# New SIT Geometry (SIT01) in Mokka Simulation

Hengne Li @ LAL

## I . Motivation

Since Brahms (the simulation and reconstruction software for TESLA), a strange material, which is called “silicon_8.72gccm”, was existing in our simulation software package, and inherited by Mokka to build SIT and FTD sub detectors.

The strange material "silicon_8.72gccm", has the same Atomic number (A=26.98) and Charge number (Z=13) as Silicon, but has the density of 8.72 g/cm$^3$ (pure Silicon is 2.33 g/cm$^3$), and hence it has the radiation length ($X_0$ = 93.7*2.33/8.72 = 25 mm), where 93.7 mm is the radiation length of pure silicon.

The strange silicon was introduced to account for the additional multiple scattering which is caused by readout electronics, support structures, and other accompanying materials which come together with the silicon sensors. But, the energy deposit in this material is incorrect. (Thanks to Adrian Vogel and Frank Gaede.)

This problem has been known for a long time, but has never been taken care of. A simple and clear solution to account for the additional effects caused by accompanying devices, instead of "invite" a new material for the sensitive layer, is to add another dead/support layer (no matter what kind of the material is, just to account for the additional effects) accompany with the sensitive layer. In this way, the dead layer would not create signals, only the sensitive layer with correct material would, and hence, the energy deposition would always be right.

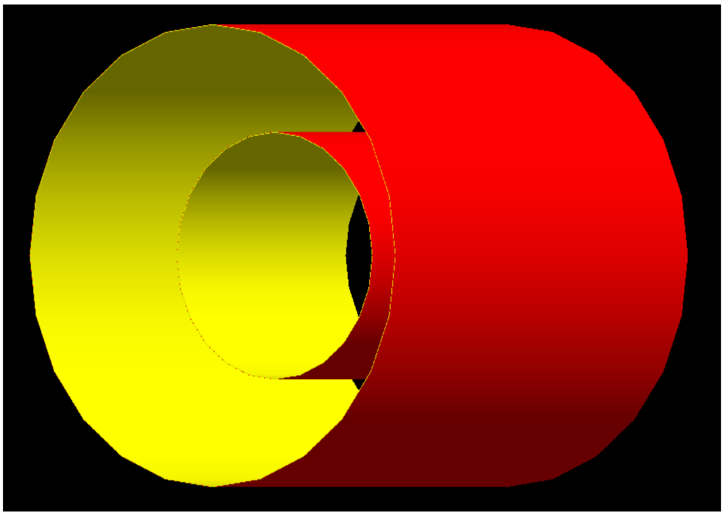
## II. Geometry Definition of Old/New SIT

### 1. Old SIT Geometry (SIT00)

- Only has sensitive part (red in upper picture). Two sensitive barrel tube layers build with silicon_8.72gccm, with radiation length of 25.0 mm.
- Thickness of each layer is 0.3 mm, 1.2 % $X_0$ ; two layers totally 2.4 % $X_0$
- Inner radius and half z for the two layers are:

| layer_id | inner_radious (mm) | half_z (mm) | thickness (mm) |
|---|---|---|---|
| 1 | 160 | 380 | 0.3 |
| 2 | 300 | 660 | 0.3 |

### 2. New SIT Geometry (SIT01)



- Two layers, sampling structure. There are sensitive part and support part for each layer, where the support part adheres to the sensitive part. In the picture above, the red part is sensitive, while the yellow one is support.
- Materials and thickness (**for one layer**) (Thanks to Aurore Savoy Navarro and SiLC Team to provide the information of thickness of silicon and total thickness in X0 )

|  | material | X0 (mm) | Thickness (mm) | Thickness in X0 |
|---|---|---|---|---|
| sensitive part | silicon | 93.7 | 0.2 | 0.21 % |
| support part | beryllium | 352.8 | 1.01 | 0.29 % |
| Total |  |  |  | 0.5 % |

- Inner radius and half z for the two layers are the same as old geometry

## *III. Comparison of Old/New SIT*

To compare the effects of New SIT with the Old one, 10000 single electrons with kinetic energy of 50 GeV was shot into the detector at 50 degrees to the beam pipe. The effects were compared in two points of view: One is the vertex distribution of radiated photons when electron passing through each part of silicon detectors. The other is 1/Pt distribution of reconstructed electron tracks.

