“5th force” at BESIII

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Prelude

- 511 KeV gamma ray observed (2003) by INTEGRAL might be due to O(MeV) dark matter annihilation (to electron-positron pair), which is mediated by "fifth force" (2004).
- Such kind of "fifth force" can be stronger than weak interaction at low energy ($Q \ll m_W$).
- Such kind of "fifth force" could be observed at low energy BEPC-II.

天方夜谭？

1. Motivation for “5th force”

Theoretical motivations

- Extra gauge group exists in new physics beyond the standard model -> new gauge interaction (5^{th}, 6^{th}…)
- Experiments didn't give any clues yet.
- Two ways out:

(1) high scale suppressed (weak scale or higher) [mainstream]

(2)coupling suppressed (low energy scale)

P. Fayet, many papers (>10) 1977~2006


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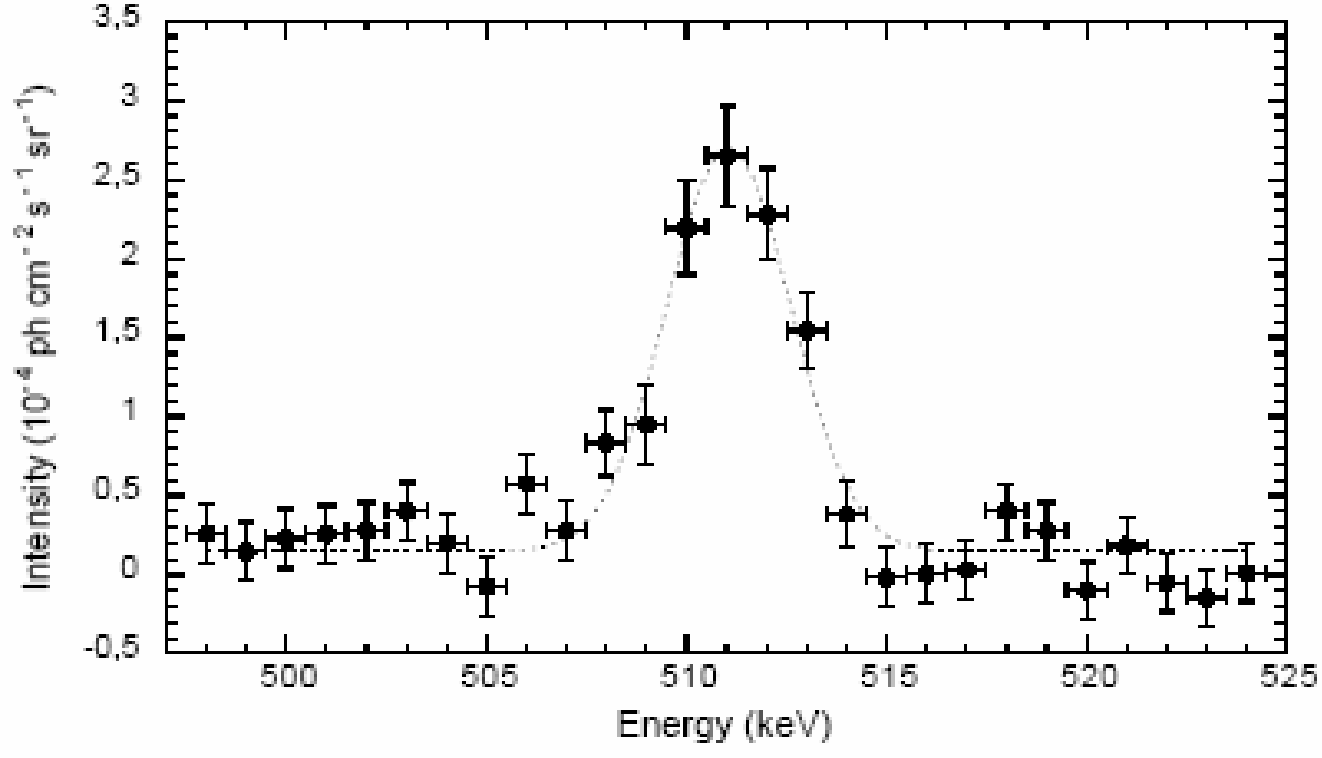
In 2003…

P. Jean et al Astron. Astro. Phys. 407(2003) L55



In 2004…

- Excess of 511 KeV (SPI spectrometer on INTEGRAL) light could be due to dark matter annihilation

  C. Boehm et.al., PRL2004

- Possible massive vector mediates interaction among MeV (scalar or majorana) dark matter and electron-positron
- Simplest case: vector gauge boson (U-boson) with mass O(1-100 MeV) ---- first sign of short distance "5th force" ?

