SEARCH FOR DARK FORCES WITH KLOE

Francesca Curciarello
on behalf of KLOE-2 Collaboration

INFN National Laboratory of Frascati (Italy)

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Motivation

Dark Sector

DAφNE and KLOE

Dark KLOE Searches

Conclusions

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Search for dark forces with KLOE
Motivation

All these anomalies could find a unique explanation with the existence of a new gauge boson called $U$, $A'$, $\gamma'$ or simply dark photon.
Moreover (now totally ruled out at least for U decays into SM particles)...

★ A low mass U boson could explain the well known $a_\mu$ discrepancy with SM:

$$a^\text{dark}_\mu \propto \frac{\alpha}{2\pi} \varepsilon^2 \text{ for } M_U \sim 10^{-100} \text{ MeV and } \varepsilon \sim 10^{-3}$$

★ The new symmetry should be spontaneously broken by an Higgs-like mechanism, thus introducing the existence of an additional scalar particle, the dark Higgs $h'$. 
Minimal Theoretical setup:
just a gauge boson U belonging to an extra abelian gauge symmetry $U_D(1)$, U is the lightest particle of the dark sector and can only decay into SM particles through kinetic mixing $\rightarrow$ visible decays

**STANDARD MODEL**
$SU(3) \times SU(2) \times U(1)_Y$
g, $\gamma$, $W^\pm$, $Z^0$, h

**DARK SECTOR**

Only a boson U ($m_U \neq 0$)

Known Forces,
Strong, EM, WEAK

New Force
$U_D(1)$
Dark sector could be much intricate...

Generalised dark sector scenario:
a non-Abelian gauge group $G_D$ which can be Higgsed (new gauge bosons) or confined (dark flavour mesons, glueball and baryons) at $\mathcal{O}(\text{MeV}–10 \text{ GeV})$.

$G_D \supset U(1)_D$, still mixing between photon and dark photon but $U$ could not be the lightest particle and decay to dark particles giving rise to invisible decays

We will focus on visible and prompt $U$ decays
The U boson would be produced during dark matter annihilation processes and then decay to light particles, as leptons or pions:
\[ \tilde{\chi} + \chi \rightarrow U + U, \ U \rightarrow l^+l^- \ (l = e, \mu, \pi), \]
if \( m_U < 1 \text{GeV} \)

Th U couples to \( \gamma \) through loops of heavy dark particles charged under both QED and dark force. The mixing is described by a kinetic mixing term of the form:

\[
L = -\frac{\varepsilon^2}{2} F_{ij}^{EW} F_{ij}^{\text{dark}}
\]

\( \varepsilon^2 = \alpha'/\alpha_{em} \) = kinetic mixing parameter
\(~ 10^{-8} - 10^{-4} \)

\( F_{ij}^{em}, F_{ij}^{\text{dark}} = \text{SM hypercharge gauge boson and dark photon tensors} \)
**DAφNE: the φ-Factory**

- $e^+e^-$ collider @ $\sqrt{s} = M_\phi = 1.0194$ GeV
- 2 interaction regions
- 2 separate rings
- 105 +105 bunches, $T_{RF} = 2.7$ ns
- $I^-_{\text{peak}} \sim 2.4$ A, $I^+_{\text{peak}} \sim 1.5$ A
- Injection during data taking
- Crossing angle: $2 \times 12.5$ mrad
- Best Performance:
  \[ L_{\text{peak}} = 1.5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1} \]
The KLOE DC

\[ \sigma_{xy} \sim 150 \mu m \]
\[ \sigma_z = 2 \text{mm} \]
\[ \sigma_{p_{\perp}} / p_{\perp} \sim 0.4\% \text{ (LA tracks)} \]
vertex resolution \(\sim 3\text{mm}\)

12,000 sense wires

Stereo geometry

4m diameter, 3m long

gas mixture: 90% He 10% \(iC_4H_{10}\)

