Beam Dump Experiment @ High Energy Electron Colliders

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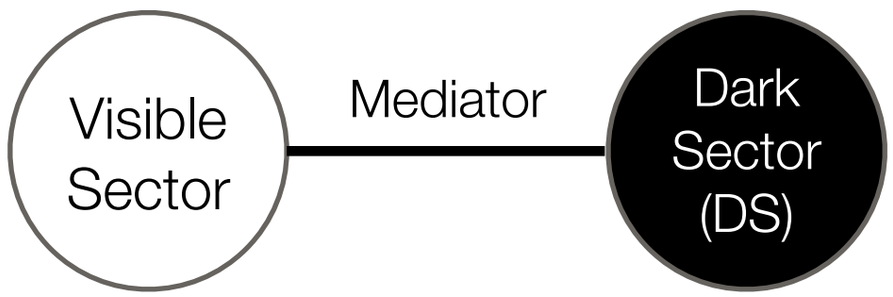
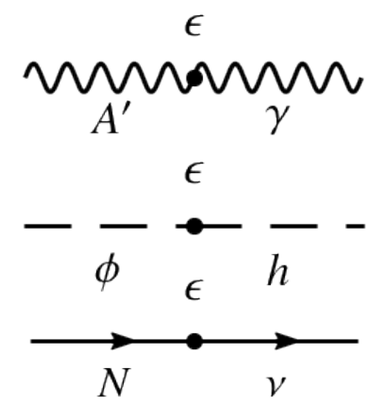
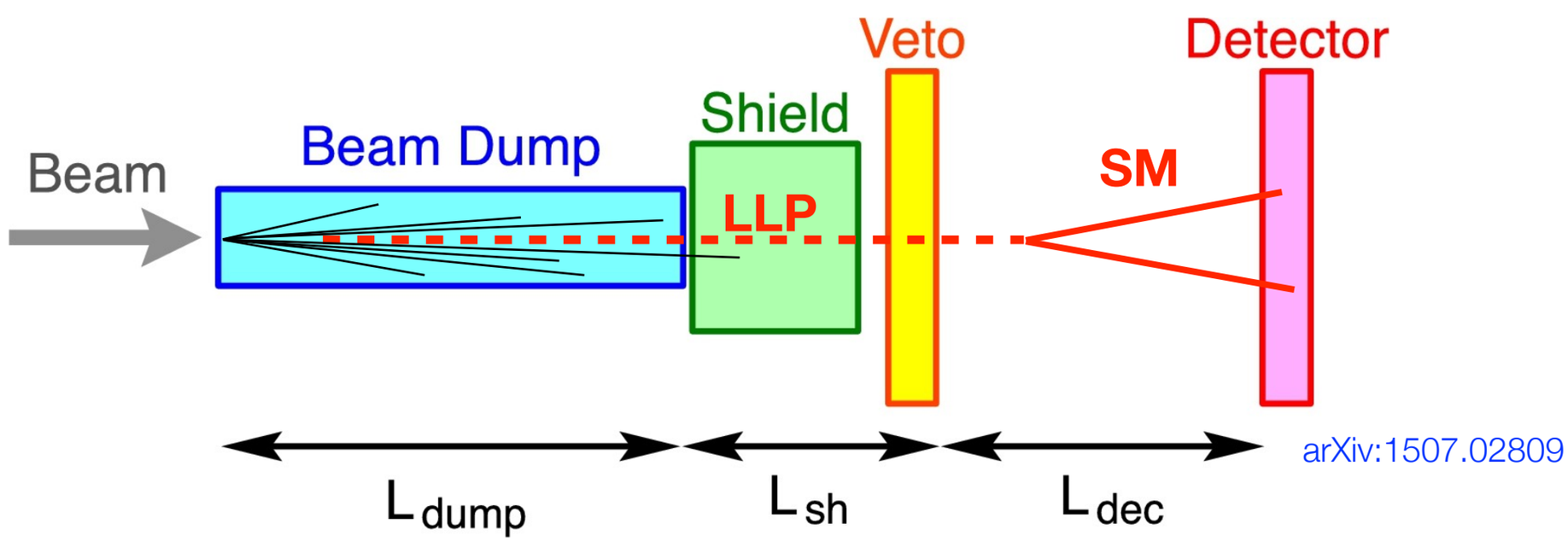
Dark Sectors and Beam Dump Experiments



