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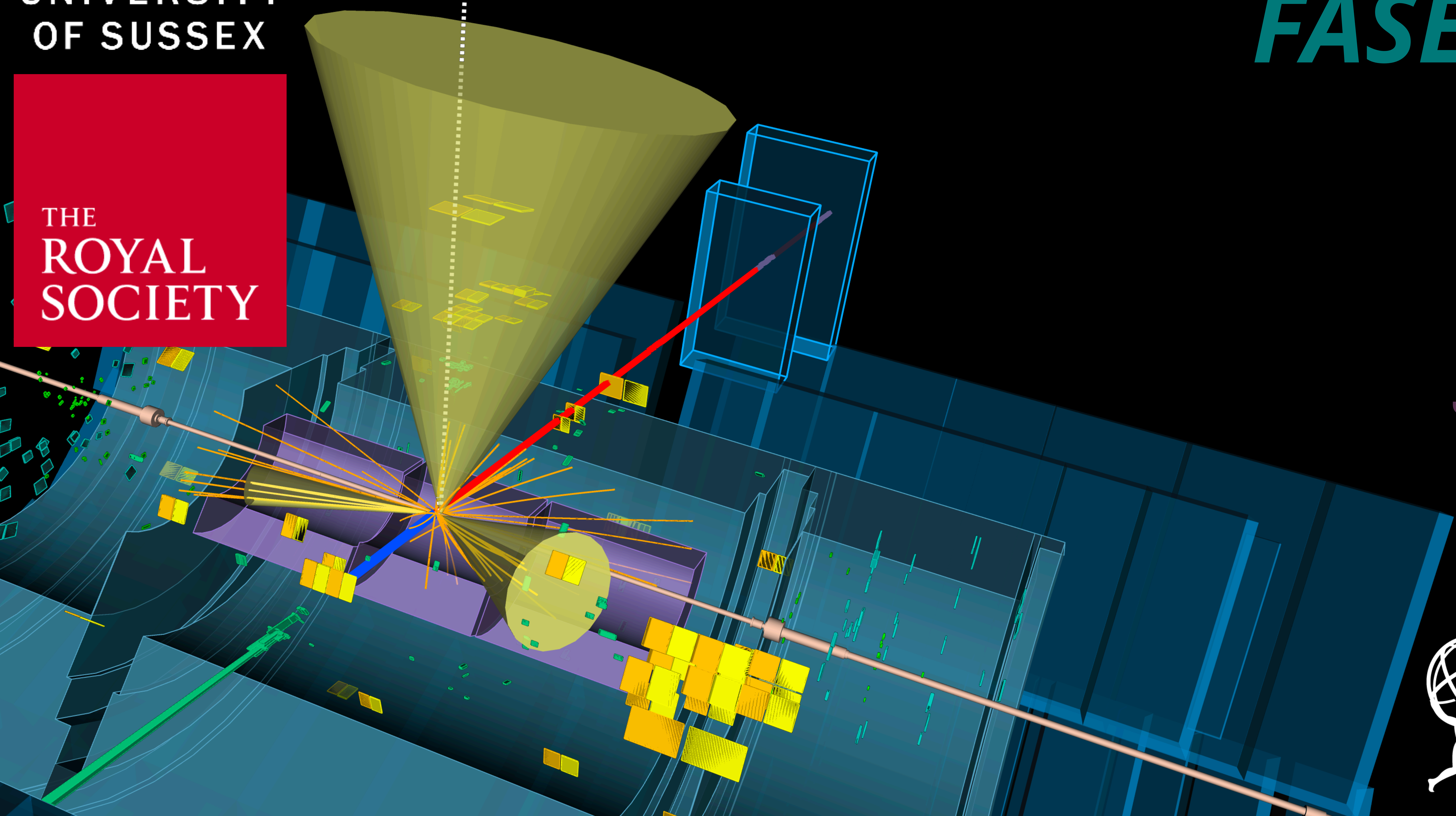

FASER and FASER2+FPF

Sussex EPP
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Josh McFayden

@JoshMcFayden

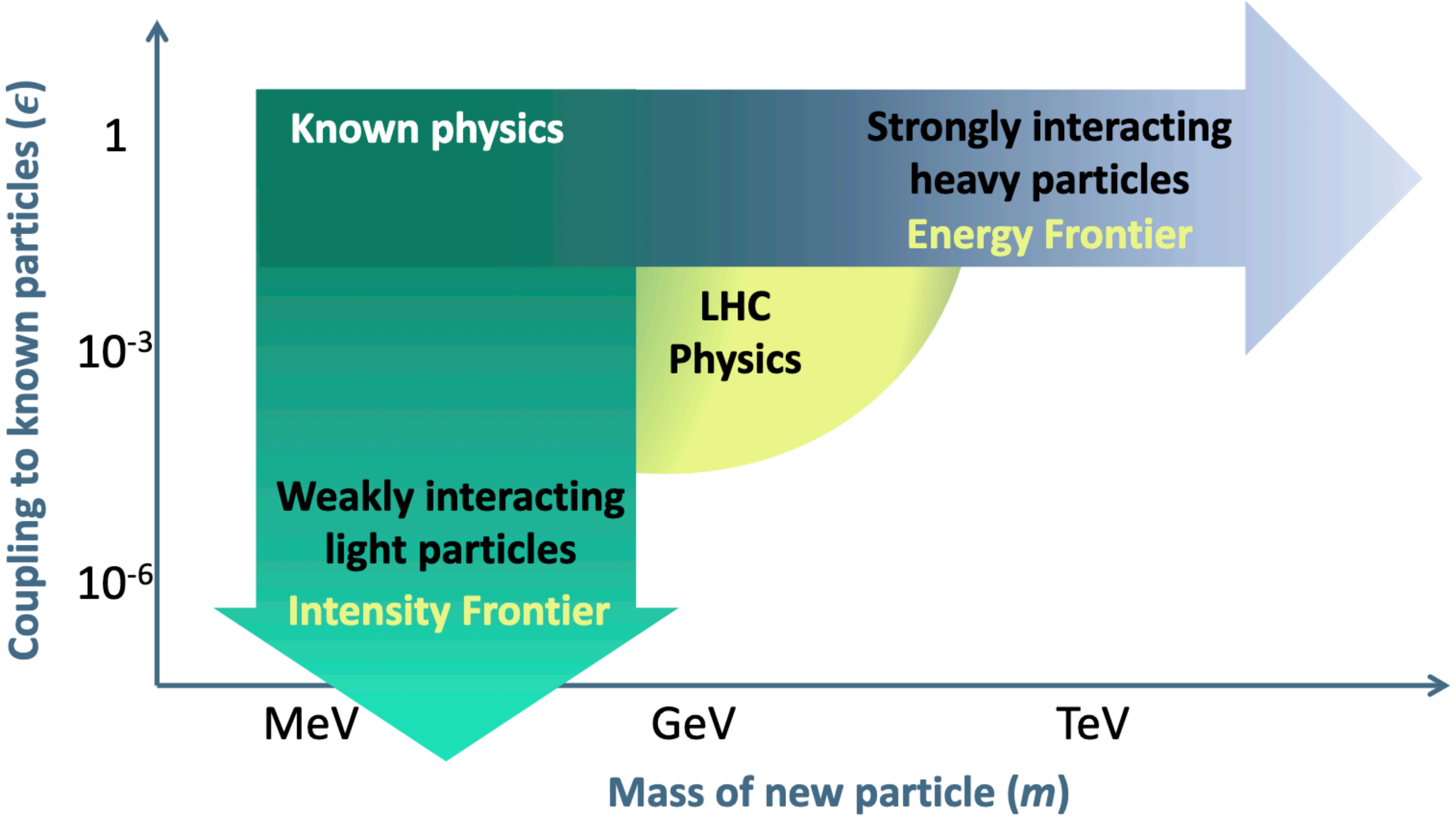
cern.ch/mcfayden

ATLAS EXPERIMENT

Light Weak DM Motivation

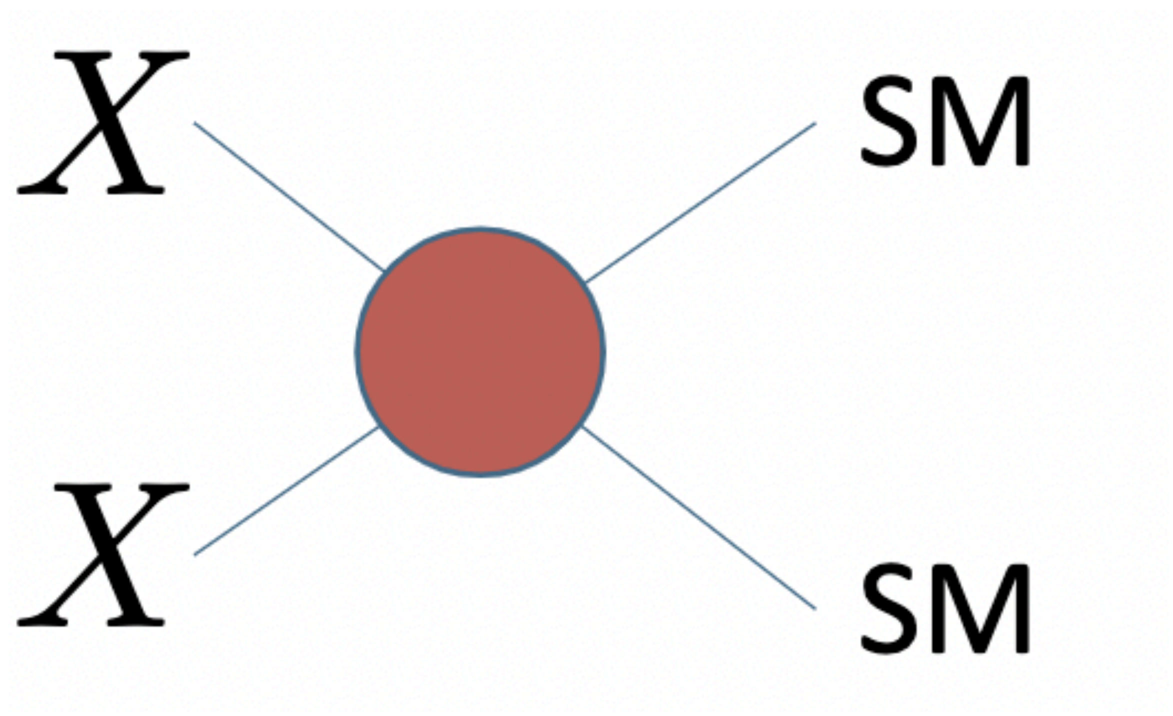
- The **LHC experiments** are producing incredible results, extending reach to more extreme phase-spaces and performing increasingly precise measurements.

