UOS-MIT mini workshop on gluon study

서울시립대학교
UNIVERSITY OF SEOUL

QCD and Gluon study by using ALEPH Data

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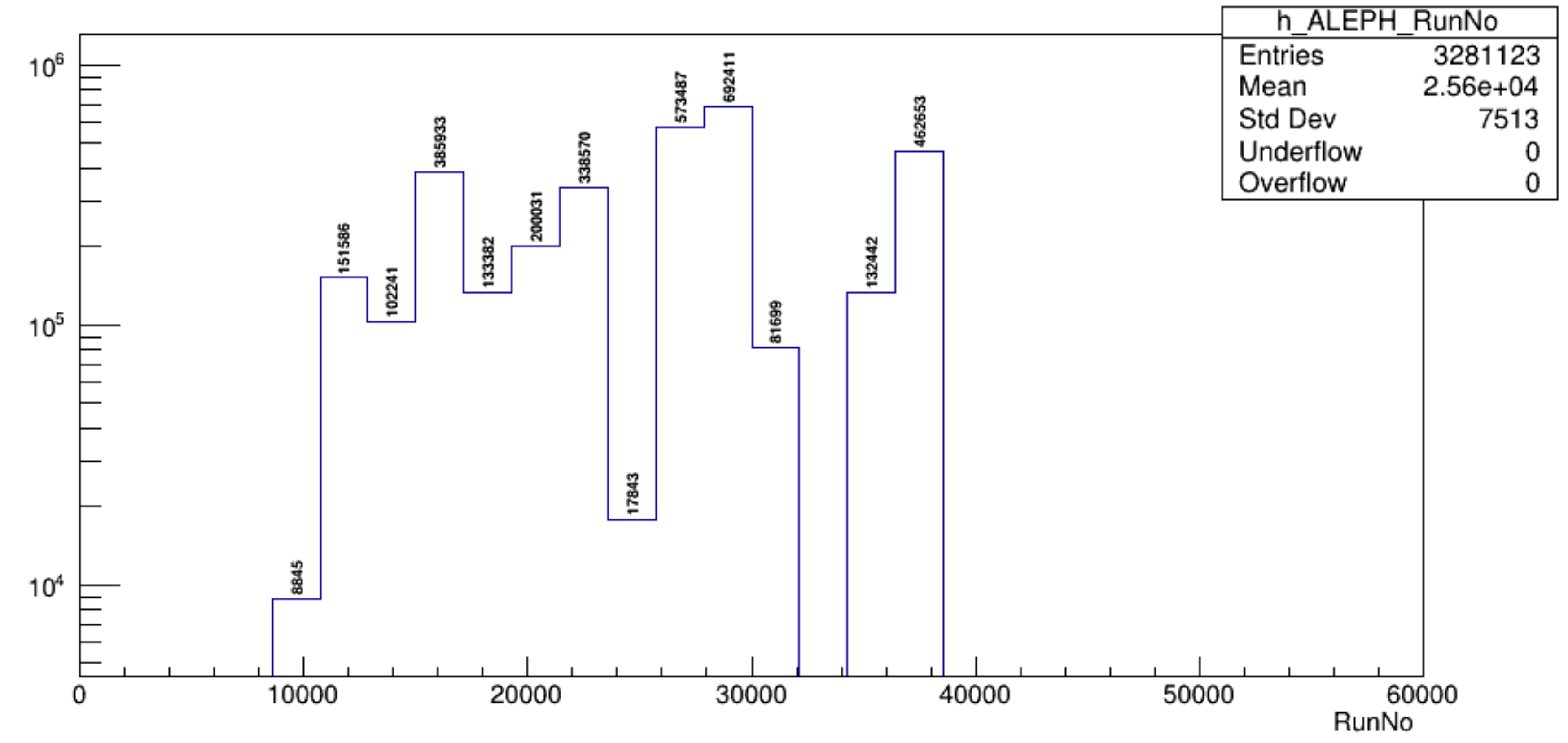
10 October 2022

Data : ALEPH



- tree
  - 'year', 'EventNo', 'RunNo', 'Energy', 'process',
  - 'nParticle',
    - 'px[nParticle]', 'py[nParticle]', 'pz[nParticle]', 'pt[nParticle]',
    - 'pmag[nParticle]', 'mass[nParticle]', 'eta[nParticle]', 'theta[nParticle]',
    - 'phi[nParticle]', 'charge[nParticle]', 'pwflag[nParticle]',
    - 'pid[nParticle]'
  - pwflag description : CHARGED_TRACK(0), CHARGED_LEPTONS1(1), CHARGED_LEPTONS2(2), V0(3), PHOTON(4), NEUTRAL_HADRON(5)
- # of Samples : 3281123

MC from MIT

Root file description

```
TFile*           /hdfs/user/youngjo/QCD/aleph_mc/LEP1MCMerged.root
 KEY: TTree      t;1        t
 KEY: TTree      tgen;1   tgen
 KEY: TTree      tgenBefore;1      tgenBefore

 KEY: TTree      akR4ESchemeJetTree;1  akR4ESchemeJetTree
 KEY: TTree      akR4WTAmodpSchemeJetTree;1 akR4WTAmodpSchemeJetTree
 KEY: TTree      akR8ESchemeJetTree;1  akR8ESchemeJetTree
 KEY: TTree      akR8WTAmodpSchemeJetTree;1 akR8WTAmodpSchemeJetTree
 KEY: TTree      BoostedWTAR8Evt;1      BoostedWTAR8Evt
 KEY: TTree      ktN2ESchemeJetTree;1   ktN2ESchemeJetTree
 KEY: TTree      ktN2WTAmodpSchemeJetTree;1  ktN2WTAmodpSchemeJetTree
 KEY: TTree      BoostedWTAktN2Evt;1    BoostedWTAktN2Evt
 KEY: TTree      ktN3ESchemeJetTree;1   ktN3ESchemeJetTree
 KEY: TTree      ktN3WTAmodpSchemeJetTree;1  ktN3WTAmodpSchemeJetTree
KEY: TTree       akR4ESchemeGenJetTree;1       akR4ESchemeGenJetTree
 KEY: TTree      akR4ESchemeGenJetBeforeTree;1         akR4ESchemeGenJetBeforeTree
 KEY: TTree      akR4WTAmodpSchemeGenJetTree;1         akR4WTAmodpSchemeGenJetTree
 KEY: TTree      akR4WTAmodpSchemeGenJetBeforeTree;1         akR4WTAmodpSchemeGenJetBeforeTree
 KEY: TTree      akR8ESchemeGenJetTree;1       akR8ESchemeGenJetTree
 KEY: TTree      akR8ESchemeGenJetBeforeTree;1         akR8ESchemeGenJetBeforeTree
 KEY: TTree      akR8WTAmodpSchemeGenJetTree;1         akR8WTAmodpSchemeGenJetTree
 KEY: TTree      akR8WTAmodpSchemeGenJetBeforeTree;1         akR8WTAmodpSchemeGenJetBeforeTree
 KEY: TTree      genBoostedWTAR8Evt;1 genBoostedWTAR8Evt
 KEY: TTree      genBoostedWTAR8BeforeEvt;1   genBoostedWTAR8BeforeEvt
 KEY: TTree      ktN2ESchemeGenJetTree;1       ktN2ESchemeGenJetTree
 KEY: TTree      ktN2ESchemeGenJetBeforeTree;1         ktN2ESchemeGenJetBeforeTree
 KEY: TTree      ktN2WTAmodpSchemeGenJetTree;1         ktN2WTAmodpSchemeGenJetTree
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 KEY: TTree      genBoostedWTAktN2BeforeEvt;1 genBoostedWTAktN2BeforeEvt
 KEY: TTree      ktN3ESchemeGenJetTree;1       ktN3ESchemeGenJetTree
 KEY: TTree      ktN3ESchemeGenJetBeforeTree;1         ktN3ESchemeGenJetBeforeTree
 KEY: TTree      ktN3WTAmodpSchemeGenJetTree;1         ktN3WTAmodpSchemeGenJetTree
 KEY: TTree      ktN3WTAmodpSchemeGenJetBeforeTree;1         ktN3WTAmodpSchemeGenJetBeforeTree
```

```
*Tree    :t         : t
*Br    0 :EventNo   : EventNo/I
*Br    1 :RunNo     : RunNo/I
*Br    2 :year      : year/I
*Br    3 :subDir    : subDir/I
*Br    4 :process   : process/I
*Br    5 :isMC      : isMC/O
*Br    6 :uniqueID  : uniqueID/I
*Br    7 :Energy    : Energy/F
*Br    8 :bFlag     : bFlag/I
*Br    9 :particleWeight : particleWeight/F
*Br   10 :bx        : bx/F
*Br   11 :by        : by/F
*Br   12 :ebx       : ebx/F
*Br   13 :eby       : eby/F
*Br   14 :nParticle : nParticle/I
*Br   15 :px        : px[nParticle]/F
*Br   16 :py        : py[nParticle]/F
*Br   17 :pz        : pz[nParticle]/F
*Br   18 :pt        : pt[nParticle]/F
*Br   19 :pmag      : pmag[nParticle]/F
*Br   20 :rap       : rap[nParticle]/F
*Br   21 :eta       : eta[nParticle]/F
*Br   22 :theta     : theta[nParticle]/F
*Br   23 :phi       : phi[nParticle]/F
*Br   24 :mass      : mass[nParticle]/F
*Br   25 :charge    : charge[nParticle]/S
*Br   26 :pwflag    : pwflag[nParticle]/S
*Br   27 :pid       : pid[nParticle]/I
*Br   28 :d0        : d0[nParticle]/F
*Br   29 :z0        : z0[nParticle]/F
*Br   30 :highPurity : highPurity[nParticle]/O
*Br   31 :ntpc      : ntpc[nParticle]/S
*Br   32 :nitc      : nitc[nParticle]/S
*Br   33 :nvdet     : nvdet[nParticle]/S
*Br   34 :vx        : vx[nParticle]/F
*Br   35 :vy        : vy[nParticle]/F
*Br   36 :vz        : vz[nParticle]/F
*Br   37 :weight    : weight[nParticle]/F
*Br   38 :pt_wrtThr : pt_wrtThr[nParticle]/F
*Br   39 :eta_wrtThr : eta_wrtThr[nParticle]/F
:
*Br  143 :Aplanarity : Aplanarity/F
*Br  144 :Sphericity_linearized : Sphericity_linearized/F
*Br  145 :STheta_linearized : STheta_linearized/F
*Br  146 :SPhi_linearized : SPhi_linearized/F
*Br  147 :Aplanarity_linearized : Aplanarity_linearized/F
*Br  148 :C_linearized : C_linearized/F
*Br  149 :D_linearized : D_linearized/F
*Br  150 :passesLEP1TwoPC : passesLEP1TwoPC/O
```

```
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*Br    0 :nref      : nref/I
*Br    1 :jtpt      : jtpt[nref]/F
*Br    2 :jteta     : jteta[nref]/F
*Br    3 :jtphi     : jtphi[nref]/F
*Br    4 :jtm       : jtm[nref]/F
*Br    5 :jtN       : jtN[nref]/I
*Br    6 :jtNPW     : jtNPW[nref][6]/I
*Br    7 :jtptFracPW : jtptFracPW[nref][6]/F
*Br    8 :zgJtPt_Beta0p00ZCut0p10 : zgJtPt_Beta0p00ZCut0p10[nref]/F
*Br    9 :zgJtPhi_Beta0p00ZCut0p10 : zgJtPhi_Beta0p00ZCut0p10[nref]/F
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*Br   11 :zg_Beta0p00ZCut0p10 : zg_Beta0p00ZCut0p10[nref]/F
*Br   12 :rg_Beta0p00ZCut0p10 : rg_Beta0p00ZCut0p10[nref]/F
```
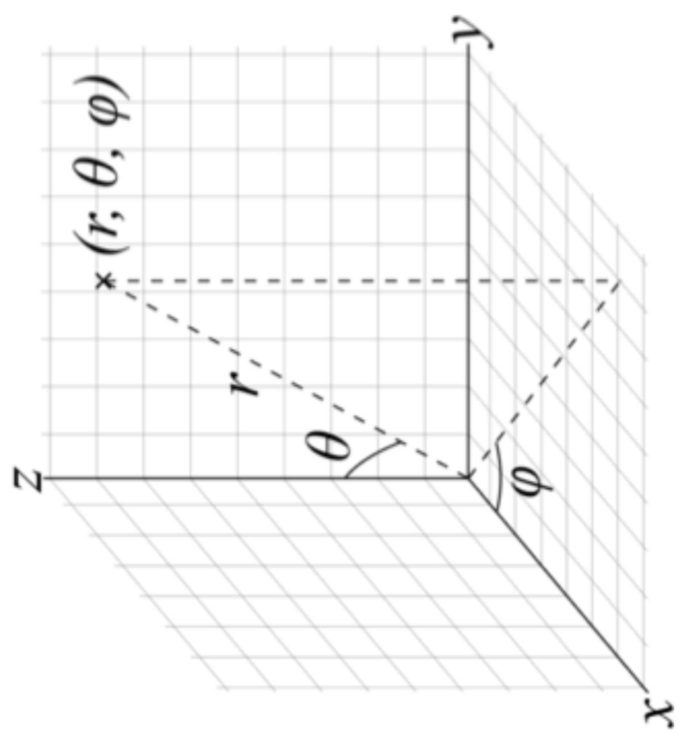
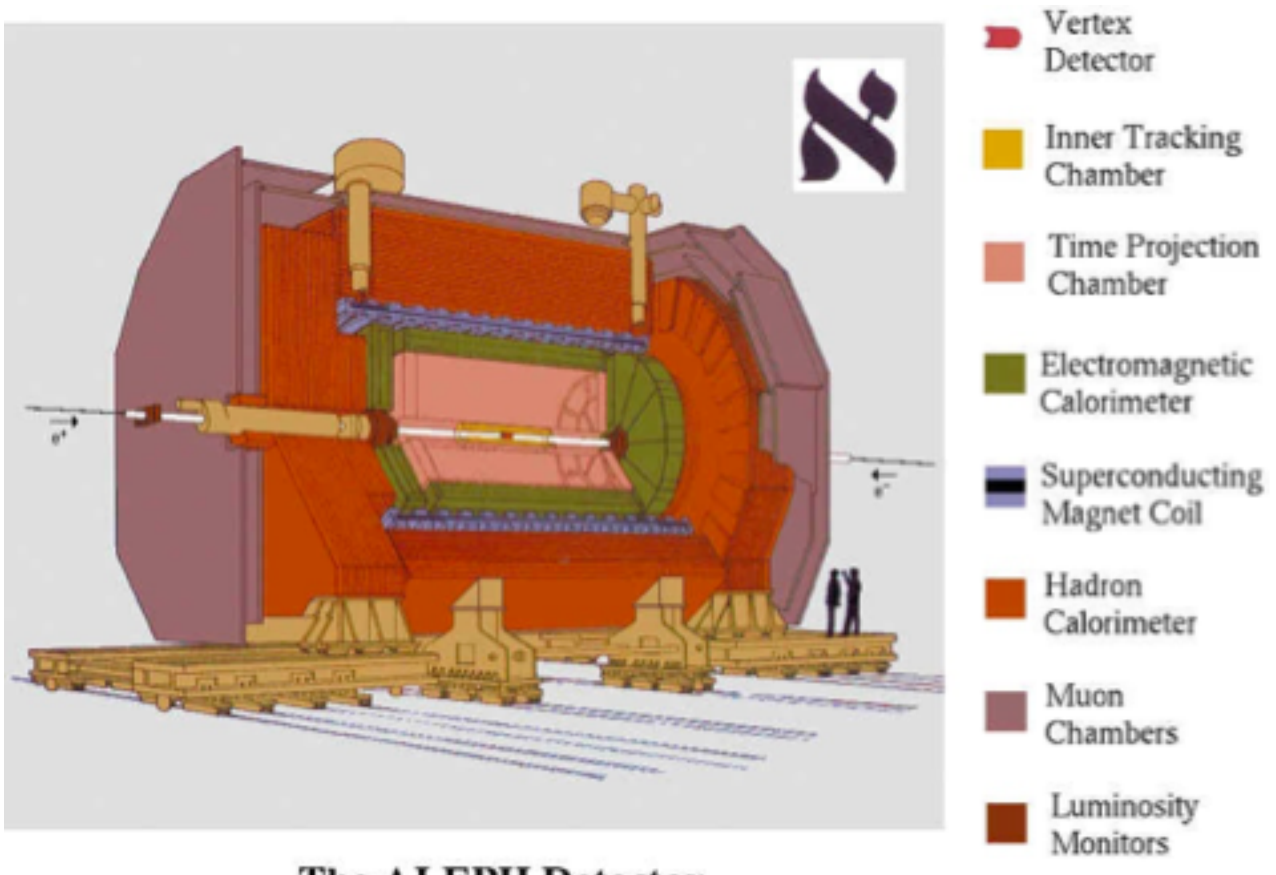

- The MC samples saved only final state particles.

Jet algorithm

- ee_genkt_algorithm
- Delta R : 0.65





The ALEPH Detector

$$\Delta R = \sqrt{(\theta_1 - \theta_2)^2 + (\phi_1 - \phi_2)^2}$$

4.5 Generalised k_t algorithm for e^+e^- collisions

FastJet also provides native implementations of clustering algorithms in spherical coordinates (specifically for e^+e^- collisions) along the lines of the original k_t algorithms [25], but extended following the generalised pp algorithm of [14] and section 4.4. We define the two following distances:

$$d_{ij} = \min(E_i^{2p}, E_j^{2p}) \frac{(1 - \cos\theta_{ij})}{(1 - \cos R)}, \tag{9a}$$

$$d_{iB} = E_i^{2p}, \tag{9b}$$

for a general value of p and R. At a given stage of the clustering sequence, if a d_{ij} is smallest then i and j are recombined, while if a d_{iB} is smallest then i is called an "inclusive jet".

For values of $R \leq \pi$ in eq. (9), the generalised e^+e^- k_t algorithm behaves in analogy with the pp algorithms: when an object is at an angle $\theta_{iX} > R$ from all other objects X then it forms an inclusive jet. With the choice $p = -1$ this provides a simple, infrared and collinear safe way of obtaining a cone-like algorithm for e^+e^- collisions, since hard well-separated jets have a circular profile on the 3D sphere, with opening half-angle R. To use this form of the algorithm, define

```
JetDefinition jet_def(ee_genkt_algorithm, R, p);
```

and then extract inclusive jets from the cluster sequence.

For values of $R > \pi$, FastJet replaces the factor $(1 - \cos R)$ in the denominator of eq. (9a) with $(3 + \cos R)$. With this choice (as long as $R < 3\pi$), the only time a d_{iB} will be relevant is when there is just a single particle in the event. The `inclusive_jets(...)` will then always return a single jet consisting of all the particles in the event. In such a context it is only the `exclusive_jets(...)` call that provides non-trivial information.

https://fastjet.fr/repo/fastjet-doc-3.4.0.pdf

Software for MC

- ROOT 6.24/06
- Madgraph5 : MG5_aMC_v3_4_0
- Pythia8 : pythia8306
- Fastjet 3.3.4
- GenJet :

```
MC
- Input :
    final state particles without neutrino
    # hadrons which are not in final state.
    dd.SetPtEtaPhiE( pT*1e-18, eta, phi, 0)
    # as ghost hadron
```

MC1 : Pythia8 Only ; 4,100,000 events

```
pythia.readString("PDF:lepton = off");
pythia.readString("WeakSingleBoson:ffbar2gmZ = on");
pythia.readString("23:onMode = off");
pythia.readString("23:onIfAny = 1 2 3 4 5 ");
// LEP1 initialization at Z0 mass.
pythia.readString("Beams:idA =  11");
pythia.readString("Beams:idB = -11");
double mZ = pythia.particleData.m0(23);
pythia.settings.parm("Beams:eCM", mZ);
```

MC2 : Madgraph+Pythia8 ; 4,100,000 events

```
MADGRAPH

import model sm-no_b_mass
define p = 21 2 4 1 3 -2 -4 -1 -3 5 -5 # pass to 5 flavors
define p = u c d s u~ c~ d~ s~ b b~
define j = p
generate e+ e- > z > j j
add process e+ e- > a > j j
add process e+ e- > z > j j g
add process e+ e- > a > j j g
```

```
 1 = ickkw          ! 0 no matching, 1 MLM
:
 10.0   = xqcut   ! minimum kt jet measure between partons
:
 10.0  = ptj       ! minimum pt for the jets
 0.0  = ptb       ! minimum pt for the b
:
```

PLB 384 (1996)

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ELSEVIER

19 September 1996

PHYSICS LETTERS B

Physics Letters B 384 (1996) 353–364

Quark and gluon jet properties in symmetric three-jet events

ALEPH Collaboration

Abstract

Quark and gluon jets with the same energy, 24 GeV, are compared in symmetric three-jet configurations from hadronic Z decays observed by the ALEPH detector. Jets are defined using the Durham algorithm. Gluon jets are identified using an anti-tag on b jets, based on a track impact parameter method. The comparison of gluon and mixed flavour quark jets shows that gluon jets have a softer fragmentation function, a larger angular width and a higher particle multiplicity. Evidence is presented which shows that the corresponding differences between gluon and b jets are significantly smaller. In a statistically limited comparison the multiplicity in c jets was found to be comparable with that observed for the jets of mixed quark flavour.

https://www.sciencedirect.com/science/article/abs/pii/0370269396008490

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

[redacted]

CERN-PPE-94-170

CERN–PPE/94–170
1 November 1994

CERN-PPE-94-170

Performance of the ALEPH detector at LEP

The ALEPH Collaboration*

Abstract

The performance of the ALEPH detector at the LEP e^+e^- collider is reviewed. The accuracy of the tracking detectors to measure the impact parameter and momentum of charged tracks is specified. Calorimeters are used to measure photons and neutral hadrons, and the accuracy obtained in energy and angle is given. An essential property of the detector is its ability to identify particles; the performance in identification of electrons, muons, neutrinos (from missing energy), charged hadrons, π^0's and V^0's is described.

https://cds.cern.ch/record/272484/files/ppe-94-170.pdf

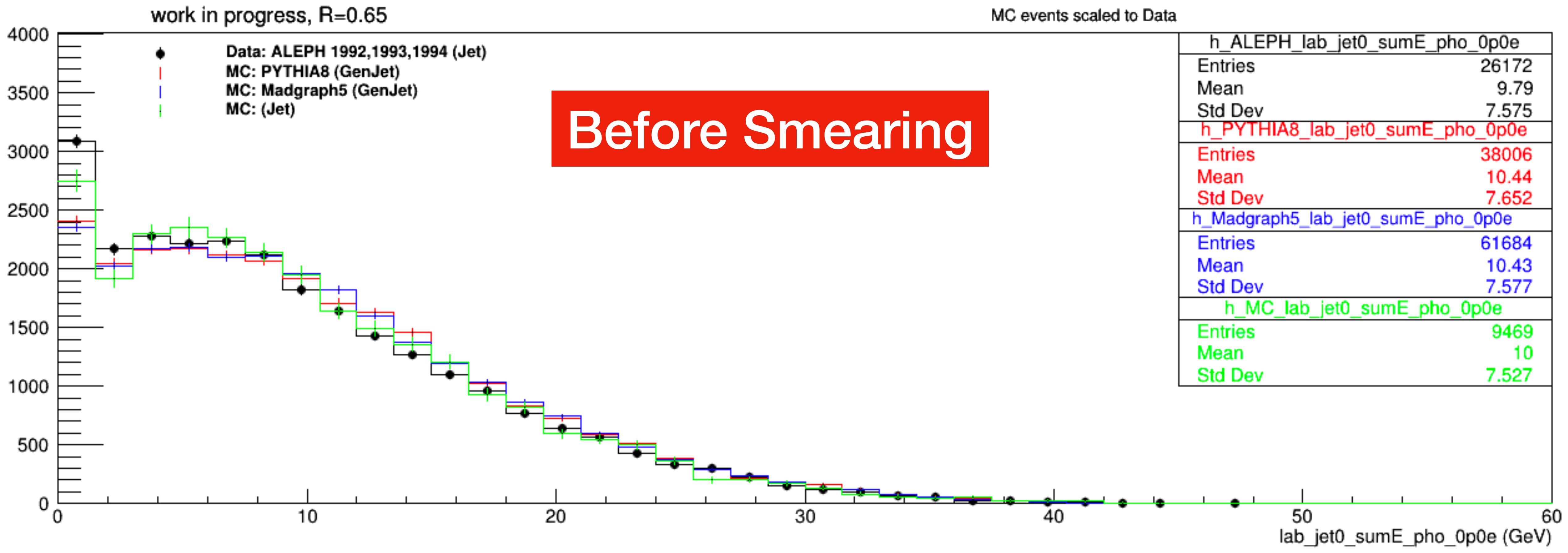
Photon smearing

Energy resolution

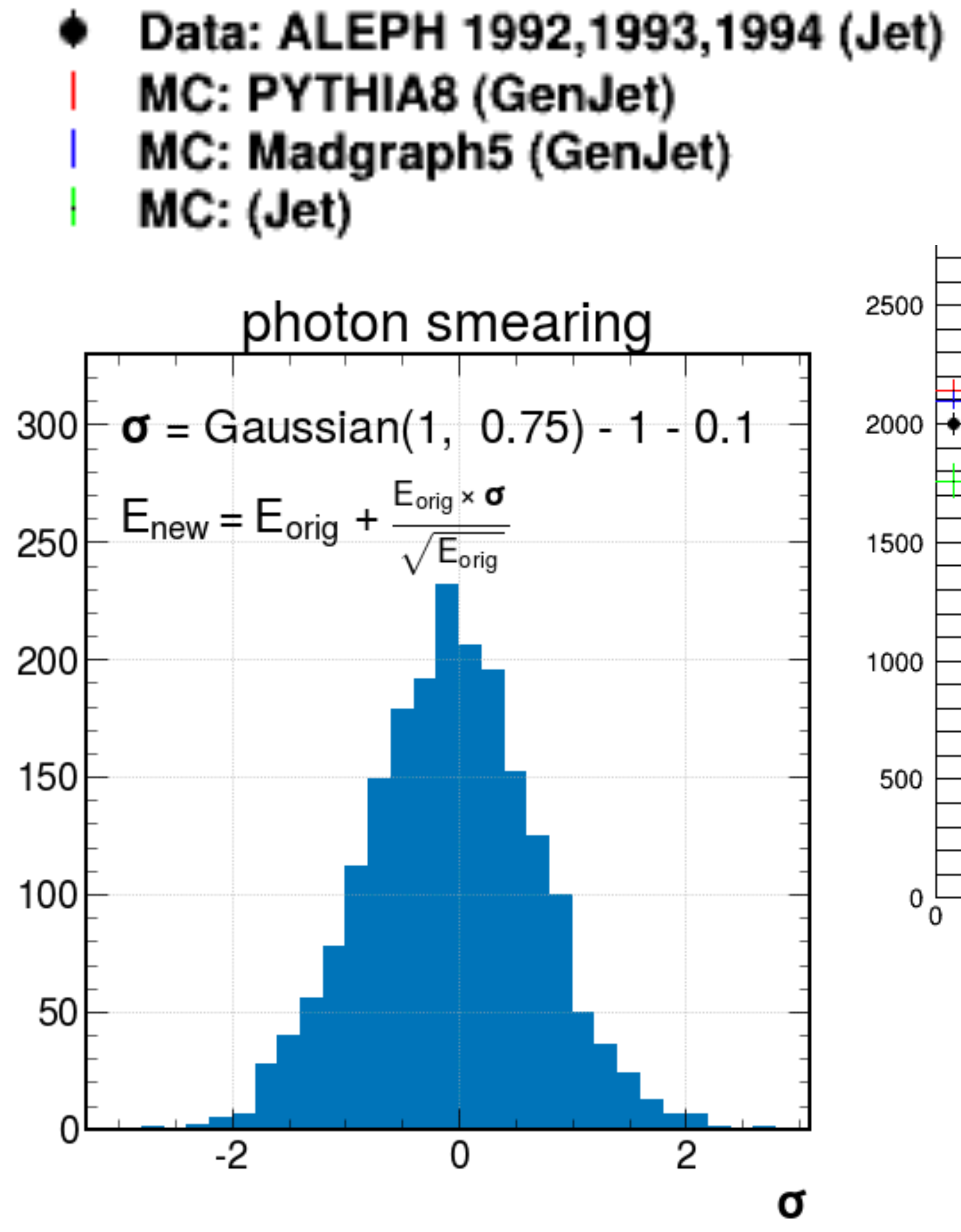
The angular resolution for an isolated cluster is the same as that described in Section 5.1. The use of only a part of the storeys to measure the energy degrades the energy resolution to $\sigma(E)/E = 0.25/\sqrt{E/\mathrm{GeV}}$ instead of the $0.18/\sqrt{E/\mathrm{GeV}}$ of Section 5.1. The efficiency and background depend strongly on the density of particle impacts on the calorimeter.

