Machine Protection and Interlocking of proton-ion operation

A first iteration

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P-ion operation

- For p-ion operation, one of the rings will be filled with a proton beam, the other one with ions (so far Pb).
- It is likely that each ring must be able to alternatively (in different fills !!) receive protons or ions.
  - Must not rely on a fixed mapping between ring and particle species.
- Aim of this presentation is to give some ideas (and proposals for interlocks) to prevent injecting the wrong particle type in either ring from the SPS
  - Assume that the injected beams are unsafe.
  - 'Design' injection (extraction) interlock.

- Proton ion filling scheme?
- Assume 100 ns proton beam with 4 standard length batches:
  - 72 bunches, 2E10 p/b → ~2E12 protons
  - Just above setup beam with nominal emittance.

- Define a protection strategy to cope with unsafe beams.

Proton vs Pb at injection

- At injection to the LHC the only noticeable difference between p and ions (Pb) is the RF frequency (due to the slower speed of ions):
  - Difference of 5.3 kHz between protons and ions (higher for p).
  - Magnetic settings are ~identical – see 2010.

- If the RF frequencies are wrong (p for ions or vice-versa):
  - Energy shift at extraction from the SPS of ±1.3% - still within the SPS aperture (but not easy with large intensity).
  - Energy shift in the LHC of ±4.1% - far outside the LHC acceptance. The beam will be not circulate and be lost on aperture (normally a collimator).

Ring mismatch

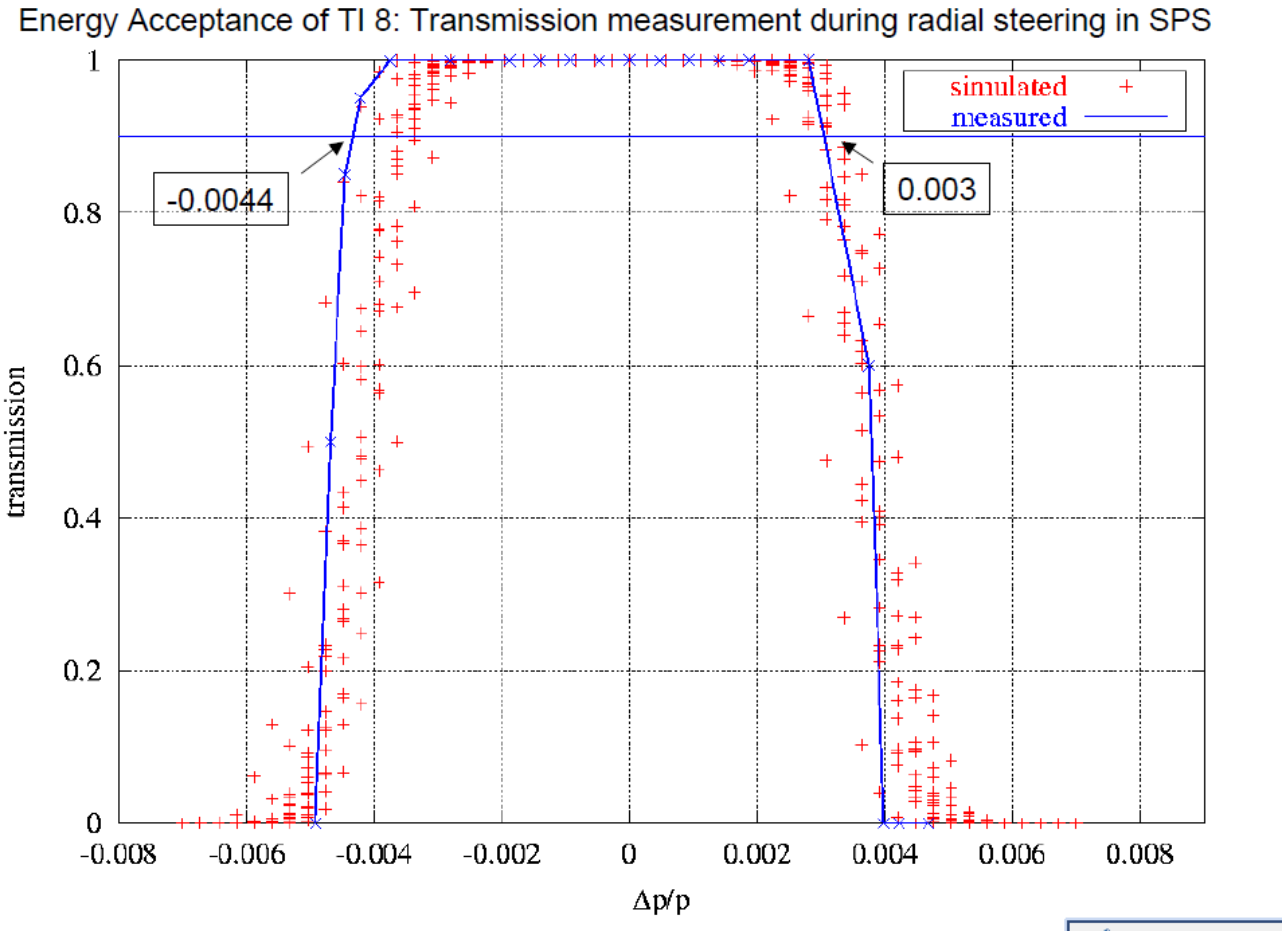
- Attempt to inject a proton beam from the SPS into a ring setup for Pb in the LHC (or vice-versa):
  - Frequency is off by ±5.3 kHz for the SPS beam, leading to an energy error of **±1.3%** at extraction from the SPS.
  - It is not clear if the re-phasing SPS-LHC would work or if the beam would survive in the SPS (at the limit of the aperture, non-linear Q' etc) – but it cannot be excluded → assume the beam could be extracted.
  - If the beam leaves the SPS it will be lost in TI2/TI8 due to the limited dp/p aperture of the lines (**±0.4 %**)