In 2006…

- Theoretical investigations of U boson at low energy electron-position colliders (B-factories and Phi-factories)

  N. Borodatchenkova etal, PRL(2006)

2. “5th force” is ruled out?

Electron g-2 measurement

C. Boehm etal, NPB(2004)
N. Borodatchenkova etal, PRL(2006)

$$-6\cdot 10^{-9} \leq \left(\frac{1\ \mathrm{MeV}}{M_U}\right)^2 \cdot (3 g_{e_L} g_{e_R} - g_{e_L}^2 - g_{e_R}^2) \leq 3\cdot 10^{-8}$$

g_{f_L} and g_{f_R}

the left– and right–handed $\bar{U} f \bar{f}$ couplings

Electron-Neutrino scattering

P. Fayet, PRD(2004)

$$g_{\nu_L}\sqrt{g_{e_L}^2+g_{e_R}^2} < M_U^2 G_F$$

For $g_{e_L} = g_{\nu_L}$ and $g_{e_R} = 0$, this would exclude the entire DM–allowed range (which is invariant under $g_{e_R} \leftrightarrow g_{e_L}$)

Natural parameter choice:

$g_{\nu L}=0$ and $g_{eL}=0$ if extra gauge group is direct product of the SM group, only g_{eR} is relevant.

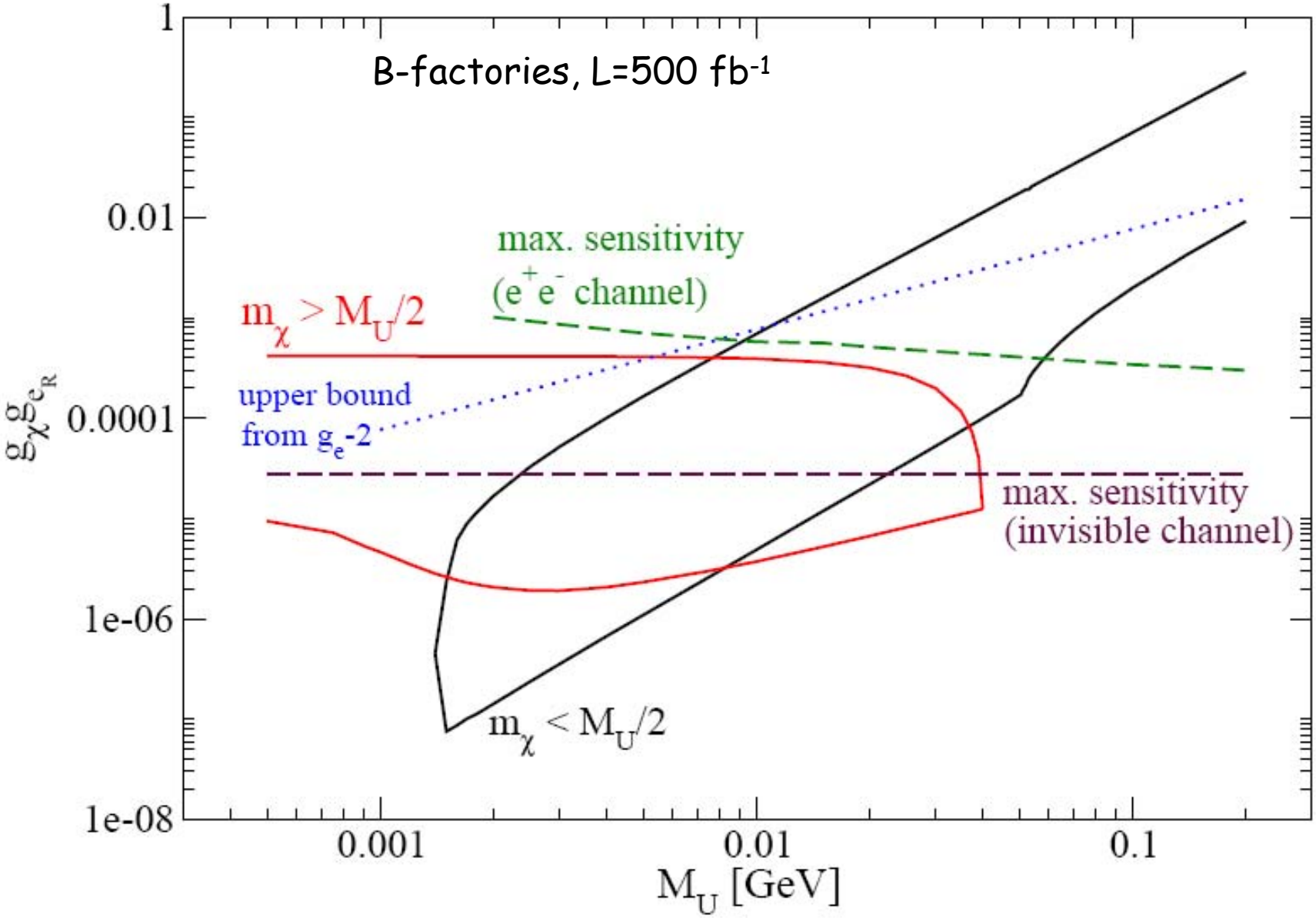
Discover (exclude) 5th force at B- and Phi-factories, via ee->U+gamma