Excellent momentum resolution
The KLOE EMC

End-caps C-shaped to minimize dead zones: 98% coverage of full solid angle

$$\sigma_E/E = 5.7\%/\sqrt{E(\text{GeV})}$$

$$\sigma_T = 54\text{ps}/\sqrt{E(\text{GeV})} + 140\text{ps}$$

Barrel + 2 end-caps:
Pb/scintillating fiber, 4880 PM

Excellent time resolution
Dark Force @ KLOE

\( \phi \) Dalitz decay:

- \( \phi \to \eta U, \ U \to e^+e^- \)
- \( \eta \to \pi^+\pi^-\pi^0 \) (BR=22.7%)
- \( \eta \to \pi^0\pi^0\pi^0 \) (BR=32.6%)

expected signature: peak in the dielectron inv. mass

\( U\gamma \) events:

- \( e^+e^- \to U\gamma, \ U \to l^+l^- (l = e, \mu, \pi) \)
- good knowledge of bckgs
- \( \sigma \sim 1/s: \) 100 times higher at DA\( \phi \)NE
- w.r.t. B-factories

expected signature: resonance peak in the dilepton or dipion inv. mass

Higgsstrahlung process:

- \( e^+e^- \to h'U \)

interesting process observed at KLOE if \( m_U + m_{h'} < m_\phi \)

expected signature for \( m_{h'} < m_U \): bump in the \( M_{ll}Vs M_{miss} \) plane
**Search for** $e^+e^- \rightarrow \phi \rightarrow \eta U$, $U \rightarrow e^+e^-$

$\phi \rightarrow \pi^+\pi^-\pi^0e^+e^-$ ev. sel.
- 4 tracks in a cylinder around IP + 2 photon candidates
- $495 < M_{\pi\pi\gamma\gamma} < 600$ MeV
- $70 < M_{\gamma\gamma} < 200$ MeV
- $535 < M_{\text{recoil}(ee)} < 560$ MeV
- ToF cuts

$\phi \rightarrow \pi^0\pi^0\pi^0e^+e^-$ ev. sel.
- 2 charged tracks in a cylinder around IP
- 6 prompt photons candidates:
  - with $E > 7$ MeV
  - not associated to any track
  - in the time window expected for a photon
    $|T_\gamma - R_\gamma/c| < \text{MIN}(3\sigma_t, 2\text{ns})$
  - acceptance: $|\cos\theta_\gamma| < 0.92$

$\text{BR}(X \rightarrow YU) \sim \varepsilon^2 \times |FF_{XY\gamma}|^2 \times \text{BR}(X \rightarrow Y\gamma)$

$\sigma(\phi \rightarrow \eta U) \sim 40\text{fb}$ for $|FF_{\phi\eta}| = 1$, $\varepsilon \sim 10^{-3}$

$\phi \rightarrow \pi^+\pi^-\pi^0e^+e^-$ sample → $L = 1.5\text{fb}^{-1}$

$\phi \rightarrow \pi^0\pi^0\pi^0e^+e^-$ sample → $L = 1.7\text{fb}^{-1}$

$\phi \rightarrow \eta e^+e^-$ MC simulation developed according to VMD model
$\phi \rightarrow \eta U$ simulation developed according to JHEP 07 051 (2009)
SEARCH FOR $e^+e^- \rightarrow \phi \rightarrow \eta U$, $U \rightarrow e^+e^-$

$\phi \rightarrow \eta U$ MC sample divided in subsamples of 1 MeV width in $5 < M_U < 470$ MeV

For each $M_U$ sub-sample, average value of $\phi \rightarrow \eta e^+e^-$ background from fit to $M_{ee}$ distribution, excluding the 5 bins centred at $M_U$

For each $M_U$ value, signal hypothesis excluded @ 90% C.L. using the CL$_S$ method (error on bckg included)


