50 years of the PS

G. Plass

This exciting story begins on 24th of November 1959 at 19.35

- FIRST ACCELERATION IN AN AGS TO DESIGN ENERGY - 25 GeV

- HIGHEST PARTICLE ENERGY EVER ATTAINED BY ACCELERATOR

Reminder of a 60th Anniversary

On the 9th of December 1949 at a Congress on European Culture at Lausanne a motion by L. de Broglie was read, suggesting to establish

….a laboratory or institution where it would be possible to do scientific work, but somehow beyond the framework of the participating states.

……

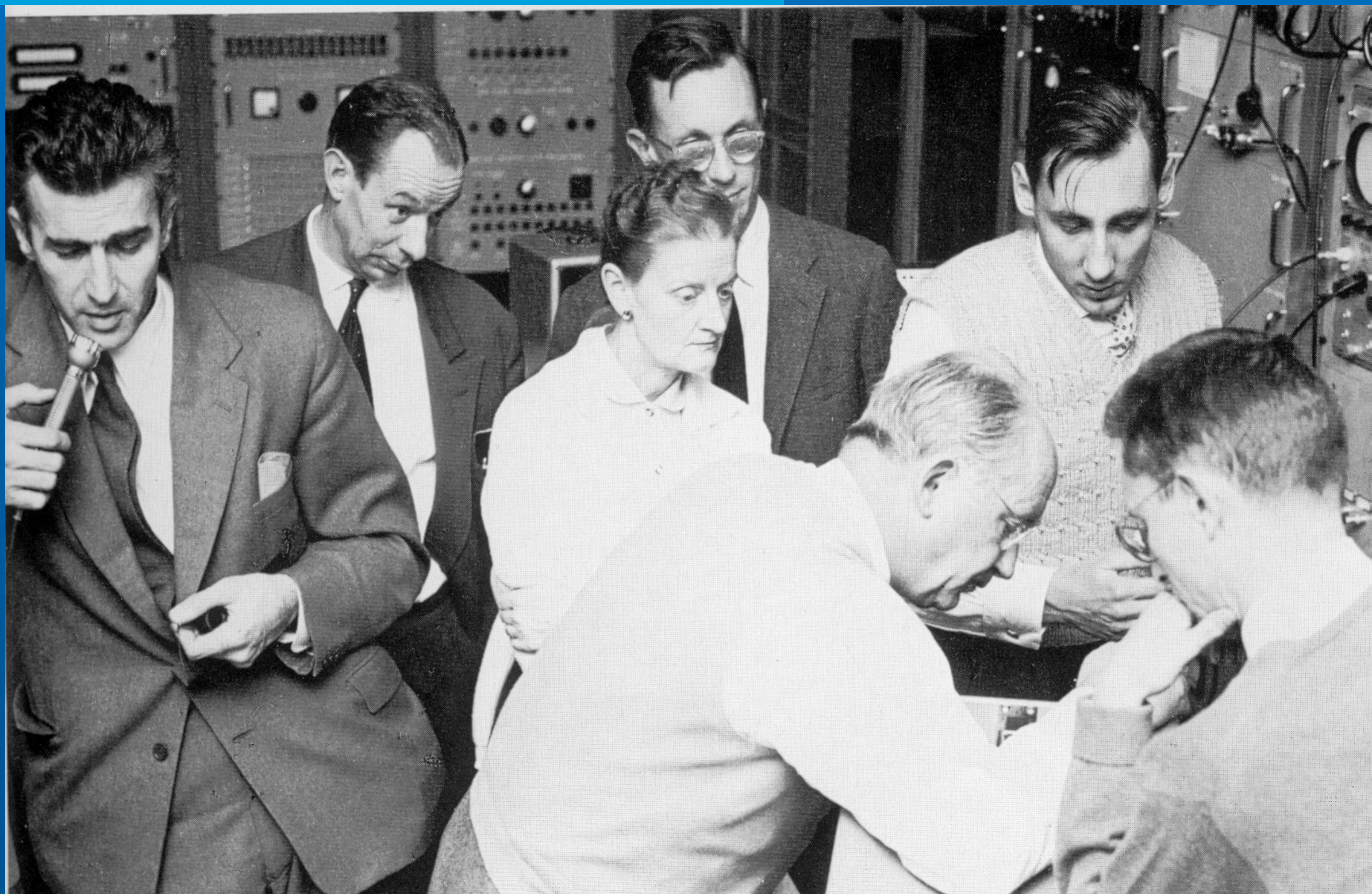
Three Steps Towards CERN and the PS

P. AUGER Mandated by UNESCO in **June 1950** to set up a Group of Experts who should work out a proposal for a nuclear physics laboratory; the proposal was submitted in **May 19**

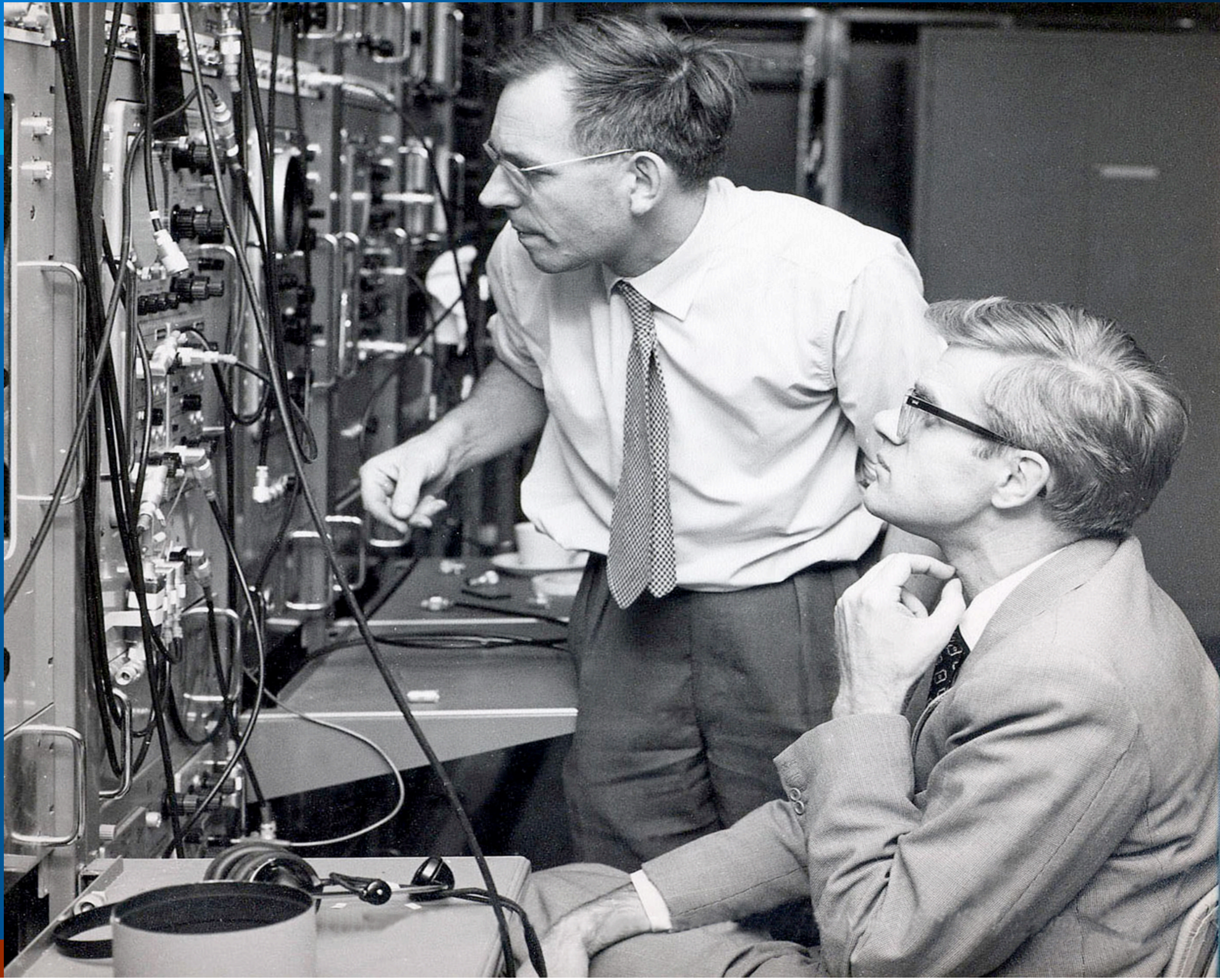
E. AMALDI Nominated in **May 1952** by the Member States Secretary-General of a 'Provisional Organization for Nuclear Research'.

O. DAHL Nominated in Head of the 'PS Group'. A visit to Brookhaven (Dahl, Goward, Wideröe). The invention of 'strong focusing' was disdussed. Convinced by the Group, **Council in October 1952 gave** green light to base studies upon this new principle.

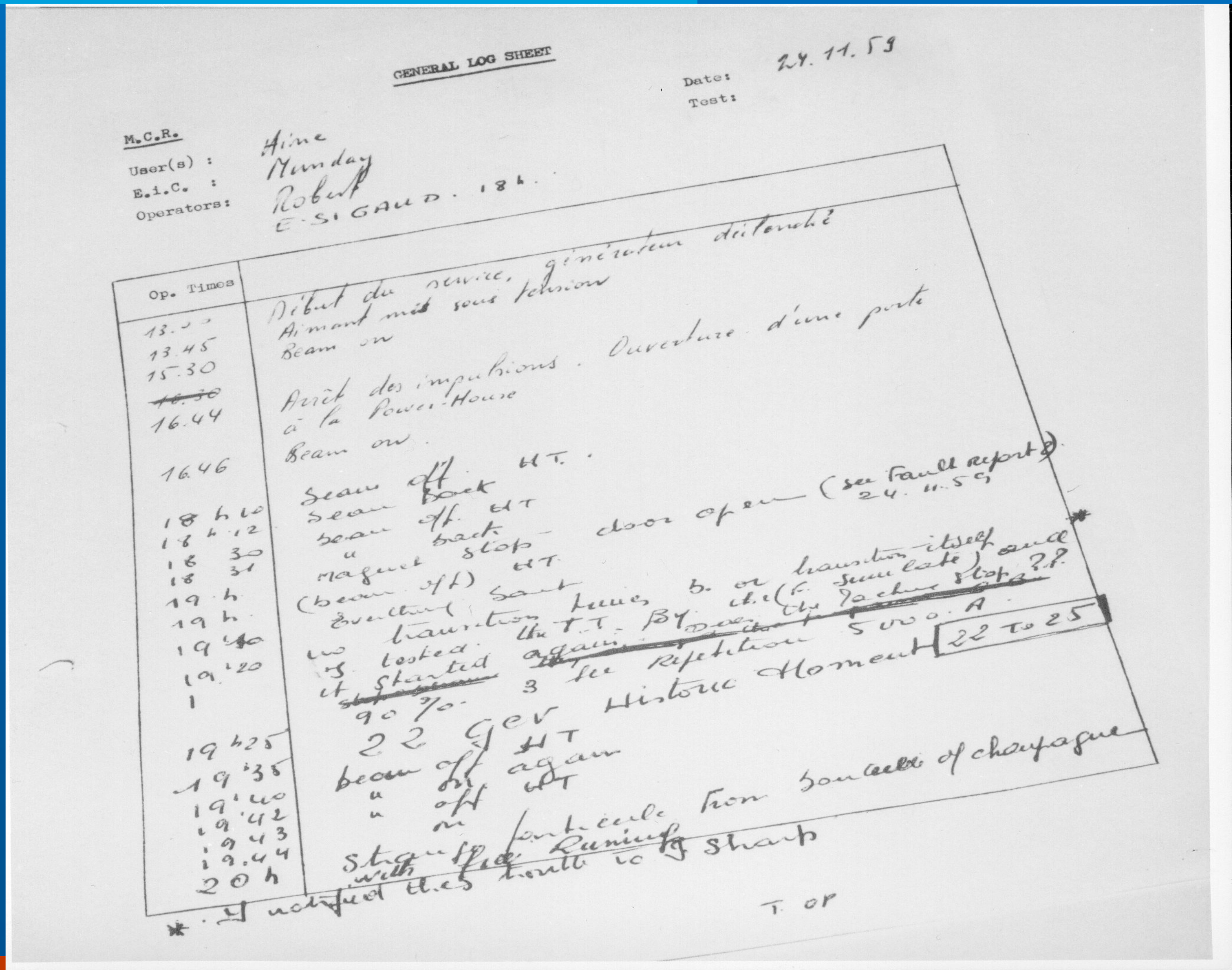
24th NOVEMBER, 1959 ABOUT 7.00 P.M.
PS CENTRAL BUILDING - RF CONTROLS



IN THE MCR: MERVIN HINE and KJELL JOHNSEN



A PAGE FROM THE LOGBOOK


GENERAL LOG SHEET

Date: 24.11.59

Test:

M.C.R. Hine

User(s) : Munday

E.i.C. : Robert

Operators: E. SIGAUD. 18h.

