ALEPH 89-94
PHYSIC 89-39
R. Settles
1.6.1989

Minutes of the QCD Meeting Held on 11.April.1989

Present: M. Bardadin, M. Bosman, H. Burkhardt, G. Cowan, J. Harton, I. ten Have, E. Lange, W. Männer, D.R. Parker, T. Ruan, G. Rudolph, M. Scarr, M. Schmelling, H.-J. Schmidt, R. Settles

0. Generalities: The next meeting will be on

Wednesday, 10. Mai 1989 at $9.^{30}$ in CERN,

At that meeting we should agree on what will be presented at Athens, which in turn means we should have concrete suggestions as to the first physics we want to do with ALEPH (.1, .3, 1, 3 pb^{-1}) and as to how to get there (how to analyze the POT). RS gave a pep-talk, which had the bottom line that we should be ready by the Z°–scan pilot run in August.

1. Fragmentation (minutes by GR):

- Heavy flavor fragmentation function:

  The arguments in favour of the value 0.015 for the Peterson ϵ parameter to be used for charm in LUND LLA and against the value 0.23 of Dugeay and Henrard were repeated. Direct comparison of MONTE CARLO with PETRA data, as suggested by M. Bosman, supports this. The difference of the x distributions for D^* mesons using the two values is substantial at 92 GeV.

- Multi–dimensional parameter fit:

  The question is how to cover the parameter space with how many points. I prefer a method in which the number of points is as small as possible (equal to the number of coefficients of an interpolating power series of 2^{nd} degree) and therefore the number of MC events/point is as big as possible, since distributions of physical quantities have weakly populated tails. A method is being developed in order to distribute a given number of points on the surface of a hypersphere requiring the mutual separation as large as possible. In addition there is a point at the center of the sphere.

2. α_s (minutes by RS):

- RS reported on a paper by E. Braaten, in which the effect of α_s on the ratio

$$R^{\tau} = \frac{\Gamma(\tau^- \rightarrow \nu_\tau + hadrons)}{\Gamma(\tau^- \rightarrow \nu_\tau e^- \nu_e^-)}$$

is shown to be similiar to that on the R_{had} or R'_{had} measurement. Therefore R^{τ} can be used to determine α_s.

- EL reviewed the status of hadronic event selection. He showed evidence supporting a D0 cut to define a good track, supporting a cut on the number of ECAL clusters with $E_{cluster} > \frac{E_{beam}}{2}$ to reject background from Bhabhas, and supporting the hope that the hadronic–event–defining cuts do not depend on E_{cm}.

3. Multigluons (minutes by M.Schm.):

- HJS reported about his attempts to fit the LUND 2^{nd} order matrix element model to the LUND shower model. This study was motivated by the prevailing opinion, that the shower model will provide a better description of the data, but that the matrix element model is up to now indispensable for the determination of the QCD–scale Λ or detailed studies of correlations within multijet events. The parameters varied were the LUND fragmentation parameters a and b, the QCD–scale Λ and the gaussian width of the fragmentation pt (σ_{pt}). The difference between the matrix element and the shower model was measured by the joint $\chi 2$ between the distributions of thrust, charged multiplicity, mean rapidity (averaged over one event) w.r.t. the thrust axis and the mean transverse momentum $< pt_{out} >$ out of the event plane. Due to finite Monte Carlo statistics the errors on $\chi 2$ turned out to make impossible any reliable determination of its derivatives w.r.t. to the parameters. Newton's method to find the minimum thus could not be employed. Therefore a simple and robust search method was used to minimize $\chi 2$. In order to optimize the efficiency of this approach point sets of almost optimum uniformity were used, the measure for uniformity being Weyl's "maximum discrepancy" (Weyl,H. Math. Ann.,77(1916)313-352). Preliminary results yield the following proposal for parameters of the LUND matrix element model:
a = 1.073 b = 0.329 Λ = 0.470 σ_{pt} = 0.436

- M.Sca. presented a new clustering algorithm which seems to combine the best features of both the JADE–algorithm "YCLUS" and the LUND–algorithm "LUCLUS". A detailed description of the new program "PRPMRG" ("perp-merge") is available from the author (SC05@UK.AC.GLA.PH.I1). Since PRPMRG uses the same measure for jet resolution as YCLUS equal performance with respect to jet multiplicities is obtained. By allowing reassignment of particles from a given cluster to another one in case that the transverse momentum relative to the other jet axis is smaller, the advantages of LUCLUS in terms of reconstruction of jet energy and direction are retained. The performance of the new alogorithm has been checked both with the LUND matrix element model and the shower model, and in no case was found to give less satisfactory results than any of the two.
- DP compared the cluster frequencies seen in the Lund 2^{nd} order matrix element model with those obtained from the Lund shower model. Cluster frequencies were determined with the Jade YCLUS–algorithm and the results plotted as function of its cutoff parameter y_{cut}. In addition the matrix element cutoff y_{min} has been varied. Independent of those variations the 4–jet rate from the matrix element model was found to be a factor of 2 below the prediction from the shower model. For large values of y_{cut} the cluster frequencies became almost independent of the matrix element cutoff y_{min}.

PRPMRG: Cluster (Jet) finding Algorithm for High Energy Hadronic Final States.

In the reaction e+ e- --> hadrons, for example, it is supposed that the initial process is e+ e- --> q q, followed by radiation of gluons and further q q pairs. The resulting shower of quarks and gluons (partons) is believed to convert locally to hadrons so that the hadron distribution is closely related to the underlying parton distribution. As a result, hadrons form jets of particles collimated about the directions of the more energetic partons. Cluster algorithms aim to identify these jets and thus provide information on parton distributions.

A jet can be defined as a cluster of particles having limited transverse momentum (Pt) with respect to the total momentum vector of the cluster. This is the definition used in PRPMRG which uses 3 steps in cluster finding.

```
 ENTRY  ------------------------------------------------------------
 ------>-| STEP 1:  Form initial clusters of limited Pt. using      |
         |          particles in order of decreasing energy.        |
        ------------------------------------------------------------
                                   |
                                   V
     -----------------------------------------------------------------
|->-| STEP 2:  Calculate effective mass of all cluster pairs, Wij.   |
|   |          Merge the two clusters of lowest effective mass,      |
|   |          IF     Wmin < WJTLIM                                  |
|   |          ELSE   Terminate.                                     |----:
|    -----------------------------------------------------------------EXIT
|                                  |
|                                  V
|    --------------------------------------------------------------------
|   | STEP 3:  The merged cluster now has momentum  Pc = Pi + Pj.
|   |          The new Pc may result in some particles of the merged
|   |          cluster having a smaller Pt relative to another cluster.
|   |          If so, particles are reassigned and the Pc recalculated.
|   |      IF     further reassignment needed the step is repeated.
--<-|      ELSE   STEP 2 is re-entered.
     --------------------------------------------------------------------
```

This algorithm attempts to combine the best features of existing routines. The following 3 sections describe the above steps in detail.

