

2nd Forward Physics Facility Meeting - May 27, 2021

BSM and Forward Physics

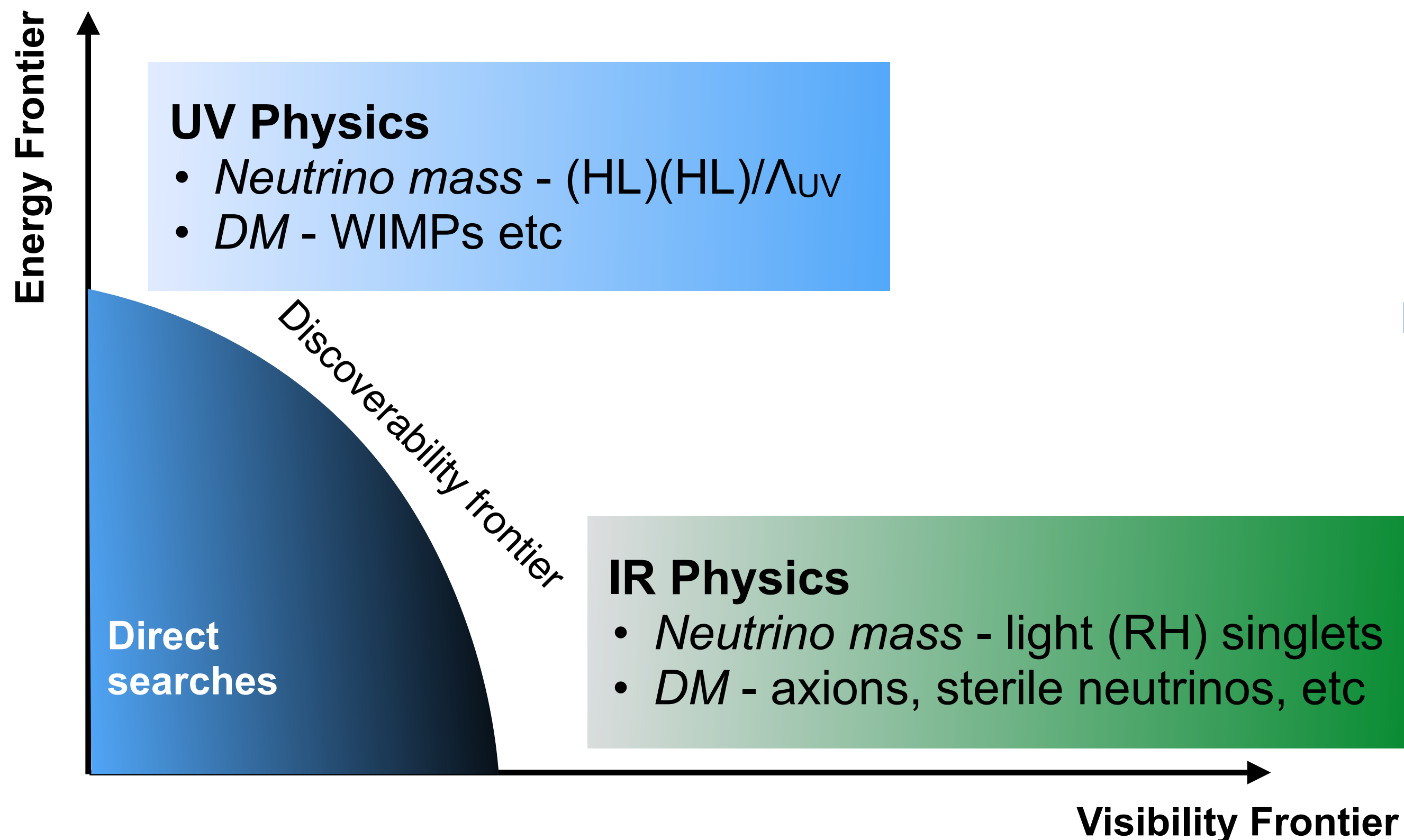
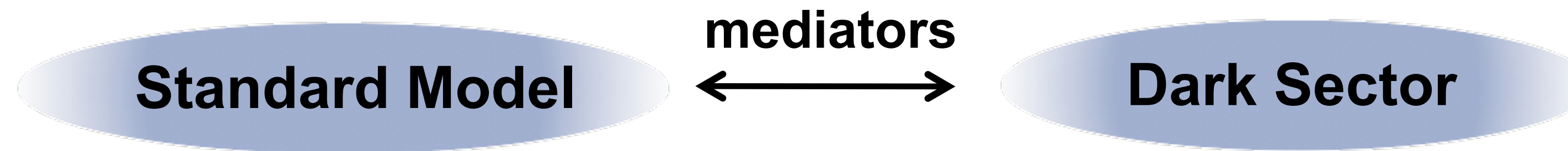
Adam Ritz

University of Victoria



New physics in a dark sector

Empirical evidence for new physics, e.g. neutrino mass, dark matter, arguably points to a dark/hidden sector (but not directly to a specific mass scale)

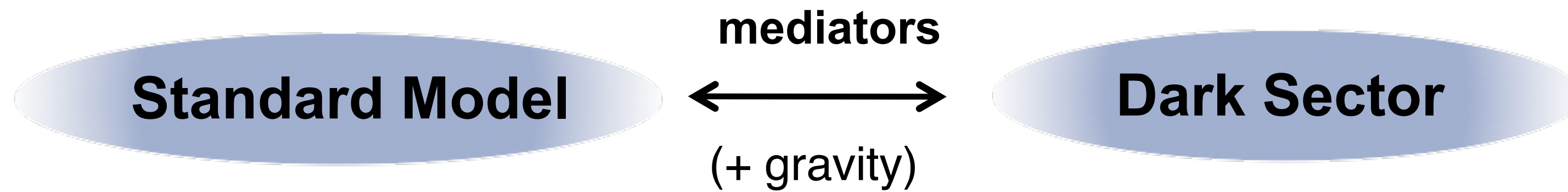


May contain *light states*, if sufficiently weakly coupled



Dark sectors present a huge model-space a priori, but an EFT approach to the mediator channel allows for a classification (large community effort over past decade)

EFT for a (neutral) dark sector



There are just three UV-complete relevant or marginal “portals” to a SM-neutral hidden sector, unsuppressed by the (possibly large) new physics scale Λ

$$\begin{aligned}
 \mathcal{L} &= \sum_{n=k+l-4} \frac{c_n}{\Lambda^n} \mathcal{O}_k^{(\text{SM})} \mathcal{O}_l^{(\text{med})} \\
 &= -\frac{\epsilon}{2} B^{\mu\nu} A'_{\mu\nu} - H^\dagger H (AS + \lambda S^2) - Y_N^{ij} \bar{L}_i H N_j \\
 &\quad + \frac{1}{f_a} \left(\text{tr}(G\tilde{G}) + c_F F \tilde{F} + c_\psi \partial_\mu j_{A\psi}^\mu \right) a + \mathcal{O}(\text{dim} \geq 5)
 \end{aligned}$$

Vector portal
 [Okun; Galison & Manohar;
 Holdom; Foot et al]

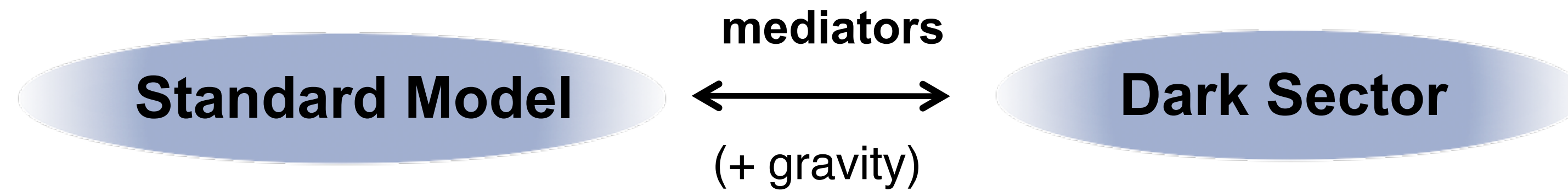
Higgs portal
 [Patt & Wilczek]

Neutrino portal

Axion portal
 [Weinberg, Wilczek, KSVZ, DFSZ]

CERN PBC
 benchmarks
 BC 1-11

EFT for a (neutral) dark sector



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 \end{aligned}$$

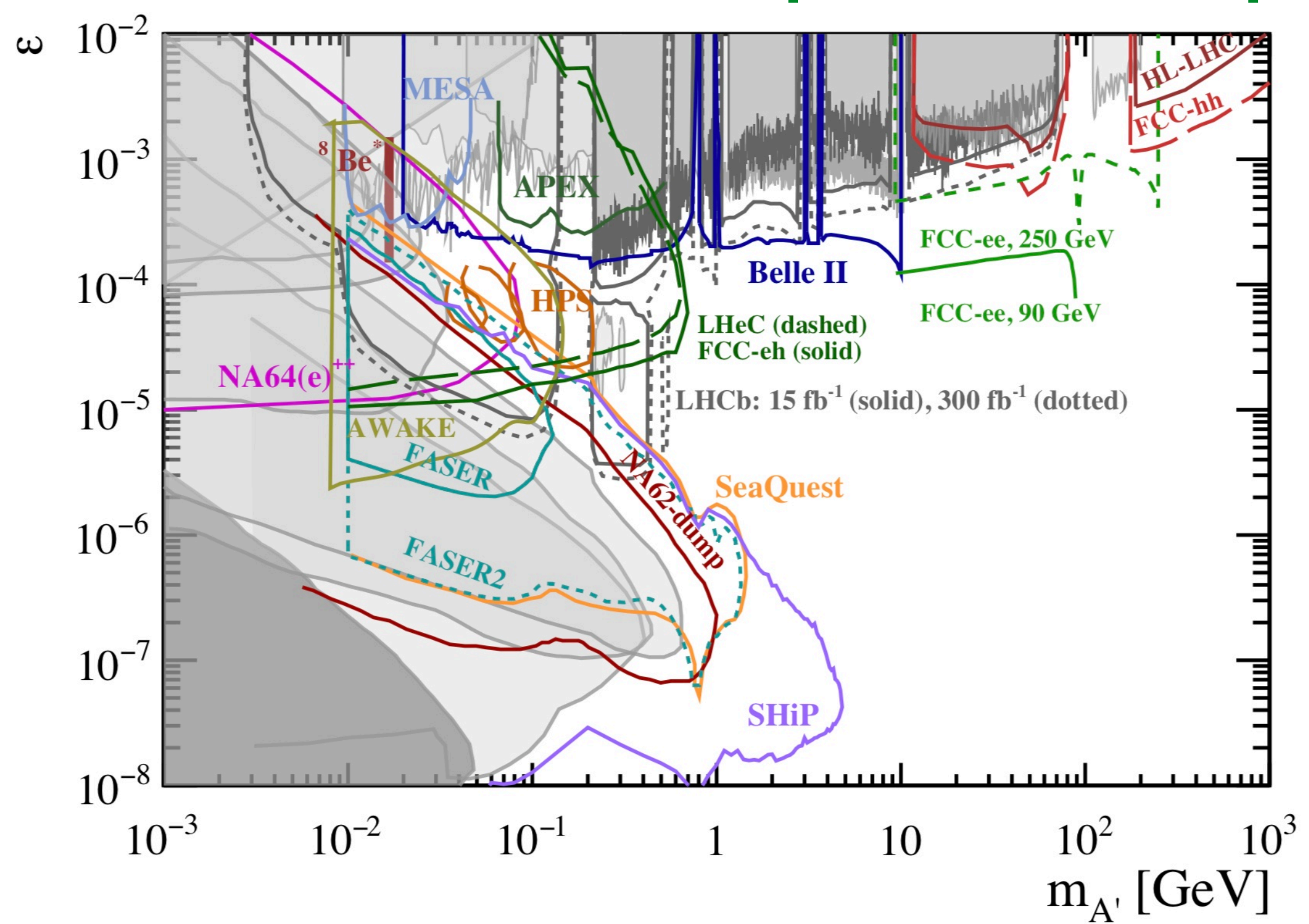
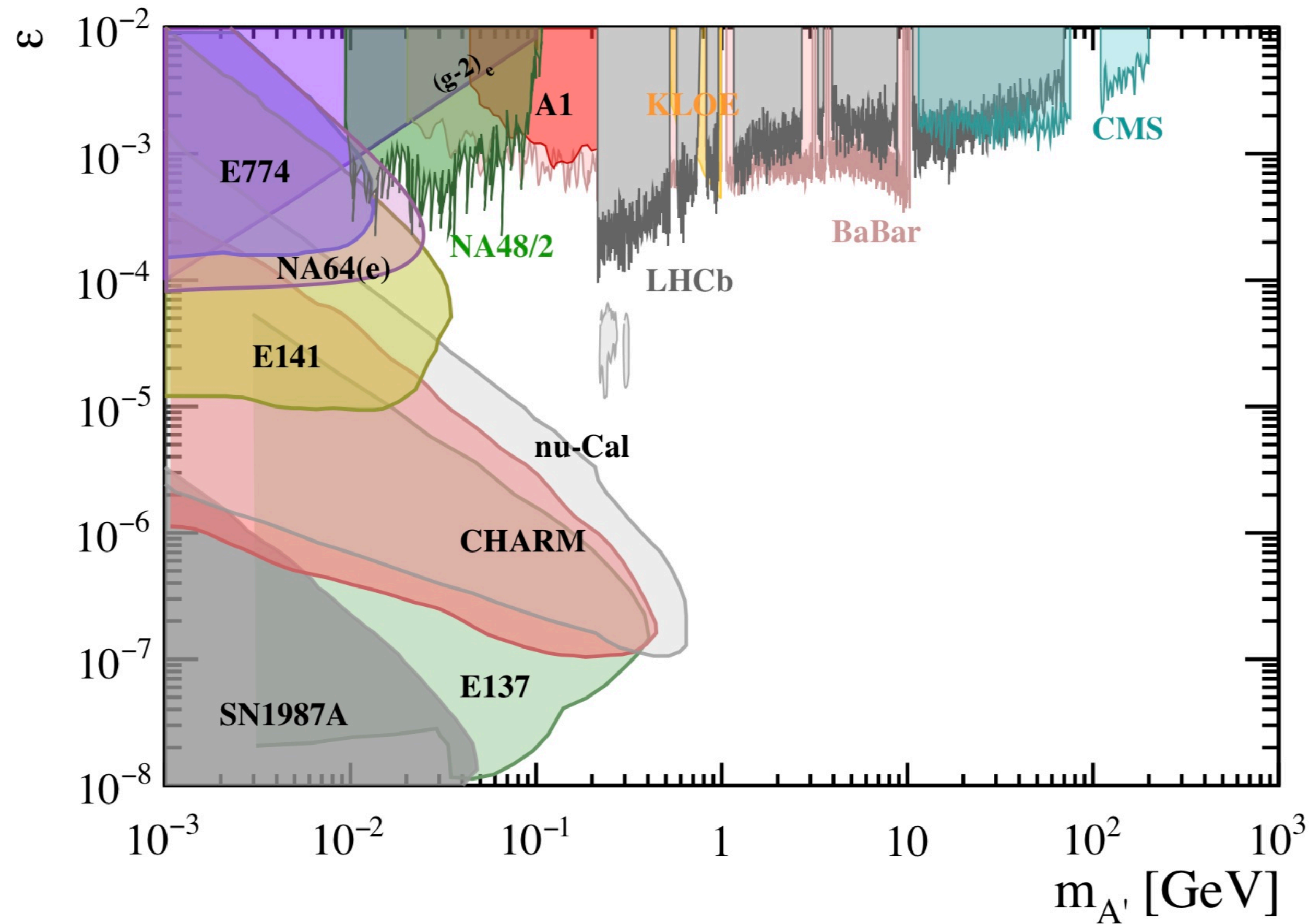
Minimal models using portals:
a, A', S and N:

