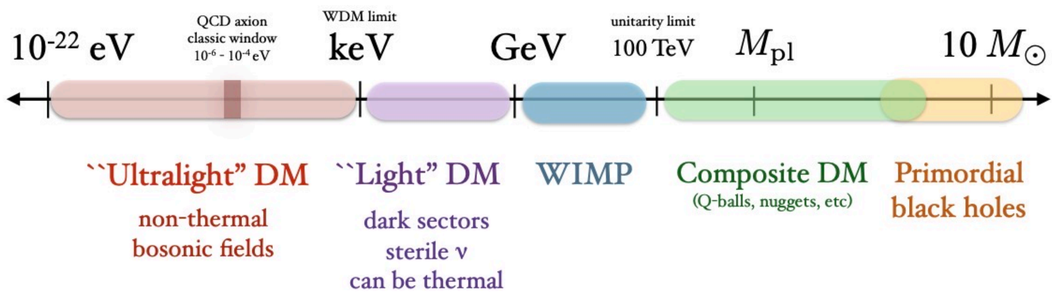
DarkSHINE: A dark photon fixed-target search experiment at the SHINE facility

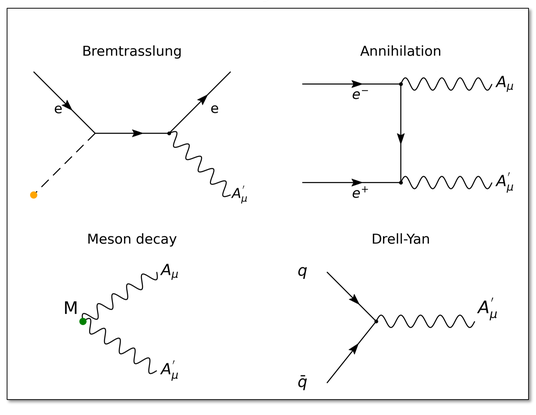
Yufeng Wang, on behalf of the DarkSHINE team
Tsung-Dao Lee Institute, SHIANGHAI JIAO TONG University

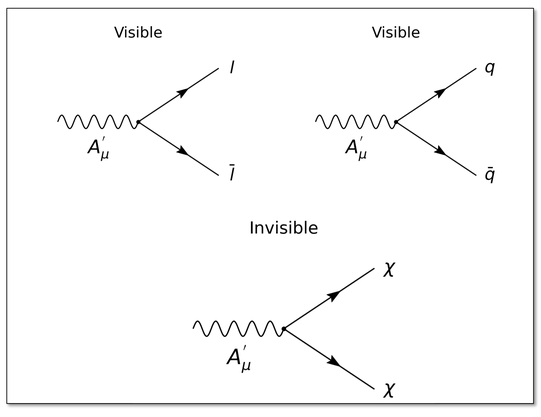
Physics Motivation

Evidences from cosmology and astronomy show that **Dark Matter (DM)** exists in the universe, constituting ~25% of the universe energy content.



Dark Matter can exist in a wide mass range. The **"freeze-out" mechanism** allows DM to have mass of a few MeV to TeV. The sub-GeV mass range (light DM) is not fully explored yet. New mediators are implied by thermal contact, e.g., a **dark photon (A').** DM may interact with the SM particles via the new "dark force".
Production and decay of the dark photon are shown below:

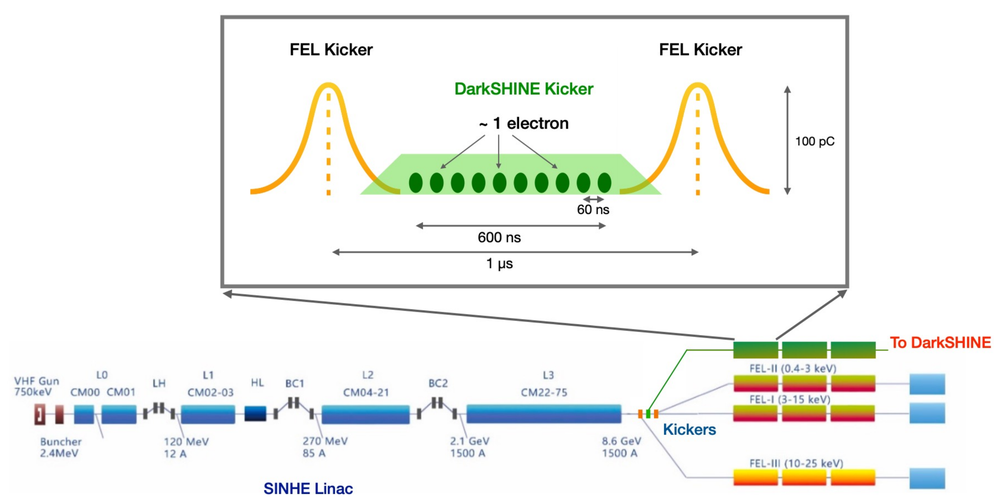




Fixed-target experiments (**Bremsstrahlung**) can provide sensitive probes of light DM using the missing energy/momentum (**invisible decay**) signature.

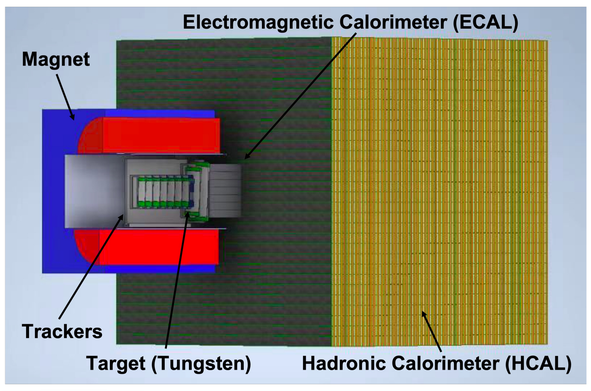
SHINE facility

The **high frequency single electron beam** required by our experiment is provided by Shanghai High Repetition-Rate XFEL and Extreme Light Facility (**SHINE**).



The SHINE is currently under construction in Zhangjiang area, Shanghai (2018-2026). It will provide an 8 GeV electron beam with frequency of 1 MHz. The beam intensity of SHINE is 100 pC, which corresponds to 6.25×10^8 electrons per bunch.
A dedicated electron beam with only **one electron per bunch** will be built in the SHINE linac using DarkSHINE kicker system, providing $\mathbf{3\times10^{14}}$ electron on target events (EOTs) each year.