For operating instructions, see Usage Details below.

STEP 1. Cluster Initialisation.

All the particles (4-vectors) are ordered according to their energy and the most energetic particle forms the nucleus of the first cluster. Then the next most energetic particle is added to this cluster if the Pt is less than some specified limit (Ptlim): otherwise it forms the nucleus of a second cluster. This proceddure continues over all particles in order of decreasing energy, the particle being added to the cluster for which Pt is least, provided Pt < Ptlim: otherwise a new cluster is formed. Pt is defined by

$$Pt^2 = \frac{(P.P)(Pc.Pc) - (P.Pc)(P.Pc)}{(P+Pc).(P+Pc)} \qquad (1)$$

where P is the particle momentum and Pc the existing cluster momentum An additional merge condition is the requirement that (P.Pc) > 0.

Equation (1) gives the Pt relative to the resultant P + Pc. Since the mean Pt is typically about 300 MeV/c, initially (Ptlim)**2 = 0.10 GeV**2 was used. Since then, a value = 0.15 GeV**2 has proved adequate, giving an increase of speed of approximately 50 %. At 93 GeV center of mass energy the result of step 1 is an initial set of some 6 - 10 clusters.

At the end of this stage, energetic jets (E > 25 GeV) are already well determined from the most energetic tracks.

In practice this step currently uses the formula

$$Pt^2 = \frac{(P.P)(Pc.Pc) - (P.Pc)(P.Pc)}{(|P|+|Pc|)**2} \qquad (1b)$$

which is simpler to compute, and underestimates Pt for particles at large angle to the jet. The use of (1b) instead of (1) has no effect on the performance of the routine (except choice of Ptlim).

STEP 2. Cluster Merging.

The details of so many clusters probably reflects only the statistical nature of the hadronic production process. Therefore the number of clusters is reduced by a merging proceedure to a level where they hopefully correlate to partons.

As is usual in such algorithms, the two clusters separated by lowest distance measure are merged at each merging step. Merging is then repeated until either the desired number of clusters is obtained or some cutoff criteria is satisfied.

This algorithm works well using equation (1) to define distance, though it is not perhaps completely clear why this is a good choice, since Pt will depend on the number of tracks in the 2 clusters (unlike step 1, where Pt is always the transverse momentum of a single particle) However, an alternative distance choice, which appears to perform slightly better, is the effective mass of the 2 clusters, offering further advantages, particularly as definition of cutoff. Therefore mass has been chosen as distance measure. In addition, the angle between the merged clusters is required to be < 90 derees.

Currently, the pseudo-mass

$$M^2 = 2\, Ei\, Ej\; (\; 1 - (Pi.Pj)/(|Pi||Pj|)\;) \qquad (2)$$

is used, which is known to be the best choice if the cluster multiplicity is required to agree with parton generation by matrix element based Monte Carlo event generators.

In the case of parton generation by parton shower Monte Carlo event generators, the choice of pseudo-mass is less clear, and the Lorentz invariant true mass

$$M^2 = (\; Pi + Pj\;)_a\; (\; Pi + Pj\;)^a \qquad a=1,4 \qquad (3)$$

might be thought better choice (pseudo-mass cannot be defined for a cluster unambiguously, since it depends on the sub-clusters). However, although the difference on results is not great, pseudo-mass is still the better choice, resulting in fewer erroneous jets (when compared to the generated partons). This may be related to the string fragmentation used in the LUND Monte Carlo (?).

On merging two clusters, the new cluster momentum, Pc, is obtained from those of the merged clusters, Pc = Pi + Pj.

STEP 3. Possible Particle Reassignment.

In this step a check is made (similar to that in LUCLUS) that all particles are assigned to that cluster for which their Pt is least: if not, they are reassigned. In practice, Pp (the parallel component is maximised, identical in effect but simpler, allowing the generalised THRUST to be obtained in addition.

$$Pp \quad = \quad (P.Pc)/|Pc| \tag{4}$$

If any reassignment occurs, the Pc are recalculated and the above check repeated. This proceedure is carried out in fairly economical fashion (frequently no reassignment occurs) and is therfore performed, with (few) necessary iterations, after each merge step.

After step 3, the algorithm repeats step 2, and so on, until the termination condition is satisfied.

USAGE DETAILS.

CALL PRPMRG(NJETUT, WVALUT, THRUST, NJTLIM, WJTLIM)

WVALUT(2) must be dimensioned 2.

Input:

NJTLIM	minimum number of clusters to be found. (occasionally this number cannot be obtained, so always check NJETUT)
WJTLIM	maximum cluster effective mass. (currently pseudo-mass) A recommended value is WJTLIM = 10 GeV since this corresponds to the minimum center of mass energy at which two jets can be clearly resolved. (set NJTLIM=0) If a fixed number of clusters is reqired, set WJTLIM high. (= center of mass energy)

Output:

NJETUT	number of clusters (jets) found.
WVALUT(1)	last pair effective mass of merged clusters.
WVALUT(2)	minimum pair effective mass of found clusters. (currently pseudo-masses)
THRUST	generalised thrust = sum of Pp/(total seen energy) where Pp is longitulinal momentum relative to relevant cluster.

The routine uses the LUND 6.3 COMMON

COMMON /LUJETS/ N,K(2000,2),P(2000,5)

The jet vectors are stored in P(J+1000,1-5) with J=1,NJETUT and K(J+1000,2) contains the number of particles forming the cluster. For each particle K(I,1) is set to the corresponding cluster number = J (I = 1,N).

The routine is written in FORTRAN 77 and has been run on IBM 4361/5 and APOLLO DM560.

PRPMRG calls subroutine ESORT for particle energy ordering. (THEPHI only called by diagnostic print)

Use of WVALUT.

For example, in a study of 4-jet events, the number of clusters to be found can be fixed at 4. Then the last merged mass together with the lowest cluster pair effective mass (WVALUT(1) and WVALUT(2) resp.) allows cluster resolution to be varied AFTER the algorithm has been applied, simplifying any study of resolution dependence.

COMPARATIVE NOTES.

The routine has been compared with other algorithms using events generated by LUND matrix element Monte Carlo for 2,3,4 jets at center o mass energy = 93 GeV. with Ycut = 0.01 (about the minimum permissible).

A) A popular cluster algorithm, initially regards each particle as a cluster, and then merges the pair with lowest pseudo-mass to a single cluster, and so on, terminating when the lowest remaining pseudo mass exceeds a given cutoff. This algorithm is well known to give good agreement of cluster multiplicity with generated parton multiplicity, however, low energy jets tend to contain too many particles.
PRPMRG performs equally well on multiplicity
(using pseudo-mass) but obtains better angular resolution and (in a hermetic detector) better energy resolution. Reassignment, as used in PRPMRG, cannot be applied to an algorithm operating entirely on (pseudo-) mass based merging of cluster pairs.

