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Herwig++
Cluster Hadronization

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Outline

- Non-Perturbative Splitting
- Primary Cluster Formation
- Cluster Fission
- Light Clusters
- Cluster Decays
  - Fortran Herwig
  - Kupco Method
  - New method for Herwig++

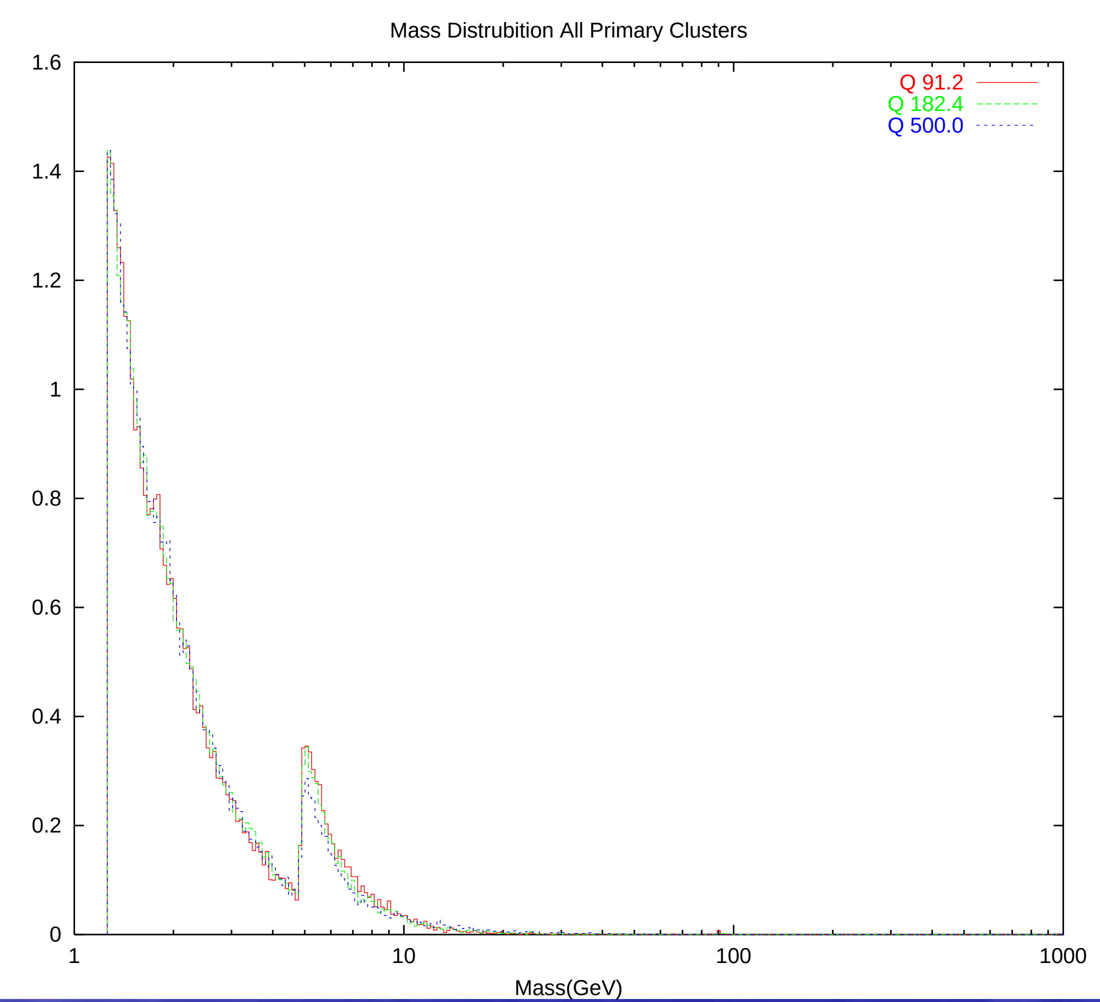
Non-Perturbative Splitting

- Shower produces partons at scale Q_0
- Gluons are given an effective mass M_g
- Quarks are produced using an isotropic two body decay $g \rightarrow q\bar{q}$
- Available flavours dictated by M_g
- Weight of flavour $q = Pwt_q$

