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SVT Hit Rate Estimation Updates

Shujie Li
with valuable discussions with Ernst Sichtermann, Zhenyu Ye, Jo Schambach, Yu Hu, Barak Schmookler, Joao De Melo, and others…

SVT General Meeting
July 6, 2026

Introduction

Same 26.04.1 simulation and analysis as presented in June 9th
With numbers in the data volume table explained

Goal: with simulation, estimate the SVT hit rate for

- Signal + machine background + sensor noise

In the form of

- Total rate per section: L0-4, ED0-4, HD0-4, and
- Max rate per **readout element:**
  - MOSAIX: 4 RSUs per fiber link
  - LAS: 5 or 6 RSUs per fiber link

Then convert hit rate to data volume:

- # of hit → # of fired pixel → data volume

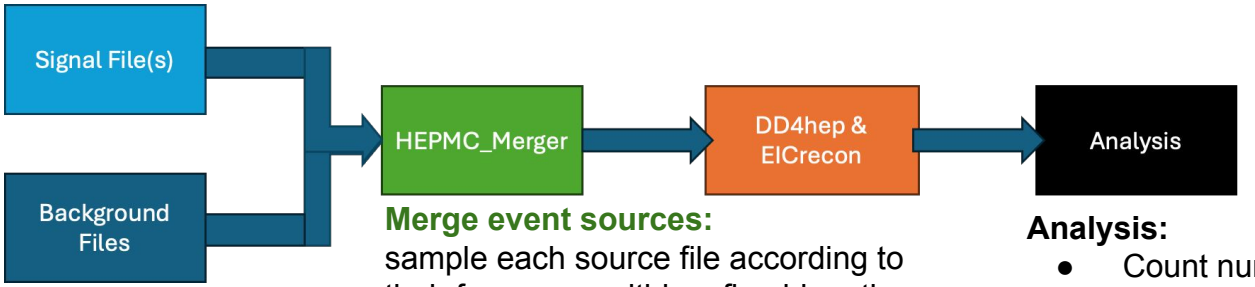
1. Signal+Background Hit Rate

- Max Hit Rate / Readout Element (Physics) (Hz)
- Max Hit Rate / Readout Element (SR) (Hz)
- Max Hit Rate / Readout Element (Other Backgrounds) (Hz)

1. Signal+Background Simulation:

Prepare realistic event sample

- One event = one 2us time slice with merged signal and background.



Merge event sources:
sample each source file according to their frequency within a fixed-length (2us) time window

Analysis:

- Count number of digitized hits on SVT per area per time
- From detector hits, trace back to mcparticle to accumulate counts **per source**

Configuration used in SVT rate study:

- **10x275** GeV beam (highest rate) from 26.04.1 simulation campaign
- Forced DIS + background events. Each contains:
  - One Q^2>1 GeV^2 NC DIS vertex
  - Several beam background collisions (SR, Bremsstrahlung, Coulomb, Touschek, proton beam gas) at calculated freq. See details at ePIC wiki

Link to spreadsheet

26.04.1 DIS+Background rate summary 10x275 beam

Simulation campaign , 26.04.1 — Shuije Li, 06.2026

10x275 GeV setting with 10um gold beampipe coating — All counts are per millisecond (ms) --> kHz

1ms of mixed data = 1000 events x (one DIS collision at Q2 >1 GeV2 per 2us + beam background per event) / 2

			Hit rate (kHz) by source					
Layer name	Total hits (kHz)	MAX hit on a single RSU (20x20mm)	DIS	SR	Bremstrahlung	Coulomb	Touschek	Proton beam gas
E-Si Disk 4	32,767	75	684	29,245	2,177	218	133	311
E-Si Disk 3	146,187	370	701	142,384	2,398	235	154	316
E-Si Disk 2	225,029	1336	742	221,153	2,456	232	141	304
E-Si Disk 1	233,208	1641	761	229,330	2,430	238	152	297
E-Si Disk 0	130,914	1594	470	127,760	2,104	196	128	255
H-Si Disk 0	112,586	1421	901	108,933	2,177	199	127	249
H-Si Disk 1	156,696	1270	1,381	152,188	2,456	239	129	302
H-Si Disk 2	37,582	180	1,879	32,603	2,451	238	118	293
H-Si Disk 3	8,362	170	3,009	2,634	2,162	212	85	260
H-Si Disk 4	6,431	155	3,201	738	2,006	199	62	225
L0	362,256	4451	1,067	357,406	3,049	298	307	129
L1	252,161	2221	961	247,634	2,817	231	239	279
L2	154,604	521	481	152,647	1,305	94	39	39
L3	183,494	270	598	182,065	679	78	36	38
L4	138,915	100	565	137,366	798	57	49	81

Max per Readout Element

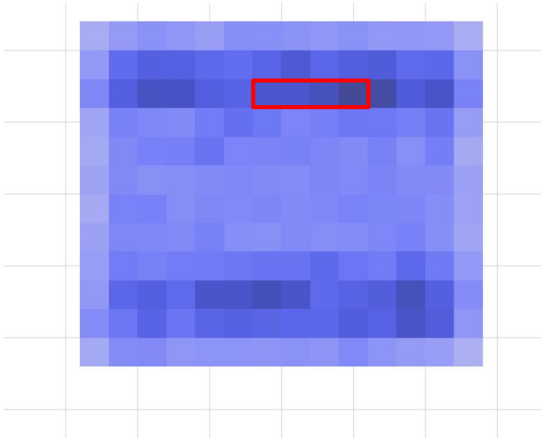
Steps:

- ➔ plot digitized hits (edep > 0.54 keV) on each SVT surface
  - rphi v.s. Z on barrels
  - x v.s. y on disks
- ➔ accumulate number of hits per
  - 2x2cm square (roughly size of one RSU = 12 tiles),
  - ~~or 9.8x3.5mm (tile)~~
- ➔ Record **accumulated/averaged** counts per **ms** (500 x 2us slices → kHz)
  - for the entire detector layer
  - and the max rate per RSU / tile

For **barrel** layers

- readout element ~ 4 RSUs along z
- Hit rates varies a lot in phi

⇒ use 4 x max(RSU) as the upper limit



Max per Readout Element

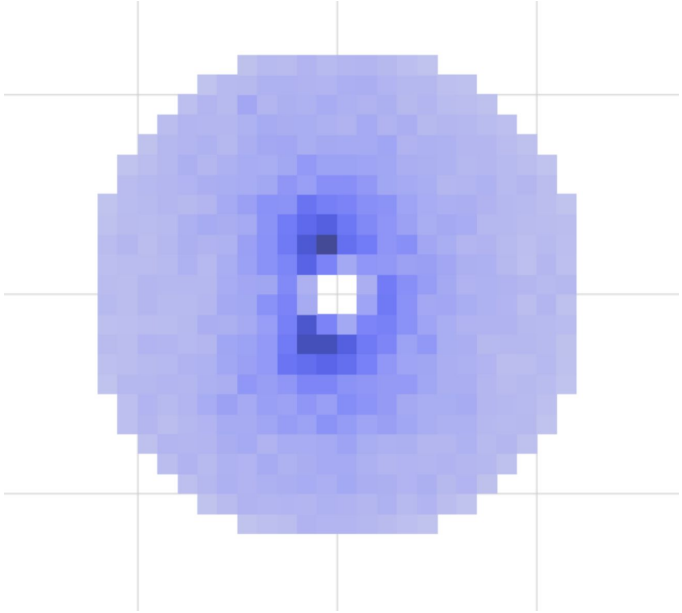
Steps:

- ➔ plot digitized hits (edep > 0.54 keV) on each SVT surface
  - ◆ rphi v.s. Z on barrels
  - ◆ x v.s. y on disks
- ➔ accumulate number of hits per
  - ◆ 2x2cm square (roughly size of one RSU = 12 tiles),
  - ◆ or 9.8x3.5mm (tile)
- ➔ Record **accumulated/averaged** counts per **ms** (500 x 2us slices → kHz)
  - ◆ for the entire detector layer
  - ◆ and the max rate per RSU / tile
  - ◆ separate by sources as needed

For **disks**,

- readout element ~ EIC-LAS: 5 or 6 RSUs along z
- Hit rates varies a lot by R

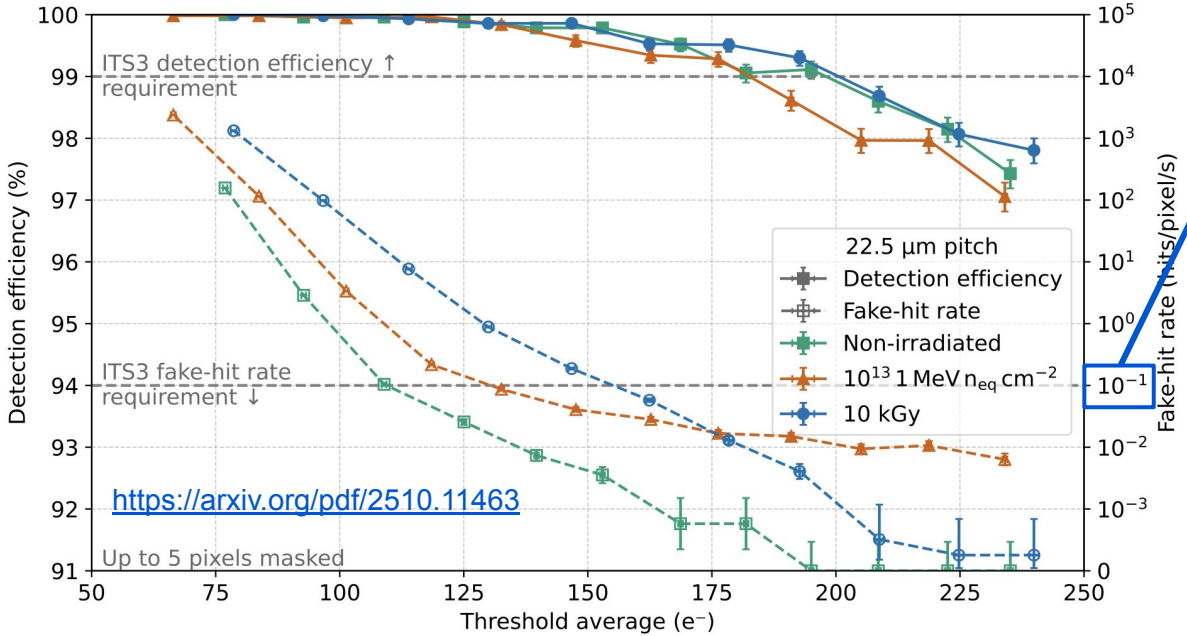
⇒ use **5** x max(RSU) as the upper limit



2. Sensor Noise

- Expected Noise Hit Rate / Readout Element (Hz)

Fake Hit Rate



(a) Pixel matrix with pitch 22.5 µm irradiated to different levels.

ITS3 requirement:
0.1/second → 1e-7/us → 2e-7/pixel/2us

Hit rate per RSU:
831,168 pixels/RSU ⇒ 0.083 MHz / RSU

Hit rate per readout element:
IB: x4 RSUs/link
OB and disks: x5 or x6 RSUs/link

3. Simulated Hits to Data Rate

- Max Hit Rate (All Sources) (Hz / Readout Element)
- Avg Hit Rate / Readout Element (Hz)
- Total Hit Rate for full Section (Hz)
- Bits/Hit
- Data Rate Full Section (Gb/s)

Combined Hit Rates

- Max Hit Rate (All Sources) (Hz / Readout Element)
  = max(DIS+background hits)/element + noise hits/element

- Total Hit Rate for full Section (Hz)
  = sum(DIS+background) per layer + noise hits per layer

  Note: the **disk** total rate is accumulated at one surface, while the actual layout will have large overlap of LAS modules on front/back side of the corrugated carbon frame ⇒ potentially higher total rate

- Avg Hit Rate / Readout Element (Hz)
  = Total Hit Rate for full Section (Hz) / # of elements per layer

Hit Rates to Data Rates

DIS+background:

- 3 pixels / hit (assumptions taken from ITS3 as an upper limit)
- 32 bits / pixel
  ⇒ **96 bits / hit**

Noise:

- 1 noise hit → 1 activated pixel
- 64 bit per MOSAIX noise hit (c.f. Jo's slide 18 at the SVT working meeting in Oxford)

Total data rate (upper limit) =

DIS+background hit rate x 3 pixels/hit x 32 bits/pixel + noise hit rate x 64 bits/hit

Will change with

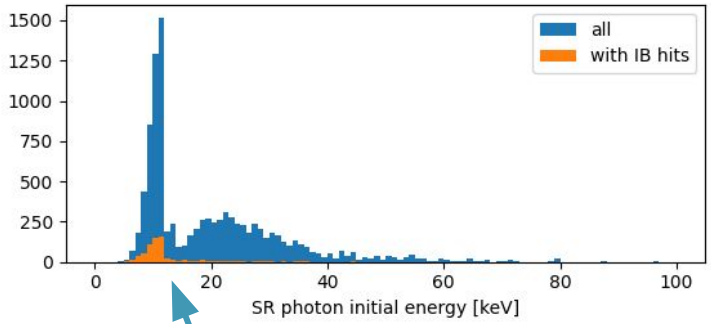
- beam background updates
- sensor structure/interaction probability

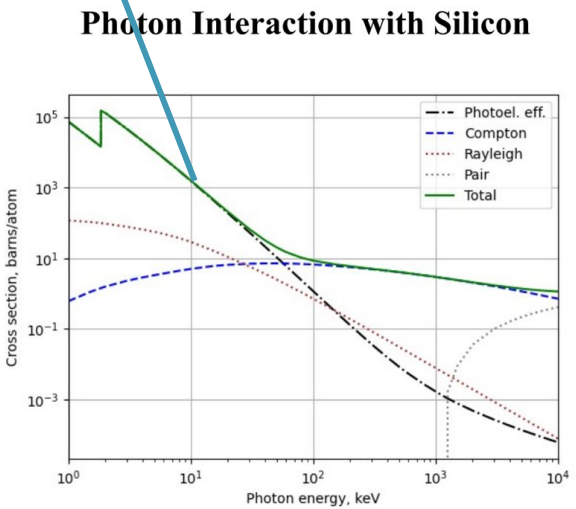
Will get updates from sensor response study

See Zhenyu's talk later

Backups

Sensor Response in Simulation: example study





SR Photon energy peaks at ~10 and 20 keV.

The **interaction probability** (dominated by **photo-electric** process in the case of SR)

$$P(E) = 1 - e^{\rho(\frac{\mu}{\rho})_{pe}(E)t}$$

At E=10 keV, the silicon mass attenuation coefficient [link]

$$(\frac{\mu}{\rho})_{pe}(E = 10\text{keV}) \approx 30\text{cm}^2/\text{g}$$

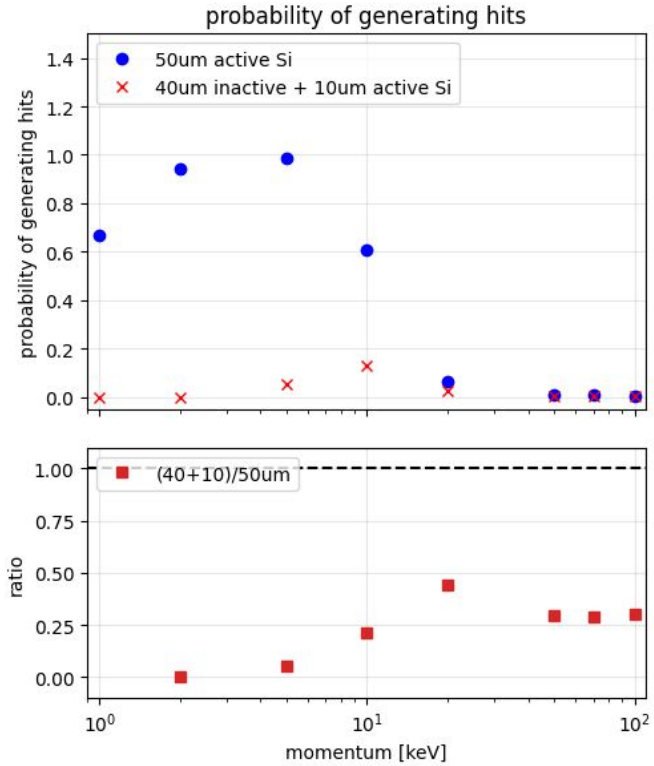
For t=O(10um) silicon (rho=2.33g/cm^3), the exponent < 0.1

⇒ probability P $\propto$ thickness t

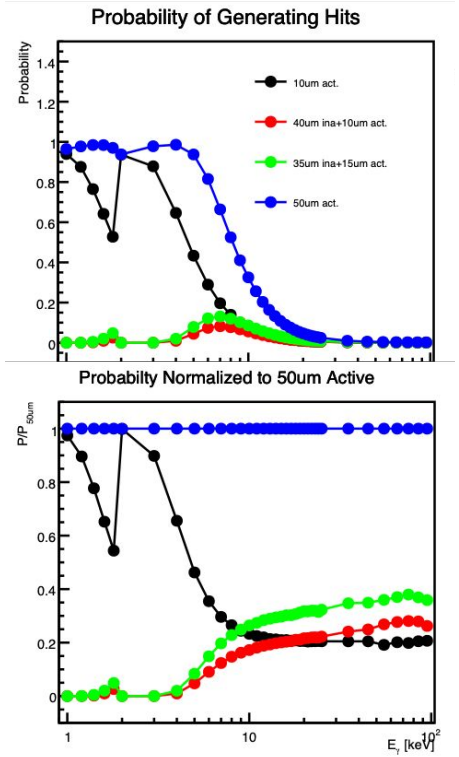
Sensor Response in Simulation: example study

Compare 50um active silicon v.s. (40um inactive followed by 10um active silicon)

DD4hep (100k photons)



Geant4 simulation from Zhenyu



- DD4hep and Geant4 simulations show consistent impact of active silicon thickness vs interaction prob.
- See Yu Hu's talk next for dedicated simulation considering detailed sensor structure
- Eventually dd4hep configuration needs to be tuned to match specialized simulation and beam test results.