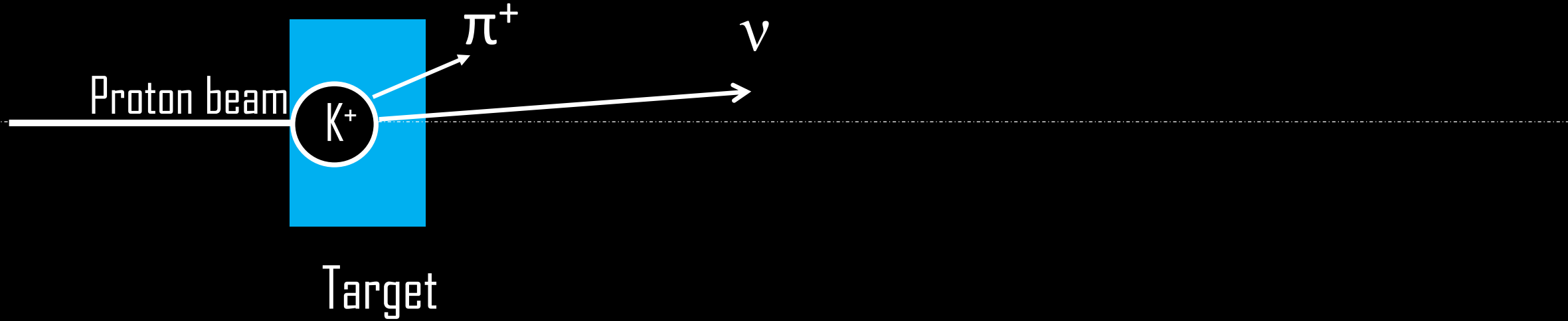




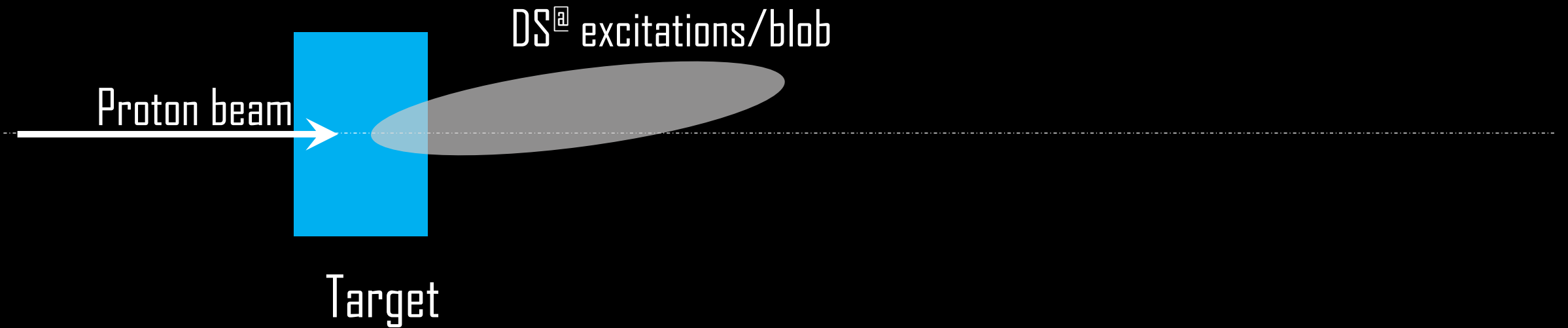
A model independent probe for dark sectors at neutrino experiments

