Heavy Flavour Production in $\gamma\gamma$ Collisions at LEP with L3

R. R. McNeil

Louisiana State University

L3 Collaboration

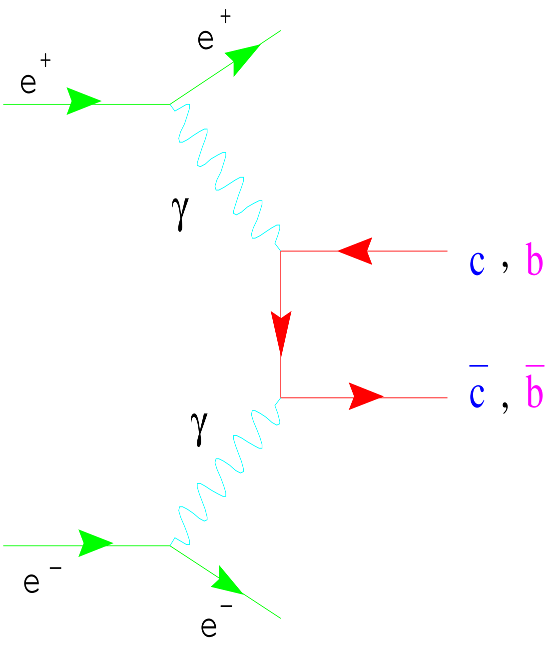
Outline

1. Motivation
2. Data Samples and Hadronic Event Selection
3. Lepton Identification
4. Results on Charm Production using Lepton Tag
5. Charm Production using D*
6. Beauty Production in $\gamma\gamma$ Collisions
7. Summary and outlook

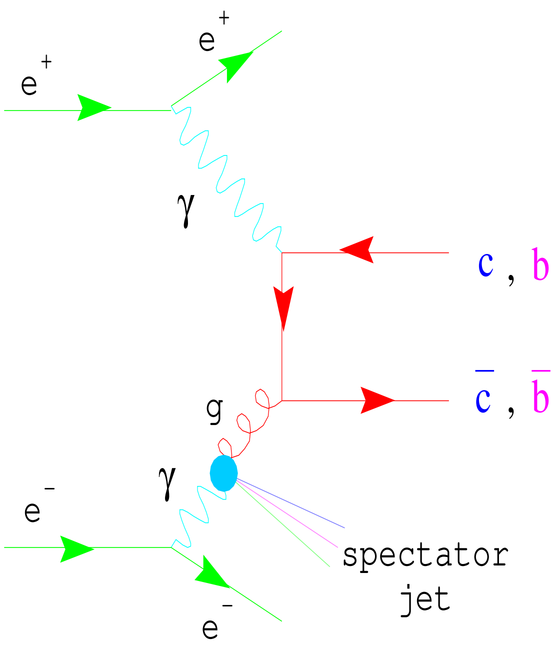
This is work of V. Andreev, S. Saremi, D. Prokofiev, and R.M.

Motivation

$$\gamma\gamma \to c\bar{c}, b\bar{b}$$



Direct



Single Resolved

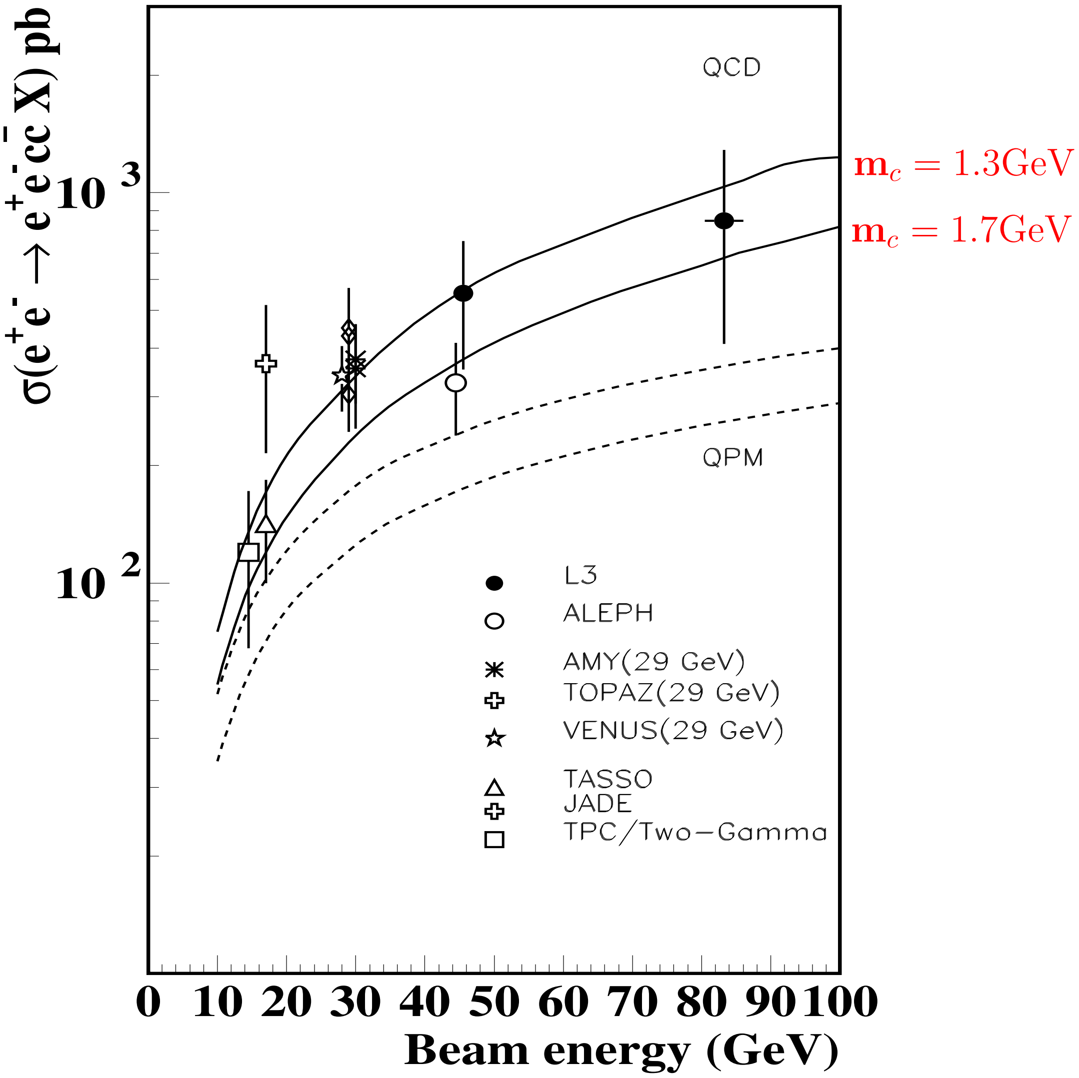
Contribution from Direct and Resolved processes are predicted to be comparable at LEP2 energies

- Direct Process depends on $m_c(m_b)$ and α_s
- Resolved process also depends on gluon content of the photon

Measurement is sensitive to gluon density

Status as of PHOTON97

Cross section for $\gamma\gamma \rightarrow c\bar{c}$



First LEP2 measurement reported using only muon tagged Events

Hadronic Event Selection

Selection of $e^+e^- \longrightarrow e^+e^-$hadrons

CUTS:

1: # Tracks > 4 (removes $\ell^+\ell^-$ backgrounds)

2: $W_{VIS} > 3$ GeV (reduces light quark $\gamma\gamma$ background)

3: $E_{vis}/\sqrt{s} < 0.38$ (removes 1-γ annihilation)

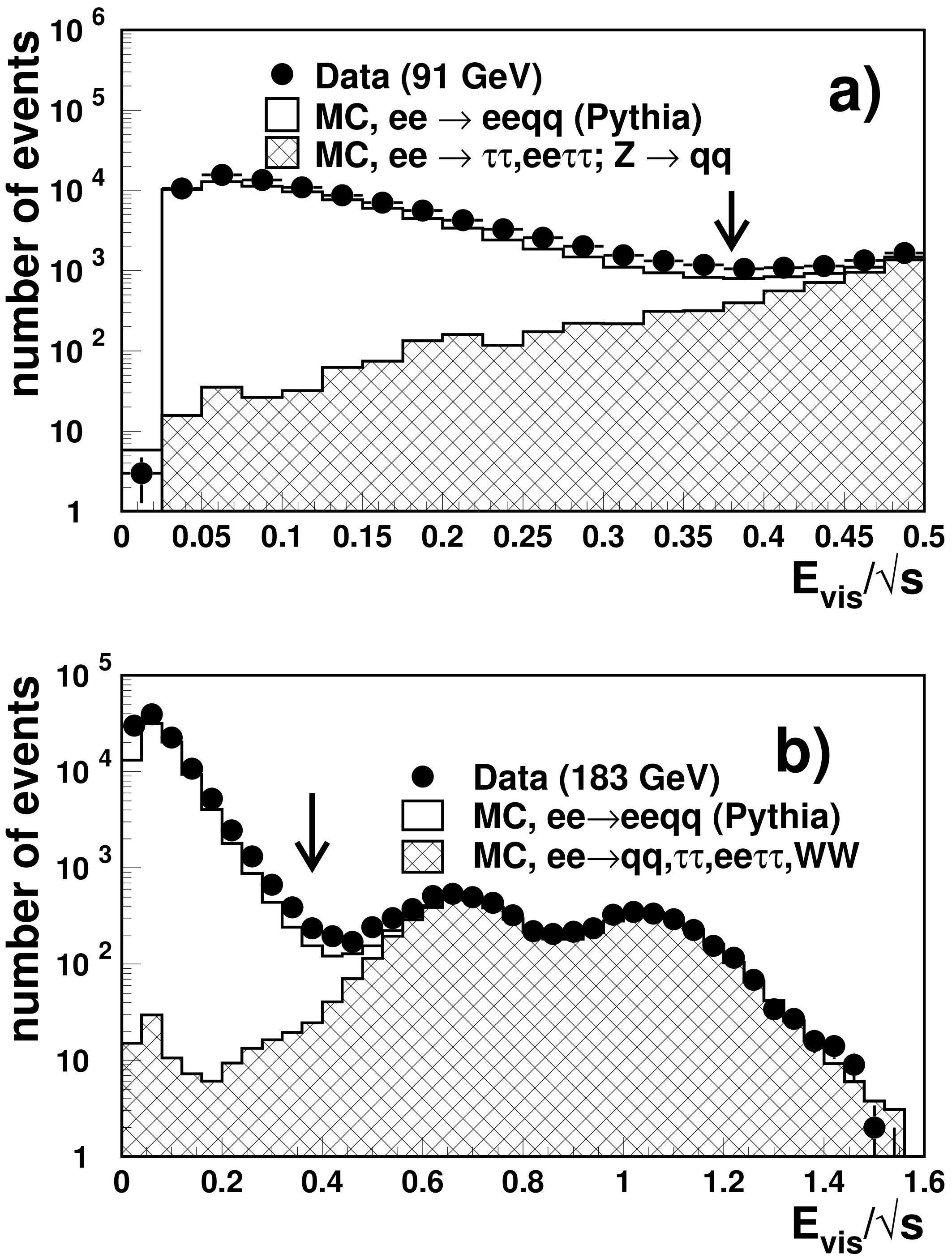
4: $E_{lumi}/E_{beam} < .4$ (anti-tag condition)

Events after cuts

$\sqrt{s}$ (GeV)	$\mathcal{L}$ (pb^{-1})	Data	background %
91	80	93024	2.4
130,136	12	21045	0.2
161,172	21	44444	0.2
183	52	116760	0.2
189	176	399755	0.14

Visible Energy for Data and Monte Carlo

All other hadronic selection cuts applied



$$E_{vis}/\sqrt{s} < 0.38$$

Lepton Identification - Charm Tagging

Tag charm by semi-leptonic decay to e or μ

$\mu^{\pm}$ Selection

track in muon ch.
$|\cos\theta| < 0.90$
$P_{\mu} > 2$ GeV/c
$P_{\mu} < 0.2E_{beam}$

$e^{\pm}$ Selection

matched e.m. shower
$|\cos\theta| < 0.90$
$P_e > 0.6$ GeV
$0.85 < E_T/p_T < 1.2$

$\sqrt{s}$ GeV	$\mathcal{L}$ pb^{-1}	Muons # ev.	Electrons # ev.
91	80	62	282
$130-140$	12	-	82
$161-172$	21	17	156
183	52	52	433
189	176	208	1685

