



New Physics Searches with Low Energy Muon Beams

Muon Collider Benchmark Workshop

November 17, 2023

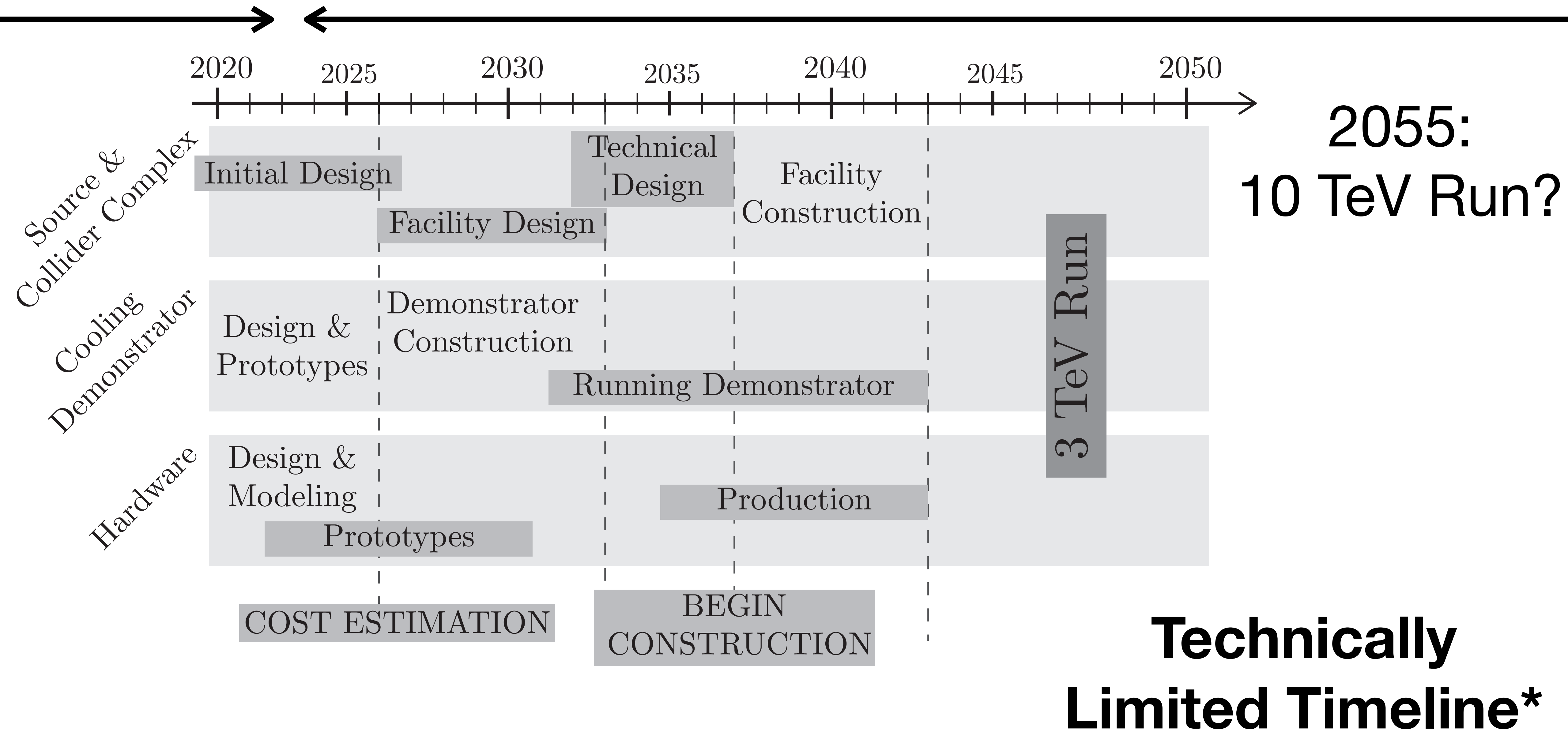
w/ R. Gambhir 2310.16110

w/ Y. Kahn, G. Krnjaic, D. Rocha, J. Spitz 2311.monday

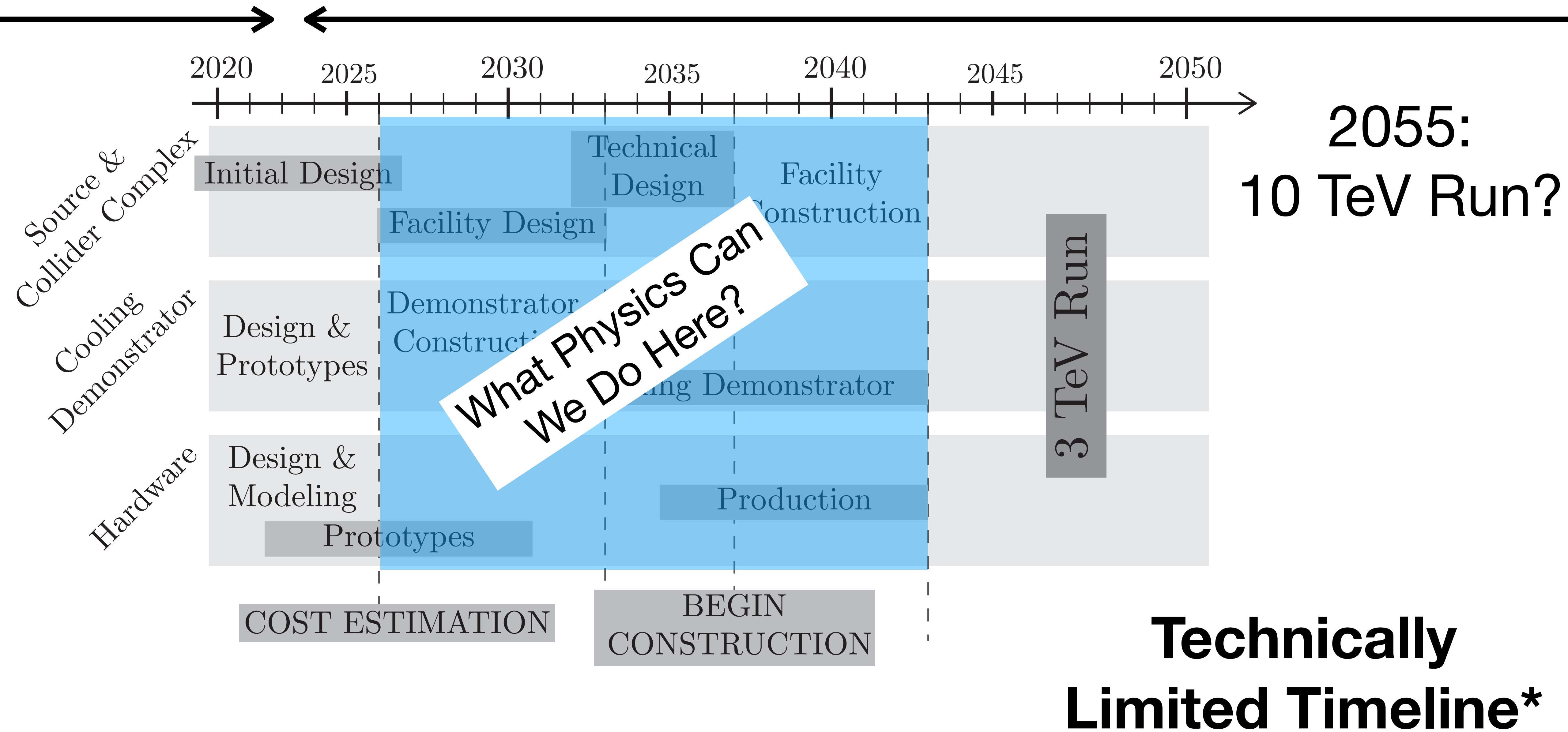
Cari Cesarotti
Postdoctoral Fellow
MIT CTP



Timescale of TeV Muons



Timescale of TeV Muons



Staging & Demonstrators



Demonstrators

Staging

Staging & Demonstrators



Demonstrators

Facilities built for the necessary demonstration of novel technology (magnets, cooling, etc.)

Staging

Staging & Demonstrators



Demonstrators

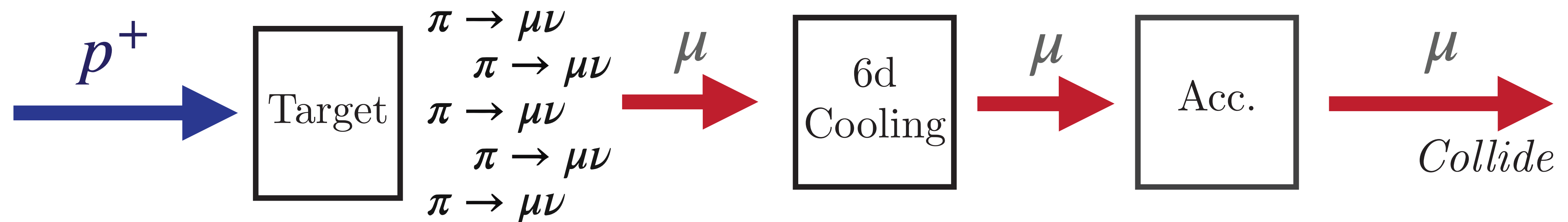
Facilities built for the necessary demonstration of novel technology (magnets, cooling, etc.)

Staging

Intermediate steps such that physics program isn't halted while collider is being built

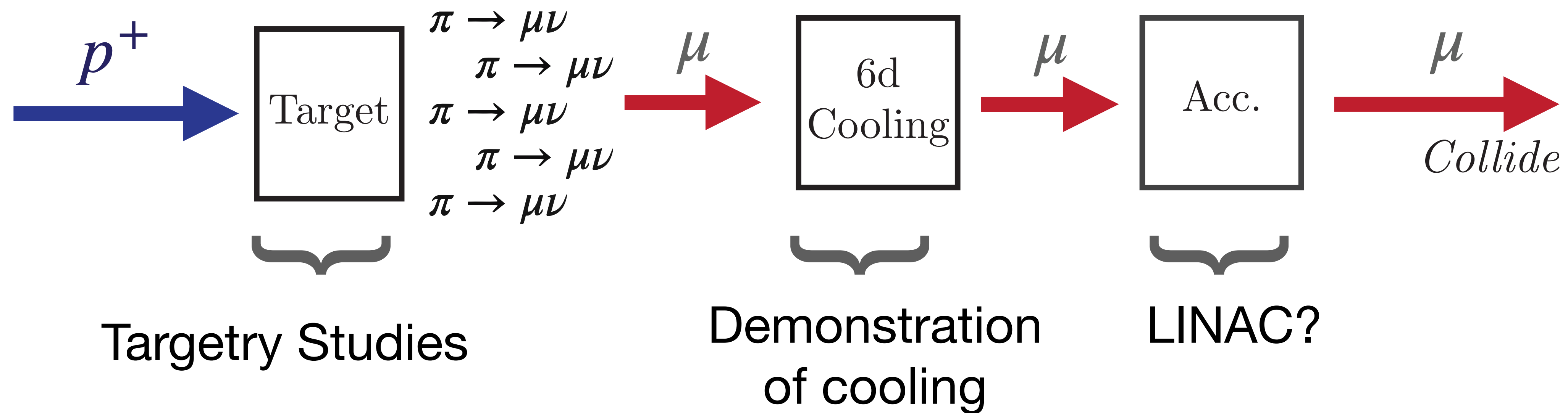
Physics Potential at Staging & Demonstrators

