MOLLER Collaboration Meeting
May 05-06, 2023

Scattered Beam Monitors (SBM) and Scanner Detectors (SD)

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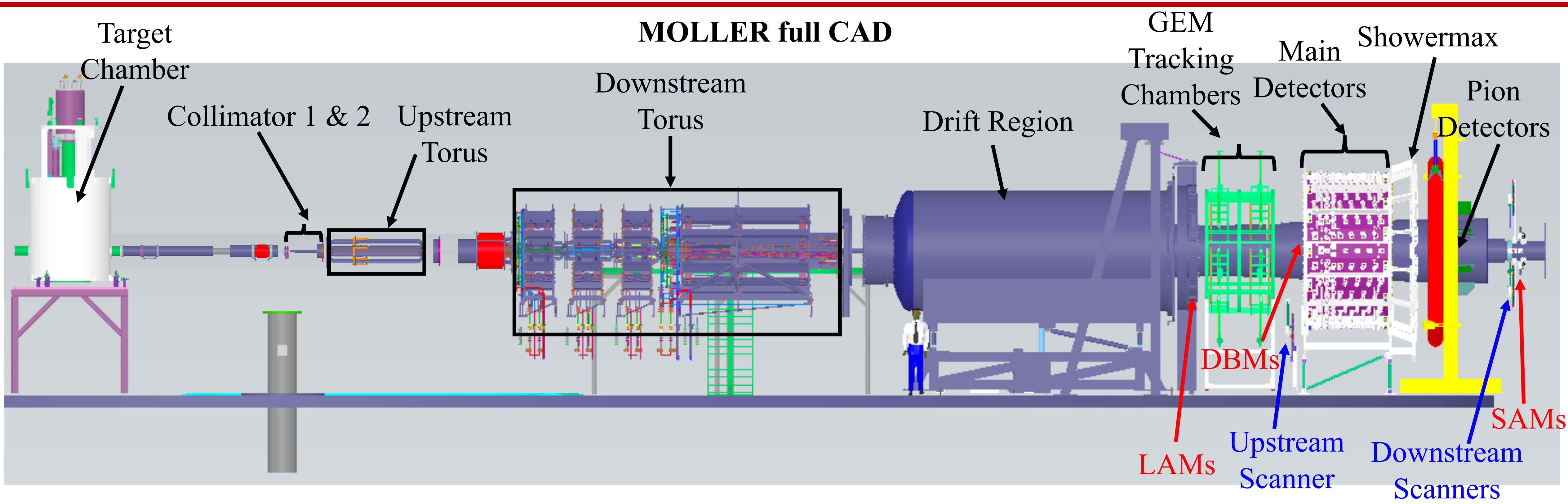
MOLLER Apparatus Overview

MOLLER full CAD



Scattered beam monitors (SBMs):

- Large Angle Monitors (LAMs) – 7
- Small Angle Monitors (SAMs) – 8
- Diffuse Beam Monitors (DBMs) – 14 DBM boxes
  - ❖ Integrating Cherenkov detectors
  - ❖ Sensitive to potential false asymmetry from rescattered background

Scanner Detectors (SDs)

- Upstream Scanner – 1
  - ❖ Scans in two dimensions
  - ❖ Counting and integrating mode Cherenkov detectors
- Downstream Scanners – 4
  - ❖ Each scanner scans radially in one dimension
  - ❖ Integrating Cherenkov detectors

MOLLER Detectors

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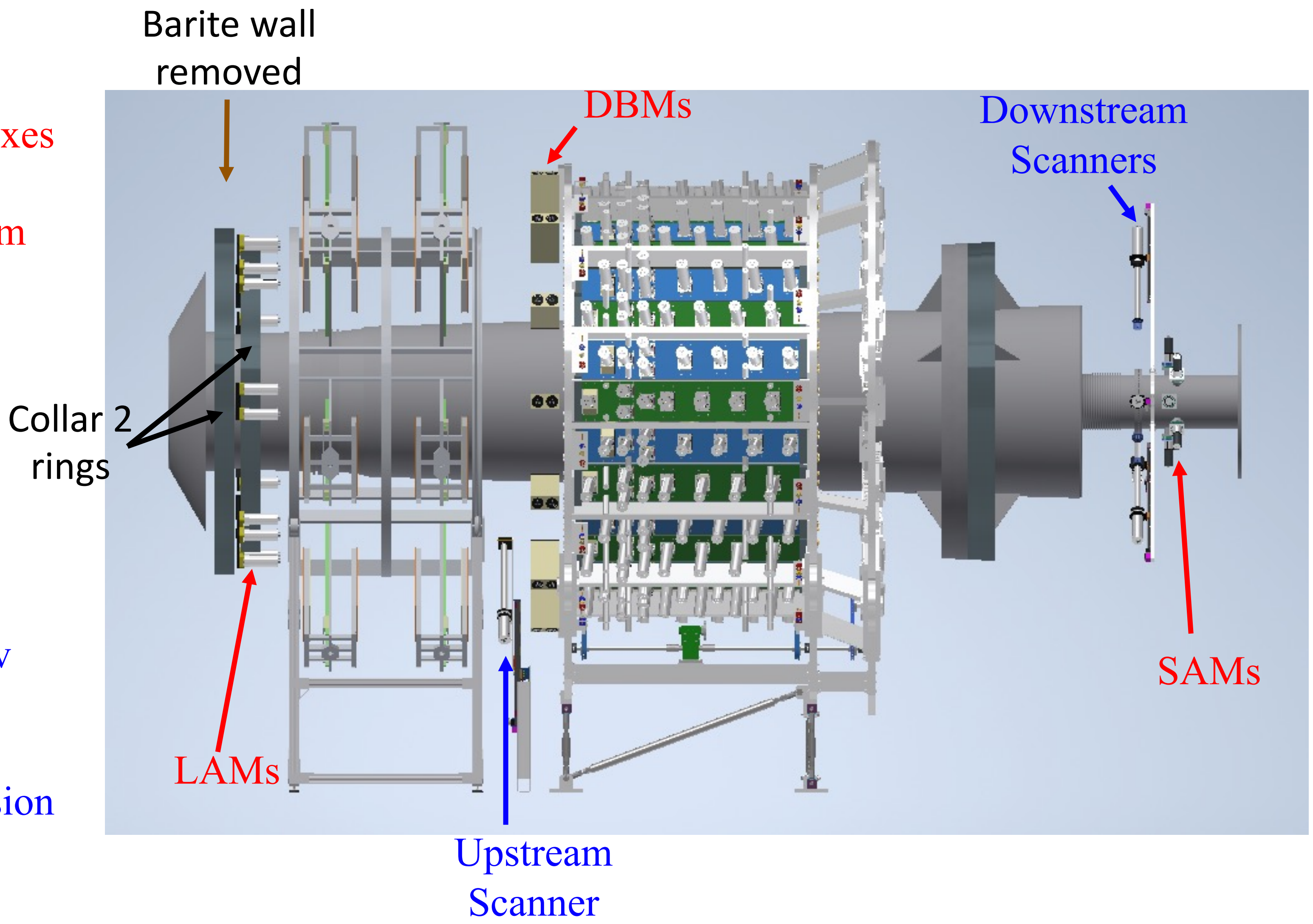


Large Angle Monitors (LAMs) Requirements

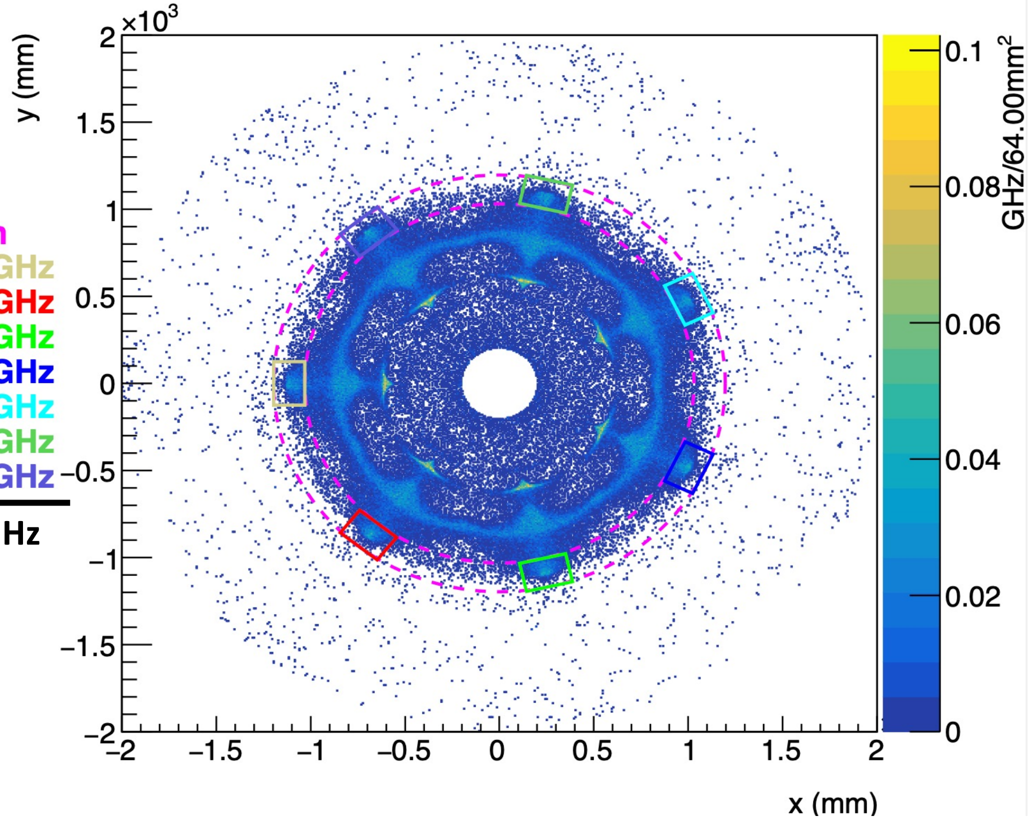
- Large angle, high rate, and small asymmetry
- "Null" asymmetry monitors as a check of helicity-correlated beam correction procedure
- Monitor for potential false asymmetries from rescattered backgrounds
- Accepted flux is dominated by e-p elastic radiative tail
- Total rate gives stat. width ~3.3 x Ring 5 (main physics); smaller (7 vs. 32 ppb) asymmetry

Process	Rate (GHz)	<A> (ppb)	<E> (GeV)
Møller	10.5	10	1.3
Elastic ep	21.2	4	1.1
Inelastic ep	0.1	332	
Total	**31.8**	**7**	

