PX Muon, Kaon, Spallation Target Requirements

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Outline

Muons

- Magnetic ("g-2") and electric dipole moments (EDM)
- Lepton violating neutrinoless decays or conversions

Kaons

- Enhancements in rare decays that are $O(10^{-11})$ in SM.

Neutrons

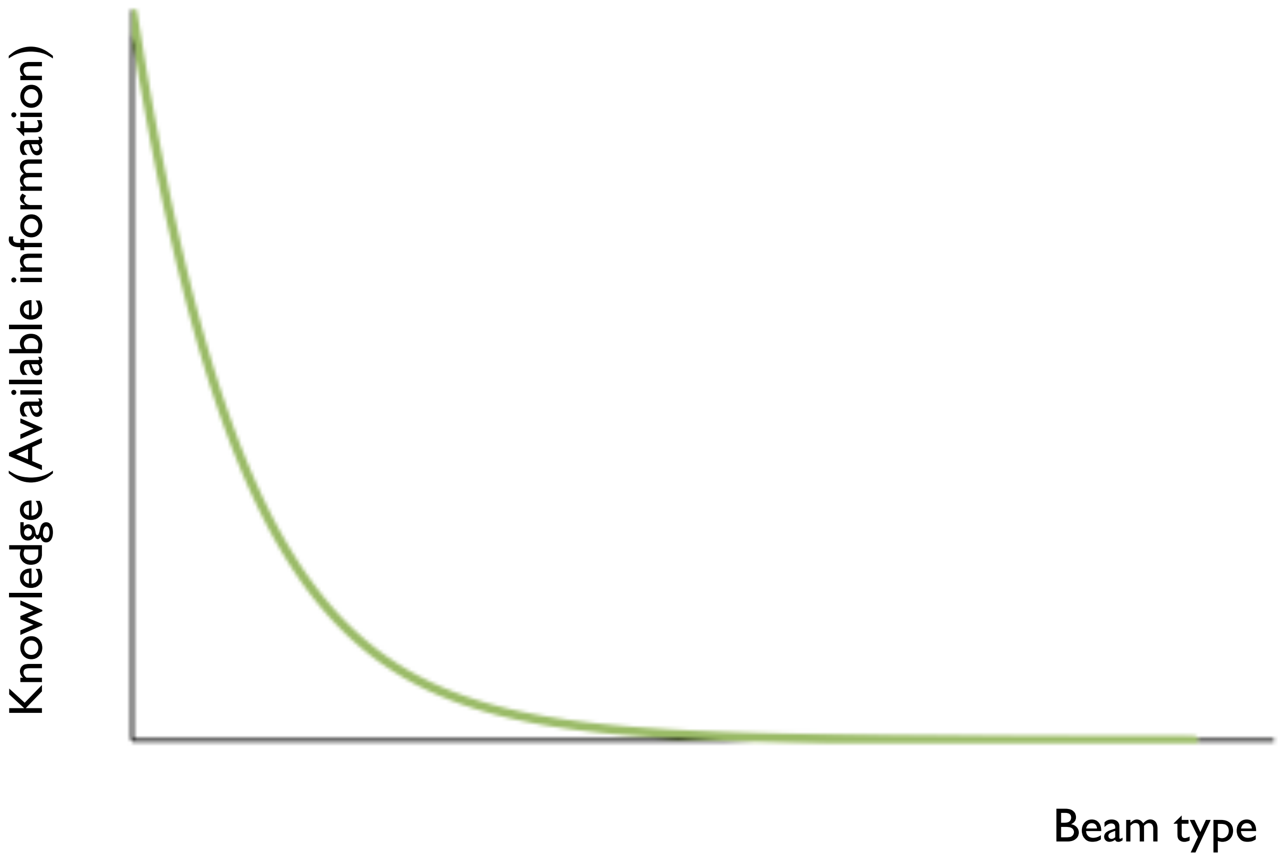
- Baryon number violating oscillations & possibly EDM

Isotopes

- Anomalous electric dipole moments

Where we are now & what PX could deliver and the target / beam requirements for that to be achieved