### 1. Photon radiation when electrons passing through SIT

The idea is when high energy electron (above 100 MeV) passing through matter, it will radiate photons as a result of the Coulomb interaction with the electric fields generated by the atomic nuclei, which is called Bremsstrahlung. The probability for one electron to radiate one photon with kinetic energy k is approximated to be:

$$P(u) = \frac{4b}{3}\frac{(1-u+3u^2/4)}{u}$$

where, $u = k/E$ , E is the kinetic energy of electron; b is the path length when electron passing through material, $b = (\text{ thickness of material in } X_0)/\sin(\theta)$

If we neglecting k<100MeV, the number of radiated photon is approximately :

$$N = \frac{4b}{3}[\ln(1/u) - 1/4]$$

and,

$$<u> \; = \frac{4b}{3}\frac{[3/4 - u + u^2/2 - u^3/4]}{N} \sim \frac{3}{4}\frac{1}{[\ln(1/u) - 1/4]}$$

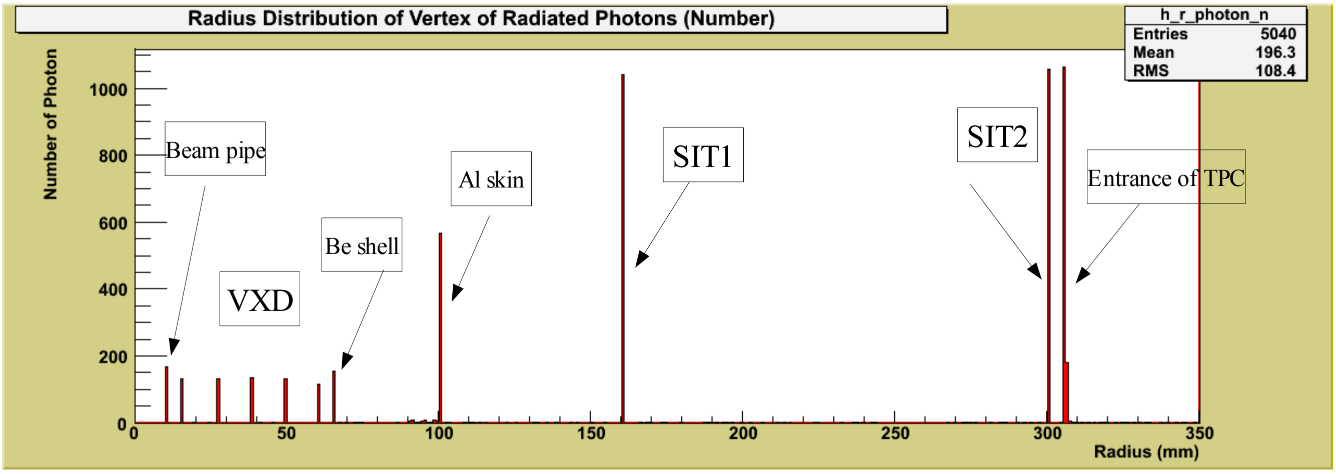
hence the average kinetic energy of the radiated photon is $<k> = <u> E$ .
Thanks to Francois Richard to provide these formula for calculation.