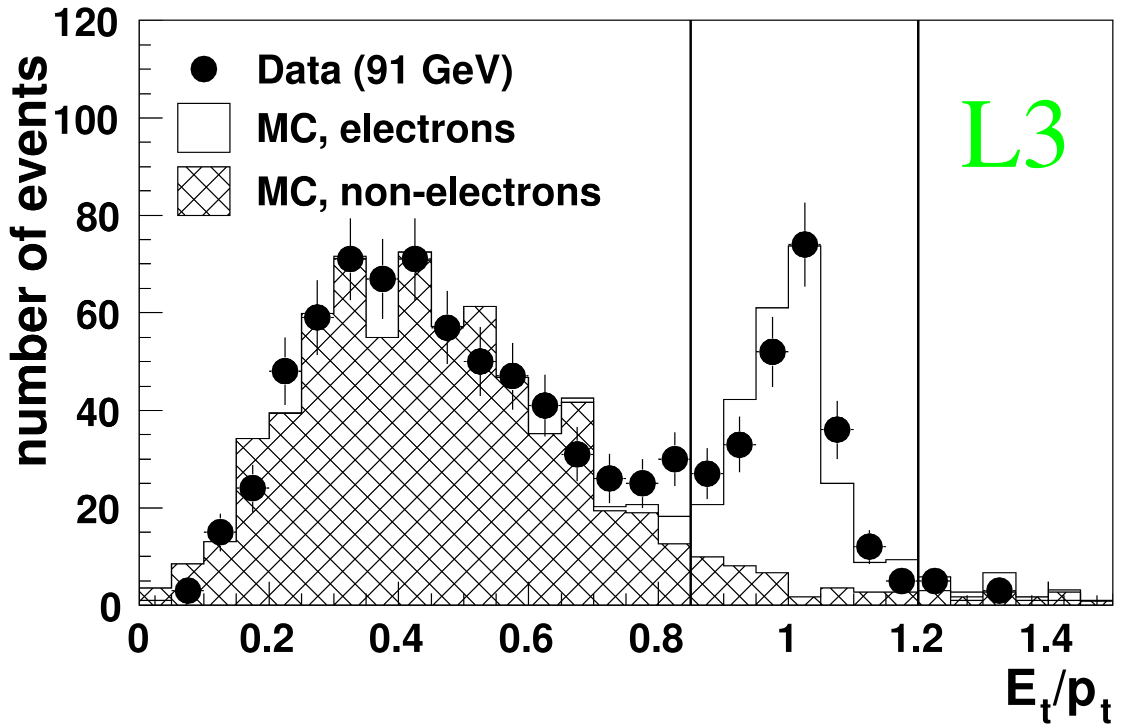
$\mu^{\pm}$ Selection

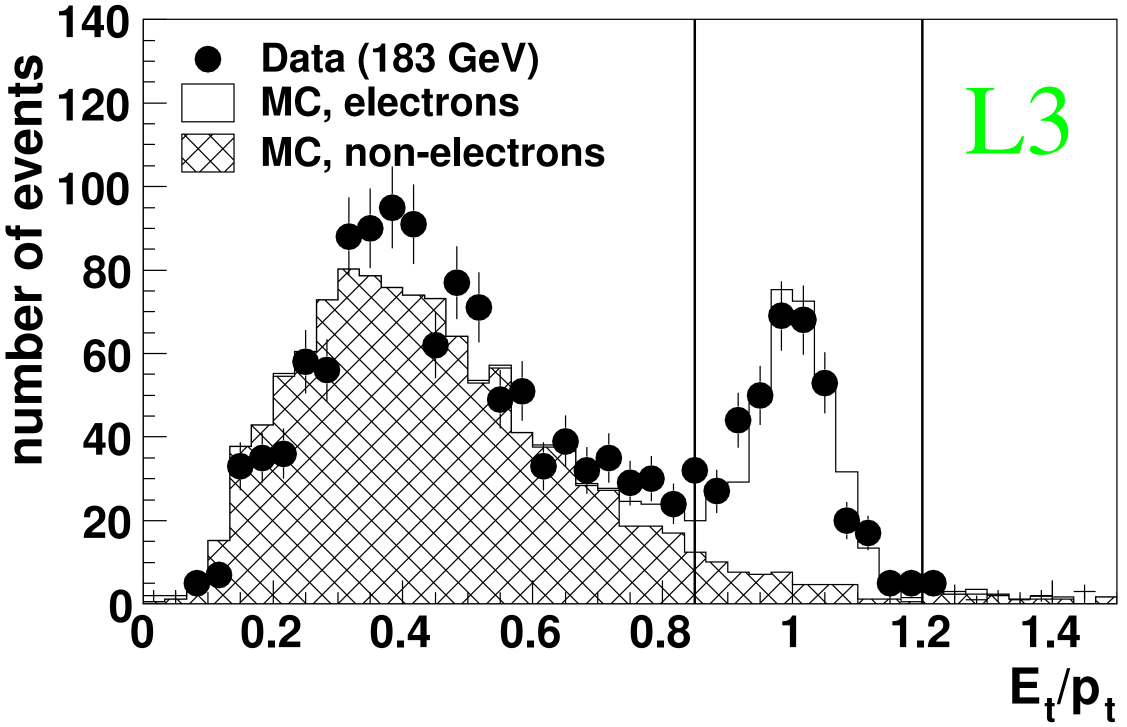
Charm Effic. $\simeq$ 0.07%
Charm purity $\simeq$ 65%

