Fast Beam Abort System @ FAIR

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Reminder from previous talk

- Machine Protection System (MPS) @FAIR by:
  - Collimation systems (passive protection)
  - Equipment monitoring and beam monitoring
  - Quench detection and protection (QD/QP)
  - SIS100: Quench prevention system (presently under discussion)
  - Interlock systems (MPS network;
  operation enveloped by ILs & SBF)
  - Injection inhibit or emergency kicker + dump

- Thereby shall be reached:
  - Avoid that a specific failure can happen
  - Detect failure at hardware level, stop beam and protect the machine
  - Detect initial consequences of failure with beam instrumentation

Reminder, why FBAS @ SIS100

- Heavy ion beam power of SIS100 is high enough to damage sensible equipment (e.g. e-Septum).

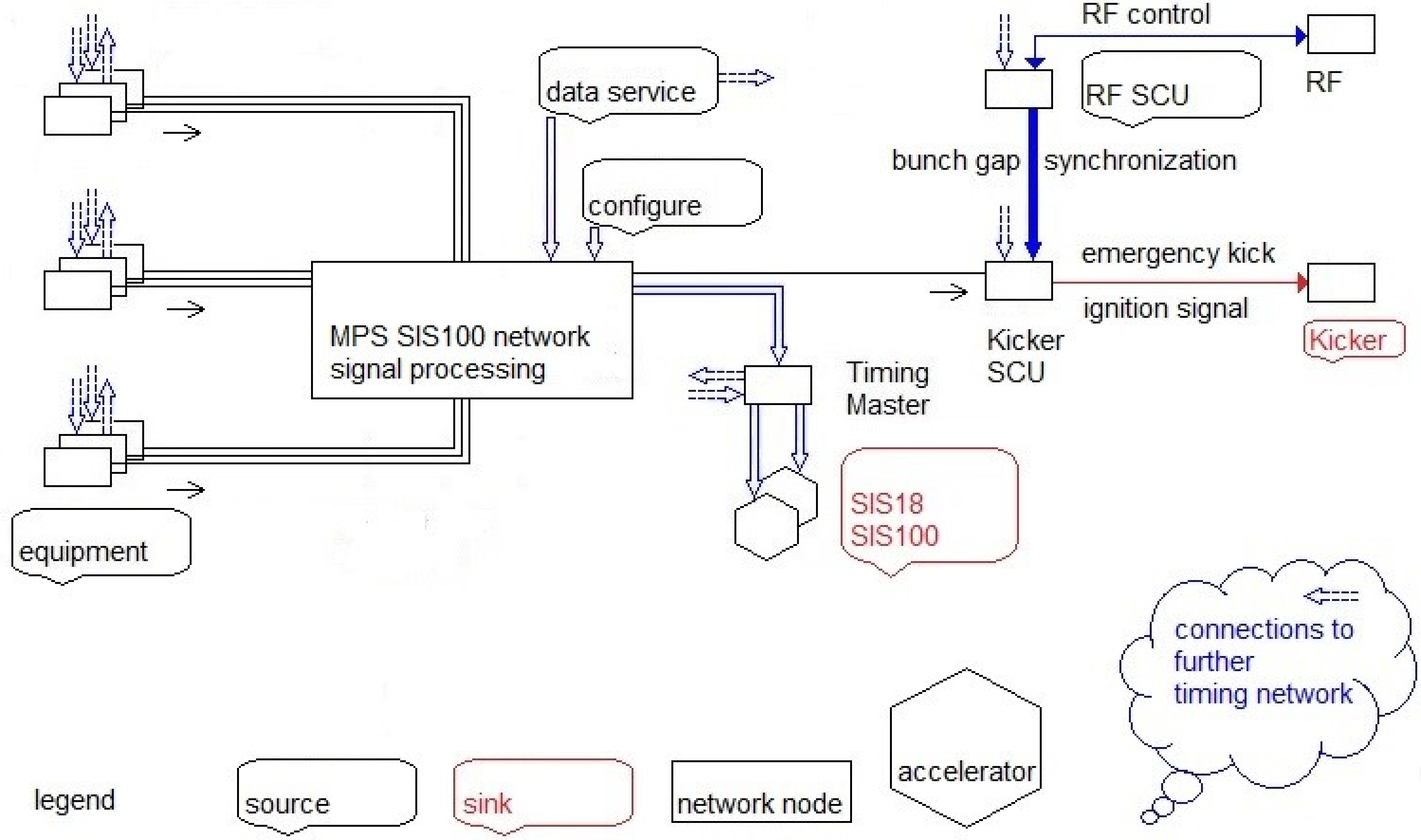
- For emergency dump: Beam losses caused by spurious errors (e.g. Power Converter problems, RF failures, quenches, ...) as well as dynamically unstable beams can be mitigated effectively by the emergency dump system.

