GenEvA

A New Framework for Event Generation

Jesse Thaler (Berkeley)

with Christian Bauer and Frank Tackmann

arXiv:0801.4026 [Physics]

arXiv:0801.4028 [Techniques]

Background Estimation

Essential for Understanding BSM signals at LHC

Partonic Strategy

Hadronic Strategy

Background Estimation

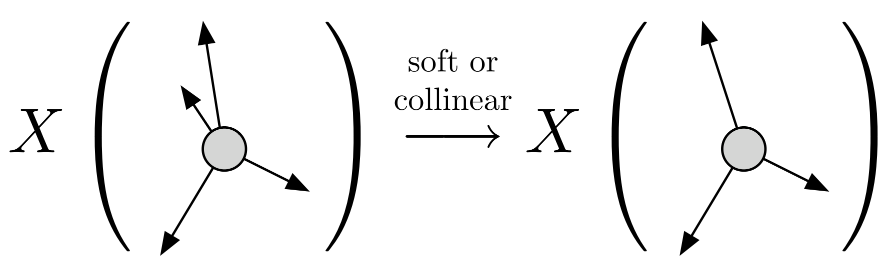
Essential for Understanding BSM signals at LHC

Partonic Strategy

Inclusive Measurement Function

$$\sigma_X = \sum_n \int d\Phi_n \left|\mathcal{M}_n\right|^2 X(\Phi_n)$$

Well-Defined if Infrared Safe



Infrared Divergences Cancel

$$\left|\mathcal{M}^{\text{loop}}\right|^2 X(\Phi) + \int_{+1} \left|\mathcal{M}^{\text{tree}}\right|^2 X(\Phi_{+1}) = \text{finite}$$

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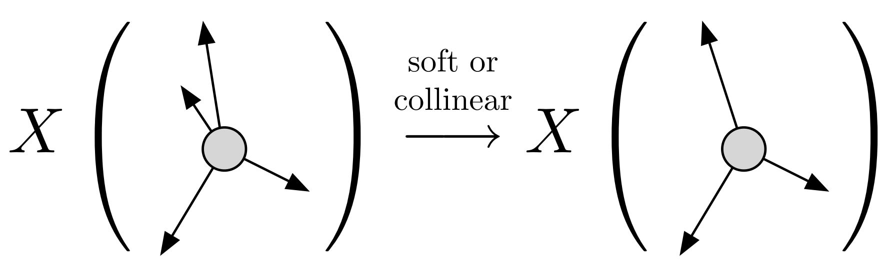

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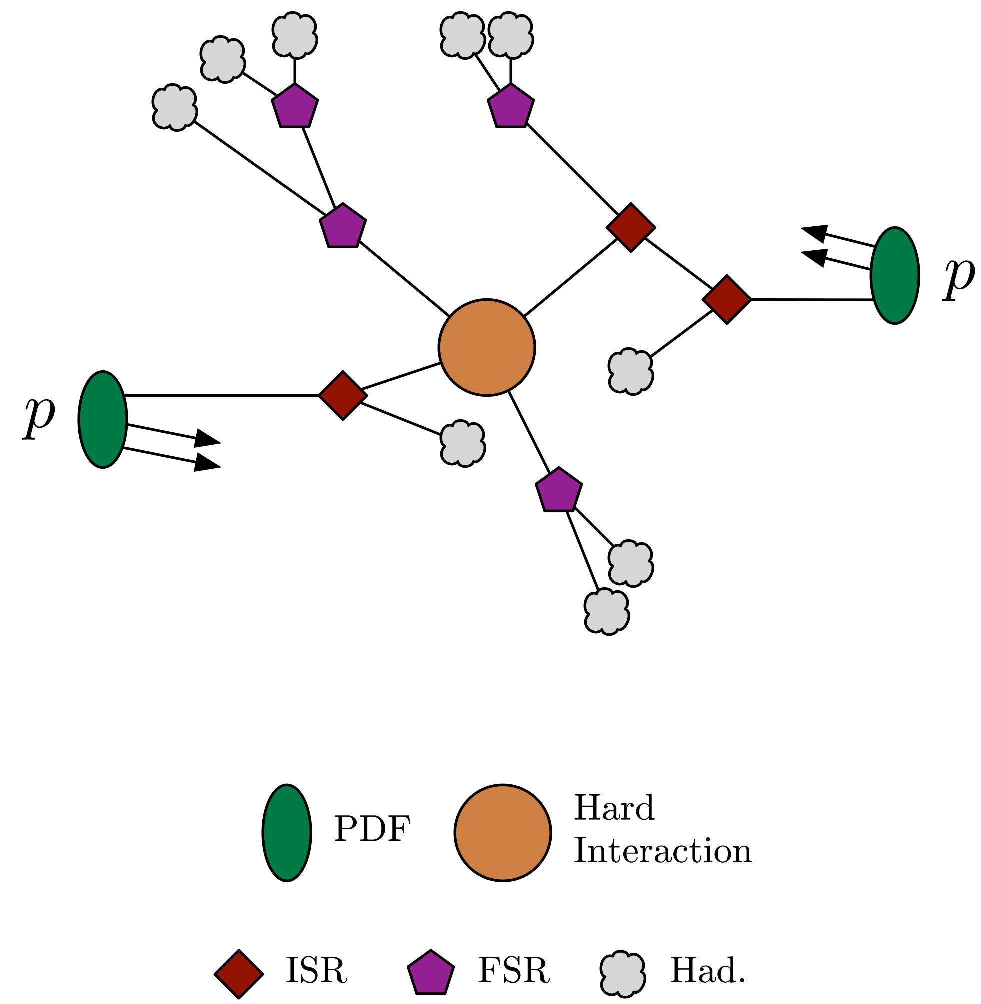
Hadronic Strategy

Exclusive Event Generation



Background Estimation

Essential for Understanding BSM signals at LHC

Partonic Strategy

Inclusive Measurement Function

+ Completely Well-Defined
+ Can quantify showering & hadronization uncertainties using factorization (SCET)
– Requires strictly infrared safe observables
– Assumes same experimental and theoretical protocols
– Need to do separate calculation for each observable

Hadronic Strategy

Exclusive Event Generation

+ Gives reasonable answers for any experimental observable
+ Can be used directly with detector simulation
– Requires care in interpreting results
– Difficult to attach meaningful error bars
– Challenging to include higher order corrections

“Ideal” Strategy

Exclusive event generator that reproduces the results of any inclusive measurement function to the calculated accuracy.

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N^jLL : Resummation of $\alpha_s^n \log^{2n-j} r$ terms

(r is ratio of kinematic scales)

Fully hadronized events (exclusive) using best perturbative calculations (inclusive).

MC@NLO is a concrete example in this direction for NLO/LL calculations (see also POWHEG)

"Ideal" is Not Generic

LO/LL :

CKKW(-L), MLM, SMPR, ...

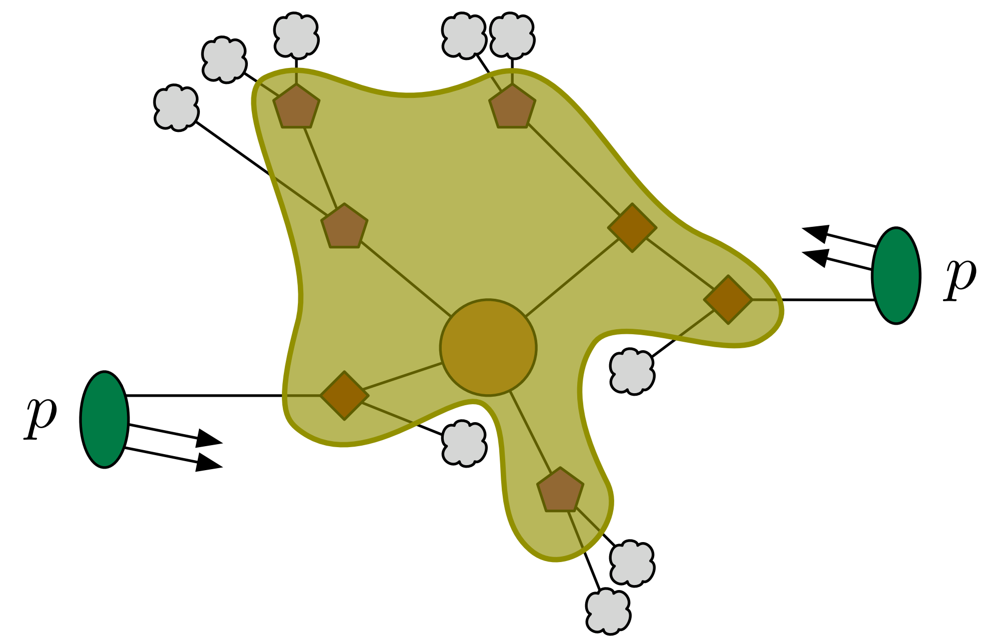
NLO/LL :

MC@NLO, POWHEG, ...

NLO/LO/LL :

Nagy & Soper, VINCIA, ...

Different algorithmic procedures for each strategy



Yet all formally equivalent

"Universal" Monte Carlo:

Framework to accomodate any* theory calculation?

GenEvA Prototype

Towards a "universal" Monte Carlo tool

$$e^+e^- \to n \text{ jets}$$

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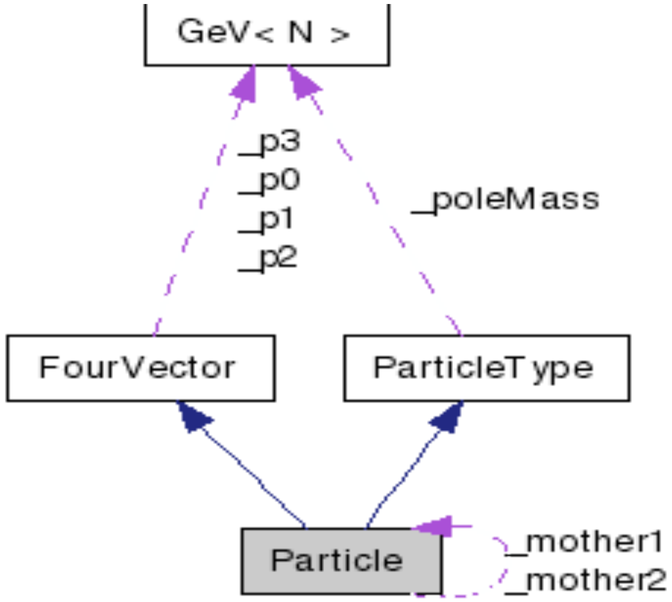

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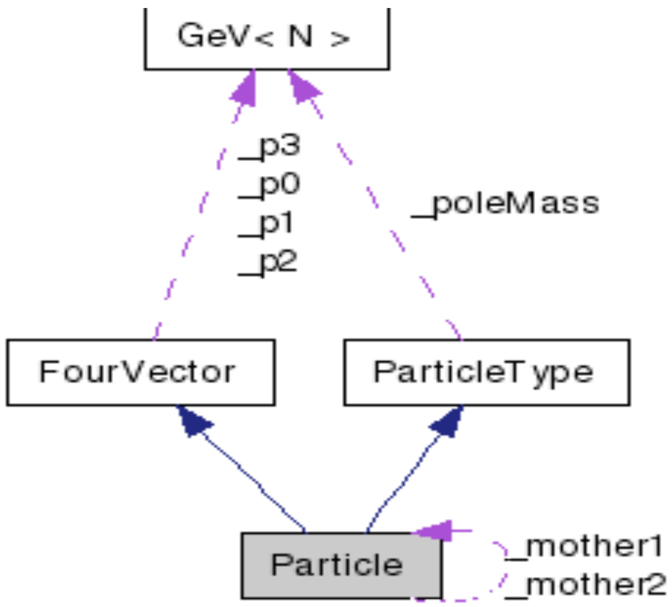

