BERKELEY LAB
Bringing Science Solutions to the World

U.S. DEPARTMENT OF ENERGY
Office of Science

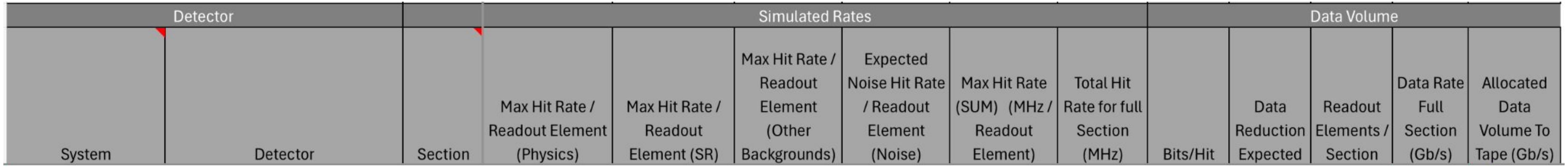
SVT Rate in Simulation Updates

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

SVT General Meeting
June 9, 2026

Introduction

Example format of the data volume summary table:



Detector			Simulated Rates						Data Volume				
System	Detector	Section	Max Hit Rate / Readout Element (Physics)	Max Hit Rate / Readout Element (SR)	Max Hit Rate / Readout Element (Other Backgrounds)	Expected Noise Hit Rate / Readout Element (Noise)	Max Hit Rate (SUM) (MHz / Readout Element)	Total Hit Rate for full Section (MHz)	Bits/Hit	Data Reduction Expected	Readout Elements / Section	Data Rate Full Section (Gb/s)	Allocated Data Volume To Tape (Gb/s)

Goal: with simulation, estimate the SVT hit rate for

- Signal + machine background + sensor noise

In the form of

- Total rate per section: L0, L1, L2, L3, L4, E-disks, H-disks, 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:

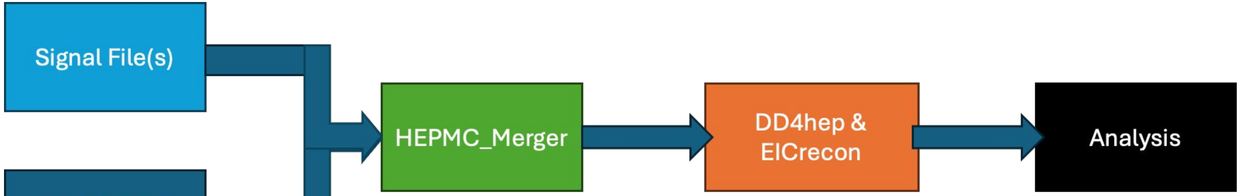
- # of hit → # of fired pixel → data volume

1. Signal+Background Rate

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

Configuration to use for SVT rate study:

