

LHC RF monitoring

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Frequency Program for Synchrotrons

$$f_{RF} = f_{\infty} \frac{B}{\sqrt{B^2 + \left(\frac{E_0 \cdot 1}{q \rho \cdot c} \right)^2}}$$

$$f_{\infty} = \frac{hc}{2\pi R}$$

B is the guide field in T: 0.539 T to 8.386 T ← LHC

$f_{inf} = 400.789\ 662$ MHz with $h=35640$ and
 $2\pi R=26658.883$ m

conceptual
design 1995

ρ is the bending radius $\rho = 2784.32$ m

E_0 is the rest energy of the particle/ion being accelerated (in eV)

q is the number of elementary charges in the particle/ion

Proton acceleration

We have:

$$E_0 = 938.26 \times 10^6 \text{ eV}$$

$$q = 1$$

The RF frequency ramps

from **400.788 790 MHz** at injection (0.539 T)

to **400.789 658 MHz** at top energy (8.386 T)

N.B.: The **bunch frequency** @ 40 MHz is **1/10** times the above RF frequency.

Ions Acceleration

E_0 = rest energy of ion = sum of energy of protons, neutrons (and electrons) minus binding energy

q = number of protons (minus number of electrons)

In all cases E_0/q will be larger than the case of proton. Ions are less relativistic at injection and the frequency swing is larger.

Lead ion acceleration

For fully stripped lead Pb_{208}^{82+} we have:

$$q = 82 \text{ (82 protons)}$$

$E_0 = 193.683\,956$ GeV considering the 82 **p** and 126 **n**
with $m_p = 938.259$ MeV, $m_n = 939.553$ MeV and a
binding energy of 7.87 MeV/nucleon

$E_0/q = 2.362 \times 10^9$ (to be compared to 0.93826×10^9
for protons)

The RF frequency ramps

from **400.784 139 MHz** at injection (0.539 T)
to **400.789 639 MHz** at top energy (8.386 T)

What could be done ?

- **Measure the 400 MHz RF** (one per ring). Needed hardware: the RF frequency + any “off the shelf” counter
- **Measure the B field**. Needed hardware: Beam Energy measured by AB/BT?
- **Compare** the measured RF with the one obtained by applying the **Frequency Program equation** (page 2) to the measured B (or energy). Needed hardware: processor?
- If outside tolerance **activate protection** interlock. Needed hardware: interface to machine interlock

Where could it be done?

- 400 MHz RF (both rings) are **generated in SR4**. Responsibility of AB/RF
- They are **transmitted to the PCR**.
Responsibility of AB/RF

Who should do it?

- In the RF WBS we only plan to transmit the 400 MHz to PCR...
- We have **no access to the Beam Energy measurement**. Our RF frequency is generated from a **function** (and not a measurement) that contains, at all time, the **intended B field**. (Note: we can rely on a function because, at 450 GeV (0.58 T), a relative precision of 10^{-4} on B gives only 2 μm radial error.)