Are there two types of gluons: ALEPH gluon study

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The 2nd UOS-MIT mini workshop on gluon study

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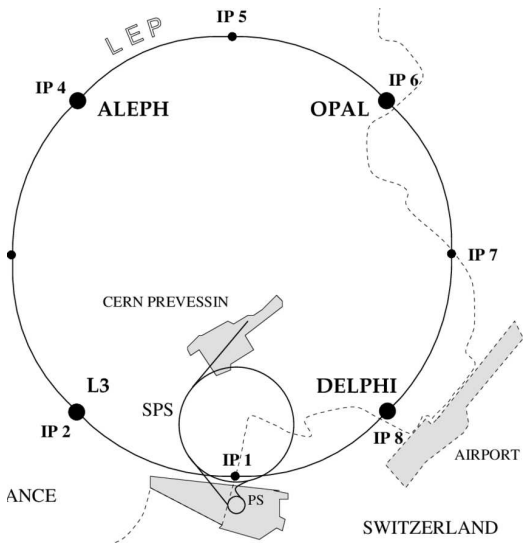
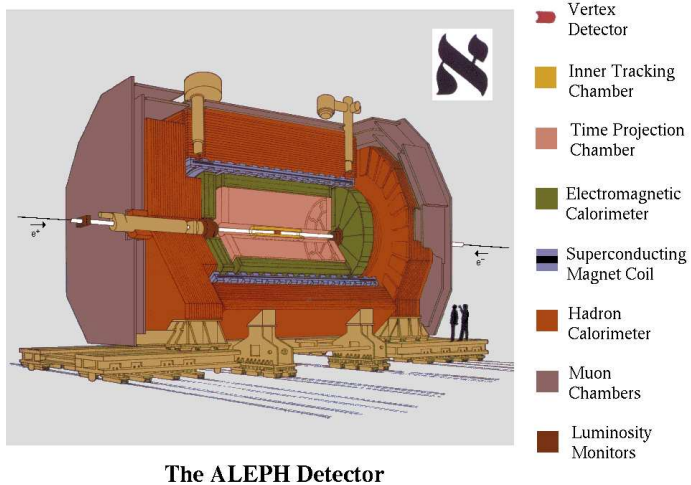
Outline

- Introduction
- Motivation
- Analysis
- Result
- Summary

Introduction

- Large Electron-Positron Collider(LEP) was accelerated electron and positron beams in the ring(27 km circumference).
  - 1st operation phase: 1989-1995, for Z boson production, energy $\sim$ 91 GeV)
  - 2nd operation phase: 1995-2000, for W pair events, energy: going up to 200 GeV)
- The 4 detectors as ALEPH, DELPHI, OPAL, L3 were collected the events from the collider.



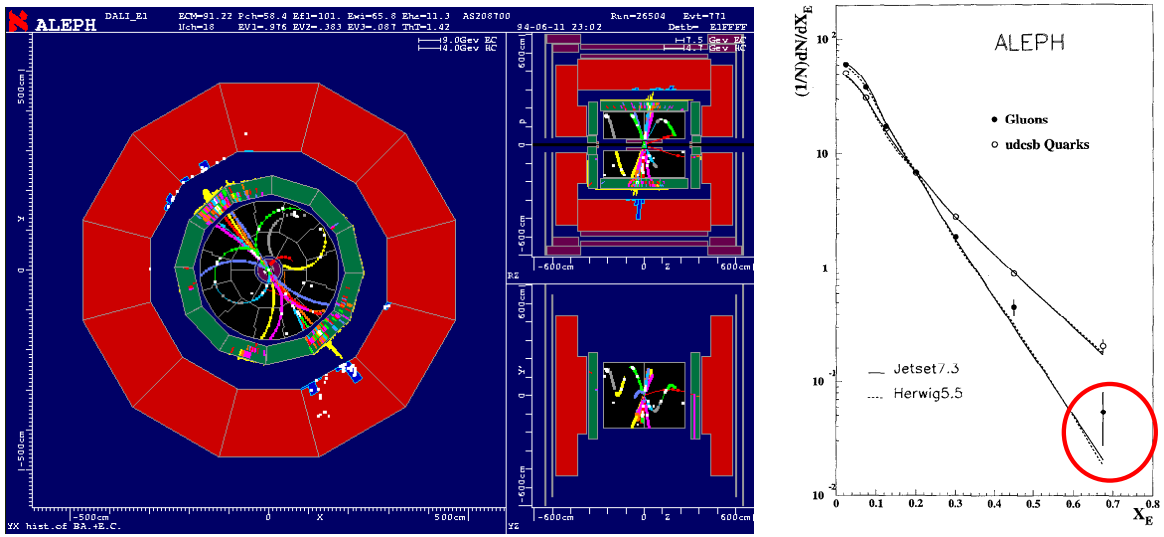


The ALEPH Detector

(Left) Schematic view of the LEP collider with its eight interaction points, (Right) ALEPH detectors layout

Motivation

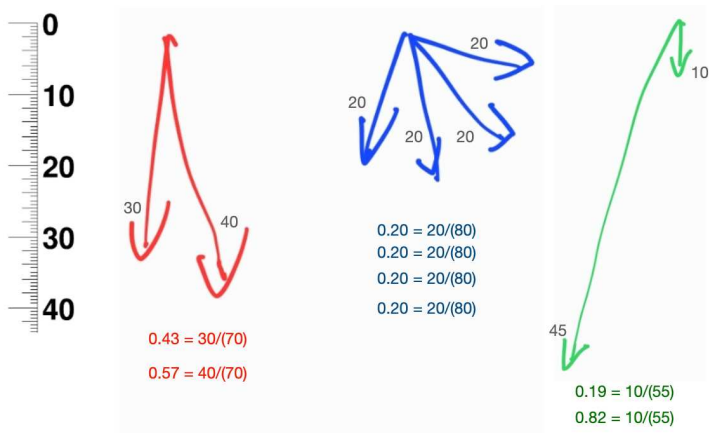
- $e^+e^- \rightarrow Z \rightarrow q\bar{q} + g$: 3 jets events
- Gluon and bQuark identification by using b-tagging method
- The red circle shows some difference between MC and Data for gluon candidates.

