CERN/PSCC/86-48
PSCC/M269

3 November, 1986



# STATUS REPORT AND REQUEST FOR FURTHER BEAM TIME PS 175

October 29, 1986

With this letter we would like to request more beam time for our experiment.



Reasons:

A Our experiment is well capable of measuring the strong interaction parameters in the protonium atom with high precision.

B External circumstances allowed us to get neither the beam intensity, nor the beam quality nor the beam momentum we requested.

A In the last two years it was demonstrated by our group, that a good understanding of the cascade process (i.e. the formation and deexcitation process) of the protonium could be reached. We were able to measure the $\bar{p}H$ ($\bar{p}D$) L-x-rays over a broad pressure range (16 - 300 mbar) (Fig. 1), and extracted absolute yields with a novel calibration method (Fig. 2). The measured values are well reproduced by the cascade code of Bethe-Borie-Leon with the product $k\sqrt{T} = 2$ (Fig. 3). T is the kinetic energy of the protonium atom in eV, k is a parameter multiplying all Stark mixing rates. From Fig. 3 it is clear, that measurements of the 2p→1s transition should be done at pressures below 10 mbar. This requires the use of our cyclotron trap at beam momenta as low as possible. Only then can three preconditions for a precision experiment be achieved.

1. Saturation of the $K_\alpha$-transition.
2. Concentrated stop distribution even at lowest pressures.
3. The use of high resolution detectors which are able to measure shift and width with eV precision. Under special conditions it is possible even to distinguish hyperfine levels of the ground state.

The measurement of the K-x-rays yields a shift and a width of the 1s level which are still too imprecise to be of value for distinguishing different potential models.

Concerning the technical aspect of decelerating antiprotons in the cyclotron trap, computer simulation shows that more than 70 % of the incoming particles can be stopped in the center at pressures even below 10 mbar, provided the beam momentum is less than about 105 MeV/c. For this beam momentum it should also be possible to match the beam emittance to the admittance band of our trap.

With the same computer simulation a stopping efficiency of 30 % at 30 mbar with 202 MeV/c particles was predicted, which agrees well with the measured value (33 ± 3)%. The detector systems which can be used are two Si(Li)-guard-ring reject detectors with an overall efficiency of $10^{-4}$ in the energy region of interest. Furthermore a detector with four crystals with an overall efficiency of $2 \times 10^{-3}$ will be used. The peak/background ratio of these devices will be a factor of 3 - 4 better than the single crystal detector which had to be used during our last run. An x-ray drift chamber will be used in addition.

With our detector systems, we can stand a stop rate of up to $1.5 \times 10^5$/s. With an assumed yield of the $K\alpha$-line of $8 \times 10^{-3}$ at 10 mbar (extrapolated from the measured value of $4.9 \times 10^{-3}$ at 30 mbar) and an efficiency between $10^{-4}$ and $10^{-3}$ we expect 0.1 - 1 $K_\alpha$ x-rays/c. This requires a total of 6 days for setting up the detector necessary checks and calibrations of the detector systems and the measurement. In addition setting up the beam, optimization and diagnosis of the deceleration process together with the measurement of the stop distribution requires 4 days at minimum.

Thus we believe that at least 2 weeks of measuring time will be necessary to fulfill our proposal. One week in addition as reserve would be ideal.

**B** During the two run periods in 1985 and 1986, we had to work under the following circumstances:

**1985**

We applied for beam intensities between $1 \times 10^5$ and $1.5 \times 10^5$/s, and requested an equal distribution of the intensity between the users. In spite of a request of the PS 182 group to use the central beam line, it turned out not to be possible to send a 202 MeV/c beam to this group. It was the decision of the coordinator over our protest to divide the intensity between the north and the south beam in the relation 80/20. This resulted in an intensity in the north beam which yielded rates greater than $3 \times 10^5 \bar{p}$/s, which paralyzed our bigger detector.

Because of a breakdown of the accelerator complex caused by a thunderstorm, we had only a total of 51 spills, which allowed us to measure the L x-rays very well with our small detectors, but did not permit measuring K x-rays. Unfortunately, our remaining quote of beam time was decreased dramatically due to the high sharing rates.

