Workshop on Long Lived Particles --200 MCHF??--

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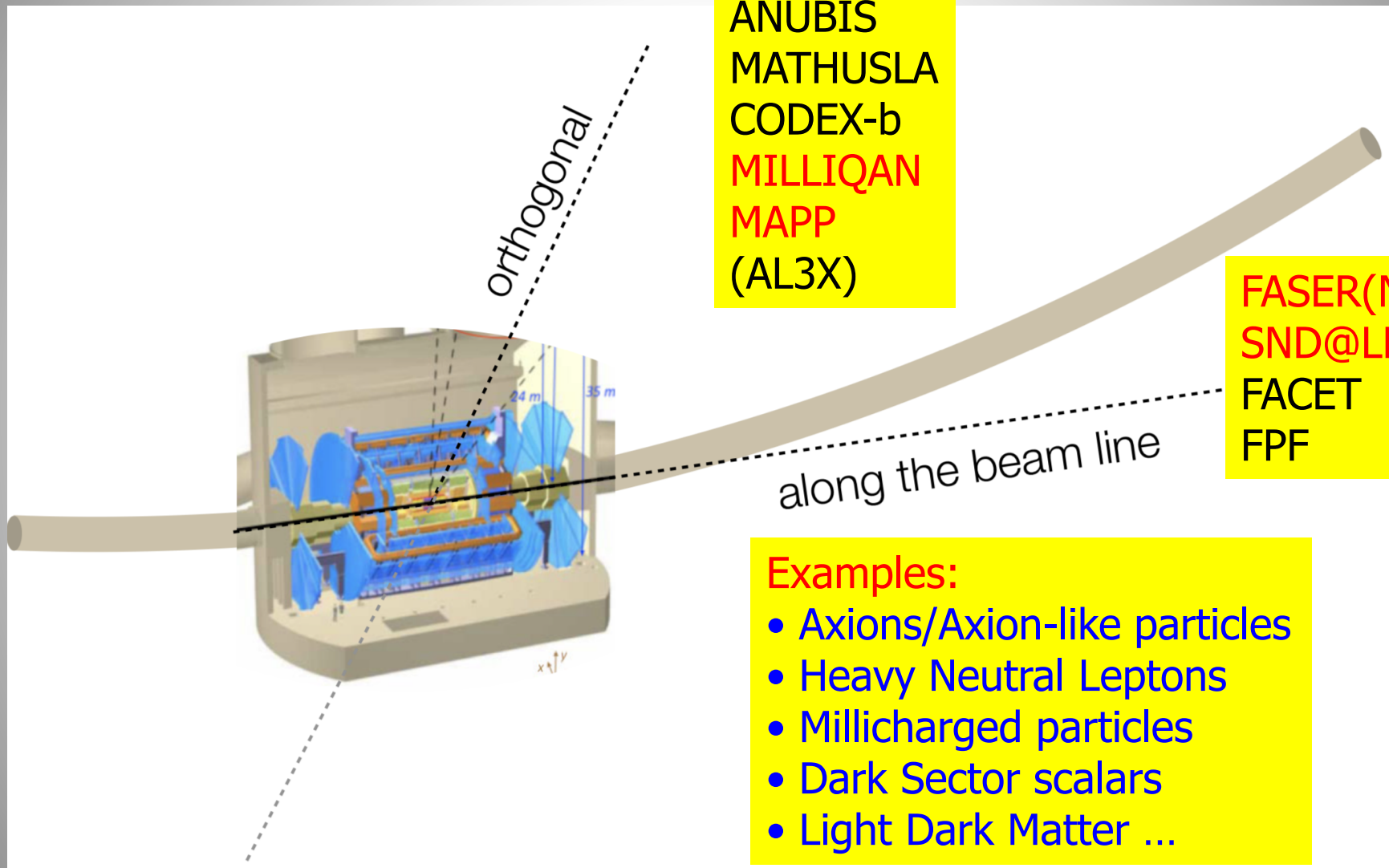
Discussion

