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MEASUREMENT OF BEAM ENERGY CHARACTERISTICS AT THE LHE-FREE NB3SN DEMO SRF E-LINAC

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Abstract

The demonstration of a 100 mA, 4.6 MeV superconducting radio frequency linear electron accelerator, based on conduction cooling and developed by the Institute of Modern Physics (IMP), aims to validate the feasibility of stable beam commissioning in a liquid helium-free 5-cell-β opt=0.82 Nb3Sn elliptical cavity, and to offer guidance for subsequent industrial applications. The beam energy characteristics, considered one of the critical parameters, need to be precisely measured. Given the high beam energy and the need for a compact, straightforward accelerator layout, we achieved high-precision measurements using only a ordinary dipole, a slit, and a Faraday Cup (FC). This paper presents the online measurement results of beam energy at different cavity voltage and provides a thorough analysis and optimization of the various errors encountered during measurement.

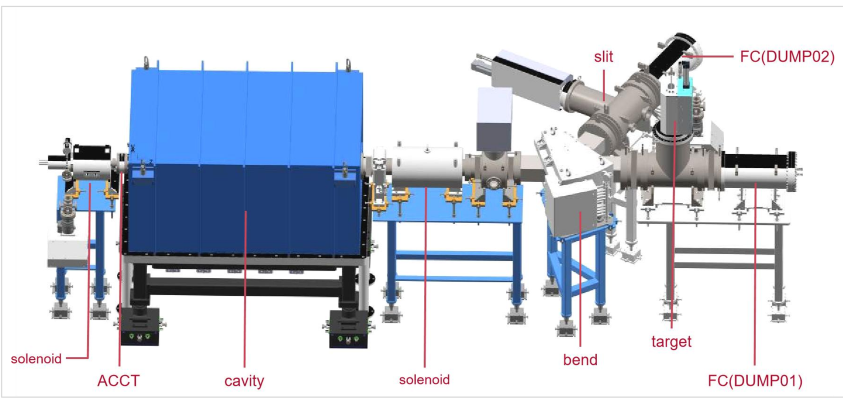
1 Introduction

The layout of the e-linac

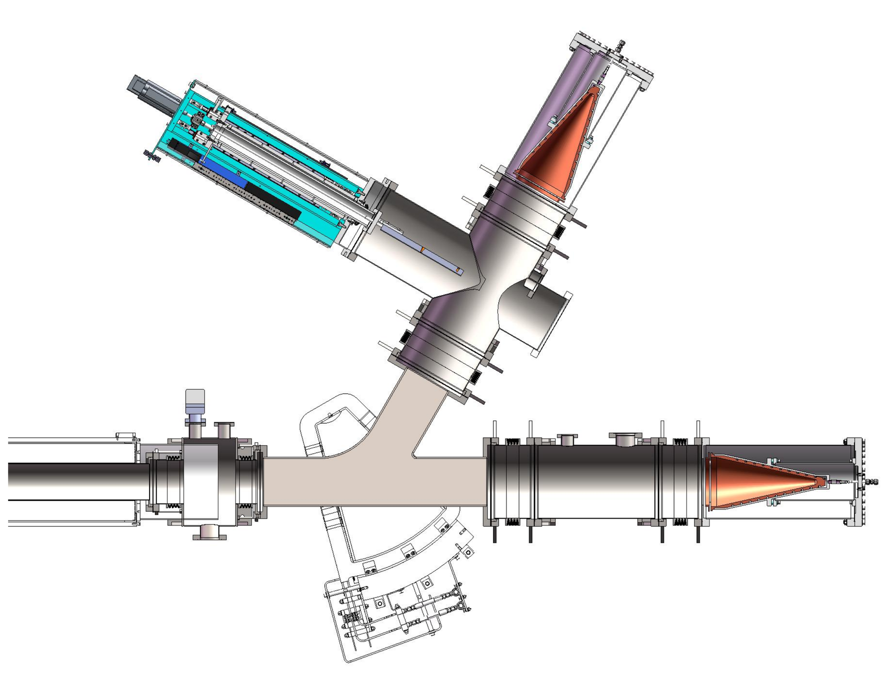
Beam Parameters	Values	Units
Accelerated particles	electron	-
Extracted Energy	0.06	MeV
Extracted Current	200	mA
Repetition Frequency	1	Hz
Pulse Width	2	us
Energy Gain	>3	MeV
Transmission Efficiency	44	%

