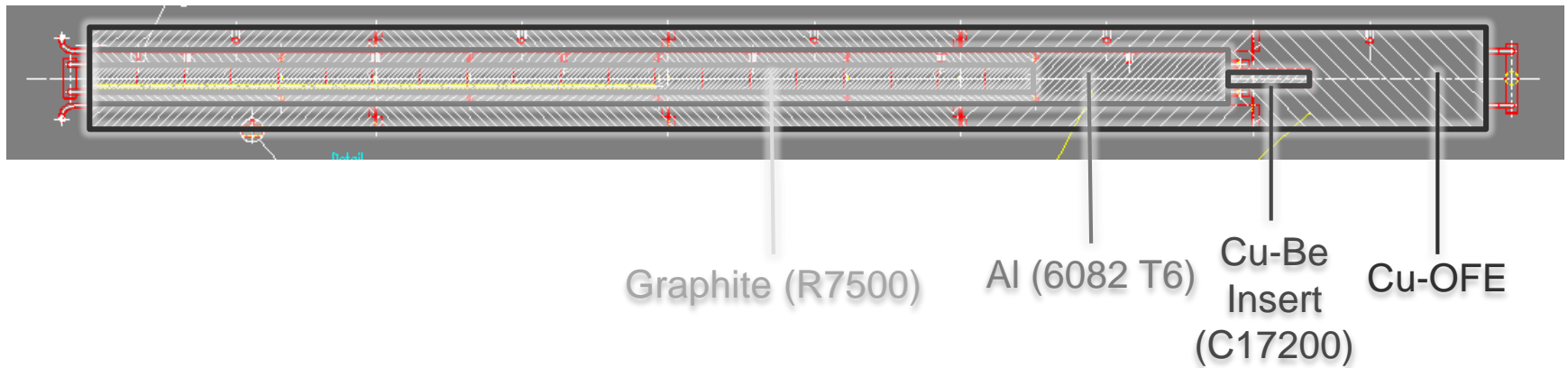# Interlock modification of SPS extraction interlock to mitigate TED limitation for LIU/HL beams

V. Kain SPS-OP

Introduction (1)

o TED: transfer line beam stopper

- Designed to absorb ultimate beam

- In air

4.3 m TED connected to Y-chamber. Can be moved into beam.

Graphite (R7500)   Al (6082 T6)   Cu-Be Insert (C17200)   Cu-OFE

o Two TEDs per 3 km LHC transfer line.

- One shortly after the SPS extraction point. One close to the LHC injection point.

Introduction (2)

o With the TEDs, part of the line can be studied without the downstream equipment necessarily available
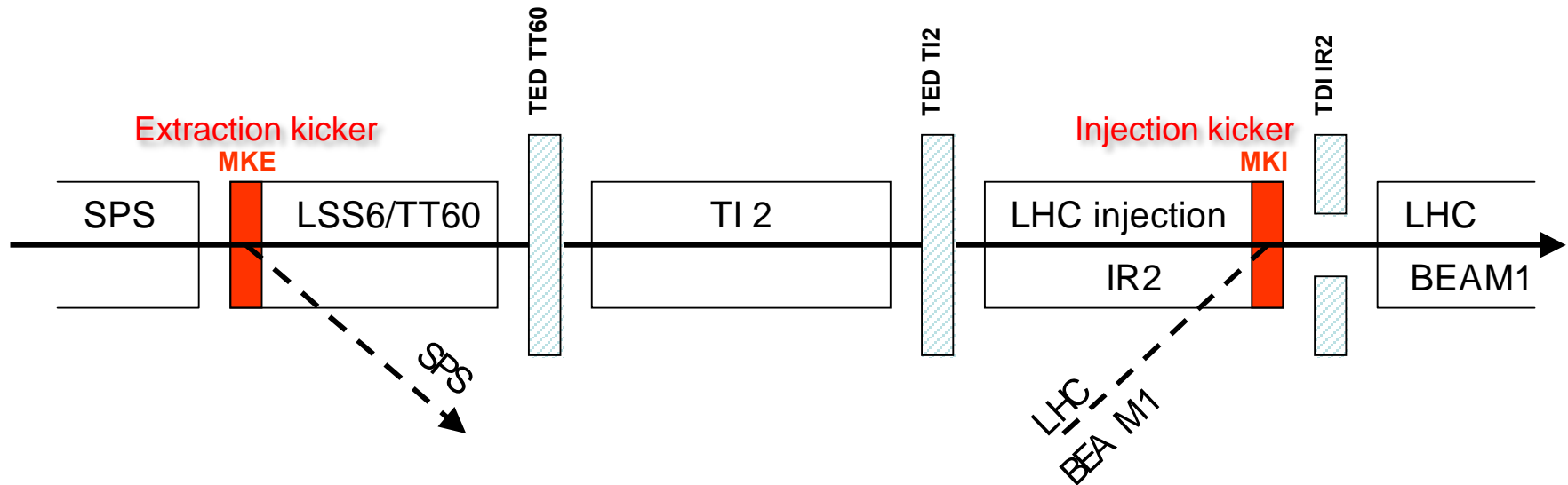
o Interlocking philosophy: If a TED is in beam the interlocks of the downstream equipment are ignored.

