Beam Dump Development for High Power Proton and Electron Beam*

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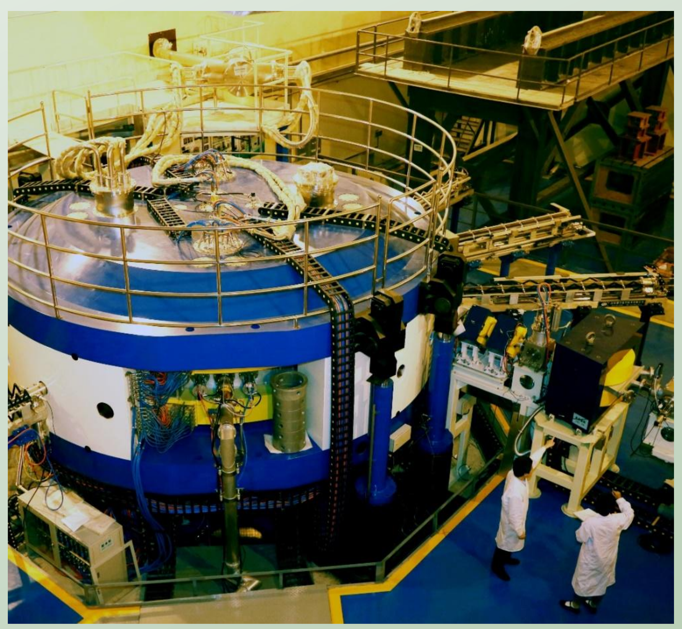
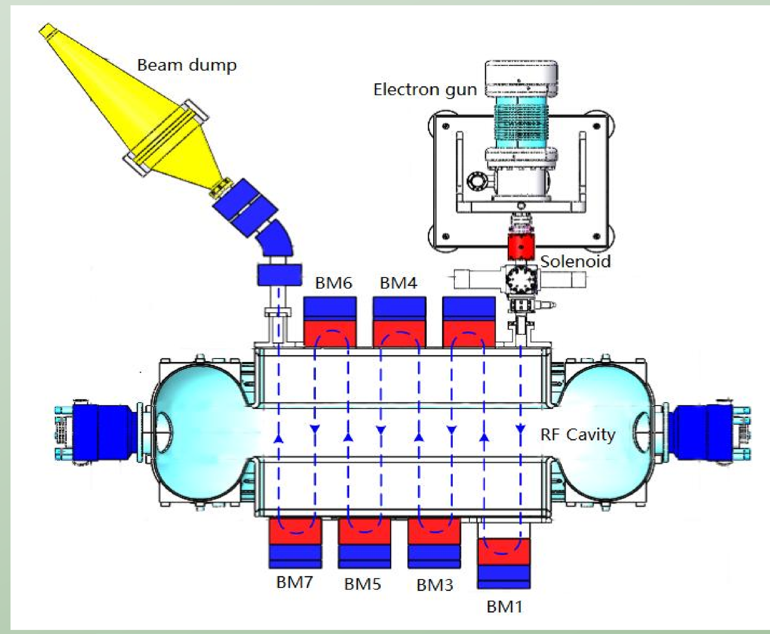
Abstract

The high-intensity 100MeV proton cyclotron CYCIAE-100 had provided 52kW beam to the beam dump in 2018, is planning to upgrade at China Institute of Atomic Energy(CIAE). It is designed to provide a 75–100 MeV, 1mA proton beam. So, a new beam dump for higher beam power have been developed since 2020. At the same time, a 1:4 scale, RF cavity with Q value up to 42000, is constructed for the engineering feasibility verification of a 2GeV/6MW CW FFAG, which is also being considered as a main accelerating cavity of a 100kW electron accelerator. The electron beam will be rotated and accelerated 7 times by the gradient dipoles and the high Q cavity. The beam dump is designed to also use for the 100kW electron beam. With the same-level beam power of the two accelerators above the content, a beam dump for absorbing two kinds of particle beams according to the characteristics of the modification was designed. The energy deposition of 100MeV proton beam and 5MeV electron beam in the beam dump was investigated by the monte-carlo simulation program FLUKA. The beam dump cooling structure was optimizing by ICEM-CFD and fluent, so that the beam dump temperature was controlled less than 100℃, and the maximum temperature on the beam dump is less than 450℃. The beam dump is designed as a cube (450*200*200,unit:mm) with two 2.5° V-type copper pentagon and two flat parts. All the details about the simulation of energy deposition, thermal distribution and structure design will be presented in the paper.



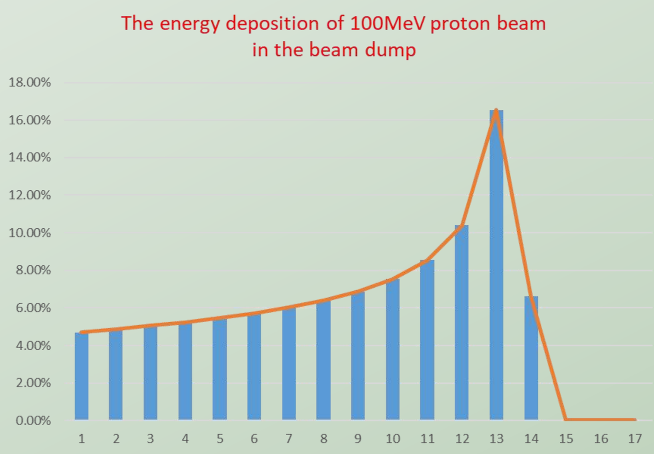
CYCCIAE-100

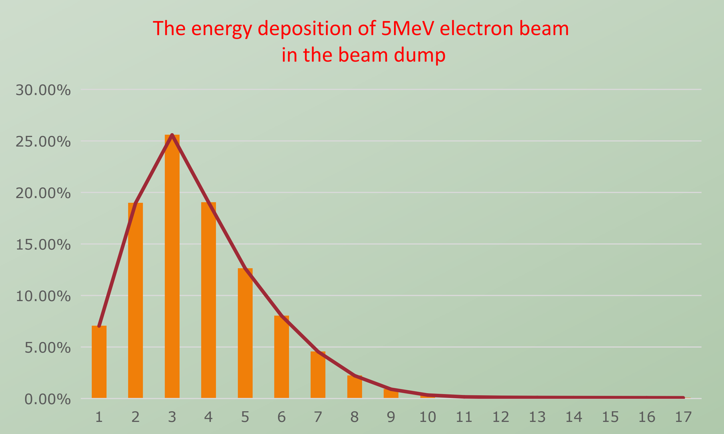


5MeV electron accelerator

The energy deposition in the beam dump

Energy has a gauss deposition in horizontal
Energy deposition from FLUKA





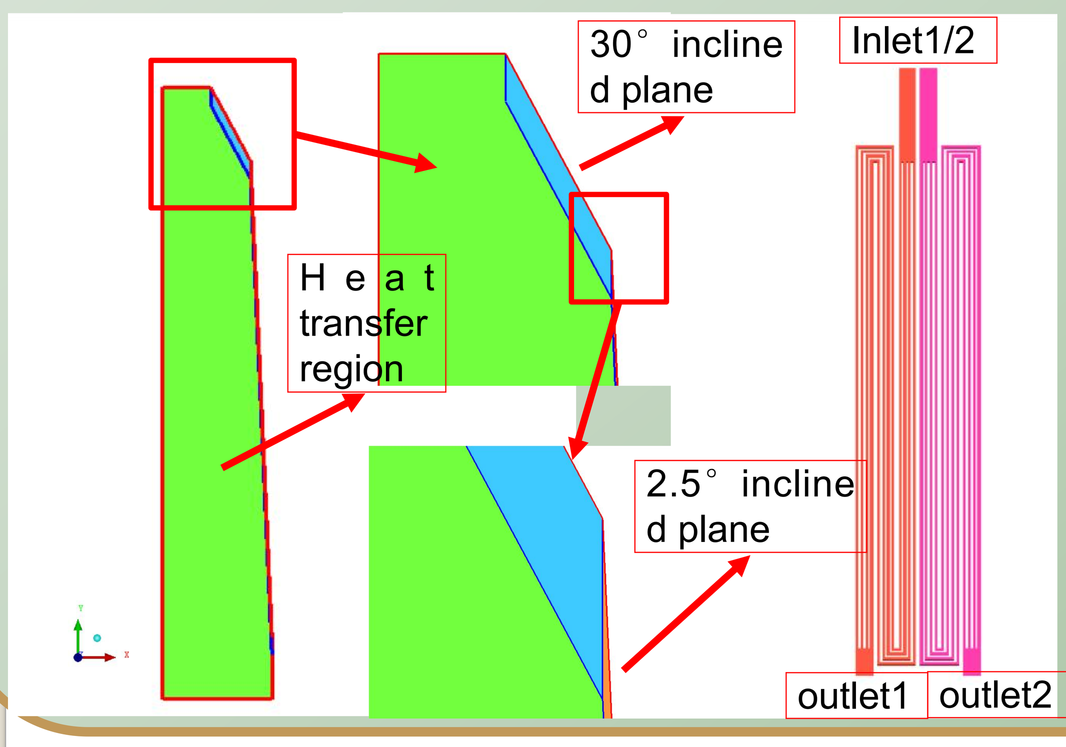
$$\text{source}(x,y,z)=\frac{qk_ik_j}{2\pi\sigma^2}e^{-\frac{(k_i\cdot x)^2+(k_j\cdot y)^2}{2\sigma^2}}\cdot p_k$$

