Two Photon physics at LEP
In memory of Theodore Todorov

F. Kapusta
LPNHE Paris

Photon2015
Novosibirsk
15-20 june 2015

Introduction

- I met Sharka Nova and Teddy Todorov in Dubna on the advice of Daniel Treille in 1991.
- The first version of TWOGAM, the NOT (Nova, Olshevski, Todorov) Monte-Carlo was running on a PC (together with Tetris3D) inspired by the Budnev Phys. Rep., a good reference.
- Teddy went to work on the hadronic decay of the Z^0 boson in the DELPHI analysis Team4 and by force was taking two-photon events as a background. SUSY colleagues doing the same.
- From CERN Courrier

Theodore Todorov 1966–2014

Teddy Todorov, who did important work on DELPHI, CMS and ATLAS, died in an accident on Mont Blanc on 19 October.

Teddy prepared his PhD, which he defended in 1993, at IReS-Strasbourg on the DELPHI experiment at CERN's Large Electron–Positron (LEP) collider. He was then recruited by CNRS, and moved on to the CMS experiment, being built at the LHC. In 2007, he moved to the Laboratoire d'Annecy-le-Vieux de physique des particules (LAPP-Annecy) and joined the ATLAS experiment.

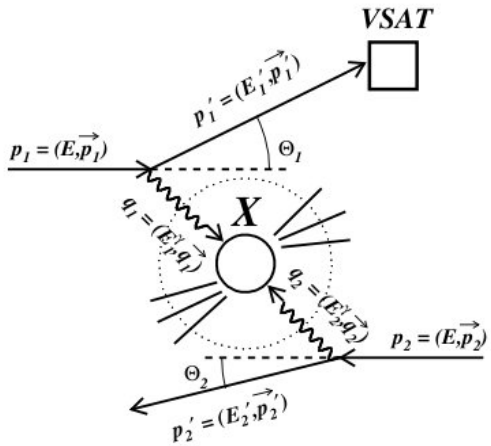
Teddy Todorov. (Image credit: Sarka Todorova.)

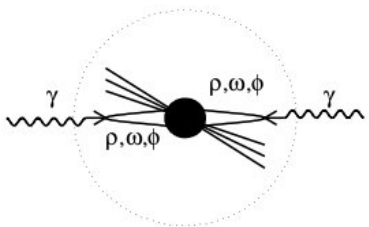
During his PhD, as a member of the DELPHI experiment, he measured the hadronic decays of the Z^0 boson and extracted Standard Model parameters, having developed fits to the data. He presented the DELPHI results in a CERN seminar in 1994.

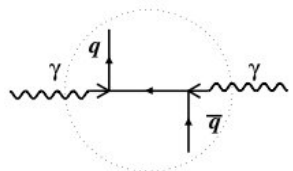
When he joined the CMS experiment in the 1990s, he very quickly became the maestro of the CMS core software. He was

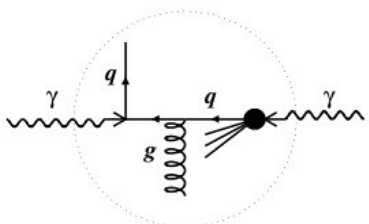
LEP after PETRA and TRISTAN : jet production in $\gamma\gamma$ collisions

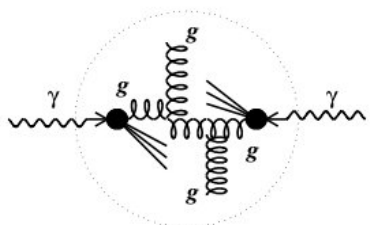
- A new machine, although built for Z^0 and later W^+W^- production and studies, was recognized as potentially bringing new data on Two-Photon interactions.
- Excesses observed at PETRA and TRISTAN over QPM and VMD would be better quantified and described at LEP with new data.
- Looking through DELPHI eyes : especially tagging photons at very low Q^2