o If TEDs are moving, extraction is never permitted. Only if **in** or **out**

o This is true for any intensity to be extracted from the SPS

TED with LIU beams

	$p^+/bunch$	ε $[\mu m]$	brightness $[\frac{10^{11}}{\mu m}]$	N_b
Standard	1.2×10^{11}	2.6	0.46	288
Ultimate	1.7×10^{11}	3.5	0.49	288
HL-LHC	2.32×10^{11}	2.1	1.1	288
BCMS LIU	2.0×10^{11}	1.3	1.54	288

o The current TED design cannot withstand more than 144 LIU intensity bunches.

- Graphite goes beyond stress limits

o Proposal:

- Keep current design

- Limit intensity to max. 144 LIU bunches to be extracted from the SPS with TEDs in the line

Result from Simulations

Conclusions

R. Esposito

All the beams, half intensity (144 bunches):
ACCEPTABLE

HL-LHC 2.32e11 ppb * 288 bunches:
RISK OF CRACKS IN GRAPHITE FOR A SINGLE PULSE

BCMS 2e11 ppb * 288 bunches:
HIGH RISK OF CRACKS IN GRAPHITE FOR A SINGLE PULSE

BCMS 2.32e11 ppb * 288 bunches:
HIGH RISK OF CRACKS IN GRAPHITE FOR A SINGLE PULSE

Simulations also done for continuous extractions over 30 minutes

Functional specification for interlocking sent for approval

o Comments received.

o In the process of
  implementing
  comments…

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EDMS NO.	REV.	VALIDITY
1839530	0.1	DRAFT

REFERENCE
SPS-OTH-ES0001

SPS Upgrade

Date: 2017-08-25

Functional Specification

Changes of SPS extraction interlock strategy for TED beam stoppers with LIU beams

ABSTRACT:

FLUKA and ANSYS simulations of LIU beams impacting the TED beam stoppers in the SPS to LHC transfer lines have shown that the stresses reached in some of the TED materials will be beyond the predicted material strength. The intensity on the TEDs with LIU beams therefore has to be limited and the SPS extraction interlocking strategy modified. This document summarizes briefly the simulation results and defines the new interlocking strategy.

