Summary of Accelerators Working Group

Conveners

Bertrand Echenard (Caltech)

Eder Izaguirre (Brookhaven National Laboratory)

U.S. Cosmic Visions: New Ideas in Dark Matter

The Case for Accelerators

Can **robustly** test light DM that was in thermal contact with SM

Ready to do it today!

Dark Matter

What we know:

Equation of state

$\rho_{\mathrm{DM}} \sim \rho_{\mathrm{SM}}$

Interacts through gravity

$10^{-20}\ \mathrm{eV} < \mathrm{m}_{\mathrm{DM}} < 10^{68}\ \mathrm{eV}$

Hypothesis:

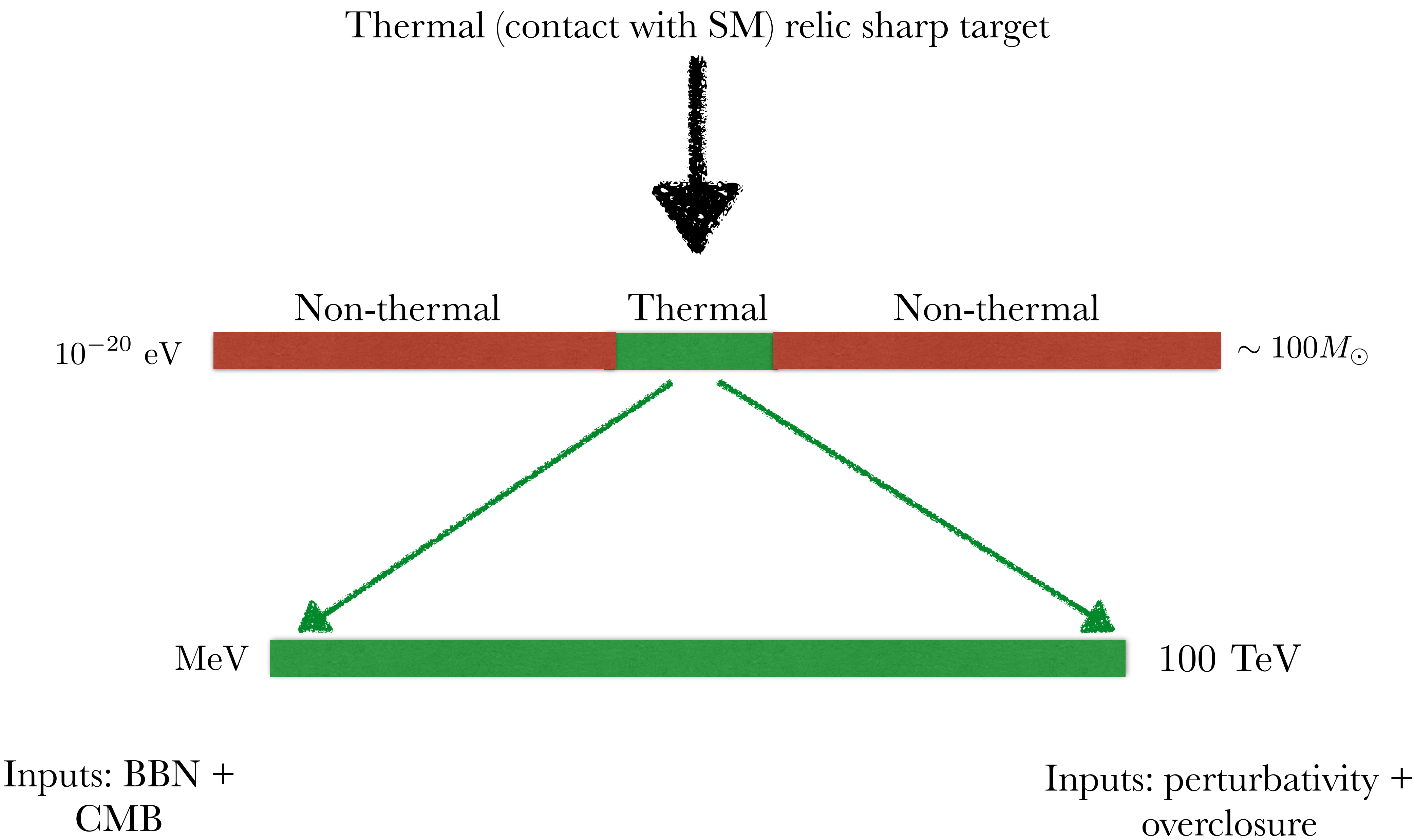
It couples to SM through 'sizable' non-gravitational interactions

(consequence)

Thermal equilibrium with SM

Abundance through freeze-out

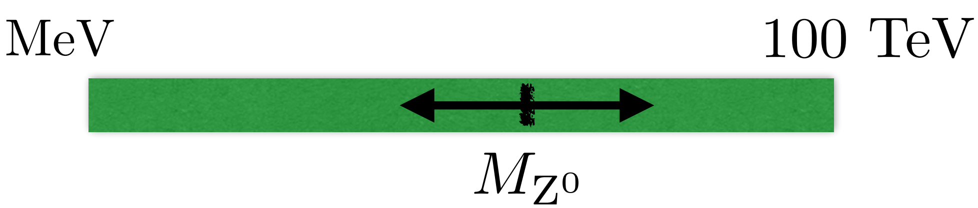
Dark Matter


Thermal (contact with SM) relic sharp target
Non-thermal
Thermal
Non-thermal
10^{-20} eV
$\sim 100 M_{\odot}$
MeV
100 TeV
Inputs: BBN + CMB
Inputs: perturbativity + overclosure

Dark Matter

Thermal relic sharp target (contact with SM)

Hypothesis:
tightly tied to EWSB

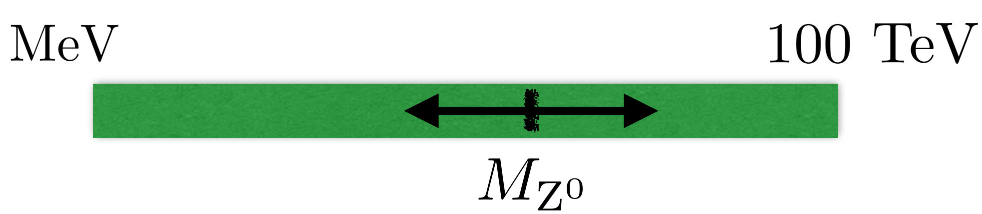


WIMPs!

Dark Matter

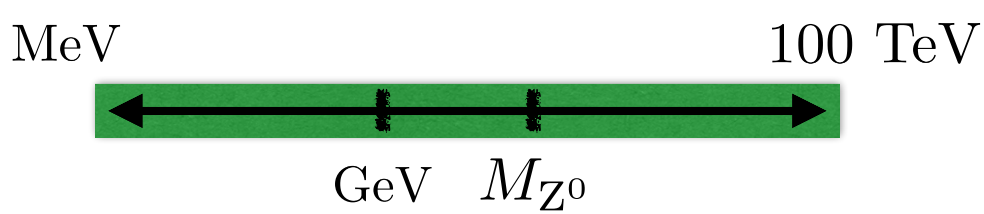
Thermal relic sharp target (contact with SM)

Hypothesis:
tightly tied to EWSB



WIMPs!

Hypothesis:
weakly tied to EWSB



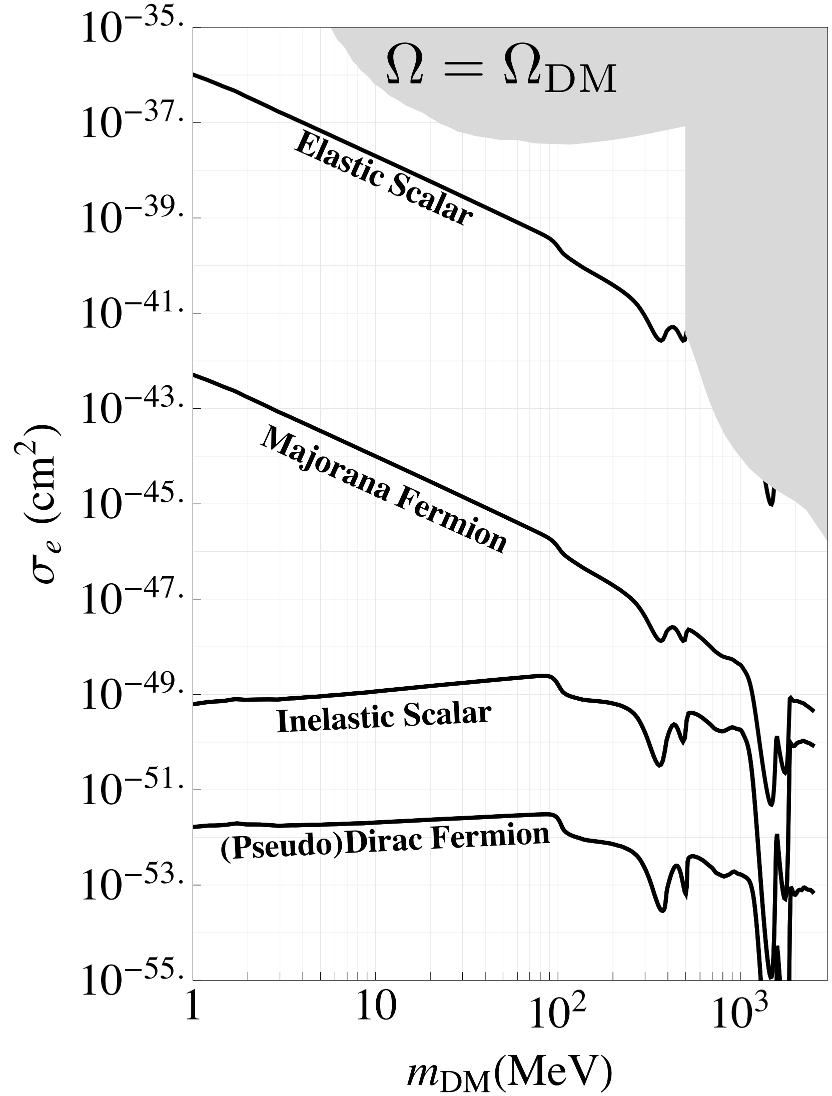
Light thermal DM
same mass range as SM: MeV - TeV

Thermal contact implies
light mediator!
(See Krnjaic and Schuster's talk)

