Memories of CELLO and PETRA, the start of the electroweak era

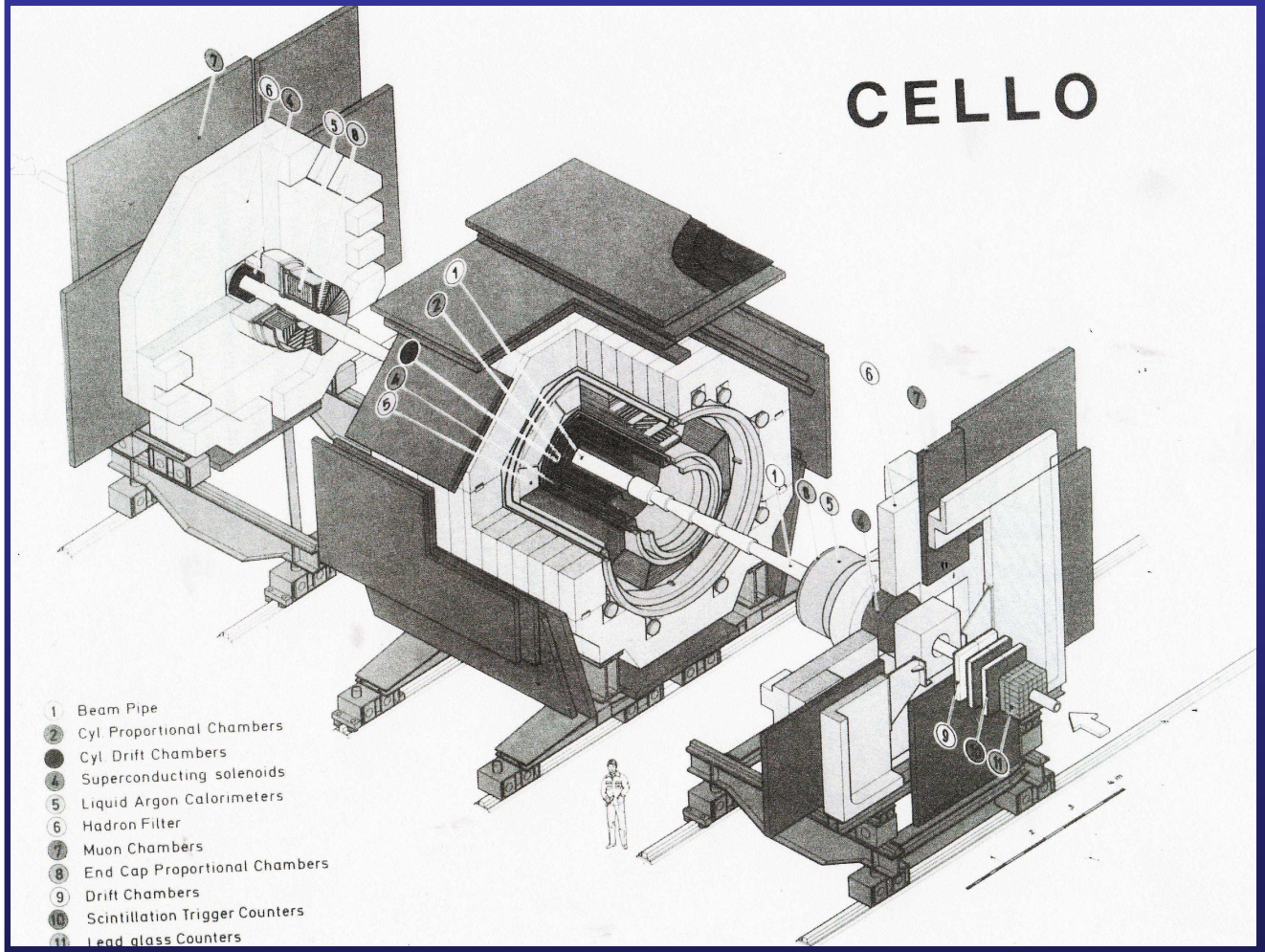
CRACOW EPIPHANY CONFERENCE ON LHC PHYSICS

4 - 6 January 2008, Cracow, Poland

A biased and partial selection of topics viewed by the "then student"

Roy Aleksan

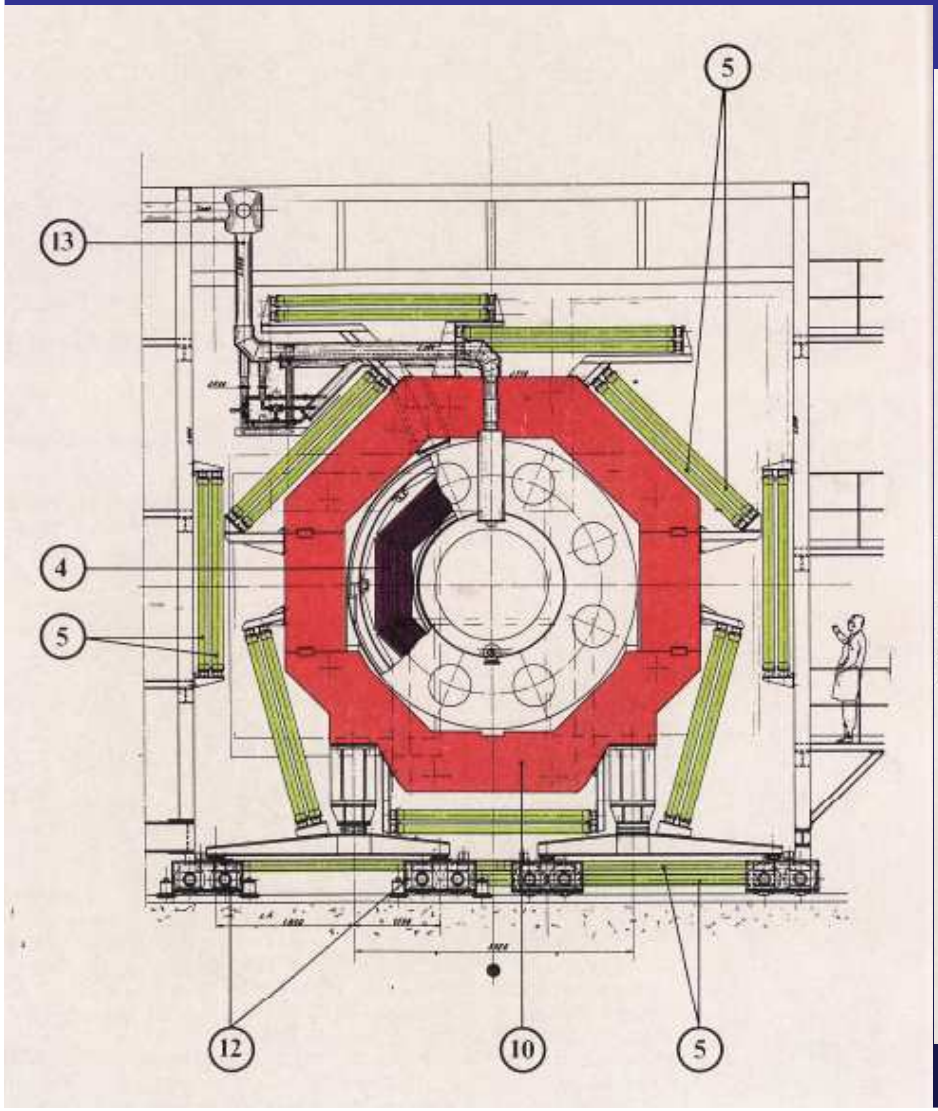
Let's set the scene



A French-German Collaboration (~60 physicists) for the construction
Increased to ~80
With groups from Israel, Italy, UK

