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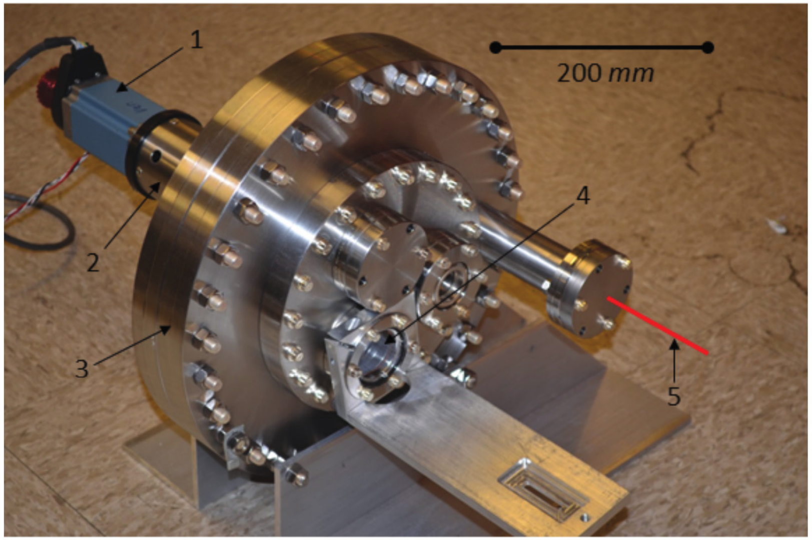

A Fast Rotating Wire Scanner
for use in High Current Accelerators

Steven Full

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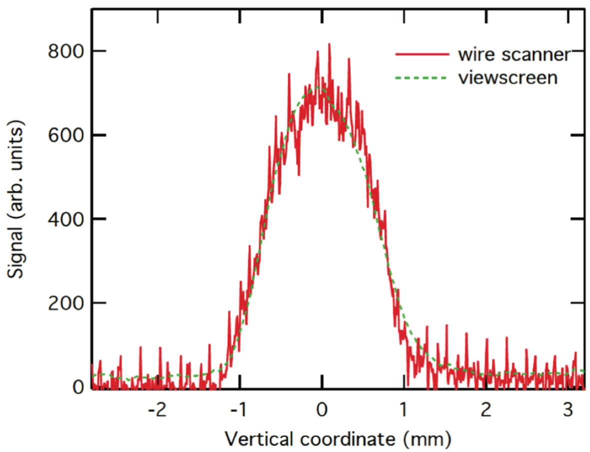
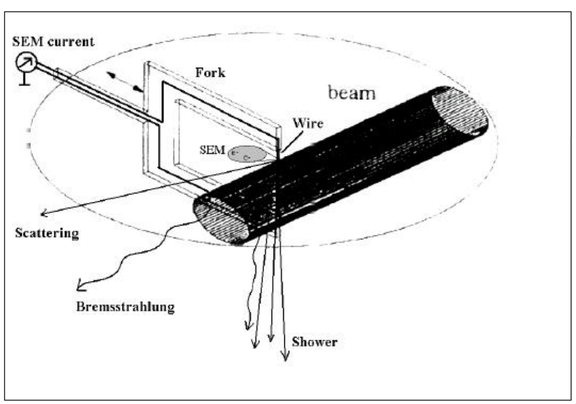
A wire scanner is a diagnostic used to measure **transverse beam profiles.**



A typical measurement



A typical measurement scheme:

1) Intercept the beam with a wire
2) Scattered x-rays (or sometimes other particles) are generated when the beam hits the wire.
3) Measure the signal, usually with a scintillator + a photomultiplier combination.
4) The signal directly corresponds to the beam's profile.

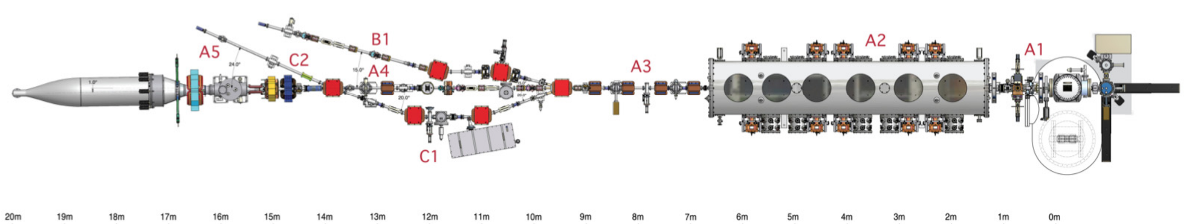
Wire acceleration methods vary, but Fork designs are the most common.

There are also more exotic designs, like laser wire scanners.

