Light dark forces at SuperB - [1007.4984]

Barzè, Balossini, Bignamini, Carloni Calame, Montagna, Nicrosini, Piccinini

Luca Barzè
University of Pavia / INFN

XVII SuperB Workshop
Kick Off Meeting

1st June 2011

Accepted this morning by EPJC

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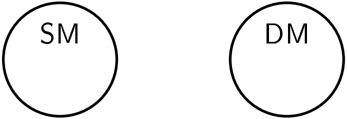
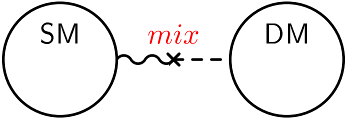
Axiom 1: Dark Matter exists

$$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{DM}$$



Axiom 1: Dark Matter exists and interacts with SM

$$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{DM} + \mathcal{L}_{mix}$$



$$\mathcal{L}_{mix} = \sum_{ij} k_{ij} \Theta^i_{SM} \Theta^j_{DM}$$

What we know about DM nature

What we ~~know~~ suppose about DM nature

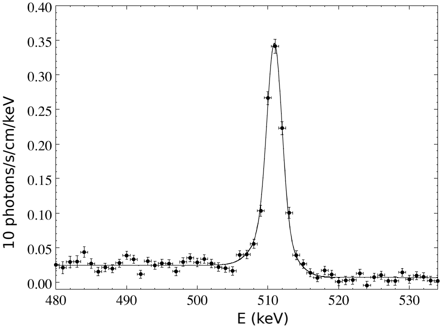
Axiom 2: DM is composed of WIMPs

Astrophysical signals

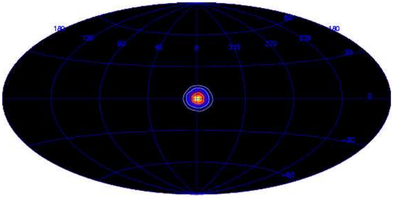
- annihilation
- decay
- scattering ...

Not observables
(if *natural* couplings)

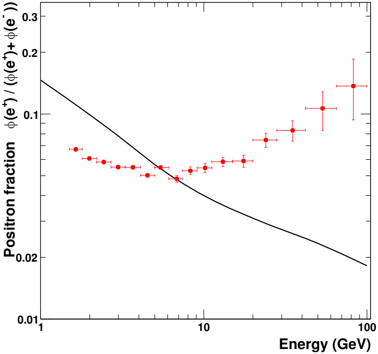
But . . . anomalies!



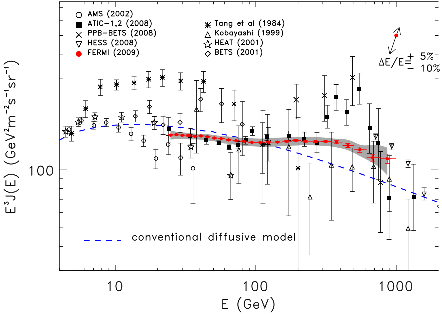
511 keV line - spectrum
astro-ph/0309484



511 keV line - sky map
astro-ph/0702621



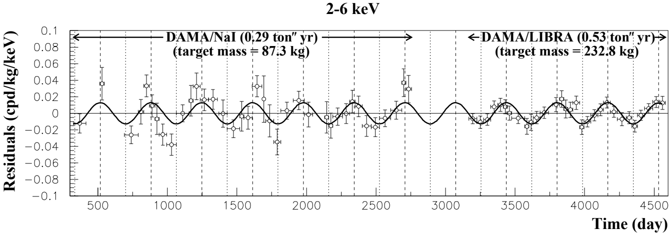
Excess of positrons - PAMELA
1001.3552



Excess of leptons - FERMI
0905.0025

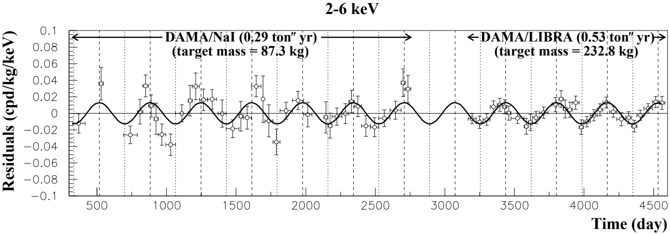
NO $\bar{p}$ excess!