Op. Times	
13.00	Début du service, générateur déclenché
13.45	Aimant mis sous tension
15.30	Beam on
~~16.30~~ 16.44	Arrêt des impulsions. Ouverture d'une porte à la Power-House
16.46	Beam on.
	Beam off HT.
18h10	Beam back
18h12	Beam off. HT
18 30	beam back
18 31	magnet stop - door open (see fault report 24.11.59)
19h	(beam off) HT
19h	Eventually sent [illegible] transition time, b. or transition itself and
19h10	[illegible] transition the T.T. By [illegible] (f. simulate) [illegible] stop ??
19h20	[illegible] tested. [illegible] again [illegible] Repetition 5000. A
	it Started 3 Sec Historic Moment 22 to 25
	90 %.
	22 GeV
19h25	HT
19h35	beam off again
19h40	" on HT
19h42	" off
19h43	" on
19h44	Stopped for particle from bouteille of champagne
20h	with the Running Staff

* [illegible] notified the [illegible] to [illegible]

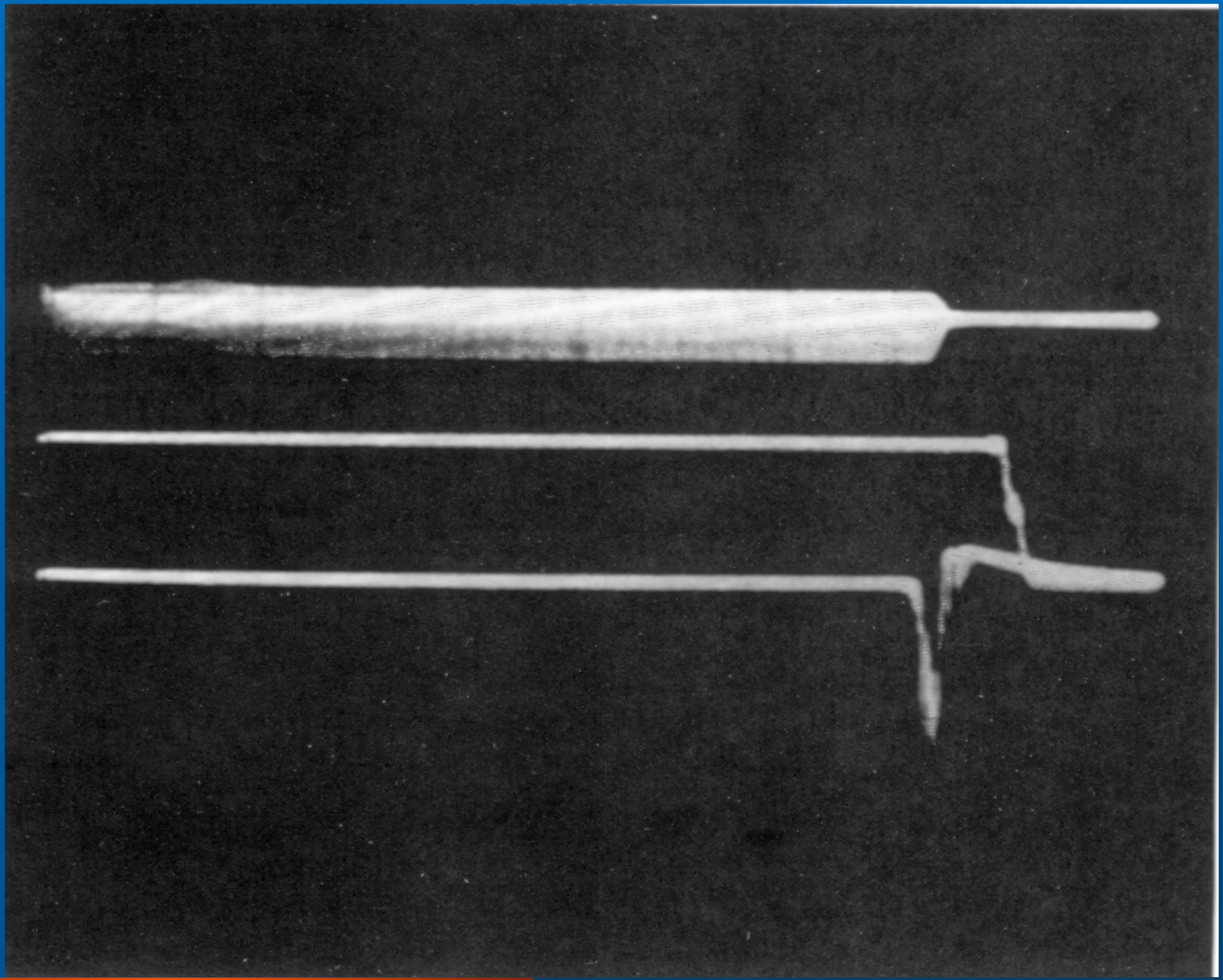
T. OP

THE PS HAS COME TO LIFE

JOHN ADAMS,

25 NOVEMBER 1959

THE FIRST SIGN OF LIFE



PS start-up: First quaterly report (nr. 1/1960)

A quotation from page 7 :

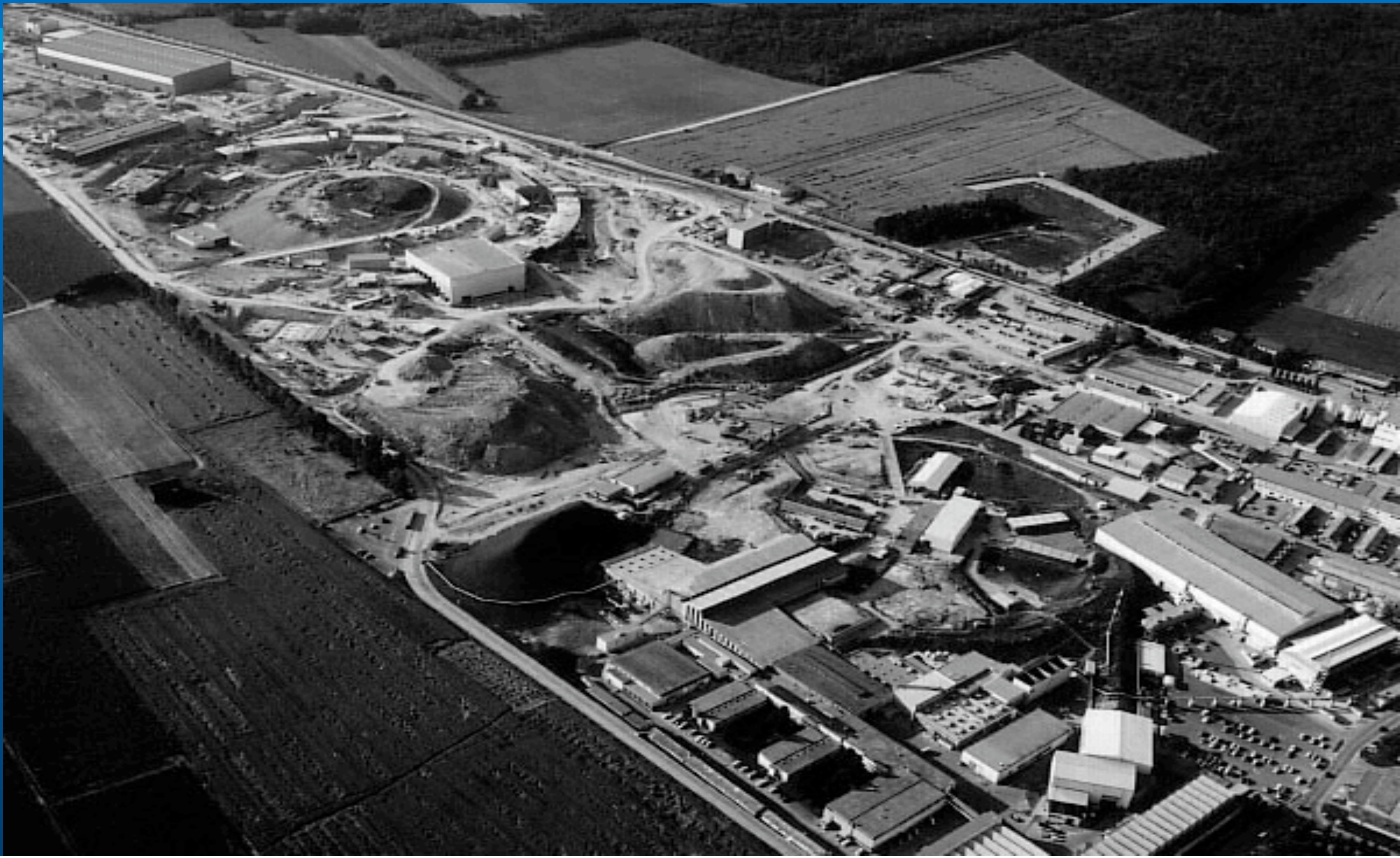
Thus the situation in December 1959 was that **the synchrotron had worked successfully** up to its design energy, and already beyond its design current, but with its builders and operators in **a state of almost complete ignorance on all the details** of what was happening at all stages of the acceleration process.

(An illustration of the state of technology at the time.)

THE PS FINISHED, 1960

1969: The PS and its EXPERIMENTAL AREAS + the ISR site

PS 10 yrs



PS EXPERIMENTAL AREAS

1960 SOUTH and NORTH HALLS

1963 EAST HALL with HBC BUILDING

1966 SOUTH EAST (neutrino) AREA: Gargamelle
later: g - 2 ring, ICE ring

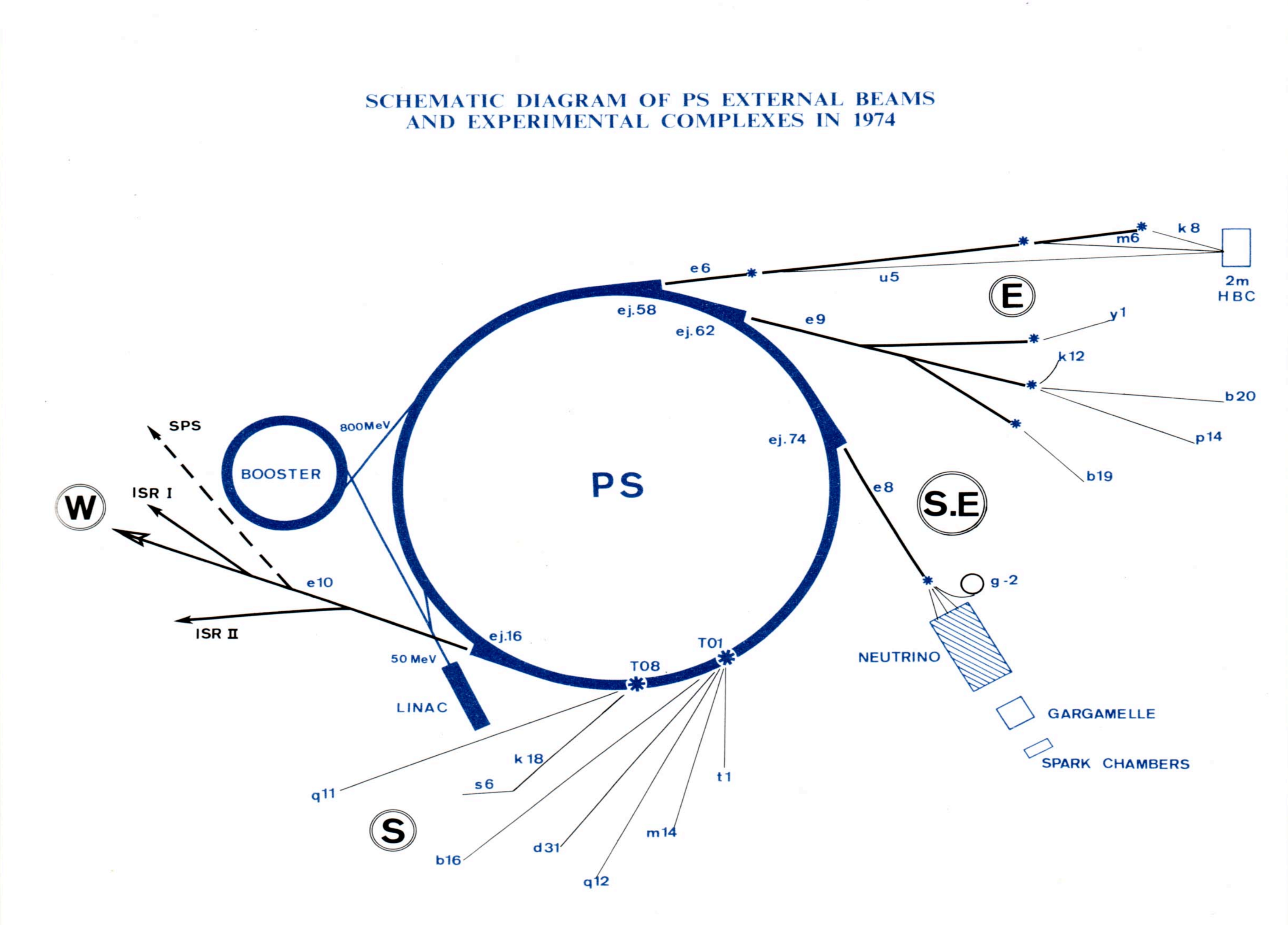
1969 WEST HALL with BEBC
turned over to SPS beams in 1976

