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LDM search @ SHiP with nuclear emulsion

(on behalf of Giovanni, Mitesh and Walter)

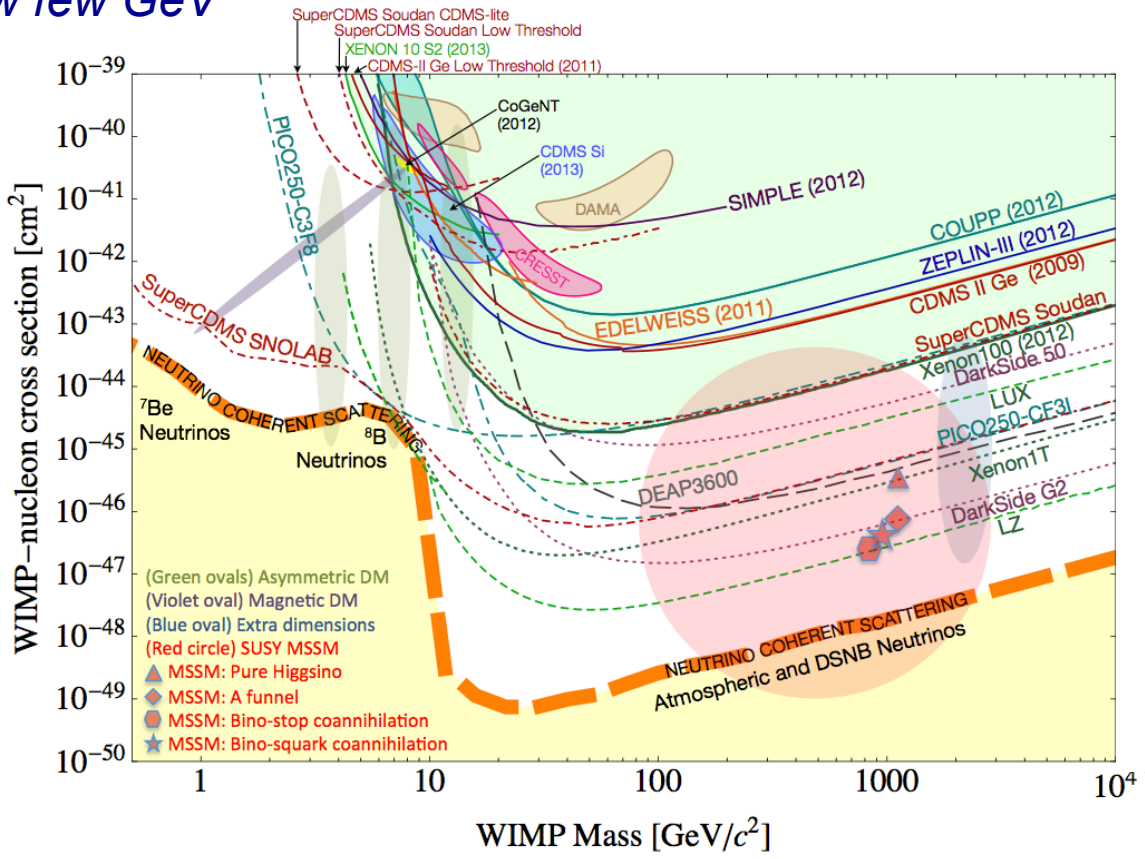
Light Dark Matter (LDM)

The prediction for the mass scale of DM spans from 10^{-22} eV to 10^{20} GeV

- ✓ *WIMP DM is a popular theoretical paradigm ("WIMP miracle")*
- ✓ *Extensive exp. search for WIMPs with masses 10 GeV – 1 TeV*
  Sensitivity is very limited below few GeV

Large classes of theor. models can make the observed relic density with sub-GeV DM:

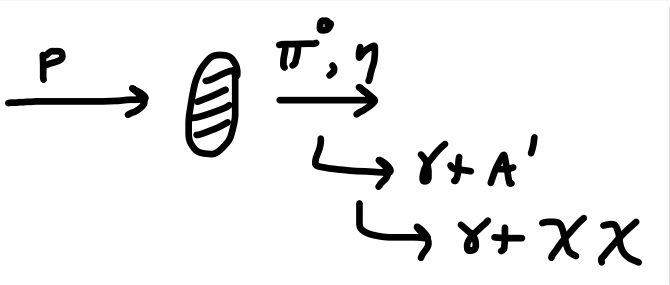
- *Hidden-sector models*
- *Supersymmetry*
- *Strongly Interacting DM (SIMP)*
- *Extra dimensions*



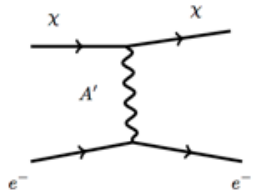
Essential to explore the sub-GeV mass range for DM

LDM search @ SHiP

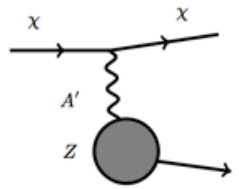
- ✓ ***LDM (χ) can be generated in a beam-dump,*** *for example in* ***decays of HS mediators****, e.g. dark photons A' → $\chi\chi$*
- ✓ *>10^{20} photons expected in SHiP for 2×10^{20} p.o.t. can be used as* ***a LDM beam***
- ✓ ***For $M_{A'} > 2M_{\chi}$***



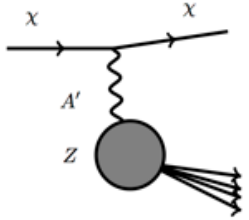
- ✓ ***Detect LDM via its scattering on atomic electrons of the neutrino target.*** *Use emulsion as a sampling calorimeter to identify electron and measure its energy and its direction*



Electron scattering

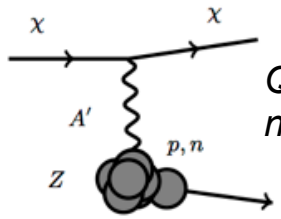


Coherent nuclear



Inelastic hadro-production

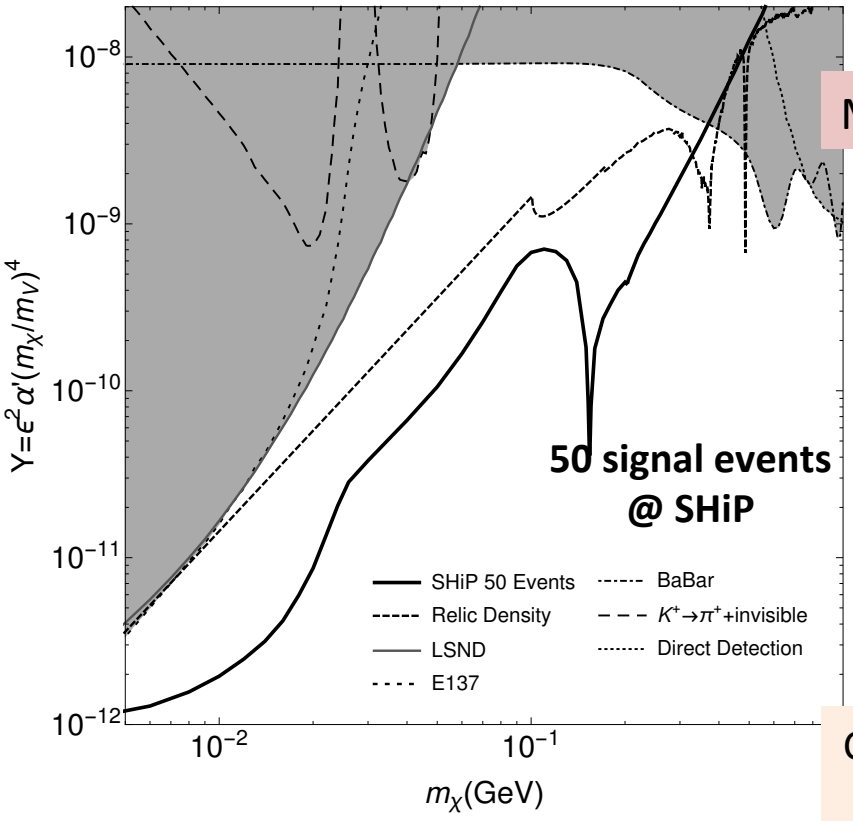
$\pi, \Delta, K \cdots$



Quasi-elastic nucleon

LDM prospects @ SHiP

*With 50 signal events SHiP would be able to probe even beyond relic density in minimal hidden-photon model provided that the **background from neutrino interactions is kept under control***



