Determinations of α_s at $\sqrt{s}$ = 14–44 GeV Using Resummed Calculations

Pedro Movilla Fernández
Max–Planck–Institut für Physik
München
(pedro@mppmu.mpg.de)

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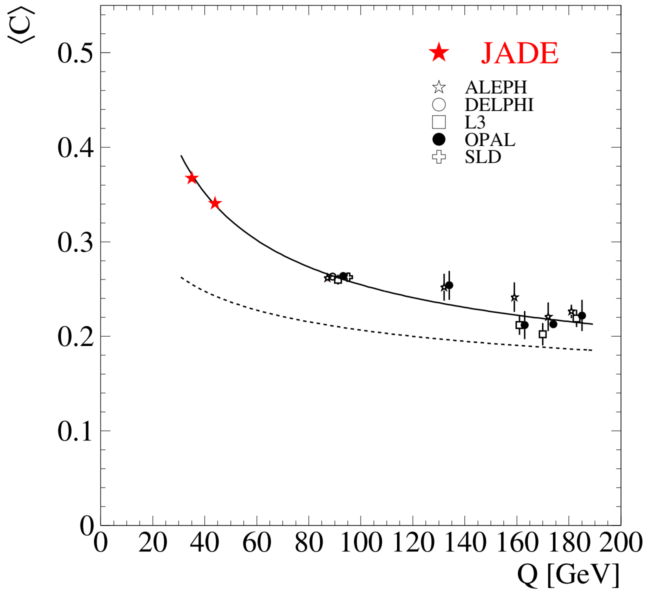
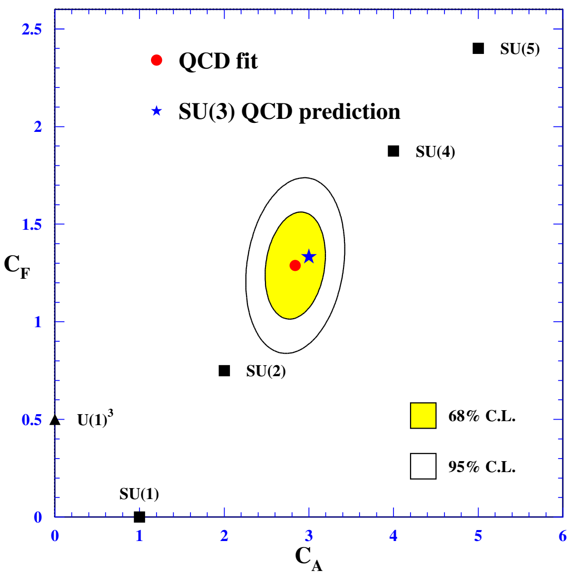
1. Introduction



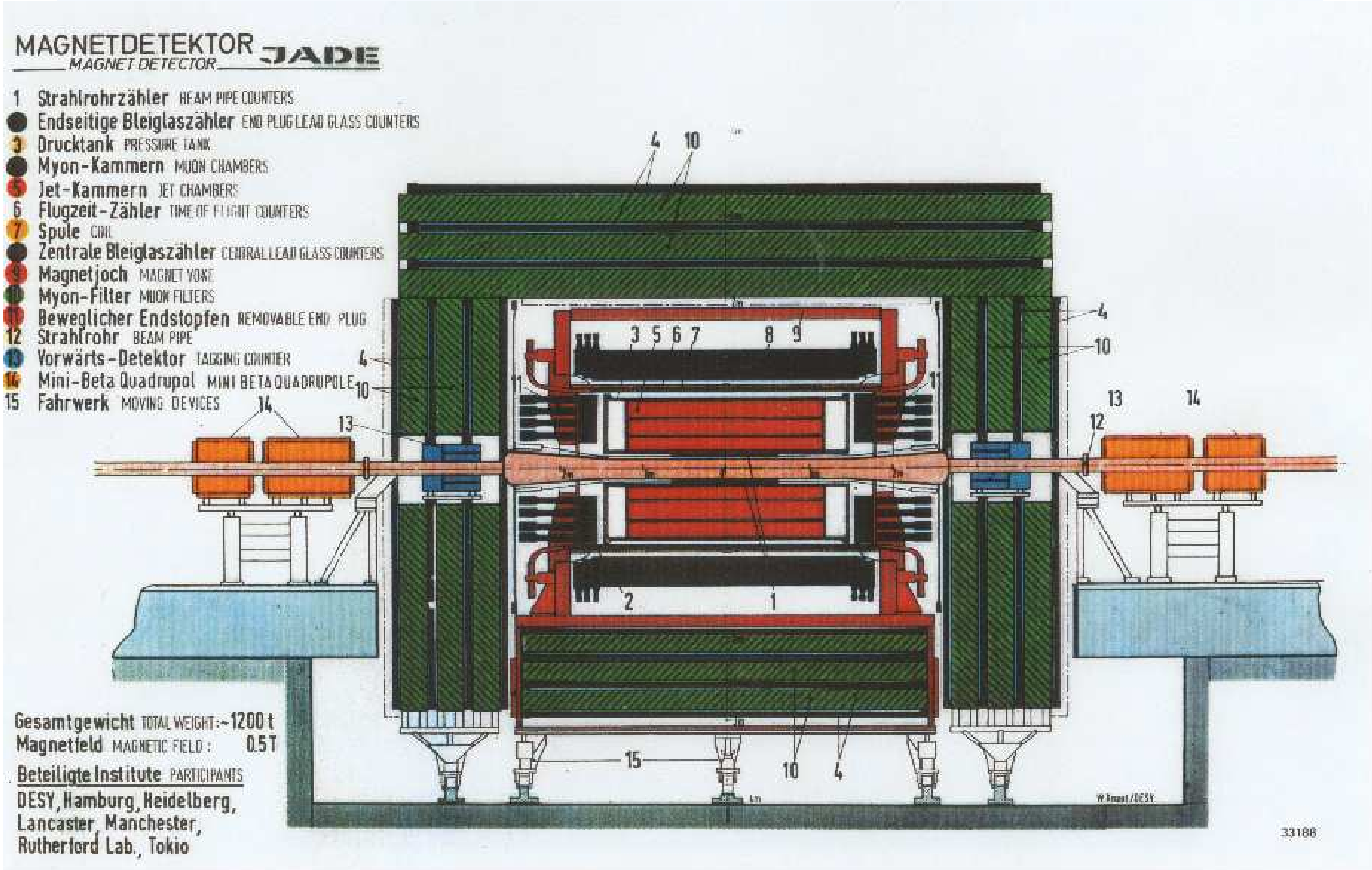


JADE provides valuable e^+e^- data for more stringent QCD tests, e.g.:

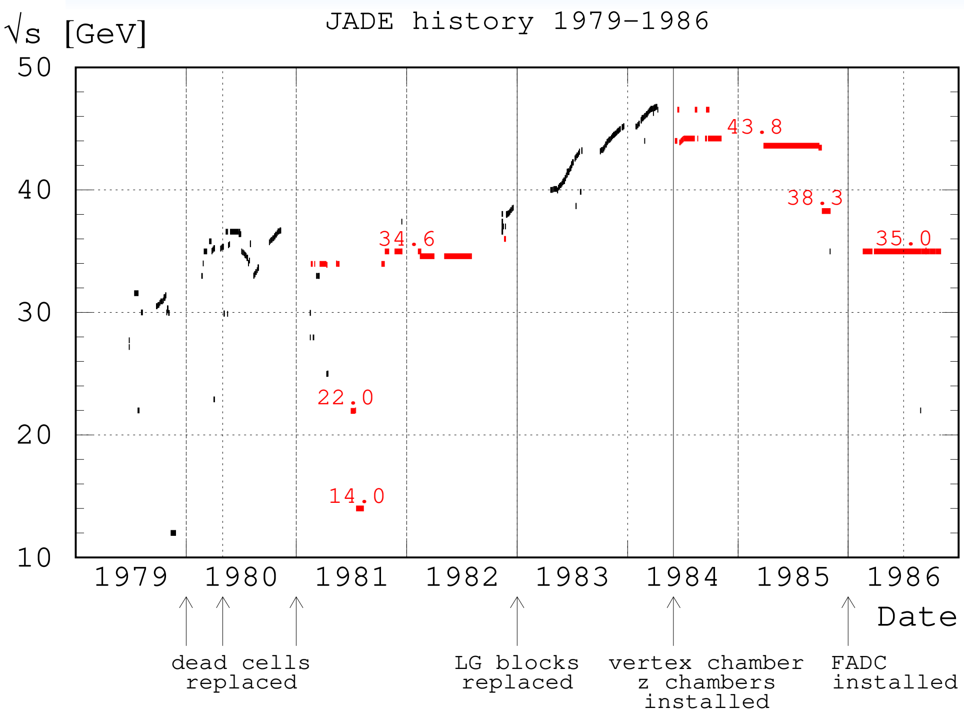
- Running of α_S
  - **Eur.Phys.J. C1 (1998), 461** [hep-ex/9708034]
  - **Phys.Lett. B459 (1999), 326** [hep-ex/9903009]
- Power corrections for event shapes
  - **Eur. Phys.J. C22 (2001), 1** [hep-ex/0105059]
  - **Nucl. Phys.B (Proc. Suppl.) 74 (1999), 384** [hep-ex/9808005]
- Gauge structure of QCD ($C_A, C_F, T_f \cdot n_f$) from event shapes
  - **Eur. Phys.J. C21 (2001), 199** [hep-ex/0012044]
- Longitudinal und transverse cross section $\sigma_{L,T}$
  - **Phys. Lett. B517 (2001), 37** [hep-ex/0106066]