1990 ISOLDE (after closure of SC)

2000 nTOF in TT1

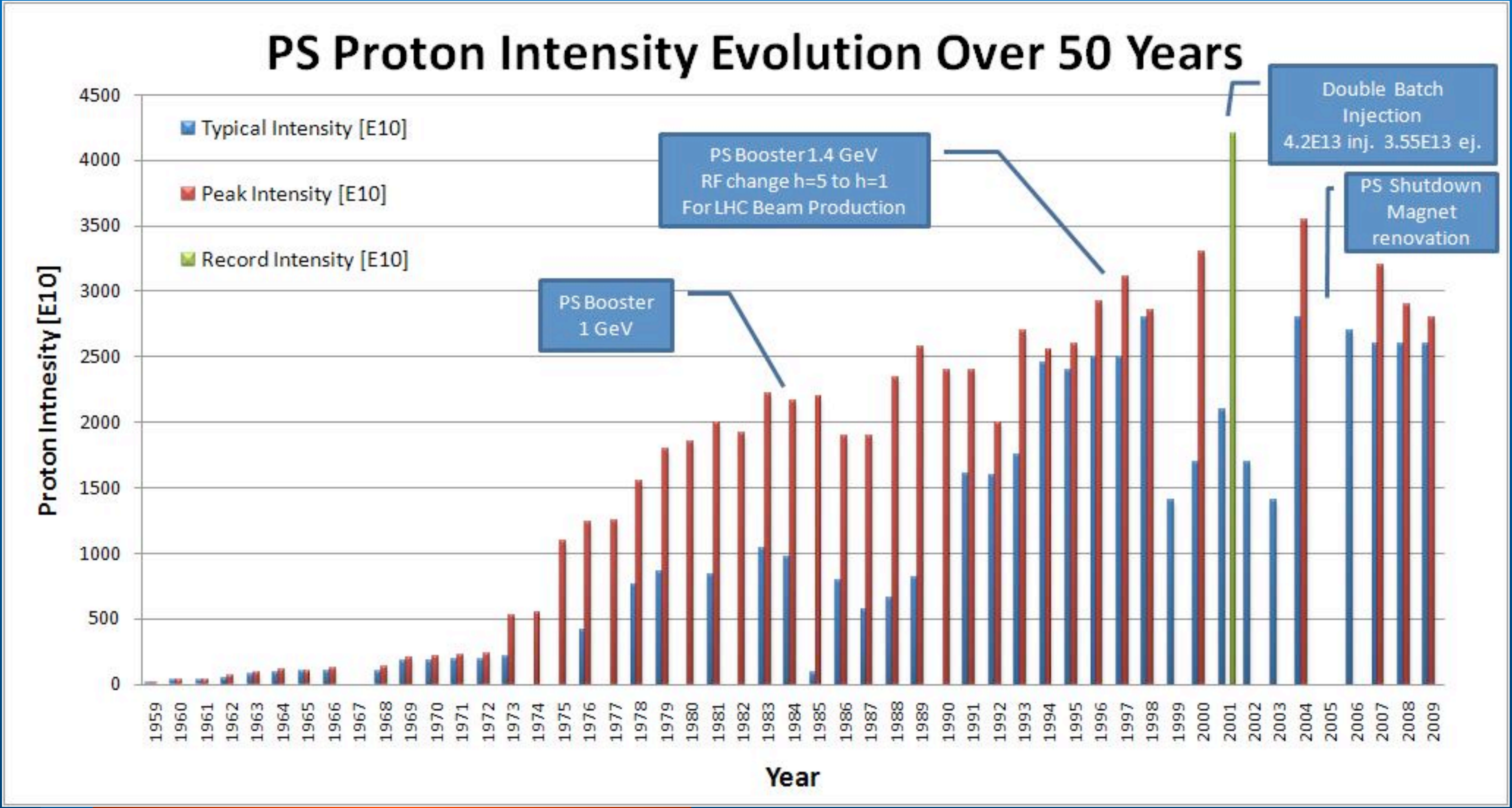
BEAMS FROM THE PS - 1974

FAST PROTON BURSTS AND SLOW SPILLS --- SECONDARIES FROM INTERNAL TARGETS



THE BASELINE:

THE HIGH



DURING THE SEVENTIES

A CHANGE OF PARADIGM

AFTER 20 YEARS OF INTENSIVE EXPLOITATION
THE ERA OF BUBBLE CHAMBERS APPROACHED IT

THE MANY EXPERIMENTS ON SECONDARY BEAMS
GAVE WAY TO LARGE COLLABORATIONS USING
MODERN (MULTIWIRE et al) CHAMBERS
While the demand for secondary beams diminished,

COLLIDERS BECAME THE TOOL OF CHOICE TO ELUCIDATE THE FUNDAMENTAL PROBLEMS:

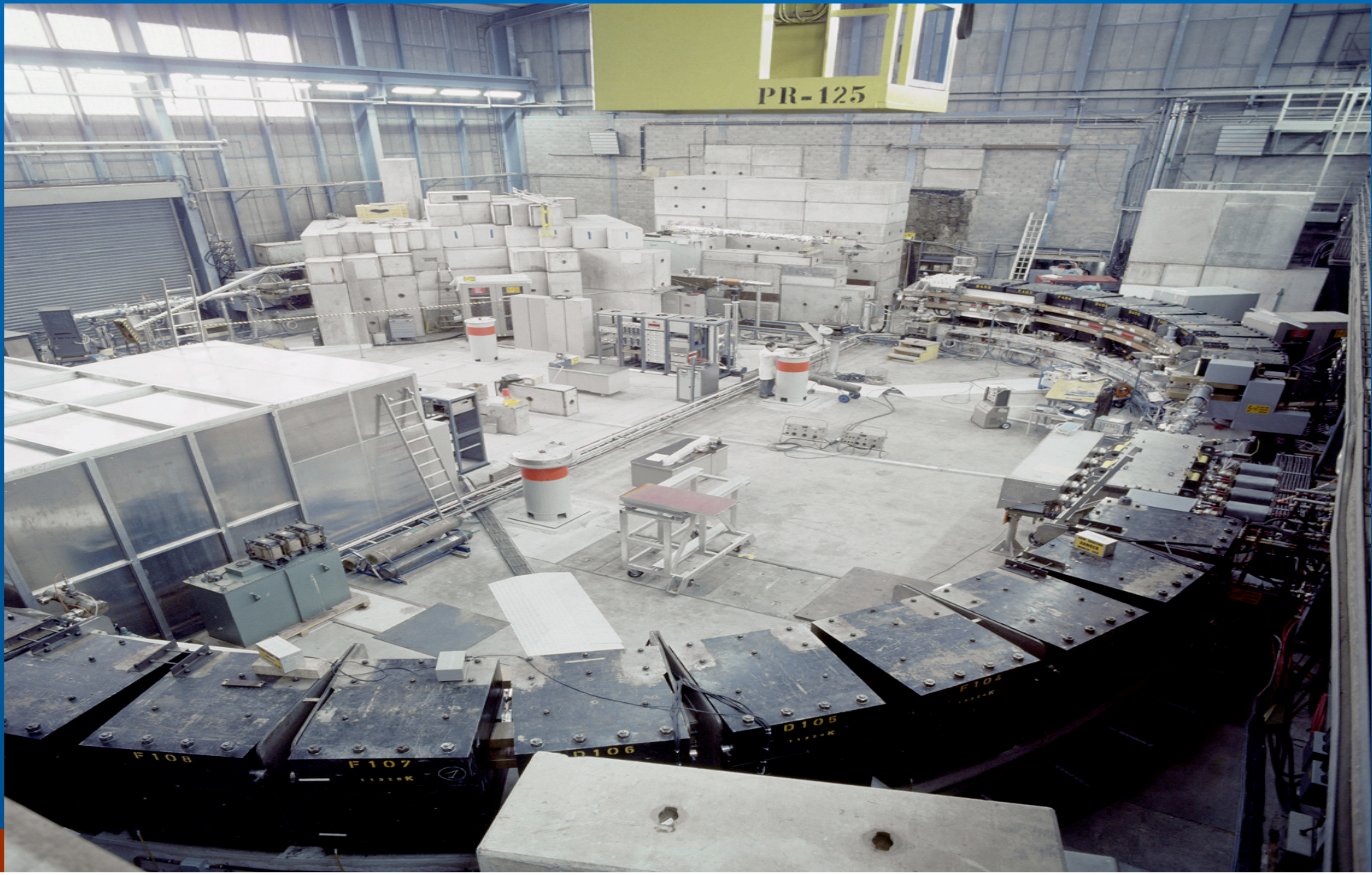
ISR(the frontrunner): proof of the principle
P-Pbar in the SPS: a most exciting proposition
LEP: the largest electron synchrotron
LHC: reaching for the limits

NEW BEAMS ==> NEW DESTINATIONS

HIGH INTENSITY PROTONS	1971	ISR
	1976	SPS
	1980	ANTIPROTON PRODUCTION
	2008	LHC
ANTIPROTONS	1981	ISR
	1981	SPPbarS (at 26 GeV/c)
	1983	LEAR (at 0.6 GeV/c)
Electrons/Positrons	1989	LEP
LIGHT IONS	1976	ISR
HEAVY IONS	1994	SPS
	2010	LHC

LAUNCHING THE P-Pbar COLLIDER

- C. RUBBIA'S SEMINAL SEMINAR IN MARCH '76
  - ==> CURIOSITY AND EXCITEMENT AMONGST STAFF
  - ==> EVALUATION OF ELECTRON- AND STOCHASTIC COOLING
- 1977: CONSTRUCTION OF THE 'ICE' BEAM COOLING EXPERIMENT