- By failsafe concept, up to 85% of the total failures in time can be detected or mitigated.

Principle of FBAS

- The **Fast Beam Abort System (FBAS)** protects SIS100 and also (being planned) subsequent accelerator or experiment actively from damage by mislead beams, uncontrolled radioactive contamination or magnets as their part from damage by electrical current. Thereby, the individual equipment is assumed self-protecting.
- Therefore, it triggers accelerator safety critical actions such as an emergency beam dump, a shutdown of magnets or a beam injection inhibit.
- In case of relevant equipment failures or other inappropriate equipment states, a MPS signal has to originate from this equipment.
- MPS propagates these signals by a proprietary net and combines them with the machine state or operator interventions. These signals must be processed to ensure the timeliness of the triggered actions. The entering of a safe equipment state is subordinate to a FBAS action:

Layout of MPS Network



Reaction times of MPS

Reaction Class	Reaction
0	no active reaction in due time possible: passive protection e.g. by collimators or redundancy of devices must be foreseen
1	a very fast beam abort within 40 µs and subsequent trigger within 600 µs of dumping magnet energy
2	a fast beam abort within about 1-5 ms and subsequent trigger within 600 µs of dumping magnet energy
3	a slow reaction within 100 ms is feasible and necessary
4	no reaction is necessary

remark: reaction classes as requirement from PB (for SIS100) not settled yet,

risk analysis from further machines partially done

Tasks of FBAS

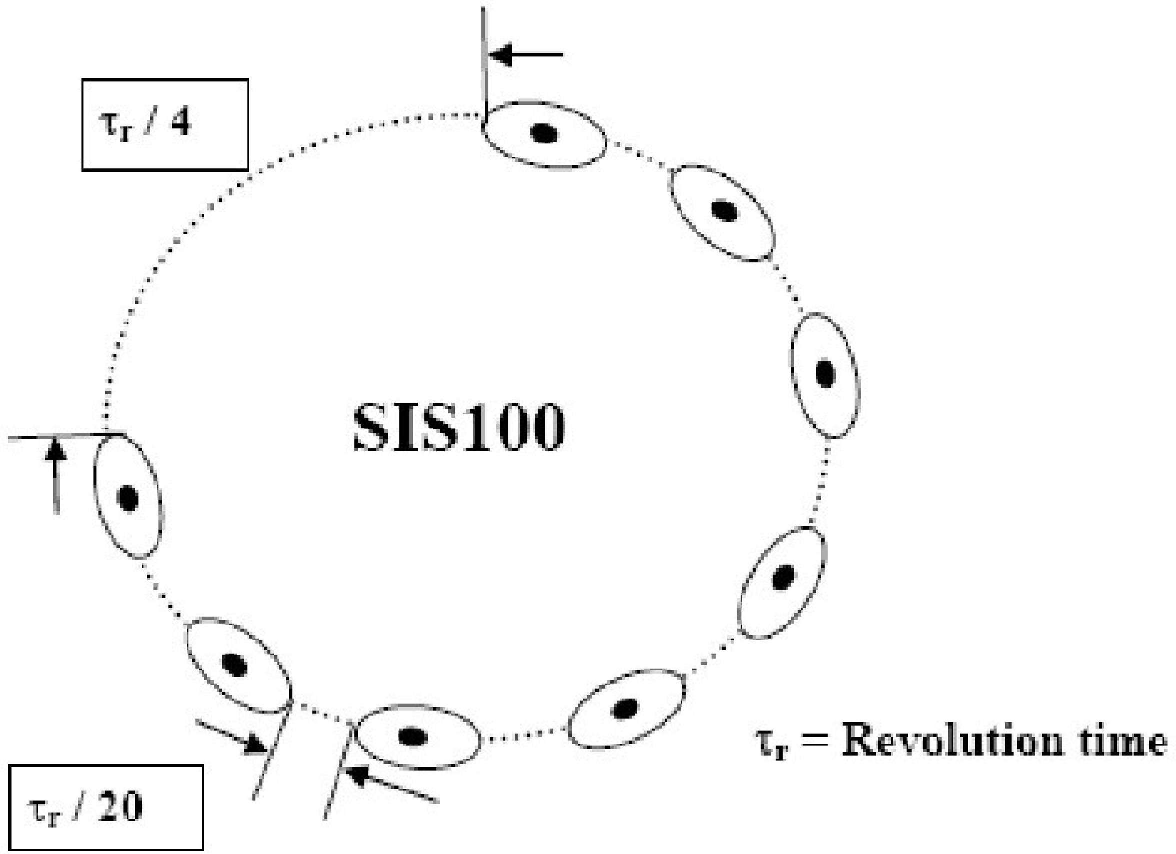
- a network gathering the MPS conditions and calculating a signal delivered to specific devices as the SIS100 extraction/dump kicker,
- a programming interface to view, reset, mask or trigger MPS conditions,
- provide specific requirements of distinguished devices (MPS sources or sinks) or software to be fulfilled