Outline

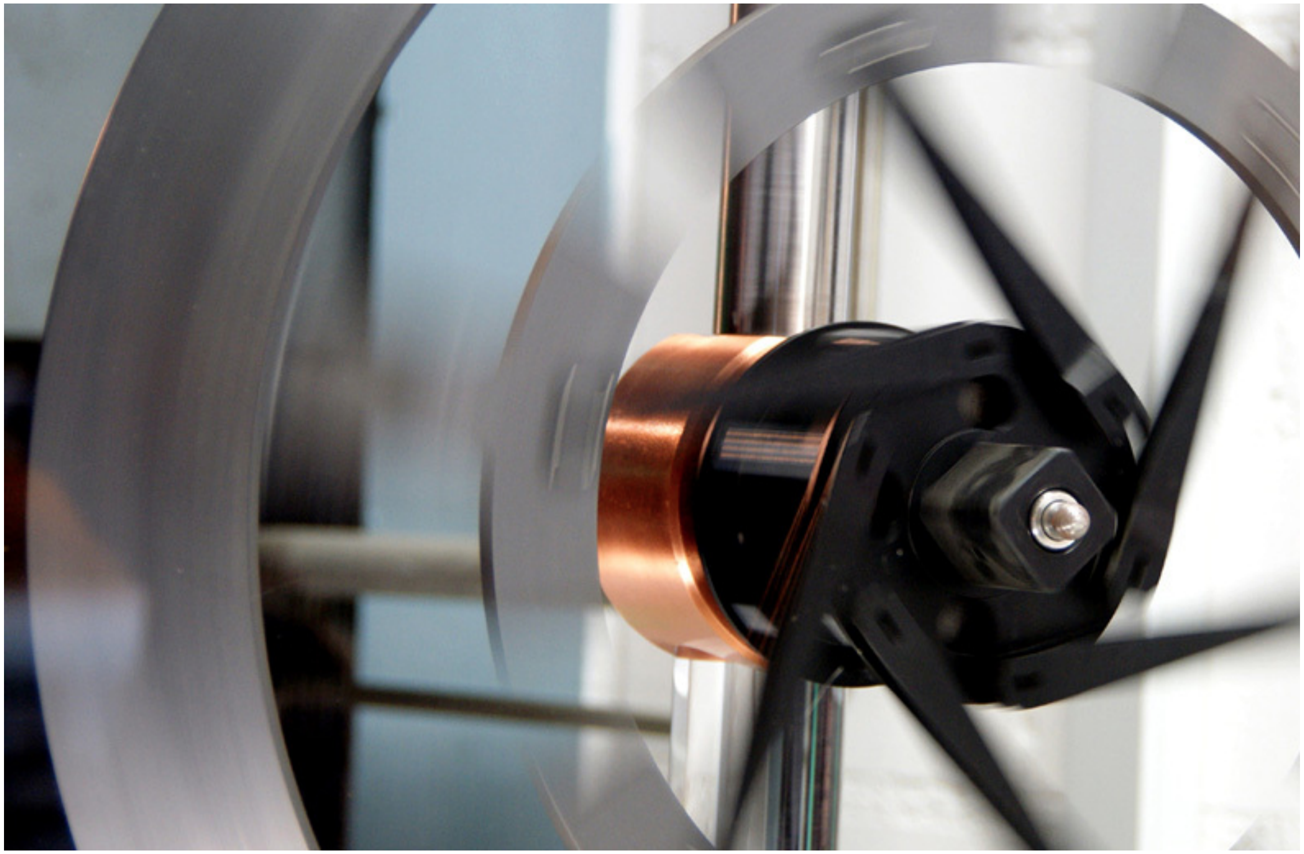


Current State of Art

PSI using two carbon targets for pion (muon) beam.

10^8 muons/sec

Beam Power : 1.3 MW



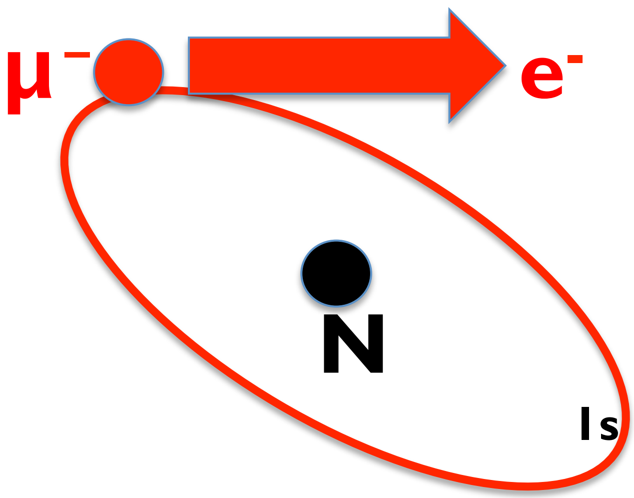
The "Flavour Problem"

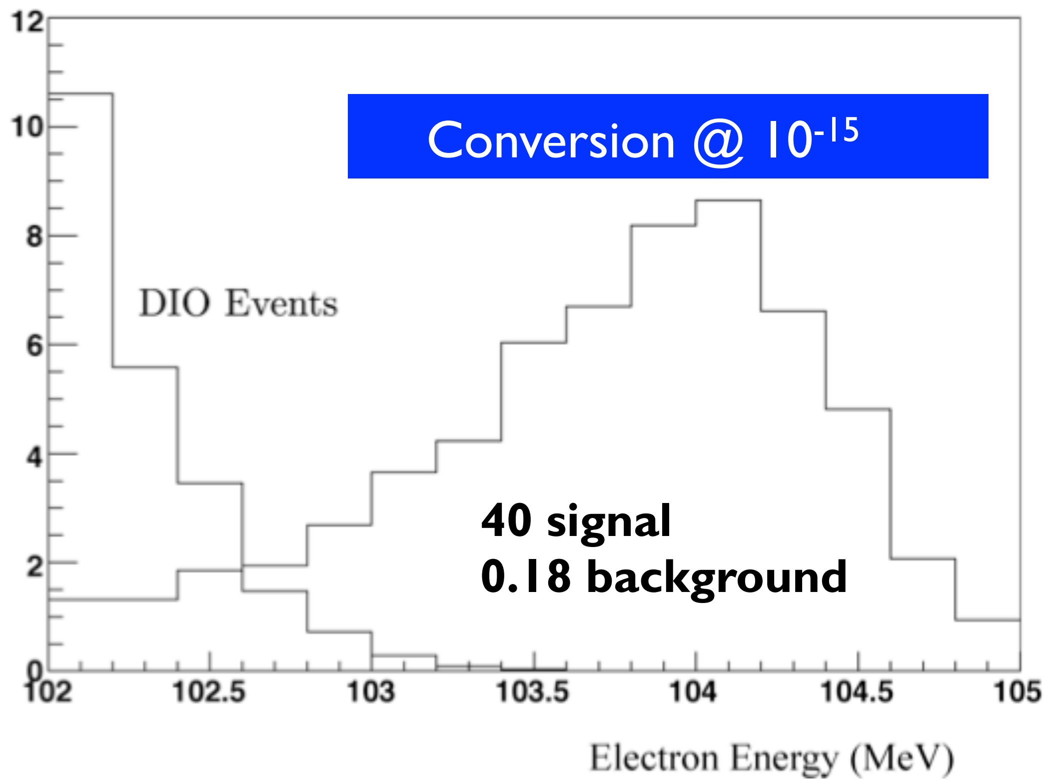
The flavour (and mass) structure of the SM remains mysterious.

In BSM theories flavour structure stems from the symmetries and dynamics of new physics.

In general this new physics produces enhancements to processes (dipole moments) that are extremely rare or absent in the SM.