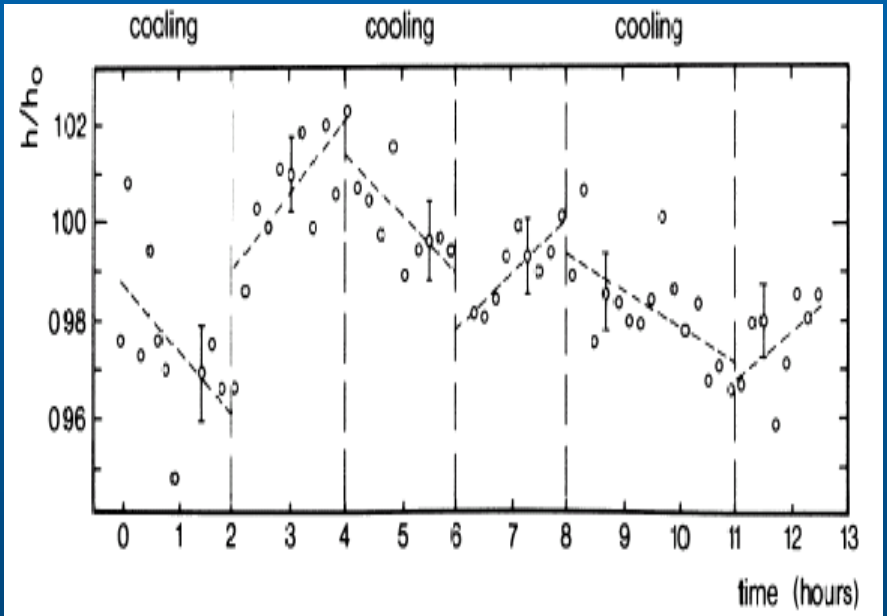


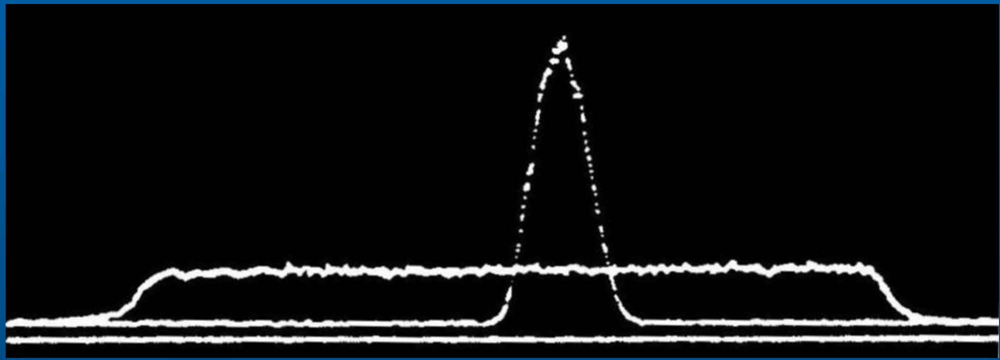
DEMONSTRATIONS OF STOCHASTIC COOLING

PROPOSED BY S.v.d.MEER ALREADY IN 1968

IN THE ISR (1974)

IN THE ICE RING (1978)

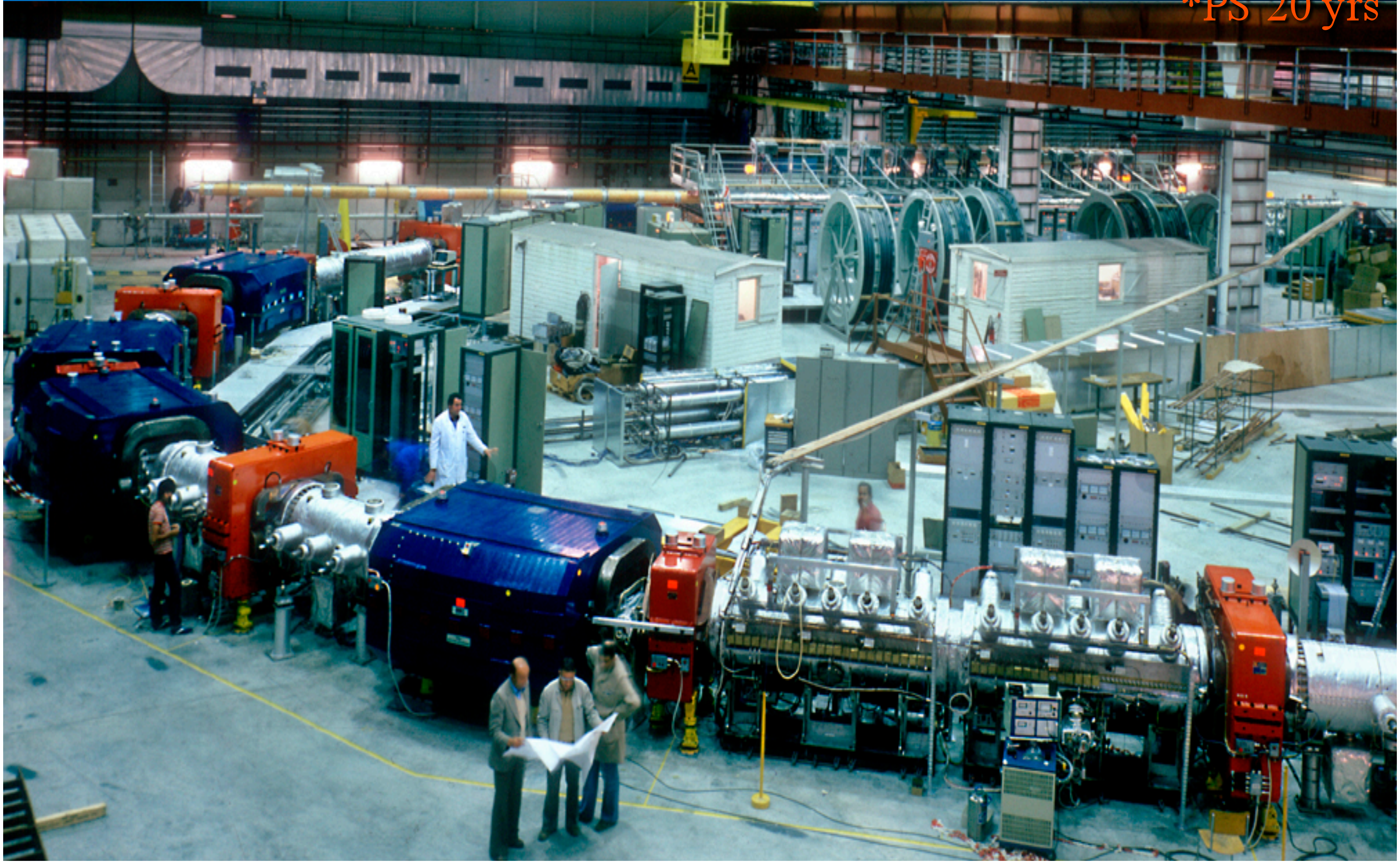




THE ANTIPROTON ACCUMULATOR

START OF CONSTRUCTION: 1979

*PS 20 yrs



Producing ANTIPROTONS for the SPPbarS

A HIGHLIGHT in the History of the PS

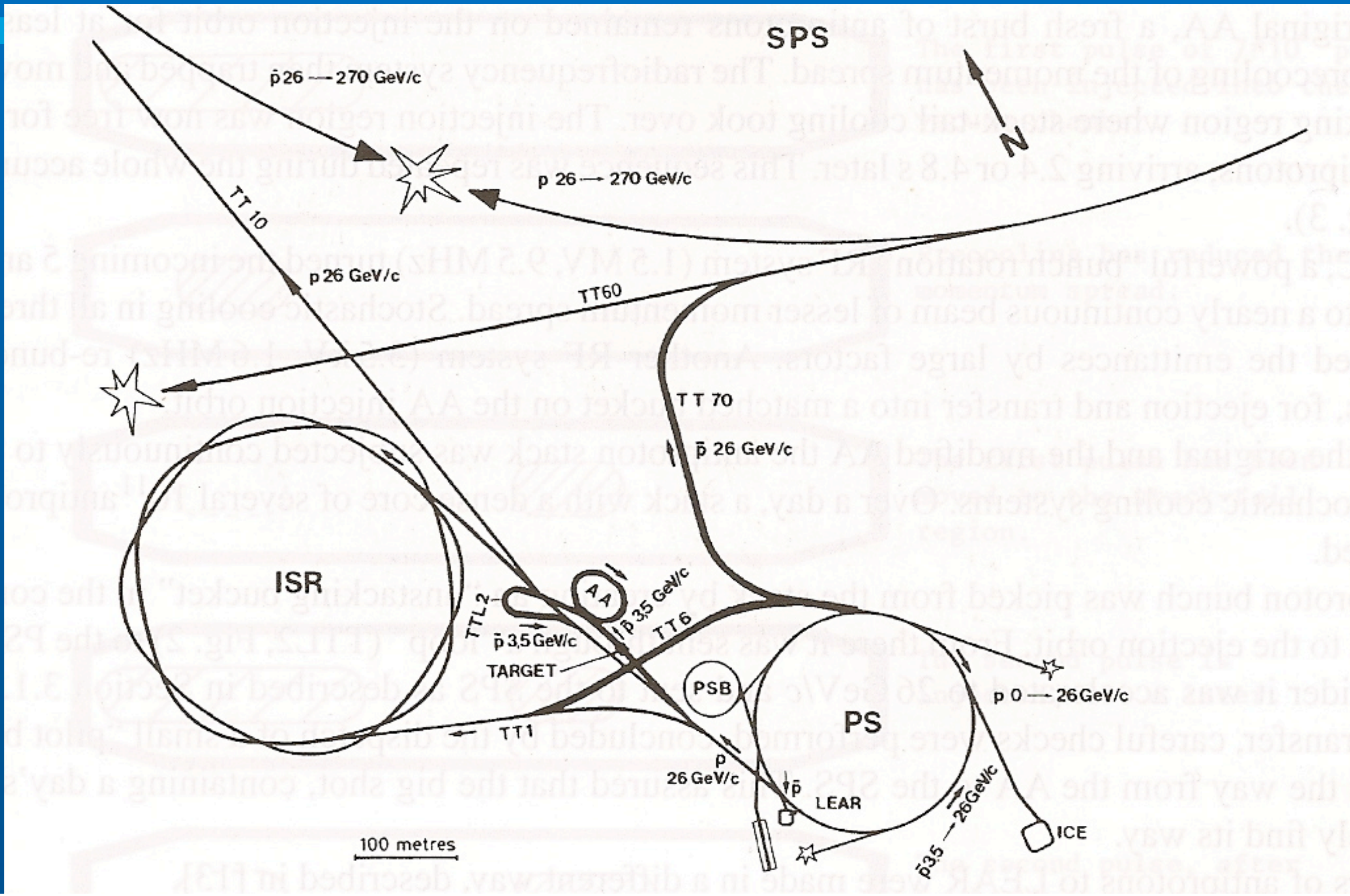
- Acceleration of highest intensity proton beam in the PS to 26 GeV/c and Merging 20 bunches into 5

  ==> matching the size of Antiproton Accumulator
- Ejection onto target through the ISR transfer tunnelTT2
- Horn-type focusing of pbar at 3.5 GeV/c

- Accumulation and cooling in AA for about 1 day => 2x10e11 pbar

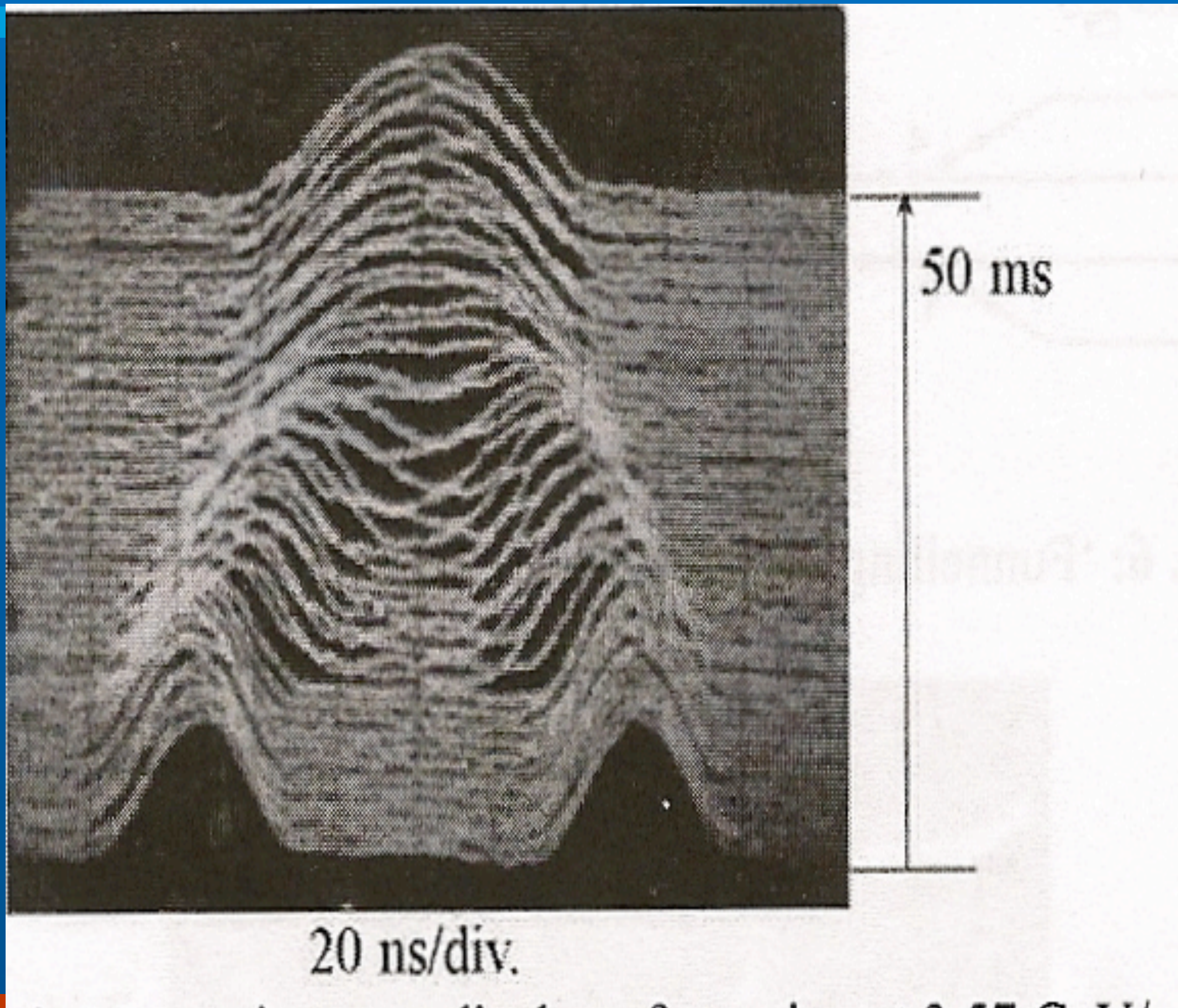
- 3 retransfers of single bunches of pbar to PS for acc'n to 26 GeV/c and bunch rotation (=> bunch length 4 ns)
- Transfer to SPS, to collide with 3 proton bunches, prepared beforehand