N. Borodatchenkova etal, PRL(2006)

FIG. 2: Parameter space of the model with a complex scalar as MeV Dark Matter χ annihilating through the exchange of spin–1 U bosons, for $g_{e_L} = g_\nu = 0$ and $g_\chi = 1$. Notation is as in Fig. 1, except that the indicated sensitivities are now those that can be achieved at the $B-$factories.

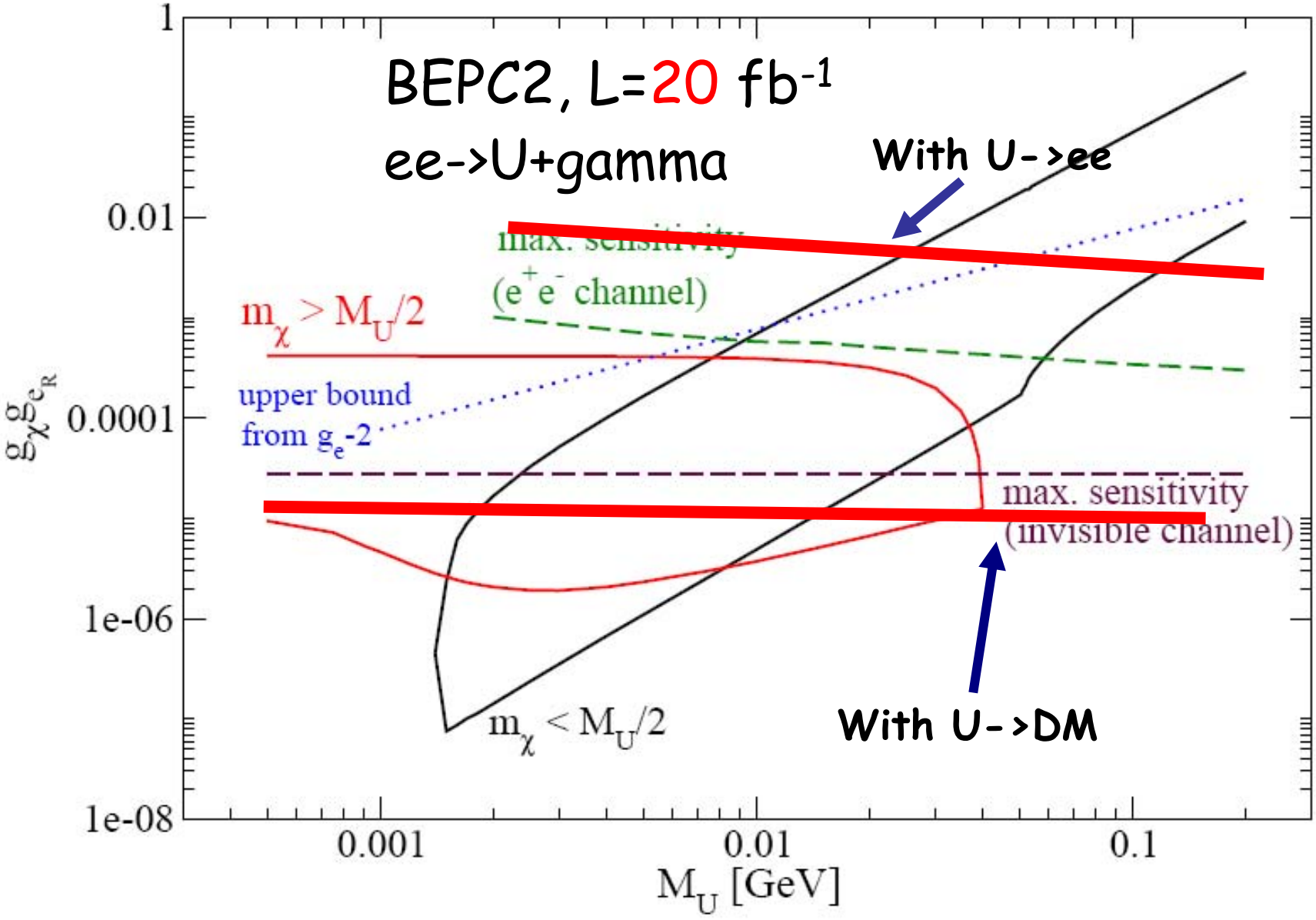
Why g_R << g_chi?

