Jet and hadron production in photon-photon interactions at L3

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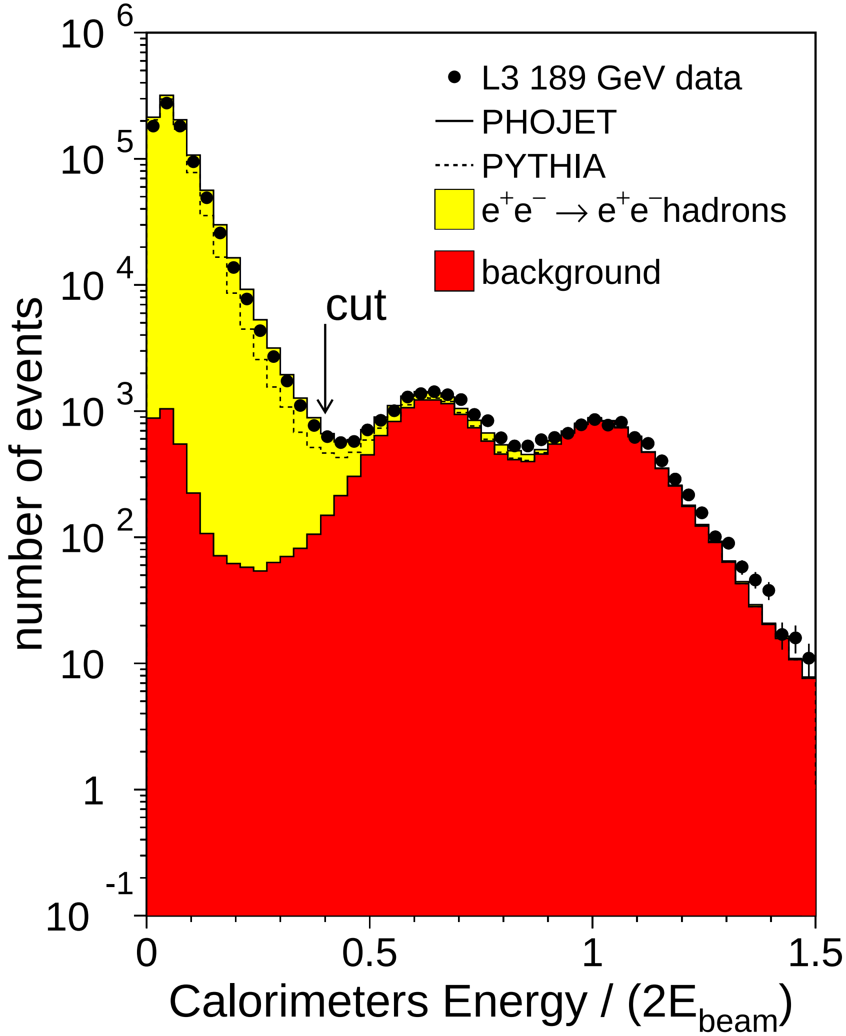
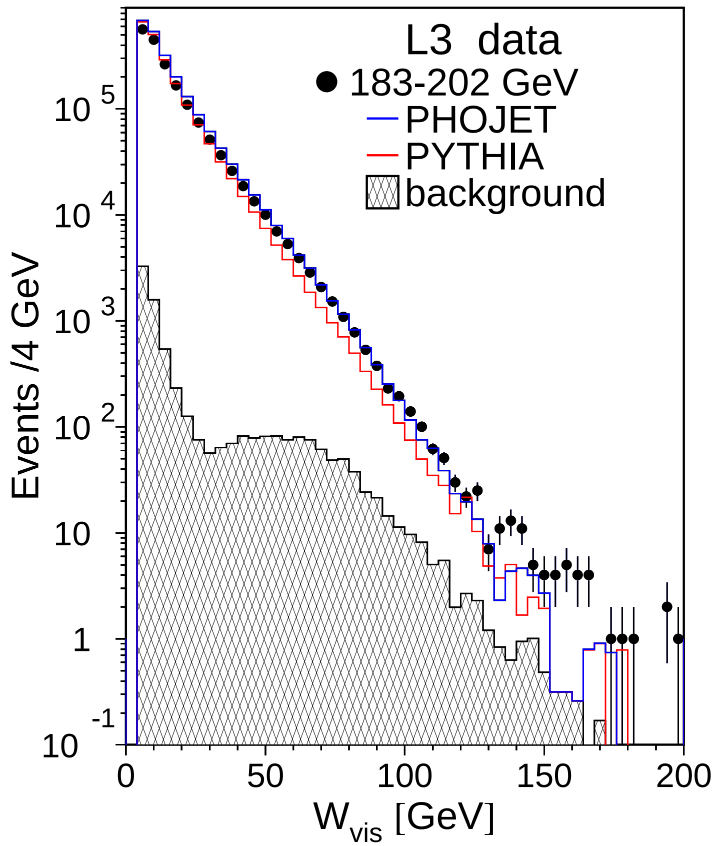
- $e^+e^- \rightarrow e^+e^-$ *hadrons* event selection
- Inclusive π^0 production
- Inclusive $h^{\pm}$ production
- Jet cross-sections
- Conclusions

Event selection $e^+e^- \to e^+e^-$ *hadrons*



- $E_{tot} \leq 40\% \sqrt{s}$
- # particles ≥ 6
- Anti-tag :
  reject if $E_{Lumi} > 30$ GeV
- $W^2_{vis} = (\sum_i E_i)^2 - (\sum_i \vec{p}_i)^2$
  $W_{vis} < W_{\gamma\gamma}$
  $W_{vis} > 5$ GeV