Muon Conversion

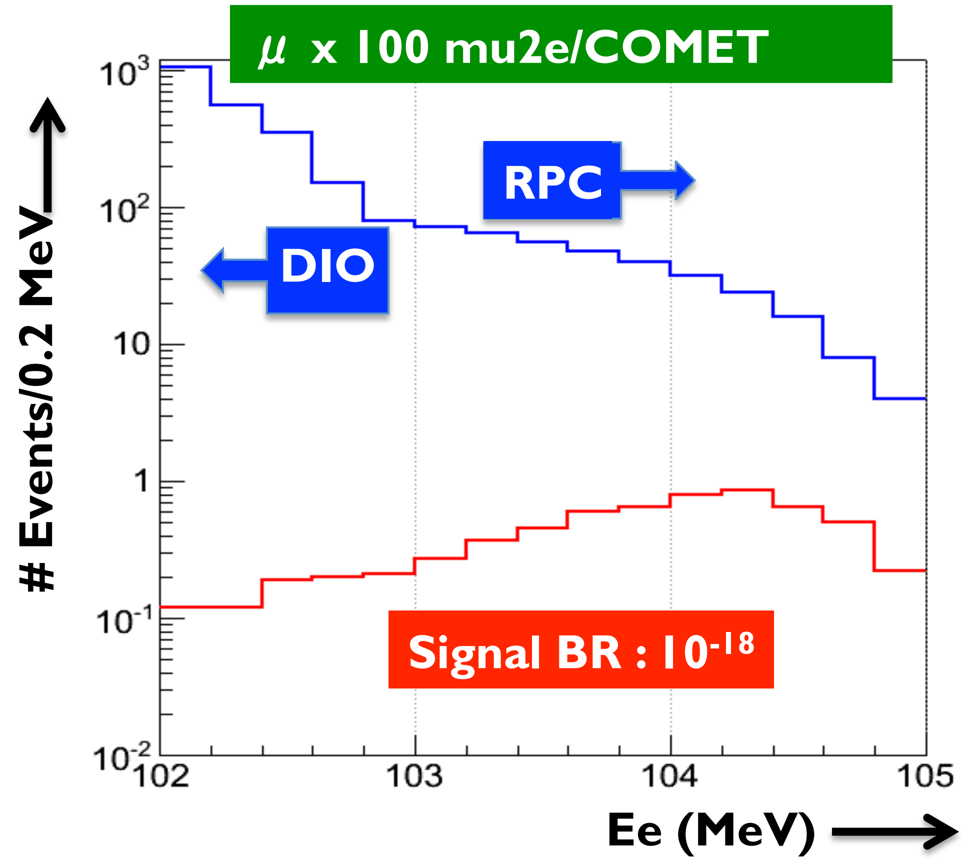




If signal established at COMET/Mu2e would like to measure with higher Z or if not to extend search by factor of 100.

Muon Conversion

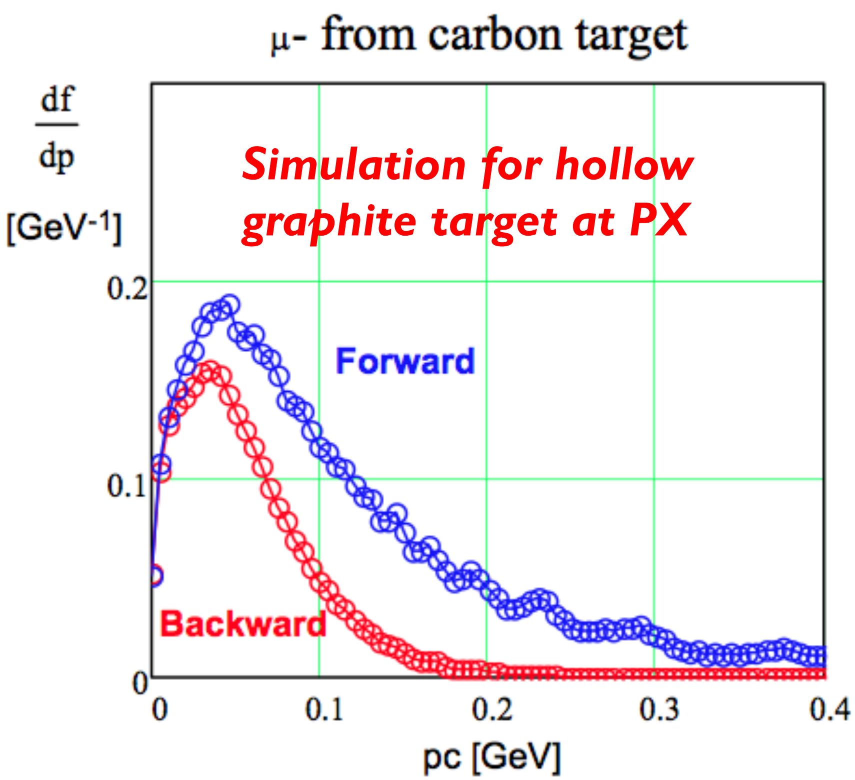
Need increase in muon rate from O(10^{10-11}/sec) to O(10^{13}/sec)

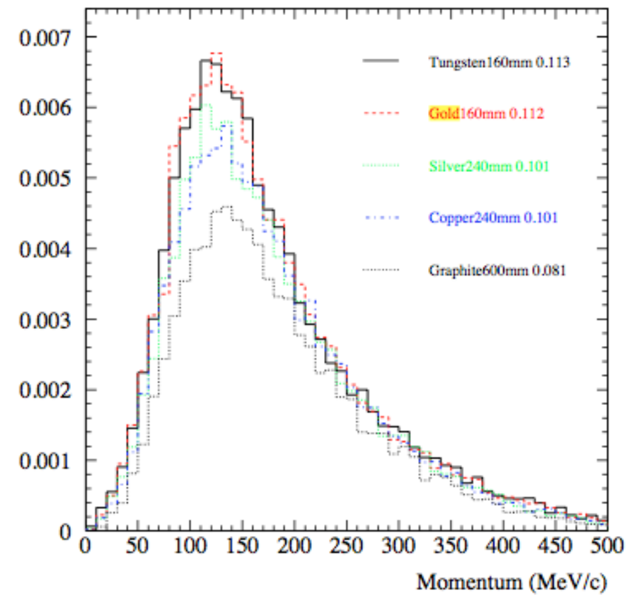


Implies power requirement increase of O(10-50 kW) to 1 MW

Muon Conversion

Current COMET/Mu2e targets are high-Z but 1 MW leaves ~ 100 kW in target requiring non-metallic (graphite) target