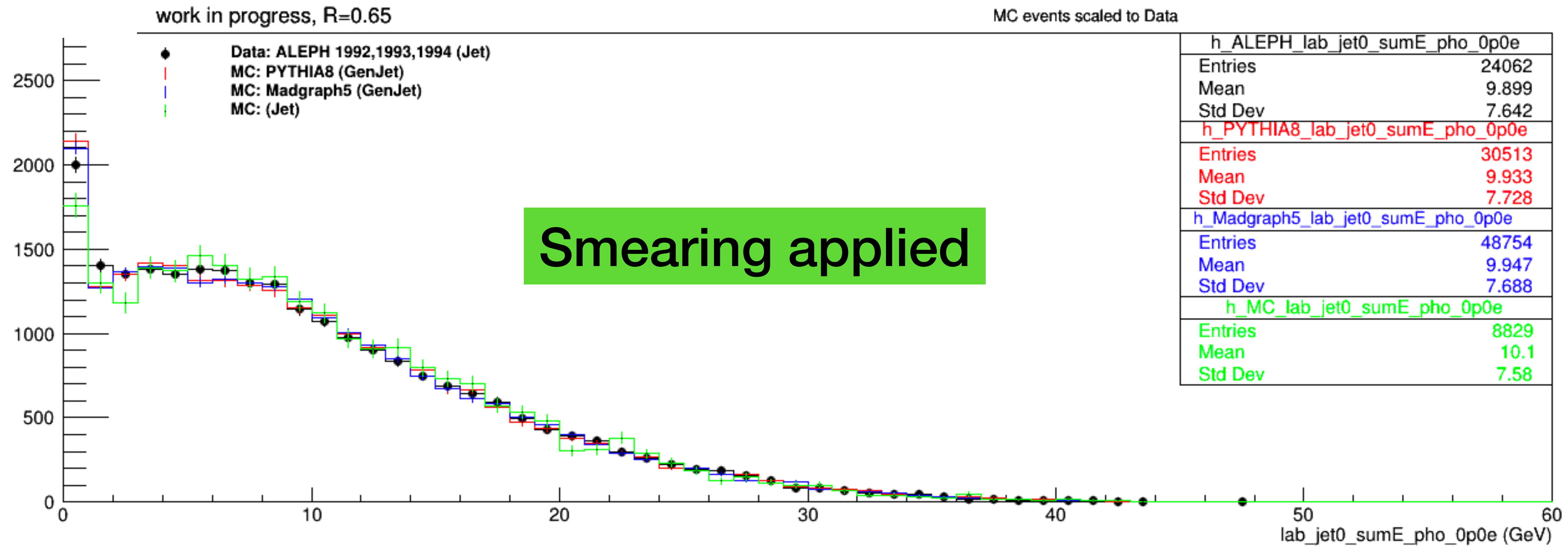
CERN-PPE-94-170

Photon resolution : $\sigma(E)/E = 0.25/\sqrt{(E/\mathrm{GeV})}$



X axis : photon energy sum of First leading jet (GeV)





pwflag description : CHARGED_TRACK(0), CHARGED_LEPTONS1(1), CHARGED_LEPTONS2(2), V0(3), PHOTON(4), NEUTRAL_HADRON(5)

Neutral Hadron smearing

Energy resolution

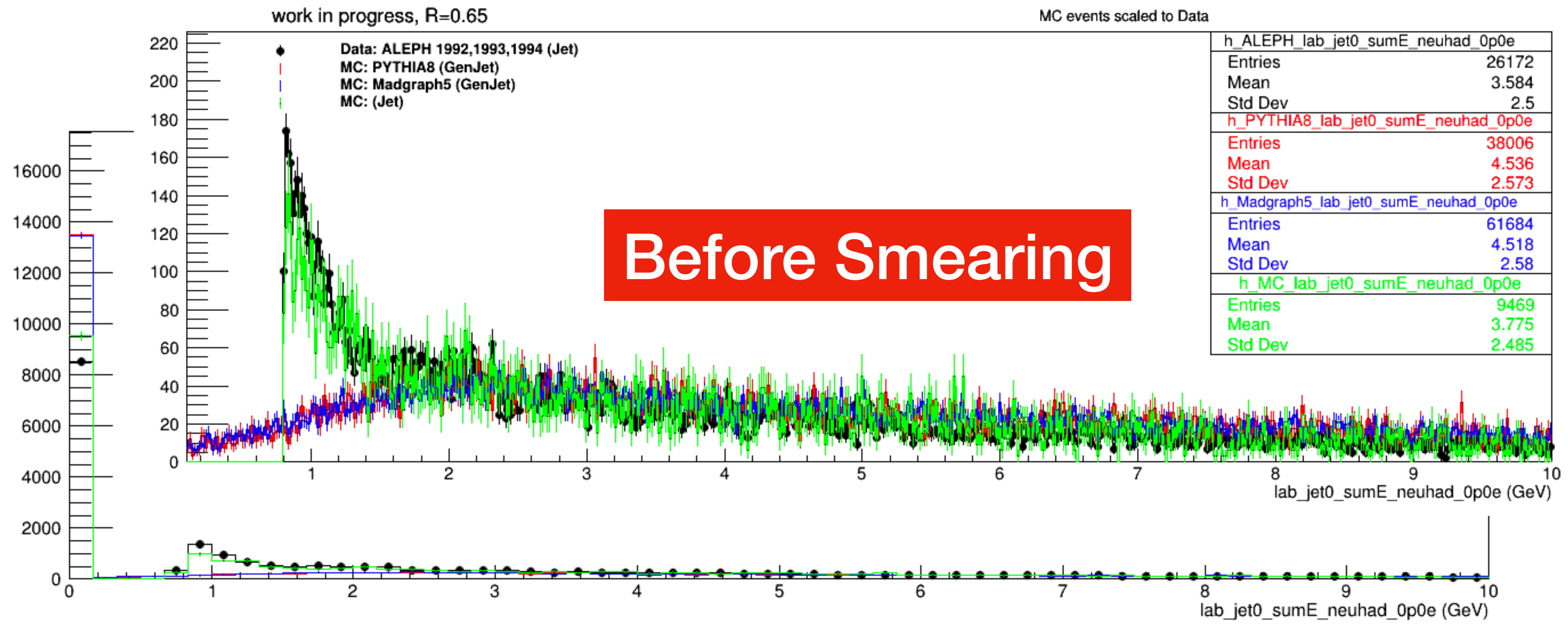
CERN-PPE-94-170

dependence of the calorimeter calibration is followed by a gas monitoring system [8] which measures variations in the calibration with a precision of about 0.4 %; variations of up to 10 % due to pressure and temperature changes have been observed over a year.

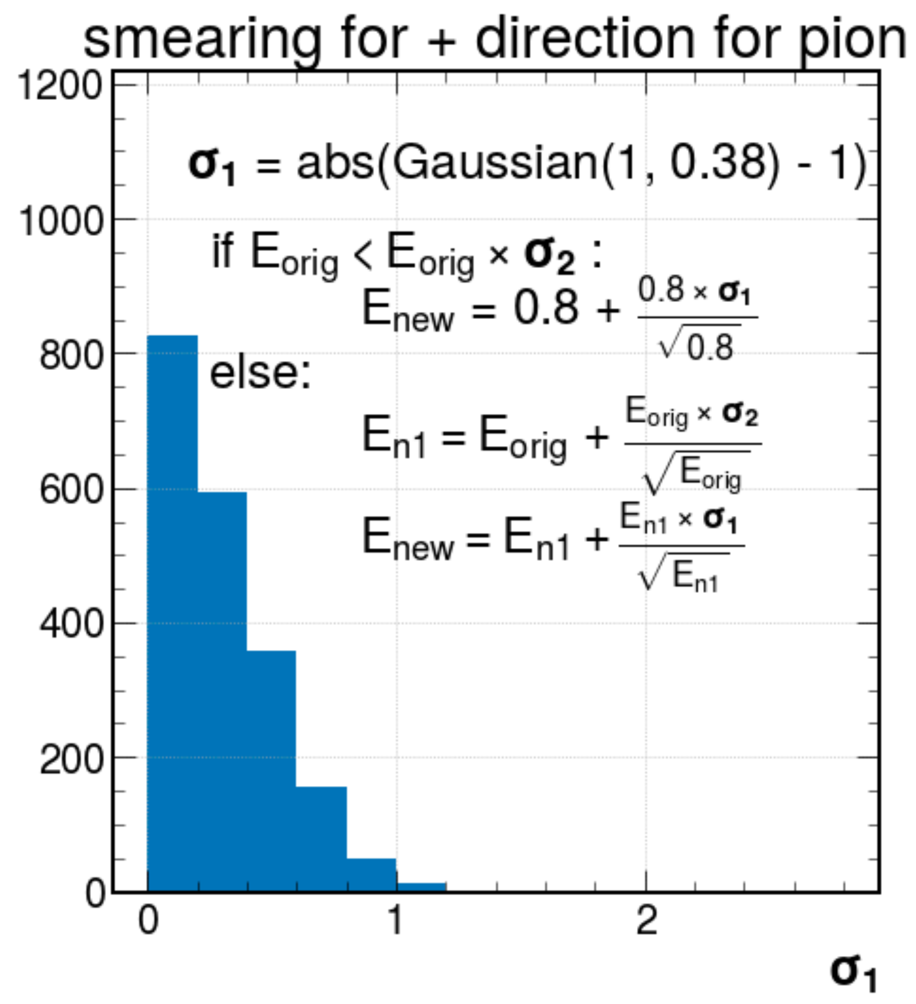
single-prong tau decays, as shown in Figure 13 for two momentum intervals. The energy resolution of the hadron calorimeter for pions at normal incidence is

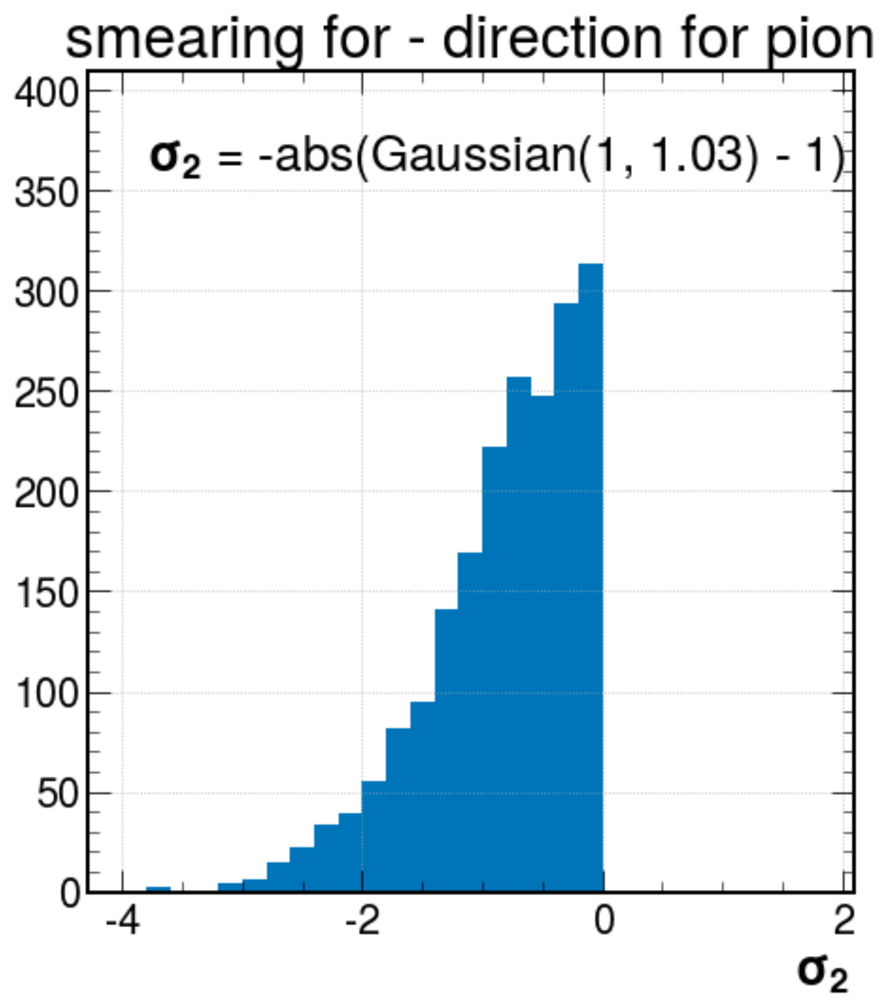
$$\frac{\sigma(E)}{E} = \frac{0.85}{\sqrt{E/\mathrm{GeV}}}. \qquad (6)$$

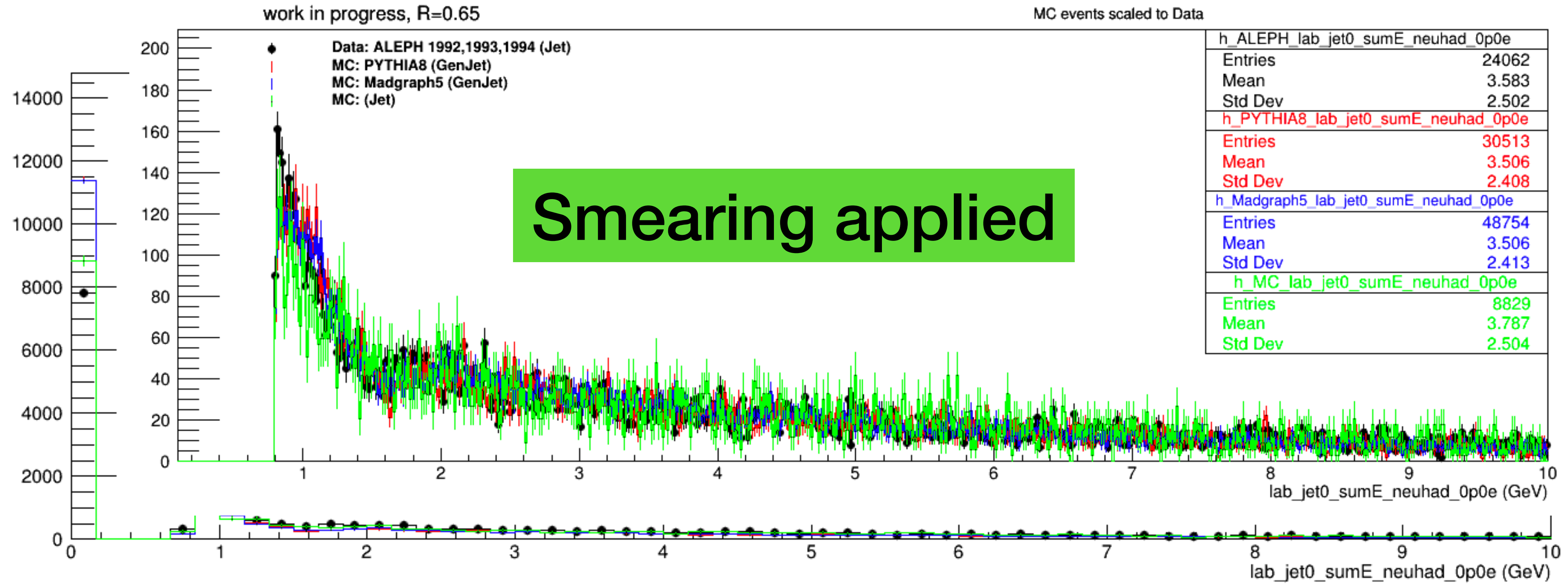
hadron resolution : $\sigma(E)/E = 0.85/\sqrt{(E/GeV)}$



X axis : Neutral energy sum of First leading jet (GeV)







pwflag description : CHARGED_TRACK(0), CHARGED_LEPTONS1(1), CHARGED_LEPTONS2(2), V0(3), PHOTON(4), NEUTRAL_HADRON(5)

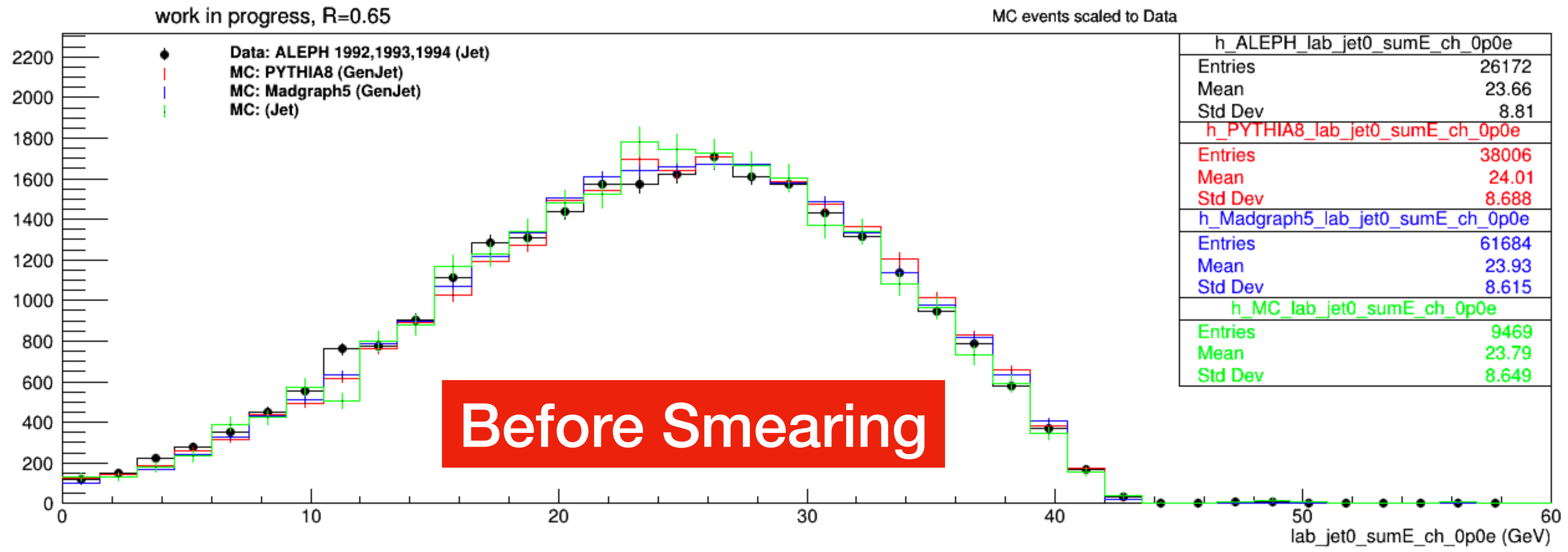
Charged particles smearing

TPC smearing

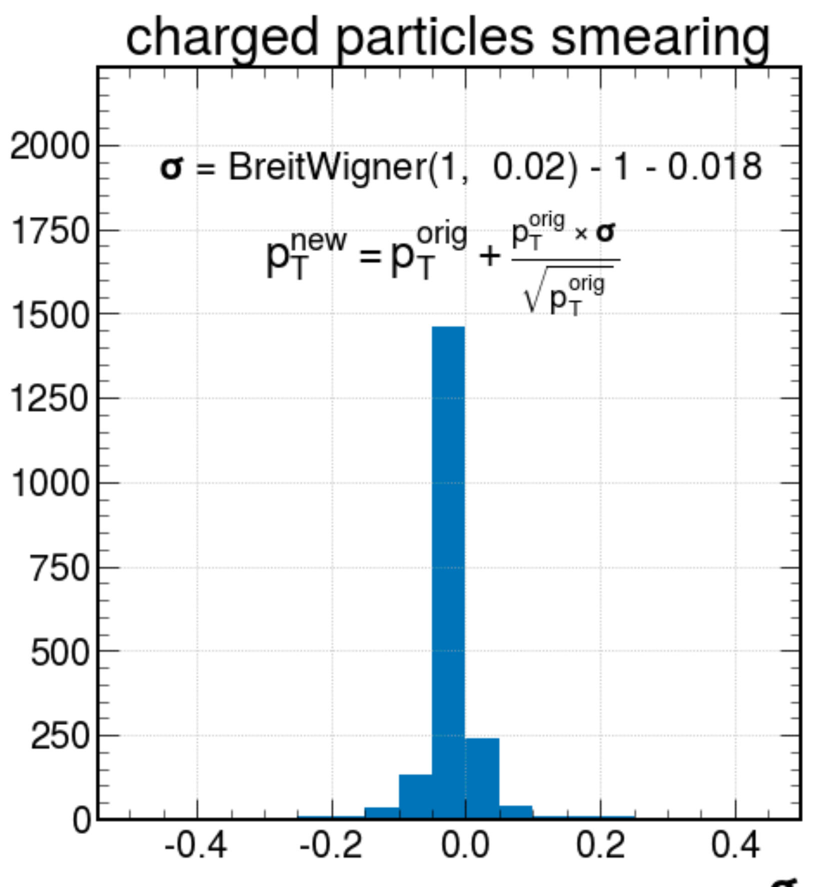
CERN-PPE-94-170

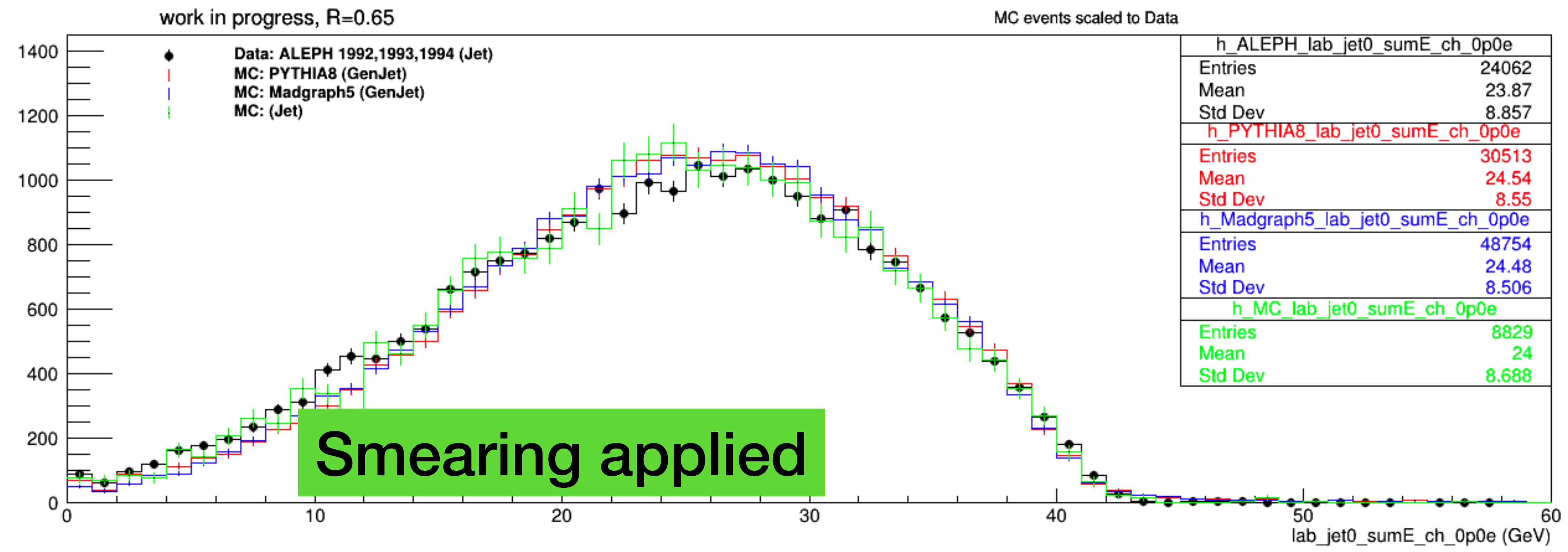
Table 1: Momentum and impact parameter resolution; the successive rows show the effect of including the detectors indicated in the fit.

