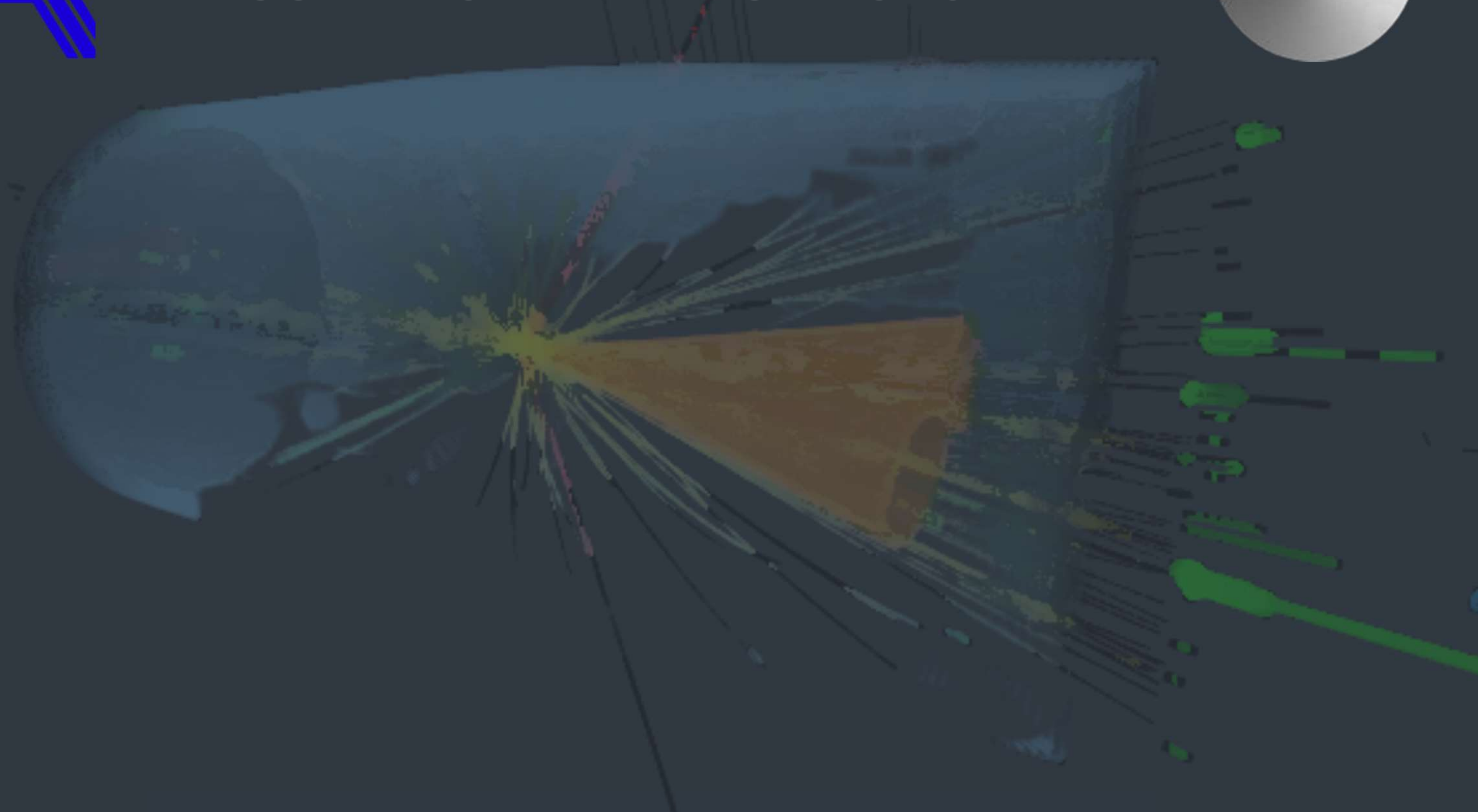
MILLICHARGED PARTICLES AT SUPER CHARM-TAU FACTORY



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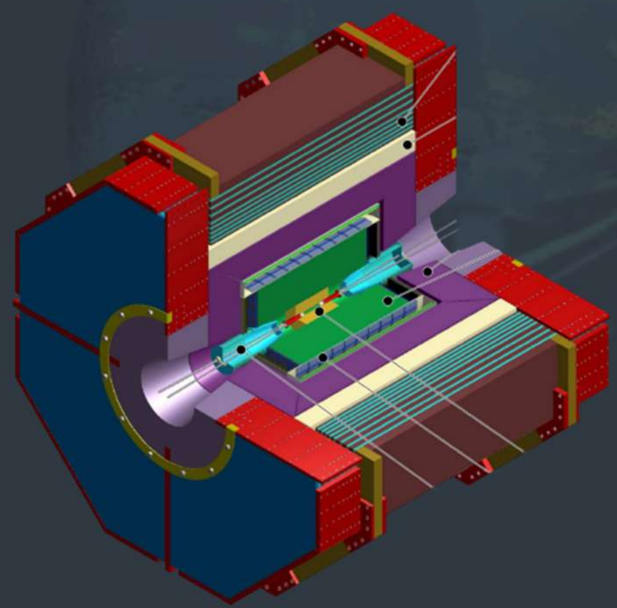
MILLICHARGED PARTICLES
Super Charm-Tau Factory

e^+e^- - collider



$\sqrt{s}, GeV$	L, fb^{-1}
3.097	300
3.554	50
3.686	150
3.770	300
4.110	100
4.650	100

