AdA at Orsay

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A brief history of AdA

- February 1960: Touschek proposes to turn the Frascati synchrotron into an electron-positron ring*.
- March 1960: Decision to engage the Frascati Laboratory in an e+e- colliding beam experiment*.
- May 1961: First electrons/positrons stored in AdA.
- July 1962 – AdA is brought to the *Laboratoire de l'Accélérateur Linéaire* in Orsay.
- Discovery of the Touschek effect and first evidence ever of collisions between counter-rotating stored particles.
- Summer 1964: AdA goes back to Frascati

(*) See Giulia Pancheri, 1959-61: *The Making of AdA*, to be published.

OUTLINE

- Why the AdA storage ring was brought to Orsay
- AdA operations at LAL
- AdA beam lifetime and the Touschek effect
- Bunch size and luminosity measurements
- Summary of the main storage ring physics results obtained with AdA at Orsay


137

Conventional accelerators recently commissioned in 1959 (Europe)

Name	Country Laboratory	Particles	Energy	First beam
Synchrophasotron	USSR Dubna	protons & ions	10 GeV	1957
SATURNE	France Saclay	protons & ions	3 GeV	1958
Proton Synchrotron (PS)	CERN	protons	20 GeV	1959
Linac	France Orsay	electrons	1 GeV	1959
Electron Synchrotrone	Italty Frascati	electrons	1.1 GeV	1959

AdA in Frascati

Why AdA was brought to Orsay

The e^+ or e^- capture rate achieved in Frascati was lower than anticipated.

Transferring AdA to Orsay meant going from a few 10^2 particles per beam to a few 10^7 per beam.

Pierre Marin (1927-2002)

1966 photograph

Pierre Marin's report

Anneaux de Stockage

2) L'étude de la durée de vie du faisceau en fonction de la pression résiduelle dans la chambre à vide.

3) La mesure de la section des faisceaux d'électrons et de positrons en fonction de la pression, à l'aide de la réaction $e^+ + e^- \longrightarrow 2\gamma$.

4) L'étude des phénomènes de charge d'espace avec les deux faisceaux en présence.

5) Des essais de variation de l'énergie du faisceau, lorsqu'on modifie le champ magnétique et la mesure de la perte éventuelle des particules.

Si les prévisions des calculs sont exactes, il semble possible de réaliser ce programme à Frascati. Le point 4 est l'un, sinon le plus important, des objectifs de ce programme. S'il s'avérait qu'il ne puisse être réalisé à Frascati, A.D.A. serait transporté à Orsay auprès de l'Accélérateur Linéaire.

II) ADONE. Un projet pour la construction d'un grand anneau de stockage, pour une énergie des électrons et des positrons de 1,5 GeV existe à Frascati.

