Andreas and the early universe (past and future)

Wilfried Buchmüller

Andreas' Fest, DESY, September 2024

First encounter: CERN 1985

HD - THEP - 85 - 18

ENTROPIEPRODUKTION, AUFHEIZEN
UND BARYOGENESE
IM
INFLATIONÄREN UNIVERSUM

Diplomarbeit
von
Andreas Ringwald

impressive Diploma thesis on early universe cosmology (246 pages): entropy production, reheating, baryogenesis, inflation …

… must be an interesting person …

subsequently PhD at Heidelberg (supervisor Michael Schmidt)

Ausgeführt am Institut für Theoretische Physik
der Universität Heidelberg

Heidelberg, September 1985

1988 - 1990: postdoc at DESY

HIGH ENERGY BREAKDOWN OF PERTURBATION THEORY IN THE ELECTROWEAK INSTANTON SECTOR

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Received 30 June 1989

famous paper, fundamental physics problem, challenging QFT problem …

of this Green function implies, according to the LSZ reduction formula [27], the existence of the process

$$q_1 + q_1 \to \bar{q}_1 + 3\bar{q}_2 + 3\bar{q}_3 + \bar{\ell}_1 + \bar{\ell}_2 + \bar{\ell}_3 \,, \tag{13}$$

or the corresponding *CP* conjugated process, where particles are replaced by anti-particles and vice versa. Here the subscripts label the generations, which we take to be three. The (anti-)quarks of the same generation should have different colors in (13). The fermion number of each "flavor" is changed by one unit in the process (13). So one expects that this process is induced by gauge fields with one unit of topological charge. The fact that the Green function (12) is non-zero was established by 't Hooft [1]. It is given by the euclidean path integral

$$G(x_1, \ldots, x_{n_f}) = \int_{Q=1} [dW][d\Phi][d\psi^\dagger][d\psi] \exp\{-S[W, \Phi, \psi^\dagger, \psi]\} \prod_{i=1}^{n_f} \psi^{(i)}(x_i) \,, \tag{14}$$

inspiration from Harry Lehmann?

story still not settled

…

→ Staff, CERN

1994 - 2001: instantons at HERA

Zooming-in on instantons at HERA

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Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

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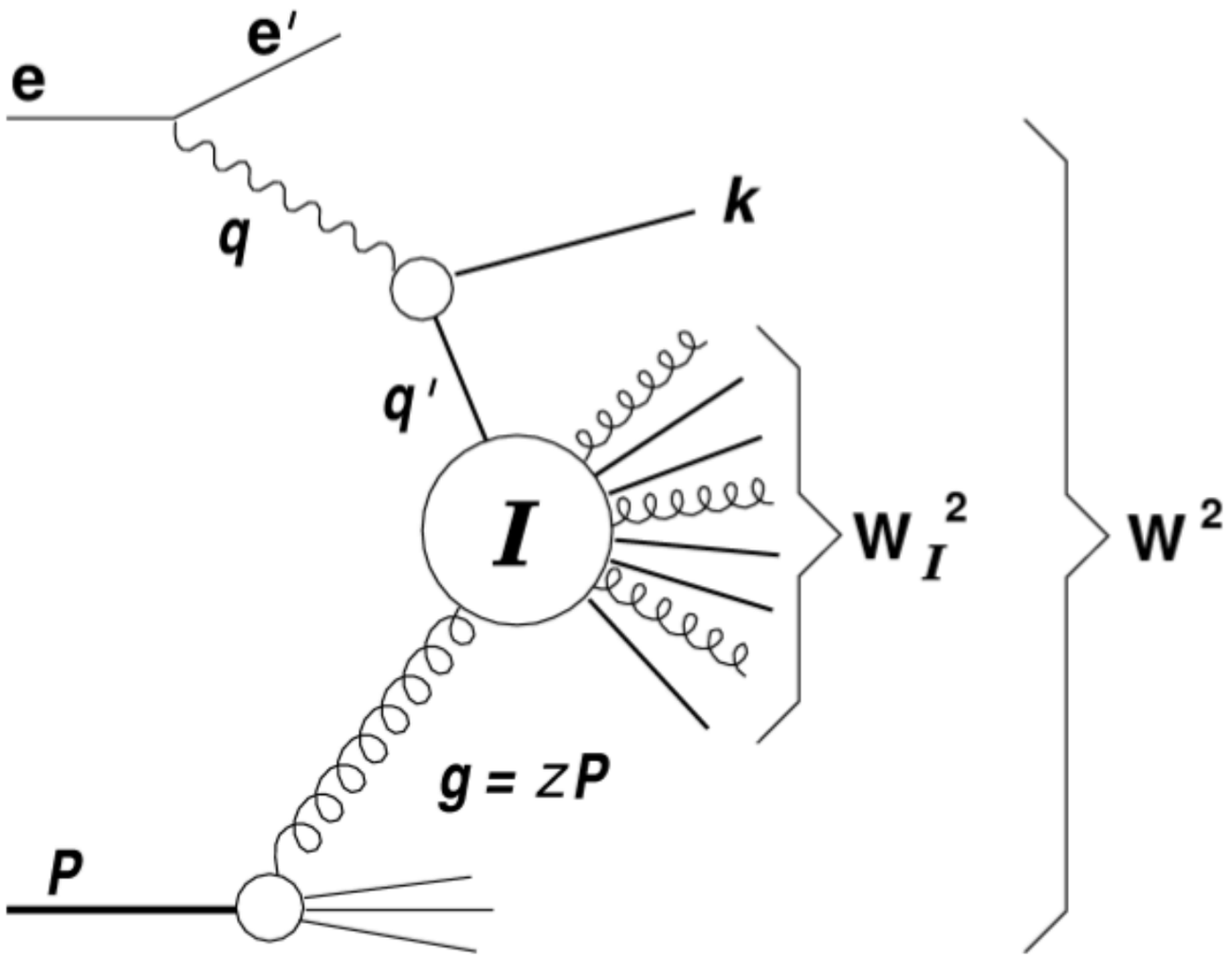
Abstract