THE ANTIPROTON FACTORY



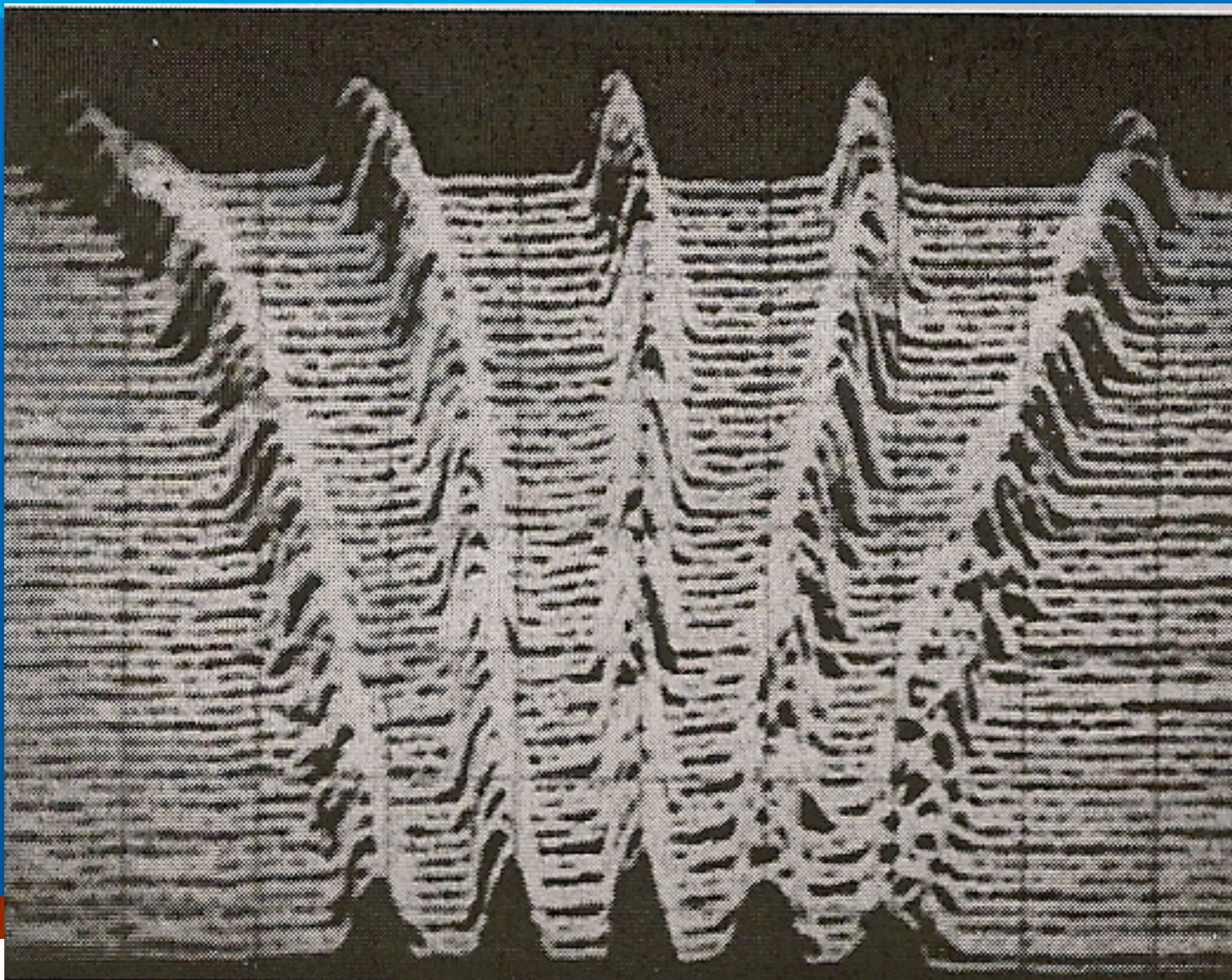
BUNCH MERGING IN THE PS: DELICATE GYMNASTICS FOR THE RF

ACT 1: 20 => 10

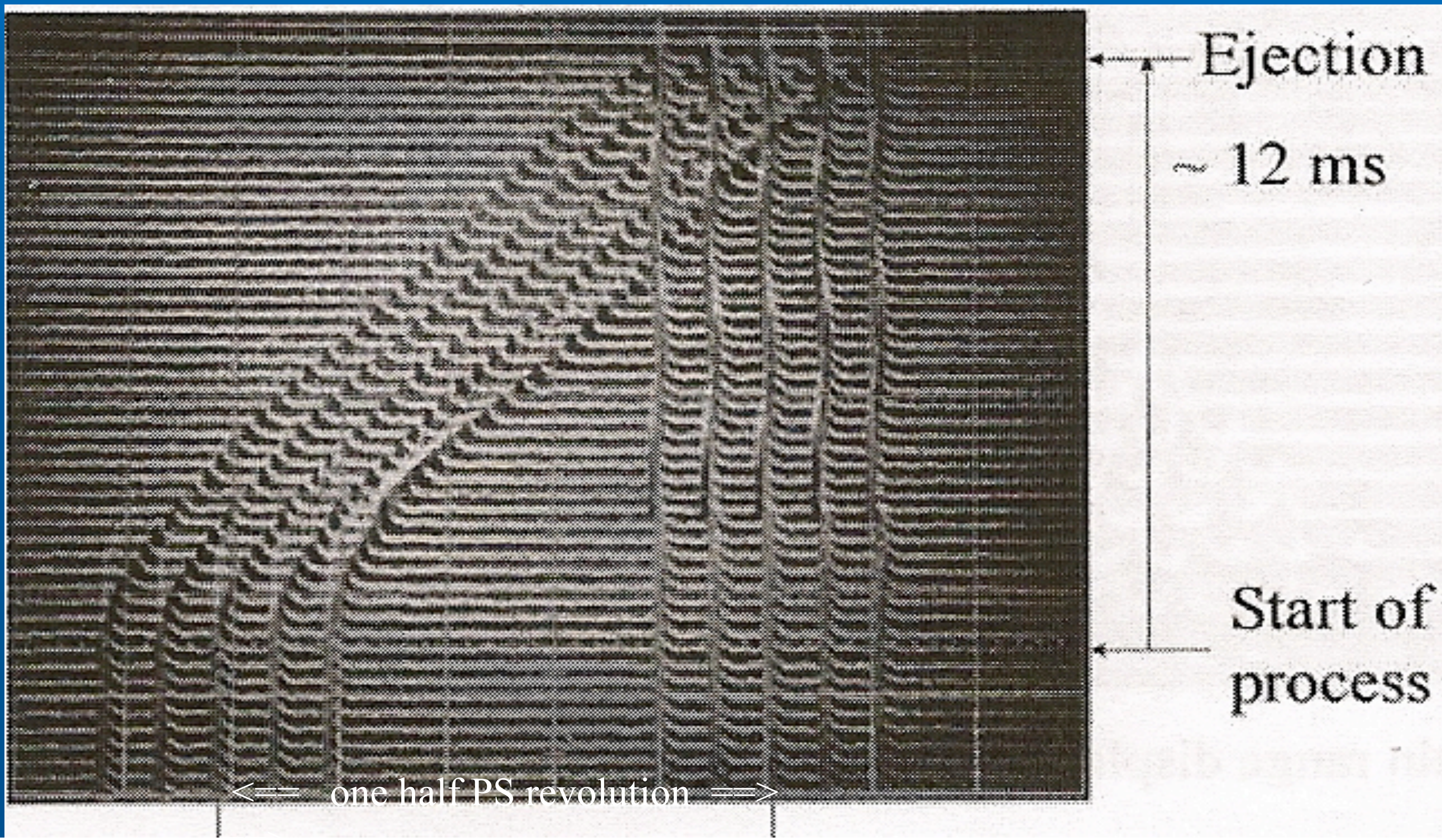


9: Mountain range display of merging at 3.57 GeV/c

BUNCH MERGING IN THE PS:
ACT 2: CREATION OF 2 GROUPS OF 5 BUNCHES



BUNCH MERGING IN THE PS:
ACT 3: BRINGING BUNCH GROUPS TO OVERLAP



NEW BEAMS ==> NEW DESTINATIONS

HIGH INTENSITY PROTONS	1971 towards	ISR
	1976	SPS
	1980	ANTIPROTON PRODUCTION target
	2008	LHC
ANTIPROTONS	1981	ISR
	1981	SPPbarS (at 26 GeV/c)
	1983	LEAR (at 0.6 GeV/c)
Electrons/Positrons	1980/1 DECISION on LEP	
	1989	LEP
LIGHT IONS	1976	ISR
HEAVY IONS	1994	SPS
	2010	LHC

*PS 30 yrs

NEW BEAMS ==> NEW INJECTORS

INJECTORS OF THE PS

LINAC 2 (replacing the original linac 1) and
BOOSTER (injection energy → 0.8 → 1.4 GeV)

ANTIPROTON ACCUMULATOR (AA, AD)

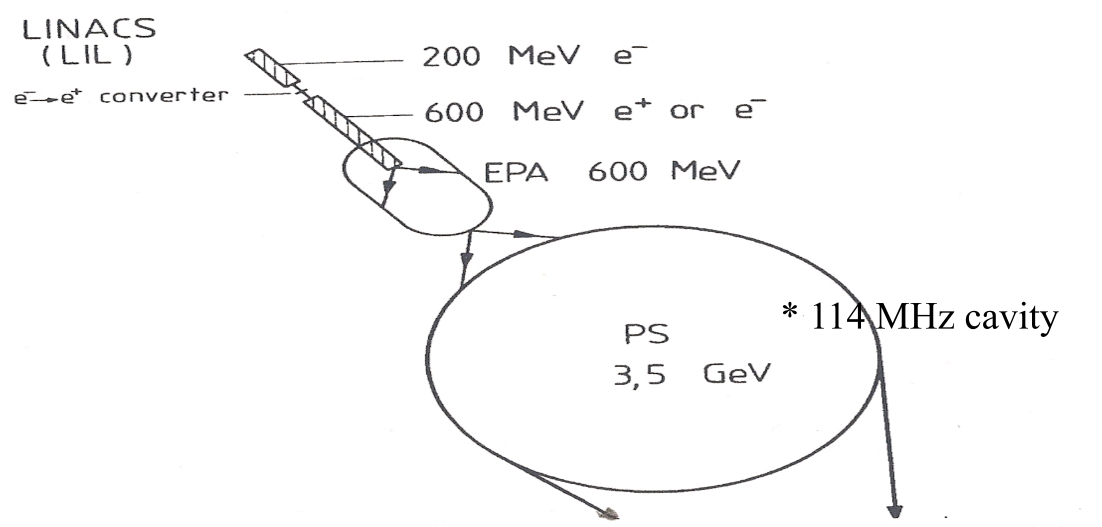
ELECTRON LINAC and
ELECTRON/POSITRON ACCUMULATOR

