

A tribute to Italo : The NA31 years

Daniel Fournier, Lydia Iconomidou-Fayard, R.D.Schaffer

Theory time-arrow of the Re(ε'/ε) size

1976 ~2% Ellis, Gaillard, Nanopoulos

1979 ~10% Gilman , Wise

~1985 >0.2% Gilman , Hagelin
~0.15%*f(m_t) Buras, Gerard

1989 ɣ-penguins Flynn, Randall

1990 $$\frac{\varepsilon'}{\varepsilon} = 11.10^{-4}\left[\frac{\eta\lambda^5 A^2}{1,3.10^{-4}}\right]\left[\frac{140MeV}{m_s(2GeV)}\right]^2\left[\frac{\Lambda^{(4)}_{\overline{MS}}}{300MeV}\right]^{0,8}[B_6 - Z(x_t)B_8]$$
Buras, Jamin,Lautenbacher

~1995 10^{-4}->16 10^{-4}
Buras et al, Ciuchini et al

2016 (1.1+-5) 10^{-4}
Kitahara et al

Few permil precision seems enough

Needs 10^{-4} precision!

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The NA31 proposal

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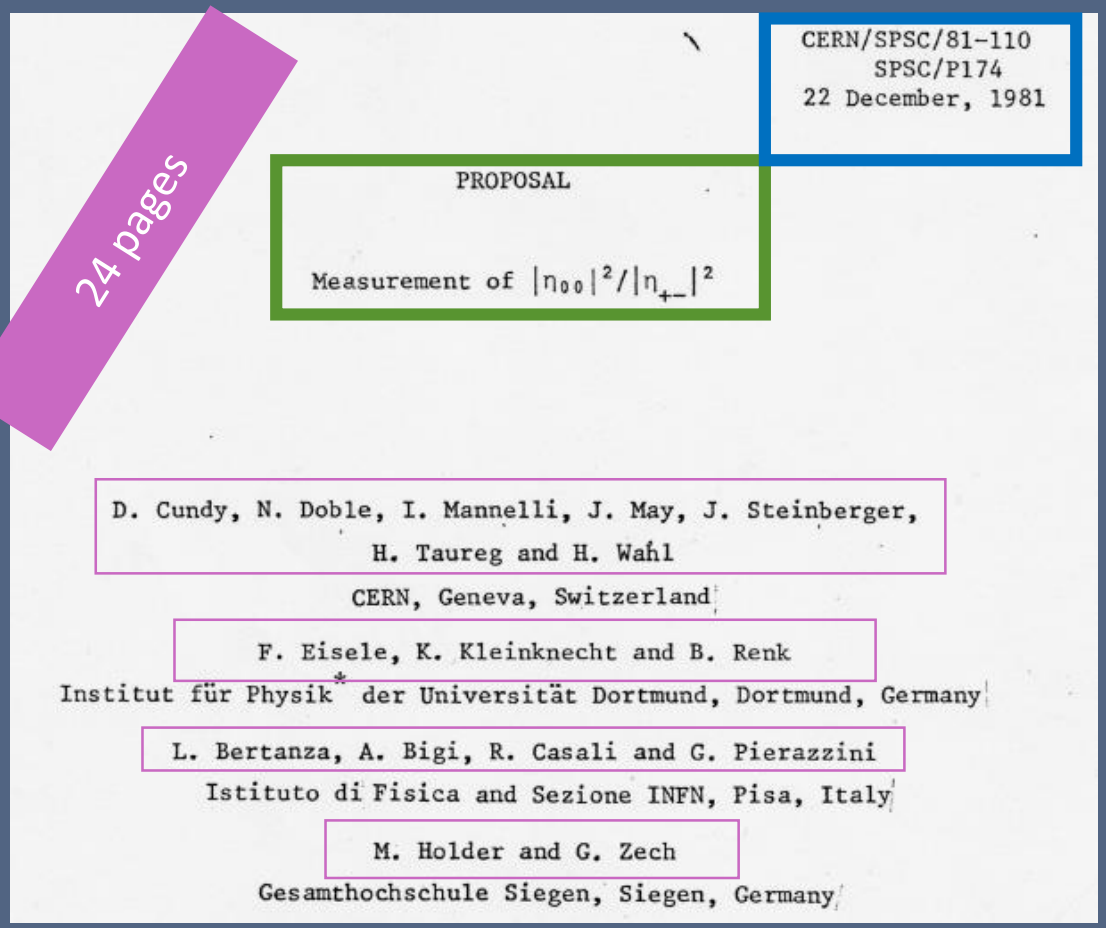
The birth of NA31 experiment



24 pages

CERN/SPSC/81-110
SPSC/P174
22 December, 1981

PROPOSAL

Measurement of $|\eta_{00}|^2/|\eta_{+-}|^2$

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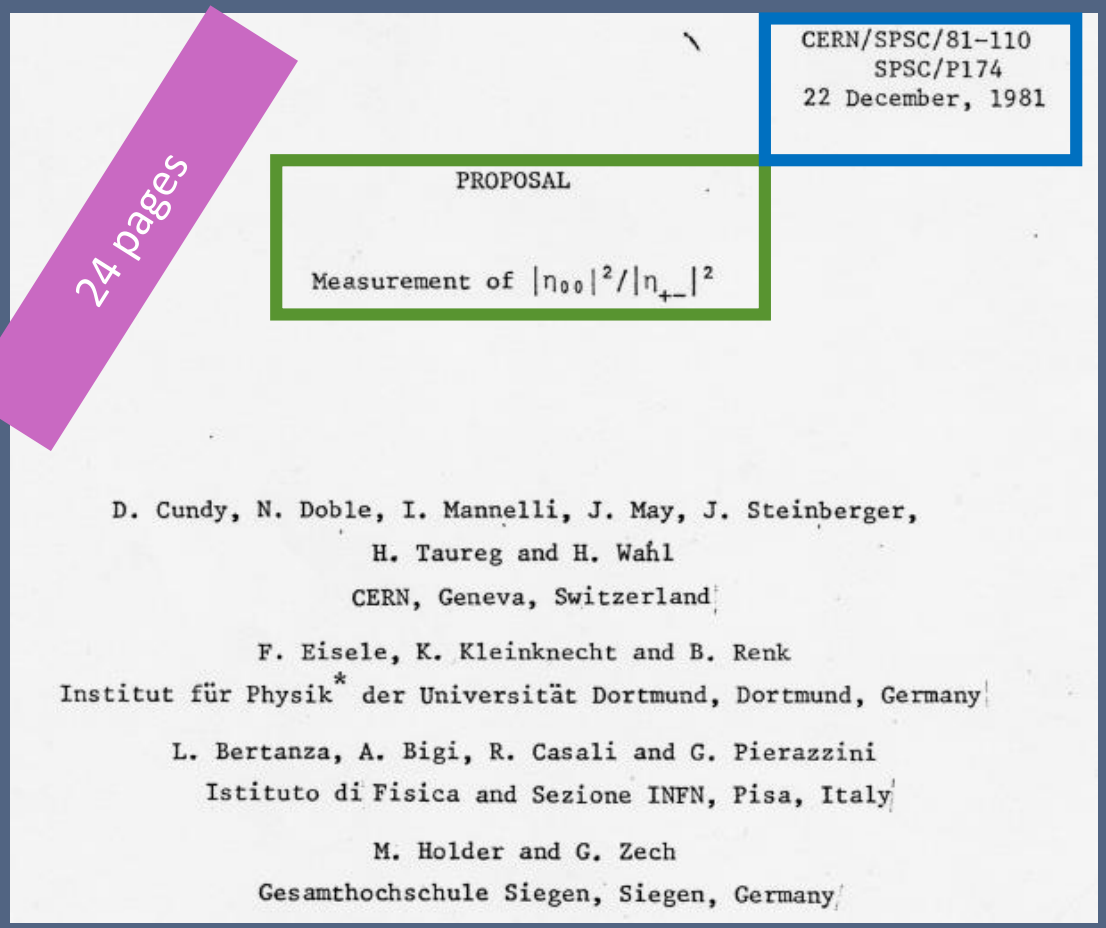

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- **14 authors from 4 Institutes**
- **10 pages of text,** with
  - 9 lines on tracking
  - 1 page on calorimetry
  - 7 lines on veto anticounters
  - ¾ of a page on trigger
  - half a page on systematics
  - 1,5 on charged and neutral background,
  - 10 lines on time scale
  - Half a page on Cost
- **11 References**
- **11 (huge) figures**

The birth of NA31 experiment

Very light and simple description of analysis, background treatment and systematics

It is essential that the uncertainties in these differences, as they affect the ratio of accepted neutral and charged decays, be kept at the one per mille level. We omit here a detailed discussion of the strategies to be employed to try to achieve this level, but limit ourselves to the claim that although the problem is very challenging, such systematic precision is possible.

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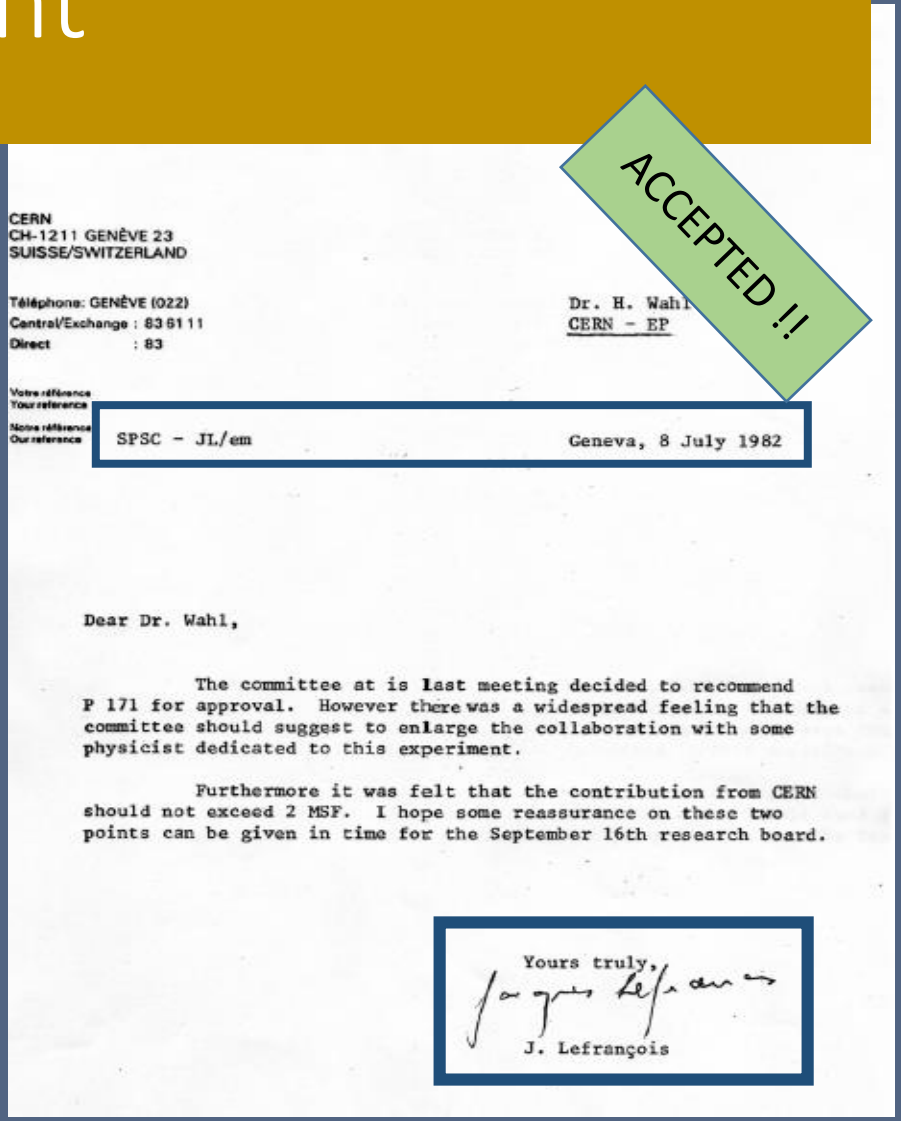

ACCEPTED !!

