# Beam Quality Checks at Injection

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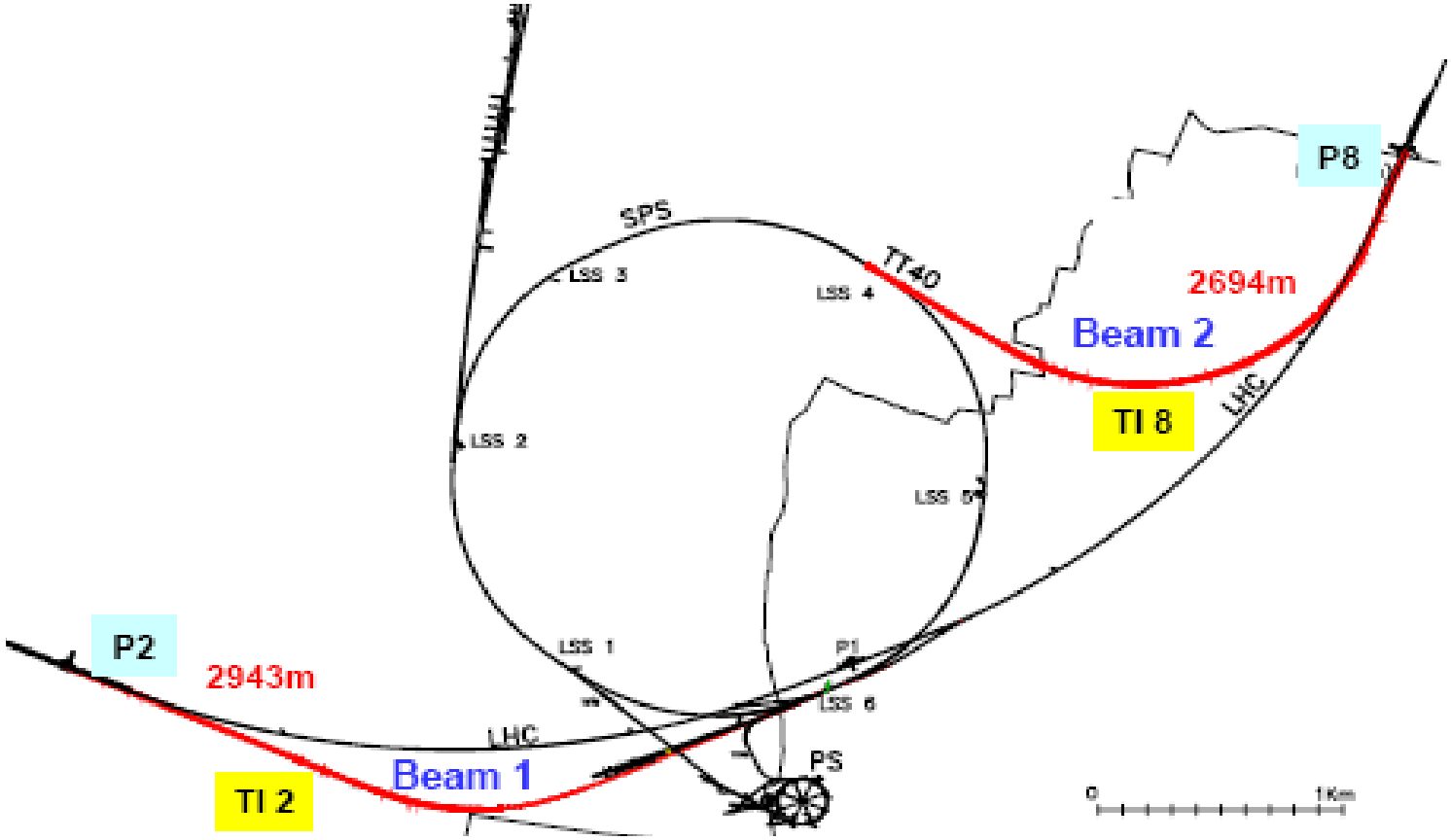
# Overview of the injection process



# Introduction – Injection Vetoes

2 types of vetoes…

- A) Interlocks: Injection Permits (& SPS extraction permits) – for safe operation
  - must be safe
  - hardware/software
  - triggered rarely, only in case of irregular/abnormal operation
  - prevents injection
- B) Quality Checks – for efficient operation and performance
  - must not continually block injection
  - software
  - triggered EVERY injection
  - can only latch NEXT injection (does NOT dump beam)

