Report on Flavianet Activities

Christopher Smith
• Outline

What is Flavianet?

Activities: New Physics searches

Activities: Predicting hadronic parameters

Conclusion
What is FlaviA.net?
A. European Research and Training Network

Marie Curie RTN within the FP6

Duration: 4 years (2006-2010)

Over 45 institutes, with ~215 particle physicists.

( http://ific.uv.es/flavianet/ )

Predecessors:

1990’s: EuroDaphne I & II
2000’s: Euridice.
A. European Research and Training Network

Focus on *training*!

Research positions (total years):
- Early stage (ESR) : 34 years.
- Experienced (ER) : 8 years.

Network activities:
- Meetings,
- Schools,
- Inter-node visits,…

Outreach activities,…
B. Scientific Objectives

Entering the high-precision era of flavour physics through the alliance of lattice simulations, effective theories, and experiment.

Historically, related to the experimental program of Frascati, i.e. physics at the 1 GeV scale (see DaΦne Physics Handbook).

Extended to the broad issue/puzzle of *flavor physics in the SM and beyond*. This requires again an excellent control over the *hadronic physics*.
B. Scientific Objectives

Phenomenological approach, with both theoretical and experimental groups.

Organized in six working groups, based on individual expertises:

**WG1** : Kaon physics  (KTeV, KLOE, NA48 / NA62, J-PARC, Project X?)

**WG2** : Beauty physics  (Belle, BaBar, Fermilab / LHCb, superB?)

**WG3** : Tau, Charm and Quarkonia  (Cleo, Belle, BaBar, Fermilab / LHCb, BES)

**WG4** : Analytic approach to Non-Perturbative QCD, e.g. effective theories

**WG5** : Lattice Methods

**WG6** : Radiative Return and Monte Carlo tools
### Working groups ↔ scientific goals ⇒ drives network collaborations and unity:

<table>
<thead>
<tr>
<th>SM strong sector</th>
<th>K</th>
<th>B</th>
<th>(\tau, c)</th>
<th>Eff. th.</th>
<th>Lattice</th>
<th>M.C.</th>
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<th>SM electroweak sector</th>
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<td>Global assessment of CKM</td>
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<th>Physics beyond the SM</th>
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<th>B</th>
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<td>Global CKM fits for New Physics</td>
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C. Activities

Over 300 papers between Sept. 2006 and Sept. 2007, and probably as much since then.

The following review is neither complete in the activities, nor in the references!!!

Rather: some selected activities related to

- New Physics searches,

- Predicting hadronic parameters : $K$, $B$, $\alpha_S$, $(g-2)_\mu$.

Essentially taken out from the Sept. 2007 report sent back to Brussels.

(available for download at the flavianet webpage [http://ific.uv.es/flavianet/](http://ific.uv.es/flavianet/) )
New Physics searches
A. The New Physics flavor puzzle

- Most New Physics (NP) models have either new flavored particles, or new flavor-breaking interactions between quarks and leptons.

→ New contributions to FCNC’s!

- At the same time, there is no signal of NP in low-energy experiments.

Experiments ~ SM predictions

\[
\begin{aligned}
&\left\{ b \rightarrow s : \right. \\
&|V_{tb}^* V_{ts}| \sim \lambda^2 \\
&\left. \right| b \rightarrow d : \\
&|V_{tb}^* V_{td}| \sim \lambda^3
\end{aligned}
\]

- New Physics cannot be both light and generic:

\[
\mathcal{L}_{\text{eff}} = \frac{c_{bs}}{\Lambda^2} (\bar{b} \Gamma s)(\bar{\nu} \Gamma \nu) + \frac{c_{bd}}{\Lambda^2} (\bar{b} \Gamma d)(\bar{\nu} \Gamma \nu) + \frac{c_{sd}}{\Lambda^2} (\bar{s} \Gamma d)(\bar{\nu} \Gamma \nu) + ...
\]

\[
c_{sd} \approx 1, \quad \Lambda \approx 75 \text{ TeV}: \text{NP very massive, beyond the reach of LHC},
\]

\[
\Lambda \approx 1 \text{ TeV}, \quad c_{sd} \ll V_{ts}^* V_{td} : \text{NP flavor structures highly non-generic.}
\]
### FLAVOUR COUPLINGS

