ECal Geometry for the Light Dark Matter eXperiment

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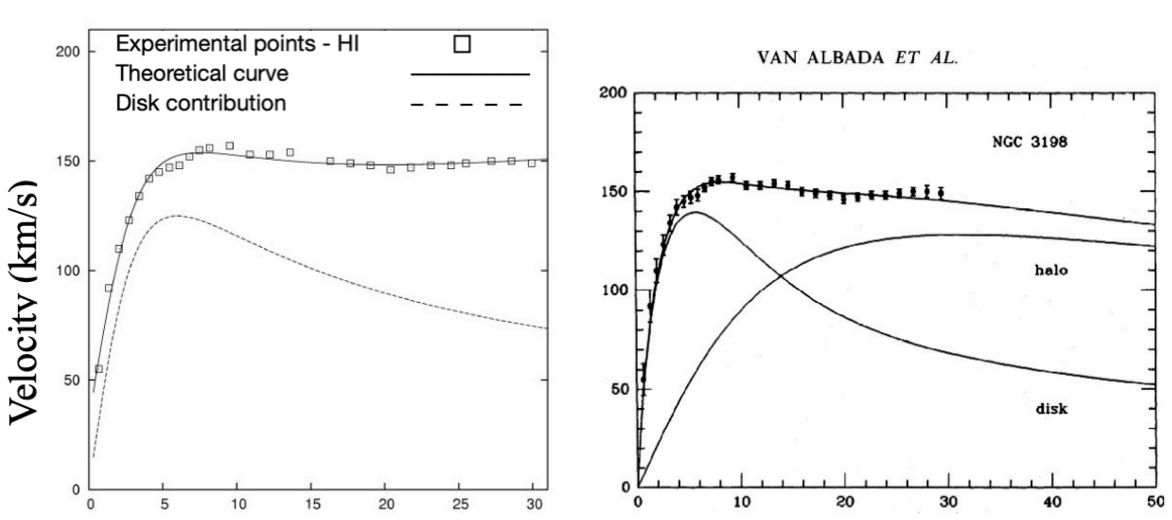
Abstract

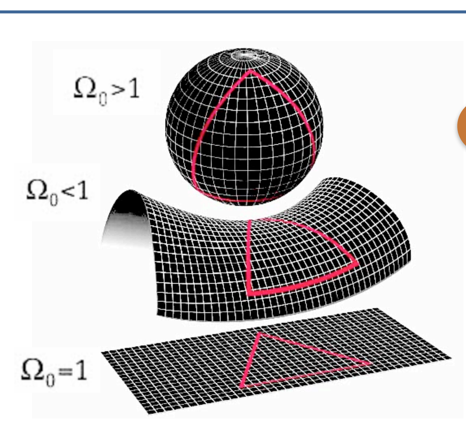
Dark matter (DM) -- beyond Standard Model (SM) matter -- could be a dark sector (or hidden sector) of particles, with their own interactions. The Light Dark Matter eXperiment (LDMX) probes into the hidden sector to identify dark matter in the sub-GeV mass scale. LDMX assumes the model of charged dark matter particles which interact under an EM-like force, described by U(1) symmetry and mediated by a dark photon. Here we will discuss the motivation for dark matter, current stages of dark matter search, and LDMX.

Motivation

1 Rotation curves (1970s)



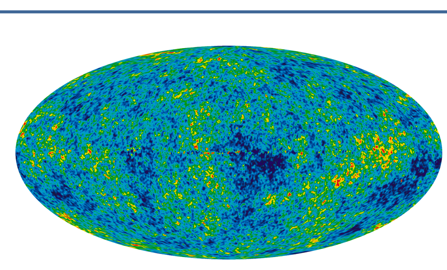
- Orbital velocity of stars and gases expected to decrease as distance from galactic center increases, but observed rotation curve appears flat.
- DM could be seen as a galactic halo around the outer reaches of a galaxy.



