersion relations are found to be violated, noncausal dispersion relations give no new information. This means that the only presently believable limit on a noncausal length is given by dimensional analysis.

- There are acausal theories where violation of dispersion relations could be pushed to arbitrarily high energies.
- First contact with BNL!
- Letter (now lost) from Sam Lindenbaum...

  [5] We have corresponded with Lindenbaum on this point, and he agrees that the specific calculation was overdoing it. This calculation has been omitted in later work from the Lindenbaum group (Ref. 2).

- Paper has 3 citations!

An amusing challenge for lattice QCD in 2014

A Letter of Intent to Jefferson Lab PAC 42

Search for Exotic Gluonic States in the Nucleus ?

W. Detmold, R. Jaffe, J. Maxwell*, R. Milner

Laboratory for Nuclear Science, MIT, Cambridge, MA 02139

D. Crabb, D. Day, D. Keller, O. A. Rondon

University of Virginia, Charlottesville, VA 22904

M. Jones, C. Keith, J. Pierce

Thomas Jefferson National Accelerator Facility, Newport News, VA 23606

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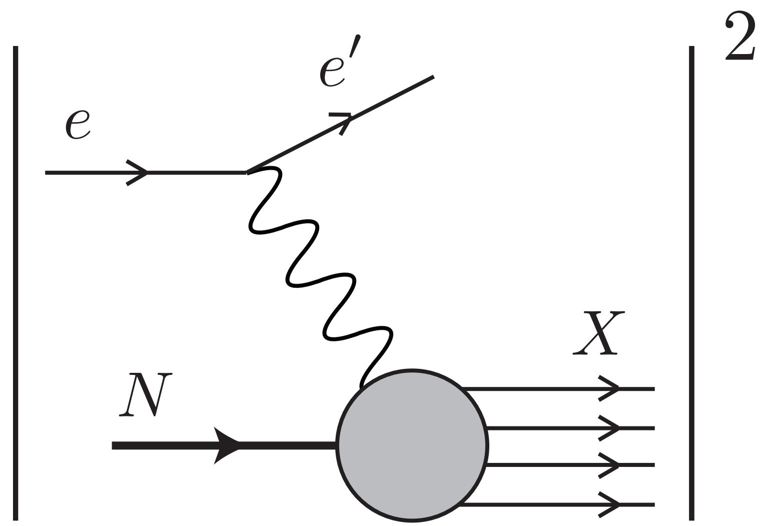

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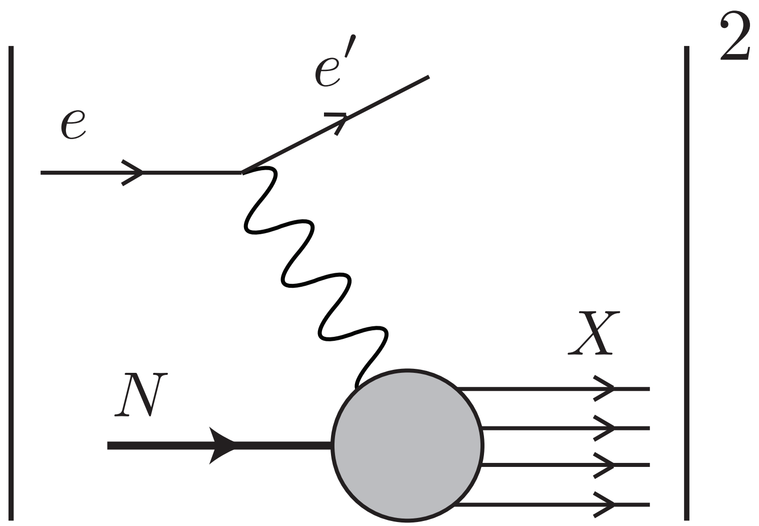

$\Longrightarrow$

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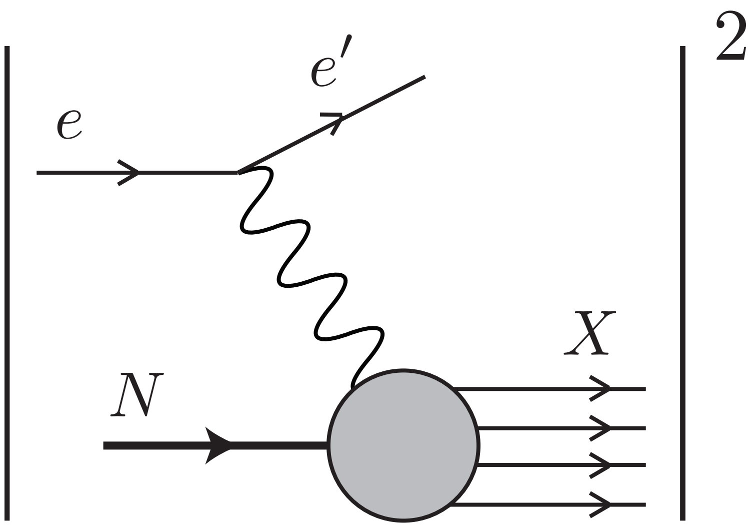

