Treatment of Small Mass Hadronic Systems in the Lund Model

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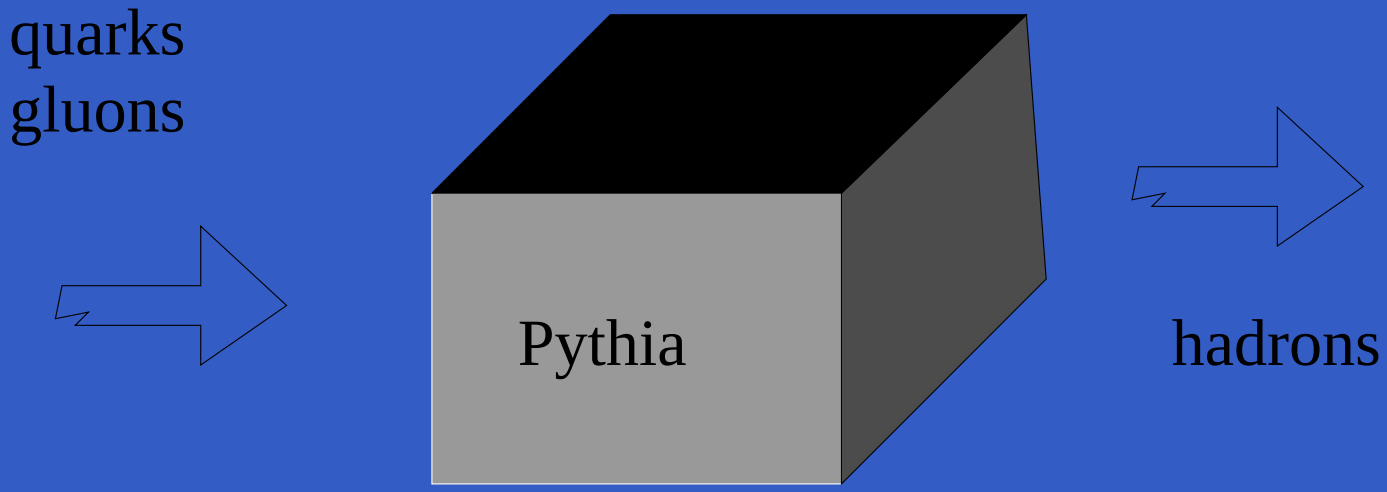
The MC black box



Outline of the talk

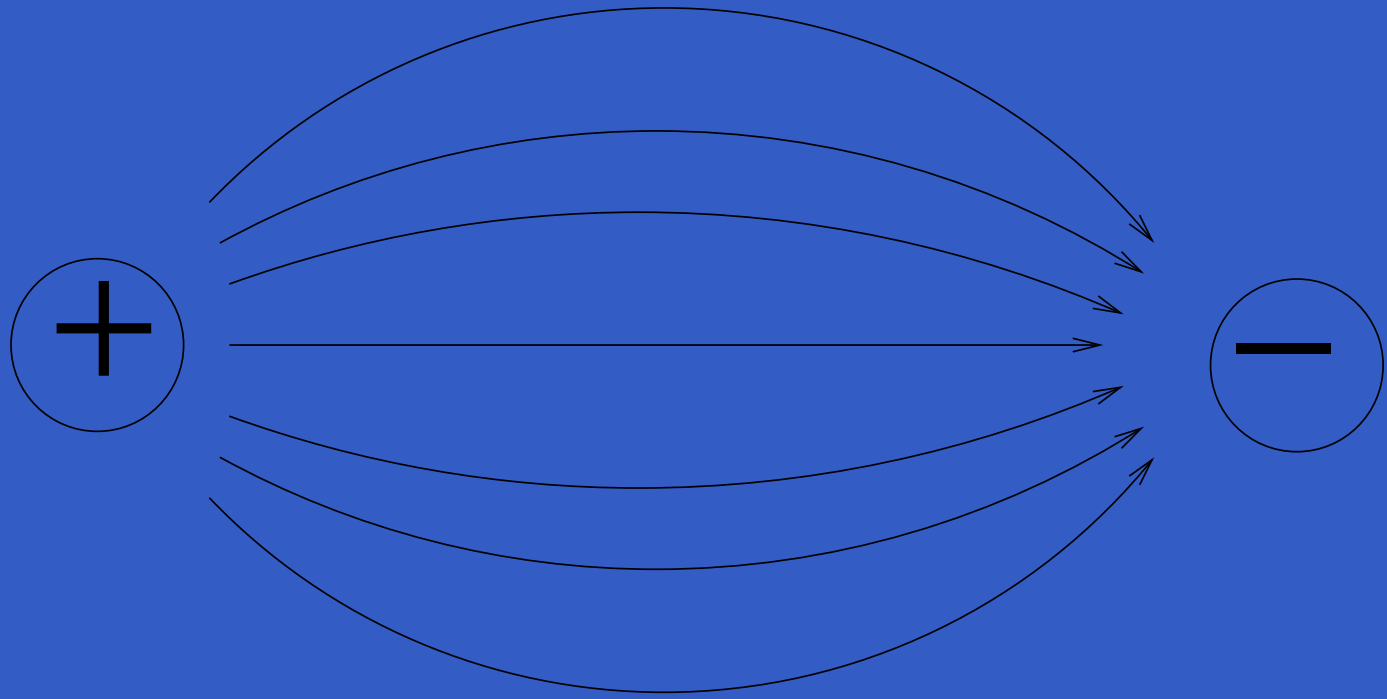
- A General Introduction to the Lund Model
- Phase Space and Small Invariant Masses
- A Strategy to handle small strings
- Concluding Remarks

Introduction to the Lund Model

Bo Andersson, Gösta Gustafson,
Torbjörn Sjöstrand, Gunnar Ingelman,
Bo Söderberg, Leif Lönblad,
Patrik Edén, Markus Ringnér,
Fredrik Söderberg
(Sandipan Mohanty)
...

