SAM Rate Simulation

Tao Ye

Stony Brook University

June 13, 2018

Contents

Background

- 2016 runs parasitic data : Spring+Fall Gmp
- Reproduce 2016 data in G4 simulation
- Goal: simulate SAM rate with a given beamline
- Input for SAM redesign

Section 1

AI Dummy Target Simulation

Spring 2016 Run info

- Target : 15 cm Al dummy (0.48 g/cm^2)
- 8.8 GeV
- 40 μA
- Helicity 30 Hz
- 2.5 mm x 3 mm Raster(spot on target is off-centered*)

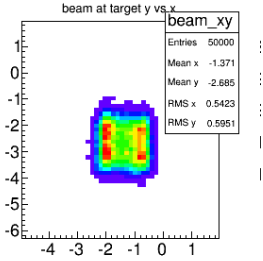


Figure: *https://logbooks.jlab.org/entry/3401601

SAM

- Geometries
  - Position: 7 m downstream from Target
  - Quartz Dimension: 3.0 cm x 2.0 cm x 1.3 cm
  - Al Can Wall thickness: 0.065 inch = 1.651 mm
  - Quartz bottom face is 5.5 cm away from beam pipe center
  - Polar Acceptance 7.8 - 12.1 mrad or 0.45 - 0.69 deg
- 30 Hz Pairwise Asymmetry
- Observed individual SAM rms width $\sim$ 60 ppm
- Estimated Rate : 4.8 GHz per SAM

SAM Rate Calculation from Spring Run

With finite energy resolution

$$\sigma^2 = \frac{1}{2N_e}\left[1 + \left(\frac{\sigma_E}{E}\right)^2\right] = (60 \quad \text{ppm})^2$$

Beam test gives photoelectron yield 7-8 PE and its resolution (Dustin's Talk)

$$\frac{\sigma_E}{E} = 39\% \sim \frac{1}{\sqrt{7}}, \quad 1 + \left(\frac{\sigma_E}{E}\right)^2 = 1.15$$

$$N_e = \frac{1.15}{2} \times \left(\frac{10^6}{60}\right)^2 = 1.6 \times 10^8$$

$$T = \texttt{vqwk\_nsamp} \times 2 \quad \text{usec} = 16564 \times 2 = 33.128 \quad \text{msec}$$

$$\boxed{\frac{N_e}{T} = \frac{1.6 \times 10^8}{33 \quad \text{msec}} = 4.8 \quad \text{GHz}}$$

Simulation

- PhysicsList: FTFP_BERT_HP (Also try with QGSP_BERT_HP, no difference)
- Target position at z=0
- No speptum or collimation
- No magnetic field
- Assuming rastered beam
  - parallel in z direction
  - centered
  - uniform spot size 3 mm x2.5 mm

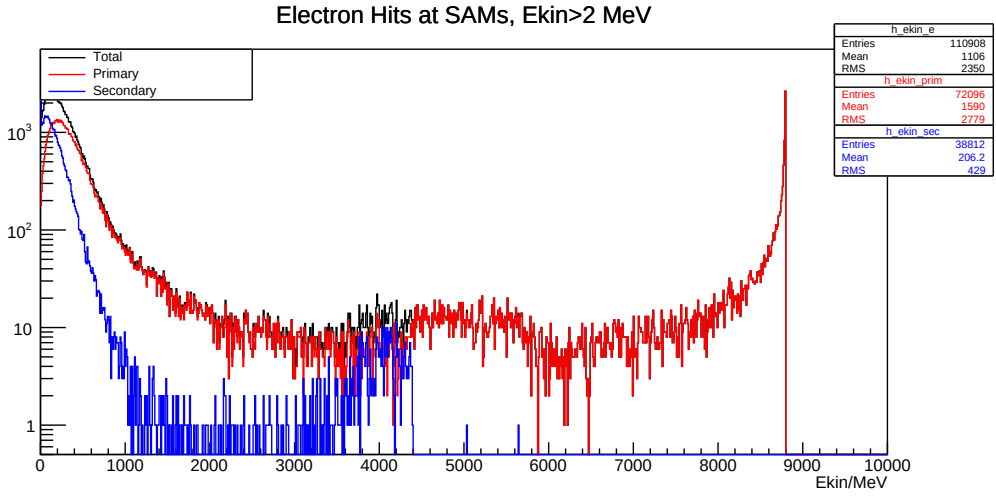
Results

- With 3×10^8 primary events, 13863 relativistic electrons hits on each individual SAM
- Scale to beam current 40 μ A

$$\frac{40 \quad \mu\mathrm{C}}{1.6 \times 10^{-19} \quad \mathrm{C}} = 2.5 \times 10^{14}$$

