$|M_{H(0)}|^2$
Factorization Scale

\[ 2 \Re \left( M_{H(0)}^*(1) H + 1 \right) M_{H(0)} \]

\[ 2 \Re \left( M_{H(0)}^*(2) H + 2 \right) M_{H(0)} \]

\[ \left| M_{H(0)}^* \right|^2 \]

Factorization Scale
Higher-Order Corrections

\[ |M_{H}^{(0)}|^2 \]

Factorization Scale
Higher-Order Corrections

$|M_{H}^{(0)}|^2$

Factorization Scale

- Unitarity
- Leading Singular
- Structure of Gauge Theory
- $\beta \neq 0$
- Leading Color
Higher-Order Corrections

\[ |M_{H}^{(0)}|^2 \]

Shower Evolution

Factorization Scale

<table>
<thead>
<tr>
<th>Unitarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leading Singular</td>
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</tr>
</tbody>
</table>

Peter Skands (QCD/Pheno)
Higher-Order Corrections

\[ 2 \text{Re} \left[ M_H^{(1)} M_H^{(0)*} \right] \]

\[ |M_{H+2}^{(0)}|^2 |M_{H+3}^{(0)}|^2 \]

\[ |M_{H+1}^{(0)}|^2 \]

Shower Evolution

Factorization Scale

Hadronization

Unitarity
Leading Singular
Structure of Gauge Theory
B ≠ 0
Leading Color

Peter Skands (QCD/Pheno)
Higher-Order Corrections

Unitarity
Leading Singular Structure of Gauge Theory
\( \beta \neq 0 \)
Leading Color
Higher-Order Singular Structures

\[
\begin{align*}
|M_{H+2}^{(0)}|^2 |M_{H+3}^{(0)}|^2 \\
|M_{H+1}^{(0)}|^2 \\
2\text{Re} \left[ M_{H+1}^{(1)} M_{H+1}^{(0)*} \right] \\
2\text{Re} \left[ M_{H+2}^{(1)} M_{H+2}^{(0)*} \right]
\end{align*}
\]
Higher-Order Corrections

Factorization Scale

Hadronization

Shower Evolution

2Re \[ M_{H+2}^{(0)} M_{H+3}^{(0)} \]

2Re \[ M_{H+1}^{(1)} M_{H+1}^{(0)*} \]

2Re \[ M_{H+2}^{(1)} M_{H+2}^{(0)*} \]

\[ |M_H^{(0)}|^2 \]

\[ |M_H^{(0)}| \]

\[ |M_{H+1}^{(0)}|^2 \]

\[ |M_{H+2}^{(0)}|^2 \]

Higgs Boson

Unitarity

Leading Singular Structures of Gauge Theory

Leading Color

\( \beta \neq 0 \)

Higher-Order Singular Structures

Peter Skands (QCD/Pheno)

The VINCIA Code

Giele, Kosower, PS

Gehrmann-de-Ridder, Ritzmann, PS

Factorization Scale
Higher-Order Corrections

\[ |M_{H+2}^{(0)}|^2 |M_{H+3}^{(0)}|^2 \]
\[ |M_{H+1}^{(0)}|^2 \]
\[ 2 \text{Re} \left[ M_{H+1}^{(1)} M_{H+1}^{(0)*} \right] \]
\[ 2 \text{Re} \left[ M_{H+2}^{(1)} M_{H+2}^{(0)*} \right] \]

Shower Evolution

Factorization Scale

Hadronization

Unitarity
Leading Singular Structure of Gauge Theory
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Leading Color
Higher-Order Singular Structures

The VINCI Code
Giele, Kosower, PS
Gehrmann-de-Ridder, Ritzmann, PS

Peter Skands (QCD/Pheno)

Sjöstrand, Ask, Corke, Mrenna, PS
PYTHIA
Higher-Order Corrections

- Shower Evolution
  - $|M_{H+2}^{(0)}|^2 |M_{H+3}^{(0)}|^2$
  - $|M_{H+1}^{(0)}|^2$
  - $2 \text{Re} \left[ M_{H+1}^{(1)} M_{H+1}^{(0)*} \right]$
  - $2 \text{Re} \left[ M_{H+2}^{(1)} M_{H+2}^{(0)*} \right]$
  - $|M_{H}^{(0)}|^2$
  - $2 \text{Re} \left[ M_{H}^{(1)} M_{H}^{(0)*} \right]$

- Hadronization
  - Unitarity
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  - Giele, Kosower, PS
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- PYTHIA
  - Sjöstrand, Ask, Corke, Mrenna, PS

- Collider Observables
Higher-Order Corrections

Shower Evolution

2Re \[ M_H^{(0)} M_H^{(0)*} \]

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2Re \[ M_{H+2}^{(1)} M_{H+2}^{(0)*} \]

Hadronization

Giele, Kosower, PS
Gehrmann-de-Ridder, Ritzmann, PS

The VINCIA Code

Sjöstrand, Ask, Corke, Mrenna, PS
PYTHIA
Collider Observables
Confrontation with Data

Peter Skands (QCD/Pheno)
Early LHC Data

- CMS “Ridge”
- Track multiplicities
- $p_T$ spectra
- Identified Particles
- Baryon Transport
- Correlations
- Central vs Forward
- Collective Effects?
- Color Correlations
- Rapidity Gaps
Early LHC Data

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Early LHC Data

Minimum-Bias
~ All collisions with \( \geq 1 \) track

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Minimum-Bias
~ All collisions with \( \geq 1 \) track

It’s a simple question:
What does the average LHC collision look like?
Early LHC Data

Minimum-Bias
~ All collisions with ≥ 1 track

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NO HARD SCALE
Extremely sensitive to IR effects
→ Excellent LAB for studying IR effects
Early LHC Data

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+ universality → can constrain models and re-use for hard processes