2 Flat Universe

Observable mass: $\Omega_m \sim 0.3$

For a a close universe: $\Omega_m \sim 1$



3 Evidence in the 2000s!

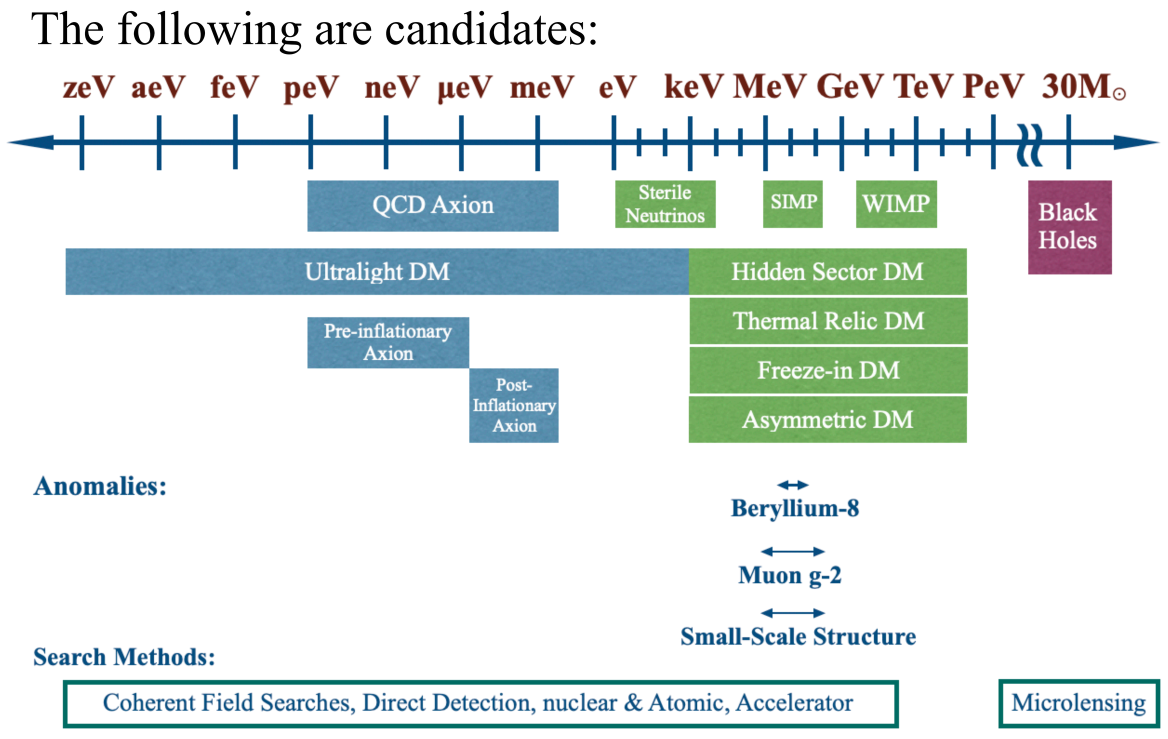
- Gravitational lensing
- Structure formation

- Cosmic Microwave Background: clumpy distribution of observable mass, but smooth thermal radiation.

