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Outline

- Motivation
- Distorted Beam Dumps
- Mosaic Beam Dumps
- Summary
Motivation

The design of beam dumps becomes difficult challenges with the increasing of the energy and intensity of the particles beams.

The proposed HE-LHC beam dump system must have the capability to absorb an energy 1.3 GJ per beam.

Construction of such beam dumps demands innovation for escaping the damage of the beam dump.
HE-LHC Beam Parameters used in Simulation

<table>
<thead>
<tr>
<th>HE-LHC</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{\text{beam}}$</td>
<td>TeV</td>
<td>13.5</td>
</tr>
<tr>
<td>$N_p/\text{bunch}$</td>
<td>$10^{11}$</td>
<td>2.2</td>
</tr>
<tr>
<td>$N_p/\text{beam}$</td>
<td></td>
<td>2760</td>
</tr>
<tr>
<td>$\sigma_x$</td>
<td>mm</td>
<td>0.94</td>
</tr>
<tr>
<td>$\sigma_x'$</td>
<td>$\mu$rad</td>
<td>1.10</td>
</tr>
<tr>
<td>$\sigma_y$</td>
<td>mm</td>
<td>0.85</td>
</tr>
<tr>
<td>$\sigma_y'$</td>
<td>$\mu$rad</td>
<td>1.21</td>
</tr>
<tr>
<td>$\sigma_p$</td>
<td>%</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The pattern are constructed such that the temperature in the dump remains acceptable (below 2000 °C).
Deposited Energy X and Y Profile in the Graphite Absorber

\[ \sigma_x = 1.7 \text{ cm} \]

\[ \sigma_y = 15 \text{ cm} \]

\[ \sigma_x = 1.7 \text{ cm} \]

\[ \sigma_y = 15 \text{ cm} \]
Energy Deposition in Graphite with different densities: 1.7 g/cm$^3$ and 1.0 g/cm$^3$

The spiral distribution of the proton bunches on the surface of the absorber solves the problem. The energy deposition in the longitudinal direction is concentrated at a distance of ~300cm or 500cm from the beam dump front surface.
1. Geometrically Distorted Absorbers

- The main idea for an improved beam dump design is to smear the energy deposition “evenly” over the whole volume of the absorber.
- This would allow to better distribute the deposited energy over the whole volume and, thereby to decrease the temperature gradient inside the absorber.
- One of the possible solutions is to use distorted geometrical shapes instead of the regular cylinders or blocks of materials.
The change in the geometrical shapes should break the symmetry in the distribution of the beam particles inside the absorber. It will redistribute protons spatially wider inside the absorber in Z direction as well.
Energy Deposition in Longitudinal Direction

Gaussian fits of the longitudinal extents of the energy deposition yield the standard deviations:

- $\sigma_z = 124$ cm
- $\sigma_z = 156$ cm
- $\sigma_z = 194$ cm
- $\sigma_z = 217$ cm

The longitudinal energy deposition is $\sim 1.5$ times wider in case of the distorted beam dump. This will decrease the temperature gradient inside the absorber.
For the distorted absorbers, the energy deposition is more deeply distributed.

This is the purpose of the added conical front part.
The maximum energy deposition density in the graphite is found to be:

\sim 3.01 \text{ kJ/cm}^3, \text{ equivalent to } 1.8 \text{ kJ/g. The associated peak temperature rise in the unit volume is } \Delta T = 2500 \ ^\circ \text{C}.

\sim 4.3 \text{ kJ/cm}^3, \text{ which is equivalent to } 2.6 \text{ kJ/g. The associated peak temperature rise in the unit volume is } \Delta T = 3400 \ ^\circ \text{C}.
Mosaic Beam Dump

We used blocks made by graphite with different densities, 1.7 g/cm\(^3\) and 1.0 g/cm\(^3\). The dimensions of blocks are 10x10x1000 cm, transversely in alternation, instead of a larger monolithic block from a single material.

- As another mitigation method, we considered mosaic beam dumps, e.g. composite dump blocks made from by sets of different materials.
- Such a mosaic beam dump can redistribute the deposited energy since the penetration depth of the energy deposition varies for different materials.
Front surface of the absorber consists of 64 cells made by Graphite with different densities.

1. 10x10x1000cm for 1.7g/cm³ and 1.0g/cm³
2. 10x10x1200cm for 1.7g/cm³ and 10x10x1000cm for 1.0g/cm³
Longitudinal Distribution of Energy Deposition in Mosaic Beam Dump

Compared with normal absorber, the energy deposition peak is shifted towards a larger distance from the surface (blue) or has two peaks (green).

Area under plots
- 1.05551e+09
- 1.01318e+09
- 1.00058e+09
Compared with normal shape absorber, the energy deposition peak is shifted towards a larger distance from the surface, since the interleaved low density subblocks have large penetration depth.
Two types of dilution system:

- **Active dilution** – using dilution kickers to spread bunches in transverse direction
- **Passive dilution** – using distorted or/and mosaic absorber to spread bunches in longitudinal direction

This was an attempt to reduce dilution kickers requirements: kick strength, frequency ...
Summary

- MC simulations illustrate that both distorted and multi-material mosaic absorbers are promising devices for the future high energy and intensity colliders.
- Effective would be a combination of the two concepts, namely a **distorted mosaic beam dump**.

**Future studies:**
- Study the mechanical design and the feasibility of such types of absorbers
- Feasibility of the concepts in case of dilution failure.
- Feasibility of the concept in case of beams transverse offset.
Thank you for your attention