EUROPEAN INSTITUTE FOR SCIENCES AND THEIR APPLICATIONS

CORFU SUMMER INSTITUTE 2022

MEMORIAL DAY FOR COSTAS KOUNNAS

4TH OF SEPTEMBER 2022

A SHORT CONTRIBUTION
TO THE MEMORY OF COSTAS

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COSTAS KOUNNAS

23 /1/ 1952 -21/1/ 2022

COSTAS AS A FRIEND AND AS A COLLEAGUE

- With Costas we had family relations soon after he finished his high school studies (1970) because of the our sisters's friendship.
- He registered at the Physics department of the university of Athens as top level student from Cyplrus according to the Greek-Cyprus University laws.
- Due to his top level grades at all courses of the Physics department he obtained his diploma

with the highest grade ever of the Physics department.

I supervised his BSc diploma work on Dirac' s paper for Hamiltonian systems with constraints. He had an amazing efficiency to understand the most difficult points .

I advised him before he continues to the graduate studies ,to serve first his army obligations in Cyprus. Unfortunately after few months Turkey invaded Cyprus and he had to participate in the front of this war. Fortunately he survived and he left Cyprus for his graduate studies at Ecole Normale Superieure with the advice and support of John Iliopoulos.

- After these difficult times I met Costas again in Paris in 1977 and I he told me that he was working on his Doctorat d Etat thesis for deep inelastic scattering,area in which I was working at Cern with my colleagues Chris Sachrajda and Douglas Ross.
- The next year (1978),I went for a 2 year Post Doc position at Theory Division of Saclay and there we collaborated together with Costas and Robert Lacage on this topics.
- We obtained the first results ever for the two loop QCD- fragmentation functions of quarks and gluons in e+e- inclusive hadron production(1981) and we checked all the results from my time at CERN.
- He was amazing in the intensity and speed of producing the correct results.
- **After some years all these results were successfully confirmed by various experiments at CERN,HERA,FERMILAB**.
- After that time Costas went very fast to the new directions of theoretical High energy Physics ,Supergravity, String Theory and Cosmology where his contributions are instrumental and internationally recognized.
- Other colleagues in this memorial day will ascertain in detail the truth of the above statements.

COMMON PUBLICATIONS WITH COSTAS

- **Higher order QCD effects in inclusive annihilation and Deep inelastic scattering**
  E.G.Floratos, C.Kounnas, R.Lacage: Nucl.Phys.B192(1981)417

- **Space and Time-like Cut vertices in QCD beyond leading order -Nonsinglet sector**
  E.G.Floratos,C.Kounnas,R.Lacage:Phys.LettersB98(1981)89

- **Space and Time-like Cut vertices in QCD beyond leading order - Singlet sector**
  E.G.Floratos,C.Kounnas,R.Lacage:Phys.LettersB98(1981)285

- **Higher order corrections in the cut vertex formalis**m
  L. Beaulieu, E. G. Floratos ,C.Kounnas: Phys. RevD 23(1981)2464

- **Parton model interpretation of the cut vertex formalism**
  L. Beaulieu, E. G. Floratos ,C.Kounnas: Nucl.Physics B166(1980)321

- **Crossing relations for deep inelastic and annihilation processes**
  L. Beaulieu, E. G. Floratos ,C.Kounnas:Physics Letters B89(1979)84

FIRST CORFU SUMMER SCHOOL 1982

Ref.TH.3470-CERN

QCD INTERACTING PARTONS

C. Kounnas
CERN - Geneva

ABSTRACT

Assuming quantum chromodynamics (QCD) to be the theory of strong interactions, we justify the perturbative calculations in some hard scattering processes. Quantitative predictions are given using the generalized parton model.

