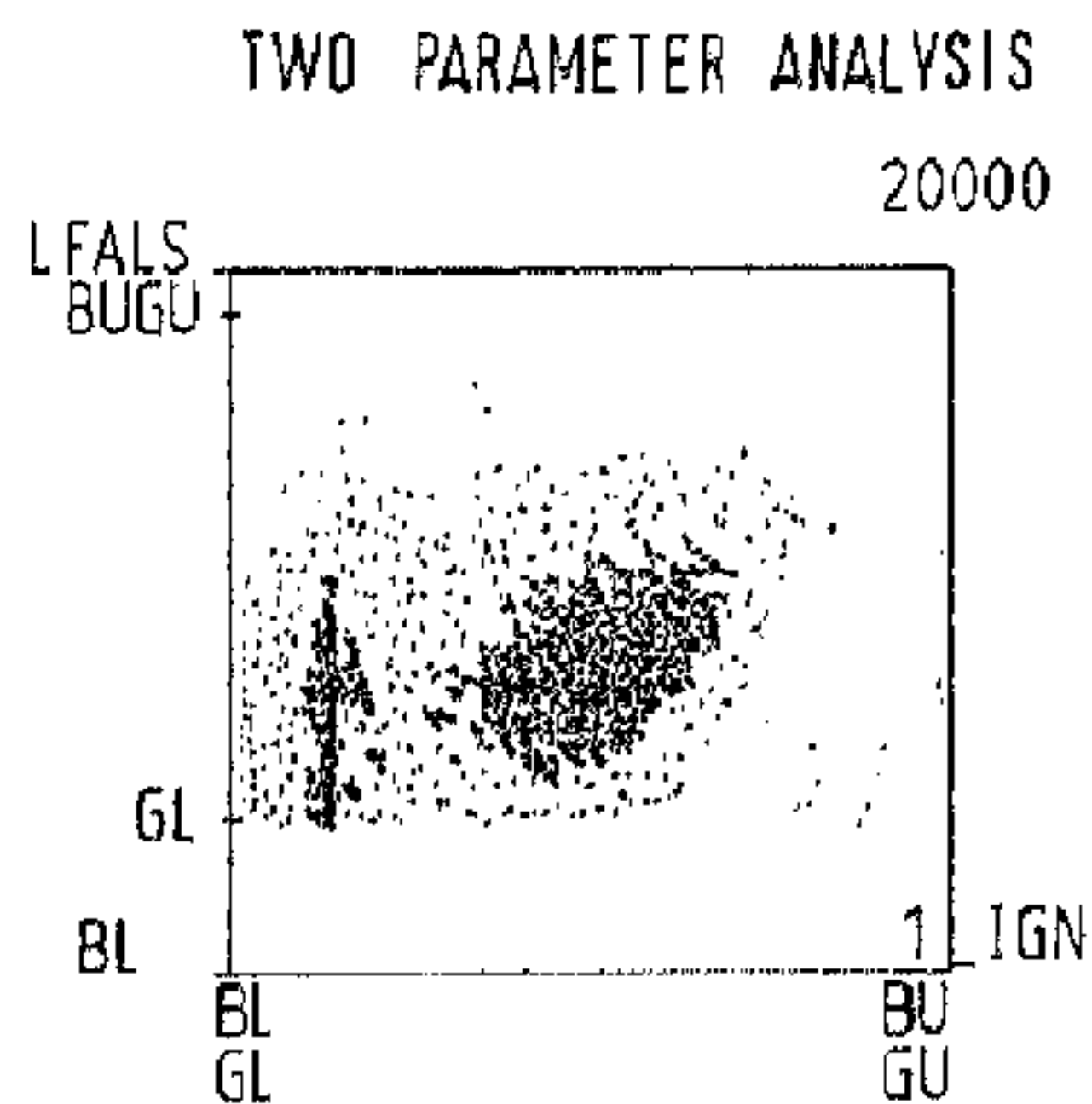
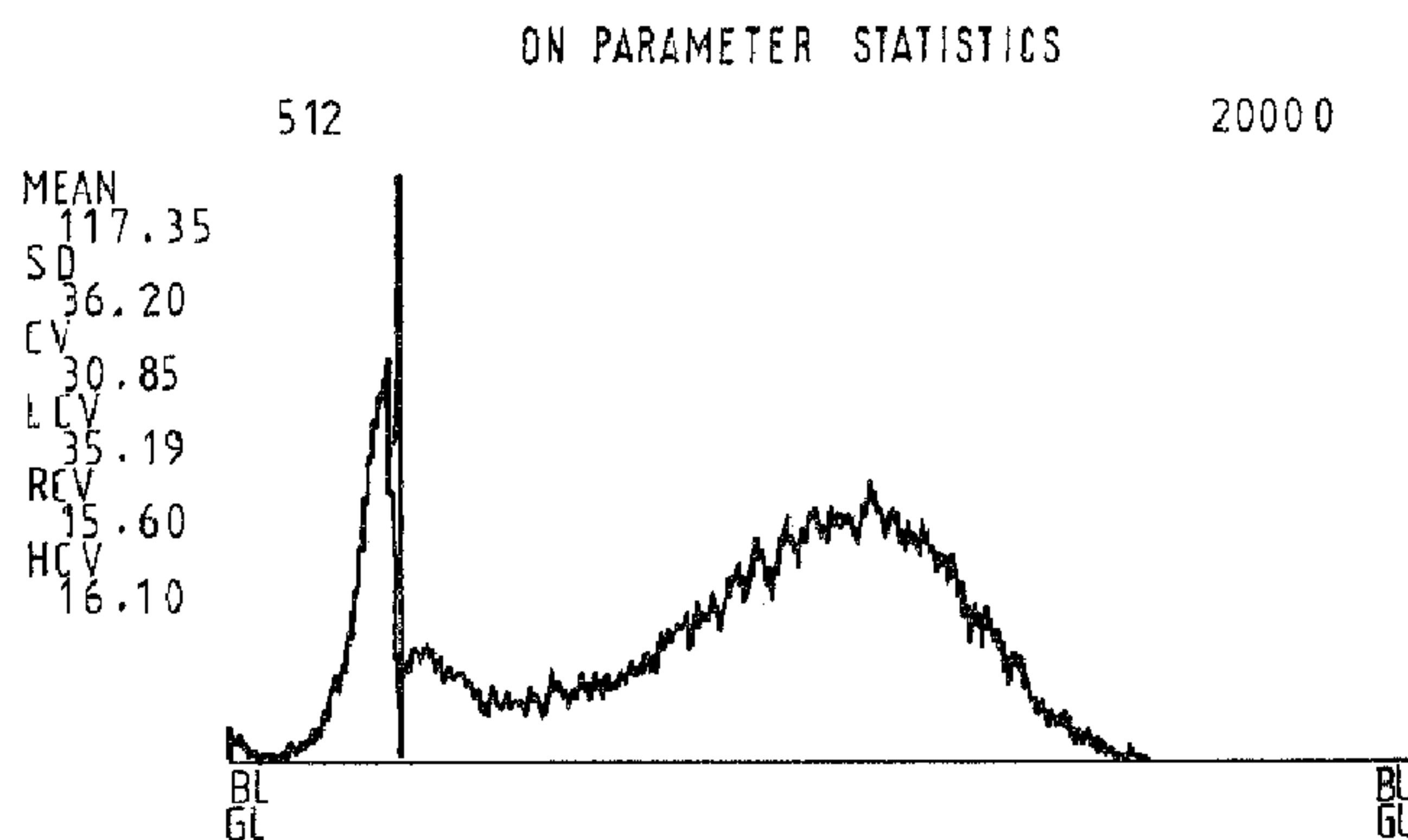




(22) Date de dépôt/Filing Date: 1994/06/17
 (41) Mise à la disp. pub./Open to Public Insp.: 1994/12/19
 (45) Date de délivrance/Issue Date: 2002/02/19
 (30) Priorité/Priority: 1993/06/18 (P 43 20 294.2) DE

(51) Cl.Int.⁶/Int.Cl.⁶ A61K 38/48, A61M 1/36, A61M 1/14,
A61L 33/00, A61K 35/14, A01N 1/02
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(54) Titre : UTILISATION DE LA PROTEINE C HUMAINE POUR LA PREVENTION ET LE TRAITEMENT DES DEPOTS DE THROMBOCYTES
 (54) Title: USE OF HUMAN PROTEIN C FOR PREVENTION AND TREATMENT OF DEPOSITIONS OF THROMBOCYTES



(57) Abrégé/Abstract:

The use of human Protein C for the prevention and treatment of deposition or aggregation of thrombocytes, microparticles of thrombocytes, and leucocytes is described. In addition, an improved method for the extra-corporeal treatment of body fluids is disclosed.

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Abstract

The use of human Protein C for the prevention and treatment of deposition or aggregation of thrombocytes, microparticles of thrombocytes, and leucocytes is described. In addition, an improved method for the extra-corporeal treatment of body fluids is disclosed.

Use of Human Protein C for Prevention and
Treatment of Depositions of Thrombocytes

The invention relates to a new range of application of human Protein C and a pharmaceutical preparation for the treatment of thrombo-embolic conditions.

