Measurements of jet rates with the anti-k_t and SISCone algorithms at LEP with the OPAL detector

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1 Introduction
2 Analysis
3 Results
4 Conclusions

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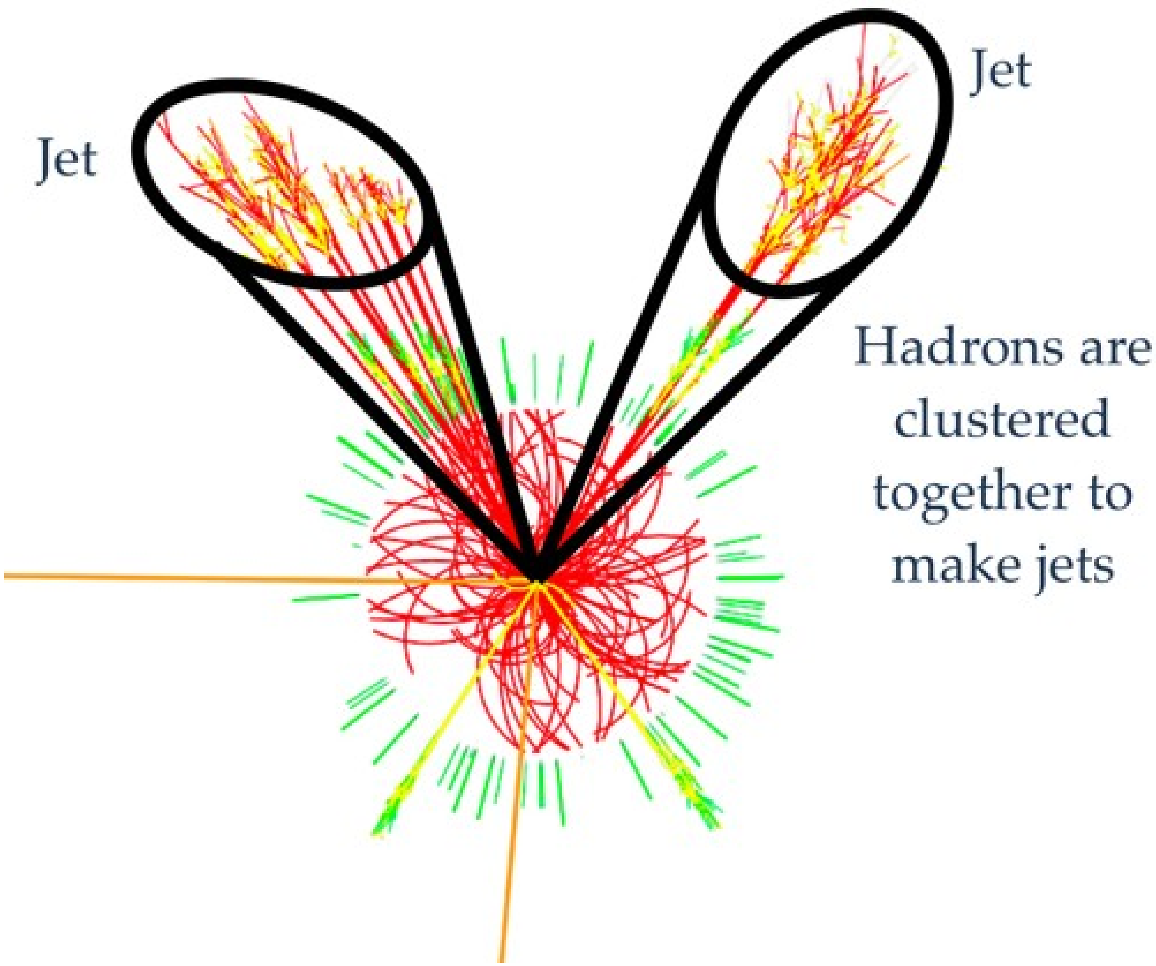
1 Introduction



[quantumdiaries.org]

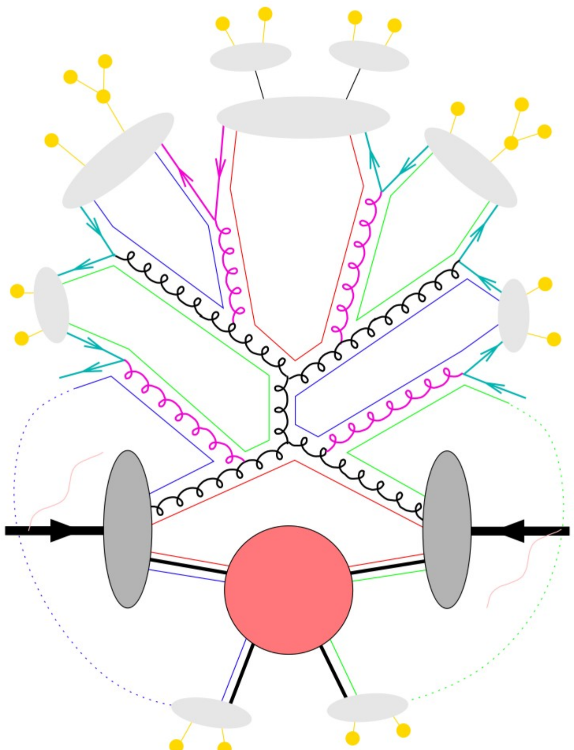
At LHC jets essential to understand and interpret final states

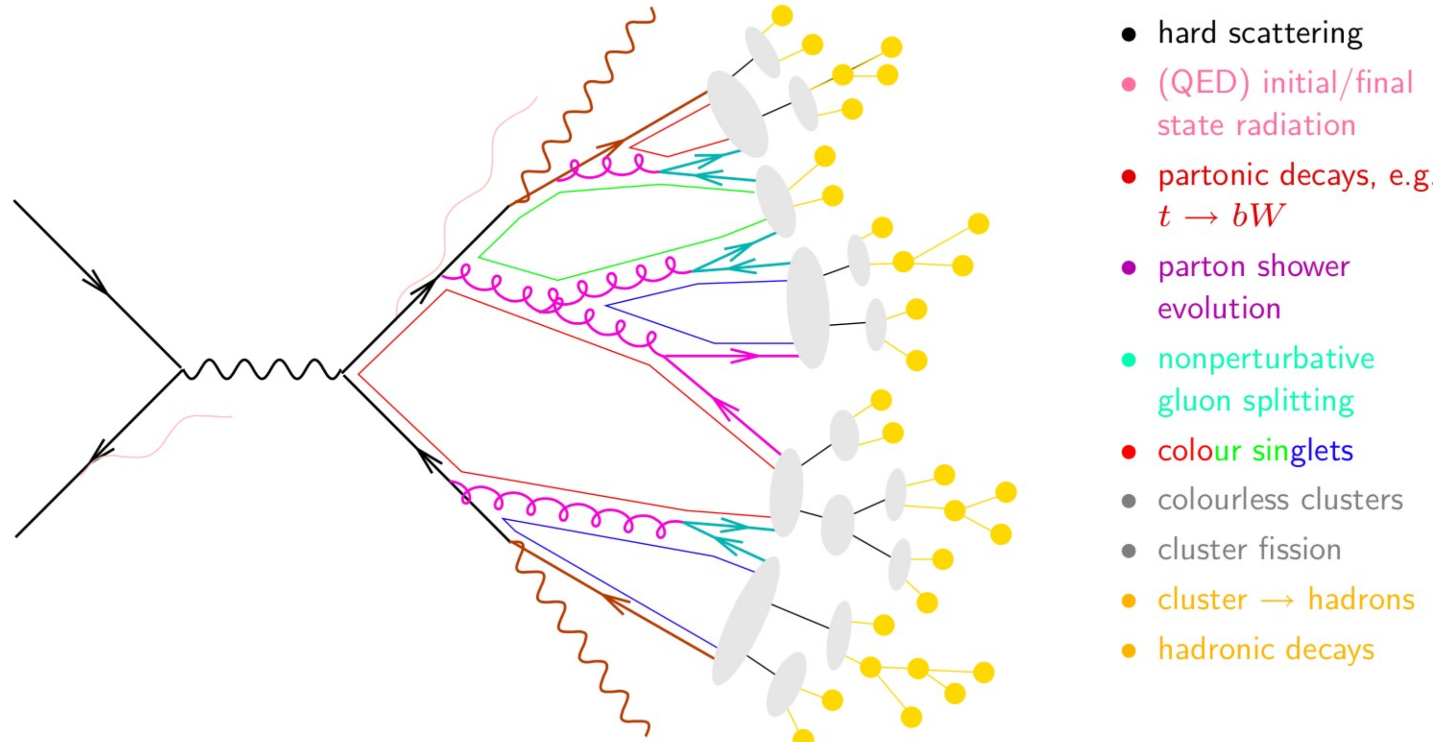
Close correspondence jets – partons of QCD

Many new algorithms since LEP, some now standard at LHC: anti-k_t, SISCone

Never tested in e^+e^- collisions

1 Hard interaction → final state





Physics of transition from hard interaction to final state is universal, QCD + had. model
In e^+e^- no (QCD) ISR, color singlet, ideal to study jet physics

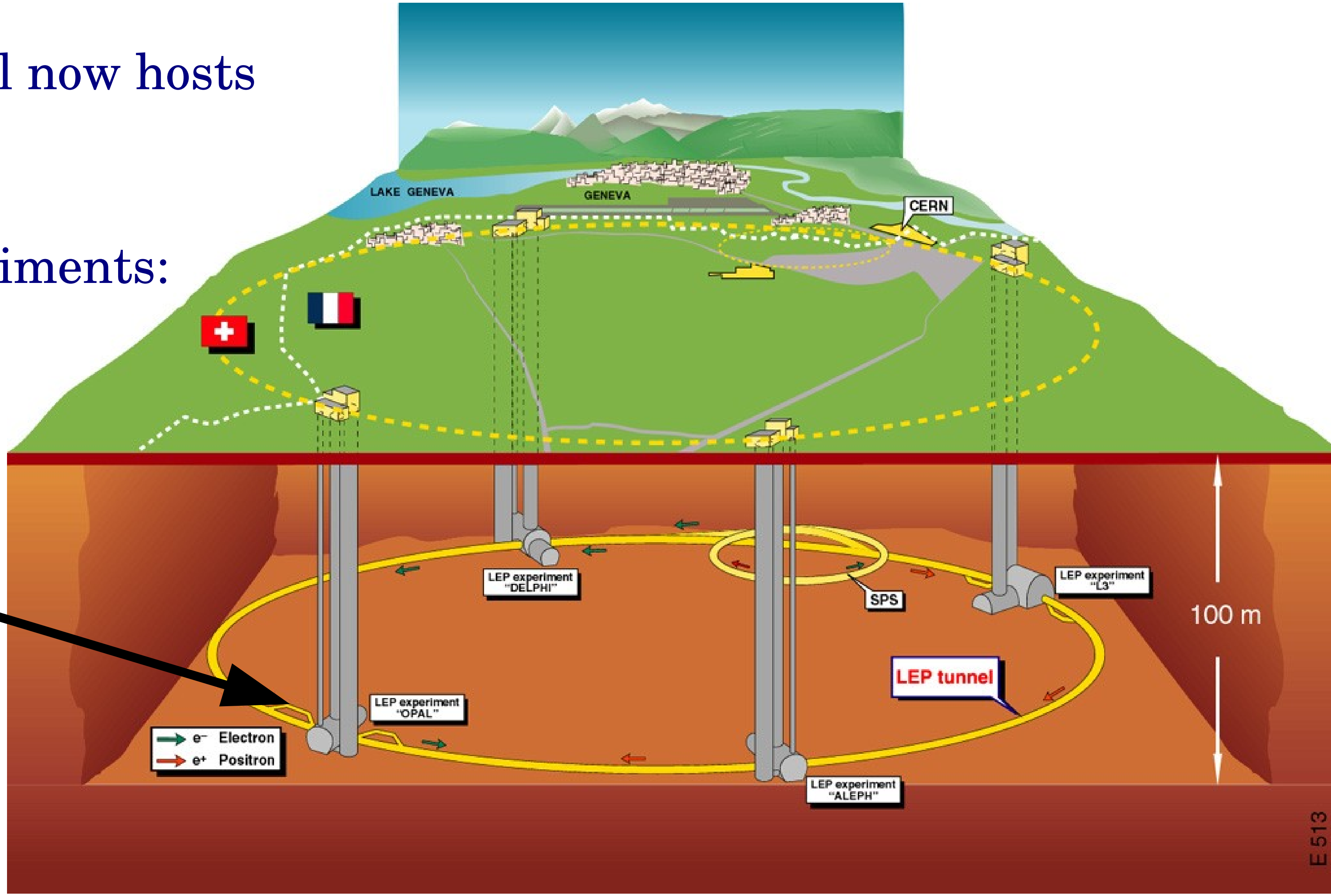
[quantumdiaries.org]