❖ **Conclude: DM ~ 85% total matter of the universe**

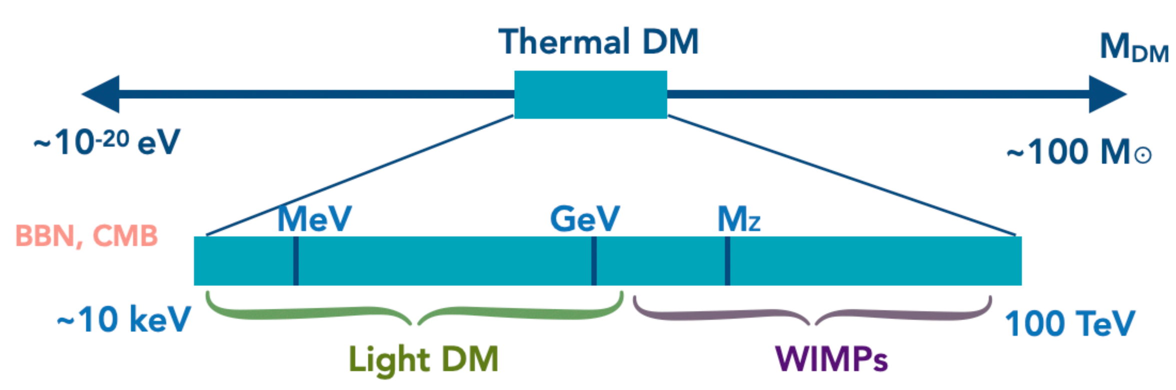
Candidates for DM

However, particle nature of DM not well understood. The following are candidates:



Weakly interacting massive particles (WIMPs) originally thought of as a strong candidate for DM, but much of its parameter space are ruled out by various experiments.

Thermal Relic DM

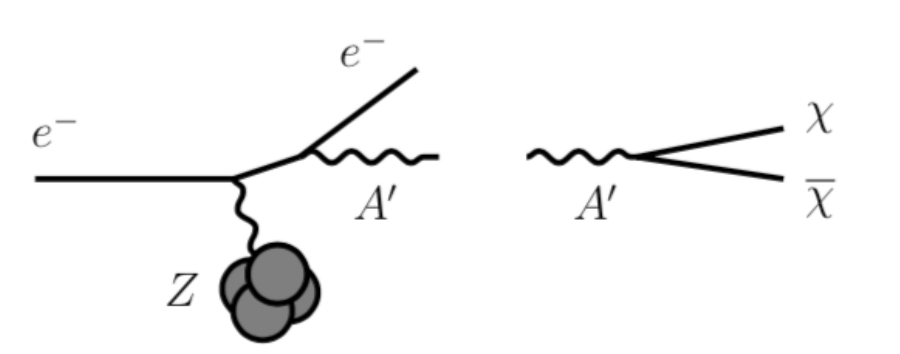


Thermal origin DM → new mediator

→ motivates Hidden Sector DM

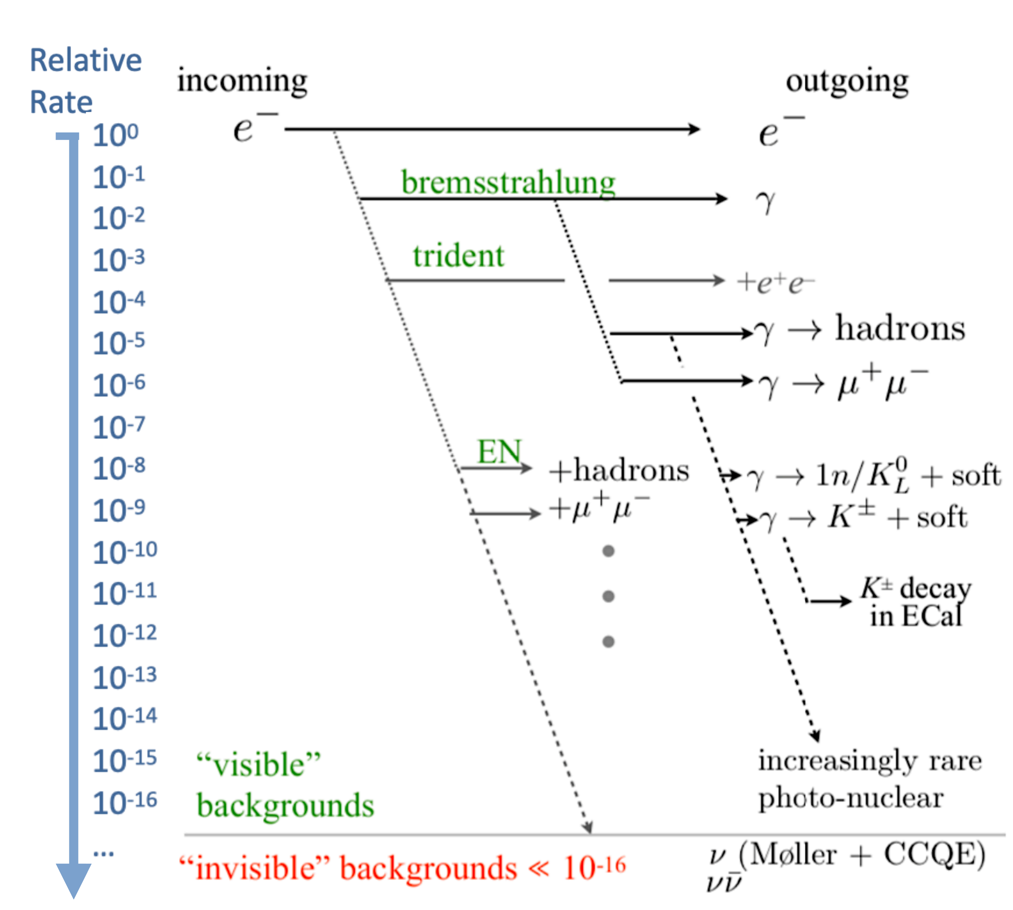
- Thermal relic DM, freeze-out mechanism hypothesis:
  - Particles in thermal equilibrium in hot early universe
  - DM and SM particles interact **besides** gravitationally
  - Universe cools down, DM density stays constant

