Production of isolated prompt photons in $\gamma\gamma$ collisions at OPAL

PHOTON 2003
Joachim Lillich
University of Freiburg

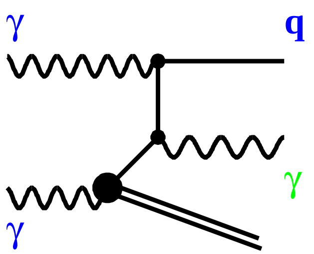
- Introduction
- Event selection
- Total and differential cross−sections
- Summary

Introduction $\gamma\gamma \rightarrow \gamma X$

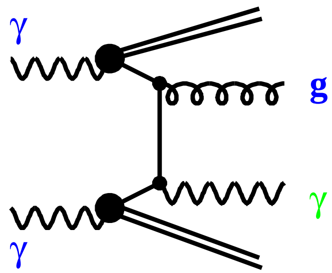
- **Motivation:** **quark and gluon structure of the photon**
- **Isolated prompt photon cross section :** PYTHIA (leading order):

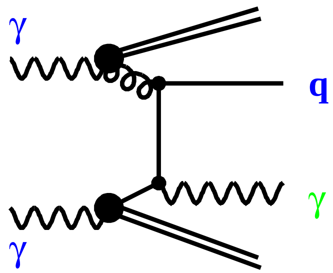
  SaS−1D pdf, $p_T^{\gamma} > 3.0$ GeV and $|\eta^{\gamma}| < 1$; $\eta = -\ln \tan \theta/2$

  - single−resolved: $\sigma_{single} = 0.13$ pb

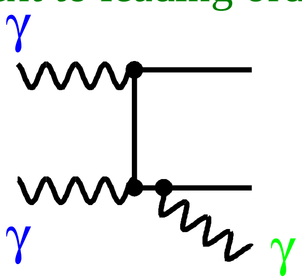


  - double−resolved: $\sigma_{double} = 0.009$ pb





- Next to leading order: *FSR* photons



Data & Monte Carlo

- Data: OPAL 1997−2000 at $\sqrt{s_{ee}} = 183 - 209\,GeV$

  Integrated luminosity 648.6 pb $^{-1}$ $\langle\sqrt{s_{ee}}\rangle = 196.6\,GeV$
- Monte Carlo:
  - Signal:
    - PYTHIA, HERWIG (only single resolved)
    - PHOJET: *FSR−photons*
  - Background: $\eta, \pi^0, \bar{n}$
    - PHOJET
    - Single particle generator: Study of ECAL showers

Event selection

Preselection

- *Anti−tag:*

  $E_{FD} < 0.5\ E_b,\ E_{SW} < 0.3E_b$

- $N_{tracks} \geq 3,\ |Q_{tot}| \leq 3$
- *Veto* e^+e^- *annihilations:*

  $5\ GeV < W_{vis} < 0.6\ E_b$

- *Veto beam−gas & beam−wall events*

  $|\ P_{longitudinal} / E_{vis}| < 0.98$

Photon candidate

- OPAL *photon finder*
- *ECAL cluster*

  $2 \leq N_{leadglass\ blocks} \leq 12$

- $p_T^{\gamma} > 3.0\ GeV$
- $|\eta^{\gamma}| < 1$
- *Time Of Flight detector:*

  $|\ T_{measured} - T_{expected}\ | < 2\ ns$

Further cuts

Electron veto

- Electron ID via dE/dx:

$| w_e | > 0.5$

Reject events, if

$n_{electrons} / n_{tracks} > 0.5$

Photon and hadronic system back to back:

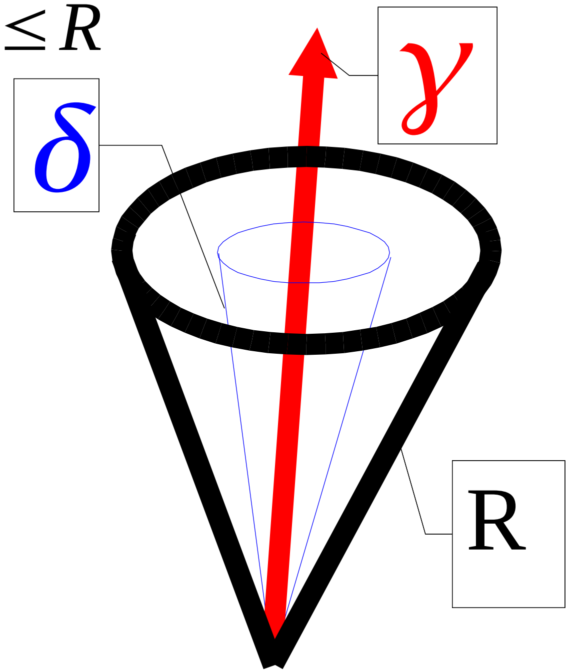
$\pi - 1 < \phi_{hadrons} - \phi_{photon} < \pi + 1$

Further cuts

Isolation

- Criterion proposed by Frixione:

$$\sum_{hadrons,i} E_{T,i}\,\Theta(\delta - R_{i,\gamma}) \le \epsilon E_{T,\gamma}\frac{1-\cos(\delta)}{1-\cos(R)}\,;\ \delta \le R$$



with R=1, ϵ=0.2

- Advantages:

➔Infrared safe

➔Background suppression

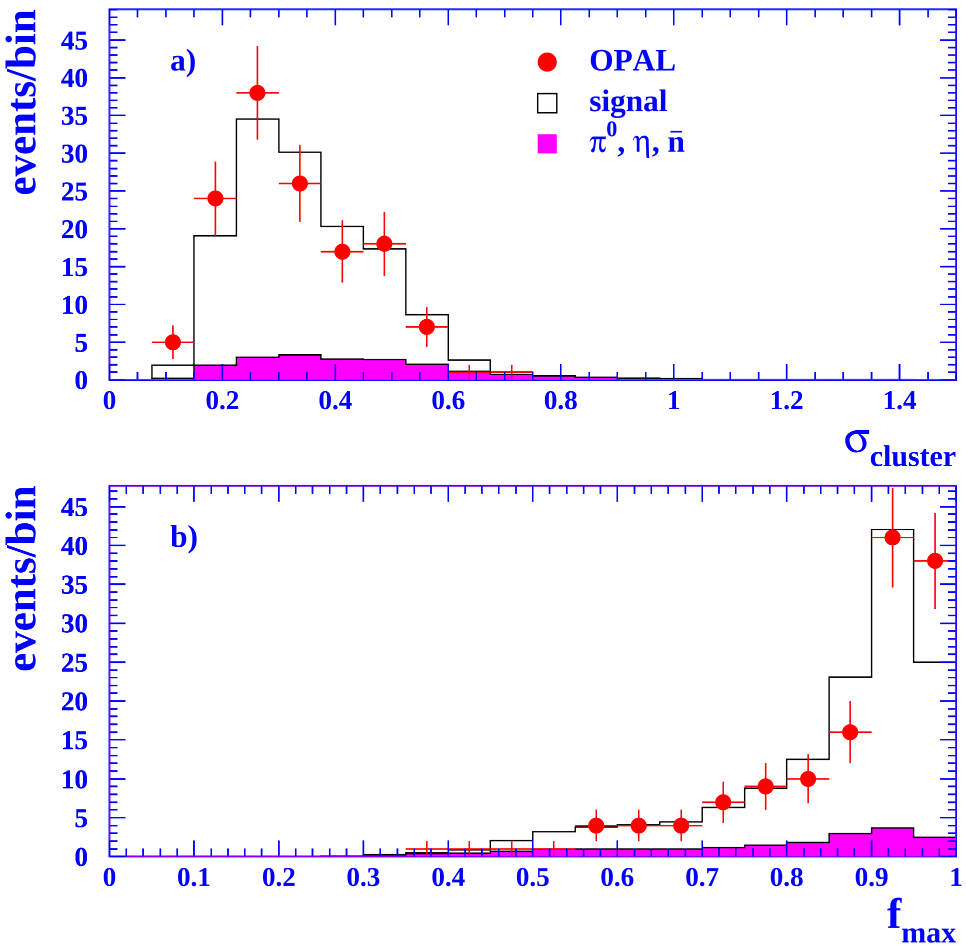
➔Similar efficiencies for single and double resolved processes

Analysis of ECAL showers

- Shower shape variables:
  - $\sigma = \sqrt{\frac{\sum[(\vartheta_i - \bar{\vartheta})^2 + (\phi_i - \bar{\phi})^2] E_i}{E_{cluster}}}$
  - $f_{max} = E_{max} / E_{cluster}$
- Binned Log−Likelihood−Fit:

$$g(\sigma, f) = a\, g_\gamma(\sigma, f) + b\, g_{\pi^0}(\sigma, f) + (1 - a - b)(c\, g_{\bar{n}}(\sigma, f) + (1 - c)\, g_\eta(\sigma, f))$$

a=0.86 ± 0.08 (stat)
b=0.12 ± 0.08 (stat)



Determination of single and double resolved contribution

- γ+ jet sample:

  cone jetfinder: R=1, E_T> 2.5 GeV

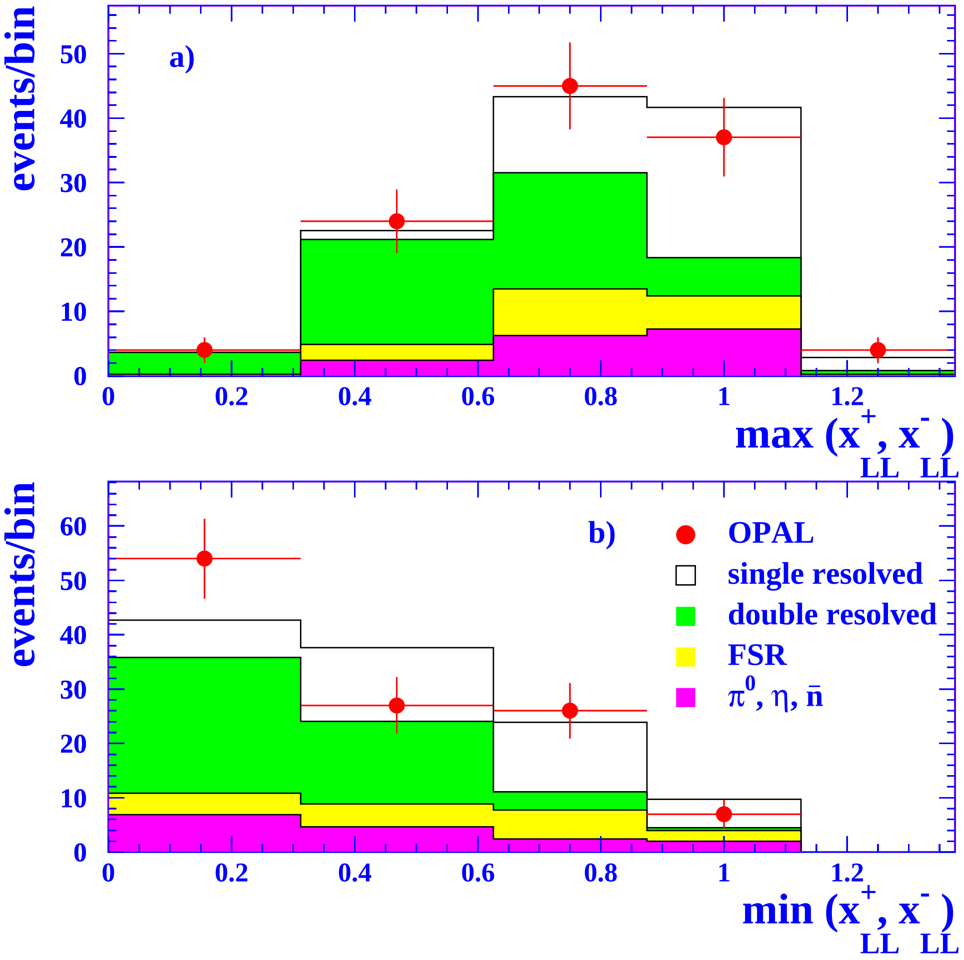
$$x^{\pm}_{LL} = \frac{p_T^{\gamma}(e^{\pm\eta_{jet}} + e^{\pm\eta_{\gamma}})}{\sum_{hadrons,jet,\gamma}(E \pm p_z)}$$

Binned Log−Likelihood−Fit:

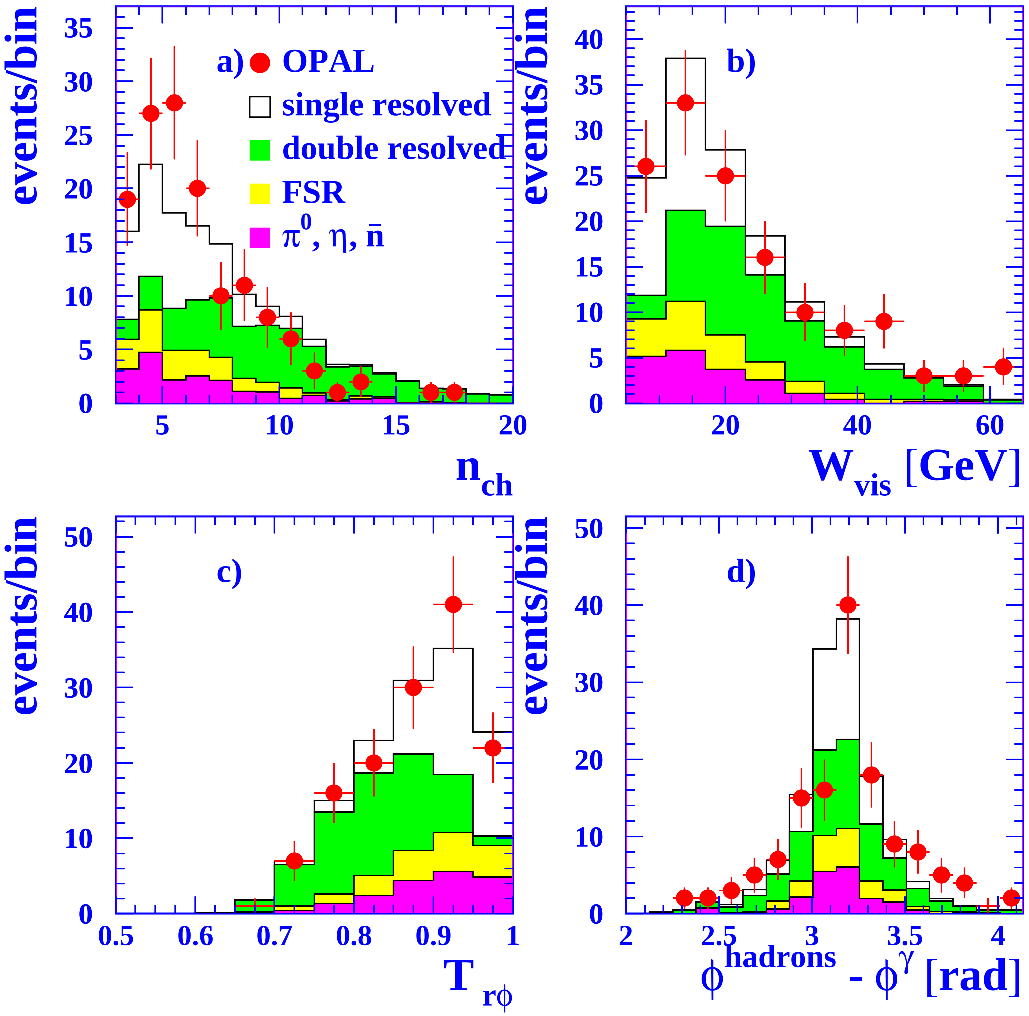
$$g(x^+_{LL}, x^-_{LL}) = r\,a\,g_{sr}(x^+_{LL}, x^-_{LL}) + (1-r)\,a\,g_{dr}(x^+_{LL}, x^-_{LL}) + (1-a)\,g_{bg}(x^+_{LL}, x^-_{LL})$$

single resolved fraction:

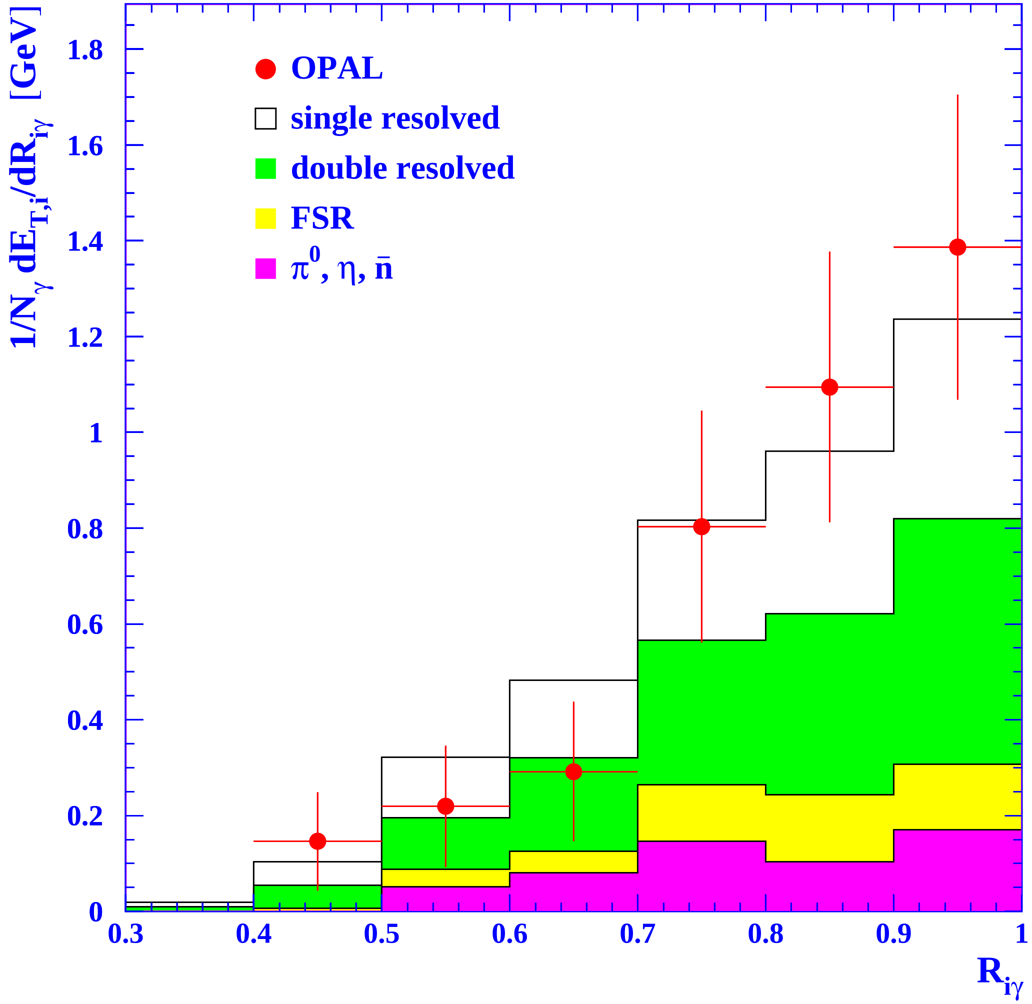
r=0.47 ± 0.11 (stat)



Prompt photons: variables



Transverse energy flow inside the isolation cone



Total isolated prompt photon cross−section

- Efficiencies for single and double resolved processes

$\epsilon_{\text{single}} = 51.8\ \%$ $\epsilon_{\text{double}} = 61.8\ \%$

- Total isolated cross−section (*FSR* included)

$$\sigma_{tot}(p_T^{\gamma} > 3.0\, GeV, |\eta^{\gamma}| < 1) = (0.32 \pm 0.04 \pm 0.04)\, pb$$

The measured cross−section is 2.3 times higher than
the PYTHIA prediction (3.2 σ).

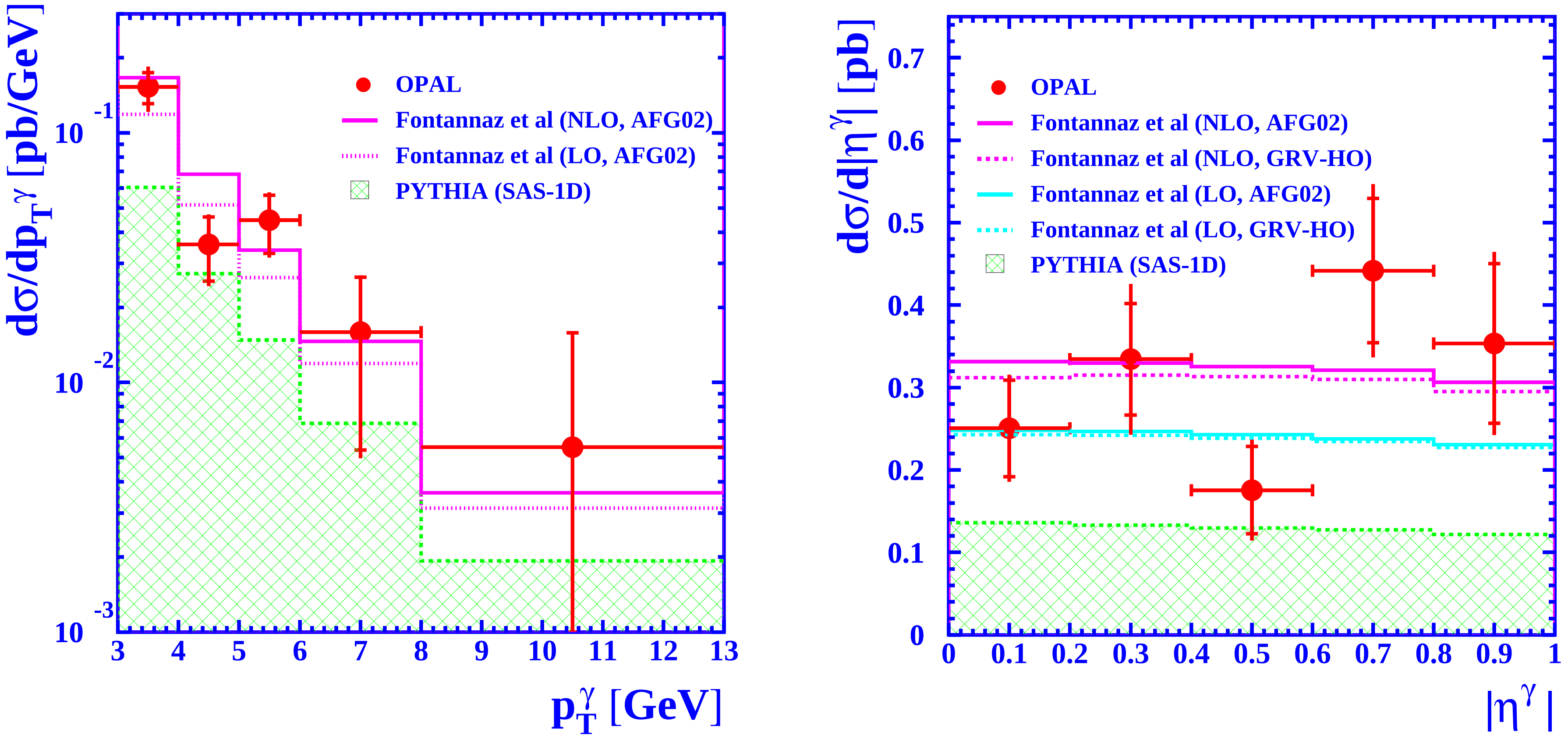
TRISTAN: $\sigma(p_T > 2.0\, GeV) = 1.72 \pm 0.67\, \mathrm{pb}$ at $\sqrt{s_{ee}} = 58\, GeV$

3 times higher than PYTHIA

Systematic uncertainties

• Binning effects	1.3%
• Cut on number of lead glass blocks	1.3%
• Ratio $\eta : \bar{n}$	2.0%
• Reweighting of single particle MC	2.8%
• Parton densitiy functions	3.8%
• Herwig instead of PYTHIA	3.8%
• Ratio single to double resolved MC	4.0%
• ECAL energy scale	7.0%
• π^0 background	8.3%
➔ TOTAL	13.5%