U couples to dark matter directly, but indirectly (via mixing with SM gauge bosons) with electron.


B-factories, L=500 fb-1
max. sensitivity
(e+e- channel)
mχ > MU/2
upper bound
from ge-2
max. sensitivity
(invisible channel)
mχ < MU/2
gχ geR
MU [GeV]
1
0.01
0.0001
1e-06
1e-08
0.001
0.01
0.1

3. “Fifth force” at BESIII (preliminary results)

(A) via ee->U+gamma


BEPC2, L=20 fb-1
ee->U+gamma
With U->ee
max. sensitivity
(e+e- channel)
mχ > MU/2
upper bound
from ge-2
max. sensitivity
(invisible channel)
mχ < MU/2
With U->DM
gχ ge_R
1
0.01
0.0001
1e-06
1e-08
0.001
0.01
0.1
MU [GeV]

(B) via J/Psi decay

"fifth force" in J/Psi decay(1)

- Why?

  (1) J/Psi in BES, 4*10^(10) (4 years)

  (2) Br(J/Psi->ee) ~ 5%

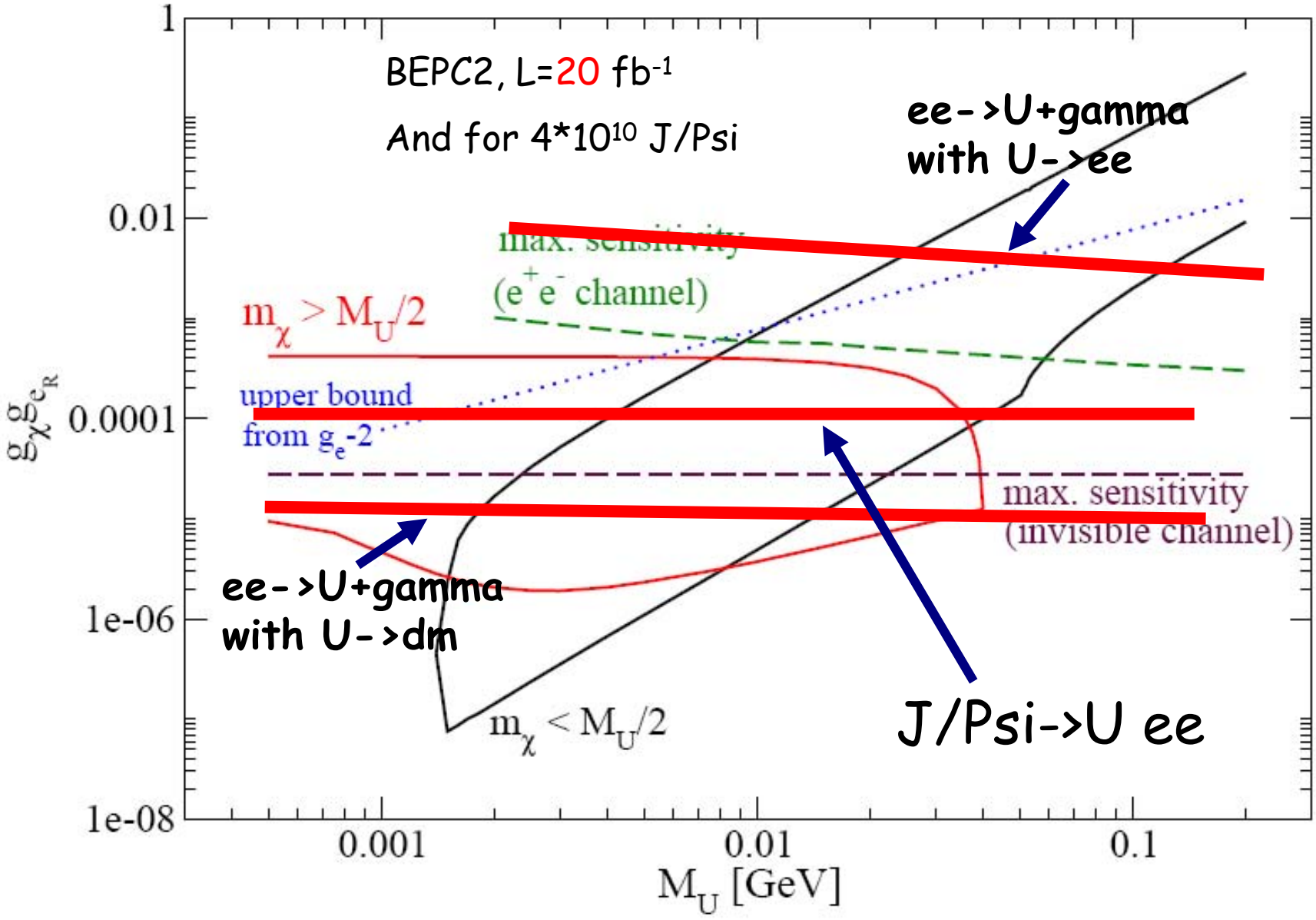
  (3) Br(J/Psi->ee gamma) ~0.9% with E(gamma)>100 MeV

  from PDG

- If U-boson does not decay into neutrino, J/Psi->ee U then U->ee (100% if mU<2 m_chi) or invisibly (100% if mU>2 m_chi)

"fifth force" in J/Psi decay (2)

- Br(J/Psi->ee U)/Br(J/Psi->ee) ~0.5 g_R^2 for mU=20 MeV.