Actual Calculations

```
+-----  Run Statistics
| Process:     Sigma +/- dS (pb)
|  Global:  0.253007 +/- 0.001779
|      2j:  0.089849 +/- 0.001760
|      3j:  0.129731 +/- 0.001333
|      4j:  0.029322 +/- 0.000462
|      5j:  0.003693 +/- 0.000104
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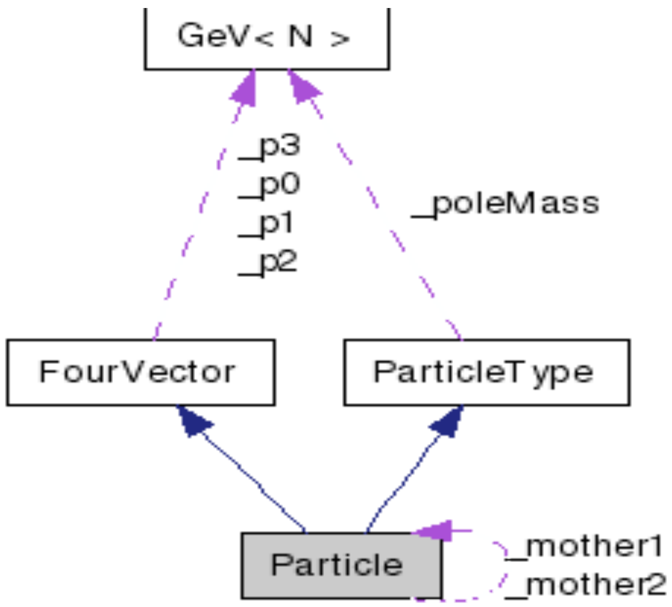

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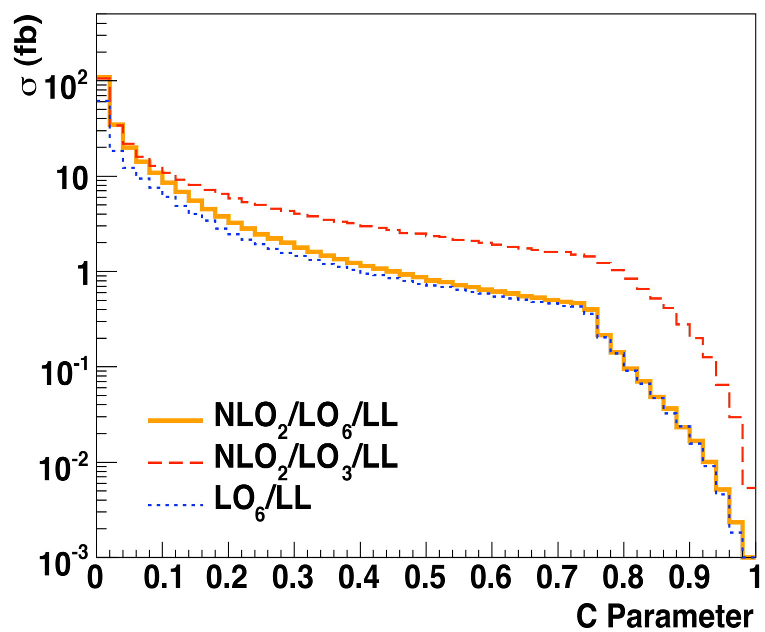

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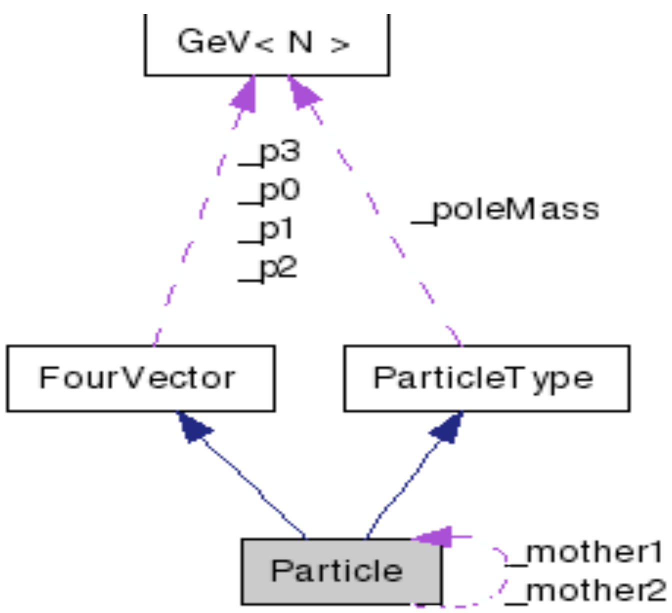

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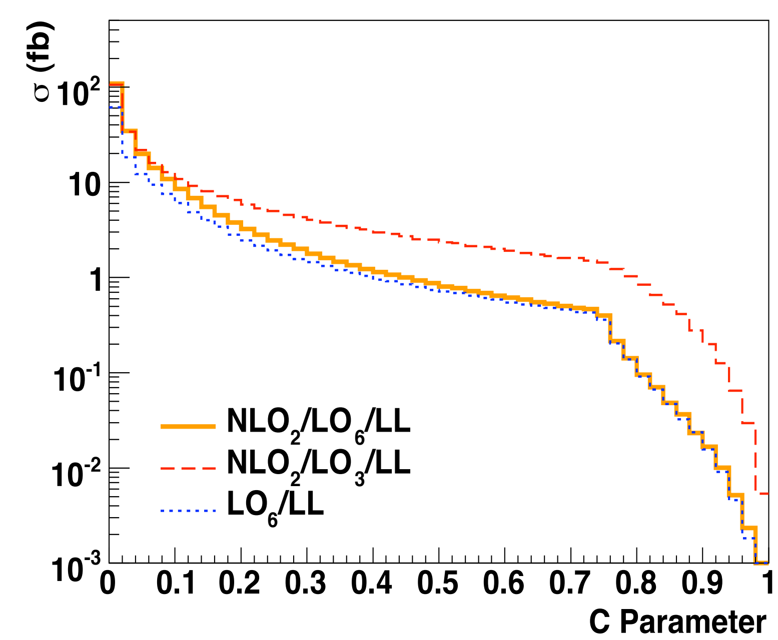


Not actually useful for the Tevatron or LHC... yet.

GENerate EVents Analytically

- Universal Monte Carlo
  - Merging Partonic and Hadronic Strategies
  - Why GenEvA?
- Approximating Amplitudes
  - Diagram Visualization
  - Calculations vs. Algorithms
- The GenEvA Strategy
  - Monte Carlo as Effective Theory
  - Results! NLO/LO/LL Example
- (Future Directions)
  - (The NLO Cascade)
  - (Heavy Resonances & Hadronic Collisions)

GENerate EVents Analytically

GenEvA is a Universal Monte Carlo tool...

...with a built-in amplitude approximation scheme...

...yielding an efficient, versatile, and improvable event generator.

Universal Monte Carlo

Merging Partonic and Hadronic Strategies

Key Assumption

Meaningful Parton → Hadron Map

Strictly speaking, only well defined quantity is

$$e^+e^- \to \text{hadrons}$$

Assume this is well approximated by

$$e^+e^- \to \text{partons} \to \text{hadrons}$$

This violates quantum mechanics, but good enough for jet-based measurements. Proved in certain cases with pQCD/SCET factorization.

Universal Monte Carlo

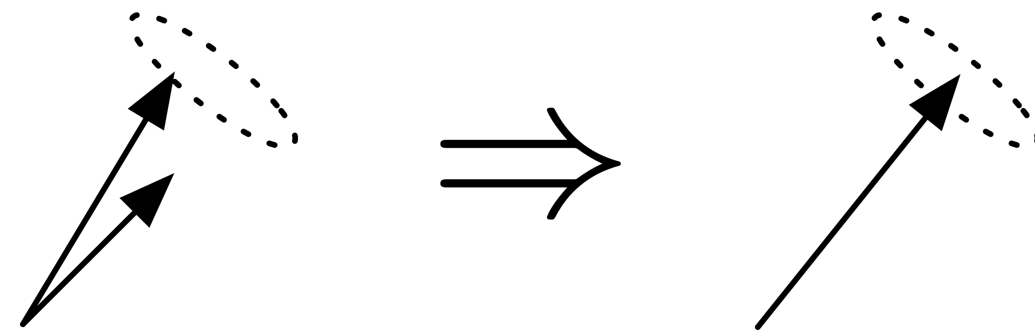
Regulated Partonic Phase Space with Hadronization

E_{CM}

Perturbative QCD

Λ_{QCD}

Hadronization



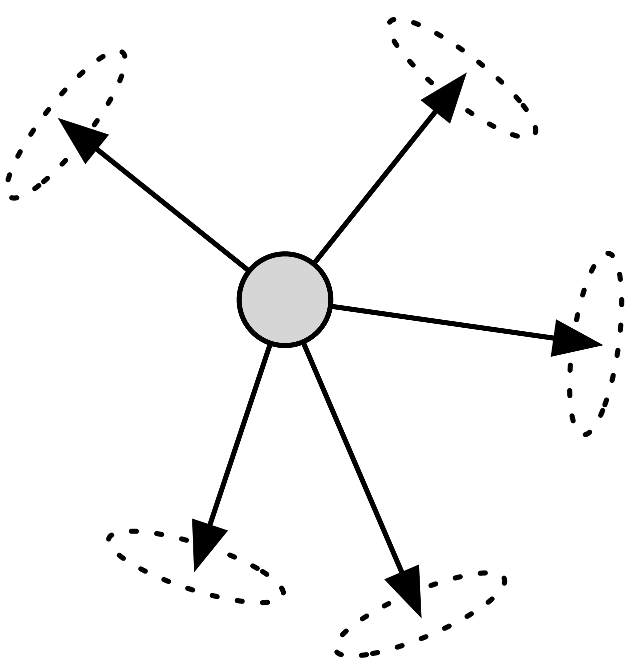
$$(p_i + p_j)^2 < \Lambda_{\mathrm{QCD}}^2$$

Integrate out partonic phase space below Λ_{QCD} and replace with some hadronization model.

Universal Monte Carlo

Regulated Partonic Phase Space with Hadronization

$$\mathrm{d}\sigma = \mathrm{Had}\left[\sum_{n=2}^{n_{\mathrm{total}}} \left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2 \mathrm{d}\Phi_n(\Lambda_{\mathrm{QCD}})\right]$$



$$\left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2 = \left|\mathcal{M}_n\right|^2 + \int_{\Lambda_{\mathrm{QCD}}} \left|\mathcal{M}_{n+1}\right|^2 + \cdots$$

$$d\Phi_n(\Lambda_{\mathrm{QCD}}) = d\Phi_n \, \theta\left((p_i + p_j)^2 > \Lambda^2_{\mathrm{QCD}}\right)$$

$$n_{\mathrm{total}} = \frac{\Lambda_{\mathrm{QCD}}}{E_{\mathrm{CM}}}$$

This is the best approximation to hadronic observables assuming a probabilistic parton → hadron map.

Trivial Version of UMC

$$\mathrm{d}\sigma = \mathrm{Had}\left[\sum_{n=2}^{n_{\mathrm{total}}} \left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2 \mathrm{d}\Phi_n(\Lambda_{\mathrm{QCD}})\right]$$

1. Choose random integer n between 2 and n_{total}
