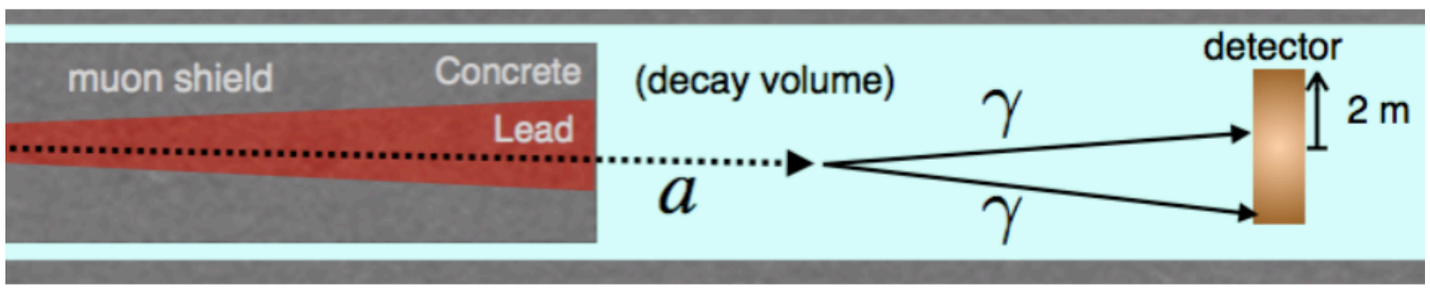
Dark Sector, Fixed-Target, and Beam Dump Experiments



M. E. Peskin
LCWS “at” CERN
March 2021

While we look for physics beyond the SM at the energies of the Higgs boson and the top quark, there is another frontier suggested by new models of cosmic dark matter.

Dark matter could reside in a sector of particles at GeV masses — or much lower — very weakly coupled to the particles of the SM.

There is now an extensive experimental program trying to probe this domain at accelerators, both with colliders and new fixed target experiments.

HItoshi Murayama asked, what can ILC contribute?

We now have an ILC working group on this subject, with Maxim Perelstein and Stefania Gori as the conveners. New contributors are welcome; to join, email Maxim at mp325@cornell.edu.

This group scheduled an interesting set of presentations on Tuesday, from Natalia Toro, Kaoru Yokoya, Yasuhito Sakaki, and Maxim Perelstein.

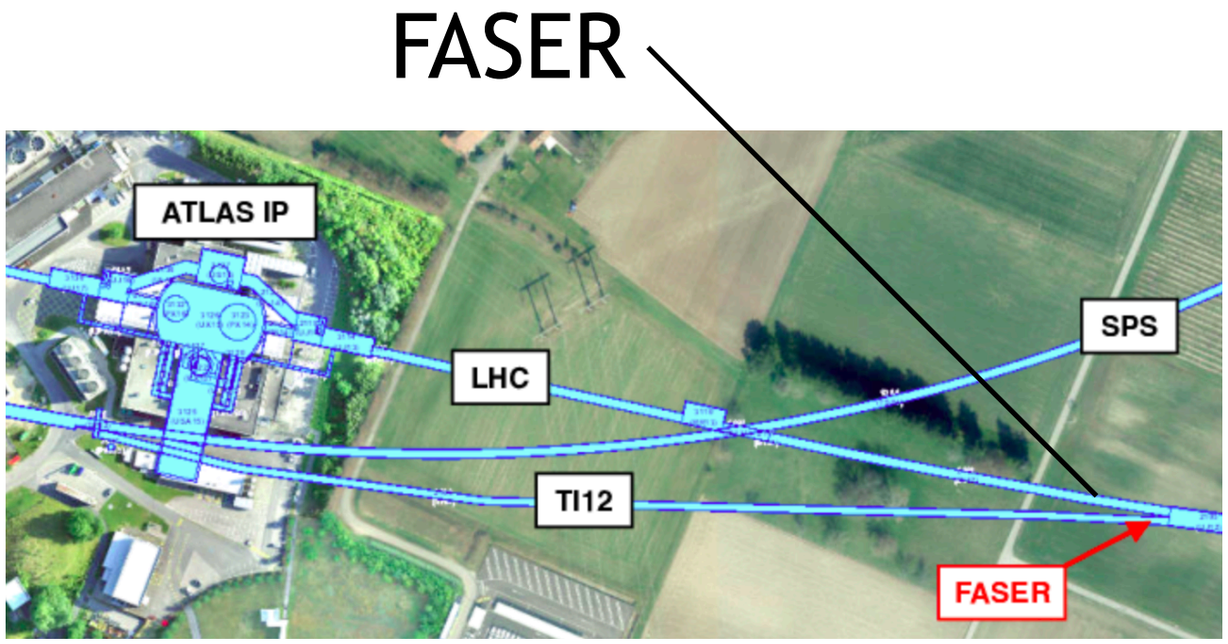
The ILC will offer the highest-energy electron beams in the world, also with unprecedented intensities (~1000 x SLAC). How can we use these to search for the dark sector ?

