Invisible session summary

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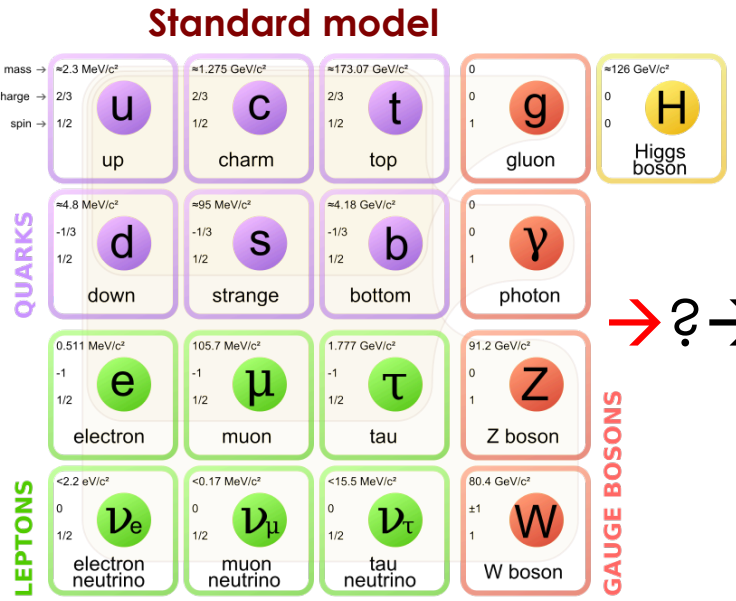
Light Dark Matter @ Accelerators La Biodola 24-28 Maggio 2017

What is the universe made of?



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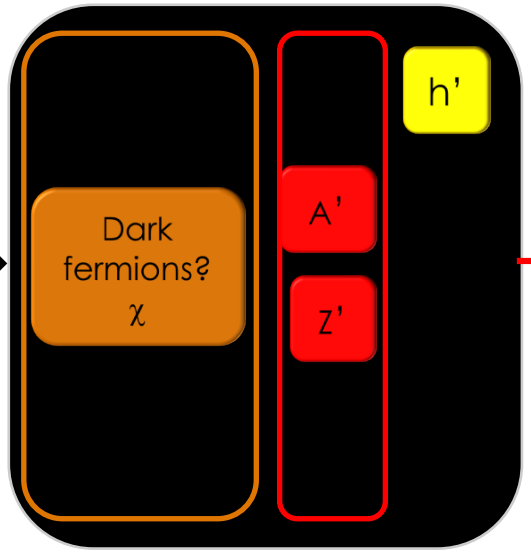

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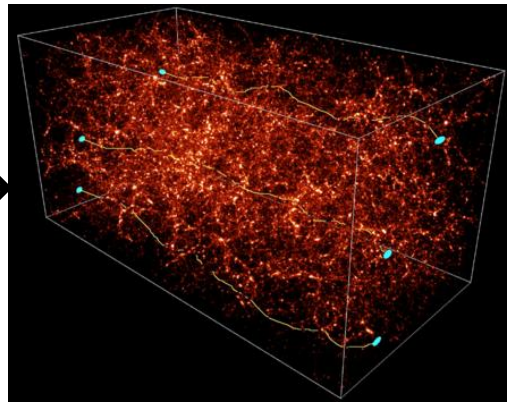
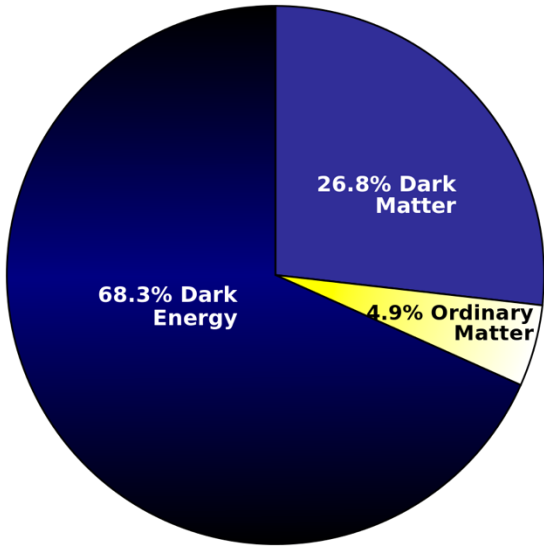


- Standard model only includes <20% of the matter in the universe
  - We only know dark matter interacts gravitationally
- Many open questions
  - What is dark Matter made of?
  - How dark matter interact, if it does, with SM particles?
  - Does one or more new dark force exist?
  - How complex is the dark sector spectrum?



Why invisible decays? Why not!

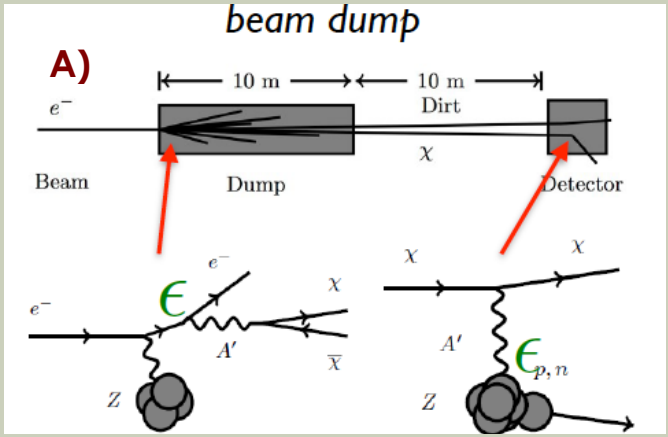
Dark sector coupling prior

m_χ prior	Weak	Strong
Light	A' invisible decays ALPs	Axions
Heavy	B-L couplings Proto-phobic (X→ee)	Visible A' decays (ee, μμ, ππ …) + universal coupling

- Early searches inspired by strong priors:
  - Heavy dark matter and universal fermion coupling!
- Its now time to take a step back in the priors and explore a wider panorama
  - Any dark matter mass no prejudice on the coupling to fermions

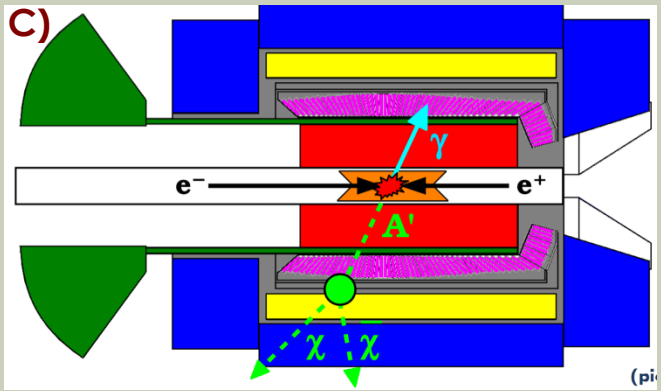
How to search for invisible decays?