In view of the intriguing, preliminary search results for instanton-induced events at HERA from the H1 Collaboration some important remaining theoretical issues are discussed. Notably, the question is addressed, to which extent the H1 analysis may be directly compared to our original predictions from instanton-perturbation theory, since certain fiducial cuts are lacking in the H1 data. Various theoretical uncertainties are evaluated and their impact on the observed excess is discussed. An improved understanding of the experimental findings along with an encouraging over-all agreement with our original predictions seems to emerge.

1994: back at DESY as staff member; no more cosmology, instead instantons in DIS at HERA; important problem of the real world (d=4, N=0), crucial for cosmology; dedicated work with Fridger Schrempp for 7 years (also experimenters, PhD Sven Moch)

Kinematics of DIS



DIS variables:

$$S = (e + P)^2,$$

$$Q^2 = -q^2 = -(e - e')^2,$$

$$x_{\mathrm{Bj}} = Q^2/(2P \cdot q),$$

$$W^2 = (q + P)^2 = Q^2(1/x_{\mathrm{Bj}} - 1),$$

$$x = Q^2/(2g \cdot q) = x_{\mathrm{Bj}}/z,$$

Variables of instanton-subprocess:

$$Q'^2 = -q'^2 = -(q - k)^2,$$

$$x' = Q'^2/(2g \cdot q'),$$

$$W_{\mathrm{I}}^2 = (q' + g)^2 = Q'^2(1/x' - 1).$$

Fig. 1. Structure and kinematic variables of the dominant instanton-induced process in deep-inelastic scattering.

search for "fireball"-like events with large number of hadrons in final state, also with "strangeness"; problem: formidable background of normal DIS; unfortunately no discovery; search continues at LHC

What about the future?

Prospects to scrutinise or smash SM*A*S*H

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SM*A*S*H is an extension of the Standard Model of particle physics which has just the minimal number of fields in order to solve six puzzles of particle physics and cosmology in one smash: vacuum stability, inflation, baryon asymmetry, neutrino masses, strong CP, and dark matter. The parameters of SM*A*S*H are constrained by symmetries and requirements to solve these puzzles. This provides various firm predictions for observables which can be confronted with experiments. We discuss the prospects and timeline to scrutinise or smash SM*A*S*H by cosmic microwave background polarisation experiments, axion haloscopes, and future space-borne gravitational wave detectors.

arxiv:2312.14679

With SM*A*S*H back to the topic of the Diploma Thesis: early universe cosmology, with few more details like axions, dark matter SGWB, exciting field, something will be discovered!

For the future: all the best !!

with excitement about physics and much joy beyond physics!!