	Transverse momentum	Impact parameter	
Detector	$\sigma(1/p_T)$ $(\mathrm{GeV}/c)^{-1}$	$r\phi$ (μm)	rz (μm)
TPC	1.2×10^{-3}	310	808
+ drift chamber	0.8×10^{-3}	107	808
+ vertex detector	0.6×10^{-3}	23	28



X axis : charged energy sum of First leading jet (GeV)





MC particle smearing

pwflag description : CHARGED_TRACK(0), CHARGED_LEPTONS1(1), CHARGED_LEPTONS2(2), V0(3), PHOTON(4), NEUTRAL_HADRON(5)

- ~~the photon and hadron(pion) resolution are applied for photon and neutral hadron in MC samples.~~
- Generate random number by Gaussian shape with resolution parameters, and applied to the photon/neutral hadron/charged energy for the smearing.

```
rnd = ROOT.TRandom3(seed)
for j in range(2000):
     photon_res.append(  rnd.Gaus(1, 0.25*3)-1.0-0.1 )
     pion_res.append(  -abs(rnd.Gaus(1, 1.03)-1) )
     pion_res2.append(  abs(rnd.Gaus(1, 0.38)-1.0) )
     tpc_res.append(  rnd.BreitWigner(1, 0.005*4.)-1.018 )
```

```
#photon
dd.SetE( orig_e + orig_e*photon_res[photon_idx]/sqrt(orig_e) )
#charged
dd.SetPtEtaPhiM( jj.pT()+jj.pT()*tpc_res[tpc_idx] ,  jj.eta(),jj.phi(),jj.m() )
#neutral-hadron
if orig_e<abs((orig_e)*pion_res[pion_idx]):
    dd.SetE( 0.8+0.8*pion_res2[pion_idx]/sqrt(0.8) )
else:
    new_e = orig_e + (orig_e)*pion_res[pion_idx] + 0.8
    dd.SetE( new_e + new_e*pion_res2[pion_idx]/sqrt(new_e) )
```

DATA vs MC

Previous study review

- Quark and gluon jet properties in symmetric three-jet events

PLB 384 (1996)

The standard ALEPH hadronic event selection [10] was applied to the 1992, 1993, and 1994 data ($\approx$ 3 million events). The $k_\perp$ (Durham) clustering algorithm [11], with the E recombination scheme and a jet resolution parameter of $y_{cut} = 0.01$ was applied to all charged and neutral particles (energy flow objects [9]) to select three-jet events. Jets were required to have a polar angle greater than 40° with respect to the beam axis.

The jets were projected onto the event plane which was defined according to the quadratic momentum tensor. One-fold symmetric configurations were selected by requiring that the angles in the event plane between the highest energy jet and each of the two lower energy jets were in the range 150° ± 7.5°. This kinematic configuration implied that the mean energy of each of the two lower energy jets was 24.7 GeV for quark jets and 24.0 GeV for gluon jets. These criteria were satisfied by 22640 events.

Difference

- ee_genkt_algorithm
- Delta R : 0.65

ALEPH 95-011

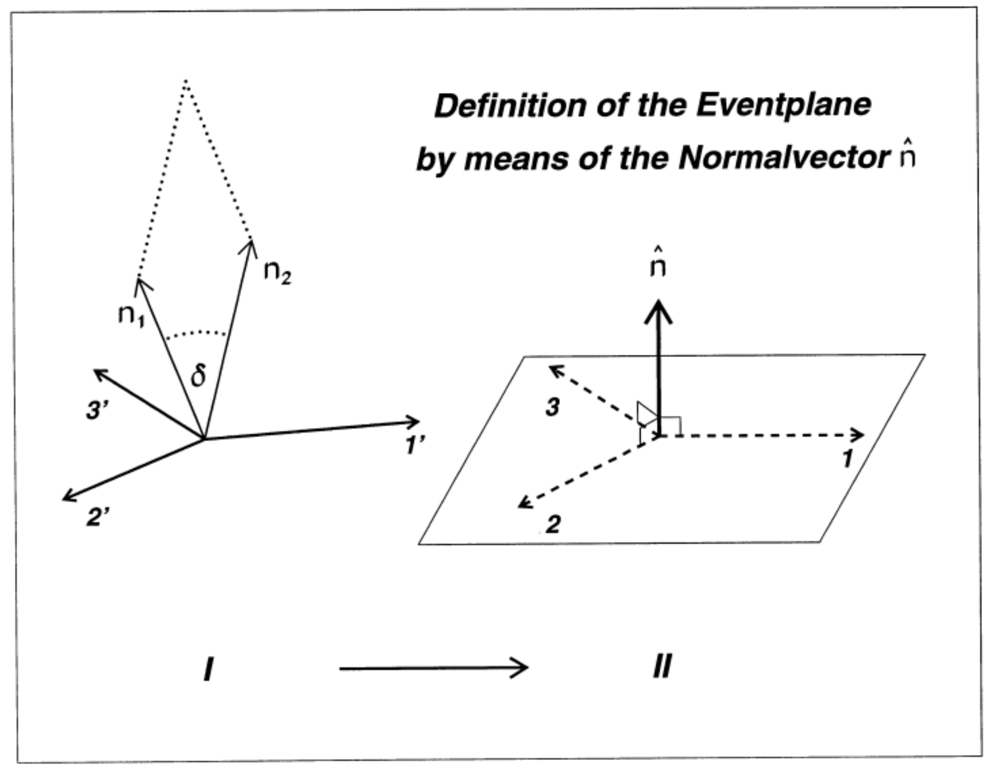


Figure 1: Definition of the event plane by the unit vector $\hat{n}$.

$$n_1 := p'_1 \times p'_3 \quad \text{and} \quad n_2 := p'_3 \times p'_2$$

$$\hat{n} := \frac{n_1 + n_2}{|n_1 + n_2|}$$

```
def getEventPlane(p1,p2,p3):
    n1 = p1.Vect().Cross(p3.Vect())
    n2 = p3.Vect().Cross(p2.Vect())
    n = (n1+n2).Unit()

    p1_ep = p1.Vect() - p1.Vect().Dot(n)*n
    p2_ep = p2.Vect() - p2.Vect().Dot(n)*n
    p3_ep = p3.Vect() - p3.Vect().Dot(n)*n

    ang_12 = p1_ep.Angle(p2_ep)
    ang_13 = p1_ep.Angle(p3_ep)
    ang_23 = p2_ep.Angle(p3_ep)
```

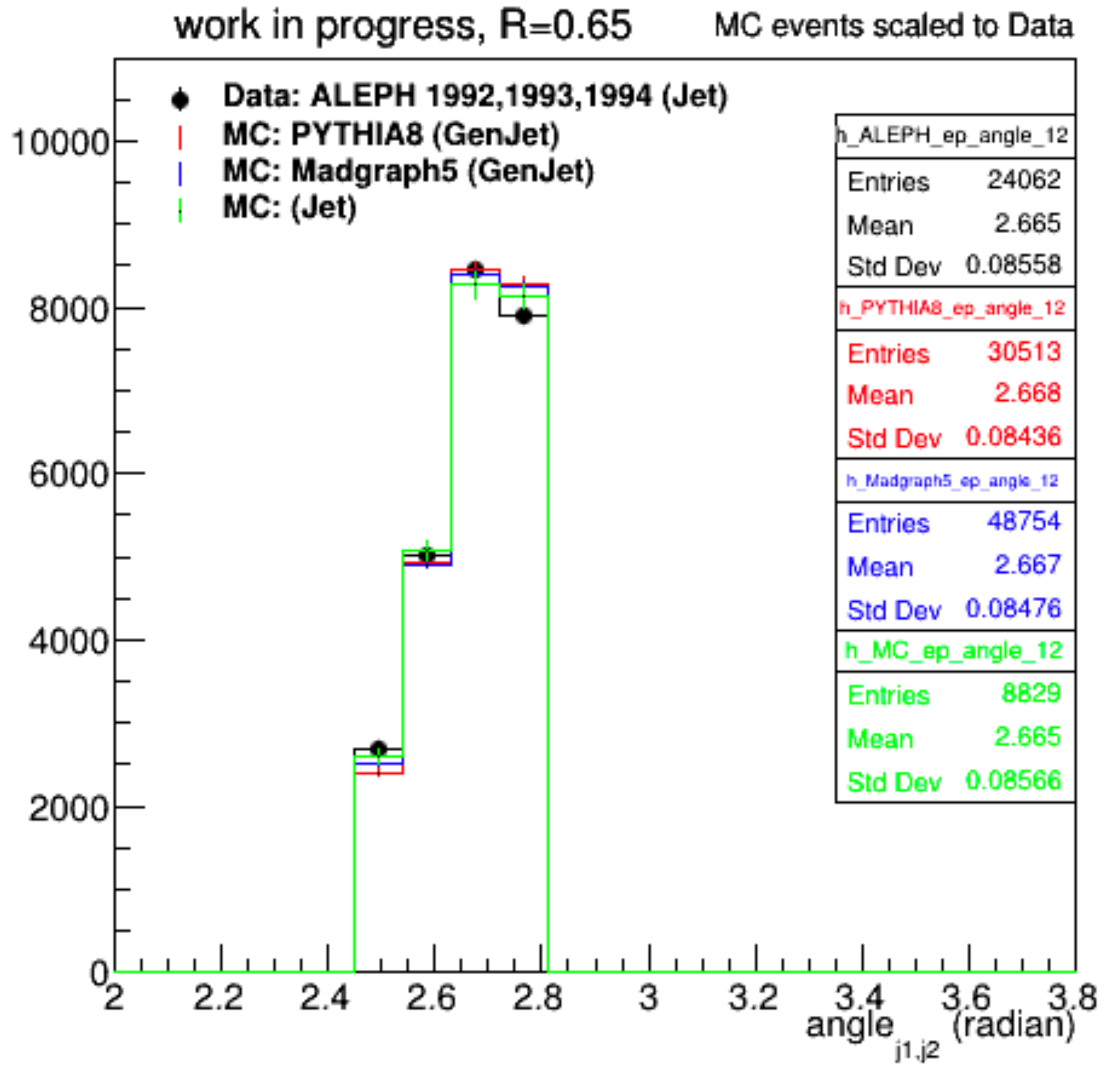
Event selection

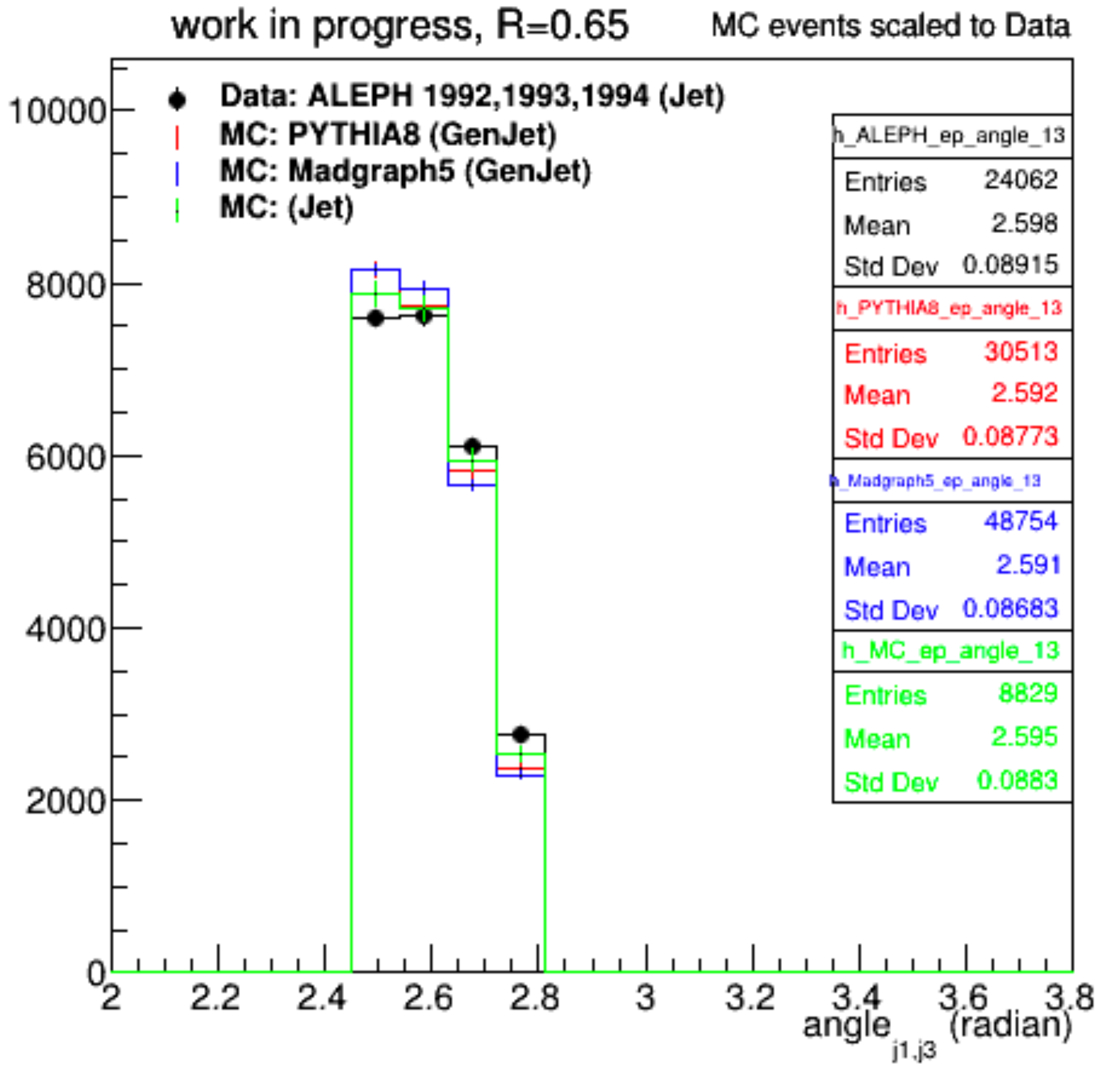
PLB 384 (1996)

The jets were projected onto the event plane which was defined according to the quadratic momentum tensor. One-fold symmetric configurations were selected by requiring that the angles in the event plane between the highest energy jet and each of the two lower energy jets were in the range 150° ± 7.5°. This kinematic configuration implied that the mean energy of each of the two lower energy jets was 24.7 GeV for quark jets and 24.0 GeV for gluon jets. These criteria were satisfied by 22640 events.

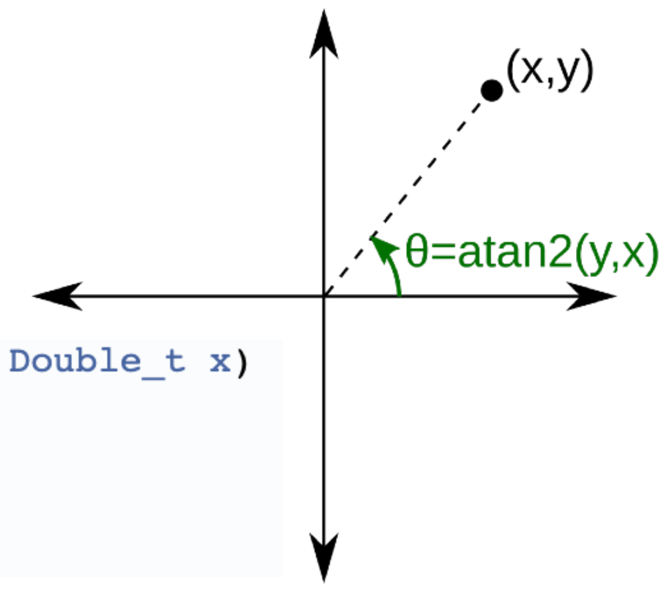
```
from math  import pi
cen=150
eee=2
drmax= (cen+7.5+eee)/180*pi  # 157.5/180 = 0.875
drmin= (cen-7.5-eee)/180*pi  # (150-7.5)/180
#drmin,drmax

df=df[ df['ep_angle_12']>drmin]
df=df[ df['ep_angle_12']<drmax]
df=df[ df['ep_angle_13']>drmin]
df=df[ df['ep_angle_13']<drmax]
df= df[ df['lab_jet2_e']>14 ]
```

- Number of particles > 10, 3rd jet Energy > 14 GeV
- Exactly, 3 jets requirements (4th jet Energy < 4 GeV)
- Angle range (**141.5 ~ 159.5**) between Jet1, jet2/jet3 in the event plane





```
inline Double_t TMath::ATan2(Double_t y, Double_t x)
   { if (x != 0) return  atan2(y, x);
     if (y == 0) return  0;
     if (y >  0) return  Pi()/2;
     else        return -Pi()/2;
   }
```




```
Theta =
TMath::ATan2(TMath::Sqrt(fX*fX + fY*fY),fZ);
```

- **Data: ALEPH 1992,1993,1994 (Jet)**
- **MC: PYTHIA8 (GenJet)**
- **MC: Madgraph5 (GenJet)**
- **MC: (Jet)**

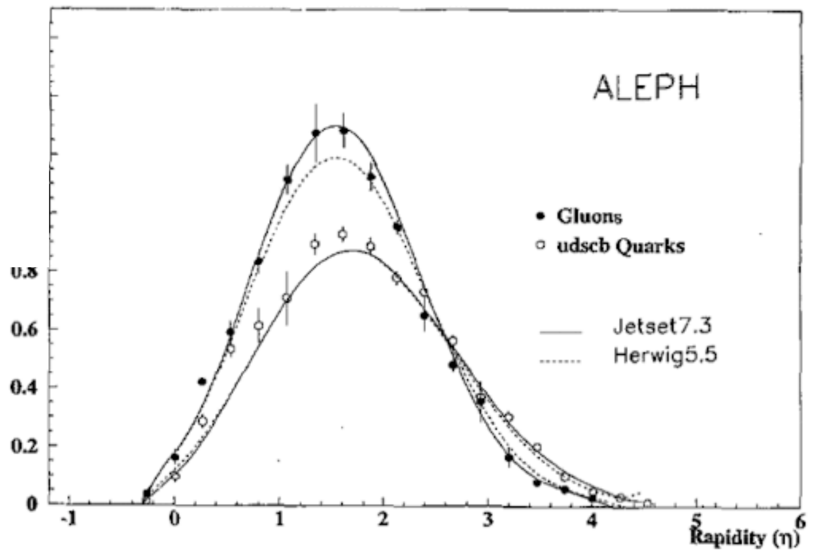


Fig. 3. Rapidity distributions for natural flavour mix quark and gluon jets.

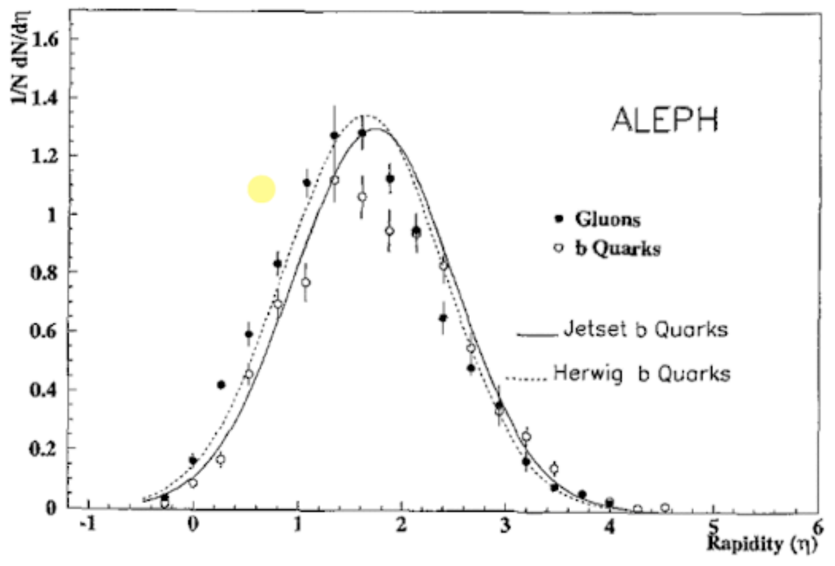
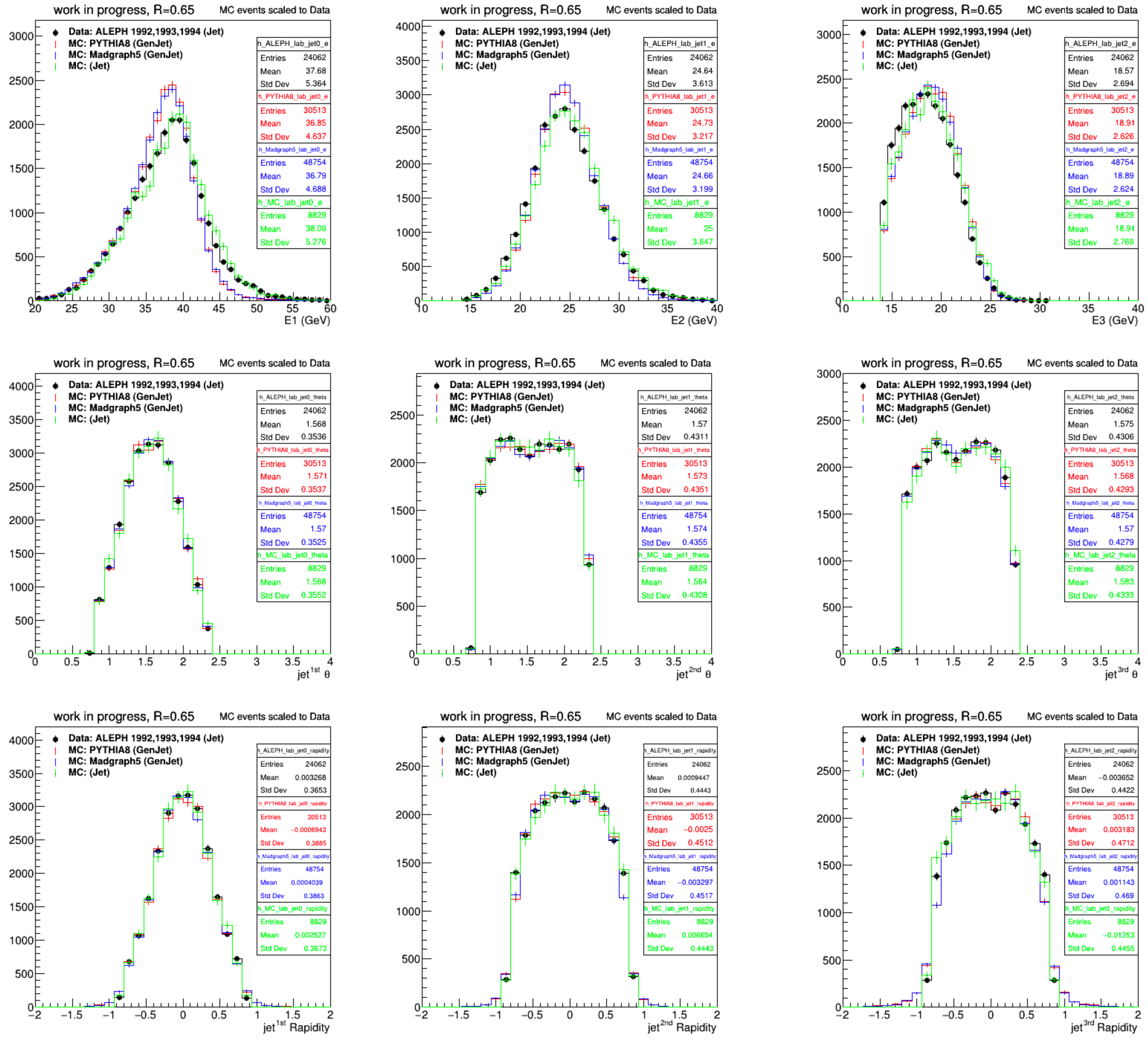