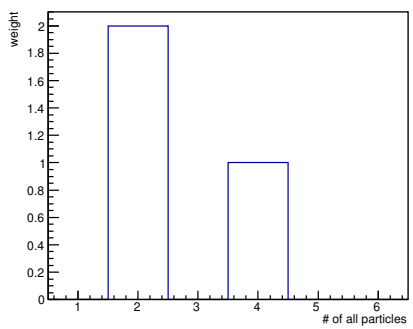


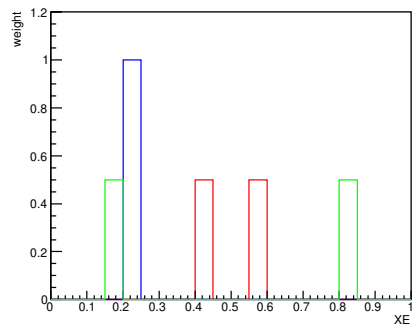
(Left) The hadronic decays of the Z0 event viewer in ALEPH detectors, (Right) Fragmentation function(XE) for quark and gluon jets in PLB 384 (1996) Page 353

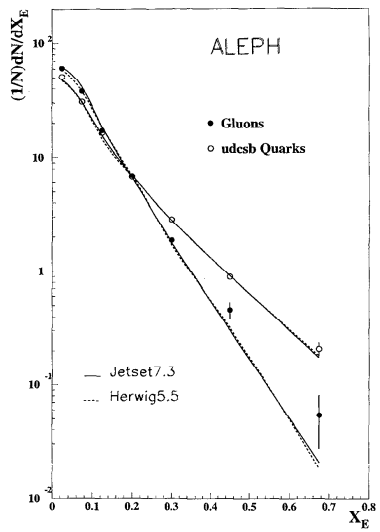
Motivation - XE definition

- Our XE(fragmentation function) definition: e_i/E_{jet} within weight $1/N$ (1 / number of particles)



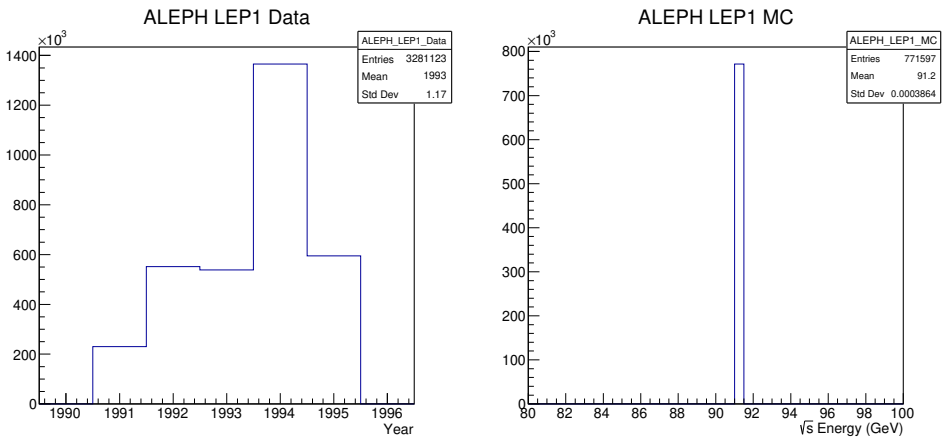






Analysis

Samples

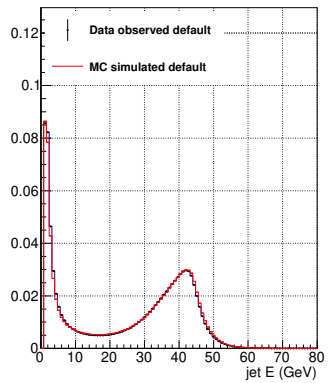


- tree "t" in Data(ALEPH LEP1), MC(energy 91.2 GeV)
- particles info.(px, py, pz, pt, mass, eta, theta, phi, charge, pwflag) in the event
- pwflag(particle identification) : charged tracks(0), leptons(1,2), v0(3, not use in our analysis), photons(4), neutral hadrons(5)

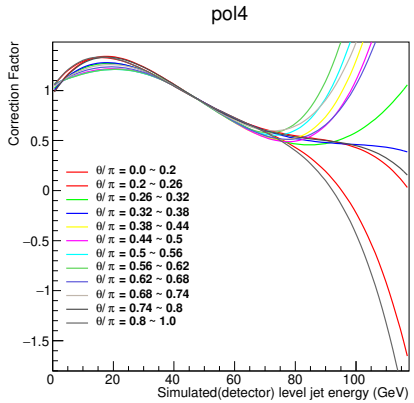
Jet reconstruction

- **fastjet**(version 3.3.4)
- Input : 4-vector information of particles
- Jet algorithm : "*ee_genkt_algorithm*"
  - Opening half-angle parameter **R**: 0.65
  - Jet minimum energy cutoff parameter **p**: 1 GeV
- b-Tagging method : lepton information (energy $>$ 1.25 GeV, and, momentum $>$ 3 GeV) in jet

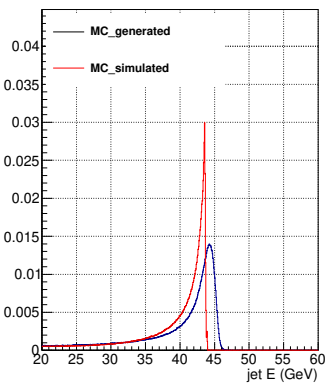
Jet energy correction



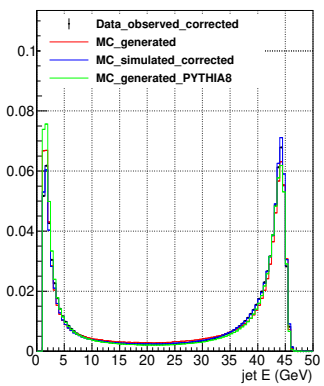
(a) detector level jet energy disistributions



(b) The polynomial (4) correction factors



(c) The correction factors were applied to MC-simulation.



(d) comparison between PYTHIA8(individual sample) and ALEPH(corrected for detector level).

- In (c),
  - Mean ratio of jet energy(gen/reco) = 1.01455 (mean)
  - Standard deviation difference: (std of MC_gen - std of MC_reco)/(mean of MC_gen) = 0.017200 (std)
- Smearing scale factor = Energy x Gaussian(mean + std/2, std*2/3)
- The factor applied to simulated MC and orserved Data in (d).
- So, by roughly similar event selection between gen and sim(reco), we will check the signal purity by using PYTHIA8 MC Sample.
- However, we have still challege issue to study detector simulation part(or unfolding).