The Light Thermal Target

It's important for direct detection to get here!
Cosmologically long-lived particle from halo

Direct Detection current bounds

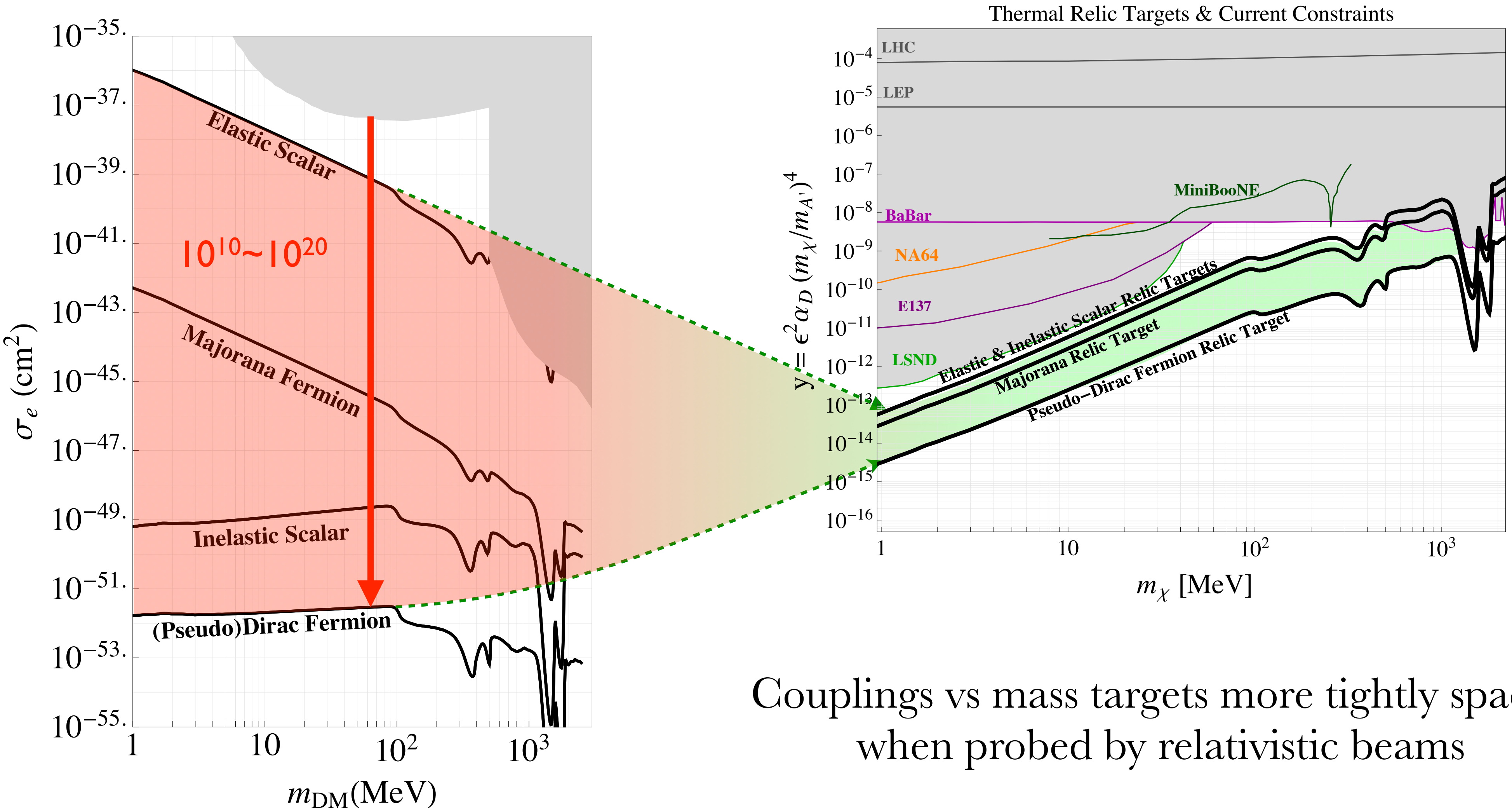


Sensitive to DM:
- abundance
- particle nature
- velocity today $v \sim 10^{-3}c$

The Thermal Target

Halo DM 'beam': non-relativistic probe

Accelerator DM beam: relativistic DM



Couplings vs mass targets more tightly spaced when probed by relativistic beams

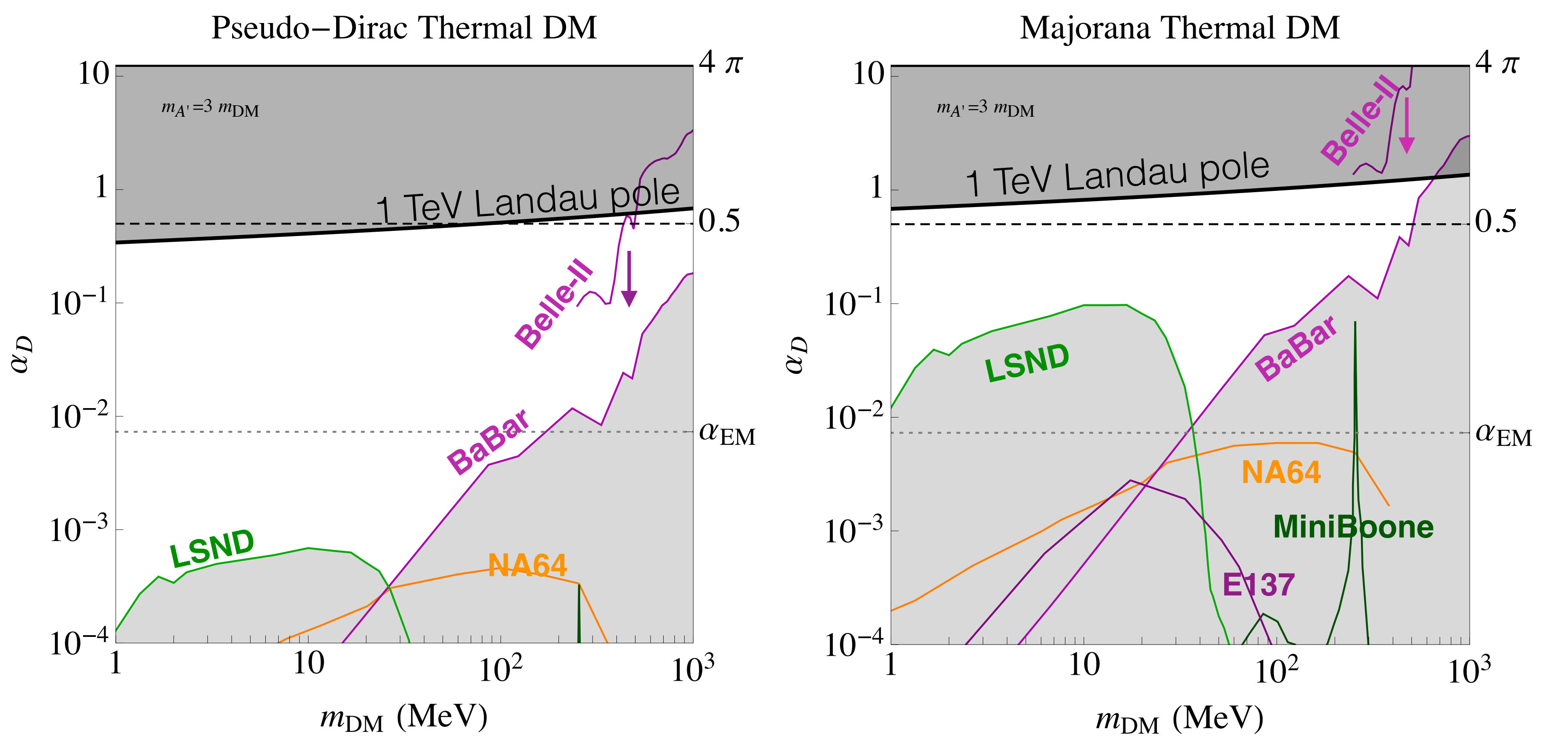
Note: Each plot self-consistent
Must be careful about direct comparisons!

Sensitive to **any** thermal relic

A Finite Thermal Target

Thermal freeze-out
means bounded parameter space

Accelerators have already covered important territory



From Schuster's talk

The Thermal Target

DM with a thermal origin paradigm is a **compelling** case

Accelerators robustly test this scenario
Light DM in the vicinity of the Weak scale big blindspot

If discovery
accelerator probes can yield
underlying mediator physics
+ mass scale

Are there proposals to achieve this with
small scale + in the next ~ 5 years?

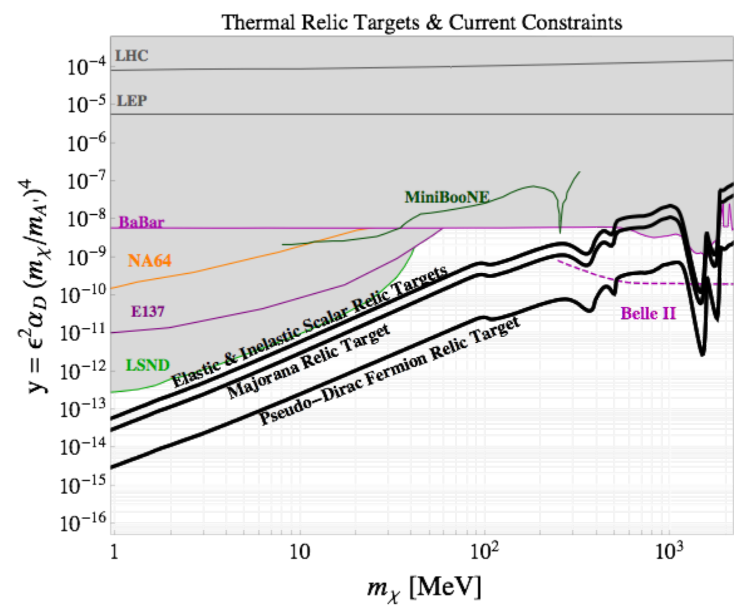
Yes!
More from Bertrand

Probing the thermal relic target with accelerator-based experiments

Very fruitful workshop! Special thanks to all contributors.

Over 20 talks in WG3 parallel sessions, including current results, new theoretical ideas, facilities and new proposals, as well as interesting discussions.