On 1976, I joined CELLO as a PhD Student

The main objectives were to study electroweak interactions and search for new particles (including t!) up to $\sqrt{S} \approx 46.8 GeV$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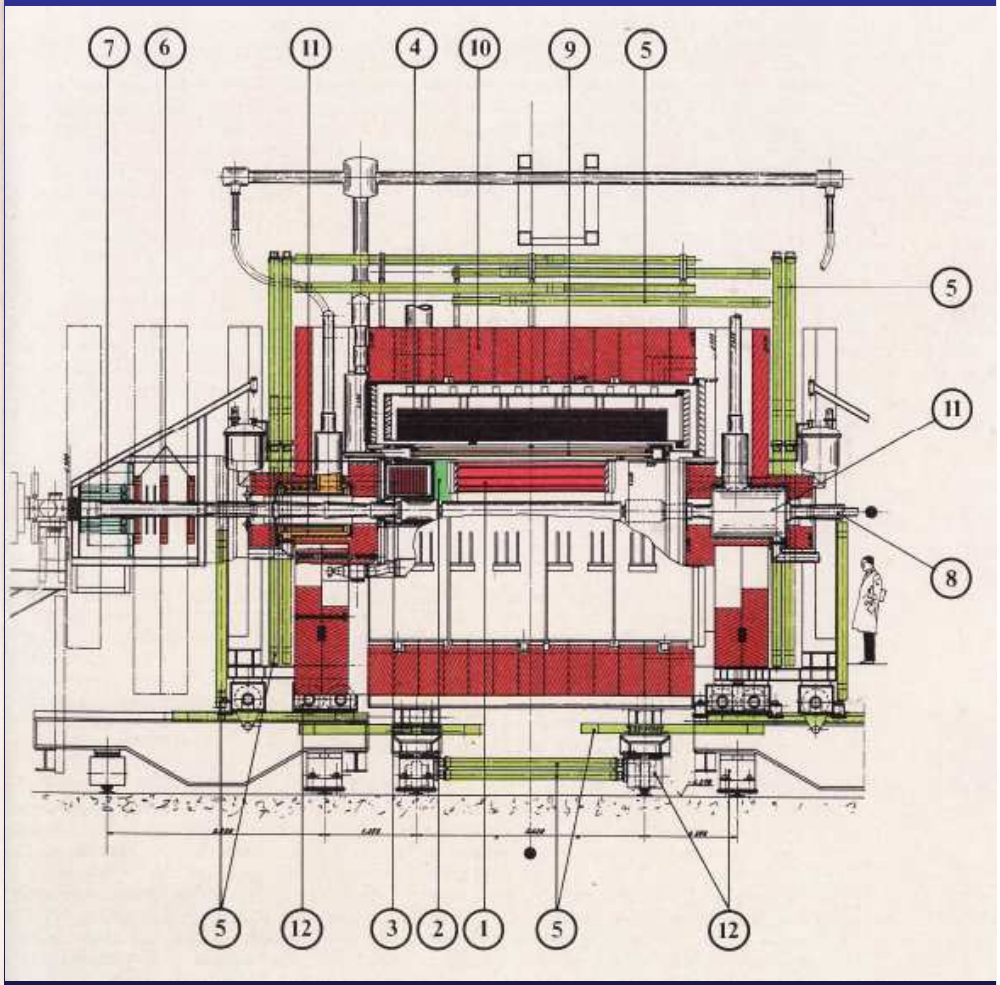
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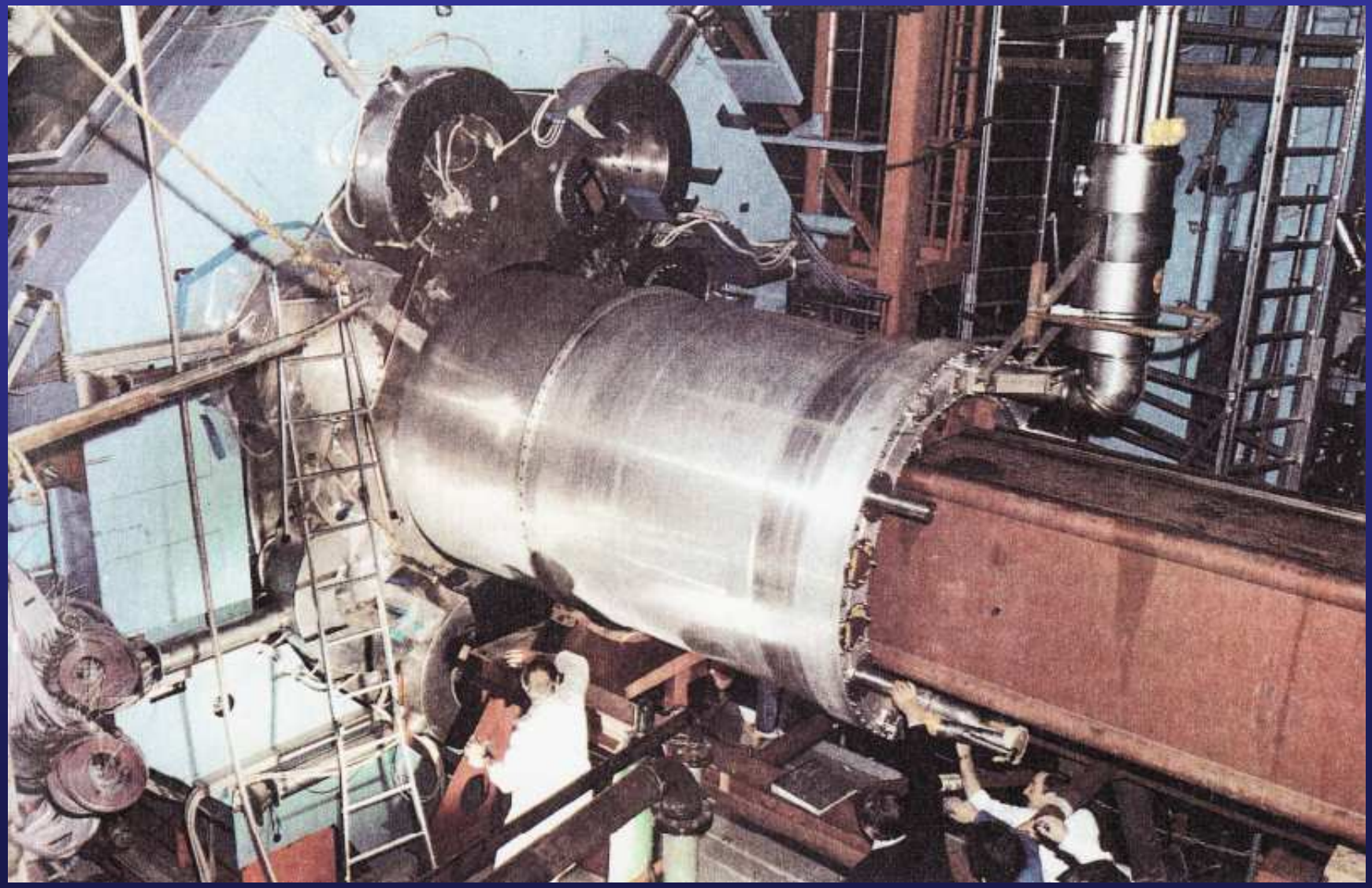
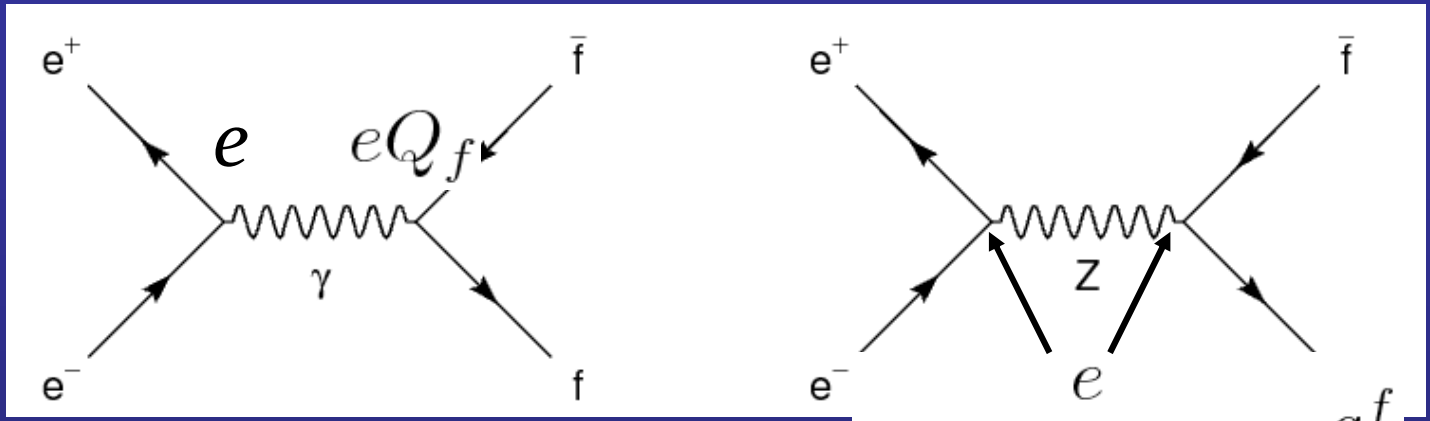
Very transparent (<0.5 X_0) and high field magnet 1.36 Tesla



and ~4π liquid argon electromagnetic calorimeter

Entering new territories for testing ElectroWeak interactions



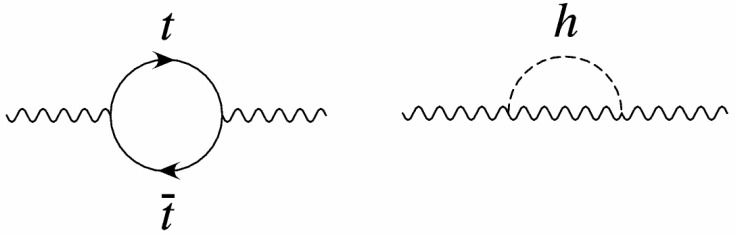
$$g^f_{(\mathrm{L,R})} = T^f_{3,(L,R)} - Q_f \sin^2\theta_{\mathrm{W}}$$

$$\frac{e}{\sin\theta_{\mathrm{W}}\cos\theta_{\mathrm{W}}}\, g^f$$

Fermion	$T^f_{3,L}$	$T^f_{3,R}$	Q_f
$\begin{pmatrix} U \\ D \end{pmatrix}$	$+1/2$ $-1/2$	0 0	$+2/3$ $-1/3$
$\begin{pmatrix} \nu_\ell \\ \ell \end{pmatrix}$	$+1/2$ $-1/2$	0 0	0 -1

The energy was not enough to see deviation in σ
But enough to see interference effects (A)