Positive evidence



$N \propto \varepsilon^4 \sim 10^{20}$ EOT (α_D and ε^2)

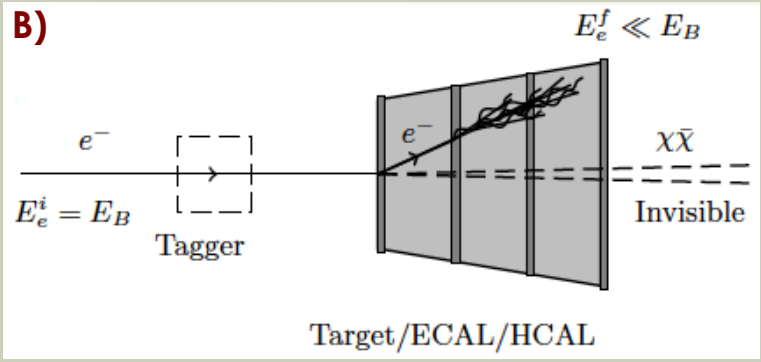
Missing Mass



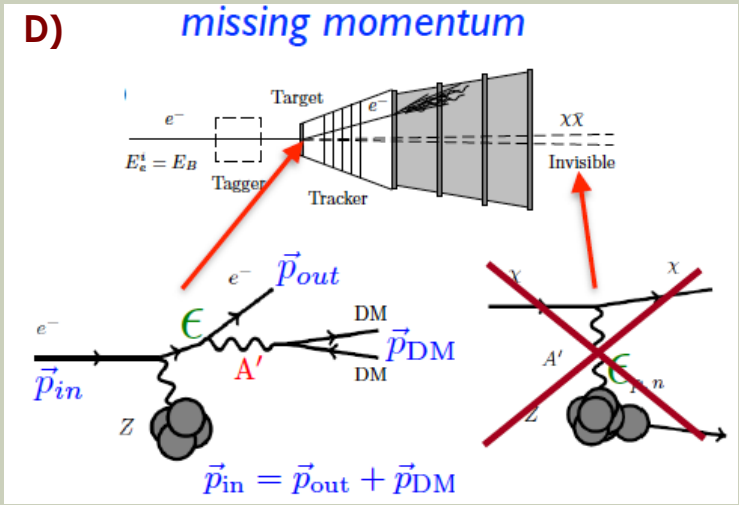
$N \propto \varepsilon^2$ sensitive to (ε,A') mass
Limited by $M^{A'} < \sqrt{2 m_e * E_B}$

Negative evidence

Missing energy

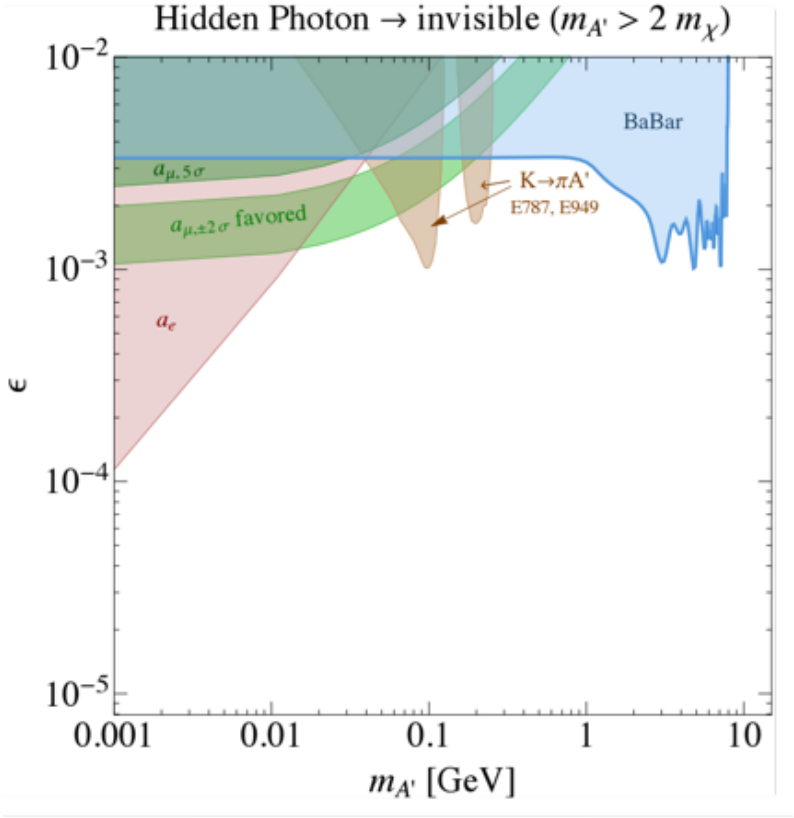


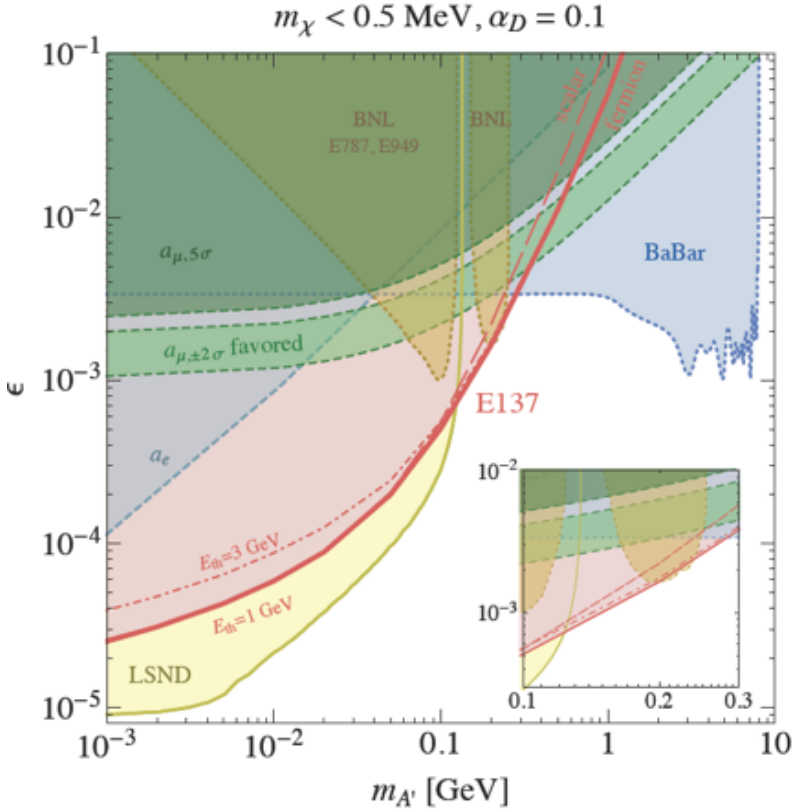
$N \propto \varepsilon^2$ (ε^2 only)



$N \propto \varepsilon^2$ contains E_{miss} exp.