$e^{\pm}$ Selection

Charm Effic. $\simeq$ 0.5%
Charm purity $\simeq$ 60%

Electron Identification

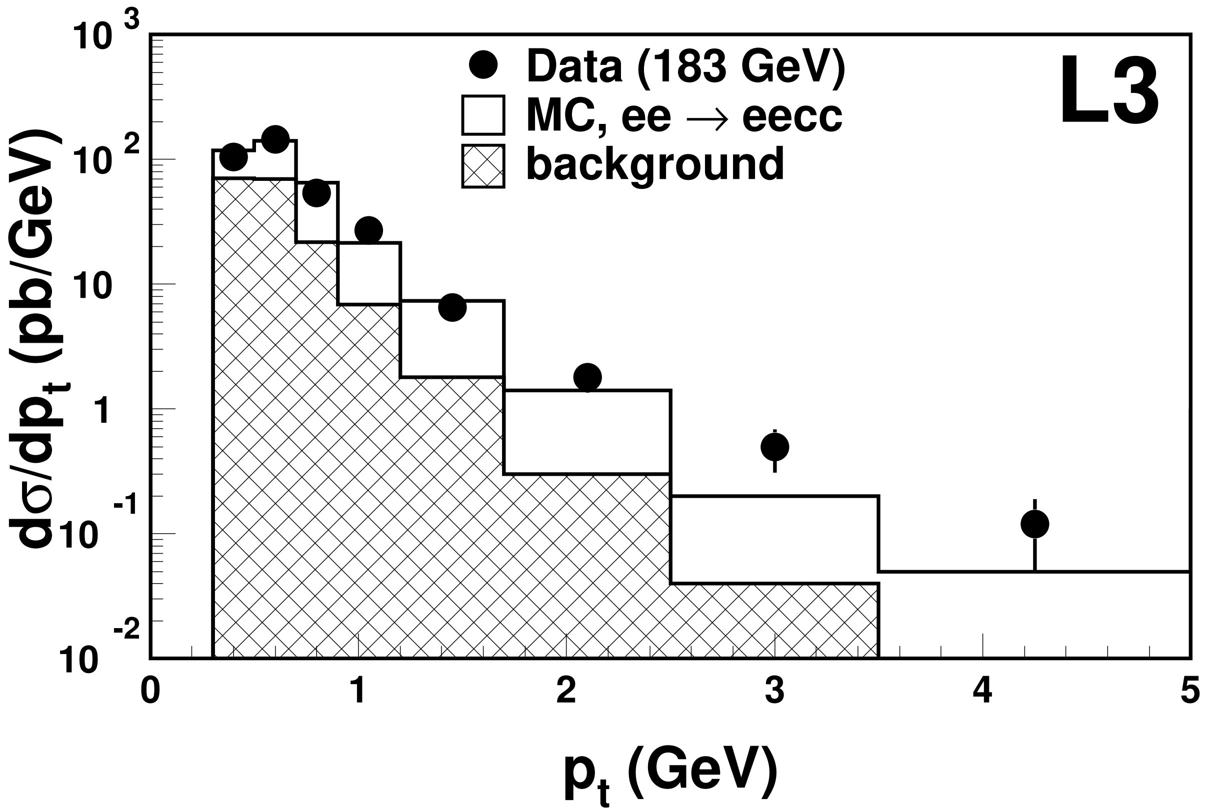




non-electron background $\sim$ 15%

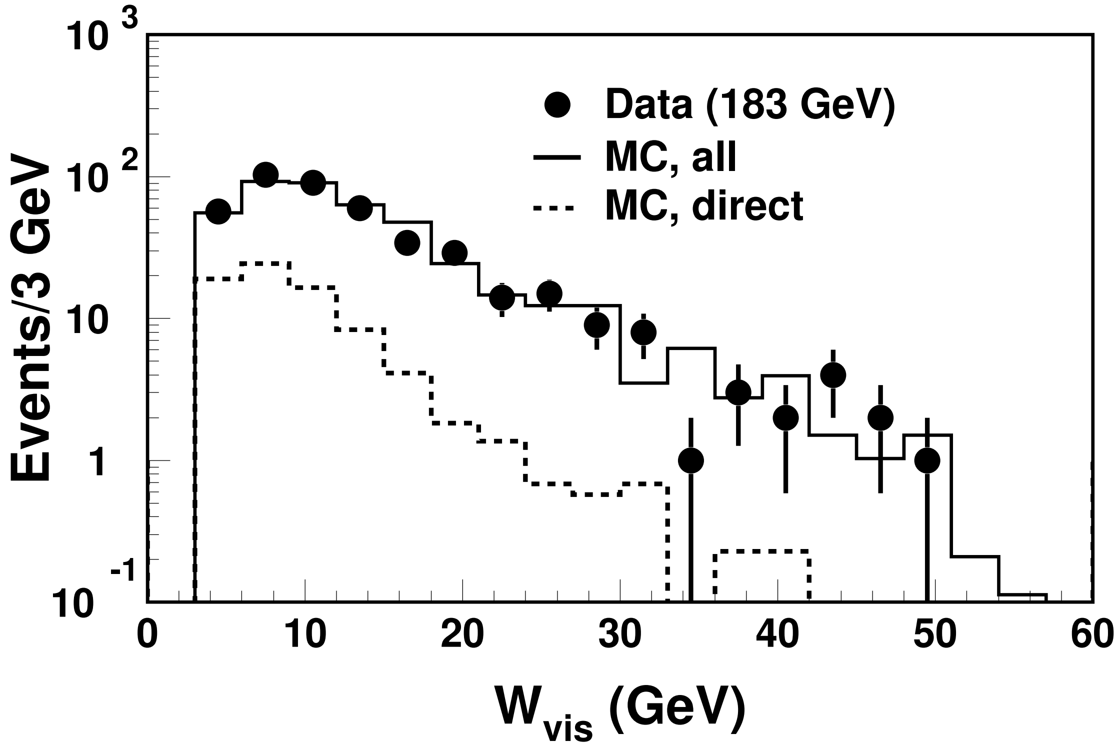
Inclusive Lepton Production

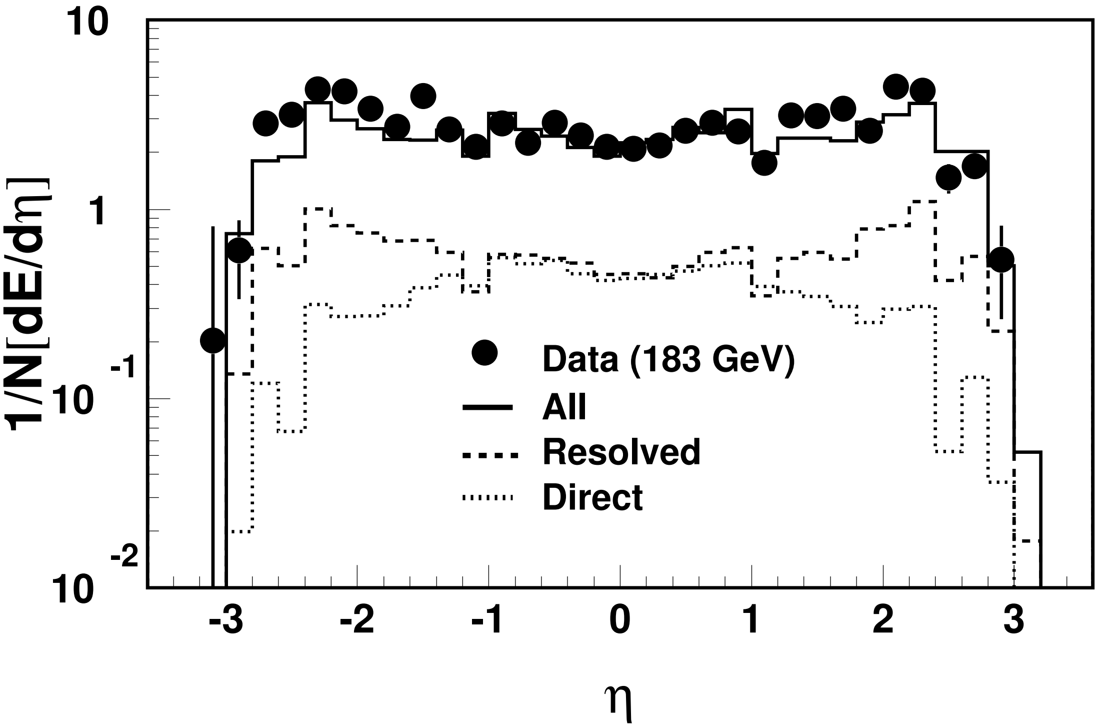
Lepton Transverse Momentum



- p_t spectrum well described by PYTHIA
- fraction of charm events increases with p_t
- Excess at high $p_t \Rightarrow e^+e^- \rightarrow e^+e^-b\bar{b}$?

Direct vs Resolved



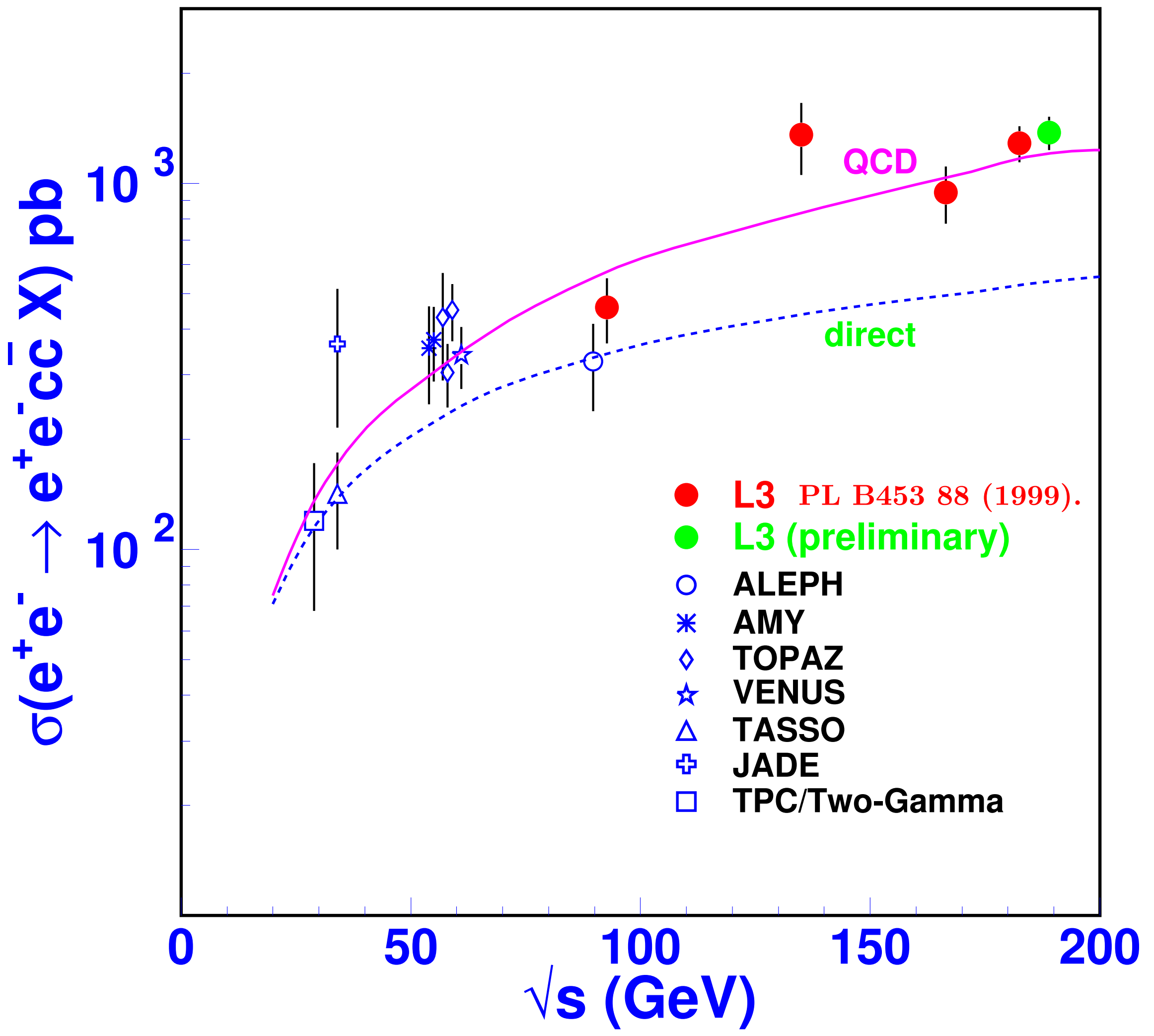


Need resolved processes to describe the data

Charm Production in $\gamma\gamma$ collisions

Preliminary measurement at $\sqrt{s} = 189$ GeV

Muons:	$\sigma_{c\bar{c}}$ =1070±144(stat.)±152(syst.) pb
Electrons:	$\sigma_{c\bar{c}}$ =1599± 60(stat.)±174(syst.) pb
Combined:	$\sigma_{c\bar{c}}$ =1378± 55(stat.)±134(syst.) pb



* Theory prediction using $m_c = 1.3$GeV from

M. Drees,M. Krämer,J. Junft and P.M. Zerwas,PL **B306** 371 (1993).

QCD prediction agrees with the data

Clear evidence for gluon content of the photon in LEP2 data

D* Production in $\gamma\gamma$ collisions

Search for $\mathrm{D}^{*\pm} \rightarrow \mathrm{D}^0\pi_\mathrm{s}^\pm \rightarrow (\mathrm{K}^\mp\pi^\pm)\pi_\mathrm{s}^\pm$

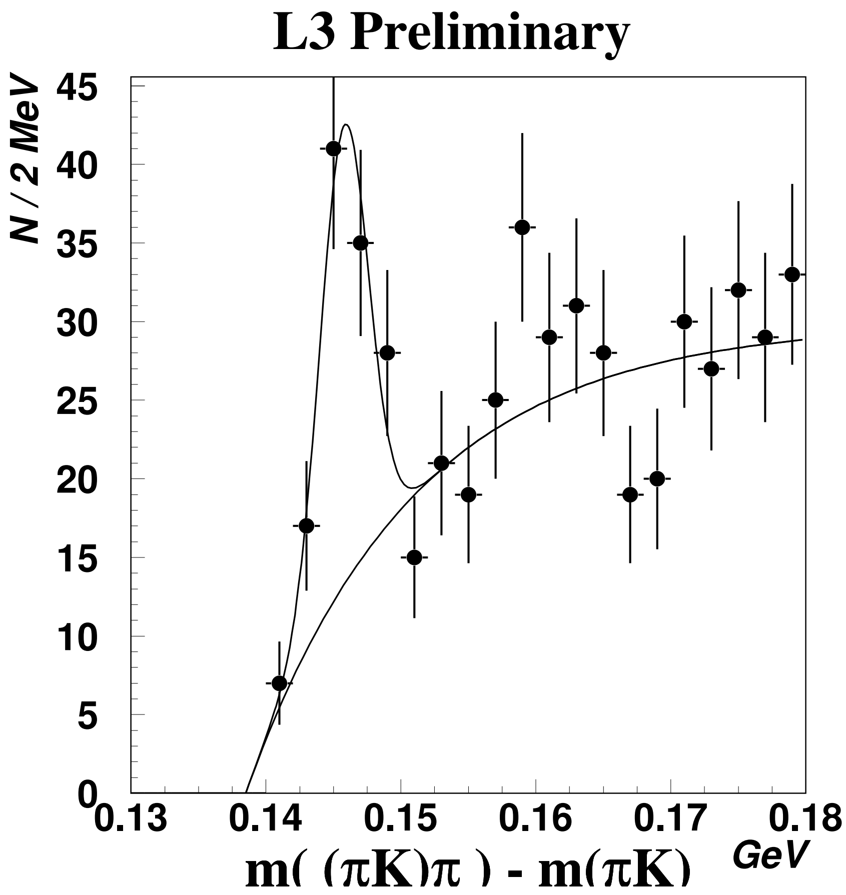
Selection:

1: Select hadronic two-photon events

2: π_s: momentum and vertex cuts

3: D^0: 2 tracks (compatible with $K^\pm\pi^\mp$ by dE/dx)

Select window for D^0 mass: $1.8 < M_{K\pi} < 1.93$

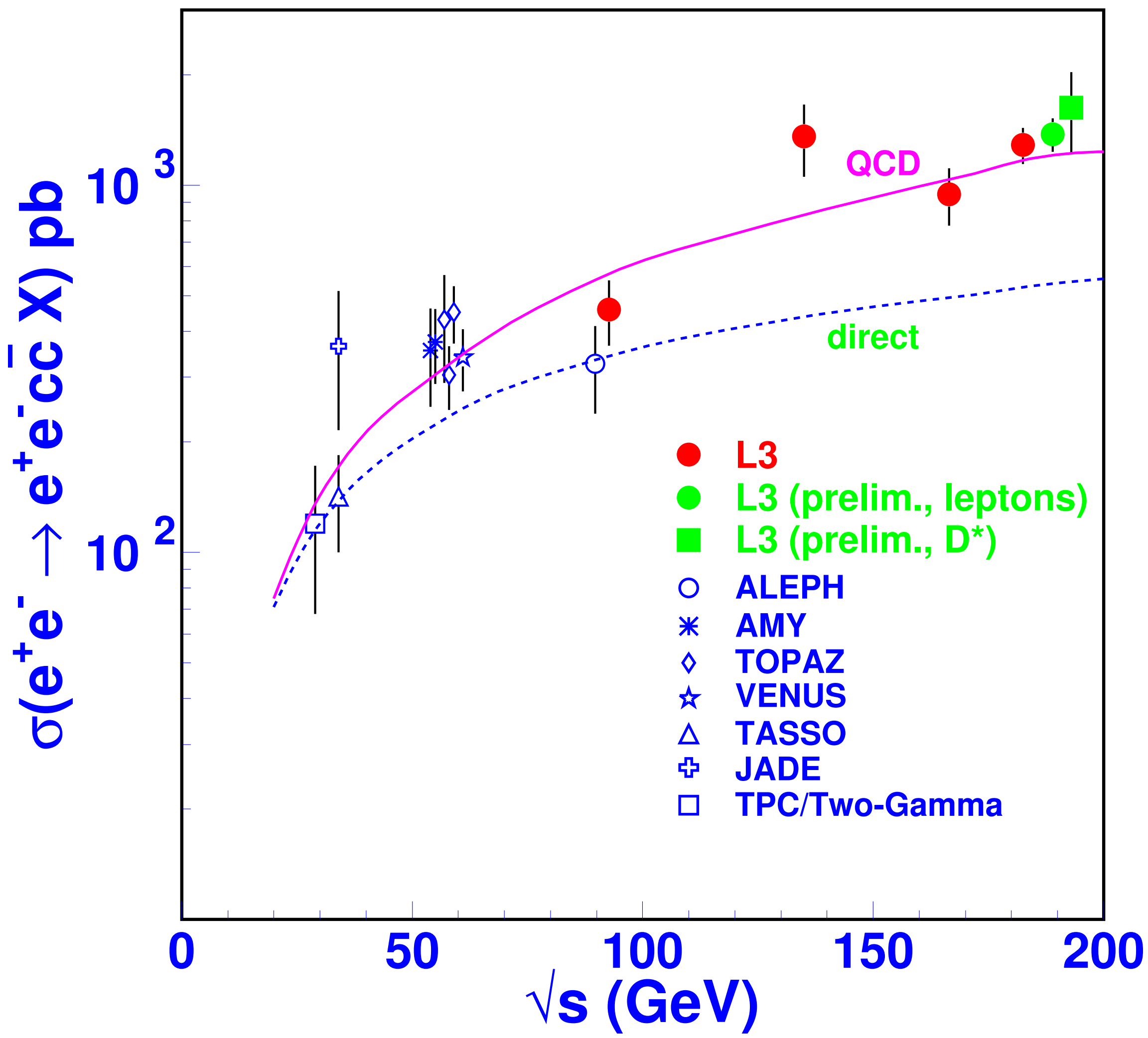


Signal Events: 66±10 ε_{D^*} =0.049% Π_{D^*} =70%

D* Production in $\gamma\gamma$ collisions

Preliminary Result at $\sqrt{s} = 189$ GeV

$\sigma = 1624 \pm 242$(stat.)± 390(syst.) pb

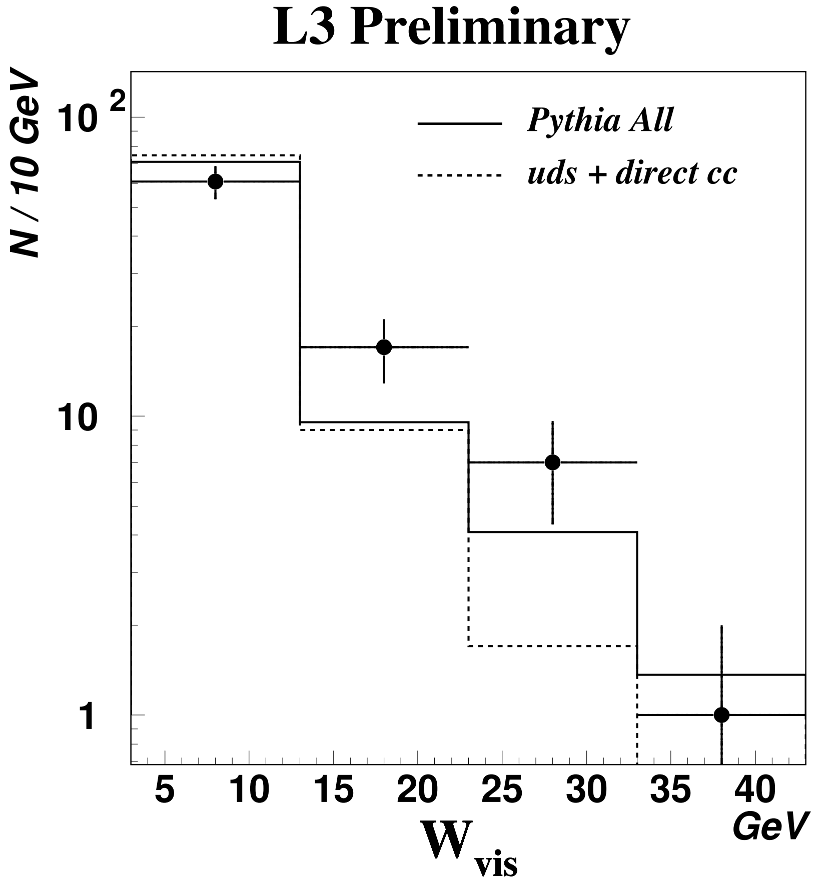


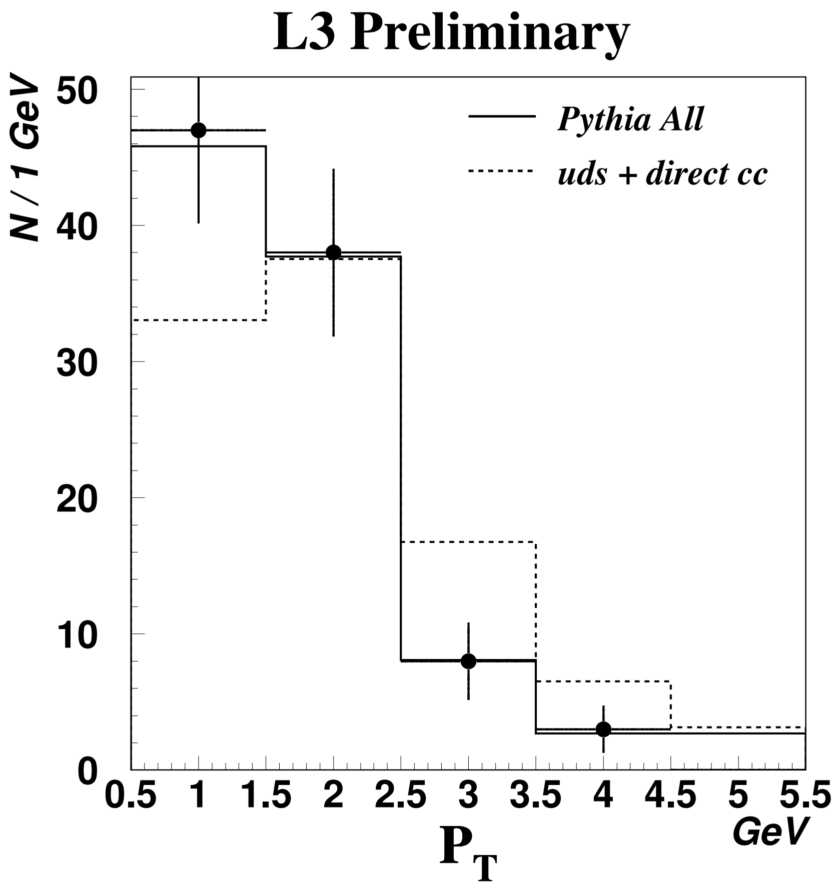
* Theory prediction using $m_c = 1.3$GeV from

