SAM Rate Simulation & Solid Angle Calculation

PREX/CREX Radiation Meeting

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In this presentation

- Reminder: By moving target 5cm upstream,
  we saw SAM rate is lower at larger angle position (R>8.5 cm)
- Purpose: just try to understand rate drop with new target position
  ☺: NOT for discussing collimator design
- Comparison 1- remove collimator :new target position vs old target position
  $\Rightarrow$ for SAM rate: rate changes at 1% with new position
- Comparison 2- at new target position : with vs w/o collimator
  $\Rightarrow$ Collimator trims off large angle events
- Solid angle effect is at 1%

Reminder: Geant 4 Run information

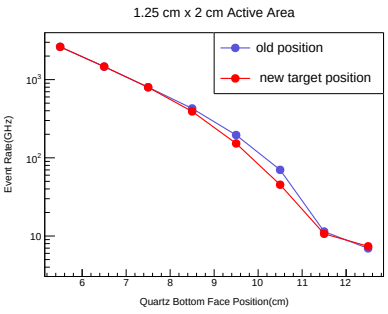
Beam Parameters

- New Target Position:-110 cm
- Target Material: Pure Lead (11.39 g/cm^3)
- Target Thickness: 0.05 cm (0.569 g/cm^2)
- Beam Energy: 1.0 GeV
- Beam Current: 70 μ A
- Raster: 4 mm x 4 mm
- Physics List: FTFP_BERT_HP

Beamline

- Collimator
- Septum
- No Magnetic Field Applied
- Al Can Wall thickness: 0.065 inch = 1.651 mm
- SAM Quartz

Reminder: SAM Rate - 1.25 cm x 2 cm Active Area, 0.6 cm thickness

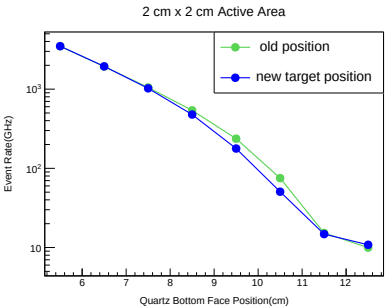


Pos.(cm)	-110 cm (GHz)	-105 cm(GHz)
5.5	2626.4	2623.7
6.5	1468.4	1464.2
7.5	796.7	800.1
8.5	391.7	427.9
9.5	152.6	195.6
10.5	45.3	70.2
11.5	10.7	11.4
12.5	7.4	7.0

Table: Rate with Collimator

Width for 70 μA beam current, 46% energy resolution, 120 Hz quadruplet Asymmetry

Reminder: SAM Rate - 2 cm x 2 cm Active Area, 0.6 cm thickness

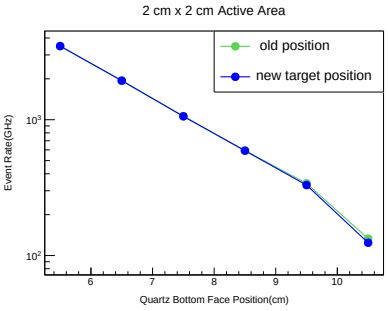


Pos.(cm)	-110 cm (GHz)	-105 cm(GHz)
5.5	3487.2	3480.0
6.5	1939.4	1930.4
7.5	1023.7	1050.5
8.5	477.8	539.9
9.5	177.8	236.6
10.5	50.7	75.2
11.5	14.8	15.3
12.5	10.8	10.0

Width for 70 μA beam current, 46% energy resolution, 120 Hz quadruplet Asymmetry

Collimator removed: New Target Position vs Old Position

SAM Rate - 2 cm x 2 cm Active Area, 0.6 cm thickness



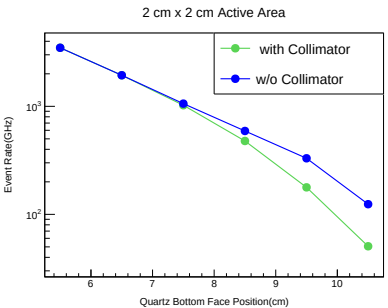
Pos.(cm)	-110 cm (GHz)	-105 cm(GHz)
5.5	3483.3	3484.2
6.5	1939.0	1940.2
7.5	1059.5	1061.0
8.5	591.5	593.8
9.5	330.4	340.0
10.5	124.2	133.2