**1986**

From our experience in 1985, we applied to a beam momentum of 105 MeV/c. We also requested, to place our apparatur nearer to the last quadrupole in order to better match the beam emittance ellipse to our admittance band. Both requests were refused by the committee. Our protest to this decision was answered by the remark that the flux of antiprotons we needed could only be guaranteed with 202 MeV/c antiprotons with the injection scheme which worked well in 1985.

It also seemed to us that an experiment at the desired rate of about $1.5 \times 10^5$ incoming antiprotons for about two weeks would be sufficient to observe the $K_\alpha$ transition and begin with a precision spectroscopy. Therefore, it was disappointing that it required about two days until the beam line was set up. Then we got only an average of $3 \times 10^4$ incoming antiprotons/s. This rate allowed us only to measure the pressure dependence of the L-x-rays in that period. The number of antiprotons of $3 \times 10^4$ compares unfavorably with a number of $6 \times 10^4$/s at a beam momentum of 105 MeV/c in the north branch in the following period. It is a curious coincidence that there was a 105 MeV/c momentum directly before and after our beam period.

The second part of our experiment was shortened compared to the originally scheduled time. It required only about 6 hours to set up the beam, but the resulting number of incoming antiprotons was still a factor of 3 smaller than anticipated. Setting up the cyclotron trap and the detection system was completed in less than 20 hours, but at the moment we began with the hydrogen measurement, a thunderstorm stopped data-taking for 2 days. The remaining time of about 30 hours was then devoted to the K-transition search. This turned out to be successfull; we obtained a 6 standard deviation signal. This signal is on a huge background because we had to measure with a conventional but big Si(Li)-detector because of lack of time (Fig. 4). All in all, we received only a third of the number of antiprotons scheduled for 1986.

## Conclusions

We would like to summarize why a beam momentum of about 100 MeV/c in addition to the possibility of using the quality of the beam parameters fully leads to major improvements.

1. By positioning our apparatur nearer to the last quadrupole, we can decrease the radial extension of the defining scintillator inside our trap from 10 to 3 mm. This makes a much smoother injection possible with a stop distribution correspondingly narrower.

2. The use of antiprotons with momenta of 105 MeV/c compared to 209 MeV/c will result in a momentum spread of the captured $\bar{p}$-beam of 0.5 % instead of 2.5 %. This improved resolution together with 1. makes a much more refined injection feasible. The radial spread in the first revolutions will be 5 mm rather than 25 mm. In addition, the excitation of axial betatron oscillations with an amplitude of about 10 mm will make an injection even at pressures well below 1 mbar feasible.

3. It will be no longer necessary to define the stopping time of antiprotons by detection of the annihilation products, which has an efficiency of only $\sim$ 50 %. Because of the small momentum spread, the stop time will be well correlated with the timing signal of the incoming antiprotons. Together with the higher stop efficiency, this will lead to factor of 4 - 5 improvement in x-ray intensity, per incoming antiproton.

4. The injection of particles with 105 MeV/c permits the field strength of our magnet to be lowered by 30 %. This facilitates the use of detectors nearer to the stop region.

Finally, we would like to summarize the parameters necessary for a successfull experiment:

1. beam momentum: 105 MeV/c or lower

2. beam emittances and momentum spread: $E_{H,V} \leq 20\ \pi$ mm mrad, $\Delta p/p \leq 10^{-3}$

3. free access to the last quadrupole

4. 3 weeks of beam with about $1 \times 10^5 \bar{p}/s$

As far as we know, we require beam quality ($E_{H,V}, \Delta p/p$) similar to that required by PS 185 (Kilian). We could share the same space of one beam line by putting our equipment on rails. Both groups are willing to use a flexible arrangement. We want to stress that the beam quality should be at least comparable with the M1 beam of previous runs.

For the PS175 group

L. Simons

## Figure Captions

### Figure 1

L-x-ray pattern at three different pressures normalized to the same number of stopped antiprotons.