Beam parameters of the e-linac

- The first fully integrated prototype of a solid conduction-cooled Nb3Sn SRF e-linac in China
- Measure beam current, transmission efficiency, and **energy**



2 Measurement Method



Layout of energy measurement

- Simple and Compact layout
- Simple magnetic deflection method (limited uniformity of ordinary dipole)

➢ **A ordinary + a slit + a FC**

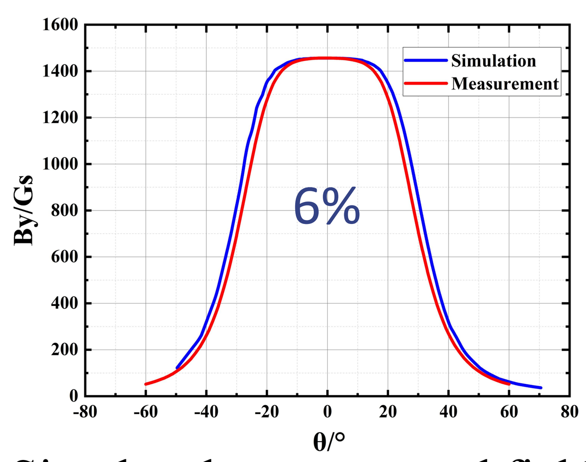
the particles that reach the FC are predominantly those traveling along the central trajectory of the dipole, where the field uniformity is relatively high

→ high measurement accuracy

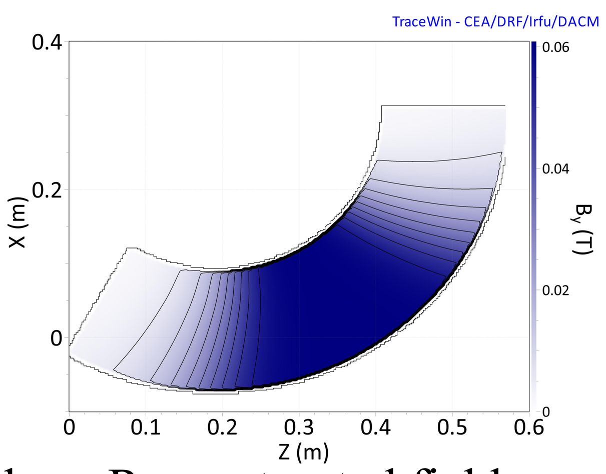
◆ Dipole field reconstruction

Beam energy passing through the dipole is selected by adjusting the magnet's excitation current.