$e^+e^- \rightarrow e^+e^-$ *hadrons*

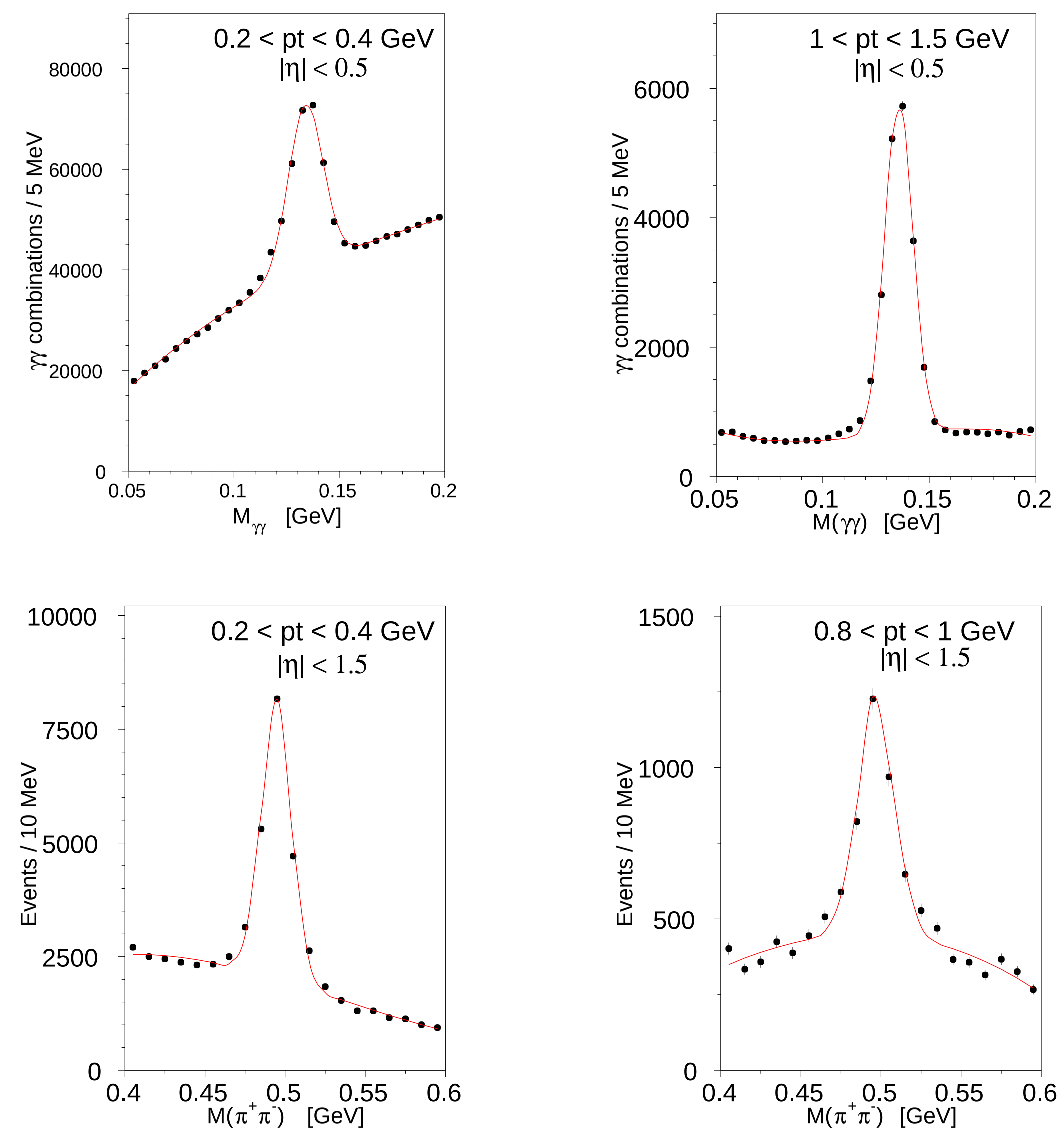


- $<\sqrt{s}>= 194$ GeV
  $L = 414 \mathrm{pb}^{-1}$
  $\Rightarrow \sim 2$ million events
- Main backgr. $(1 - 15\%)$:
  $e^+e^- \rightarrow e^+e^-\tau^+\tau^-$
  $e^+e^- \rightarrow hadrons$
- Monte Carlo :
  PYTHIA 5.722, PHOJET 1.05c
- Phase space defined by MC:
  $W^2_{\gamma\gamma} < 5$ GeV , $Q^2 < 8$ GeV^2

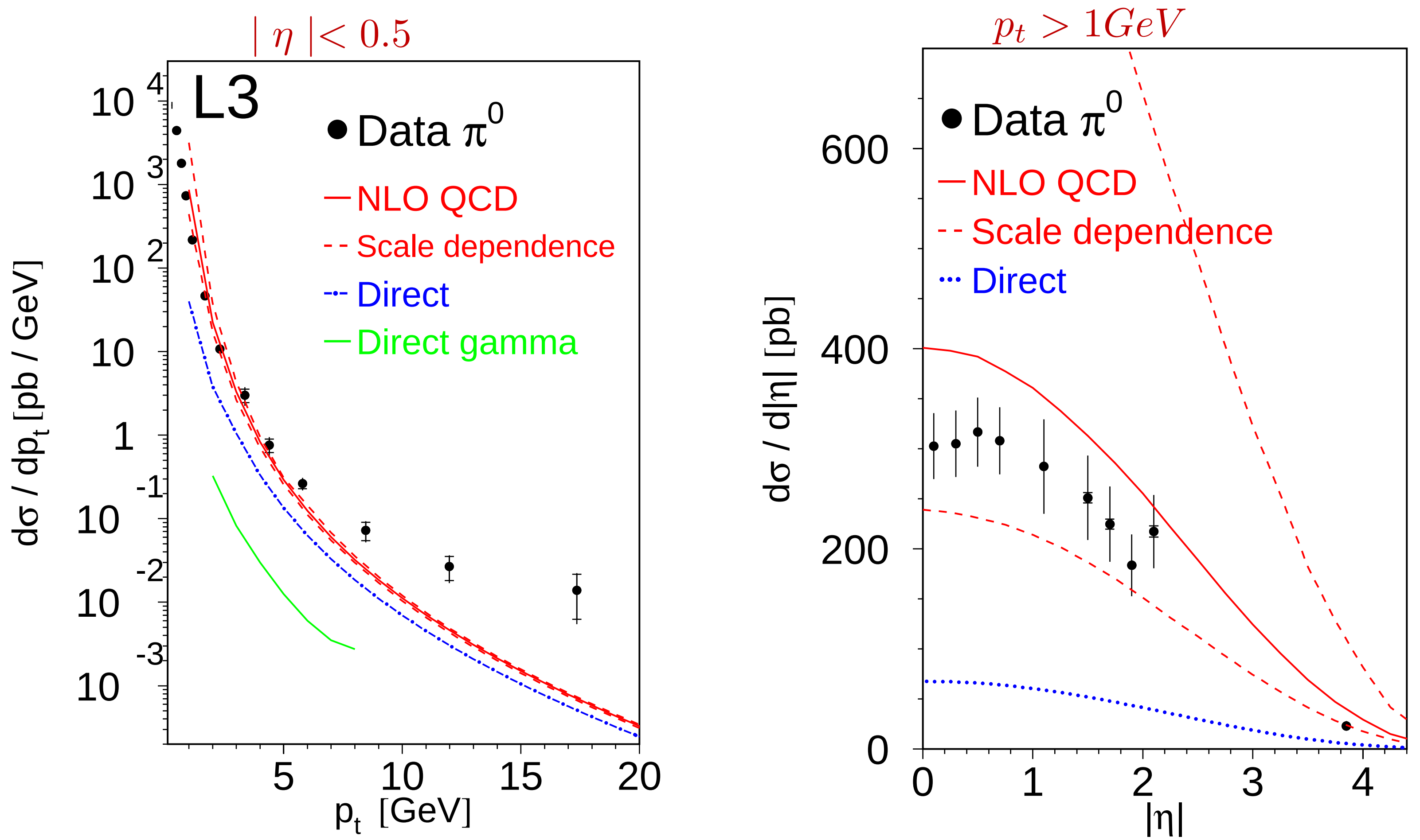
Inclusive single hadron production

π^0 and K_S^0 published in PLB524 (2001)44.
$\pi^\pm$ and $K^\pm$ published in PLB554 (2003)105.

π^0 and K_S^0 reconstruction

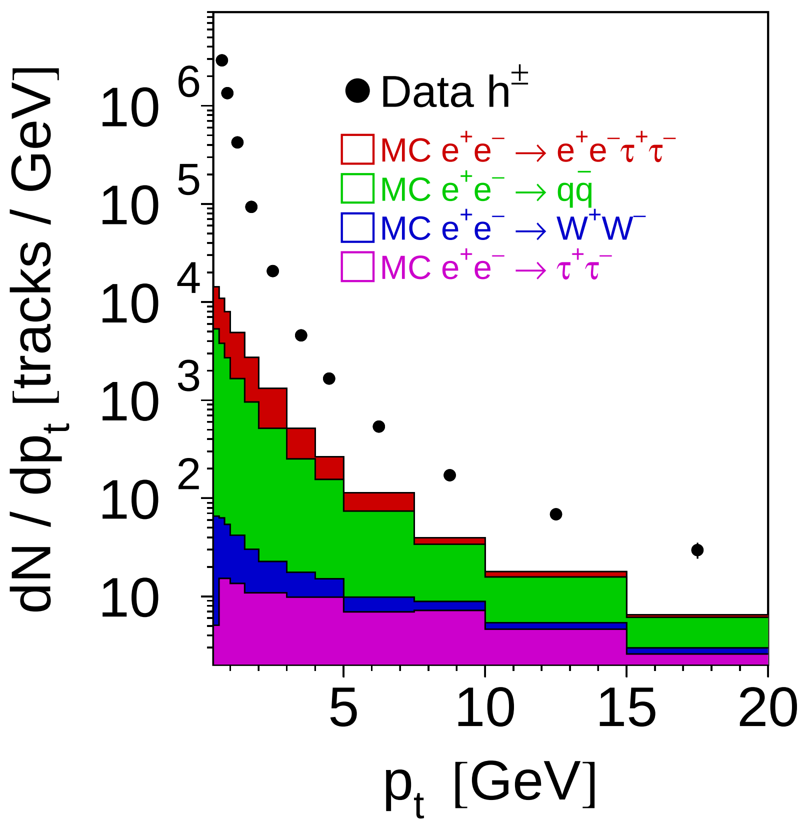


π^0 : Comparison with NLO QCD



- Measurements exceed QCD predictions (B.A.Kniehl) at high p_t
- No anomaly in η distribution