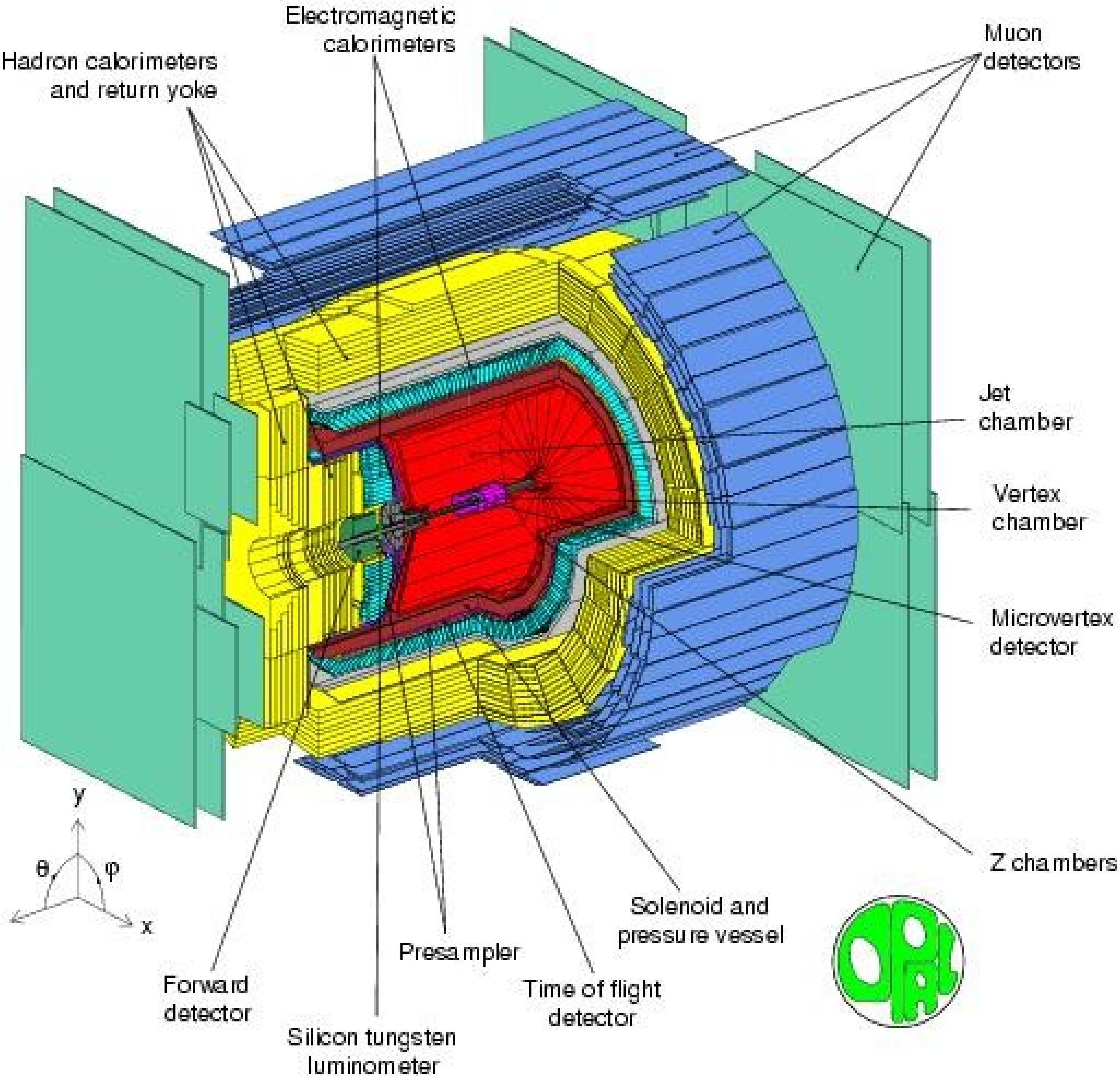
1 LEP @ CERN

1989 – 2000

LEP tunnel now hosts LHC

Four experiments:
ALEPH
DELPHI
L3
OPAL





1 OPAL at LEP

Omni-Purpose Apparatus at LEP

1989 - 2000

Almost 4π coverage

Good momentum and energy resolution

1 OPAL Data and Monte Carlo

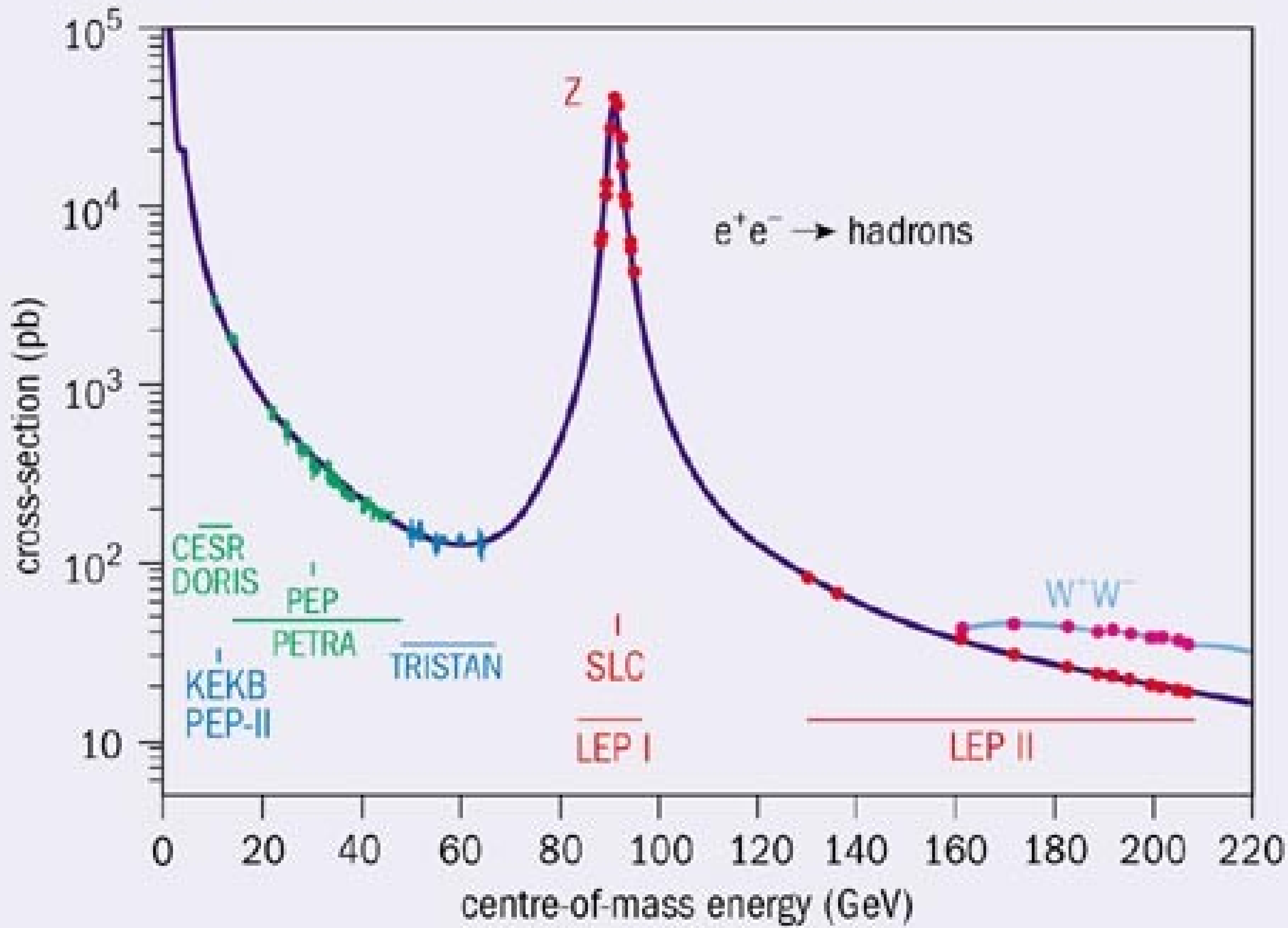
Data sets

Year	Range of $\sqrt{s}$ (GeV)	Mean $\sqrt{s}$ (GeV)	Integrated luminosity (pb^{-1})	Number of selected events	Expected number
1996–2000	91.0 – 91.5	91.3	14.7	395695	—
1995, 1997	129.9 – 136.3	133.1	11.26	630	698
1996	161.2 – 161.6	161.3	10.06	281	275
1996	170.2 – 172.5	172.1	10.38	218	232
1997	180.8 – 184.2	182.7	57.72	1077	1084
1998	188.3 – 189.1	188.6	185.2	3086	3130
1999	191.4 – 192.1	191.6	29.53	514	473
1999	195.4 – 196.1	195.5	76.67	1137	1161
1999, 2000	199.1 – 200.2	199.5	79.27	1090	1131
1999, 2000	201.3 – 202.1	201.6	37.75	519	527
2000	202.5 – 205.5	204.9	82.01	1130	1090
2000	205.5 – 208.9	206.6	138.8	1717	1804

Physics (and detector) simulation with KK2f and PYTHIA 6 or HERWIG 6 for parton shower and hadronisation

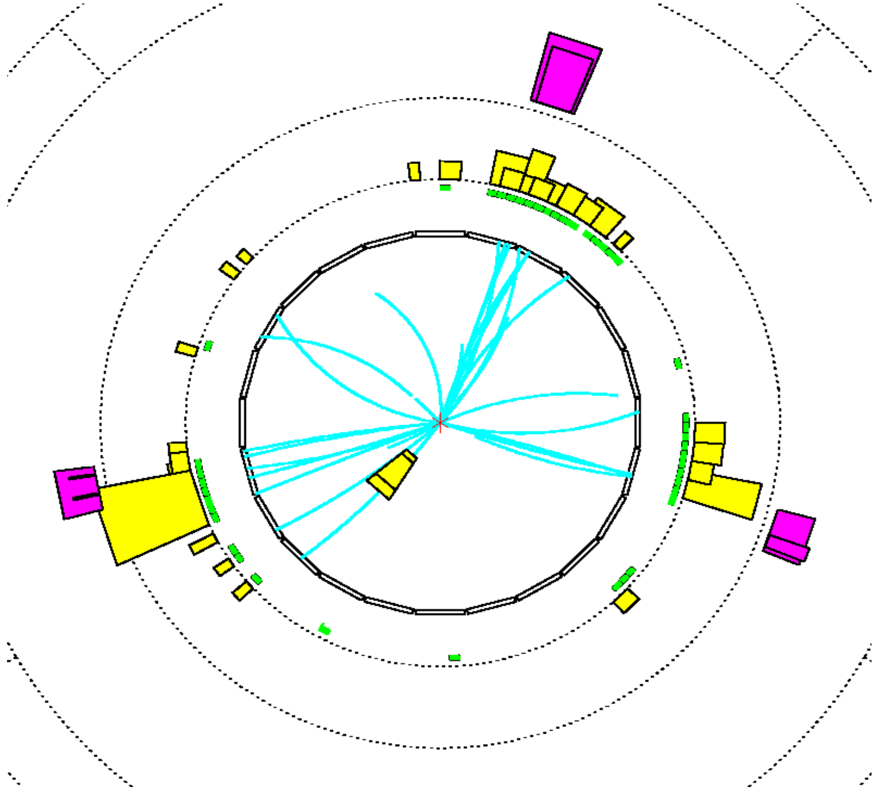
EW MCs (grc4f, KORALW) for W pair production and other bkgs

1 Cross section $e^+e^- \to$ hadrons



[CERN Courier 2004]

1 Jet algorithms



Anti-k_t: phase space distances

$d_{ij} = \min(E_i^{-2}, E_j^{-2})\,(1-\cos\theta_{ij}) / (1-\cos R)$

$d_{i,B} = E_i^{-2}$

If d_{ij} smallest combine i and j,

else if $d_{i,B}$ i is "inclusive jet"

SISCone (for e^+e^- in θ-ϕ space): stable cone when (θ_c, ϕ_c) of cone equal to (θ, ϕ) of sum of momenta in cone of radius R

