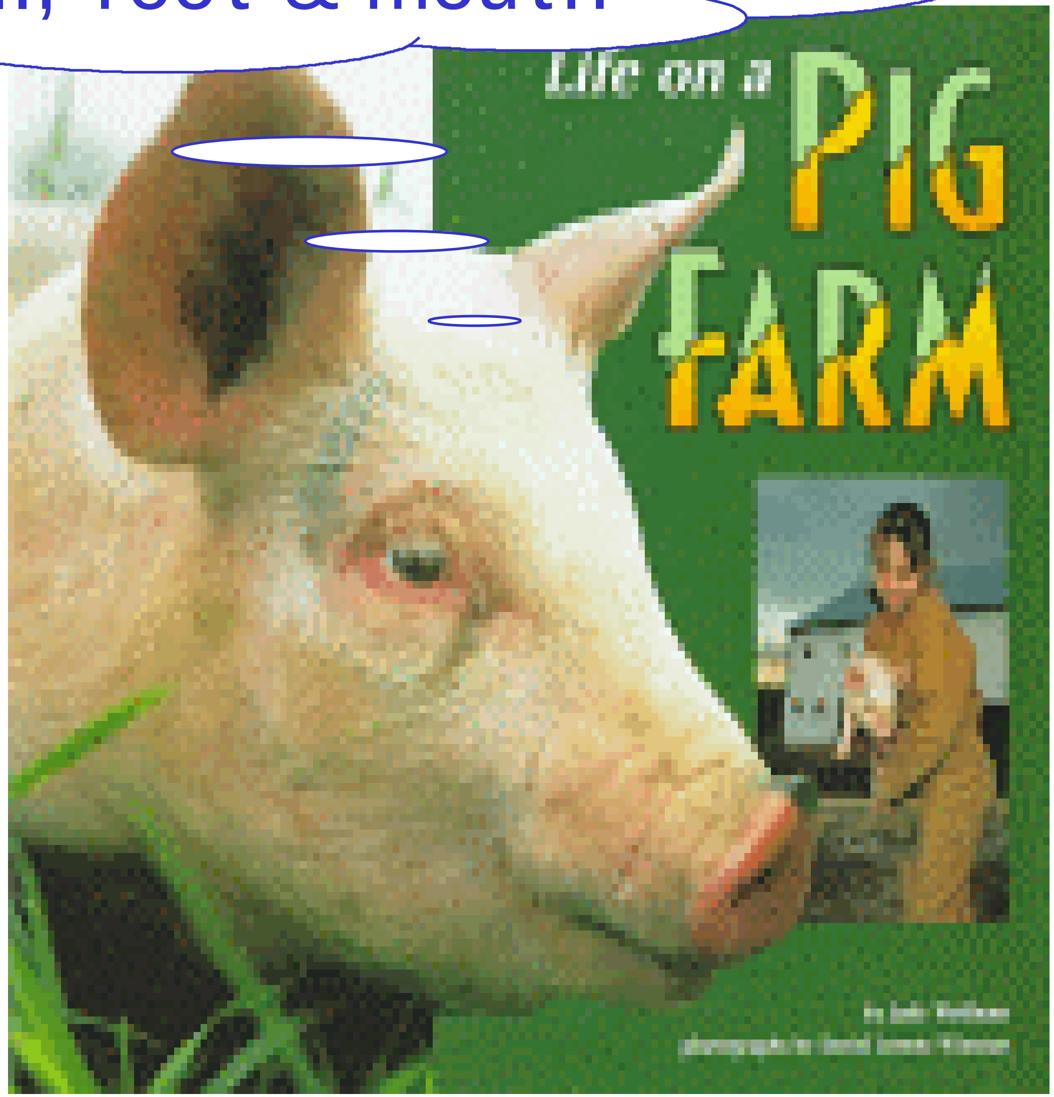
LHC Analysis WG progress

- Preliminary Aims of LAWG:
  - Use Case operational scenarios to establish controls requirements
  - Target specific novel control infrastructure issues to establish requirements & possible solutions
  - Establish and confirm low level level functionality required of equipment by high level controls

- This talk
  - A word about responsibilities
  - How the LHC will be operated
  - Use Case
  - Control requirements
  - Logical architecture
  - Real time
  - Conclusions

LHC operations

Fooking hell, foot & mouth

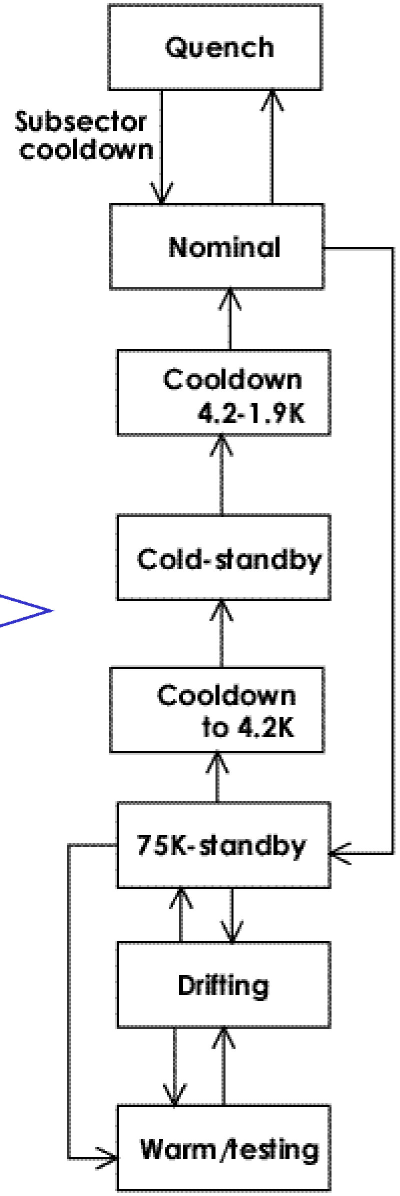


Responsibilities - PCR

- **Power On**
- **Monitor interlock system**
- **Monitor beam & power abort systems**
- **Prepare for access, give access, and access recovery**
- **Drive machine through operational cycle with beam and pick up the pieces**
- **Perform first pass post-mortem analysis**
- **Monitor multipoles factory, first pass diagnostics**
- **Monitoring vacuum, first pass diagnostics**
- **Monitoring transfer lines, injection steering.**
- **Communication with experiments**