Table: Rate without Collimator

Position effect is below 1%
or it could be solid angle effect
or Random number error

New Target Position: with vs w/o Collimator

SAM Rate - 2 cm x 2 cm Active Area, 0.6 cm thickness



Pos.(cm)	w (GHz)	w/o (GHz)
5.5	3487.2	3483.3
6.5	1939.4	1939.0
7.5	1023.7	1059.5
8.5	477.8	591.5
9.5	177.8	330.4
10.5	50.7	124.2

Table: Rate at new target position

Lower rate (starting at R=8.5 cm) is caused by collimator

Solid Angle Calculation

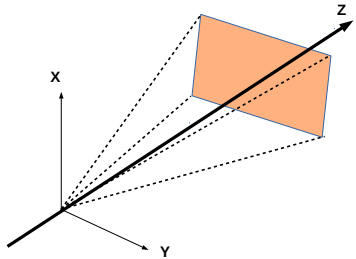
- Two Methods are used for cross-check
  1. Analytical Calculation
  2. Monte-Carlo Sampling Method
- Solid Angle affect at ~ 1 %

Solid Angle Calculation: Simple case

For a rectangle plate (a cm x b cm) placed at z=d cm, normal to $\hat{z}$, the solid angle respect to origin

$$\begin{aligned}\Omega(a,b,d) &= \int_{-a/2}^{a/2} \mathrm{d}x \int_{-b/2}^{b/2} \mathrm{d}y \frac{1}{x^2+y^2+d^2} \\ &= 4 \arccos\left(\sqrt{\frac{1+\alpha^2+\beta^2}{(1+\alpha^2)(1+\beta^2)}}\right),\end{aligned}$$

where $\alpha = \frac{a}{2d}$, $\beta = \frac{b}{2d}$.



Solid Angle in off-axis: for SAM quartz

For a 2x2 cm SAM quartz , of which the bottom is placed at $(R, 0, 810)$,
i.e. bottom face is R cm from beampipe center, new target position(110 cm upstream from pivot)

$$\Omega_{SAM} = \frac{1}{2}\Big[\Omega(2R+4, 2, 810) - \Omega(2R, 2, 810)\Big]$$

Note: 810 cm is given from prexSim-1.9.0 gdml

$$810 = 110 + (237.635 - 105) + 567.765$$

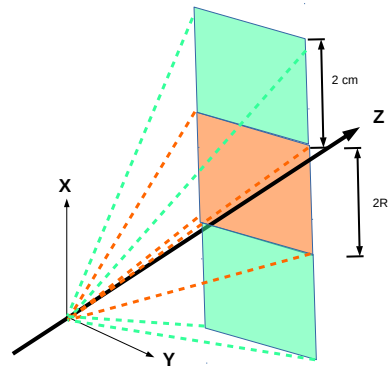


Figure: not in scale

Cross-check: Monte-Carlo Sampling

Let Geant4 particle gun shoot primary pariticles isotropically in 4π solid angle

$$\cos\theta = \mathrm{Uniform}(-1, 1)$$

$$\phi = \mathrm{Uniform}(0, 2\pi)$$

Place SAM quartz (2x2 cm) at (R,0,810) and count hits

$$\frac{N_{SAM}}{N_{tot}} = \frac{\Omega_{SAM}}{4\pi}$$

So,

$$\Omega_{SAM} = 4\pi \times \frac{N_{SAM}}{N_{tot}}$$

In practice, beam direction is biased in a 0.0004 π cone to get 1% precision with 10^8 event s

$$\Omega_{SAM} = 0.0004\pi \times \frac{N_{SAM}}{10^8} \sim 10^{-6}\mathrm{sr}$$

Solid Angle Calculation: Results

	New Target Position		Old Target Position(μ sr)	
R*(cm)	Analytical(μsr)	M.C.(μsr)	Analytical(μsr)	M.C.(μsr)
5.5	6.09583	6.04	6.17196	6.11
7.5	6.09561	6.04	6.17155	6.12
9.5	6.09508	6.04	6.17102	6.12
11.5	6.09445	6.00	6.17037	6.07

*Note :R is the quartz bottom face position w.r.t beam pipe center

Change from solid angle is $\sim 1\%$