- Why 200 MCHF? What defines the number
- We have the LHC and its detectors/cavern..
  - Additional detectors is a compromise/optimization... some measurements not easily possible in central detector..
  - Extra caverns? FPF, other?
  - Upgrade existing detectors -> upgrades for HL-LHC ongoing for run4, eg timing added, muon area
  - More upgrades to study/explore?
- Beyond LHC:
  - “Active” caverns: eg HECTATE
  - Extra Caverns: DELIGHT nearby MATHUSLA
- Non- LHC experiments? Eg DAMSA, SHIP, Shadows…; opportunities at Neutrino experiments/beam dump
- Experiments in outer space, on the moon? (Jupiter…)
- Using cosmic rays? (Eg monopoles and HNLs in Icecube)

New Directions/Detectors



ANUBIS
MATHUSLA
CODEX-b
MILLIQAN
MAPP
(AL3X)

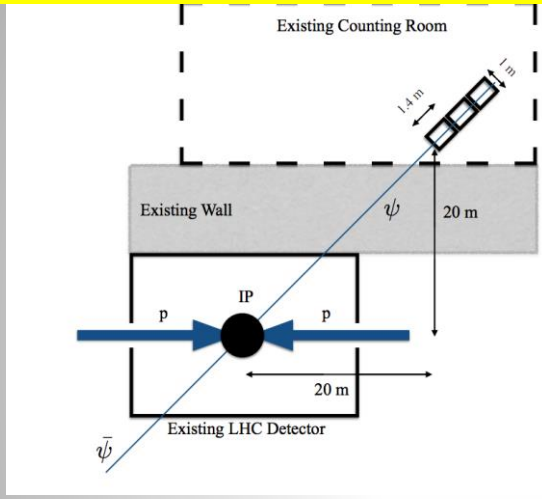
FASER(Nu)
SND@LHC
FACET
FPF

Examples:
- Axions/Axion-like particles
- Heavy Neutral Leptons
- Millicharged particles
- Dark Sector scalars
- Light Dark Matter …

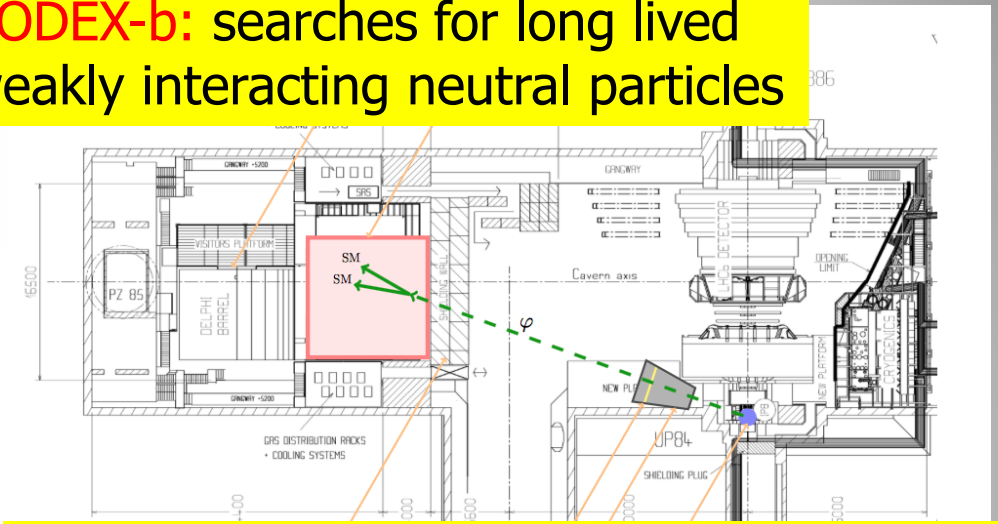
"Transverse Experiments" have minimal to no impact on the LHC machine