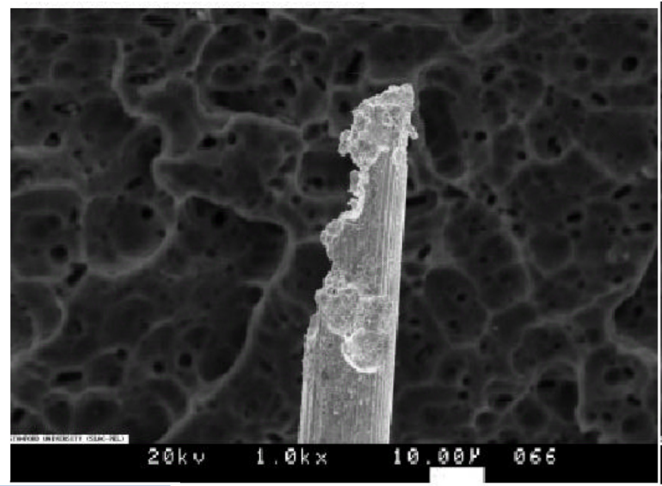
Why we wanted a wire scanner:

- Beam studies in Cornell’s high intensity photoinjector
- We have diagnostics for low beam currents
  - Ex. viewscreens, slits for emittance measurements
- Want to study beams at high current **(intense beams)**.
  - But most materials will melt
- Diagnostics must be interceptive
  - We can’t rely on synchrotron or diffraction radiat

Parameter	Used for experiments	Nominal
Beam type	Electron	“
Energy	4 MeV	10 MeV
Power	**0.5 MW**	**1 MW**
Current	**< 35 mA**	**100 mA**
Bunch Charge	< 27 pC	77 pC
Repetition rate	1.3 GHz / 50 MHz	“
Emittance	0.3 μm	< 0.3 μm
Trans. Beam Size	~ 3 mm	“



Wire scanner design goals



Main Goal:

Avoid melted wires

Requirements:

1) Wire speeds > 20 m/s (45 mph)
2) ~10 μm resolution
3) Ultra high vacuum ~ 10^{-10} torr
4) Cheap
5) Compact
6) Quick to build and implement

Most wire scanners move at mm/s or cm/s.

The wirescanner at the LHC's interaction point also operates at 20 m/s.

Why we need 20 m/s:

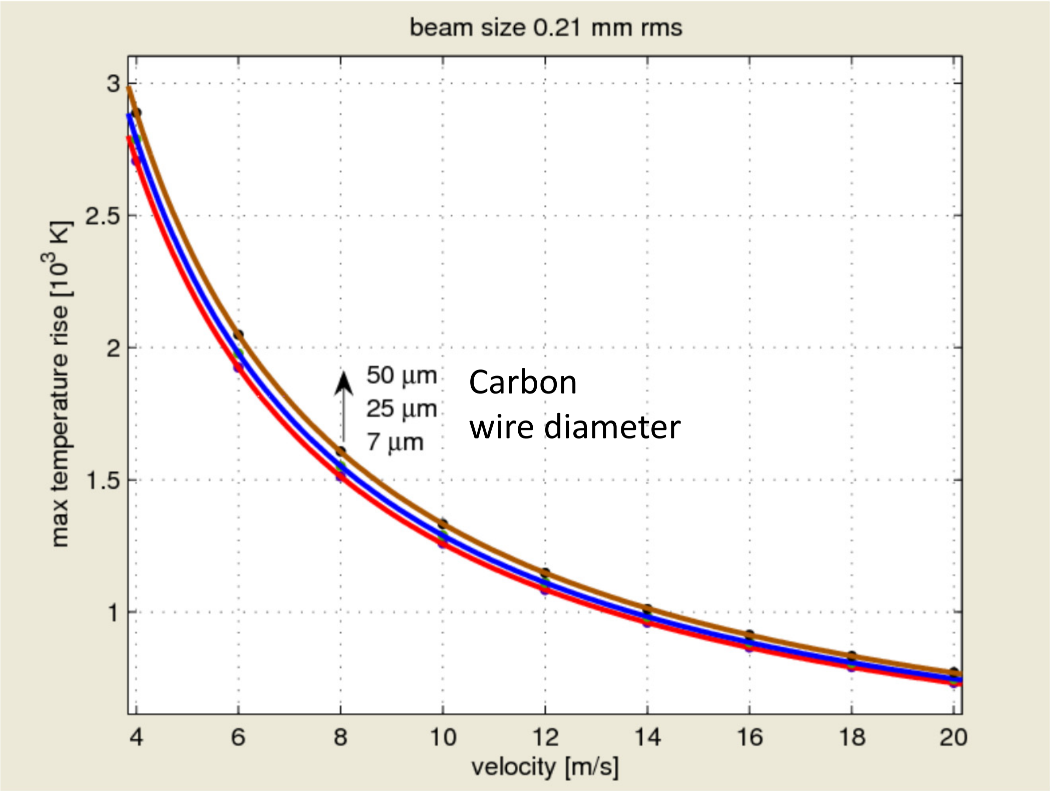
Intense beams will melt most materials in ~10 μs.

The number of electrons deposited into a wire during a single scan is the relevant parameter.