**Focus on B) in this talk** – however, borders between A) and B) somewhat blurred:

- functionality, consequence of veto (interlock/alarm)

- technology - see below

# What needs to be “injection quality” checked?

## Beam parameters and configuration

- in the SPS at extraction
- in the transfer line
- in the LHC at injection
- in the LHC during first turns

## Equipment parameters and performance measurements

- extraction & injection systems, RF stuff

## Different parameters must have different priorities/levels

- injection blocked by quality check only for rare cases
  - e.g. last injection ended up in wrong bucket
- 2 levels:
  - Level 1: LATCH – next injections inhibited (needs reset)
  - Level 2: WARN – alarms, operator needs be informed to enhance performance

# What needs to be “injection quality checked”?

## Parameters to be monitored for injection quality check…

| Parameter | equipment | what | tolerance | where | level | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| bunch-by-bunch intensity variation | FBCT | | < 10 % | SPS/LHC | 2 | warn 2 | latch 1 |
| injection oscillations | | | < 4 mm ?? | LHC | 2 | | |
| waveform | MKE / MKI | | | SPS/LHC | 2 | | |
| local trajectory diff. | MSI | | | TL | 1 | | |
| | TDI | | | LHC | 1 | | |
| | TCLI | | | LHC | 1 | | |
| Δ(BCTsps - BCTendti8) | | | | | 2 | | |
| Δ(BCTendti8 - BCTfirstturn) | | | | | 2 | | |
| RF bucket number, pattern | | | no tolerance | LHC | 1 | | |
| emittance | synchotron light monitor/ wire scanner | | < 3.75 mm | SPS/LHC | 2 | | |
| local arc excursion | | B-field diff. between arcs | | LHC | 2 | | |
| energy mismatch | | | | SPS - LHC | 2 | | |
| abort gap population | abort gap monitor | | 1e+7 p+/m | | 2 | | |
| ghost bunch intensity | | | < 5 % | SPS | 2 | | |
| RF synchro phase | | | | LHC | 2 | | |
| RF synchro B-field | | | | LHC | 2 | | |
| bunch length | | | | LHC | | | |
| max beam loss around ring | | | | LHC | 2 | | |
| beam loss | D2 | | | LHC | 2 | | |
| | MSI | | | LHC | 2 | | |
| | mask infront of Q6 | | | LHC | 2 | | |
| transfer line losses | | | | TL | 2 | | |

Work in progress

# Requirements…

- In case of “quality check” veto
  - **SEQUENCER** should **not** request any **LHC beam from the injector complex**.
  - clean way:
    - not producing any LHC beam
    - required reaction time from last injection: ~ 1 s (tight!) ← **This should be the aim!!**
  - less clean way:
    - dumping the next LHC beam in the SPS
    - required reaction time < 20 s (relaxed)

- “Quality check” tool should
  - be easily configurable
    - to start with a small sub-set of the beam parameters and extend if needed
  - interface to
    - Injection BIC
    - Sequencer
    - Alarms
  - can be reset by sequencer