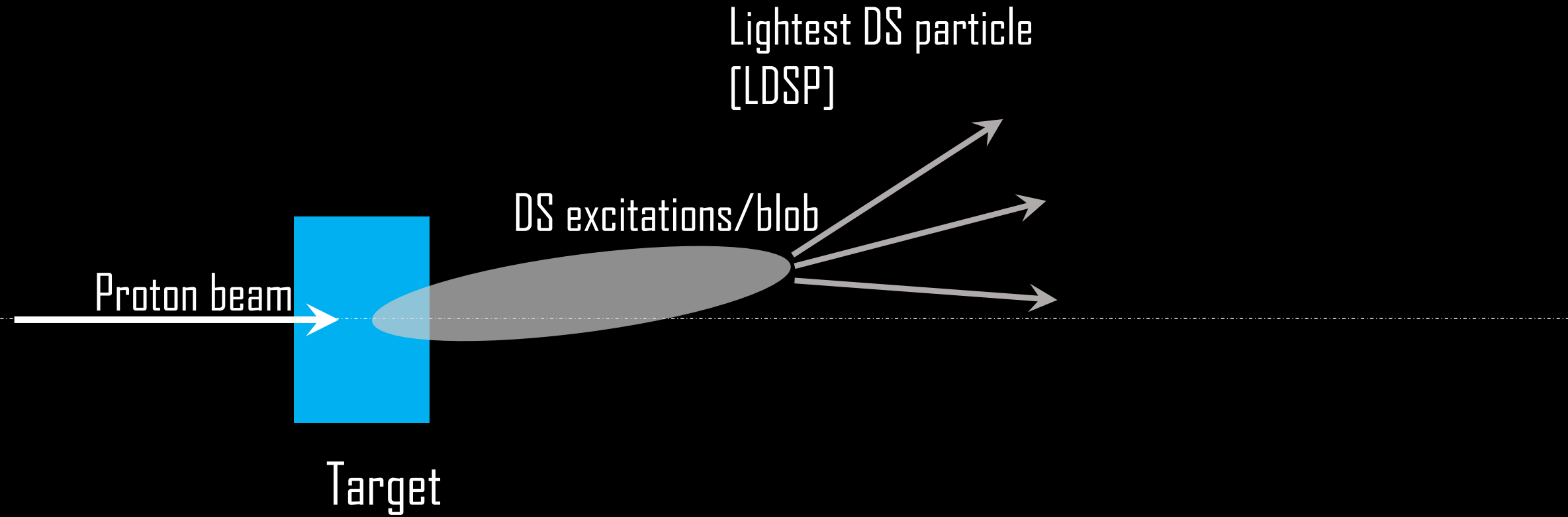


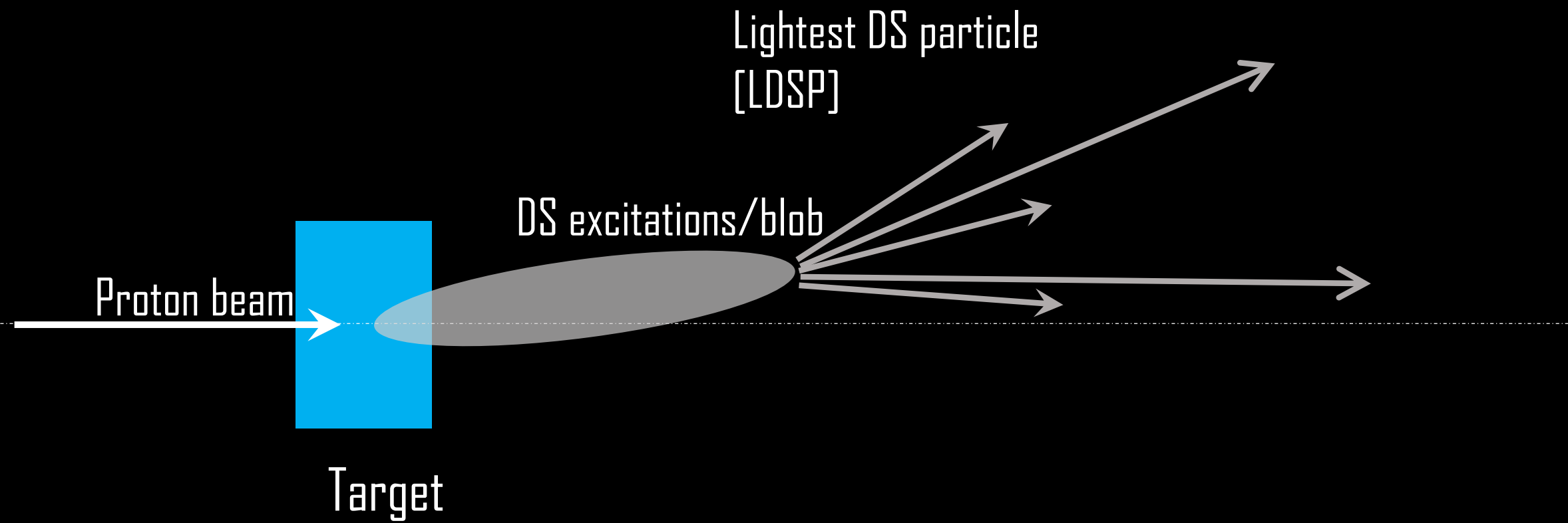
$$K \rightarrow \pi + \text{DS}$$

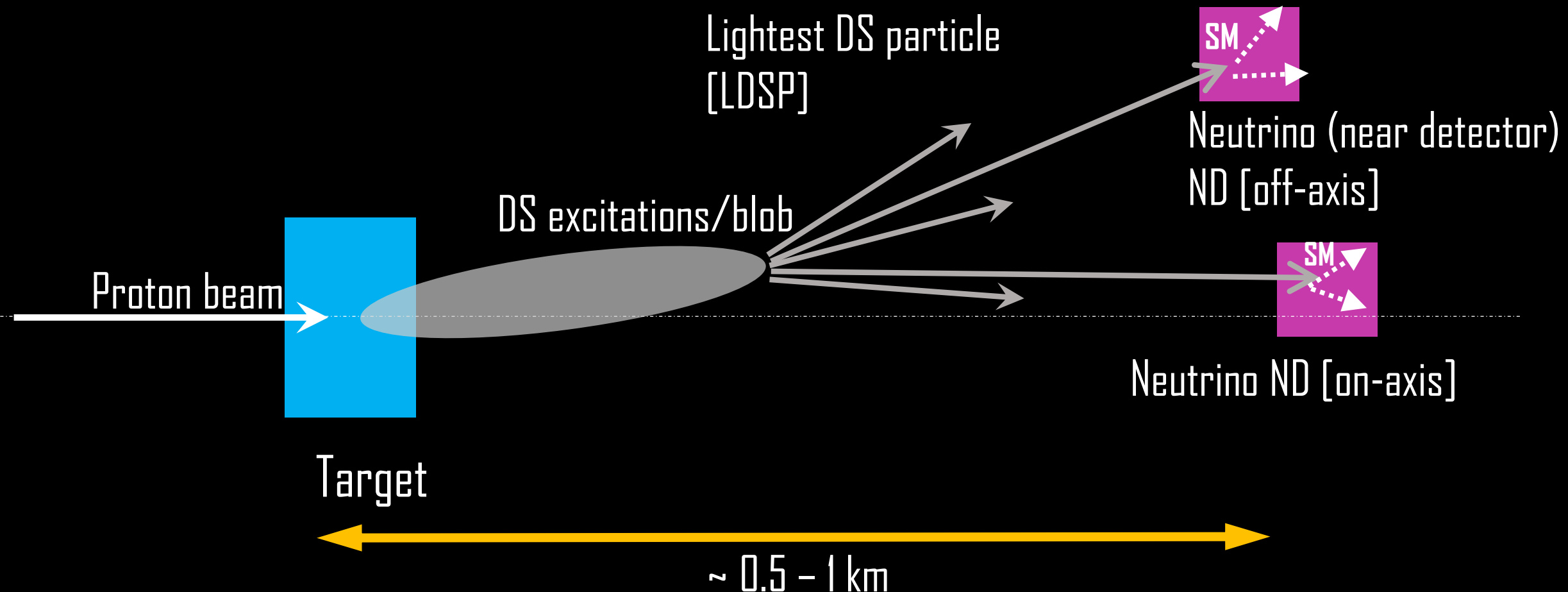
$$\text{partons} \rightarrow \text{DS}$$