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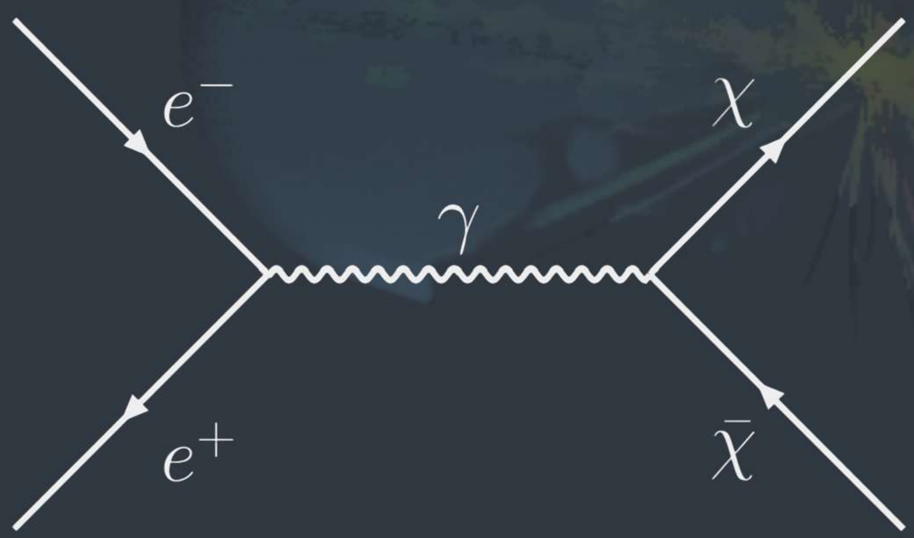
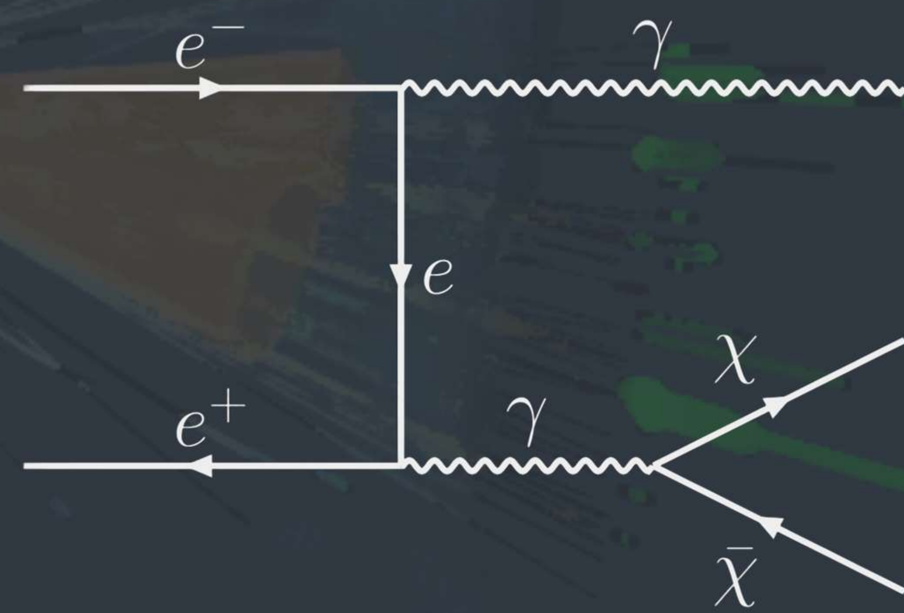
MILLICHARGED PARTICLES
Couplings

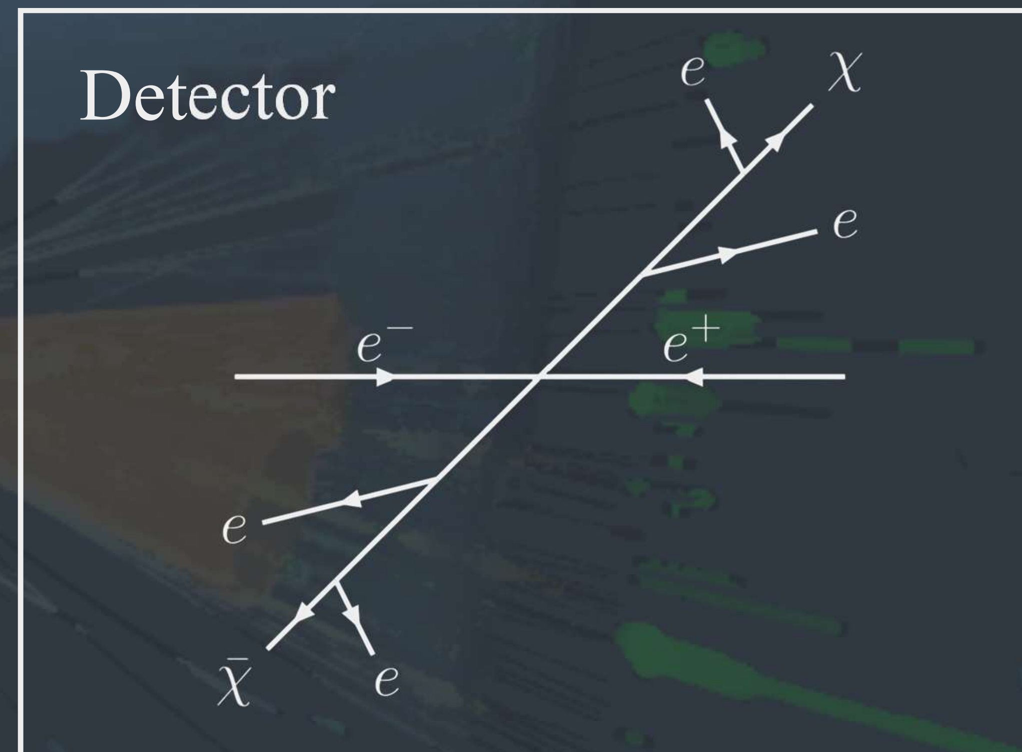
$$\mathcal{L} = \epsilon e \, A_\mu \bar{\chi} \gamma^\mu \chi \,, \qquad \epsilon = \frac{Q_\chi}{e}$$





