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
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 1951.

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 discussed. 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
<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:20</td>
<td>Some work started</td>
</tr>
<tr>
<td>15:45</td>
<td>Continued working</td>
</tr>
<tr>
<td>16:00</td>
<td>Break for lunch</td>
</tr>
<tr>
<td>16:45</td>
<td>Resumed work</td>
</tr>
<tr>
<td>18:00</td>
<td>End of work day</td>
</tr>
</tbody>
</table>

**Note:**
- The logbook was written in English.
- The events are recorded in a chronological order.
- The logbook contains both work hours and breaks.
- The logbook is a handwritten document.
THE PS HAS COME TO LIFE

JOHN ADAMS,
25 NOVEMBER 1959
THE FIRST SIGN OF LIFE
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
<table>
<thead>
<tr>
<th>Year</th>
<th>Area Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>SOUTH and NORTH HALLS</td>
</tr>
<tr>
<td>1963</td>
<td>EAST HALL with HBC BUILDING</td>
</tr>
<tr>
<td>1966</td>
<td>SOUTH EAST (neutrino) AREA: Gargamelle later: g - 2 ring, ICE ring</td>
</tr>
<tr>
<td>1969</td>
<td>WEST HALL with BEBC turned over to SPS beams in 1976</td>
</tr>
<tr>
<td>1990</td>
<td>ISOLDE (after closure of SC)</td>
</tr>
<tr>
<td>2000</td>
<td>nTOF in TT1</td>
</tr>
</tbody>
</table>
BEAMS FROM THE PS - 1974
FAST PROTON BURSTS AND SLOW SPILLS --- SECONDARIES FROM INTERNAL TARGETS
THE BASELINE:

THE HIGH INTENSITY PROTON BEAM

PS Proton Intensity Evolution Over 50 Years

- Typical Intensity [E10]
- Peak Intensity [E10]
- Record Intensity [E10]

PS Booster 1.4 GeV
RF change h=5 to h=1
For LHC Beam Production

Double Batch Injection
4.2E13 inj. 3.55E13 ej.

PS Booster 1 GeV

PS Shutdown Magnet renovation
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

<table>
<thead>
<tr>
<th>Beam Type</th>
<th>Year</th>
<th>Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Intensity Protons</td>
<td>1971</td>
<td>ISR</td>
</tr>
<tr>
<td></td>
<td>1976</td>
<td>SPS</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>Antiproton Production</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>LHC</td>
</tr>
<tr>
<td>Antiprotons</td>
<td>1981</td>
<td>ISR</td>
</tr>
<tr>
<td></td>
<td>1981</td>
<td>SPPbarS (at 26 GeV/c)</td>
</tr>
<tr>
<td></td>
<td>1983</td>
<td>LEAR (at 0.6 GeV/c)</td>
</tr>
<tr>
<td>Electrons/Positrons</td>
<td>1989</td>
<td>LEP</td>
</tr>
<tr>
<td>Light Ions</td>
<td>1976</td>
<td>ISR</td>
</tr>
<tr>
<td>Heavy Ions</td>
<td>1994</td>
<td>SPS</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>LHC</td>
</tr>
</tbody>
</table>
LAUNCHING THE P-P\bar{p} 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 ANTI PROTON 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 tunnel TT2

• 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 ANTI PROTON FACTORY
BUNCH MERGING IN THE PS: DELICATE GYMNASICS FOR THE RF
ACT 1: 20 => 10

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

Ejection ~ 12 ms
Start of process

one half PS revolution
# NEW BEAMS ==> NEW DESTINATIONS

<table>
<thead>
<tr>
<th>Category</th>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HIGH INTENSITY PROTONS</strong></td>
<td>1971</td>
<td>towards ISR</td>
</tr>
<tr>
<td></td>
<td>1976</td>
<td>SPS</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>ANTIPROTON PRODUCTION target</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>LHC</td>
</tr>
<tr>
<td><strong>ANTIPROTONS</strong></td>
<td>1981</td>
<td>ISR</td>
</tr>
<tr>
<td></td>
<td>1981</td>
<td>SPPbarS (at 26 GeV/c)</td>
</tr>
<tr>
<td></td>
<td>1983</td>
<td>LEAR (at 0.6 GeV/c)</td>
</tr>
<tr>
<td><strong>Electrons/Positrons</strong></td>
<td>1980/1</td>
<td>DECISION on LEP</td>
</tr>
<tr>
<td></td>
<td>1989</td>
<td>LEP</td>
</tr>
<tr>
<td><strong>LIGHT IONS</strong></td>
<td>1976</td>
<td>ISR</td>
</tr>
<tr>
<td><strong>HEAVY IONS</strong></td>
<td>1994</td>
<td>SPS</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>LHC</td>
</tr>
</tbody>
</table>

*PS 30 yrs*
NEW BEAMS ==> NEW INJECTORS

INJECTORS OF THE PS

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

ANTIPROTON ACCUMULATOR (AA, AD)

ELECTRON LINAC and
ELECTRON/POSITRON ACCUMULATOR

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

LINAC 4 (under construction
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
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
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

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»
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
LHC - Large Hadron Collider
SPS - Super Proton Synchrotron
PS - Proton Synchrotron
AD - Antiproton Decelerator
CTF-3 - Clic Test Facility
CNGS - Cern Neutrinos to Gran Sasso
LEIR - Low Energy Ion Ring
LINAC - LINear ACcelerator
n-TOF - Neutrons Time Of Flight
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?

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SUBJECT</th>
<th>MEMORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>TWO NEUTRINOS</td>
<td>LATE ARRIVAL ==&gt; FRUST</td>
</tr>
<tr>
<td>1973</td>
<td>NEUTRAL CURRENT</td>
<td>EARLY DEATHS ==&gt; PROFOUND REGRETS</td>
</tr>
<tr>
<td>1983</td>
<td>Z_{zero}</td>
<td>FULL HIT!! ==&gt; PRIDE ABOUT ITS PARTICIPATION</td>
</tr>
</tbody>
</table>

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.