Scaled event rate from simulation

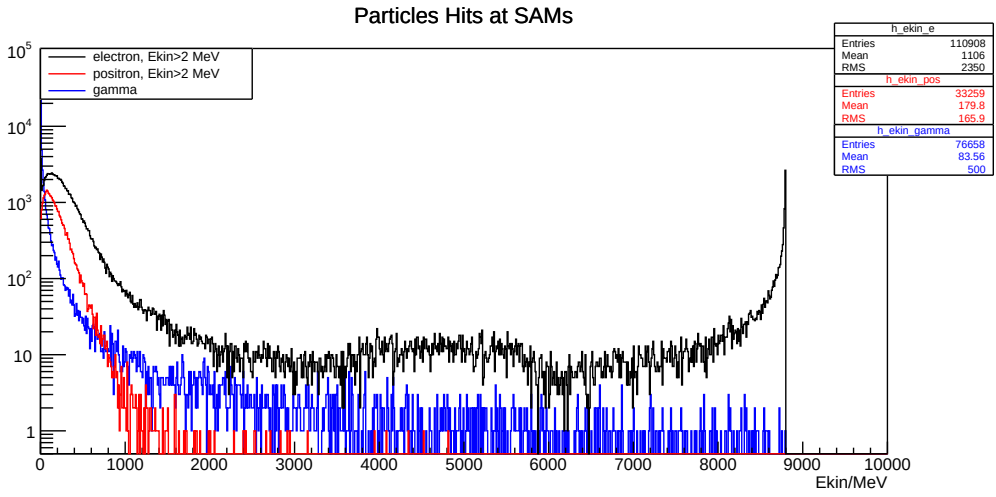
$$13863 \times \frac{2.5 \times 10^{14}}{3 \times 10^8} = 11.5 \quad \mathrm{GHz}$$



$$\text{Moller Scattering} : \theta_{lab}^2 = 2m_e\left(\frac{1}{E'} - \frac{1}{E}\right)$$

$$E'(\theta_{lab} = 7.8 \text{ mrad}) = 5.77 \text{ GeV}, \quad E'(\theta_{lab} = 12.1 \text{ mrad}) = 3.89 \text{ GeV}$$

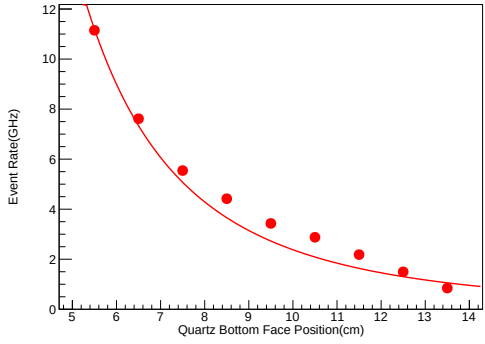
Electron, Positron and Gamma



Quartz Position Scan for Al run

Only electron(> 2 MeV) counts, not including positron and gamma

Bot. Face Pos.(cm)	Rate (GHz)
5.5	11.2
6.5	7.6
7.5	5.5
8.5	4.4
9.5	3.4
10.5	2.9
11.5	2.2
12.5	1.5
13.5	0.8



Red curve: prediction from Rutherford scattering, normalized to the first point

Next steps

- Compare G4 physicsList with remoll Al Generator
- Revisit other 2016 runs: 2.2 GeV Al etc.
- From spring 2016 data, asymmetric SAM widths
  - Beam spot center offset: from Hall A logbook, -2 mm offset in X and Y
  - Rastered beam angle divergence: SAM is sensitive to beam angle

SAM ID	width(ppm)*	Rate(GHz)**
1	75	3.1
3	75	3.1
4	48	7.6
5	37	12.7
7	51	6.7
8	65	4.1

*normalized, regressed. BCM and BPMs resolution are subtracted

** Assuming 39% resolution, i.e. 7 P.E./e

Section 2

PREX-II Simulation

Beam On Target

- Target Position: -105 cm
- Target Material: Pure Lead (11.39 g/cm^3)
- Target Thickness: 0.05 cm (0.569 g/cm^2)
- Beam Energy: 1 GeV
- Beam Current: 70 μ A
- Raster: 4 mm x 4 mm
- Physics List: FTFP_BERT_HP