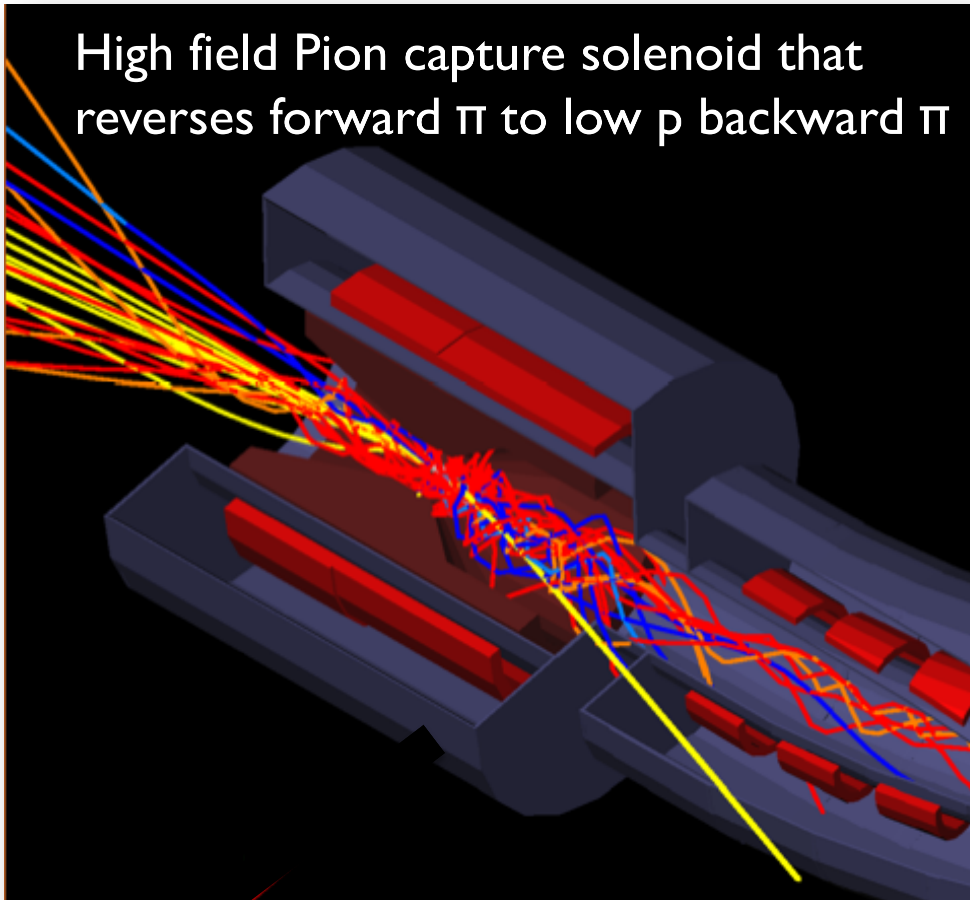


Use backward (pions) muons since

- beam dump simpler
- average p is lower

Muon Conversion

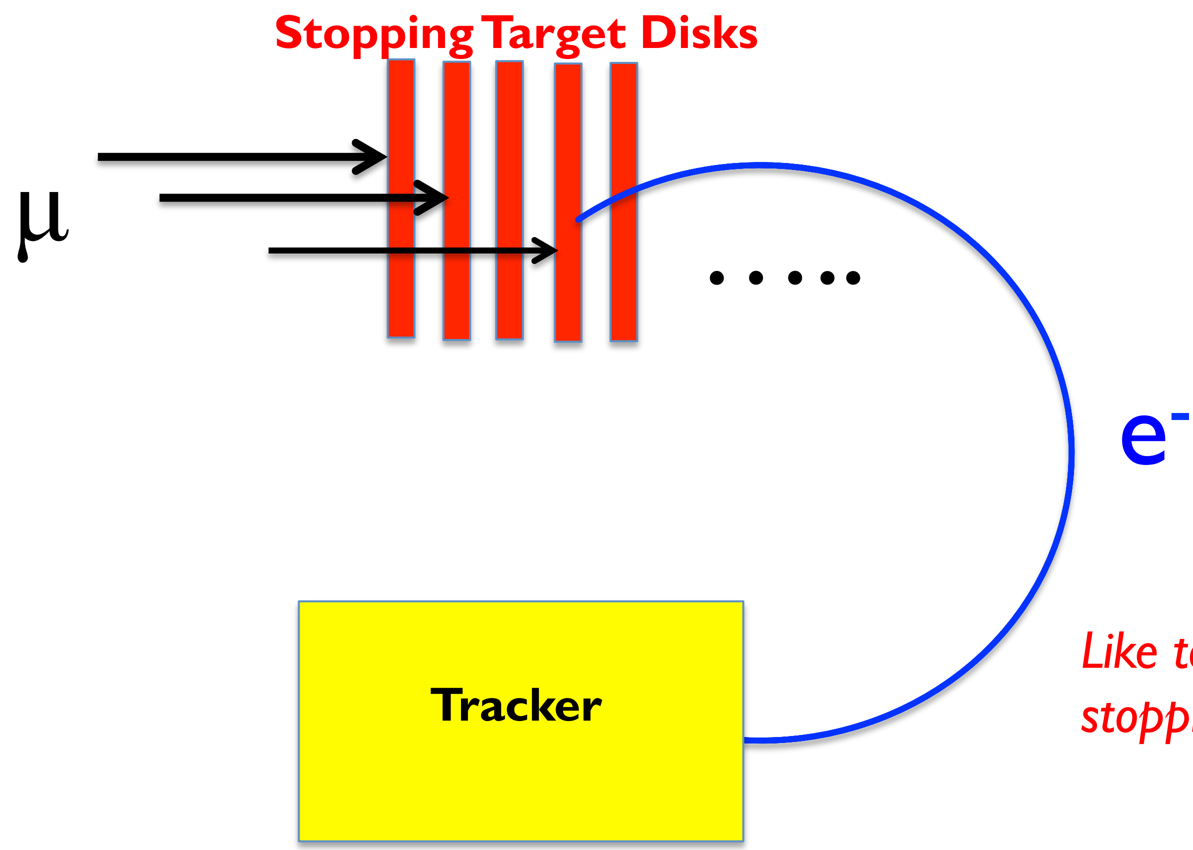
Use pion capture solenoid to enhance rate



