Pyramid

High Dose-Rate Applications

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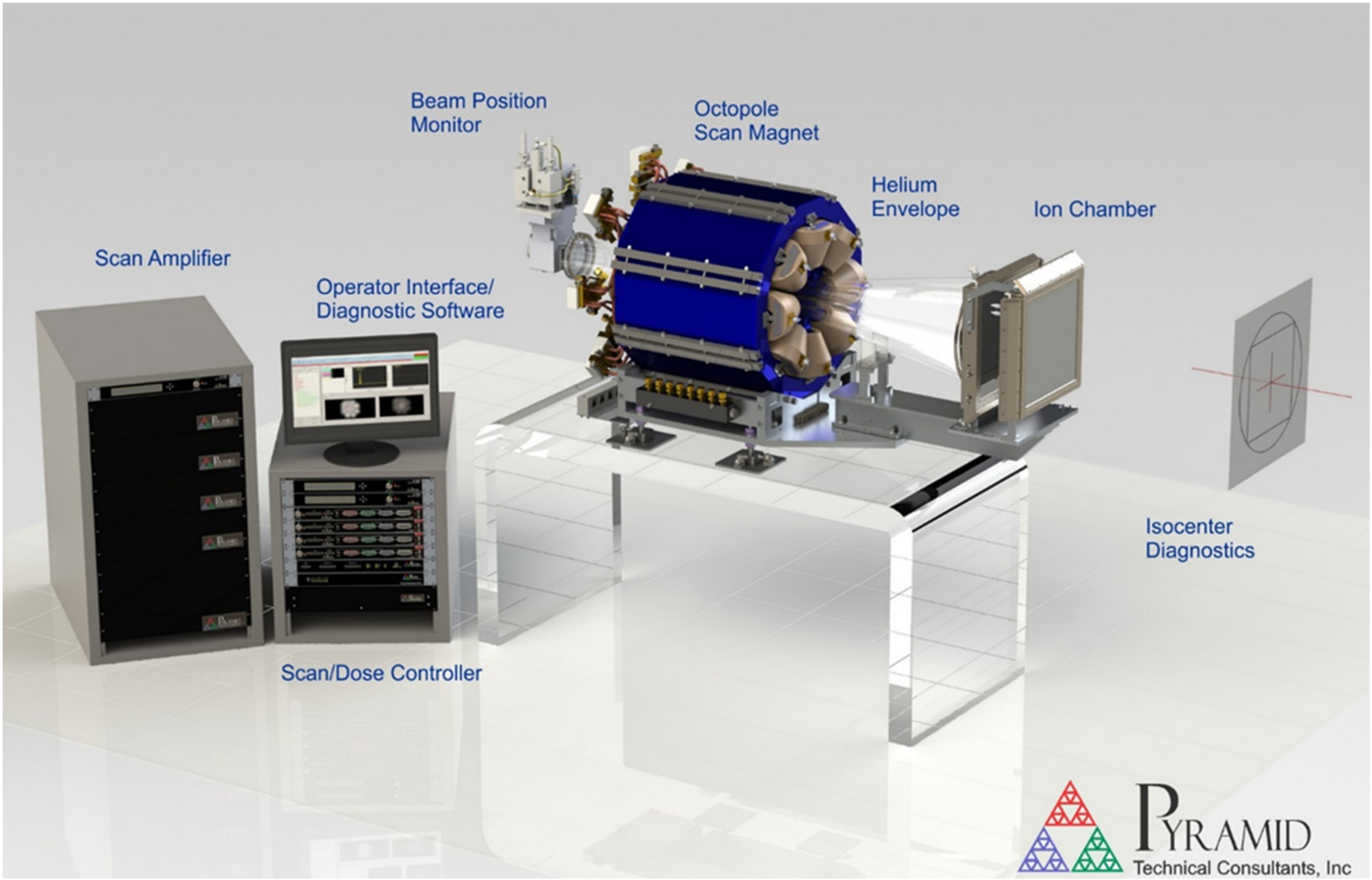
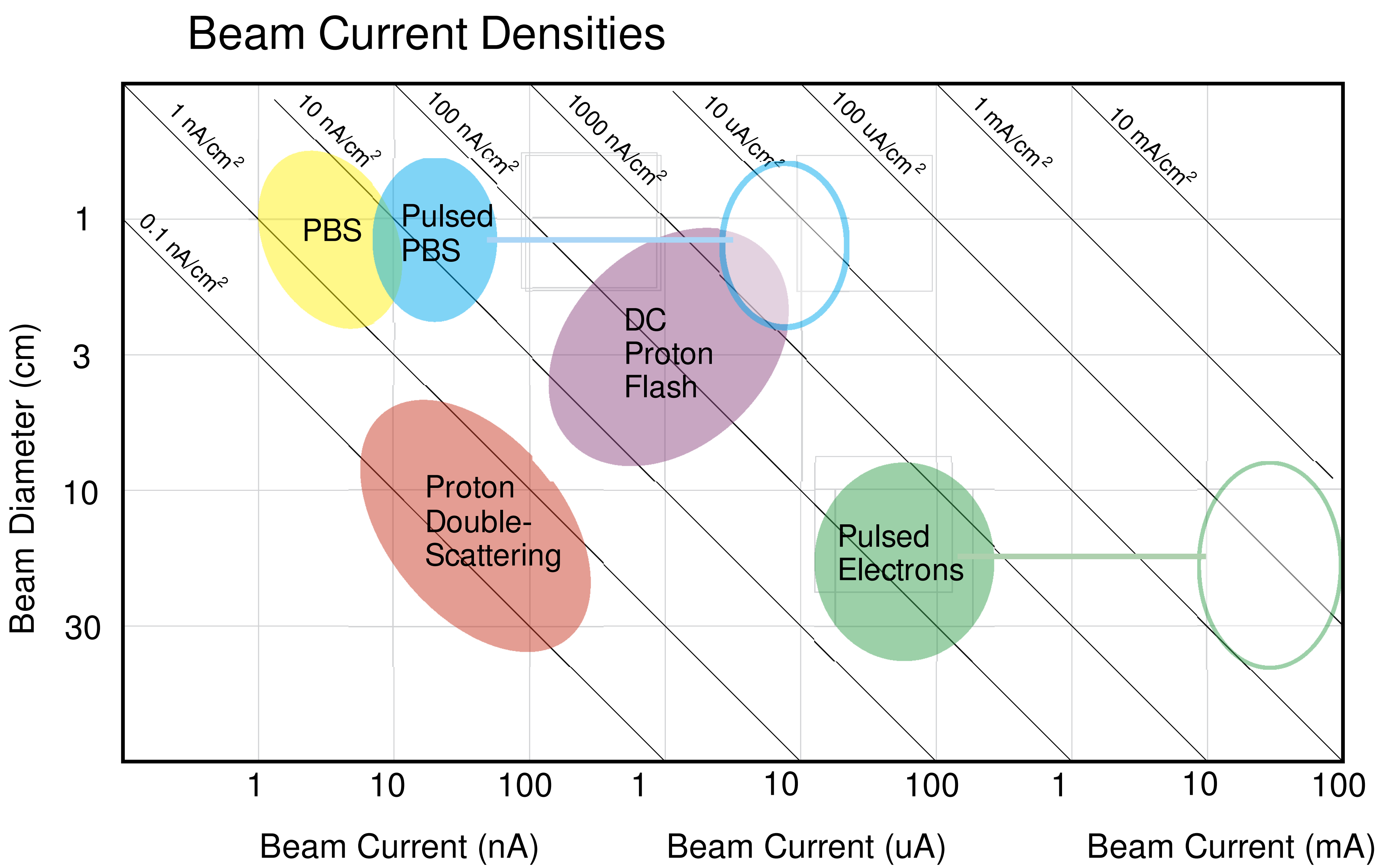
Typical Dose Delivery Components