But . . . anomalies!



DAMA modulation signal
Confirmed by CoGENT (?)

But . . . anomalies!



DAMA modulation signal
Confirmed by CoGENT (?)

Astrophysical sources → maybe

Axiom 3: Data due to DM
at least some of them

Implications

- PAMELA / Fermi spectrum $\Rightarrow M_{DM} \sim 100 - 1000$ GeV
- e^+ anomalies without $\bar{p}$
- PAMELA event rates really high $\Rightarrow \langle \sigma v \rangle^{present} \gg \langle \sigma v \rangle^{freeze-out}$

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new physics at $\sim$ GeV scale

annihilation into light states

annihilation enhanced

(by Sommerfeld enhancement)

A simple way

$$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$$

$$\mathcal{L}_{SM} = \mathcal{L}_{SM}^F + \mathcal{L}_{SM}^B + \mathcal{L}_{SM}^H$$

$$\mathcal{L}_{DM} = ?$$

A simple way: a New Symmetry

$$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)_{DM} \otimes \ldots$$

$$\mathcal{L}_{SM} = \mathcal{L}_{SM}^F + \mathcal{L}_{SM}^B + \mathcal{L}_{SM}^H$$

$$\begin{aligned} \mathcal{L}_{DM} &= \mathcal{L}_{DM}^F(\chi) && \Rightarrow \quad M_\chi \sim \text{100 - 1000 GeV} \\ &+ \mathcal{L}_{DM}^B(U) && \Rightarrow \quad m_U \sim \text{1 GeV} \\ &+ \ldots \end{aligned}$$

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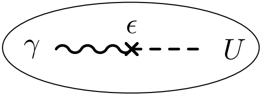
$$\begin{aligned} \mathcal{L}_{mix} &= \epsilon F^{DM\mu\nu} F^{EM}_{\mu\nu} \\ &+ \epsilon h H_{DM} \end{aligned}$$



Small effects at low energies.

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$$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)_{DM} \otimes \dots$$

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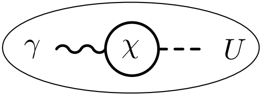
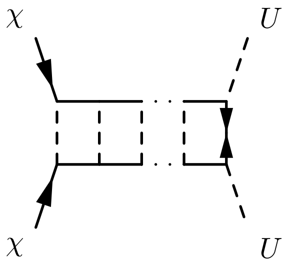
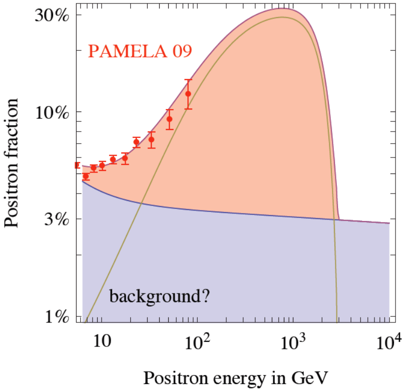


Small effects at low energies.

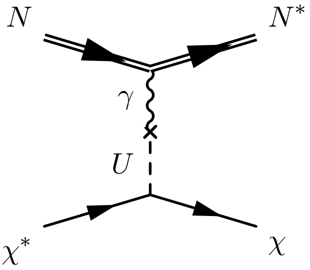
An excess of e^+ without $\bar{p}$

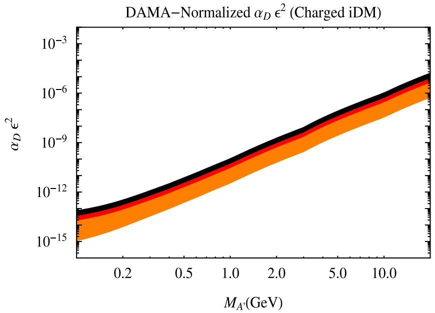




hep-ph[0810.0713] - Arkani-Hamed, Finkbeiner, Slatyer, Weiner
A Theory of Dark matter
hep-ph[0905.0480] - Meade, Papucci, Strumia, Volansky
Dark Matter Interpretations of the $e^{\pm}$ Excesses after Fermi

Dama modulation signal





DAMA/CoGeNT signals

hep-ph[0903.3941] - Essig, Schuster, Toro
Probing Dark Forces and Light Hidden Sectors at Low-Energy e^+e^- Colliders

Constraints:

From Particle Physics. . .