B) PRPMRG gives a resolution similar to LUCLUS - perhaps marginally better, but has the advantage that the resolution is defined in terms of effective mass. With Ptlim = 0.15 for the initial stage PRPMRG is approximately x3 faster than LUCLUS.

To summarise, the PRPMRG algorithm appears to combine the best features of both LUCLUS and the purely mass based merge proceedure.

(Revised 89. III. 13)

SUMMARY

It is perhaps worth stating that PRPMRG does not depend on any careful tuning, and is not very sensitive to its only parameter (Ptlim Further, although it seems to operate best using pseudo - mass, it performed almost as well with several other variables (slightly higher error rates). This suggests that PRPMRG is robust.

Comparison of Jet Algorithms with Monte Carlo generated Parton Distributions.

ALGORITHMS

Three jet finding algorithms have been tested to determine how well the found jets correspond to the generated partons (quarks and gluons). The algorithms used, in decreasing order of merit, were

1) PRPMRG - for details see separate document DOX¶89.3

2) LUCLUS - routine provided with LUND Monte Carlo.

3) The JADE type algorithm (here called MASMRG). Initially, all particles are considered as clusters, and the pair of lowest pseudo-mass are merged to a single cluster, and so on, until some limit is reached. For example, combination ceases when the lowest pseudo-mass exceeds Mlim Pseudo-mass is defined by

$$M^2_{ij} = 2 E_i E_j (1 - \cos(\theta_{ij}))$$

COMPARISON

The comparison was made using the LUND 6.3 Monte Carlo to generate e+ e- --> hadron events. No detector effects or losses have been included, but particles of energy less than 0.2 GeV have been excluded. Two methods were used:

a) 4-jet events were generated with the Matrix Element Monte Carlo with ylim = 0.01 (approximately the lowest value possible) at a center of mass energy of 93 GeV. The algorithms were run to find 4 clusters (or jets) which were then compared with the generated partons. Results of the comparison are shown in figs 1 and 2 and table I.

b) The LUND shower Monte Carlo was used (Qo = 1 GeV). Algorithms 1 and 3 ran with Mlim = 10 Gev (equivalent to ycut = 0.0116 at Ecms = 93 GeV). LUCLUS used PARE(33) = 3.5, which is roughly equivalent. The comparison shown here is for those events found by the algorithms to be 4-jet events (conclusions from 3- and 2-jet events are similar).
Because of the complexity of the parton shower tree, the comparison is more difficult for this case. Details of the method are given in the appendix.
Results of the comparison are shown in figs 3 and 4 and table II.

The tests in a) and b) were performed with both light (u) quarks and heavy (b) quarks.

RESULTS and CONCLUSIONS.

1) In these tests the performance of PRPMRG over a sample of events was never bettered by the other 2 algorithms either for resolution or number of errors (where found jets do not agree with generated partons).

2) PRPMRG and MASMRG (the JADE type algorithm) agree closely on the found jet multiplicity distributions. (which agree with those generated by the LUND matrix element Monte Carlo)

3) LUCLUS and PRPMRG give better jet resolution than MASMRG

for lower energy jets.

4) For heavy (b-quark) 4 jet events with a low energy gluon, LUCLUS tends to split a b-quark jet into 2 clusters and merge the low energy gluon. (This occurs both for (a) matrix element generated events where the number of clusters is fixed, and for (b) where the number of clusters found is determined by a resolution parameter. This behavior is much less frequent with MASMRG or PRPMRG. (table III)

5) PRPMRG runs about x3 faster than LUCLUS. (similar speed to MASMRG)

6) PRPMRG has also been tested on Monte Carlo events where only charged particles were retained. About half the particle energy is lost, but PRPMRG still found 90% of the jets correctly. (not tried for other algorithms)

7) For Ejet < 5 GeV, all the algorithms start to become unreliable.

FIGURES

For each algorithm, the figures show (above) the angle deviations (degrees) between parton and jet directions versus parton energy, and (below) Eparton - Ejet (GeV) versus Eparton (GeV).

