Recent Developments of the Lund Fragmentation Model.

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Outline:

I Review of the Lund fragmentation model.

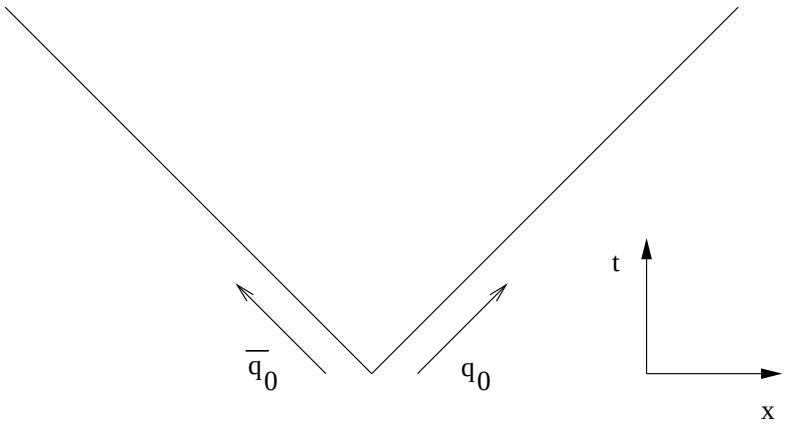
II How to fragment a gluonic string according to the area law.
→ Monte Carlo implementation: ALFS.

III Model predictions: the Coherence chains.

IV Status report: implementing B.E.-effects in ALFS.

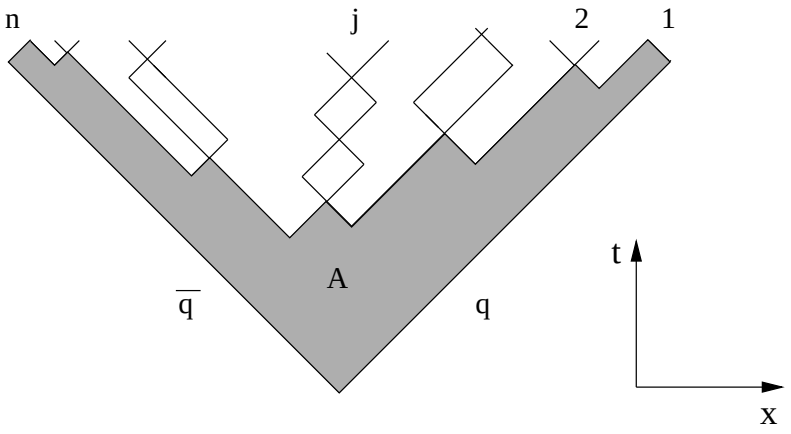
The Lund Model (1+1-D)

- Use the Massless Relativistic String as a model for the QCD force field acting upon the q and $\overline{q}$ placed at the endpoints.
- $q\ \overline{q}$ pair produced (e^+e^-) at a single space-time point moving apart, stretching the field in between them.



The Lund Model (1+1-D)

- String state may decay by the production of new $q\ \overline{q}$ pairs at different vertices along the string field.
- The vertices are space like separated.
- No interaction between the $q\ \overline{q}$ from the same vertex i.e. the field ends on the endpoint charges. Confinement



String $\rightarrow$ Minimal Surface

- The surface is stable against small deformations. Infrared stability
- The dynamics is completely determined by a single boundary curve, the Directrix.
- There is a wave moving across the surface, bouncing at the endpoints (q,$\overline{q}$). The internal excitations will affect the endpoints in turn.
- Therefore,