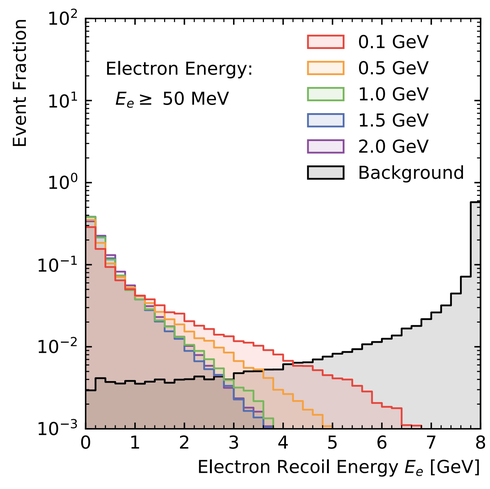
DarkSHINE detector



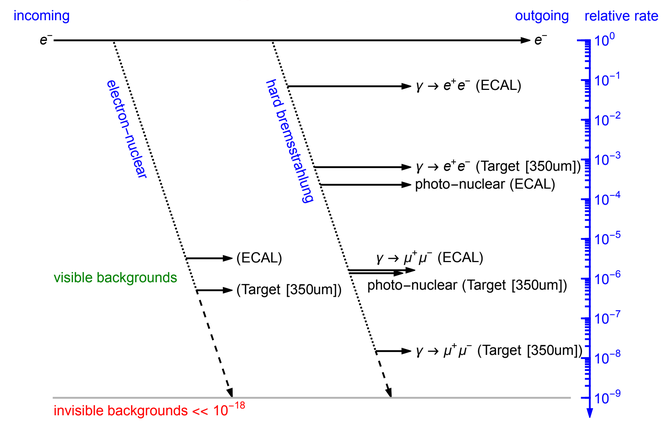
- **Tagging tracker & recoil tracker:**
  Measure the track of the incident and recoil electrons.
  - 7+6 layers of silicon strip sensor modules.
  - Tungsten target, 1.5 T magnet field.
- **Electromagnetic calorimeter (ECAL):**
  Measure the deposited energy of electrons and photons.
  - LYSO crystal + SiPM readout system.
- **Hadronic calorimeter (HCAL):**
  Measure the deposited energy of muons and hadron backgrounds.
  - Scintillator based sampling calorimeter with steel absorbers.

Invisible signal signature

Missing particle signature: soft recoil electron, large missing energy & p_T.



Leading background: SM photon bremsstrahlung
Other rare background processes:



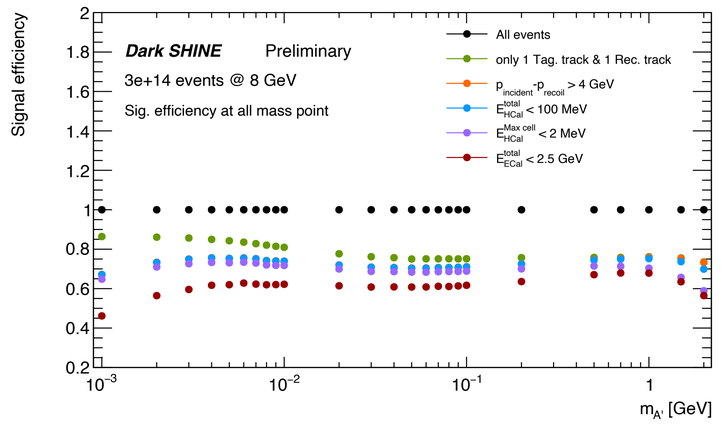
Signal region definition and efficiency

2.5×10^9 inclusive bkg. events and **10^5 signal events** for each mass point are generated.

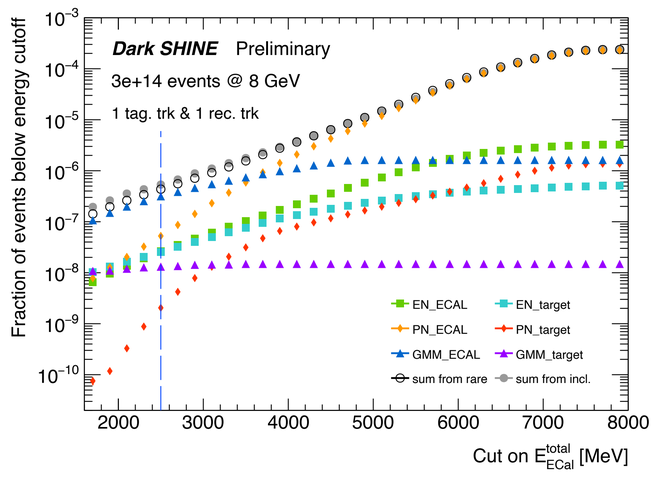
Good signal efficiency (~60%) obtained when the following cuts are applied:

- only 1 incident track and 1 recoil track;
- $p_{inc.} - p_{rec.} > 4$ GeV
- $E_{ECAL}^{total} < 2.5$ GeV
- $E_{HCAL}^{total} < 100$ MeV
- $E_{HCAL}^{\max\ cell} < 2$ MeV

No background event survives the cut-flow.