. . . From Astrophysics

There is quite a wide window not excluded by any obvious laboratory measurement or astrophysical argument

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Indirect Detection

PAMELA,Fermi,. . .

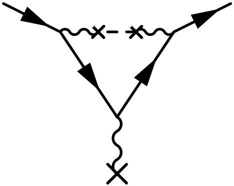
Direct Detection

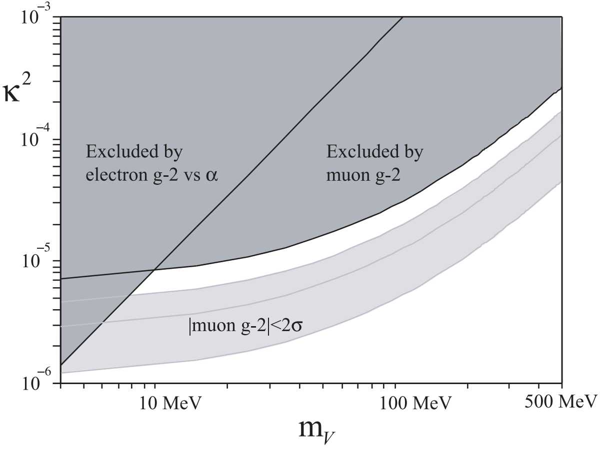
DAMA

Particle Physics?

Colliders?

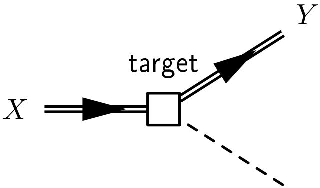
Predictions are testable: anomalous magnetic moment





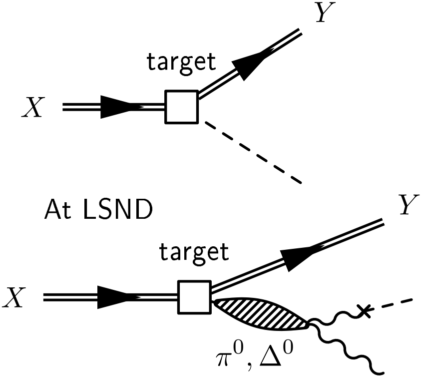
hep-ph[0811.1030] - Pospelov
Secluded U(1) below the weak scale

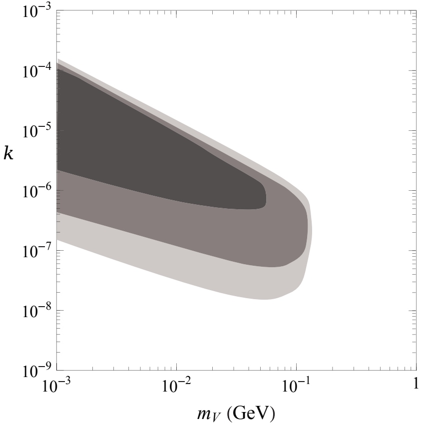
Predictions are testable: beam dump



hep-ph[0906.5614] - Batell, Pospelov, Ritz
Exploring portals to a hidden sector through fixed targets

Predictions are testable: beam dump





hep-ph[0906.5614] - Batell, Pospelov, Ritz
Exploring portals to a hidden sector through fixed targets

Flavour factories: An Ideal Enviroment

- Low energy $\sim$ GeV ($\sigma \propto E^{-2}$);
- high luminosity ($\sim$ 75 ab^{-1} at SuperB);
- clear signatures.

