Injection protection commissioning
## *Changes for 2015 startup*

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MPP, 24th October 2014

Outline

- Existing test list

- Changes
  - TCDI validation - Transfer line loss maps
  - TCDI gap control – Virtual β^*
  - MKI vacuum
  - TDI validation
  - BETS interlocks TDI/MSI/TCDQ

Existing test list

CERN
CH-1211 Geneva 23
Switzerland

the
**Large
Hadron
Collider**
project
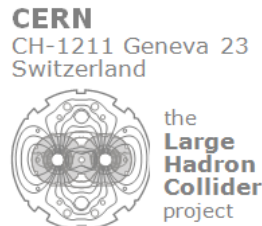
LHC Project Document No.
LHC-OP-MPS-0003.v3

CERN Div./Group or Supplier/Contractor Document No.
BE/OP/LHC

EDMS Document No.
889343

Date: 2009-03-25

MPS Commissioning Procedure

THE COMMISSIONING OF THE LHC MACHINE PROTECTION SYSTEM

MPS ASPECTS OF THE INJECTION PROTECTION SYSTEM COMMISSIONING

Abstract

This document describes the set of tests which will be carried out to validate for operation the machine protection aspects of the **LHC Injection Protection system.** The area concerned by these tests extends over the LHC injection regions (including SPS extraction to some extent) for each of the two LHC beams.

These tests include Hardware Commissioning, machine check-out and tests with beam.

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MPS Task List 2014

New ▾ | Actions ▾

Test Name 📎 Start Date End

⊟ **Phase : Beam Commissioning (127)**

⊞ System : BLM (7)

⊞ System : Collimation (13)

⊞ System : EMCM (3)

⊞ System : Injection-Beam1 (6)

⊞ System : Injection-Beam2 (5)

⊞ System : LBDS-Beam1 (38)

⊞ System : LBDS-Beam2 (38)

⊞ System : MPS Global tests (2)

⊞ System : SIS (6)

⊞ System : SMP (9)

⊟ **Phase : Machine Checkout (220)**

⊞ System : BIS (3)

⊞ System : BLM (1)

⊞ System : Collimation (9)

⊞ System : Experiments (6)

⊞ System : Injection (3)

⊞ System : Injection-Beam1 (25)

⊞ System : Injection-Beam2 (25)

⊞ System : LBDS-Beam1 (54)

⊞ System : LBDS-Beam2 (54)

⊞ System : PIC (4)

⊞ System : RF (2)

TCDI Alignment Procedure
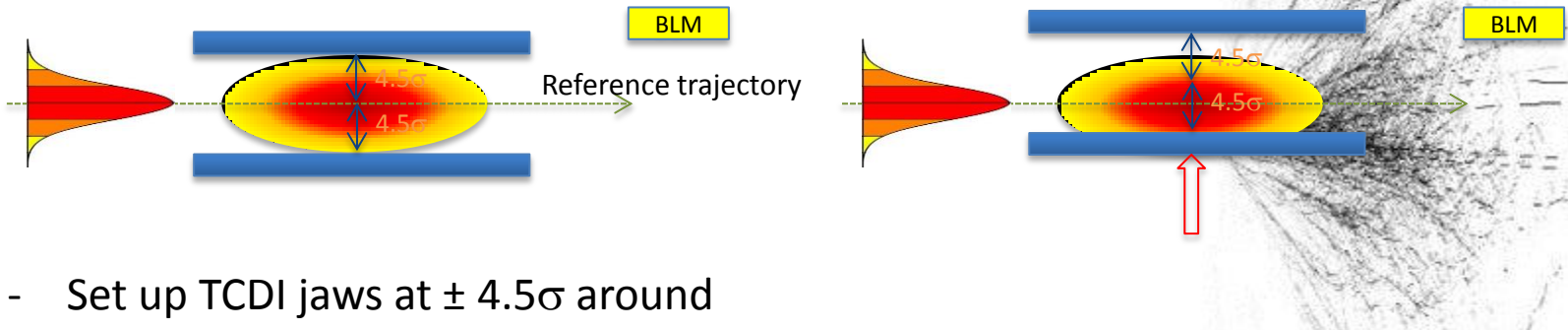
- Set up TCDI jaws at ± 4.5σ around reference trajectory

- Pilot beam (5E9 ➔ 1E10) in Inject&Dump

- Move one TCDI jaw, keeping gap fixed, into the beam with 0.5σ steps ➔ beam ➔ BLM losses ➔ next step

- Repeat with other jaw

$y = 1.2457x^2 + 0.6049x - 0.2155$
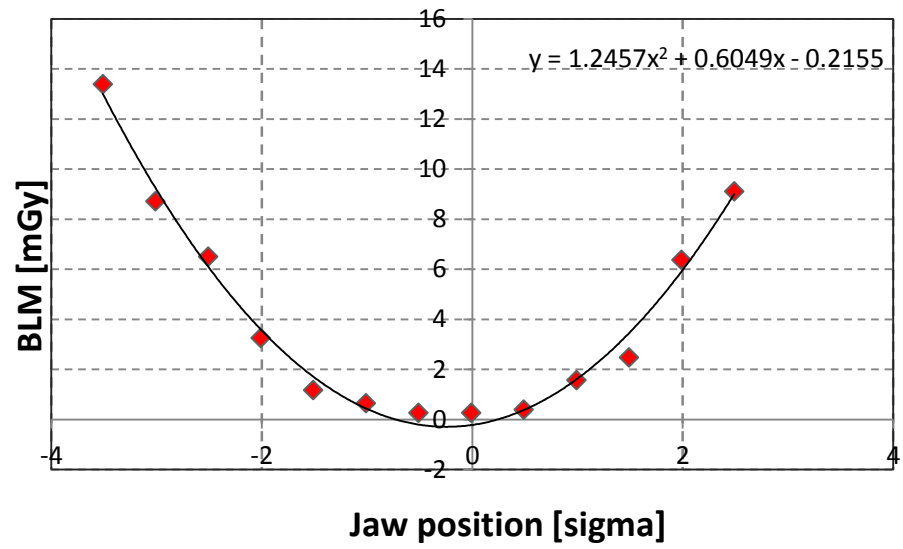
Beam Centre = -0.243σ