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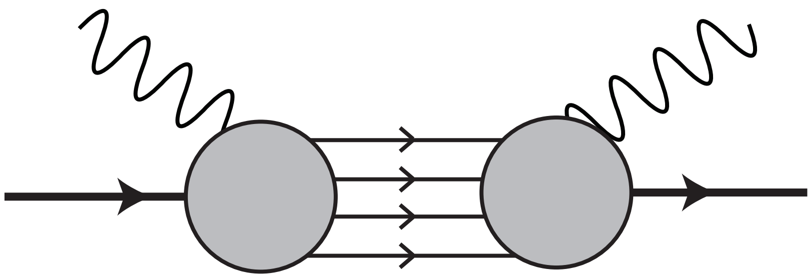

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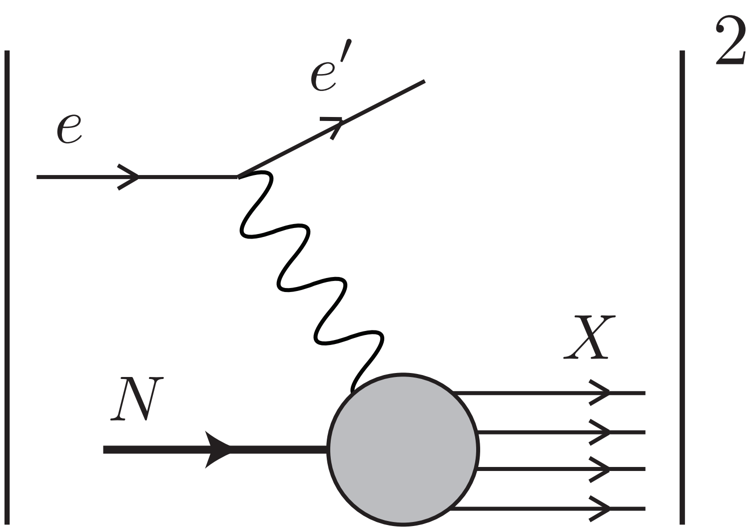
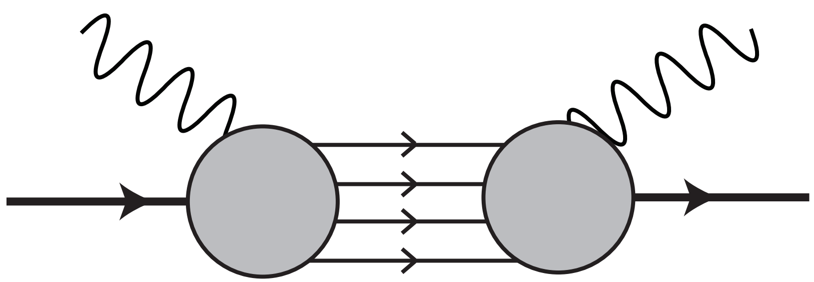


$\Longrightarrow$

Virtual photon helicity ±1



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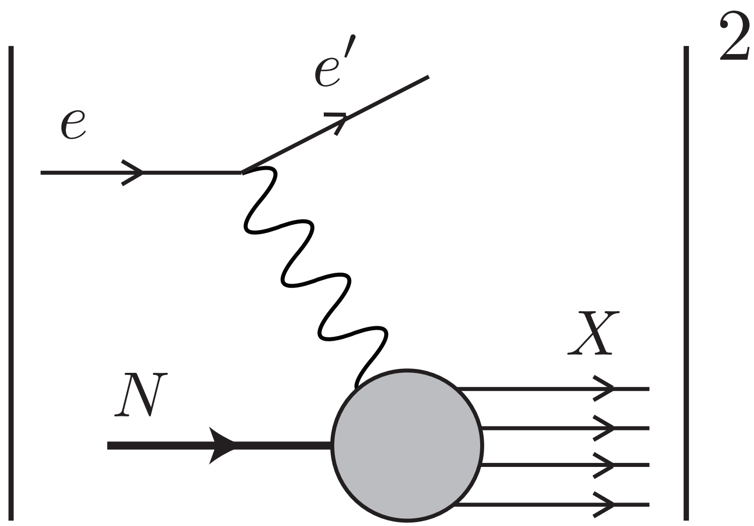

