Long-Lived Light Mediators from Higgs Boson Decay

@ HL-LHC & FCC-hh

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MOTIVATION

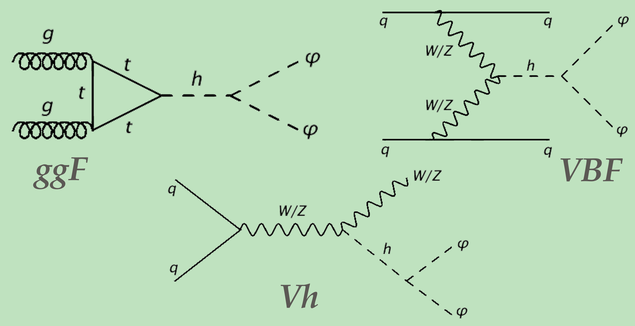
1 Light scalar mediators?

Dark matter model solving small scale crisis in structure formation of the Universe

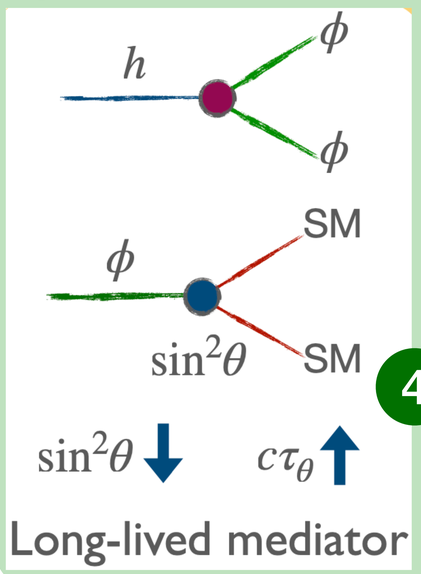
2 Higgs portal?

Theoretical - leading renormalisable portal connecting SM with new physics

Experimental - scope to add new physics couplings, and <u>presence of various production modes</u>



3 Long-lived?

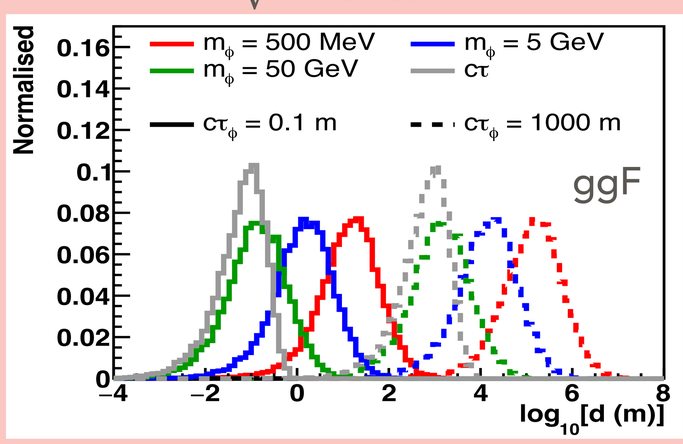


Additional selection cuts using prompt objects associated with production

4 Displaced activity in Muon spectrometer?

1. Lesser pile-up
2. Large decay volume
3. Sensitive to a number of final states

$\sqrt{s} = 14\,\text{TeV}$



Distribution of decay length in the lab frame, $d = \beta\gamma c\tau$

HL-LHC
14 TeV
3 ab^{-1}

Decay modes:

$\mu^+\mu^-, \pi^+\pi^-, K^+K^-, gg, s\bar{s}, c\bar{c}, \tau^+\tau^-, b\bar{b}$

Implemented magnetic field till muon spectrometer in Delphes for correct $\Delta\phi$ – important in boosted and displaced cases

1 CMS Muon Spectrometer (MS)

Presented limits with 100% branching to each decay mode & combined as per branching of minimal model

$\mu^+\mu^-$

"Displaced muons"

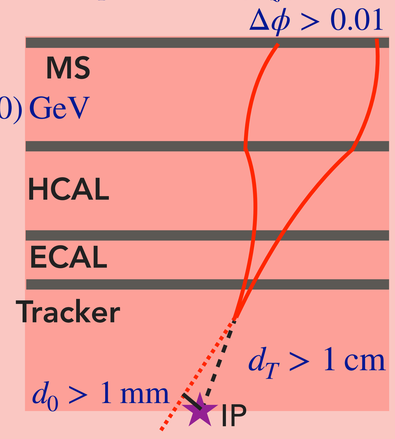
Decay volume:

$d_T < 6\,\text{m}$ & $|d_z| < 9\,\text{m}$

$|\eta| < 2.8$

$p_T > 10\,(20)\,\text{GeV}$

$\Delta\phi > 0.01$ Ref. 2



$\text{Br}(h \to \phi\phi) < 3 \times 10^{-6}$
for $m_\phi = 60\,\text{GeV}$, $c\tau = 0.5\,\text{m}$

$b\bar{b}$

"MS cluster"

Decay volume:

$d_T > 4\,\text{m}$ or $|d_z| > 7\,\text{m}$ &
$d_T < 6\,\text{m}$ & $|d_z| < 9\,\text{m}$

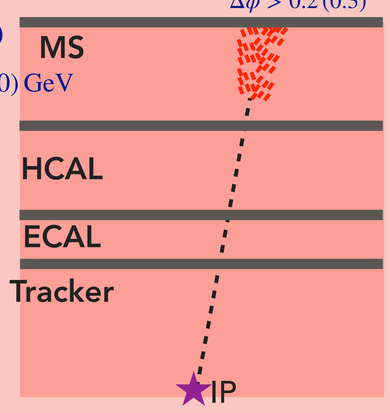
Ref. 3

$n^{ch}_{dSV} > 3\,(5)$

$\sum p_T > 20\,(50)\,\text{GeV}$

$\Delta\phi > 0.2\,(0.3)$

Hadrons, e, γ: shower in iron yokes of MS



$\text{Br}(h \to \phi\phi) < 1.7 \times 10^{-5}$
for $m_\phi = 60\,\text{GeV}$, $c\tau = 5\,\text{m}$

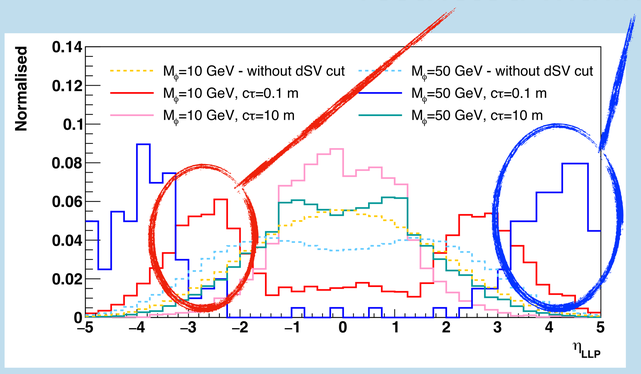
HL-LHC
↓
FCC-hh :
$\sigma \times L$
improve by $\times 150$

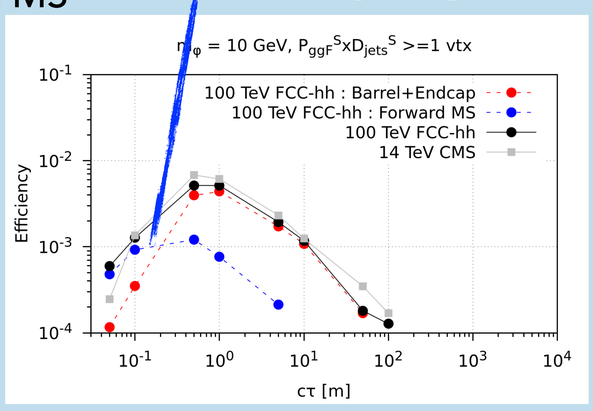
FCC-hh 100 TeV 30 ab^{-1}

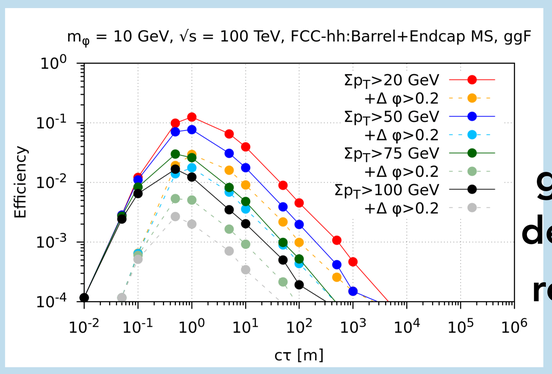
1 FCC-hh Muon Spectrometer

LLPs more in forward direction for lower $c\tau$ when decay is restricted within MS