Beam Current Densities



Beam Current Densities

For Ion chambers:

Dose Rate (Gy/s) -> Current Density (amperes/cm^2)

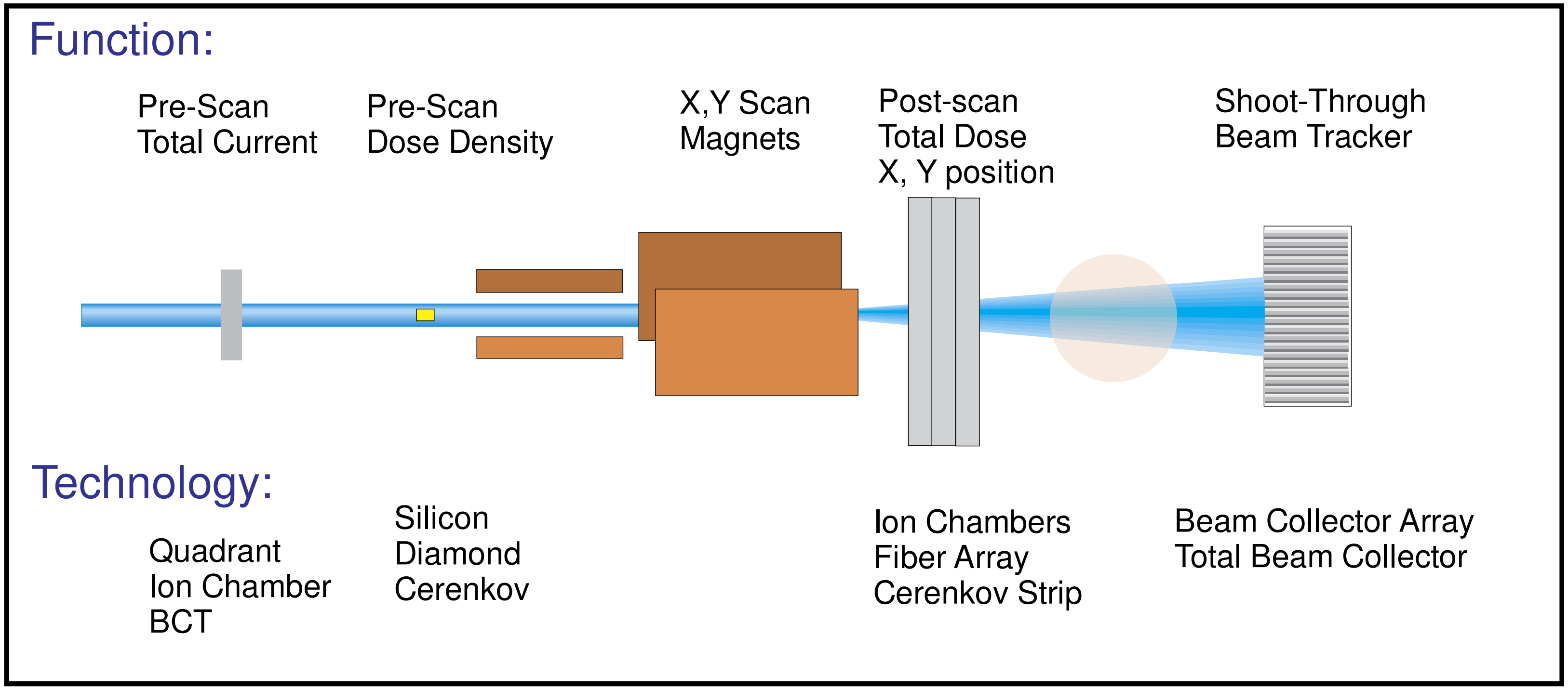
High dose rates are a problem for ion chambers

Mode	Current Density (uA/cm2)	Ion Chamber Gap (mm)	1% Dose Control Response (ms)
Double Scattering	0.1	10	1000
Pencil Beam Scanning	10	3-5	0.1 to 1
FLASH	1000+	<=1	.001

Safety is a key consideration: A 1 uA beam at 230 MeV is 230 Watts!! Beam shutdown delays need to be carefully considered

Pyramid electronics is now under development with microsecond detection and response