$$\text{source}(x,y,z)=\frac{qk_ik_j}{2\pi\sigma^2}e^{-\frac{(k_i\cdot x)^2+(k_j\cdot y)^2}{2\sigma^2}}\cdot f(z)$$

$$f(z)=\begin{cases}0.0927y-0.0134;(y<0.003)\\0.6955e^{-0.611y}(0.003<y<0.01)\end{cases}$$

Structure and Mesh

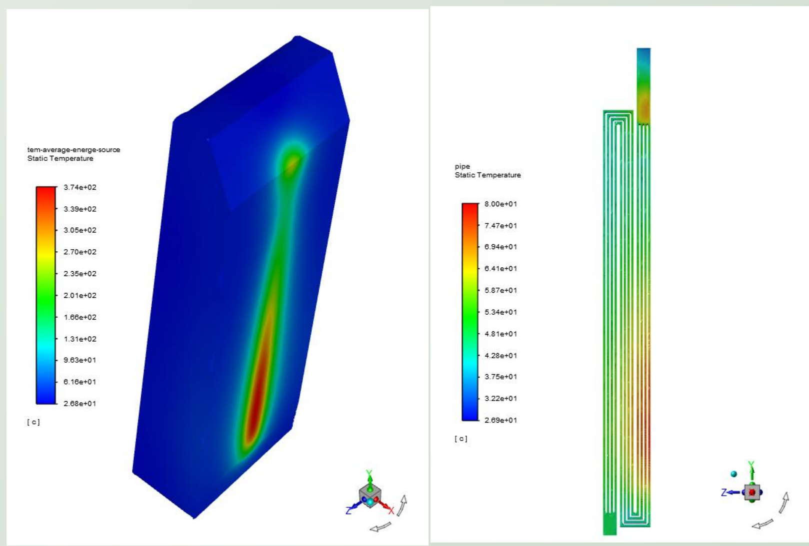
The fluid regions are distributed symmetrically along the Z-plane.
The cross section of the S-shape tube is 12.5*10mm²
The gap of the tube is 3mm and with 3 fins, the thickness of which is 1.5mm.
The distance between the tube and 2.5° deposition zones is ~25mm.
The distance between the tube and 30° deposition zones is 25~20mm.



Region	Mesh quantity	Mesh type
2.5°beam deposition zone	70 thousand	Hexa-mesh
30°beam deposition zone	16 thousand	Hexa-mesh
Tube A	27 thousand	Hexa-mesh
Tube B	27 thousand	Hexa-mesh
Heat transfer region	600 thousand	Tetra-mesh

A cube (450*200*200,unit:mm) with two 2.5° V-type copper pentagon and two flat is shown on the left.
The five regions were divided into mesh with ICEM respectively.
The five meshes merged with fluent.
Beam deposition zone was meshed in range director