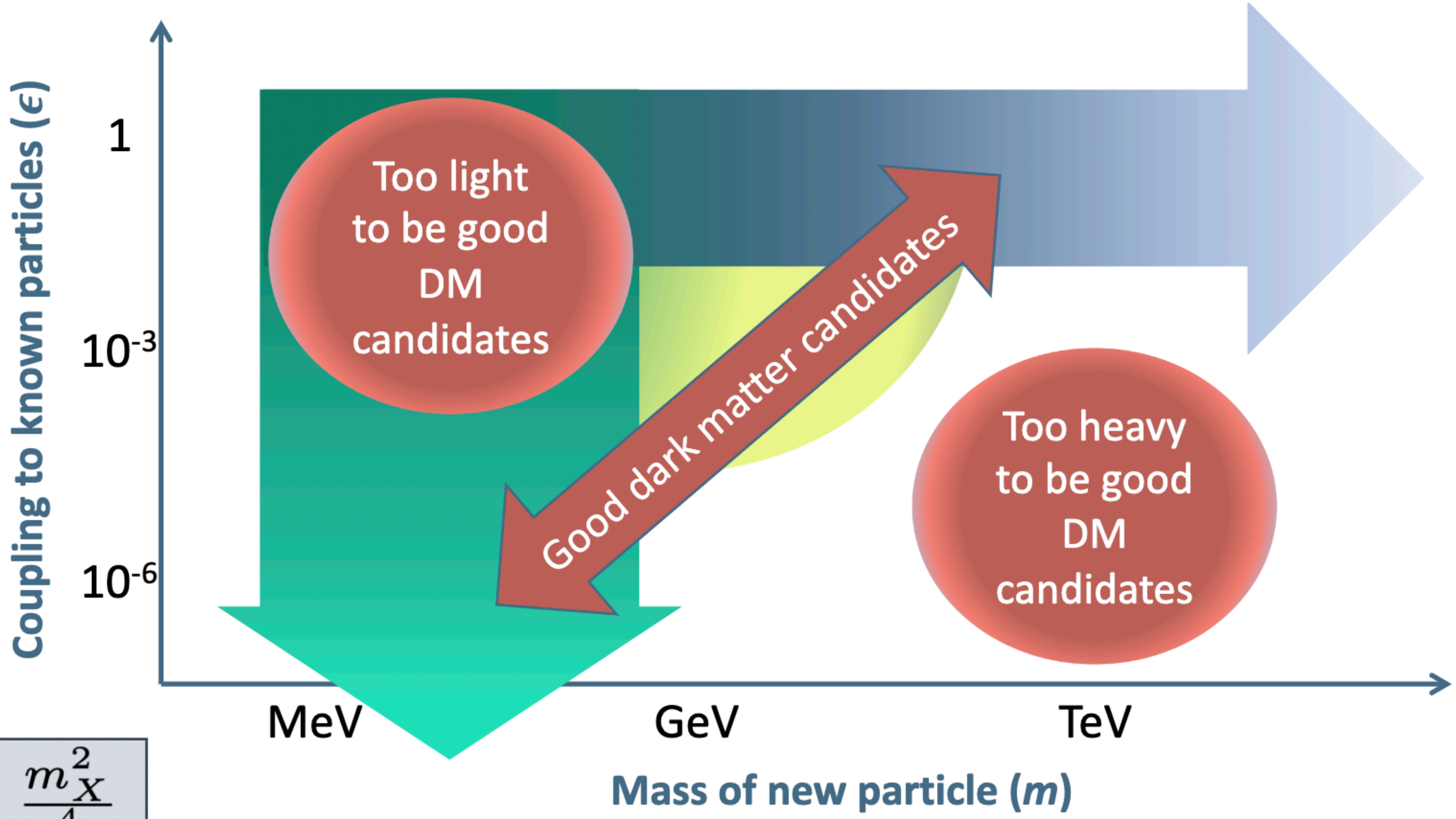
- But the lack of any observation of BSM physics motivates **looking elsewhere** too.



Light Weak DM Motivation

- Main region of interest is for new particles that satisfy DM relic density requirements.

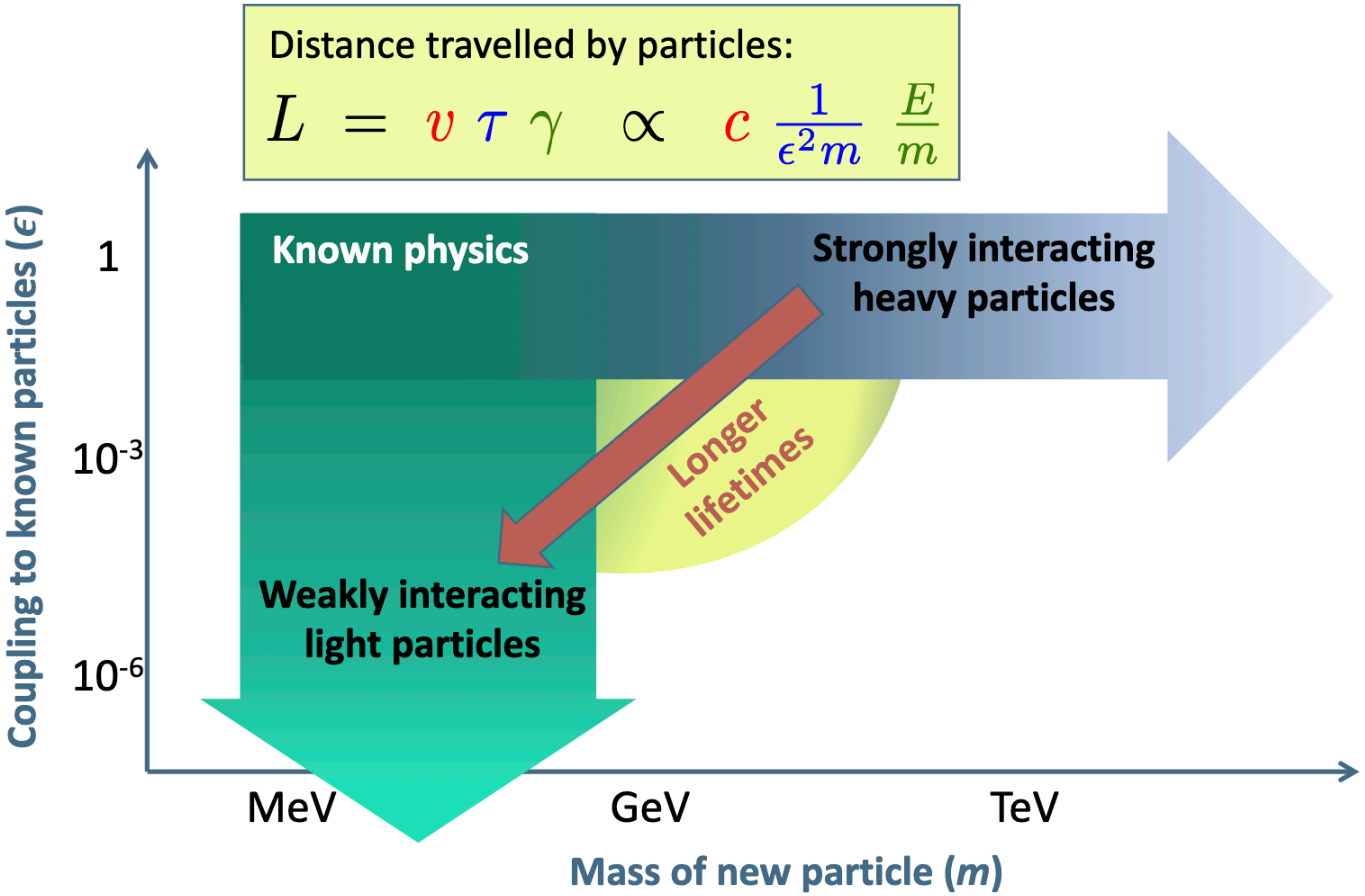




Surviving DM density: $\Omega_X \propto \frac{m_X^2}{\epsilon_X^4}$

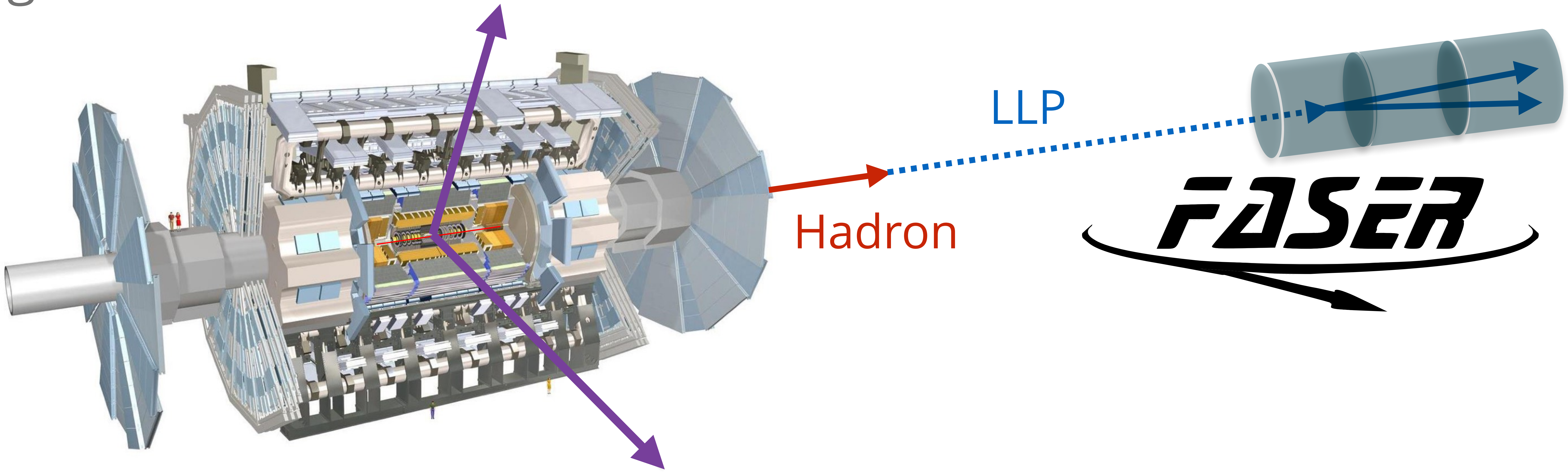
Light Weak DM Motivation

- One of the defining characteristics of weakly interacting light particles is their **long lifetime**.
- Distinct signatures
- But could still be produced in large numbers in hadron decays at ATLAS!