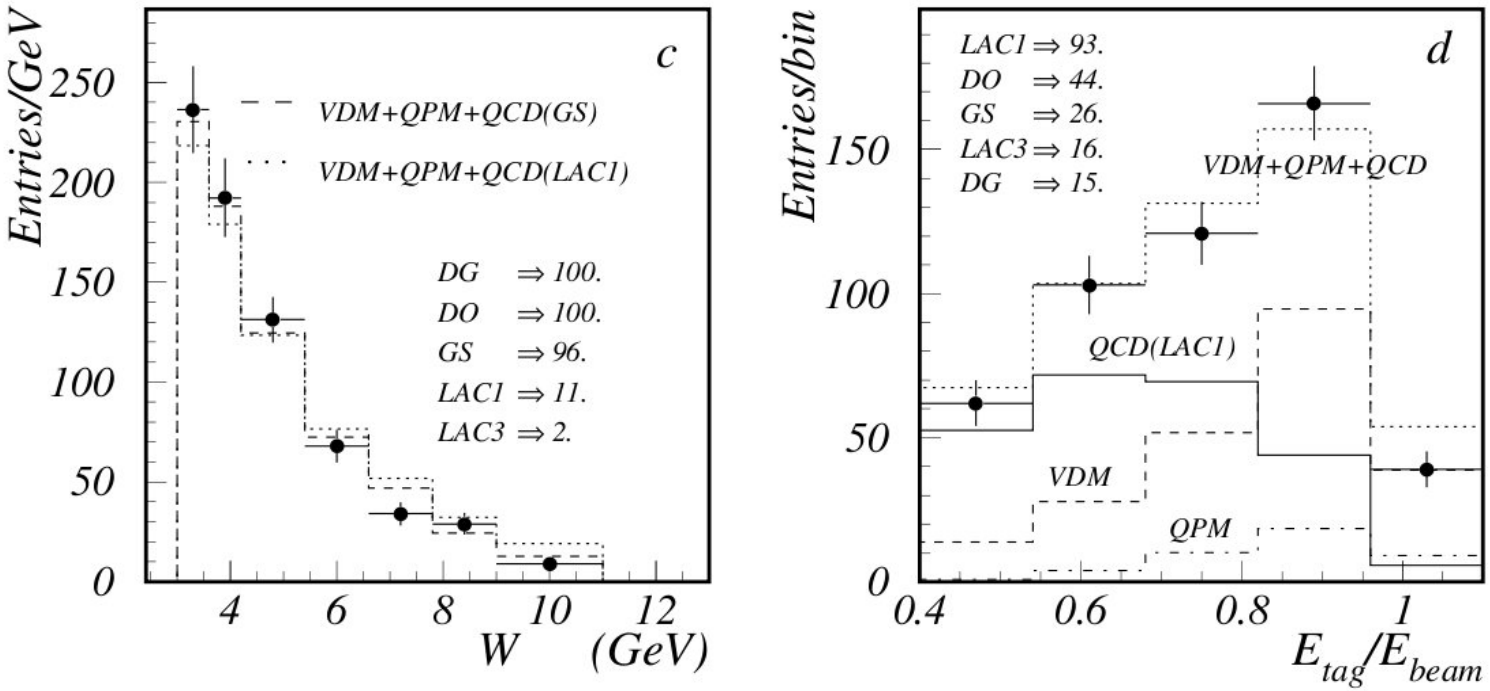






LEP after PETRA and TRISTAN :Jet production in $\gamma\gamma$ collisions

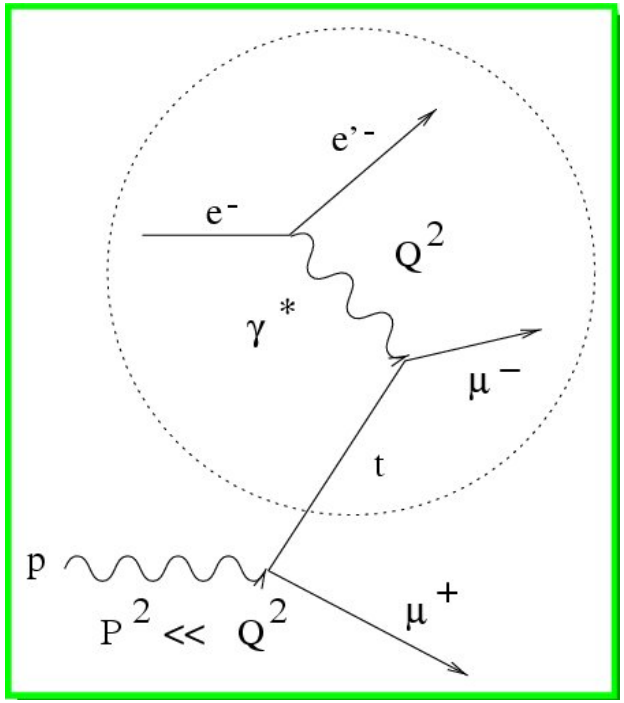
- $(q^{\gamma}(x, p_T^2), g^{\gamma}(x, p_T^2)) \otimes p_T^{min}$



- Important rôle of the Monte-Carlo in the extraction of parton density function.
- Never succeeded to extract the total cross section from VSAT double-tag events.

