Low-Energy Kaon-Nucleus Interactions at a ϕ–Factory

Paolo M. Gensini*, **Univ. di Perugia e Sez. I.N.F.N. di Perugia,**

Giulia Pancheri, Lab. Naz. I.N.F.N. di Frascati,

Yogendra N. Srivastava, Univ. di Perugia e Sez. I.N.F.N. di Perugia,

Galileo Violini, Univ. della Calabria e Lab. Naz. I.N.F.N. di Frascati – Gr. Coll. di Cosenza

***) speaker at the meeting**

"Meeting on $e^+ e^-$ Physics Perspectives (non-K-decays)" at LNF, Frascati, 20 January 2006

List of contents

1. A little piece of history.

The season of systematic investigations of kaon - nucleon interactions suffered an abrupt ending around 1980, with the closing down of most of the machines and of the beam lines dedicated to this branch of hadronic physics.

Despite many valiant efforts to resurrect the field (the European Hadron Facility and KAON at TRIUMF, just to name but the bravest), the few remaining kaon beam lines have been barely sufficient to keep hypernuclear physics alive.

So many of the statements on the successes of flavour SU(3) - just to mention one single case in the physics of the Standard Model - so abundant in particle physics textbooks are in reality based on a handful of old, low-statistics, low-resolution experiments, that nobody would even think today of proposing to a selecting committee.

Of course kaons have problems not presented by pions (whose beams have indeed continued to be in - relative - availability), but the physics to be performed with them can not be replaced by anything else.

It is enough to mention that, while $G_{\pi NN}^2$ is known to a few percent, uncertainties on $G_{KN\Lambda}^2$ and $G_{KN\Sigma}^2$ are at the levels, respectively, of about ten and thirty percent, not to speak of pion-hyperon couplings, where *standard dispersive techniques* yield errors of order 100%!

Also, a cursory glance at the PDG tables shows that there are a lot of "missing" Λ and Σ states (not to mention the even more missing Ξ's and Ω's), which only an accurate PWA can uncover, given data of quality comparable to that of the πN ones.

Recently, even the nature of the Λ(1405) – a four-star state according to PDG – has been questioned on the basis of (admittedly low-statistics) data from the Crystal Ball.

Λ(1405)

Hemingway, NPB 253 (1985) 742

(data shown in next slide)

Prakhov *et al*, PRC 70 (2004) 034605

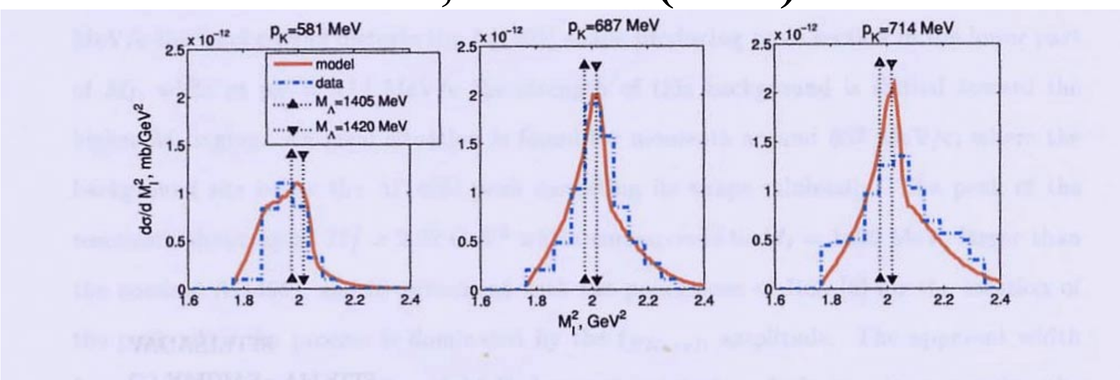
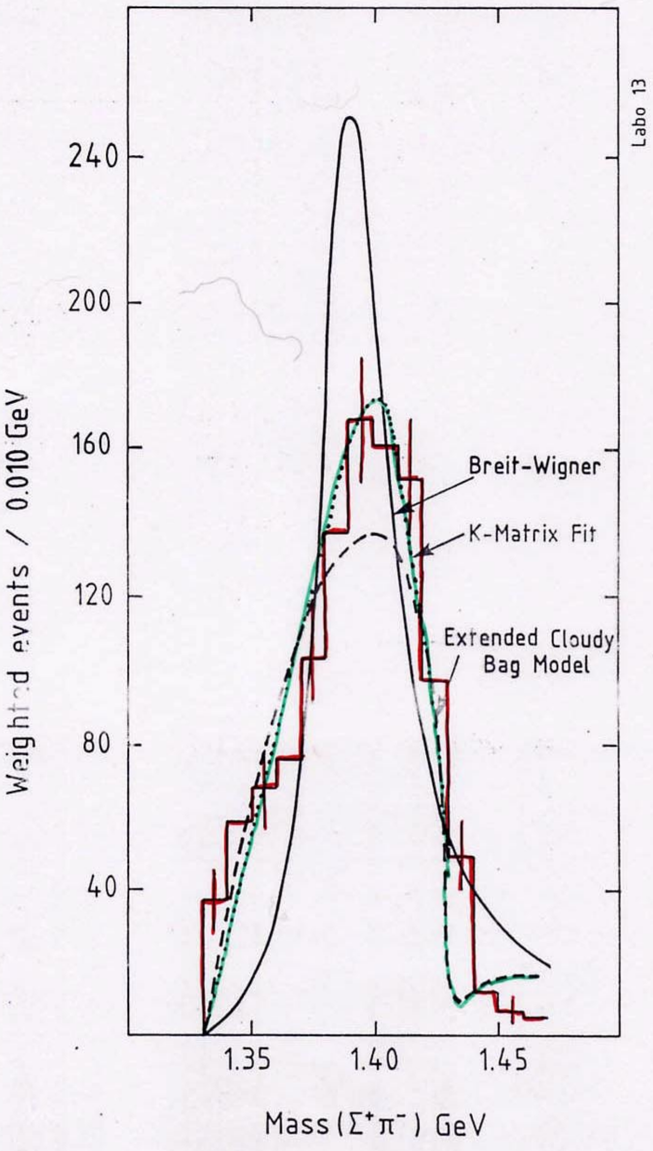