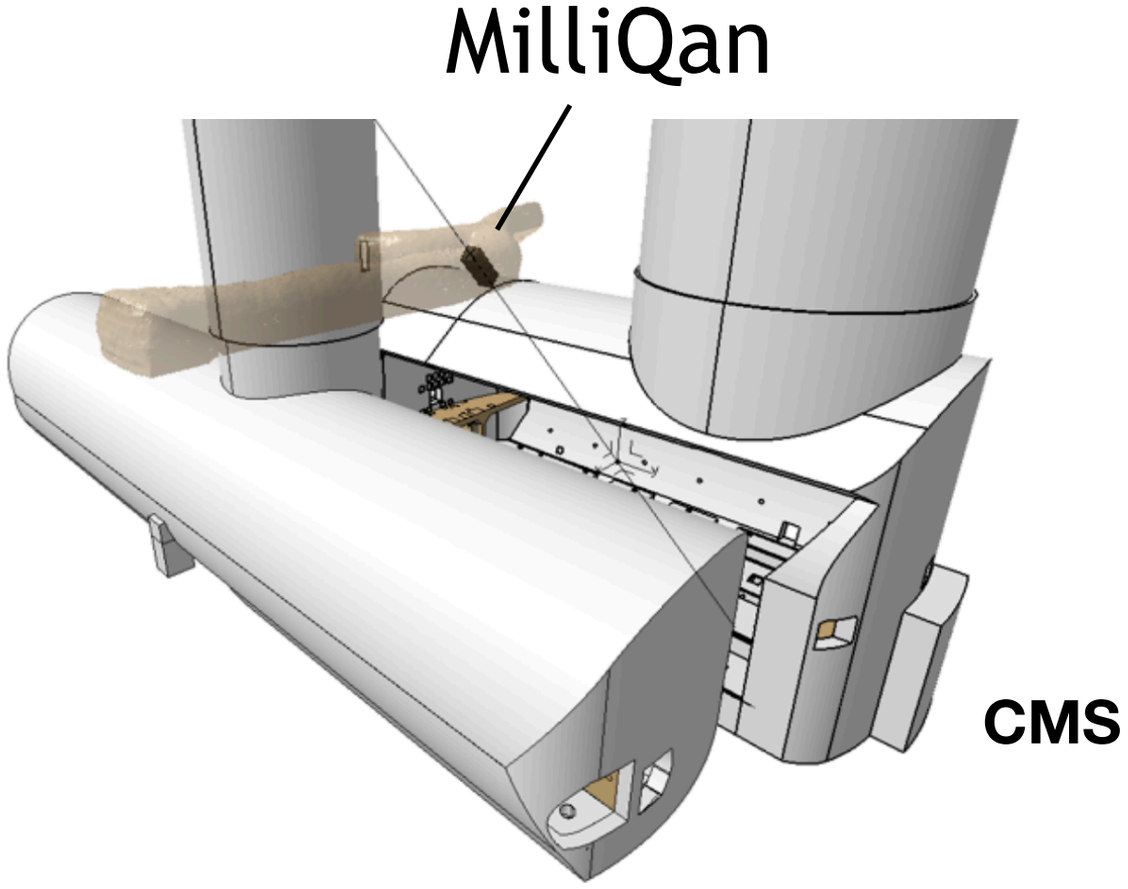
Due to constraints of SM gauge invariance, dark sectors are connected to SM particles thorough a specific set of operators, called “portals”. Some examples are

$$\frac{1}{2}\epsilon_Y F^Y_{\mu\nu} F'^{\mu\nu} \qquad \epsilon_H |H|^2 |\Phi|^2 \qquad \epsilon_a \frac{a}{f_a} F_{\mu\nu} \tilde{F}^{\mu\nu}$$

These allow a rigorous analysis of the ILC possibilities and the comparisons to other experiments.

At the LHC, experiments search for dark particles produced by pp collisions are placed in existing tunnels and caverns at CERN.





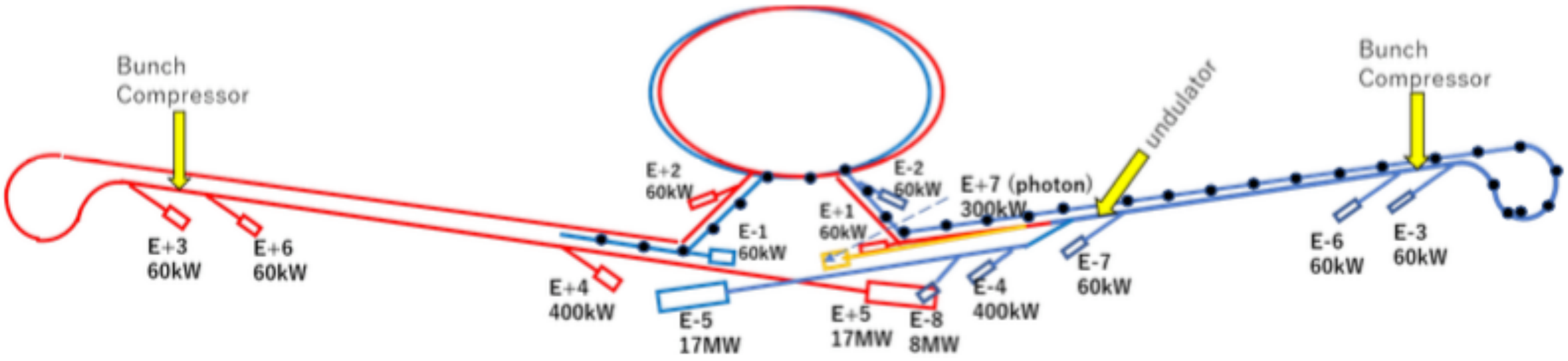
At the ILC, we have the opportunity to design dark sector facilities from scratch and in optimal locations, as long as these are small additions to the ILC design.