New Transverse Experiment Proposals

MilliQan: searches for millicharged particles
MAPP: MoEDAL upgrade

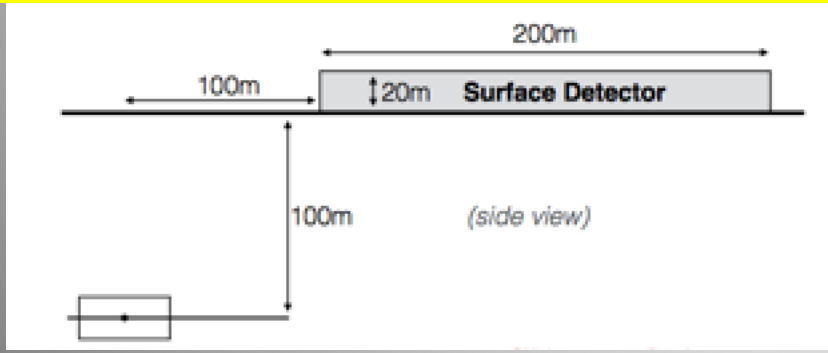


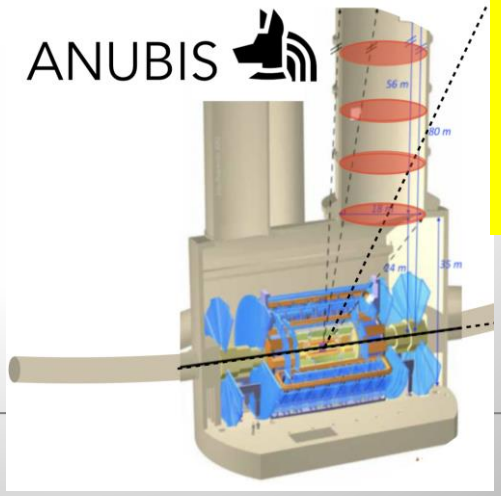
CODEX-b: searches for long lived weakly interacting neutral particles



Also: AL3X ('ALICE' for LLP arXiv.1810.03636).

MATHUSLA: searches for long lived weakly interacting neutral particles



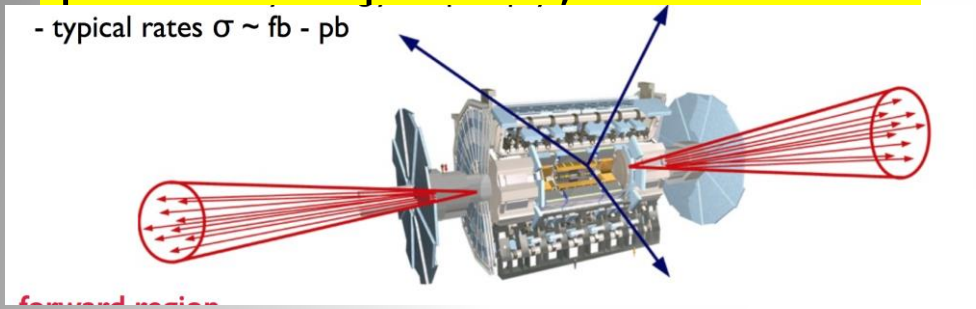


ANUBIS: searches for long lived weakly interacting neutral particles

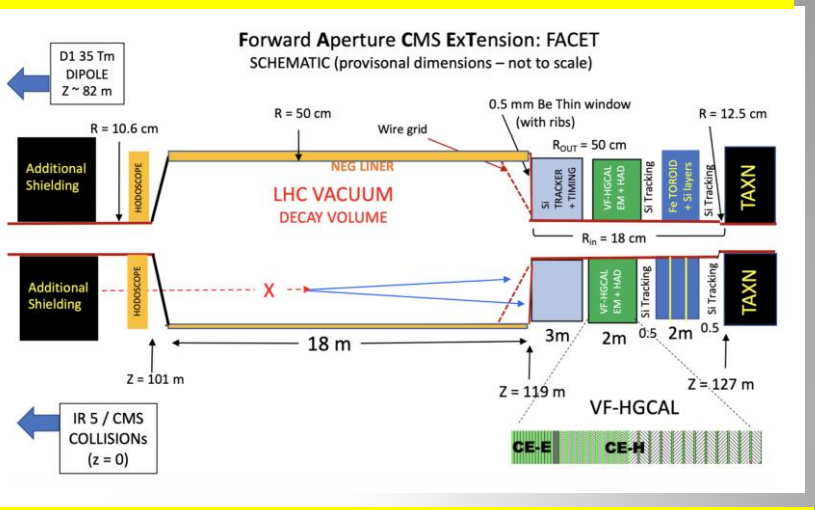
+Recently (2021): a new detector for CMS cavern..