LDM | FASER

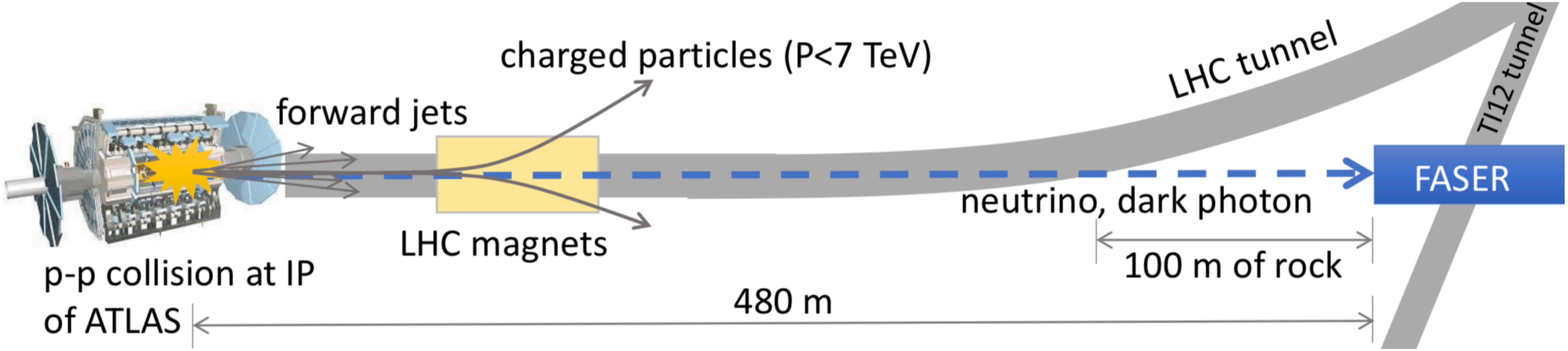
- FASER is a new experiment at CERN!
  - Data-taking starts in Run 3



- Detector is 480m from ATLAS IP1
  - Directly in line with beam collision axis.
  - Transverse radius of only 10cm covering the mrad regime (η>9.1)
- Inelastic pp cross section is huge → 10^{16} collisions in Run 3 → 10^{17} π, 10^{13} B
  - From only 10^{-8} of solid angle 1% of π_0s are in acceptance.

FASER Location

- The TI12 service tunnel just happens to be in just the right place for FASER:



- Old SPS → LEP tunnel
  - On line-of-sight (with some digging)
  - Shielded by ~100m rock/concrete
  - Low beam backgrounds
    - Charged particles bent by LHC magnets

FASER Location

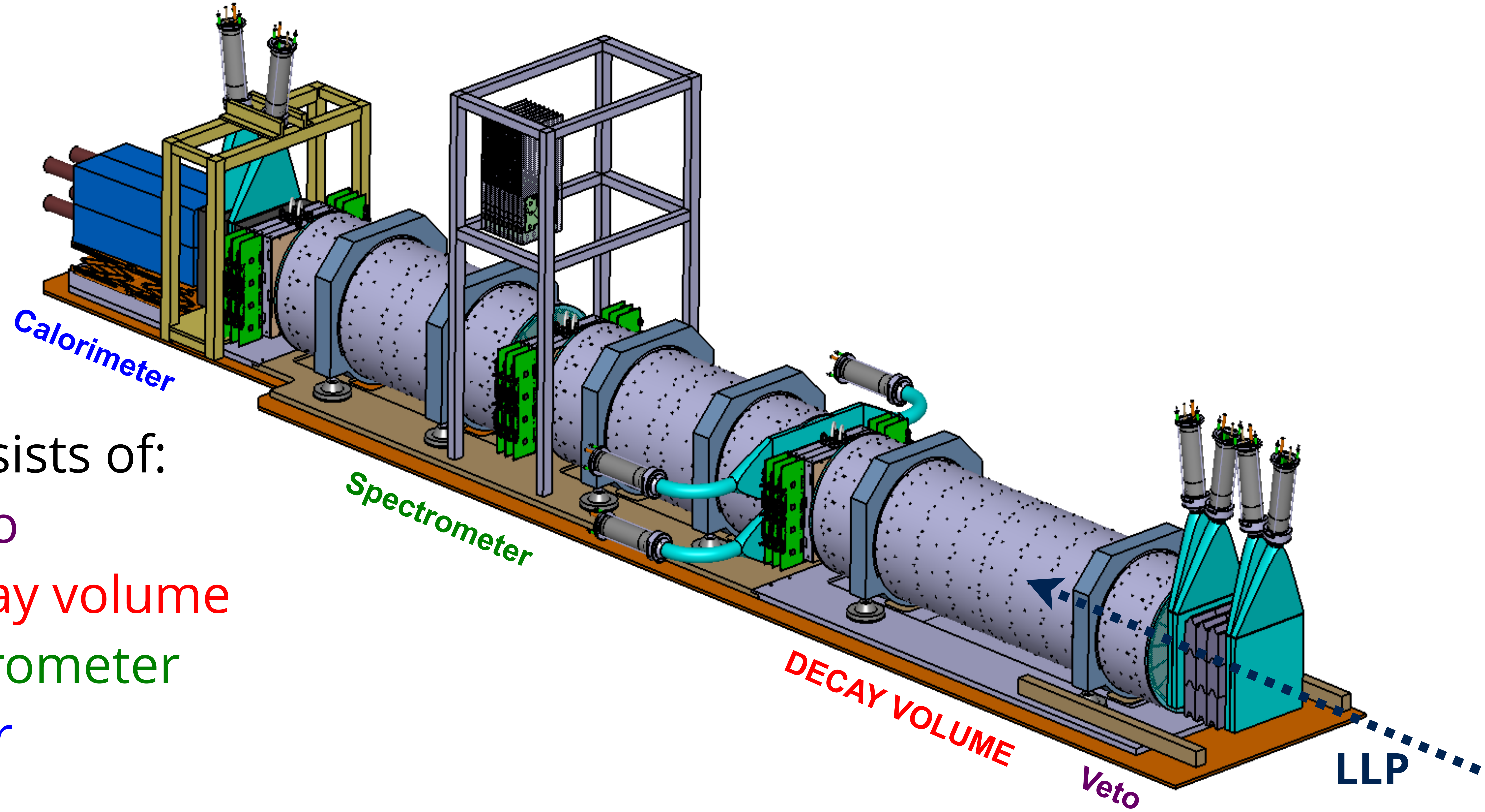
- In relation to ATLAS at Point 1

FASER Now Installed!

FASER Now Installed!

FASER Now Installed!

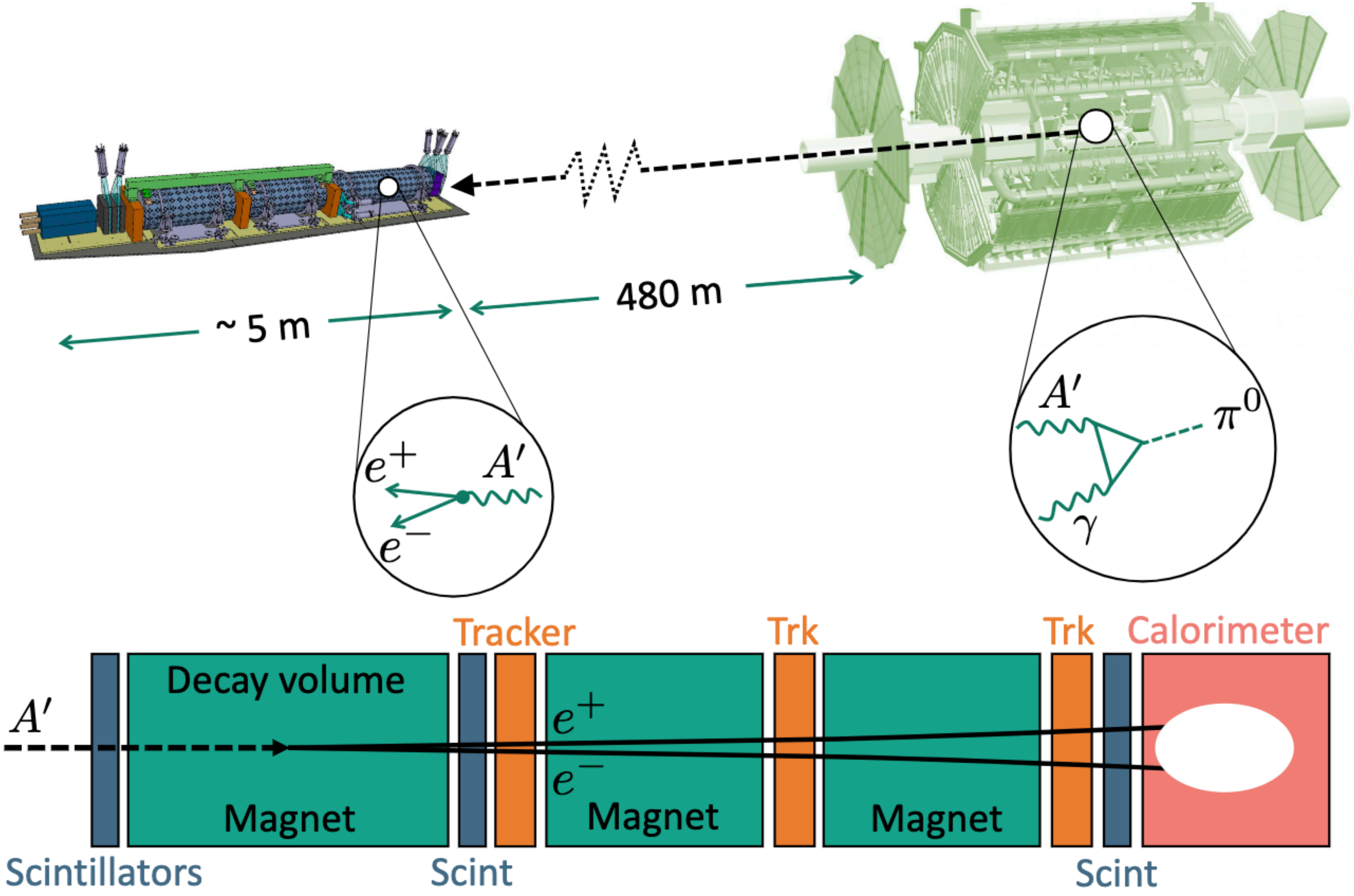
FASER Detector



The detector consists of:

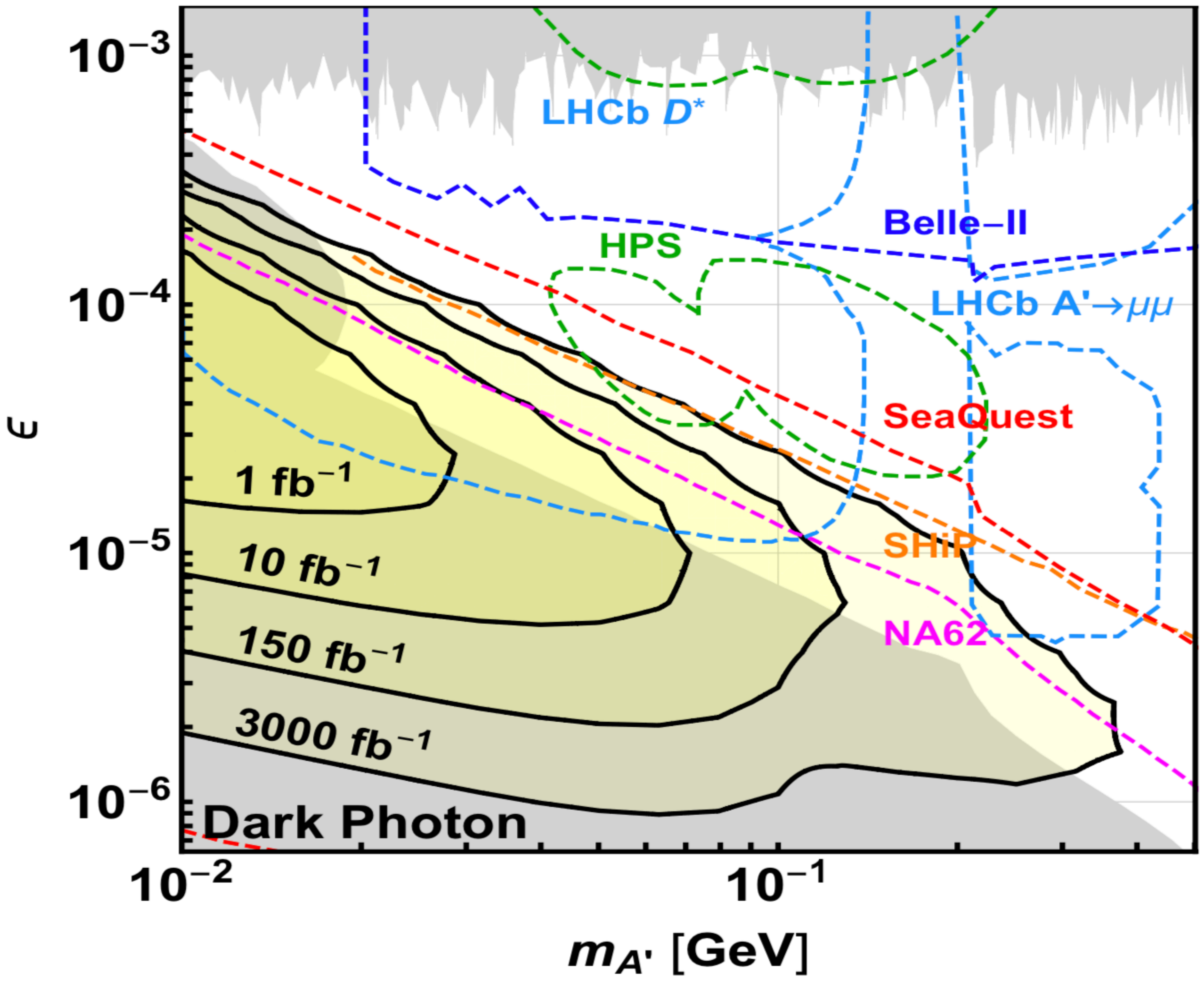
- Scintillator veto
- 1.5m long decay volume
- 2m long spectrometer
- EM calorimeter

Target scenarios | Dark photon



Target scenarios | Dark photon

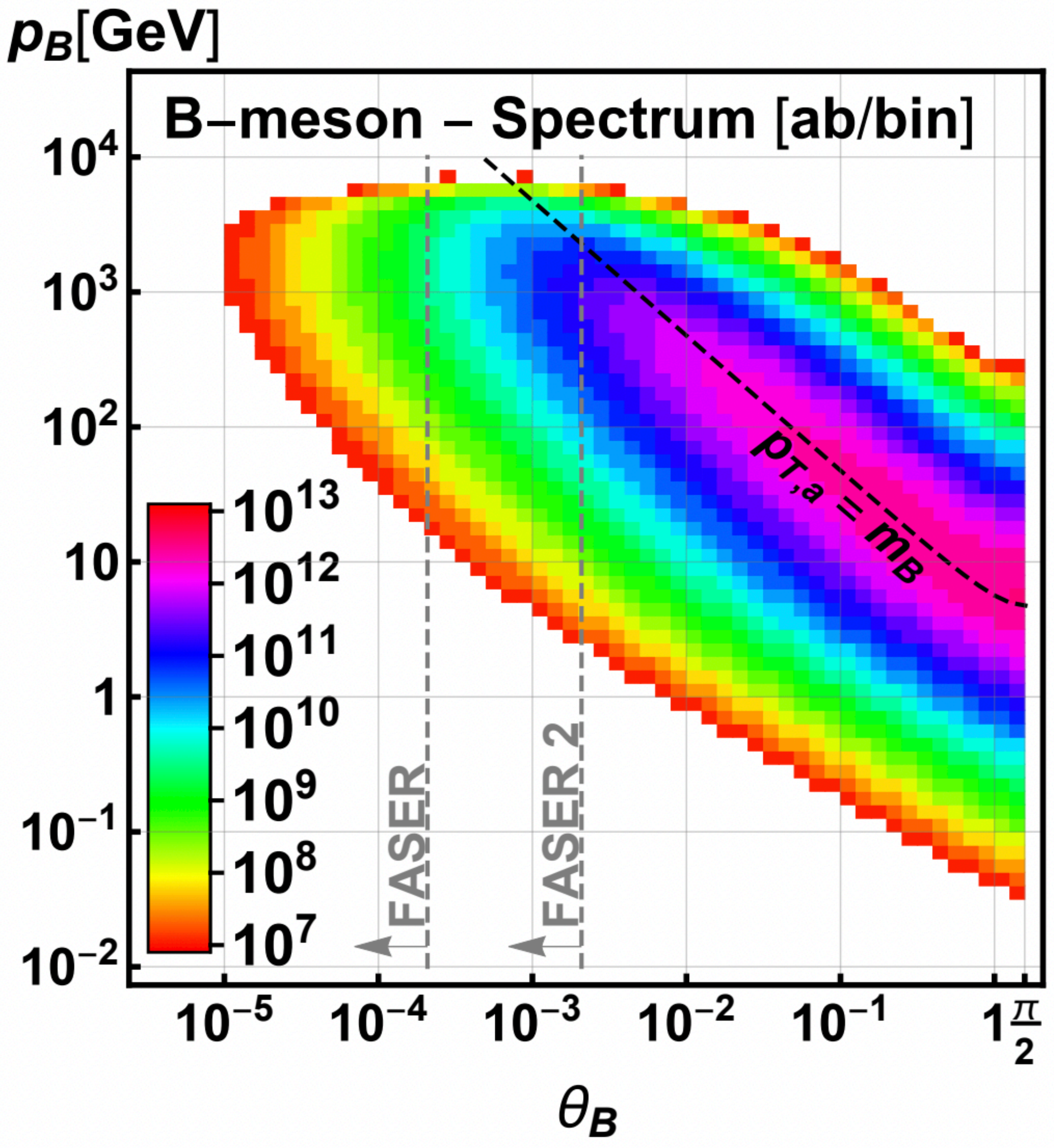
- Expected sensitivity of FASER for **dark photons**
- Detector signature:
  - A' → e+e-
  - Charged tracks appearing in decay volume
  - Opposite charges separate through detecto
  - Significant energy deposit in calorimeter
- Sensitivity
  - Considers all production channels
    - Assumes no background, requires N=3 events
  - Reach limited by decay length (high ε) and production rate (low ε)



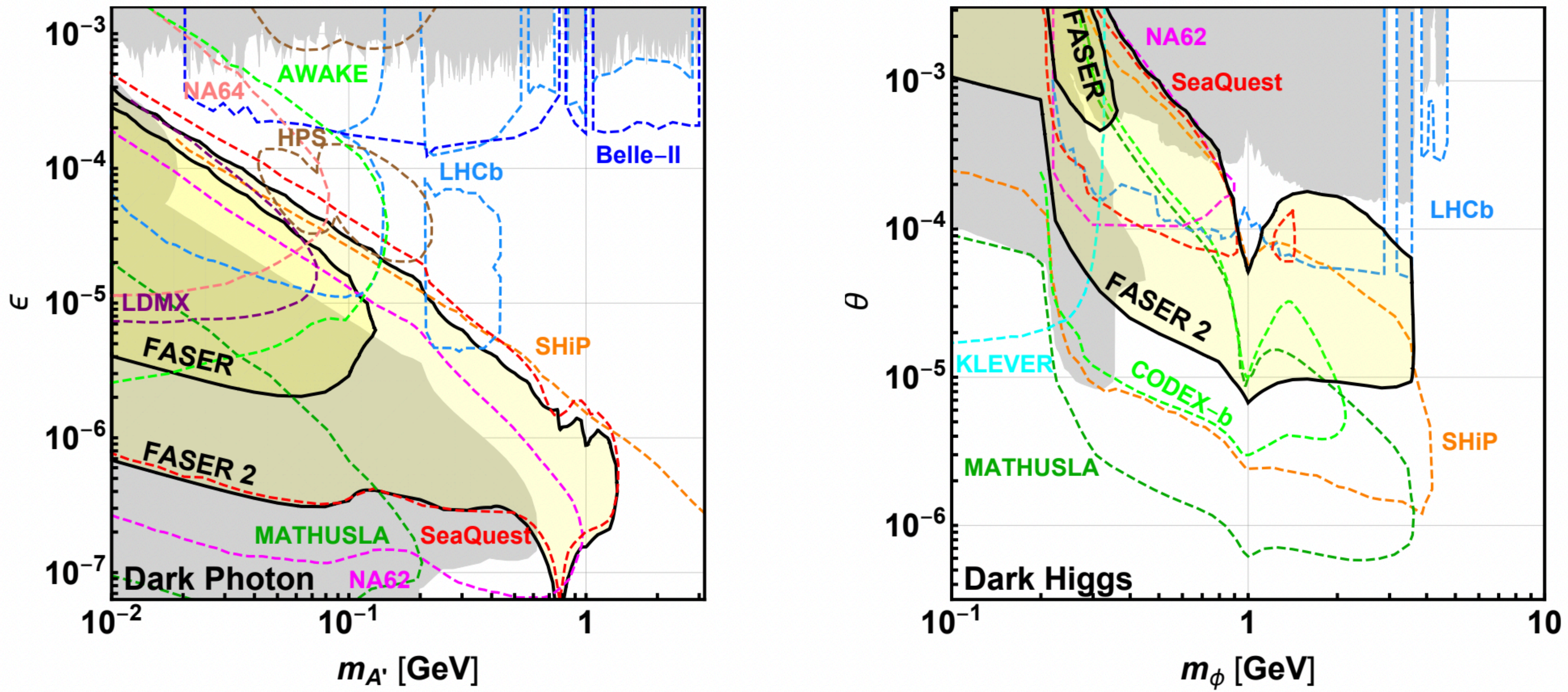
- **New parameter space probed with just 1 fb^{-1} in 2022**

FASER Upgrade for HL-LHC?

