



## Beam Quality Checks at Injection

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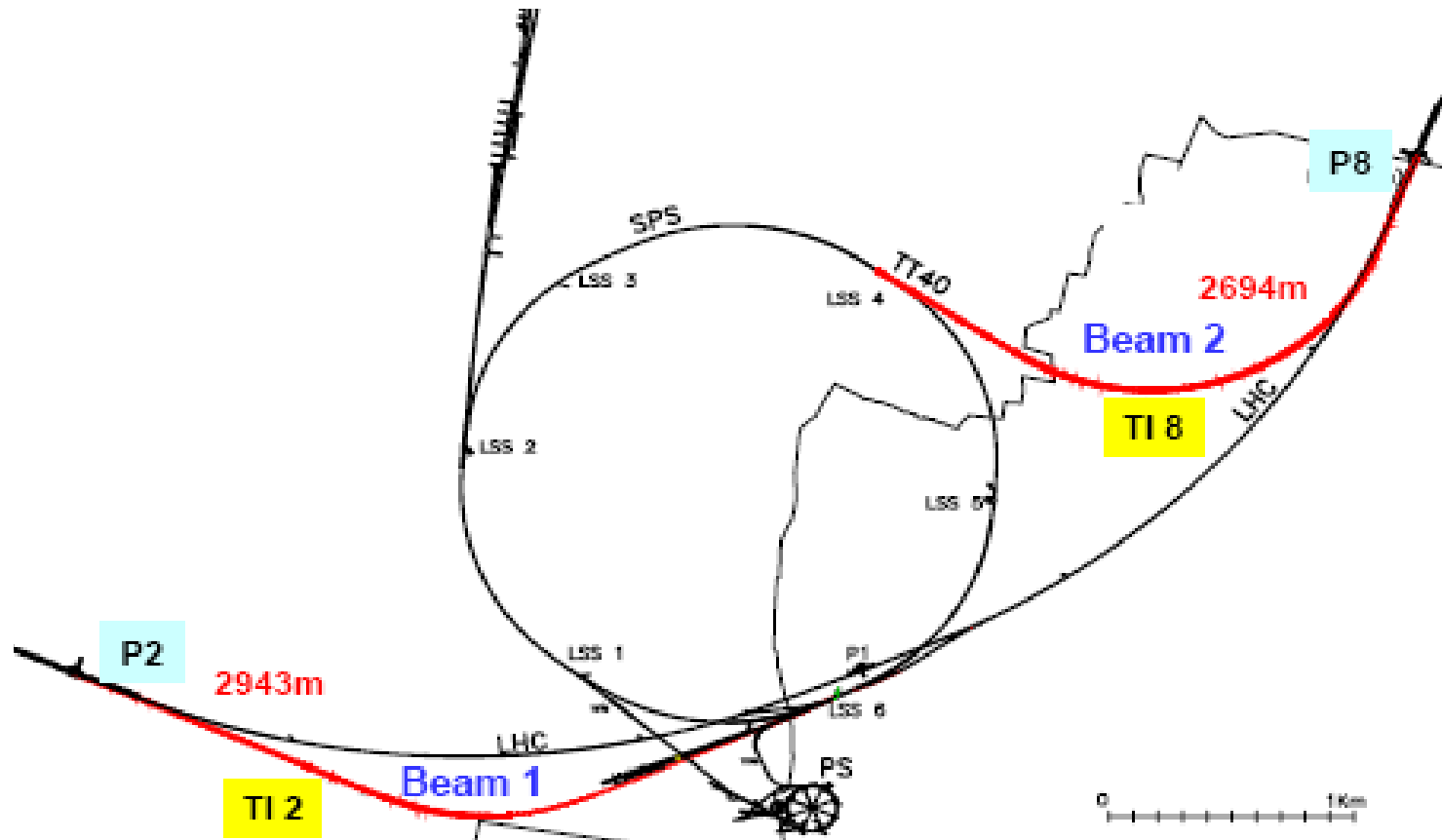
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E. McCrory