Lectures given at the 1st Hellenic School on Elementary Particle Physics, Corfu, 1982

Ref.TH.3470-CERN
22 November 1982

2LOOP QCD- KERNELS

e+e-: SINGLET SECTOR

(i) P_{qq}^{NS}, quark-quark non-flavour causing transition [u→u, ū→ū],

(ii) $P_{q\bar{q}}^{NS}$, quark-antiquark non-flavour causing transition [u↔ū],

(iii) P_{QQ}, singlet quark ↔ singlet quark transition [Q↔Q, Q̄↔Q̄],

(iv) $P_{Q\bar{Q}}$, singlet quark ↔ singlet antiquark transition [Q↔Q̄],

(v) P_{QG}, gluon-singlet quark transition [G→Q, G→Q̄],

(vi) P_{GQ}, singlet quark → gluon transition [Q→G, Q̄→G]

(vii) P_{GG}, gluon-gluon transition [G↔G].

In Fig. 5, we show some second-order graphs which give a non-zero contribution to the seven P_{ij} independent kernels.

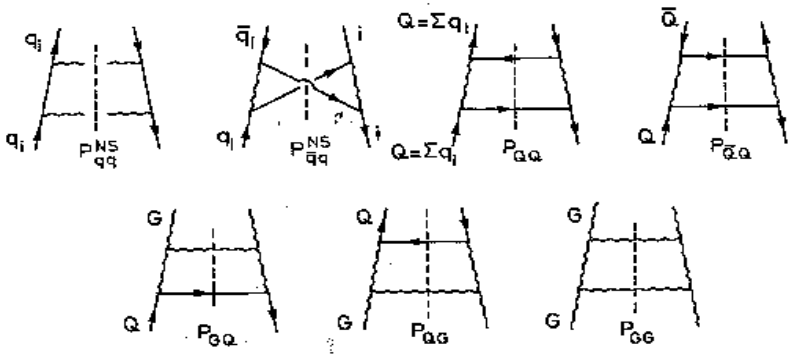

Figure 5 - Second-order graphs contributing to the seven independent kernels.

Equations (6.1a,b,c) are couple differential equations of $(2N_f+1)$ functions. It is convenient to define some particular parton combinations which satisfy uncouple equations. We classify these combinations according to their transformation properties under $SU(N_F)$ flavour and under charge conjugation.

- 2LOOP QCD- KERNELS
  e+e-: SINGLET SECTOR

$$K_{FF}(x,\alpha) = \frac{\alpha}{4\pi}\left[8\delta(1-x) + \frac{16}{3}\frac{1+x^2}{(1-x)_+}\right] + \left(\frac{\alpha}{4\pi}\right)^2 \frac{16}{9}\Big\{ 244.053\,\delta(1-x)$$
$$+\frac{1}{3}\left(\frac{208}{x} - 830 - 11x - 64x^2\right) + 4(1-3x+24x^2)\log x$$
$$-4(1+x)\left(12\,Li_2(x) + 13\log^2 x - \frac{11}{4}\pi^2\right) + \left(\frac{32}{x} + 49 + x - 32x^2\right)\log(1-x)$$
$$+\frac{1+x^2}{1-x}\log x\left(38 + 9\log x - 16\log(1-x)\right)$$
$$-2\frac{1+x^2}{1+x}\left(\frac{1}{2}\log^2 x - 2\,Li_2(-x) - 2\log x\log(1+x) - \frac{\pi^2}{6}\right)$$
$$+ 85.616\,\frac{1}{(1-x)_+} - 50\left(\frac{\log(1-x)}{1-x}\right)_+ \Big\} \qquad (A.4)$$

