Dark SHINE: A new initiative for Dark Photon search at SHINE facility

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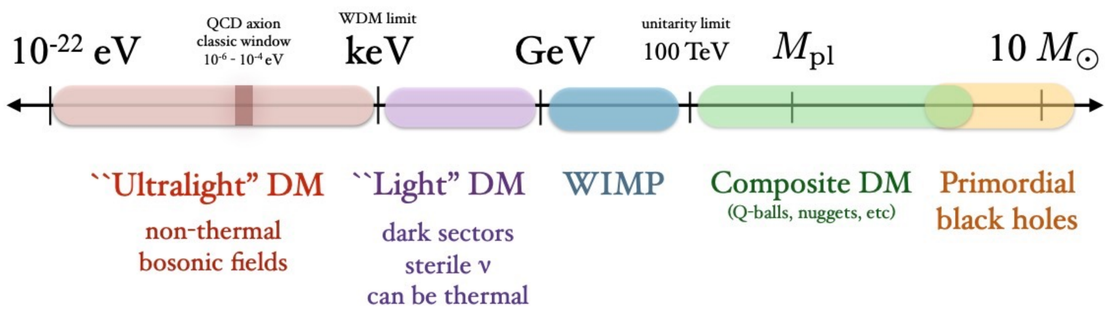
Introduction

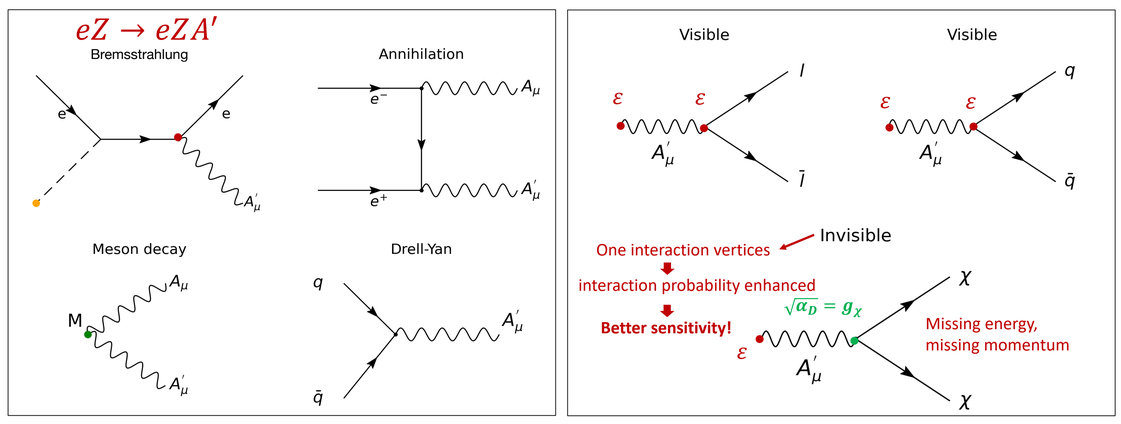
Dark SHINE is a newly proposed ***fixed-target experiment*** at SHINE (Shanghai high repetition rate XFEL and extreme light facility). Dark SHINE aims to search for the new mediator, ***Dark Photon (A')***, bridging the Dark sector and the ordinary matter. In this work, we present the idea of this new project and 1st prospective study in search for A' decaying into light dark matter.

Physics Motivation

- Various astrophysical observations told us ***dark matter (DM)*** exists in our universe. DM is the mysterious substance that makes up roughly a quarter of the Universe.



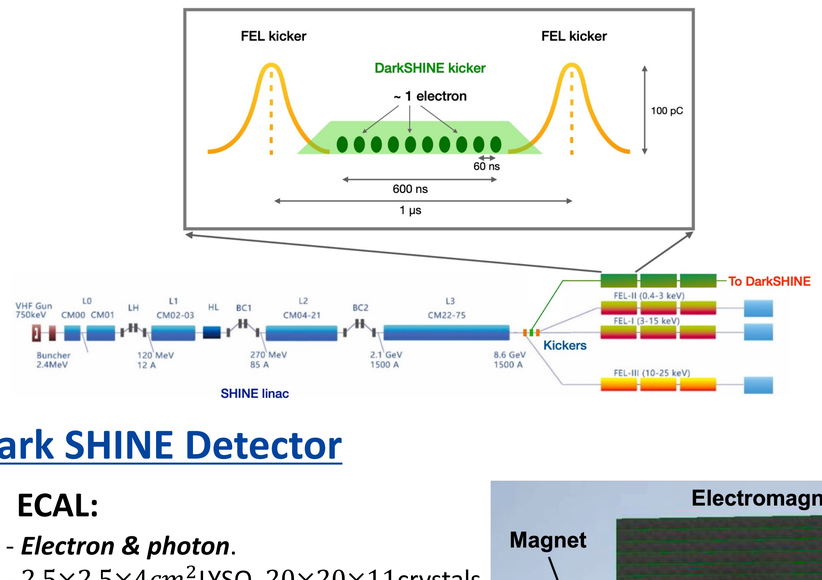
- DM can exist in wide mass range. Sub-GeV mass range is not fully explored yet. A' is one of the candidates in ***sub-GeV mass range***. DM particles may interact with other DM particles via a new force mediated by A'.