M. Drees, M. Krämer, J. Junft and P.M. Zerwas, PL **B306** 371 (1993).

D* result consistent with that from lepton tags and QCD

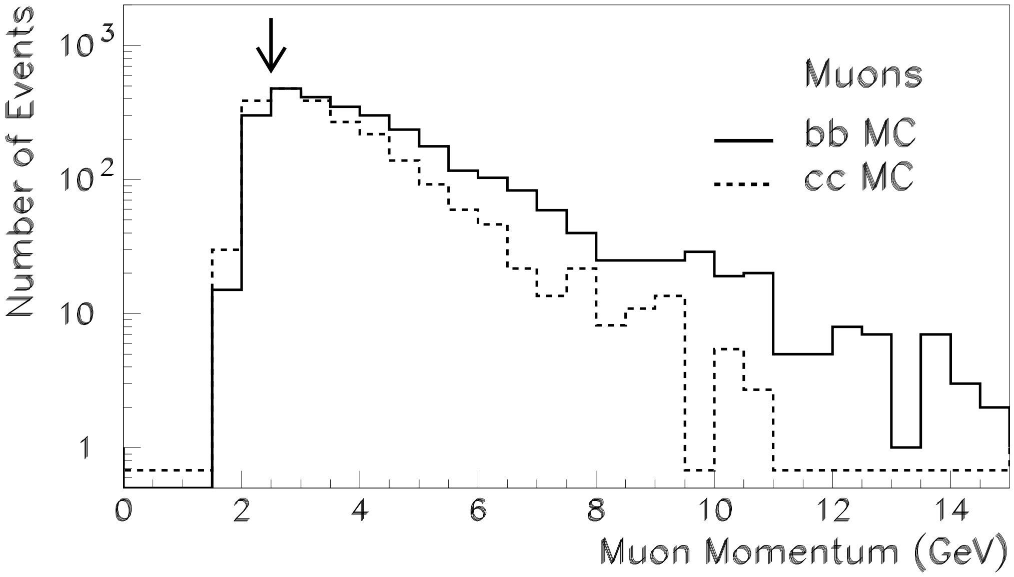
W_{vis} and p_t of D^*

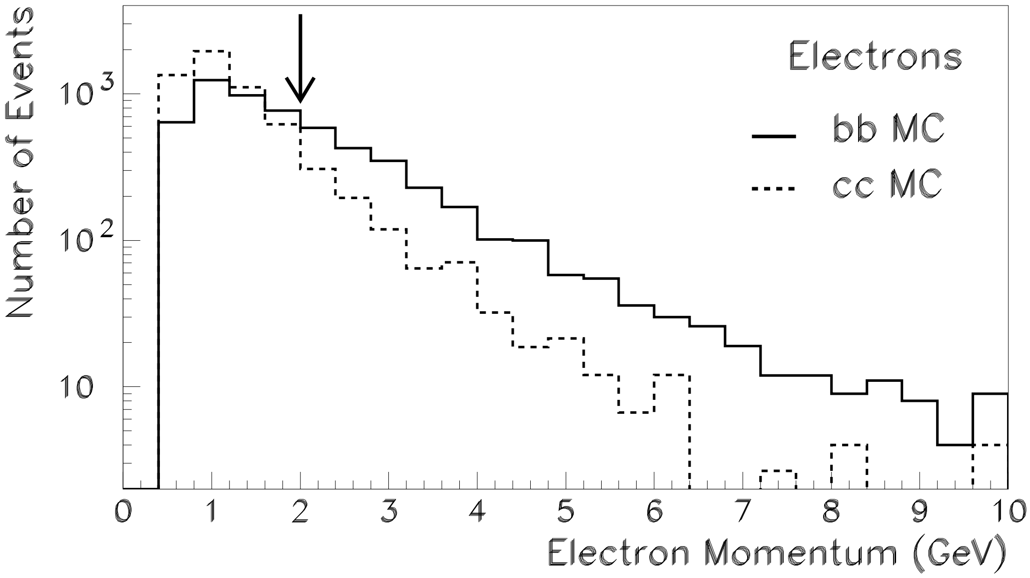




Tag b by semi-leptonic decay to e or μ

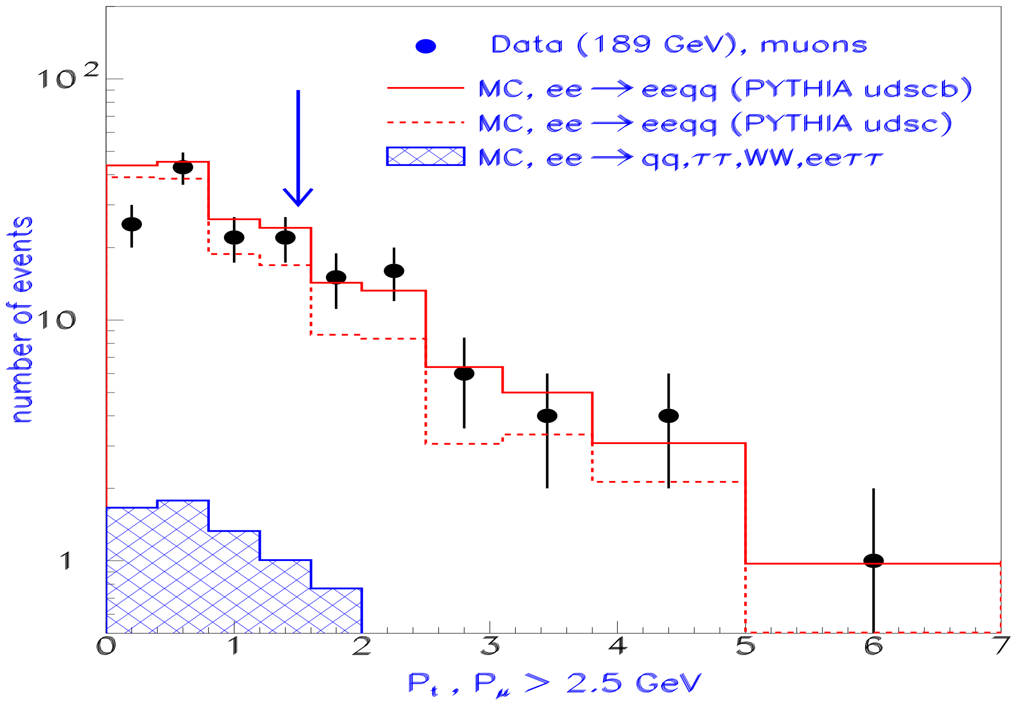
Momentum of Lepton Candidate from the Monte Carlo