Protein C is a vitamin K-dependent protein that is synthesized in the liver and circulates as an inactive zymogen in a concentration of 4 mg/l. It is transformed by the thrombin-thrombomodulin complex into the active serine protease (activated Protein C) on the vessel wall surface (endothelium). It is known that activated Protein C has profibrinolytic properties. It also has anticoagulatory effects because it inactivates Factor Va, the co-factor for the Factor Xa-induced prothrombin activation (thrombin formation), and Factor VIIIa, the co-factor for Factor IXa-induced Factor X activation, by proteolysis.

The activation of Protein C in vivo constitutes a negative feedback reaction of thrombin generation. In order to develop optimal biological activity, a co-factor (Protein S) is necessary.

In the European patent application EP 0 406 216 a pharmaceutical preparation is described which contains Protein S, optionally, in combination with activated Protein C, and can be employed for the treatment or prevention of thrombosis and thrombo-embolic complications.

According to EP 0 519 900 the use of a Protein C-containing pharmaceutical preparation together with a thrombolytically effective substance for the treatment of thrombosis and for the prevention of re-occlusion is possible. It was found that

during the thrombolysis therapy a deficiency of Protein C results wherefore the substitution with Protein C is recommended.

The effect of the inactive zymogen of Protein C differs fundamentally from the active enzyme, activated Protein C.

Activated Protein C enables the prevention of arterial thrombosis or stenosis, preferably in combination with a thrombolytically effective agent (tissue plasminogen activator, tPA); for this, see EP 0 318 201.

It is also known that in blood platelet-enriched plasma (PRP) activated Protein C suppresses platelet aggregation which is induced by thrombin activation. However, a higher concentration of activated Protein C leads to an opposite effect, namely to the aggregation of the blood platelets (E.N. Santander et al., *Acta Physiologica Latino-Americana* 33 (2), 1983).

Activated or stimulated blood platelets possess the glycoprotein IIb-IIIa complex which functions as a receptor for various adhesion molecules. Among the adhesion proteins that bind to GP IIb-IIIa of stimulated blood platelets are fibrinogen, von Willebrand Factor, and fibronectin. It is supposed that a tri-peptide sequence, namely Arg-Gly-Asp (RGD), of the adhesion proteins binds to the receptor. Among the proteins with a RGD sequence are also human Protein C and activated Protein C. However, the interaction of Protein C or activated Protein C with blood platelets is uncertain. It was found, for example, that activated Protein C binds to non-stimulated blood platelets in the presence of Protein S, and by this, the inactivation of Factor Va is potentiated. Protein C does not, however, bind to the blood platelets (*J. Biol. Chem.*, 260 (4), 2007-10, 1985).

With the help of flow cytometry for thrombocytes, surfaces of thrombocytes can be examined. Flow Cytometry allows the fast and sensitive analysis of receptor proteins on a single cell. During the examinations, a flow rate from 400 - 1000 thrombocytes per second is employed. The size of the thrombocytes is expressed by the light scattering. By the use of antibodies coupled with fluorescein-isothiocyanate, the binding of ligands (adhesion proteins) on a thrombocyte can be measured (description of the method in Blood, 86 (1), 173-179, 1986).

The binding of fibrinogen to stimulated thrombocytes leads finally to the aggregation and/or deposition of these on injured endothelium and therewith to occlusion of the wound. Thrombo-embolic complications or stenosis are also attributable to the binding of fibrinogen to stimulated thrombocytes. For example, balloon angioplasty leads to an injury of the endothelium and therewith to a predisposition for arterial restenosis.

The object of the invention is to extend the range of application of human Protein C and to make a preparation available that can be administered for the prevention and treatment of the deposition and/or aggregation of thrombocytes.

The object is solved according to the invention by a new use of human Protein C for the production of a pharmaceutical preparation which is suitable for the prevention and treatment of deposition and/or aggregation of thrombocytes, microparticles of thrombocytes (dust), and leucocytes with pro-coagulatory activity. Protein C prevents the deposition on vessel surfaces or vessel stenoses, in particular on injured, virus-infected or damaged endothelium and/or on exposed subendothelium or artificial vessel surfaces or vessel

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prostheses with or without endothelium. It was found that the binding of fibrinogen on stimulated blood platelets can be prevented by the addition of human Protein C in a dose-dependent manner. PRP was stimulated by addition of adenosine diphosphate (ADP) and the fibrinogen binding measured. The addition of a fluorescein-isothiocyanate-coupled antibody against fibrinogen allowed the detection of the fibrinogen found in PRP bound on thrombocytes by measurement on the flow cytometer. The prevention of the fibrinogen binding on stimulated thrombocytes was all the more surprising because activated Protein C had no influence on the fibrinogen binding. Therefore, it is probable that the RGD sequence in a protein can not alone be responsible for the prevention of the fibrinogen binding.

According to one aspect, the invention provides use of human Protein C in the zymogen form for the preparation of a pharmaceutical preparation for the prevention or treatment of deposition or aggregation of thrombocytes, microparticles of thrombocytes and leucocytes with pro-coagulatory activity on vessel surfaces or vessel stenoses.

According to another aspect, the invention provides a method for the prevention of deposition or aggregation of thrombocytes in vitro comprising adding an effective amount of human Protein C in the zymogen form to thrombocytes in vitro.

According to another aspect, the invention provides a method for the prevention of deposition or aggregation of thrombocytes in a circulation apparatus for the extra-corporeal treatment of body fluids, comprising adding a suitable concentration of Protein C in the zymogen form to the extra-corporeally-treated body fluid.

According to another aspect, the invention provides a use of human Protein C in the zymogen form for the prevention

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or treatment of deposition or aggregation of thrombocytes, microparticles of thrombocytes and leucocytes with pro-coagulatory activity on vessel surfaces or vessel stenoses.

Experiments with monoclonal antibodies (for example, 5 PAC-1, an IgM antibody that only recognizes the activated form of the IIb-IIIa complex; S.J. Shattil, J. Biol. Chem. 260, 11107, 1985) make it clear that the GP IIb-IIIa complex exposed by the activation of thrombocytes is not bound by the antibodies in the presence of Protein C. A competitive binding 10 of protein C to GP IIb-IIIa is therefore supposed. Instead of PAC-1, however, the use of other monoclonal antibodies against thrombocyte activation-dependent epitopes is also possible, for example, PADGEM (J. Clin. Invest., 78, 130, 1986), GMP (J. Biol. Chem., 264, 1816, 1989), and 2.28 (Blood 70, 838, 1987). 15 Hence, the binding site of fibrinogen is blocked. In contrast to the other adhesion proteins, the aggregation of the thrombocytes is not promoted, but instead prevented by this. Experiments with a perfusion chamber demonstrated that Protein C prevents the adhesion of thrombocytes in a rabbit aorta that 20 is flushed with blood. The endothelium is stabilized then in the presence of Protein C, whereby the adhesion of stimulated thrombocytes is prevented.

Protein C, as a native protein, as a derivative thereof, or mutant with an RGD sequence can be used according to the invention. Protein C in its inactive form as a zymogen is usable. This has the advantage that the protein does not have to be activated in order to prevent the fibrinogen binding or von Willebrand Factor binding on stimulated blood platelets. Therefore, Protein C can also be used according to the invention in certain conditions, like homocysteinuria, diabetes, or uremia, in which the endogenous activation of Protein C is inhibited. The zymogen Protein C also does not have the disadvantage of the activated Protein C, namely that it leads in a high concentration to an aggregation of the thrombocytes.

The experiments with the help of flow cytometry confirm that human Protein C is suitable above all for the prevention of arterial restenosis. According to the invention, Protein C can therefore be used with all interventions of angioplasty, but also with use of a catheter, in order to prevent negative interactions with stimulated thrombocytes among themselves, with leucocytes, and with the endothelium.

On the basis of the found mechanism of action of Protein C, a process according to the invention is possible for the extracorporeal treatment of body fluids, such as blood or ascites, with which the deposition and/or aggregation of thrombocytes in a circulation apparatus should be prevented. This method finds application, for example, in a dialysis apparatus or an artificial kidney.

By the following examples, the invention is further described.

Fibrinogen binding to activated PRP

10 ml of blood was drawn in citrate. PRP was obtained by

conventional centrifugation. The addition of ADP resulted in the stimulation of thrombocytes. Subsequently, a fluorescein-isothiocyanate-coupled antibody against fibrinogen was added, and the fibrinogen bound on thrombocytes was determined by measurement on the flow cytometer (FACScan[®], Becton Dickinson). The fibrinogen binding was determined by the Green Fluorescence Intensity (one parameter statistics, x-axis "Log Green Fluorescence" (bound anti-fibrinogen), y-axis "Number of Cells") as well as by the light scattering (two parameter analysis, x-axis "Log-Green Fluorescence", y-axis "Log-Light Scatter" (size of the thrombocytes)).

Figures 1-3 show the intensity of the fluorescence, i. e. the fibrinogen binding on stimulated thrombocytes as well as the size of the thrombocytes. Figure 1 shows the fibrinogen binding in the PRP after ADP stimulation. The application of the agonist leads to a fibrinogen binding on the cell surface, but also to a change of the size of the thrombocytes. In comparison to this, Figure 2 shows the fibrinogen binding after ADP stimulation in the presence of Protein C in a concentration that corresponds to the 4-fold plasma concentration. A significant reduction of the fibrinogen binding is recognizable. As opposed to this, activated Protein C in this test mixture leads to no decrease of the fibrinogen binding on thrombocytes.

Binding of PAC-1 on activated thrombocytes

The monoclonal antibody PAC-1 reacts with the glycoprotein IIb-IIIa complex on the surface of thrombocytes after activation of the thrombocytes with ADP.

