EURIDICE, Frascati, 18 October 2002

Lund Node and Oslo Subnode

Johan Bijnens

Lund University

- People
- Links
- Expertise
- Projects Oslo
- Projects Lund
  - π and K electromagnetic formfactors
  - Anomalies at one-loop
  - Nonleptonic Matrix Elements

People

Lund: Department of Theoretical Physics, Lund University
Oslo: Department of Physics, University of Oslo

Senior

Johan Bijnens, Lund

Jan Olav Eeg, Oslo

Postdoc

Edisher Lipartia, Lund

Ph.D. Students

Pierre Dhonte, Lund

Aksel Hiorth, Oslo

Fredrik Persson, Lund

Master Students

Olof Strandberg, Lund

Lund

Granada: Prades, Gamíz
Barcelona: Talavera
Karlsruhe: Khodjamirian
Bern: Gasser
Wien: Ecker
Zürich: G. Colangelo
ECT*: Rusetsky, Girlanda

Oslo

CERN: Polosa
Trieste: Bertolini, Fabbrichesi
Zagreb: Picek, Kumerički
Ljubljana: Fajfer

Oslo

- Chiral Quark Model
- CP violation, Higher order chiral corrections to ε'/ε
- Heavy Light Systems
- Checking the importance of often neglected effects

Lund

- ChPT in the meson sector:
  - Two-loop calculations in three flavour strong and semileptonic
  - One-loop in the nonleptonic weak sector
  - Anomalous processes to one-loop
  - isospin breaking from $m_u - m_d$.
- Nonleptonic Matrix elements
  - Short-distance-long-distance matching scheme dependence
  - Higher order chiral effects
  - ENJL model in intermediate energy regimes
- Hadronic Bound Systems
  - Connection ChPT $\longleftrightarrow$ Potential Calculations in pionium
  - Pionic Hydrogen

HEAVY LIGHT CHIRAL QUARK MODEL

Development of the model:

A. Hiorth, J.O. Eeg, Phys.Rev. D66 (2002) 074001 [hep-ph/0206158]

Extending the CQM to the heavy light sector.

Phenomenological applications

- A. Hiorth, J.O. Eeg, B^0-$\overline{B^0}$ mixing, in progress
- J.O. Eeg, K. Kumericki, I. Picek, $B \to K\eta'$, in progress
- J.O. Eeg, A. Hiorth, A.D. Polosa, A gluonic mechanism for $B \to D\eta'$, Phys.Rev. D65 (2002) 054030 [hep-ph/0109201]

Rare D decays

J.O. Eeg, S. Fajfer, J. Zupan, Nonfactorizable contributions to the decay mode $D^0 \to K^0\bar{K}^0$, Phys.Rev. D64 (2001) 034010 [hep-ph/0101215]

Factorizable is zero, estimate nonfactorizable via Chiral Loops and heavy-light CQM tree level (both are $\mathcal{O}(p^3)$.

Both chiral loops and gluon condensate contributions: same order as the experimental amplitude

Hadronic Atoms

Hadronic potentials from effective field theories,

E. Lipartia, V.E. Lyubovitskij, A. Rusetsky,

Phys.Lett. B533 (2002) 285 [hep-ph/0110186]

Ground state energy of pionic hydrogen to one loop,

J. Gasser, M.A. Ivanov, E. Lipartia, M. Mojzis, A. Rusetsky, hep-ph/0206068

$\Longrightarrow$ Edisher Lipartia

One-loop in the non-leptonic sector

$K \to 3\pi$ in ChPT, JB, P. Dhonte, F. Persson, hep-ph/0205341

In progress: isospin breaking effects

$\Longrightarrow$ Fredrik Persson

Three flavour two-loop ChPT

(G. Amorós,) JB, P. Talavera: reported in EURODAΦNE meetings

Recent work:

Pion and Kaon Electromagnetic Form Factors

JB, P. Talavera, hep-ph/0203049, JHEP 03(2002)046

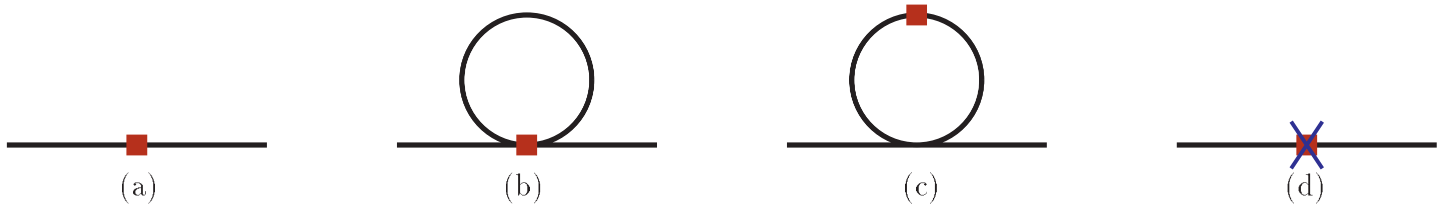
In progress: $K_{\ell 3}$:

Isospin conserving: first numerics done, some numerical disagreement with P. Post and K. Schilcher, Eur. Phys. J. C **25** (2002) 427 [hep-ph/0112352]

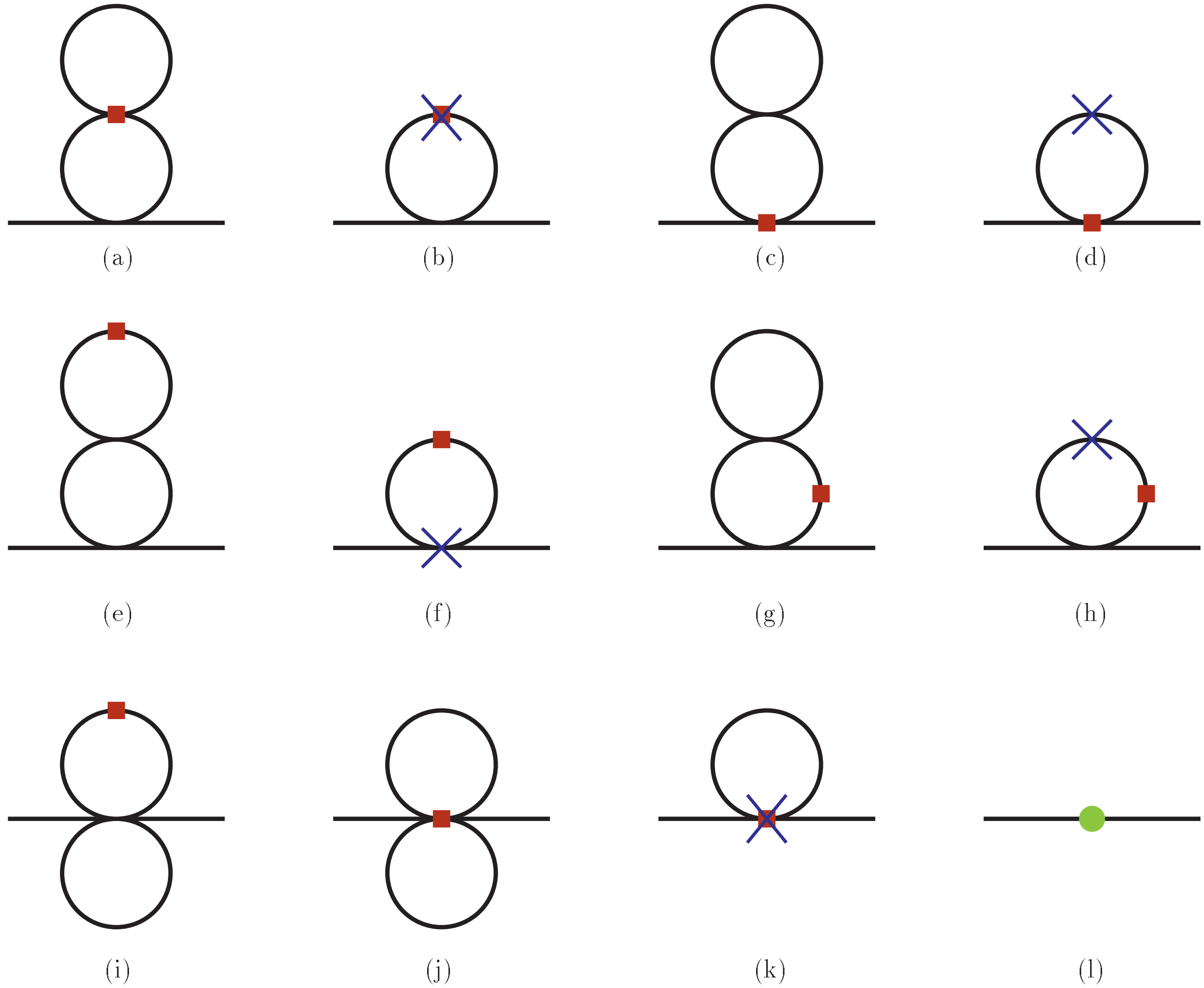
Isospin breaking: diagrams done but putting together and numerics in progress

Pion and Kaon Electromagnetic Formfactors

One loop and tree level:

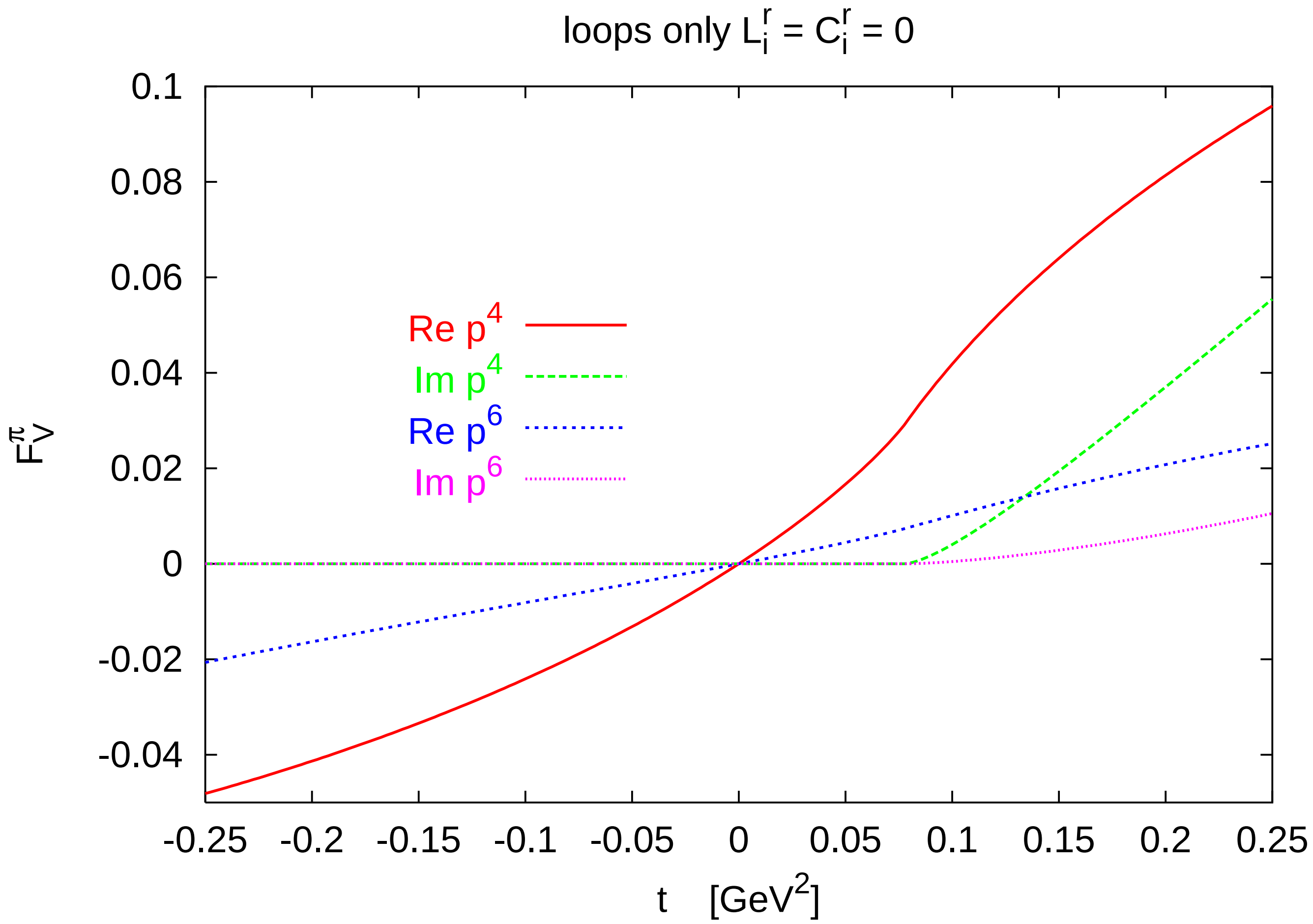


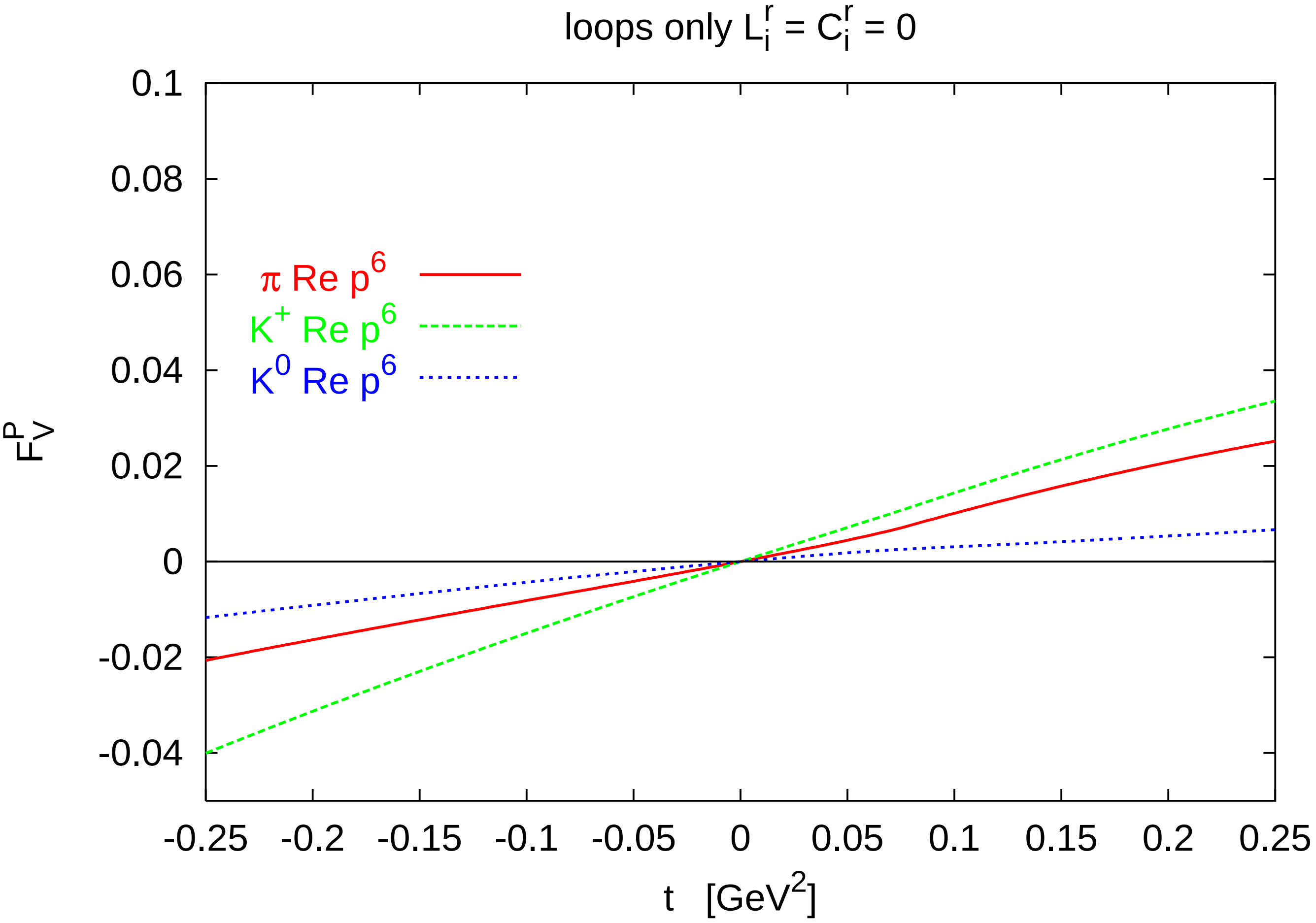
Two-loop 'simple':