Limit on $\varepsilon \rightarrow$ formula from Reece and Wang JHEP 07 (2009)

$b_{\phi \eta} \sim 1\text{GeV}^{-2}$

$\varepsilon^2 = \alpha'/\alpha < 1.7 \times 10^{-5}$ @ 90% C.L. for $30 < M_U < 400$ MeV

$\varepsilon^2 = \alpha'/\alpha < 8 \times 10^{-6}$ @ 90% C.L. for the $50 < M_U < 210$ MeV
Search for $e^+e^- \rightarrow U\gamma$, $U \rightarrow \mu^+\mu^-$

Statistics: KLOE data collected on 2002 corresponding to $L = 240 \text{ pb}^{-1}$.

Small angle event selection
$(50 < \theta_\mu < 130, \theta_\gamma < 15, > 165)$

High statistics ISR signal
Significant reduction of $\phi$ resonant and FSR bckgs
Good $\pi/\mu$ separation thanks to kinematical cuts ($M_{\text{trk}}$ and $\sigma_{M_{\text{trk}}}$ cuts)

![Graph showing $d\sigma/dM_{\mu\mu}$ vs. $M_{\mu\mu}$](image-url)
Search for $e^+e^- \rightarrow U\gamma$, $U \rightarrow \mu^+\mu^-$

$\varepsilon^2 = \frac{N_{CLS}/\varepsilon_{\text{eff}}}{H \cdot I \cdot L}$

$N_{CLS} =$ UL on number of U-boson candidates at 90% CL (CLS technique)

$H = \frac{d\sigma_{\mu\mu\gamma}}{dM_{\mu\mu}}/\sigma(\mu^+\mu^- \rightarrow \mu^+\mu^-, M)$

$I = \int \sigma^{U}_{\mu\mu} \, dM_{\mu\mu}$

$\varepsilon_{\text{eff}} = 2 - 15\%$

Systematic error of 1.4–1.8%

$L = 239.3 \, \text{pb}^{-1}$

$\varepsilon^2 < 1.6 \times 10^{-5} - 8.7 \times 10^{-7} \, @ \, 90\% \, \text{C.L. for} \, 520 < M_U < 980 \, \text{MeV}$

SEARCH FOR $e^+e^- \rightarrow U\gamma, U \rightarrow e^+e^-$

Data sample corresponding to $L = \int \mathcal{L} = 1.5\text{fb}^{-1}$

2 oppositely charged tracks ($55 < \theta_e < 125$)

Large angle event selection ($50 < \theta_\gamma < 130$)

High statistics radiative Bhabha events in KLOE data

Per mil level background contamination, or better
Search for $e^+e^- \rightarrow U\gamma$, $U \rightarrow e^+e^-$

$$\varepsilon^2 = \frac{N_{CLS}}{\epsilon_{\text{eff}}} \frac{H \cdot I \cdot L}{H}$$

$N_{CLS} = UL$ on number of U-boson candidates at 90% CL (CLS technique)

$H = \frac{d\sigma_{ee\gamma}/dM_{ee}}{\sigma(e^+e^- \rightarrow e^+e^-,M)}$

$I = \int \sigma^U_{ee} dM_{ee}$

$\epsilon_{\text{eff}} = 1.5 - 2.5\%$

Systematic error < 2%

$L = 1.54$ fb$^{-1}$

$\varepsilon^2 \sim 10^{-6} - 10^{-4}$ @ 90% C.L. for $5 < M_U < 520$ MeV
**Search for** $e^+e^- \rightarrow U\gamma$, $U \rightarrow \pi^+\pi^-$

Statistics: full KLOE statistics corresponding to $L=1.93 \text{ fb}^{-1}$.