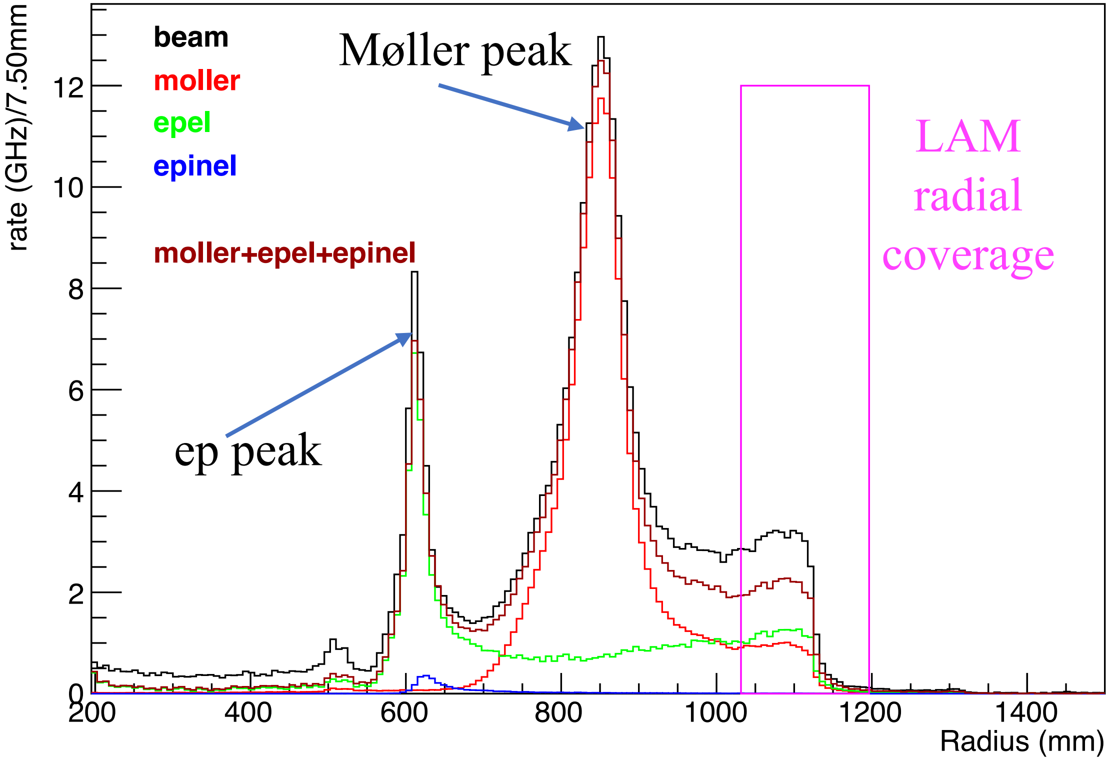
e-/π- (E>1 MeV) XY dist. on det174 (LH2_beam_V40)

L = 250mm
W = 165mm
IR = 1031.5mm
integral=4.39 GHz
integral=4.40 GHz
integral=4.66 GHz
integral=4.64 GHz
integral=4.72 GHz
integral=4.50 GHz
integral=4.44 GHz

Total=31.75 GHz

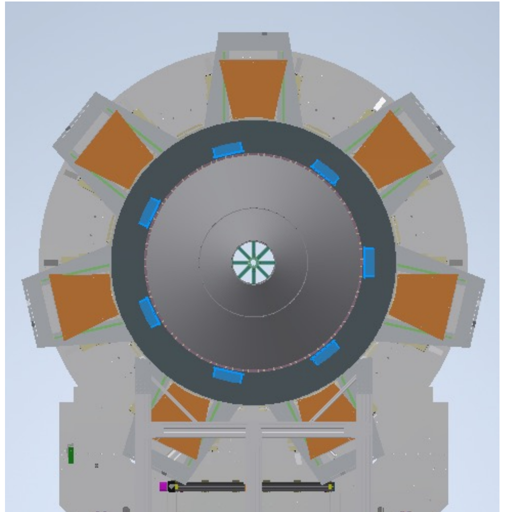


e-/π- (KE>1 MeV) radial dist. at LAM plane

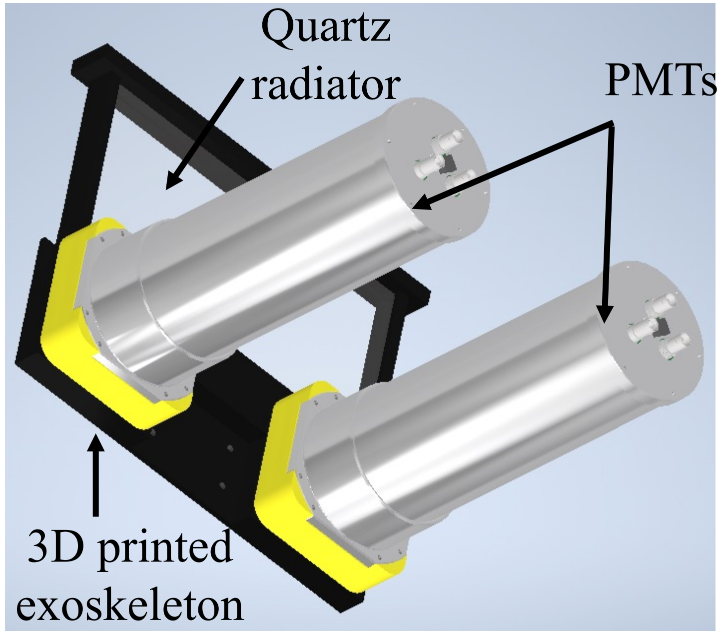


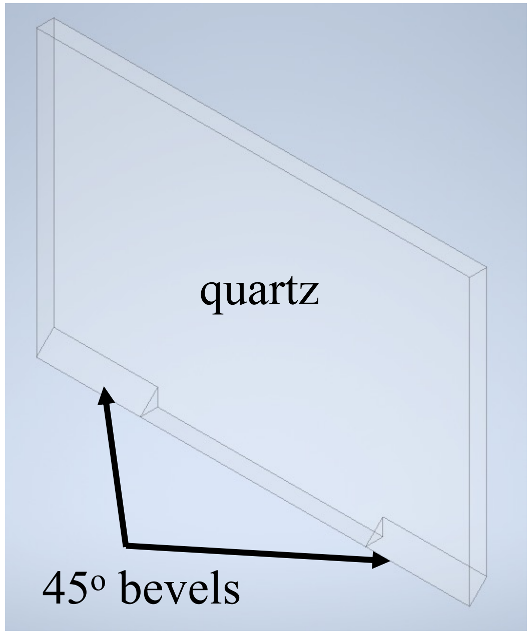
Large Angle Monitors (LAMs) Design

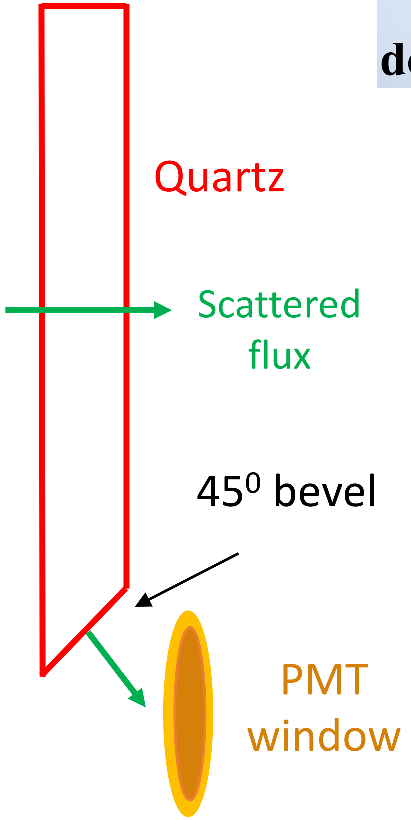
- Seven modules; one in each open sector
- Collar 2 blocks particles scattered (mostly secondaries) at large angles, has two rings made of lead
- Quartz radiator → $25\times16.5\times1$ cm^3, zero bounce design (no need of lightguide)
- LAM quartz sits in between collar 2 outer and inner rings
- PMTs and bevel part of quartz will be behind the shadow of collar 2 outer ring