Figure 2: The $(\pi^0\Sigma^0)$ invariant mass distribution for three different initial kaon momenta.

Hemingway 1985

10-14

The Λ(1405) profile



NB: $\Sigma^{\pm}\pi^{\mp}$ only

Fig. 4

2. A "source" of kaons rather than a beam?

DAΦNE:

@ $L = 5 \times 10^{32}\ cm^{-2}\ s^{-1}$

1.2×10^{3} K^{-}/s @ 126.9 MeV/c ($\Delta p/p \sim 1.1 \times 10^{-2}$)

850 K_L/s @ 110.1 MeV/c ($\Delta p/p \sim 1.5 \times 10^{-2}$)

Pions (and leptons) can be eliminated by collinearity and momentum cuts (even at the trigger level).

So DAΦNE is a source of low-momentum kaons that though not able to compete in intensity with hadron machines has the advantage of the extreme cleanliness of the produced particles over these latter.

That a clean source of kaons is definitely an advantage for low-energy physics has been fully demonstrated by the success of DEAR.

Clearly the energy limitation of ϕ-factories (kaons can be slowed down but not accelerated in the detectors) makes them complementary to beam - target experiments, where kaons have to be transported from the primary target to the apparata, and have to be energetic enough in order to survive the trip, however short.

One can perform and analyse scattering and production experiments with a source at the cost of a little more trouble, e.g. using

$$dN_r = (3/8\pi)\rho^{-2}\,[L\,\sigma_\phi\,B_\phi]\,(e^{-\rho/\lambda}\sin^2\theta)$$
$$(\sigma_r\,\rho_t)\,\rho^2\sin\theta\,d\rho\,d\theta\,d\phi\,,$$

namely going spherical instead of planar as in a conventional fixed-target geometry.

Of course the target has to surround the source, covering most of the 4π sterads, but we have already a (gigantic, on the scale we need, by at least a factor of 3) detector of such a kind in KLOE.

K^-p final states in H_2 gas @ 1 atm:

-> K^-p	**3.6×10^6**	**events/year**
-> K^0p	**$\sim 10^6$**	**events/year**
-> $\pi^+\Sigma^-$	**2.4×10^6**	**events/year**
-> $\pi^0\Sigma^0$	**$\sim 10^6$**	**events/year**
-> $\pi^-\Sigma^+$	**$\sim 10^6$**	**events/year**
-> $\pi^0\Lambda$	**$\sim 10^6$**	**events/year**
-> $\pi\pi\Lambda$	**$\sim 10^5$**	**events/year**
-> $\gamma(\Lambda,\Sigma^0)$	**$\sim 10^4$**	**events/year**

More or less the same rates *for the protons* in ^{4}He, *plus* those *on the neutrons, minus absorption, plus nuclear distortions.*

3. A “minimalist” proposal for “new” physics at KLOE.

a) A less restrictive trigger in the existing apparatus, accepting K^+, K^- and K_L interactions in the gas of the wire chamber.

b) (Off-line) reconstruction of all πY, $\pi\pi Y$, γY ($Y = \Lambda, \Sigma$) spectra, including “exotic” charge combinations.

