NEW SIGNALS AT FASER AND FASER2

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SIMONS FOUNDATION

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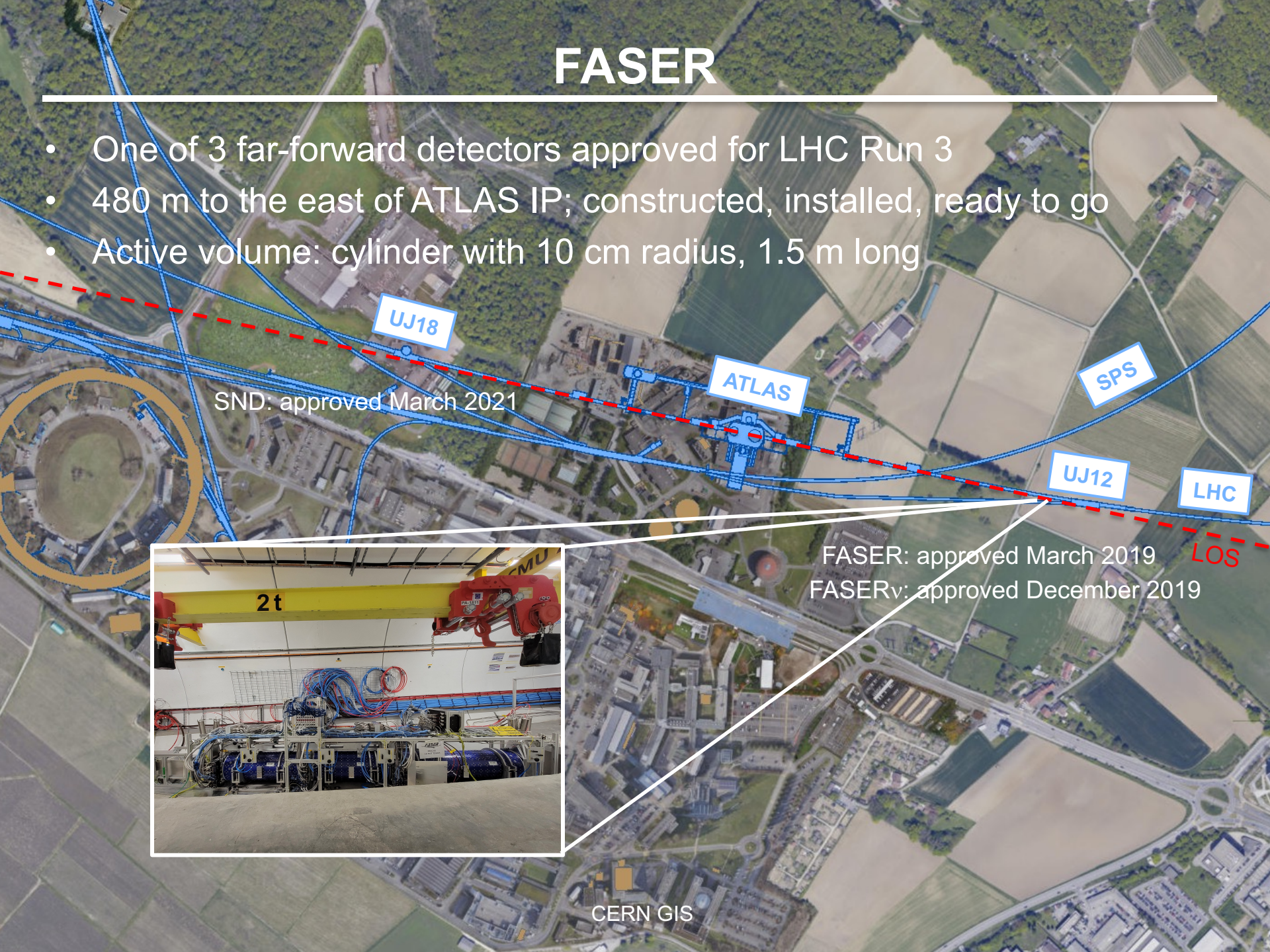
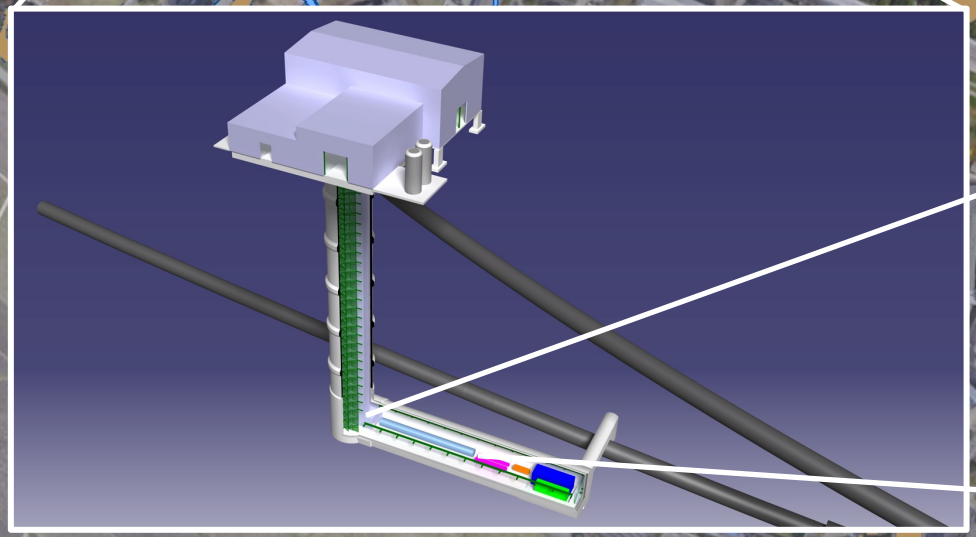
FASER