The drawing of blood occurred in EDTA/ Trasylol. Thereafter, platelet-enriched blood plasma (PRP) and plasma in which the blood platelets were depleted (PPP) was produced by

conventional centrifugation. PRP was diluted 1:40 in PPP. Thereafter, PAC-1 was added with ADP and, optionally, Protein C or activated Protein C and incubated at room temperature for 10 minutes. After addition of an anti-mouse antibody (fluorescence conjugated, FITC from Sigma Chemical Co.) and a further incubation time of 20 minutes, the binding of the PAC-1 on thrombocytes was detected by flow cytometric examination.

Figure 4

Binding of the PAC-1 to PRP/ADP

Figure 5

The PAC-1 Binding to Thrombocytes is Prevented in the Presence of Protein C.

Figure 6

Activated Protein C Leads to no Influencing of the PAC-1 Binding on ADP-stimulated Thrombocytes.

Blood Platelet Deposition on the Subendothelium in the Perfusion Experiment

Venous blood was anticoagulated with citrate-phosphate-dextrose (19 mM). Protein C (Immuno AG) was reconstituted and added to 20 ml of the anticoagulated blood before the perfusion. Perfusions were performed at 37°C in a perfusion chamber (experimental description in *Thromb. Haemost.*, 37, 1-16, 1977). Enzymatically-treated aorta samples from rabbit were mounted in a perfusion chamber. With the aid of a haemodialysis blood pump (Renal Systems, Minneapolis, Minn., USA) an appropriate flow rate was set. After 5 minutes of perfusion, the aorta

samples were washed with buffer and fixed (glutaraldehyde: formaldehyde = 2%:3% (v/v)). Thereafter, these were embedded in JB4 (Polyscience, Warrington, USA), stained with Toluidine Blue, and morphometrically examined. With the help of a computer program (described in Haemostasis, 16, 8-14, 1986), the blood platelets were classified as follows: adhesion (blood platelet layer $< 5\mu\text{m}$), thrombi (aggregation $\geq 5\mu\text{m}$), both expressed in percent of the total length of the blood vessel. The results are given in Table 1. At concentrations of less than $16\ \mu\text{g/ml}$, Protein C demonstrates no effect on the adhesion of blood platelets in comparison to controls. At concentrations of 16 and $32\ \mu\text{g/ml}$, the covered surface was significantly reduced.

Table 1

Blood Platelet Deposition on Subendothelium in the Perfusion Experiment with Citrate-anticoagulated Blood in Dependence on the Protein C Concentration ($n=3, \bar{x} \pm \text{SD}$) (flow rate = $800\ \text{s}^{-1}$)

	coated surface	Adhesion	Clots
Control	18.1 ± 5.3	9.3 ± 4.5	8.8 ± 1.9
Protein C $16\ \mu\text{g/ml}$	13.1 ± 3.5	4.8 ± 0.9	8.3 ± 2.9
Protein C $32\ \mu\text{g/ml}$	9.6 ± 5.7	4 ± 2.5	5.6 ± 3.4

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CLAIMS:

1. Use of human Protein C in the zymogen form for the preparation of a pharmaceutical preparation for the prevention or treatment of deposition or aggregation of thrombocytes,
5 microparticles of thrombocytes and leucocytes with pro-coagulatory activity on vessel surfaces or vessel stenoses.
2. Use according to claim 1 wherein said vessel surface is injured, virus-infected or damaged endothelium, exposed subendothelium, artificial vessel surfaces or vessel
10 prostheses.
3. Use according to claim 1 wherein said Protein C is native Protein C or a derivative thereof.
4. Use according to claim 1 wherein said Protein C is mutant Protein C with an RGD sequence.
- 15 5. Use according to any one of claims 1 to 4 characterized in that the preparation is suitable for the prevention of arterial restenosis.
6. Method for the prevention of deposition or aggregation of thrombocytes in vitro comprising adding an
20 effective amount of human Protein C in the zymogen form to thrombocytes in vitro.
7. Method for the prevention of deposition or aggregation of thrombocytes in a circulation apparatus for the extra-corporeal treatment of body fluids, comprising adding a
25 suitable concentration of Protein C in the zymogen form to the extra-corporeally-treated body fluid.
8. Use of human Protein C in the zymogen form for the prevention or treatment of deposition or aggregation of thrombocytes, microparticles of thrombocytes and leucocytes

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with pro-coagulatory activity on vessel surfaces or vessel stenoses.

9. Use according to claim 8 wherein said vessel surface is injured, virus-infected or damaged endothelium, exposed
5 subendothelium, artificial vessel surfaces or vessel prostheses.

10. Use according to claim 8 wherein said Protein C is native Protein C or a derivative thereof.

11. Use according to claim 8 wherein said Protein C is
10 mutant Protein C with an RGD sequence.

12. Use according to any one of claims 8 to 11 characterized in that the preparation is suitable for the prevention of arterial restenosis.