### Figure 2

Calibration spectrum $\bar{p}N_2$. The fact is used that the yields of the transition lines are the same on the $10^{-2}$-level.

### Figure 3

Data points for the L-yields as a function of pressures and theoretical curves from the cascade code of Borie and Leon. P.R.A. 21 (1980) 1460.

### Figure 4

K-x-ray spectrum. The oxygen lines stam from a known water contamination. The background is flat and well-reproduced with a 4th order polynomial.

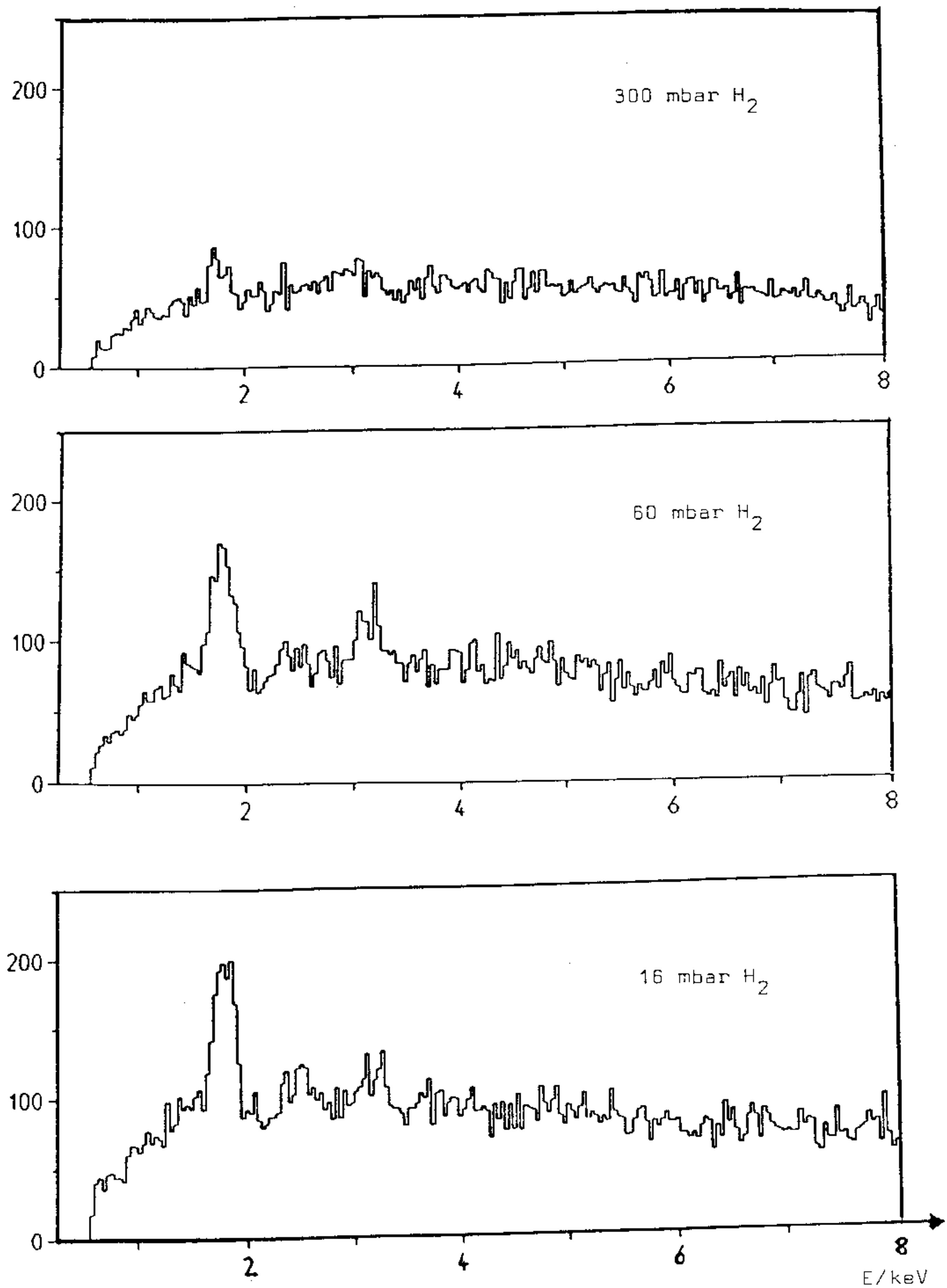
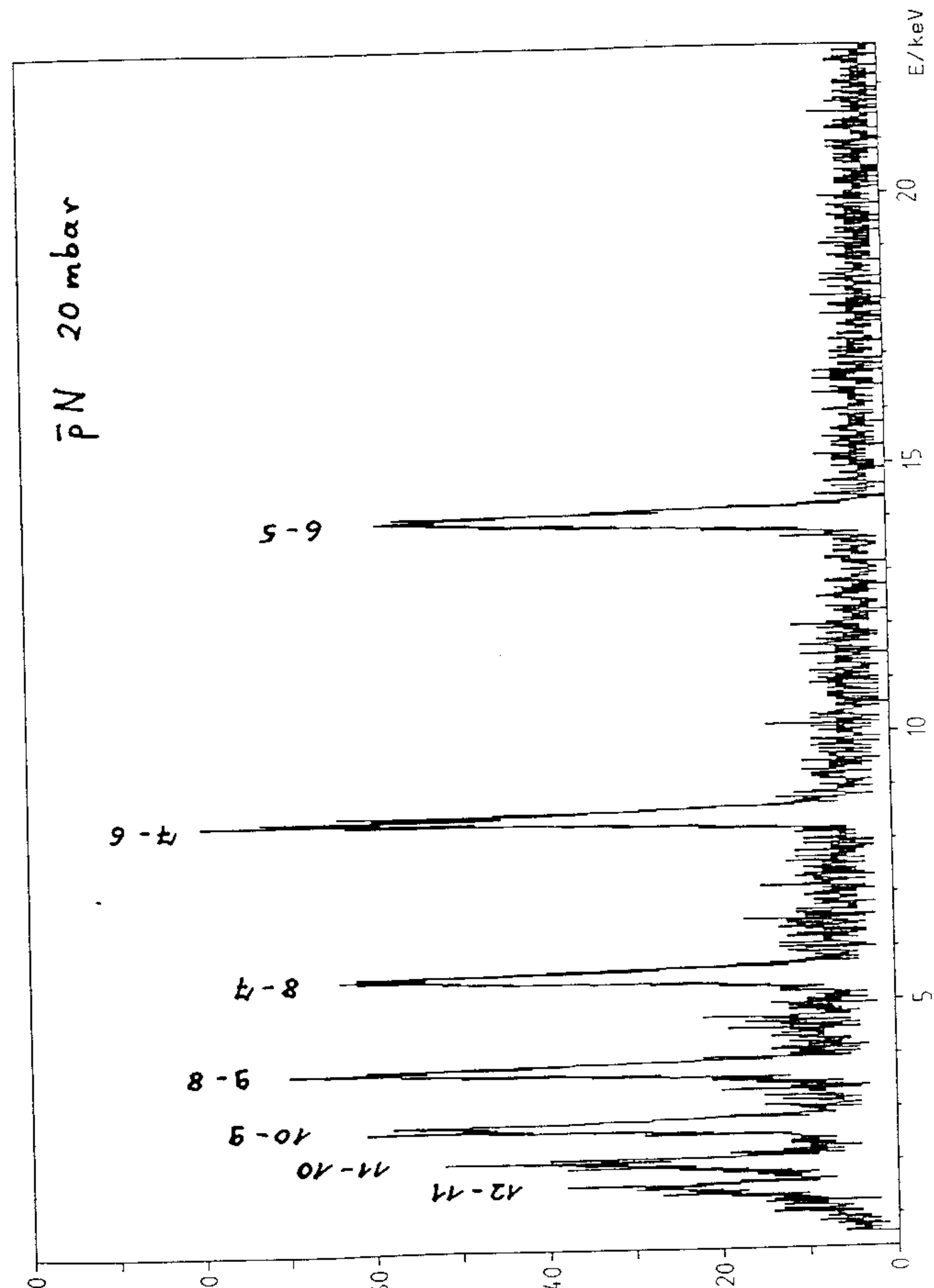