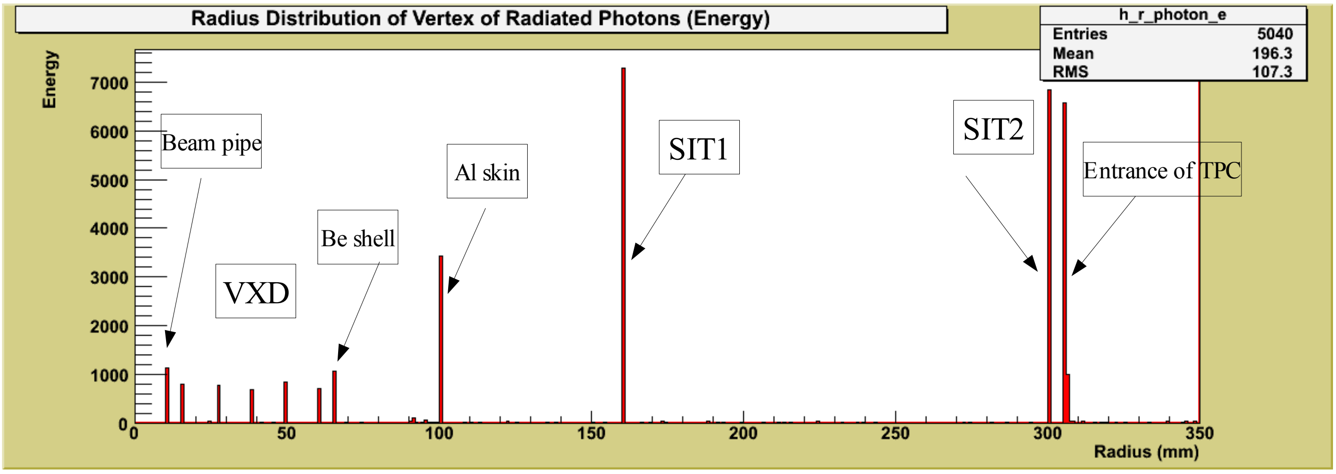
### ***Old SIT (SIT00)***

For old SIT geometry, after calculation, the number of photons radiated in each layer should roughly be 1200, and the energy of radiated photon should totally roughly be 7500 GeV, for 10000 electrons. After simulation, two plots were got from Monte Carlo truth information:

- the radius distribution of the vertex where photon radiated, where the radius is the distance (in r-phi view) to the collision point of the vertex; and
- the same plot but weighted by the kinetic energy of each radiated photon

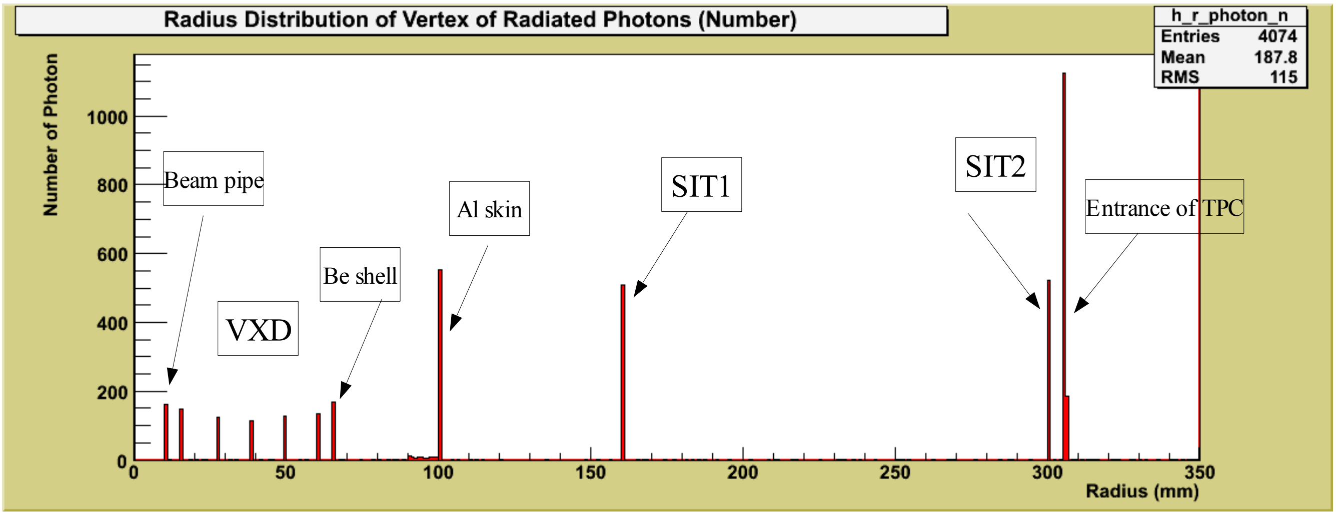
These two plots corresponding to the calculation, see below,