Primary Cluster Formation

- Primary Clusters are formed by combining the colour connected partners into a cluster.
- In baryon violating events, a cluster may be made of a quark and a diquark (or anti-quark anti-diquark)
- Cluster Mass distribution independent of CM energy (colour preconfinement)

Primary Cluster Mass Distribution



Cluster Fission

- Clusters composed of flavours i and j whose mass exceed the constraint:

$$M^P > C^P + (m_i+m_j)^P$$

  are fissioned.
  - M is the mass of the cluster
  - C and P are parameters
- First a new flavour k is drawn from *u,d* and *s* flavours.
- This leads to a decay of $M_{ij} \rightarrow M_{ik}+M_{kj}$

Cluster Fission … continued(1)

- First there is a check, if $M_{ij} < m_i+m_j+2m_k$ then do not fission. (mostly in b clusters)
- There are two different mass distributions

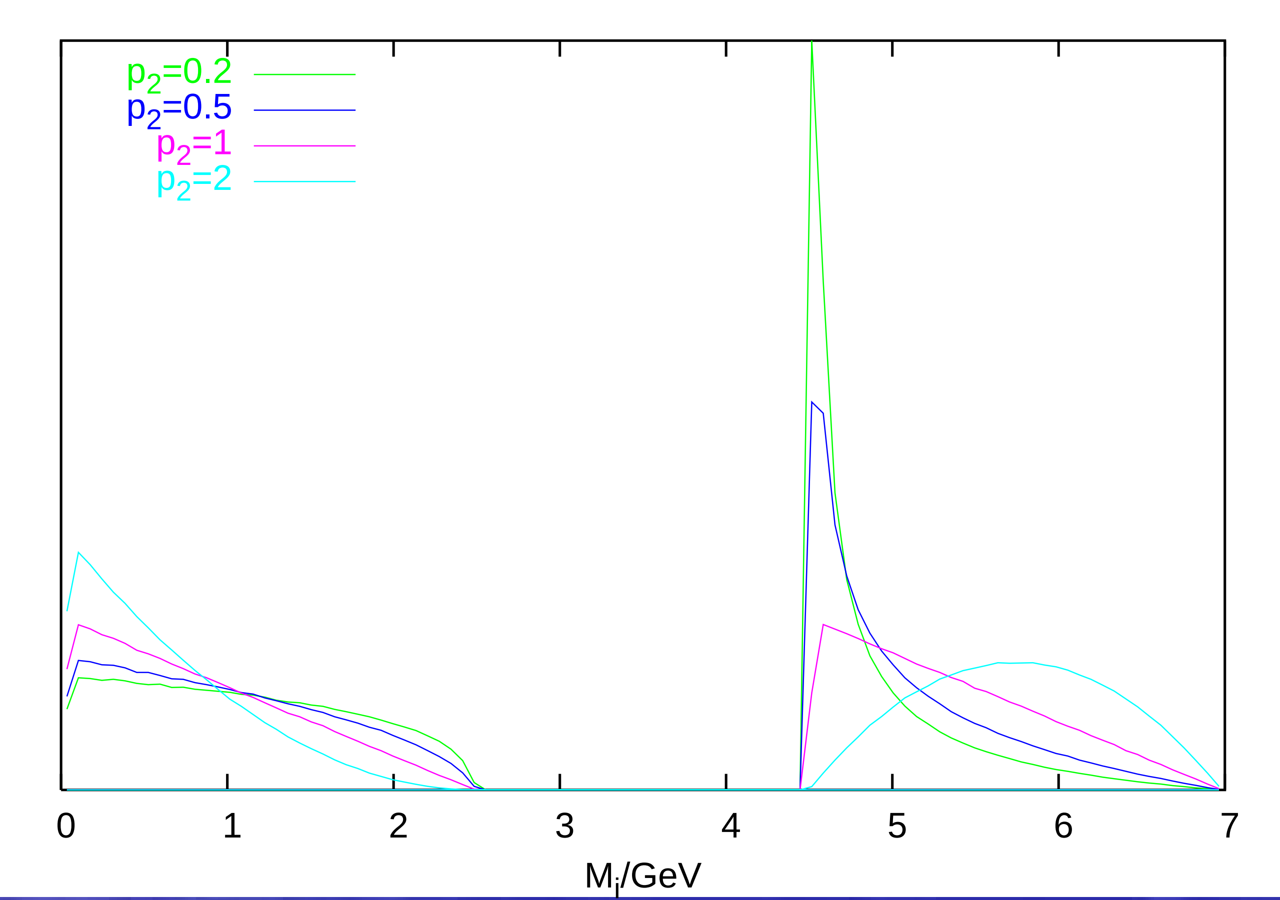
Parton Shower Distribution

- $M_{ik} = m_i + (M_{ij} – m_i – m_j)r^{1/x}$
- r is a random number [0,1]
- x is a parameter, PSPLT(1) for $i = udsc$, PSPLT(2) for $i=b$

