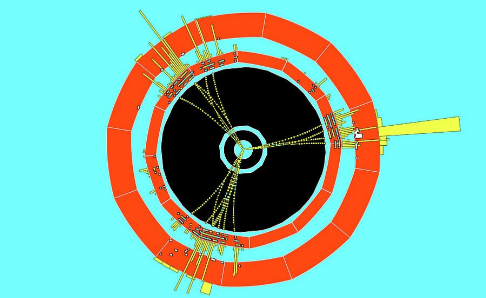
Positivity in energy correlators

Johan Henriksson (CERN)
19 May 2026

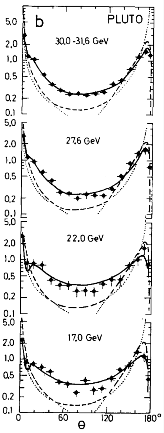
Simons Collaboration on Confinement and QCD Strings Workshop

Based on **work in progress** with A. Belin, N. Borak, R. Piron, and A. Zhiboedov

Introduction



[ALEPH 1990's]



[PLUTO 1981]

Observable: $\langle \Psi | \mathcal{E}(\vec{n}_1) \cdots \mathcal{E}(\vec{n}_n) | \Psi \rangle$

$$\mathcal{E}(\vec{n}) = \text{energy flux in direction } \vec{n}$$

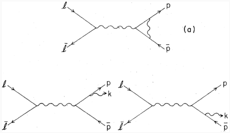
Recently, lot of interest from theory and experiment!

Motivation

- Energy correlators are well-defined in almost any theory considered in high-energy physics
  Collider physics, CFT, gravity
- Energy correlators are positive

  pointwise $\mathcal{E}(\vec{n}) \geqslant 0$ & unitarity $C_J \geqslant 0$

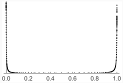
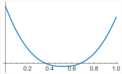
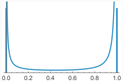
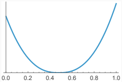
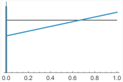
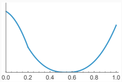
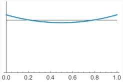
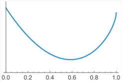
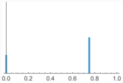
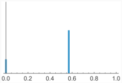
  ANEC $\langle \Psi | \mathcal{E}(\vec{n}_1) | \Psi \rangle \geqslant 0$ [Hofman, Maldacena 2008]
- Today: Towards a complete understanding of positivity



[Basham, Brown, Lowell Ellis, Love 1978]

Understand the **shape** *of positive energy correlators*

Positive and not-so-positive two-point energy correlators

Allowed		Disallowed!	
	Experimentally measured (binned data)		Negative at some z_0
	1-loop QCD perturbative		Not attaining maximal value at $z = 0$
	Free particles at large multiplicity		$\mathcal{C}^k$ disc. at $z_0 \neq 0$ despite regular at $z = 0$
	Gravity in AdS		Counter example of theorem of [Devinatz 1959] [Gneiting 2011]
	Extremal solution maximizing C_3		Coefficient of $\delta(z - z_0)$ violating bound

Plan for the presentation

1. Background
2. Positivity in energy correlators
3. Two-point energy correlators and atomic models
4. Constraints on real-world data
5. Summary

Plan for the presentation

1. **Background**
2. Positivity in energy correlators
3. Two-point energy correlators and atomic models
4. Constraints on real-world data
5. Summary

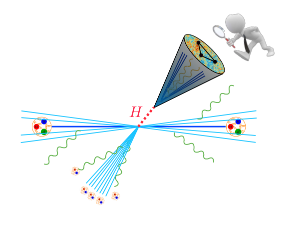
Background

Consider n-point energy correlators in state $|\Psi\rangle$

$$\mathrm{E}^n\mathrm{C}(\vec{n}_1,\ldots,\vec{n}_n) = \langle\Psi|\mathcal{E}(\vec{n}_1)\cdots\mathcal{E}(\vec{n}_n)|\Psi\rangle$$

Energy correlators are a rich set of observables

- Vary theory
- Vary state $|\Psi\rangle$
- Vary total energy Q
- Vary n
- Vary relative angles
- Replace $\mathcal{E}$ (charge correlators, "on tracks," etc.)