MILLICHARGED PARTICLES
Signal for direct searches

Energy loss



δ-electrons

MILLICHARGED PARTICLES
Limits. Energy loss

$$\frac{dE}{dx} = \frac{\rho K}{2}\frac{Z}{A} \times \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{\beta^2}} \times ln\left(\frac{2m_e\beta^2 T_{max}}{I^2}\right) \Rightarrow \frac{dE}{dx} \approx 25\ eV/cm \times \left(\frac{\epsilon}{\epsilon_0} \times \frac{\beta_0}{\beta}\right)^2$$

$$\frac{dE}{dx} > 25\ eV/cm$$

$$\frac{\epsilon}{\beta} > 0.18$$

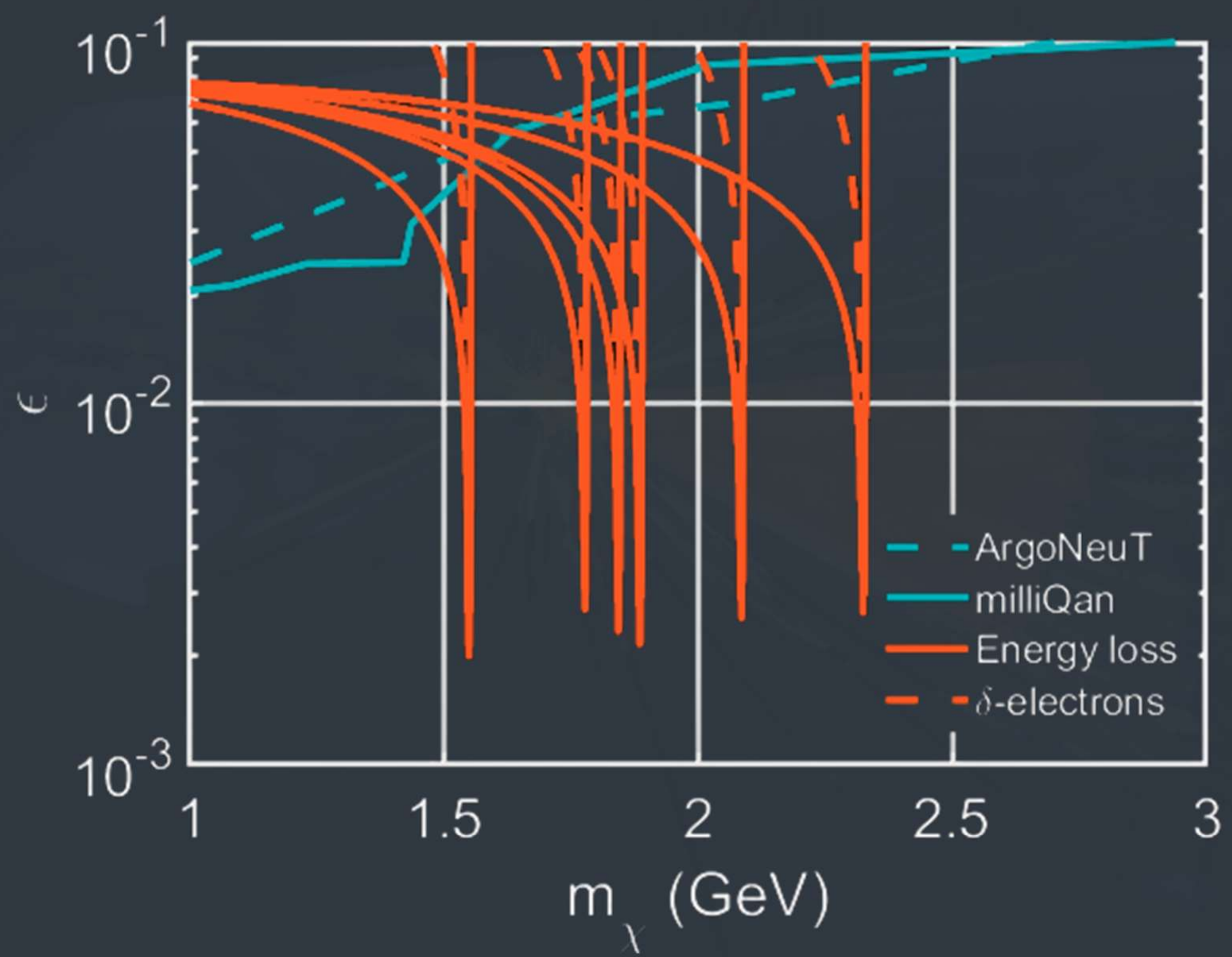
MILLICHARGED PARTICLES
Limits. δ-electrons

$$N_\delta = \frac{\rho K}{2}\frac{Z}{A} \times \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{\beta^2}} \times L\left(\frac{1}{T_{min}} - \frac{1}{T_e}\right) \Rightarrow N_\delta = 28.6\left(\frac{\epsilon}{\epsilon_0} \times \frac{\beta_0}{\beta}\right)^2 \times \left(1 - \frac{1\,keV}{E_\chi}\right)$$