Small angle event selection

$(50 < \theta_\pi < 130$, $\theta_\gamma < 15$, $> 165)$

High statistics ISR signal

Significant reduction of $\phi$ resonant and FSR bckgs

Good $\pi/\mu$ separation thanks to kinematical cuts ($M_{\text{trk}}$ cut)

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**Figure:**

- **Graph:** Observed spectrum smeared $\pi\pi$ PHOK. GS $|F_\pi|^2$ smeared + residual background

- **Axes:**
  - $x$-axis: $M_{\pi\pi}$ (GeV)
  - $y$-axis: Entries / 2 MeV

- **Data Points:**
  - Observed spectrum
  - $\pi\gamma$ PHOK. GS $|F_\pi|^2$ smeared + residual background
Search for $e^+e^- \rightarrow U\gamma$, $U \rightarrow \pi^+\pi^-$

$$\varepsilon^2 = \frac{N_{CLS}/\epsilon_{eff}}{H \cdot I \cdot L}$$

$N_{CLS} =$ UL on number of U-boson candidates at 90% CL (CLS technique)

$$H = \frac{d\sigma_{\pi\pi\gamma}/dM_{\pi\pi\gamma}}{\sigma(\pi^+\pi^- \rightarrow \pi^+\pi^- , M)}$$

$$I = \int \sigma^U_{\pi\pi} dM_{\pi\pi}$$

$\epsilon_{eff} = 2 - 40\%$

Systematic error $\leq 1\%$

$L = 1.93$ fb$^{-1}$

$$\varepsilon^2 < 1.82 \times 10^{-5} - 1.93 \times 10^{-7} @ 90\%$ C.L. for $527 < M_U < 987$ MeV
**Dark Higgsstrahlung**

Two different scenarios:

\[ m_{h'} = 2m_U \]

- decays:
  \[ h' \to UU \to 4l, \ 2l + 2\pi, \ \pi \]

- \[ m_{h'} < m_U \] with \( h' \) invisible

**Invisible scenario:**

\[ \varepsilon \sim 10^{-3}, \alpha_D = \alpha_{em}, \ m_U \sim 100\text{MeV} \to \tau_{h'} < 5\mu s \]

\[ \to \beta \gamma ct < 100m \to h' \] invisible at KLOE up to \( \varepsilon \sim 10^{-2} - 10^{-1} \) depending on \( m_{h'} \)

**Final state signature:** 2 muons + missing energy \( \rightarrow \) bump in the \( M_{miss} - M_{\mu\mu} \) plane

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**Event Selection:**

- Two oppositely charged tracks with vertex inside a 4 \times 30\text{cm} cylinder around IP
- EMC cluster associated to each track
- Momentum direction inside the barrel: \( |\cos \theta| < 0.75 \)
- \( P_{track} < 460 \text{ MeV} \)
- \( |P_{miss}| > 40 \text{ MeV} \)
- \( E_{miss} \): calorimeter veto
- PID: two muons
- vtx-IP cut (anti K\(^+\)K\(^-\))

**Results for on-peak (1.65 fb\(^{-1}\) ) and off-peak samples (0.2 fb\(^{-1}\) )**
Dark Higgsstrahlung

Combined UL from on- and off-peak samples corresponding to $\varepsilon^2 \sim 10^{-6}$ to a few $10^{-8}$ (if $\alpha_D = \alpha_{em}$)


90% CL bayesian UL on number of events converted in terms of $\alpha_D \times \varepsilon^2$ by using:

- $L$ and signal efficiency information
- $\sigma_{hU}$ and BR of the $U \rightarrow \mu^+\mu^-$

Combined UL take into account the different $L$, signal efficiencies and cross sections of the two samples

Syst. errors included

$\alpha_D \varepsilon^2 = \frac{N_{90\%}}{\varepsilon_{eff}} \cdot \frac{1}{L \cdot \sigma(\alpha_D \varepsilon^2 = 1)}$

$\sigma_{hU} \sim \frac{1}{s} \cdot \frac{1}{(1 - \frac{m_U^2}{s})^2}$

Dark Searches at KLOE2: present and future

New dark analysis will profit of:
* an increased luminosity (factor $2 \div 3$)
* an IT-DC combined tracking (under study) → lower systematic errors

