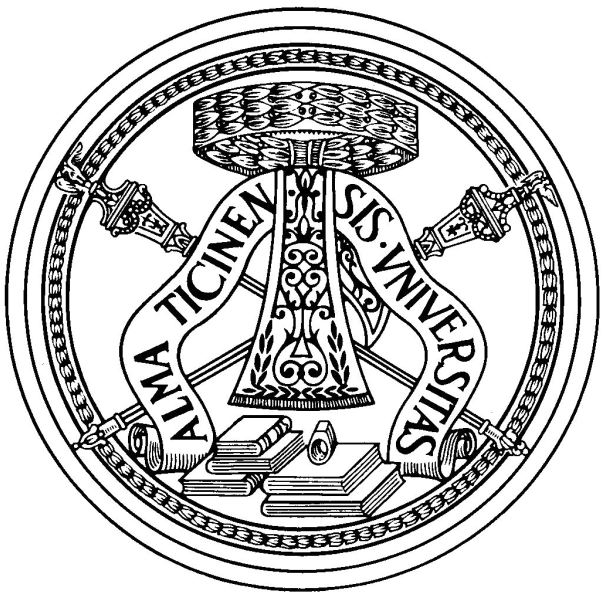
Light dark forces at flavour factories - [1007.4984]



Luca Barzè

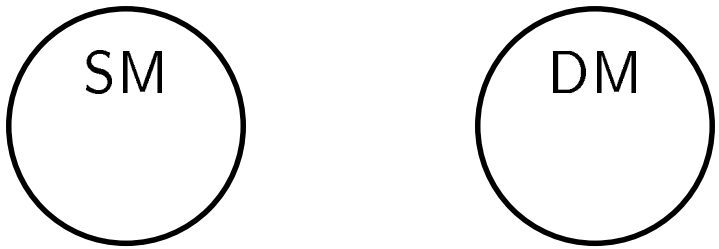
University of Pavia
INFN

Discrete 2010
10th December 2010

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

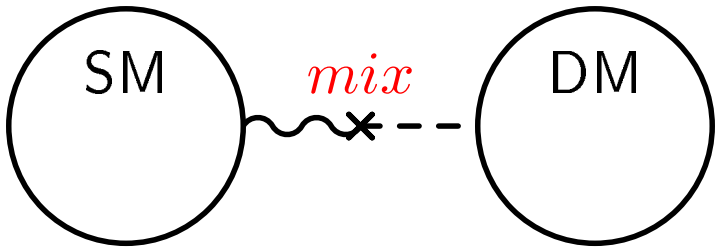
Axiom 1: Dark Matter exists

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



Axiom 1: Dark Matter exists and interacts with SM

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



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

A simple way

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

$$\mathcal{L}_{SM} = \mathcal{L}^F_{SM} + \mathcal{L}^B_{SM} + \mathcal{L}^H_{SM}$$

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

A simple way: a New Symmetry

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

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$$\begin{aligned} \mathcal{L}_{DM} &= \mathcal{L}^F_{DM}(\chi) && \Rightarrow \quad M_\chi \sim \text{10 - 100 GeV (WIMP)} \\ &+ \mathcal{L}^B_{DM}(U) && \Rightarrow \quad m_U \sim \text{?} \\ &+ \dots \end{aligned}$$

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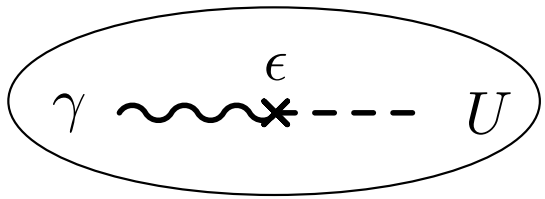
SSB

$$\mathcal{L}_{mix} = \frac{\epsilon}{2} F^{DM\mu\nu} F^{EM}_{\mu\nu}$$



Small effects at low energies.

A simple way: a New Symmetry

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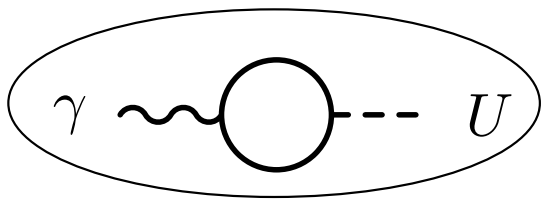

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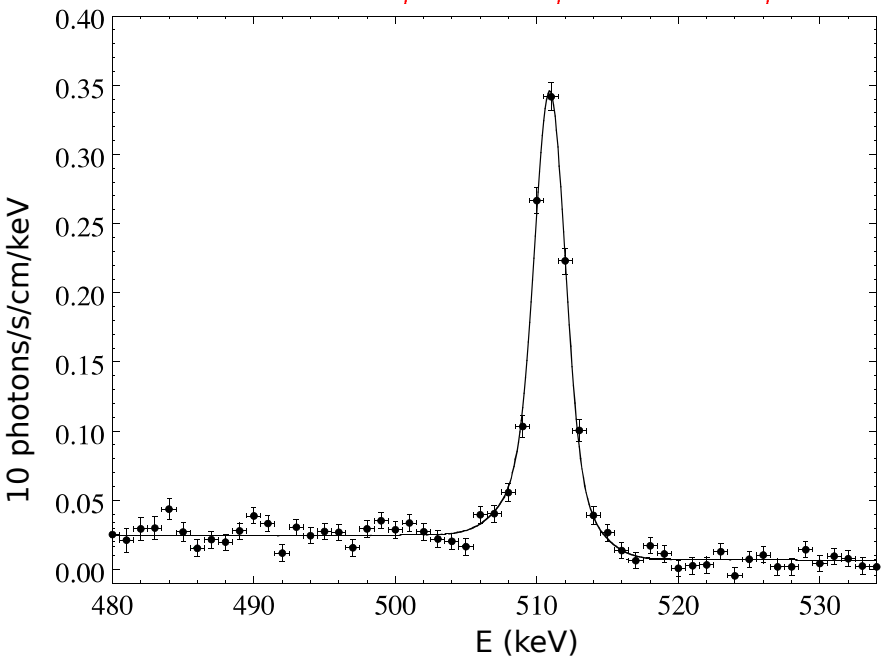
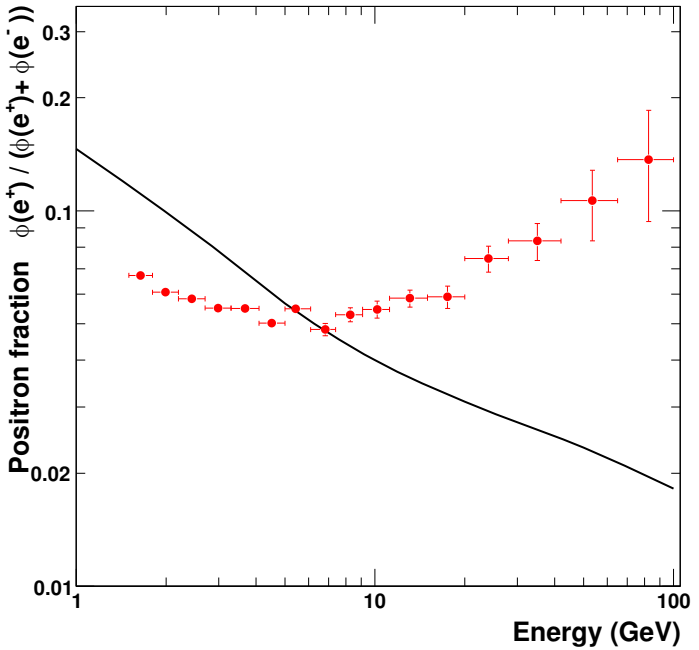