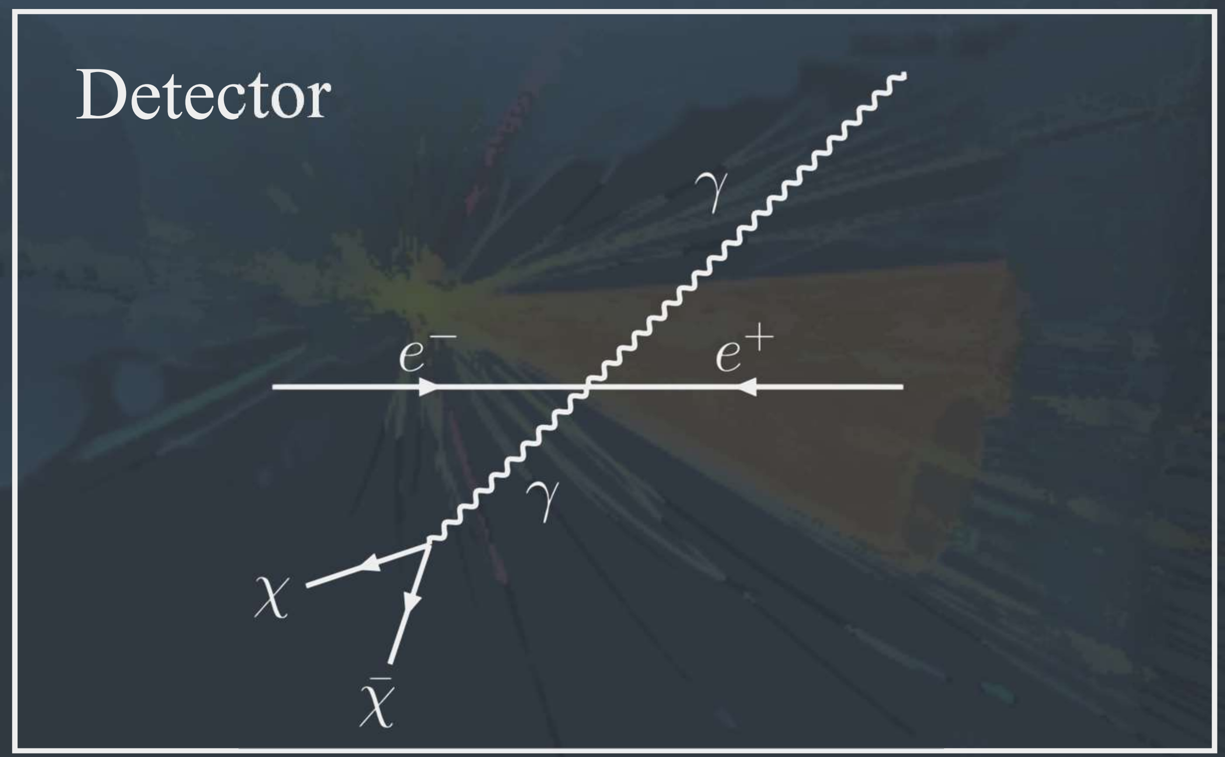
$$N_\delta > 2$$

$$\frac{\epsilon}{\beta} > 0.343 \times \left(1 - \frac{1\,keV}{E_\chi}\right)^{-1/2}$$

MILLICHARGED PARTICLES
Direct



MILLICHARGED PARTICLES
Signal with missing energy



MILLICHARGED PARTICLES
Background

Reducible

$e^+e^- \rightarrow \gamma \; e^+e^- \; (\mu^+\mu^-, \gamma\gamma)$

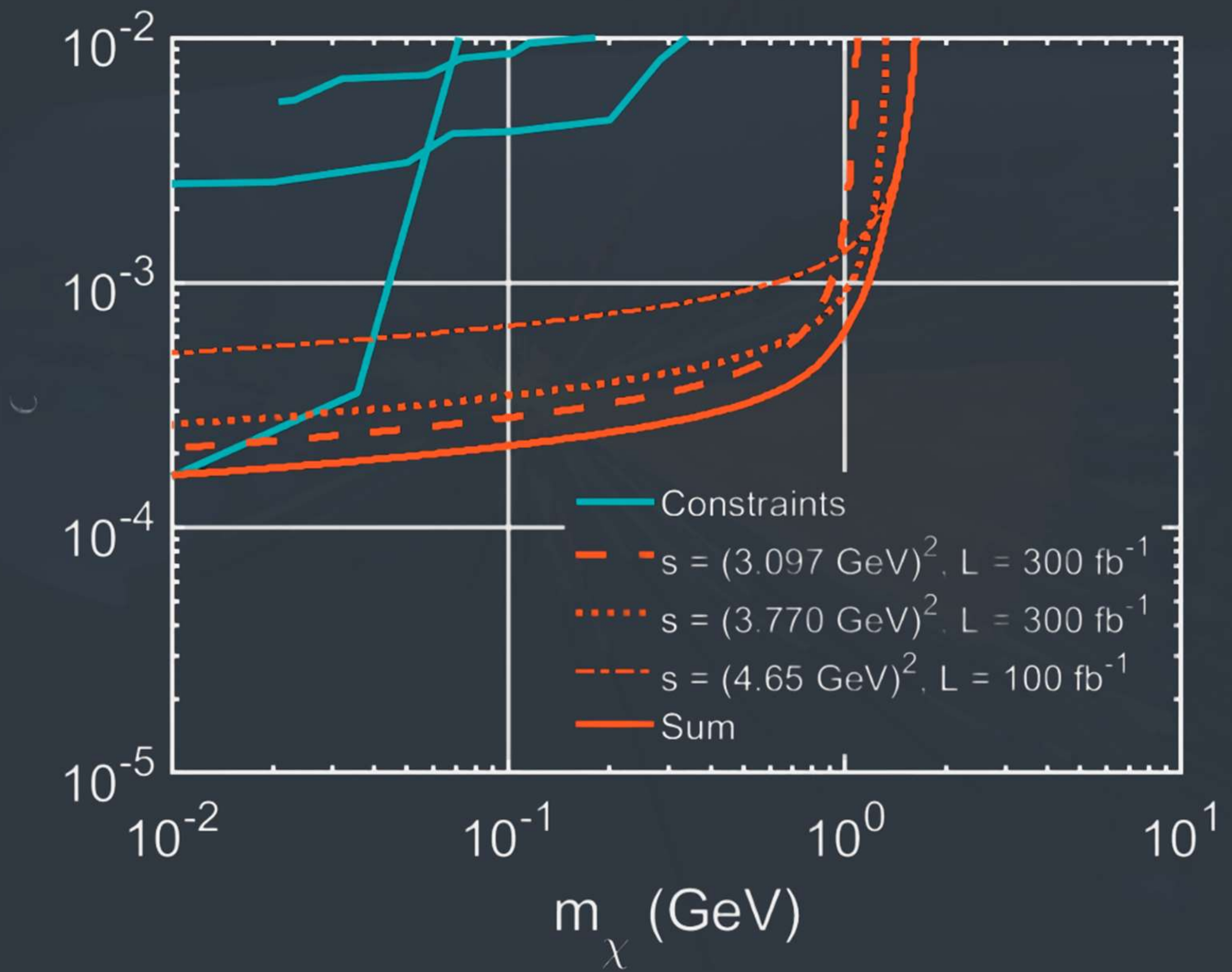
$E_\gamma > E_{\gamma min}(cos\theta_\gamma)$