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Flavour factories: An Ideal Enviroment

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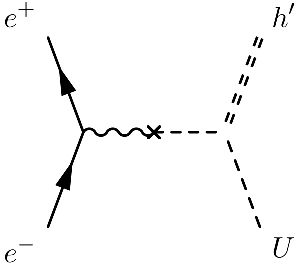
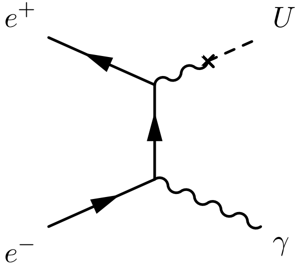
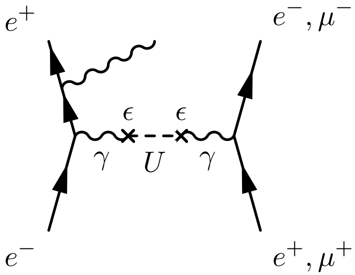




resonances ($\Upsilon, \Phi \to X + \not{E}_T$)

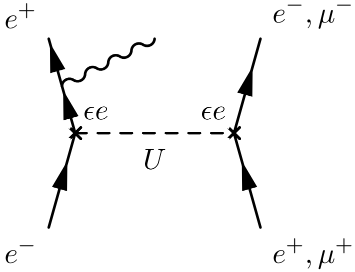
$l^+ l^- \gamma$

A useful channel



- Resonant channel:
  - particular signal shape $\neq$ BG;
- radiative return:
  - energy scan;

A useful channel



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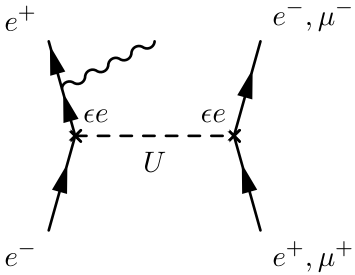
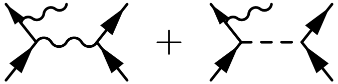


- Resonant channel:
  - particular signal shape $\neq$ BG;
- radiative return:
  - energy scan;

- 2nd order process,
- 2 ϵ:
  - really small signal! $(\sigma_U \sim 10^{-7}\sigma_{BG})$
    $(\sigma_Z(1\text{ GeV}) \sim 10^{-3}\sigma_{BG})$
- An accurate estimate of the background is mandatory.

|  $+ \cdots$ 14 terms for $e^{\pm}$, 6 for $\mu^{\pm}$ $|^2$

ALPHA

BabaYaga

- Exact tree level calculation;
- very well tested generator.

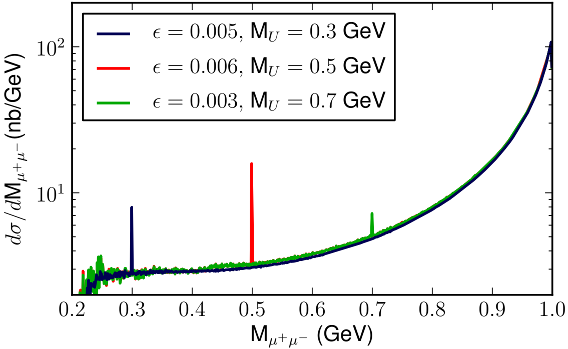
hep-ph[0607181] - Balossini, Carloni Calame, Montagna, Nicrosini, Piccinini
Matching perturbative and Parton Shower corrections to Bhabha process at flavour factories

hep-ph[9507237v1] - Caravaglios, M. Moretti
An algorithm to compute Born scattering amplitudes without Feynman graphs

A MCEG for Light Dark Matter at Leptonic Colliders

- Exact tree level calculation for the process $e^+e^- \to U, Z, \gamma \to l^+l^-\gamma$;
- exact three body kinematics;
- vacuum polarization (hadronic contribution → HADR5N09 from Jegerlehner
  → HMNT from Teubner et al.);
- radiative corrections → structure functions of the electron;
- theoretical error $\mathcal{O}(\alpha)$ (second order processes).

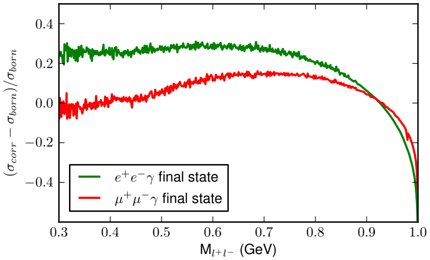
A possible signal

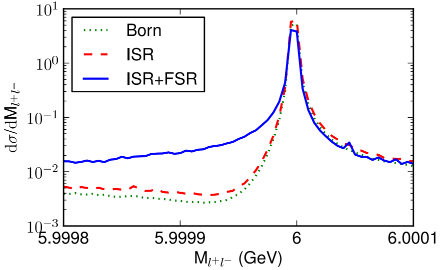


Final state invariant mass for different ϵ and m_U.