The number of deposited electrons depends on:

1) Bunch charge
2) Repetition rate
3) Transverse beam dimensions
4) Scanning time

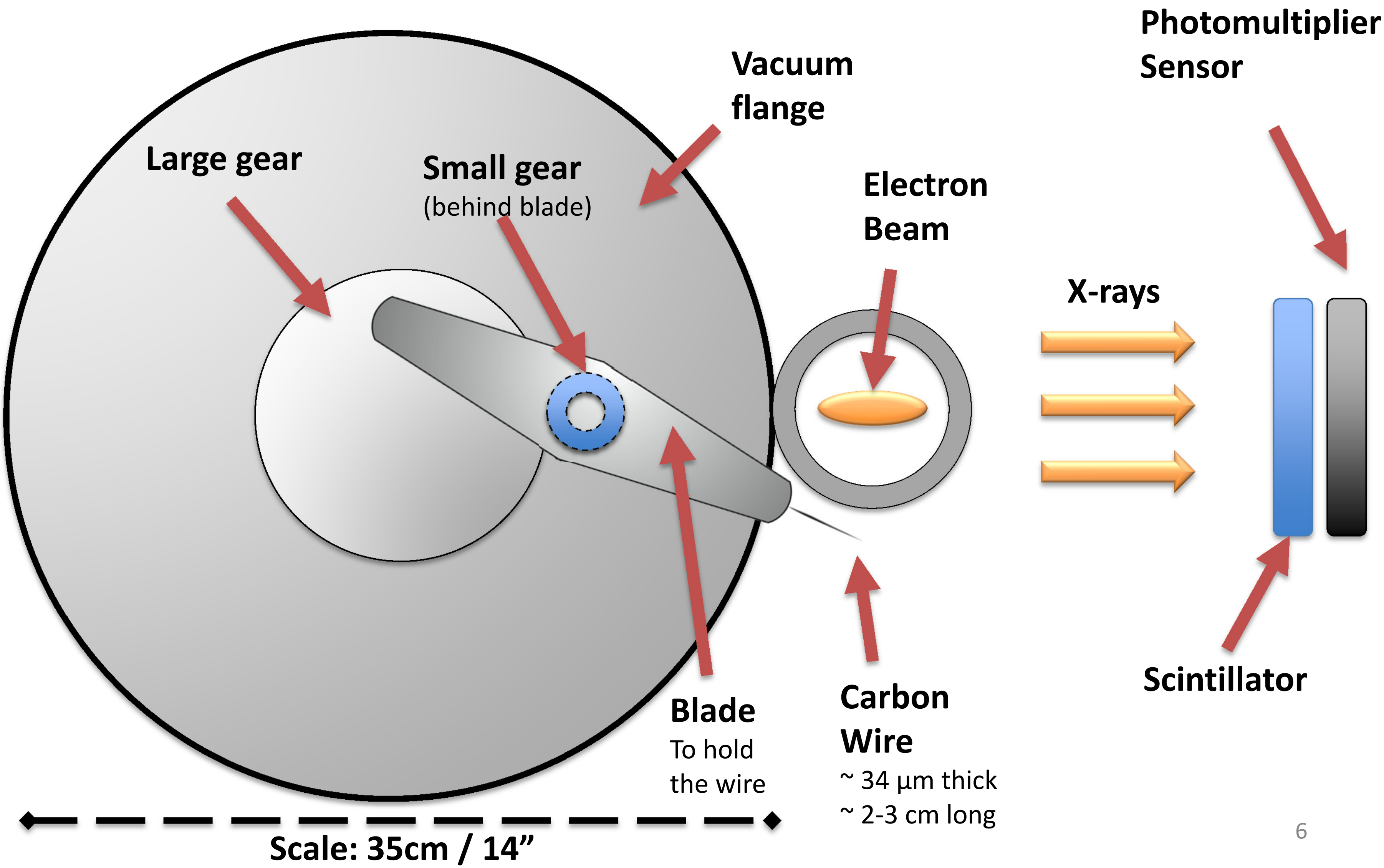
Ask yourself: Would this wire scanner design be right for your machine?