Nice review [Moult, Zhu 2025]

Examples

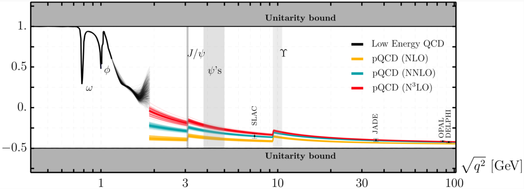
- One-point in rotationally-invariant state

$$\langle \mathcal{E}(\vec{n}) \rangle = \frac{Q}{4\pi}$$

- One-point in non-trivial state. Example: $|J_\mu\rangle$ **[Hofman, Maldacena 2008]**

$$\langle \mathcal{E}(\vec{n}) \rangle = \frac{Q}{4\pi} \left(1 - A(3\cos^2\theta - 1)\right) \geqslant 0 \qquad -\frac{1}{2} \leqslant A \leqslant 1$$

Interpolates between free fermion and free boson. In QCD **[Riembau, Son 2025]**



- Two-point $\qquad \vec{n}_1 \cdot \vec{n}_2 = \cos\theta = 1 - 2z, \quad z \in [0,1]$

$$\text{EEC}(z) = \int d^2\vec{n}_1 d^2\vec{n}_2 \delta(z - \tfrac{1}{2}(1 - \vec{n}_1 \cdot \vec{n}_2)) \langle \mathcal{E}(n_1)\mathcal{E}(n_2) \rangle = 1 + \sum_{J=1}^{\infty} C_J P_J(1-2z)$$

Definitions

Consider momentum eigenstates $P^\mu|\Psi\rangle = q^\mu \delta^{\mu 0}|\Psi\rangle$, $q^\mu = (Q,0)$

$$\langle \Psi'|\mathcal{E}(\vec{n}_1)\cdots\mathcal{E}(\vec{n}_n)|\Psi\rangle = \delta(q-q')\langle\mathcal{E}(\vec{n}_1)\cdots\mathcal{E}(\vec{n}_n)\rangle$$

and (unless specified) rotationally symmetric states with $Q=1$.

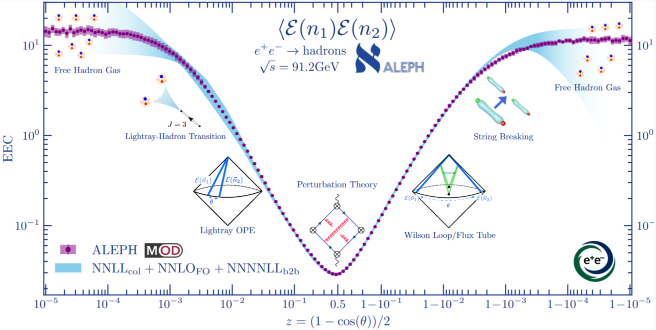
- In a theory with particles $d\sigma_{\Psi\to N} \geqslant 0$

$$\langle\mathcal{E}(\vec{n}_1)\mathcal{E}(\vec{n}_2)\cdots\mathcal{E}(\vec{n}_k)\rangle = \frac{1}{\sigma}\sum_{N=2}^{\infty}\int d\sigma_{\Psi\to N}\prod_{i=1}^{k}\left(\sum_{j=1}^{N}E_j\delta\Big(\frac{\vec{q}_j}{|\vec{q}_j|}-\vec{n}_i\Big)\right)$$

- In a general QFT (including CFT) [Korchemsky, Oderda, Sterman 1997]

$$\mathcal{E}(\vec{n}) = \lim_{r\to\infty} r^{d-2}\int_{-\infty}^{\infty} dt T_{0i}n^i(t, r\vec{n})$$

  is the simplest **light-ray operator** [Balitsky, Braun 1989]
  - Spectrum of light-ray operators in CFT $\leftrightarrow$ analyticity in spin, [Kravchuk, Simmons-Duffin 2018], ...
  - Light-ray OPE: $\mathcal{E}(\theta)\mathcal{E}(0) \sim \theta^{-2+\gamma(3)}\mathbb{O}_{J=3}$ [Hofman, Maldacena 2008], ...