2. Pick a random point in n-body Lorentz invariant phase space, subject to Λ_{QCD} constraint
3. Assign that point a weight

$$w_{\mathrm{point}} = \frac{\left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2}{\mathcal{P}(n, \Phi_n)} \qquad \mathcal{P}(n, \Phi_n) = \frac{1}{n_{\mathrm{total}} - 1} \frac{1}{\int d\Phi_n(\Lambda_{\mathrm{QCD}})}$$

4. Run hadronization scheme on phase space point

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Cross section for any measurement:

$$\sigma_X = \langle w_{\text{point}} X_{\text{point}} \rangle$$

Trivial Version of UMC

Works on paper, but completely impractical!

$$\sigma_{\text{total}} = \langle w \rangle \qquad \delta\sigma_{\text{total}} = \sqrt{\frac{\langle w^2 \rangle - \langle w \rangle^2}{N}}$$

Minimize error if weight distribution peaks at one value

$$w = \frac{\left|\mathcal{M}_n(\Lambda_{\text{QCD}})\right|^2}{\mathcal{P}(n, \Phi_n)}$$

Flat phase space is really inefficient!

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Flat phase space is really inefficient!

GenEvA (which is a UMC) solves this problem by choosing a probability distribution that knows about the singularity and symmetry structure of QCD.

Trivial Version of UMC

Ok, it might be practical, but it needs too much information.

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$\left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2$ only known for $n \leq n_{\mathrm{max}} \ll n_{\mathrm{total}}$

$\left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2$ usually only known to tree level
(loop if we're lucky,
two loop if we're really lucky)

UMC useless unless we can approximate all orders amplitudes.

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Pythia/Herwig/etc. work well out of the box because they contain really good amplitude approximations.

GenEvA is a Universal Monte Carlo that takes user-specified partial amplitudes and creates full amplitude approximations out of them.

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If you don't like the way that GenEvA approximates amplitudes, no problem. Create a user-specified full amplitude, and GenEvA will use that instead.

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GenEvA is a Universal Monte Carlo tool...

$$\mathrm{d}\sigma = \mathrm{Had}\left[\sum_{n=2}^{n_{\text{total}}} \left|\mathcal{M}_n(\Lambda_{\text{QCD}})\right|^2 \mathrm{d}\Phi_n(\Lambda_{\text{QCD}})\right]$$

...with a built-in amplitude approximation scheme...

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Approximating Amplitudes

From Loops & Legs to Running & Matching

Diagram Visualization

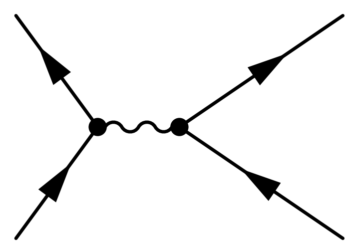
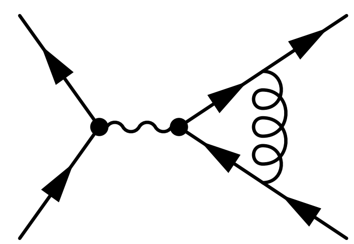
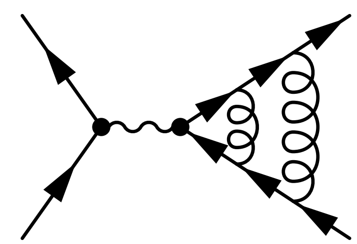
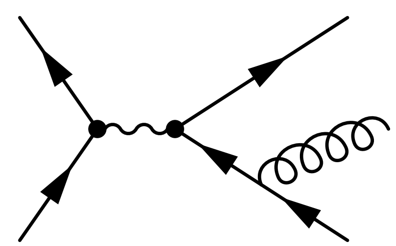
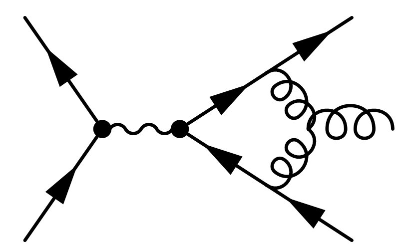
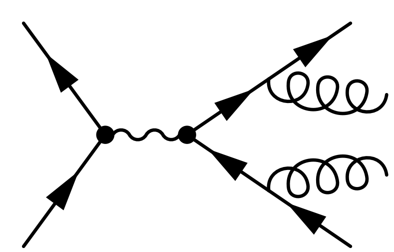
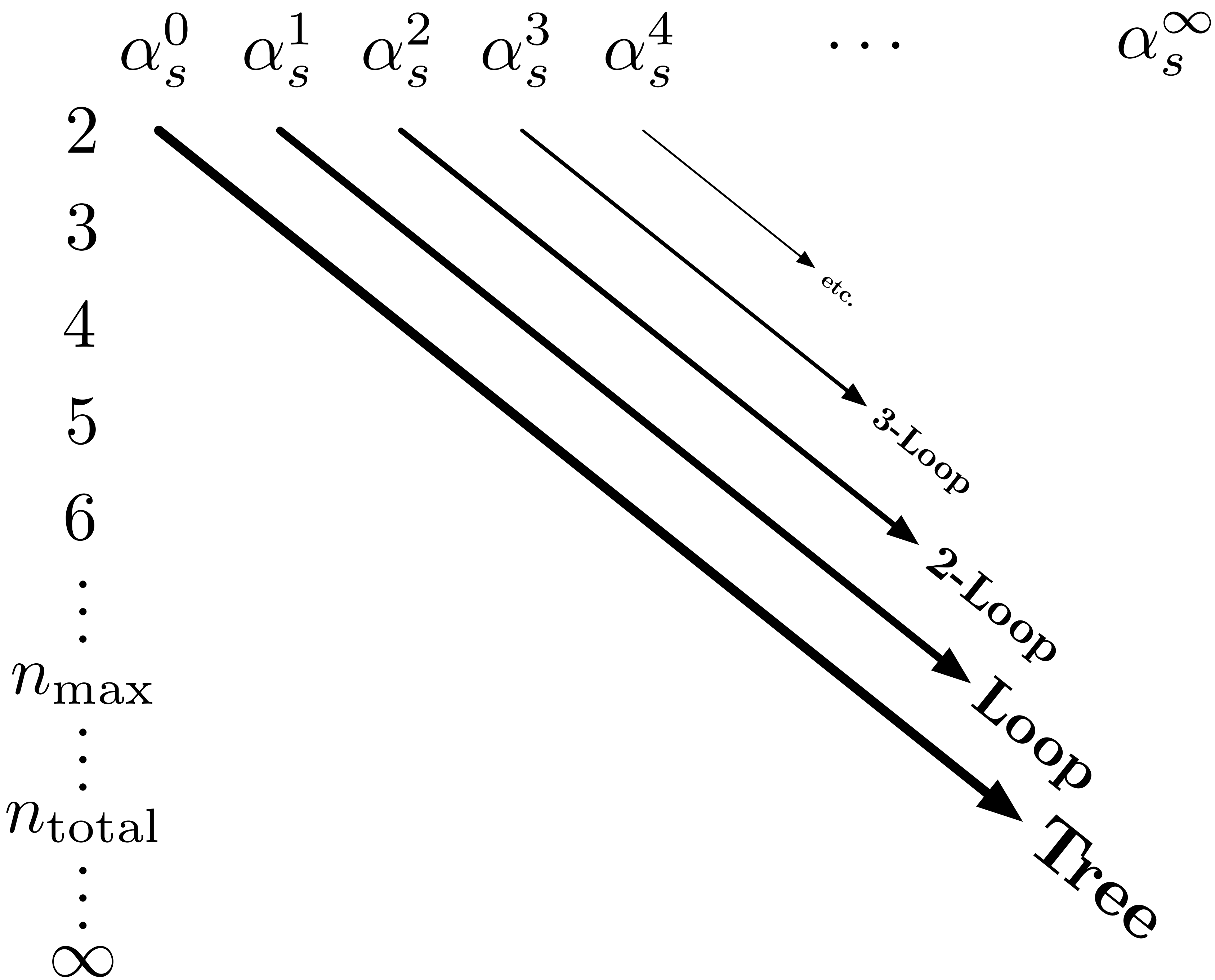
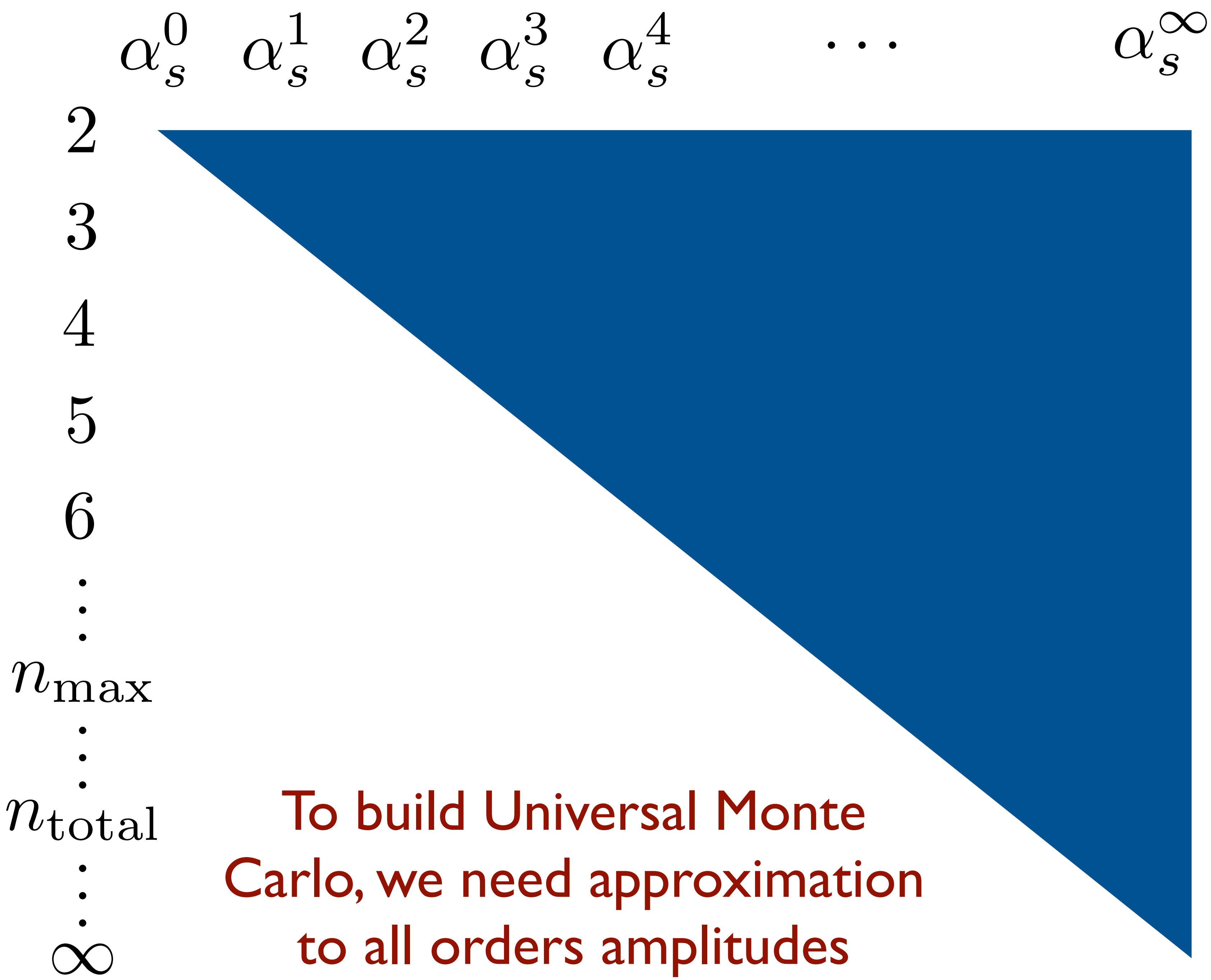