Edoardo Amaldi

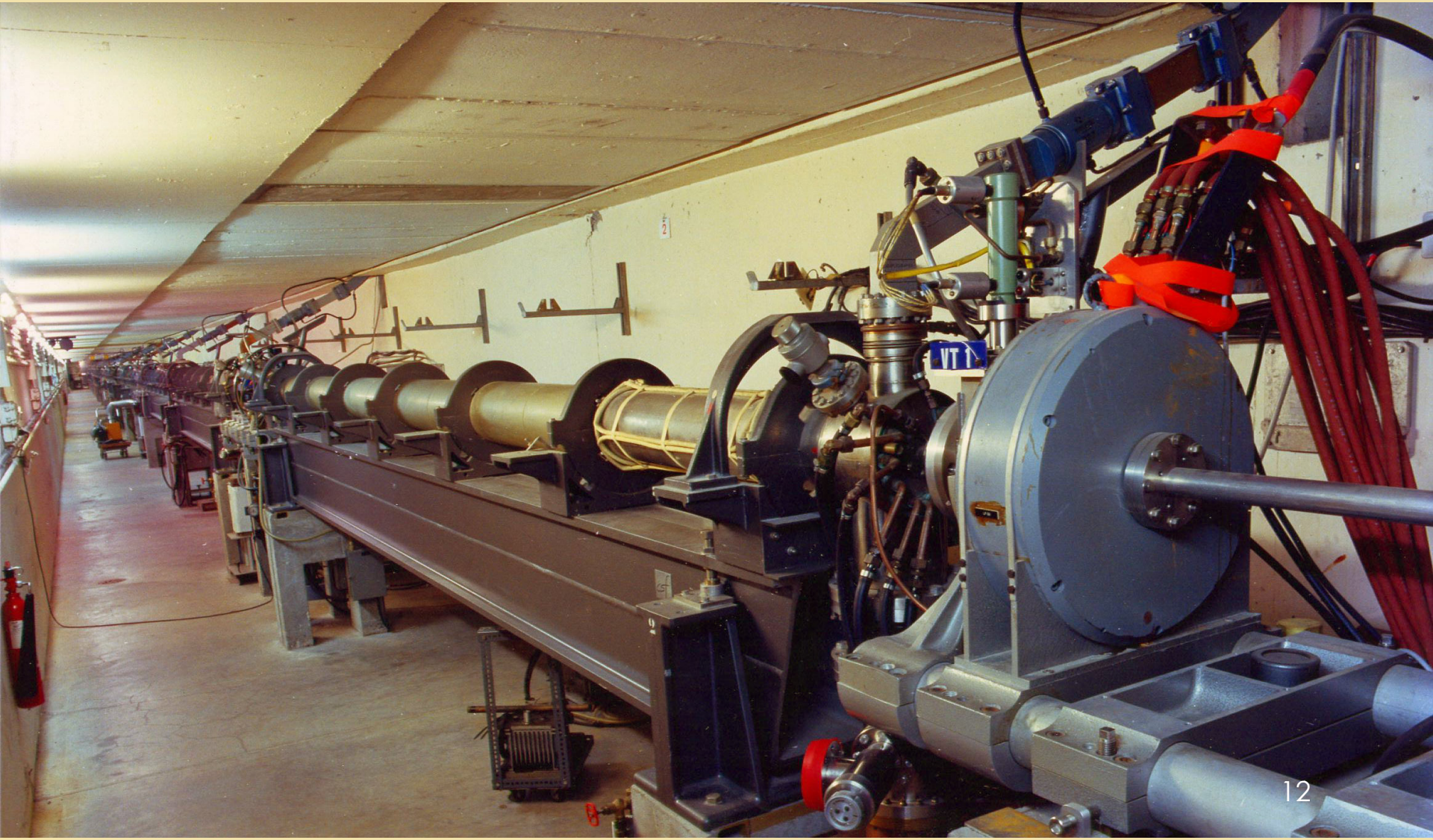
Giorgio Salvini

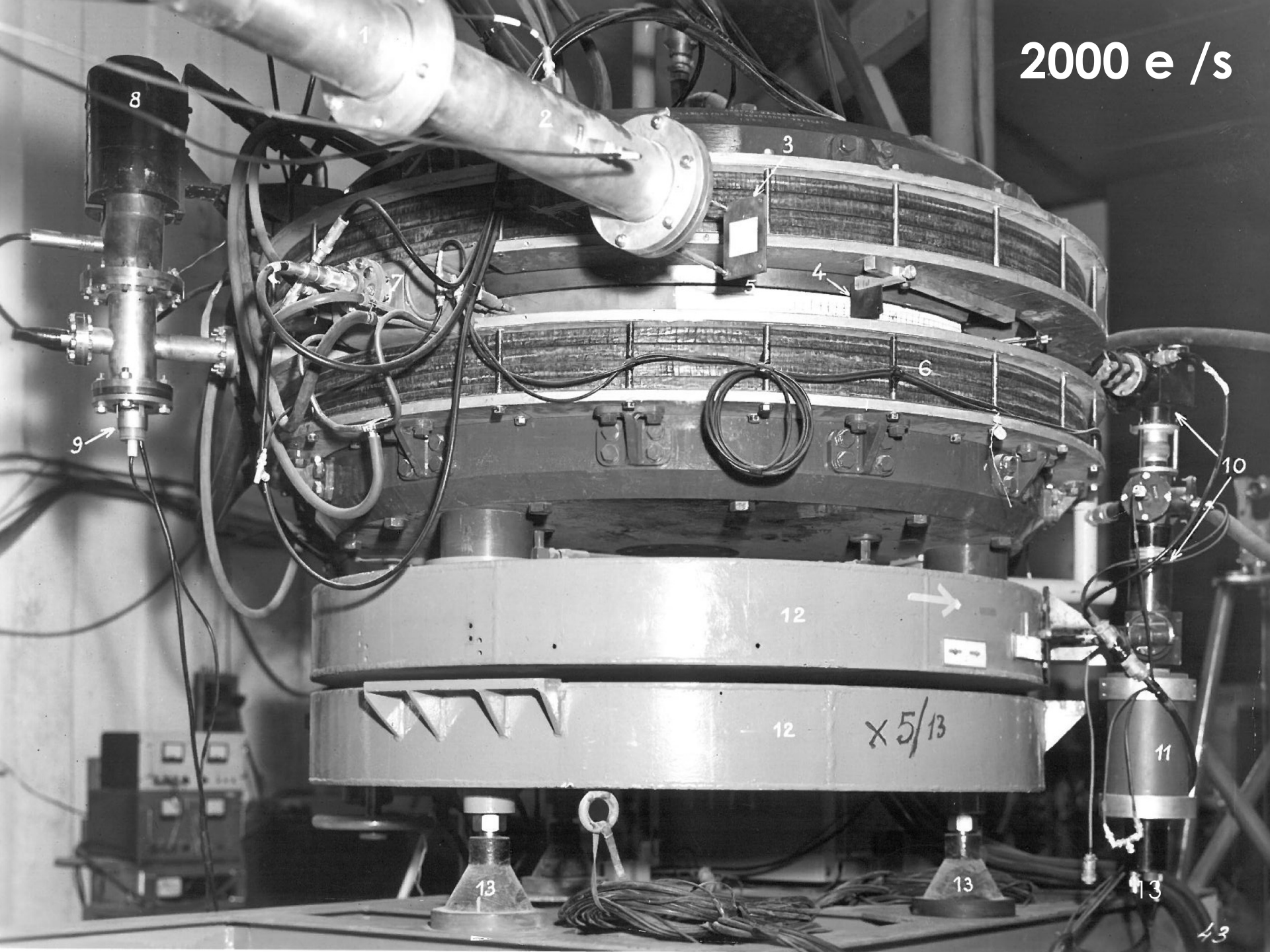
Frederico Quercia

André Blanc-Lapierre

Pierre Marin

The Orsay linear accelerator wave guide

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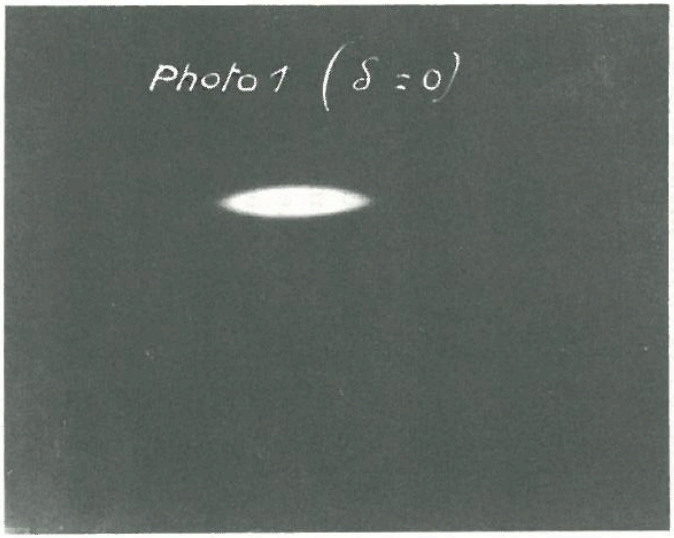
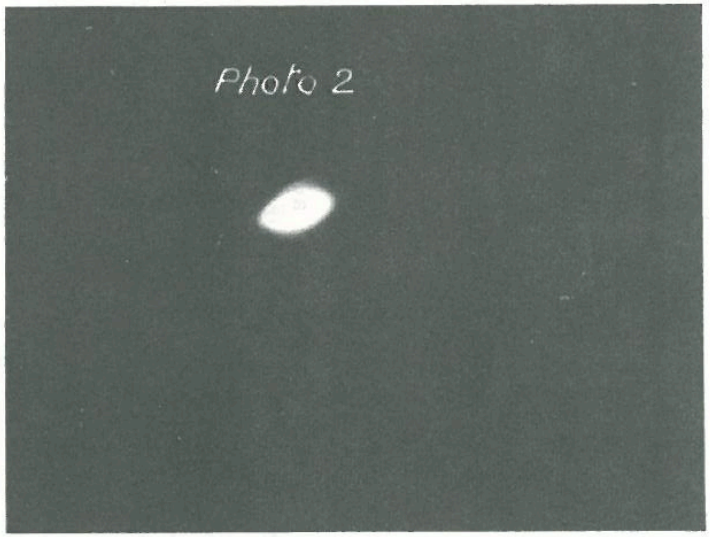