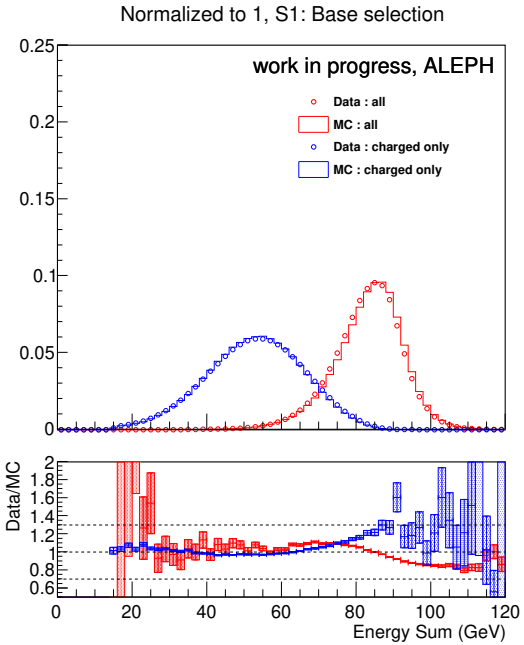
Event selection

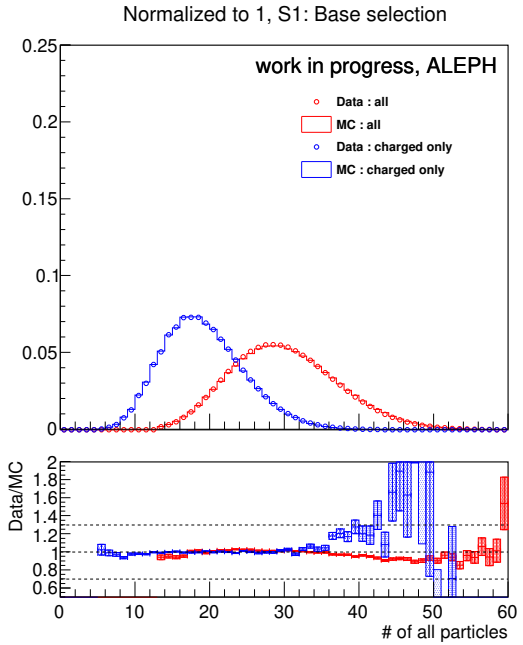
- S1: base selection: number of all particles $>= 13$, number of charged particles $>= 5$, and charged particles's energy's sum > 15 GeV
- S2: 3rd jet Energy > 15 GeV among jets within angle(z-axis, θ of jet) > 40 degree
- S3: only 1 b-tagged of 2nd, 3rd jets (b-tagged for bQuark, non-b-tagged for Gluon)
- S4: requirements by angle range in $150 \pm 7.5^{\circ}$ between 1st jet and each 2nd or 3rd jet.

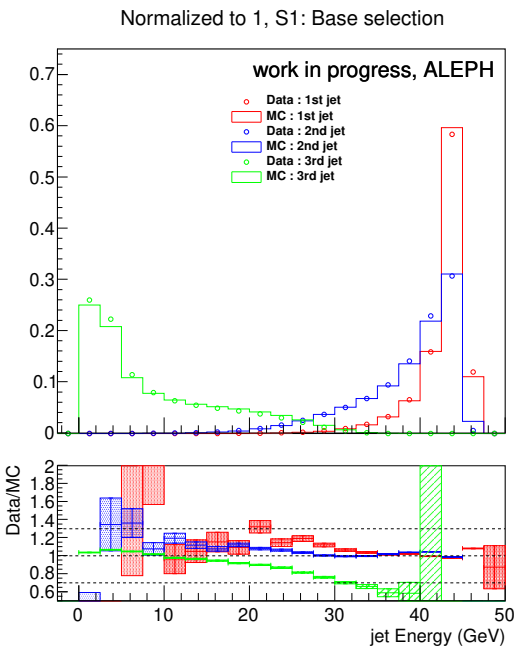
Sample	S1	S2	S3	S4
Data	3264500	706802	58607	5488
MC	(scale to Data) $\pm$ 3720	762010 $\pm$ 1797	63092 $\pm$ 517	6126 $\pm$ 161

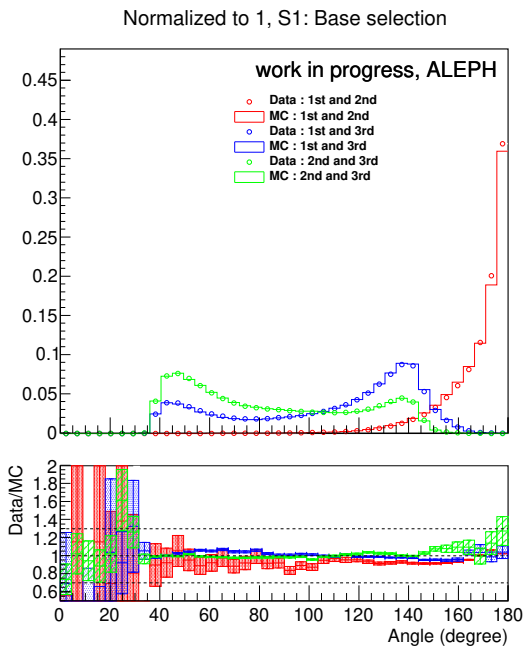
Table: Event selection flow between Data and MC

Event selection - S1: base selection









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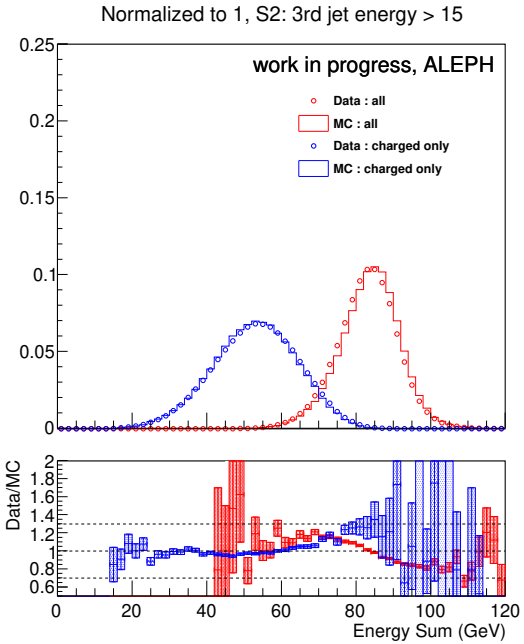
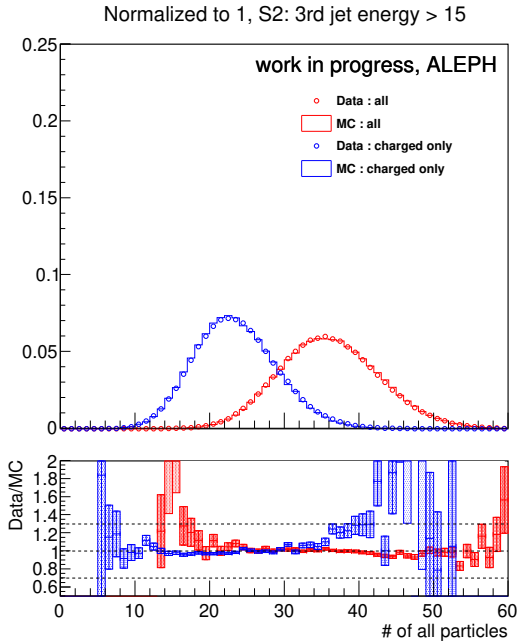
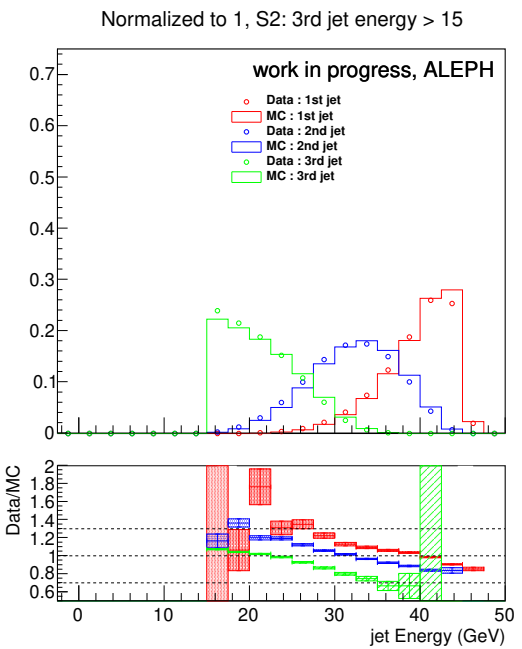
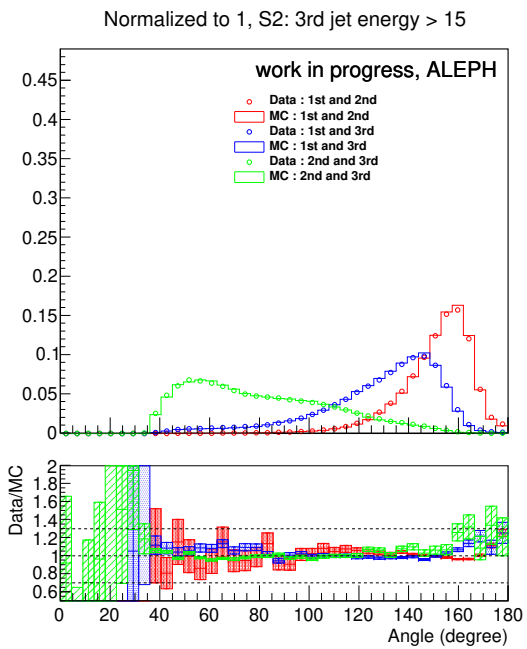
Event selection - S2: 3rd jet energy > 15 GeV