Means target must be in high B field (5 T) and presence of superconducting solenoid requires:

- a low DPA O(10^{-6}/year)
- neutron flux < 10^{22} m^{-2}

Muon Conversion



Like to have only one thin stopping target

Power increase alone is not enough, also require:

1. Muons to arrive at stopping target close in time (50 ps)
2. Muons to have low momentum spread and low KE (< 2 MeV)

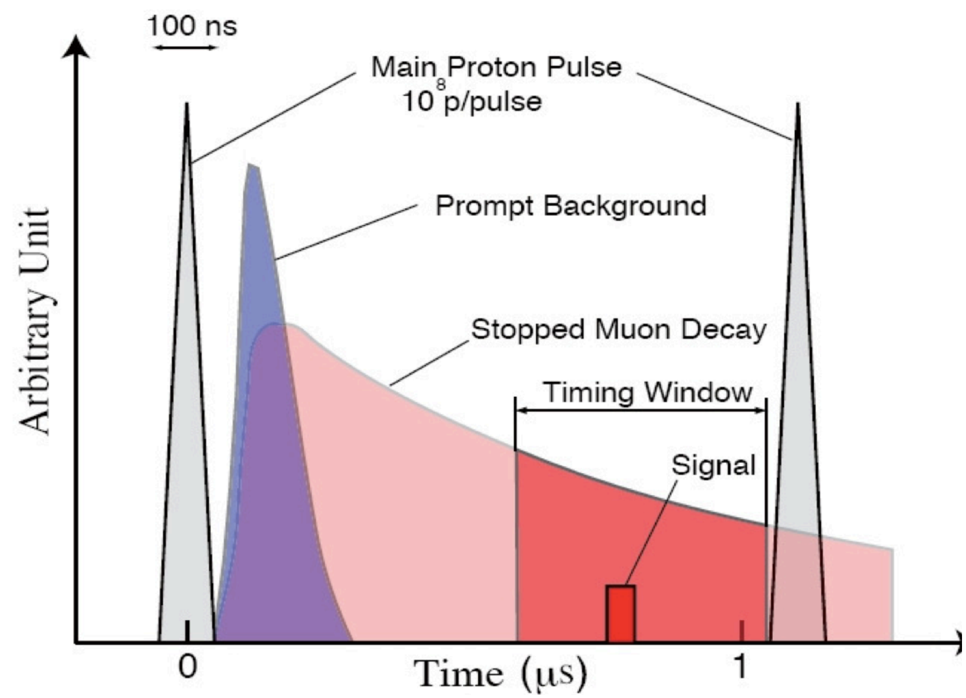
Muon Requirements

Power : 1 MW
Target : low-Z (hollow graphite)
Muons : 10^{13} /sec
Muons to have low KE (< 2 MeV) and low Δp (few MeV) & Δt (50 ps)
Operation in high (5T) field
DPA : 10^{-6} /year
Neutrons : 10^{22} m^{-2} (lifetime : 5 yr)

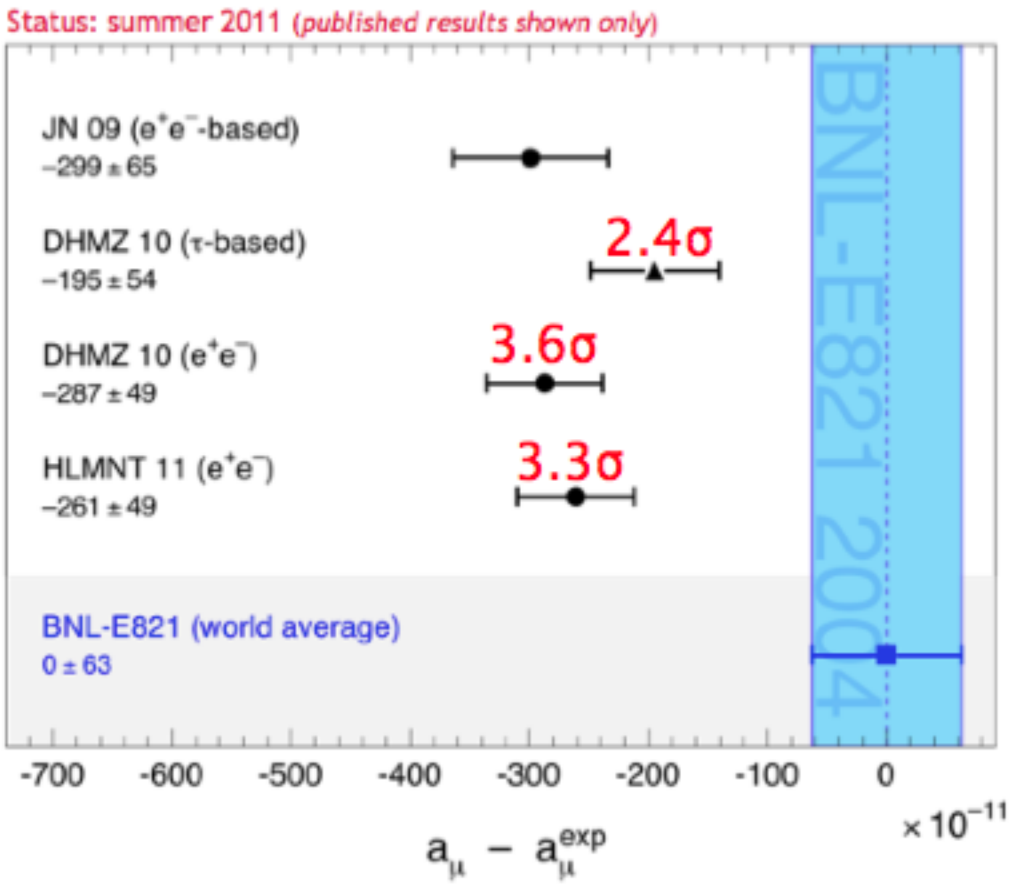
"cooling" after the target

Proton beam pulsed (200-1200 ns)