1. Vector: $\epsilon F^{\mu\nu} F'_{\mu\nu}$
2. Scalar: $\epsilon |h|^2 |\phi|^2$
3. Neutrino: $\epsilon \ell h N$



- For small enough couplings, mediators travel macroscopic distances before they decay. Here, beam dump experiments shine!



arXiv:1507.02809

Advantages of Linear Electron Colliders

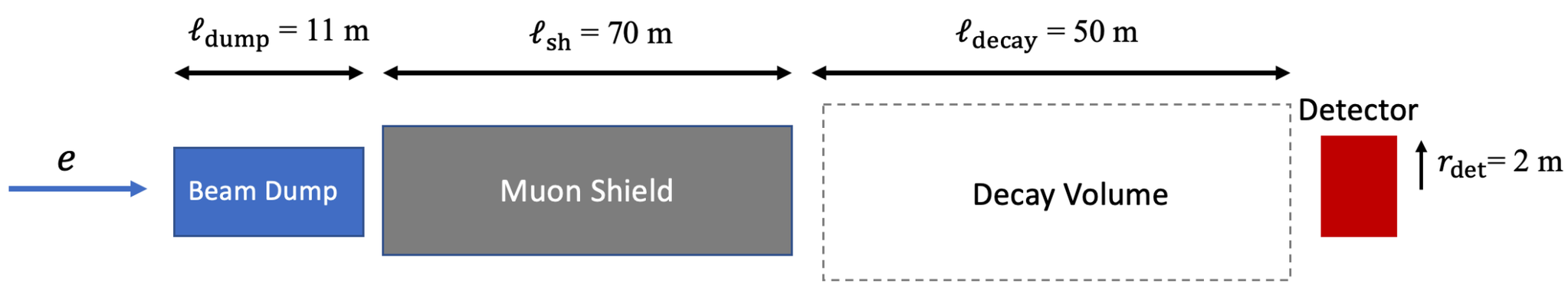
- **Large beam energies:** 125 GeV, 500 GeV, 1.5 TeV compared to past/current beam dump experiments: higher energy → heavier dark sector particles
- **High luminosities:** $\sim 10^{21}$ electrons-on-target per year produced a large flux of dark sector particles
- What about beam dumps of circular colliders e.g. FCC-ee, LHC? Much lower electrons/protons on target by design — beams are recycled in the collider and dumped only a few times per day.

Collider-$\sqrt{s}$ [GeV]	ILC-250/1000	C^3-250	C^3-3000	CLIC-3000
Bunches/Train	1312	133	75	312
Train Rep. Rate [Hz]	5	120	120	50
Bunch Charge [nC]	3.2	1	1	0.6
Effective Luminosity [cm^{-2} s^{-1}]	1.6×10^{39}	1.2×10^{39}	6.9×10^{38}	6.9×10^{38}
EOT/Year	4.1×10^{21}	3.1×10^{21}	1.8×10^{21}	1.8×10^{21}

P. Giffin, S. Gori, Y.D-Tasi, and DT arXiv:2206.13745

Unique opportunity: a facility to search for dark sectors can be designed from scratch!

ILC Beam Dump Experiment Configuration



- Beam dump material: water
- Muon shield: lead and concrete
- 50 meter decay volume. Cylindrical detector with 2 meter radius.
- Optimal beam dump configuration for C^3 has not been discussed! Highly dependent on installation site, but current studies can assume a similar set up as ILC. Expect similar reach for dark sector particles as ILC/CLIC

Case Study: Heavy Neutral Leptons

- Heavy neutral leptons are a well-motivated extension of the SM.
  - Connections to neutrino masses, BAU, and dark matter, for example.
- Production from the decays of mesons and directly in charged-current scattering if the HNL mixes dominantly with the electron-neutrino.
  - First place where a beam dump experiment at other electron colliders besides the ILC is investigated!