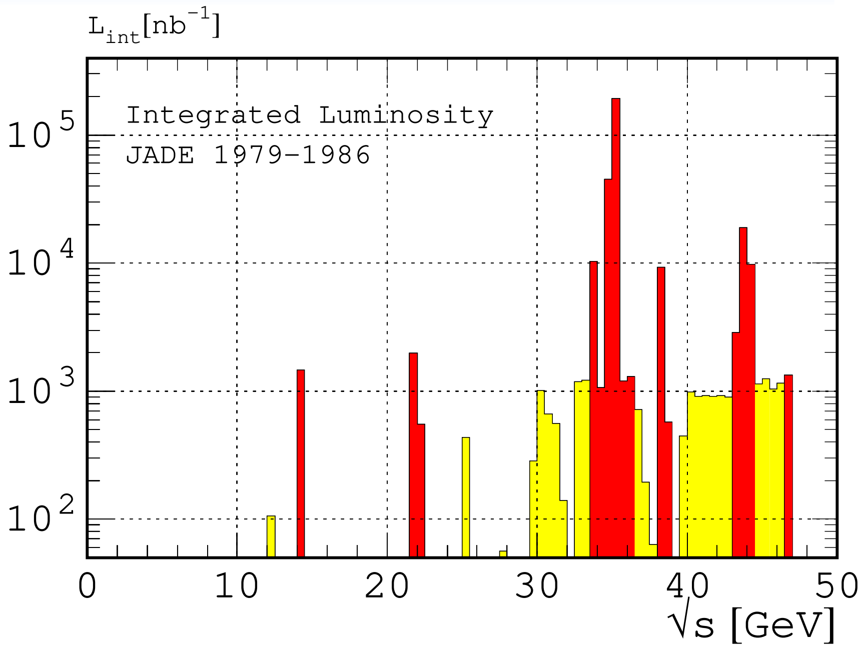
Now: can utilise data down to $\sqrt{s}$ = 14 GeV due to the successful resurrection of original JADE simulation and event reconstruction software

The JADE Experiment



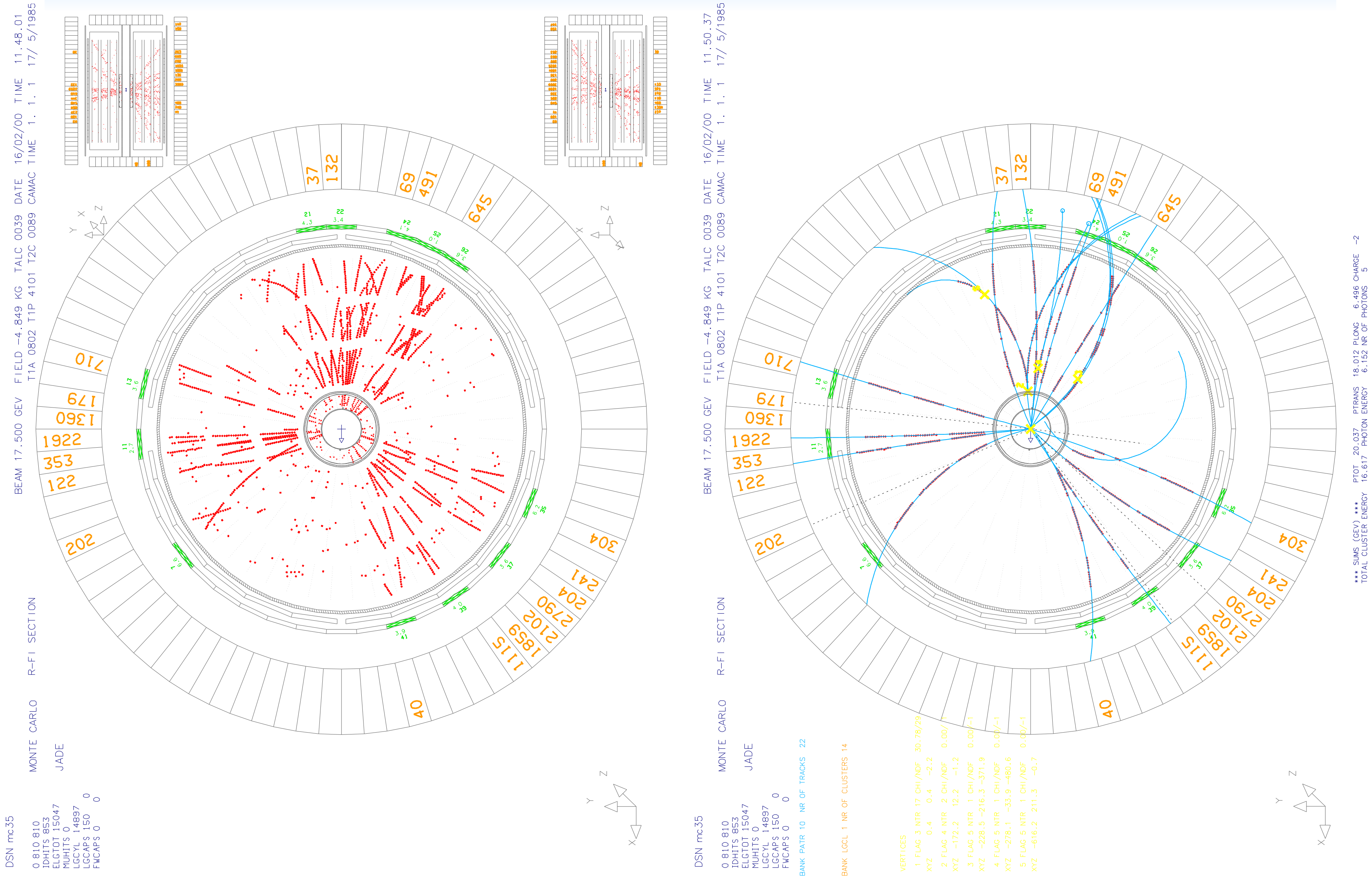
2. JADE Data and MC Simulation





$<\sqrt{s}>$[GeV]	$\sqrt{s}$-range[GeV]	period	$\mathcal{L}$ [pb$^-1$]	MH data
14.0	14.0	Jul.-Aug. 1981	1.46	1734
22.0	22.0	Jun.-Jul. 1981	2.41	1390
34.6	33.8 - 36.0	Feb. 1981 - Aug. 1982	61.7	14372
35.0	35.0	Feb.-Nov. 1986	92.3	20925
38.3	38.3	Oct.-Nov. 1981	8.28	1587
43.8	43.0-46.6	Jun. 1984 - Oct. 1985	28.8	3940