Introduction to the Lund Model

Field lines between electric charges spread out



Introduction to the Lund Model

"Dual" superconductor

inside a "dual" superconductor

Introduction to the Lund Model

"Field lines" between colour charges

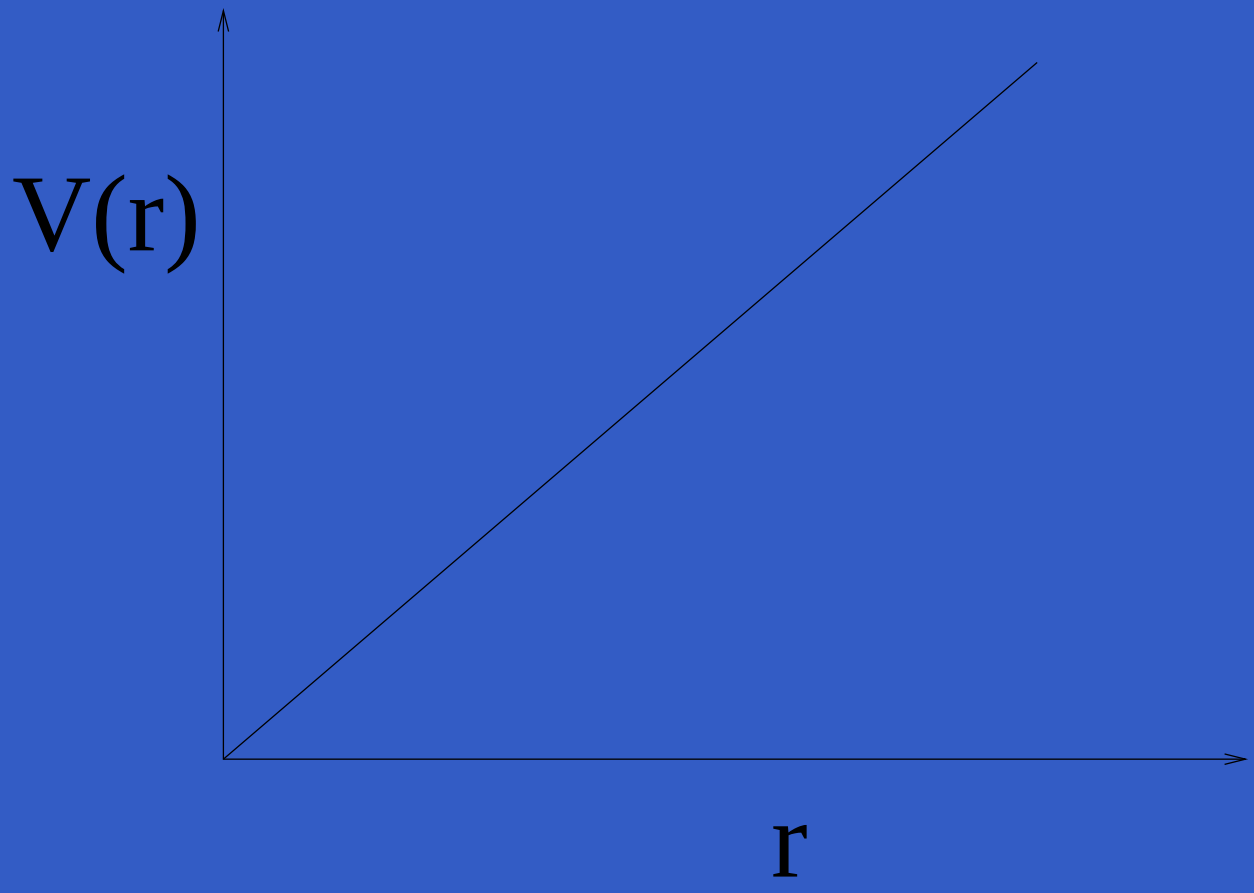
ordinary space

colour anti−colour

confining force field

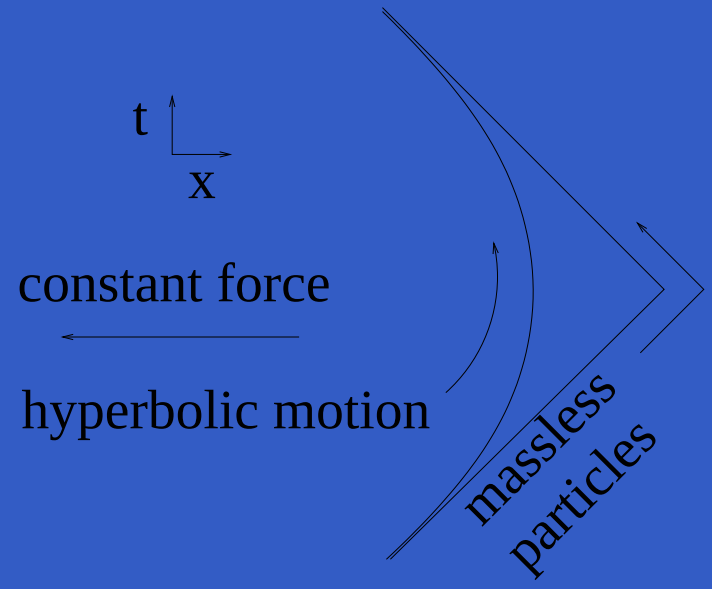
Introduction to the Lund Model

Constant energy density $\Longrightarrow$ linear potential



Introduction to the Lund Model

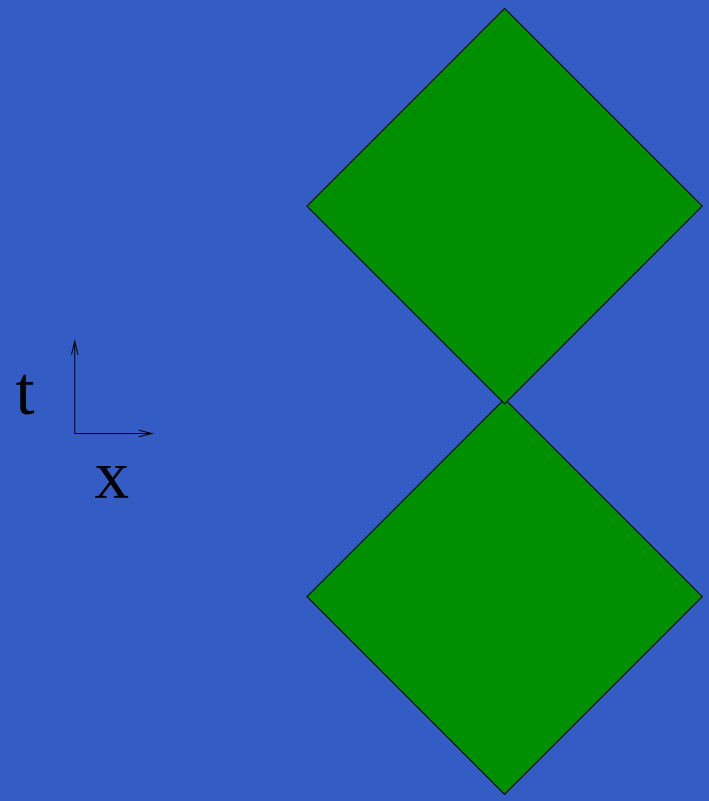
Hyperbolic motion in constant force field



Introduction to the Lund Model

Bound colour anti-colour pair execute oscillatory motion

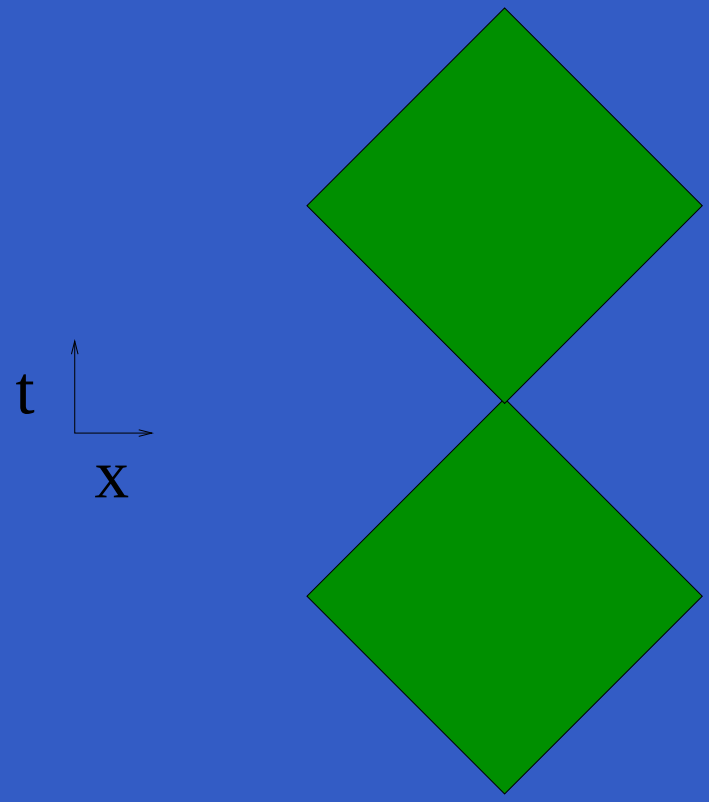
- Turning Points in the same half period have space like interval