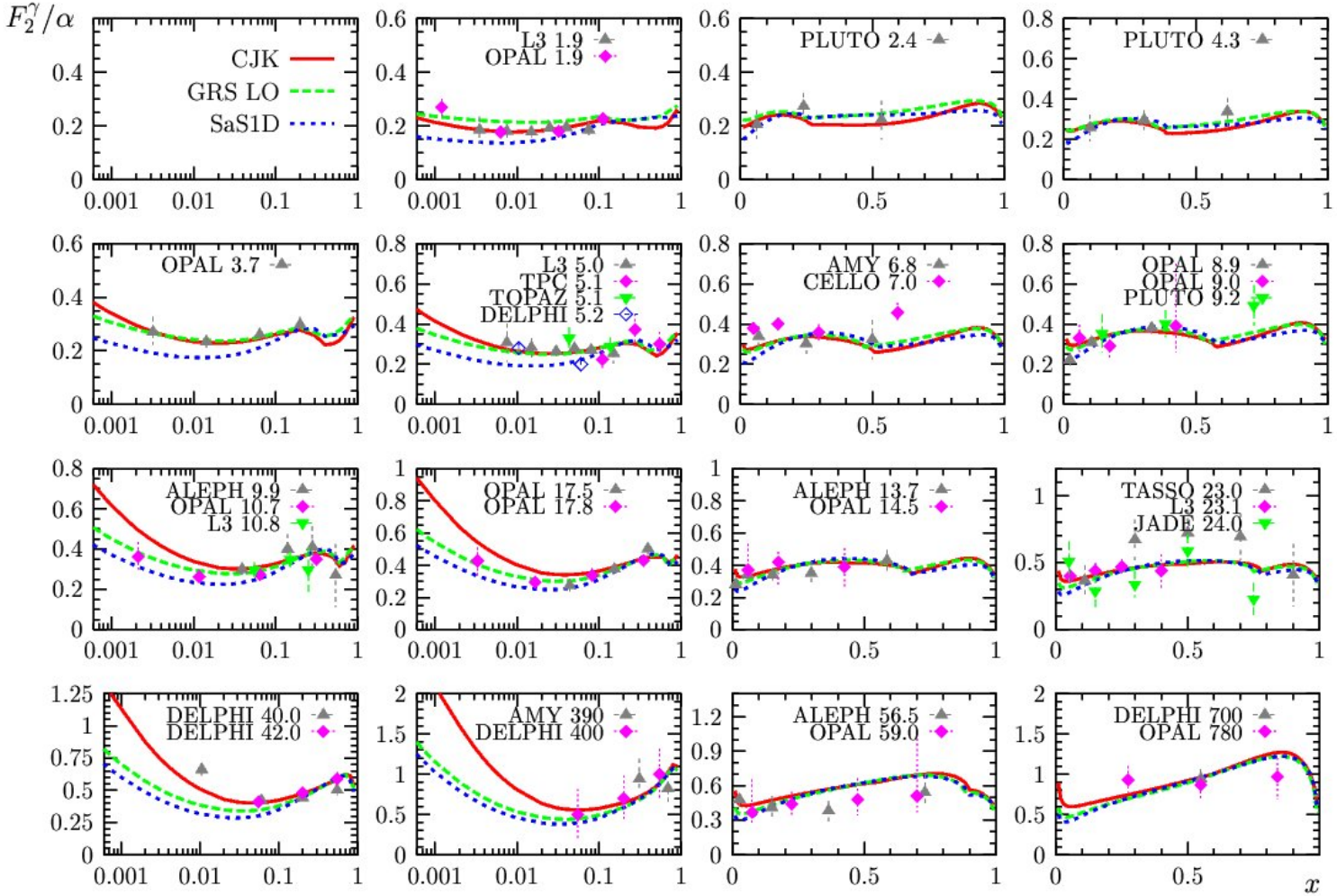
QED $e\gamma^* \to e\mu^+\mu^-$ as the many scales basic process