$M_{A'}/M_\chi=5$

Courtesy of Patrick deNiverville

50 signal events of the LDM scattering correspond to 2.5t of lead (cylinder with 0.52m radius and 2.1m length) and 2×10^{20} pot. Selection efficiency is assumed to be 50%.

Backgrounds

Dominant background comes from neutrino interactions !

Neutrino interactions can generate electrons in a number of ways:

	ν_e	$\bar{\nu}_e$	ν_μ	$\bar{\nu}_\mu$	all
Quasi-elastic scattering	105	73			178
Elastic scattering on e^-	16	2	20	18	56
Resonant scattering	13	27			40
Deep inelastic scattering	3	7			10
Total	137	109	20	18	284

Note: Background has been estimated for the 10t of lead

The uncertainties in neutrino flux and cross-sections are ~15-25%

Dominated by inelastic neutrino scattering (~250 events) that is accompanied by additional particles (in contrast to LDM scattering)

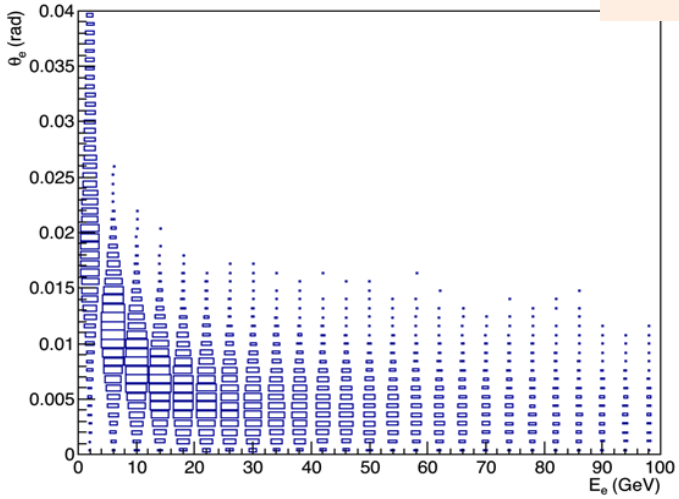
Present design of the emulsion brick has 1 mm thick absorber plates
Tracks with P<100 MeV can not be reconstructed

→ *Reduce the thickness of the absorber plates (down to 0.5 mm ?)*
→ *Veto on the activity in emulsion rather than on the reconstructed tracks to further reduce contribution from inelastic neutrino interactions*

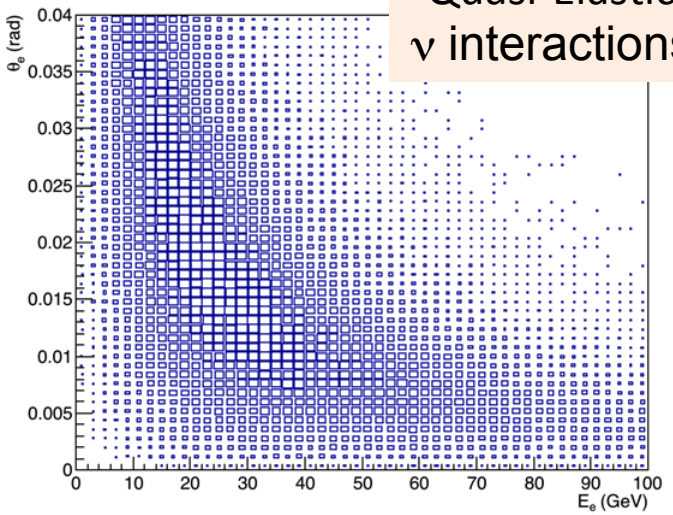
Backgrounds (cont.)