Muon beams may be available earlier at lower energies



Physics Potential at Staging & Demonstrators

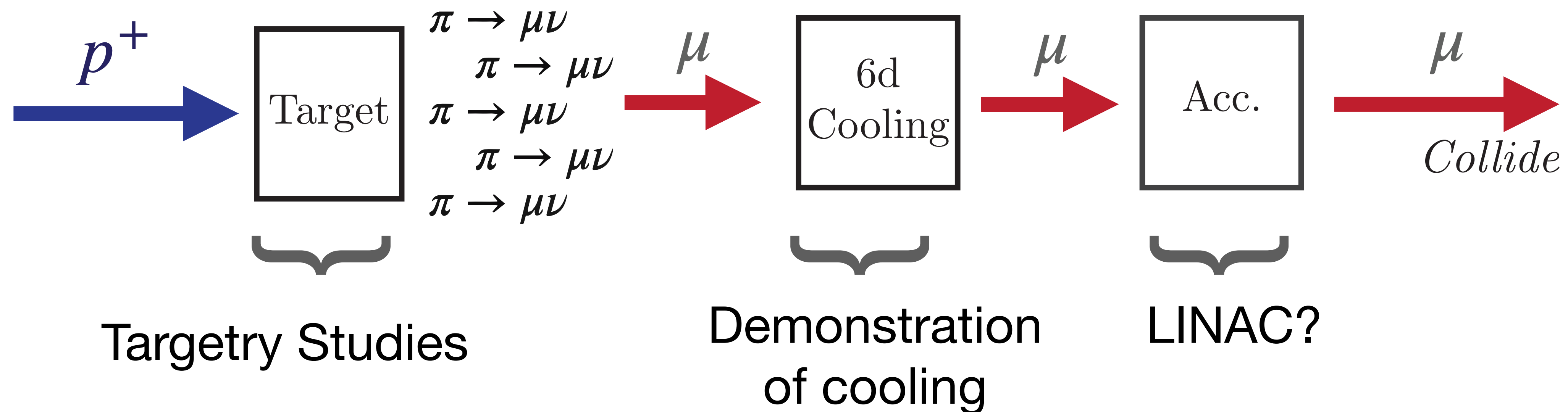
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+ Synergies with other experiments

Physics Potential at Staging & Demonstrators

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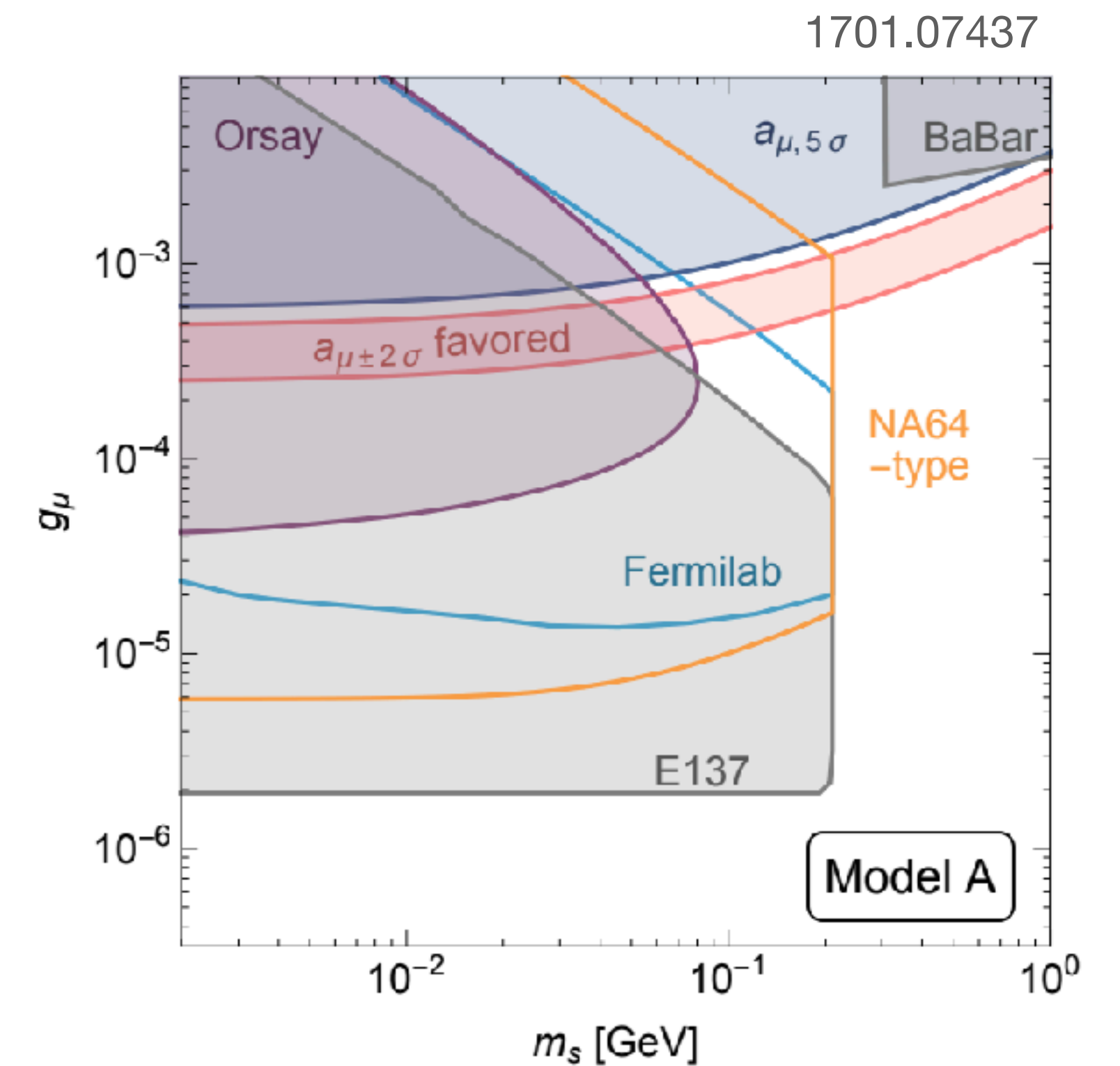
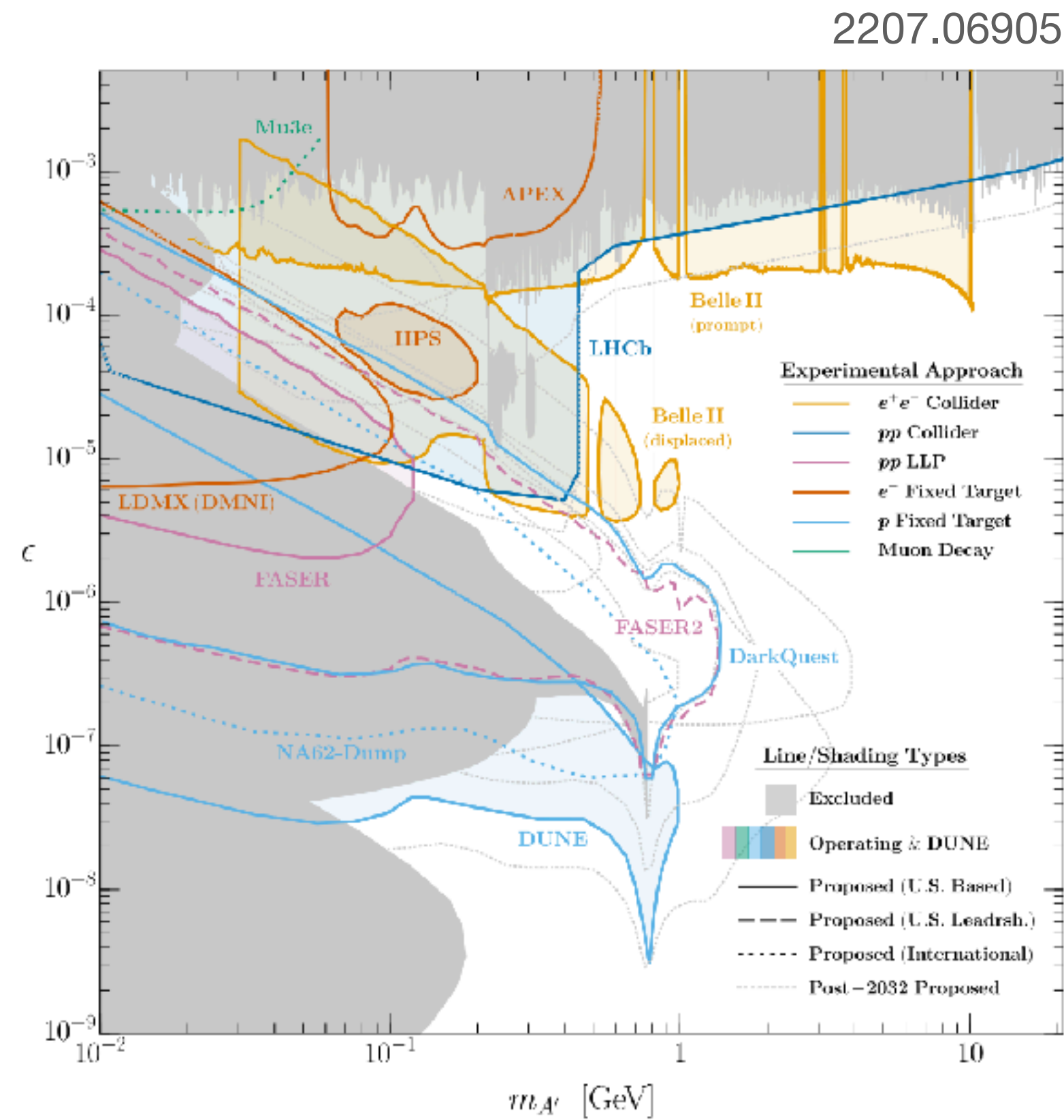
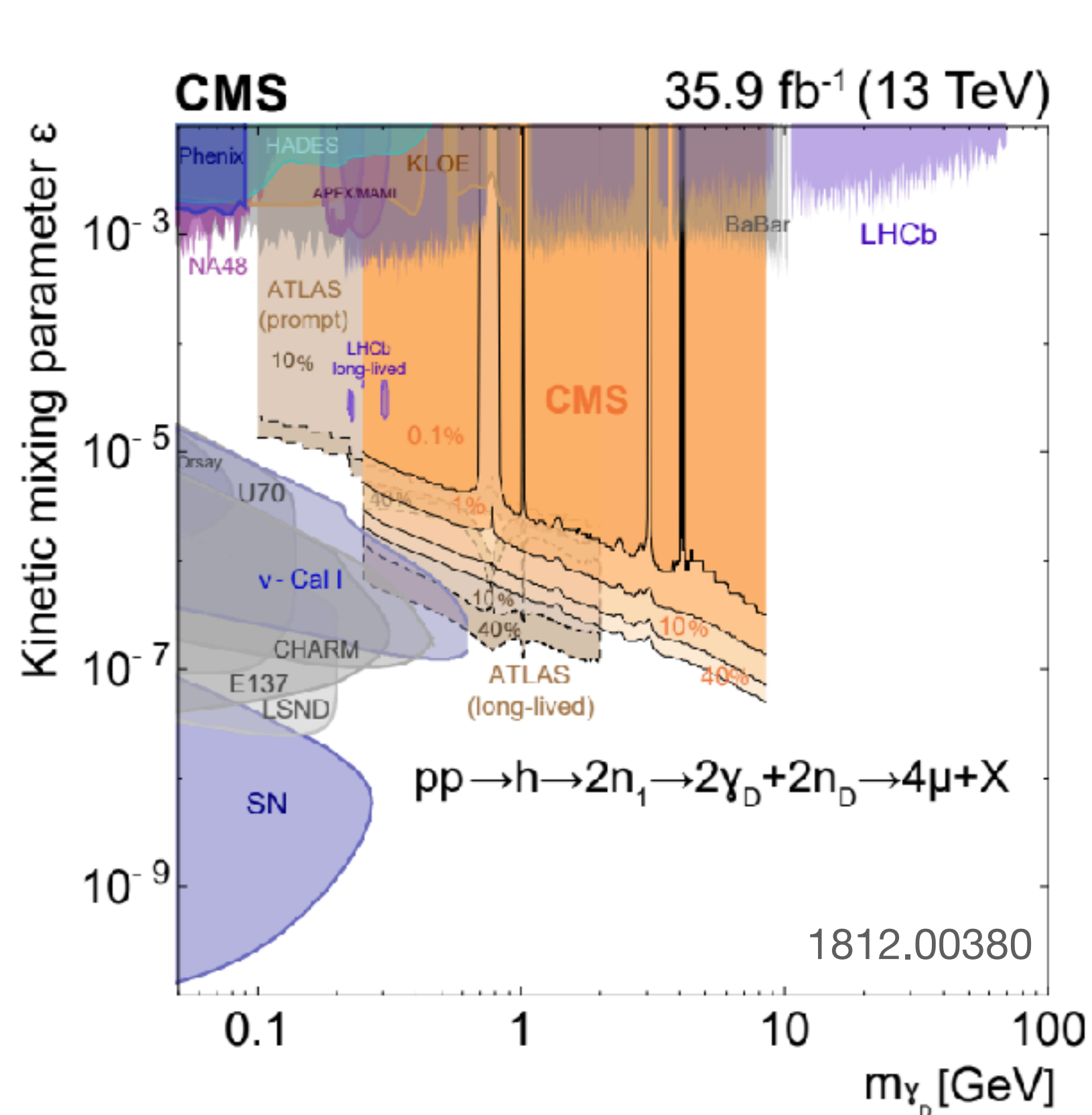
+ Synergies with other experiments