New Forward Detector Proposals

FASER: searches for long lived dark photons-like particles, neutrinos



FACET: Instrumented Beampipe for CMS



SND@LHC: neutrino measurements and long lived particle searches

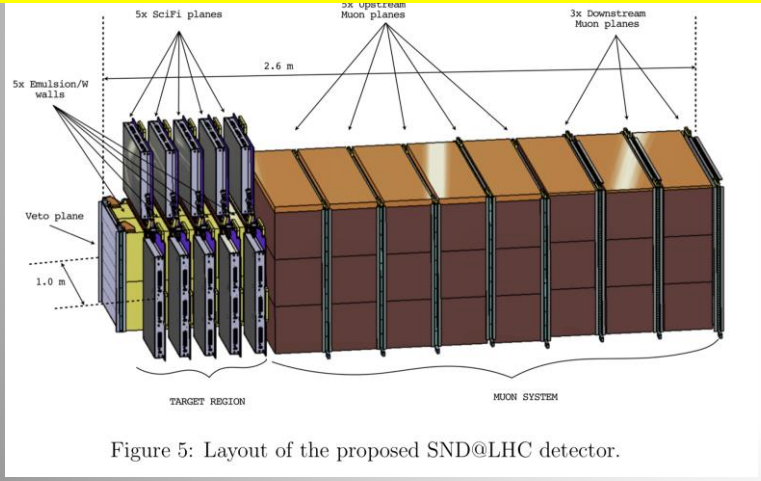
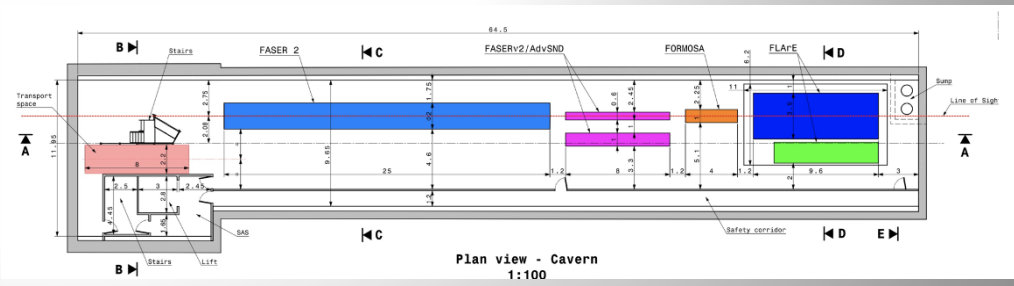


Figure 5: Layout of the proposed SND@LHC detector.

FPS: A Facility for Forward Physics Containing several experiments



FASER and SND@LHC have been approved in 2019/2020 and will be ready to take data during Run 3 starting next month

Transverse Detectors

Comparison of detector design — Neutral LLPs @ LHC

	Collision point	Distance from IP	Fiducial volume	Use main experiment?	Shielding cosmics	Shielding collision	Technology
MATHUSLA	CMS	~90 m	25m x 100m x 100m	Under study	NO	YES	Scintillators (+ 1 RPC)
ANUBIS	ATLAS	~25 m	~56m x $(9m)^2$	YES	Partial	NO	RPC (scintillators to be explored)
CODEX-b	LHCb	~35 m	10m x 10m x 10m	Under study	YES	YES	RPC
AL3X	ALICE	~4.25 m	~12m x $(2.5m)^2$	NO	YES	YES	Gas TPC

- For a given decay volume,
  - More solid angle if closer to the IP
  - Number of decays higher if closer to the IP
  - LHC collision backgrounds more important if closer to the IP (depending on shielding)