Beam monitoring
- extinction rate between pulses
- pulse width



Muons : Dipole Moments



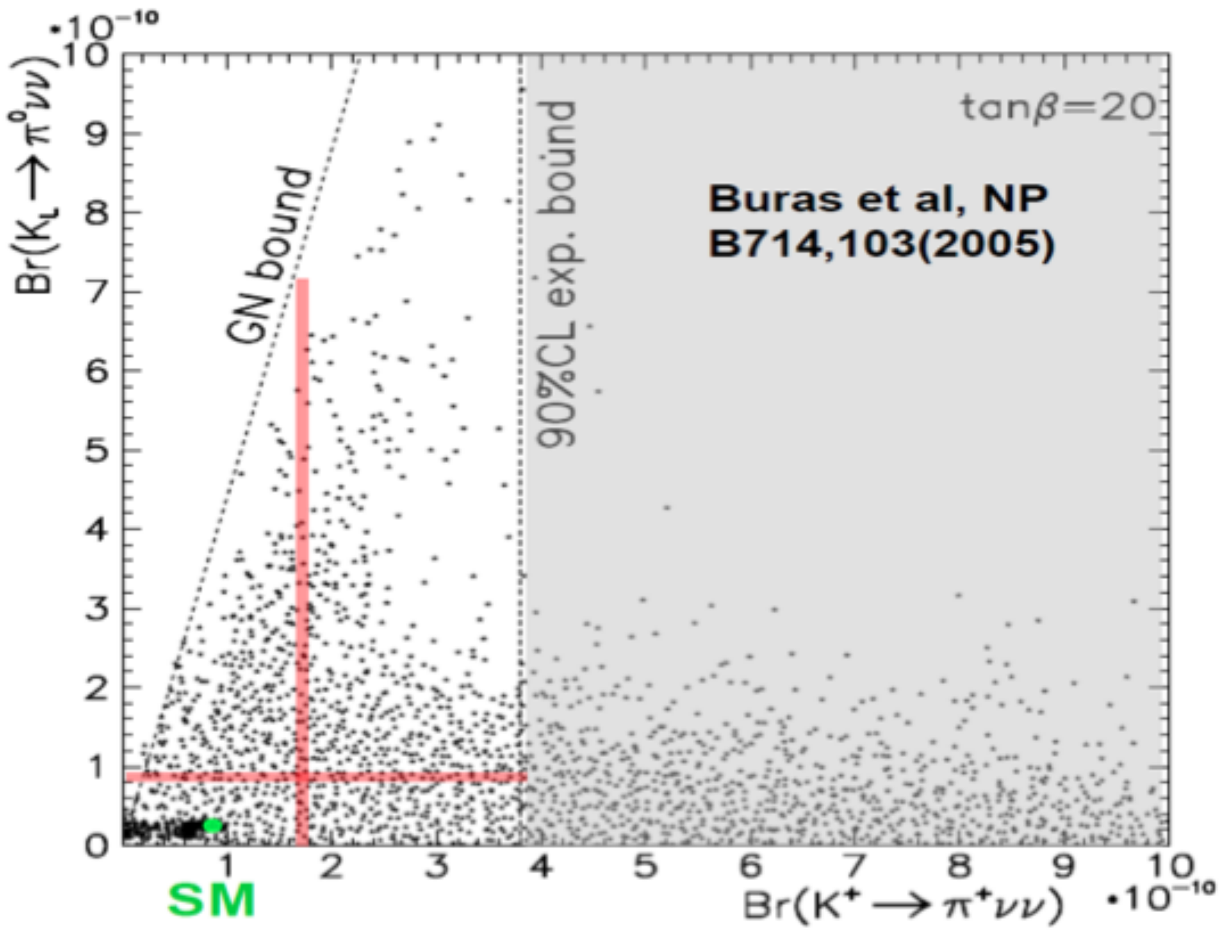
Prior to PX this will be measured x4 better.

Limiting factor will be theory error.

PX allows further improvement if merited by reduced theory uncertainty & high rate allows μ^- and μ^+ measurement.

Target requirements less severe than conversion.

Kaons



Excellent BSM reach and sensitivity

Kaons

$K_L \to \pi^0 \nu \bar{\nu}$

Rate is 3×10^{-11} in SM and KOTO (J-PARC) expects to be able to make 1st observation with a handful of events.
1 MW at PX could yield 1000 event sample