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2017

Implications for TED as EIS

o The TEDs are EIS for the SPS and LHC

- TT40 SPS chain 2, TT60 TED SPS chain 4,

- TEDs TI2 and TI8 LHC safety chain

o TBSEs are same design as TEDs

- TBSE TI8 SPS chain 3

- TBSE TI2 SPS chain 5
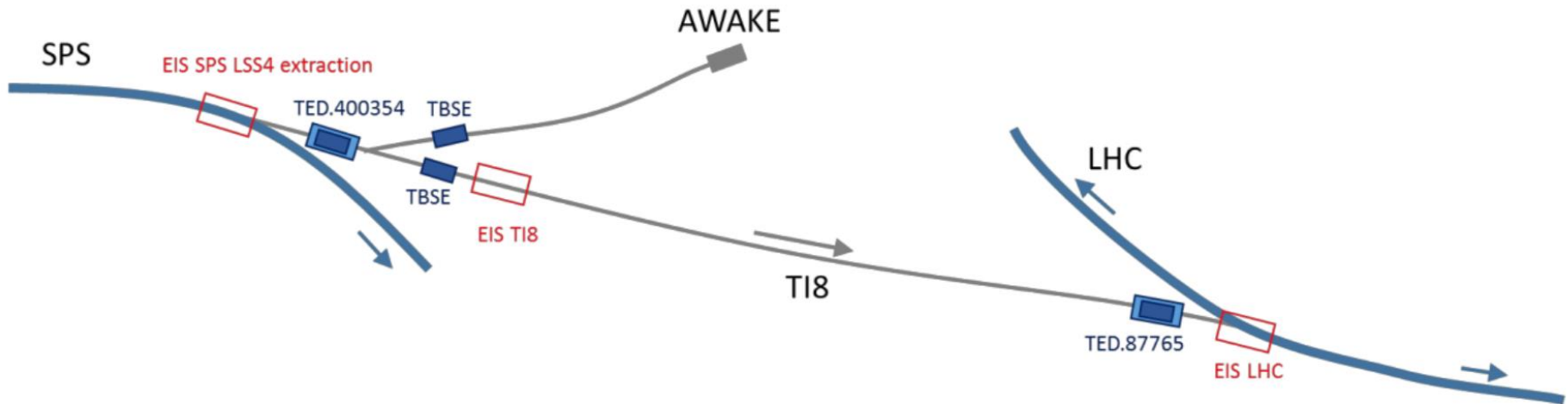
Implications for TED as EIS

Safety file: LIU SPS Safety-Package: SPS Ring and Transfer Lines SPS-L-SF-0006

Quote:

o The robustness limitation with LIU beams does not reduce the safety provided by the TED/TBSEs for personnel, as even in the event of cracking of the core the beam is stopped by the device. No catastrophic failure is expected even in case of impact of 288 bunches.

Scenarios 1:

o Intrusion into LHC zone 8 while filling high intensity beam
  - LHC access chain and SPS chain 3 open
  - LHC injection EIS interlocked - **no beam can be injected into LHC**
  - TI8 EIS interlocked - **no beam can be transmitted to downstream part of TI8**
  - TED.87765 (EIS) automatically moves to "IN BEAM" position (slow movement ~60 seconds)
  - TBSE in TI8 automatically moves to "IN BEAM" position (slow movement ~60 seconds)
  - SPS LSS4 extraction inhibited by BIS system (via non-maskable inputs TED/TBSE moving, TI8 downstream, LHC beam permit, LHC injection BIC, ...) - **no beam can be extracted from SPS LSS4**

Implications for TED as EIS

Scenario 2:

o Intrusion into another LHC access zone while filling high intensity beam

- LHC access chain open

- LHC EIS interlocked - **no beam can be injected into LHC**

- TED.87765 (EIS) automatically moves to "IN BEAM" position (slow movement ~60 seconds)

- SPS LSS4 extraction inhibited by BIS system (via non-maskable inputs TED/TBSE moving, LHC beam permit, LHC injection BIC, …) - **no beam can be extracted from SPS LSS4**

For the other uses cases, see safety file

Implications for TED as EIS

Conclusion in safety file:

For all use cases, the fast EIS (power converters and extraction kickers) as well as the extraction interlock system always ensure that no beam above $144 \times 2.32 \times 10^{11}$ protons will impact the slowly moving TEDs/TBSEs even in case of an access system intrusion interlock.

No modification of the TED and TBSE behaviour for the access system is therefore required.

Any comments from the DSOs?

Extra slides

Proposed interlocking implementation

o New Safe Machine Parameter Flag in the SPS: **SPS TED BEAM FLAG A and B**

- **SPS_TBF**

o The new flag is taken into account in the user permit on the beam interlock controller of the TEDs, where it is checked whether it is moving or not.

- The logic will be completed to take into account the SPS_TBF as follows:

    User Permit = TRUE when ((TED_IN $\cap$ SPS_TBF=TRUE) $\cup$ TED_OUT)

    else User Permit = FALSE

o The affected Beam Interlock Controllers

    - input 1 of the slave BIC TT60B (in BA6) for Extraction 1

    - input 1 of the slave BIC TT40B (in BA4) for Extraction 2

    - input 1 of the slave BIC TI2D (in SR2) for Extraction 1

    - input 1 of the slave BIC TI8D (in SR8) for Extraction 2