Need to have **physics deliverables** before the multi-decade timescale

Muon beam is 'free' so might as well use it

“Low” Energy Muons: Physics Motivation

MeV - GeV Masses still unexplored at small couplings



“Low” Energy Muons: Physics Motivation

MeV - GeV Masses still unexplored at small couplings

Weak bounds for stronger couplings to heavy flavor

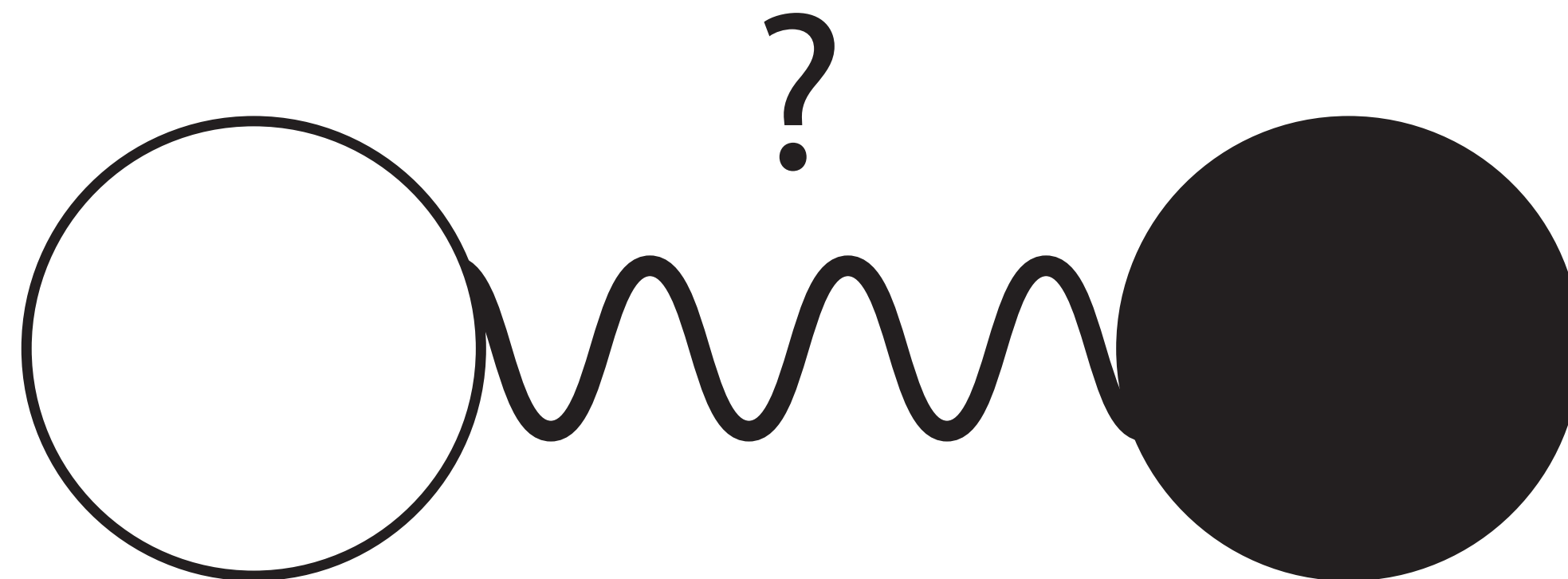
$$\mathcal{L} \supset g \frac{m_l}{v} \phi \bar{l} l$$

“Low” Energy Muons: Physics Motivation

MeV - GeV Masses still unexplored at small couplings

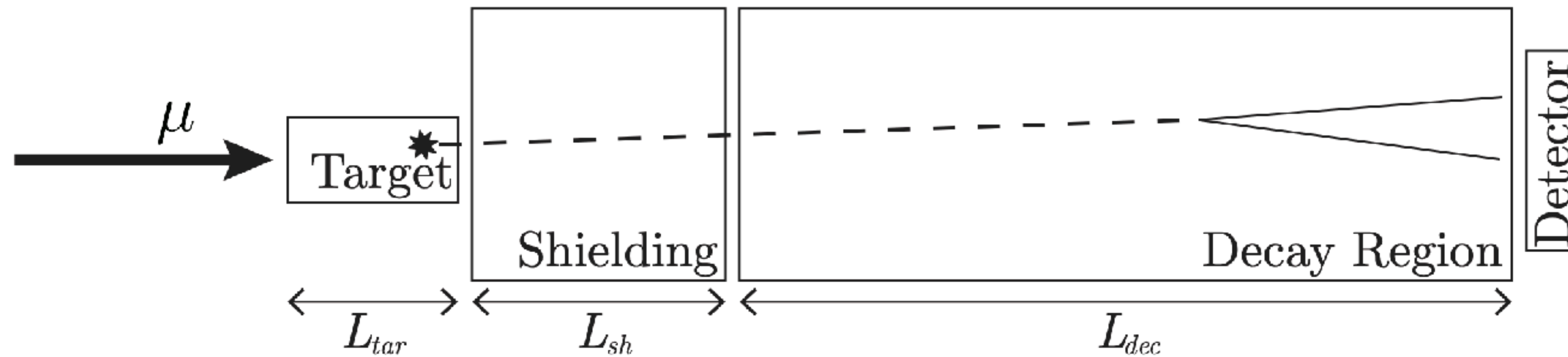
Weak bounds for stronger couplings to heavy flavor

Leave no stone unturned paradigm



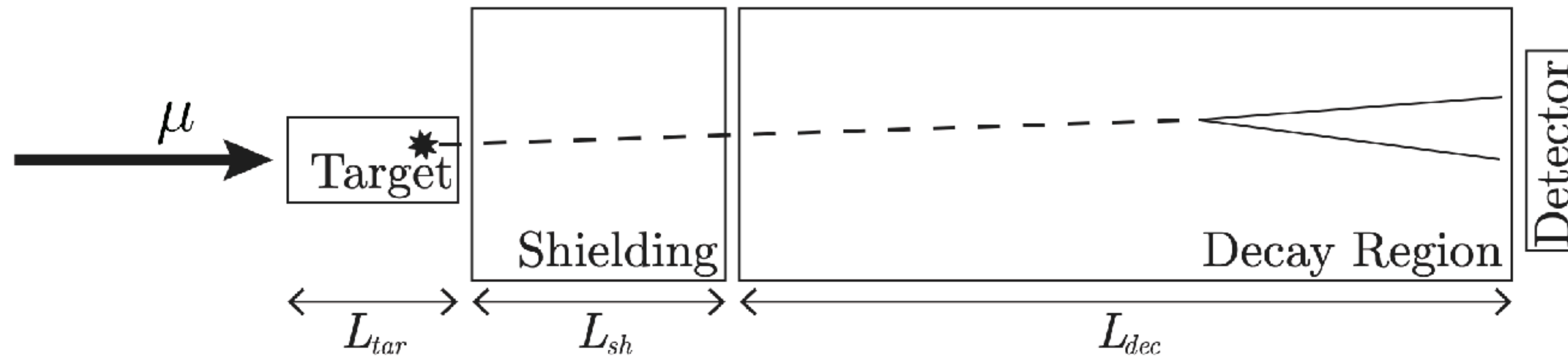
Demonstrator Facilities & Beam Dump

Beam dumps are **low-cost** auxiliary experiments with **complementary** reach to main collider



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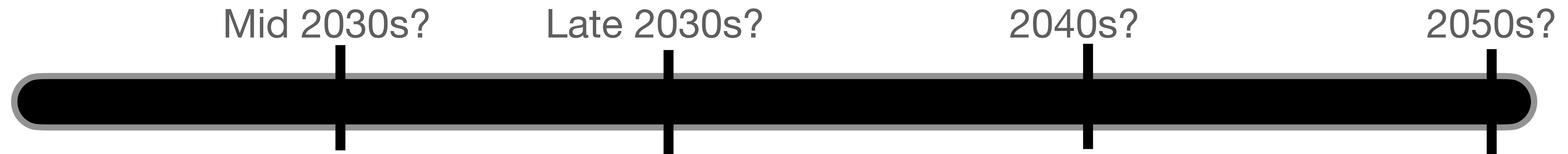


$$m_{\text{NP}} \lesssim \sqrt{E_0 M}$$

$$l_{\text{NP}} = \gamma \tau_0 \approx \frac{E_0}{m_{\text{NP}}} \times \frac{1}{g^2 m_{\text{NP}}} \\ \approx \left(\frac{E_0}{\text{TeV}} \right) \times \left(\frac{g}{10^{-6}} \right)^{-2} \times \left(\frac{m_{\text{NP}}}{10 \text{ MeV}} \right)^{-2} \times 100\text{m}$$

