Higgs Decay with Displaced Vertices

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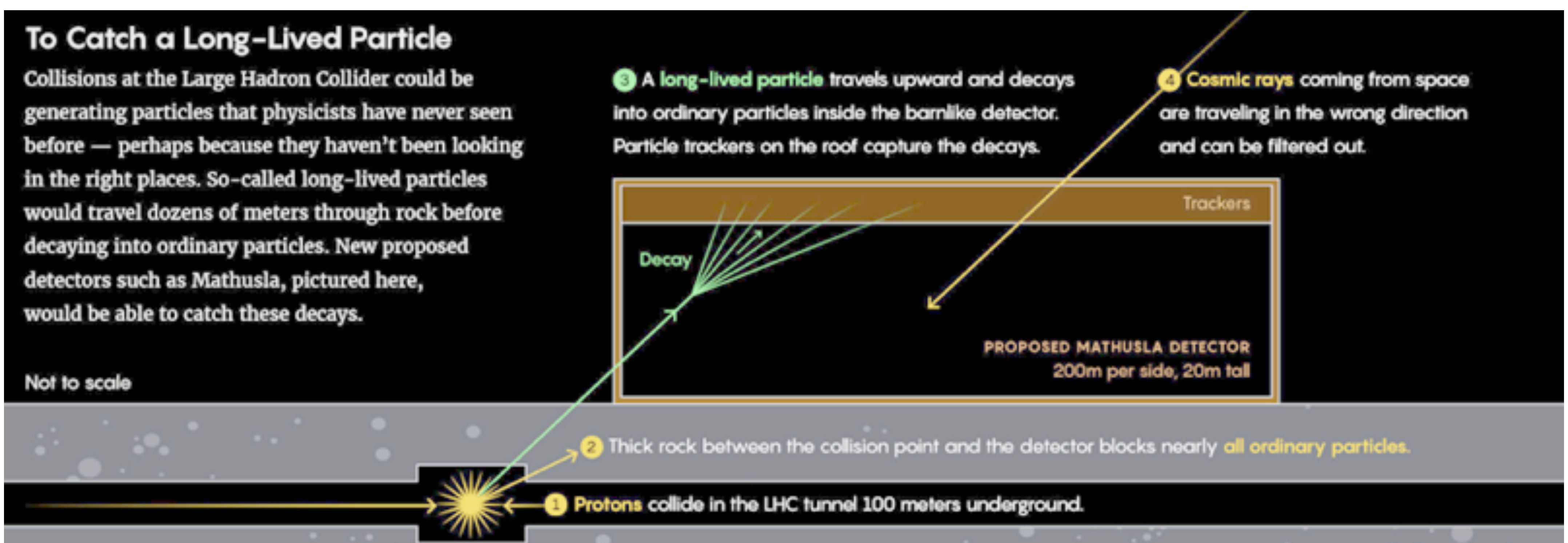
Based on work in progress with S. Alipour-Fard

International Workshop on CEPC, Beijing 2017

Higgs Displaced Decays

Much attention of the precision Higgs program currently focused on SM measurements, prompt exotic decays of the Higgs

But displaced exotic Higgs decays an increasingly hot topic:



For example: Twin Higgs

[Chacko, Goh, Harnik ‘05]

Standard Model $\xleftrightarrow{Z_2}$ **Standard Model**

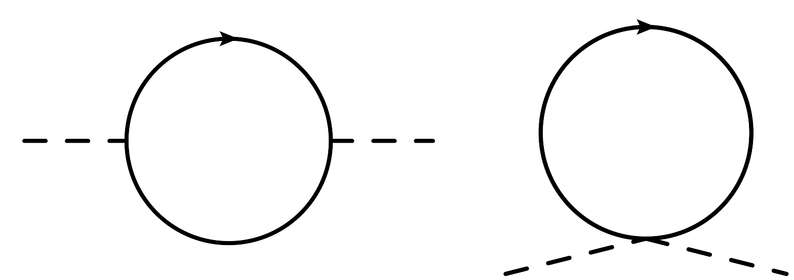
Radiative corrections to the Higgs mass are SU(4) symmetric thanks to Z_2:

$$V(H) \supset \frac{9}{64\pi^2} g^2 \Lambda^2 \left(|H_A|^2 + |H_B|^2 \right)$$

Higgs is a PNGB of ~SU(4), but partner states neutral under SM.