- Measurement in $e^+e^- \to$ hadrons at LEP, $Q = m_Z$
- Purple: Precise angular resolution using ALEPH archival data **[Bossi et al 2025]**
- Blue: Theoretical analysis **[Jaarsma, Li, Moult, Waalewijn, Zhu 2025]**
- Probe of confinement at fixed energy: $\Lambda_{\text{eff}} \sim \theta Q$

Plan for the presentation

1. Background
2. **Positivity in energy correlators**
3. Two-point energy correlators and atomic models
4. Constraints on real-world data
5. Summary

Positivity in energy correlators

Main idea: $E^n C$ must fit into a "positive template"

Simplest conditions

- Energy and probability non-negative $\Rightarrow$ pointwise positive (non-negative)
- Unitarity $\Rightarrow$ lower bound $C_J \geqslant 0$ $\qquad (C_0 = 1)$

$$C_J = \frac{2J+1}{2} \int_{-1}^{1} d\cos\theta\, P_J(\cos\theta) \text{EEC}\left(\frac{1-\cos\theta}{2}\right)$$
$$= \frac{1}{4\pi} \int d^2\vec{n}_1 d^2\vec{n}_2 \sum_{m=-J}^{J} Y^*_{Jm}(\vec{n}_1) \langle \Psi | \mathcal{E}(\vec{n}_1) \mathcal{E}(\vec{n}_2) | \Psi \rangle Y_{Jm}(\vec{n}_2)$$
$$= \frac{1}{4\pi} \sum_{m=-J}^{J} \left| \int d^2\vec{n} Y_{Jm}(\vec{n}) \mathcal{E}(\vec{n}) | \Psi \rangle \right|^2 \geqslant 0$$

- Upper bound $C_J \leqslant 2J+1$ [Fox, Wolfram 1978]. For even J saturated by

$$\text{EEC}(z) = \frac{1}{2}\left(\delta(z) + \delta(z-1)\right)$$

Positive hierarchy of energy correlators

Hierarchy of energy correlators satisfying

- $\langle \mathcal{E}(\vec{n}_1) \cdots \mathcal{E}(\vec{n}_n) \rangle \geqslant 0$ (pointwise)
- $\langle \mathcal{E}(\vec{n}) \rangle = \frac{1}{4\pi}$
- Nested measure

$$\langle \mathcal{E}(\vec{n}_2) \cdots \mathcal{E}(\vec{n}_n) \rangle = \int d^2\vec{n}_1 \langle \mathcal{E}(\vec{n}_1)\mathcal{E}(\vec{n}_2) \cdots \mathcal{E}(\vec{n}_n) \rangle$$

- Commutativity $[\mathcal{E}(\vec{n}_i), \mathcal{E}(\vec{n}_j)] = 0$

Hewitt–Savage theorem [1955] implies the existence of a fundamental probability measure μ (cross-section to give an event) on the space of probability measures (energy distribution per event)

$$d\mu \sim \frac{1}{\sigma} \sum_{N=2}^{\infty} \int d\sigma_{\Psi \to N}(\vec{n}_1, \ldots \vec{n}_N), \qquad \vec{n}_i \in S^2$$

E^{n}C are moments of this distribution (similar ideas in [Hofman, Maldacena 2008])

Exists even in a theory without particles

Plan for the presentation

1. Background
2. Positivity in energy correlators
3. **Two-point energy correlators and atomic models**
4. Constraints on real-world data
5. Summary

Two-point energy correlators

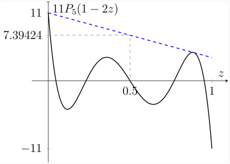
- So far $\cos\theta = 1 - 2z$

$$\text{EEC}(z) = 1 + \sum_{J=1}^{\infty} C_J P_J(1-2z), \qquad 0 \leqslant C_J \leqslant 2J+1$$

saturated for even J

- Non-trivial bounds for odd C_J [Dempsey, Karlsson, Pufu, Zahraee, Zhiboedov 2025] [Talk by Robin Karlsson]

$$\max C_J \sim (2J+1)\underbrace{\frac{1-J_0(j_{1,1})}{2}}_{0.70138}, \qquad \text{large } J \text{ odd}$$