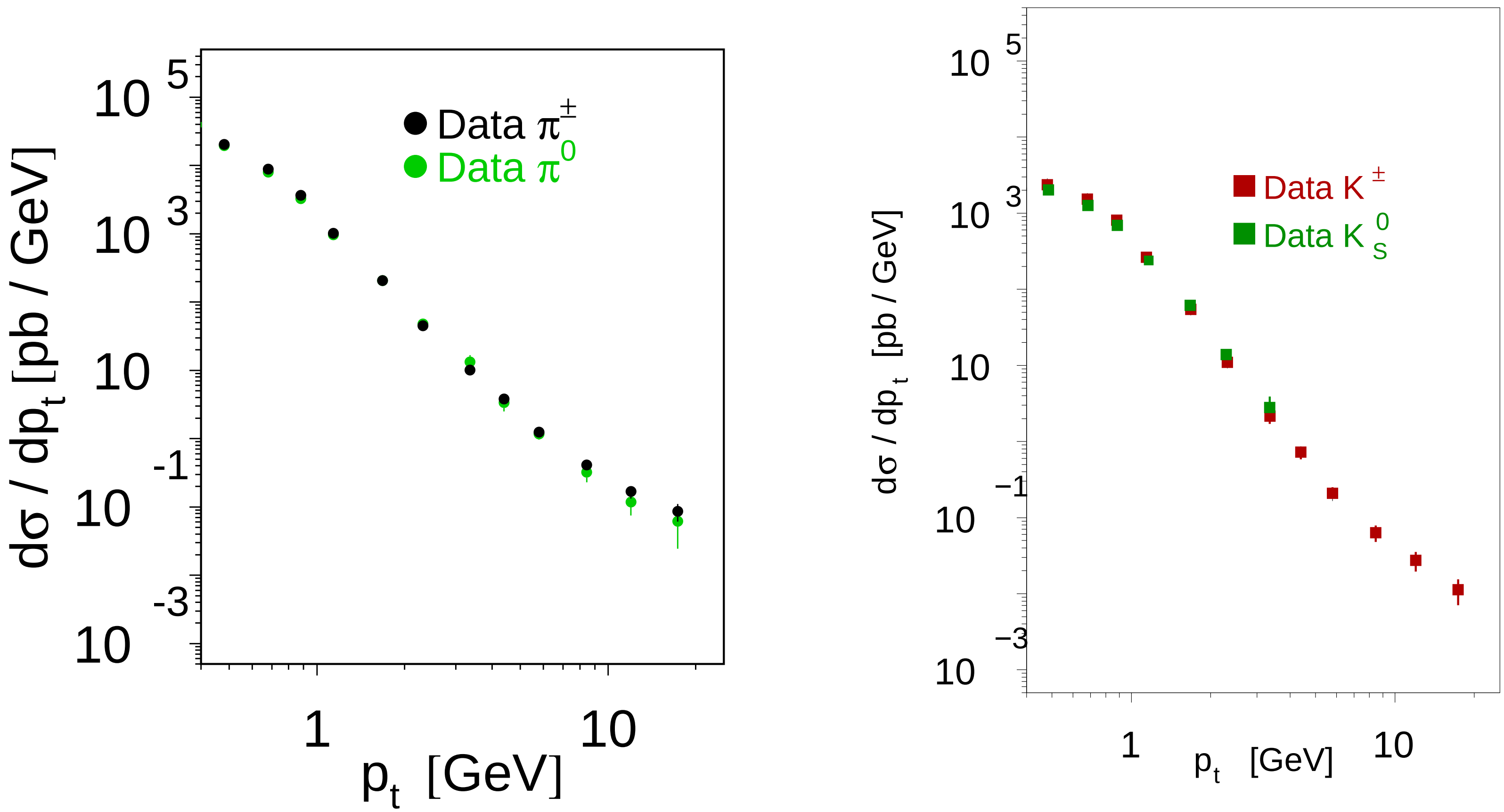
$h^{\pm}$ selection



- Track selection:
  $p_t > 400$ MeV, DCA < 4 mm,
  $> 80\%$ expected hits.
- $\mid \eta \mid < 1$
- $\sigma_{p_t}/p_t \simeq (0.015\ \mathrm{GeV}^{-1})\ \ p_t$
- Efficiency $\sim 60 - 80\%$
- Systematics :
  MC models: 5-25%
  Selection efficiency: 10-1%
  Background subtraction: 0.1-5%

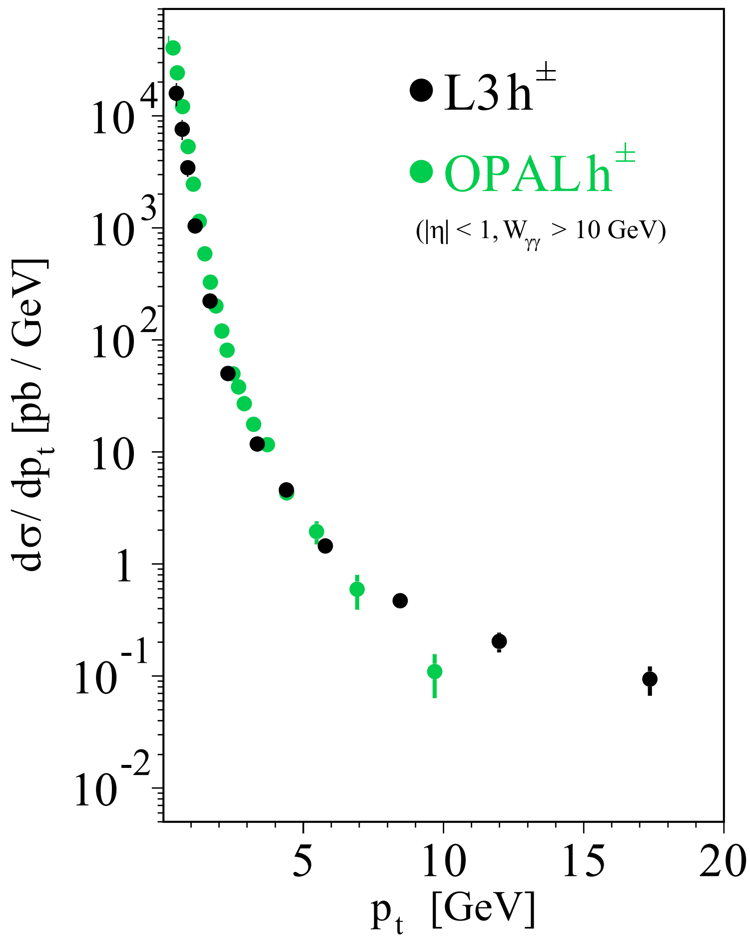
$\pi^{\pm}$ and $K^{\pm}$

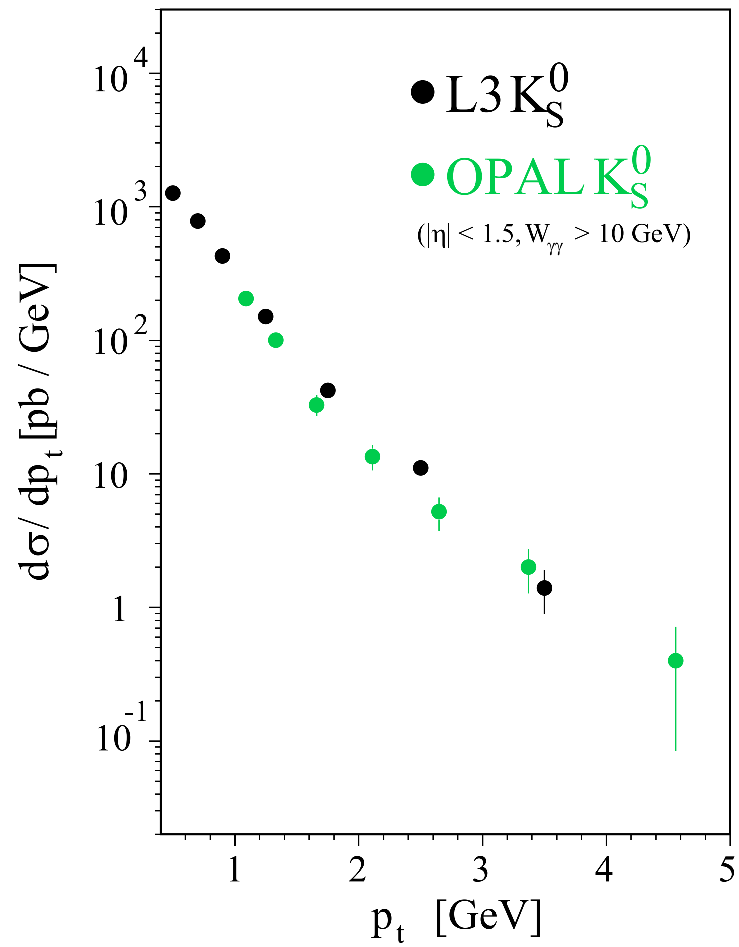
Separation by Monte Carlo ratios (JETSET 7.409).