- Dark SHINE is a ***fixed-target experiment*** to search for A'.
  - ***Invisible decay***: $m_{A'} > 2m_\chi$, **missing energy / missing momentum.**
  - Search for A' in $[m_{A'}, \varepsilon]$ parameter space.

SHINE Facility

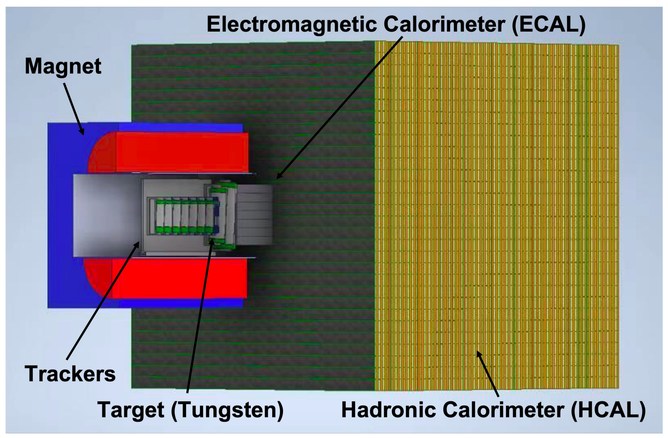
- Under construction in Zhangjiang area, Shanghai (2018-***2026***).
- $E_{beam} = 8GeV$ with frequency 1MHz, beam intensity: 6.25×10^8 electrons/bunch.
- A Dark SHINE kicker will be built to provide ***single electron beam***.



3×10^{14} electron-on-target(EOTs) per year!

Dark SHINE Detector

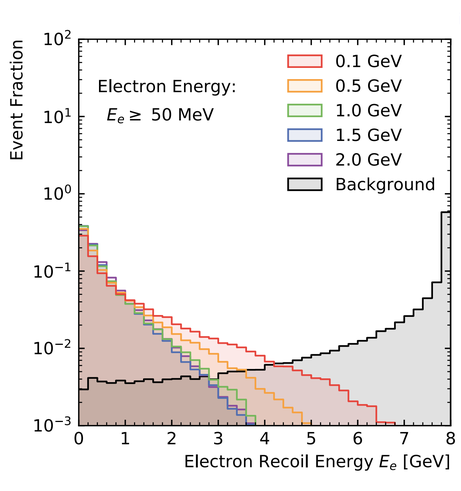
- **ECAL:**
  - ***Electron & photon***.
  - $2.5\times2.5\times4cm^2$LYSO, $20\times20\times11$crystals (X,Y=2.5cm, Z=4cm,radiation length: 1.14cm).
  - Designed energy resolution **~ 5%**.
  - ***LYSO crystal*** ($Lu_{(1-x-y)}Y_{2y}Ce_{2x}SiO_5$):
- **HCAL:**
  - ***Veto muon & hadronic*** background
  - Scintillator w/ steel absorber
  - $4\times4\times1$ modules
- **Tracking System**
  - Tagging tracker (7 layers) + recoil tracker (6 layers)
  - ***Incident and recoil electron tracks***
  - Two silicon strip sensors w/ a small angle (0.1rad)
  - Resolution: $\boldsymbol{6\mu m}$(horizontal), $\boldsymbol{60\mu m}$(vertical)

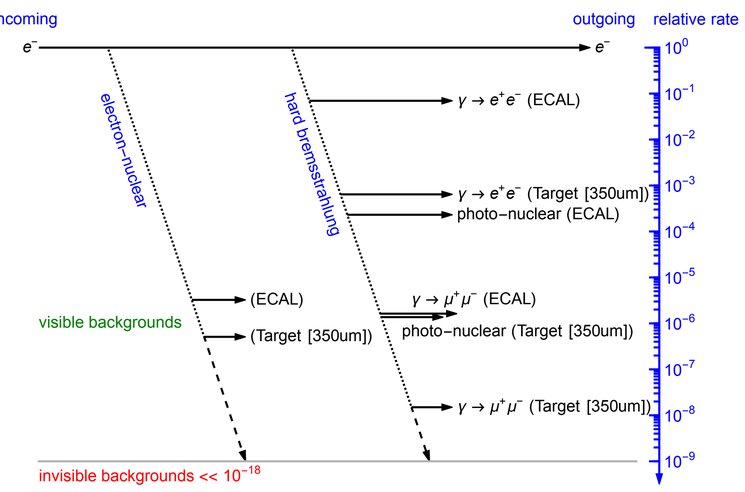


- **Additional system**
  - Readout electronics, trigger system, TDAQ, magnetic system (1.5T)

Signal Signature

- Most of the incident momentum is transferred to A'.