	α_s^0	α_s^1	α_s^2	$\cdots$
2 body				$\cdots$
3 body				$\cdots$
4 body				$\cdots$
$\vdots$				$\ddots$

Diagram Visualization

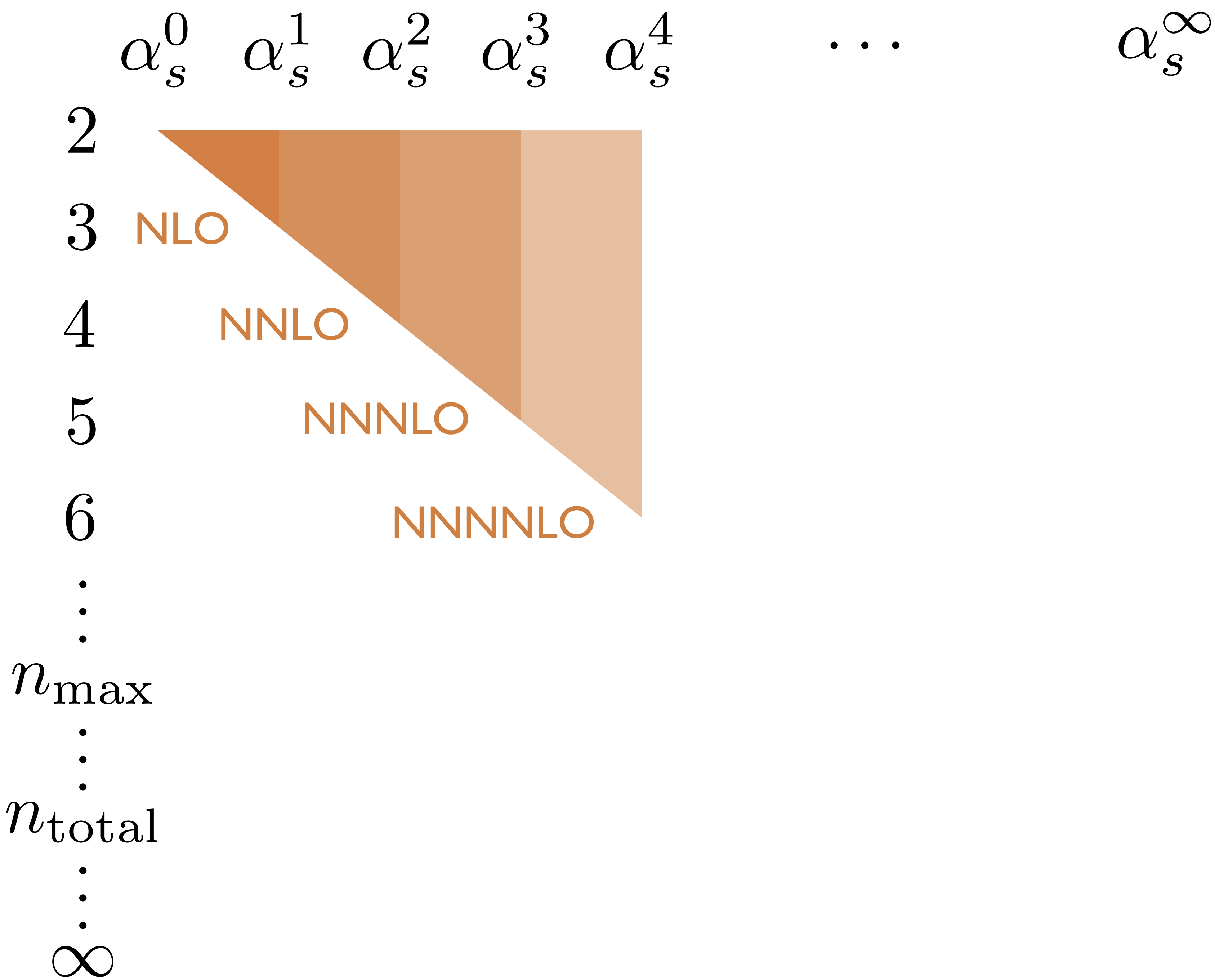


Universal Monte Carlo?

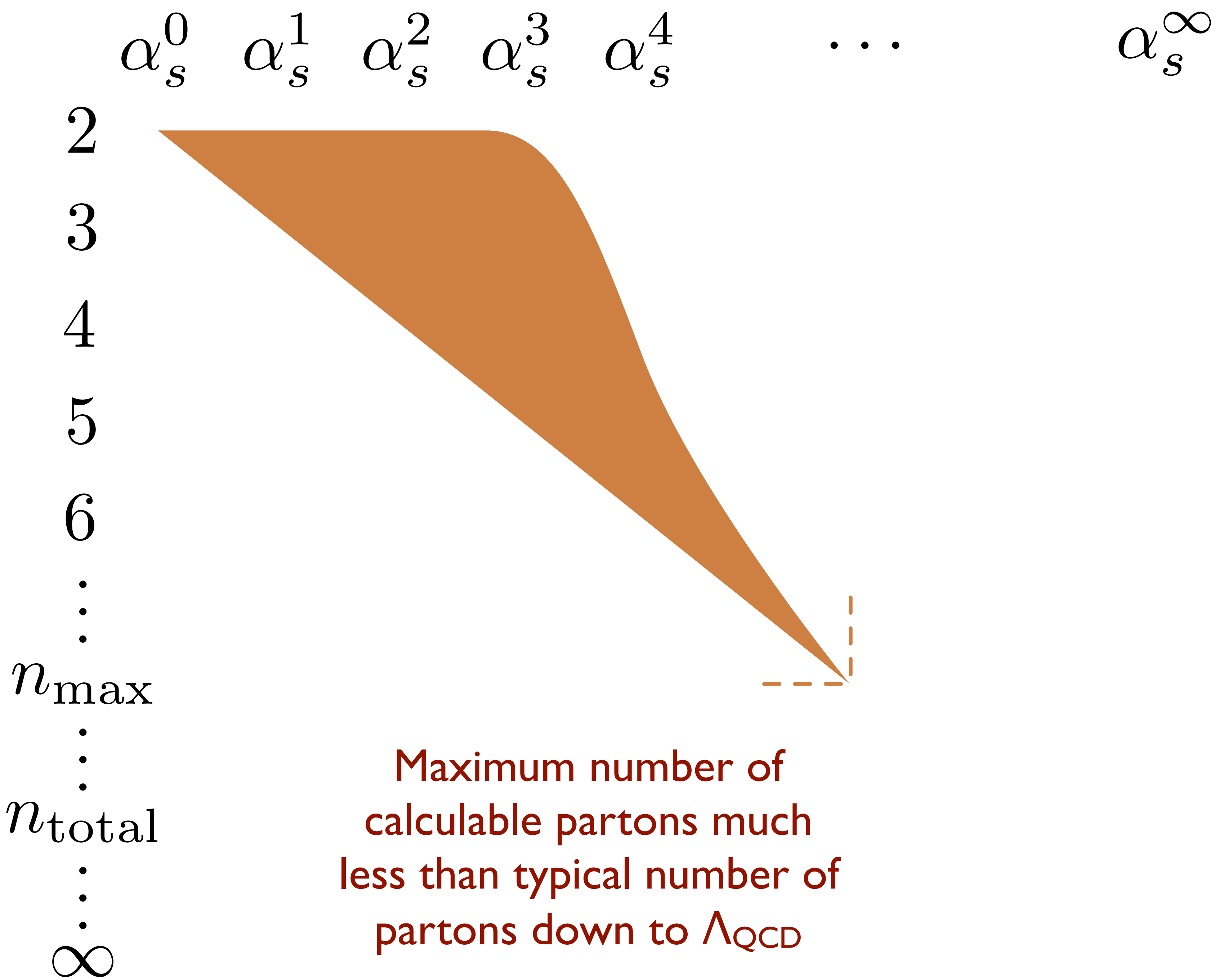


To build Universal Monte Carlo, we need approximation to all orders amplitudes

Fixed-Order Calculations (N^{i}LO)



Known Diagrams



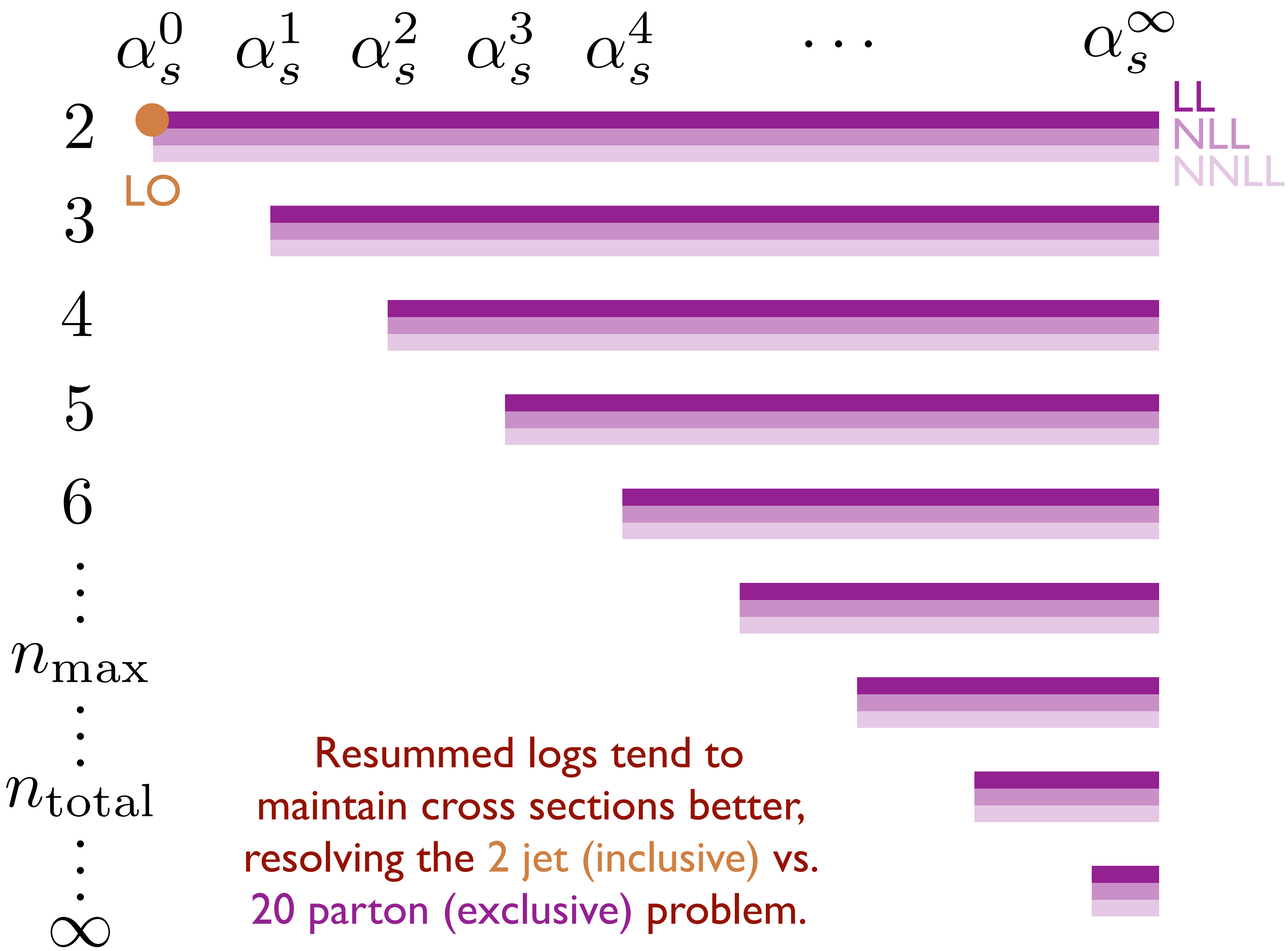
Known Diagrams

For UMC, very bad approximation to take unknown diagrams as zero.

E.g.: 2 jet cross section well approximated by 2 parton tree diagram (α_s^0). But in UMC, a typical 2 jet event has 20 partons (α_s^{18}). $\int \alpha_s^{18} \neq \alpha_s^0$

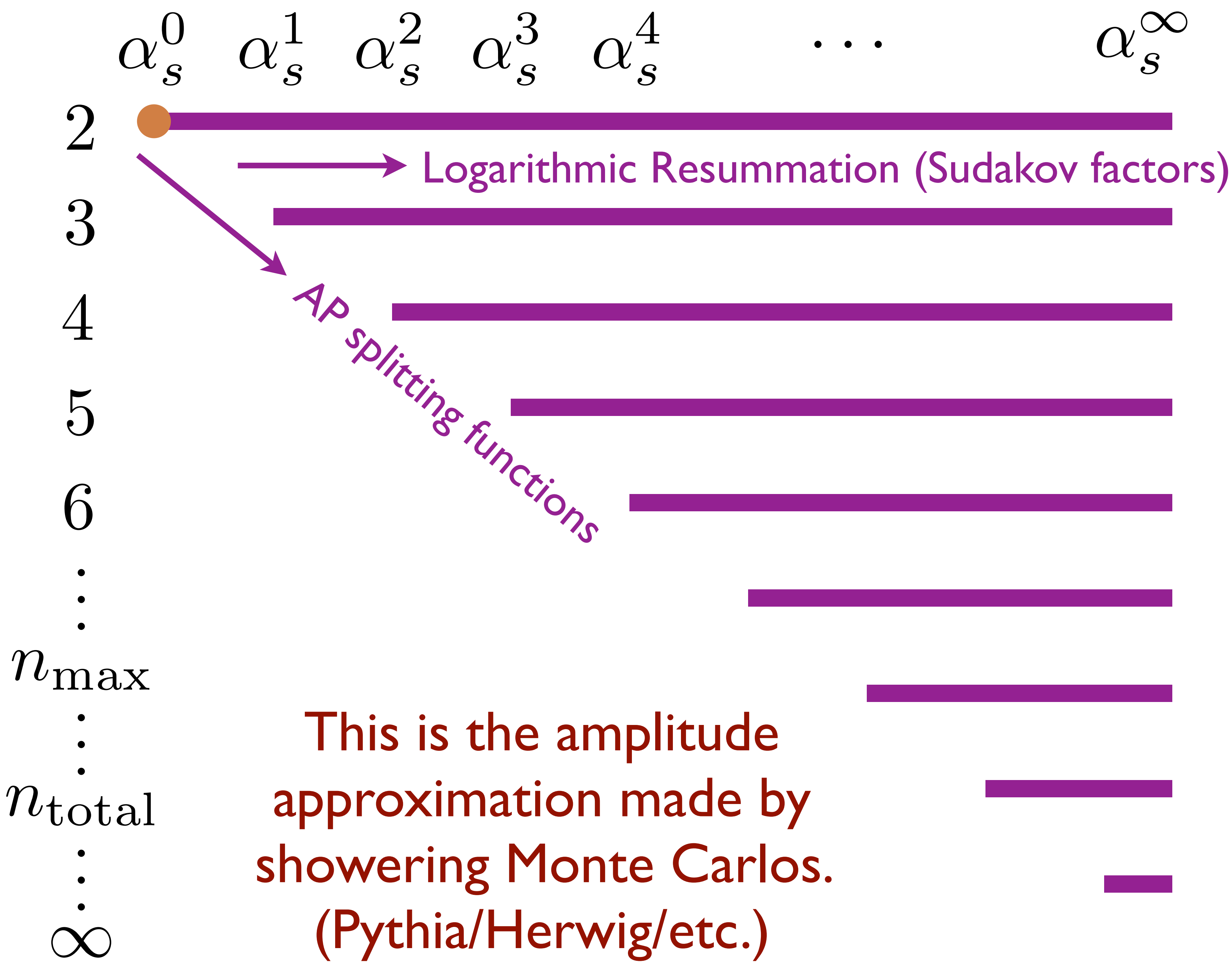
Maximum number of calculable partons much less than typical number of partons down to Λ_{QCD}

Logarithmic Resummation (N^{j}LL)



Resummed logs tend to maintain cross sections better, resolving the 2 jet (inclusive) vs. 20 parton (exclusive) problem.

Logarithmic Resummation (LL)



This is the amplitude approximation made by showering Monte Carlos. (Pythia/Herwig/etc.)

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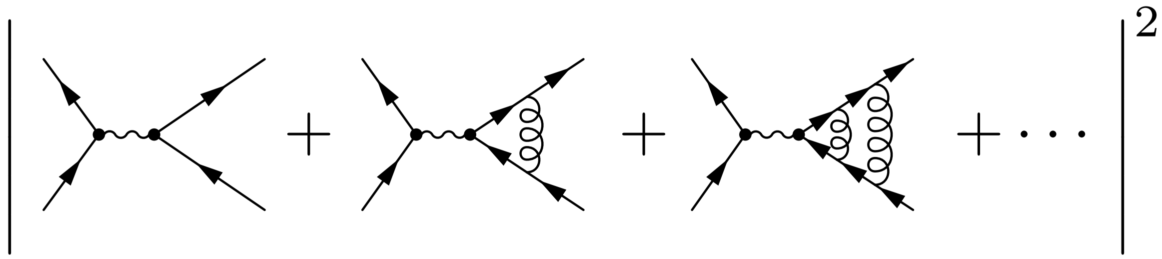
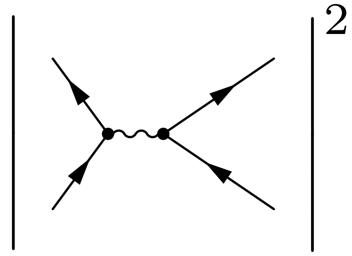
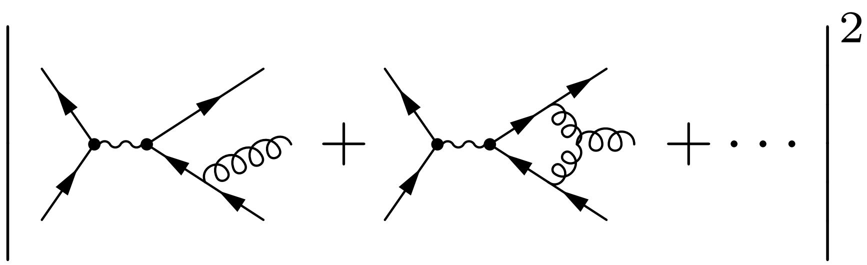


$$\simeq$$



$$\times \exp\left[-\int_{\Lambda_{\mathrm{QCD}}}^{E_{\mathrm{CM}}} dt\, Q(t)\right]$$



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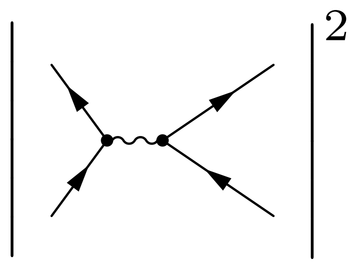

$$\times Q(t) \times \exp\left[-\int_{t}^{E_{\mathrm{CM}}} dt'\, Q(t')\right] \times \exp\left[-\int_{\Lambda_{\mathrm{QCD}}}^{t} dt''\, \tilde{Q}(t'')\right]$$

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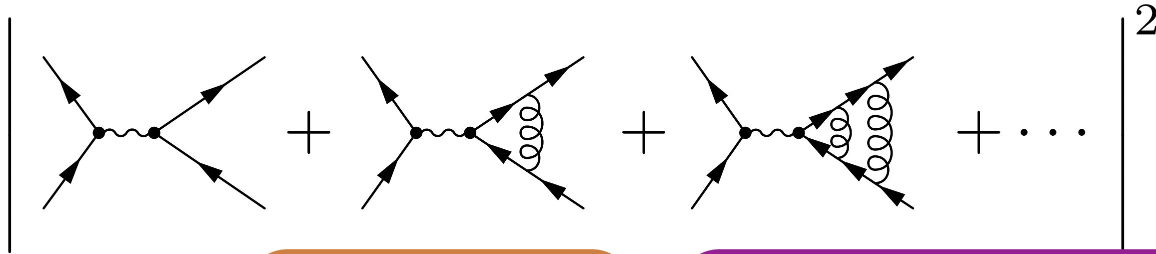

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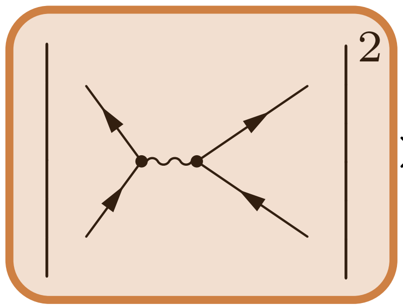
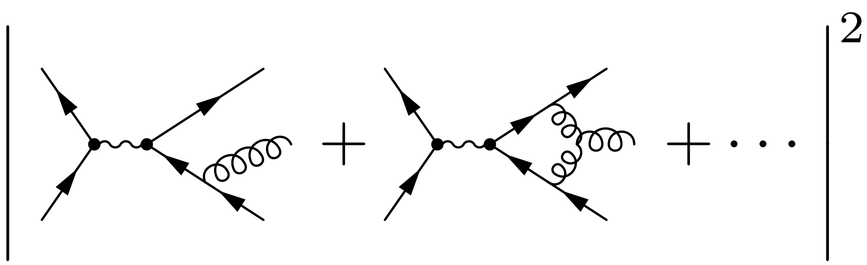


$$\times \exp\left[-\int_{\Lambda_{\mathrm{QCD}}}^{E_{\mathrm{CM}}} dt\, Q(t)\right]$$

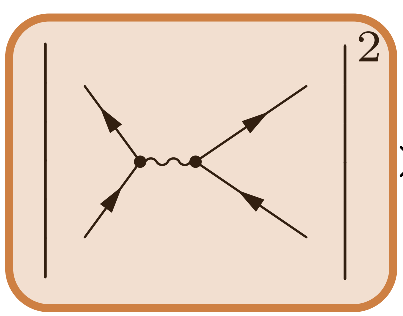
Born Amplitude

Splitting Function

Sudakov Factor



$$\simeq$$



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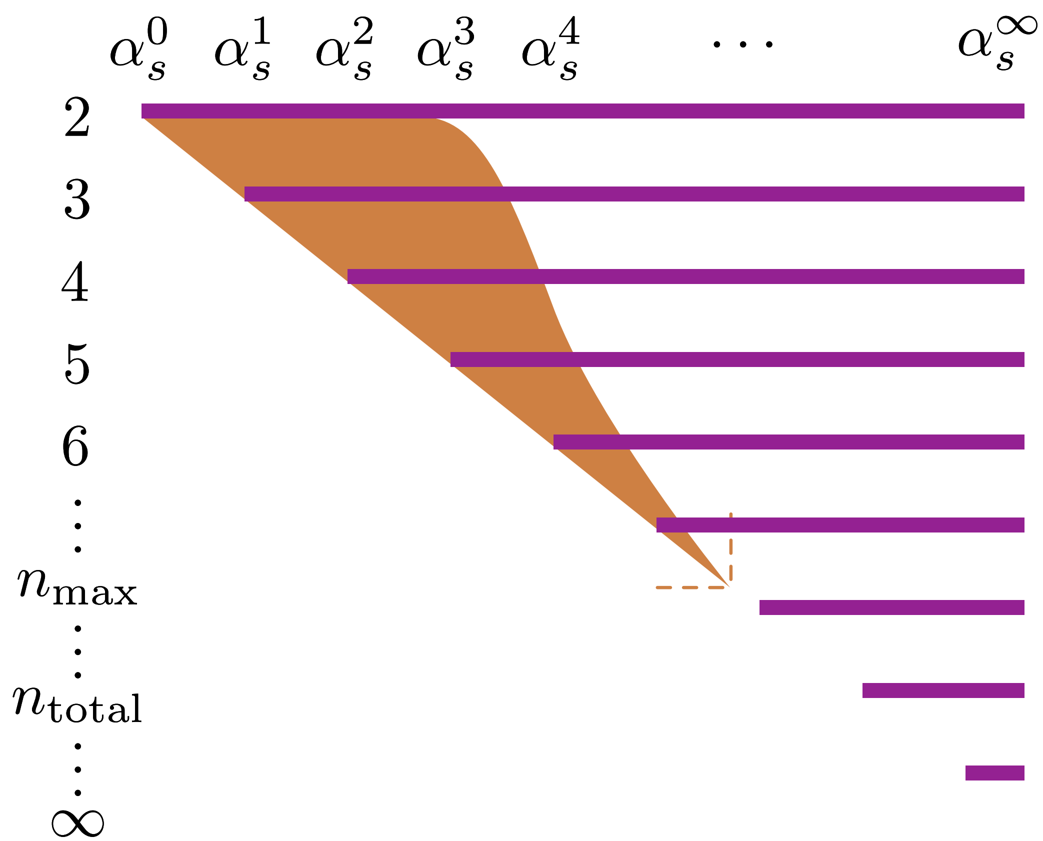
NⁱLO/NʲLL?

How do we build inclusive/exclusive amplitude approximation?
(Morally equivalent to merging partonic/hadronic strategies.)



$\mathrm{N^iLO/N^jLL}$?

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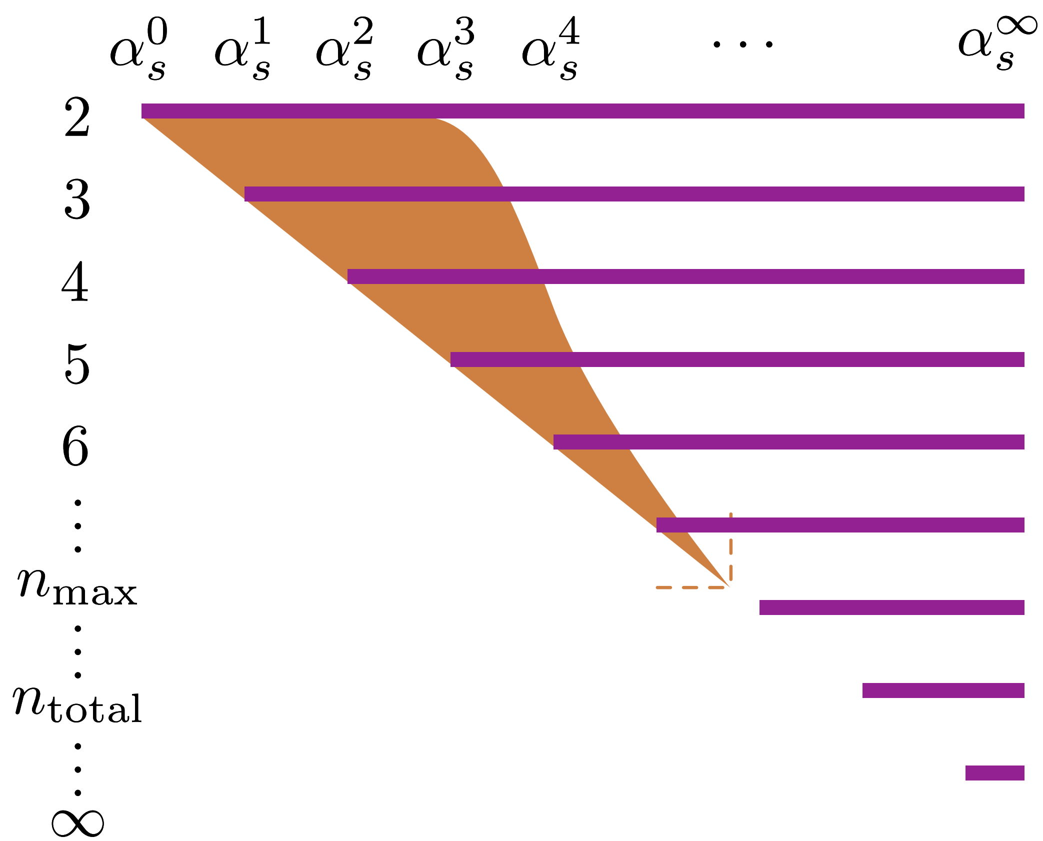
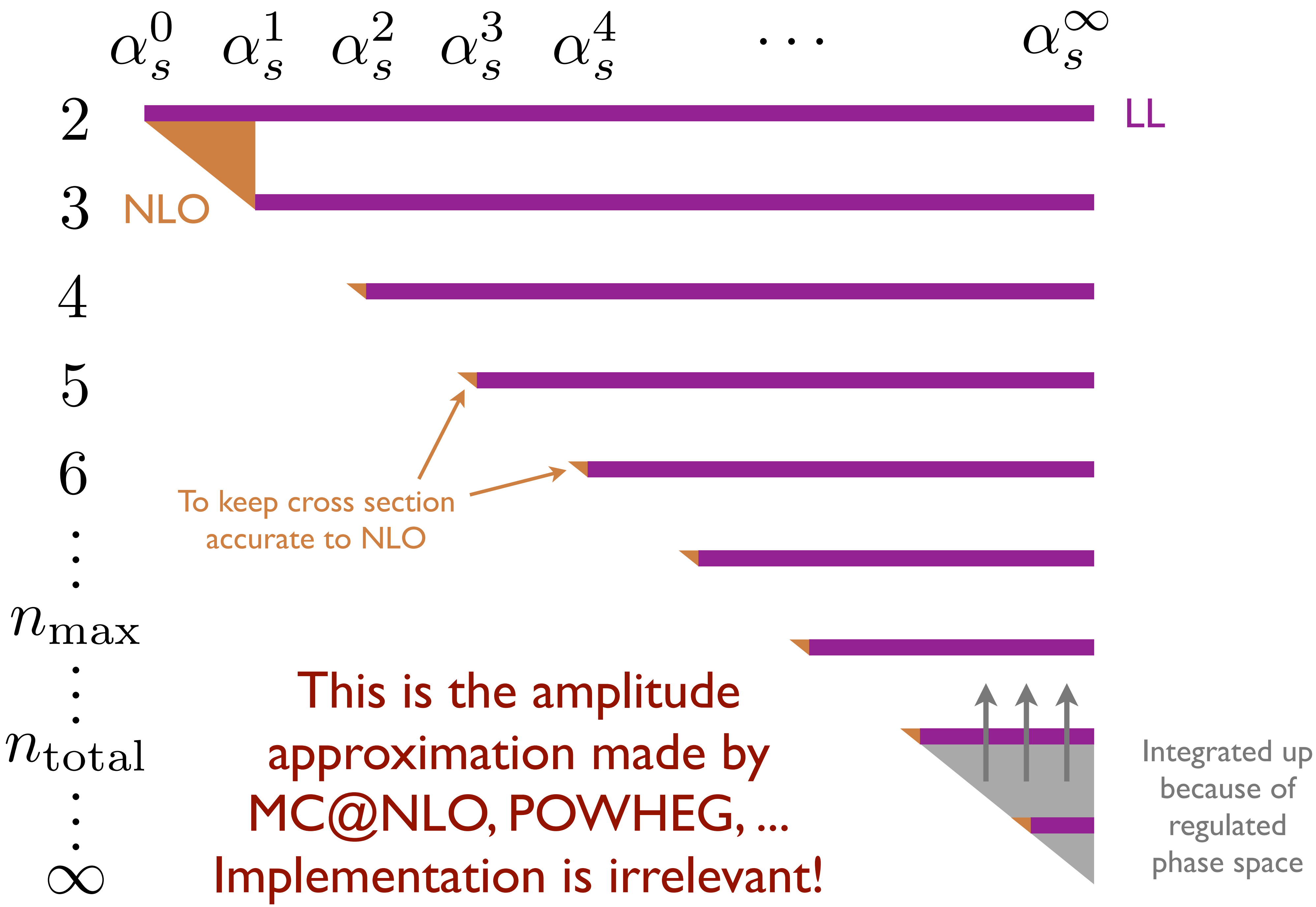


Just write down a formal expression with $\mathrm{N^iLO/N^jLL}$ accuracy and hand it to a UMC.

$$\left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2$$

NLO/LL Calculation



This is the amplitude approximation made by MC@NLO, POWHEG, ... Implementation is irrelevant!

NLO/LL Calculation

Combine Loop Diagrams (NLO) with Sudakov Factors (LL)

$$\mathrm{d}\hat{\sigma}^{n}_{\mathrm{MC@NLO}}(\mu) = \mathrm{d}\sigma^{n}_{\mathrm{tree}}\Delta_{\mathrm{Sudakov}}(\mu) + \left(\mathrm{d}\sigma^{n}_{\mathrm{loop}} - \mathrm{d}\sigma^{n}_{\mathrm{tree}}\int Q_{\mathrm{split}}\right)\Delta_{\mathrm{Sudakov}}(\mu)$$