EW observables depend on: α, G_F, M_Z



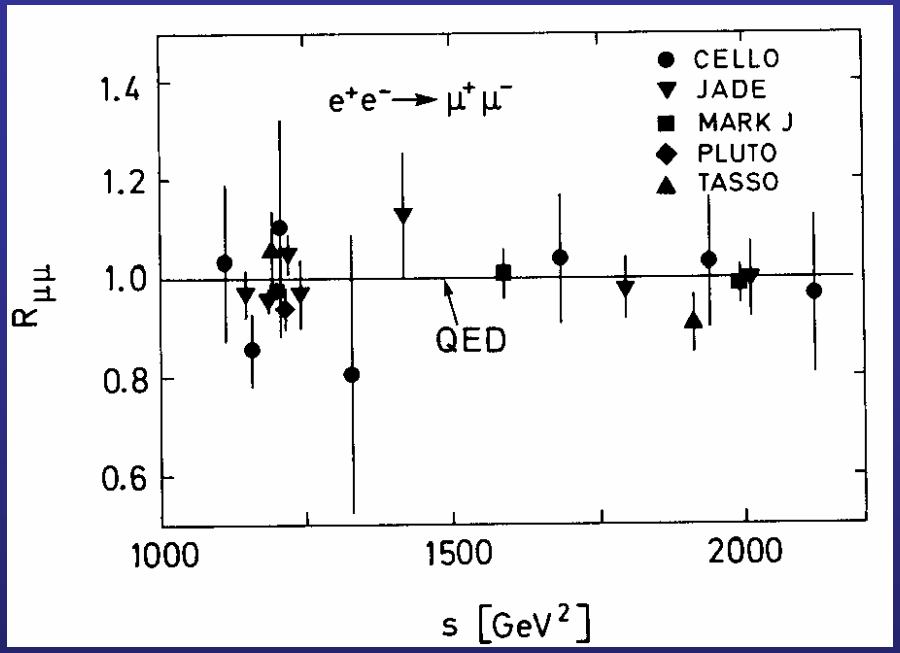
Adding loops

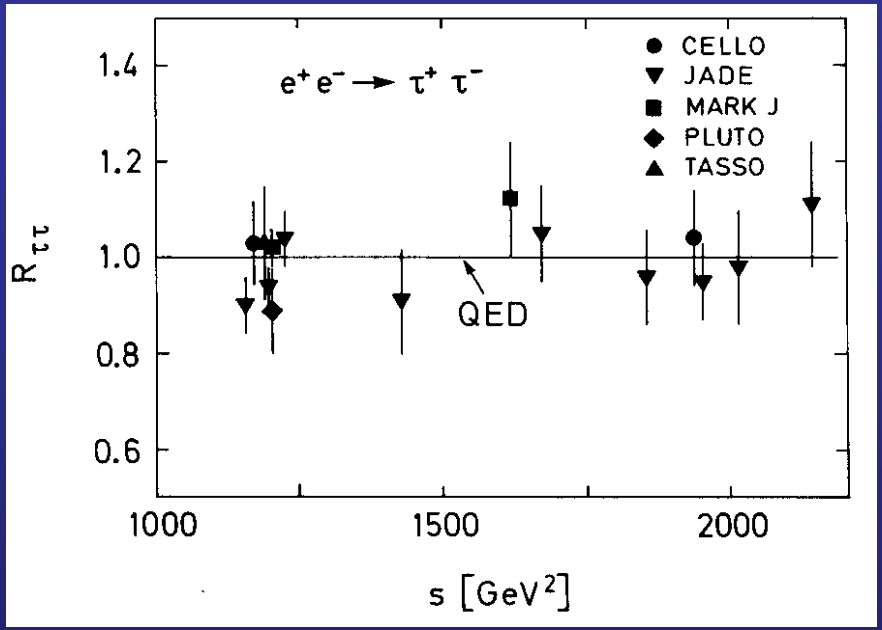
$$g^f_{(\mathrm{L,R})} = \sqrt{(1+\Delta\rho)}\,(T^f_{3,(L,R)} - Q_f \sin^2\theta^{\mathrm{eff}}_{\mathrm{W}})$$

EW observables then depend on:
α, G_F, M_Z, M_t, M_H

But E and stat. were too low ⇨ LEP

Illustrations with $\mu^+\mu^-$ and $\tau^+\tau^-$





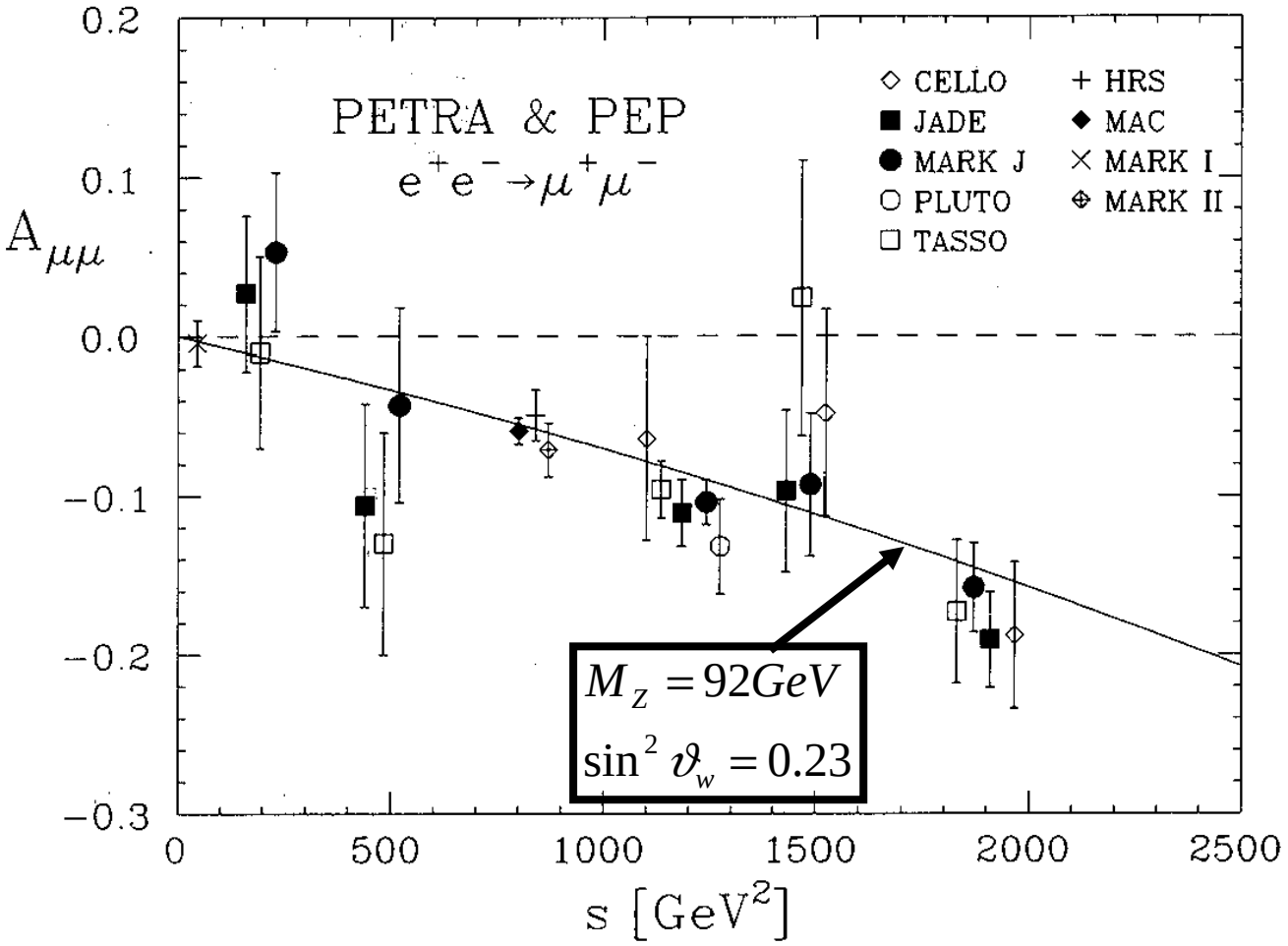
No deviation from QED was observed and was quantified by adding a form factor term

$$F(s) = 1 \pm \frac{s}{s - \Lambda_{\mp}^2}$$

Leading to $\Lambda_{\pm} > \sim 200\,\mathrm{GeV}$

$e^+e^- \to \mu^+\mu^-$

$$A_f^{FB} = -\frac{3a_e a_f}{4Q_f}\,\mathrm{Re}\,\chi \quad \text{where} \quad \chi = \frac{\rho G_F}{\sqrt{2}}\,\frac{M_Z^2}{4\pi\alpha}\,\frac{s}{s - M_Z^2 + iM_Z\Gamma_Z}$$