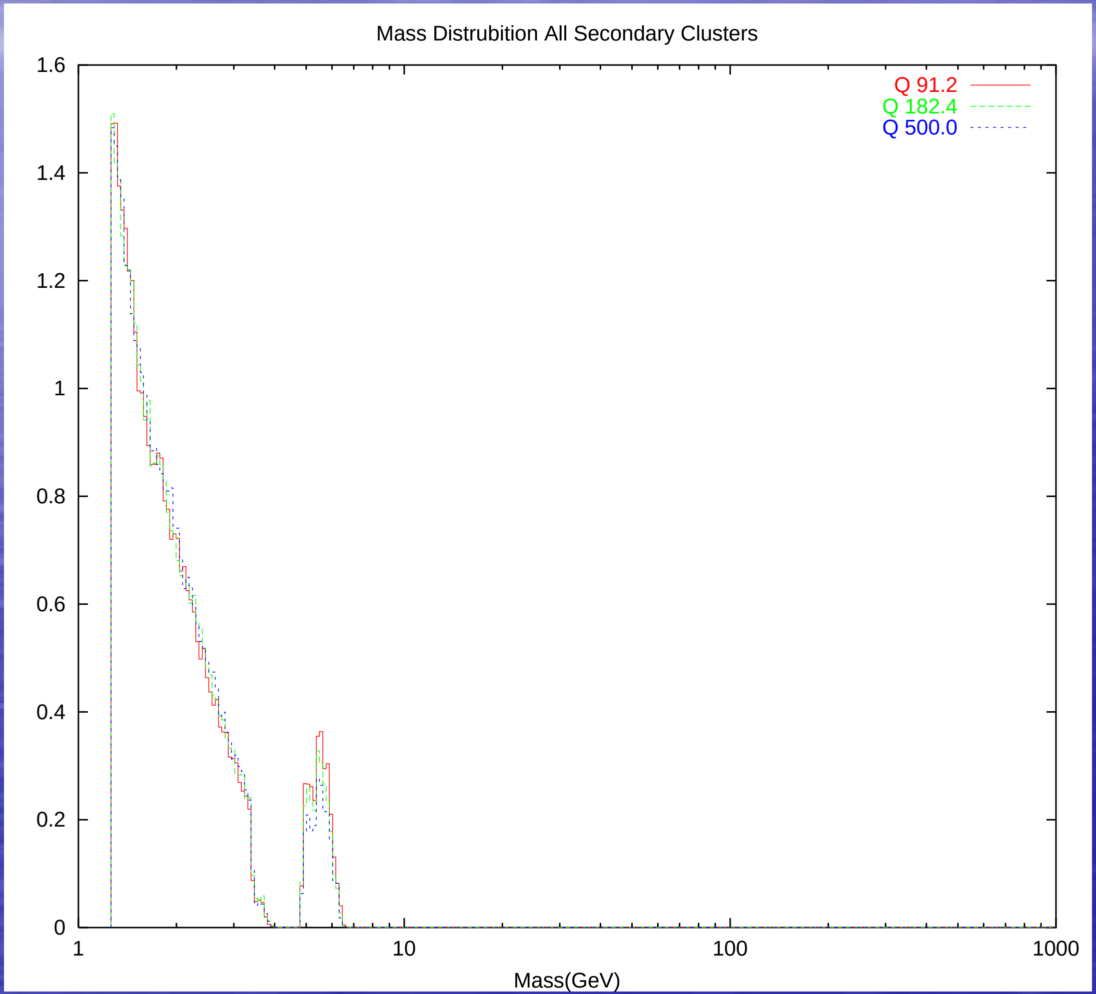
Beam Remnant Distribution

- $M_{ik} = m_i + m_k – \log(r)/b$
- $b=2/y$
- r is a random number $[r_{min}, 1-r_{min}]$
- r_{min} is $\exp(-b(M_{ij} – m_i – m_j – 2m_k))$

Cluster Fission … continued(2)



Cluster Fission … continued(3)



Cluster Fission … continued(4)

- Sometimes the new cluster mass is not sufficient to produce the lightest pair of hadrons
  - Force the light cluster to set its mass to exactly that of lightest hadron (of flavour *i,j*), then do 1→1 decay into that hadron.
  - If there isn't enough phase space for this force both clusters to decay directly into hadrons (like a premature cluster decay)