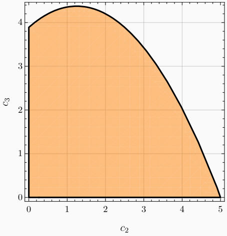


- Primal insight: maximum $C_3 = 4.375$ attained by

$$\text{EEC}(z) = \frac{1}{3}\left(\delta(z) + 2\delta(z - 3/4)\right)$$

corresponding to the fundamental measure

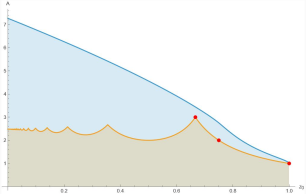
$$\mu = \mu_{\triangle} = \frac{1}{3}\left(\delta_{\phi_0} + \delta_{\phi_0+2\pi/3} + \delta_{\phi_0+4\pi/3}\right)$$

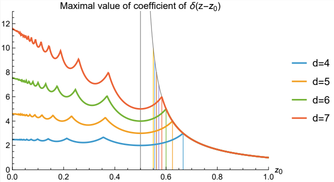


Relation to "atomic measures" [Winkler 1988]. Let us bound the simplest atomic model

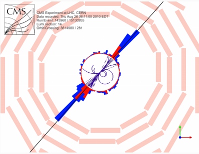
$$\mathrm{EEC}(z) \propto \delta(z) + A\delta(z - z_0)$$

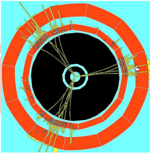
Weak bound on A follows from $$\left\langle \left(\int_{\delta\Omega_{\vec{n}_1}} d^2\vec{n}\,\mathcal{E}(\vec{n}) - \int_{\delta\Omega_{\vec{n}_2}} d^2\vec{n}\,\mathcal{E}(\vec{n}) \right)^2 \right\rangle \geq 0$$

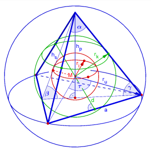


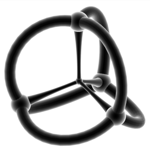


First peak in d dimensions: $(d-1)$-dimensional hypertetrahedron!









Bounds on the shape

Positive-definite functions: $\sum_{i,j} c_i^* c_j f(x_i, x_j) \geqslant 0$ [Gneiting 2011] $\leftrightarrow C_J \geqslant 0$

The next result states conditions that prohibit membership in the class Ψ_1, and therefore in any of the classes Ψ_d. Heuristically, the common motif can be paraphrased as follows:

> If a positive definite function admits a certain degree of smoothness at the origin, it admits the same degree of smoothness everywhere.

Let $\text{EEC}(z) = f(z)$

1. $f(z) \leqslant f(0)$. Proof $P_J(1-2z) \leqslant P_J(1)$
2. If $f'(0) = 0$, then $f(z) = 1$ for all z
3. Bounds on contact terms
   If $f(z) = A\delta(z) + \sum_i B_i \delta(z - z_i)$, then the B_i are bounded
4. Consequence of theorem 8a of [Gneiting 2011]
   If $f(z)$ is regular at $z = 0$ but has $\mathcal{C}^k$ discontinuity elsewhere, then it is not positive-definite
5. Theorem 8d of [Gneiting 2011], from [Devinatz 1959]
   If $f(\frac{1-\cos\theta}{2})$ extends to an even analytic function in θ of period $\neq 2\pi$, then it is not positive-definite

Bounds on the shape

Positive-definite functions: $\sum_{i,j} c_i^* c_j f(x_i, x_j) \geqslant 0$ [Gneiting 2011] $\leftrightarrow C_J \geqslant 0$

The next result states conditions that prohibit membership in the class Ψ_1, and therefore in any of the classes Ψ_d. Heuristically, the common motif can be paraphrased as follows:

> If a positive definite function admits a certain degree of smoothness at the origin, it admits the same degree of smoothness everywhere.

Let $\text{EEC}(z) = f(z)$

1. $f(z) \leqslant f(0)$. Proof $P_J(1-2z) \leqslant P_J(1)$
2. If $f'(0) = 0$, then $f(z) = 1$ for all z
3. Bounds on contact terms
   If $f(z) = A\delta(z) + \sum_i B_i \delta(z - z_i)$, then the B_i are bounded
4. Consequence of theorem 8a of [Gneiting 2011]
   If $f(z)$ is regular at $z = 0$ but has $\mathcal{C}^k$ discontinuity elsewhere, then it is not positive-definite
5. Theorem 8d of [Gneiting 2011], from [Devinatz 1959]
   If $f(\frac{1-\cos\theta}{2})$ extends to an even analytic function in θ of period $\neq 2\pi$, then it is not positive-definite

Bounds on the shape

Positive-definite functions: $\sum_{i,j} c_i^* c_j f(x_i, x_j) \geqslant 0$ [Gneiting 2011] $\leftrightarrow C_J \geqslant 0$

The next result states conditions that prohibit membership in the class Ψ_1, and therefore in any of the classes Ψ_d. Heuristically, the common motif can be paraphrased as follows:

> If a positive definite function admits a certain degree of smoothness at the origin, it admits the same degree of smoothness everywhere.

Let $\text{EEC}(z) = f(z)$

1. $f(z) \leqslant f(0)$. Proof $P_J(1-2z) \leqslant P_J(1)$
2. If $f'(0) = 0$, then $f(z) = 1$ for all z
3. Bounds on contact terms
   If $f(z) = A\delta(z) + \sum_i B_i \delta(z - z_i)$, then the B_i are bounded
4. Consequence of theorem 8a of [Gneiting 2011]
   If $f(z)$ is regular at $z = 0$ but has $\mathcal{C}^k$ discontinuity elsewhere, then it is not positive-definite
5. Theorem 8d of [Gneiting 2011], from [Devinatz 1959]
   If $f(\frac{1-\cos\theta}{2})$ extends to an even analytic function in θ of period $\neq 2\pi$, then it is not positive-definite

Bounds on the shape

Positive-definite functions: $\sum_{i,j} c_i^* c_j f(x_i, x_j) \geqslant 0$ [Gneiting 2011] $\leftrightarrow C_J \geqslant 0$

The next result states conditions that prohibit membership in the class Ψ_1, and therefore in any of the classes Ψ_d. Heuristically, the common motif can be paraphrased as follows:

> If a positive definite function admits a certain degree of smoothness at the origin, it admits the same degree of smoothness everywhere.

Let $\text{EEC}(z) = f(z)$

1. $f(z) \leqslant f(0)$. Proof $P_J(1-2z) \leqslant P_J(1)$
2. If $f'(0) = 0$, then $f(z) = 1$ for all z
3. Bounds on contact terms
   If $f(z) = A\delta(z) + \sum_i B_i \delta(z - z_i)$, then the B_i are bounded
4. Consequence of theorem 8a of [Gneiting 2011]
   If $f(z)$ is regular at $z = 0$ but has $\mathcal{C}^k$ discontinuity elsewhere, then it is not positive-definite
5. Theorem 8d of [Gneiting 2011], from [Devinatz 1959]
   If $f(\frac{1-\cos\theta}{2})$ extends to an even analytic function in θ of period $\neq 2\pi$, then it is not positive-definite

Bounds on the shape

Positive-definite functions: $\sum_{i,j} c_i^* c_j f(x_i, x_j) \geqslant 0$ [Gneiting 2011] $\leftrightarrow C_J \geqslant 0$

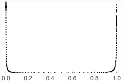
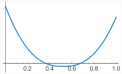
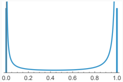
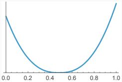
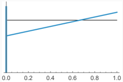
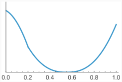
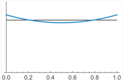
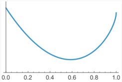
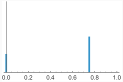
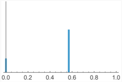
The next result states conditions that prohibit membership in the class Ψ_1, and therefore in any of the classes Ψ_d. Heuristically, the common motif can be paraphrased as follows:

> If a positive definite function admits a certain degree of smoothness at the origin, it admits the same degree of smoothness everywhere.

Let $\text{EEC}(z) = f(z)$

1. $f(z) \leqslant f(0)$. Proof $P_J(1-2z) \leqslant P_J(1)$
2. If $f'(0) = 0$, then $f(z) = 1$ for all z
3. Bounds on contact terms
   If $f(z) = A\delta(z) + \sum_i B_i \delta(z - z_i)$, then the B_i are bounded
4. Consequence of theorem 8a of [Gneiting 2011]
   If $f(z)$ is regular at $z = 0$ but has $\mathcal{C}^k$ discontinuity elsewhere, then it is not positive-definite
5. Theorem 8d of [Gneiting 2011], from [Devinatz 1959]
   If $f(\frac{1-\cos\theta}{2})$ extends to an even analytic function in θ of period $\neq 2\pi$, then it is not positive-definite