Common theme amongst new proposals: robustly probing the thermal relic target in the MeV-GeV range with different approaches.



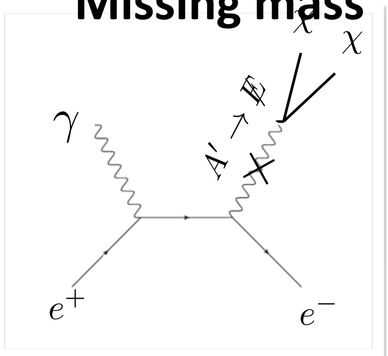
Advantage of accelerator-based approaches

- Vast majority of these proposals are based on proven technology / techniques
- Leveraging existing facilities / accelerators (parasitic runs / small additions)

Cost effective and deployable in the near future.

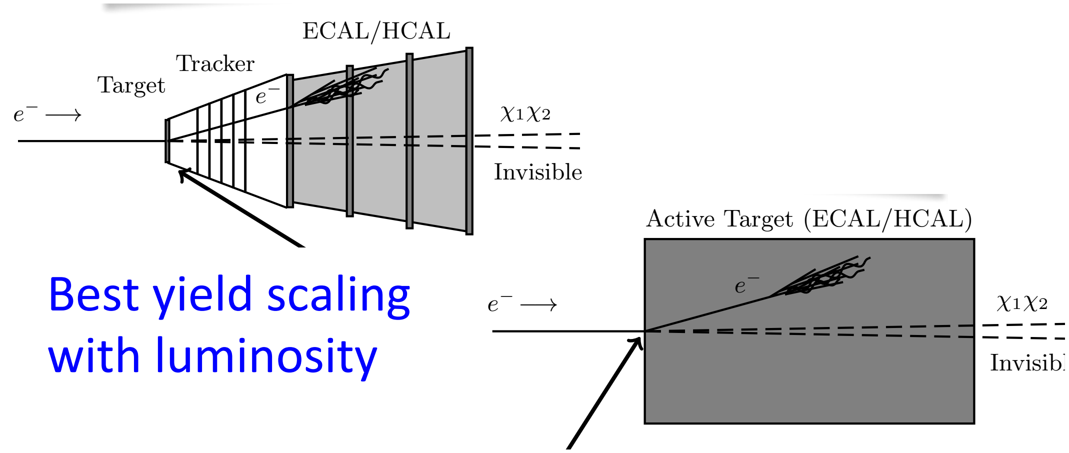
Probing the thermal relic target with accelerator-based experiments

Missing mass



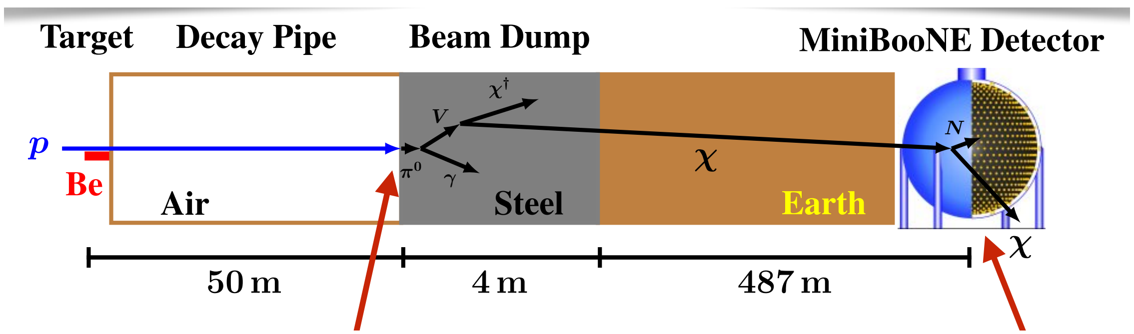
Resonance signal, rate gives coupling information

Missing energy / missing momentum



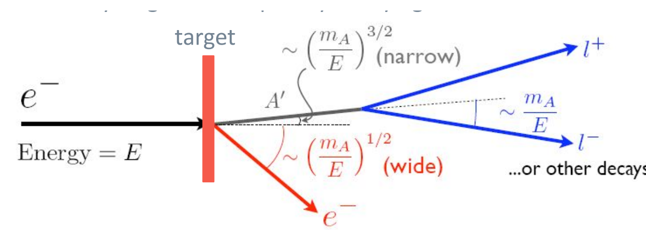
Best yield scaling with luminosity

Proton / electron beam dump



Probes DM interaction twice

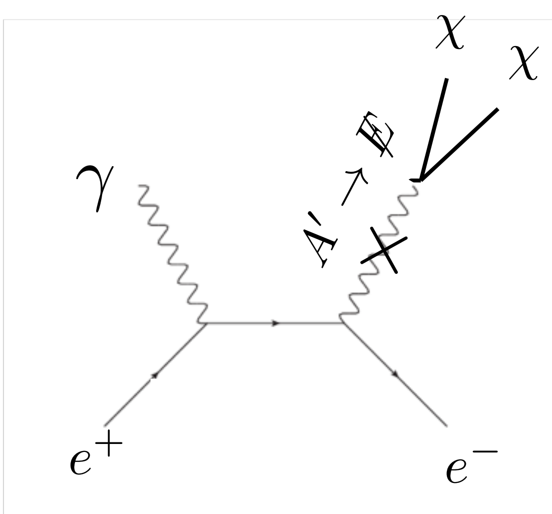
Searches for the mediator



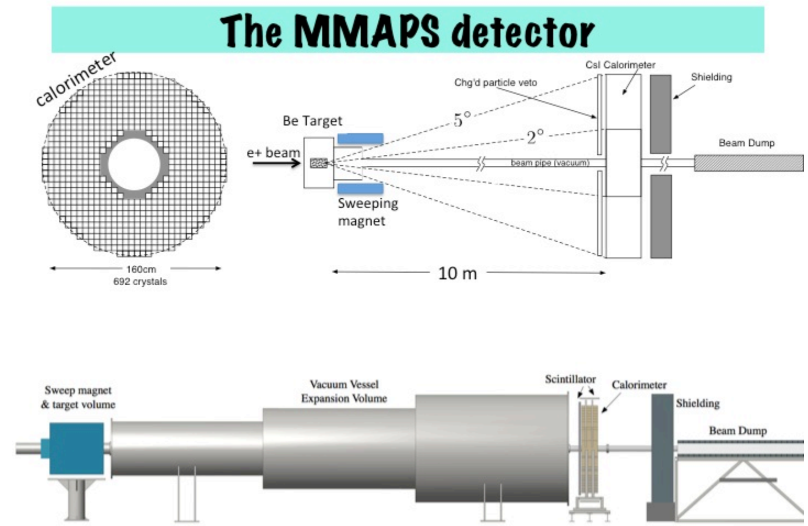
Complementary to DM searches

Disclaimer: some sensitivity plots are based on different assumptions and should not be directly compared

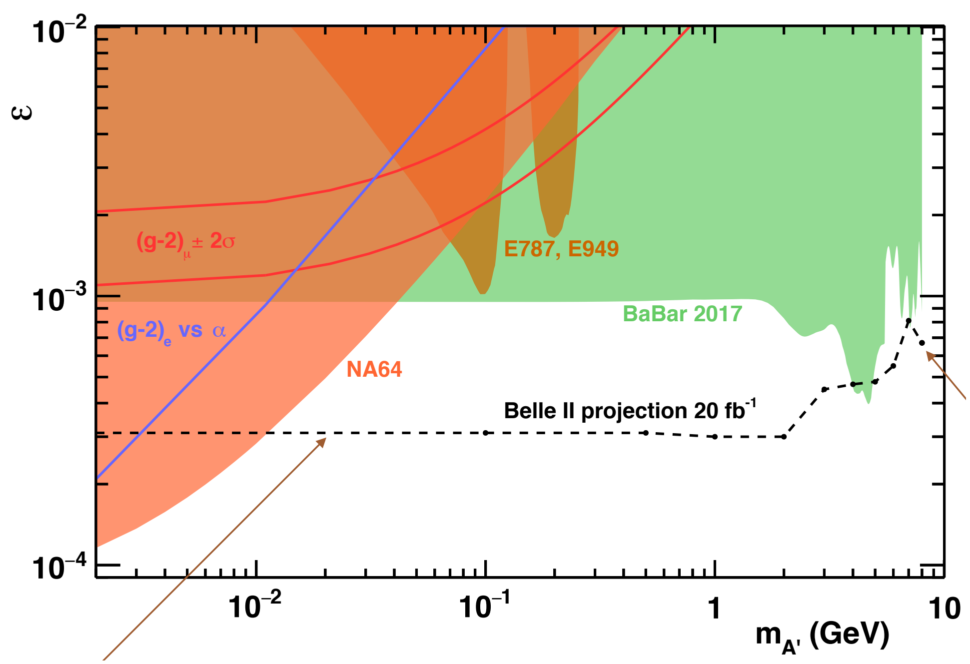
Highlights from the missing mass approach

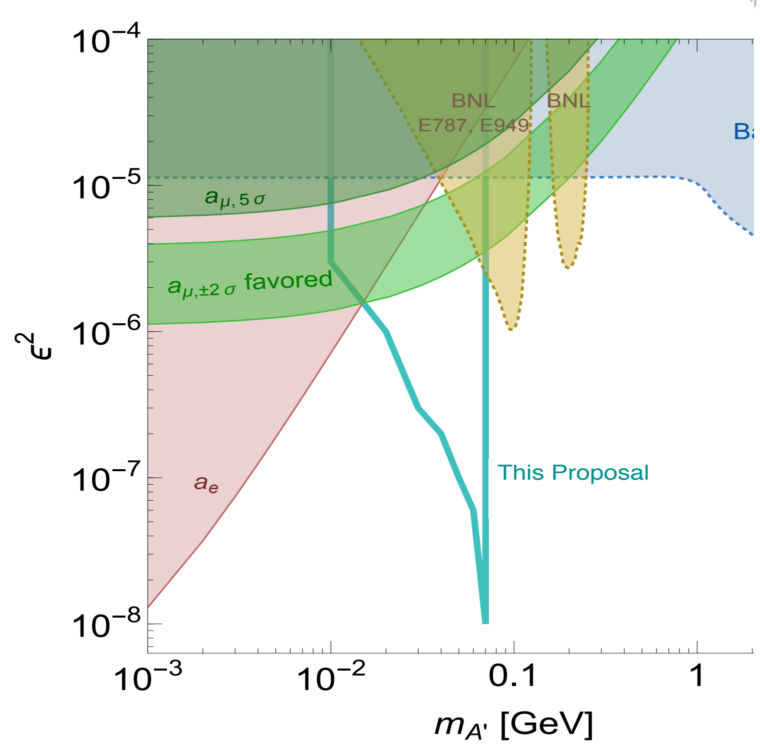


MMAPS (J. Alexander)



