"Quirks" at the LHC

Jack Setford

University of Sussex

with S. Knapen, H.K. Lou and M. Papucci, LBNL Berkeley and UC Berkeley.

Talk outline

- What?
- Why?
- How?

Talk outline

- What are quirks?
- Why should we care?
- How do we find them?

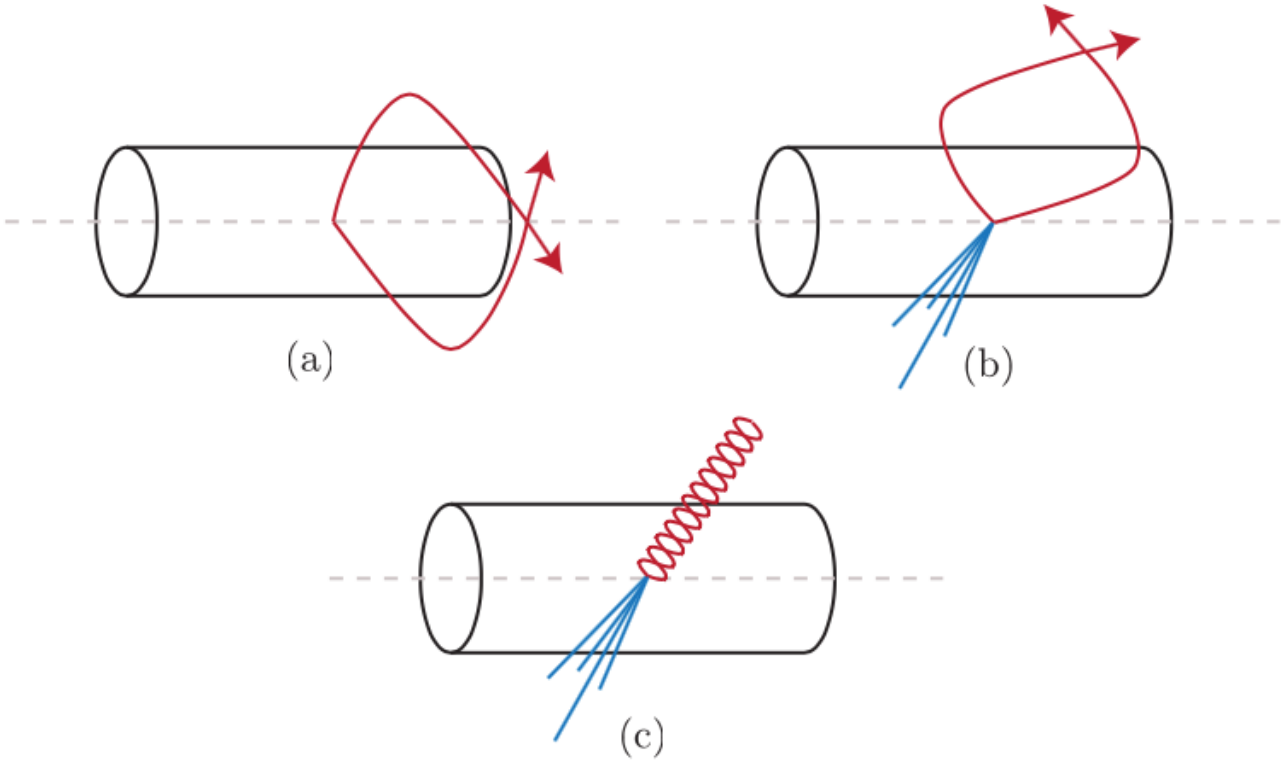
What are quirks?

- Sort of like quarks, but not quite.
- Charged under an unbroken non-Abelian gauge force which confines at low energies.
- Unlike QCD, the confinement scale is significantly less than the mass of the lightest quirk.

$$\Lambda \ll m_Q$$

- No bound states, no hadronisation.

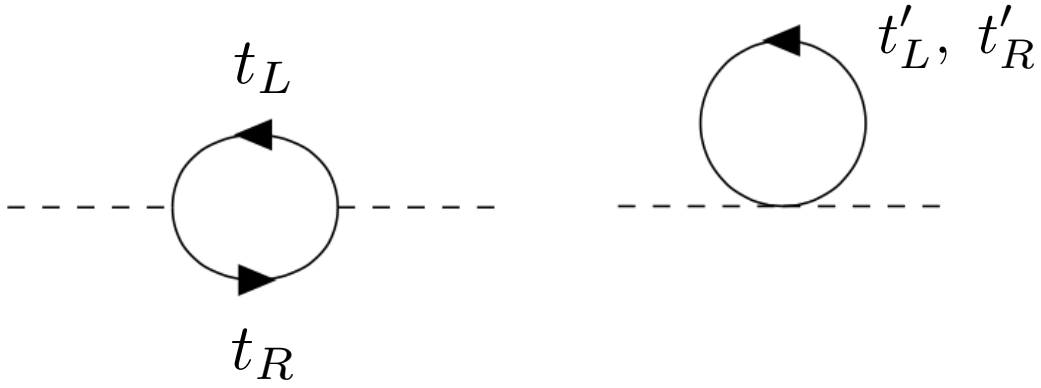
What are quirks?