Positive and not-so-positive two-point energy correlators

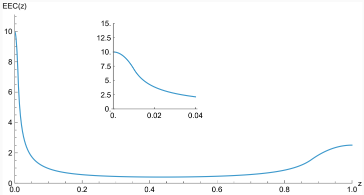
Allowed		Disallowed!	
	Experimentally measured (binned data)		Negative at some z_0
	1-loop QCD perturbative		Not attaining maximal value at $z = 0$
	Free particles at large multiplicity		$\mathcal{C}^k$ disc. at $z_0 \neq 0$ despite regular at $z = 0$
	Planar $\mathcal{N} = 4$ SYM at strong coupling		Counter example of theorem of [Devinatz 1959] [Gneiting 2011]
	Extremal solution maximizing C_3		Coefficient of $\delta(z - z_0)$ violating bound

Restoring positivity

Assume a theoretical interpolation model: 1) $A + Bz^2$, 2) $C/z^{1-\gamma/2}$, 3) $D\,\mathrm{EEC}(z)_{\text{1-loop QCD}}$, 4) $E + F(1-z)^2$. (7 parameters)

Impose normalisation and $\mathcal{C}^0$, $\mathcal{C}^1$ continuity at $z = 0.01,\ 0.1,\ 0.88$

$$C_0 = 1, \quad C_1 = 0.00448, \quad C_2 = 0.3662, \quad C_3 = 0.094, \quad C_4 = 0.1440, \ldots$$



Violates some of our conditions!

Indeed: Find $C_{18} = -0.00163 < 0$ (!)

- Rescue 1: add contact term $A_\delta \delta(z)$

$$C_J \to \frac{1}{1 + A_\delta}\left(C_J + (2J+1)A_\delta\right)$$

- Rescue 2: Force C_J positive for $J \geqslant 18$ (new convergent sum)
  Result: Builds a peak at small z

Assume a theoretical interpolation model: 1) $A + Bz^2$, 2) $C/z^{1-\gamma/2}$, 3) $D\,\mathrm{EEC}(z)_{\text{1-loop QCD}}$, 4) $E + F(1-z)^2$. (7 parameters)

Impose normalisation and $\mathcal{C}^0$, $\mathcal{C}^1$ continuity at $z = 0.01,\ 0.1,\ 0.88$

$$C_0 = 1, \quad C_1 = 0.00448, \quad C_2 = 0.3662, \quad C_3 = 0.094, \quad C_4 = 0.1440, \ldots$$

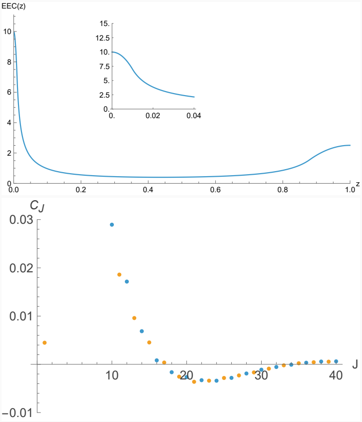
Violates some of our conditions!

Indeed: Find $C_{18} = -0.00163 < 0$ (!)

- Rescue 1: add contact term $A_\delta \delta(z)$

$$C_J \to \frac{1}{1+A_\delta}\left(C_J + (2J+1)A_\delta\right)$$

- Rescue 2: Force C_J positive for $J \geqslant 18$ (new convergent sum)
  Result: Builds a peak at small z



Restoring positivity

Assume a theoretical interpolation model: 1) $A + Bz^2$, 2) $C/z^{1-\gamma/2}$, 3) $D\,\mathrm{EEC}(z)_{\text{1-loop QCD}}$, 4) $E + F(1-z)^2$. (7 parameters)

Impose normalisation and $\mathcal{C}^0$, $\mathcal{C}^1$ continuity at $z = 0.01,\ 0.1,\ 0.88$

$$C_0 = 1, \quad C_1 = 0.00448, \quad C_2 = 0.3662, \quad C_3 = 0.094, \quad C_4 = 0.1440, \ldots$$

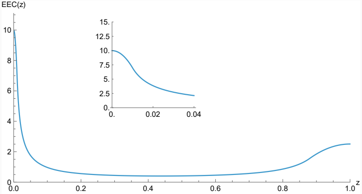
Violates some of our conditions!