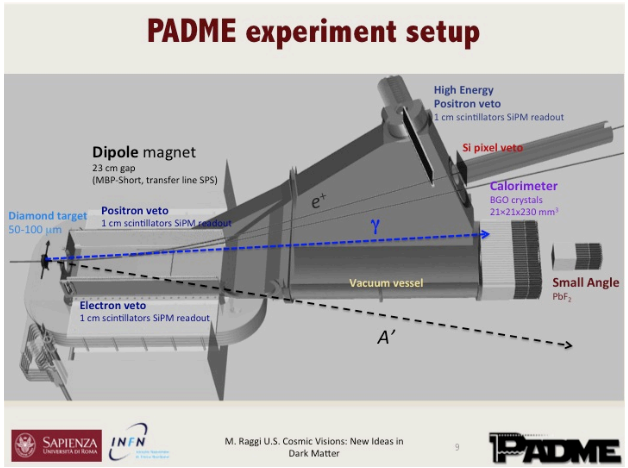
BABAR / Belle II (C. Hearty)

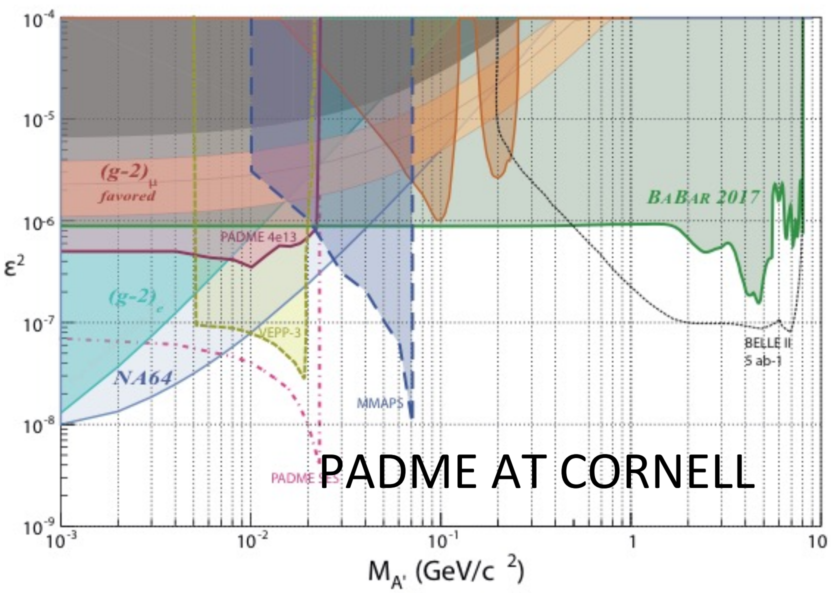




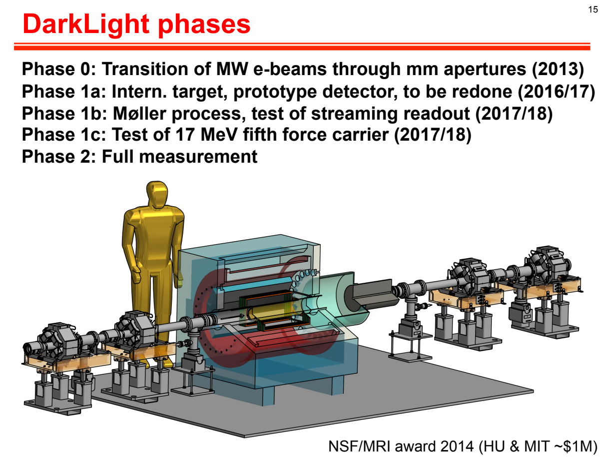
Highlights from the missing mass approach

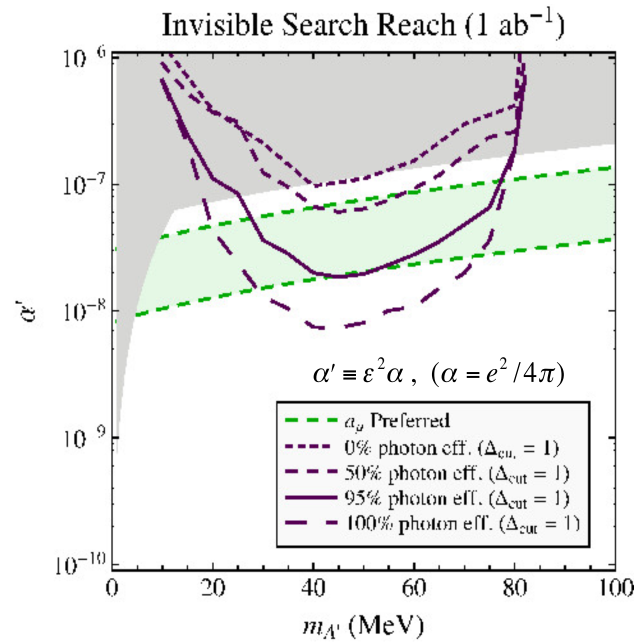
PADME (M. Raggi)





DarkLight (M. Kohl)





Fully developed concepts, ready to be build or already in construction

Resonance search ➔ robust technique

Highlights from the beam dump approach

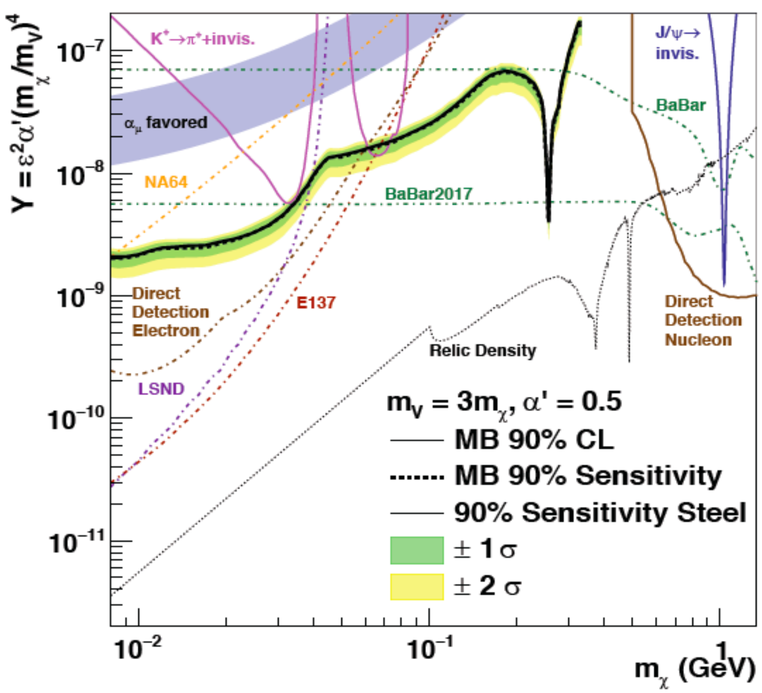
MiniBooNE

R. Cooper

- 2014 Ran beam off target, collected 1.86E20 POT.
- 2017 First results on DM search with NCE sample.

Confidence Limit Results

- Many ways to "slice" parameter space
- This parameter choice is rejected as solution for *g-2* anomaly (Vector Portal)



New Mexico State University
All About Discovery!
nmsu.edu

3/23/17 R.L. Cooper - U.S. Cosmic Visions 25

On-going analyses

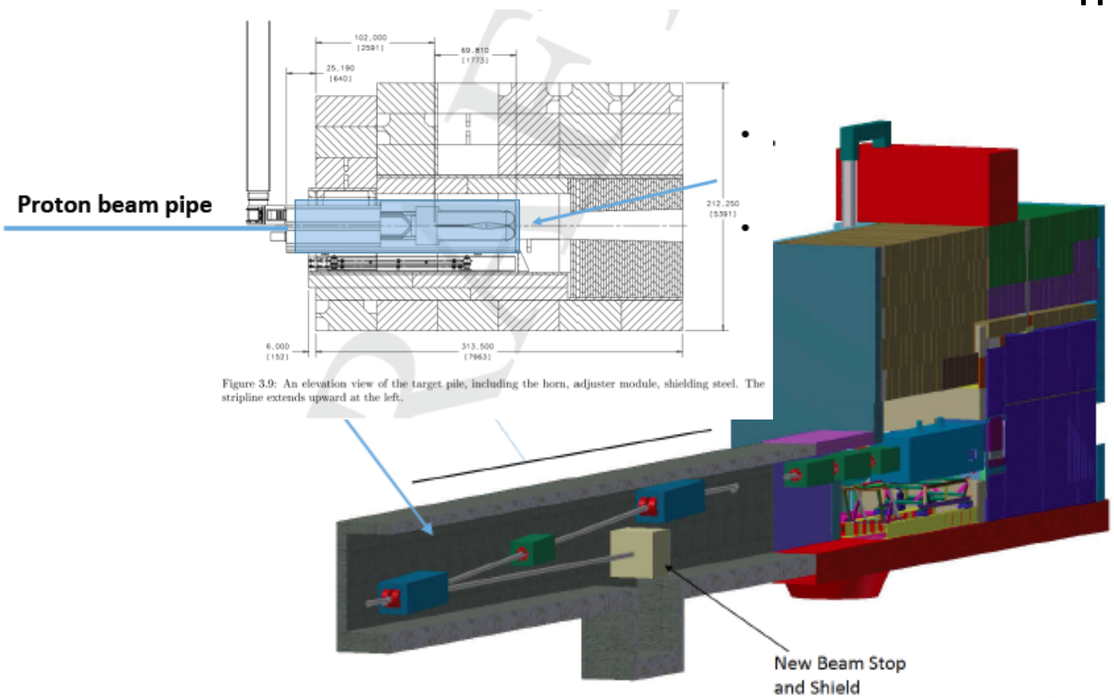
- use timing to search for heavier DM
- additional scattering channel

Proof of principle

Future prospects: proton beam dump

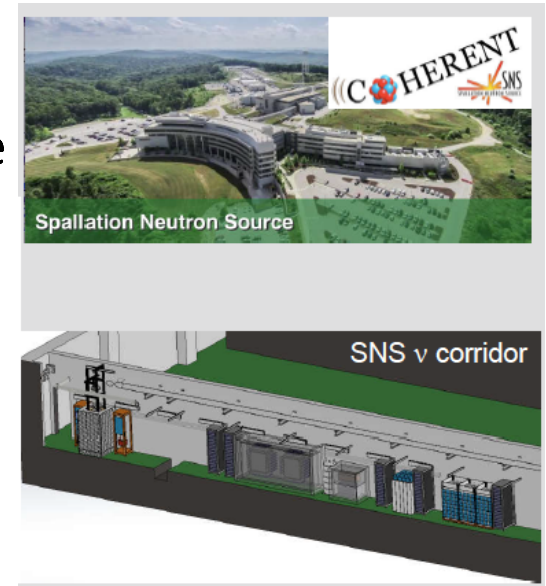
Fermilab: leveraging neutrino exp.
(R. Van de Water)

Proposed sub-GeV DM search with SBND – several options to improve on MiniBooNE by order of magnitude.