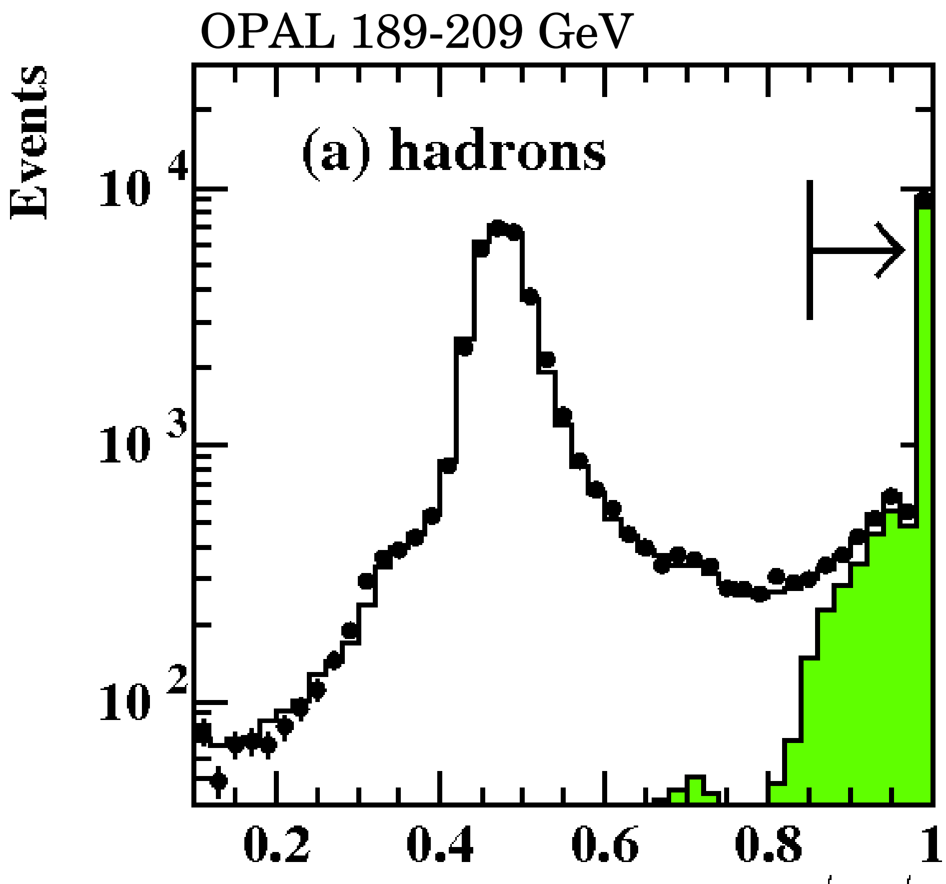
Split/merge: merge stable cones if shared momentum sum > cut

Eur.Phys.J. C71 (2011) 1565, Erratum: ibid 1717

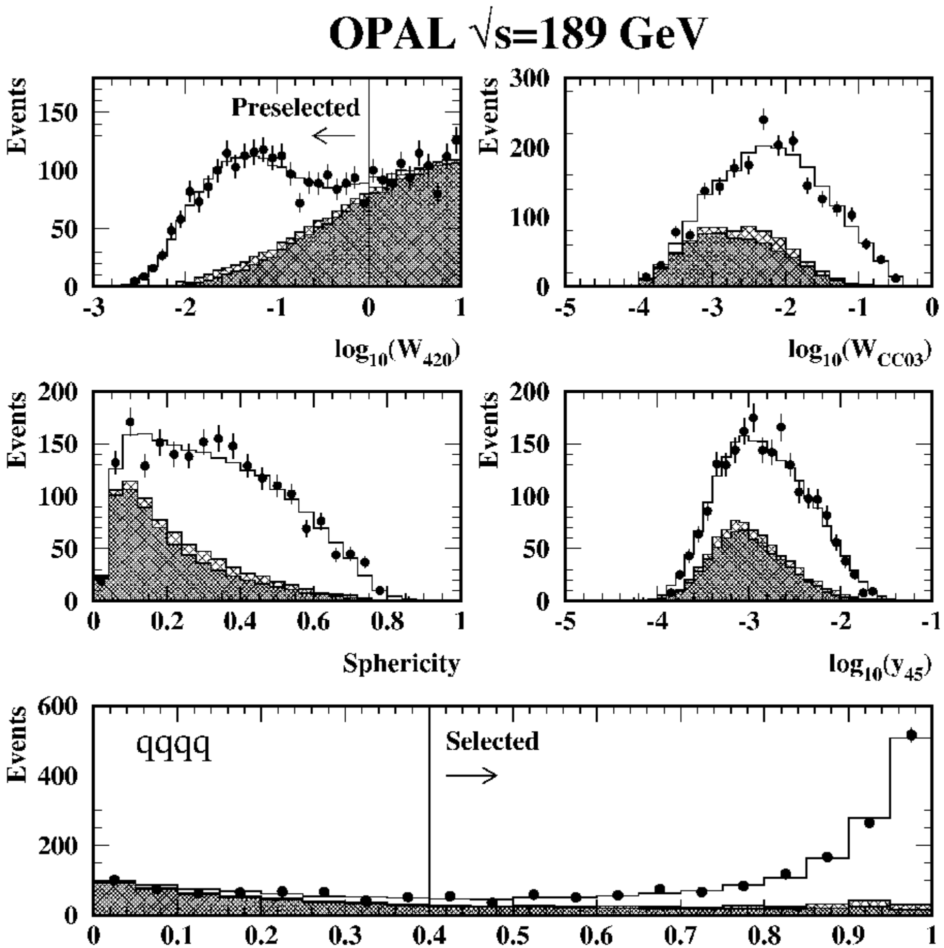
Use transformation $y = 1 - \cos(R)$ and cut $E_{min} / E_{vis} = \varepsilon = 0.077$ or fixed $R = 0.36$ for anti-k_t and SISCone

In addition: traditional e^+e^- Durham (k_t) algorithm

2 Event selection



[Eur.Phys.J.C33(2004)173]

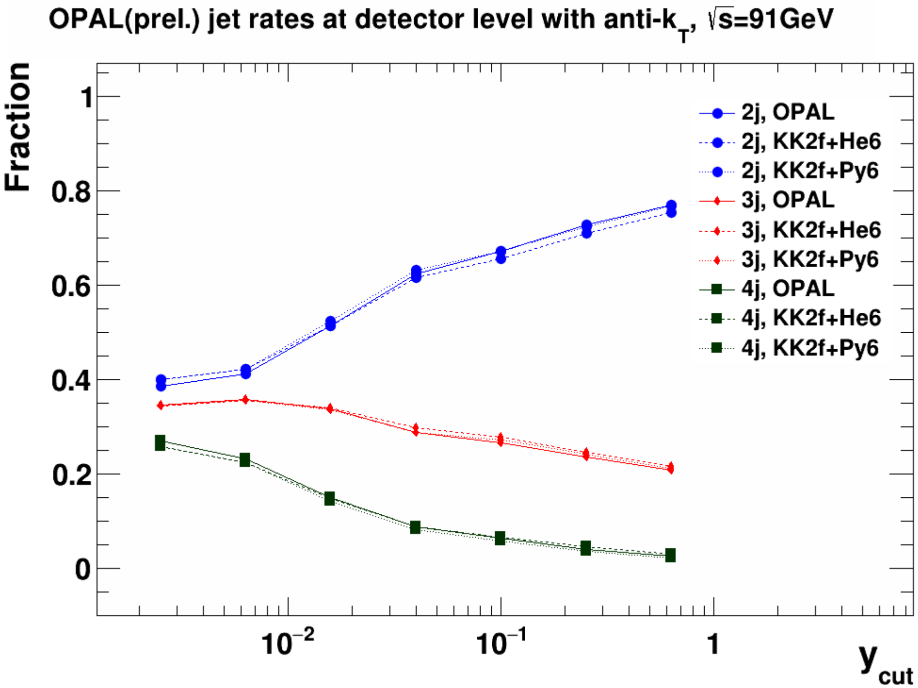


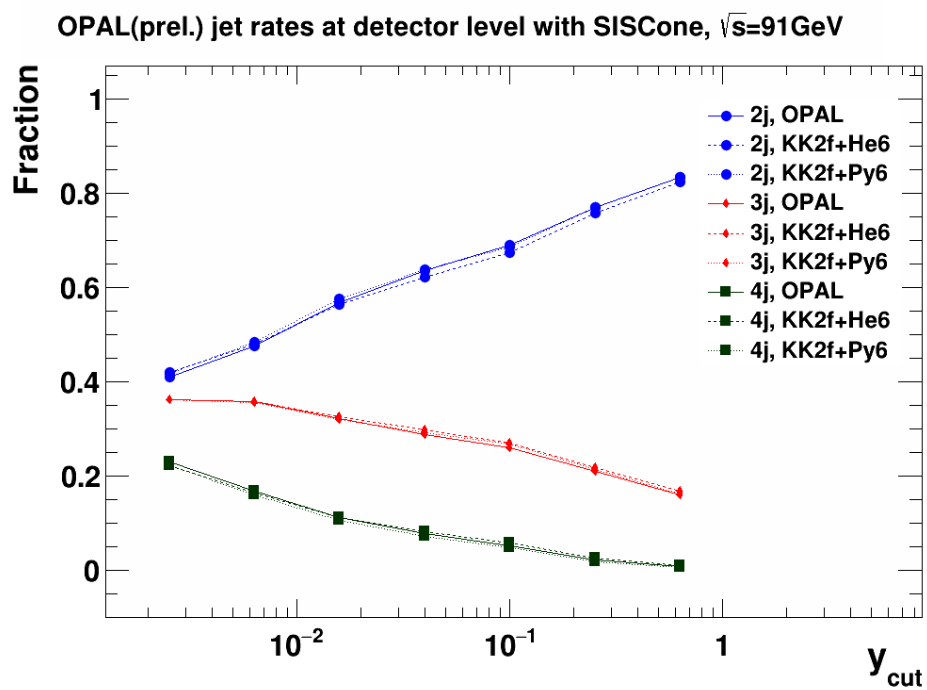
[Phys.Lett.B493(2000)249]

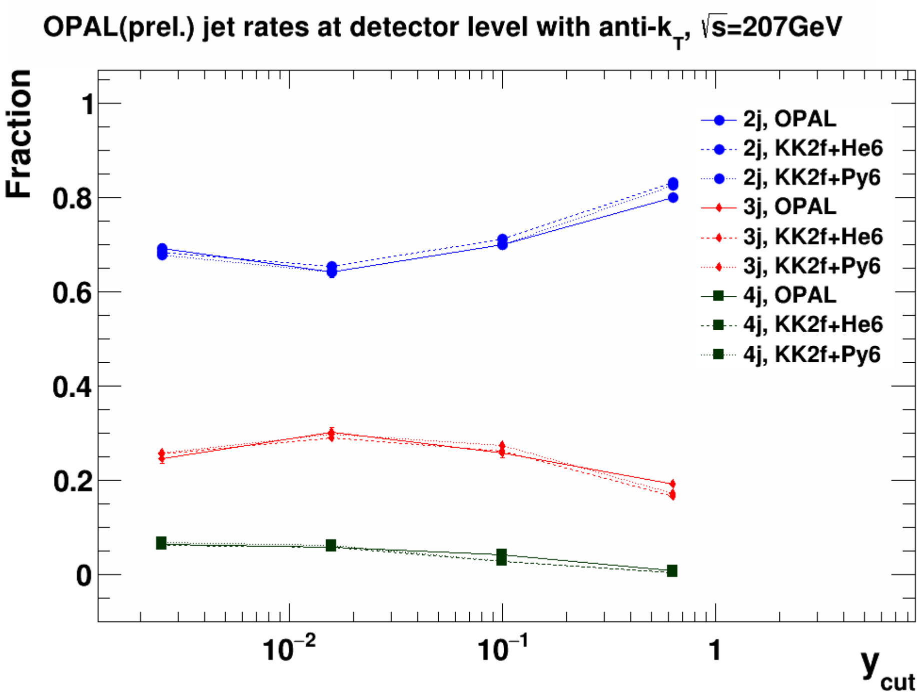
Find isolated γ, force 4 jets, kin. fit constrained to √s for jets and possible missing $p_{z,\gamma}$