Some preferred locations are:

1. An area behind the e- and e+ main beam dumps and muon shields.

2. A dedicated fixed-target experimental hall with electron beams at E-4.

3. A cavern off of the collider hall access tunnel (e.g., for long-lived particles from Higgs decays)

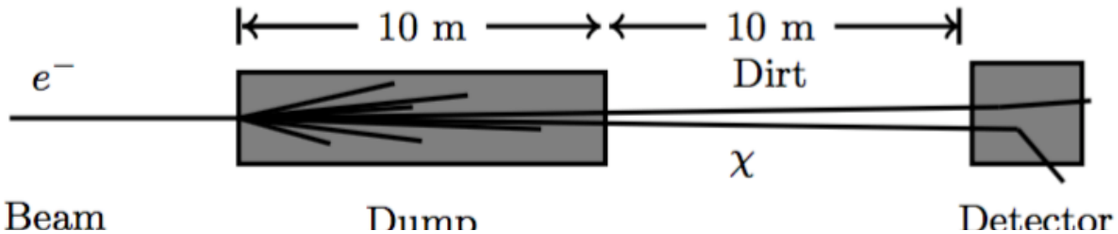


thanks to Kaoru Yokoya !

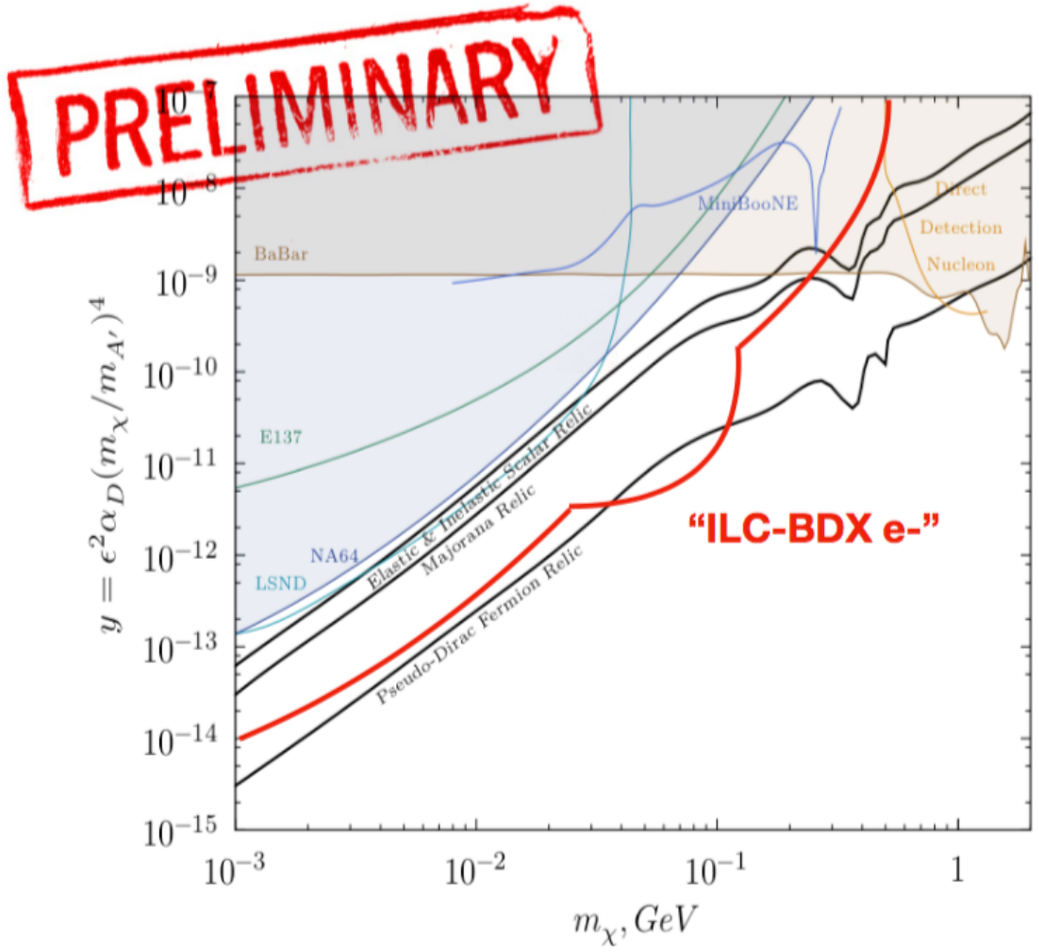
Experiments behind the main beam dumps

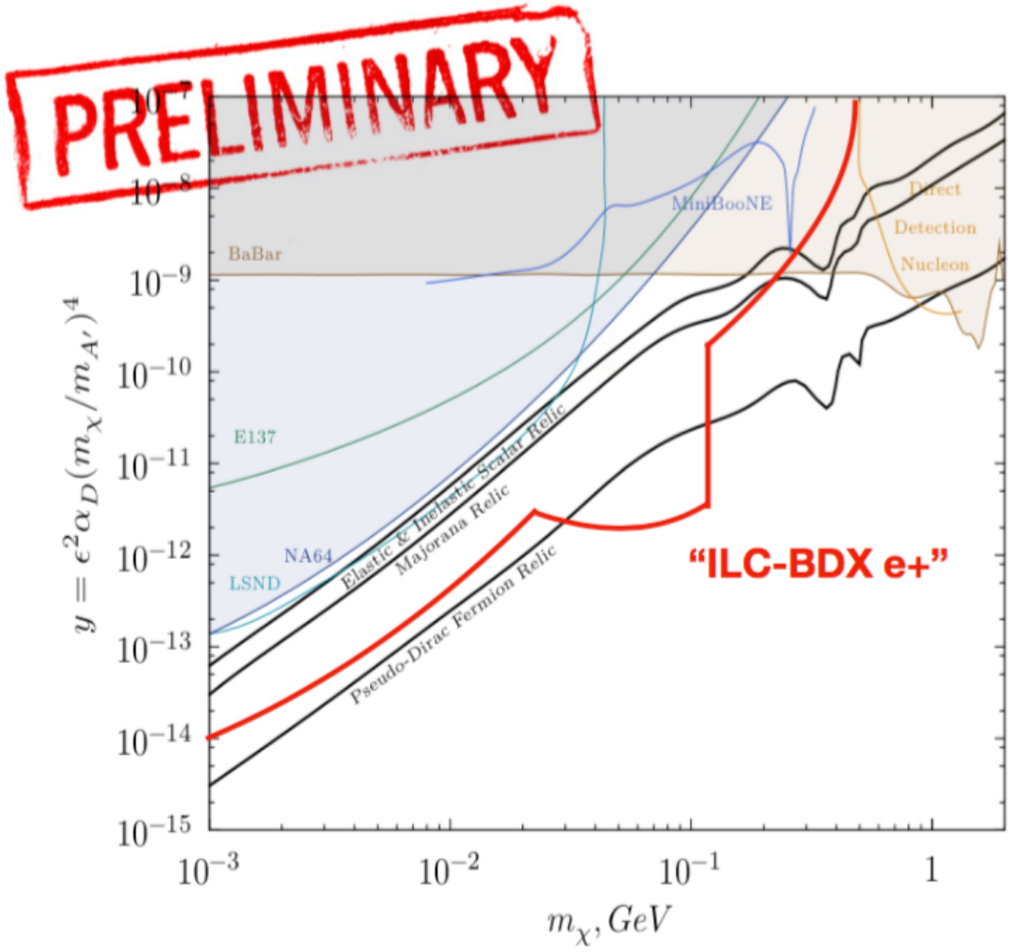
125 GeV beams, 4×10^{21} e-/e+ per year, parasitic

example of an experiment modeled on BDX at JLab:

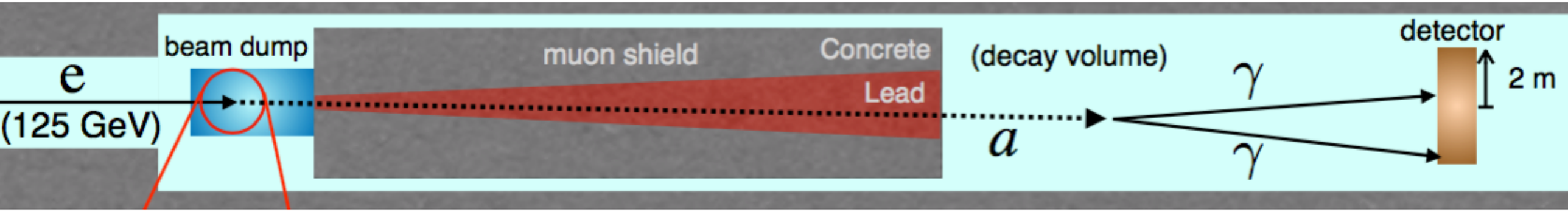


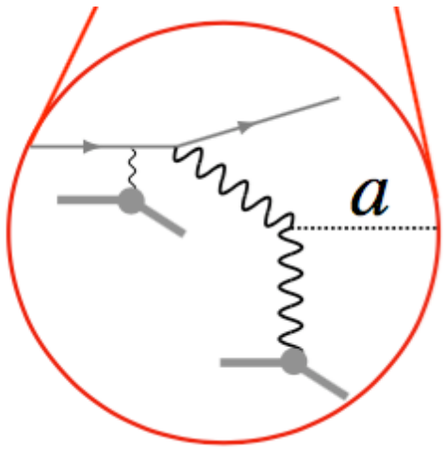
Perelstein

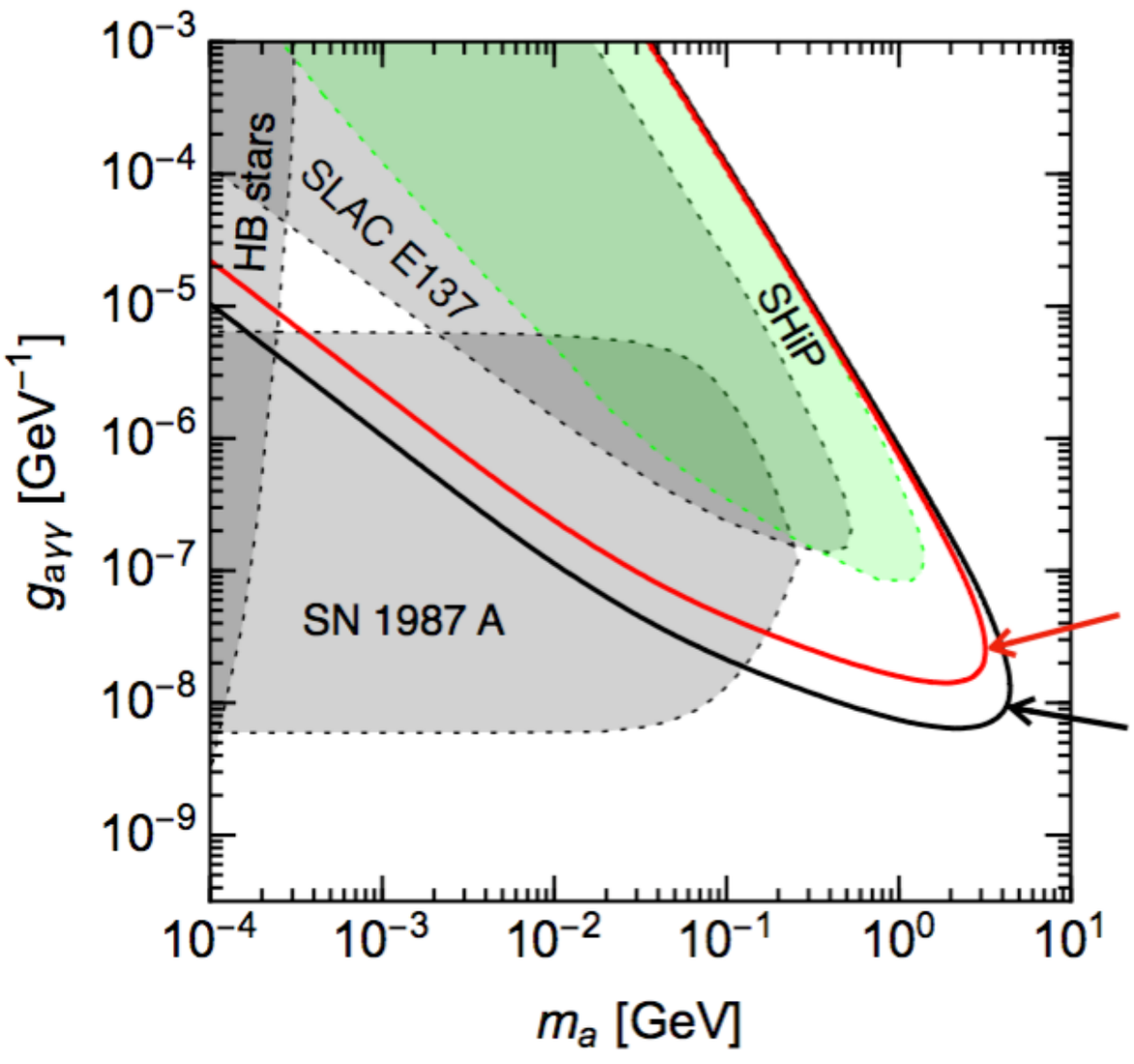




example of an axion/ALP search



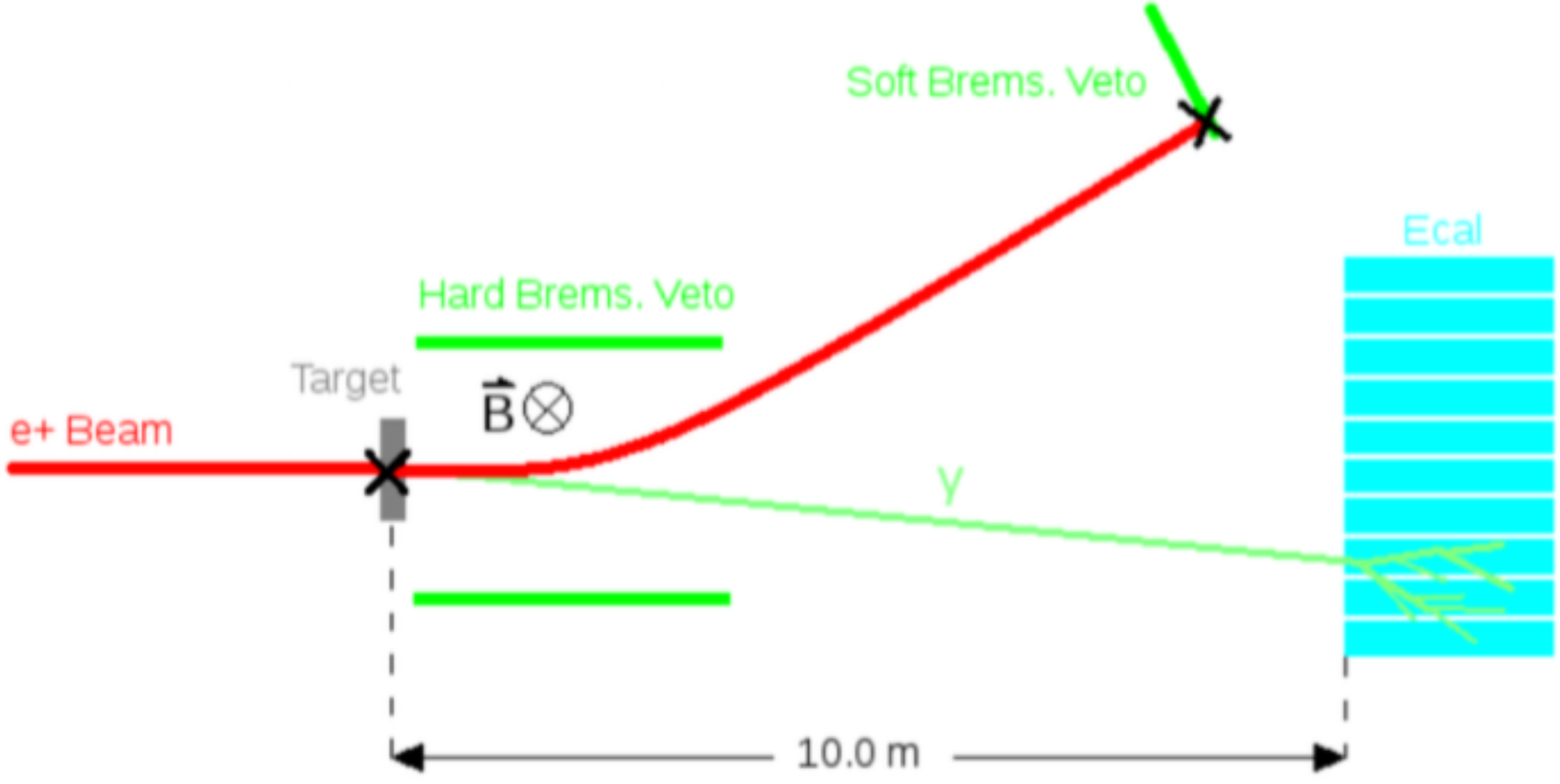




Sakaki

dedicated e- fixed target experiments