511 keV line - INTEGRAL



Excess of positrons - PAMELA

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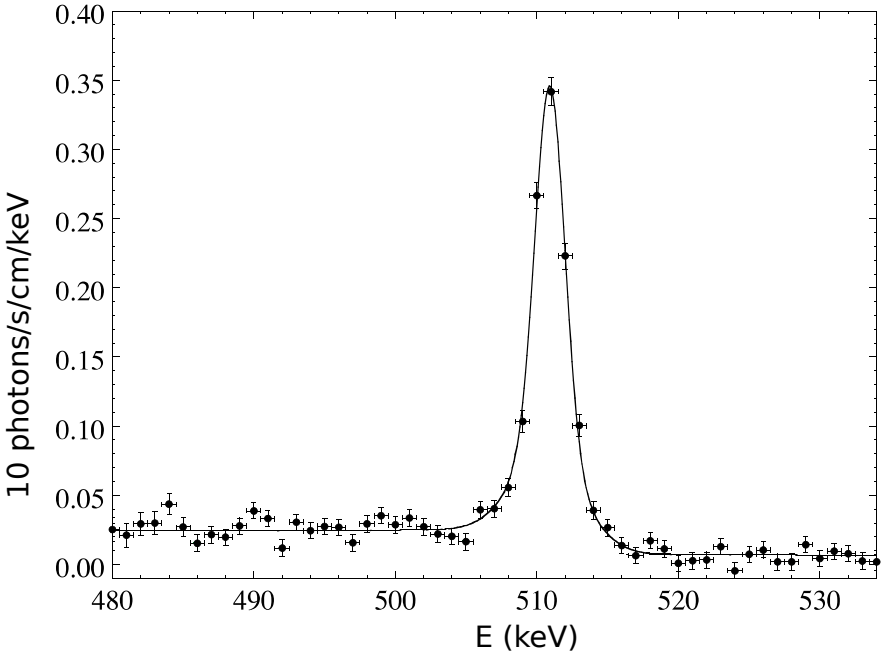

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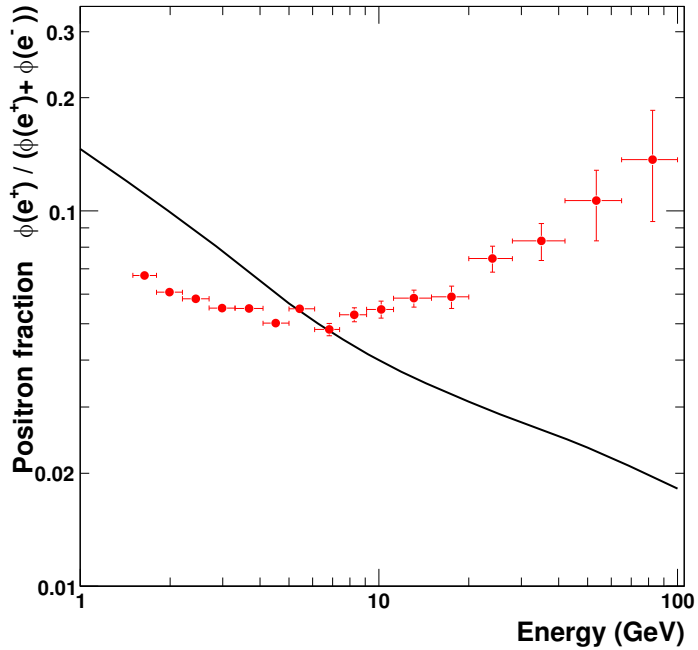
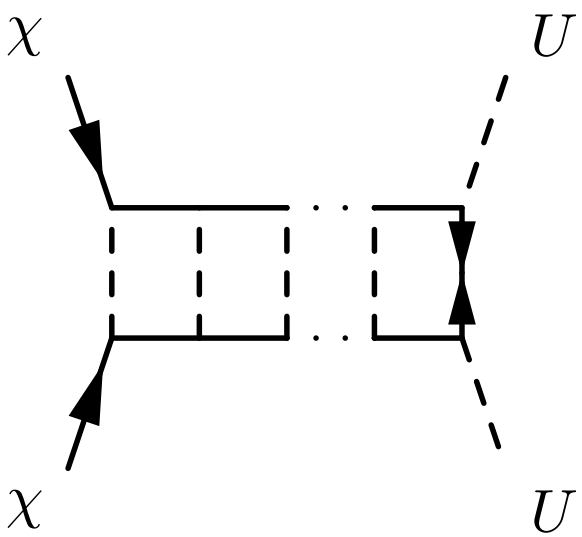


Excess of positrons - PAMELA

Astrophysical sources $\rightarrow$ difficulties

Axiom 2: Data due to DM

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



No $\bar{p}$ excess $\rightarrow U$ must be light ($\sim$ MeV - GeV) $\Rightarrow \epsilon \lesssim 10^{-2,-3}$

hep-ph[0810.0713] - Arkani-Hamed, Finkbeiner, Slatyer, Weiner
A Theory of Dark matter

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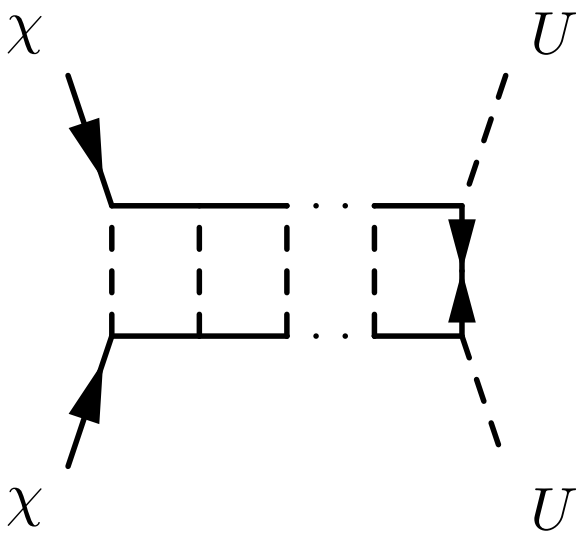

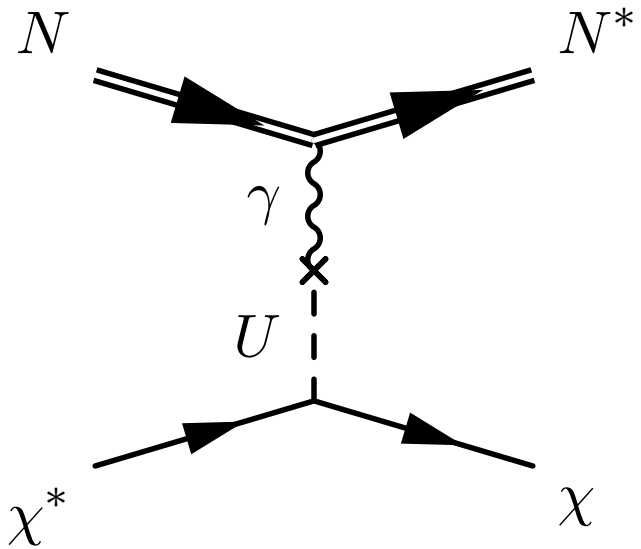

DAMA/CoGeNT signals

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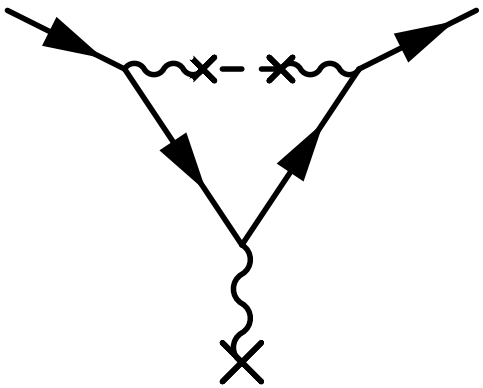
Constraints:

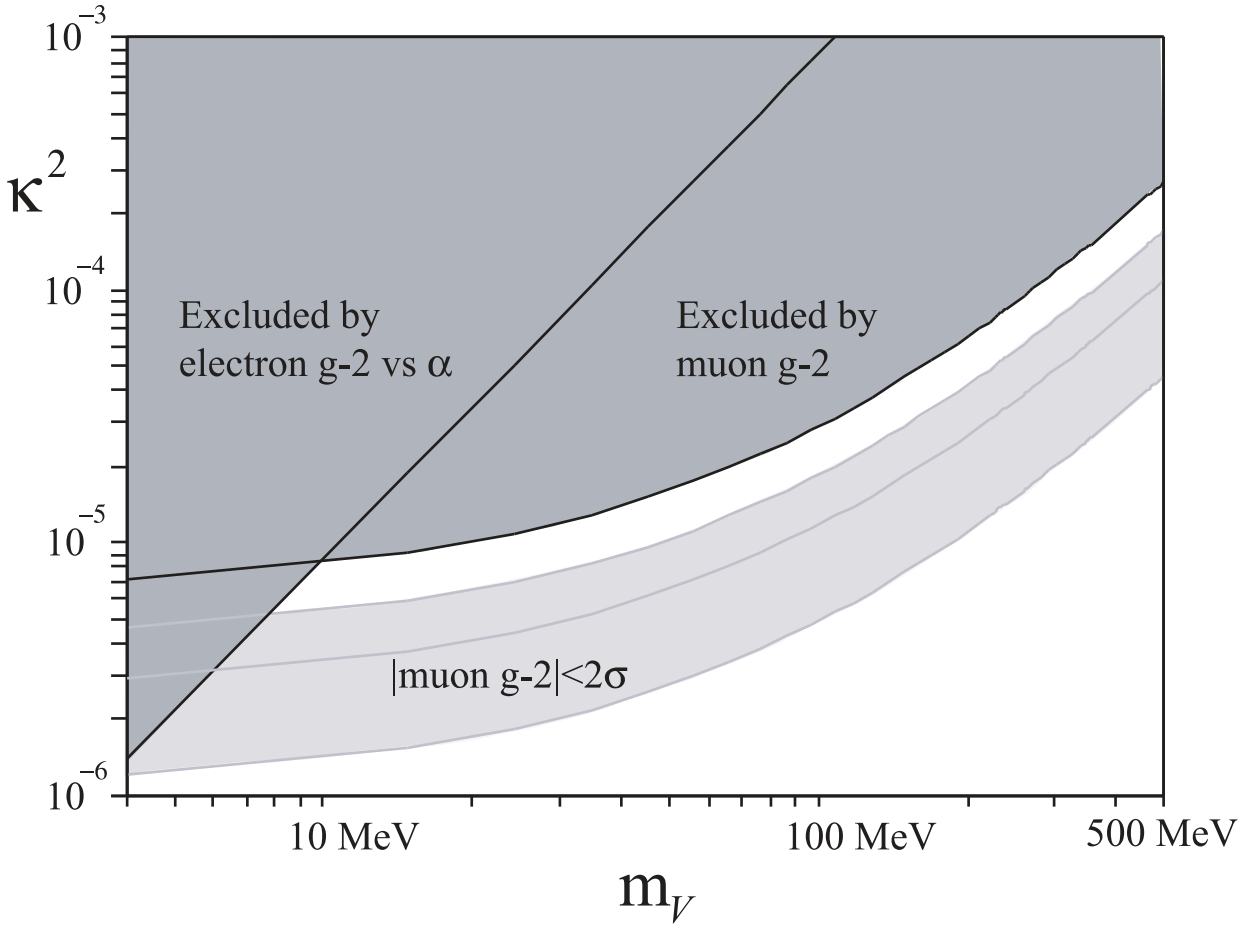
From Particle Physics...

...From Astrophysics

There is quite a wide window not excluded by any obvious laboratory measurement or astrophysical argument, while the INTEGRAL or observation could be easily accounted for

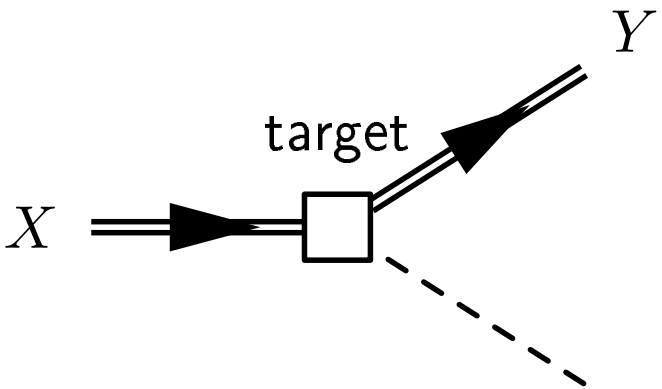
Predictions are testable: anomalous magnetic moment





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

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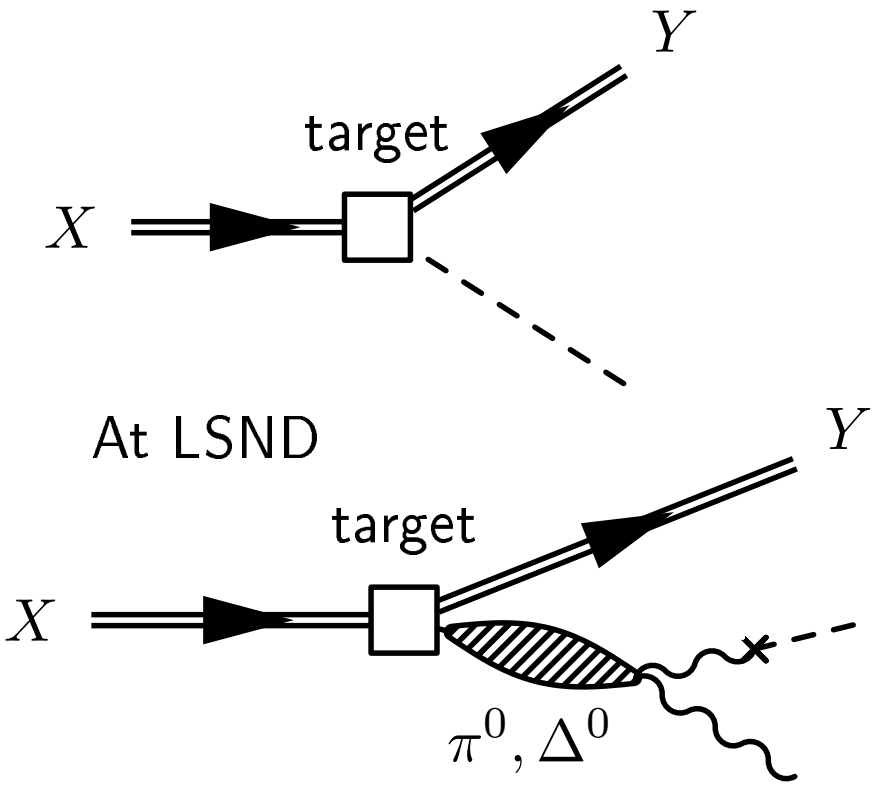