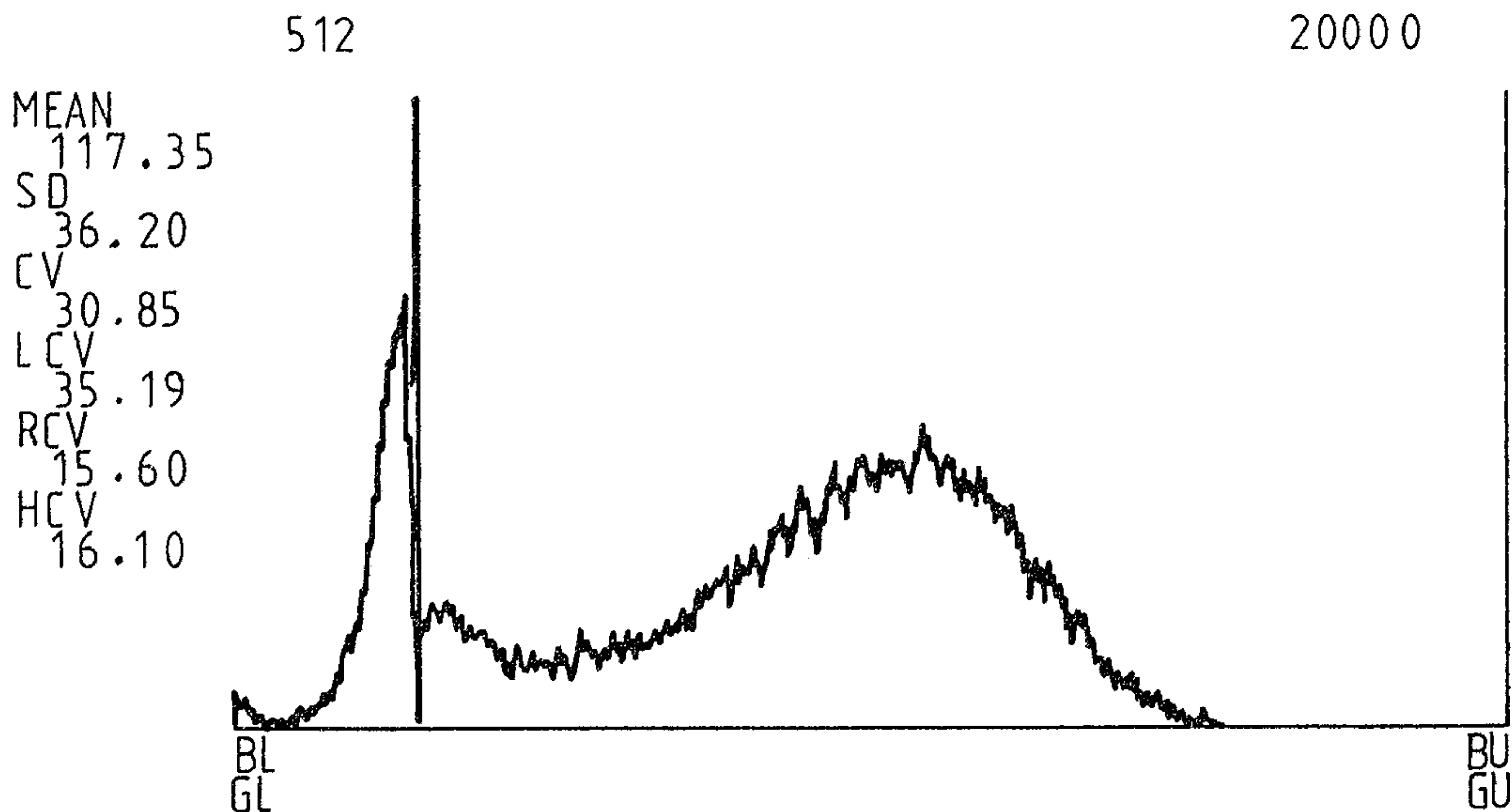
SMART & BIGGAR

OTTAWA, CANADA

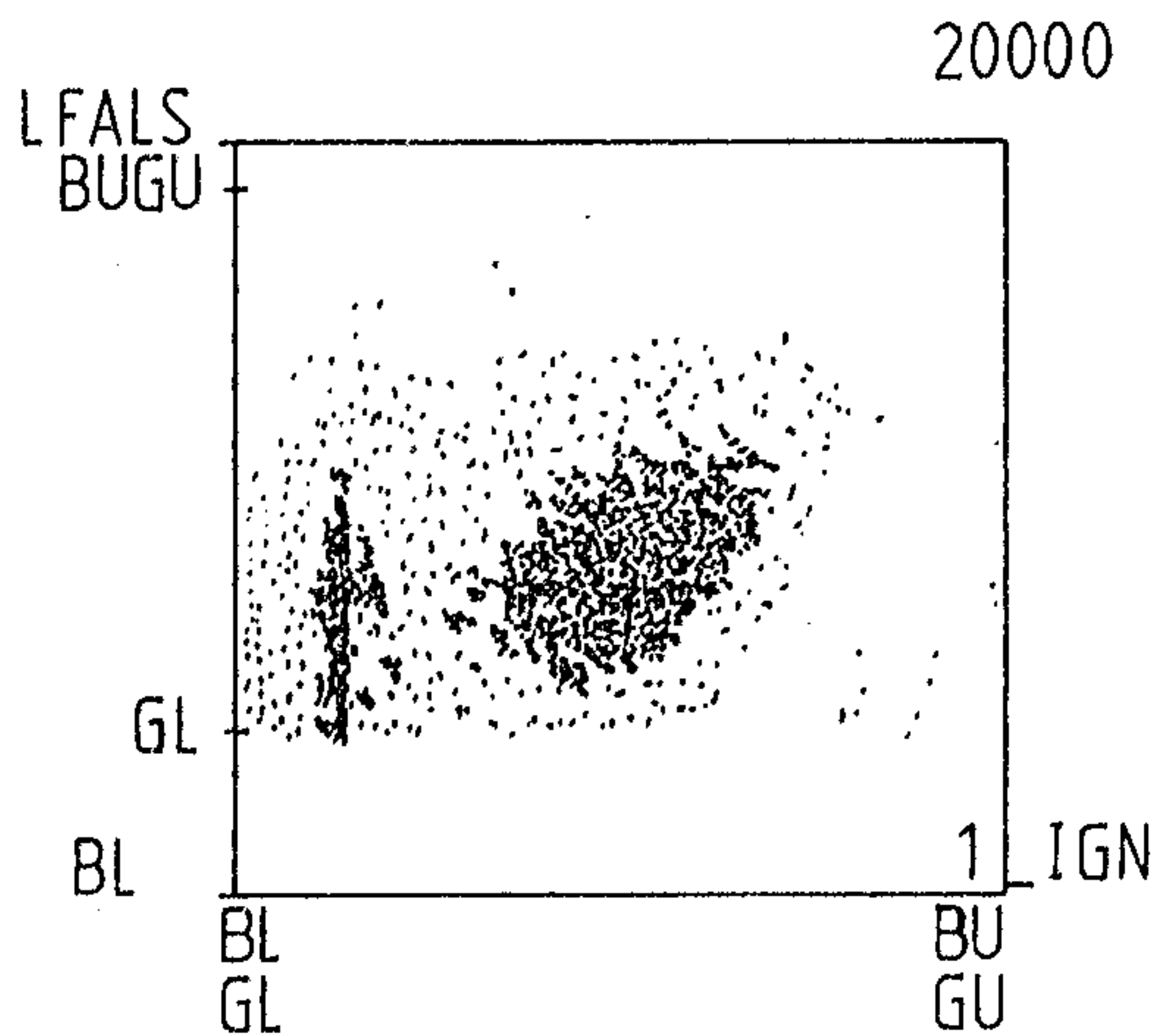
PATENT AGENTS

Fig. 1

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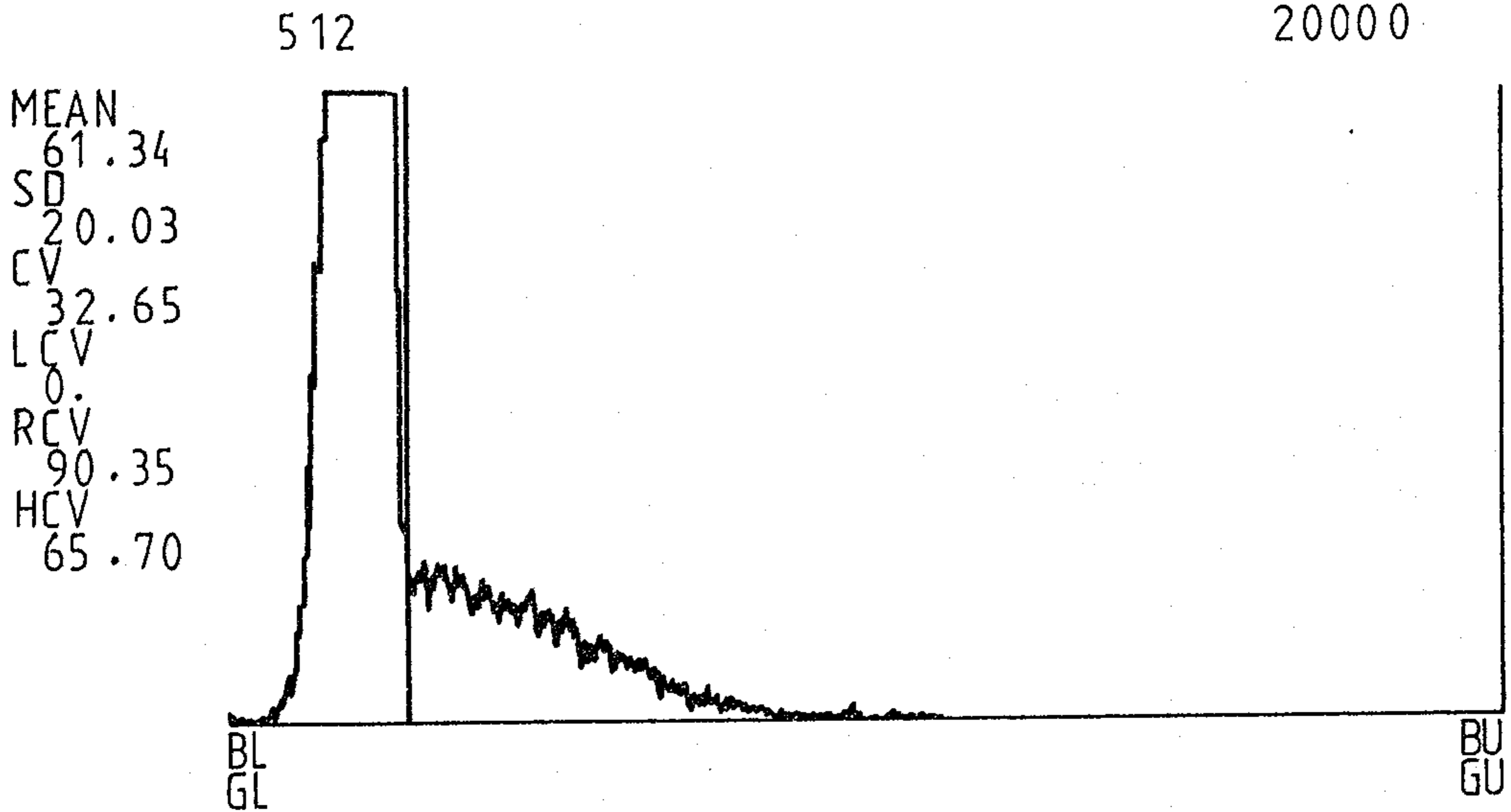
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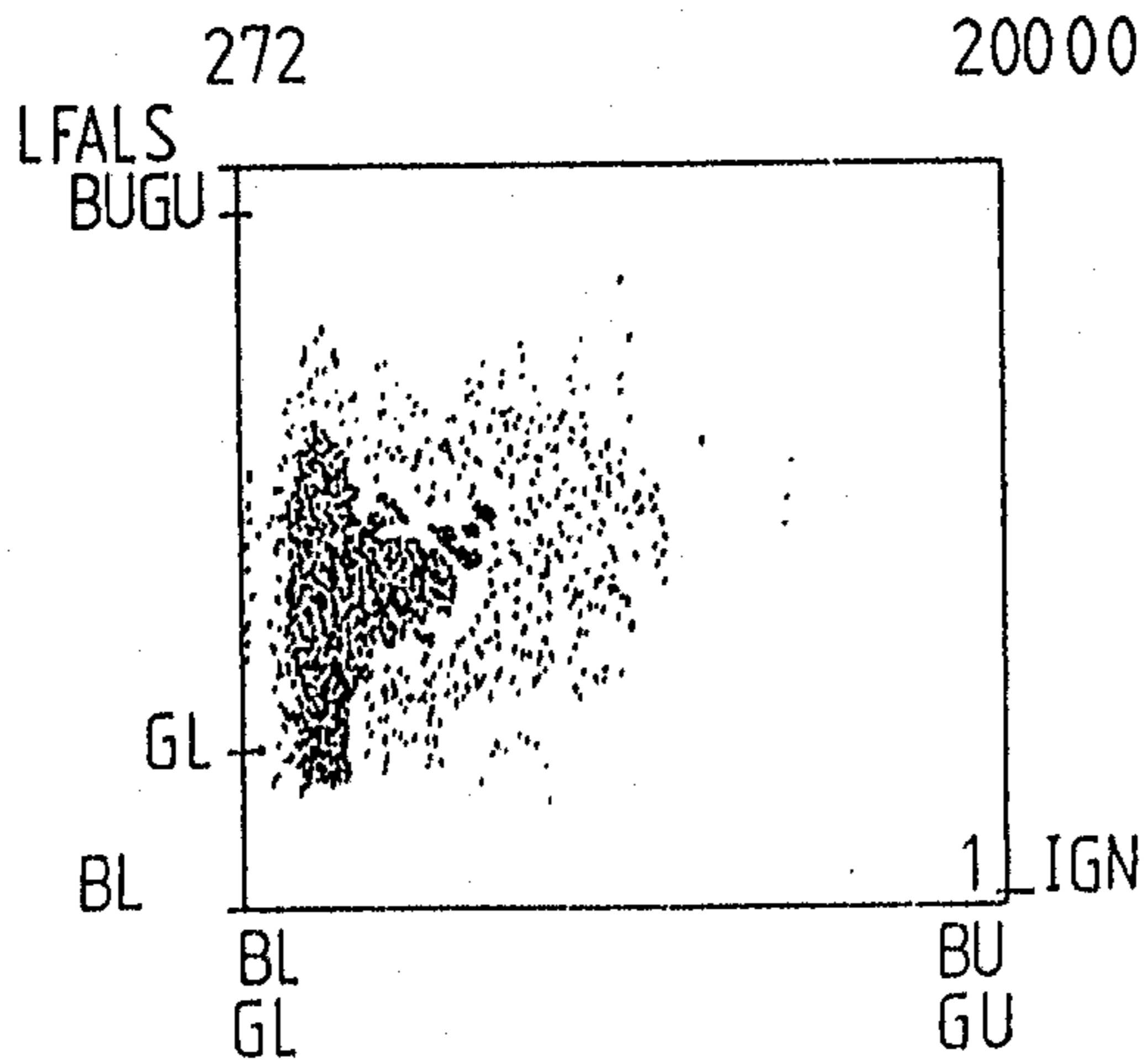
*Robert ...
Sweet ...*