FBAS will define requirements for

- Beam Instrumentation & Diagnostics – System Integration
  e.g. beam loss (BLMs) under discussion,
  accuracy of BTMs (pilot beam) for SBF
- Accelerator Hardware – System Integration
  e.g. Power converter, RF, injection/extraction kicker
- Control System
  e.g. archiving, role-based-access for masking MPS signals (maskable, automated reset)
- Components
  e.g. Post-mortem (incl. analysis ?), setup-beam settings management (beam permit flag in real-time, MPS analysis for SBF offline ?),
  MPS network
- Applications
  e.g. GUIs
- Facility Analysis
  e.g. FBAS ready to operate, training of BLM thresholds with nominal intensities (?)

Example for techn. requirement

Kicker pulse rise time has to fit within bunch gap; from SIS100 TDR:



Required kicker ignition accuracy

budget of ignition accuracy	time slice	reason
synchronization forecast error	< 500 ps	turn by turn variation of the deflecting or accelerating electromagnetic fields (neither short circuited to ground nor arcing) over the ignition delay of ≤ 25 µs
synchronization accuracy	< 500 ps	accuracy of timestamps for synchronization including bending of fixed cable below a tolerance and temperature drift (from spec.)
ignition delay drift	≈ 400 ns	systematic drift of the ignition period, slow compared to accelerator cycle (U. Blell, private comm.)
ignition jitter	≤ 10 ns	short term fluctuation of ignition delay drift (see above)

<table>
<tr><th>calculated accuracy</th><th>SIS100</th><th>SIS300</th></tr>
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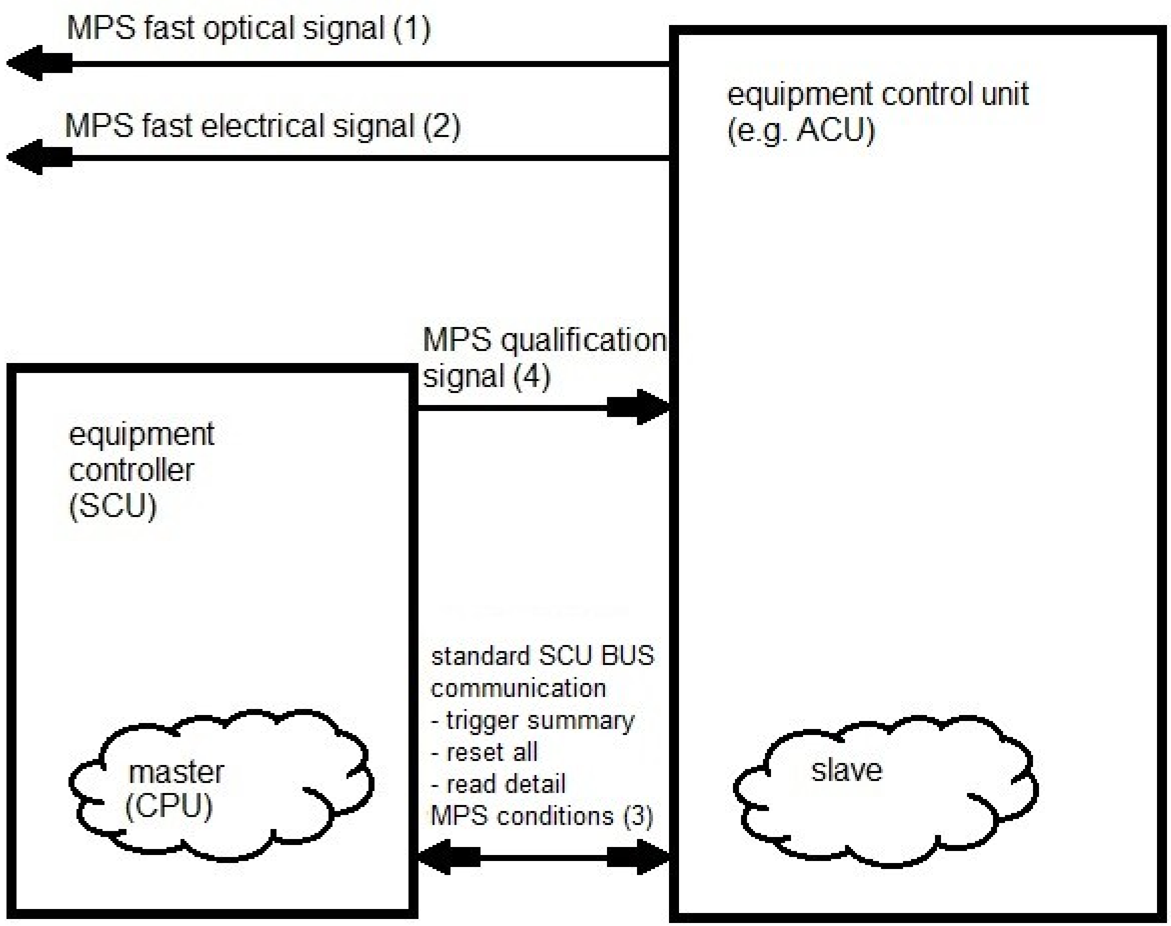
Examples for further requirements

