M^3:
Muon Missing Momentum

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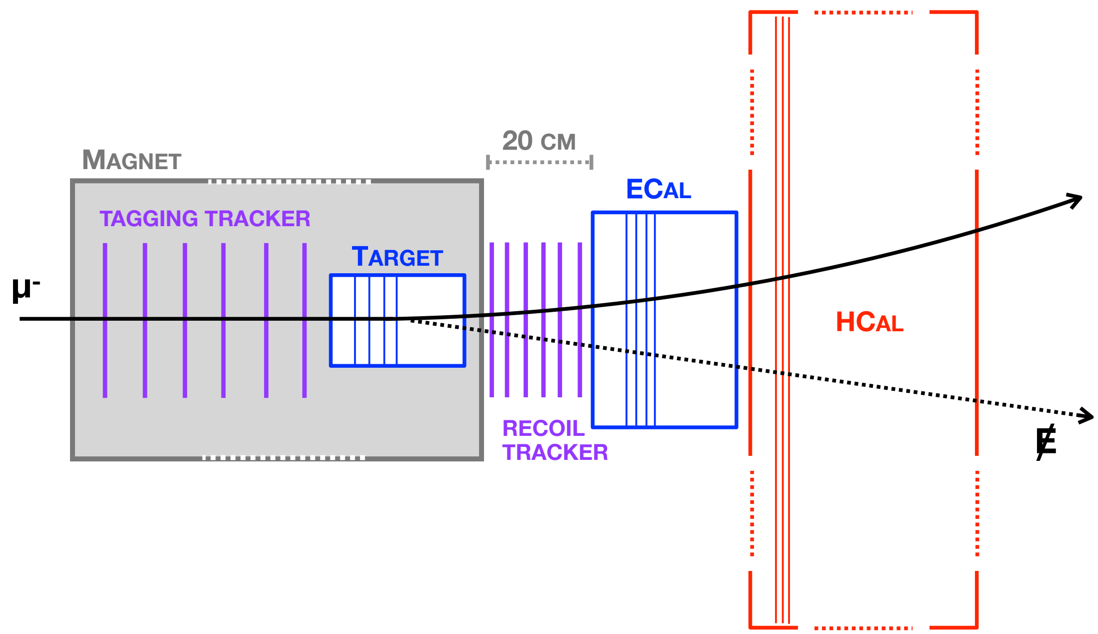
Muon missing momentum



You heard about missing momentum with electrons — now with muons!
Could be "LDMX but with muons", or more substantial differences in ECAL/HCAL ⟵ will focus on "LDMX with muons"

Main differences from LDMX: **thicker active target**
(muon is a MIP, loses less energy per unit length than an electron),
and outgoing muon momentum measured **exclusively by recoil tracker**
(ECal and HCal for veto only)

Why muons?

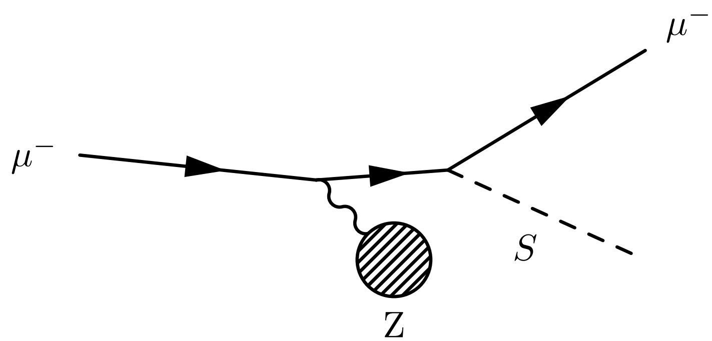
Theoretical:

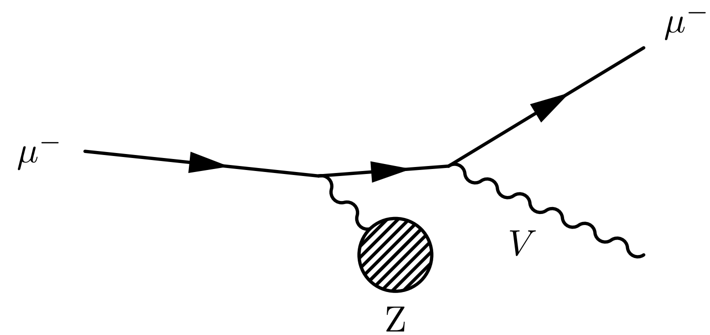
- Longstanding anomaly in g-2, Brookhaven result will be tested very shortly; new light particles could contribute
- Dark matter which only couples to muons could explain null results in direct and indirect detection

Practical:

- Heavier than electrons, brem less (lower QED-related backgrounds); better reach than electron beam for high-mass invisibles
- Only a few labs in the world have a sufficiently intense GeV-scale muon beam, and Fermilab is one of them!

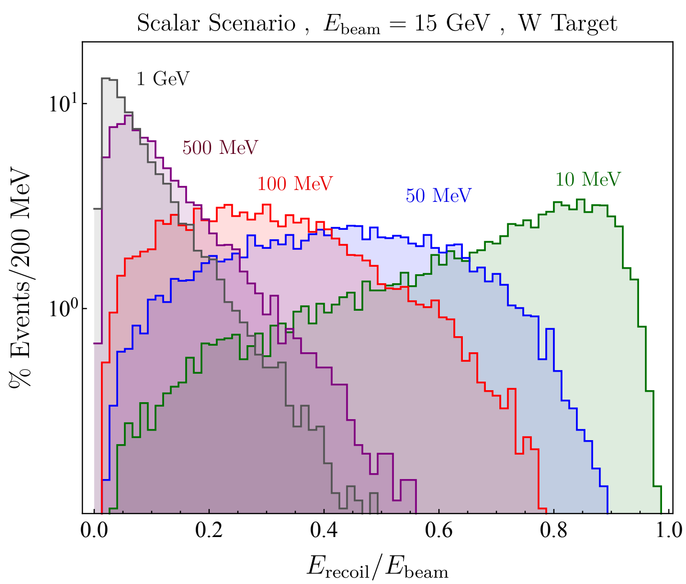
Setup



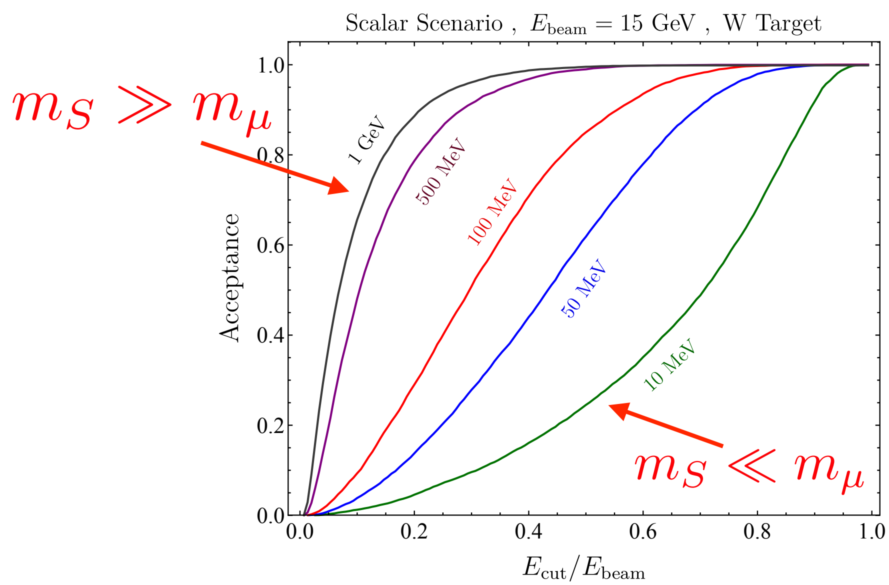


some new particle which couples to muons: scalar or vector

Z = some thick target, e.g. tungsten with 50 X_0 thickness



outgoing energy distribution



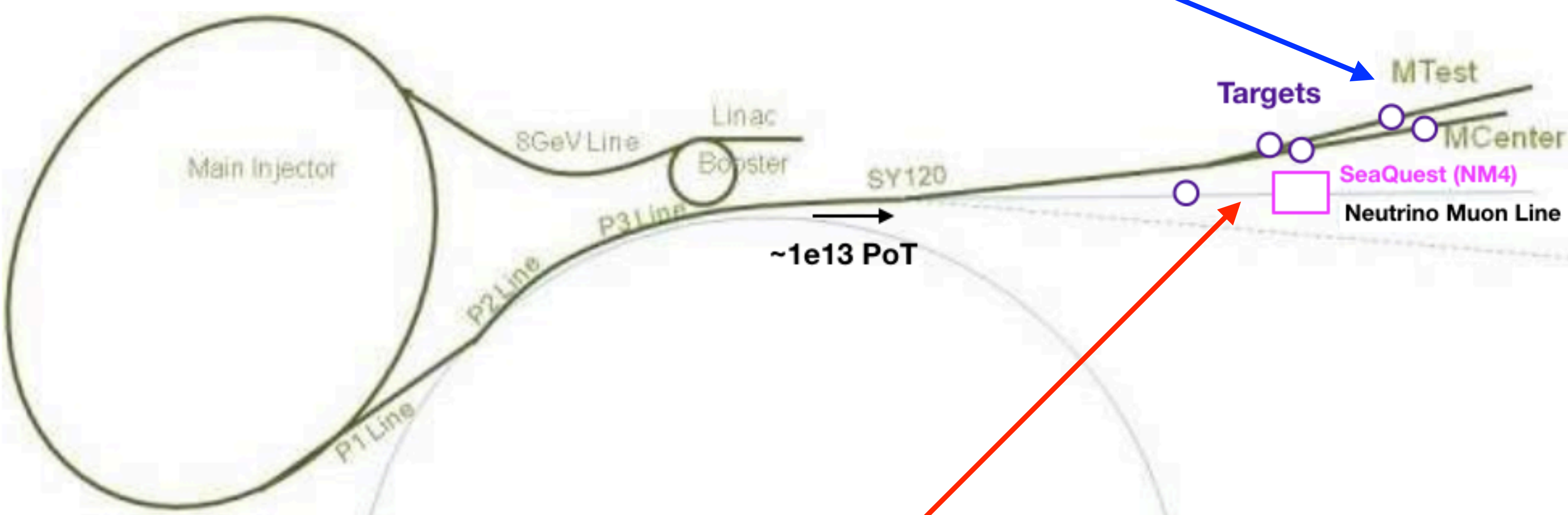
acceptance

Unlike electron beam, invisible particle doesn't take all the beam energy:
low-mass invisibles are QED-like (and hard to distinguish from background)