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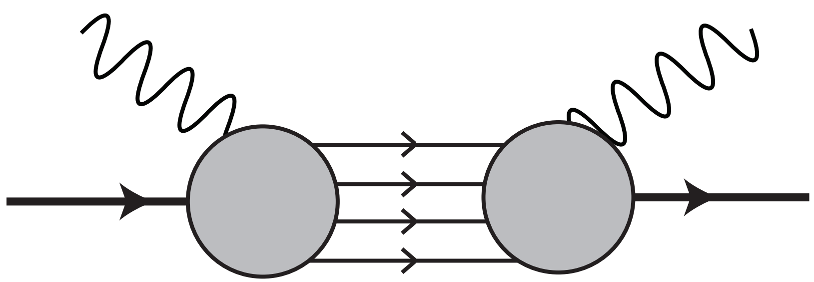
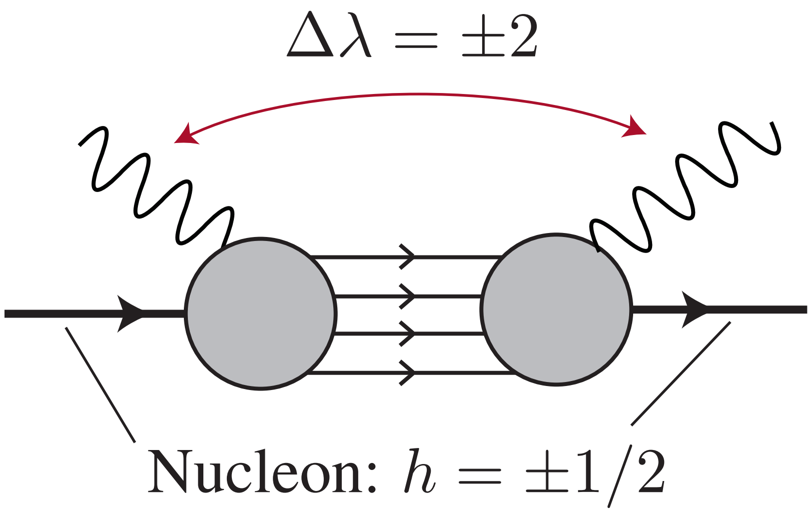
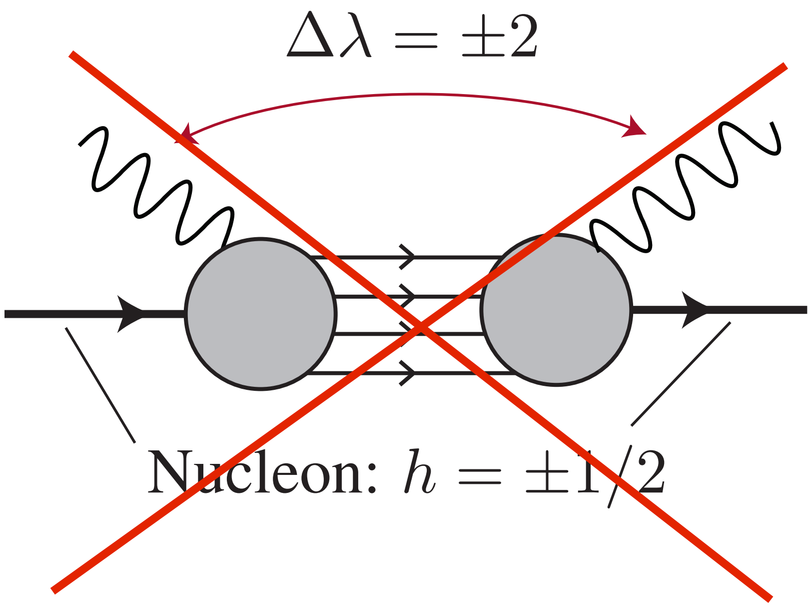
Virtual photon helicity ±1



Double helicity flip?