Responsibilities - CCR

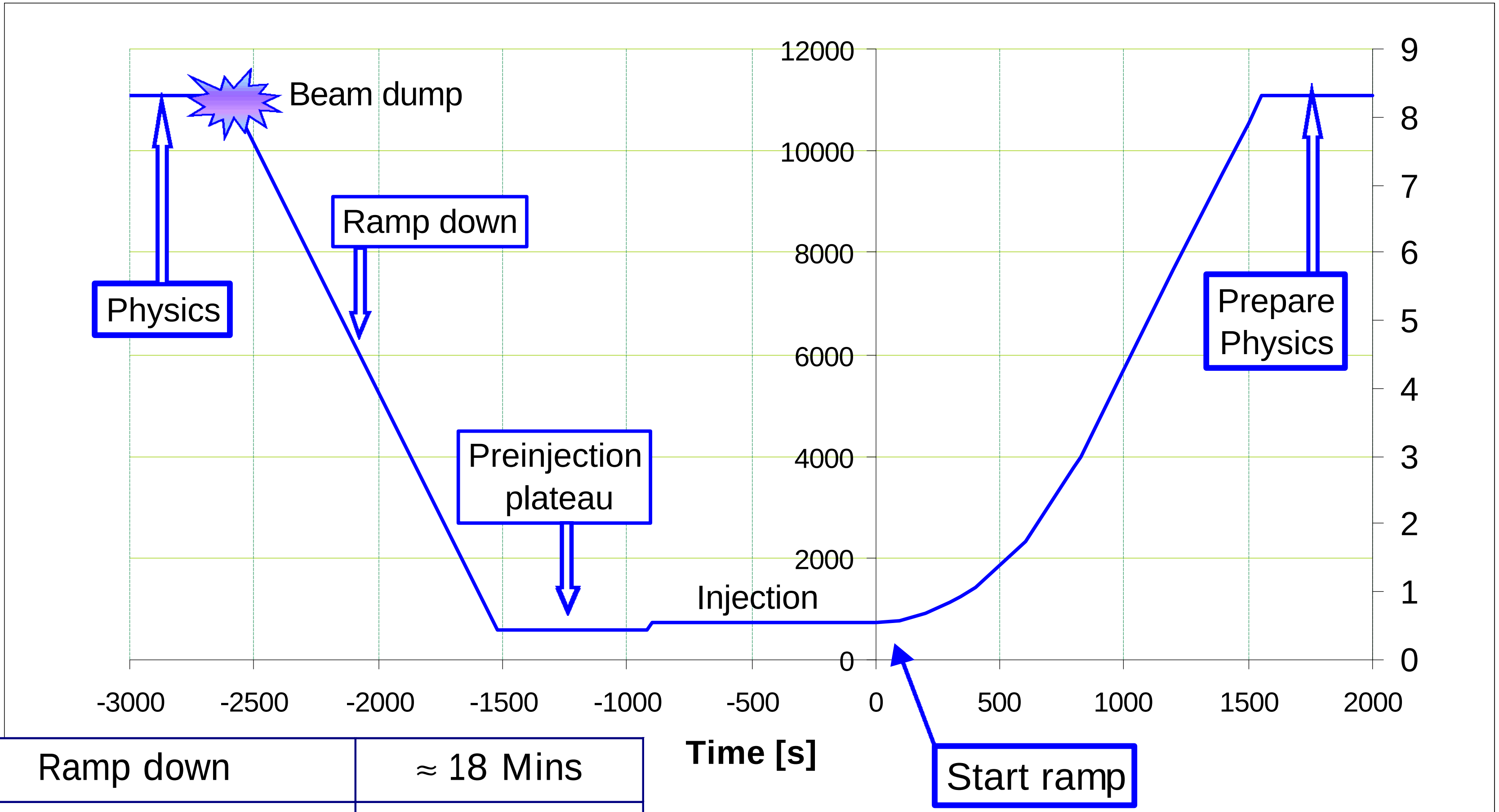
- Drive cryogenics system:
- Cool down - standard sequence
- Green light for powering
- Quench recovery
- Green light for powering after quench
- On-line monitoring
- Monitoring vacuum
- Warm up



Responsibilities - TCR

- Monitors and operates 24 hours a day, 365 days a year the entire technical infrastructure of CERN comprising
  - the electrical distribution network and energy consumption management
  - heating, cooling, ventilation and air conditioning equipment
  - safety installations, any other infrastructure equipment
  - control systems
- Calls for breakdown and stand-by services
- Troubleshooting coordination:
  - CERN specialist, subcontractors
  - TCR on - site interventions

Baseline cycle



Ramp down	≈ 18 Mins
Pre-Injection Plateau	15 Mins
Injection	≈ 15 Mins
Ramp	≈ 28 Mins
Squeeze	< 5 Mins
Prepare Physics	≈ 10 Mins
Physics	10 - 20 Hrs