LINAC 3 (LEAD LINAC) and
LEIR (heavy ion accumulator)

LINAC 4 (under construction
X for future LHC luminosity upgrade)

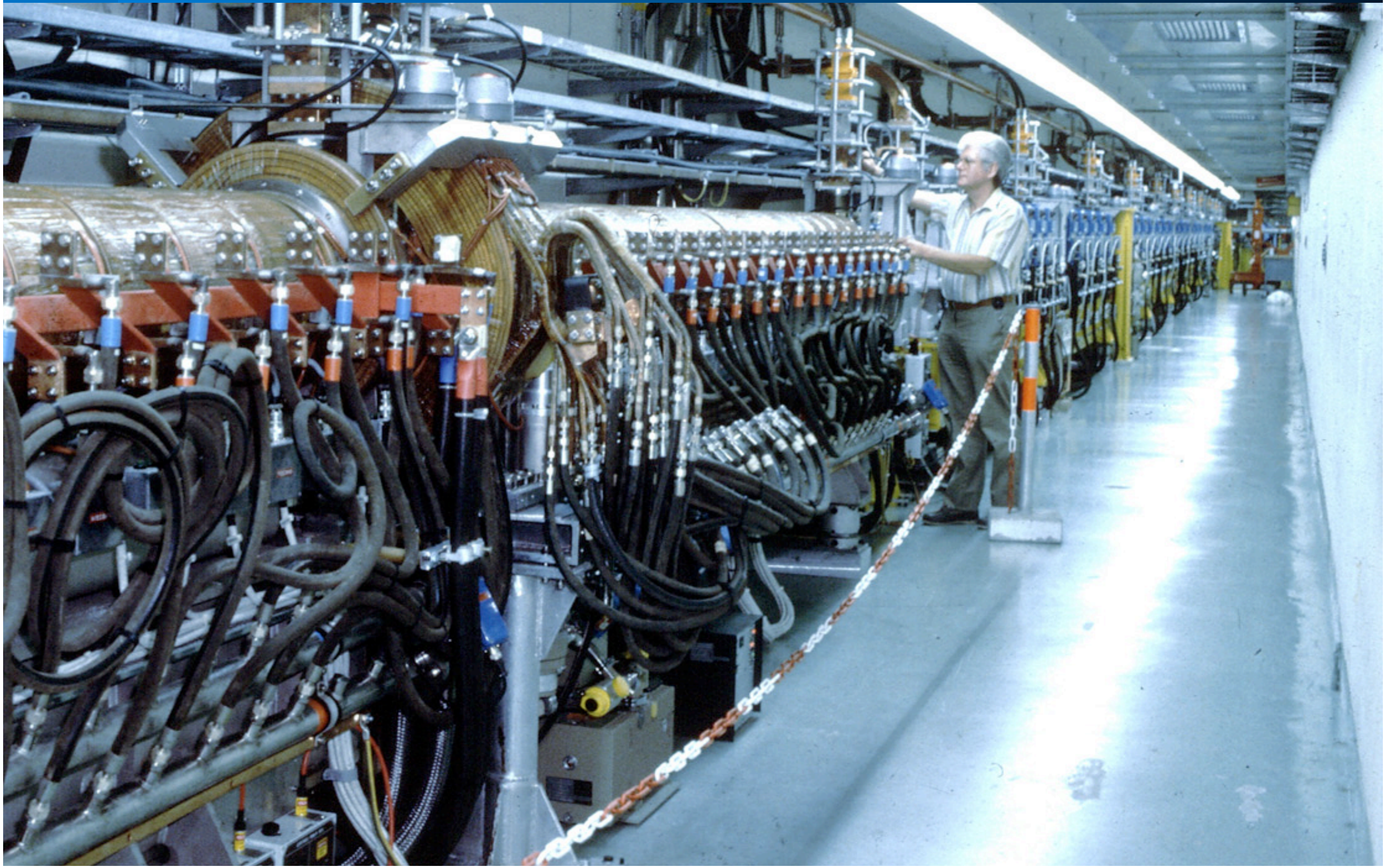
INJECTOR SYSTEM for ELECTRONS and POSITRONS

Built in collaboration with LAL at Orsay



BEAMS TOWARDS SPS

THE ELECTRON LINAC FOR LEP



THE PS BEING EQUIPPED ....

BEAM TRANSFER (EJECTION) SYSTEMS

FAST EJECTION (single bunch, single turn)

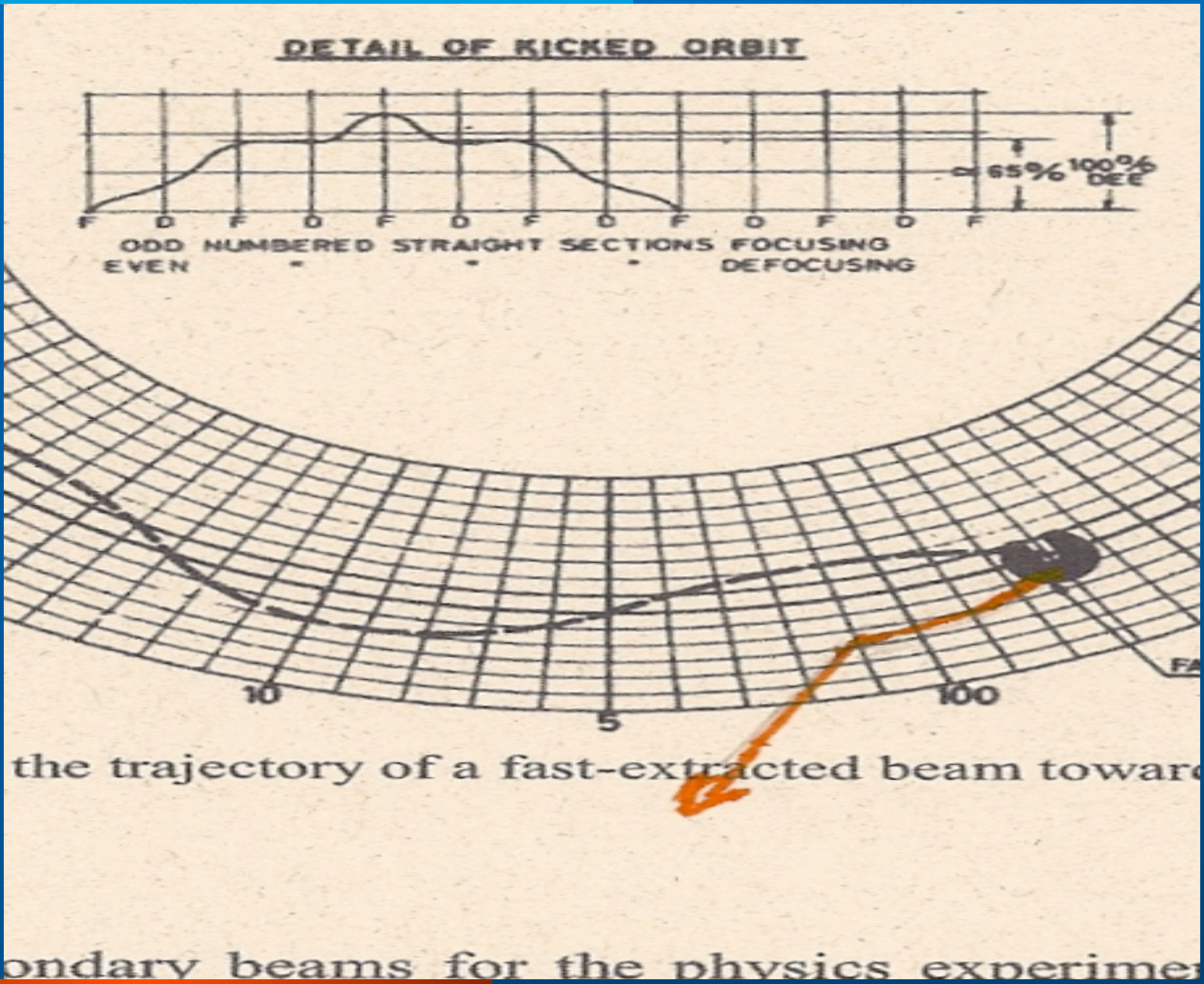
→ South hall neutrino beam (1963)
East Hall (for 2m chamber)
South East neutrino area
West Hall (for BEBC)
ISR
AA for pbar production

SLOW EJECTION(resonant, one third integer)

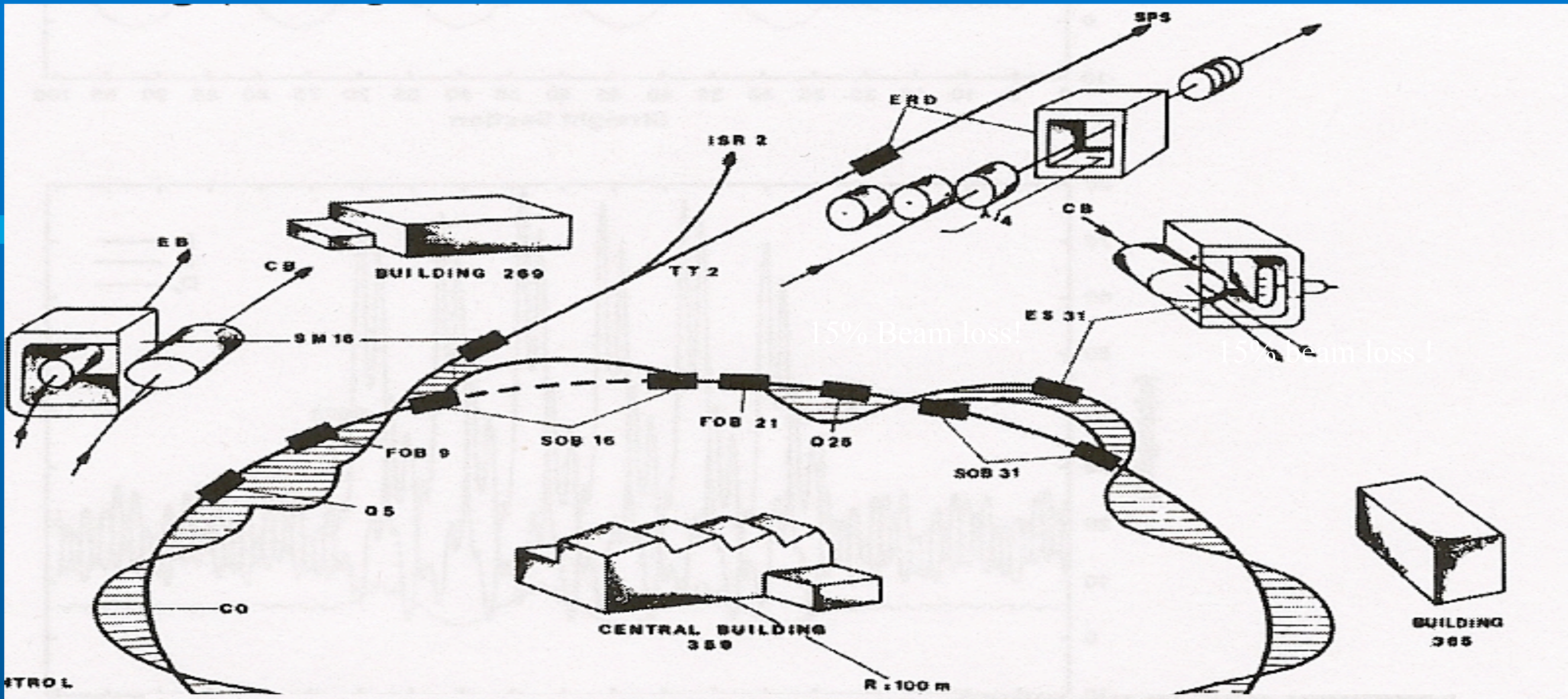
→ East Hall
West Hall

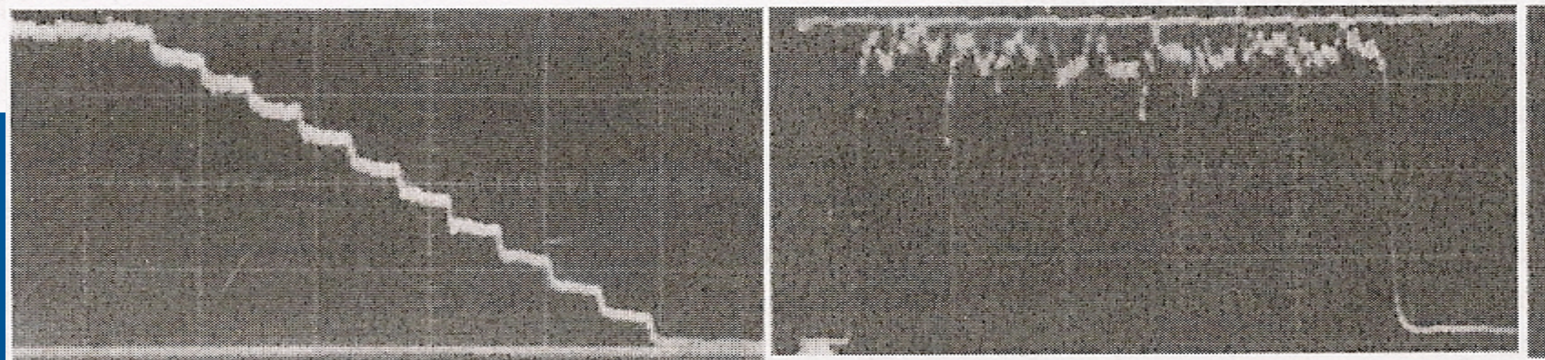
'CONTINUOUS' (for transfer to SPS)
'MULTI-TURN' (for high intensity beams for SPS + LHC)

