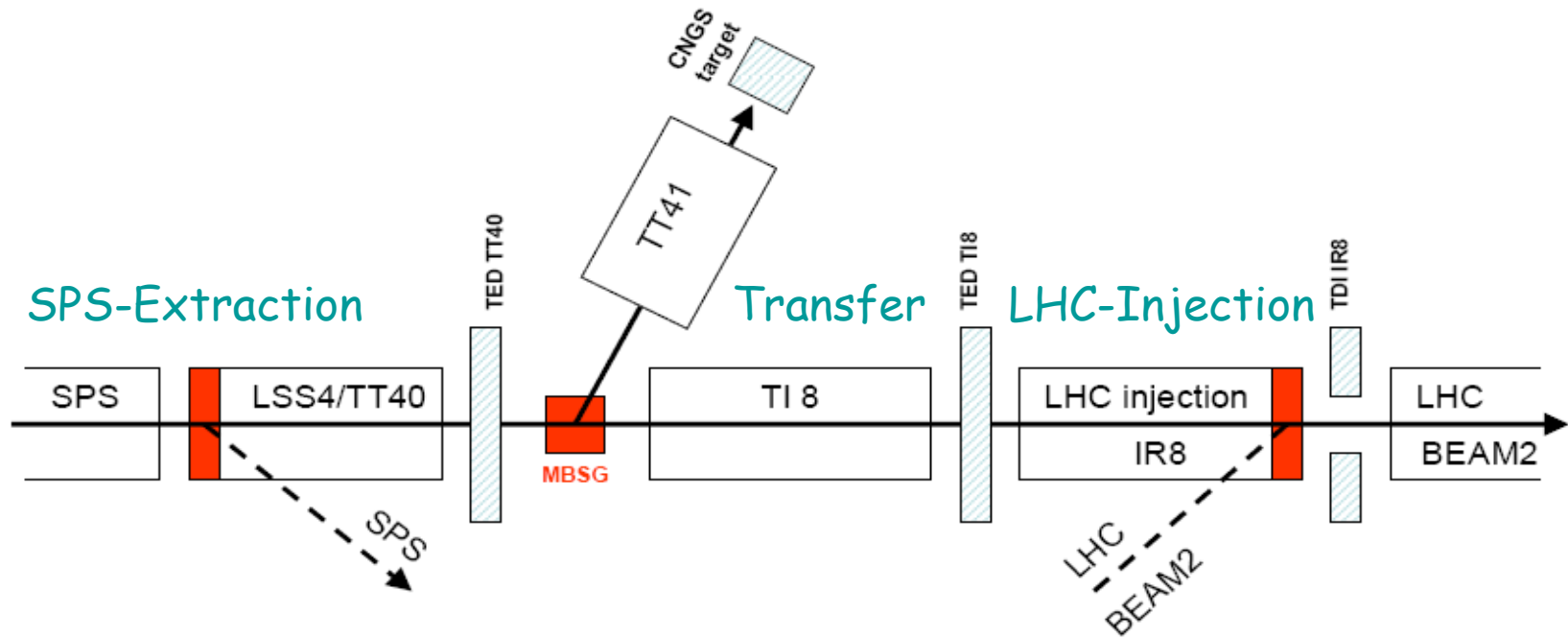# LHC Injection SPS Extraction Interlocking

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J. Wenninger

- Introduction
- Main concepts – main requirements
- Masters and slaves
- The SPS Master BIC
- The Master BIC's Logic
- Plans for testing

# Introduction

- **Extraction of LHC beam 2:**
  - same extraction also used for CNGS extraction