Likelihood from 4 inputs to suppress W pairs

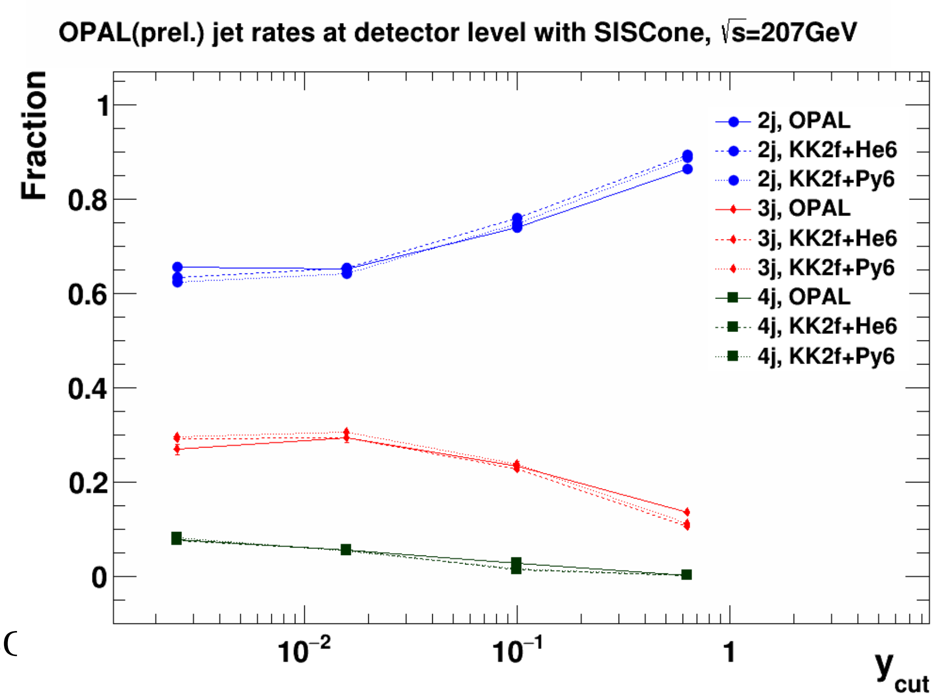
2 Data vs old OPAL MC det. level



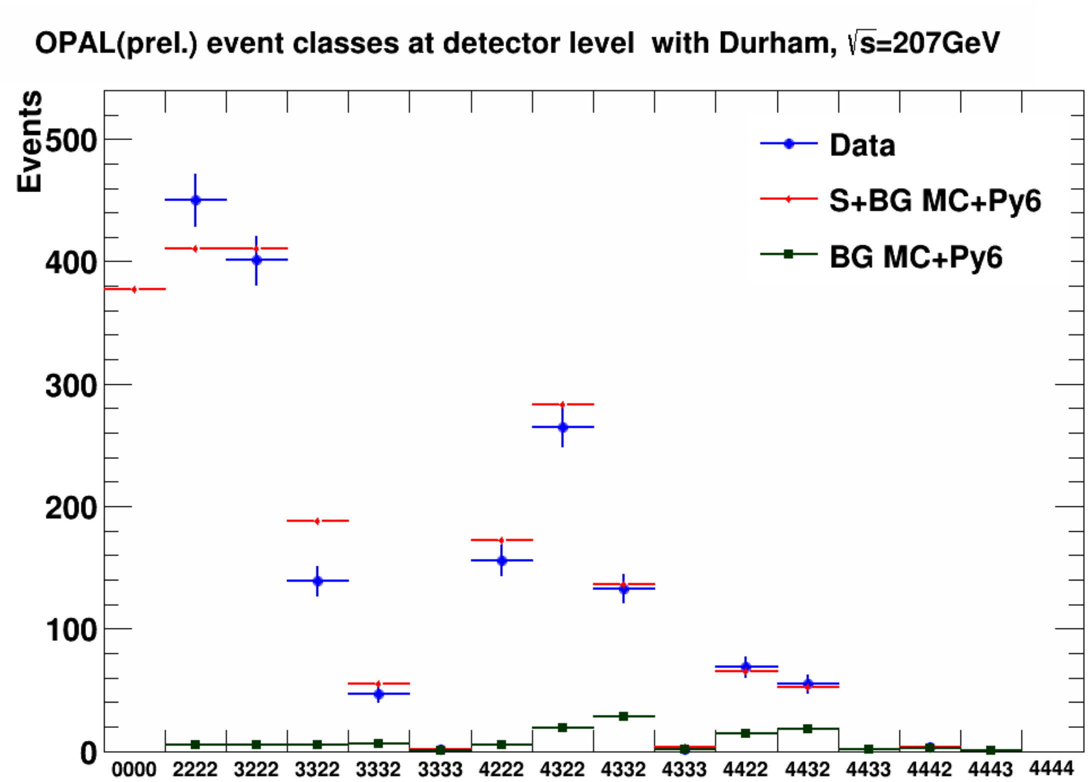




d SISC

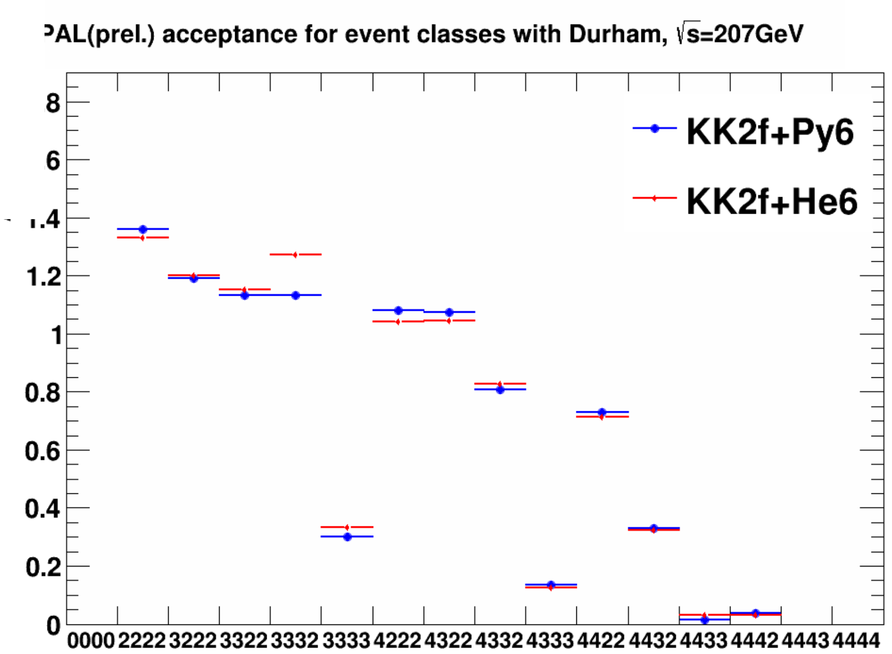


2 Event classification



Classify events by jet topology evolution, e.g. with 4 y (or R) points can have sequence 4322

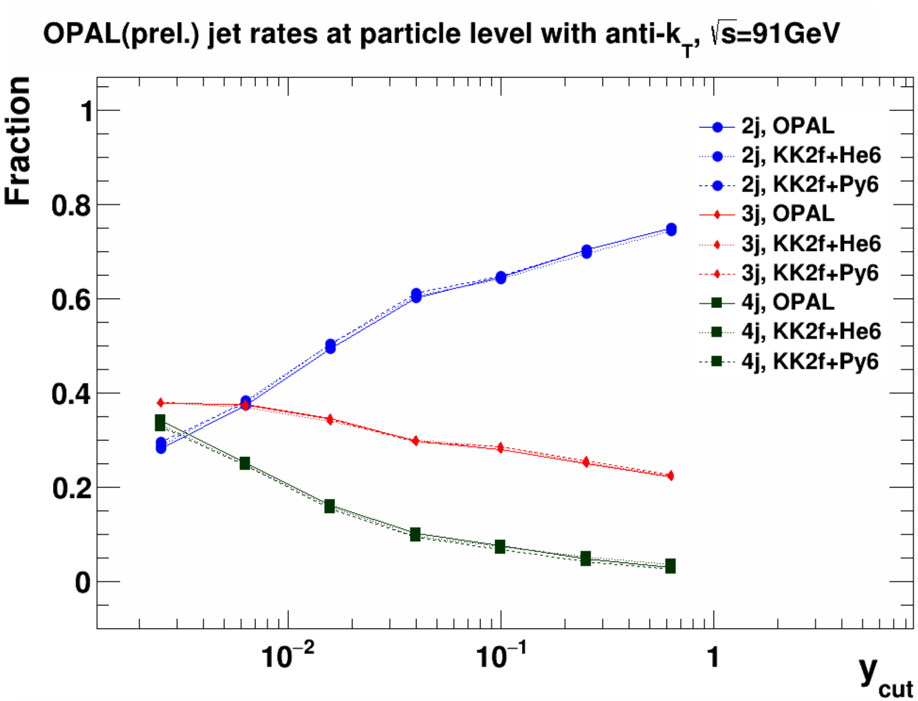
Background concentrates in classes with many (4) jets at large y (or R) due to W pairs

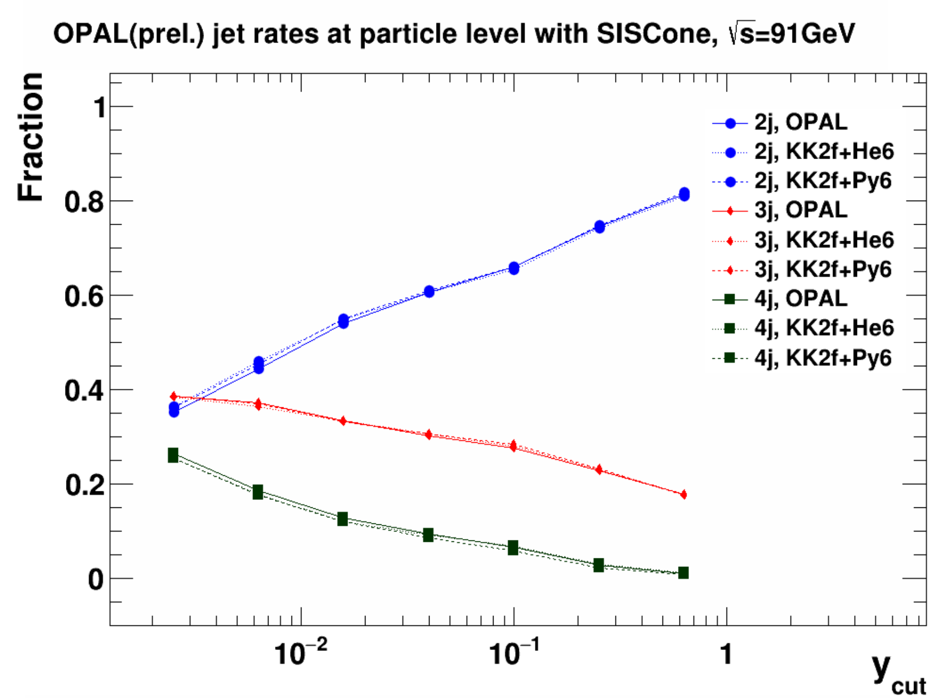


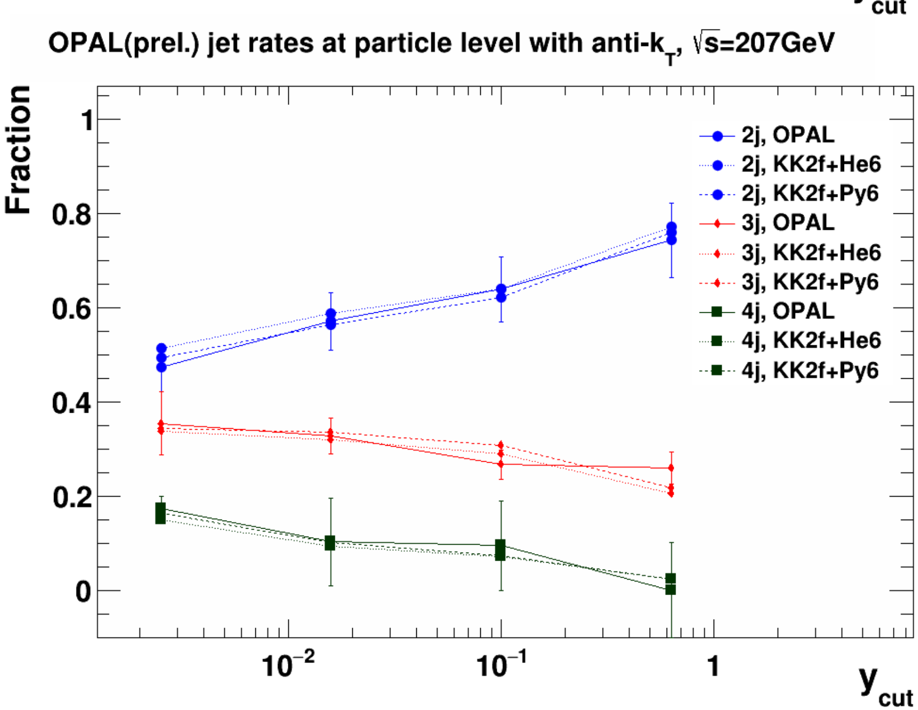
e.g. $R_3(y_2) = 1/N \sum_{ijkl,j=2} n_{ijkl}$