$\Delta\lambda = \pm 2$
Nucleon: $h = \pm 1/2$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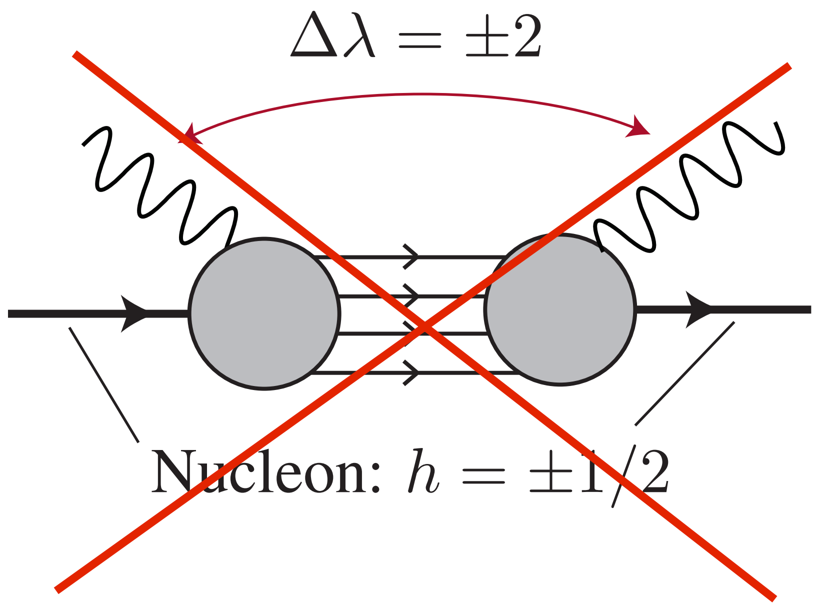
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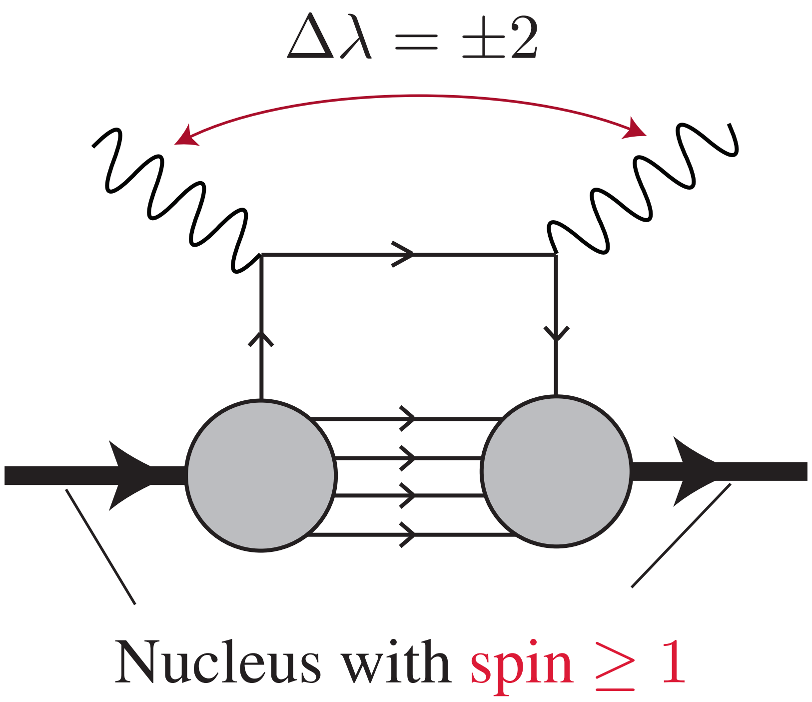
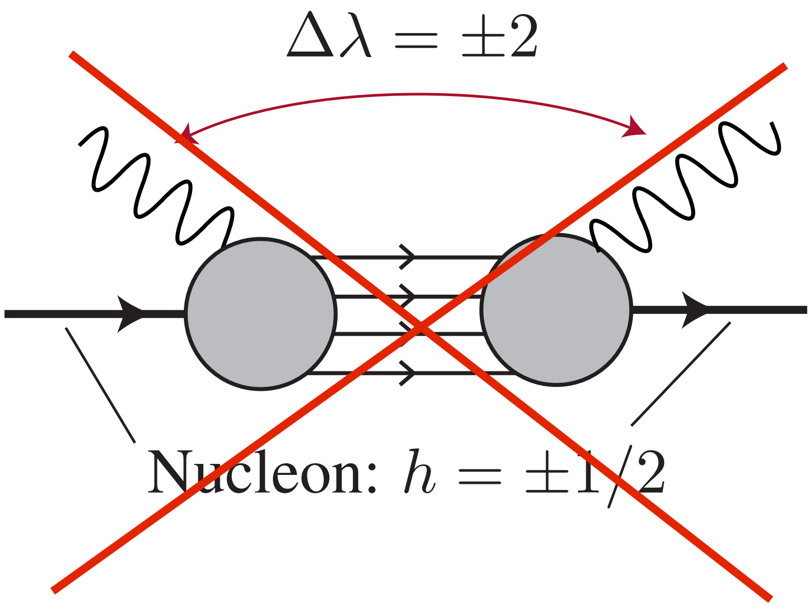