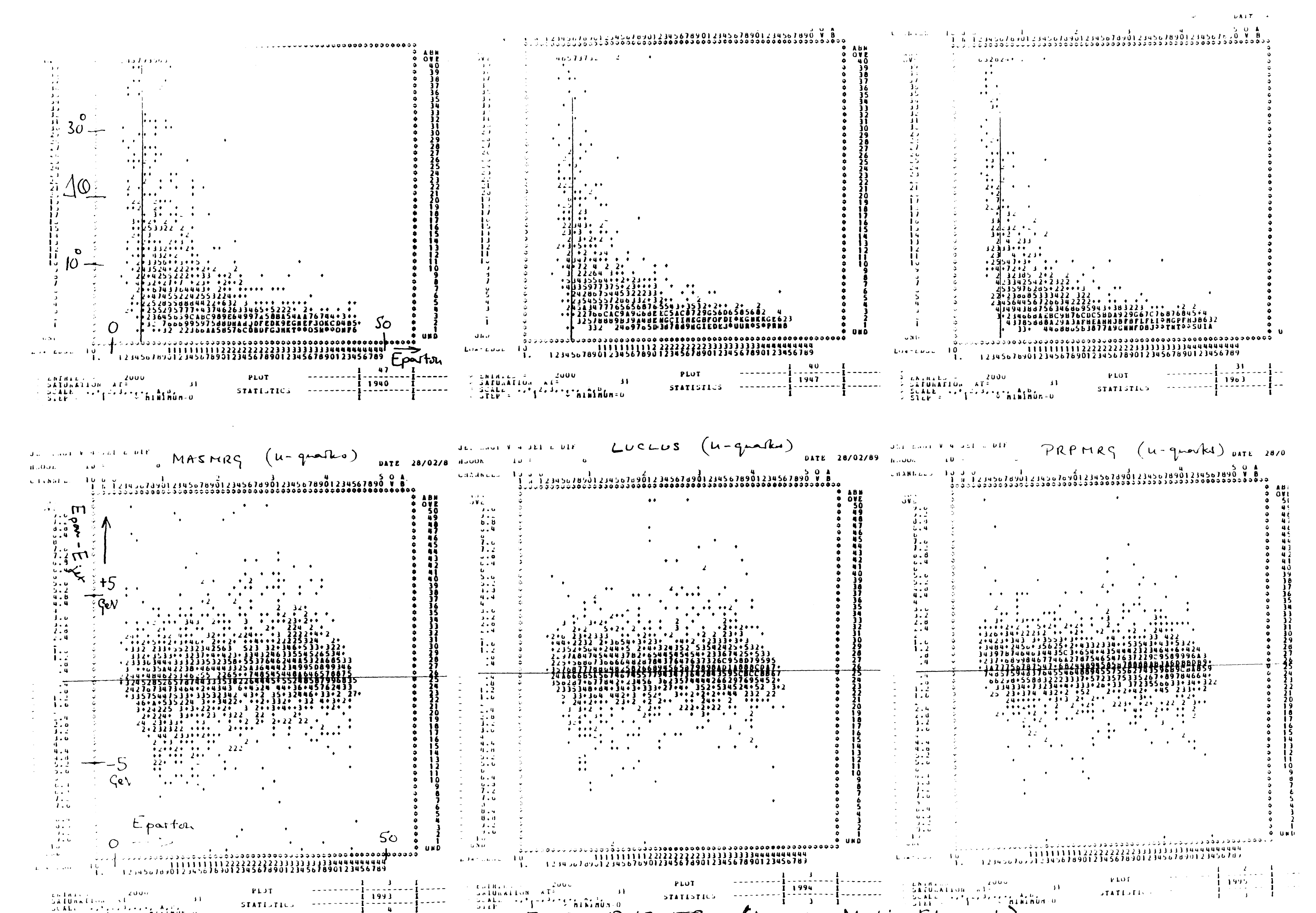
TABLES

Tables I and II show mean values of angle deviations and Eparton - Ejet (and their RMS values) for 3 ranges of Eparton
Table III compares b-quark jet splitting for MASMRG and PRPMRG.

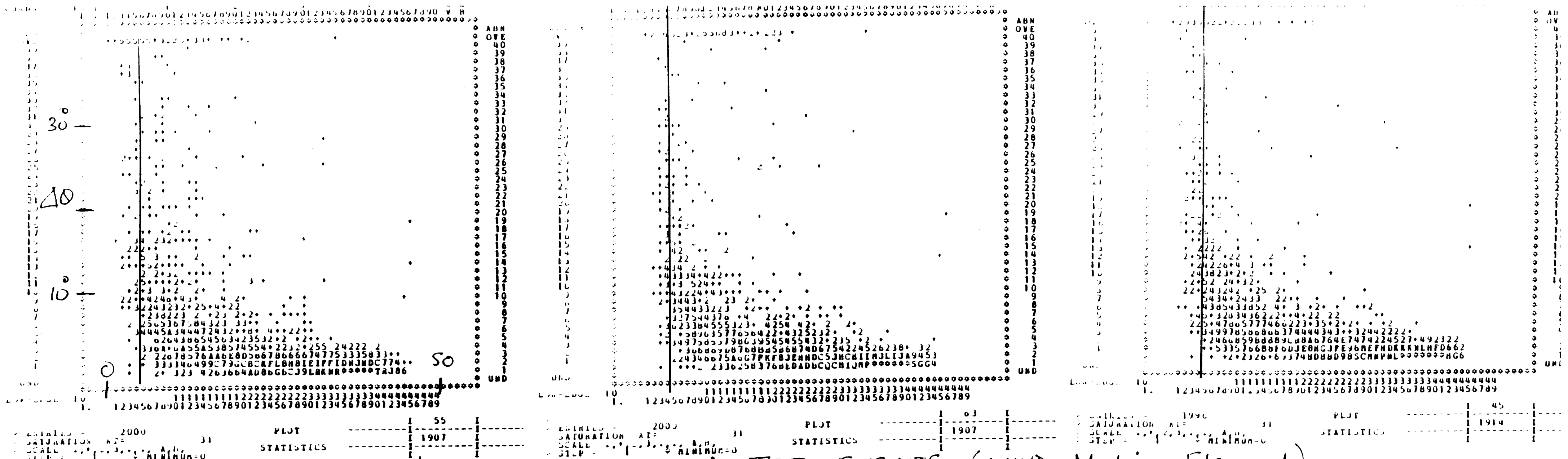
SUMMARY

PRPMRG appears to perform the best in the tests made. Whether this will significantly improve any physics analysis is not known.

It is perhaps worth stating that PRPMRG does not depend on any careful tuning, and is not very sensitive to its only parameter (Ptlim, see PRPMRG document). Further, although it seems to operate best using pseudo-mass, it performed almost as well with several other variables (slightly higher error rates). This suggests that PRPMRG is robust and not simply tuned for a given event generator.



N - Quarks 4 JET EVENTS (LUND Monte ...