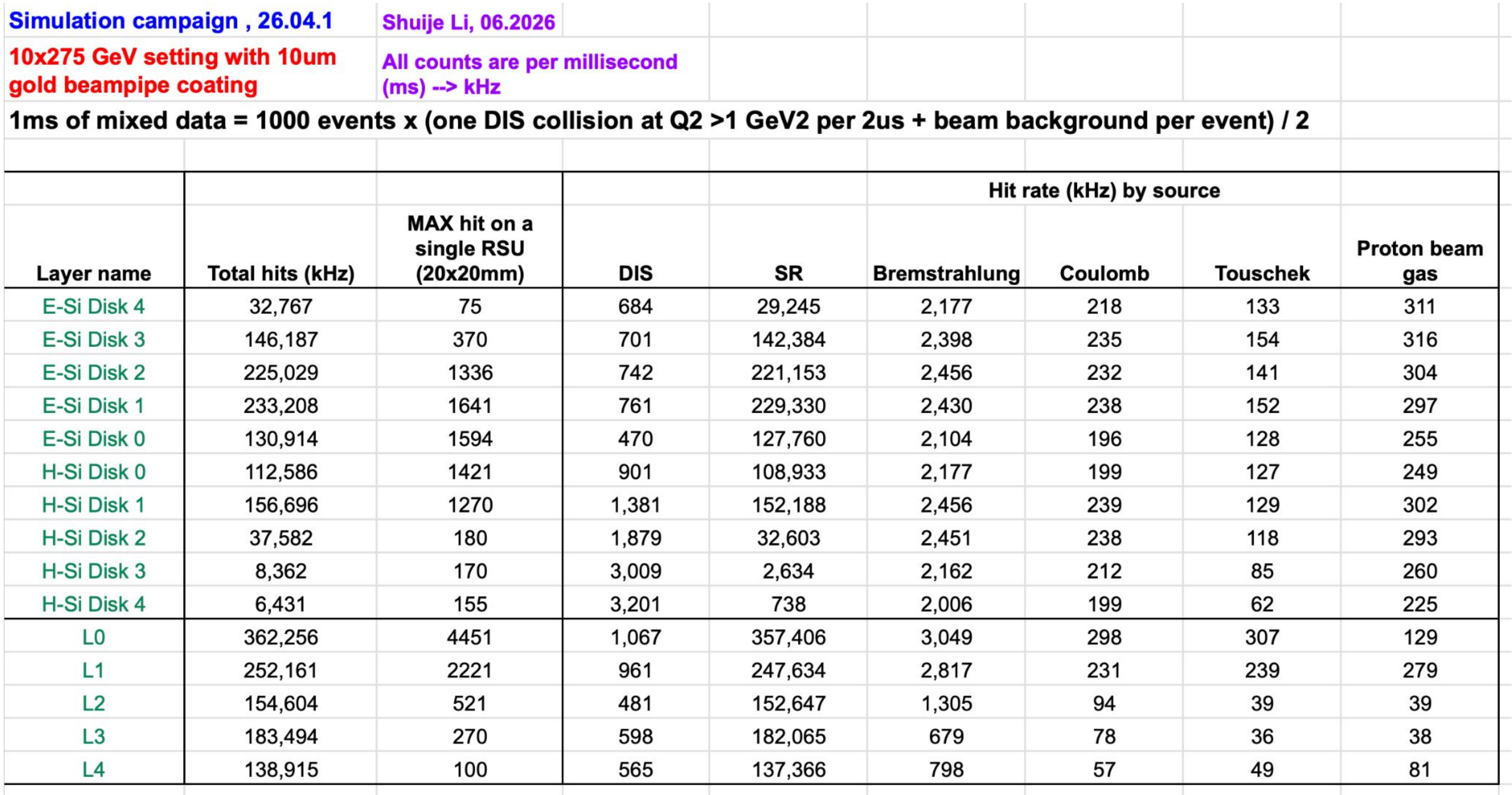
- **10x275** GeV beam (highest rate)
- Forced DIS + background events. Each contains:
    - One $Q^2>1$ GeV^2 NC DIS vertex
    - Several beam background collisions (SR, Bremsstrahlung, Coulomb, Touschek, proton beam gas) at calculated freq. See details at ePIC wiki

Previous studies presented at TIC (Barak and Shujie):

- 26.01 geometry with 10um Au coating, **10x275** beam link
- Simulation campaign 26.03, **10x100** beam link