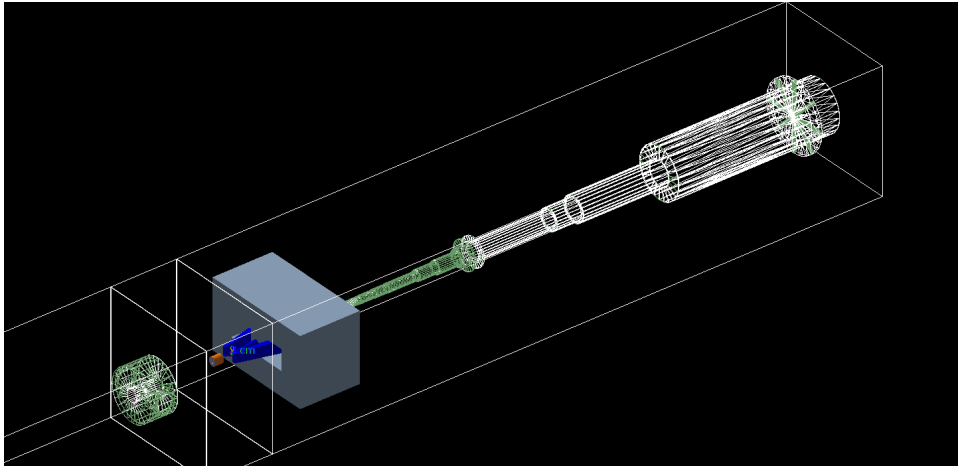
Downstream from Target

- Collimator
- Septum
- No Magnetic Field Applied
- Al Can Wall thickness: 0.065 inch = 1.651 mm
- SAM Quartz
  - Dimension 3 cm x 2 cm x 1.3 cm
  - Bottom face: 5.5 cm away from beam pipe center
  - Position: 7 meter downtream from pivot(z=0)
  - Polar acceptance: 6.8 - 10.6 mrad

$$\theta_{min} = \frac{0.055}{8} = 6.8 \quad \text{mrad}$$

$$\theta_{max} = \frac{0.085}{8} = 10.6 \quad \text{mrad}$$

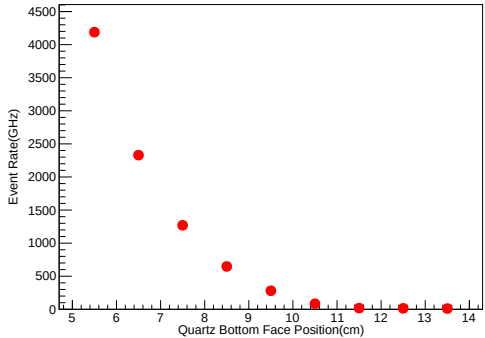
Beamline for PREX-II simulation



SAM Position Scan

Only electron(> 2 MeV) counts, not including positron and gamma

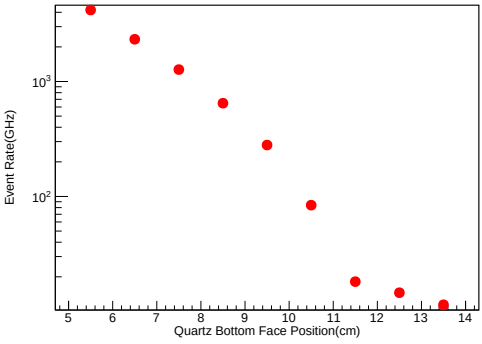
Bot. Face Pos.(cm)	Rate (GHz)
5.5	4188.1
6.5	2330.0
7.5	1269.7
8.5	647.6
9.5	280.2
10.5	84.0
11.5	18.2
12.5	14.5
13.5	11.4

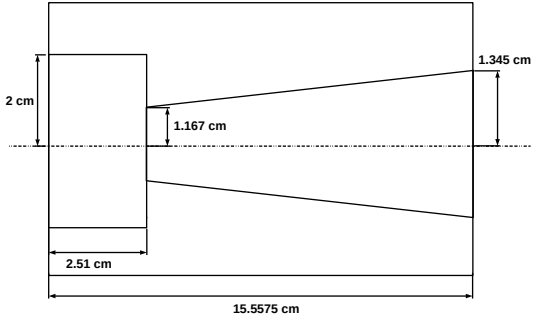


Ratio to Gmp Al dummy run (Simulation)

$$\frac{4188\ GHz}{11.5\ GHz} = 366$$

In log scale, Collimator shadowing





X-axis is the bottom face position.
Quartz length = 3 cm .
Shadow starts at 7.89 cm in this plot.
Completely behind the shadow at 10.89 cm