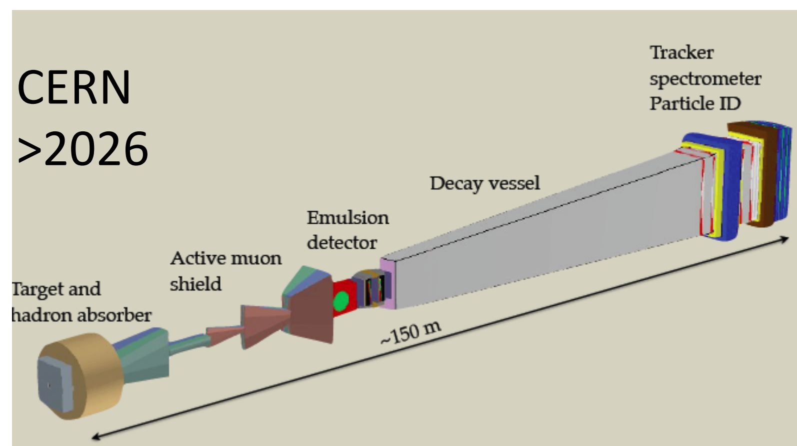


Using COHERENT at SNS
(R. Tayloe)

Existing LAr & NaI detectors – can be upgraded to larger mass



SHIP (A. di Crescenzo)