$$p + p \rightarrow \text{DS [ISR]} + X$$

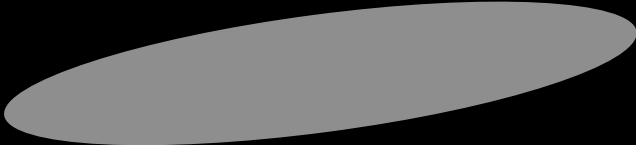




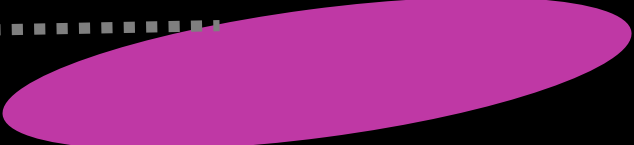




Dark Sector

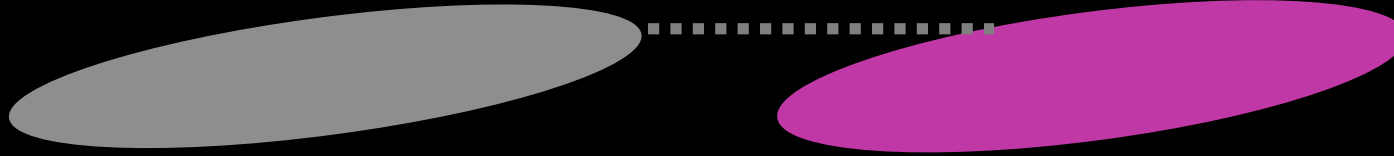


Standard Model



Dark Sector

Standard Model



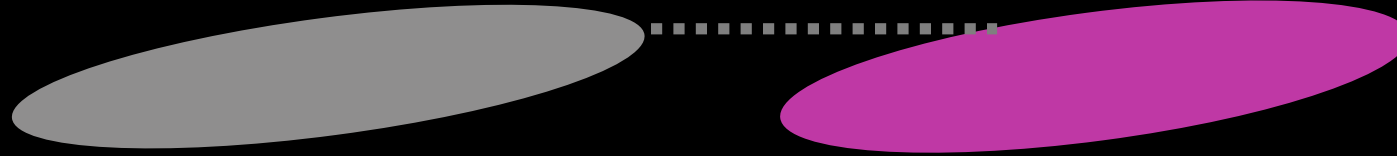
$$\mathcal{L}_{\text{portal}} = \mathcal{O}_{DS} \mathcal{O}_{SM}$$

Dark sector
Singlet operator

SM Singlet operator

Dark Sector

Standard Model



$$L_{\text{portal}} = \frac{\kappa}{\Lambda_{\text{UV}}^{D-4}} \mathcal{O}_{\text{DS}} \mathcal{O}_{\text{SM}}$$

Very elusive DS!

$$\text{dim} = [\mathcal{O}_{\text{SM}}] + [\mathcal{O}_{\text{DS}}] > 4$$

Irrelevant Portals

[Contino, Max, Mishra '20],
[Darme, Ellis, You '20]...



**A model
independent
probe for dark
sectors at
neutrino
experiments**

SCUOLA
NORMALE
SUPERIORE



Sonali Verma
EuCAPT
24 May 2022



Work in progress
with Marco Costa,
Rashmish K. Mishra.



Istituto Nazionale di Fisica Nucleare

Minimal Assumptions?

Contino, Max, Mishra JHEP 06 (2021) 127



Minimal Assumptions?



Let's us be model independent!

Model Independence?



Inclusive cross section
for DS production

$$\sigma \propto \sum_n \int d\Phi_{\text{DS}} |\langle 0 | \mathcal{O}_{\text{DS}} | n \rangle|^2 = 2 \text{Im}[i \langle 0 | \mathcal{O}_{\text{DS}} \mathcal{O}_{\text{DS}} | 0 \rangle]$$

Model Independence?



Inclusive cross section
for DS production

DS phase space

$$\sigma \propto \sum_n \int d\Phi_{\text{DS}} |\langle 0 | \mathcal{O}_{\text{DS}} | n \rangle|^2 = 2 \text{Im}[i \langle 0 | \mathcal{O}_{\text{DS}} \mathcal{O}_{\text{DS}} | 0 \rangle]$$

Model Independence?



Inclusive cross section
for DS production

DS operator interpolating DS
state $|n\rangle$ from vacuum

$$\sigma \propto \sum_n \int d\Phi_{\text{DS}} |\langle 0 | \mathcal{O}_{\text{DS}} | n \rangle|^2 = 2 \text{Im}[i \langle 0 | \mathcal{O}_{\text{DS}} \mathcal{O}_{\text{DS}} | 0 \rangle]$$

Model Independence?



Inclusive cross section
for DS production

From conformal invariance

$$\sigma \propto \sum_n \int d\Phi_{\text{DS}} |\langle 0 | \mathcal{O}_{\text{DS}} | n \rangle|^2 = 2 \operatorname{Im} [i \langle 0 | \mathcal{O}_{\text{DS}} \mathcal{O}_{\text{DS}} | 0 \rangle]$$

Optical Theorem

Model Independence?