DELIGHT: idea for a LLP detector at FCC-hh

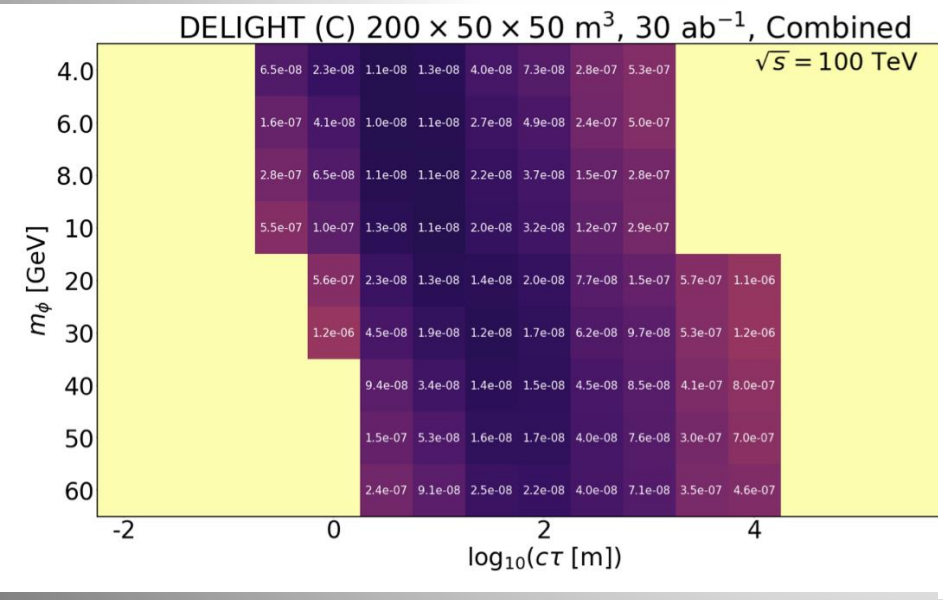
Long-Lived Light Mediators from Higgs boson decay studied for multiple decay modes of the scalars

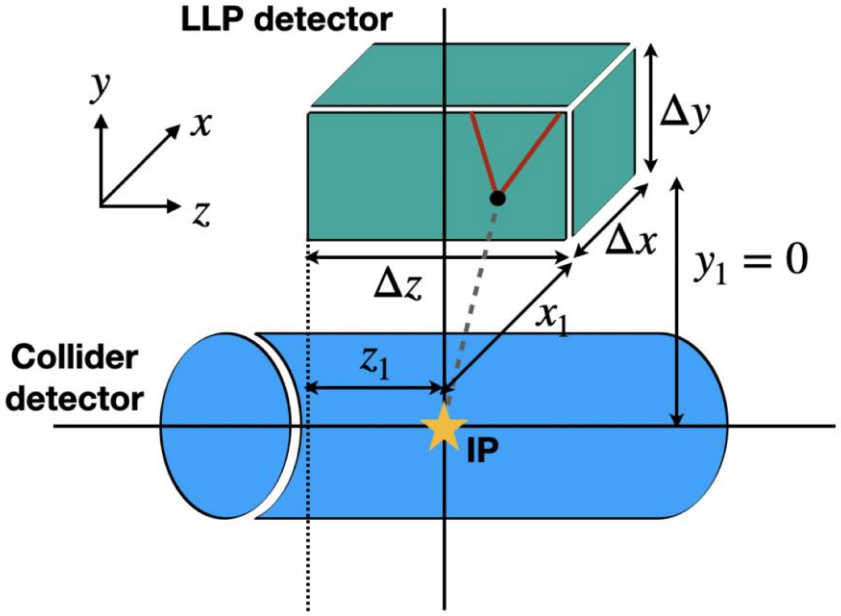
2111.02437

DELIGHT
Detector for long-lived particles at high energy of 100 TeV

DELIGHT (C): The same decay volume as the MATHUSLA detector with different dimensions, i.e. $\Delta x \times \Delta y \times \Delta z = 200 \times 50 \times 50\,\mathrm{m}^3$.