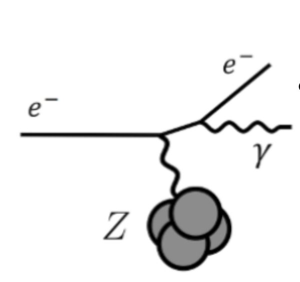
LDMX Model



- **Light DM: thermal freeze-out** mechanism.
- **Dark matter particle** χ charged — interact under **U(1)** symmetry, analogous to SM EM force.
- We aim to produce dark photon (A') via a **dark bremsstrahlung** process shown above. A' could decay into charged DM particles χ.

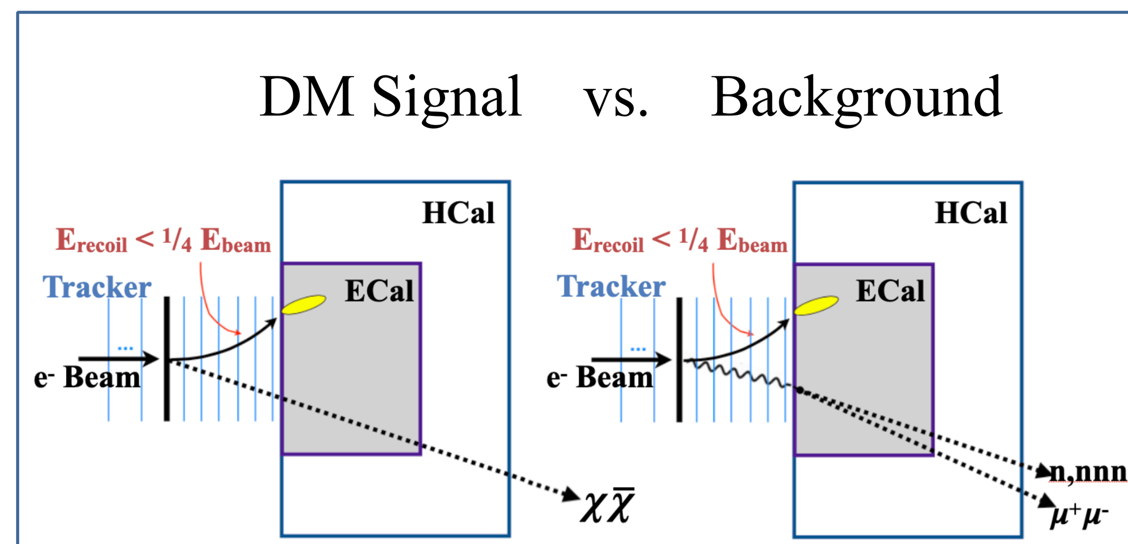
Background Processes





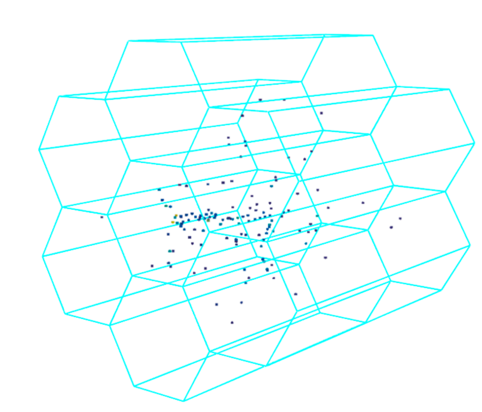
- Task: identify background processes that resemble DM signal. A leading source is the SM hard bremsstrahlung, shown on the left.

Detector Setup

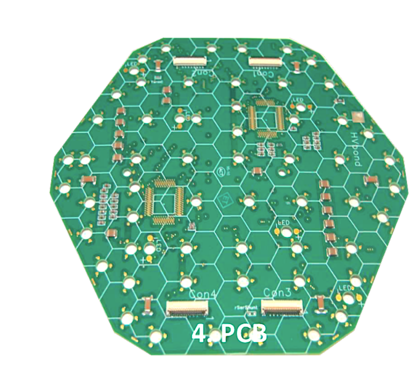


- DM signal: **Significant missing momentum**
- Aim a 4-16 electron beam at a fixed tungsten target
- Final products: SM particles and/or DM particles.