- Huge background on e^+e^-
- Really tiny $\Gamma \Rightarrow$ experimental resolution is a crucial parameter

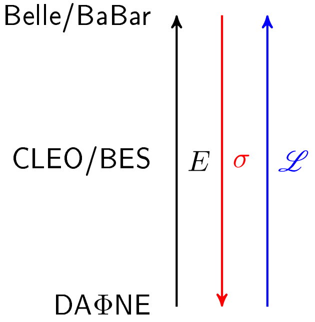
Effects of radiative corrections

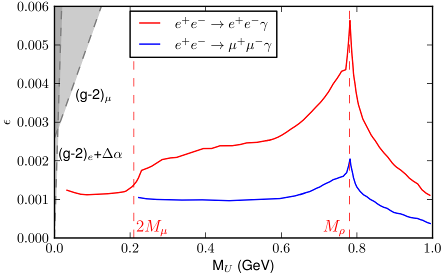




Statistical significance

$$\frac{\#S}{\sqrt{\#B}} = \frac{\mathscr{L}(\sigma_{SM+U} - \sigma_{SM})}{\sqrt{\mathscr{L}\sigma_{SM}}} \equiv \sqrt{\mathscr{L}}\frac{\sigma_S}{\sqrt{\sigma_{SM}}} > 5 \text{ for discovery}$$





5 σ reach at KLOE+KLOE2 "Large Angle"

hep-ph[0904.1743] - Reece, Wang
Searching for the light dark gauge boson in GeV-scale experiments

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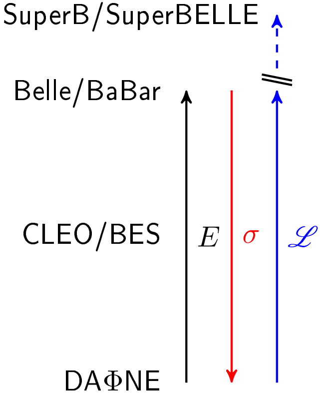

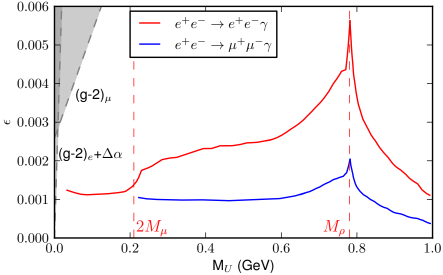

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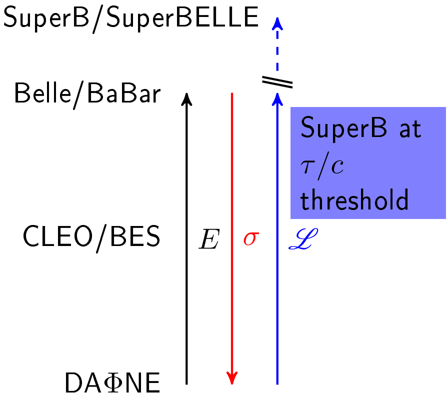

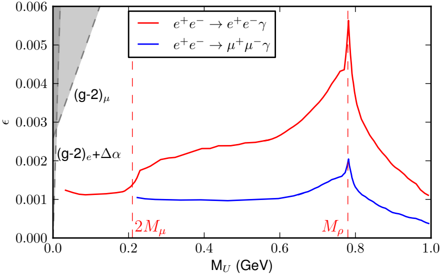

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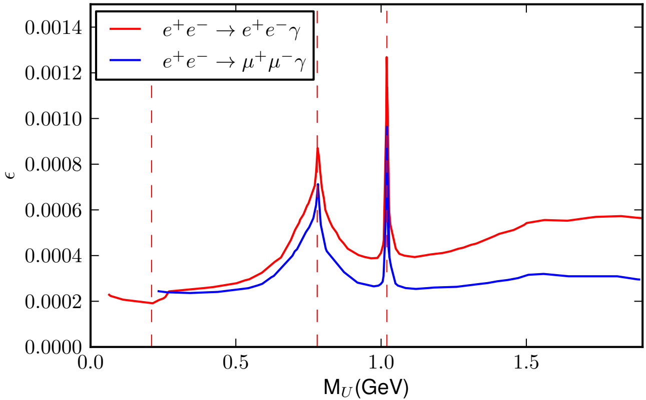

5 σ reach at SuperB (100 ab^{-1} - 10.56 GeV)
(better result if $E \sim \tau/c$ threshold.)