Parameter space end of 2016





- Two techniques are used: missing E-P-mass A' search, dark matter χ scattering searches
  - Missing E-P-mass searches for A' only depend on 2 parameters : ε^2 and $M_{A'}$
  - χ scattering searches depend on 4 parameters: ε^2, $M_{A'}$,Mχ and α_D
- Kaon constraints are on the other hand more model dependent

Invisible session program

11:00 - 13:00 II Invisible A

11:00 **Invisible decays of the dark photon at BaBar** *25'*
Speaker: Alberto Lusiani (PI)
Material: Slides

Type C) Results shown e^+e^- collider M_{Miss}

11:25 **NA64 at CERN** *25'*
Speaker: Mr. Michael Hösgen (University Bonn)
Material: Slides

Type B) Results shown e^- dump E_{Miss}

11:50 **The PADME experiment at LNF** *25'*
Speaker: Venelin Kozhuharov (LNF)
Material: Slides

Type C) In construction e^+ on target M_{Miss}

12:15 **The MMAPS proposal at Cornell** *25'*
Speaker: Ms. Cari Cesarotti (Institut für Physik der Johannes Gutenberg-Universität Mainz)
Material: Slides

Type C) Proposal e^+ on target M_{Miss}

17:45 - 19:05 IV Invisible B

17:45 **Beam Dump experiments at JLab and SLAC** *20'*
Speaker: Dr. Elton Smith (Jefferson Lab)
Material: Slides

Type A) Proposal e^- dump scattering

18:05 **Status of BDX DRIFT** *20'*
Speaker: Dr. Daniel Snowden-Ifft (Occidental College)

18:25 **LDMX at SLAC** *20'*
Speaker: Timothy Nelson (SLAC)
Material: Slides

Type D) Proposal e^- dump P_{Miss}

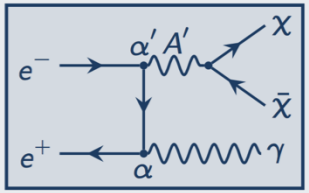
18:45 **sub-GeV DM Searches at FNAL** *20'*
Speaker: Dr. Remington Thornton (Indiana University)
Material: Slides

Type A) Results shown p dump scattering

Babar result 2017

Analysis strategy

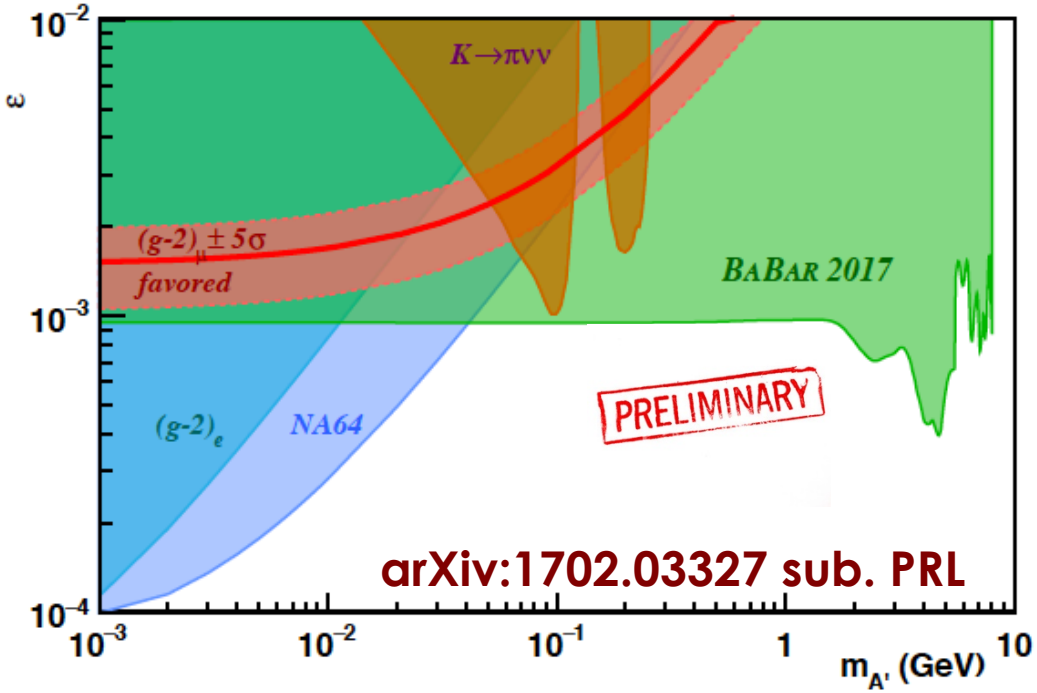
search for
- $e^- e^+ \to \gamma A'$, $A' \to$ invisible (e.g. $\chi\bar{\chi}$) i.e. one single photon and nothing else



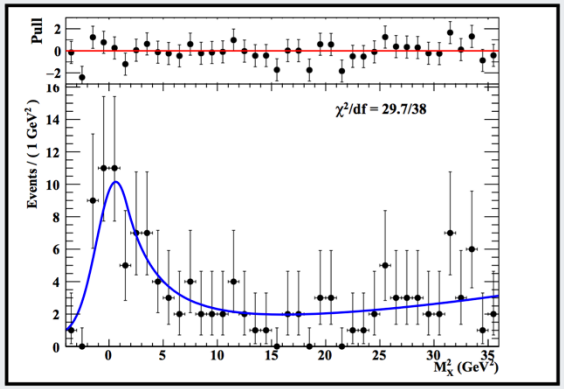
$\sigma \propto \alpha'\alpha = \epsilon^2\alpha^2$

- reconstruct A' mass, $M^2_{A'} = s - 2\sqrt{s}E^*_\gamma$
- scan $M^2_{A'}$ distribution, fitting bumps over smooth background, compute significance [A' decay width $\Gamma_{A'}$ expected $\ll$ experimental resolution on $M_{A'}$]

BABAR collected **~53 fb^{-1}** of data with dedicated single γ triggers **Y(3S)** and **Y(2S)** peaks Hard. trigger ≥1 EMC cluster with **E_{LAB} > 800 MeV**



Example low-mass background fit



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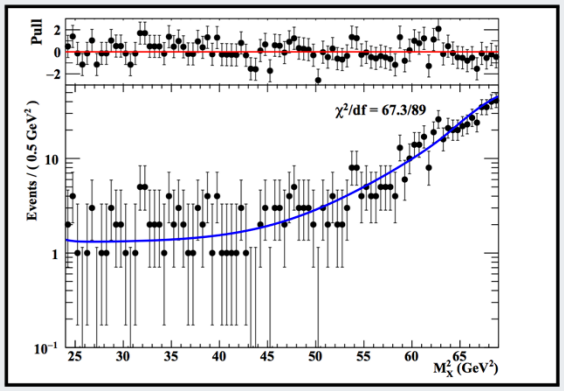
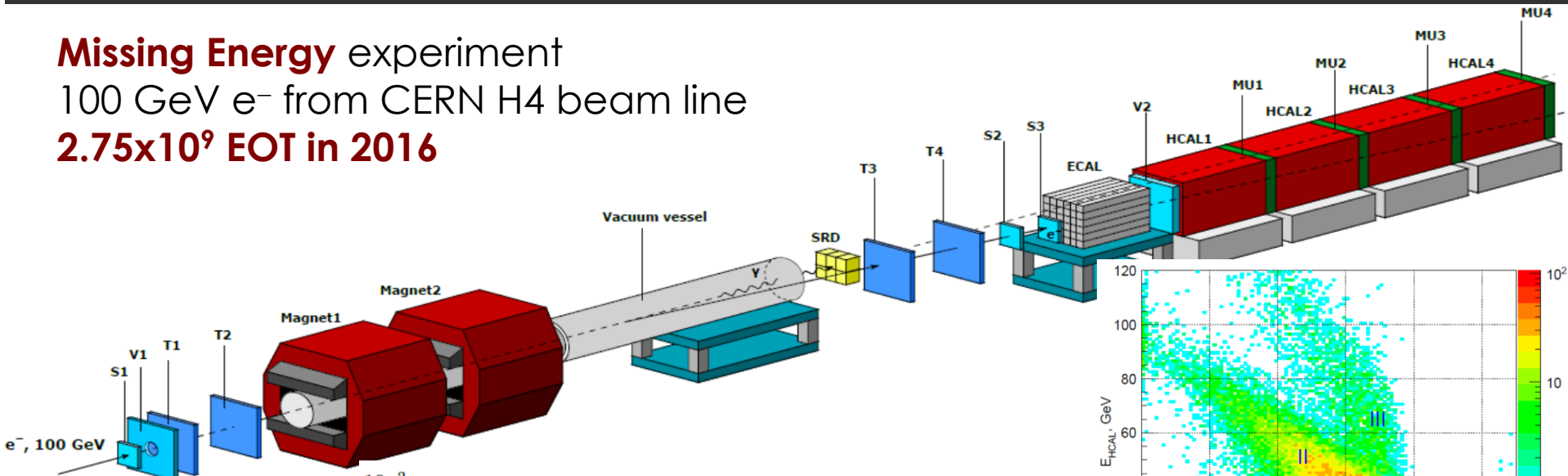
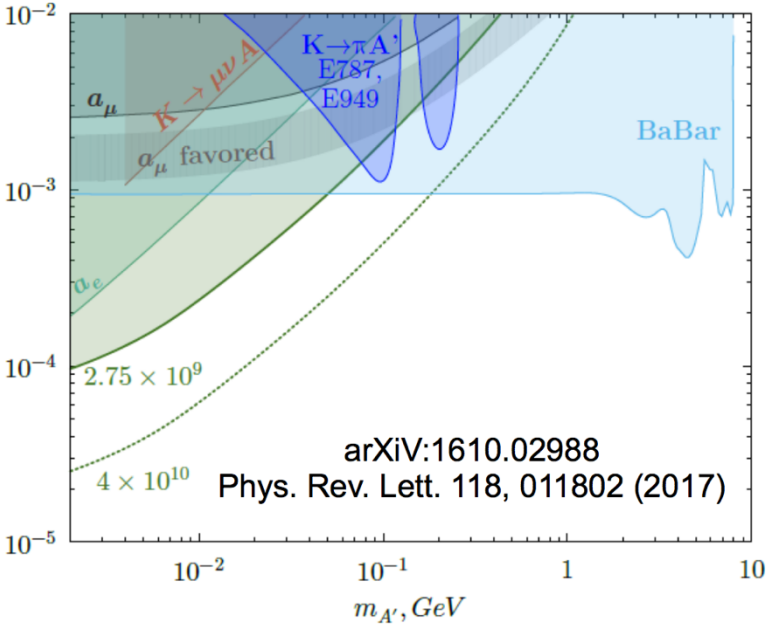
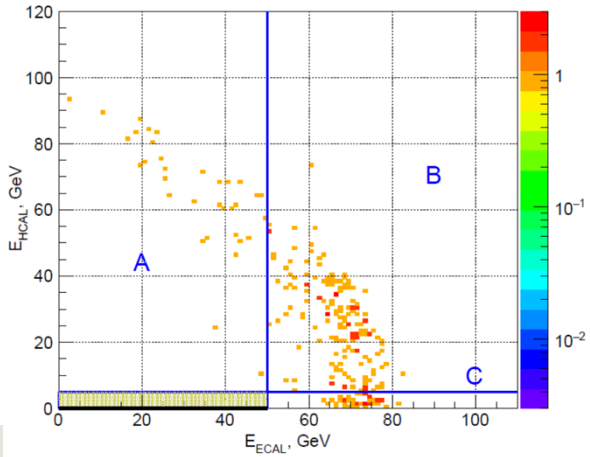


NA64 at CERN

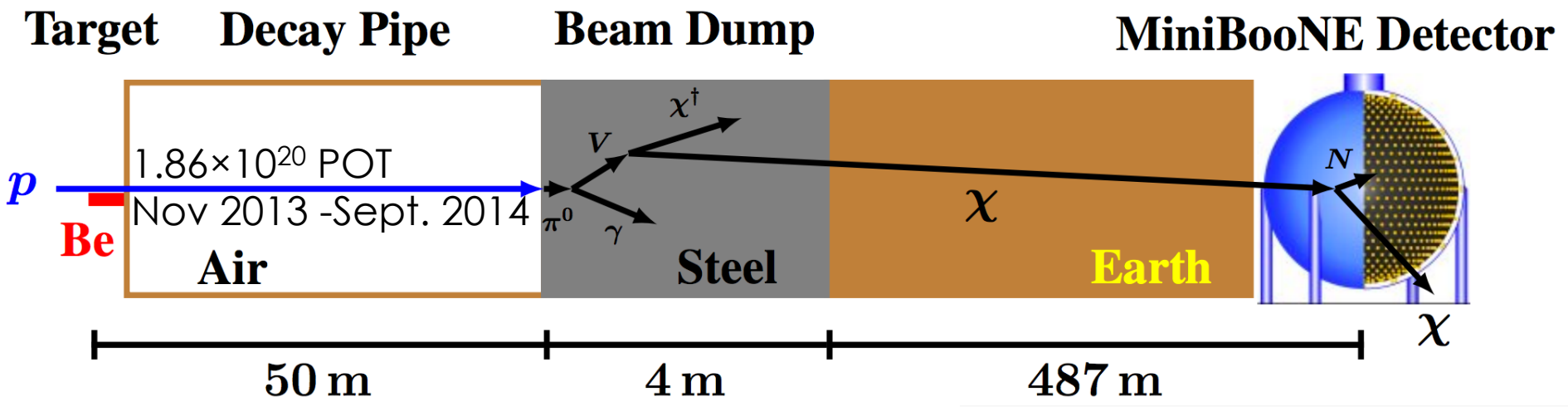
Missing Energy experiment
100 GeV e⁻ from CERN H4 beam line
2.75x10⁹ EOT in 2016





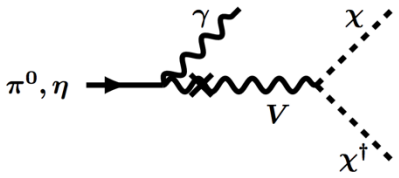


MiniBooNE at Fermilab

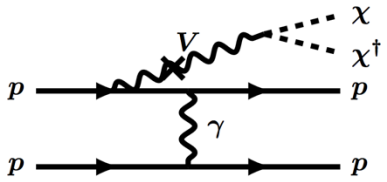


Production ($O(\epsilon^2 g_D)$)