- minimal models of neutrino mass, and leptogenesis
- viable (and minimal) non-thermal cold DM candidates (sub MeV)
- new ‘dark force’ mediators enabling sufficient annihilation of thermal relic MeV-GeV dark matter in the early universe

Progress over the past decade

E.G. Visible decays $A' \rightarrow$ dileptons

[Fabbrichesi et al '20]



Forward Physics at the HL-LHC

Dark mediators

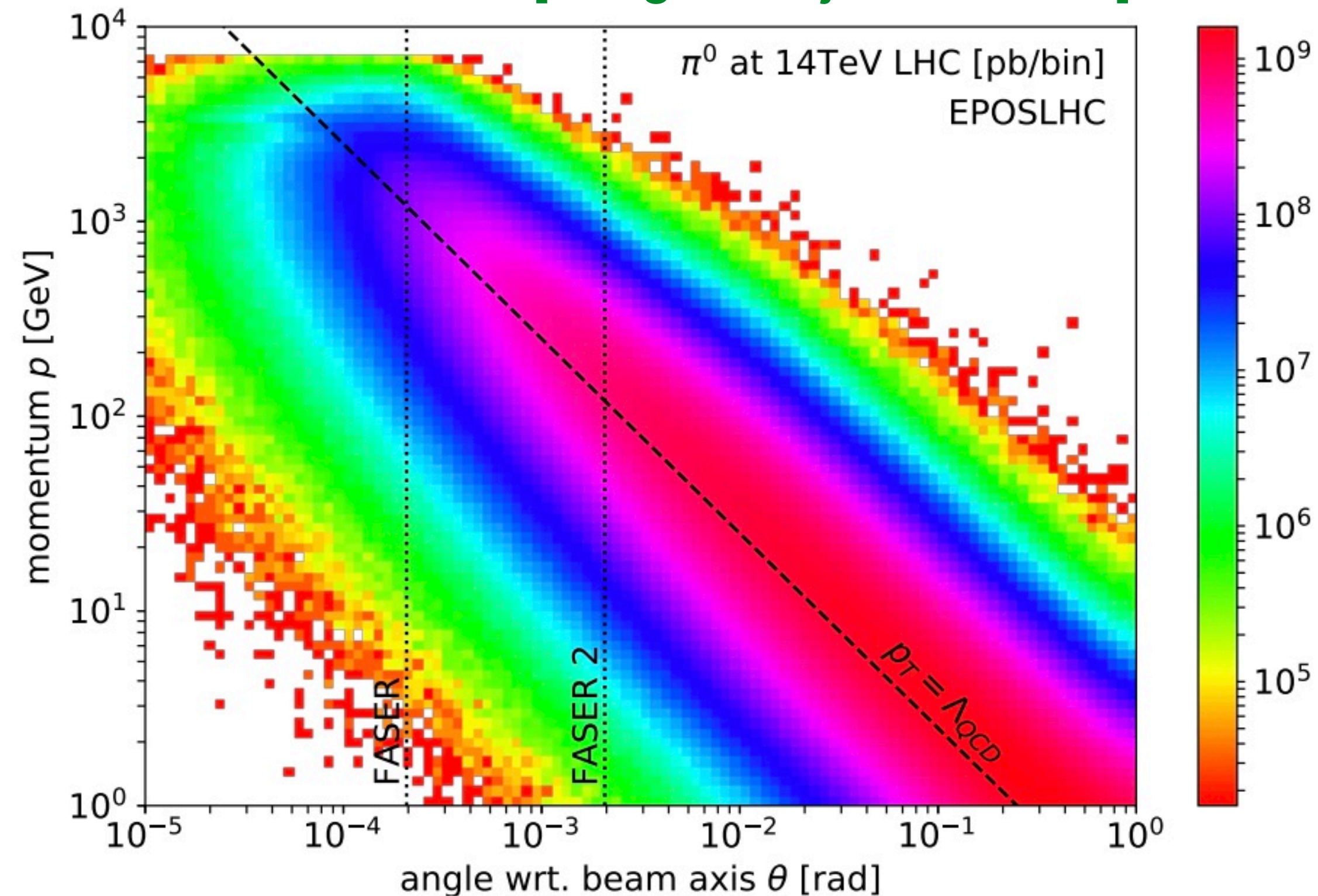
- $10^{18} \pi^0 \rightarrow A'$
- $10^{15} B \rightarrow S$
- etc



Light DM
LLPs & mediators
Millicharge
More...

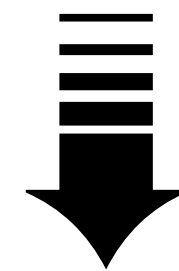
Unique combination of sensitivity to GeV-mass new physics (LLPs), and TeV neutrino (and muon) beams.

[Kling & Trojanovski '21]



Neutrinos

- $10^{18} \pi \rightarrow \nu_\mu$
- $10^{17} K \rightarrow \nu_e$
- $10^{16} D \rightarrow \nu_\tau$

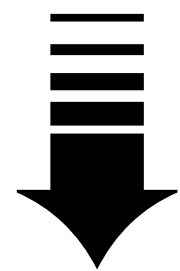


TeV neutrinos
Cross sections
 ν DIS

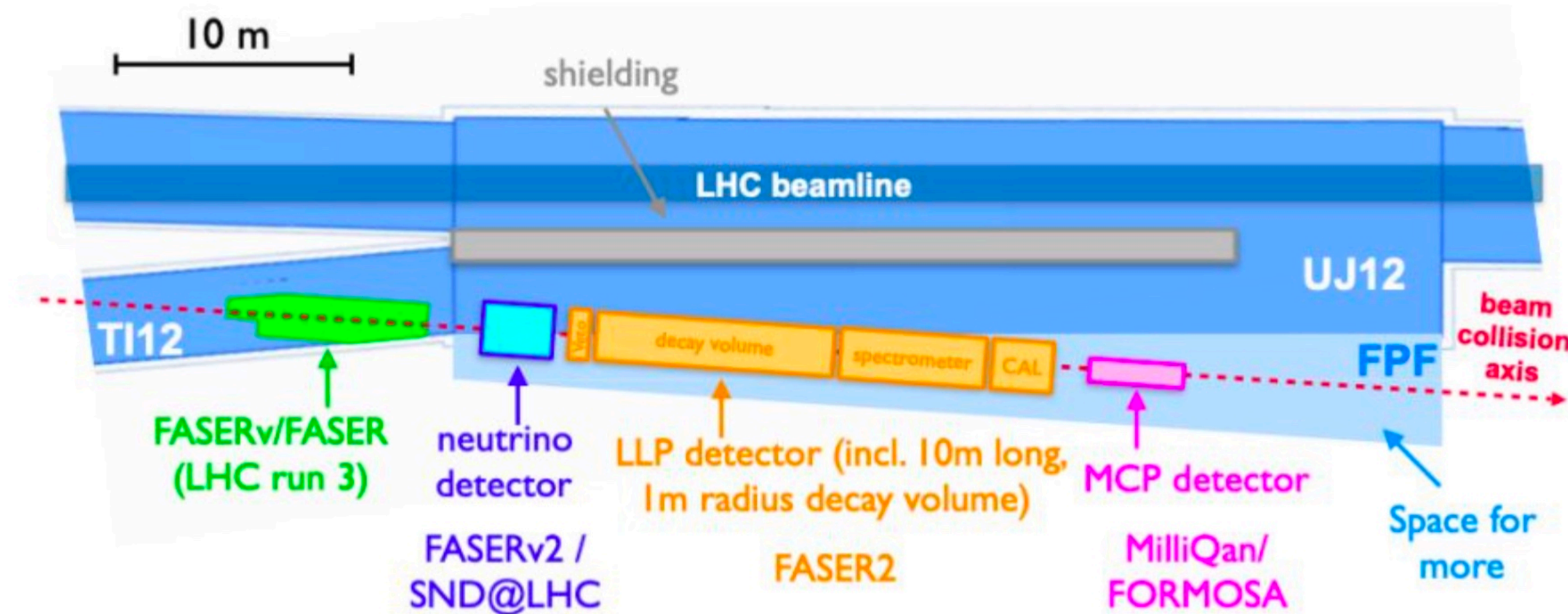
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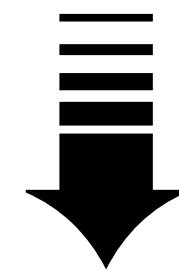


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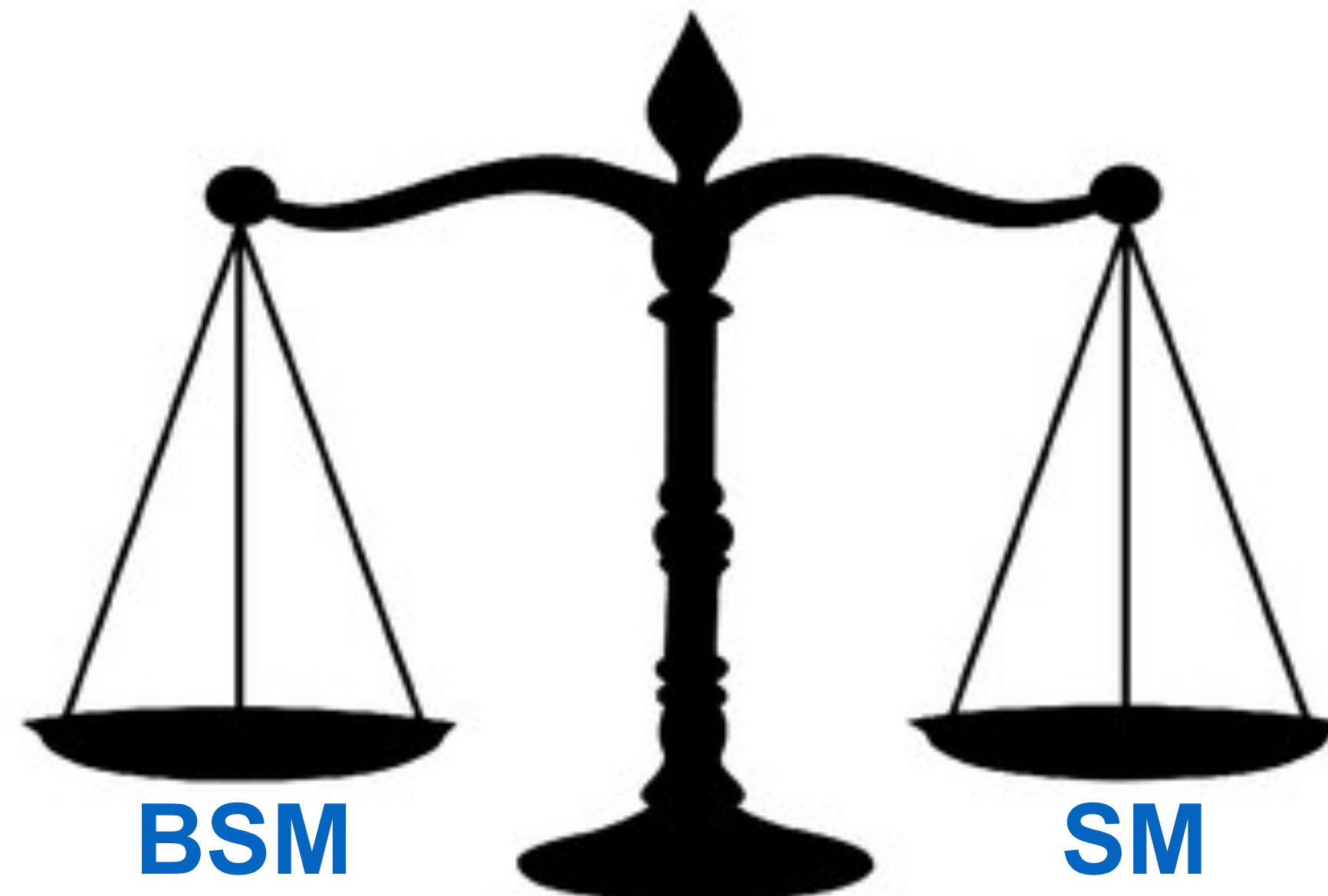