Detector Simulation

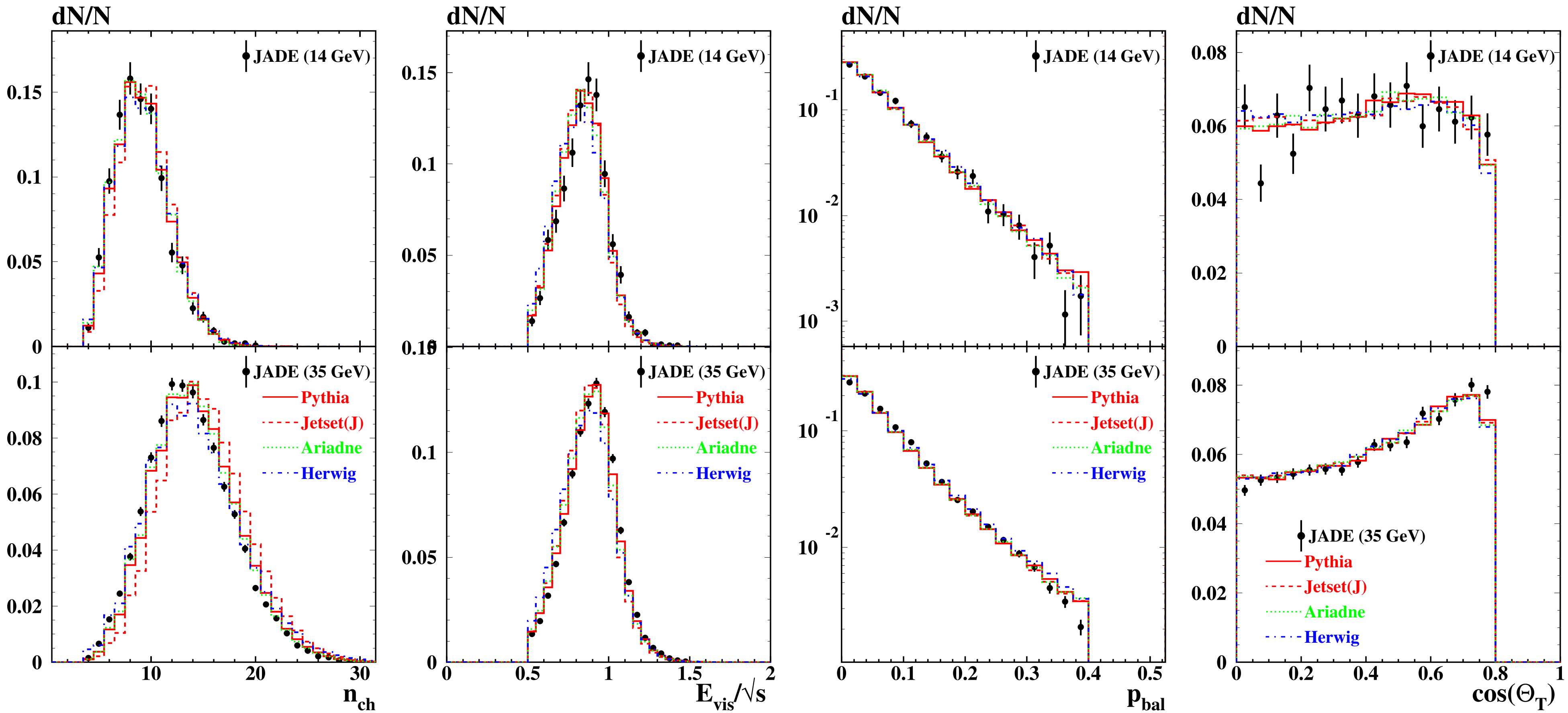


Data vs. MC Simulation

Pythia 5.7, Ariadne 4.08, Herwig 5.9 (OPAL tune), Jetset 6.3 (JADE tune)
+ JADE Simulation

MH event selection:
- $n_{ch} > 4$
- $E_{vis} > \sqrt{s}/2$, $p_{bal} < 0.4$
- $p_{miss} < 0.3\cdot\sqrt{s}$, $\cos(\theta_T) < 0.8$, ...

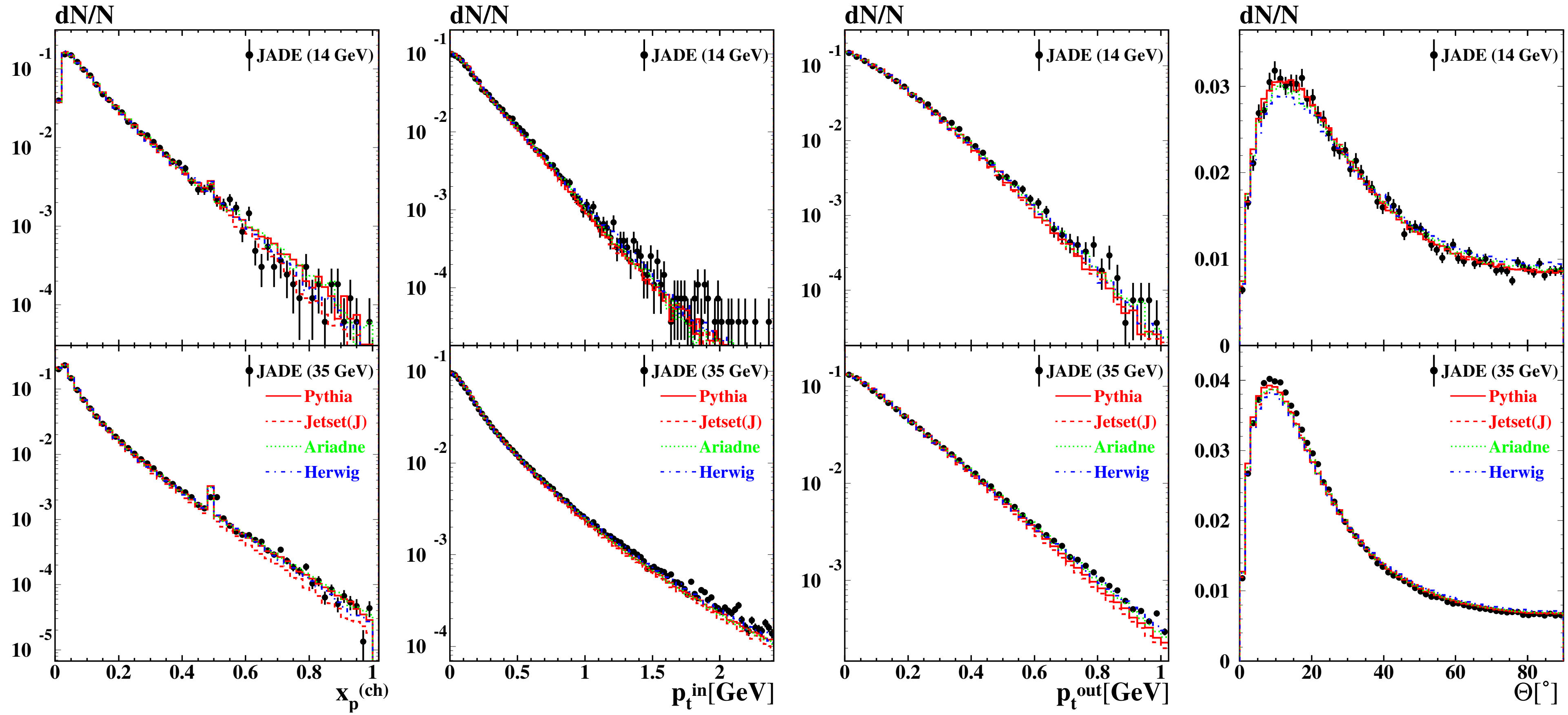
Residual background from $\tau^+\tau^-$, $\gamma\gamma \approx 1\%$



Data vs. MC Simulation

Particle spectra { x_p (ch), p_t^{in}, p_t^{out}, dN/dθ, ...

Pythia (O)	... o.k.
Ariadne	... o.k.
Jetset (J)	... n_{ch} higher, x_p softer
Herwig	... o.k., particle flow more spherical



3. Event Shapes at PETRA Energies

Event shape observables commonly used for α_s measurements:

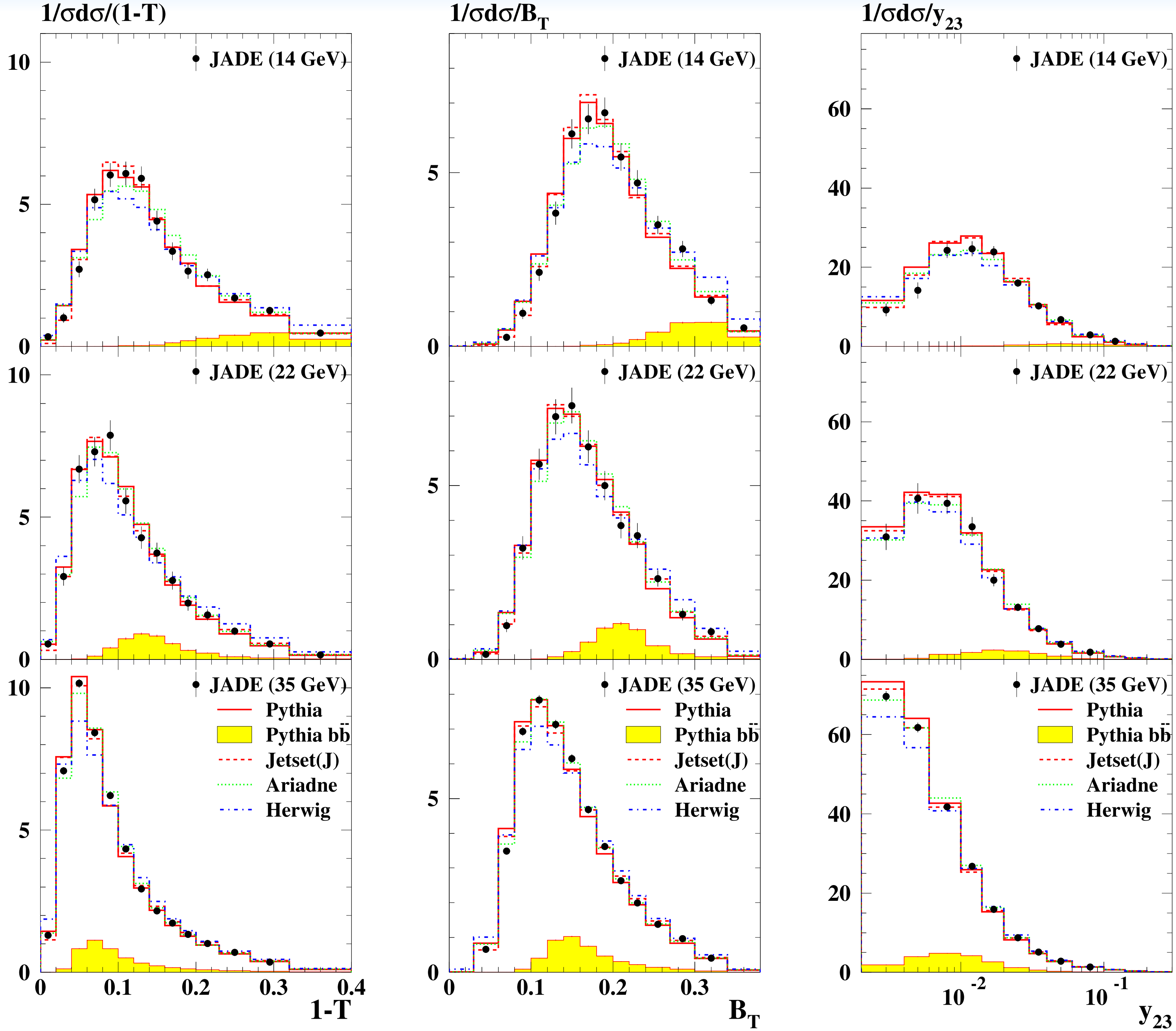
- Thrust T $\quad T = \max_{\vec{n}} \left(\frac{\sum_i |\vec{p}_i \cdot \vec{n}|}{\sum_i |\vec{p}_i|} \right) \quad \Rightarrow \vec{n}_T, H_\pm$

$$B_\pm = \frac{\sum_{i \in H_\pm} |\vec{p}_i \times \vec{n}_T|}{2 \sum_i |\vec{p}_i|}$$

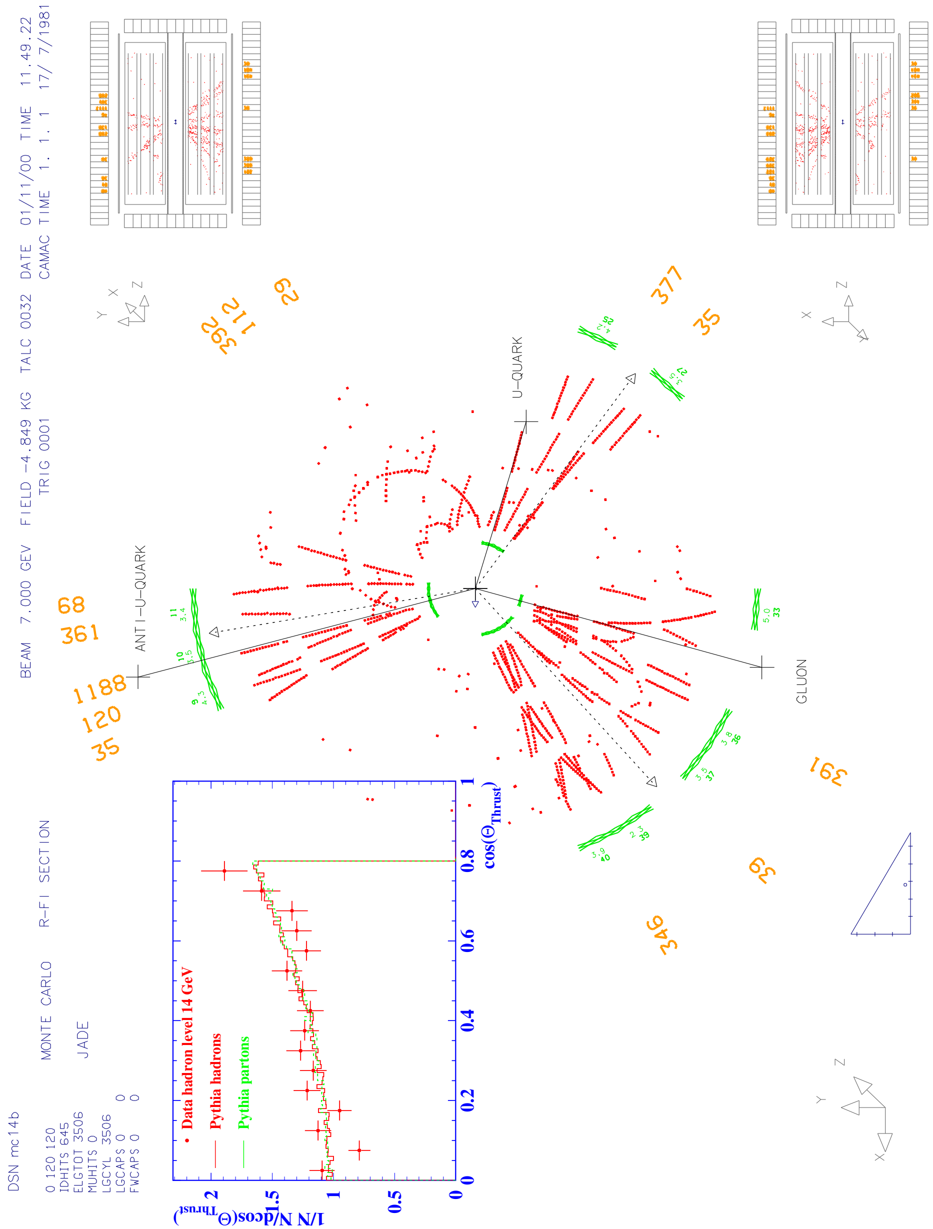
$$M_\pm^2 = \left(\sum_i E_i^2 - \sum_i p_i^2 \right)_{i \in H_\pm}$$

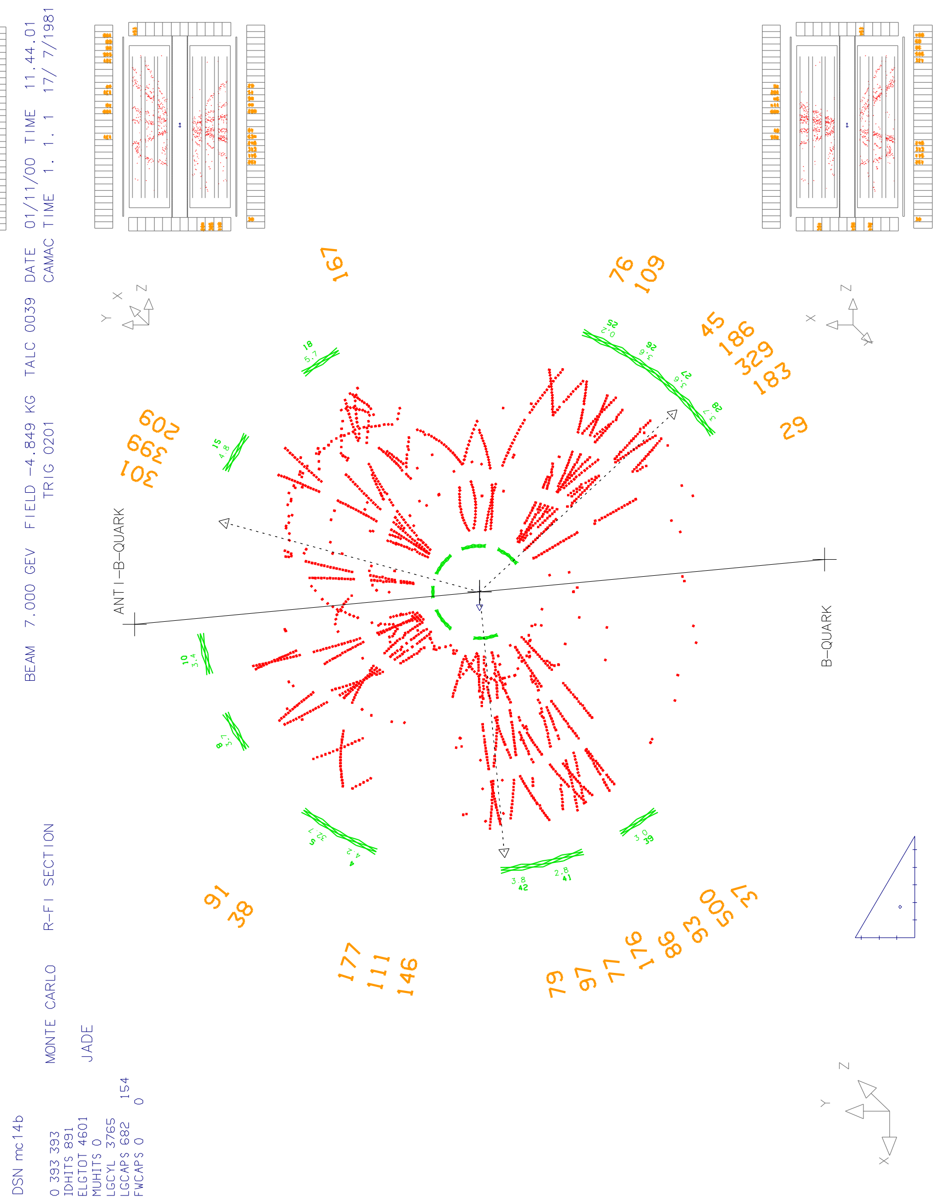
- Heavy jet mass M_H $\quad M_H^2 = \max\left(M_+^2, M_-^2\right)$
- Jet broadening B_T, B_W $\quad B_W = \max\left(B_+, B_-\right)$, $\quad B_T = B_+ + B_-$
- C parameter $\quad C = 3(\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_1\lambda_2), \lambda_i \; EV \; of \; \Theta_{ij} = \frac{\sum_k p_k^i p_k^j / |\vec{p}_k|}{\sum_k |\vec{p}_k|}$
- Differential 2–jet rate y_{23}
  - Jet resolution: $\quad y_{ij} = 2 \min\left(E_i^2, E_j^2\right)\left(1 - \cos\Theta_{ij}\right) / \sum_k E_k^2$
  - Combine particles i,j with smallest y_{ij} into pseudoparticles and proceed until $y_{ij} > y_{cut} = y_{23}$ for 2 remaining pseudoparticles.