- g_R can be measured down to 10^(-4) if we require 10 eeU events.
- Backgrounds to J/Psi->ee+ U(->DM) is negligibly small
- Backgrounds to J/Psi->ee+ U(->ee) is large


BEPC2, L=20 fb-1
And for 4*10^10 J/Psi
ee->U+gamma
with U->ee
max. sensitivity
(e+e- channel)
mχ > MU/2
upper bound
from ge-2
max. sensitivity
(invisible channel)
ee->U+gamma
with U->dm
mχ < MU/2
J/Psi->U ee
gχ geR
1
0.01
0.0001
1e-06
1e-08
0.001
0.01
0.1
MU [GeV]

4. Conclusions

- Low energy collider (Q<<m_W) is irreplaceable, provided that INTEGREL 511KeV can be interpreted as the sign of weakly coupled "fifth force".
- Two methods to detect U-boson at BESIII:
  (1) ee->U+gamma
  (2) J/Psi decays into eeU
- If U decay dominantly into dark matter, the backgrounds (to neutrino) are small (Q/mW suppressed)
- If U decay dominantly into usual matter, the backgrounds are huge due to QED.
- Need more investigation, especially background studies.
- Realistic steps: (1) What can BESII tell us? (2) What will BESIII tell us?


We should
work
hard !


We should
work hard !

Thanks for your attention!