- **Beam absorbers: TEDs in the transfer lines.**
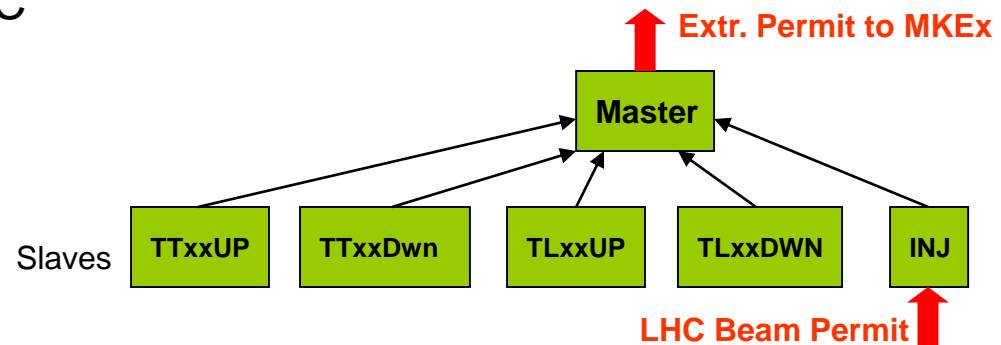  - When TT40 TED in: can study extraction and TT40.

# Main Concepts – Main Requirements

- Flags sent around by the LHC and SPS timing system: Safe beam parameters

- Interlocking depends on the state of the flags, e.g. safe beam flag (TRUE/FALSE)

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- Only inject high intensity beam into the LHC if there is already ANY INTENSITY beam circulating – BEAM PRESENCE FLAG

- If no beam is circulating, can only inject beam up to $10^{11}$ protons (special requirement of experiments) – LOW INTENSITY SPS EXTRACTION FLAG

- Interlocks can be masked up to safe beam intensity limit at 450 GeV: $10^{12}$ protons – SAFE BEAM FLAG

- The safe beam flag in the SPS and the LHC transfer lines depends on the intensity in the SPS, the one in the LHC depends on the intensity in the LHC $\Rightarrow$ even if there is safe beam circulating in the LHC, the LHC safe beam flag must be FALSE, if we are preparing high intensity in the SPS – LHC NO SAFE BEAM FLAG

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- The SPS Extraction/LHC Injection Interlock System must guarantee:
  - TLs + extraction regions, injection regions (injection permit), LHC ring (LHC beam permit) equipment OK
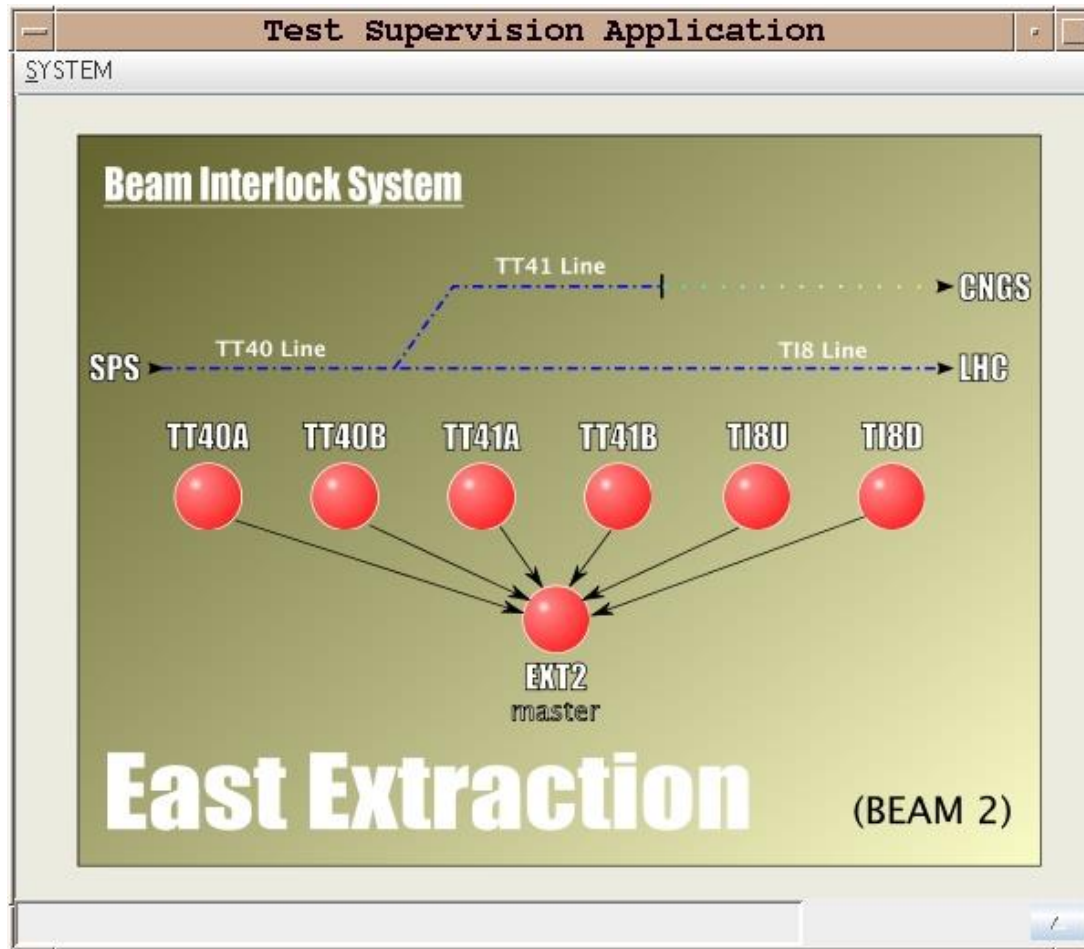  - Conditions above met