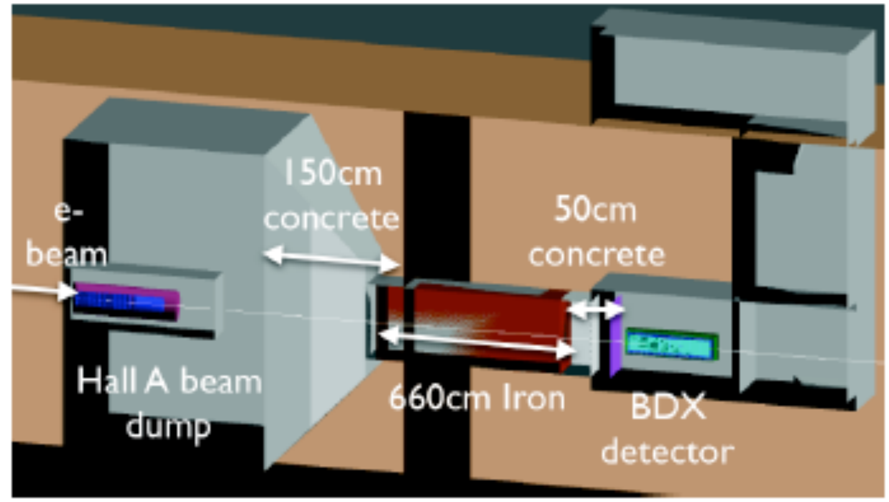


Future prospects: electron beam dump

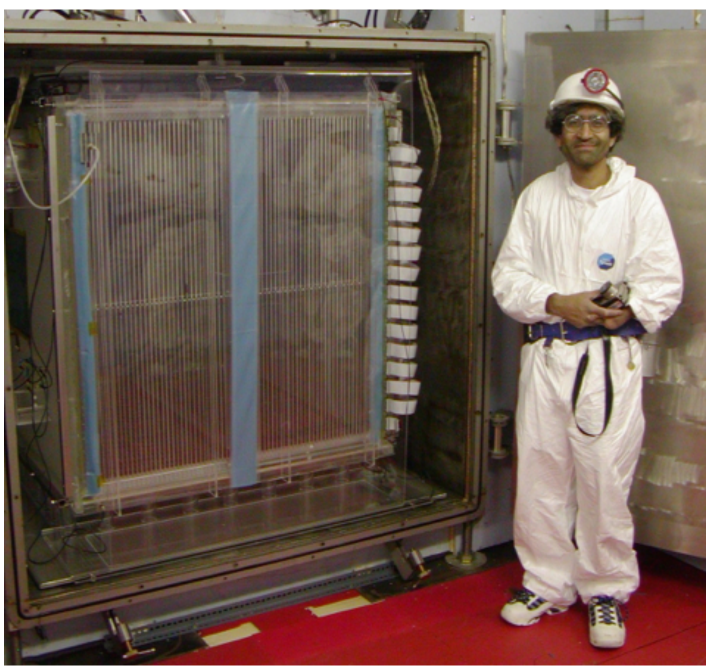
A. Celentano

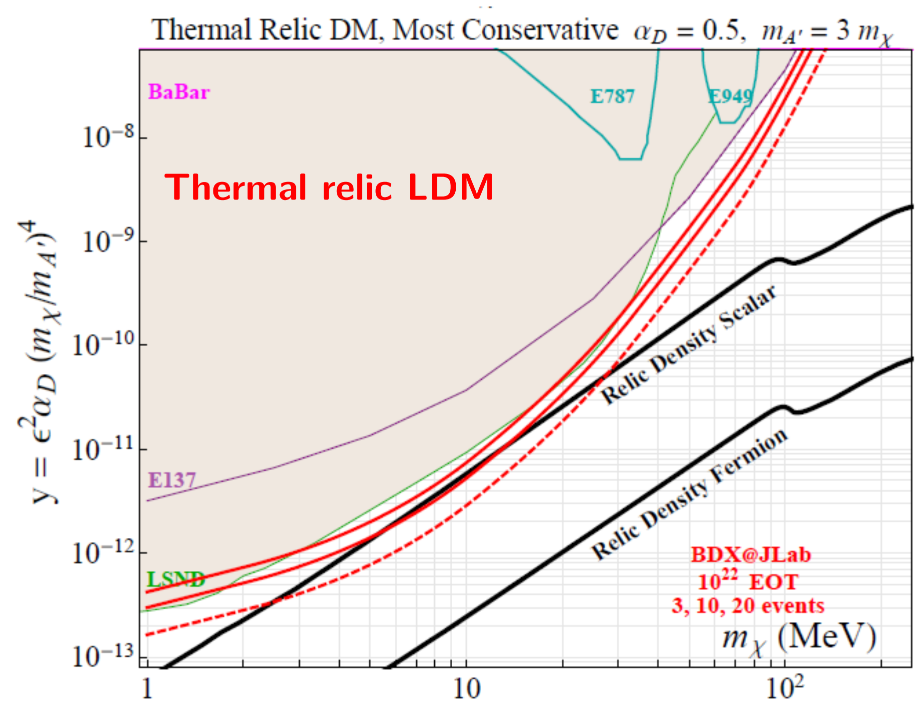
BDX: Lower neutrino bkg from e^- beam

Several sites investigated, JLab Hall A most promising

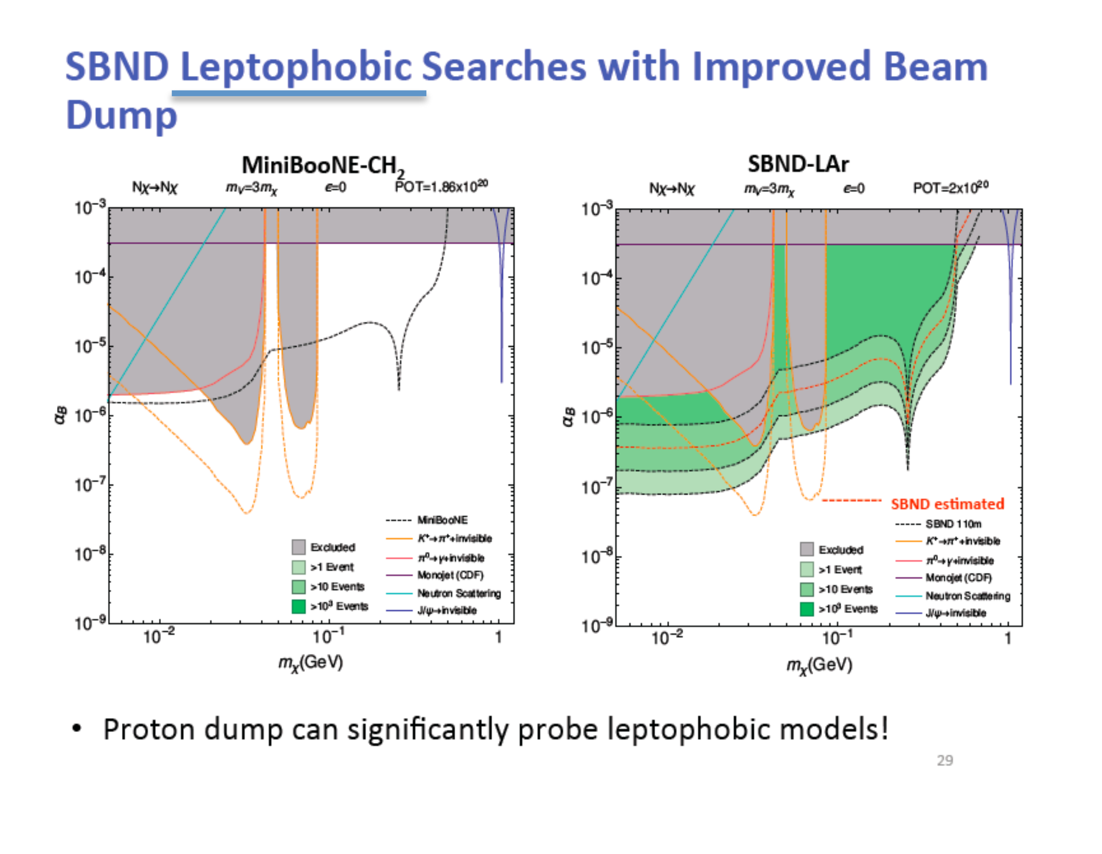


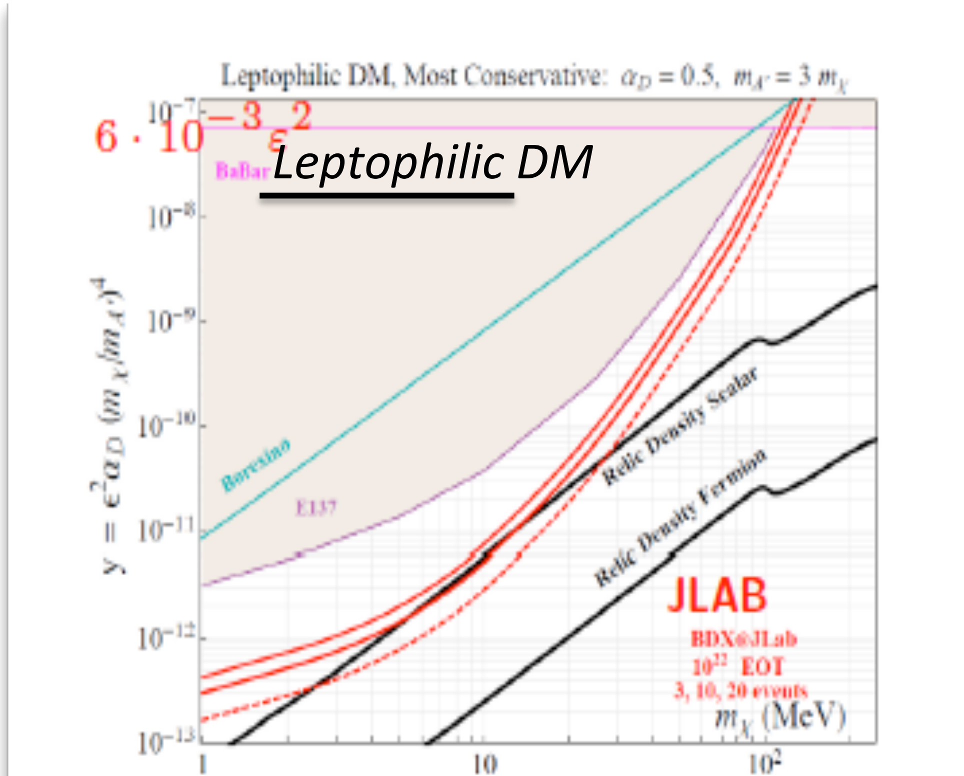
BDX-DRIFT: Complementary sensitivity from low-threshold TPC (D. Snowden-Ifft)





Complementarity between proton and electron beams





A. Celentano

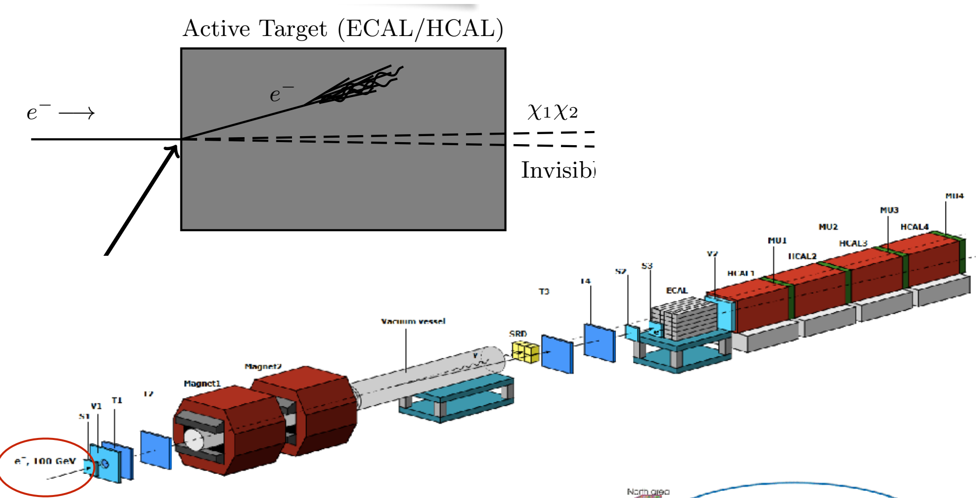
Electron beam probes lepton couplings

Proton beam probes hadronic couplings

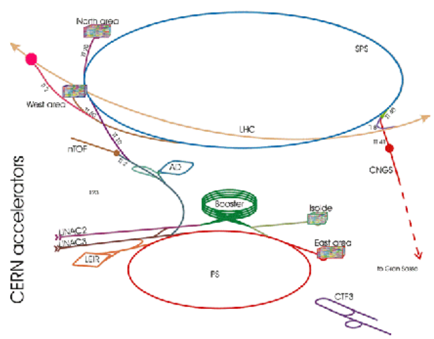
Both couplings are possible

Highlights from the missing energy / momentum approach

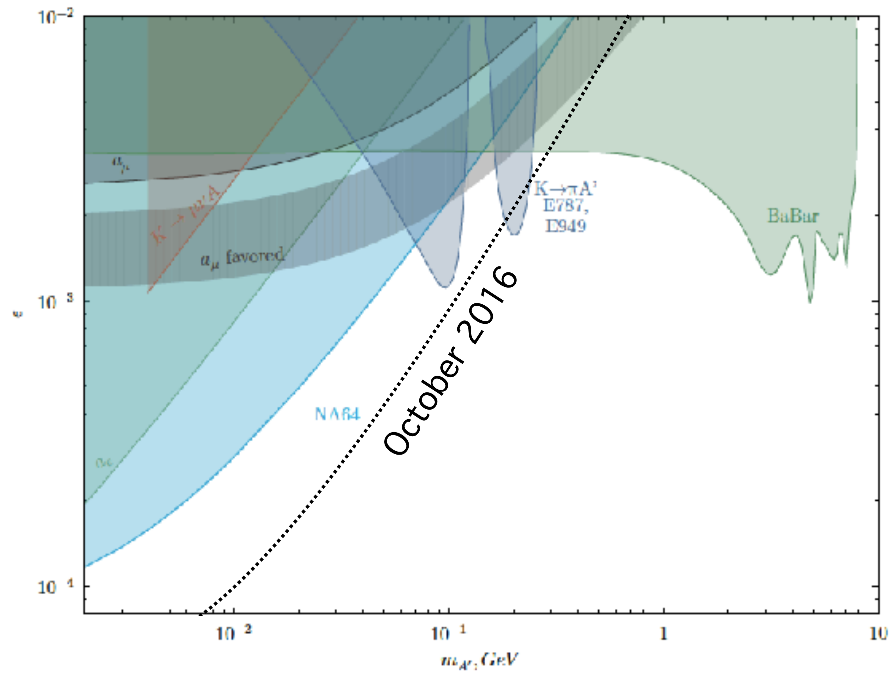
NA64



Key Features of the setup:
- High energy beam to trigger the reaction: 100 GeV e- beam from the CERN SPS.
- Max intensity ~ 5 x 10[6] e-/ spill.
- Typically 2 spills/min
- Main impurities of H4 beam: π–, low energy e– (~1%) μ– and K– (≤0.1%)



D. Banerjee



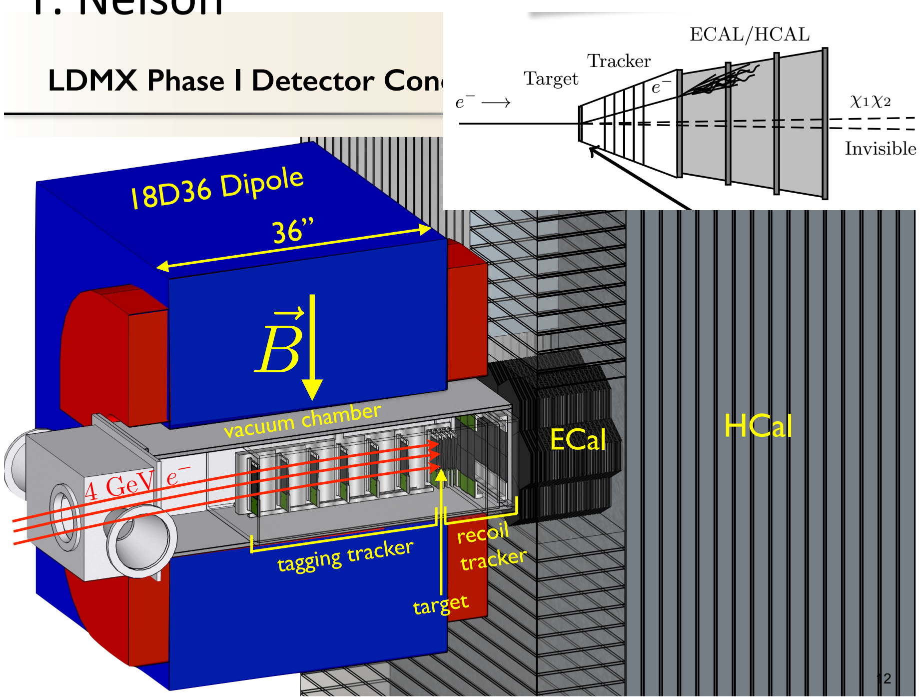
The run 2017 :

