Energy deposition studies for HL beams

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On behalf of HL-LHC WP14

TDIS Internal Review

December 01$^{\mathrm{st}}$, 2016

Introduction

- Recap of **failure scenarios**
  - Different MKI failure scenarios for injected and stored beams and number of bunches affected
  - Impact positions on TDIS jaws (differences IR2/IR8)
- Recap of **HL beam** and **optics parameters** at the TDIS
- **Energy deposition** studies for TDIS
  - **FLUKA model** of the TDIS
  - Peak energy density and temperatures in absorber blocks, cooling pipes, stiffener, frame (clamps)

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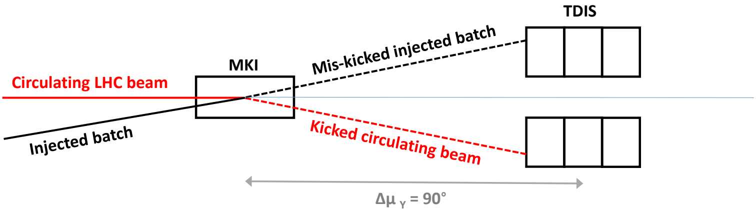
MKI Failure Scenarios

- **Malfunction** of the MKIs **can affect** the **injected** or the **stored** beam
- For specific kicker timing errors **also both beams** can be affected **in the same event**
- **Different kick strengths** lead to **different impact positions** on the TDIS jaws
- Summary of possible MKI failure scenarios (expected kick strength as fraction of the nominal kick strength):

Failure Case	Bunches	Kick Strength
Charging failure	288 (inj.)	99 - 101 %
Main switch erratic	159 (inj. or circ.)	$\leq$ 100 %
Main switch missing	288 (inj.)	75 %
Magnet breakdown	$\leq$ 288 (inj.)	75 - 125 %
Timing error	$\leq$ 288 (inj.)	0 %
	$\leq$ 288 (circ.)	100 %

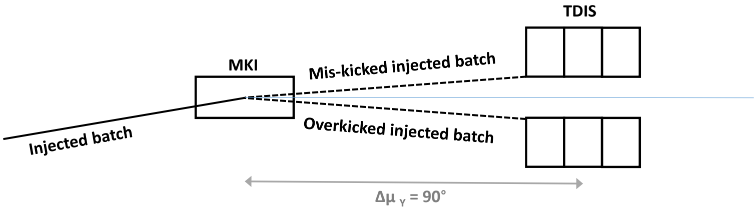
MKI Failure Scenarios

- **Large impact**, e.g. in case on a **timing error**:
  - No MKI kick on injected beam or
  - 100% kick on circulating bunches
    - → possible impact of bunches on the TDIS **31 mm (IR2)** - **36 mm (IR8)** from the absorber block edge due to **different optics in IR2 and IR8**



MKI Failure Scenarios

- **Small impact**, e.g. in case on a **Main switch erratic** or **kicker magnet breakdown**:
  - Deflection of **injected** beam by approximately **90 %** or **110 %** (impact on the upper or lower jaw) or
  - Kick of **circulating** beam with $\sim$ **10 %** of the nominal MKI strength (impact on the lower jaw)
    - $\rightarrow$ bunches **impact close to the edge** or **graze** along the jaws
    - $\rightarrow$ higher energy deposition in downstream magnets due to secondary particle showers escaping through the TDIS gap



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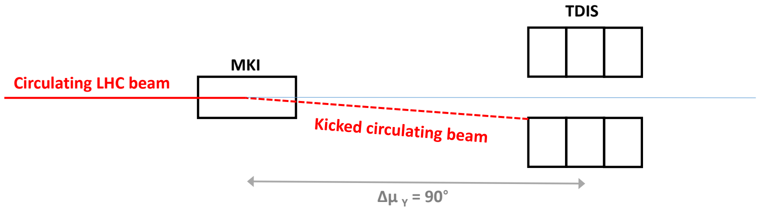

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Assumed beam and optics parameters

- The **same normalized emittance** and **bunch intensity** were assumed as for **LIU** protection/dump upgrades in **SPS/TLs**
- **Beam parameters:**