Conclusions

- An hidden $U(1)$ could explain astrophysical anomalies;
- signatures in Particle Physics:
  - existing data;
  - new data (SuperB, beam dump).
- Useful channels at SuperB:
  - $\mu^+\mu^-\gamma$
  - Higgs channel;
  - W-like channels;
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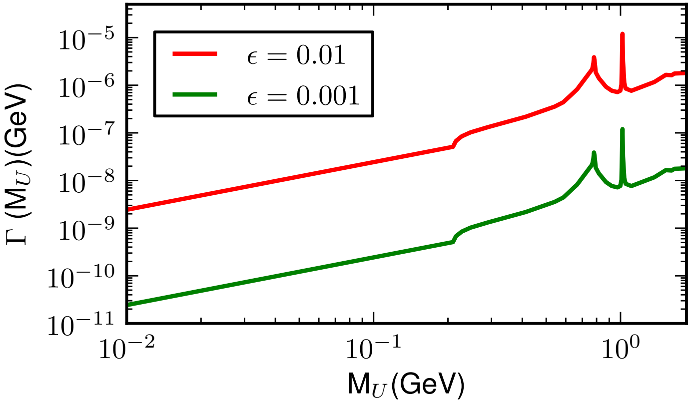
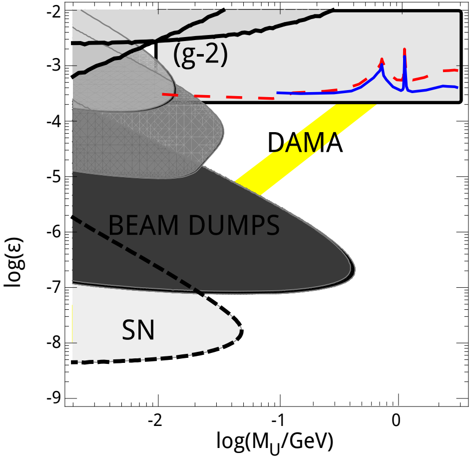
THANK YOU!

Width of U boson

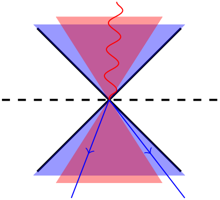


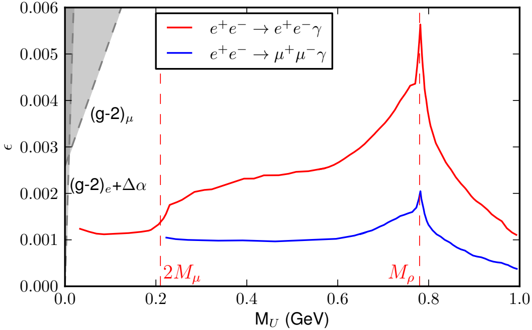


(g-2)
DAMA
BEAM DUMPS
SN
log(ε)
log(M_U/GeV)
-2
-3
-4
-5
-6
-7
-8
-9
-2
-1
0

Simulation's results

Large Angle Selection





5 σ reach at KLOE+KLOE2 (5 fb^{-1} - 1.02 GeV)

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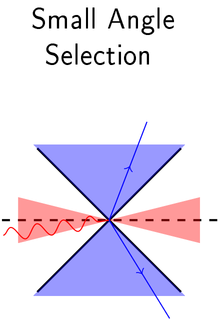

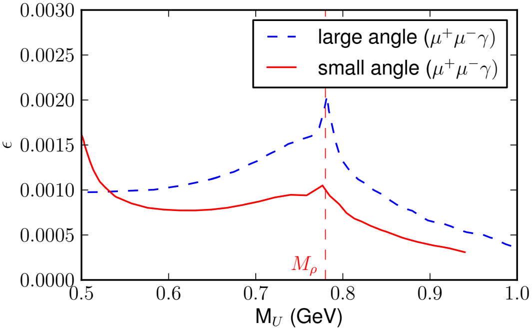

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