Introduction to the Lund Model

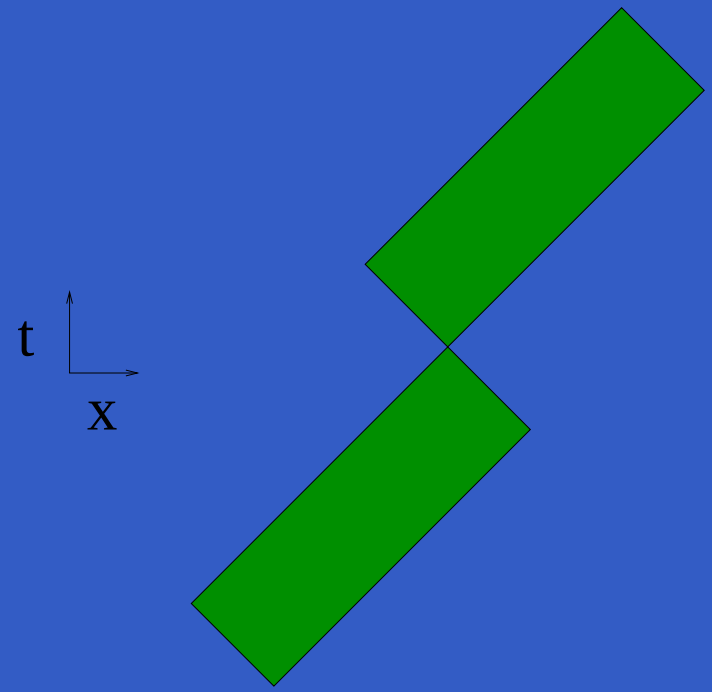
Bound colour anti-colour pair execute oscillatory motion

- Area traced in half period = squared mass of the system



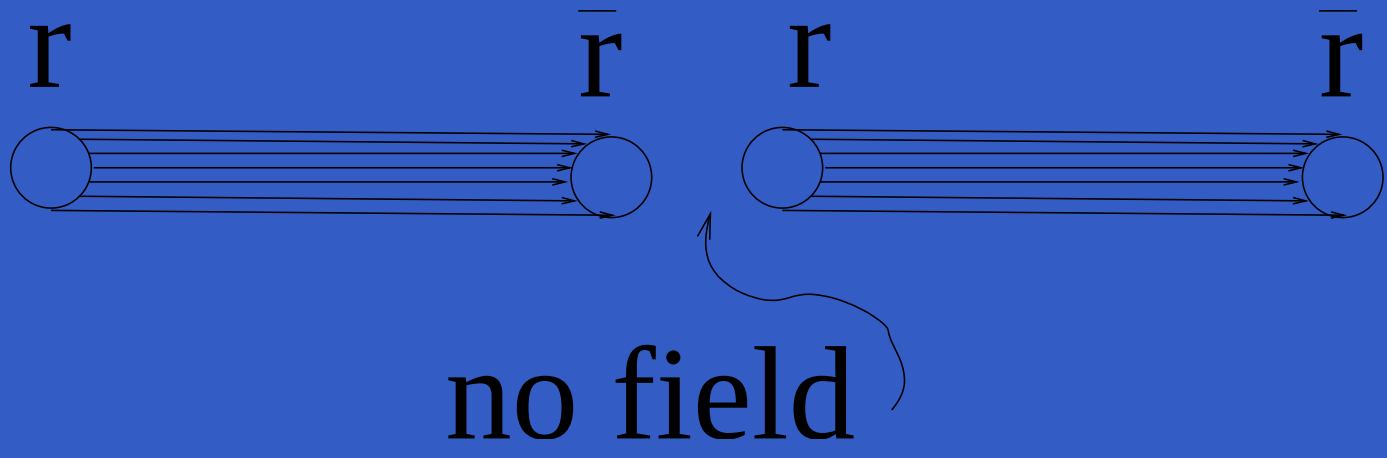
Introduction to the Lund Model

"Yoyo" mode in motion



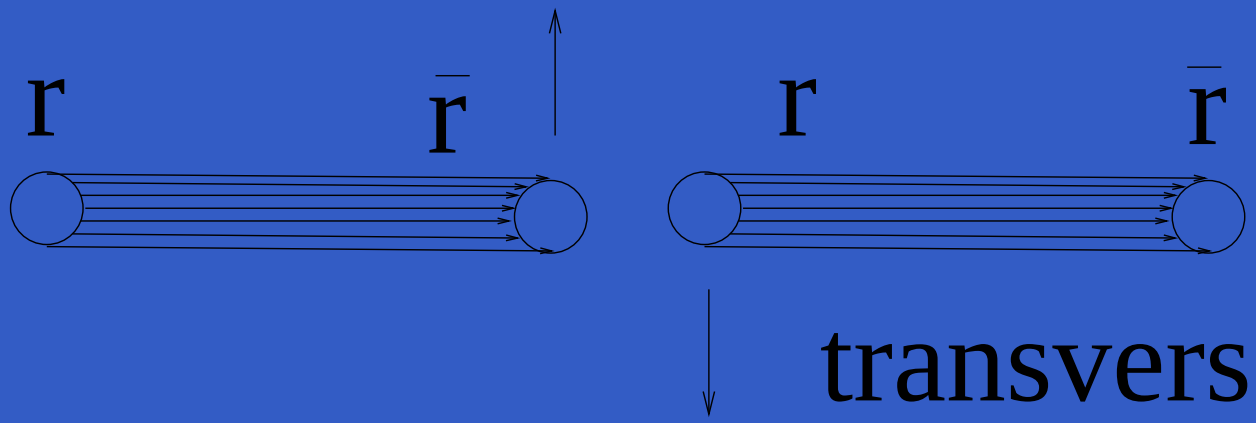
Introduction to the Lund Model

Pair production of colour anti-colour breaks the string

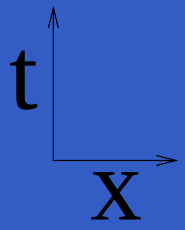


Introduction to the Lund Model

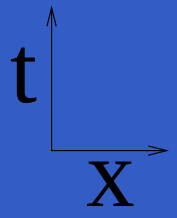
Uncertainity principle : transverse momentum generation