Neutral-Meson Decay

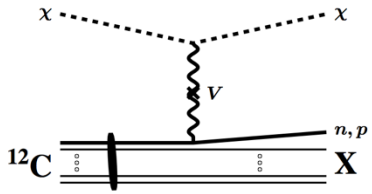


Proton Bremsstrahlung

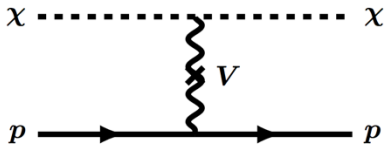


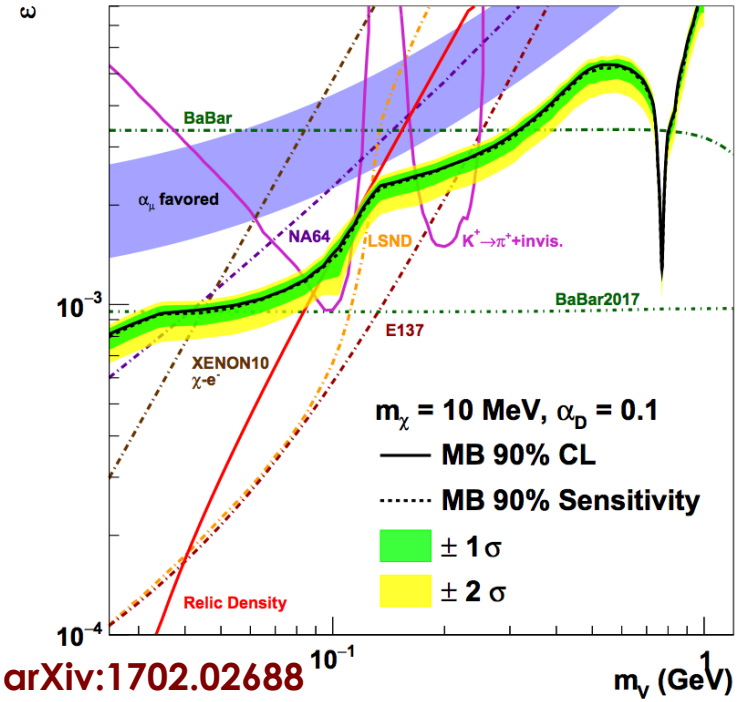
Detection ($O(\epsilon^2 g_D)$)