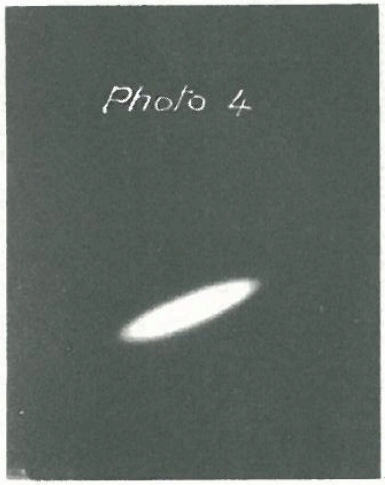
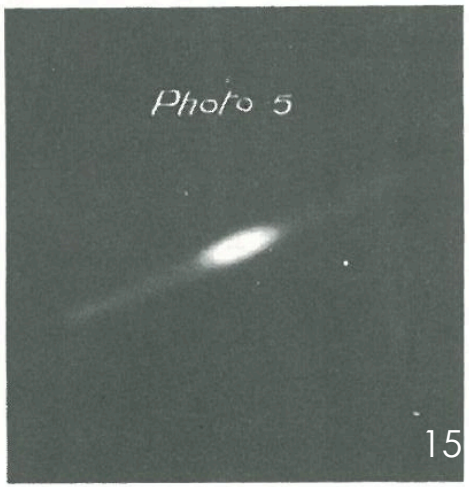
Giuseppe di Giugno

AdA transverse bunch shape *without and with* an applied coupling









A few AdA parameters

Parameter	Value or typical operation value	Units
Orbit length	4.1	m
Energy per beam	225	MeV
Luminosity	~10^{25}	$cm^{-2}\ s^{-1}$
Beam current, per beam	0.5	mA
Vacuum pressure	1	nTorr