Measured and Simulated Event Shapes (Detector Level)



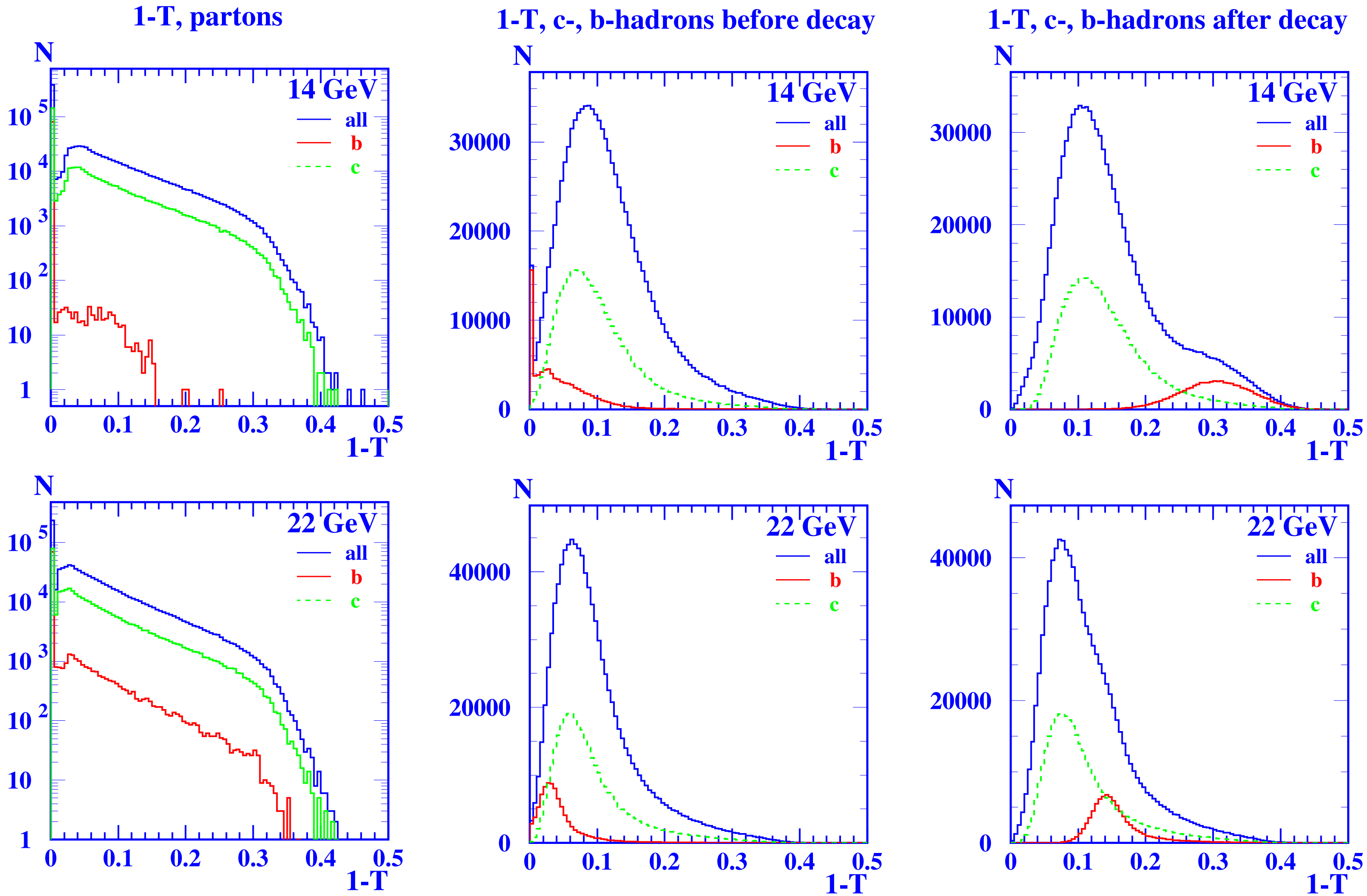
$b\bar{b}$ Event @14 GeV



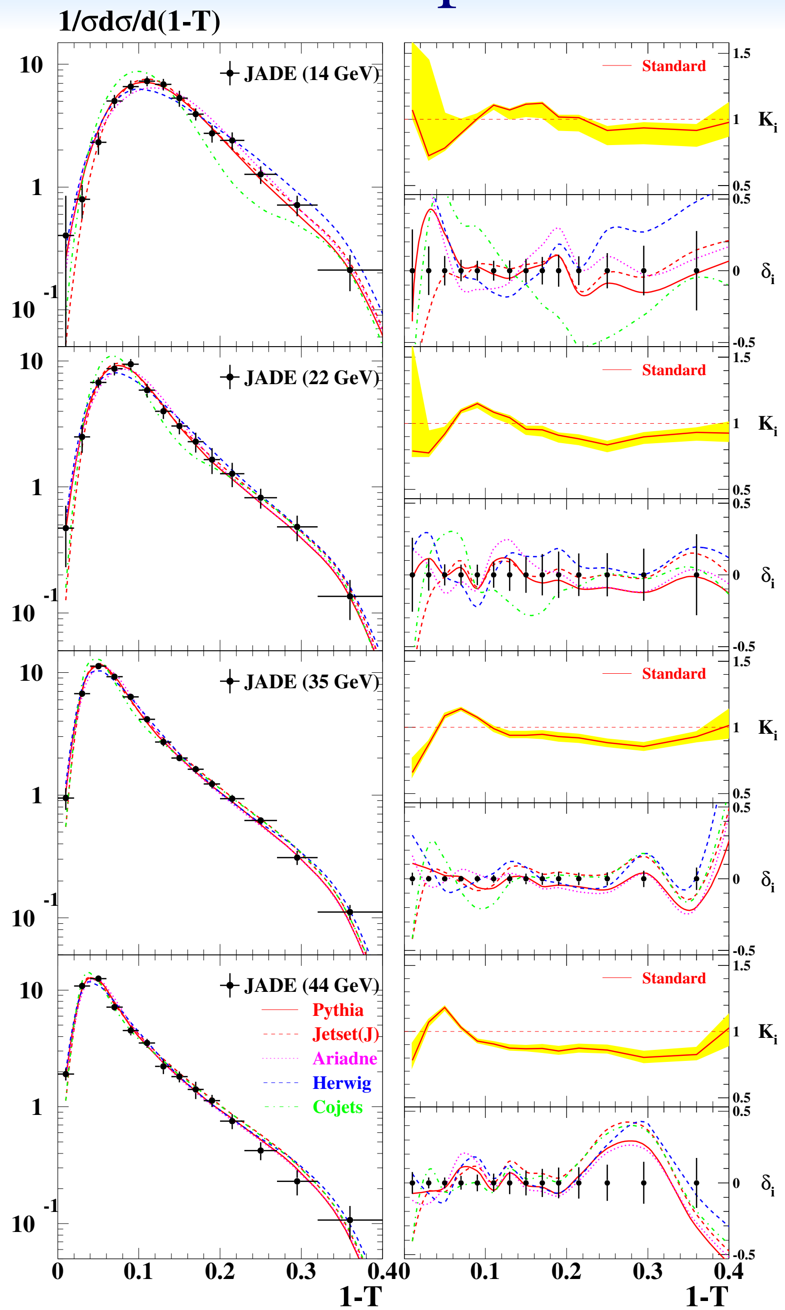


$b\bar{b}$ Events

- Distortion of the distribution due to electroweak effects



Event Shape Data vs. QCD MC (Hadron Level)