This would allow the study of:
–> $\Lambda(1405)$, $\Sigma(1385)$ (and interferences)
-> Radiative captures
➔ Nuclear effects

4. Further perspectives (a “letter to Santa”).

A “dedicated” detector for scattering and production experiments with gaseous “targets” would look very much like a “scaled-down” copy of KLOE, and it would thus be realisable at a cost much less than that of KLOE: breaking the total cost of KLOE into

$$C_K = C_0 + C_1 + C_2 + C_3 \quad ,$$

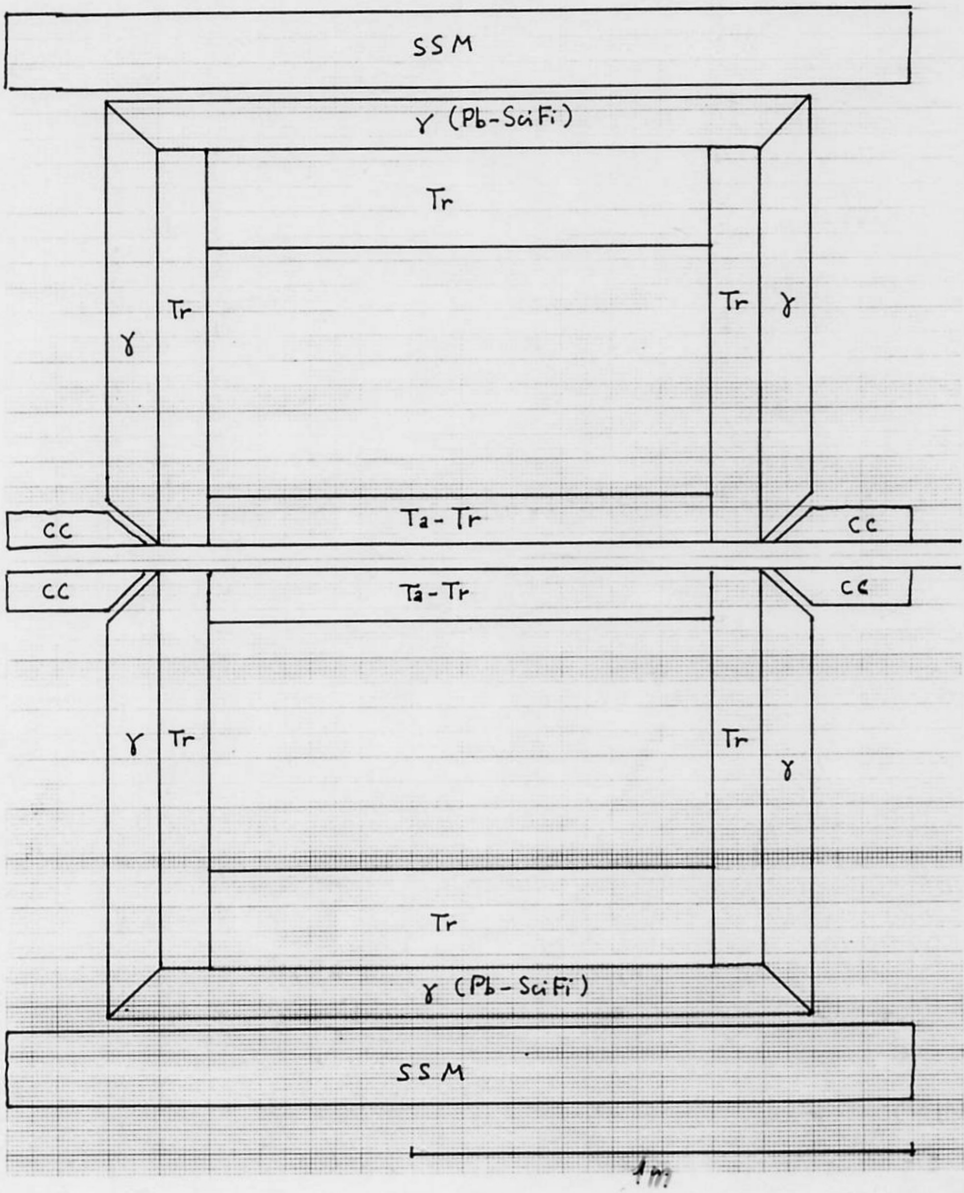
one gets, scaling down by 1/3 (decays make a bigger detector useless),