Fig. 2

ONE PARAMETER STATISTICS



TWO PARAMETER ANALYSYS



*Patent Agents
Smart & Wise*

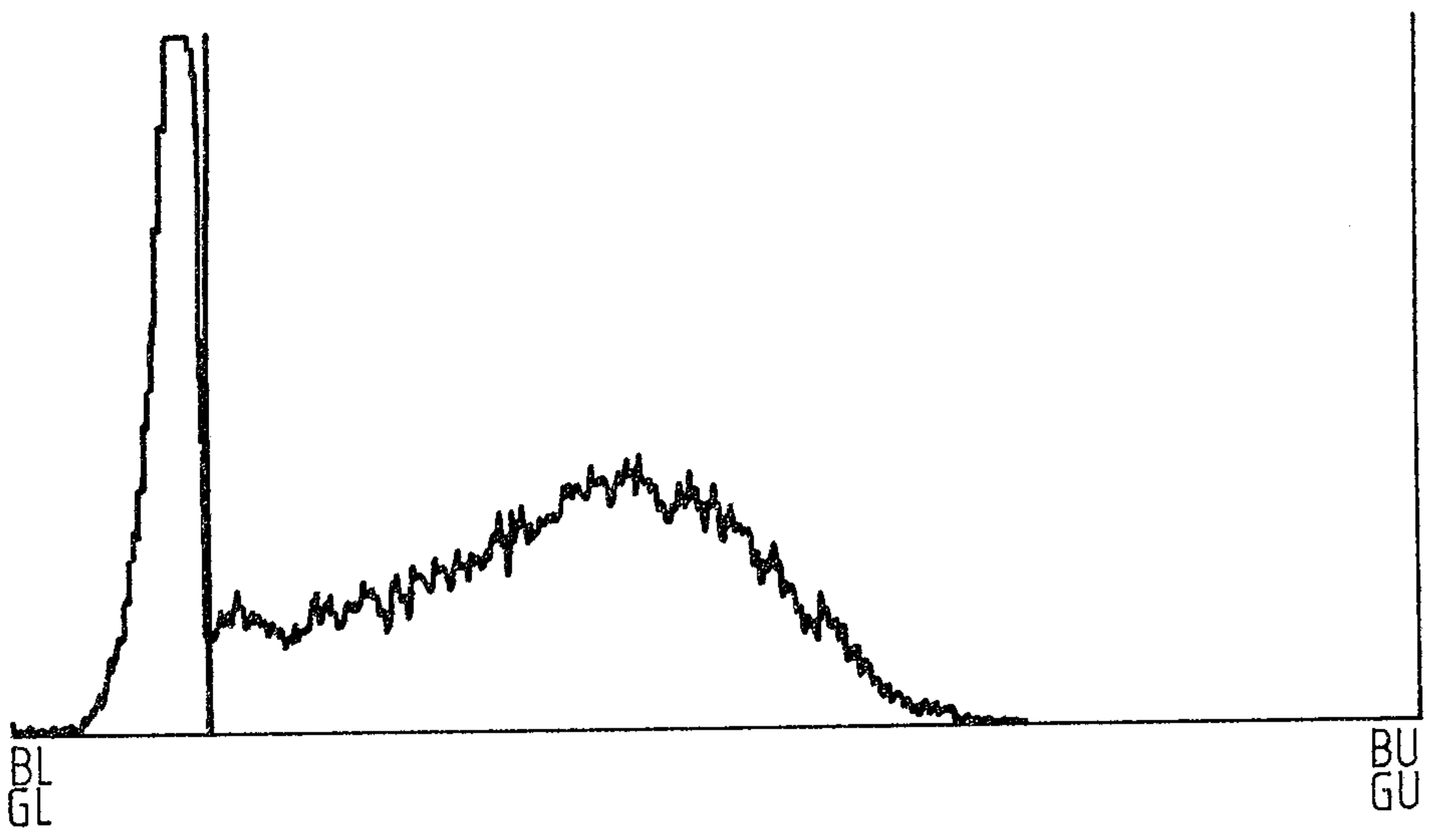
Fig. 3

ONE PARAMETER STATISTICS

512

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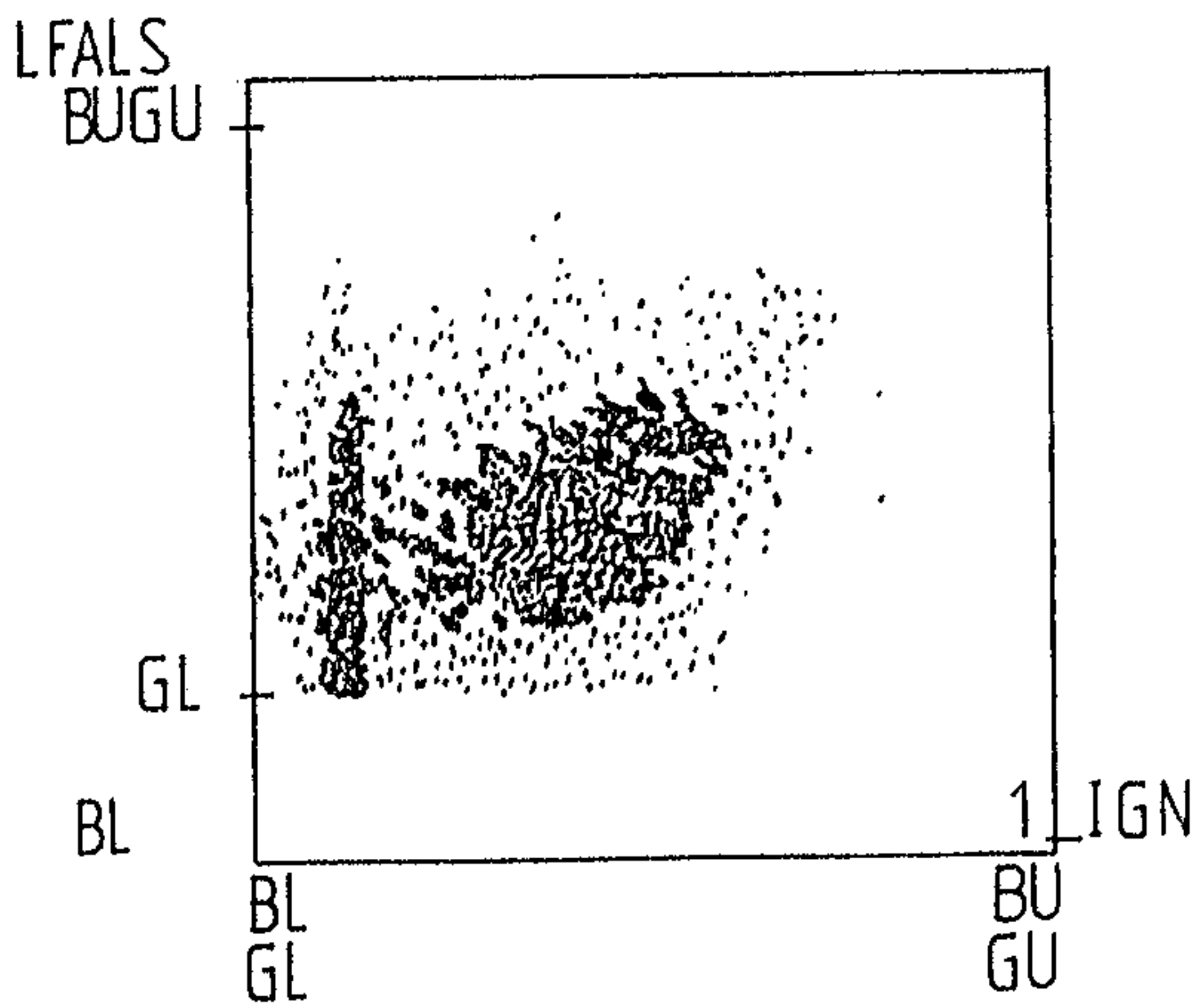
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 SD
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 CV
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 LCV
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 RCV
 20.82
 HCV
 25.67