Typical Detector Functions

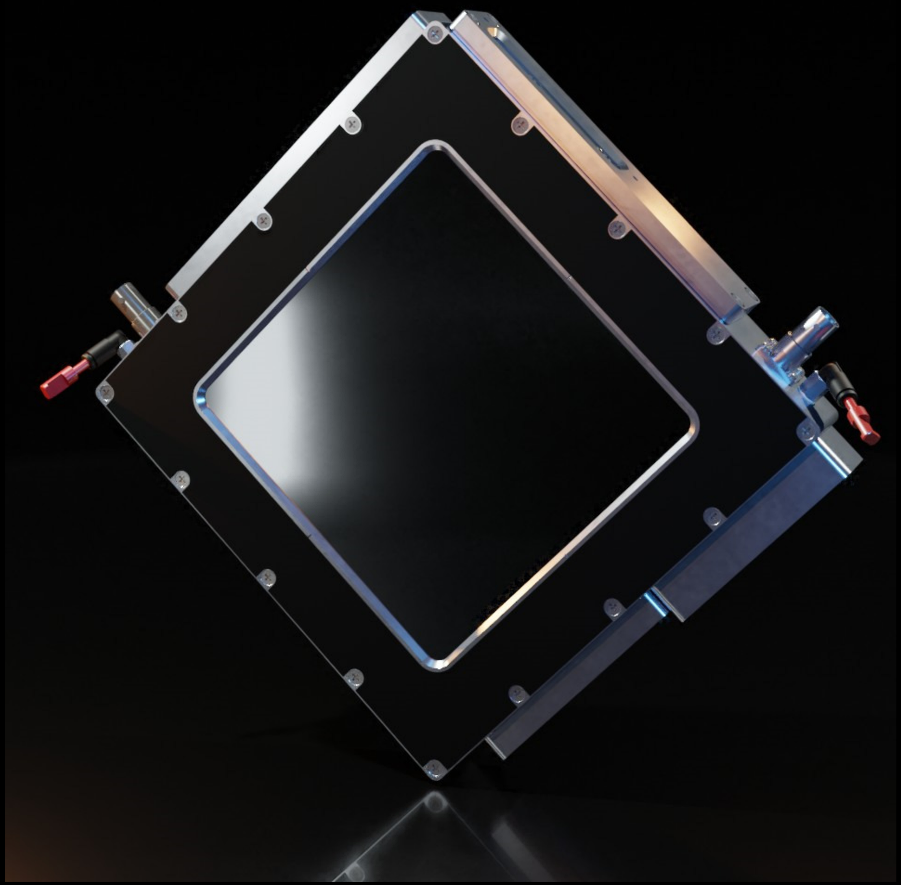


- Total fluence detector measure amps,
- Current density detector measure amps/ cm^2, suitable for broad beams that are then collimated
- Fast scan magnets needed for scanned pencil-beams
- Position-sensitive detector, suitable for verifying the position of scanned beams, overall position and size of broad beams
- Total beam current detector, measuring the beam intensity independent of position
- Beam collector, suitable for direct measurement of total beam current. Useful for diagnostics, or beam measurement when the beam passes through the subject.

Transmission Ion Chambers

These detectors measure beam though gas ionization

- Protons, electrons, heavy ions, photons
- Linear below a current density limit
- Minimal effect on the beam
- Measures total dose, beam position and shape
- High precision tensioned films for stability and accuracy
- Signals are at ground, simplifies electronics



IC64-6 Small flash IC

- 6x6 centimeter active area
- 2x1 mm gas layer for extended current density
- Radiation resistant to 10^8 Gy
- Dedicated dose plane
- 64 strip x 64 strip position electrodes
- WET of 100 microns

Transmission Ion Chambers

IC64-16 FLASH IC for scanned beams

- 16x16 centimeter active area
- 2x1 mm gas layer for extended current density
- Radiation resistant to 10^8 Gy
- Dedicated dose plane
- 64 strip x 64 strip position electrodes

Beam Collector

These detectors measure beam currents directly

- Protons, electrons, heavy ions
- Highly linear
- Capable of very high currents and current densities
- Capable of sub-microsecond time resolution

