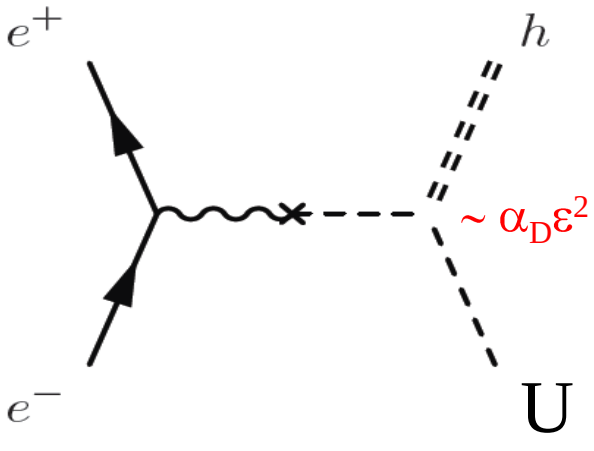
Some possibilities of dark force searches at Belle/Belle2

E. Graziani

- Dark Higgstrahlung (invisible scenario): from Kloe to Belle
- Non minimal models
- Dark Scalars & τ's

The $e^+e^- \to hU$ higgsstrahlung process



$\varepsilon = 10^{-3}$

$\alpha_D = \alpha_{em}$

$m_{U,h} \sim 100$ MeV

Very different scenarios depending on

$m_h < m_U \Rightarrow$ "invisible" → KLOE

$m_h > m_U \Rightarrow h \to uu \to 4l,\pi + 2l,\pi$ → BaBar, Belle

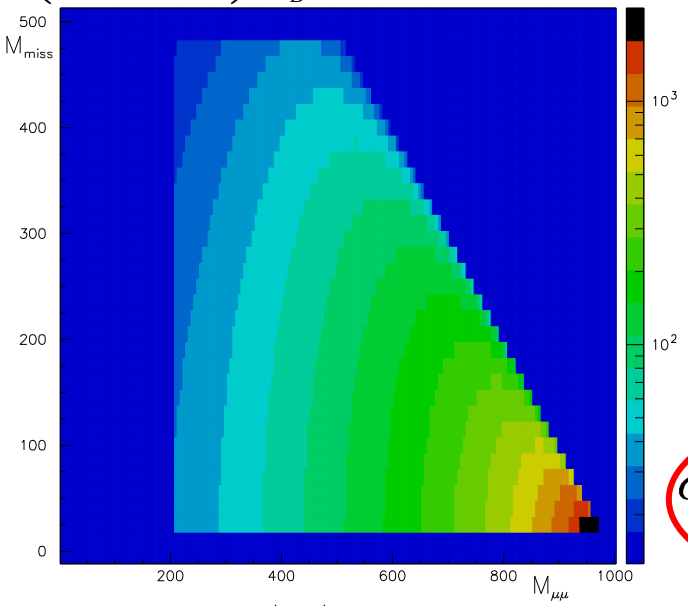
$\tau_h > 5\ \mu s \to \beta\gamma c\tau > 100$ m

rapidly increasing with decreasing ε

invisible up to $\varepsilon \approx 10^{-2} \div 10^{-1}$ depending on m_h

KLOE: Only the muon case $m_h < m_U$: $e^+e^- \to \mu^+\mu^- +$ missing energy

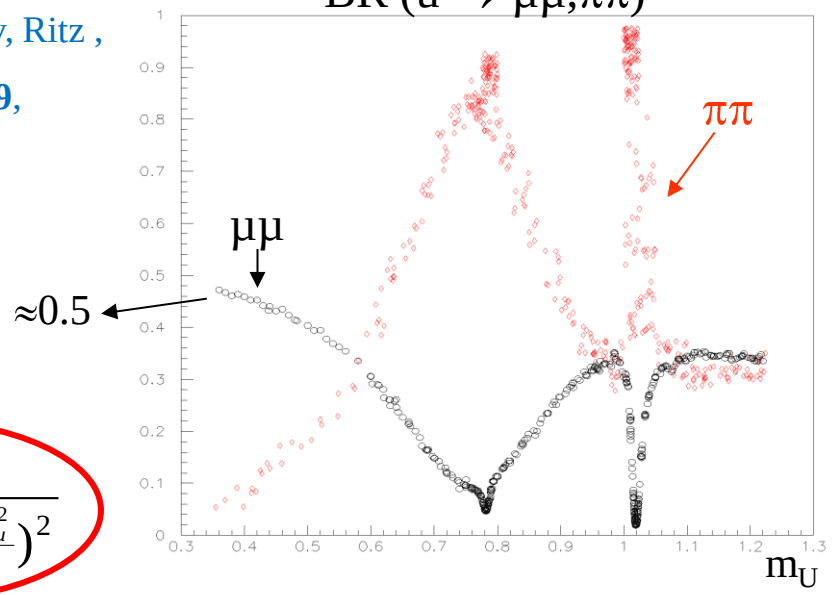
$\sigma(e^+e^- \to hU)$ $\alpha_D = \alpha$, $\varepsilon = 10^{-3}$, $s = 1$ GeV^2 fb



Batell, Pospelov, Ritz , Phys. Rev. D **79**, 115008 (2009)

$$\sigma_{hU} \propto \frac{1}{s} \frac{1}{(1 - \frac{m_u^2}{s})^2}$$

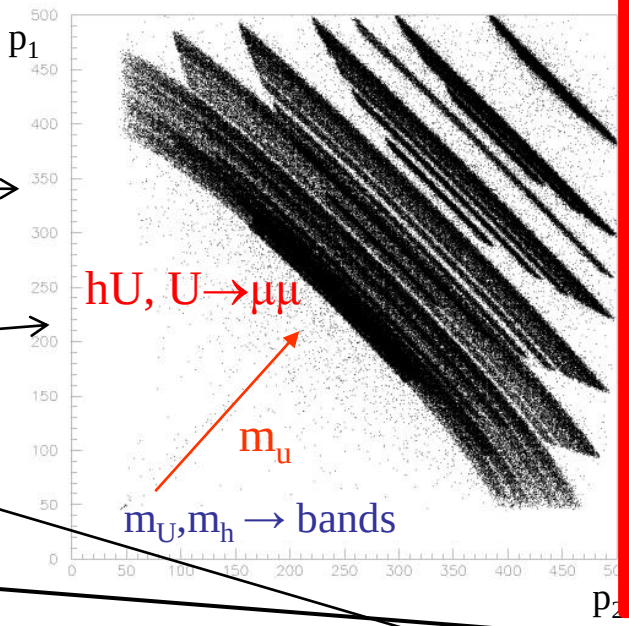
BR ($u \to \mu\mu, \pi\pi$)



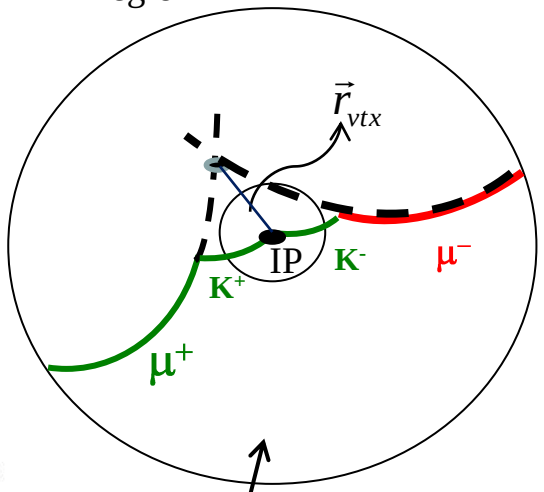
Phys. Lett. B747 (2015) 365

$e^+e^- \to hU$: selections

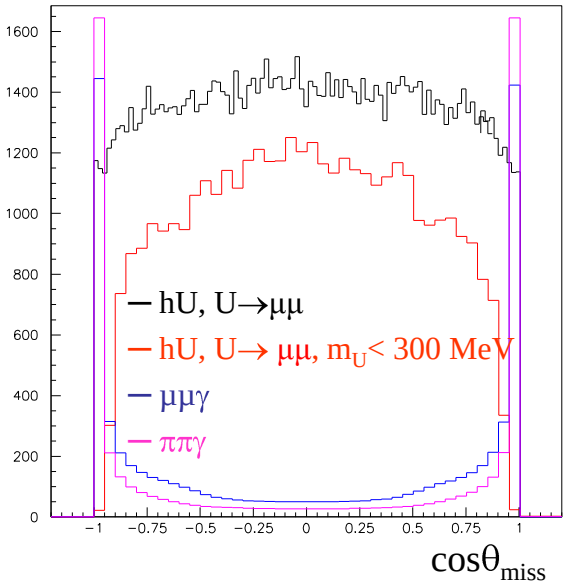
- two charged tracks, $q_1+q_2=0$
- vertex in a cylinder around IP
- $p_{1,2} < 460$ MeV
- $\cos\theta_{miss} < 0.75$, $\cos\theta_{1,2} < 0.8$
- $p_1 + p_2 > 450$ MeV
- E_{miss}: calorimeter veto
- PID: two muons
- vtx-IP cut (anti K^+K^-)

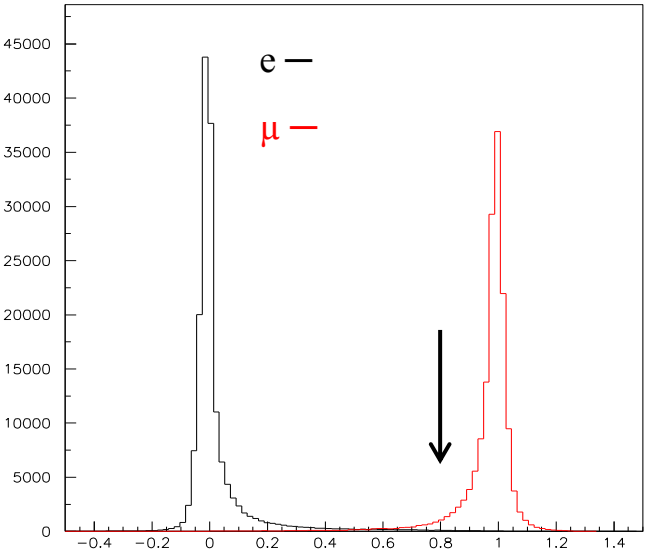


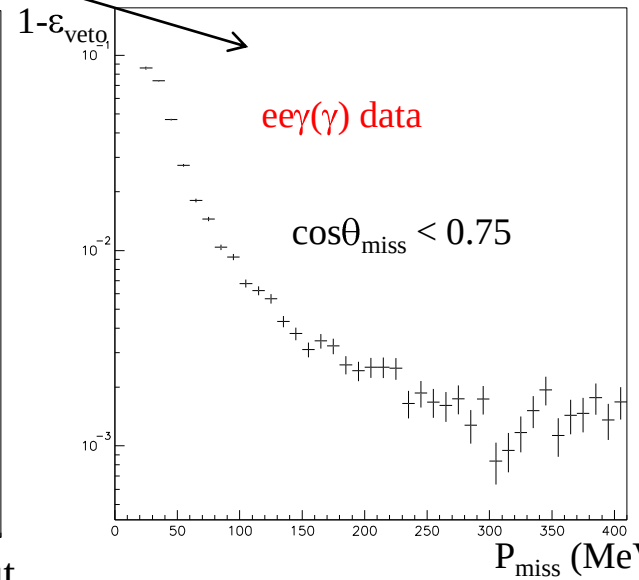
$K^+K^- \to \mu^+\mu^-\nu\nu$ decaying in the IP region



sinθ distribution!

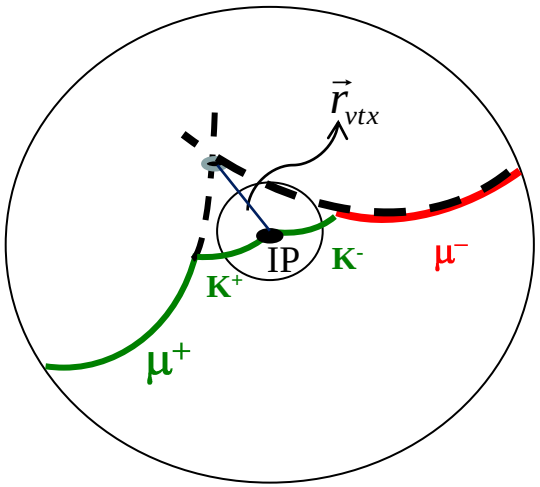


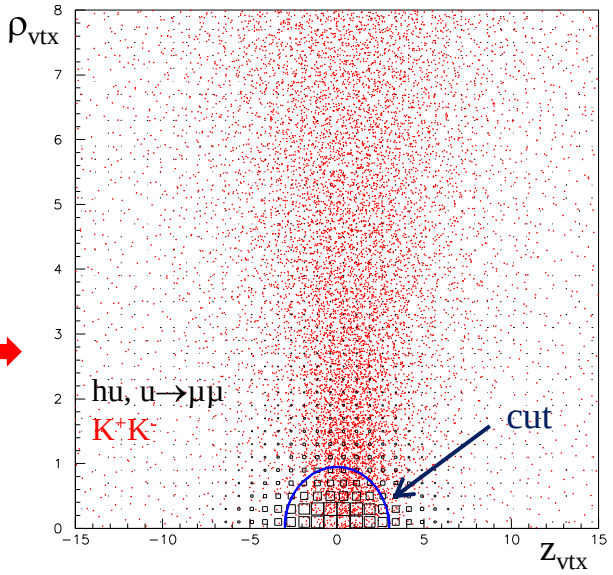




Vertex cut to suppress K^+K^- background

$K^+K^- \rightarrow \mu^+\mu^-\nu\nu$ decaying in the IP region

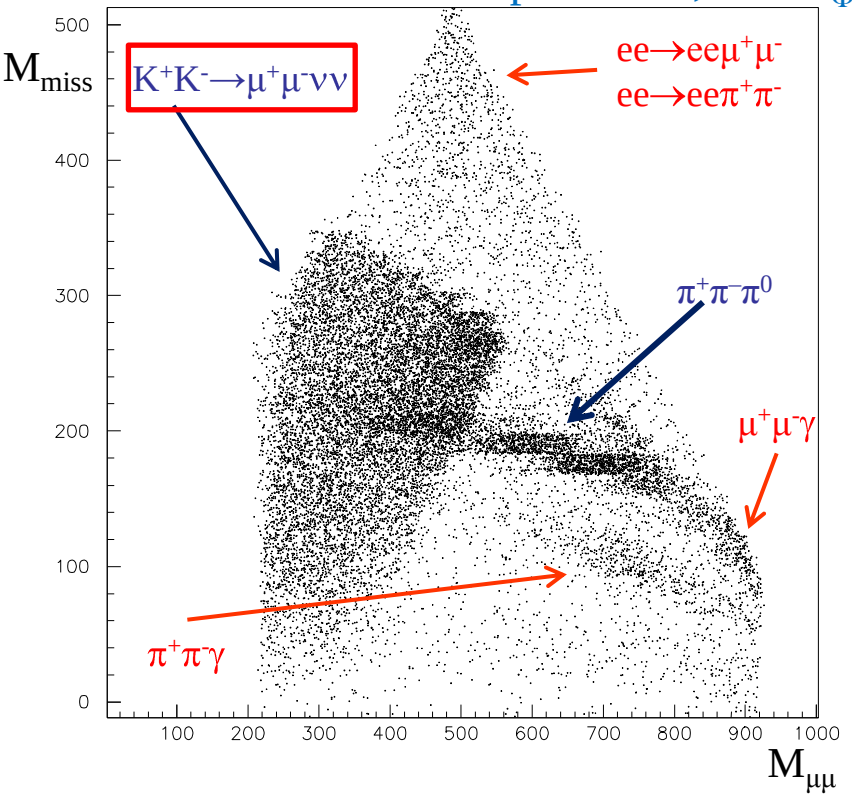




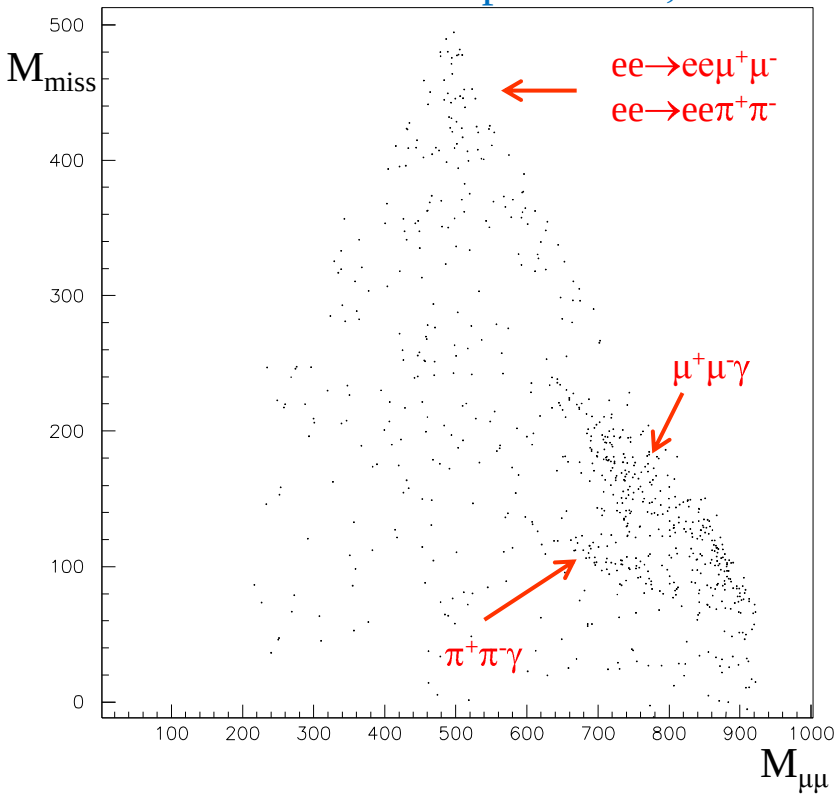
Typical signal efficiency ≈ 20%, with a 10% relative syst. error.

$e^+e^- \to hU$ results: on peak + off peak data

$L=1.65\ fb^{-1}$ on peak data, $\sqrt{s}=M_\Phi$



$L=0.2\ fb^{-1}$ off peak data, $\sqrt{s}=1$ GeV



Backgrounds

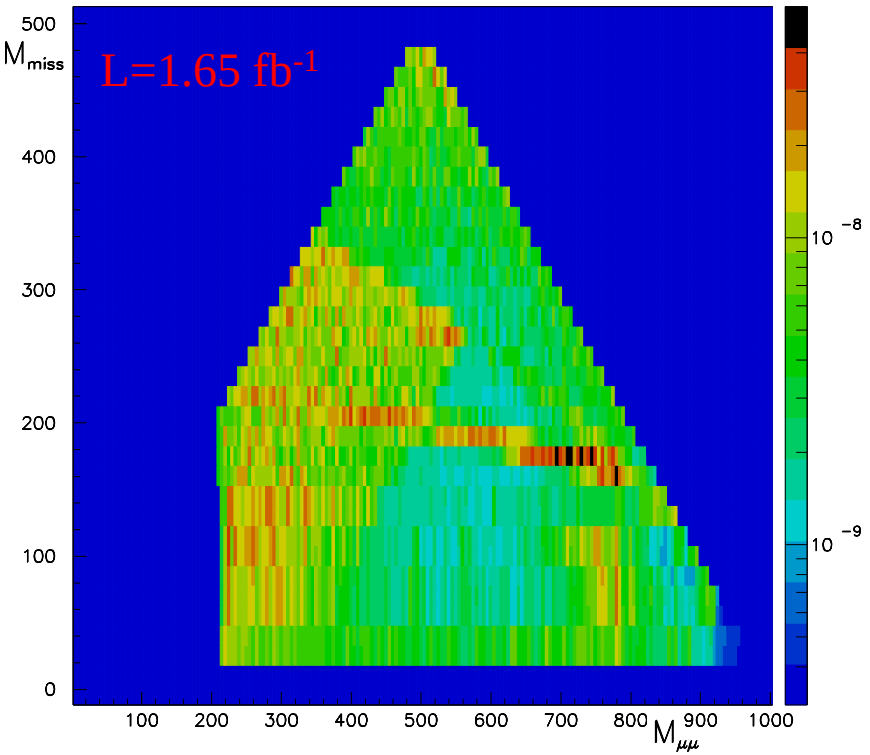
- $\Phi \to K^+ K^-, K \to \mu\ \nu$ ← Φ decays
- $\Phi \to \pi^+\pi^-\pi^0$ ← Φ decays
- $e^+e^- \to \mu^+\mu^-\gamma$ ← continuum
- $e^+e^- \to \pi^+\pi^-\gamma$ ← continuum
- $e^+e^- \to e^+e^-\mu^+\mu^-$
- $e^+e^- \to e^+e^-\pi^+\pi^-$

$e^+e^- \rightarrow hU$ Results: 90% CL limits

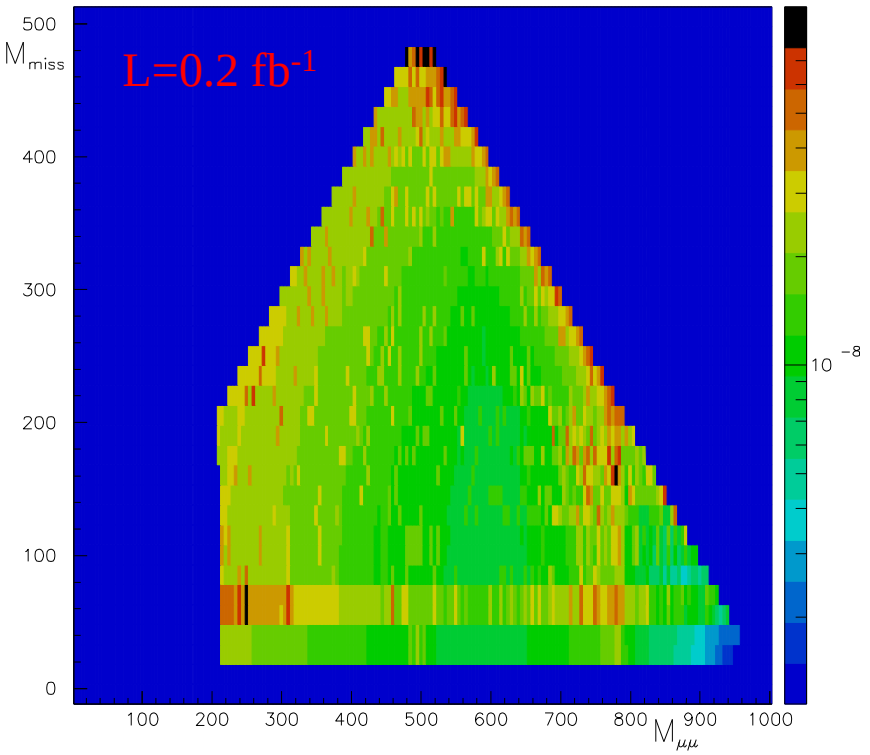
Phys. Lett. B747 (2015) 365

Limits are in terms of $\alpha_D\varepsilon^2$ vs $M_U M_h$

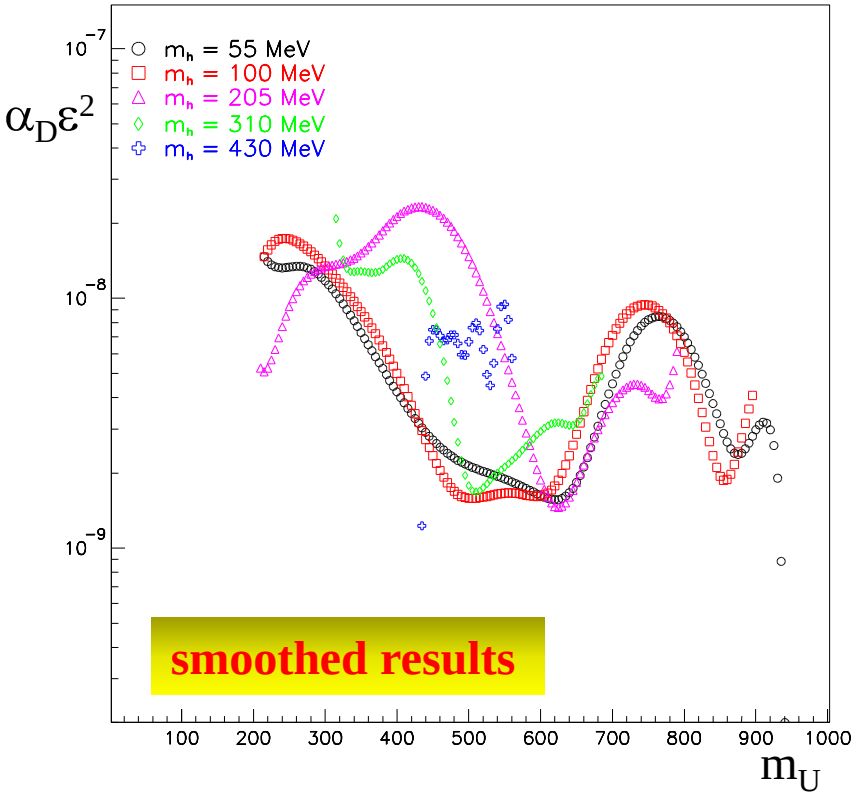
On Φ peak

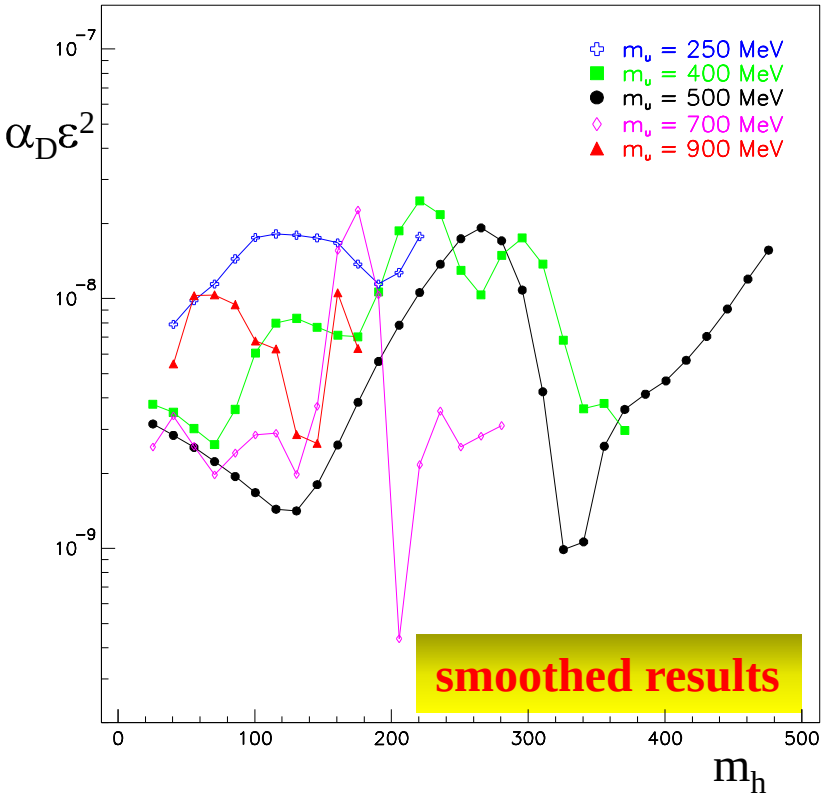


Off peak



$e^+e^- \to hU$ results: 90% CL limits combined (projections)





Phys. Lett. B747 (2015) 365

Limits ~ $10^{-8} \div 10^{-9}$ in $\alpha_D\varepsilon^2$, which translate in $10^{-3} \div$ some 10^{-4} in ε, if $\alpha_D = \alpha_{em}$

Complementary with Belle and Babar results

Thinking in terms of Belle/Belle2

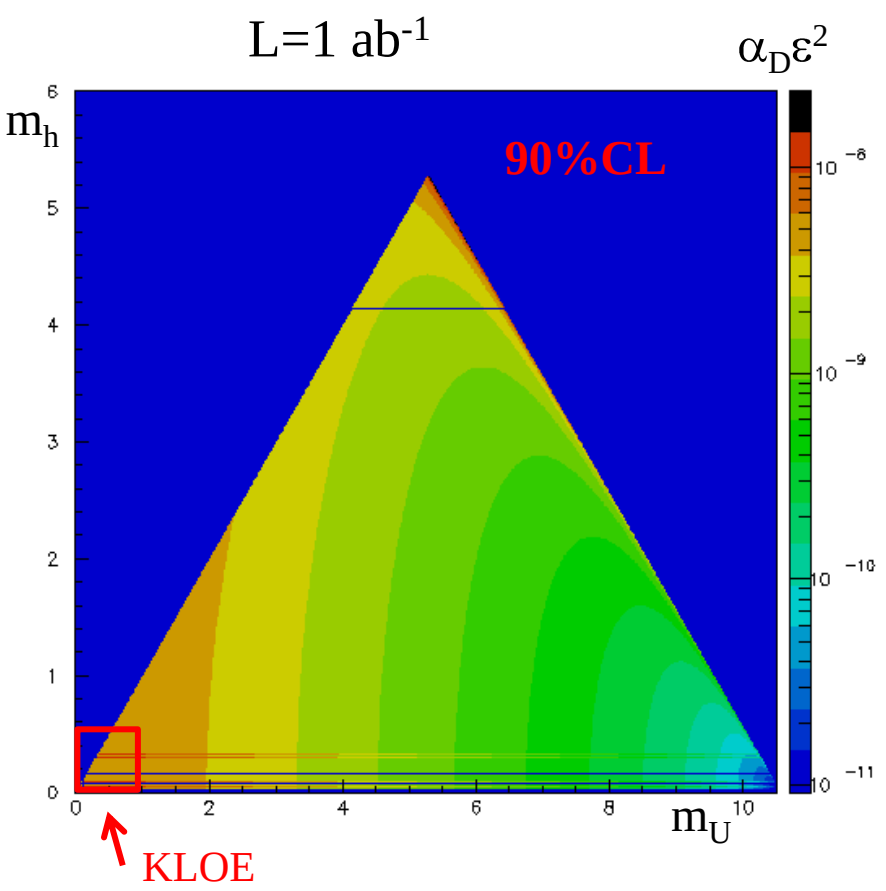
- 1/s factor in cross section + almost ‘no resonance’ effect in the interesting range
- Much favourable integrated luminosity
- $\tau \leftrightarrow K^{\pm}$, with much shorter lifetime (but much better resolution)
- e-μ-π

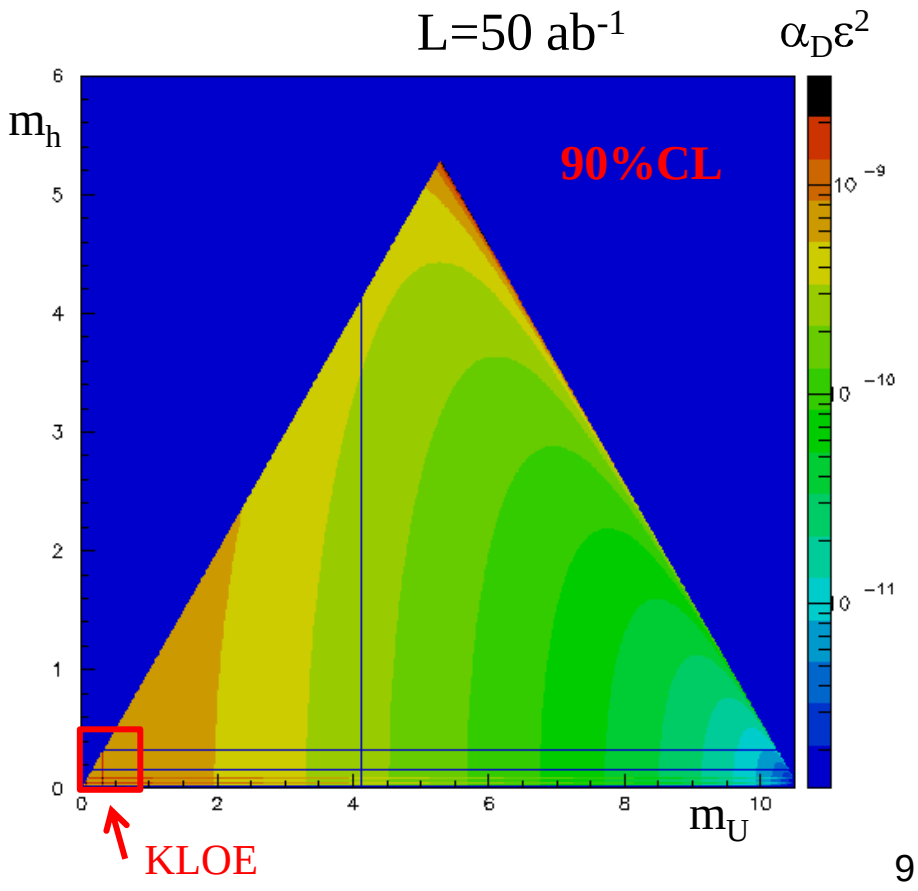
VERY rude feasibility analysis

- No MC, even at generator level
- Only ττ background; only $\tau \to e\nu\nu$, $\tau \to \mu\nu\nu$, $\tau \to \pi\nu$
- Perfect PID
- Only τ’s undergoing the same decay contribute to the background
- $\sigma_{\tau\tau}$= 1 nb
- $\varepsilon_{\tau\tau}$ = 80%
- ε_{hU}=20%
- 5 MeV mass resolution
- No lifetime based cuts
- Background events uniformly spreaded over the plane (realistic in number, but not realistic as distribution)

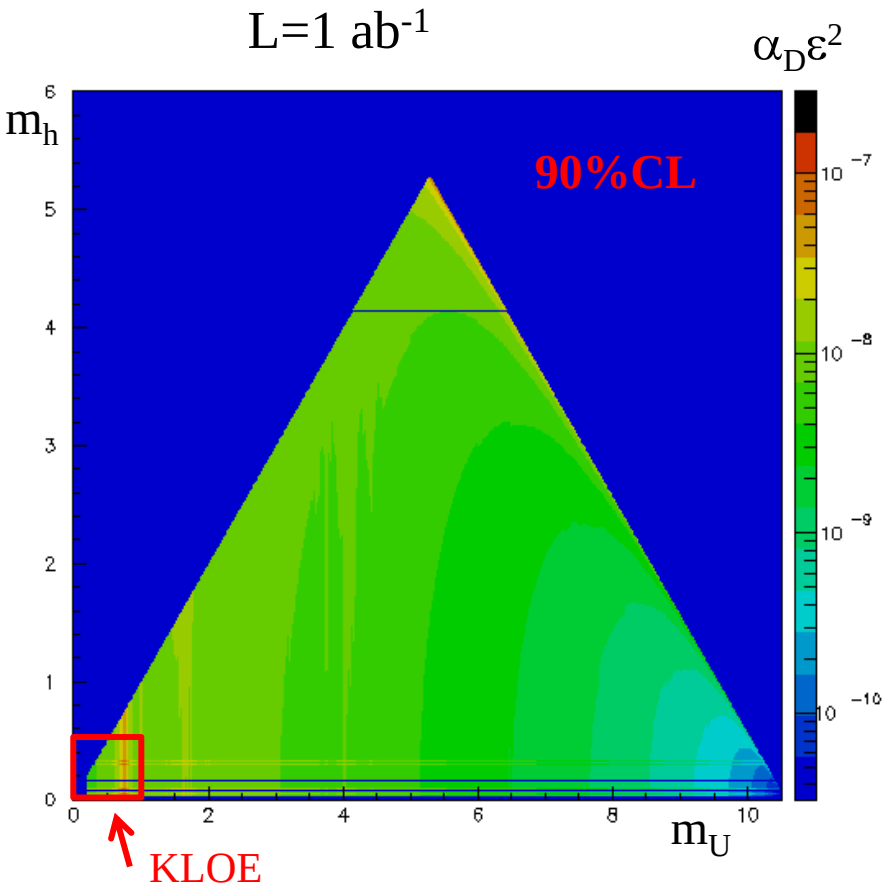
Two photon and continuum (other than τ) background missing
Background from Y?
Background from charm?

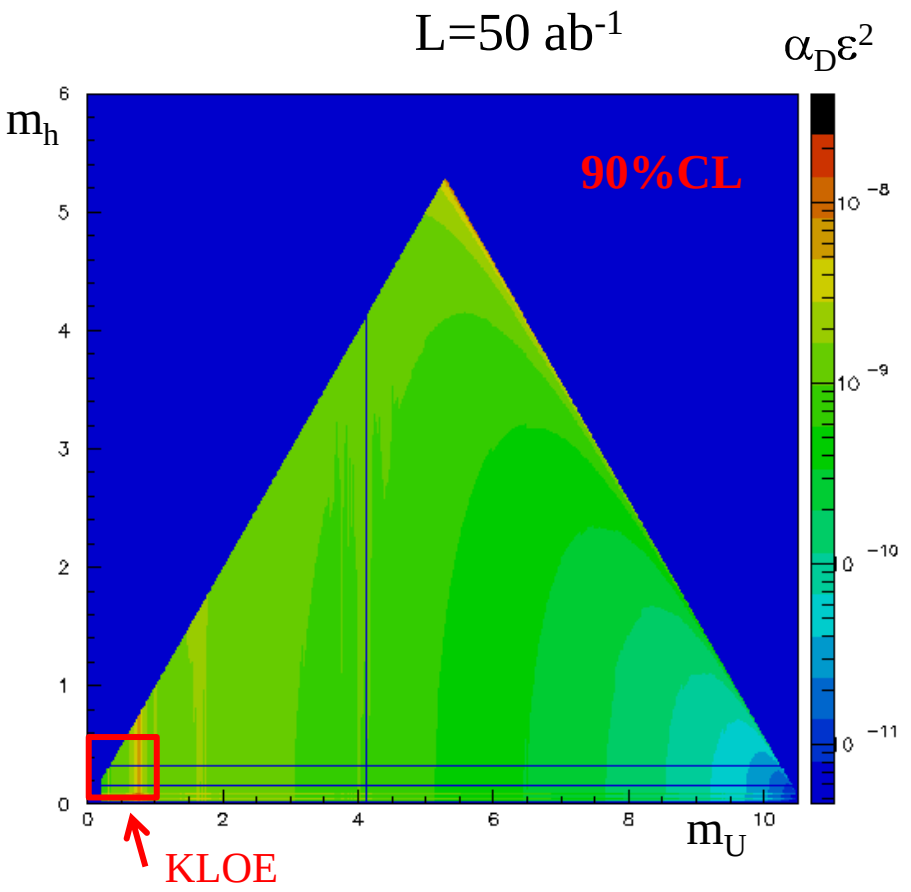
$U \rightarrow ee, \mu\mu, \pi\pi$



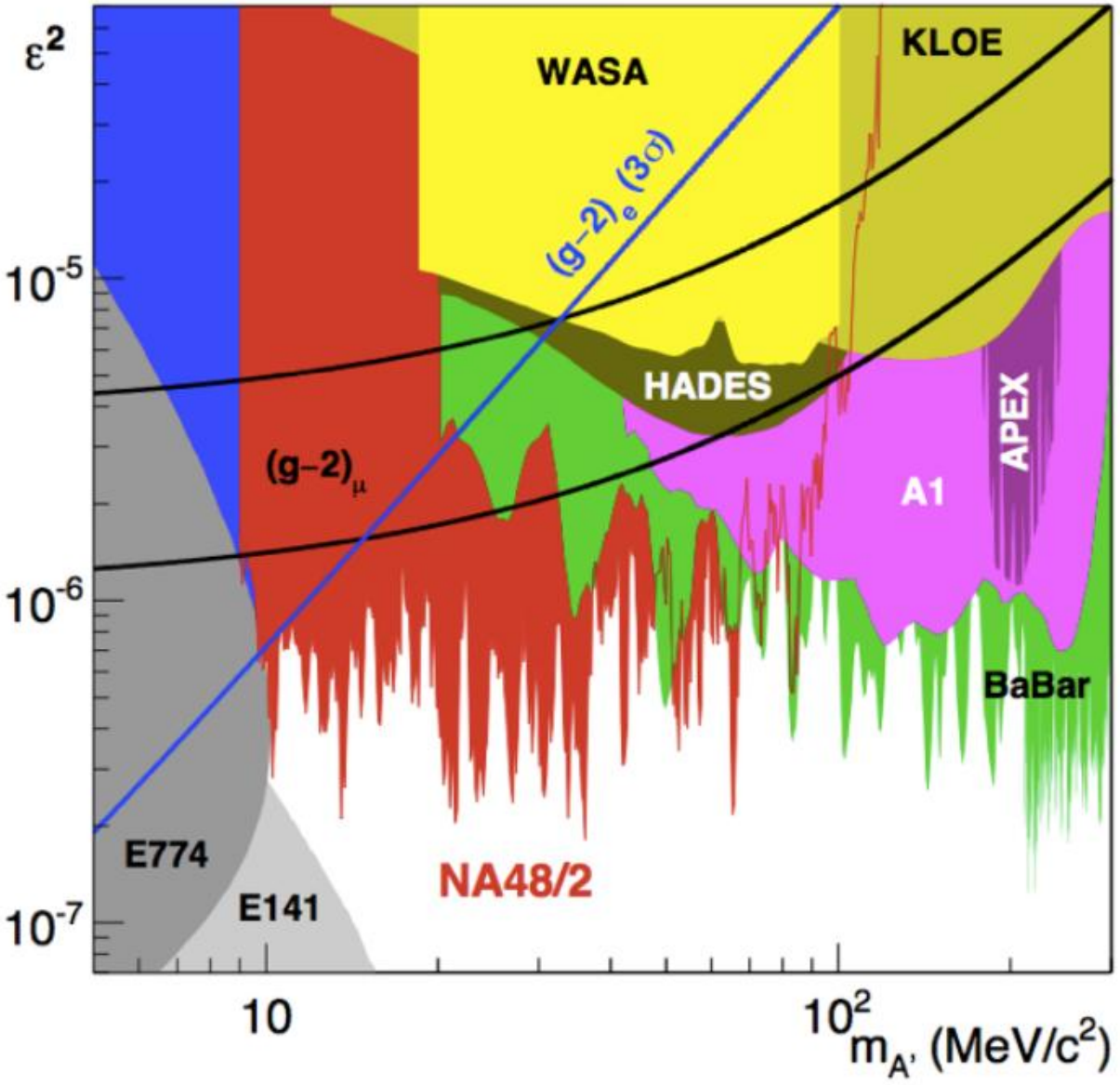


$U \to \mu\mu$





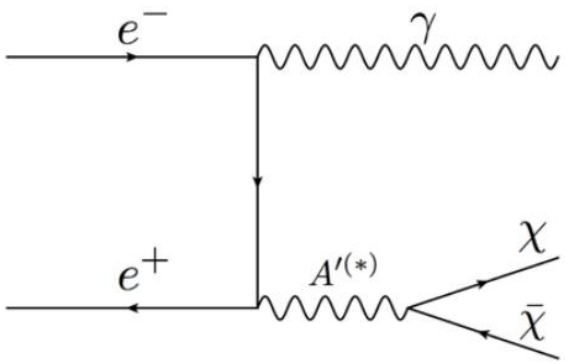
To be seen as rough order of magnitude estimates



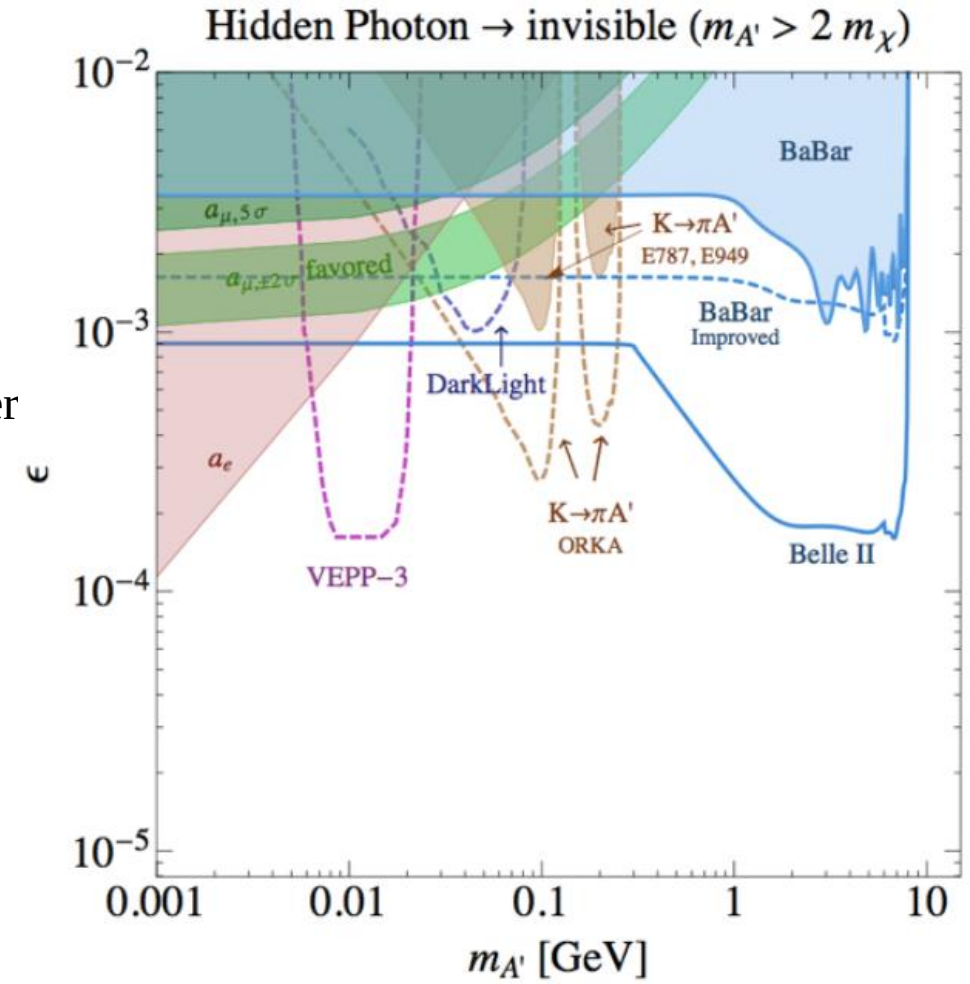
NA48/2 closes the possibility ox explaining $(g-2)_\mu$ with a dark photon $\rightarrow$ non minimal models with (for example) very light dark matter

Very light dark matter

Probably the most interesting



Strongly based on the single photon trigger
Covered by T. Ferber in Belle



Other ideas: ligh dark matter in bound states $\chi\chi$ (M. Pospelov)

$$1.68 m_V < \alpha_D m_\chi$$

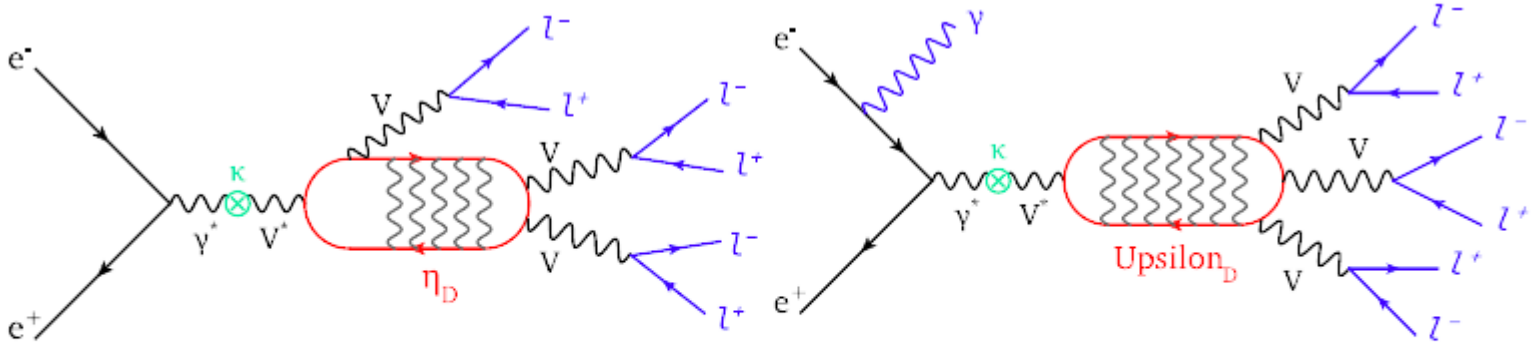


FIG. 1. Diagram for η_D and Υ_D production and decay at B-factories.

$$e^+e^- \to \eta_D + V; \quad e^+e^- \to \Upsilon_D + \gamma;$$

$$^1S_0\ (J^{PC} = 0^{-+}) \qquad ^3S_1 (J^{PC} = 1^{--})$$

Small α_D or larger $m_V/m_\chi \rightarrow$ no $\chi\chi$ bound states.

Mediators can still be produced via FSR

$$e^+e^- \rightarrow \chi\bar{\chi} + nV$$

Multileptonic + missing energy signature

Dark scalars

Basically unconstrained, never looked for, cosmologically interesting

M. Pospelov (and collaborators)

Dark scalar a which couples to leptons ~ m_l

Very interesting for τ: $e^+e^- \rightarrow \tau\tau a$, $a \rightarrow \mu\mu$

Paper soon