TCDI Alignment Procedure

Automatic JAVA-tool:

- Send command to move collimator jaws
- Check beam extraction from SPS into TL
- Record BLM signal
- If no beam extracted ➔ wait for next shot before moving collimator
- Perform the data analysis: beam centre!
- Possible sending beam centre position to LHC "TRIM" application (operational settings)
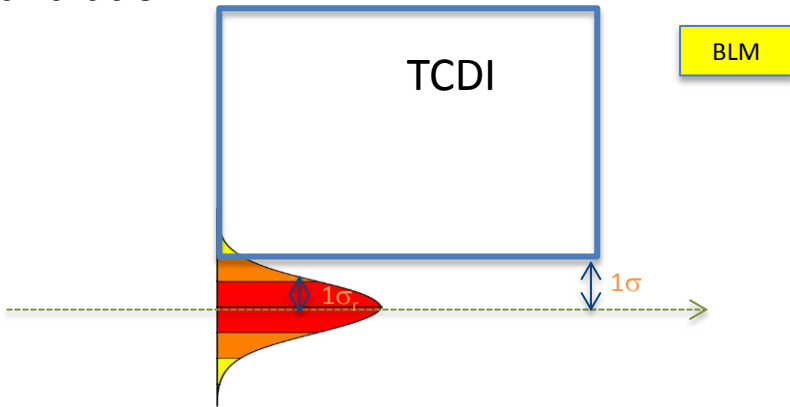