✦ Good agreement with π^0 and K^0_s data

Comparison with OPAL

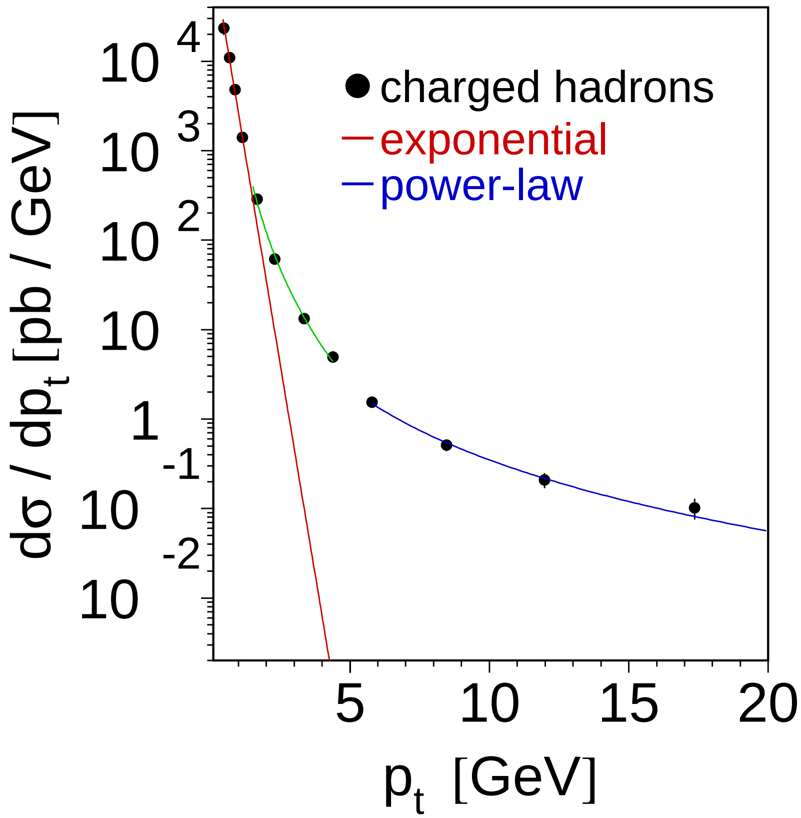




K. Ackerstaff et al. Eur. Phys. J. C 6 (1999) 253.

$< \sqrt{s} > \simeq 165$ GeV , $| \eta |< 1.5$

Fits to the data



- For $p_t < 1.5$ GeV

  Exponential $Ae^{-p_t/<p_t>}$

  $< p_t > \simeq 230$ MeV for $\pi^{\pm}, \pi^0$
  $\simeq 300$ MeV for $K^{\pm}, K^0_S$

  $\Rightarrow$ Soft interactions

- For $p_t > 1.5$ GeV

  power law Ap_t^{-B}
  $1.5 \leq p_t < 5.$ GeV B $= 4.2 \pm 0.2$
  $\chi^2/d.o.f. = 4.7/2$

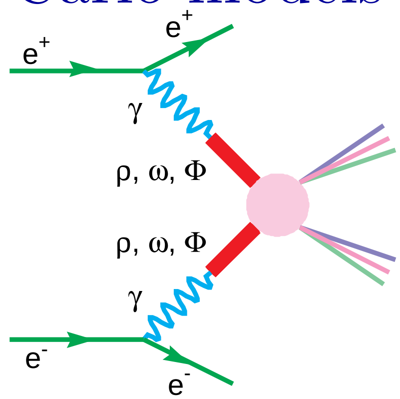
  $5.0 \leq p_t < 20.$ GeV B $= 2.6 \pm 0.3$
  $\chi^2/d.o.f. = 0.7/2$

  $\Rightarrow$ Direct and resolved (QCD)

Diagrams contributing to $\gamma\gamma$ interactions

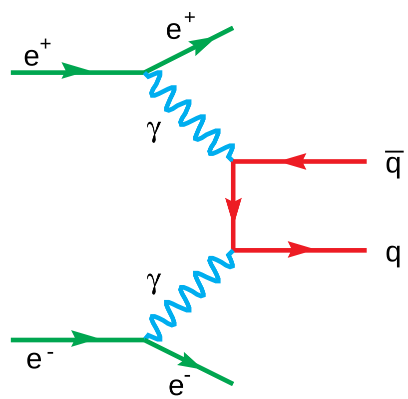
Monte Carlo models : VDM, LO QCD (DGLAP), pdf in the photon

SOFT:

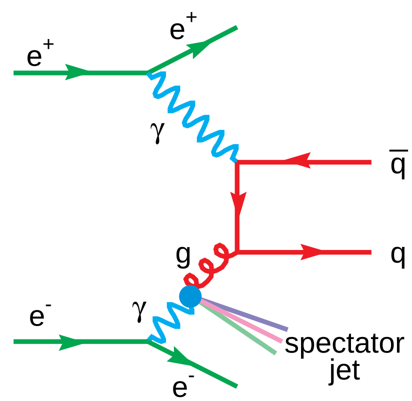


VDM

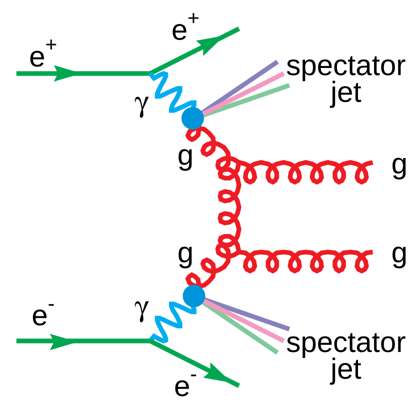
HARD:



Direct

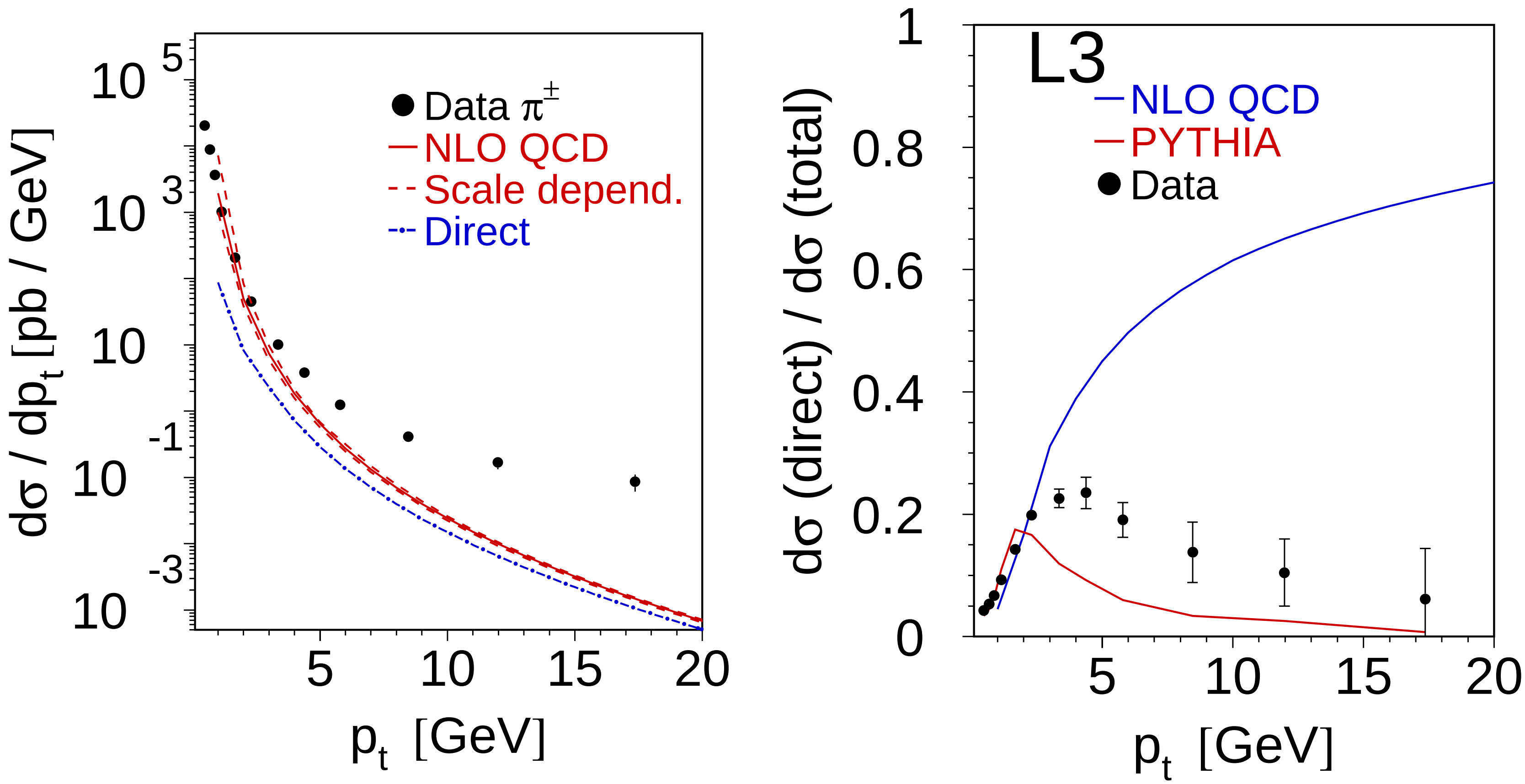


Single Resolved



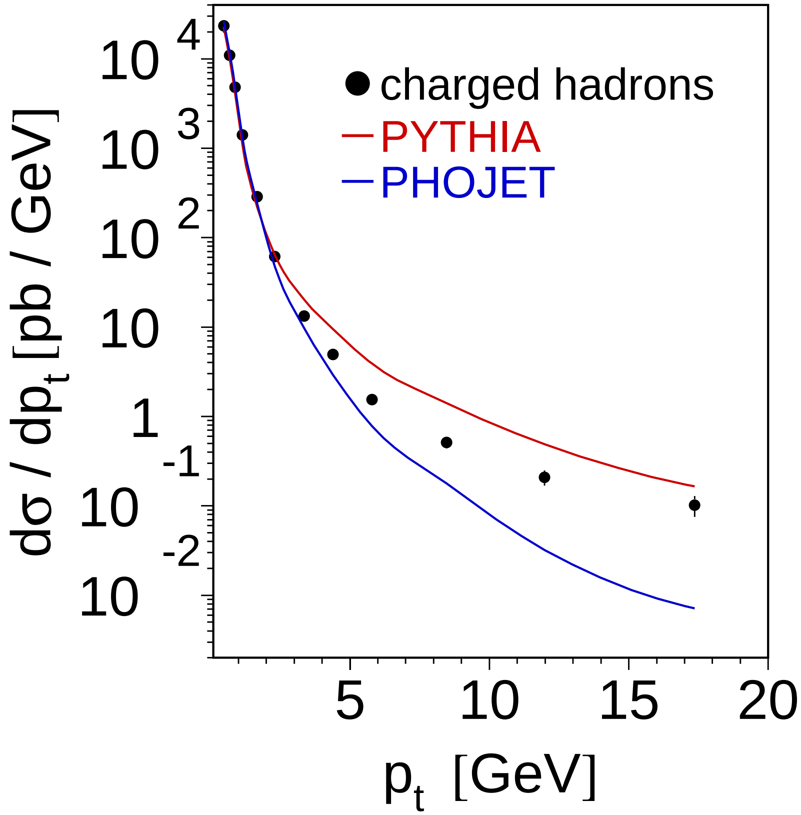
Double Resolved

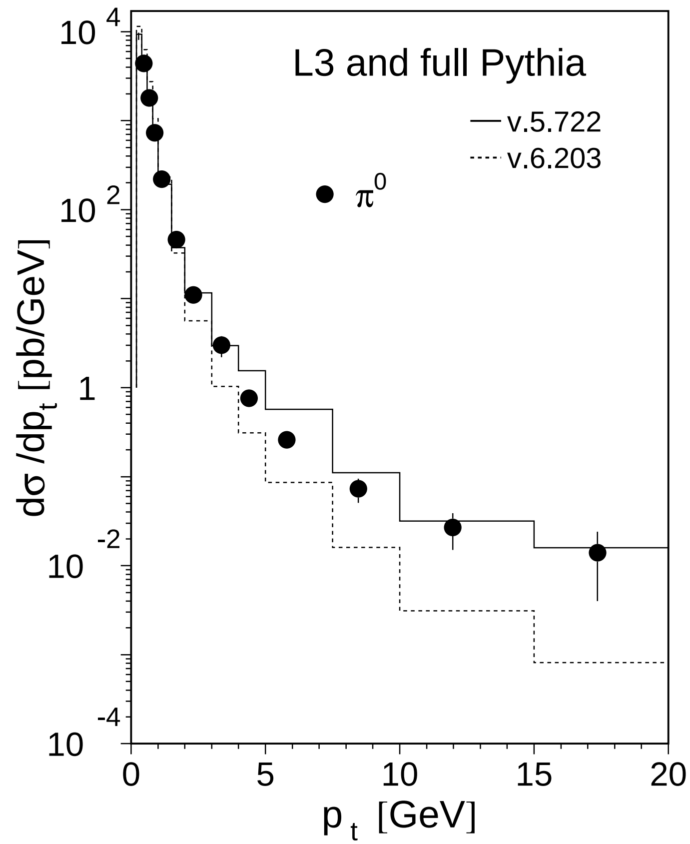
Comparison with Theory



- Measurements exceed QCD predictions (B.A.Kniehl) at high p_t
- The data are largely beyond the direct contribution