# Masters and Slaves (1)

- Once the beam is extracted from the SPS, cannot stop it anymore.

  - If state not OK in TL, LHC,…must not extract from the SPS and dump the beam in the SPS.

    - EXTRACTION PERMIT acts on the SPS extraction kicker (MKEx)

    - INJECTION PERMIT acts on the LHC injection kicker

- All the information on state of equipment and necessary conditions must be combined in the EXTRACTION PERMIT

- The extraction permit is generated by the SPS Master BIC(s).

  - all other BICs (extraction region, transfer lines, injection region) are input (SLAVES) to the SPS Master BIC

**Extr. Permit to MKEx**

**Master**

Slaves | **TTxxUP** | **TTxxDwn** | **TLxxUP** | **TLxxDWN** | **INJ**

**LHC Beam Permit**

# Masters and Slaves (2)
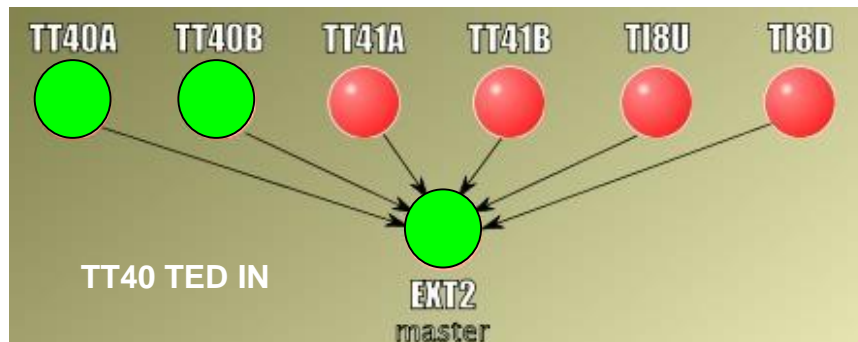
- Example for LHC Beam 2 Extraction in the SPS



Injection BIC not yet there…

# Masters and Slaves (3)

Main difference between Master BICs and Slave BICs…

- For operational efficiency and flexibility use position of TEDs and type of beam (CNGS/LHC) to "mask" entries into master BIC