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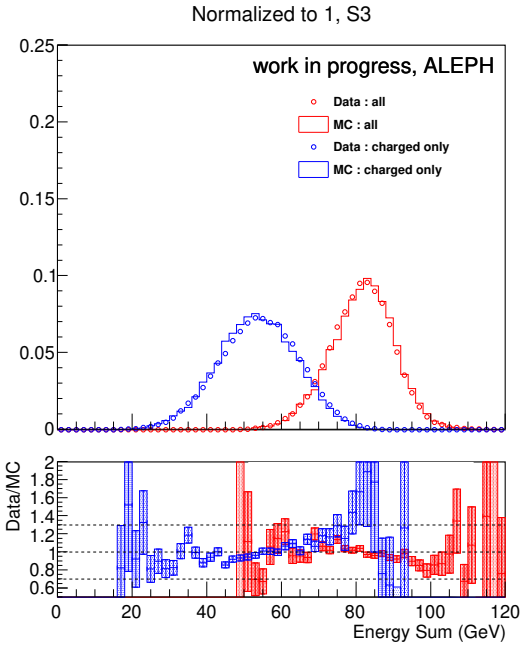
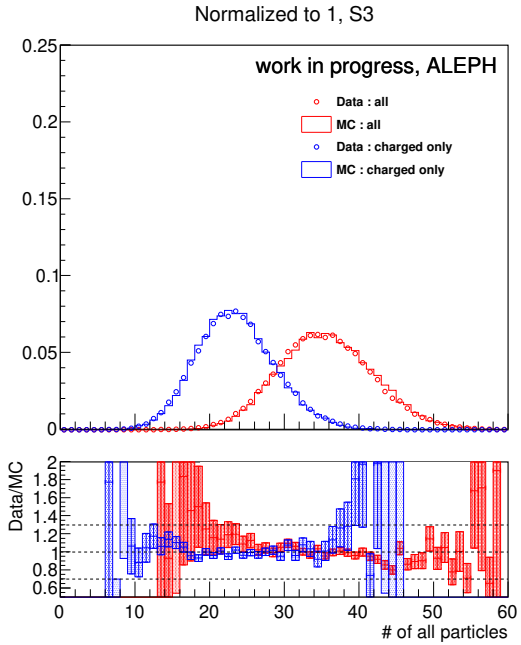
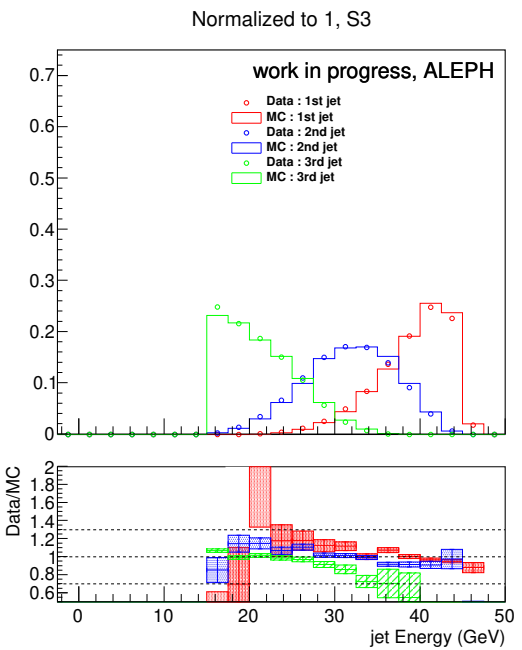
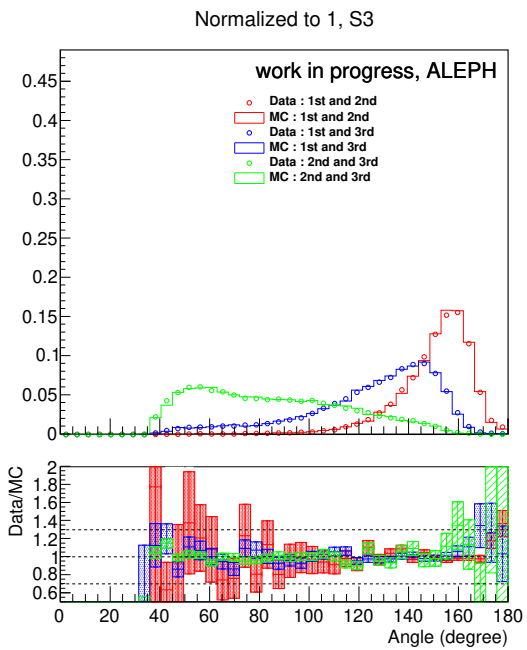
Event selection - S3