$$K_{FG}(x,\alpha) = \frac{\alpha}{4\pi}\,16(1-2x+2x^2) + \left(\frac{\alpha}{4\pi}\right)^2 \frac{16}{3}\Big\{\left(\frac{52}{x} - 157 - 304x + 432x^2\right)$$
$$+ 2(2 - 208x + 201x^2)\log x - (41 + 134x + 82x^2)\log^2 x$$
$$+ 2\left(\frac{18}{x} - 13 + 156x - 177x^2\right)\log(1-x)$$
$$- 4\,(13 + 28x + 8x^2)\left(Li_2(x) - \pi^2/6\right)$$
$$- 2(1-2x+2x^2)\left(26\log x\log(1-x) - 9\log^2(1-x) + \frac{17}{6}\pi^2\right)$$
$$+ 18(1+2x+2x^2)\left(\frac{1}{2}\log^2 x - 2\,Li_2(-x) - 2\log x\log(1+x) - \frac{\pi^2}{6}\right)\Big\} \qquad (A.5)$$

$$K_{GF}(x,\alpha) = \frac{\alpha}{4\pi}\frac{16}{3}\left(\frac{2}{x} - 2 + x\right) + \left(\frac{\alpha}{4\pi}\right)^2 \frac{32}{9}\Big\{-\frac{1}{3}\left(\frac{53}{x} - 125 - 41x - 132x^2\right)$$
$$-(100 + 37x + 24x^2)\log x + \frac{9}{2}\left(\frac{2}{x} + 6 + 3x\right)\log^2 x$$
$$+\left(\frac{50}{x} - 58 + 37x\right)\log(1-x) - \left(\frac{2}{x} - 2 + x\right)\left(10\log x\log(1-x) + \frac{1}{6}\pi^2 - \log^2(1-x)\right)$$
$$+ 4\left(\frac{4}{x} - 2 + x\right)\left(Li_2(x) - \frac{\pi^2}{6}\right)$$
$$-9\left(\frac{2}{x} + 2 + x\right)\left(\frac{1}{2}\log^2 x - 2\,Li_2(-x) - 2\log x\log(1+x) - \frac{\pi^2}{6}\right)\Big\} \qquad (A.6)$$

- 2LOOP QCD- KERNELS
  e+e-: SINGLET SECTOR

$$K_{66}(x,\alpha) = \frac{\alpha}{4\pi}\left(\frac{50}{3}\delta(1-x) + 24\left(\frac{1}{x} - 2 + x - x^2\right) + \frac{24}{(1-x)_+}\right)$$

$$+ \left(\frac{\alpha}{4\pi}\right)^2 8\left\{45.789\,\delta(1-x) + 24.058\,\frac{1}{(1-x)_+}\right.$$

$$- \frac{1}{18}\left(552/x - 343 + 1117x - 360x^2\right) - 3\pi^2\left(\frac{1}{x} - 2 + x - x^2\right)$$

$$- \frac{1}{9}(843 - 225x + 1252x^2)\log x + 9\left(\frac{1}{x} + 2 + 5x - x^2 + \frac{1}{1-x}\right)\log^2 x$$

$$- \frac{16}{9}\left(\frac{9}{x} + 3 - 3x - 4x^2\right)\log(1-x) + \frac{32}{3}(1+x)\left(Li_2(x) - \pi^2/6\right)$$

$$- 36\left(\frac{1}{x} - 2 + x - x^2 + \frac{1}{1-x}\right)\log x \log(1-x)$$

$$\left. - 18\left(\frac{1}{x} + 2 + x + x^2 - \frac{1}{1+x}\right)\left(\frac{1}{2}\log^2 x - 2Li_2(-x) - 2\log x \log(1+x) - \frac{\pi^2}{6}\right)\right\} \qquad \text{(A.7)}$$

The function $Li_2(x)$ in Eqs. (A.1), (A.4)-(A.7) is defined as

$$Li_2(x) = -\int_0^x dy\,\frac{\log(1-y)}{y} \qquad \text{(dilogarithm function)} \qquad \text{(A.8)}$$

$$= \sum_{k=1}^{\infty} \frac{x^k}{k^2} \qquad \text{when} \quad -1 \le x \le 1$$

COSTAS WAS INDEED AMAZING HE COULD FLY VERY HIGH

COSTAS WE MISS YOU!