CERN
CH-1211 GENÈVE 23
SUISSE/SWITZERLAND

Téléphone: GENÈVE (022)
Central/Exchange : 83 61 11
Direct : 83

Dr. H. Wahl
CERN - EP

Votre référence
Your reference

Notre référence
Our reference

SPSC - JL/em

Geneva, 8 July 1982

Dear Dr. Wahl,

The committee at is last meeting decided to recommend P 171 for approval. However there was a widespread feeling that the committee should suggest to enlarge the collaboration with some physicist dedicated to this experiment.

Furthermore it was felt that the contribution from CERN should not exceed 2 MSF. I hope some reassurance on these two points can be given in time for the September 16th research board.

Yours truly,

J. Lefrançois

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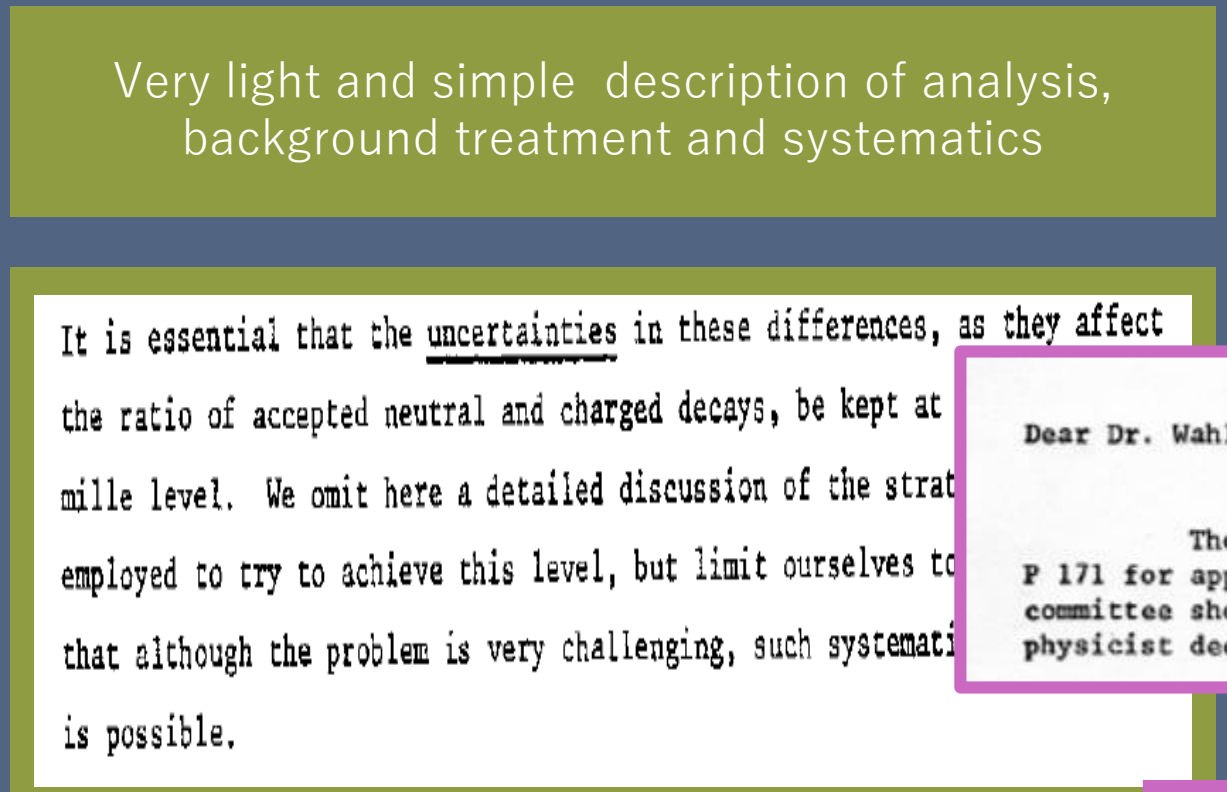

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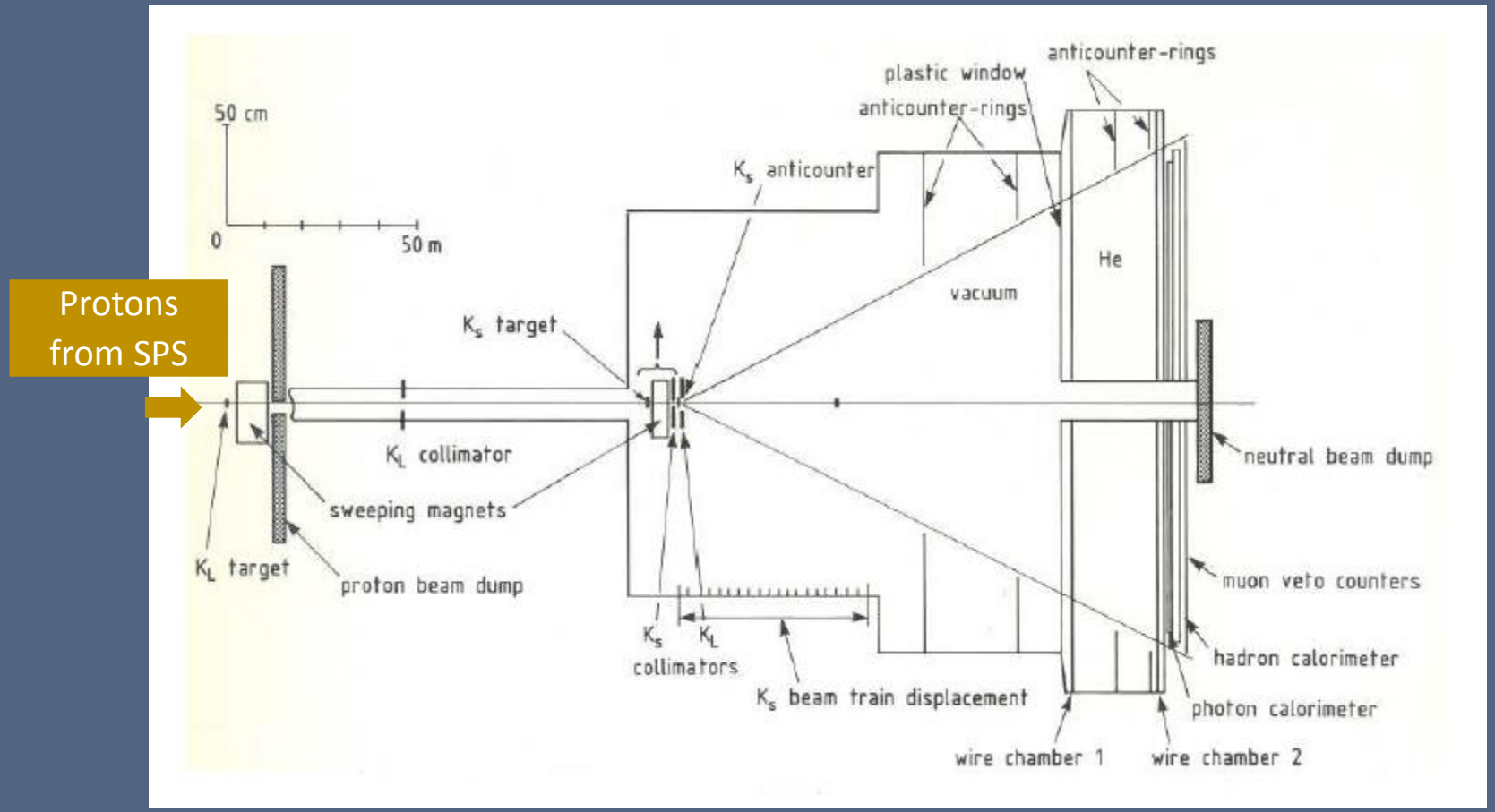
Edimburg and Orsay joined in 1983

The NA31 experiment in a sketch



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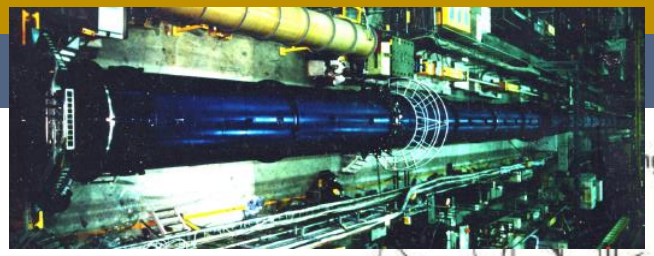

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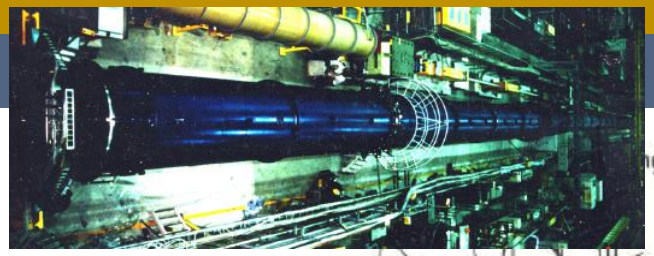