Muon Collider Beam Dump

Examples of Physics Deliverables, in reverse order
of MuC Maturity



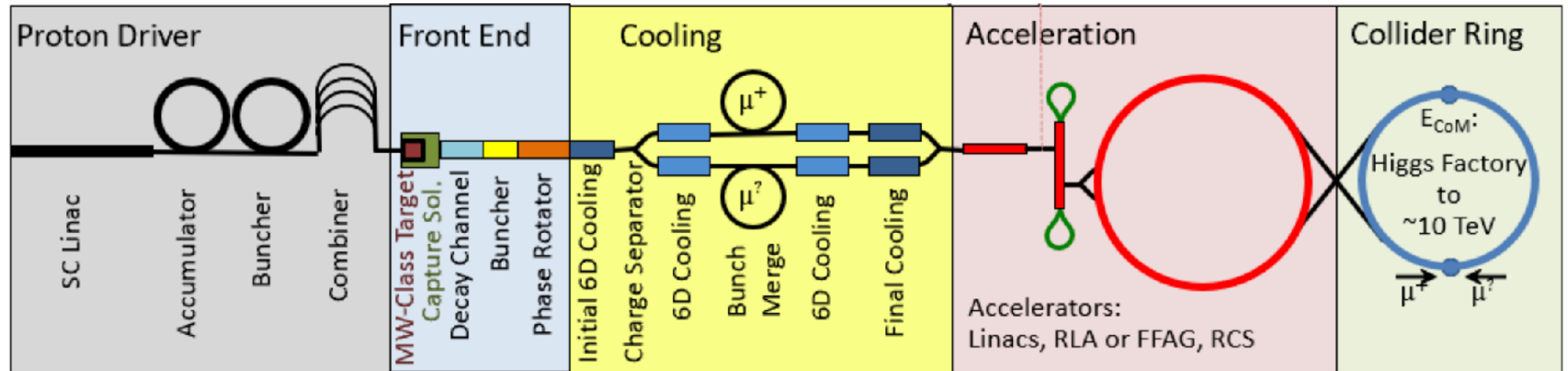
Muon Collider Time Scales

2050ish

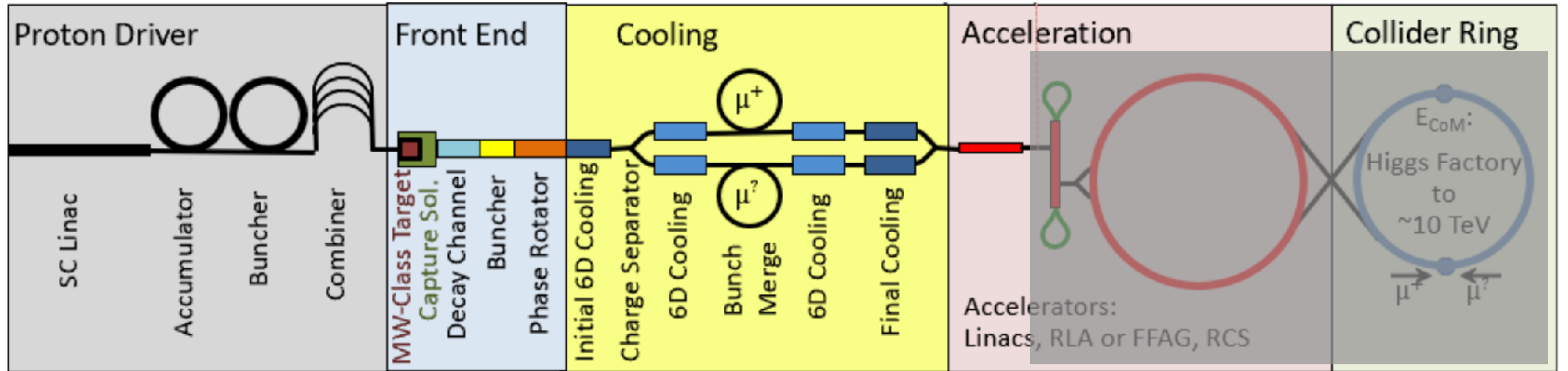


Full Collider

3, 10 TeV MuC



Staging Facility Beam Dump



Staging Facility Beam Dump

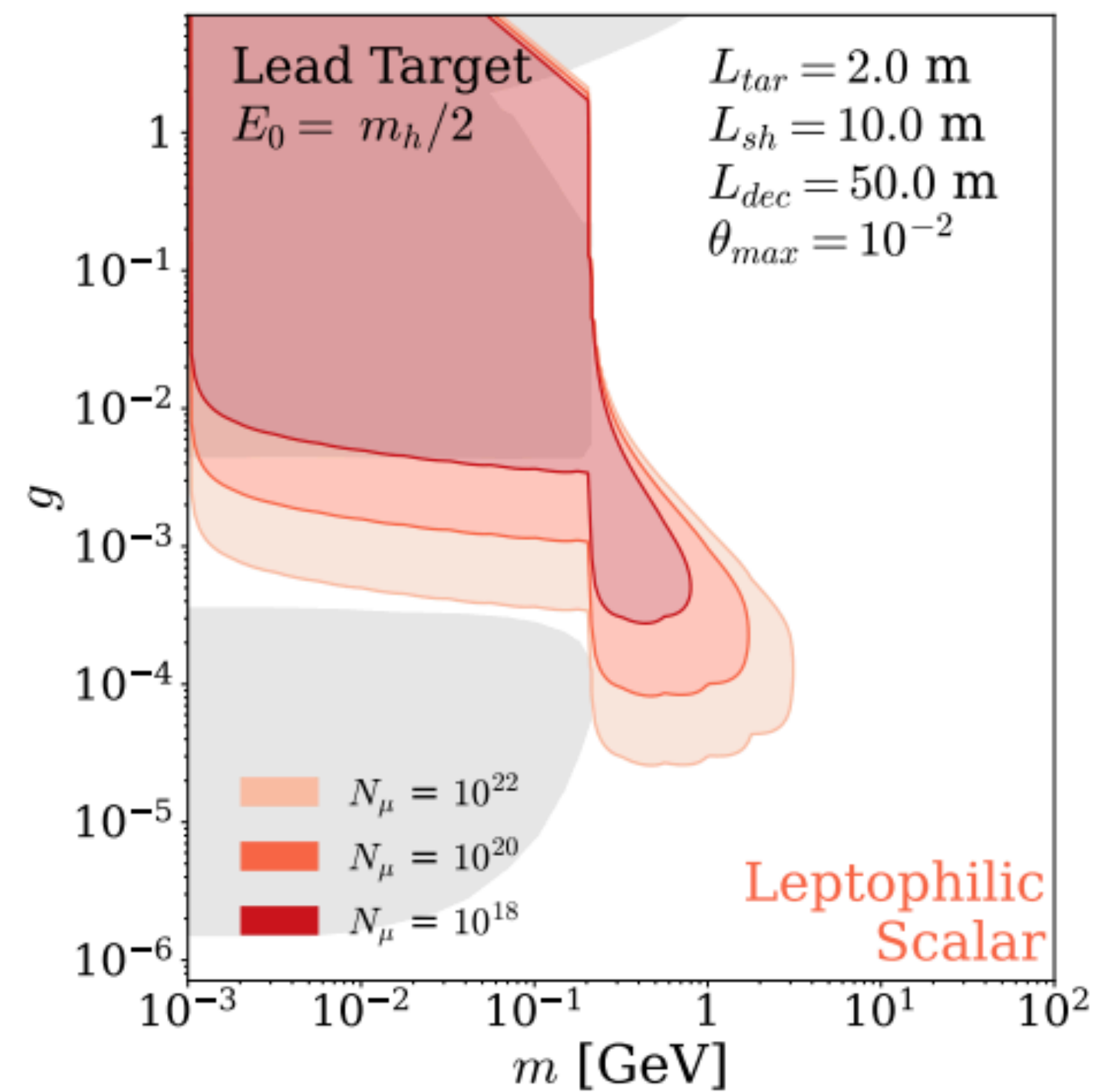
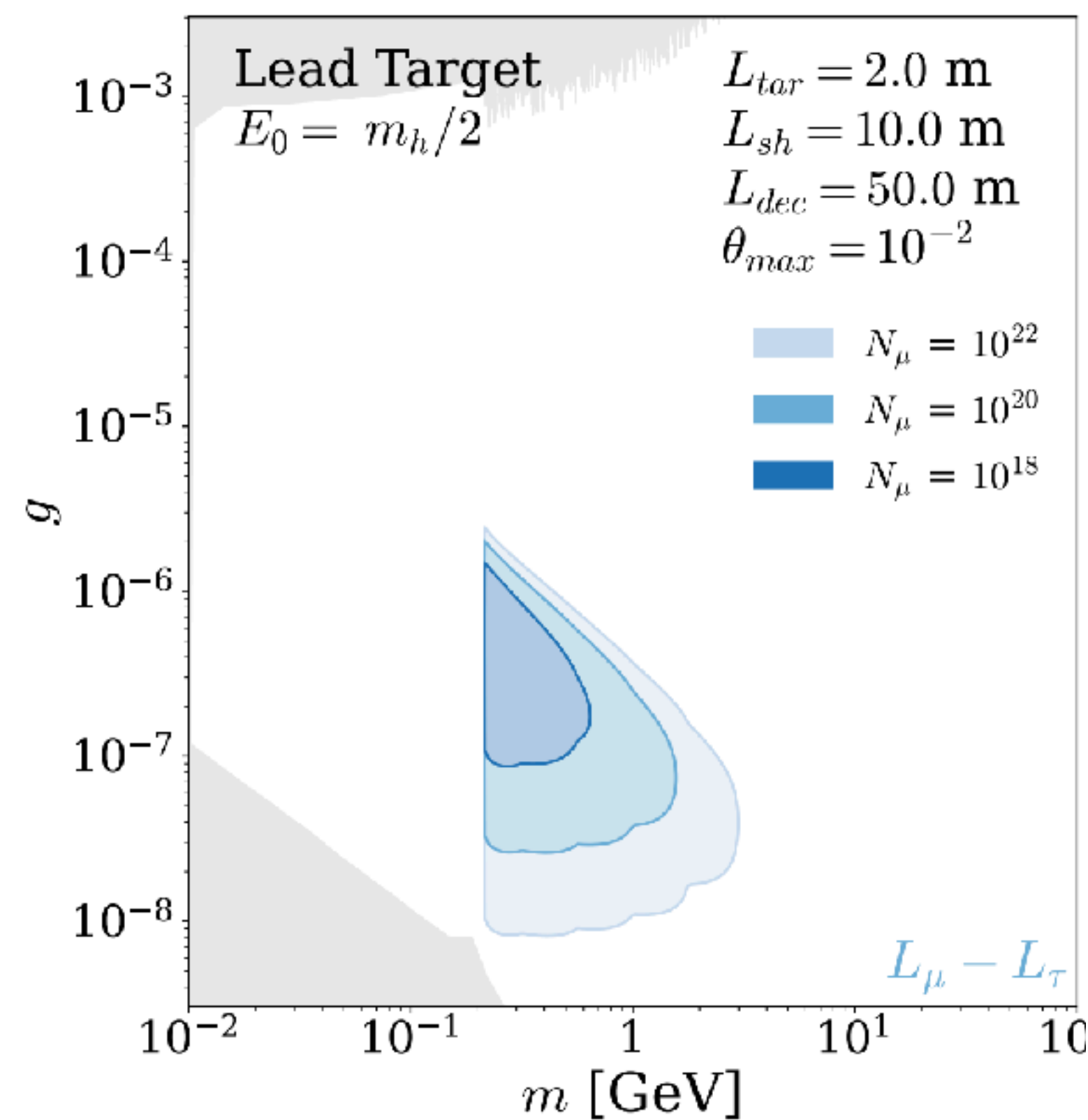
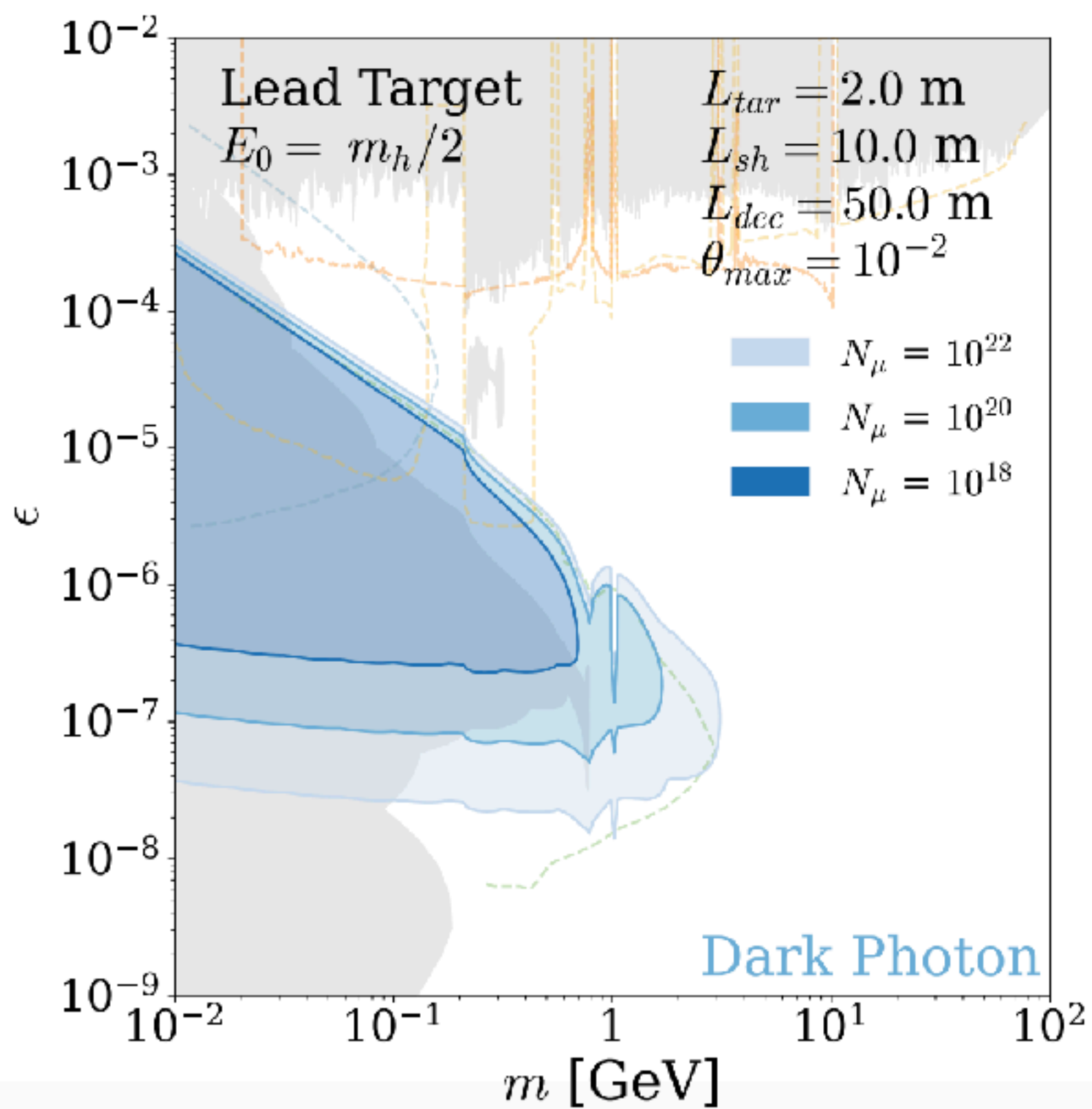
2040ish