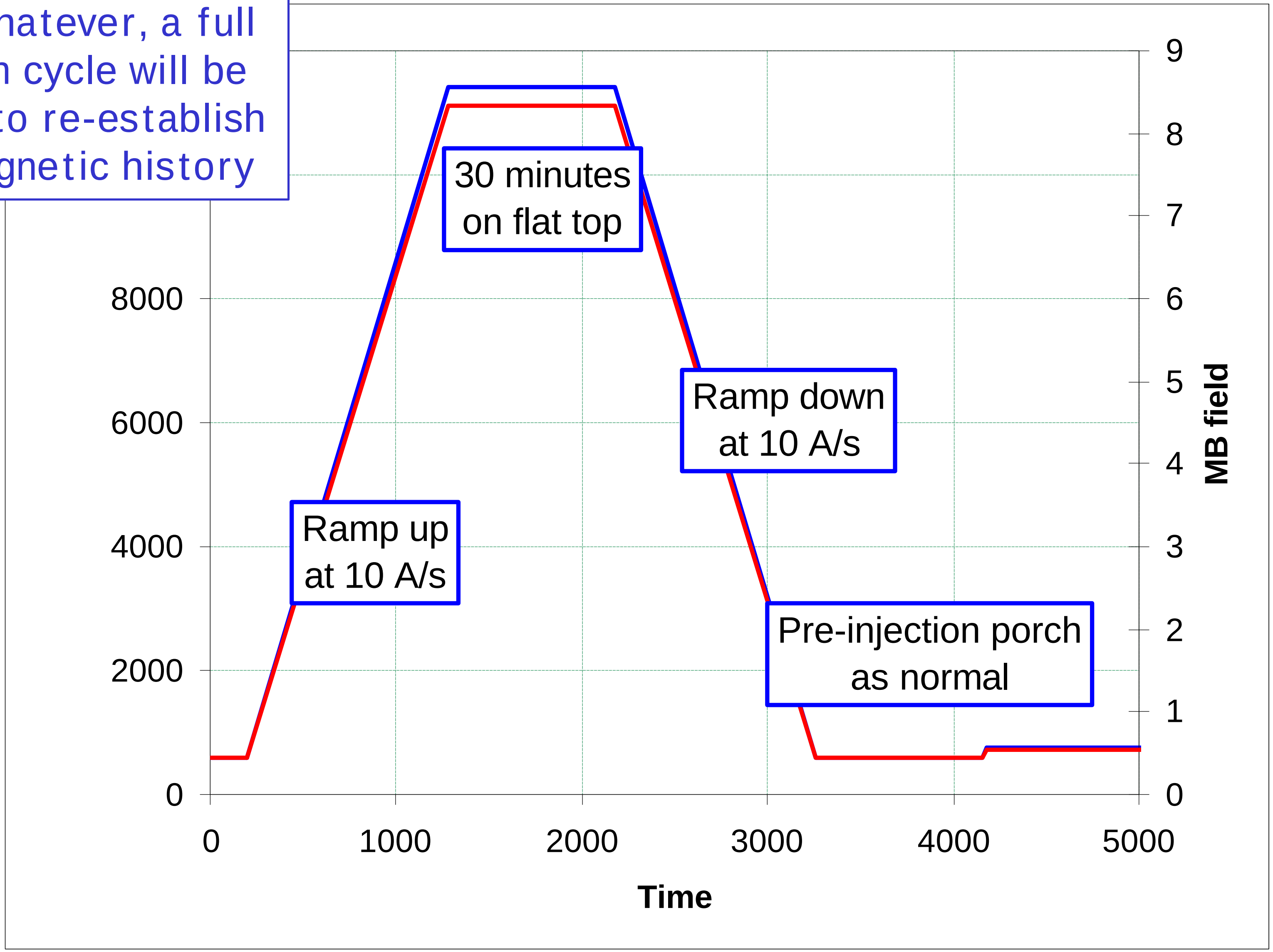
In the normal operations the LHC will perform a standard cycle which will be more-or-less set in stone.

The baseline cycle - hiccups

- **Abort**
  - **beam loss**
    - in ramp: finish cycle, wait on flat top, normal cycle
    - in coast:
      - if longer that 30 minutes - ramp down
      - if less than 30 minutes wait..
  - **power abort - recover, set minimum, re-cycle**
  - **quench - ramp everything else down, wait at minimum, re-cycle when recovered.**
- **Access**
  - **at minimum, re-cycle when finished.**
- **Following cool-down**
  - **standard re-cycle**
- **Stop at Intermediate energy is anticipated**

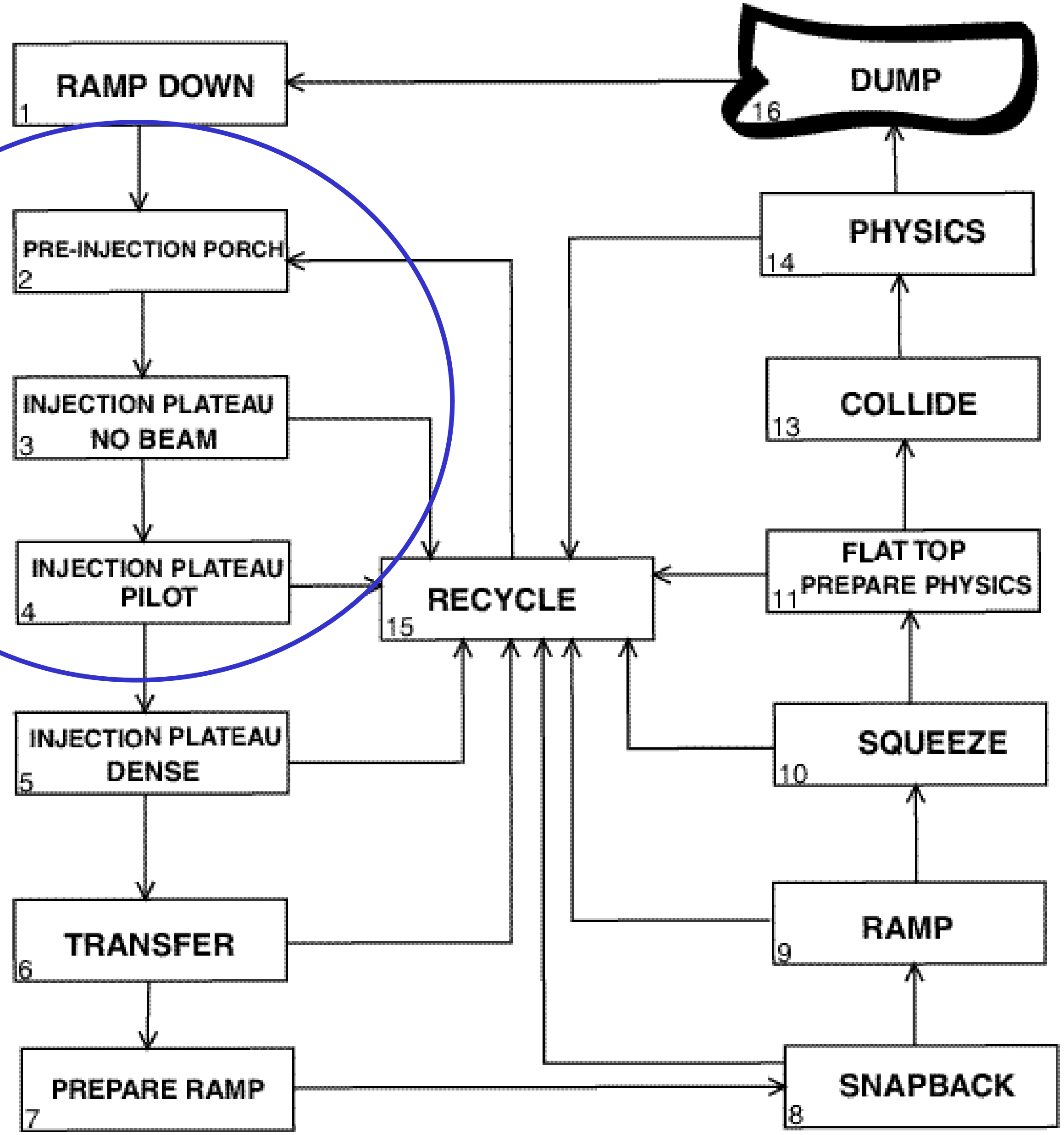
The pre-cycle

In the event of power abort, or whatever, a full preparation cycle will be performed to re-establish a known magnetic history



The baseline cycle can be broken down into states which we can then Use Case our way through wrt to equipment, instrumentation and the control system.

