Tuning the Primordial Transverse Momentum in PYTHIA

Yiannis Polychronakos

Supervisors: Korinna Zapp, Christian Bierlich

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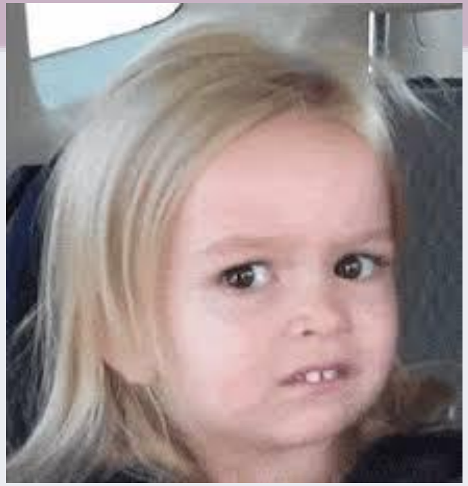
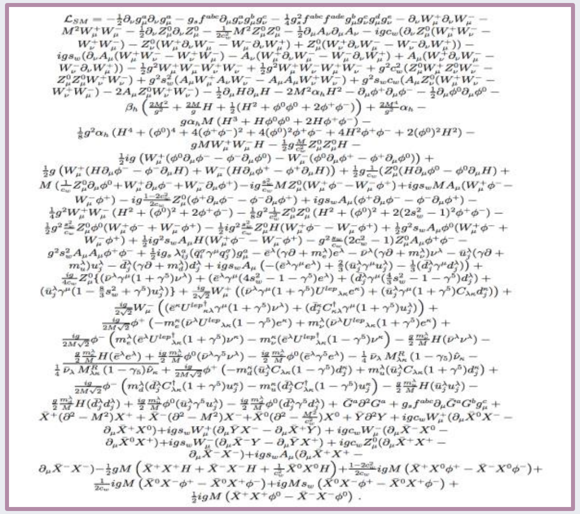
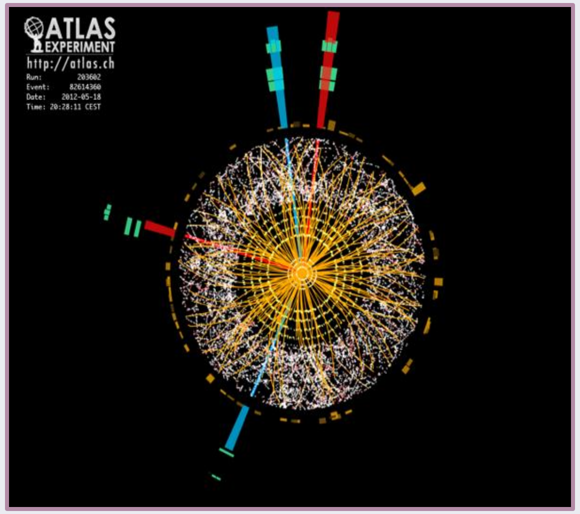


General-Purpose Monte Carlo Event Generator



- Hundreds of Final State Particles
- Non-perturbative Physics
- Multiple orders of magnitude in energy



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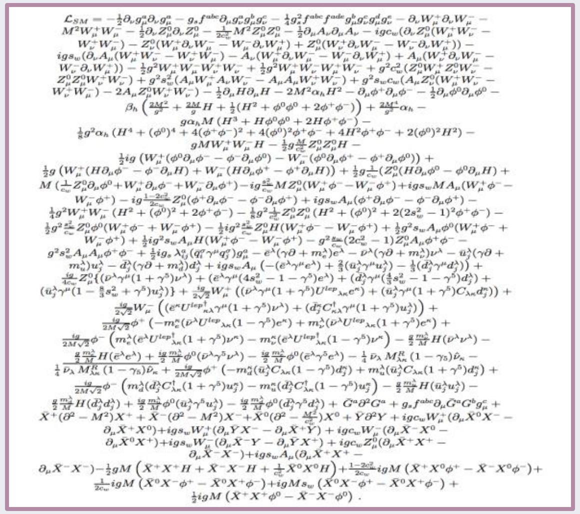

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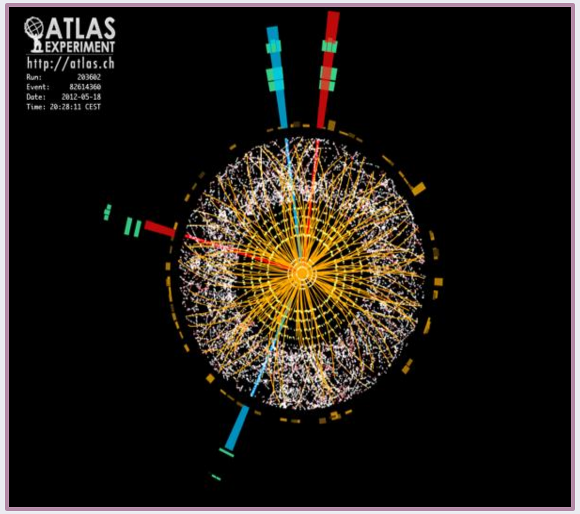

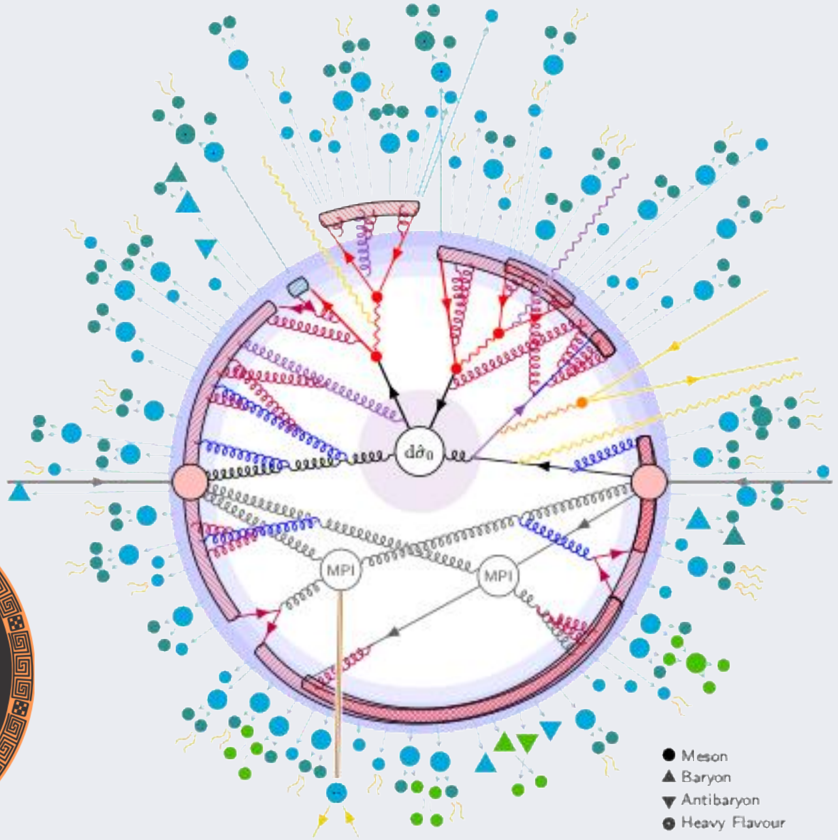

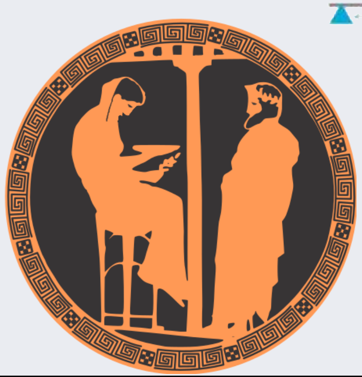

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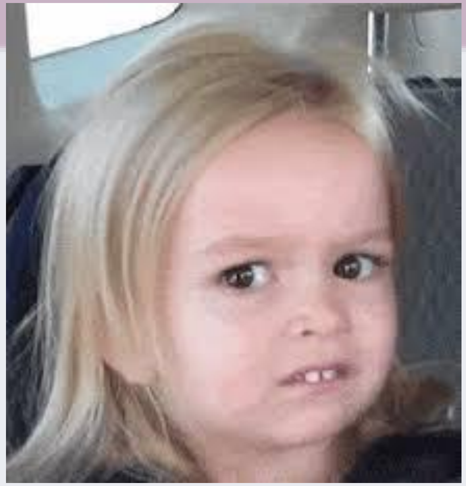


Find the parameters that fit the most data

Every model has free parameters that need to be ”tuned” by experiment.

Standard Model: 19 free parameters

- Fermion Masses (9)
- Gauge Couplings (3)
- CKM matrix (4)
- θ_{QCD} (1)
- Higgs vev (1)
- Higgs mass (1)

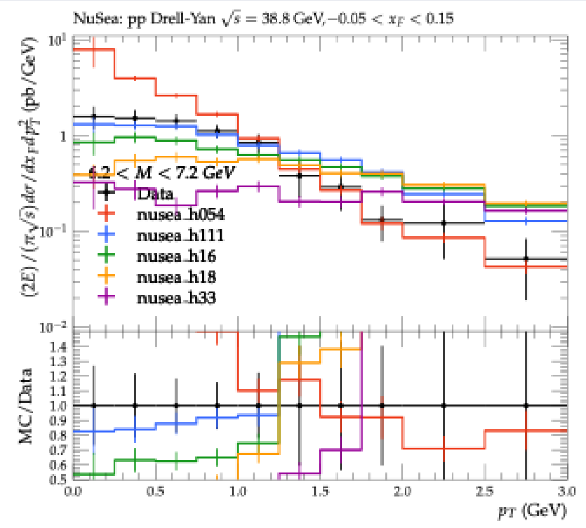
PYTHIA: ~ 60 free parameters (from Monash Tune)

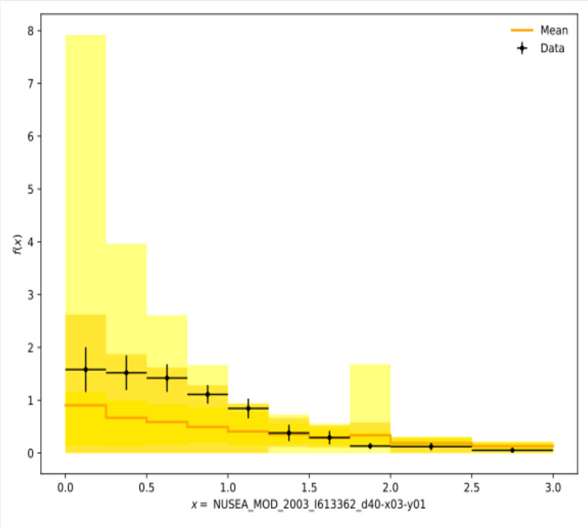
- Final State Radiation (6)
- Initial State Radiation (15)
- PDF and Matrix Elements (3)
- Multiple Parton Interactions (12)
- Hadronization (23)

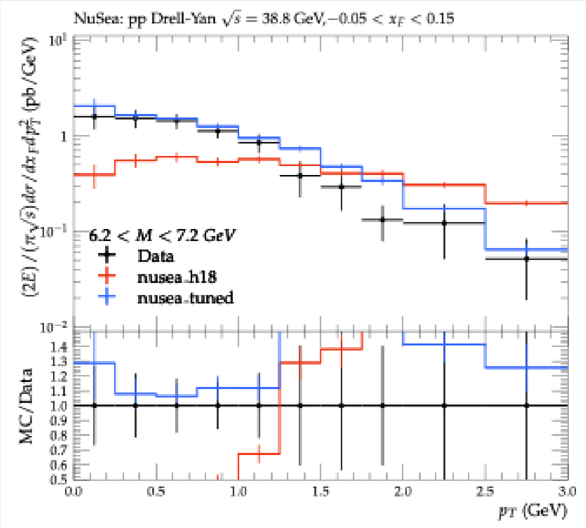
How do we tune so many parameters?

Surrogate Models with PROFESSOR
(at least for now)

Parameter Space Sampling → Bin by bin Polynomial Interpolation → χ^2 minimization → Prediction







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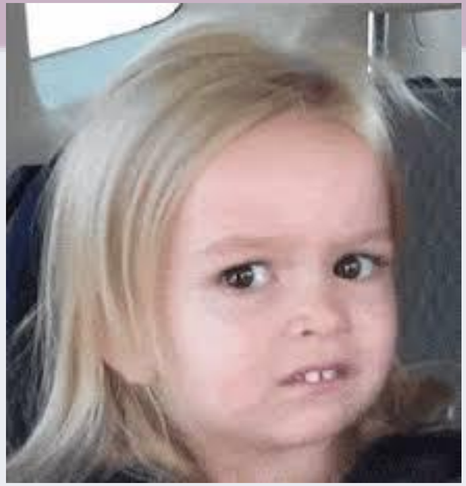
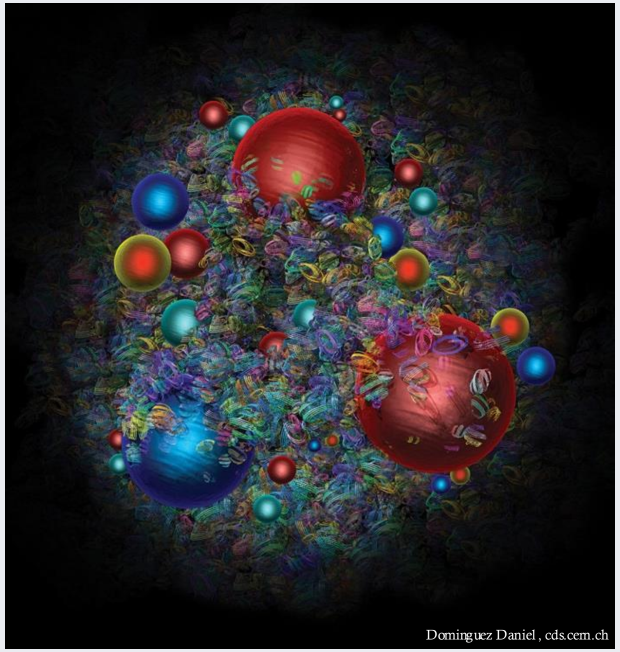


Initial momentum transverse to the beam direction

Proton at Rest



We expect the partons to have, at least, an average momentum of the order of $\Lambda_{QCD} \sim 300 MeV$

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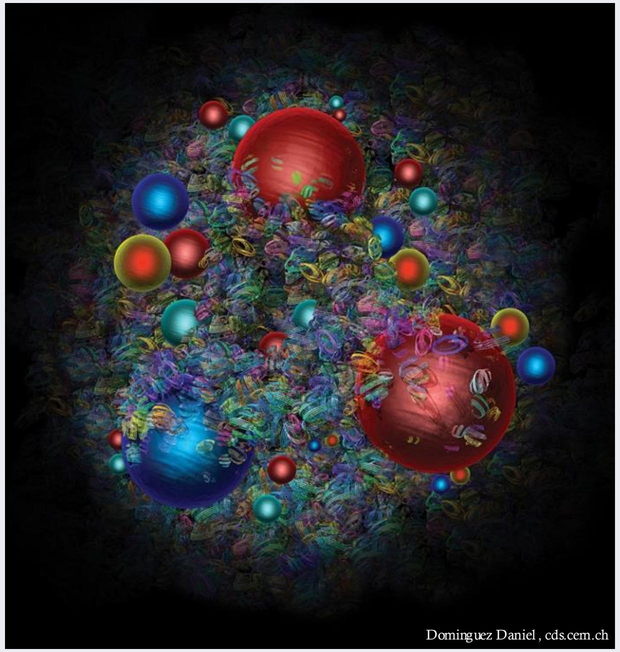

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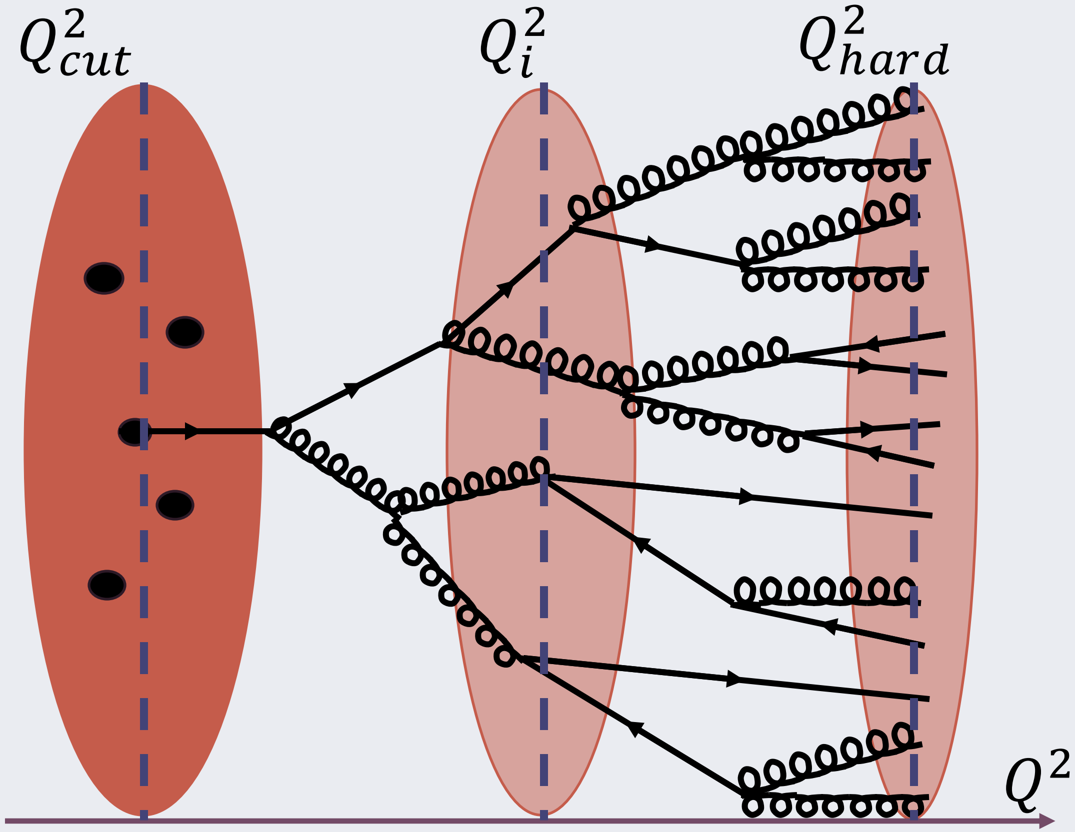
Initial State Radiation (Space-like Parton Shower)



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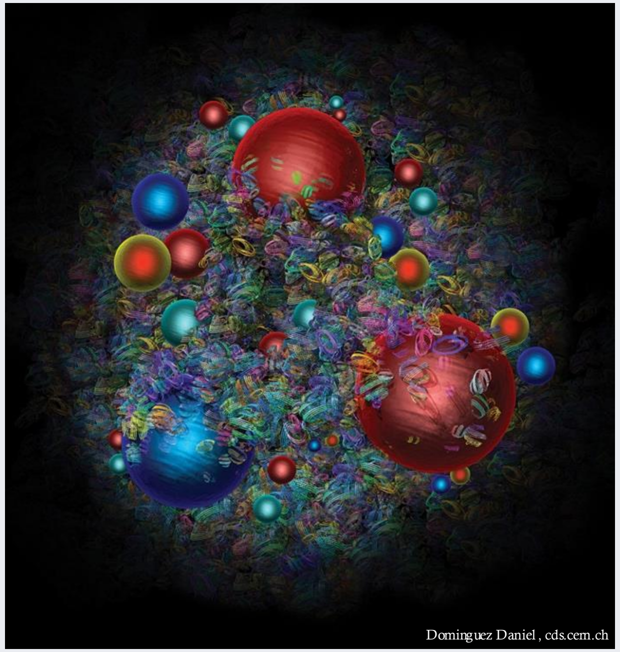

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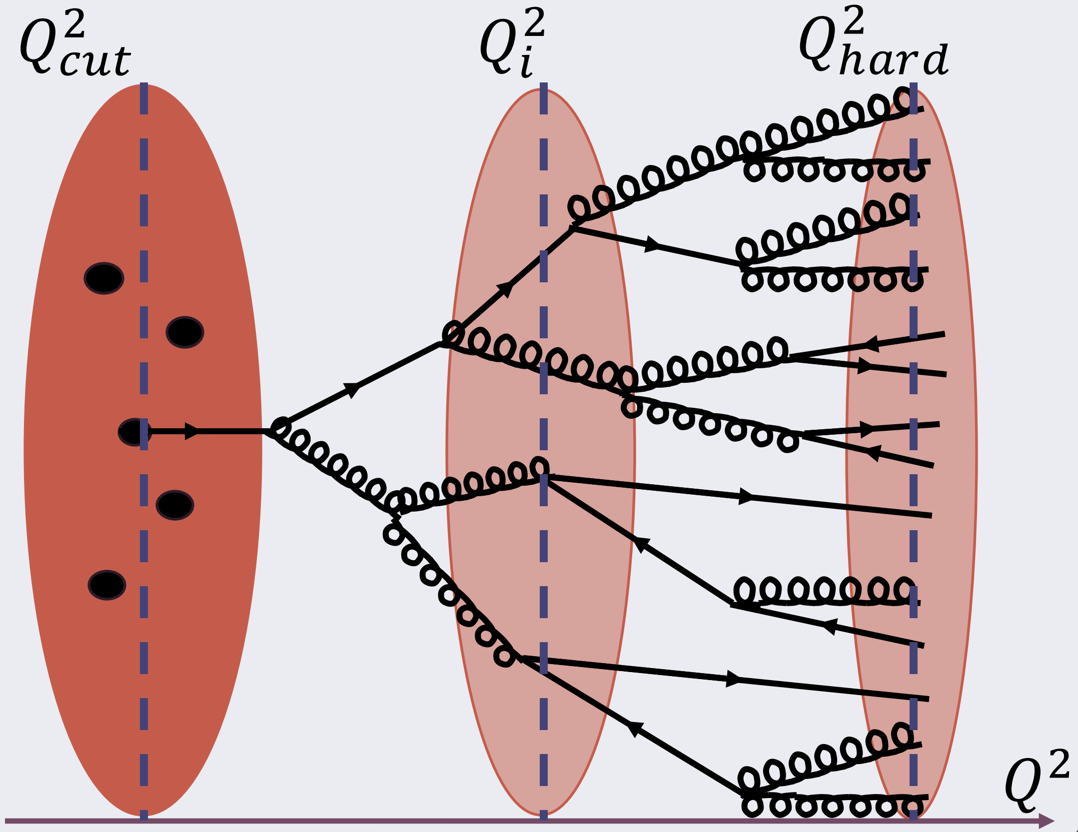


Role of Primordial k_T

Fermi motion of partons below the ISR cut-off.

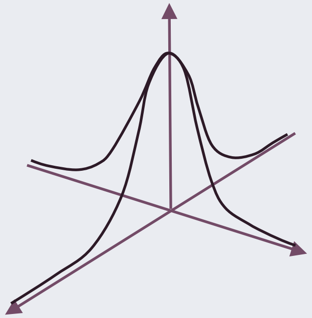
Radiation not accounted for by the parton shower evolution.

Primordial kT in PYTHIA

In PYTHIA the primordial k_T is applied as a correction on the transverse momentum that the space-like parton shower produces.

Parametrization is two gaussians: $\propto e^{-k_{\mathrm{i}}^2/\sigma^2}$

All the parameters are in the width!



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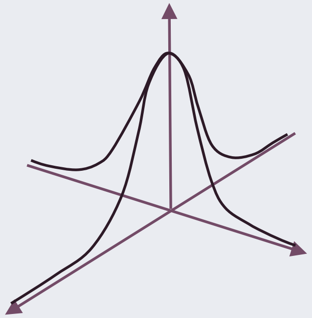

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"Technical Dampening Factor"

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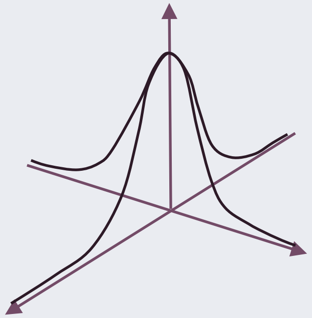

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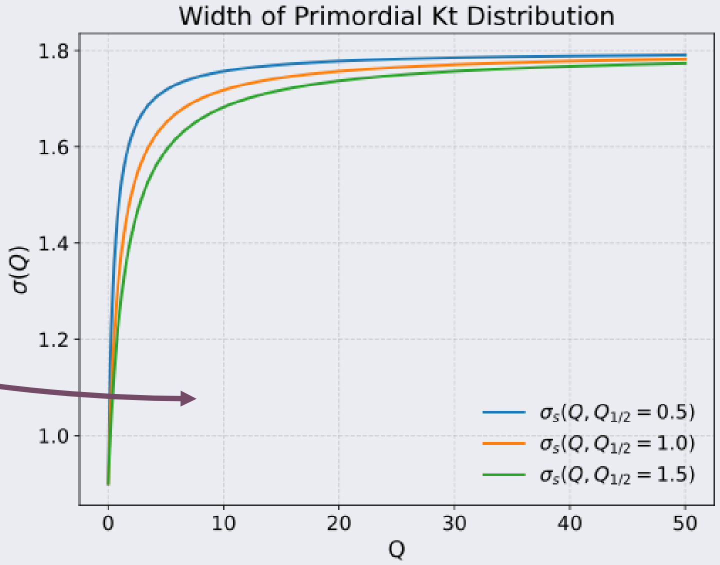

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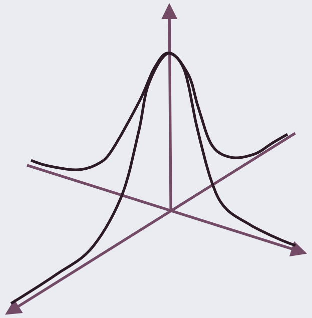

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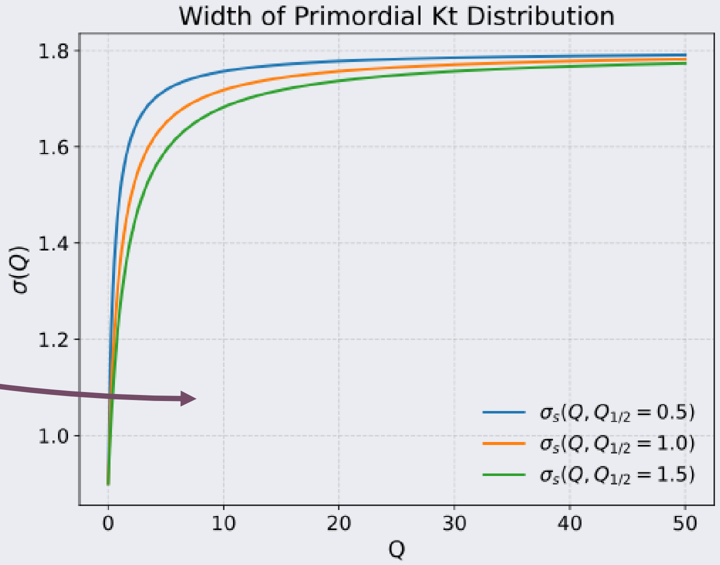


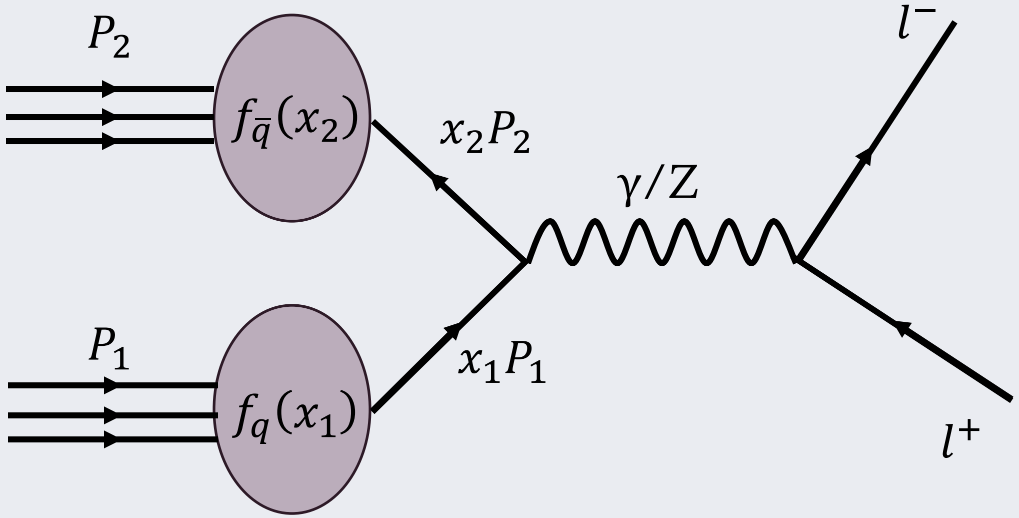
"Technical Dampening Factor"

Default values:

$Q_{1/2} = m_{1/2} = 0$ → $\sigma = \sigma_{hard}$

Drell –Yan Process as Primordial kT Probe

Collinear Factorization: $\sigma_{AB} = \sum_q \int dx_1 dx_2 f_q(x_1, Q^2) f_{\bar{q}}(x_2, Q^2) \sigma_{q\bar{q}\to l^+ l^-}$



We generalize the PDFs:

$$dx f(x) \to d^2k_T dx P(\overrightarrow{k_T}, x) = d^2k_T dx\, h(\overrightarrow{k_T}) f(x)$$

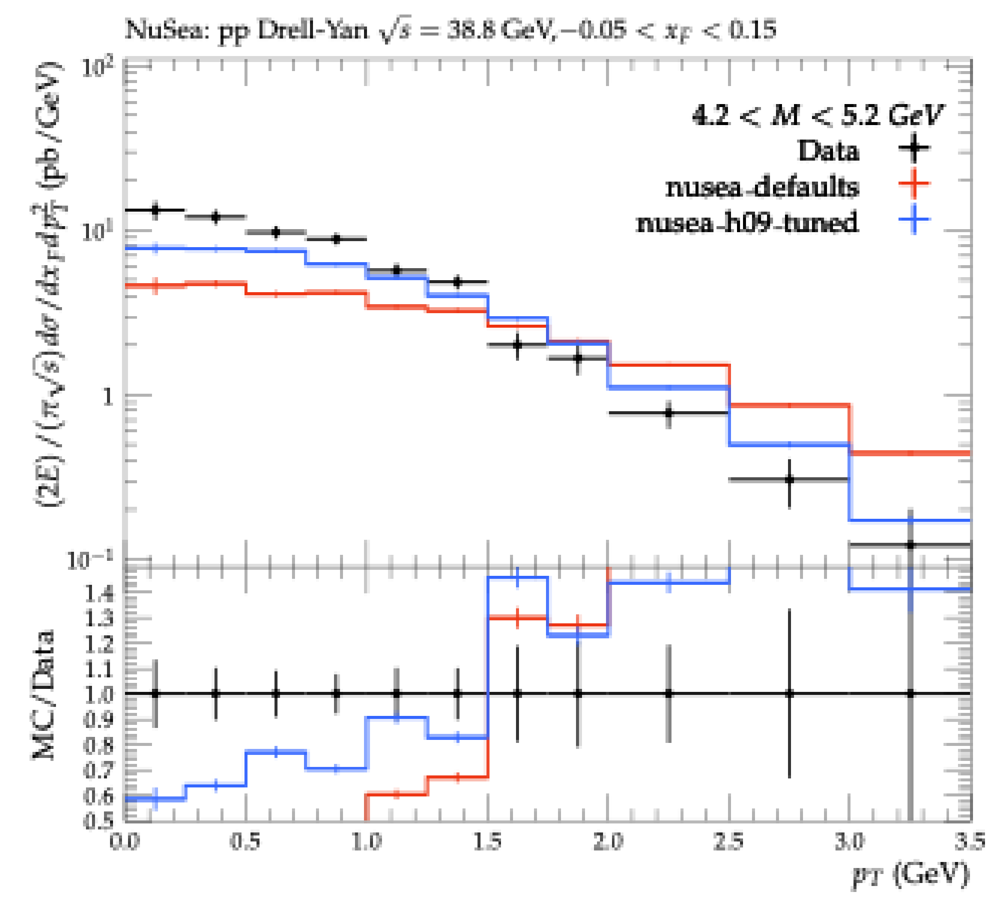
In the simple model of a Gaussian Distribution:

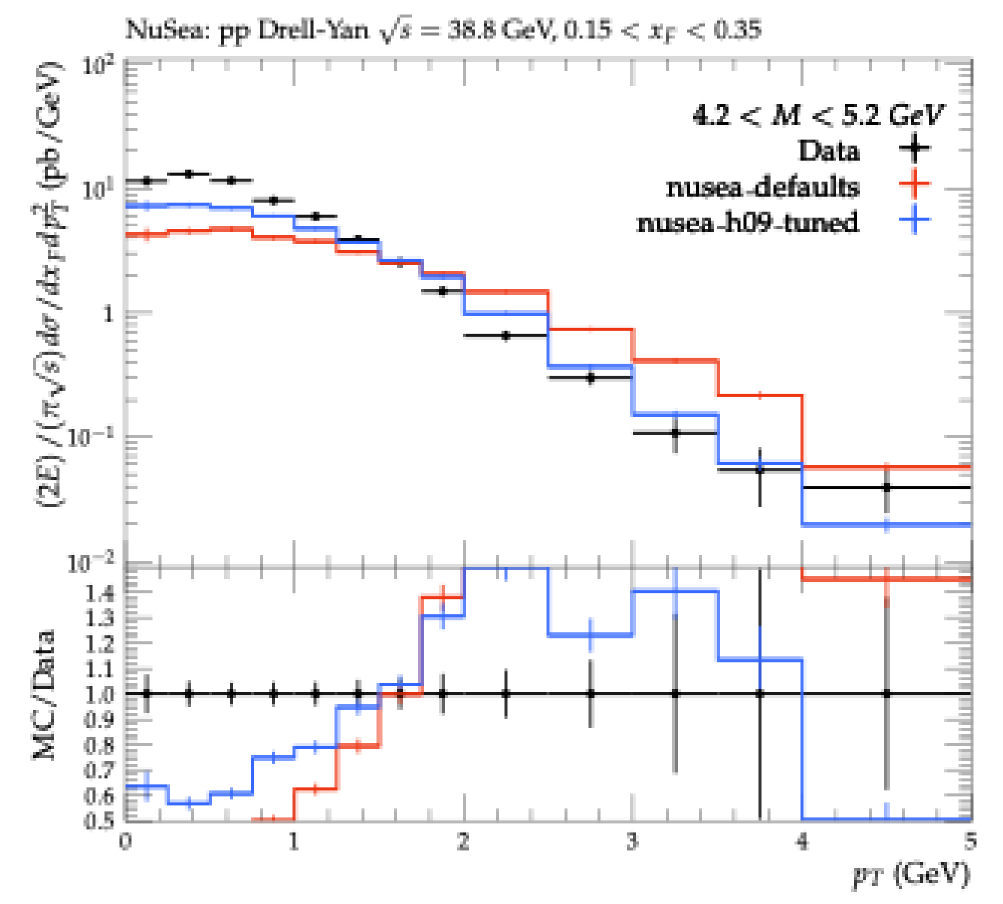
$$h(\overrightarrow{k_T}) = \frac{1}{\pi\sigma^2} e^{-k_T^2 / \sigma^2}$$

$$\frac{M^4}{\sigma} \frac{d^4\sigma}{dM^2\, dy\, d^2p_T} = \frac{1}{2\pi\sigma^2} e^{-p_T^2/2\sigma^2}$$

Some Tuning Results

NuSea Data: Drell-Yan dimuon production ($pp \rightarrow \mu^- \mu^+ + X$) at $\sqrt{s} = 38.8$ GeV.





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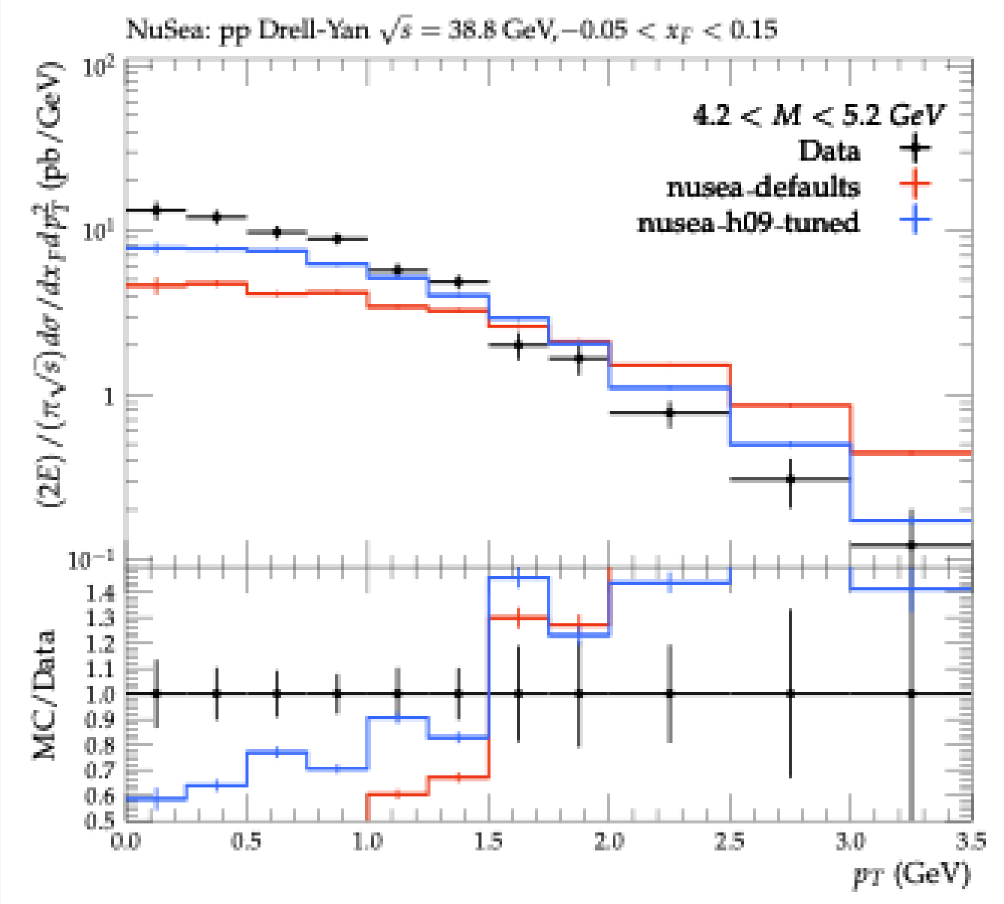

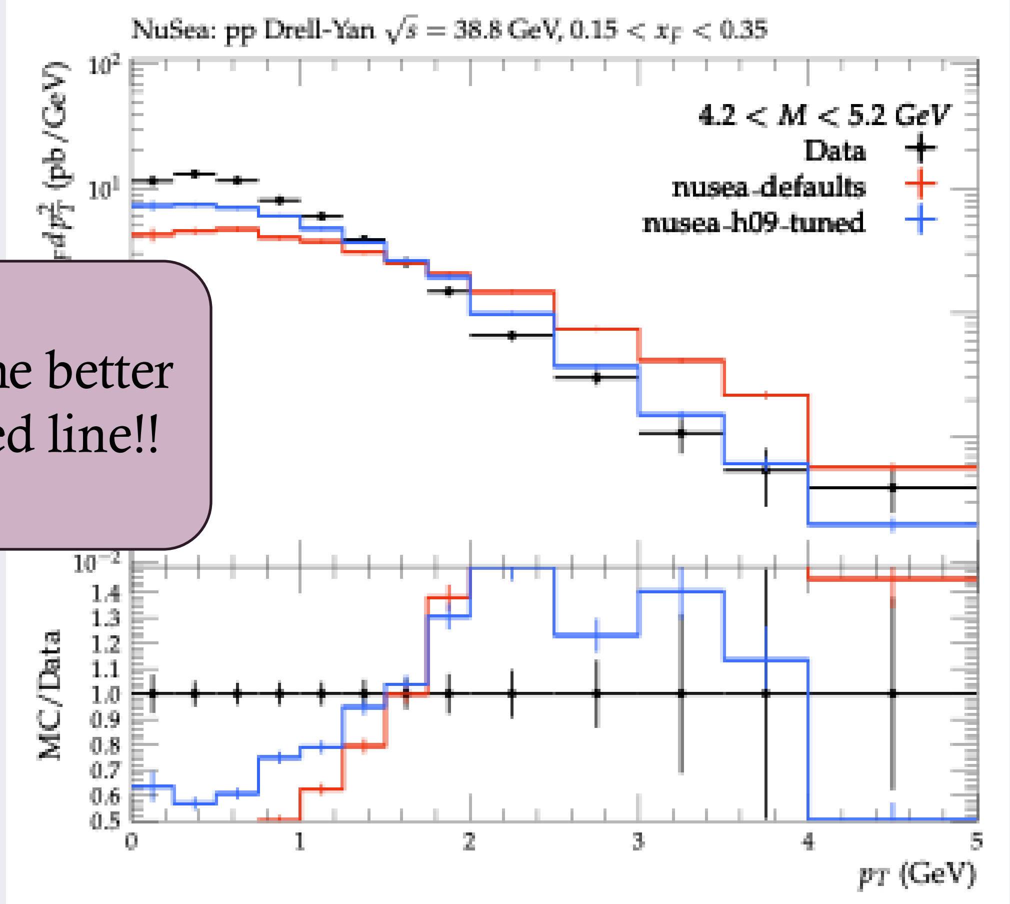

Blue line better than red line!!

Work in Progress

Experiment:	$\sqrt{s}$	Q (GeV)
NUSEA	38.8 GeV	[4.2 , 6.2, 7.2, 8.7, 10.9, 12. 9]
PHENIX	200 GeV	[4.8 , 8.2]
CDF	1.96 TeV	[66, 116]
ATLAS	7 TeV	[66, 116]
CMS	13 TeV	[50, 1000]
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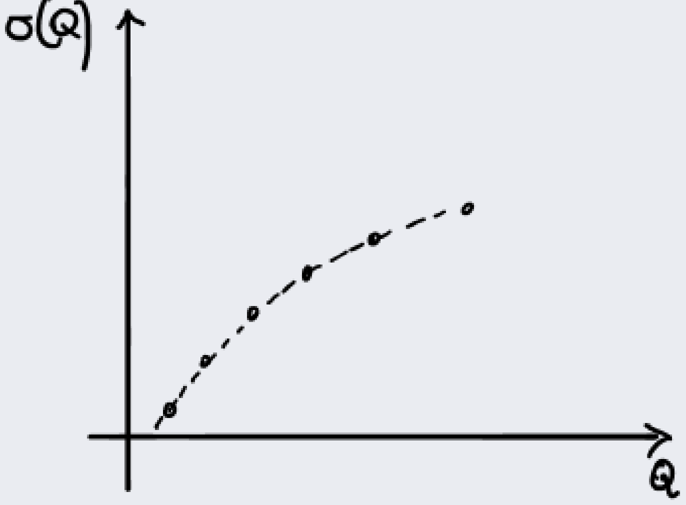

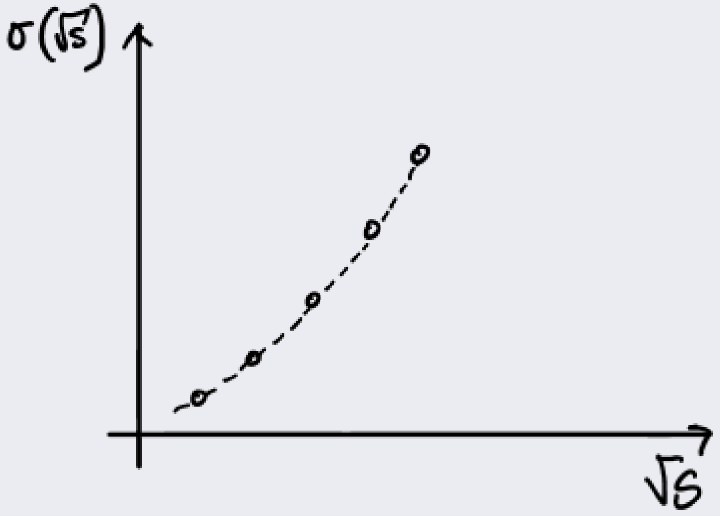

Last tune was Monash 2013 with very few data points

New tune bound to happen and maybe re-parametrization of the primordial kT in PYTHIA!

THANK YOU FOR LISTENING!

Division of Particle and Nuclear Physics – PhD Day