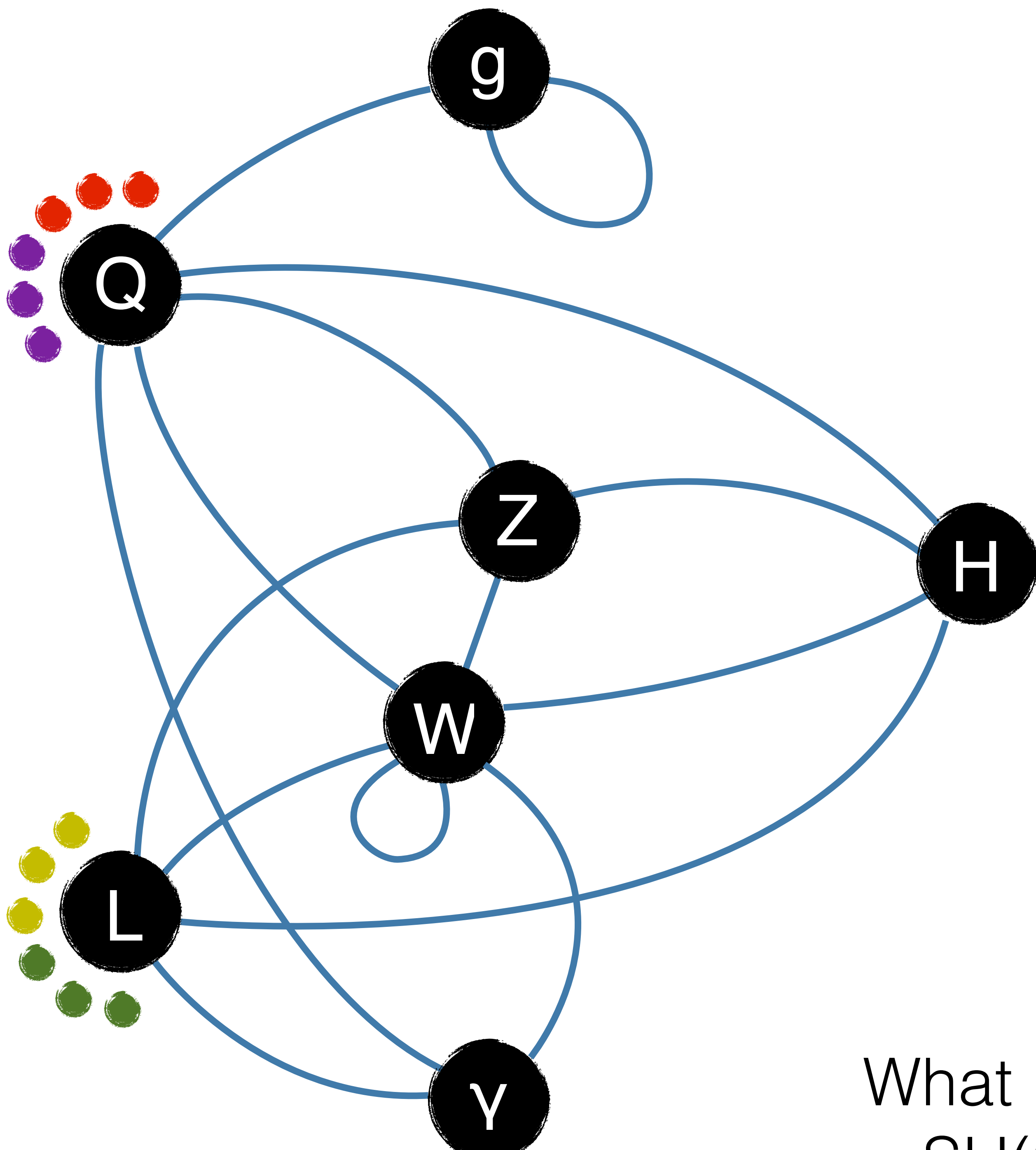
$$\mathcal{L} \supset -y_t H_A Q_3^A \bar{u}_3^A - y_t H_B Q_3^B \bar{u}_3^B$$

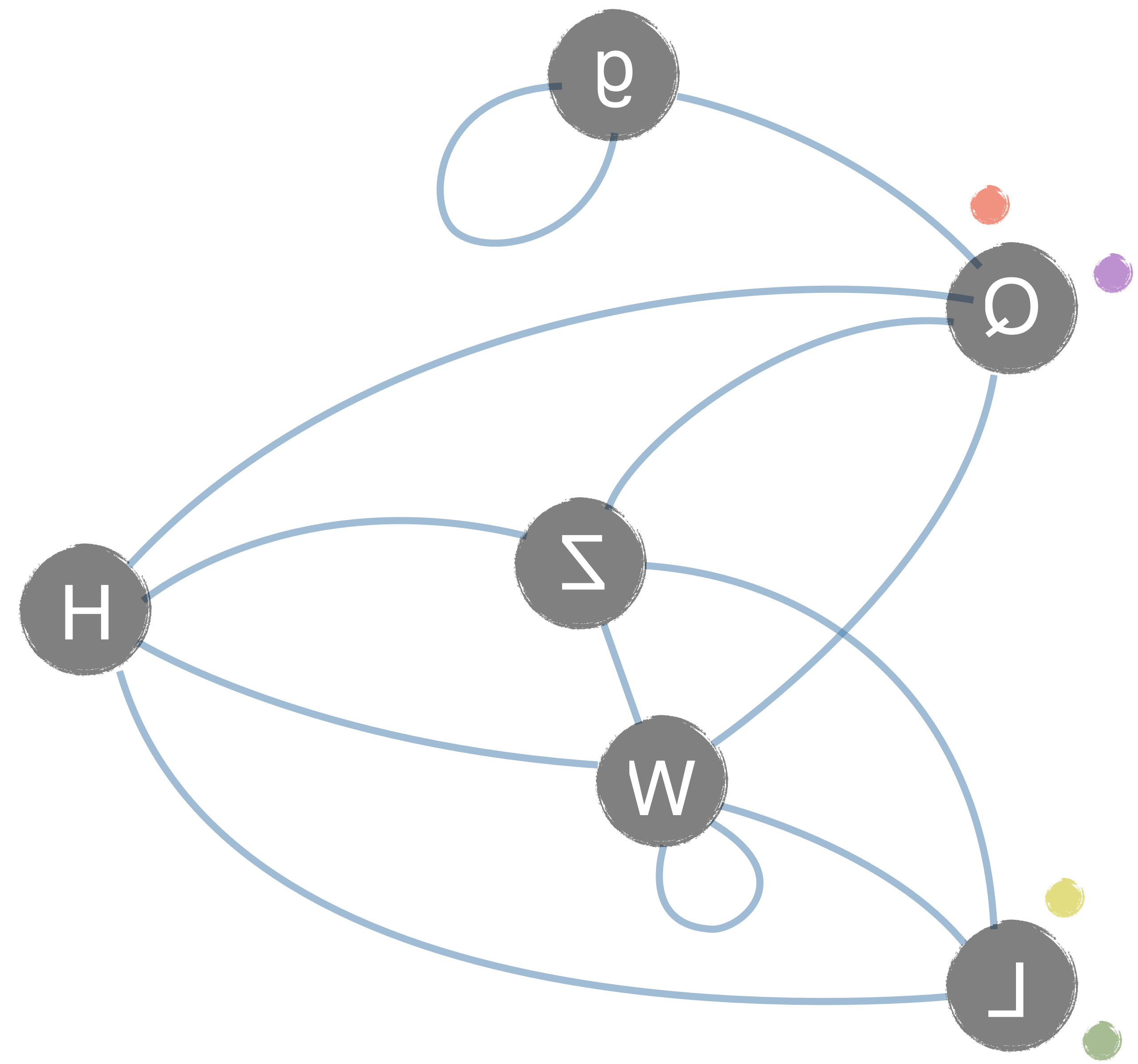
$H_A \to h + \ldots$, $\quad H_B \to f - \frac{h^2}{2f} + \ldots$