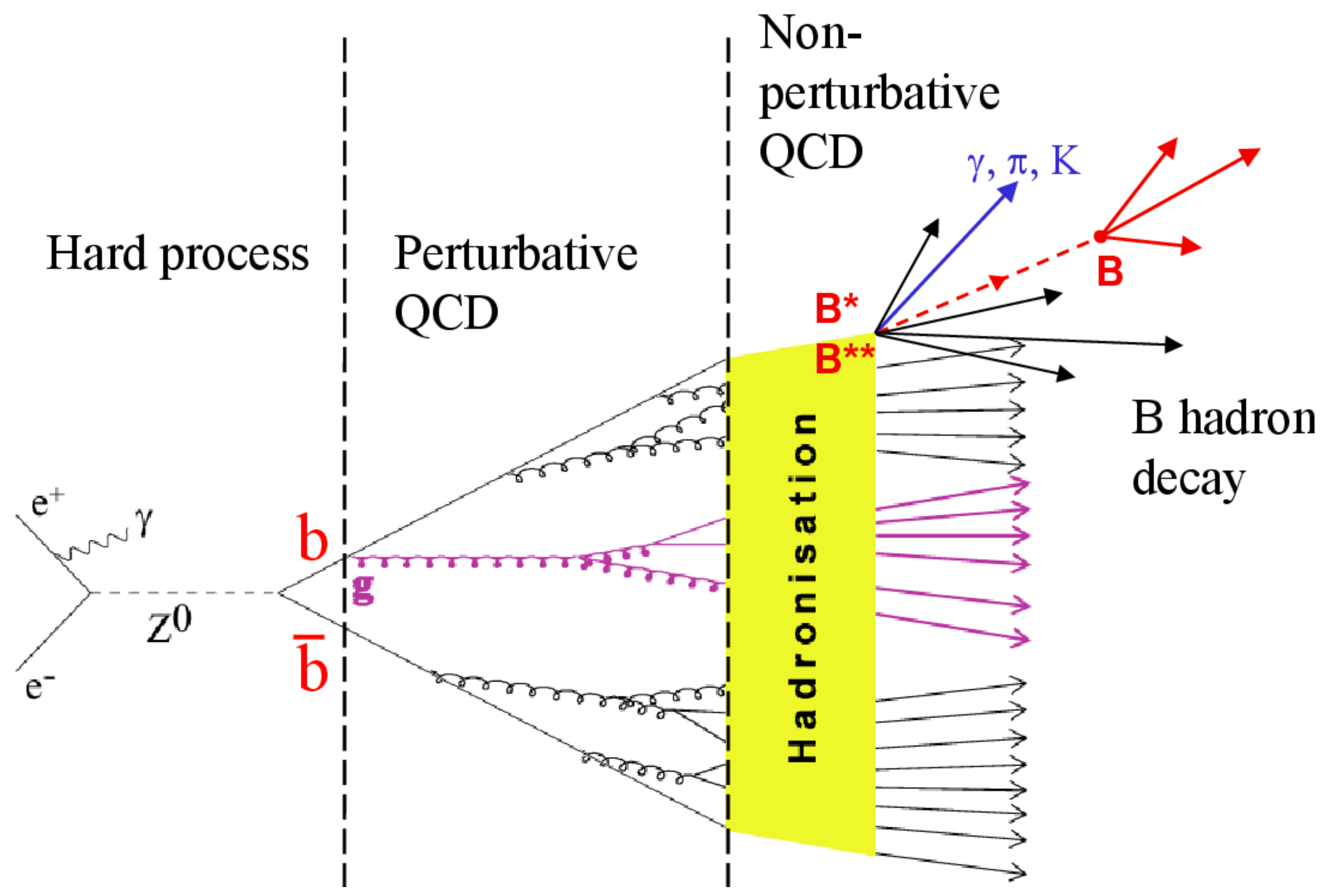
Fig. 4. Rapidity distributions for b quark and gluon jets.

```
Rapidity =
 0.5*log( (E()+Pz()) / (E()-Pz()) );
```



Signal definition for b b-bar g

- B quark matching with jet has ambiguity.
- (I guess) Only b quark in hard process is not good to matching with the jet.
- Gluon also can be always set intermediate between quarks or gluon.
- So I will use the jet high hadron flavor which is used for hadron constituents (as ghost within pt(or energy) set almost 0).
- high gluon energy matching with jet in delta R < 0.65

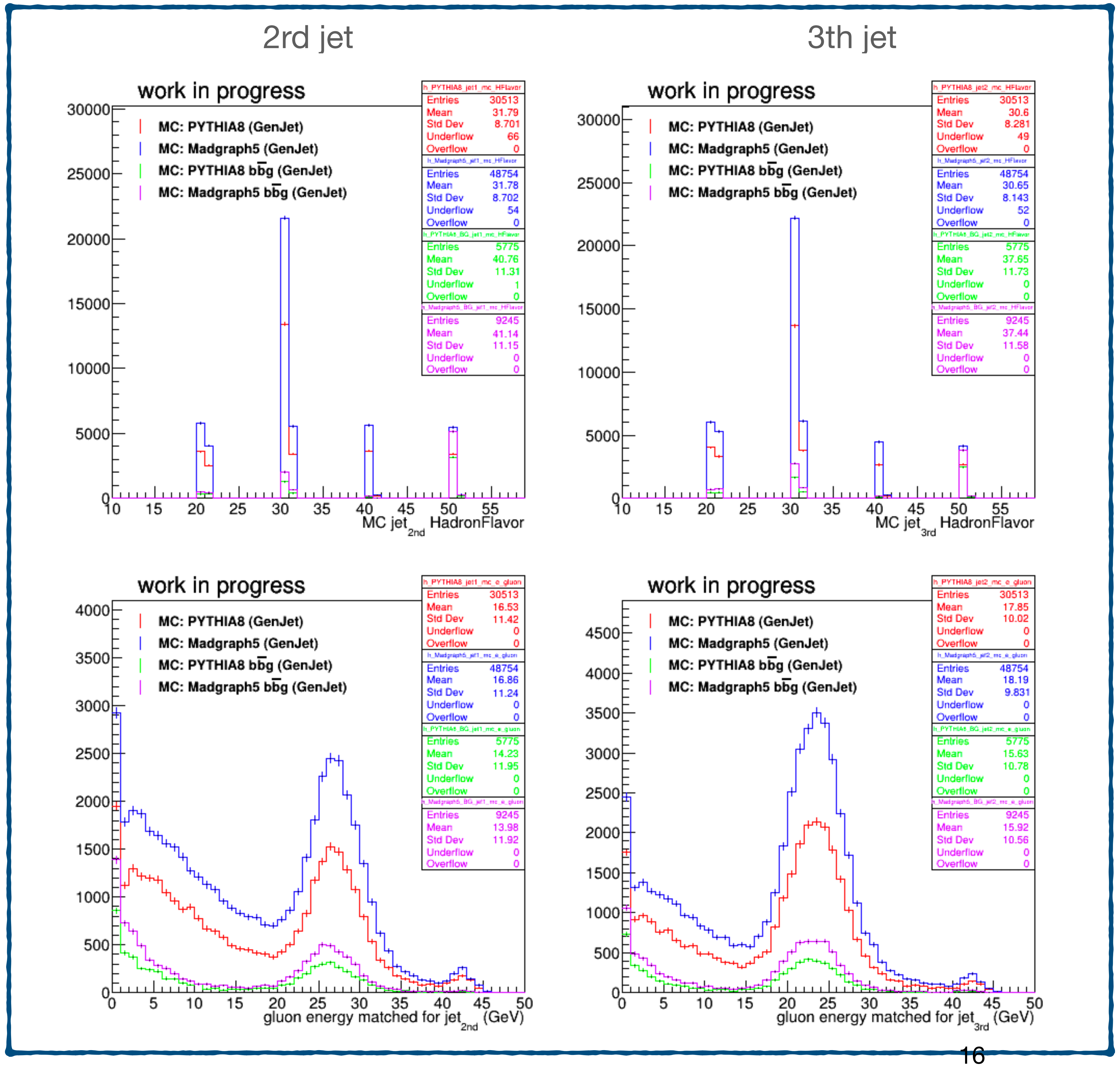


Ben-Haim, E.. "The b Quark Fragmentation Function, From LEP to TeVatron." (2004).

B B-bar + gluon definition
- Quark and gluon Purity check

Name	pdgId
d	1
u	2
s	3
c	4
b	5
t	6

Ghost Meson/Baryon High Flavor In jet



Matched Gluon Energy In jet

2nd jet with b hadron (HadFlavor > 45)
and
3rd jet with gluon energy > 14 GeV

or

3rd jet with b hadron (HadFlavor > 45)
and
2nd jet with gluon energy > 14 GeV

Previous study review

- Quark and gluon jet properties in symmetric three-jet events

PLB 384 (1996)

4.2.2. The B sample: Lepton tag

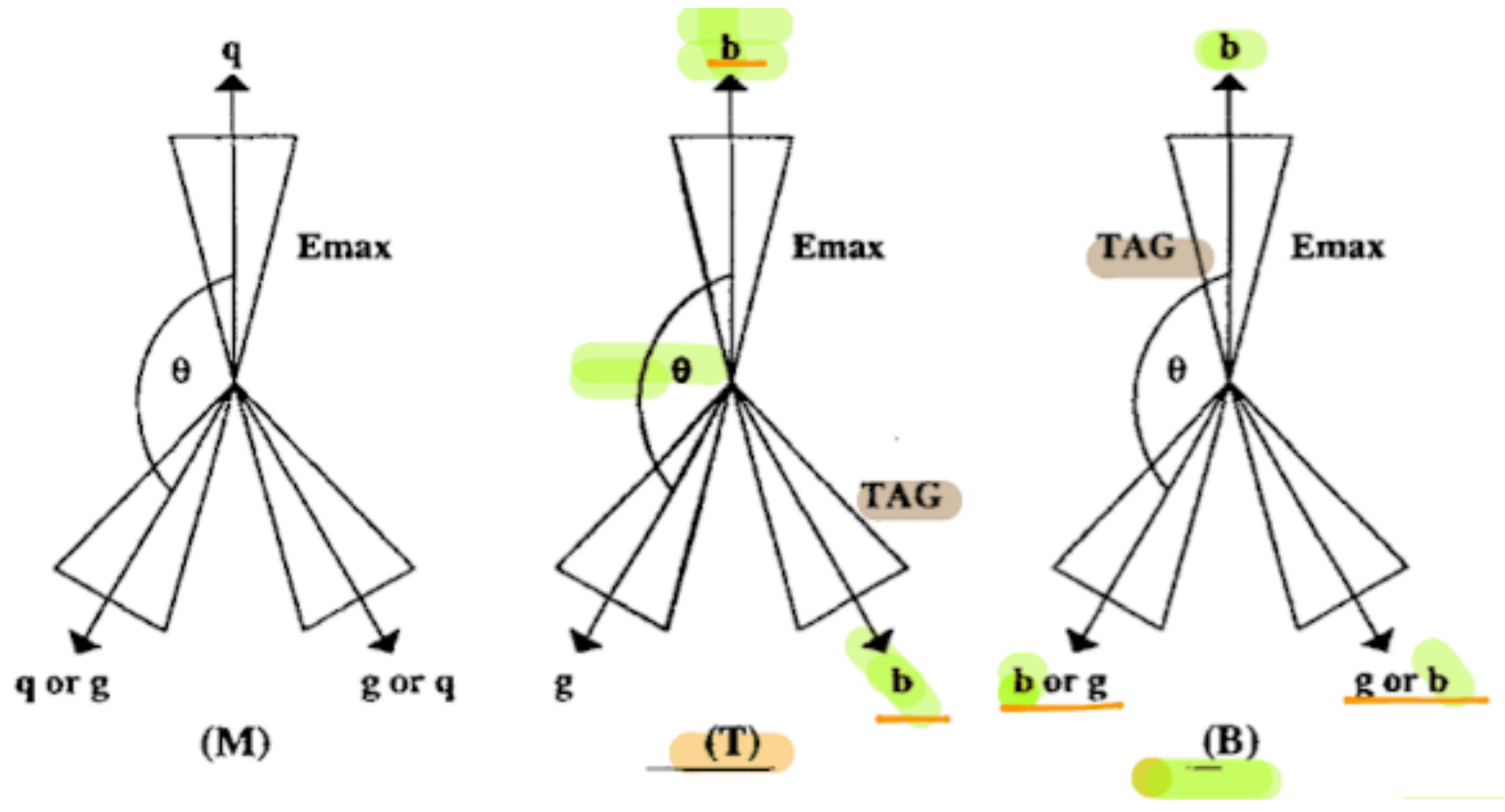
The presence of a high transverse momentum ($P_\perp$) lepton has been widely used in the tagging of heavy flavour events and a standard lepton selection definition [15] exists within the ALEPH collaboration. Electrons and positrons were selected using the dE/dx capabilities of the TPC and estimators based on the shape of the energy depositions in the ECAL. Muons were selected according to digital hit information recorded by the HCAL and the muon chambers. The minimum momentum of any selected lepton was 3 GeV/c. In turn, the momentum of each selected lepton was removed from its jet and its $P_\perp$ was calculated with respect to the resulting jet axis. This is known as the exclusive transverse momentum ($P_\perp^{excl}$) of the lepton.

The *B* sample was selected by requiring the presence of a lepton with $P_\perp^{excl} > 1.25$ GeV/c in the highest energy jet. According to Jetset the flavour composition of this sample was: 88.9 ± 1.2% b, 6.1 ± 1.1% c and 5% uds. The errors on these coefficients are mainly systematic. They arise primarily from the uncertainties in the Monte Carlo simulation of the b and c fragmentation, lepton decay spectra and are estimated as in [16].

Using this tagging technique another gluon-tagged sample, T_l, was obtained by finding a high $P_\perp$ lepton in one of the two lower energy jets. Its gluon purity was ≈ 82%. In contrast to the impact parameter

- B tagging
  - Lepton tag as a constituent of the jet
    - Momentum of lepton > 3 GeV/c
  - Exclusive transverse momentum of the lepton
    - > 1.25 GeV/c

- Categories (jjj, 123 order)
  - M : qqq or qqg or qgq
  - **T : bgbT, bbTg**
  - B : bTbg, bTgb, bTbTg, bTgbT



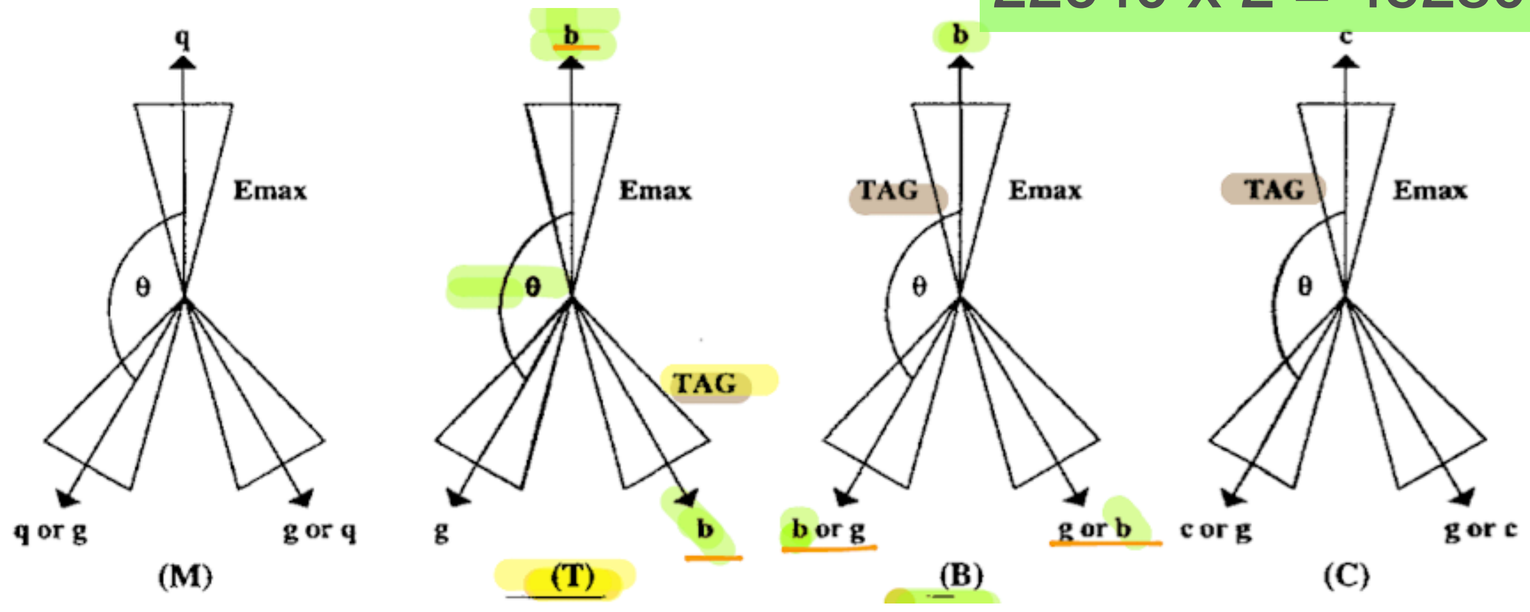
b-tagging

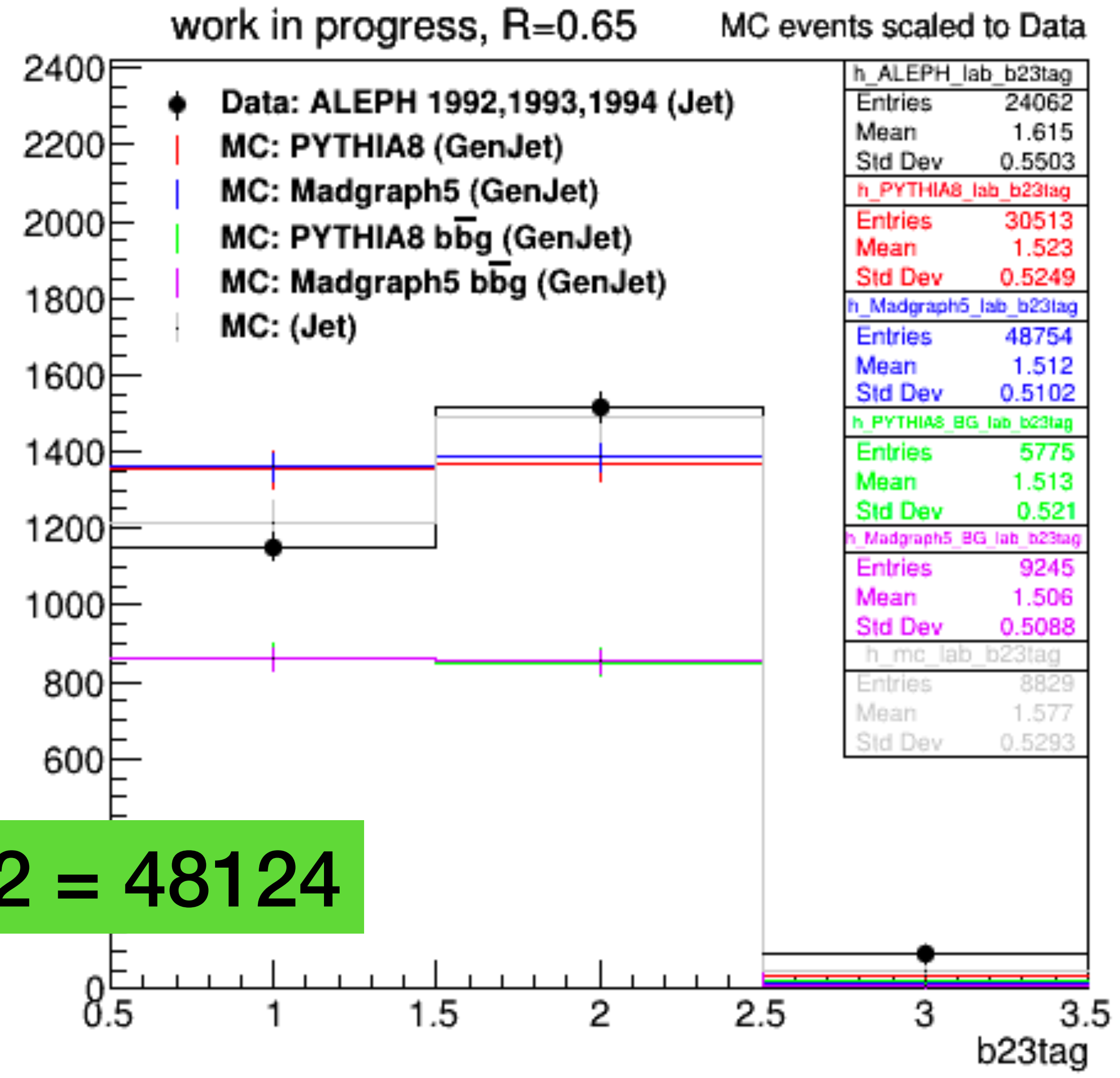
- B23tag : b-tagged for second and third jets
  - 0 : untagged all(second, third)
  - 1 : second jet b-tagged
  - 2 : third jet b-tagged
  - 3 : both(second and third) jets b-tagged

PLB 384 (1996)

The jets were projected onto the event plane which was defined according to the quadratic momentum tensor. One-fold symmetric configurations were selected by requiring that the angles in the event plane between the highest energy jet and each of the two lower energy jets were in the range 150° ± 7.5°. This kinematic configuration implied that the mean energy of each of the two lower energy jets was 24.7 GeV for quark jets and 24.0 GeV for gluon jets. These criteria were satisfied by 22640 events.

22640 x 2 = 45280

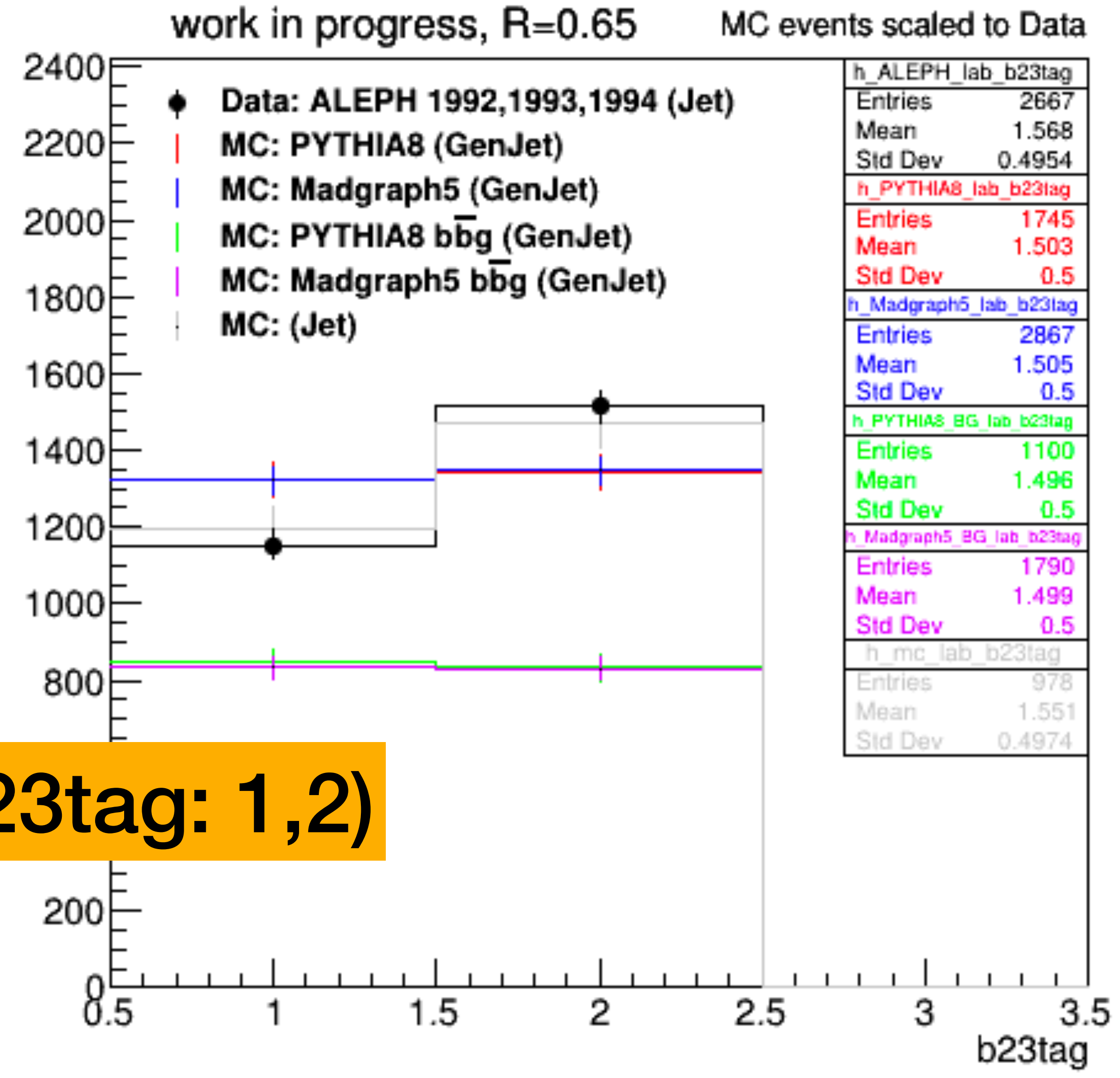




ALEPH M : 24062 x 2 = 48124

Table 1
Summary of the four jet samples used.