Exp. corrections for each event class → similar bkg and topology

2 Data vs old OPAL MC had. level







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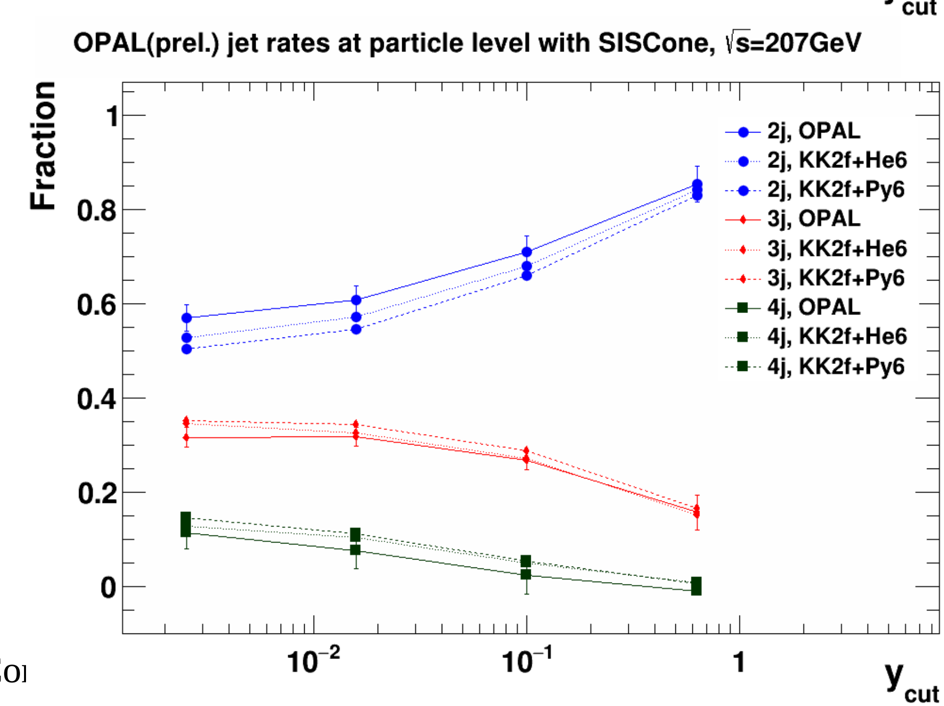
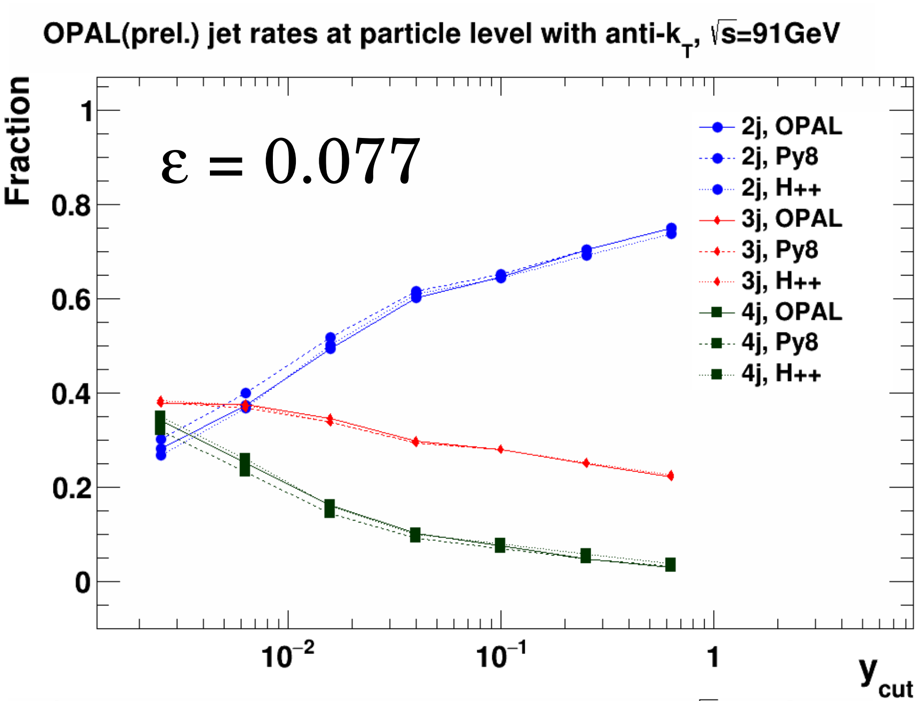
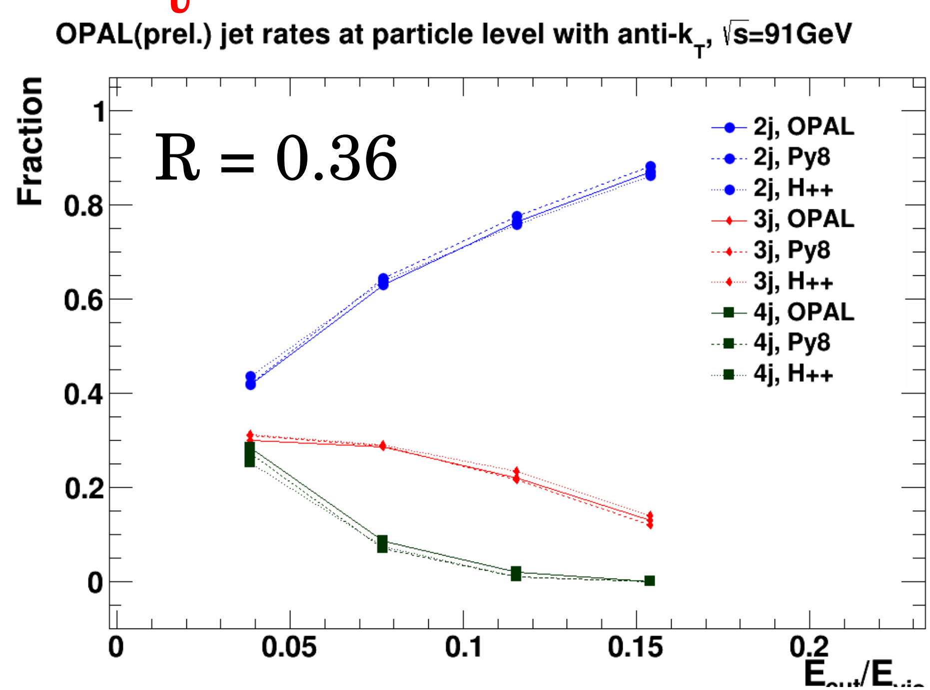


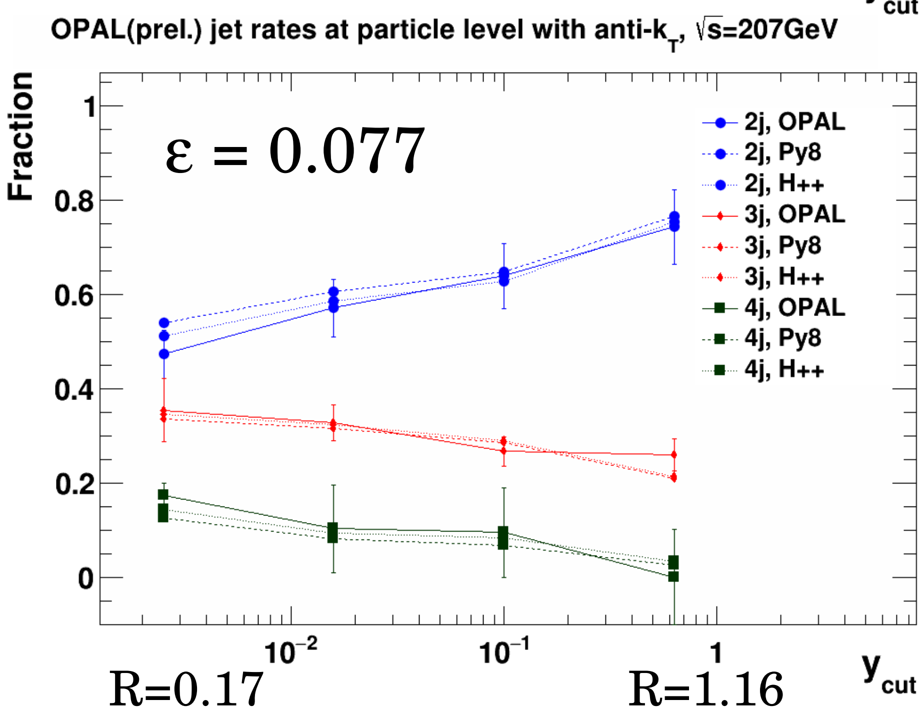
3 New jet algorithms vs new MCs

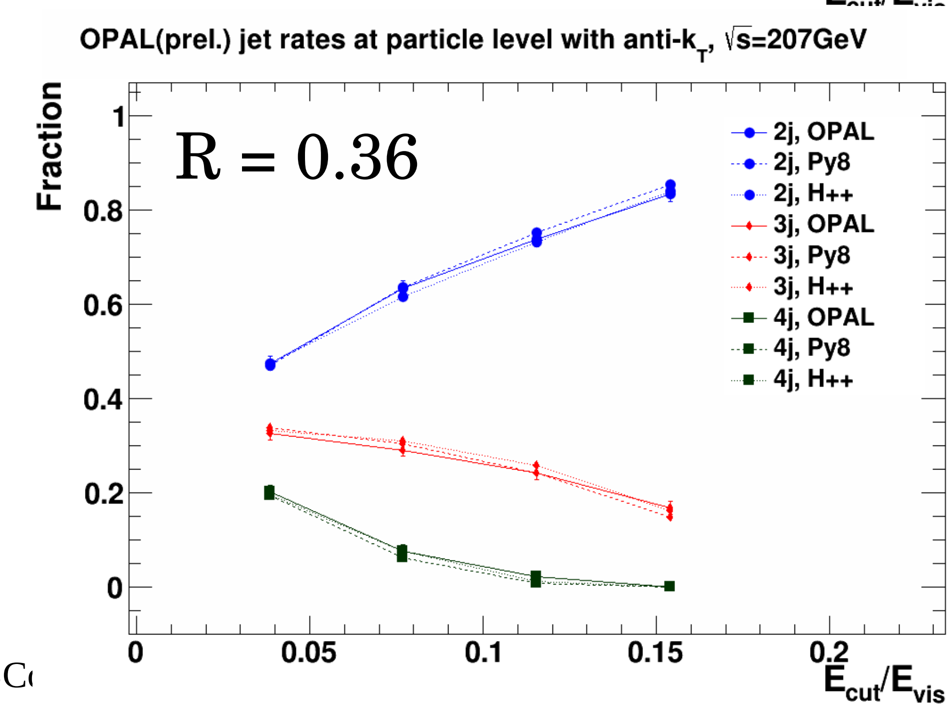
- OPAL MCs ~20 years old, but well tuned to LEP data
  - LO+NLL parton shower
- Pythia 8 and Herwig++ represent new MCs
  - Improved parton shower algorithms
  - Possible to use NLO (not yet in this analysis)
- Compare data to new MCs with their standard settings
  - Basis for hadronisation corrections

3 anti-k_t

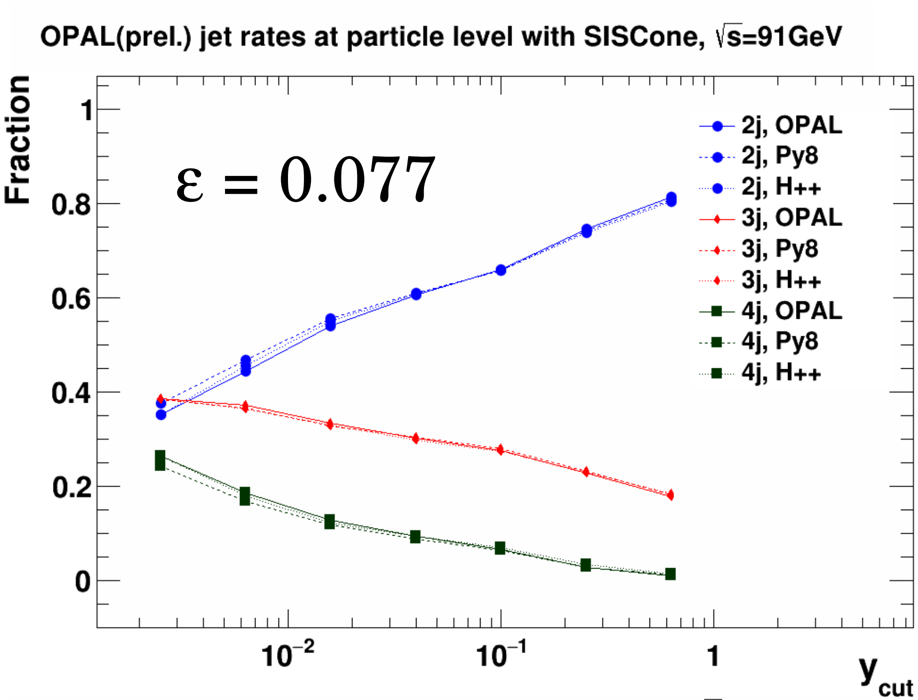

OPAL(prel.) jet rates at particle level with anti-k_T, √s=91GeV
ε = 0.077
Fraction
y_cut
2j, OPAL
2j, Py8
2j, H++
3j, OPAL
3j, Py8
3j, H++
4j, OPAL
4j, Py8
4j, H++