TWO PARAMETER ANALYSIS

127

20000



*Petrol Agents
Smart & Wise*

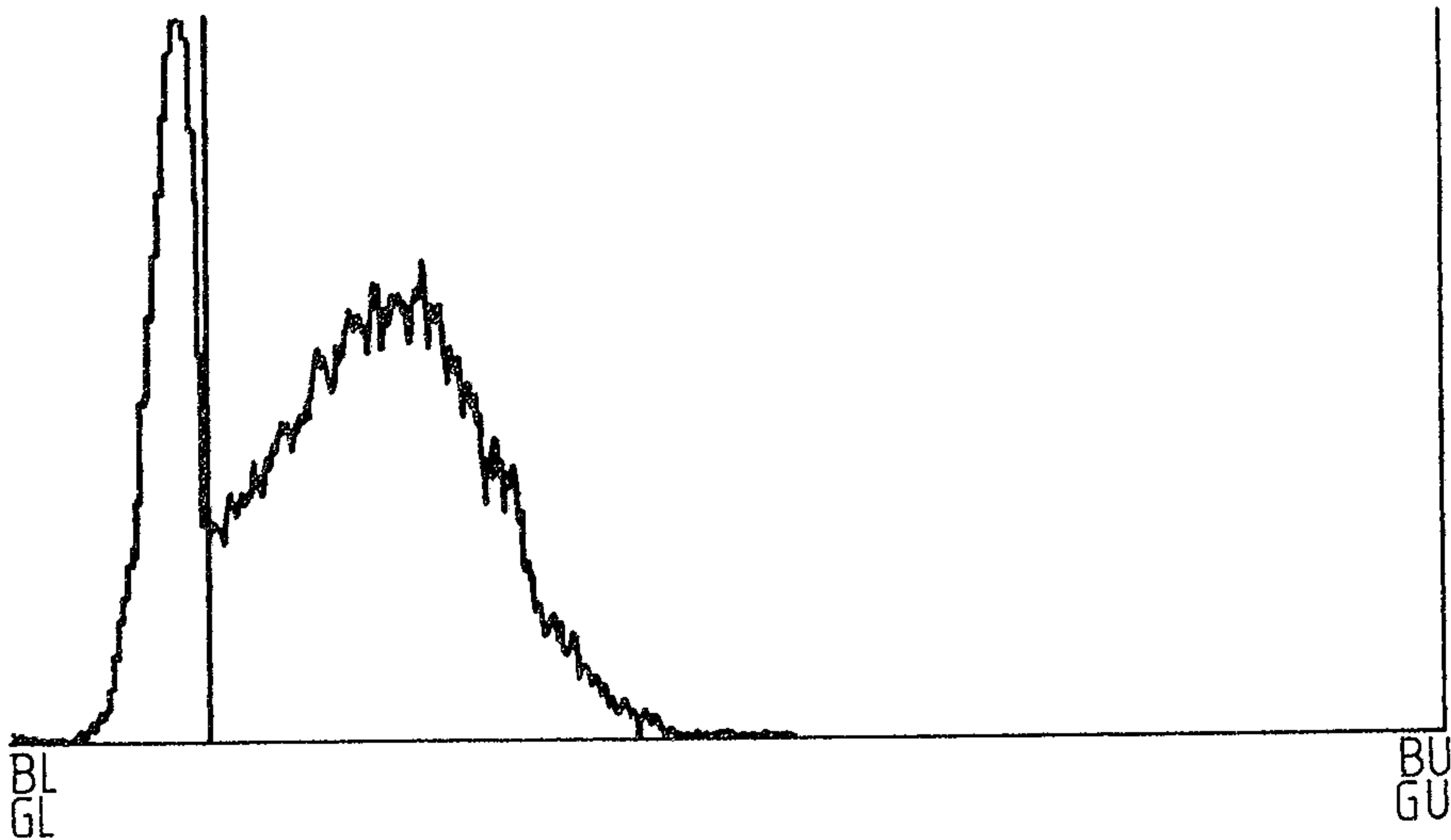
Fig. 4

ONE PARAMETER STATISTICS

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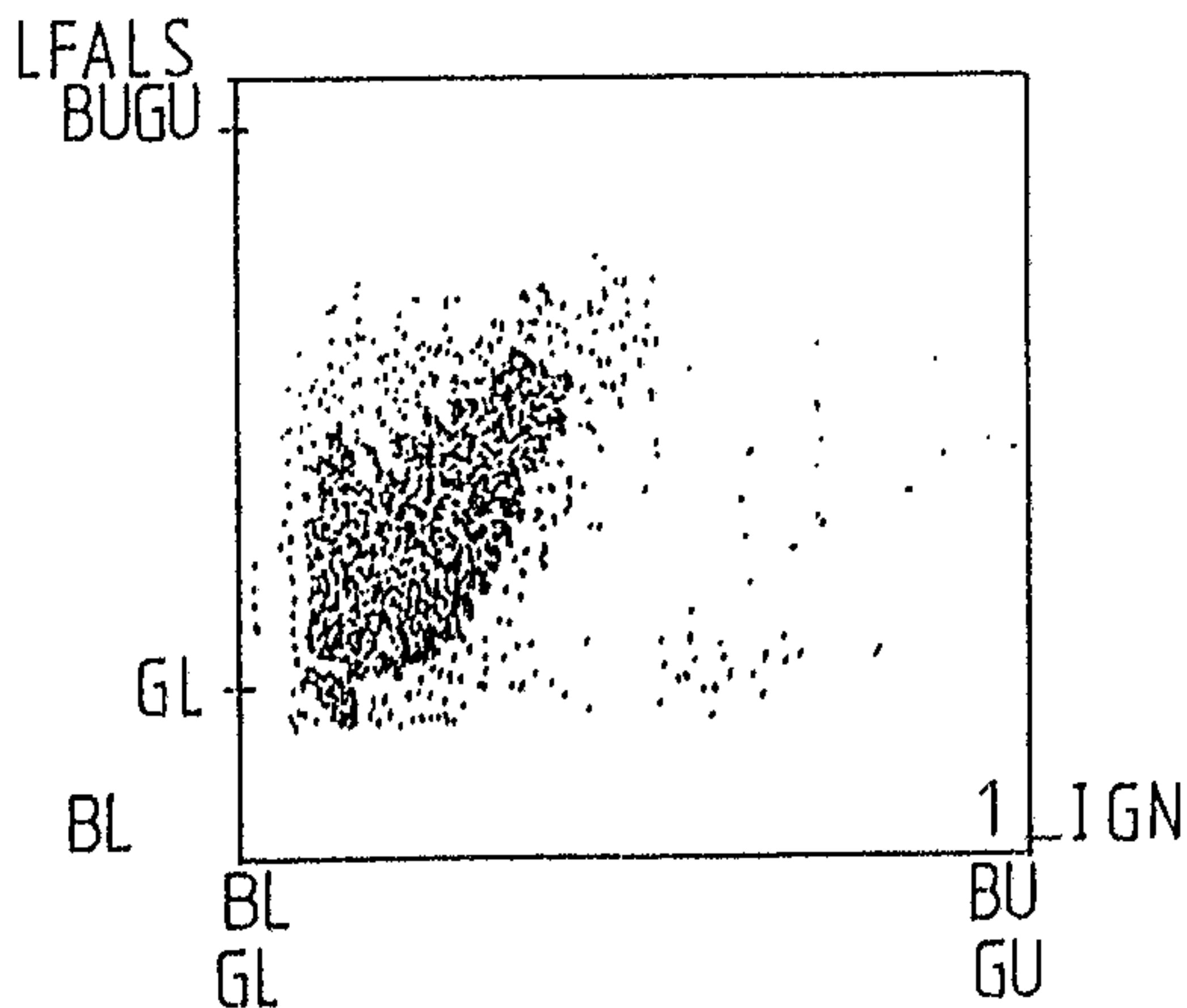
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CV
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LCV
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RCV
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HCV
27.85



TWO PARAMETER ANALYSIS

123

20000



Robert L. ...
Stat. C. ...