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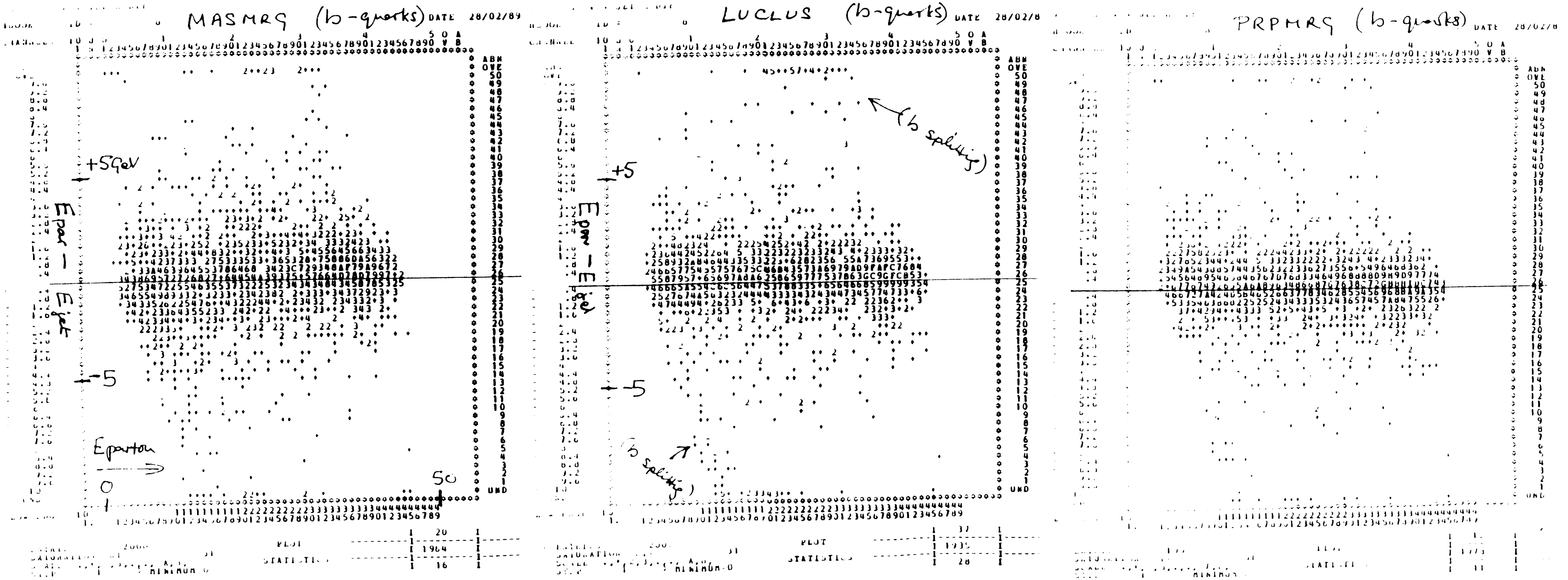
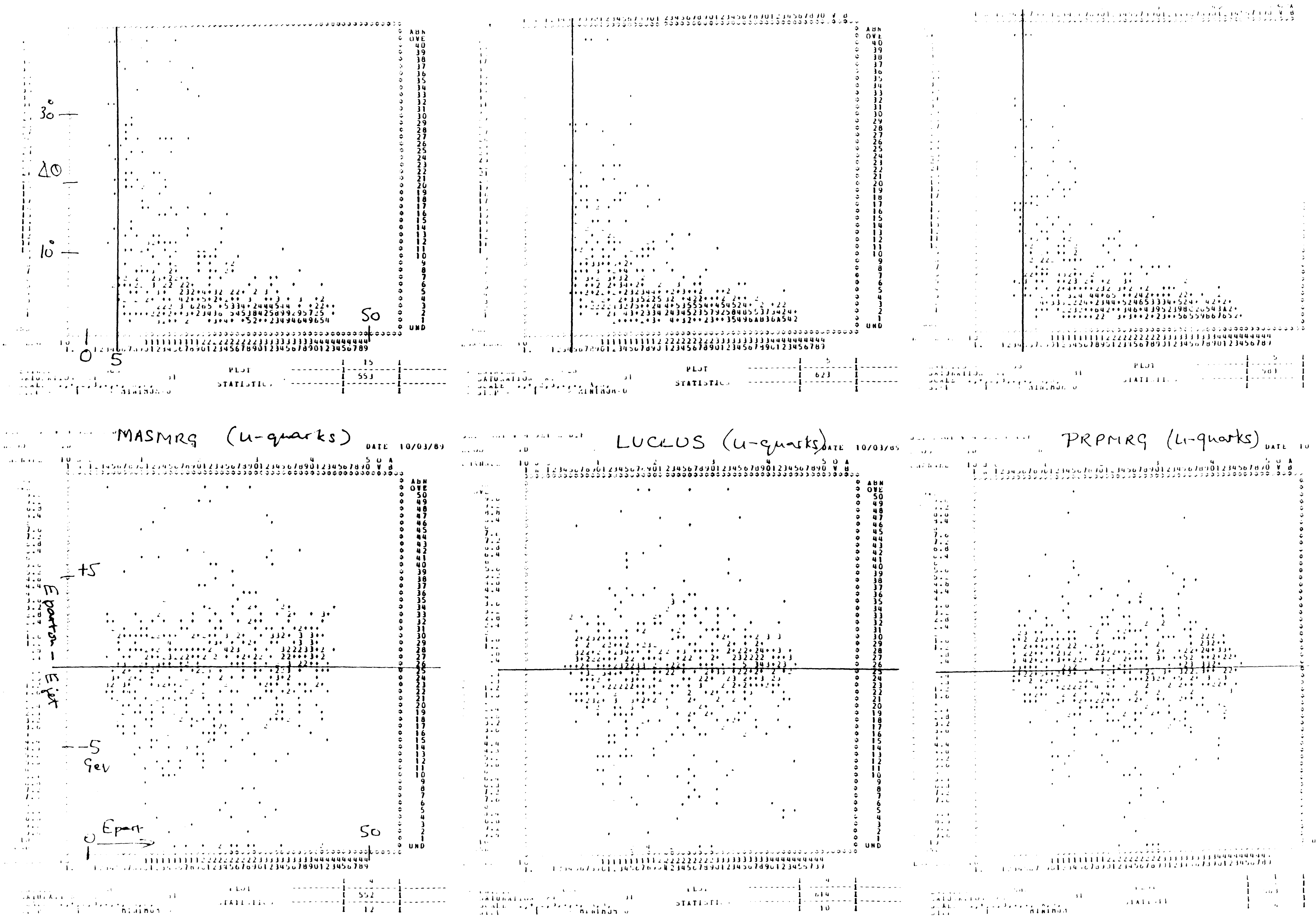
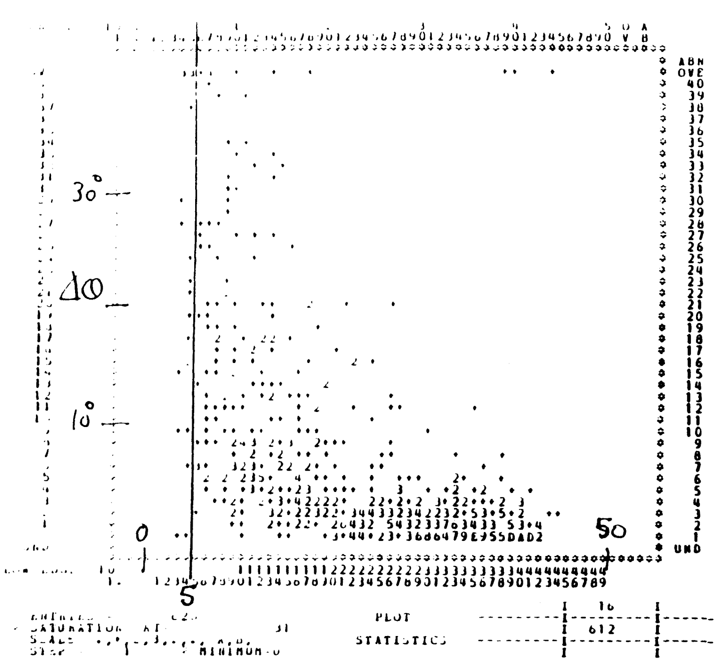
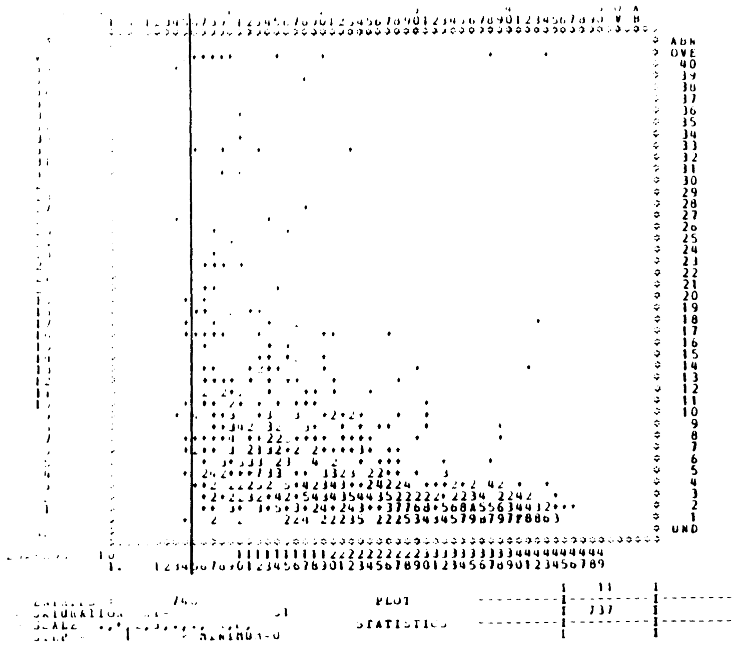
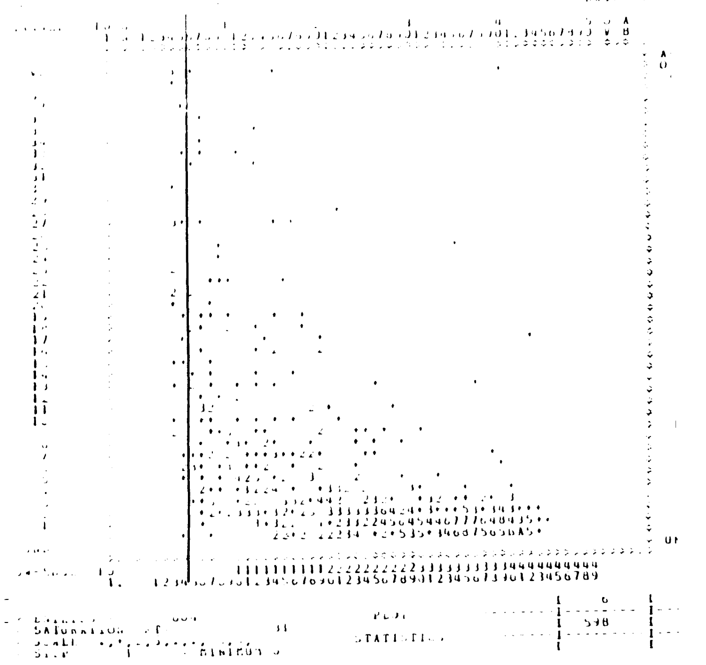


