## 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 $\varepsilon\left(<10^{-3}\right)$ with SM
- Dark vector boson U which mixes with photon:

$$
\mathcal{L}_{m i x}=-\frac{\epsilon}{2} F_{\mu \nu}^{Q E D} F_{d a r k}^{\mu \nu}
$$

- KLOE:


$$
\begin{aligned}
- & \varphi \rightarrow \eta \mathrm{U} \text { with } \mathrm{U} \rightarrow \mathrm{e}^{+} \mathrm{e}^{-} \\
- & \mathrm{e}^{+} \mathrm{e}^{-} \rightarrow \mathrm{UY} \text { with } \mathrm{U} \rightarrow \mu^{+} \mu^{-} \\
- & \mathrm{e}^{+} \mathrm{e}^{-} \rightarrow \text { Uh' with } \mathrm{h}^{-} \rightarrow \text { invisible } \\
- & \mathrm{e}^{+} \mathrm{e}^{-} \rightarrow \text { UY with } \mathrm{U} \rightarrow \mathrm{e}^{+} \mathrm{e}^{-} \\
- & \mathrm{e}^{+} \mathrm{e}^{-} \rightarrow \text { UY with } \mathrm{U} \rightarrow \pi^{+} \pi^{-}
\end{aligned}
$$

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


S. Tulin (Phys. Rev. D 89, 114008 (2014))

- B boson couples mainly to quarks
- Most basic model $\rightarrow$ coupling to baryon number

$$
\mathscr{L}=\frac{g_{B}}{3} \bar{q} \gamma^{\mu} q B_{\mu} \quad g_{B} \lesssim 10^{-2} \times\left(m_{B} / 100 \mathrm{MeV}\right) .
$$

- $\Phi \rightarrow \eta$ 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
- ~ 13000 events after background subtraction
- From ~ 4.7 Mevents $\Phi$
- 2005 largest and more stable sample

| Decay $\rightarrow$ | $B \rightarrow e^{+} e^{-}$ | $B \rightarrow \pi^{0} \gamma$ | $B \rightarrow \pi^{+} \pi^{-} \pi^{0}$ |
| :--- | :---: | :---: | :---: |
| Production $\downarrow$ | $m_{B} \sim 1-140 \mathrm{MeV}$ | $140-620 \mathrm{MeV}$ | $620-1000 \mathrm{MeV}$ |
| $\pi^{0} \rightarrow B \gamma$ | $\pi^{0} \rightarrow e^{+} e^{-\gamma}$ | $\ldots$ | $\ldots$ |
| $\eta \rightarrow B \gamma$ | $\eta \rightarrow e^{+} e^{-\gamma}$ | $\eta \rightarrow \pi^{0} \gamma \gamma$ | $\ldots$ |
| $\eta^{\prime} \rightarrow B \gamma$ | $\eta^{\prime} \rightarrow e^{+} e^{-\gamma}$ | $\eta^{\prime} \rightarrow \pi^{0} \gamma \gamma$ | $\cdots \rightarrow \eta \gamma$ |
| $\omega \rightarrow n B$ | $\omega \rightarrow \eta e^{+} e^{-}$ | $\omega \rightarrow n \pi^{0} \gamma$ | $\eta^{\prime} \rightarrow \pi^{+} \pi^{-} \pi^{0} \gamma$ |

## 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
- $1^{\text {st }}$ fit with 9 constrains
- $\mathrm{T}-\mathrm{R} / \mathrm{c}=0$ for all 5 gammas $\mathrm{w} /$ respect to Phi vtx
- Total 4 momentii of the gammas = E_e- + E_e+
- $\mathrm{X}^{2}<=27$
- Selection
- Combinatorics to choose the best $\eta-\pi$ pair
- ${ }^{\text {nd }}$ Kinematic Fit with 11 constraints
- Add eta and pion mass to the fit


## $1^{\text {st }}$ Kinematic 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-
- $x^{2}<=27$ (recipe 2001 analysis)

Black before KinFit Blue after Kinfit



## Data selection

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

$$
\chi^{2}=\frac{\left(m_{i j}-m_{\eta}\right)^{2}}{\sigma_{\eta}^{2}}+\frac{\left(m_{k l}-m_{\pi}\right)^{2}}{\sigma_{\pi}^{2}}
$$

$\sigma_{\pi}=6 \mathrm{MeV}$
$\sigma_{\eta}=9 \mathrm{MeV}$

## Data selection



## $2^{\text {nd }}$ Kinematic Fit

hchi2

hchi2


Fit with 11 constrains

- $\mathrm{T}-\mathrm{R} / \mathrm{c}=0$ 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)
- $\mathrm{X}^{2}<=20$



## $2^{\text {nd }}$ Kinematic Fit

- Fit with 11 constrains
- $\mathrm{X}^{2}<=20$



## $2^{\text {nd }}$ Kinematic Fit



- Fit with 9 constrains
- $\mathrm{X}^{2}<=20$
signal to bkg ratios
f0: 1.7358
etagg: 685.777
eta3pi0: 2.97586
etapgg: 30.5779
omegapi0: 0.694625 piOg: ---

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Before $2^{\text {nd }}$ Kinematic
Fitgnal to bkg ratios

| f0: | 0.909 | $\longleftarrow$ |
| :--- | :---: | :--- |
| Etagg: | 231.46 |  |
| Eta3pi0: | 0.73 | $\longleftarrow$ |
| Etapi0gg: | 16.63 |  |
| omegapi0: | 0.55 | $\longleftarrow$ |
| Pi0g: | ------ |  |

## $2^{\text {nd }}$ Kinematic Fit

- Fit with 9 constrains
- $\mathrm{X}^{2}<=20$

Low statistics sample


## Refined selection

- 263 pb-1 $\rightarrow$ statistics still increasing (only three jobs per user: offline priority)
- New cut to remove the $\omega \pi / \mathrm{fO}$ background
- After Kinecmatic Fit use the fitted photon information to recombine to all possible $\pi \pi$ pairs
- Cut on the distance from piO 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 $\pi-\pi$
- Selection by minimizing $\mathrm{X}^{2}$

$$
\chi^{2}=\frac{\left(m_{i j}-m_{\pi}\right)^{2}}{\sigma_{\pi}^{2}}+\frac{\left(m_{k l}-m_{\pi}\right)^{2}}{\sigma_{\pi}^{2}}
$$

$\sigma_{\pi}=6 \mathrm{MeV}$

## 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


[^0]
## 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 $\rightarrow 3$ pio ??
- Substract directly from MC ?
- We could use the data to do a new fit of the a0
- Extract upper limit
- Referees for the analysis???


## spares

Kinematic Fit 2


## Kinematic Fit 2



Kinematic Fit 2




Photon \#4 Pi0
SIGNAL

## Kinematic Fit 2



Kinematic Fit 2






Photon \#5

SIGNAL


[^0]:    Myץ [MeV]