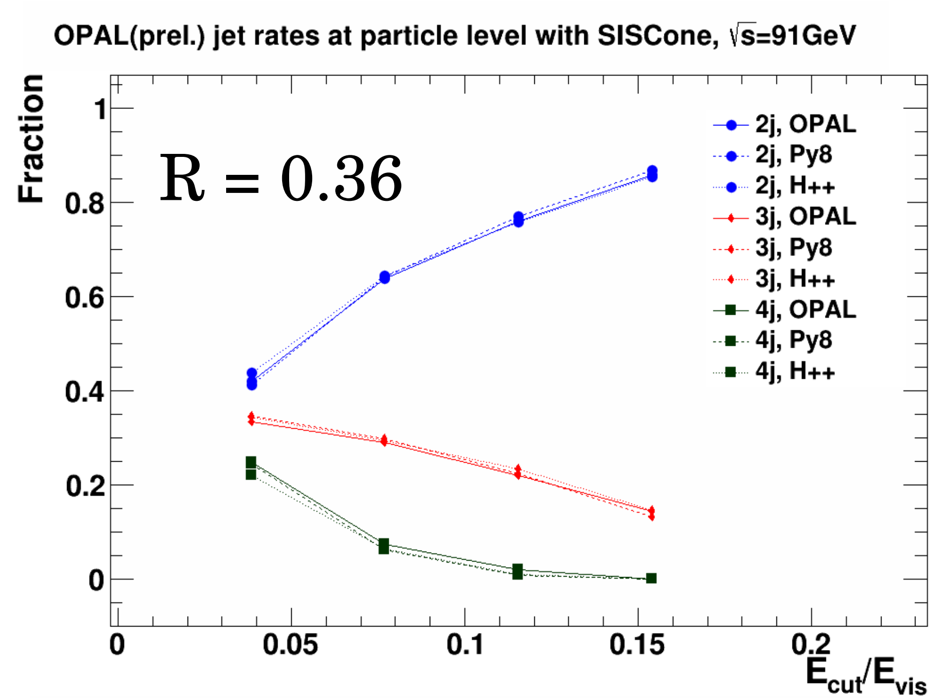

OPAL(prel.) jet rates at particle level with anti-k_T, √s=91GeV
R = 0.36
Fraction
E_cut/E_vis
2j, OPAL
2j, Py8
2j, H++
3j, OPAL
3j, Py8
3j, H++
4j, OPAL
4j, Py8
4j, H++

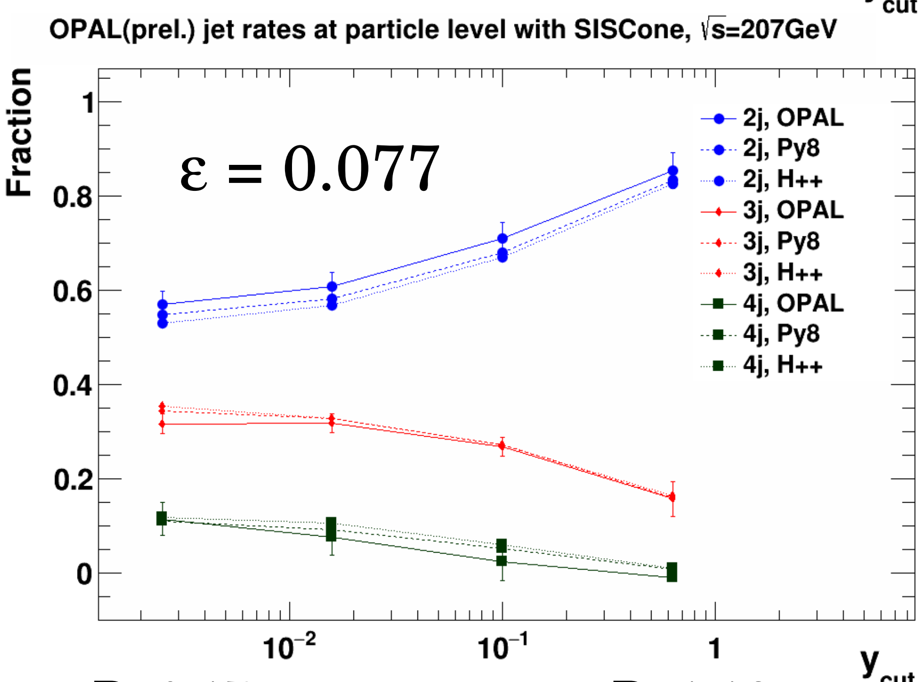

OPAL(prel.) jet rates at particle level with anti-k_T, √s=207GeV
ε = 0.077
Fraction
y_cut
2j, OPAL
2j, Py8
2j, H++
3j, OPAL
3j, Py8
3j, H++
4j, OPAL
4j, Py8
4j, H++
R=0.17
R=1.16

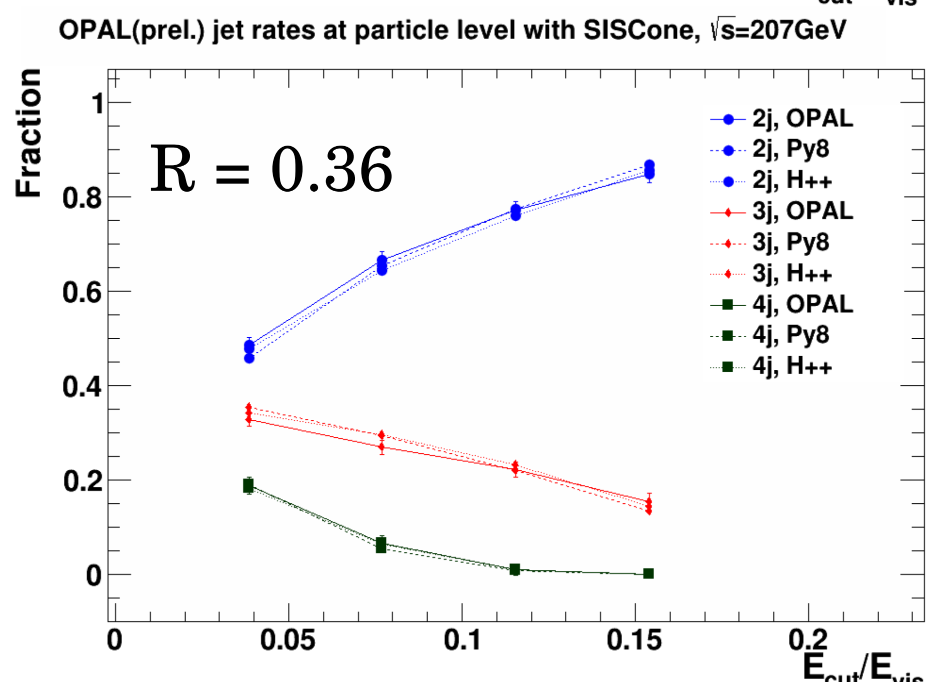

OPAL(prel.) jet rates at particle level with anti-k_T, √s=207GeV
R = 0.36
Fraction
E_cut/E_vis
2j, OPAL
2j, Py8
2j, H++
3j, OPAL
3j, Py8
3j, H++
4j, OPAL
4j, Py8
4j, H++