The AdA collaboration at Orsay

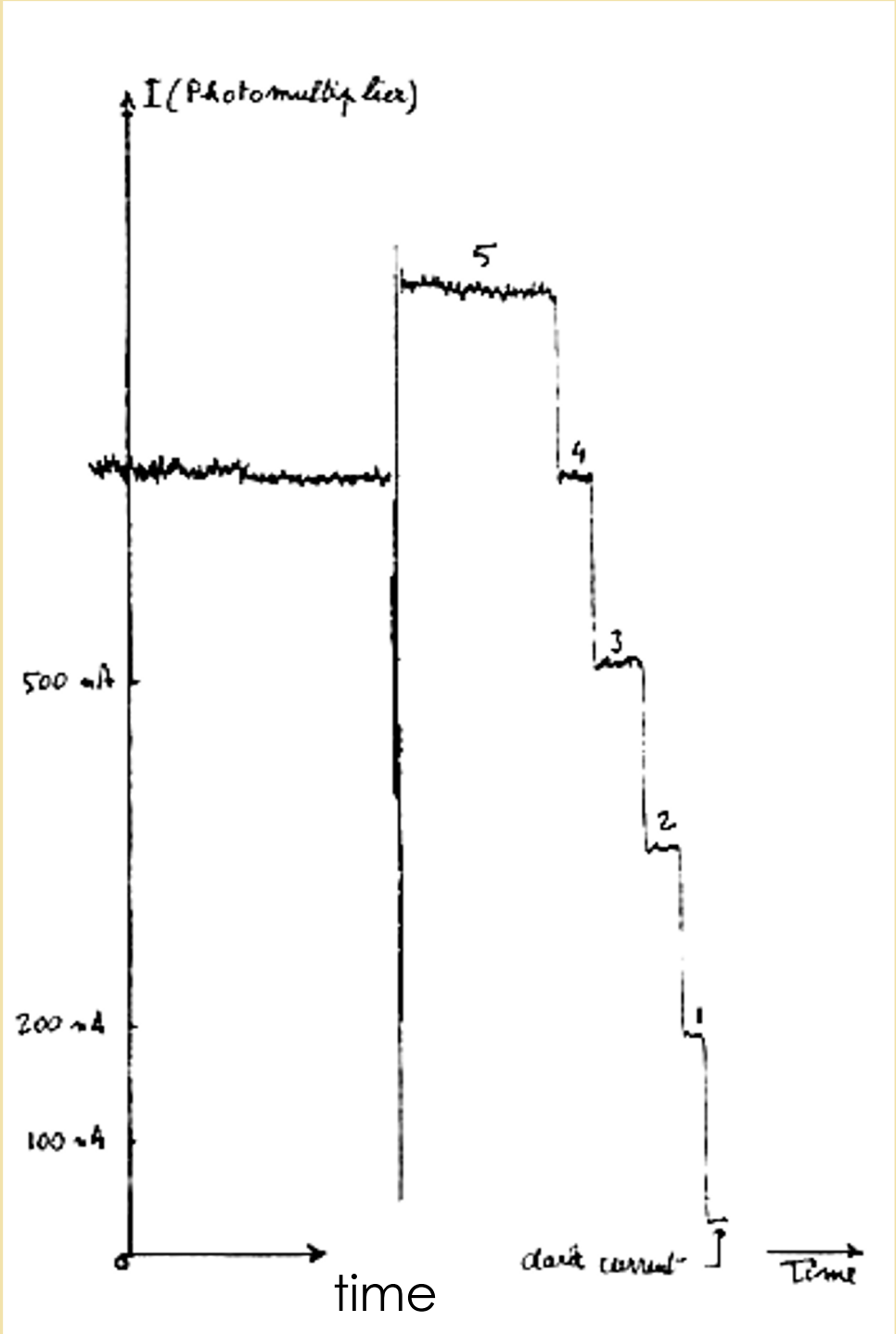
C. Bernardini, G. F. Corazza,

G. Di Giugno, F. Lacoste → J. Haïssinski,

P. Marin, R. Querzoli, B. Touschek

The Orsay scientific program

1. Beam life-time
2. e^- and e+ bunch size
3. Collision rate (ring luminosity)



photomultiplier current

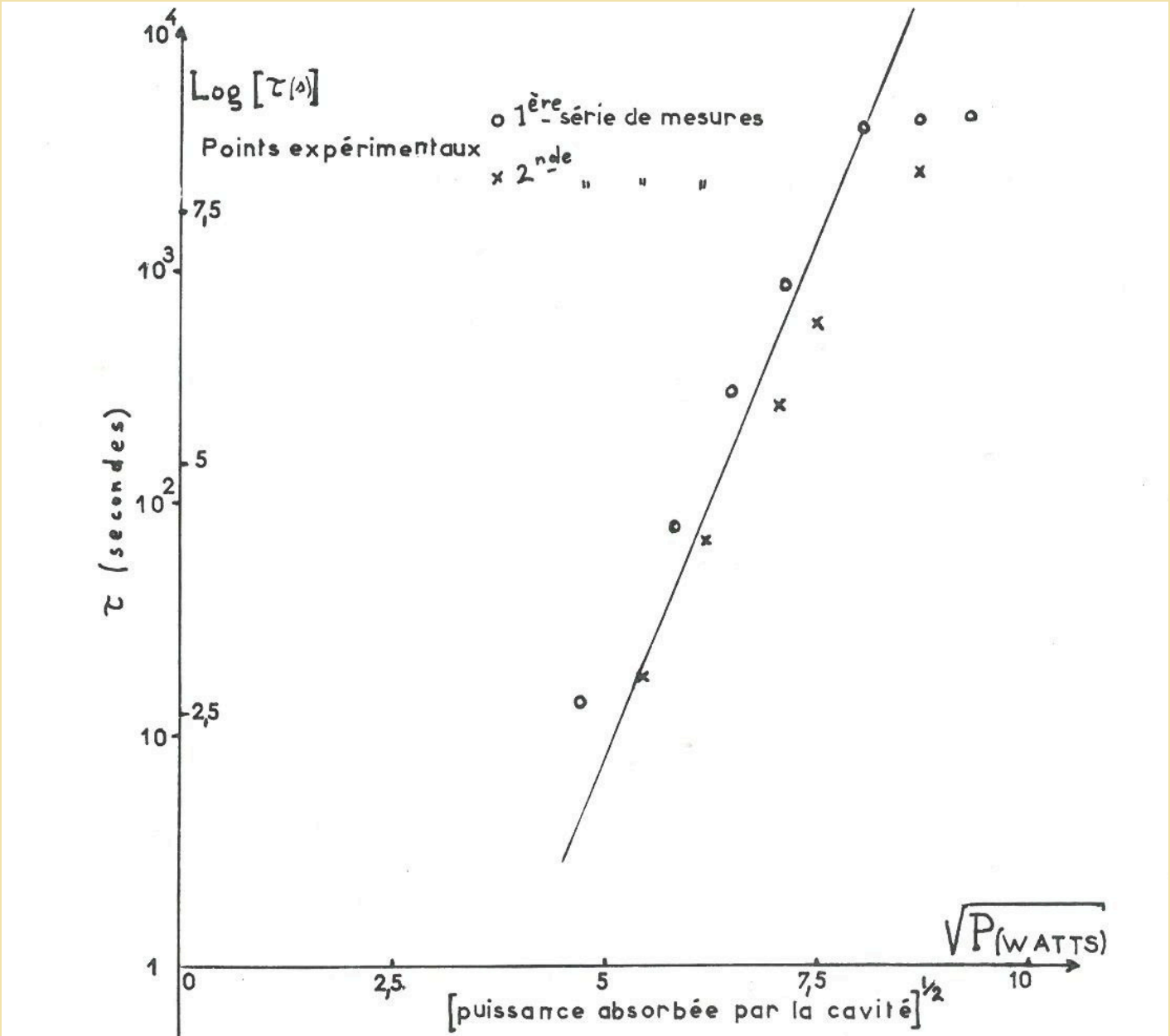
Dealing with electrons one by one!

A glass of water contains about 30 trillion trillion electrons

Beam lifetime (1)

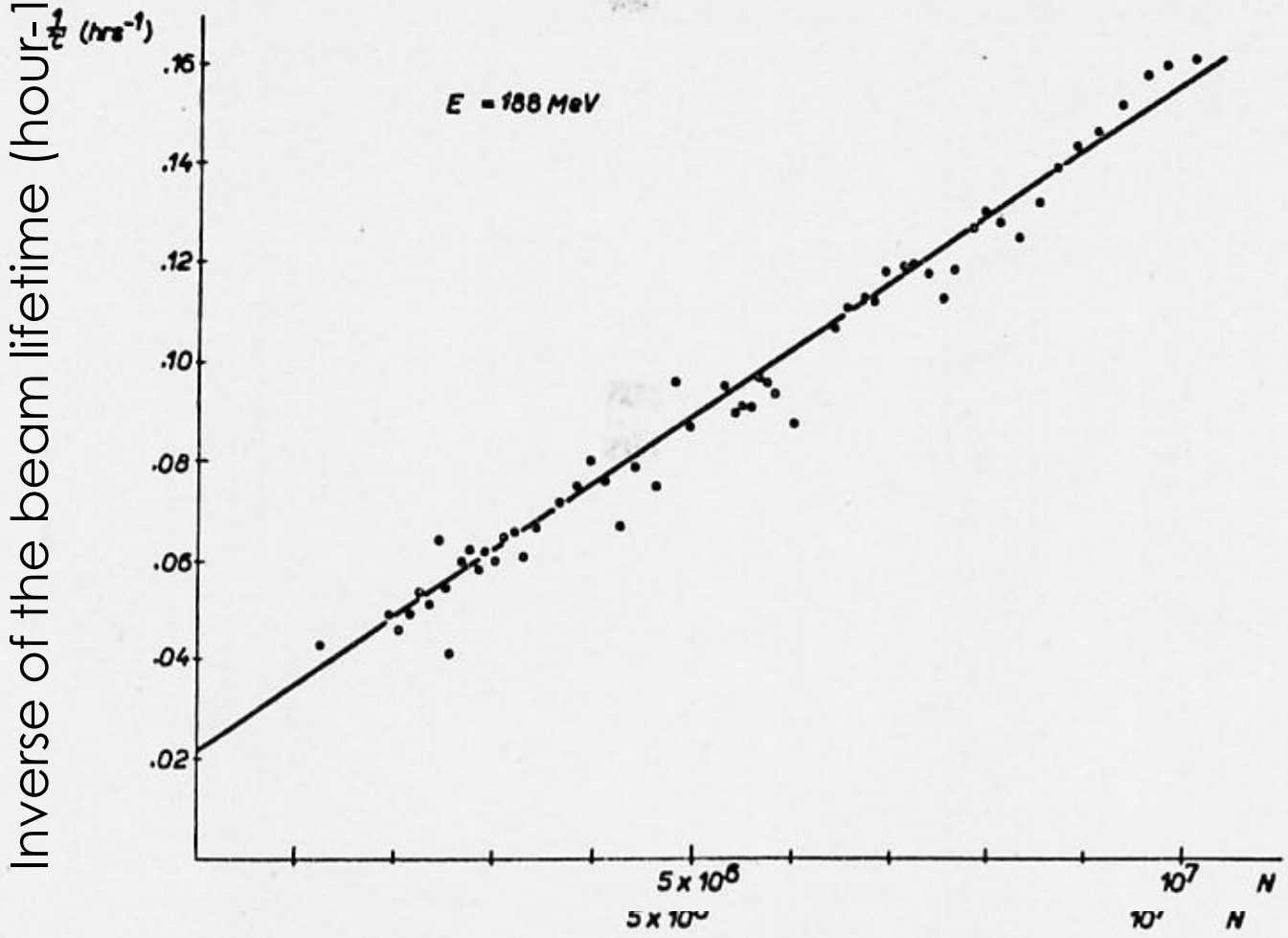
Particle losses due to quantum fluctuations