Have a look at these in a bit more detail...



The Use Case challenge

The cycle

- Switch on
- Injection Setup
- Establish circulating beam
- Injection
- Injection Optimisation
- Prepare ramp
- Nominal snapback
- Ramp
- Programmed stop in ramp
- Squeeze
- Collide, Physics
- Luminosity optimisation
- Ramp down

+ exceptions and faults

Equipment and instrumentation

- Power converters
- RF
- Collimators
- TDI & TDE, Dumps
- Kickers
- Beam Instrumentation
- Multipoles Factory
- Interface to cryogenics & vacuum
- Interface to experiments

The control system

- Timing & Synchronisation
- Real-time
- Middleware
- Architecture

Pre-injection plateau

- Ramp down to ~ 600 A. Check that power converters have performed cycle down properly.
- Collimators out - check
- TDI to parking - check
- Kickers to standby
- Dumps - active - check
- Check kicker timing and BST.
- RF: 200 MHz, 400 MHz & transverse dampers:
  - ➔ Set RF frequency to injection level, ➔ Set the gain of the phase loop amplifier ➔ Set the gain and time constant of the synchronization loop amplifier, ➔ Close the phase loop around the VCO, ➔ Switch the RF DRIVE ON, ➔ Switch the phase loop to the cavity sum signal, ➔ Reset the revolution frequency generator following reset of TTC
- Check: interlock system operational
- Check: magnet protection system
- Check: beam and power abort system operational.

Pre-injection plateau

- Power converters:
  - check state & tolerances
- Multipoles factory
  - check hardware
  - produce prediction of persistent current based on powering history, incorporate into settings
- SPS
  - Check synchronization. Foresee training sequence in SPS for a pulse or two on the LHC cycle, during this time synchronization can be established.
- Transfer lines
  - Pilots to TEDs, check converters, instrumentation, steering etc.

↓

Ramp power converters to injection level

Injection plateau - before beam

- **Power converters:**
  - Verify that all power converters have reached the required current and are within tolerance.
  - Based on predictions from multipoles factory and history, correction will be sent to multipole correctors via real-time channel throughout duration of injection plateau. Check.
  - Horizontal orbit correctors will be driven to compensate b1 drift. (via a knob)
- **Multipoles factory**
  - Start tracking and correcting for drifts in b1, b2 and b3 (at least) via readings from the reference magnets (here we include Hall Probes etc.). Corrections via real-time channel.
- **Online monitoring of other systems**
  - collimators out, TDI parked, RF OK, etc...

Take Pilot I

- Issue injection request
  - before each injection, update the bucket selector and the phase of the 400 MHz sent to the SPS. (Bucket and ring ID required)
  - generate injection pulses for the kickers
  - generate injection pulses for BI
- Take PILOT into BLUE (or YELLOW) ring
- Low level RF synchronizes transfer
  - jump phase loop onto beam, switch synchro loop on
  - resynchronise the divider that provides the gating of the long. feedback input/out to act on the incoming batch only
  - function generator will raise and then lower gain of longitudinal feedback,

Take Pilot II

- If beam circulates carry on. If beam doesn't - go to "Establish Circulating Beam".
- Measure (& correct if necessary):
  - transverse injection oscillations,
  - energy,
  - RF feedback,
  - Q, Q',
  - separation at IPs,
  - closed orbit.
- Adjust TDI with respect to closed orbit
- Adjust collimators with respect to closed orbit
- Operator will have ability to trim corresponding physics parameters (tune, chromaticity, orbit etc..)
  - Note: real-time correction of these parameter, use of corresponding actuators probably going on.

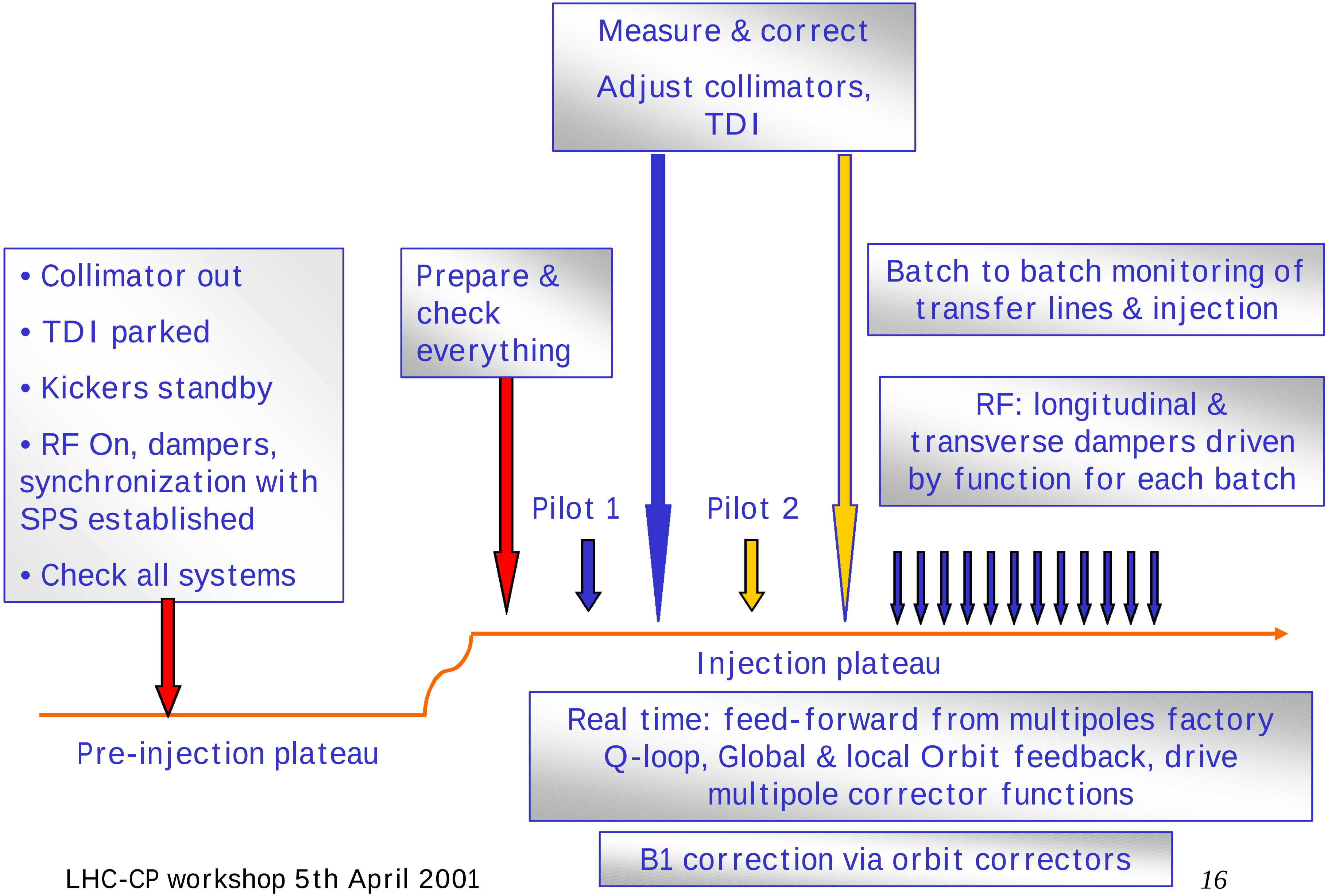
Beam size at collimators?

Effect of beta beating?

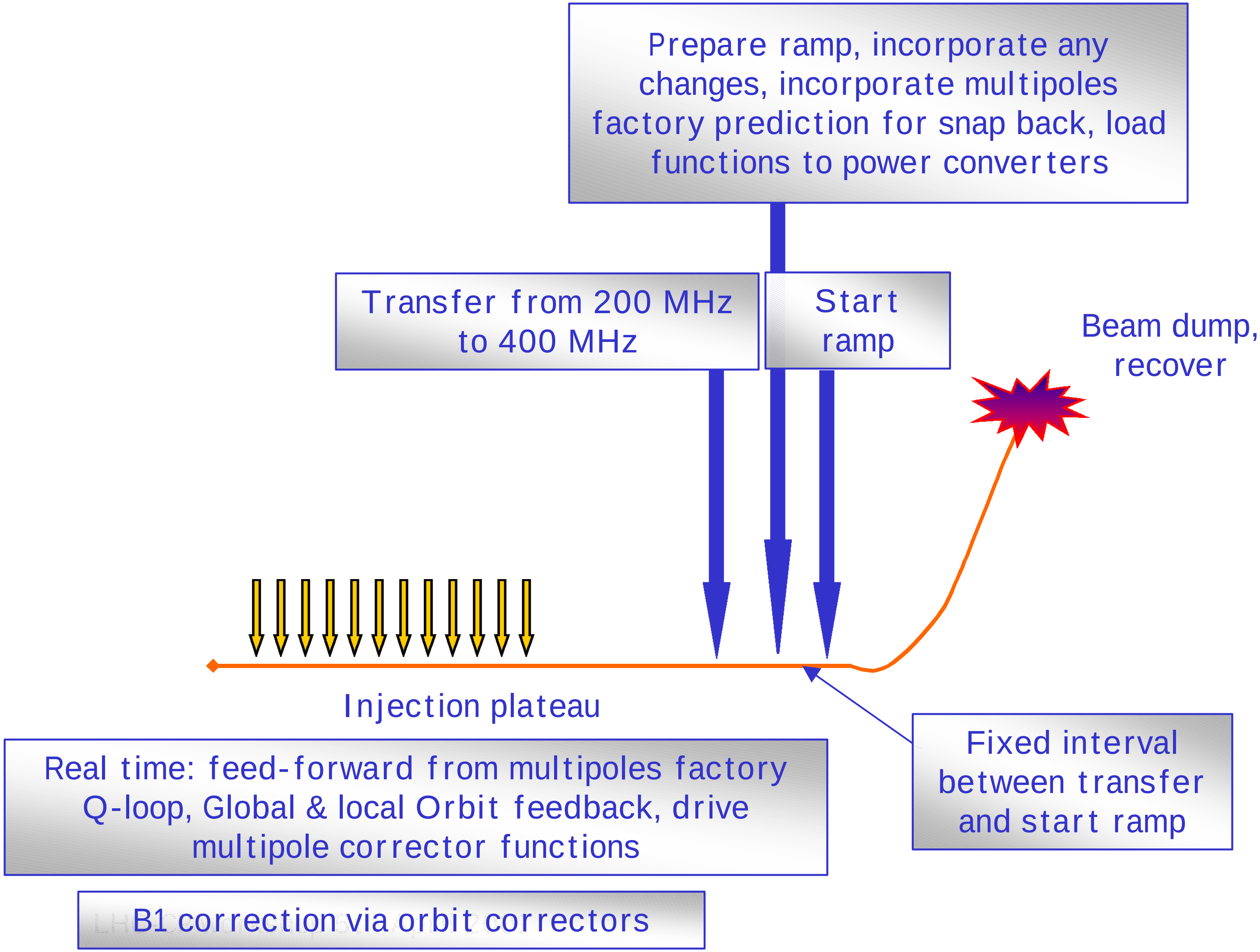
Local orbit feedback?

Emittance variations from SPS?

Injection…for example



Injection, for example...



From this...

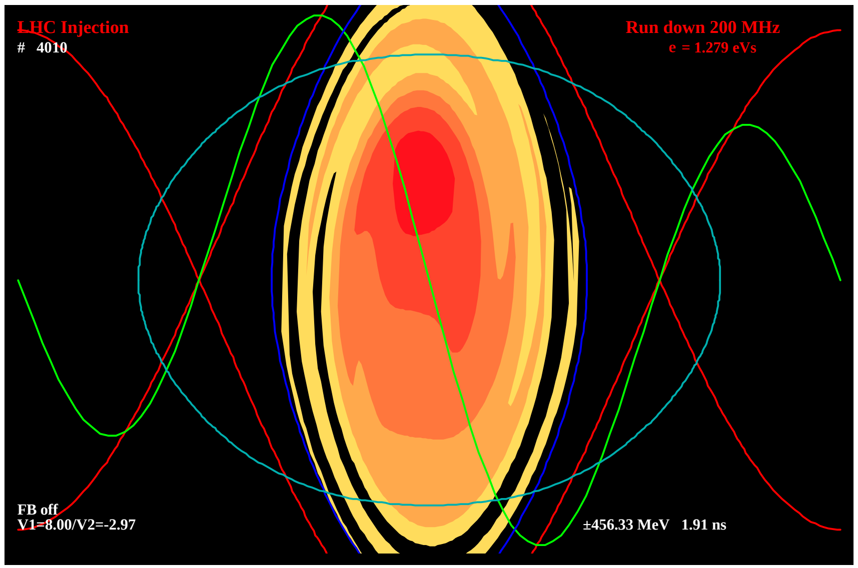
- **Attempt to establish:**
  - required high level functionality
  - control requirements of involved equipment
  - logical architecture
  - novel requirements of control system architecture
  - misconceptions
  - and unanswered questions