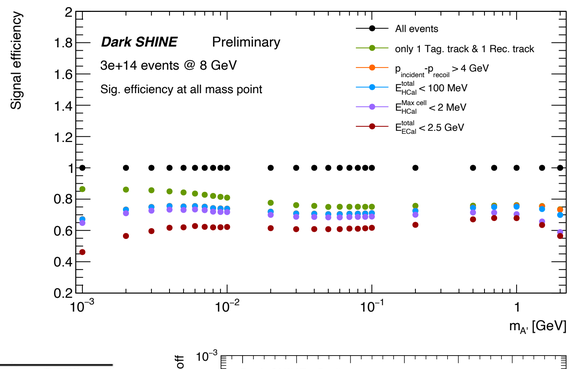




- Leading background → photon bremsstrahlung. Rare processes (photon-nuclear, $\gamma \to \mu\mu$, electron-nuclear) also have some contribution.

Signal Efficiency

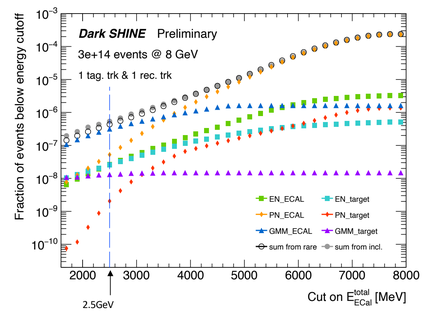
- Signal samples: 25 mass points are produced (1×10^5 events in each sample).
- Around ***60%*** signal events survive the cut-flow.

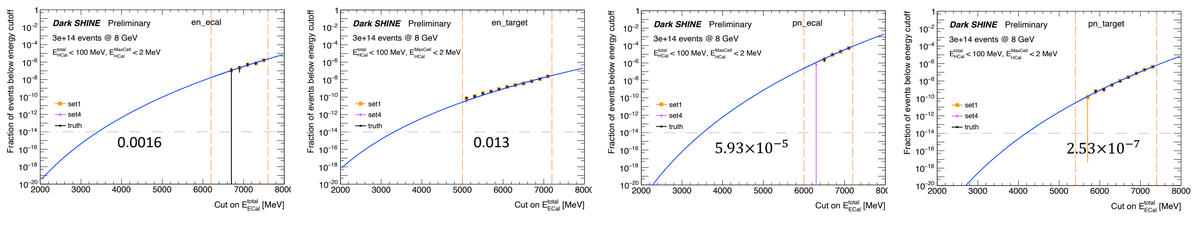


Background Estimation

- No background events left after signal region selection.
- Lack of statistics →extrapolate from fit results.

Process	EOTs
Inclusive	2.5×10^9
Bremsstrahlung	1.5×10^8
GMM_target	4.3×10^{14}
GMM_ECAL	6.0×10^{12}
PN_target	4.0×10^{12}
PN_ECAL	4.4×10^{11}
EN_target	1.6×10^{12}
EN_ECAL	1.8×10^{12}





Method	Cut flow	Rare. extra.	Incl.- extra.	Incl. vali.
Yield	0	1.5×10^{-2}	2.53×10^{-3}	9.23×10^{-3}

⇨

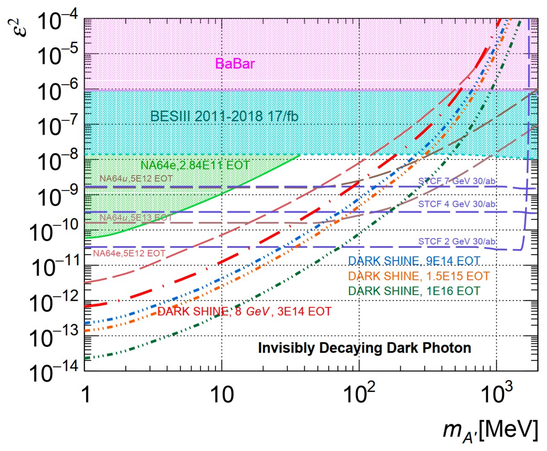
Extrapolate from rare processes simulation.

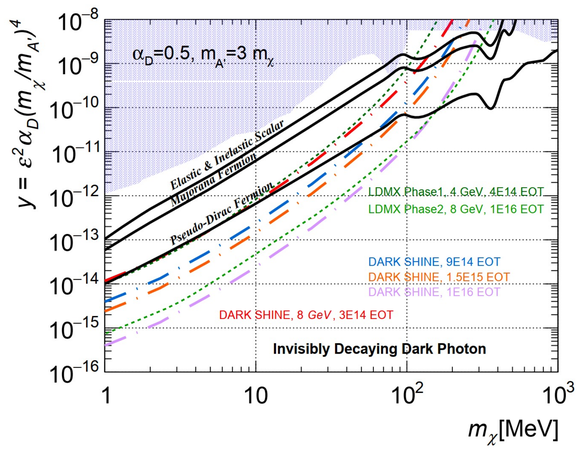
Extrapolate from inclusive background simulation.

Validate Incl.-extra: Scale low E_{beam} events to match the shoulder with $E_{beam} = 8$ GeV events.

Sensitivity Study

- 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).





- Comparing with other experiments, Dark SHINE can provide competitive sensitivity.

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