Kang, J and Luty, M. arXiv:0805.4642 (2008)

Why should we care?

- Quirk-like particles are generic predictions of models such as twin Higgs and folded supersymmetry.
- In both cases, the particle that cuts off the top loop is charged under a copy of $SU(3)_c$.

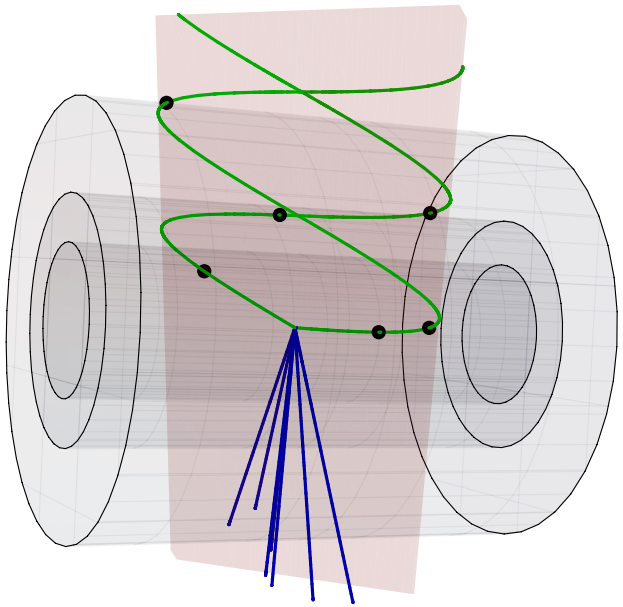


Poorly covered by LHC searches

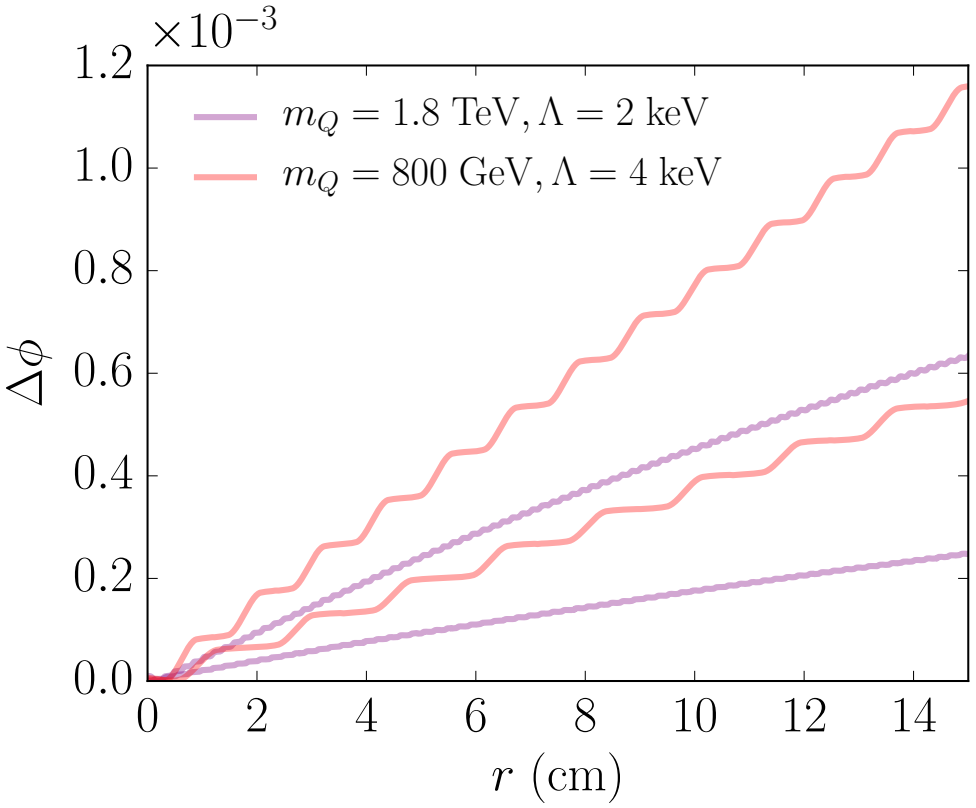
- For $m_Q \gtrsim 100\ \mathrm{GeV}$ and $1000\ \mathrm{eV} \lesssim \Lambda \lesssim 10\ \mathrm{keV}$, oscillation length is of order the size of the detector.
- Anomalous tracks are not picked up by track reconstruction algorithms – which look for circular/helical tracks.
- Quirk events would currently show up as missing energy + jets – current constraints not very good.