Fermilab beam facilities

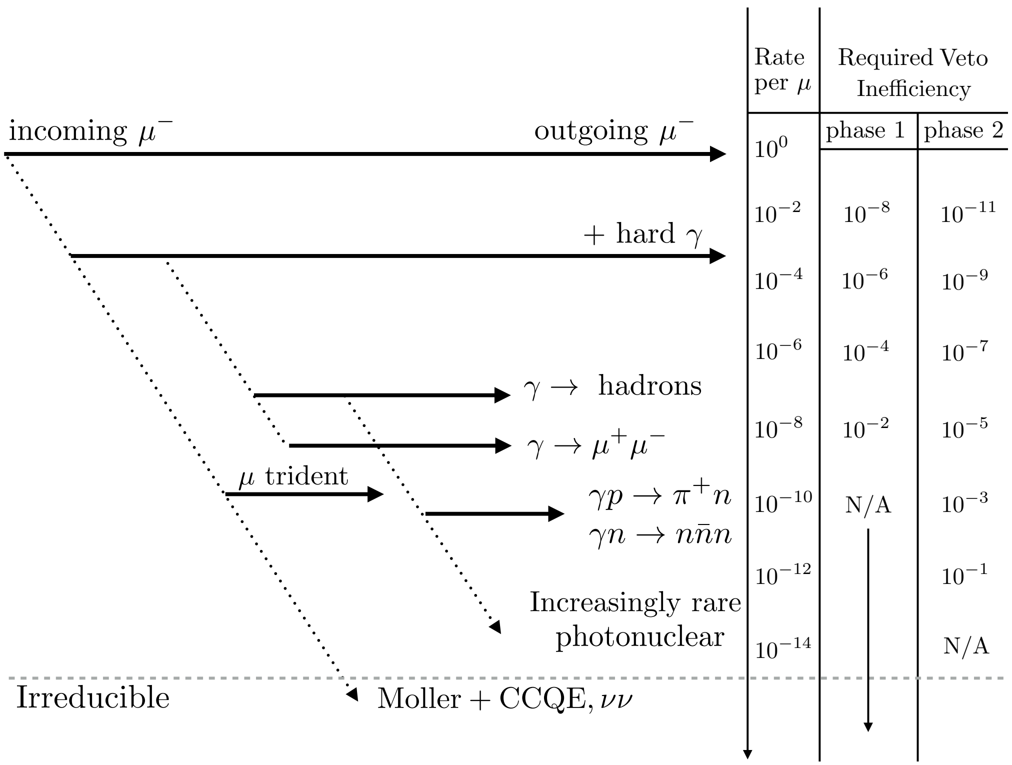
(At least) two possibilities for a 15 GeV muon beam:

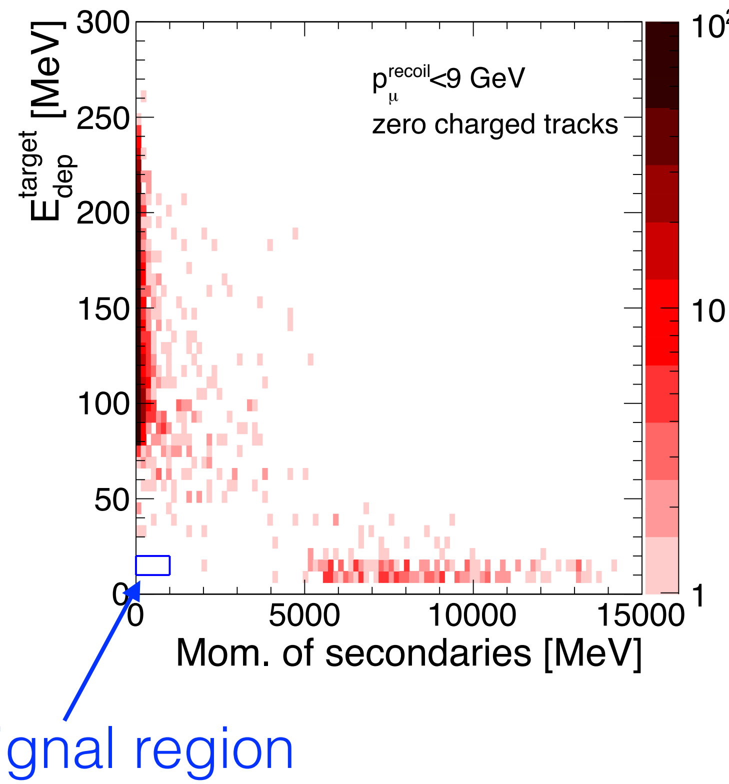
Phase 1: 10^{10} MOT at MTest ("out of the box")