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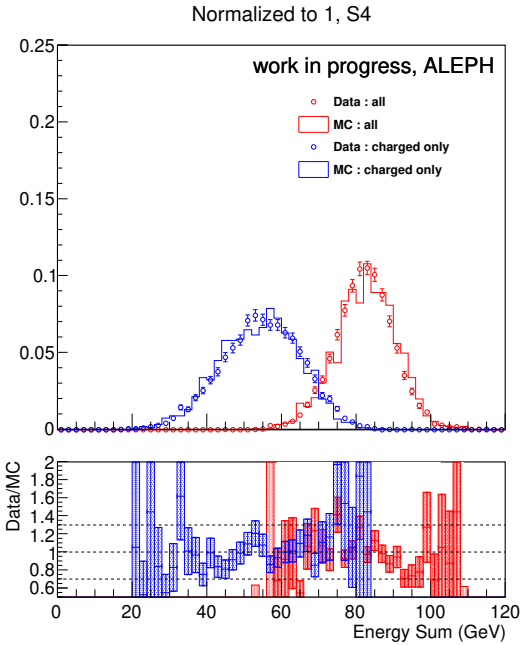
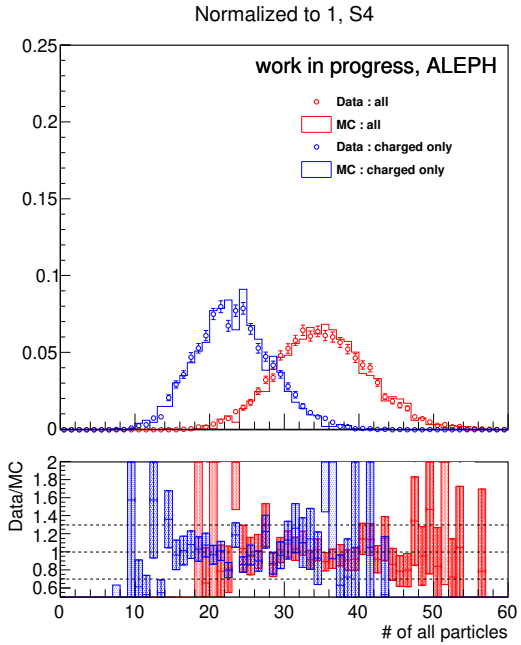
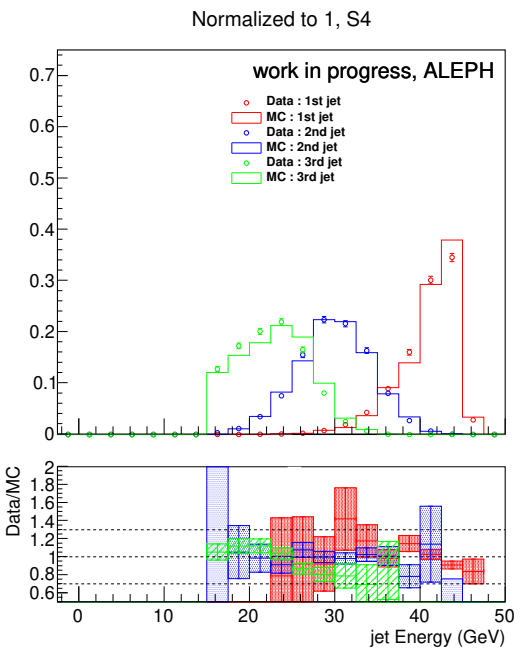
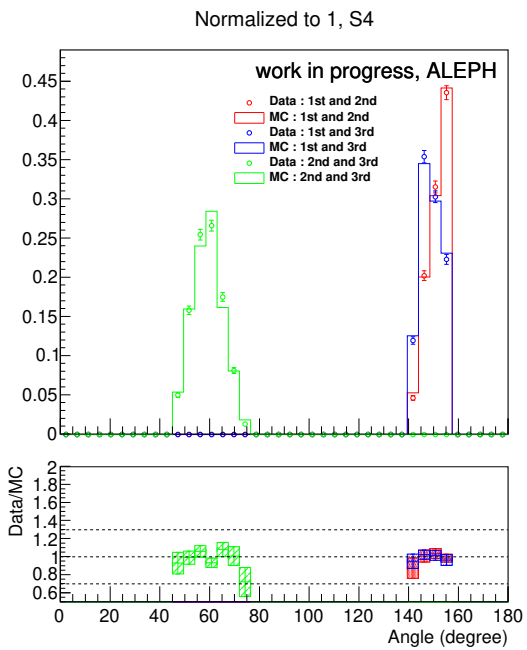
Event selection - S4