Elastic Bound Nucleon



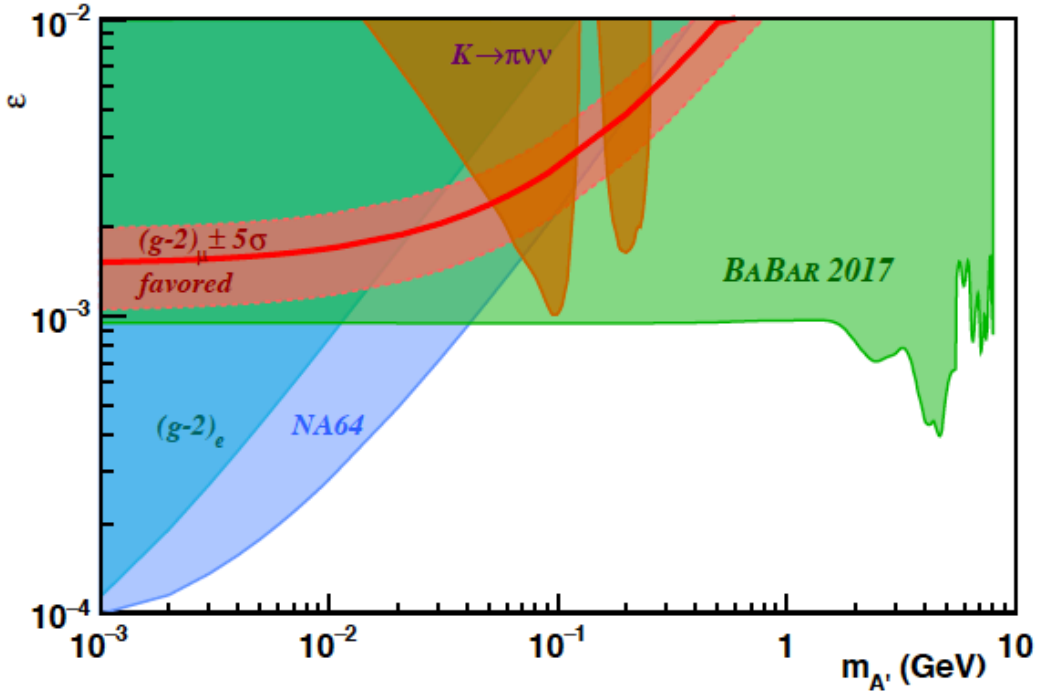
Elastic Free Nucleon

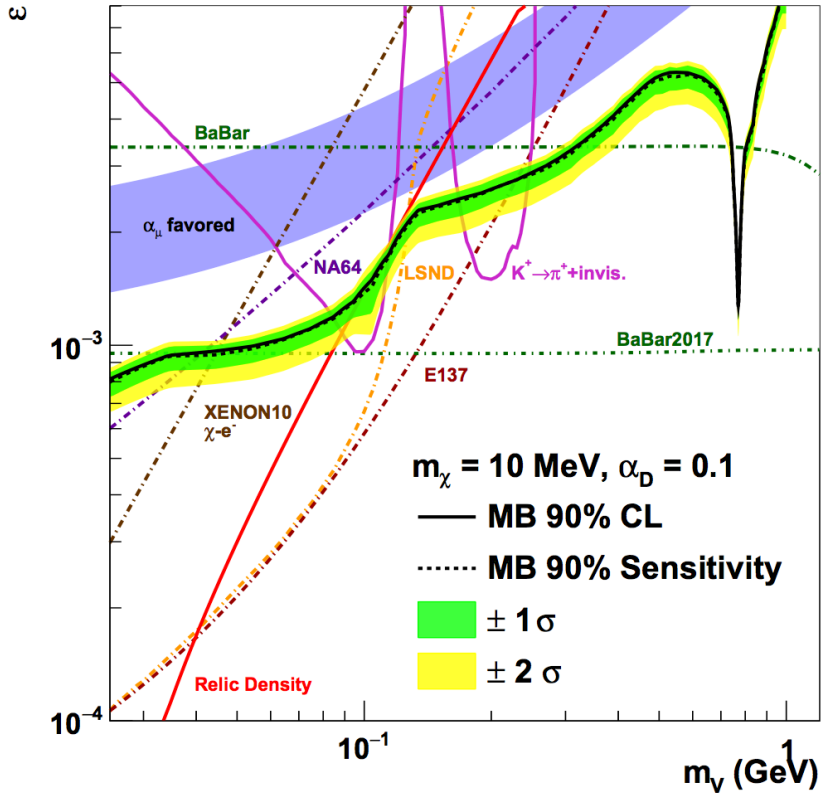




arXiv:1702.02688

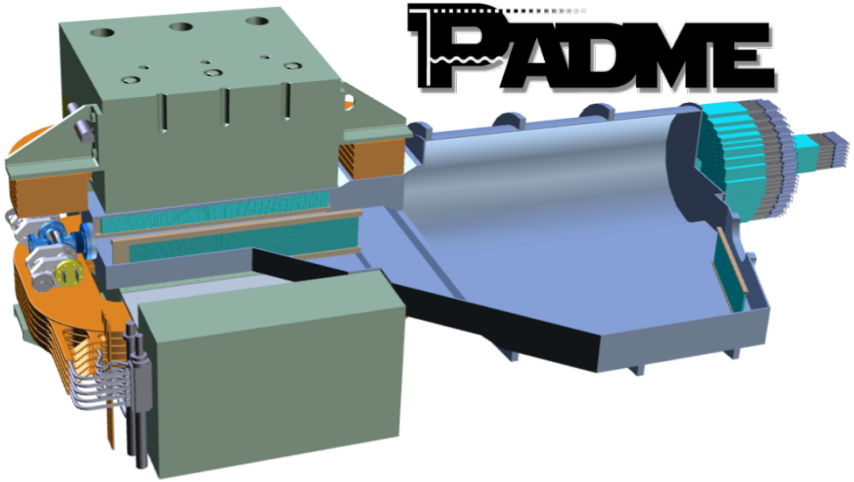
Present status of exclusions



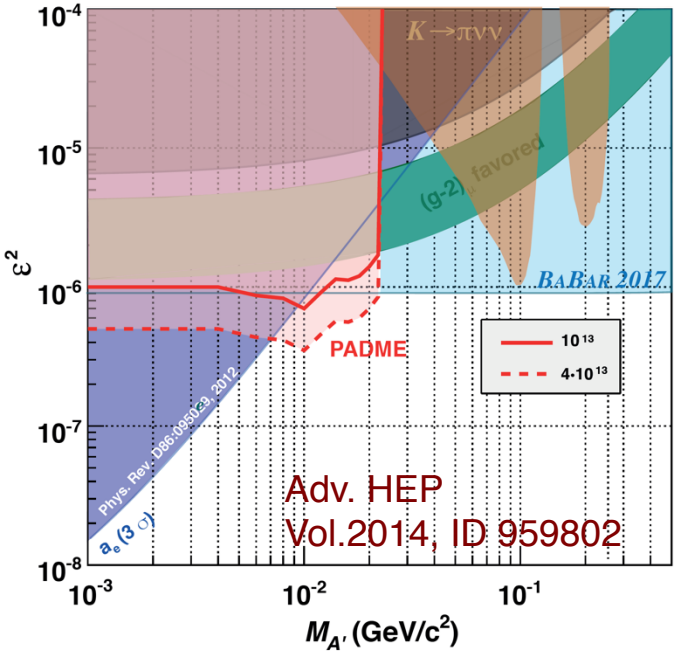


- Great progress in the beginning of 2017
  - Still large regions of parameter space unexplored
  - Only 1 experiment in most of the parameter space covered

Future M_{Miss} experiments

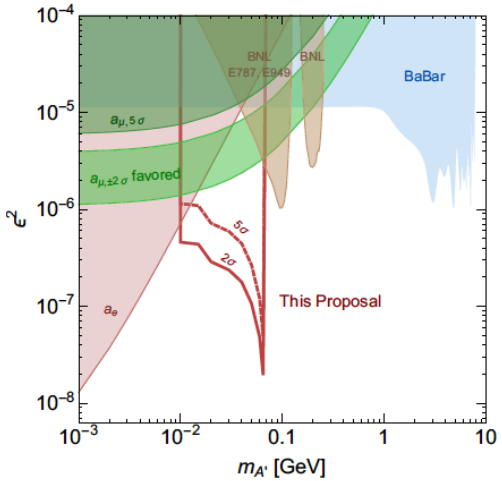


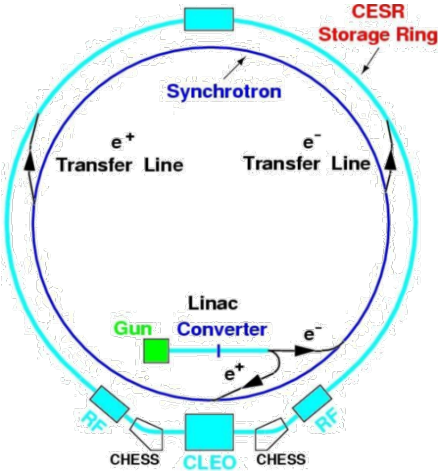
10^{13}e+ on target at LNF 2018



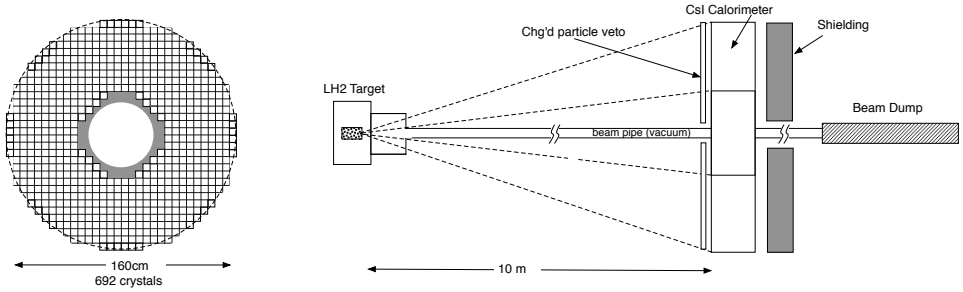
Adv. HEP
Vol.2014, ID 959802

MMAPS @ Cornell





EPJ Web of Conferences 142, 0 01 (2017)



PADME + MMAPS? (2020?)