  – Example: if TT40 TED in, TI8 BICs and TT41 BICs are not taken into accound for the extraction permit.
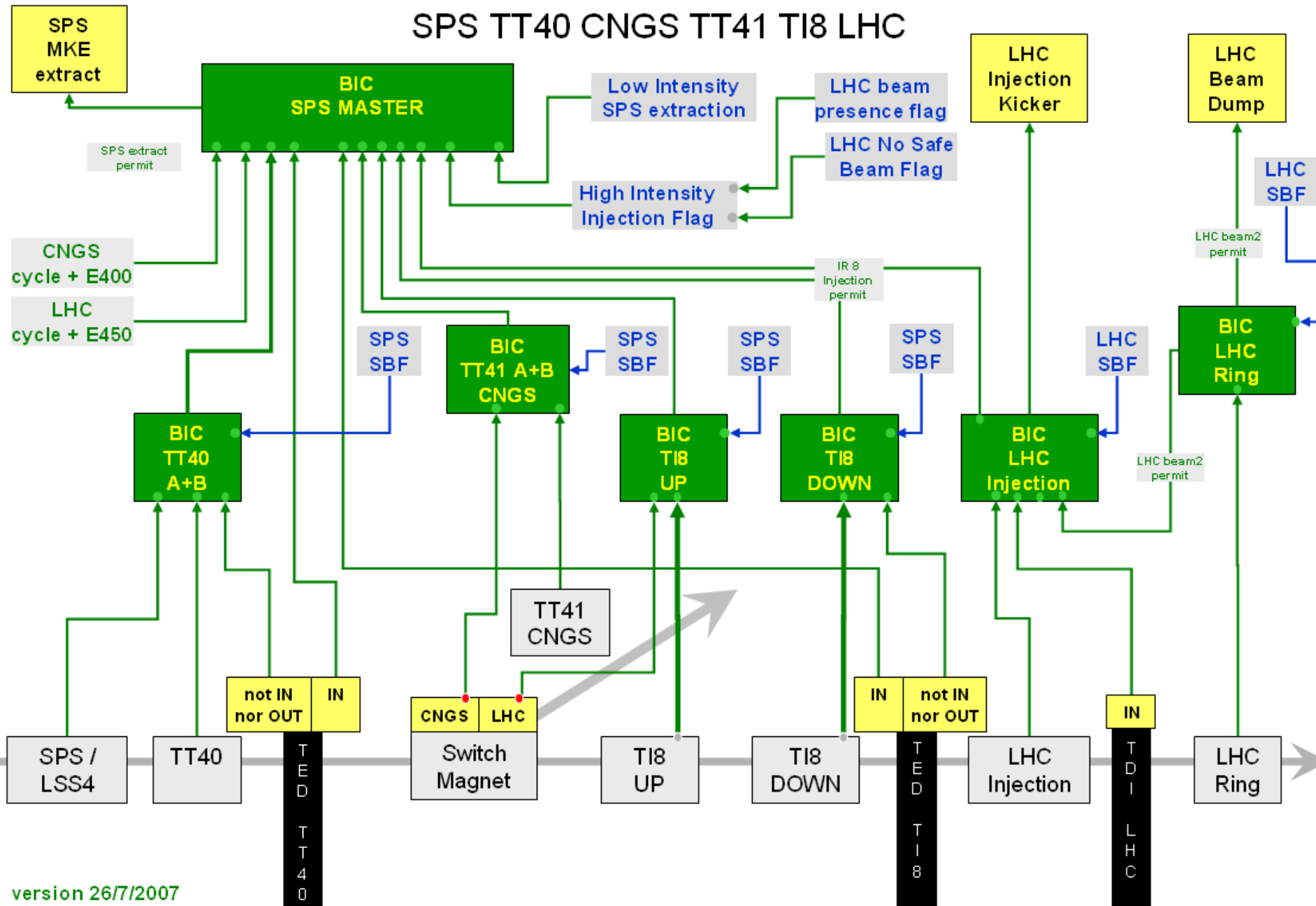


