A Beam Dump Experiment at Future Muon Colliders

Cari Cesarotti, MIT CTP

Muon Collider Physics & Detector Workshop at Fermilab

Dec 16, 2022

(2202.12302) w/ S. Homiller, R. Mishra, M. Reece

What do we want from a future collider? (BSM perspective)

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Expand energy & intensity frontiers

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Construction of a new collider

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Muon Colliders (μC)

LHC (pp) μC

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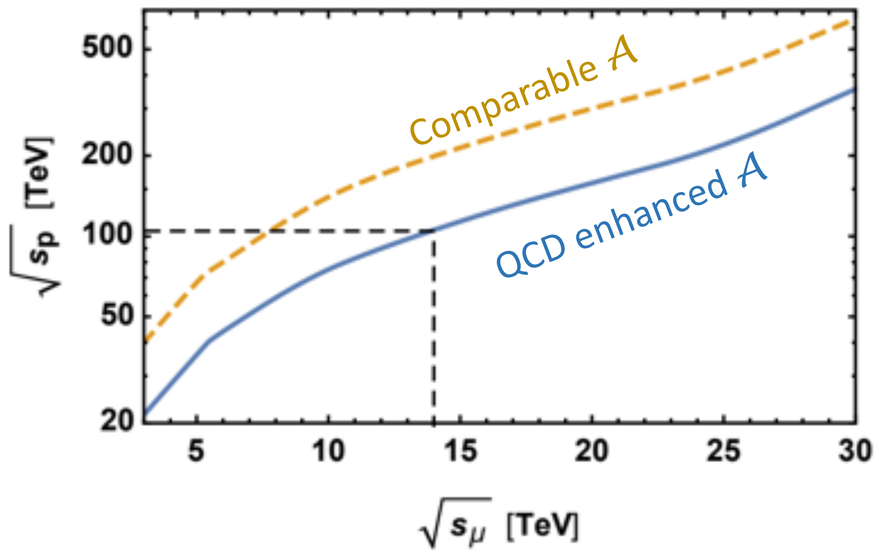
- $\sqrt{\hat{s}} \ll \sqrt{s}$

μC

- $\sqrt{\hat{s}} \simeq \sqrt{s}$

1901.06150



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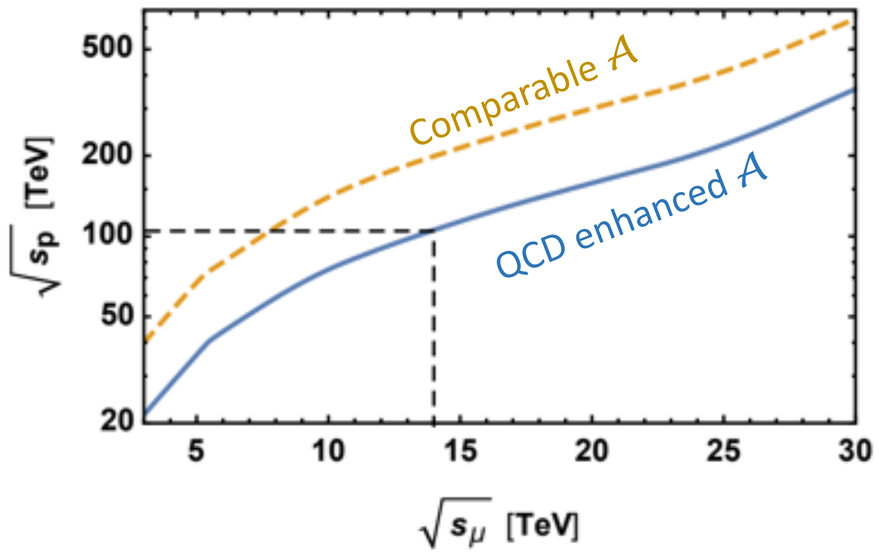
- Electroweak production

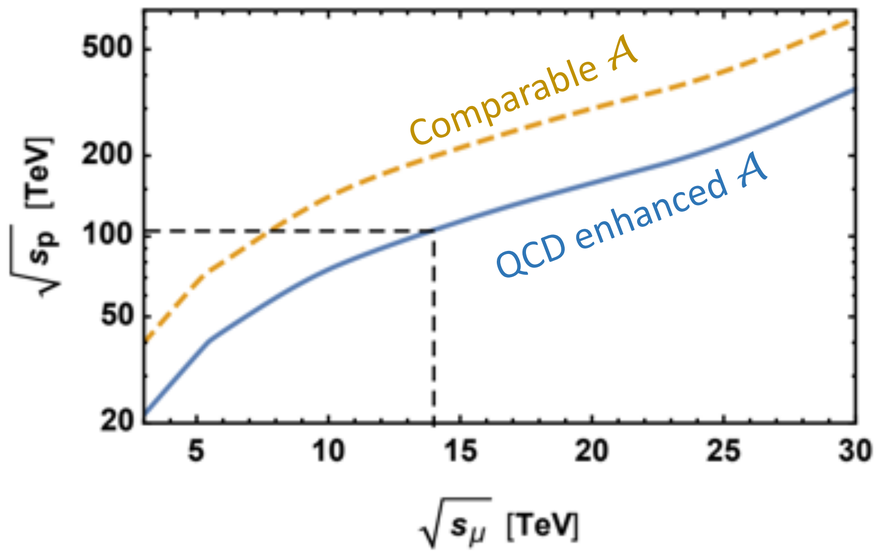
1901.06150



Muon Colliders (μC)

LHC (pp)	μC
• $\sqrt{\hat{s}} \ll \sqrt{s}$	• $\sqrt{\hat{s}} \simeq \sqrt{s}$
• Color production	• Electroweak production
• Hadronized final states	• Small QCD background

1901.06150



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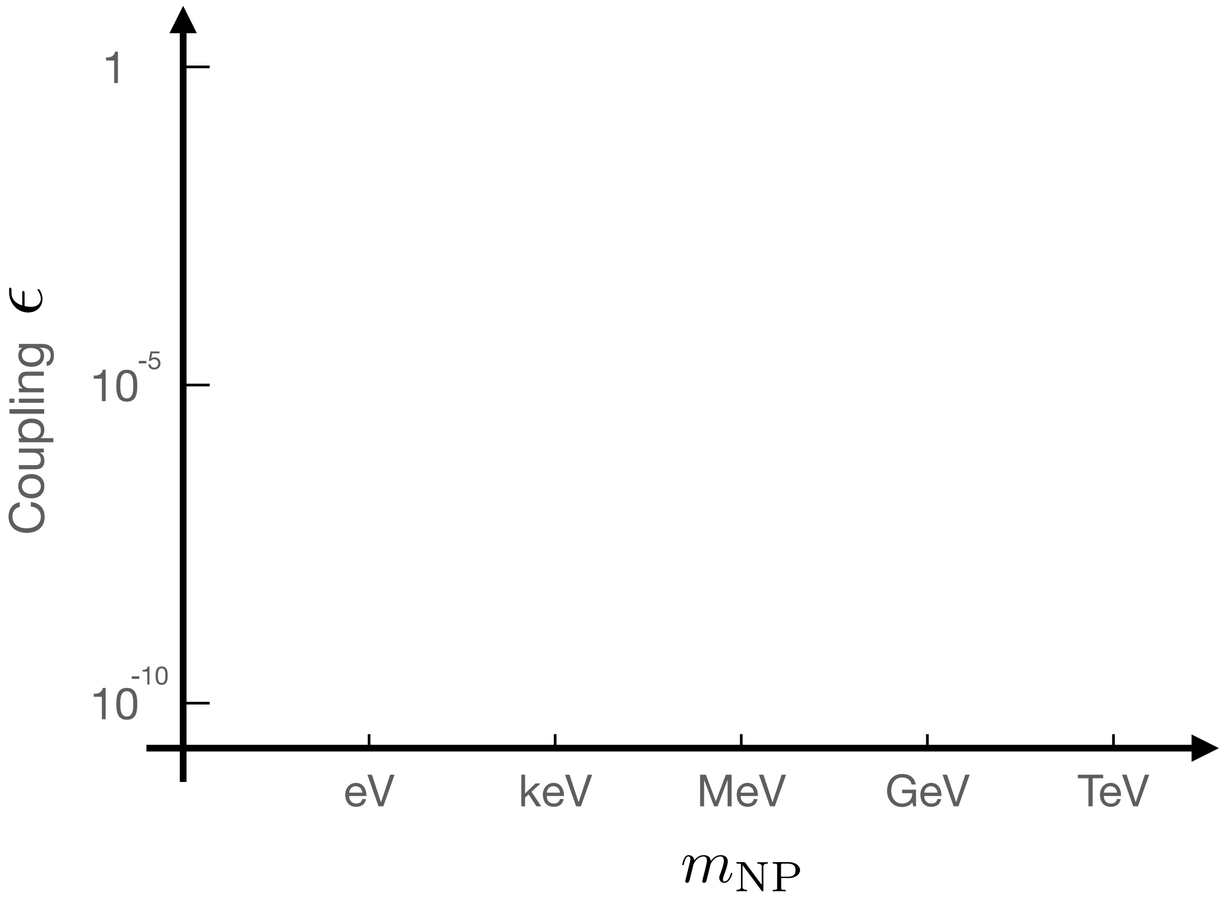
	• 2nd gen couplings	• 1st gen couplings

Future multi-TeV μC provides a complementary physics program



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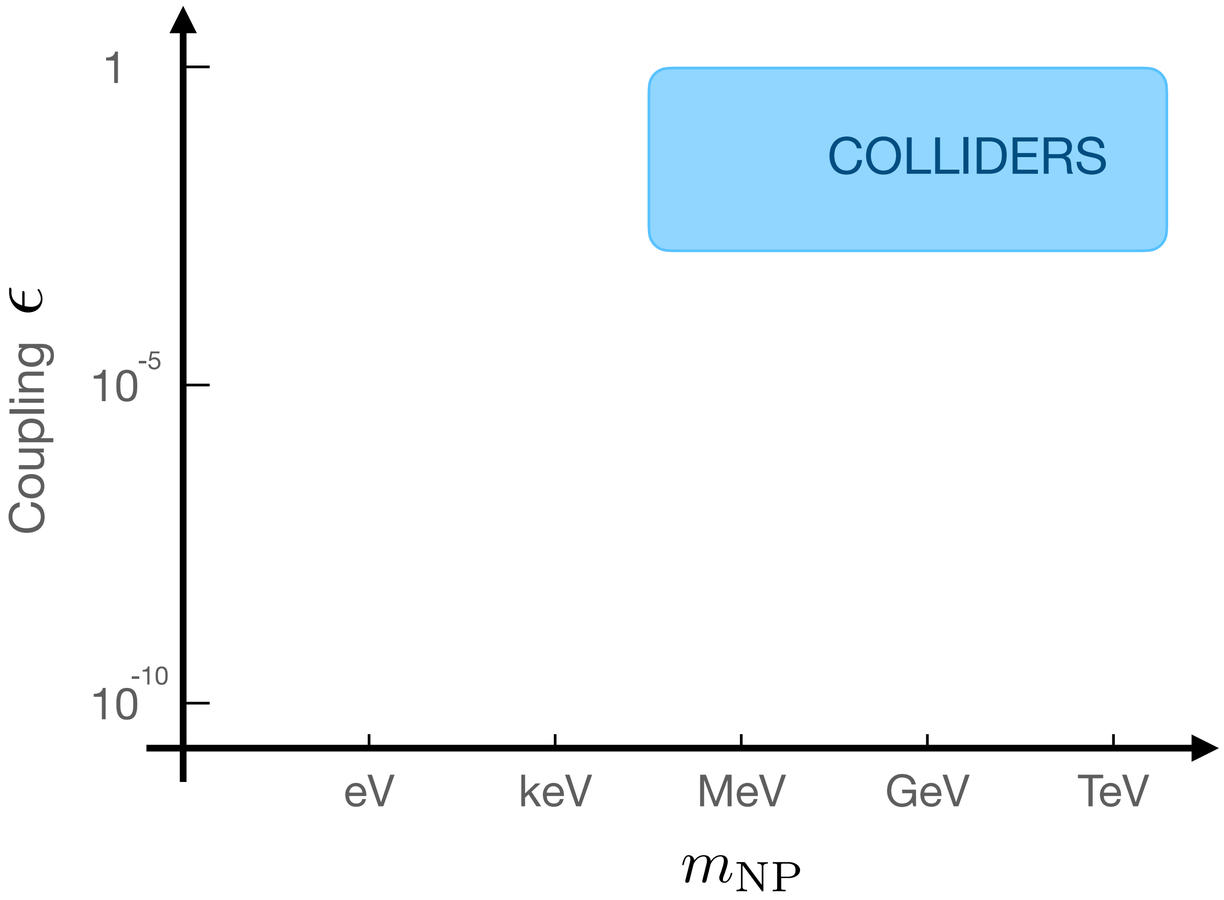

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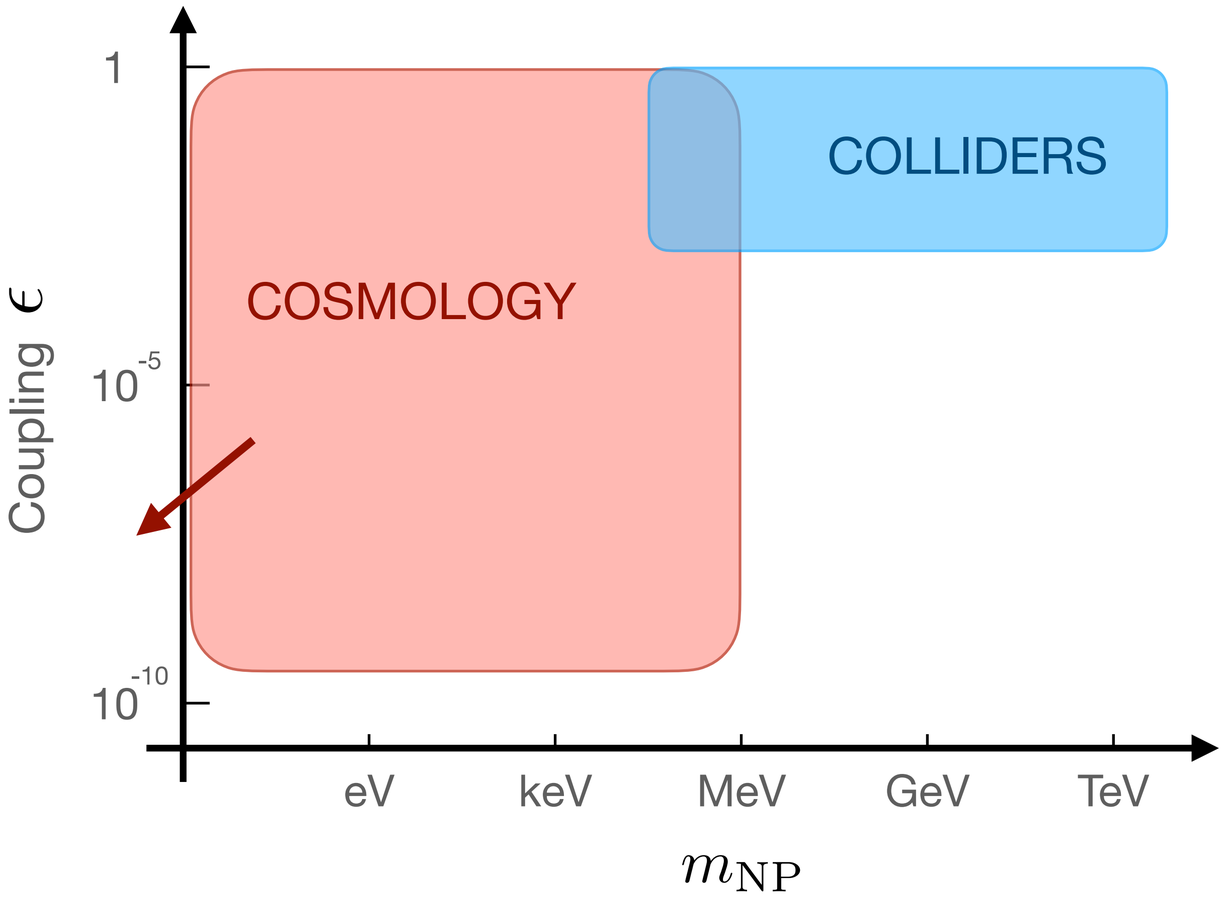

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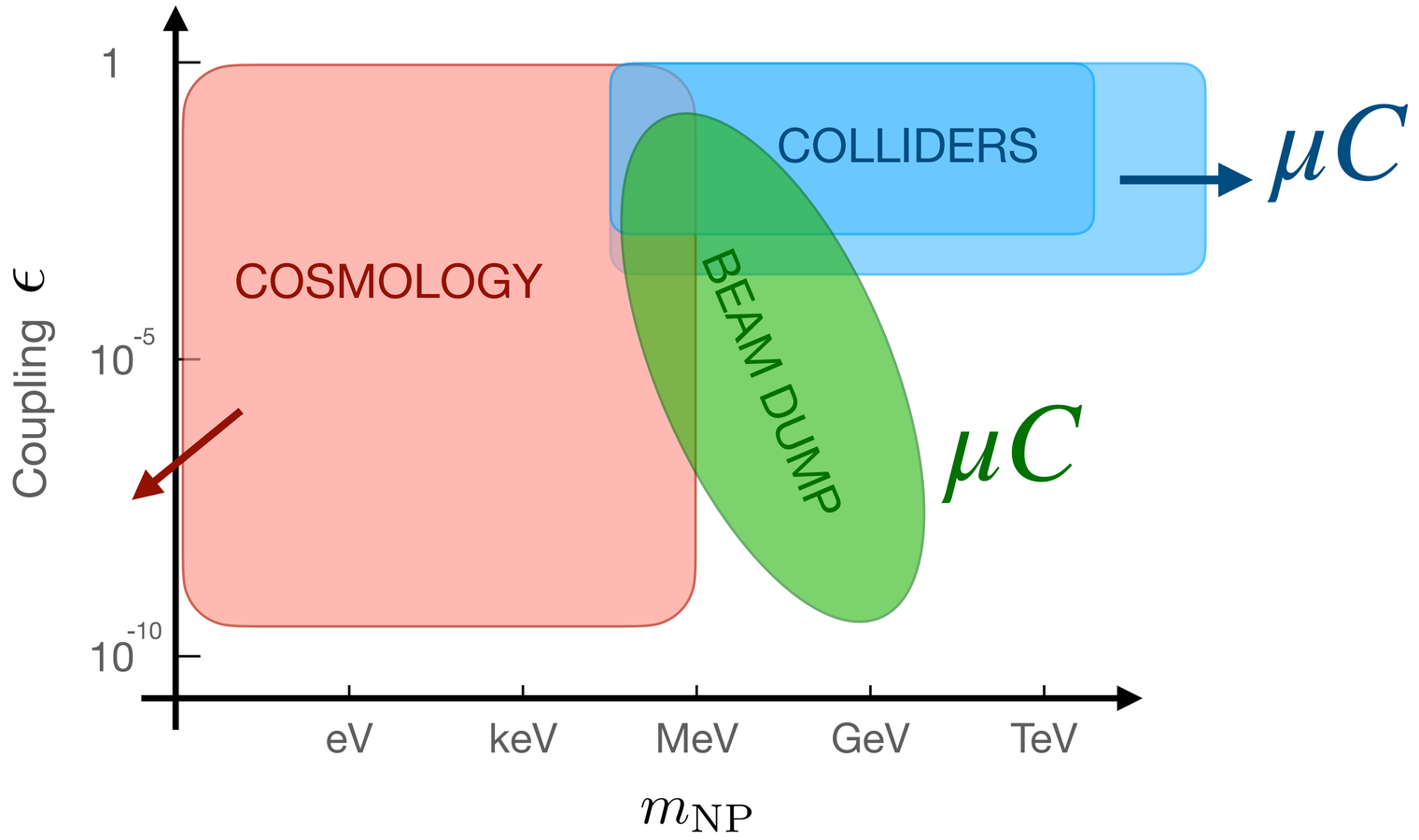

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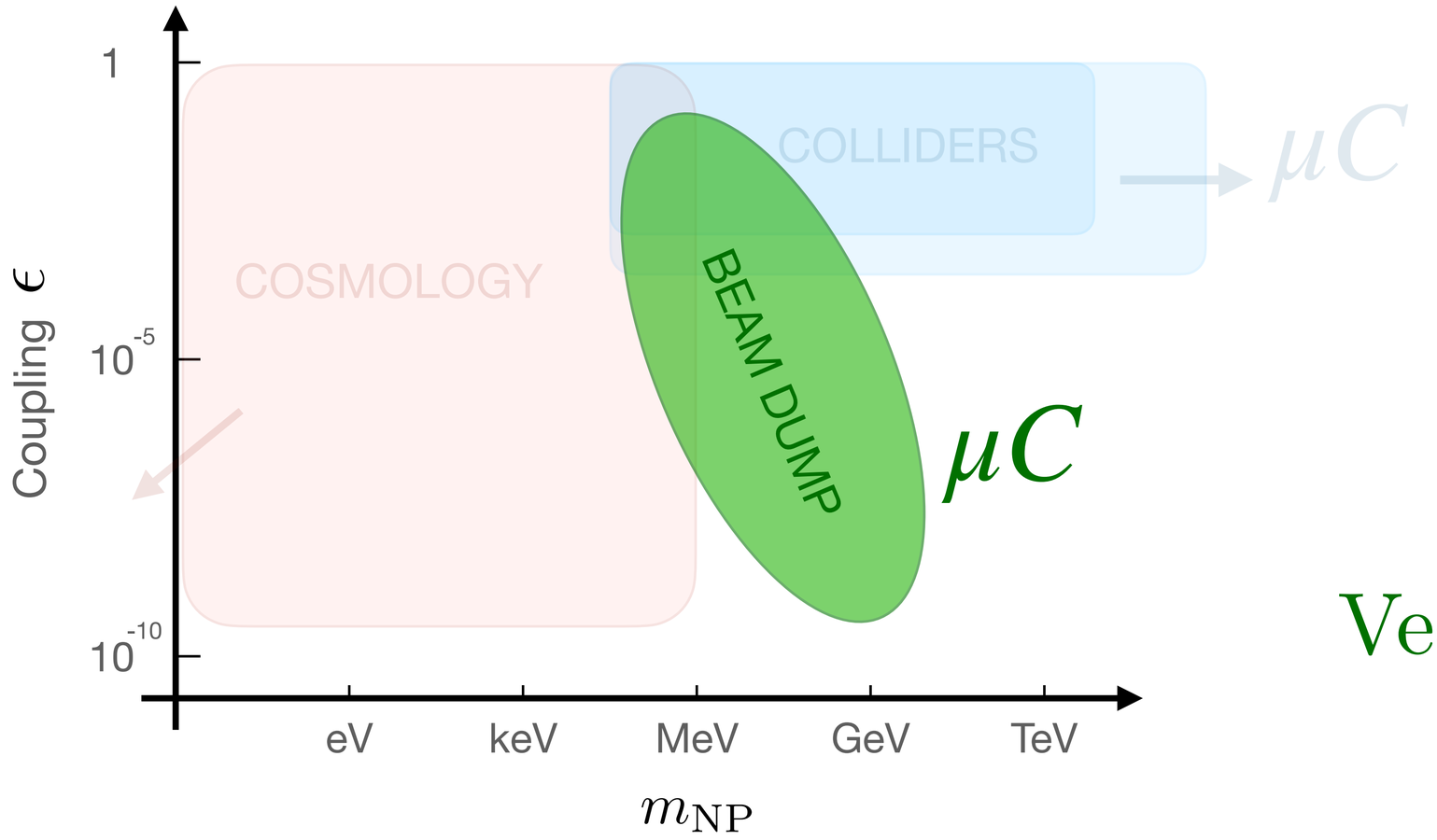

Vector Bosons @ BD

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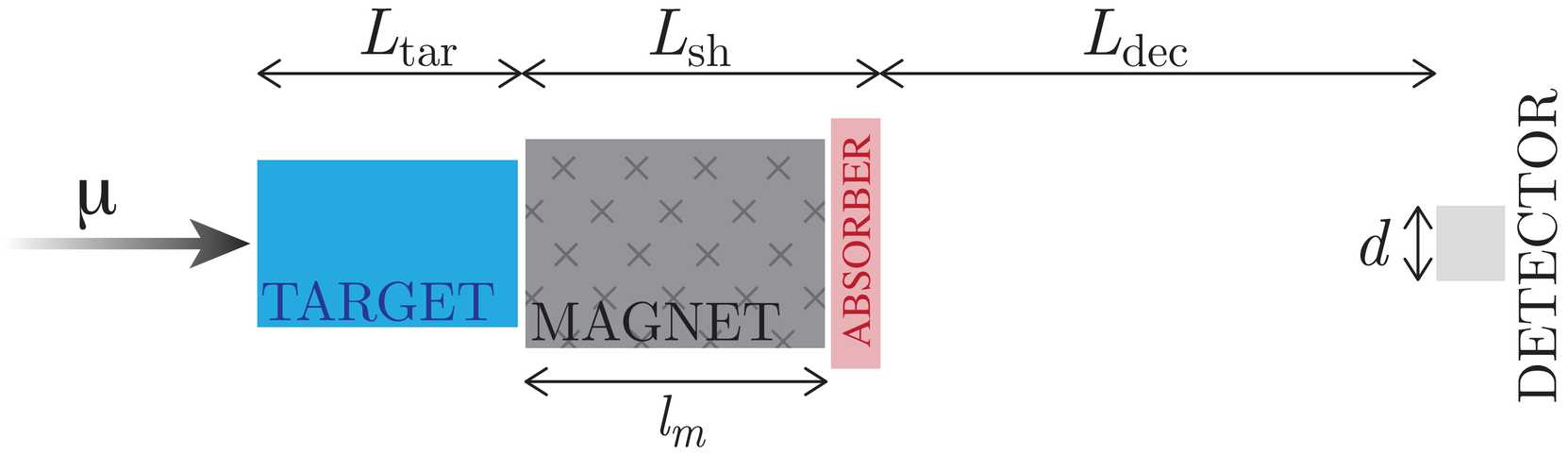
A beam dump experiment at the μC allows us to push into both the energy and the intensity frontier



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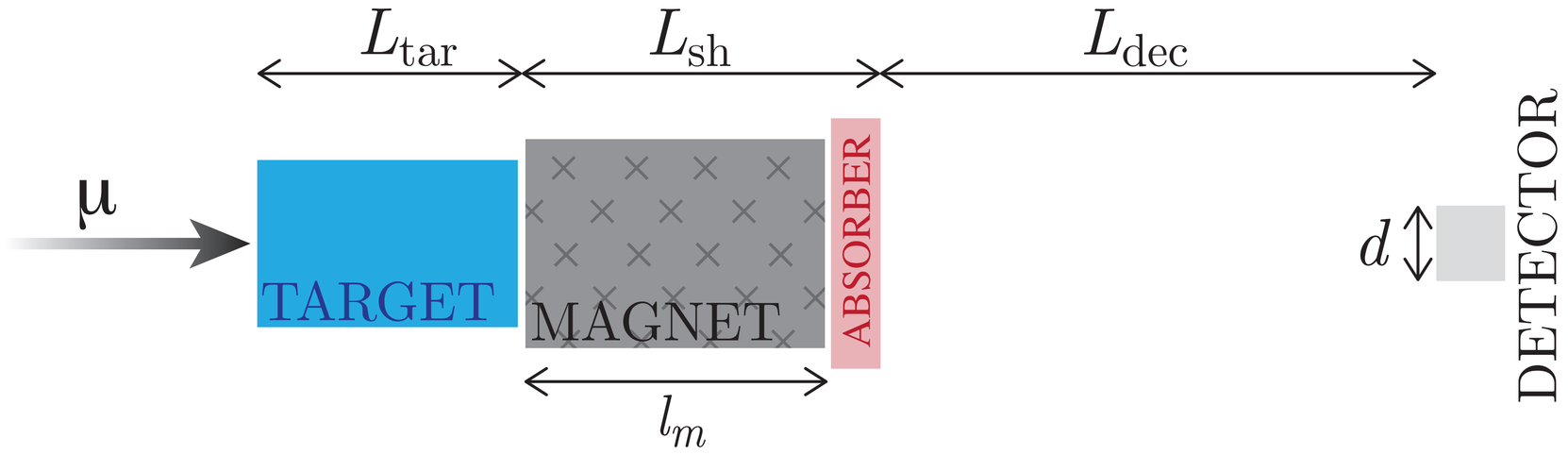

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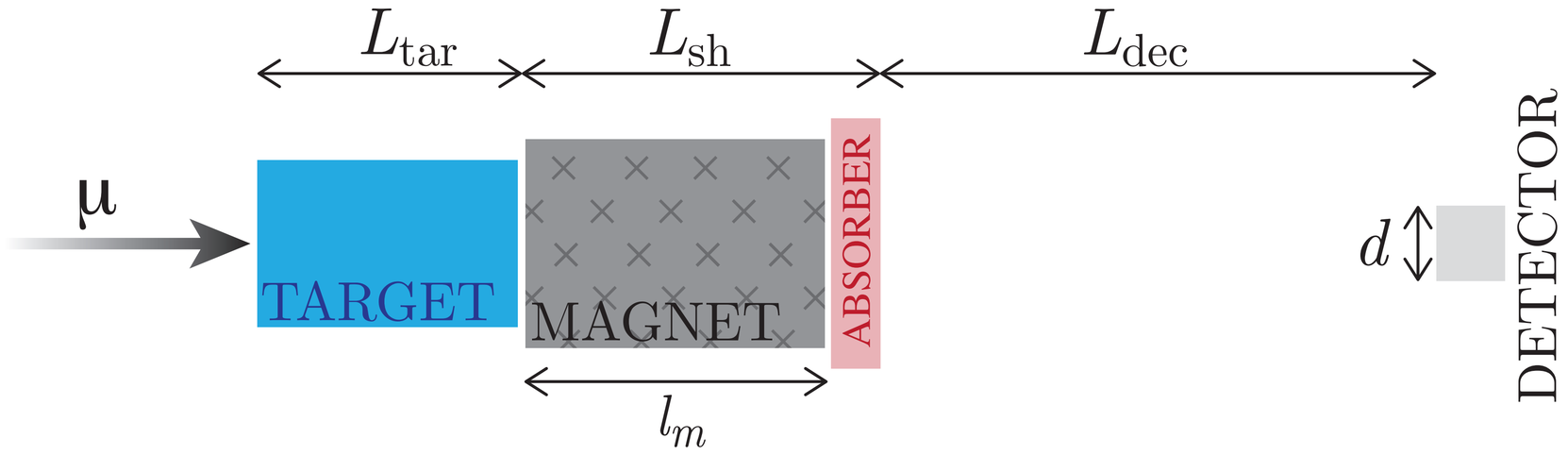

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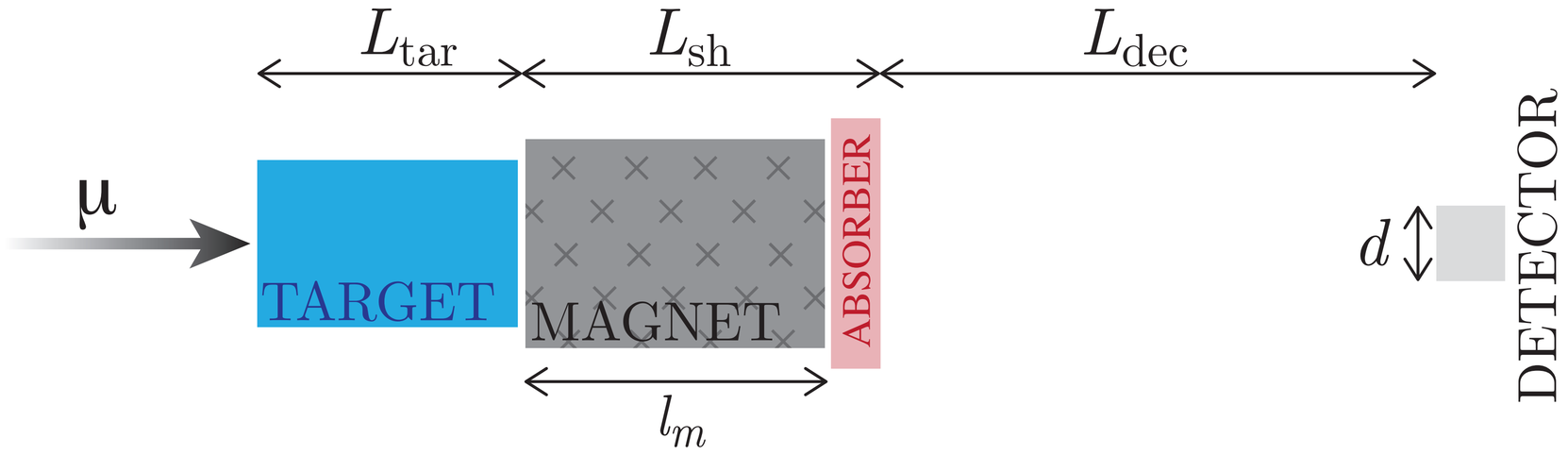

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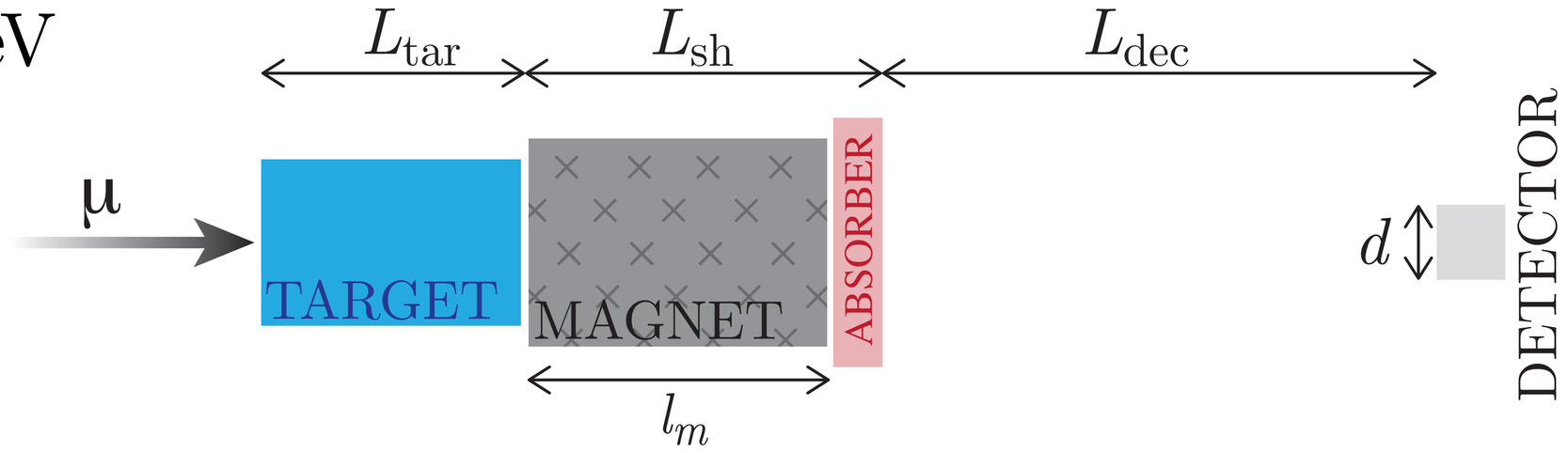
A beam dump experiment at the μC allows us to push into both the energy and the intensity frontier

Can probe NP scenarios with:

- Very weak couplings
- Couplings to 2nd gen. leptons
- Masses $\lesssim$ 100 GeV



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We search for vector new physics signals at μC beam dump

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$$\sqrt{s} \sim \text{ TeV}$$

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We consider 2 models:

- Dark Photon
- Gauged Flavor Symmetry $L_\mu - L_\tau$

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New physics Z' Scenarios

Dark Photon

$L_\mu - L_\tau$

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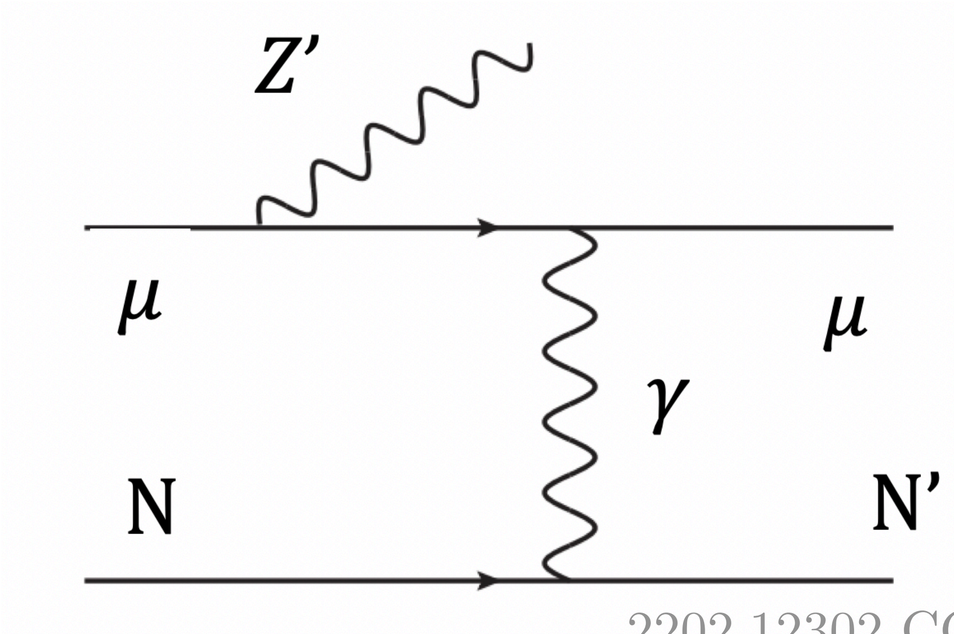

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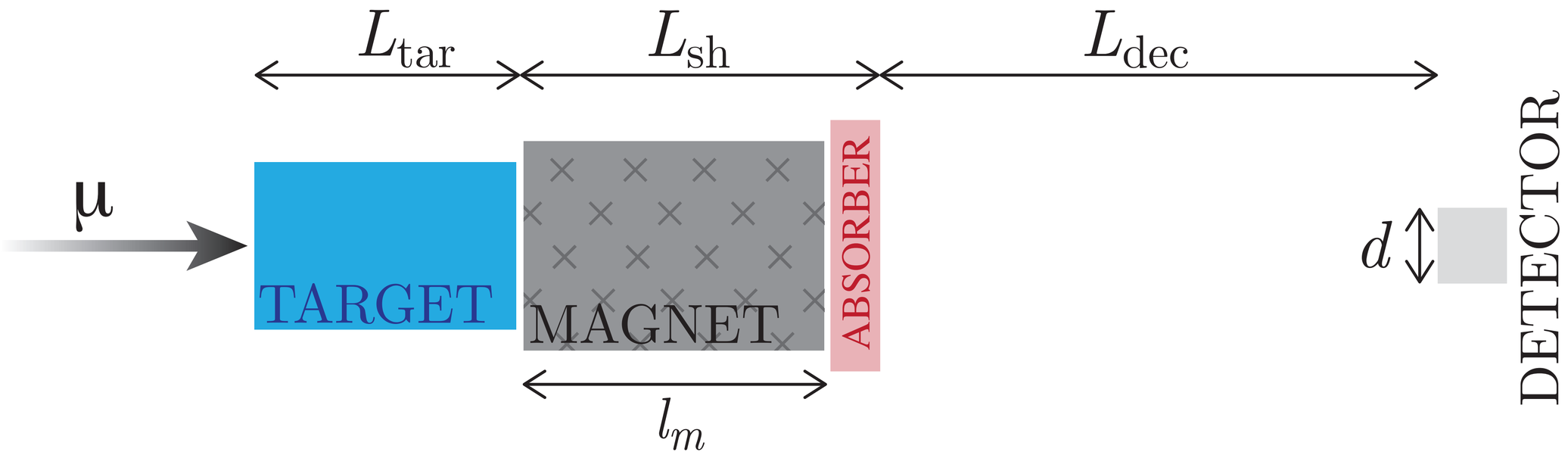
Beam Dump Setup



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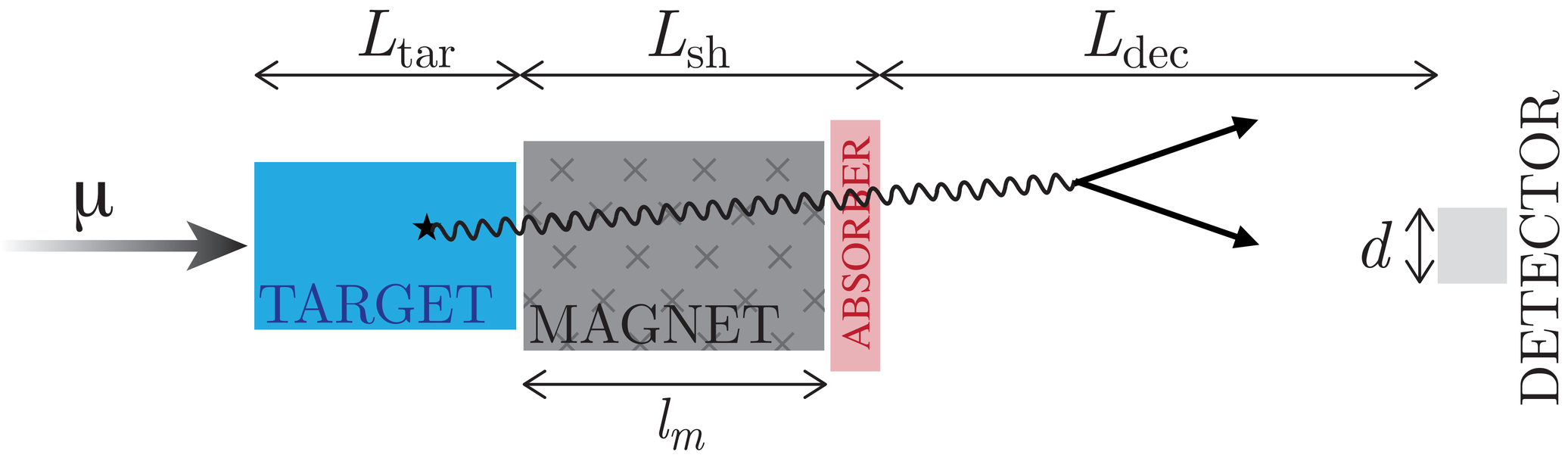

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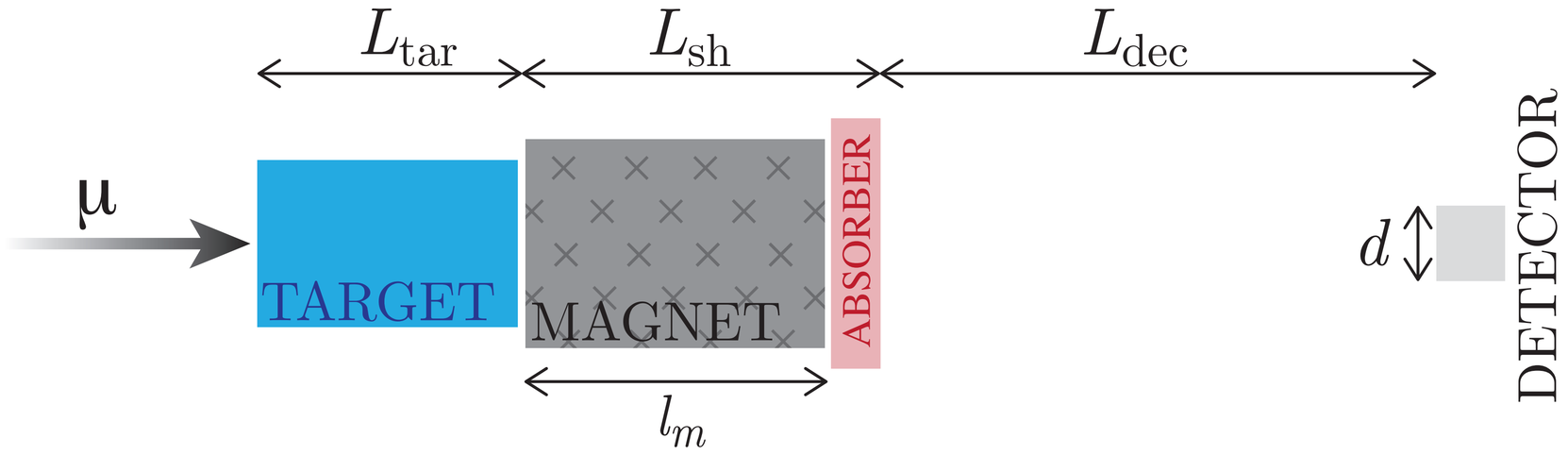
Number of signal events depends on l_0 and experiment geometry



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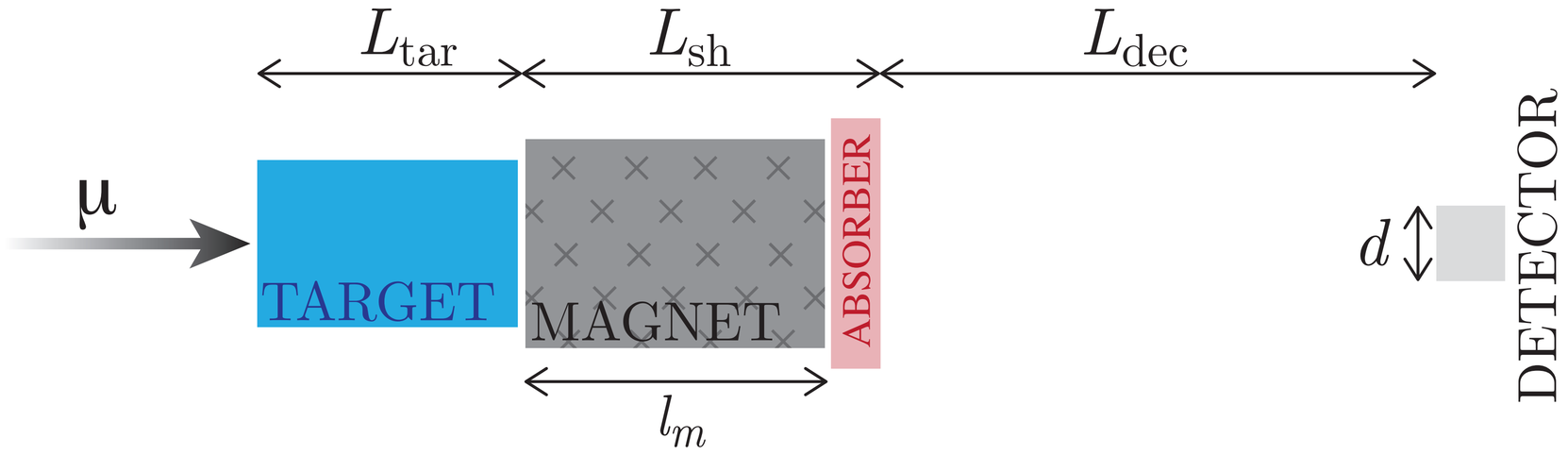
$$\frac{dN}{dx} = N_\mu \frac{N_0 \rho l_0}{A} \frac{d\sigma}{dx} \left(e^{L_{tar}/l_0} - 1\right) e^{-(L_{tar}+L_{sh})/l_0} \left(1 - e^{-L_{dec}/l_0}\right)$$



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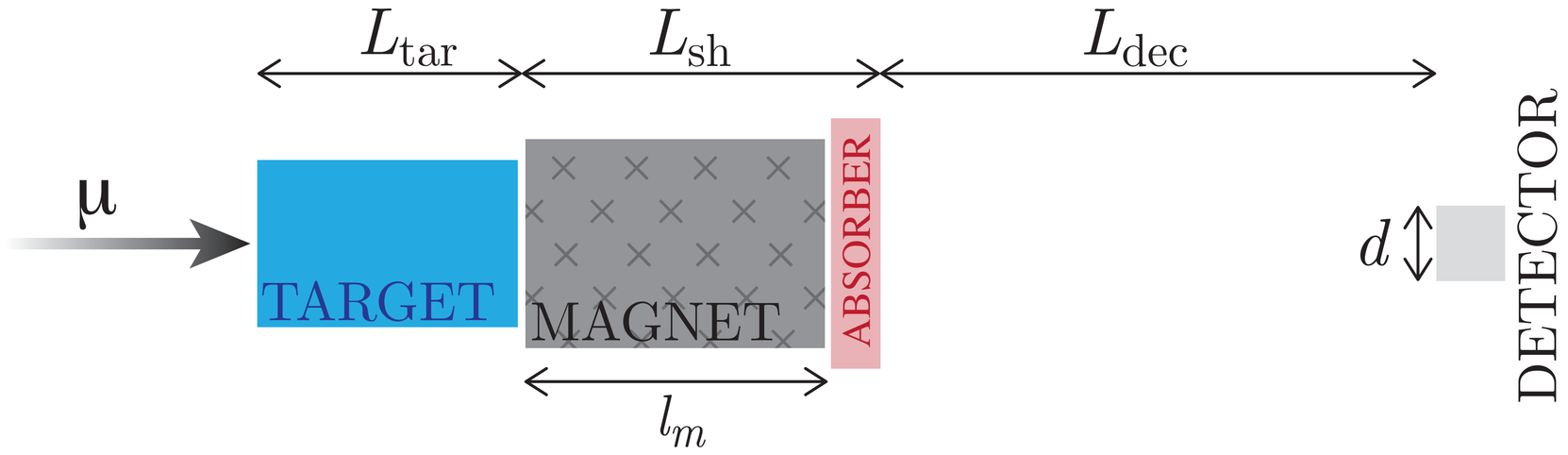
Signal events

$$x \equiv \frac{E_{Z'}}{E_{beam}}$$



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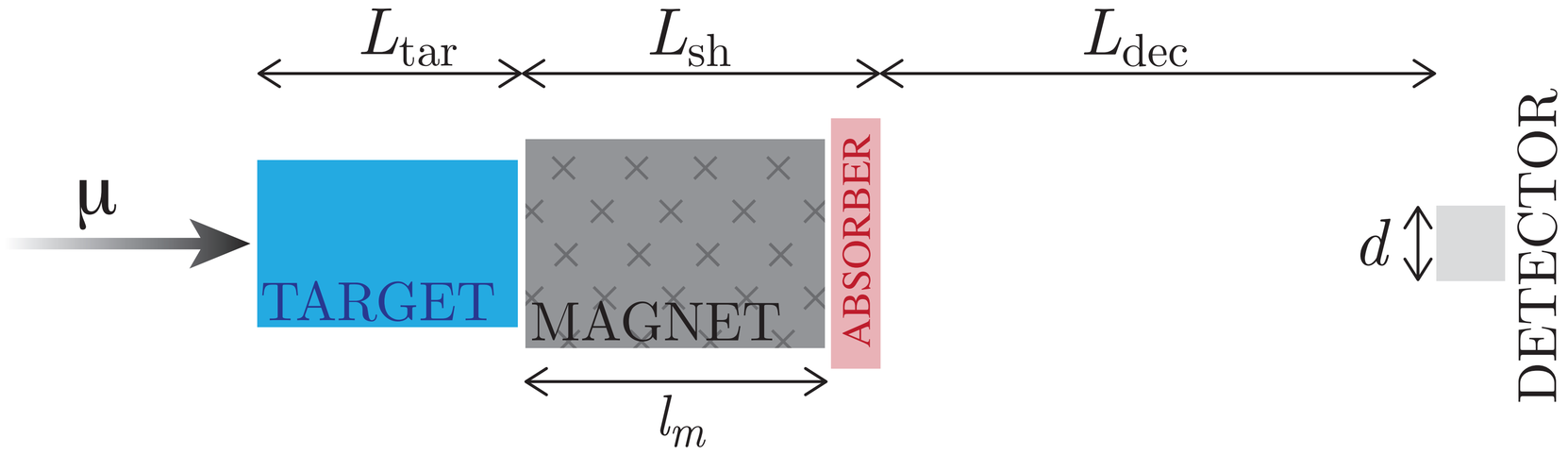

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Target material

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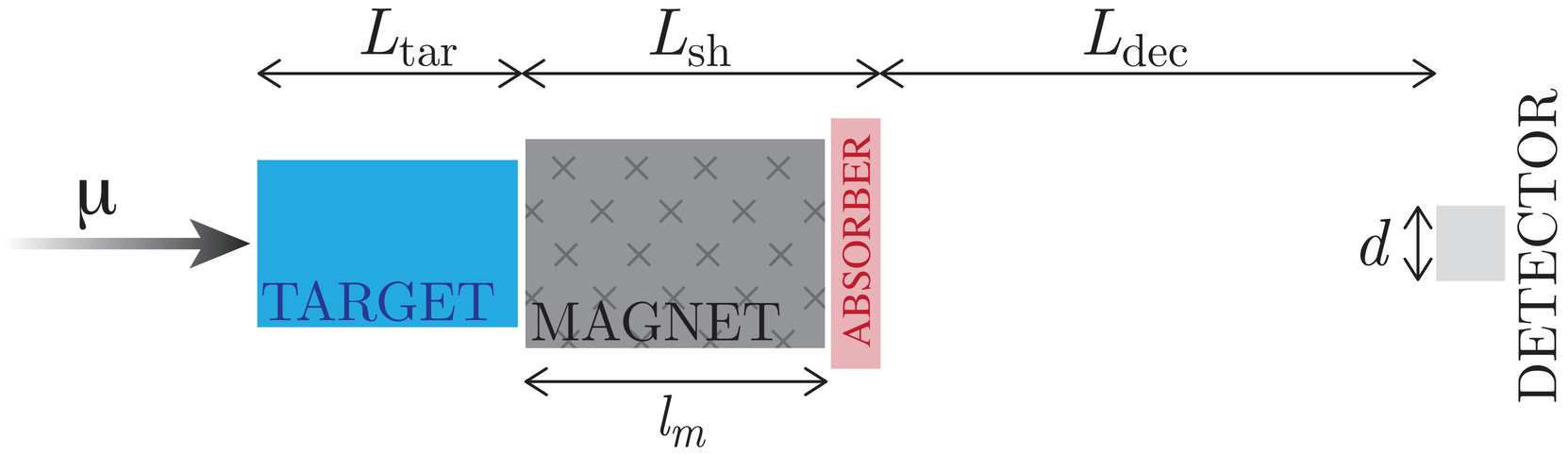

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Production cross section

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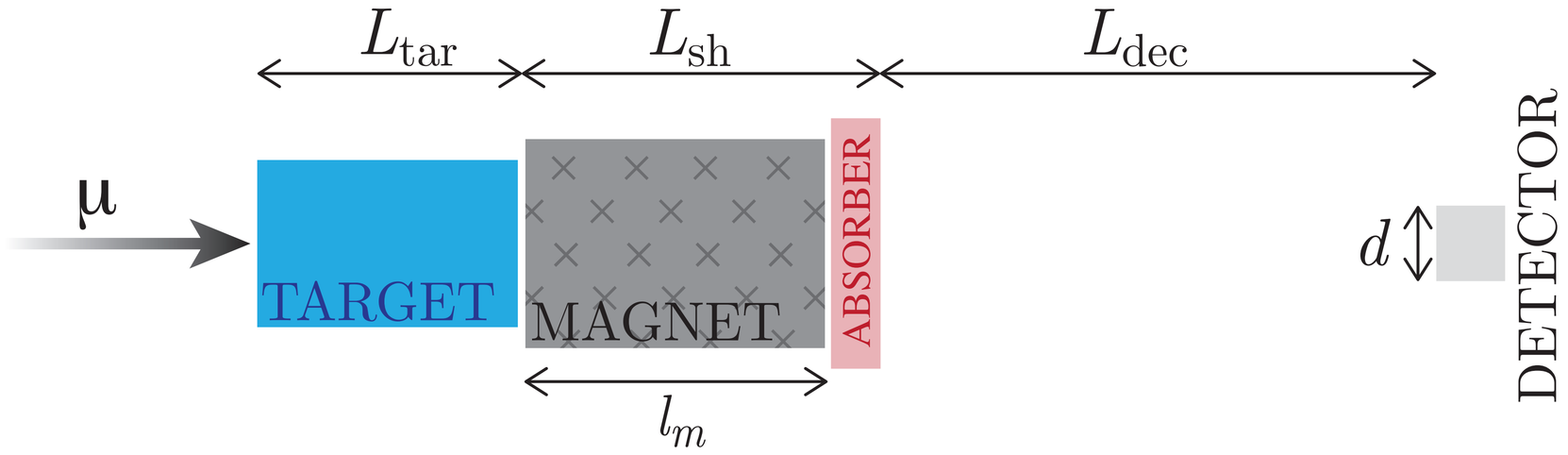

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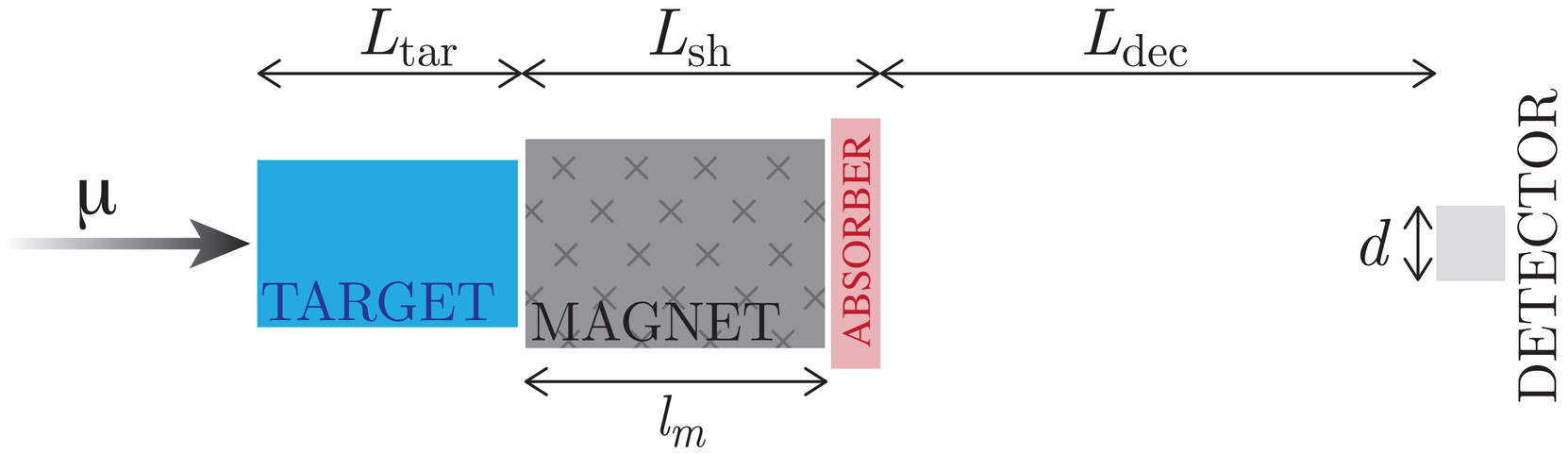
Probability of decay

$$x \equiv \frac{E_{Z'}}{E_{beam}}$$



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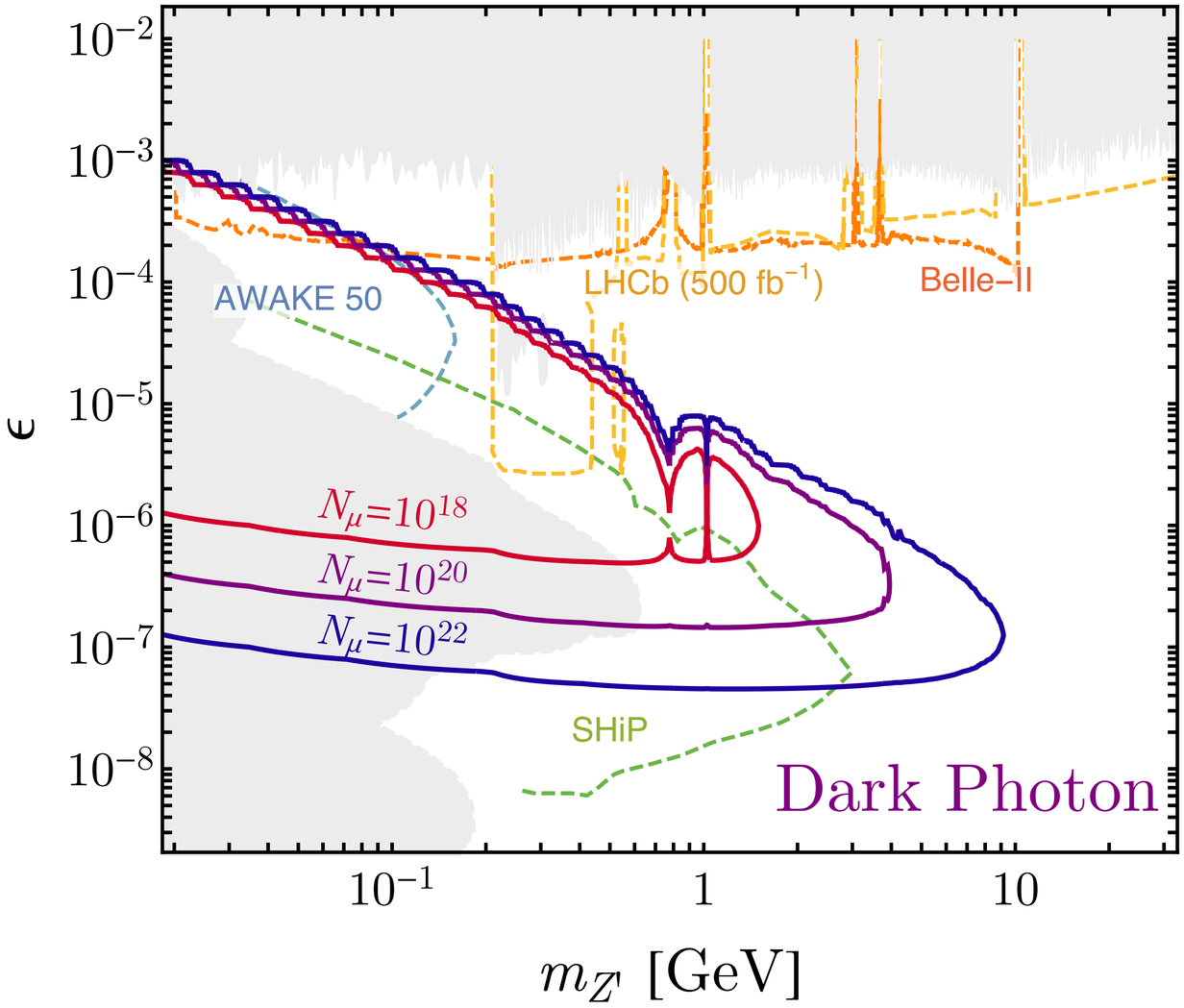
Dark Photon Reach

$$\mathscr{L}_V \supset -i\epsilon e Z'_\mu \sum_{l \in e,\mu,\tau} \bar{l}\gamma^\mu l$$



Water target

$L_{\rm tar} = 10$ m

$L_{\rm sh} = 10$ m

$L_{\rm dec} = 100$ m

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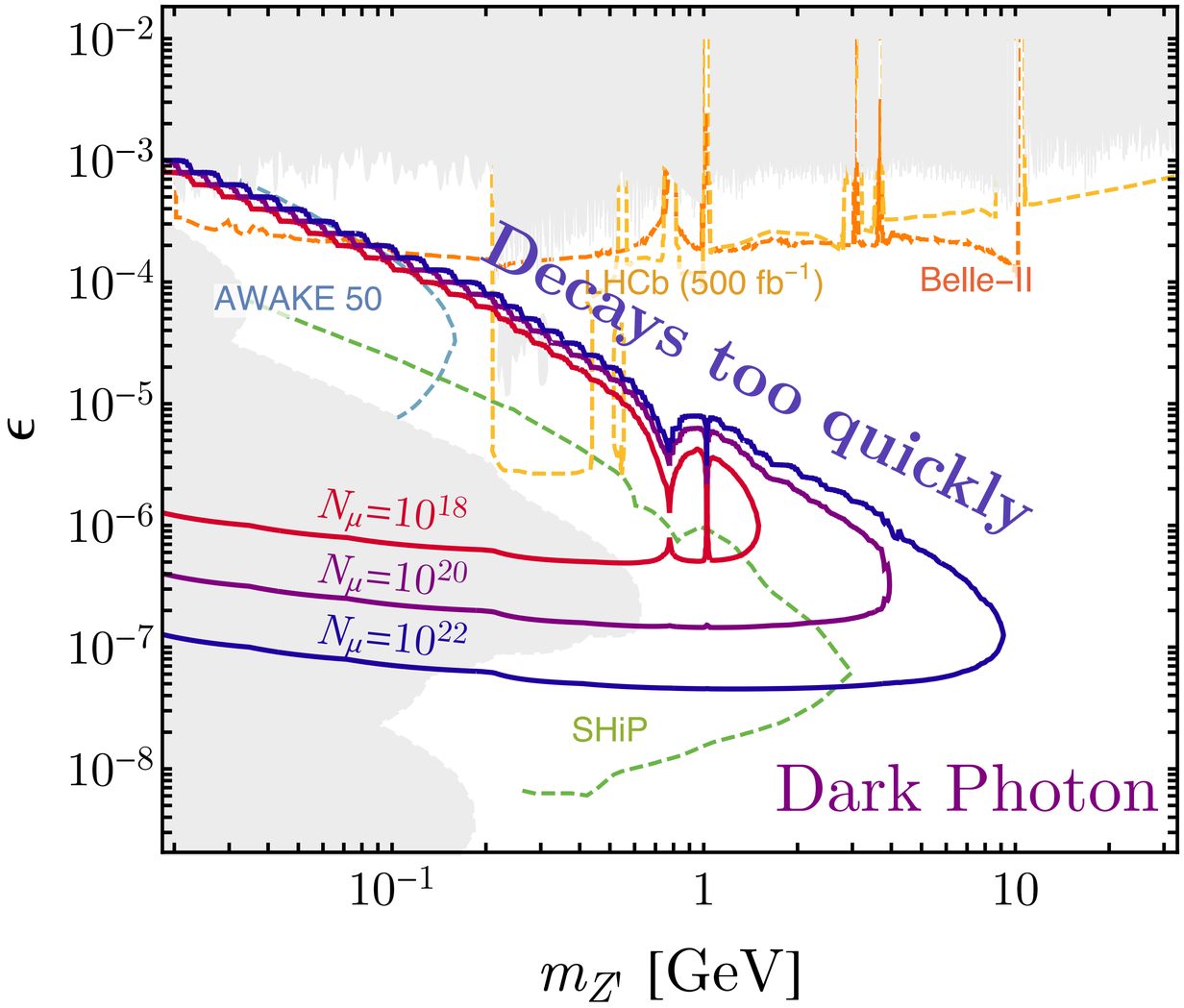

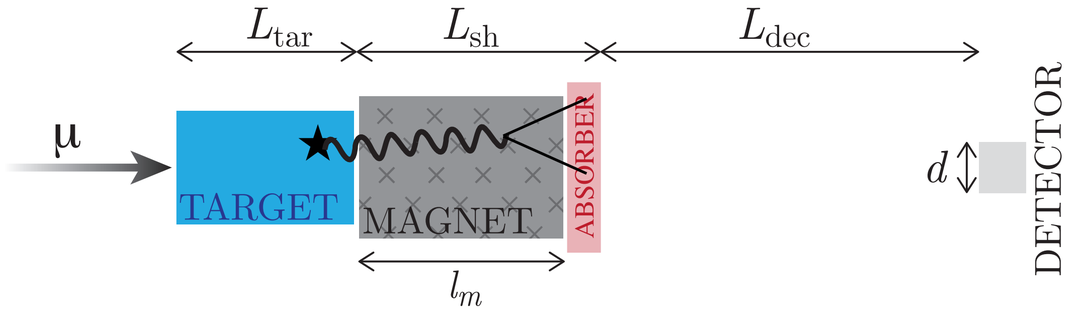

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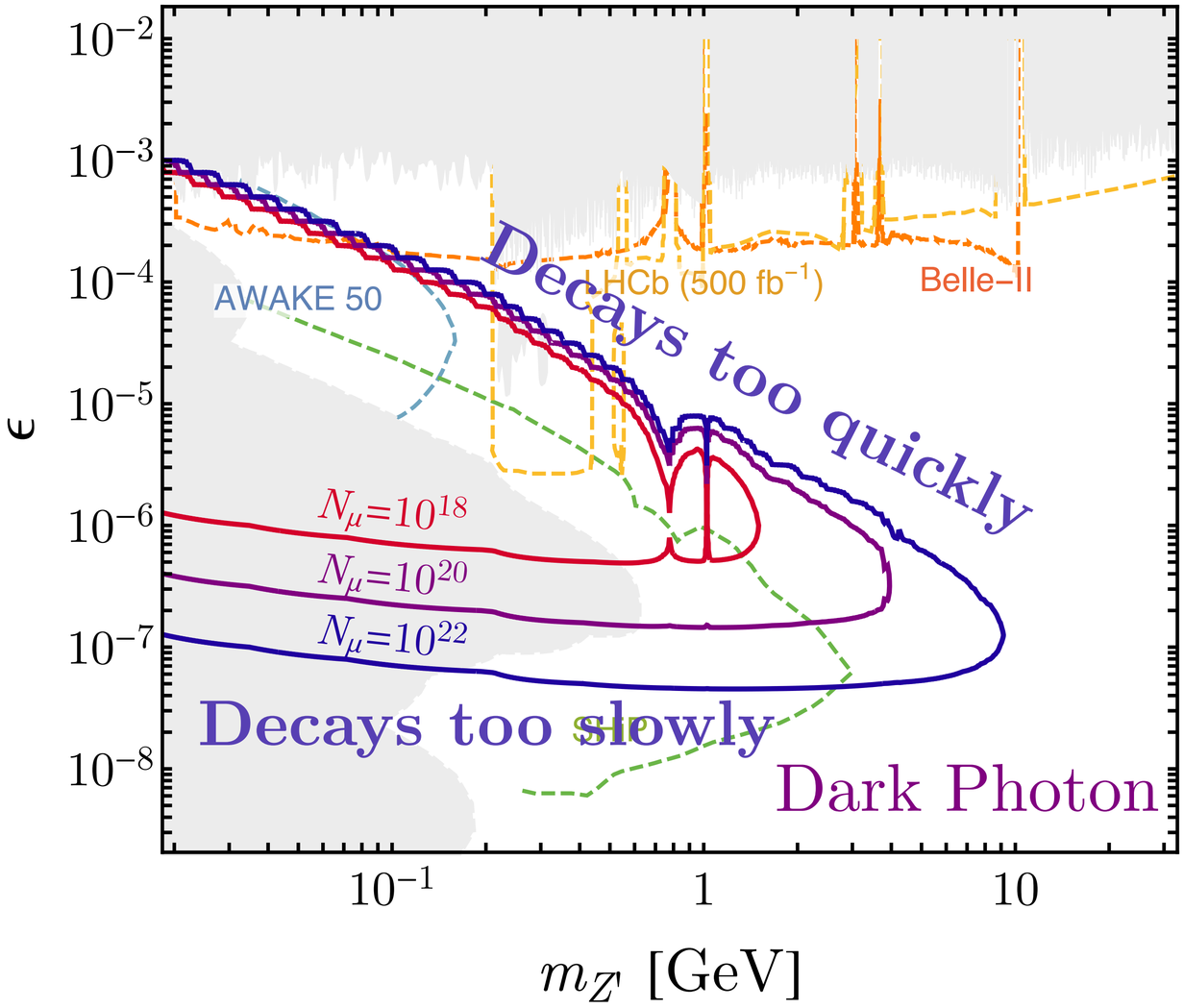

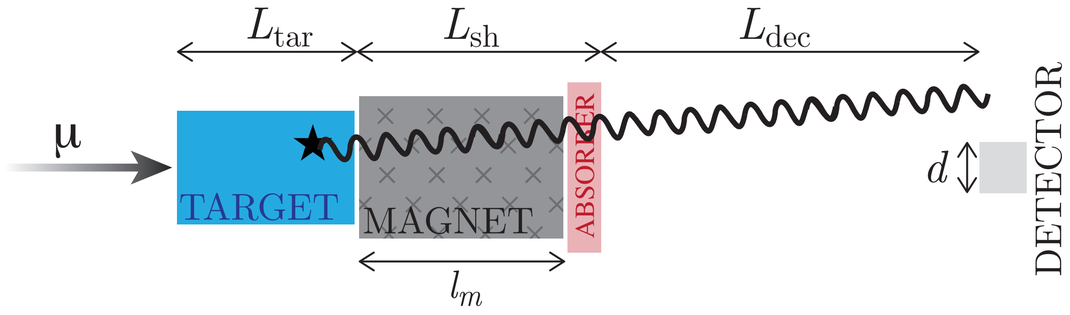

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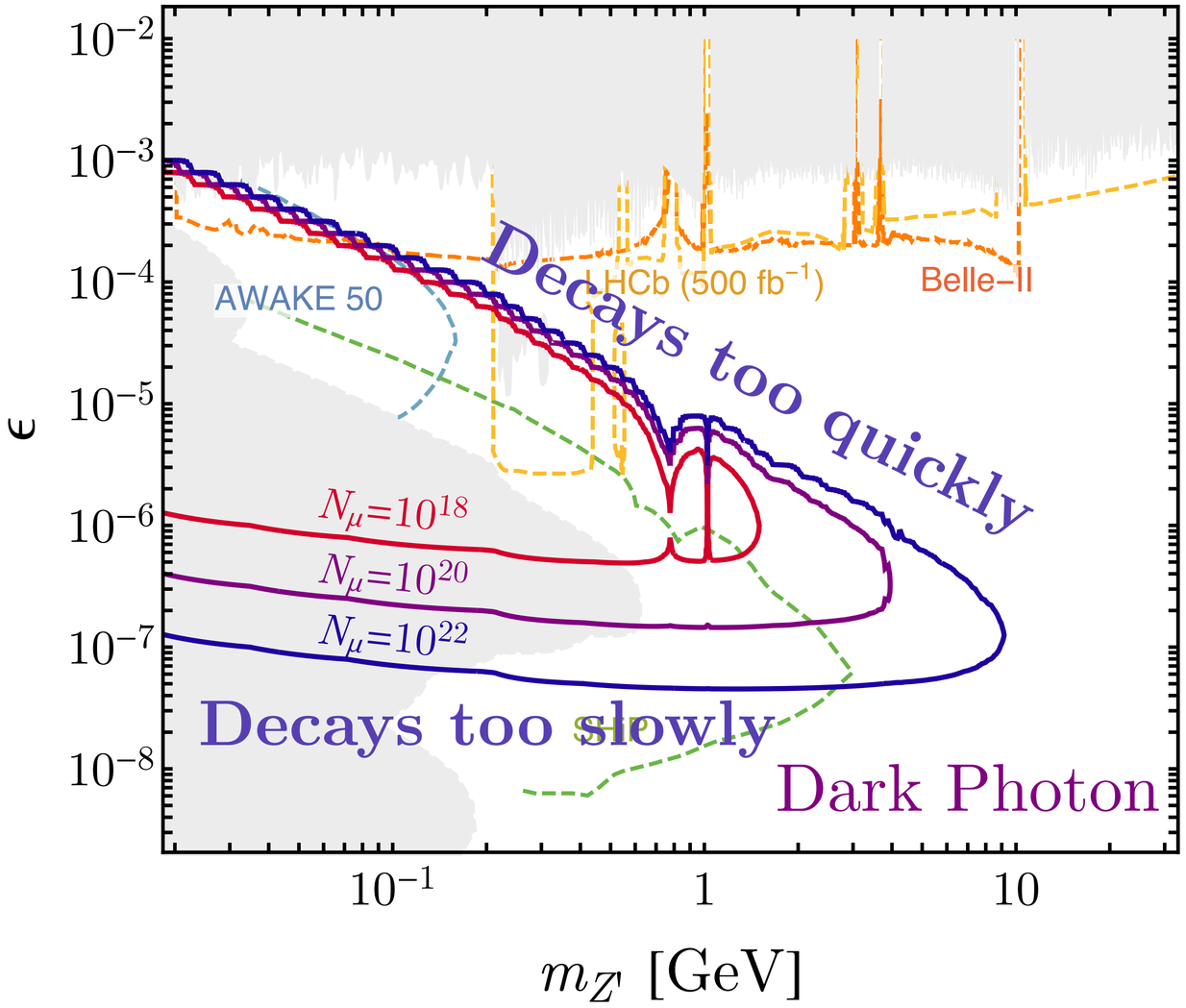