2050ish

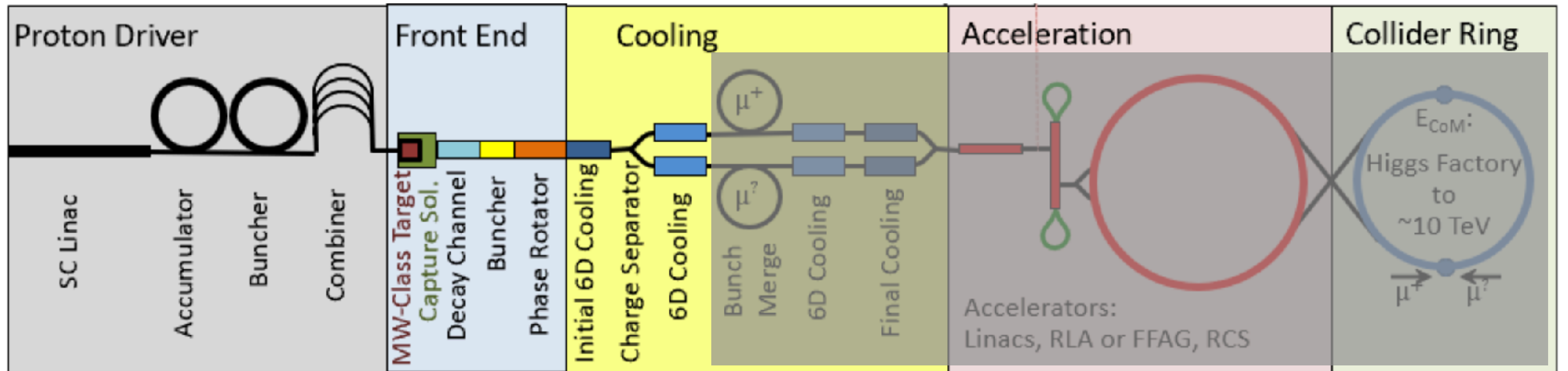
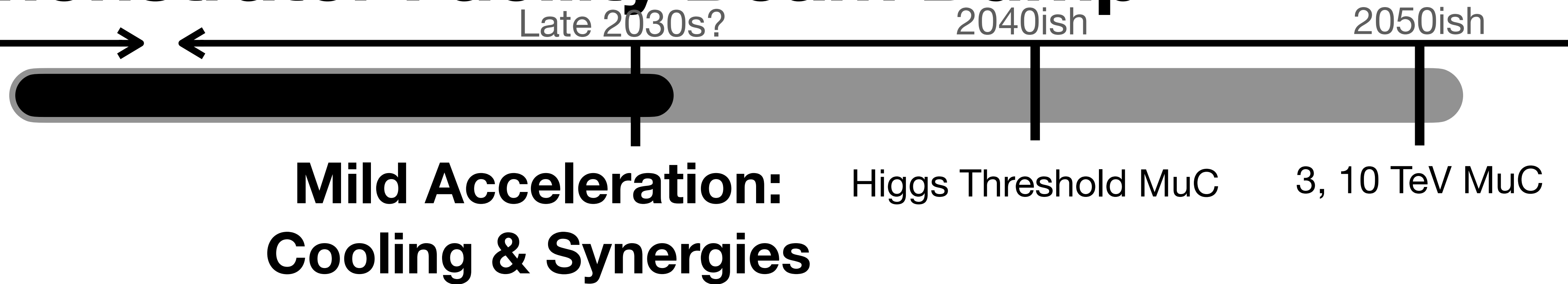


Higgs Threshold MuC 3, 10 TeV MuC

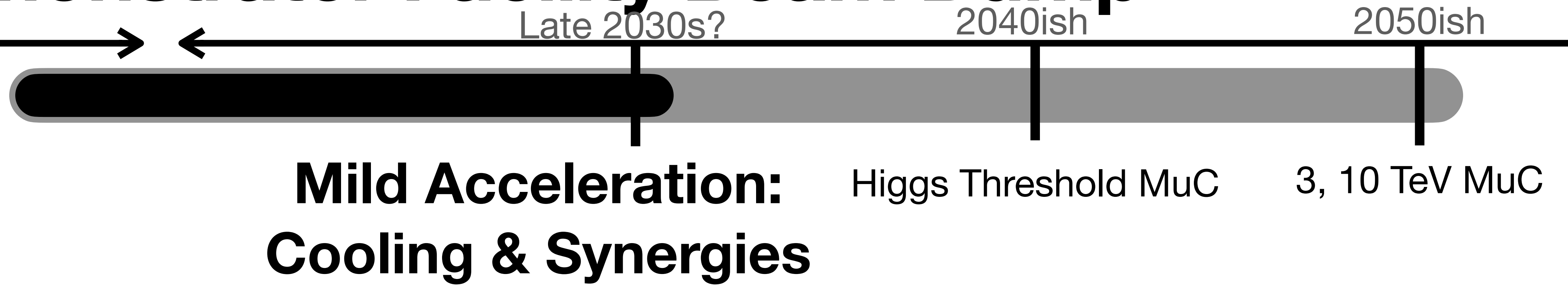
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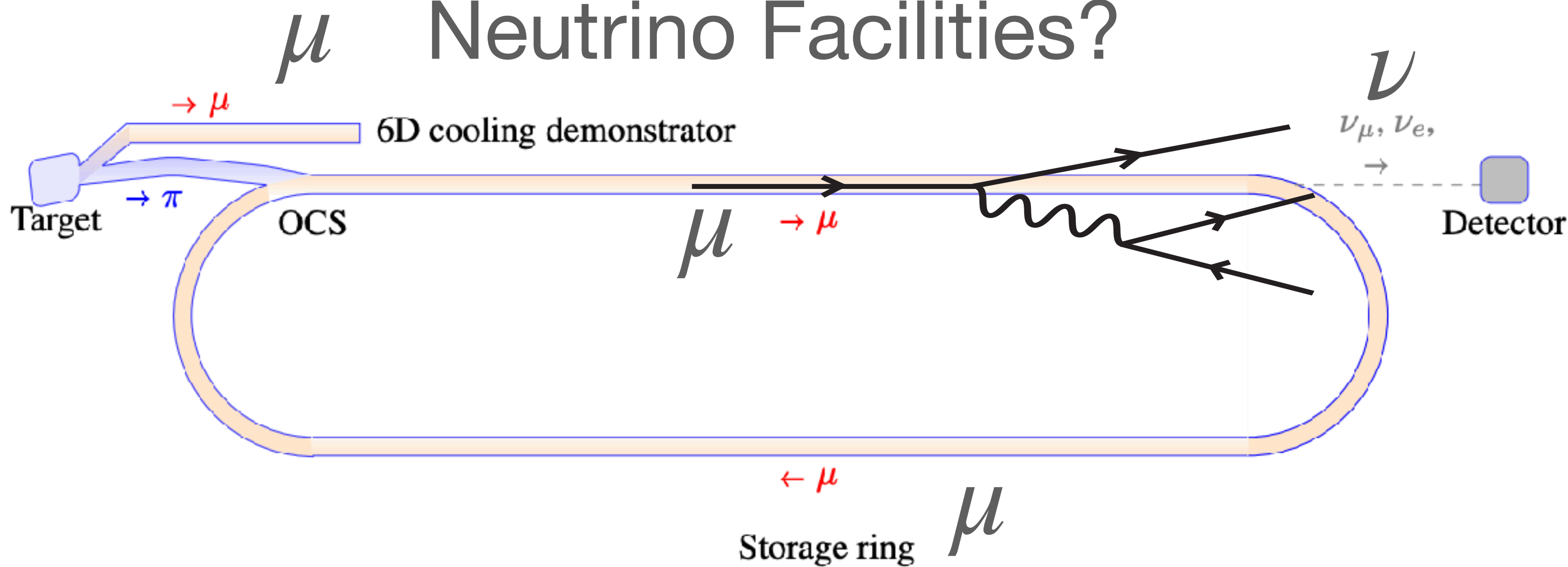
Demonstrator Facility Beam Dump