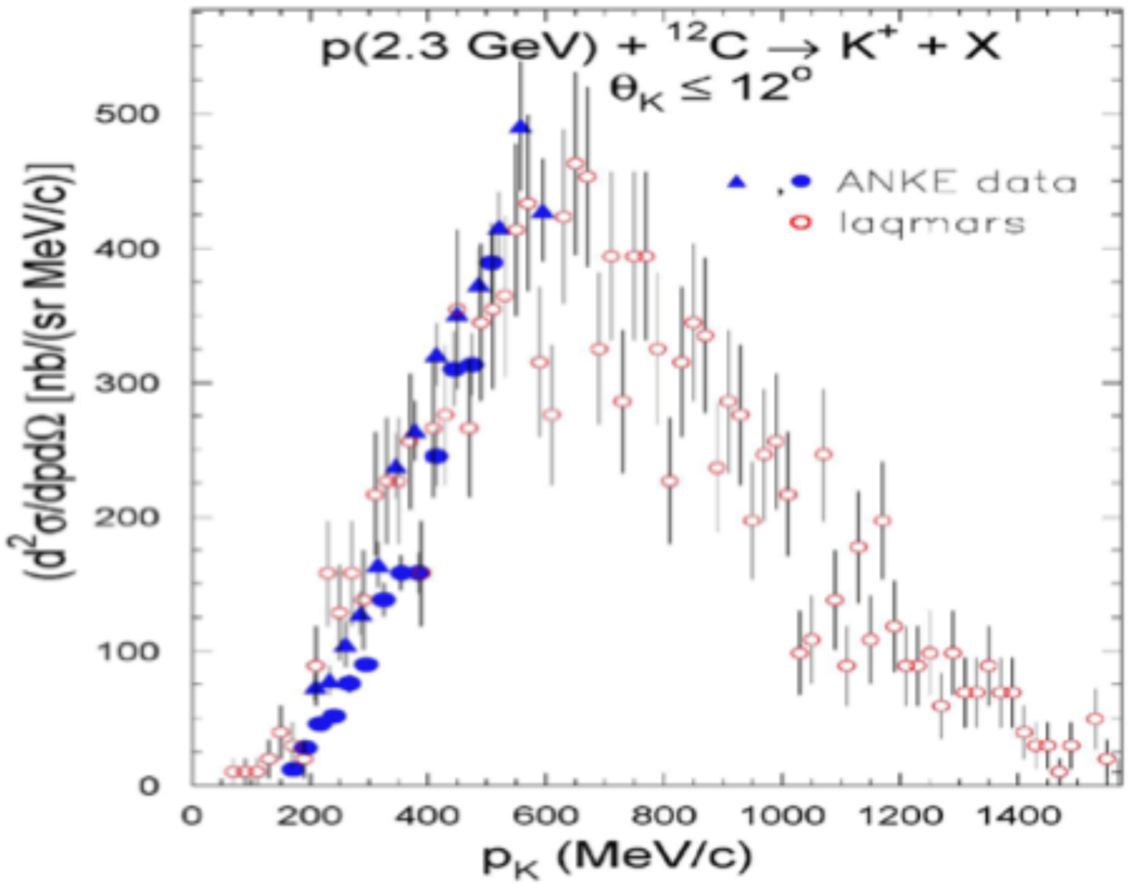
$K^+ \to \pi^+ \nu \bar{\nu}$

Rate is 8×10^{-11} in SM and NA62 (CERN) will have 100-event sensitivity.
1 MW at PX could yield 1000 event sample

Requirements are very similar to muons:

- Low-Z target
- Small Δt (50 ps) to improve pion rejection and TOF discrimination
- Low KE (increase stopping K+ and better TOF K_L)
- Rates : 10^8 s^{-1} (K+), 5×10^8 s^{-1} (K_L)
- Pulsed 40ns separation