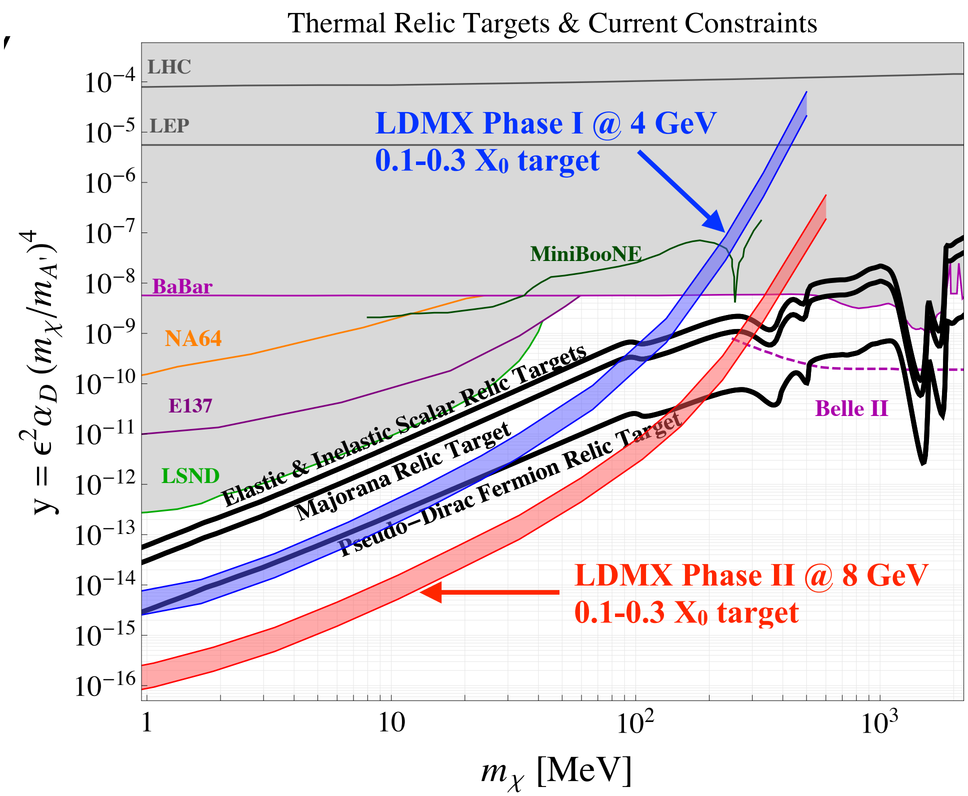
- *Plan to collect up to few 10^{11} electrons on target for the invisible channel and cover significant area of the A' parameter space.*
- *Upgrades to the tracking system as well as to the synchrotron radiation detectors are foreseen.*
- *We also intend to switch to visible mode to collect few 10^{10} eot (> 1 week) to address the Be8 decay anomaly which could be explained by a 17 MeV boson.*

Highlights from the missing energy / momentum approach

LDMX

T. Nelson



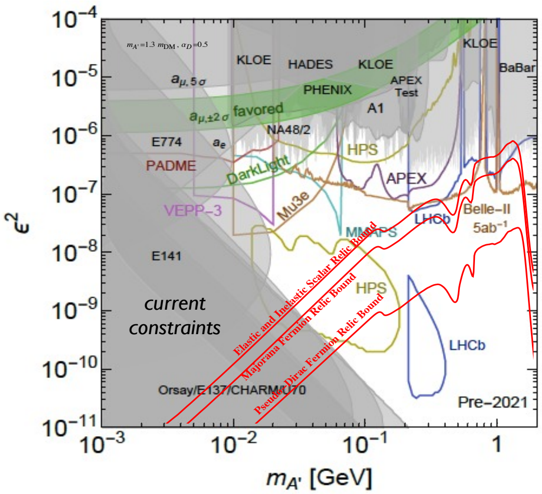


Two-stage experiment:

- Start at 4 GeV towards the end of 2021 -- sensitivity to 10^{-14}
- BES plans accelerator upgrade (LCLS-II HE / 8 GeV) -- sensitivity to 10^{-16}

Highlights from the mediator search

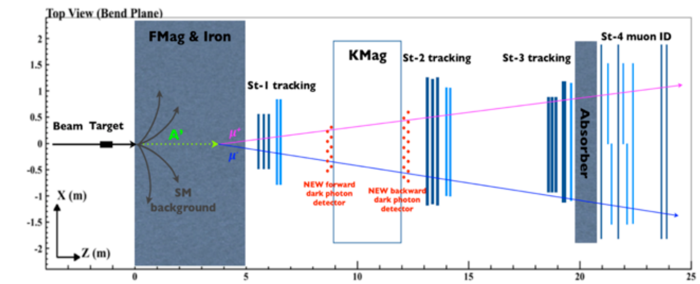
P. Schuster

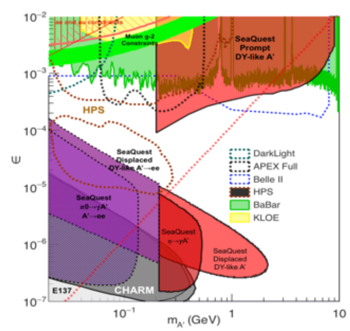


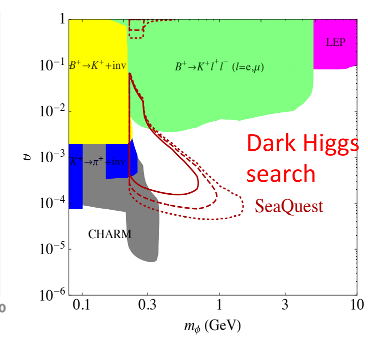
Mediator $m_A < 2 m_{DM}$ will decay visibly

Thermal target

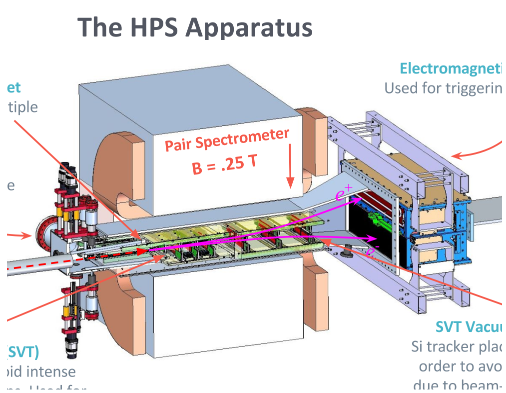
SeaQuest (M. Liu)

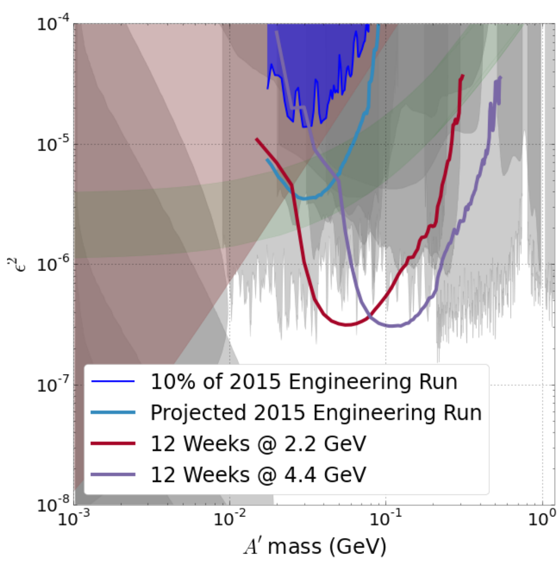






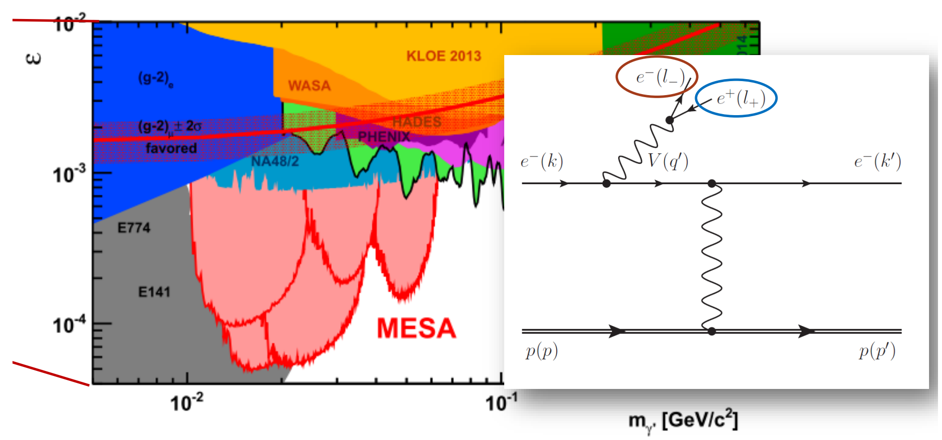
HPS (O. Moreno)





More to come soon

Magix @ MESA(S. Caiazza)

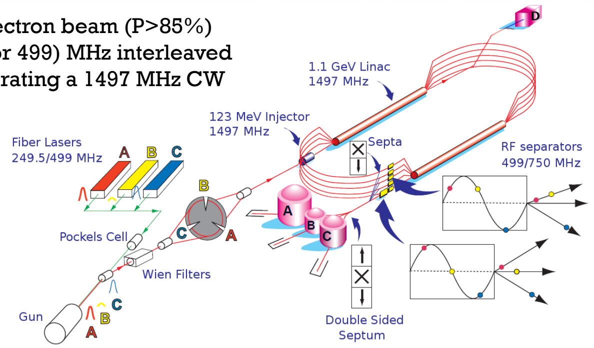


Some experiments already probing new parameter space

Enabling the science: JLab facilities

12 GeV CEBAF Overview

- Polarized electron beam (P>85%)
- Four 249.5 (or 499) MHz interleaved beams, generating a 1497 MHz CW beam



- CW SRF linacs
- Design energy 2.2 GeV/pass:
  - 5 passes, 11 GeV (Halls A,B & C)
  - 5.5 passes, 12 GeV (Hall-D)
- Flexible extraction options for ABC, 1st…5th pass
- Hall A & C 1 MW high power dumps

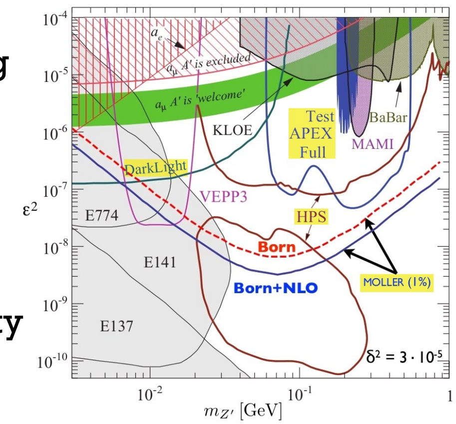
A. Freyberger

Summary

The JLab electron beam facilities, CEBAF and LERF, are actively being used to search for Dark Matter.