(→ decreasing SM contribution →)

<table>
<thead>
<tr>
<th>FCNC</th>
<th>$b \to s$ ($\sim \lambda^2$)</th>
<th>$b \to d$ ($\sim \lambda^3$)</th>
<th>$s \to d$ ($\sim \lambda^5$)</th>
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| $\Delta F = 2$ | $\Delta M_{Bs}$  
$A_{CP}(B_s \to \psi\phi)$ | $\Delta M_{Bs}$  
$A_{CP}(B_d \to \psi K)$ | $\Delta M_{K}, \varepsilon_K$ |
| $\Delta F = 1$ | 4-quark  
$B_d \to \phi K, \pi K, \ldots$ | $B_d \to \pi\pi, \rho\pi, \ldots$ | $\varepsilon'/\varepsilon, K \to \pi\pi\pi, \ldots$ |
| gluon penguin | $B_d \to X_s \gamma, \pi K, \ldots$ | $B_d \to X_d \gamma, \pi\pi, \ldots$ | $\varepsilon'/\varepsilon, K_L \to \pi^0\ell^+\ell^-, \ldots$ |
| $\gamma$ penguin | $B_d \to X_s \gamma, X_s \ell^+\ell^-, \pi K, \ldots$ | $B_d \to X_d \ell^+\ell^-, \pi\pi, \ldots$ | $\varepsilon'/\varepsilon, K_L \to \pi^0\ell^+\ell^-, \ldots$ |
| $Z^0$ penguin | $B_d \to X_s \ell^+\ell^-, \mu^+\mu^-$,  
$B_s \to \mu^+\mu^-$,  
$B_d \to \phi K, \pi K, \ldots$ | $B_d \to X_d \ell^+\ell^-, \mu^+\mu^-$,  
$B_d \to \pi\pi, \ldots$ | $\varepsilon'/\varepsilon, K \to \pi\nu\bar{\nu}, \ldots$  
$K_L \to \pi^0\ell^+\ell^-\mu^+\mu^-$ |
| $H^0$ penguin | $B_s \to \mu^+\mu^-$ | $B_d \to \mu^+\mu^-$ | $K_L \to \pi^0\ell^+\ell^-, \mu^+\mu^-$ |
B. Global CKM fits and constraints on New Physics

Flavianet members contribute to CKMfitter and UTfit analyses:

Bayesian vs. frequentist?  \[ \text{Charles, Hocker, Lacker, Le Diberder, T'Jampens '06} \]

Hint of a large new physics phase in $b \rightarrow s$ transitions?  \[ \text{Bona et al. '08} \]
C. Bottom-up approach to the New Physics flavor puzzle

**Minimal Flavor Violation:** New Physics scale as in the SM.

\[
\mathcal{L}_{\text{eff}} = \frac{c_{qq'}}{\Lambda^2} (\bar{q} \Gamma q')(\bar{\nu} \Gamma \nu) + \ldots \quad \text{with} \quad c_{qq'} \sim |V_{tq}^* V_{tq'}| \implies \Lambda \leq 1 \text{ TeV}
\]

"Constrained" MFV: No new phase, no new operator.
"Symmetric" MFV: Only the Yukawas can break the \( SU(3)^5 \) flavor-symmetry.