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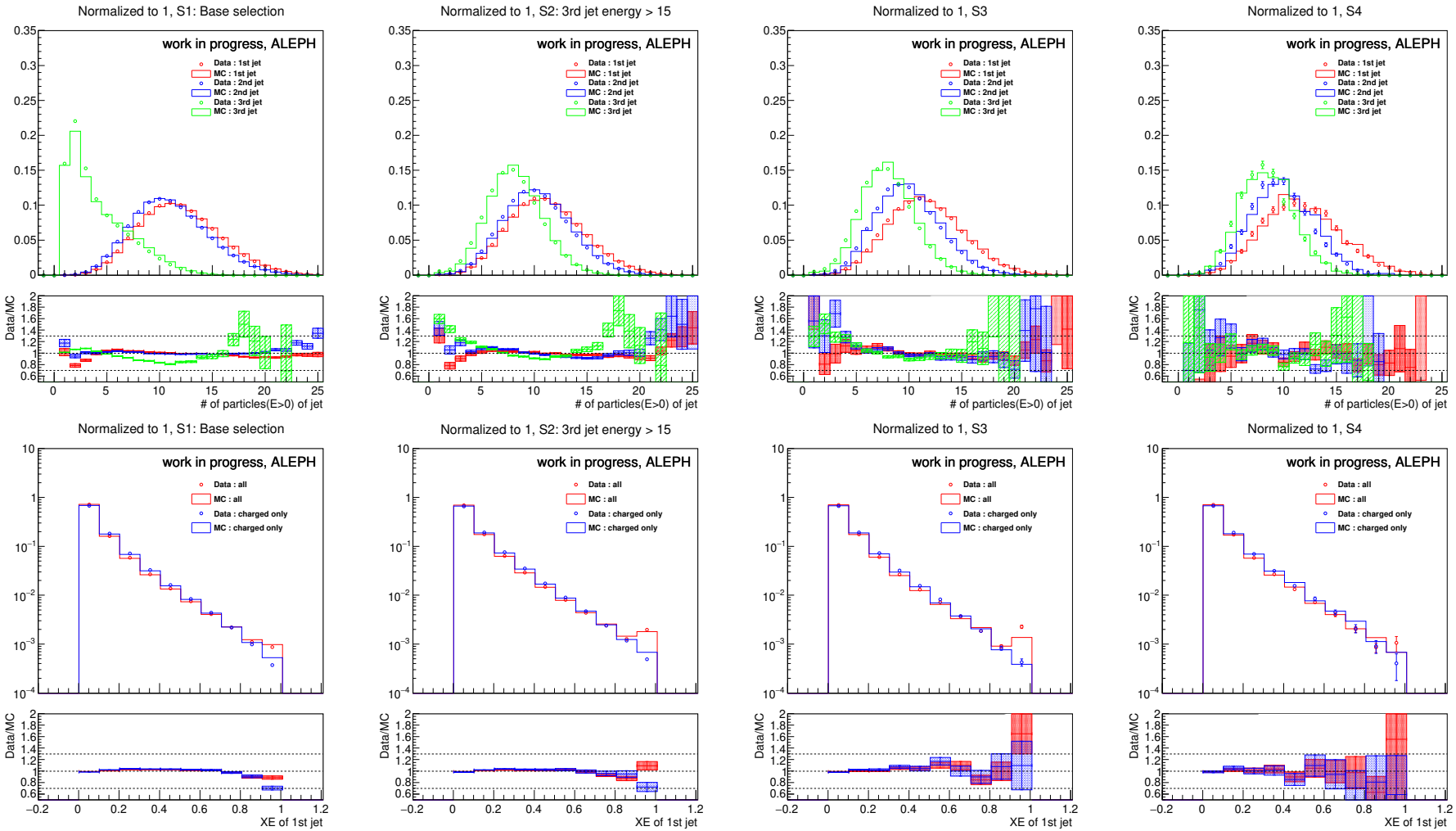
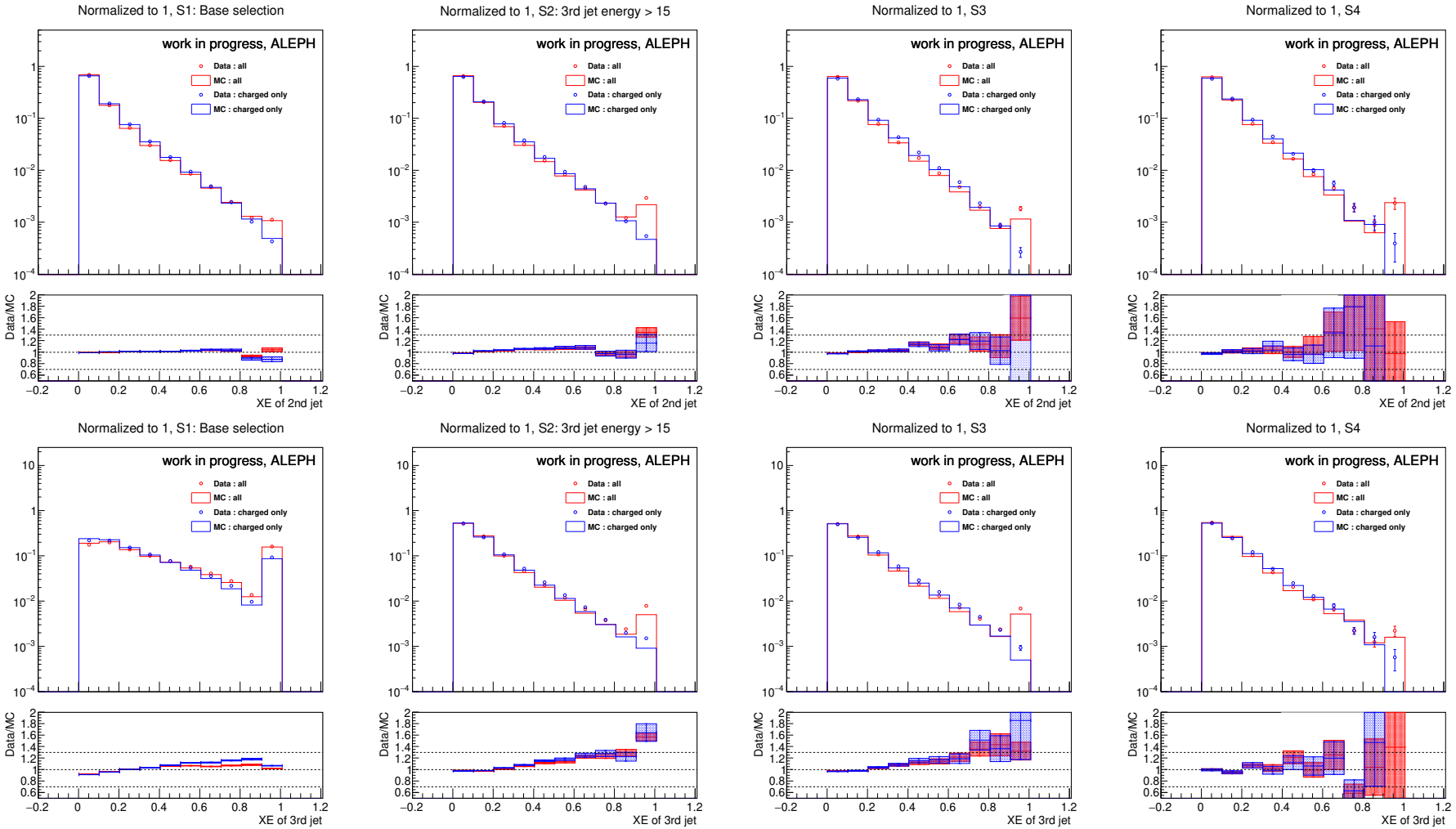
XE

XE for 1st jet



- (Top) number of particles of 1st/2nd/3rd jets
- (Bottom) our XE(fragmentation function) definition : e_i/E_{jet} within weight $1/N$(1 / number of particles)
  - Charged only case: weight $1/N_{charged}$ (1 / number of charged particles)