1. High level functionality

- **Measure and correct**
  - Threading, trajectory oscillations, steering, orbit from pilots , adjustment of TDI and collimators, matching, screens, measurement of optics parameters
  - closed orbit of both rings, global & local correction etc. etc.
  - signals such as BCT, lifetimes, beam loss, luminosity, beam sizes
  - measurements of tune & chromaticity
- **Control** Set, commands, functions: RF, dampers, power converters, kickers, dumps, collimators, TDI, etc. etc.
- **Feedback** to provide stability of machine parameters, Track Q, Q', energy during injection plateau, for example
- **Feed-forward** from multipoles factory and experience
- **Tools** Correlations, scans, Coupling between control and beam instrumentation e.g. synchronised acquisitions. Trims, sequencer, fixed displays.
- **Data management** control of ramp & squeeze settings, history, rollback
- **Logging & post-mortem analysis** for post-run, post-MD analysis and statistics
- **Diagnostics, On-line optics model, Re-boot facility**

2. Equipment - high level control

- **Collimators:**
  - **asynchronous set, 1 mm step size,**
  - **synchronized movement between primary and secondary collimators,**
  - **timing, functions (of some sort) will need to track squeeze**
  - **local orbit feedback required.**
- **RF (NB: fast digital control at the low level)**
  - **command-response,**
  - **functions invoked by millisecond timing:** damper gating, gain ramping (200 MHz)
  - **lots of slow timing requirements**
  - **setting management**

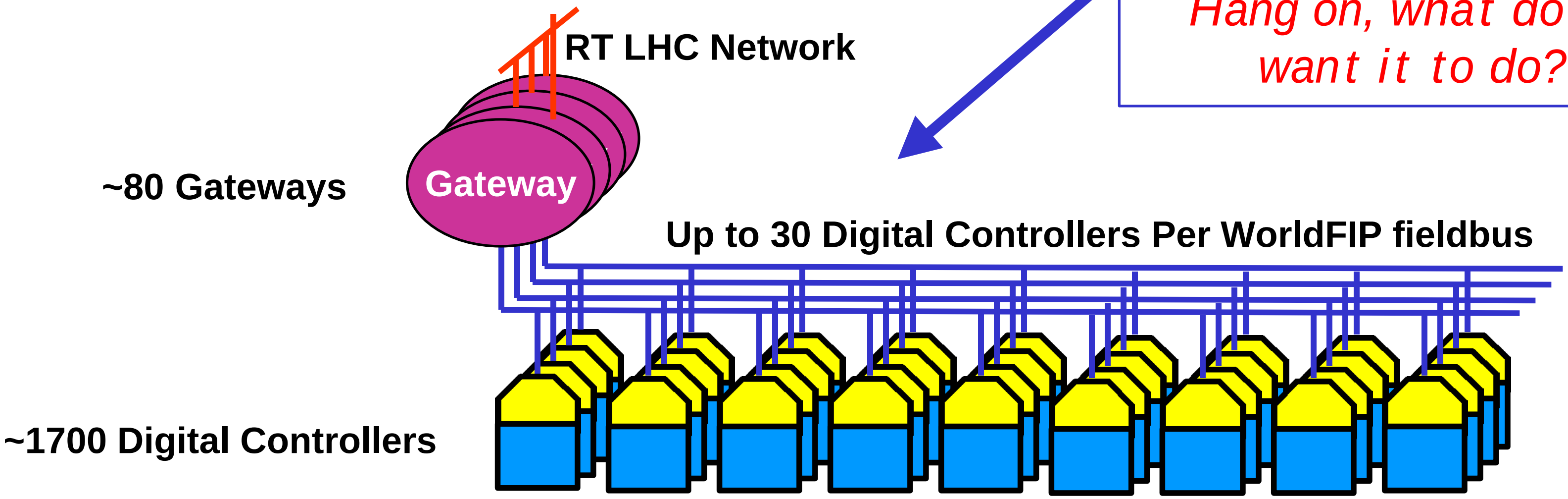


2. Equipment - high level control

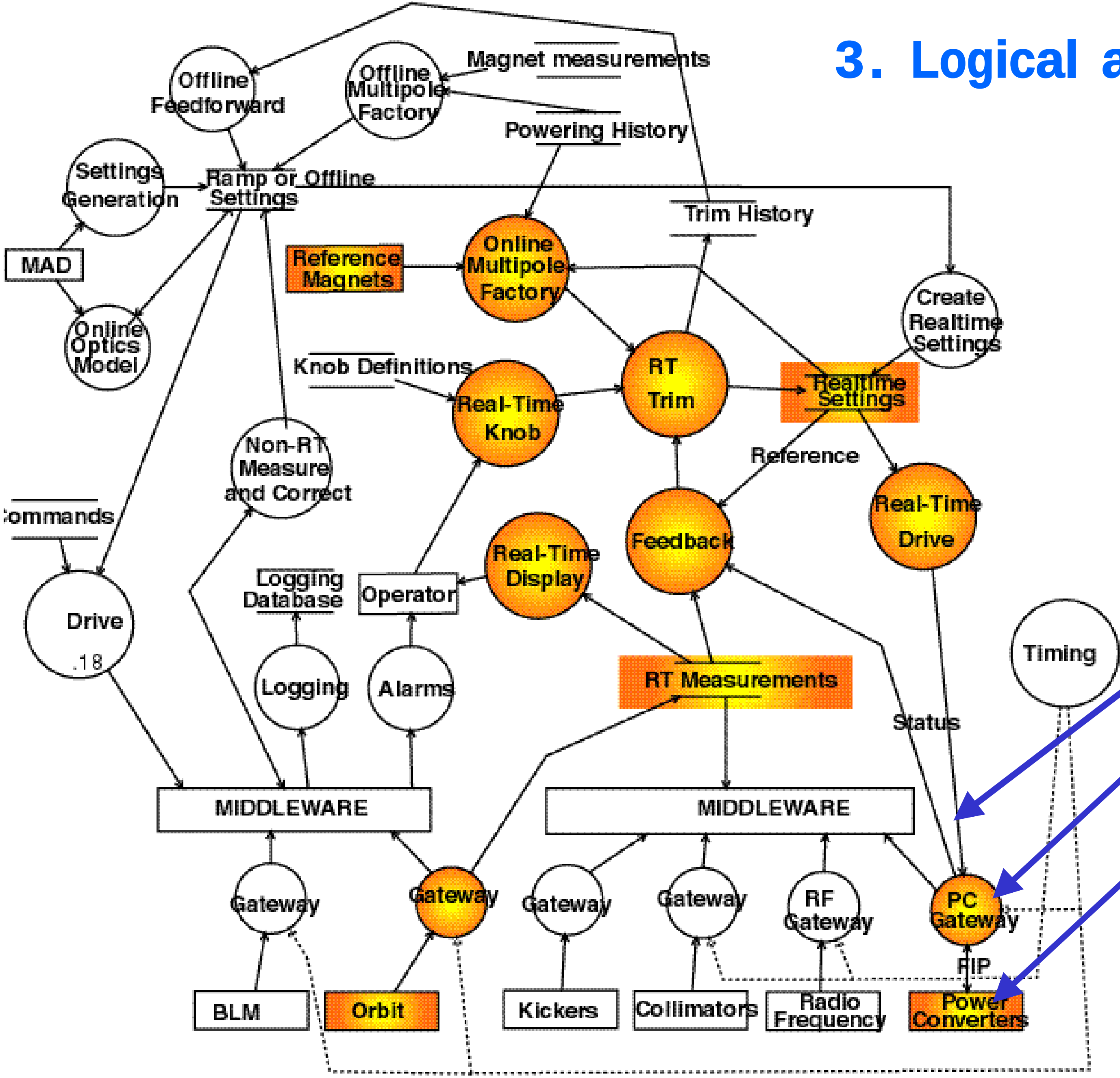
- **Power Converters**
  - asynchronous set (different methods),
  - synchronous set - millisecond timing
  - command-response,
  - functions (number of points, splines, download, deltas v. absolute)
  - slow timing,
  - post mortem, alarms,
  - real-time correction channel

