BEAM-HALO EXPERIMENT AT THE LOS ALAMOS LEDA FACILITY

Muon Cooling Instrumentation Workshop
J. Douglas Gilpatrick
LANSCE-1 Beam Diagnostics Team
Los Alamos National Laboratory
November 10 & 11, 2000

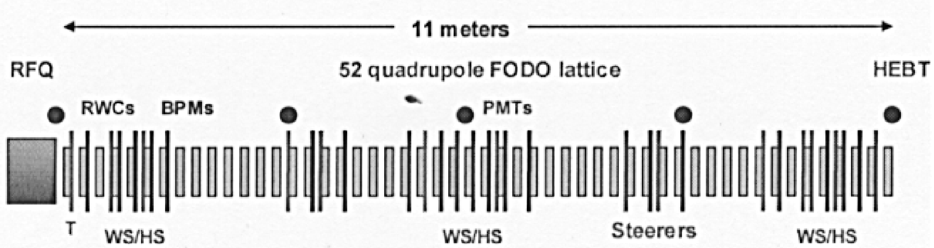
Outline

- Summarize halo formation physics and types of halos
- Discuss experimental layout
- Beam parameters
- Describe primary instrumentation
  - Wire scanner/halo scraper for projected transverse beam distributions
- Summary and status

Our Present Picture of Halo Formation in a Beam Transport Line or Linac

- Beam mismatch is a condition that with space charge can lead to significant halo growth.
- Beam mismatch excites coherent modes of the beam. The most important modes involve oscillations of the rms beam envelopes.
- In beam transport channels there are two modes, breathing mode (x and y in phase) and quadrupole mode (x and y out of phase).
- Both coherent modes can resonate with the halo particles increasing their amplitudes. For a general mismatch both modes are present.
- This mechanism is an effective way to produce an undesirable extended halo.
- These halo modes can result in beam loss and activated structures.
- Halo experiment looks to compare beam data with the simulated halo-formation physics.

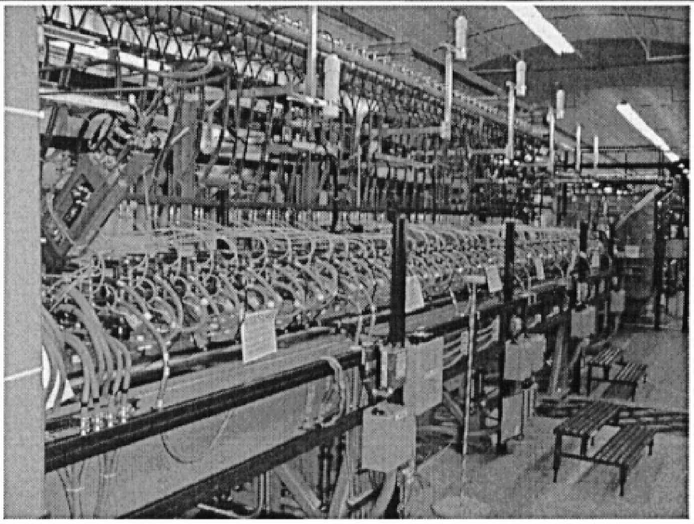
Fully Instrumented LEDA Beam-Halo Lattice



First 4 quadrupoles independently powered for generating mismatch modes.

52 Quadrupoles
9 Wire Scanners/Halo Scrapers (Projected Distributions)
3 Toroid (Pulsed Current)
5 PMT Loss Monitors (Loss)
10 Steering Magnets
10 Beam Position Monitors (Position)
2 Resistive Wall Current Monitors (Central Energy)