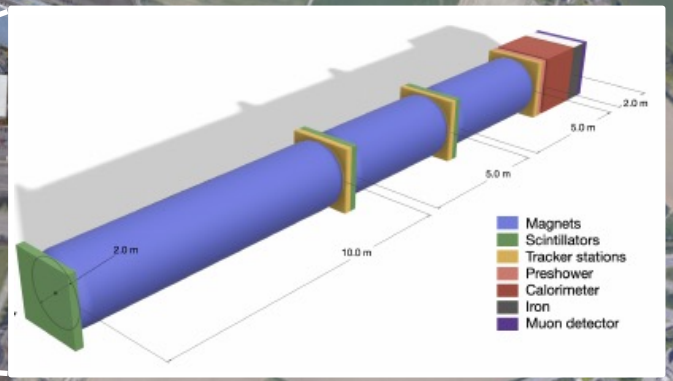
- One of 3 far-forward detectors approved for LHC Run 3
- 480 m to the east of ATLAS IP; constructed, installed, ready to go
- Active volume: cylinder with 10 cm radius, 1.5 m long



FASER2

- One of ~5 far-forward detectors proposed for the HL-LHC
- 640 m to the west of the ATLAS IP in the Forward Physics Facility
- Active Volume: cylinder with 1 m radius, 20 m long





CERN GIS

BSM SIGNALS

- FASER and FASER2 have discovery prospects for many PBC Benchmarks. For FASER, the dominant signatures considered have been $A' \to e^+e^-$, and $a \to \gamma\gamma$.

Benchmark Model	Underway	FPF	References
BC1: Dark Photon	FASER	FASER 2	Feng, Galon, Kling, Trojanowski, 1708.09389
BC1': $U(1)_{B-L}$ Gauge Boson	FASER	FASER 2	Bauer, Foldenauer, Jaeckel, 1803.05466 FASER Collaboration, 1811.12522
BC2: Dark Matter	–	FLArE	Batell, Feng, Trojanowski, 2101.10338 Batell et al., 2107.00666
BC3: Milli-Charged Particle	–	FORMOSA	Foroughi-Bari, Kling, Tsai, 2010.07941
BC4: Dark Higgs Boson	–	FASER 2	Feng, Galon, Kling, Trojanowski, 1710.09387 Batell, Freitas, Ismail, McKeen, 1712.10022
BC5: Dark Higgs with hSS	–	FASER 2	Feng, Galon, Kling, Trojanowski, 1710.09387
BC6: HNL with e	–	FASER 2	Kling, Trojanowski, 1801.08947 Helo, Hirsch, Wang, 1803.02212
BC7: HNL with μ	–	FASER 2	Kling, Trojanowski, 1801.08947 Helo, Hirsch, Wang, 1803.02212
BC8: HNL with τ	–	FASER 2	Kling, Trojanowski, 1801.08947 Helo, Hirsch, Wang, 1803.02212
BC9: ALP with photon	FASER	FASER 2	Feng, Galon, Kling, Trojanowski, 1806.02348
BC10: ALP with fermion	–	FASER 2	FASER Collaboration, 1811.12522
BC11: ALP with gluon	FASER	FASER 2	FASER Collaboration, 1811.12522