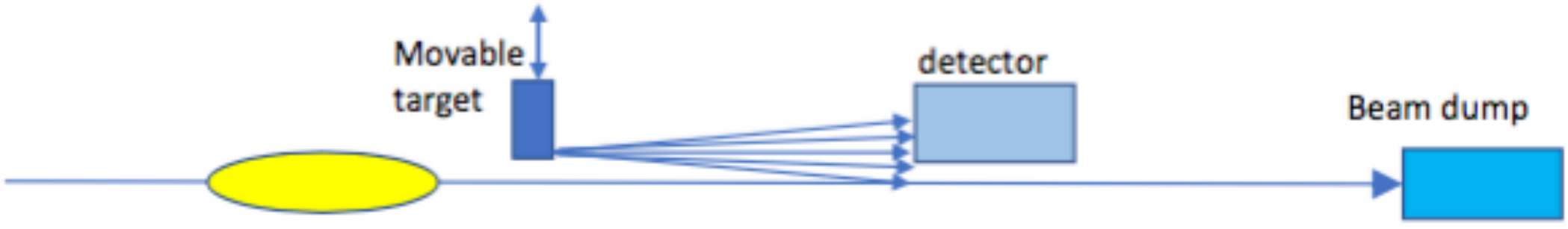
Exploit the large ILC beam energy to search for ALP or dark photon as missing energy, searching for $e^- N \to e^- + (\text{invisible})$ or $e^+ + \text{atomic e}^- \to \gamma + (\text{invisible})$, modeled on the LDMX and PADME experiments.