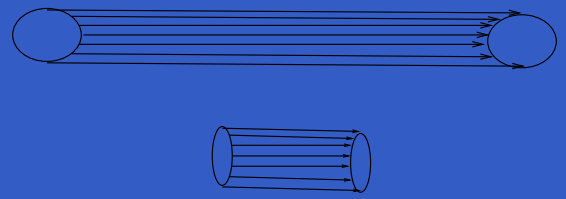


String breakup sequence 1

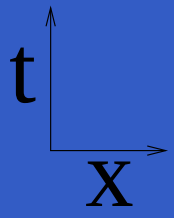


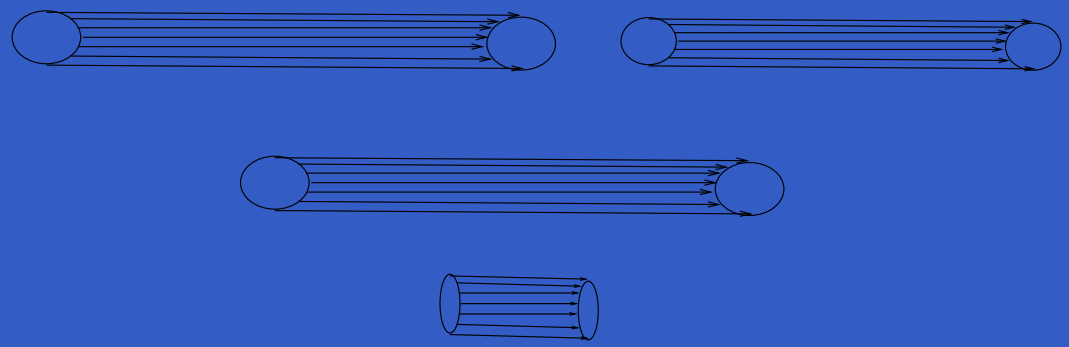
String breakup sequence 2



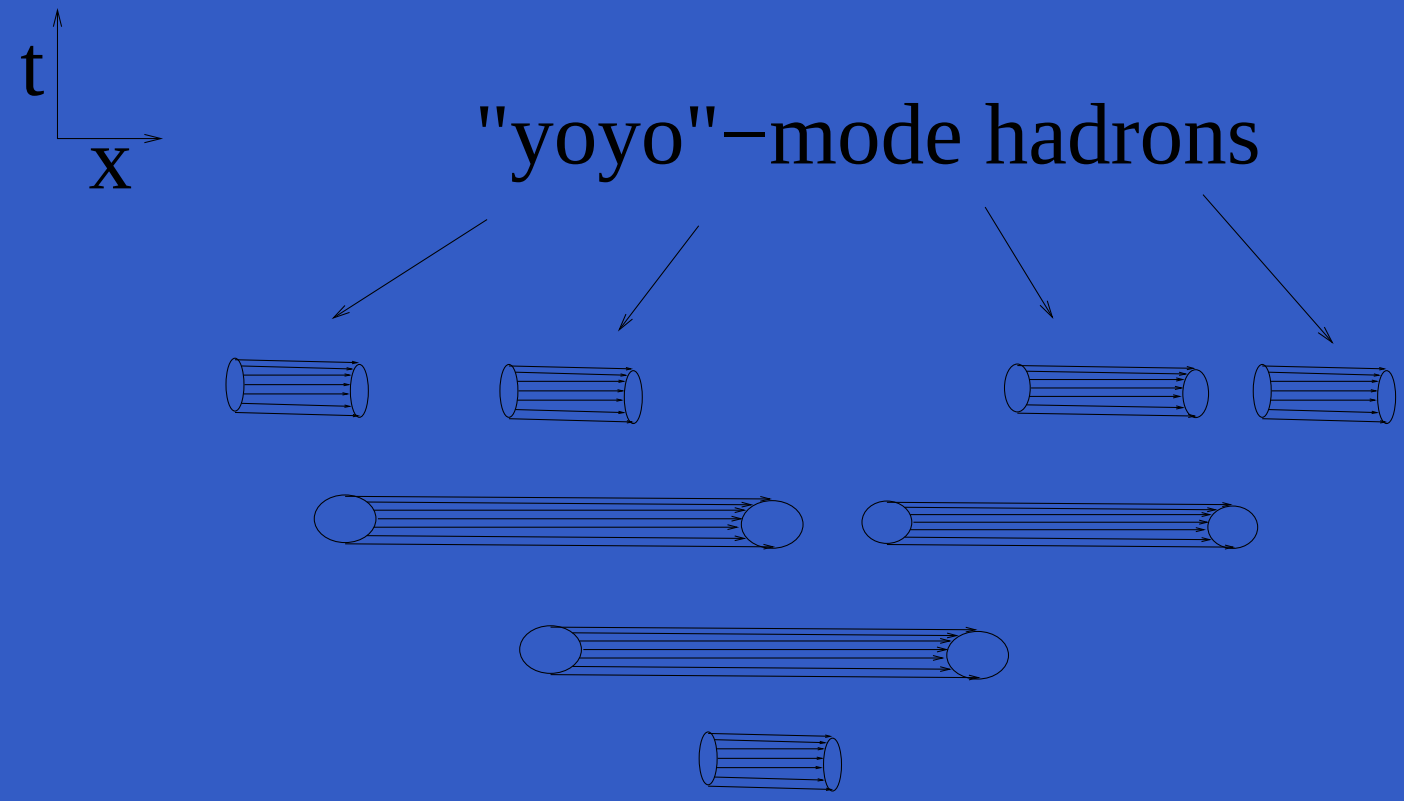


String breakup sequence 3

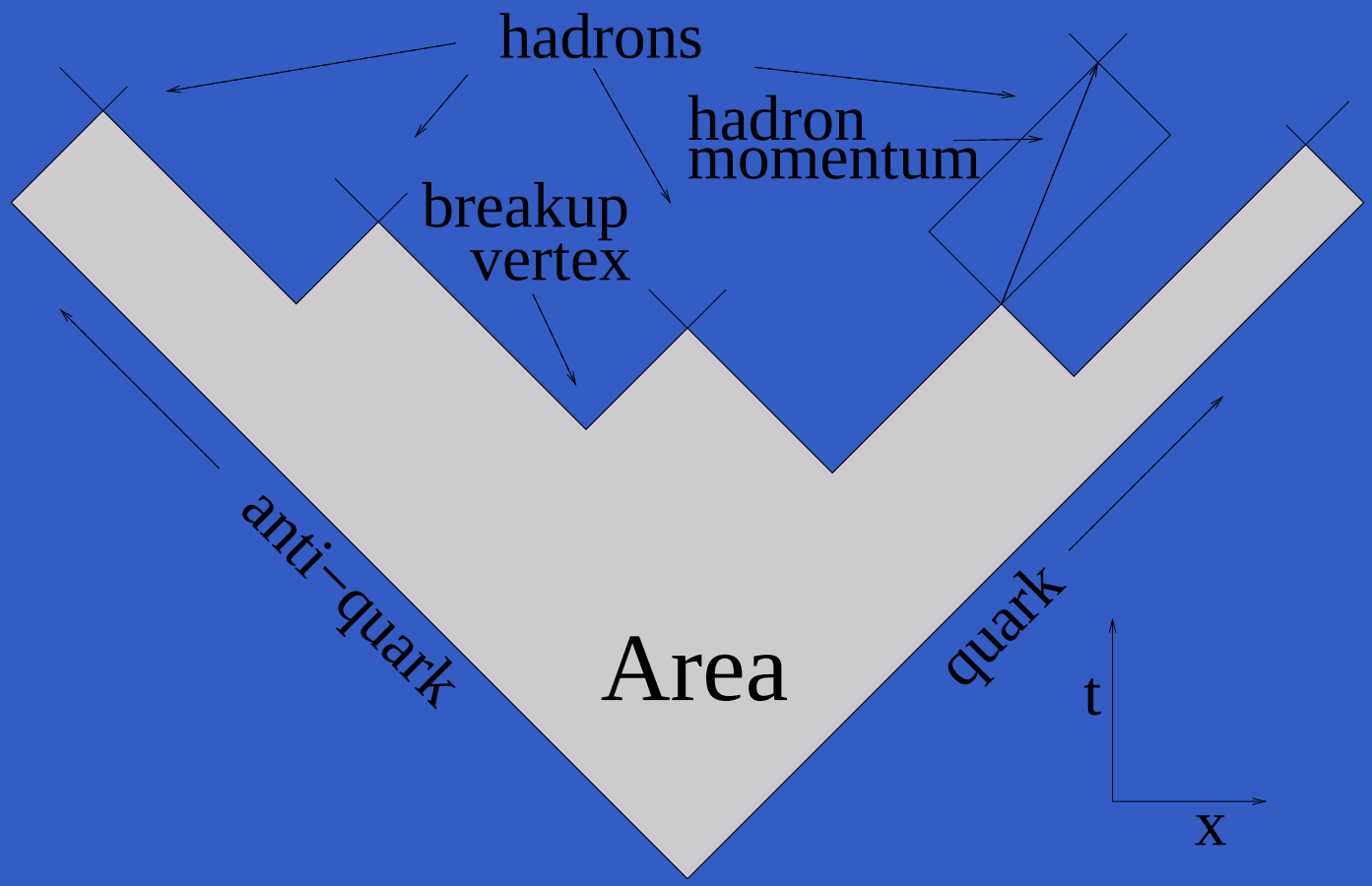




String breakup sequence 4



Lund Model: The Area Law



Lund Model: The Area Law

- Time ordering is frame dependent: no “first” vertex etc.
- Frame independent “light-cone” or rank ordering possible
- Hadrons from over an extended region in space time rather than at a point
- No coloured object is “fragmented” into a colour neutral hadron, but instead a colour neutral set of partons is projected into a hadronic state