$$= \mathrm{d}\sigma^{n}_{\mathrm{tree}} + \mathrm{d}\sigma^{n}_{\mathrm{loop}} + \mathcal{O}(\mathrm{NNLO})$$

$$\mathrm{d}\hat{\sigma}^{n+1}_{\mathrm{MC@NLO}}(\mu) = \mathrm{d}\sigma^{n+1}_{\mathrm{tree}} + Q_{\mathrm{split}}\left(\hat{\sigma}^{n}_{\mathrm{MC@NLO}}(\mu) - \mathrm{d}\sigma^{n}_{\mathrm{tree}}\right)$$
$$= \mathrm{d}\sigma^{n+1}_{\mathrm{tree}} + \mathcal{O}(\mathrm{NNLO})$$

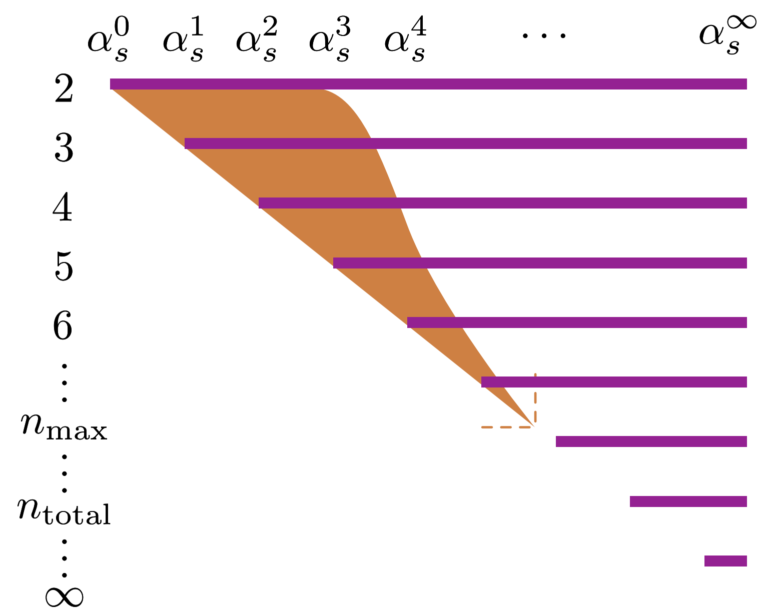
LL running while also canceling IR divergences. Clever!

(MC@NLO, POWHEG, ...)

If existing N^iLO/N^jLL methods are equivalent to choosing an amplitude approximation, why isn't there already a UMC program on the market?

N^iLO

(Inclusive)

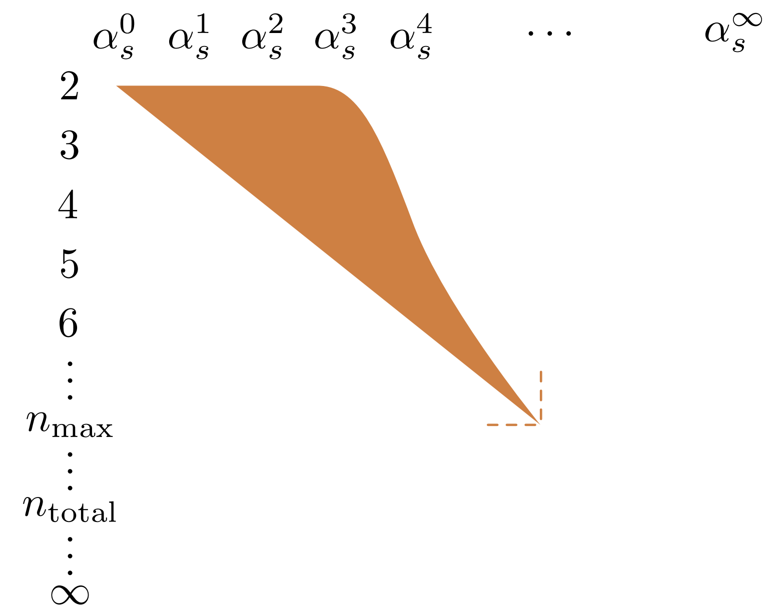


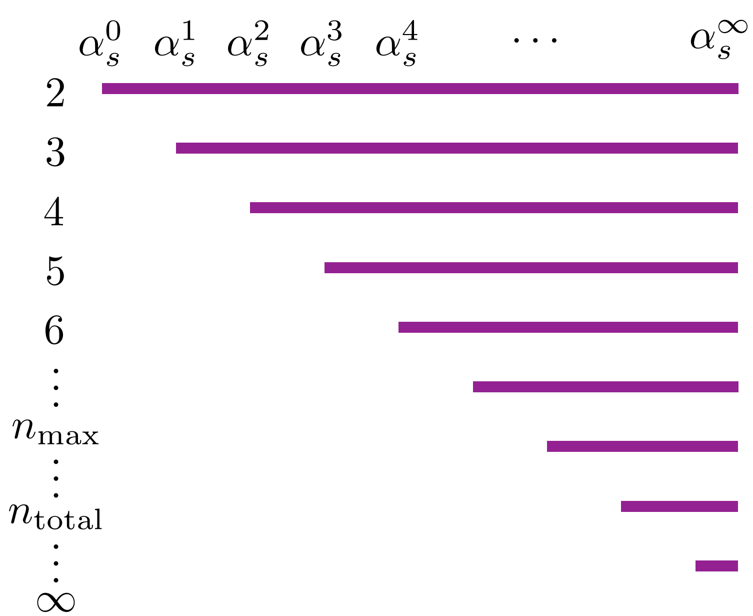
N^jLL

(Exclusive)

Partonic Strategy

(Fixed-Order Calc.)



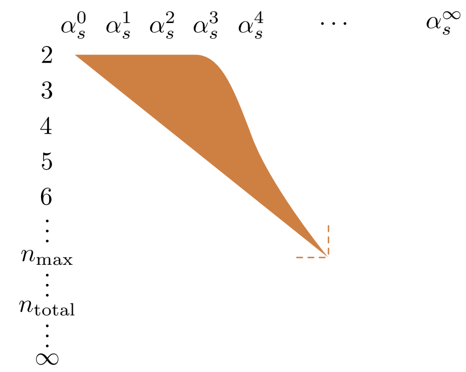


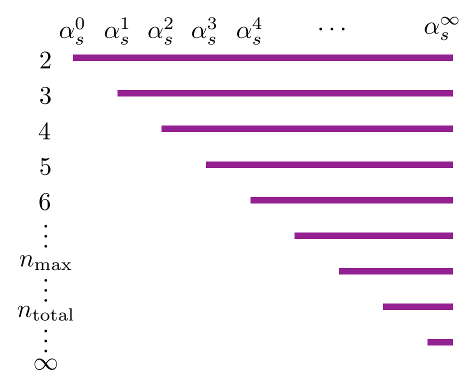
Hadronic Strategy

(Parton Shower)

Partonic Strategy

(Fixed-Order Calc.)





Hadronic Strategy

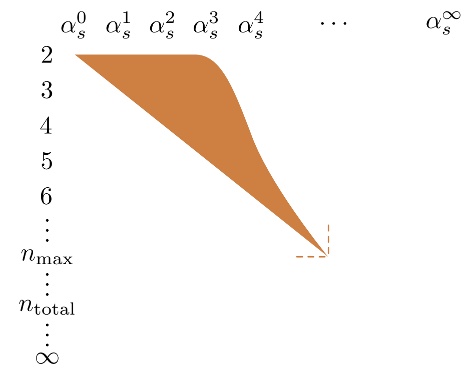
(Parton Shower)

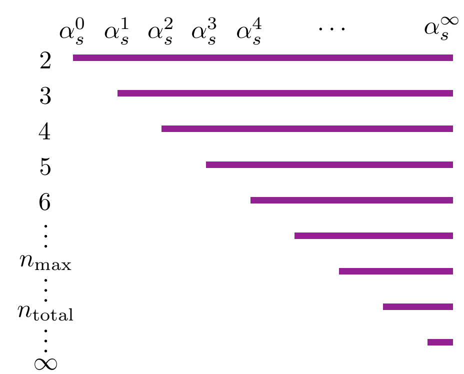
Partonic Strategy

(Fixed-Order Calc.)

Perturbative α_s Expansion

Fixed n-body Phase Space





Hadronic Strategy

(Parton Shower)

Perturbative
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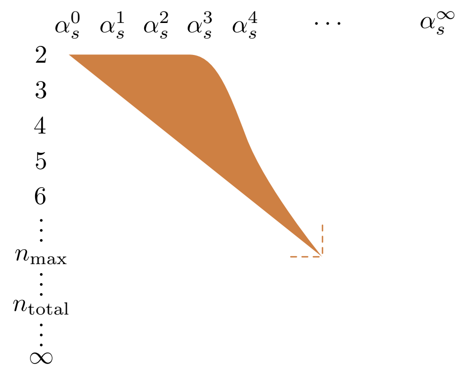
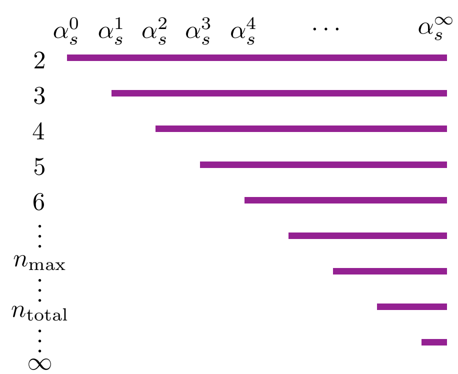
Partonic Strategy

(Fixed-Order Calc.)



Fixed n-body
Phase Space

Soft Collinear
Limit



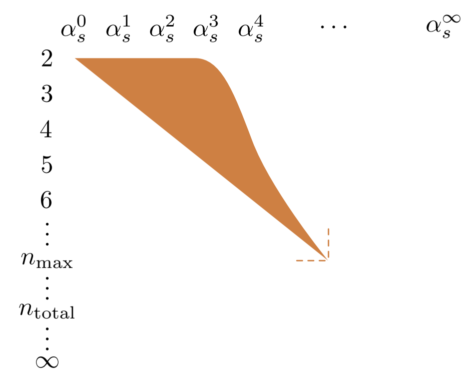
Hadronic Strategy

(Parton Shower)

Recursive
Phase Space

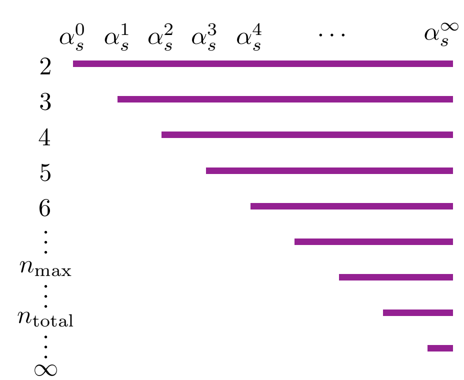
Perturbative
α_s Expansion

Partonic
Strategy
(Fixed-Order Calc.)



Fixed n-body
Phase Space

Soft Collinear
Limit

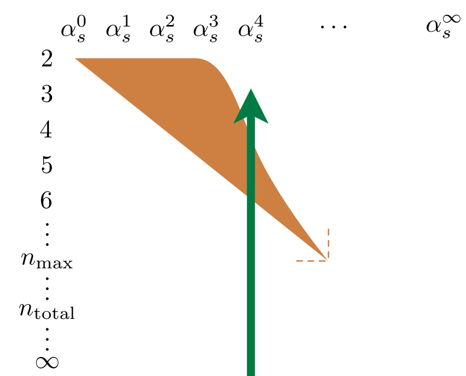


Hadronic
Strategy
(Parton Shower)

Recursive
Phase Space

Perturbative
α_s Expansion

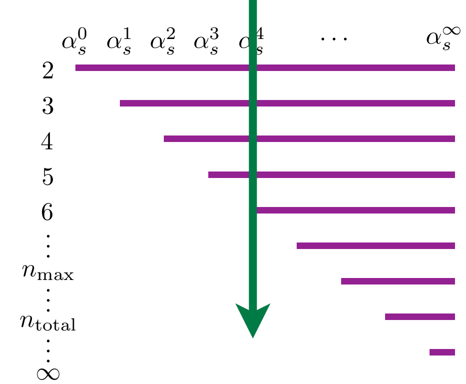
Partonic
Strategy
(Fixed-Order Calc.)



Fixed n-body
Phase Space

Merge?

Soft Collinear
Limit



Recursive
Phase Space

Hadronic
Strategy
(Parton Shower)

Perturbative
α_s Expansion

Fixed n-body
Phase Space

Soft Collinear
Limit

Recursive
Phase Space

Perturbative
α_s Expansion

Fixed n-body
Phase Space

Soft Collinear
Limit

Recursive
Phase Space

Perturbative
α_s Expansion

QCD
Question

Soft Collinear
Limit

Fixed n-body
Phase Space

Recursive
Phase Space

Perturbative
α_s Expansion

QCD
Question

Soft Collinear
Limit

Fixed n-body
Phase Space

Algorithmic
Question

Recursive
Phase Space

Perturbative
α_s Expansion

QCD
Question

Soft Collinear
Limit

Fixed n-body
Phase Space

Solved!
We have a UMC

Recursive
Phase Space

Perturbative
α_s Expansion

Amplitude
Approximation?

Soft Collinear
Limit

Fixed n-body
Phase Space

Solved!
We have a UMC

Recursive
Phase Space

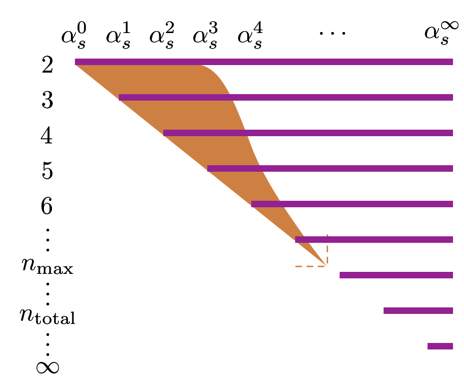
Perturbative
α_s Expansion

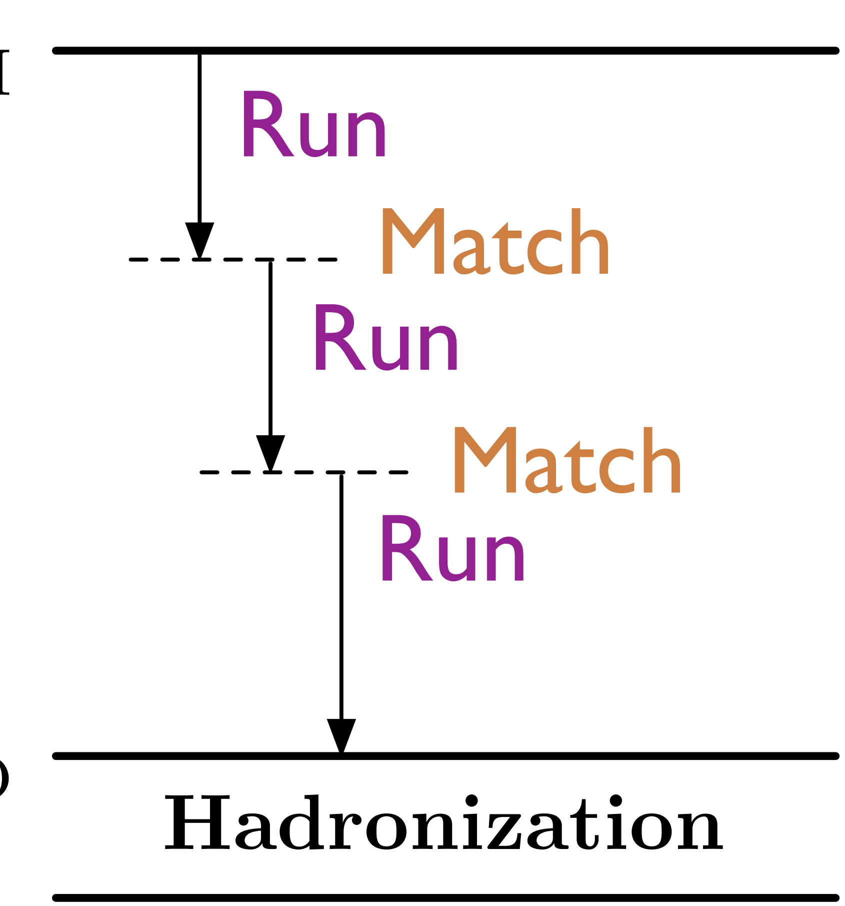
Amplitude
Approximation?

Soft Collinear
Limit

GenEvA

Organize MC same way
you would organize EFT!





(Just a choice of amplitude approximation)

GENerate EVents Analytically

GenEvA is a Universal Monte Carlo tool...

$$d\sigma = \mathrm{Had}\left[\sum_{n=2}^{n_{\mathrm{total}}} \left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2 d\Phi_n(\Lambda_{\mathrm{QCD}})\right]$$

...with a built-in amplitude approximation scheme...

$$\left|\mathcal{M}_n^{\mathrm{best}}(\Lambda_{\mathrm{QCD}})\right|^2 = \sum_m \left|\mathcal{M}_m^{\mathrm{best}}(\mu)\right|^2 \times f_{m\to n}(\mu, \Lambda_{\mathrm{QCD}})$$

Matching Running

...yielding an efficient, versatile, and improvable event generator.

The GenEvA Strategy

Monte Carlo as Effective Theory

Key Technical Advance

$$d\sigma = \mathrm{Had}\left[\sum_{n=2}^{n_{\mathrm{total}}} \left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2 d\Phi_n(\Lambda_{\mathrm{QCD}})\right]$$

Key Technical Advance

$$d\sigma = \mathrm{Had}\left[\sum_{n=2}^{n_{\mathrm{total}}} \left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2 d\Phi_n(\Lambda_{\mathrm{QCD}})\right]$$

Amplitude Approximation Scheme

$$\left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2$$

is

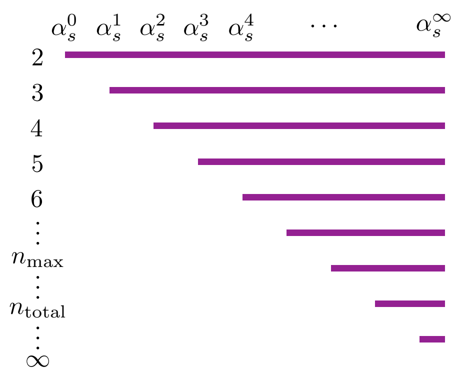
Phase Space Generator

$$d\Phi_n(\Lambda_{\mathrm{QCD}})$$

The Parton Shower

For high enough multiplicity, the only tractable amplitude approximation is a leading log parton shower.

$$d\sigma = \mathrm{Had}\left[\sum_{n=2}^{n_{\mathrm{total}}} \left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2 d\Phi_n(\Lambda_{\mathrm{QCD}})\right]$$



$$\left|\mathcal{M}_n^{\mathrm{shower}}(\Lambda_{\mathrm{QCD}})\right|^2 = \prod \mathrm{Splittings} \times \mathrm{Sudakovs}$$

GenEvA has an efficient algorithm for Generating Events according to this Analytic amplitude approximation.

$$\mathcal{P}(n, \Phi_n) = \left|\mathcal{M}_n^{\mathrm{shower}}(\Lambda_{\mathrm{QCD}})\right|^2 \qquad w = \frac{\left|\mathcal{M}_n(\Lambda_{\mathrm{QCD}})\right|^2}{\mathcal{P}(n, \Phi_n)} = 1$$

The Parton Shower

$$\left|\mathcal{M}_n^{\text{shower}}(\Lambda_{\text{QCD}})\right|^2 = \prod \text{Splittings} \times \text{Sudakovs}$$

Parton Showers are Markovian
(kind of like Effective Theories being "single scale")

$$\left|\mathcal{M}_n^{\text{shower}}(\Lambda_{\text{QCD}})\right|^2 = \sum_m \left|\mathcal{M}_m^{\text{shower}}(\mu)\right|^2 \times f_{m\to n}(\mu, \Lambda_{\text{QCD}})$$

The Parton Shower

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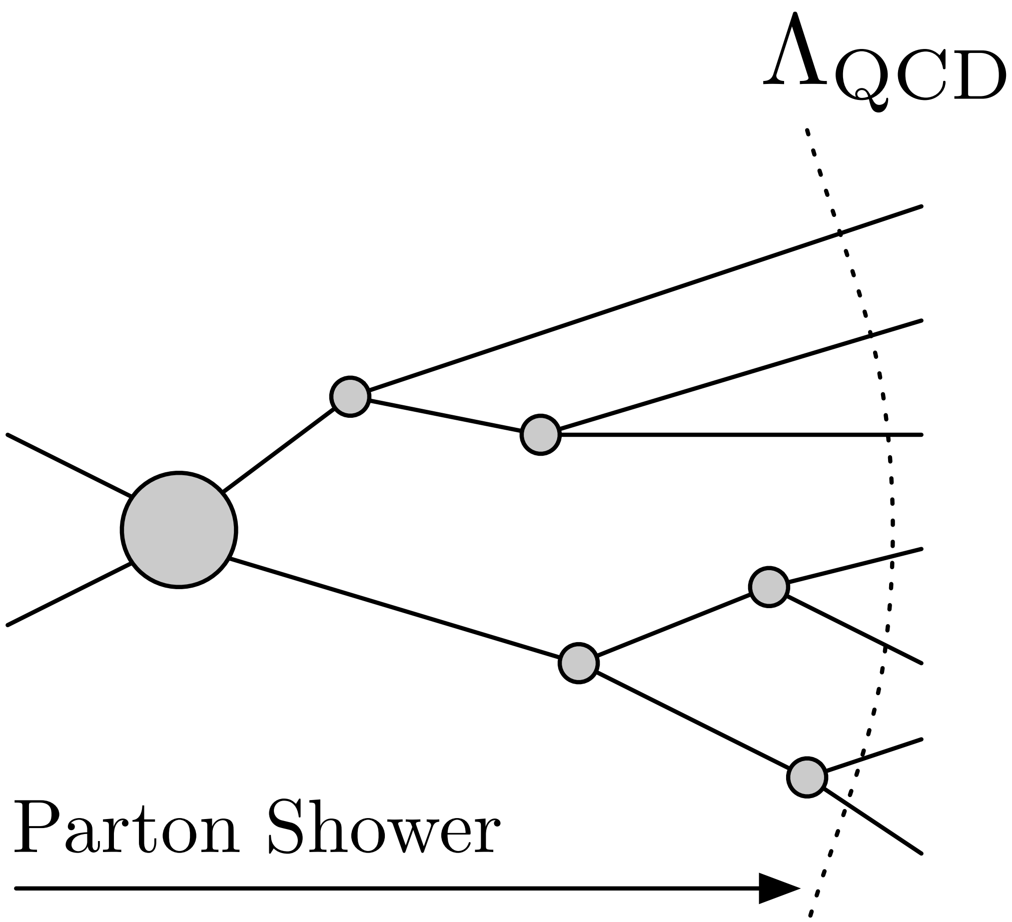
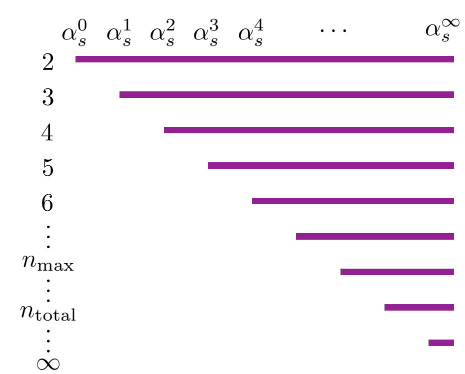
$$\left|\mathcal{M}_n^{\mathrm{shower}}(\Lambda_{\mathrm{QCD}})\right|^2 = \sum_m \left|\mathcal{M}_m^{\mathrm{shower}}(\mu)\right|^2 \times f_{m\to n}(\mu, \Lambda_{\mathrm{QCD}})$$

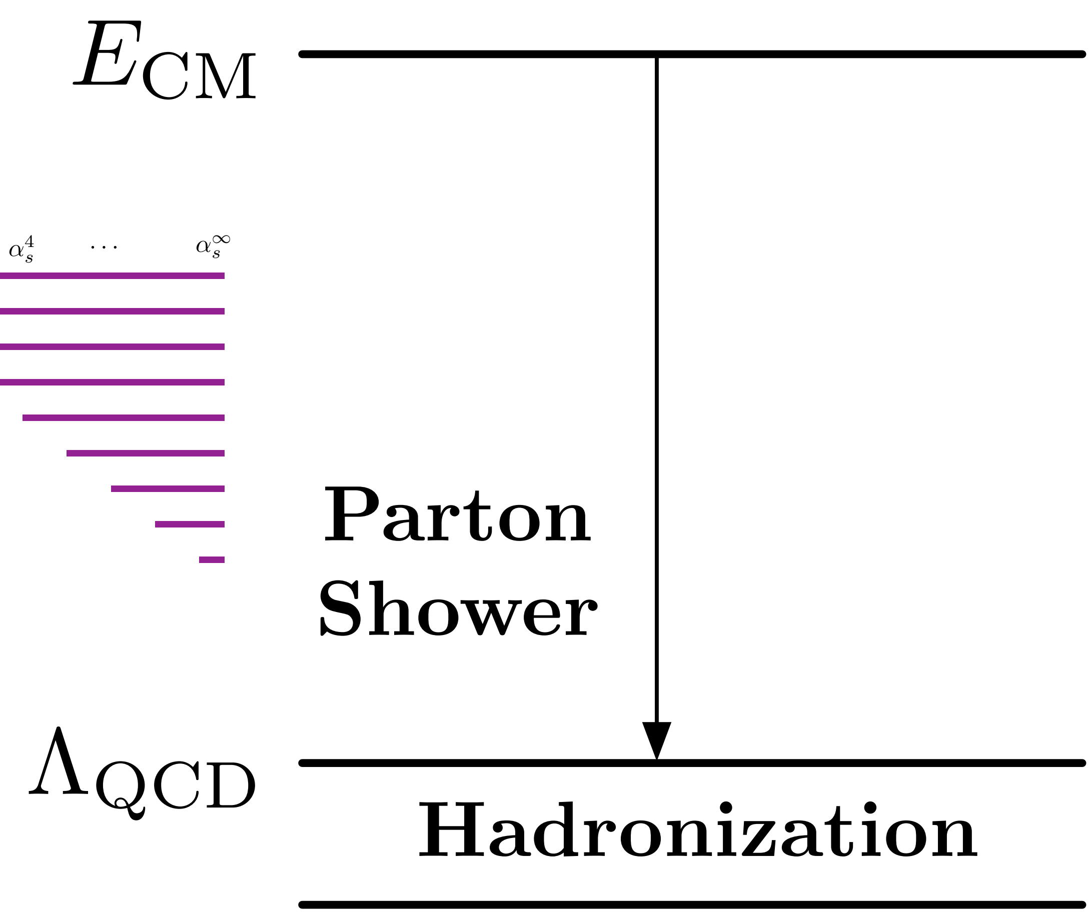
Choose a scale μ with tractable number of final state partons.
Swap out the shower approximation for a better amplitude.

$$\left|\mathcal{M}_n^{\mathrm{best}}(\Lambda_{\mathrm{QCD}})\right|^2 = \sum_m \underbrace{\left|\mathcal{M}_m^{\mathrm{best}}(\mu)\right|^2}_{\text{Matching}} \times \underbrace{f_{m\to n}(\mu, \Lambda_{\mathrm{QCD}})}_{\text{Running}}$$

The GenEvA Strategy



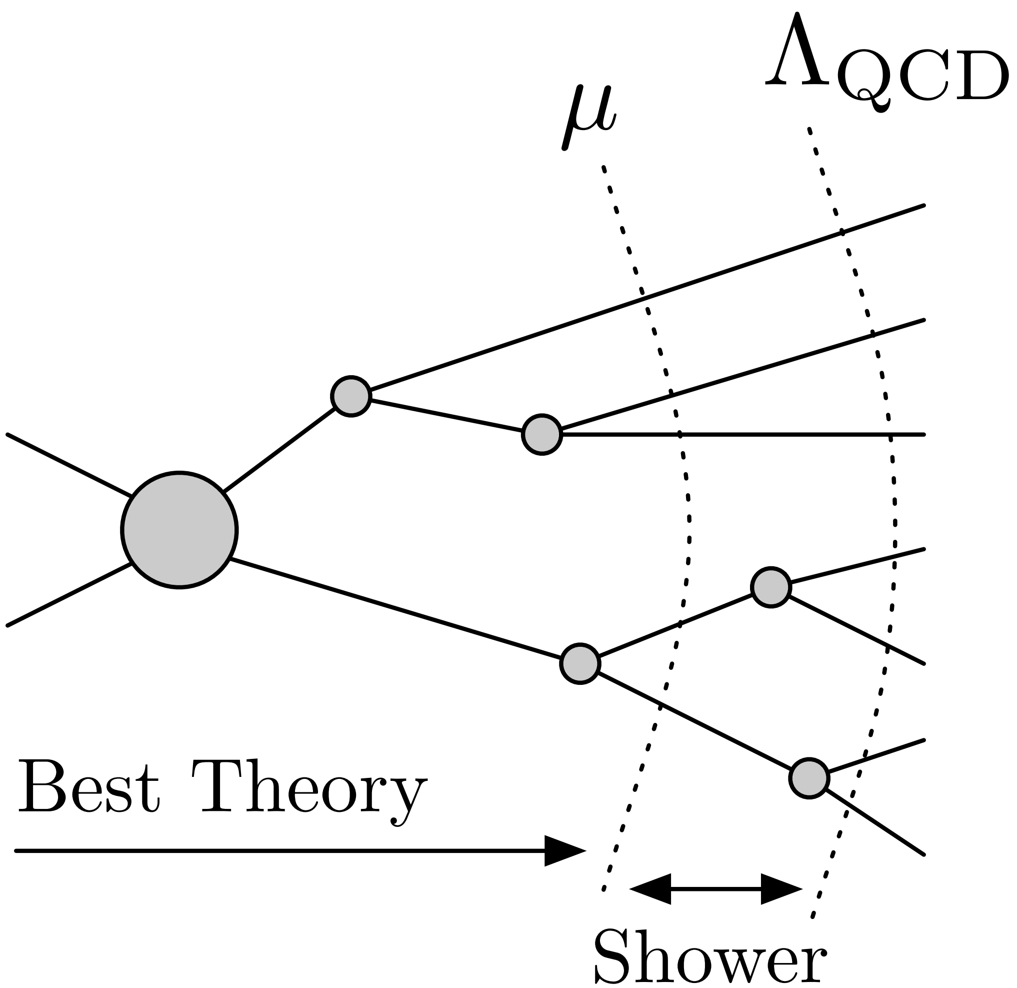


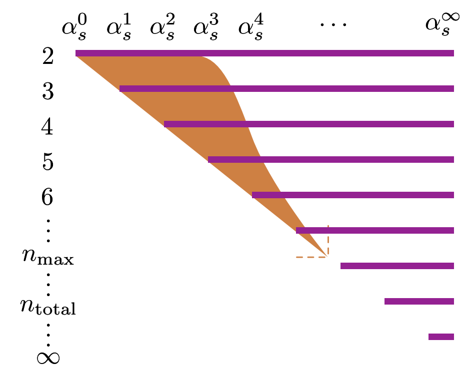


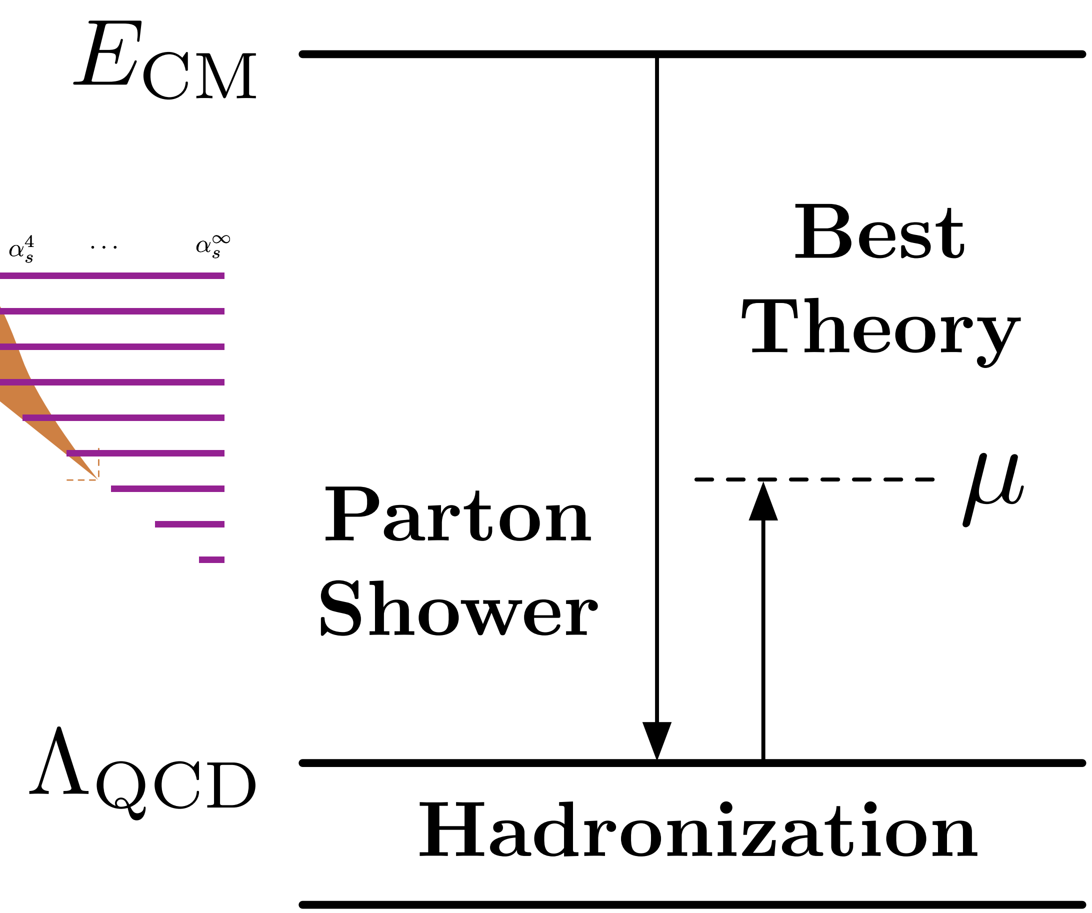
$$\left|\mathcal{M}_n^{\mathrm{best}}(\Lambda_{\mathrm{QCD}})\right|^2 = \left|\mathcal{M}_n^{\mathrm{shower}}(\Lambda_{\mathrm{QCD}})\right|^2$$

$$w = 1$$

The GenEvA Strategy







$$\left|\mathcal{M}_n^{\mathrm{best}}(\Lambda_{\mathrm{QCD}})\right|^2 = \left|\mathcal{M}_n^{\mathrm{shower}}(\Lambda_{\mathrm{QCD}})\right|^2 \times \frac{\left|\mathcal{M}_m^{\mathrm{best}}(\mu)\right|^2}{\left|\mathcal{M}_m^{\mathrm{shower}}(\mu)\right|^2}$$

$$w = \left|\mathcal{M}_m^{\mathrm{best}}(\mu)\right|^2 \Big/ \left|\mathcal{M}_m^{\mathrm{shower}}(\mu)\right|^2$$

The GenEvA Strategy

$$w = \left|\mathcal{M}_m^{\text{best}}(\mu)\right|^2 \Big/ \left|\mathcal{M}_m^{\text{shower}}(\mu)\right|^2$$

Efficient MC!

Shower has singularities/symmetries of QCD built in. Difference between shower and improved theory is small. We also use numeric tricks inspired by ALPGEN & MadEvent for speed.

Versatile MC!

Same kinematics can yield multiple theory predictions, even if different amplitude approximations require different μ scales!

Improvable MC!

Discrepancy between theory and experiment? Do a better calculation with lower μ scale and improve weight even after detector simulation.

The GenEvA Strategy

$$w = \left|\mathcal{M}_m^{\text{best}}(\mu)\right|^2 \Big/ \left|\mathcal{M}_m^{\text{shower}}(\mu)\right|^2$$

As theorists, we have a non-trivial task.

$$\left|\mathcal{M}_m^{\text{best}}(\mu)\right|^2$$

This is a complicated object with μ scale dependence.
Need N^iLO/N^jLL expressions for this partial amplitude.
Will use heavily the methods and experience of

CKKW(-L), MLM, SMPR, MC@NLO,
POWHEG, Nagy & Soper, VINCIA, ...

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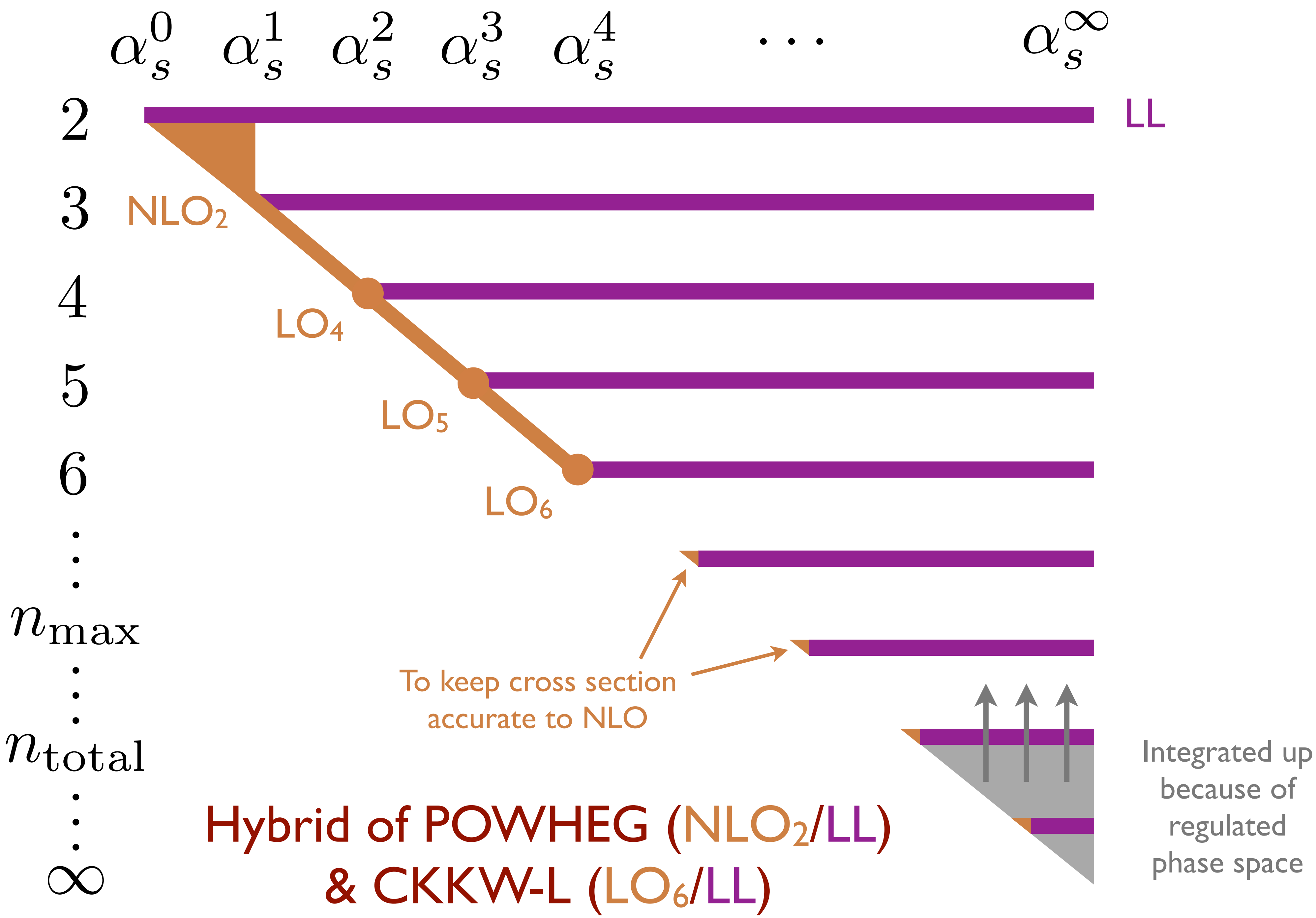
...yielding an efficient, versatile, and improvable event generator.

$$w = \left|\mathcal{M}_m^{\mathrm{best}}(\mu)\right|^2 \Big/ \left|\mathcal{M}_m^{\mathrm{shower}}(\mu)\right|^2$$

Results!

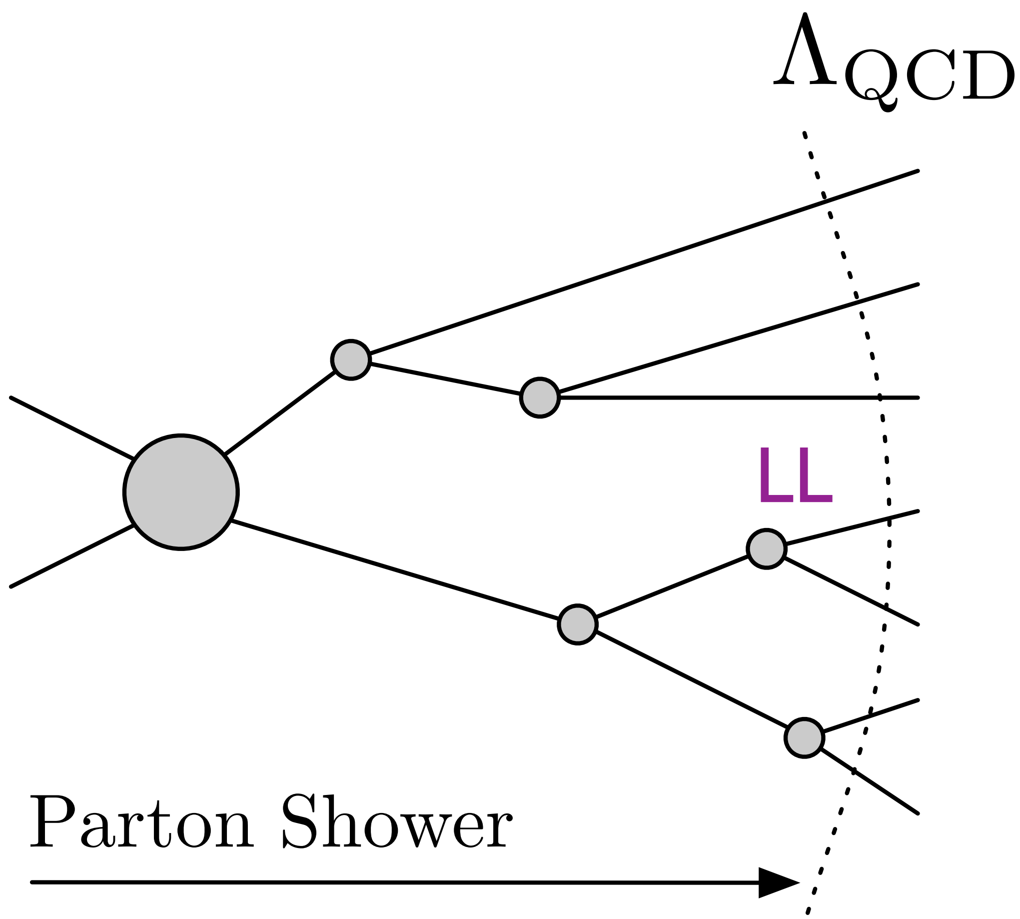
NLO$_2$/LO$_6$/LL Calculation

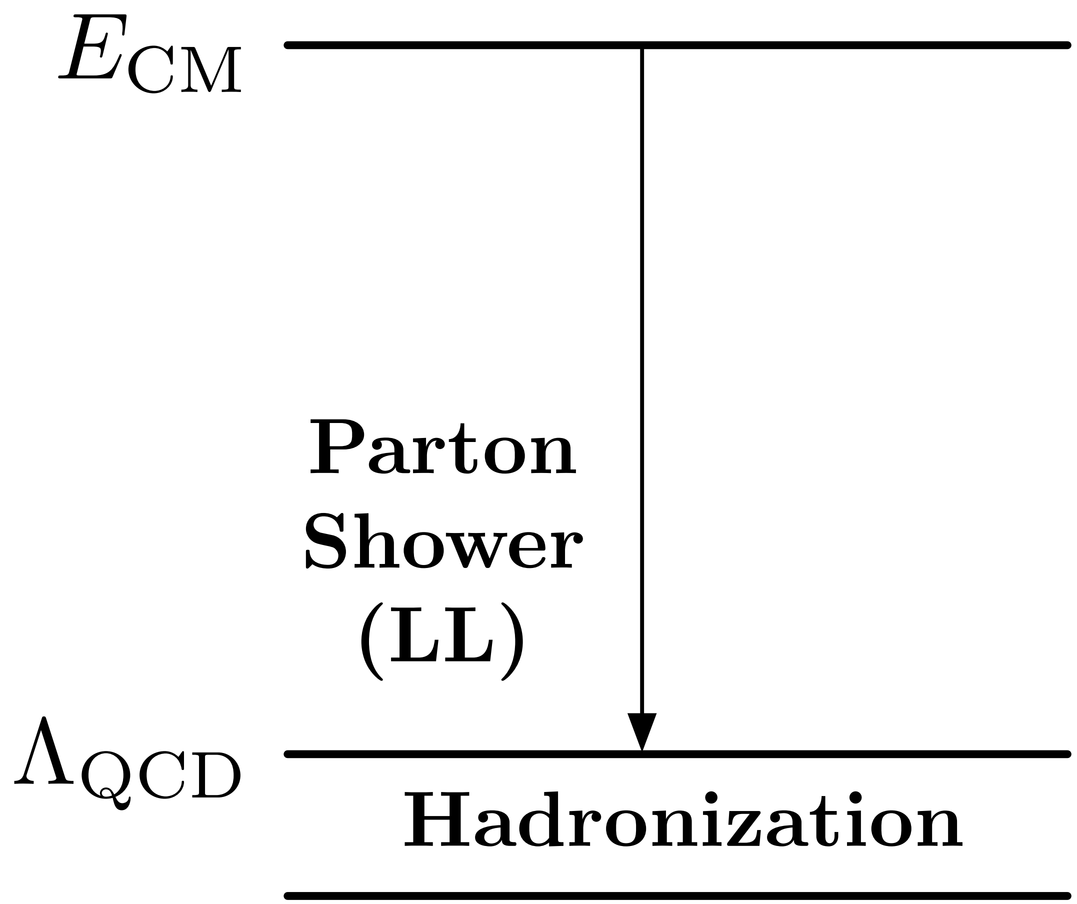


Hybrid of POWHEG (NLO$_2$/LL)
& CKKW-L (LO$_6$/LL)

NLO/LO/LL Method?

Running and matching to the extreme!

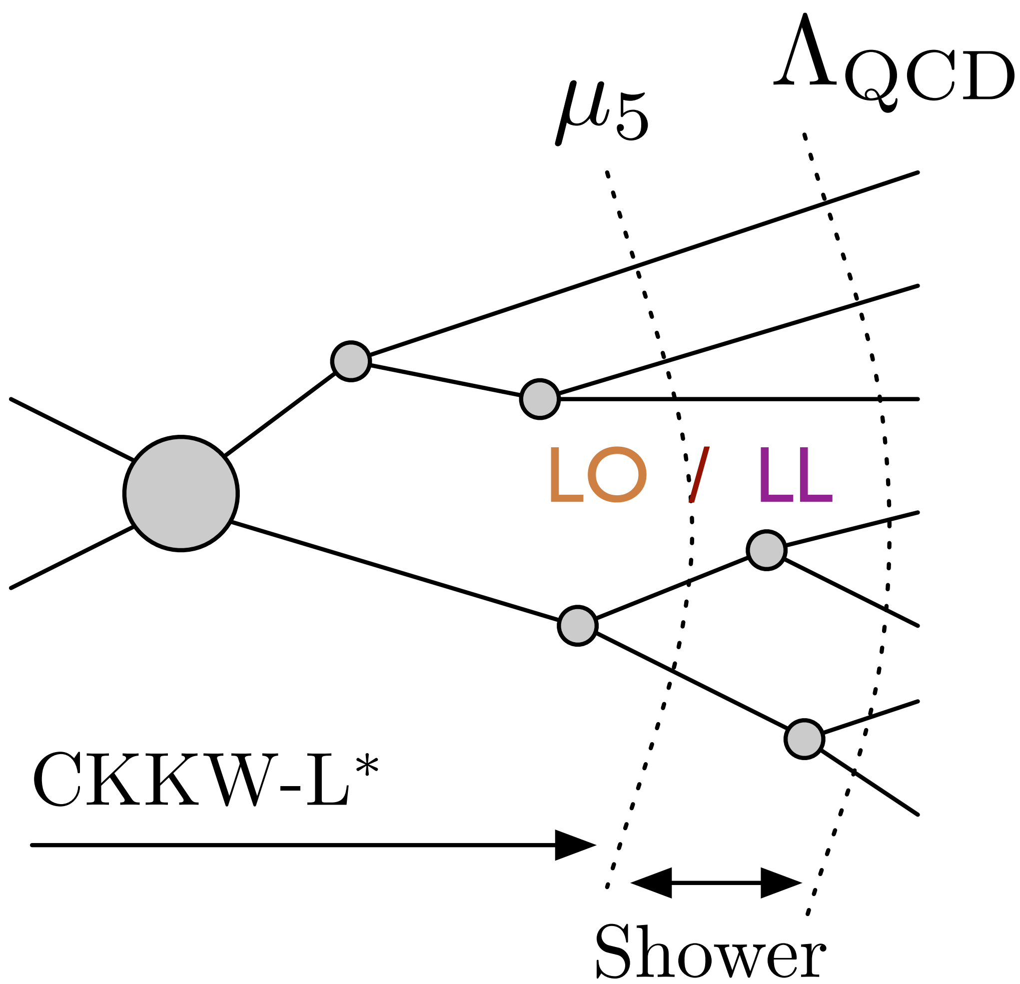


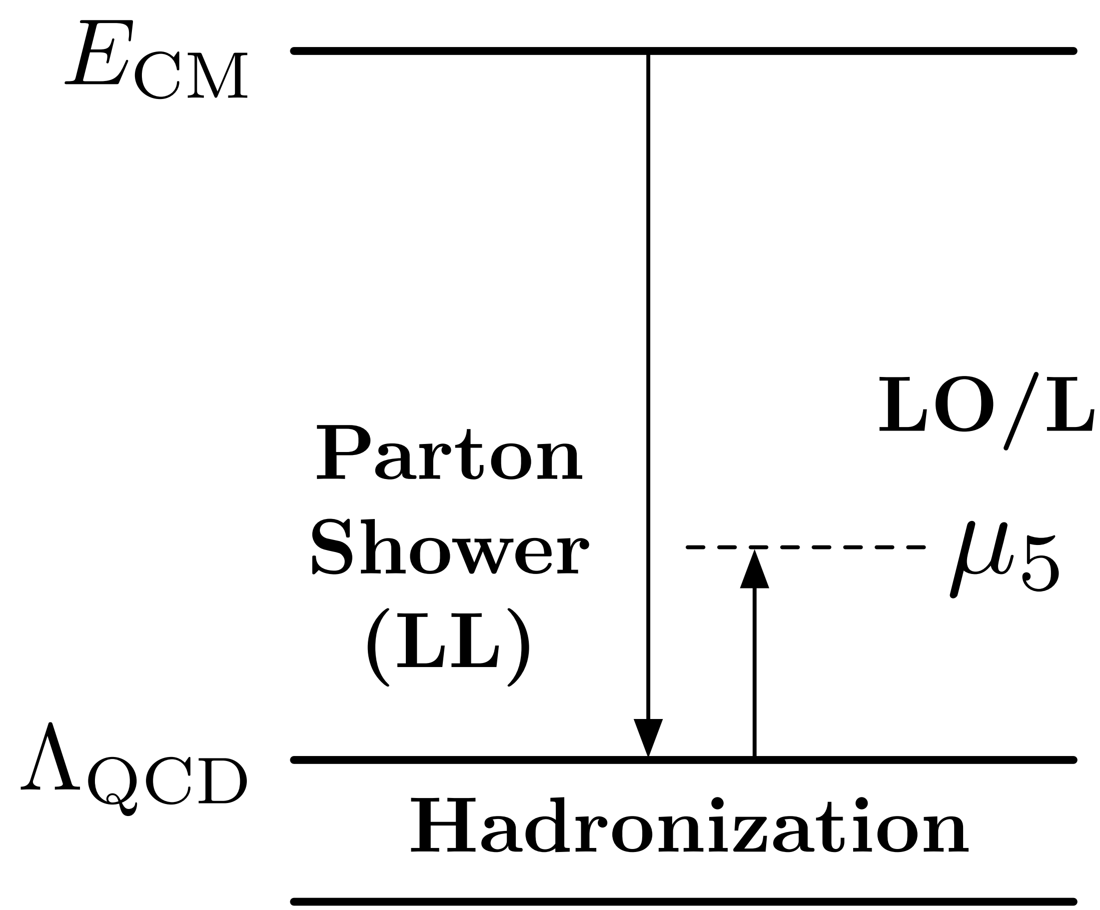


$$\left|\mathcal{M}^{\rm best}(\Lambda)\right|^2 = \left|\mathcal{M}^{\rm shower}(\Lambda)\right|^2$$

NLO/LO/LL Calculation

Running and matching to the extreme!

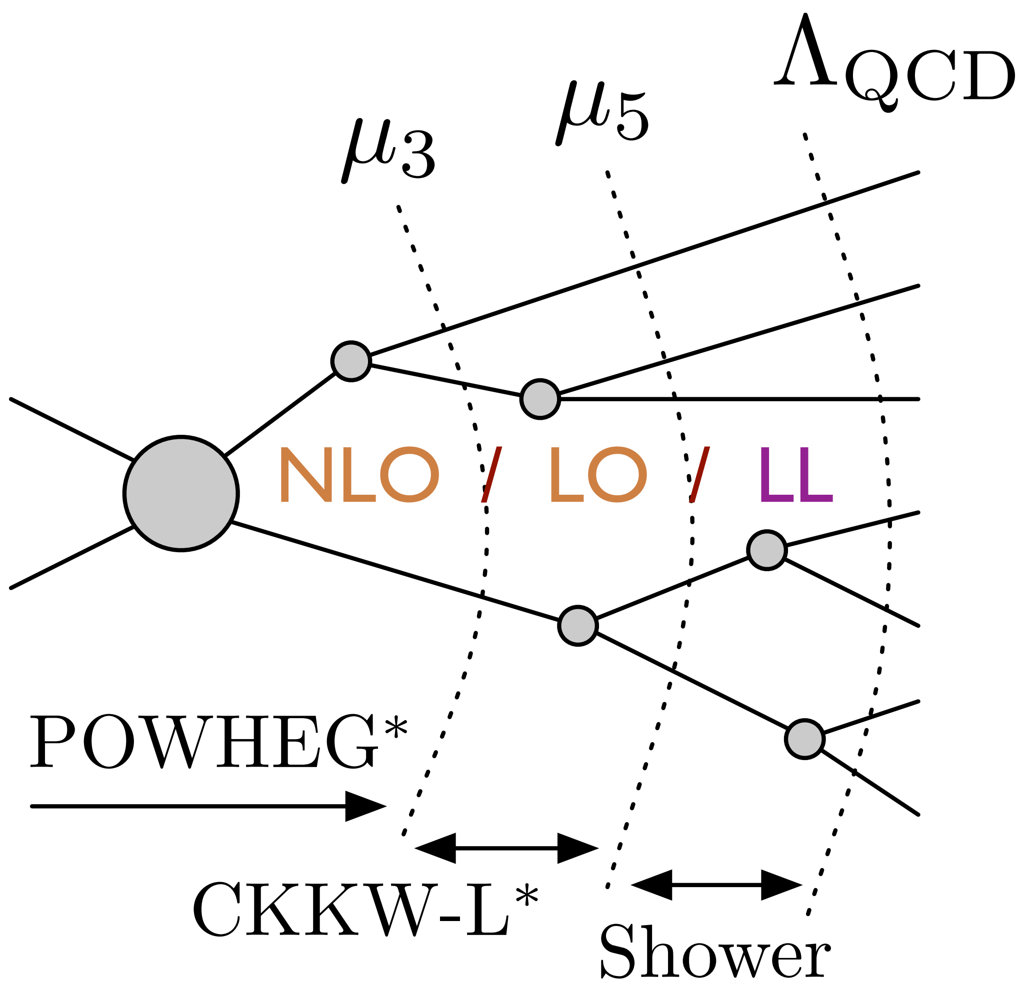


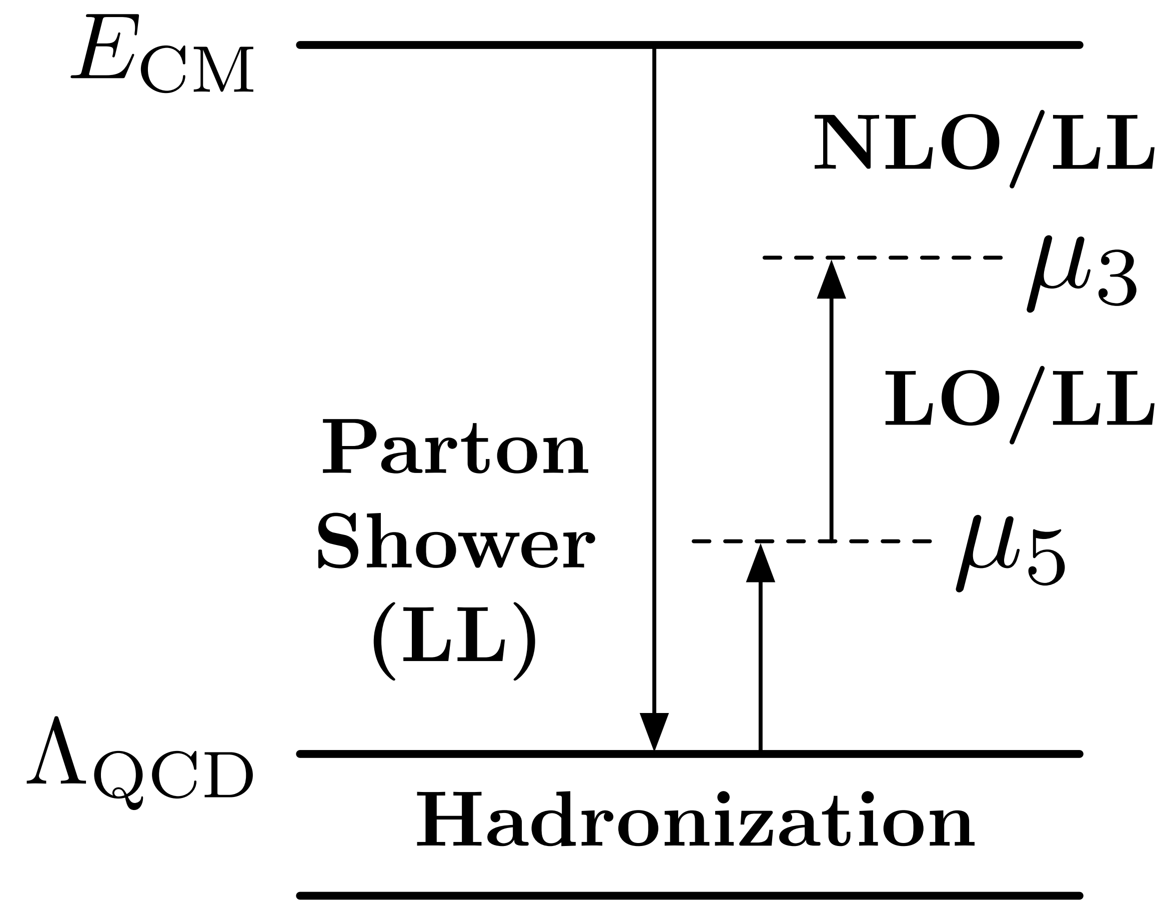