Beam energy: 195 MeV



Beam lifetime (2)
The Touschek effect

VOLUME 10, NUMBER 9 PHYSICAL REVIEW LETTERS 1 MAY 1963



Number of stored particules (N)

Touschek's interpretation and calculation (3)

$1/\tau \sim N/V$ (density in number within the bunch)

→ intra-bunch process (collective effect)

→ this process allows the measurement of the bunch volume

Touschek effect paper

LIFETIME AND BEAM SIZE IN A STORAGE RING

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and

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B. Touschek
Istituto Nazionale de Fisica Nucleare, Roma, Italy
(Received 1 April 1963)

We want to report on measurements of the lifetime of stored beams carried out with the Frascati e^+e^- storage ring (AdA) at the Laboratoire de l'Accelerateur Lineaire of the Science Faculty at Orsay. The design parameters of the ring have already been published[1] as well as preliminary results about operation at a low stored intensity.[2] The use of the Orsay linac as injector allowed the storage of a big enough number of electrons to observe the following effects.

$\alpha(E)$ has a maximum at about 70 MeV. Below this energy the lifetimes increase very rapidly. Lifetime measurements below 50 MeV were not carried out because of the difficulties in revealing the synchrotron radiation at such low energies.

The lifetime of a given beam is independent of the presence of the other, so that the effect described must be interpreted as a "self-interaction" of the particles in each bunch.

A theoretical explanation of the effect can be

Bunch size

- σ_{radial} was measured optically → σ_{radial} = 0.5 mm
- $\sigma_{longitudinal}$ was inferred from the measured lifetime due to quantum fluctuations → σ_l ~7 cm

  (@ E = 195 MeV & V_{RF} = 5.5 kV)

- $\sigma_{vertical}$ was the only big unknown. From the Touschek effect $\sigma_{vertical}$ ~20 μ, while $\sigma_{vertical}$ expected from synchrotron radiation recoil effects was only 2 μ.

Fall 1963 - Spring 1964: first observation ever of e^+- e^- collisions in a storage ring