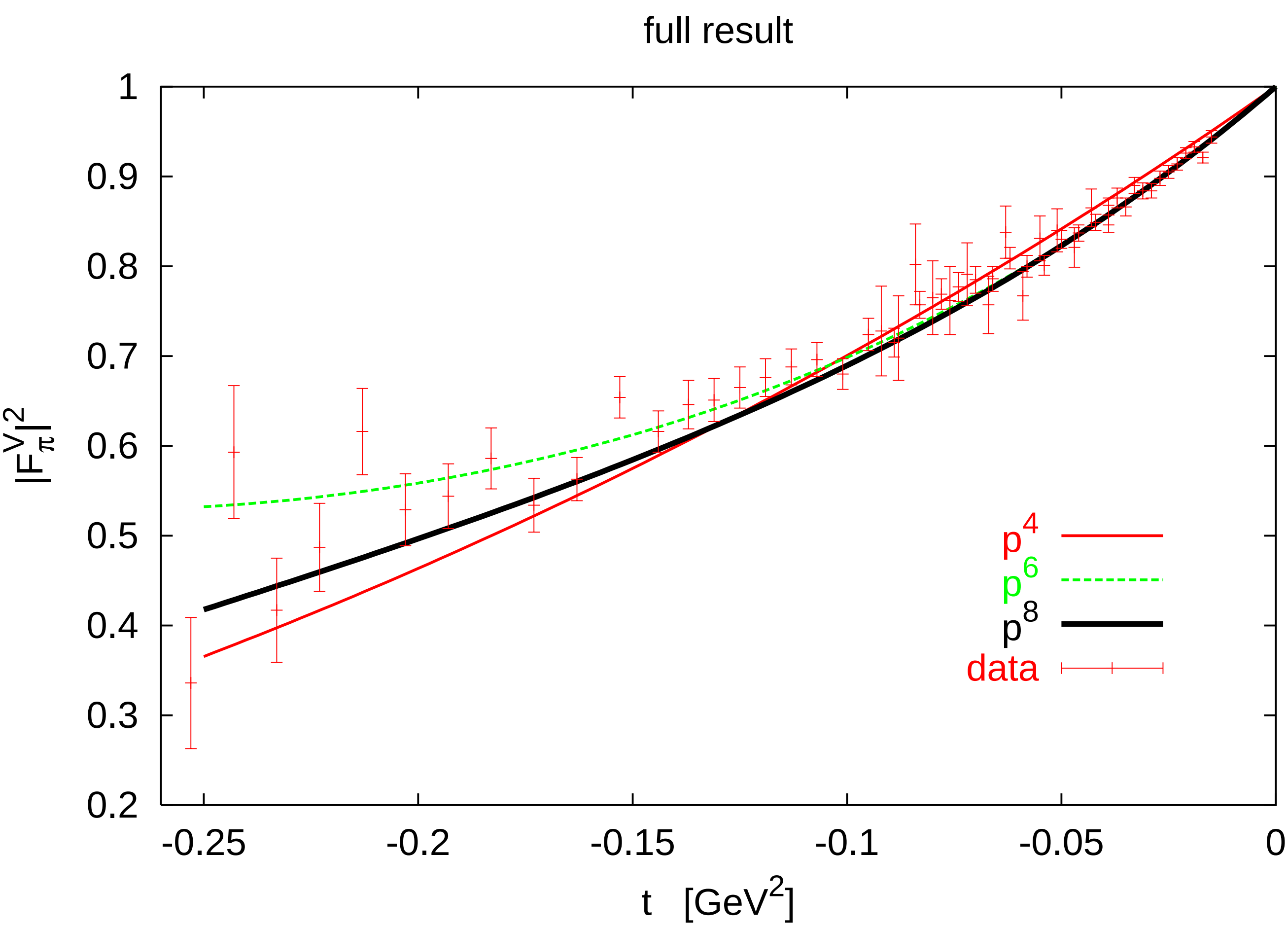


