



### **"Kasemann-Fest":** Special Symposium for Matthias Kasemann The early years of Matthias

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### **Questions 1983 ...**

... when Matthias began his PhD in Dortmund in the group of Franz Eisele and Konrad Kleinknecht

- What are the properties of the W and Z bosons just discovered by UA1/2?
- Does a partner of the b-quark, the top-quark, exist and what is its mass ?
- What is the origin of the violation of the matter- anti-matter symmetry (CP) first observed by Cronin, Fitch and Turlay in Kaon decays ?
- Will there ever be something better than this  $\rightarrow$



How can one analyze and visualize large amounts of data? We had neither PAW nor Root, not even PDF; PostScript was brand-new !











### **Available Tools**





## **Decision**: join "NA31" Experiment

#### NA31:

- an experiment proposed in 1982
- as a CERN-Edinburgh-Mainz-Pisa-Siegen collaboration
- at the K4 neutral beam line of the SPS
- Measurement of the double ratio

resp. 
$$\frac{\epsilon'}{\epsilon} \simeq \frac{1}{6} \left( 1 - \left| \frac{\eta_{00}}{\eta_{+-}} \right|^2 \right)$$

$$\frac{\eta_{00}}{\eta_{+-}}\Big|^2 = \frac{\Gamma(K_{\rm L}^0 \to \pi^0 \pi^0) \ \Gamma(K_{\rm S}^0 \to \pi^+ \pi^-)}{\Gamma(K_{\rm L}^0 \to \pi^+ \pi^-) \Gamma(K_{\rm S}^0 \to \pi^0 \pi^0)}$$

**Theoretical motivation:** 3x3 CKM matrix in Standard Model with three generations (Kobayashi and Maskawa 1973) allows a phase  $\delta$  that causes CP violation, i.e. a value of the relative CP violation parameter  $\epsilon$ ' different from 0.





### What we did not know for sure in 1984

In the Standard Model,  $K^0 - \overline{K}^0$  mixing is caused by "box diagrams"



 $|K_1\rangle = (|K^0\rangle + |\bar{K}^0\rangle)/\sqrt{2}$  CP even, decays to 2 pions  $|K_1\rangle = (|K^0\rangle - |\bar{K}^0\rangle)/\sqrt{2}$  CP odd, cannot decay to 2 pions, long-lived

Experiment by Cronin & Fitch, 1964: observed decays of long-lived K<sub>L</sub> to 2 pions  $|K_S\rangle = (|K_1\rangle + \epsilon |\bar{K}_2\rangle)/\sqrt{1 + |\epsilon|^2} |K_L\rangle = (\epsilon |K_1\rangle + |\bar{K}_2\rangle)/\sqrt{1 + |\epsilon|^2} \qquad \text{small admixture of "wrong" CP state}$ 

? Is the above mixing mechanism the source of CP violation, or a new "5<sup>th</sup> force" ? ! A precise measurement of  $\left|\frac{\eta_{00}}{\eta_{+-}}\right|^2$  can tell the difference ! Kasemann-Fest, DESY June 26, 2023 G. Quast

### NA31: a high-tech experiment at the time



The NA31 kaon decay tunnel



- simultaneous measurement of neutral and charged decay modes
- movable K-short target to mimic K-long decay length
- wire chambers in He-tank to minimize multiple scattering
- liquid Argon calorimeter for excellent photon resolution
- hadron calorimeter to measure pions
- "FASATBUS" readout (also used by LEP experiments)
- Peak finder and Arithmetic FASTBUS interface for calo clusters
- double 168E system with FASBUS connection as software trigger



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# NA31: a high-tech experiment (2)





## Matthias @ work & leisure







### Matthias' activities

• iron-scitillator w. 48 iron plates 2700x2700x24 mm<sup>3</sup>



- 44 scintillator strips / plane with plexiglas light-guides
  - 6.7 nucl. abs. lengths
    - Laser calibration system
    - $\sigma_E = 65\%/\sqrt{E}$