$e^+ + e^- \longrightarrow e^+ + e^- + \gamma$ ray

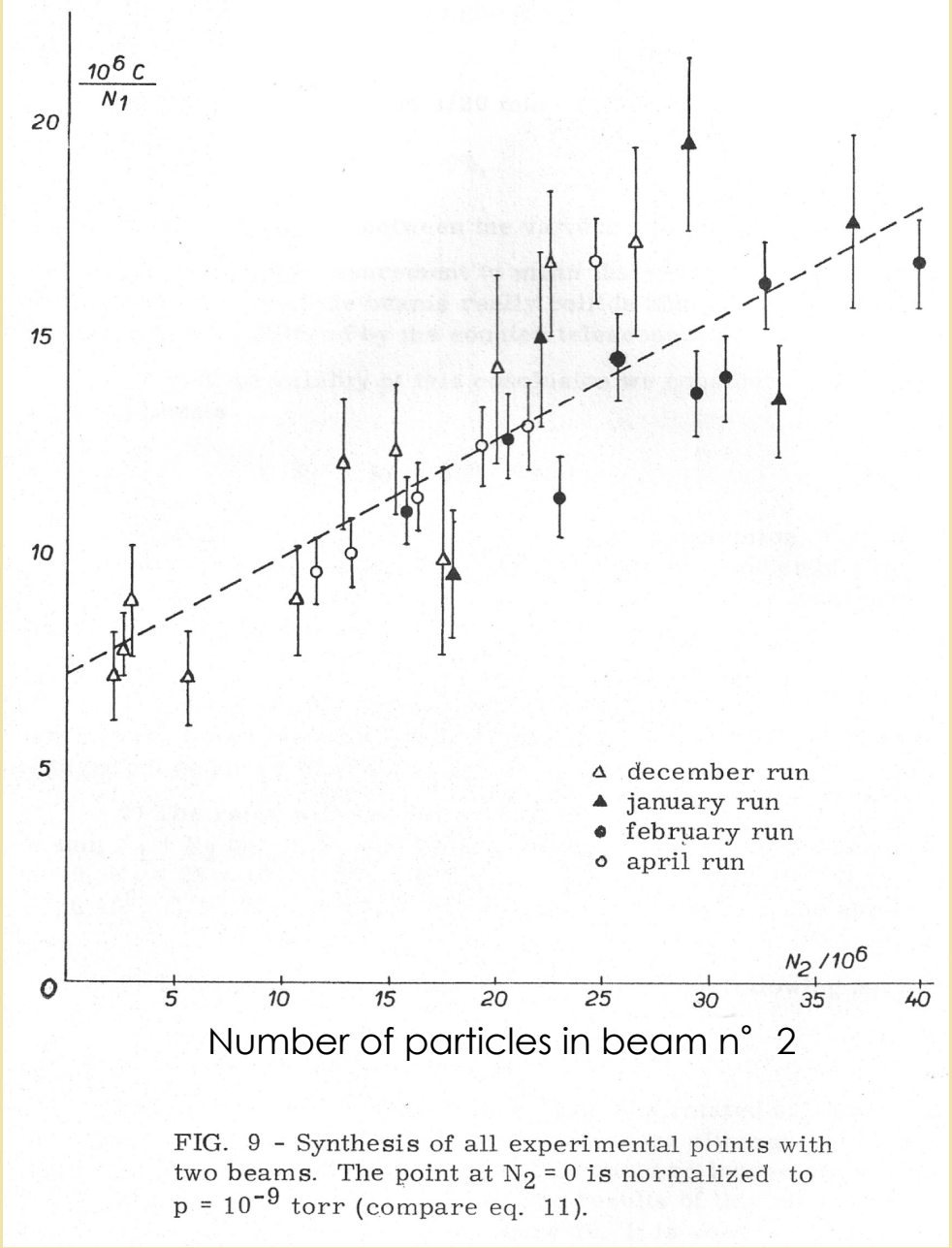

FIG. 9 - Synthesis of all experimental points with two beams. The point at $N_2 = 0$ is normalized to $p = 10^{-9}$ torr (compare eq. 11).

Second and last article published by the AdA collaboration

C. BERNARDINI, *et al.*
16 Dicembre 1964
Il Nuovo Cimento
Serie X, Vol. 34, pag. 1473-1493

Measurements of the Rate of Interaction between Stored Electrons and Positrons (*).

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J. HAISSINSKI and P. MARIN
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B. TOUSCHEK
Istituto Nazionale di Fisica Nucleare - Sezione di Roma

(ricevuto il 16 Luglio 1964)

Summary. — The paper describes a series of experiments carried out with the purpose of observing the γ-rays produced in the collision between stored beams of electrons and positrons. The interaction rate has been measured and was found to be in good agreement with the hypothesis that there is a complete overlap between the two beams and that the dimensions of the beams are those calculated from the lifetime effect.

Main storage ring physics obtained with AdA

✓ Check of the calculation of the beam scattering effects by the residual gas

✓ Theory of the RF lifetime due to synchrotron radiation quantum fluctuations is OK

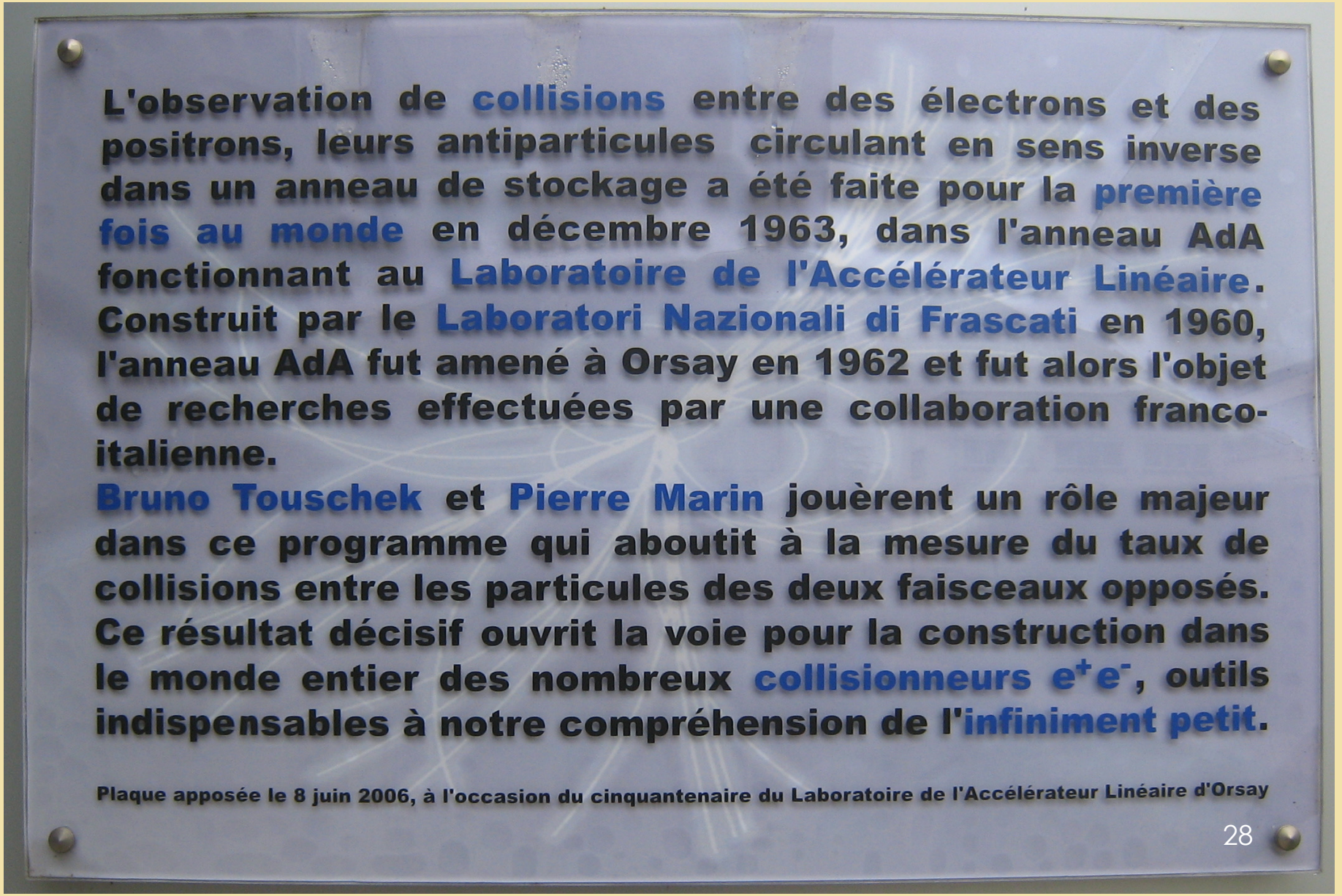
✓ Discovery and theory of the Touschek effect