Fig. 1



p̄N 20 mbar
6-5
7-6
8-7
9-8
10-9
11-10
12-11
E/keV
0
5
10
15
20
20
40
60
80
100


Fig. 2

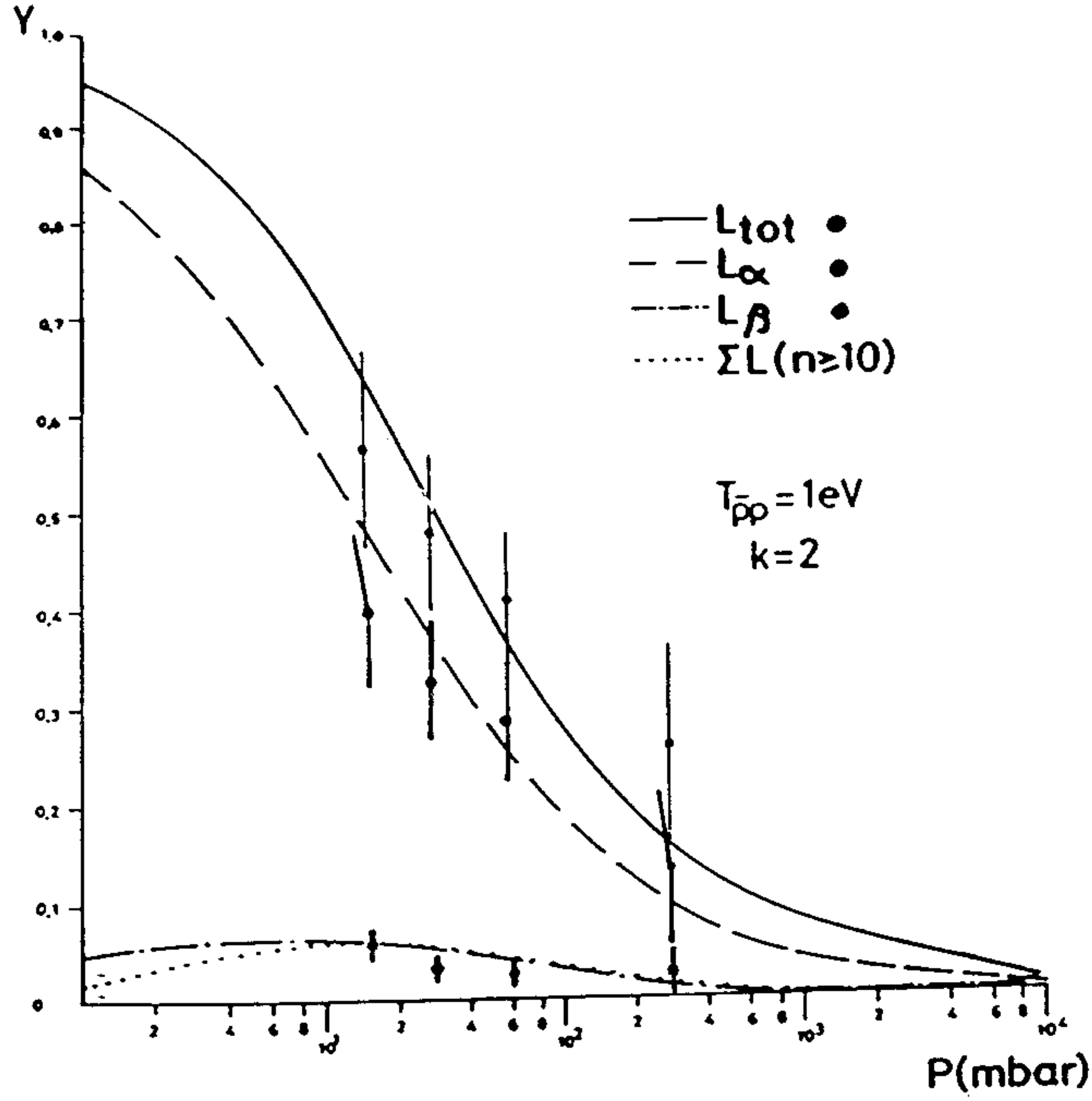