Irreducible

$e^+e^- \rightarrow \gamma\nu\nu$

e^- - beam polarization

MILLICHARGED PARTICLES
Invisible



MILLICHARGED PARTICLES
Ways to increase sensitivity

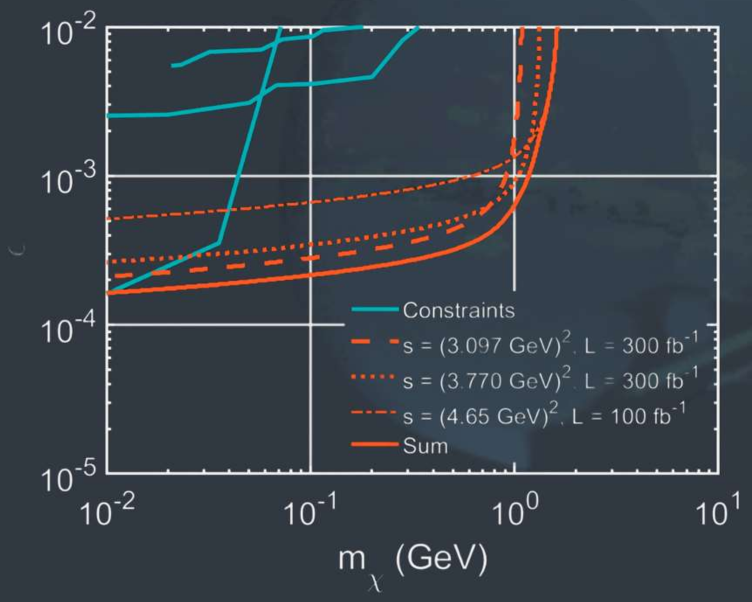
- Greater luminosity
  For direct detection energy limits remain. For invisible signal we also get larger background but we can apply additional cuts to reduce it

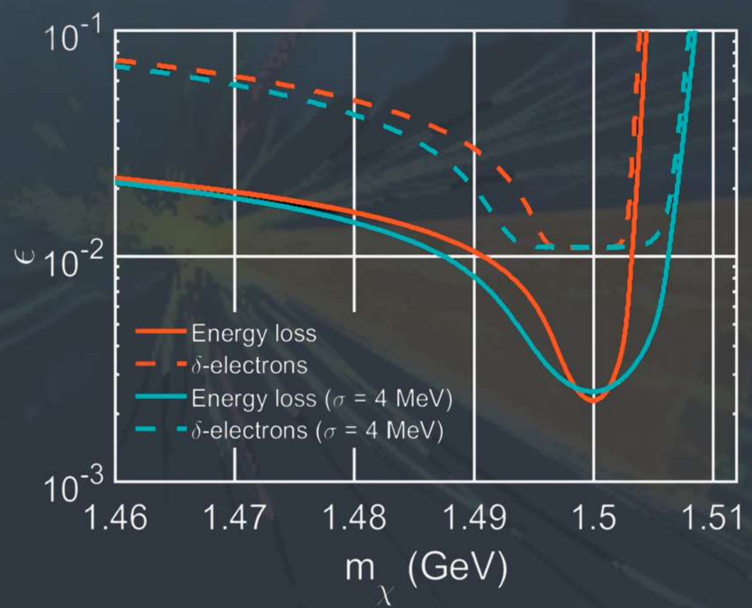
- Monochromatic beam
  More particles with small β but suppressed production, $\sigma \propto \epsilon^2 \beta$

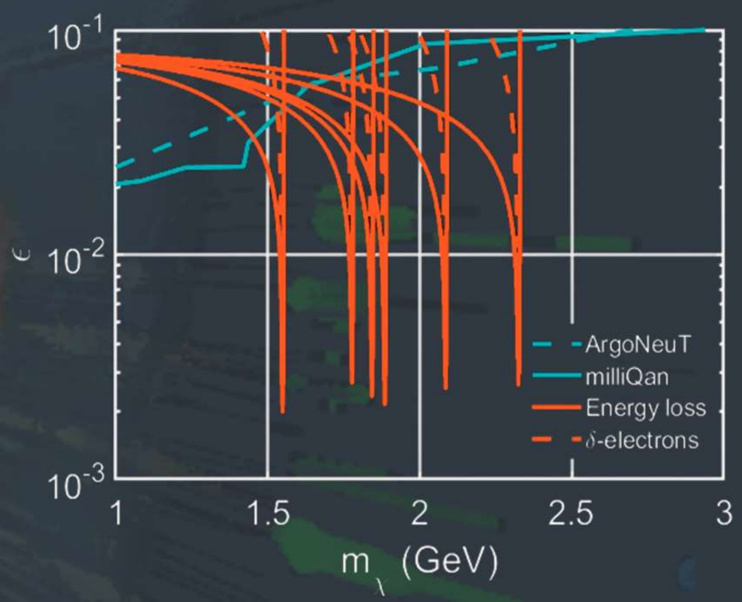
- Other gases
  To weaken the limits on ϵ/β but it alters the zero background condition