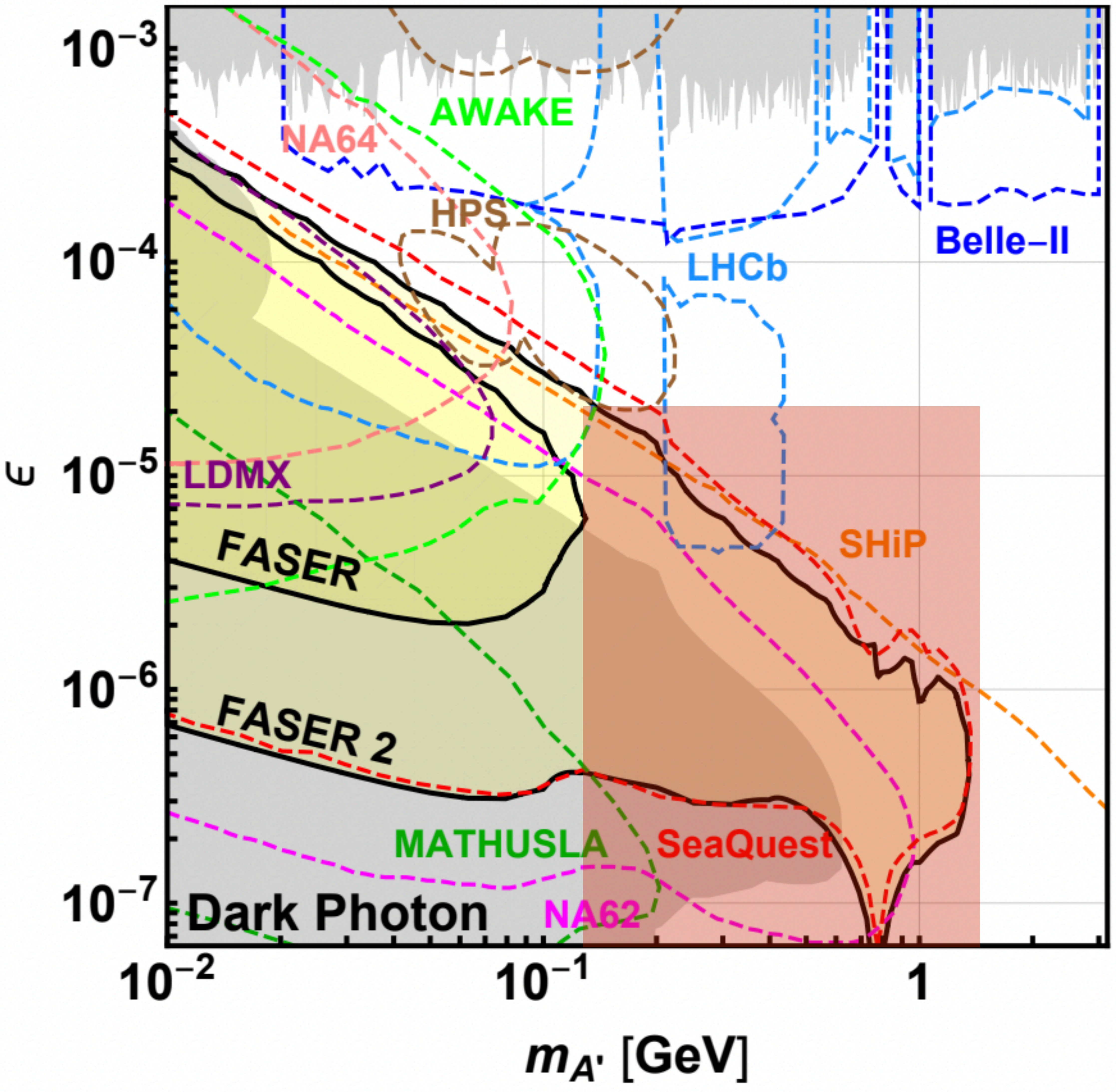
- The existing FASER experiment is already set to probe new phase space.
- But FASER's size is heavily constrained by the available space underground
- The potential reach with an enlarged detector "FASER2" is under study
  - Decay Volume: Length=5m, Diameter=2m
- 4 orders of magnitude improvement in Reach
  - Angular acceptance of of all neutral pions:
    - 0.6% in FASER
    - 10% in FASER2
  - Improves sensitivities to LLPs produced in decays of heavy mesons
  - Improves sensitivity to larger LLP masses