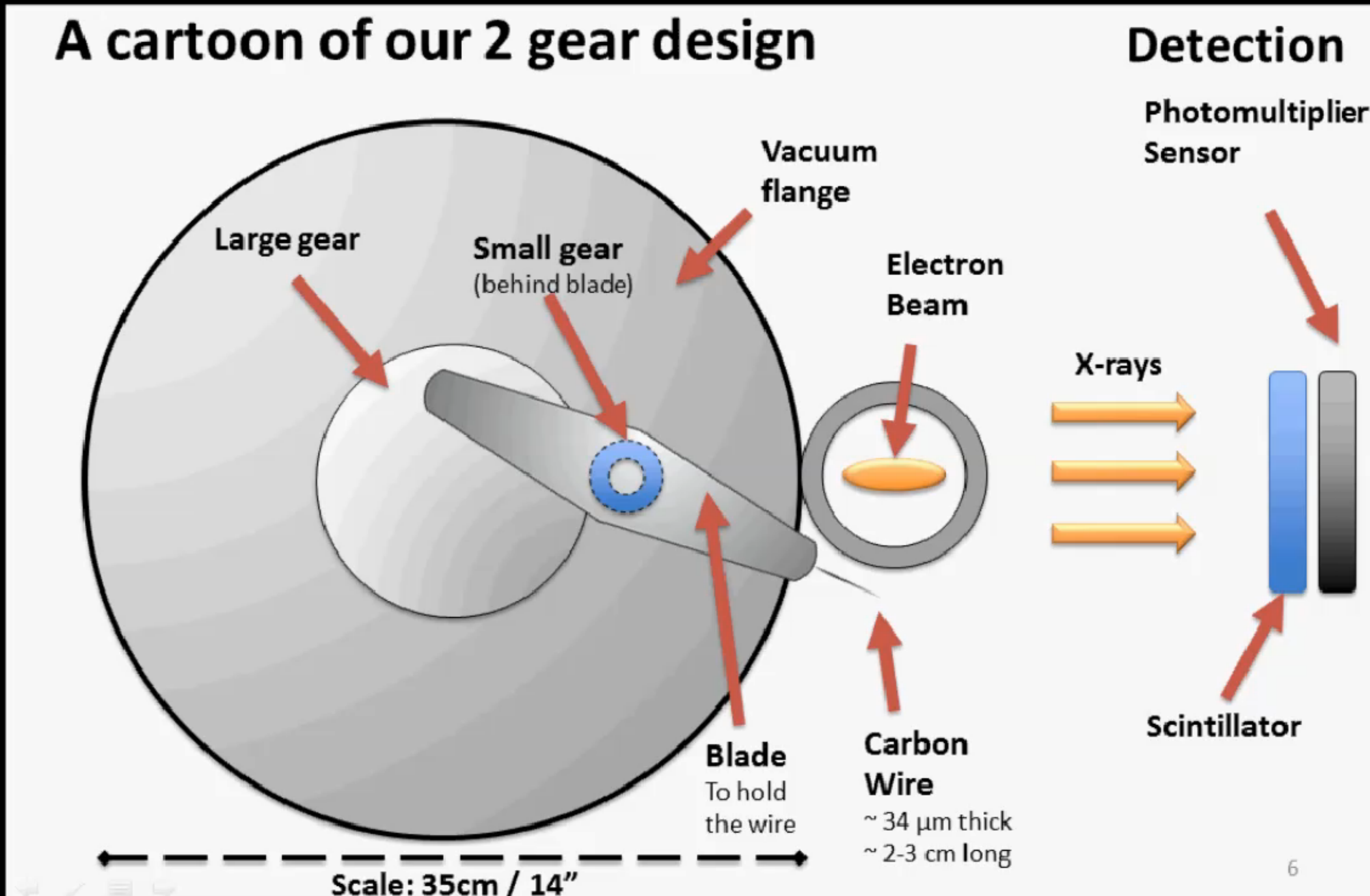


Temperature rise for a carbon wire

A cartoon of our 2 gear design

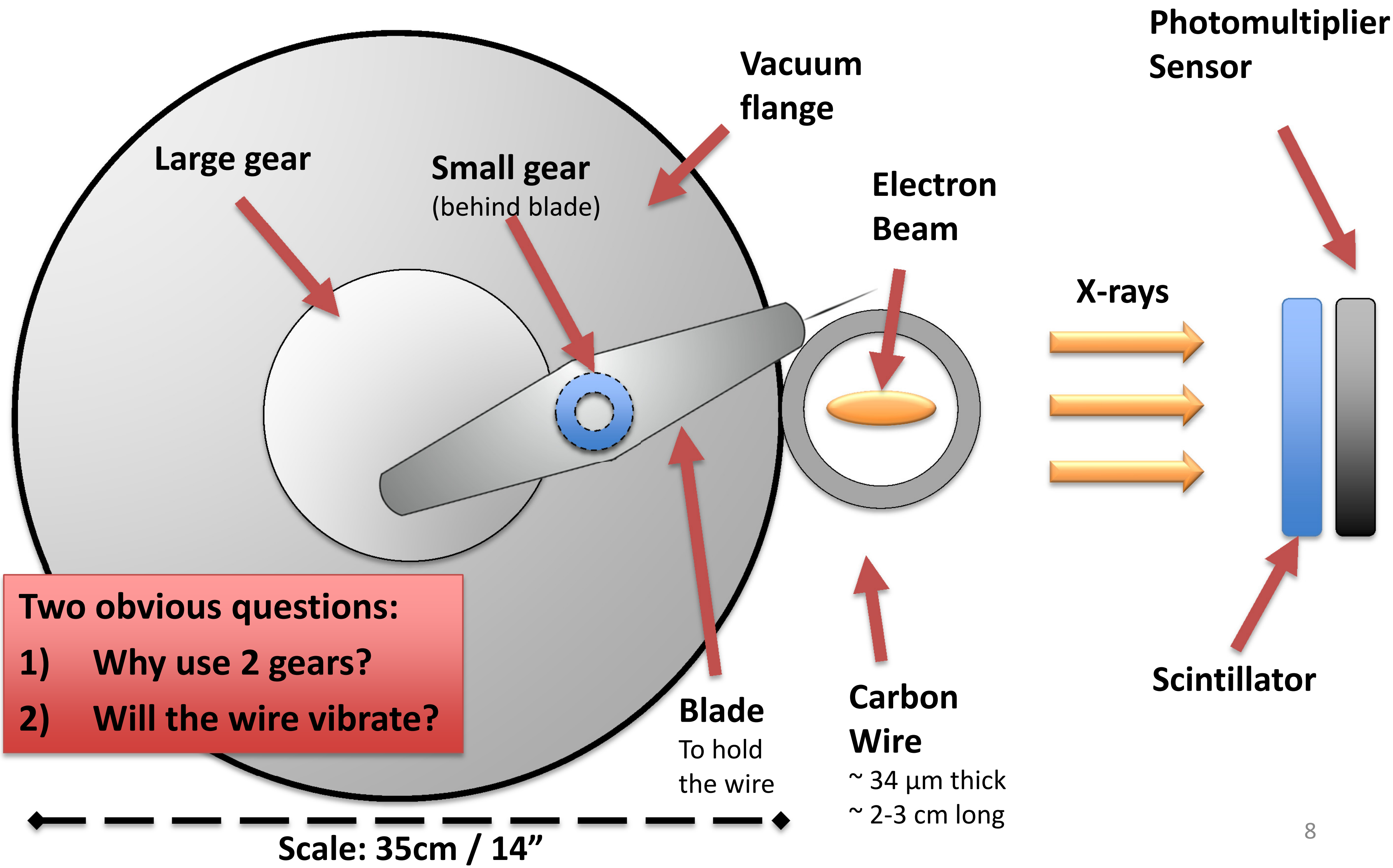
Detection




A cartoon of our 2 gear design
Detection
Photomultiplier Sensor
Vacuum flange
Large gear
Small gear
(behind blade)
Electron Beam
X-rays
Blade
To hold the wire
Carbon Wire
~ 34 µm thick
~ 2-3 cm long
Scintillator
Scale: 35cm / 14"
6

A cartoon of our 2 gear design

Detection



Two obvious questions:

1) **Why use 2 gears?**
2) **Will the wire vibrate?**

3D model of the design

Large stationary gear

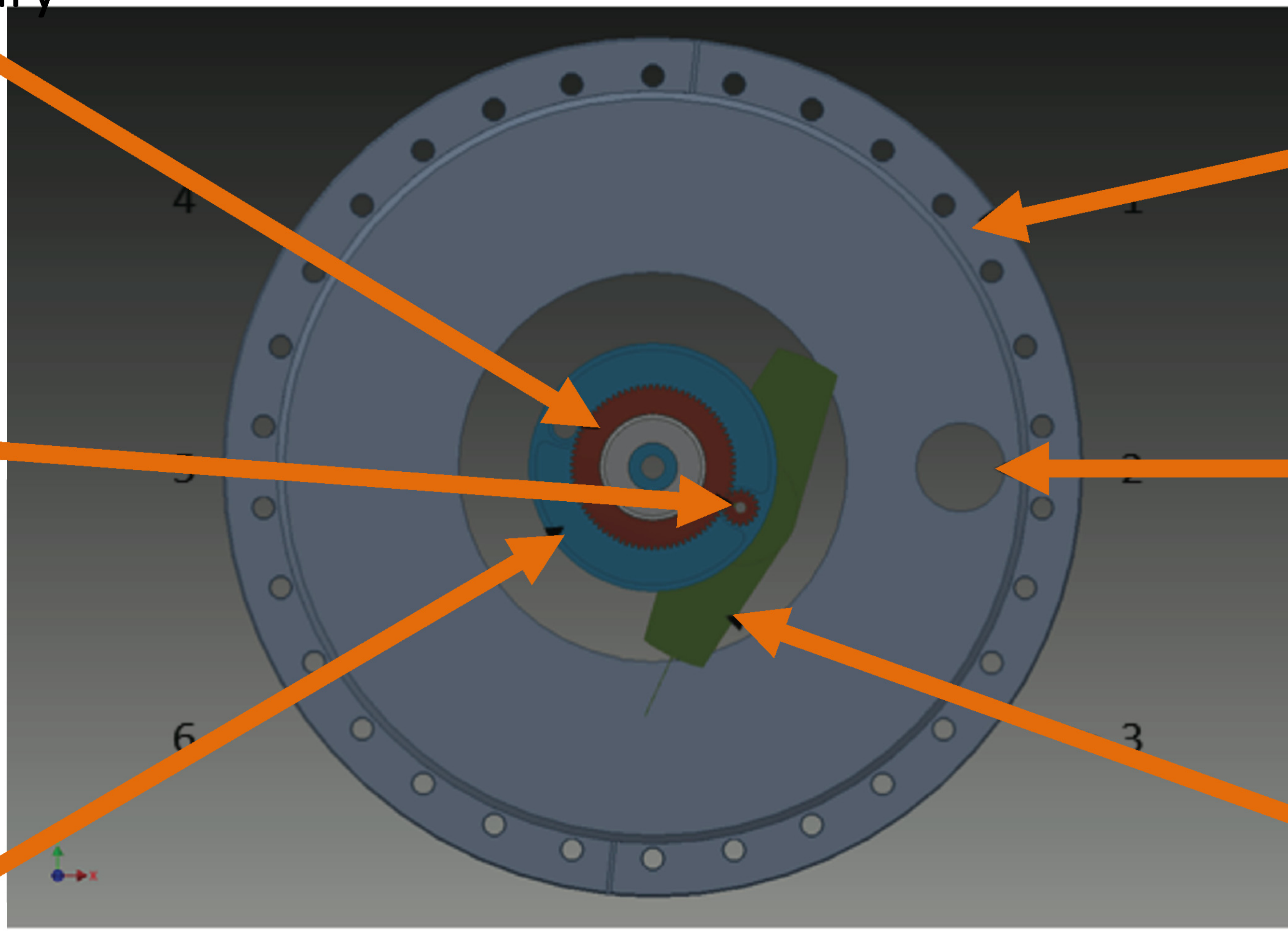
Small rotating gear

Rotating Gear box

Vacuum Flange

Beam

Blade + carbon wire attached



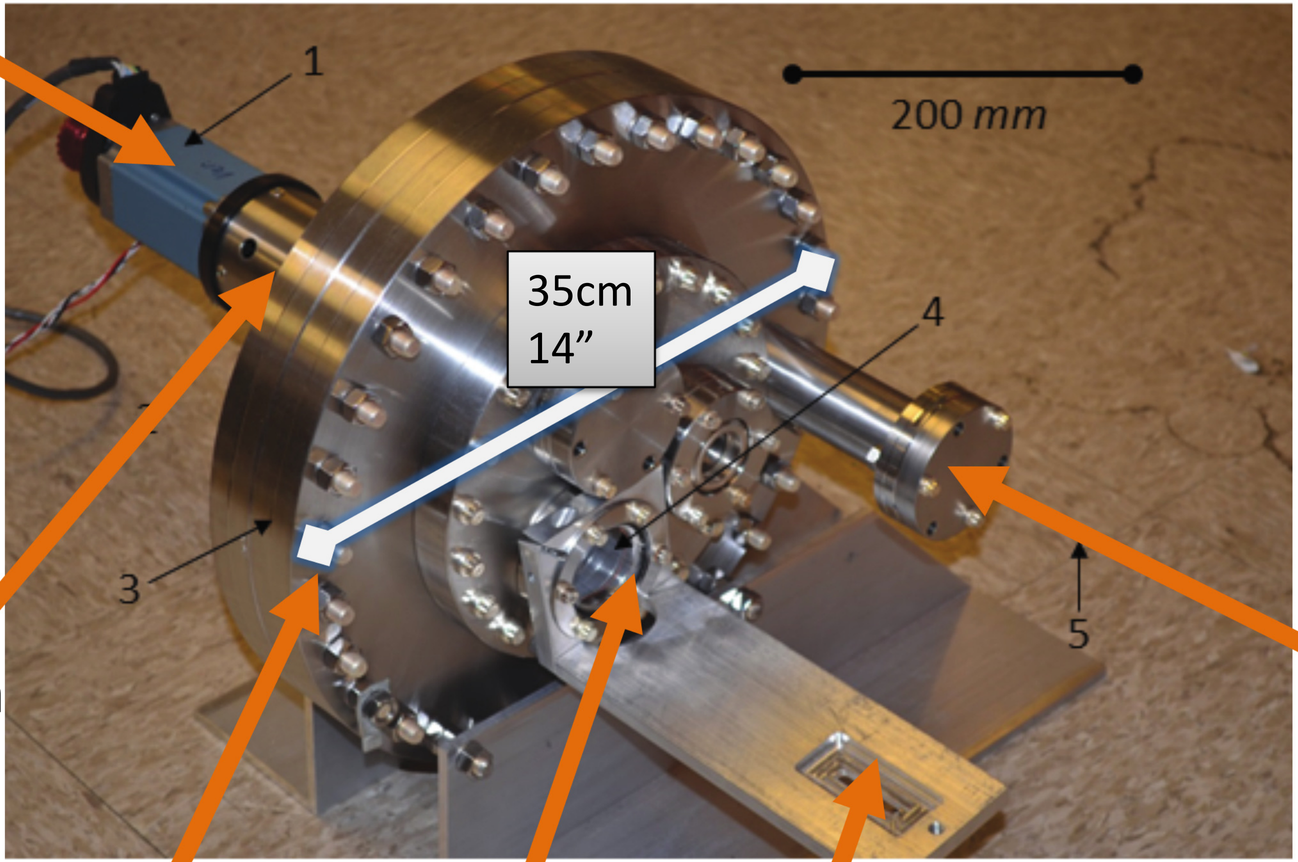
