OVERVIEW OF DAΦNE

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Outline

1. Introduction
2. DAFNE, the Machine
3. DAFNE Physics
4. KLOE
5. Early Results
6. DEAR
7. The Future
1. Introduction

The initial motivition for DAFNE was the study of direct $CP$ violation in kaon decays, a chapter of particle physics which was opened in 1964 and is, still, quite far from a conclusion. Even though last year it was finally proved that there is direct $\mathcal{CP}$, a good measurement of the relevant parameter, $\Re(\epsilon'/\epsilon)$ is not yet available. On the basis of results in the range $6 - 28 \times 10^{-4}$ it has been concluded that $\Re(\epsilon'/\epsilon)=19.3 \pm 2.4 \times 10^{-4}$. 
It is still desirable to perform measurements of $\Re(\epsilon'/\epsilon)$ in a different way. KLOE, the main general purpose detector at DAΦNE was conceived primarily for the study of $CP$ in $K$-mesons from $\phi$-decays. It is however true that much physics of interest to $\chi$PT is ideally done at DAΦNE with KLOE.
Some relevant design parameters of DAΦNE are

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<tbody>
<tr>
<td>1.</td>
<td>2 rings, 15 mrad crossing</td>
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<td>2.</td>
<td>( \mathcal{L} = \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1} = 1 \text{ nb}^{-1}/\text{s} )</td>
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<td>3.</td>
<td>Fast topping up</td>
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<td>4.</td>
<td>( \geq 100 \text{ min lifetime} )</td>
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<td>5.</td>
<td>( I^+ = I^- = 5 \text{ A} )</td>
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<td>6.</td>
<td>Operation with two IR</td>
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This should result in a deliverable integrated luminosity of 10,000 pb\(^{-1}/\)year.
Collisions in DAΦNE were first observed early in 1998. The machine has not however achieved its goals so far.

3. DAΦNE Physics

DAΦNE is a so called φ–factory which is very much a kaon factory and its physics is dominated by the study of processes involving kaons from φR to the study of K-mesic x-rays (DEAR) and hypernuclei (FiNuDa).

KLOE was approved for an initial delivered luminosity of 10 fb⁻¹ or 10¹⁰ µb⁻¹ which correspond to the production of some 3 × 10¹⁰ kaon pairs.
Just about everything in $K$-physics is related to Chiral
Dynamics. For example:

1. $\text{BR}(K_S \rightarrow \pi^+\pi^-, \pi^0\pi^0)$, $\text{BR}(\phi \rightarrow K^\pm, K^0\bar{K}^0)$

2. Computing $\mathcal{R}(\epsilon'/\epsilon)$, explaining $\Delta I = 1/2$

3. $K_{\ell_3}, K_{\ell_4}, K \rightarrow n\gamma + \pi$'s, scalars...

We can also study $\phi$-decays to scalar, pseudoscalar and vector
mesons. At one end we have $\phi \rightarrow \rho \pi$, $\text{BR} \sim 15\%$, at the other
radiative $\phi$-decays to $f_0, \eta'$, $\text{BR} \sim 10^{-4}$, $\eta$ etc. Finally there are
$e^+e^- \rightarrow 2\pi + \gamma$ leading to the 2 pion continuum and two photon
processes.

The above is the physics of KLOE, in addition to $\varpi R$ studies.
4. DEAR

DEAR proposes to measure the energy and width of $K_\alpha, K_\alpha$ x-rays from $p-K^-$ and $p-K^-$ atoms. One can thus obtain real and imaginary part of the $I-0, 1 N - K$ scattering lengths. The DEAR experiment has not been installed yet and hopes to begin stopping kaons in nitrogen for some initial calibration. Charged kaon pairs produced in $\phi$-decays were observed in a pair of scintillation counters last December. Also background spectra have been taken as shown. At $L \sim 10^{33}$ cm$^{-2}$ s$^{-1}$ they expect to collect $10 \times$ more data in one week than collected so far.
$e^+e^- \rightarrow \phi \rightarrow K^\pm$ signal
CCD signal with single beam
5. KLOE

KLOE is a typical $e^+e^-$ collider detector, with cylindrical symmetry and dimensions dictated by $\lambda(K_L) \sim 3.4$ m.