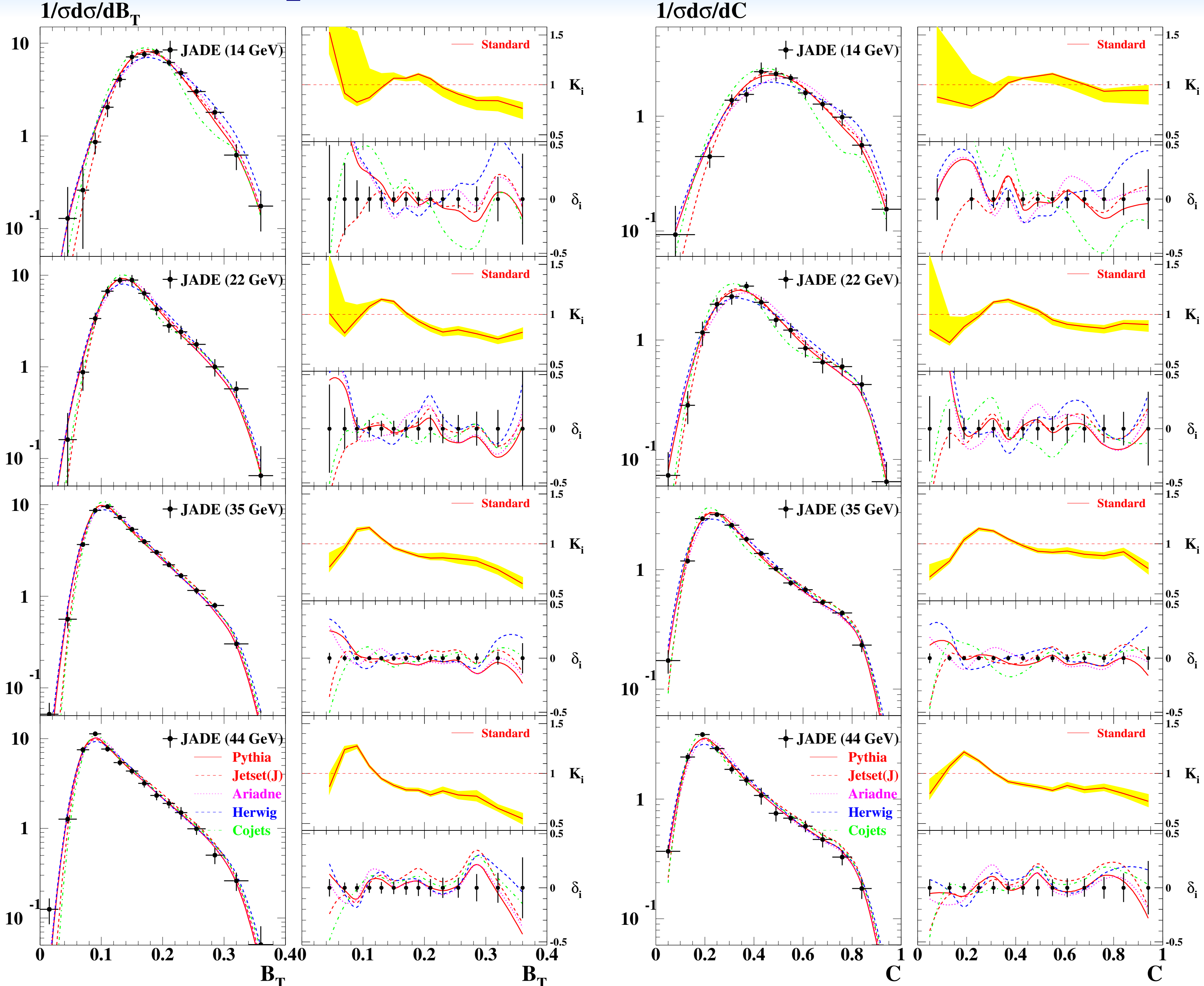
Correction procedure:

- $b\bar{b}$ subtraction at detector level (fraction ≈ 9%)
- bin–by–bin unfolding with factors $K(i)=MC^{had}(i)/MC^{det}(i)$ based on udsc MC samples

Performance of QCD models:

- Pythia 5.7 (OPAL):
  good overall description of data
- Herwig 5.9 / Ariadne 4.08:
  moderate at 14+22 GeV, slightly better at higher c.m.s. energies
- Jetset 6.3 (JADE):
  good at 14+22 GeV, slightly worse at higher c.m.s. energies
- Cojets 6.23:
  strongly disfavoured at 14+22 GeV, remains worse at higher c.m.s. energies

Event Shape Data vs. QCD MC (Hadron Level)



4. Measurements of α_s

- pQCD prediction $R(y)=\int^y dy' 1/\sigma \cdot d\sigma/dy'$ for event shape y:

  NLO: $R(y)=1+A(y)\cdot\alpha_s+B(y)\cdot\alpha_s^2$

  NLLA: $R(y)=(1+C_1\cdot\alpha_s+C_2\cdot\alpha_s^2)\exp\{Lg_1(\alpha_s L)+g_2(\alpha_s L)\}$

  $L = \log(1/y)$

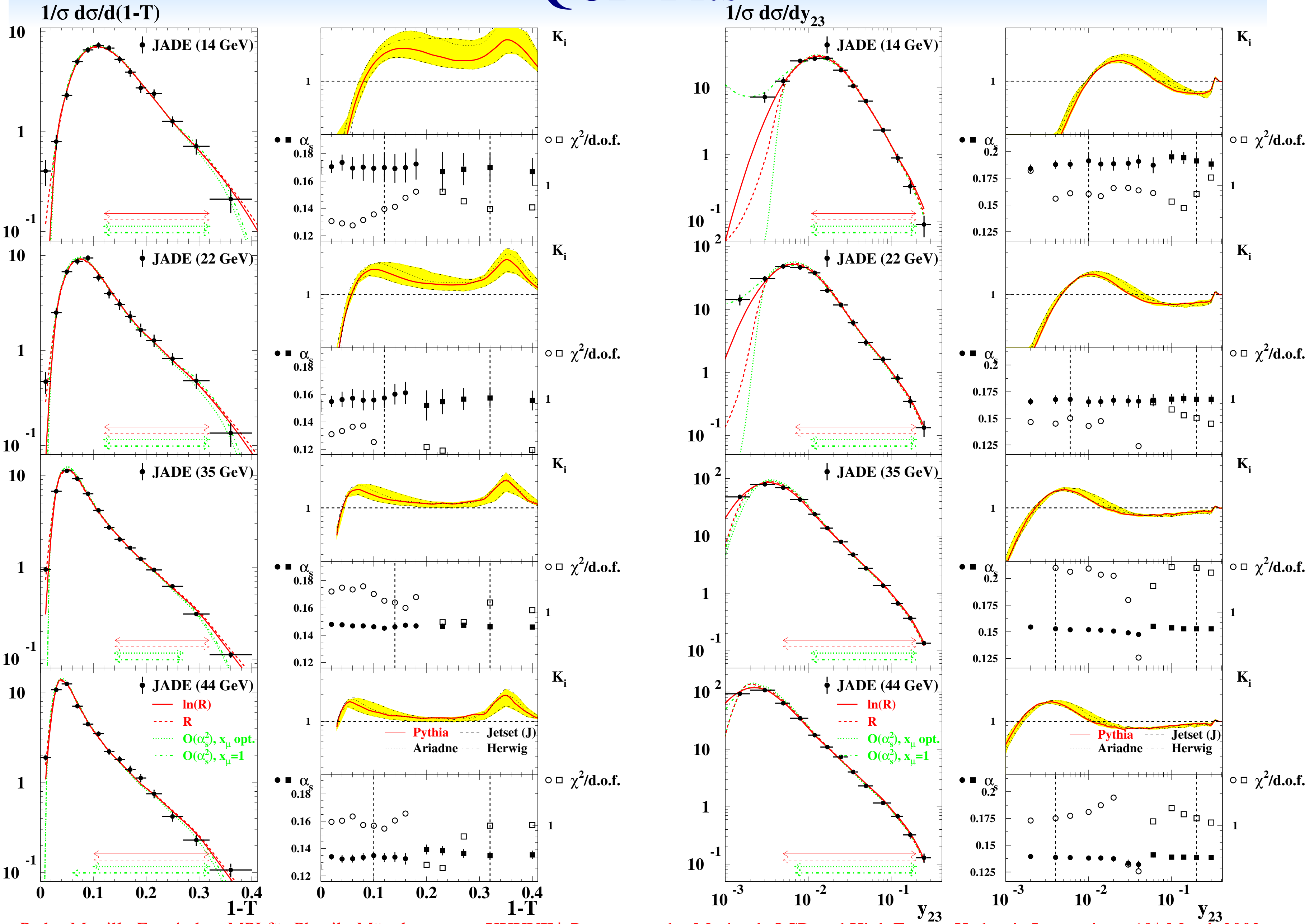
  Combine NLO with NLLA (ln(R)–matching).