Some new ideas under study:
* B boson search in two channels:
  $\phi \rightarrow \eta B, B \rightarrow \pi^0 \gamma$ and $\eta \rightarrow B \gamma, B \rightarrow \pi^0 \gamma$
  (leptophobic, in progress)
* Invisible U decays to light dark matter (with or without the single $\gamma$ trigger)

Data taking stopped this July $\sim 2.5 \text{ fb}^{-1}$ of data acquired up to now
milestone2: $2.5 \text{ fb}^{-1}$ by July 2016 (fulfilled)

Data taking will restart on mid September 2016, final goal: $5 \text{ fb}^{-1}$ in two years
KLOE searched for a new light gauge boson in three processes in six different reactions:

- **φ meson decay:**
  \[ \phi \to \eta U, \ U \to e^+e^-, \ \eta \to \pi^+\pi^-\pi^0, \ \eta \to \pi^0\pi^0\pi^0 \]
  
  PLB 720 (2013) 111

- **Continuum processes** \( e^+e^- \to U\gamma \):
  - \( e^+e^- \to U\gamma, \ U \to \mu^+\mu^- \)  
  - PLB 736 (2014) 459
  - \( e^+e^- \to U\gamma, \ U \to e^+e^- \)  
  - PLB 750 (2015) 633
  - \( e^+e^- \to U\gamma, \ U \to \pi^+\pi^- \)  
  - PLB 757 (2016) 356

- **Higgsstrahlung (invisible scenario):**
  \[ e^+e^- \to Uh', \ U \to \mu^+\mu^- + E_{\text{miss}} \]
  
  PLB 747 (2015) 365

We found no evidence of U-boson signature and set limits on the mixing parameter \( \varepsilon^2 (\alpha_D \times \varepsilon^2) \) as function of U \( (h') \) mass of \( 10^{-5} \div 10^{-7} \) depending on the process.

DAFNE2 increased luminosity + KLOE2 sub-detectors are expected to improve our sensitivity by a factor \( \sim 2 \) or better.
Thank You!

KLOE-2 Workshop on e+e- collision physics at 1 GeV

https://agenda.infn.it/conferenceDisplay.py?confId=11722
there will be also a dedicated item on dark force searches!
SPARES
\( \phi \rightarrow \eta U, \ U \rightarrow e^+e^- \)

\[
\sigma(e^+e^- \rightarrow \phi \rightarrow \eta U) = \varepsilon^2 |F_{\phi\eta}(m_U^2)|^2 \frac{\lambda^{3/2}(m_\phi^2, m_\eta^2, m_U^2)}{\lambda^{3/2}(m_\phi^2, m_\eta^2, 0)} \sigma(e^+e^- \rightarrow \phi \rightarrow \eta\gamma)
\]

\[
\lambda(m_1^2, m_2^2, m_3^2) = [1 + m_3^2/(m_1^2 - m_2^2)]^2 - 4m_1^2m_3^2/(m_1^2 - m_2^2)^2
\]

\[
F_{\phi\eta}(q^2) = \frac{1}{1 - q^2/\Lambda^2} \quad q = M_{ee}
\]

FF slope:
\[
b = \left. \frac{dF}{dq^2} \right|_{q^2=0}
\]
\[
b_{\phi\eta} = \Lambda_{\phi\eta}^{-2} \approx 1/m_{\phi}^2 \approx 1\text{GeV}^{-2} \rightarrow \text{VMD expectation}
\]

Data/MC comparison

UL on Number of event (top)
UL on BR(\( \phi \rightarrow \eta U \rightarrow \eta e^+e^- \)) for the two eta decays and the combined one (bottom)
**Uγ CHANNEL: π/µ SEPARATION**