  – This logic is done in the Masters

  – **OR logic in Master BICs**, in Slave BICs only AND logic

  – No mask with safe beam flag for the Masters

# The SPS Extraction Master BIC

Example for Extraction LHC Beam 2:
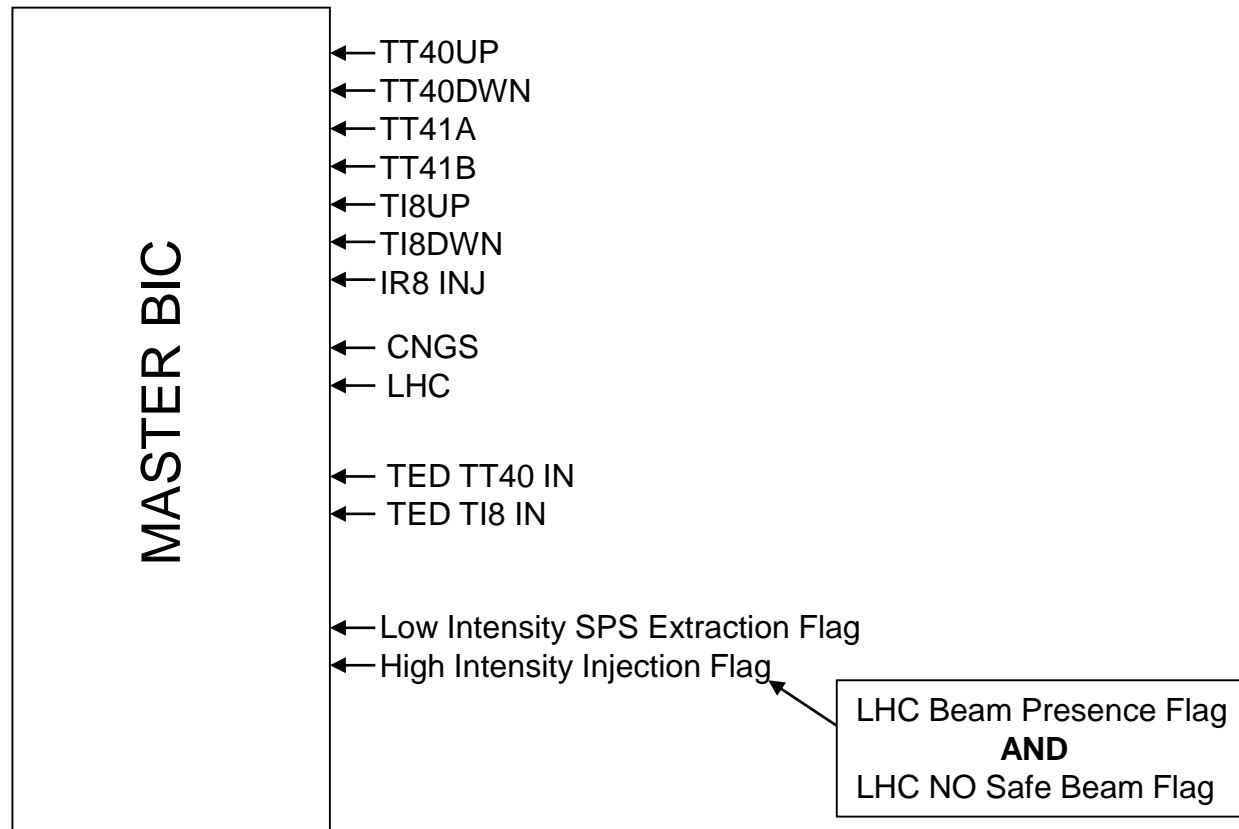
# SPS TT40 CNGS TT41 TI8 LHC

SPS MKE extract

BIC SPS MASTER

SPS extract permit

Low Intensity SPS extraction

LHC beam presence flag

LHC No Safe Beam Flag

High Intensity Injection Flag

LHC Injection Kicker

LHC Beam Dump

LHC SBF

CNGS cycle + E400

LHC cycle + E450

IR 8 Injection permit

LHC beam2 permit

BIC LHC Ring

SPS SBF

BIC TT41 A+B CNGS

SPS SBF

SPS SBF

SPS SBF

LHC SBF

LHC SBF

LHC beam2 permit

BIC TT40 A+B

BIC TI8 UP

BIC TI8 DOWN

BIC LHC Injection

not IN nor OUT | IN

TT41 CNGS

CNGS | LHC

IN | not IN nor OUT

IN

IN

SPS / LSS4

TT40

T E D T T 4 0

Switch Magnet

TI8 UP

TI8 DOWN

T E D T I 8

LHC Injection

T D I L H C

LHC Ring

version 26/7/2007

# The Master BIC's Logic (1)

- LSS4: extraction permit = (non(LHC) && case 1) || (non(CNGS) && case 2)

case 1 = {CNGS && TT40 BICs && [TT40 TED in || (non(TT40 TED in) && TT41 BICs)]}

case 2 = {LHC && TT40 BICs && [TT40 TED in || (non(TT40 TED in) && TI8 BICs && [TI8 TED in  || (non(TI8 TED in) && Inj Permit && F)])]}