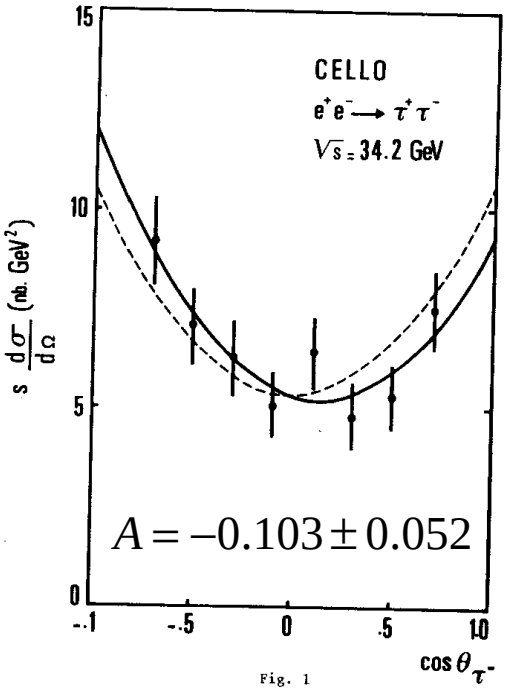
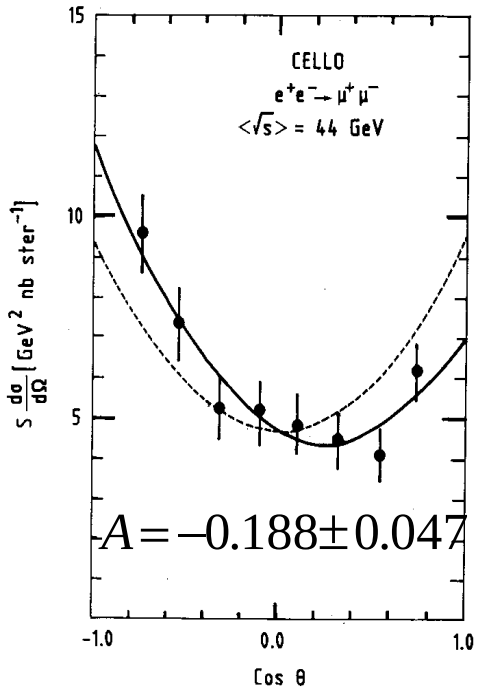
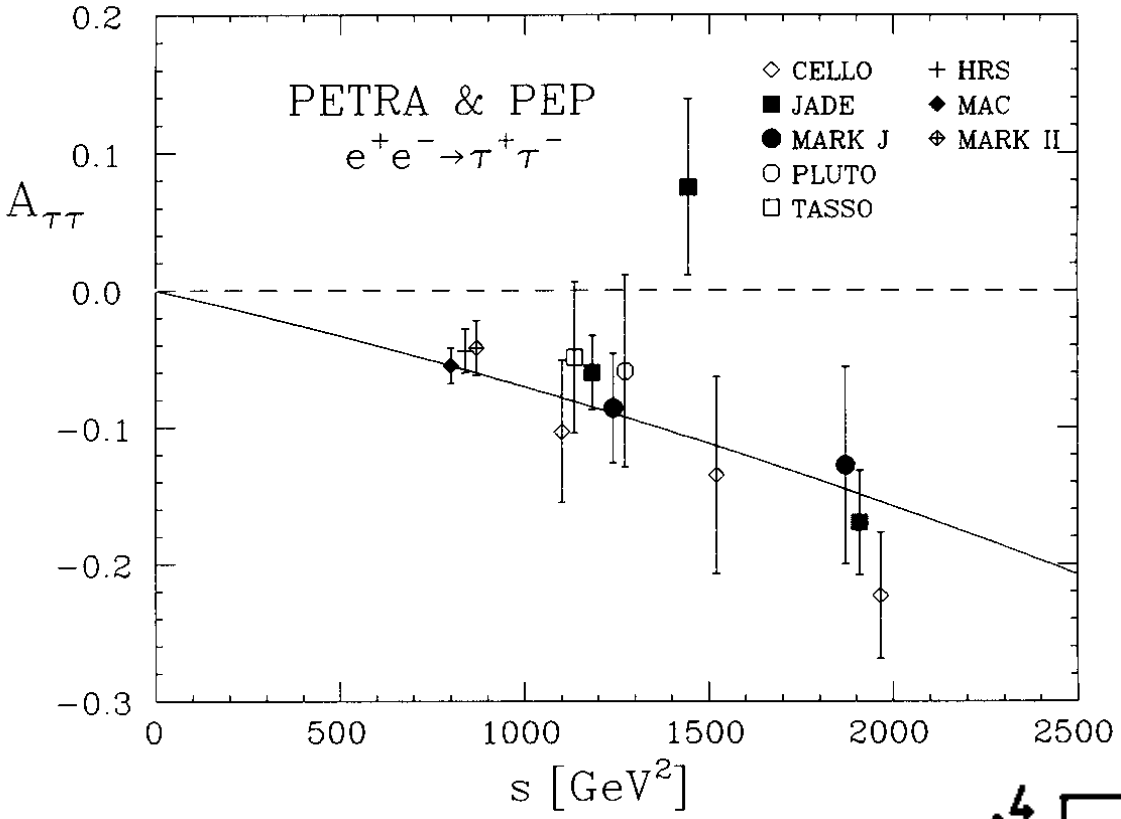
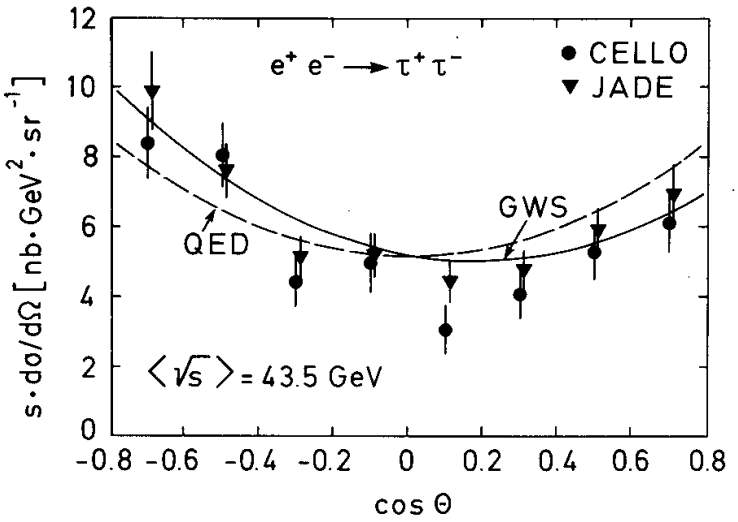