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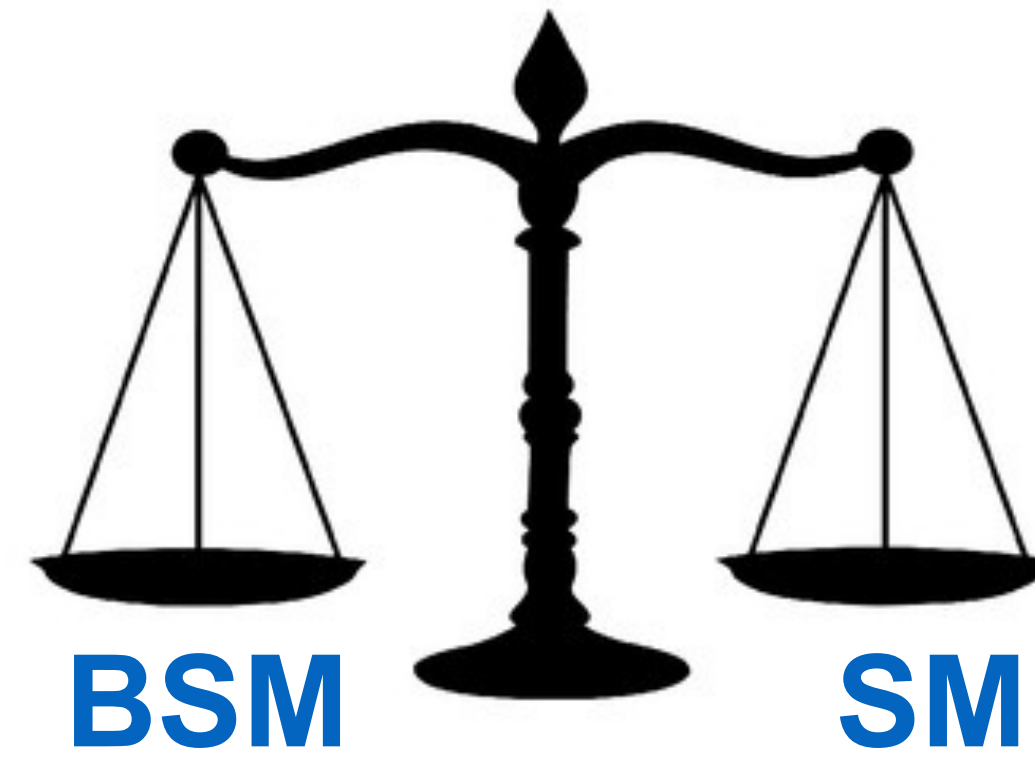
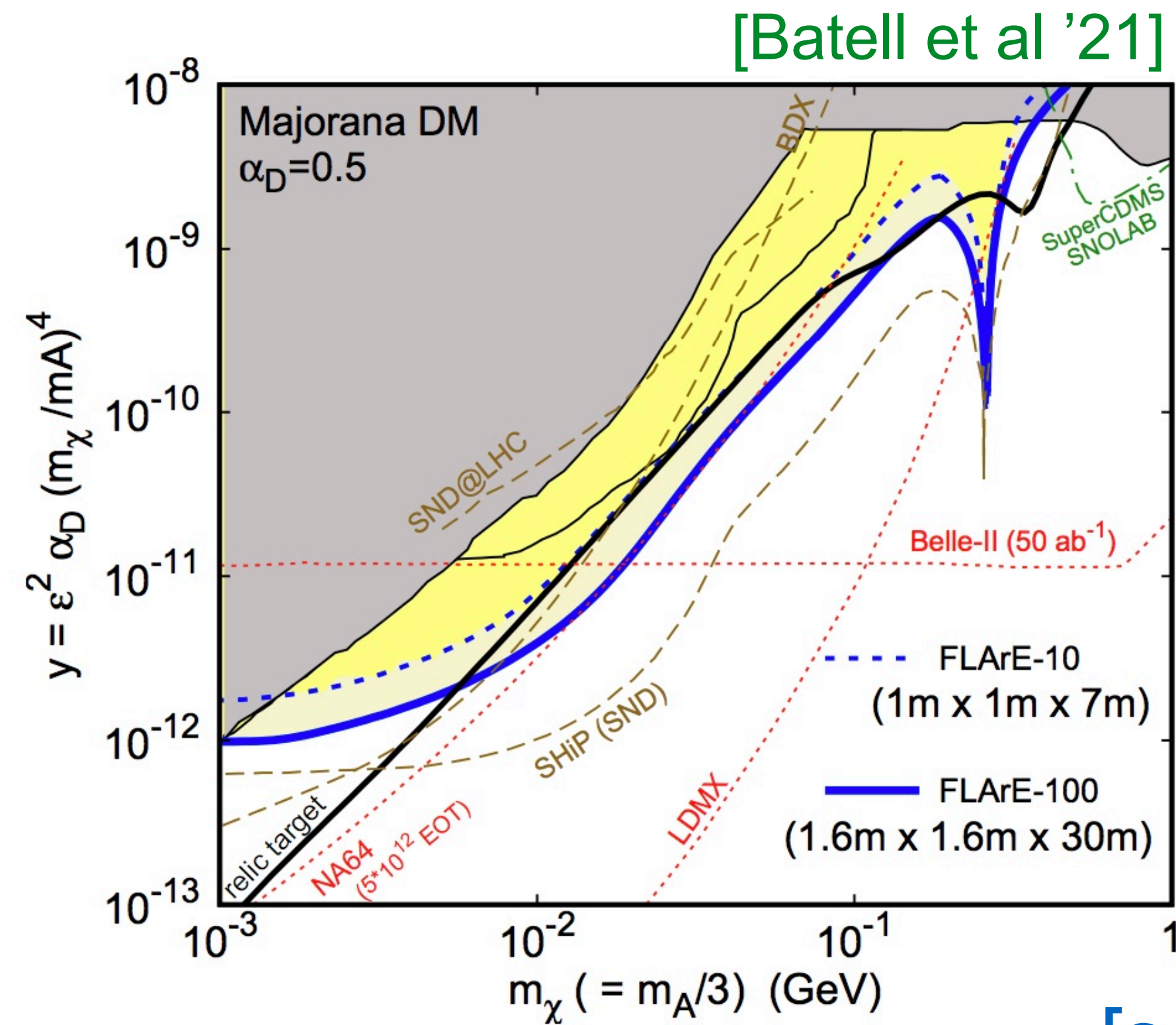


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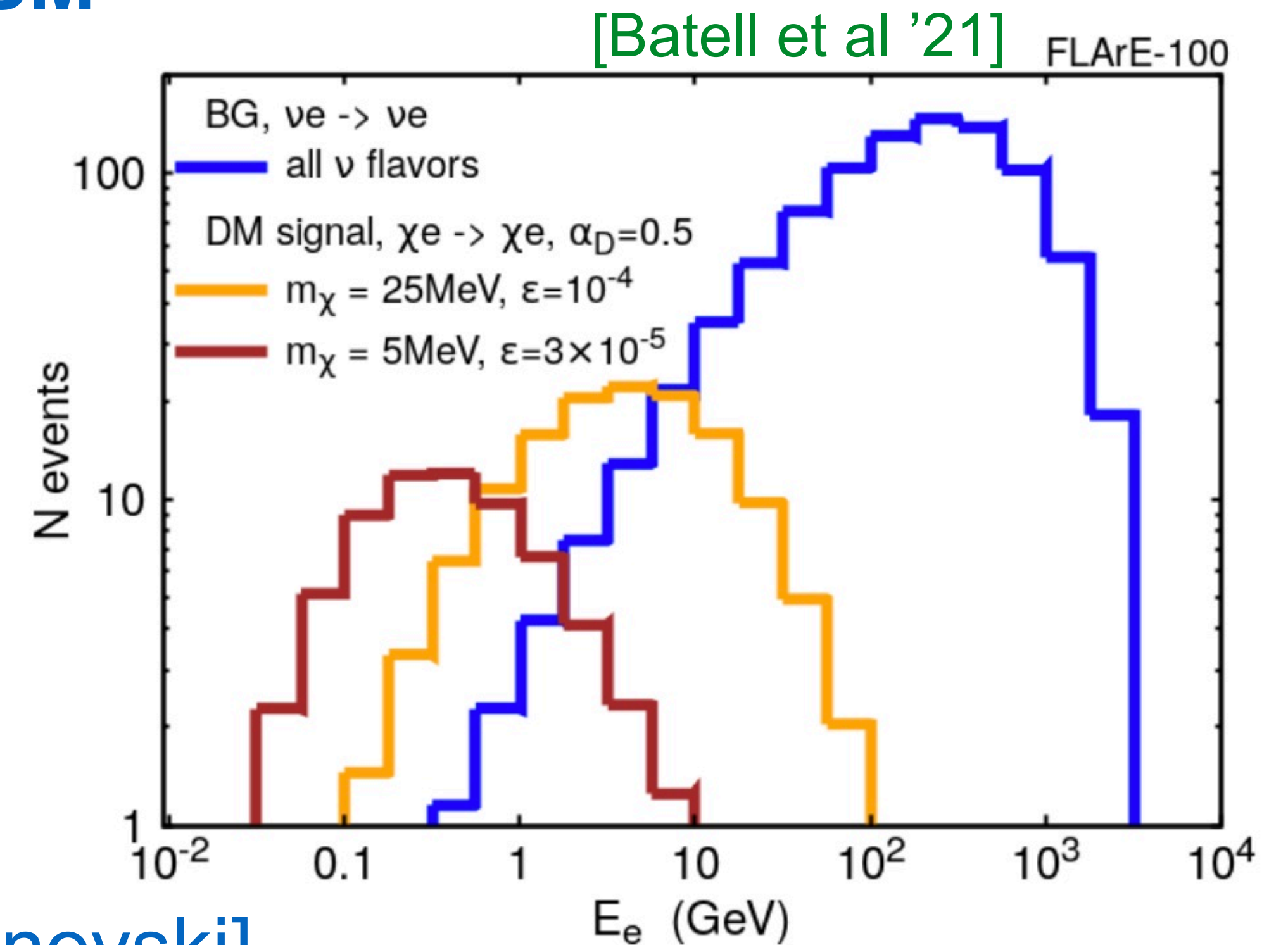
Forward Physics at the FPF

Light DM



TeV neutrinos

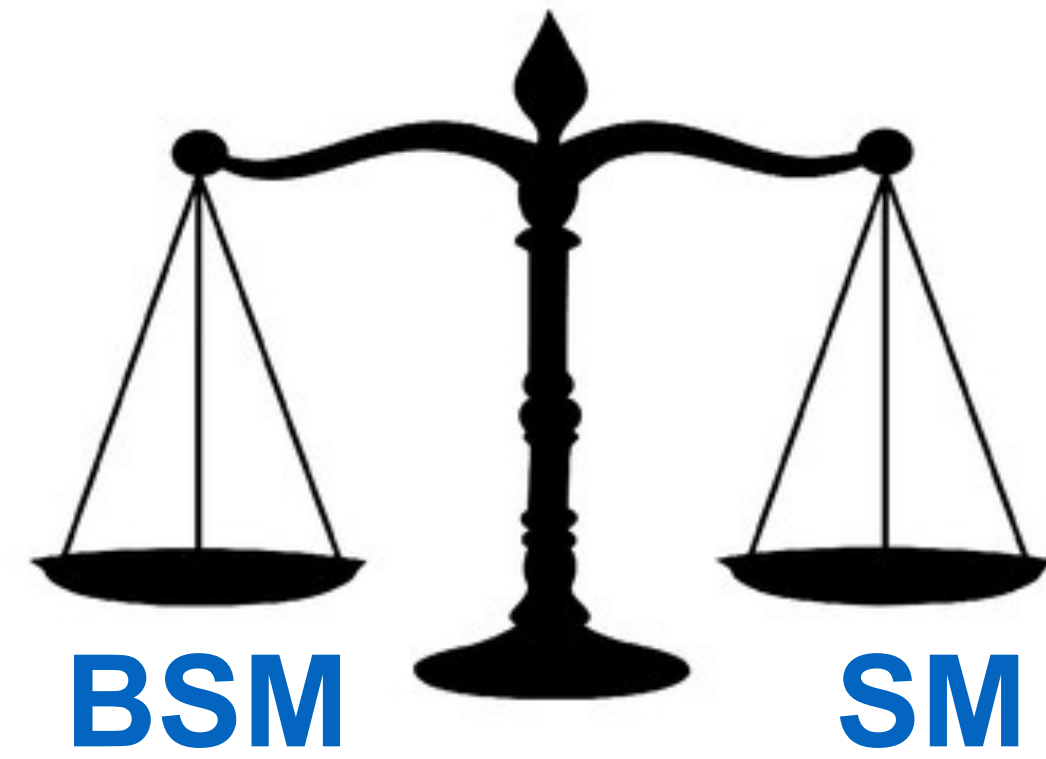
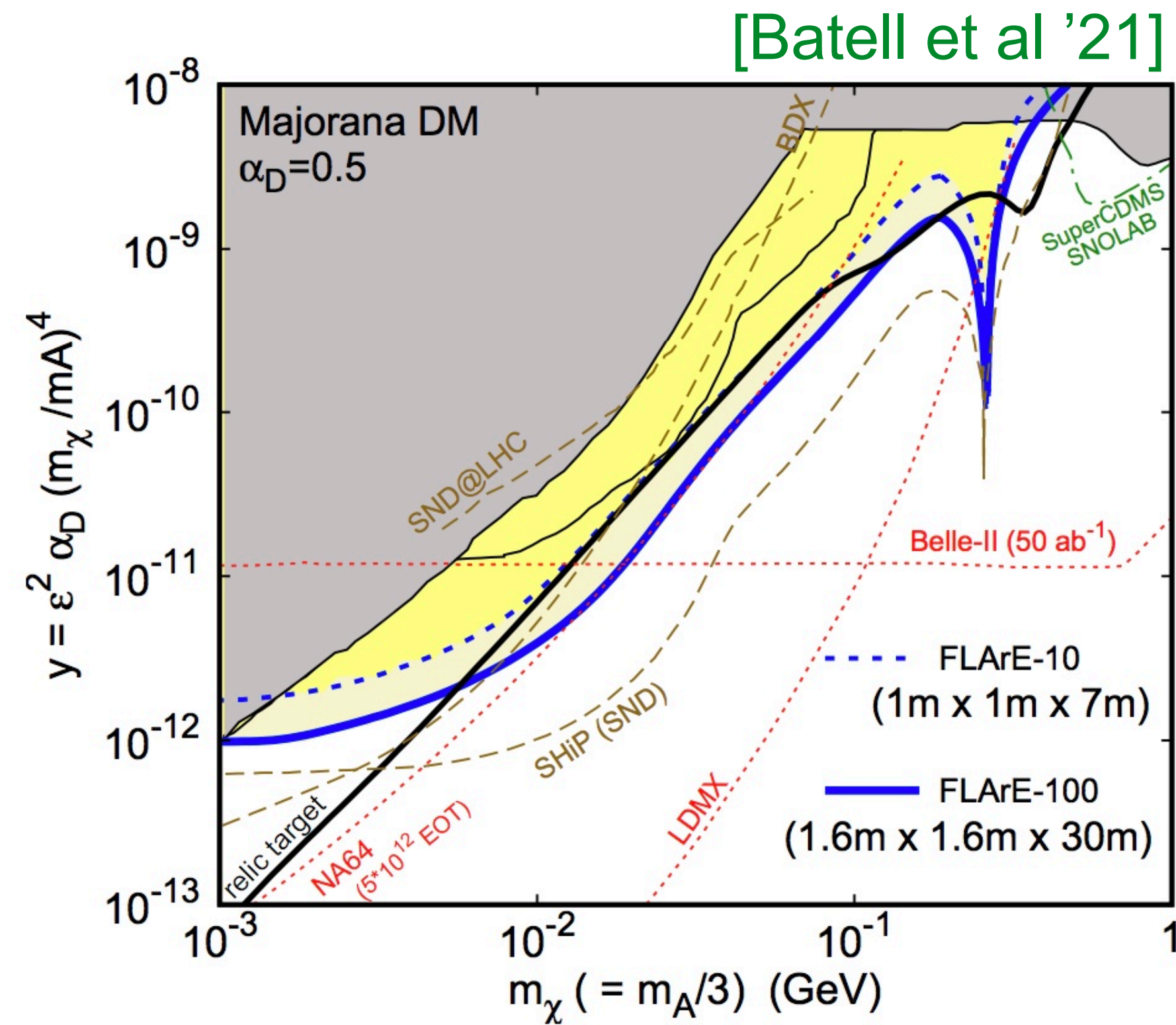
High-energy scattering signatures