How do we find them?

- Key observation – hits lie in a plane.



Angle drift


$\times 10^{-3}$
1.2
1.0
0.8
0.6
0.4
0.2
0.0
$\Delta\phi$
$m_Q = 1.8$ TeV, $\Lambda = 2$ keV
$m_Q = 800$ GeV, $\Lambda = 4$ keV
0
2
4
6
8
10
12
14
r (cm)

Plane-finding algorithm

- Optimal plane minimises mean-squared distance between candidate points and the plane.

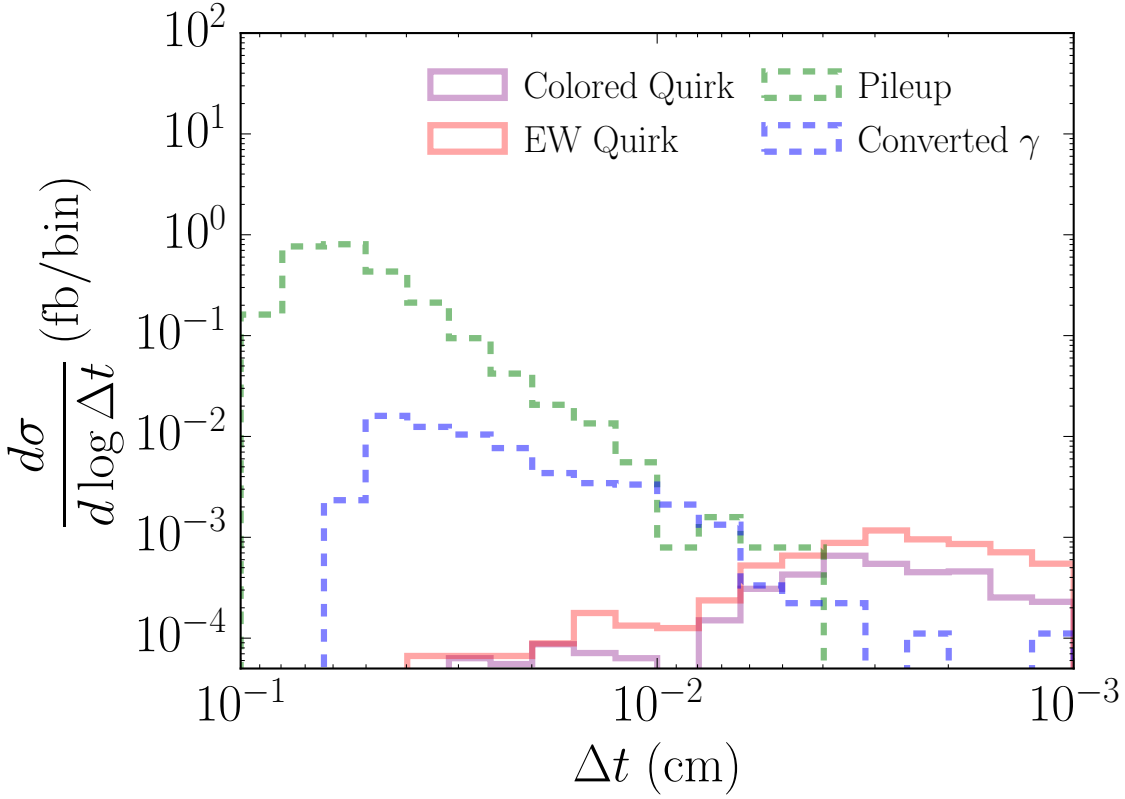
$$d^2 = \mathbf{p}^T \mathbf{T} \mathbf{p} \qquad \mathbf{T}(\mathbf{x}_a) \equiv \frac{1}{N-1} \sum_{a=1}^{N} \mathbf{x}_a \mathbf{x}_a^T$$

- Smallest eigenvalue ΔT roughly gives the thickness of the plane.
- Which hits to take as candidate points?
- $\mathcal{O}(1000)$ hits due to pileup.