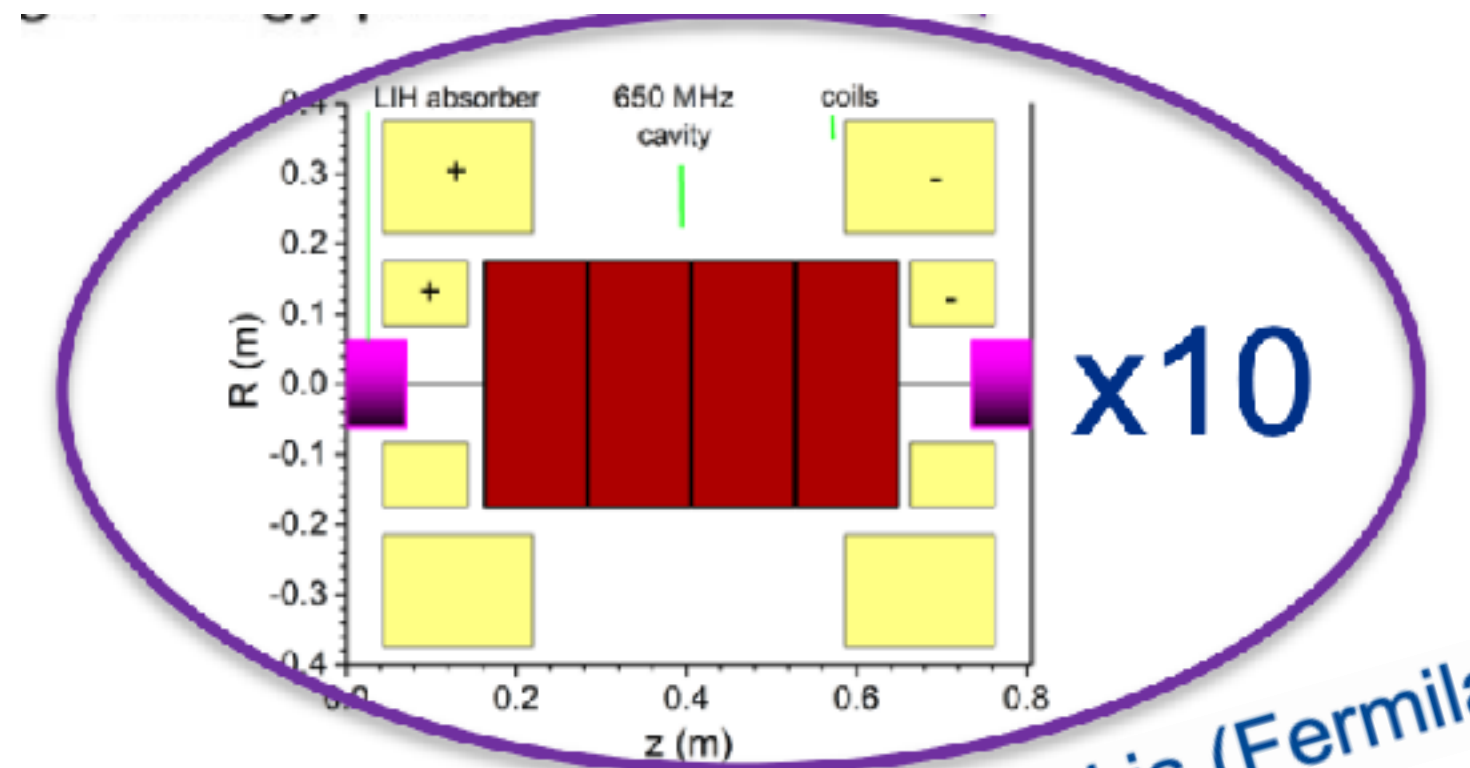
Demonstrator Facility Beam Dump



**Motivation:
Neutrino Facilities?**



**Motivation:
Cooling Demonstrator?**



Diktys Stratakis (Fermilab)

Demonstrator Facility Beam Dump

Late 2030s?