B. Gottschalk
E. Cascio

BC145

- 145 mm diameter
- Up to 250 MeV Protons
- Pure copper core

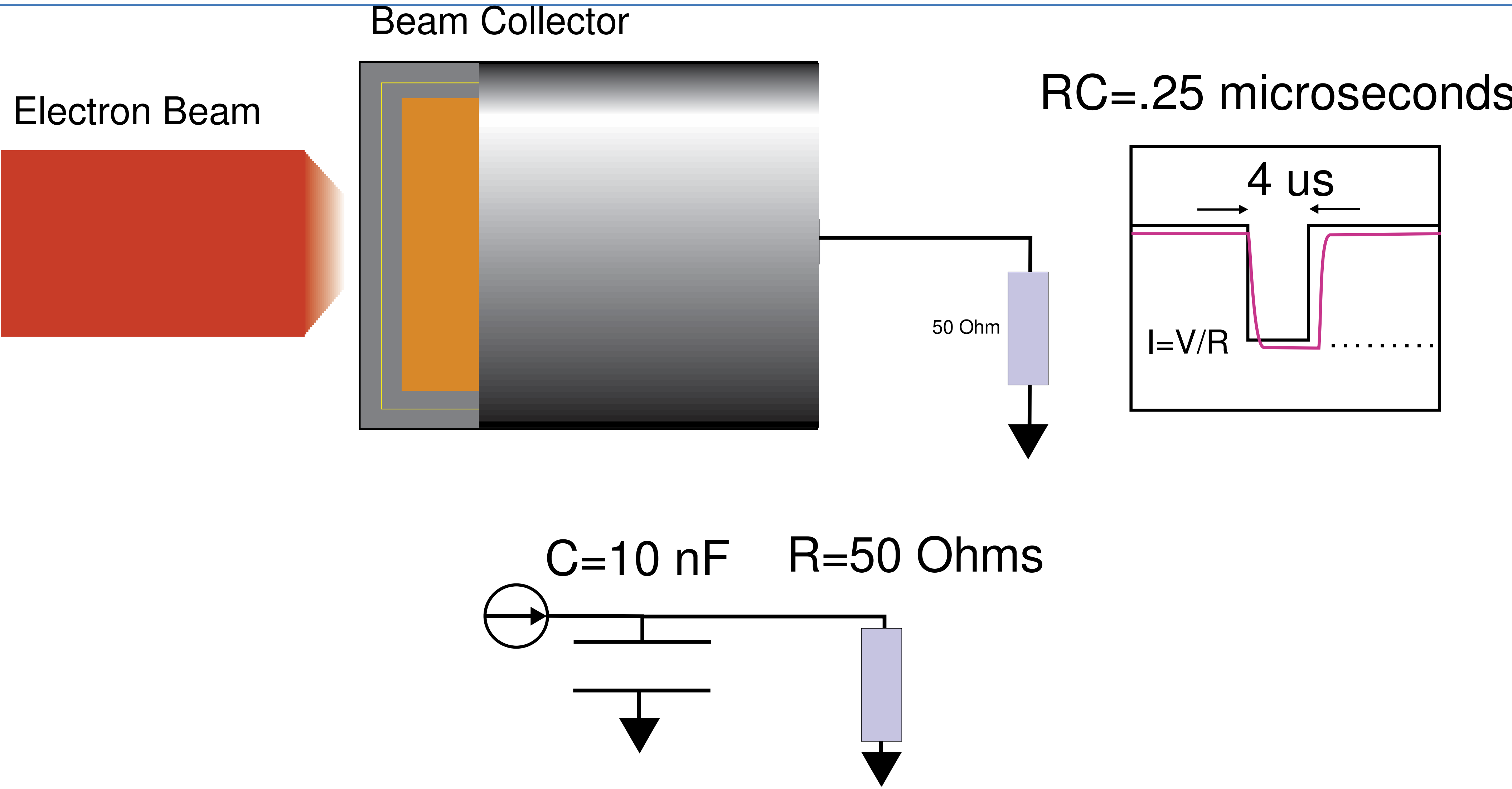
BC75

- 75 mm diameter
- 10-250 MeV Protons
- Pure copper core

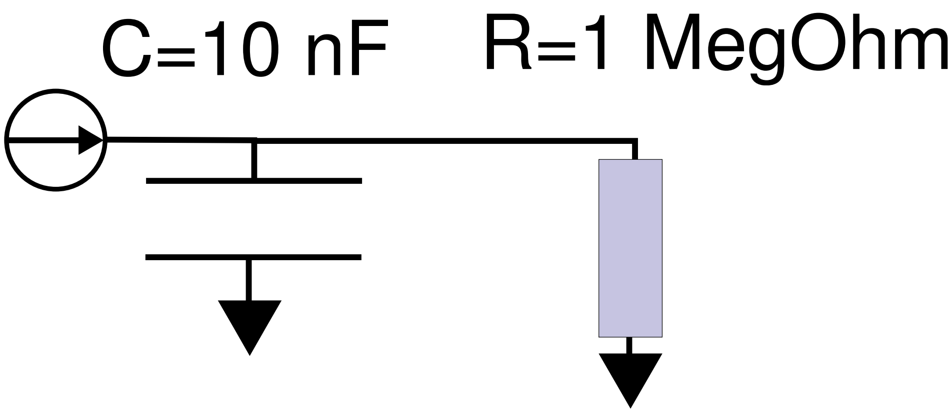
BC145e

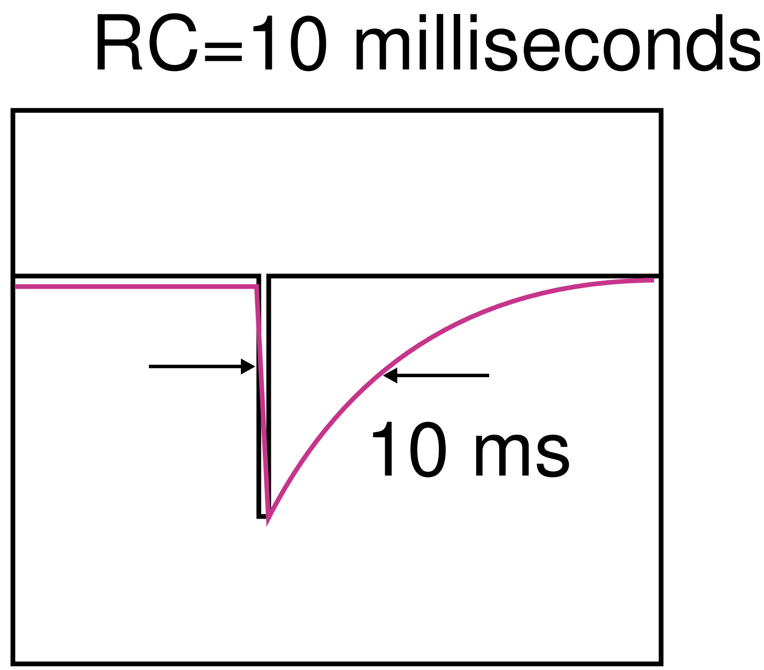
- 145 mm diameter
- Up to 50 MeV Electrons
- Aluminum Core

Beam Collector



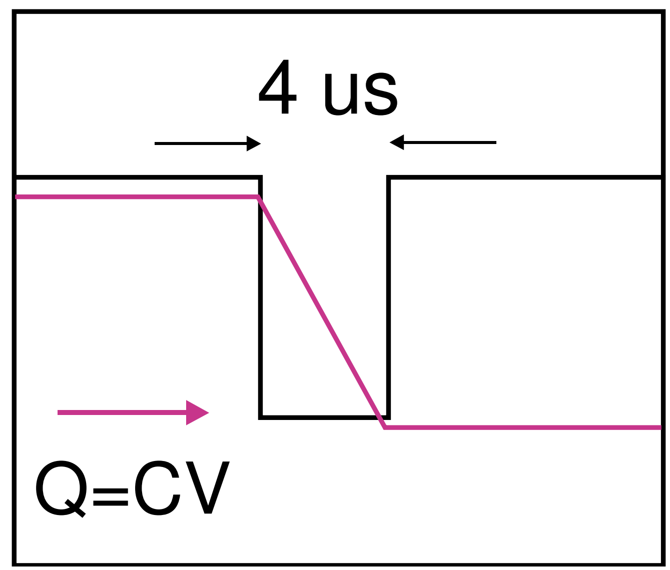
Beam Collector





We use specialized amplifiers to handle very low currents, where a direct connection won’t work.