#### Matthias:

- planning & building
- optical calibration
  - system
  - operation from 1986 1987
  - data analysis





### **NA31 Detector Paper**

#### THE BEAM AND DETECTOR FOR A HIGH-PRECISION MEASUREMENT OF CP VIOLATION IN NEUTRAL-KAON DECAYS

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Received 4 November 1987





# NA31 in action

#### NA31 online event display



Charged  $2\pi$  decay

Neutral  $2\pi$  decay



Wait

WC1

WC2

LAC (F)

LAC (B)

HAC (F)

HAC (B)

PVL 2

PVR 2

PHB 1

PHT 2

Neutr.

Cyc 1.5

168 Acc

0

6

0.000

# NA31 Data Analysis



Fig. 2. Number of accepted 4 $\gamma$  events as a function of  $\chi^2$ , for  $K_S \rightarrow 2\pi^0$  and  $K_L \rightarrow 2\pi^0$  data, and a Monte Carlo calculation for background originating from  $K_L \rightarrow 3\pi^0$  decays. The signal region is taken as  $\chi^2 < 9$ .



# NA31 Data Analysis (2)

 $K_{S,L} \to \pi^+\pi^-$ 

discriminating variable: "distance to target" dT



295 k events 0.6% background

Fig. 3. Event distribution for charged decays as a function of distance  $d_T$  between the decay plane and the production target, for K<sub>s</sub> and K<sub>t</sub> decays and for various background components.



### **E731**: "the other experiment"



- four sets of drift chambers
   + magnet
- lead glass calorimeter
- regenerator to produce Ks



### Matthias' Thesis and result



still no pdf or www, "papers" were printed on ordinary paper !



### PhD defense and post-exam in Mainz

Matthias passed the defense of his thesis and the exam

#### "with distinction"

He also did quite well in the traditional "post-exam"



Matthias received the **PhD prize 1988** by Johannes Gutenberg-Universität Mainz for "**outstanding scientific work**"





### **NA31 Official Result**

#### FIRST EVIDENCE FOR DIRECT CP VIOLATION

56 authors

#### CERN-Dortmund-Edinburgh-Mainz-Orsay-Pisa-Siegen Collaboration

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#### Phys. Lett. B, Vol. 206 n. 1 (1988)

#### Table 3

Systematic uncertainties on the double ratio R (in %).

background subtraction for $K_1 \rightarrow 2\pi^0$	0.2
background subtraction for $K_L \rightarrow \pi^+ \pi^-$	0.2
$2\pi^0/\pi^+\pi^-$ difference in energy scale	0.3
regeneration in the K <sub>L</sub> beam	< 0.1
scattering in the Ks beam	0.1
Ks anticounter inefficiency	< 0.1
difference in $K_S/K_L$ beam divergence	0.1
calorimeter instability	< 0.1
Monte Carlo acceptance	0.1
gains and losses by accidentals	0.2
pretrigger and trigger inefficiency	0.1
total systematic uncertainty	±0.5%

$$\Re\left(\frac{\epsilon'}{\epsilon}\right) = (3.3 \pm 1.1) \times 10^{-3}$$





### **Continuation of the CP story**

#### after Matthias left NA31

#### ε'/ε status Lepton-Photon 1989 (Stanford)



**Contradiction** required a new generation of experiments:

- NA48 @ CERN
- KTeV @ FNAL





we hat to wait until 1999 for first new results:

**KTeV, March 1999:** 
$$\Re\left(\frac{\epsilon'}{\epsilon}\right) = (2.8 \pm 0.41) \times 10^{-3}$$
  
**NA48, August 1999:**  $\Re\left(\frac{\epsilon'}{\epsilon}\right) = (1.85 \pm 0.73) \times 10^{-3}$ 





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Latest PDG Value: 
$$\Re\left(\frac{\epsilon'}{\epsilon}\right) \simeq \frac{\epsilon'}{\epsilon} == (1.63 \pm 0.23) \times 10^{-3}$$



# **EPS Prize 2005 for the NA31 collaboration**



17 years after his thesis result, the European Physics Society confirms that Matthias' result on ε'/ε was right ! (a bit on the high side, though ...)