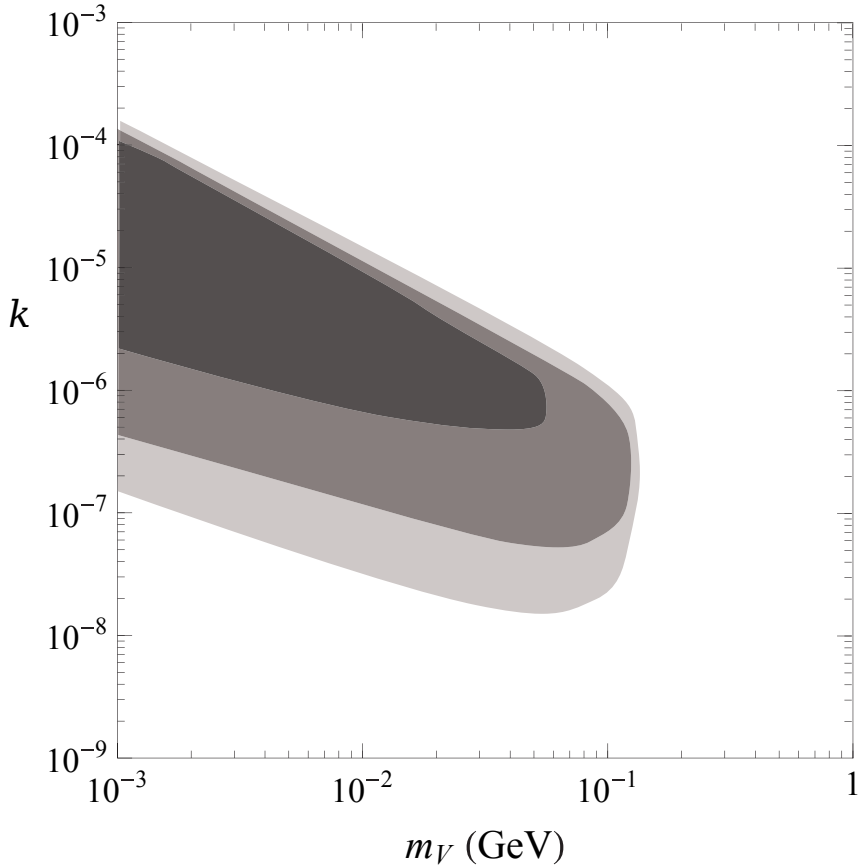

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Exploring portals to a hidden sector through fixed targets

Flavour factories: An Ideal Enviroment

- Low energy $\sim$ GeV ($\sigma \propto E^{-2}$);
- high luminosity (up to ab^{-1} at BaBar/Belle);
- clear signatures:

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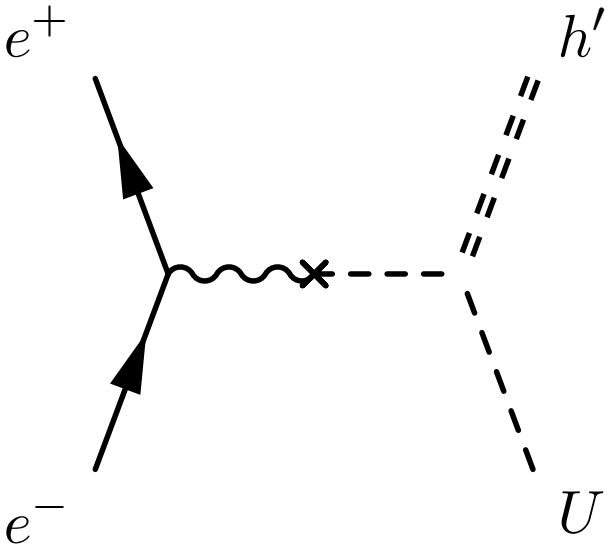
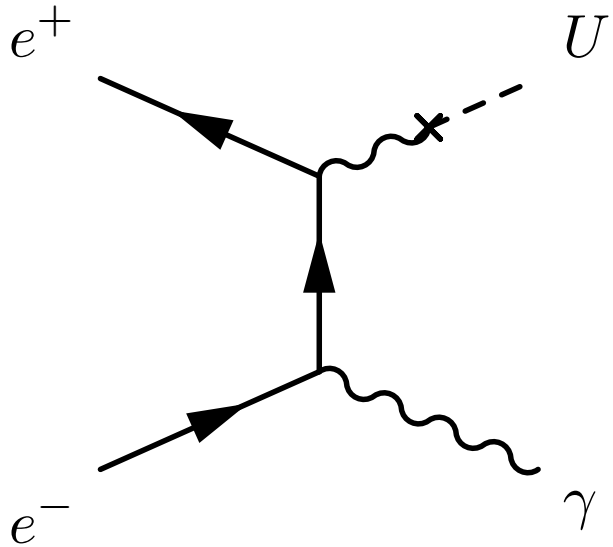
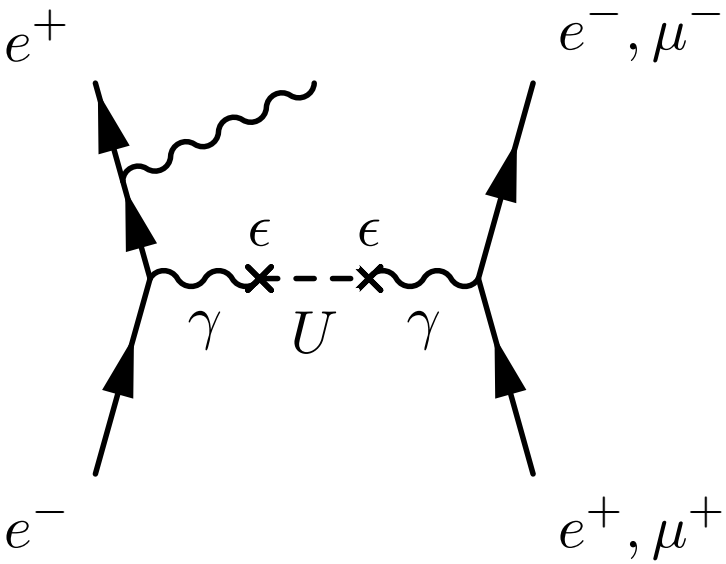


resonances ($\Upsilon, \Phi \to X + \not{E}_T$)
model dependent



$l^+l^-\gamma$
model independent

A really difficult channel



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

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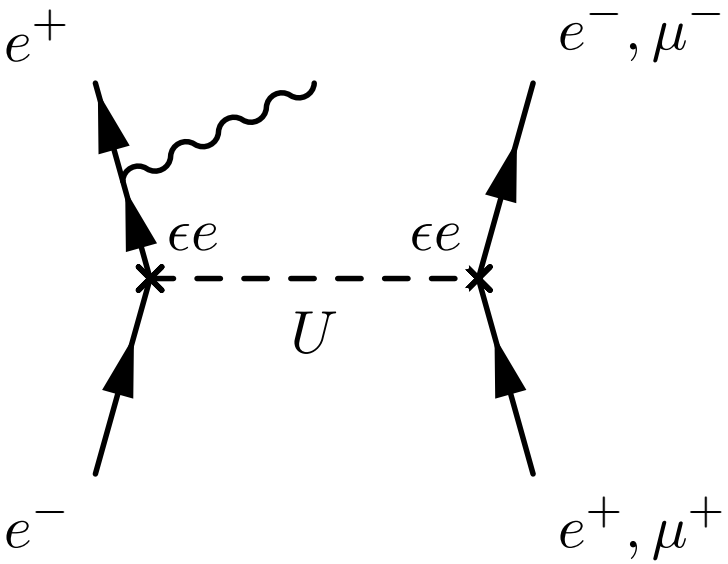