XE for 2nd and 3rd jet

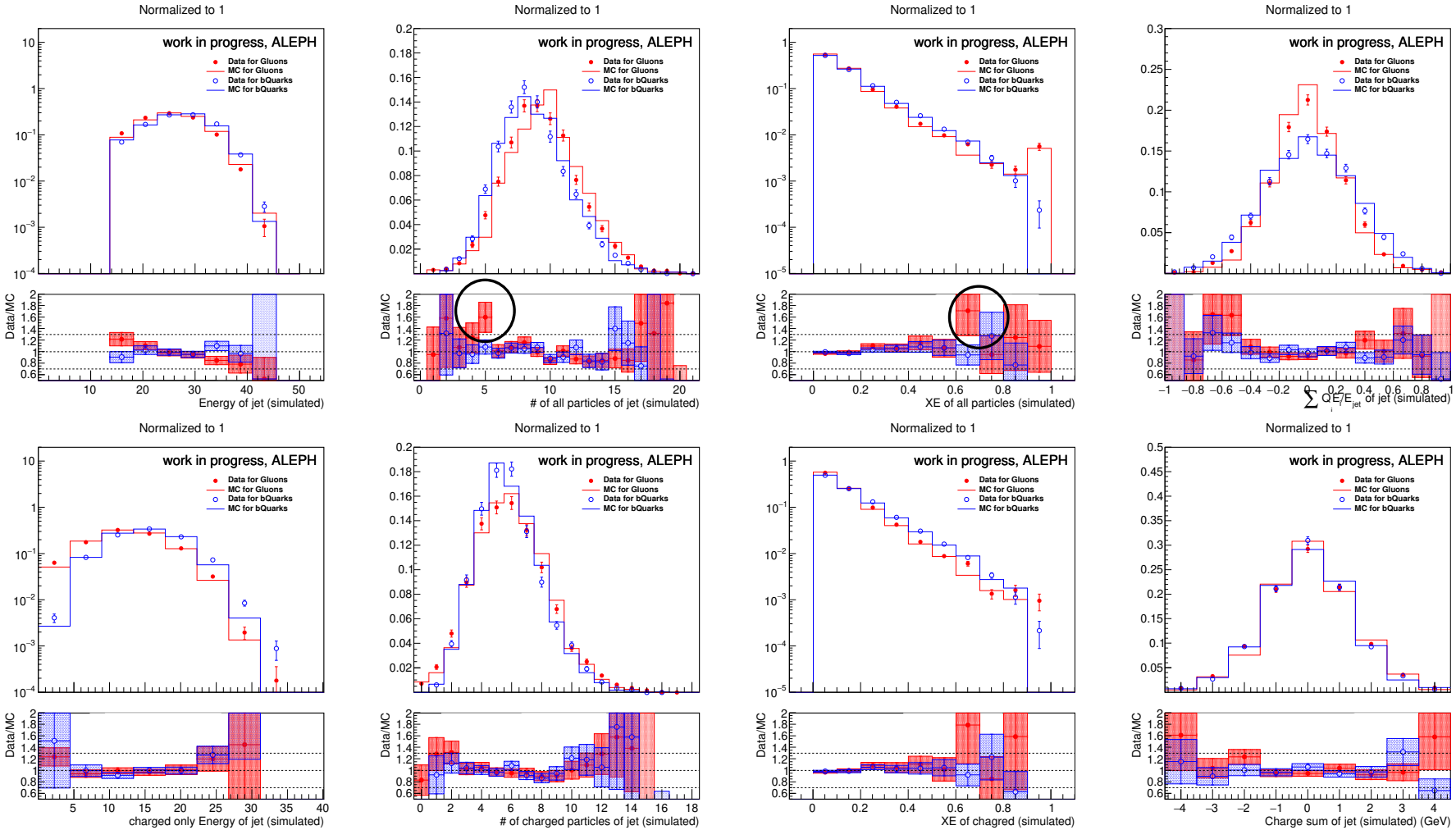


- (Top) XE for 2nd jet
- (Bottom) XE for 3rd jet

Result

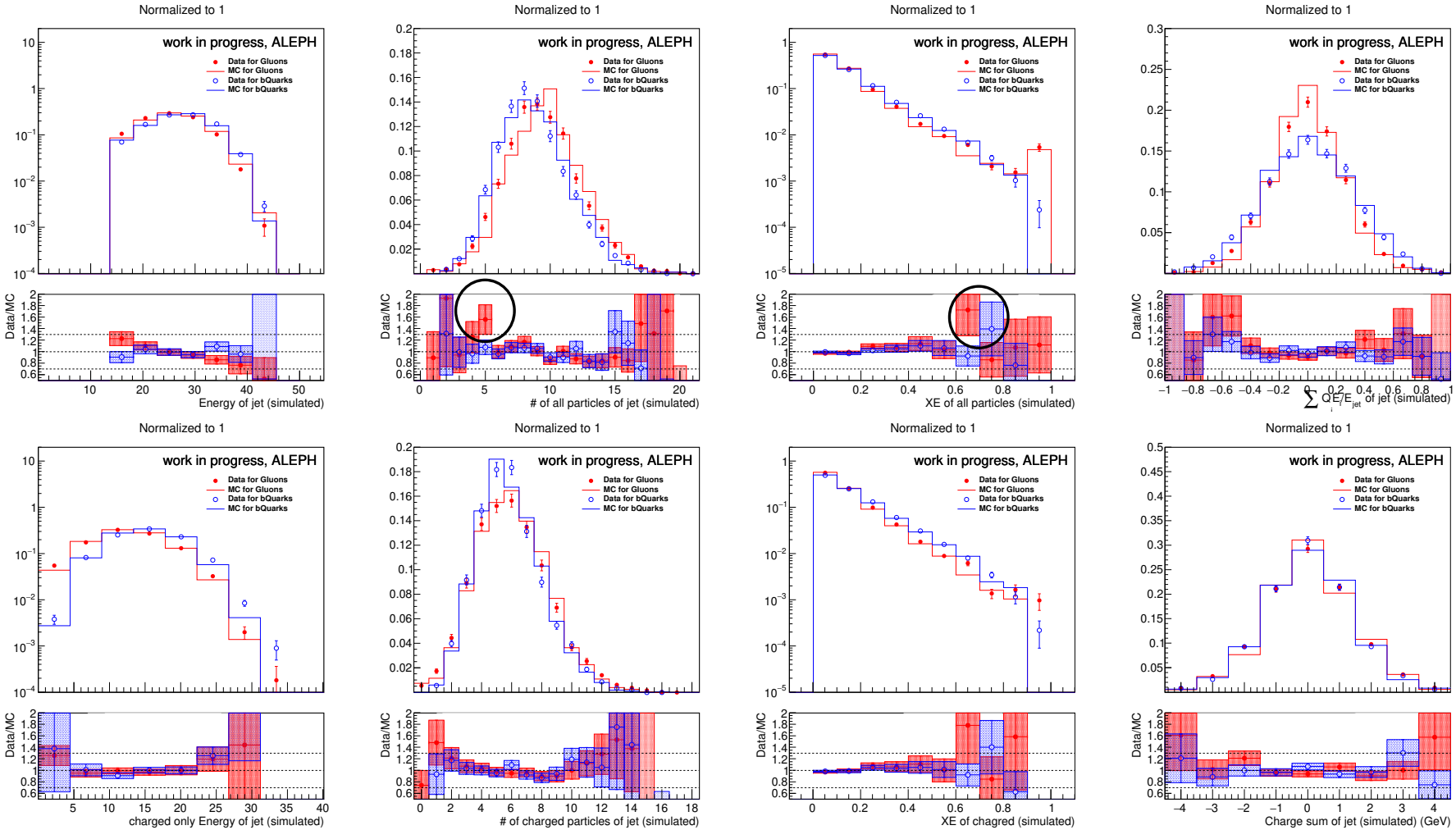
for gluon and bquark candidates

Event selection - S3



- Gluons: non-b-tagged jet between 2nd and 3rd jet
- bQuarks: b-tagged jet between 2nd and 3rd jet
- S3: only 1 b-tagged of 2nd, 3rd jet

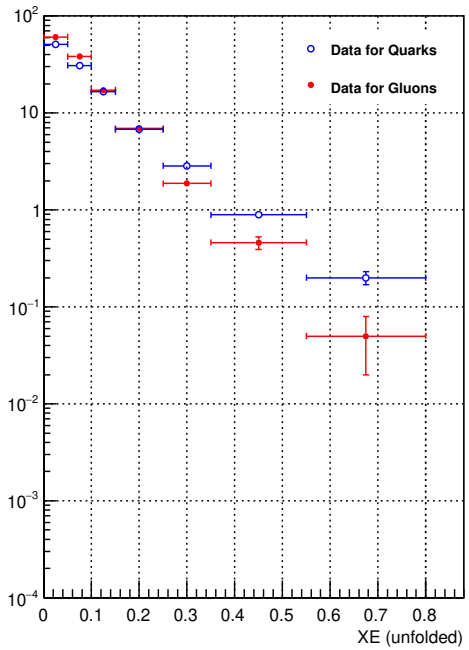
Event selection - S4



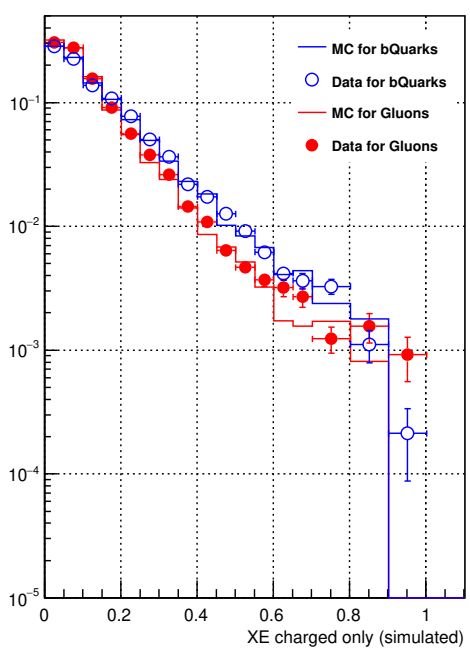
- Gluons: non-b-tagged jet between 2nd and 3rd jet
- bQuarks: b-tagged jet between 2nd and 3rd jet
- S4: requirements by angle range in $150 \pm 7.5^\circ$ between 1st jet and each 2nd or 3rd jet