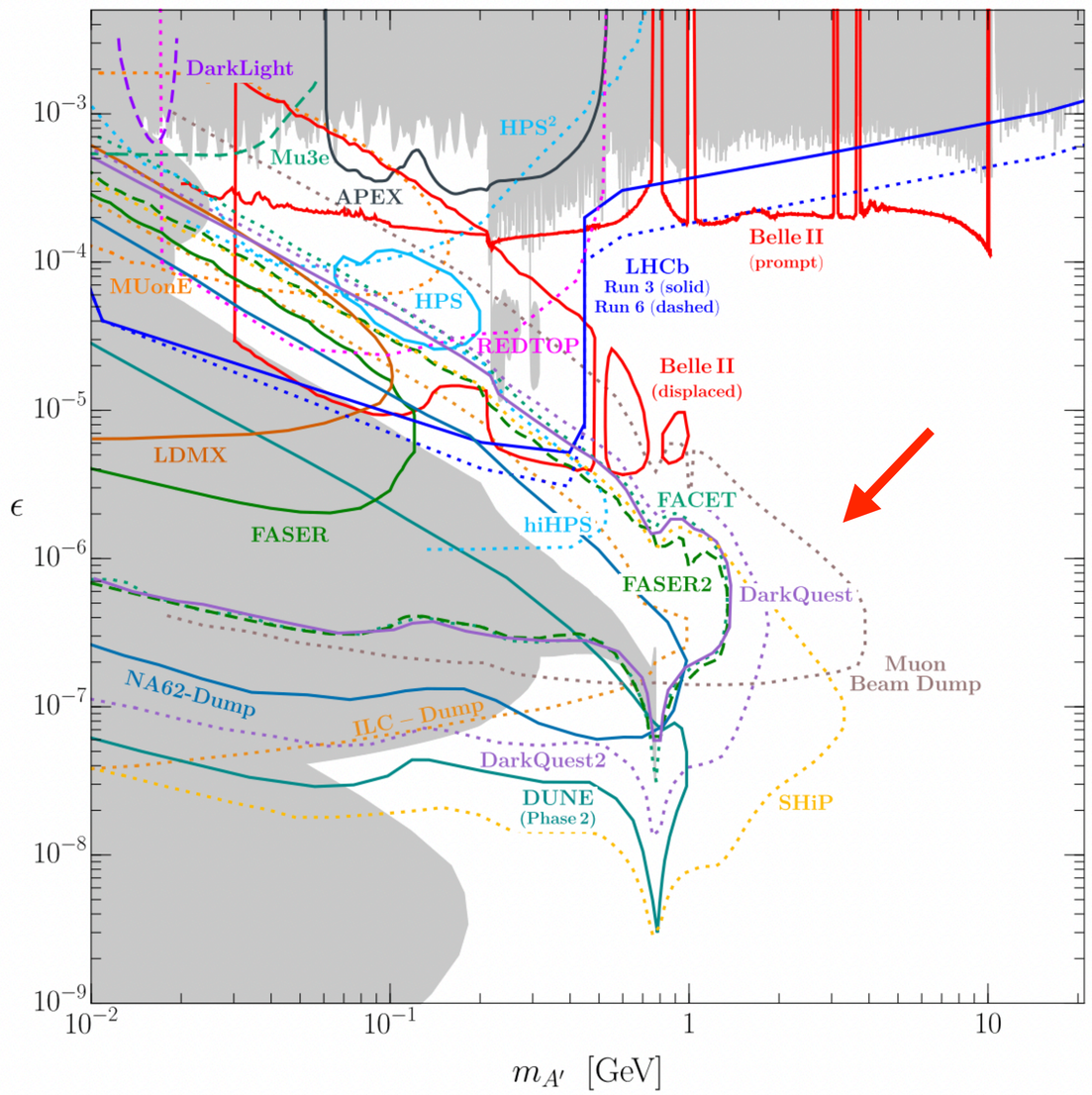

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$L_\mu - L_\tau$ Reach

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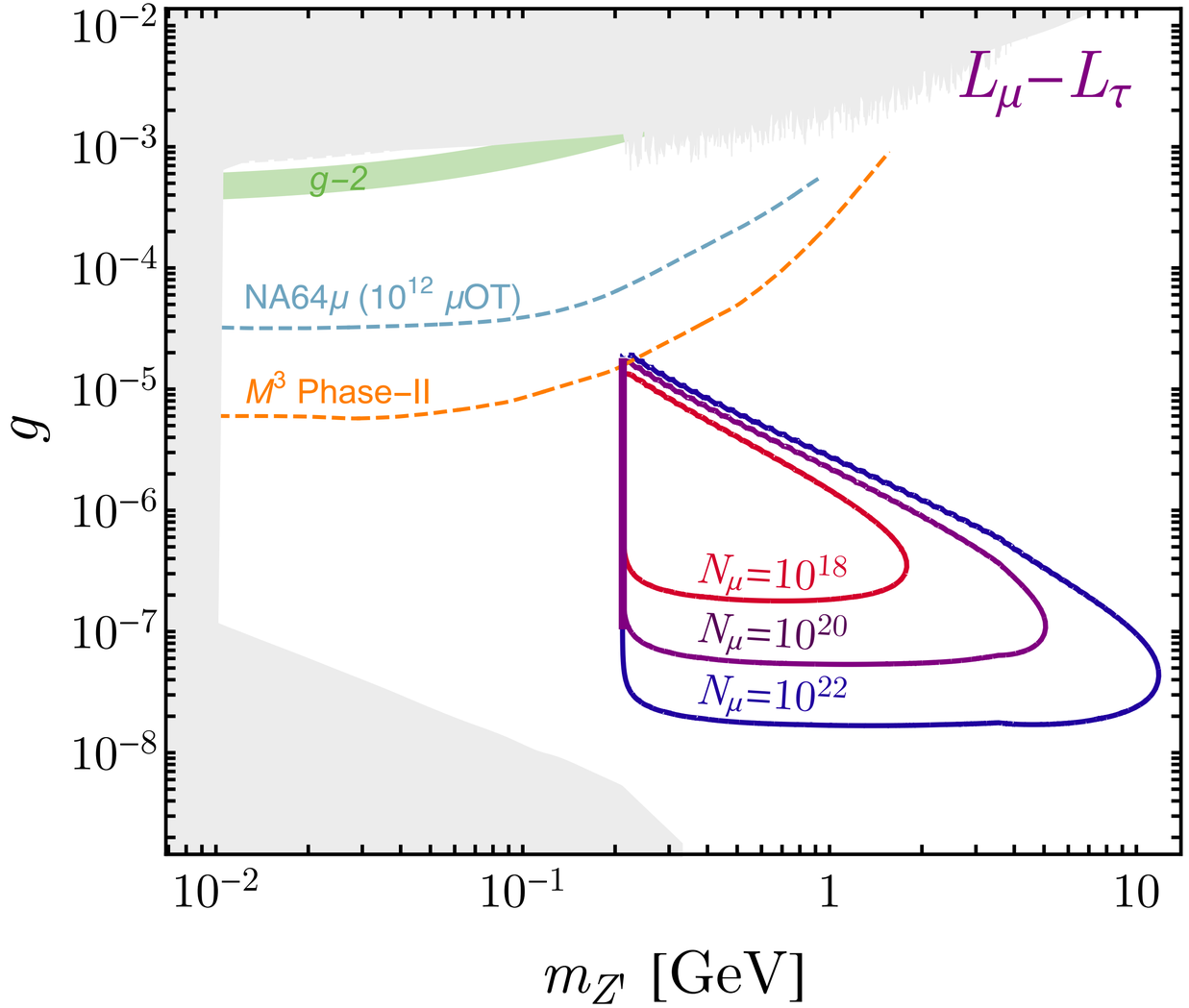

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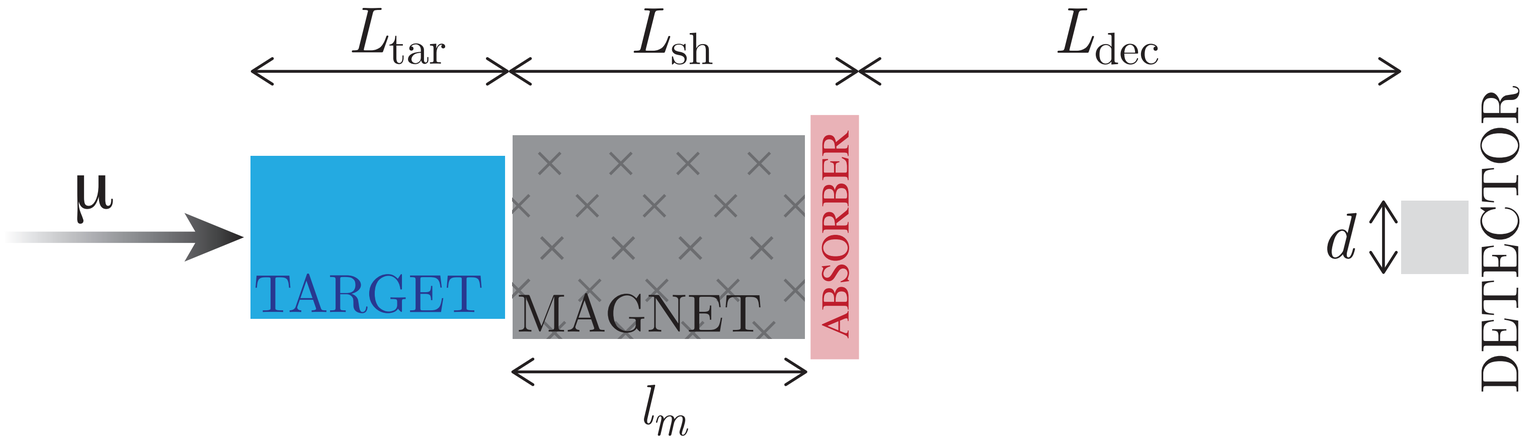
Beam Dump Outlook

Work in progress:



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Work in progress:

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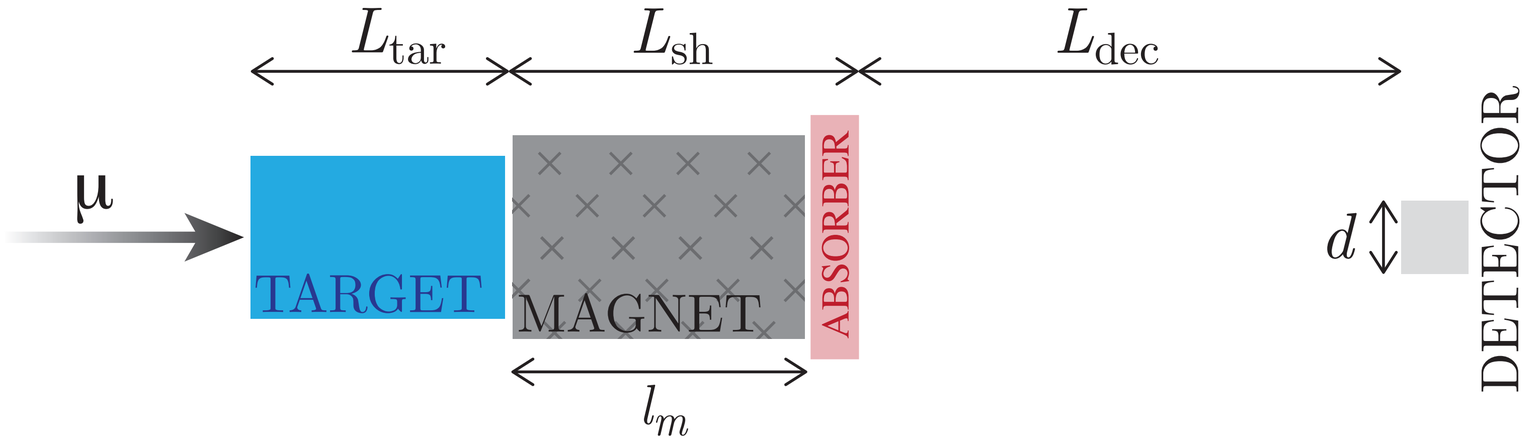
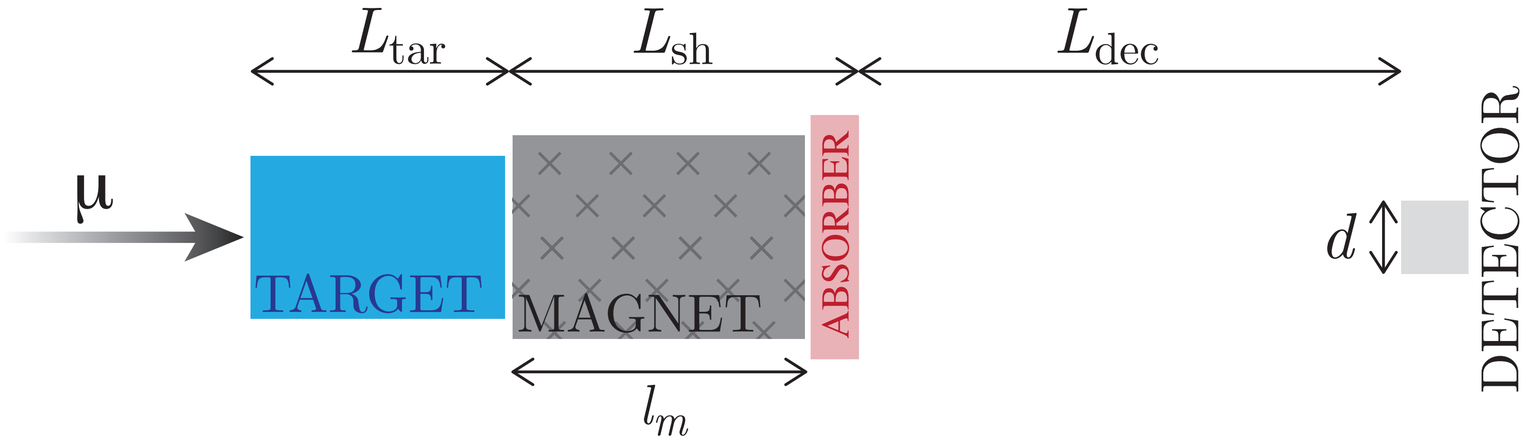


Beam Dump Outlook

Work in progress:

- More NP scenarios (scalars, ALPs...)
- Different $\sqrt{s}$: low (R&D) and high (10 TeV collider)



Summary

Future multi-TeV μC provide a complementary and robust physics program

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Progress can be made in studies along the way

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Backups

Muon Beam Dump (μBD)

Existing BD literature

At existing experiments

New Fixed-Target Experiments to Search for Dark Gauge Forces

James D. Bjorken,[1] Rouven Essig,[1] Philip Schuster,[1] and Natalia Toro[2]

At future experiments

Beam Dump Experiment at Future Electron-Positron Colliders

Shinya Kanemura[(a)], Takeo Moroi[(b)], Tomohiko Tanabe[(c)]

Leptophilic Gauge Bosons at ILC Beam Dump Experiment

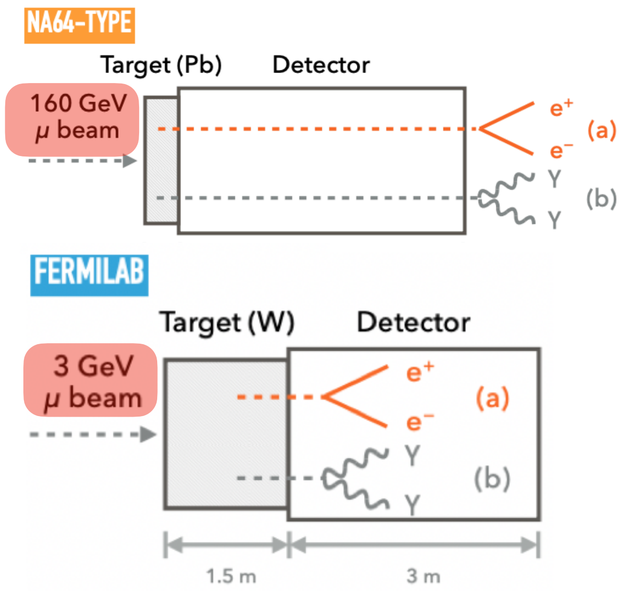
Kento Asai[(a,b)], Takeo Moroi[(a)] and Atsuya Niki[(a)]

With μ

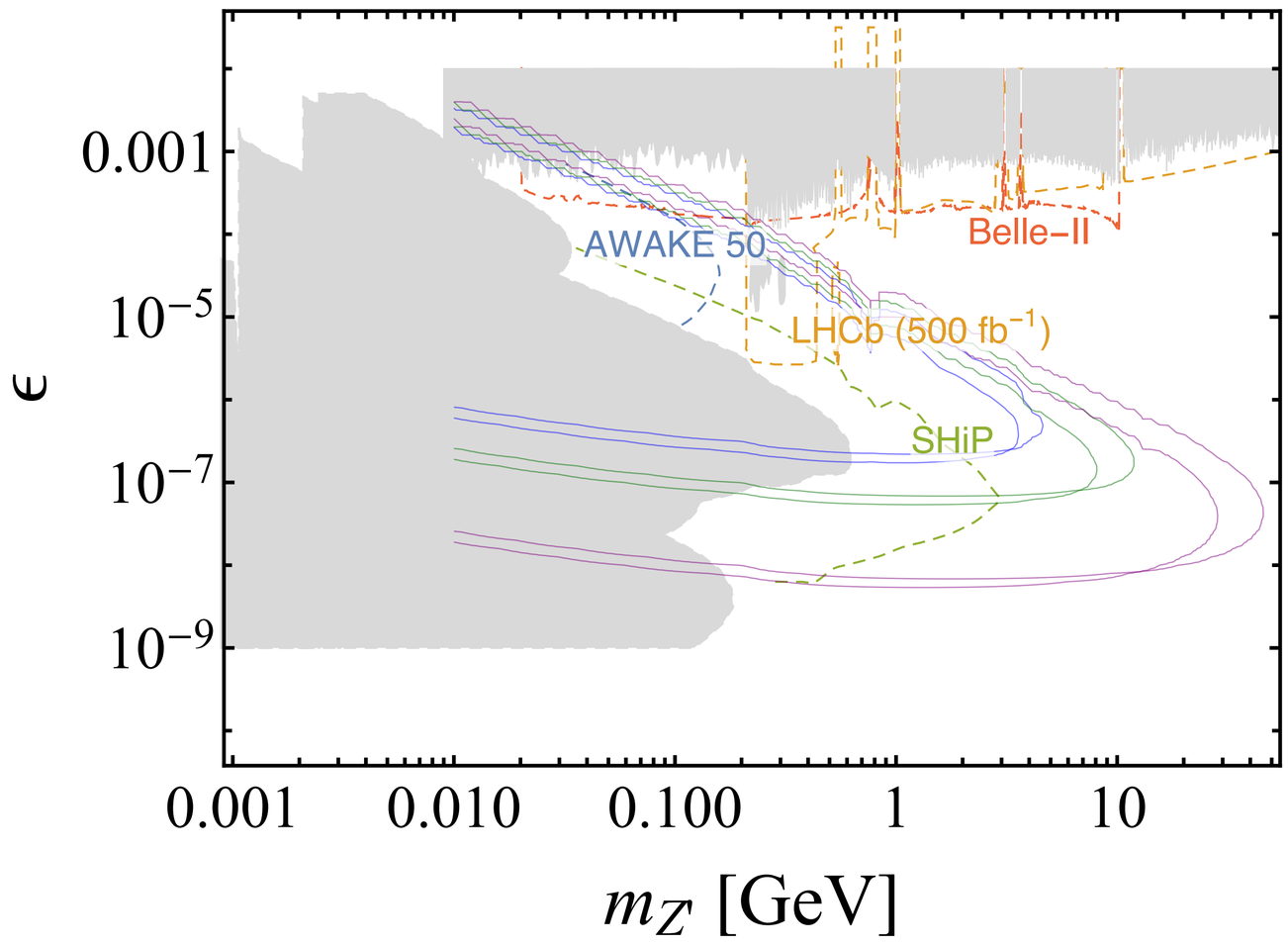
Muon Beam Experiments to Probe the Dark Sector

Chien-Yi Chen,[1,2,*] Maxim Pospelov,[1,2,†] and Yi-Ming Zhong[3,‡]

- 160 GeV, 3 GeV
- Light scalars



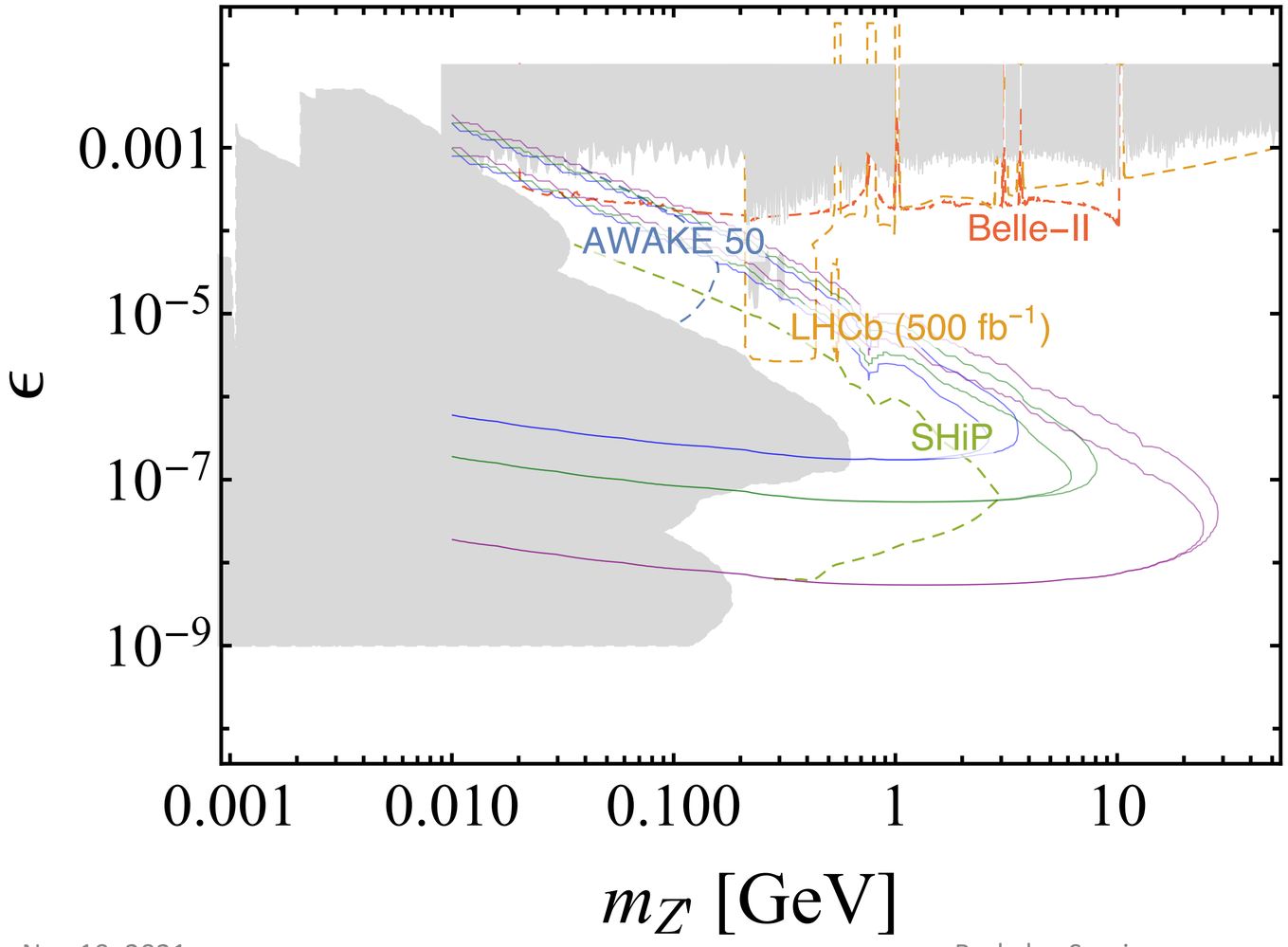
Dark Photon Projection



3 TeV → 10 TeV

Dark Photon Projection

1901.09966



L_{SH} = 10m – 50 m