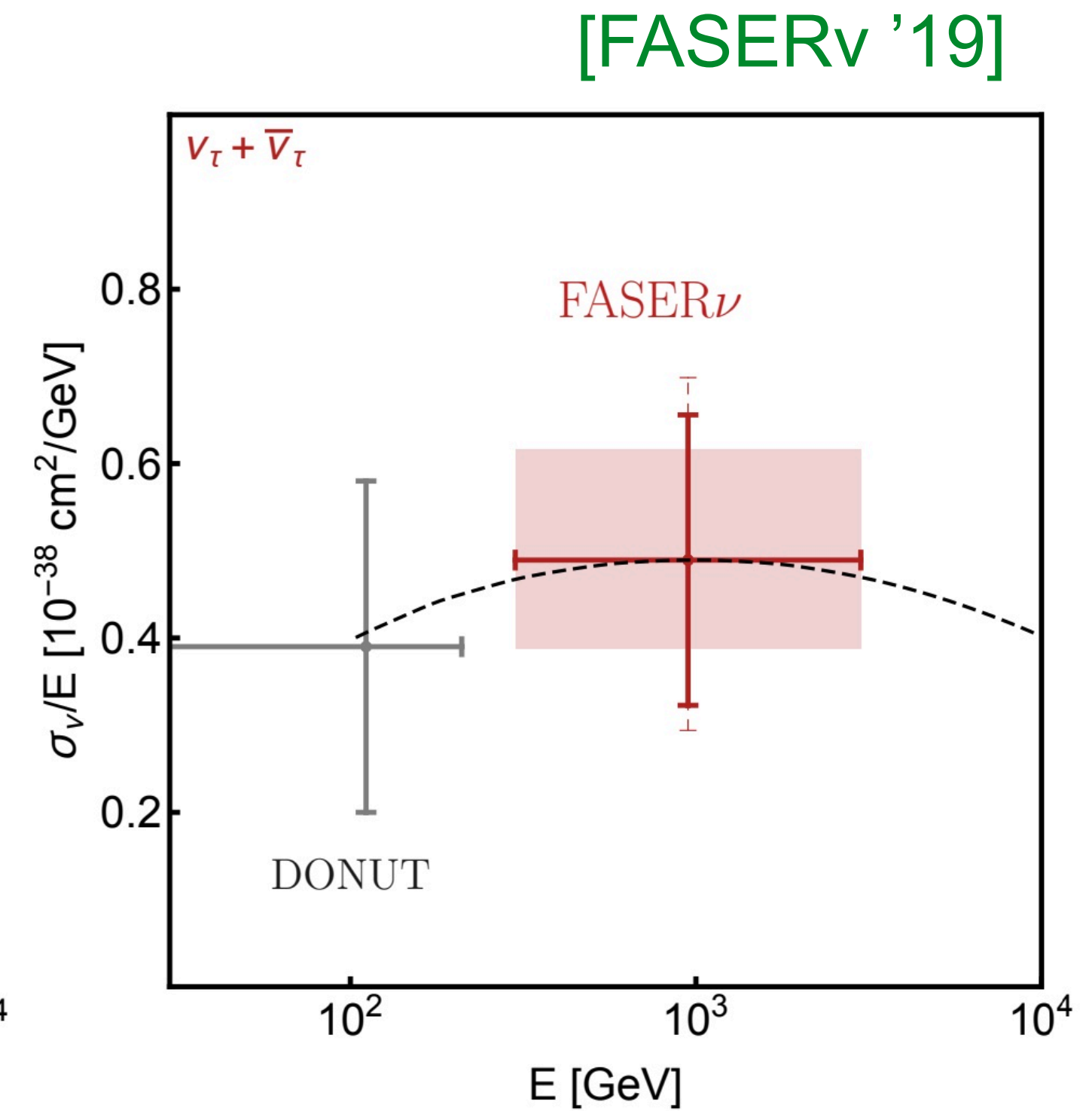
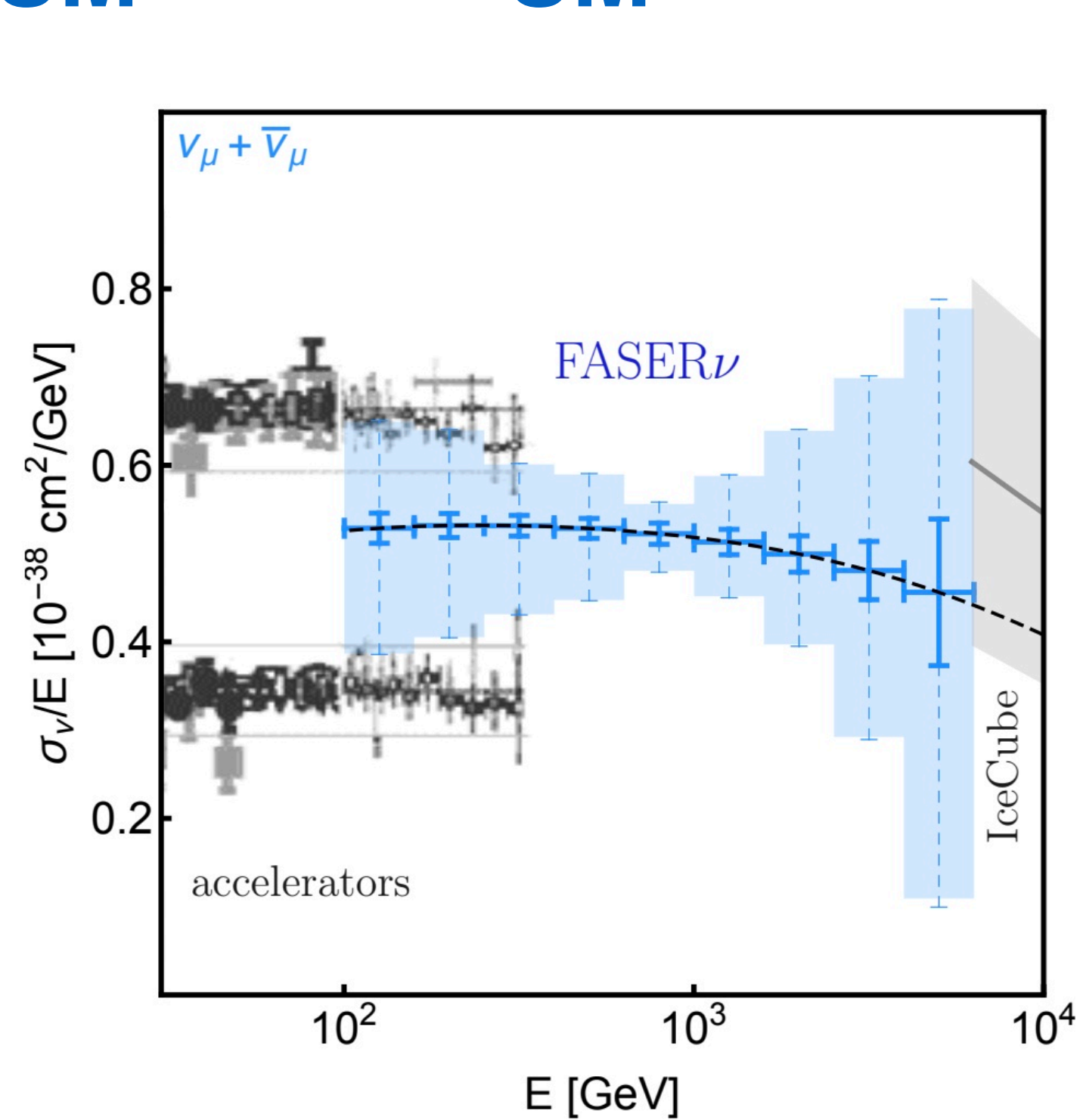
[see talk by S. Trojanovski]