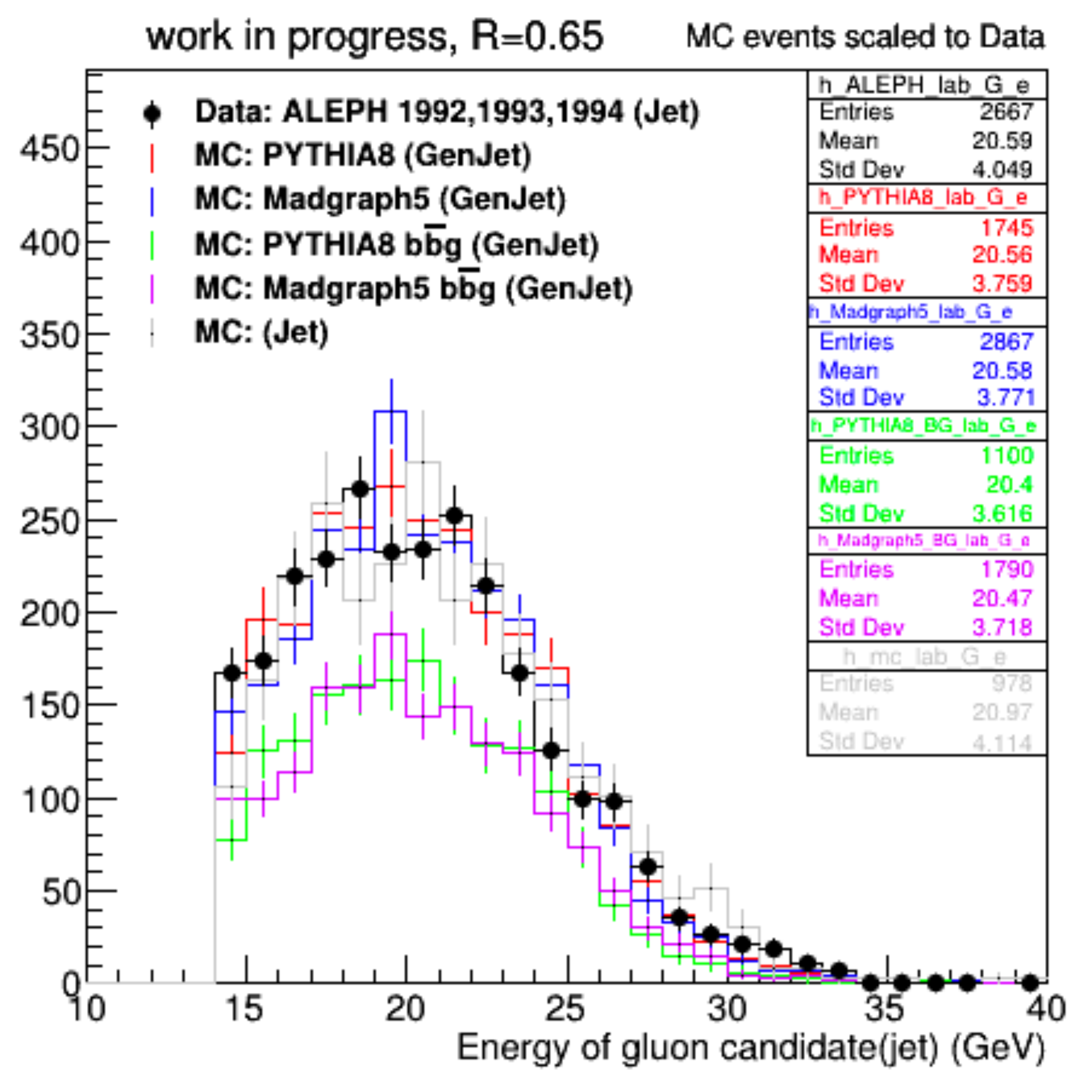
Sample	Number of jets	uds	c	b	g
M (J2 and J3)	45280	31.4	8.8	11.3	48.5
T (J2 or J3)	2071	6.1	1.7	2.2	90.0
B (J2 and J3)	872	2.5	3.0	44.5	50.0
C (J2 and J3)	40	0	35	15	50

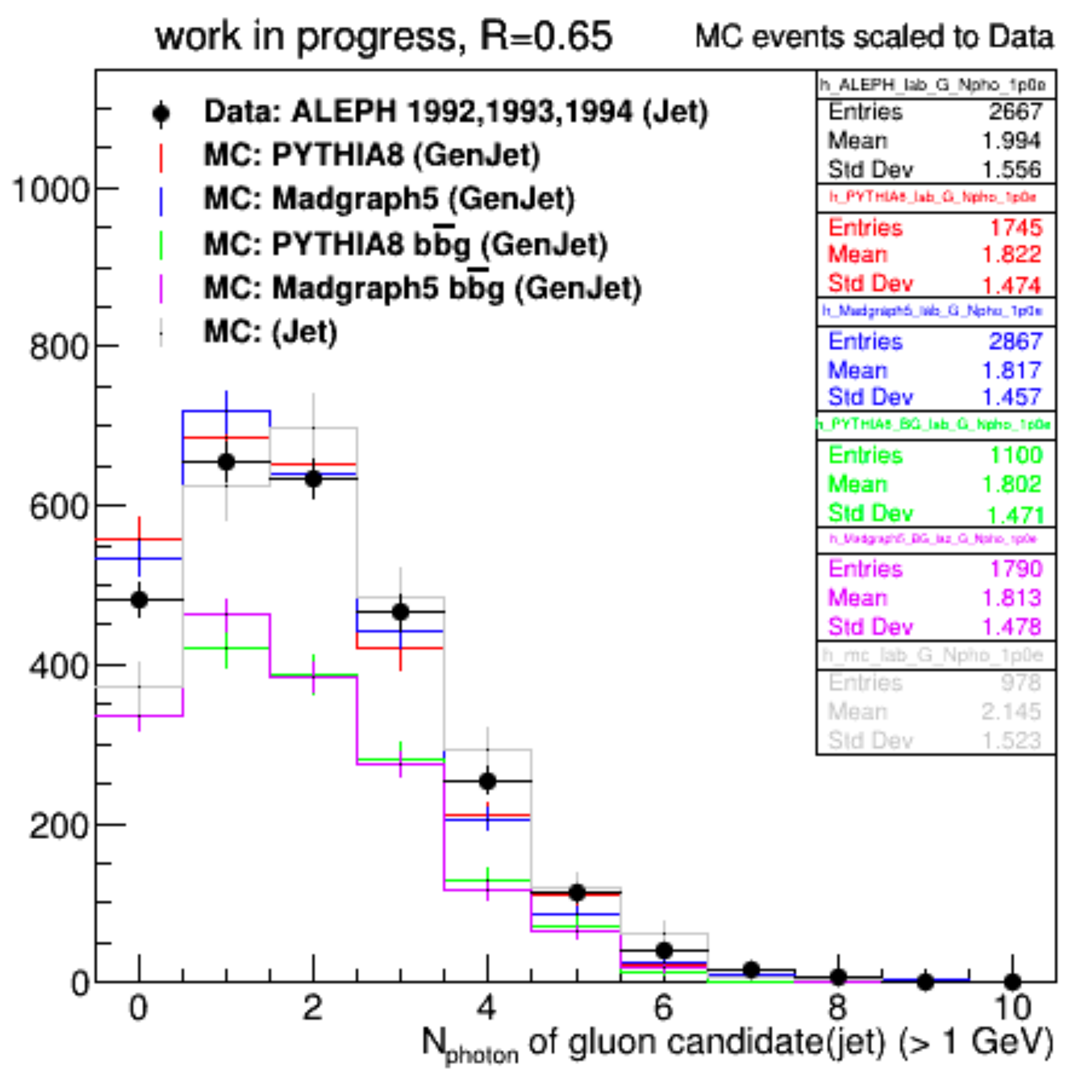


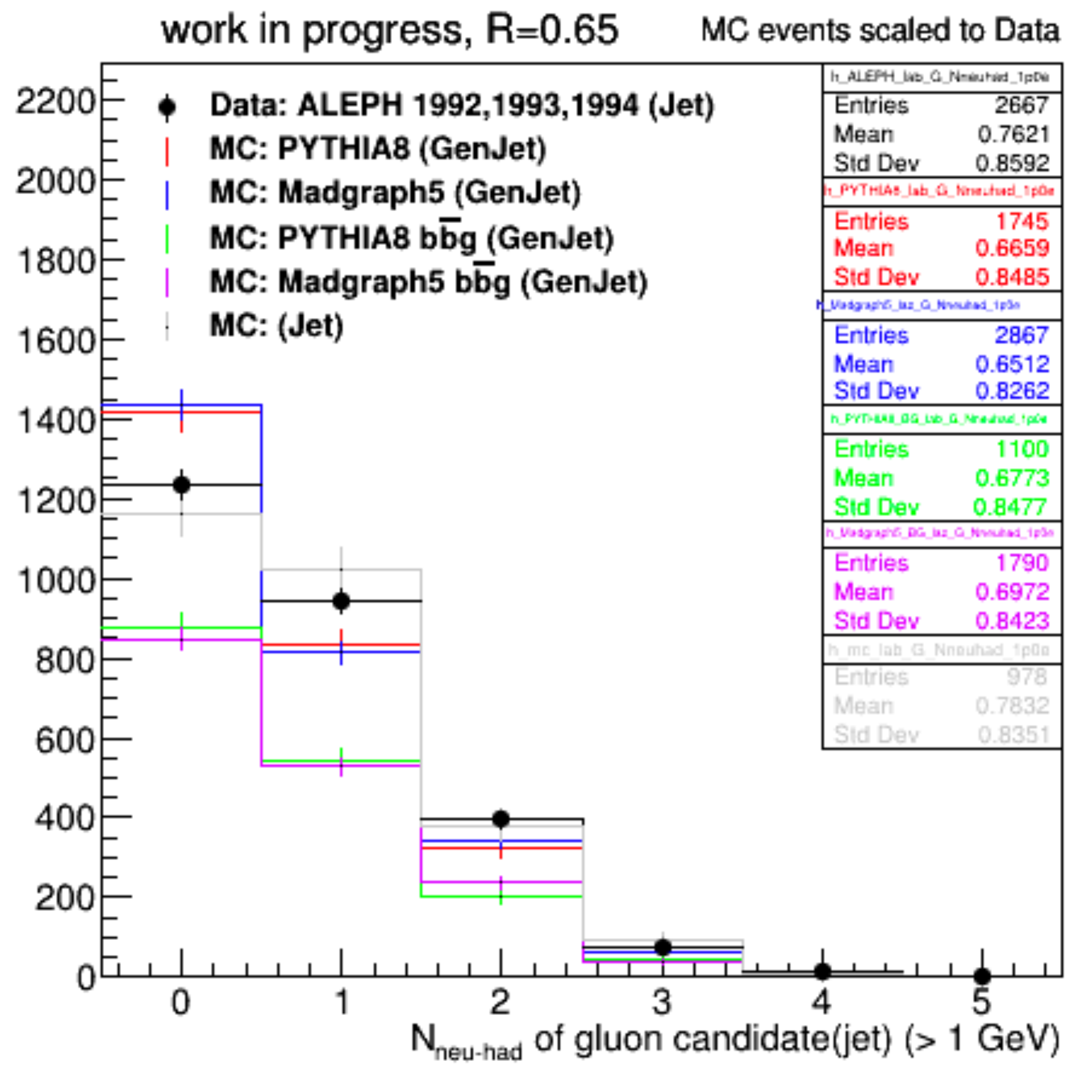
ALEPH T : 2667 (only b23tag: 1,2)

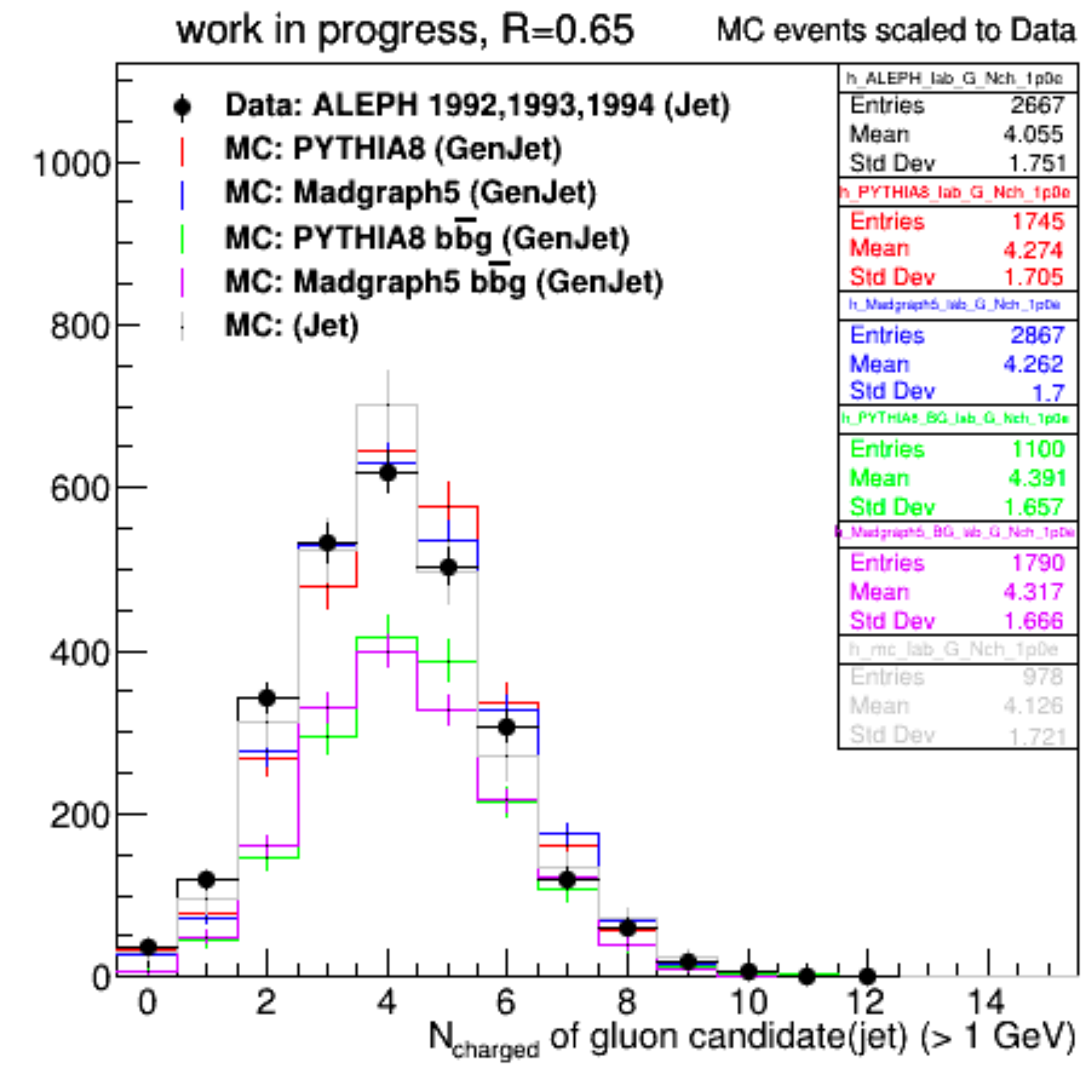
ALEPH T : 2667 (only b23tag: 1,2)