Comparison with Monte Carlo

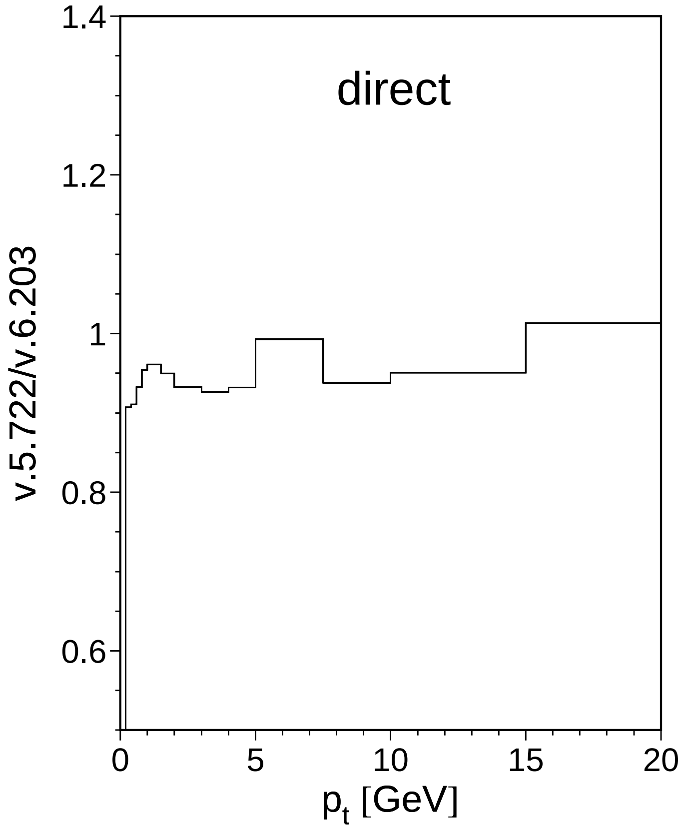


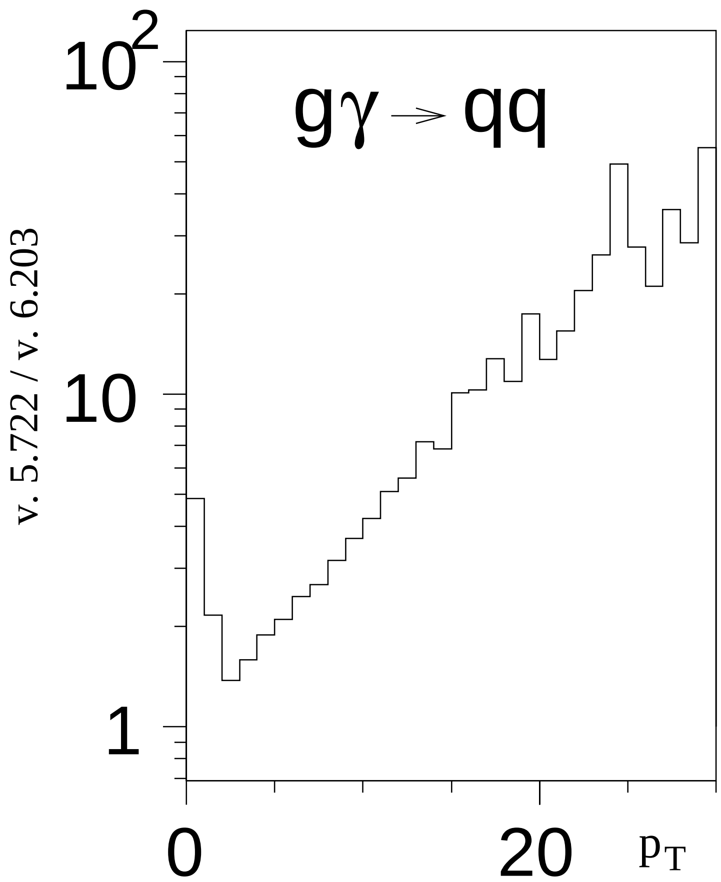


⇨ PHOJET is too low (similar to NLO calculations)

⇨ PYTHIA has changed ! Becomes consistent with PHOJET

Compare Pythia versions



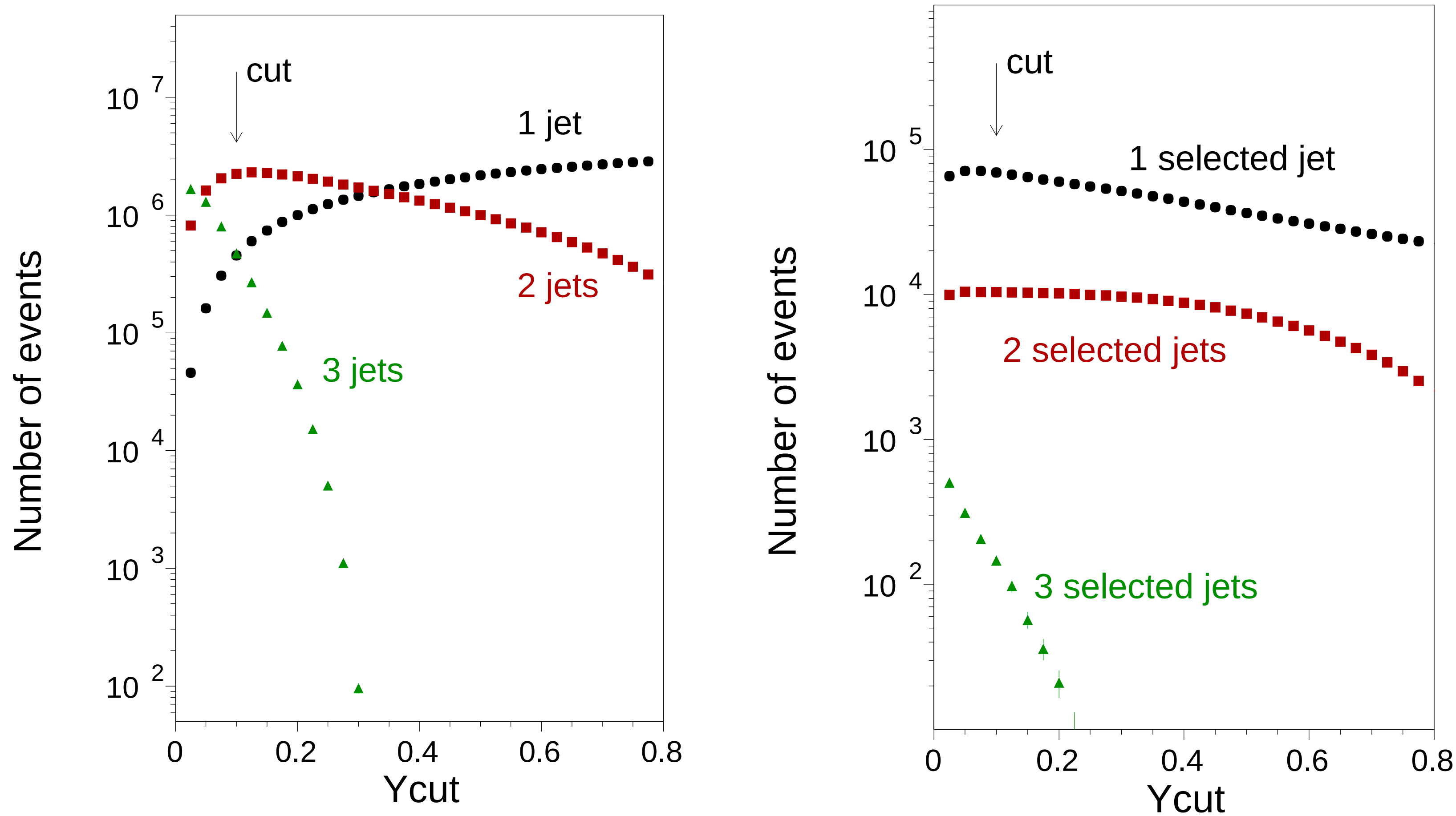


✦ Striking difference, pointing to QCD diagrams!

Jet analysis

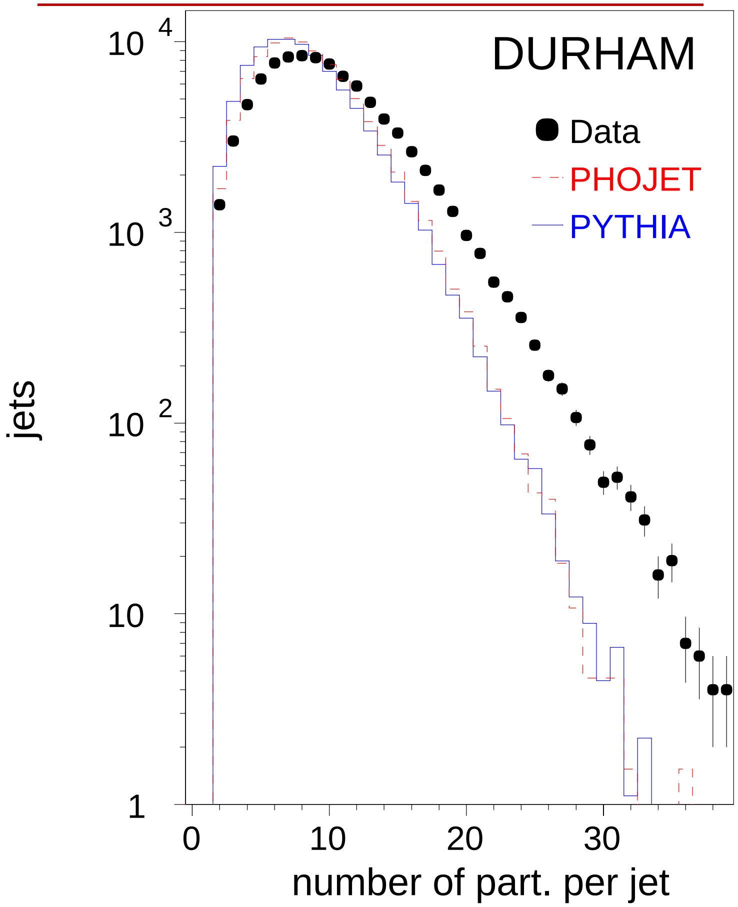
- Generated jets : $\gamma, \quad \pi^{\pm}, \quad p, \quad n, \quad \mathrm{k}^{\pm}$
- Reconstructed jets : tracks $0.4 \leq p_t \leq 100\mathrm{GeV}$
  e.m. clusters $E > 0.1\mathrm{GeV}$
- Kinematical range :
  $p_t > 3\mathrm{GeV} \qquad \mid \eta \mid < 1$
- Algorithms
  DURHAM : $y_{ij} = 2min(E_i^2, E_j^2)(1 - \cos\theta_{ij})/E_{vis}^2$
  $y_{cut} = 0.1$
  KTCLUS :
  $d_{ij} = min(p_{ti}^2, p_{tj}^2)((\eta_i - \eta_j)^2 + (\Phi_i - \Phi_j)^2)/D^2$
  $D = 1$