Forward Physics at the FPF

Light DM



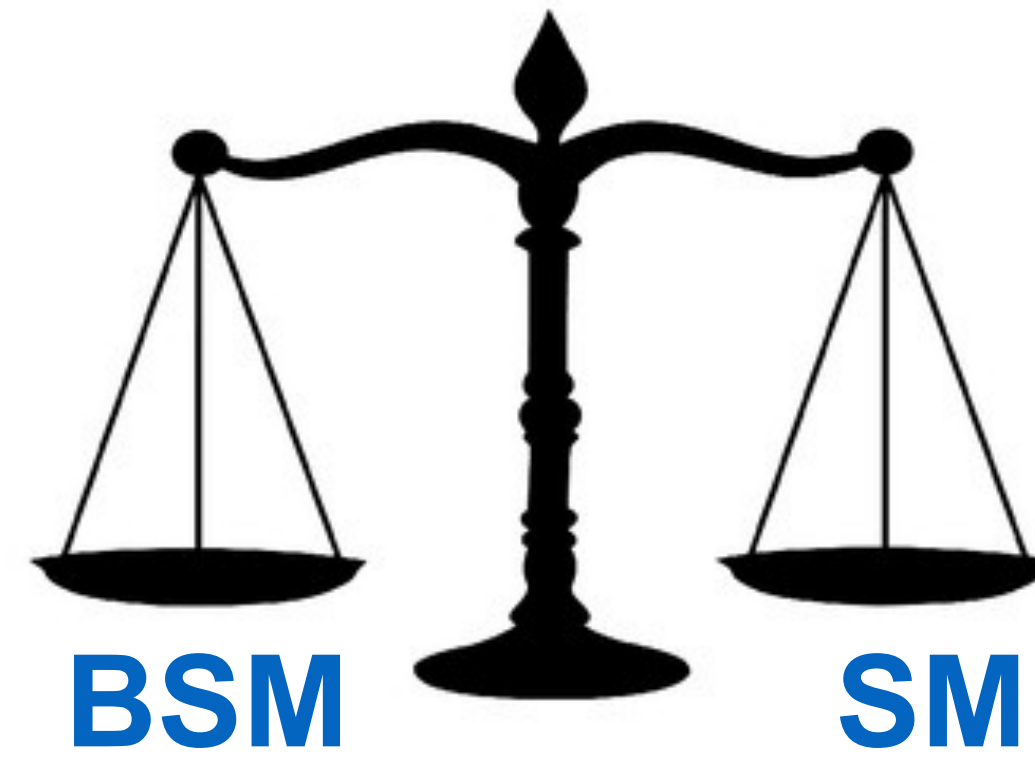
TeV neutrinos



Forward Physics at the FPF

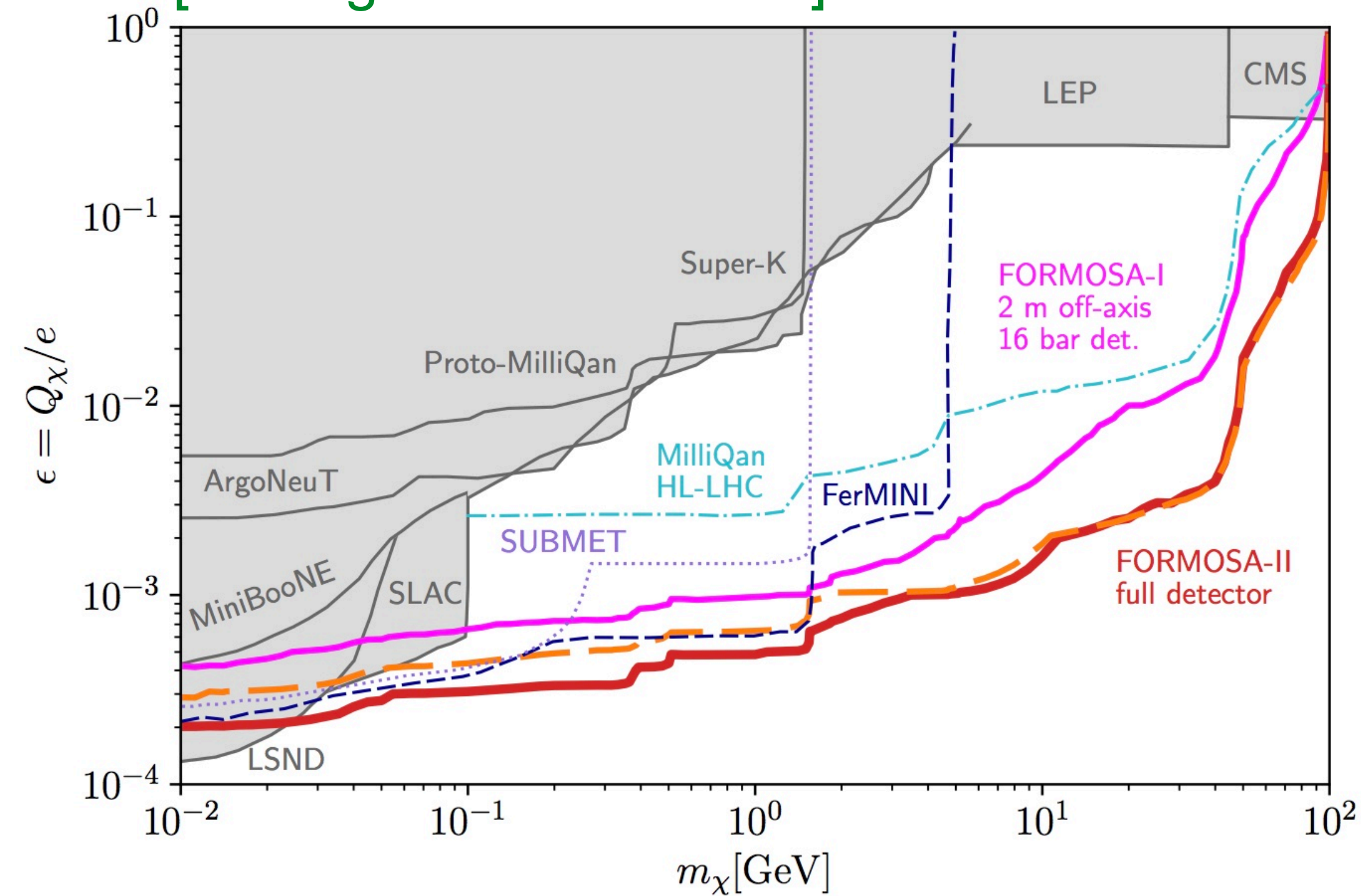
Millicharge

TeV Muons

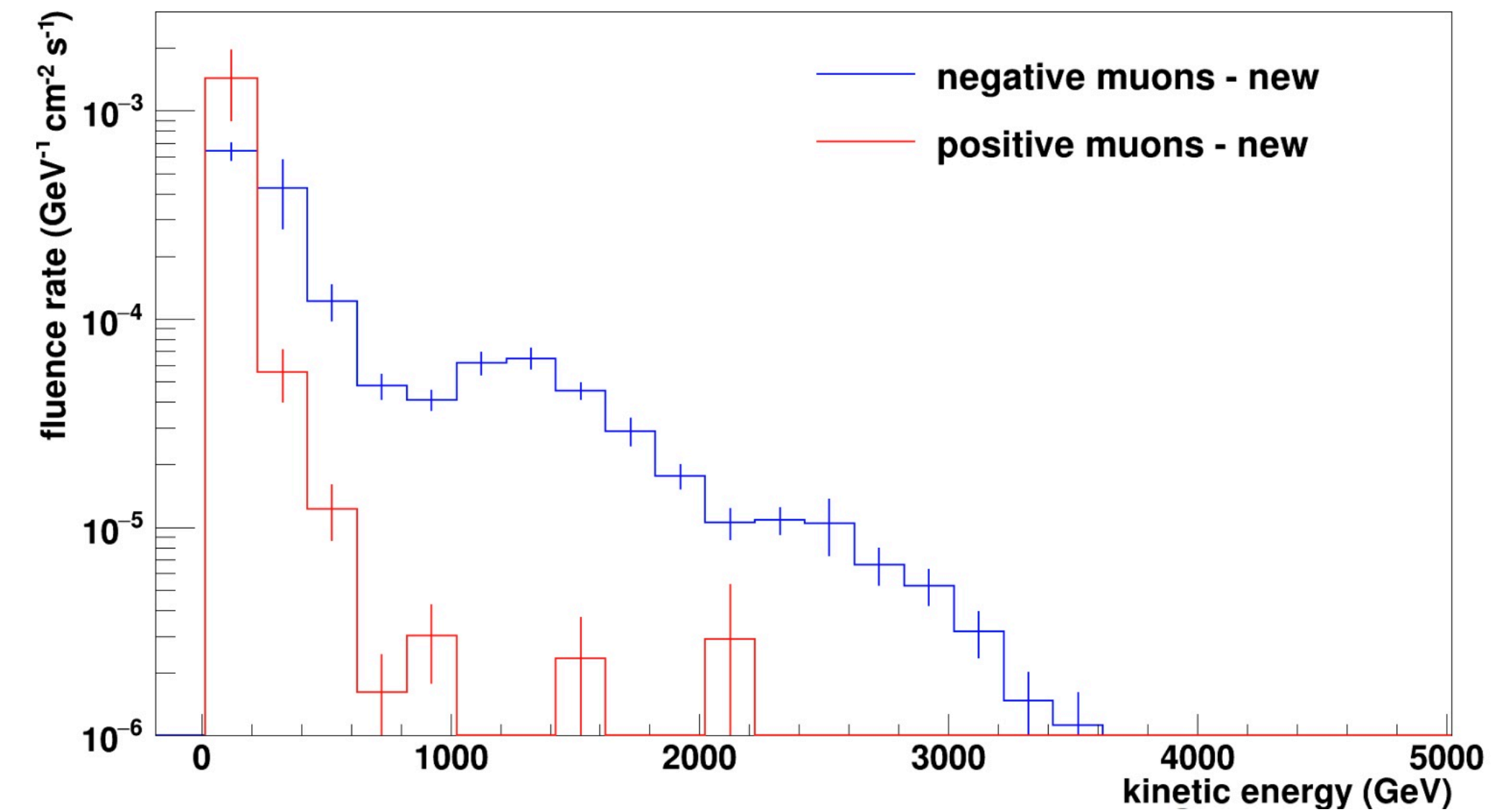


[Foroughi-Abari et al '20]

[FASERv '19]

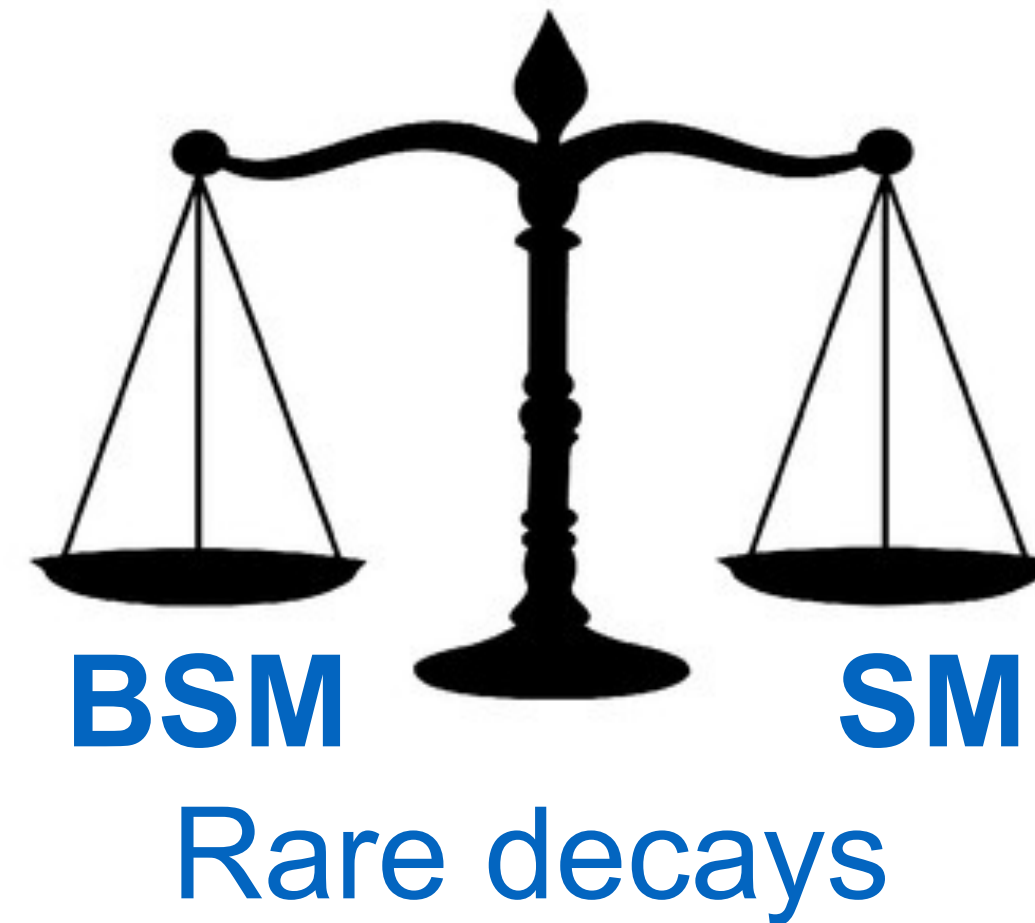


Fluence rate ($\text{GeV}^{-1} \text{cm}^{-2} \text{s}^{-1}$) for muons: 10 GeV threshold



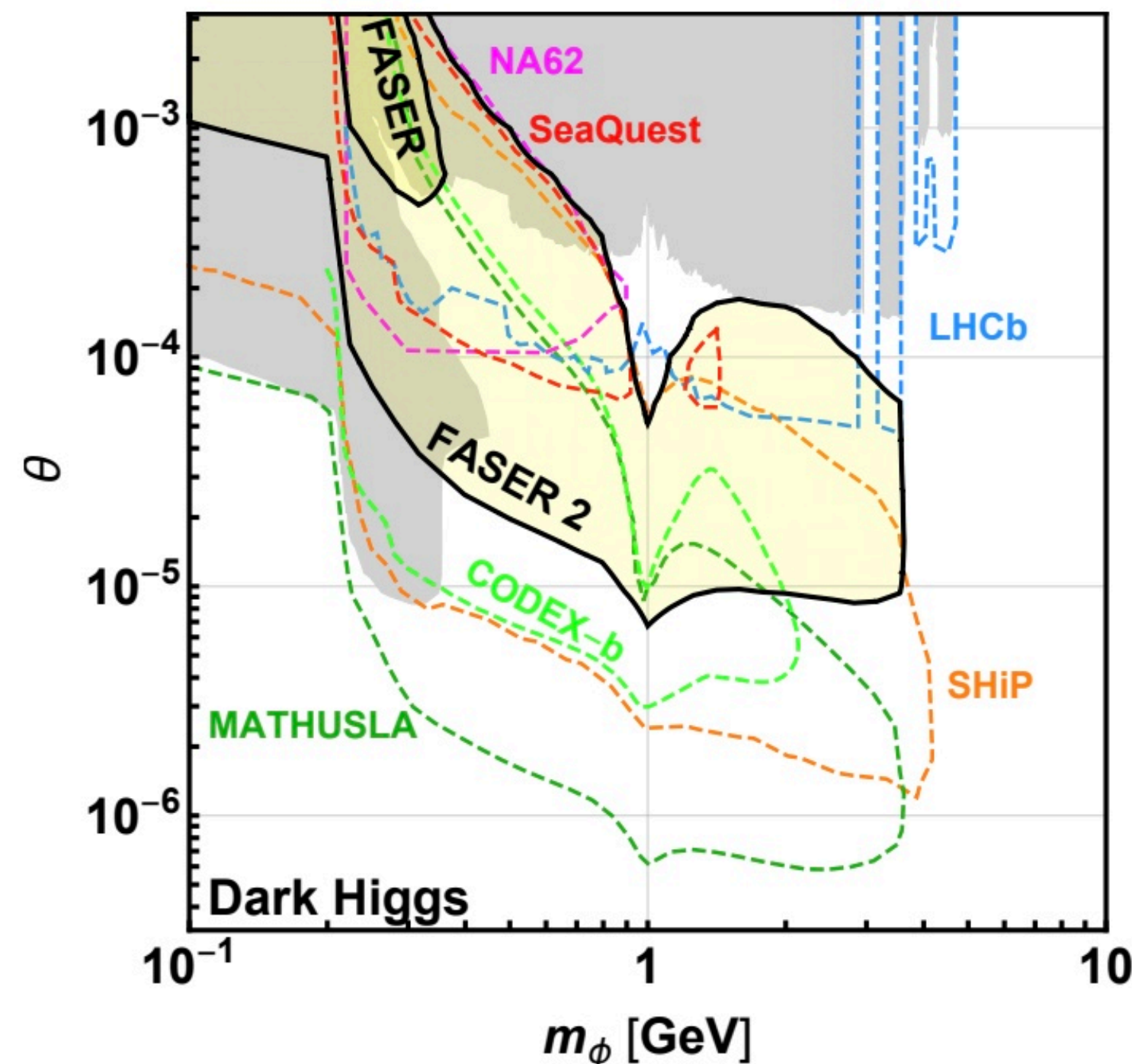
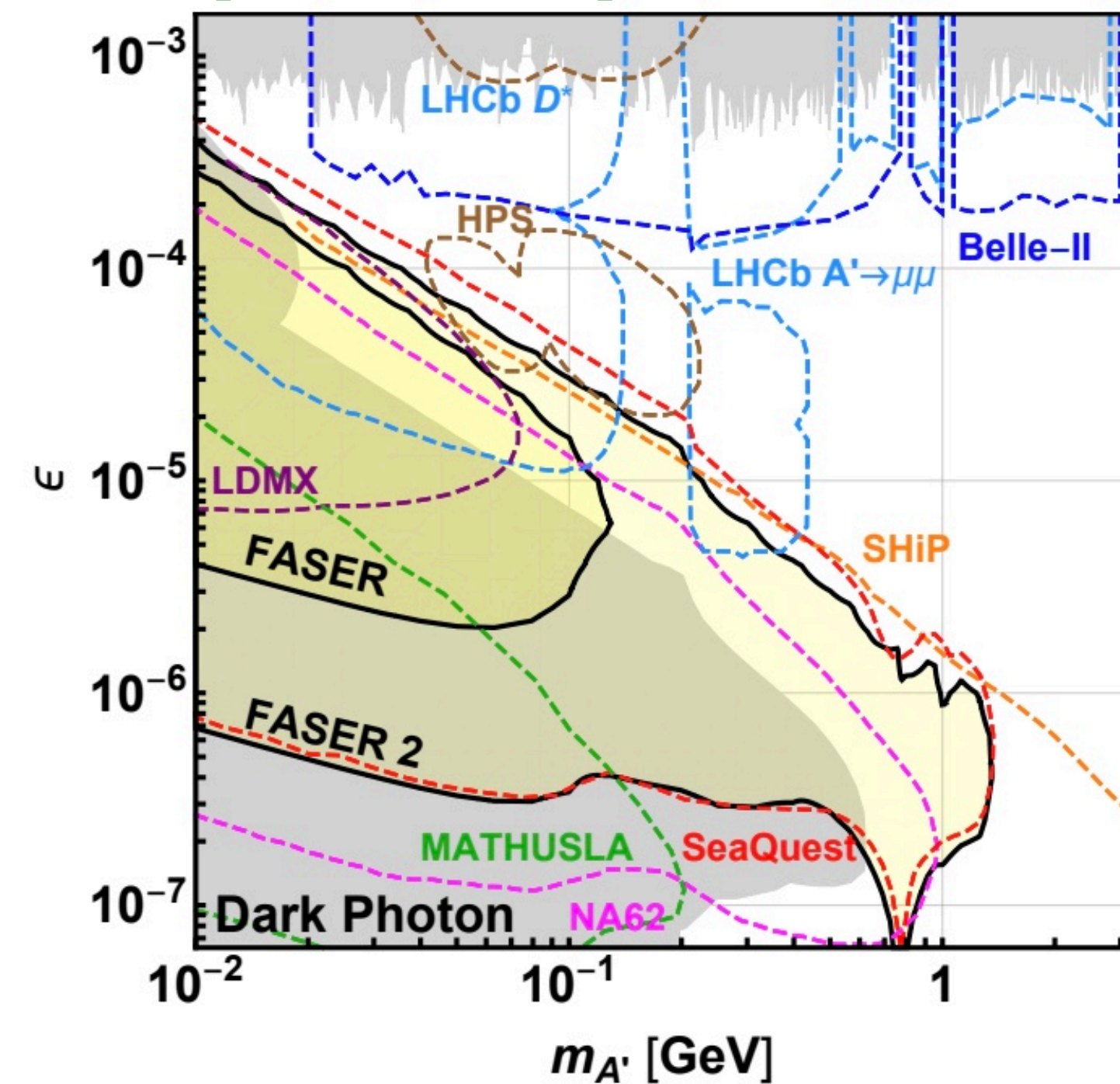
Forward Physics at the FPF