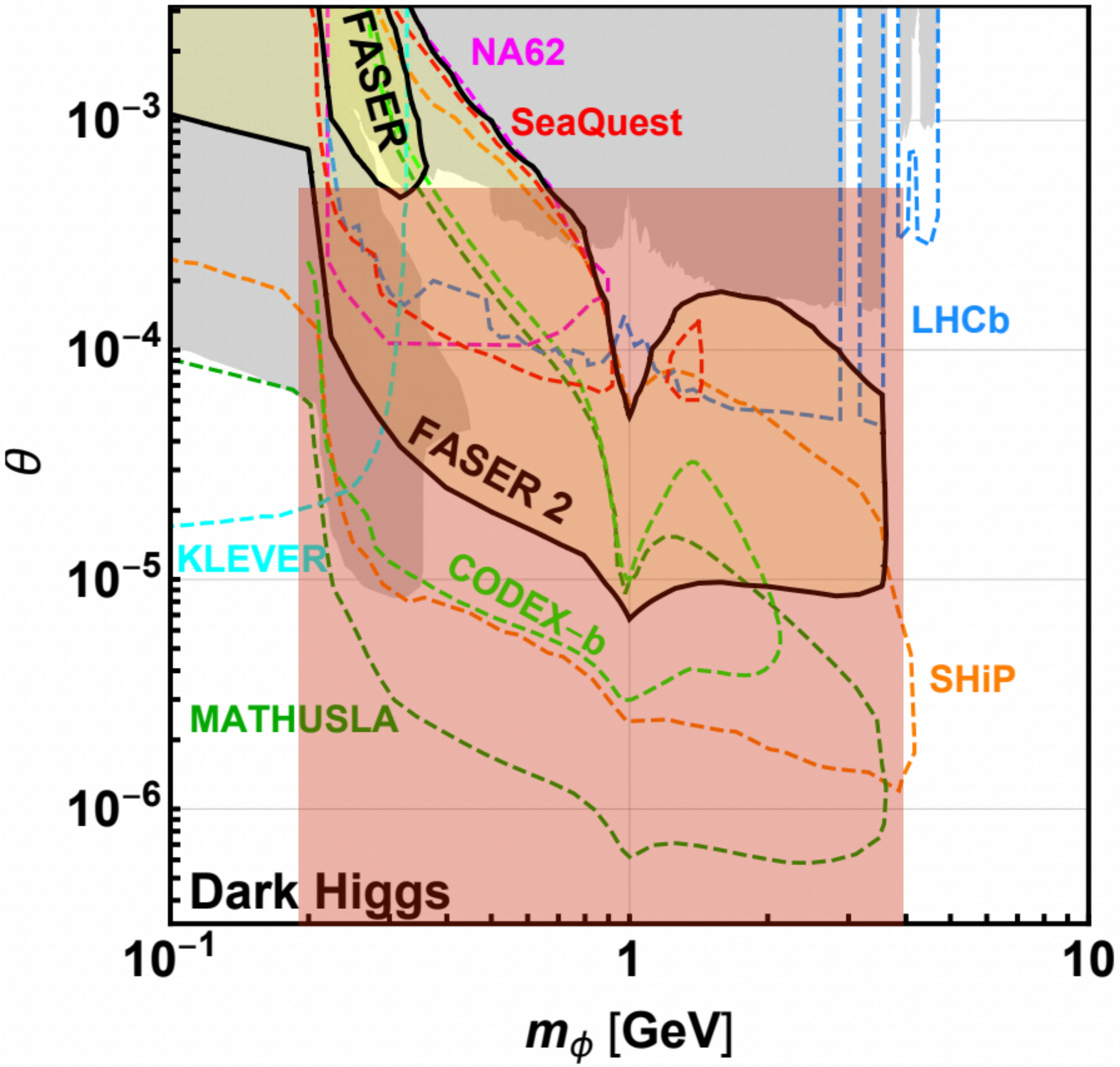


FASER2 Reach

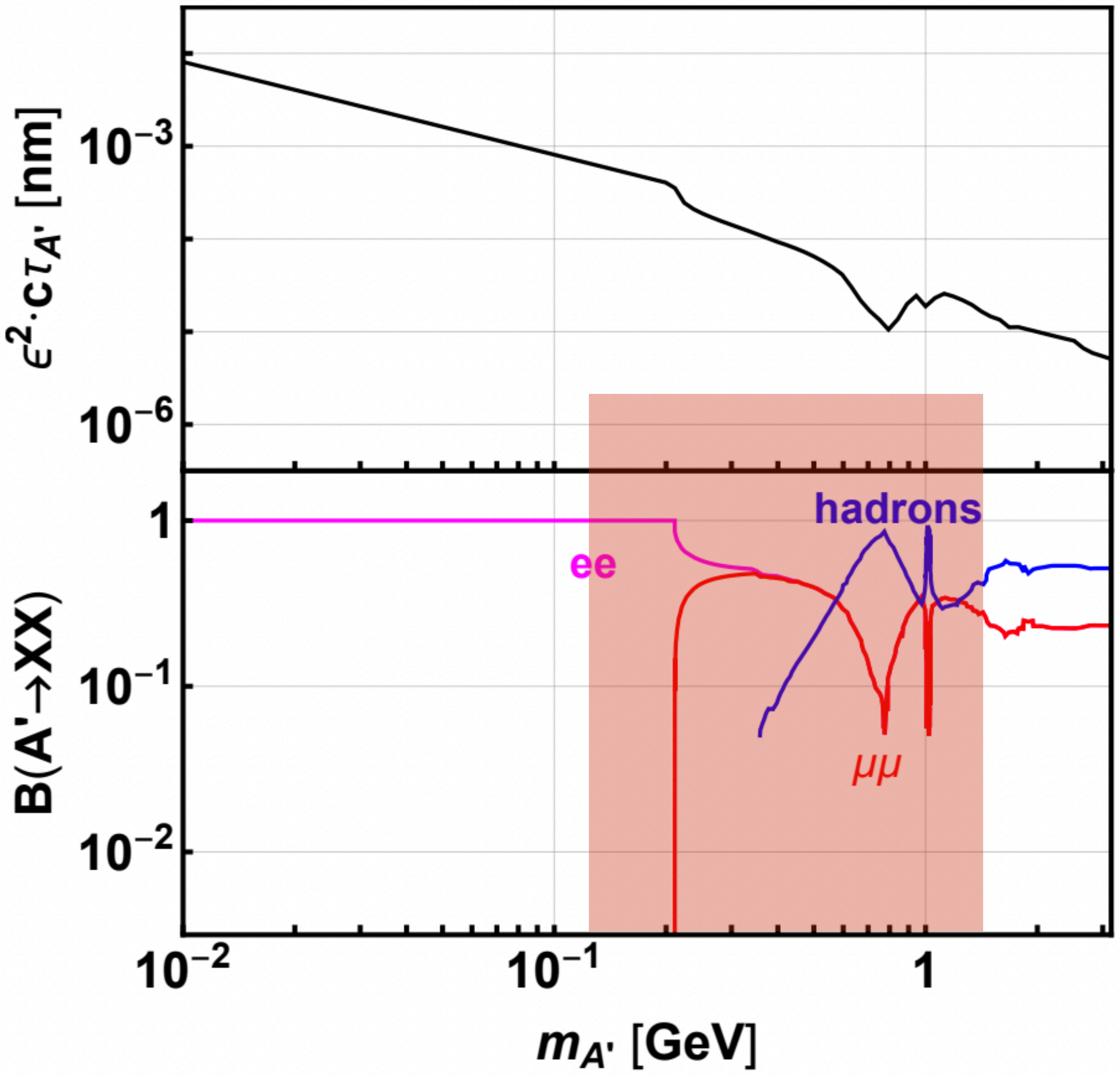


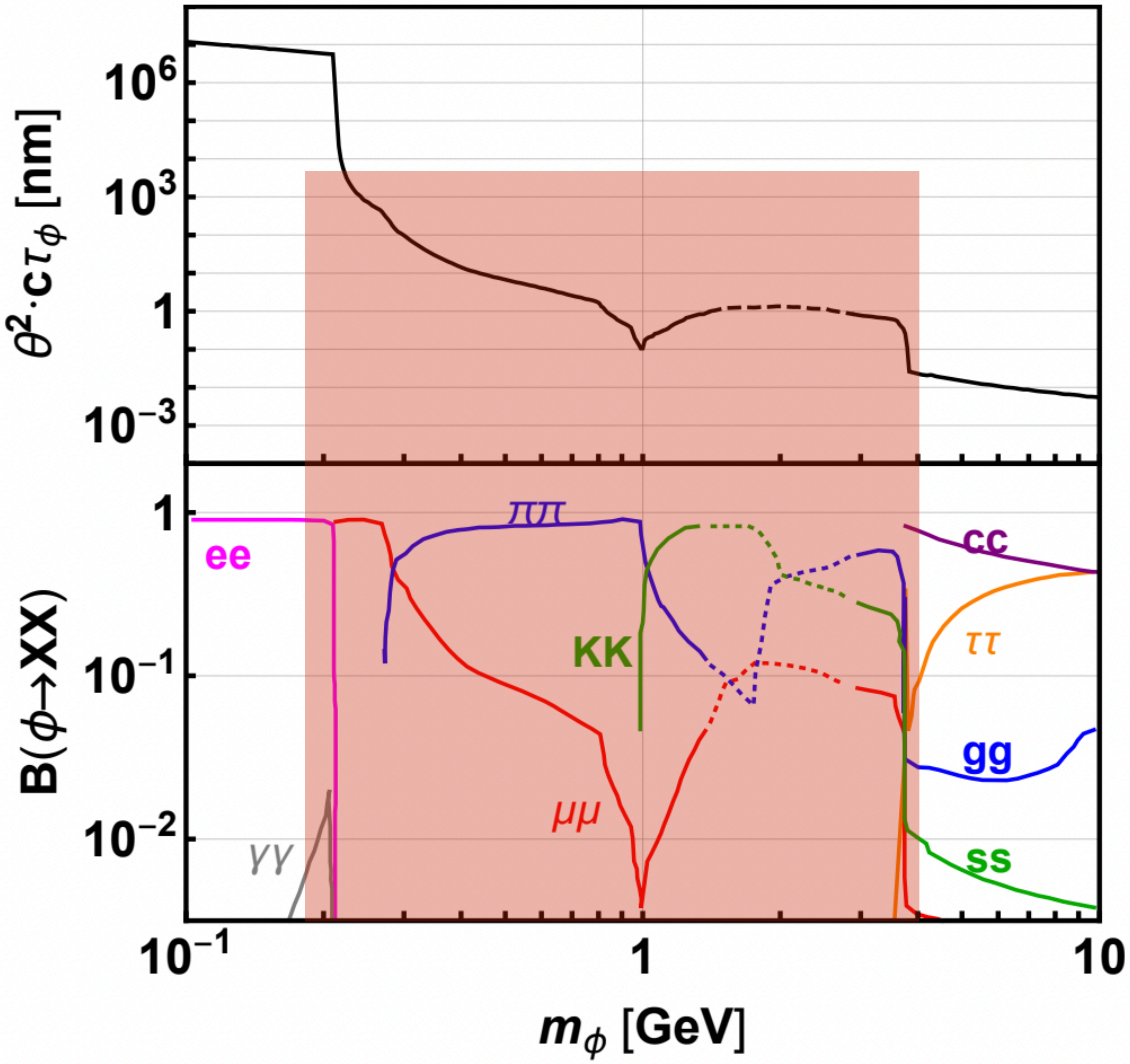
FASER2 Reach





FASER2 Reach

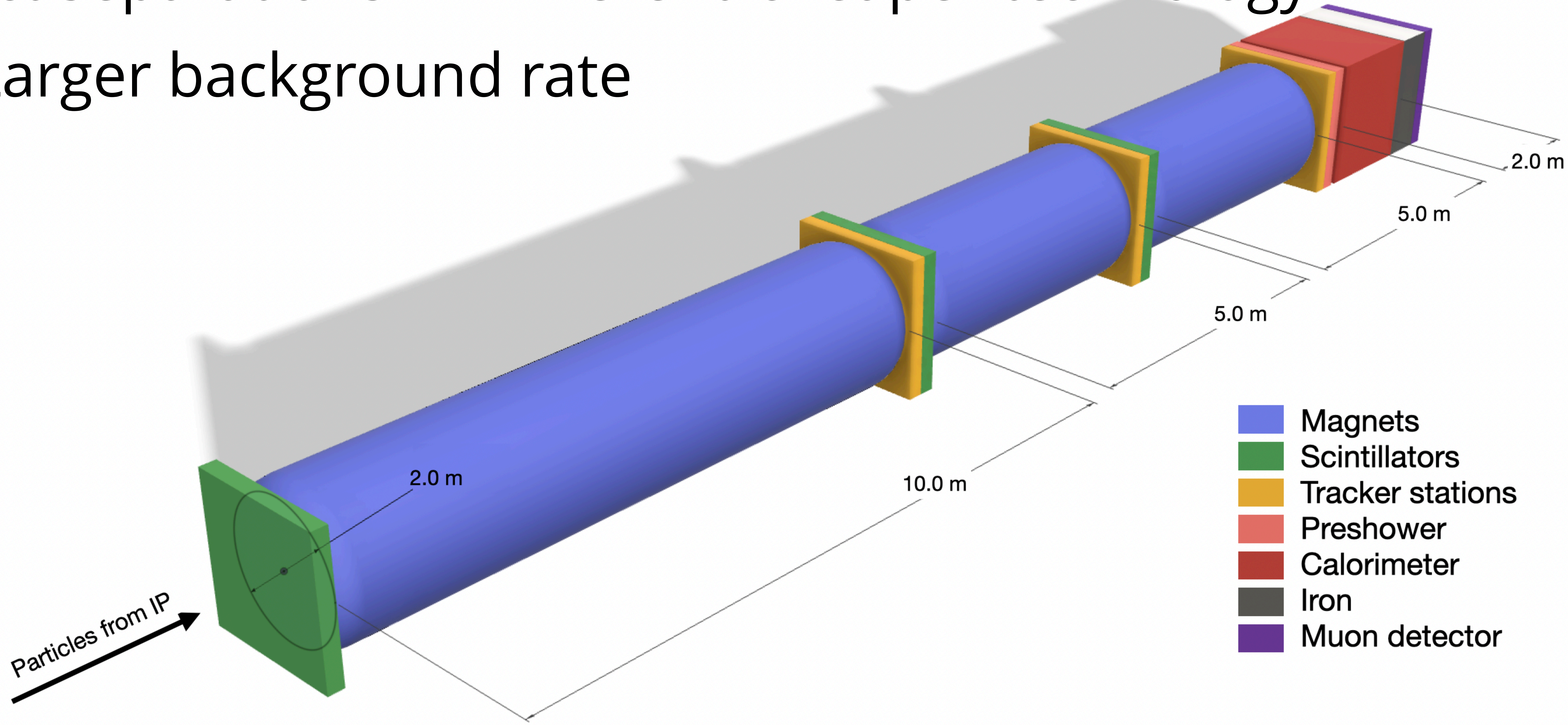




FASER2 Design

- **Design considerations for FASER2**
  - Larger radius → Being on-axis less important
  - More decay channels → Need for particle ID
  - Larger decay product separations → Different/cheaper technology
  - Larger detector → Larger background rate

- Still much to be studied in terms of possible detector configurations and technologies.