F = Low Intensity SPS Extraction Flag || [LHC No Safe Beam Flag && Beam Presence]
  = Low Intensity SPS Extraction Flag || High Intensity Injection Flag

- LSS6: extraction permit ~ case 2
    - no entries for CNGS/LHC
    - TI8→TI2, TT40→TT60

# The Master BIC's Logic (2)

| | | Beam to TED TT40 | Beam to TED TI8 | Beam to LHC IR8 low Intensity | Beam to LHC IR8 high Intensity | Beam to CNGS |
|---|---|---|---|---|---|---|
| BIC MASTER LSS4 SPS: condition for extraction (version 26 July 2007) | | | | | |
| 1 | Cycle LHC | T/F | TRUE | TRUE | TRUE | FALSE |
| 2 | Cycle CNGS | T/F | FALSE | FALSE | FALSE | TRUE |
| 3 | BIC TT40 A | TRUE | TRUE | TRUE | TRUE | TRUE |
| 4 | BIC TT40 B | TRUE | TRUE | TRUE | TRUE | TRUE |
| 5 | TED TT40 IN | TRUE | FALSE | FALSE | FALSE | FALSE |
| 6 | BIC TT41 A | T/F | FALSE | FALSE | FALSE | TRUE |
| 7 | BIC TT41 B | T/F | FALSE | FALSE | FALSE | TRUE |
| 8 | BIC TI8 up | T/F | TRUE | TRUE | TRUE | FALSE |
| 9 | BIC TI8 down | T/F | TRUE | TRUE | TRUE | FALSE |
| 10 | TED TI8 IN | T/F | TRUE | FALSE | FALSE | T/F |
| 11 | BIC LHC Injection IR8 | T/F | T/F | TRUE | TRUE | T/F |
| 12 | Low Intensity SPS extraction | T/F | T/F | TRUE | T/F | T/F |
| 13 | High Intensity Injection Flag | T/F | T/F | T/F | TRUE | T/F |
| 14 | free | | | | | |
| 15 | not used | | | | | |

Comments:
SPS Safe Beam Flag changed into Low Intensity SPS extraction that can be different from the SPS Safe Beam Flag
High Intensity Injection Flag requires two conditions: a) Beam Presence in LHC b) Safe Beam Flag in LHC = FALSE
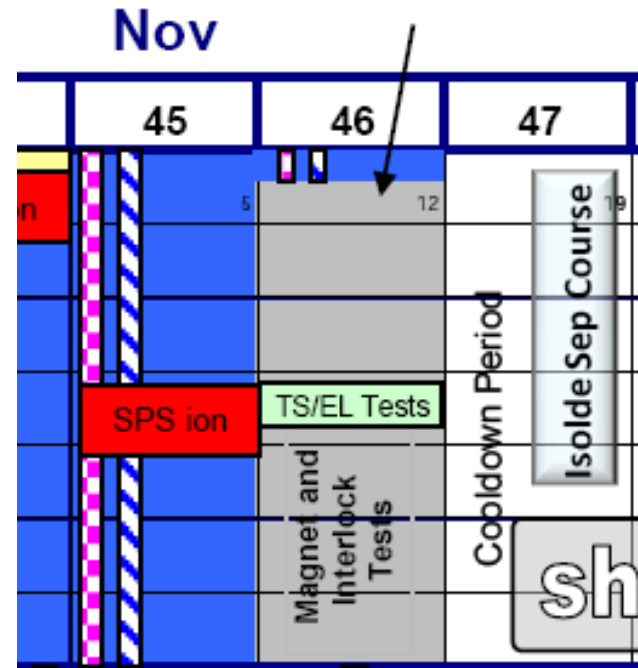
# One more thing…

- Before high intensity injection into the LHC

  - Safe beam flag in the LHC must be FALSE (+ beam presence TRUE), even with safe beam circulating (*)…otherwise we do not get the extraction permit

- How will we do this?

