History of the CERN Proton Synchrotron
The Early Days

• Setting the scene
• Design period
• Decision and Construction
• Running-in
• Beginning as user facility
Setting the scene


Brief for Study Group: Conclude “...which proton energy in the range 1 and 20 BeV is most useful....Then the feasibility will be studied....”

• End June 1952: Study group presents a 10 – 15 GeV synchrotron, a scaled-up version of the 3 GeV weak-focusing BNL Cosmotron (1 GeV reached then). (Bevatron 6 GeV under construction at LBL)

• **Council** asked for design and planning of 10 GeV version
Cosmotron at BNL

1952 – 1966  3.3 GeV in 1953  Magnets 1730 t  $2\pi R = 144.5$ m
Vacuum chamber 20 x 60 cm
Bevatron
LBL

1954 – 1971 (93)
6.2 GeV in 1953
Magnets 1000 t
$2\pi R = 128$ m

Vacuum chamber 31 x 122 cm
Getting down to business

• August 1952: Dahl, Goward & Wideroe visited BNL
  Got introduced to Alternating-Gradient (AG) Principle = Strong-Focusing Principle with effect of drastic reduction of magnet size.
• October 1952 in 3rd Council: O.Dahl presented

<table>
<thead>
<tr>
<th>Project</th>
<th>Energy</th>
<th>Magnet</th>
<th>Constr. time</th>
<th>Cost MCHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (w-f)</td>
<td>10 GeV</td>
<td>6000 t</td>
<td>6 - 7 years</td>
<td>60</td>
</tr>
<tr>
<td>II (AG)</td>
<td>30 GeV</td>
<td>700 t</td>
<td>5 - 6 years</td>
<td>60</td>
</tr>
</tbody>
</table>

advocating project II also because
“it offers new opportunities for new contributions to the art of experimental physics”!

Council entrusts his Group with studying Project II and, by the way, chooses Geneva as site.
Cold feet

- **Design is not robust:**
- **Magnet imperfections and alignment errors => loss of beam stability.** Learn from celestial mechanics:
  
  
  e.g. betatron phase space with 3rd order resonance
  
  (Hagedorn & Schoch CERN 57-14)

An analogue model developed by M. Barbier & A. Schoch

(Barbier and Schoch, CERN 58-5)

CERN-PHOTO-5512288
Valse of parameters

- Lead to many design iterations: e.g.

<table>
<thead>
<tr>
<th>Date</th>
<th>Jan.53</th>
<th>April 53</th>
<th>March 54</th>
<th>Final 59*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field index n</td>
<td>4000</td>
<td>900</td>
<td>278</td>
<td>288.4</td>
</tr>
<tr>
<td>W magnet (t)</td>
<td>800</td>
<td>≤ 10000</td>
<td>3300</td>
<td>3400 Fe</td>
</tr>
<tr>
<td>Vac.dimension (cm)</td>
<td>4 x 5</td>
<td>≤ 16 x 20</td>
<td>8 x 12</td>
<td>7 x 14</td>
</tr>
</tbody>
</table>

Cost 100 MCHF

Effective help by Hildred and John Blewett from BNL!

*) M.G.N.Hine, Synchroton Data, HEACC 1959 p.383
Decision and construction

- October 1953 7th Council decided to follow Cockcroft
  ➔ AG synchrotron 25 GeV, Bmax= 12 kG
  After Heisenberg’s conclusion: design for easy reach of 20 GeV but enable 30 GeV


PS tunnel construction 1955 - 1957

1st PS combined-function magnet end 1956
1959 Running-in

- August 24: linac at 50 MeV (= design)
- September 16: first turn in PS

Drama: Beam did not cross transition energy!
i.e. $E_{tr} \approx 6$ GeV => longitudinal focusing vanishes
Remedy: radial loop feed-back acts on RF phase instead on RF amplitude

- November 24: 24 GeV
- December 8: 28.3 GeV

3.10^{10} p/pulse

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.

J. Adams, 1st PS Quarterly report, CERN 60-23, p. 7
Confronting the reality of big science

- **1960**: *accelerator* reached $N=3 \times 10^{11} \text{ p/p} \Rightarrow 3 \times \text{design, } T_{\text{op}}=102 \text{ d, } \eta_{\text{inj}} = 25 \text{ to } 60\%$, short and long pulse, 14 internal targets

- **Slow start of experimental programme**: dearth of experimental proposals and serious lack of beam transport elements (e.g. equipment borrowed, power by welding machines etc.)

- However, 1st run in January and $\approx 10$ experiments in total with 30 cm $\text{H}_2$ bubble chamber, counters and emulsion experiments.

- **In 1961 set-back**: 1st $\nu$-experiment (2 neutrino species ??) planned for spring 1961 was abandoned $\Rightarrow$ flux $10 \times$ too small (found out by von Dardel)

  - Discovery of $\nu_\mu$ in 1962 $\Rightarrow$ AGS/BNL (Started July 1960)

  - Creating dissatisfaction and disillusionment

  V. Weisskopf, Council June 1962:
  “It is no good in this field to be excellent and always late”
Gathering momentum

- **2nd ν-experiment** in 1963 and 1964 with two seminal advances in technology by NPA-division to improve the rate of

\[ p \rightarrow \text{target} \rightarrow \pi^+ \rightarrow \mu^+ \nu_\mu \]

- Fast proton ejection
  Plass, Kuiper CERN 59-30

- Horns create strong pulsed magnetic fields to focus π ‘s
  S.Van der Meer CERN 61-07
1963 PS in full swing

\[ <N> = 6.10^{11} \text{ p/p, realignment } \Delta (h,v) \approx 3 \text{ mm} \]
Tribute

- **Founding fathers** for their wisdom and foresight in choosing a design with a large potential for a long-term evolution and a striking versatility

- **PS and NPA staff** which made it work and exploited this potential with tenacity and perseverance

- **CERN staff** at large which continuously has upgraded, adapted and improved the PS, its external beams, injectors and associated accelerators as AA, AC, AD, LEAR, LEIR and ELENA.
Thanks

Reviews