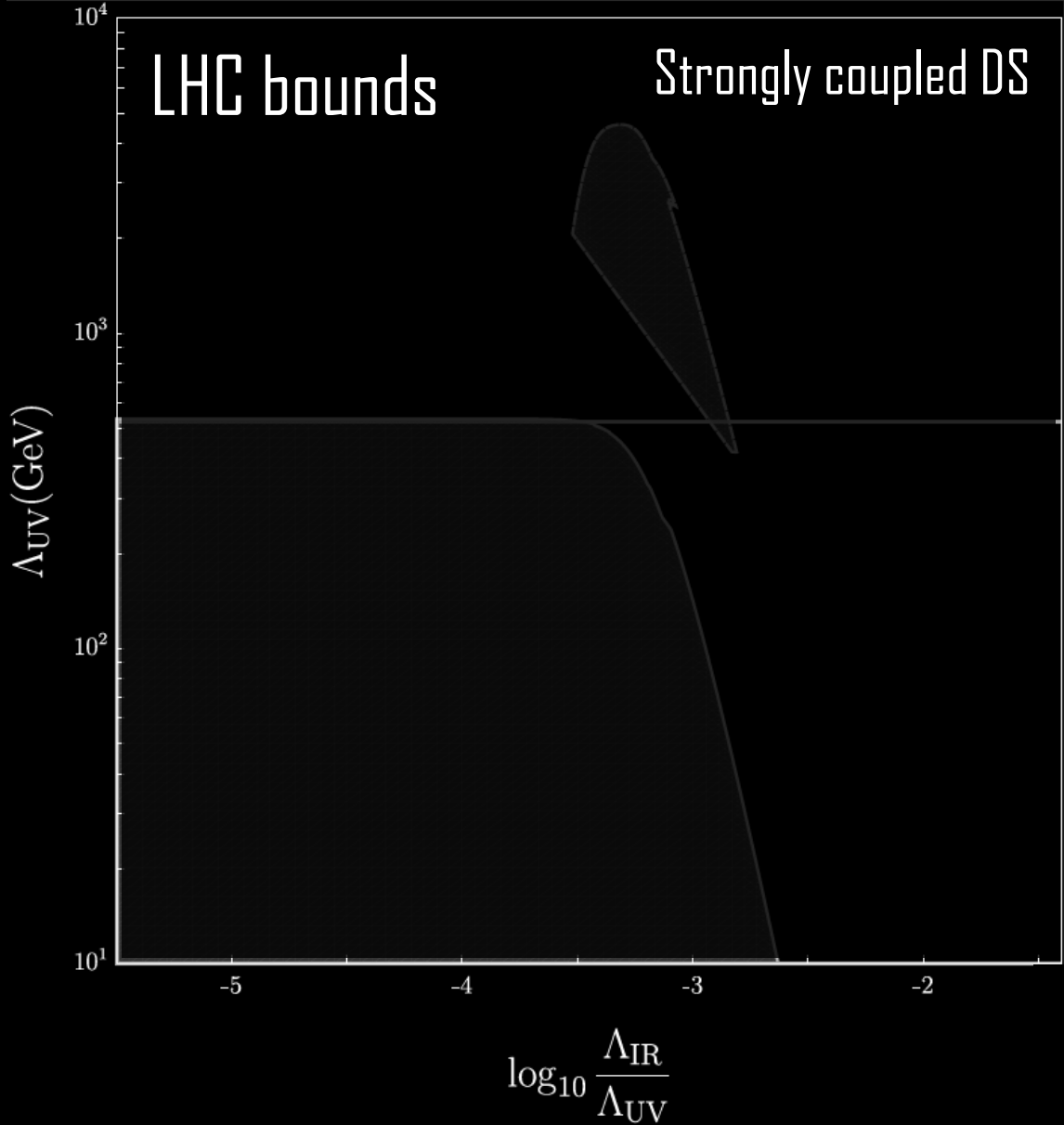
Approximate inclusive DS production cross section in a model independent way when well above threshold!

Inclusive cross section
for DS production

$$\sigma \propto \sum_n \int d\Phi_{\text{DS}} |\langle 0 | \mathcal{O}_{\text{DS}} | n \rangle|^2 = 2 \operatorname{Im} [i \langle 0 | \mathcal{O}_{\text{DS}} \mathcal{O}_{\text{DS}} | 0 \rangle]$$