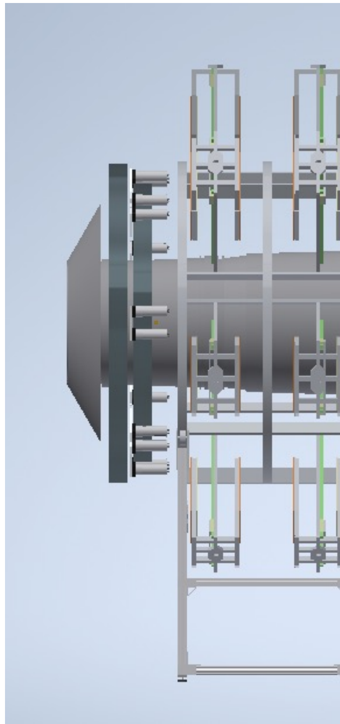


LAM ring looking downstream from target





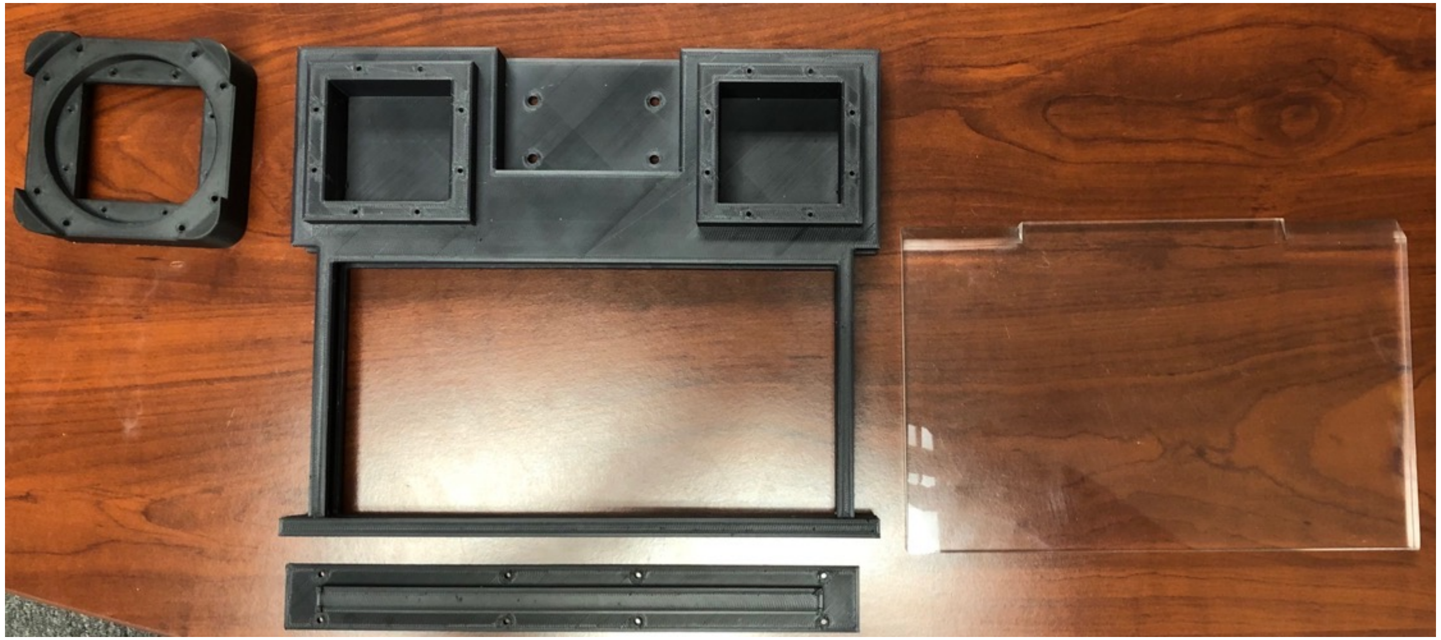


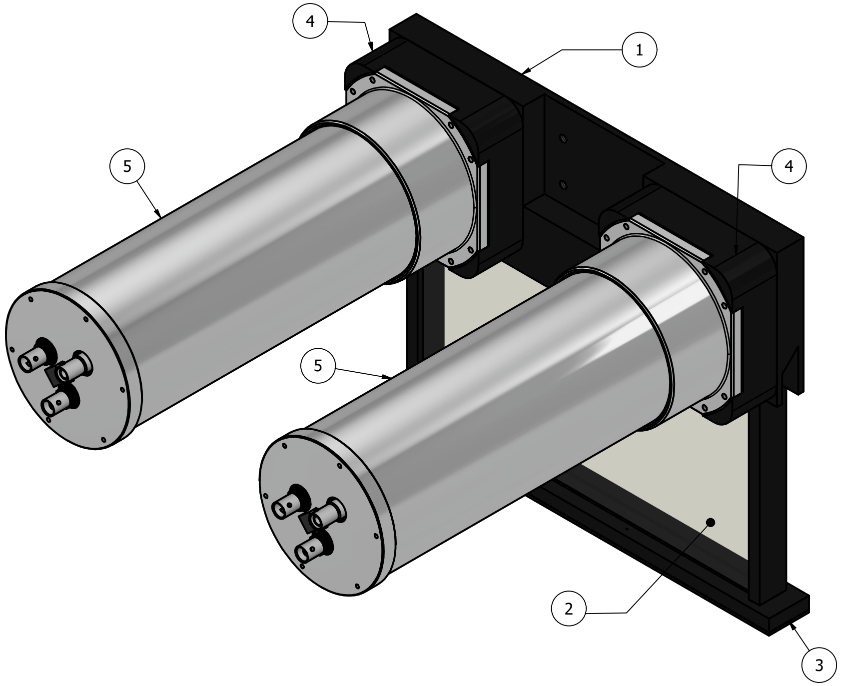


Large Angle Monitors (LAMs) Design

- Each LAM → quartz radiator ($25 \times 16.5 \times 1$ cm^3) and two ET 9305 QKB PMTs
- 3D printed exoskeleton and no lightguide
- PMT housing will be redesigned to encase only PMT and base; will use standalone pre-amplifier
- Prototype construction underway; initial testing with UVT lucite in place of quartz to allow for cosmic ray testing of light yield
- Primary rate of 2 GHz @ 29 PE/event/phototube
- $I_{cathode}$ ~9 nA; @PMT gain = 540; I_{anode} ~5 µA
- I-V preamp, ~0.5 MΩ gain, 2.5 V output
- Similar operating conditions as main detector Ring 5

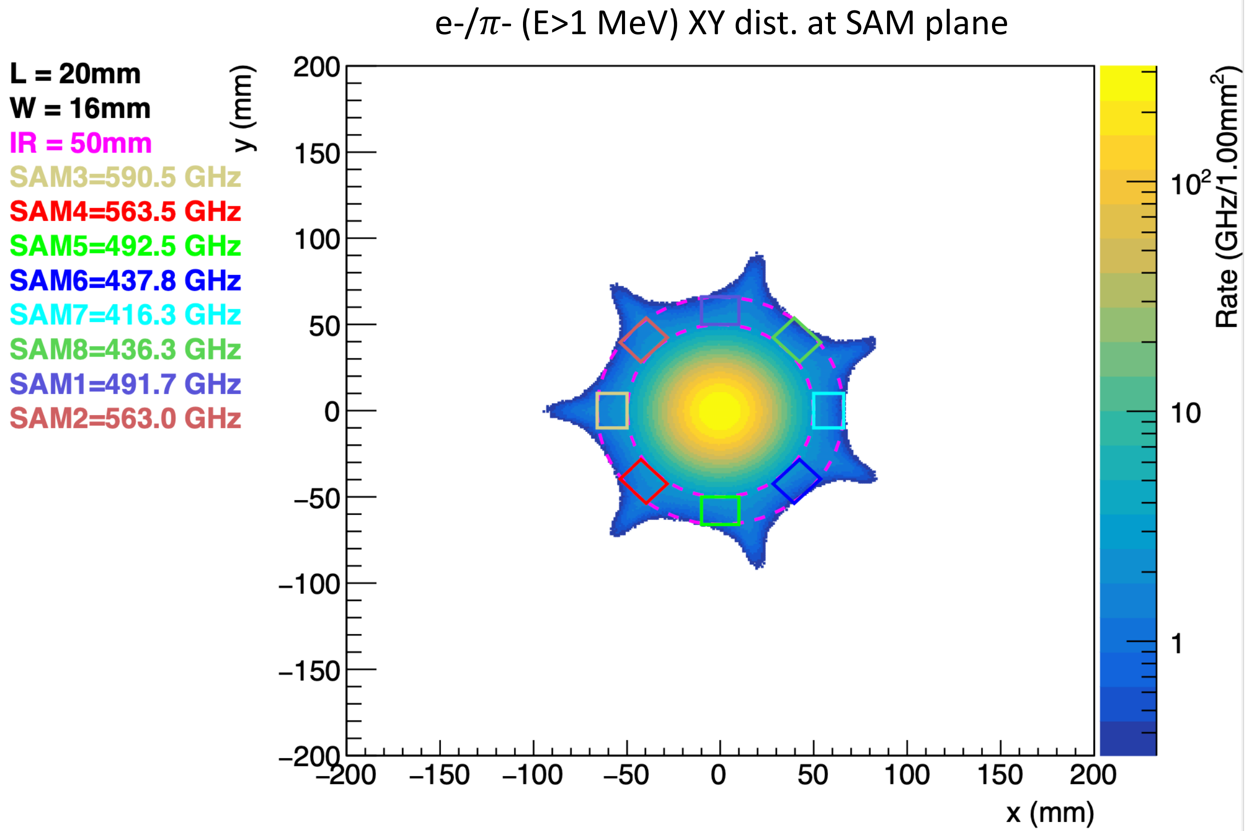
PARTS LIST				
ITEM	QTY	PART NAME	MATERIAL	DESCRIPTION
1	1	LAM Tray	ABS Plastic	3D Printed
2	1	Lams quartz crystal	Quartz	Spectrosil-2000
3	1	LAM Tray Bottom Cover	ABS Plastic	3D Printed
4	2	LAM LG PMT Interface	ABS Plastic	3D Printed
5	2	PMTHousing	Aluminum housing includes ET 9305QKB PMT and base	The housing will be similar to the main detector housing with an exception that the pre-amplifier will be standalone

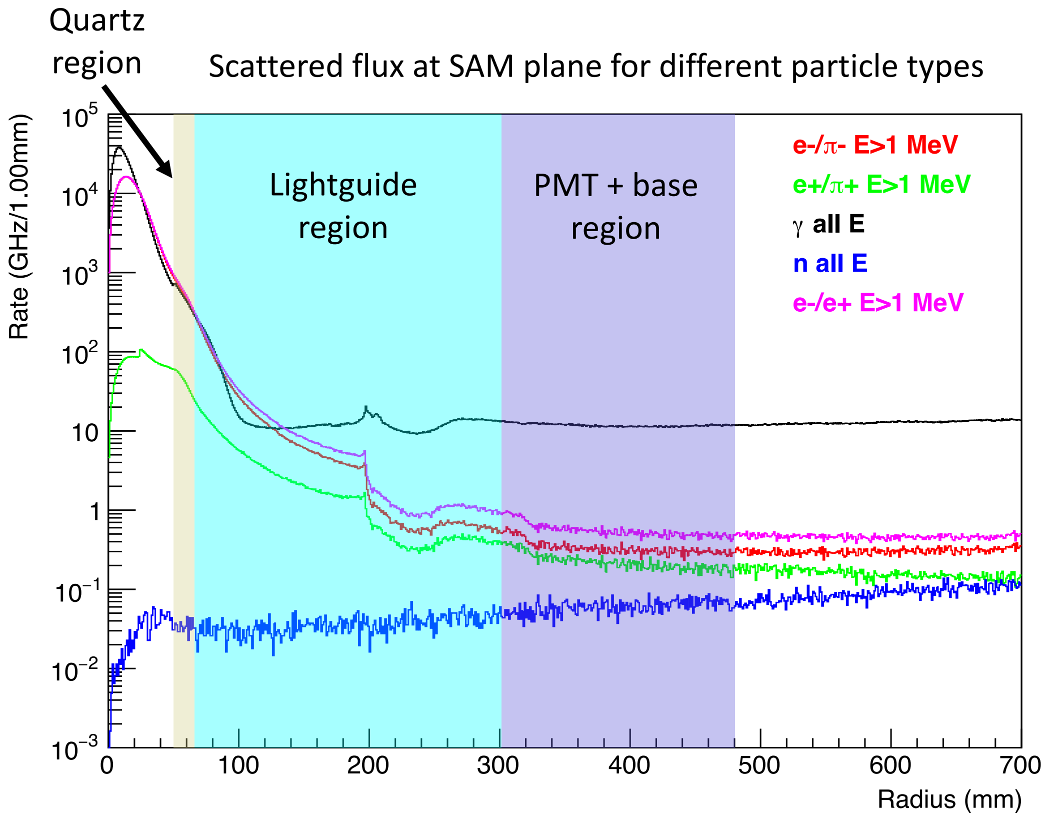




Small Angle Monitors (SAMs) Requirements

- Small lab scattering angle ~0.1^0 (50 mm – 66 mm radial distance)
- Small quartz block (1.6 x 2.0 x 0.6 cm^3), air-core light guide, and PMT (Hamamatsu R375)
- High rate ~450 GHz per SAM, rate depends on at with azimuth the SAM is located
- Small asymmetry ~3 ppb, order of magnitude smaller than main Møller asymmetry
- "Null" asymmetry monitors as a check of helicity-correlated beam correction procedure
- Monitor for potential false asymmetries from rescattered backgrounds

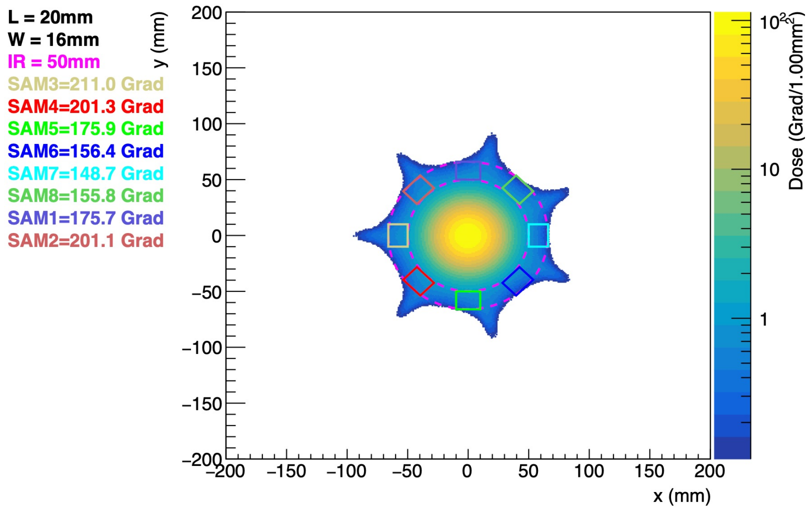


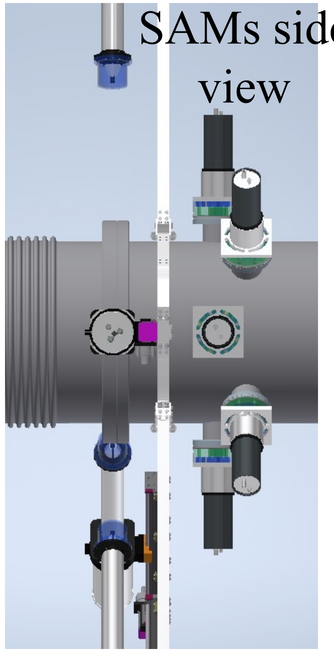


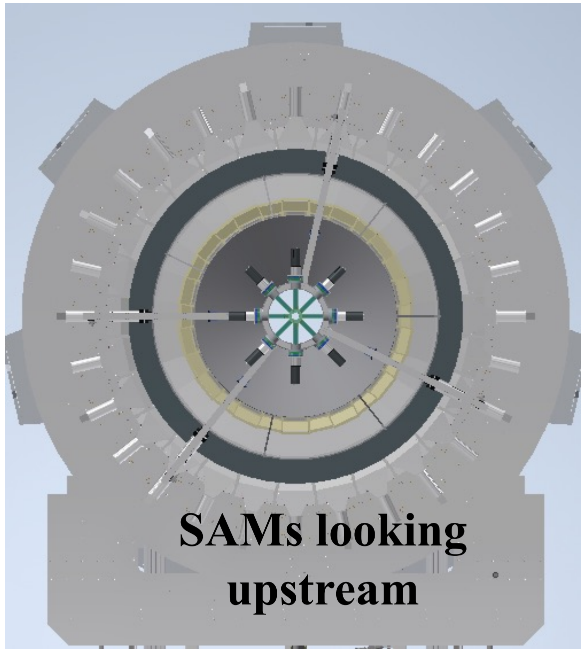
Small Angle Monitors (SAMs) Design and Radiation Damage Concern

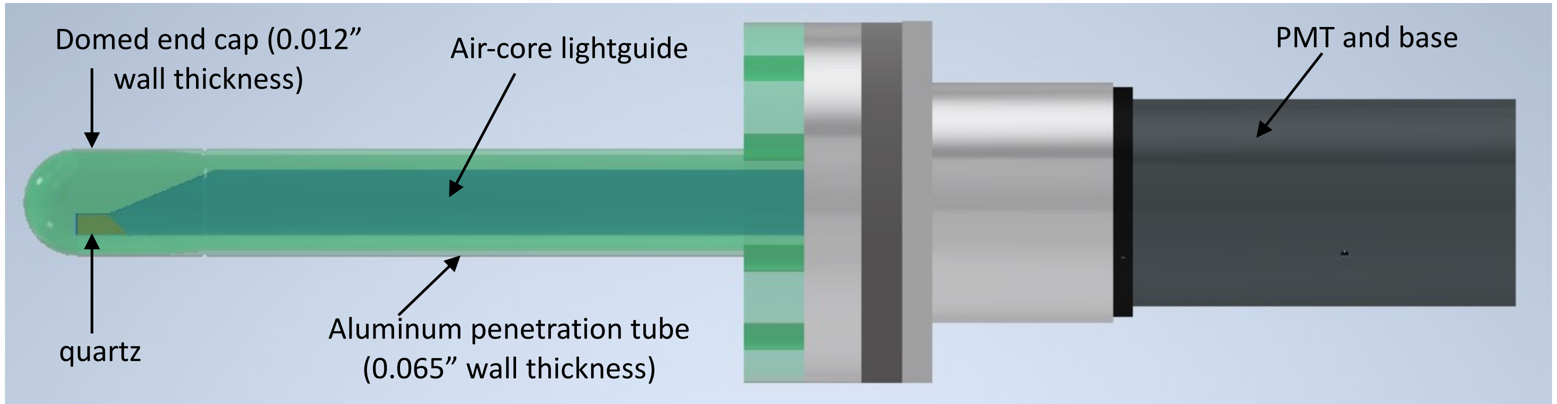
- Interfaced to downstream beampipe
- 8 SAMs symmetric around azimuth
- The total dose for 8256 hours of production running was estimated in simulation in two different ways:
  - ❖ 170 Grad (MIP Energy Deposition method)
  - ❖ 140 Grad (Energy Deposit in Quartz)
  - ❖ Choose 170 Grad to be conservative
- Q_{weak} “SAM” quartz had dose of ~35 Grad with no evidence of damage
- ~57 Grad dose per year for MOLLER production running
  - ❖ New quartz replacement at the beginning of each calendar year can mitigate the risk of damage
  - ❖ SAM PE yield could drop from ~8 PE to ~1 PE and the detectors would still satisfy their requirements

Dose from MIP energy deposition



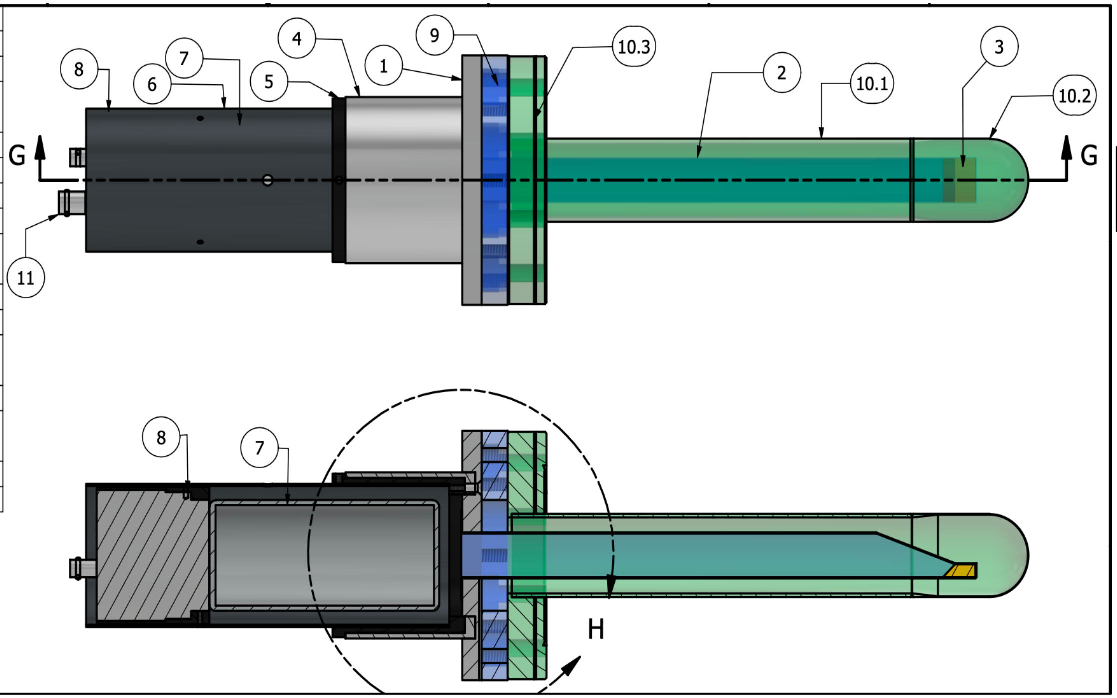


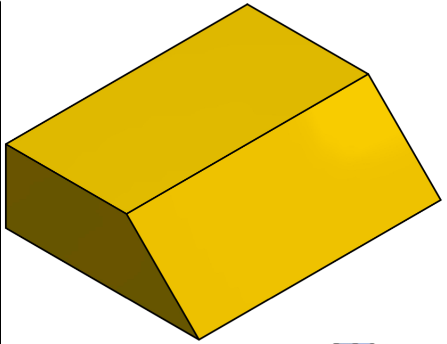


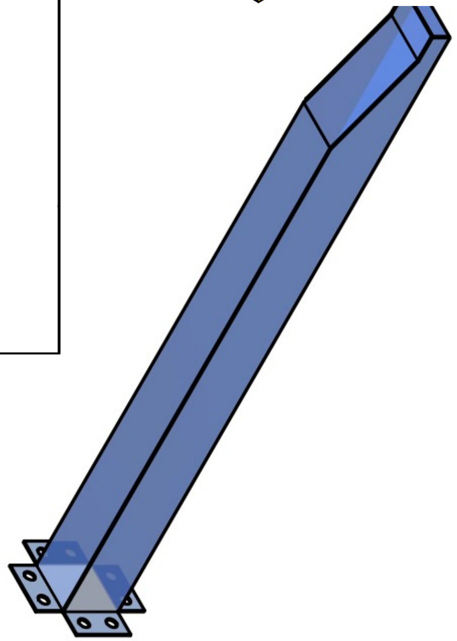


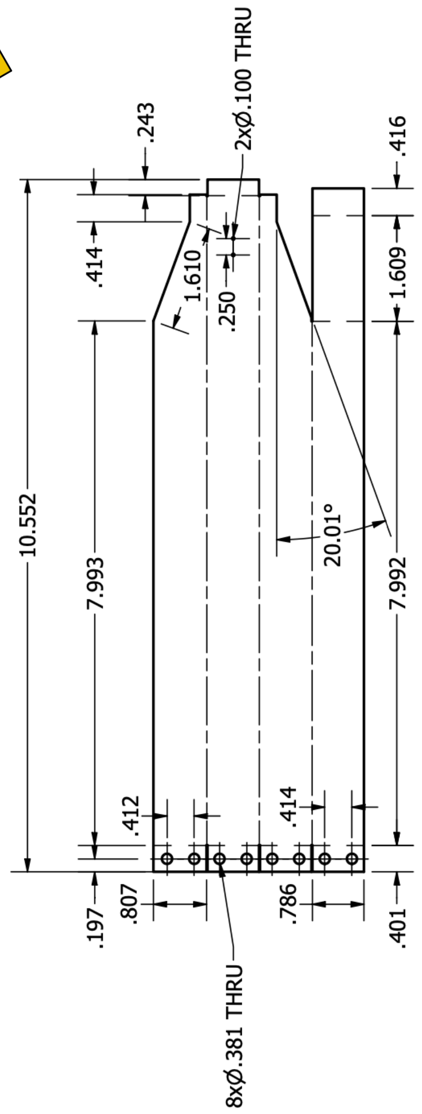
Small Angle Monitors (SAMs) Design Details

PARTS LIST				
ITEM	QTY	PART NAME	MATERIAL	DESCRIPTION
1	1	SAM Front Plate	Aluminum 6061	Machined
2	1	SAM LG sheet	Silvered Reflective Sheet	Machined
3	1	SAM Quartz	Quartz	Spectrosil-2000
4	1	SAM tube holder	Aluminum 6061	Machined
5	1	SAM Plastic Insert	ABS Plastic	3D Printed
6	1	SAM housing	Aluminum 6061	Machined
7	1	SAM PMT	Glass	Inside (Hamamatsu R375)
8	1	SAM Plastic tube	ABS Plastic	Inside (3D Printed)
9	1	SAM Adaptor Plate	Aluminum 6061	Machined
10	1	SAM insert	Aluminum 6061, Welded	Welded
10.1	1	SAM insert pipe	Aluminum 6061	Machined
10.2	1	SAM insert domed cap	Aluminum 6061	Machined
10.3	1	CFTA-0450-04	Titanium/Aluminum	Atlas Bimetal Ti/Al
11	1	SAM PMT base		Custom (TRIUMF)





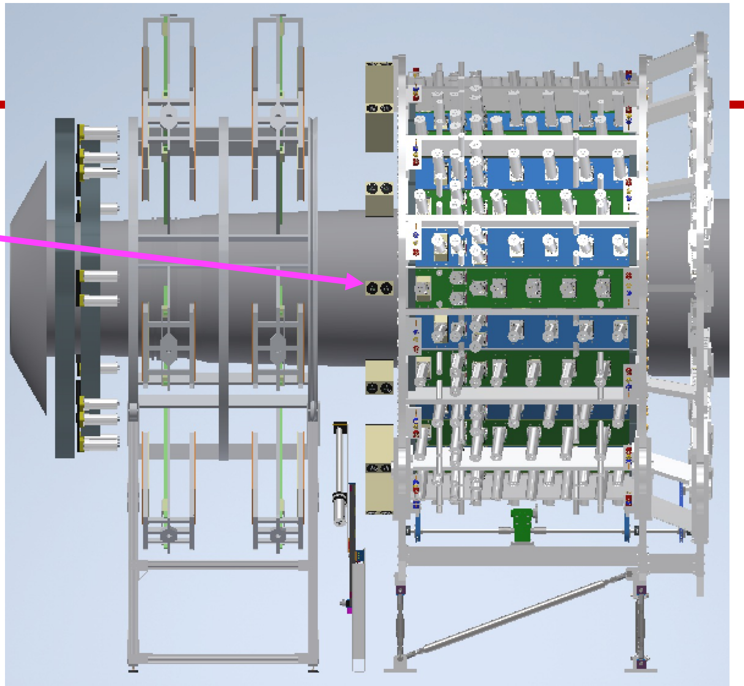




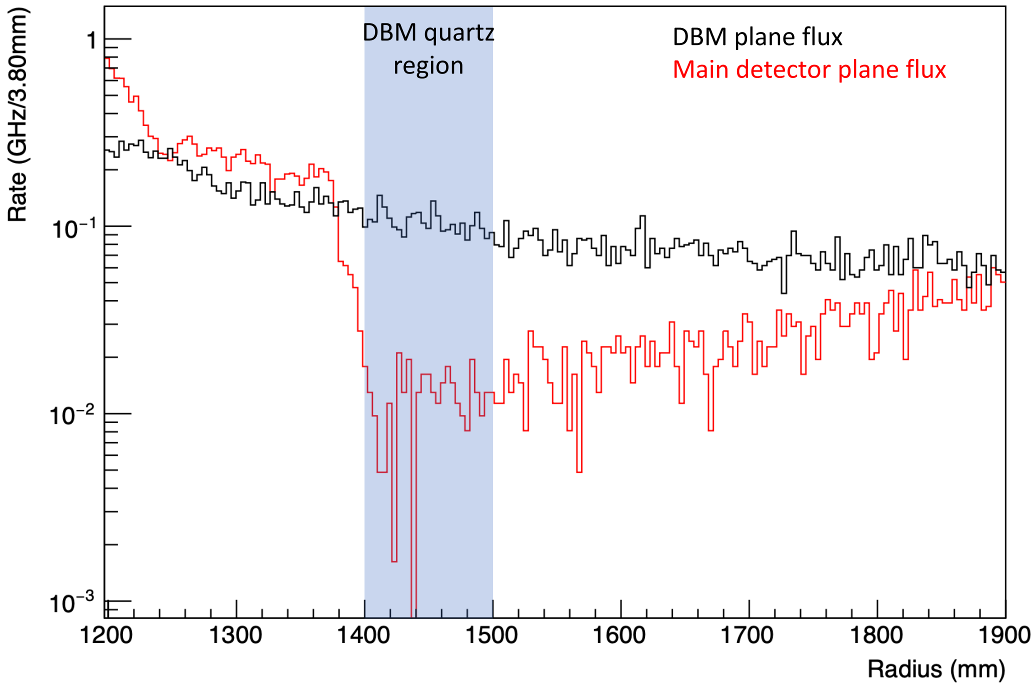
- Prototype construction under way: will study light transport with UVT lucite (instead of quartz) to benchmark simulation
- Electronics readout parameters
  - ❖ Primary rate of 450 GHz @ 8 PE/event
  - ❖ $I_{cathode}$ ~600 nA
  - ❖ Unity-gain base
  - ❖ I-V preamp, ~2.0 MΩ gain, 1.2 V output
- New geometry was implemented in simulation; no significant radiation effect and background to the main detectors due to SAM geometry (including detectors, insertion tubes, flanges, etc) was seen

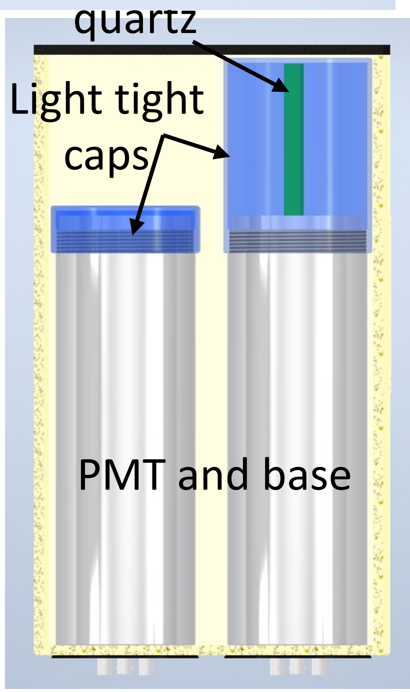
Diffuse Beam Monitors (DBMs)

- “Shadow” of lead collar 2 will have no flux from primary interactions in target – only secondary diffuse background is observed here
- The location just upstream of main detector array satisfies the requirements for diffuse beam monitor detectors
- Locate 14 DBM boxes: one bare ET 9305 QKB PMT and one PMT attached to quartz block 10 x 7.1 x 1.0 cm^3 with SES406 (Shin-Etsu) optical glue in open and closed sectors
- Rate in each quartz DBM detector ~36 MHz during production running, dominated by secondary interactions



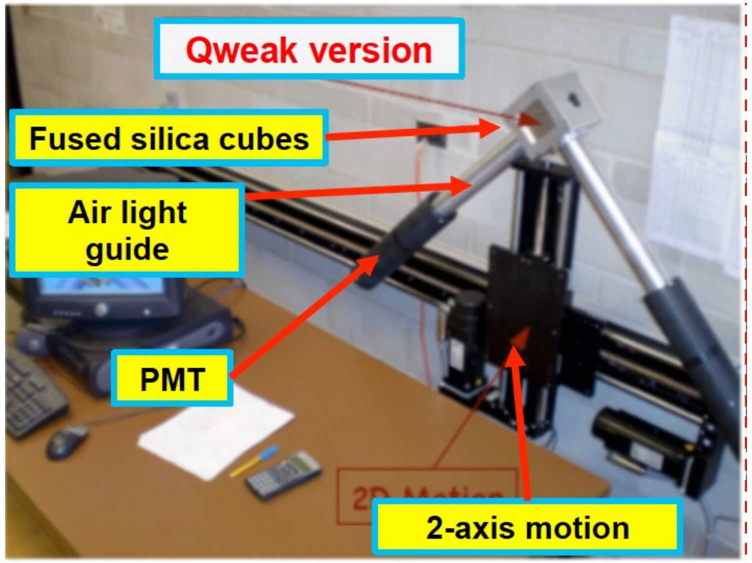
Scattered electron flux at MD and DBM plane

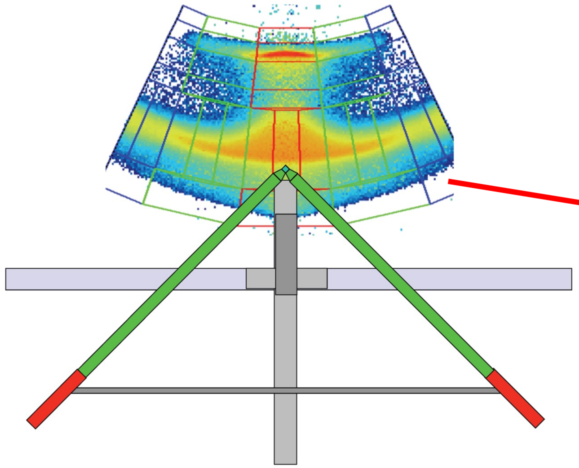


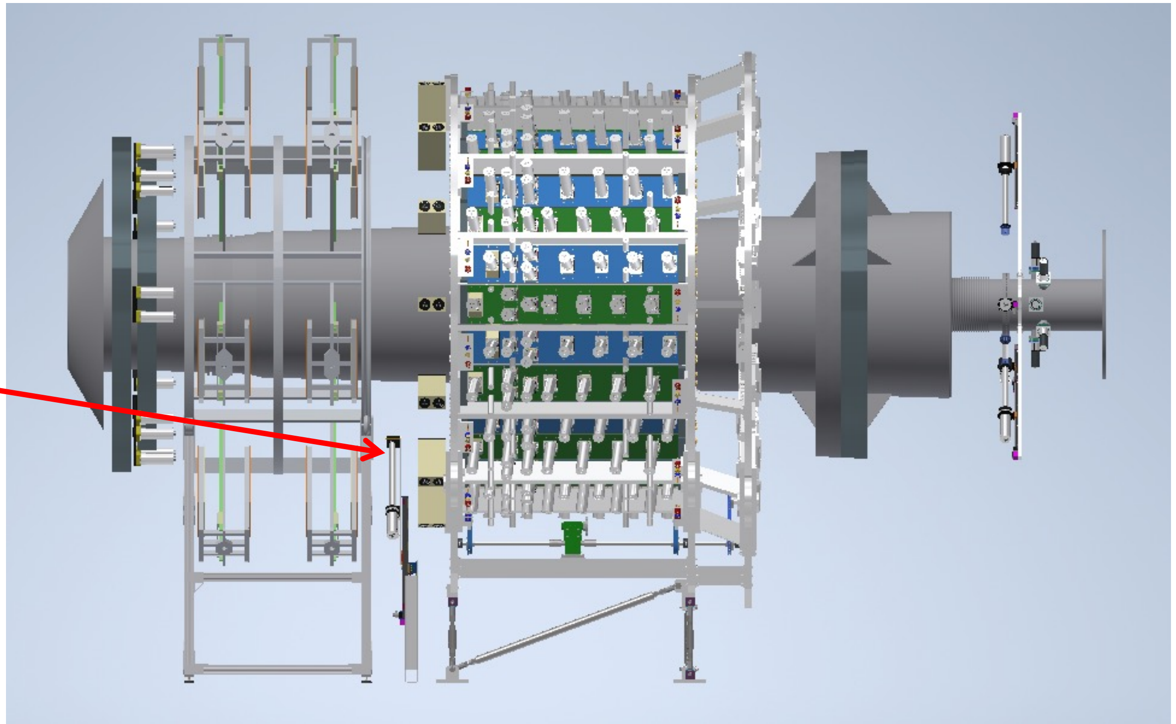


Upstream 2D Scanner Requirements

- Measure the scattered rate distribution in a sector (or combination of two sectors to make a complete one) at low and high beam currents; verify they are the same; monitor stability of kinematics and backgrounds
- Operates in counting and integrating modes
- Full scan in < 1 hour
- Can monitor for shifts ~0.5 mm in the profile, which could happen from a drift of 10^{-3} in the B*dl of the spectrometer field
- Can provide a more regular (if needed) monitor of the stability of the profile than the full tracking system which will only be deployed every few weeks

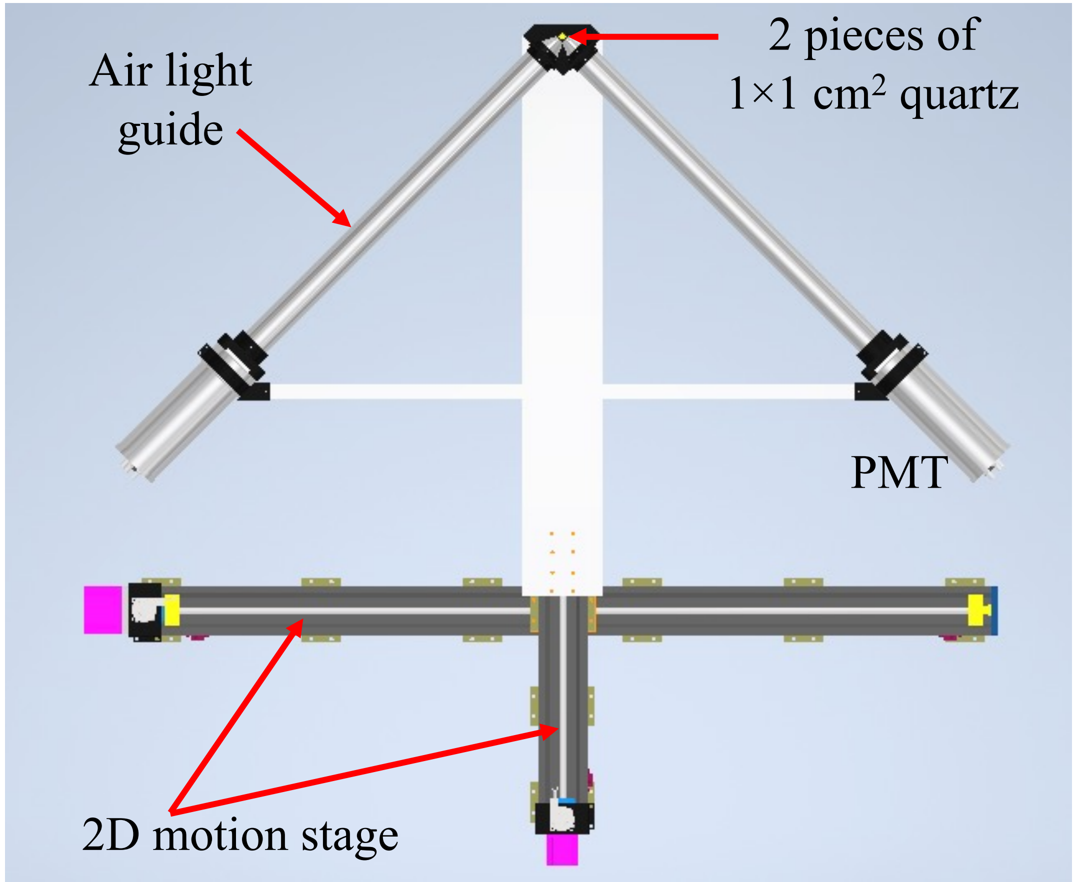






Upstream 2D Scanner Design and Expected Rate

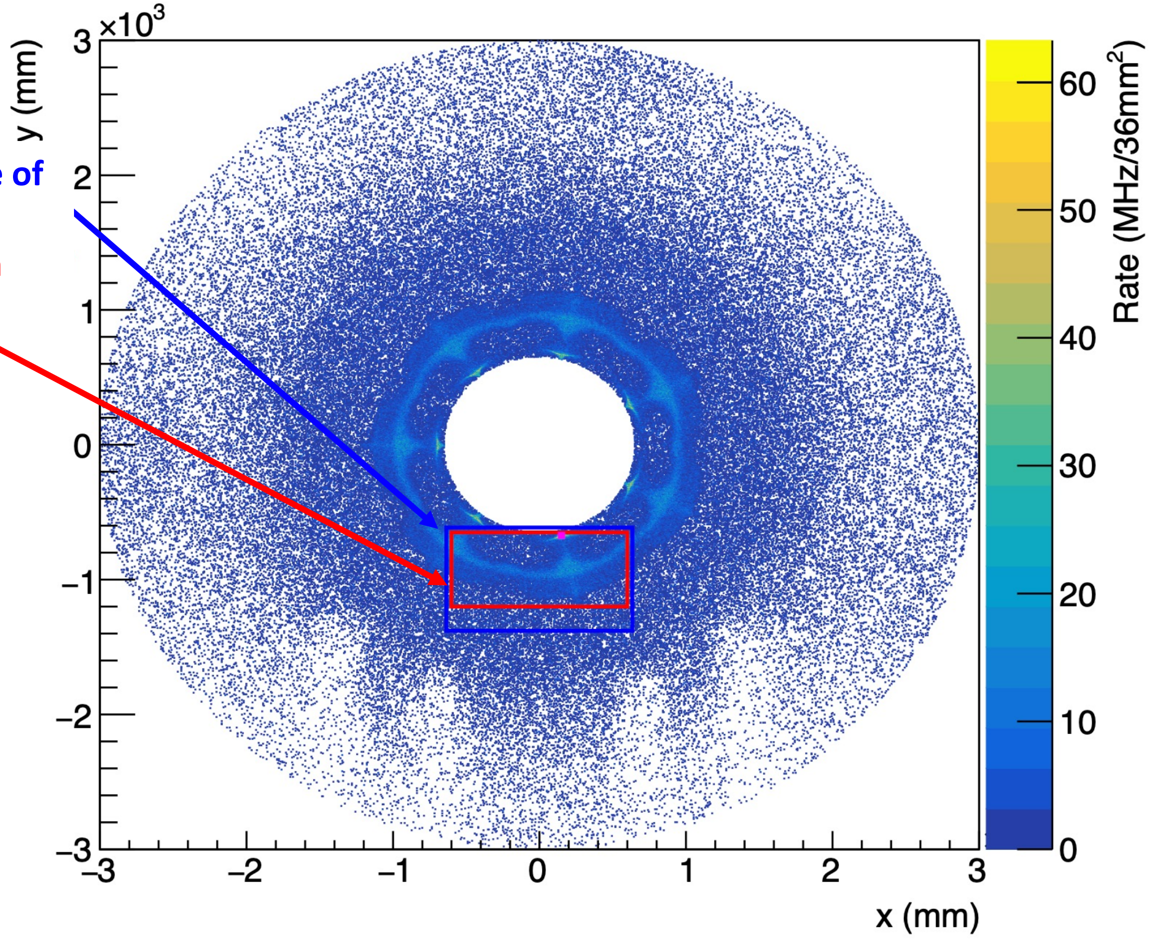
- A preliminary design uses the concept from Q_{weak} (1×1 cm^2 quartz tile)
- Monitor scattered rate distribution for combination of two sectors at low and high beam currents
- Will see a rate up to ~2.62 MHz/μA
- Ferrous material content in the scanner motor and potential background in main detectors was studied and found to be non-issue



Scanner full range of motion

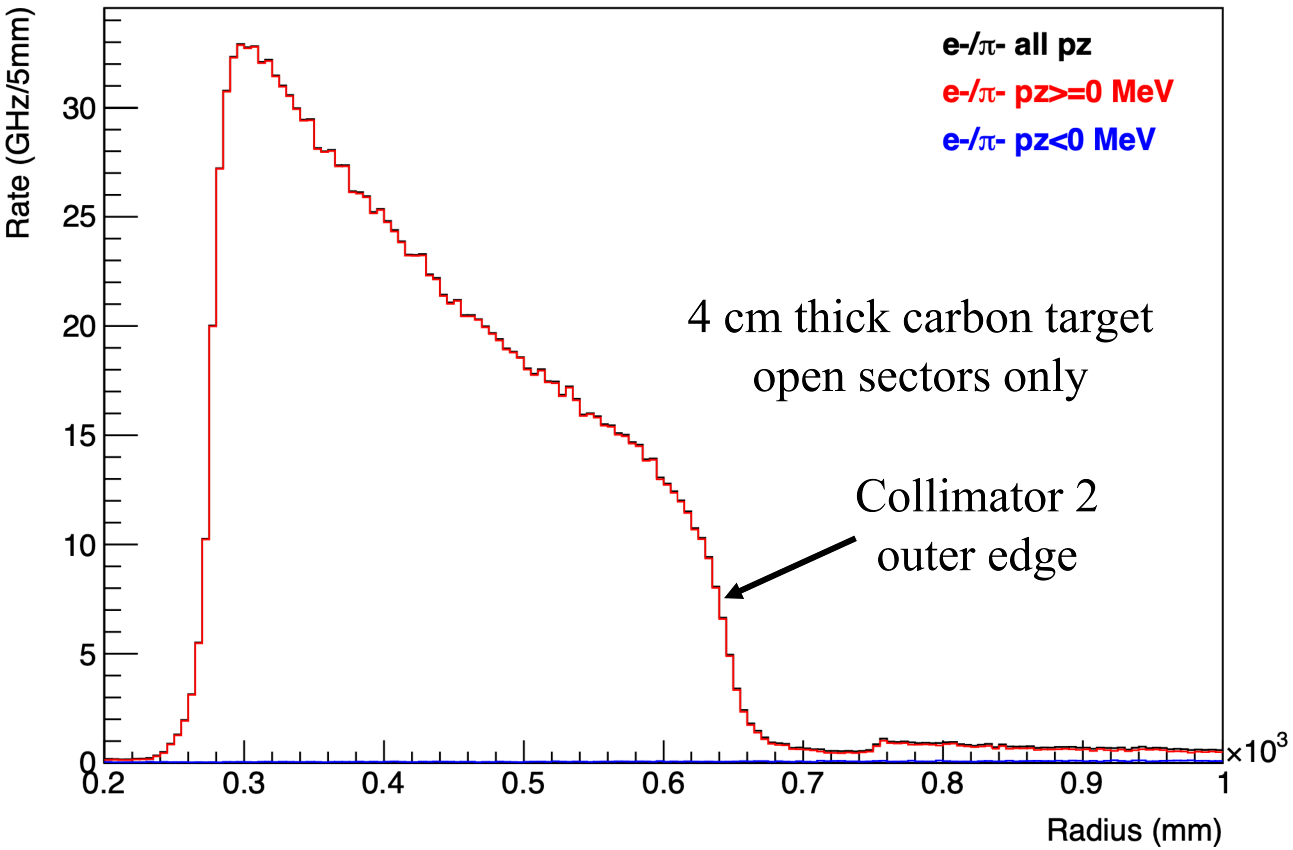
Typical 2D scan coverage

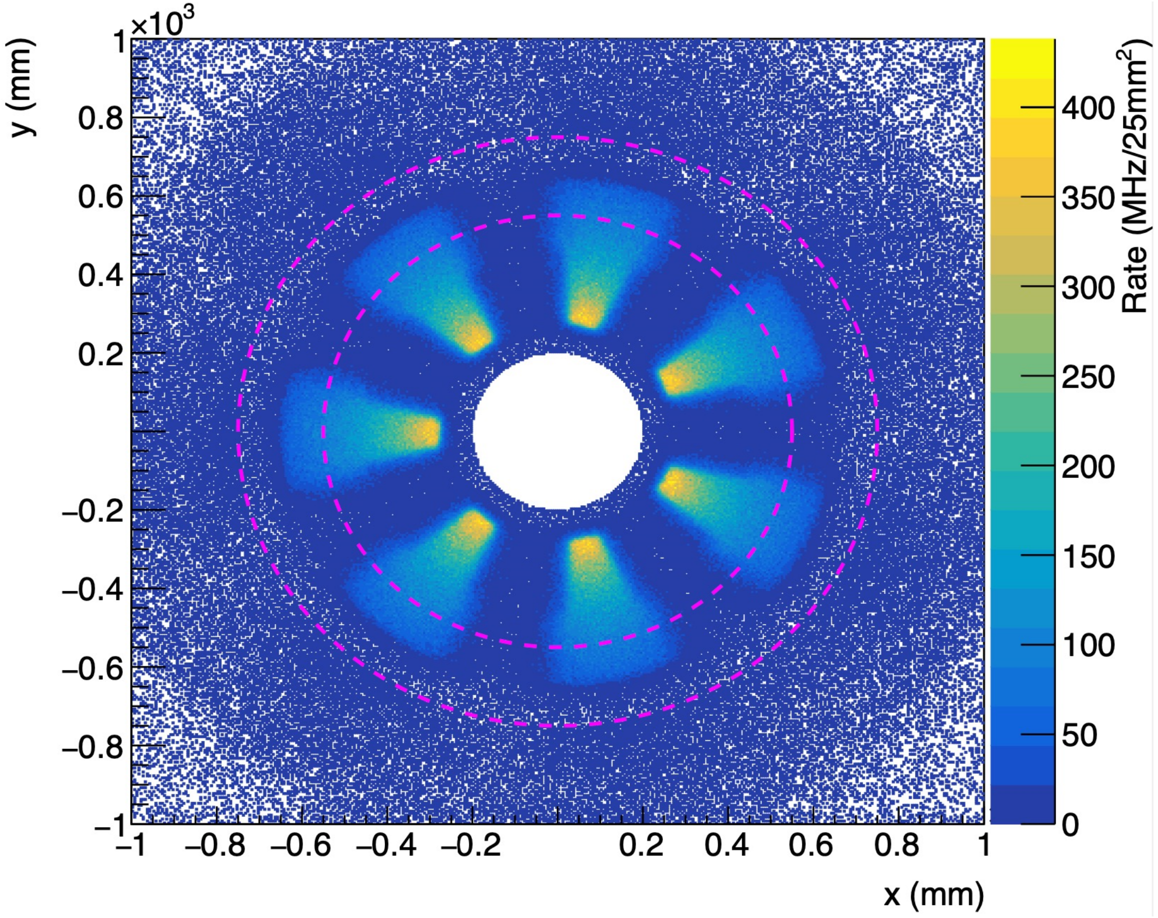
e-/π- (KE>1 MeV) XY dist. at US scanner plane



Rate Profile in Downstream Linear Scanners Requirements

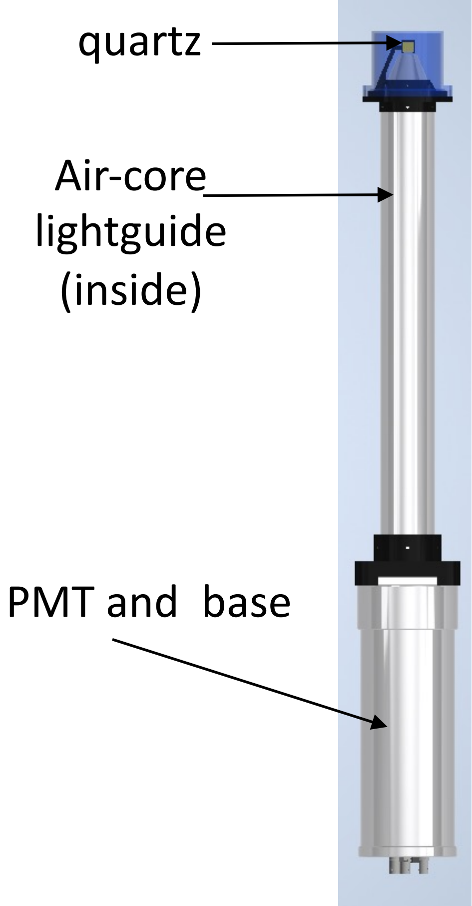
- Use magnet off spectrometer with thick carbon target
- Use to do a beam-based alignment verification of the acceptance defining collimator (collimator 2)
- Sharp transition of e-/ π- rate around 650 mm radius is due to the acceptance defining collimator (collimator 2) cutoff

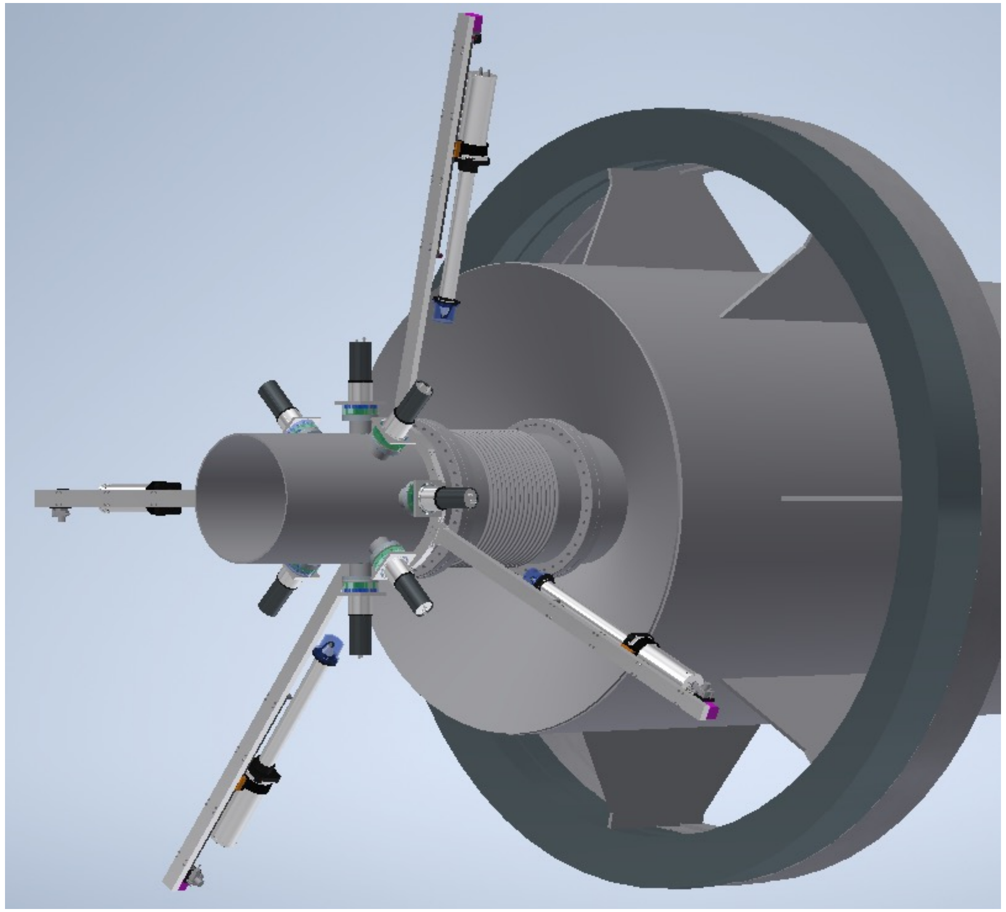


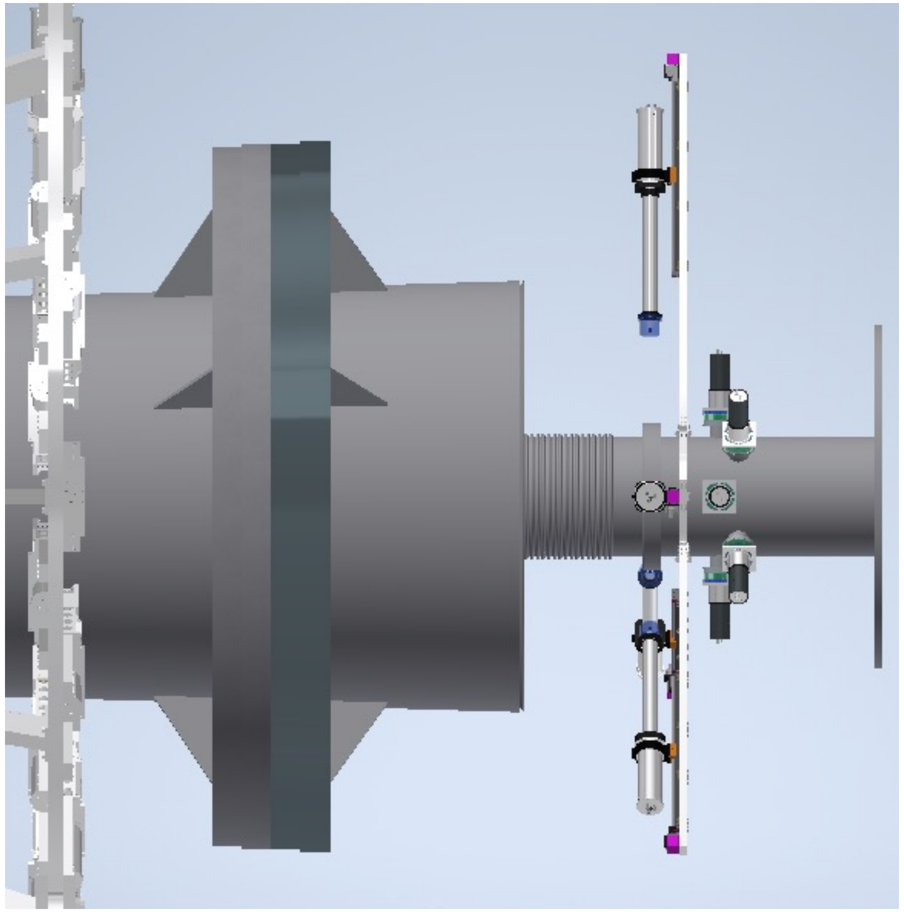


Downstream Linear Scanner Design

- Four 1-D scanners scan radially 55 – 75 cm at four azimuthal locations (open sectors)
- It uses 1×1 cm^2 quartz tile
- Air-core lightguide and ET 9305 QKB PMT
- Velmex sliding motion stage for linear motion
- Will be parked at larger radii when not in use



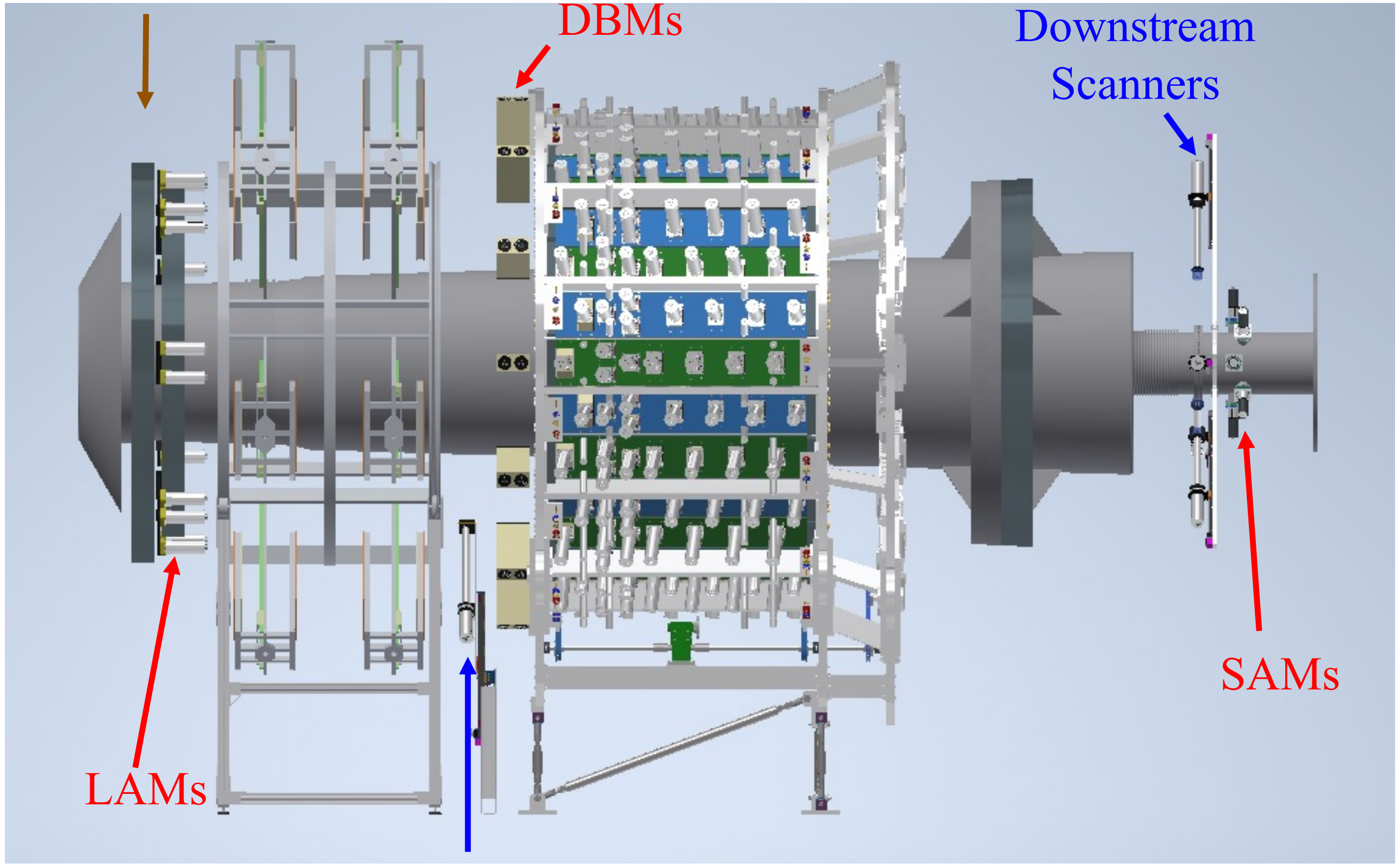




Summary

- The scattered beam monitors can check for potential false asymmetries from rescattered background
- The upstream scanner can monitor for a small drift in spectrometer field
- The downstream scanners will monitor for potential misalignment of collimator 2
- Prototype construction is underway with testing starting now

MOLLER detector CAD



Thank You

LAM Acceptance Changes from Before

Old collar 1 dimensions April 2022:

R_{US}^{IN} = 605.8789, R_{US}^{OUT} = 755.8659, R_{DS}^{IN} = 616.0770, R_{DS}^{OUT} = 755.8659

New collar 1 dimensions April 2023:

R_{US}^{IN} = 550.00, R_{US}^{OUT} = 755.8659, R_{DS}^{IN} = 563.12, R_{DS}^{OUT} = 755.8659

Process	Rate (GHz)	<A> (ppb)	<E> (GeV)
Møller	19	10	1.8
Elastic ep	76	4	1.4
Inelastic ep	0.2	332	
Total	**95**	**6**	

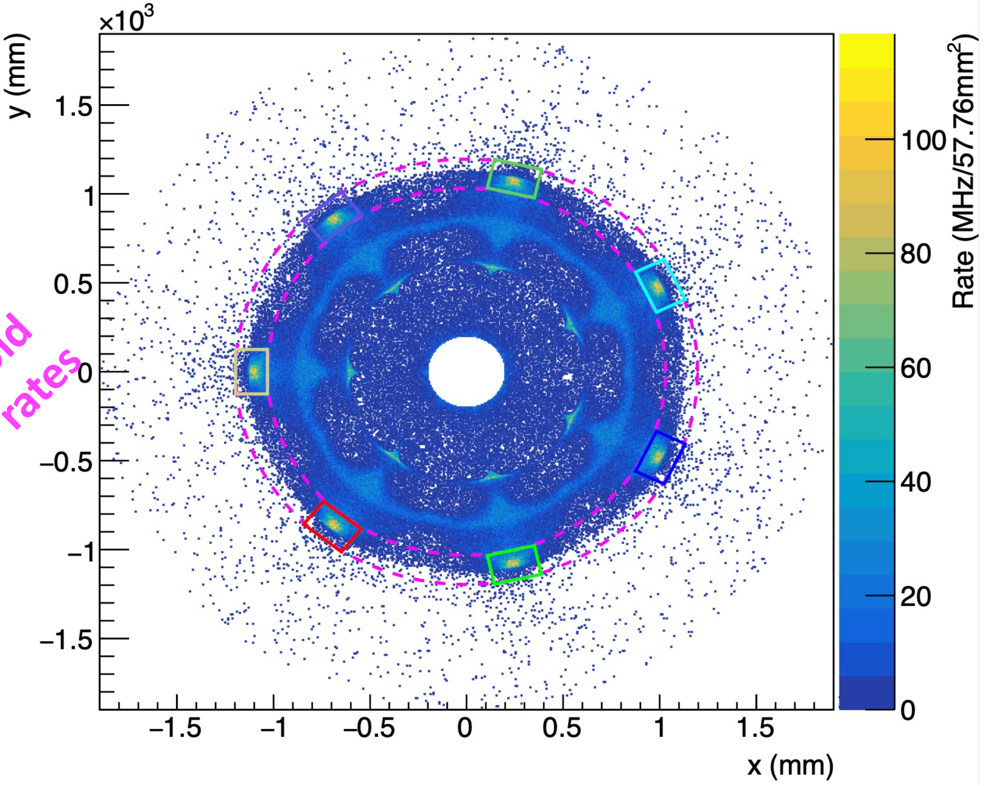
Old rates

e-/π- (KE>1 MeV) XY dist. at LAM plane

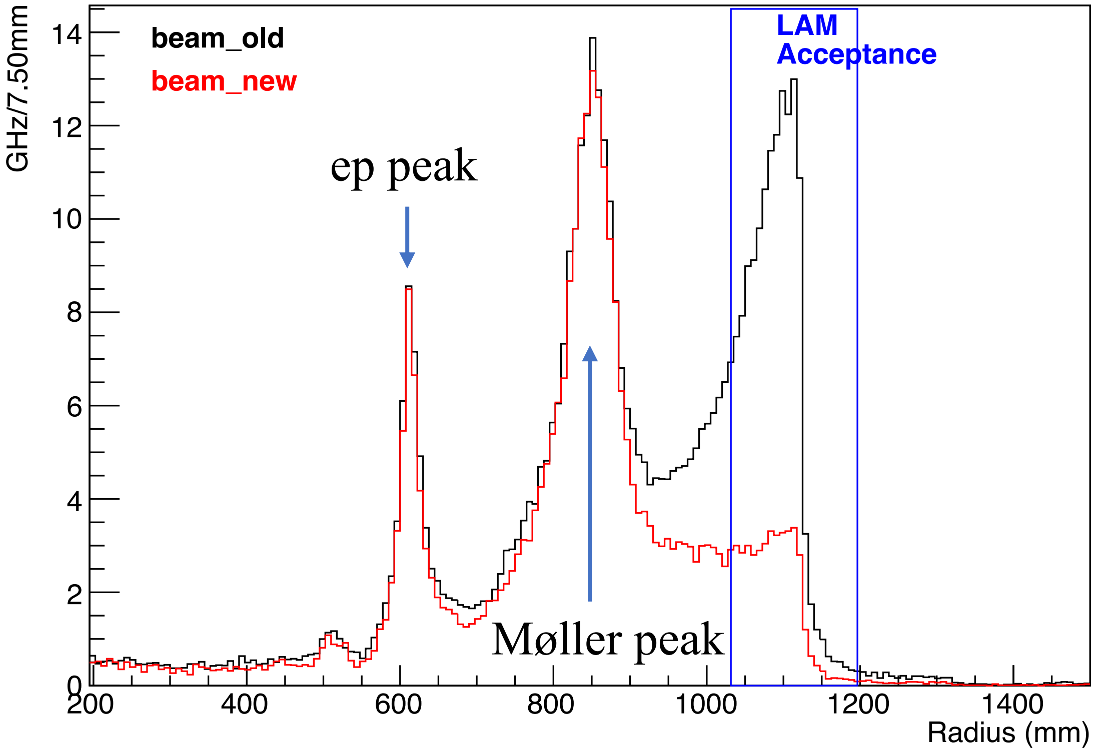
L = 250mm
W = 165mm
IR = 1031.5mm
LAM1=13.2
LAM2=14.2
LAM3=13.7
LAM4=13.3
LAM5=13.8
LAM6=13.8
LAM7=13.5

Total rate: 95 GHz

Old rates



e-/π- (KE>1 MeV) radial dist. at LAM plane



Energy Distributions at LAM Detector Plane