  - Force the LHC safe beam flag FALSE via software (LHC sequencer)

    - Safe because of (*)

  - Sequencer can only force FALSE (not TRUE):

    - forcing = overwriting the measurement from BCT plus energy

    - sequencer can also "unforce": measurement no longer overwritten

# Plans for Testing

- **Test of Master BICs week 46**



- **Requirements:**

  - Safe Machine Parameter controller:

    - CNGS/LHC via BETS

    - Low Intensity SPS Extraction flag (forceable for FALSE)

    - **<u>Fake</u>** High Intensity Injection flag

  ⇐ In this way test of combination of LHC Beam Presence and LHC No Safe Beam Flag still outstanding.

  - Injection BICs

  - All TL  BICs commissioned, all TEDs moveable

  - SPS supercycle with CNGS and LHC

# And then we can do this for real…
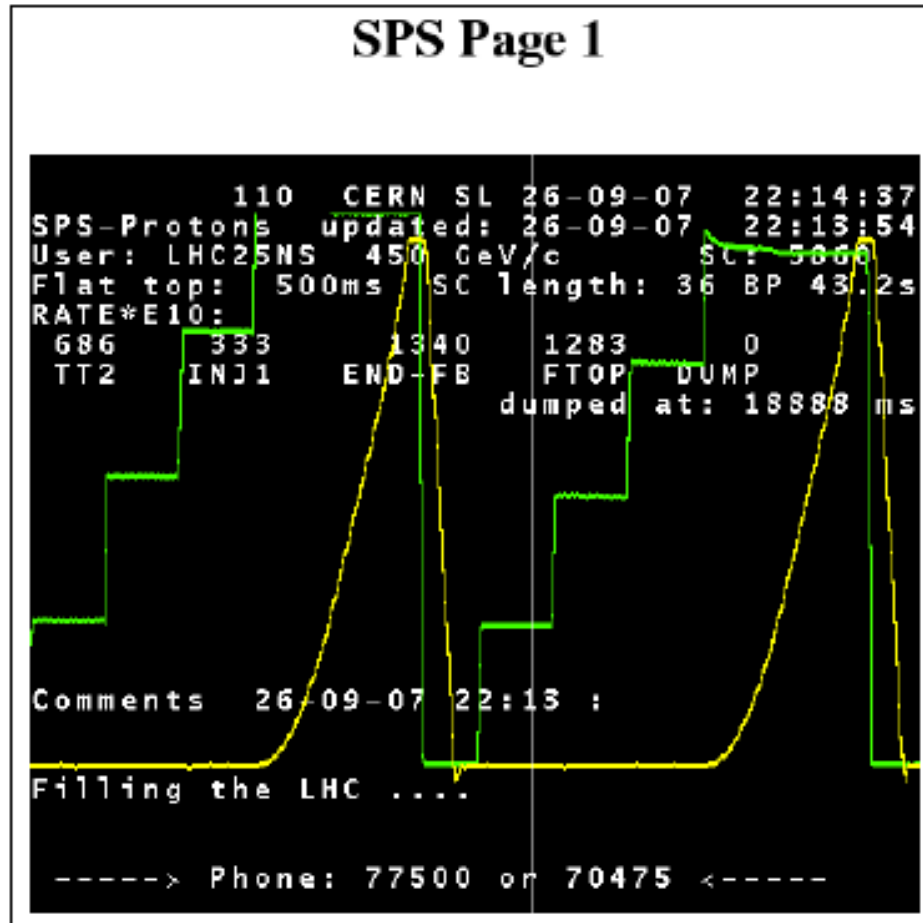


About 1.3 x $10^{13}$ protons per extraction