Gluon

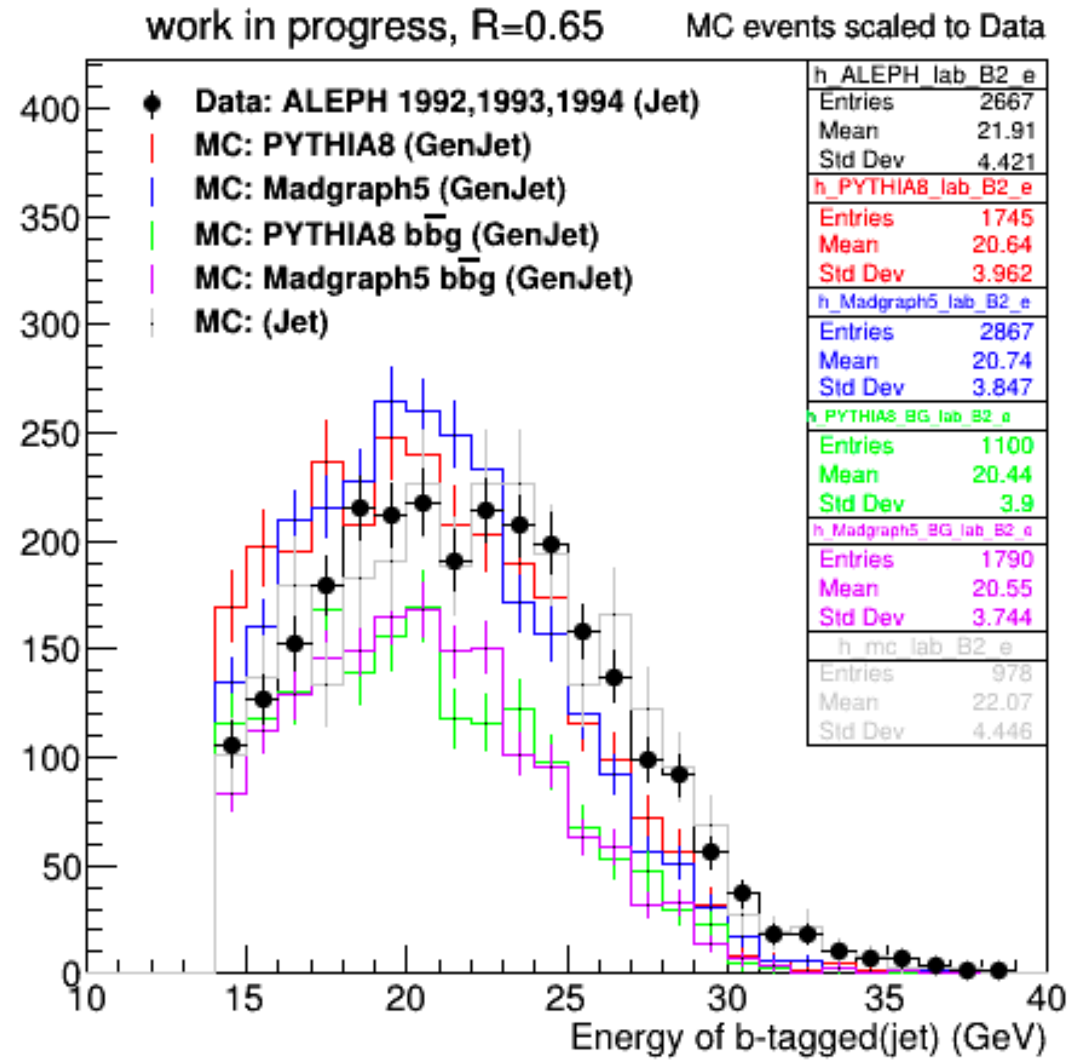


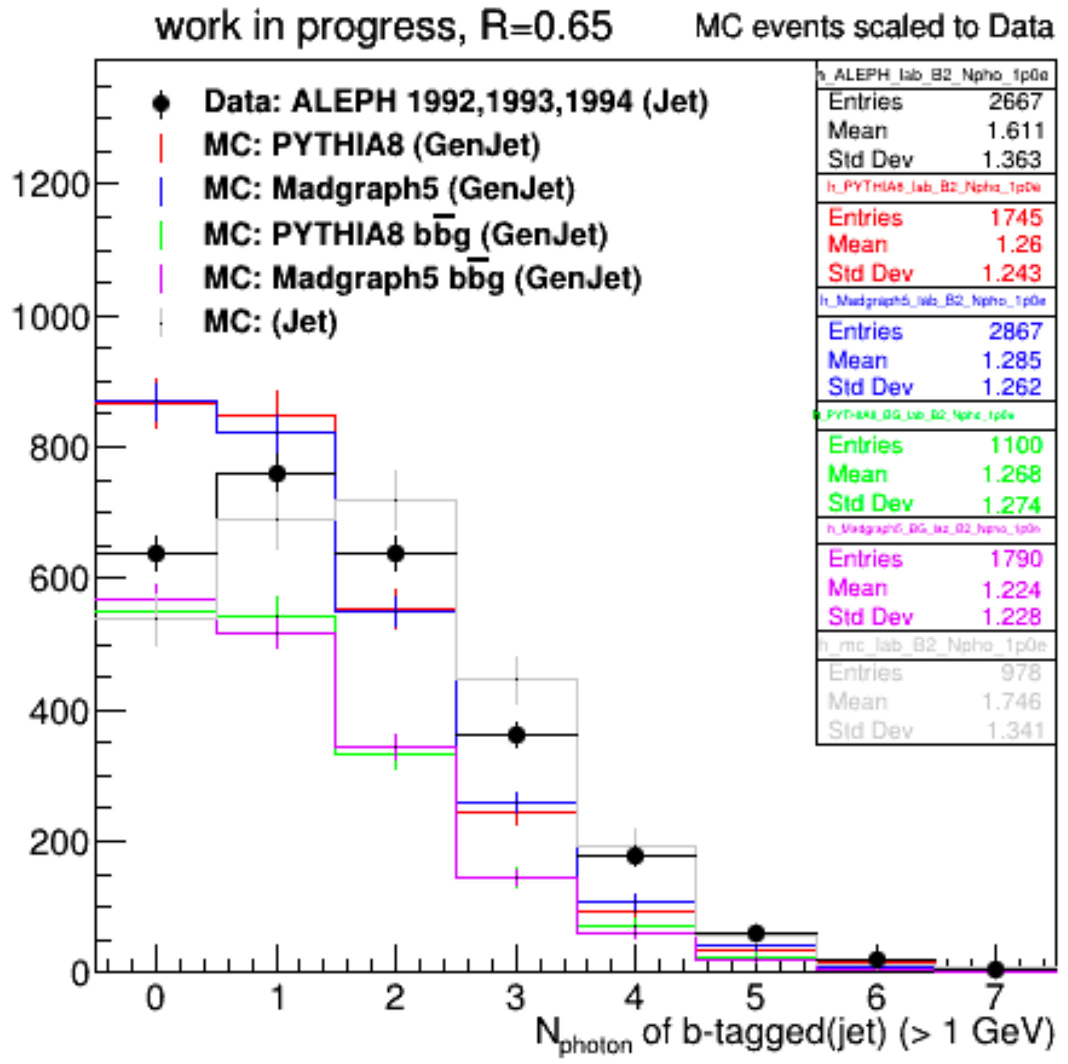


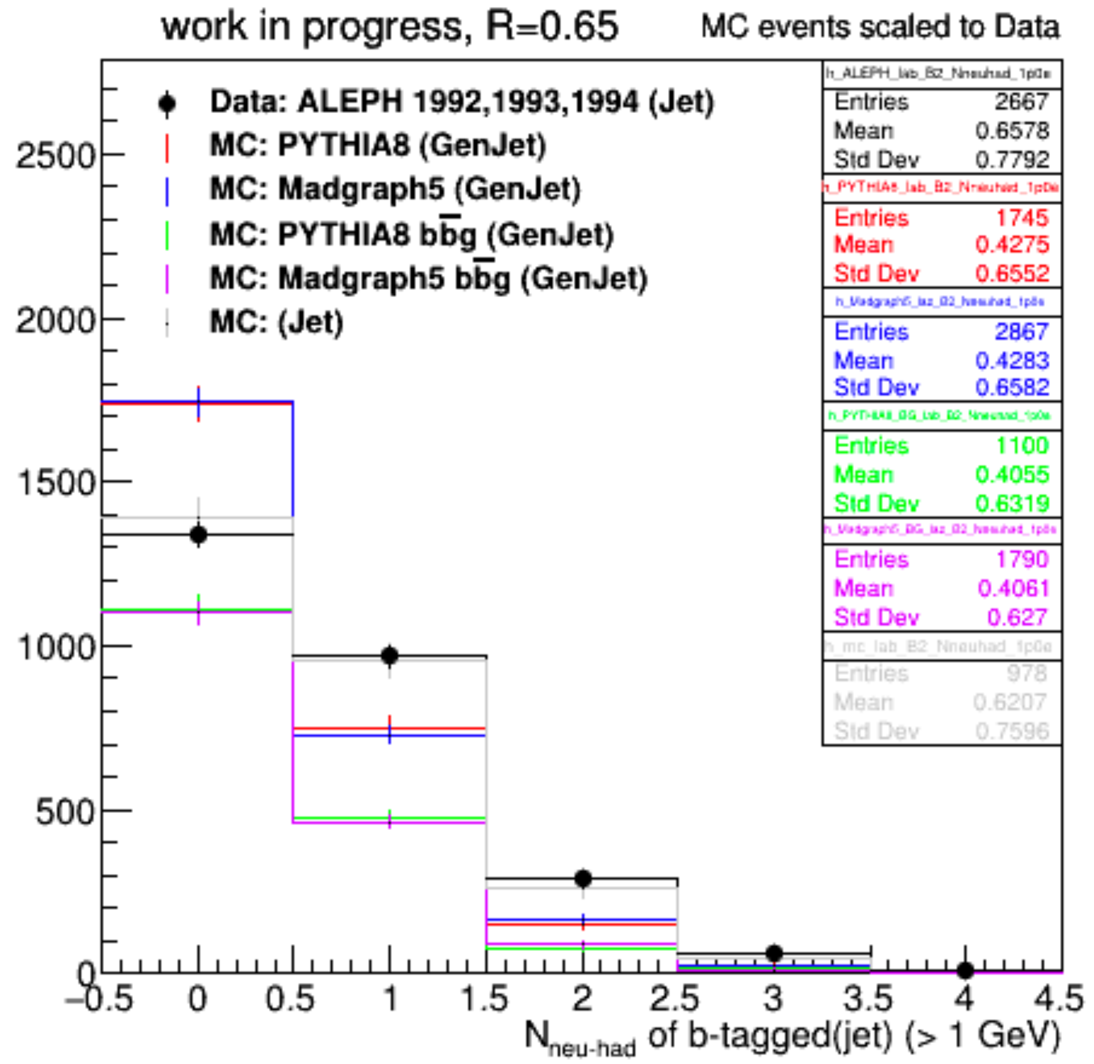


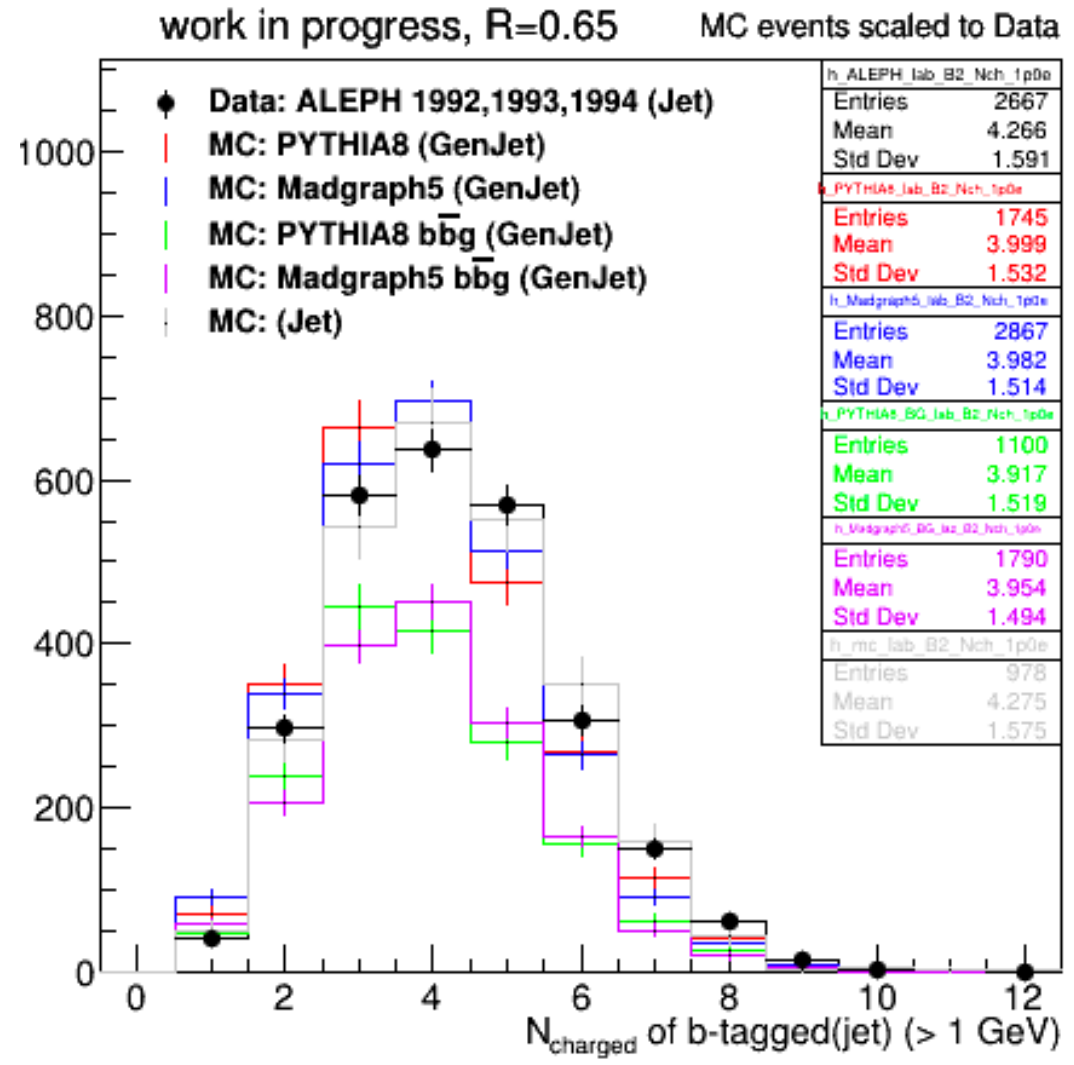


B quark



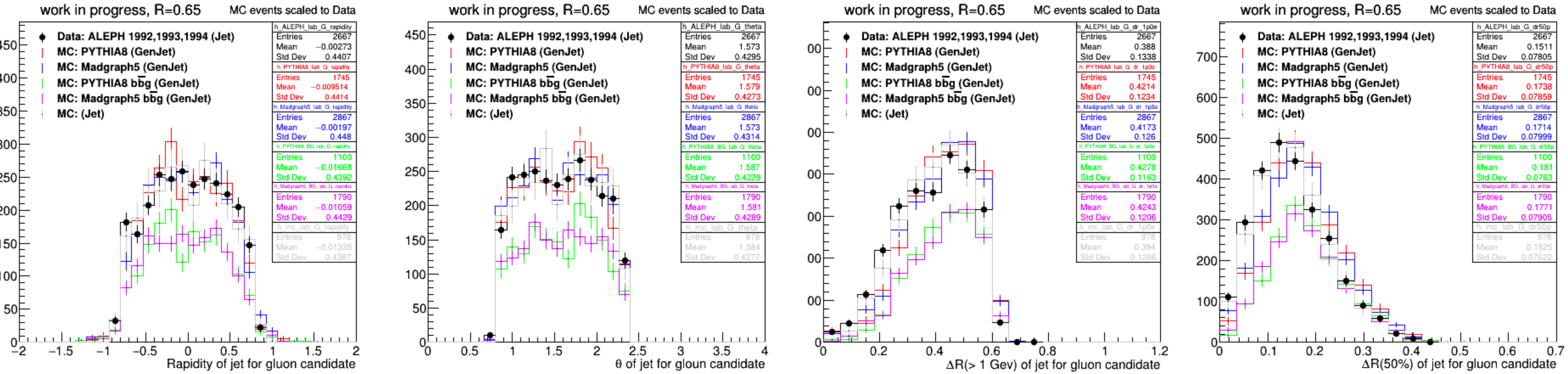




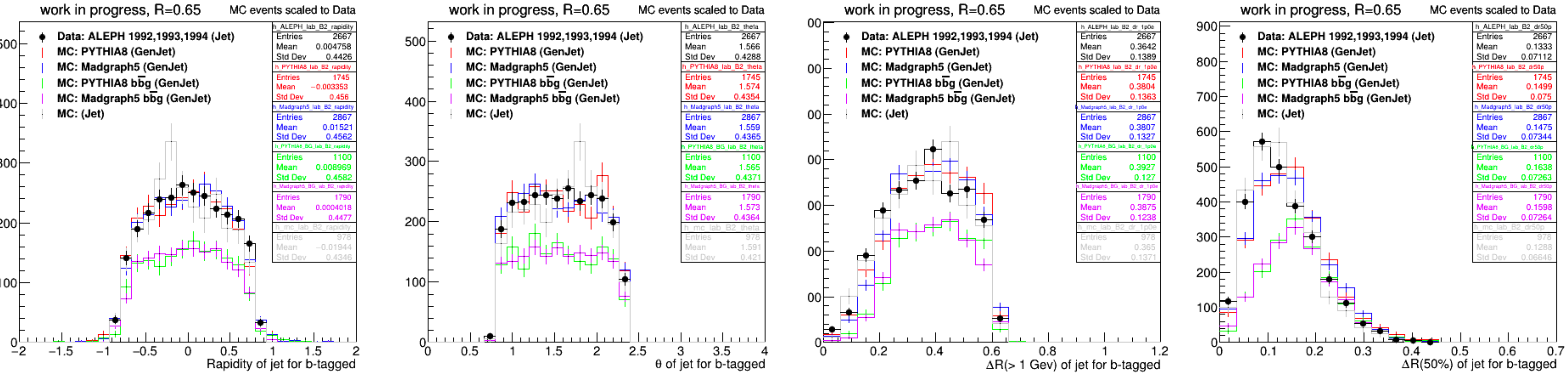


ALEPH T : 2667 (only b23tag: 1,2)

Gluon



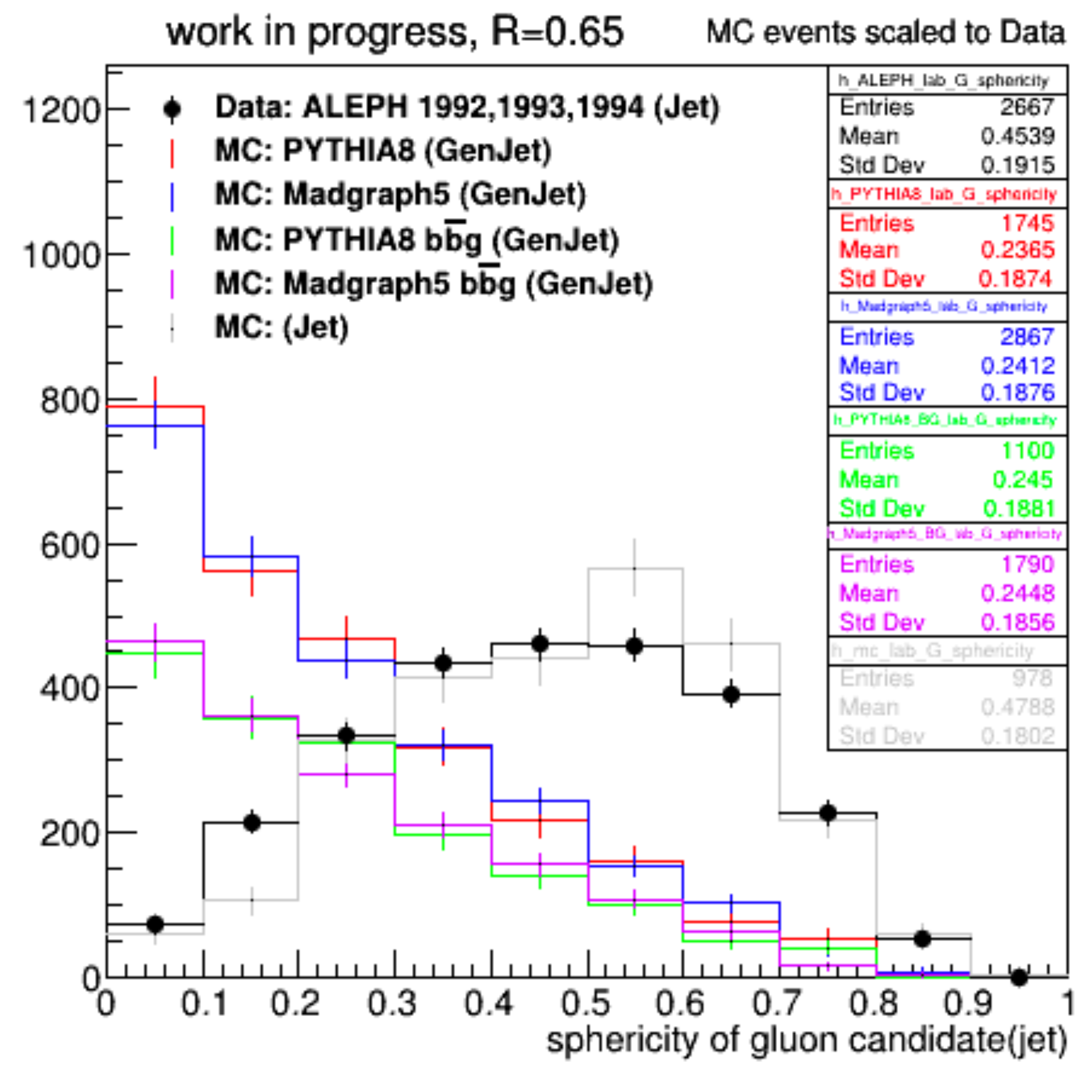
B quark

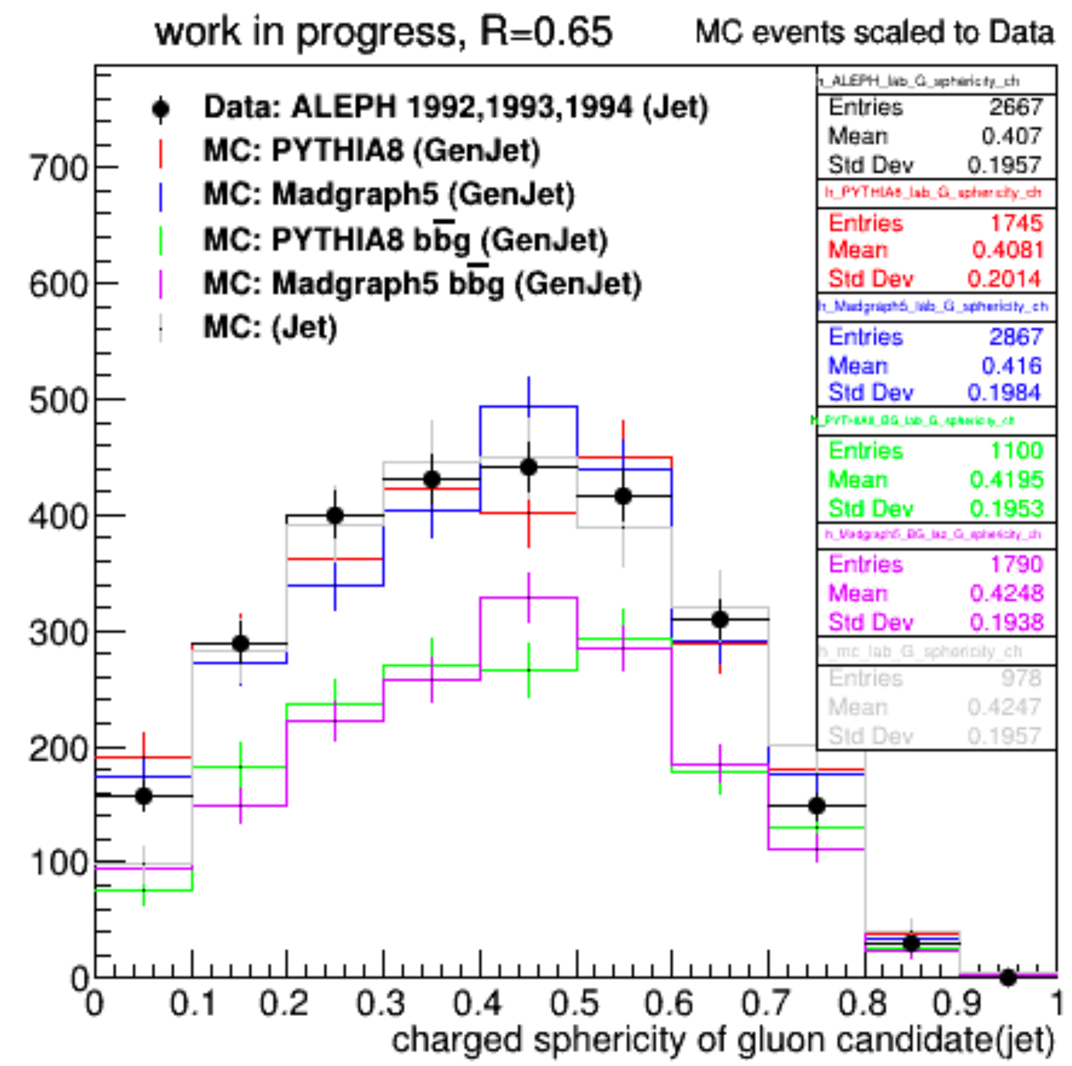


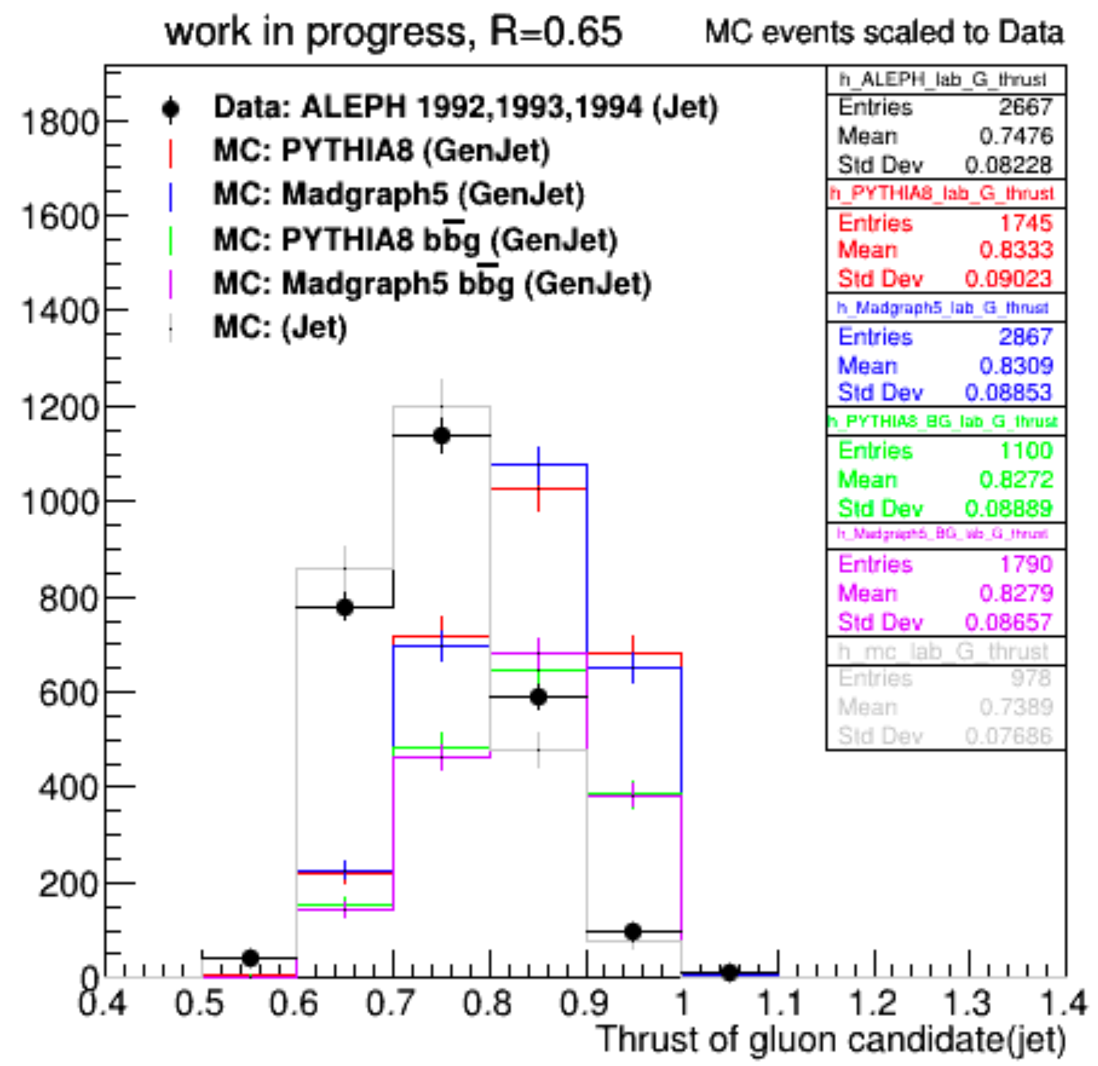
ALEPH T : 2667 (only b23tag: 1,2)

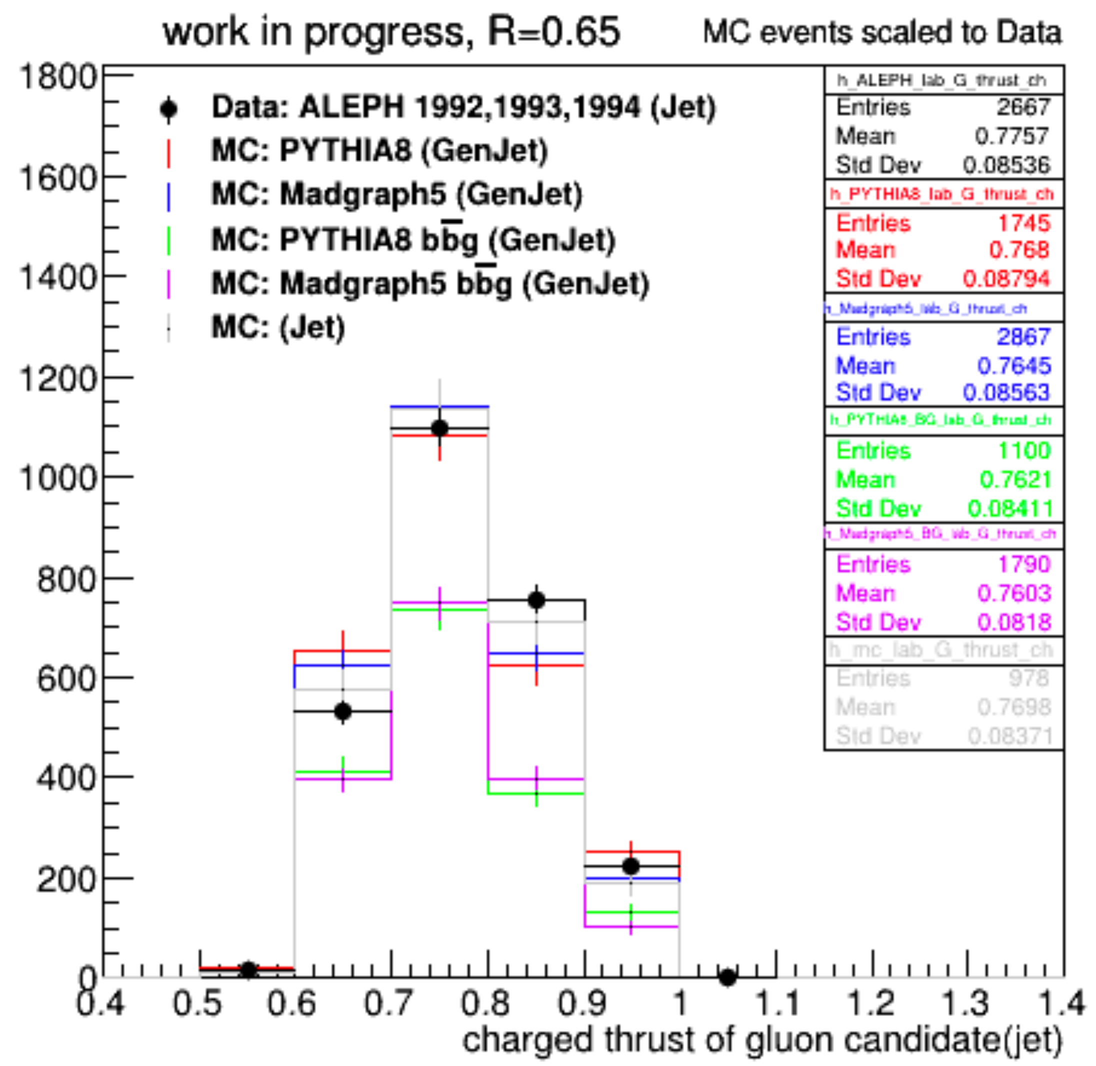
Jet constituents are boosted to jet.