Enabling beam properties include:

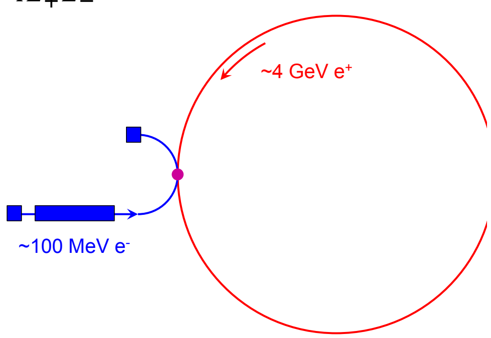
- Low beam halo (HPS, DarkLight)
- Beam stability
- High beam polarization and parity quality
- CW beam
- Large dynamic range in bunch charge (beam current)
- Beam energies from 100 MeV up to 12 GeV

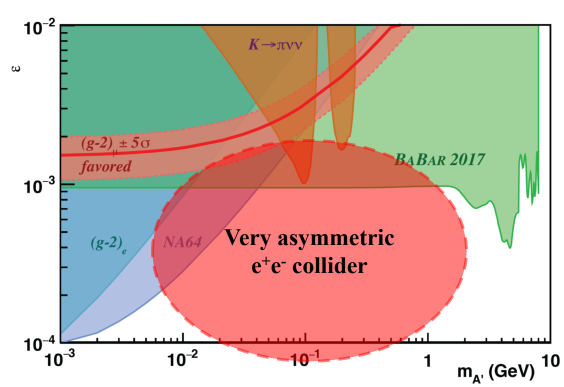


Aleksejevs et. al. (arXiv:1603.03006v1)

Very Asymmetric Collider

- High-quality low-energy electron beam from a linac
  + High-quality high-energy positron beam stored in a ring
  = Small $s = 4E_+E_-$





A. Morozov

The JLab electron beam facilities used to search for DM

BUT

Waiting time O(decade)

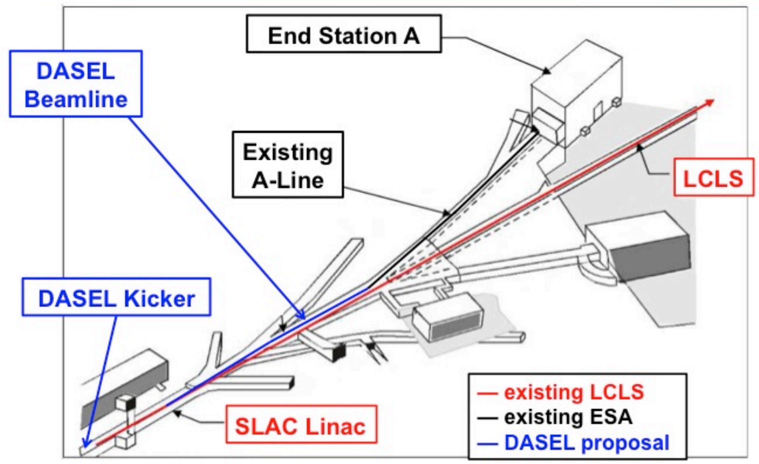
Enabling the science: DASEL at SLAC (DArk Sector Experiments at LCLS-II)

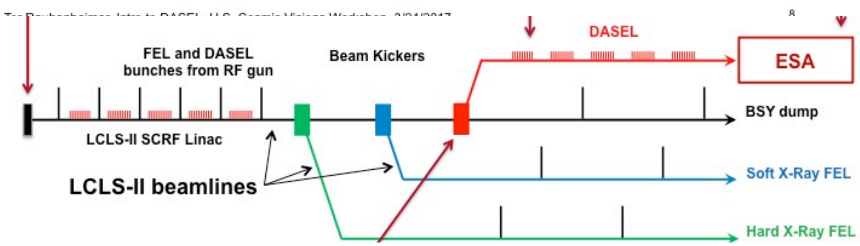
Multi-GeV CW beam (parasitic to LCLS-II)

T. Raubenheimer

DASEL Opportunity: End Station A (ESA)

SLAC





DASEL Summary

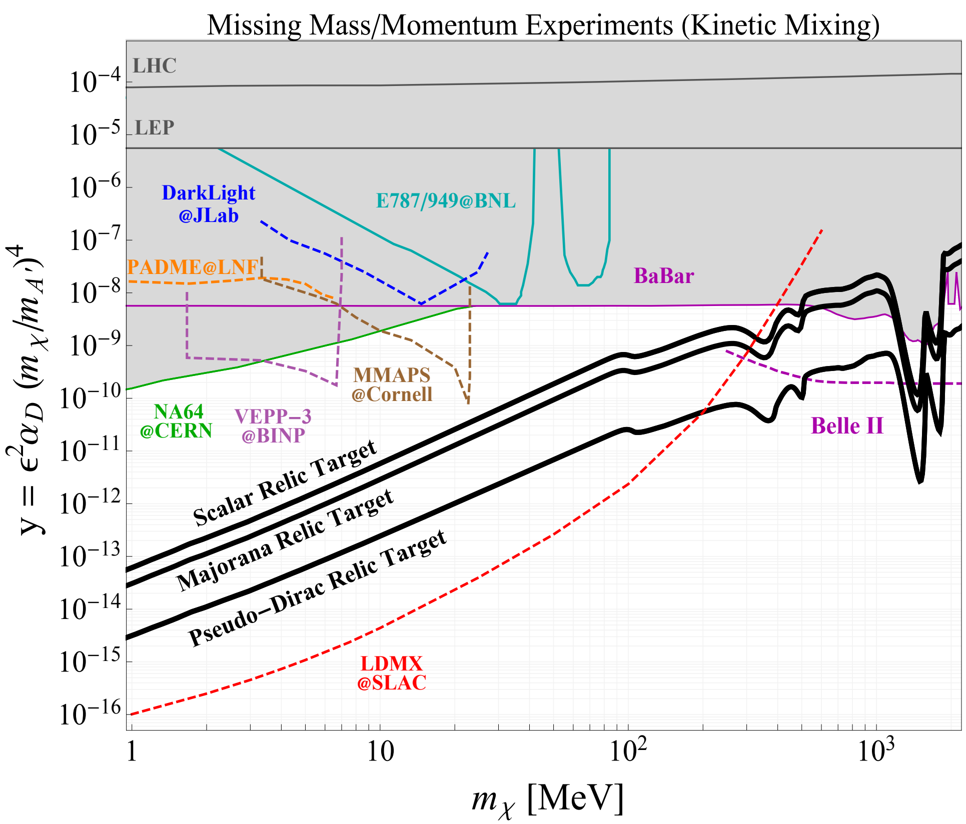
SLAC

- DASEL fills a need for a dedicated multi-GeV CW electron beam for high-impact dark sector experiments
- DASEL is a very cost-effective project
  - Leverages major infrastructure:
    LCLS-II SCRF linac, A-line, and End Station A
  - Facility will not interfere with the LCLS-II XFEL program
  - Benefits from LCLS-II engineering design and reuses existing hardware
  - Total cost <10M$
- DASEL would operate in a parasitic mode with ~5000 hrs/year and:
  - Beam Energy: 4 GeV (likely upgraded to 8 GeV)
  - Beam Current: 1e-/25 ns – 25 nA (upgradable to 1μA)

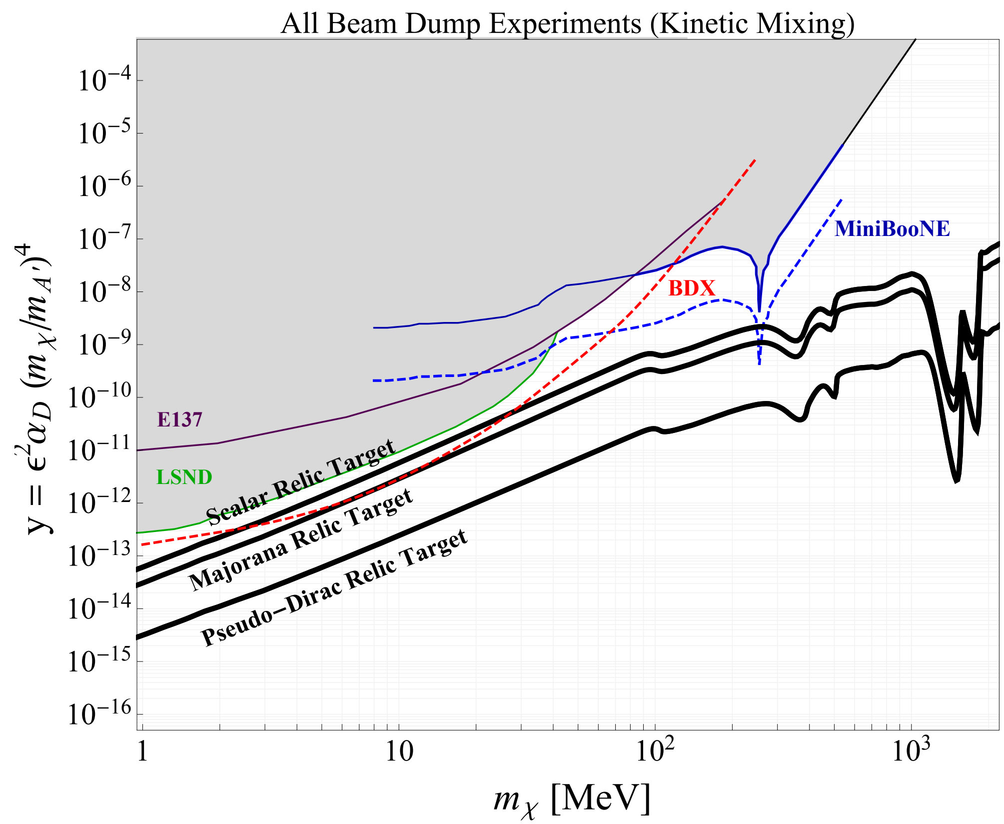
Building DASEL now is an opportunity to enable Dark Matter searches in 2020

Summary

Missing mass / momentum / energy



Beam dump



Robust exploration of thermal targets

Big discovery space!

Conclusion

If dark matter has been in thermal equilibrium with the SM, accelerators can discover it (MeV–GeV)

Cost effective – leveraging existing technologies and facilities

Ready to start now

Accessibility to large discovery space – can measure the parameters of the sector