Owing to the difficulties of measuring $\Re(\epsilon'/\epsilon)$ and also the very low energy of charged and neutral particles to be detected, KLOE is very simple and conservative in its design, but takes full advantage of many technologies.

In particular it has a very sophisticated and also very complex data acquisition and processing system.
\[
\begin{align*}
\gamma Y + S Y & \leftrightarrow Y Y \\
0 Y + 0 Y & \leftrightarrow \varphi + \varphi
\end{align*}
\]
φ resonance scan

$K^0\bar{K}^0$ signal

$W=2E_{\text{beam}}$ (MeV)

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KLOE $\int \mathcal{L} \, dt$ to date  2.42 pb$^{-1}$

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KLOE Performance

1. $K^0 \to \pi^+ \pi^- : \sigma(m_{K^0}) = 0.9 \text{ MeV}, \sigma(p_{K^0}) = 2 \text{ MeV}/c$

2. $K_L$ in the calorimeter, $\sigma(\beta) = 0.004$

3. $\sigma(W) = 1 \text{ MeV}$, from $p(K_S^0) = 1 \text{ MeV}$, from $\beta(K_L)$

4. $\sigma(W) = 4 \text{ MeV}$, $\sigma(IP) = 1 \text{ mm}$, from Bhabha

5. $\sigma(t) = 100 \text{ ps}$ for $e, \gamma$ at 500 MeV in calorimeter

6. $M(2\gamma) = 15 \text{ to } 40 \text{ MeV}$ with calorimeter

7. $K_S \to \pi^0 \pi^0 : \sigma(m_{K^0}) = 27 \text{ MeV}$
$K_s \rightarrow 2\pi^0 \rightarrow 4\gamma$
\( \delta W(\Delta \phi \Delta \epsilon) = 1 \text{ MeV} \)
gives \( \delta \beta = 0.004 \)

\( \sigma(t) = 700 \text{ ps} \)
\( \sigma(\beta) = 0.0039 \)

\( \beta = 0.2133 \)
KLOE Luminosity Requirements

In 2000 with 20 pb$^{-1}$

1. $K\ell_3$ form factors
2. $\phi \rightarrow K\overline{K}$, $K^\pm$, $K_S \rightarrow \pi^+\pi^-\pi^0\pi^0$
3. Radiative $\phi$ decays

In 2001 with 200 pb$^{-1}$

1. $K_{e4}$
2. Non leptonic radiative decays
3. $\Re(\epsilon'/\epsilon)$ to $\sim 10^{-3}$
DEAR Program

In 1999 nb\(^{-1}\)
\(e^+ e^- \rightarrow K^\pm\) seen in scintillation counters

In 2000 with ? pb\(^{-1}\)
Proof of feasibility with NTP \(N_2\) target

In 2001 with 100 pb\(^{-1}\)
First measurements with \(H_2\) and/or \(D_2\)
6. Early Results

With $\mathcal{L}=2.4$ pb$^{-1}$ KLOE has collected

1. Bhabha, $\gamma\gamma$, etc, $13.5 \times 10^6$ events, not for physics

2. $K_S \rightarrow \pi^+\pi^-$: $1.1 \times 10^6$ ev.; $\rightarrow \pi^0\pi^0$: $0.56 \times 10^6$ ev.

3. $K_L$ crash: $0.6 \times 10^6$ ev.

4. $K^\pm$: $0.59 \times 10^6$ ev

5. $\rho\pi$: $0.66 \times 10^6$ ev

6. $\pi^+\pi^-\gamma$: 2800 ev.
Physics:

$e^+e^- \rightarrow \pi^+\pi^-$

$\phi \rightarrow \text{scalar} + \gamma$

etc

$f_0$ not very visible
Some Preliminary Results

$\phi \rightarrow \eta \gamma$: KLOE calibration

$\sigma(e^+e^- \rightarrow \phi) = 3.19 \pm 0.02 \text{ (stat)} \pm ? \text{ (syst)} \mu\text{b}$
\[ \phi \rightarrow \eta \gamma, \phi \rightarrow \eta' \gamma \]