Plane-finding algorithm

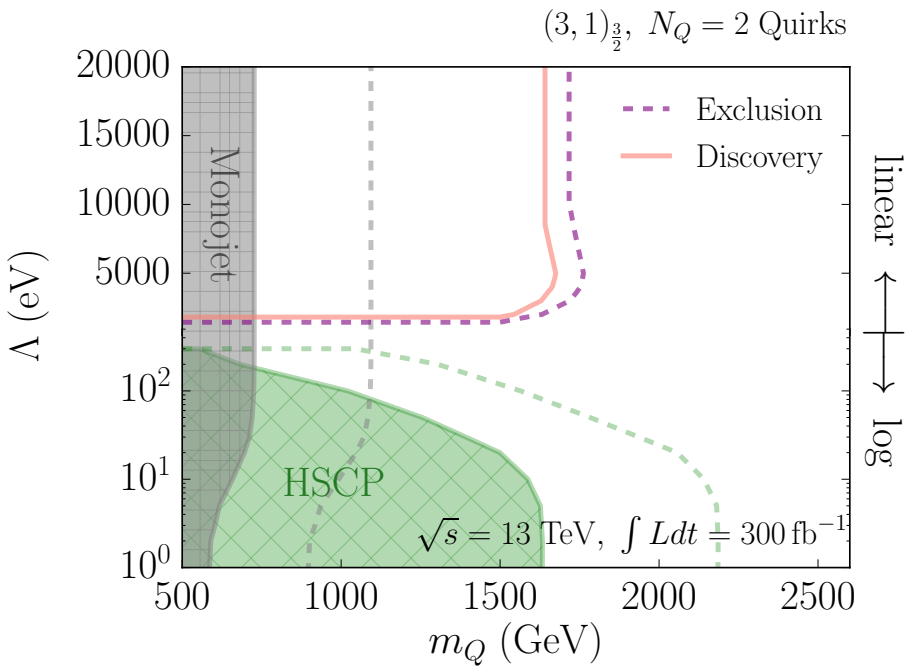
- Start with outer two layers, collect pairs of hits with $\Delta\phi < 0.1$ and $\Delta z < 2\ \mathrm{cm}$.
- Each pair of pairs is a candidate, keep only those which approximately lie in a plane $(\Delta T < 0.05\ \mathrm{cm})$.
- Work iteratively back through the layers, adding hits to the list if they are close enough to the candidate plane.
- Register a signal if at least one plane is reconstructed, and passes further cuts.

Plane-finding algorithm

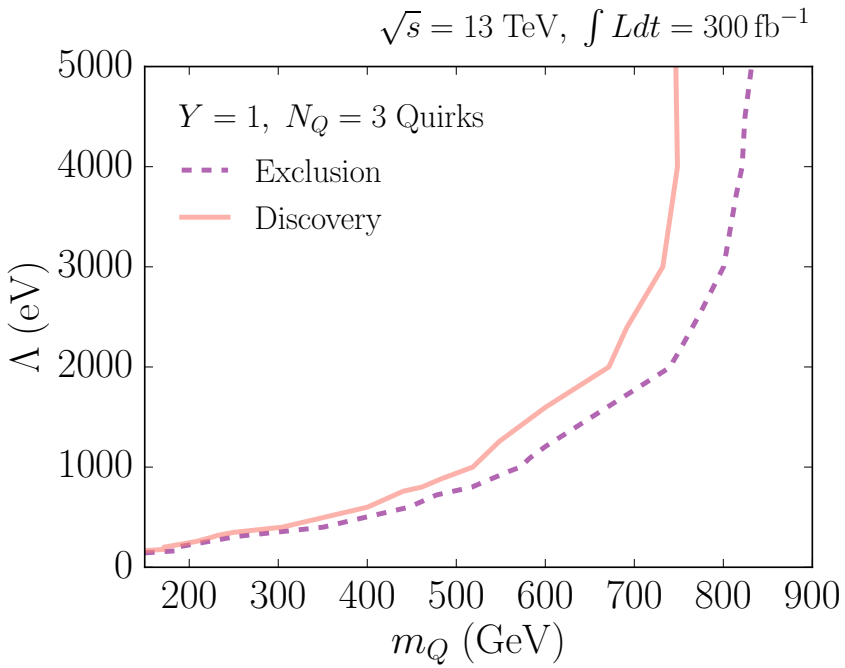


Results

Coloured quirks



Electroweak quirks



Conclusions

- Quirk-like states are predictions of many models.
- Strange ‘quirky’ tracks are currently not reconstructed by LHC detectors.
- We propose a search strategy that covers a broad range of quirk masses and confinement scales.
- Search for hits than lie on a plane.

Thanks for listening!