NEW SIGNALS: QUIRKS

Kang, Luty (2008)

- Quirks are matter particles charged under a hidden strong force with mass m >> Λ_{hidden}. E.g., m ~ 100 GeV – TeV, Λ_{hidden} ~ keV.

- Quirks may also have SM charge and color. They are then pair produced at the LHC, and are connected by a hidden color string.

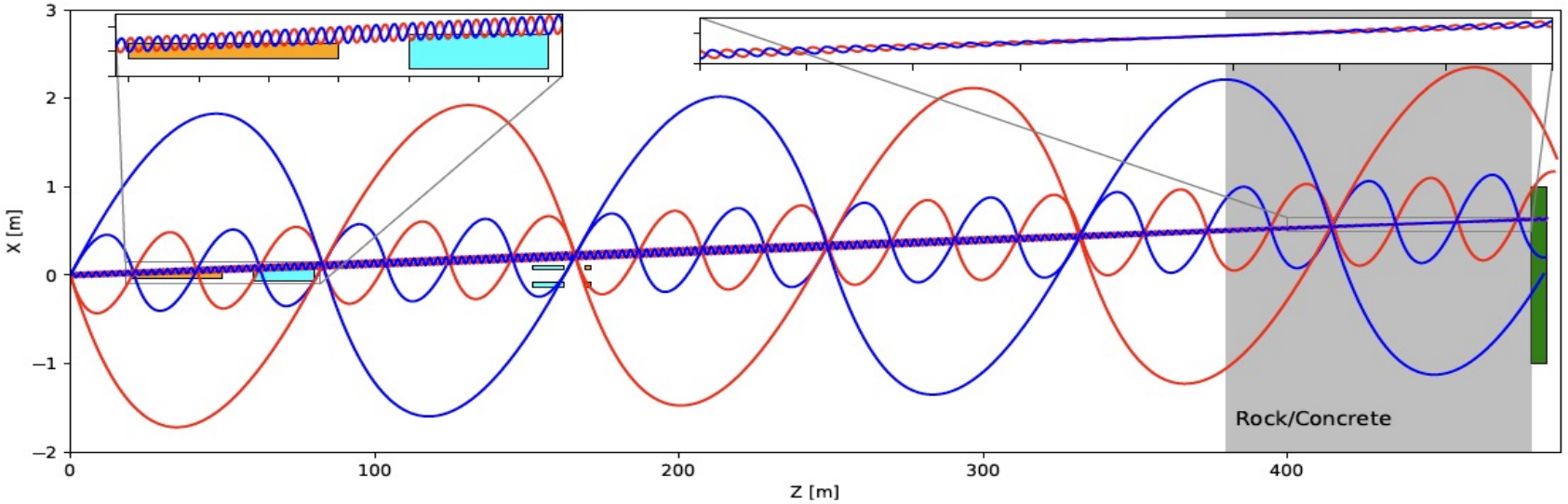
- For quarks and standard QCD, m << Λ_{QCD}, and so it becomes energetically favorable to pair produce new quarks from the vacuum. Quarks hadronized.

- But for quirks, since m >> Λ_{hidden} , it is never energetically favorable to break the string by pair producing quirks from the vacuum: quirks do not hadronize, they oscillate.

QUIRK SIGNATURE

- Of course, the quirk – anti-quirk system has low p_T.
- The pair therefore oscillates, with length scale ~ 1/ Λ_{hidden}.
- For a range of Λ_{hidden} , the quirk system travels down the beamline, escaping most LHC detectors, but ultimately leaving (strange!) tracks in FASER.