Able to be mass produced!

Only custom parts: 1) Blade 2) Rotating Gear Box

Outside view

Stepper motor

Ferrofluidic Rotary feedthrough



Beam pipe

Vacuum flanges

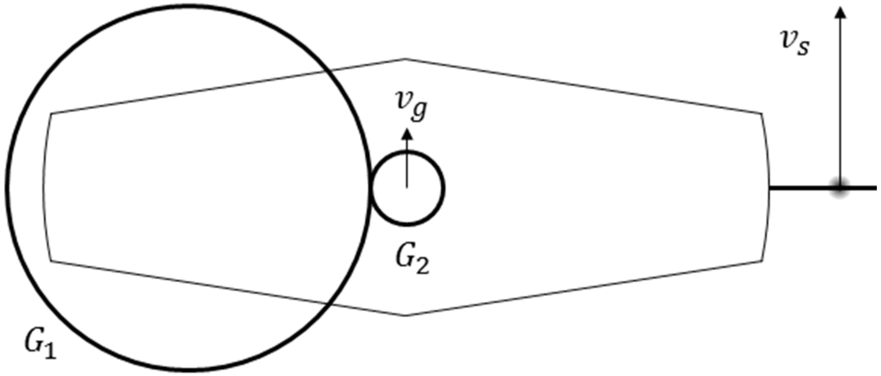
Viewports

Camera mount

Why use 2 gears?