Amplifier/processor modules can use the BC to do active dose control.



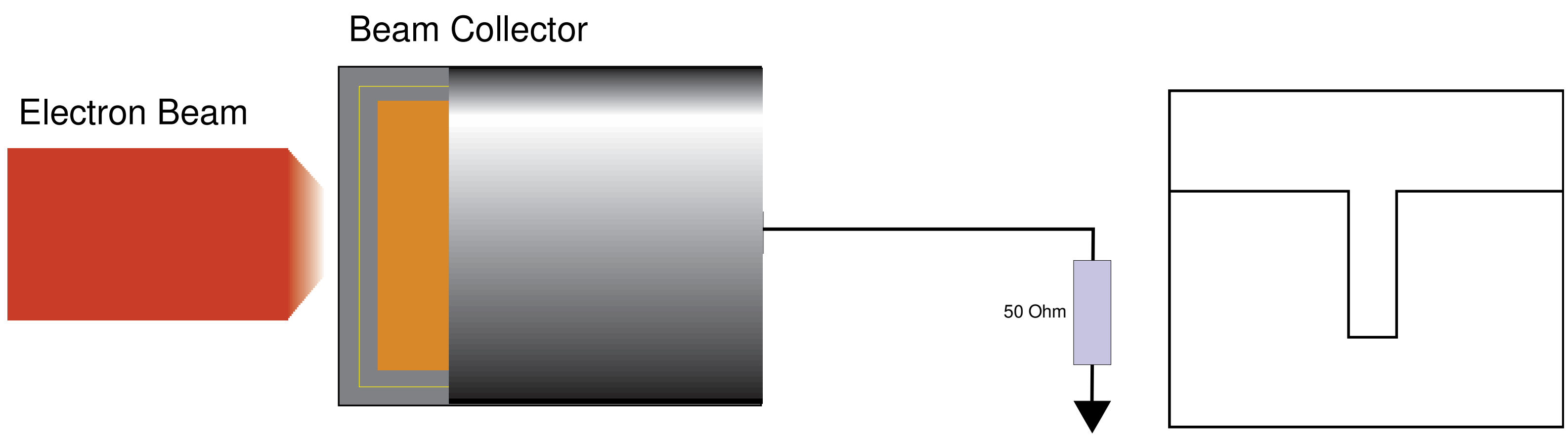
Visit to Dartmouth

Jennifer Wei Zou, UPenn
Rongxiao Zhang,Dartmouth

Beam Collector terminated at 50 Ohms:

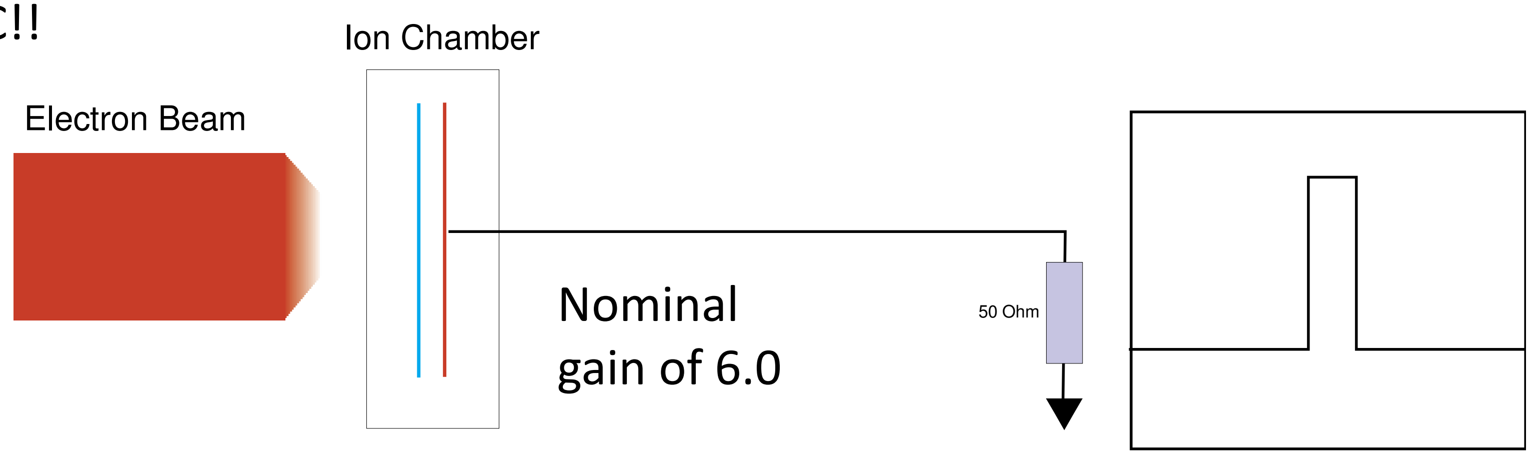
- Accurate pulse structure with microsecond resolution