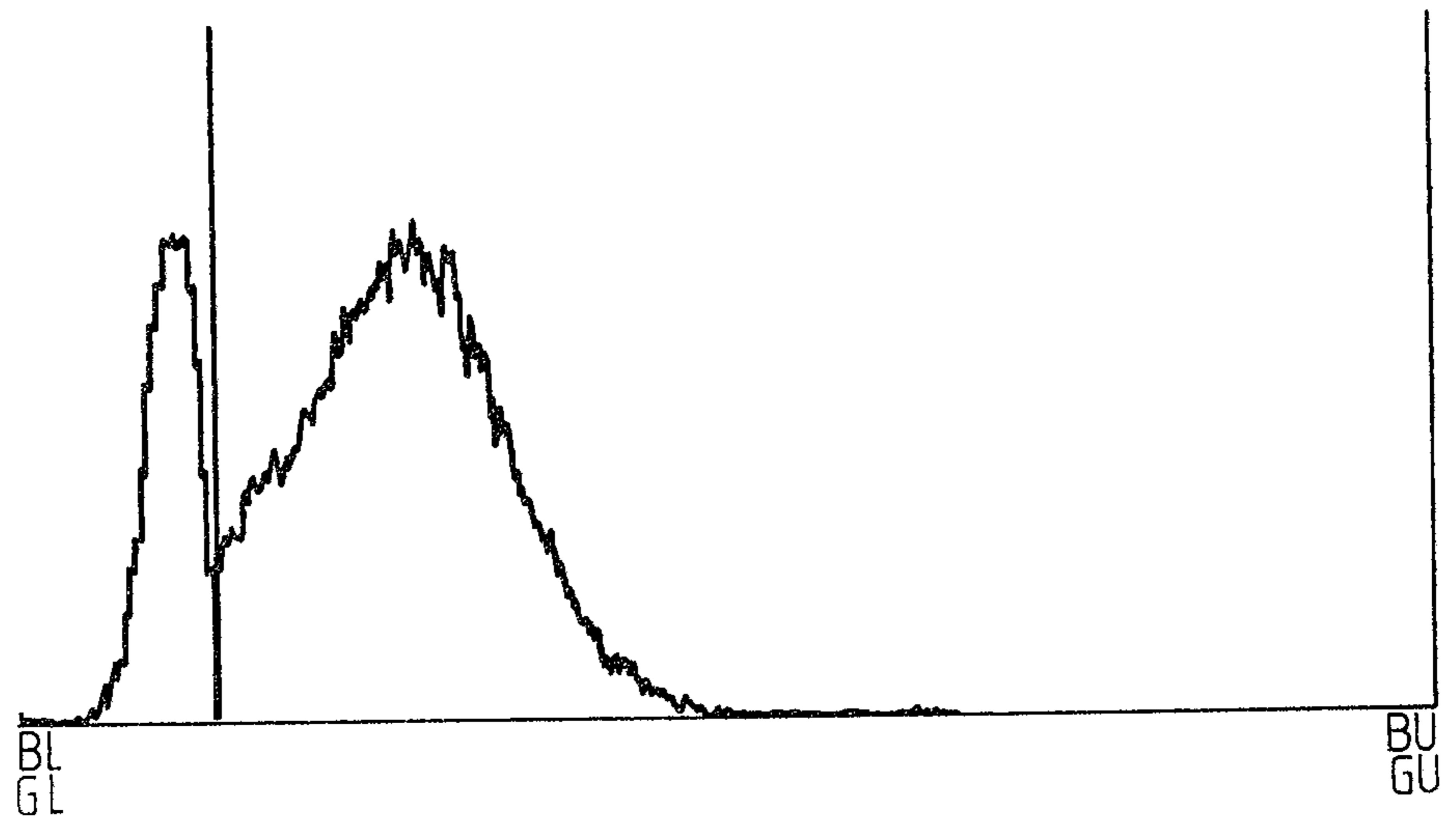
Fig. 5

ONE PARAMETER STATISTICS

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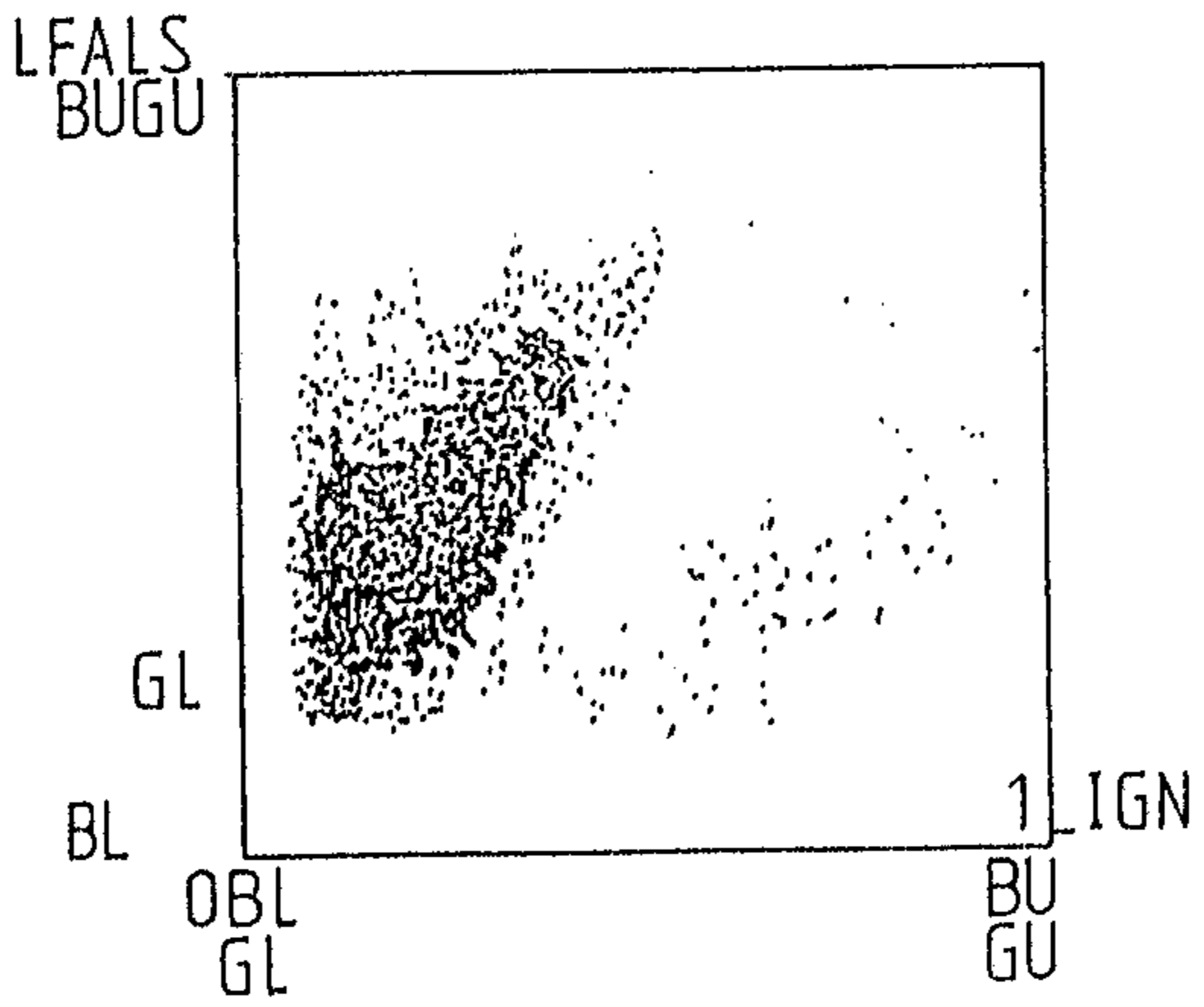
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 CV
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 LCV
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 RCV
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 HCV
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TWO PARAMETER ANALYSIS