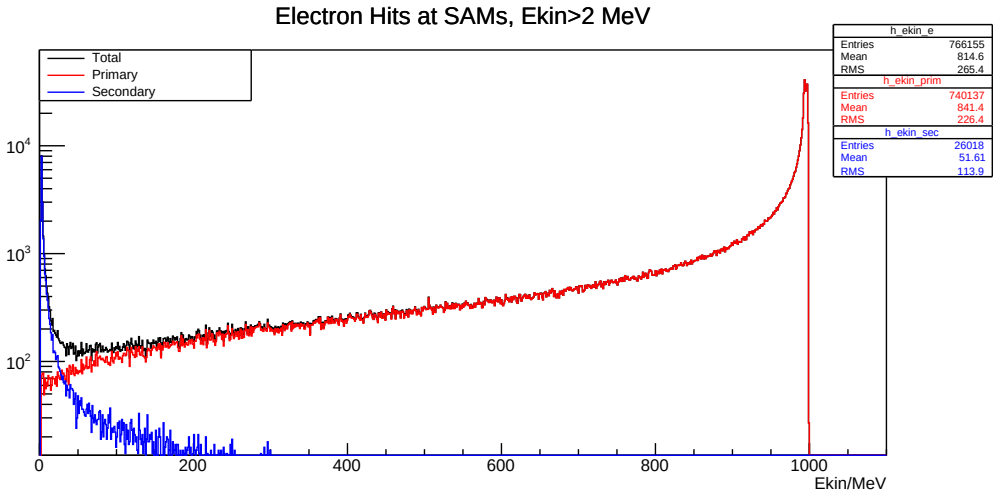
Shadowing projected to SAM plane

$$\frac{1.167\ cm}{85.7\ cm} \times 800\ cm = 10.89\ cm$$

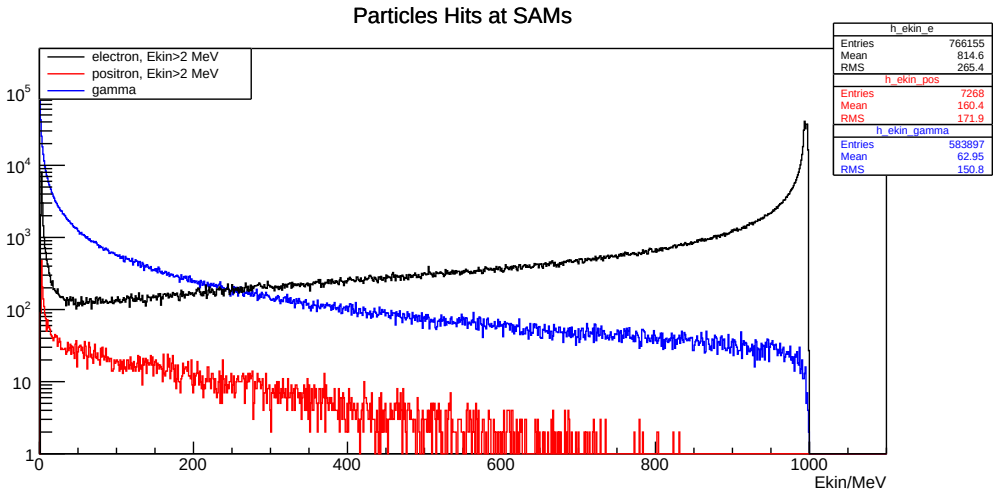
- Realistic raster generator: spot size, position, angle distribution
- Magnetic field is off in this simulation
- Countings: how about positron and gamma?
- How about CREX?
- noise floor of SAM signal: 0.3 ADC pedestal Noise $\rightarrow$ 6 ppm

Position(cm)	Rate(GHz)	Width(ppm)
5.5	4188.1	2.7
6.5	2330.0	3.6
7.5	1269.7	4.9
8.5	647.6	6.8
9.5	280.2	10.3
10.5	84.0	18.9
11.5	18.2	40.6
12.5	14.5	45.5
13.5	11.4	51.3
PREX-I	1	173

Table: SAM width for 120 Hz quadruplet asymmetry


Electron Hits at SAMs, Ekin>2 MeV
Total
Primary
Secondary
h_ekin_e
Entries 766155
Mean 814.6
RMS 265.4
h_ekin_prim
Entries 740137
Mean 841.4
RMS 226.4
h_ekin_sec
Entries 26018
Mean 51.61
RMS 113.9
10^4
10^3
10^2
0
200
400
600
800
1000
Ekin/MeV

Electron, Positron and Gamma



Backup slides

$$\mathrm{d}\sigma = \frac{Z^2}{E^2 \sin^4 \frac{\theta}{2}} \Big[\quad ... \quad \Big] \sin\theta \mathrm{d}\theta \mathrm{d}\phi$$

Leading Order term

$$\left(\frac{Z_{pb}}{Z_{Al}}\right)^2 \times \frac{1}{\left(\frac{E_{PREX}}{E_{Gmp}}\right)^2} = \frac{(82/13)^2}{(1/8.8)^2} = 3000$$

Integral over polar acceptance

$$\left(\frac{1}{1-\cos\theta_1} - \frac{1}{1-\cos\theta_2}\right)_{prex} / \left(\frac{1}{1-\cos\theta_1} - \frac{1}{1-\cos\theta_2}\right)_{Gmp} \approx 1.2$$

Beam current

$$I_{PREX}/I_{Gmp} = 70/40 = 1.75$$

Target atom number density

$$\frac{(0.56\ g/cm^2)/208}{2 * (0.48\ g/cm^2)/27} = 0.08$$

$$\boxed{N_{prex}/N_{gmp} = 3000 * 1.2 * 1.75 * 0.08 = 500}$$