  - If this still isn't possible, throw out the event.
- Decays are all 1→2 isotropic decays

Light Clusters

- If a cluster didn't fission, then make sure it is heavy enough to decay into two hadrons
  - If this isn't possible, then decay into one
  - Reshuffle 4-momentum with a nearby cluster
  - Once a partner is found, force the light cluster to decay 1→1 into its lightest hadron.

Cluster Decays

- Three different algorithms for cluster decays currently in Herwig++
  - Fortran Herwig
  - Kupco[1] Method
  - A new method (currently in development)

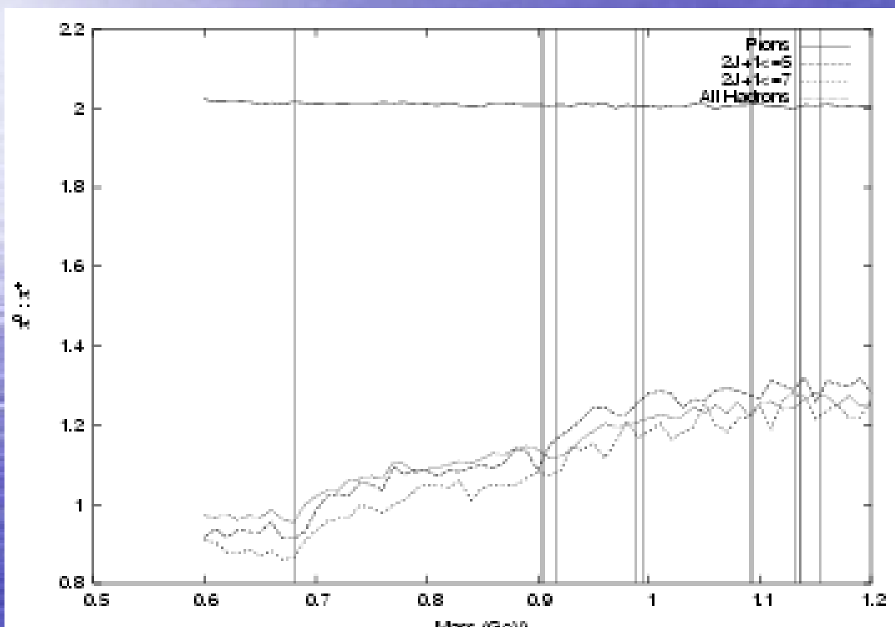
[1]A. Kupco, *Cluster Hadronization in Herwig 5.9*, hep-ph/9906412