*Trackmass* variable, $M_{trk}$, defined by momentum and energy conservation laws, by requiring that the tracks belong to particles of the same mass $m_x$ in the process: $e^+e^- \rightarrow x^+x^-\gamma$, $x = \mu, \pi, e$

\[
\left( \sqrt{s} - \sqrt{|p_+|^2 + M_{trk}^2} - \sqrt{|p_-|^2 + M_{trk}^2} \right)^2 - (p_+ + p_-)^2 = 0
\]

- $80 \text{ MeV} < M_{trk} < 115 \text{ MeV}$ for muons
- $M_{trk} > 130 \text{ MeV}$ for pions
- $-70 \text{ MeV} < M_{trk} < 70 \text{ MeV}$ for electrons
**Motivation:** $M_{\text{trk}}$-distribution left tail of $\pi^+\pi^-\gamma$ that contaminates the signal region is mainly due to poorly reconstructed tracks

$\sigma_{M_{\text{trk}}}$ **cut**: quality cut based on the error on the $M_{\text{trk}}$ obtained by the helix fit of both DC tracks (cut efficiency: 70-80%)

**Effect:** Suppression of the $\pi^+\pi^-\gamma$ fractional bckg of about 40% depending on $M_{\mu\mu}$ slice
\[ \sigma^2_{\text{M}_{\text{trk}}} = \sum_{i,j} \frac{\partial \text{M}_{\text{trk}}}{\partial x_i} M_{i,j} \frac{\partial \text{M}_{\text{trk}}}{\partial x_j} \]

\[ \sigma^2_{\text{M}_{\text{trk}}} : \text{error of a function of many variables, } x_i \ (x_j): i_{th} \ (j_{th}) \text{ variables of the function} \]

\[ \text{covariance matrix } M \text{ with elements: } M_{i,i} = \sigma^2_{x_i}, \quad M_{i,j} = \rho_{x_i x_j} \]

\[ \sigma^2_{\text{M}_{\text{Trk}}} = \left( \begin{array}{cccccc} \frac{\partial \text{M}_{\text{trk}}}{\partial k_1} & \frac{\partial \text{M}_{\text{trk}}}{\partial \cot \theta_1} & \frac{\partial \text{M}_{\text{trk}}}{\partial \varphi_1} & 0 & 0 & 0 \\ \frac{\partial \text{M}_{\text{trk}}}{\partial k_2} & \frac{\partial \text{M}_{\text{trk}}}{\partial \cot \theta_2} & \frac{\partial \text{M}_{\text{trk}}}{\partial \varphi_2} & 0 & 0 & 0 \\ \end{array} \right) \times \left( \begin{array}{cccccc} \frac{\partial \text{M}_{\text{trk}}}{\partial k_1} & \frac{\partial \text{M}_{\text{trk}}}{\partial \cot \theta_1} & \frac{\partial \text{M}_{\text{trk}}}{\partial \varphi_1} & 0 & 0 & 0 \\ \frac{\partial \text{M}_{\text{trk}}}{\partial k_2} & \frac{\partial \text{M}_{\text{trk}}}{\partial \cot \theta_2} & \frac{\partial \text{M}_{\text{trk}}}{\partial \varphi_2} & 0 & 0 & 0 \\ \end{array} \right) \]

No correlation assumed between variables associated to different tracks

Available information: Error on track curvature k, on polar and azimuthal angle and on \( \sigma^2_{x_i}, \rho_{x_i x_j} \)