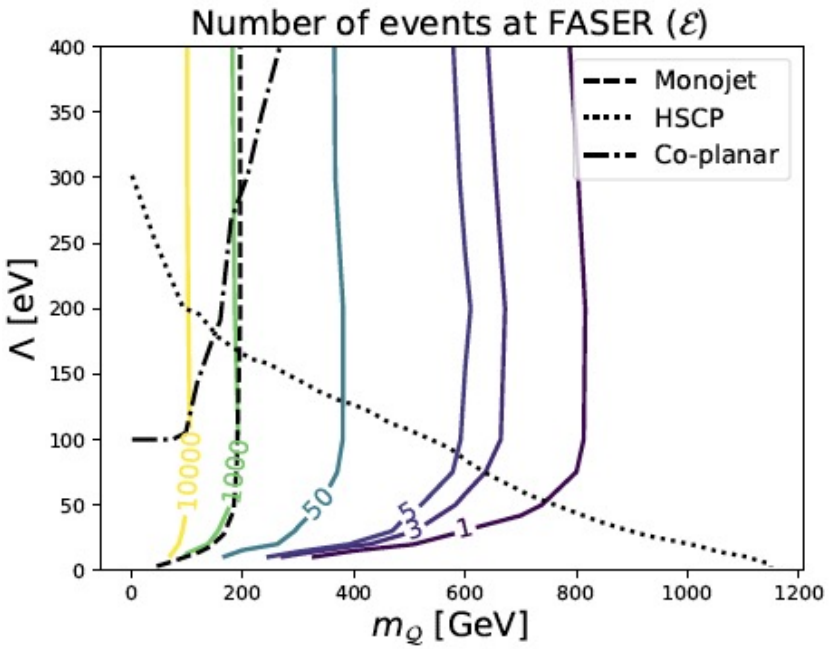
Li, Pei, Ran, Zhang, 2108.06748

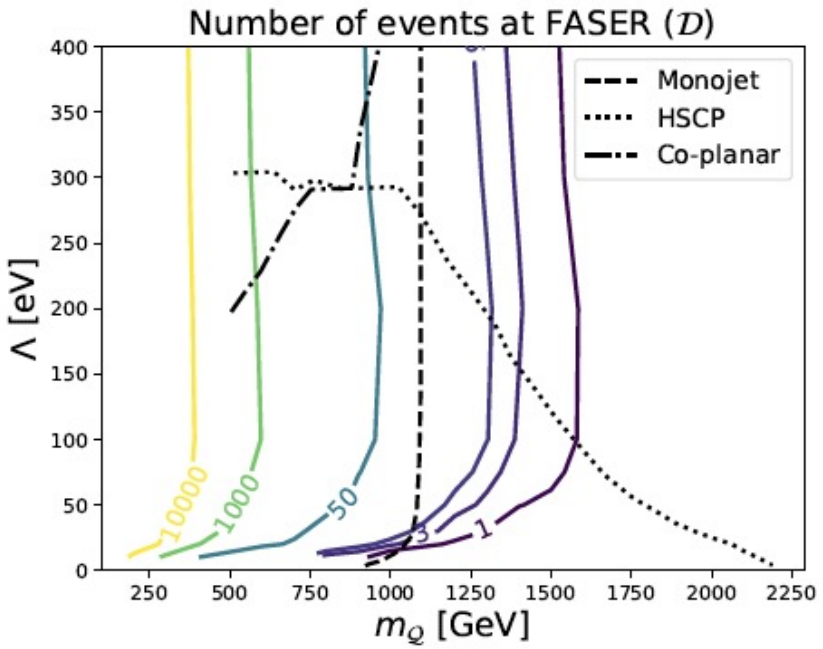


QUIRK DISCOVERY PROSPECTS

- Far-forward detectors at the LHC are ideally suited to search for quirks.
  - Like heavy particles, they require the LHC to be produced
  - Like light particles, they are dominantly produced along the beamline