- Estimation of hadronisation effects:

Pythia 5.7 (OPAL)/	
Jetset 6.3 (JADE)	... LLA parton shower + string fragmentation
Ariadne 4.08	... colour dipole + string fragmentation
Herwig 5.9	... MLLA parton shower + cluster fragmentation

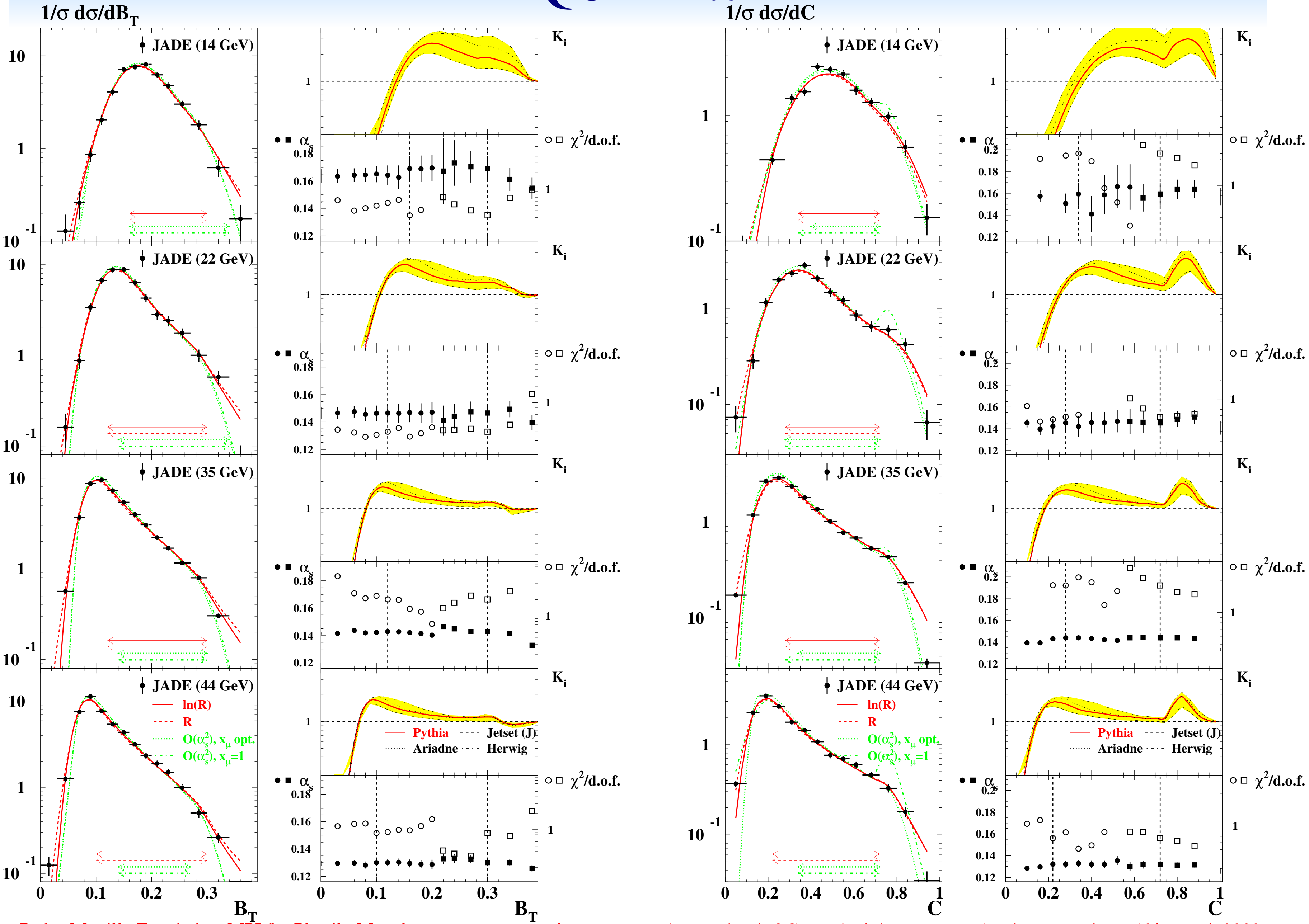
- Fit QCD + bin–by–bin hadronisation correction (of cumulative prediction)

QCD Fits



1/σ dσ/d(1-T)
1/σ dσ/dy23
JADE (14 GeV)
JADE (22 GeV)
JADE (35 GeV)
JADE (44 GeV)
ln(R)
R
O(αs2), xμ opt.
O(αs2), xμ=1
Ki
αs
χ2/d.o.f.
Pythia
Jetset (J)
Ariadne
Herwig
1-T
y23

QCD Fits



1/σ dσ/dB_T
JADE (14 GeV)
JADE (22 GeV)
JADE (35 GeV)
JADE (44 GeV)
ln(R)
R
O(α_s^2), x_μ opt.
O(α_s^2), x_μ=1
K_i
α_s
χ²/d.o.f.
Pythia
Jetset (J)
Ariadne
Herwig
B_T
1/σ dσ/dC
C

Systematic Errors

- Experimental:

  MH selection cuts (E_{vis}, p_{bal}, p_{miss}, $\cos\theta_T$, n_{ch})

  Merging of tracks and clusters

  Data reconstruction version (9/87, 5/88)

- Hadronisation:

  Tune uncertainties (b, σ_q, ε_c, ε_b, Q_0)

  Pythia 5.7 (OPAL) / Jetset 6.3 (JADE)

  [large tune differences due to L=1 meson multiplets and diquark suppression factors]

  Alternative MC: Herwig, Ariadne

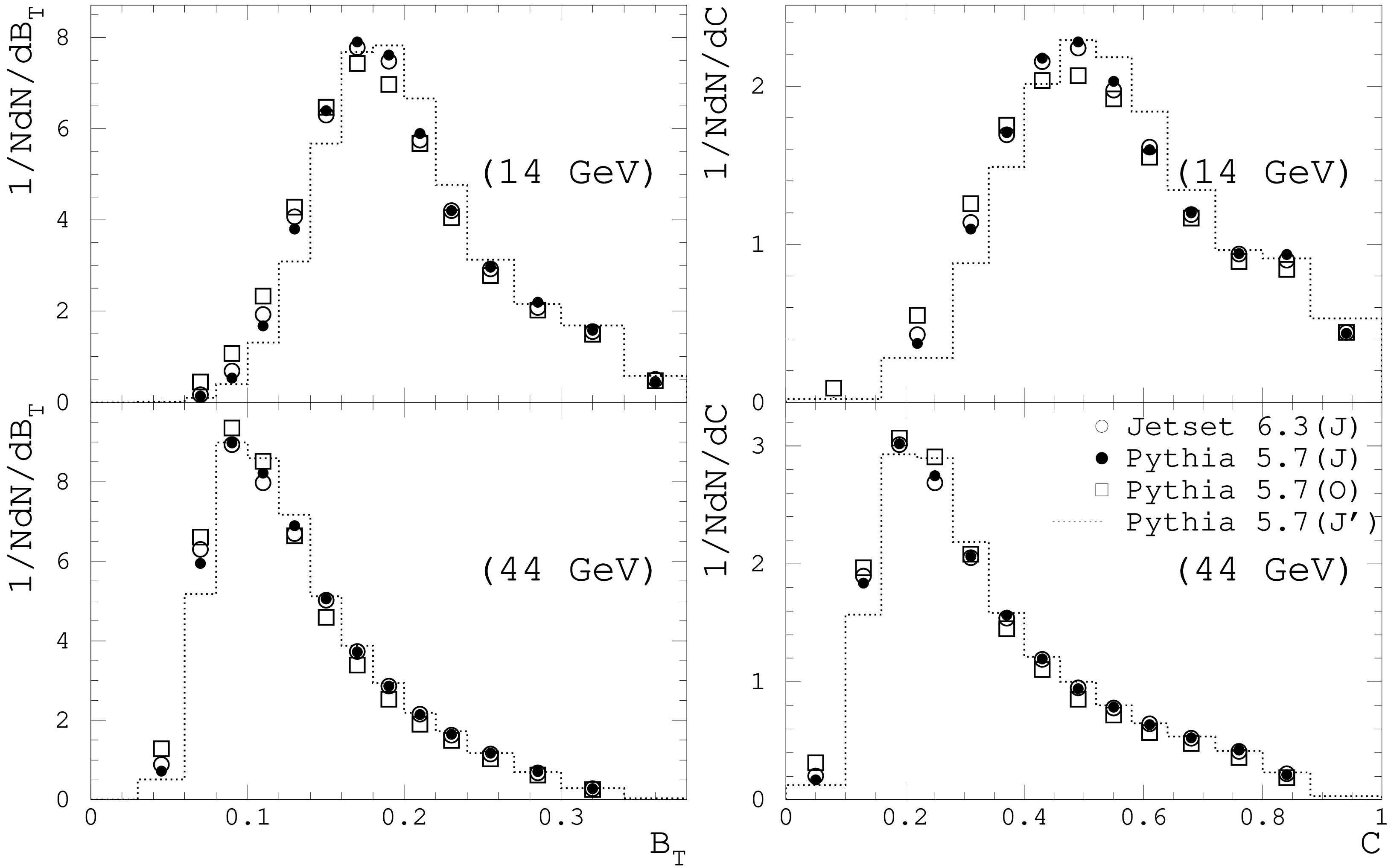
- pQCD:

  Renormalisation scale: $x_\mu = 0.5 \ldots 2.0$

  Matching scheme: ln(R), ln(R) mod., R, R mod.