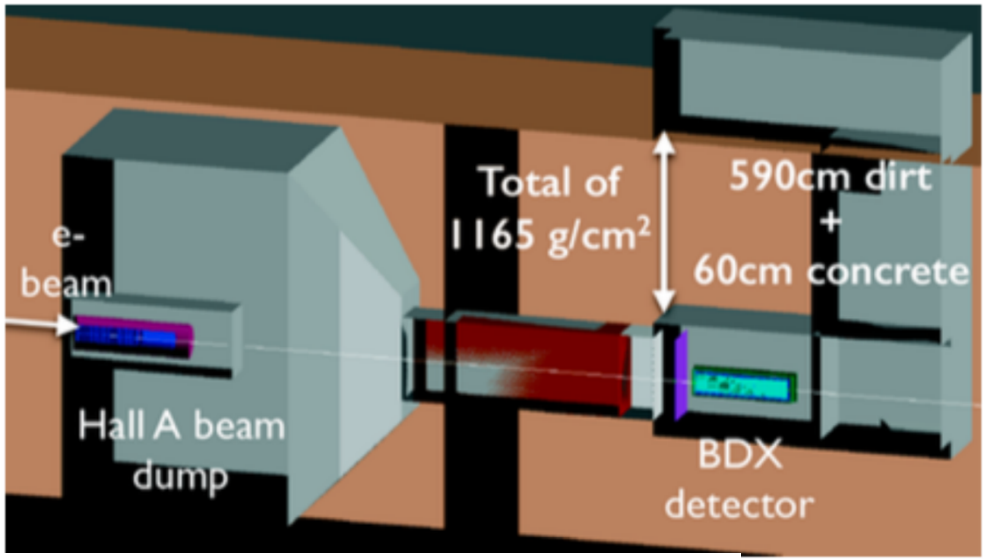
PADME: E_B~500 MeV, 2 year @ INFN BTF

Cornell: 12x E_B, **10^4x EOT**

PADME: Better M_{miss}, faster detector

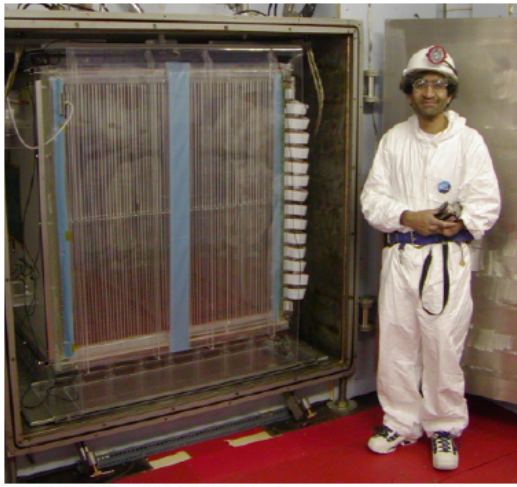
Future dump experiments: BDX

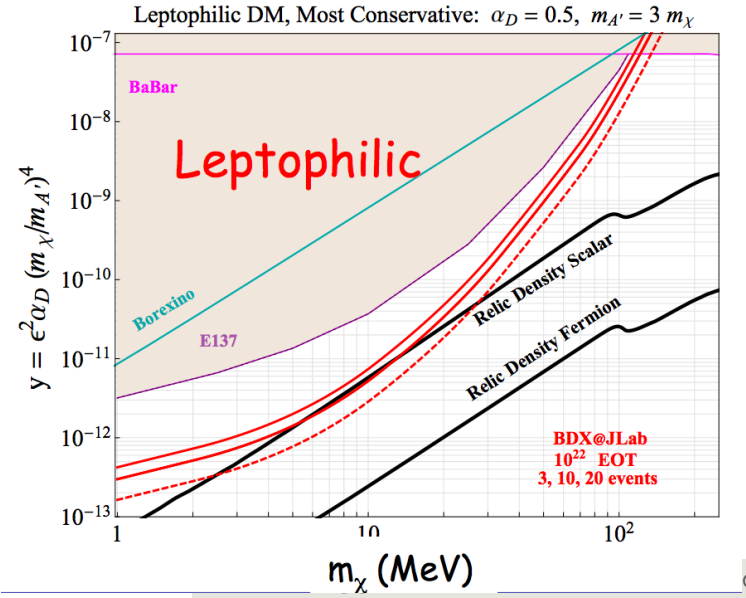
BDX @ JLAB 10^{22} EOT scattering experiment