Fig. 1



$e^+e^- \rightarrow \tau^+\tau^-$

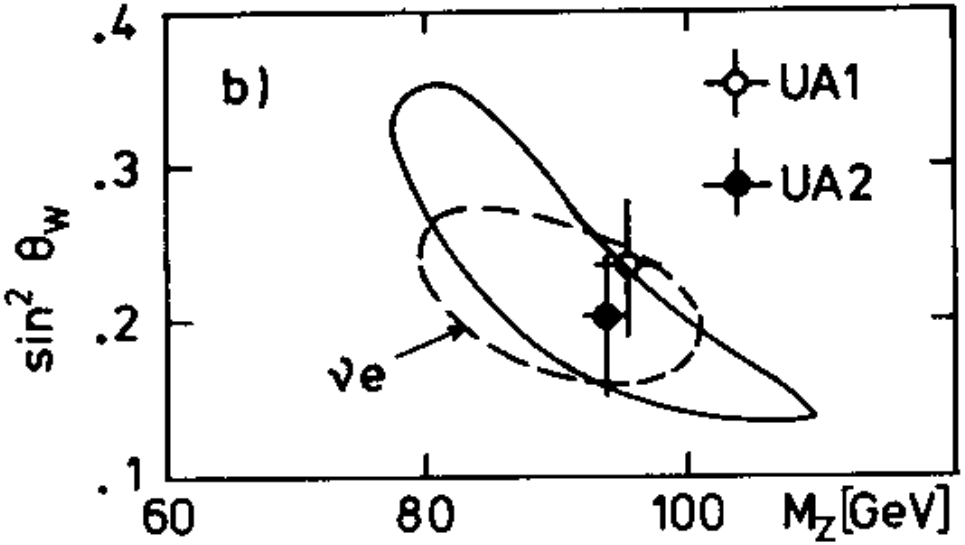




Fit of μ and τ asymmetries

$$\sin^2 \vartheta_w = 0.20^{+0.02}_{-0.02}$$

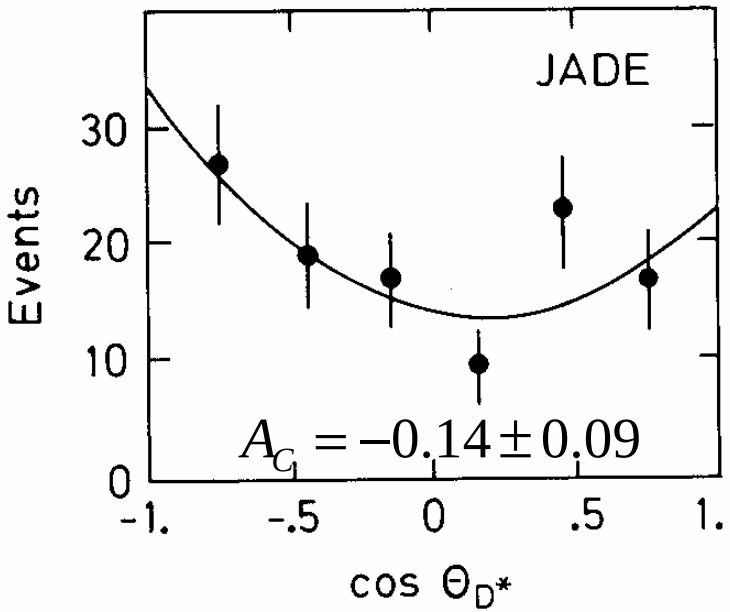
$$M_Z = 90.0^{+2.1}_{-1.8}$$

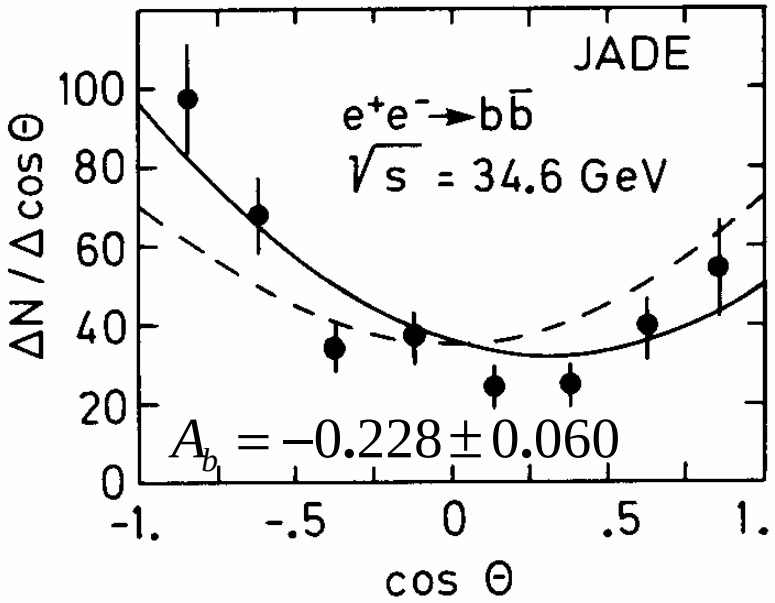


$e^+e^- \to c\bar{c},\ b\bar{b}$

Larger A expected thanks to Q_f

$$A_f^{FB} = -\frac{3a_e a_f}{4Q_f}\,\mathbf{Re}\,\chi$$





For all these measurements, higher precision and more simulations tools with full radiative corr. were needed, requiring dedication and professionalism

Exp.	lepton	$A_{b\bar{b}}$ [%]
CELLO	e	− 38 ± 21
	μ	− 43 ± 31
JADE	μ	− 22.8 ± 6.0
MARKJ [32]	μ	0 ± 14 ± 8
PLUTO [18]	μ	− 36 ± 25
TASSO	e	− 25 ± 22
	μ	− 38 ± 28

Nuclear Physics B202 (1982) 63–88

RADIATIVE CORRECTIONS TO MUON PAIR AND QUARK PAIR PRODUCTION IN ELECTRON–POSITRON COLLISIONS IN THE Z_0 REGION

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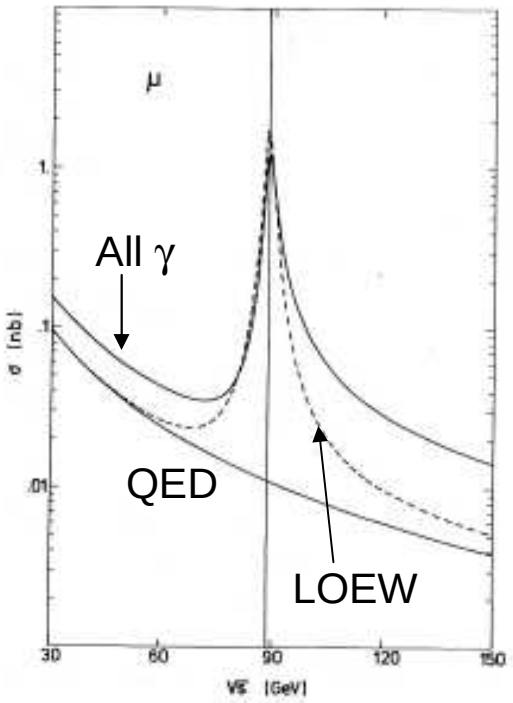
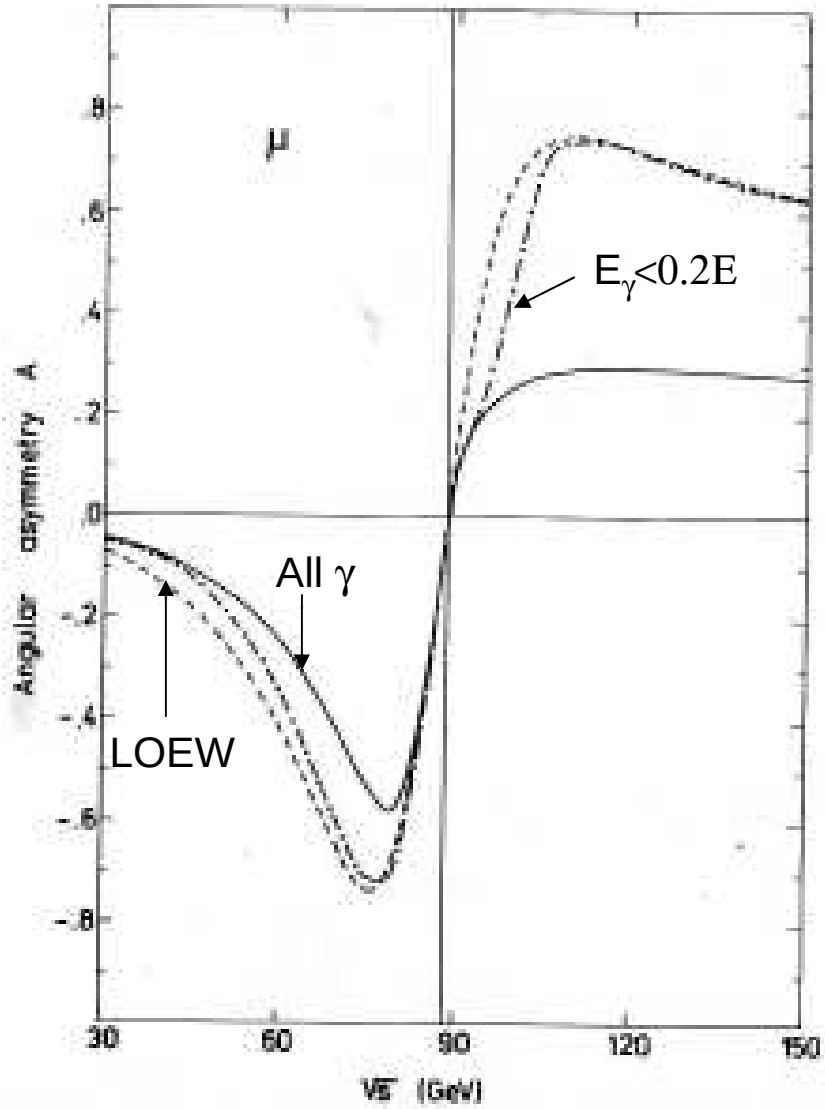
Received 25 January 1982

A calculation of first-order radiative corrections to the process $e^+e^- \to \mu^+\mu^-$ is presented, which is in particular applicable to the Z_0 region. The emphasis is on a detailed treatment of hard photon effects, which affect the size of the corrections in the Z_0 region considerably. The technique used is that of a Monte Carlo simulation of $\mu^+\mu^-$ and $\mu^+\mu^-\gamma$ events. In an appendix the generalization to quark pair production is presented.

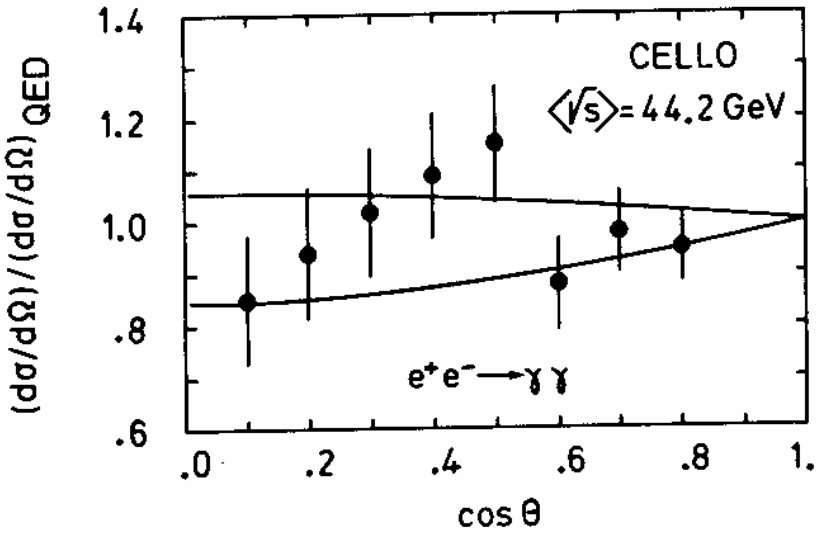
Very famous paper, more than 370 citations!