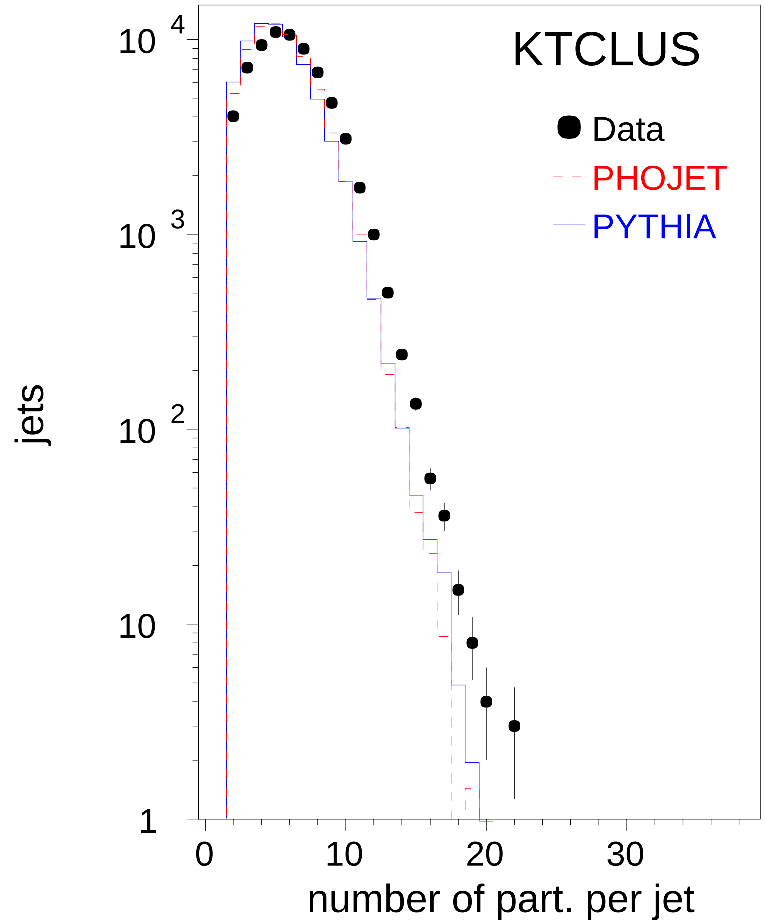
Durham Jet definition



- $y_{cut} = 0.1$ maximise 2-jet events
- Number of jets with $p_t > 3\text{GeV}$ and $\mid \eta \mid < 1$ ~independent of y_{cut}

Particles inside a jet

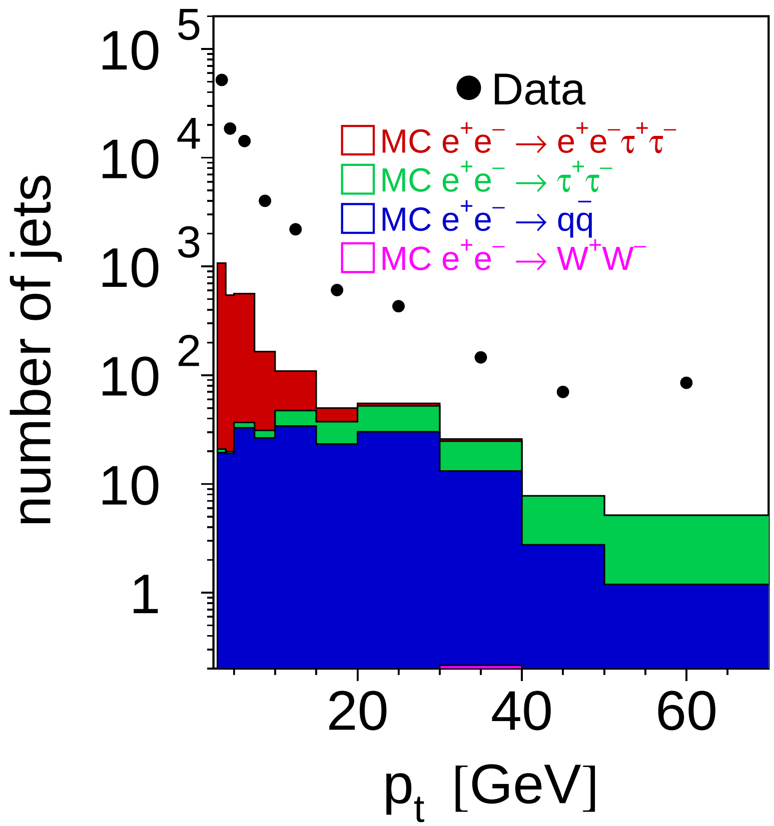




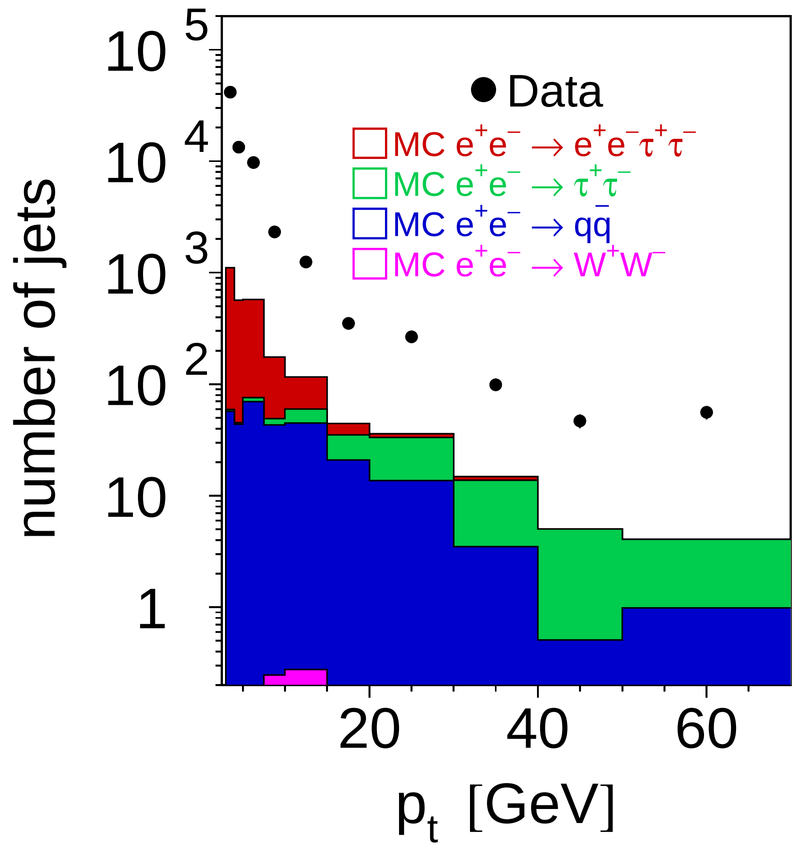
- Less particles in KTCLUS jets
- Durham is used at LEP for e^+e^-, spherical configurations
- KTCLUS is used in cylindrical configurations and NLO theory