- Mass scan
  Better sensitivity to masses of χ, but worse to ϵ

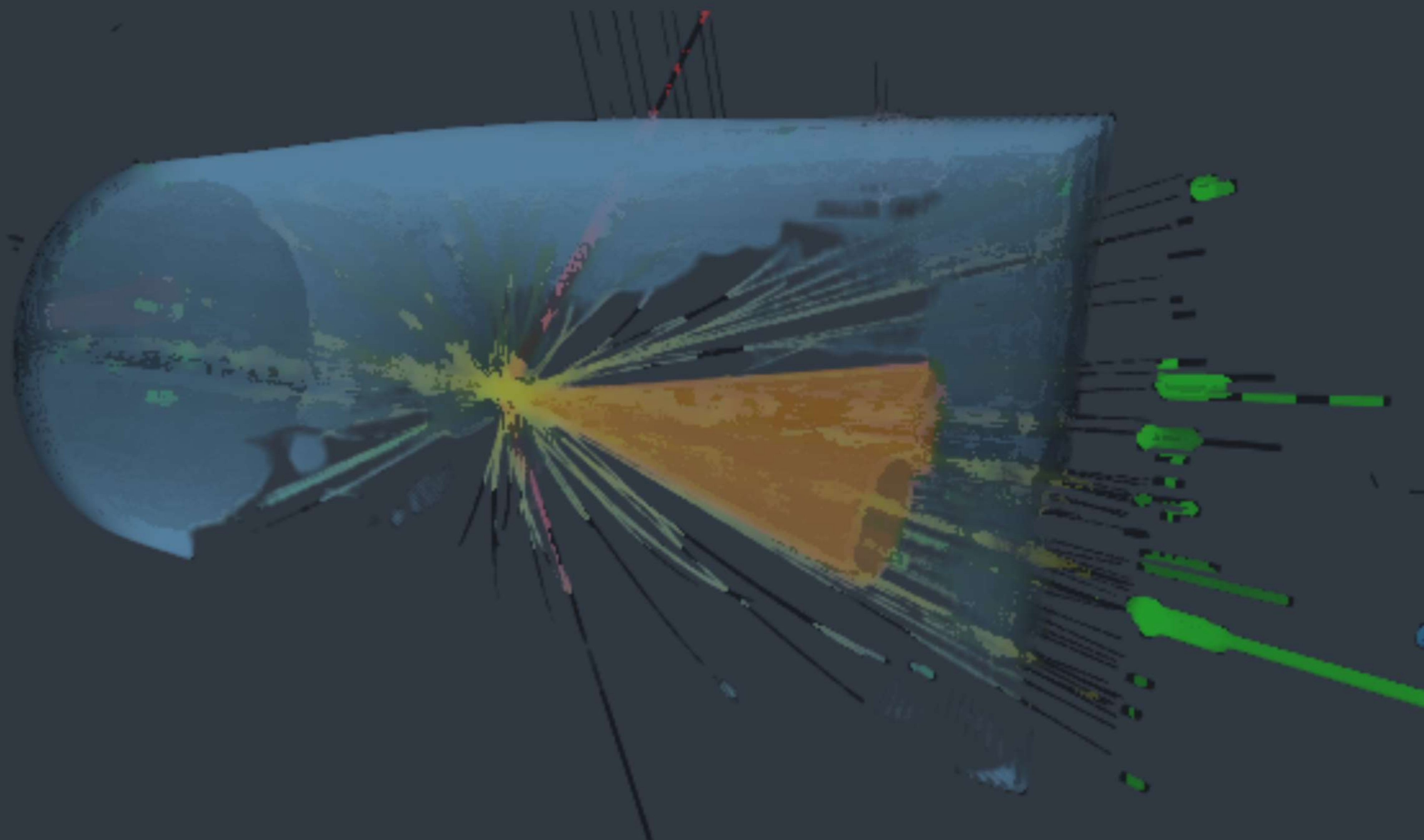
MILLICHARGED PARTICLES
Ways to increase sensitivity







MILLICHARGED PARTICLES



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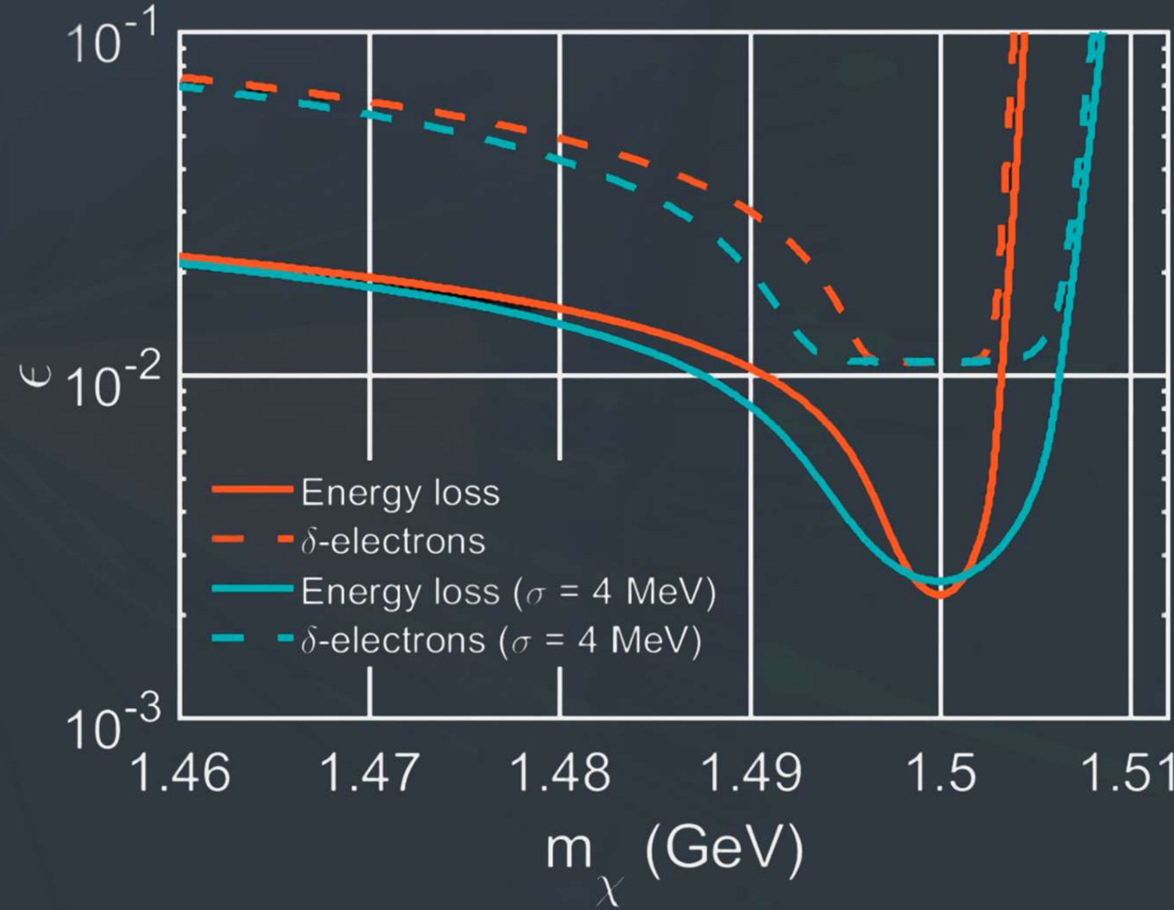
MILLICHARGED PARTICLES
Non-monochromatic energy

$$\frac{\mathrm{d}L}{d\sqrt{s}} = \frac{L_0}{\sqrt{2\pi}\sigma} \times exp\left(-\frac{\left(\sqrt{s}-\sqrt{s_0}\right)^2}{2\sigma^2}\right)$$