✓ Evidence for the mechanism that determines the stored bunch height

✓First evidence ever of collisions between opposite stored beams

Basic underlying concept of the e+e- colliders was esablished

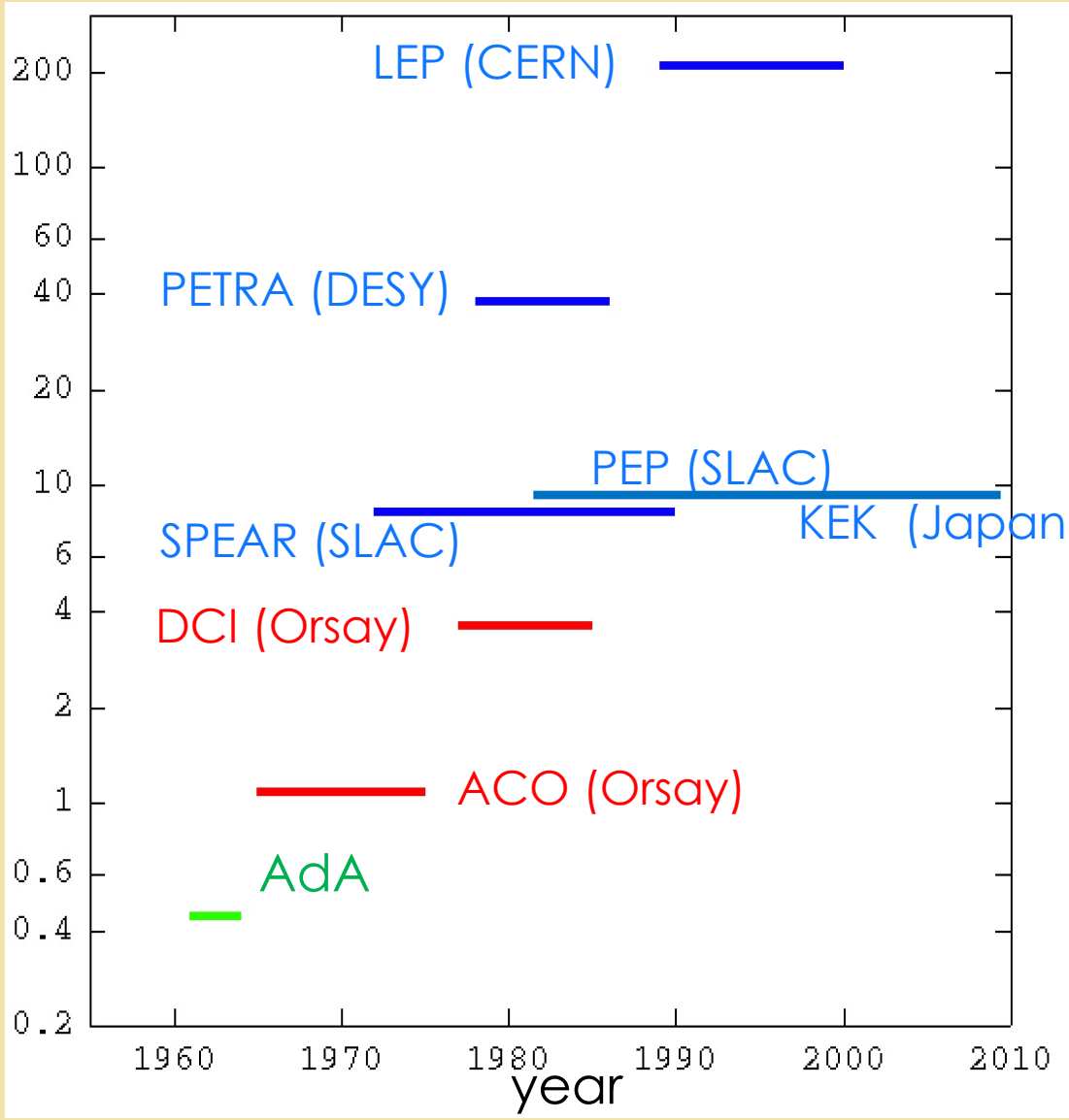
Commemorative plaque at the LAL entrance



The scientific impact of the coming of AdA in Orsay

Three storage rings were built at Orsay : ACO, DCI and Super-ACO.

PhD students trained at LAL pursued their research at other e+ e- colliders abroad (USA, Germany, CERN, Japan) with major responsabilities given to them.



Thank you for your attention