### Contents:

- Introduction
- Which parameters need quality check?
- Requirements
- How...
- “Post mortem” of injection quality check
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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		
$\Delta(\text{BCTsps} - \text{BCTendi8})$					2		
$\Delta(\text{BCTendi8} - \text{BCTfirstturn})$					2		
RF bucket number, pattern			no tolerance	LHC	1		
emittance	synchrotron 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 in front 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

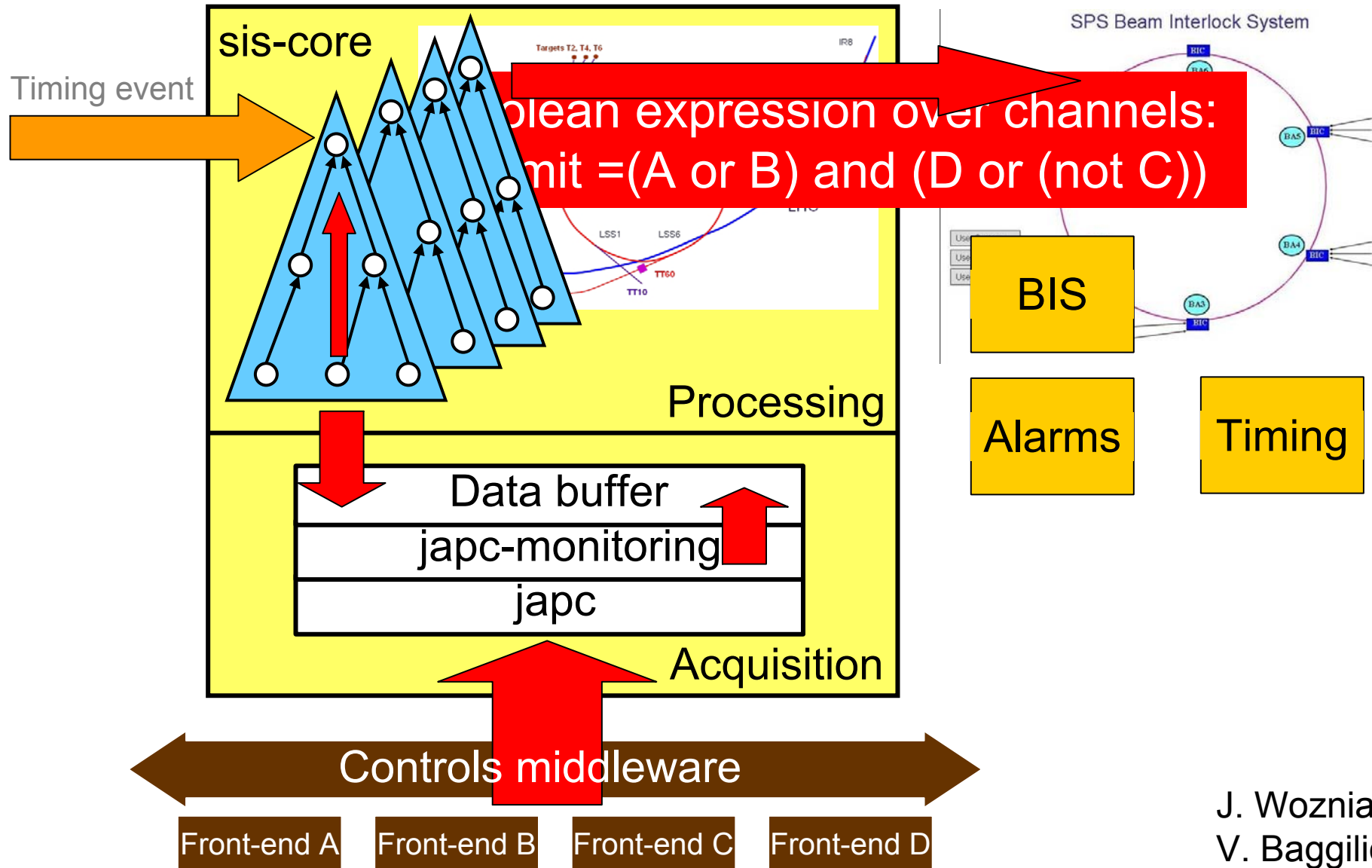
within  
similar to

Software Interlock System  
(SIS)