- Basic process to test the tagging devices
- Test of Unfolding
- Exact computation of all helicity amplitudes
- $< P^2 >$, $< Q^2 >$, m_μ^2, $p_T^2 + m_\mu^2$ scales
- $F_2^{gamma}(x, Q^2) \propto \ln \frac{t_{max}}{t_{min}}$ with $t_{max} \simeq Q^2/x$ and $t_{min} \simeq \frac{m_\mu^2}{1-x} + P^2 x$ with $x(1-x)$ terms coming from $2xm_\mu^2 \int_{t_{min}}^{t_{max}} \frac{dt}{t^2}$ giving $\frac{2x(1-x)m_\mu^2}{m_\mu^2 + P^2 x(1-x)}$
- Experimentally isolate "peripherical" diagrams with kinematical cuts
- Study azimuthal correlations.



DIS $e\gamma$

- Many new results from ALEPH, DELPHI, L3, OPAL after TPC2γ, CELLO, JADE, PLUTO, TASSO, AMY and TOPAZ (Plot from Maria Krawczyk).

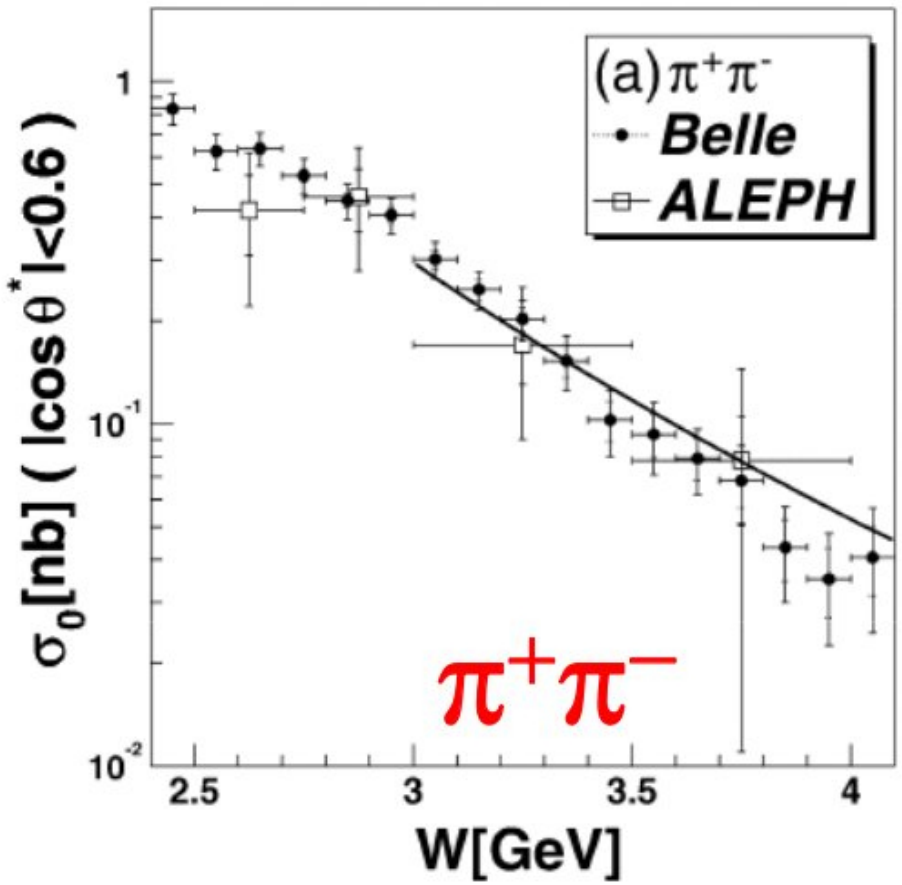


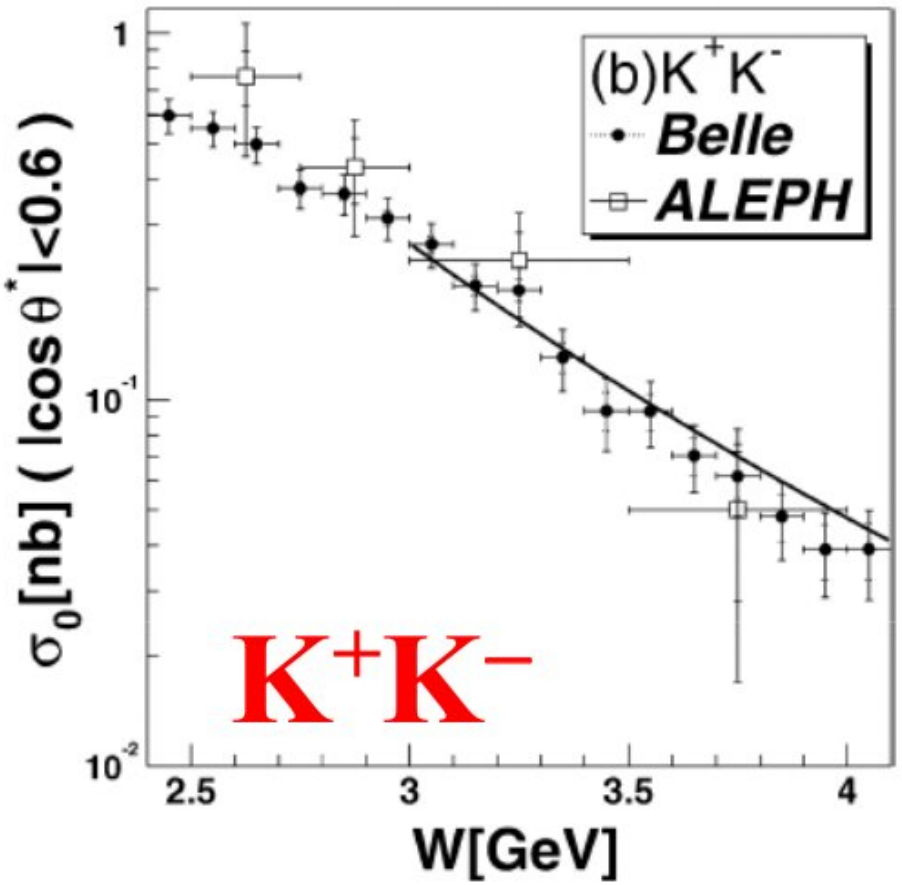
Comments

- The right time to get new parametrizations of the partonic content of the photon with physical inputs.
- It took nearly 7 years to PYTHIA to include p_T cuts in SaS parametrizations, with comments on FKP by G. Schuler.
- FKP arose from the question of how to build a Monte Carlo from $F_2^\gamma(x, Q^2)$. Just unintegrate, using APE and choosing you kinematical boundaries. Thanks to the tuesday theory seminar at DESY in 1979 and the Reya QCD course.
- Even Fontannaz used a cut without saying it in the AFG parameterization.
- The 1992 Two-Photon Conference saw the end of PETRA, the start of LEP and the preparation of HERA (under the impulse of David Miller, Two Photon Conferences became PhotonXX starting 95, including officially single photon interactions).
- In the 1992 conference A. Finch commented the total $\gamma\gamma$ cross-section : difficult to unfold a component you do not see at low angles or only a few tracks.
- Rely anyway on Monte-Carlo for acceptance effects.
- Resonances and exclusive processes suffered from the lack of a good trigger simulation.

Exclusive processes

- LEP could not compete with BELLE.