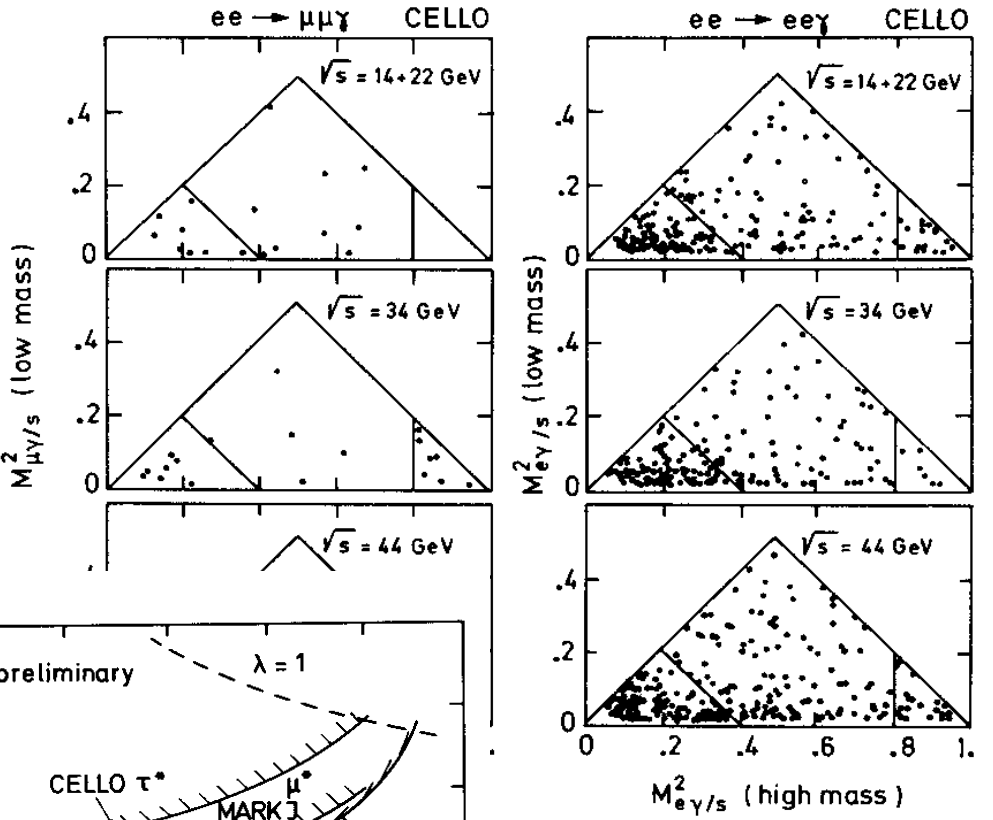


And searching new particles and phenomena

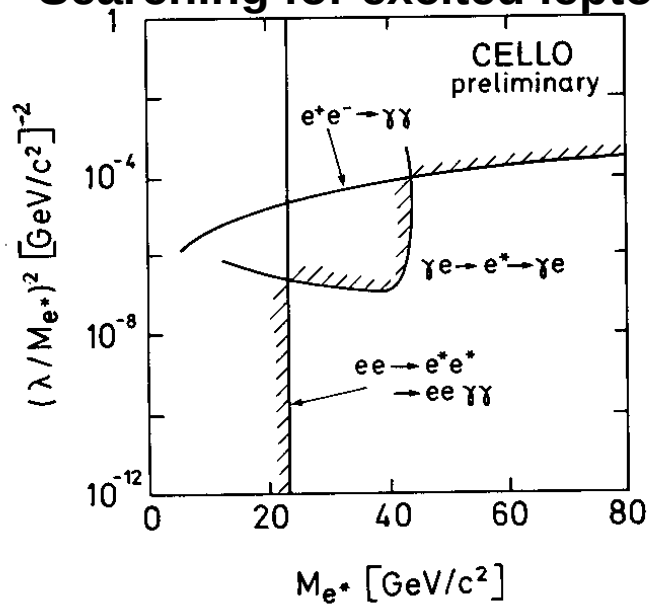
Probing QED with $\gamma\gamma$ events

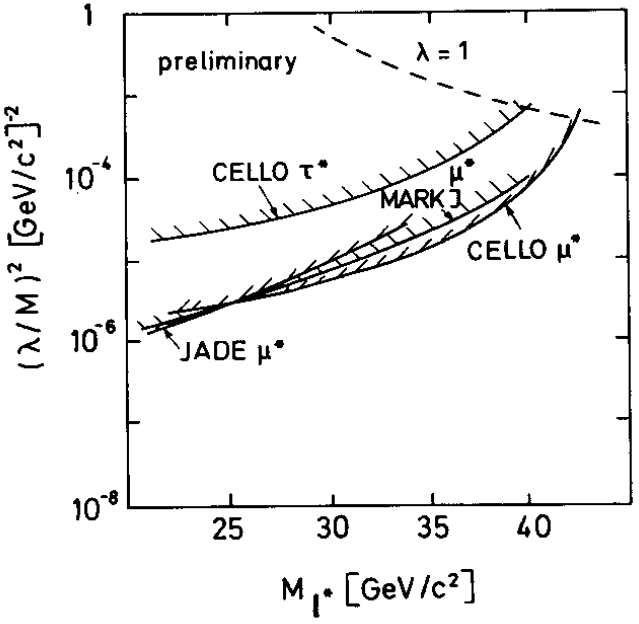


Probing QED with $ll\gamma$ events



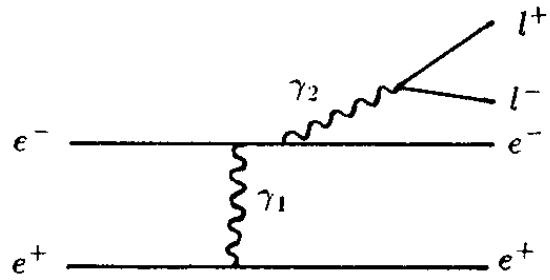
Searching for excited leptons





In all cases MC with complete radiative corrections were vital

From llγ to 4 leptons (+γ)



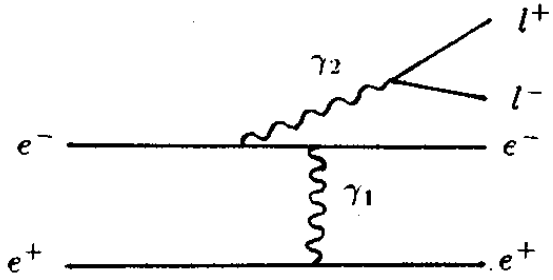
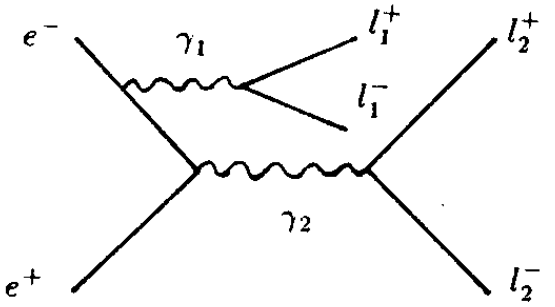


Figure 1.a



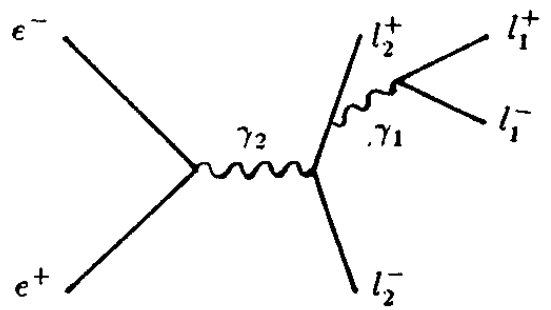
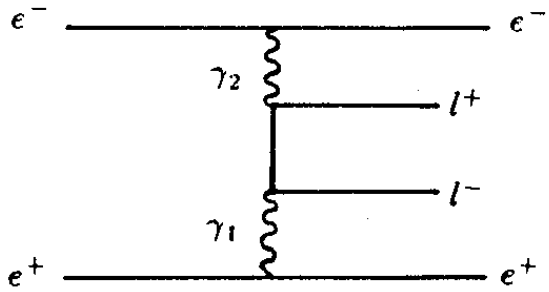