Does this do what we want it to do?

Hang on, what do we want it to do?



3. Logical architecture



Mixture of logical and physical which reflects reality

Power converters, for example: Digital controllers connected to VME by world FIP, IRIG-B/TG8 presumably Gigabit Ethernet to high level

Novel Control infrastructure

- **Timing:** under auspices of TIWG, hopefully LHC requirements are more-or-less elucidated. See Gary's talk...
- **Middleware:**
  - CORBA III Orb,
  - Servers written in C++,
  - GUI's in VB/DELPHI with CORBA/COM fast bridging technology.
  - Use Oracle V8 DB,
  - will need orb with event service.
- **Real Time:** ➔

RT requirements II

		Acquisition	Actuators
Reference magnets	3 - 10 Hz		Trim quads, sextupoles…
Global orbit feedback	1 Hz	As below…	2*500
Chromaticity	1 Hz	Single instrument	Trim sextupoles
Tune feedback	10 Hz	Single instrument	Trim quad PC
Beam loss display + poss input to feedback system	10 Hz	250 crates 130 Kbytes/s	N/A
Real-time knobs	10 Hz	Real-time display	1 to 500
Global orbit acquisition	10 Hz	250 crates 200 Kbytes/s	N/A
Local orbit correction & acquisition	Max 100Hz	~10 PUs	~5 correctors

Response limited by PC/magnet

Latencies

Acquisition	10 ms
Network	5 ms
Collection of data	5 ms
Alogrithm	10 ms
Broadcast to gateway	5 ms
Transport over FIP	0 - 10 ms
Power Converter	10 ms
Magnet	10 ms

Keep your hats on, numbers under discussion

Which should allow us to suppress beam perturbations at a maximum of 1 Hz
i.e. good enough for snapback, decay etc...