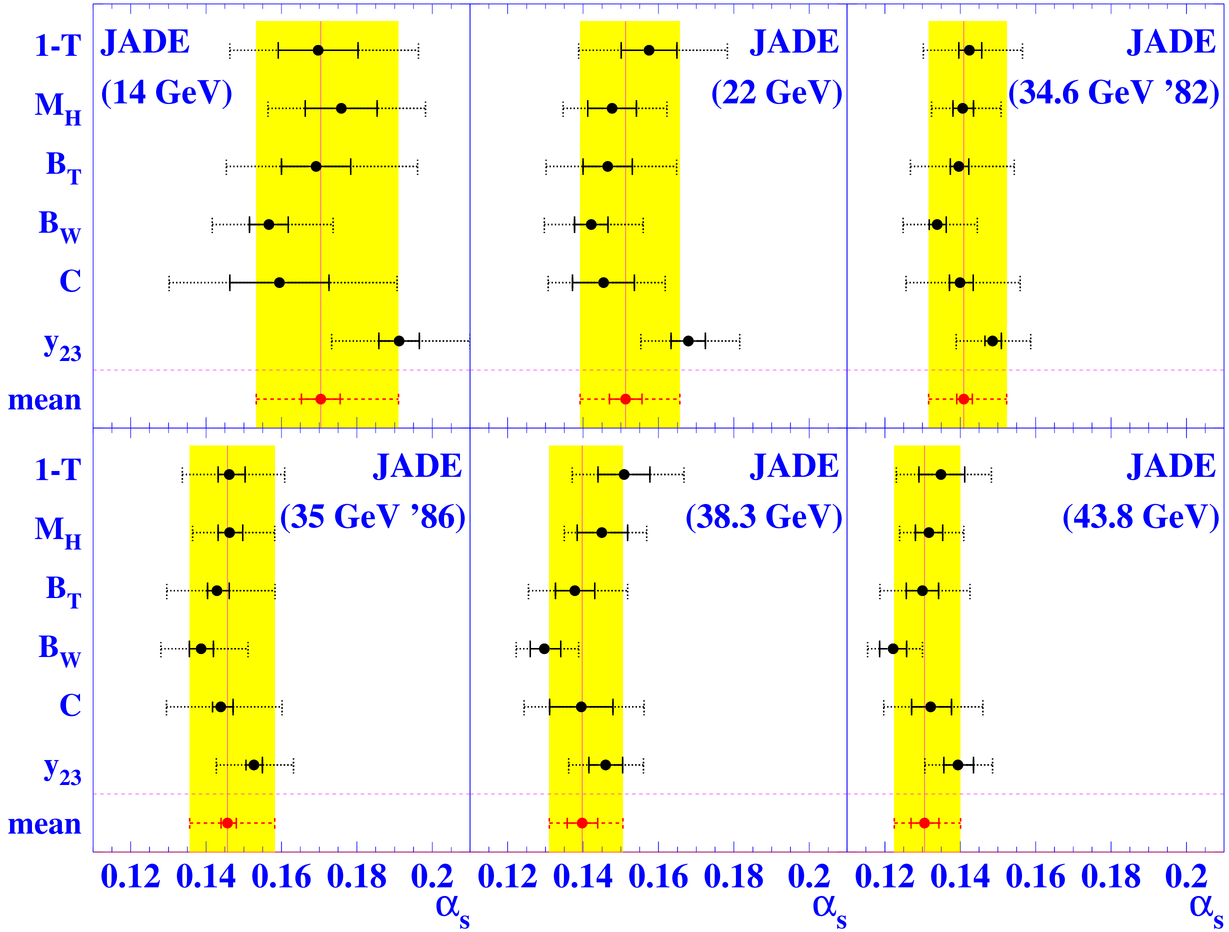
Pythia 5.7 (OPAL) vs. Jetset 6.3 (JADE)

J: JADE tune w/o L=1 multiplets & 'old' diquark suppression factors
J': JADE tune with L=1 multiplets & current diquark suppression factors
O: OPAL tune with L=1 multiplets & current diquark suppression factors



α_S Results

(Preliminary)

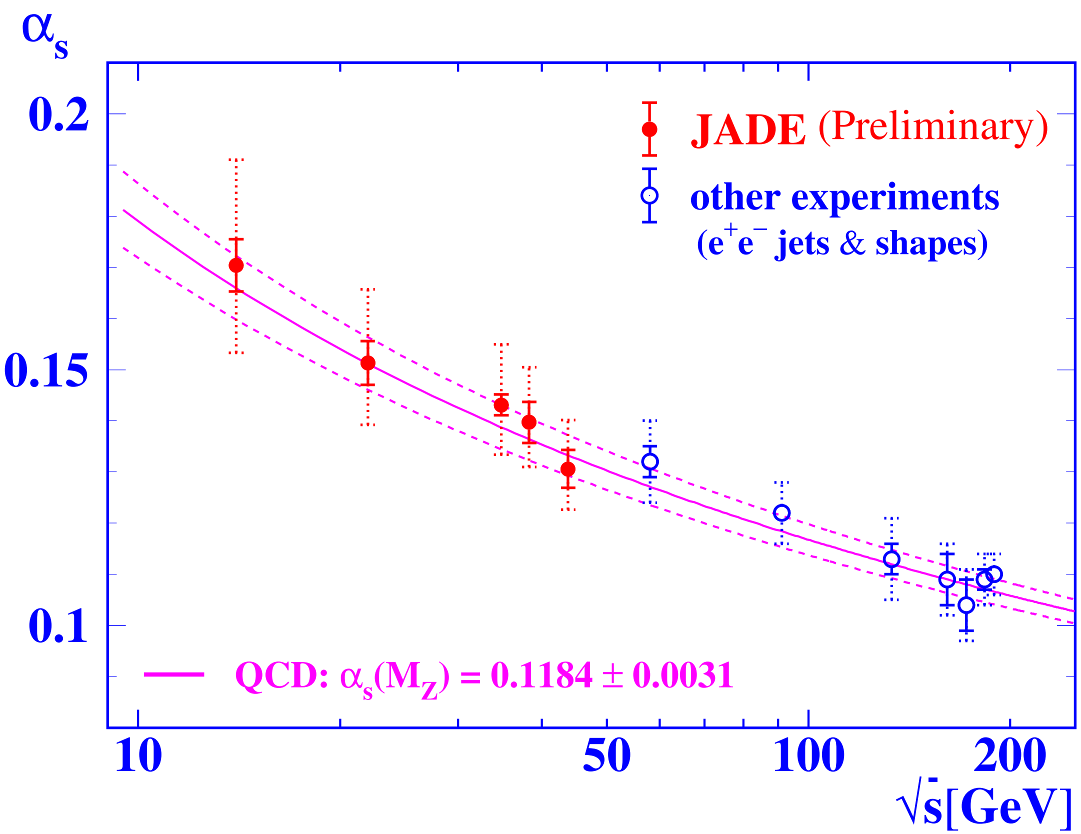


- χ^2/d.o.f.= 0.2 ... 2.0
- stable fits
- consistent results
- hadronisation uncertainties at 14+22 GeV !

$\langle\sqrt{s}\rangle$ [GeV]	$\alpha_S(\sqrt{s})$	fit error	experimental	hadronisation	higher orders	total
14.0	0.1704	$\pm0.0051^*$		$^{+0.0141}_{-0.0136}$	$^{+0.0143}_{-0.0091}$	$^{+0.0206}_{-0.0171}$
22.0	0.1513	$\pm0.0043^*$		±0.0101	$^{+0.0101}_{-0.0065}$	$^{+0.0144}_{-0.0121}$
34.6 ('82)	0.1409	±0.0012	±0.0017	±0.0071	$^{+0.0086}_{-0.0057}$	$^{+0.0114}_{-0.0093}$
35.0 ('86)	0.1457	±0.0011	±0.0020	±0.0076	$^{+0.0096}_{-0.0064}$	$^{+0.0125}_{-0.0101}$
38.3	0.1397	±0.0031	±0.0026	±0.0054	$^{+0.0084}_{-0.0056}$	$^{+0.0108}_{-0.0087}$
43.8	0.1306	±0.0019	±0.0032	±0.0056	$^{+0.0068}_{-0.0044}$	$^{+0.0096}_{-0.0080}$

5. Summary and Conclusions

- Resurrection of JADE software:
  e^+e^- data at $\sqrt{s}$=14–44 GeV ready for state–of–the–art QCD studies
- Performance of LEP tuned hadronisation MC at PETRA energies:
  Pythia o.k., Ariadne/Herwig moderate (need re–tune?), Cojets disfavoured
- Measurements of α_s: Resummed NLO+NLLA reliable down to $\sqrt{s}$ =14 GeV



- First determinations at 14+22 GeV
- Much higher precision than in old PETRA publications
- Method consistent with LEP/SLC measurements
- Hadronisation uncertainties at 14 GeV ≈ $O(\Delta\alpha_s^{\text{ren.scale}})$
- Fit of QCD expectation:
  $\alpha_s = 0.1213 \pm 0.0006$
  χ^2/d.o.f. = 8.3/11 (exp. errors)
- Fit of α_s =const:
  χ^2/d.o.f. = 43.1/11 (tot. errors)
  $P(\chi^2) \approx 10^{-5}$