$$\sigma = \sqrt{2} \times 0.01\% \ \frac{\sqrt{s}}{2}$$

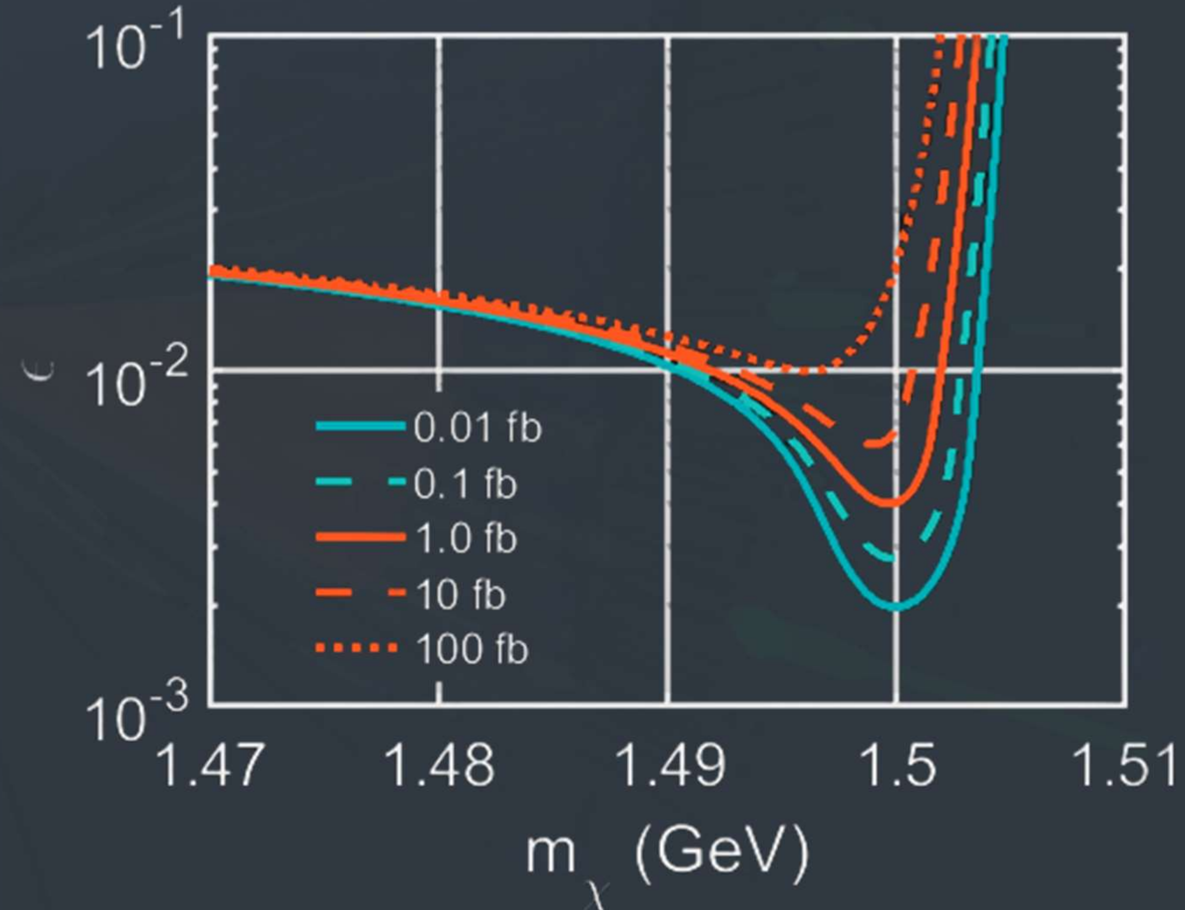
$$\sigma(e^+e^- \to \chi\bar{\chi}) \propto \varepsilon^2\beta$$



MILLICHARGED PARTICLES
Cross-section

$$\sigma = \frac{4\pi\alpha^2\epsilon^2}{3s}\sqrt{1-\frac{4m_\chi^2}{s}}\left(1+\frac{2m_\chi^2}{s}\right)$$

$$\sigma = \frac{2\pi\alpha^2\epsilon^2\beta}{s}, \qquad \beta \ll 1$$



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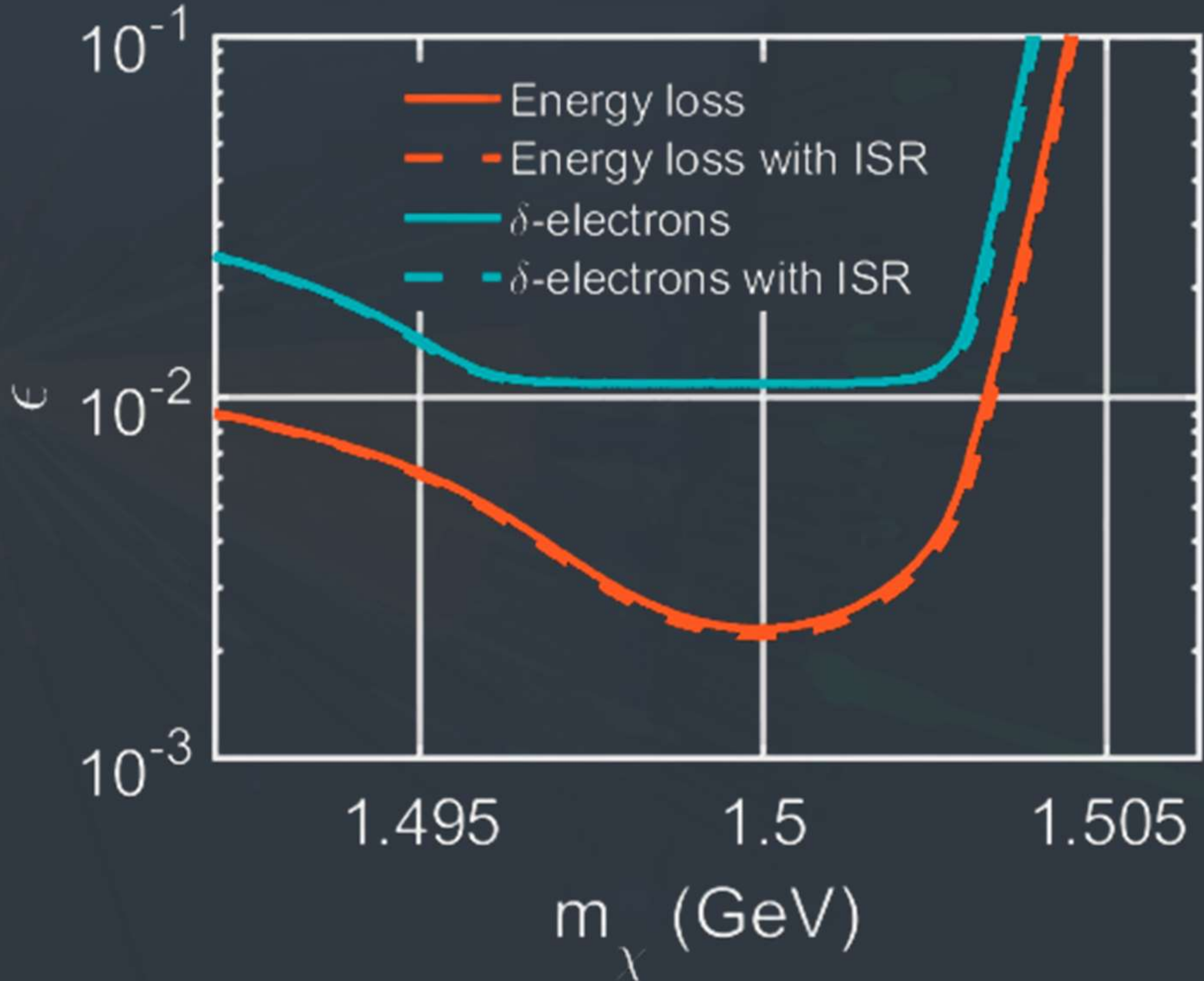
MILLICHARGED PARTICLES
Initial State Radiation