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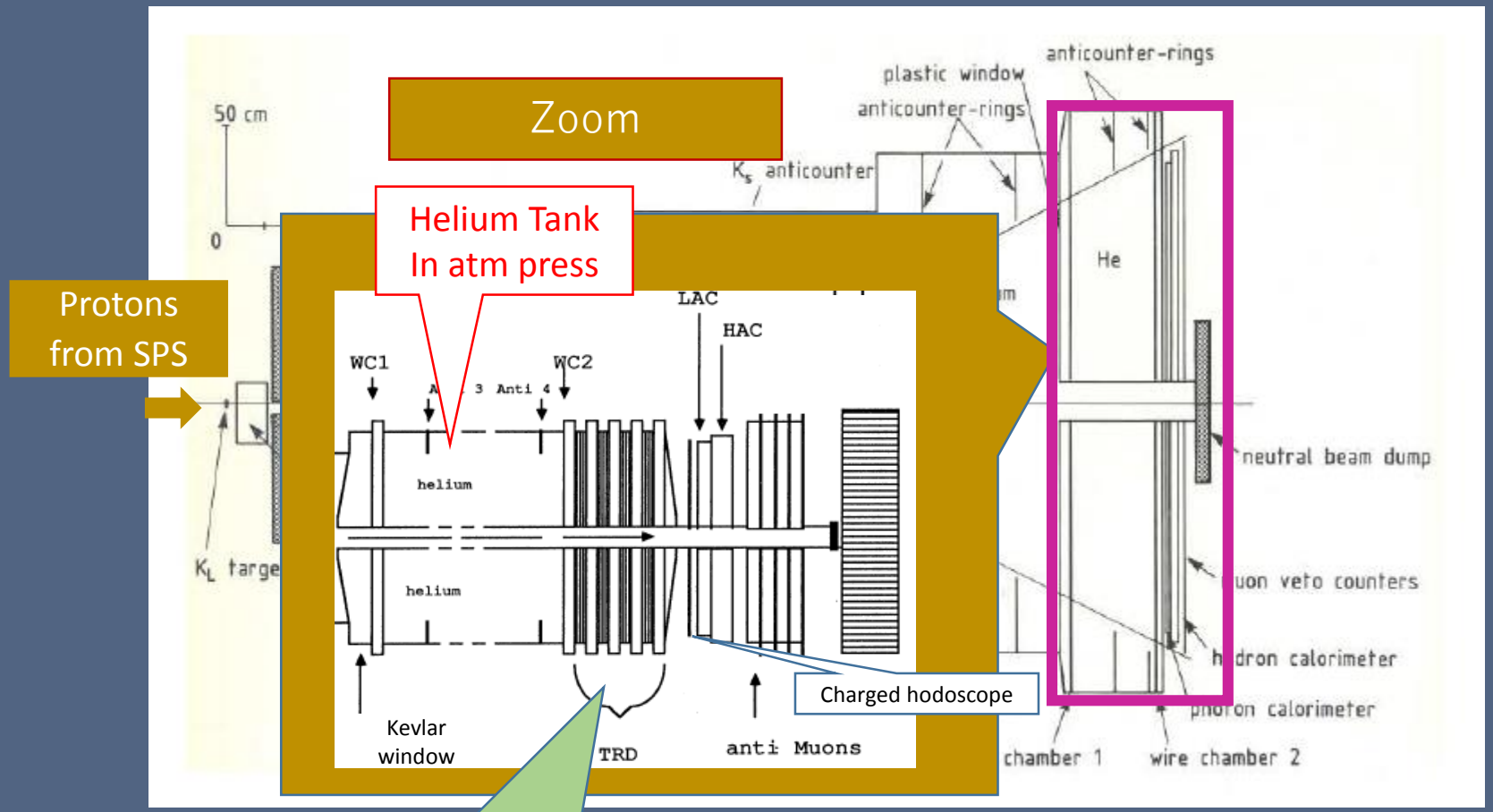

TRD added in 1988

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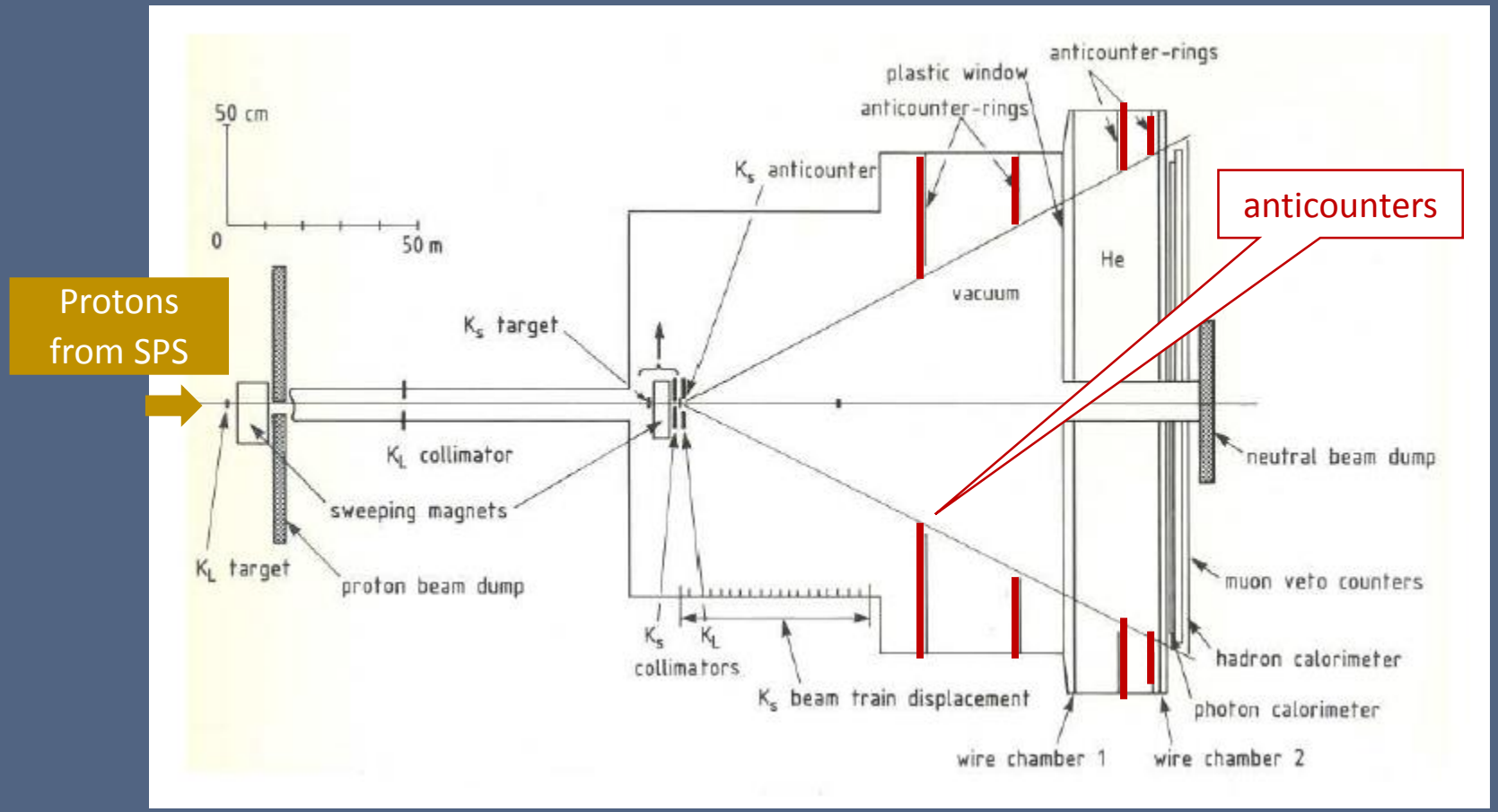
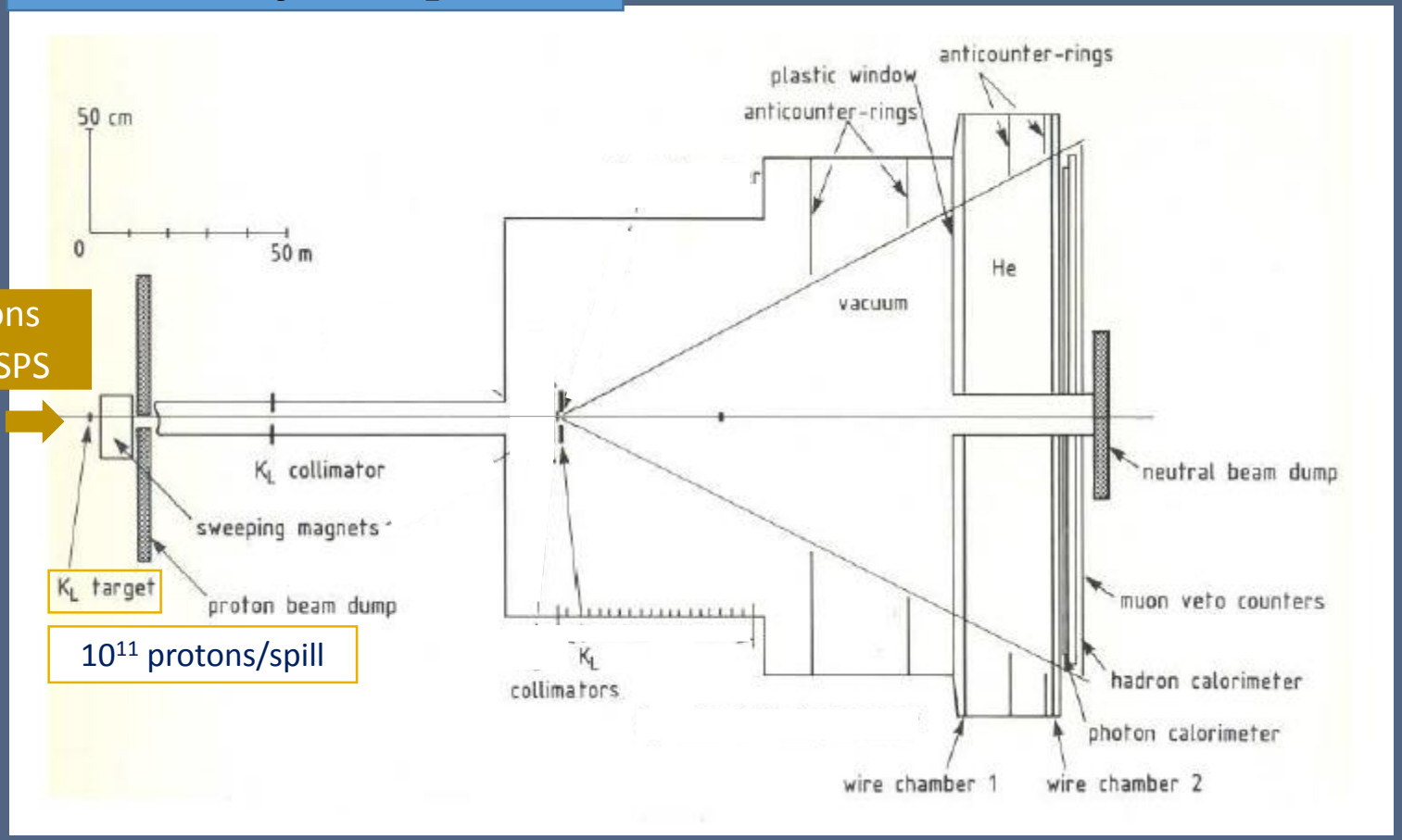