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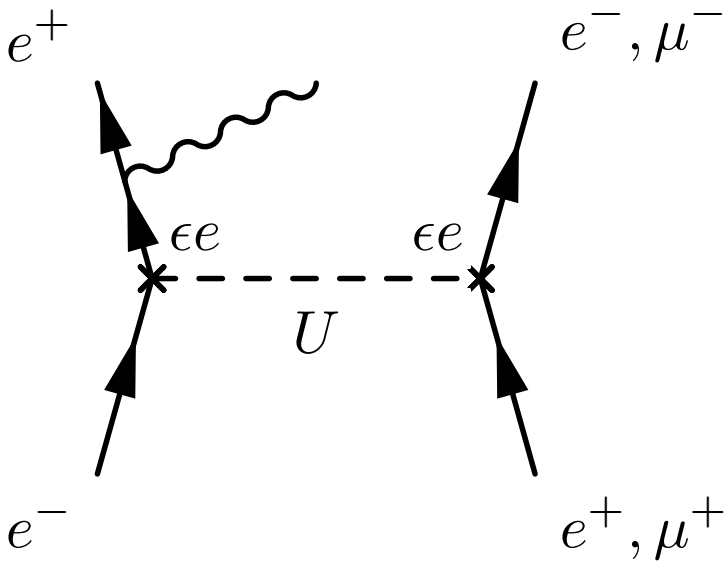
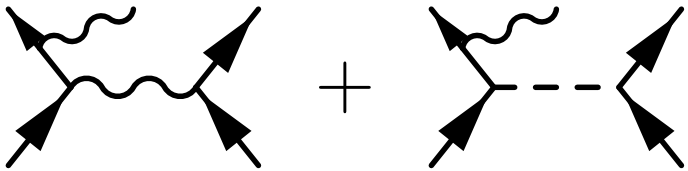


- Resonant channel:
  - particular signal shape $\neq$ BG;
- radiative return:
  - energy scan;

- 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.

Necessity of a very accurate event generator

$|$  $+$ $+ \cdots$ 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

BabaYaga

A MCEG for $e^+e^- \to e^+e^-, \mu^+\mu^-, \gamma\gamma$ processes at flavour factories.

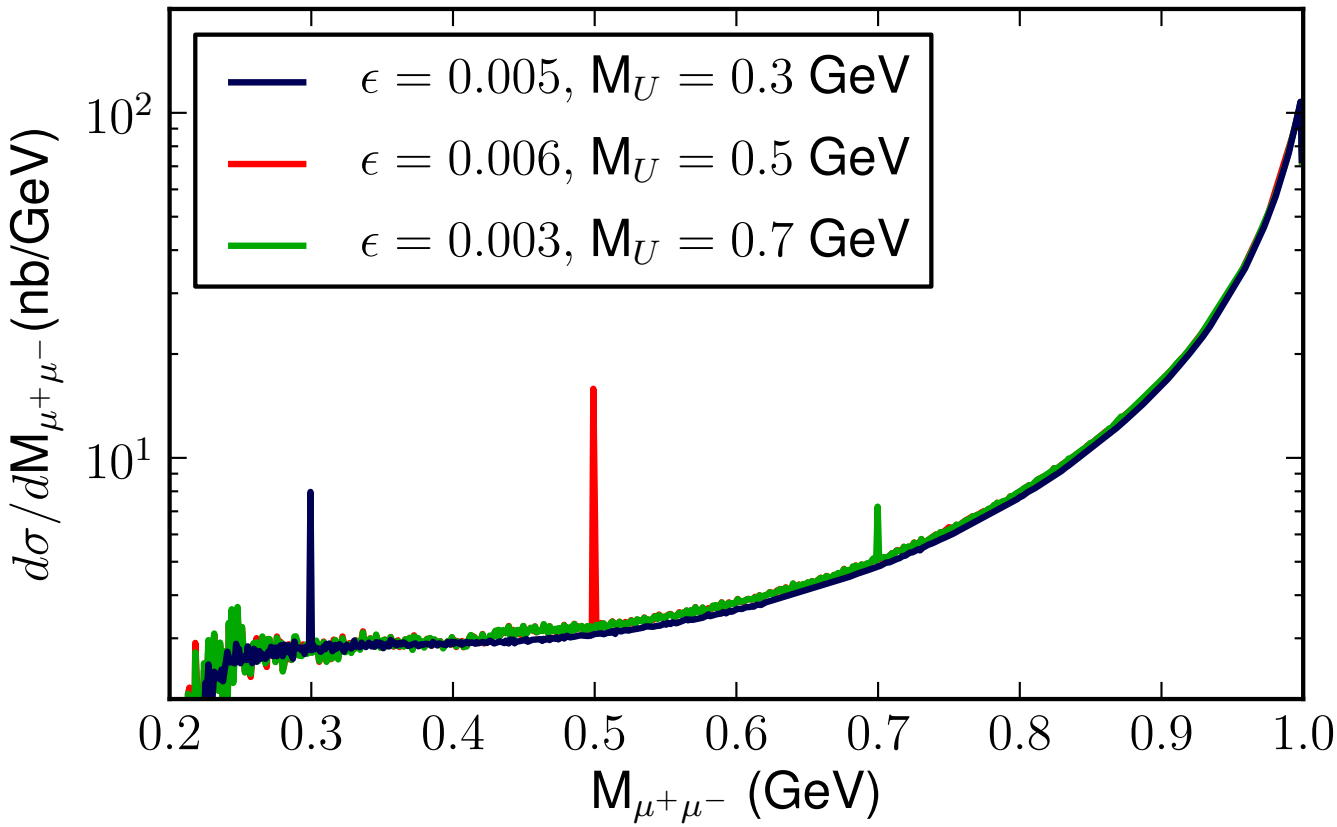
- Commonly used for the determination of flav. factories luminosity:
  - $(g-2)_\mu$, R, $\Delta\alpha_{had}$;
- theoretical error $\sim 1‰$ ($\mathcal{O}(\alpha^2)$) for first order processes.

`http://www.pv.infn.it/hepcomplex/babayaga.html`

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 $\to$ `HADR5N09` from Jegerlehner $\to$ `HMNT` from Teubner et al.);
- radiative corrections $\to$ structure functions of the electron;
- theoretical error $\mathcal{O}(\alpha)$ (second order processes).

A possible signal

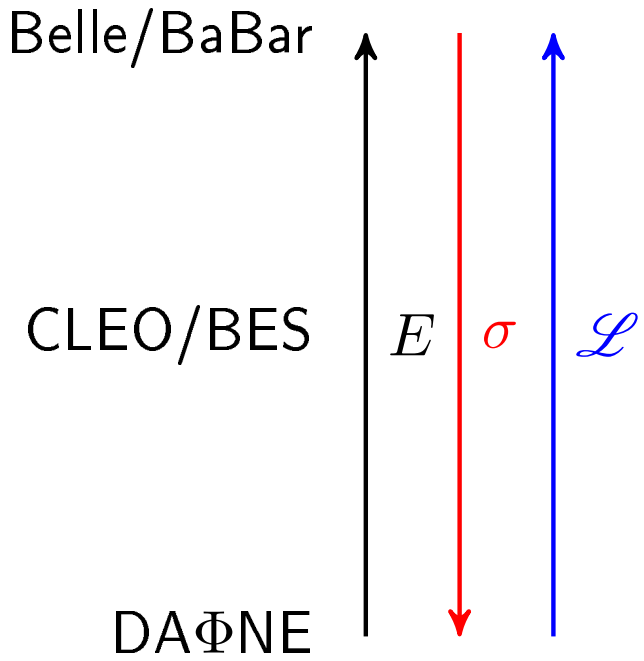


Final state invariant mass for different ϵ and m_U.