Subscription to the parameters of concern



# Software Interlock System (SIS) - SPS



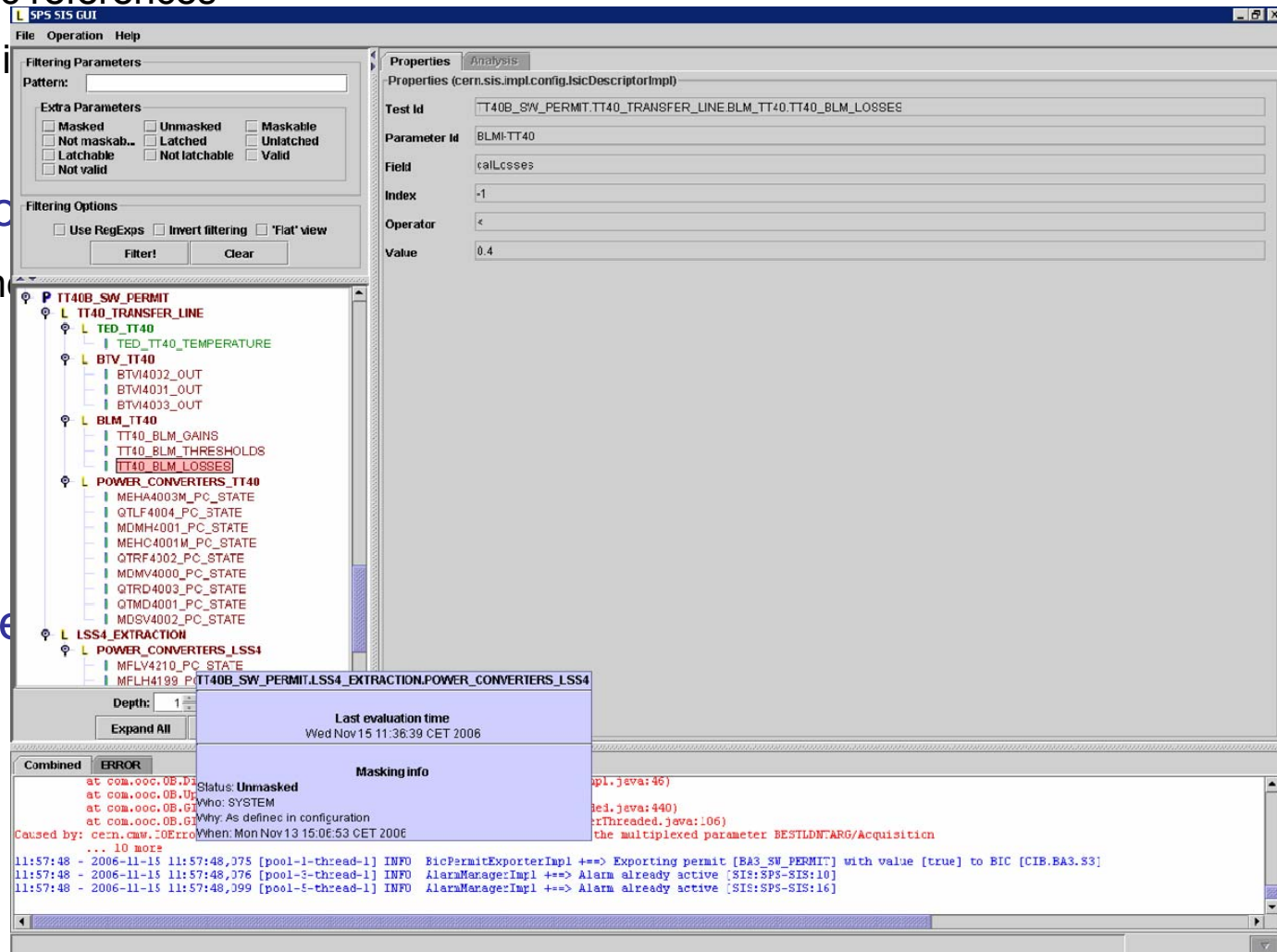
J. Wozniak  
V. Baggilioni





# Injection Quality Check ↔ SIS

- Needs new features
  - Dynamic references
  - Combining
- Had a well worked
- the same





# “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)

ExtraPoc - EXTRACTION TRAnsfer Post Operational Check

File Configuration

Post Mortem Analysis Reference Shots Management

Beam & Cycle : CNGS

Start Date: (UTC time) DD-MM-YYYY HH:MM:SS 06-08-27

End Date: (UTC time) DD-MM-YYYY HH:MM:SS 06-08-27 2

Last 1

History Buffer - CIB.BA4.TT40A - 2006-10-27 08:58:27.672000000

AVB	DESCRIPTION	TIME (S)	TIME (US)	DELTA (MS)	DELTA (US)	POSITI
PC Bumpers (A) goes from FALSE to TRUE	10:58:03	141186	4270	4270199	POSITI	
PC Bumpers (B) goes from FALSE to TRUE	10:58:03	141186	4270	4270199	POSITI	
BPL record found (0xe)	10:58:03	141252	4270	4270265	POSITI	
BPL record found (0xf)	10:58:03	141252	4270	4270265	POSITI	
PC TT40 (A) goes from FALSE to TRUE	10:58:03	141253	4270	4270266	POSITI	
PC TT40 (B) goes from FALSE to TRUE	10:58:03	141253	4270	4270266	POSITI	
PC MSE (A) goes from TRUE to FALSE	10:58:03	144160	4273	4273173	POSITI	