[NC, Katz, Strassler, Sundrum '15]

Fraternal twins



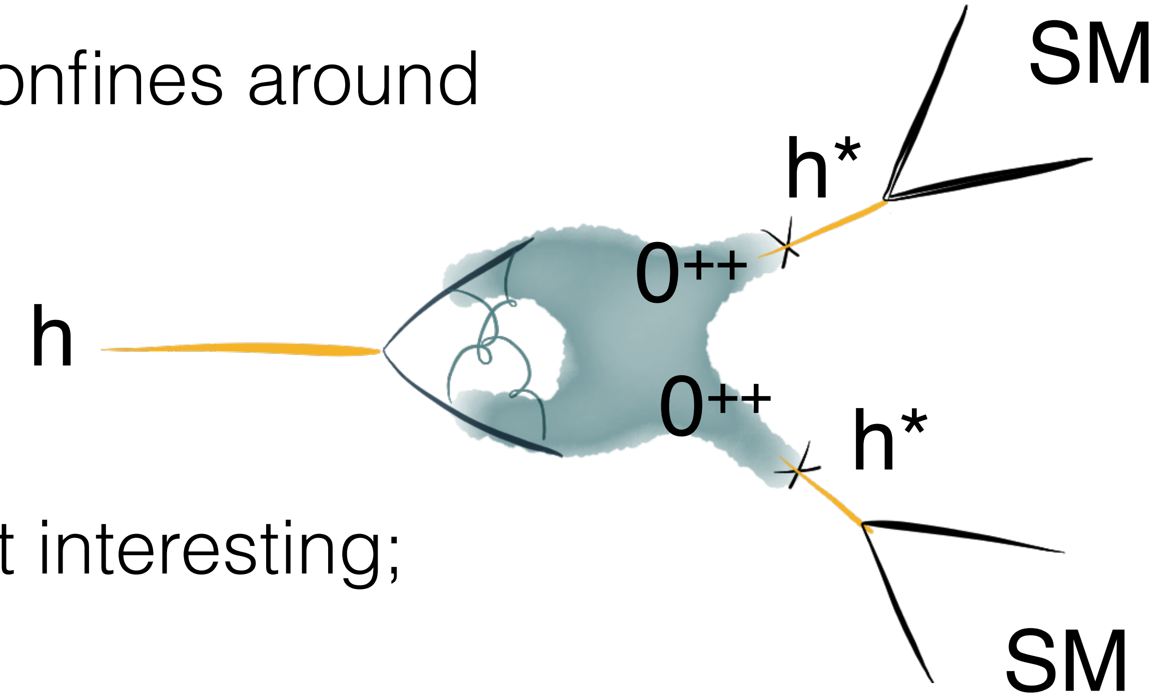


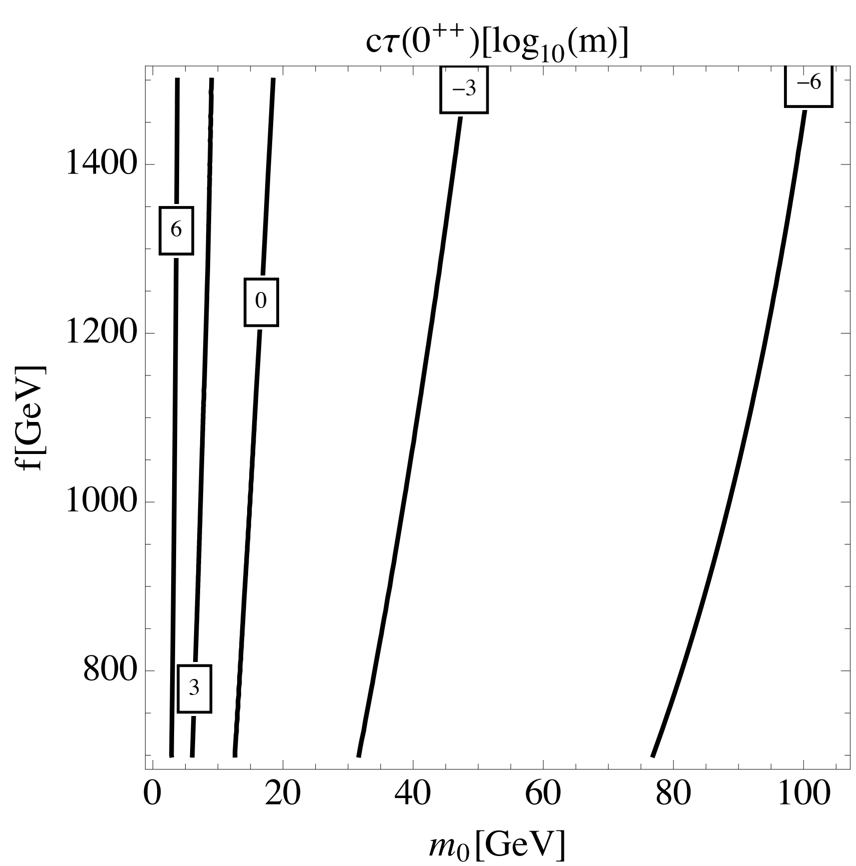
What really matters for naturalness:
SU(3)xSU(2) & third generation
⇒ Dark QCD

[NC, Katz, Strassler, Sundrum '15]

Exotic Higgs Decays

- Twin sector must have twin QCD, confines around QCD scale
- Higgs boson couples to bound states of twin QCD
- Various possibilities. Glueballs most interesting; have same quantum # as Higgs