Lund Model: The Area Law

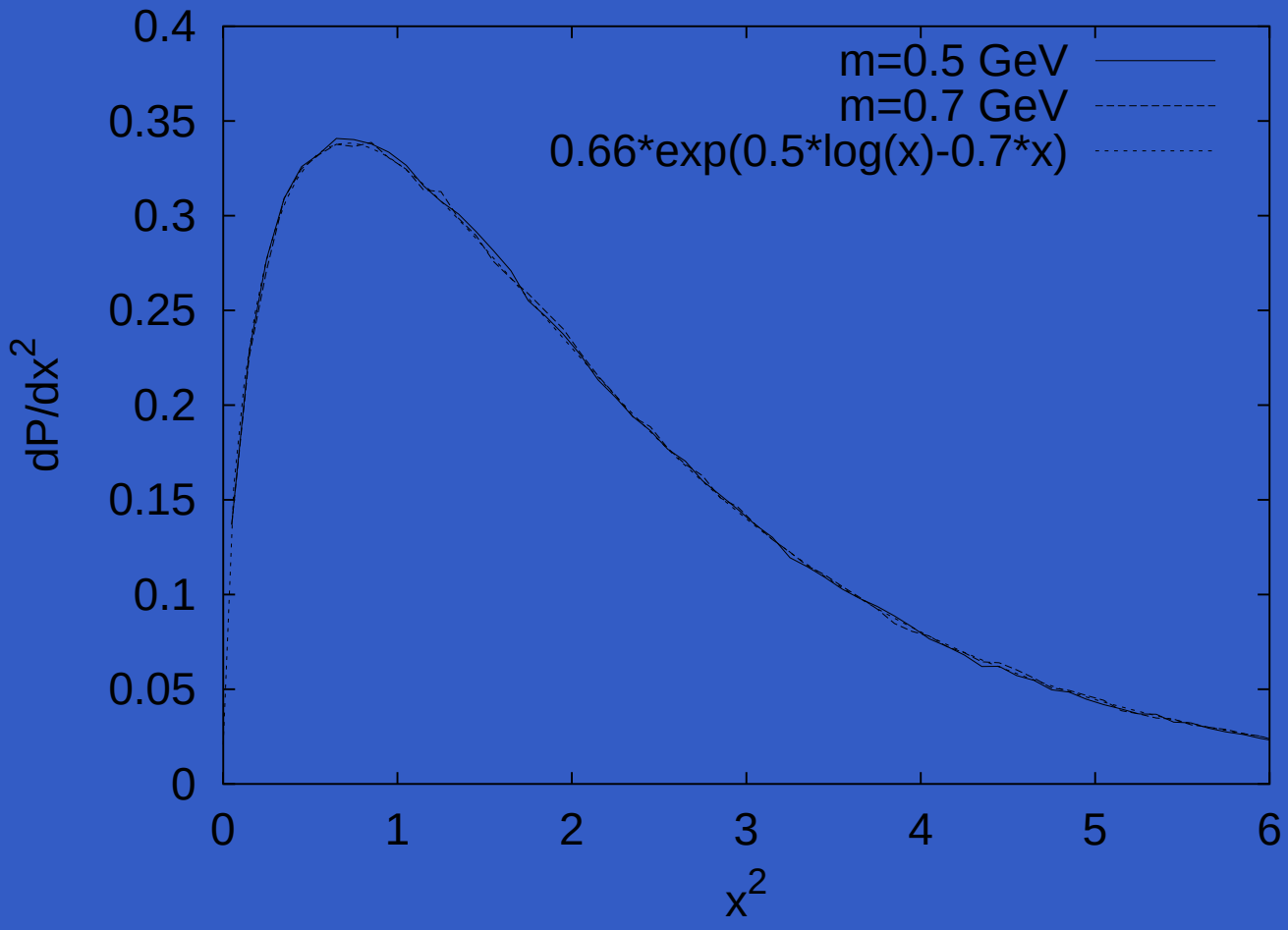
Probability for the production of an N-particle cluster of hadrons in the model is given by:

$$dP_n(\{p_j\}; P_{tot}) = \prod_{j=1}^{n} N_j d^2p_j \delta(p_j^2 - m_j^2) \delta(\sum_{j=1}^{n} p_j - P_{tot}) \exp(-bA)$$

where A is the area spanned by the string "before" the breakup.

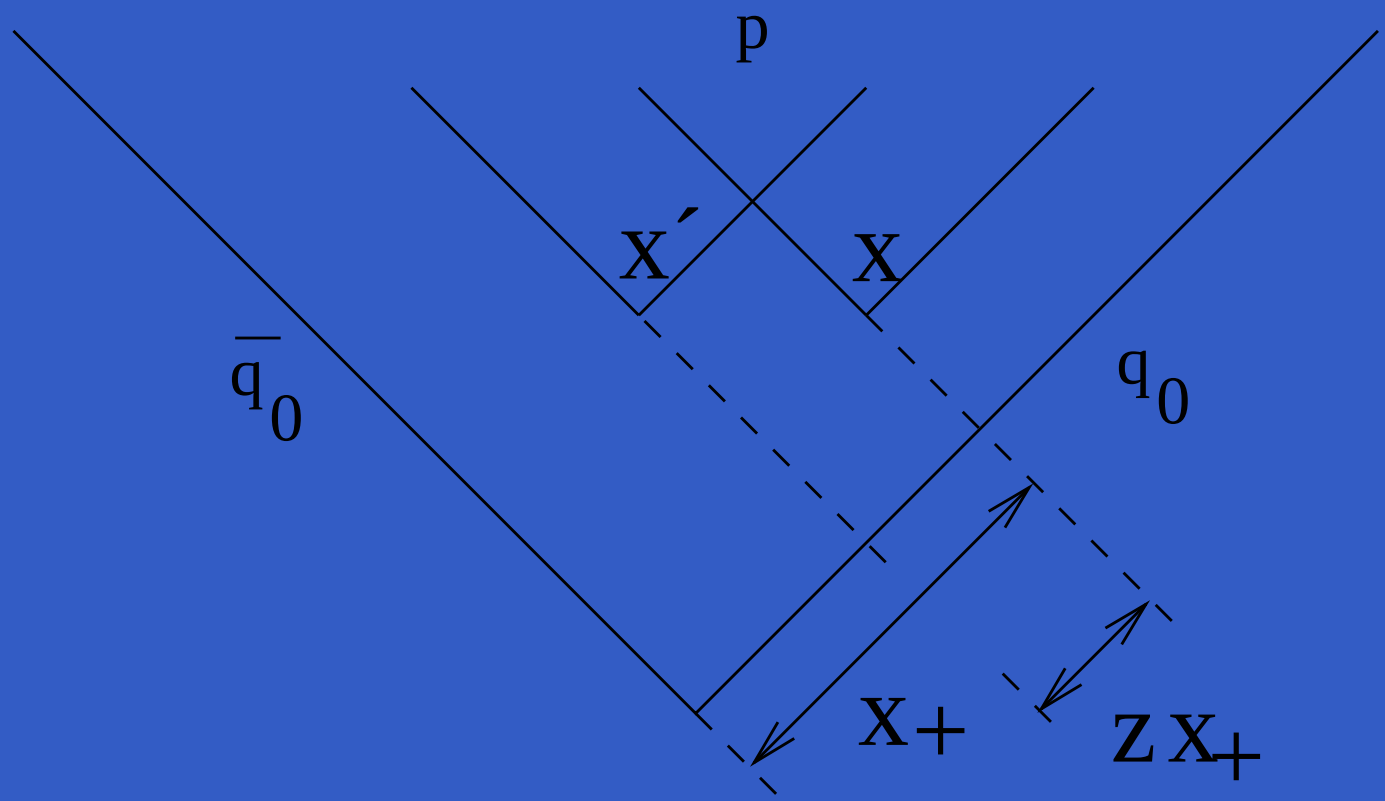
Competition between the area law and available phasespace leads to a typical hyperbolic decay region...