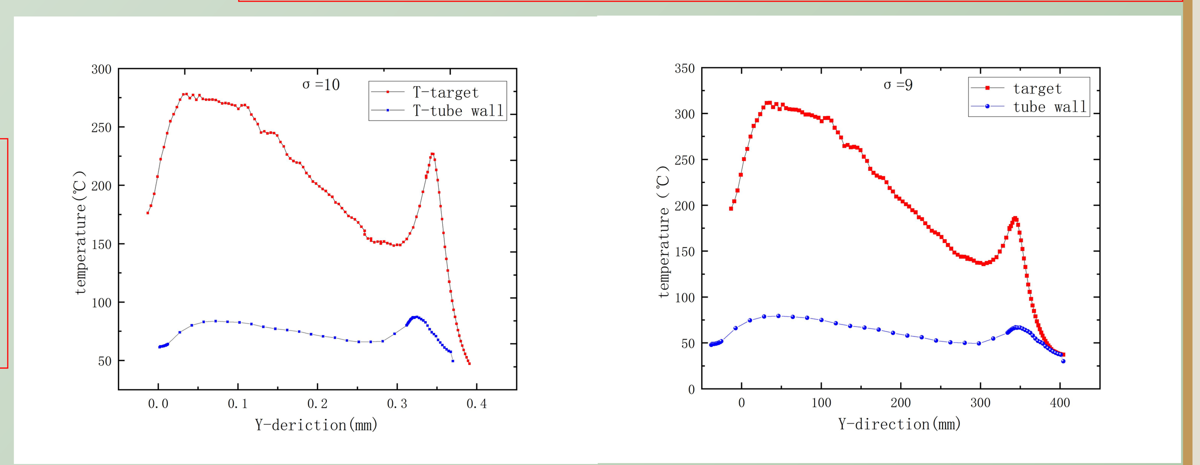
100MeV proton beam thermal distribution



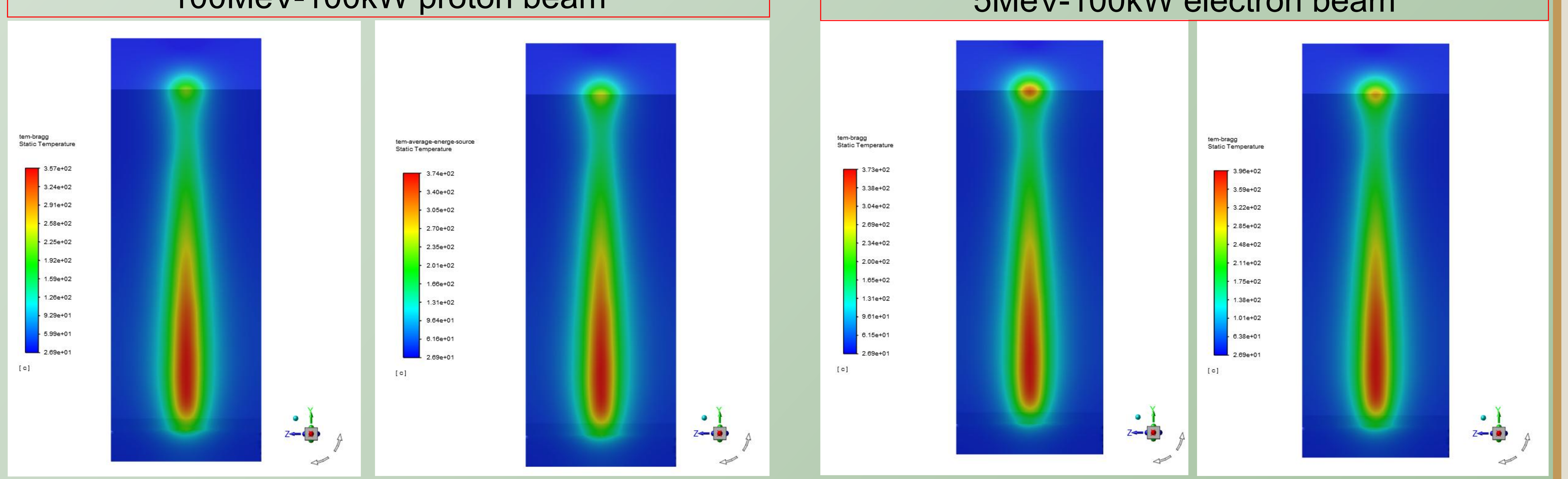
Two Heat source:
Source FLUKA: Guass deposition + energy deposition from FLUKA
Source AVE: Guass deposition + average in range director

Temperature distribution of beam dump and tube wall by 100kW@100MeV proton beam.
On 2.5° plane, the maximum temperature is 357℃, the peak temperature on the tube wall is 80℃.
On 30° plane, the peak temperature of a relative high zone is 189℃, and the tube wall close to this zone is near 70℃.

With the increase of the beam size from 9mm to 10mm, more attention should be paid to the tube wall temperature at the connect zone.