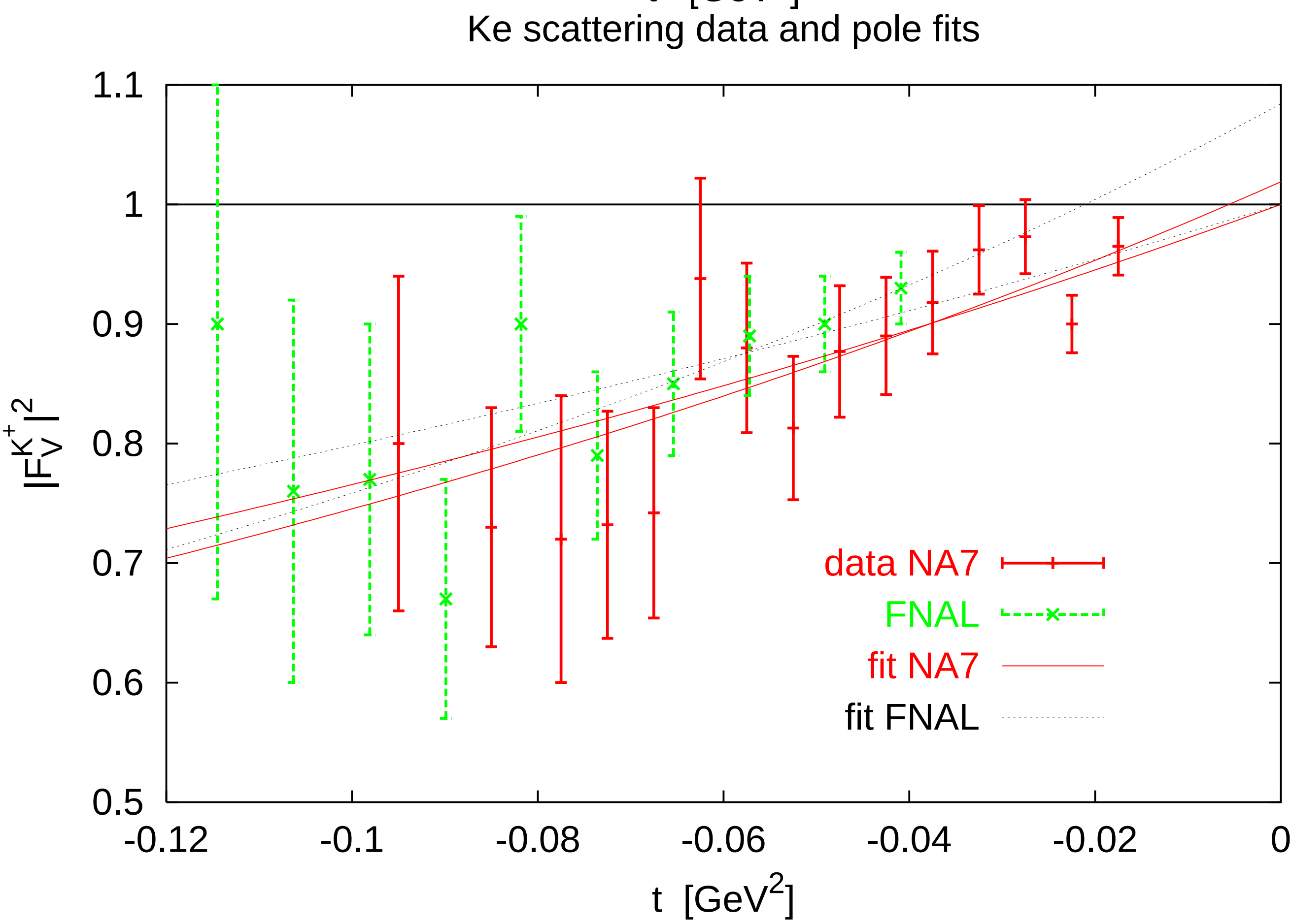
Two-loop difficult:

(l) is easy to calculate: creates all the difficulties C_i^r


loops only $L_i^r = C_i^r = 0$
Re p^4
Im p^4
Re p^6
Im p^6
F_V^π
t [GeV^2]
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25


loops only $L_i^r = C_i^r = 0$
π Re p^6
K^+ Re p^6
K^0 Re p^6
F_V^P
t [GeV^2]
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25


full result
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
-0.25
-0.2
-0.15
-0.1
-0.05
0
$|F^V_\pi|^2$
t [GeV^2]
p^4
p^6
p^8
data


Ke scattering data and pole fits
1.1
1
0.9
0.8
0.7
0.6
0.5
-0.12
-0.1
-0.08
-0.06
-0.04
-0.02
0
$|F^{K^+}_V|^2$
t [GeV^2]
data NA7
FNAL
fit NA7
fit FNAL

Part with $\mathcal{L}_6$ constants C_i^r

$$
\begin{aligned}
F_\pi^4 F^\pi_{V\mathbf{C}}(q^2) &= -4q^2 m_\pi^2 (4C_{12}^r + 4C_{13}^r + 2C_{63}^r + C_{64}^r + C_{65}^r + 2C_{90}^r) - \\
&\quad -8q^2 m_K^2 (4C_{13}^r + C_{64}^r) - 4q^4 (C_{88}^r - C_{90}^r) \\
&= q^2 R^\pi_{V1} + q^4 R^\pi_{V2}
\end{aligned}
$$

$$
\begin{aligned}
F_\pi^4 F^{K^+}_{V\mathbf{C}}(q^2) &= -q^2 m_\pi^2 \left(16C_{13}^r + \frac{8}{3}C_{63}^r + 4C_{64}^r - \frac{4}{3}C_{65}^r\right) - \\
&\quad -q^2 m_K^2 \left(16C_{12}^r + 32C_{13}^r + \frac{16}{3}C_{63}^r + 8C_{64}^r + \frac{16}{3}C_{65}^r + 8C_{90}^r\right) - \\
&\quad -4q^4 \left(C_{88}^r - C_{90}^r\right), \\
&= q^2 R^{K^+}_{V1} + q^4 R^\pi_{K^+}
\end{aligned}
$$

$$
F_\pi^4 F^{K^0}_{V\mathbf{C}}(q^2) = \frac{8}{3} q^2 (m_\pi^2 - m_K^2)(2C_{63}^r - C_{65}^r) = q^2 R^{K^0}_{V1}\,.
$$

Results

$$
R^{K^0}_{V2} = 0 \qquad R^{K^+}_{V2} = R^\pi_{V2}
$$

$$
L_9^r = (5.93 \pm 0.43) \times 10^{-3}
$$

with factor two error on estimate of $R^\pi_{V1} = -0.49 \times 10^{-5}$ GeV^{-2}

$$
\begin{aligned}
R^\pi_{V2} &= -4\left(C_{88}^r - C_{90}^r\right) = (0.22 \pm 0.02) \times 10^{-3}\,, \\
R^\pi_{V1} - R^{K^+}_{V1} &= (0.0 \pm 1.4) \times 10^{-5}\,\mathrm{GeV}^2 \quad \text{CERN} \\
R^\pi_{V1} - R^{K^+}_{V1} &= (1.9 \pm 1.9) \times 10^{-5}\,\mathrm{GeV}^2 \quad \text{FNAL} \\
R^{K^0}_{V1} &= (-0.4 \pm 0.9) \times 10^{-5}\,\mathrm{GeV}^2
\end{aligned}
$$