- ~1000 of events possible at FASER in Run 3

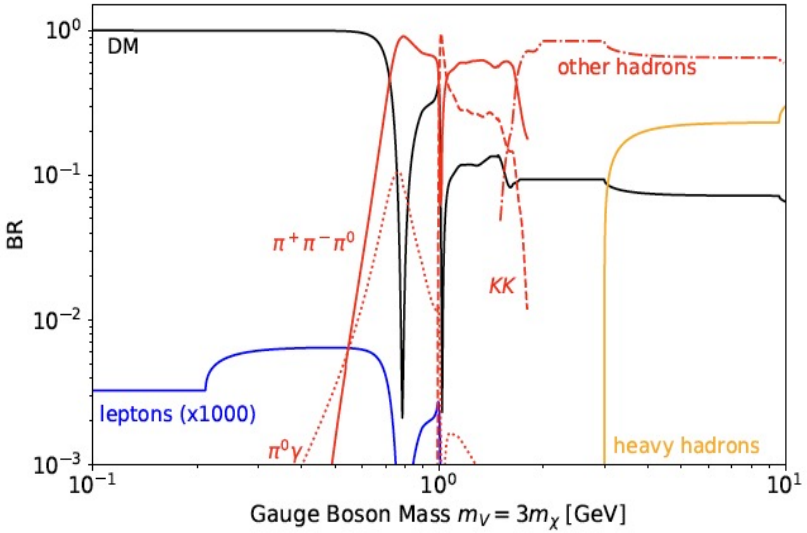


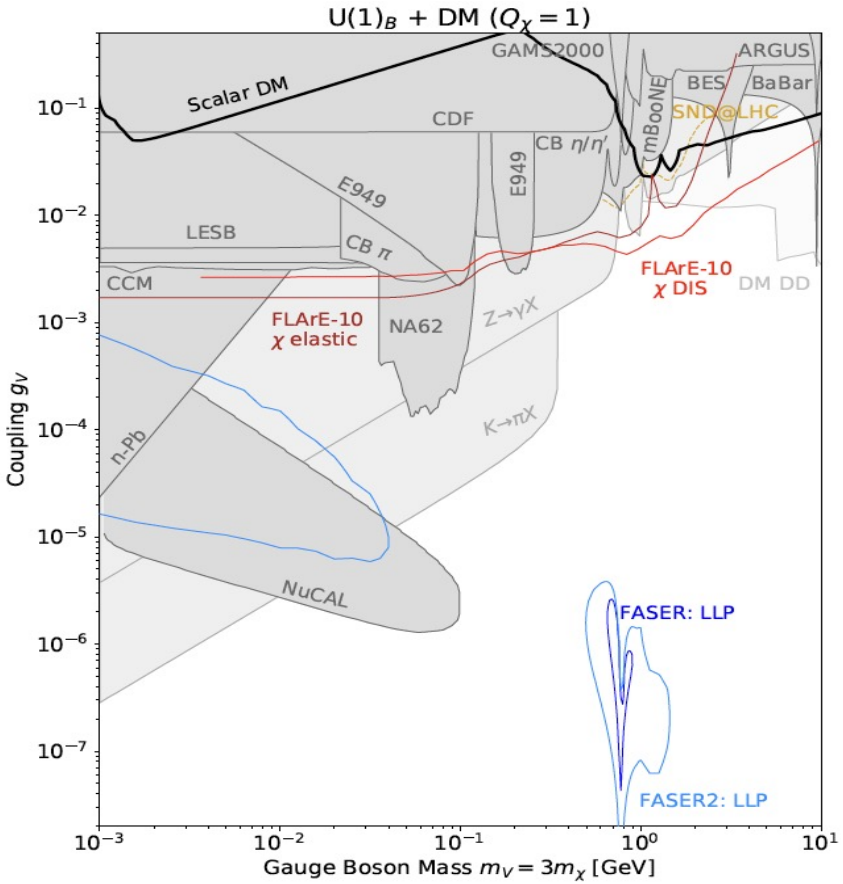


Li, Pei, Ran, Zhang, 2108.06748

NEW SIGNALS: B AND B-3τ GAUGE BOSONS

- Consider a light gauge boson coupled to baryon number
- Produced through $q\bar{q} \rightarrow V$
- Many interesting hadronic decays
  $V \rightarrow \pi^0\gamma,\ \pi^+\pi^-\pi^0,\ K^+K^-,\ K_S K_L$
- Greatly expands the standard e^+e^-, $\gamma\gamma$ signatures; similar signatures for "anomaly-free" gauge bosons