$\Delta\lambda = \pm 2$
Nucleus with spin ≥ 1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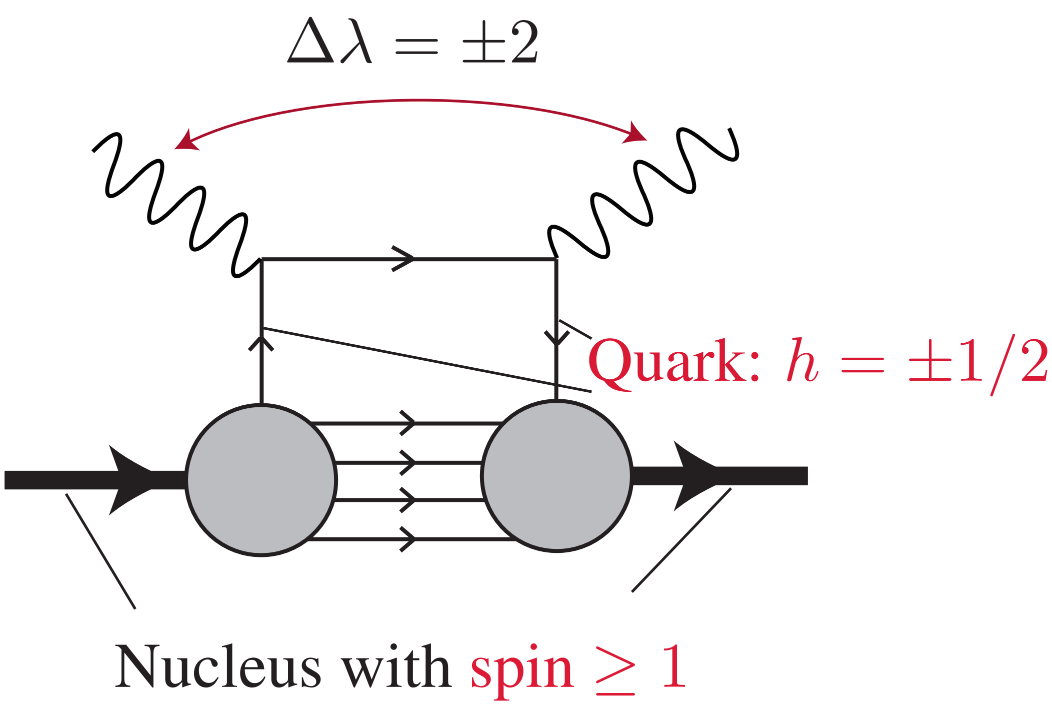
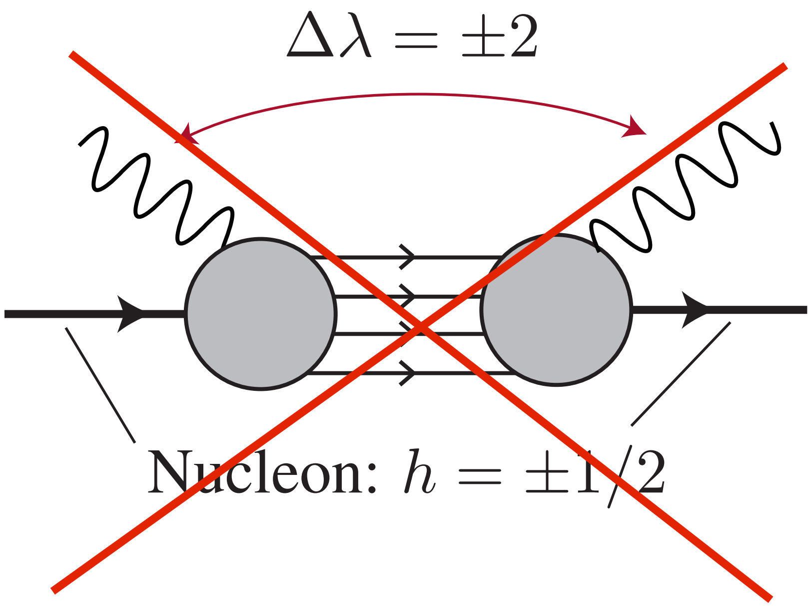

$\Delta\lambda = \pm 2$
Quark: $h = \pm 1/2$
Nucleus with spin ≥ 1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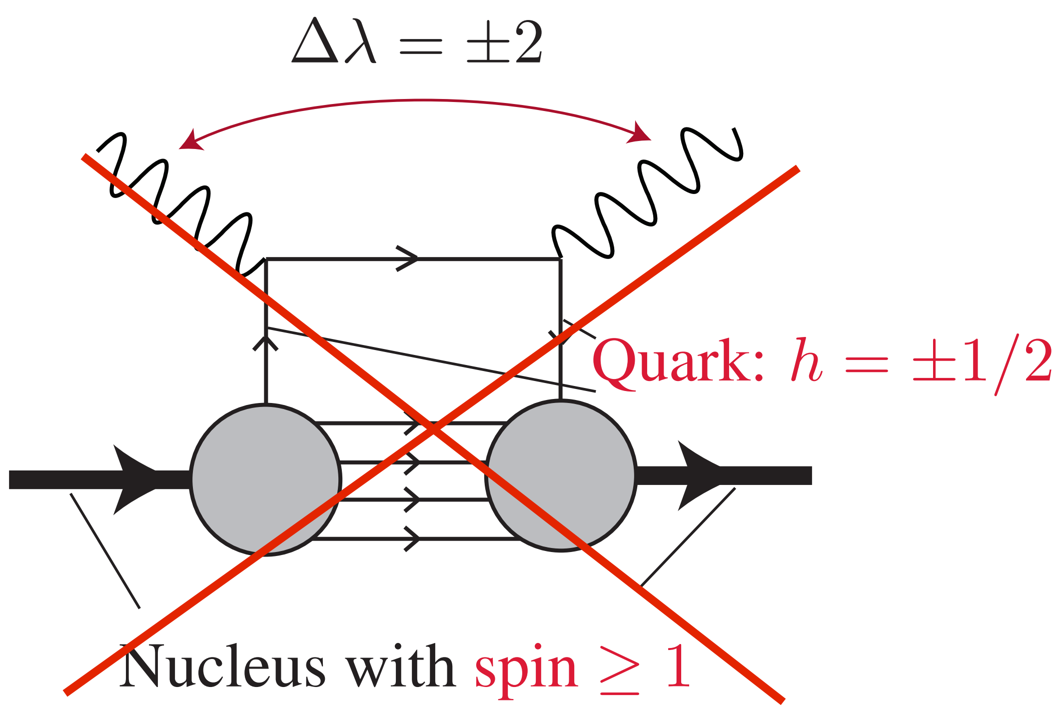
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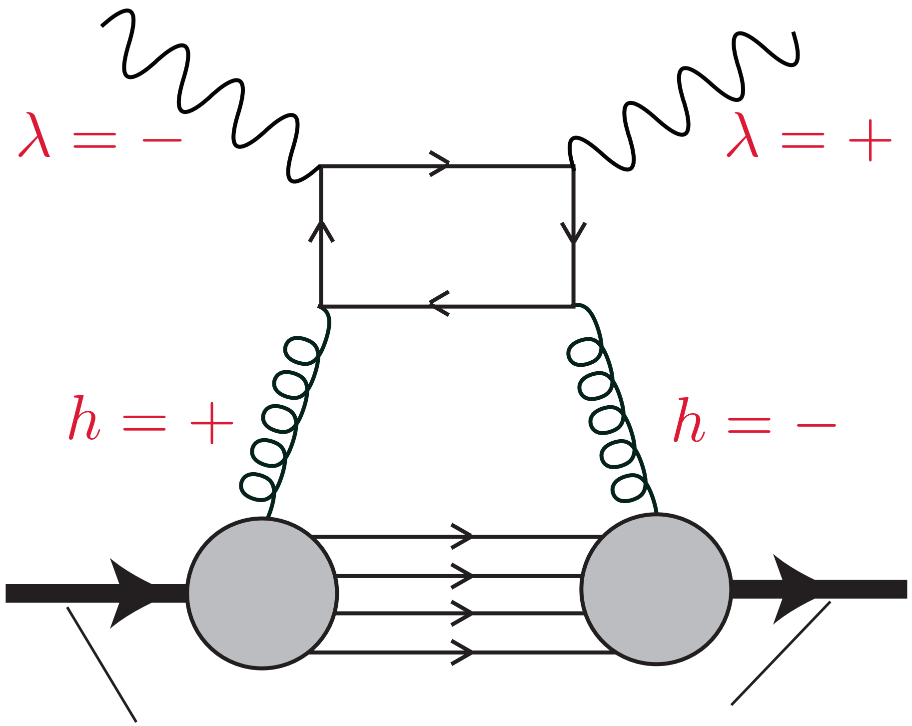
Nucleus with spin ≥ 1