→ Reduce magnetic field error

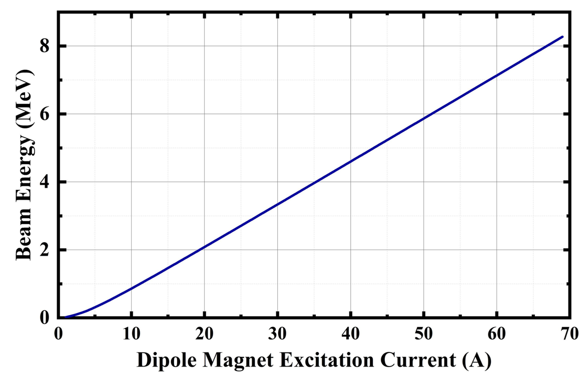


Simulated vs. measured fields



Reconstructed field

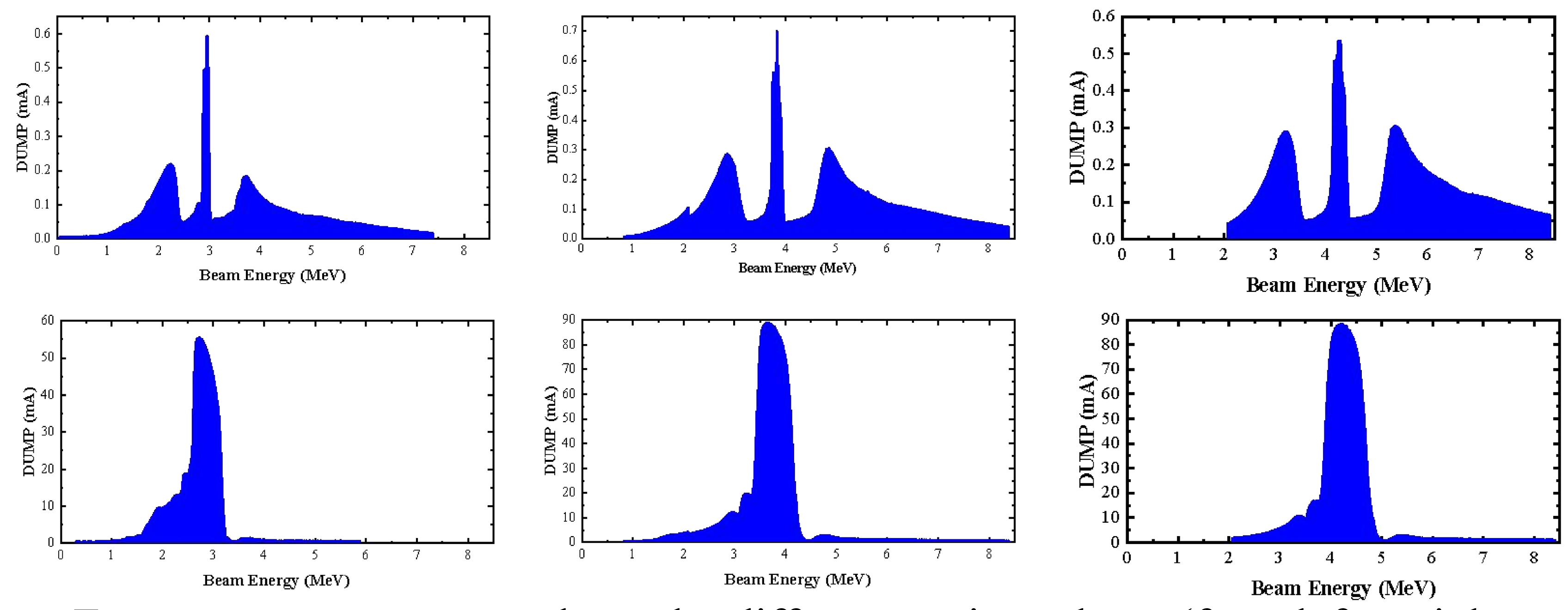
◆ Calibration of Dipole Excitation Current with Electron Energy



$$E = 0.12598 * I - 0.43512$$

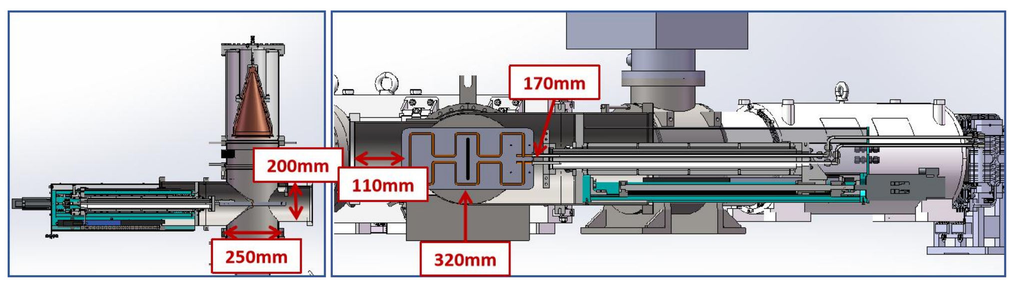
This linear equation was subsequently used to convert between the excitation current and electron energy during the experiments