$$\mathcal{L} \supset -\frac{\alpha_3'}{6\pi}\frac{v}{f}\frac{h}{f}G'^{a}_{\mu\nu}G'^{\mu\nu}_{a}$$

Produce in rare Higgs decays (BR~10^{-3}-10^{-4})

$$gg \to h \to 0^{++} + 0^{++} + \ldots$$

Decay back to SM via Higgs

$$0^{++} \to h^* \to f\bar{f}$$

Long-lived, decay length is macroscopic; length scale ~ collider detectors

Displaced Decays @ CEPC

LHC advantage: 3×10^7 Higgses produced at ATLAS+CMS with 300/fb at 14 TeV

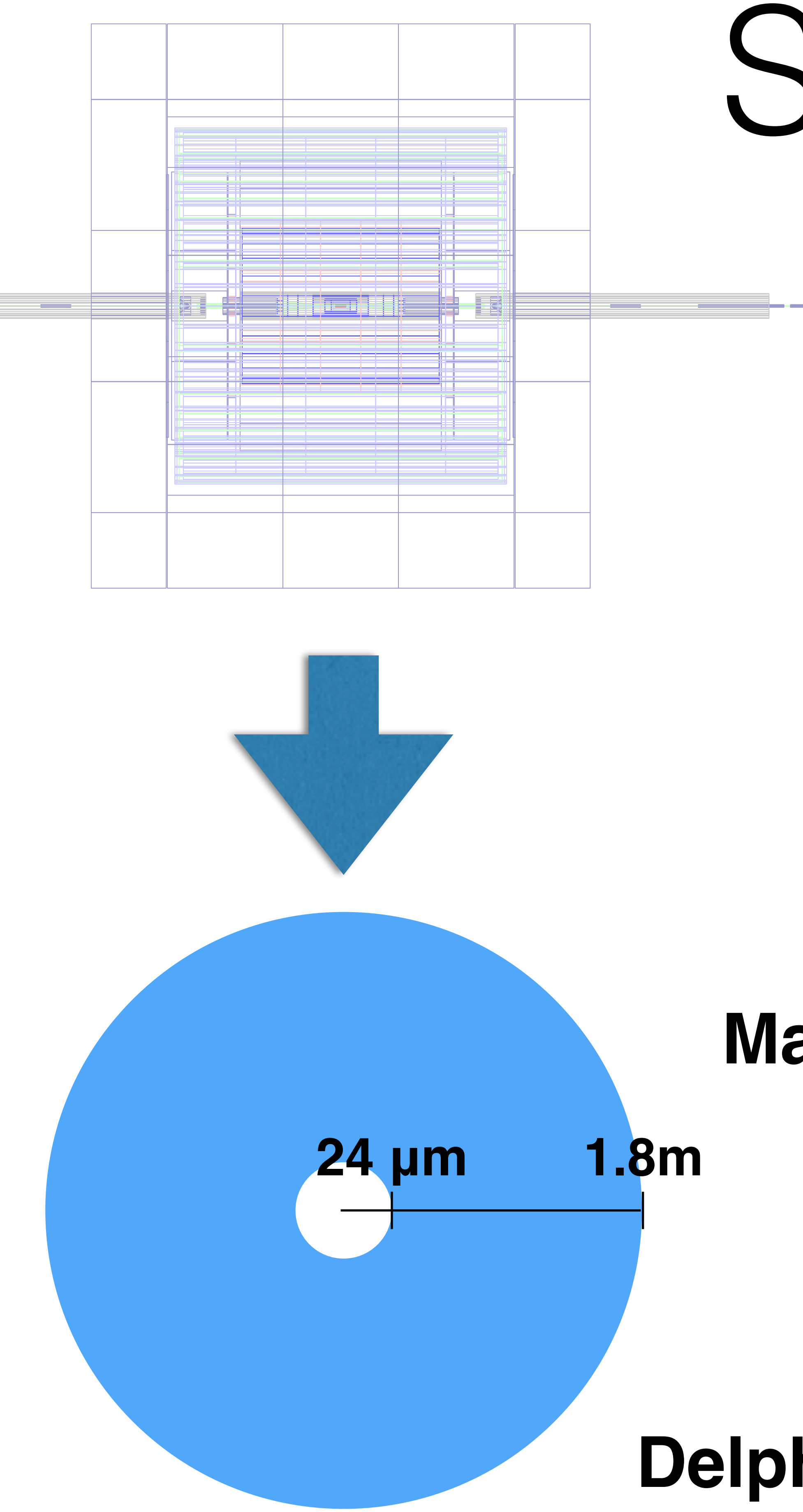
LHC disadvantage: Triggering (e.g. no vertex-based displaced search sensitive to Higgs @ 8 TeV)