3 SISCone



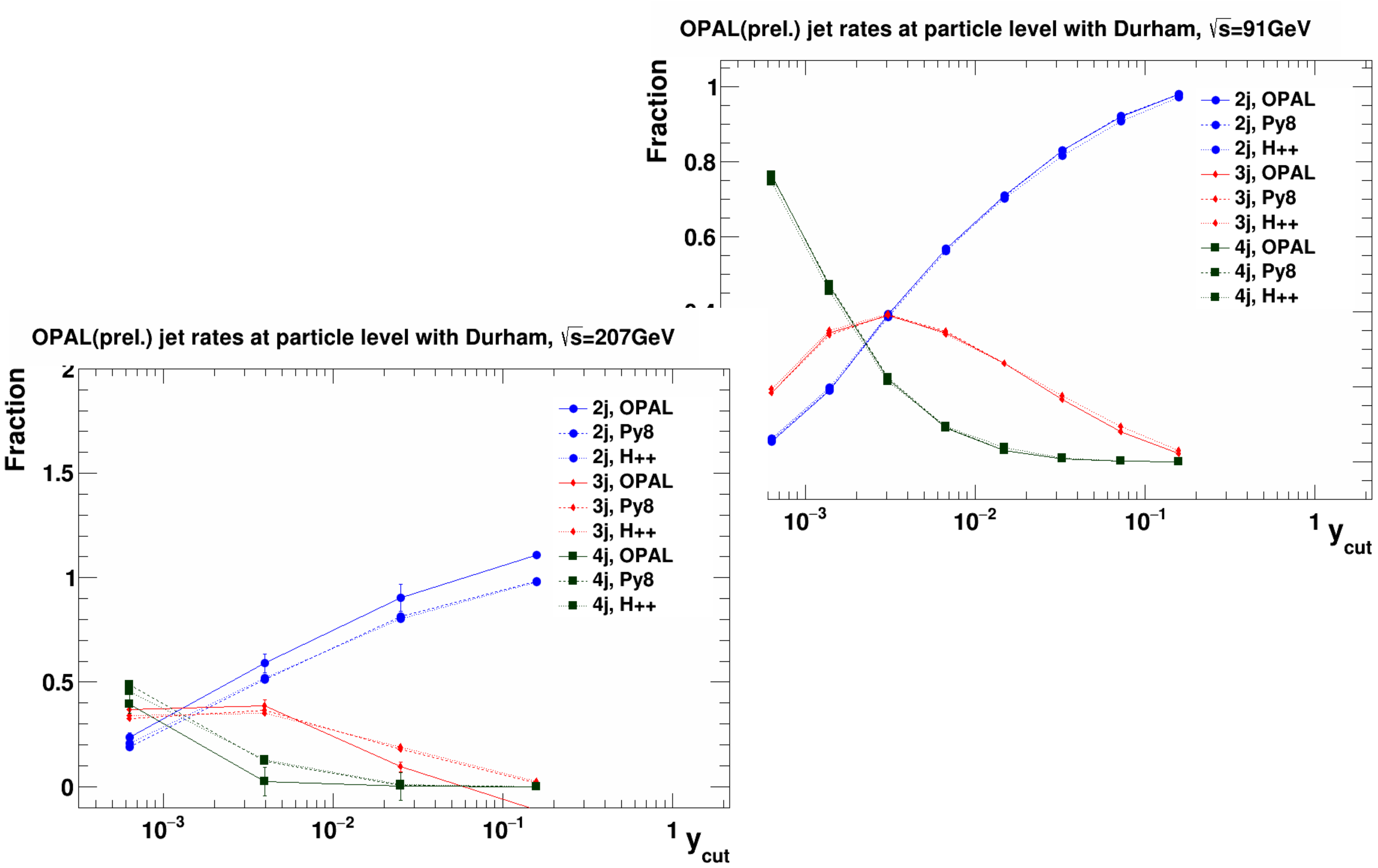






R=0.17 R=1.16

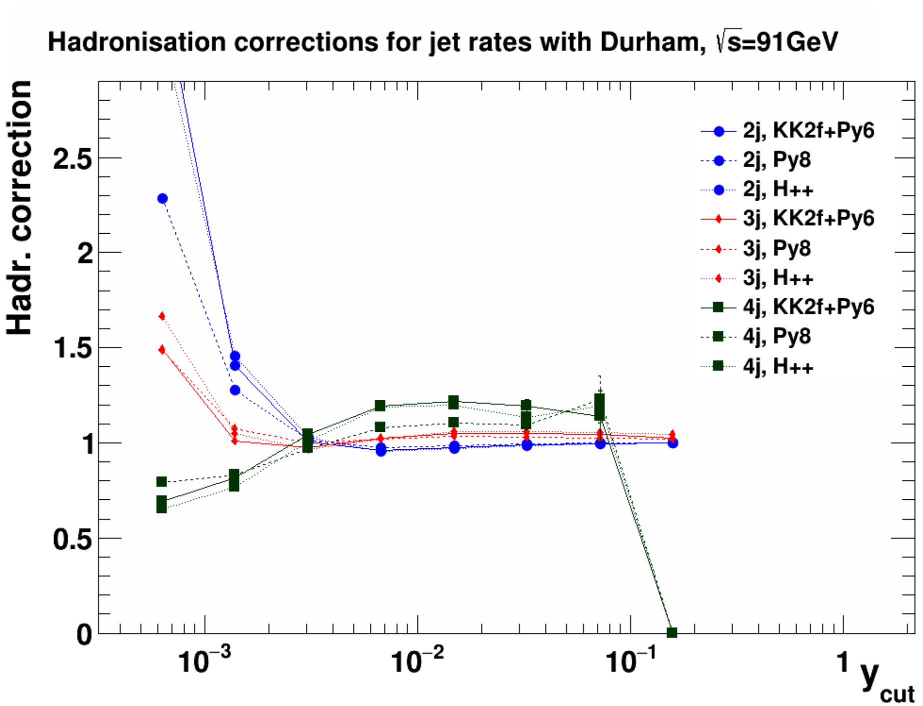
3 Durham

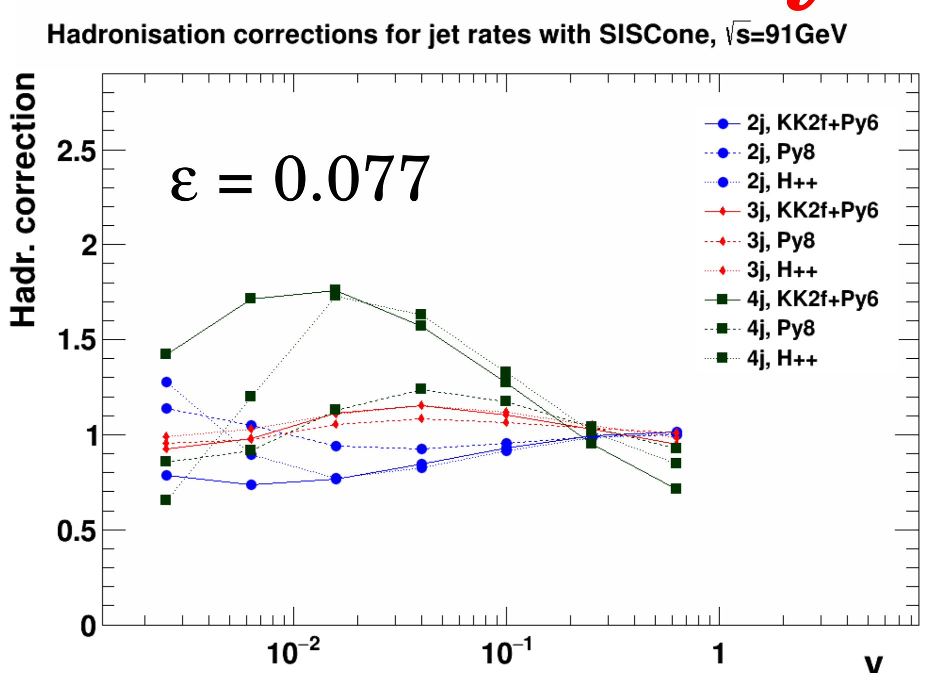

OPAL(prel.) jet rates at particle level with Durham, √s=91GeV
Fraction
2j, OPAL
2j, Py8
2j, H++
3j, OPAL
3j, Py8
3j, H++
4j, OPAL
4j, Py8
4j, H++
y_cut
OPAL(prel.) jet rates at particle level with Durham, √s=207GeV
Fraction
2j, OPAL
2j, Py8
2j, H++
3j, OPAL
3j, Py8
3j, H++
4j, OPAL
4j, Py8
4j, H++
y_cut

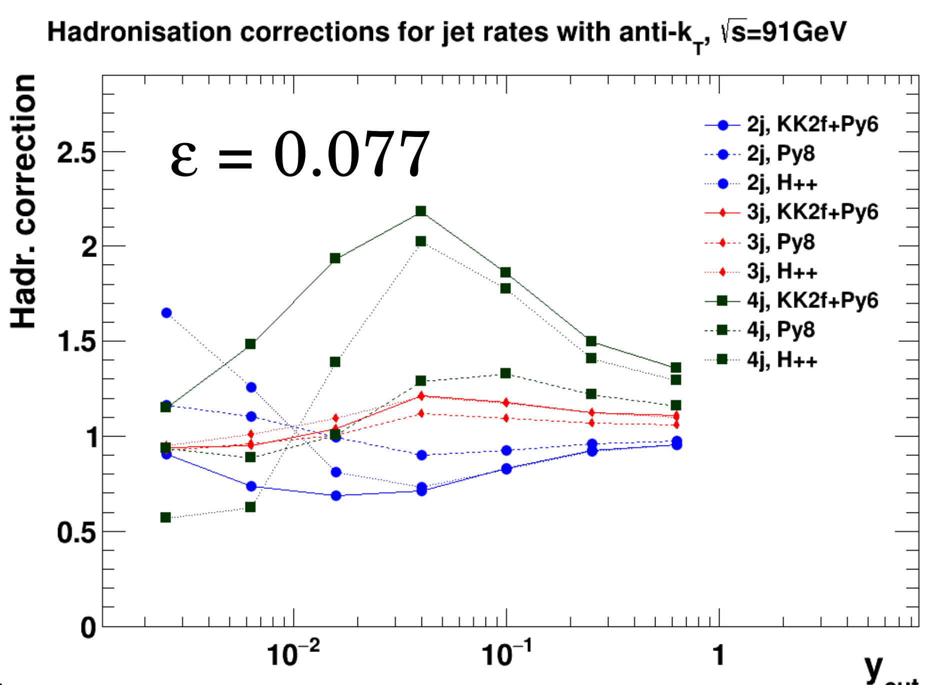
3 Hadronisation corrections

- Phenomenology with new MCs
- (Where) are new jet algorithms reliable?
  - Correlation partons $\leftrightarrow$ jets?
- Calculate ratio parton-level / hadron-level
  - Parton-level: after hard interaction + parton shower
  - Hadron-level: after hadronisation and unstable particle decays ($\tau < 300$ps)

