# A Robust Measure of Event Isotropy at Colliders

Cari Cesarotti, Harvard University

(2004.06125) w/ J. Thaler, MIT

Phenomenology 2020 Symposium

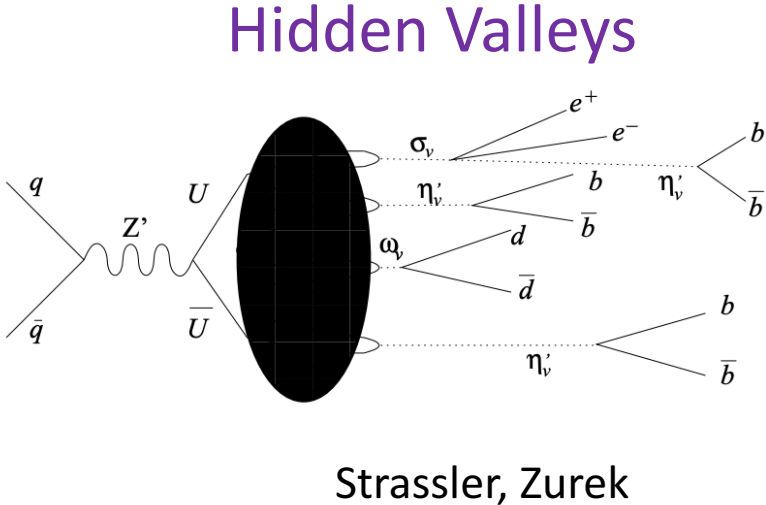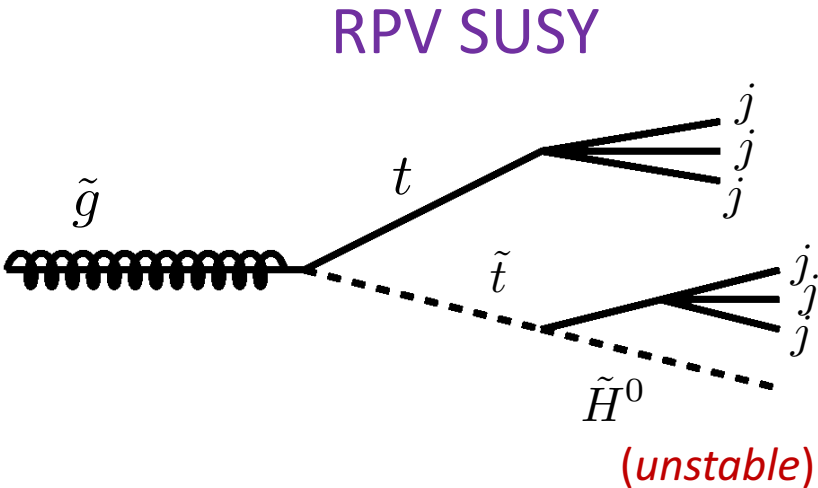May 4, 2020

Tools Parallel Session

# Motivation

LHC has enormous discovery potential, but we haven't seen evidence of new physics

⟶ Could be new physics at electroweak scale hiding with rare kinematic signatures

⟶ Strategy for new physics searches: identify signatures *fundamentally* different from QCD

# Motivation

QCD at TeV scale is characterized by soft, collinear splittings, and therefore looks very *jetty*

But many new physics signatures look quasi-isotropic:

RPV SUSY



$\tilde{g}$

$t$

$j$
$j$
$j$

$\tilde{t}$

$j$
$j$
$j$

$\tilde{H}^0$

(*unstable*)

Hidden Valleys



$q$

$\bar{q}$

$Z'$

$U$

$\bar{U}$

$\sigma_v$

$e^+$
$e^-$

$\eta'_v$

$b$
$\bar{b}$

$\eta'_v$

$b$
$\bar{b}$

$\omega_v$

$d$
$\bar{d}$

$\eta'_v$

$b$
$\bar{b}$

Strassler, Zurek

Also:
- Black holes
- Soft bomb (SUEPs)
- Many more…

# Motivation

There are lots of new physics scenarios with quasi-isotropic radiation patterns

When trying to quantify event shape
- Event shape observables designed to measure distance from *dijet*
  - *Thrust, C/D-parameter, sphericity, spherocity...*
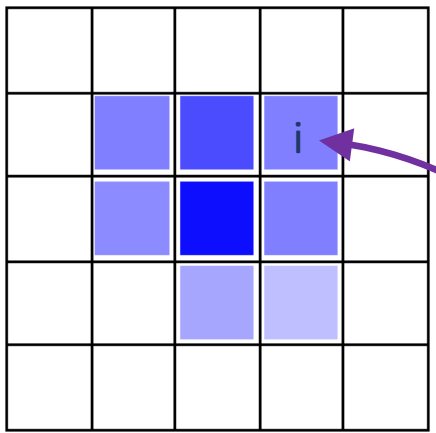- Want distance from *isotropy*

