Writeup MI BPM Meetings, Tuesday 6/21/05 and Thursday 6/23/05

Based on a few tranperencies presented by Dave Capista,
an intensive discussion of trying to understand the MI BPM operation in
in detail followed.
This writeup covers the discussions on MI BPM operation modes, data acquisition
and related topics of the MI BPM meetings on Tuesday, 6/21/05 and
Thursday, 6/23/05.

Here the (partial!) summary of the discussion,
at least the parts what I perhaps understood:

1. Some important definitions:
- Cycle, ramp
  "Cycle", "ramp" are the same thing. Particles are injected from
  a source machine into the MI, and "ramped" from energy A to energy B
  and finally ejected to a target (machine). During the ramp all
  electromagnetic fields acting on the particles, driven by magnets and RF,
  have to follow the wanted energy vs. time characteristic. Typically
  a "ramp-cycle" takes a few seconds. When a ramp is finished, energy B
  is reached and the particles are ejected, and the MI has to be cycled back
  to the default 8.9 GeV "start"-condition.
  Each consecutive "ramp-cycle" might be different! The kind of cycles
  following eachother are set by the time-line-generator (TLG), which also
  defines the so-called "supercycle": a repetitive set of - different -
  ramp-cycles.
- Buckets, Bunches, Batches, Turns, Revolutions, RF, etc.
  Particles to be accelerated the MI are not random distributed along the ring.
  Acceleration is done by the longitudinal EM-fields in the cavities, which
  bunches the particles according to the their resonant frequency. In the MI
  2 different radio-frequency (RF) systems with 2.5 MHz and 53 MHz are used for
  acceleration. During the energy ramp, this frequency variies slightly
  (52.8 -> 53.1 MHz), because the particles are not fully "relativistic".
  1 revolution or turn in the MI corresponds to 588 RF oscilations of 53 MHz
  (the so-called "harmonic #" of the MI is 588). This gives 588 "bucket"
  locations (time spaced by 1/53 MHz = 19 ns) along the MI circumfence which
  can be filled with particles. A bucket filled with particles is called
  "bunch", which has typically 10...100 E9 particles. Not all 588 buckets
  in the MI are filled with particles to be accelerated. Even for high intense
  beams some buckets have to stay empty for proper kicker operation.
  In practice up to 84 consecutive 53 MHz buckets can be filled with protons,
  forming a so-called "batch". Up to 6 batches of maximum 84 bunches can be
  accelerated in the MI. Although the proposed MI BPM system cannot time resolve
  individual bunches, in wideband mode it can time resolve a batch! Therefore
  a revolution synchroneous trigger has to point to a bucket location, where
  the batch to be measured is located (applies only in wideband turn-by-turn
  mode).
- MDAT event status
  An MDAT frame is used to communicate the MI state information to the MI LLRF.
  Currently there are 31 different MI states defined (out of 255 possible).
  Each operation-line in a LLRF State definition controls a specific command.
  Among these commands, there is also one which defines the bucket positions
  of the batches being injected.
- "State"
  The "state" in which the MI appears is defined in the TLG and transmitted
  on an MDAT frame. The state information on the MDAT frame is valid
  before the TCLK time event starts the ramp-cycle.
  Personal remark: The word "state" is very dangerous, as there seems to be
  many definitions...
- TClock events (TCLK)
  TCLK is a decodable time event. Some TCLK events define the start of a
  MI ramp-cycle. MECAR (MI Excitation Control And Regulation) responds to the

TClock event and defines the magnet settings for that ramp.
TCLK is NOT synchronous with the RF, and therefore NOT synchronous with turns, buckets (bunches) or batches of bunches in the MI ring.

- AA marker
  The AA marker is a hardware generated revolution clock signal - derived from the LLRF - which points to bucket # 1 in the MI.
- BeamSync event or clock (MIBS)
  Similar to TCLK, a BeamSync (BS) is a decodable time event, BUT: a BS is synchroneous to the beam revolutions in the accelerator! Thus makes it possible to point a specific bucket position in the MI using the MIBS plus a fixed delay.
  This is the way, how the BS is usually generated (see also ACNET page T63):

  TCLK -> fixed delay -> arm BS -> next AA marker -> output BS

  The BS is used to trigger all the hardware which has to operate beam synchroneous, e.g. kickers, most beam instrumentation, etc.