These experiments require

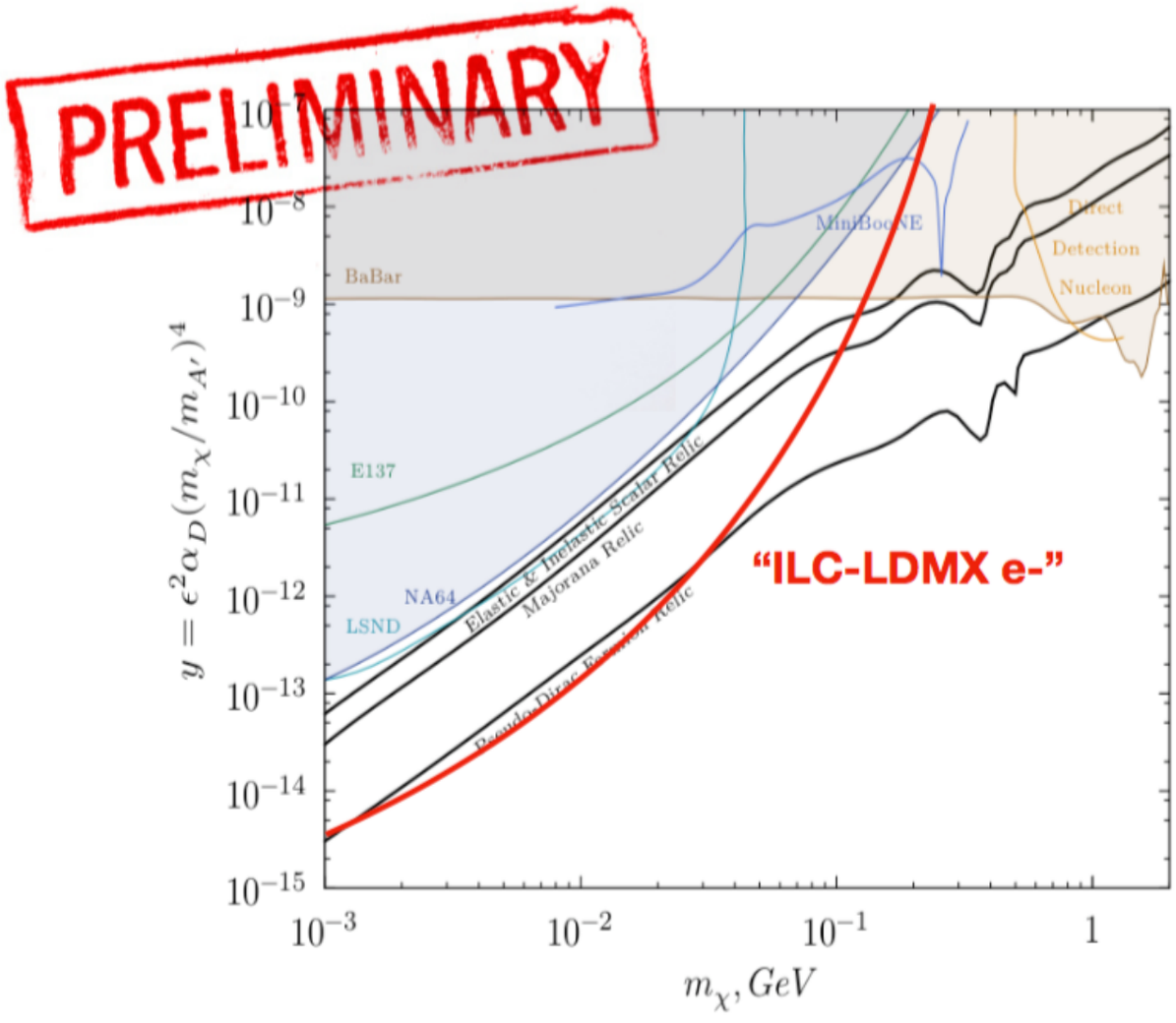
few events/bunch crossing

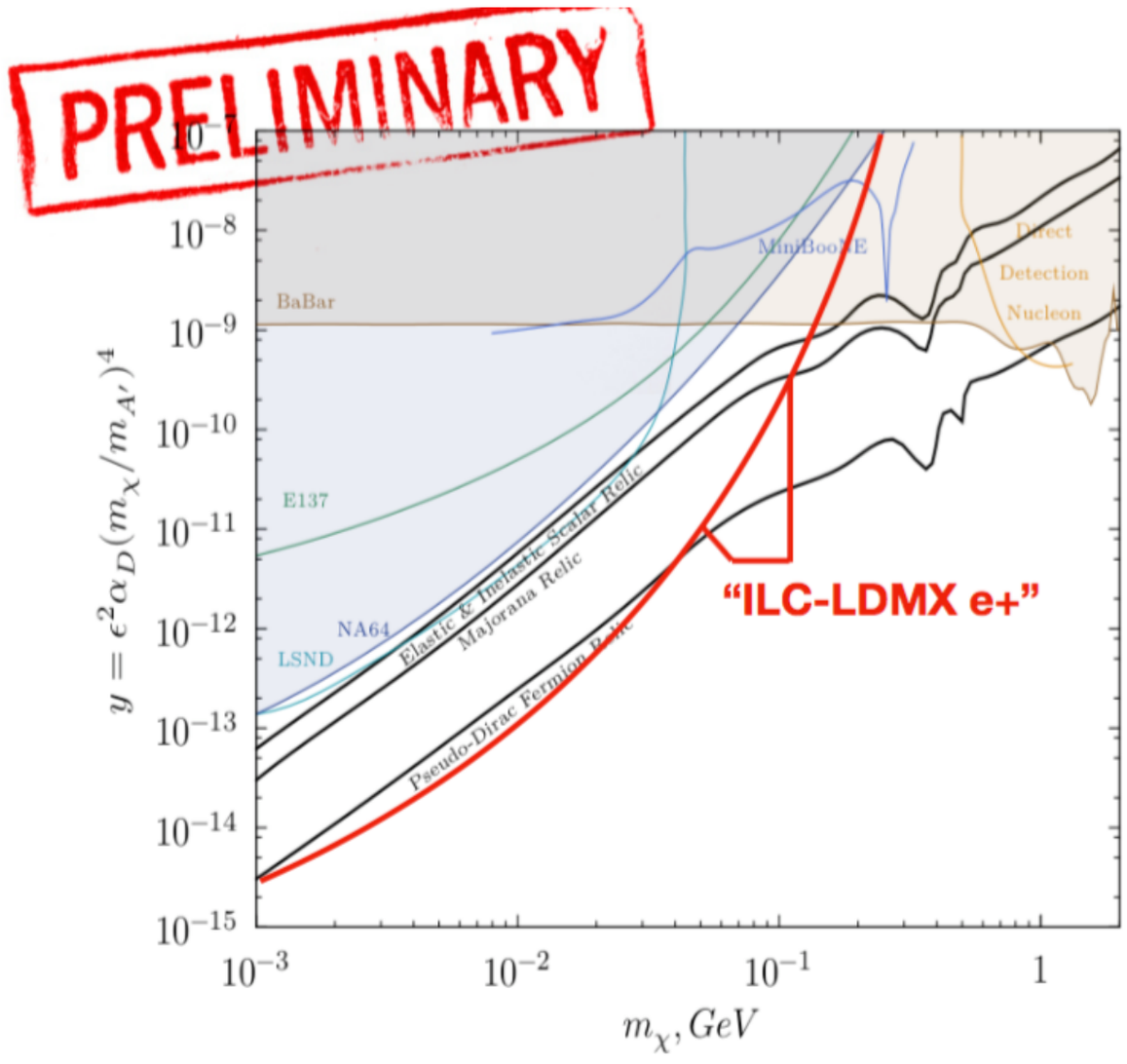
so, very low intensity beams. Beams must have high enough current to be visible to BPMs for steering. With an auxiliary electron gun, it is possible to fill all buckets in the linac, producing bunches with 0.77 nsec spacing and 10^6 e/bunch. A movable target can peel off the halo of each bunch for the experiment.