Figure 1.b



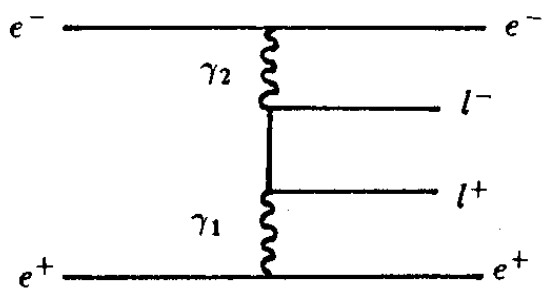
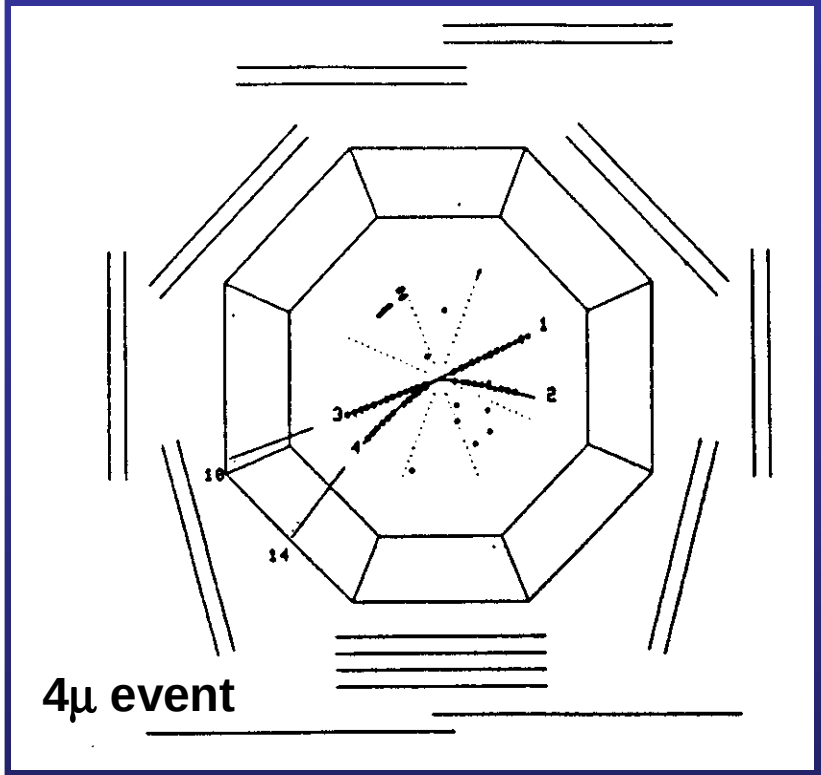
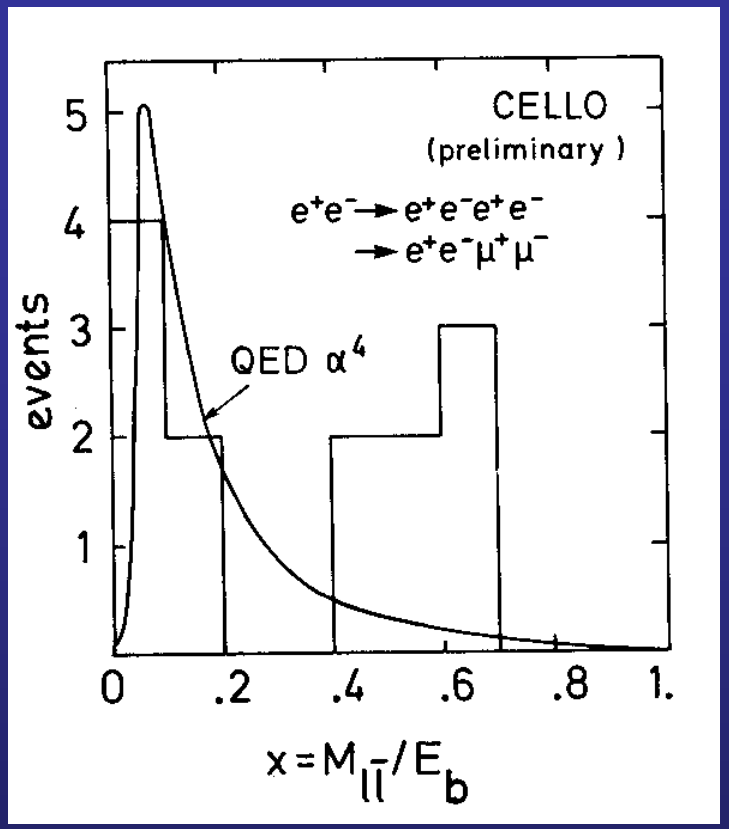


Figure 1.c

Figure 1 : Examples of Feynman diagrams corresponding to the three groups G_{conv_1}, G_{conv^2} and G_{mul}.

From llγ to 4 leptons (+γ)

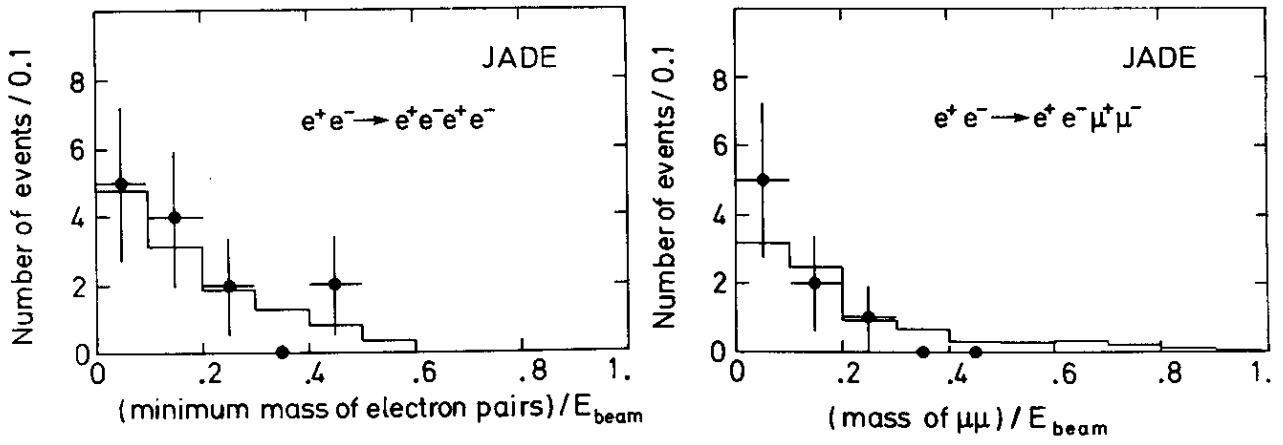




7eeee
6μμμμ
1eeττ
5 out of 14
with γ
(Eg>0.5 GeV)

Importance of
Radiative corr.

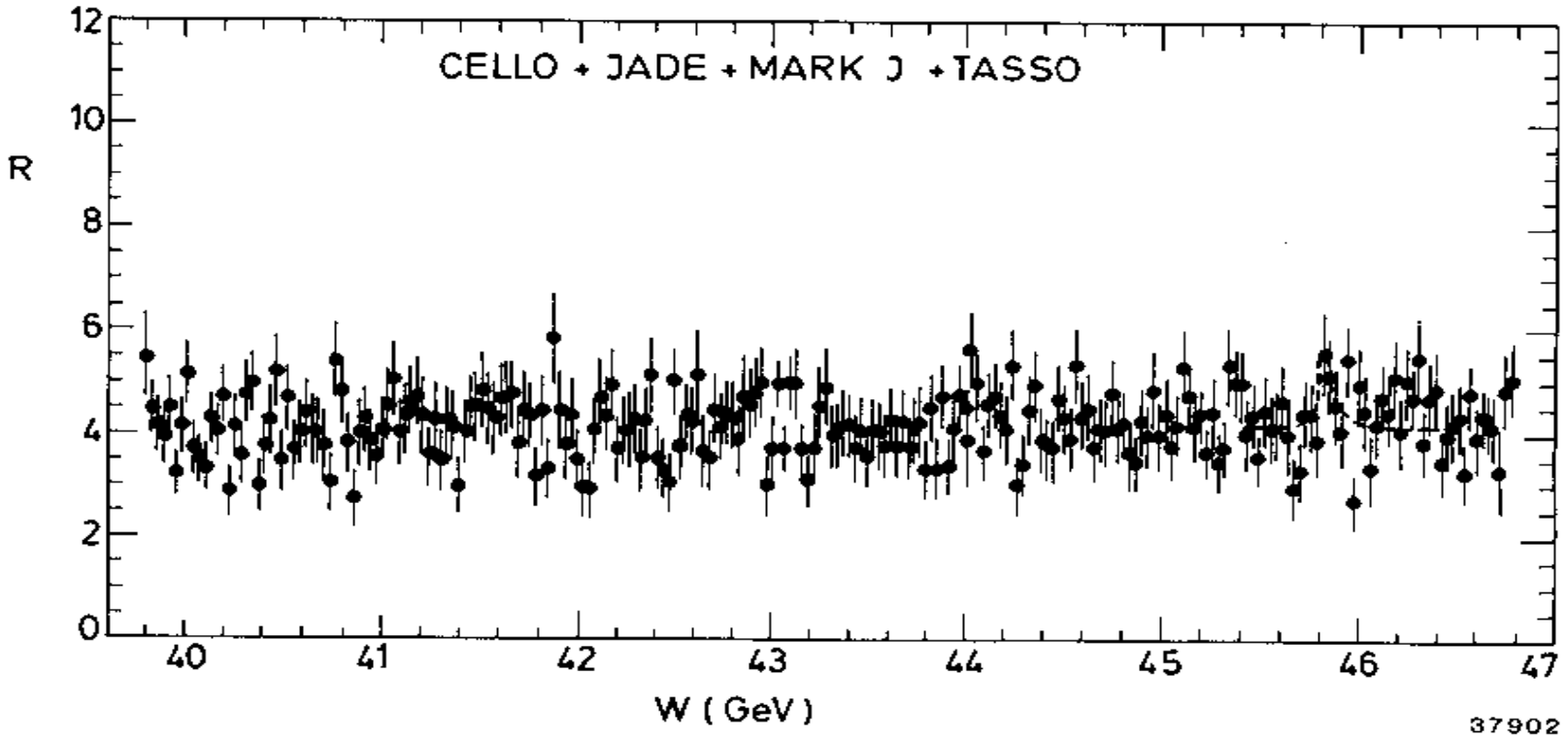
No confirmation from other PETRA experiments