Link to spreadsheet

26.04.1 DIS+Background rate summary 10x275 beam



Simulation campaign , 26.04.1

Shuije Li, 06.2026

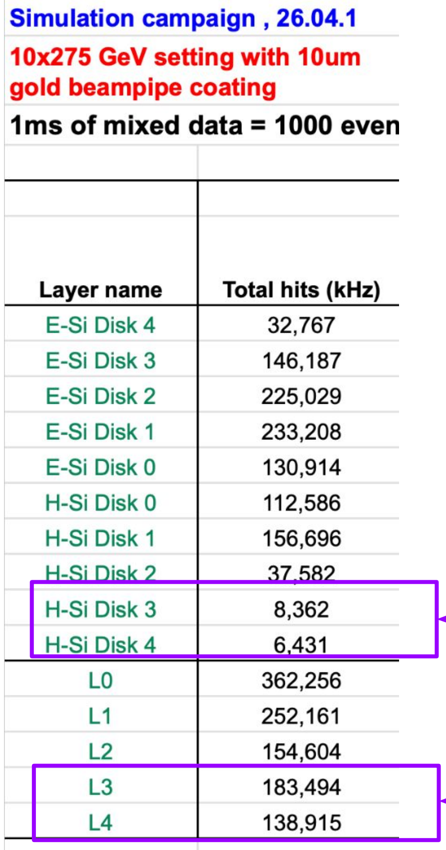
10x275 GeV setting with 10um gold beampipe coating

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

Changes:



Simulation campaign , 26.04.1

10x275 GeV setting with 10um gold beampipe coating

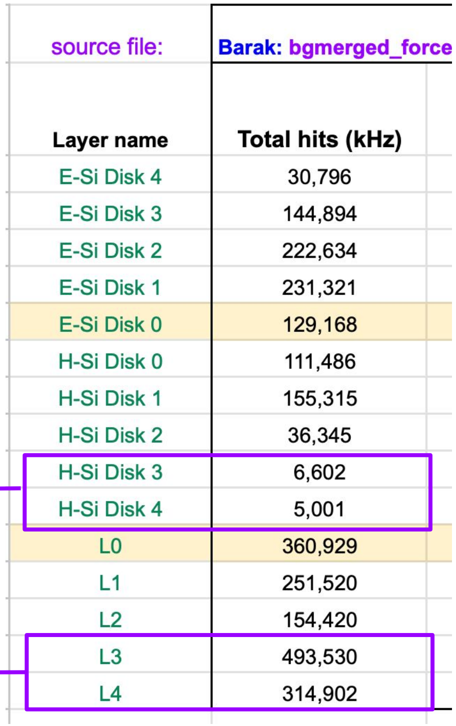
1ms of mixed data = 1000 even

Layer name	Total hits (kHz)
E-Si Disk 4	32,767
E-Si Disk 3	146,187
E-Si Disk 2	225,029
E-Si Disk 1	233,208
E-Si Disk 0	130,914
H-Si Disk 0	112,586
H-Si Disk 1	156,696
H-Si Disk 2	37,582
H-Si Disk 3	8,362
H-Si Disk 4	6,431
L0	362,256
L1	252,161
L2	154,604
L3	183,494
L4	138,915

HD3, HD4 position change

OB Si sensor thickness fix (see next slides)

Jan 2026

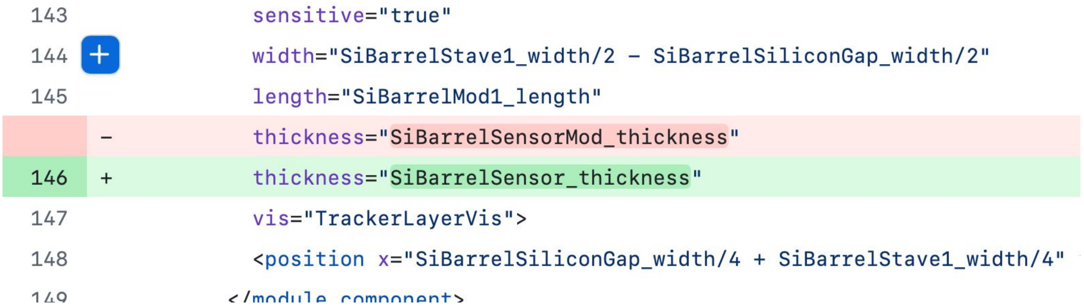


source file:	**Barak: bgmerged_force**
Layer name	**Total hits (kHz)**
E-Si Disk 4	30,796
E-Si Disk 3	144,894
E-Si Disk 2	222,634
E-Si Disk 1	231,321
E-Si Disk 0	129,168
H-Si Disk 0	111,486
H-Si Disk 1	155,315
H-Si Disk 2	36,345
H-Si Disk 3	6,602
H-Si Disk 4	5,001
L0	360,929
L1	251,520
L2	154,420
L3	493,530
L4	314,902