Jets

Durham



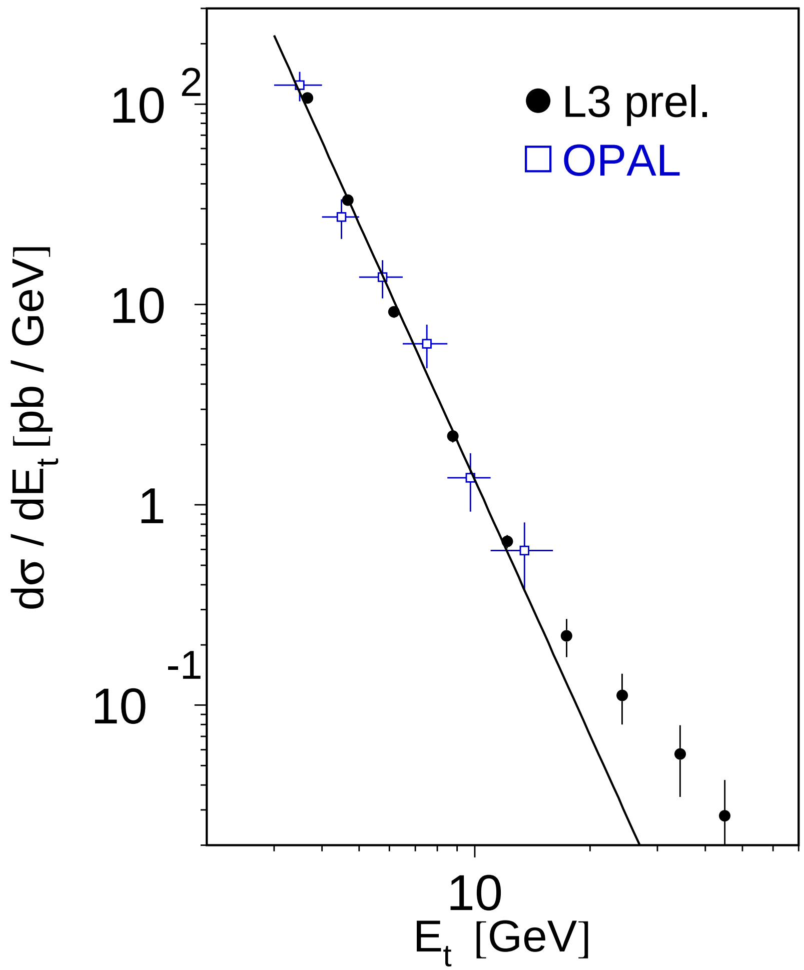
KTCLUS



Systematics due to Monte Carlo model : 5-60 %

Jets: Comparison with OPAL

Using KTCLUS algorithm



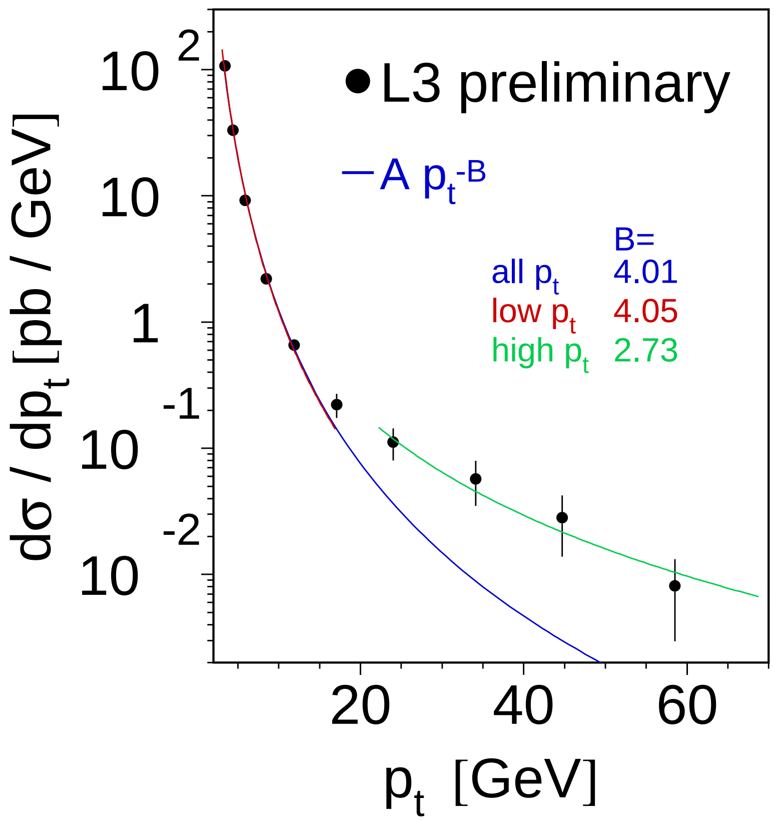
K. Ackerstaff et al.
Z. Phys.C 73 (1997) 433.

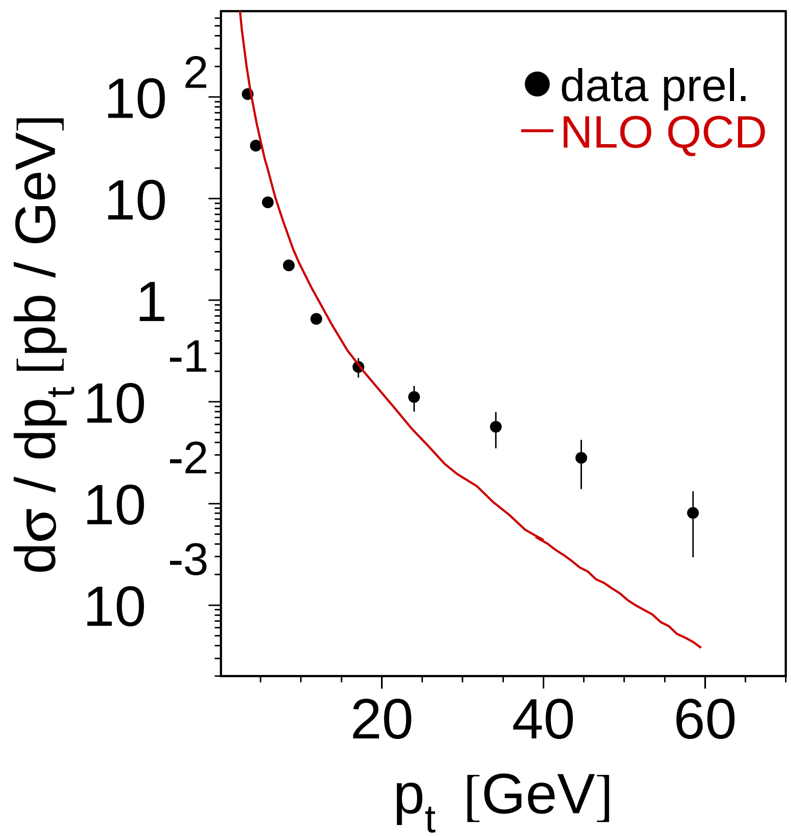
$< \sqrt{s} > \simeq 133$ GeV , $W_{\gamma\gamma} > 3$ GeV

Jets: Fits and NLO calculations

Using KTCLUS algorithm

NLO QCD : S. Frixione and L. Bertora





☛ Again an excess at high pt ! For $2 \rightarrow 2$ process B=3

Conclusions

- Unexpected deviations from theoretical predictions are observed:
  - $\sigma(\gamma\gamma \to hadrons)$
  - $\mathrm{d}\sigma/\mathrm{d}p_t$ of π^0 and $\pi^{\pm}$ for $p_t > 5\mathrm{GeV}$
  - $\mathrm{d}\sigma/\mathrm{d}p_t$ of inclusive jet production for $p_t > 20\mathrm{GeV}$
  - $\sigma(\gamma\gamma \to \mathrm{b\bar{b}})$
- Two questions arise :

  Are these phenomena correlated?

  Which is their origin?