A FIRST FAST EJECTION: SOUTH HALL NEUTRINO BEAM (1963)



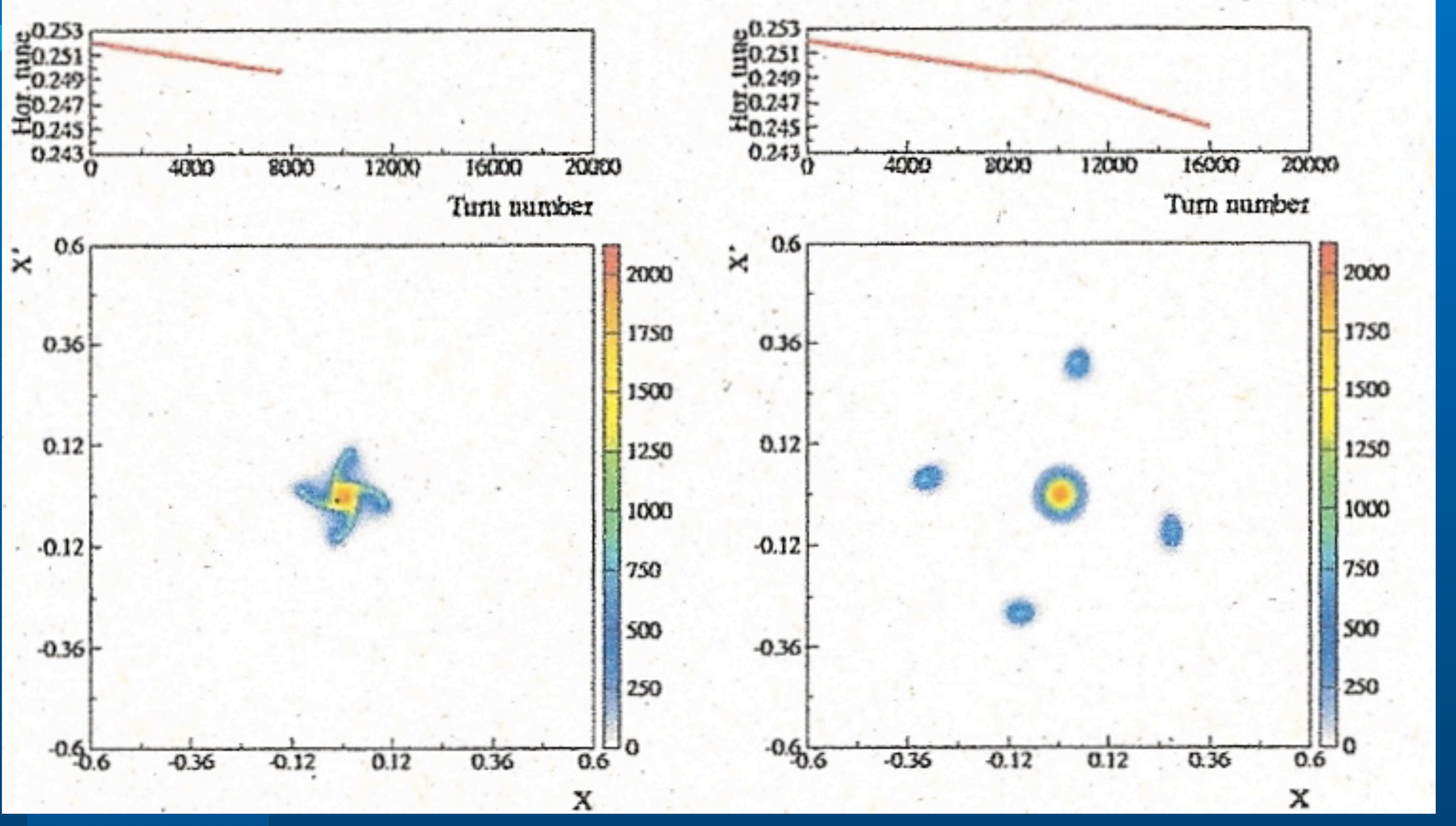
Beam Transfer towards SPS





NEW MULTITURN EXTRACTION:

BEAM SPLITTING ON STABLE PHASE SPACE ISLANDS ON A 4TH ORDER RESONANCE



NEW MULTITURN EXTRACTION:
BEAM SPLITTING ON STABLE PHASE SPACE ISLANDS ON A 4TH ORDER RESONANCE

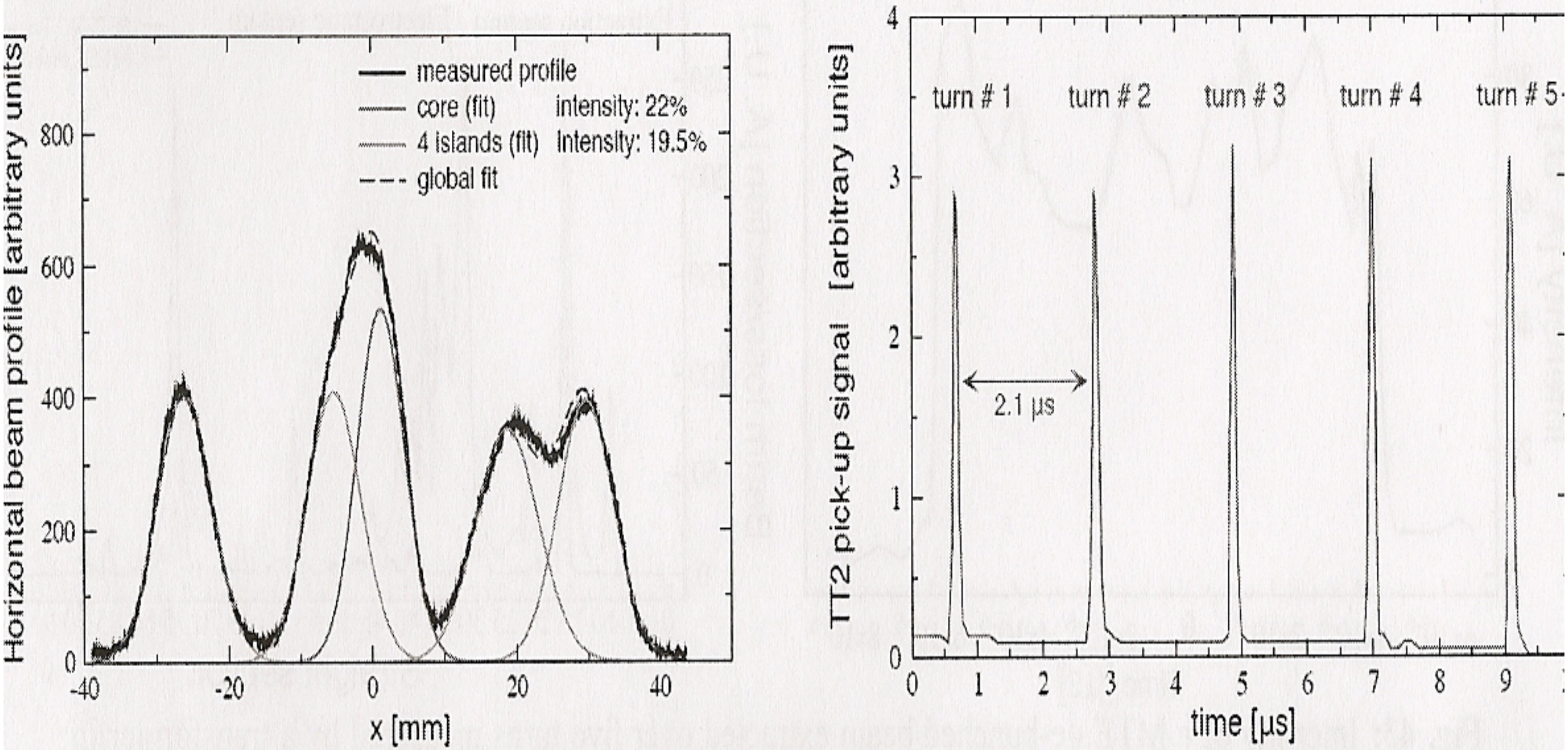
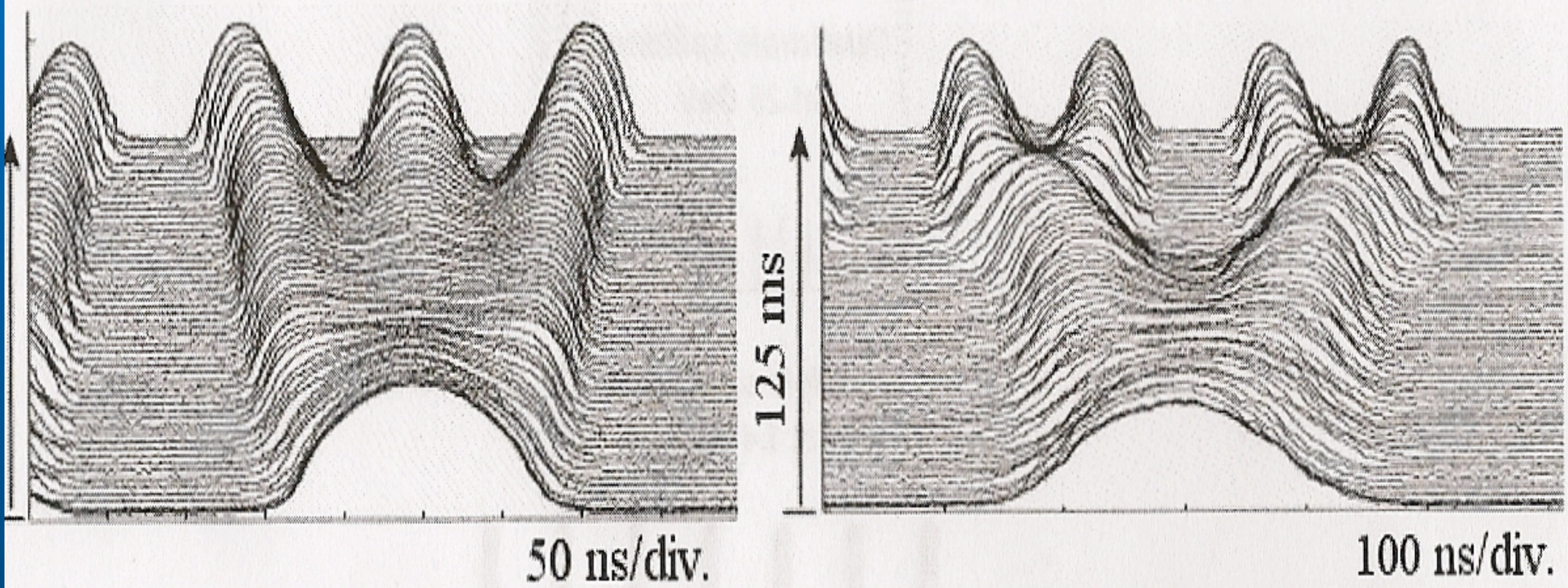


Fig. 42: Transverse profile of the beamlets before extraction (left) and intensity signal of a pick-up in

BUNCH SPLITTING: MORE GYMNASTICS FOR THE RF ….



a: Triple splitting at 1.4 GeV

b: Quadruple splitting at 25 GeV

THE PS BEING IMPROVED ……

PS RING IMPROVEMENTS

(1966) New main power supply (short cycle, flat 'tops')
(seventies) Thyristor power supplies replacing MG sets
(continuously) Improved vacuum system
(continuously) Improved beam observation
New aux. Magnets (orbit bump dipoles, quads, sext's)
Raising injection energy 0.05 → 0.8 (1975) → 1.0 GeV/c (1985)
→ 1.4 GeV/c (1998)
Qjump at transition
Radiation hardening (repair of 25 magnet units)
Drastic reduction of p losses

THE PS BEING EQUIPPED ………

Table 3

ACCELERATION RF SYSTEMS

New high power 10 MHz system
200 MHz cavities for SPS beams
114 MHz cavities for LEP beams
40 MHz and 80 MHz cavities for LHC p beams
13.3 MHz and 20 MHz cavities for LHC ion beams
sophisticated procedures → debunching, rebunching
change of harmonic number

BEAM DIAGNOSTICS

Beam position – electrostatic pick-ups
Beam current transformers
Beam profile – moving targets vs. beam current
Ionization monitor
Wire scanner – Be wire (fatigue problem)
Twisted carbon fibers
Phase-space tomography (1995)

THE PS CONTROLS being adapted………
TO NEEDS AND TO PROGRESS IN TECHNOLOGY

CONTROLS

Exposed to the extremely rapid progress of technology.
Sometimes two approaches to similar tasks did compete..
Initially electronics developed in-house for several years.