LLPs & mediators

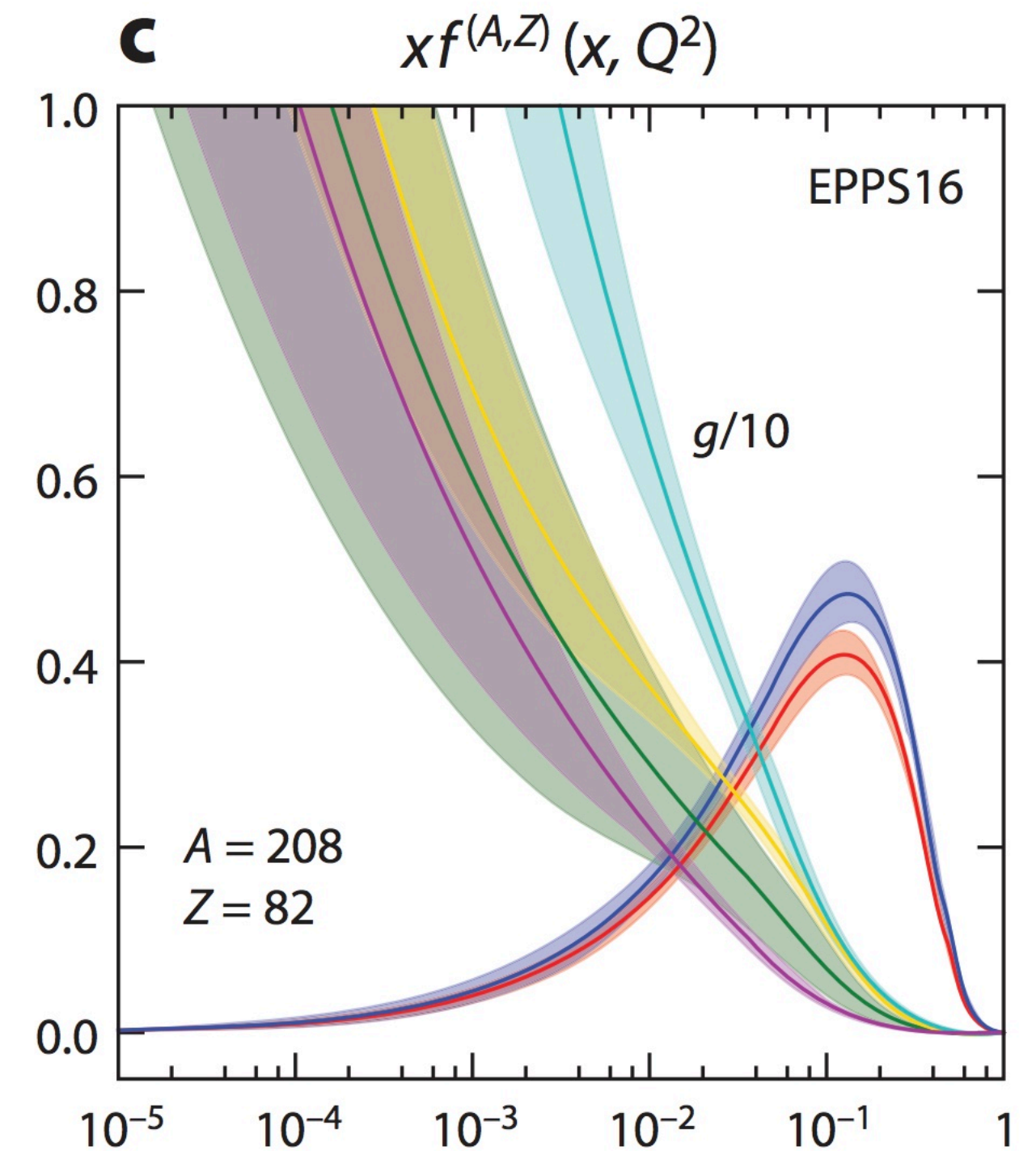


QCD pdfs from ν DIS

[FASER '19]

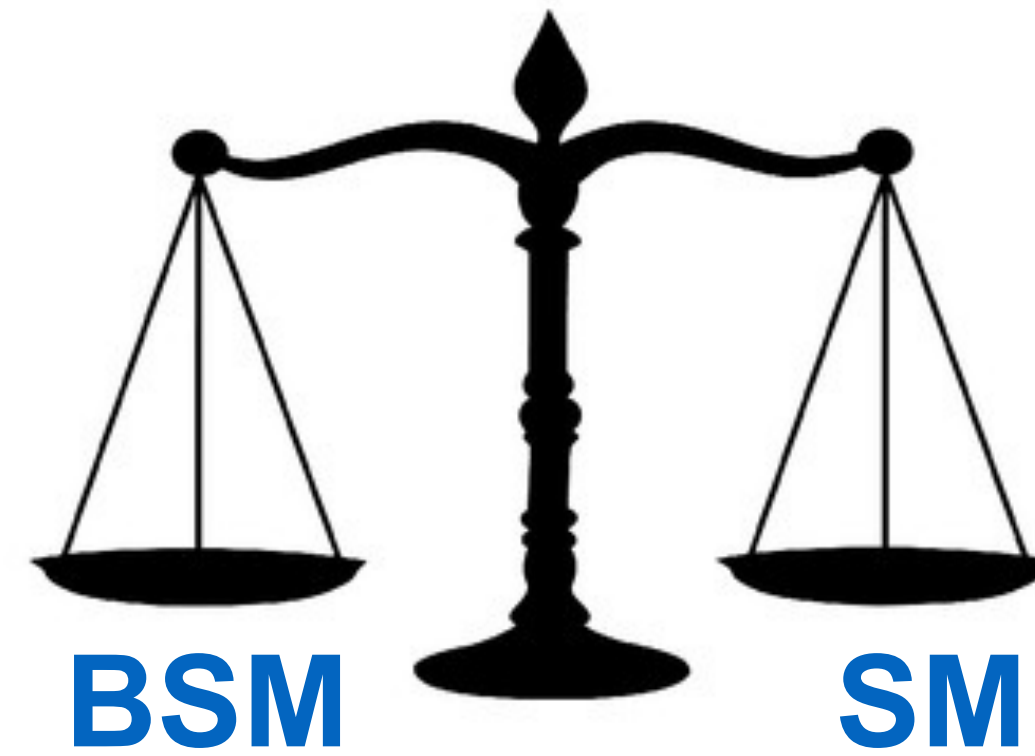


[Ethier & Nocera '20]



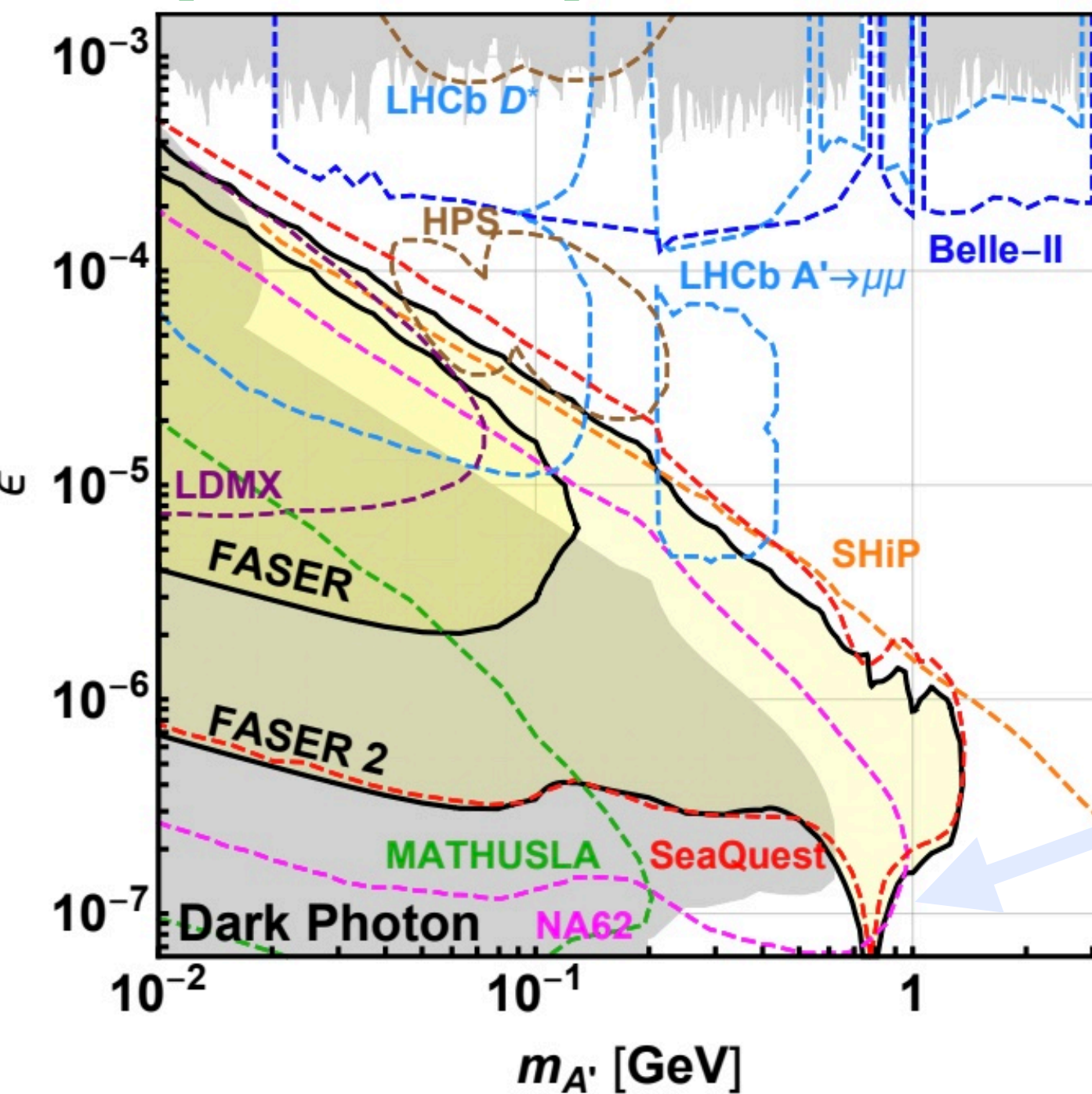
Forward Physics at the FPF

LLPs & mediators



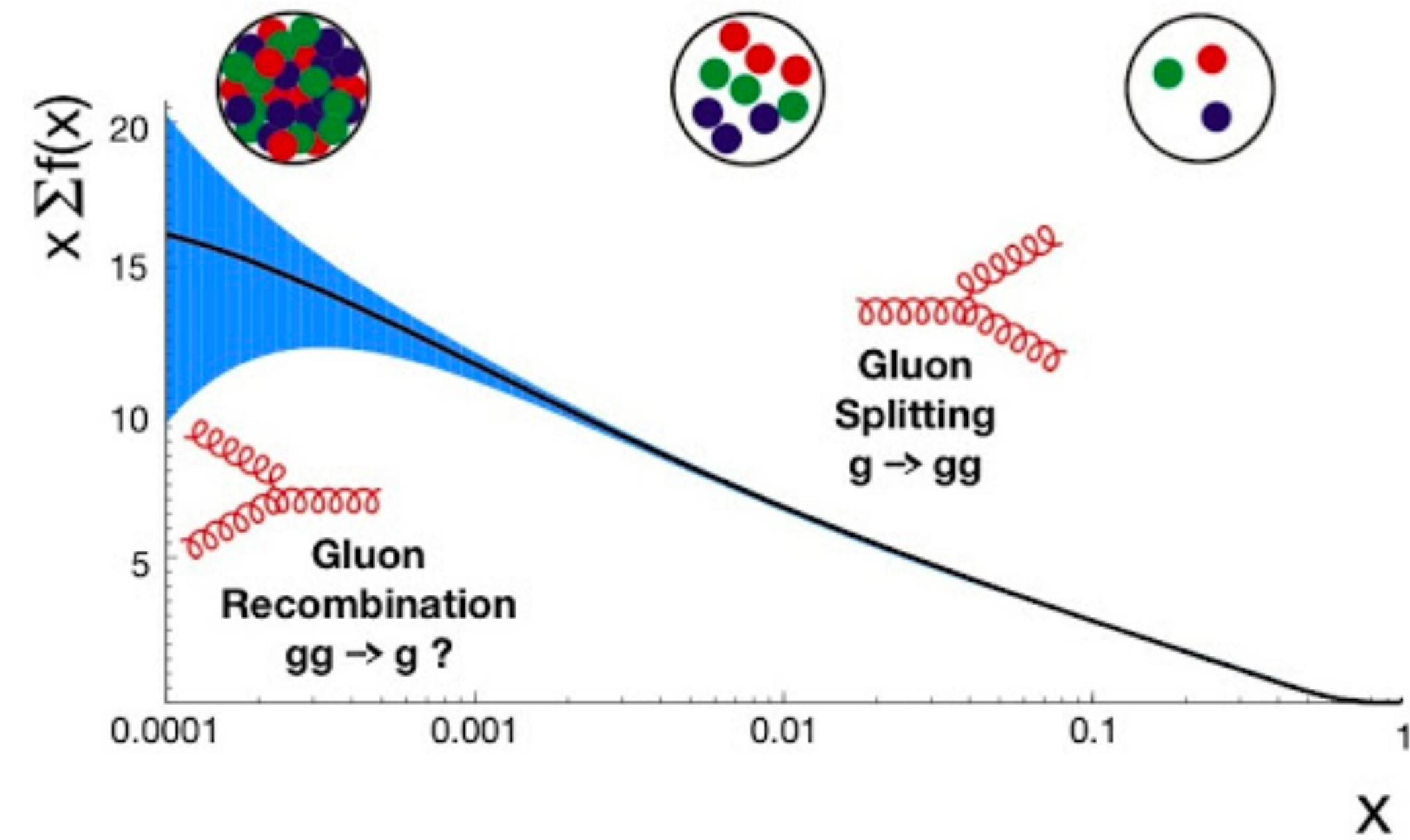
QCD in the forward region

[FASER '19]