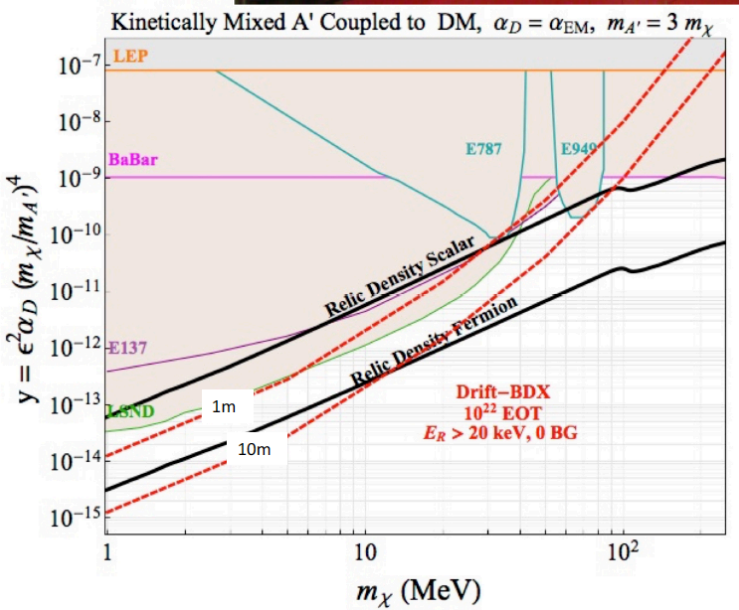


Drift @ BDX

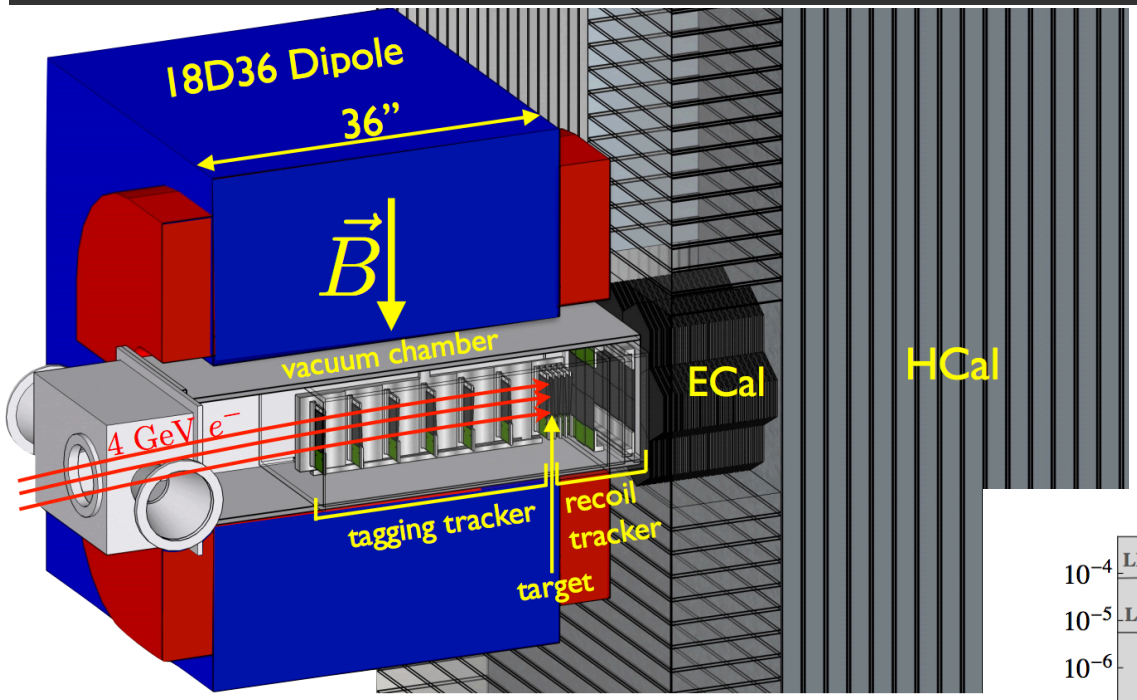
Directional WIMP DM detector







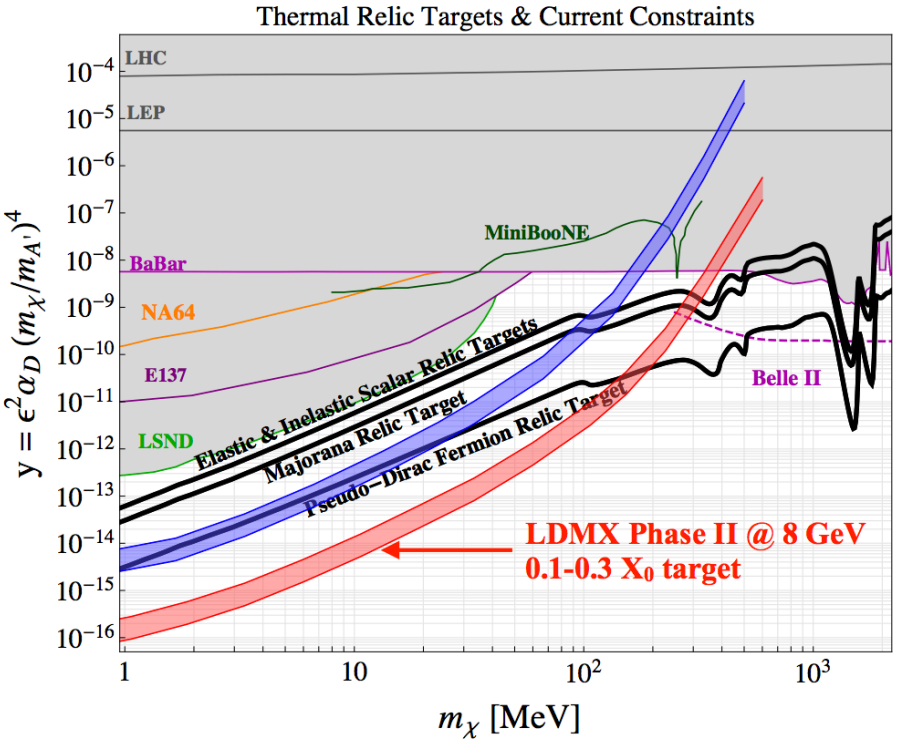
LDMX: P_{Miss} experiment



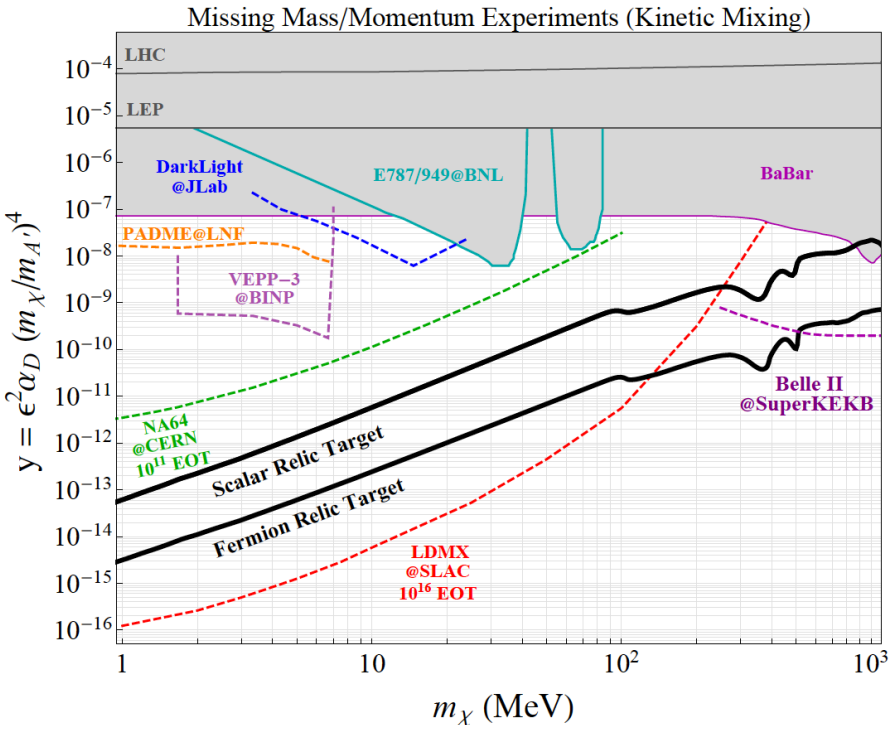
Two-stage approach to LDMX:
4×10¹⁴ “Phase I” late 2021
1x10¹⁶ “Phase II” late 2023-2024

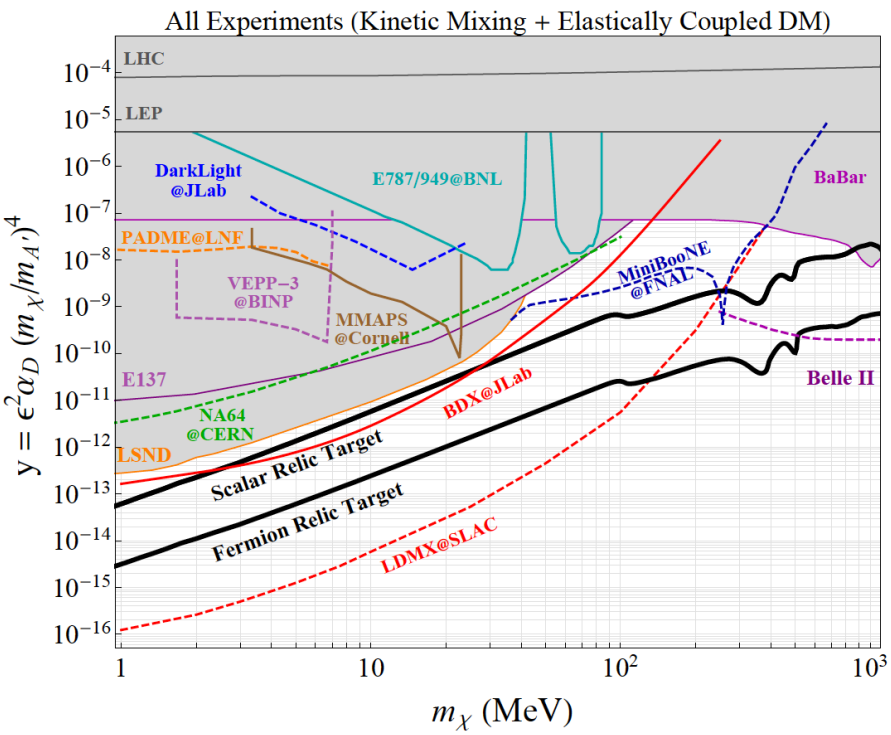
Beam: individual tag of 10^{16} incident e-
- A low-current, multi-GeV, e^- beam (10^{16}/year ≈ 1 e- /3 ns).

Possibilities:
- DASEL@SLAC (4/8 GeV)
- CEBAF@JLab (up to 11 GeV).
- Large beam spot (~10 cm²)



Group photos





- This is what we can do all together so keep pushing on your project!

Group photos

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See you in LDMA 2019 with new results!