Accident Scenarios

Preliminary estimates for asynchronous dump

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Introduction

• Motivation
  – Prediction of $\Delta T$ and total load w.r.t. damage limits
    • graphite jaws
    • copper cooling

• Scope
  – realistic asynchronous dump distribution
  – usual (detailed) IR7 geometry
  – simple adiabatic model for $\Delta T$ calculation

• Changes from previous simulation
  – finer data mesh around impact positions
    • avoids “dilution” of energy during scoring (now 100 micron in x,y)
  – $C_p(T)$ quoted for °K in reference but it is actually for °C
Input Data

• Proton distributions
  – from MAD
  – 23 bunchs in total
  – (x,y,z) and (x’,y’) at TCP.C6L7 front face
  – sampled in simulation to give 20K simulated p+/bunch (460K total)
Pre-processing

- Input data was preprocessed in MatLab to give correct rotational and transverse transforms to the simulation coordinate system.
Simulation

• TCDQ removes swept beam beyond $10\sigma$
  – totally removes outer 3 bunches
  – truncates some remainder bunches
• Simulation handles 20 innermost bunches
  – each processed separately
  – $10\sigma$ cut applied at runtime
• Output
  – outputs summed to give expected full sweep load
  – output data are per primary proton (post-process)
Post-processing (2)

- $\Delta T$ calculation
  - takes scaled J/cm$^3$ data as input
  - employs temperature dependant specific heats
    
    \[
    c_p^{\text{graph}}(T) = 528.75 - 205.9 T^{1/3} + 154.21 T^{1/2} - 1.53 T + 9.15 \times 10^{-5} T^2
    \]
    \[
    c_p^{\text{Cu}}(T) = 381.12 + 0.16 T - 1.09 \times 10^{-4} T^2
    \]
  - $\Delta T$ can be extracted, assuming system is initially at 20°C, by solving numerically the upper limit of
    
    \[
    \frac{dE}{dV} = \rho \int_{T_0}^{T_0 + \Delta T} c_p(T) dT
    \]
Post-processing (1)

- MatLab used to post-process data.
  - Input data
    - GeV/cm$^3$ per proton in a Cartesian mesh
  - Scaling
    - scale to expected $1.1 \times 10^{11}$ protons per bunch
    - adjust for TCDQ scraping (9.5%)
  - Processing
    - convert to J/cm$^3$
    - integrate per material region (total load)
    - locate positions of max deposit per material region
    - create profiles intercepting max in each coordinate
Results: Jaw loads

Table 1 Total deposited energy per region in Horizontal collimator TCP6L1

<table>
<thead>
<tr>
<th>Region</th>
<th>Total Deposit (J)</th>
<th>Statistical Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite Left Jaw</td>
<td>74.8</td>
<td>? 31 %</td>
</tr>
<tr>
<td>Graphite Right Jaw</td>
<td>27.59</td>
<td>? 30 %</td>
</tr>
<tr>
<td>Copper Left Jaw</td>
<td>22.12</td>
<td>? 31 %</td>
</tr>
<tr>
<td>Copper Right Jaw</td>
<td>20.55</td>
<td>? 31 %</td>
</tr>
</tbody>
</table>

Table 2 Total deposited energy per region in Skewed collimator TCP6L1

<table>
<thead>
<tr>
<th>Region</th>
<th>Total Deposit (J)</th>
<th>Statistical Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite Left Jaw</td>
<td>186.6</td>
<td>? 31 %</td>
</tr>
<tr>
<td>Graphite Right Jaw</td>
<td>182.5</td>
<td>? 31 %</td>
</tr>
<tr>
<td>Copper Left Jaw</td>
<td>213.4</td>
<td>? 32 %</td>
</tr>
<tr>
<td>Copper Right Jaw</td>
<td>270.9</td>
<td>? 32 %</td>
</tr>
</tbody>
</table>

Table 3 Total deposited energy per region in Secondary collimator TCSPA6L1

<table>
<thead>
<tr>
<th>Region</th>
<th>Total Deposit (J)</th>
<th>Statistical Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite Left Jaw</td>
<td>9390</td>
<td>? 8 %</td>
</tr>
<tr>
<td>Graphite Right Jaw</td>
<td>9155</td>
<td>? 4 %</td>
</tr>
<tr>
<td>Copper Left Jaw</td>
<td>6161</td>
<td>? 16 %</td>
</tr>
<tr>
<td>Copper Right Jaw</td>
<td>8099</td>
<td>? 4 %</td>
</tr>
</tbody>
</table>
Results: Flange loads

- Only TCSGA6 flanges are in geometry

- upstream inner: 363.3 ± 6% J
- upstream outer: 142.0 ± 6% J
- downstream inner: 730.3 ± 9% J
- downstream outer: 171.9 ± 10% J
Results: $\Delta T$

TCPC6 (Prim. Horizontal) impacted jaw.

$\Delta T_{\text{max}}^{\text{graphite}} \approx 160^\circ C$  

$\Delta T_{\text{max}}^{\text{Cu}} \approx 0.38^\circ C$
Results: $\Delta T$

TCSSG6 (secondary)

$\Delta T_{\text{max}}^{\text{graphite}} \approx 11^\circ C$  
$\Delta T_{\text{max}}^{\text{Cu}} \approx 17^\circ C$
Comments

• Reasonable agreement now exists with previous (simple) model.
  – Differences attributed to greater level of detail
    • pencil beam → diverging beam
    • interpolated Cp → integrated function of T
    • no chamfers → chamfers

• Data previously handed to Alessandro still valid for everything except TCPC6 (fine mesh)
  – His interest was in TCS so everything is OK