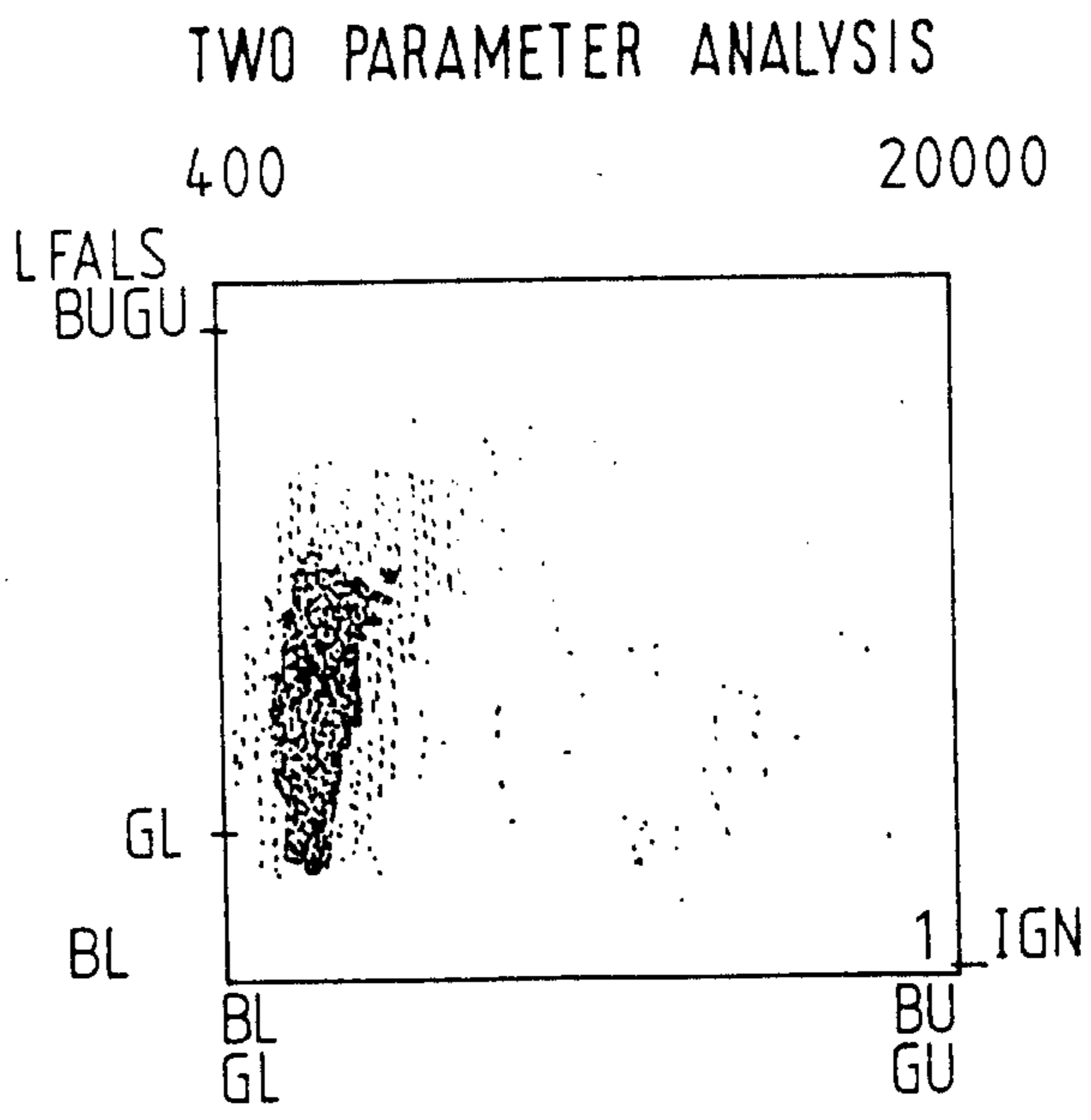
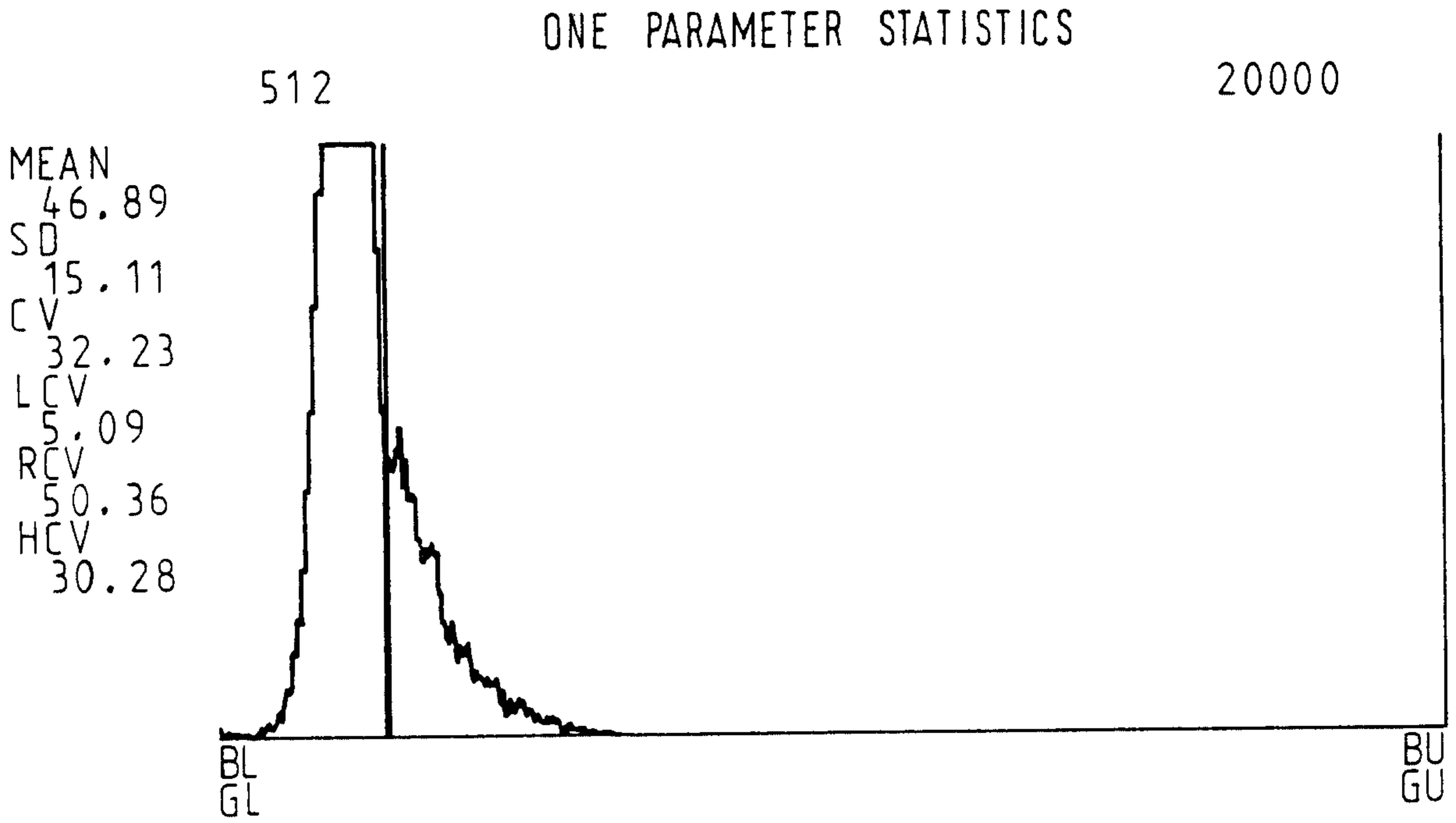
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*Patent Agents
 Smart & Wynn*

Fig. 6

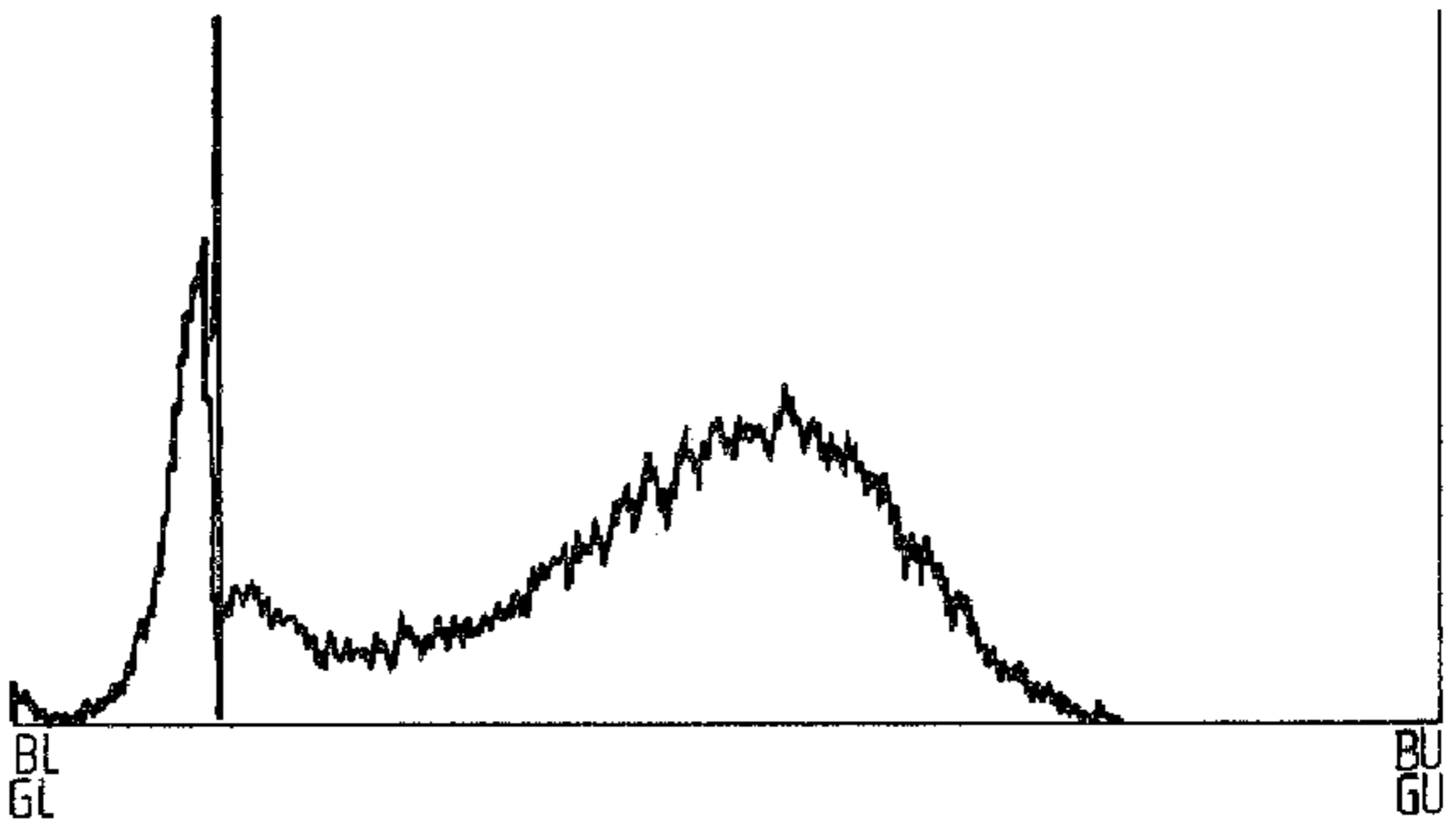


ON PARAMETER STATISTICS

512

20000

MEAN
117.35
SD
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EV
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LCV
35.19
REV
15.60
HCV
16.10



TWO PARAMETER ANALYSIS

20000

