### B boson search studies



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## Outlook

- Motivation: B boson
- Data selection
  - Selection of prompt events
  - Selection of signal events
    - Selection cuts
    - Kinematic Fit 2 with constrains
- Cut on wrong hypothesis to clean omega/f0
- ToDo list / Summary



# New GeV-scale forces: Dark Photon

- A new low energy gauge interaction mediated by a neutral light mass vector particle, usually named the U boson, with a small kinetic mixing ε (<10<sup>-3</sup>) with SM
- Dark vector boson U which mixes with photon:  $e^+$

$$\mathcal{L}_{mix} = -\frac{\epsilon}{2} F^{QED}_{\mu\nu} F^{\mu\nu}_{dark}$$

• KLOE:

- $\phi \rightarrow \eta U \text{ with } U \rightarrow e^+ e^-$
- $e^+ e^- \rightarrow U\gamma$  with  $U \rightarrow \mu^+ \mu^-$
- $e^+ e^- \rightarrow Uh'$  with  $h' \rightarrow invisible$
- $e^+ e^- \rightarrow U\gamma$  with  $U \rightarrow e^+ e^-$

-  $e^+ e^- \rightarrow U\gamma$  with  $U \rightarrow \pi^+ \pi^-$ 

Phys. Lett B 706 (2012) 251-255 Phys. Lett B 720 (2013) 111-115

Phys. Lett B 736 (2014) 459-464

Phys.Lett. B747 (2015) 365-372

Phys.Lett. B750 (2015) 633-637

Phys.Lett. B SUBMITTED

• Search for dilepton resonances

#### Leptophobic Dark Matter mediator search with KLOE-2



- B boson couples mainly to quarks
- Most basic model → coupling to baryon number

$$\mathscr{L} = \frac{g_B}{3} \bar{q} \gamma^{\mu} q B_{\mu} \qquad \qquad g_B \lesssim 10^{-2} \times (m_B/100 \text{ MeV}) \\ \alpha_B = \frac{g_B^2}{4\pi} \lesssim 10^{-5} \times (m_B/100 \text{ MeV})^2$$

- $\Phi \rightarrow \eta B$  with  $B \rightarrow \pi^0 \gamma$ 
  - Channel used for a0(980) scalar meson
- Look for resonance in  $\pi^0\gamma$  invariant mass
- 2001/2002 data analysis
  - $\sim$  13000 events after background subtraction
  - From ~ 4.7 Mevents  $\Phi$
- 2005 largest and more stable sample

	Decay $\rightarrow$ Production $\downarrow$	$B \rightarrow e^+ e^-$ $m_B \sim 1 - 140 \text{ MeV}$	$B \rightarrow \pi^0 \gamma$ 140–620 MeV	$B \rightarrow \pi^+ \pi^- \pi^0$ 620–1000 MeV	$B \to \eta \gamma$
	$ \begin{array}{c} \pi^0 \to B\gamma \\ \eta \to B\gamma \end{array} $	$\pi^0  ightarrow e^+ e^- \gamma \ \eta  ightarrow e^+ e^- \gamma$	$\eta \rightarrow \pi^0 \gamma \gamma$		
KLOE searches	$\begin{array}{l} \eta' \to B\gamma \\ \omega \to \eta B \end{array}$	$\eta'  ightarrow e^+ e^- \gamma \ \omega  ightarrow \eta e^+ e^-$	$\eta'  ightarrow \pi^0 \gamma \gamma \ \omega  ightarrow n \pi^0 \gamma$	$\eta'  ightarrow \pi^+ \pi^- \pi^0 \gamma$	$\eta'  ightarrow \eta \gamma \gamma$
	$\phi \to \eta B$	$\phi  ightarrow \eta e^+ e^-$	$\phi \to \eta \pi^0 \gamma$		