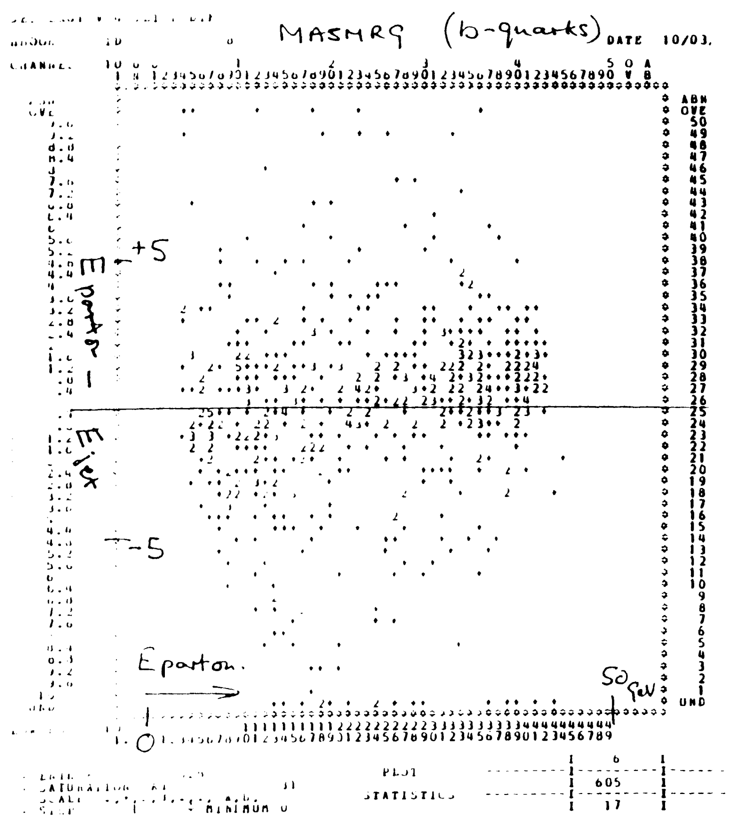
b- Quarks 4 JET EVENTS (LUND Matrix Element)

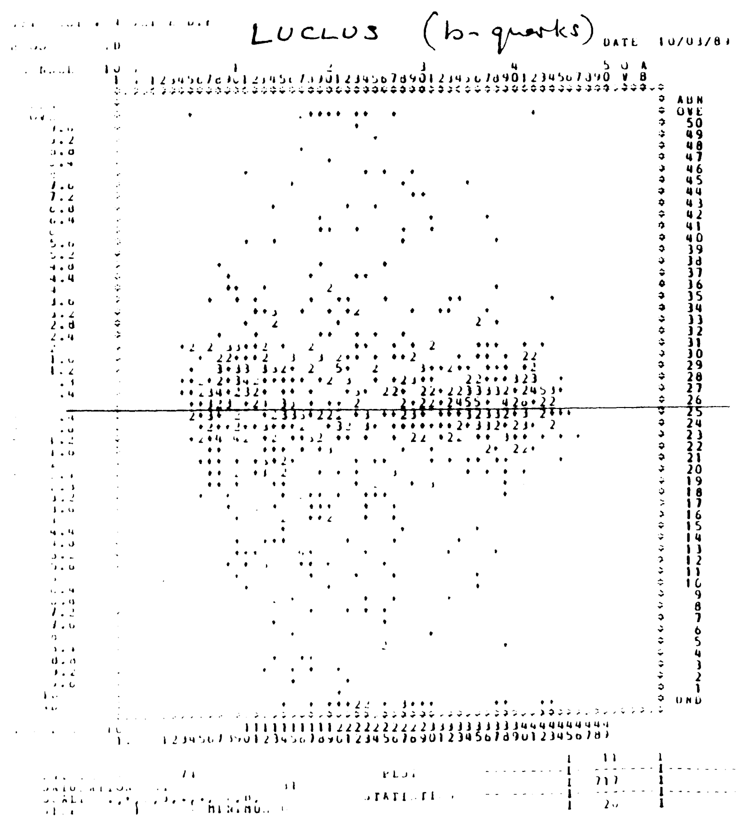

MASMRG (u-quarks)
LUCLUS (u-quarks)
PRPMRG (u-quarks)
DATE 10/03/89
30°
10°
0
5
50
+5
-5
Gev
Eparton - Ejet
Epart
PLOT
STATISTICS


30°
20
10°
0
5
50
PLOT
STATISTICS


PLOT
STATISTICS




MASMRQ (b-quarks)
DATE 10/03.
+5
E parton - E jet
-5
E parton.
0
50 GeV
PLOT
STATISTICS


LUCLUS (b-quarks)
DATE 10/03/8
PLOT

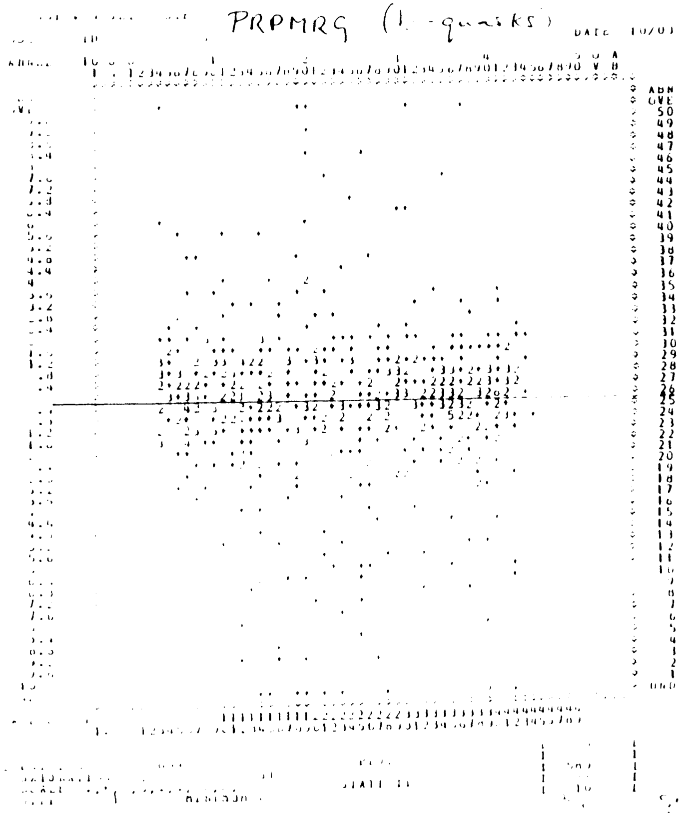

PRPMRQ (l-quarks)

TABLE 1

Comparison I. LUND MATRIX ELEMENT 4 JETS ($Y_{cut} = 0.01$ at $\sqrt{s} = 93$ GeV)

ROUTINE	⟨PARTON ENY − JET ENY⟩ (RMS) a) $5 < E_J < 10$	b) $10 < E_J < 20$	c) $20 < E_J < 50$	⟨Δ ANGLE⟩ DEG (RMS) a)	b)	c)	QUARK
MASMRG	−0.503 (1.99)	−0.103 (2.36)	0.414 (2.02)	10.6 (7.8)	5.3 (4.9)	1.6 (1.7)	u
	−0.134 (2.08)	−0.234 (2.64)	0.445 (2.03)	10.7 (8.3)	5.7 (5.9)	1.8 (2.6)	b
LUCLUS	−0.143 (1.77)	0.140 (1.68)	0.214 (1.53)	8.8 (6.7)	4.1 (3.4)	1.4 (1.1)	u
	0.209 (1.83)	−0.097 (2.54)	0.224 (1.75)	9.1 (7.1)	4.6 (4.8)	1.7 (2.8)	b
PRPMRG	0.285 (1.60)	0.160 (1.54)	0.065 (1.44)	7.8 (5.3)	4.1 (3.3)	1.5 (1.2)	u
	0.454 (1.70)	0.168 (2.17)	0.110 (1.63)	8.6 (6.4)	4.3 (4.0)	1.5 (2.2)	b

Note: tracks with Energy < 0.2 GeV are not used.

↑ Here RMS gives info. about the tails of distrib. The relevant quantity is RMS/⟨Δ⟩

TABLE 4

COMPARISON II LUND SHOWER M.C.

ROUTINE	⟨PARTON ENY − JETENY⟩ (RMS) a) $5 < E_J < 10$	b) $10 < E_J < 20$	c) $E_J > 20$	⟨Δ ANGLE⟩ DEG. (RMS) a)	b)	c)	QUARK	
MASMRG (Ycut = 0.0116 ≡ Wcut = 10 GeV)	−1.671 (2.11)	−1.198 (3.03)	0.457 (2.48)	16.8 (10.0)	7.7 (6.4)	1.9 (2.9)	3 jet	c
	−0.433 (2.57)	−0.788 (3.11)	0.245 (2.97)	14.0 (9.9)	8.5 (8.3)	2.7 (2.6)	4 jet	
	−1.306 (2.40)	−0.514 (3.03)	0.477 (2.26)	13.8 (9.7)	8.1 (7.8)	1.8 (2.6)	3 jet	b
	−1.029 (2.43)	−0.493 (3.39)	0.449 (2.75)	15.7 (10.1)	8.6 (7.5)	2.4 (2.8)	4 jet	
LUCLUS (dlim = 3.5 gives similar jet multiplicity to above)	−0.239 (1.54)	−0.607 (3.03)	0.090 (2.23)	11.5 (9.1)	6.6 (5.6)	1.8 (2.4)	3 jet	c
	−0.093 (1.72)	−0.586 (3.02)	−0.323 (2.65)	10.3 (5.7)	6.7 (5.5)	2.1 (1.5)	4 jet	
	−0.236 (1.57)	−0.615 (3.35)	0.328 (2.29)	11.0 (7.7)	6.9 (5.6)	1.8 (2.6)	3 jet	b
	0.161 (1.71)	−0.043 (3.47)	−0.033 (2.71)	10.1 (7.5)	6.9 (6.2)	2.6 (3.4)	4 jet	
PRPMRG (Wcut = 10 GeV, 20 for MASMRG)	0.300 (1.77)	−0.299 (2.54)	0.009 (2.05)	11.3 (9.1)	6.1 (5.5)	1.8 (2.7)	3 jet	c
	0.642 (1.73)	−0.173 (2.67)	−0.375 (2.40)	11.9 (6.9)	6.6 (6.8)	2.2 (1.6)	4 jet	
	0.018 (1.98)	−0.186 (2.27)	0.265 (1.81)	11.9 (8.4)	6.0 (5.4)	1.7 (2.9)	3 jet	b
	0.280 (1.85)	0.314 (2.85)	−0.370 (2.58)	11.2 (8.4)	6.0 (5.7)	2.3 (2.7)	4 jet	
	PRPMRG and MASMRG give close agreement on jet multiplicity when using same Wcut.							

Table III

From 500 4-jet events generated by LUND Matrix element M.C., 37 cases occurred where <u>either LUCLUS or PRPMRG</u>* (or both) found jets badly in disagreement with the generated partons due to splitting the b (or $\bar{b}$) associated jet. ($E_{parton} - E_{jet} > 10$ GeV.)

The performance by the individual algorithm on these 37 events is shown in the table.

Algorithm	Failed	Successful
PRPMRG (using pseudo-mass)	12	25
PRPMRG (using true mass)	26	11
LUCLUS	36	1

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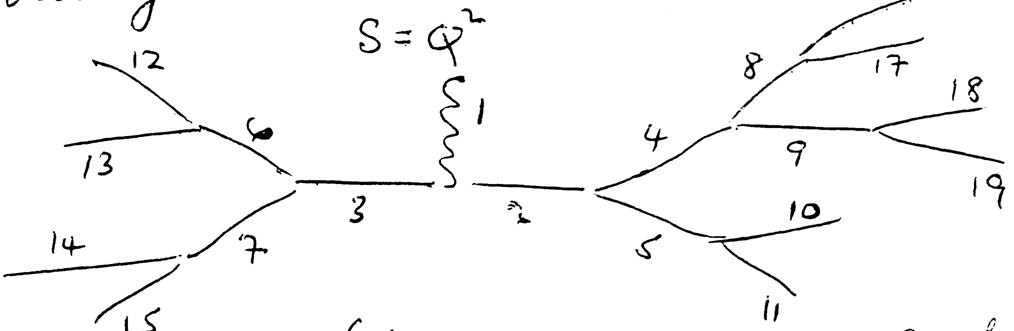
* Using pseudo-mass.

Appendix

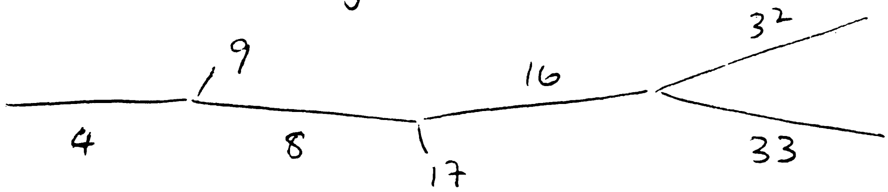
Comparison of found jets (clusters) with partons of the LUND parton shower Monte Carlo

In this case, comparison is much more difficult due to the large number of partons at different levels of the shower tree. We proceeded as follows. The partons of the tree are labelled in a binary scheme



(fig 1) and so on.

Ancestors of found by integer division by 2. The labeling is such that $E_{2i} > E_{2i+1}$ where i = parent label. The typical branch contains several gluons of low energy which will never be detectable, viz.

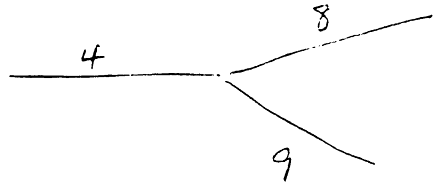


(fig 2)

e.g. branches 9 and 17 cannot be found.
Such splittings are ignored if $E < E_{lim}$.
We have used arbitrarily $E_{lim} = 2\,GeV$ and have not tried other values. Now fig 2 appears as

(fig 3 ------ = removed parton)

and relabelling is performed so that finally we have in the above case



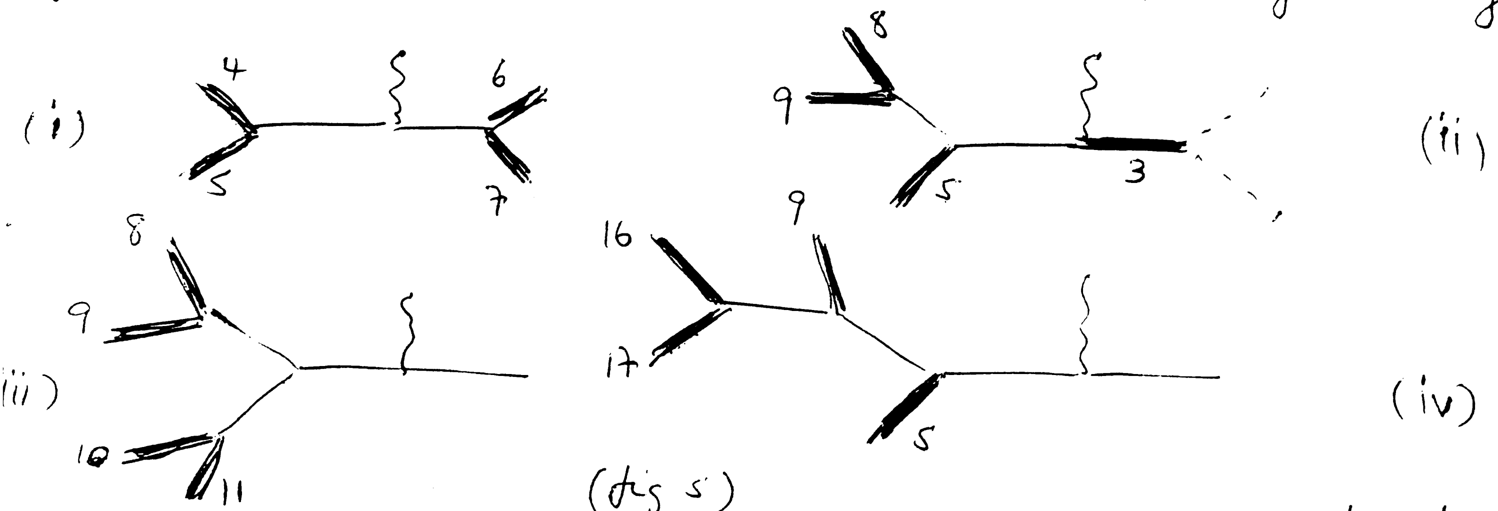
(fig 4)

32 became 8
33 became 9
(of course energy is no longer exactly conserved.)

Then we finally throw away branches with high labels depending on the number of jets found by the Algorithm. (W_{lim} = 10 GeV was used ≡ $Y_{cut} \simeq 0.0$

# Jets Found	1	2	3	4	5	. . . n
Highest Permitted Label	3	7	15	31	63	.. $2^{(n+1)}-1$

Even this cut, due to the energy ordering of the labels is higher than necessary. For example, the configurations for a 4 jet event which we allow are (found jets heavy)



(fig 5)

of steadily decreasing probability. (The labelling shown is the most probable

The matching algorithm matches the most energetic jet first on the basis of angular direction* Inconsistent matches are not allowed.

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* Footnote: next page.

However, in some (few) cases the best match is not found. We assume this not to invalidate the comparison as a whole. Results of algorithm comparison with the Parton Showers is shown in Fig 3 a[illegible] and Table II. The conclusions are similar to those obtained using the LUND Matrix Element Monte Carlo event generator.

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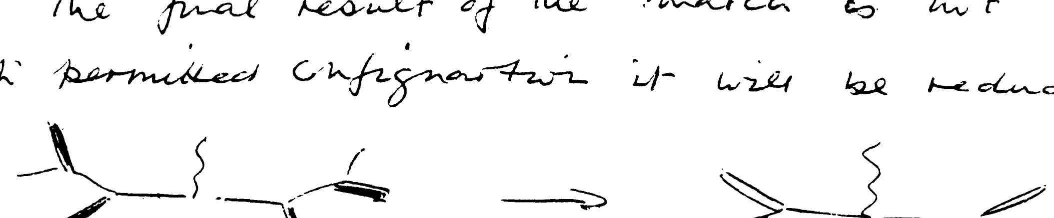
* If the final result of the match is not consistent with permitted configuration it will be reduced

eg



The reverse procedure to reduction can occur where necessary.