PC MSE (B) goes from TRUE to FALSE	10:58:03	144160	4273	4273173	POSITI	
BPL record found (0xb)	10:58:03	144161	4273	4273174	POSITI	
BPL record found (0xa)	10:58:03	144161	4273	4273174	POSITI	
PC Bumpers (A) goes from TRUE to FALSE	10:58:03	144204	4273	4273217	POSITI	
PC Bumpers (B) goes from TRUE to FALSE	10:58:03	144204	4273	4273217	POSITI	
PC TT40 (A) goes from TRUE to FALSE	10:58:03	144388	4273	4273401	POSITI	
PC TT40 (B) goes from TRUE to FALSE	10:58:03	144392	4273	4273405	POSITI	
BPL record found (0x8)	10:58:03	156946	4285	4285959	POSITI	
BPL record found (0xd)	10:58:03	156947	4285	4285960	POSITI	
FMCM MSE (A) goes from TRUE to FALSE	10:58:03	193631	4322	4322644	POSITI	
FMCM MSE (B) goes from TRUE to FALSE	10:58:03	193631	4322	4322644	POSITI	
Timing marker detected (861995)	10:58:04	870987	6000	6000000	POSITI	
Timing marker detected (861995)	10:58:04	870987	0	0	POSITI	
SBF (A) goes from FALSE to TRUE	10:58:07	201998	2331	2331011	POSITI	
SBF (B) goes from FALSE to TRUE	10:58:07	201998	2331	2331011	POSITI	
Timing marker detected (861996)	10:58:10	870988	6000	6000001	POSITI	
Timing marker detected (861996)	10:58:10	870988	0	0	POSITI	
SBF (A) goes from TRUE to FALSE	10:58:13	302296	2431	2431308	POSITI	
SBF (B) goes from TRUE to FALSE	10:58:13	302308	2431	2431320	POSITI	