- the MPS network @ SIS100 must be easily extendable (by configurable parts and additional connections) to FAIR
- the latency of the MPS network must comply with the required overall performance of the network
- the reliable detection (with error fractions and detection times) of the MPS events is a requirement to the accelerator equipment

Principle of FBAS II

- Safety critical actions for which 100 ms is in due time are propagated by the **Interlock System (ILK)**.
- A controlled reset of the MPS signal through input from the operator must be supplied for controlled equipment. In addition to internal fault conditions, external signals fed from other systems shall also lead to a MPS condition for controlled equipment, i.e. a triggered MPS condition for testing or commissioning purpose. The detailed MPS condition must be published to the control system.
- Therefore, a standard interface for the equipment has to be defined, in addition to ILK:

Present fast equipment - MPS interface @ FAIR



Documents

- Equipment, failure scenarios with probabilities and reaction times have to be described by a S-FMEA, e.g. Dr. C. Omet, PB for SIS100.
- Fast Interface to be defined: F-TG-C-05e-Control-System-Equipment-MPS-Interface.
- Requirements for the MPS are to be defined: F-TC-C-02e-SIS100_fast_beam_abort_system_requirements.
- Technical concept for realization to be described: F-TC-C-03e-SIS100_fast_beam_abort_system_concept.
- ILK interface, Dr. R. Bär, CSCO: F-TG-C-03e-Control-System-Equipment-Interlock-and-Status-Signal-Interface-v3.0.
- ILK Design, G. Cuk et al., COSYLAB:2014-08-26-DES-CSL-FAIR-Interlock-System-Design

Scope of delivery by CSCO

Within the work package “Machine Protection System” (PSP 2.14.10.11.2) and “Interlock System” (PSP 2.14.10.11.3) the following scope is conveyed for SIS100:

- network class 1: connections, signal aggregation, logic of the network (trigger matrixes)
- network class 2: connections, signal aggregation, logic of the network (trigger matrixes)
- network class 3: connections, signal aggregation, logic of the network (trigger matrixes)
- GUI to read out MPS conditions, edit and view masks
- evaluation scripts for logged events
- test scripts for each network
- extraction(/transfer) kicker control for SIS18 and SIS100 by CSCO-FE and CSCO-HW.

The delivery of the remaining interfaces to the networks are besides logging system not in charge of CSCO.

Summary

- Principle layout of the FBAS network done
- Prototype for logic module ready
- Network easily extendable for whole FAIR
- Interface description in preparation
- Requirements for software components planned

Open issues

- Reaction and partially detection times (needed for detailed planning)
- Reliability of kicker ignition
- Risk analysis for further machines
- Realization of Beam_Permit_Flag in real-time
- Integration of BLMs and further beam instrumentation