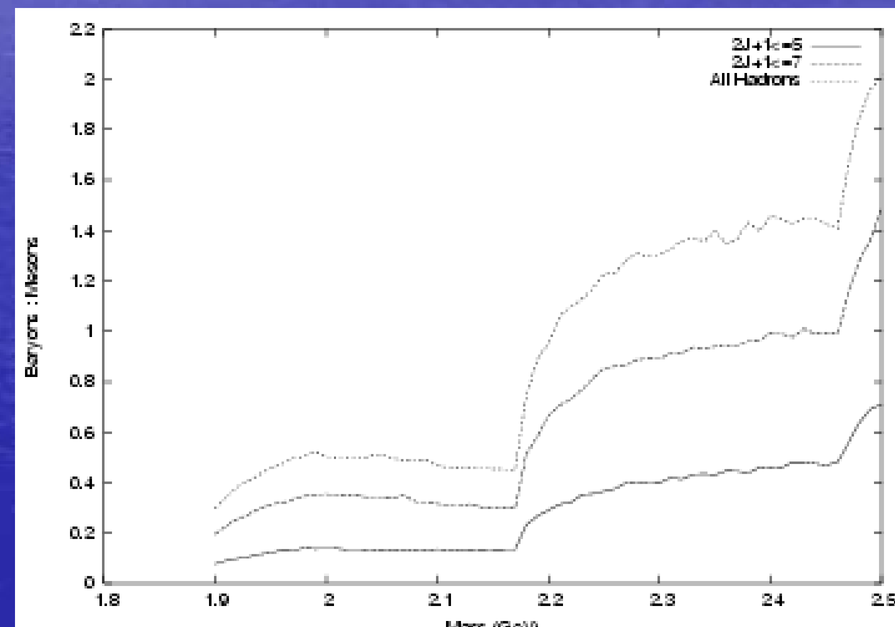
Fortran Herwig

- Probability a cluster flavour *i,j* decays into hadrons *a* and *b*, by drawing a flavour *k* from the vacuum is

  $P(a,b|i,j,k)=P_k\, w_a/N_{ik}\, w_b/N_{jk}\, p^*_{a,b}/p_{max}$
  - P_k is the probability of choosing flavour *k*
  - *w* is the weight of a given hadron (spin, mixing)
  - N_{ij} is the number of hadrons of flavour *i,j*
  - p^*_{ab} is the cm energy available for the decay
- Problem: As new decay modes are added less chance of choosing another mode of the same flavour
  - Also, many properties are dictated by N's