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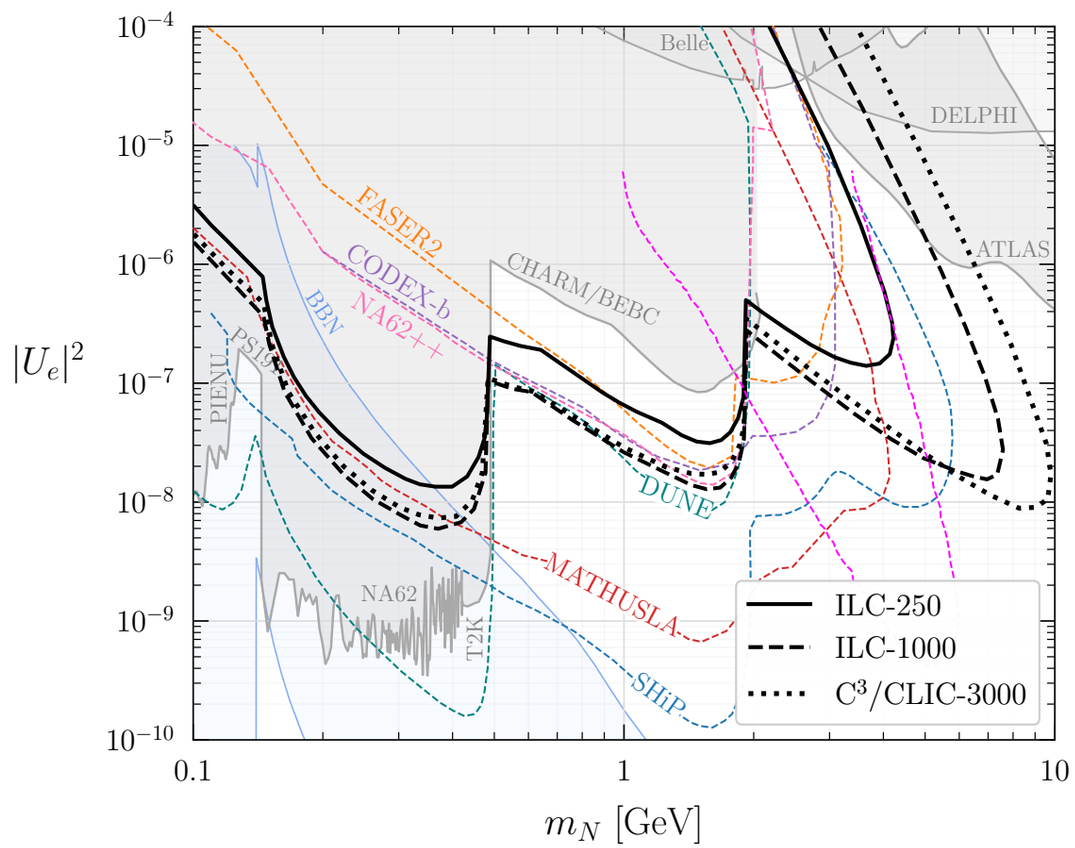
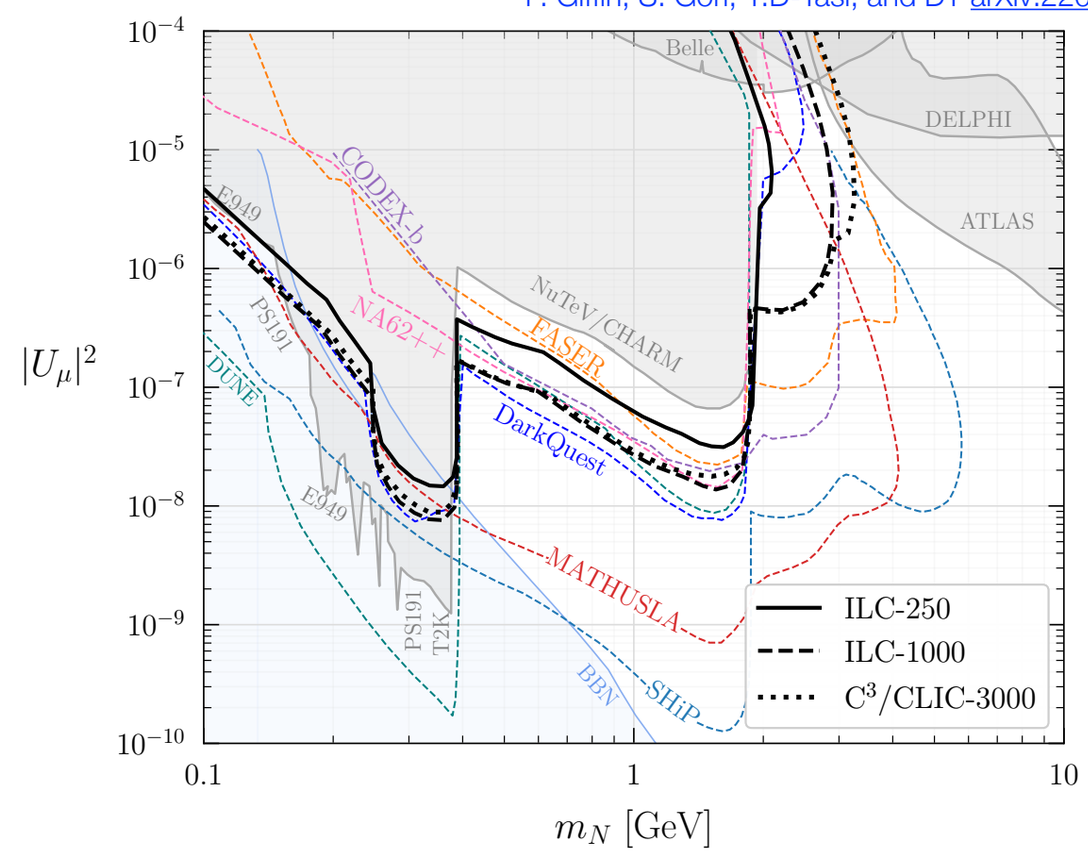