3 Measurement Results

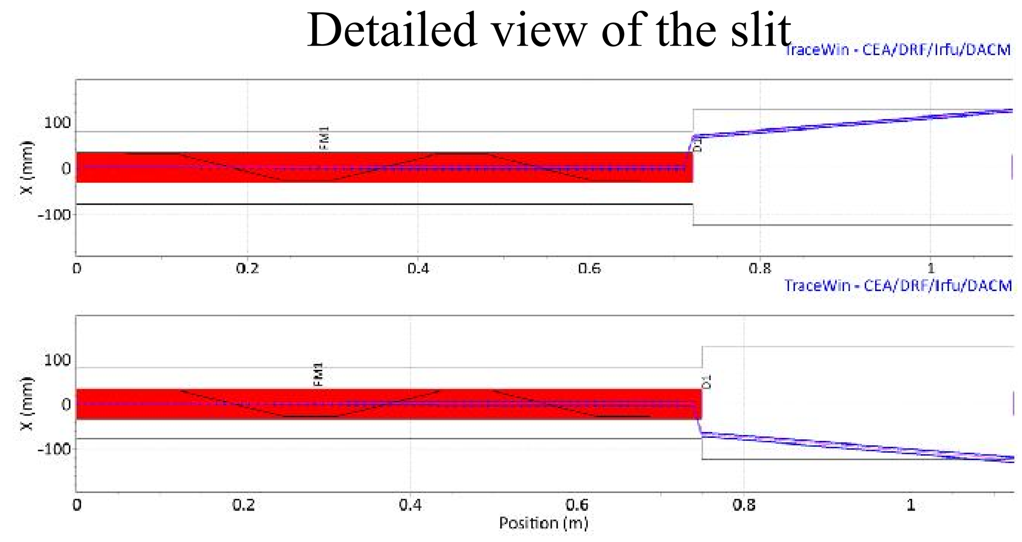


Energy measurement results under different cavity voltage (from left to right: Epk = 9, 12, 14 MV/m) with (top) and without (bottom) the slit

◆ Three distinct peaks (with the slit)



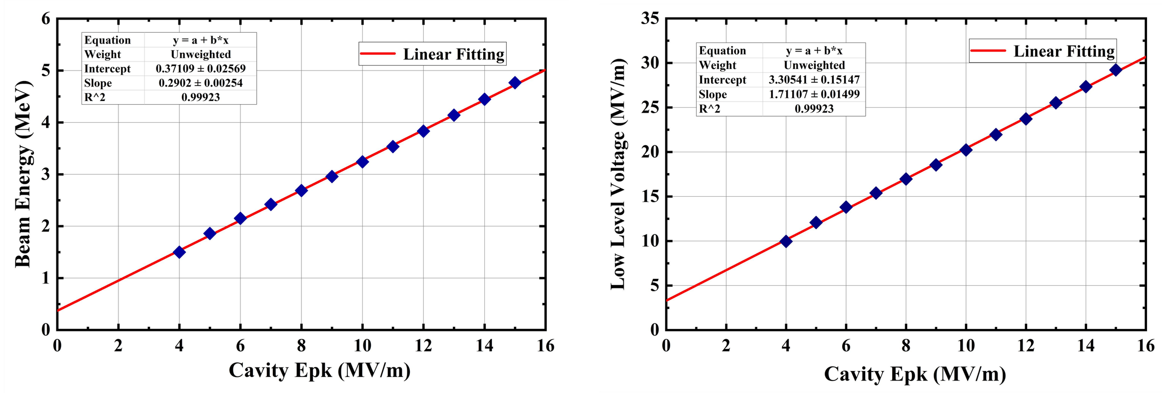
Detailed view of the slit



particle trajectories under different magnetic field

When scanning the dipole's excitation current, the beam can be deflected onto the pipe wall, producing secondary electrons that cantransport through the gap between the slit and pipe wall → adjusting the slit dimensions or modifying the scanning range

◆ Remeasure



The relationship between cavity voltage and electron energy

4 Summary

✓ This paper presents a method for measuring the energy of a SRF e-linac using a deflection magnetic field combined with a slit and a FC, achieving high measurement accuracy while accommodating the accelerator's compact layout.

✓ This approach effectively addresses the uniformity issues associated with standard dipole magnets.

✓ The paper also analyzes the issue of the energy distribution exhibiting three peaks and reports beam energy measurements conducted at various cavity voltage.