2040ish

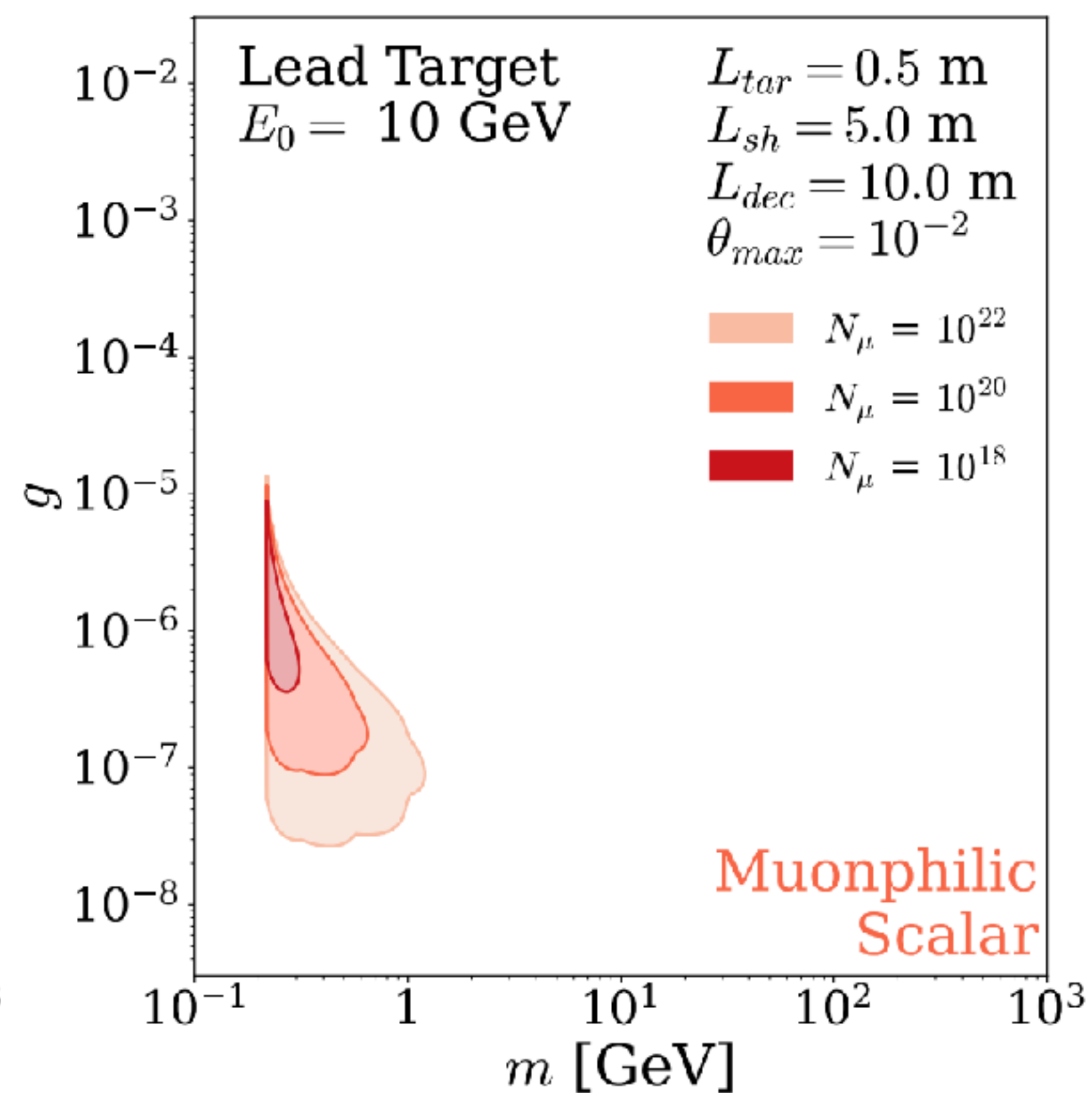
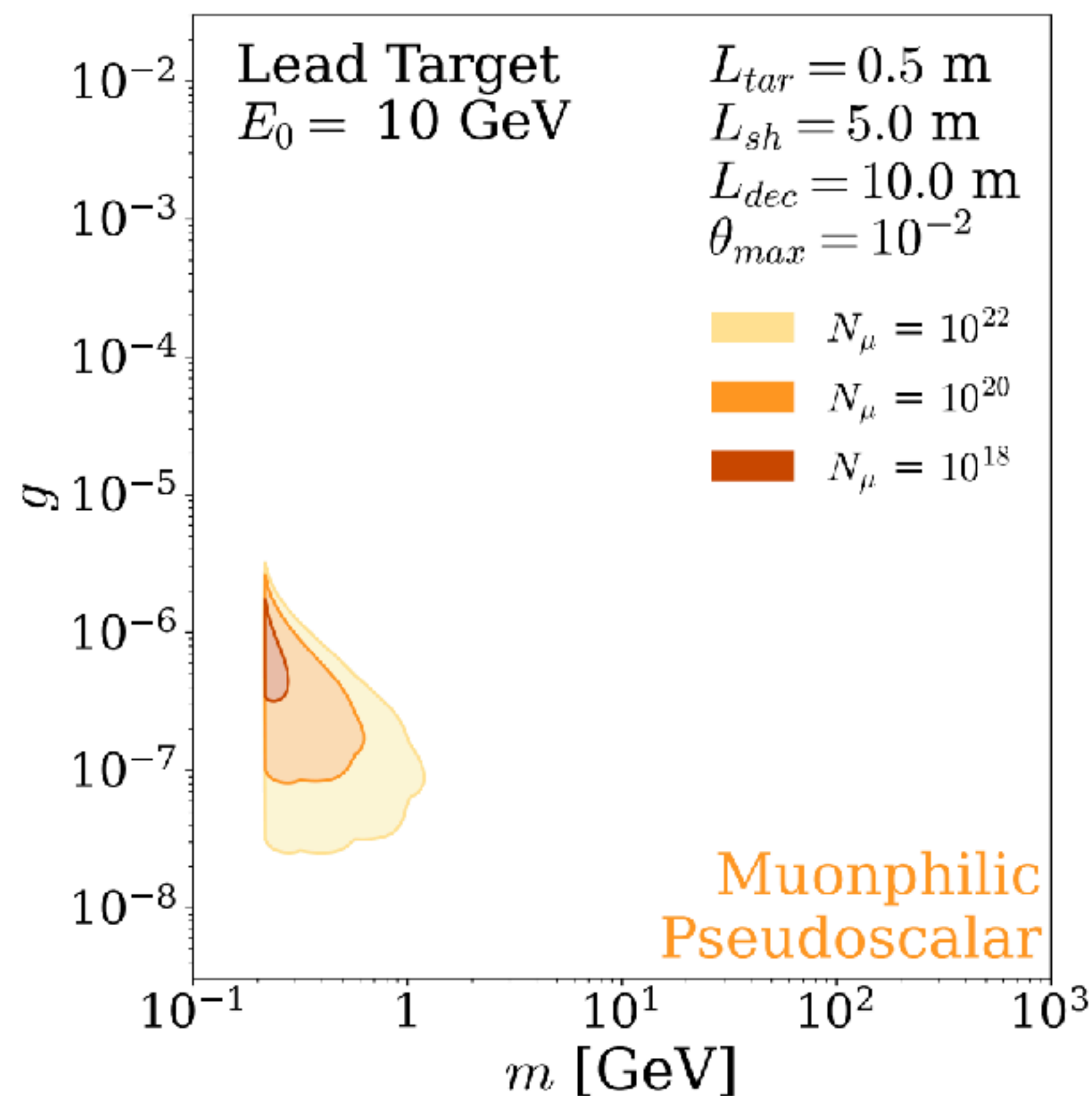
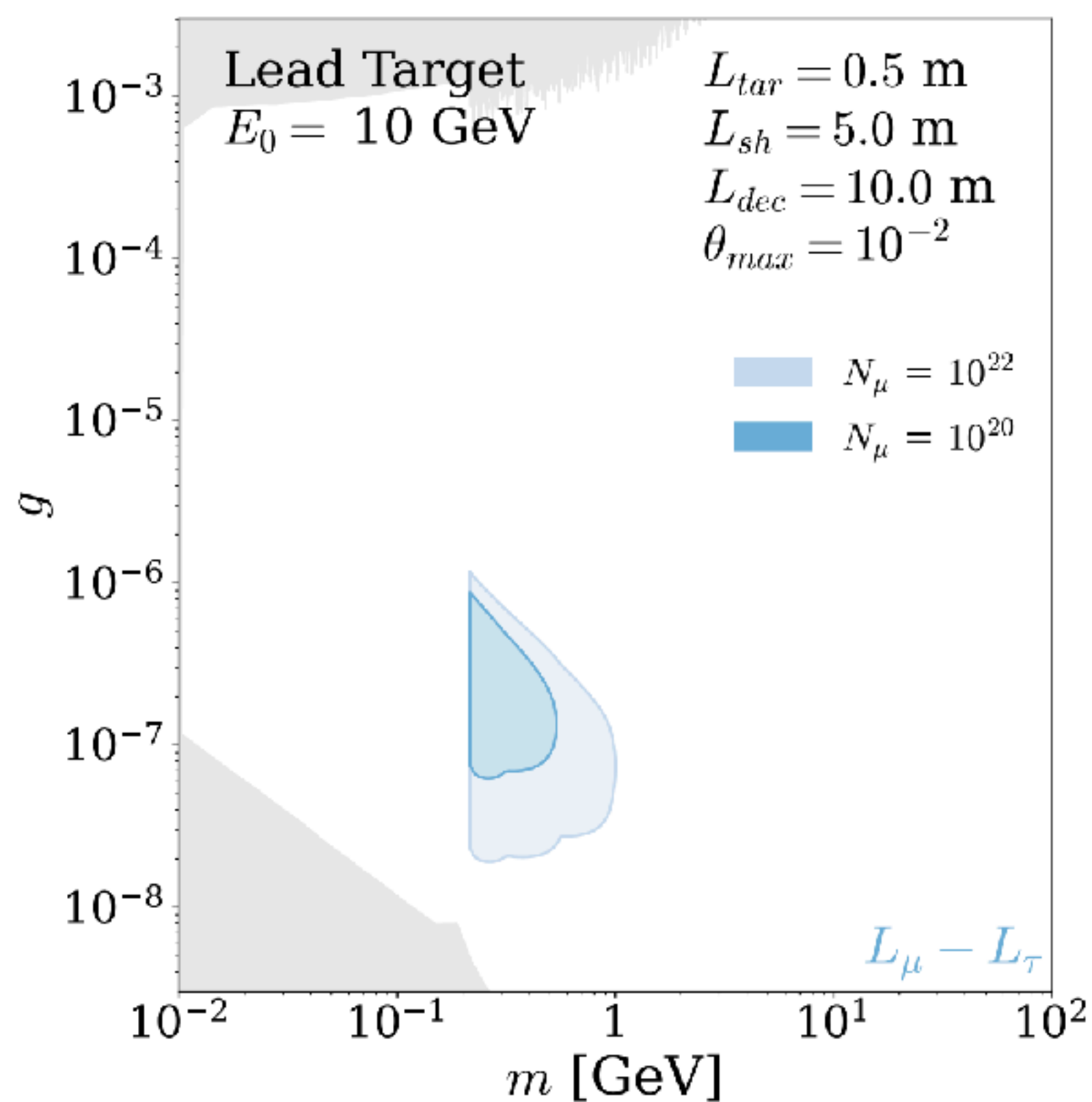
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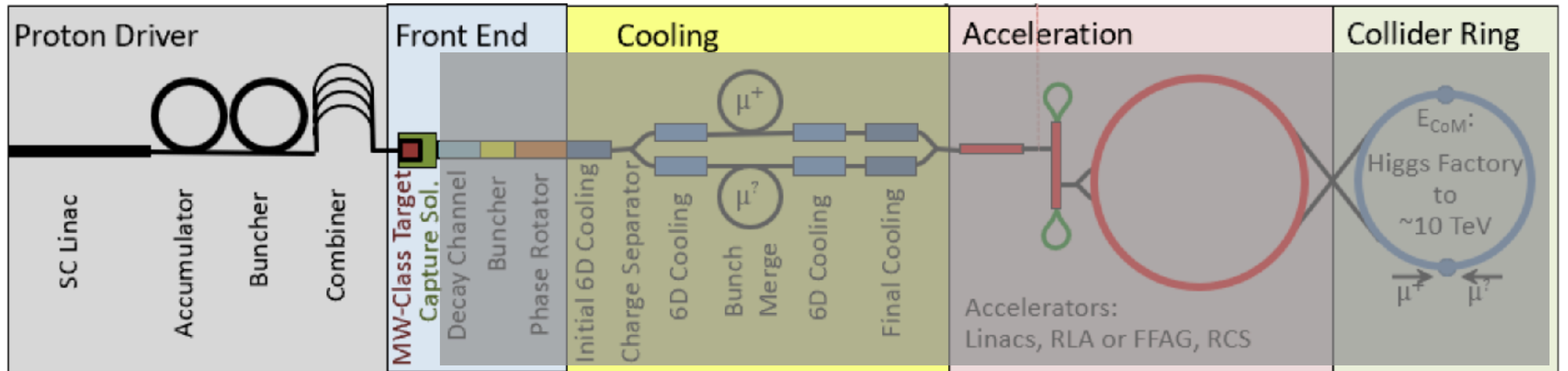
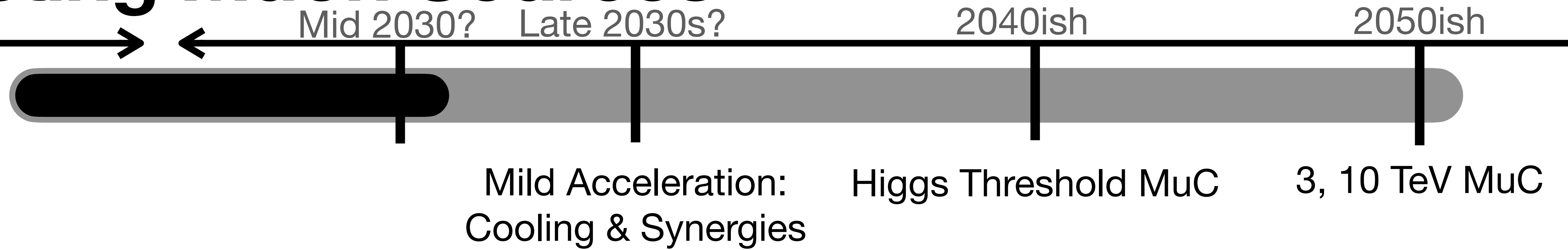
Mild Acceleration: Cooling & Synergies

Higgs Threshold MuC

3, 10 TeV MuC

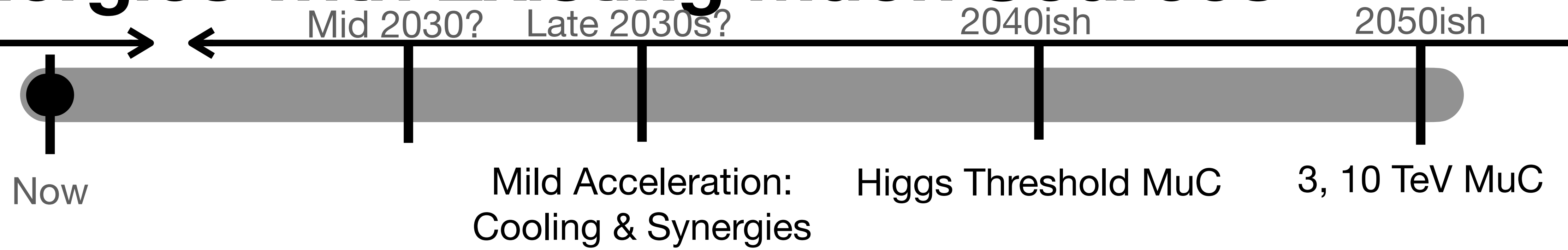


Existing Muon Sources



Programs at J-PARC, PSI, Fermilab, etc.