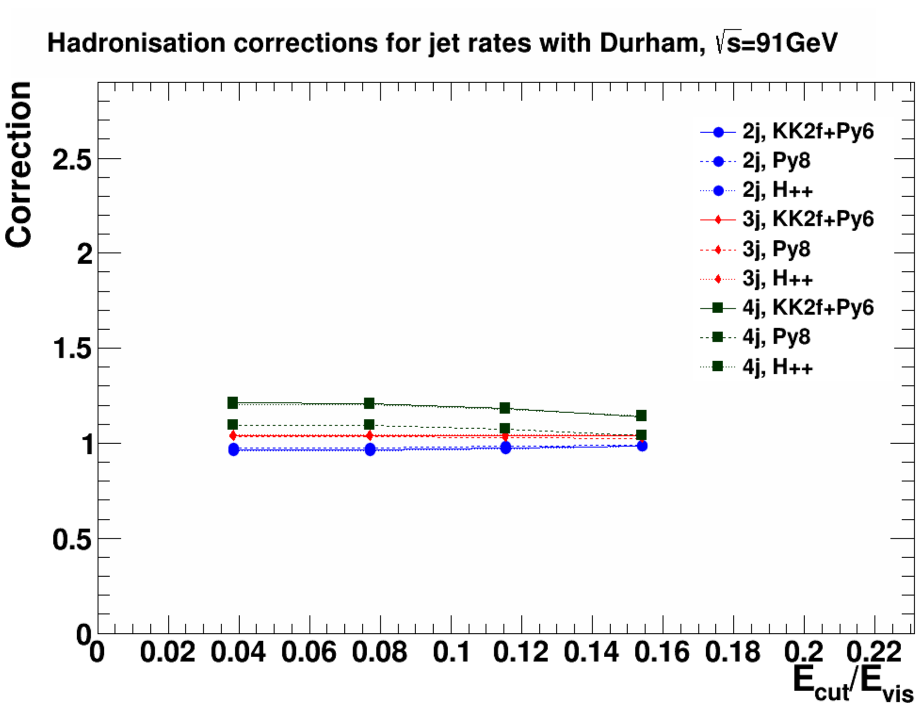
3 Had'n corrections 91 GeV vs y

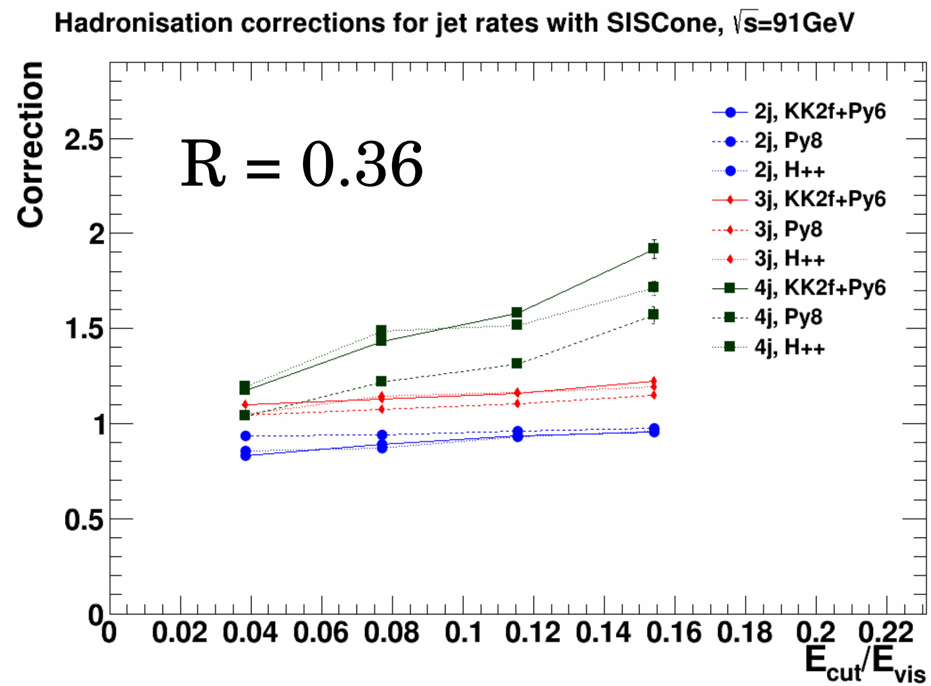


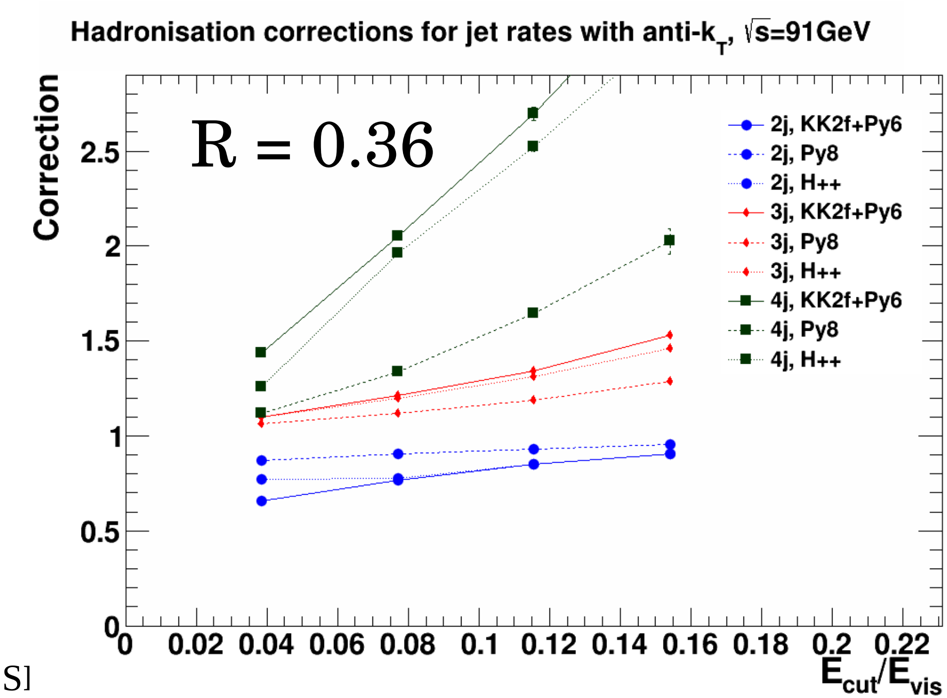




3 Had'n corrections 91 GeV vs ε

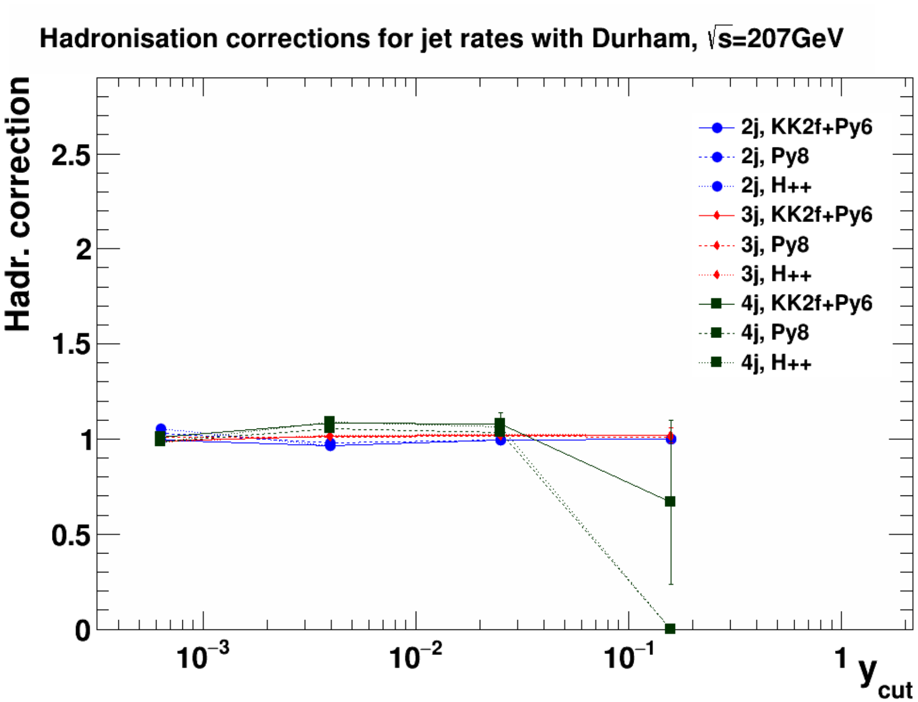


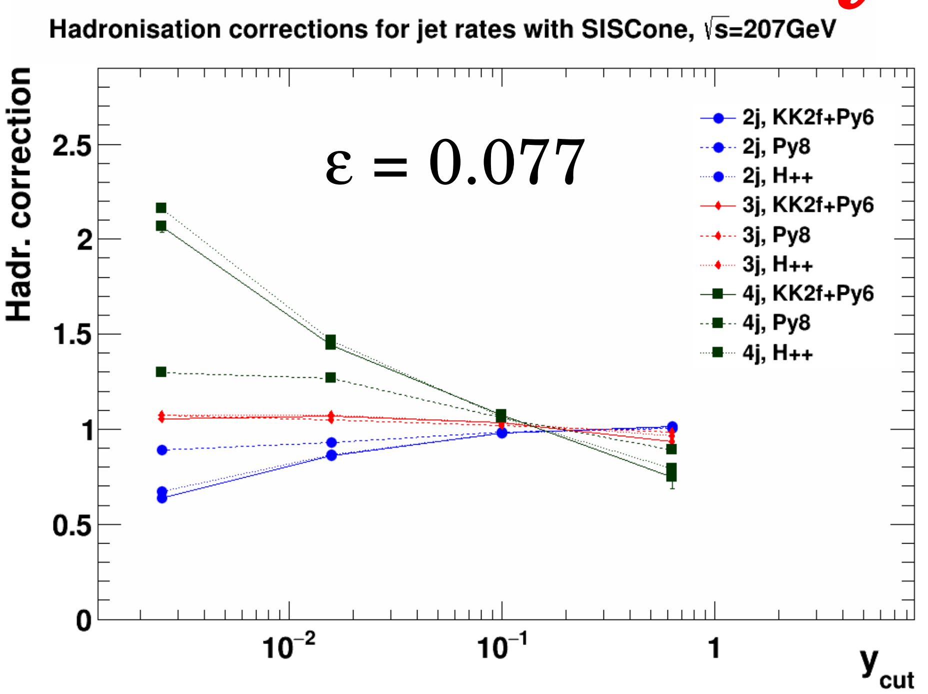


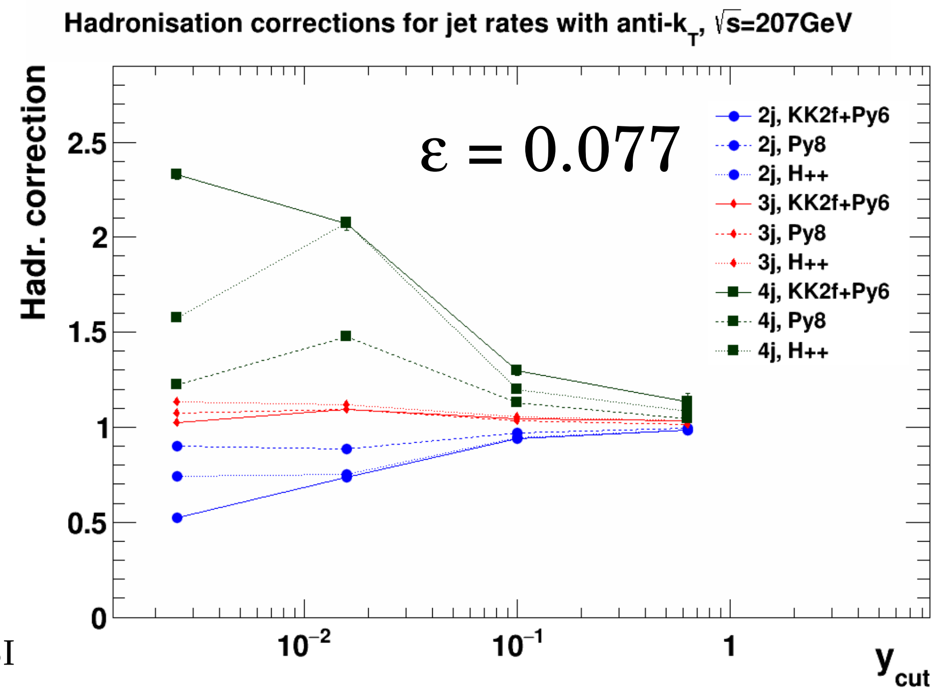


anti-kt and SI

3 Had'n corrections 207 GeV vs y

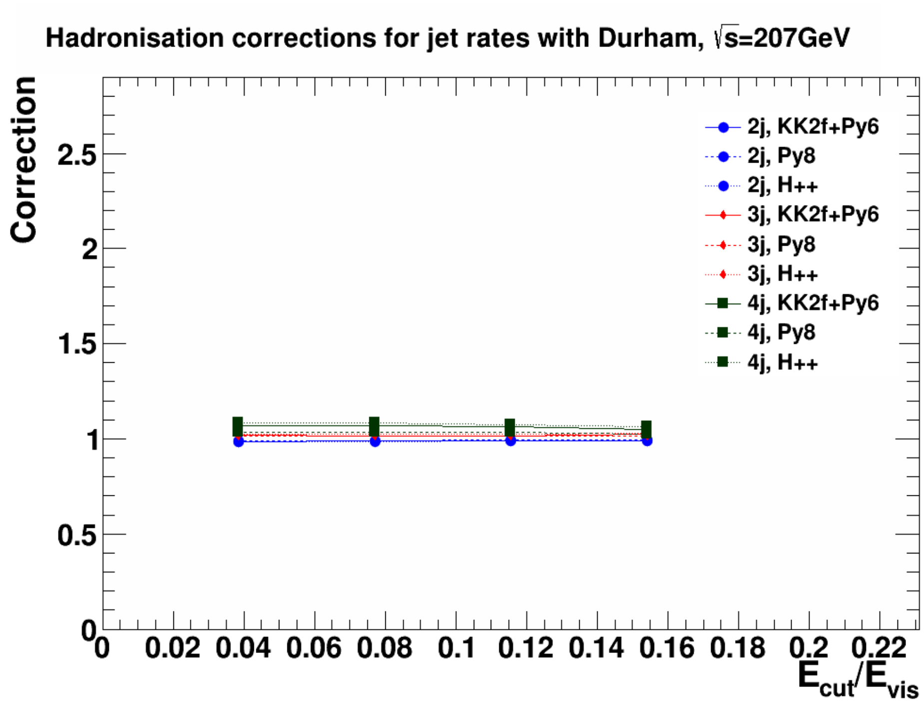


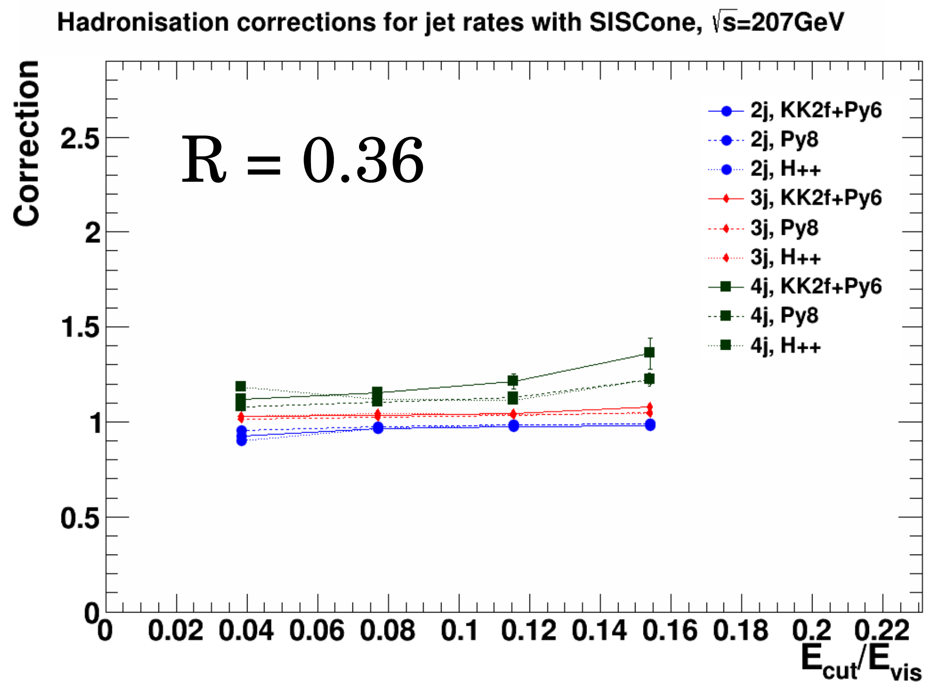


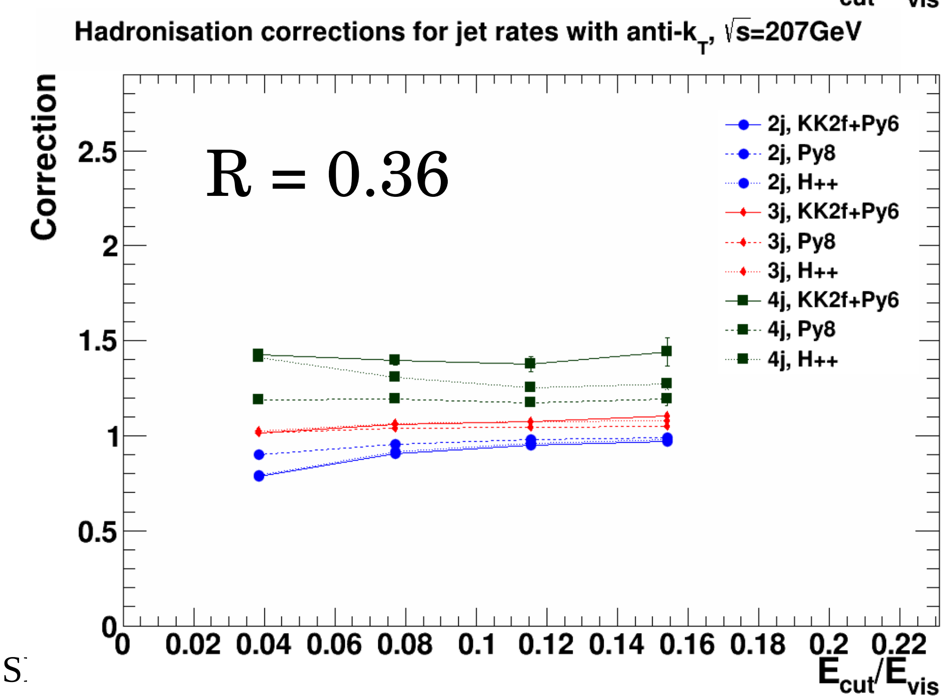


anti-kt and SI

3 Had'n corrections 207 GeV vs ε







anti-kt and S

4 Conclusions

- Studied new LHC jet algorithms
- Comparison to new MCs Pythia8 & Herwig++ works well
- Had. corrections interesting
  - R > 0.2 to avoid too large and unstable corrections
  - Durham < SISCone < anti-k_t
- Measurement of strong coupling possible
  - Had. corrections for anti-k_t and SISCone (but Durham still rules)
  - NNLO + NNLL (Durham, others under discussion with theorists)