

New Sector





Hidden Un/Valley Quirk Model X

X is a heavy colored fermion

QCD-like confinement → hidden valley stringy confinement → quirks no confinement → unparticles

Hidden Un/Valley Quirk Model X

X is a heavy colored fermion

stringy confinement \longrightarrow quirks n=0 QCD-like confinement \longrightarrow hidden valley n=few no confinement \longrightarrow unparticles n=many





* a different way to calculate in CFT's

phase space looks like a fractional number of particles

Georgi hep-ph/0703260, 0704.2457

unparticle propagator

$$\begin{aligned} \Delta(p,d) &\equiv \int d^4x \, e^{ipx} \langle 0|T\mathcal{O}(x)\mathcal{O}^{\dagger}(0)|0\rangle \\ &= \frac{A_d}{2\pi} \int_0^\infty (M^2)^{d-2} \frac{i}{p^2 - M^2 + i\epsilon} dM^2 \\ &= i \frac{A_d}{2} \frac{\left(-p^2 - i\epsilon\right)^{d-2}}{\sin d\pi} \end{aligned}$$

$$A_d = \frac{16\pi^{5/2}}{(2\pi)^{2d}} \frac{\Gamma(d+1/2)}{\Gamma(d-1)\,\Gamma(2d)}$$

unparticle phase space

$$d\Phi(p,d) = A_d \theta \left(p^0\right) \theta \left(p^2\right) \left(p^2\right)^{d-2}$$

 $d\Phi(p,1) = 2\pi \,\theta\left(p^0\right) \,\delta(p^2)$

IR cutoff propagator

$$\begin{split} \Delta(p,\mu,d) &\equiv \int d^4x \, e^{ipx} \langle 0|T\mathcal{O}(x)\mathcal{O}^{\dagger}(0)|0\rangle|_{\mu} \\ &= \frac{A_d}{2\pi} \int_{\mu^2}^{\infty} (M^2 - \mu^2)^{d-2} \frac{i}{p^2 - M^2 + i\epsilon} dM^2 \\ &= i \frac{A_d}{2} \frac{\left(\mu^2 - p^2 - i\epsilon\right)^{d-2}}{\sin d\pi} \\ \Delta(p,\mu,1) &= \frac{i}{p^2 - \mu^2 + i\epsilon} \end{split}$$

Fox, Rajaraman, Shirman hep-ph/0705.3092

unparticle phase space

 $d\Phi(p,\mu,d) = A_d \,\theta\left(p^0\right) \,\theta\left(p^2 - \mu^2\right) \,\left(p^2 - \mu^2\right)^{d-2}$

 $d\Phi(p,\mu,1) = 2\pi\,\theta\left(p^0\right)\,\delta(p^2-\mu^2)$

Spectral Densities





Quarks are Unparticles



FIG. 1. Comparison of the unparticle spectral density (2) (dashed) and the spectral density (9) of a massless quark jet at next-to-leading order in QCD (solid). We use parameters M = 10 GeV and $\eta = 0.5$. The right plot shows the same results on logarithmic scales.

Neubert hep-ph/0708.0036

electrons are Unparticles

resummed electron propagator

$$\Delta_e(p) = \frac{i}{\not p - m} (p^2 - m^2)^{\gamma}$$

cf Yennie Gauge

unparticle propagator



$$- = A_d \theta (p^0) \theta (p^2 - \mu^2) (p^2 - \mu^2)^{d-2}$$

Heavy Mediator

• Important Operators

$$\mathcal{O}_{1} = \frac{\mathcal{C}_{\mathcal{U}} \Lambda_{\mathcal{U}}^{d_{\mathcal{B}Z}-d_{\mathcal{U}}}}{\mathcal{M}^{k}} Z^{\mu\nu} Z_{\mu\nu} \mathcal{O}_{\mathcal{U}}$$
$$\mathcal{O}_{2} = \frac{\mathcal{C}_{\mathcal{U}}' \Lambda_{\mathcal{U}}^{d_{\mathcal{B}Z}-d_{\mathcal{U}}}}{\mathcal{M}^{k}} A^{\mu\nu} A_{\mu\nu} \mathcal{O}_{\mathcal{U}}$$
$$\mathcal{O}_{3} = \frac{\mathcal{C}_{\mathcal{U}}'' \Lambda_{\mathcal{U}}^{d_{\mathcal{B}Z}-d_{\mathcal{U}}}}{\mathcal{M}^{k}} m_{Z}^{2} Z^{\mu} Z_{\mu} \mathcal{O}_{\mathcal{U}}$$