# How…

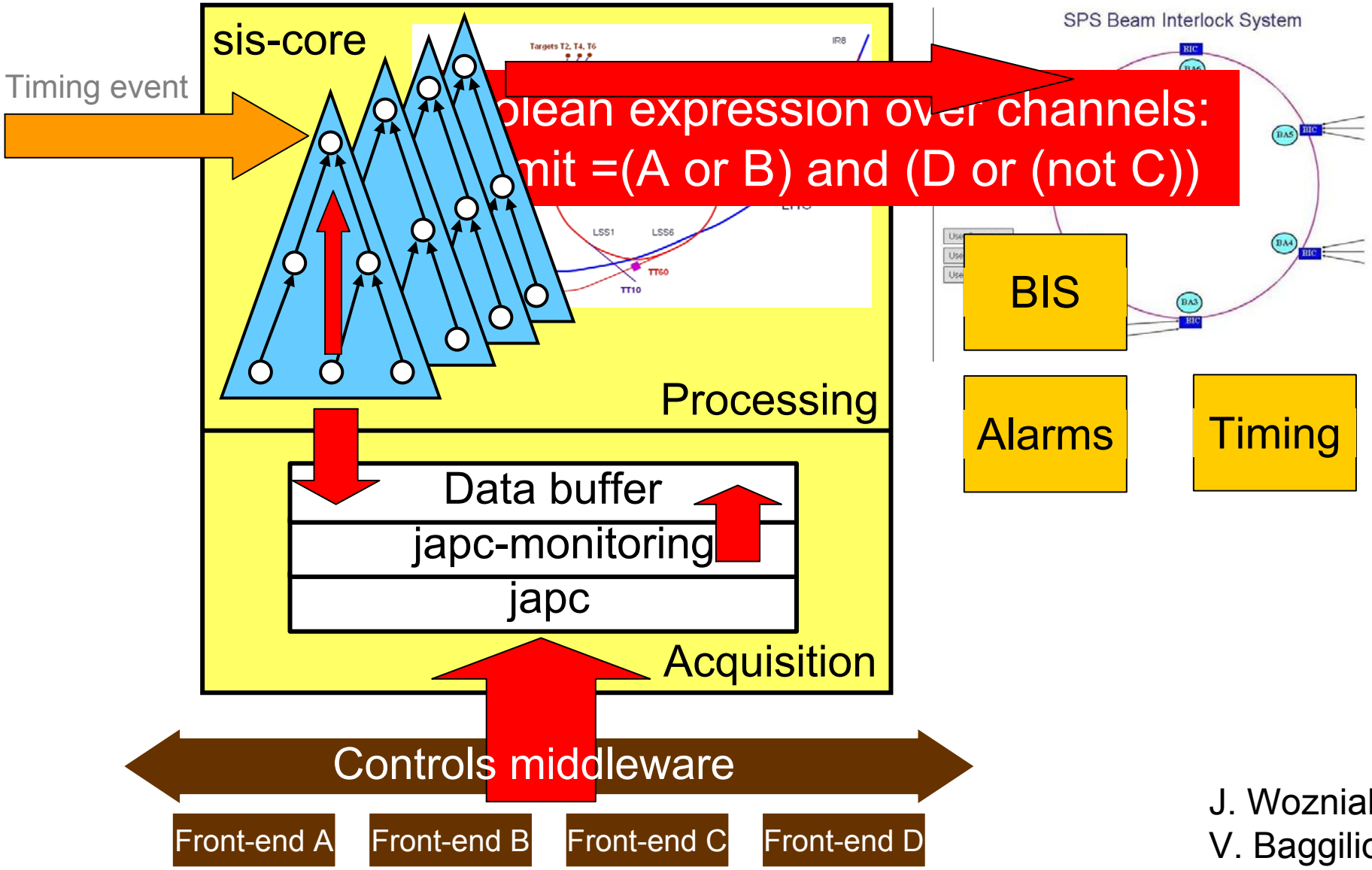
- Need to perform the Injection Quality Check for EVERY injection
  - During regular operation: no interlock → no post mortem data

- Using logging data is not fast enough
  - Hence the idea:

Injection Quality Check **within / similar to** Software Interlock System (SIS)

Subscription to the parameters of concern

# Software Interlock System (SIS) - SPS

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# Injection Quality Check ↔ SIS