Beam	$\epsilon^n_{x,y}$	I_b	Brightness/Brightness$_{LHCultimate}$
HL Std 25 nsec	2.08 μm·rad	2.3×10^{11}	2.3
LIU BCMS	1.37 μm·rad	2.0×10^{11}	3.0
LHC ultimate	3.5 μm·rad	1.7×10^{11}	1
LHC design	3.5 μm·rad	1.15×10^{11}	0.7

- Beta-Functions do not significantly change with the HL upgrade
- **Optic Parameters:**

	β_x (m)	β_y (m)	σ_x (μm)	σ_y (μm)
HL Std 25 nsec	104	43	670	430
LIU BCMS	104	43	540	350

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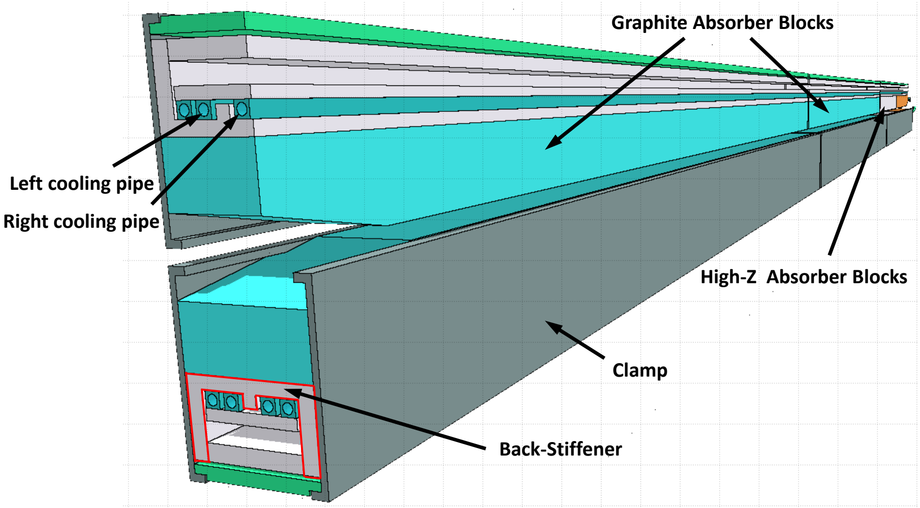
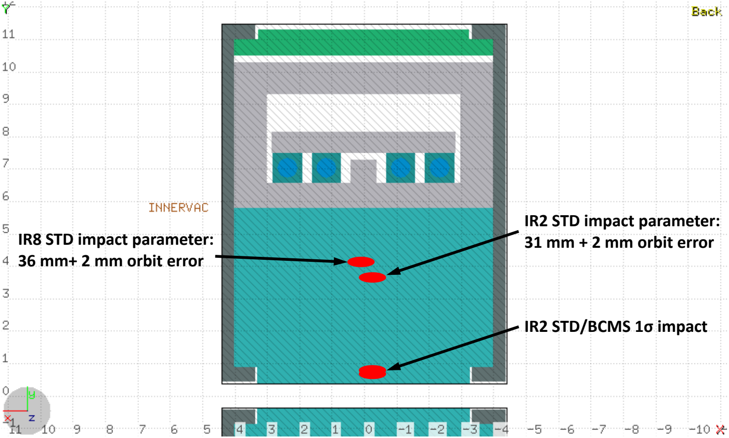
FLUKA Model of the TDIS