10 MeV pulsed electron beam
100 mA, 4 us
Current density 1-10 mA/cm^2



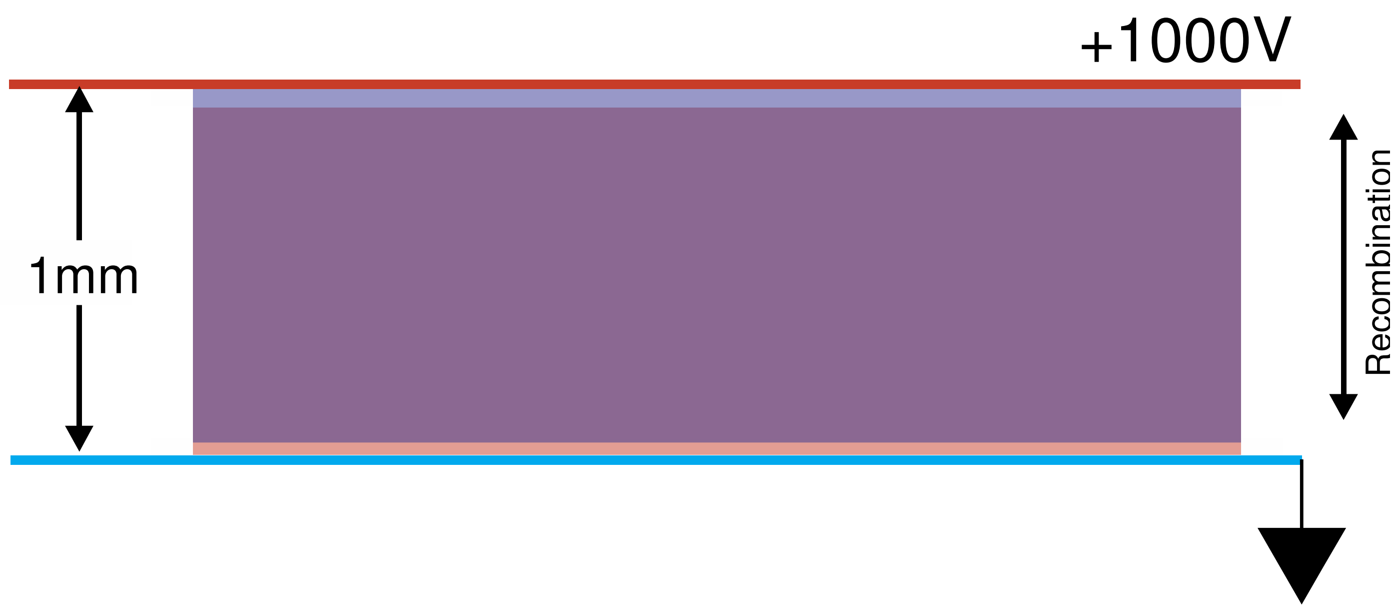
Ion Chamber terminated at 50 Ohms:

- Current density > 1 mA/cm^2 far beyond design specs.
- Still generated a pulse time structure very close to the BC!!



Highly Recombined Ion Chamber

- 1 mm gas layer would have a gain of about 6 at low current densities
- At 1 mA/cm^2 mean-free path for recombination is reduced, but not zero
- Suggestion: very thin layers near the electrodes contribute, giving a lowered gain
- Result would be nonlinear, but can be corrected when combined with positional electrodes
- More research to be done, but this could mean that beam shape and position is a tractable measurement at very high current densities.