- Needs new features
  - Dynamic references
  - Combini
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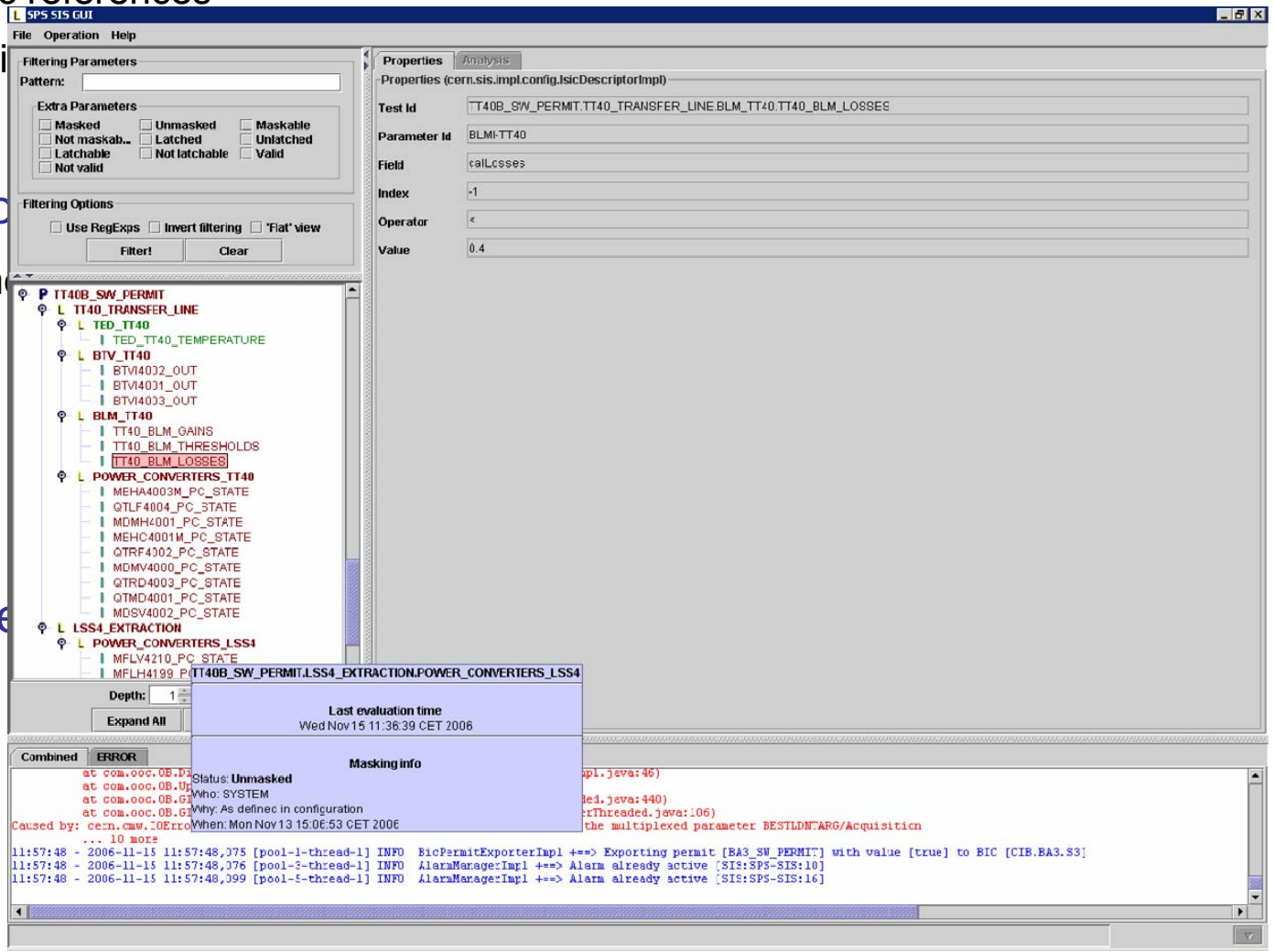


