PS/AR/NOTE 90-06

6 April 1990

DISTRIBUTION OF THE PARTICLES FROM THE ULTRA-SLOW EXTRACTION PROCESS AT LEAR

M. Chanel, C. Fernández-Figueroa, G. Molinari

ABSTRACT

This study examine the probability law of the particles arriving in a target owing to "the ultra-slow stochastic extraction process" at LEAR and conclude that the "Poisson distribution" is the more probable.

1. INTRODUCTION

We will study the "inter-arrival times of the particles" in a glass-scintillator as target. The signal (event), produced by a particle or a cluster of particles, is conducted to a photomultiplier tube and its response is analysed as shown in Fig. 1.1. The range of analysis is from 25 ns to 10 μs and the resolution per channel depends on the scale-conversion factor selected in the C.A.T. ADC module.

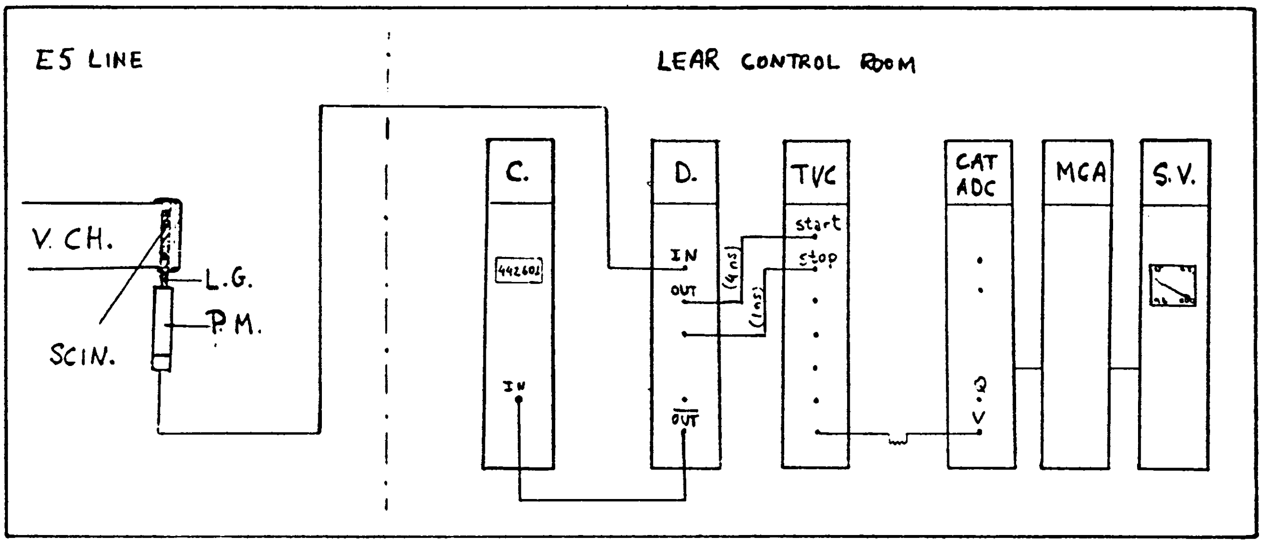
2. PHYSICAL PROCESS

The purpose of the "ultra-slow stochastic extraction process" is to furnish particles to the physical experiments during long spills, more than one hour.

Once the required momentum has been reached in the machine, the longitudinal distribution is made rectangular using a rf noise signal with a defined bandwidth applied to a harmonic of the revolution frequency. After this shaping is completed and the betatron tune and chromaticity adjustments have been performed, a second rf noise is swept into the coasting beam. The particles under the influence of this noise diffuse slowly onto the extraction resonance ($3Q = 7$), and are extracted using an electrostatic septum together with a magnetic septum. The power of this second noise signal and the speed at which it is displaced into the beam, control the rate of diffusion of the particles onto the resonance and thus the spill rate. In order to reduce the time modulation of the spill, due principally to power supply ripple, a third noise (chimney) is applied around the extraction resonance[1).

3. EXPERIMENTAL SET-UP

The setting of modules to analyse the "inter-arrival times" is showed in Fig. 1.