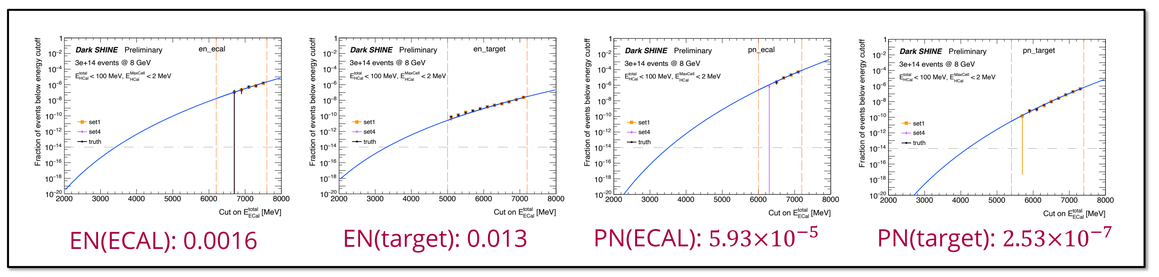
Background estimation of 1 year run



To estimate the number of bkg. events corresponds to $\mathbf{3\times10^{14}}$ EOTs:

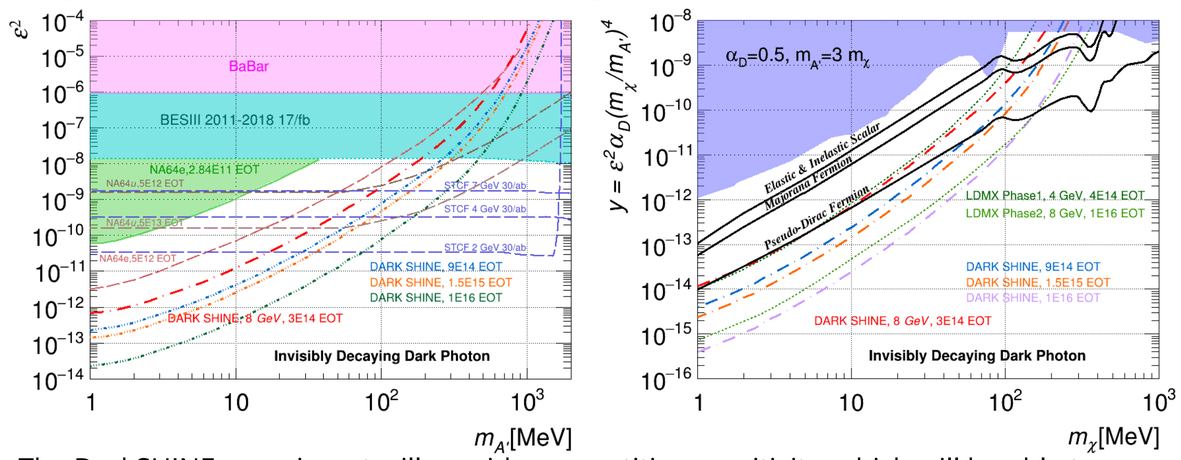
- **dedicated rare bkg. production with large statistics**
  - $10^7 \sim 10^8$ events are produced for each rare bkg. process.
- **extrapolation method**
  - expected bkg. yield are computed from the event ratio at given ECAL energy cut for each process.

→ Expected number of total background events per year: **0.015**



Conclusion

With an estimated total background yield of **0.015/year**, the expected 90% C.L. limit estimated with 3×10^{14} EOTs (running ~1 year), 9×10^{14} EOTs (~3 years), 1.5×10^{15} EOTs (~5 years) and 1×10^{16} EOTs (with Phase-II upgrade) are shown below:



The DarkSHINE experiment will provide competitive sensitivity, which will be able to exclude most sensitive regions.

TSUNG-DAO LEE INSTITUTE
Yufeng.wang@sjtu.edu.cn