Optical Theorem

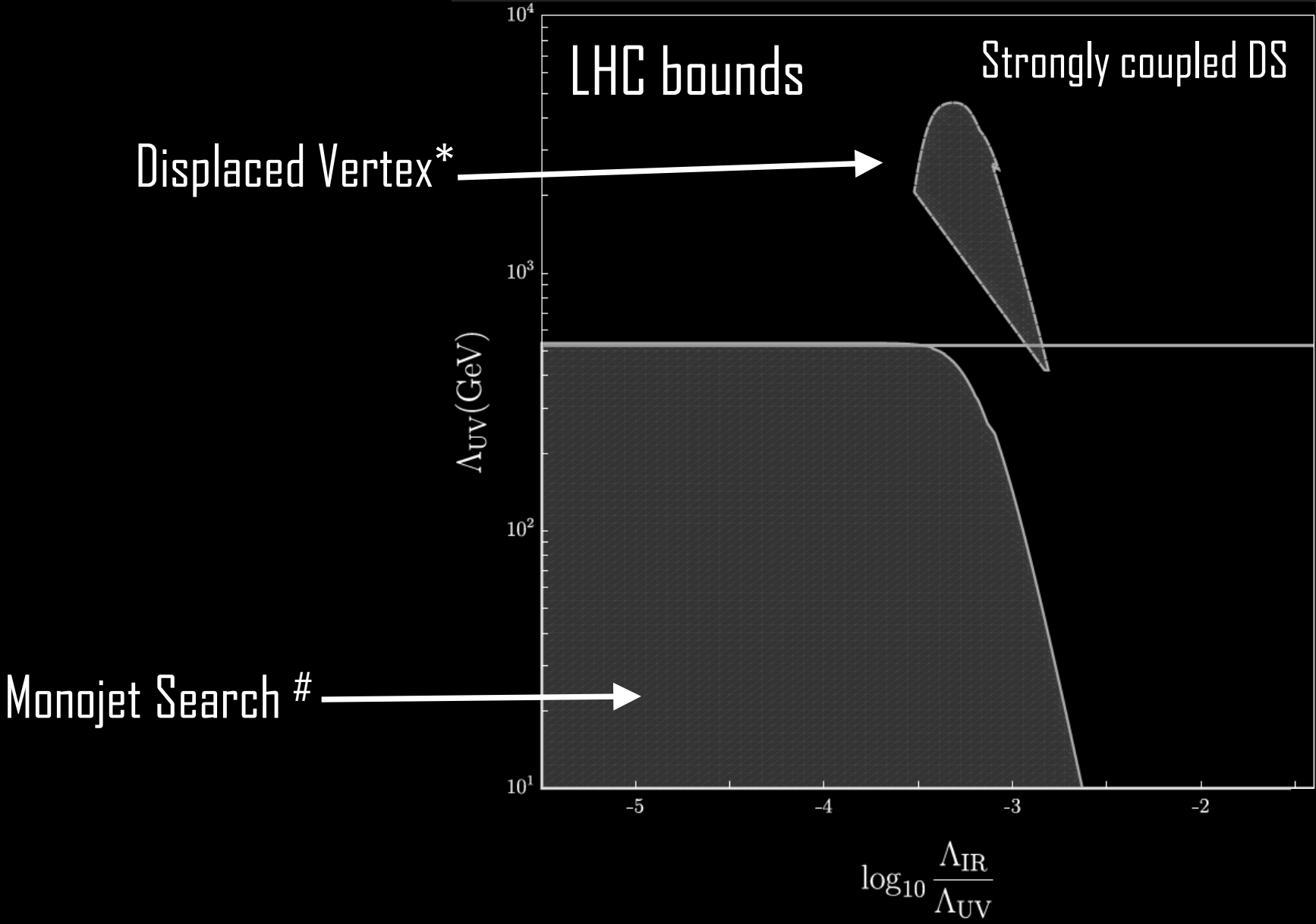
From conformal invariance



Portal: $H^\dagger i D_\mu H J_{DS}^\mu$



$\nu m_z Z_\mu J_{DS}^\mu$

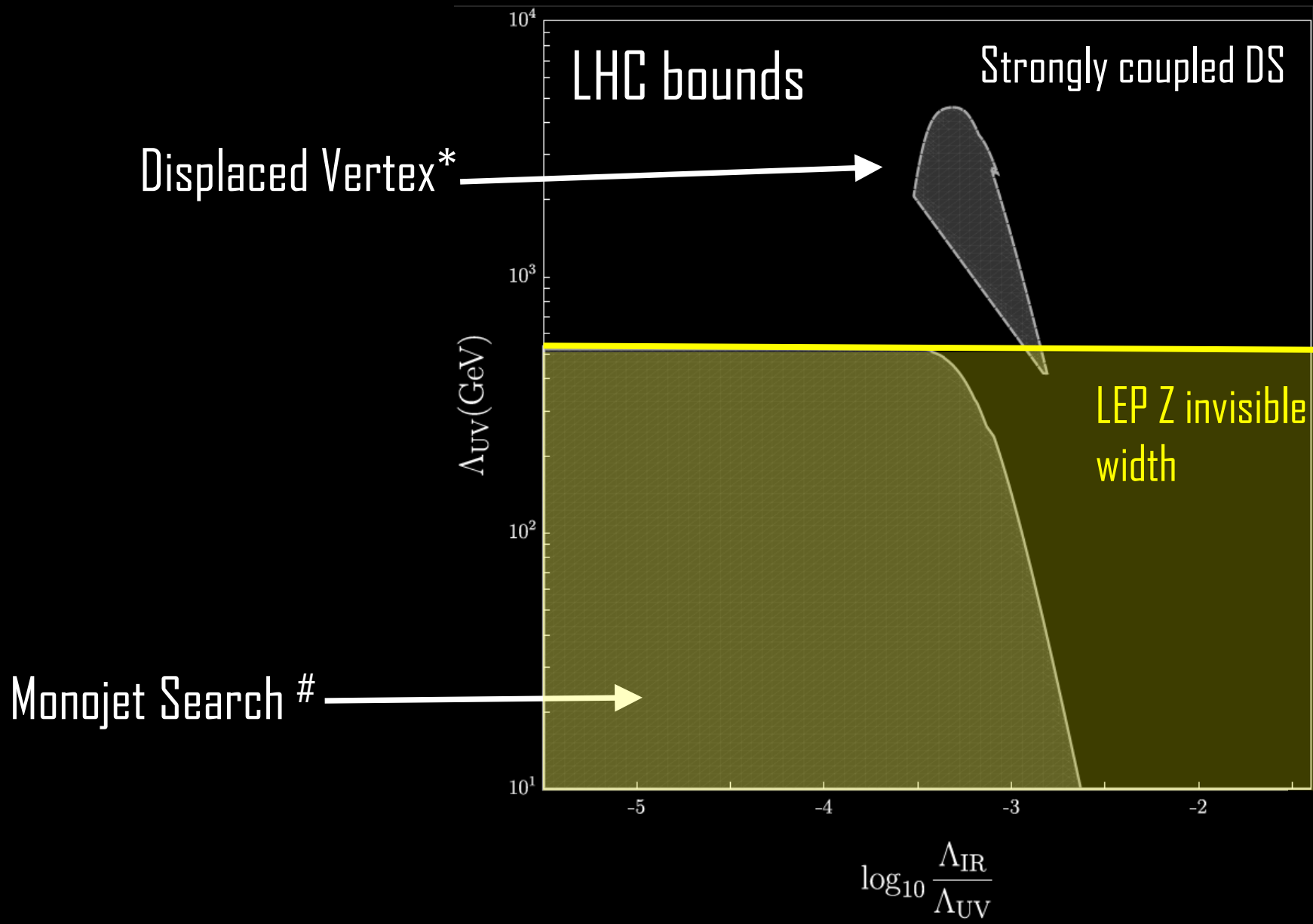


Portal: $H^\dagger i D_\mu H J_{DS}^\mu$

↓
 $\nu m_z Z_\mu J_{DS}^\mu$

*ATLAS search for Displaced Vertex PRD (2019)(2020)