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decode BS -> delay -> kicker
decode BS -> delay -> beam instrument
decode BS -> delay -> ...
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2. BPM state system for the MI
Dave presented his proposal for a state orientated MI BPM system.
This system houses varoius buffers and registers, filled with BPM data during a ramp-cycle. The data of all BPM stations in the different MI houses has to be collected through ACNET and finally displayed on a console display. Depending on the request, the data collection procedure may take longer than the time between beam ejection and the injection for the following ramp-cycle, thus the data has to be kept until read-out completely. A TCLK event $79 (MI BPM prepare for beam) might be used to clear all data from the previous ramp-cycle, and preventing by it's absence overwriting of data which still has to be read-out.
BPM data is acquired in either:

- narrowband closed orbit mode
- wideband turn-by-turn (TBT) mode

Some details:

- BPM data
  All acquired BPM data should be made available as formated data (position: mm displacement, intensity: # of particles of beam current) and raw data; with a time stamp (absolute CPU time or TCLK referenced time, the time stamp has to resolve the batch location, i.e. 100 ns resolution) and a flag for it's "kind", i.e. 2.5 or 53 MHz data.
- BPM operating mode command
  A "BPM operating mode command" has to be defined, which is executed in the state command list (MDAT frame). This command arms the BPM system in the wanted state for data acquisition, i.e.:
  - narrowband (closed-orbit) or wideband (TBT),
  - selects for 2.5 or 53 MHz data,
  - sets the attenuation in the analogue signal path (in 6 dB steps),
  - enable/disable the command line message in the state definition.

a) BPM narrowband, closed-orbit operation
For each MI state a set of memory registers / buffers is required to acquire the narrowband, cloesd-orbit BPM data. With the BPM hardware in narrowband, closed-orbit mode (2 kHz bandwidth) a 2 msec data sampling (update rate) should be feasible.
The following registers/buffers are defined:

- Profile Frame Buffer

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  Narrowband BPM data is entered into this 128 entry long FIFO buffer on
  user configurable TCLK $7A events. An error message appears if the
  buffer is full. (What should happen in this case ?)
- Display Frame Buffer
  Narrowband BPM data is updated in the single entry register on
  TCLK $7B events.
- Fast Time Plot Buffer
  Every 2 ms narrowband BPM data sample updates this single entry register.
- User Data Buffer
  Narrowband BPM data is entered into this 128 entry long FIFO buffer on
  a user requested event(?).

b) BPM wideband, turn-by-turn (TBT) operation
In TBT mode the BPM system has a 200 kHz bandwidth and can time resolve
individual batches. Apart one exception (particles/batches from the booster)
the correct timing is simply handled by decoding the correct BeamSync (BS)
event plus a fixed delay. Main purpose of the TBT mode is the beam observation
at times of beam in- and ejection (first and last turn(s)). Two different
TBT modes are foreseen:
- pre-programmed modes of 512 turns acquisition
  Activation is done by one of the following MIBS events:
  $xx*, $7A, $D6, $D8: for first turn(s) data acquisition.
  $A1, $A6, $74, $75, $76, $7B, $7C, $7D, $7E: for last turn(s) data acquisition.
  *: beam from booster, see below.
  Activation is also done on one of the following RBBS (Recycler Beam BS) events:
  $A3, $A6, $A7: for first turn(s) data acquisition.
  $A0, $A1, $A2: for last turn(s) data acquisition.
  A set of registers and buffers are defined to acquire the data:
  - Flash Turn Buffer (#1...#20)
    TBT data on an "activated" BS event is captured by this 512 entry long
    FIFO buffer. TBT data of every new BS event within a ramp-cycle is
    acquired in a following Flash Turn Buffer (FTB). A total of 20 FTB's is
    foreseen to capture all first and last turn(s) events which could appear
    within a ramp-cycle.
  - First Turn Closed Orbit Buffer (#1...#20)
    A First Turn Closed Orbit Buffer is related to each of the FTB's.
    This single entry register keeps the avarage value of the 512 turns
    in the FTB. It can be seen as entry 513 of the FTB. The average value
    of the first 512 turns represents the closed orbit, which is used as
    reference to minimize the injection oscillations.
  - Flash Buffer
    This is a 20 entry first/last turn buffer. From the 512 turns acquired
    in the FTB's, always the first/last turn value is mapped into the
    equivalent cell of this buffer. While the FTB's keep always the data of
    512 turns, this Flash Buffer keeps only the data of one turn for each
    BS event; and this should be always a first or last turn!
- a user programmable TBT mode with 2048 turns acquisition
  The user programmable Turn-by-Turn Buffer is a 2048 entry long FIFO buffer.
  Data of 2048 consequtive turns is acquired on a programmeble BS event plus
  an also programmable delay. If this TBT Buffer is active, the pre-programmed
  buffers mentioned above are NOT active.

*: $xx MIBS event
Currently there is no decodable BS event to trigger on beam from the booster.
This is a serious issue still to be adressed. In our discussions we could not
find a satifying solution for this problem, thats why the booster BS gets the
magic $xx. Currently the booster kickers are fired on a hardwired BES
(Booster Extraction Sync) trigger events. It is possible to distribute this
signal to all MI houses with optical fibers and repeaters.

It was also noted that this proposed system is compatible with the
current BPM system to aid in installation.
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