Missing information: \( \vec{p}_1 \) and \( \vec{p}_2 \) components
\[ H(s, s_l, \cos \theta) = \frac{d\sigma_{ll\gamma}}{ds_l} / \sigma(e^+e^- \rightarrow l^+l^-, s_l) \]

\[ s_l = M_{ll}^2 \quad s = E_{cm}^2 \quad l = e, \mu \]

\[ H = \frac{\alpha}{\pi s} \left[ \frac{s^2 + s_l^2}{s(s-s_l)} \log \frac{1+c_{\min}}{1-c_{\min}} - \frac{s-s_l}{s} \right] c_{\min} \]

\[ c_{\min} < \cos \theta_{\gamma} < c_{\min} \]

\[ \sigma(e^+e^- \rightarrow \mu^+\mu^-, s_\mu) = \frac{4\pi\alpha^2}{3s_\mu} \frac{\beta_\mu(3-\beta_\mu^2)}{2} \]

\[ \beta_\mu = \sqrt{1 - \frac{4m_\mu^2}{s_\mu}} \]

\[ N_{QED} = \sigma_{i, QED}^{ll\gamma} \cdot L = \int \Delta_i \left( \frac{d\sigma_{ll\gamma}}{ds_l} \right) ds_l \cdot L = \left\langle \frac{d\sigma_{ll\gamma}}{ds_l} \right \rangle \Delta_i \cdot L \]

\[ N_U = \sigma_{i, U}^{ll\gamma} \cdot L = \left\langle \frac{d\sigma_{ll\gamma, U}}{ds_l} \right \rangle \Delta_i \cdot L = \left\langle \sigma_U H \right \rangle_i \Delta_i \cdot L \approx \left\langle H \right \rangle_i \int \Delta_i \frac{\sigma_U^{ll}}{\Delta_i} ds \Delta_i \cdot L = \int \Delta_i \frac{\sigma_U^{ll}}{\Delta_i} ds \cdot HL = I'_l \cdot H \cdot L \]

\[ I'(s_l) = \int \sigma_{U}^{ll} ds_l \]

\[ = \int \frac{12\pi \Gamma(U\rightarrow e^+e^-)\Gamma(U\rightarrow \mu^+\mu^-)}{(s_l-m_U^2)^2+M_U^2\Gamma_{tot}^2} \]

\[ = \frac{12\pi^2 \Gamma(U\rightarrow e^+e^-)\Gamma(U\rightarrow \mu^+\mu^-)}{M_U\Gamma_{tot}} \]

\[ I'(\sqrt{s_l}) \approx I'(s_l)/2\sqrt{s_l} \quad I' = \varepsilon^2 I \]

\[ \frac{N_U}{\sqrt{N_{QED}}} = \int \sigma_{U}^{ll} ds_l \cdot HL = 1 \]

\[ \frac{\varepsilon^2 I \cdot HL}{N_U} = 1 \]

\[ \varepsilon^2 = \frac{N_U/L}{H \cdot I} \quad N_U = N_{CLS}/\epsilon_{\text{eff}} \]
**Higgsstrahlung Process:** $M_{\mu\mu}$ and $M_{\text{miss}}$ Spectra
Higgsstrahlung process: off-peak
Sample-bidimensional limits
FROM DAFNE TO DAFNE2

Luminosity vs Current Product

CRAB Optics
- 24/11/2008
- 16/05/2008 4 months
- 20/04/2008 3 months

KLOE/FINUDA
- 12/04/2007 Finuda best
- 16/09/2005 17 months
- 15/09/2004 4 months
- 23/07/2004 3 months

Crab sextupoles ON

Crab sextupoles OFF
From KLOE to KLOE2

INNER TRACKER:

★ four layers of cylindrical triple GEM
★ better vertex reconstruction near IP
★ higher acceptance to low $p_t$ tracks

CCALT:

★ LYSO crystal + SiPM
★ increase of angular acceptance to $\gamma$'s from IP from $21^\circ$ to $10^\circ$

QCALT:

★ W + Scintillator tiles+ WLS/SiPM
★ QUADS coverage for $K_L$ decays

LET and HET:

★ Low and High energy tagger stations for $e^+e^-$ coming from two-photon interaction
★ LET: LYSO + SiPM
★ HET: EJ228 plastic scintillator hodoscope + Xilinx Virtex-5 FPGA