Main result: the reach of C³ is complementary to ILC

Wishlist for C^3

- Optimal beam dump set up? Beam dump material? Shielding? Decay volume length? These questions are highly dependent on the installation site of C^3.

- BSM benchmarks? Depends on the beam dump set up and, in some cases, on meson production.

- Study meson production at “medium” energies? Experimental data is missing and C^3 is uniquely positioned to study this in its multi-energy stages.

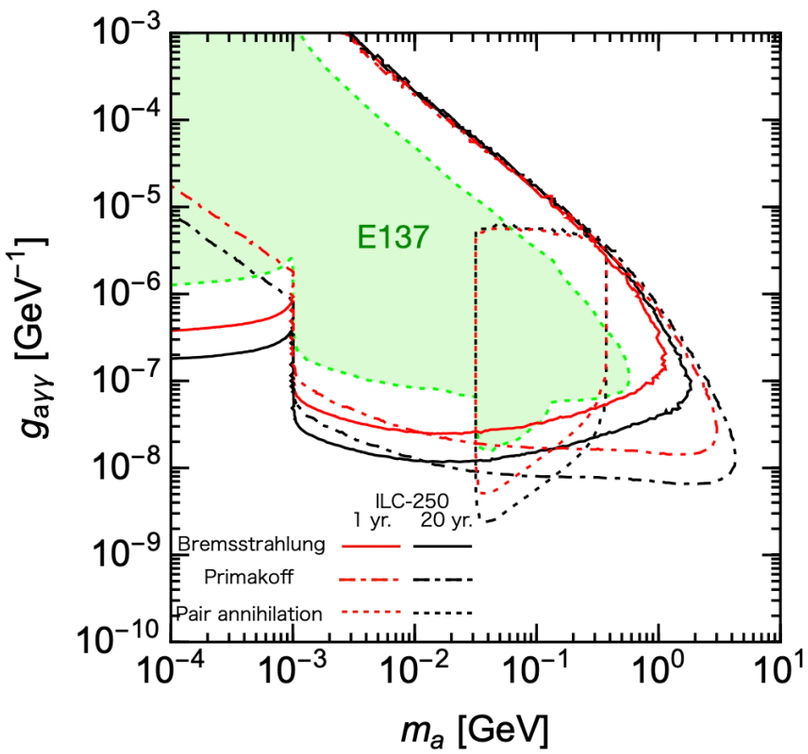
Thanks!

Questions?