Preliminary note: from all these numbers plus slopes in $K_{\ell 3}$

$\Rightarrow f_+(0)$

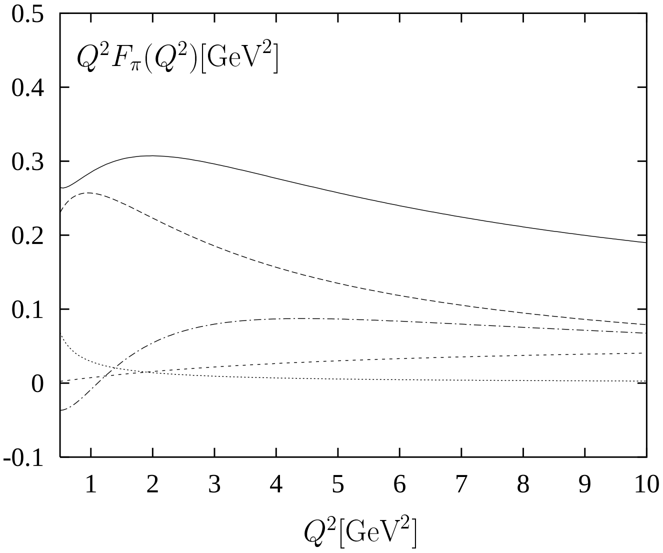
Pion and Kaon Electromagnetic Formfactor: large Q^2

Exploring Light-Cone Sum Rules for Pion and Kaon Form Factors,

JB, A. Khodjamirian, hep-ph/0206252, Eur. Phys. J. C

HOPE: Light cone sum rules alternative to models in intermediate energy regime

Problem: Unknown distribution amplitudes ($\approx$ Fock wave functions)



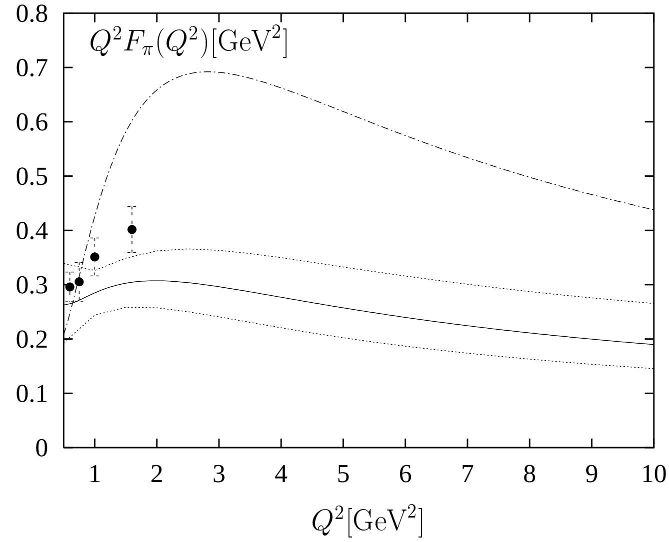
Pion form factor asymptotic pion DA (solid)

2 leading-order (long-dashed)

twist 2 $O(\alpha_s)$ (short-dashed)

twist 4 (dash-dotted)

factorizable twist 6 (dotted)



Pion form factor and Jefferson Lab data

asymptotic pion DA (solid)

estimated theoretical uncertainty (dashed)

CZ model (dash-dotted)

Alternative derivation of DA identities from Ward Identities (plus new one)

Constraints on wave functions from LCSR with π or K on lightcone

p^6 Lagrangian Clarified

JB, L. Girlanda, P. Talavera,

Eur. Phys. J. C **23** (2002) 539 [hep-ph/0110400]

T. Ebertshauser, H. W. Fearing and S. Scherer,

Phys. Rev. D **65** (2002) 054033 [hep-ph/0110261]

Result: there are 24 terms for N_f flavours, 23 for three and 13 for two.

Ongoing:

JB, O. Strandberg:

what are the experimental constraints on the C_i^{Wr}?

Do we need explicit η_0 or can this be dealt with perturbatively?

$\pi^0 \to \gamma\gamma$ and Electromagnetic

B. Ananthanarayan and B. Moussallam,

Electromagnetic corrections in the anomaly sector,

JHEP **0205** (2002) 052 [hep-ph/0205232]

($N_f = 2$ work, notice L_4 versus ℓ_4)

J. L. Goity, A. M. Bernstein and B. R. Holstein,

The decay $\pi^0 \to \gamma\gamma$ to next to leading order in ChPT, hep-ph/0206007

L. Ametller, M. Knecht and P. Talavera,

Electromagnetic corrections to $\gamma\pi^{+-} \to \pi^0\pi^{+-}$,

Phys. Rev. D **64** (2001) 094009 [hep-ph/0107127]

J. Prades, E.Gamíz, E. Lipartia,...

ε'/ε JB, J. Prades, ε'/ε in the chiral limit,
JHEP **0006** (2000) 035 [arXiv:hep-ph/0005189]
Sizable corrections from scheme dependence
Large corrections to gluonic Penguin: $B_6 \gtrapprox 2$