100MeV-100kW proton beam | 5MeV-100kW electron beam



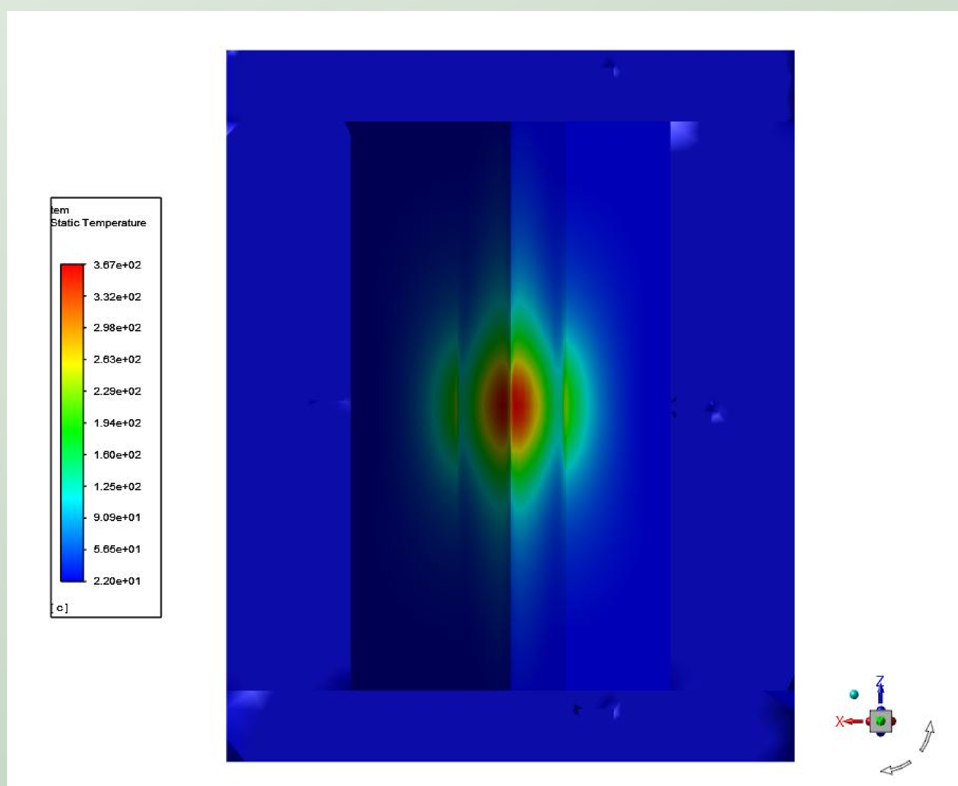
Source FLUKA T_{max}=357℃; $T_{tubewall}$=80℃

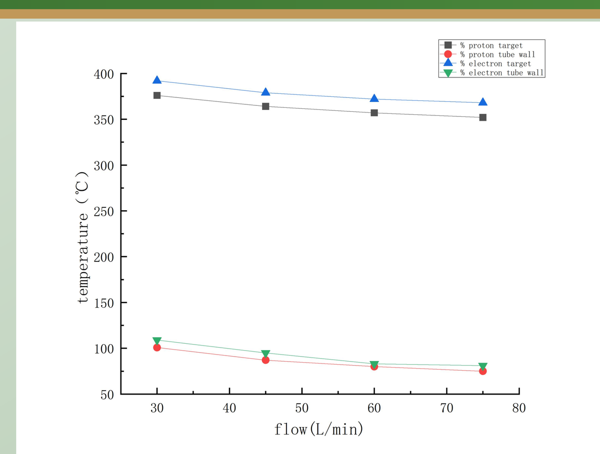
Source FLUKA T_{max}=374℃; $T_{tubewall}$=82℃

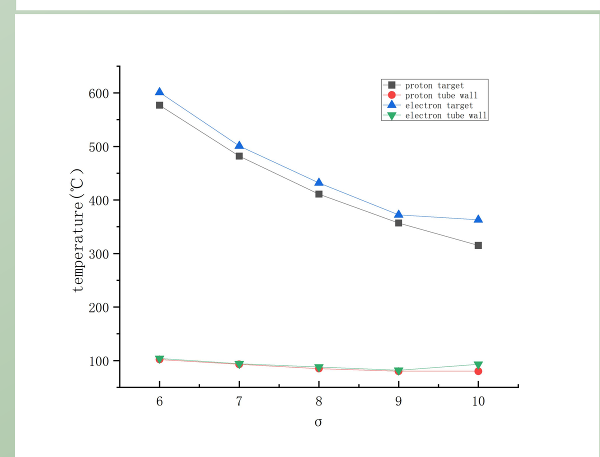
Source FLUKA T_{max}=373℃; $T_{tubewall}$=84

Source AVE T_{max}=396℃; $T_{tubewall}$=86

Different conditions







Conclusions

The design of a beam dump for 100kW proton beam and 100kW electron beam is described in this paper. The probability density of particle energy deposition in the range direction was calculated by FLUKA, which is used as the input condition to calculate the temperature distribution of the beam dump. The cooling structure of the beam dump is optimized. The flow and beam size were used as variables to study the working conditions of the beam dump under different working conditions. The beam dump is currently being manufactured, the installation and test will be carried out in the near future.