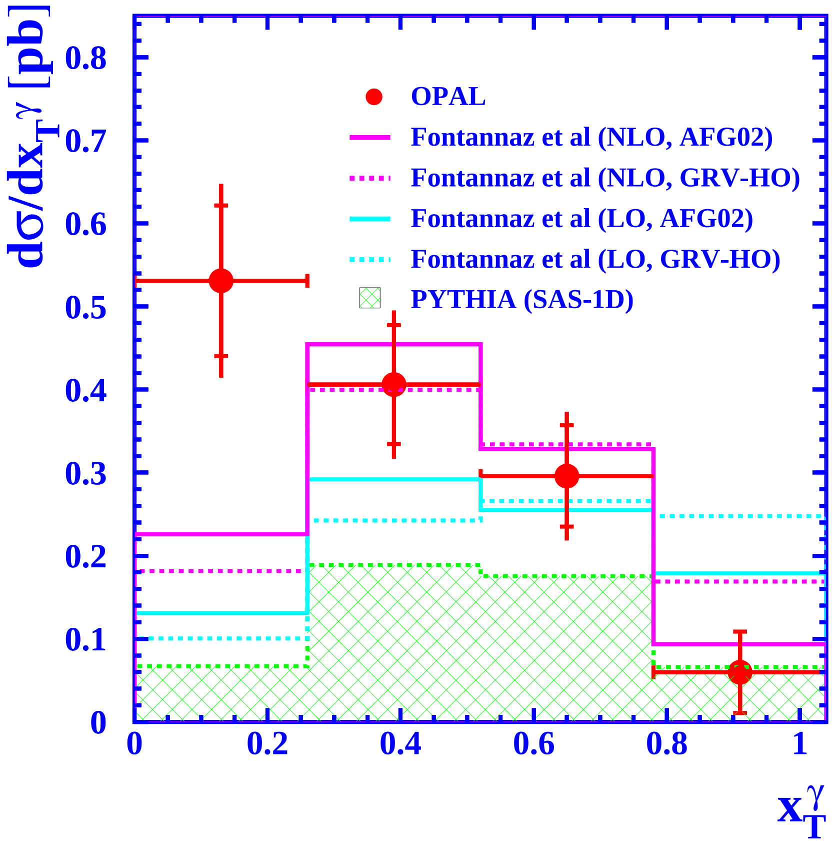
Differential cross−sections



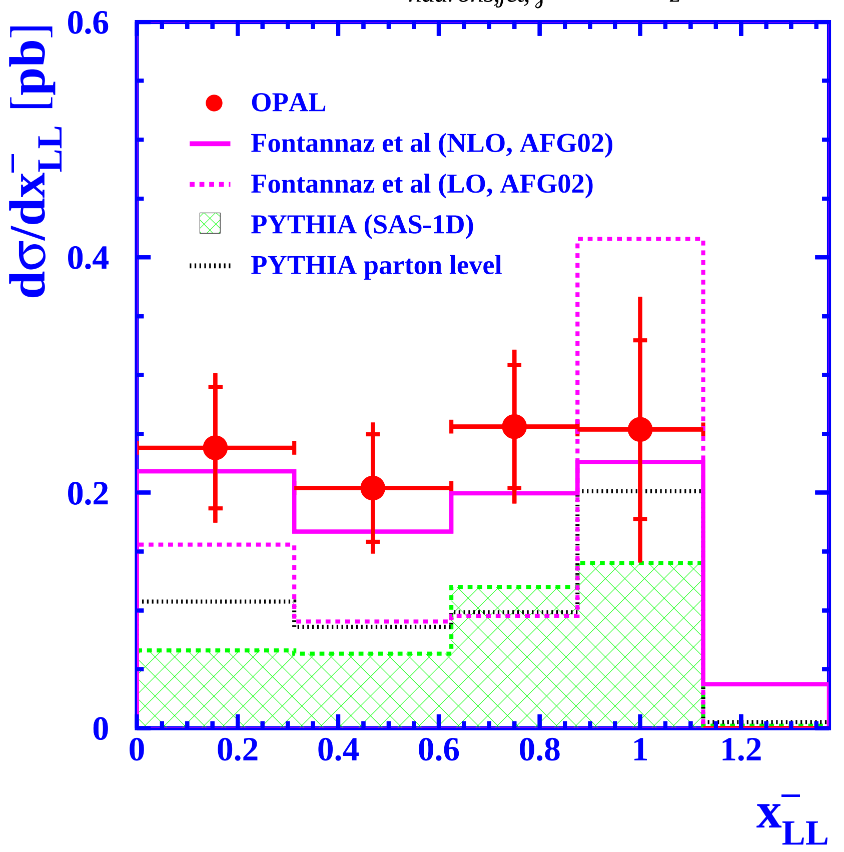
Fontannaz et al: Eur. Phys. J. C23 (2002) 503

Differential cross−sections

$$x_T^{\gamma} = \frac{2\,p_T^{\gamma}}{W_{vis}}$$



$$x_{LL}^{-} = \frac{p_T^{\gamma}(e^{-\eta_{jet}} + e^{-\eta_{\gamma}})}{\sum_{hadrons,jet,\gamma}(E - p_z)}$$



Fontannaz et al: private communications

Summary

- In the data taken from 1997 to 2000 137 events are selected.
- Main background: neutral particles produced in $\gamma\gamma$ collisions
- Separate signal from background with shower shape variables.
- For $p_T^{\gamma} > 3.0$ GeV and $|\eta^{\gamma}|<1$:

➔ $\sigma_{tot} = (0.32 \pm 0.04\ (\text{stat}) \pm 0.04\ (\text{sys}))$ pb

➔ PYTHIA reproduces the shape of $d\sigma/dp_T^{\gamma}$ and $d\sigma/d|\eta^{\gamma}|$ but underestimates the cross−sections

➔ Good agreement with NLO calculations