Nucleus with spin ≥ 1

NUCLEAR GLUONOMETRY ☆

R.L. JAFFE and Aneesh MANOHAR
Center for Theoretical Physics, Laboratory for Nuclear Science
Cambridge, MA 02139, USA

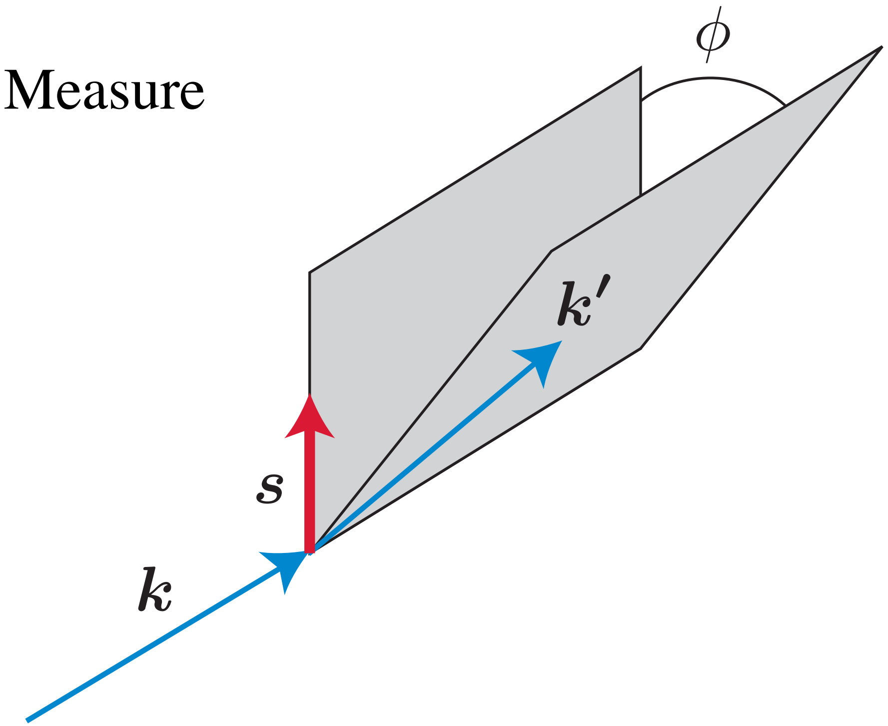
Received 24 March 1989

Photon double helicity flip is sensitive to

- Gluons in target with spin ≥ 1
- But only those not associated with a single nucleon
- Possibly very small, but very interesting...

Virtual ρ's, Δ's?
Gluons "in flight"?
...