Dark mediators

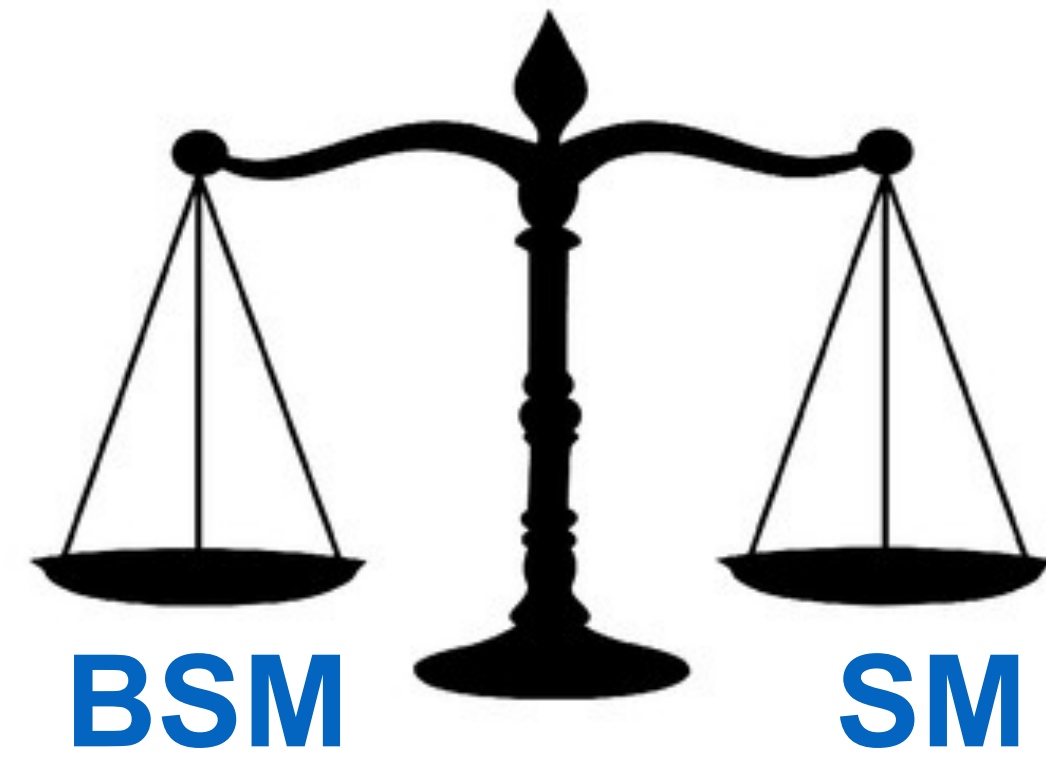
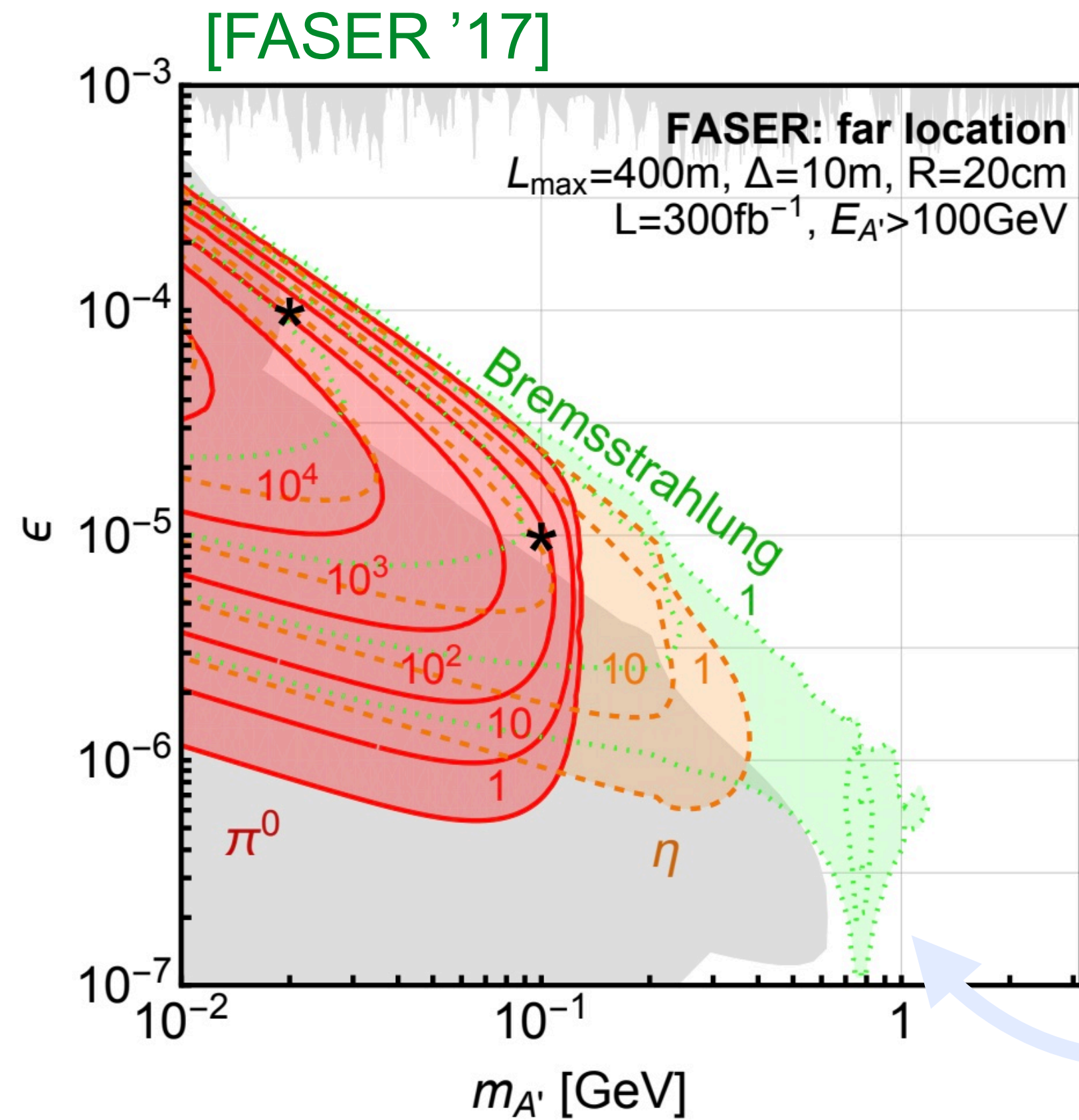
- $10^{18} \pi^0 \rightarrow \gamma A'$
- $10^{16} \eta \rightarrow \gamma A'$
- Bremsstrahlung



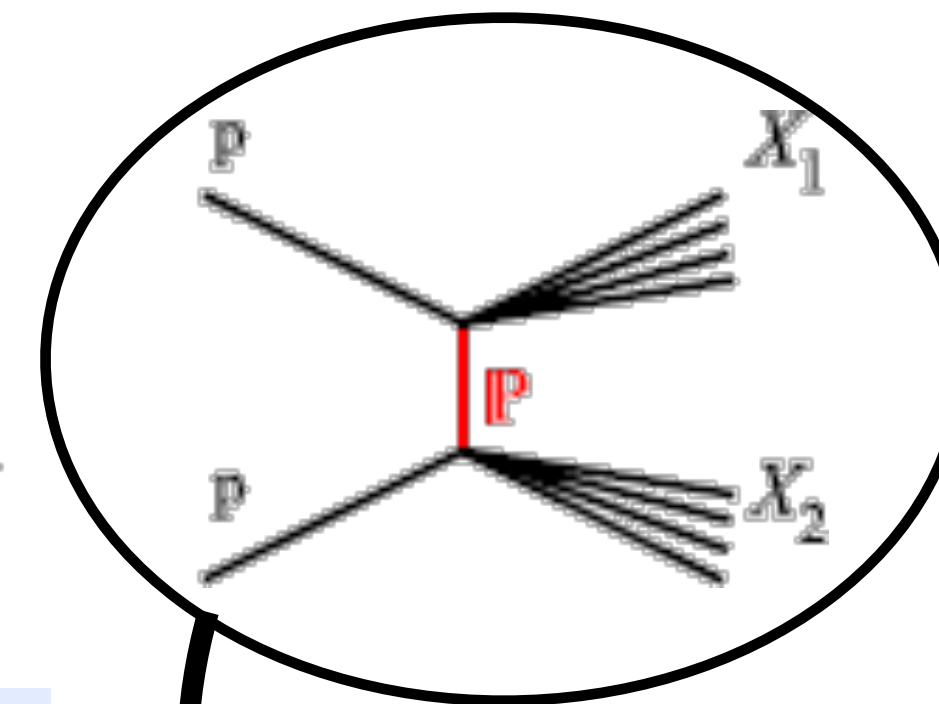
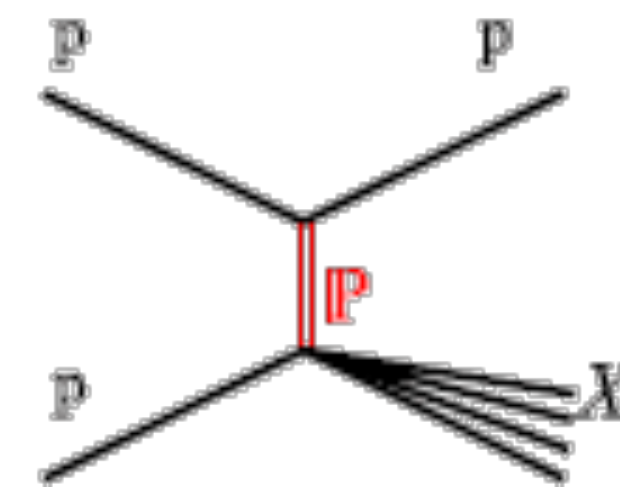
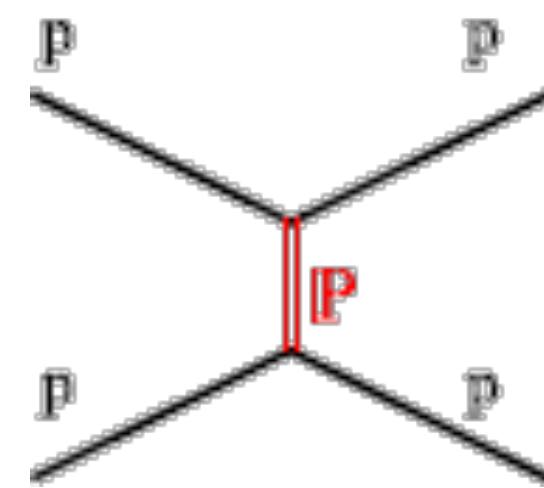
Forward Physics at the FPF



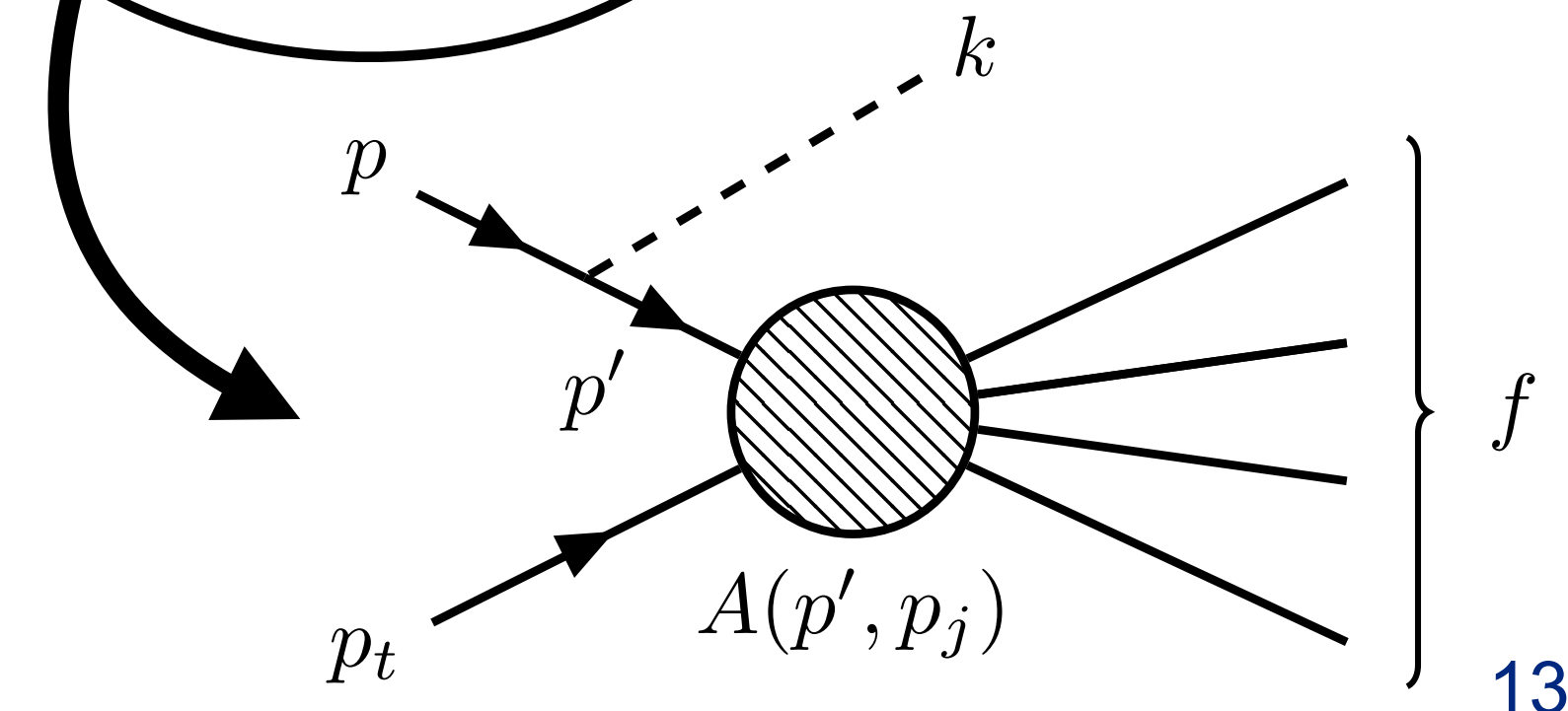
LLPs & mediators



[see talk by S. Foroughi-Abari]