- MSSM at large \( \tan \beta \equiv v_u / v_d \) \hspace{1cm} Freitas,Gasser,Haisch '07
- MSSM: UT fit in the B sector \hspace{1cm} Isidori,Mescia,Paradisi,Temes '07
- MSSM: running MFV \hspace{1cm} Altmannshofer,Buras,Guadagnoli '07
- MFV as an alternative to R-parity \hspace{1cm} Altmannshofer,Buras,Guadagnoli,Wick '07
- Extra quarks: connection with LHC \hspace{1cm} Paradisi,Ratz,Schieren,Simonetto '07
- Generic: constraints from \( Z \rightarrow b\bar{b}, \ldots \) \hspace{1cm} Nikolidakis,CS '07
- Lepton sector & leptogenesis \hspace{1cm} Grossman,Nir,Thaler,Volansky,Zupan '07

............

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D. Top-down approach to the New Physics flavor puzzle

Specific New Physics models: identifying interesting scenarios, and studying their impact on flavor physics, including their correlation with LHC observables.

**Supersymmetry:**
- Generic MSSM
  - with MFV
  - with large $\tan \beta$
  - with RPV

Supersymmetric GUT scenarios

Alternatives:
- Little Higgs
- Higgsless
- Extra-dimensions
- Unparticles

(see e.g. Refs. on the previous slide)

Dorsner, Fileviez Perez, Rodrigo ‘06
Cuichini, Masiero, Paradisi, Silvestrini, Vempati, Vives ‘07
Albrecht, Altmannshofer, Buras, Guadagnoli, Straub ‘07
Altmannshofer, Guadagnoli, Raby, Straub ‘08

Blanke, Buras, Recksiegel, Tarantino, Uhlig ‘07
Blanke, Buras, Recksiegel, Tarantino ‘08
Bernard, Oertel, Passemar, Stern ‘07
Barbieri, Isidori, Rychkov, Trincherini ‘08

Davidson, Isidori, Uhlig ‘07, Haisch, Weiler ‘07
Colangelo, De Fazio, Ferrandes, Pham ‘06
Zwicky ‘07, Freitas, Wyler ‘07
Predicting hadronic parameters
A. Kaon physics and the QCD non-perturbative regime

Goal: $V_{us}$ / Probe QCD at low-energy / Signal of New Physics

Tools: ChPT, OPE,… & Lattice

Data: KLOE, KTeV, NA48, and prepare for NA62, J-PARC, Project X?

- $K \rightarrow \pi \nu \bar{\nu}$ for their NP sensitivity, but also: identify new opportunities!!!
- Other rare K decays $K_L \rightarrow \pi^0 \ell^+ \ell^-$
- Leptonic and semi-leptonic decays for $V_{us}$ & universality,…
- Radiative decays $K \rightarrow \pi \gamma \gamma$, $K \rightarrow \gamma^* \gamma^*$ for $\Delta M_K$, $K_L \rightarrow \mu^+ \mu^-$,…
- Forbidden decays like $K \rightarrow (\pi)e\mu$ for LFV.

→ See talk by E. Passemar

- Chiral Perturbation Theory:
  - SU(2)-SU(3) at $p^6$ Haefeli,Ivanov,Schmid,Ecker ‘07, Gasser,Haefeli,Ivanov,Schmid ‘07
  - Large $N_C$ Rosell,Sanz-Cillero,Pich ‘07, Portoles,Rosell,Ruiz-Femenia ‘07
  - $\eta \rightarrow 3\pi$ Masjuan,Peris ‘07, Kampf,Novotny,Trnka ‘06
  - $\gamma\gamma \rightarrow \pi\pi$ Bijnens,Ghorbani ‘07
  - $\eta \rightarrow 3\pi$ Gasser,Ivanov,Sainio ‘06, Oller,Roca,Schat ‘07, Pennington ‘07

- Lattice simulations: Many activities! See report at http://ific.uv.es/flavianet/.
B. Beauty physics

**Goal**: Unitary triangle & signals of New Physics

**Tools**: QCDf, SCET, HQET,… & Lattice

**Data**: BaBar, Belle, Cleo, Fermilab, and prepare for LHCb, superB?

*Semi-leptonic* B decays \((V_{ub}, V_{cb}, \text{charged Higgs}):\)