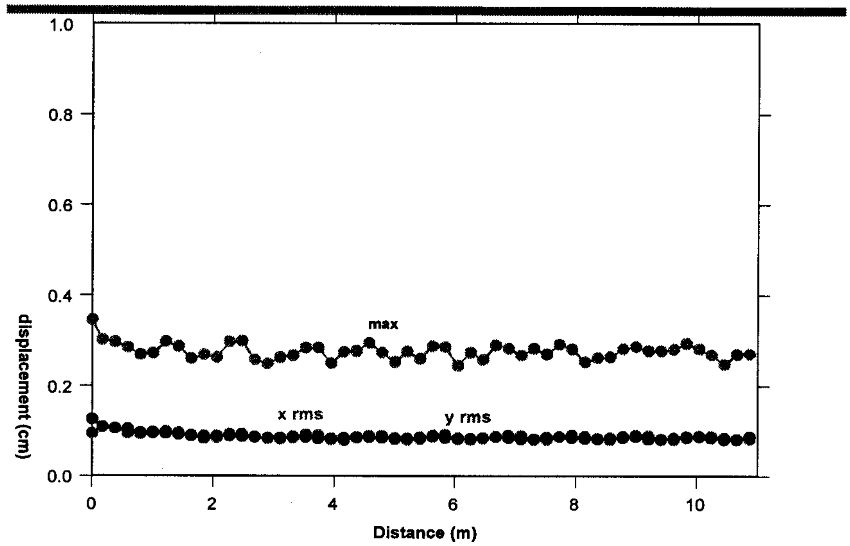
LEDA Facility Halo Lattice



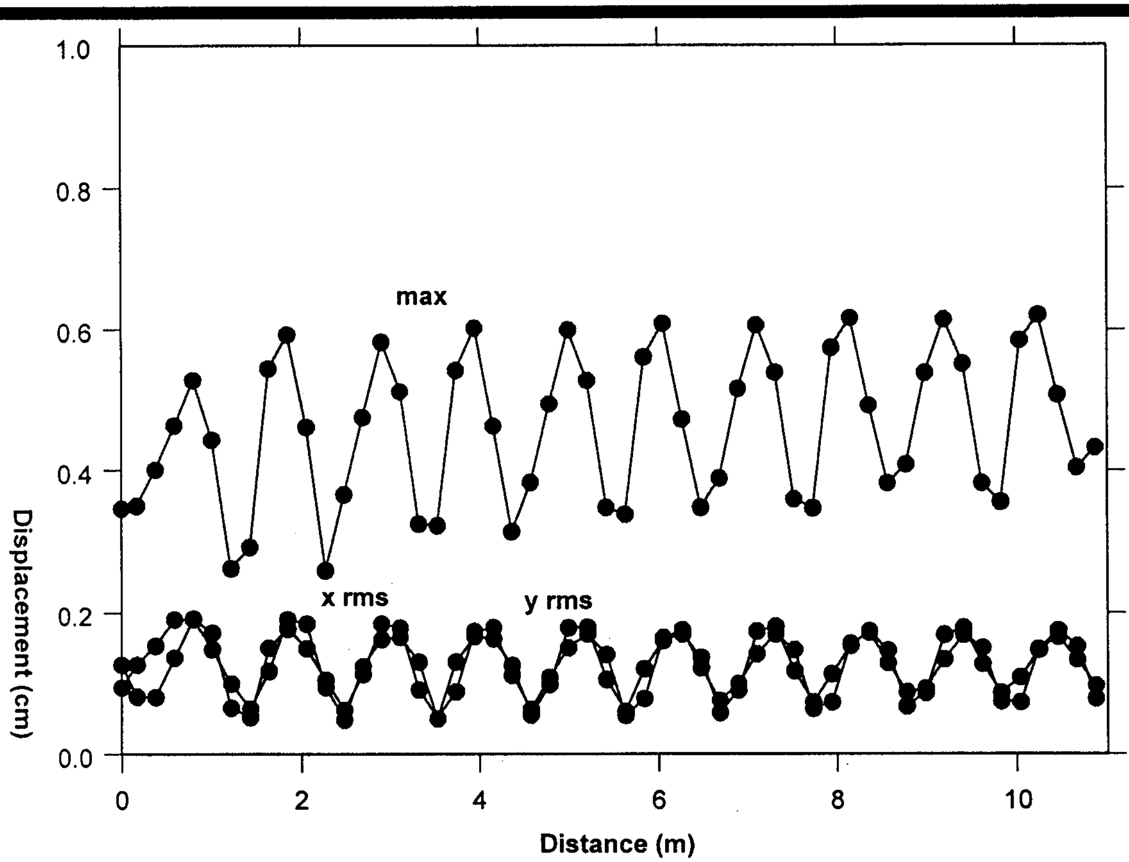
LEDA Beam Parameters

- Proton beam energy exiting the RFQ: 6.7 MeV
- LEDA injector and RFQ nominally produces CW beams
  - Halo experiment duty factor very low
    - Expected pulse lengths: 0.02- to 0.1-ms
    - Expected repetition rates: 1- to 3-Hz
- Peak beam currents: 100 mA
- Expected matched-beam rms widths in the halo lattice: 1-mm