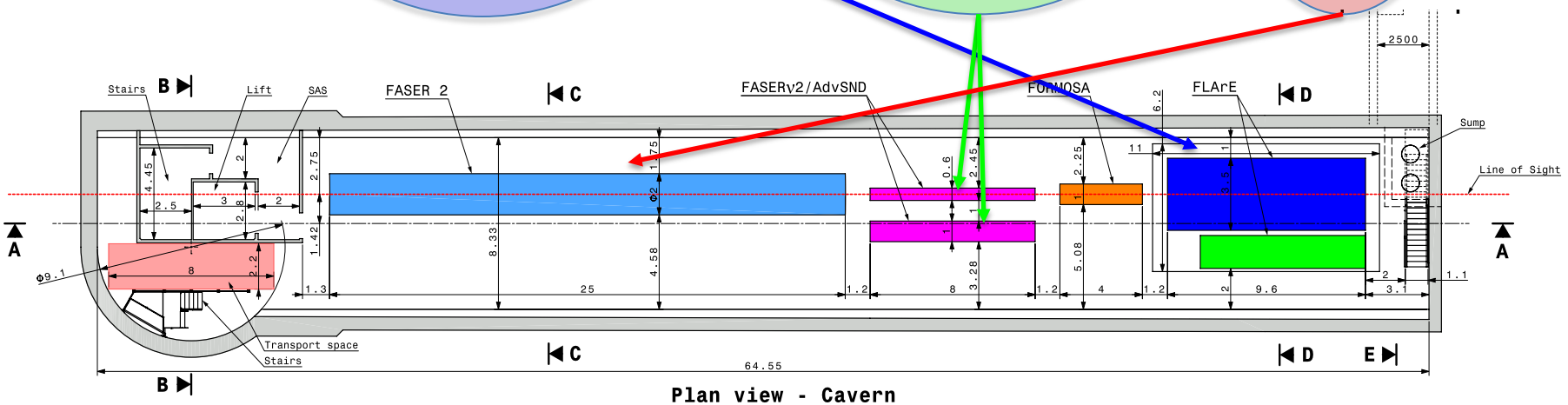




Batell, Feng, Fieg, Ismail, Kling, Abraham, Trojanowski, 2111.10343; see also Boyarsky, Mikulenko, Ovchynnikov, Shchutska, 2104.09688

SIGNATURES FOR OTHER FPF EXPERIMENTS

Signature	DM DIS	DM Elastic	ν NC DIS	ν_τ CC DIS	LLP decays
Models	$U(1)_B$, $U(1)_{B-3\tau}$	$U(1)_B$, $U(1)_{B-3\tau}$	$U(1)_{B-3\tau}$	$U(1)_{B-3\tau}$	$U(1)_B$, $U(1)_{B-3\tau}$
Production	$pp \to V \to \chi\chi$	$pp \to V \to \chi\chi$	$pp \to D_s \to \nu_\tau$	$pp \to V \to \nu_\tau\bar{\nu}_\tau$	$pp \to V$
Detection	$\chi N \to \chi X$	$\chi p \to \chi p$	$\nu_\tau N \to \nu_\tau X$	$\nu_\tau N \to \tau X$	$V \to$ hadrons



Plan view - Cavern
1:100

Batell, Feng, Fieg, Ismail, Kling, Abraham, Trojanowski, 2111.10343

PLANS

- The physics case for far-forward experiments at the LHC (FASER, FASER2, FASERν, FASERν2, SND@LHC, Advanced SND, FLArE, FORMOSA, …) continues to be studied and continues to grow.
- Looking forward to continued progress within the PBC framework and also the Snowmass community exercise.
- FPF meetings
  - FPF Kickoff Meeting, 9-10 Nov 2020, https://indico.cern.ch/event/955956
  - FPF2 Meeting, 27-28 May 2021, https://indico.cern.ch/event/1022352
  - FPF3 Meeting, 25-26 Oct 2021, https://indico.cern.ch/event/1076733
- FPF Short Paper: 75 pages, 80 authors completed in Sept 2021 (2109.10905).
- The FPF White Paper (~200-300 pages) is being prepared to be submitted to Snowmass in February-March 2022.