Albertus et al. ’06, Ball ’06, ’07
De Fazio, Feldmann, Hurth ’07
Flynn, Nieves ’07, Nierste, Trine, Westhoff ’08
Kamenik, Mescia ’08, Duplancic et al. ’08

\(b \rightarrow s \gamma\) and other rare B decays

Misiak et al. ’06, Misiak, Steinhauser ’06
Asatrian, Ewerth, Gabrielyan, Greub ’06
Colangelo, De Fazio, Ferrandes, Pham ’06

\(\Delta M_{d,s}\)

Lenz, Nierste ’06, Becirevic, Fajfer, Kamenic ’06, Ball ’07
Grozin et al. ’07, Della Morte et al. ’07
Mannel, Pecjak, Pivovarov ’07

**Hadronic** decays

Descotes-Genon ’07, Ciuchini, Pierini, Silvestrini ’07
Zupan ’07, Cavoto, Fleischer, Trabelsi, Zupan ’07, Botella, Nebot ’07
Baek, London, Matias, Virto ’06, Descotes-Genon, Matias, Virto ’07
Beneke, Rohre, Yang ’06, Beneke, Jager ’06
Fleischer, Recksiegel, Schwab ’07

**SuperB** physics case

Bona et al. ’07, Browder, Gershon, Pirjol, Soni, Zupan ’08
C. The strong coupling constant

Goal: To improve the extraction of the least precisely known SM coupling
Tools: $\tau$ decays, quarkonia (NRQCD),…
Data: BES, Cleo, Belle, BaBar,…

Extraction of $\alpha_S(\mu)$ and value at $M_Z$:

- $\Upsilon(1S)$ decays: $\alpha_S(M_Z) = 0.119^{+0.006}_{-0.005}$, Brambilla, Garcia i Tirmo, Soto, Vairo '07
- $\sigma(e^+e^- \rightarrow \text{hadrons})$ with $E < 10\text{GeV}$: $\alpha_S(M_Z) = 0.119^{+0.009}_{-0.011}$, Kuhn, Steinhauser, Teubner '07
- $\tau$ decays: $\alpha_S(M_Z) = 0.1180^{+0.0008}_{-0.0008}$, Beneke, Jamin '08

Running of $\alpha_S(M_Z)$ up to the GUT scale

Harlander, Jones, Kant, Mihaila, Steinhauser '06
Harlander, Mihaila, Piclum, Steinhauser '07
Harlander, Mihaila, Steinhauser '07

Value of the charm mass: $m_c(m_c) = 1.286(13)\text{GeV}$, Kuhn, Steinhauser, Sturm '07
D. The muon anomalous moment

**Goal**: To precisely estimate the hadronic contributions to \((g - 2)_\mu, \alpha_{em}(M_Z)\)

**Tools**: ChPT, \(\tau\) decays, Monte-Carlo,…

**Data**: KLOE, BaBar, Belle, Novosibirsk,…

**Current**: \(a^\text{exp}_\mu - a^\text{th}_\mu = (28 \pm 9) \cdot 10^{-10} \sim 3\sigma\)

**Hadronic contributions**:

\[
\gamma \rightarrow \mu^- \pi^+ \pi^- = (692 \pm 6) \cdot 10^{-10}
\]

\[
\gamma \rightarrow \mu^- \pi^0 \rho^- = (11 \pm 4) \cdot 10^{-10}
\]

**Vacuum polarization** from energy scans, radiative return, or \(\tau\) decays:

Radiative corrections: Phokhara, Tauola, Photos

Was ‘06, Rodrigo ’07, Czyz, Grzelinska ’07
Conclusion
Euroflavour 08
Annual meeting
& Mid-term Review
of FlavIA network

September 22 - 26, 2008
Durham

Kaon decays
B-physics
Analytic approaches to QCD

Tau-charm & quarkonia

Lattice methods
Radiative return & Monte Carlo tools

www.ippp.dur.ac.uk/euroflavour08