Y. Le Borgne
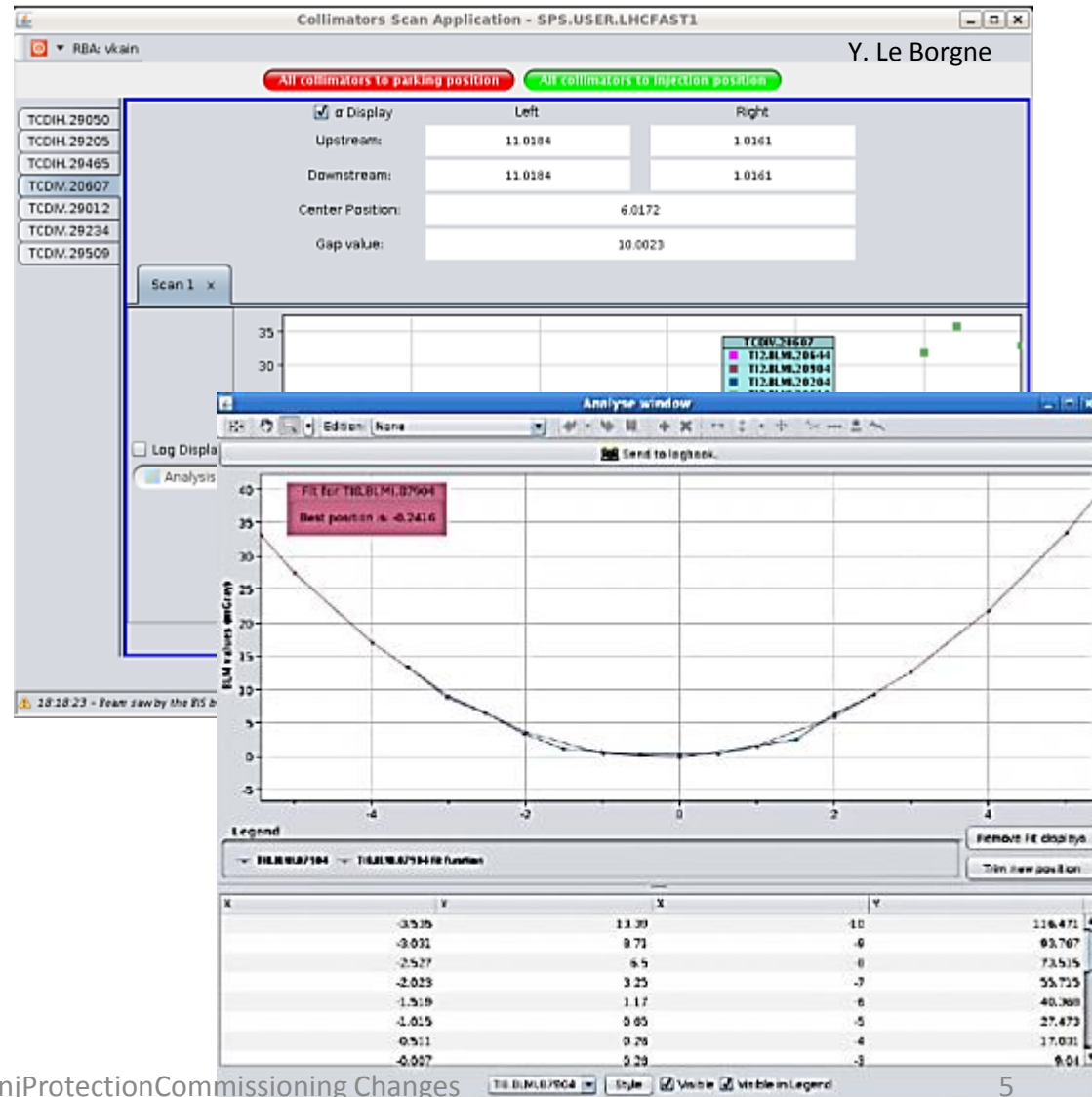
TCDI Setup Validation

- All collimators at 4.5σ (σ calculated for nominal emittance and β function)
- Knob: oscillations with varying phase and amplitude (using correctors in TL)
  - Phase from 0 ➔ 2π
  - Amplitude from 4σ ➔ 5σ (0.5σ step)
  - Repeat in H and V plane
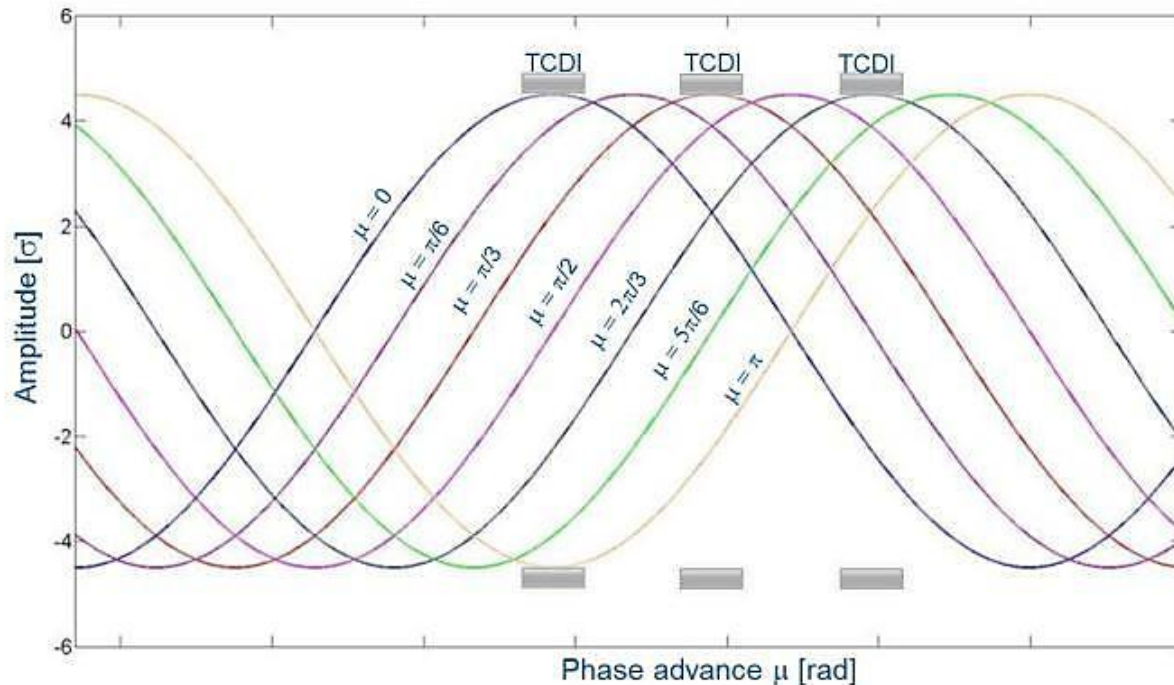
TCDI Setup Validation

Calibration

TCDI

BLM

1σ

$1\sigma_r$

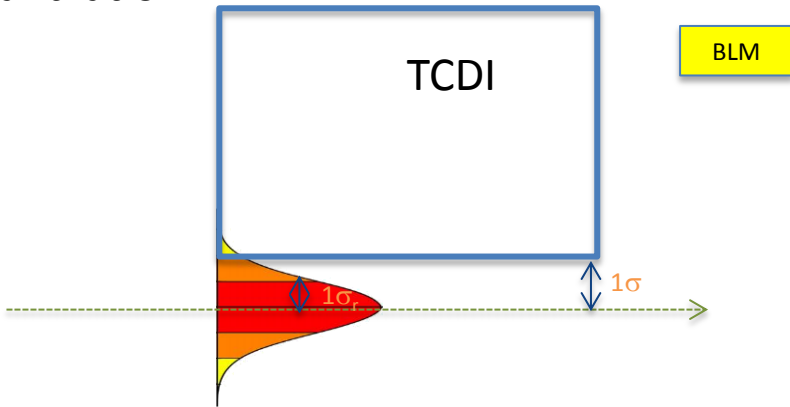Calibration procedure:
- Measure emittance ε_r and $\Delta p/p$ in SPS
- Define σ_r using ε_r and taking into account the dispersion

$$\sigma_r = \sqrt{\varepsilon_r \cdot \beta + (D \cdot \Delta p / p)^2}$$

- TCDI Collimator set @ 1σ (other TCDIs open) ➔ convert into $n\sigma_r$ ➔ $n\sigma_r$ = *xx*% beam intercepted (from theory for a perfect Gaussian distribution)
- Extract beam on TCDI ➔ K = BLM signal normalised wrt beam intensity (FBCT) ➔ reference value K for *xx*% intercepted beam