Phase 2: 10^{13} MOT (NM4 beam line with modifications)

Backgrounds and signal selection

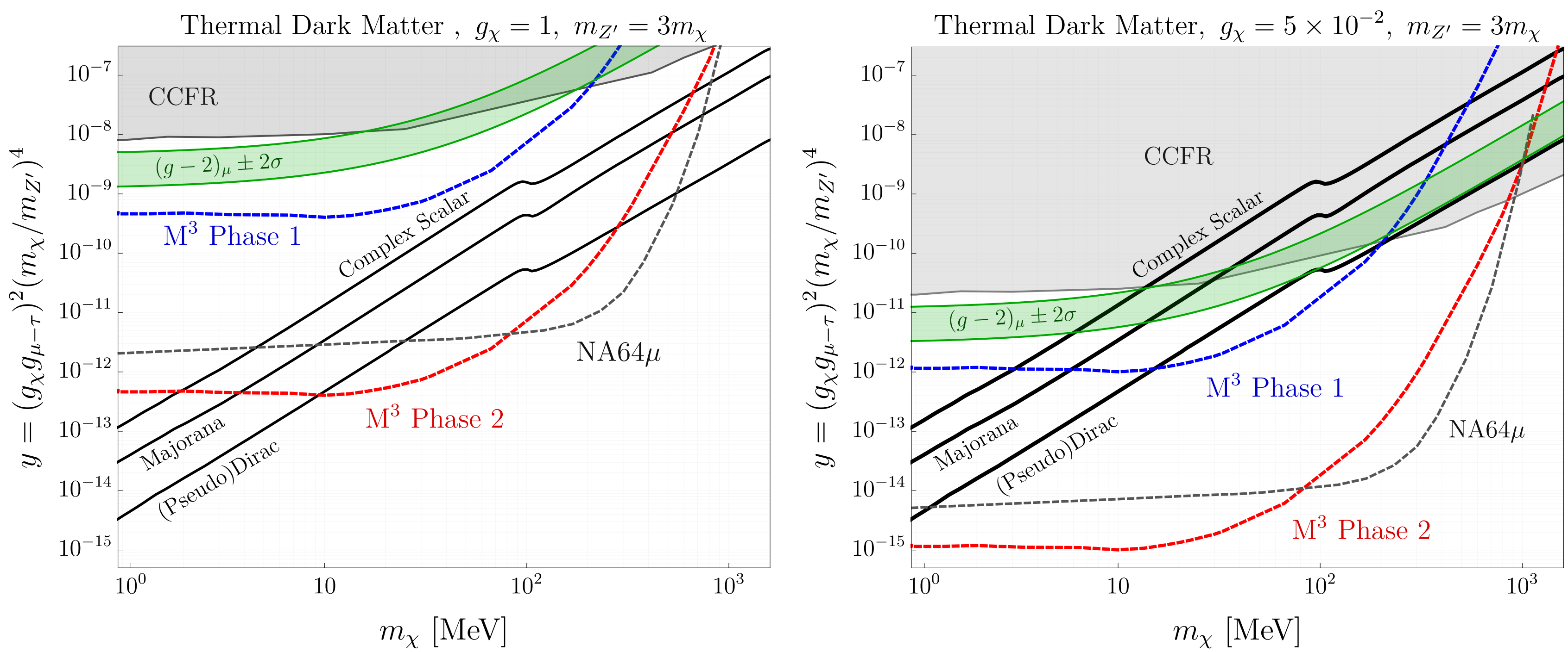




Key takeaway: phase 1 is **QED backgrounds only**

(zero events in signal region for 10^7 MOT GEANT simulation)

Reach



Phase 1: **complete coverage of g-2 region** for any invisibly-decaying particle lighter than the muon

Phase 2: can probe large parts of well-motivated DM parameter space

NA64 is a potential competitor at CERN:
let's do this experiment at Fermilab!