Legend : V.CH. - Vacuum Chamber
SCIN. - Scintillator
L.G. - Light Guide
P.M. - Photomultiplier tube
D. - Discriminator
C. - Counter
TVC - Time to Voltage Converter
CAT ADC - Charge, Amplitude and Time ADC
MCA - Multichannel Analyser
S.V. - Spectrum-Video

Fig. 1 - Signal acquisition

The detector is a "cerium-activated lithium silicate glass scintillator" (type NE901)[2] placed inside the vacuum chamber at the end of E5 line, at LEAR. The light signals are conducted from the scintillator to the "photomultiplier (PM) tube", placed as near as possible to the scintillator. The response of the PM tube is sent to the LEAR control room, where we have the counting device. A "discriminator" receives the signals and provides output signals to a "counter" and a "time-to-voltage converter" module (TVC). In this module the inter-arrival times are converted in amplitude signals, which are conducted to an "amplitude analog-to-digital converter" (CAT ADC), where the signals are digitalized. From here, these signals are analysed in a "multi-channel analyser", and displayed in a "spectrum-video" of 1024 channels.

The time calibration of the scale is made with a HP8116A P/F generator.

4. RESULTS

We present the results of two spills, the first one "protons at 309 MeV/c" and the second one "antiprotons at 200 MeV/c".

The spill I of protons was taken as described in the experimental set-up. The display obtained in the spectrum-video during 2215 s is shown in Fig. 2. The maximum time at full scale was 1 μs for 1024 channels.

The spill II of antiprotons was taken from the "CP Violation" experiment data, placing these signals in our discriminator. The spectrum obtained is shown in Fig. 3, for a collecting time of 3600 seconds, with 10 μs of full scale and 1024 channels.

In both cases we can observe the effect of "chimney" like a modulation over the base line of the inter-arrival times counting.

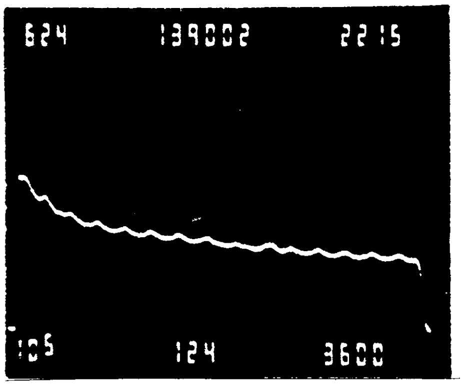
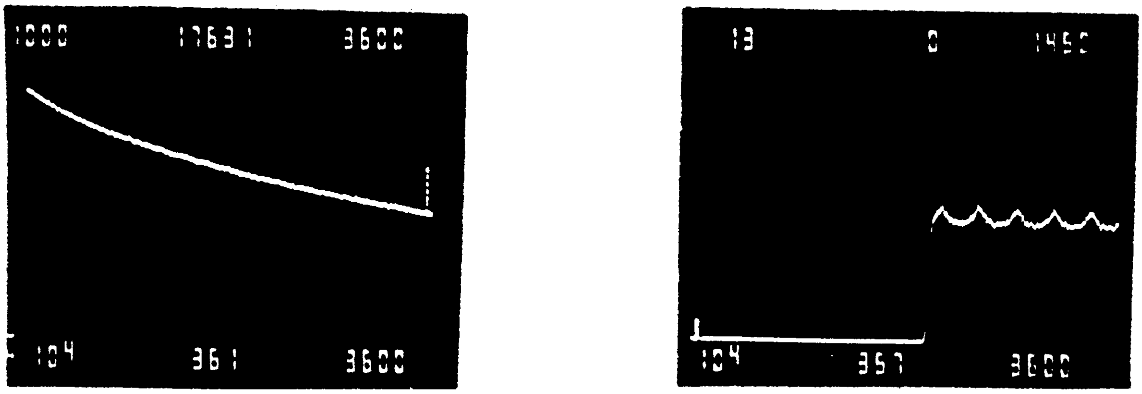


Fig. 2 - Display of the spill of protons at 309 MeV/c. Full scale 1 μs (1024 channels).



a) b)

Fig. 3 - a) Display of the spill of antiprotons at 200 MeV/c. Full scale 10 μs (1024 channels).
b) Detail of the "chimney noise" like a modulation around 12900 kHz.