Matched beam

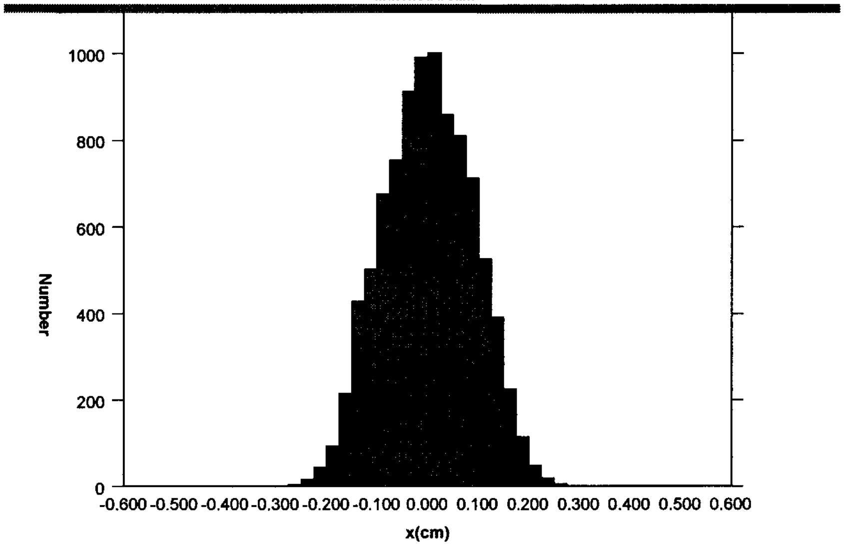


Breathing mode mismatch m=1.0



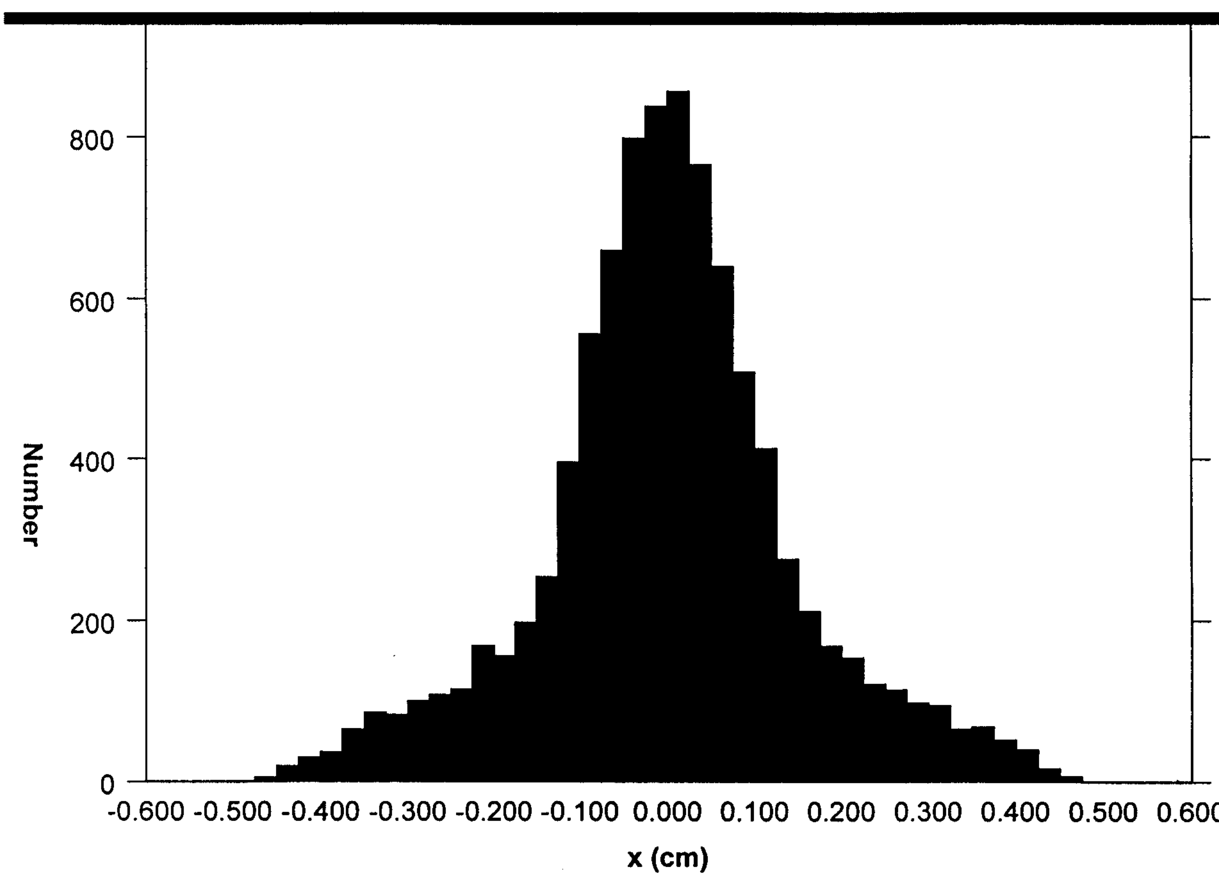
x profile at center of drift after quad 49