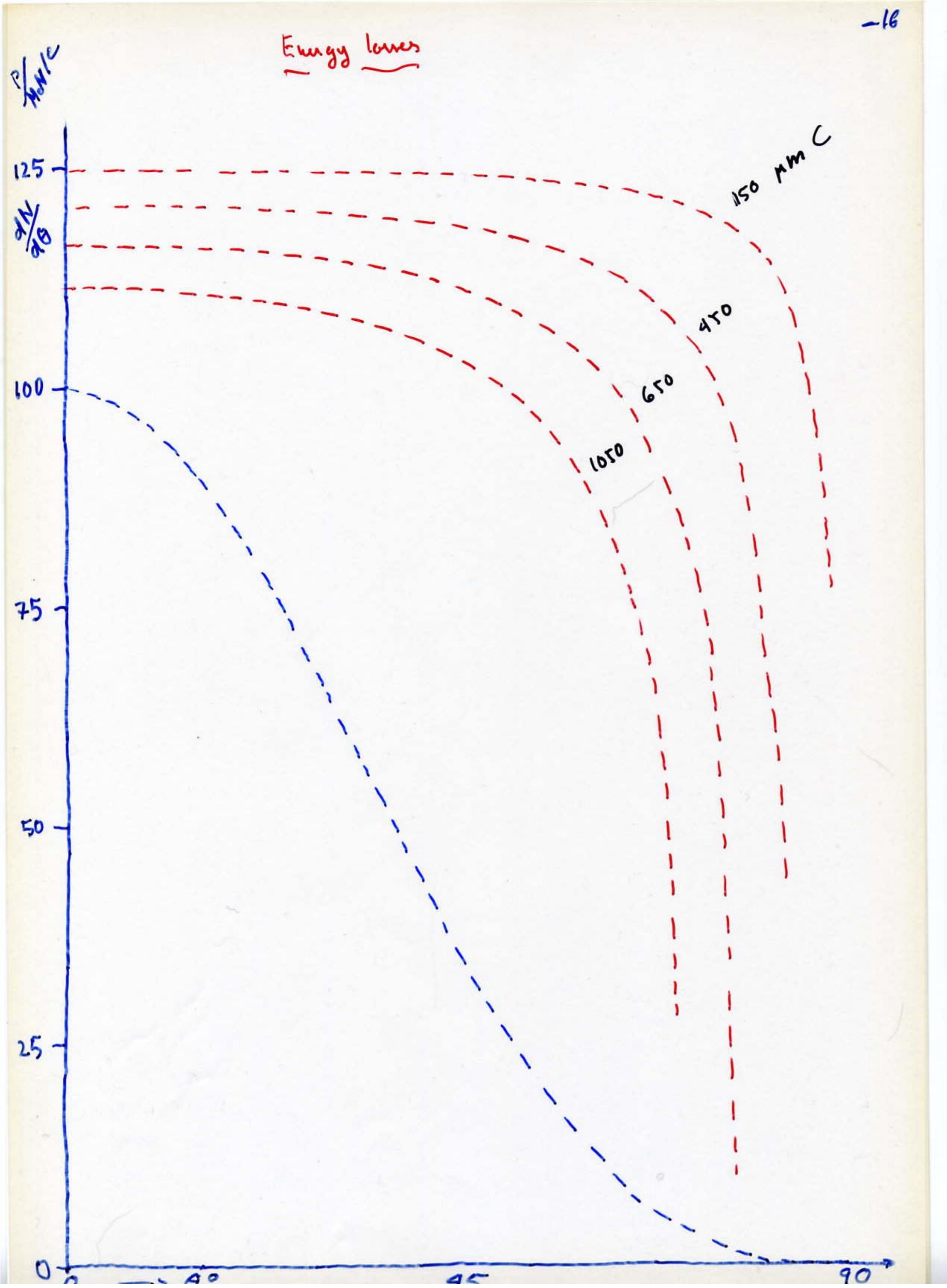
$$C' = C_0 + C_1/3 + C_2/9 + C_3/27 \, ,$$

with an evident reduction of *at least* one order of magnitude (C_2 is the dominant term).

Next two slides show a cartoon of a typical “KLOE/3” detector (without a wire chamber to work with all *pure* gases) and a calculation on the “moderation” to be expected on charged kaons by small layers of material (carbon fiber was what we had in mind – red curves – the lower curve is to show the angular distribution of produced kaons – the angle is measured with respect to the perpendicular to the beam direction)

Tg = tagging
Tr = tracking
γ = e.m. calorimetry





Energy losses
-16
p/MeV/c
dN/dθ
125
100
75
50
25
0
150 μm C
450
650
1050
45
90