    → the beam will never make it into the LHC.

    → **LHC is safe** – we must protect TI2 and TI8 !

TI2/8 energy acceptance

- The energy acceptance of the TI2/8 lines is around 0.4 %



TI8 test 2005
(V. Kain)

How can one differentiate ions and p?

Concentrate here on 'useable' signals…

- LHC:
  - RF frequency difference of 5.3 kHz.
- SPS:
  - RF frequency at extraction – unfortunately no fast measurement available.
  - Radial position (centered) – arc BPMs.
  - RF low-level controls settings (timings, delays ….).
  - Momentum of the beams at injection:
    - 26 GeV for protons.
    - 17 GeV (proton equivalent setting) for Pb.

Need to merge information dispersed across SPS+LHC → mostly SIS interlocks

SIS interlock proposal - 2011

- Proton conditions – applied for each ring
  - **LHC**: RF frequency within **1kHz of proton reference**.
    - Monitoring at 0.2 Hz, accuracy ~ 20 Hz.
  - **LHC** : particle type in CPTY telegram = proton.
  - **SPS**: user name **LHCx** or **LHCFASTx** (x = 1,2,3,4…).
  - **SPS**: injection line TT10 settings consistent with **26 GeV**:
    - Current interlock on 2 dipole and 2 main quadrupole strings.
- Pb conditions – applied for each ring
  - **LHC** : RF frequency within **1kHz of Pb reference**.
    - Monitoring at 0.2 Hz, accuracy ~ 20 Hz.
  - **LHC** : particle type in CPTY telegram = Pb
  - **SPS** : user name **LHCIONx** (x = 1,2,3,4…).
  - **SPS** : injection line TT10 settings consistent with **17 GeV**:
    - Current interlock on 2 dipole and 2 main quadrupole strings.

SIS continued

- SIS will allow injection into a given ring if the settings are consistent with ions or with protons.
  - Flexible – no a priori knowledge on which ring is used for which species.
  - Will also work to avoid injecting ions during p-p runs (and vice-versa).
- The TT10 injection is used and not the SPS main dipole current (also a good candidate) due to 'technical' issues with the current readout.
  - May disappear in the near future when FGC SW is deployed in the LHC (2012??).

SPS Extraction Interlock (BIS)

- It is possible to include 2 arc BPMs (dispersion > 2 m) into the beam position interlock at extraction (→ BIS).
  - 'Effectively' ensures that the RF frequency is correct and that the beam is centered.
  - Replaces the SPS RF frequency measurement.

Status & outlook

- Given the limited risk (? tbc) and the geographical distribution of the information needed for interlocking, the SIS (+BPM at extraction) solution should be adequate for 2011/2012.
  - Everything in place by September.
- Local test SIS version with SPS user and LHC RF frequency.
  - Will go to production next week (maskable).
- Arc BPMs added to SPS extraction interlock : next week.
- TT10 PC settings : after next TS (latest).
- More possibilities:
  - The SPS BETS systems used to provide the SPS energy information may also used to provide the injection momentum – tbc.