Many other particles have been searched

- Heavy leptons (charged and neutrals)
- Higgs (charged and neutral)
- Techniparticles
- SUSYparticles
- …

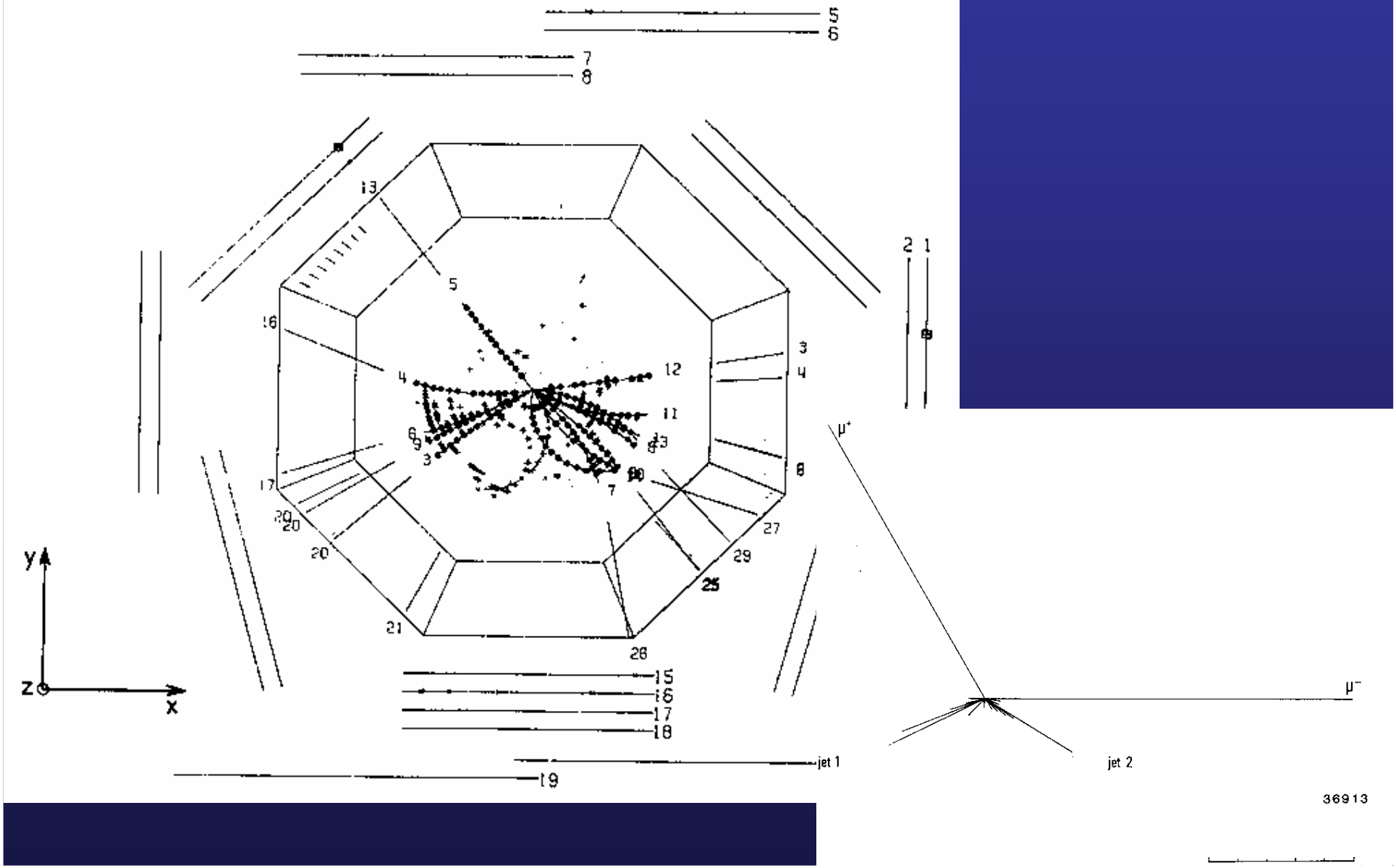
This talk wouldn’t be complete omitting the search of the *top* quark



What about the Gluon?

Nothing but my biggest frustration!!!

Instead we had the “CELLO event”



Conclusions (1/2)

This (PETRA/CELLO) era helped

- Understanding better the SM and opened the era of precision measurements at LEP

  Maybe this was for me the trigger to study other type of asymmetries (CP violation)

  …but this is another (BaBar) story

- Understanding the effects of radiative corrections
  It was the initiator of a series of many great tools

  KORALZ, KORALW, KORALB, TIPTOP,
  YFSWW, YFSZZ
  BHLUMI, BHWIDE
  TAUOLA, PHOTOS

- Understanding QCD (gluon discovery , α_s measurement…) and quark fragmentation

- It was a lot of fun searching for new particles and new phenomena

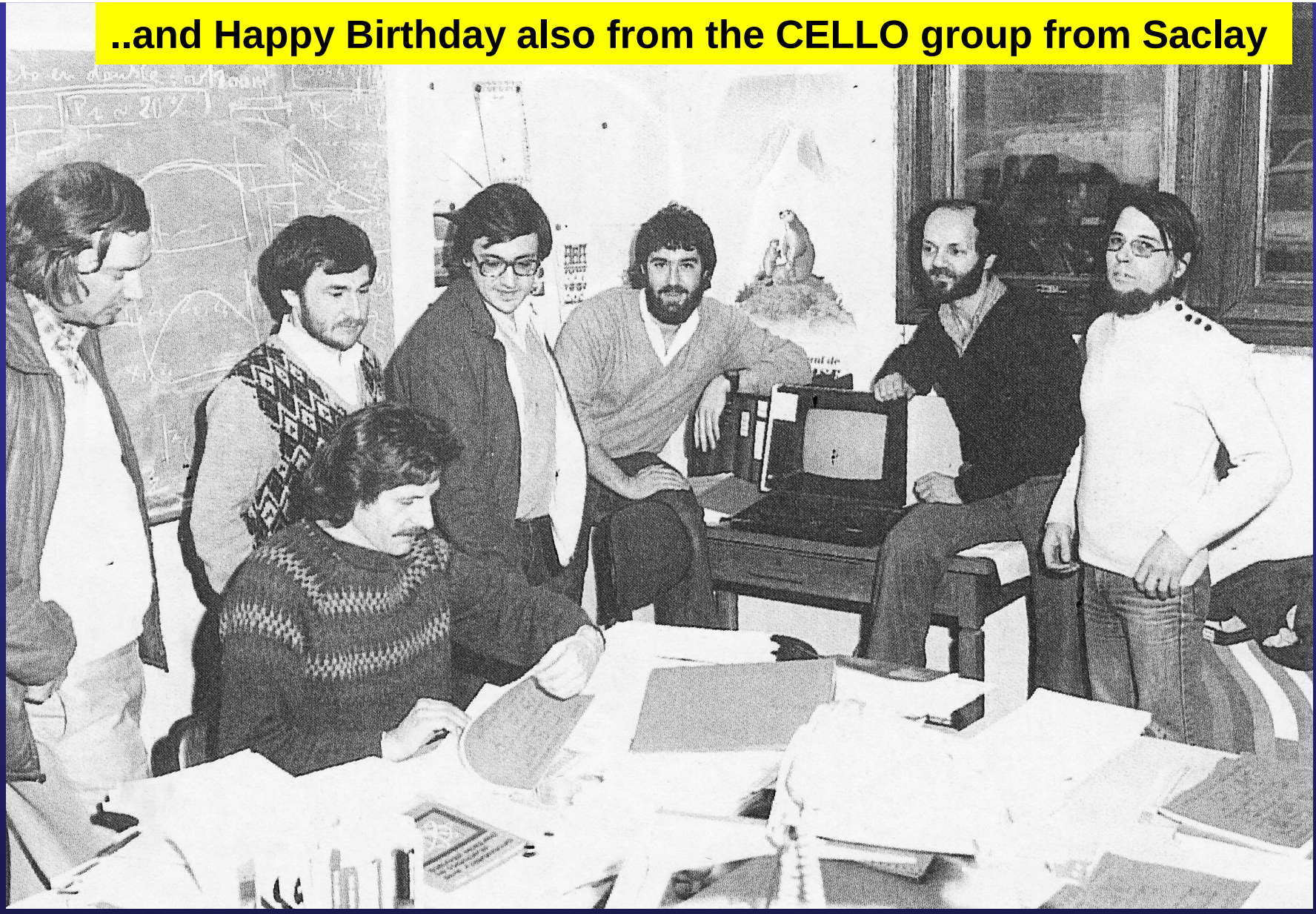
Conclusions (2/2)

I did not discover new particles although the searches helped setting many constraints on new physics…

…but more importantly, I did find a friend

Happy Birthday, Staszek …
with my best wishes for the New Year

..and Happy Birthday also from the CELLO group from Saclay



From left to right: J. Bouchez, J.-P. Pansart, F. Pierre (sitting), V. Hajjar, P. Jarry, R. Aleksan, A. Gaidot