Matched beam



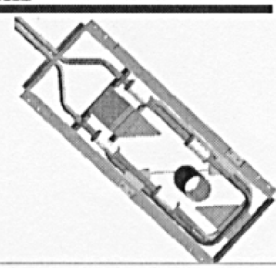
x profile at center of drift after quad 49

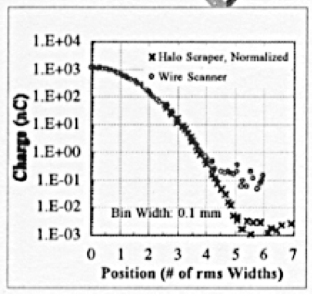
Breathing mode mismatch m=1.0



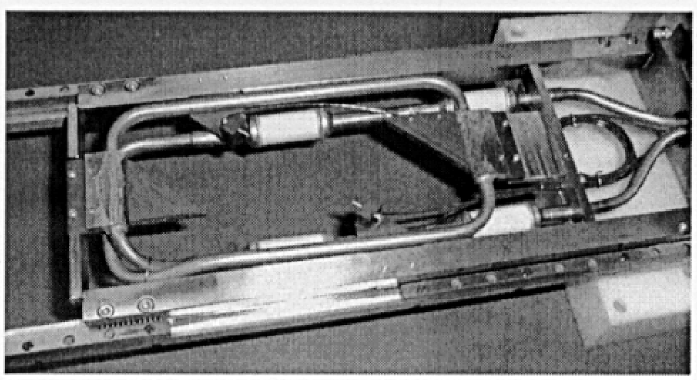
Halo Measurement Experiment has Integrated Wire Scanner and Halo Scraper Profile Measurement Capable of Detecting 5 rms Widths

- Horizontal and vertical distributions measured
- Wire scanner: 33-µm C fiber measures distribution core
  - Secondary electronics (S. E.) detected
  - Protons not stopped in fiber (range in C: 0.3 mm)
  - Fiber biased to optimize S. E. emission
- Scraper: Graphite brazed on Cu scraper measures distribution tails
  - Range out protons in 1.5-mm thick of graphite
- Measured wire placement error: < 0.02 mm
- Electronics integrate S. E. or proton current
  - Measured equivalent noise in lab: 0.04 fC
- Simulated distribution measurement shows
  - Combined dynamic range of 10^6 : 1 possible
    - Wire scanner can detect to 4 rms widths
    - Halo scraper acquires another rms width
  - Errors: wire placement, electronics noise, beam current and position variations