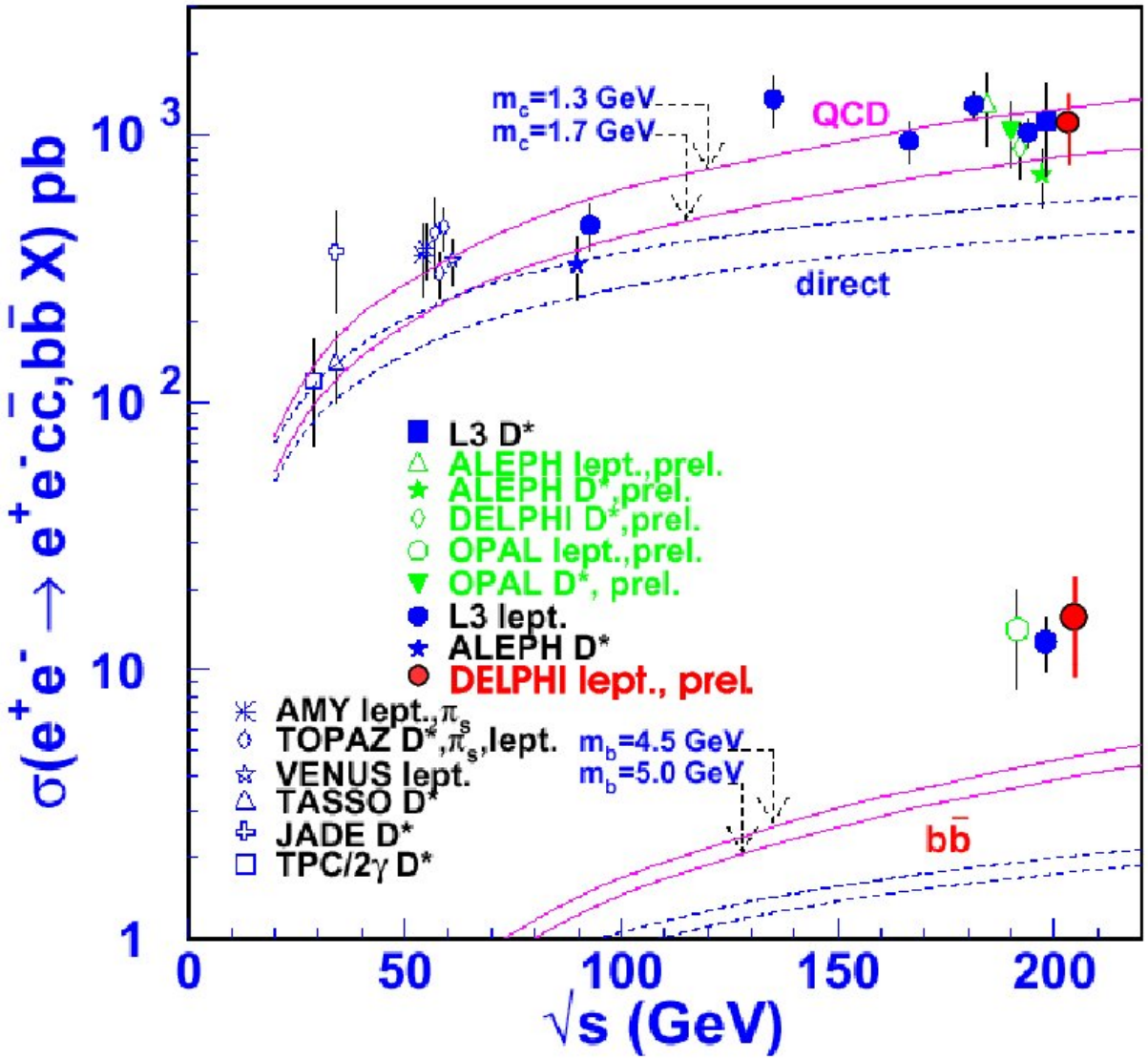


Sociology of Two-Photon Physics at LEP

- LEP1 and LEP2 periods correspond to the "Golden Age" of Two-Photon Physics with new data available.
- In DELPHI, request to Ugo Amaldi to create a T13 after showing that multihadrons from two-photon interactions where clearly present in visible energy plots. Agreed with two conveeners Igor Tyapkin and I, but imposing that not too many physicists would join.
  In ALEPH : Alex Finch, in L3 : John Field, Maria Kienzle, in OPAL : David Miller.
  HERA colleagues joined afterwards.
- Two Photon Physics : an eastern Europe activity at least in DELPHI. Strong links with Dubna, Krakow, Lund, Prague, Serpukhov and Warsaw.
- 2008 Dubna Scientific Prize for DELPHI $\gamma\gamma$.
- ALEPH, DELPHI, L3 and OPAL brought many results proportional to the weight of physicists in each experiment and the way two-photon physics was perceived by their colleagues.

Delphi unpublished result

- 2003 in Frascati



Conclusions

- LEP the Lord of the Colliding Rings was dismantled abruptly in 2000, leaving physicists without additional high energy e^+e^- collider data and the possibility to develop a demonstrator of real $\gamma\gamma$ collisions. And still now we miss a high energy e^+e^- collider.
- 1991 was the year of the first official meeting in Saariselka concerning a future linear collider and a Photon Linear Collider project was presented in San Diego in 1992.
- A Low (and Large) Energy Photon Collider (LEPC) has to be built to describe more precisely the partonic content of the photon before the LEP generation disappears.

Conclusions

- We are happy to have Higgs boson production with two photon decay

- Would like to measure any decay of produced Higgs boson in two-photon collisions.