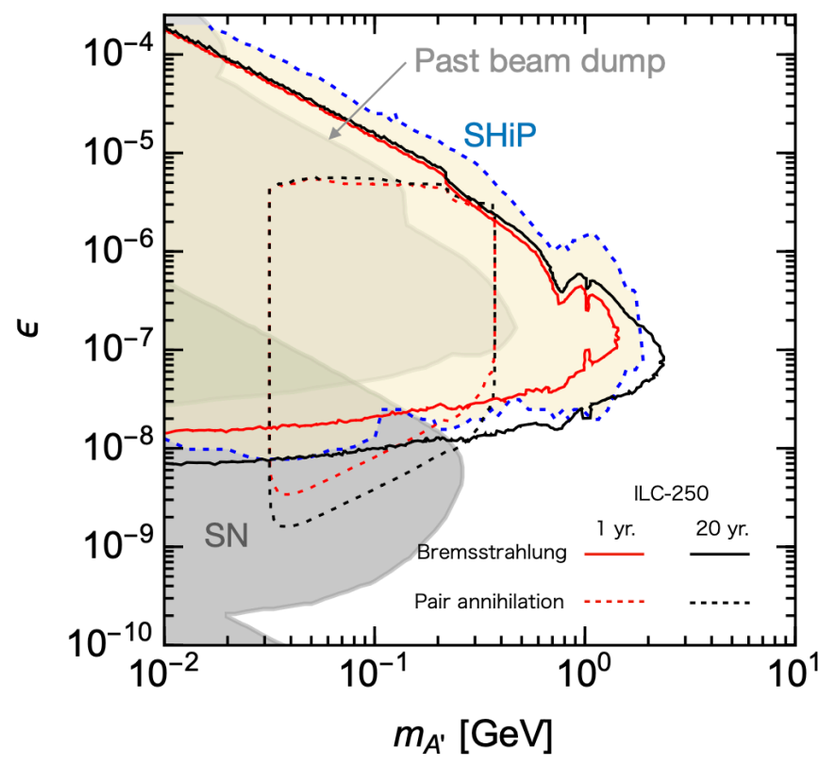
Additional BSM Scenarios

- Existing BSM studies for an ILC beam dump experiment. C^3 will place similar bounds.

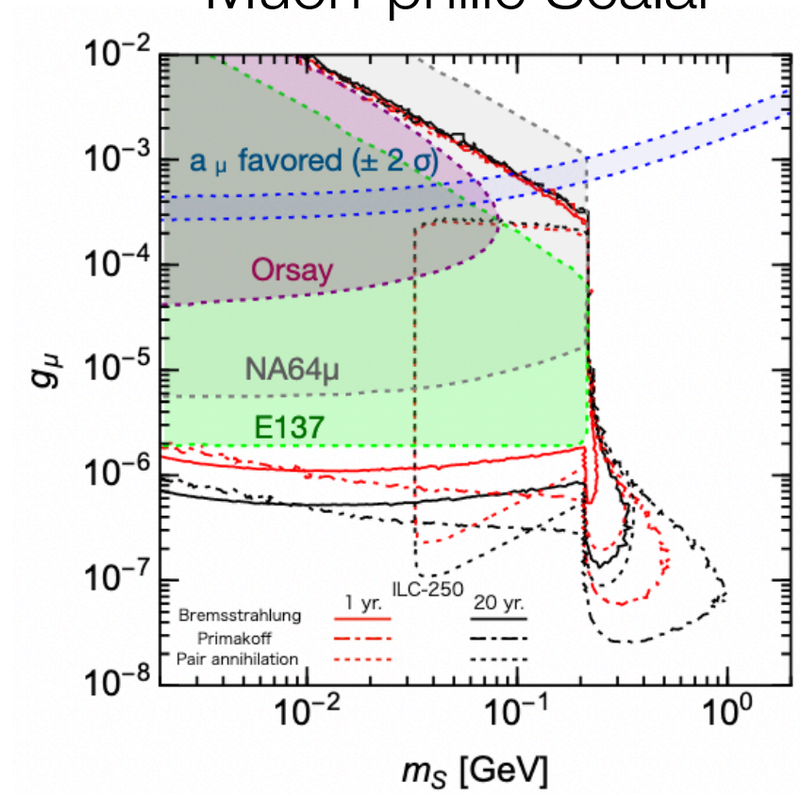
Axion-like Particles



Dark Photon



Muon-philic Scalar



K. Asai, S. Iwamoto, Y. Sakaki, and D Ueda arXiv:2105.13768