#ATLAS JHEP 01 (2018) 126



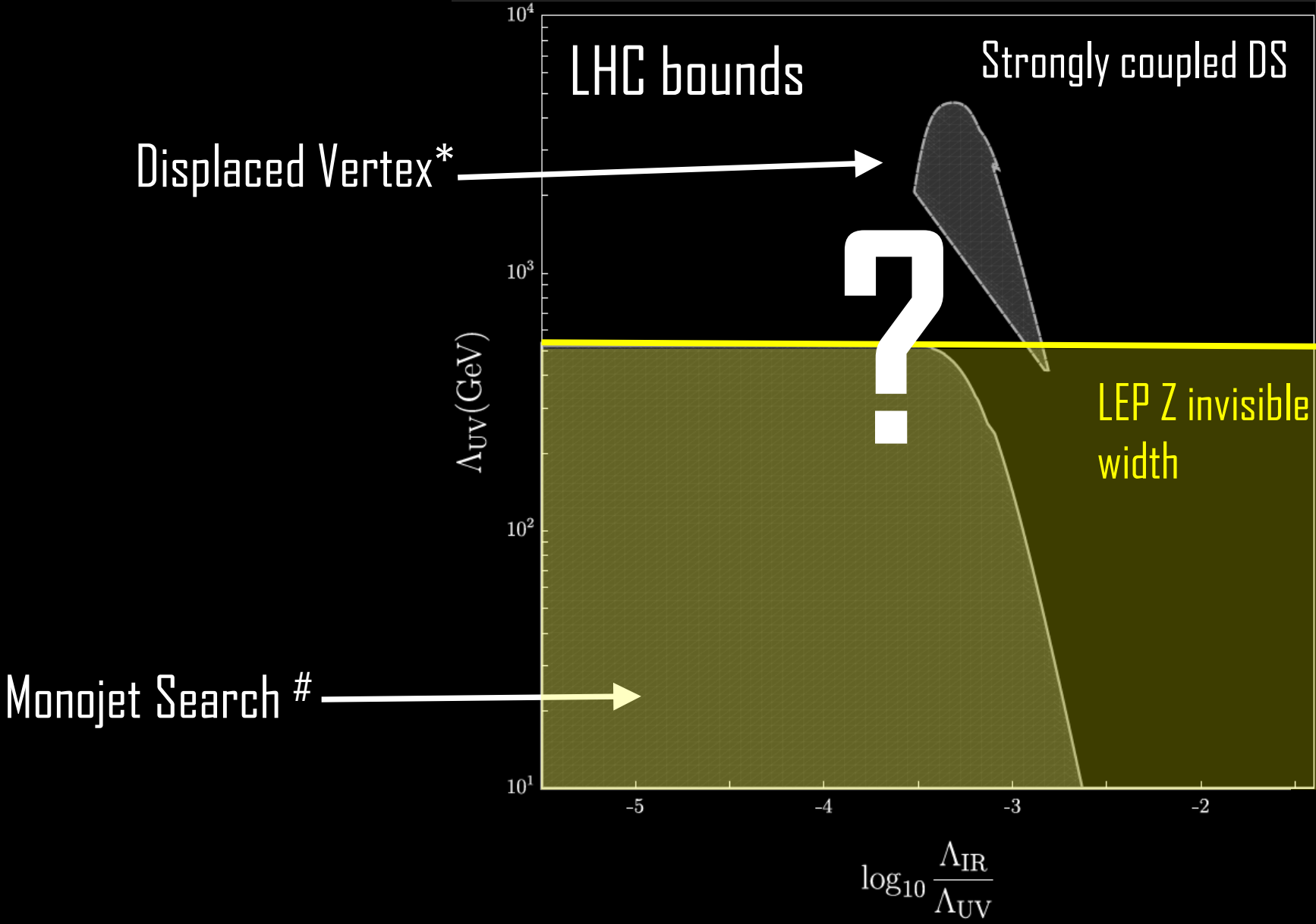
Portal: $H^\dagger i D_\mu H J_{DS}^\mu$

↓

$\nu m_z Z_\mu J_{DS}^\mu$

*ATLAS search for Displaced Vertex PRD (2019)(2020)