Measure



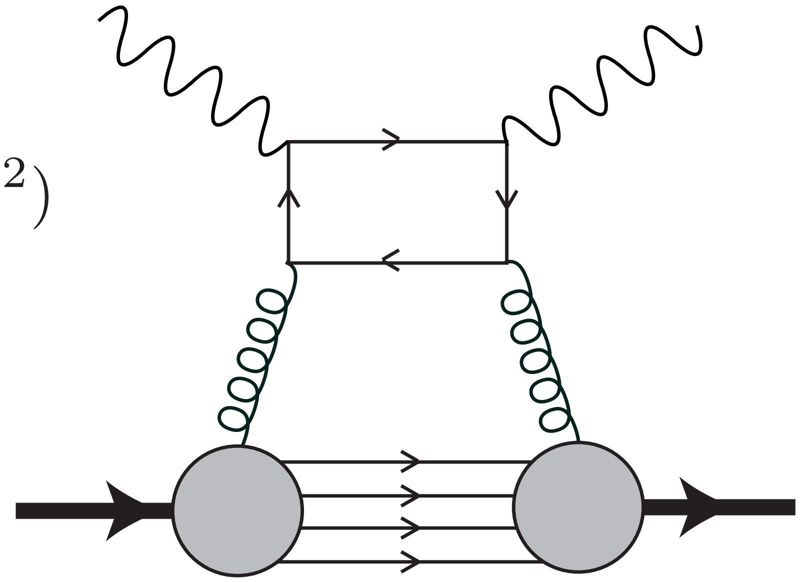
- Scattering of unpolarized electrons from a spin ≥ 1 target.
- Aligned at an angle (e.g. 90º) to the electron beam.

- Either measure azimuthal dependence, or
- Compare cross sections with spin rotated by 90º

$$\frac{2\pi\frac{d\sigma}{dxdxd\phi}}{\frac{d\sigma}{dxdy}} = 1 - \frac{1}{2}\frac{x(1-y)\Delta(x,Q^2)\cos 2\phi}{xy^2 F_1(x,Q^2) + (1-y)F_2(x,Q^2)}$$

What is being measured?

$$\Delta(x,Q^2) = \frac{\alpha_s(Q^2)}{2\pi}\mathrm{Tr}\mathcal{Q}^2\, x^2 \int_x^\infty \frac{dy}{y^3} a(y,Q^2)$$



A tower of gluon operators that is independent of

$G(x,Q^2)$ and $\Delta G(x,Q^2)$

$$\mathcal{O}_{\mu\nu\mu_1\ldots\mu_n} \equiv \frac{1}{2}\left(\frac{i}{2}\right)^{n-2} \mathcal{S}\left\{G^a_{\mu\mu_1}\overleftrightarrow{D}_{\mu_3}\ldots\overleftrightarrow{D}_{\mu_n}G^a_{\nu\mu_2}\right\}$$

$$\langle p,E|\mathcal{O}_{\mu\nu\mu_1\ldots\mu_n}|p,E'\rangle = \{\ldots\}\,A_n(Q^2)$$

$$A_n(Q^2) = \int_0^1 dx\, x^{n-1} a(x,Q^2)$$

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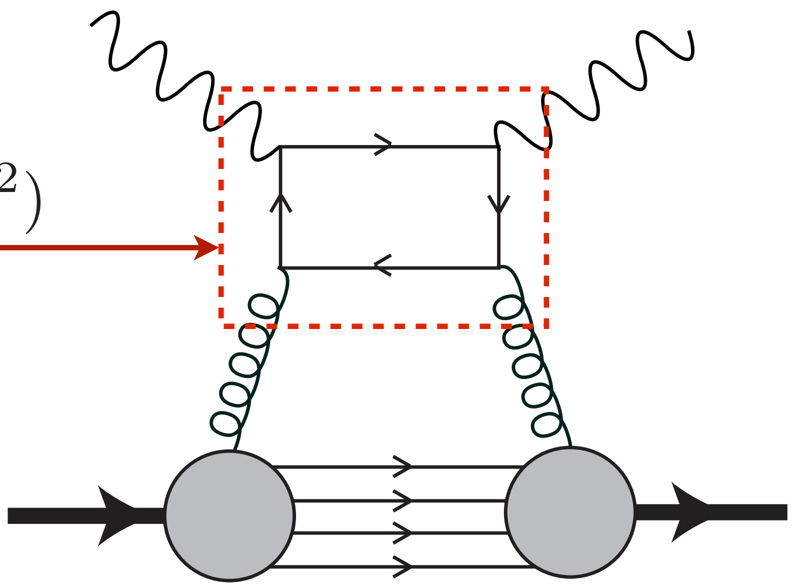

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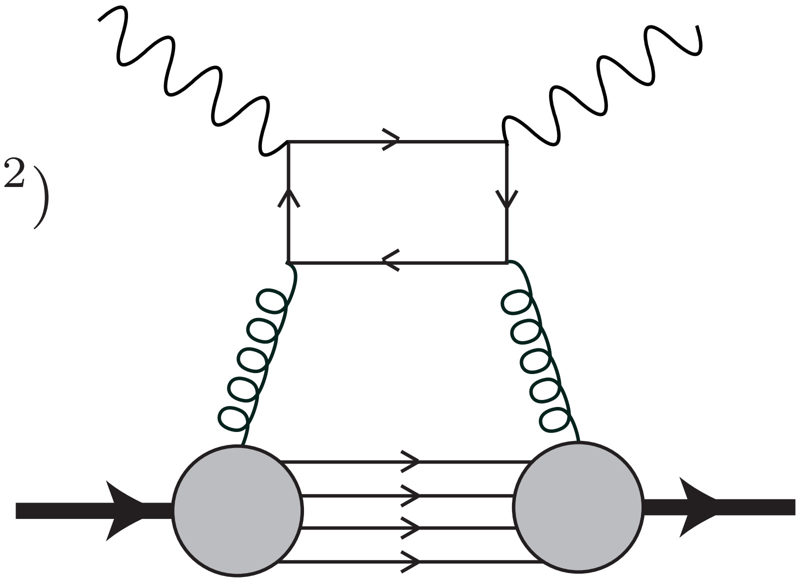