• Representative Feynman Graph



Lineshape Bounds from LEP

$$\begin{aligned} d_{\mathcal{U}} &= 1 \qquad \mathcal{C}_{\mathcal{U}}^{2} \left(\frac{\Lambda_{\mathcal{U}}}{\mathcal{M}}\right)^{2\mathcal{B}\mathcal{Z}} \frac{1}{\Lambda_{\mathcal{U}}^{2d_{\mathcal{U}}}} \Big|_{d_{\mathcal{U}}=1} \geq 5 \times 10^{-12} \text{ GeV}^{-2} \\ d_{\mathcal{U}} &= 1.5 \qquad \mathcal{C}_{\mathcal{U}}^{2} \left(\frac{\Lambda_{\mathcal{U}}}{\mathcal{M}}\right)^{2\mathcal{B}\mathcal{Z}} \frac{1}{\Lambda_{\mathcal{U}}^{2d_{\mathcal{U}}}} \Big|_{d_{\mathcal{U}}=1.5} \geq 6.4 \times 10^{-13} \text{ GeV}^{-3} \\ d_{\mathcal{U}} &= 2.0 \qquad \mathcal{C}_{\mathcal{U}}^{2} \left(\frac{\Lambda_{\mathcal{U}}}{\mathcal{M}}\right)^{2\mathcal{B}\mathcal{Z}} \frac{1}{\Lambda_{\mathcal{U}}^{2d_{\mathcal{U}}}} \Big|_{d_{\mathcal{U}}=2} \geq 1.3 \times 10^{-13} \text{ GeV}^{-4} \\ d_{\mathcal{U}} &= 2.5 \qquad \mathcal{C}_{\mathcal{U}}^{2} \left(\frac{\Lambda_{\mathcal{U}}}{\mathcal{M}}\right)^{2\mathcal{B}\mathcal{Z}} \frac{1}{\Lambda_{\mathcal{U}}^{2d_{\mathcal{U}}}} \Big|_{d_{\mathcal{U}}=2.5} \geq 2.8 \times 10^{-14} \text{ GeV}^{-5} \\ d_{\mathcal{U}} &= 3.0 \qquad \mathcal{C}_{\mathcal{U}}^{2} \left(\frac{\Lambda_{\mathcal{U}}}{\mathcal{M}}\right)^{2\mathcal{B}\mathcal{Z}} \frac{1}{\Lambda_{\mathcal{U}}^{2d_{\mathcal{U}}}} \Big|_{d_{\mathcal{U}}=3} \geq 3.2 \times 10^{-15} \text{ GeV}^{-6} \\ d_{\mathcal{U}} &= 3.5 \qquad \mathcal{C}_{\mathcal{U}}^{2} \left(\frac{\Lambda_{\mathcal{U}}}{\mathcal{M}}\right)^{2\mathcal{B}\mathcal{Z}} \frac{1}{\Lambda_{\mathcal{U}}^{2d_{\mathcal{U}}}} \Big|_{d_{\mathcal{U}}=3.5} \geq 5.3 \times 10^{-17} \text{ GeV}^{-7} \end{aligned}$$

The bounds are derived assuming final state electrons. They are more stringent than the literature. Use these values in the following analysis. Devin Walker



MonoPhotons



K. Cheung et. al. hep-ph/0706.3155

dơ/dE_γ (pb/GeV)



FIG. 8: Differential cross section $d\sigma/dE_j$ versus E_j for the monojet signal at the LHC, with various $d_{\mathcal{U}}$. We have set $\Lambda_{\mathcal{U}} = 1$ TeV and $\lambda_0 = \lambda_1 = 1$.

K. Cheung et. al. hep-ph/0706.3155

10° jang energy mass scale. The signal already that gery different kinematics seen d try a simple E_T kinematic variable. d try a simple version of the simple E_T kinematic variable. We do the simple version of the same transformed by the second se optimal cuts stouthationiza it hat signal to hat dag zound retide We it at a ratio ematic varfables of whether and the size of the state of e mass bias marses stick variables have a definite mass scale which introduces a mass plas marses stick variables use as for buy plathoses seless the out purposes of the mass our purpose the (clusten)ptampskeersadaeaasharanabharanaatatbeenaasastatatatatatatatata pp->WW Missing eT (GeV) W). It is defined as

 $r \operatorname{both} pp \to ZZ \operatorname{\tilde{a}}_{10} \operatorname{\tilde{p}}_{10} \operatorname{\tilde{p}}_{10$ $\operatorname{xim}_{4n}^{2} = \operatorname{at}(\operatorname{th}_{7,n}^{2} + \operatorname{s}_{1}^{1} + \operatorname{s}_{1$ ssing energy liss the soluty number of the matrix valuation of the matrix of the solution of the solution of the matrix of the solution of the matrix of the solution of the ben every lon as the statistic of the s a Nive for the variable that does not have bien to be signated as in the haffective as bias is the

The effective mass for the $d_{\mathcal{U}} = 1, 2, 3$ (left panel) and $d_{\mathcal{U}} = 1.5, 2.5, 3.5$ (right e should panel) aigs if the reconstruction off each event T Wer do this in ord Left/right panels visible lack solid), 2 (green solid), 3 (blue dot-dashed) make optimal cuts to maximize the signal-to-background ratio. We no sivermasnfaPisnischierenissen von her son son and state and son the state of the second state of the second s s. The marganel) signal. ple is the (cluster) transporte mass variable used to reconstruct $pp \rightarrow Z$

Higgs Mediator

We will use the Higgs portal to unparticles ^a

 $\mathcal{L} = -\kappa_U |H|^2 \mathcal{O}_U$

Mariano Quiros

THE HIGGS CONNECTION - P.2/1

^aP.J. Fox, A. Rajaraman and Y. Shirman, arXiv:0705.3092



Width of the Higgs boson from unparticle merging Mariano Quiros

Colored Mediator

Strong production rate, similar to heavy colored particles

$$\sigma_{unparticle} = (2 - d)\sigma_{particle} \quad d < 2$$

Hadronization: they form heavy (stable) meson-like states (charged, neutral...)

Unjets: containing SM hadrons + CFT stuff

R-Hadrons, anomalous jets/E loss

Only a small fraction of the energy is in hadrons (visible)

Look like (maybe broader) QCD jets + p_T

Guido Marandella,

Giacomo Cacciapaglia

unquark production



unquark production



 $\sigma_{unparticle} = (2 - d)\sigma_{particle}$

Colored Mediator 2 jets + p_T



Pair production p_T is aligned to visible p_T

CFT stuff radiation p_T not aligned