Gluon

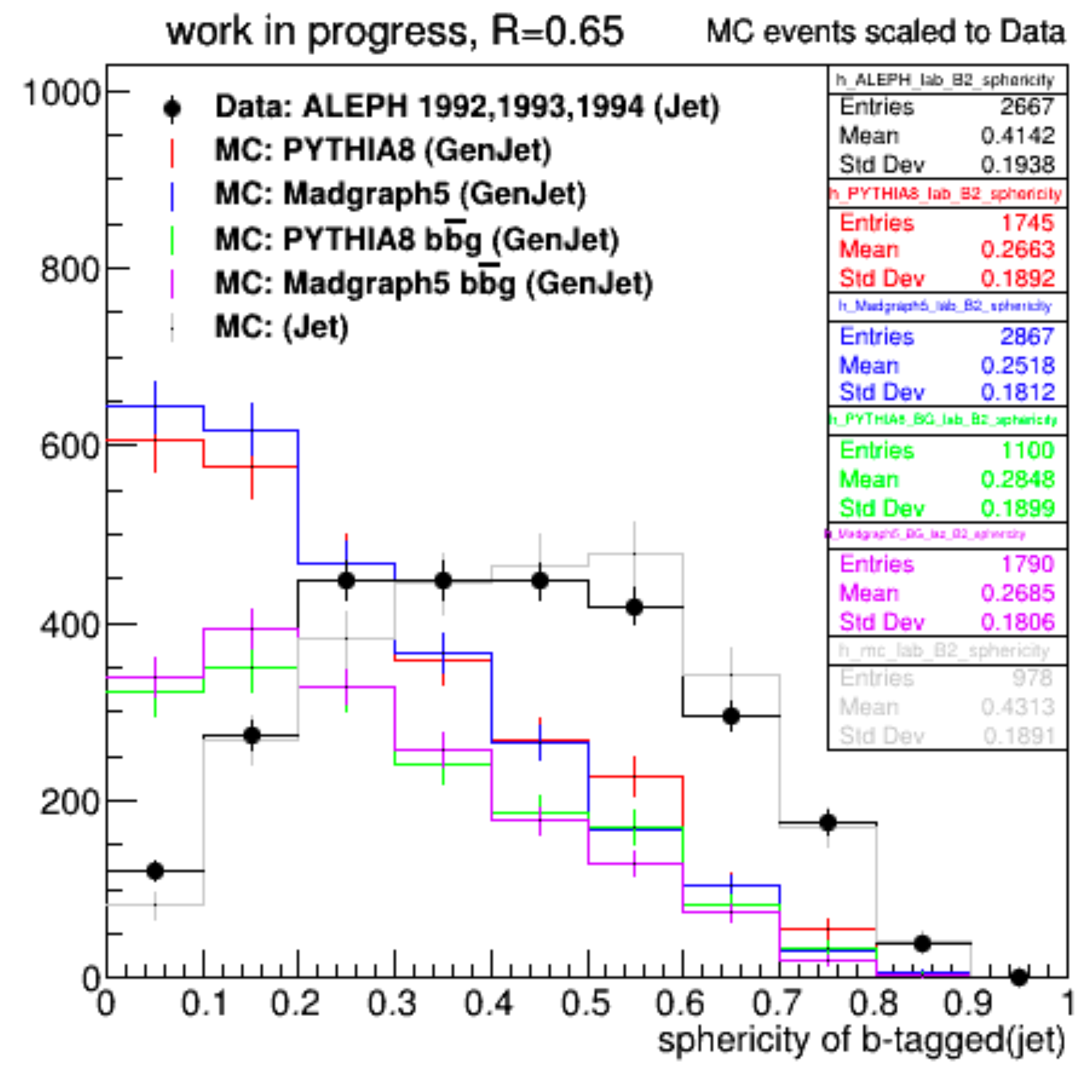


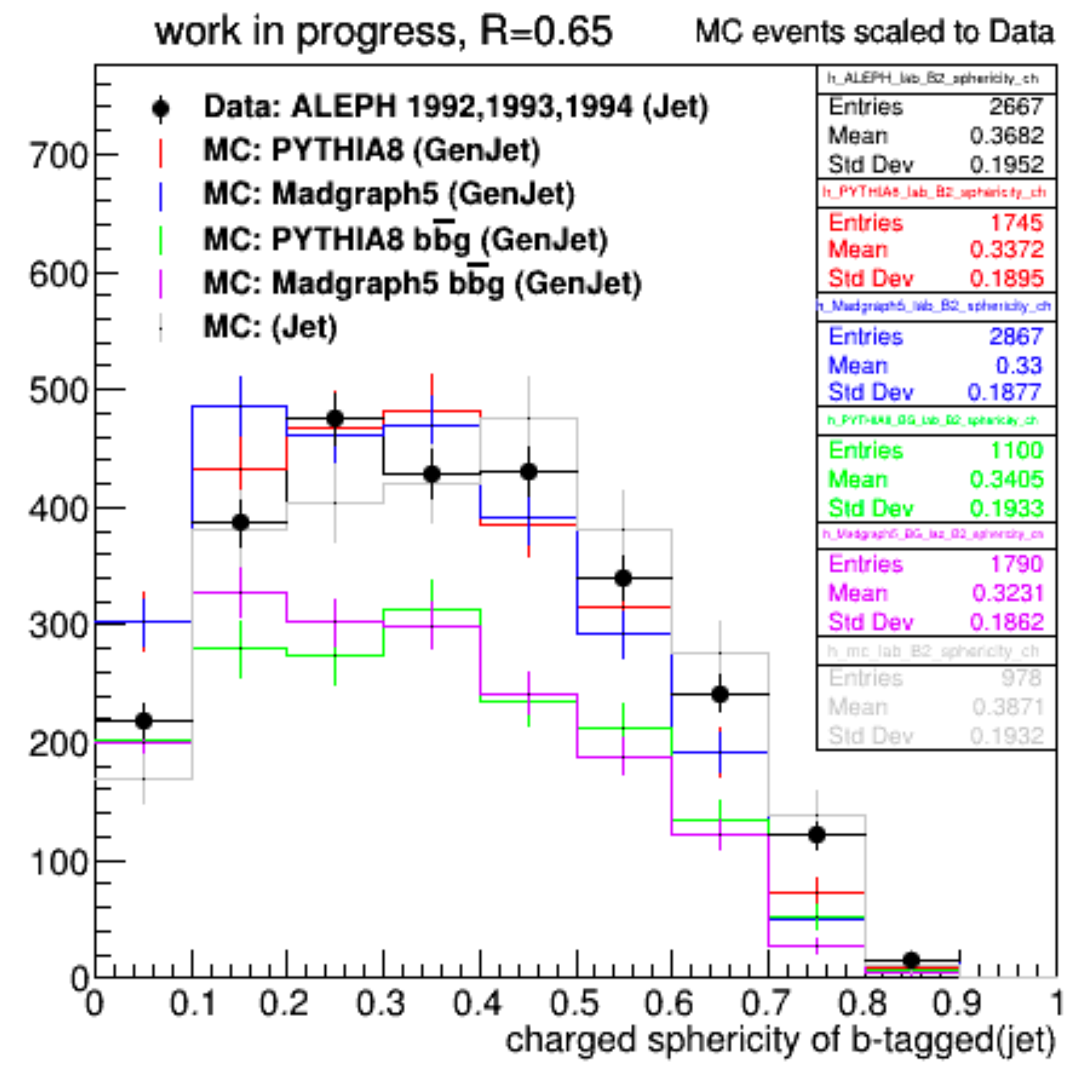


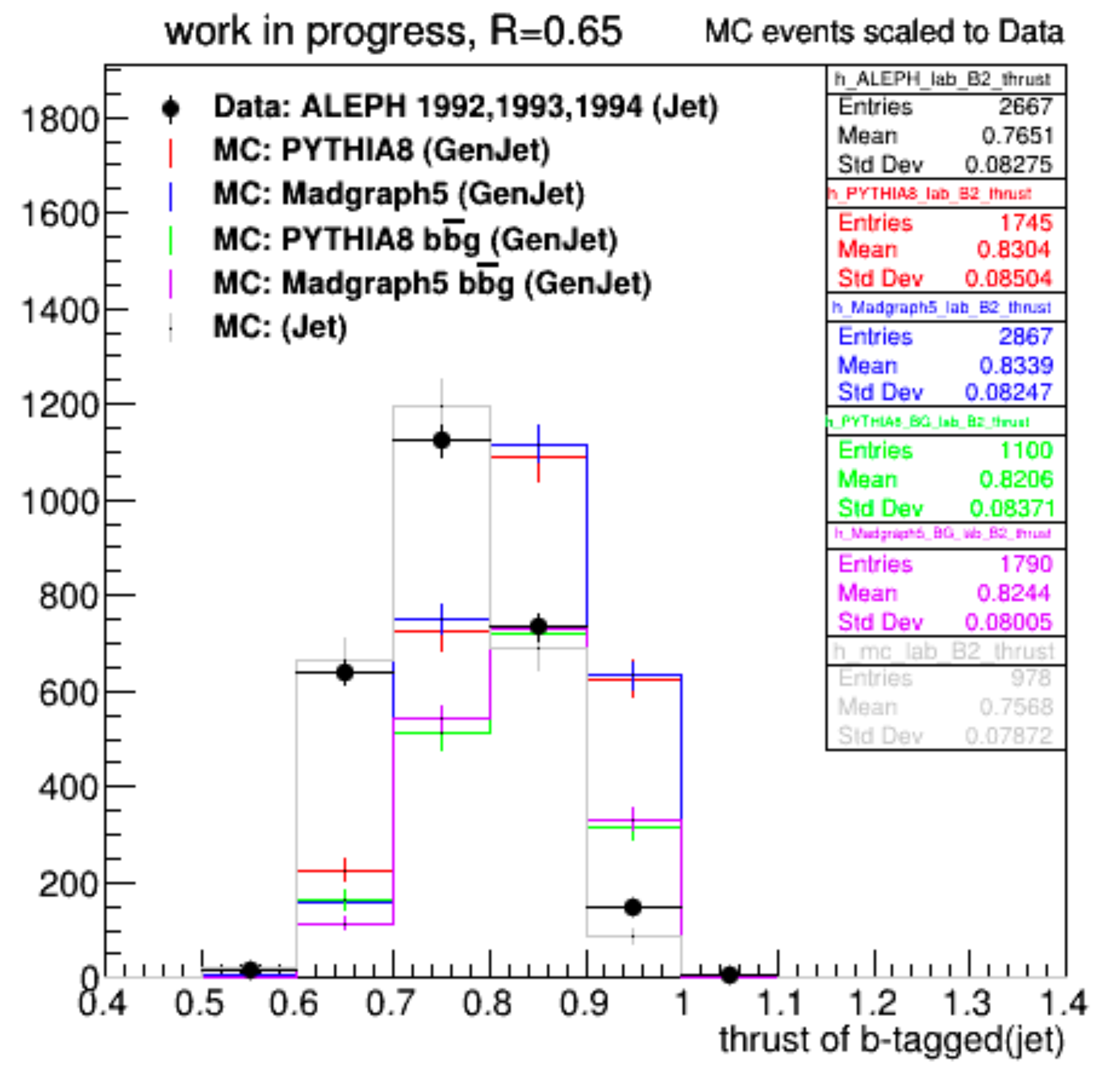


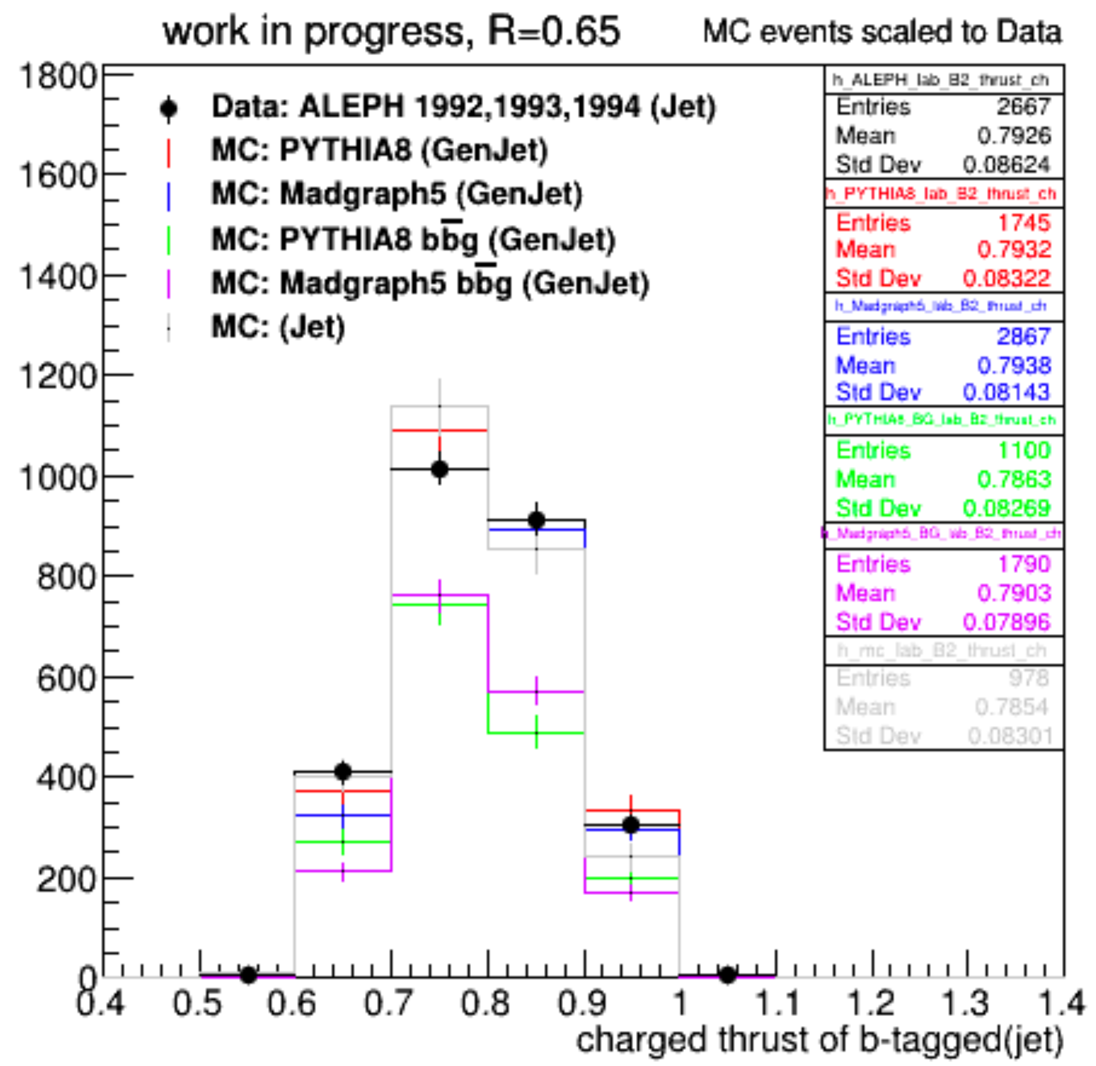


B quark



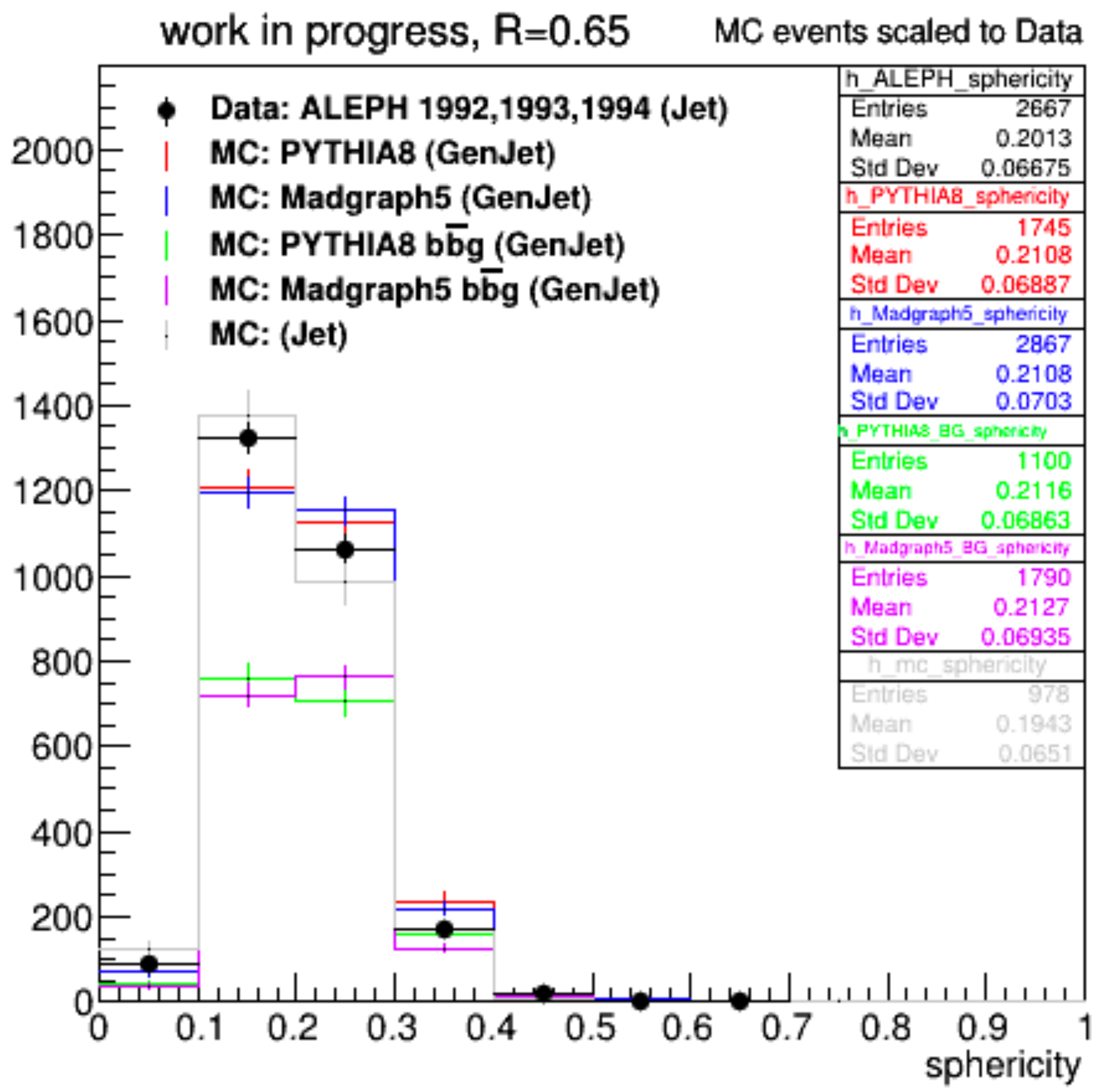


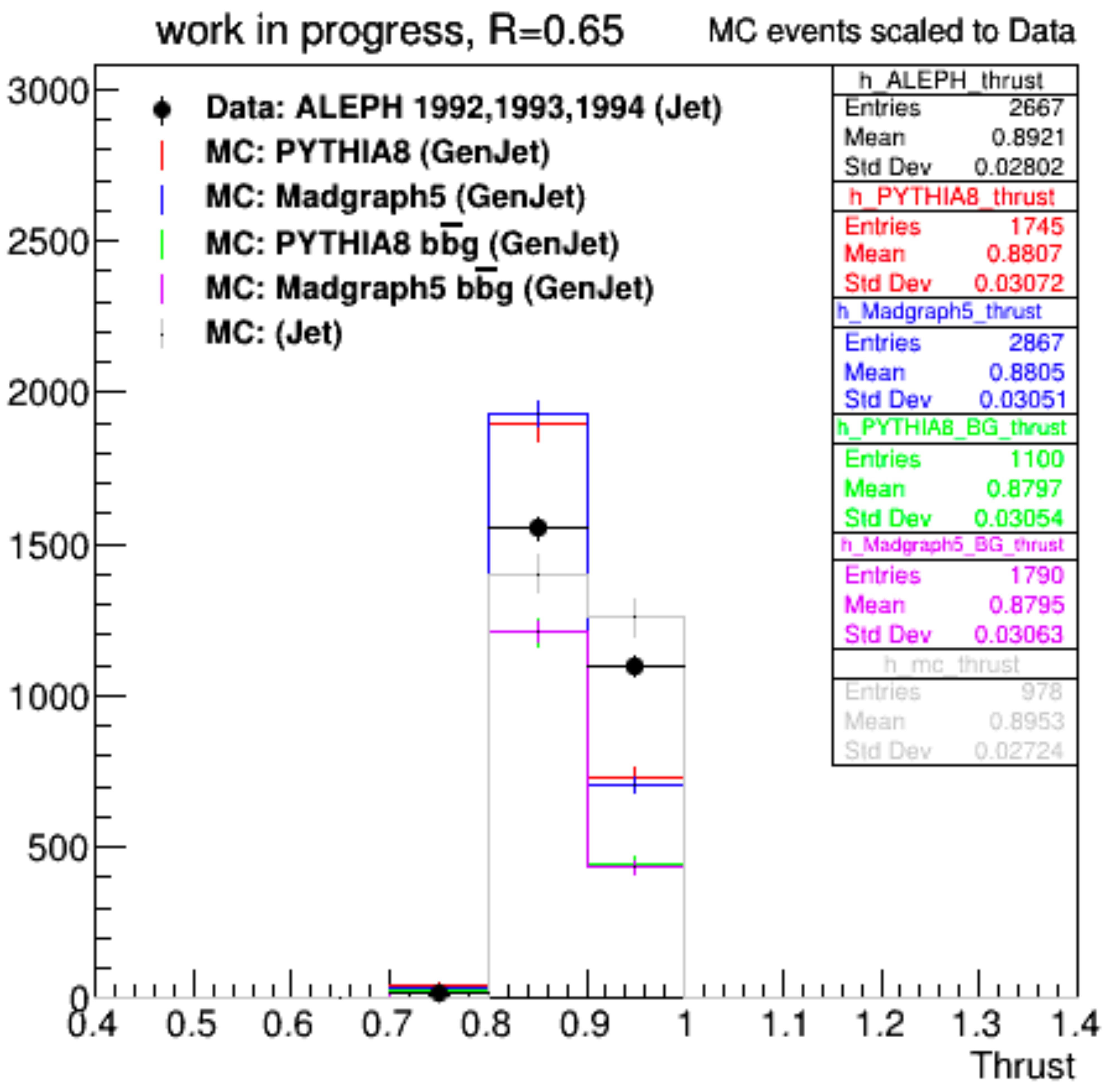




ALEPH T : 2667 (only b23tag: 1,2)

In the event





https://github.com/alisw/pythia8/blob/master/include/Pythia8/Analysis.h

ALEPH T : 2888 (only b23tag: 1,2)

XE - Fragmentation function

Fill variables as the ratio = charged particle energy / jet energy sum and by the weight as 1/number of charged particles.

Fig. 2 shows the unfolded and corrected fragmentation function, $(1/N)dN/dX_E$, with $X_E = E_{particle}/E_{jet}$, for charged particles measured together with the estimates of the JETSET and HERWIG Monte Carlo models. Gluon jets have more particles carrying small frac-

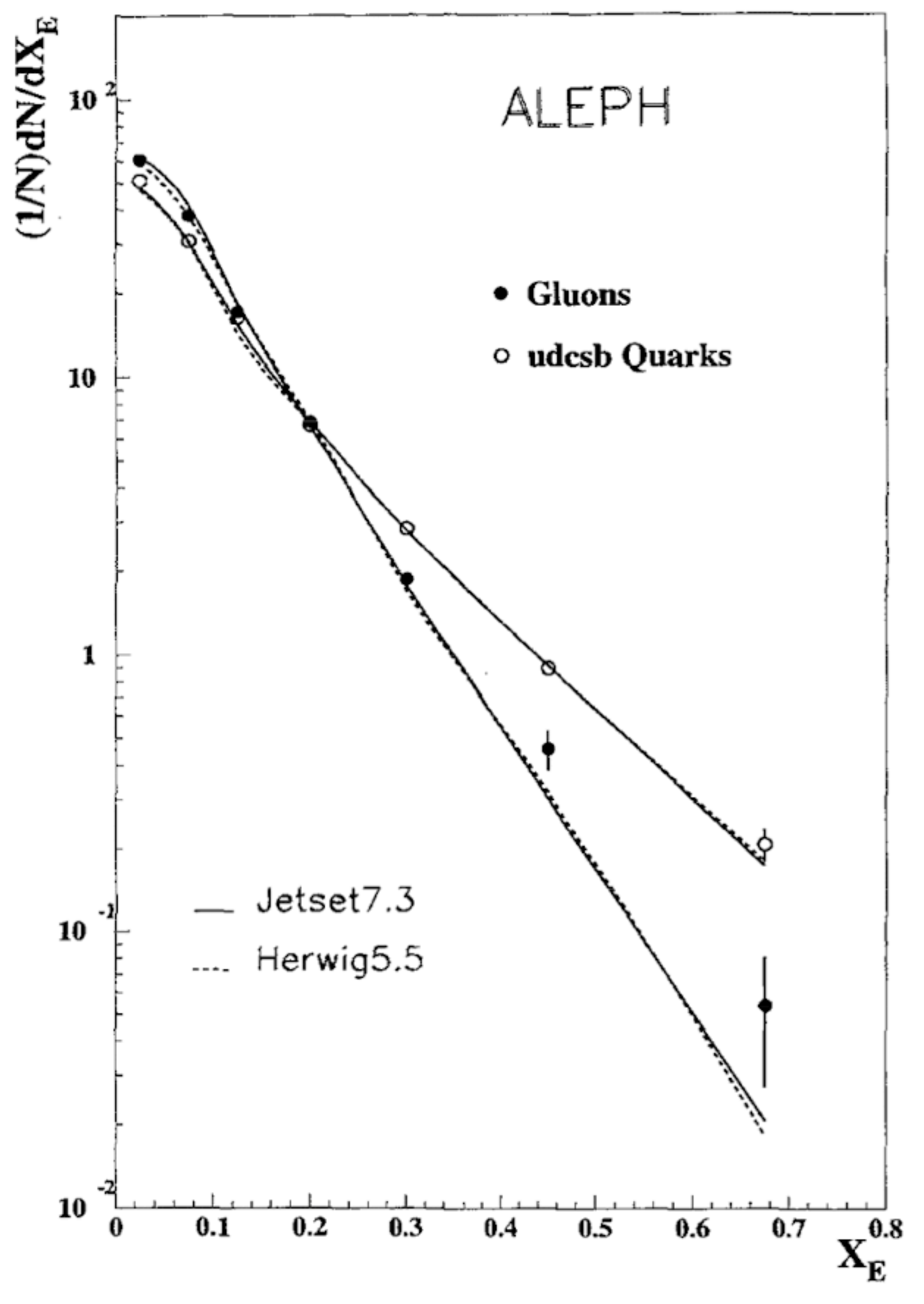
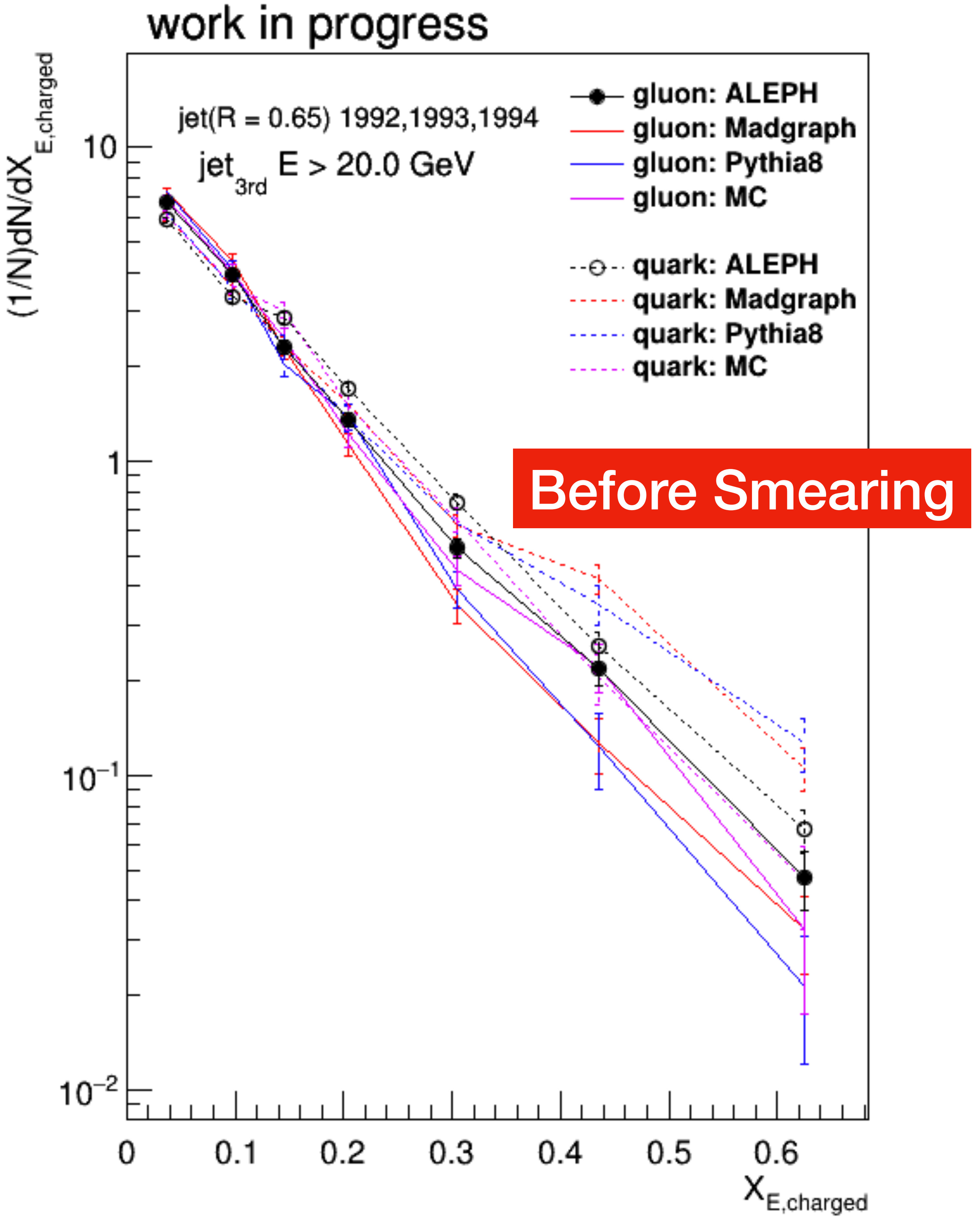
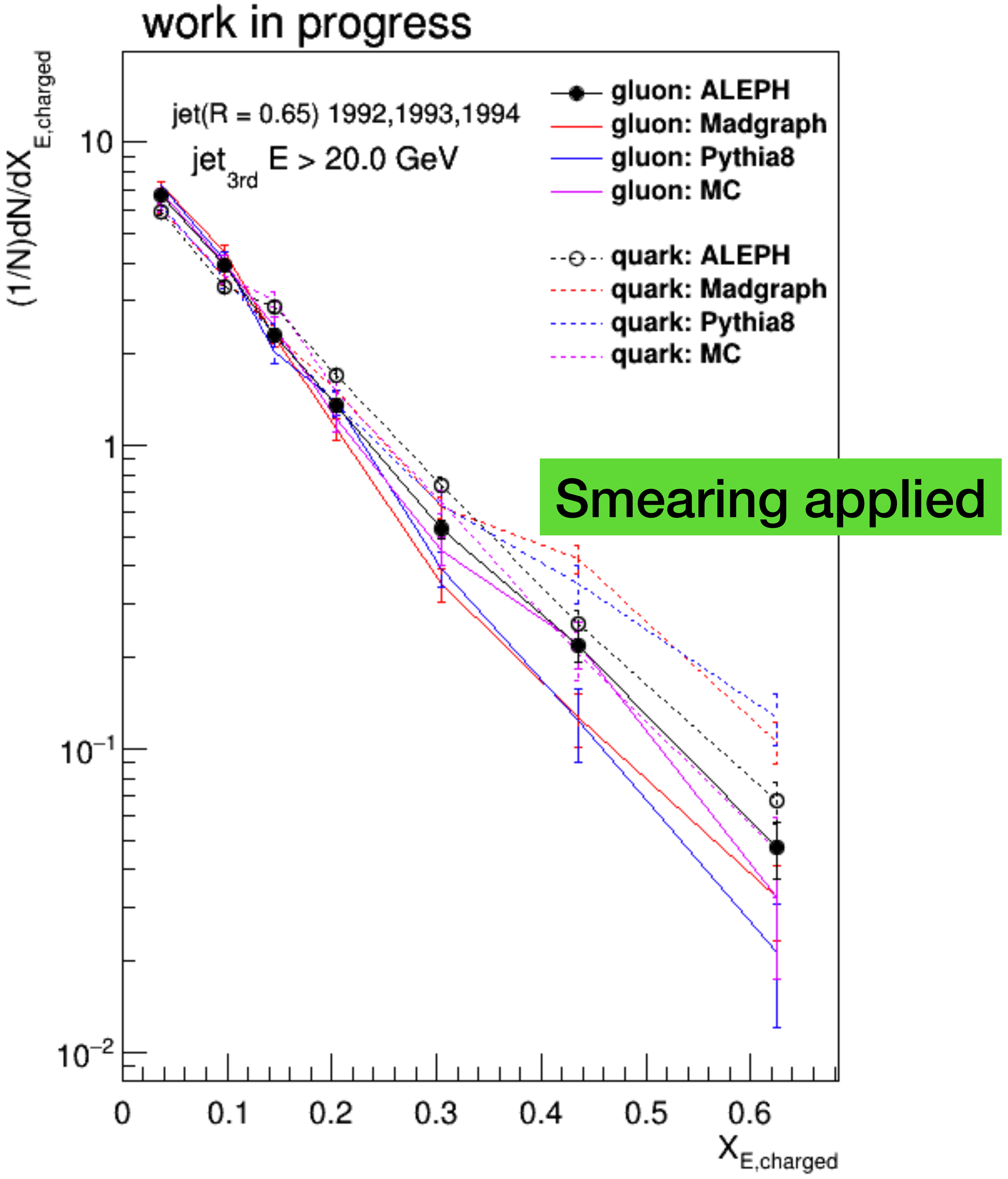