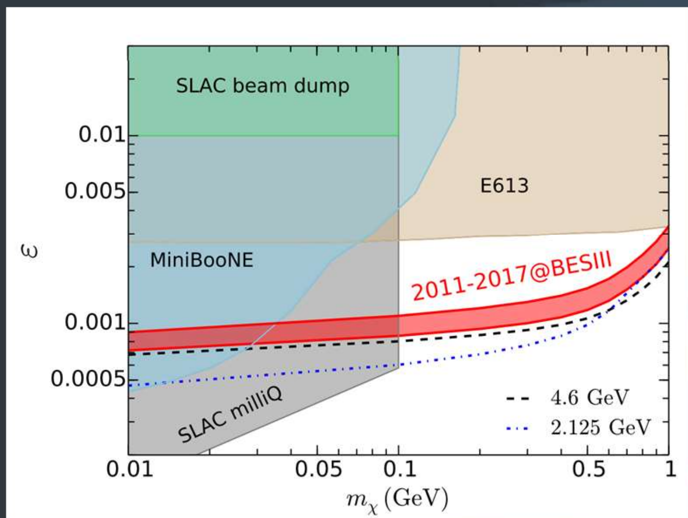
$$\sigma_{corr} = \int_0^{x_{max}} \sigma\big((1-x)s\big)\, H(x,s)$$

$$E_\gamma < 25\ MeV$$

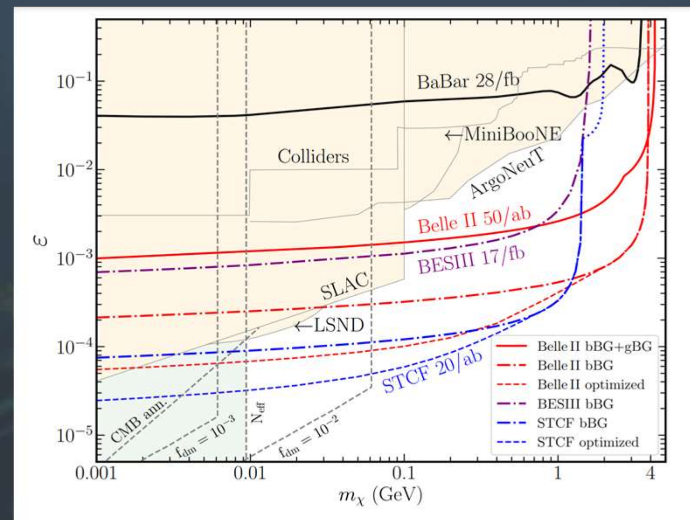
O. Nicrosini, Luca Trentadue.
Phys.Lett.B 196 (1987), 551



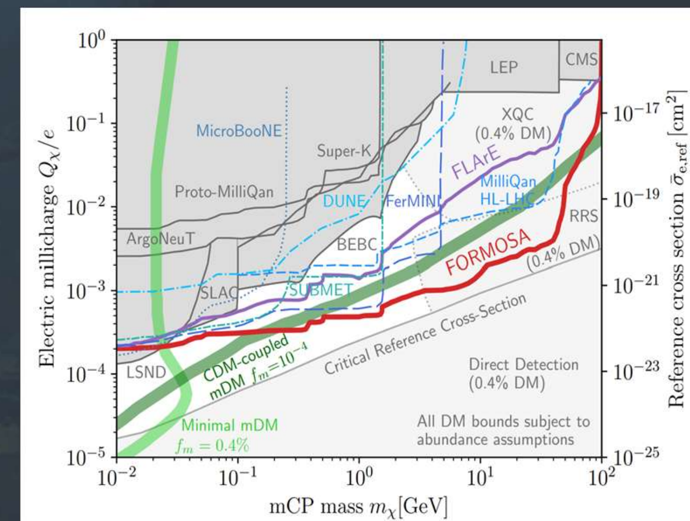
MILLICHARGED PARTICLES
Other studies



Zuowei Liu, Yu Zhang. Probing millicharge at BESIII. Phys. Rev. D 99, 015004 (2019) [1808.00983]



Jinhan Liang, Zuowei Liu, Yue Ma, Yu Zhang. Millicharged particles at electron colliders. Phys. Rev. D 102, 015002 (2020) [1909.06847]



Jonathan L. Feng et al. The Forward Physics Facility at the High-Luminosity LHC. Contribution to Snowmass 2021 [2203.05090]

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