Q_7, Q_8

JB, , E. Gamiz, J. Prades,
Matching the electroweak penguins Q_7, Q_8 and spectral correlators,
JHEP **0110** (2001) 009 [arXiv:hep-ph/0108240]
Note: see also talk by Cirigliano and de Rafael

$$\langle 0|Q_7|0\rangle_\chi^{\rm NDR}(\mu_R) = \frac{3}{32\pi^2}\left(1+\frac{1}{24}\frac{\alpha_S}{\pi}\right)\mathcal{A}_{LR}(\mu_R) + \frac{1}{48}\frac{\alpha_S}{\pi}\mathcal{B}_{SP}(\mu_R)$$

$$\langle 0|Q_8|0\rangle_\chi^{\rm NDR}(\mu_R) = \left(1+\frac{23}{12}\frac{\alpha_S}{\pi}\right)\mathcal{B}_{SP}(\mu_R) + \frac{3}{32\pi^2}\frac{9}{2}\frac{\alpha_S}{\pi}\mathcal{A}_{LR}(\mu_R)$$

$$\mathcal{A}_{LR}(\mu_R) \equiv \int_0^{s_0} {\rm d}t\, t^2\, \ln\left(\frac{t}{\mu_R^2}\right)\frac{1}{\pi}\,{\rm Im}\Pi_{LR}^T(t)$$

$$\begin{aligned}\mathcal{B}_{SP}(\mu_R) &\equiv 3\langle 0|\overline{q}q|0\rangle^2_{\overline{MS}}(\mu_R) \\ &\quad+\frac{1}{16\pi^2}\int_0^{\hat{s}_0} {\rm d}t\, t\, \ln\left(\frac{t}{\mu_R^2}\right)\frac{1}{\pi}\,{\rm Im}\Pi_{SS+PP}^{(0-3)}(t)\,.\end{aligned}$$

s_0 and $\hat{s}_0$ are the onsets of local QCD duality.

From OPAL and ALEPH tau decay data

$$\mathcal{A}_{LR}(2\mathrm{GeV}) = (4.35 \pm 0.50) \cdot 10^{-3}\,\mathrm{GeV}^6$$

$\mathcal{B}_{SP}(\mu_R)$:
Integral is $1/N_c^2$ and has double suppression from $0-3$ and S-P cancellations. Various estimates $\lessapprox 40\%$, set zero in main result.

Alternative: (Donoghue-Golowich 00, Knecht Peris de Rafael 01, Cirigliano et al., BGP01)

$$\begin{aligned} M_2 &\equiv \int_0^{s_0} \mathrm{d}t\, t^2\, \frac{1}{\pi}\, \mathrm{Im}\Pi^T_{LR}(t) \\ &\simeq -\frac{4\pi}{3}\alpha_S(s_0)\left(1 + \frac{25}{8}\frac{\alpha_S(s_0)}{\pi}\right)\, \langle 0|Q_8|0\rangle_\chi^{\mathrm{NDR}}(s_0) \end{aligned}$$

ALEPH OPAL: $M_2 = -[1.9 \pm 1.0] \cdot 10^{-3}\,\mathrm{GeV}^6$
nonfactorizable in $\mathcal{B}_{SP} = 0$: $M_2 = -[2.0 \pm 0.9] \cdot 10^{-3}\,\mathrm{GeV}^6$

Method	$-60\,\langle 0\vert Q_7\vert 0\rangle_\chi$	$\langle 0\vert Q_8\vert 0\rangle_\chi$
B_7^χ(2 GeV)= B_8^χ(2 GeV)=1	3.2 ± 1.3	1.0 ± 0.4
This Work, Im$\Pi^{(0-3)}_{SS+PP} = 0$	2.4 ± 0.3	1.2 ± 0.5
This Work, Data & Duality FESR	2.4 ± 0.3	1.2 ± 0.7
Cetal, Data & Fitted FESR	2.1 ± 0.3	1.5 ± 0.3
Cetal, Weighted Data & Fitted FESR	2.2 ± 0.3	1.6 ± 0.4
Cetal, Weighted Data	1.6 ± 1.0	2.1 ± 0.6
Knecht et al., $N_c \to \infty$, MHA	1.1 ± 0.3	2.3 ± 0.7
Narison, Data & Tau-like FESR	2.1 ± 0.6	1.4 ± 0.4
Donini et al., Lattice (Wilson)	1.5 ± 0.4	0.7 ± 0.2
CP-PACS Coll., Lattice (Chiral)	2.4 ± 0.3 (stat.)	1.0 ± 0.2 (stat.)
RBC Coll., Lattice (Chiral)	2.7 ± 0.3 (stat.)	1.1 ± 0.2 (stat.)

Cetal $=$ Cirigliano, Donoghue, Golowich, Maltman

See paper for Higher Dimension Operators

In Progress

Making analytic connection between ENJL and MHA type of saturations

ENJL analytic rather than numerical: shows explicitly how short-distance is included

Why has B_K so large quark mass corrections