Synergies with Existing Muon Sources

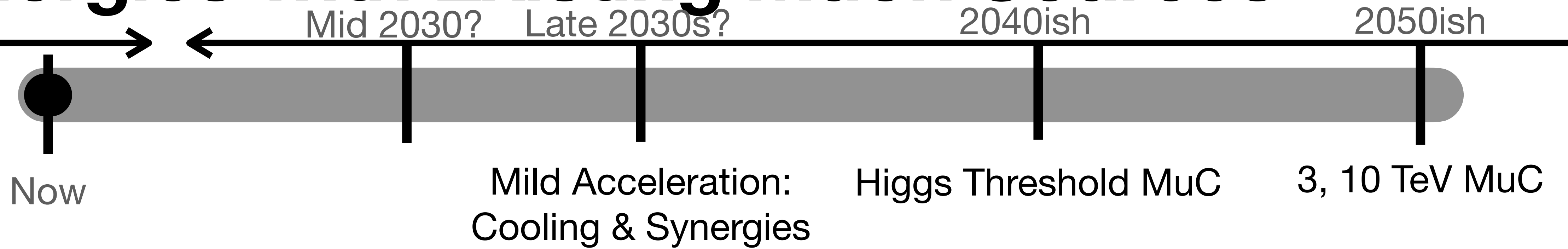


e.g. Micro/MiniBooNE

$$\nu N \rightarrow \nu N \pi^0$$

$$\pi^0 \rightarrow \gamma\gamma$$

Synergies with Existing Muon Sources



e.g. Micro/MiniBooNE

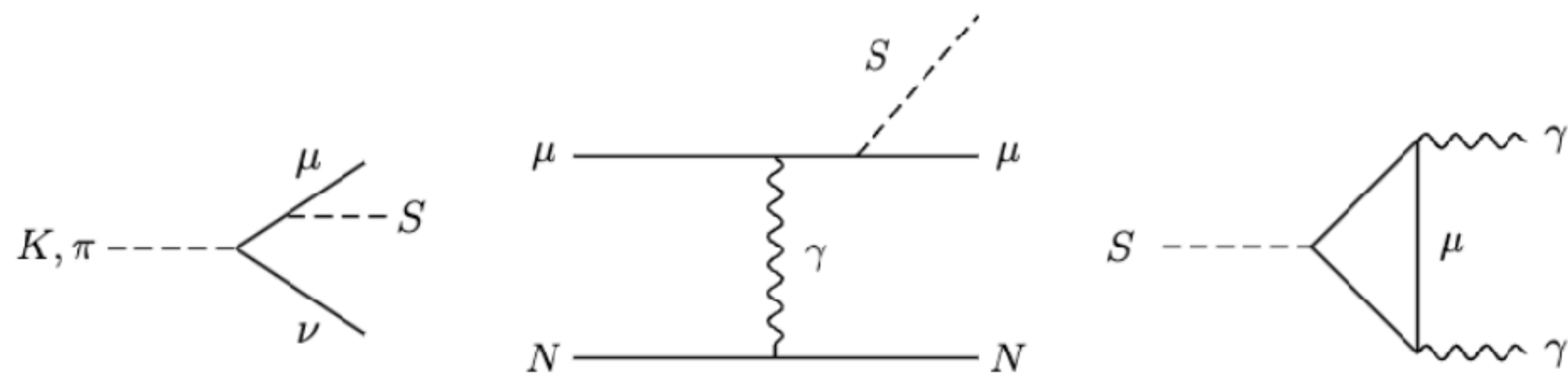
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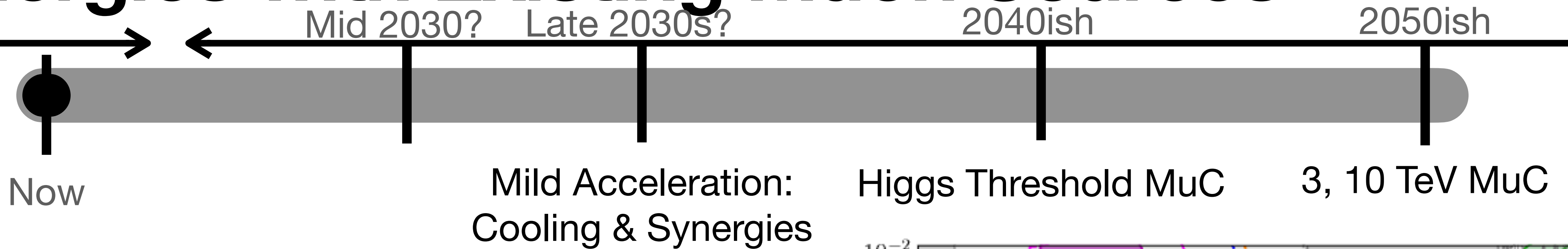
$$K^\pm, \pi^\pm \rightarrow \mu\nu S$$

$$\mathcal{L} \supset y S \bar{\mu} \mu$$

$$S \rightarrow \gamma\gamma$$



Synergies with Existing Muon Sources



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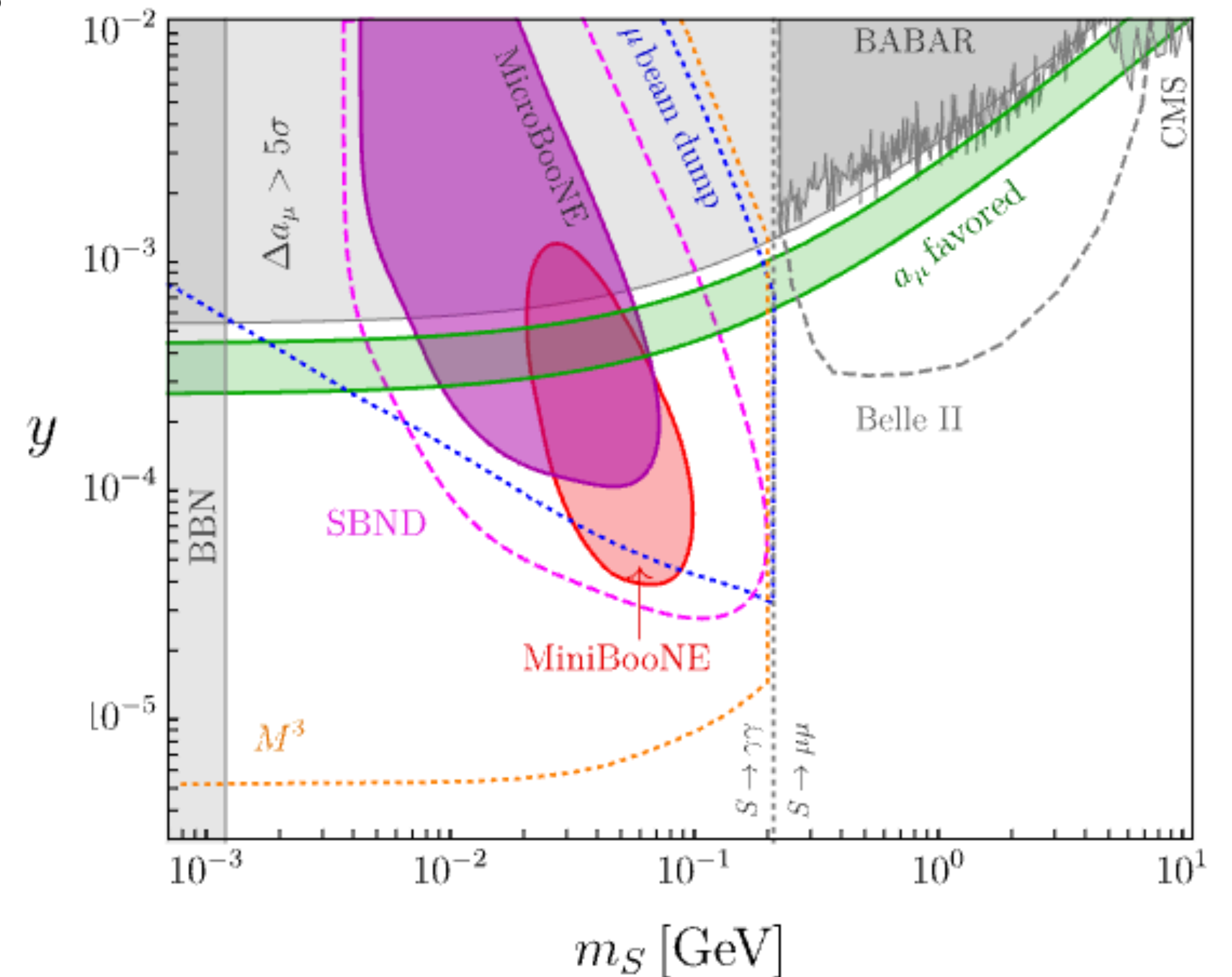
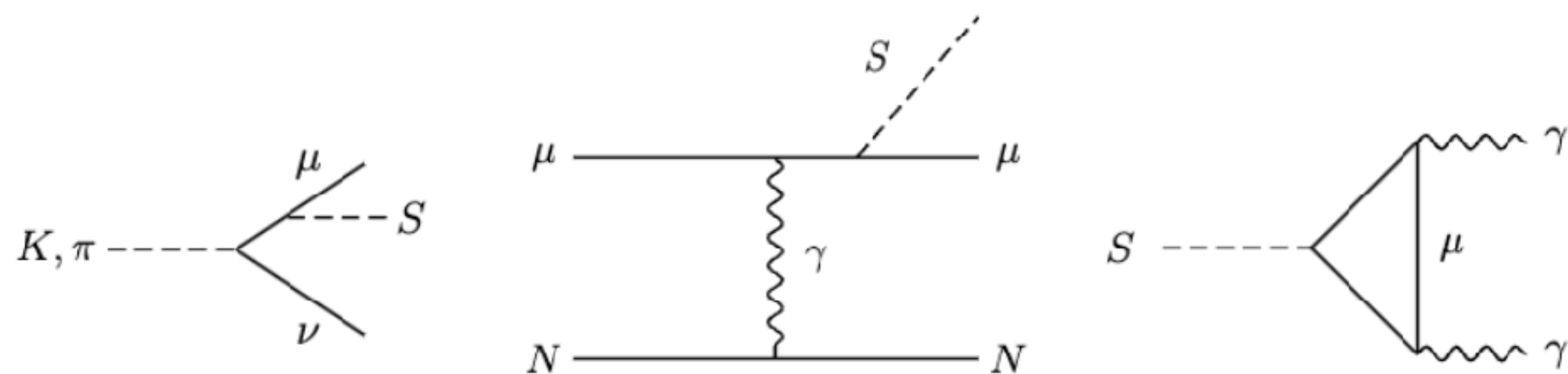
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Outlook



We need an experimental program that does the most **“new stuff”**

Technology must be tested and we should take advantage of intermediate steps

Consider synergistic experimental programs