Fig. 2. Fragmentation function for natural flavour mix quark and gluon jets.

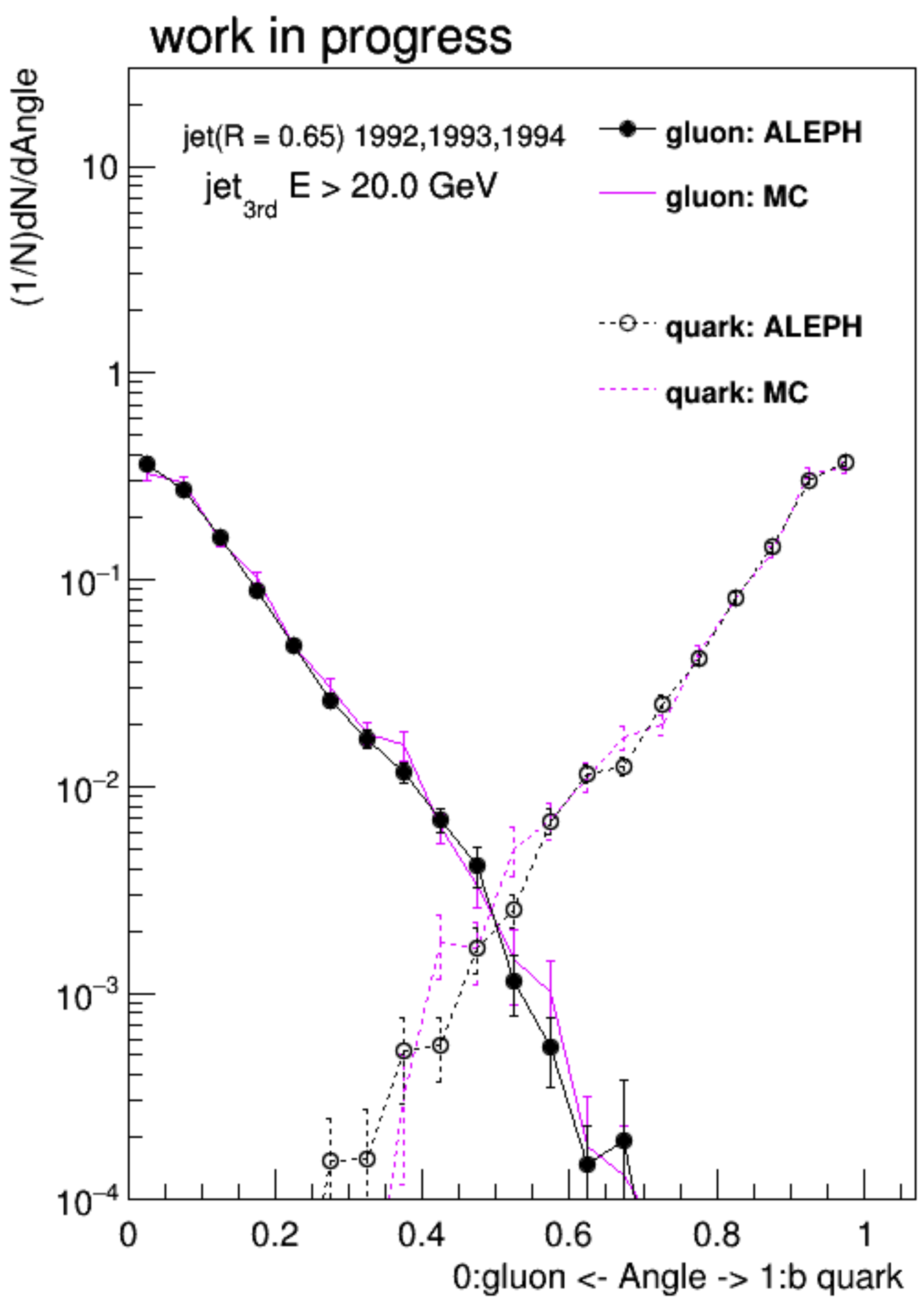
Phys.Lett.B 384 (1996) 353-364

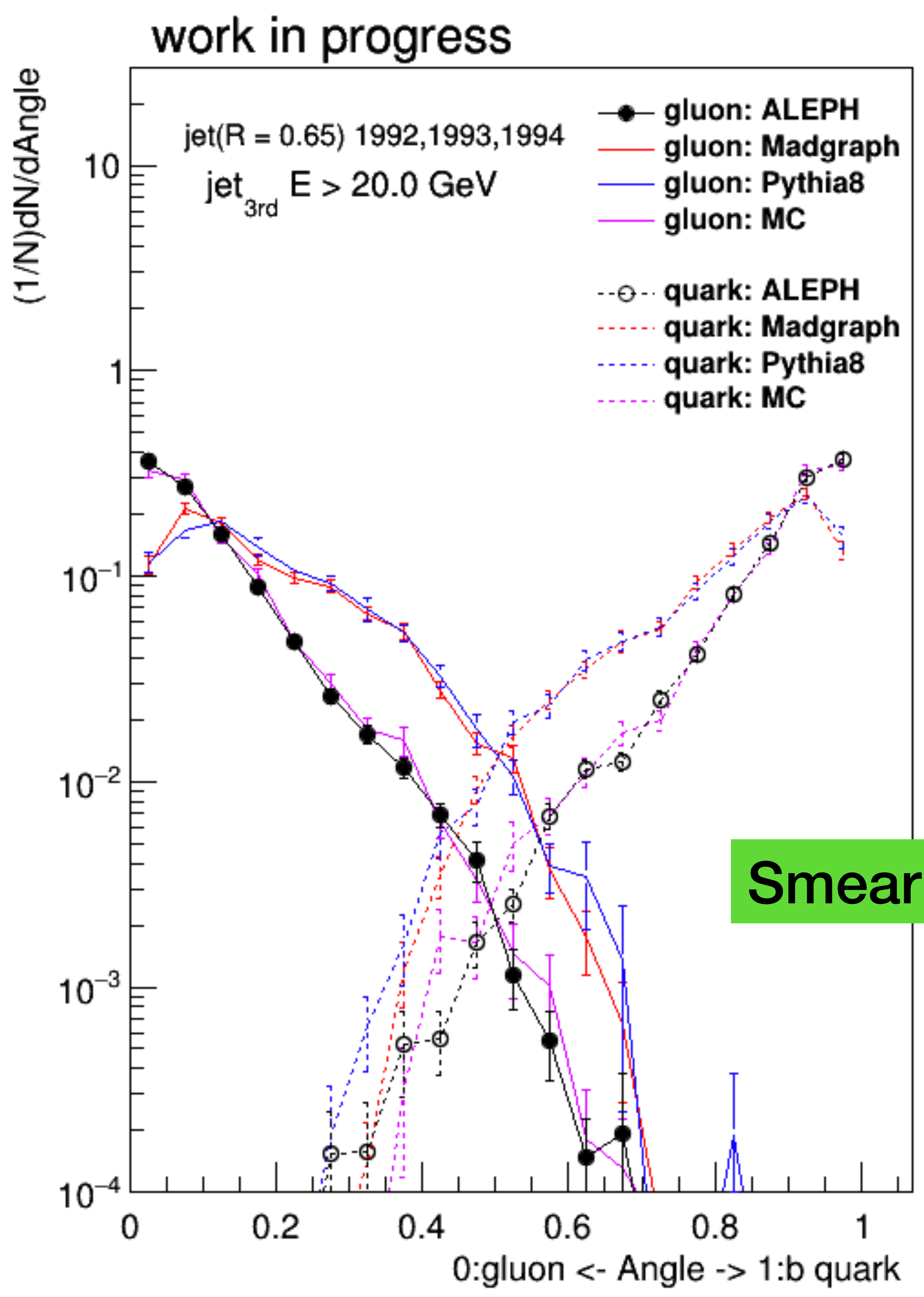




Angle between gluon and b-quark

- In 2rd,3th jets,
- Select bquark and gluon candidates.
- And, all constituents are boosted to center of mass frame in 2rd and 3th jets.
- And, check the angle between b quark and gluon.





Smearing applied

Summary

- We are trying to see distributions(multiplicity, sphericity and etc.) for gluon properties.
- However, we still need to study more information and detector simulation(or smearing) for MC samples.
- MIT MC Sample has very good energy shape which is compare with ALEPH Data.
  - If we can see the smearing(or simulation) information, we can improve the our mc samples.
  -

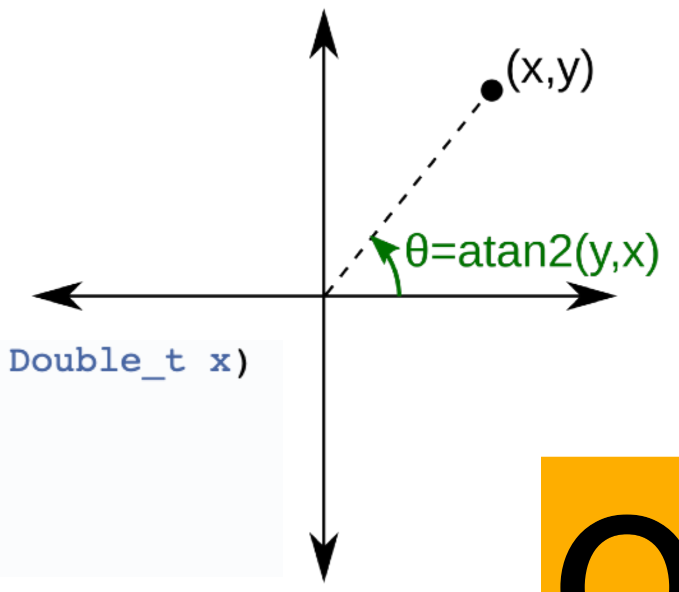
Question?

- For MC samples, Preselection definition, Smearing method for particle and identification
  - How to use the values from ALEPH Detector performance paper(CERN—PPE-94-170)?
  - Which is better for simulation effect? A simple way(we are trying to find the way)? Or GEANT simulation?
  - Do we need to trigger or vertex of MC in study?
  - Track overlap range for detector angle resolution?
- What is different among the t, tgen, tgenbefore of MC from MIT?
- Which is better in Jet algorithm as based on energy vs. transverse momentum?

```
TFile*          /hdfs/user/youngjo/QCD/aleph_mc/LEP1MCMerged.root
 KEY: TTree     t;1     t
 KEY: TTree     tgen;1  tgen
 KEY: TTree     tgenBefore;1    tgenBefore
```

Back up

```
inline Double_t TMath::ATan2(Double_t y, Double_t x)
   { if (x != 0) return  atan2(y, x);
     if (y == 0) return  0;
     if (y >  0) return  Pi()/2;
     else        return -Pi()/2;
   }
```




```
Theta =
TMath::ATan2(TMath::Sqrt(fX*fX + fY*fY),fZ);
```

Old

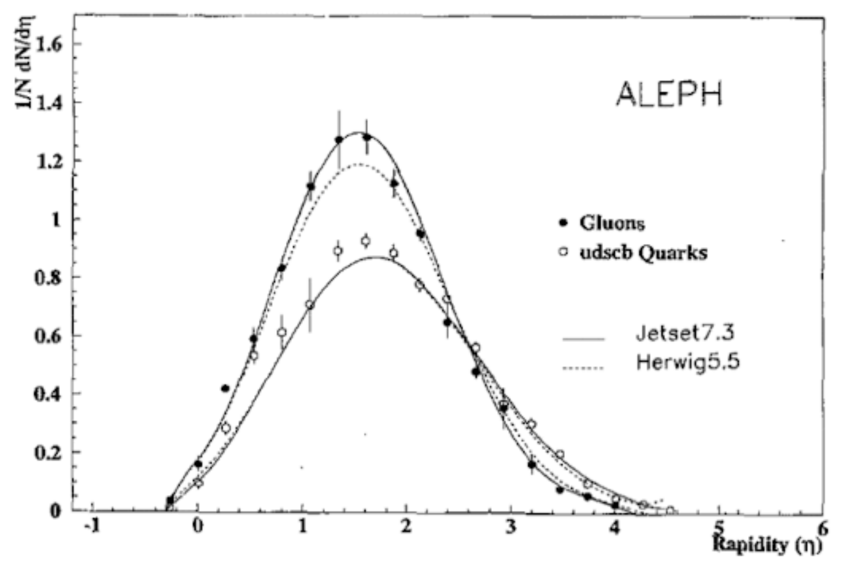


Fig. 3. Rapidity distributions for natural flavour mix quark and gluon jets.

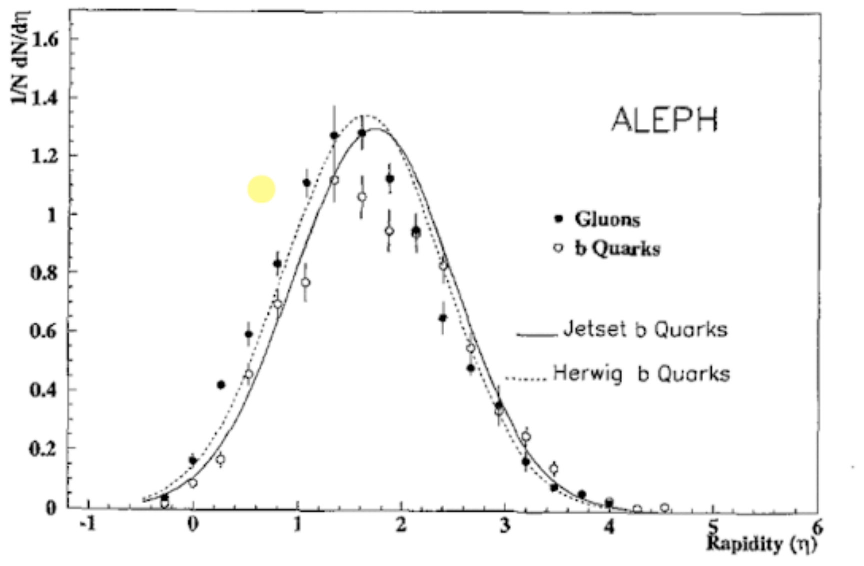
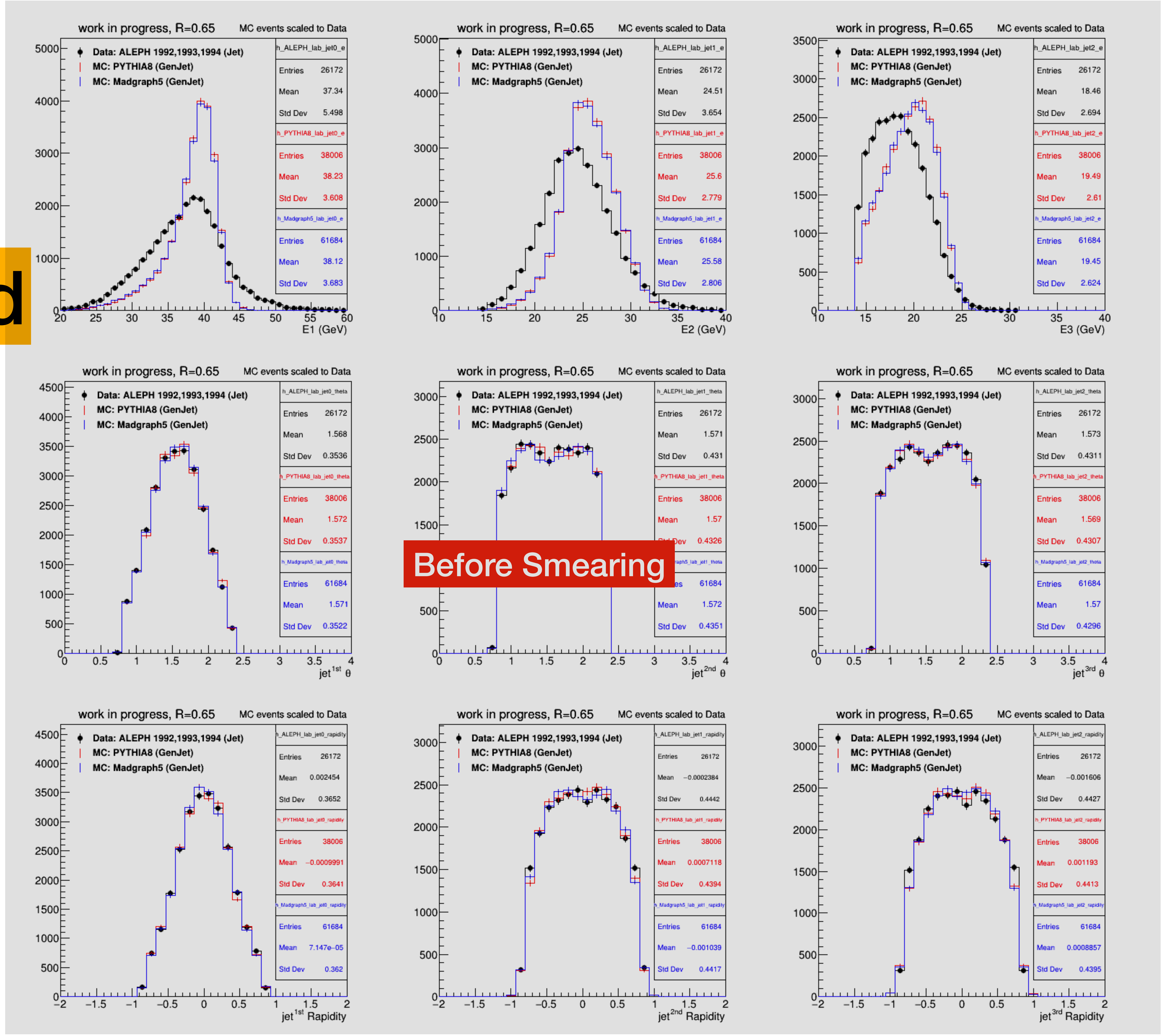


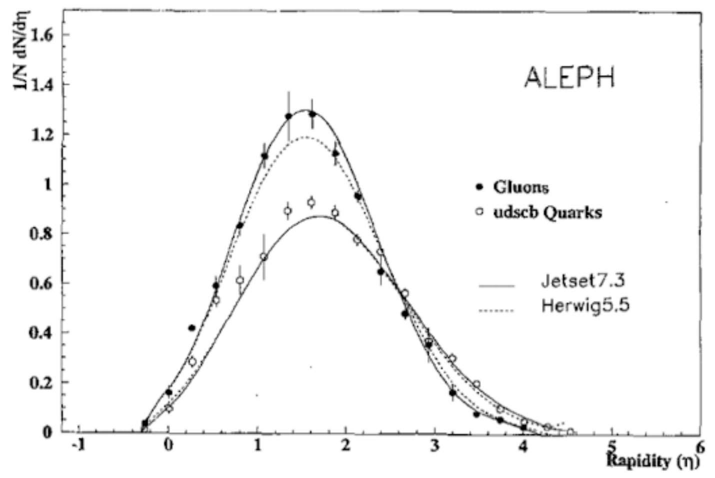
Fig. 4. Rapidity distributions for b quark and gluon jets.

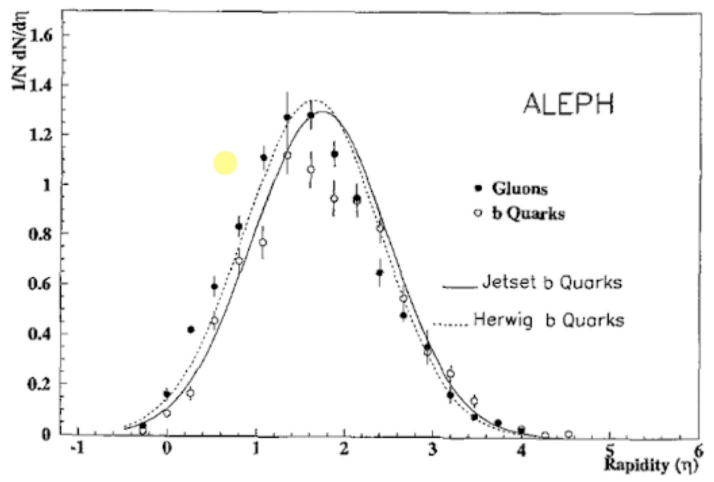
```
Rapidity =
 0.5*log( (E()+Pz()) / (E()-Pz()) );
```



ALEPH T : 2888 (only b23tag: 1,2)

ALEPH T : 2888 (only b23tag: 1,2)





Old

Before Smearing