- Huge background on e^+e^-

Statistical significance

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



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

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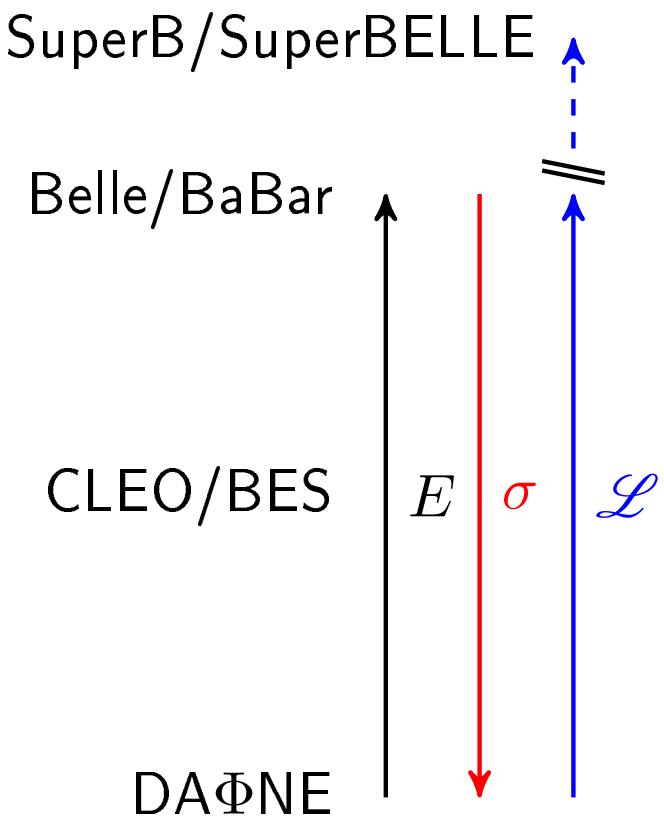

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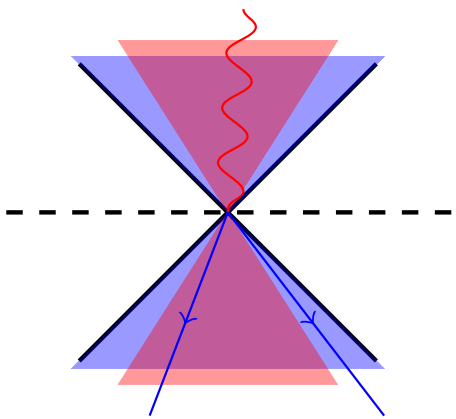
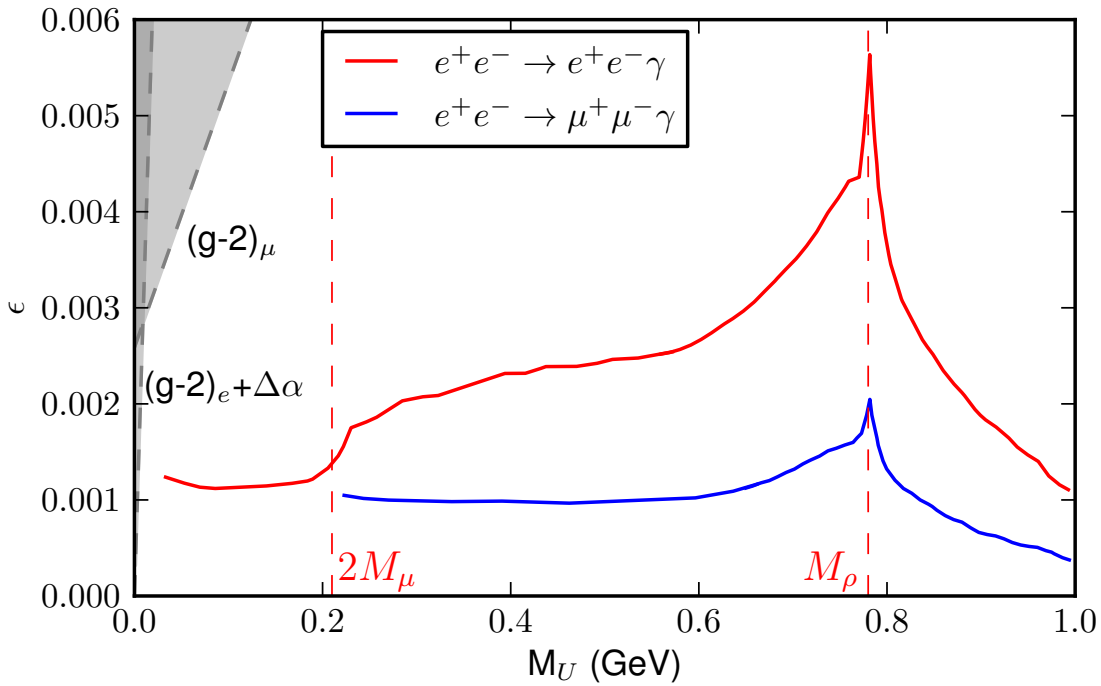
Simulation's results

Large Angle Selection

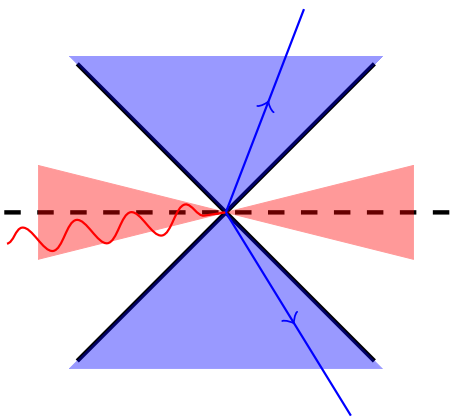


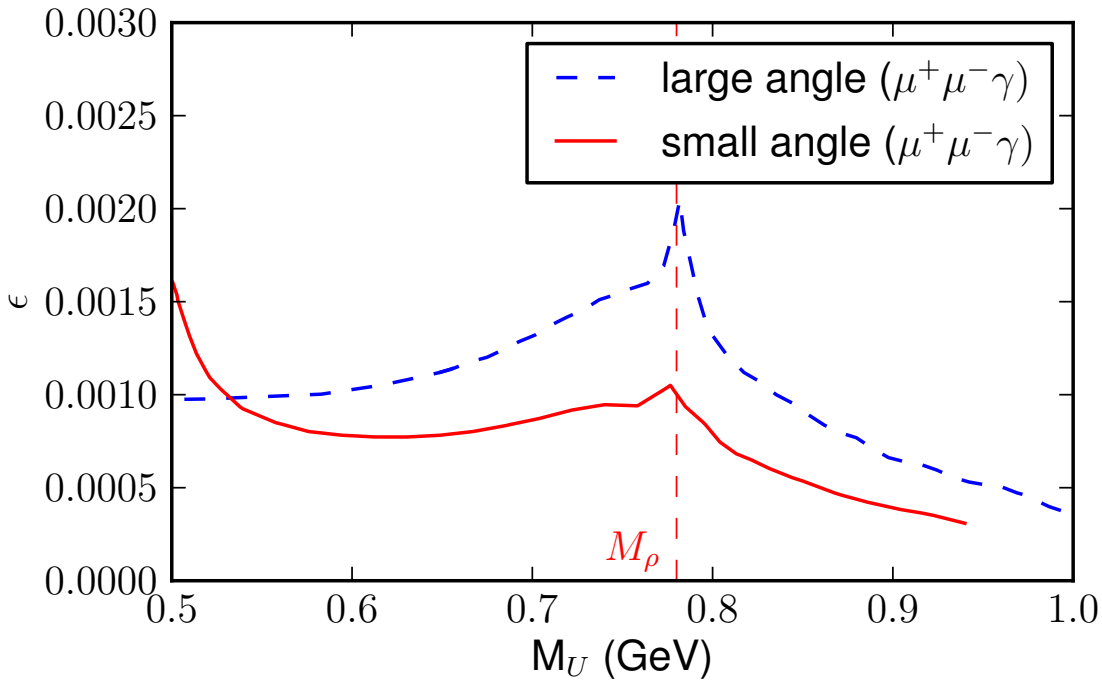


5 σ reach at KLOE+KLOE2 (5 fb^{-1} - 1.02 GeV)