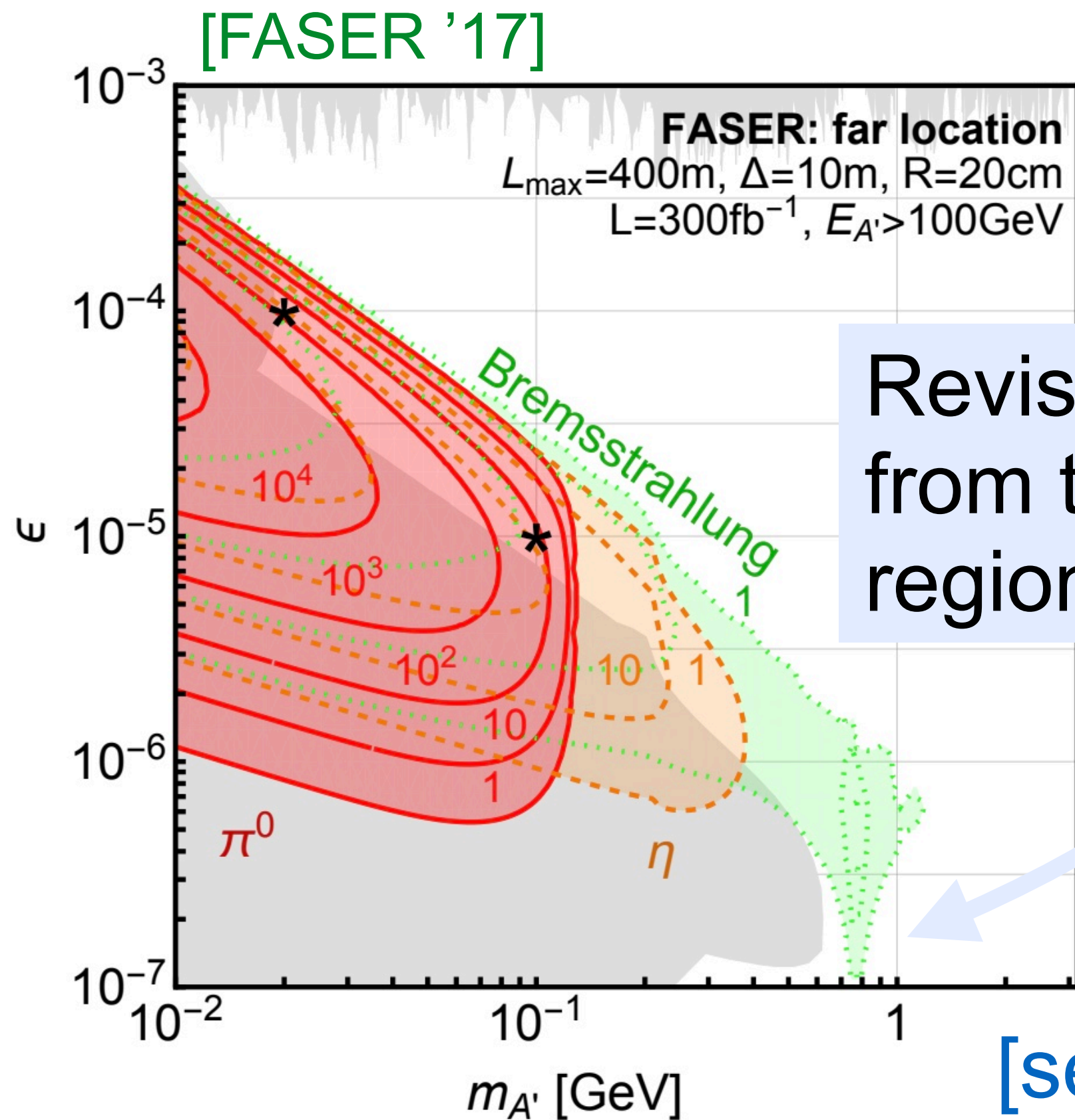
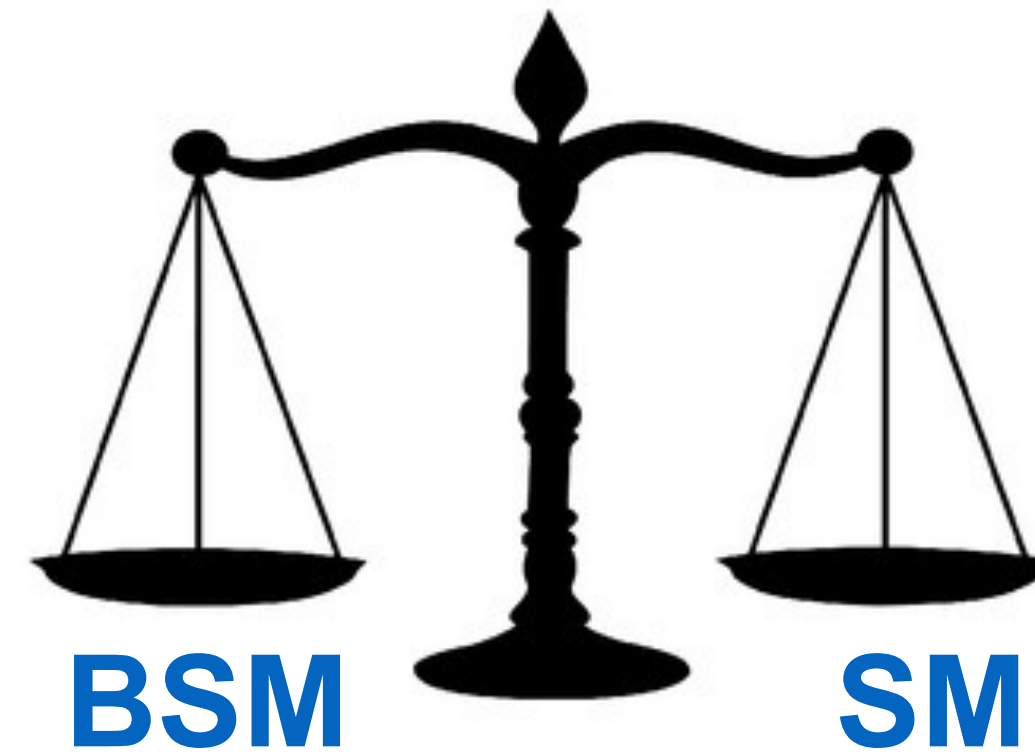
Revisiting A' production from the ρ/ω resonance region



Forward Physics at the FPF



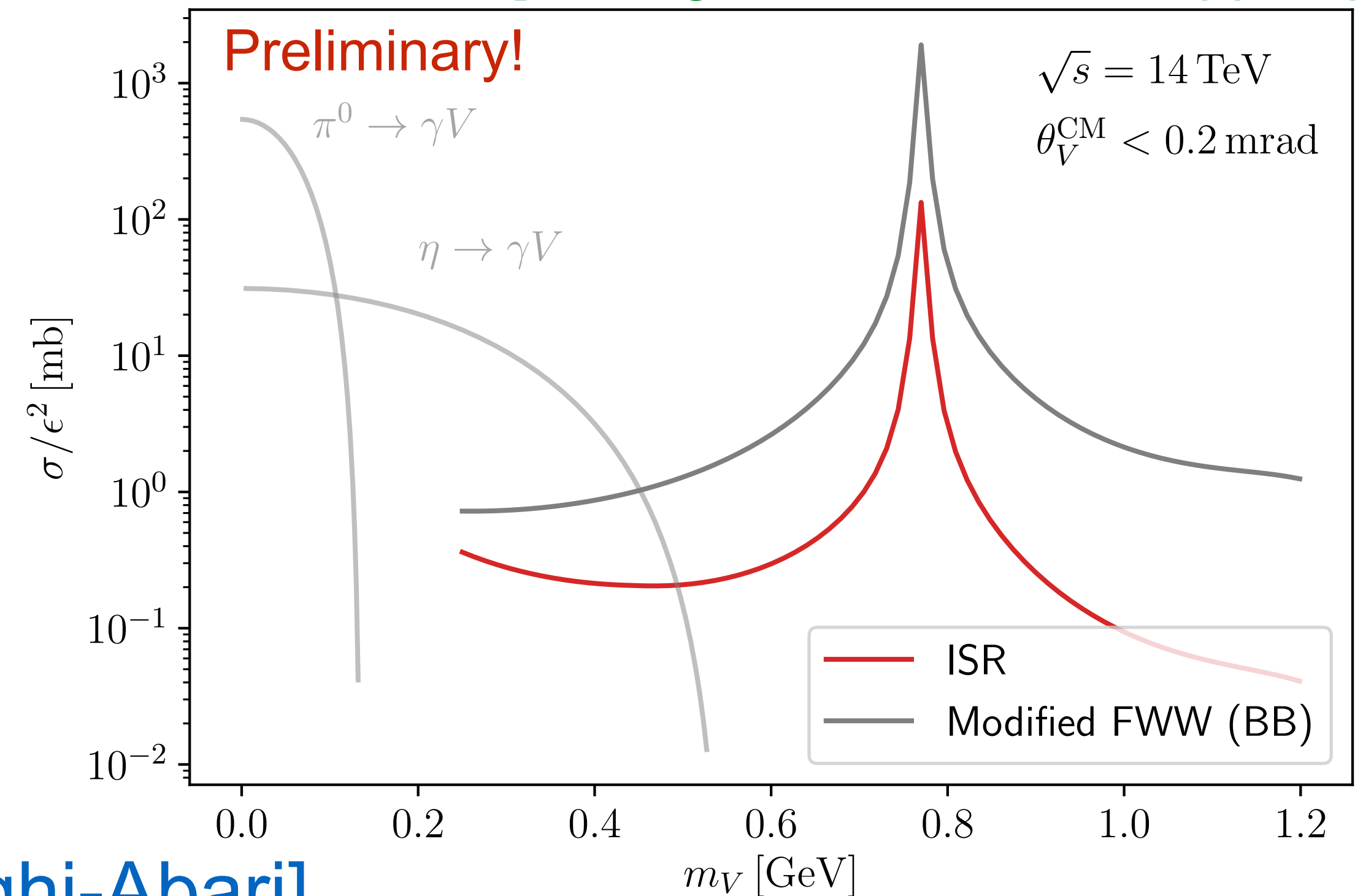
LLPs & mediators



Revisiting A' production from the ρ/ω resonance region

[see talk by S. Foroughi-Abari]

[Foroughi-Abari & AR, to appear]



Outlook

07:00	Neutrino cross-section opportunities at FPF <i>Dr Vishvas Pandey</i> 07:00 - 07:15	
	FPF constraints on Effective Field Theory <i>Zahra Tabrizi</i> 07:20 - 07:35	
	Further Thoughts and Discussion <i>Alexander Friedland</i> 07:40 - 08:00	
08:00	Search for Lepton Flavour Violating Decay at FASER <i>Kento Asai</i>	Semi-hard reactions at the Forward Physics Facility <i>Michael Fucilla</i>
	Searching for anomaly-free gauge bosons at forward phy... <i>Patrick Foldenauer</i>	Hadronic structure at a Forward Physics Facility <i>Dr Francesco Giovanni Celib...</i>
	Crunching dilaton, hidden naturalness <i>Ameen Ismail</i> 08:30 - 08:45	Probing PDFs via Neutrino Scattering with FASER ν <i>Jason Arakawa</i>
	Charming ALPs <i>Christiane Scherb</i> 08:45 - 09:00	LEvEL: Low-Energy Neutrino Experiment at the LHC <i>Kevin Kelly</i>
09:00	Updated projections for FASER2 at the FPF <i>Josh McFayden</i> 09:00 - 09:15	Addressing the cosmic ray muon excess by probing a "fi... <i>Julien Manshanden</i>
	Update from milliQan <i>Matthew Daniel Citron</i> 09:15 - 09:30	Dark Sectors via Proton Bremsstrahlung <i>Saeid Foroughi-Abari</i>
	Neutrino fluxes: 1st contribution <i>Maria Vittoria Garzelli</i> 09:30 - 09:45	
10:00	Small-x prediction for forward charm prediction <i>Anna Stasto</i> 09:50 - 10:05	
	Further Thoughts and Discussion <i>Rikard Enberg</i> 10:10 - 10:30	
	Forward charm production and intrinsic charm in the nucleon: constraints from the IceCube Neutrino Observatory and ... <i>Rafal Maciula</i>	
11:00	Towards Intrinsic Charm exploration at the FPF: CTEQ PDFs and intrinsic charm <i>Marco Guzzi</i> 10:50 - 11:05	



- FPF at the HL-LHC provides a unique combination of BSM + SM opportunities:
- sub-GeV new physics (LLPs, light DM, MCPs, other)
 - TeV neutrino interactions
 - Forward QCD, MC validation, neutrino DIS
 - TeV muons
 - Cosmic ray physics
 - More...