$x_1 = 25$ m
$y_1 = 0$ m
$z_1 = -\Delta z/2$





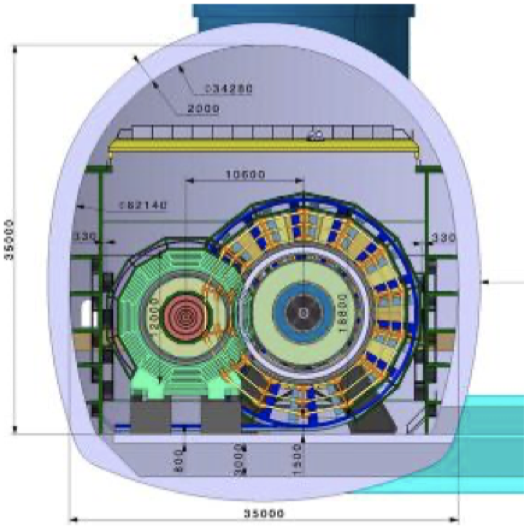
LLP @ Next Collider Projects

LLPs @ FCC-hh, FCC-ee

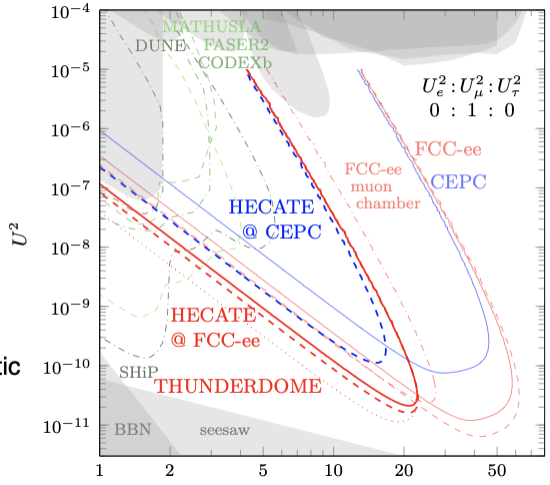
Proposal: 2011.01005

HECATE: HErmetic CAvern TrackER. A long-lived particle detector concept for FCC-ee or CEPC

- For FCC-hh / FCC-ee, main detector will be relatively smaller than the cavern
- Cover detector cavern walls with scintillator plates or RPCs
  - >= 2 layers of 1 m^2 separated by a sizeable distance — timing
  - >= 4 layers for good tracking
  - 4π coverage LLP detector
- FCC main detector as active veto
- Sensitive to a unique area of phase space



- Cavern size: r~15 m and z~50 m
- Main detector size =(10m)



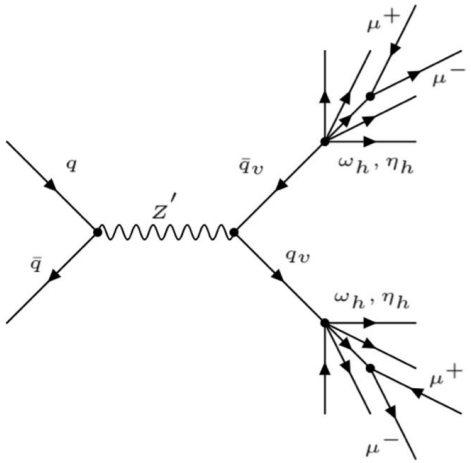
- Example: HNLs
- THUNDERDOME: Totally Hyper-UNrealistic DEtectoR in a huge DOME (maximum distance from IP=100m for comparison)

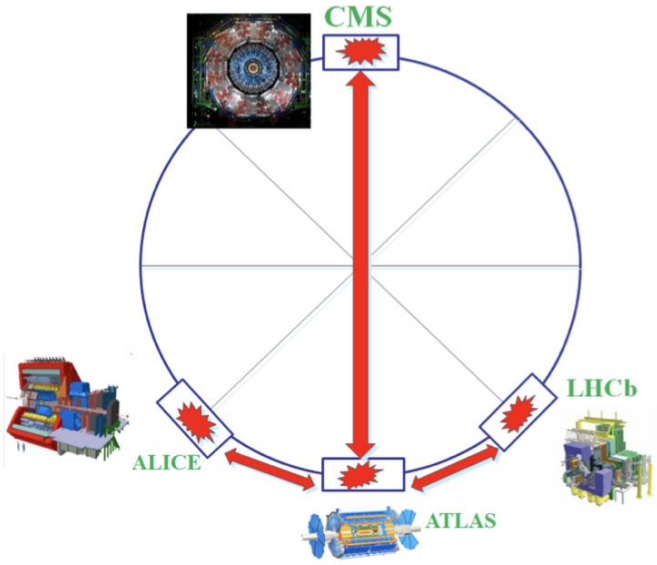
Important: take LLP requirements into account from the start (Snowmass2021)