FASER2 Design

- **Design considerations for FASER2**
  - Larger radius → Being on-axis less important
  - More decay channels → Need for particle ID **→ Dual Readout Calo?**
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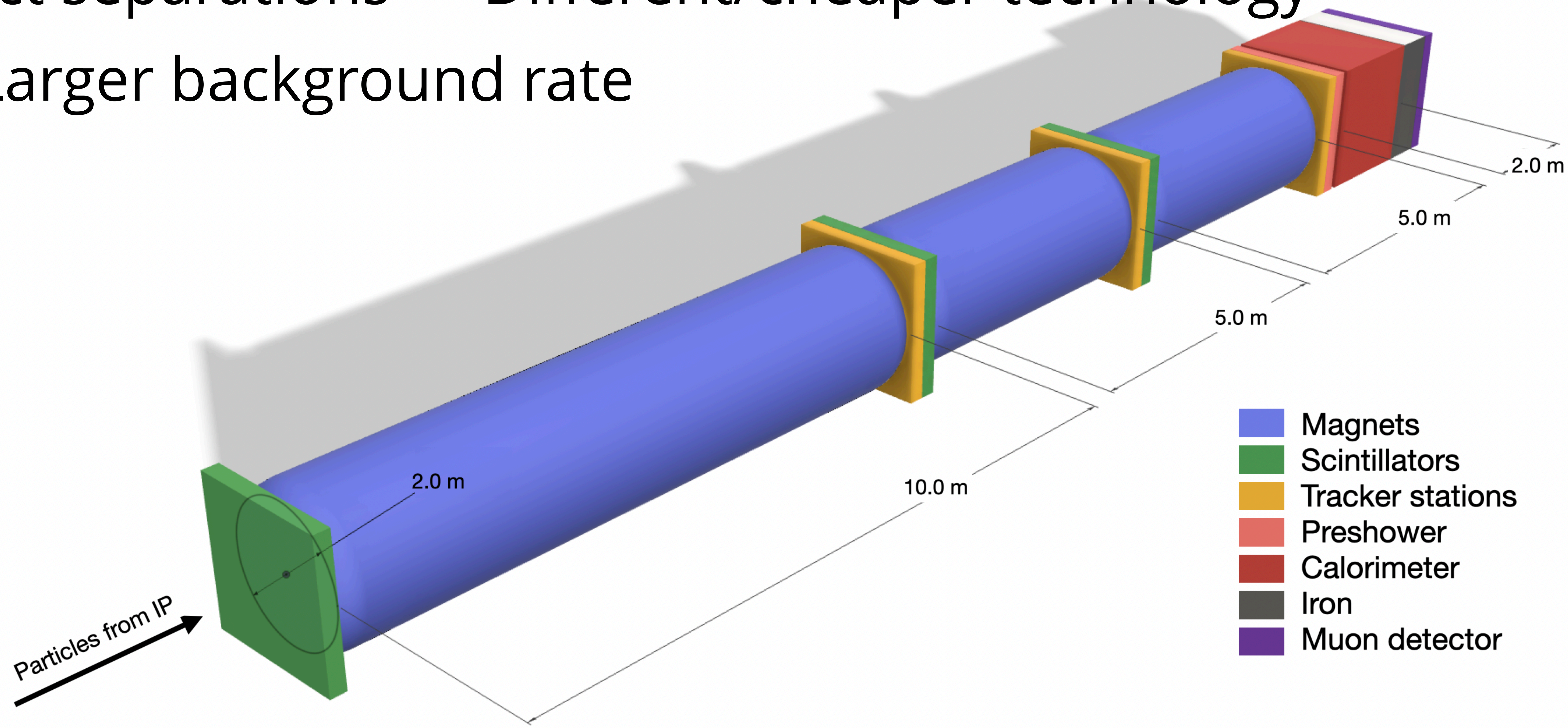
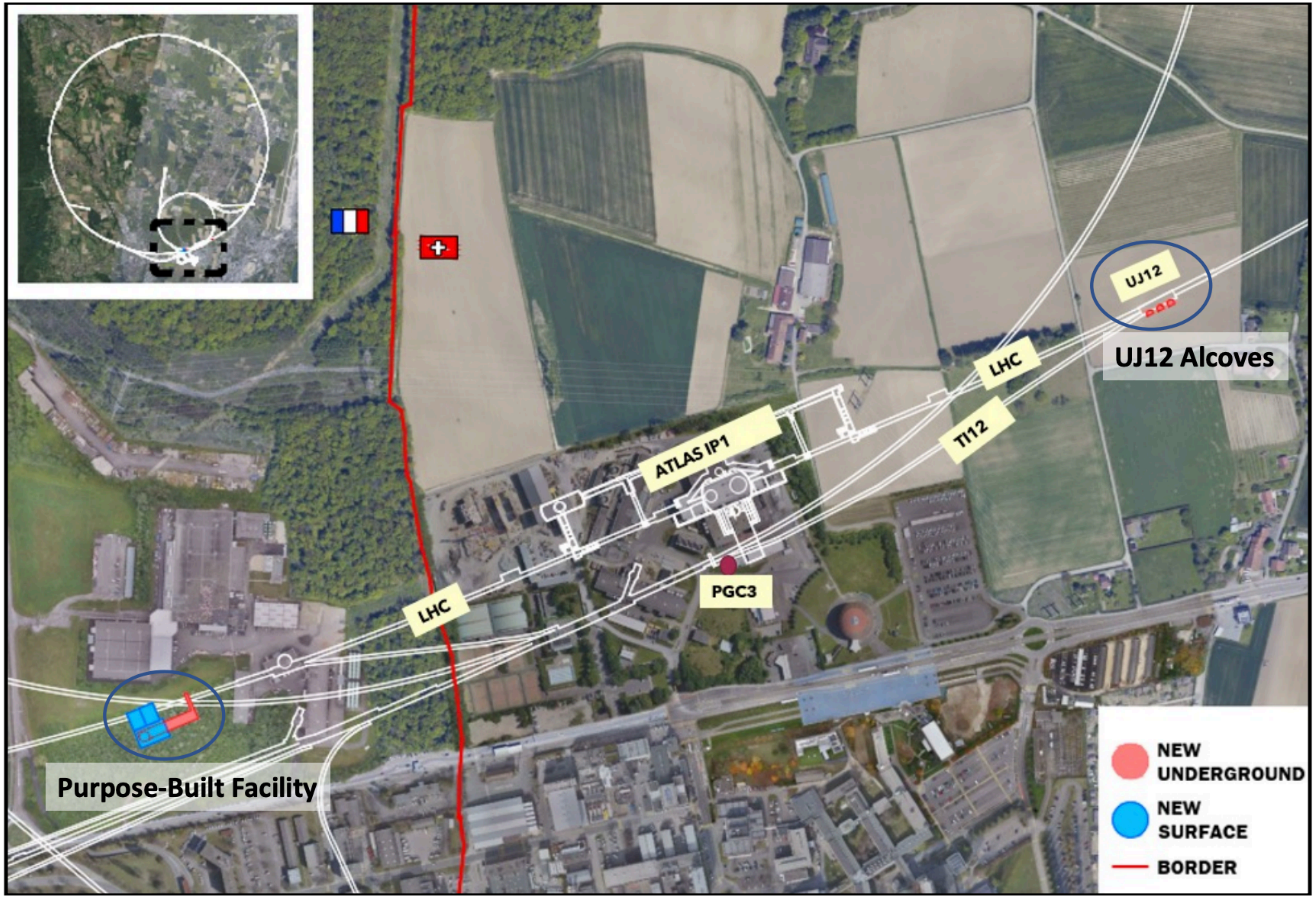


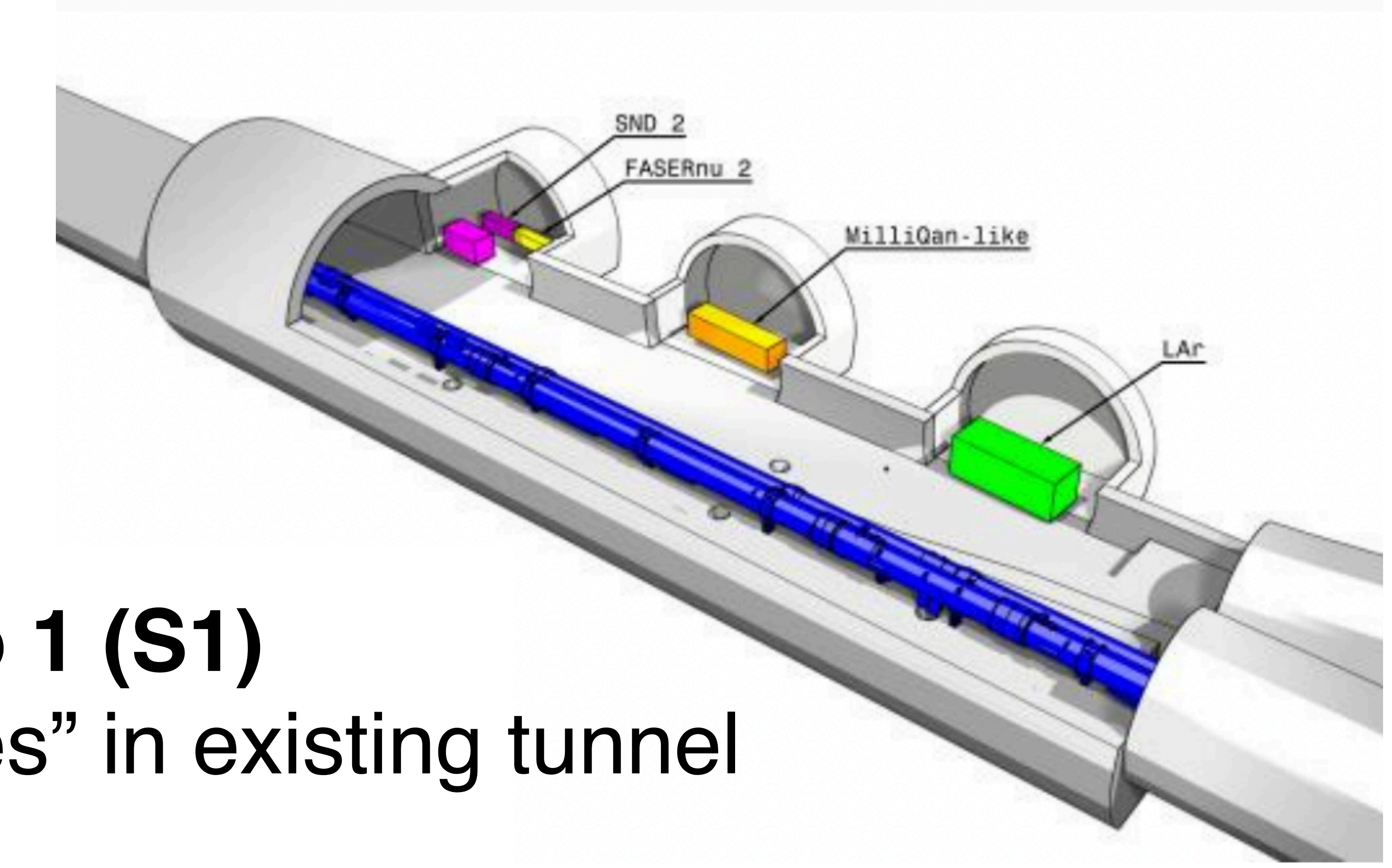
FASER2 Location - The FPF

- There has been recent work to define the civil engineering work required, dector designs and physics reach for a dedicated Forward Physics Facility (FPF)
  - [arxiv:2109.10905]