Lund Model: The Area Law



Lund Model: The Area Law

The Area Law can be formulated as an iterative scheme



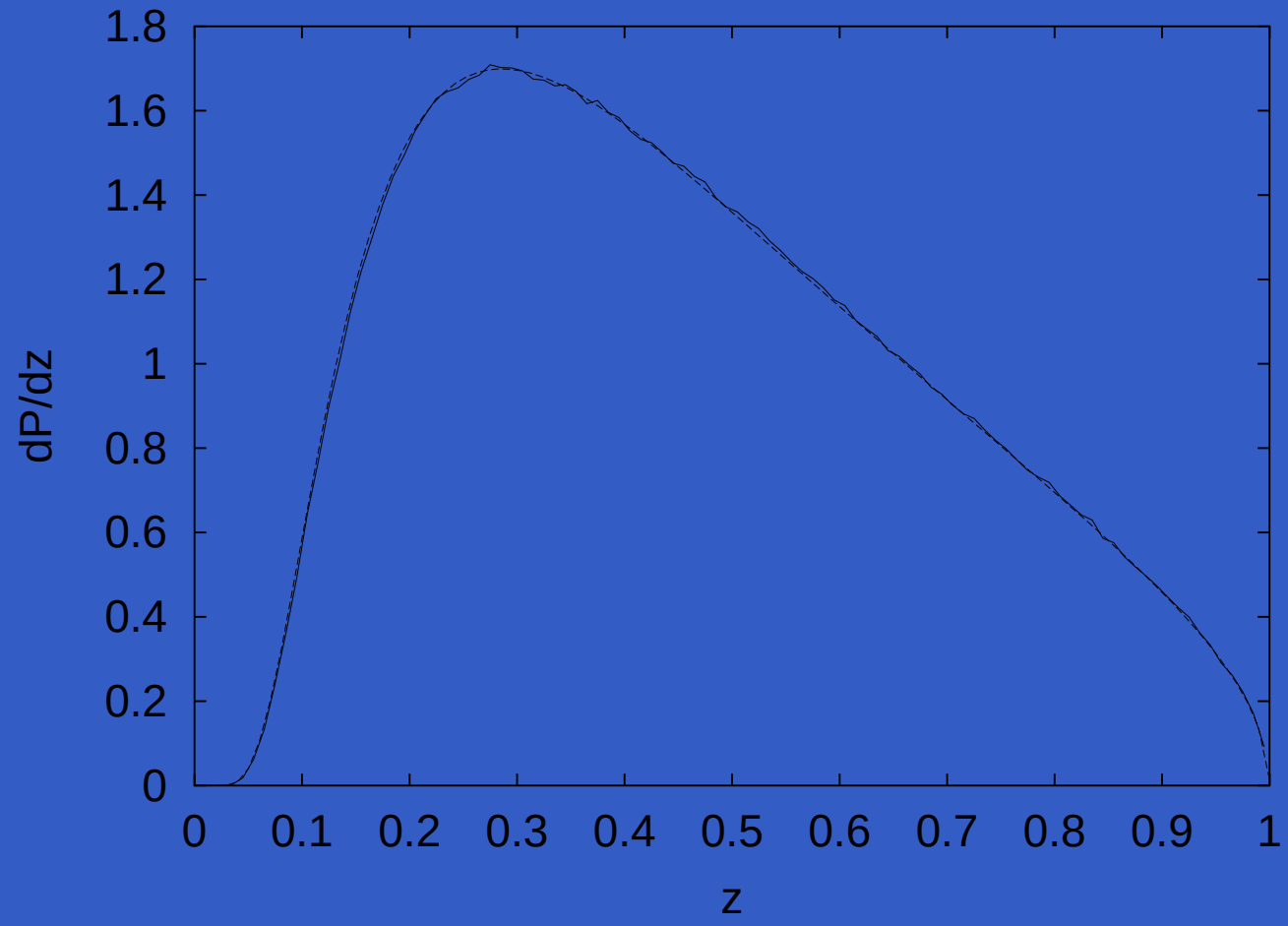
Lund Model: The Area Law

- Requirement that all yoyo modes must have specific masses, i.e., masses of hadrons, is a non-trivial constraint

For asymptotically large invariant masses of the string, the distribution $f(z)$ of light cone momentum fraction z is uniquely determined:

$$f(z)dz = N\frac{dz}{z}e^{-b\frac{m^2}{z}}(1-z)^a$$

Lund Model: The Area Law



A(n) (Over-)simplified MC algorithm

- Find out light cone directions and energy momenta available in cms
- Choose a flavour for the colour anti-colour pair production vertex
- Combine flavours from adjacent vertices and select a particular hadron with that flavour composition, using knowledge of branching ratios etc.

A(n) (Over-)simplified MC algorithm

- Generate transverse momentum from known distribution
- Calculate transverse mass of the hadron
- Generate a light cone fraction z from distribution $f(z)$
- Calculate positive light cone momentum component using this fraction and the available momentum

A(n) (Over-)simplified MC algorithm

- Calculate negative light cone component which will put the particle on mass shell
- Calculate space–time location of final vertex for the particle
- Repeat all steps except the first until remaining energy momentum in the string falls below a threshold
- Let the remaining string decay into two hadrons.

Lund Model

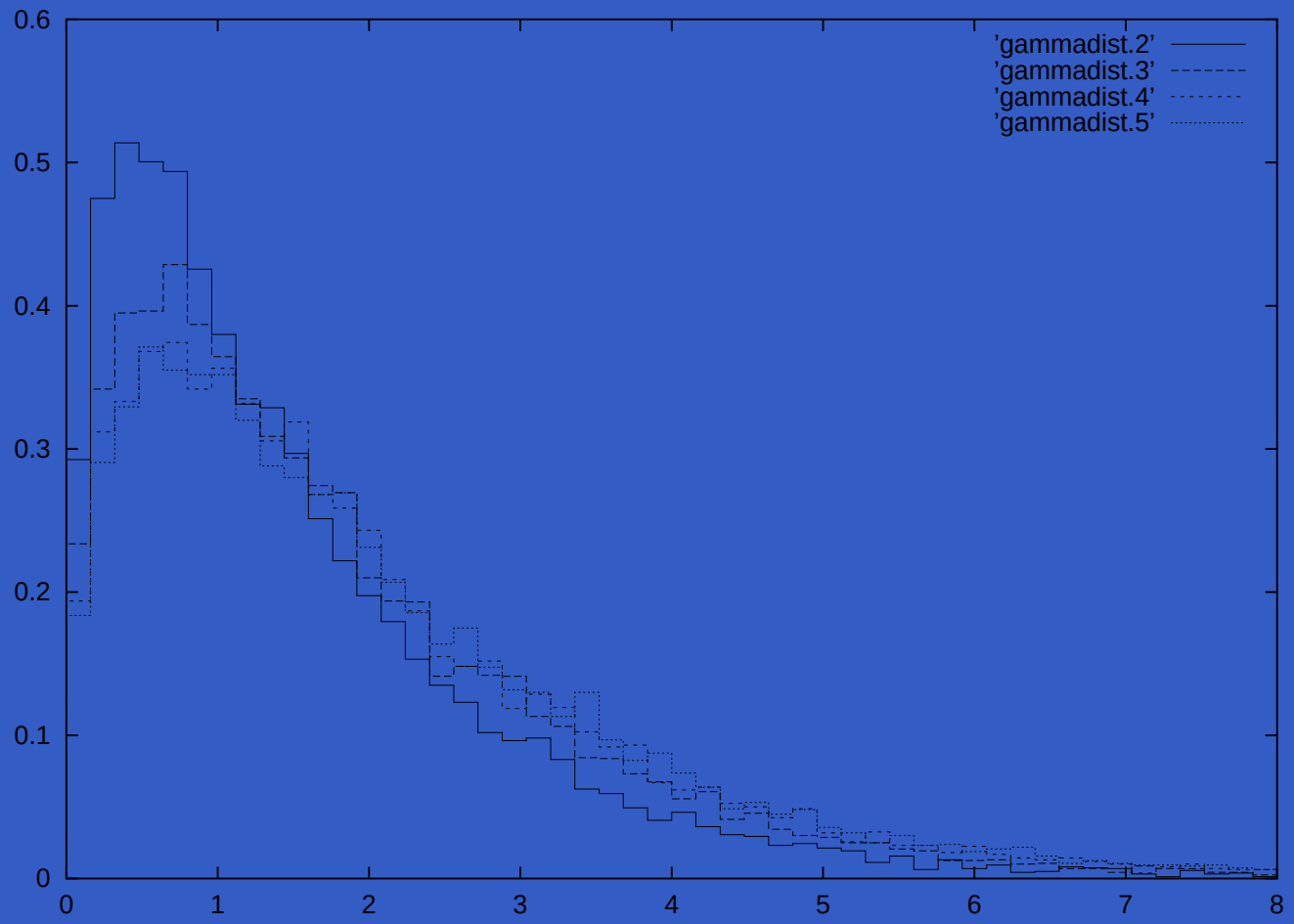
Implemented in PYTHIA. Widely used as a hadronization MC. Quite successful. But,

- Some approximations were made which could affect the detailed properties of the final states. For studies of correlations and fluctuations results from PYTHIA might be different from the model predictions.
- One example : PYTHIA does not strictly adhere to the Area Law while fragmenting multigluon strings on an event to event basis.

Lund Model

- The asymptotic fragmentation function is not valid for systems with small invariant masses.

Small Multiplicities



The Available Phase Space

Each step in iteration ...

- Selection of a light cone fraction z weighted with only the area law
- Mass shell condition on the hadron + kinematics
- Weight the event with the ratio of the values of the phase space integrals after and before the step.

The Available Phase Space

Each step in iteration ...

- Large invariant mass $\Longrightarrow$ Phase space grows like s^a. This is what gives the $(1-z)^a$ term in $f(z)$
- At small masses the relevant integral equations have to be solved. A typical resulting z distribution and phase space ...

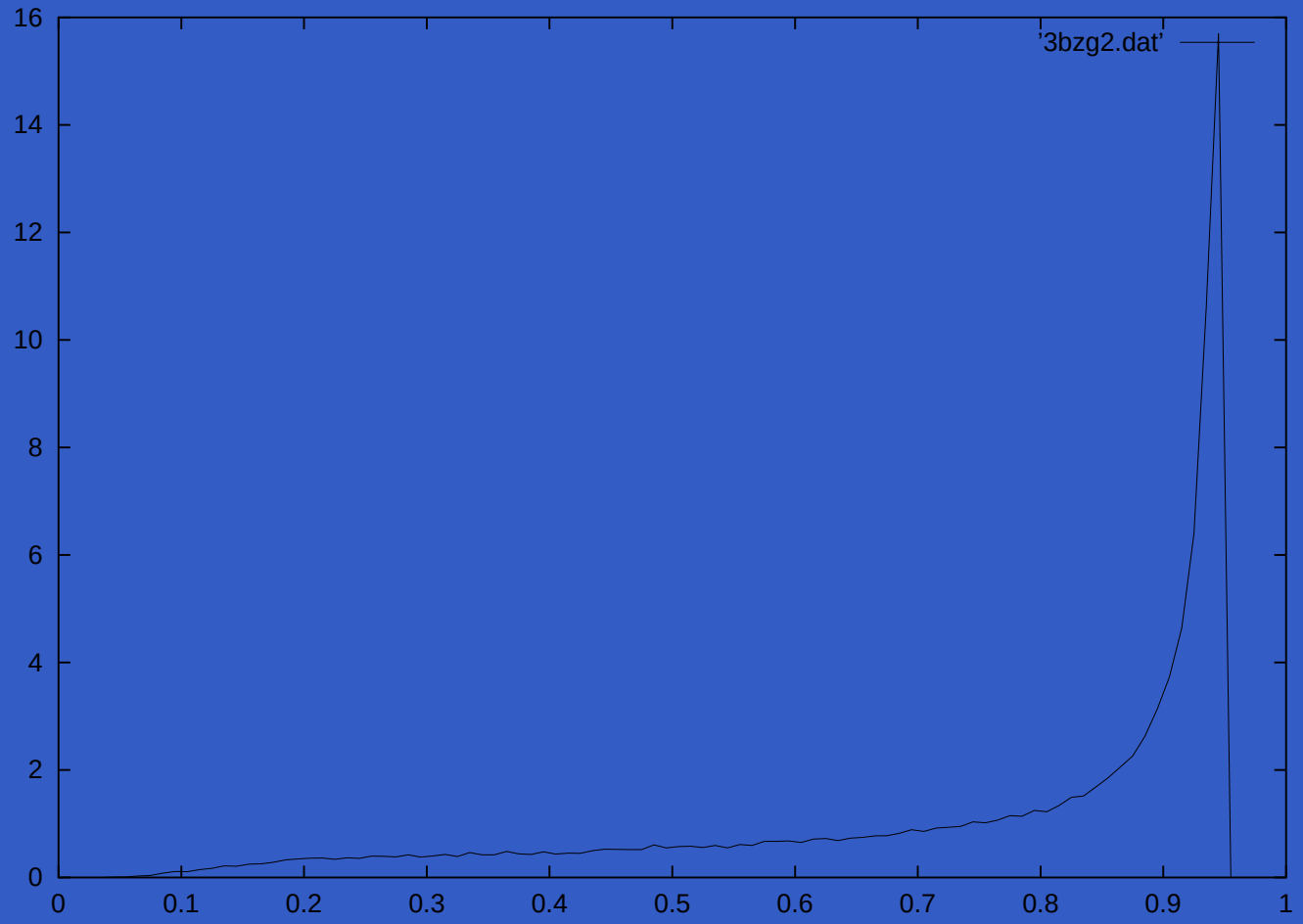
Equation for phase space function g(s)

$$g(s) = \int_0^{\inf} \frac{ds'}{\sqrt{\lambda(s,s',m^2)}} cosh(\frac{b}{2}\sqrt{\lambda(s,s',m^2)}) e^{-\frac{b}{2}(s+m^2-s')} g(s'),$$