Without a two gear design, for any wire scanner to reach 20 m/s (45 mph), you would need either:

1) More acceleration
   - Just difficult to do and expect the wire to survive
2) Larger path length
   - Size issues



A two gear design results in a significant speed boost:

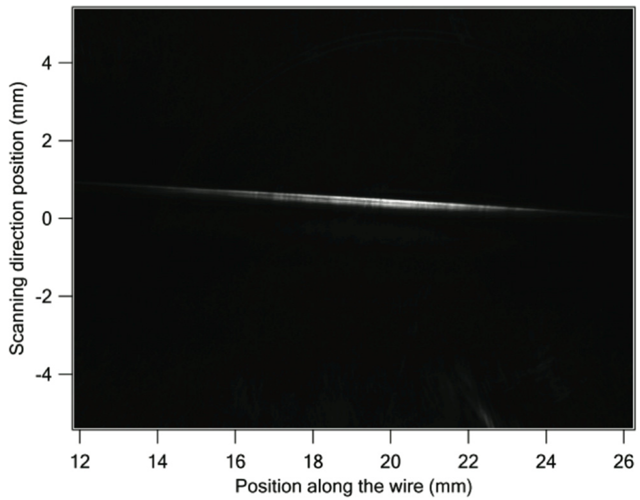
$$v_s = v_g\left(\frac{R}{R_2} + 1\right)$$

R = distance from center of blade to center of beam pipe
R2 = radius of small gear

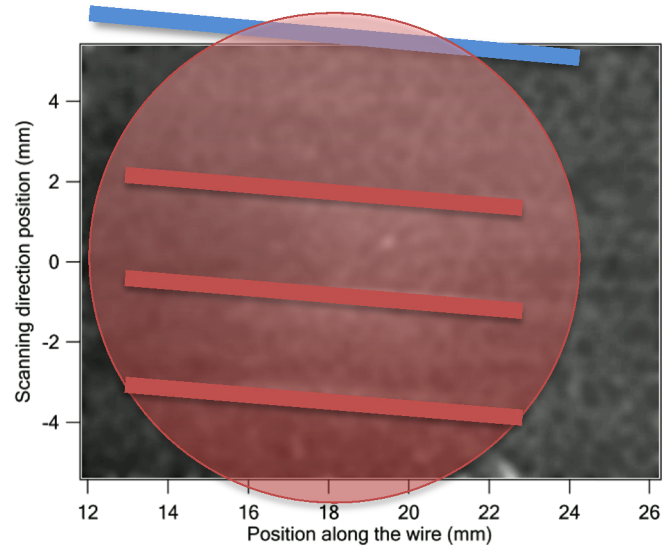
$v_s \sim 6\, v_g$

Our design is about 6x faster than a single gear design

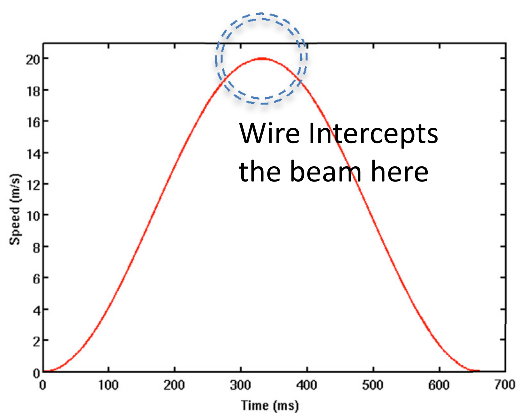
The wire doesn't "whip" around.



Stationary wire



Moving wire



The wire's velocity profile

We captured several images of the moving wire on a single camera frame, by using a modulating laser (8 KHz rep rate, 7 µs pulse duration).

Large scale vibrations are prevented because we program the motor to follow a smooth velocity profile.

Advantages of the design

- Speed > 20 m/s, and beyond
- Costs < $5000
- Mass production possible
- Compact: About 15 cm of beam pipe long, about 40 cm wide
- Gradual acceleration profile control
- Vibration isn't an issue
- Viewports for checking wire (quality of life!)
- Most importantly…

It works.