The NA31 experiment : K_L set-up

Alternate K_S and K_L beams



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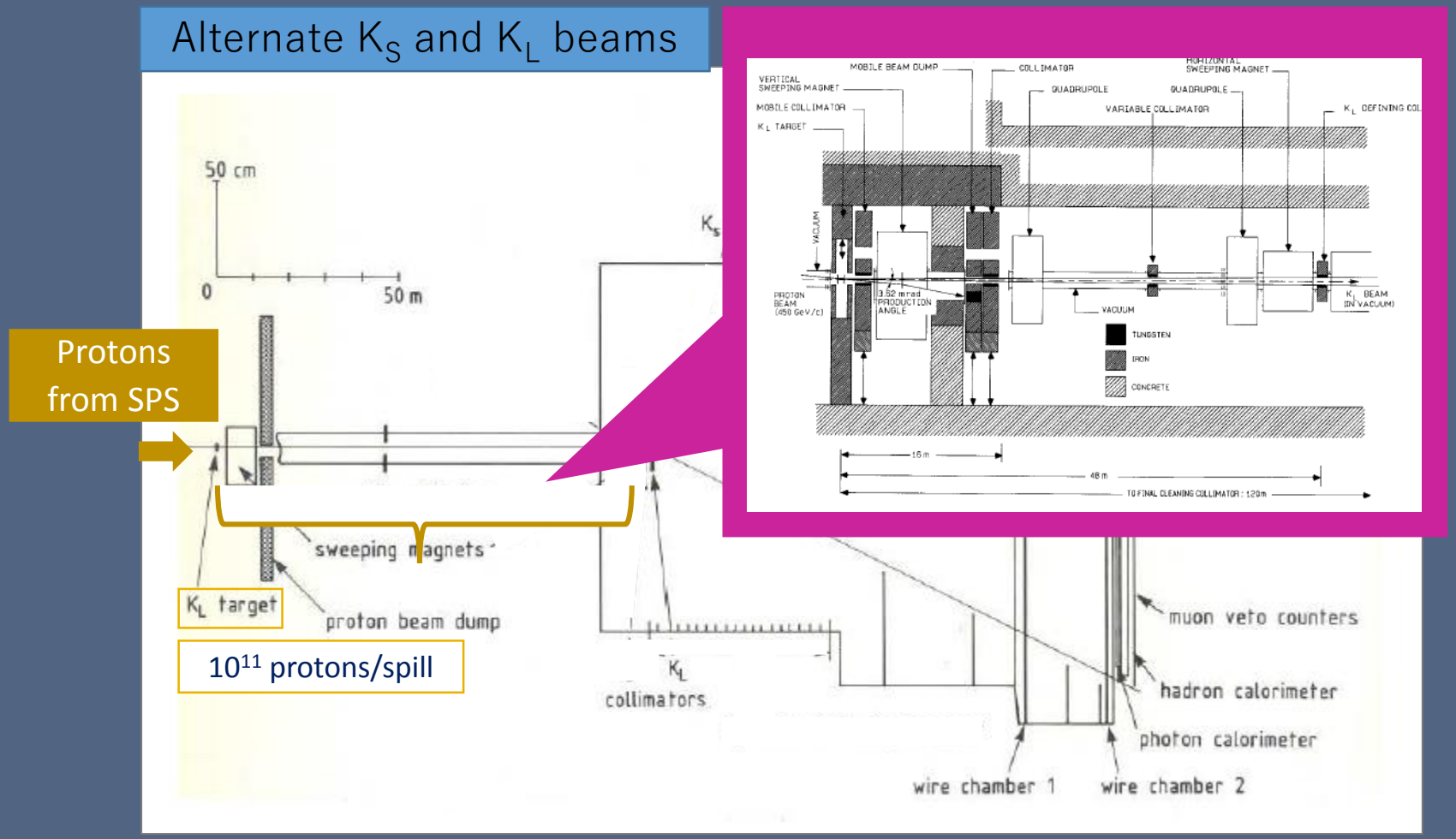

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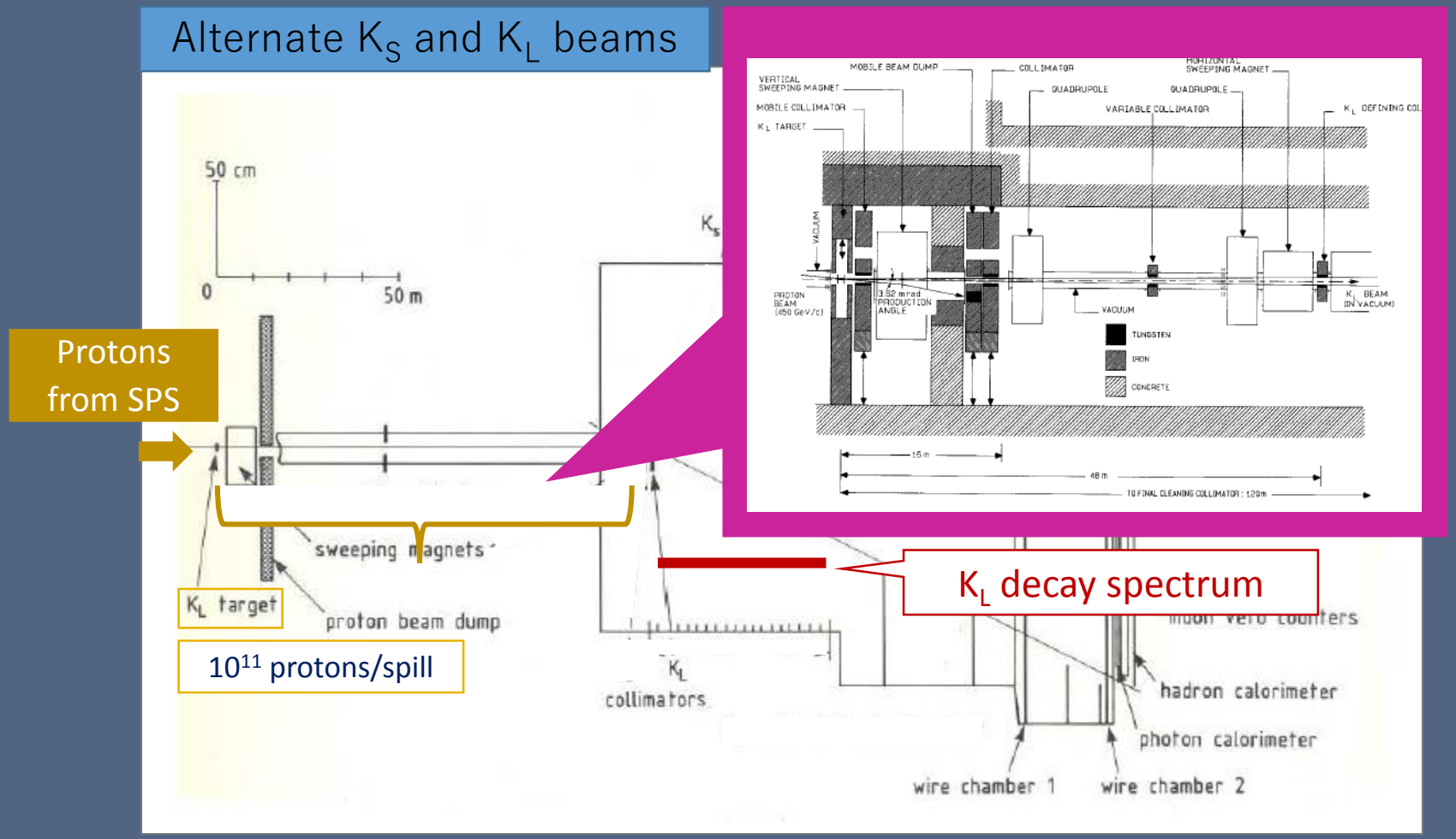

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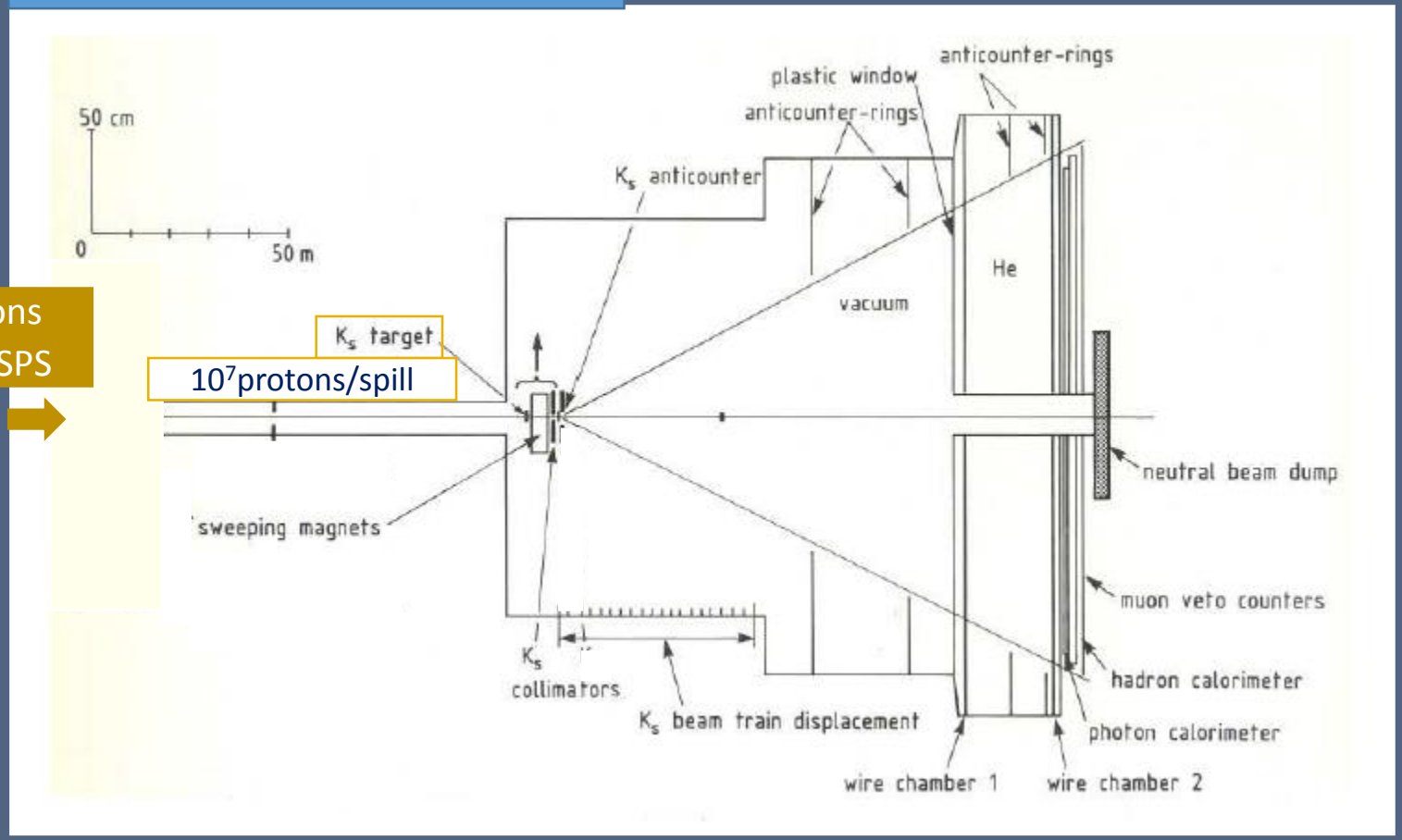