#ATLAS JHEP 01 (2018) 126



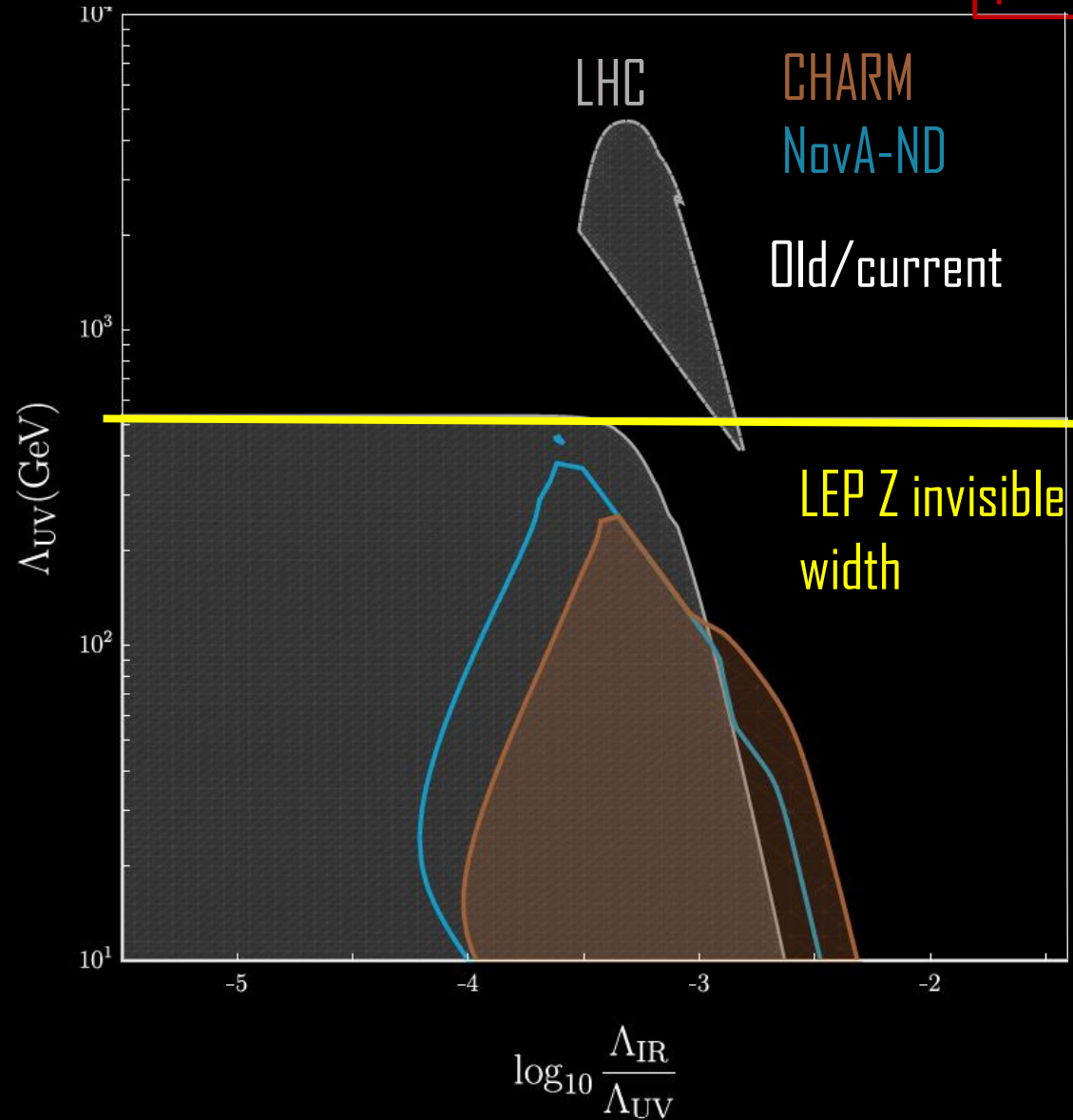
Portal: $H^\dagger i D_\mu H J_{DS}^\mu$

\downarrow
 $\nu m_z Z_\mu J_{DS}^\mu$

*ATLAS search for Displaced Vertex PRD (2019)(2020)