This plan is consistent with the E-4 beam dump capability of only 400 kW.

This experiment also can reach the region of thermal dark matter models,.





Perelstein

A dedicated fixed target hall at E-4 can serve other customers:

Nuclear Physics

hadron-parton transition region

e- production of antinuclei

Strong Field QED

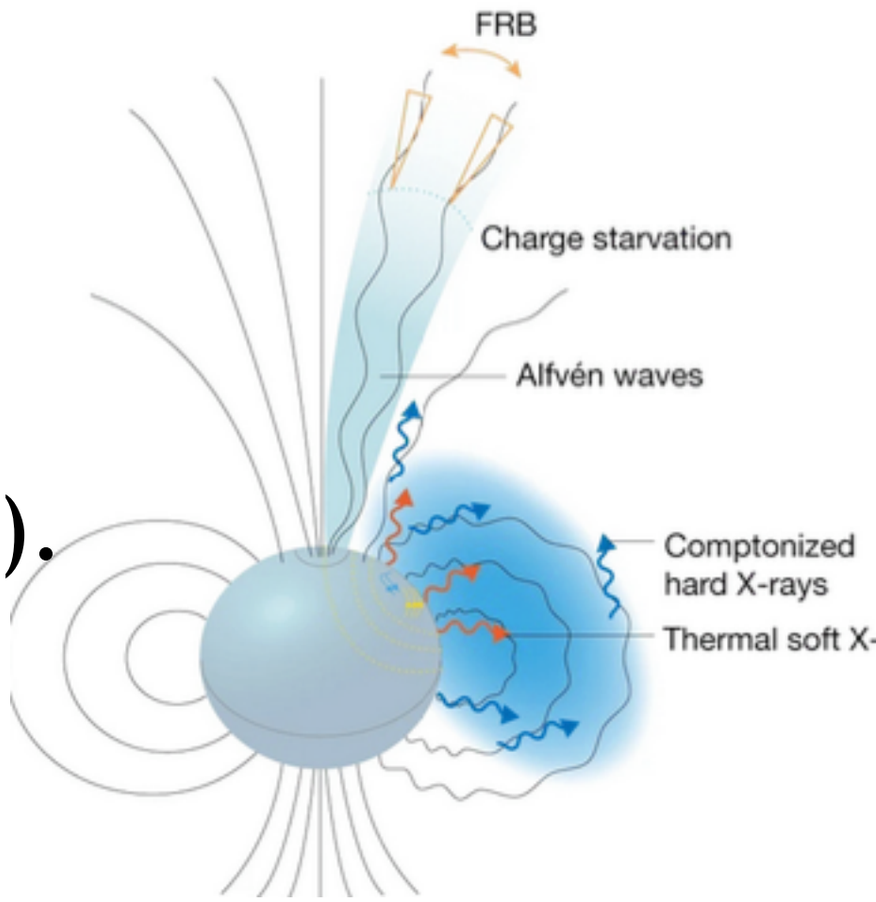
fields above the Schwinger critical field,

physics of the e+e- plasma

Strong Field QED:

(see Meuren's talk on Monday - N3)

EM fields above the Schwinger critical field can spontaneously create an e+e- plasma. Such strong fields appear in extreme astrophysics (magnetars, FRBs). We would like to produce the e+e- plasma under controlled conditions at accelerators.



The interaction of a 100 GeV electron beam with a 100 PW laser goes far into this regime: $E/E_c \gg 25$ in the electron frame. The beam requirements are similar to those of the program at E-4 described above.

The ILC offers a fixed-target program with potentially interesting opportunities for dark sector searches and other science goals.

The study of these experiments is just beginning. We hope to evaluate them in detail in the next year.