TCDI Setup Validation

Calibration

Validation
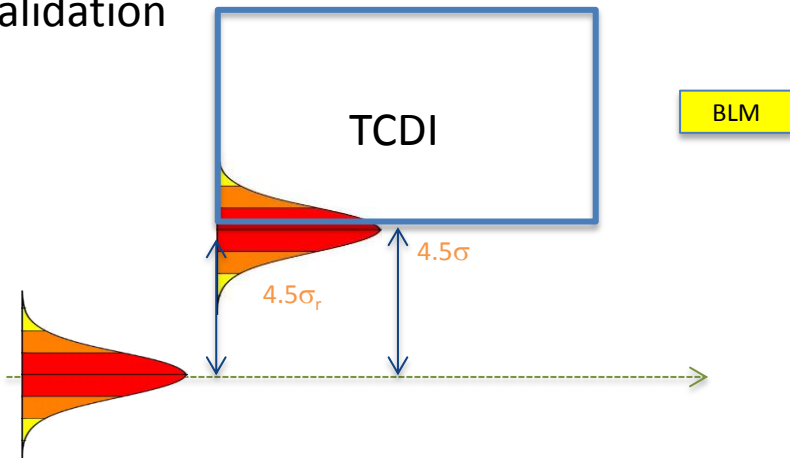

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Validation:
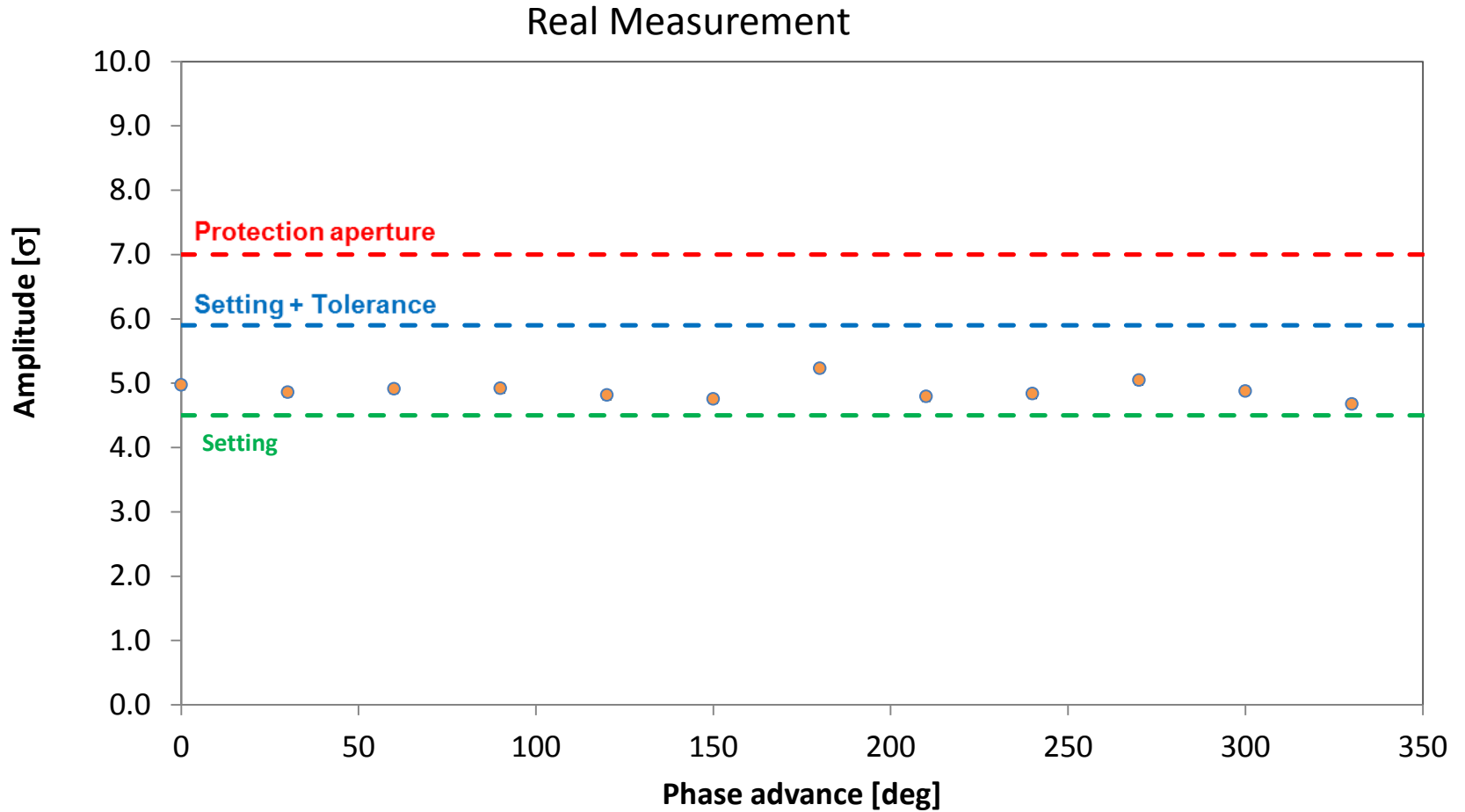- All TCDIs at 4.5σ
- Oscillations with increasing amplitude ➔ BLM signal normalised wrt beam intensity ➔ xx% intercepted beam (normalising wrt K) ➔ nσ_r (from theory for perfect Gaussian)