Interest: \( \eta - \eta' \) mixing angle \( \theta_p \), gluon in \( \eta' \)

1. \( \phi \rightarrow \eta' \gamma \rightarrow \pi^+ \pi^- 3\gamma \)

2. \( \phi \rightarrow \eta' \gamma \rightarrow 7\gamma \), first observation

\[
\Gamma(\phi \rightarrow \eta' \gamma) / \Gamma(\eta \gamma) = (7.1 \pm 1.6) \times 10^{-3} \quad \pi^+ \pi^- 3\gamma
\]

\[
\Gamma(\phi \rightarrow \eta' \gamma) / \Gamma(\eta \gamma) = (6.8 \pm 2.8) \times 10^{-3} \quad 7\gamma
\]

\[
\text{BR}(\phi \rightarrow \eta' \gamma) = (8.9 \pm 2) \times 10^{-5}
\]

\[
\theta_p = -18.9^\circ \pm 3.2^\circ
\]

Preliminary. Systematic errors \( \sim 20\% \) of statistical.
\[ \phi \rightarrow \pi^0 \pi^0 \gamma \]

Interest: \( f_0 \)

Background: \( e^+ e^- \rightarrow \omega \pi^0 \rightarrow \pi^0 \pi^0 \gamma \)

Before cos\( \psi \) cut

After cos\( \psi \) cut

\[ \sigma(e^+ e^- \rightarrow \omega \pi^0) = (0.67 \pm 0.06) \times 10^{-3} \text{ nb} \]
$\phi_0$ signal

\begin{align*}
N(\phi \rightarrow f_0\gamma) &= 193 \pm 21 \\
\text{BR}(\phi \rightarrow f_0\gamma(\pi^0\pi^0\gamma)) &= (0.81 \pm 0.11) \times 10^{-4} \\
\text{BR}(\phi \rightarrow f_0\gamma(\pi^+\pi^-\gamma)) &< 1.64 \times 10^{-4} \\
\text{BR}(\phi \rightarrow a_0\gamma(\eta\pi^0\gamma)) &= (0.69 \pm 0.18) \times 10^{-4}
\end{align*}
\[ K_S \rightarrow \pi^+ \pi^- , \pi^0 \pi^0 \]

\[
\begin{array}{cccc}
\text{PDG} & \text{KLOE} \\
K_S \rightarrow \pi^+ \pi^- / K_S \rightarrow \pi^0 \pi^0 & 2.19 \pm 0.01 & 1999 \text{ data} \\
K_S \rightarrow \pi^+ \pi^- \gamma / K_S \rightarrow \pi^+ \pi^- \gamma & 2.6 \pm 0.08 \times 10^{-3} & \pm 0.1 \times 10^{-3} \\
\end{array}
\]
$K_L \rightarrow K_S$ regeneration

Counts

chamber wall

25 cm

beam pipe

10 cm

$R$ (decay point), cm
\[ \phi \rightarrow \rho \pi, \ 3\pi \]

3 contributions to Dalitz plot

\[ \phi \rightarrow \rho^{\pm} \pi^{0} \]
\[ \phi \rightarrow \pi^{+} \pi^{-} \pi^{0} \text{ (direct)} \]
\[ e^{+} e^{-} \rightarrow \omega \pi^{0} \]

Amplitudes of \( \rho \pi \) and direct terms not well established

Analysis of Dalitz plot sensitive to \( \rho \) line shape

Measure \( \rho^{\pm} \pi^{0} \) simultaneously

- 2-track vertex from origin
- \( 90 < M_{\text{miss}} < 180 \text{ MeV}/c^2 \)
- 2 prompt neutral clusters
- \( \cos \theta_{\pi} < -0.98 \)
- \( \theta_{\gamma} < 175^\circ \) (reject \( e^{+} e^{-} \rightarrow e^{+} e^{-} \gamma \gamma \))

\[ |A(\text{direct})/A(\rho \pi)| = 10 \pm 1\% \]

Mass difference. EM and \( \gamma - \rho \) mixing contributions.
3 body $K$-decays

![Graph of 3 body $K$-decays](image)