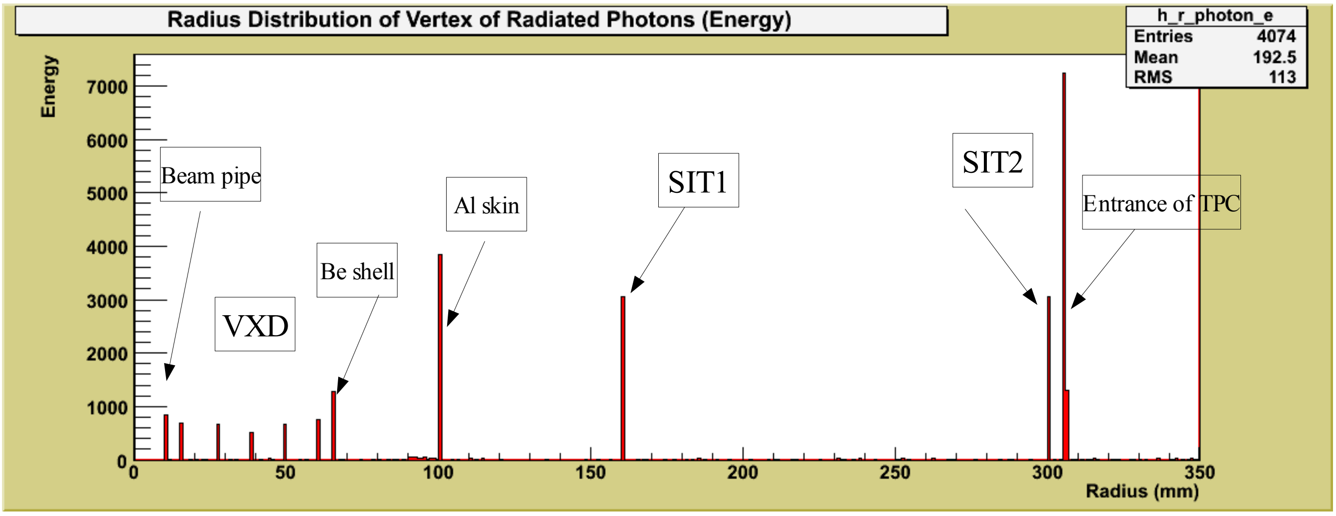




*New SIT (SIT01)*

For new SIT geometry, after calculation, the number of photons radiated in each layer should roughly be 520, and the energy of radiated photon should totally roughly be 3300 GeV. The same plots were provided trough simulation, see below,





*Comparison*

As what we saw, the probability of photon radiation largely reduced in the New SIT geometry, only ~ 50% of witch in Old SIT geometry.

## 2. Reconstructed electron tracks

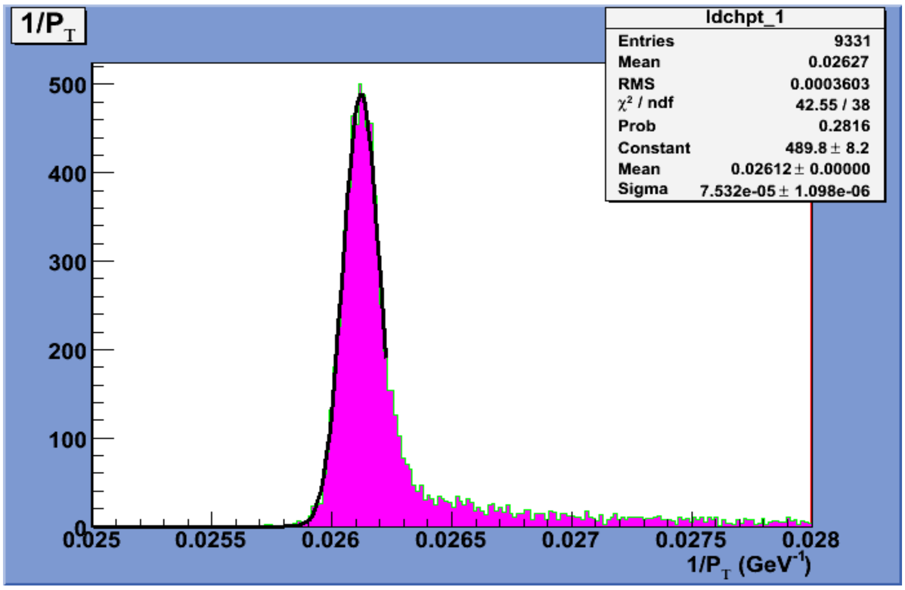
The electron track reconstruction was done by FullLDCTracking processor (author, A. Raspereza) in MarlinReco.

After reconstruction, only one track events were considered. To do like this, is because the number of reconstructed tracks in a particular event can be more than one, and without an electron identifier implemented, we cannot easily decide which track is coming from the initial electron. The additional tracks can be the tracks of secondaries, and can also be track segments of true mother after large kinetic photon radiated. This reduces the purity of true mother electron tracks. Of cause we have LDCTracks to MCP relations collection, which makes it possible to use MC information, but the most easiest way is to select only events with one track reconstructed. Even do like this, it is still hard to say all the tracks are coming from the true mother electrons, but it truly largely increases the purity.