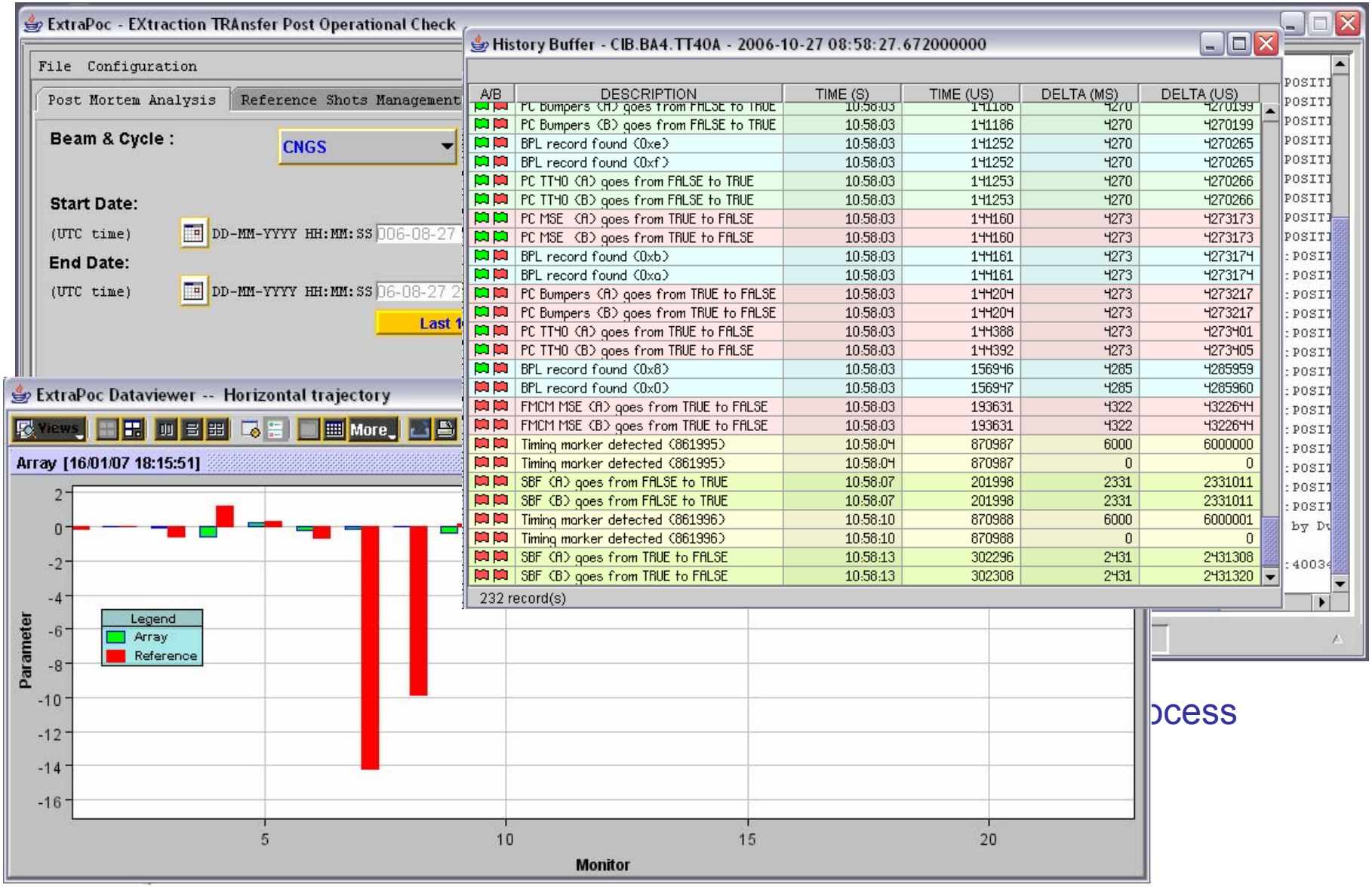
# “Post mortem” of Injection Quality Check

If quality check rejects last injection…

- SIS↔IQC GUI / Alarm screen signals which parameter was not within specification. SIS returns status only.

- To improve performance, analysis is needed
  - Analysis of transient recording
  - Shot-by-shot logging (as for CNGS, the SPS extractions and the transfer lines)
  - **SDA: Sequenced Data Acquisition**
    - LARP collaboration (E. McCrory, T. Bolshakov, D. Nicklaus, J. Cai @ Fermilab)
    - SDA = event-driven data acquisition and event-indexed DB
    - any form and size of data can be stored
    - data is acquired and stored for abstract stages (shot-case-set) building logical trees
    - e.g. all data related to the last injection could be stored under: fill 157 [injection, injection1]