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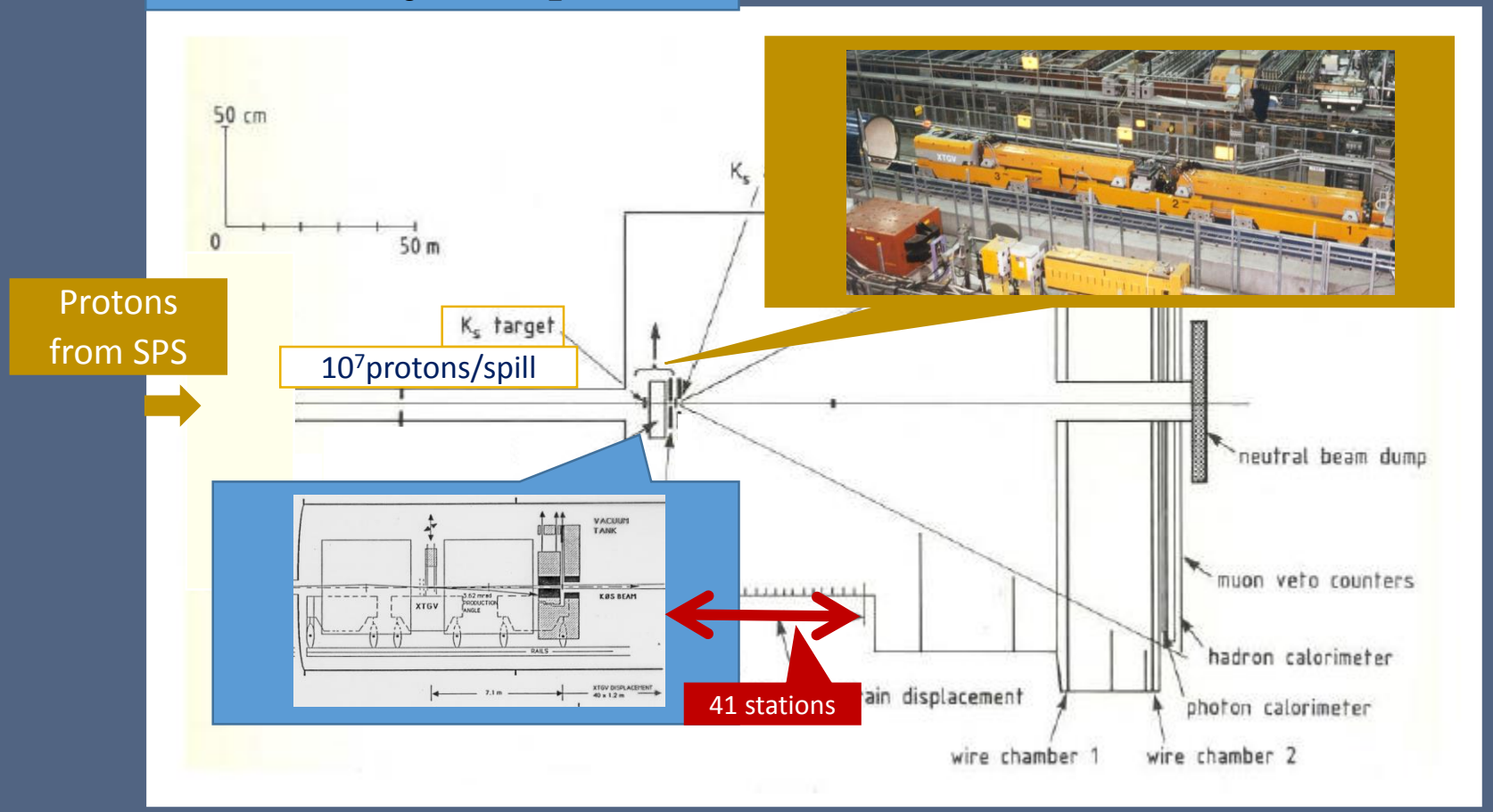

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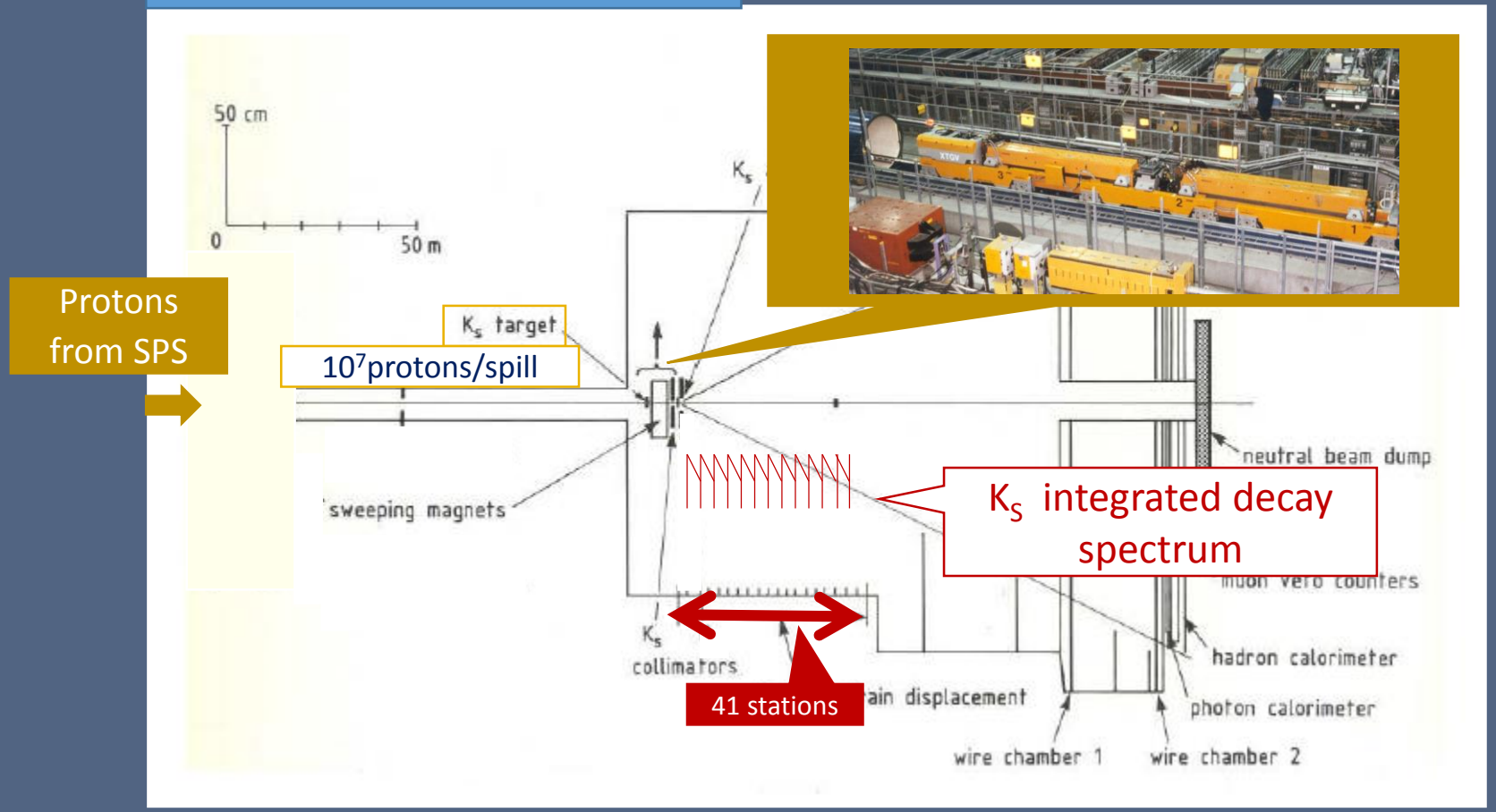


The NA31 method

$$Re\left(\frac{\varepsilon'}{\varepsilon}\right) \approx \frac{1}{6}\left(1 - \left|\frac{\eta_{00}}{\eta_{+-}}\right|^2\right)$$

$$R = \frac{\Gamma(K_L \to \pi^0\pi^0)}{\Gamma(K_S \to \pi^0\pi^0)} \Big/ \frac{\Gamma(K_L \to \pi^+\pi^-)}{\Gamma(K_S \to \pi^+\pi^-)}$$

Alternate Ks and Kl beams
Detect concurrently Charged and Neutral Decays

Italo's contributions : The LAC (Liquid Argon Calorimeter)

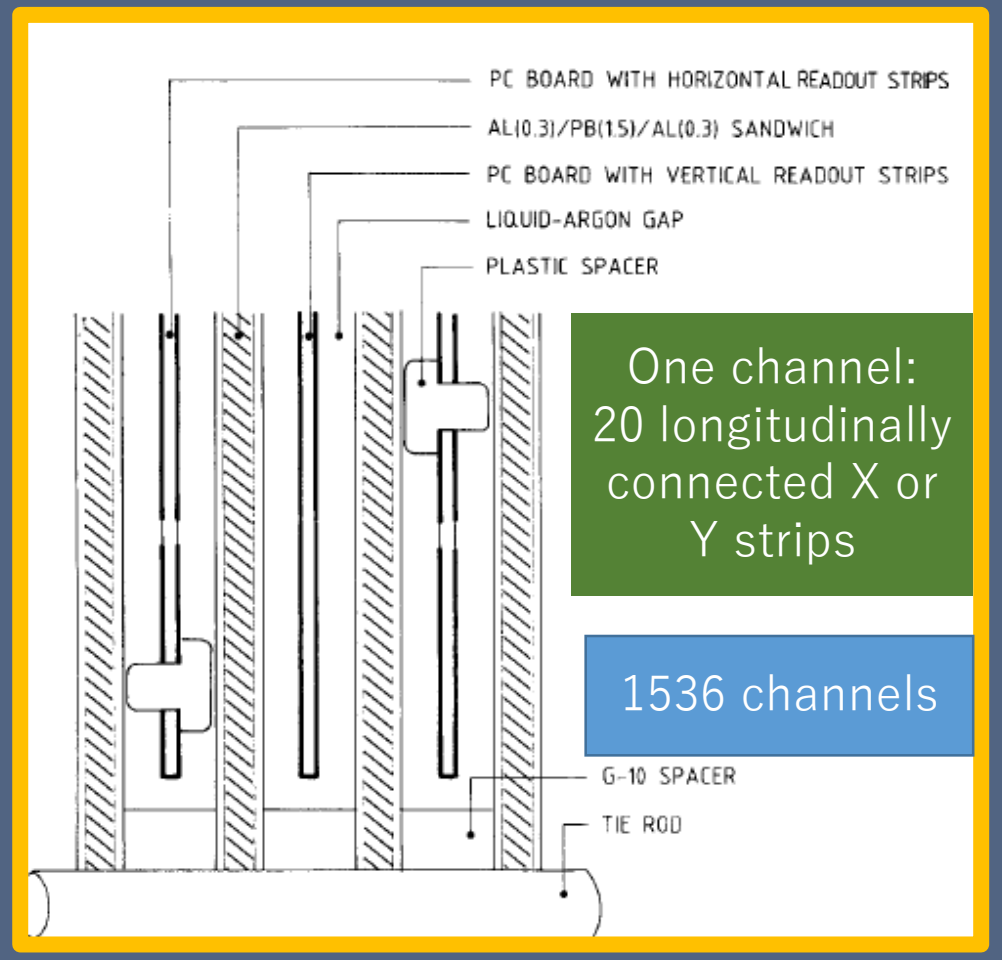
Historical detail :

The SPC scenario of using the lead-glass calorimeter of GAMS experiment was quickly abandonned, the detector was in use.

A dedicated Lead-Liquid Argon Calorimeter was finally chosen. Good energy response with less tails and good position resolution.

Italo's contributions : The LAC (Liquid Argon Calorimeter)

→ **Design of the detector** (with CERN and G.Kesseler).



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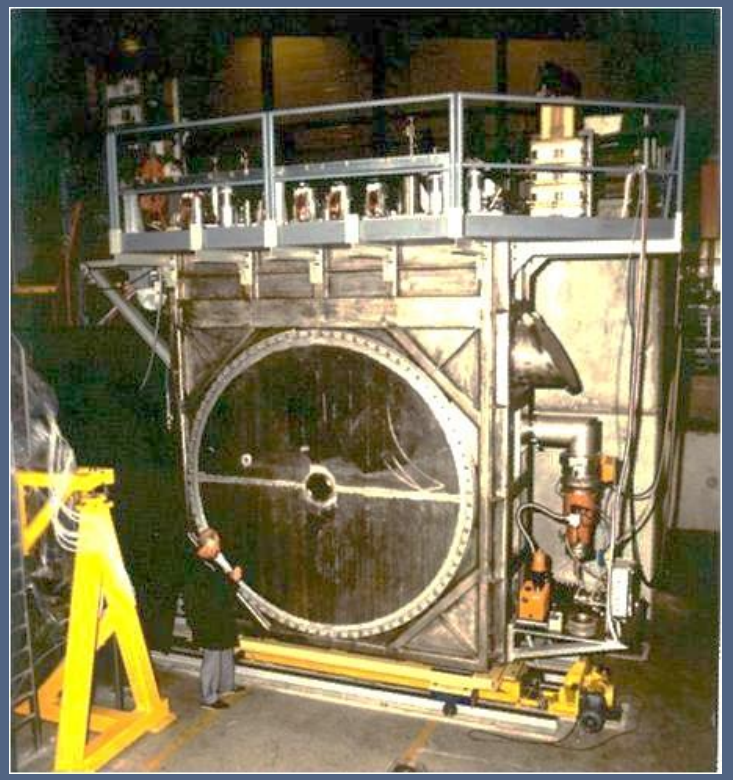

Some troubles with LAC

Shorts : appearing during the various cool-down periods. Up to 6% of channels disconnected.

Connecting channel strips in 2 Interleaved groups of 10. In case of shorts, read only one (half sampling).

A shorted region in the Back was cured after inserting honey-comb. Probably delamination of the G10..

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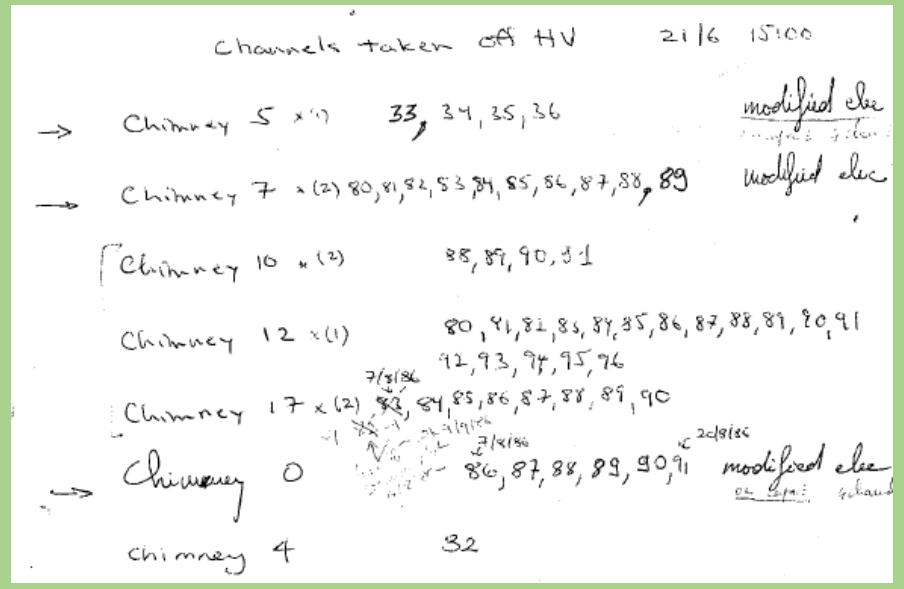

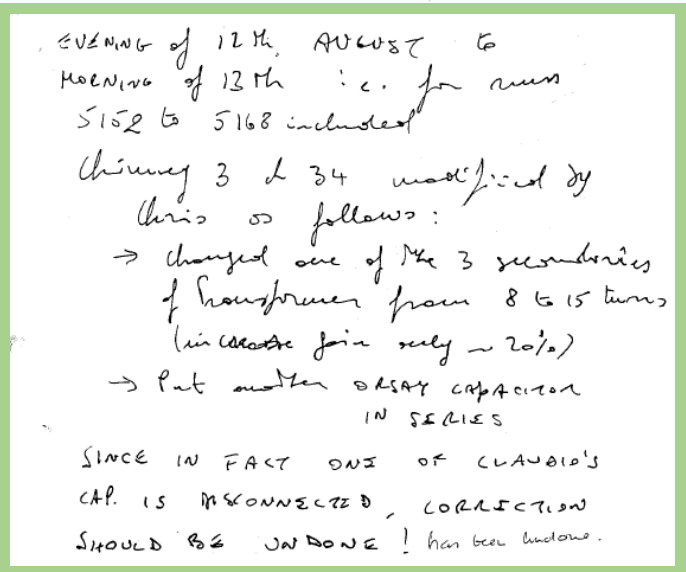

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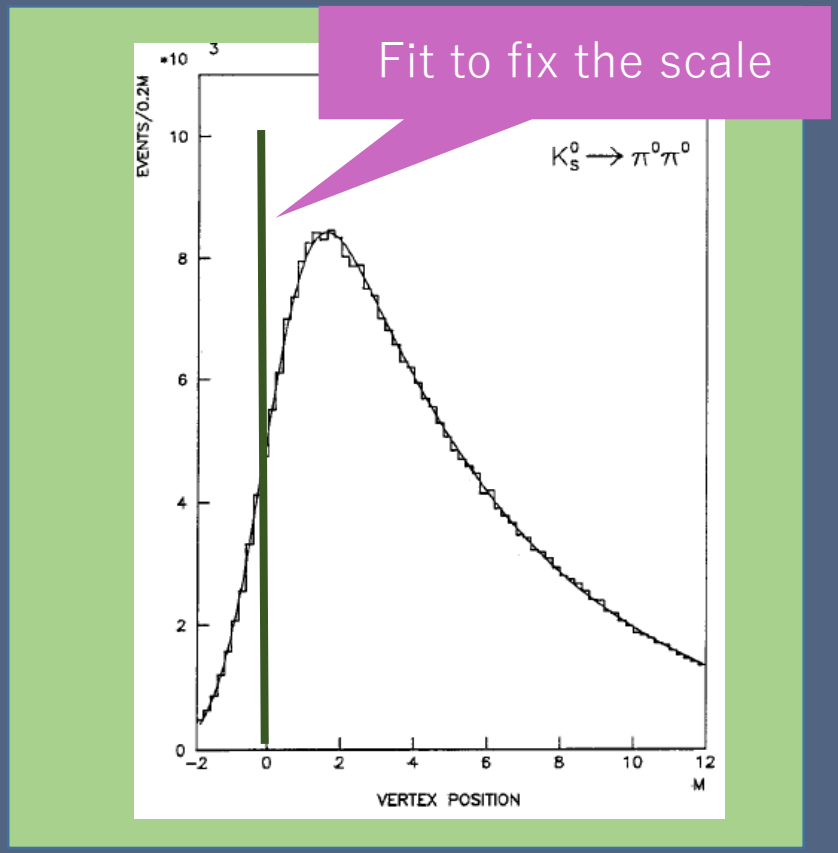
Energy reponse drop from 0.03% to 0.5% per day. Recovered with frequent re-fills Controlled by AKS.



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→ **Design of the detector** (with CERN and G.Kesseler).

→ **Electronic calibrations** in cold (with C.Cerri)

→ **PeakFinder** (hardware trigger with Galeotti) to identify energy peaks in the calorimeter

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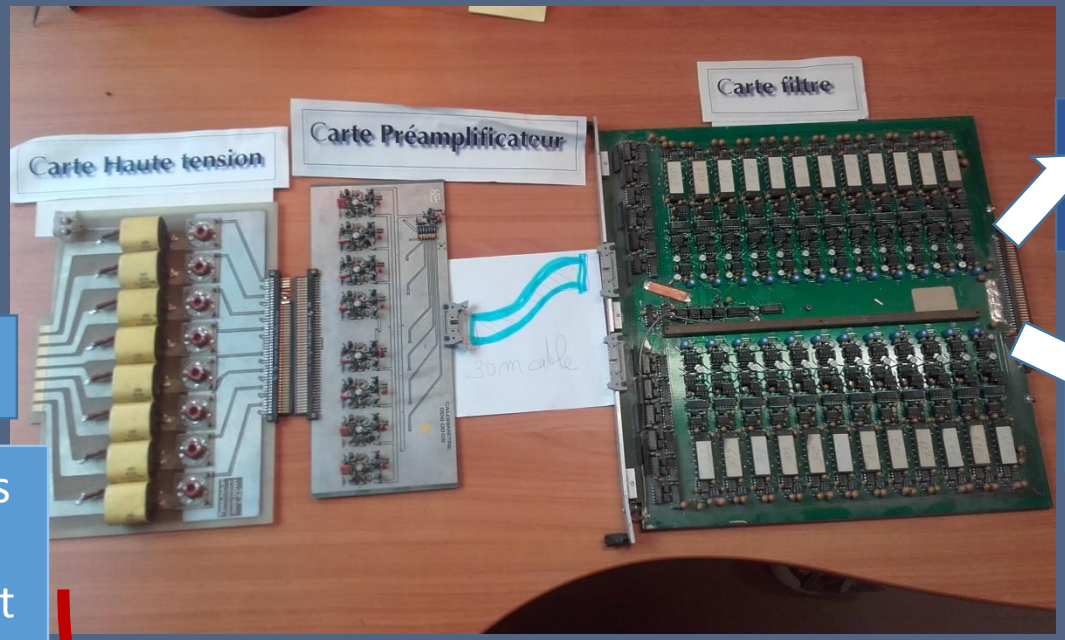
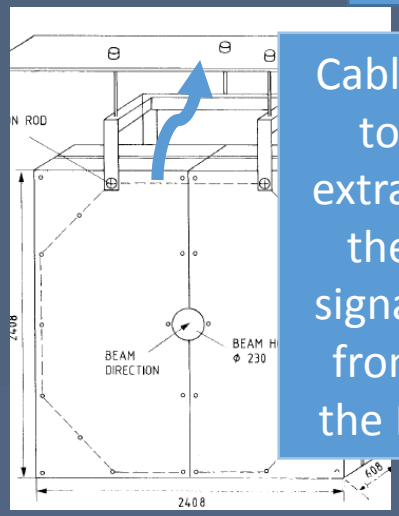


FT



Cables to extract the signals from the FT

Orsay (Bob Chase et al)

Italo's contributions : the Neutral Hodoscope

→ **Design of the detector** (with CERN and G.Kesseler).

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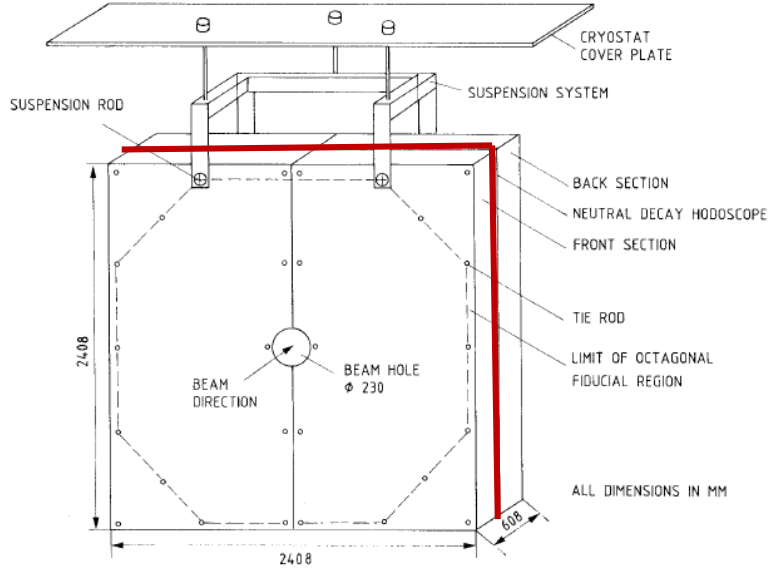
→ **PeakFinder** (hardware trigger with Galeotti) to identify energy peaks in the calorimeter

→**Neutral Hodoscope** (with Pisa people) between Front and Back parts).



Left –right coincidence required

Italo's contributions : the KL Anticounters

→ **Design of the detector** (with CERN and G.Kesseler).

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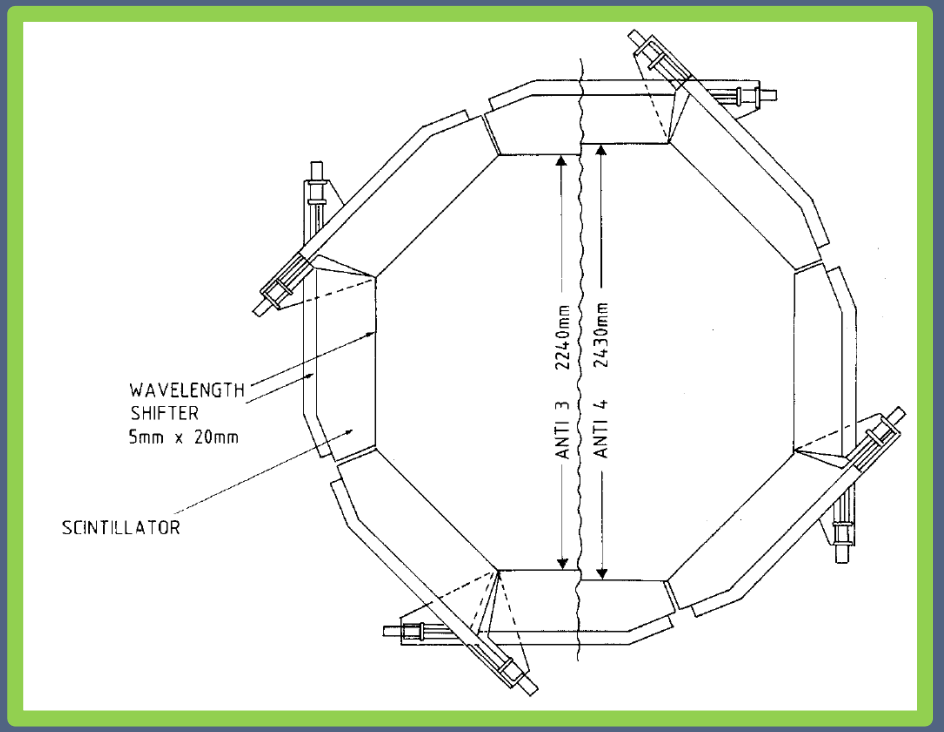
→ **PeakFinder** (hardware trigger with Galeotti) to identify energy peaks in the calorimeter

→**Neutral Hodoscope** (with Pisa people) between Front and Back parts).

→ **Anticounters** (with Pisa people)

→ **Tests on neutral reconstruction** (with Roberto Casali)



Italo's contributions: The Overlay method

Particles accompanying the beam, recorded during an event acquisition.

Can cause gain or loss of a good event

Different in K_S and K_L !!!!

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1) Record random triggers=f(I)
2) Overlay them to the data
3) Each event on tape as : original, random, overlayed.

With N.Doble

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Effect on K_L events

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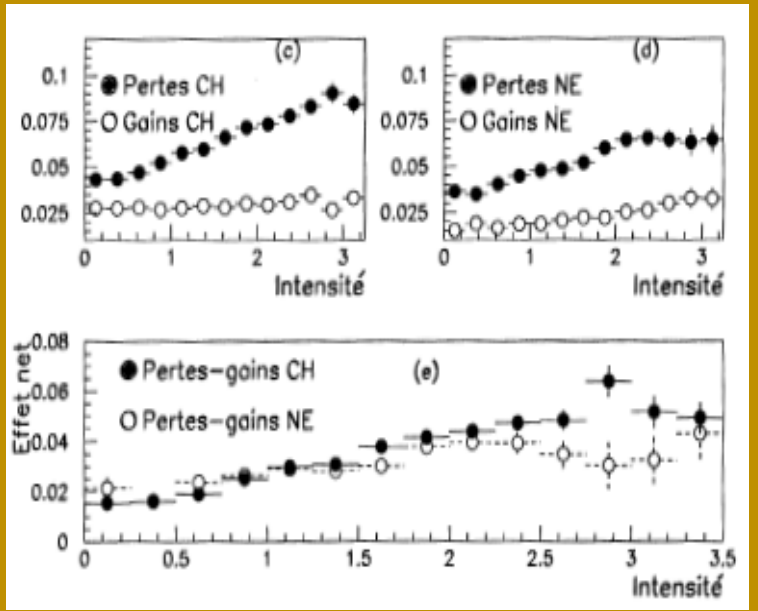

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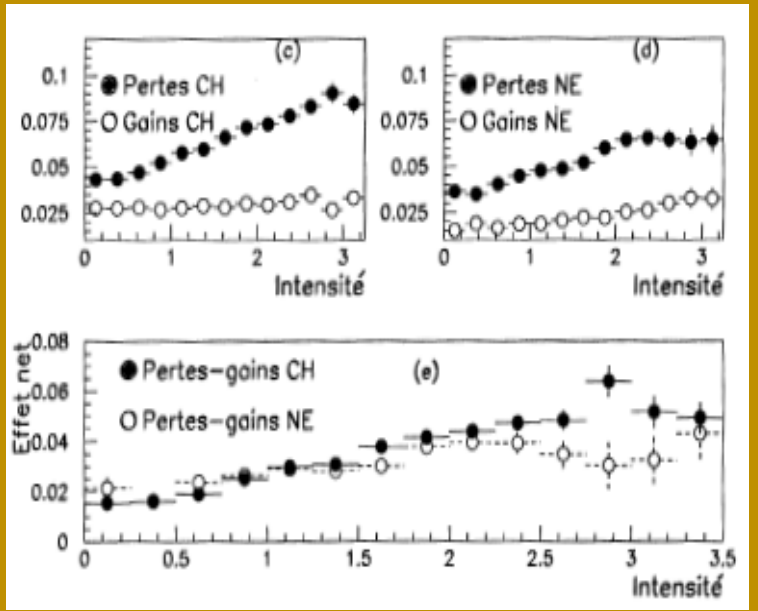

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Difficult technically. Work with Carosi, Calafiura, Augé. Since, a variant of this pionnering work is used to take into account of the accidental activity (NA48, ATLAS, CMS..)

NA31 Direct CPV results

55 authors, 7 labs

FIRST EVIDENCE FOR DIRECT *CP* VIOLATION

CERN–Dortmund–Edinburgh–Mainz–Orsay–Pisa–Siegen Collaboration

H. BURKHARDT [1], P. CLARKE, D. COWARD [2,3], D. CUNDY, N. DOBLE, L. GATIGNON, V. GIBSON, R. HAGELBERG, G. KESSELER, J. VAN DER LANS, I. MANNELLI [4], T. MICZAIKA [5], A.C. SCHAFFER [6], J. STEINBERGER, H. TAUREG, H. WAHL, C. YOUNGMAN[7]
CERN, CH-1211 Geneva 23, Switzerland

G. DIETRICH, W. HEINEN [8]
Institut für Physik, Universität Dortmund, D-4600 Dortmund 50, Fed. Rep. Germany [9]

R. BLACK, D.J. CANDLIN, J. MUIR, K.J. PEACH, B. PIJLGROMS [10], I.P. SHIPSEY [11], W. STEPHENSON
Physics Department, University of Edinburgh, Edinburgh EH9 3JZ, UK

H. BLÜMER, M. KASEMANN, K. KLEINKNECHT, B. PANZER, B. RENK
Institut für Physik, Universität Mainz, D-6500 Mainz, Fed. Rep. Germany [9]

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A. BIGI, M. CALVETTI [13], R. CAROSI, R. CASALI, C. CERRI, G. GARGANI, E. MASSA, A. NAPPI, G.M. PIERAZZINI
Dipartimento di Fisica e Sezione INFN, I-56100 Pisa, Italy

C. BECKER [5], D. HEYLAND [5], M. HOLDER, G. QUAST, M. ROST, W. WEIHS and G. ZECH
Fachbereich Physik, Universität Siegen, D-5900 Siegen 21, Fed. Rep. Germany [14]

Received 31 March 1988

1988

Re(ε'/ε)=(3.30+-1.09)10^{-3}

Combined NA31 : (23.0+6.5) 10^{-4} 3.5σ

49 authors, 6 labs

A new measurement of direct *CP* violation in the neutral kaon system

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1993

Re(ε'/ε)=(2.03+-0.67)10^{-3}

The next era

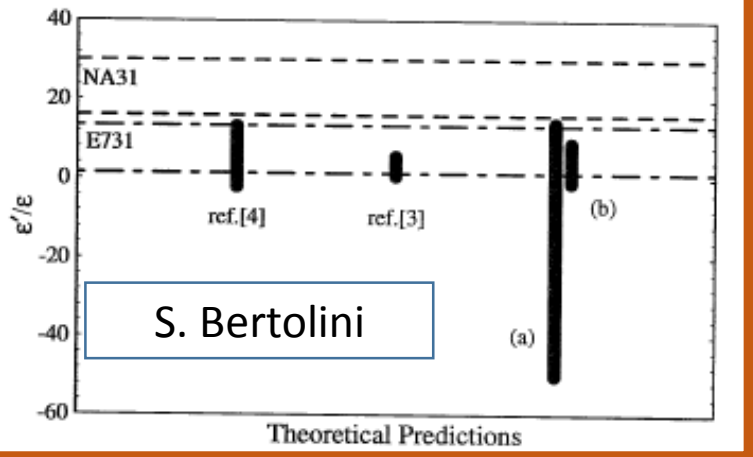
E731 Collaboration - FermiLab
L.K.Gibbons et al., Phys.Rev.Lett. 70 (1993) 1203.

Our final result is

$$\mathrm{Re}(\varepsilon'/\varepsilon) = [7.4 \pm 5.2(\mathrm{stat}) \pm 2.9(\mathrm{syst})] \times 10^{-4}.$$

The combined uncertainty is 5.9×10^{-4}. Compared to our previous publication [5], the statistical (systematic) error is a factor of 2.7 (2.1) smaller. Our value is not significantly different from zero. It implies $\mathrm{Re}(\varepsilon'/\varepsilon) < 17 \times 10^{-4}$ (95% confidence), which does not support earlier evidence [4] for a large $\mathrm{Re}(\varepsilon'/\varepsilon)$.

Most theory schools favoured
➔The « very small ε'/ε» region



Kaon Physics Orsay 1996

More precise experiments, capable to achieve a precision of few 10-4 have been designed to challenge the tension:
KTeV and NA48 (see Marios+Guillaume's talk)

Souvenirs with Italo

→Continiusly trying to improve the trigger (to resist : « the Anti-Mannelli Panelli »)

→Full of rich and diverse ideas

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- His role was determinant into the epsilonPrime saga
- He did the announcement of the first result in the LP1987
- NA31+Wahl : EPS 2005
- Italo: 2007 Panofski Prize


Happy
Birthday!

BACKUP

The zero suppression

To save space on disk/tape, only the ADC above a certain threshold (~70 MeV) were readout together with 2 more channels on the left and right to collect all energy.
After the first run it was realized that some energy was lost in the case where the energy in the back (readout independently from the front) was small and no strip passed the readout threshold. To avoid this a hardwired connection was added from each strip in the front to its counterpart in the back(at the level of the ADC crate) in such a way that every strip readout in the front triggered the readout of its counterpart in the back(and vice versa). Internal note by RDS.

Sources of systematics on double Ration R

Source	Correction (%)	Systematic uncertainty (%)
Background to $K_L \to 2\pi^0$	2.67	0.13
Background to $K_L \to \pi^+\pi^-$	0.63	0.10
Accidental activity	0.16	0.14
Energy scale calibration and stability		0.13
Trigger and K_S anti-counter inefficiencies	0.51	0.09
Monte Carlo acceptance	0.14	0.10
Wire chamber inefficiency		0.10
Total systematic uncertainty		0.30

Reconstruction of $\pi^0\pi^0$ in a nutshell

Only four clusters in LAC

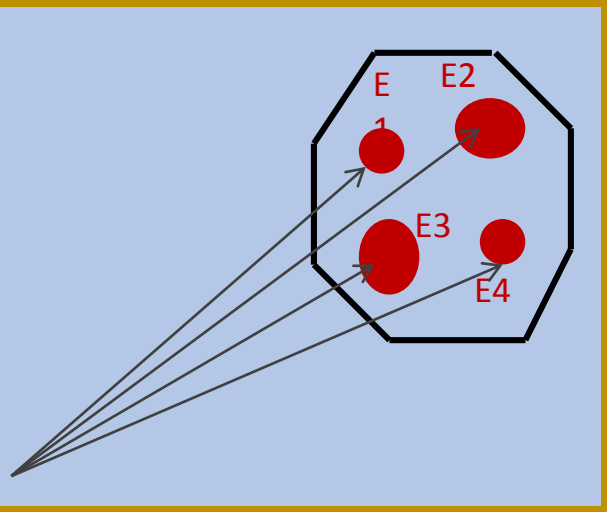
$$Z_{K^0} = Z_{LAC} - \frac{1}{M_{K^0}} \times \sqrt{\sum_{i=1,j>i}^{4} E_i \times E_j \times [(x_i - x_j)^2 + (y_i - y_j)^2]}$$

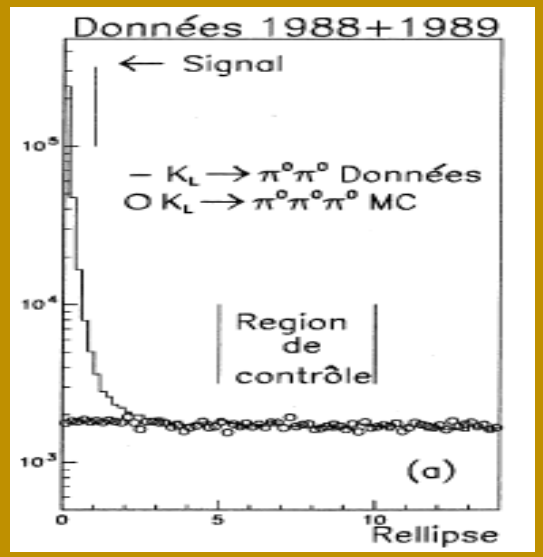
$$M_{\gamma_i\gamma_j} = \frac{1}{Z_{K^0}} \times \sqrt{E_i \times E_j \times [(x_i - x_j)^2 + (y_i - y_j)^2]}$$

Use a χ^2 to test event compatibility with a $2\pi^0$-decay

$$R_{ellipse} = \left(\frac{m_{\pi_1^0} - m_{\pi_2^0}}{S\sigma_1(E_{\gamma_{min}})}\right)^2 + \left(\frac{m_{\pi_1^0} + m_{\pi_2^0} - 2 \times M_{\pi^0}}{S\sigma_2(E_{\gamma_{min}})}\right)^2$$

$3\pi^0$ background with fused or lost photons appear at the tail of the Rell distribution





Reconstruction of $\pi^+\pi^-$ in a nutshell

→Charged tracks from the 2 WC

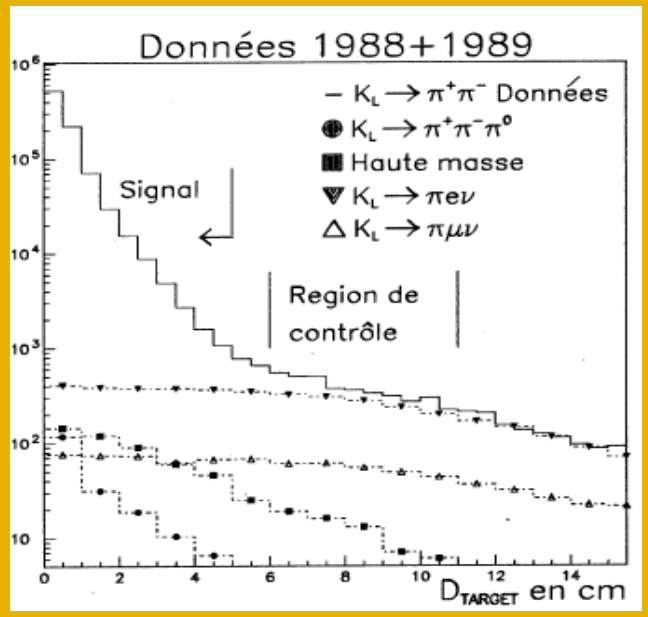
→ E1 and E2 energies from LAC +HAC

$$E_{K^0} = \frac{1}{\vartheta} \times \sqrt{(M_{K^0}^2 - m_\pi^2 \times T) \times T)}$$

$$T = 2 + \frac{E_1}{E_2} + \frac{E_2}{E_1}$$

$$M^2_K = \vartheta^2 (E1+E2)^2/T + M^2_\pi T$$

Require NO accoplanarity



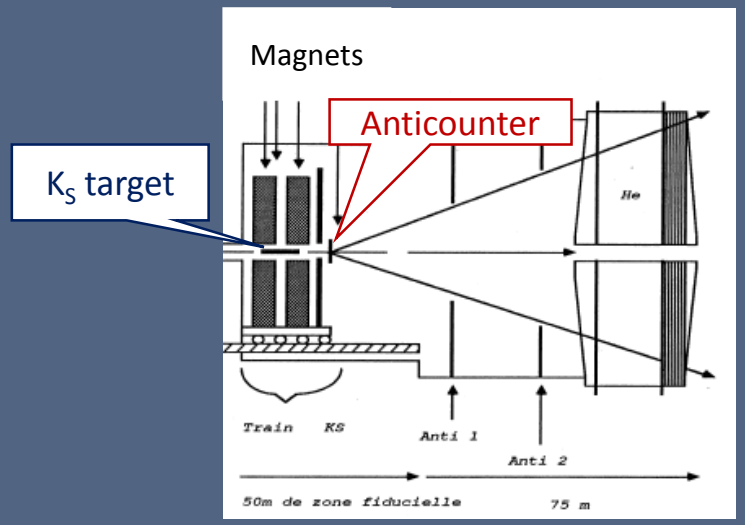
➔ Reject $\pi\mu\nu$: muon vetoes
➔Reject $\pi e\nu$: looking at LAC1/HAC
➔Reject $\pi^+\pi^-\pi^0$: no close photon

Checked from 1988 on with the Transition Radiation Detector

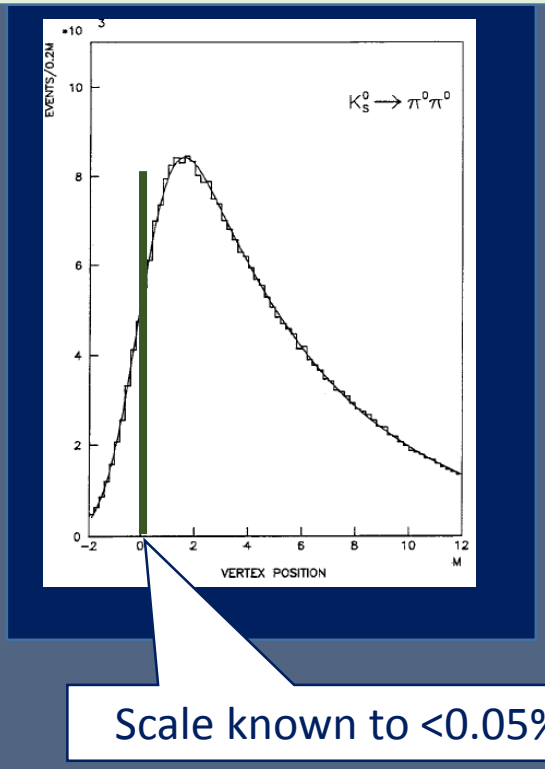
The Energy Scale determination

$$Z_{K^0} = Z_{LAC} - \frac{1}{M_{K^0}} \times \sqrt{\sum_{i=1,j>i}^{4} E_i \times E_j \times [(x_i - x_j)^2 + (y_i - y_j)^2]}$$

Energy Scale = Distance Scale



Anticounter's main goal:
Veto early K_S decays
Used also as a distance scale



Scale known to <0.05%

The NA31 way

Alternate K_S and K_L beams in the same detector

Detect concurently charged and neutral

3-level trigger system to select 2π and reject 3body events.
Synchronous part : Counters, Energy, Hits
Asynchronous part: Energy, CoG, calo shower , acoplanarity
Single rates ~10^5 , pretrigger 10KHz, write on tape 1000events/burst

Date read via FASTBUS into a dual 168E array
DAQ controled by a VAX11/750

$\pi^0\pi^0$: High energy and position precision LAr calorimetry

$\pi^+\pi^-$: No magnet. Two drift chambers with 4 wire planes each.

Make K_S spectra similar to K_L

Reduce acceptance corrections