Simulation's results

Small Angle Selection





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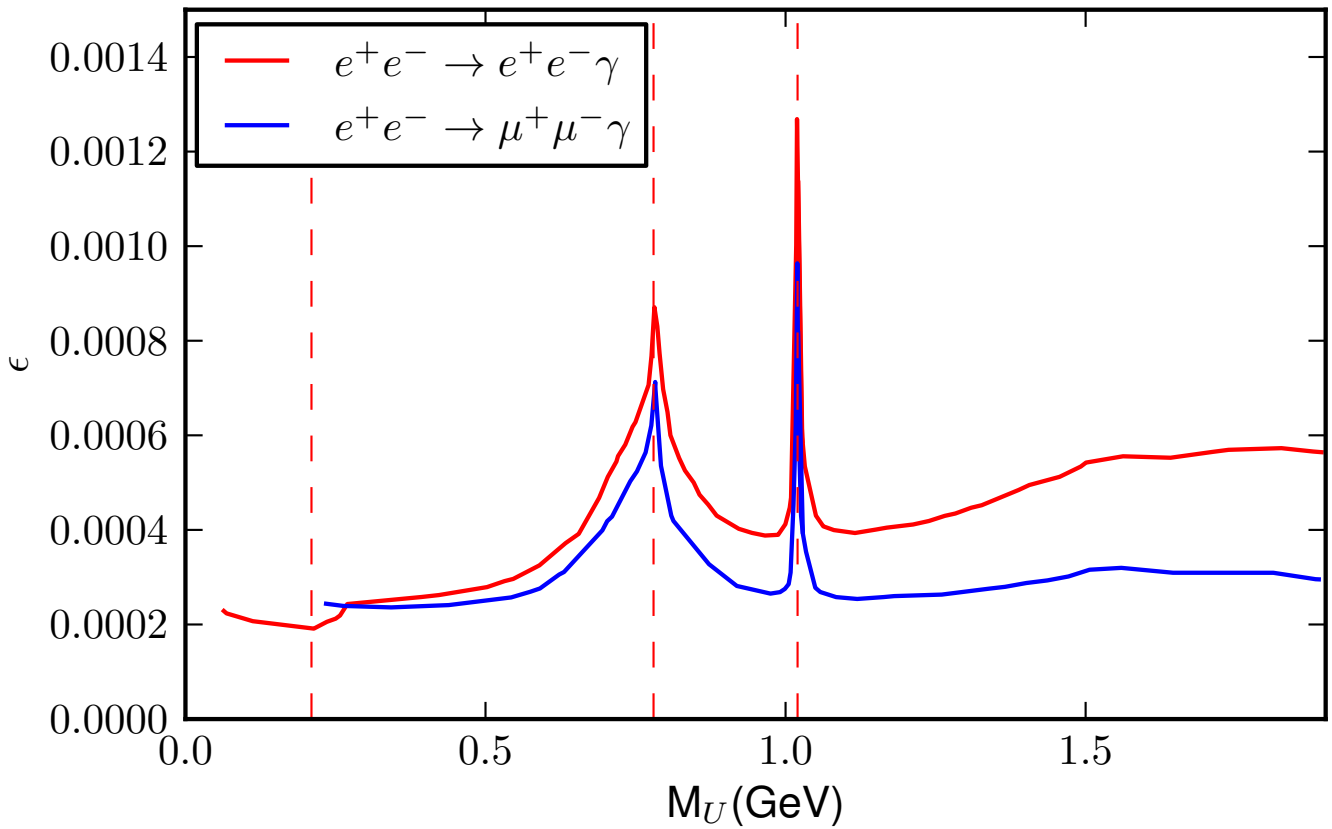
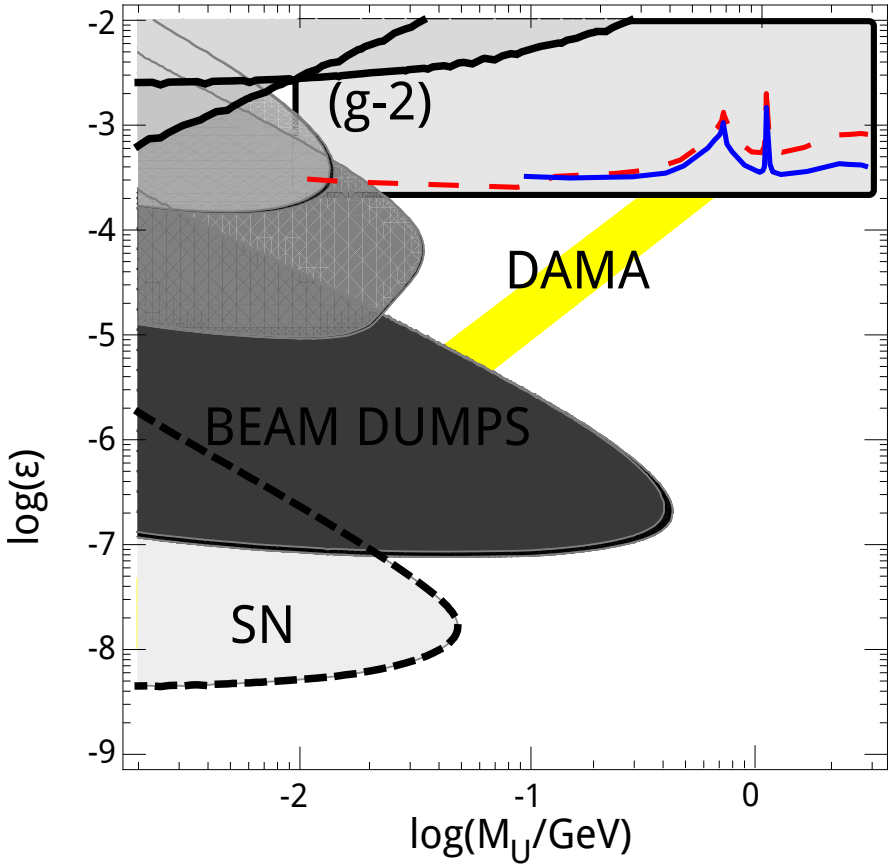


5 σ reach at Possible SuperB (100 ab^{-1} - 10.56 GeV)

Not satisfied?