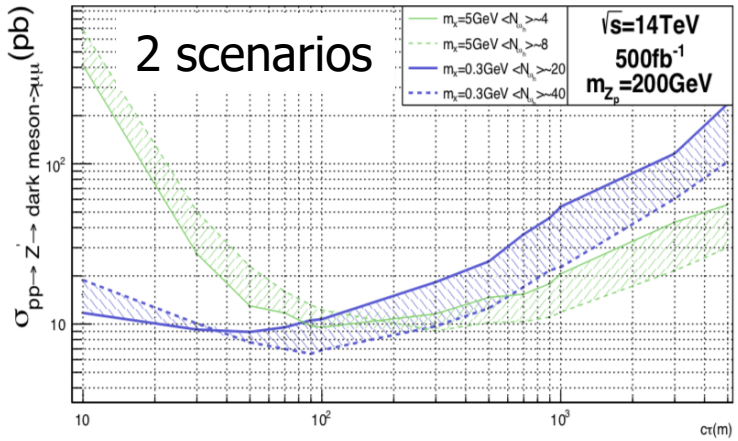
A Crazy Idea?

- LLPs can escape the detector at the collision point and accidentally decay in the vicinity of detectors far away. Spooky?
- Estimates using ATLAS and ALICE for (favourable) Hidden Valley scenario, detecting the muons..

2004.08820

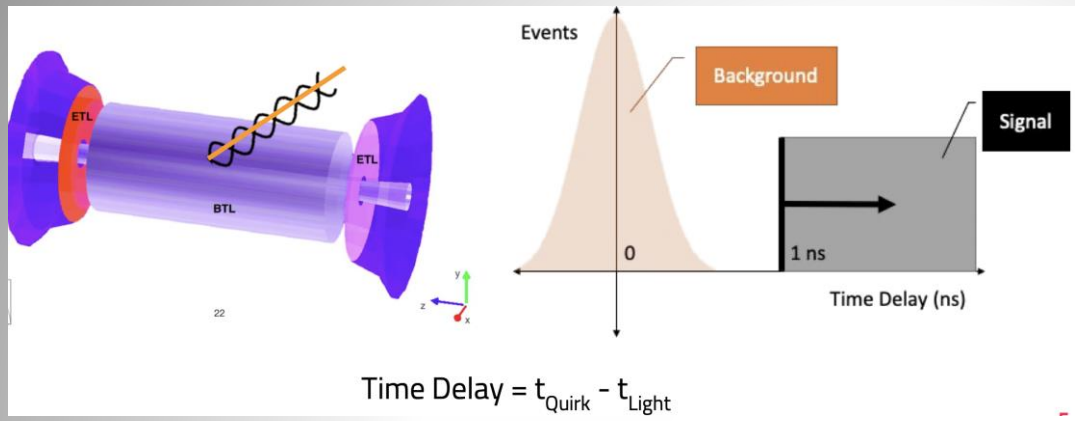


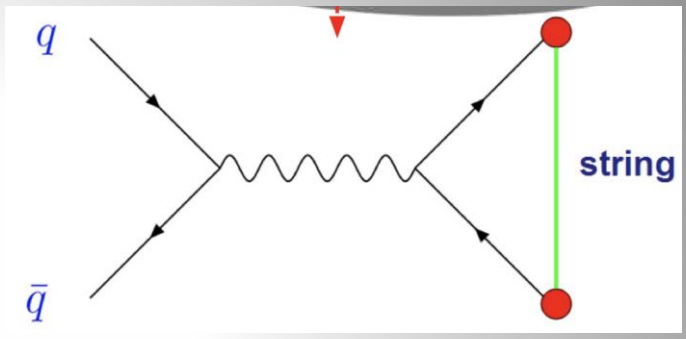




Careful: some flaws in the numbers in this paper

Quirk Study in CMS





Time Delay = t_{Quirk} - t_{Light}

Nathan Suri
Work in progress…