  - Tracker
  - Dipole magnet
  - ECal and HCal

Electromagnetic Calorimeter (ECal)



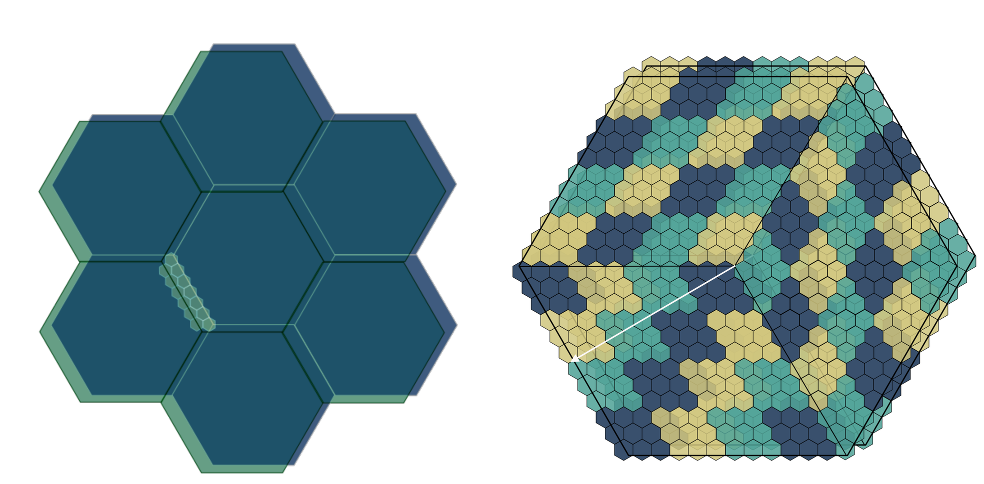
Simulation of hits



Hexagon Module

- ECal: 34 layers, each with 7 hexagon modules
- Hexagon module: silicon pad sensors with detection cells
- Problem: dead regions between hexagon
  i. Might miss DM signals
  ii. Might mistake background as signal

Solution: Layer Shift



- Resolve dead regions
- Higher pixel cell groups → higher efficiency

References

[1] LDMX Collaboration, T. kesson et al., "Light Dark Matter eXperiment (LDMX)", arXiv:1808.05219.

[2] Wilkinson Microwave Anisotropy Probe (WMAP) - NASA (2001).

[3] S. Nerlich, Universe Today (2015).

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