Fortran Herwig … continued





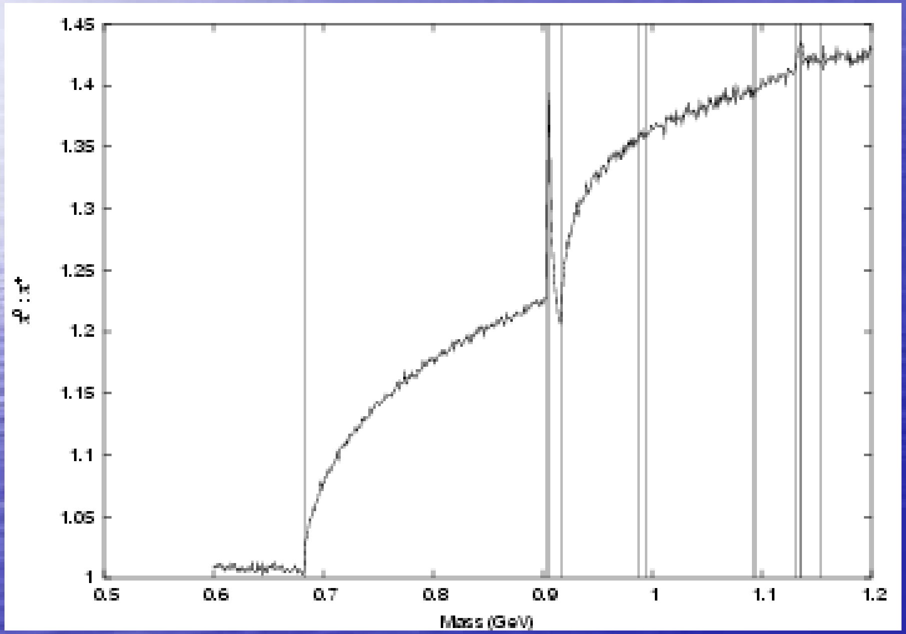
Ratio of π^0 to π^+

Ratio of baryons to mesons

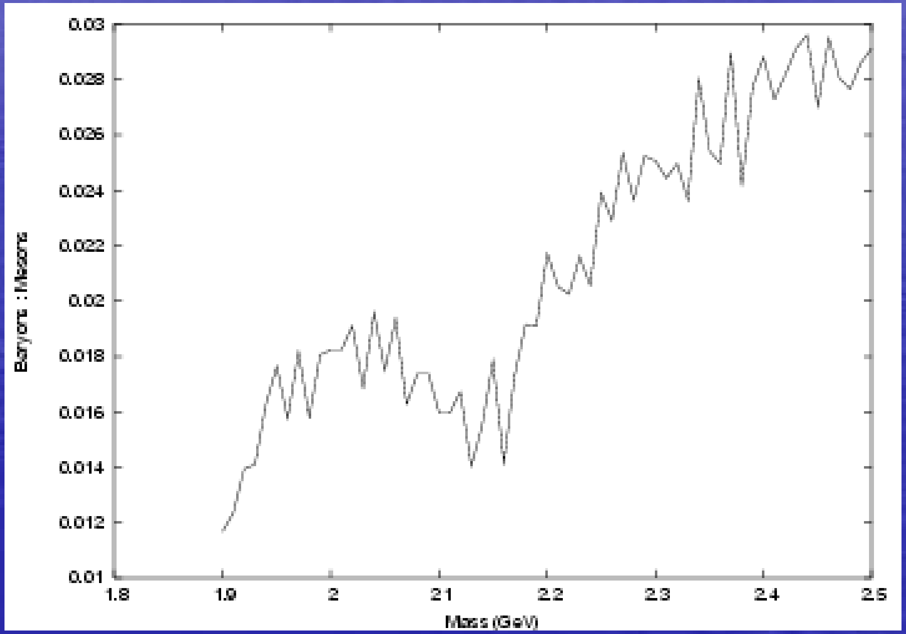
Kupco Method

- Kupco suggested instead that add up all the modes available and chose from those
  - $w_{ab} = P_k w_a w_b p^*_{ab}$
  - $P(a,b|i,j,k) = w_{ab} / \Sigma\, w_{cd}$
- *Problem: As more mesons are added, the baryons are suppressed.*

Kupco Method … continued



Ratio of π^0 to π^+

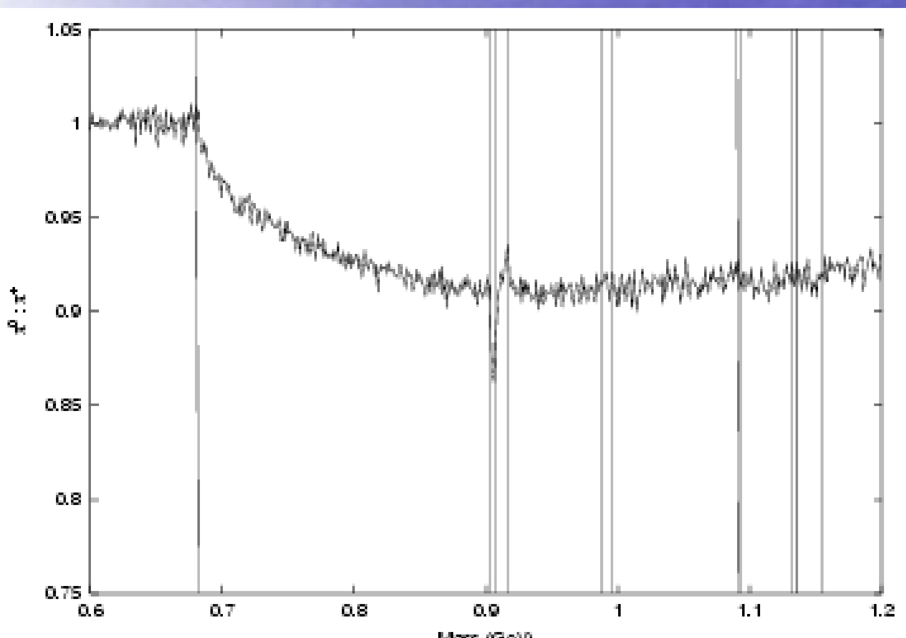


Ratio of baryons to mesons

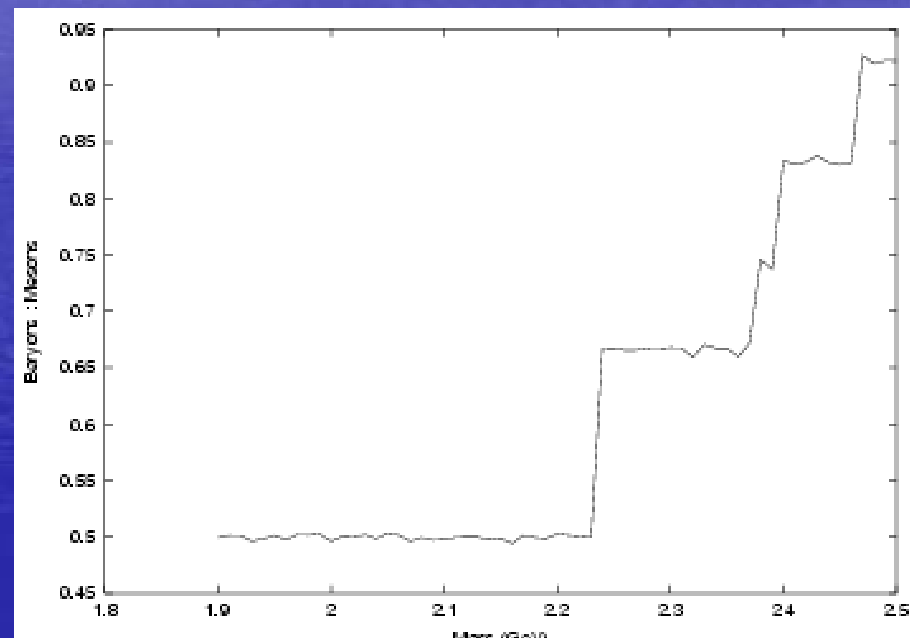
A new method

- Separate flavour drawn from vacuum from selection of particular hadrons
- Still use the idea of Kupco's that only modes with available phase space are used.
- full details still in development

A new method … continued



Ratio of π^0 to π^+



Ratio of baryons to mesons

Conclusion

- Most of algorithm identical to fortran Herwig
- New cluster decay method is performing as expected
- Problems with hadron decay currently prevent further comparisons
  - Multiplicities
  - momentum distributions
- Still a work in progress