5. FIT OF EXPERIMENTAL DATA

To analyse the results we have registered the counts of each channel, which previously has been calibrated with the frequency generator.

We have taken an exponential function to fit the experimental data, and we have obtained a good agreement with this hypothesis.

The exponential function is:

$$\phi(t) = N \exp(-\lambda t)$$

where N is the number of counts at first channel, λ is the rate of extraction (number of events per second), and the variable t is the time.

We have used the MINUIT routine implemented in the central VAX. The results are shown in Table I.

Table I: Fits of the experimental data with an exponential function.

	Spill I protons at 309 MeV/c		Spill II antiprotons at 200 MeV/c	
	Fit	Experiment	Fit	Experiment
λ	451370	From 250000 to 500000	66350	From 60000 to 70000
N	43081	39956	33698	31802
χ^2 (*)	5.02 (9)		2.79 (9)	

(*) Degrees of freedom

The probability, P, that on repeating the series of measurements, larger deviations from the expected values would be observed, is 0.80 for the spill I and 0.96 for the spill II. Interpreting the values of P, we may say that the assumed distribution very probably corre–sponds to the observed one.

6. DISCUSSION

With the preceeding results, we can consider the "inter-arrival times distribution of particles from LEAR" as an exponential distribution.

Now, we are going to search the distribution that the "extraction process" follows. At this point, it will be useful to know that a scintillator is a "non-paralyzable" counter[3)].

The ultra-slow extraction process studied as a probability process has the following properties:

a) The chance for a particle to be extracted in any particular time interval is the same for all particles in the beam (all particles identical).

b) The fact that a particle is extracted in a given time interval does not affect the chance that other particles may be extracted in the same interval (all particles independent).

c) The chance for a particle to be extracted during a given time interval is the same for all time intervals of equal size.

d) The total number of particles and the total number of equal time intervals are large (hence statistical averages significant).

These are the necessary and sufficient conditions under which the Poisson distribution is valid[4)].

Theorem: "If the inter-arrival times {Tn} are exponentially distributed with mean $1/\lambda$, then the renewal counting process $\{N(t), t>0\}$ is a Poisson process with an intensity λ".

The proof of this theorem is shown in Ref. 3. Here we are going to calculate the "probability density function $f(\tau)$" for our inter-arrival times process. It is known that $\Pr(\tau < t, t \leq \tau + d\tau) = f(\tau)d\tau$, and in our case will be:

$$\Pr(\tau < t) = \exp(-\lambda\tau)$$

$$\left.\begin{array}{r}\Pr(t \leq \tau + d\tau) = 1 - \exp(-\lambda\Delta\tau)\\ \textit{and when}\,\Delta\tau \to 0\end{array}\right\}\textit{then}\Pr(t \leq \tau + d\tau) = \lambda$$

in this way, we have the probability density function as:

$$f(\tau) = \lambda \exp(-\lambda\tau).$$

Now it is easy to calculate the mean:

$$\bar{\tau} = \int_{-\infty}^{+\infty} f(\tau)d\tau = \int_0^{+\infty} \lambda e^{-\lambda\tau} d\tau = 1/\lambda$$

$$\bar{\tau} = 1/\lambda$$

These results prove that the counting of events of the ultra-slow extraction process follows a "Poisson process" and will be said to be in agreement with a Poisson process at a mean rate λ. Hence the probability of observing n events in the time t will be

$$Pn(t) = [(\lambda t)^n \exp(-\lambda t)]/n!$$

where λt is simply the true mean value for the number of events in time t.

7. CONCLUSION

We have proven that "the ultra-slow stochastic extraction process" at LEAR follows a Poisson distribution with a mean rate λ (number of events per second), from the analysis of the inter-arrival times of the particles in a scintillation counter.

REFERENCES

1. The LEAR team, Performances Update on LEAR, CERN/PS 87-26.
2. Glass-Scintillator Characteristics NE901, Nuclear Enterprises.
3. E. Parzen, Stochastic Processes, Holden-Day (1962).
4. Yuan and Wu Editors, Methods of Experimental Physics, Tome 5/B. Academic Press (1963).

<u>Distribution</u>: AR Group