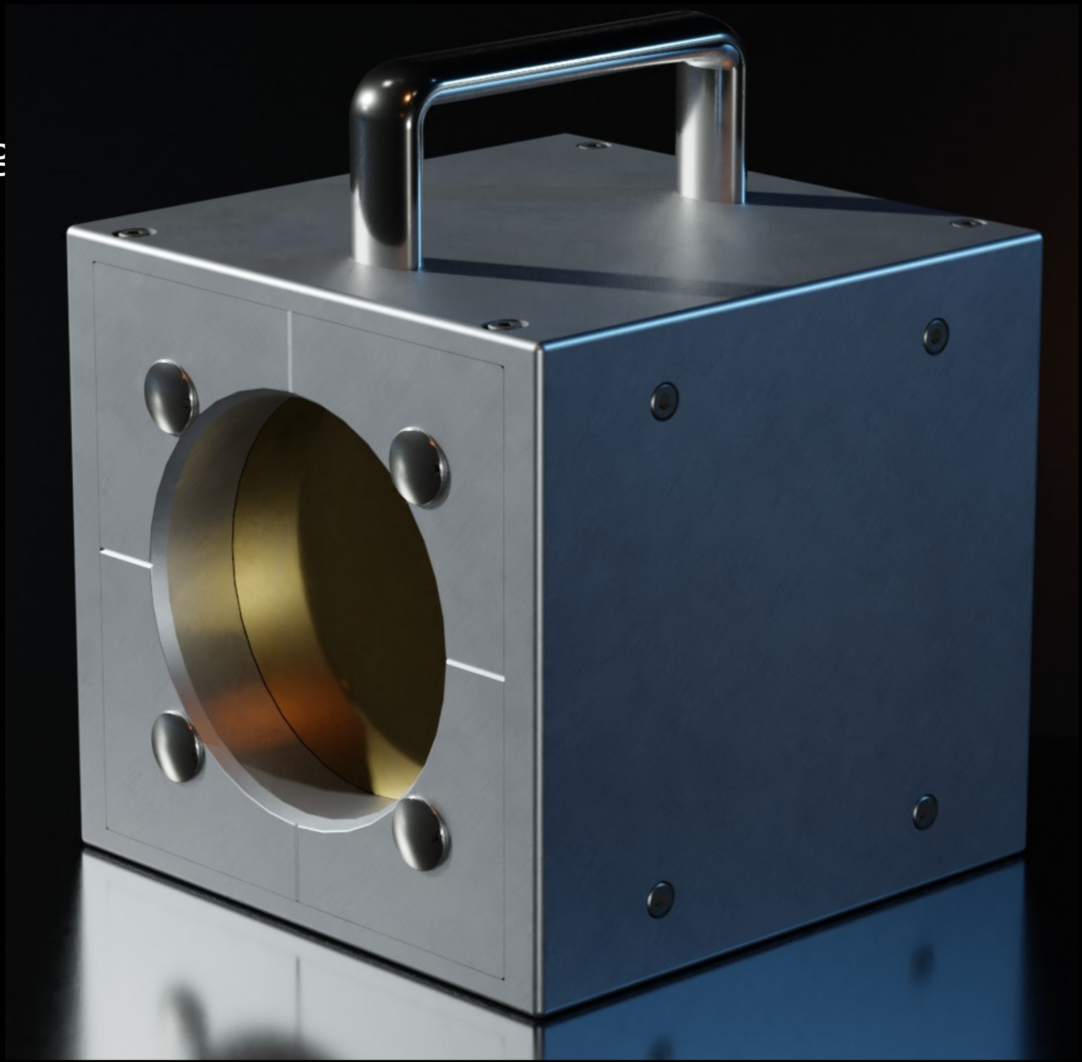


Multilevel Faraday

128 Layer beam collector for determining the range of a charged particle beam

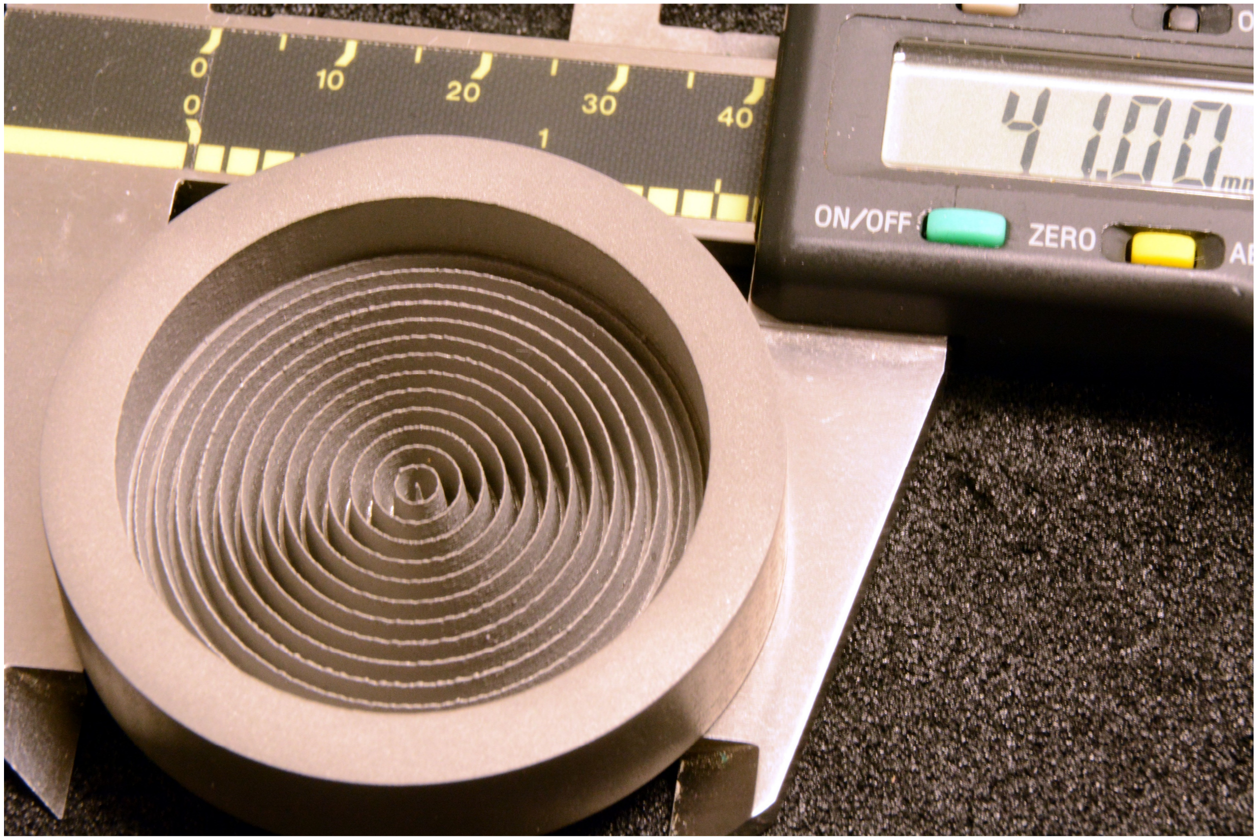
- Can operate at high currents
- Can operate at high current densities
- Large-area versions are in the future, can be combined with a position-sensitive detector.
- 30, 60, 250 MeV versions

B. Gottschalk



Structured Range Modulator

- 41mm sphere with a single energy layer (90 MeV)
- Pencil-Beam scanning is required to create uniform dose.
- A single-energy scan can be done in < 80 ms.
- Stainless Steel: Low-profile structure



MLFC can be used to track precise range distributions as a function of beam position, verifying the volumetric distribution.