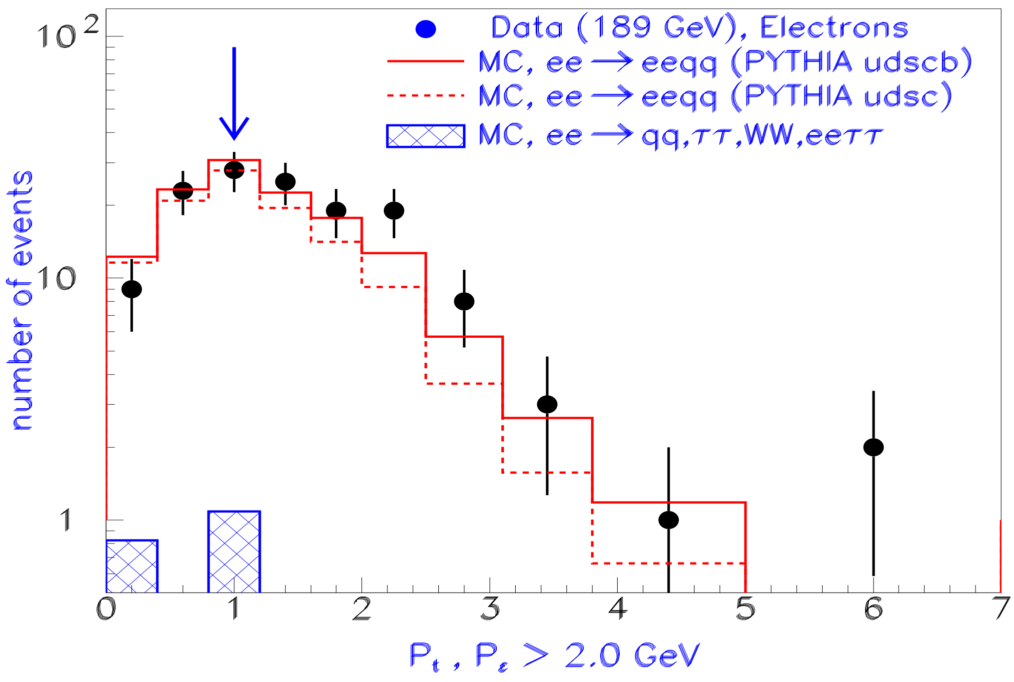


Leptons from bottom decays have higher momentum than from charm.

p_t with respect to the nearest jet



$P_t^\mu > 1.5$ GeV
$N_{ev}^\mu = 49$
$\varepsilon_b^\mu = 0.9\%$
$\Pi_b^\mu = 34\%$



$P_t^e > 1$ GeV
$N_{ev}^e = 96$
$\varepsilon_b^e = 1.6\%$
$\Pi_b^e = 28\%$

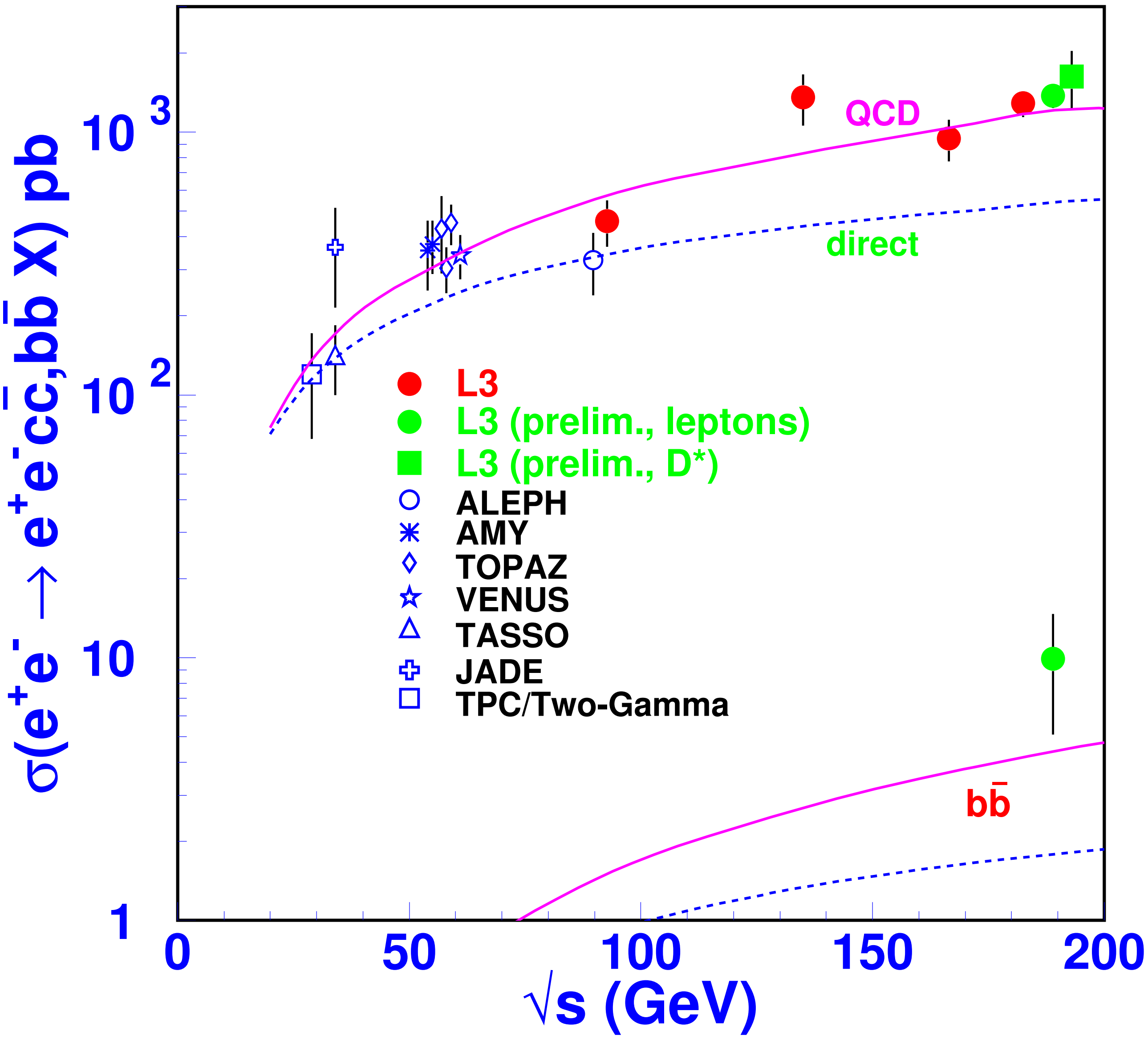
Leptons from bottom decays have higher p_t.

Beauty production in $\gamma\gamma$ collisions

Preliminary measurement at $\sqrt{s} = 189$ GeV

Muons:	$\sigma_{b\bar{b}} = 10.3 \pm 4.6(\mathrm{stat.}) \pm 3.3(\mathrm{syst.})$ pb
Electrons:	$\sigma_{b\bar{b}} = 9.6 \pm 3.6(\mathrm{stat.}) \pm 4.1(\mathrm{syst.})$ pb
Combined:	$\sigma_{b\bar{b}} = 9.9 \pm 2.9(\mathrm{stat.}) \pm 3.8(\mathrm{syst.})$ pb

$$\gamma\gamma \longrightarrow \mathbf{c\bar{c}},\ \mathbf{b\bar{b}}$$



- Theory prediction from
  M. Drees, M. Krämer, J. Junft and P.M. Zerwas, PL **B306** 371 (1993);
  $m_c = 1.3$ GeV, $m_b = 5.0$ GeV.

Summary and Future Outlook

- Charm cross section measured with lepton tag agrees with QCD predictions. New Preliminary result at 189 GeV.
- Resolved processes are needed to describe the data.

Evidence for gluon content of the photon

- Preliminary charm cross section from D^* tags is consistent with QCD predictions and the result from lepton tags.
- First measurement of $\gamma\gamma \rightarrow b\bar{b}$!

What's Next

- Unfolding $\gamma\gamma$ cross section for charm
- More data in 1999 and 2000 for heavy flavour studies.