CEPC in principle: 1×10^6 Higgses with 5/ab at 240 GeV
Significantly reduced triggering & cleaner environment

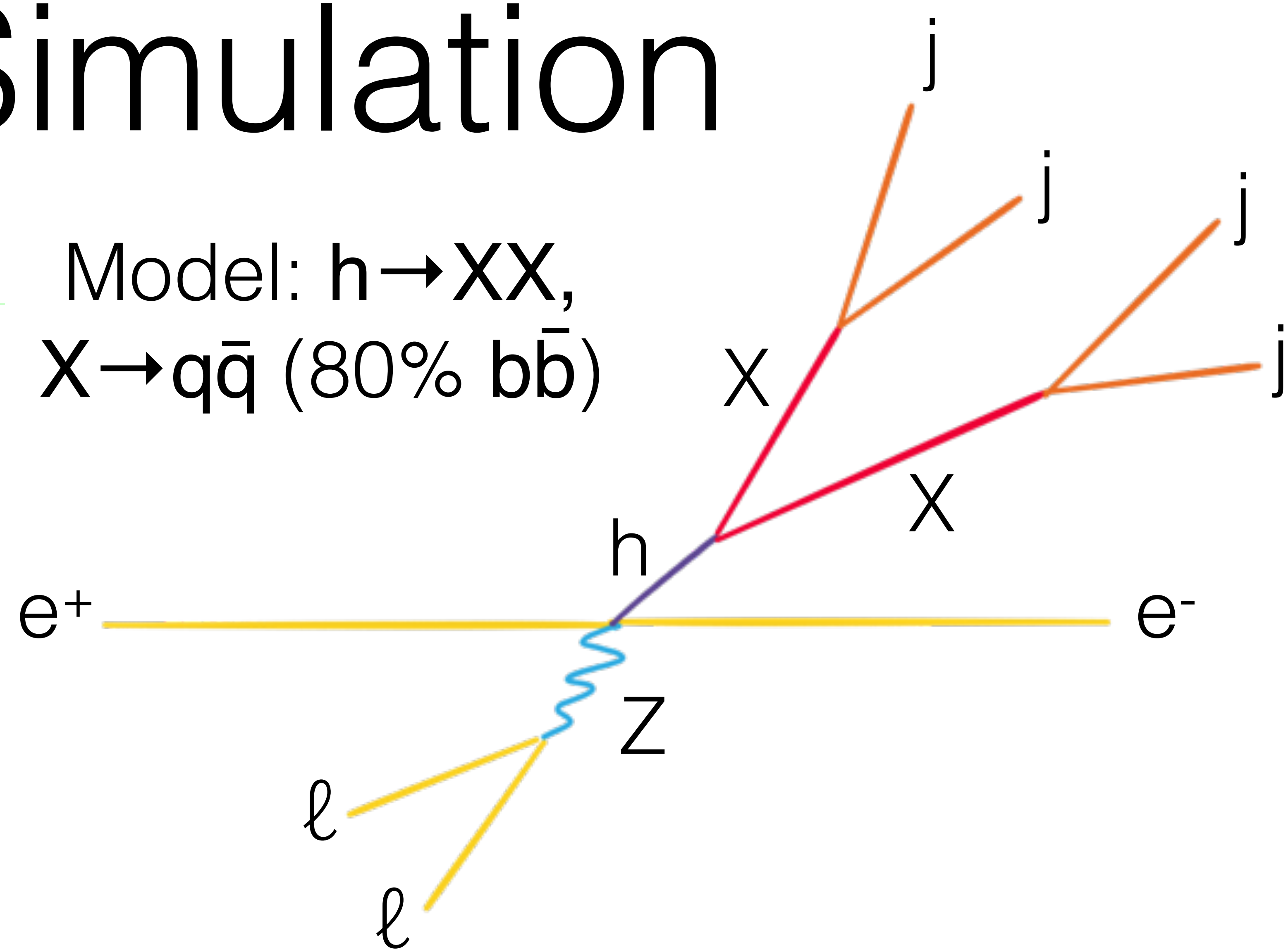
Maximal CEPC sensitivity: BR ~ 4×10^{-6}
(4 evts, no bkg, perfect acceptance)

Little/no study of BSM displaced physics objects so far
(Exception: RHN, [Antusch, Cazzato, Fischer '16])