# B Boson search summary

- Selection
  - Exactly 5 **prompt** photons
  - Cut in Eclu and Theta cluster to reduce bkg from accidentals
- Kinematic Fit
  - Fortran wrap in  $c^{++} \rightarrow KLOE$  code
  - 1<sup>st</sup> fit with 9 constrains
    - T R/c = 0 for all 5 gammas w/ respect to Phi vtx
      - Total 4 momentii of the gammas = E\_e- + E\_e+
      - $X^2 \le 27$
- Selection
  - Combinatorics to choose the best  $\eta$ - $\pi$  pair
- 2<sup>nd</sup> Kinematic Fit with 11 constraints
  - Add eta and pion mass to the fit



C++ KinFit

- 9 constrains:
  - T-R/c = 0 of all g's w/ respect to Phi vtx (5)
  - Total 4 Momentii of  $g's = E_e + + E_e$  (4)
- χ<sup>2</sup> <= 27 (recipe 2001 analysis)

Black before KinFit Blue after Kinfit



## K

## Data selection

- Photon pair recombination
- Allowed to use 5 photon
- Recombine to all possible pairs forming  $\eta$ - $\pi$
- Selection by minimizing  $X^2$

$$\chi^{2} = \frac{(m_{ij} - m_{\eta})^{2}}{\sigma_{\eta}^{2}} + \frac{(m_{kl} - m_{\pi})^{2}}{\sigma_{\pi}^{2}}$$

 $\sigma_{\pi} = 6 MeV$ 

 $\sigma_{\eta} = 9 \, MeV$ 

### **Data selection**



Myy [MeV]



Fit with 11 constrains

- T R/c = 0 for all 5 gammas w/ respect to Phi vtx (5)
  - Total 4 momentii of the gammas = E\_e- + E\_e+ (4)
  - Gamma-gamma mass to eta (1)
  - Gamma-gamma mass to pi0 (2)

•  $X^2 \le 20$ 





Fit with 11 constrains
X<sup>2</sup> <= 20</li>







• Fit with 9 constrains

•  $X^2 \le 20$ 

signal to bkg ratios f0: 1.7358 etagg: 685.777 eta3pi0: 2.97586 etapgg: 30.5779 omegapi0: 0.694625 pi0g: ---



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Before 2<sup>nd</sup> Kinematic Fit fo: 0.909 Etagg: 231.46 Eta3pi0: 0.73 Etapi0gg: 16.63 omegapi0: 0.55 Pi0g: -----



Fit with 9 constrains
X<sup>2</sup> <= 20</li>

#### Low statistics sample



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## Refined selection

• **263 pb-1**  $\rightarrow$  statistics still increasing (only three jobs per user: offline priority)

- New cut to remove the  $\omega\pi$  / f0 background
  - After Kinecmatic Fit use the fitted photon information to recombine to all possible  $\pi\pi$  pairs
  - Cut on the distance from pi0 mass to remove those possible real pion pairs

# Second combinatorics to exclude pion pairs

- Photon pair recombination
- Allowed to use 5 photon
- Recombine to all possible pairs forming  $\pi\text{-}\pi$
- Selection by minimizing X<sup>2</sup>

$$\chi^{2} = \frac{(m_{ij} - m_{\pi})^{2}}{\sigma_{\pi}^{2}} + \frac{(m_{kl} - m_{\pi})^{2}}{\sigma_{\pi}^{2}}$$

 $\sigma_{\pi} = 6 MeV$ 

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# Second combinatorics to exclude pion pairs

2pi0 recombination after the second fit with 11 constraints Check the best combination of pi0-pi0 and build the chi^2 Cut on the chi^2 distribution to exclude the events that form a good pi0 couple





## **Results: Invariant Masses**





## **Results: Invariant Masses**



## To Do list

#### Fit MC/data

Continue increasing statistics to use all 2005 data (maybe 2004 too)

- 2004 different conditions
- Tunning of resolutions for MC
- 3pi0 from eta is the biggest background remaining
  - Studying the missing mass, missing angle and TMVA to further reduce eta  $\rightarrow$  3pi0 ??
  - Substract directly from MC ?
- We could use the data to do a new fit of the a0
- Extract upper limit
- Referees for the analysis???