Forward MS increases sensitivity to lower decay lengths





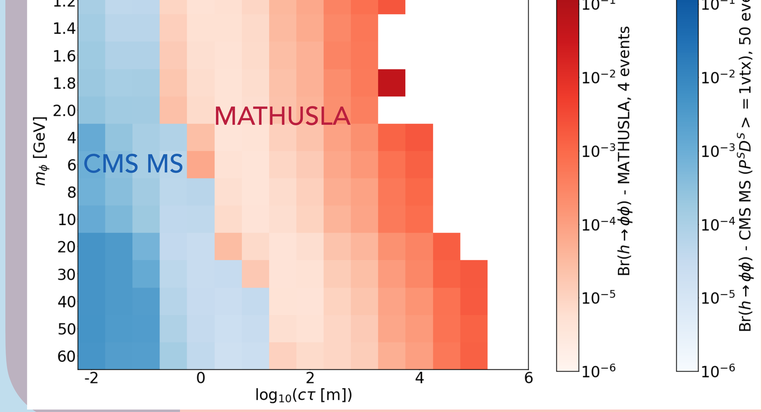


100 TeV - increase energy threshold

High granular detector - relax $\Delta\phi$ cut

	$\sum p_T > 20\,\text{GeV}$	50 GeV	100 GeV
$\Delta\phi > 0.2$	$\times 75$	$\times 34.5$	$\times 4.5$
$\Delta\phi > 0.0$	$\times 250$	$\times 150$	$\times 24$

improvement factors w.r.t. HL-LHC



2 MATHUSLA vs CMS Muon Spectrometer

CMS MS + MATHUSLA : probe $c\tau \lesssim 10^5\,\text{m}$ for $m_\phi = 60\,\text{GeV}$, without any gap if $\text{Br}(h \to \phi\phi) \gtrsim 0.1\,\%$

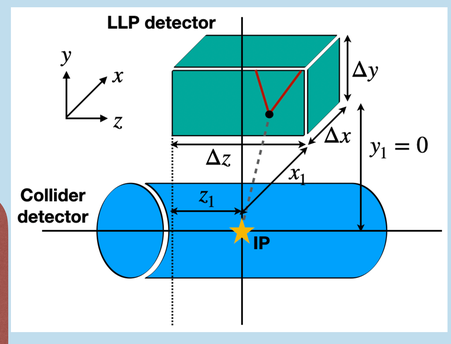
2 New proposal of dedicated LLP detectors for FCC-hh

DELIGHT

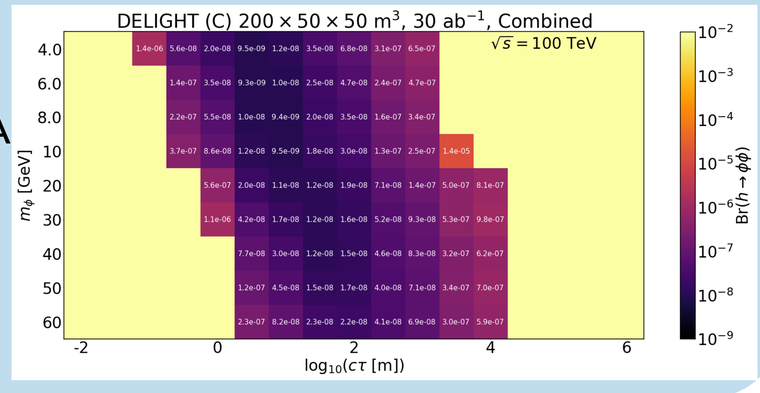
***De**tector for **l**ong-**li**ved particles at **h**igh energy of 100 **T**eV*

DELIGHT (C)

– same decay volume as MATHUSLA
– closer to IP
– long tunnel-like detector
– better shielding against cosmic rays



Improvement by $\times 430$ compared to MATHUSLA



HIGHLIGHTS

1. First detailed study of long-lived mediators from Higgs boson decay combining multiple production and decay modes in the CMS MS
2. First study on sensitivity of FCC-hh for long-lived particles
3. New proposal and study of prospects of DELIGHT detector near the FCC-hh

REFERENCES

1. B. Bhattacherjee, S. Matsumoto and R. Sengupta, <u>arXiv:2111.02437 [hep-ph]</u>
2. ATLAS, <u>ATL-PHYS-PUB-2019-002</u>
3. CMS, <u>arXiv:2107.04838 [hep-ex]</u>

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