#ATLAS JHEP 01 (2018) 126

preliminary

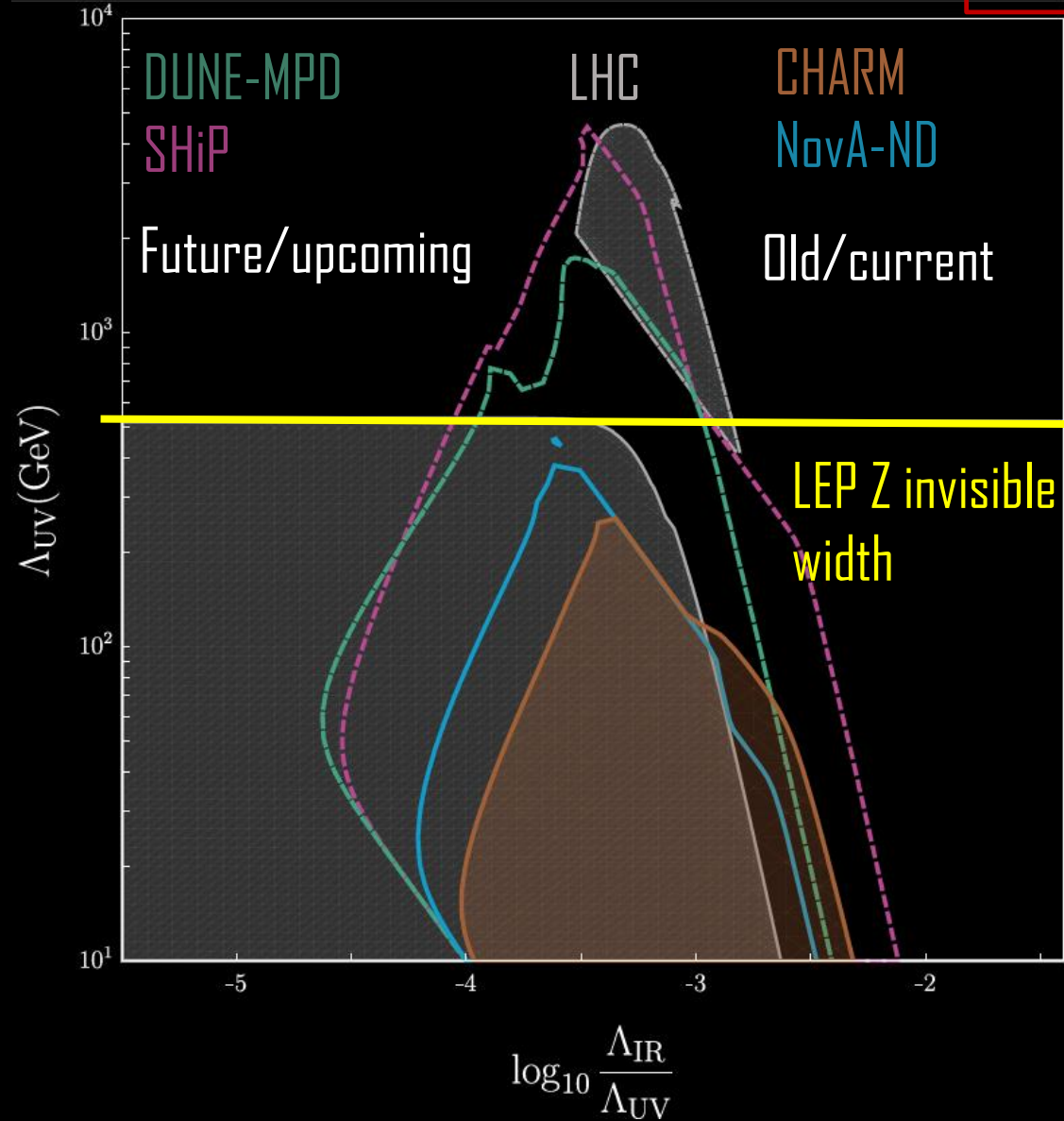


Portal: $H^\dagger i D_\mu H J_{DS}^\mu$

↓

$\nu m_z Z_\mu J_{DS}^\mu$

preliminary

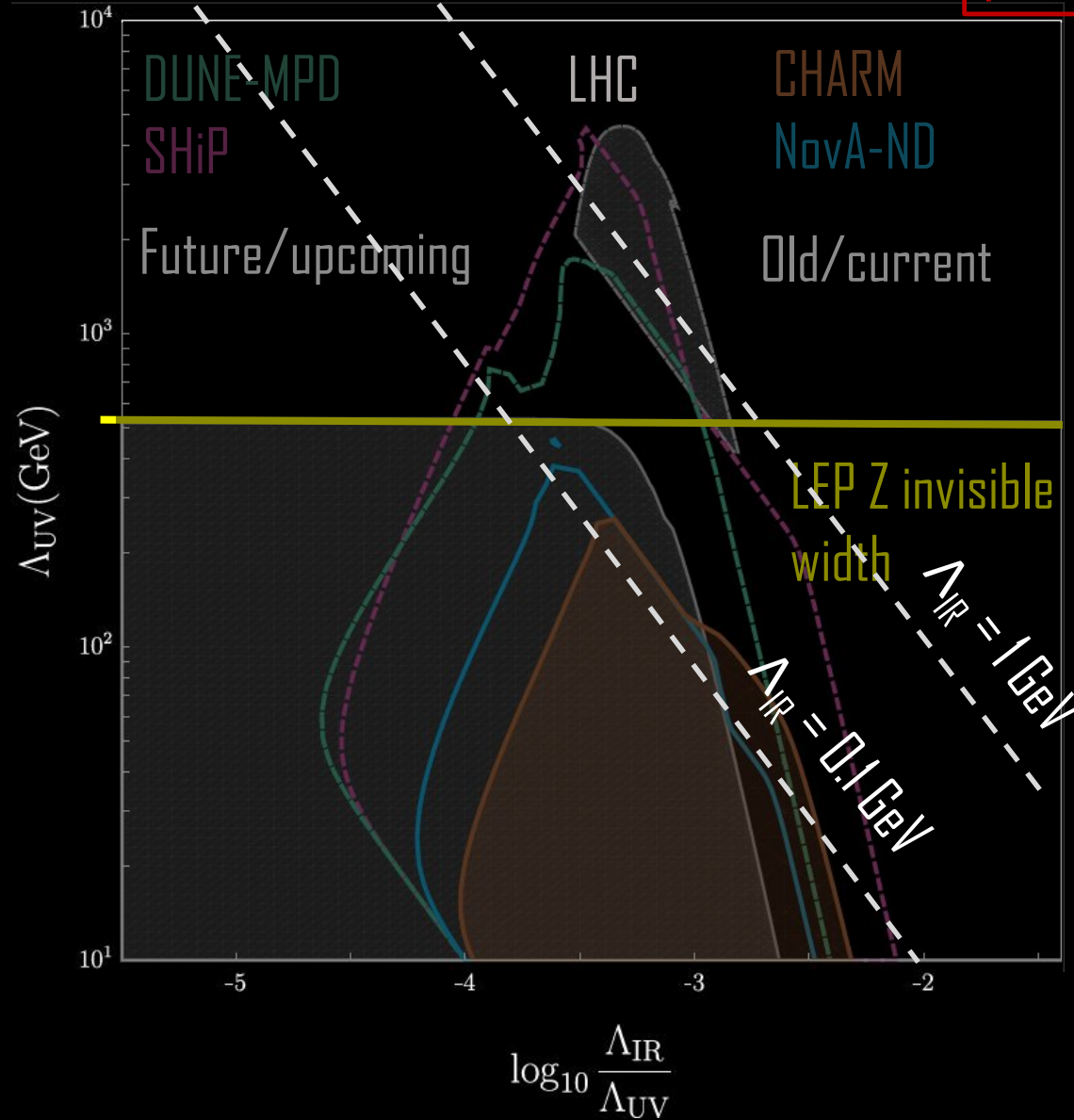


Portal: $H^\dagger i D_\mu H J_{DS}^\mu$

↓

$\nu m_z Z_\mu J_{DS}^\mu$

preliminary



Portal: $H^\dagger i D_\mu H J_{DS}^\mu$

↓

$\nu m_z Z_\mu J_{DS}^\mu$

Conclusions

- We can use constrain elusive DS using a model independent framework.
- Future neutrino experiments and LLP search experiments like SHiP will be important probes.
- Will complement LHC searches as elusive DS probes in a short timescale.

Since **“WE HAVE NO IDEA”** [B. Shakya's talk] ,
maybe we should look everywhere?