### NA31 and the Higgs Boson

NA31 also searched for a (very) light Higgs in  $K_L \rightarrow \pi^0 H, H \rightarrow e^+e^-$ 

**Signature:** displacement between  $\pi^0$  and  $e^+e^-$  points of origin

90% CL limits on  $Br(K_L \to \pi^0 H) \times Br(H \to e^+e^-)$ 





# **NA31 measurement of K<sup>0</sup> Oscillations**

A textbook plot of flavour oscillations,

measured by NA31 with a modified <sup>2</sup> experimental set-up to determine the phases of the CP-violating amplitude and to test CP-invariance.



Decays of neutral Kaons to pairs of neutral and charged pions



# The next career step – looking for new challenges





G. Quast

# The next career step – looking for new challenges





### The next career step: ALEPH

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and returned

ETP

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## **The ALEPH Detector**







# The ALEPH Detector



#### Views inside Time Projection Chamber







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### **ALEPH TPC**

### TPC



- $r\varphi$  from pad position
- z from drift time (pads + wires)
- dE/dx from wires and pads

- Length = 4.7 m
- Outer radius = 1.8 m
- Total weight = 3.6 t
- Drift length  $2 \times 2.2$ m
- Up to 21 space points / track
- 18 wire chambers / endplate
- 47340 channels in total
- B = 15 kG
- HV (Membrane) = -27.5 kV
- Gas
  - Volume  $43 m^3$
  - Argon/Methan (91:9) at atmospheric pressure
- Angular coverage
  - $2\pi$  in  $\varphi$
  - 21 pad rows hit for  $\cos\Theta \le 0.8$
  - At least 3 pad rows for  $\cos \Theta \le 0.97$





#### **ALEPH TPC Group**

Search Picture: Were is Matthias ?





## An Example of Matthias way of working ...

Minutes of the ALEPH DAQ Software Meeting

September 27, 1988

**Matthias Kasemann** spoke about work that has been done on producing a histogramming system. It is necessary to share data between monitoring tasks and the presenter, which may be running on different machines. A database has been devised which contains HBOOK4 information, access information, operation information and presentation information which is used to present the data saved in a global section. The system is presently working with successful sharing of information between tasks. It would be good to make the fill and access routines more user friendly and Kasemann asked to share the work and responsibility with someone from the online group. John Harvey asked what the time scale for the completion of the project was and was told it would require the effort of one person working full-time for 2-3 weeks.



### First Z Boson seen at LEP



First recorded Z decay at LEP (13 August 1989 at 23:17, OPAL experiment)



### An early event seen by ALEPH



Hadronic Z decay, ALEPH 1989



## Matthias in the TPC group

• Monte Carlo studies for the cross section measurement of  $e^+e^- \rightarrow \mu^+\mu^-$ 

preparation of the data taking system

• detector calibration with cosmic rays

coordination of TPC online



software for data acquisition, debugging and monitoring

• data analysis: measurement of the  $\tau$ -Neutrino mass





#### **ALEPH TPC Event Picture**





#### Important early ALEPH results – Number of Neutrinos

from measurements of the "hadronic lineshape", i. e. 
$$\sigma_{e^+e^- \to hadrons}(E_{CM})$$
 with  
 $\sigma_{f}^{peak} = \frac{12\pi}{M_Z^2} \frac{\Gamma_{ee}\Gamma_f}{\Gamma_Z^2} (1 - \delta_{rad}) \equiv \sigma_{f}^0 (1 - \delta_{rad}) , \Gamma_Z = N_v \Gamma_v + 3\Gamma_{ee} + \Gamma_{had}$ 