After one track selection, 1/Pt was calculated from the curvature of reconstructed tracks, and the distribution of 1/Pt was drawn.

*Old SIT (SIT00)*

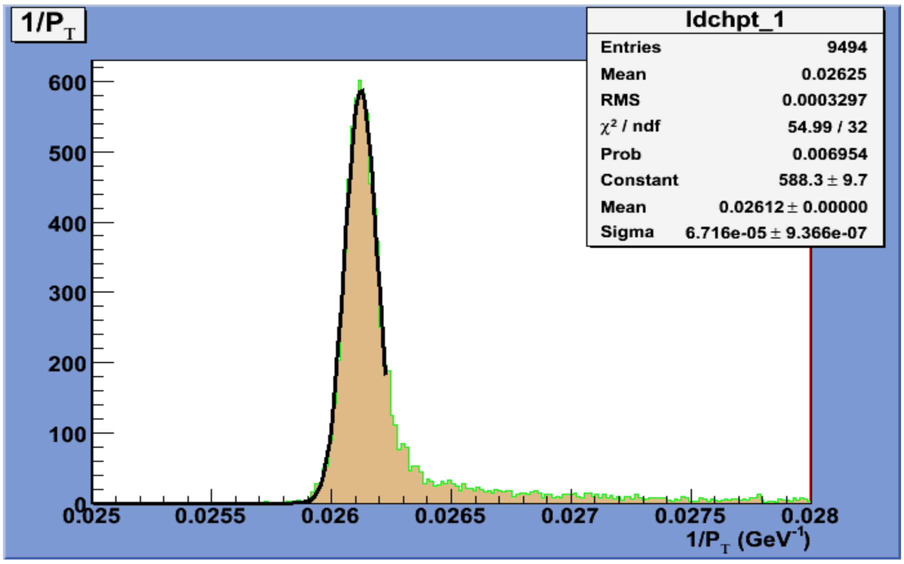
For old SIT geometry, after one track selection, 9331 events left (from 10000 events). See plot below:



Through Gaussian Distribution fit, where the long tail are excluded, the mean value of 1/Pt is 0.02612(±0.00000), which is correctly reconstructed, and the sigma value of the fit is 7.532*10$^{-5}$ (±1.098*10$^{-6}$) . If we define events with 1/Pt larger than "<mean value> + 3*Sigma" are "the tail events", and after the tail events rejected, we have 6742 events left. This means 27.7 % events are tail events, and if including the rejected events by one track selection, 32.6 % events were rejected. Since the tail events is caused mainly by photon radiation, which reduced the kinetic energy of mother electron, and the photon radiation proportional to the thickness of material which electron passing through, so percentage of the tail events reflect the material budget of detectors.

### *New SIT (SIT01)*

For new SIT geometry, after one track selection, 9494 events left (from 10000 events). See plot below:



Through Gaussian Distribution fit, the mean value of 1/Pt is 0.02612(±1.04954e-6), which is correctly reconstructed, and the sigma value of the fit is 6.716e-5(±9.366e-7). The same treatment as for old geometry implemented, define events with 1/Pt larger than “<mean value> + 3*Sigma” are “the tail events”, and after the tail events rejected, we have 7123 events left, which means 25.0 % events are tail events, and if including the rejected events by one track selection, 28.8 % events were rejected.

### *Comparison*

Comparing these digits with that of old SIT geometry, we have 3.8% events saved, and the sigma decreased by 10.8 % . And also, the events number in the peak roughly increased by 20%.

## IV. Technical Aspects of the New SIT

The Sit01 sub detector driver implements the new SIT geometry, and is tested. The default settings are described above. In order to increase the flexbility of the driver, two Mokka commands are reserved to modify the settings by users. These commands are, e.g.:

```
/Mokka/init/userInitDouble sit_sp_thickness 1.01
```

-- thickness of support part, in mm.

```
/Mokka/init/userInitString sit_sp_material beryllium
```

-- material of support part, a string, the name of materials should exist in Mokka material database, if not, Mokka will report error and exit automatically.

Users can modify the support layer material and thickness through putting these two commands into their Mokka steer files. If no such commands putted into Mokka steer file, the default settings will be chosen to build the SIT.