Kaons

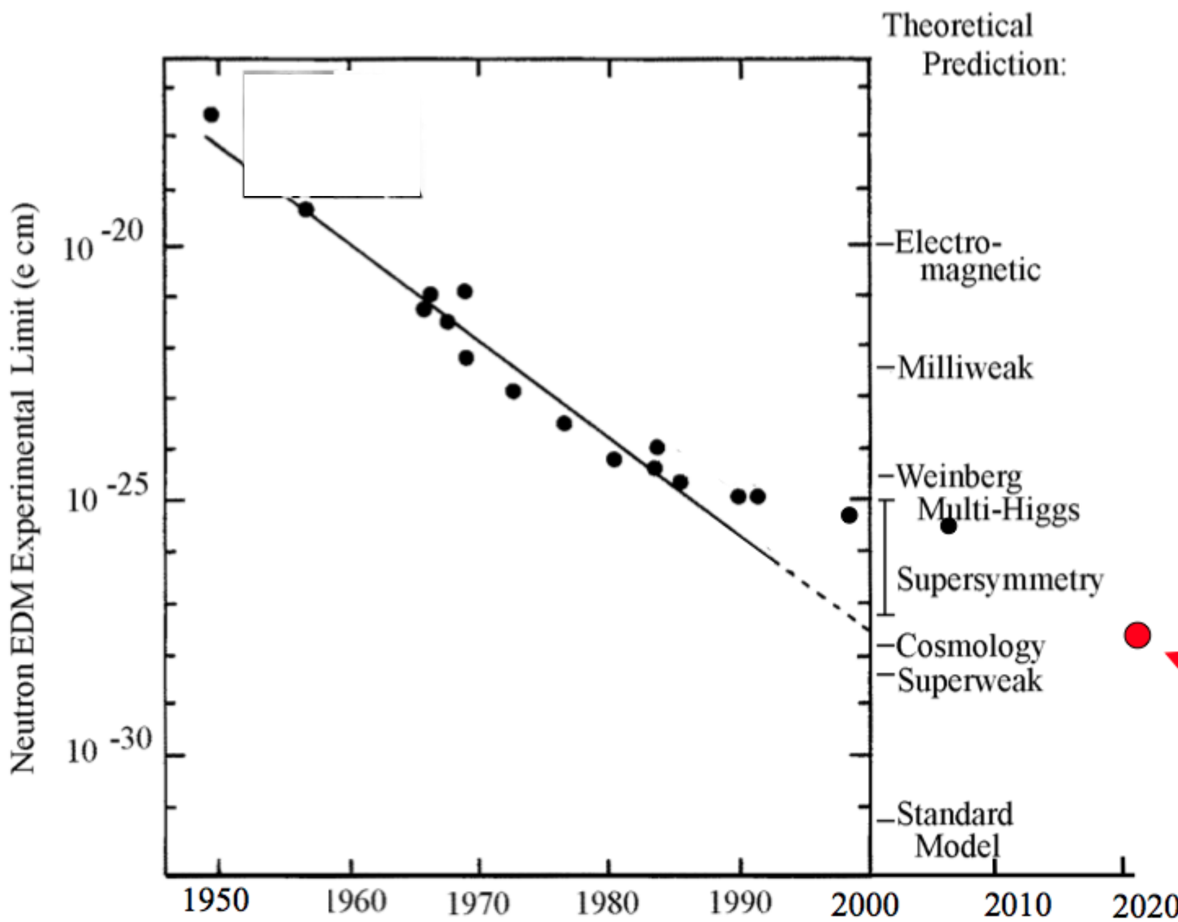


P at ~ 500 MeV

K/π = 1:80

Neutrons

Two measurements with cold neutrons : oscillations and EDM

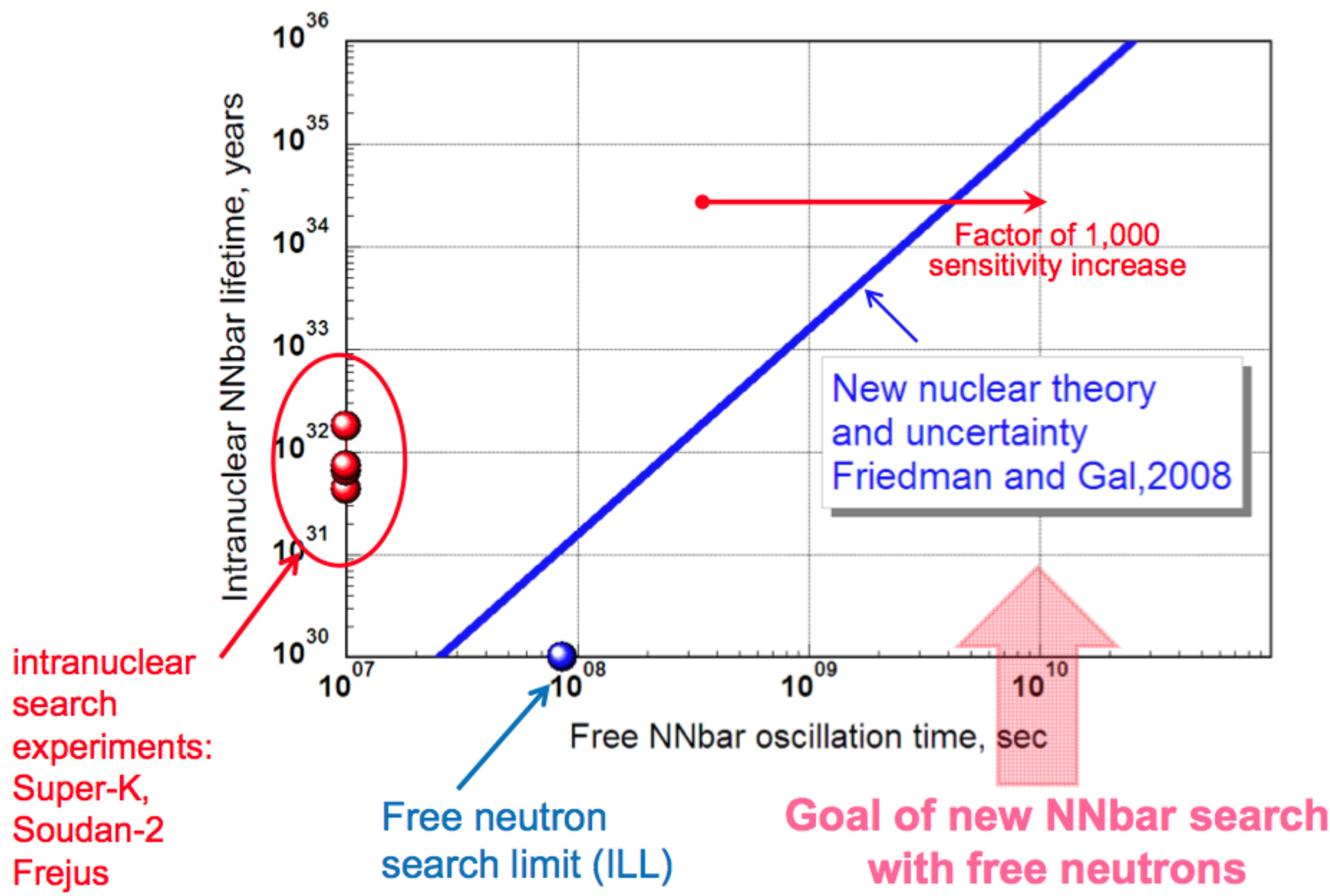


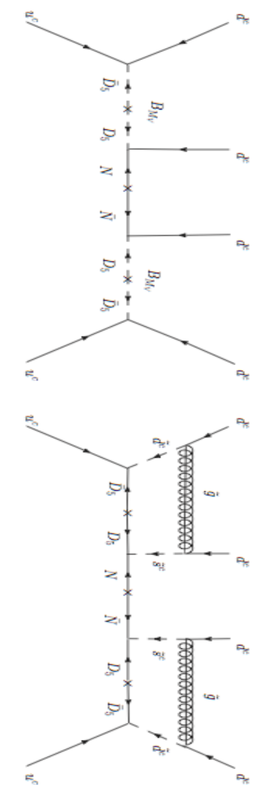
ILL : 3×10^{-26} (UK led)

US EDM aiming for 10^{-28} using 1.4 MW (1 GeV) at SNS

Neutrons

Many BSM extensions particular GUTS pertaining to neutrino mass & baryongenesis allow $\Delta B=2$ processes (complement $\Delta B=1$ p decay, $\Delta L=2$ 0υDBD)





Neutrons

Both measurements require large intensity of cold neutrons ($v < 7$ m/s) from spallation target (Pb or Hg).

Challenge is obvious:

- MW beam inside cryogenic (^3He) cooler

Requirement

- 10^8 n/sec
- continuous not pulsed

Atomic EDM

BSM (violating P,T) induce EDMs : magnified by Z^{2-3} in atoms.

Use octopole deformed nuclei like ^{225}Ra or ^{223}Rn : extra $O(10^{2-3})$ sensitivity over ^{199}Hg

Use target and in situ chemistry for isotope separation (ISOL)

Requirement:

- 500 kW on ^{232}Th target to produce ^{225}Ra at 10^{12-13} s^{-1} (also Rn) and Fr (e^- EDM)

Summary

All require 0.5 – 1 MW power

	Rate/s^{-1}	Type	DPA	Neutrons /m^{-2}	Time
Muon	10^{13}	C	10^{-6}	10^{22}	Pulsed (50ps, 200-1200 ns)
Kaon	10^{8}	C			Pulsed (50ps,40ns)
Neutron	10^{8}	Pb/Hg			
Atom	10^{13}	Th			