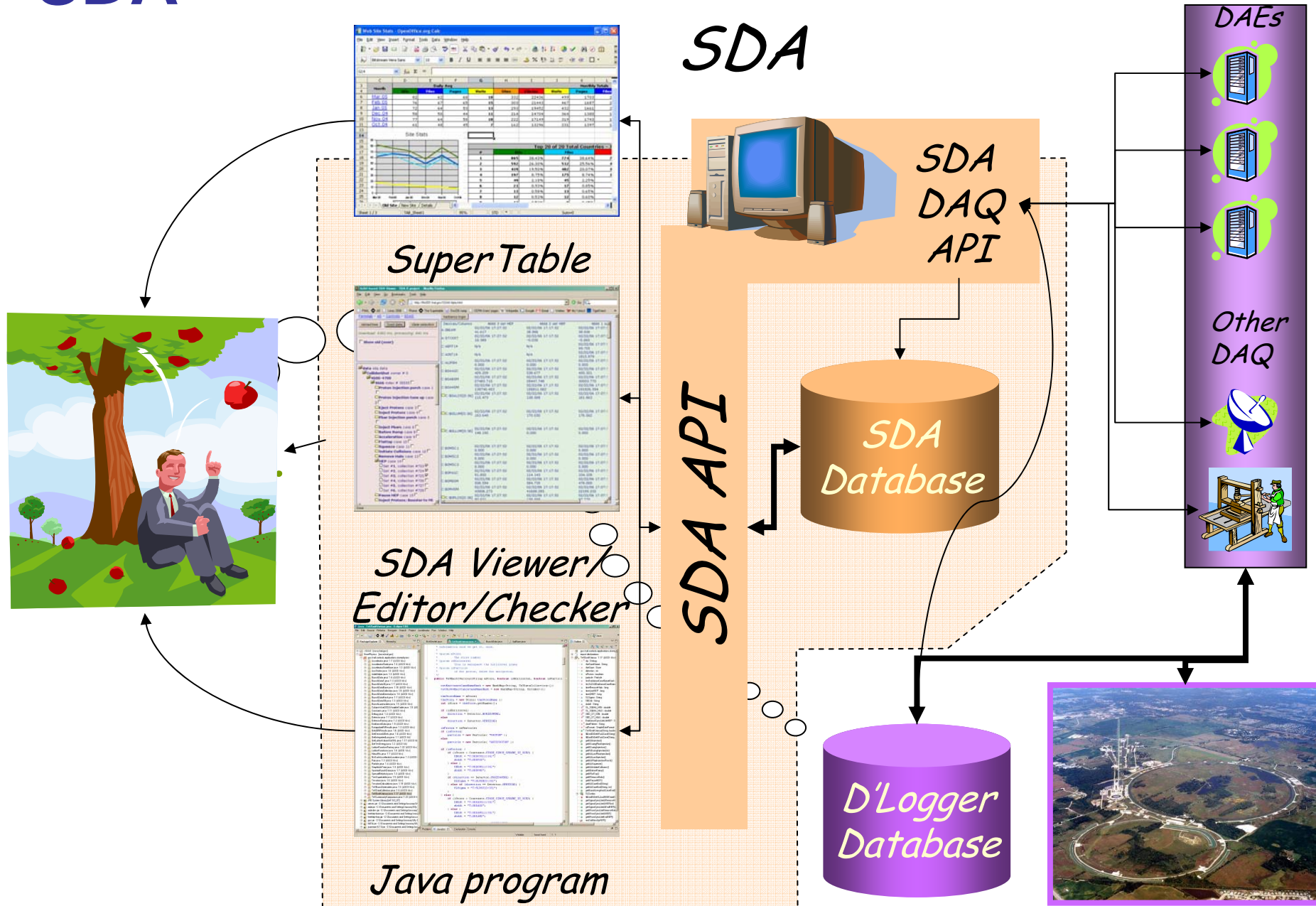
232 record(s)

ExtraPoc Dataviewer -- Horizontal trajectory

Array [16/01/07 18:15:51]

Process

# SDA





# 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 ( $\leftrightarrow$  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.