# Example: Extraction Transfer Post Operational Check (CNGS, SPS extraction, LHC transfer lines)

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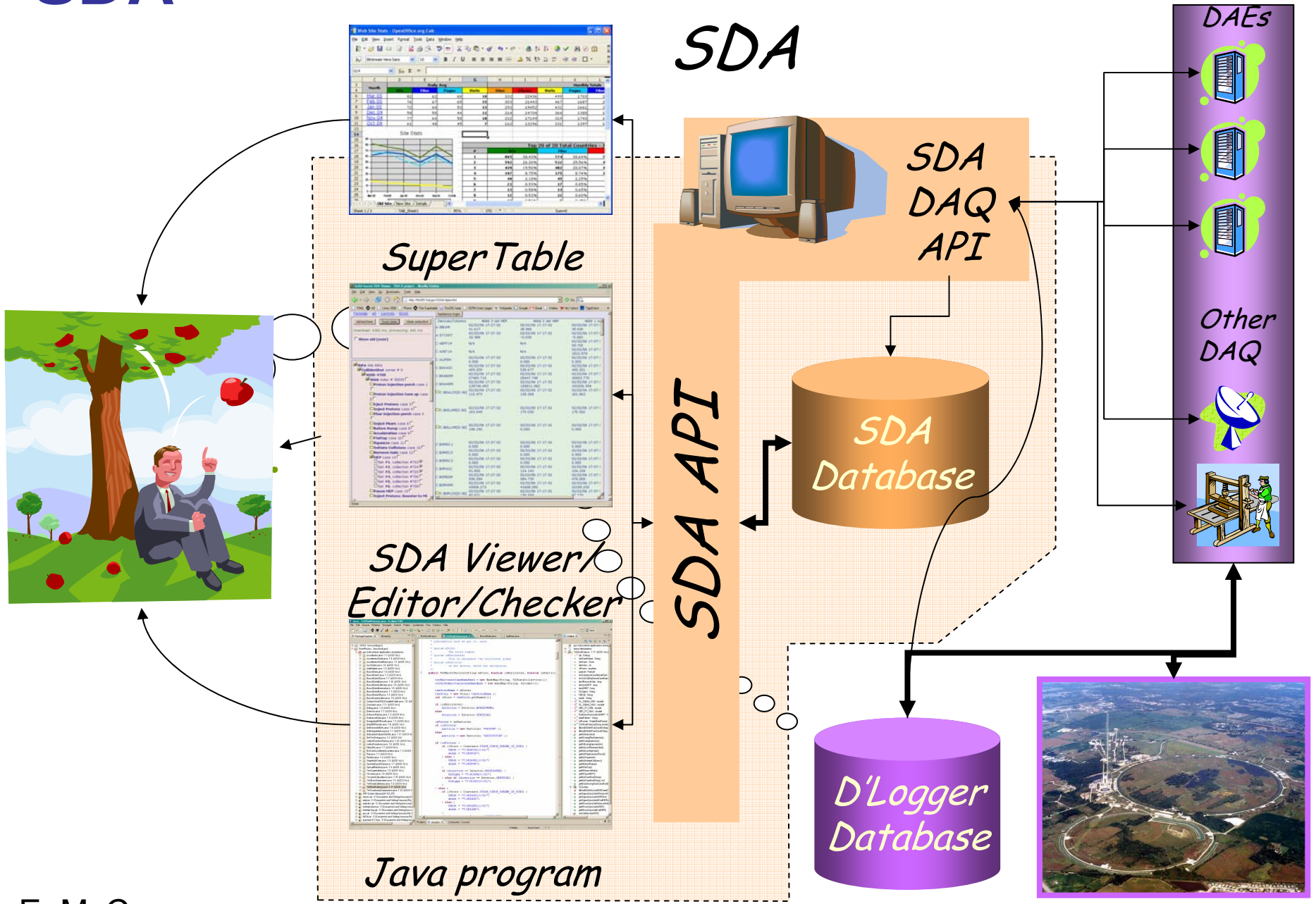
# SDA




E. McCrory

# Remarks

- SIS ↔ IQC: short time window…1 s
  - data collection is the bottleneck
  - e.g. LHC BLM data is published with 1 Hz
- Triggering of acquisition e.g. LHC BPMs, etc. according to injected bunch pattern
  - Sequencer needs to configure BPM system (and other instrumentation) for next injection, set filters according to injected bunch pattern
  - IQC also needs to know requested bucket number etc. for comparison
    - SIS has timing card
  - Telegram with injection bucket from sequencer via timing system required
- Can only be fully tested with beam. Needs beam commissioning time.

# IQC – Plans for 2007

- Set up injection quality check within SIS for LHC start-up

- Restrict first version to minimum sub-set of monitored parameters
  - Bucket number (needs telegram from sequencer)
  - Trajectory (↔ energy)
    - easy test: e.g. every pickup < 4 mm
  - Losses

- Plans for SDA:
  - now: software architecture for LHC SDA at Fermilab
  - May 2007: test SDA at SPS
  - autumn 2007: SDA implementation for LHC

# Summary

- Injection beam quality check is required to enhance the performance.
- The Software Interlocking System seems to be a good candidate to do this job.
  - We will start with this…
- Shot-by-shot logging data and SDA is required for a “post mortem” of the Injection Quality Check.
- We will have a first version of the injection beam quality check for the LHC start-up in 2007.