Simulation



Model: **h→XX,**
X→q$\bar{q}$ (80% b$\bar{b}$)



MadGraph: $e^+e^- \to Zh \to \ell\ell + XX$ ($\sqrt{s}$ = 240 GeV)

Pythia: X→q$\bar{q}$, hadronization/showering

Delphes: SiD card for generic object efficiencies

Analysis

Reproduce Higgs selection w/ recoil mass in leptonic Zh:

- $Z \to ee$ or $\mu\mu$. Lepton p_T: $10 \leq p_T(\ell) \leq 90$ GeV.
- Dilepton invt mass: $70 < M_{ee} < 110$ GeV, $81 < M_{\mu\mu} < 101$ GeV.
- Recoil mass requirement: $120 < m_{recoil} < 150$ GeV.

Plus selection for displaced Higgs decay:

- Require two jets (vetoing hadronic τs), R=0.5
- Construct secondary vertex, require $d_{min} < d < 1.8$m

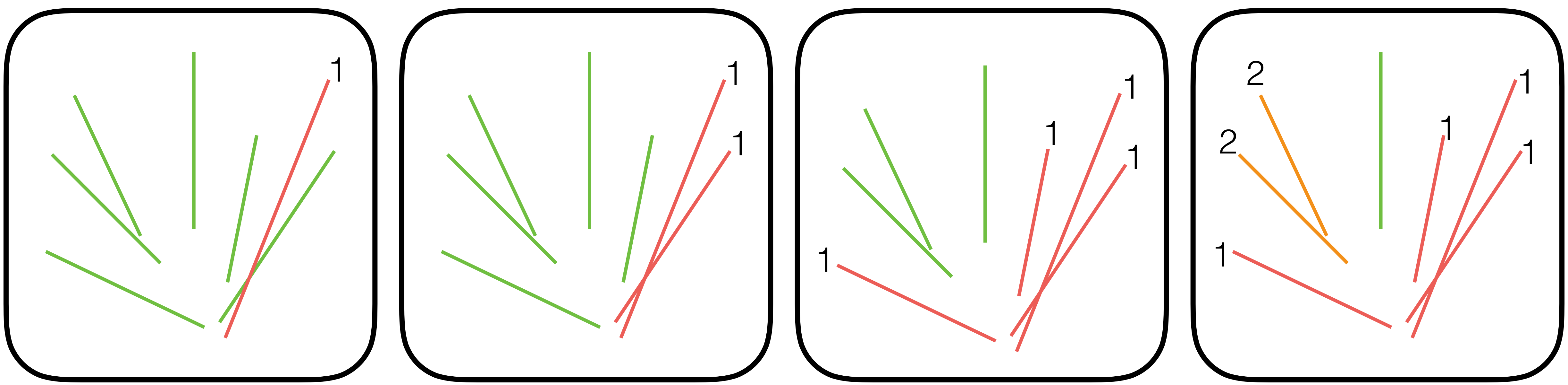
Assume most backgrounds handled by Higgs selection

Irreducible backgrounds: $e^+e^- \to ZZ \to \ell^+\ell^- + b\bar{b}/c\bar{c}/\tau_h\tau_h$

Secondary vertices

Roughly emulating CMS secondary vertex-finding algorithm

1. Form clusters using a depth-first algorithm running over all possible jet pairs, clustering tracks w/ origins within 1mm of another track.



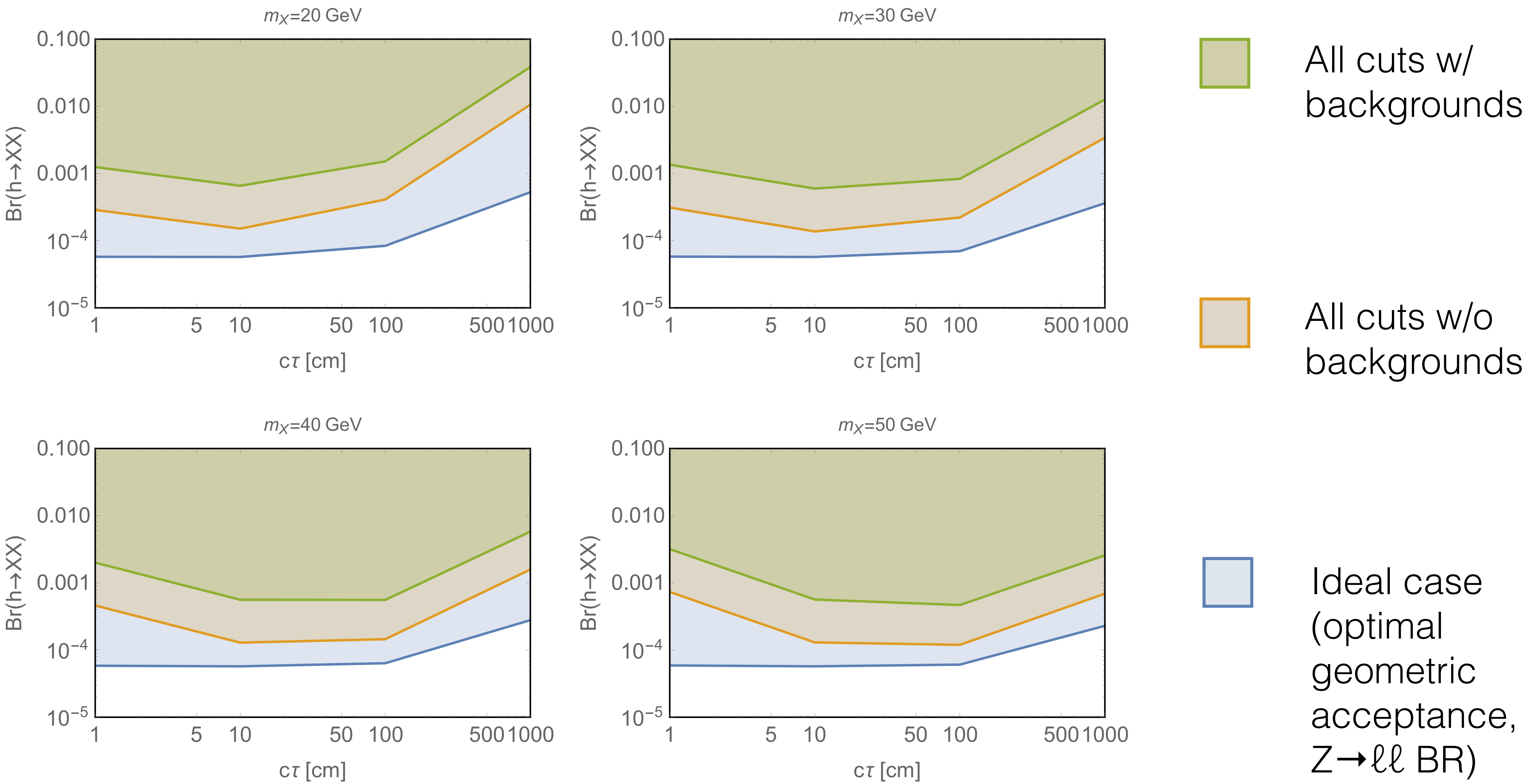
2. Take highest-multiplicity cluster containing at least one track from each of the two jets.