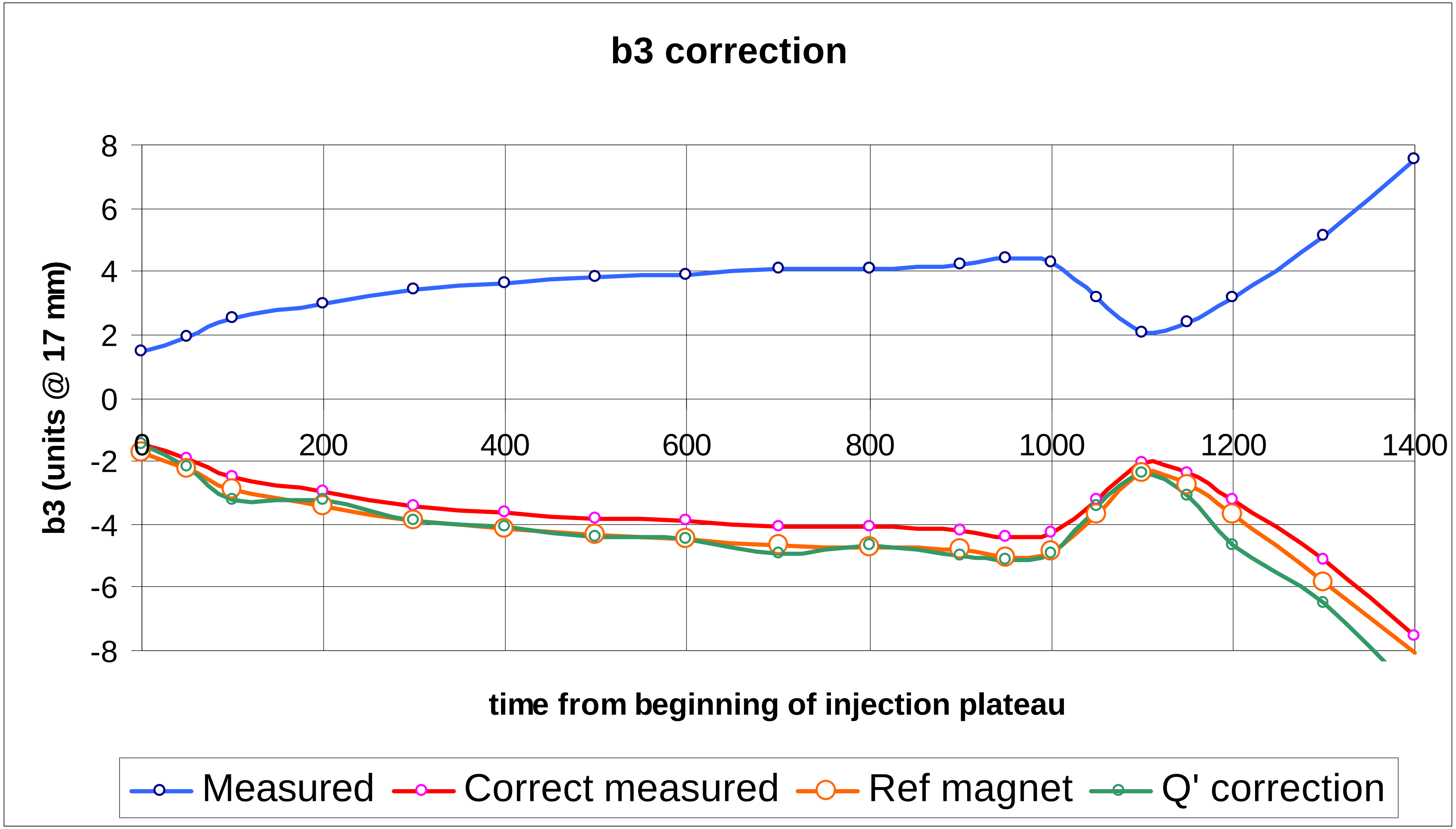
Real time

Beam Instrumentation and Power Converter systems are planning on providing real-time acquisition and correction from the front-ends to at least the gateway level.

Ethernet by appears to be capable of providing the necessary level of performance via ***<u>dedicated</u>*** Gigabit Ethernet

A real-time environment will be necessary at the high-level.
A logical architecture is required to allow the implementation of a well-designed, integrated system
A generic approach will be adopted to provide standard facilities.

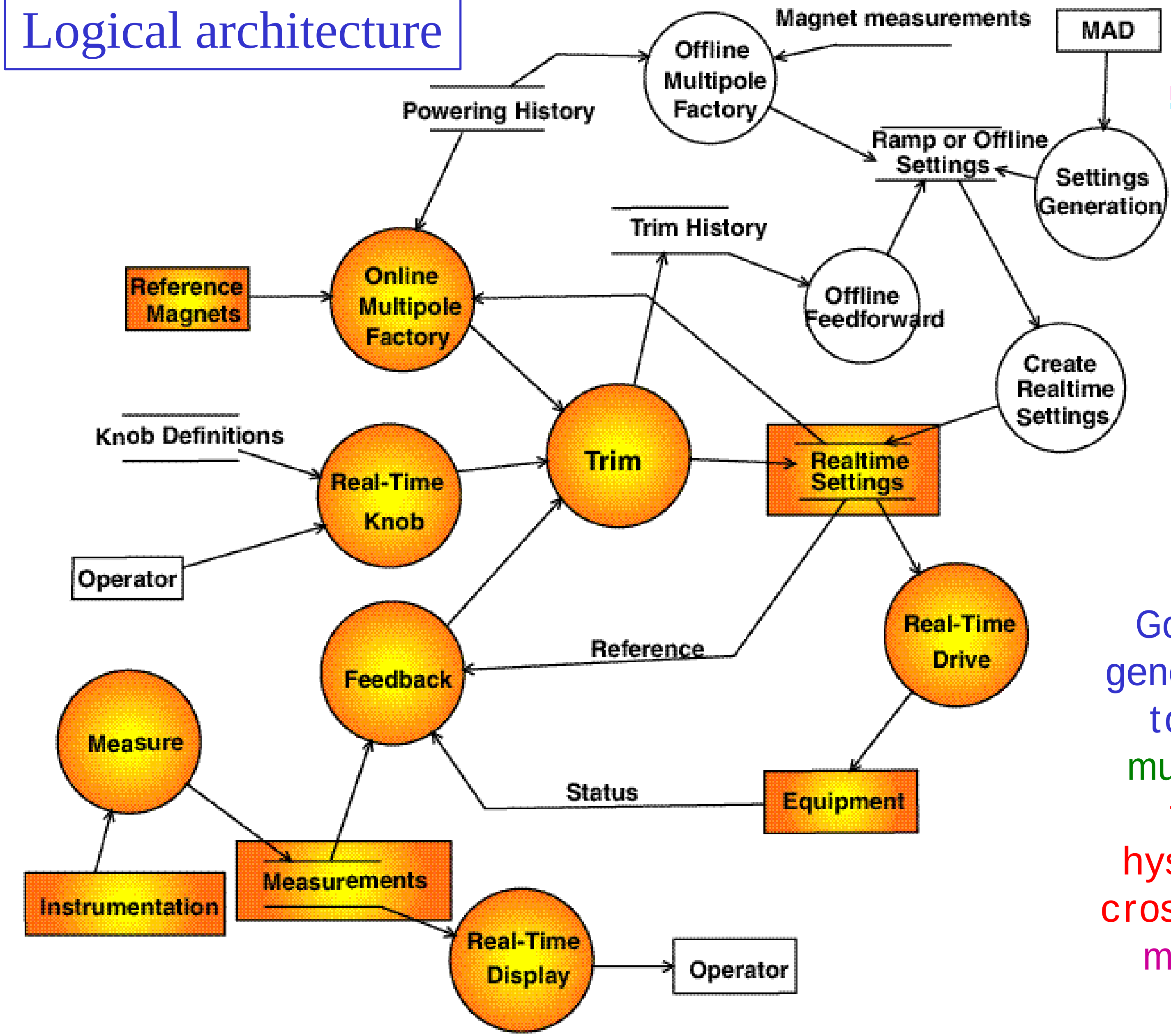
Multiple inputs - single output



Essential challenge of many sub-systems hitting common actuators

Not to mention the problem of hysteresis loop crossing

Logical architecture



Going to need generic facilities to deal with: multiple users, things like hysteresis loop crossing and data management.

RT - where do we go from here?

- **Have established**
  - the requirements,
  - the need for a coherent approach to RT use,
  - and are in the process of trying to understand the detailed issues.
- **Need to:**
  - establish a RT framework with the help of a consultant/expert on RT control engineering
  - develop a rigorous model of the plant dynamics
  - develop the logical architecture
  - request a dedicated Gigabit Ethernet

Objectives for the year

- Framework established. Use Case is painstaking and meeting-centric, but no real alternative if we really want to gain understanding.
- Need to continue anticipating the choices that will effect our ability to control the machine:
  - real-time - good progress made
  - timing - in the bag
  - middleware requirements to be established
- Need to make sure that low level design choices match high level requirements,
  - e.g. Review low-level Power converter functionality in the light of what we've uncovered.
- Finish a first pass Use Case of all relevant equipment through the complete cycle (plus logical architecture) and publish.
- Look at interfaces to other systems
- Capturing on the Web for the moment
  - Rational Rose, UML, DSDM/ODP methodology and some Project Management method will eventually be used. Cough.

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- **Details**
  - **http://lamontm.home.cern.ch/lamontm/lawg/Lawghome.htm**