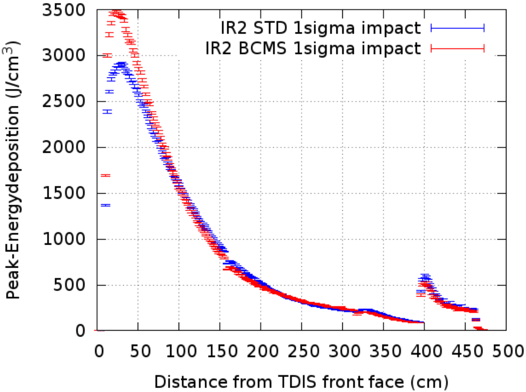
Beam Impact Positions on TDIS

- Impact positions for MKI failure scenarios with 1 σ and large impact parameter



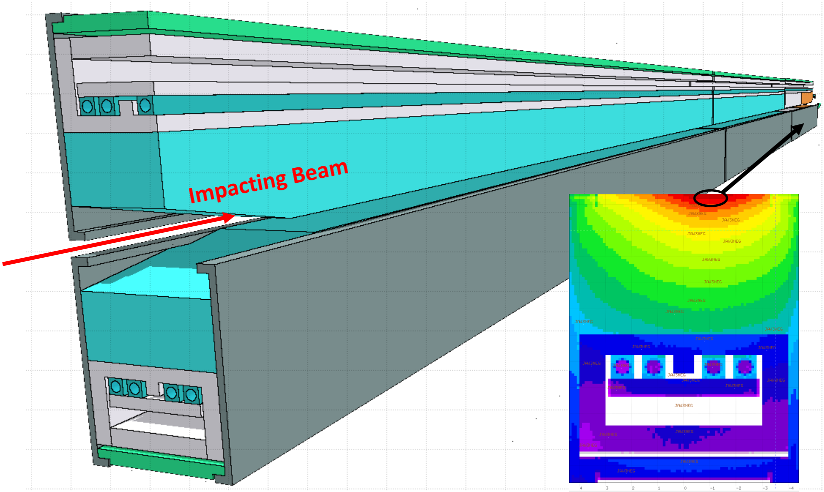
Small Impact Parameter: Absorber Blocks

- Peak energy deposition in **absorber blocks** of upper jaws, **Std.** and **BCMS** beams:



- Highest energy density in 1st jaw: $\sim$**3.5** kJ/cm^3 for BCMS, $\sim$**2.9** kJ/cm^3 for Std.
- Smaller beam size leads to higher peak energy deposition for BCMS beams

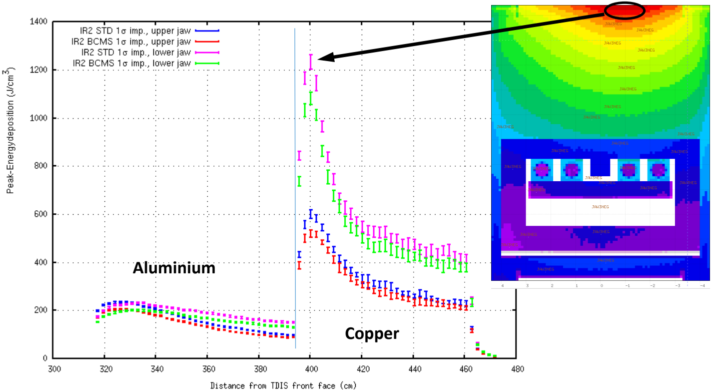
Small Impact Parameter: Absorber Blocks



- Peak-Energy deposition **higher** in high-Z absorber blocks of the **lower** jaws due to higher exposure to **secondary showers** from first two jaws

Small Impact Parameter: Absorber Blocks

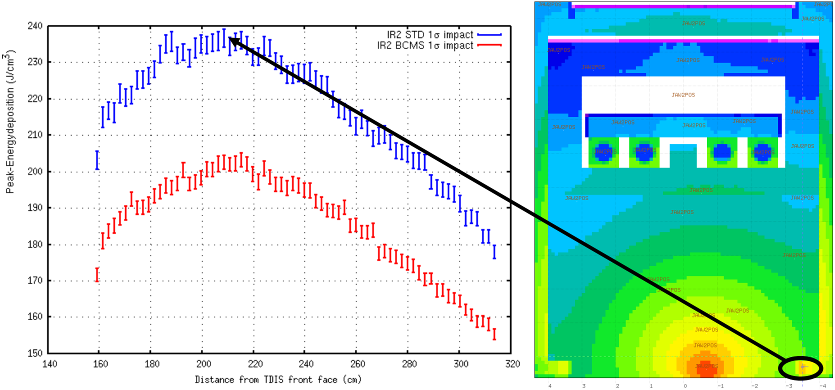
- **Impact parameter** of **1 σ worst case** in the **thermo-mechanical** point of view since the impact occurs close to absorber block surface reflecting the shockwaves
- Peak-Energy deposition in **higher-Z absorber blocks**, lower and upper jaw:



- Maximal temperature increase in Aluminium: $<$ **100 K**
- Maximal temperature increase in Copper: $\sim$ **360 K**
- Due to possible **misalignment** of the jaws **additional energy deposition** of $\sim$ **15 %** has to be taken into account

Small Impact Parameter: Clamp

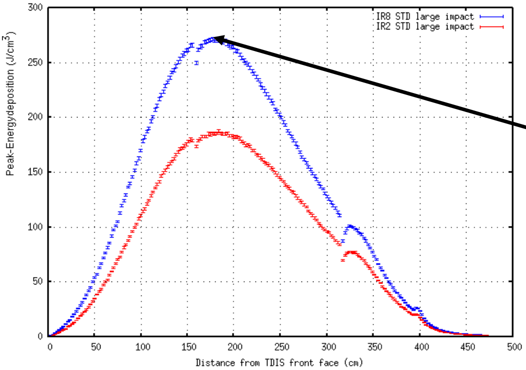
- Peak-Energy deposition in **clamp** of **2nd jaw**:

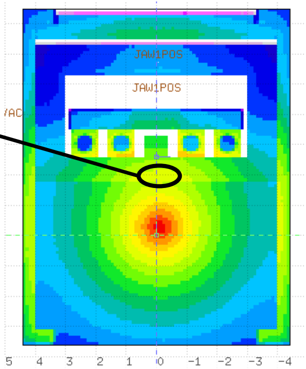


- Highest energy density: $\sim$ **235** J/cm^3 for IR2 Std. beams

Large Impact Parameter: Back-Stiffener

- **Peak-Energy deposition higher in IR8** than in IR2 due to closer beam impact to the back-stiffener:

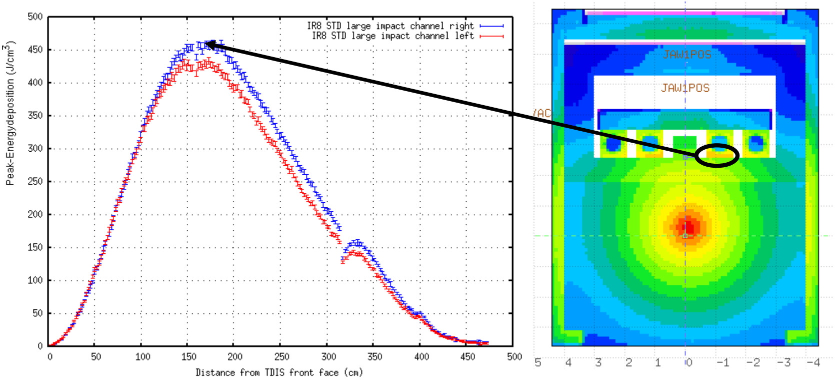




- Maximal temperature increase in back-stiffener (Aluminium): **~112 K**

Large Impact Parameter: Cooling Pipes

- Also for the cooling pipes **higher energy deposition in IR8** than in IR2 due to a closer beam impact
- Peak-Energy deposition in the left and right cooling pipe of IR8:



- Maximal temperature increase in cooling pipes (CuNiFeMn): **$\sim$130 K**

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Conclusions

- The **TDIS has to resist** beam impacts with **large** as well as with **small impact** parameters.
- Both cases already happened in RUN 1+2 $\rightarrow$ **highly relevant**
- **Worst-case scenarios** (in the sense of impact position on the TDIS) are **different** for different components.
- In case of a small impact parameter the effect of a possible **misalignment has to be taken into account**, especially in the higher-Z absorber blocks. **Additional $\sim$15 %** in energy deposition were calculated.
- Energy deposition studies serve as base for the thermo-mechanical analysis presented in the following talk.
- **Higher-Z absorber blocks** are still **under study**. Studies on more suitable materials and modified lengths of the blocks within the downstream jaws are ongoing.

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Energy Deposition for Large Impact Parameter

- Peak-Energy deposition in **cooling pipes**, IR2: