PRONOVA

Affiliate of PROVISION HEALTHCARE

Thompson Proton Center

Covenant HEALTH®

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1.

Overview of ProNova Facilities at the Thompson Proton Center
in Knoxville, TN

ProNova Solutions Radiation Effects Testing at the Thompson Proton Center A Thompson Cancer Survival Center Covenant Health

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Location

Service Provider:

ProNova Solutions, LLC
330 Pellissippi Place
Maryville, TN 37804

All testing will be performed at the Thompson Proton Center in Knoxville, TN.

Radiation Effects Testing Location. Ship your equipment to the following location care of:

"Rad Effects Testing, Casey Corbridge or Jewell Overton".

Thompson Proton Center – Covenant Health
6450 Provision Cares Way
Knoxville, TN 37909

Shipping and Receiving

Address

Thompson Proton Center – Covenant Health
C/O Rad Effects - Jewell Overton or Casey Corbridge
6450 Provision Cares Way
Knoxville, TN 37909

Shipping & Receiving Notes

- Shipments can be accepted Monday-Friday, 8:00 am- 3:00 pm only.
- No shipments on the weekend unless the customer is onsite to receive the items.
- Please contact: Jewell Overton at (865)368-0944, or
  Casey Corbridge at (615) 336-4040 for assistance.
- There is no loading dock. **For heavy items, a truck with a lift gate is required.**
- Please provide our staff the number of items, weight, and size in advance of shipping.
- Once shipping is in order, please provide our team with a tracking number and expected date and time for delivery.
- NOTE: The Thompson clinic staff is not responsible for receiving ProNova rad effects customer's shipments. You must provide your tracking information and date and time of delivery prior to the shipment's arrival, or it will be denied.

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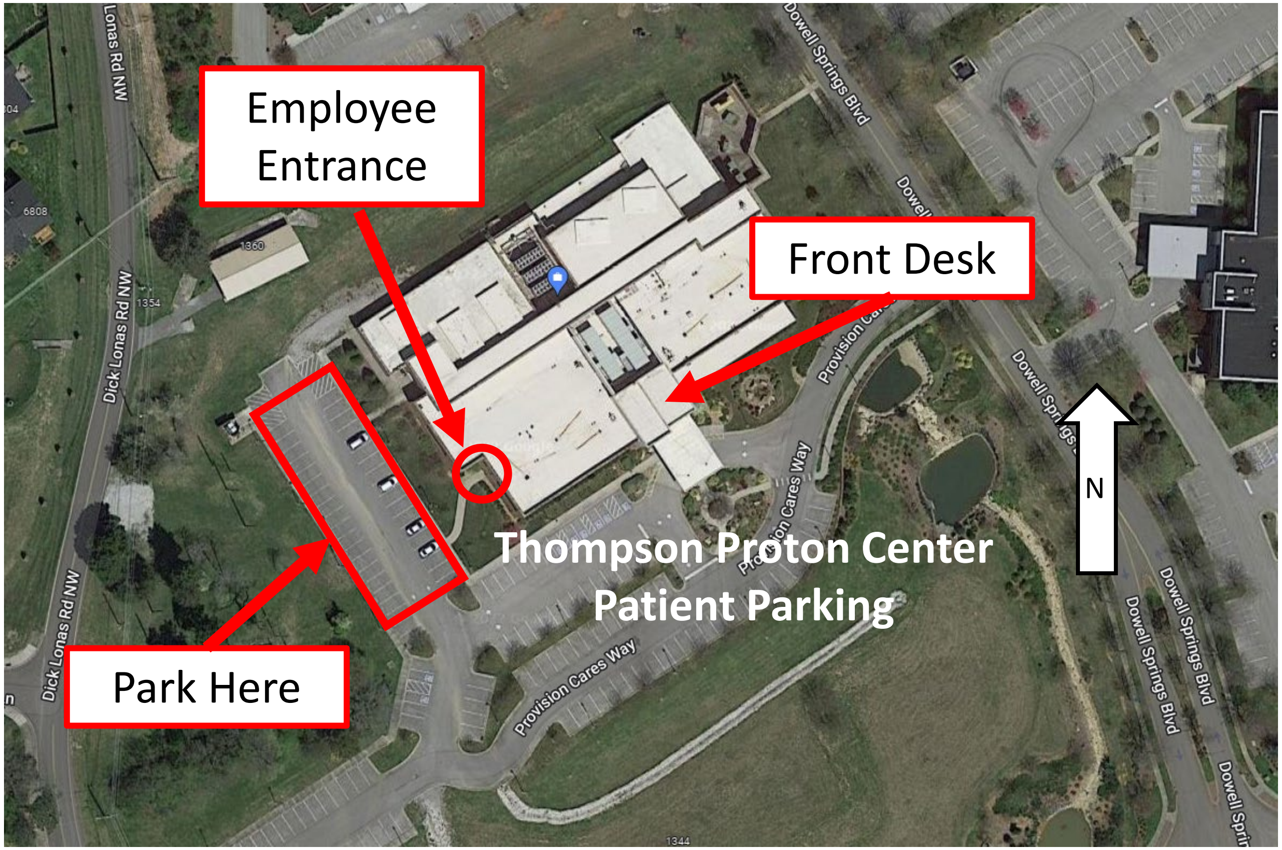
Facility Entrance for Rad Effects

Please call your ProNova Point of Contact. You will be met in the parking area and escorted to the front desk where you will sign in and get a badge. Enter the Employee Entrance if you've been signed in and badged.



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Advantage: Flexible Scheduling Options

Beam time is available weekdays, evenings and weekends with an 8 hour minimum per day and up to 12 hours per day on request.

Cancellation policy is straightforward: Give us a minimum 21 day advanced notice and there will be no charge. Within 21 days, no charge if we find a replacement customer for your time.

Booking is simple: call or email Jewell Overton your desired time and we can accommodate you a week in advance if there is an available slot.

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Advantage: Cost Savings

Because of a dedicated beamline, you will discover that workflow is better streamlined, and work efficiency is enhanced.

You will get more done in one single day of testing.

Two Payment Options

Option 1: Pay in advance (Prepay) for 50 hours or more and get a 10% discount.

Option 2: Pay 50% in advance of confirming booking and get invoiced for the remaining 50% on completion of testing.

COVID 19: COVID protocols may change as needed. Please contact Jewell Overton for the most up-to-date-information.

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Advantage: Cost Savings

Because of a dedicated beamline, you will discover that workflow is better streamlined, and work efficiency is enhanced.

You will get more done in one single day of testing.

Prepay customers: Purchase 50 hours or more prepaid in advance to get the following advantages:

- 10% reduction in hourly rate
- Setup and tear-down time is included up to 4 hours for a 40 hour booking (Post-pay users are charged for setup and tear-down).
- First day OR last day minimum is reduced to 4 hours from 8 hours for 40 hour bookings.
- Reservations are confirmed immediately and will have priority over post-pay users
- Post-pay users can be overbooked any time prior to receiving their 50% deposit

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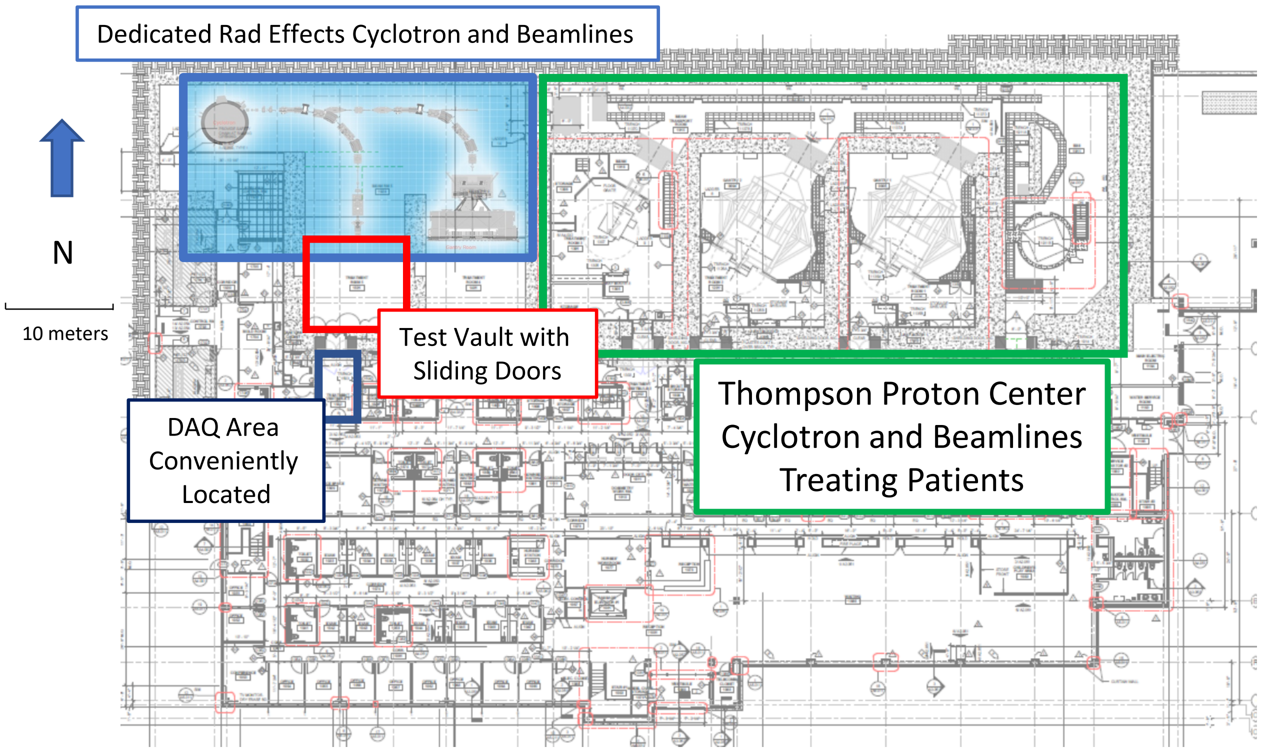
ProNova's Rad Effects at Thompson Proton Center



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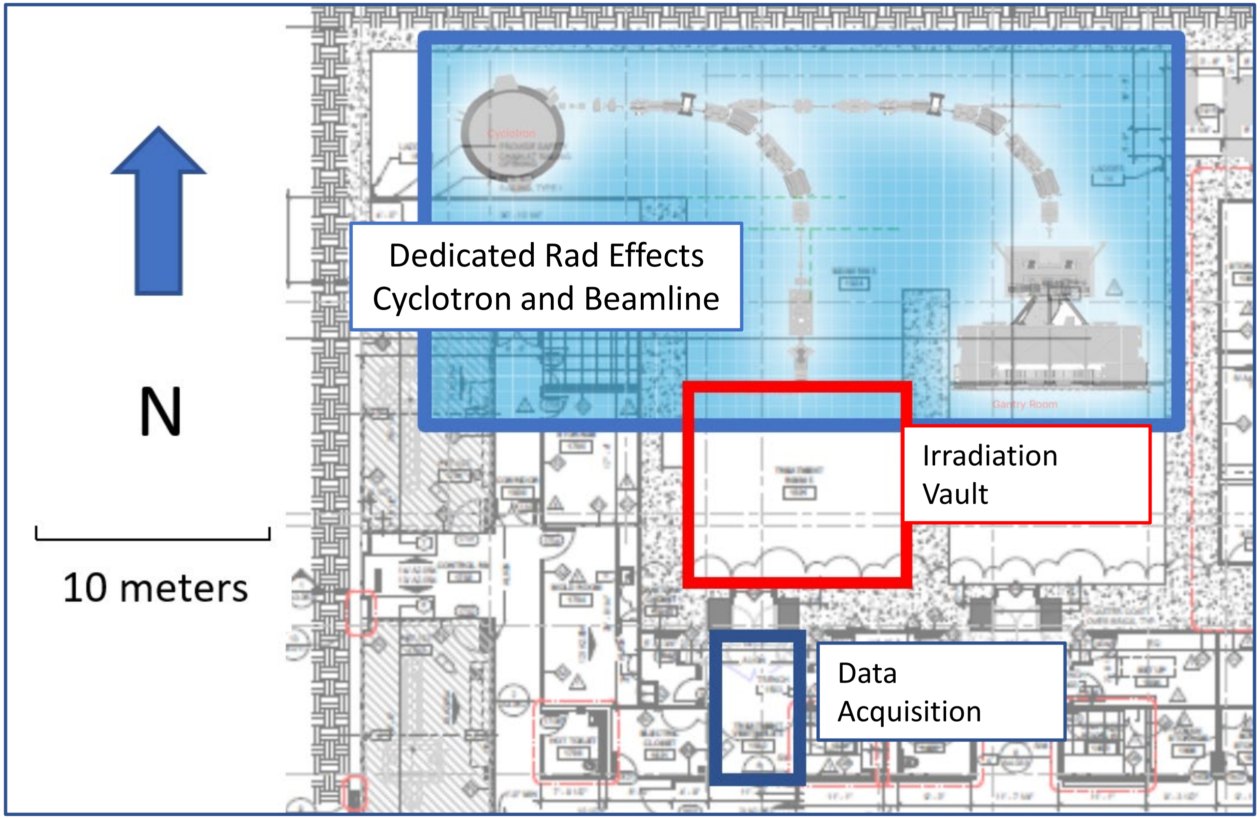
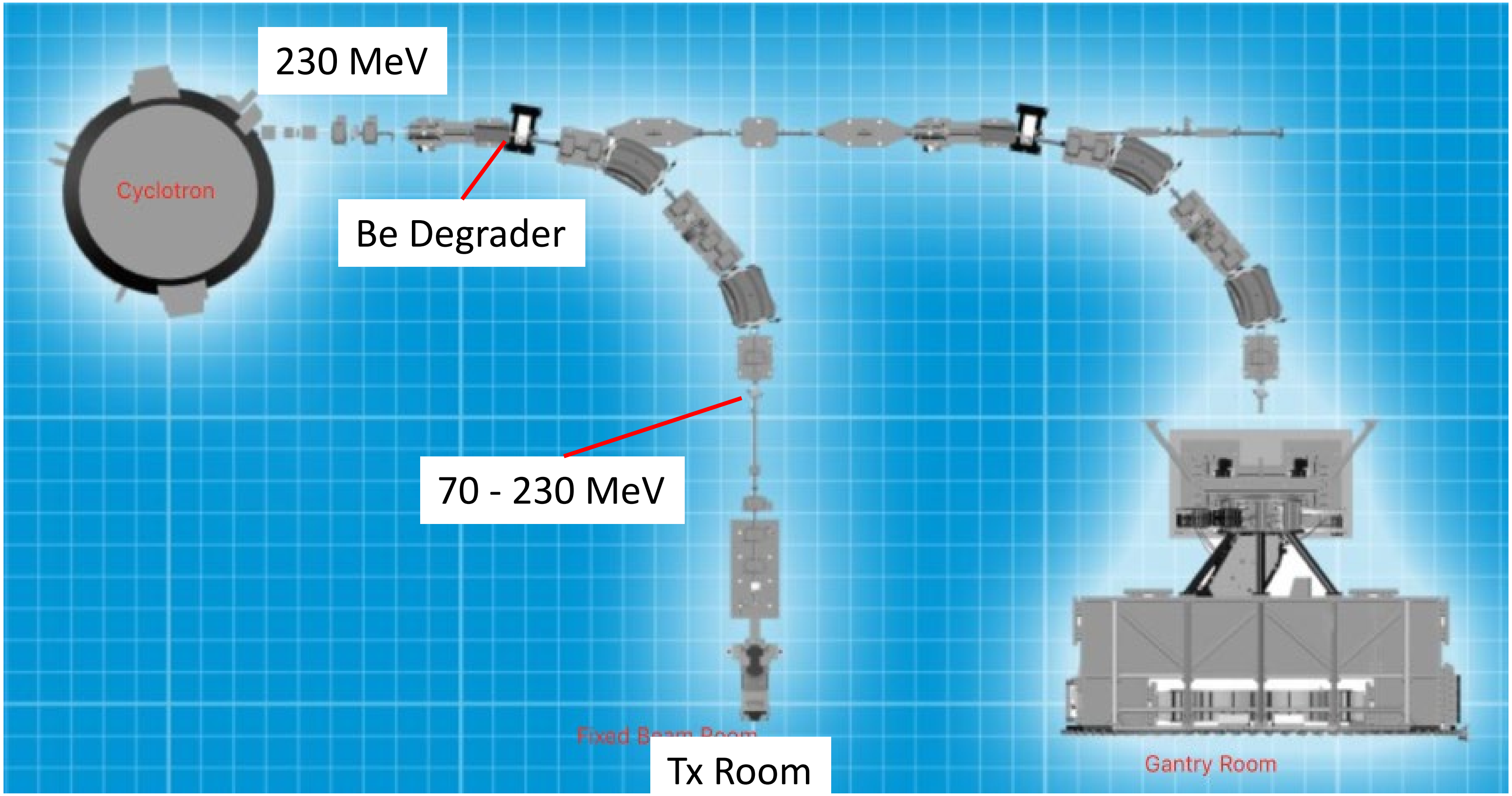
ProNova's Rad Effects at the Thompson Proton Center





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230 MeV Proton Cyclotron, CW Beam

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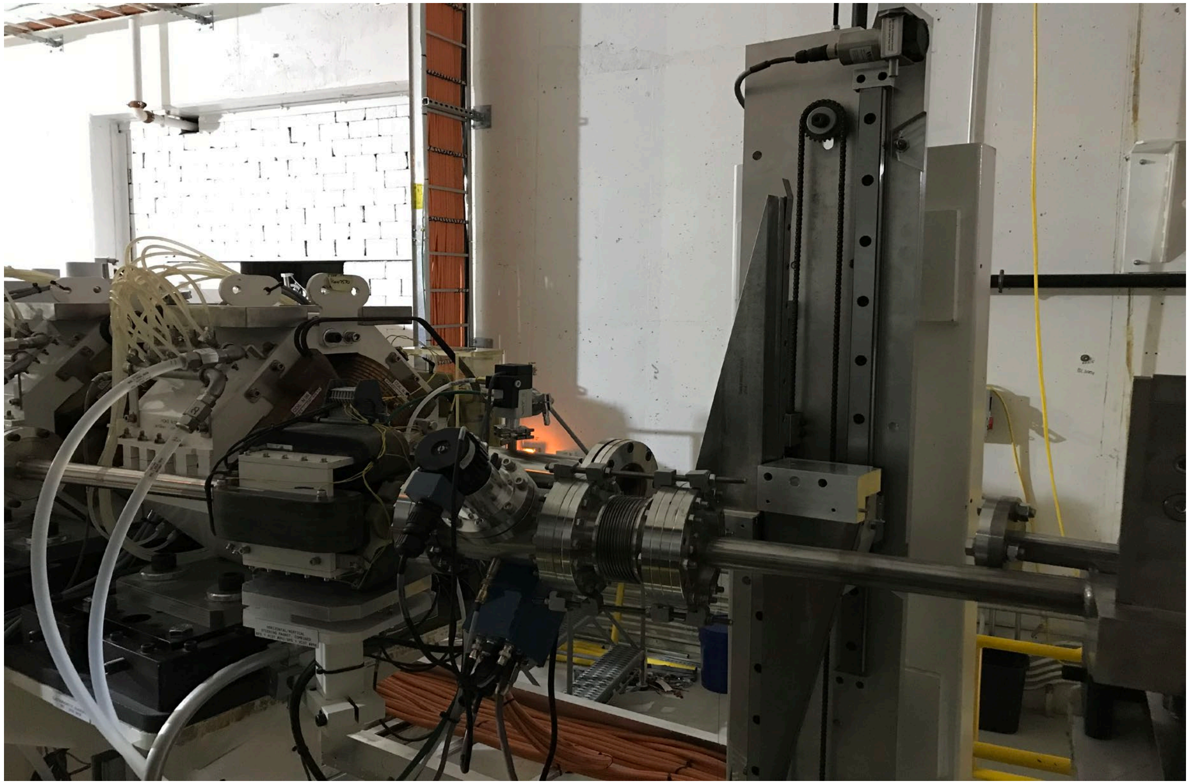
Beryllium Energy Degrader



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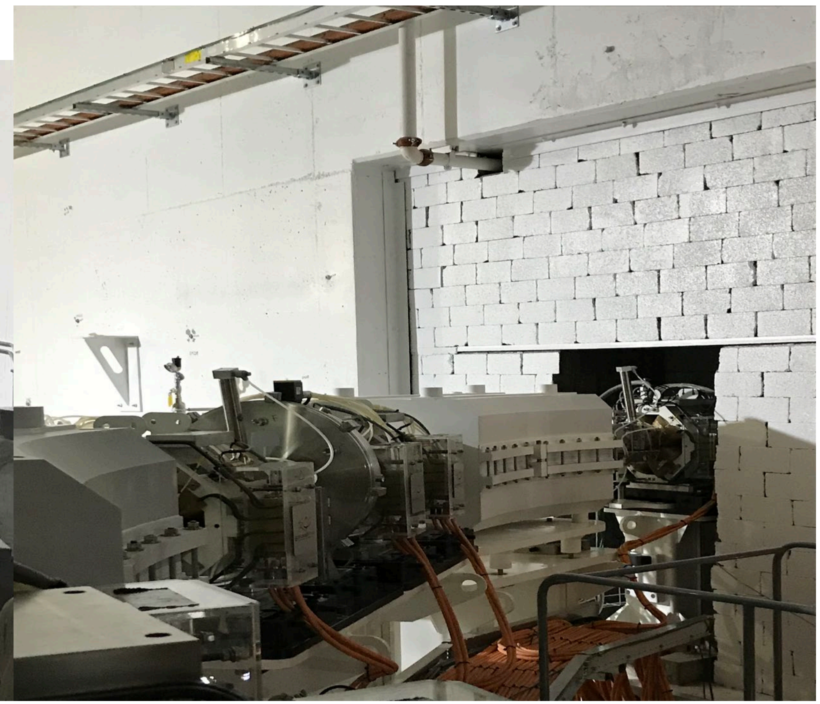
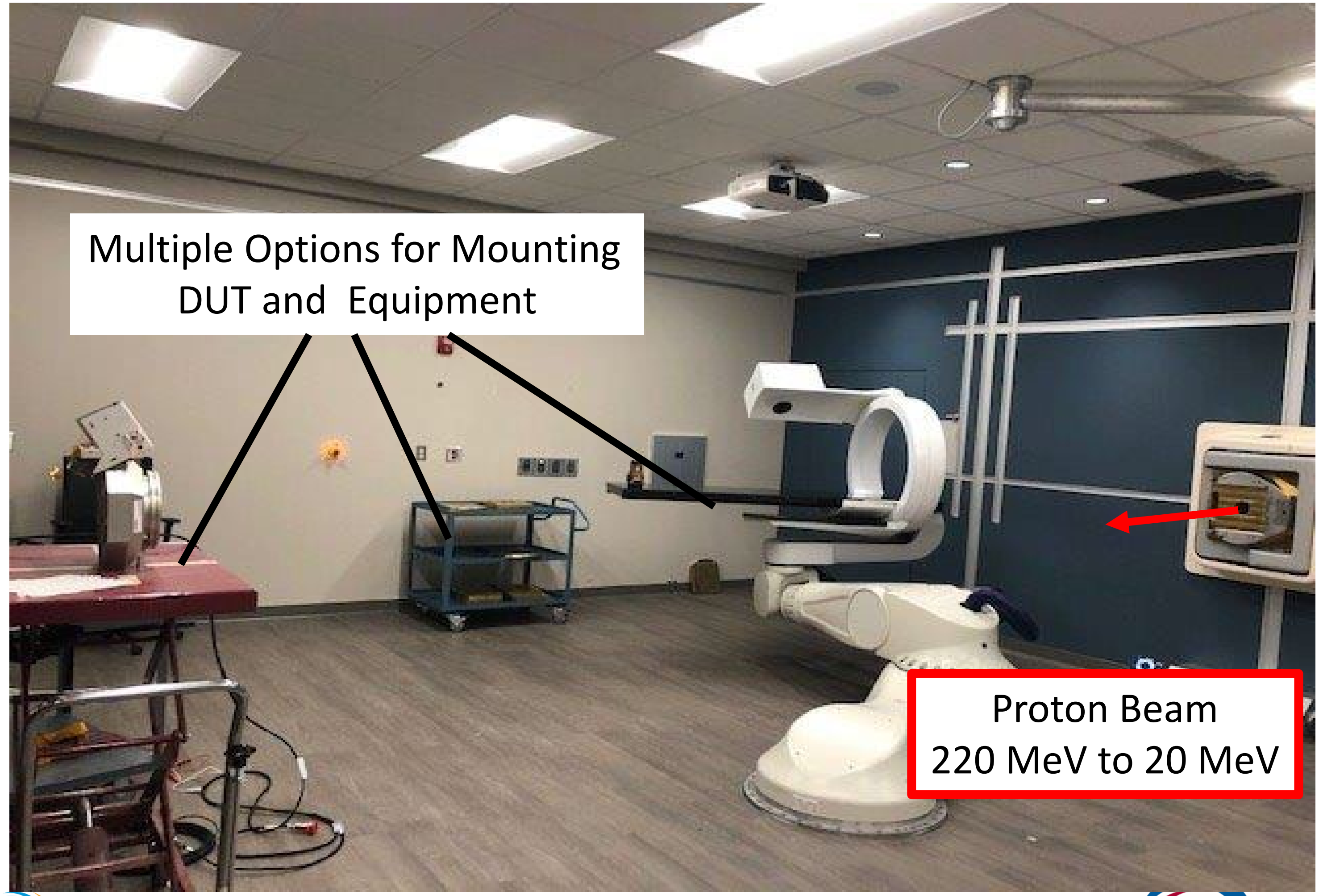
Achromatic Beamlines



Spacious Irradiation Vault



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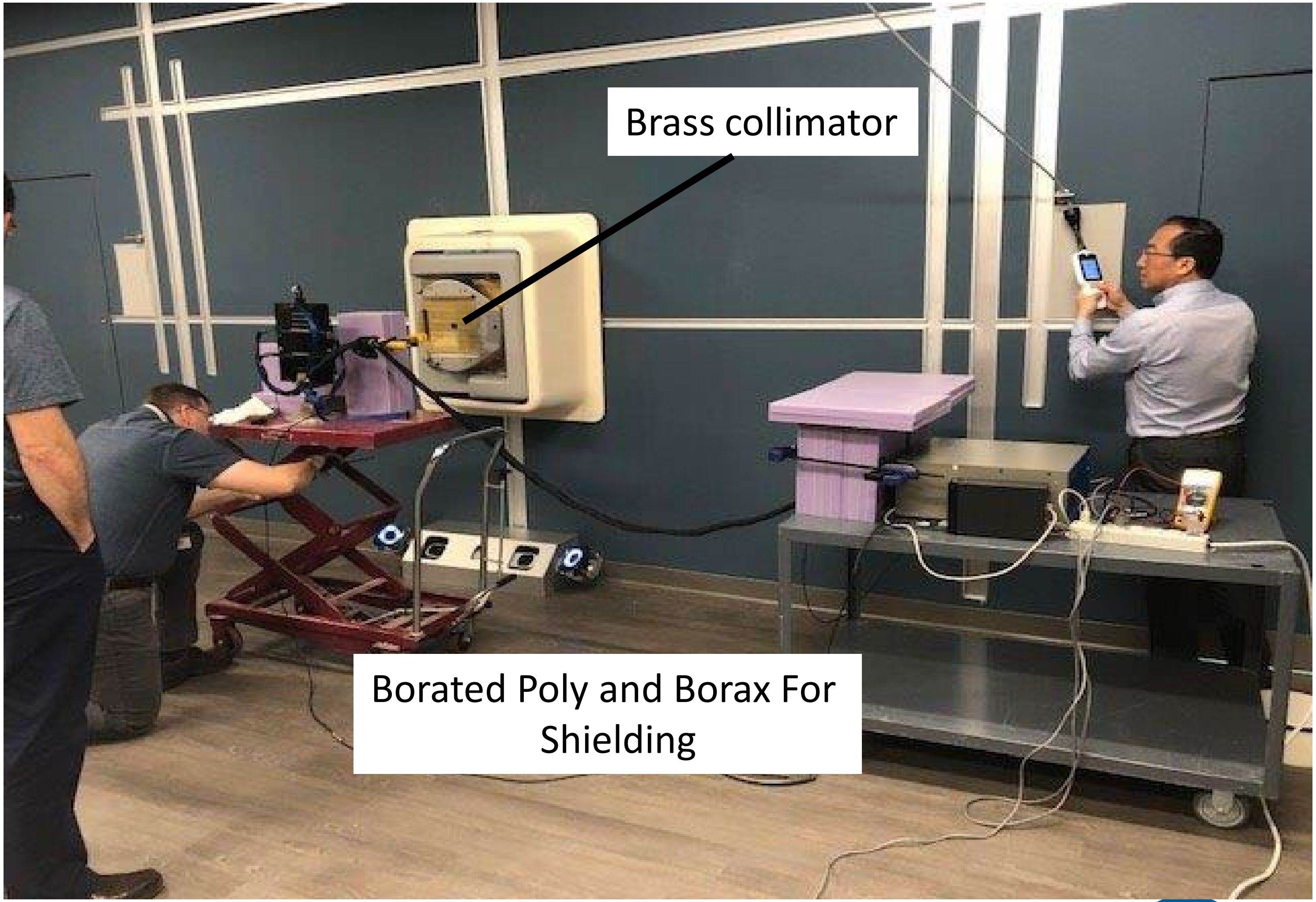
Setup example



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Setup Example

Proton energies from 50 MeV to 220 MeV, 20 MeV beams by request.

Field size range is 1.8 cm square to 20 cm diameter. Proton fluences (protons/cm^2) up to E+12 (1x10^{12}) are regularly delivered.

Proton fluxes (protons/cm^2/s) range from 1E+04 to ~E+09, depending on the proton energy

Testing setup for a major aerospace engineering company.

NASA Testing an air ventilation system used in the International Space Station

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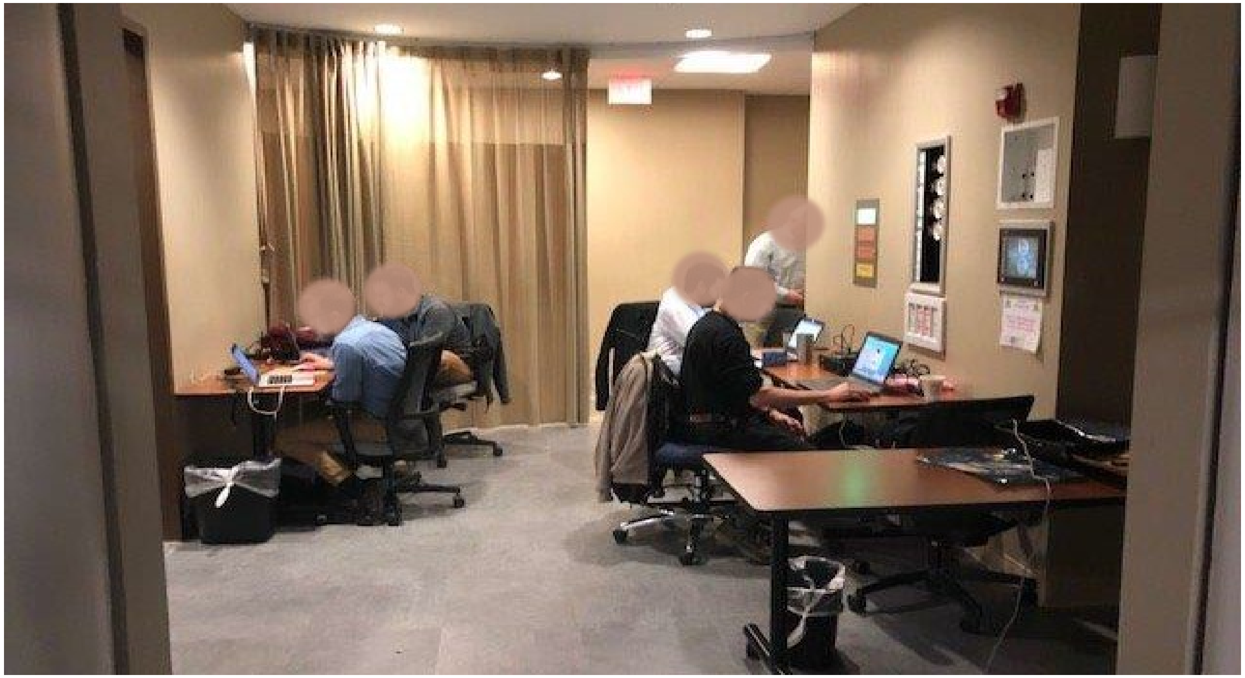
Work Area/Staging Area

60 feet (20 yards) from target station to the data acquisition area. 70-80 feet of cables would be plenty.

Operator's control room is to the left of the screen.

Secondary monitors to display dosimetry information



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Equipment Shielding Materials

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Equipment Shielding Materials

1. Borated PE. This is the standard 5% variety. Our inventory is as follows:
   a. One of 15 ¾" x 33" x 1"
   b. 30 of 12" square x 1"
   c. 9 of 15 ¾" square x 1"
   d. 4 of 15 ¾" x 8" x 1"
   e. 3 or 4 smaller pieces, odd sizes.
   f. See images.
   g. 4 x ~26" x ~37" x 1"
2. About 40 boxes of Borax powder.
3. Lead Bricks: About 15 lead bricks.
4. Room details: The drawings of the facility and blow ups of the room are to scale. There is a 10-meter scale next to two of the drawings that you may use. Look at pages 16 through 19 for pictures of the treatment room area where you will be setting up your equipment.

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Holding Fixtures

Holding fixtures: The Panavise type equipment we have is shown in the images below. For mounting light equipment in the beam, we can use the robotic patient positioning couch or a cart. Heavier equipment could certainly be mounted on a cart.

Terminology

The ProNova SC360 proton therapy system is designed to be used for treating cancers in humans. Currently it is only used for continuing R&D and testing of the SC360 medical device and to provide protons for radiation effects testing.

Because we are geared to the medical treatment of cancers, we use a different language to describe the quality of proton beams:

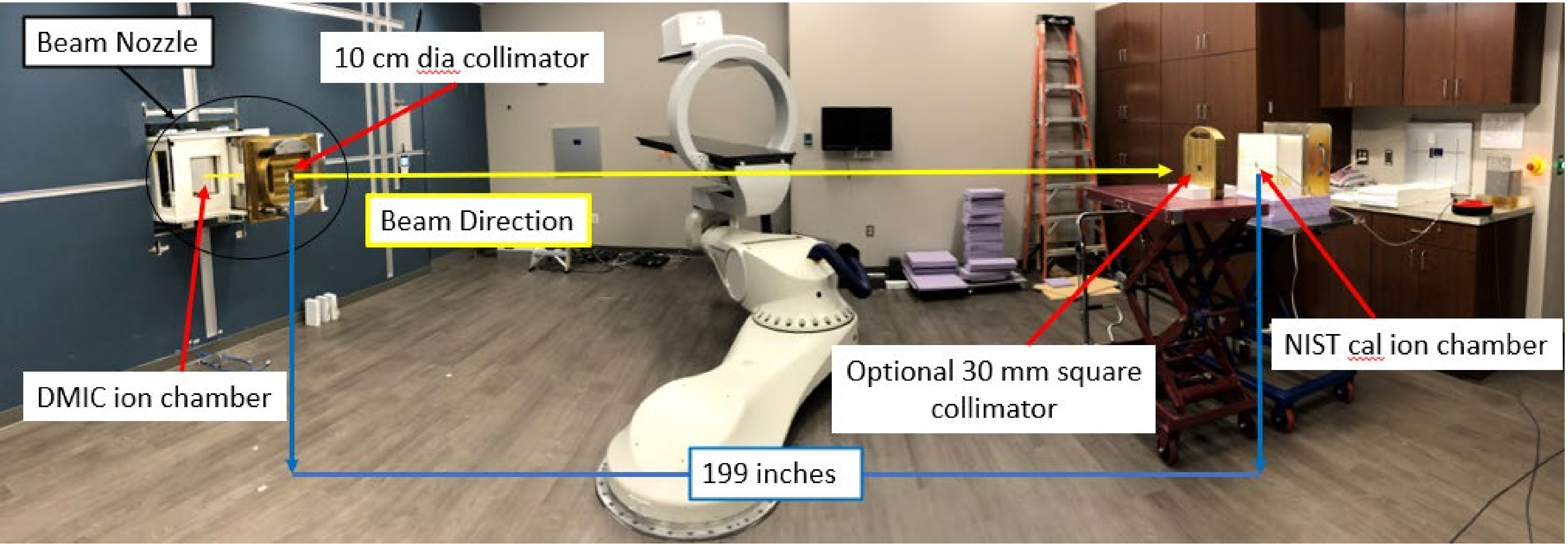
Rad Effects Terminology	Medical Device Terminology
Proton Energy (MeV)	Range in Water (g/cm^2)
Dose in Si or SiO_2 (kRad)	Dose in Water (Gray)
Flux ($p/cm^2/s$)	Dose Rate in DMIC (MU/s or counts/s)
Fluence (p/cm^2)	Dose in DMIC (MU or counts)
LET* (MeV cm^2/mg)	Stopping Power or -dE/dx (MeV/cm)
Collimator	Aperture
Energy Degrader	Range Shifter

* Electronic Mass Stopping Power

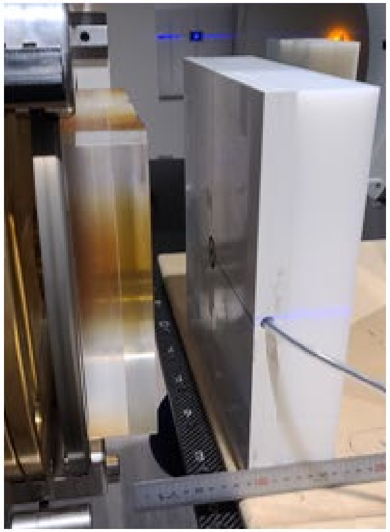
2.

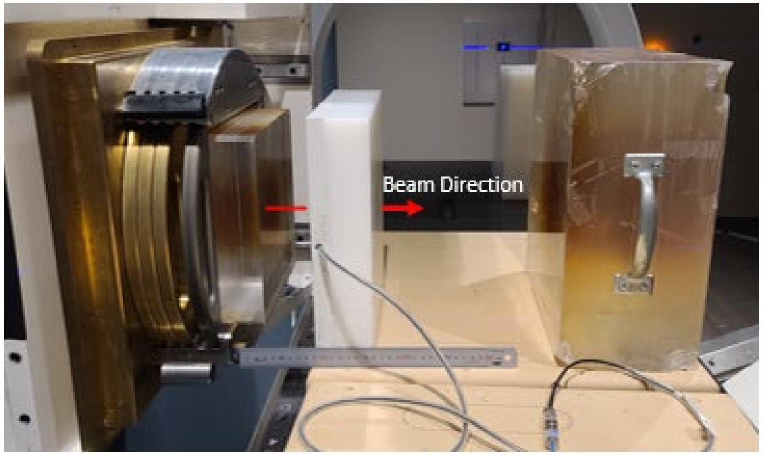
Calibrating the ProNova Beam

Low Flux Large Beam Setup



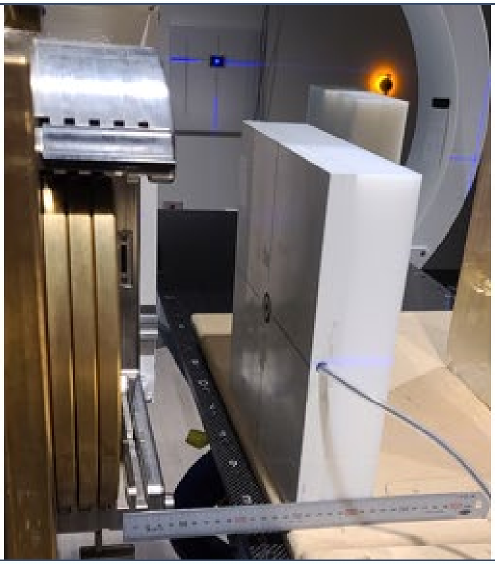
High Flux Small Beam Setup

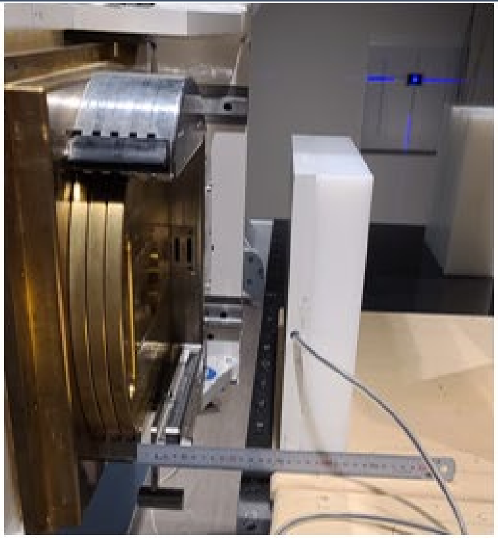




100 MeV, 80 MeV, 60 MeV and 40 MeV setup uses an acrylic energy degrader. Ion chamber is at test article location.

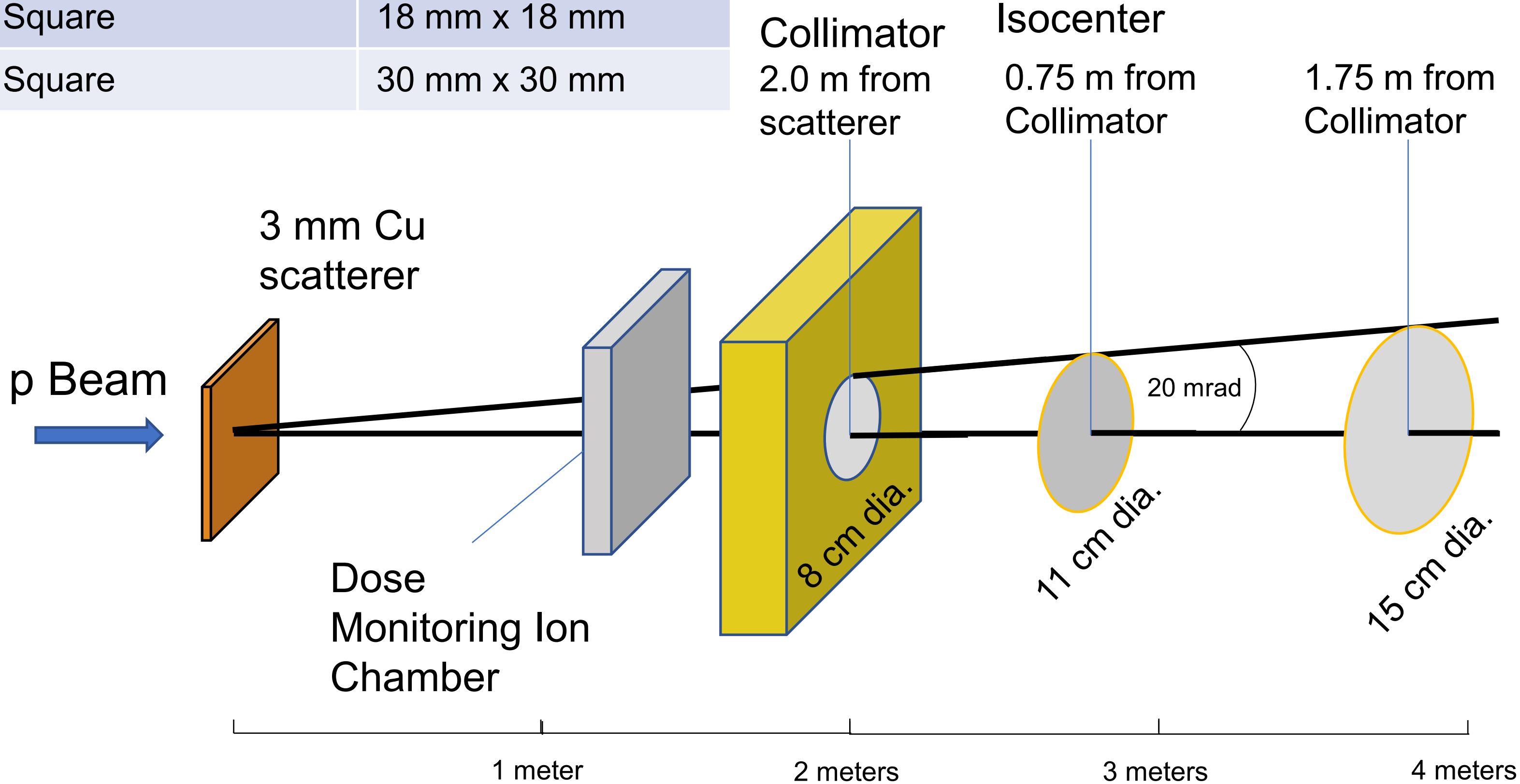
200 MeV and 120 MeV setup Does not use a degrader. 8 cm dia brass collimator is installed.

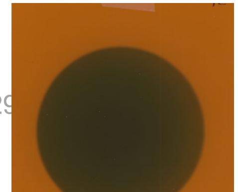




Available Collimators at ProNova	
Shape	Dimension
Round	2 cm dia
Round	8 cm dia
Round	10 cm dia
Square	18 mm x 18 mm
Square	30 mm x 30 mm

Example:
Divergence of a beam from a 3 mm Cu Scatterer collimated by an 8 cm aperture.

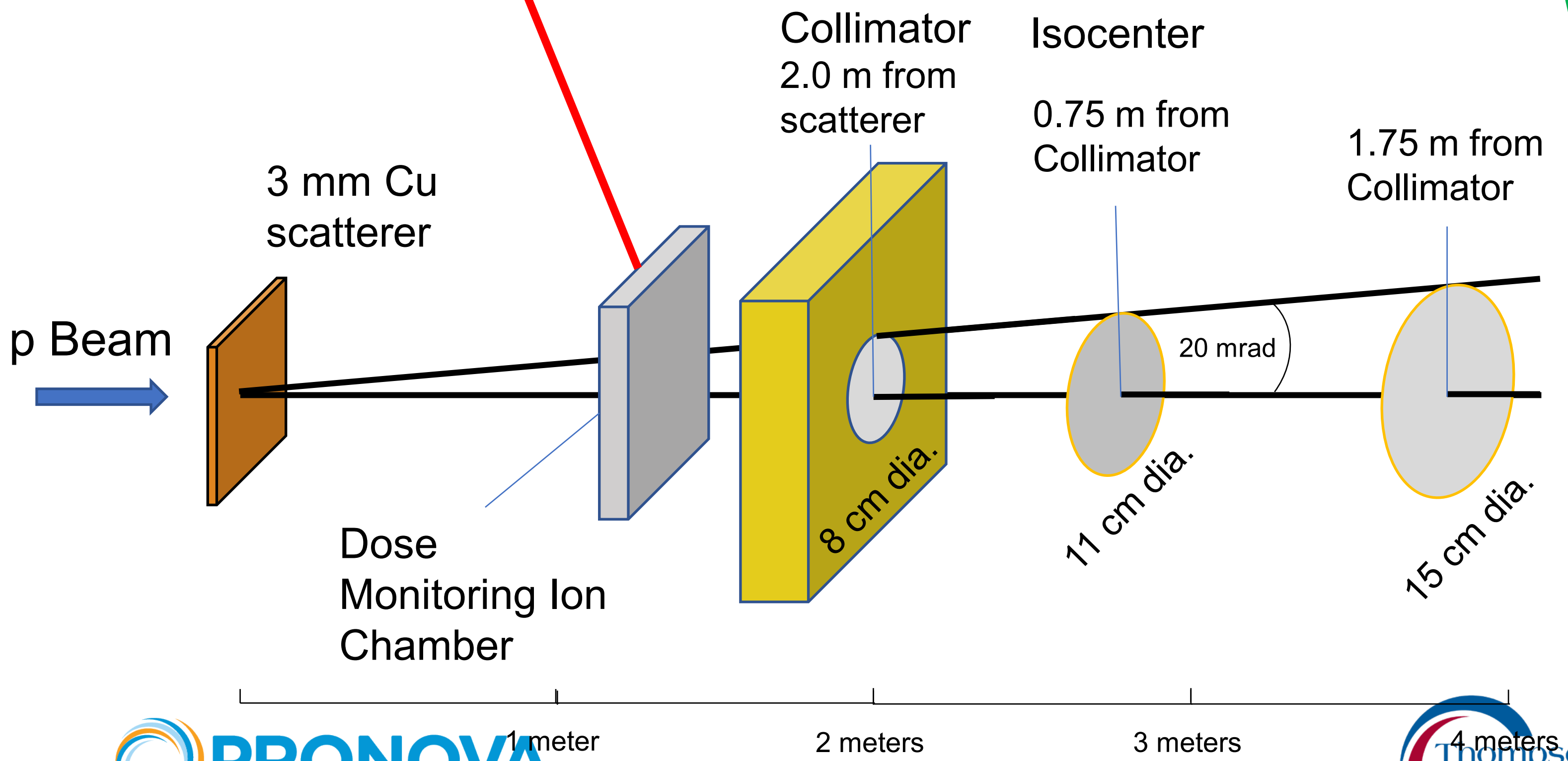




Calibrating the ProNova Beam

The Dose Monitor Ion Chamber is used to measure the number of protons transmitted to the collimator.

A NIST calibrated ion chamber is placed at the location of the test article.



Calibrating the Flux/Fluence

Date	IC Used	Distance From Aperture Face [in]	Aperture Type	Energy in Room [MeV]	Requested (nA)	Counts Measured	Calibrated IC Measured Charge [nC]	Measured Dose [Gy]	Gy/MU	Flux [p/cm^2/s]
6/17/2021	PPC05 (1093)	199	8 cm dia	200	200.00	2,992,060	1.184	0.720	1.20E-04	1.40E+07
6/17/2021	PPC05 (1093)	199	8 cm dia	200	40.00	1,143,680	0.451	0.274	1.20E-04	2.45E+06
6/17/2021	PPC05 (1093)	199	8 cm dia	200	8.00	130,741	0.051	0.031	1.20E-04	4.95E+05
6/17/2021	PPC05 (1093)	199	8 cm dia	200	1.00			0.000	#DIV/0!	7.00E+04
6/17/2021	PPC05 (1093)	199	8 cm dia	200	0.10			0.000	#DIV/0!	5.00E+03
			8 cm dia	**200 MeV**					**1.20E-04**	

MuToGy Sheet in the Dose Record

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Calibrating the Flux/Fluence

Proton Energy at DUT		200 MeV	25.96	cmR H2O
Range Shifter [cmR H2O]	0	200.00 MeV	25.96	cmR H2O
Cu spreader thickness [mm]	1.875	205.06 MeV	27.09	cmR H2O
BMS range setting		27.09 cm		

Dose (Water) per MU	4.15E-03	Gy/MU
	2.59E+04	MeV/mg/MU
	4.150E-04	krad /MU
LET(H2O)	4.49E-03	$MeV/mg/cm^2$
LET(SiO2)/LET(H2O)	0.833	
Fluence (p's/sq cm)/MU	5.77E+06	$p's/cm^2/MU$
(Dose(H2O)/MU)/LET(H2O, Ed)	5.77E+06	

Material Type	Si
LET	3.628E-03

Setup:

Nozzle Position:	Retracted
Apertures:	30 mm square
Number of Apertures	3
Range Shifter:	None
Cu Spreader:	1.875 mm
Notes:	
1. Place test article 25 cm from face of aperture.	
2. 1.875 mm = 1mm square Cu spreader + brass plate	

Enter Flux Requested	1.00E+09
Requested [nA]	30.18
RSST [nA]	5.84

Part ID	Run #	Date	Start Time	Run Duration [sec]	Counts	Dose [MU]	Fluence $[p's/cm^2]$	LET (Si) [MeV / mg/cm2]	Dose (Si) [kRad]	Flux Meter $[p's/cm^2/s]$	Comments
	1					0.0	0.00E+00	3.628E-03	0.000		
	2					0.0	0.00E+00	3.628E-03	0.000		
	3					0.0	0.00E+00	3.628E-03	0.000		
	4					0.0	0.00E+00	3.628E-03	0.000		
	5					0.0	0.00E+00	3.628E-03	0.000		

Data Sheet in the Dose Record

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Rate Monitor

Fluence (p+/cm2)

0.00E 00

Flux on DUT (p+/cm2/s) Energy = 200 MeV Dose Calib = 1.19E-04 Gy/MU

0.00E 00

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Rate Monitor Log

DateTime	Counts	Fluence (p+/cm2)	Flux on DUT (p+/cm2/s)
8:32:32 AM	0	0.00E+00	0.00E+00
8:32:35 AM	626	2.07E+05	6.88E+04
8:32:38 AM	1,417	4.69E+05	8.68E+04
8:32:41 AM	2,222	7.35E+05	8.84E+04
8:32:44 AM	3,020	9.99E+05	8.76E+04
8:32:47 AM	3,819	1.26E+06	8.78E+04
8:32:50 AM	7,353	2.43E+06	3.88E+05
8:32:53 AM	30,504	1.01E+07	2.54E+06
8:32:56 AM	58,216	1.93E+07	3.04E+06
8:32:59 AM	86,337	2.86E+07	3.09E+06
8:33:02 AM	114,239	3.78E+07	3.06E+06
8:33:05 AM	142,197	4.70E+07	3.07E+06
8:33:08 AM	169,241	5.60E+07	2.97E+06
8:33:11 AM	196,020	6.48E+07	2.94E+06
8:33:14 AM	222,799	7.37E+07	2.94E+06
8:33:17 AM	249,845	8.26E+07	2.97E+06
8:33:20 AM	276,704	9.15E+07	2.95E+06
8:33:23 AM	303,414	1.00E+08	2.93E+06

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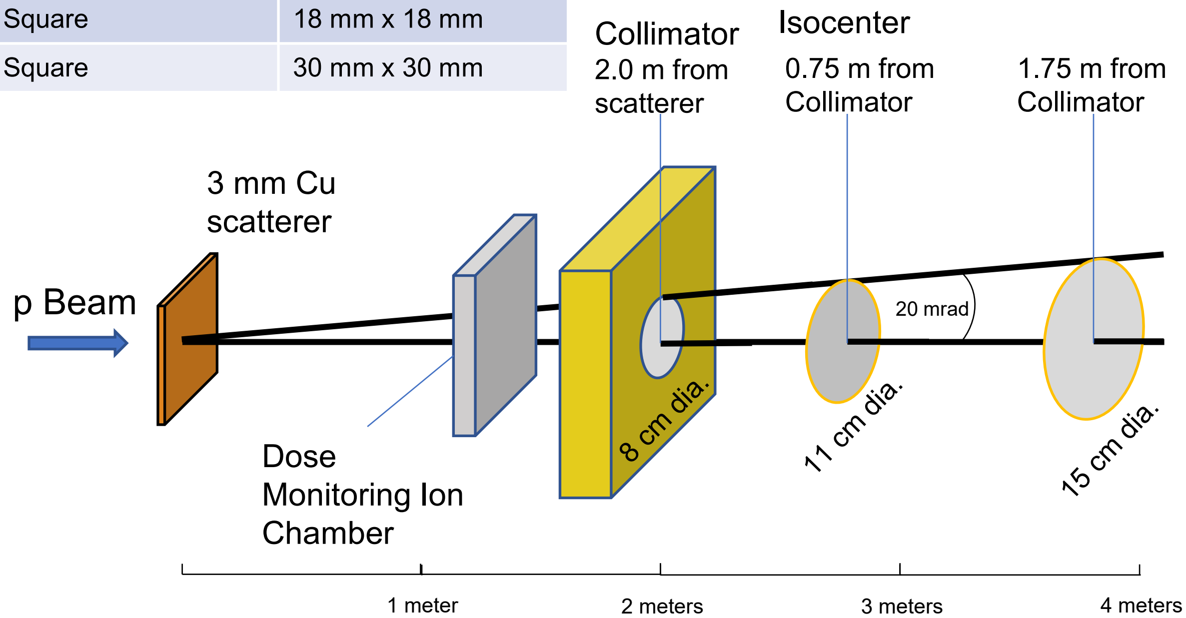
3.

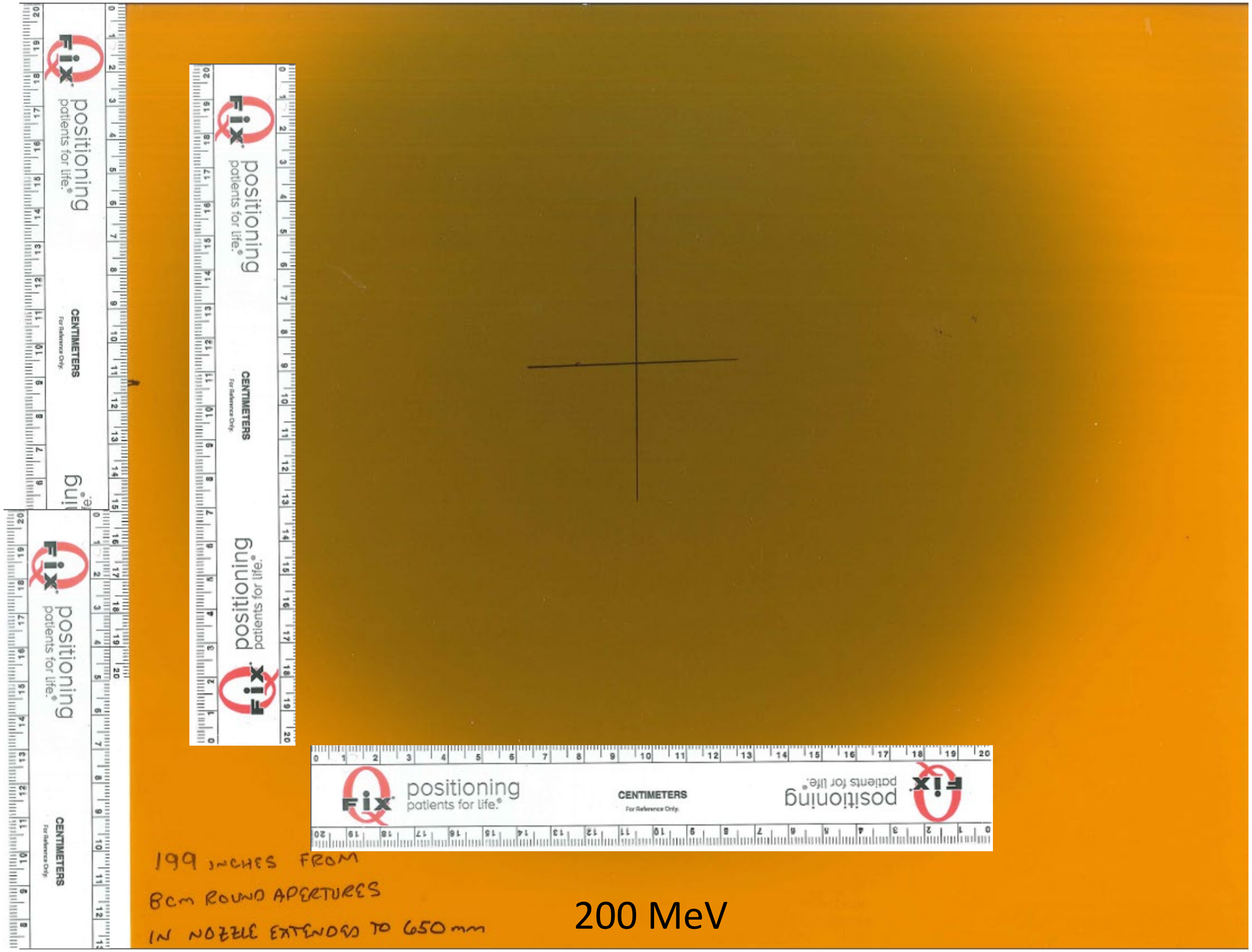
Beam Performance: Size

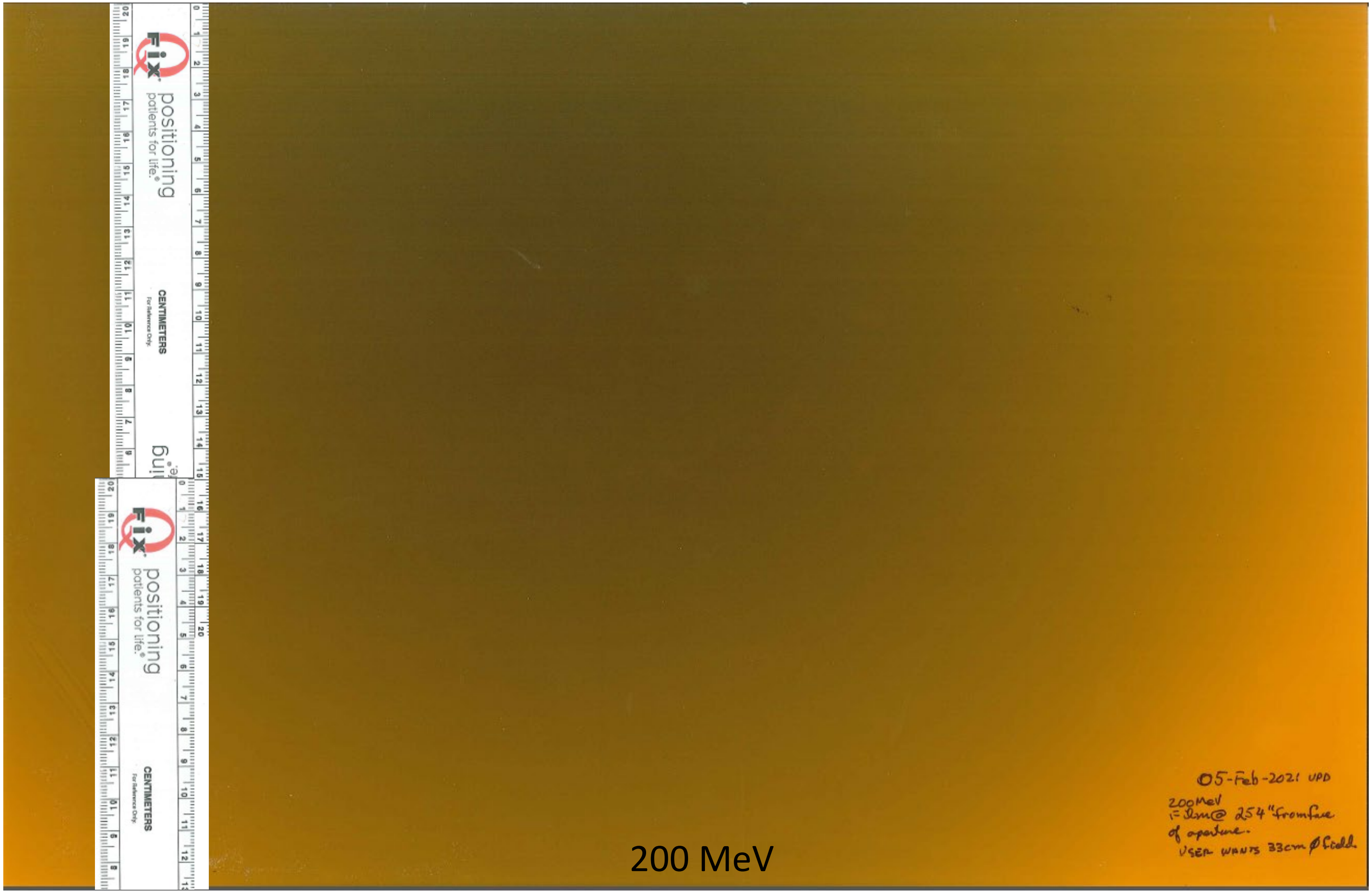
Range of Beam Sizes Available

Available Collimators at ProNova	
Shape	Dimension
Round	2 cm dia
Round	8 cm dia
Round	10 cm dia
Square	18 mm x 18 mm
Square	30 mm x 30 mm

Example:
Divergence of a beam from a 3 mm Cu Scatterer collimated by an 8 cm aperture.




199 INCHES FROM
8cm ROUND APERTURES
IN NOZZLE EXTENDED TO 650mm
200 MeV



positioning
patients for life.®
CENTIMETERS
For Reference Only.
05-Feb-2021 UPD
200MeV
1=Ilm@ 254"fromface
of aperture.
USER WANTS 33cm Ø field.
200 MeV

ADSH-ARG-IDD-001 - Adobe Acrobat Pro DC (32-bit)

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Home Tools 2021 ProNova Provi... ADSH-ARG-IDD-001 × Klas-VoyagerVM3-0... ×

53 / 105 154%

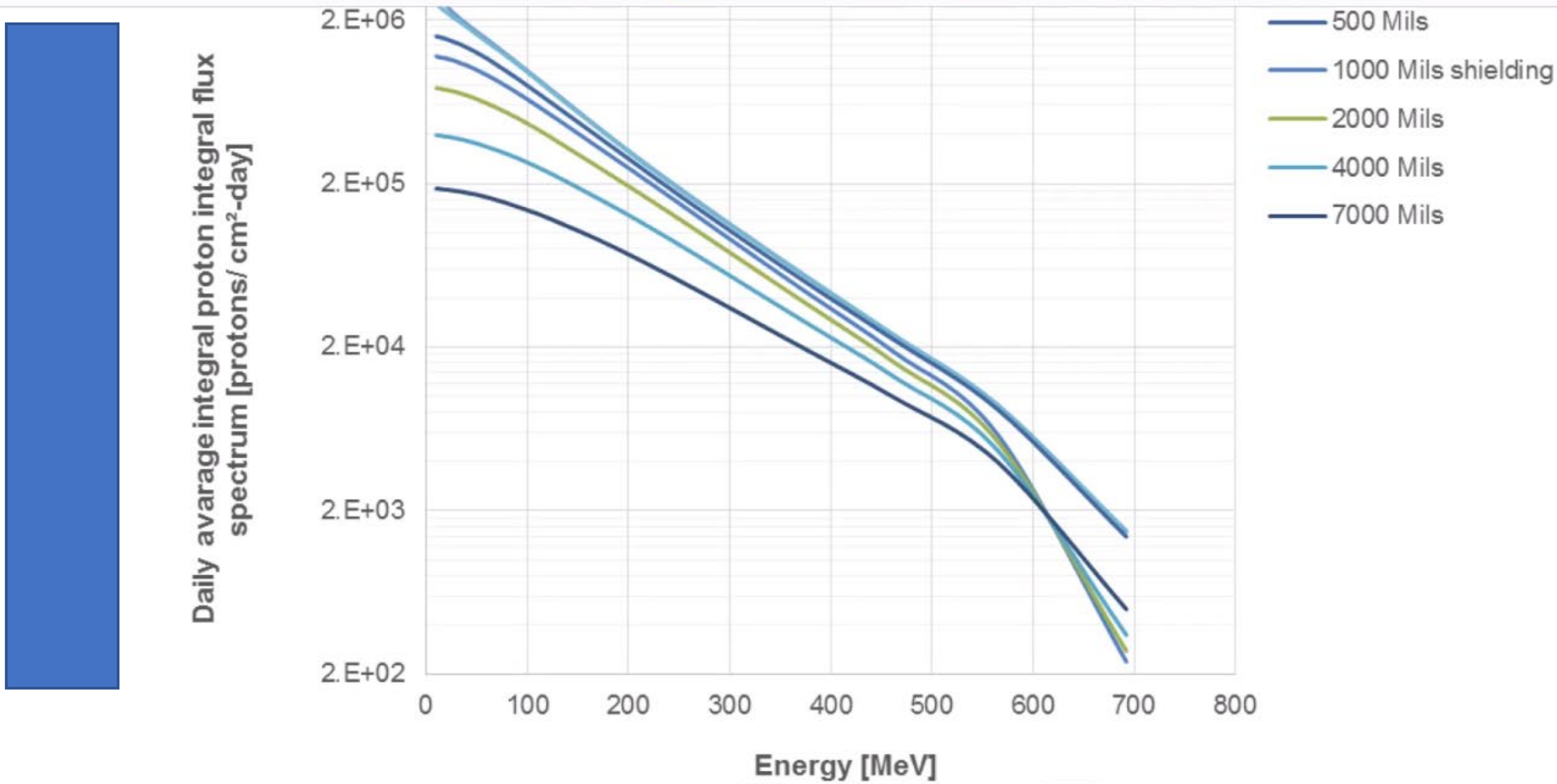
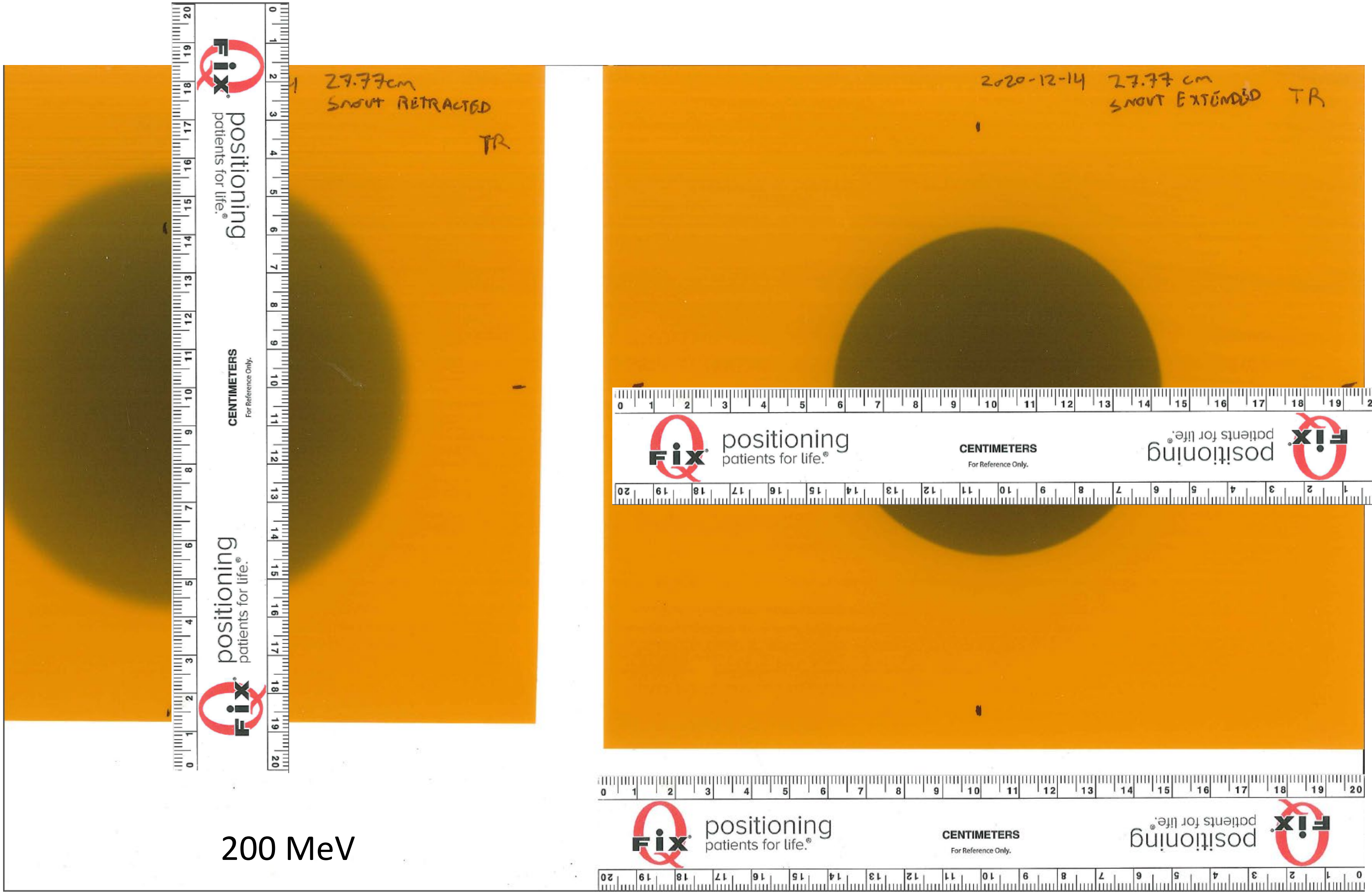
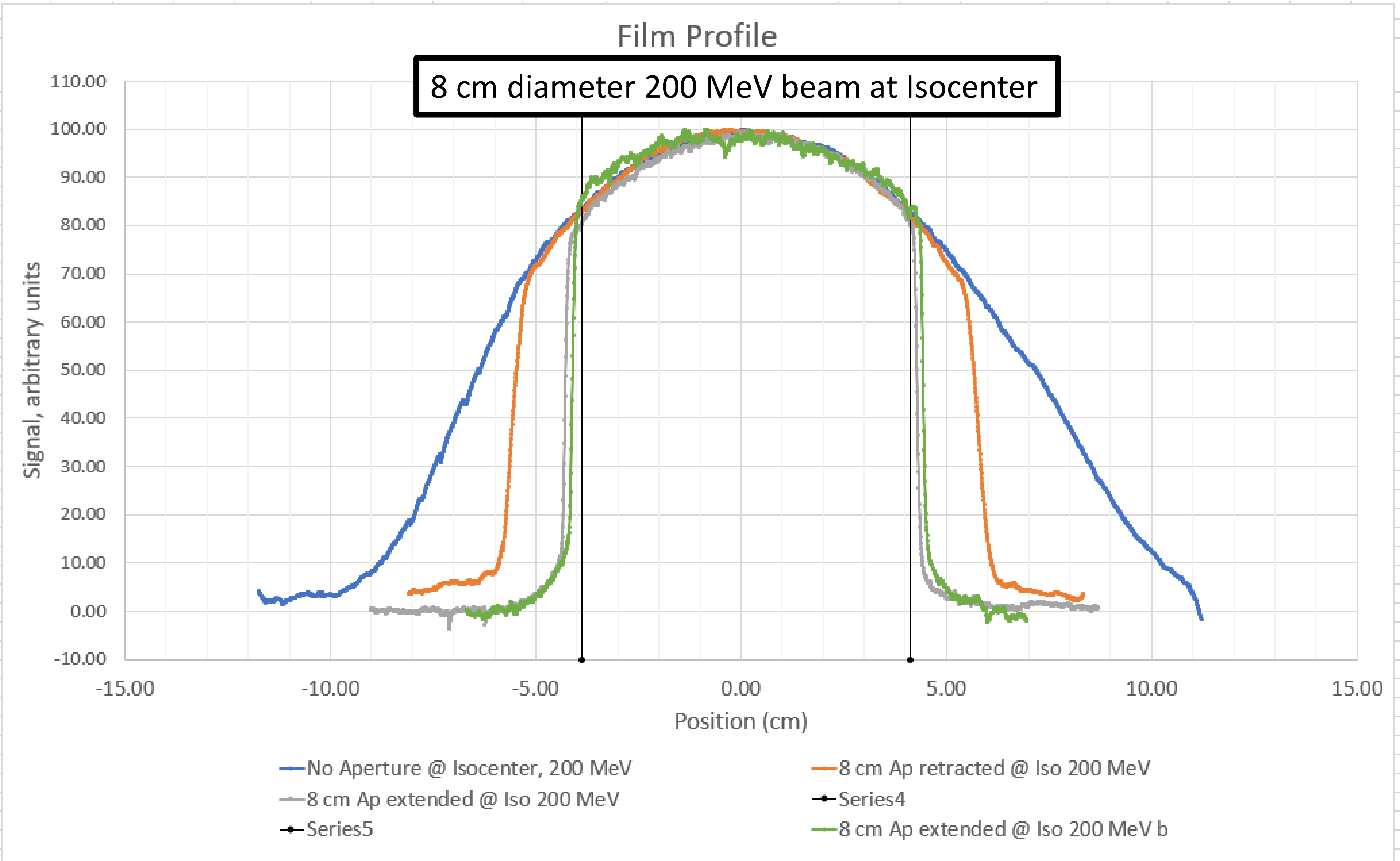


Figure 3-5 **Daily average integral proton integral flux spectrum Robotic Transfer Environment**


27.77cm
SNOUT RETRACTED
TR
2020-12-14 27.77 cm
SNOUT EXTENDED TR
positioning
patients for life.
CENTIMETERS
For Reference Only.

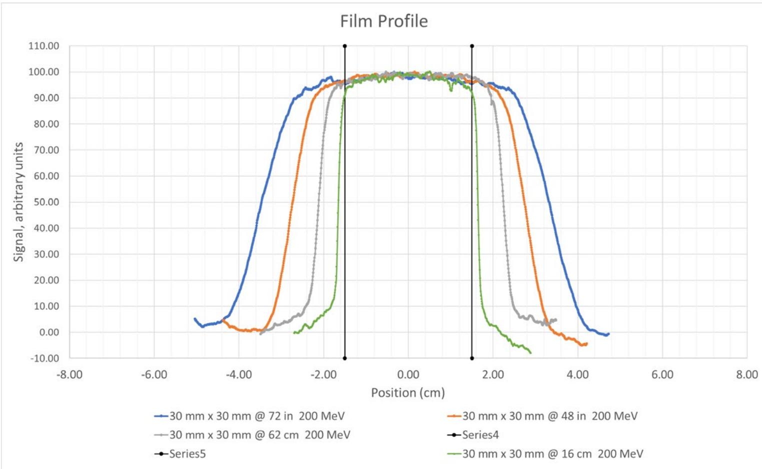
200 MeV

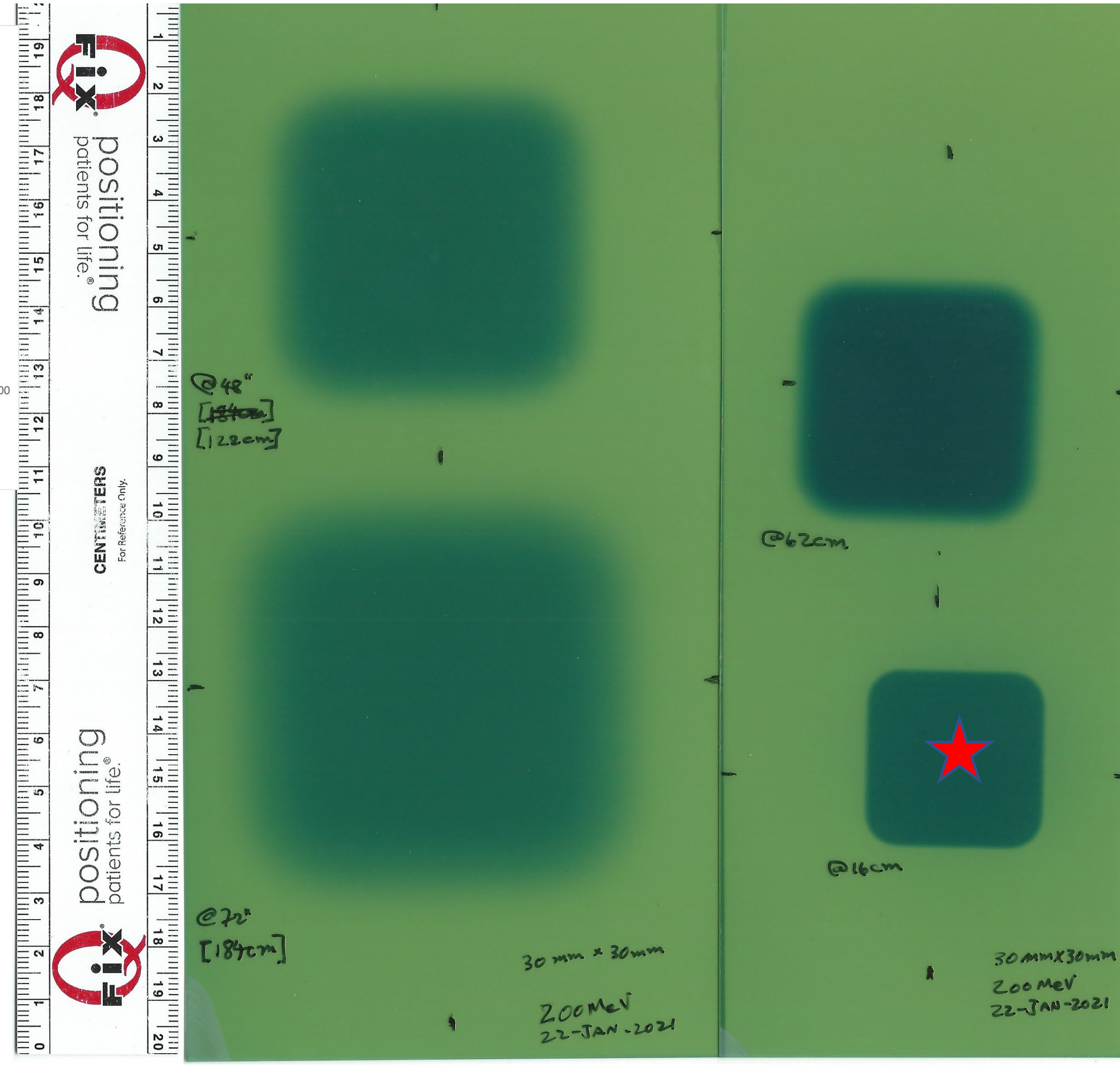


Flatness Calculation Region

	8	Edge of collimation	
X Offse	**X**	**Y**	
0.12	-3.88	-10	Left edge
	-3.88	110	Left edge
0.12	4.12	-10	Right edge
	4.12	110	Right edge

Flatness =	**9.41%**	No Aperture @ Isocenter, 200 MeV
Flatness =	**10.793%**	8 cm Ap extended @ Iso 200 MeV
Flatness =	**10.14%**	8 cm Ap extended @ Iso 200 MeV b

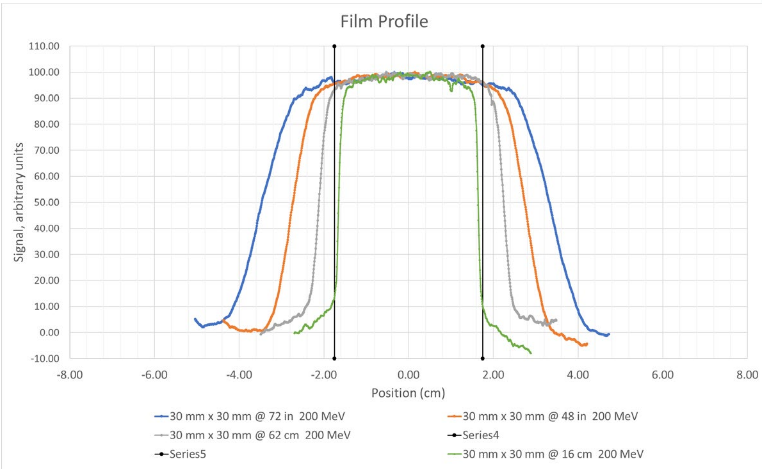


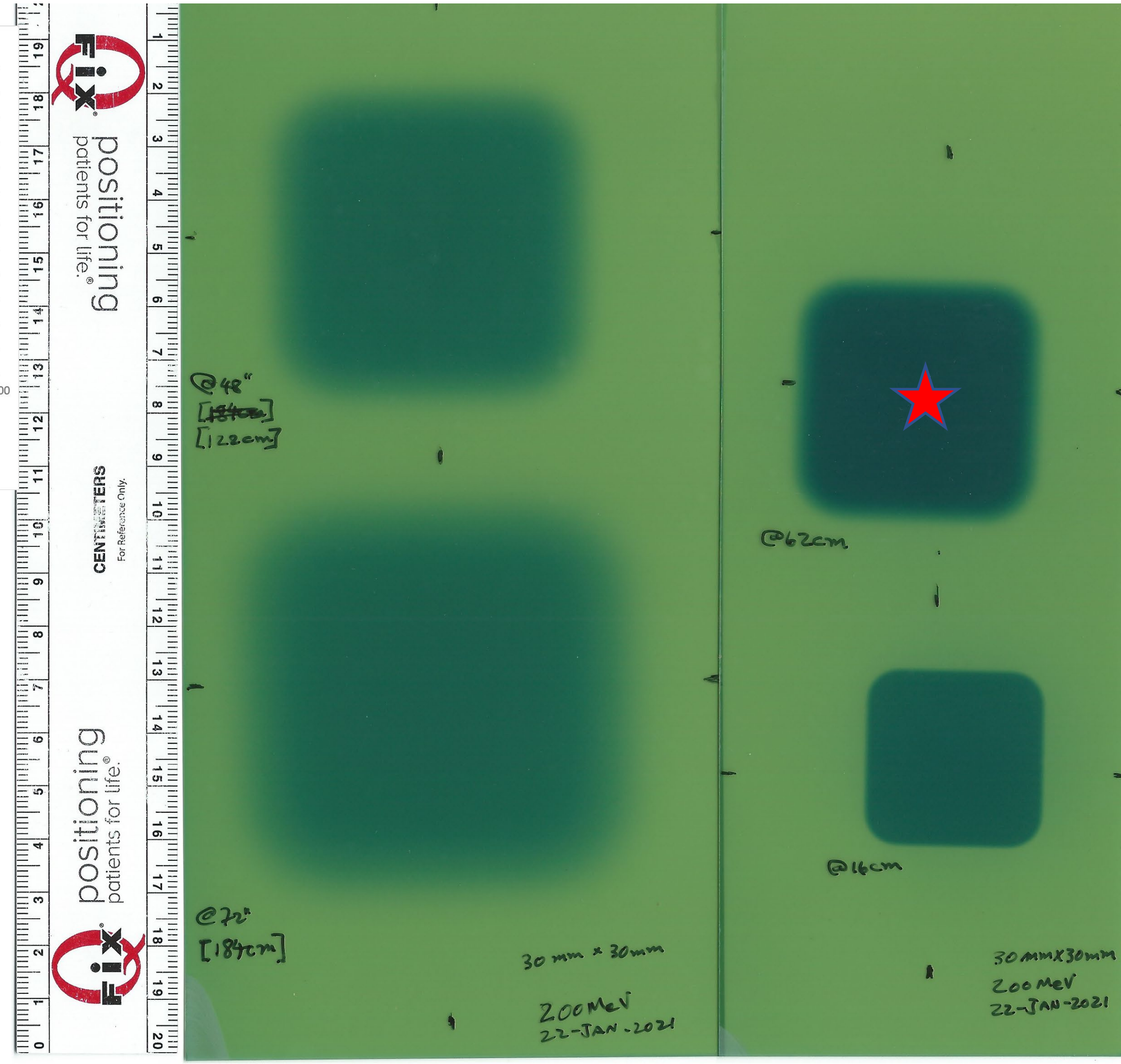


Flatness =	2.4%	30 mm x 30 mm @ 72 in 200 MeV
Flatness =	2.0%	30 mm x 30 mm @ 48 in 200 MeV
Flatness =	2.1%	30 mm x 30 mm @ 62 cm 200 MeV
Flatness =	4.7%	30 mm x 30 mm @ 16 cm 200 MeV

3.00 cm Width

200 MeV

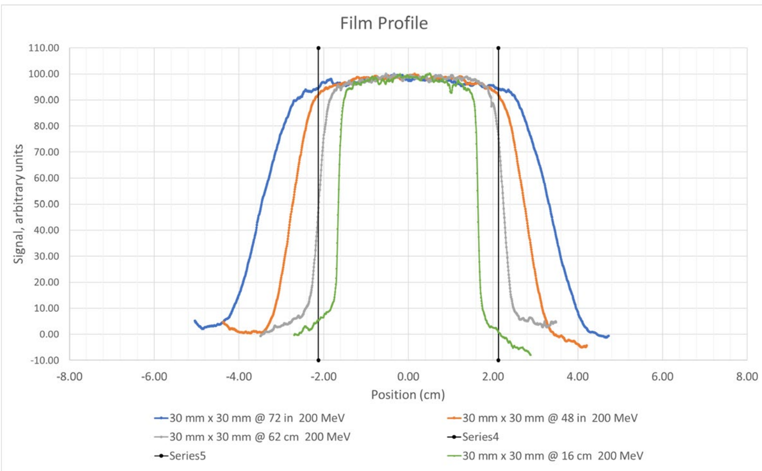


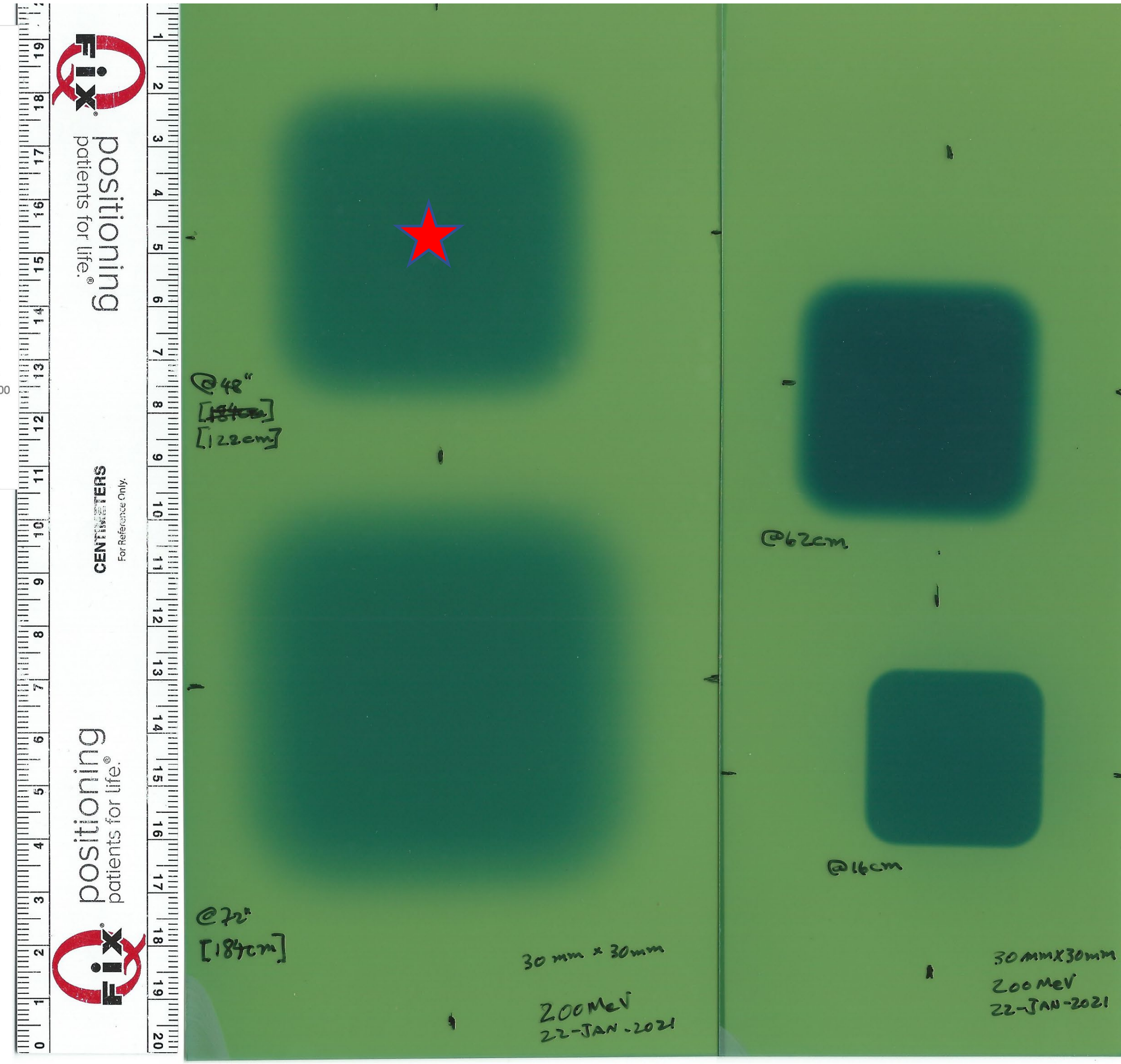


Flatness =	**2.6%**	30 mm x 30 mm @ 72 in 200 MeV
Flatness =	**2.2%**	30 mm x 30 mm @ 48 in 200 MeV
Flatness =	**3.3%**	30 mm x 30 mm @ 62 cm 200 MeV
Flatness =	**80.4%**	30 mm x 30 mm @ 16 cm 200 MeV

3.50 cm Width

200 MeV

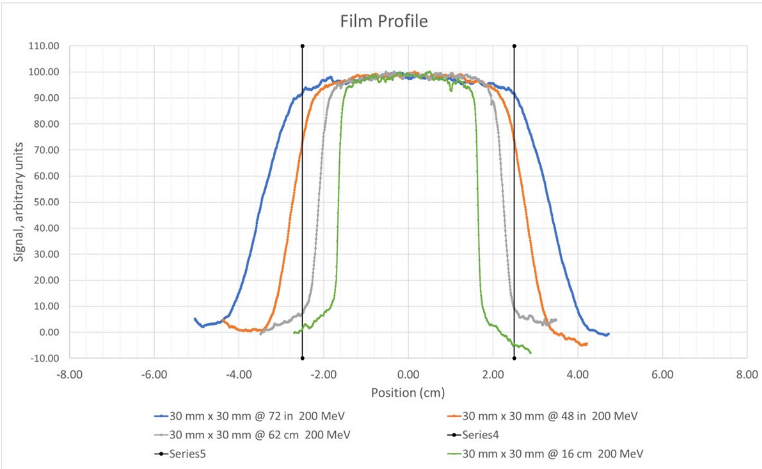




Flatness =	3.1%	30 mm x 30 mm @ 72 in 200 MeV
Flatness =	4.3%	30 mm x 30 mm @ 48 in 200 MeV
Flatness =	34.7%	30 mm x 30 mm @ 62 cm 200 MeV
Flatness =	97.8%	30 mm x 30 mm @ 16 cm 200 MeV

4.25 cm Width

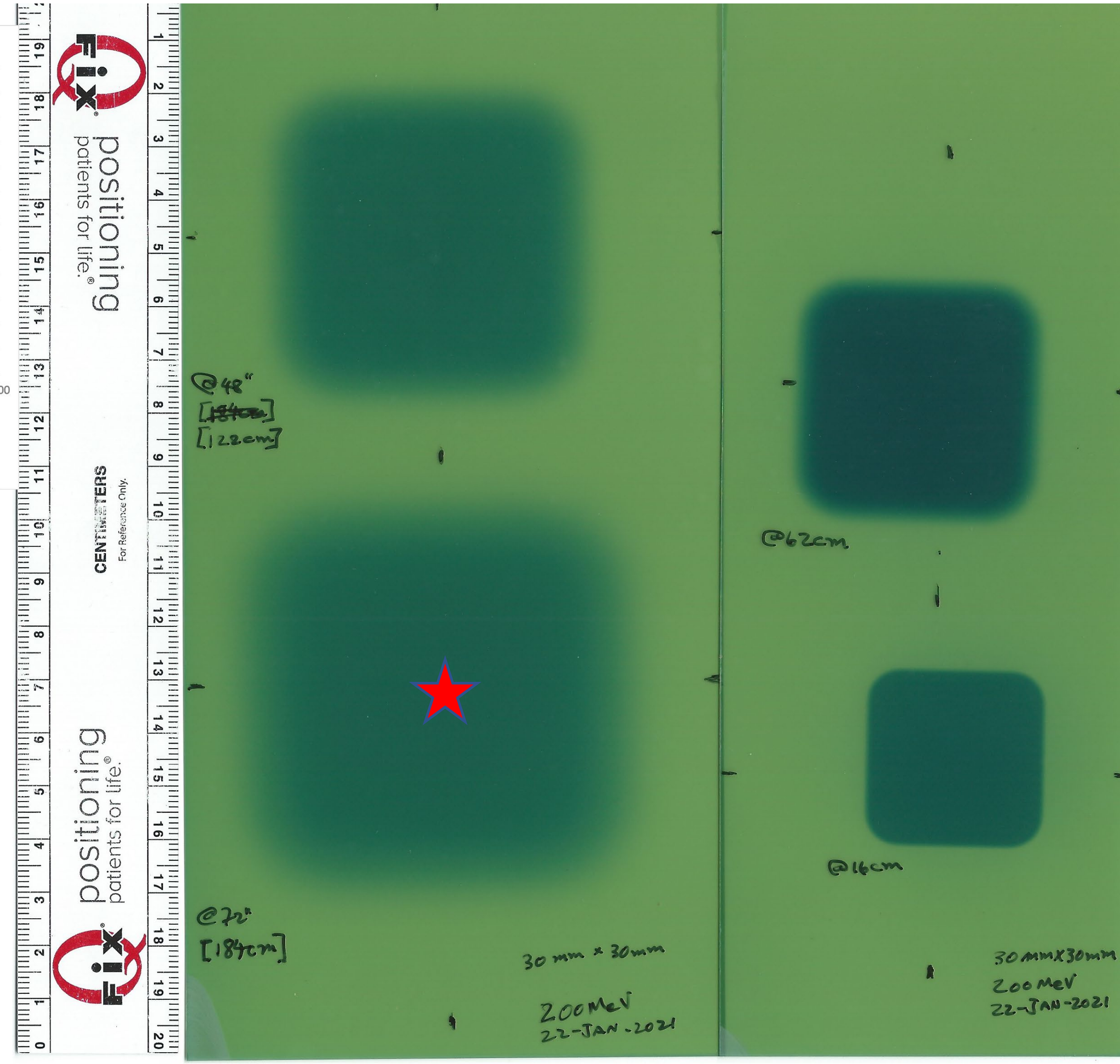
200 MeV



Flatness =	4.3%	30 mm x 30 mm @ 72 in 200 MeV
Flatness =	14.9%	30 mm x 30 mm @ 48 in 200 MeV
Flatness =	85.9%	30 mm x 30 mm @ 62 cm 200 MeV
Flatness =	111.0%	30 mm x 30 mm @ 16 cm 200 MeV

5.00 cm Width

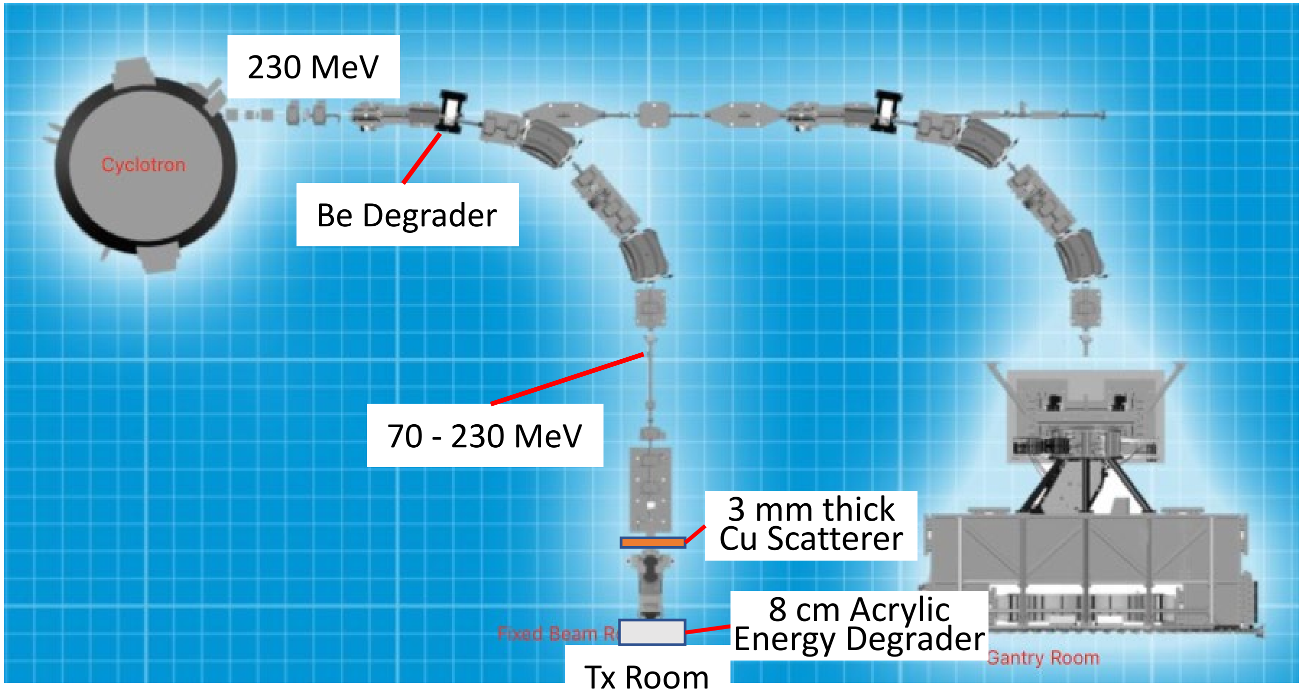
200 MeV



4.

Beam Performance: Flux and Fluence

Beam Transmission into the Treatment Room



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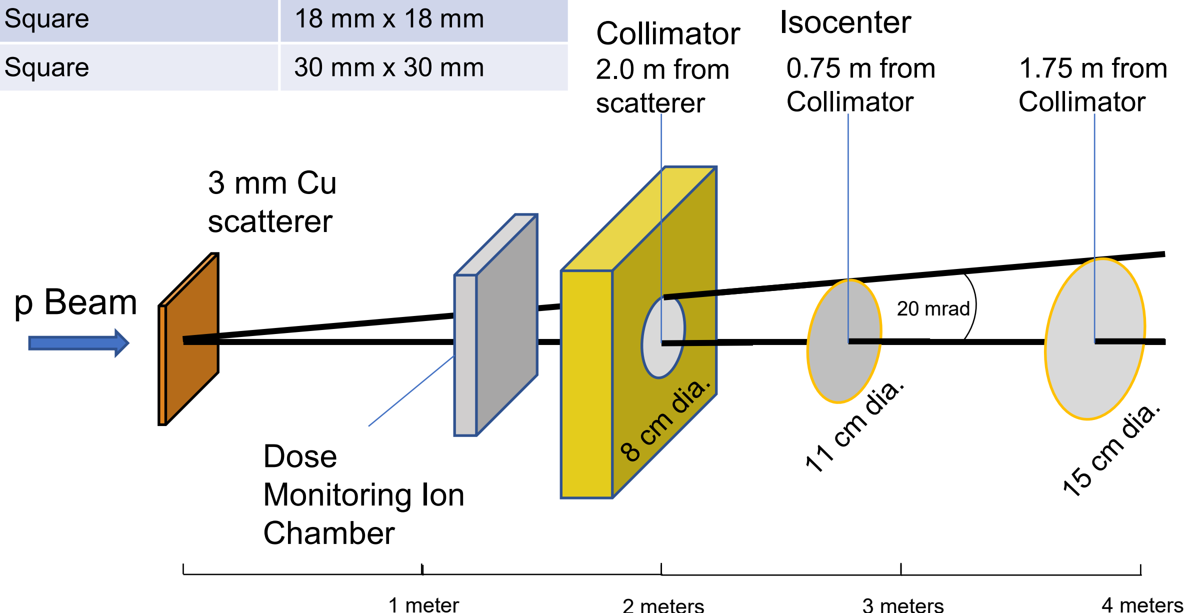
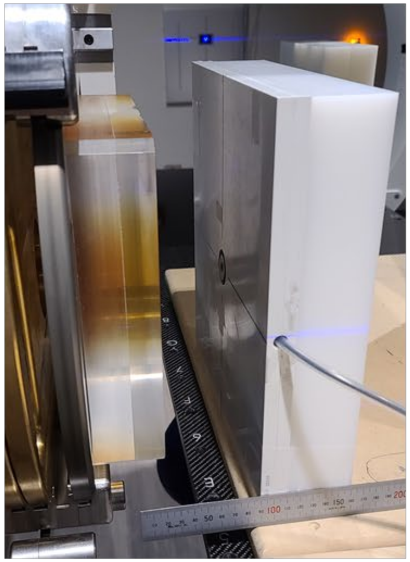
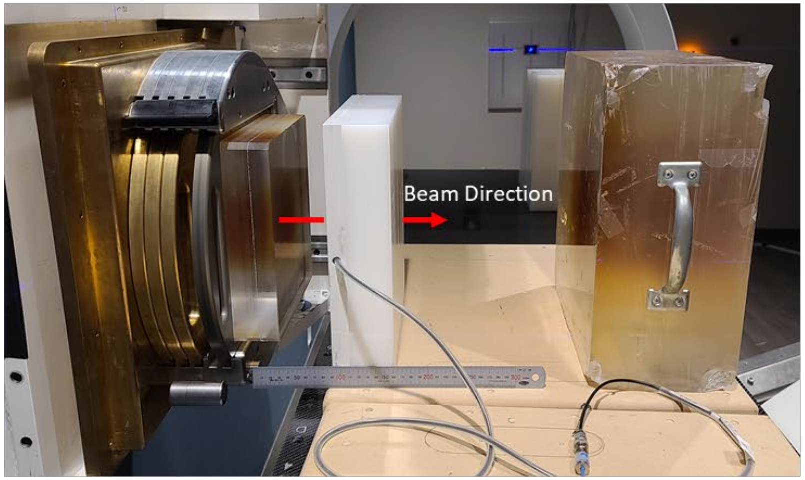
Available Collimators at ProNova	
Shape	Dimension
Round	2 cm dia
Round	8 cm dia
Round	10 cm dia
Square	18 mm x 18 mm
Square	30 mm x 30 mm

Example:
Divergence of a beam from a 3 mm Cu Scatterer collimated by an 8 cm aperture.



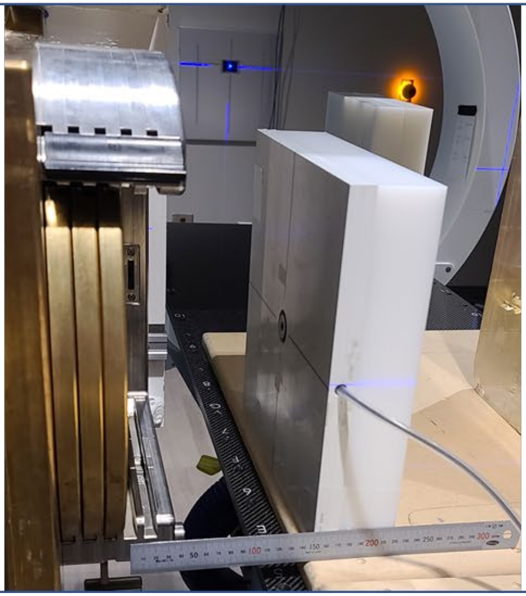
High Flux Small Beam Setup

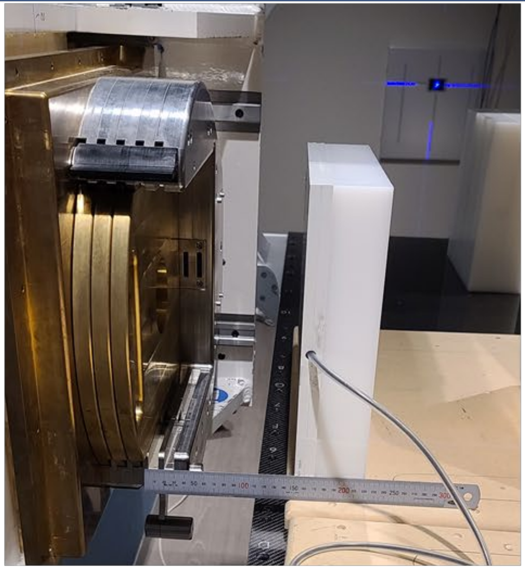




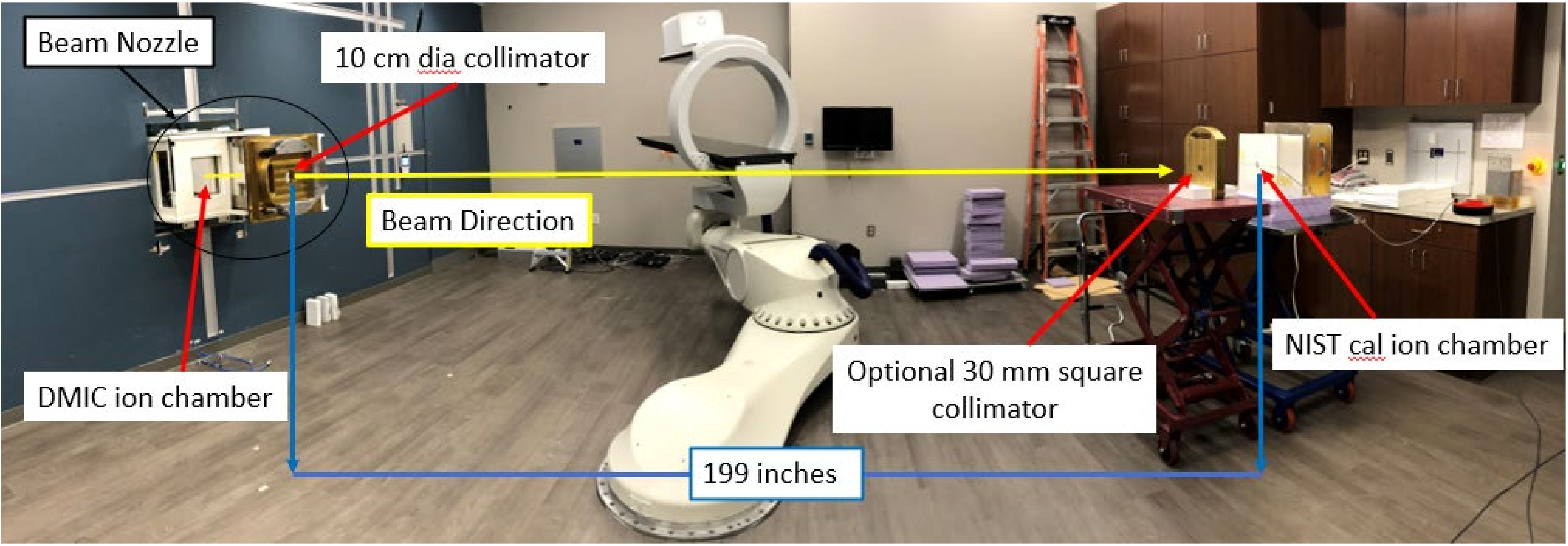
150 MeV, 100 MeV, 80 MeV, 60 MeV and 40 MeV setups typically use an acrylic energy degrader. Ion chamber is at test article location.

200 MeV setup Does not use a degrader. 8 cm dia brass collimator is installed.





Low Flux Large Beam Setup



Flux – What Determines Max and Min Flux?

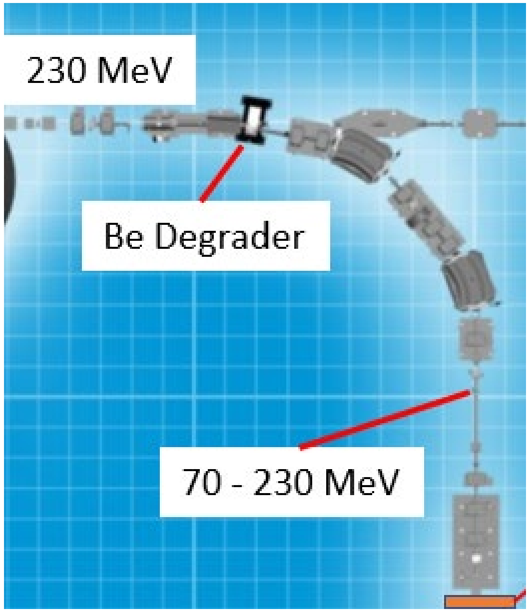
Extracted Beam From Cyclotron:

Maximum	250 nA
Minimum	≤ 20 pA

Measured transmission through Beryllium Degrader:

Variable depending on Energy

@ 200 MeV	~ 32%
@ 150 MeV	~ 7.5%
@ 100 MeV	~ 7.0%
@ 50 MeV	~ 3.4%



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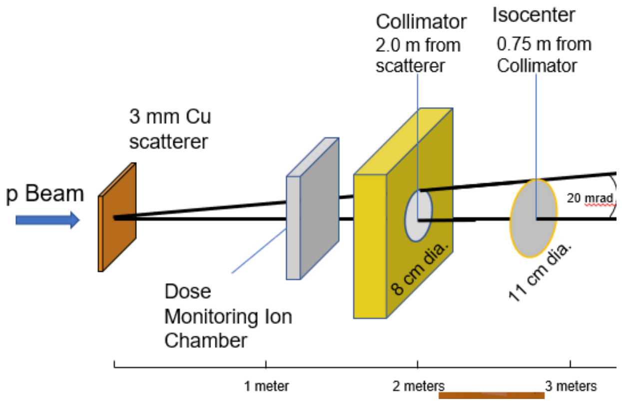
Flux – What Determines Max and Min Flux?

Beam to test article after 3 mm Cu Scatterer:

	Energy at target	3 cm diam
	200 MeV	13%
	150 MeV	9%
Add range shifter		
	100 MeV	8%
	50 MeV	4%



Using TRIM to calculate transmission through the nozzle to get this transmission.

Flux – What Determines Max and Min Flux?

Maximum and Minimum flux is limited by the transmission and the lowest beam current we can get from the cyclotron:

Maximum Flux Calculation for small area close to nozzle					Calculated
	Energy		Requested	# Protons	# Protons at Target Max
	200 MeV	Limited to	18.0 nA	1.1E+11 p/s	6.7E+08 p/cm^2/s
	150 MeV		200.0 nA	1.3E+12 p/s	1.2E+09 p/cm^2/s
	100 MeV		200.0 nA	1.3E+12 p/s	1.0E+09 p/cm^2/s
	50 MeV		200.0 nA	1.3E+12 p/s	2.6E+08 p/cm^2/s
Minimum Flux Calculation for small area close to nozzle					
	Energy		Requested	# Protons	# Protons at Target Min
	200 MeV	Limited to	0.05 nA	3.1E+08 p/s	1.9E+06 p/cm^2/s
	150 MeV		0.05 nA	3.1E+08 p/s	2.9E+05 p/cm^2/s
	100 MeV		0.05 nA	3.1E+08 p/s	2.6E+05 p/cm^2/s
	50 MeV		0.05 nA	3.1E+08 p/s	6.6E+04 p/cm^2/s

Using TRIM to calculate transmission through the nozzle to arrive at flux.

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Flux – What Determines Max and Min Flux?

Maximum and Minimum flux is limited by the transmission and the lowest beam current we can get from the cyclotron:

Maximum Flux Calculation for large area 5 meters downstream of nozzle					
	Energy		Requested	# Protons	# Protons at Target Max
	200 MeV	Limited to	18.0 nA	1.1E+11 p/s	4.8E+07 p/cm^2/s
	150 MeV		200.0 nA	1.3E+12 p/s	8.4E+07 p/cm^2/s
Minimum Flux Calculation for large area 5 meters downstream of nozzle					
	Energy		Requested	# Protons	# Protons at Target Min
	200 MeV		0.02 nA	1.3E+08 p/s	5.3E+04 p/cm^2/s
	150 MeV		0.02 nA	1.3E+08 p/s	8.4E+03 p/cm^2/s

Using TRIM to calculate transmission through the nozzle to get this transmission.

Flux – What Determines Max and Min Flux?

The Min and Max Flux are very dependent on the setup. Actual maximum flux is less than what is calculated.

Maximum flux achievable for 200 MeV **~ 7.0 E+08 p/cm^2/s**

Maximum flux for a large field at 200 MeV **~ 3.0 E+07 p/cm^2/s**

Minimum flux achievable for 200 MeV **~ 5.0 E+03 p/cm^2/s**

(with some tricks ☺)

Maximum and Minimum flux is lower for lower energies.

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Beam Performance: Energy

Proton Energy Range

Calibrated Proton Energy Ranges

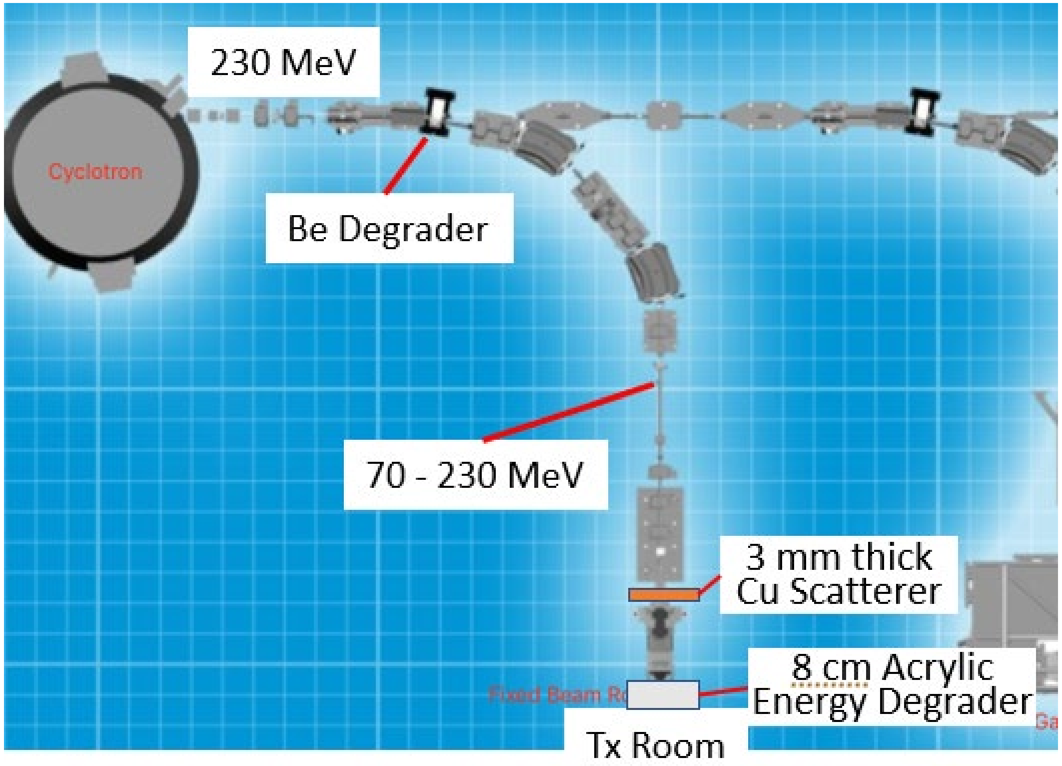
221 MeV to 50 MeV

Lower energy is theoretically possible, to be explained.

Beam Performance - Energy

Proton Energy Accounting:

Fixed Cyclotron Energy: 230 MeV
Be Degrader Range: 230 – 70 MeV
Copper Scatterer: (8.1 – 11.3 MeV)
Acrylic Degrader: (34.1 – 85.1 MeV)
Air Path: (~ 0.5 MeV/meter)



Beam Performance - Energy

The ProNova SC360 proton therapy system is designed to be used for treating cancers in humans. Currently it is only used for continuing R&D and testing of the SC360 medical device and to provide protons for radiation effects testing.

Because we are geared to the medical treatment of cancers, we use a different language to describe the quality of proton beams:

Rad Effects Terminology	Medical Device Terminology
Proton Energy (MeV)	Range in Water (g/cm^2)
Dose in Si or SiO_2 (kRad)	Dose in Water (Gray)
Flux ($p/cm^2/s$)	Dose Rate in DMIC (MU/s or counts/s)
Fluence (p/cm^2)	Dose in DMIC (MU or counts)
LET* (MeV cm^2/mg)	Stopping Power or -dE/dx (MeV/cm)
Collimator	Aperture

* Electronic Mass Stopping Power

Beam Performance - Energy

You will see some of this in the calculation of the beam energy on target based on the requested range setting of the SC360.

Proton Energy at DUT		200 MeV	25.96	cmR H2O
Range Shifter [cmR H2O]	0	200.00 MeV	25.96	cmR H2O
Cu spreader thickness [mm]	1.875	205.06 MeV	27.09	cmR H2O
BMS range setting		27.09 cm		

Dose (Water) per MU	4.15E-03	Gy/MU
	2.59E+04	MeV/mg/MU
	4.150E-04	krad /MU
LET(H2O)	4.49E-03	MeV/mg/cm^2
LET(SiO2)/LET(H2O)	0.833	
Fluence (p's/sq cm)/MU	5.77E+06	p's/cm^2/MU
(Dose(H2O)/MU)/LET(H2O, Ed)	5.77E+06	

Material Type	Si
LET	3.628E-03

Setup:

Nozzle Position:	Retracted
Apertures:	30 mm square
Number of Apertures	3
Range Shifter:	None
Cu Spreader:	1.875 mm
Notes:	
1. Place test article 25 cm from face of aperture.	
2. 1.875 mm = 1mm square Cu spreader + brass plate	

Enter Flux Requested	1.00E+09
Requested [nA]	30.18
RSST [nA]	5.84

Part ID	Run #	Date	Start Time	Run Duration [sec]	Counts	Dose [MU]	Fluence [p's/cm^2]	LET (Si) [MeV / mg/cm2]	Dose (Si) [kRad]	Flux Meter [p's/cm^2/s]	Comments
	1					0.0	0.00E+00	3.628E-03	0.000		
	2					0.0	0.00E+00	3.628E-03	0.000		
	3					0.0	0.00E+00	3.628E-03	0.000		
	4					0.0	0.00E+00	3.628E-03	0.000		
	5					0.0	0.00E+00	3.628E-03	0.000		

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Proton Energy Range

Some customers have asked for 20 MeV beam.

Although the dose record spreadsheet can calculate settings for 20 MeV, calibrating for flux, fluence and dose in the test article is problematic.