Halo WS/HS Assembly

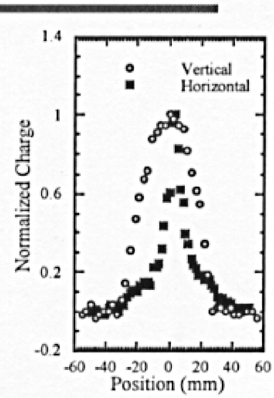


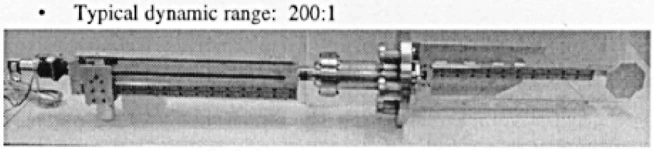
Summary and Status

- Halo formation physics and simulations are fairly mature.
- Halo experiments will compare beam data with the simulation physics.
- Experiment layout uses a 52 quadrupole FODO lattice to create the matched and mismatched beam conditions for the 2 mismatch modes.
- Fully diagnosed lattice uses WS/HS assemblies to acquire 9 horizontal and vertical projected distributions with > 10^4 dynamic range (10^6 possible).
- Lattice beamline fully assembled and ready for beam.
  - WS/HS #4 and HEBT WS installed
- Early stages of commissioning the halo lattice beamline.

LEDA HEBT Wire Scanner Verified Beam Width for Beamstop Protection and Performed "Quad Scans" Emittance Measurement.

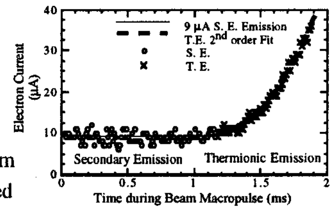
- HEBT Wire scanner: based on LANSCE design
  - Fiber bias: optimize secondary electron coefficient
    - Only one sense wire in beam at a time
    - Bias wires on each side of sense wire
  - Senses emitted secondary electrons depleted from fiber
  - Two fibers used: 100-µm SiC/C
  - Processing electronics: replacement charge is integrated with a lossy integrator.
- Peak and cw current densities: 16- to 0.1-mA/mm^2
- Nominal peak beam current: 100 mA
- Normal operation pulse lengths: 0.02- to 0.5-ms
  - RF blanking: powering RFQ after injector pulse has stabilized
- Typical dynamic range: 200:1

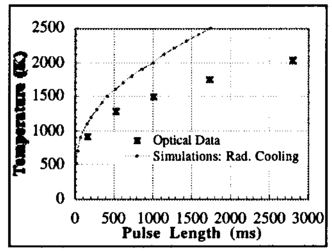




LEDA Wire-Scanner-Fiber Secondary and Thermionic Emission

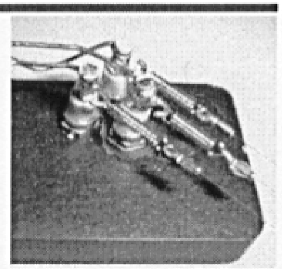
- Measured secondary emission coefficient: 3.3%
- Thermionic emission limitation (see graph)
  - Distorts profile core distribution shape
  - Two SiC fiber robustness tests performed
- Positioned fiber in beam core, varied pulse length
  - Acquired optical spectrometer data, 450- to 750-nm
  - Initial conclusion: fibers more robust than expected
    - 1st test: fiber severed at 25 ms
  - Some indication outer jacket dislodged at 4 ms
    - 2nd test: fiber severed at 2 ms
  - Optical data and thermionic-electron-data correlated
  - Optical data and simulation w/o thermionic emission bracket fiber temperature of 1575K to 2050K
- Considered ionizing radiation detection methods: 6.7-MeV protons on SiC or C barely produces sufficient γ radiation over background

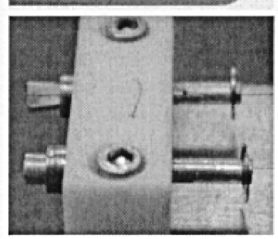




Wire Scanner Fiber Clamping Technique Improves the Reliability of the Electrical Connection and Mechanical Fiber Support