$$\left|\mathcal{M}^{\mathrm{best}}(\Lambda)\right|^2 = \left|\mathcal{M}^{\mathrm{shower}}(\Lambda)\right|^2 \times \frac{\left|\mathcal{M}^{\mathrm{CKKW\text{-}L^*}}(\mu_5)\right|^2}{\left|\mathcal{M}^{\mathrm{shower}}(\mu_5)\right|^2}$$

NLO/LO/LL Calculation

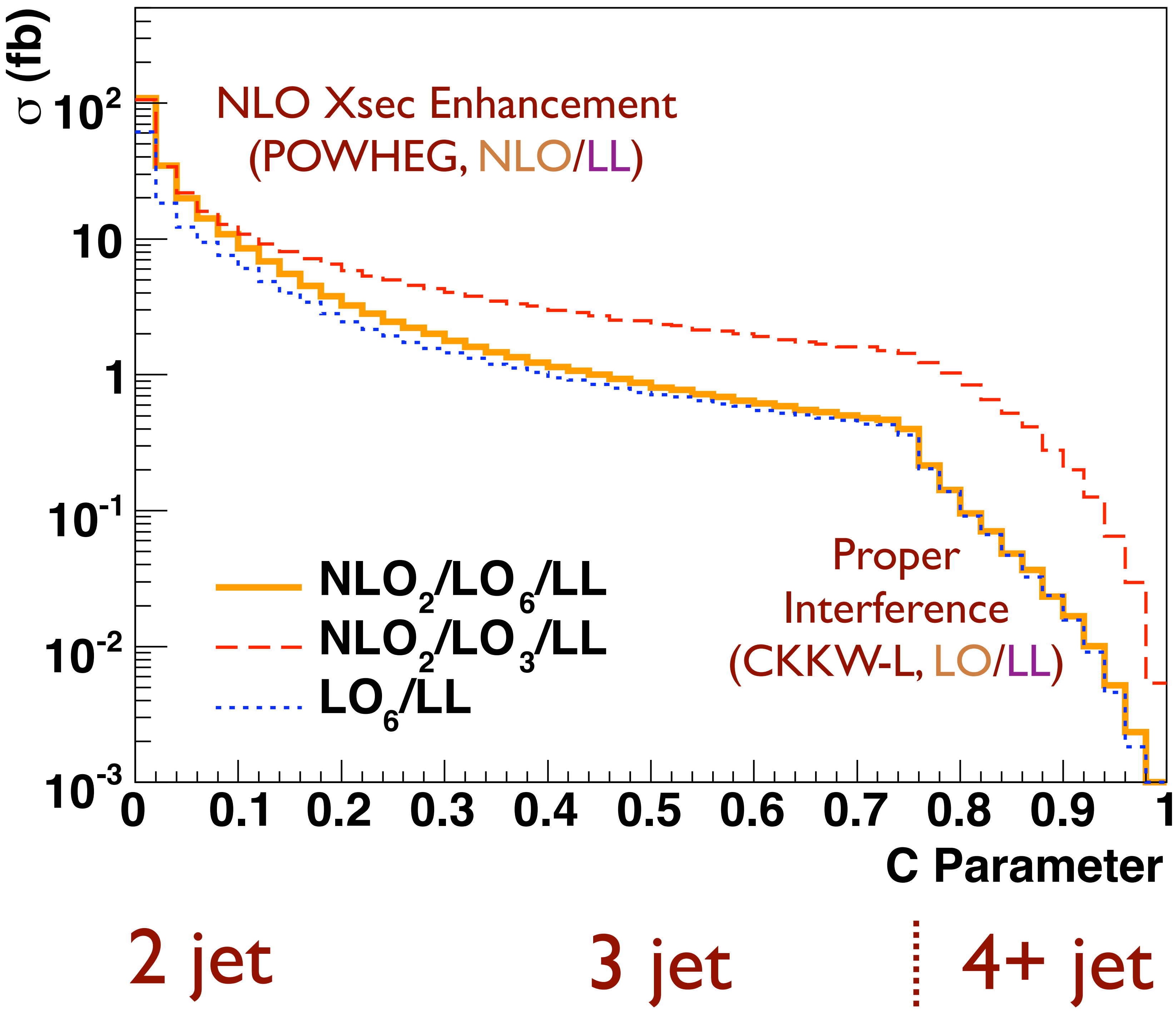
Running and matching to the extreme!



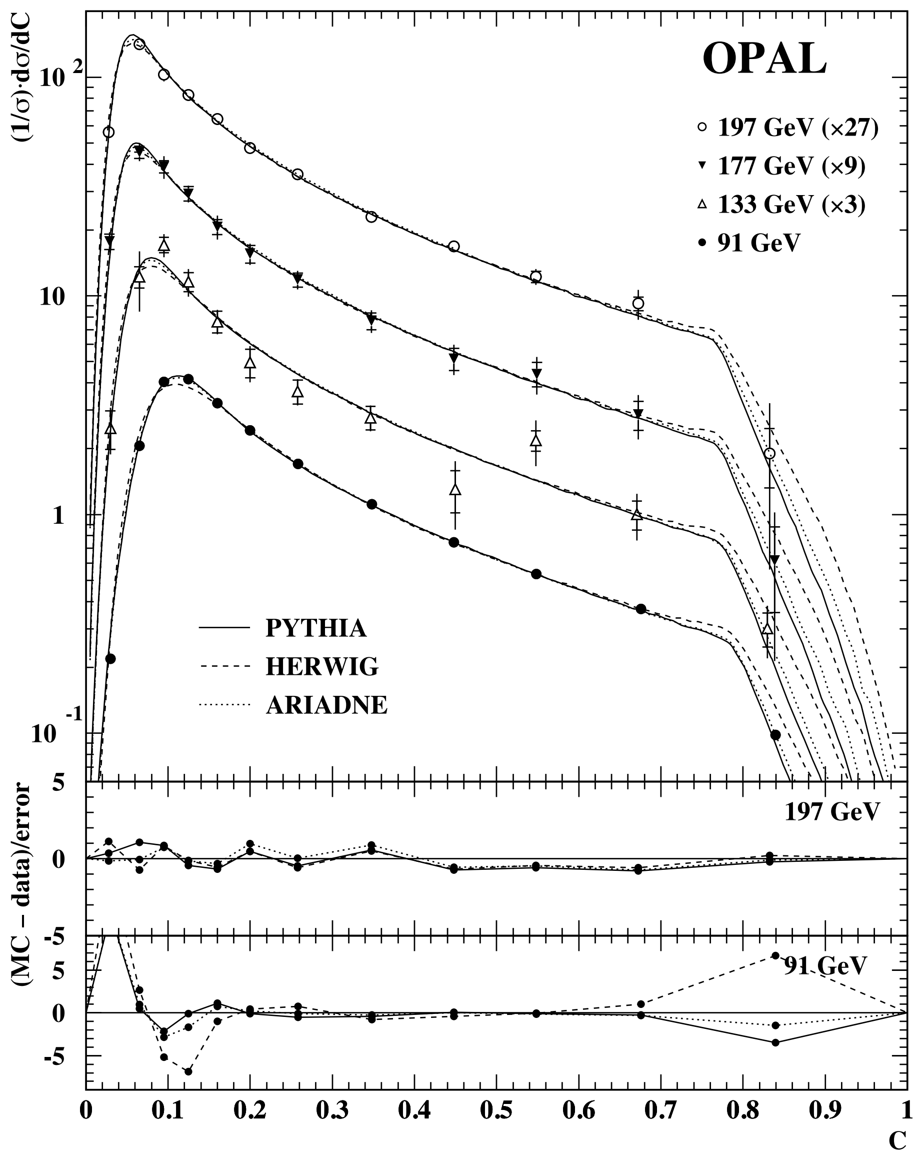


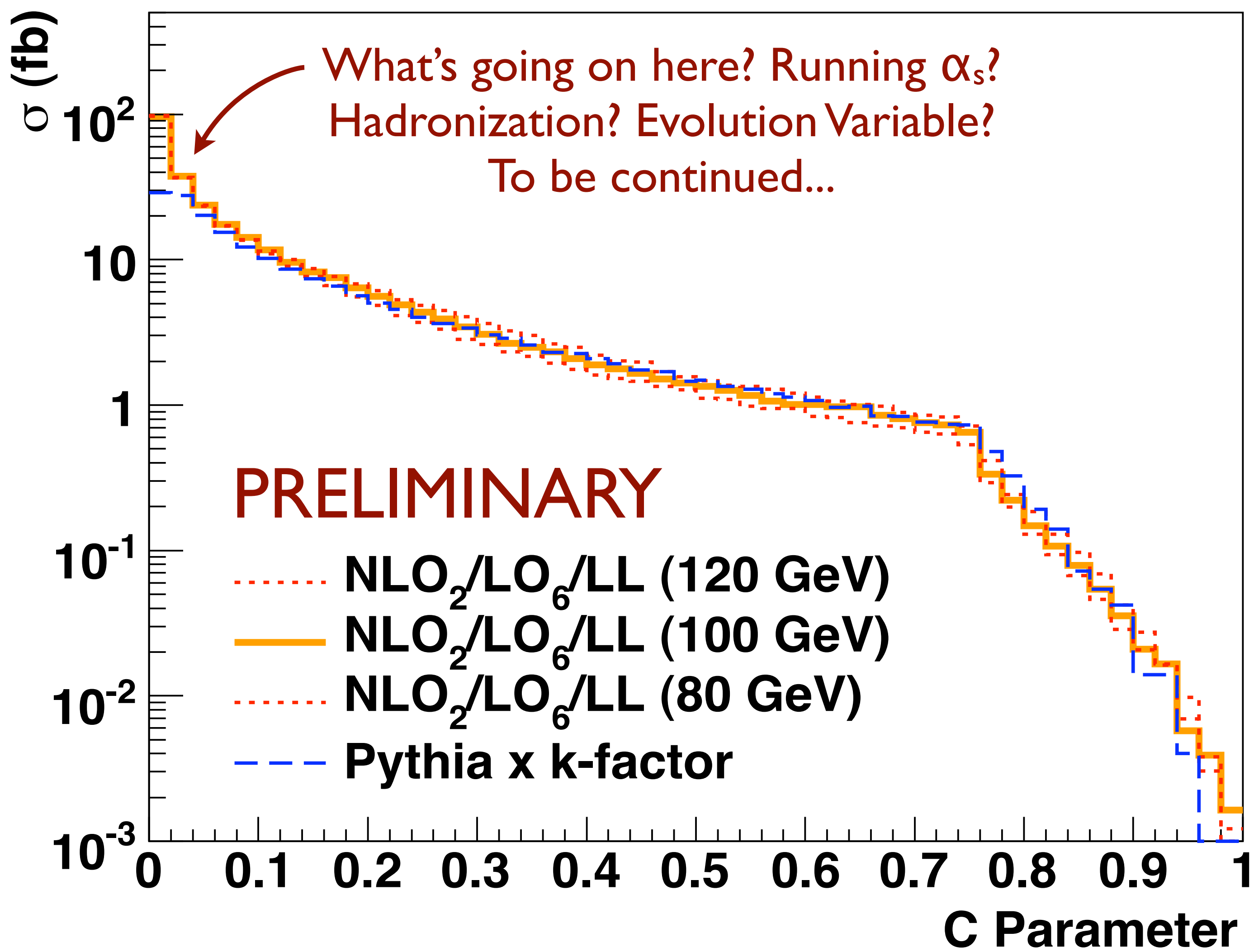
$$\left|\mathcal{M}^{\mathrm{best}}(\Lambda)\right|^2 = \left|\mathcal{M}^{\mathrm{shower}}(\Lambda)\right|^2 \times \frac{\left|\mathcal{M}^{\text{CKKW-L}^*}(\mu_5)\right|^2}{\left|\mathcal{M}^{\mathrm{shower}}(\mu_5)\right|^2} \times \frac{\left|\mathcal{M}^{\mathrm{POWHEG}^*}(\mu_3)\right|^2}{\left|\mathcal{M}^{\text{CKKW-L}^*}(\mu_3)\right|^2}$$

NLO/LO/LL Calculation



“Data” Comparison





LEP ≈ Pythia, Pythia* ≈ GenEvA (large angle region)

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...yielding an efficient, versatile, and improvable event generator.

$$w = \left|\mathcal{M}_m^{\mathrm{best}}(\mu)\right|^2 \Big/ \left|\mathcal{M}_m^{\mathrm{shower}}(\mu)\right|^2$$

GENerate EVents Analytically

Will it work with hadronic collisions?

Will it work with more loop diagrams?

Will it work with subleading logs?

GENerate EVents Analytically

Will it work with hadronic collisions?

Yes. “All” you need to do is determine
an analytic expression for the amplitude
approximation to initial state radiation.

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Will it work with subleading logs?

GENerate EVents Analytically

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Yes. “All” you need to do is determine
an analytic expression for the amplitude
approximation to initial state radiation.

Will it work with more loop diagrams?

Yes. “All” you need to do is figure out how to deal with
one-loop 3-body diagrams if the two-loop 2-body
diagrams are unknown. (Uncanceled IR divergences.)

Will it work with subleading logs?

GENerate EVents Analytically

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Yes. “All” you need to do is figure out how to deal with one-loop 3-body diagrams if the two-loop 2-body diagrams are unknown. (Uncanceled IR divergences.)

Will it work with subleading logs?

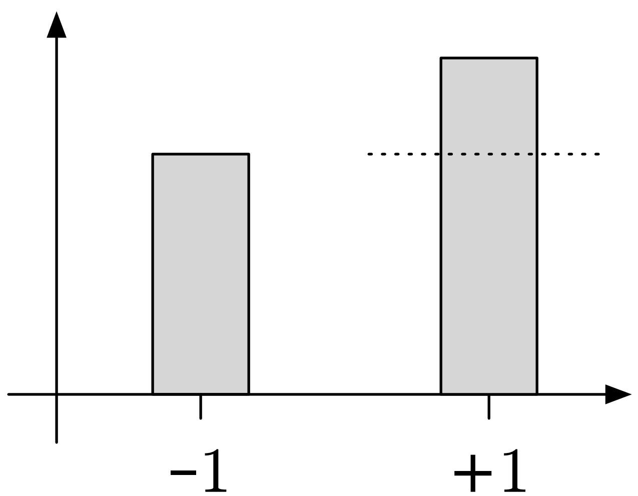
Yes. “All” you need to do is figure out how to interpret the hard/jet/soft functions of SCET in terms of the Universal Monte Carlo formula.

Backup Slides

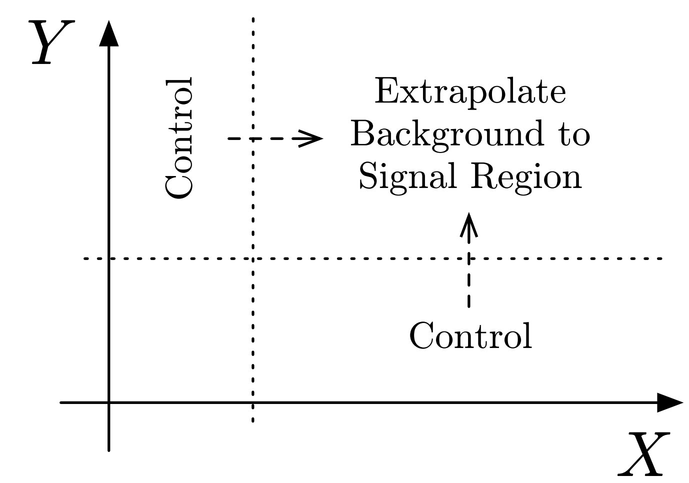
Signal/Background

Signal/Background

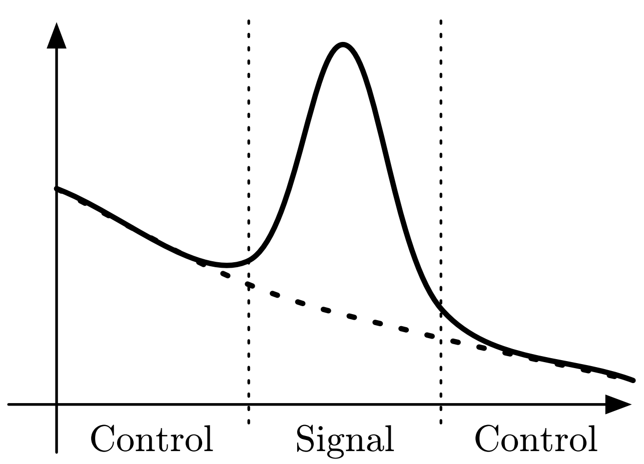
Self-Calibrating



Cross-Calibrated

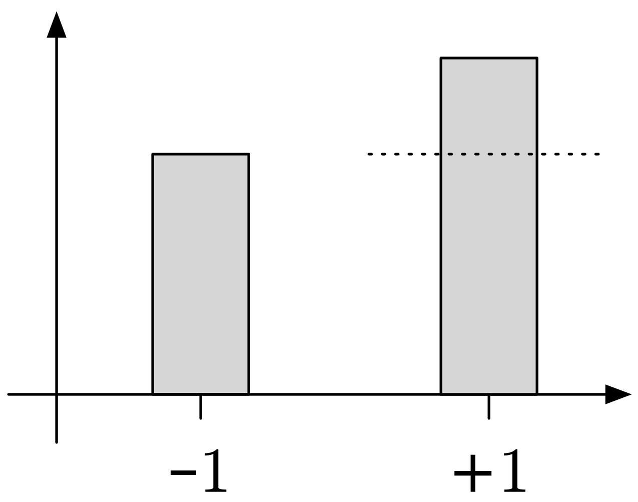


Sidebandable

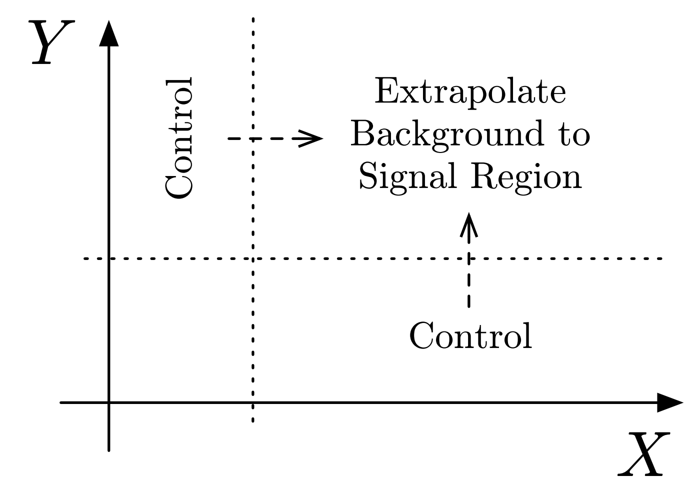


Signal/Background

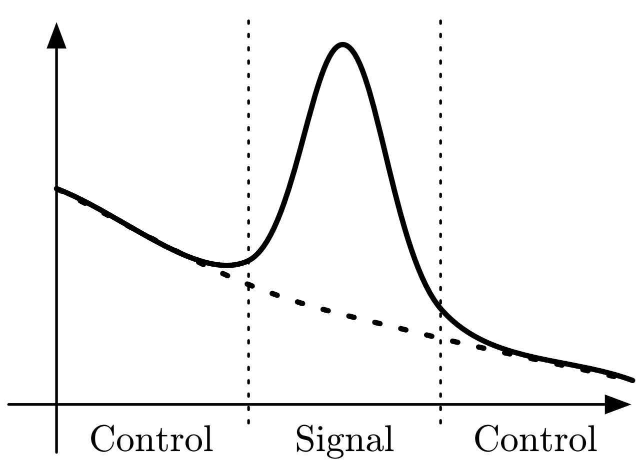
Self-Calibrating



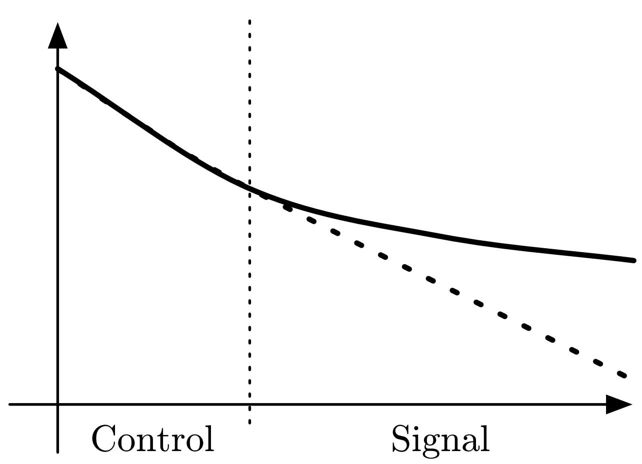
Cross-Calibrated



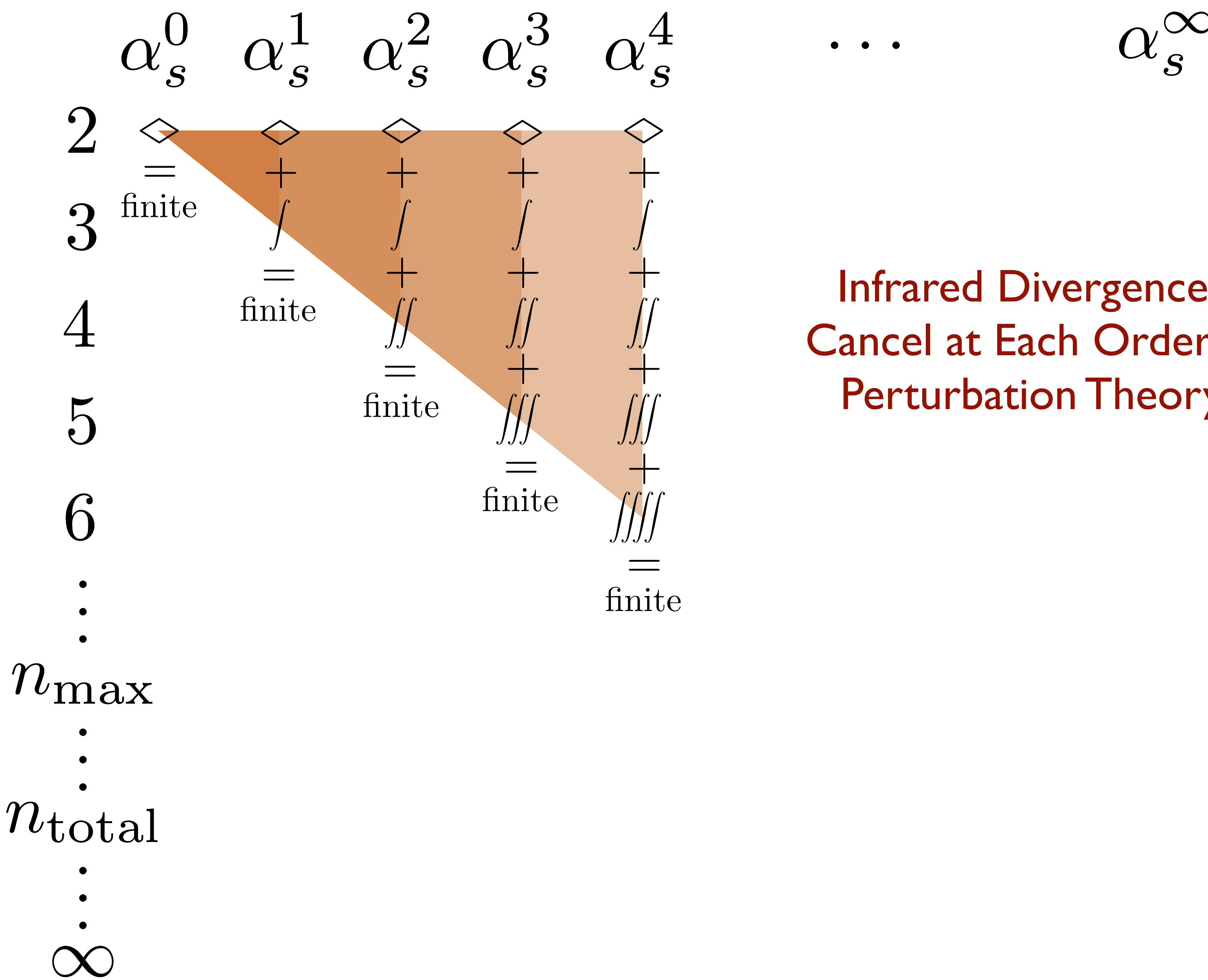
Sidebandable



Semi-Calibrated



Infrared Divergences



Infrared Divergences Cancel at Each Order in Perturbation Theory