TCDI Setup Validation

Real Measurement

TCDI Setup Validation

Real Measurement

Limits:
- Still nominal β and dispersion (very close to nominal)
- Perfect Gaussian beam
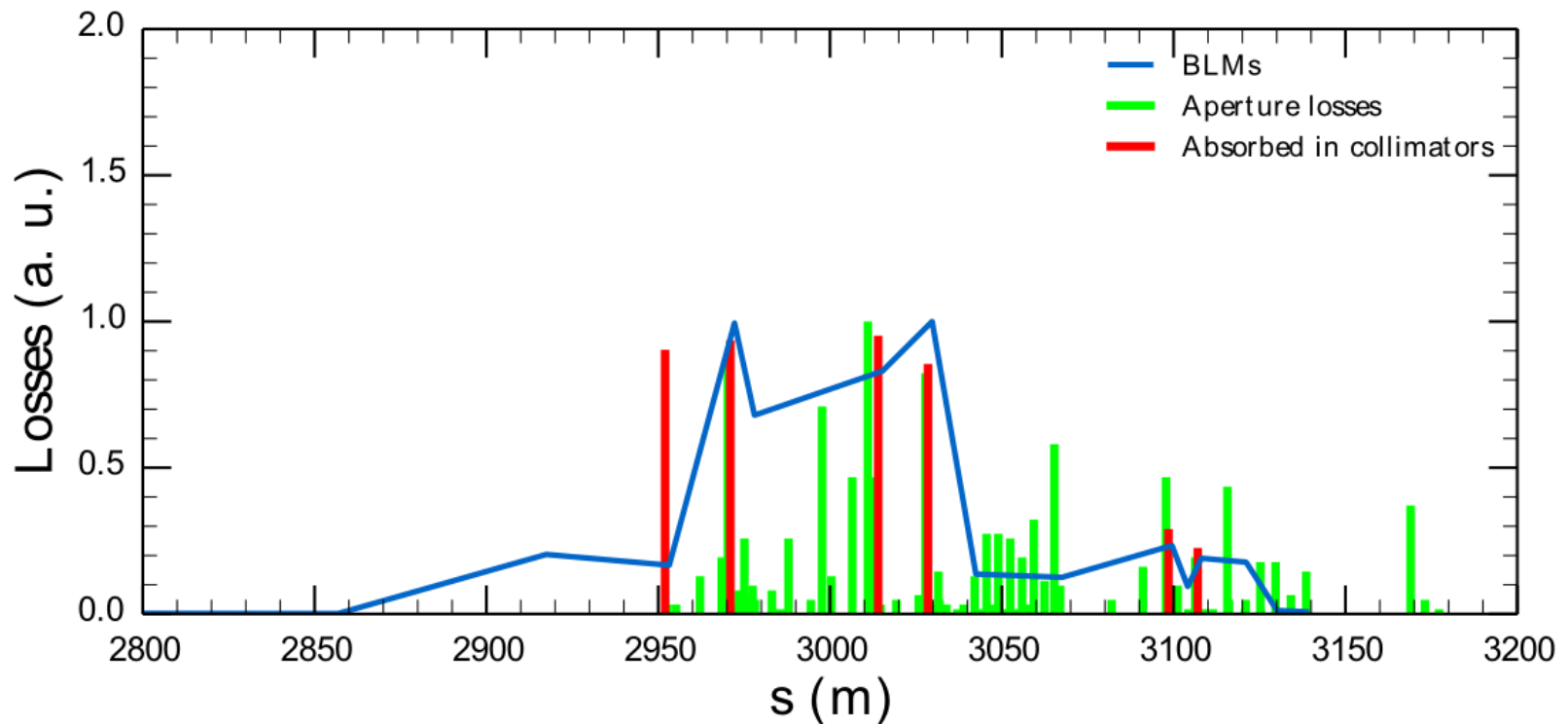
Post LS1 operation: use reference loss maps for validation!
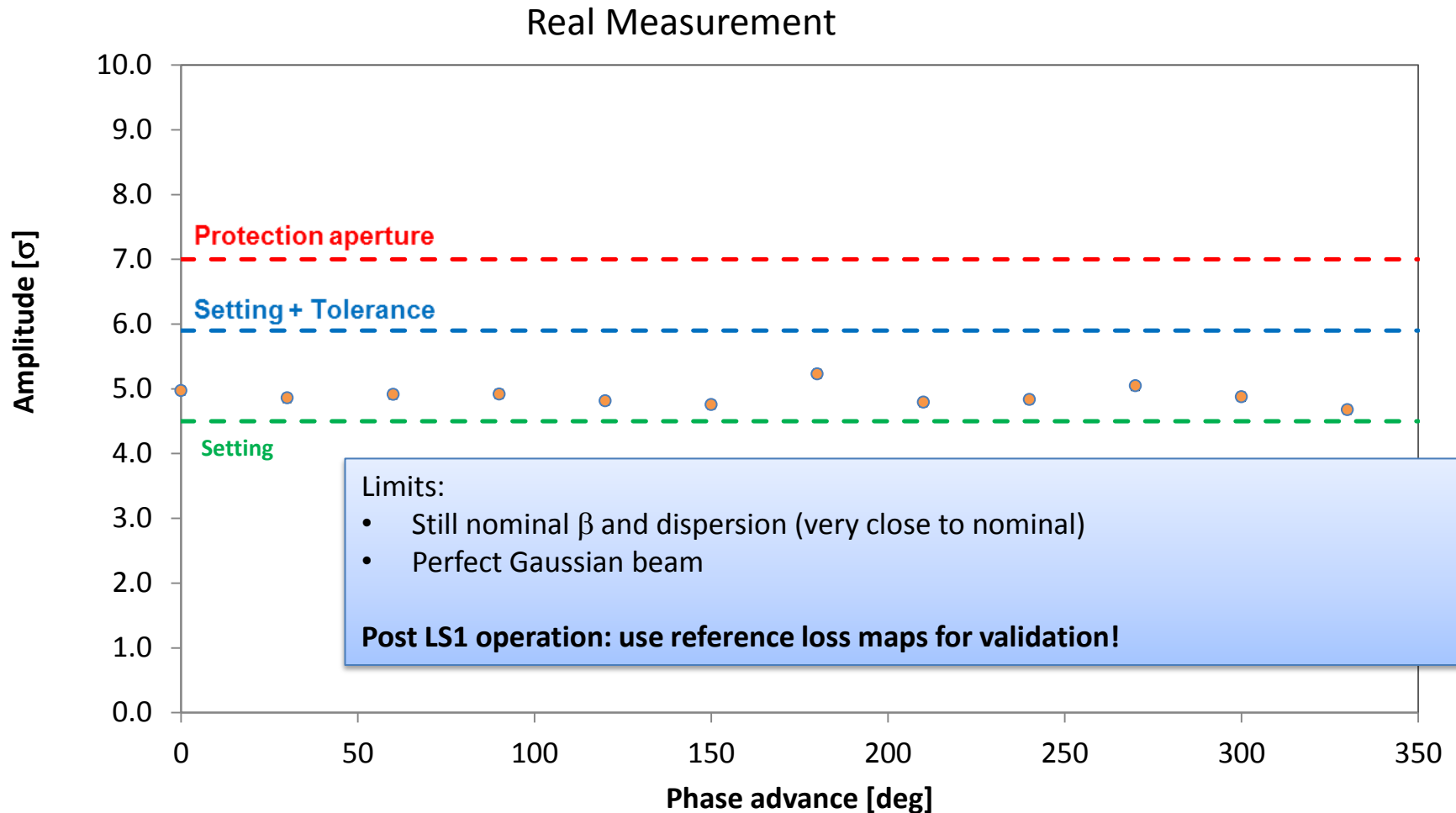
Additional new TCDI validation

Calculate loss maps with Francesco's pyCollimate code for each phase and compare expected/measured losses

TCDI gap control (virtual β*)

- Automatic check of TCDI gaps vs optics in TL
- For each optics
  - Store all quad currents as critical settings in LSA
  - Associate unique β*
- SIS compares for every cycle reference settings and published currents
- If current settings in tolerance publish virtual β* which is checked on TCDI side if in limit
- Needs about half a day of implementation for database and code
- Can be checked without beam during checkout
  - Play wrong cycle
  - Set wrong TCDI gap
  - Set wrong quadrupole current

MKI

- Vacuum interlock level
  - Within Vacuum controls for reasons of noise on the analog value
  - Vacuum controls sends digital value to MKI for interlocking
  - Envisage a 'sign off' procedure of the pressure level to be interlocked on

TDI validation

- Measure attenuation
  - Record losses ds TDI for different impact parameters
  - Focus on most likely MKI failure of 10% miskick
  - Establish reference attenuation map
    - to be compared to after full beam impact
    - to be compared to in case of heating issues

- Compare to simulated loss maps (Francesco's pyCollimate results)
  - Also for TCLI

- Verify TCP-TDI hierarchy (X-measurement)
  - Angle validation

TDI monitoring

- To be checked continuously during the run
  - TDI Position drifts
  - TDI Temperature drifts

Beam Energy Tracking System

- BETS already existed during Run I on beam dumping system
  - Main Bends, 4 sectors
  - MKD, MKB and MSD (dump and dilution kickers, dump septum)
  - Q4 quadrupole L/R 6
- Run II: add similar system on
  - MSI (injection septum)
    - RMSI power converter has become an LHC type pc → ramp down
    - These functions need to be defined as well together with OP, including degauss cycle to be applied
  - TDI (Injection absorber)
  - TCDQ (dump absorber)

  See also MPP meeting 19/7/2013:
  http://lhc-mpwg.web.cern.ch/lhc-mpwg/MPP-Meetings/No79-19-07-2013/NVoumard_BETS%20on%20MSI%20TDI%20and%20TCDQ_v2.pptx

BETS transfer function for MSI

- Change of transfer function to be done locally in the tunnel
- Transfer function to be checked by MCS
- Arming sequence for BETS on MSI not needed (standalone)
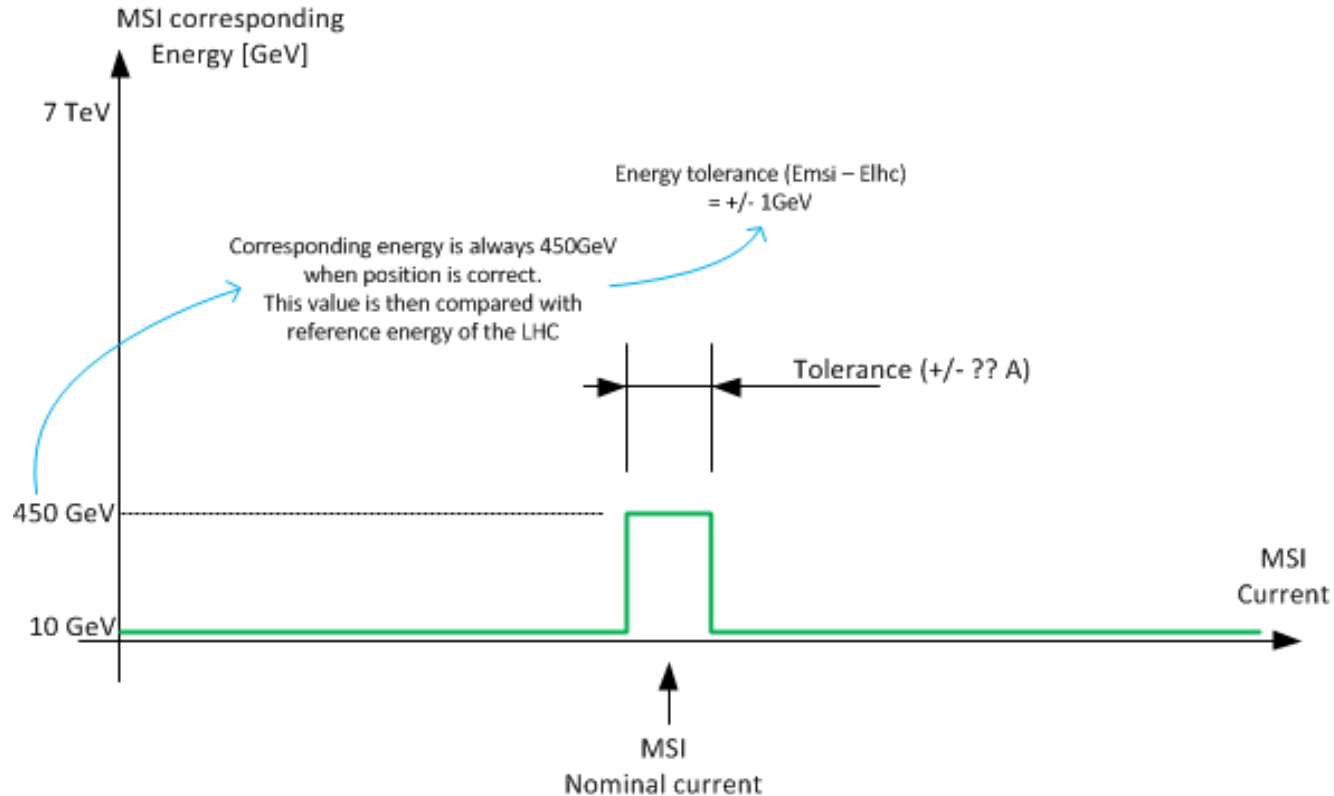
BETS on MSI

- Description
  - Works on absolute current
  - Maskable interlock, connected to injection BIC
  - Proposed tolerance 7 μrad ≈ 1 sigma oscillation = 5e-4 tolerance on the MSI current
- Proposed procedure / actions:
  - Preparation:
    - Contact EPC and ask for current stability measurements (Hugues Thiesen)
    - Set BETS transfer function to +/- 5e-4 relative error (Nicolas Voumard)
    - Check we have rights to move the MSI current outside the above window
      - MCS rights & trim rights
  - Test:
    - Close Injection BIS loop with MSI at nominal current. Move current of MSI outside tolerance window both ways and check each time the BETS stops injection permit
    - Change BETSIM to 452 GeV and check injection BETS stops injection permit
    - Check if MCS reference not correct, cannot arm injection BIS
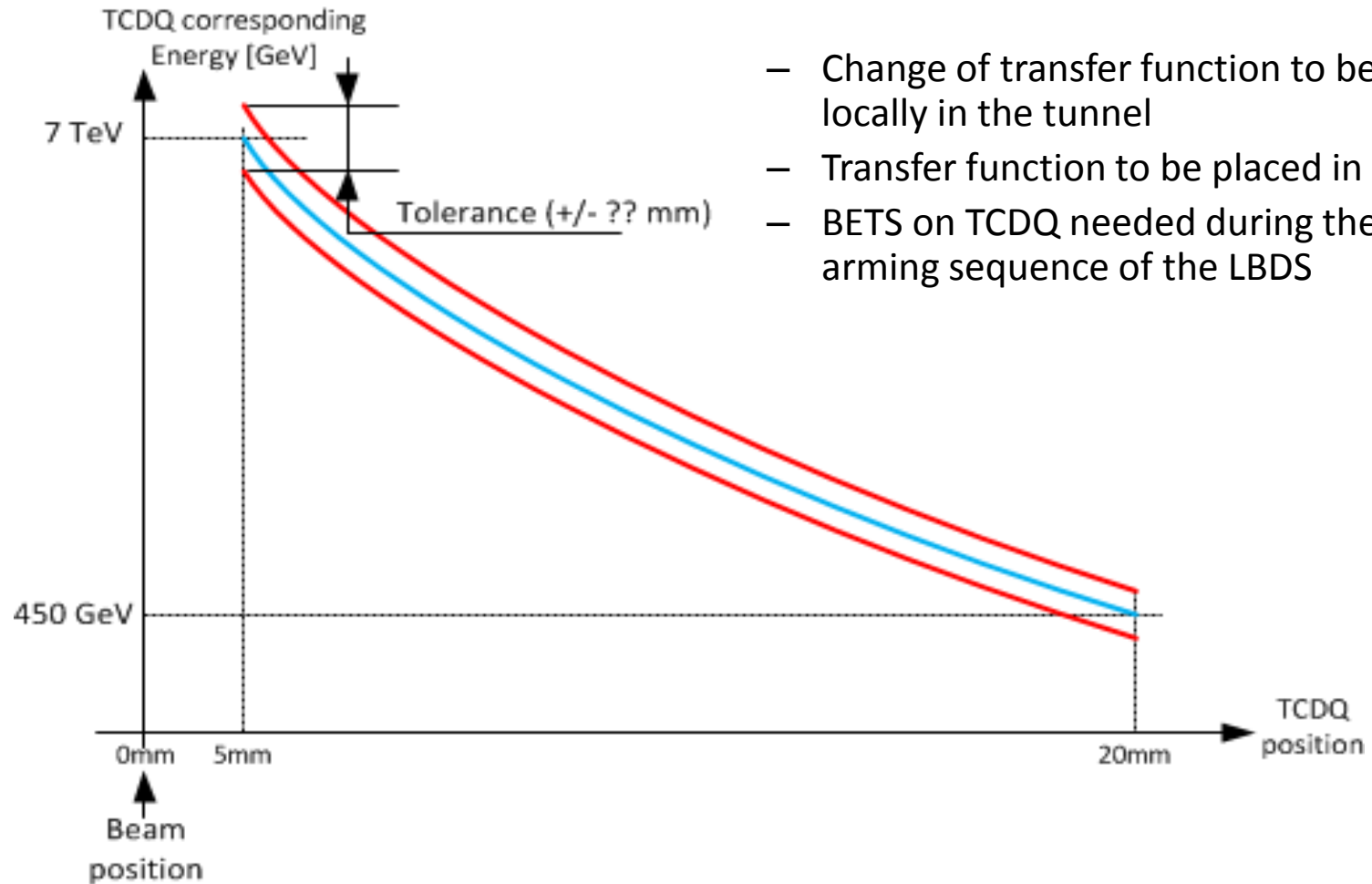
BETS transfer function for TDI

- – Change of transfer function to be done locally in the tunnel
- – Transfer function to be checked by MCS
- – Arming sequence for BETS on TDI not needed (standalone)
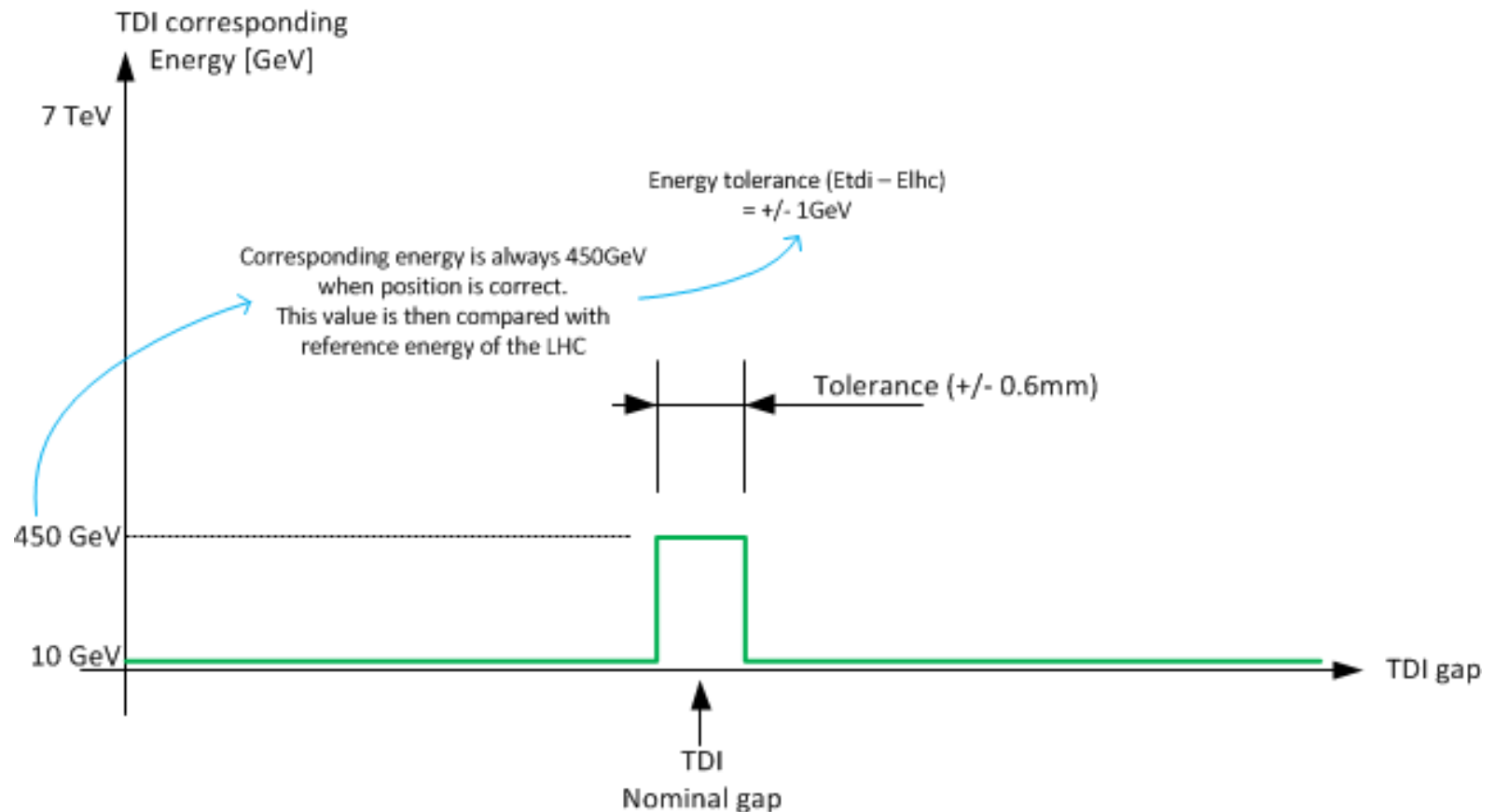
BETS on TDI

- Description
  - Works on gap between the two jaws
    - To start with LVDT, 2016 on interferometry if all goes well
  - Maskable interlock, connected to injection BIC
  - Proposed tolerance ±1 sigma, about ± 0.6 mm

- Proposed procedure / actions:
  - Preparation:
    - Check stability of LVDT / interferometry gap measurement
    - Set new BETS interlock window +/- 0.6 mm (Nicolas Voumard)
    - Check energy limit used (+/- 1 GeV)
    - Check we have rights to move the TDI (collimator role & MCS for BETS)
  - Test:
    - Close Injection BIS loop with TDI at nominal position. Move current TDI position outside tolerance window by moving first one jaw and then repeat with other jaw, check each time the BETS stops injection permit
    - Set BETSIM to 452 GeV and check one cannot inject
    - Check if MCS reference not correct, cannot arm injection BIS

TCDQ transfer function

- Change of transfer function to be done locally in the tunnel
- Transfer function to be placed in MCS
- BETS on TCDQ needed during the arming sequence of the LBDS

BETS on TCDQ

- Description
  - Works on absolute position of upstream and downstream side of jaw
  - Maskable interlock to BIS in point 6
  - Proposed tolerance ±1 sigma, about ± 0.XXX mm → to be determined
- Proposed procedure / actions:
  - Preparation:
    - Check stability position readings up and downstream
    - Set new BETS interlock function +/- 0.XXX mm around 'random' reference function for up and downstream position (Nicolas Voumard)
    - Check we have rights to move the TCDQ (collimator role & MCS for BETS)
  - Test:
    - At injection energy move TCDQ upstream outside tolerance window and check that interlock is generated. Repeat for downstream part of jaw.
    - Repeat for both jaws at 6.5 TeV beam energy (real or BETSIM)
    - Modify TCDQ ramp function so that requested position of one jaw is 2 x tolerance at 3 TeV, perform energy ramp (with nominal machine if available or with BETSIM) and check interlock is generated.
    - Check if MCS reference not correct, cannot close BIS

Summary

- Quite some modified or new HW (Realignment, MKI, TDI, BETS)
  - Existing tests remain essential

- Additional tests
  - TCDI alignment automatised
  - TCDI/TDI protection validation by loss maps – transparent in beam time
  - TDI attenuation, hierarchy – extra beam time for X measurement required
  - TCDI gap control – without beam
  - MKI vacuum interlock level – sign off
  - BETS tests for MSI, TDI, TCDQ – without beam