#### DETERMINATION OF THE LEPTONIC BRANCHING RATIOS OF THE Z

ALEPH Collaboration

11 January 1990



$\Gamma/\Gamma_{had}$ ratio			
Decay	P	В	I (MeV)
Z→e*e=	$0.0472 \pm 0.0061$	$0.0323 \pm 0.0021$	85.9 1 6.9
Z ∙µ⁺µ	0.0435 - 0.0060	0.0298 ±0.0046	79.3 ± 12.8
Z →τ⁺τ⁻	0.0483 1 0.0051	0.0331 ± 0.0041	88.0 ± 11.7
Z .ℓ+ℓ-	0.0466 ± 0.0034	0.0321 ± 0.0013	85.4 - 5.3
Z →hadrons		$0.689 \pm 0.030$	1833 1116
Z +invisible		0.214 ± 0.029	569 ± 92

- · ·

**Consistent with lepton universality !** 



 $\tau$  pair event

# ALEPH results presented by M.K.

Moriond 1990 Search for New Particles with ALEPH presented by M. Kasemann for the ALEPH Collaboration The results of the following searches have been published by the ALEPH Collaboration: Search for the standard model neutral Higgs boson <sup>[2][3]</sup> Search for supersymmetric standard model neutral Higgs bosons [3][4] Search for charged Higgs bosons [5] Search for neutralinos [6] Search for supersymmetric particles [7] Search for new and leptons [8] Search for excited leptons <sup>[9]</sup> • Search for Z decays to  $\pi^{\circ}\gamma, \eta\gamma, \eta'\gamma^{[10]}$ 

In this talk we restrict ourselves to a description of the searches for the standard model and supersymmetric standard model neutral Higgs bosons and for neutralinos.



### Search for the Standard-Model Higgs Boson



Branching ratios of the Higgs decays in the non-perturbative QCD mass range.



Figure 2: The number of events expected above 212 MeV from the ALEPH searches for a standard model Higgs from Z decay. The 95% confidence level limit at 3 expected events is shown, corresponding to zero observed candidates.



# ALEPH and its heautiful results must be seen after Matthias left

ALEPH and its beautiful results must be seen in the context of all four LEP experiments



- Precision Measurements of SM processes
- Searches for new phenomena





### Properties of the Z-Boson



#### **Repeated measurements of the hadronic cross-section**



# **Properties of the Z-Boson**

The ALEPH, DELPHI, L3, OPAL and SLD Collaborations / Physics Reports 427 (2006) 257-454



Hadronic line shape

#### Lepton forward-backward asymmetries



### **Properties of the Z-Boson: Couplings**

The ALEPH, DELPHI, L3, OPAL and SLD Collaborations / Physics Reports 427 (2006) 257-454



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#### Weak Mixning Angle



#### Vector and axial-vector couplings





#### LEP 2





Kasemann-Fest, DESY June 26, 2023

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# CERNCOURIER | Reporting on international high-energy physics



February 2001

A possible Higgs glimpsed by the Aleph detector, with four emerging sprays of particles. The red/yellow pair and the blue/green pair emerge back to back, suggesting the production of a Higgs and a Z boson.

Really a Higgs or just back ground ? (The answer came 11 years later ...)

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### Higgs @ LEP 2

The ALEPH Collaboration et al. / Physics Reports 532 (2013) 119-244



Matthias' and my ways and scientific careers have crossed many times also after the early days:

- CMS

- Alliance "Physics at the Terascale"
- Computing for LHC

But I'll stop here honoring Matthias' may achievements

- there are others to take over

Matthias, my best wishes on your way from "Plicht zur Kür" (duty to freestyle)

Enjoy your "(Un-)Ruhestand" !!!

From leo.org English translator:

**Ruhestand** = end of working life (mandatory pension age in Germany at 65).

Someone is in

**Unruhestand** when that person remains active afterwards, pursuing time-consuming hobbies, doing volunteer work or whatever.