[0904.1743] - Bjorken, Essig, Schuster, Toro
New Fixed-Target Experiments to Search for Dark Gauge Forces

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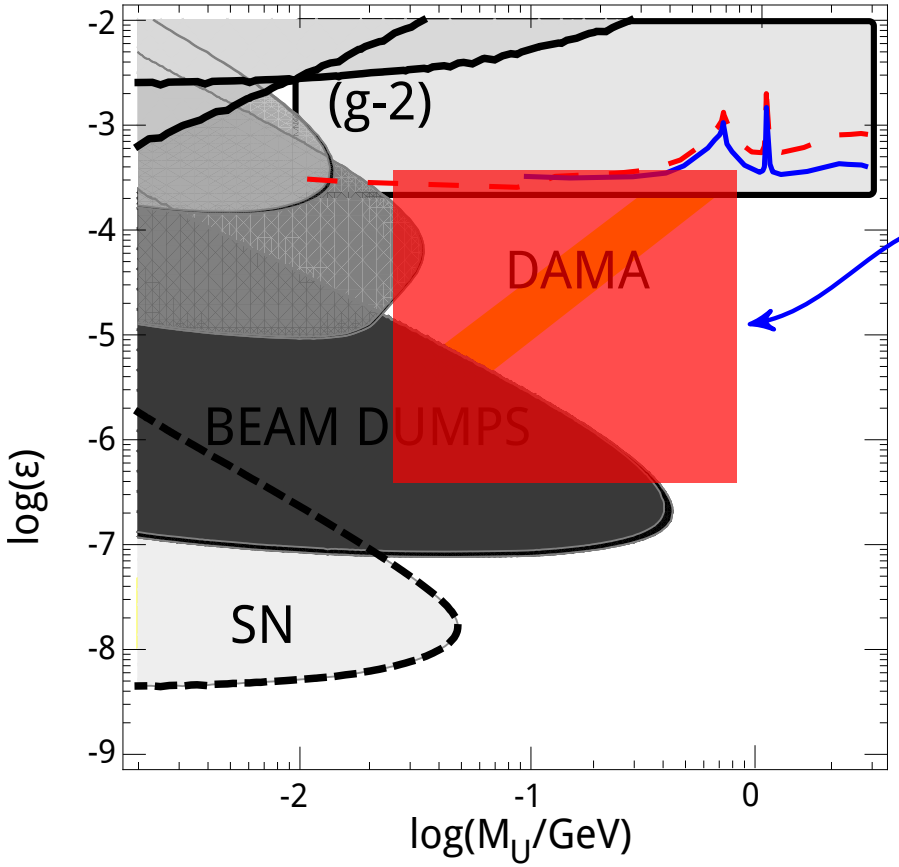
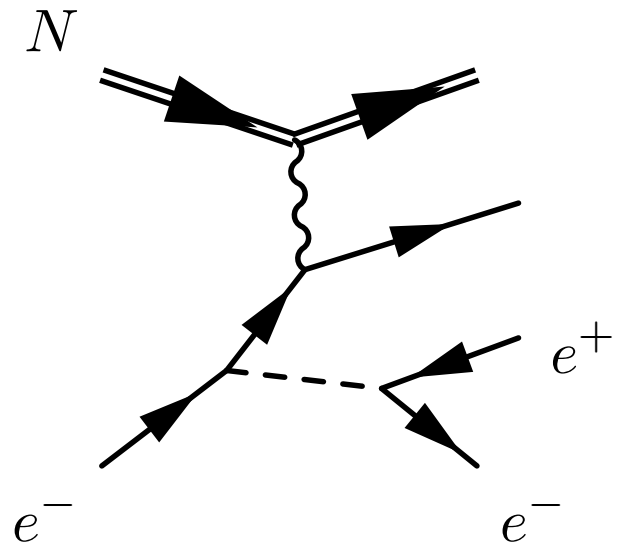


Fixed target experiment

really high luminosity!



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New Fixed-Target Experiments to Search for Dark Gauge Forces

A lot of work to do!

- Experimental:
  - analyze existing data;
  - produce new data (flavour factories, beam dump);
- model builders:
  - explain the experimental data;
  - explain ALL the data at the same time;
- phenomenologists;
  - describe other possibile signatures;
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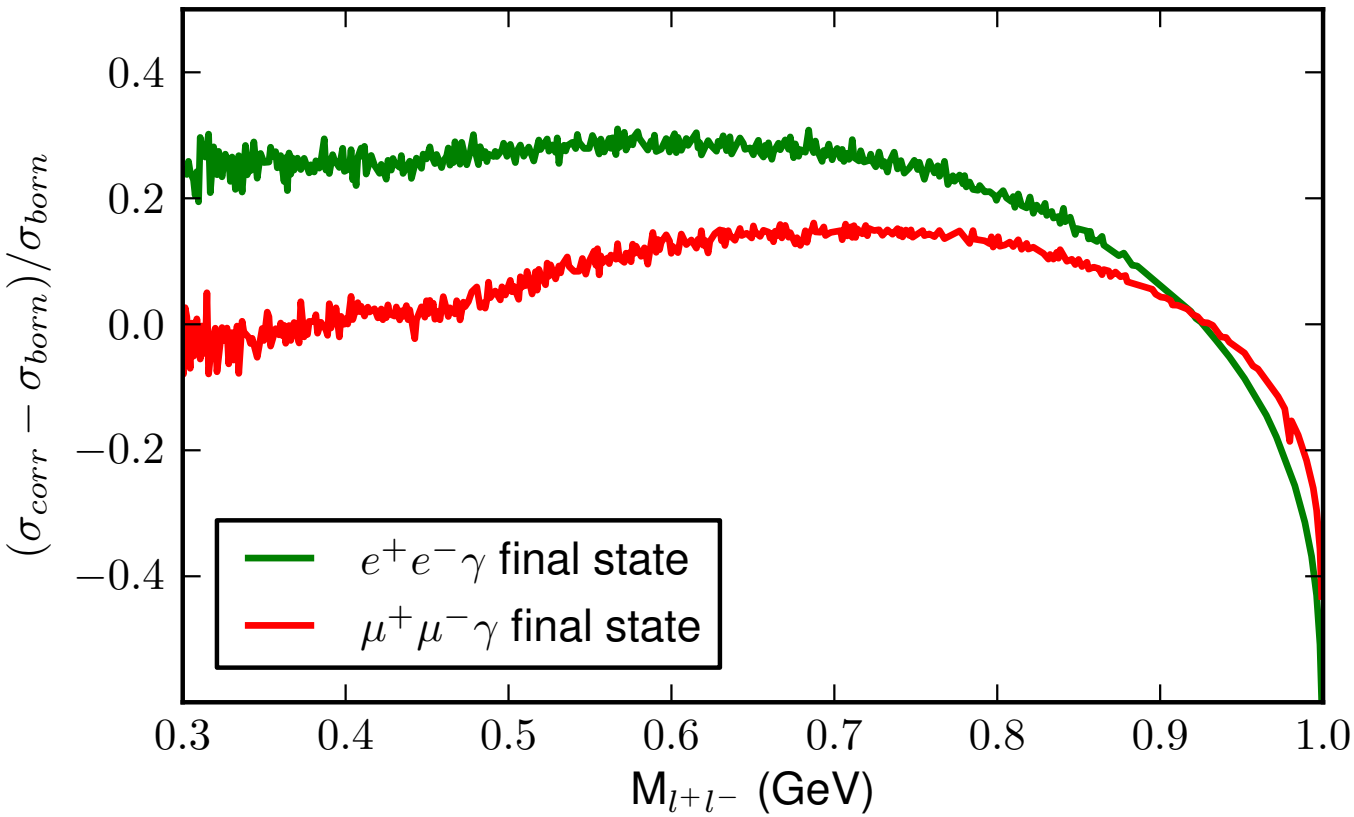
THANK YOU!
to Gauss & Kandinsky by G Martinelli

Effects of radiative correction



Width of U boson