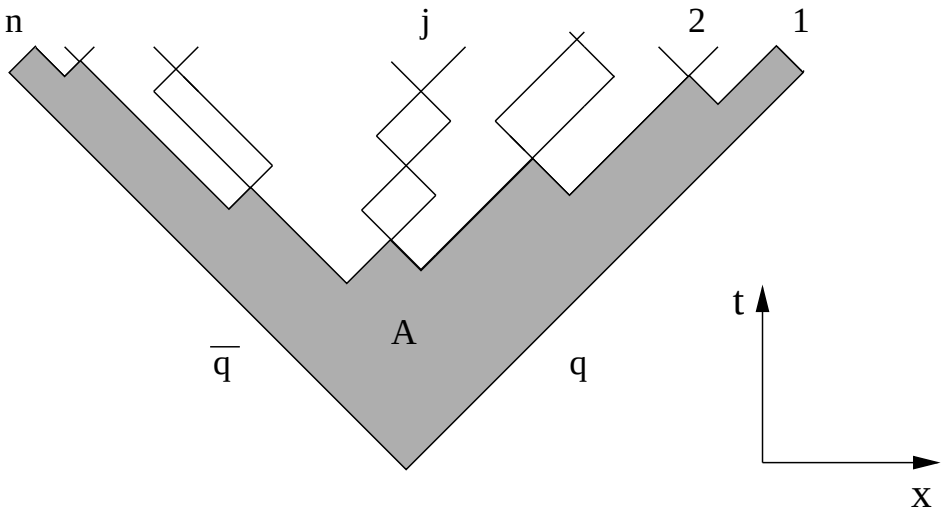
  a process on the string surface $\equiv$

  $\equiv$ a process along the Boundary.

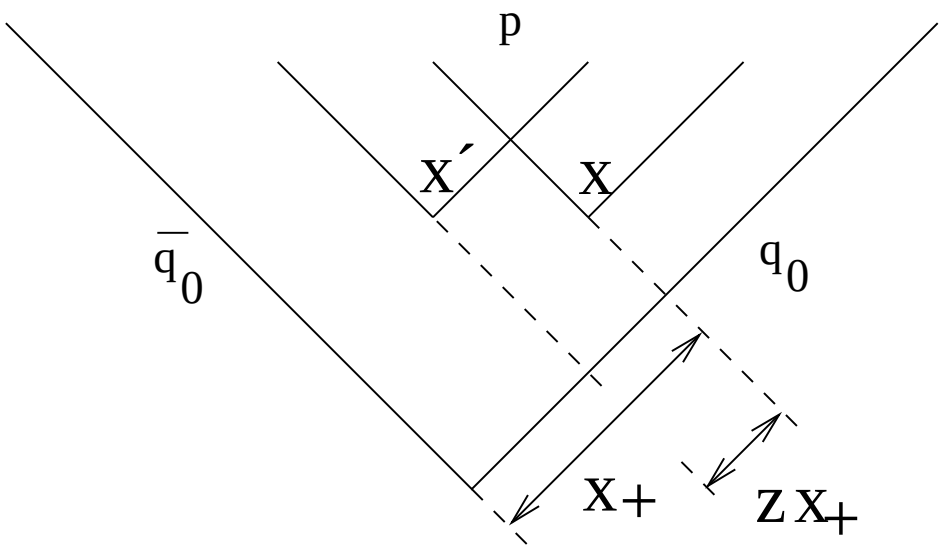
The Breakup Problem: Find the Probability

- The Lund Area Law:

$$dP_n = \prod N d^2p_j \delta(p_j^2 - m_i^2) \delta(\sum_1^n p_j - p_{tot}) \times$$
$$\times \exp(-bA)$$



The Breakup Problem: Find the Probability.

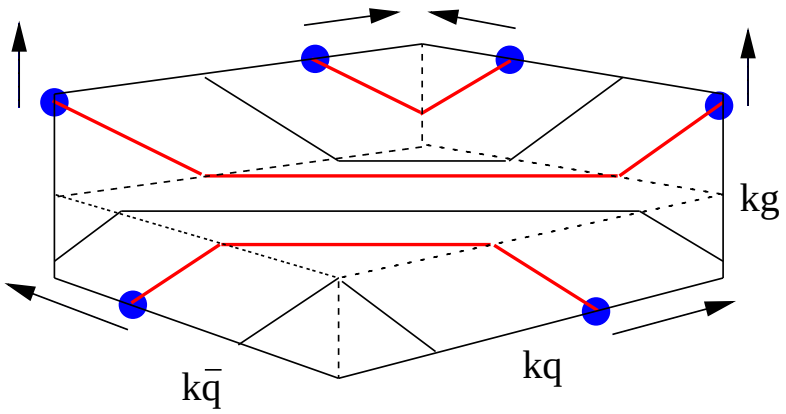


- Assume that we have reached the vertex x.
- Probability to produce the hadron p_j $\rightarrow$ f(z) dz.
- Lund Fragmentation Function:

$$f(z) = N\frac{1}{z}(1-z)^a exp\left(-\frac{bm^2}{z}\right)$$

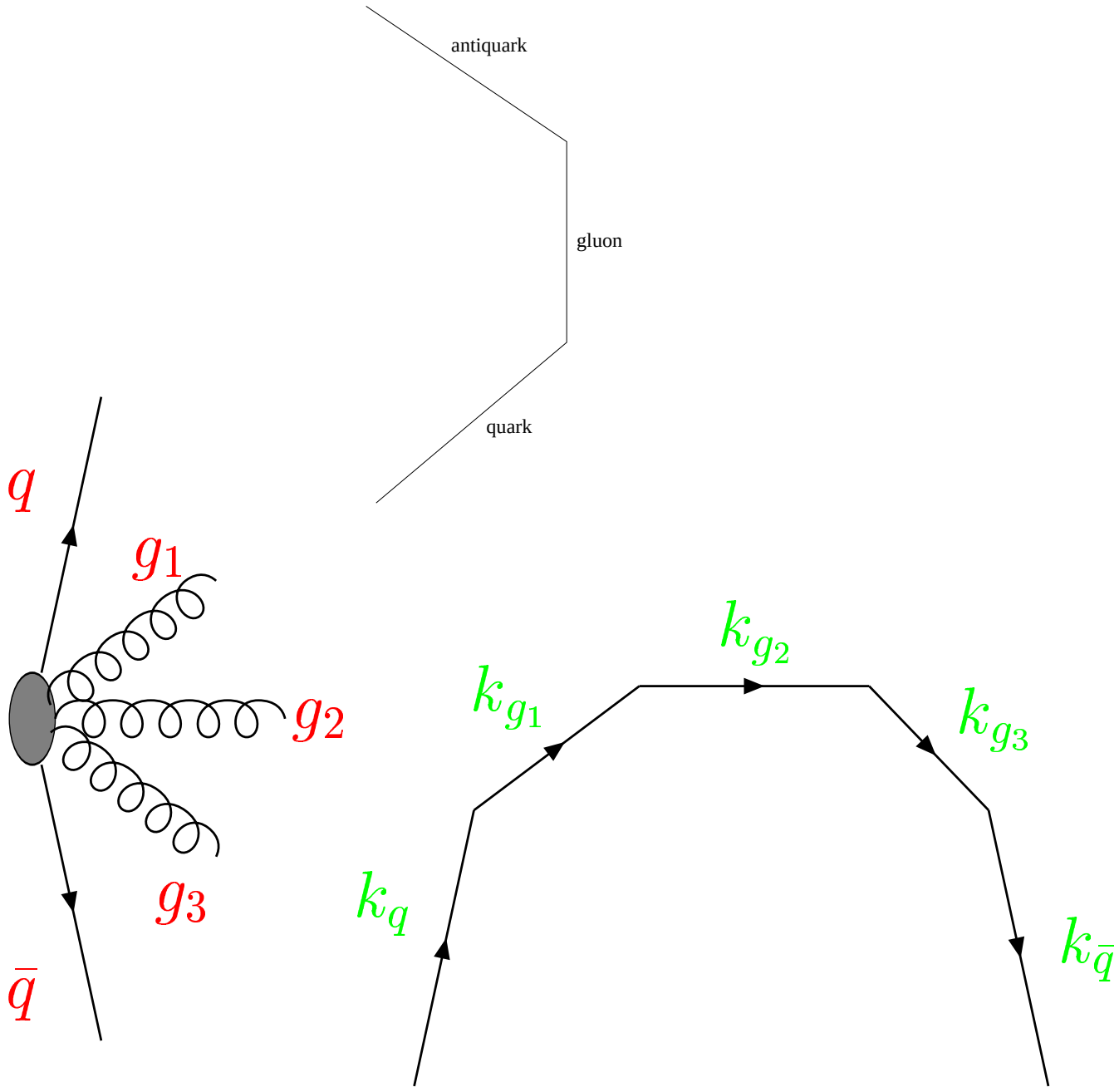
The Lund Model (3+1-D)

- Gluons are interpreted as internal excitations on the string .
- The space-time surface spanned by the string is a minimal surface.



The Directrix

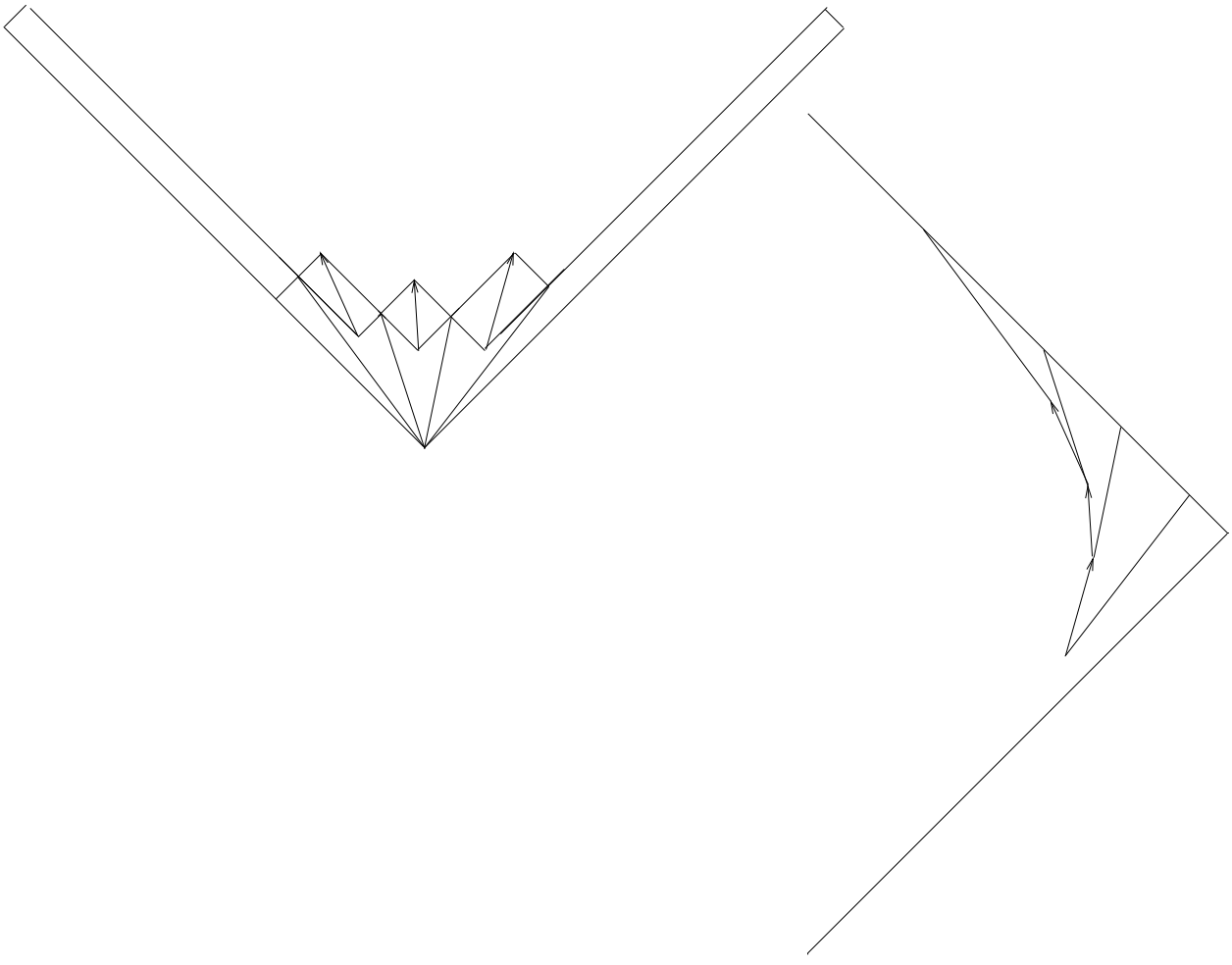
- The Directrix can be constructed by laying out the parton energy-momenta in colour order.



How do we Fragment a Multigluonic String (According to the Area-law)?

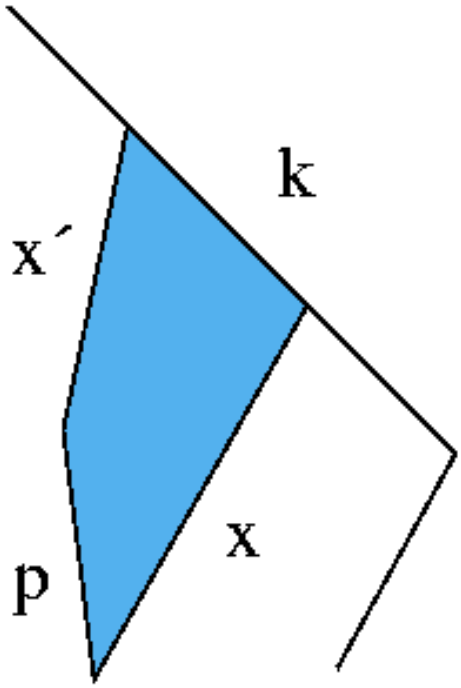
How to Fragment a Multigluonic String

- (1+1)-D $\rightarrow$ (generalise) $\rightarrow$ (3+1)-D
- Remember: a process on the string surface $\equiv$ a process along the Boundary.
  Fragmentation process along the directrix.
- Symmetries (string dynamics): There are many ways to represent the same area.



Fragmentation in (3+1)-D

"Building the plaquettes"



$p = z \cdot x + \bar{z} \cdot k$

$x' = (1 - z) \cdot x + (1 - \bar{z}) \cdot k$

($\bar{z}$ fixed because $p^2 = m^2$)

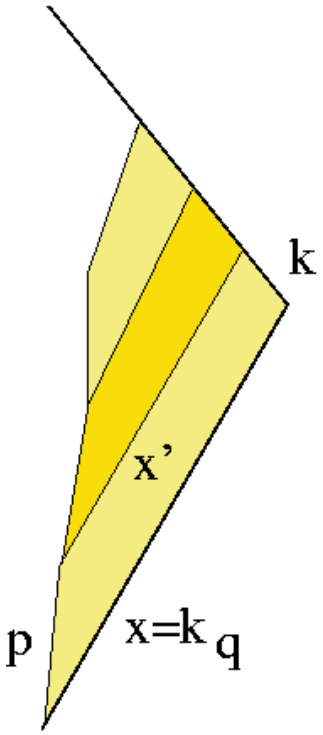
$$p = zx + \frac{k}{2}\left(1 - \frac{zx^2}{xk}\right)$$

$$x' = (1 - z)x + \frac{k}{2}\left(1 + \frac{zx^2}{xk}\right)$$

$$k \cdot x = \frac{m^2}{z}$$

Fragmentation Recipe

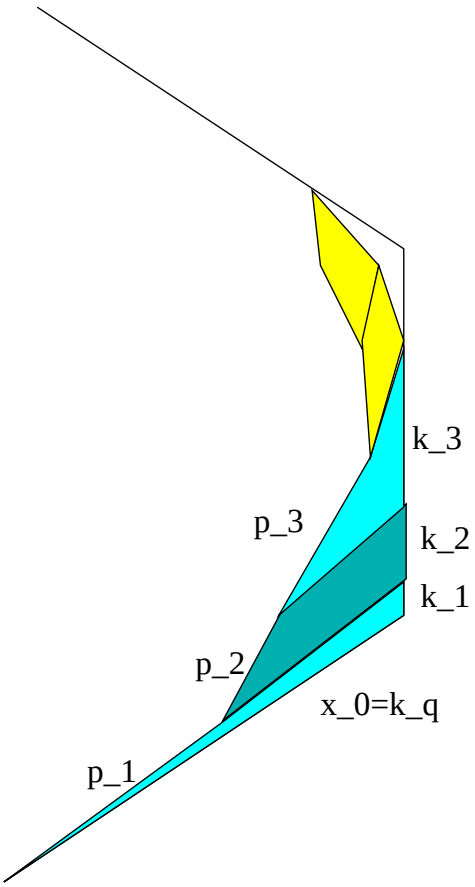
- initialize x = k_q.
- generate a z value from the distribution f(z).
- find a segment along the directrix k, such that $k \cdot x = \frac{m^2}{z}$
- find hadron momentum p, and the next x.
- repeat all steps (except initialisation!)



DOES IT WORK ?

No!

Why?



- Close to a gluon corner $k \cdot x < \frac{m^2}{z}$
- We note: the Directrix is defined down to some cut-off.
- Our method: Modify it locally $\rightarrow$ pass the corners. It will produce excitations at the hadronic mass scale.

It works!

- B. Andersson, S. Mohanty & F. Söderberg
  Eur. Phys. J. C21 (2001) 631
  hep-ph/0106185
- The model is implemented in a Monte-Carlo
  ALFS
  Author: S. Mohanty (sandipan@thep.lu.se)
  Language: C++/Fortran interface $\exists$

Will soon be published!

Predictions

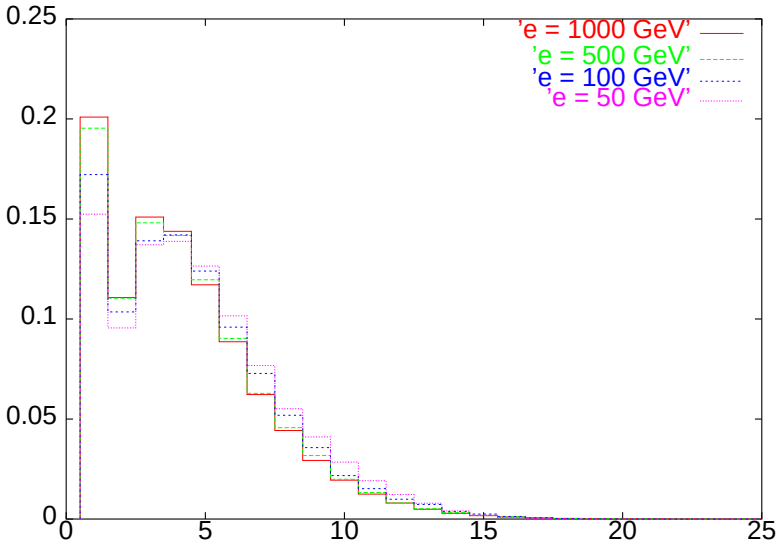
- The plaquettes (1+1-D surface embedded in 3+1-D) are central in ALFS.
- What does the geometry look like?
- Flat regions? (up to $p_\perp^2 < \delta$). If they $\exists \rightarrow$ How many hadrons are there? Regularities?

$$\{p_1\} \oplus \underbrace{\{p_2, \ldots, p_j\}}_{C.C.} \oplus \{p_{j+1}\} \oplus \underbrace{\{p_{j+2}, \ldots, p_n\}}_{C.C.}$$

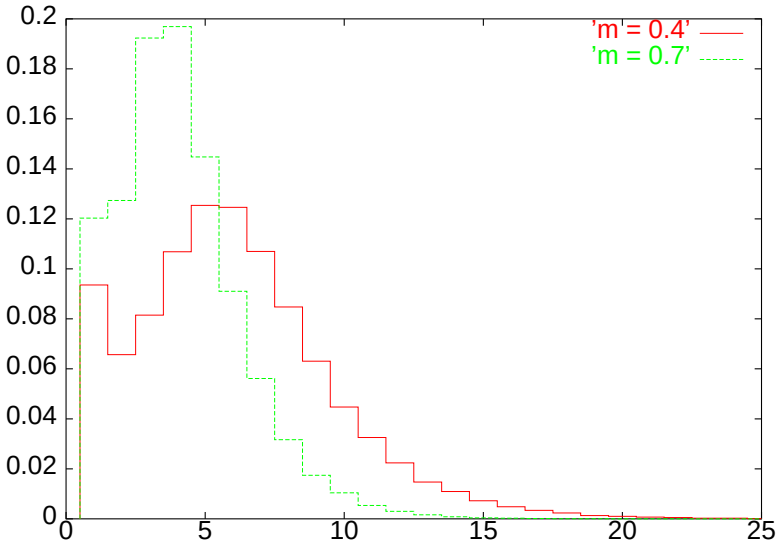
Flat Regions $\exists \rightarrow$ Coherence Chains

only a single hadron mass is used!

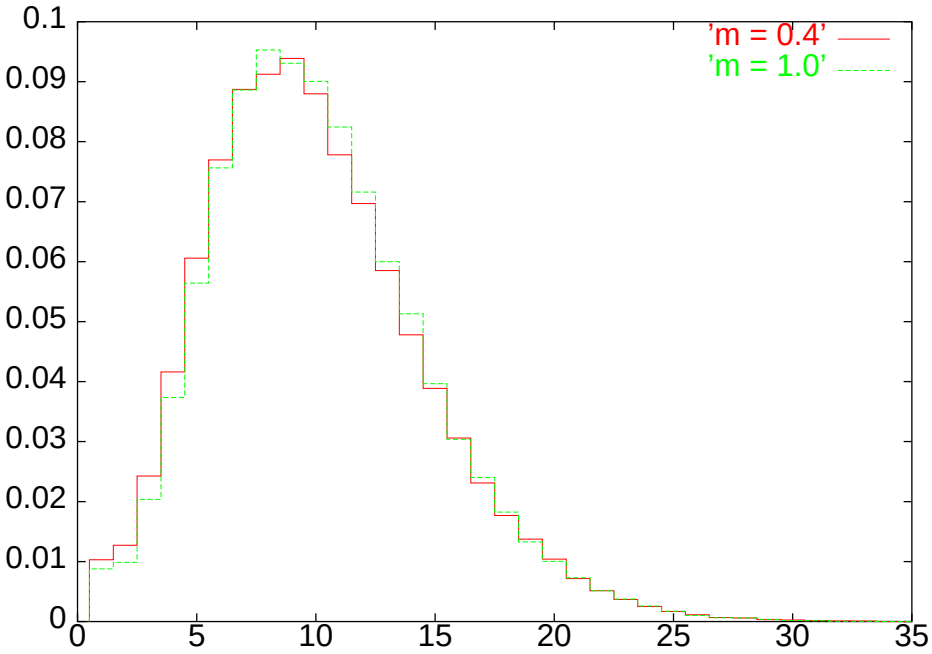
fragmentation model without $p_\perp$!



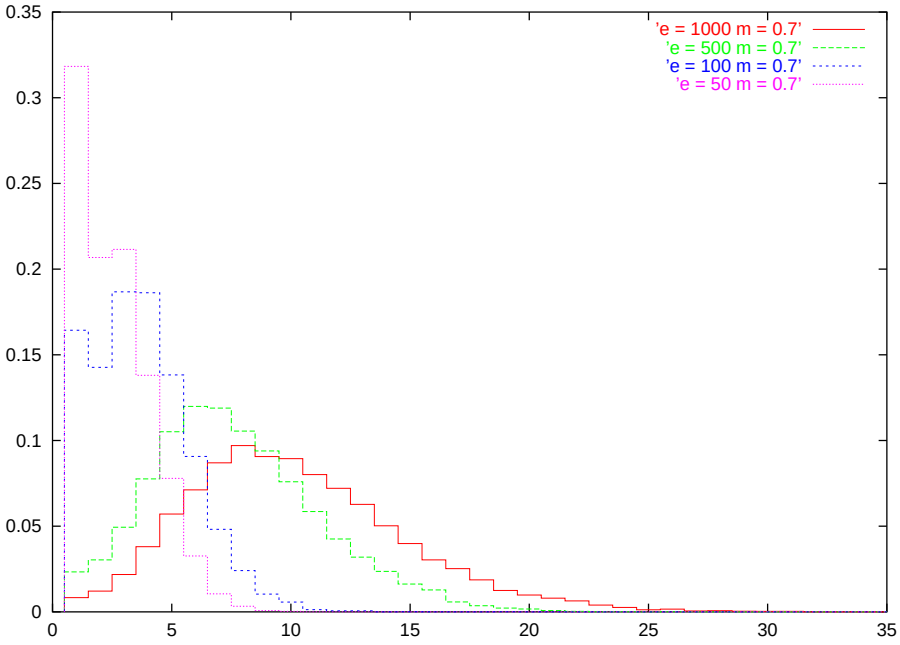
Chainlength (n) independent of cms-energy.



But smaller the mass, more the number of particles that will fit into a chain.



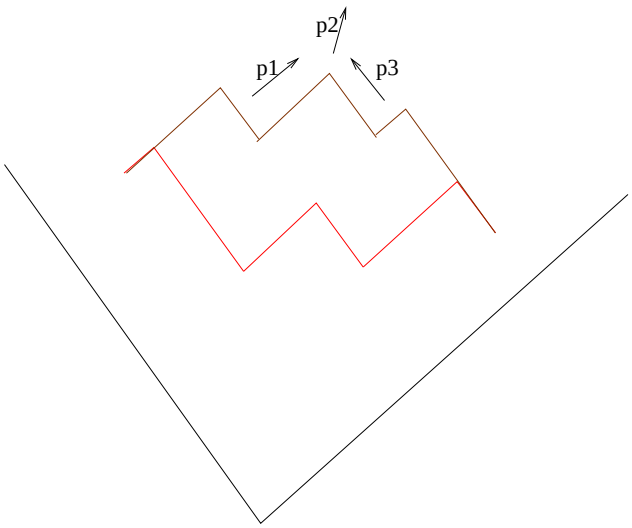
Particle mass has almost no effect on the number of chains detected.



Total number of chains is a function of global event variables.

Bose-Einstein Correlations

- Identical particles → same final state of particles can be obtained in many different ways.



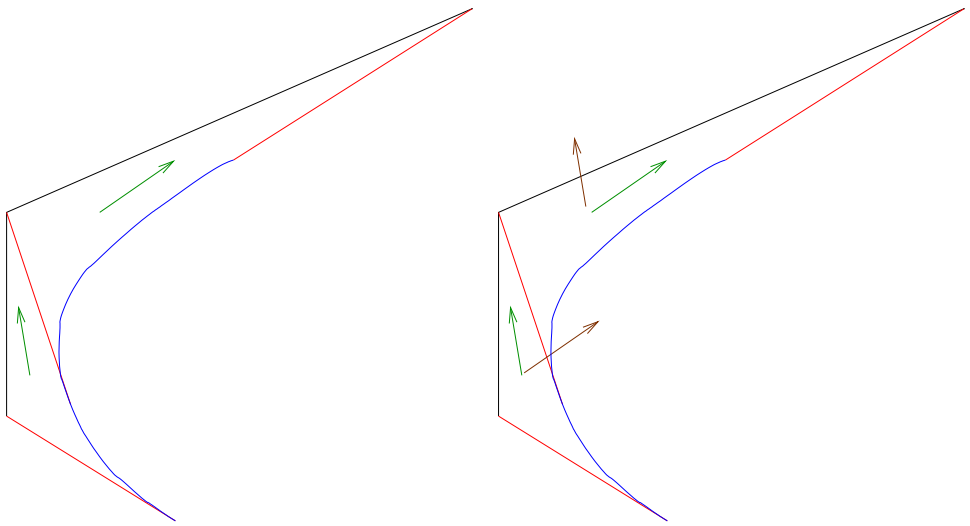
- Monte Carlo (probabilistic description) → event weight.

$$w = 1 + \frac{cos(\frac{\Delta A}{2\kappa})}{cosh(\frac{b\Delta A}{2} + \frac{\Delta(\Sigma p_\perp^2)}{2\sigma_{p_\perp}^2})}$$

- Effect: Enhancement of probability for production of identical bosons with similar energy momenta.
- Large multiplicities ⇒ large number of calculations would be required.

Flat Regions → Coherence Chains

- Amplitudes for events where particles have been exchanged across a hard gluon corner is small.



- Coherence chains are big enough to be expected to give some BE effect, while small enough to allow calculations to be done.
- We only need to consider exchanged 'diagrams' in which particles are exchanged with other particles in a group where the energy momenta are all in a plane?

Summary

- String fragmentation can be formulated as a process along the directrix.
- Fragmentation $\rightarrow$ building a set of plaquettes along the directrix.
- Our model has been implemented in a Monte-Carlo: ALFS.
- The hadronic curve passes through a set of (almost) planar regions $\rightarrow$ Coherence Chains.
- String Symmetrisation will soon be implemented in ALFS and it will be based upon the Coherence Chains.