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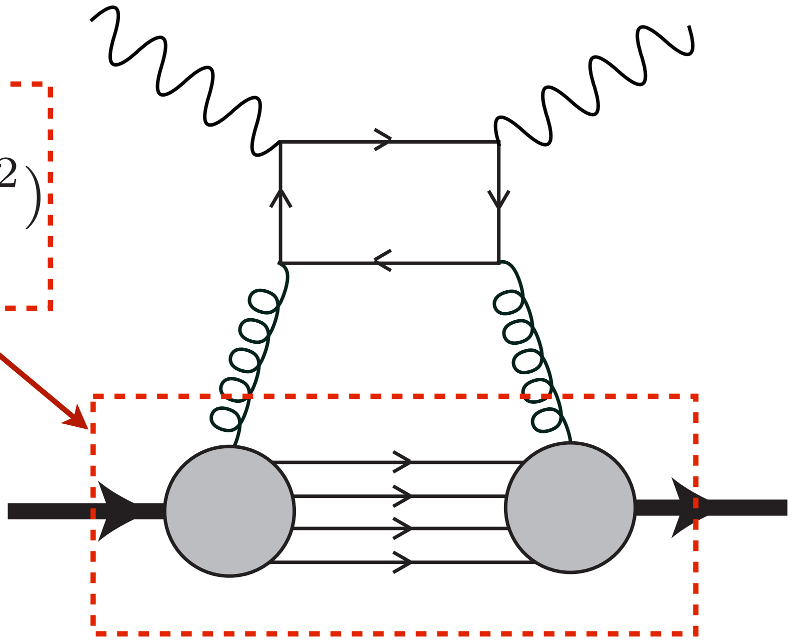

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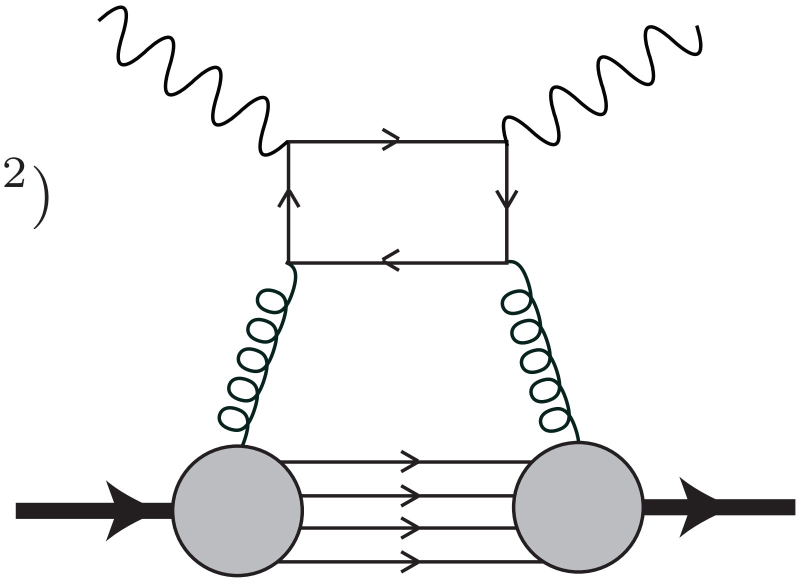

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$$A_n(Q^2) = \int_0^1 dx\, x^{n-1} a(x,Q^2)$$

Interpretation?

Suppose target is aligned in the $\hat{\boldsymbol{x}}$ direction and $g_{\hat{\boldsymbol{n}}}(x,Q^2)$ is distribution of gluons linearly polarized in $\hat{\boldsymbol{n}}$ direction, then

$$a(x,Q^2) = g_{\hat{\boldsymbol{x}}}(x,Q^2) - g_{\hat{\boldsymbol{y}}}(x,Q^2)$$

Quarks:

Spin average: $q(x,Q^2)$

Helicity difference: $\Delta q(x,Q^2)$

Transversity difference: $\delta q(x,Q^2)$

Gluons:

Spin average: $G(x,Q^2)$

Helicity difference: $\Delta G(x,Q^2)$

Transversity difference: $a(x,Q^2)$

"Soffer inequality":

$$|a(x,Q^2)| \leq \frac{1}{2}\left(G(x,Q^2) + \Delta G(x,Q^2)\right)$$

Lattice calculation?

$a(x, Q^2)$ does not mix with any other leading twist operators

- What nucleus?
- Lowest moment is a spin-4 operator...
- Will Detmold (MIT) & Phiala Shanahan (Adelaide) -- work in progress!