### Event Isotropy
(CC, J. Thaler, 2004.06125)

# Event Isotropy

We propose a new event shape observable: *event isotropy*
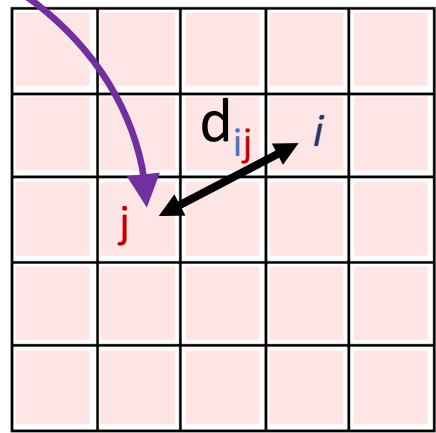
Dimensionless distance from a collider event to an isotropic radiation distribution using *energy mover's distance* (EMD)

P



$$\mathcal{I}(\mathcal{E}) = \mathrm{EMD}(\mathcal{U}, \mathcal{E})$$

Komiske, Metodiev, Thaler

$$\mathrm{EMD}(P, Q) = \min_{\{f_{ij}\}} \sum_{ij} f_{ij} d_{ij}$$

$f_{ij}$ : weight
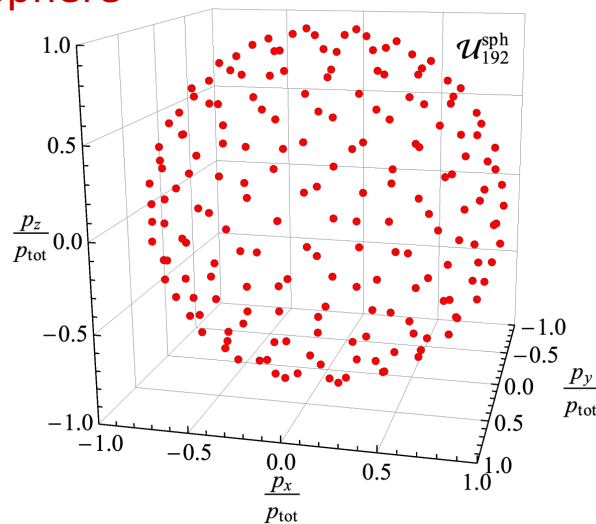
$d_{ij}$ : distance measure

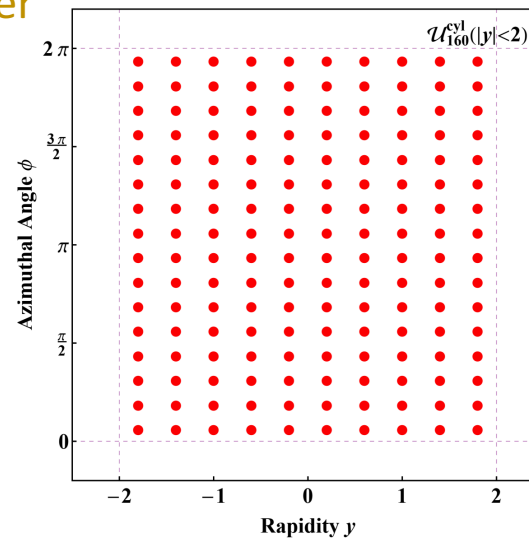$$f_{ij} \geq 0 \qquad \sum_{ij} f_{ij} = 1$$

# Event Isotropy

$$\mathcal{I}_n^{\mathrm{geo}}\left(\mathcal{E}\right) = \mathrm{EMD}_{d_{ij}}\left(\mathcal{U}_n^{\mathrm{geo}}, \mathcal{E}\right)$$

- *Geo*: Geometry of isotropic radiation pattern (sphere, cylinder, ring)

- *n*: Number of particles in quasi-uniform sample
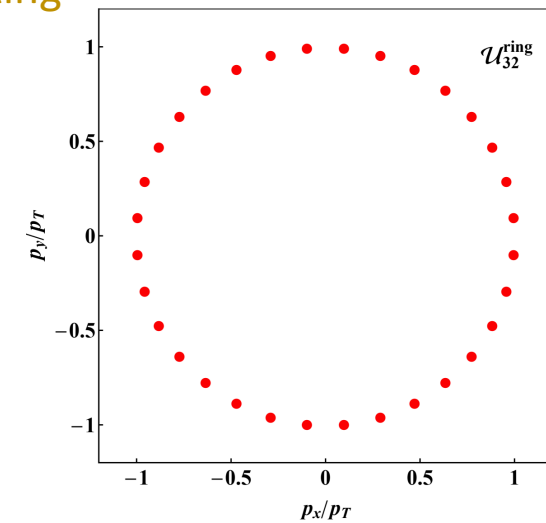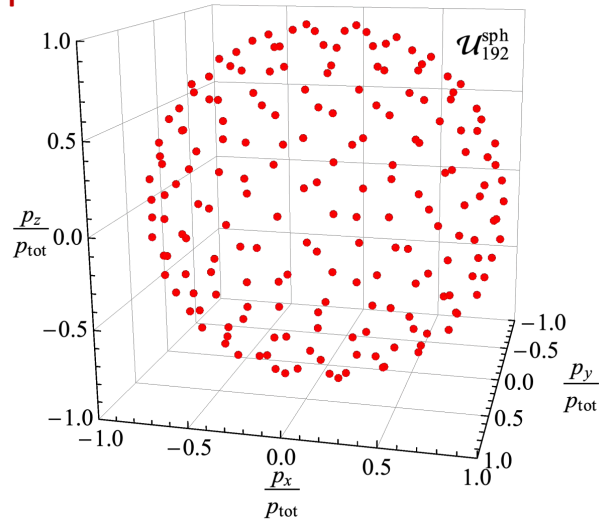
- $d_{ij}$: Distance measure

# Event Isotropy

$$\mathcal{I}_n^{\text{geo}}\left(\mathcal{E}\right) = \text{EMD}_{d_{ij}}\left(\mathcal{U}_n^{\text{geo}}, \mathcal{E}\right)$$



**Sphere**

$\mathcal{U}_{192}^{\text{sph}}$

$e^+e^-$

$$w_i = E_i/E_{\text{tot}}$$

$$d_{ij} = 2\left(1 - \cos\theta_{ij}\right)$$

**Cylinder**

$\mathcal{U}_{160}^{\text{cyl}}(|y|<2)$
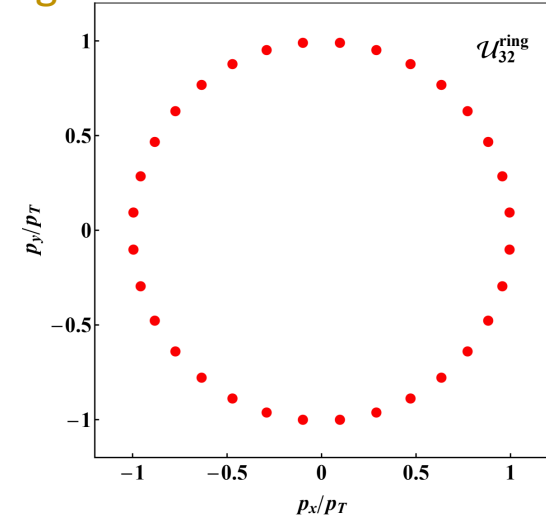
**Ring**

$\mathcal{U}_{32}^{\text{ring}}$
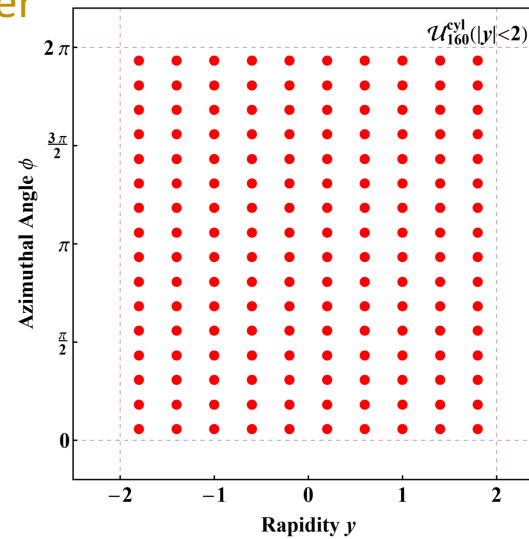
*pp*

$$w_i = p_{T,i}/p_{T,tot}$$

$$d_{ij} = \frac{12}{\pi^2 + 16 y_{\max}^2}\left(y_{ij}^2 + \phi_{ij}^2\right)$$

$$d_{ij} = \frac{\pi}{\pi - 2}\left(1 - \cos\phi_{ij}\right)$$

# Event Isotropy

$$\mathcal{I}_n^{\mathrm{geo}}\left(\mathcal{E}\right) = \mathrm{EMD}_{d_{ij}}\left(\mathcal{U}_n^{\mathrm{geo}}, \mathcal{E}\right)$$

- IRC safe

- Dimensionless

- $\mathcal{I} \in [0, 1]$, where 0 is isotropic and 1 is dijet

# Applications of Event Isotropy (2004.06125)

- Discrimination of QCD dijet vs. top pair production

- Discrimination of SM from high multiplicity new physics

- Characterization of new physics *(Work in progress: CC, M. Reece, M. Strassler)*