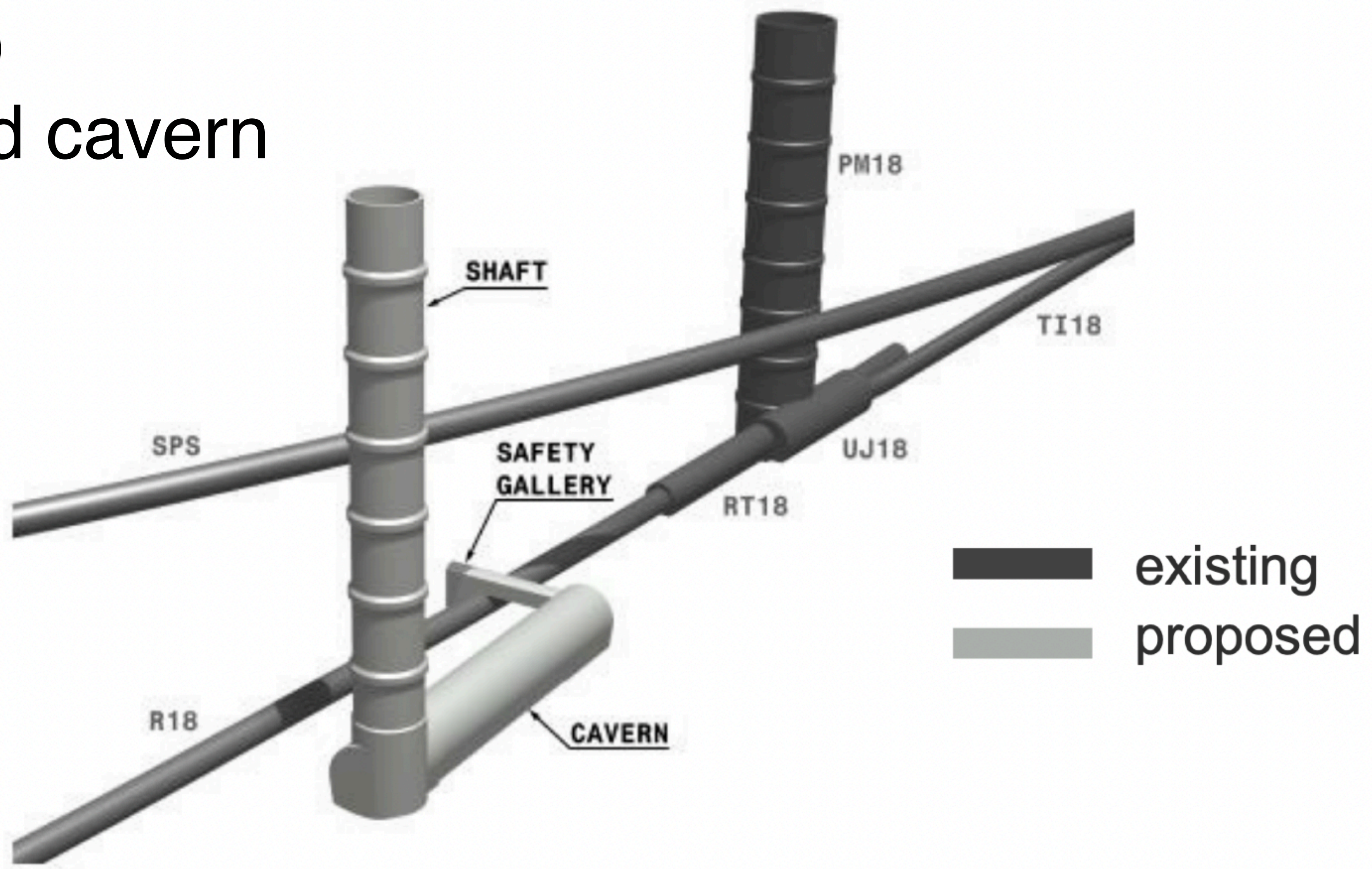
FASER2 | Parameters

- Available space for FASER2 based on different facility scenarios:



Scenario 1 (S1)
- “Alcoves” in existing tunnel

Scenario 2 (S2)
- New dedicated cavern

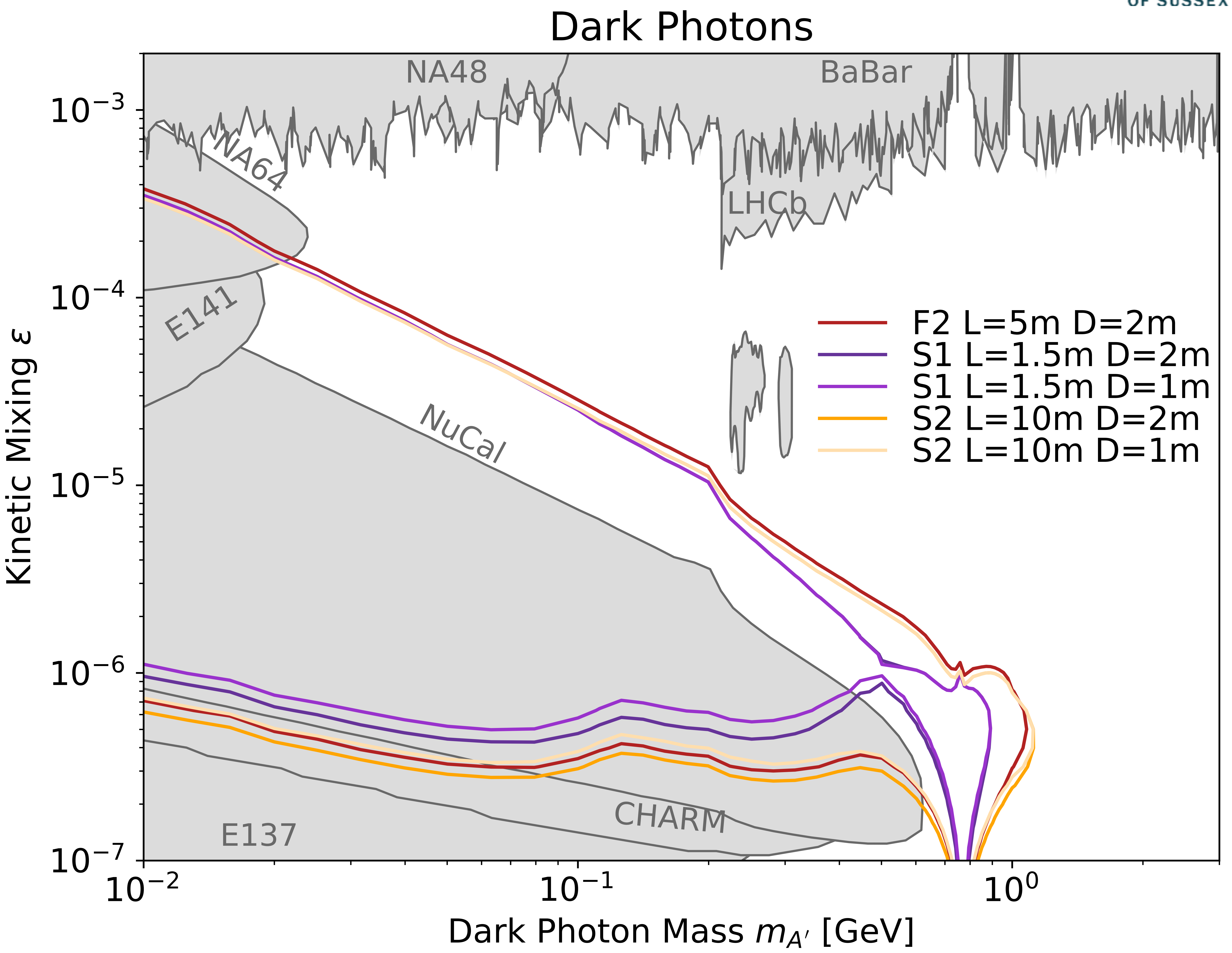


- Possible detector configurations:

FPF Scenario	Distance to IP [m]	Available Length [m]	Decay Volume Length [m]	Available Diameter [m]	Decay Volume Diameter [m]
F2: Original FASER2	480	15	5	2	2 (/ 1 / 0.5)
S1: UJ12 Alcoves	500	5	1.5 (/ 2)	1.52	2 / 1 (/ 0.5)
S2: Purpose-Built Facility	620	25	10 (/ 15 / 20)	2	2 / 1 (/ 0.5)

FPF Scenarios | Dark photons

- **FASER2-default**
- **Scenario 1:**
  - Significantly degraded sensitivity due to reduced decay volume length
- **Scenario 2:**
  - Comparable sensitivity to FASER2-default, but somewhat improved due to larger decay volume length.
  - Very small degradation in diagonal due to increased distance from IP.



FPF Scenarios | Dark Higgs

- **FASER2-default**
- **Scenario 1:**
  - Significantly degraded sensitivity due to reduced decay volume length
- **Scenario 2:**
  - Diameter of detector much more important here. Due to larger angle emission from B-hadrons of LLP.