Vertical beam profile measurements taken at Cornell's ERL Photoinjector

Parameter	Used for experiments
Beam type	Electron
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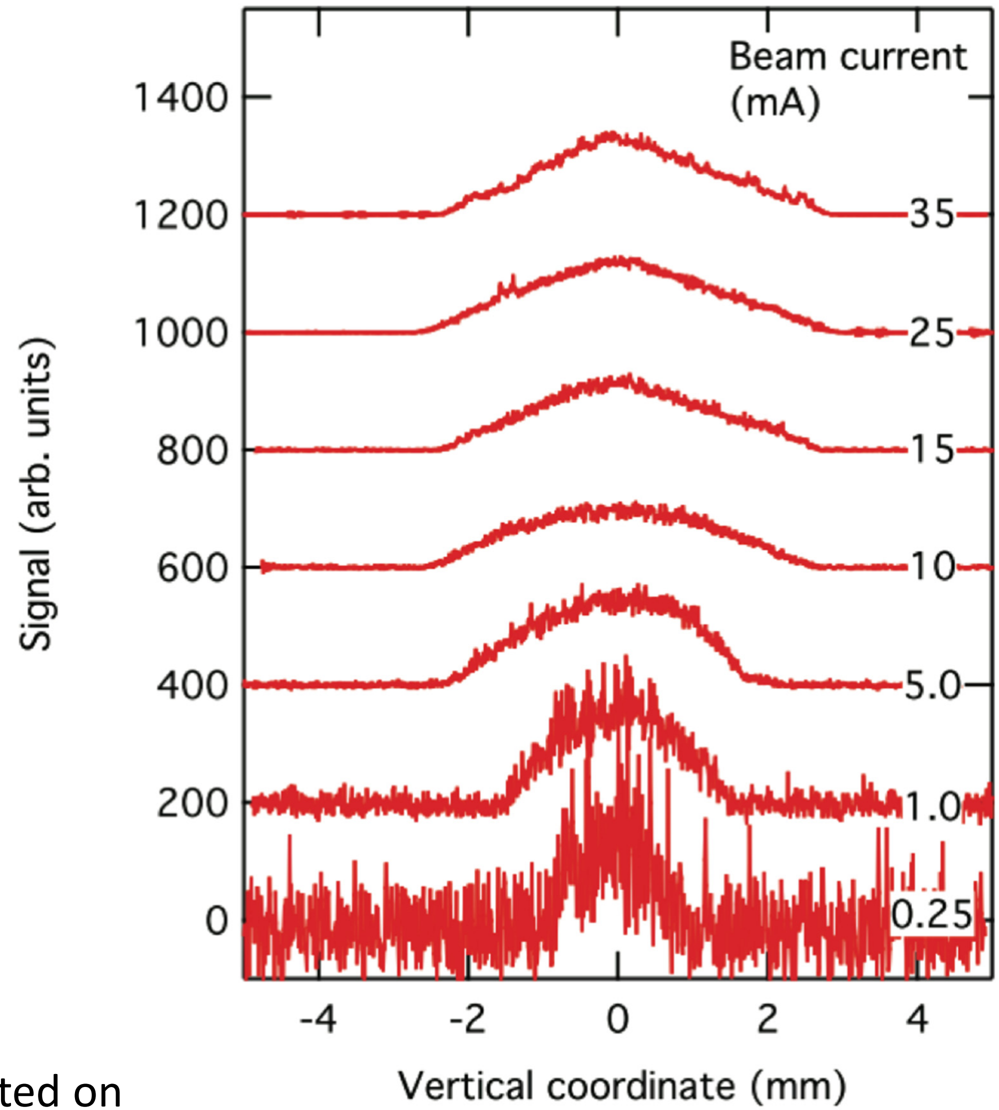
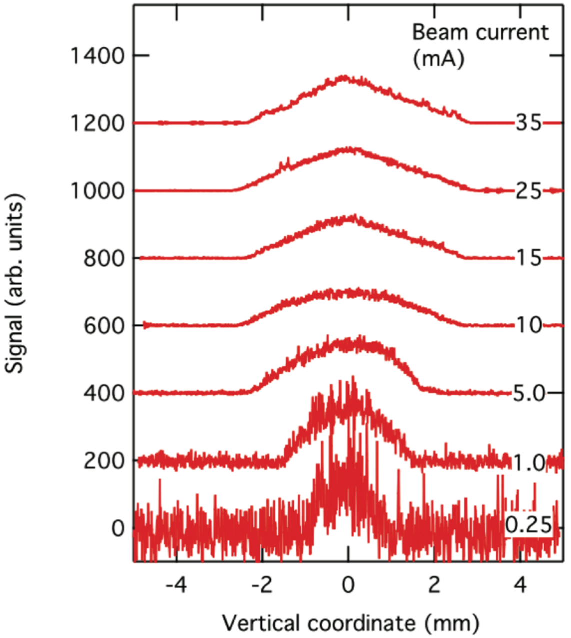


Note: Each (normalized) curve is presented on the same plot only for easy comparison.

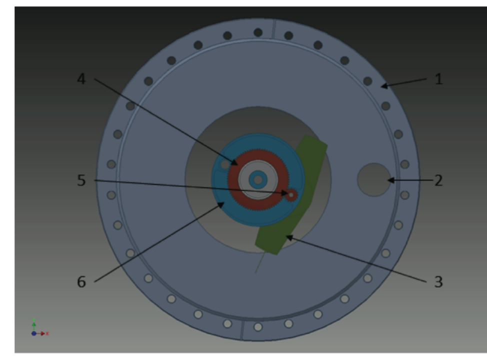
Future work

- Room for improvement
  - Increase speed by:
    - Decrease mechanical friction
    - Reduce moment of inertia
    - More robust wires
- Part upgrade wish list
  - Better rotary feedthrough
  - Servo motor
  - Commercially manufactured carbon wires
- High current beam studies
  - Unravel the mystery of the triangular beam



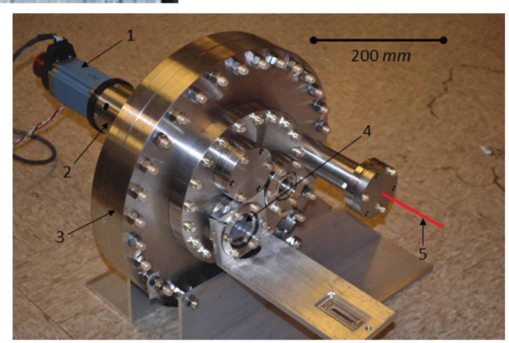
Thank you for listening!

Thanks to Tobey Moore, our vacuum technician, for inventing this great design. And reminding us to keep it simple!



Also, thanks to the rest of the Cornell team:

Nick Agladze
Ivan Bazarov
Adam Bartnik
John Dobbins
Bruce Dunham
Yulin Li
Jim Savino
Karl Smolenski



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