OB (L3 and L4) rates vs ePIC Geometry version

Jan 15, 2026: PR to use the correct variable for OB sensitive Si thickness (reduced by a factor of 2.7):

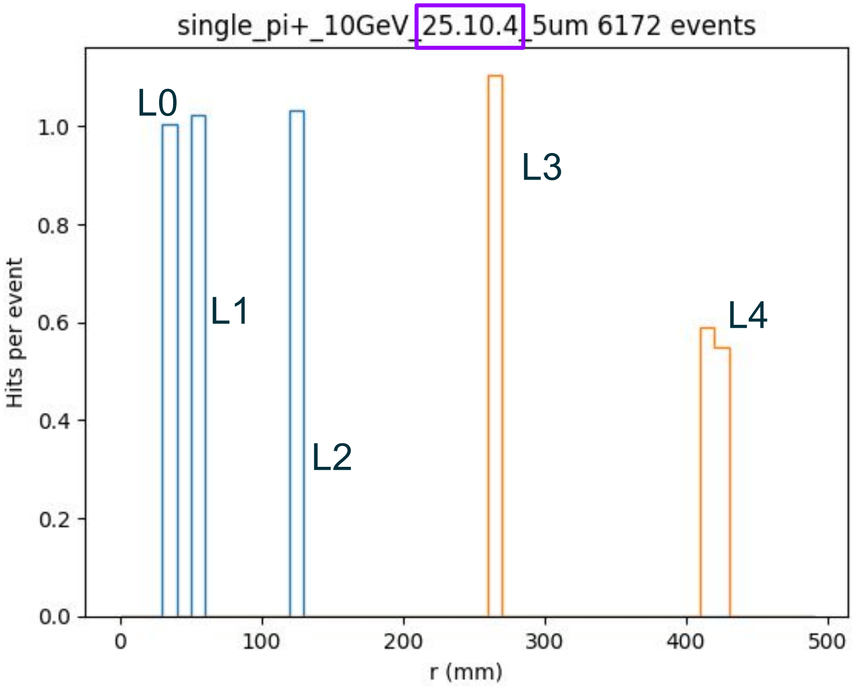
```
    <constant name="SiBarrelSensor_thickness" value="40*um" />
    <constant name="SiBarrelSensorMod_thickness" value="SiBarrelSensor_thickness*2.7" /> <!-- multiply thickness by 2.7 this increases
thickness by 0.00034 -->
    <constant name="SiBarrelSiliconGap_width" value="1*mm" />
```

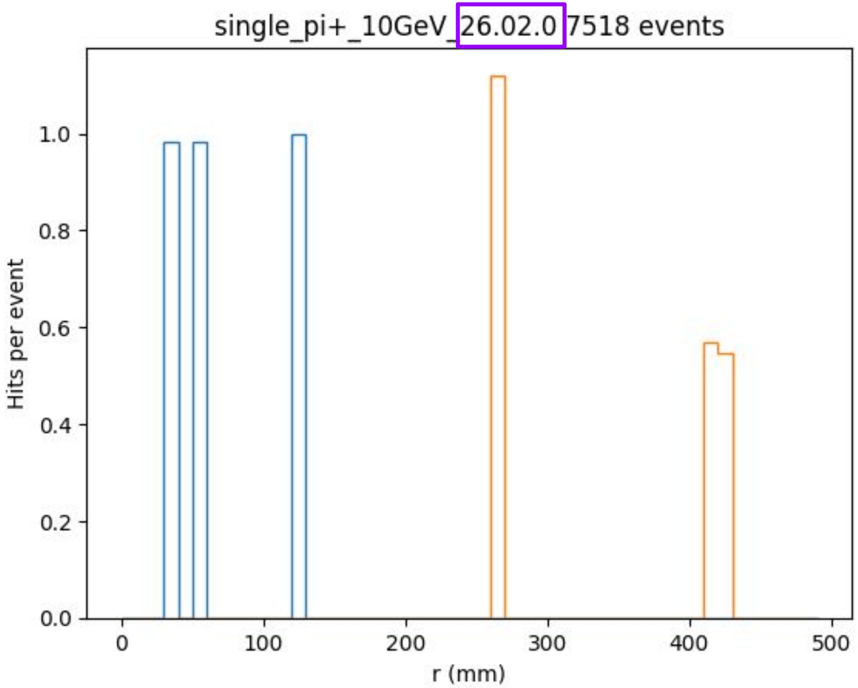


```
                sensitive="true"
                width="SiBarrelStave1_width/2 - SiBarrelSiliconGap_width/2"
                length="SiBarrelMod1_length"
-               thickness="SiBarrelSensorMod_thickness"
+               thickness="SiBarrelSensor_thickness"
                vis="TrackerLayerVis">
                <position x="SiBarrelSiliconGap_width/4 + SiBarrelStave1_width/4"
             </module_component>
```

OB (L3 and L4) rates vs ePIC geometry version

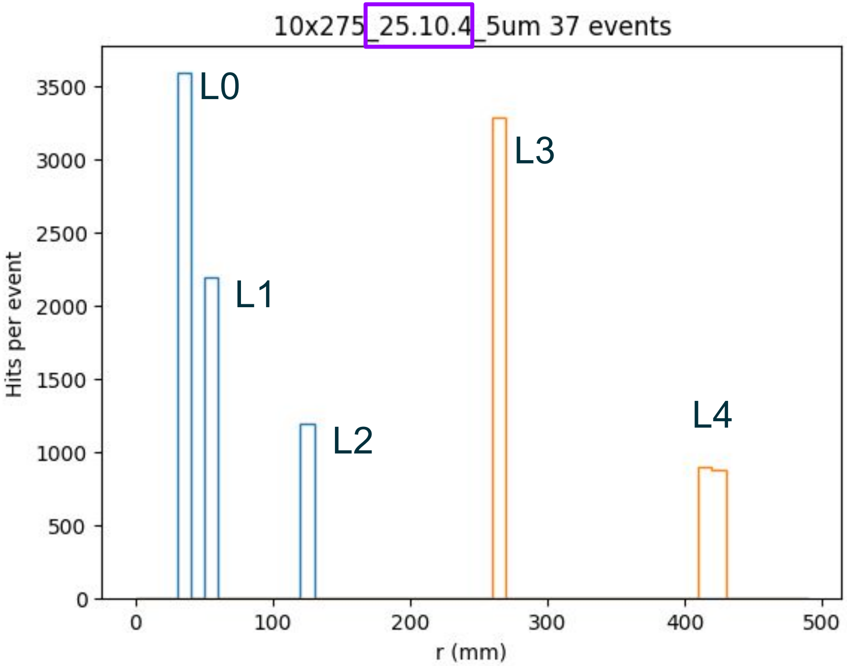
Single Pion rate: no change.

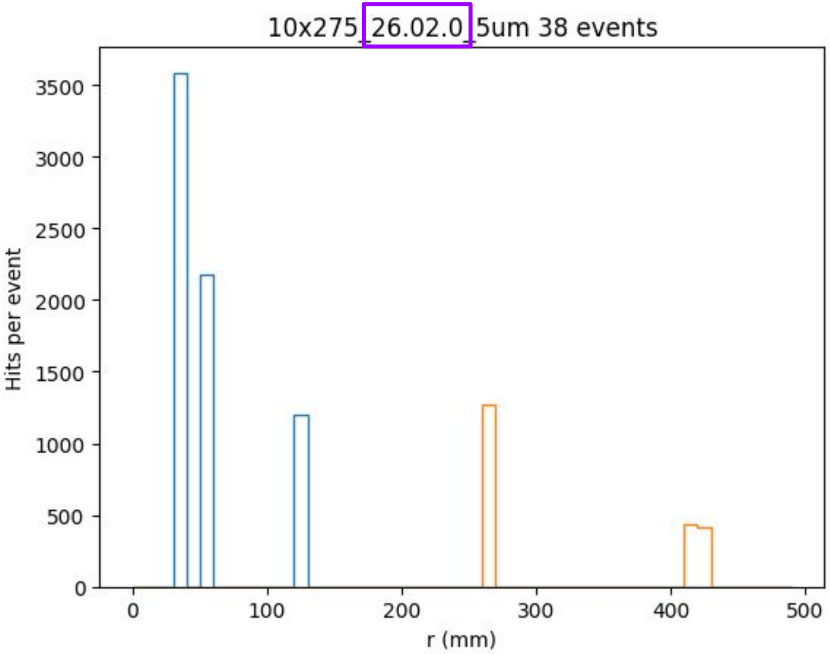




OB (L3 and L4) rates vs ePIC Geometry version

DIS+Background rate: thinner active silicon → lower interaction probability with SR photons.


10x275_25.10.4_5um 37 events


10x275_26.02.0_5um 38 events

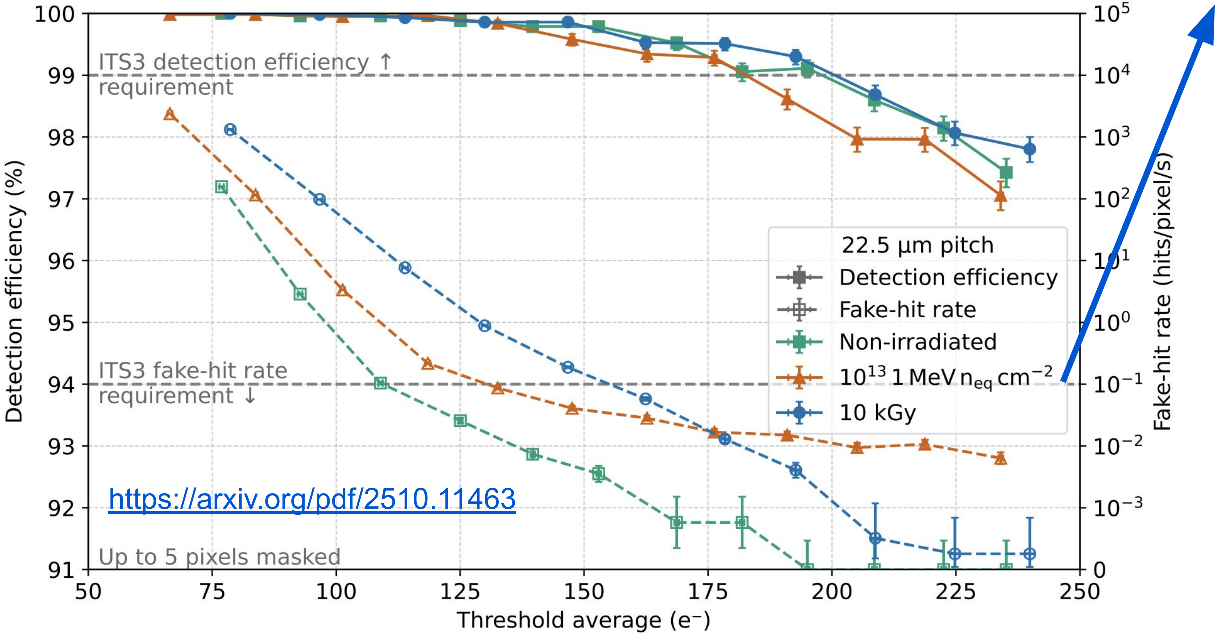
1. Summary of DIS+Background Hit Rate Study

The hit rate (total per section and max per RSU) are extracted with 26.04.1 epic geometry. Changes from previous estimations were understood.

- Things can still evolve:
  - The background source sample and frequency
  - Detailed SVT geometry in simulation
- More to study:
  - Frame-by-frame fluctuations (ongoing discussion with Joao)
  - Max rate per readout element (now we take max per RSU and scale to get an upper limit)

2. Sensor Noise

Fake Hit Rate



https://arxiv.org/pdf/2510.11463

(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

Data rate conversion:

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

3. Simulated Hit to Data Rate

Sensor Response in Simulation: baseline

- Sensor structure:
  - 40um thick of active silicon, 20um x 20um grid to simulate the pixel size.

- Particle steps through material:
  - Accumulates deposits from the same G4Track, writes ONE hit at midpoint hit the volume boundary or track ends: only save one combined hit if the track with an incident angle transversed through multiple pixels.

- Digitization and reconstruction:
  - No charge-sharing, no clustering

Hit rate to data rate:

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

Total data rate (upper limit) =
DIS+background hit rate x 3 pixels/hit x 32 bits/pixel + noise hit rate x 64 bits/hit

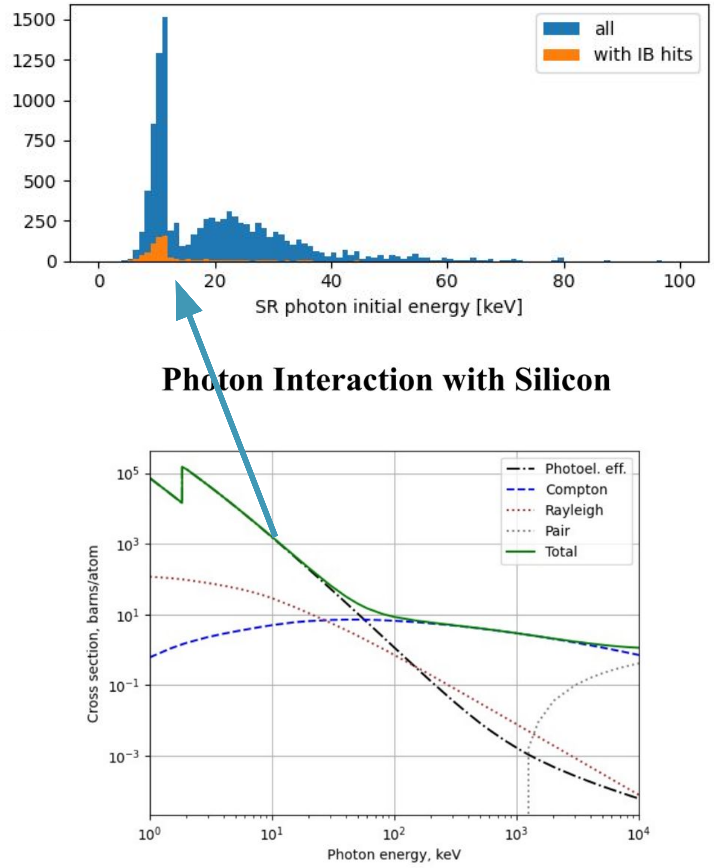
Sensor Response in Simulation: adding details

- Sensor structure:
  - 40um thick of active silicon, 20um x 20um grid to simulate the pixel size.

    How to describe epitaxial and substrate in simulation with the settings of active/inactive? See Yu Hu's talk next

- Particle dependence:
  - Charged particle:
    - Usually going through the material
    - # of pixels per hit can be parameterized as a function of incident angle according to beam test, then introduce clustering algorithm accordingly.
  - Low energy photon:
    - absorption → photo-electron emission
    - Interaction probability sensitive to material thickness (see next slide for example)
    - # of pixels per photon?

Sensor Response in Simulation: example study



Zhenyu Ye

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]

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

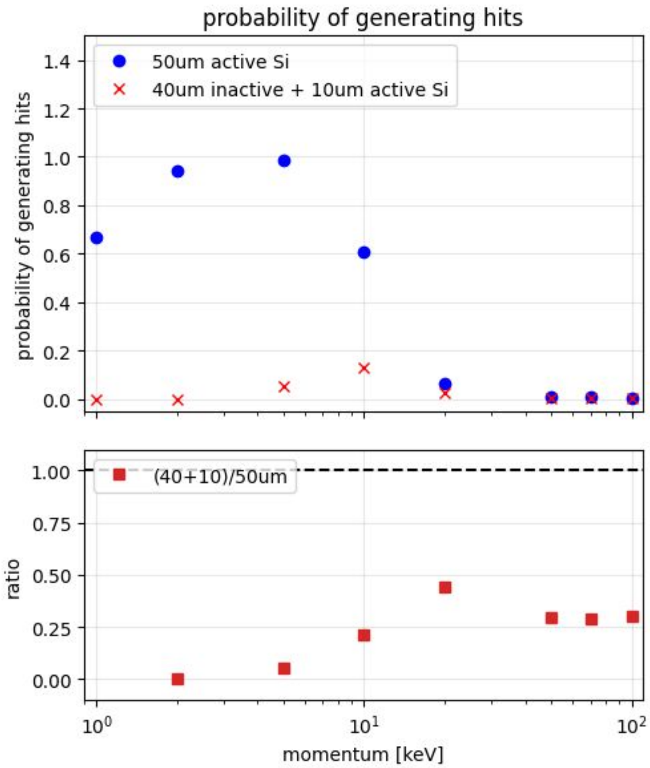
For t=O(10um) silicon (rho=2.33g/cm^3), the exponent < 0.1

⇒ probability P $\propto$ thickness t

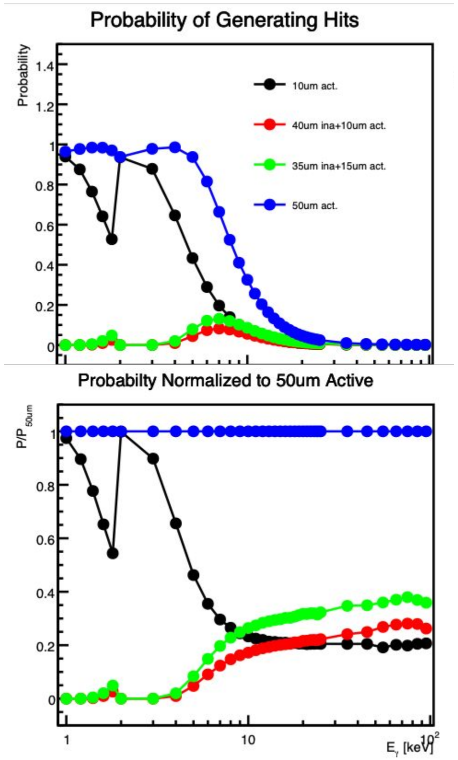
Sensor Response in Simulation: example study

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.

Summary

- The SVT simulation hit rate is updated for:
  - highest rate configuration (10x275, forced DIS+all background)
  - 26.04.1 geometry
  - Physics, each background source, and total
  - Max per RSU → max per readout element (fiber link), and total per section (L0, …, L4, E-Disks, H-Disks)

- Fake hit rate (noise) is estimated at ITS3 limit (2e-7/pixel/2us), then scaled by # of pixels per area

With this, an upper limit of data volume can be obtained as:

$$\underbrace{\text{DIS+background hit rate}}_{\text{Will change with beam background updates and sensor structure/interaction probability in simulation}} \text{ x } \underbrace{\text{3 pixels/hit}}_{\text{This assumption will be updated with further studies on sensor response}} \text{ x 32 bits/pixel + fake hit rate x 64 bits/hit}$$