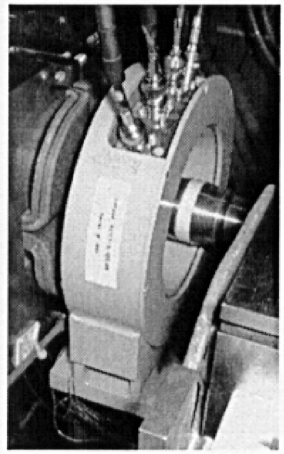
- Mechanically support the wire and keep it under tension during motion and thermal loading.
  - Two techniques used at LANSCE and LEDA
  - SiC/C fiber: drawn-Cu tube crimped clamp (see picture)
  - C fiber: plated, no spring, soldered pad
- Why develop new design?
  - Older design difficult to attach.
  - Time consuming process to assemble connections.
  - Requires the exact length of wire.
  - We need to be able to hold a smaller diameter fiber.
- New collet based clamp advantages
  - Easier/quicker to attach wire.
  - Allows use of a smaller-diameter wire.
  - Doesn't require the exact length of wire.
  - Spring is not in the signal circuit





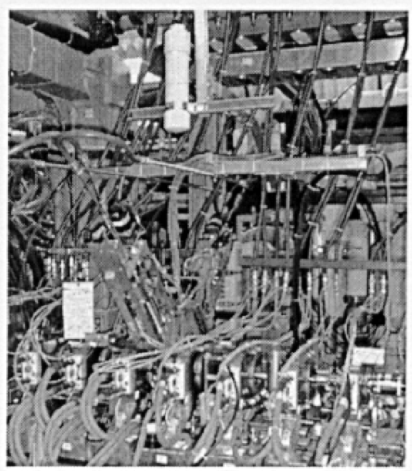
Beam Current Measurements

- Single high-permeability toroidal-core from Bergoz provides pulsed current measurements
  - Multi-turn secondary winding measures peak macro-pulse beam current
    - Electronics preamplifier reduces L/R time constant of secondary winding
  - Extra in-situ 10-T winding provides a calibration current pulse
  - Iron magnet shield isolates core from external magnetic fields.
- Typical error < 0.5 mA
- Bandwidth: <10 Hz to > 200 kHz



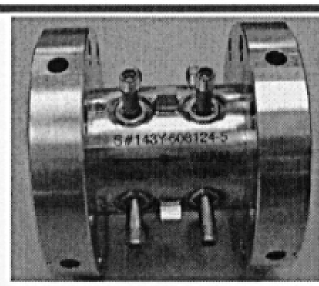
Beam Loss Measurements

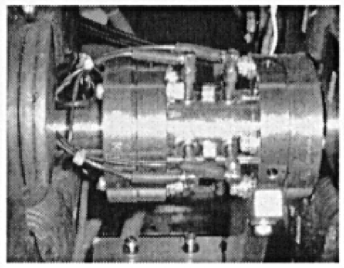
- 5 located in FODO lattice and 2 located in HEBT
- 2 Types: differential current and ionizing radiation
- Differential current
  - 2 sequential pulsed current toroids
  - DSP applies calibration and differential summation on each 2-ms sample
  - Fast protection input
- The PMT/ CsI loss monitors also provide fast protection inputs.
- PMT w/ CsI resolution: 1 nA
  - Based on previous measurement 10^5 better resolution w/ 6.7-MeV protons on SiC
  - Bandwidth: 170 kHz
    - Sufficiently fast to see 1 μs variations



Beam Position: Traditional Micro-stripline Design

- Steering plan: several possibilities
  - Primary plan uses position information from 2 BPMs (72 deg phase advance between pairs) for every 10 magnets
- In the 52-magnet lattice
  - 14-mm radius, 45 deg subtended angle, 50-mm long
  - Qty: 5 pairs or 10 total
  - Wire measurement: 2.17 dB/mm
- In the H EBT (Qty: 3)
  - 25-mm radius, 45 deg subtended angle, 50-mm long
    - Wire measurement: 1.39 dB/mm
- In front of the beam stop (Qty: 2)
  - 75 mm radius, 45 deg subtended angle, 50-mm long
    - Wire measurement: 0.44 dB/mm





BPM Processor Operation

- Log ratio processor uses DSP for real time correction of
  - AD 8307 log amp logarithmic non-conformity (shown below)
  - Losses in cables and BPM
- Dynamic range: Should be > 60 dB within ±0.1 dB, (former version, left)
  - Approximately 1000:1 in current
- Resolution: <50 μm
  - 2.17 dB/mm BPM (2.8-cm aperture)
- Repeatability: <100 μm
- Bandwidth: 200 kHz