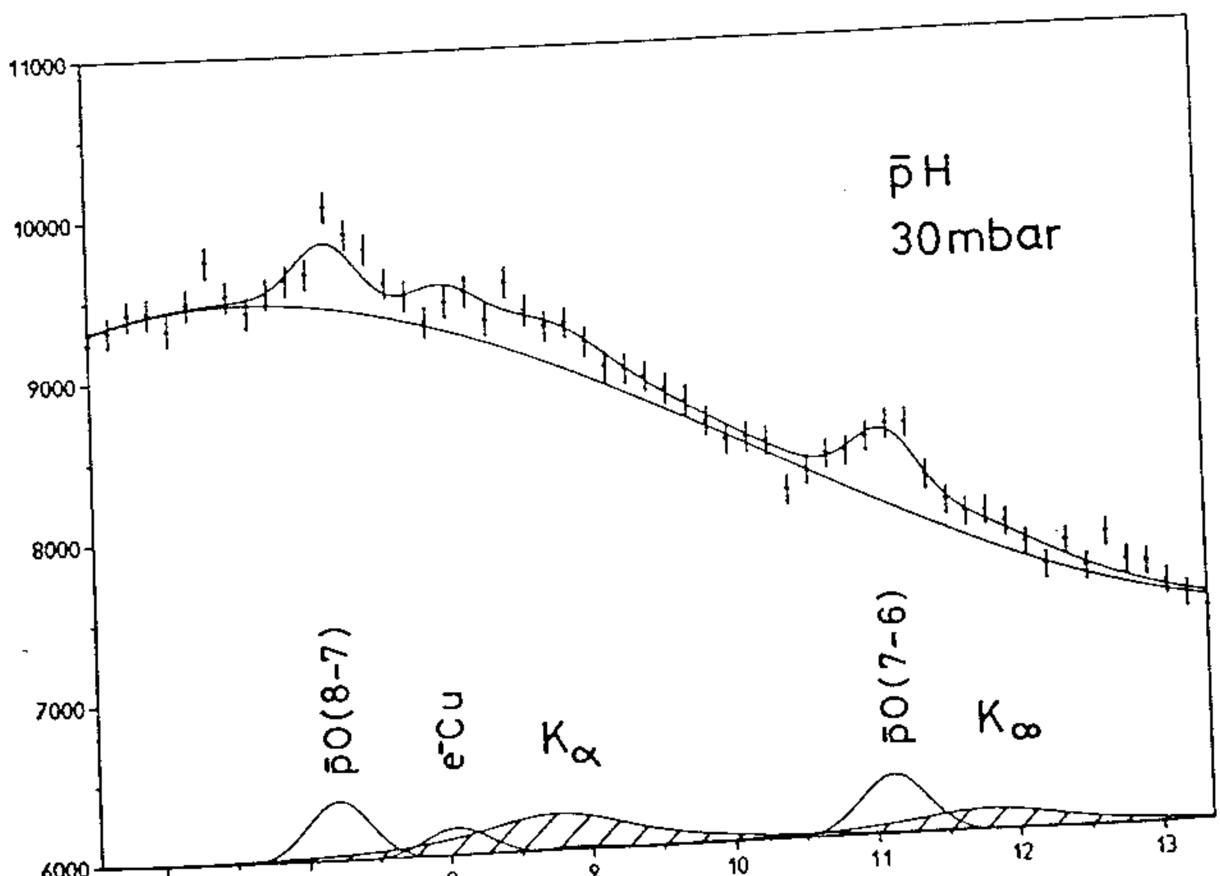



Fig. 3



p̄H
30mbar
p̄O(8-7)
e⁻Cu
Kα
p̄O(7-6)
K∞
11000
10000
9000
8000
7000
6000
6
7
8
9
10
11
12
13
E/keV


Fig. 4