3. Average origins of tracks in this cluster to define displacement.

Acceptance x Efficiency

	ZZ→ bbll	m_X = 30 GeV, cτ = 1cm	m_X = 30 GeV, cτ = 10cm	m_X = 30 GeV, cτ = 1m	m_X = 30 GeV, cτ = 10m
$p_T(l)$, M_{ll}	0.95	0.96	0.96	0.96	0.96
m_{recoil}	0.0055	0.91	0.91	0.91	0.91
≥ 2j	0.0027	0.51	0.51	0.36	0.047
displaced dijet w/ d_{min}= 1cm	0.0005	0.18	0.42	-	-
displaced dijet w/ d_{min} = 10cm	0.0003	-	-	0.25	0.016

Preliminary Results

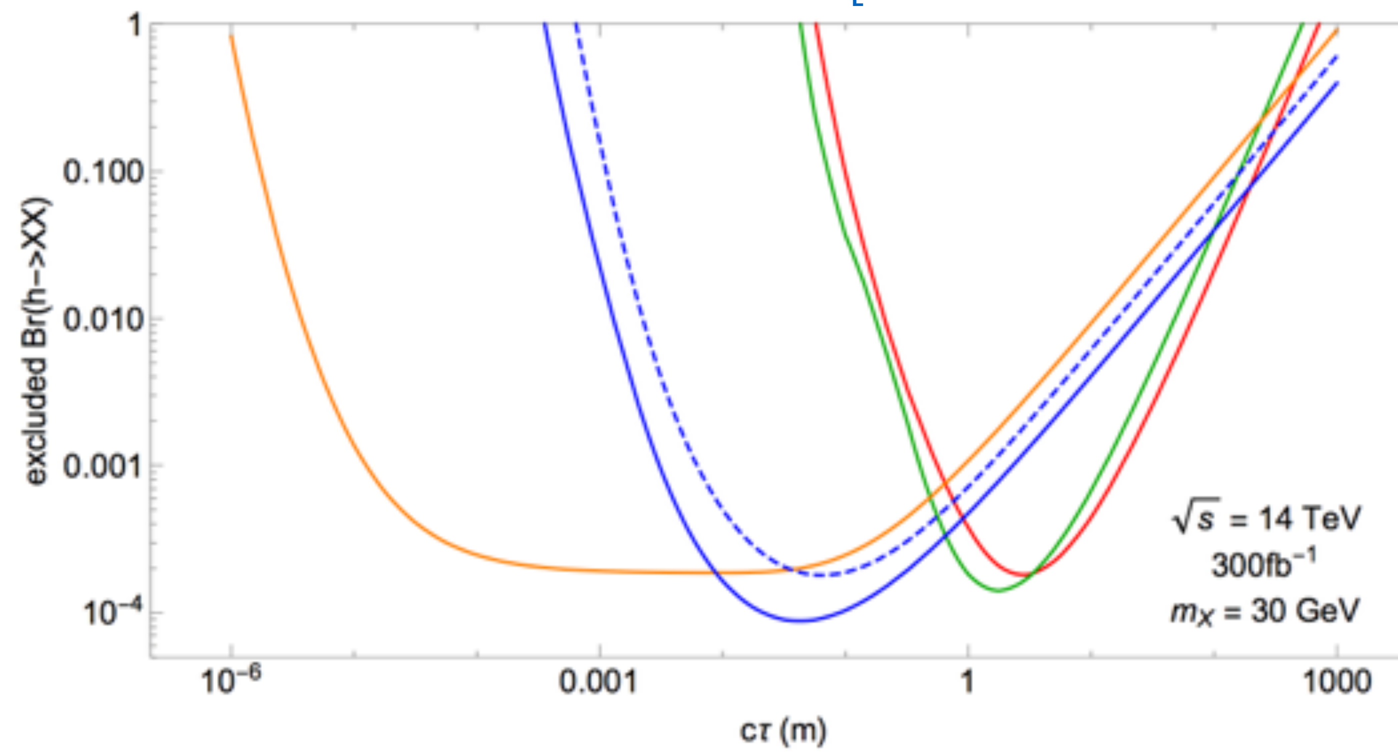


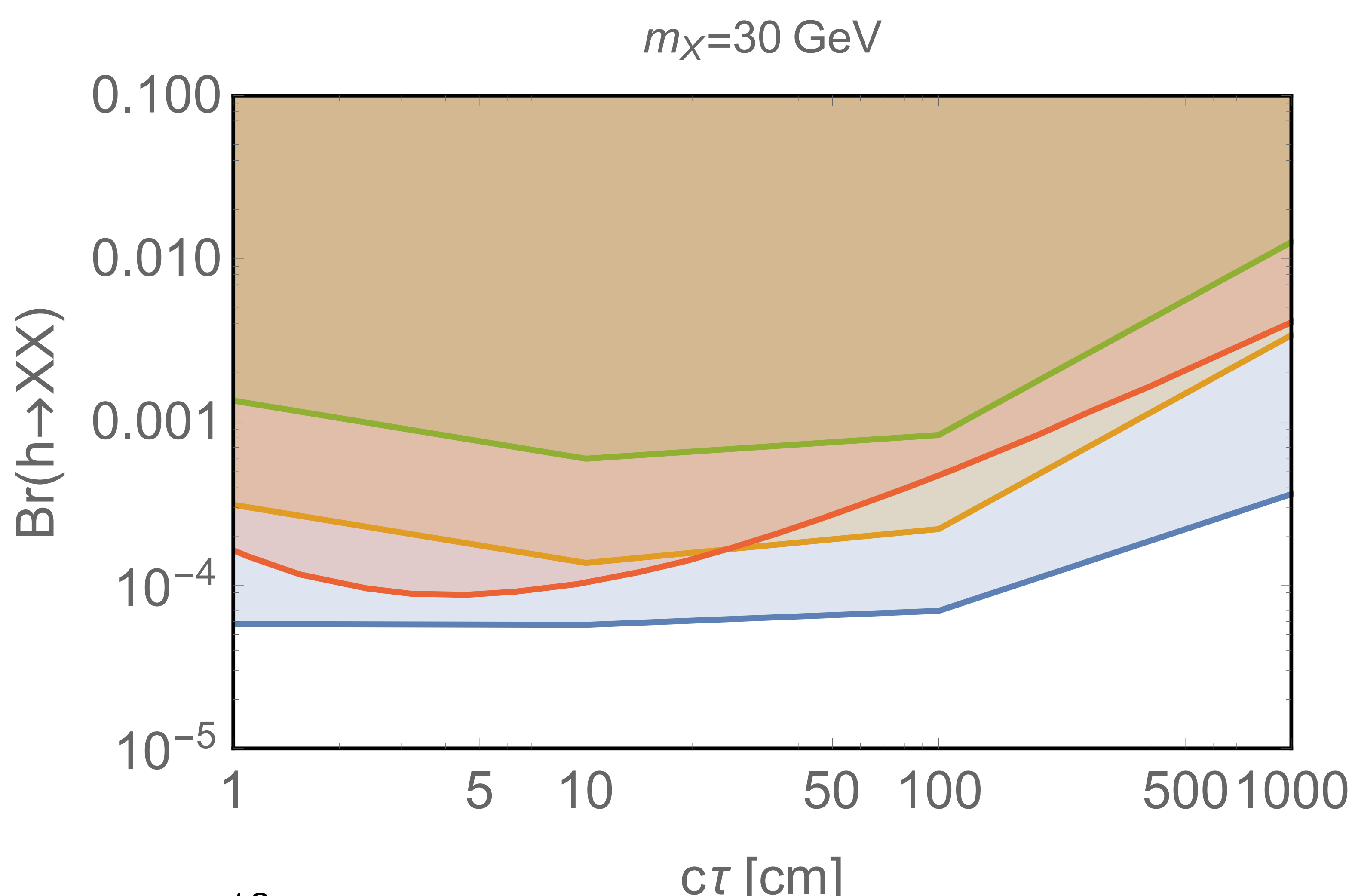
vs LHC

No official projections of LHC14 sensitivity, just theory estimates [Curtin & Verhaaren '15, Csaki, Kuflik, Lombardo, Slone '15]

LHC projections account only for trigger efficiency & geometric acceptance; assume no background, no pileup, and neglect systematics

[Curtin & Verhaaren '15]





Conclusions

- Displaced decays of the Higgs provide a highly motivated target for a precision Higgs program.
- CEPC capable of improving the limits on displaced Higgs decays relative to LHC.
- Current results preliminary; significant refinement & expansion of the analysis forthcoming, w/ improved background discrimination.
- Improved sensitivity for lighter X possible with a dedicated boosted analysis. Hadronic Z decays also merit consideration…

Thank you!