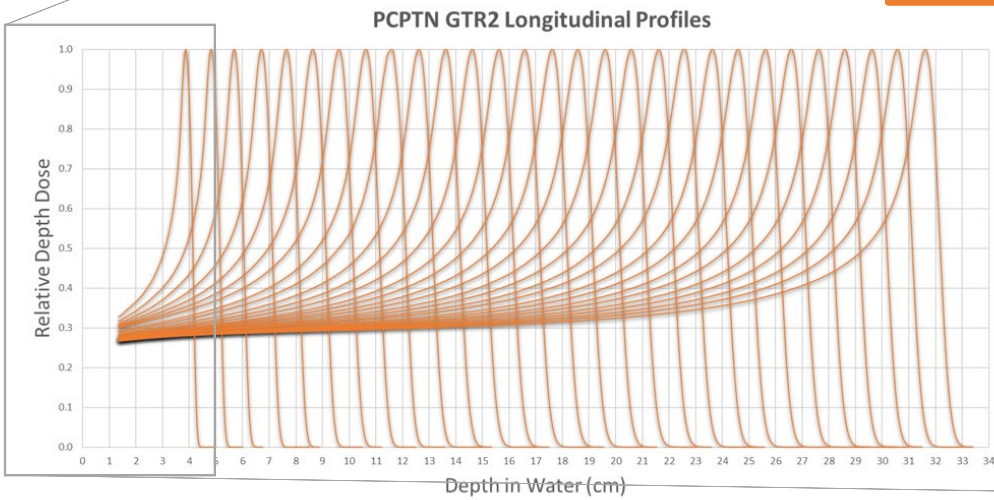
The Difficulty with 20 MeV Protons

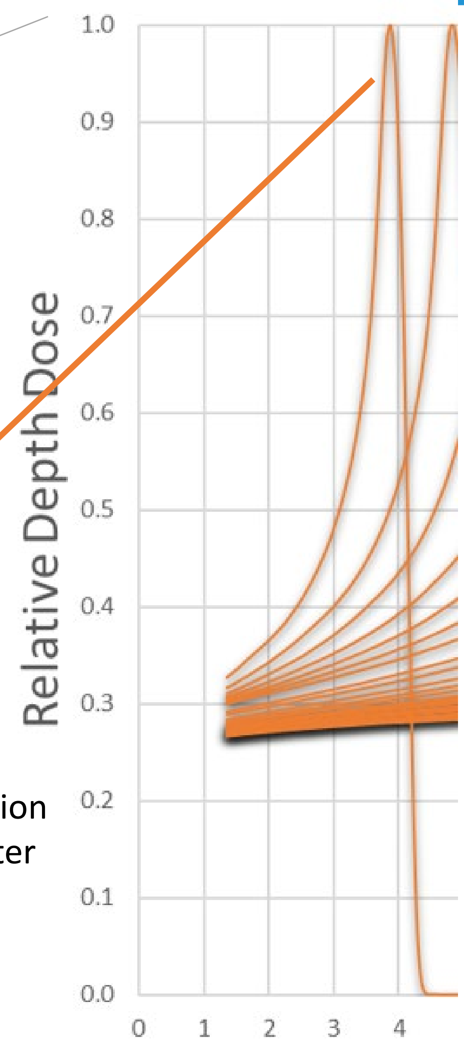
For a Proton Therapy System, the depth in water is used to calibrate the proton energy. We use a PPC05 "Markus" ion chamber, a parallel plate ion chamber with an entrance window of 1mm plastic and a volume of 46 mm^3 of air. Here are some measured Bragg Peaks.

Range is defined as the 80% distal point of the Bragg Curve.

Longitudinal Bragg Peak Profiles

Measured Bragg Peak Profiles



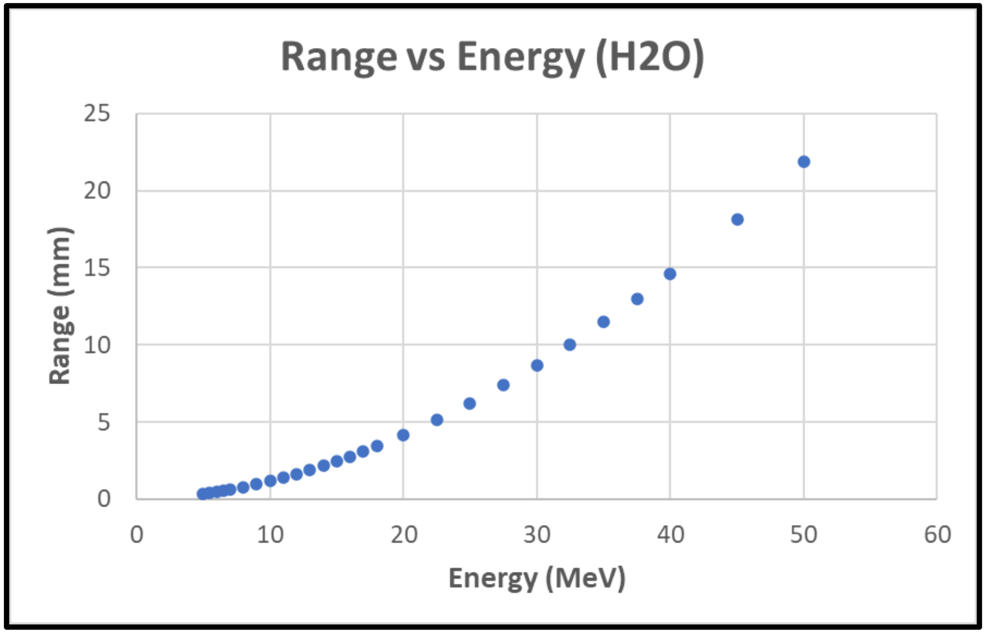


Bragg Peak curves are measured by scanning an ion chamber in depth in a water tank.

The Difficulty with 20 MeV Protons

The 4 cm range Bragg Peak requires 70 MeV protons.

At 20 MeV, the calculated proton range, in H_2O, is only 4.17 mm!!

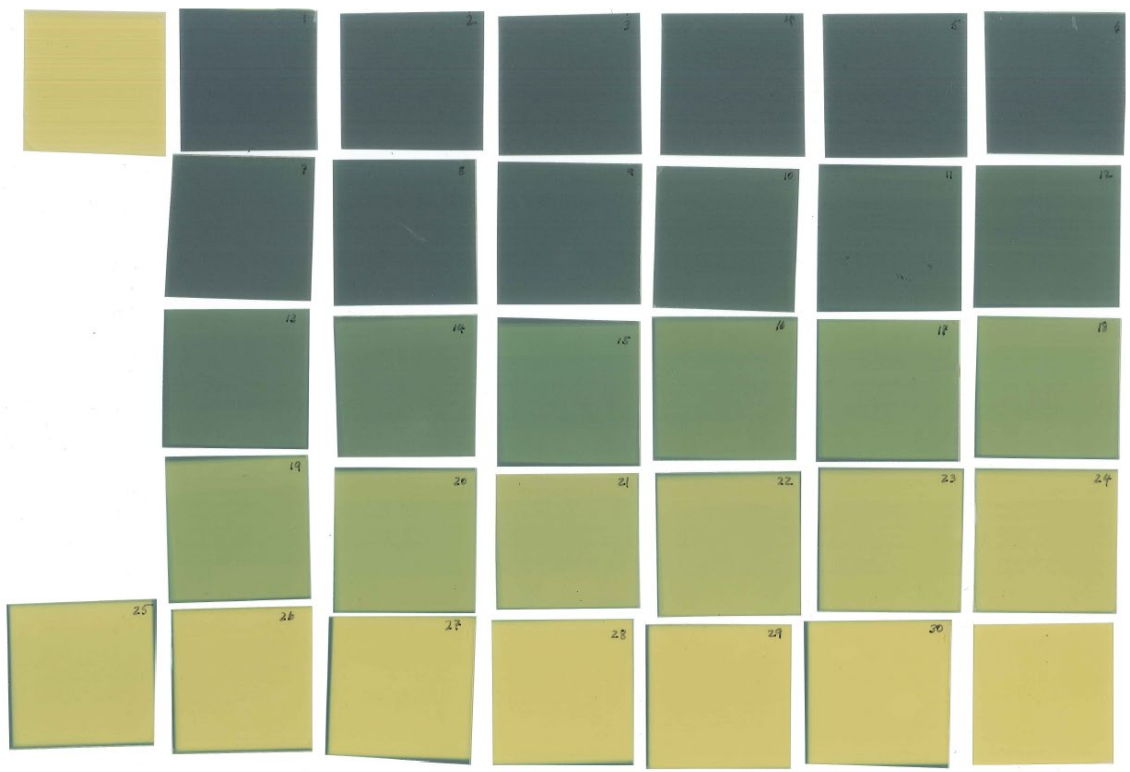


Data obtained using SRIM.

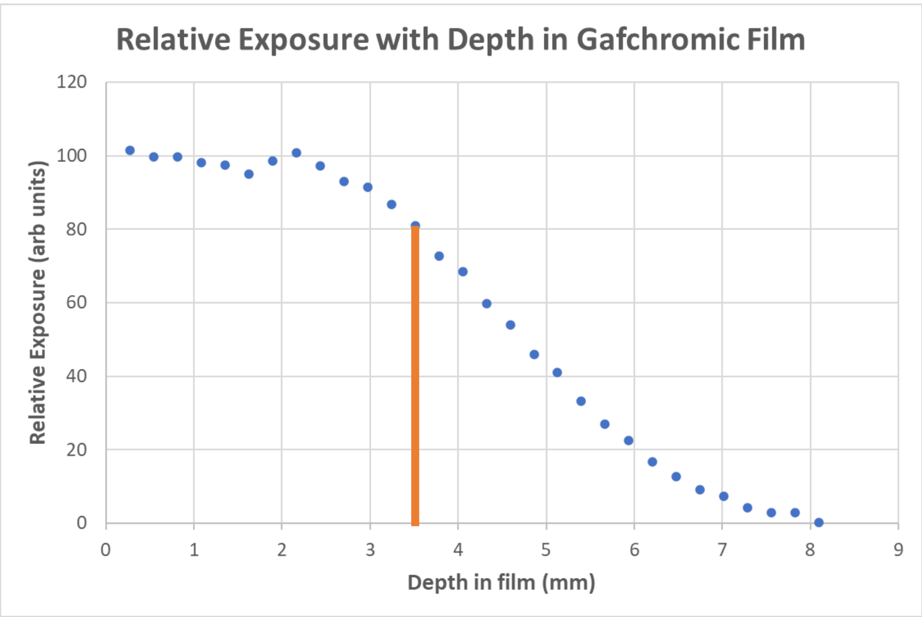
Question: How reliable is the flux/dose calibration using a Markus type ion chamber?

Measuring Depth Dose of 20 MeV Protons: Method 1

Energy Verification Method: EBT3 Gafchromic film was cut into 2” squares and stacked to 7.56 mm thick. The SC360 was setup to deliver 20 MeV beam.
Film was exposed, scanned, and density evaluated to generate the plot in the next slide.



Measuring Depth Dose of 20 MeV Protons : Method 1



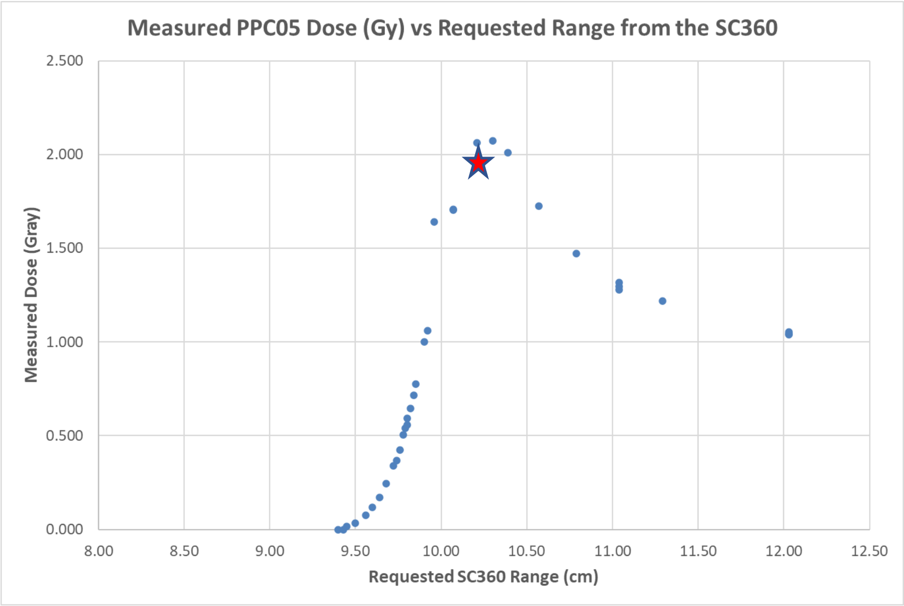
Result: The 80% distal point on the curve falls at 3.5 mm of film thickness. This is roughly equivalent to 4.17 mm of water.

The film density is about 1.2 g/cm^2 compared to water 1.0 g/cm^2.
Ratio of the range of water to measurement is 4.17 mm/3.5 mm = 1.19.

This result is evidence that the energy is close to the 20 MeV expected.
The flat entrance dose is due to longitudinal straggling in the acrylic degrader.

Measuring Dose Calibration of 20 MeV Protons: Method 2

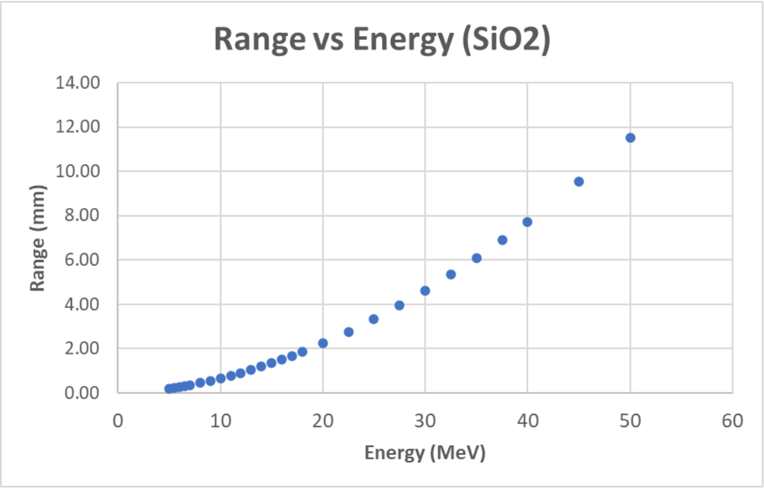
Dose Calibration Method: A PPC05 "Markus" type ion chamber was placed in the beam path. The requested range of the SC360 was varied between 12 cm and 9.4 cm corresponding to 50 MeV and 0 MeV requested. The dose delivered was measured.



Result: The distribution resembled a Bragg Peak. The actual range expected at the ion chamber is the requested minus the range loss in the Cu scatterer and the Acrylic degrader. For 20 MeV this should be ~ 10.21 cm.

The measured distal 80% point is ~ 10.2 cm correspond to a range of 4.0 mm, similar to the film measurement and verifying that the beam is 20 MeV.

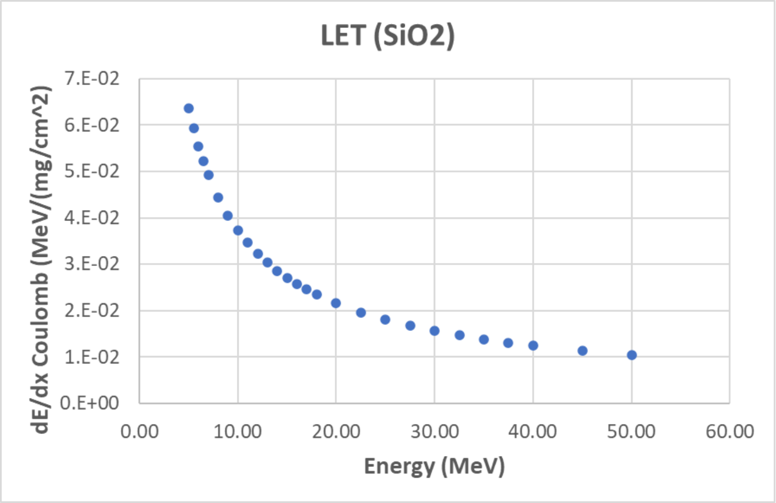
Measuring Dose Calibration of 20 MeV Protons



The range in SiO_2 for 20 MeV protons is only 2.1 mm!!

What dose is your device receiving??

Uncertainty of energy (20 MeV +/- 5 MeV) and longitudinal straggling contribute to averaging out the LET vs depth as seen with the film results.



Measuring Dose Calibration of 20 MeV Protons

Question: How reliable is the flux/dose calibration using a PPC05 Markus type ion chamber?

Answer: Due to the rapidly changing LET with depth of penetration of a 20 MeV beam, the flux calibration is best determined by estimation only.

Bottom line is that if you want 20 MeV, it is your responsibility to understand the quality of the beam and its contribution to the dosimetry. This applies to almost any facility willing to deliver 20 MeV proton beam.

Advantage: Comprehensive

- Proton energies from 50 MeV to 200 MeV are standard. 20 MeV and 220 MeV beams by request.
- Field size range is 1.8 cm square to ~20 cm diameter. Pristine un-scattered beam can also be delivered by request.
- Proton fluxes (protons/cm^2/s) range from ~ 1E+04 to ~ 7E+08, depending on the proton energy and field size required.
- Proton fluences (protons/cm^2) up to 1E+12 (1×10^{12}) can be achieved in a reasonable time.
- Experienced and knowledgeable cyclotron engineers who can assist in supporting your missions.

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6. Conclusion

- ProNova is ready to provide services at the Thompson Proton Center for radiation effects testing with protons.
- A dedicated accelerator and beamline eliminate any beam sharing with the operating clinic.
- A spacious irradiation vault makes setup of your DUT and test equipment convenient.
- A wide range of support materials are ready for you to use.
- Cables can be run under the shielding doors from your test equipment to your data acquisition computers and electronics.

COVID 19: COVID protocols may change as needed. Please contact Jewell Overton for the most up-to-date-information.

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Contact Information

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