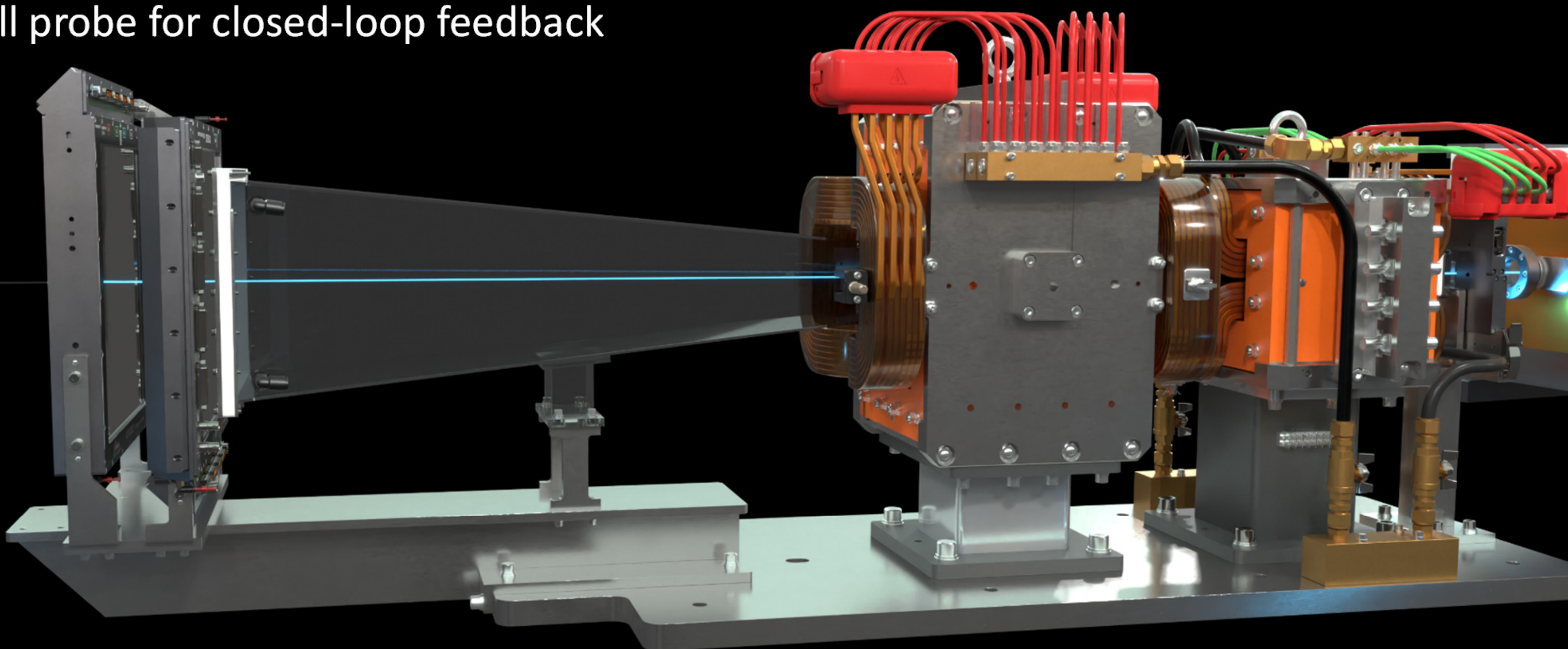
End

Thanks to all of our research partners, and to the support of McLaren Health Care.

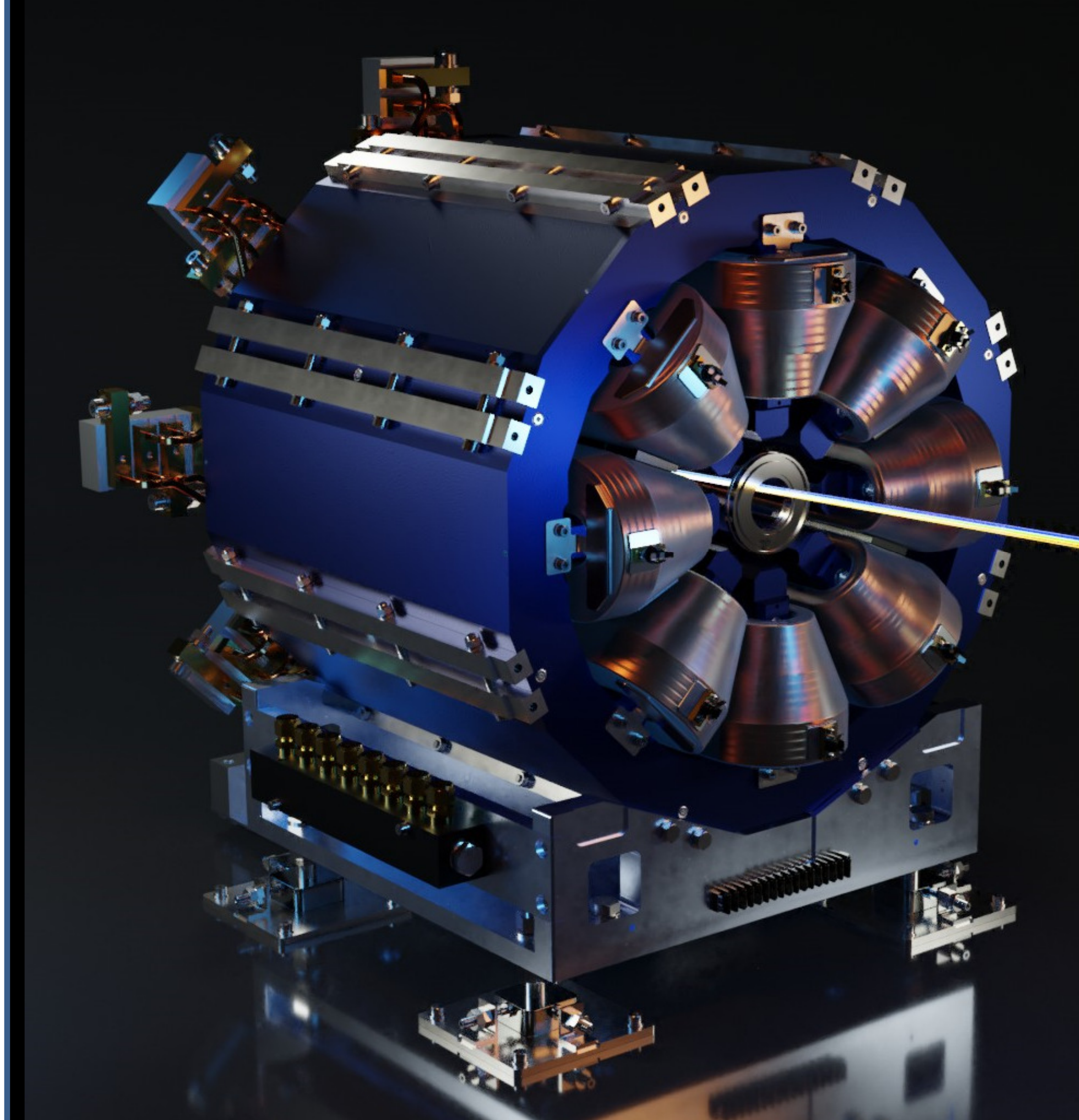
Fast XY Scan Magnet

X/Y Scanning Magnets

- Typical scan area 30x30 cm
- Step response of 100 us: Ideal for raster scanning
- Typical Raster scan in 80 milliseconds
- Up to 250 MeV Protons
- Hall probe for closed-loop feedback



Octopole Scan Magnet



R/Theta Scanning Magnet

- Typical scan area 30x30 cm
- Up to 250 MeV Protons
- Extremely good optics for small spot sizes
- Suitable for scanned beams/ small animal studies

Electronic Products

Highly-integrated electronics featuring fiber-optic communications, embedded digitization and data handling.

Low-current measurement
- I3200, I6400, I128, I400, I404, IC101, F100, F460, F3200E

Pulse counting
- D100, C400, CP10-A, CP10-B

Magnetic field measurement
- H20, MFP-30

General I/O
- M10, M10C, M40, B10, N2400

Real-time control and communications
- A500, A560, A360