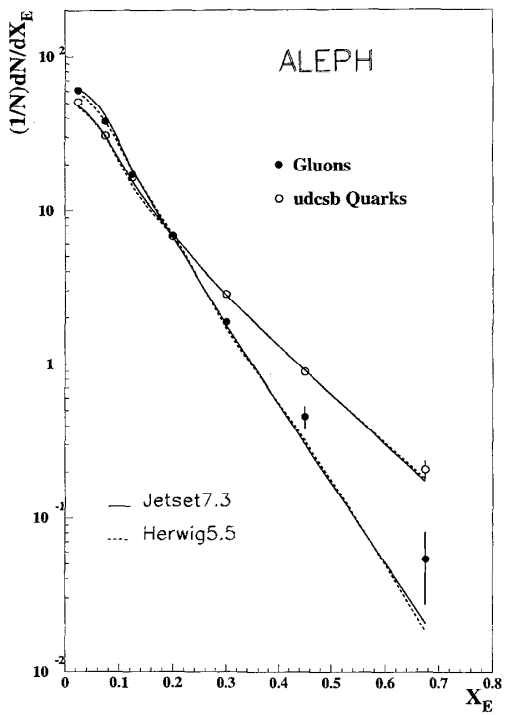
comparison with old paper

PLB-384(1996) 353



Our result, normalized to 1





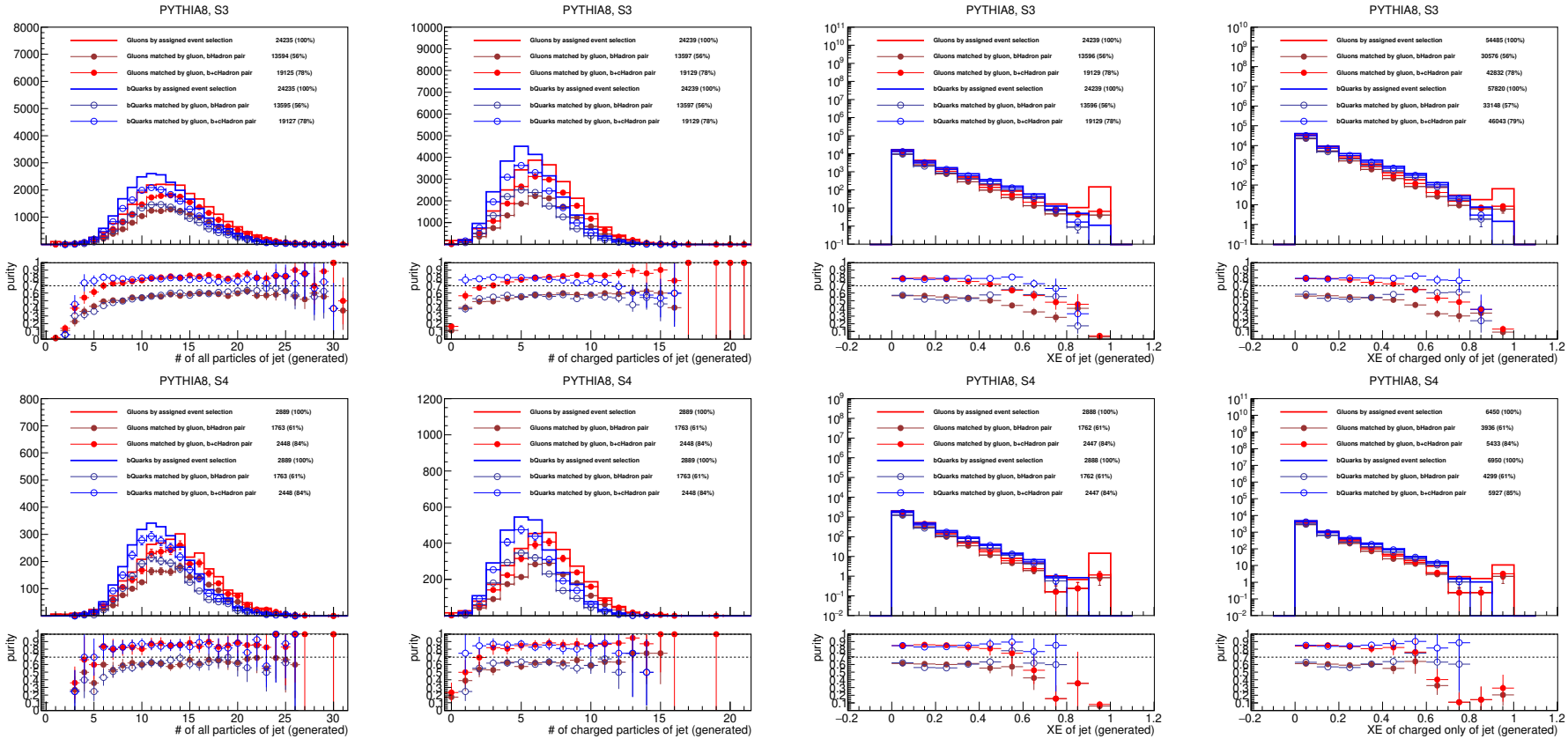
- Paper: Physics Letters B 384(1996), Page: 353 https://www.sciencedirect.com/science/article/abs/pii/0370269396008490
- Our XE(fragmentation function) definition : e_i/E_{jet} within weight $1/N_{charged}$(1 / number of charged particles)
- Our event selection: S4(angle cut)

purity study in generated level

signal definition for purity

- jet matching with gluon
  - $\Delta R < 0.65$ between jet and gluon
  - closest gluon first from Z decay
- jet b or c hadron matching
  - b or c hadron(ghost as energy $\rightarrow 0$) in jet reconstruction input
- signal categorization
  - gluon jet
    - jet matched with gluon and the gluon energy $>$ 15 GeV
    - in pair(2nd and 3rd jets), the other's jet within b hadron or c hadron
  - b or b+c jet
    - jet within b hadron or c hadron
    - in pair, the other's jet matched with gluon and the gluon energy $>$ 15 GeV

Purity



- Gluons: non-b-tagged jet between 2nd and 3rd jet
- bQuarks: b-tagged jet between 2nd and 3rd jet
- (Top) S3, (Bottom) S4

Summary

- We studied Gluon/bQuark properties by using ALEPH Data and MC Sample.
- XE distribution are similar with previous paper.
- For gluon candidates, we can see some difference between MC and Data in XE and number of particles's distributions.
- Roughly, we also checked the signal purity by using individual MC Sample(PYTHIA8).