In 1967 an 8 kbyte IBM 1800 was acquired and used for automatic program sequencing.
In the seventies PDP 11 minicomputers were used for controls of subsystems and CAMAC modules for equipment controls.

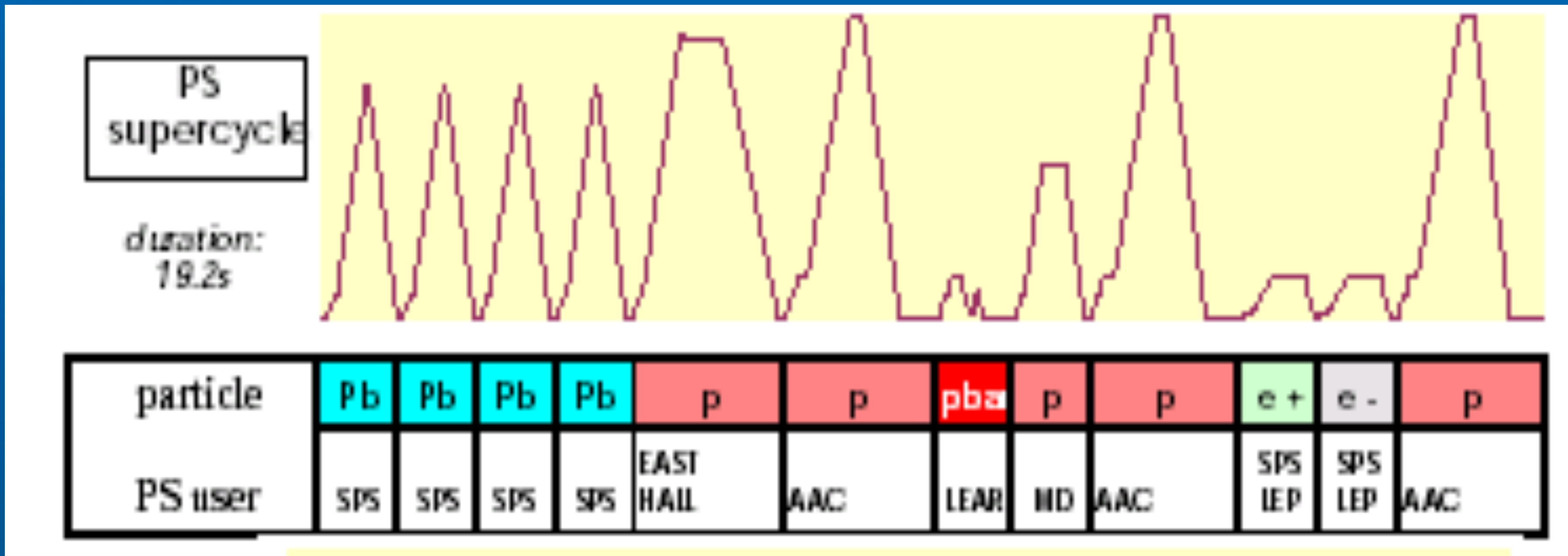
From 1980, the PS controls renovation project: aiming at an integrated system for all machines of the PS complex. Based on CAMAC technology and NORD mini-computers

From 1990, an integrated controls project for all CERN machines including SPS and LEP
Based on DEC workstations, CAMAC replaced by VME, recently by industrial PC's
Adoption of open standards: Linux for front-end computers.

Timing went through similar iterations; since 2003 the UTC second (PPS) is used to condition an atomic clock producing a 10 MHz pulse train, from which all other timings are derived.

SERVING MULTIPLE USERS OF THE PS:

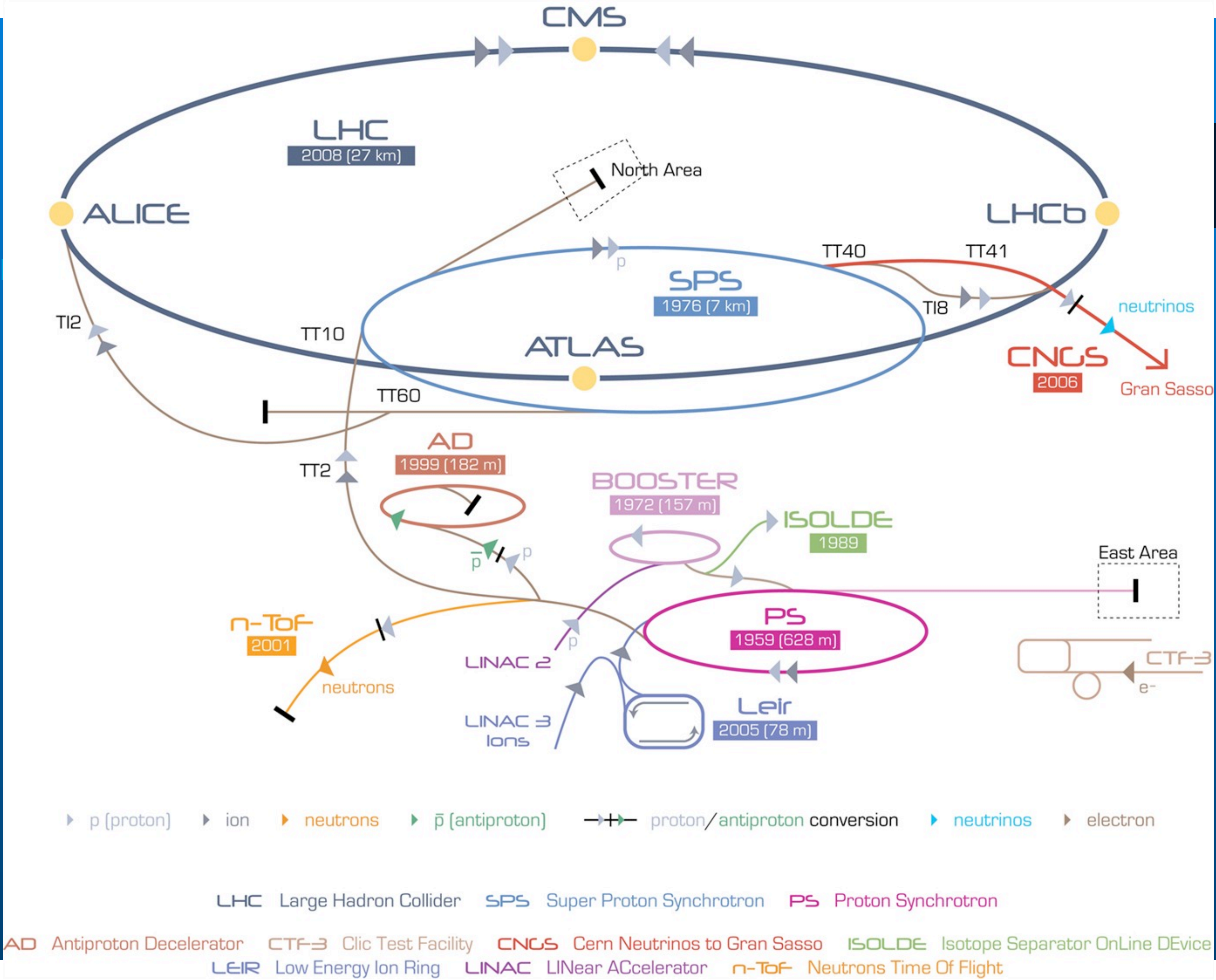
AN EXAMPLE OF A «SUPERCYCLE»



D.J.Simon EPAC 96

THE ONLY COMPONENTS INSTALLED AS FROM THE ORIGIN ARE THE 100 UNITS OF THE MAIN MAGNET (except for repairs and some reshuffling)

UNTITLED FROM 1956



CMS
LHC
2008 (27 km)
North Area
ALICE
LHCb
TT40
TT41
p
SPS
1976 (7 km)
TI8
neutrinos
TI2
TT10
ATLAS
CNGS
2006
Gran Sasso
TT60
AD
1999 (182 m)
TT2
BOOSTER
1972 (157 m)
ISOLDE
1989
p̄
p
East Area
n-ToF
2001
PS
1959 (628 m)
p
LINAC 2
CTF3
e–
neutrons
LINAC 3
Ions
Leir
2005 (78 m)
p (proton)
ion
neutrons
p̄ (antiproton)
proton/antiproton conversion
neutrinos
electron
LHC Large Hadron Collider
SPS Super Proton Synchrotron
PS Proton Synchrotron
AD Antiproton Decelerator
CTF3 Clic Test Facility
CNGS Cern Neutrinos to Gran Sasso
ISOLDE Isotope Separator OnLine DEvice
LEIR Low Energy Ion Ring
LINAC LINear ACcelerator
n-ToF Neutrons Time Of Flight

CONCLUSIONS ……

THESE 50 YEARS OF ACTIVE LIFE OF THE PS WERE A MOST FASCINATING EXPERIENCE DUE TO THE ENTHUSIASM AND INVENTIVENESS OF THE STAFF WORKING AROUND THE PS AND AT LARGE IN THE GROWING ACCELERATOR SECTOR.

AMONGST THE 'YOUNG' STAFF OF TO-DAY, I FIND THE DEDICATION AND PERSONAL IDENTIFICATION WITH THE UNIQUE PROJECTS IN A UNIQUE LABORATORY AS IN THE EARLY DAYS OF THE PS.

THUS THE PS WILL SURELY REMAIN A RELIABLE SOURCE OF BEAMS FOR LHC AS WELL AS TRADITIONAL USERS FOR MANY YEARS TO COME.

…….. and an AFTERTHOUGHT
…….. 50 YEARS OF NOBEL MEMORIES ……

MIGHT THE **PS**, DEEP IN ITS MIND, HAVE ANY PERTINENT MEMORIES ?

BITS OR BYTES PERHABS, AS THE EXPERIMENTS ON ITS BEAMS HAVE CONTRIBUTED SO MUCH TO THE DEVELOPMENT OF THE STANDARD MODEL.

MAYBE SOME MEMORIES MORE SUBSTANTIAL?

YEAR	SUBJECT	MEMORIES
1963	TWO NEUTRINOS	LATE ARRIVAL ===> FRUST
1973	NEUTRAL CURRENT	EARLY DEATHS ==> PROFOUND REGRETS
1983	Zzero	FULL HIT !! ===> PRIDE ABOUT ITS PARTICIPATION

CONGRATULATIONS AGAIN TO CARLO +

MY CONCLUSION

Fifty years of active life of the PS

were a fascinating time for all those working around the PS and meant continued improvement and acquisition of a detailed understanding of *what happens to the beam at all stages of the acceleration process*

as well as the adaptation of the synchrotron to new challenges with new hardware systems and by the development of ever more sophisticated operation procedures, most recently those in view of the LHC project.

With a dedicated staff responding with enthusiasm to all challenges, the PS will surely remain a reliable source of beams for the LHC as well as for the traditional users during many years to come.