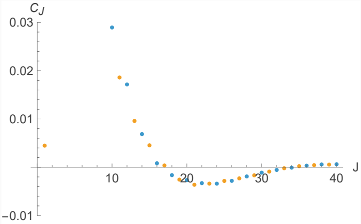
Indeed: Find $C_{18} = -0.00163 < 0$ (!)

- Rescue 1: add contact term $A_\delta \delta(z)$

$$C_J \to \frac{1}{1 + A_\delta}\left(C_J + (2J+1)A_\delta\right)$$

- Rescue 2: Force C_J positive for $J \geqslant 18$ (new convergent sum)
  Result: Builds a peak at small z





Restoring positivity

Assume a theoretical interpolation model: 1) $A + Bz^2$, 2) $C/z^{1-\gamma/2}$, 3) $D\,\mathrm{EEC}(z)_{\text{1-loop QCD}}$, 4) $E + F(1-z)^2$. (7 parameters)

Impose normalisation and $\mathcal{C}^0$, $\mathcal{C}^1$ continuity at $z = 0.01,\ 0.1,\ 0.88$

$$C_0 = 1, \quad C_1 = 0.00448, \quad C_2 = 0.3662, \quad C_3 = 0.094, \quad C_4 = 0.1440, \ldots$$

Violates some of our conditions!

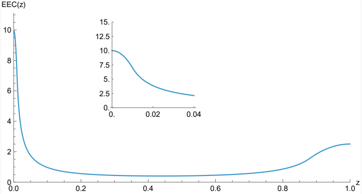
Indeed: Find $C_{18} = -0.00163 < 0$ (!)

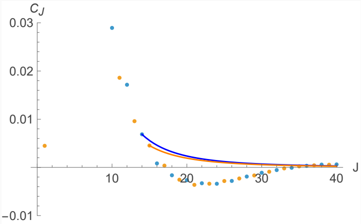
- Rescue 1: add contact term $A_\delta \delta(z)$

$$C_J \to \frac{1}{1 + A_\delta}\left(C_J + (2J+1)A_\delta\right)$$

- Rescue 2: Force C_J positive for $J \geqslant 18$ (new convergent sum)

  Result: Builds a peak at small z





Restoring positivity

Assume a theoretical interpolation model: 1) $A + Bz^2$, 2) $C/z^{1-\gamma/2}$, 3) $D\,\mathrm{EEC}(z)_{\text{1-loop QCD}}$, 4) $E + F(1-z)^2$. (7 parameters)

Impose normalisation and $\mathcal{C}^0$, $\mathcal{C}^1$ continuity at $z = 0.01,\ 0.1,\ 0.88$

$$C_0 = 1, \quad C_1 = 0.00448, \quad C_2 = 0.3662, \quad C_3 = 0.094, \quad C_4 = 0.1440, \ldots$$

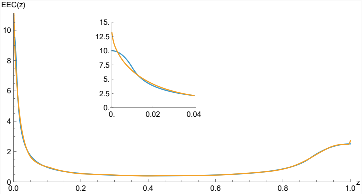
Violates some of our conditions!

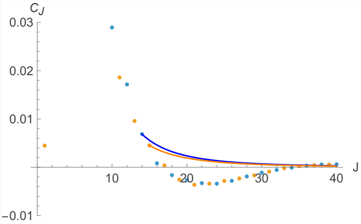
Indeed: Find $C_{18} = -0.00163 < 0$ (!)

- Rescue 1: add contact term $A_\delta \delta(z)$

$$C_J \to \frac{1}{1 + A_\delta}\left(C_J + (2J+1)A_\delta\right)$$

- Rescue 2: Force C_J positive for $J \geqslant 18$ (new convergent sum)
  Result: Builds a peak at small z

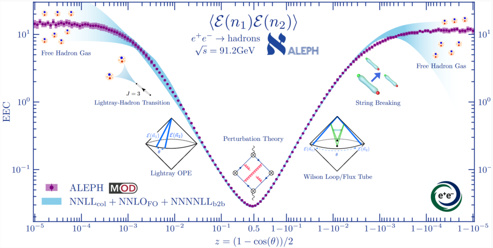


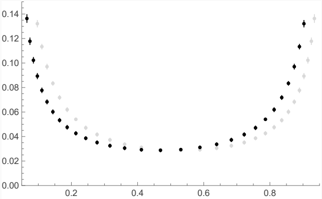


Plan for the presentation

1. Background
2. Positivity in energy correlators
3. Two-point energy correlators and atomic models
4. **Constraints on real-world data**
5. Summary