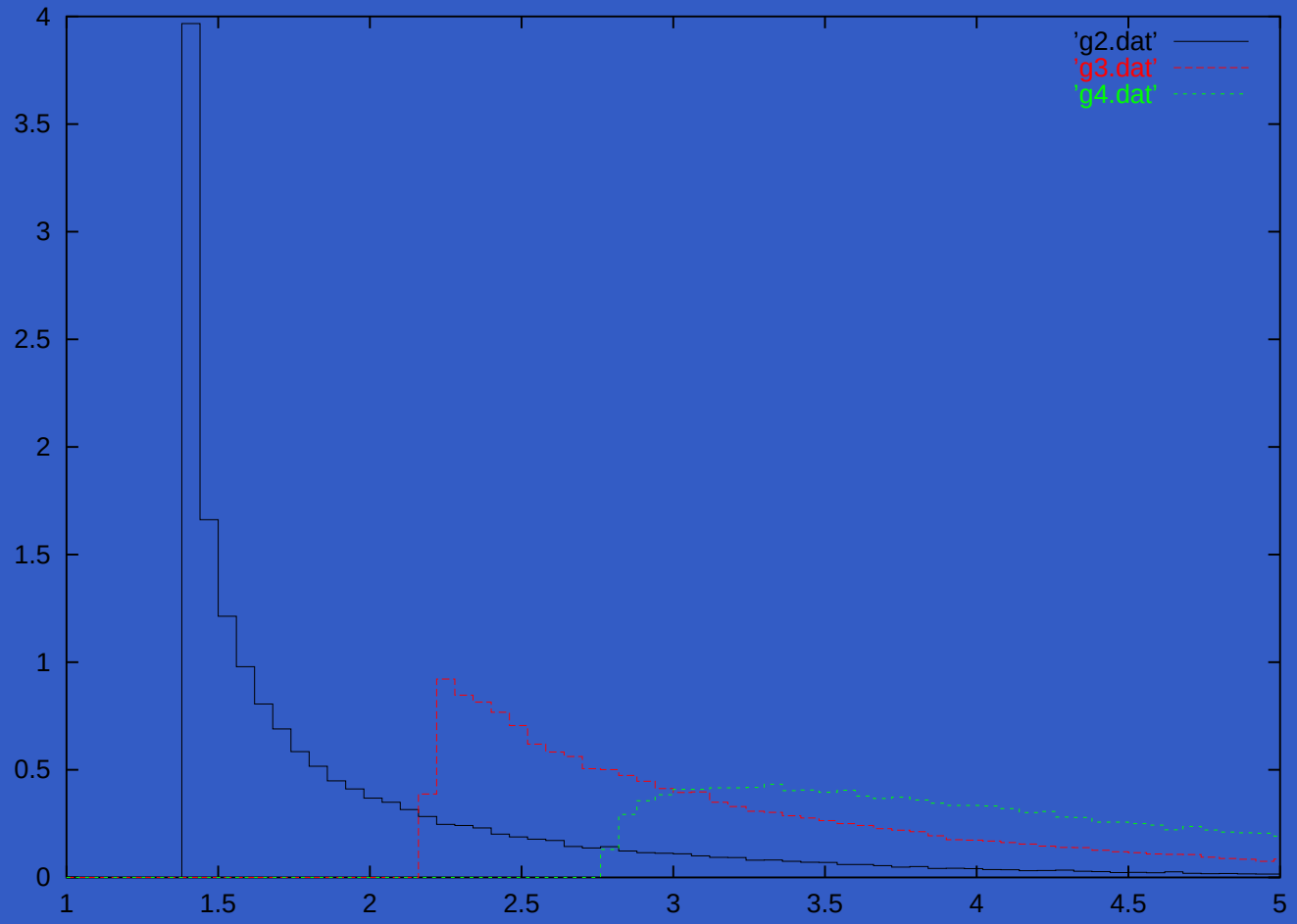
with

$\lambda(x,y,z) = x^2 + y^2 + z^2 - 2xy - 2yz - 2zx$ where s and s' are invariant masses of the system before and after the production of a particle of mass m

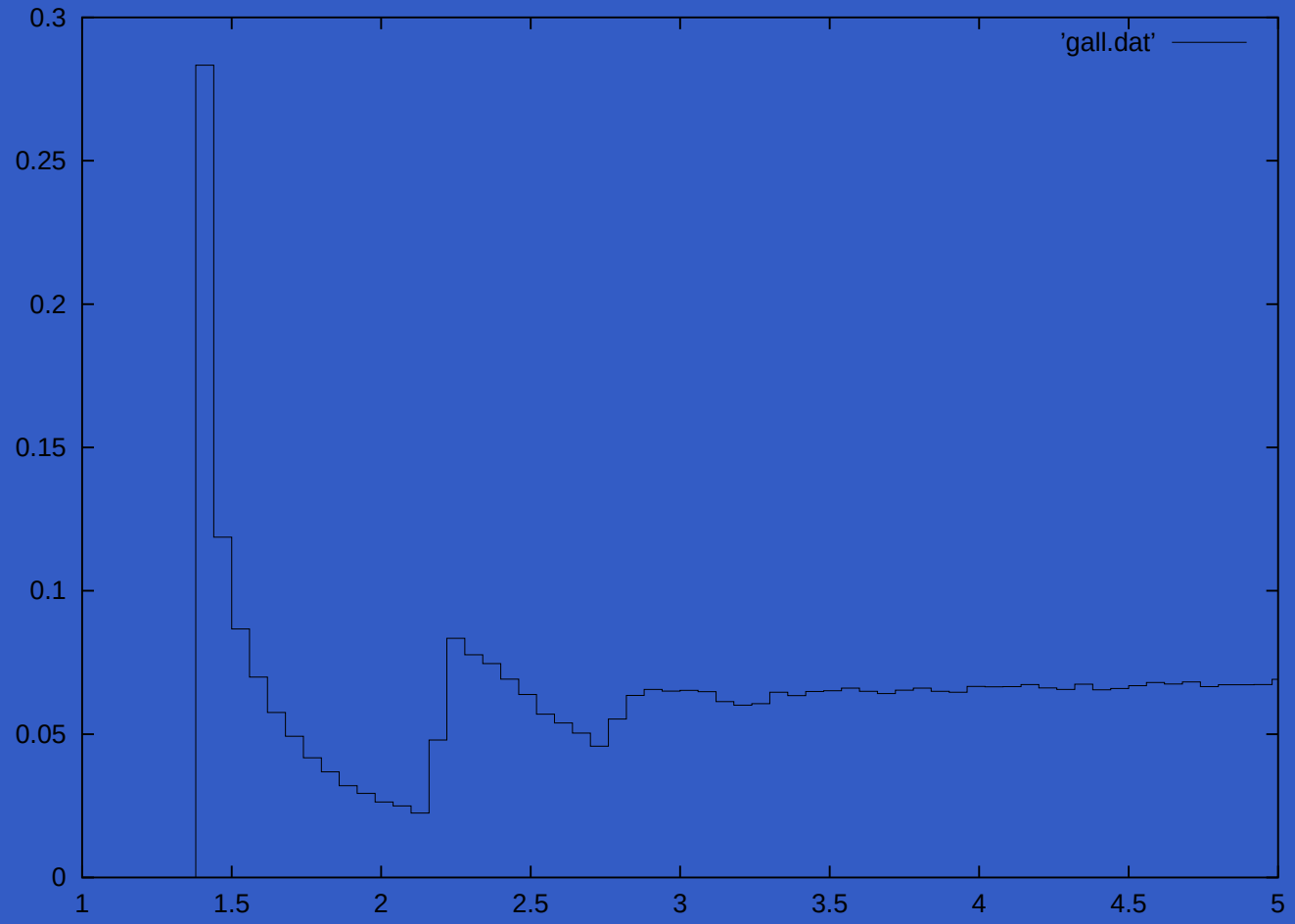
Lund Model: The Phase Space



Lund Model: The Phase Space



Lund Model: The Phase Space



String ?

Concluding Remarks

- Limited Phase Space at small invariant masses changes the fragmentation function in the Lund Model.
- Studies of the effects of phase space and a project to incorporate it into a string fragmentation MC is currently underway in Lund.