→ *Use energy-angular correlation to discriminate LDM scattering against inelastic neutrino interactions (requires MVA selection)*

LDM



Quasi-Elastic
ν interactions



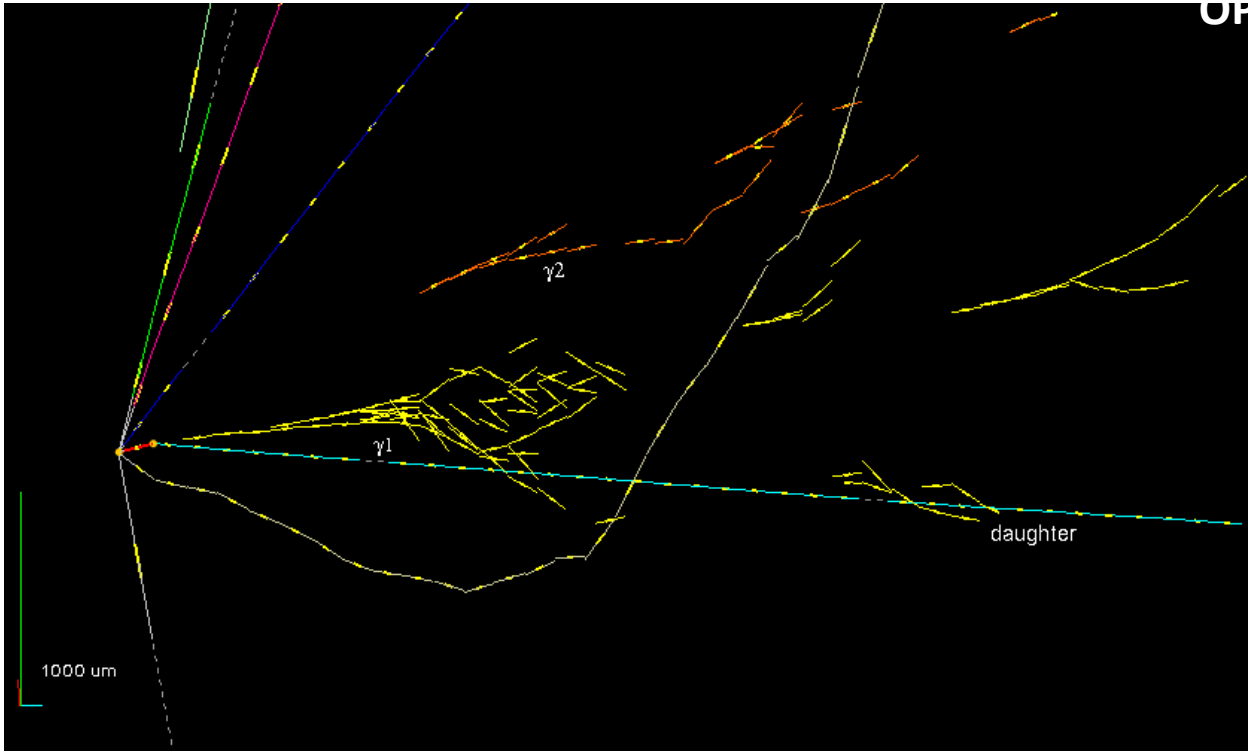
→ *Use different Pt of neutrinos produced in hadron decays and LDM from dark photons. Optimize the shape of emulsion detector for LDM search*

- ✓ *Preliminary estimation indicates that the background from quasi-elastic neutrino interactions can be reduced by an order of magnitude*
- ✓ *Background from elastic neutrino scattering can be reduced by a factor 2-3 depending on the LDM mass*

- ✓ ***50 signal events correspond to >5σ observation if the total background is at the level of ≤ 50 events***

Emulsion as a sampling calorimeter

The feasibility has been demonstrated by the OPERA experiment
Two photon showers are clearly seen:

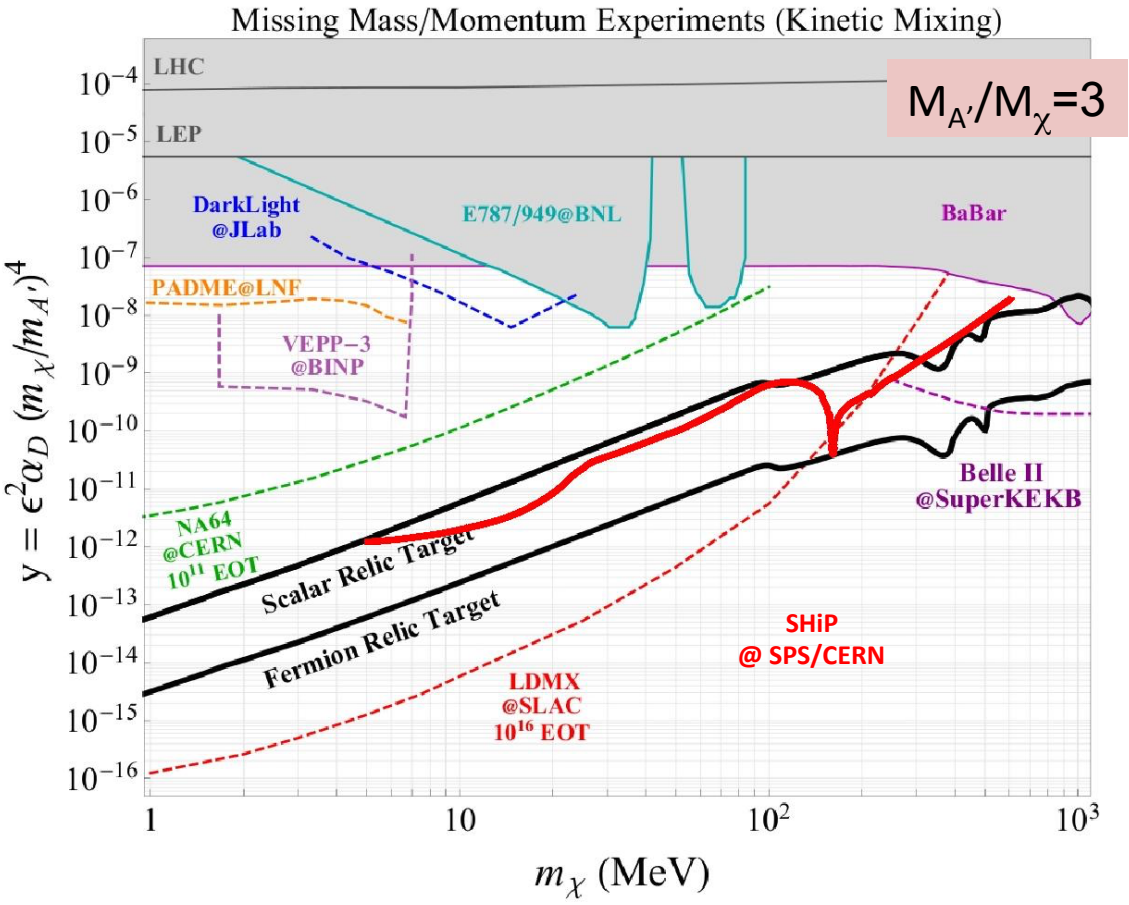


Optimize SHiP emulsion spectrometer to reconstruct electron showers

- *Energy (angular) resolution of ~5% (1mrad) seems to be achievable with 0.5 mm thick absorber plates*
- *Usage of W as an absorber will narrow the em-showers*

Comparison with future facilities

Direct Detection exp.
- **SHiP has unique potential for M_χ <1GeV**
- BDX in JLab may have a competitive sensitivity for M_χ <10 MeV with 10^{22}eot.



Missing mass / momentum experiments
- Belle II – comparable to SHiP for M_χ>0.5 GeV with 50 ab^{-1} provided that low energy mono-photon is implemented
- LDMX (under discussion at SLAC) has the best prospects for M_χ< 100 MeV with 3×10^{21} eot. Time scale is unclear.

Dark sectors 2016: 1608.08632

Conclusion

- ✓ *LDM searches have strong potential at SHiP – will further widen our physics programme*
- ✓ *Programme requires dedicated simulation and prototyping effort to establish extent to which background can be controlled, optimise detector design and develop reconstruction techniques*
- ✓ *Seeking new postdoctoral effort to collaborate on these topics*