Constraining contact term





Measurements on tracks (only $q \neq 0$ particles) **[Bossi et al 2025]**

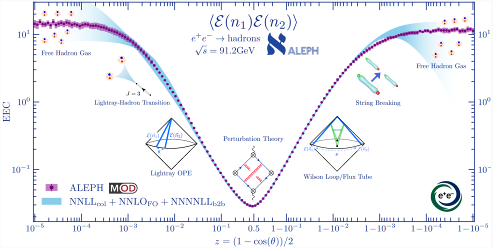
Measured distribution is skewed to the right

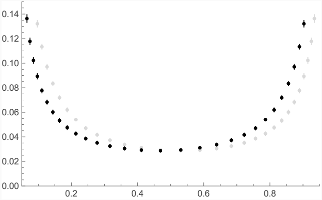
$\Rightarrow C_1 \propto \int dz(1-2z)\text{EEC}(z) < 0 \quad \Rightarrow \quad$ Add $A_\delta \delta(z)$

$$\text{EEC}(z) = A_\delta \delta(z) + \sum_{J=0}^{\infty} A_J P_J(1-2z)$$

and impose $C_J = (2J+1)A_\delta + A_J \geqslant 0$

Constraining contact term





Measurements on tracks (only $q \neq 0$ particles) **[Bossi et al 2025]**

Measured distribution is skewed to the right

$\Rightarrow C_1 \propto \int dz(1-2z)\text{EEC}(z) < 0 \quad \Rightarrow \quad$ Add $A_\delta \delta(z)$

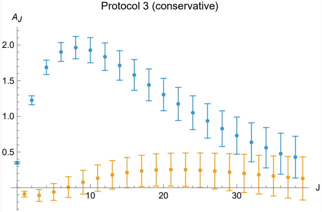
$$\text{EEC}(z) = A_\delta \delta(z) + \sum_{J=0}^{\infty} A_J P_J(1-2z)$$

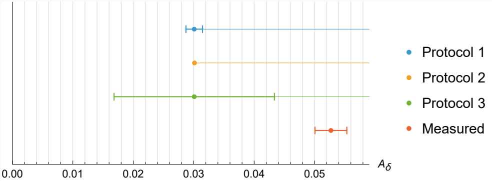
and impose $C_J = (2J+1)A_\delta + A_J \geqslant 0$

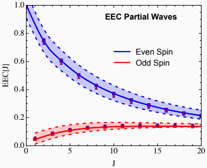
Constraining contact term

$$\mathrm{EEC}(z) = A_\delta \delta(z) + \sum_{J=0}^{\infty} A_J P_J(1-2z)$$

Strategy: Add A_δ and impose $C_J = (2J+1)A_\delta + A_J \geqslant 0$







$$A_\delta \gtrsim 0.030$$

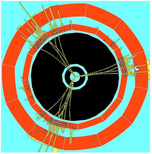
$$\nu_{q\neq 0,\mathrm{eff}} = \sqrt{C_0} \gtrsim 0.63,$$

$$N_{q\neq 0,\mathrm{eff}} = \frac{\sqrt{C_0}}{A_\delta} \lesssim 21.2$$

[Jaarsma, Li, Moult, Waalewijn, Zhu 2025]

Summary

- Energy correlators are well-defined observables in almost any theory considered in high-energy physics
- They must fit in a consistent hierarchy deriving from a (hidden) probability distribution
- We derived general bounds on partial-wave coefficients C_J and shape of two-point energy correlators
- For experimental data, our bunds imply a lower bound on contact term
- For CFT, constraints on OPE coefficients and a species bound **[In progress]**



$$\mathrm{E}^n\mathrm{C}(\vec{n}_1,\ldots,\vec{n}_n) = \langle\Psi|\mathcal{E}(\vec{n}_1)\cdots\mathcal{E}(\vec{n}_n)|\Psi\rangle$$

Thank you for your attention!