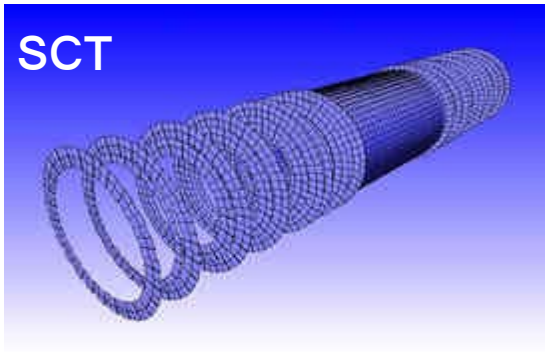


Charge Trapping in the Simulation of the ATLAS Semi-Conductor Tracker

Marco Filipuzzi[a], Taka Kondo[b], Kerstin Tackmann[a], Peter Vankov[a],

21st RD50 Workshop, CERN

14.11.2012

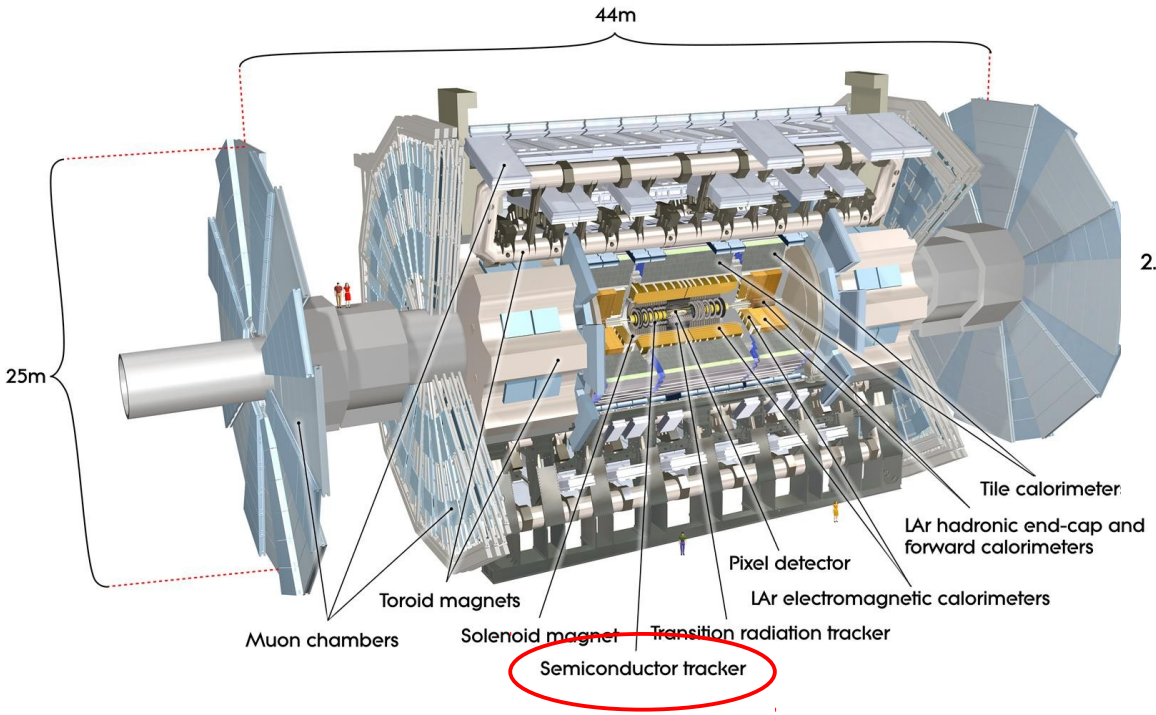
([a]DESY, Hamburg; [b]KEK)

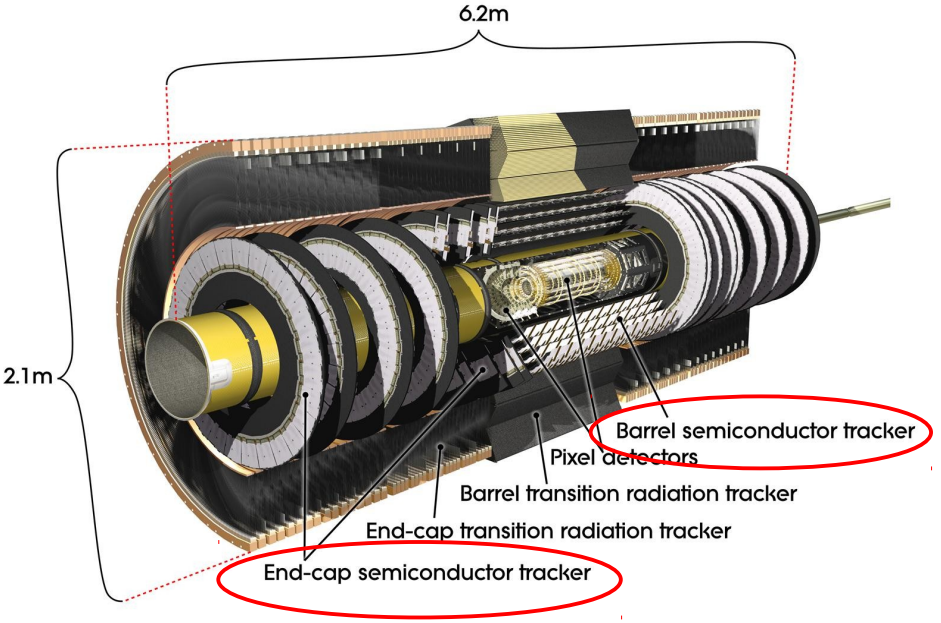
Outline

- ATLAS Semi-Conductor Tracker (SCT)
- Charge Trapping
- Implementation in the SCT simulation code
- Results

ATLAS SCT detector

Semi-Conductor Tracker inside Atlas:



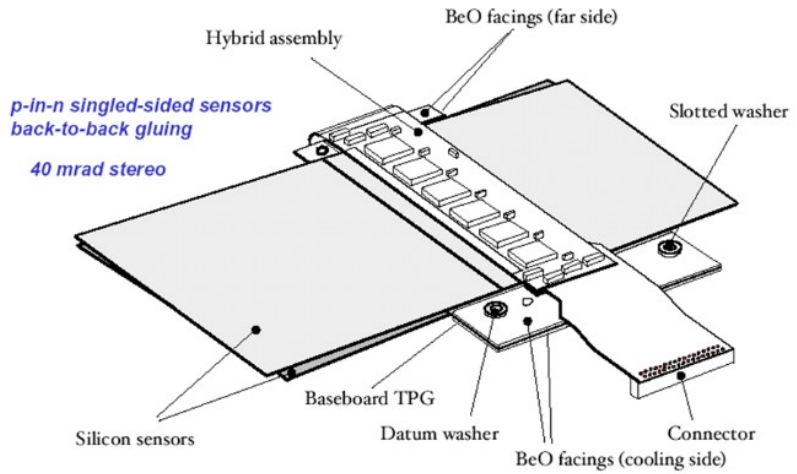


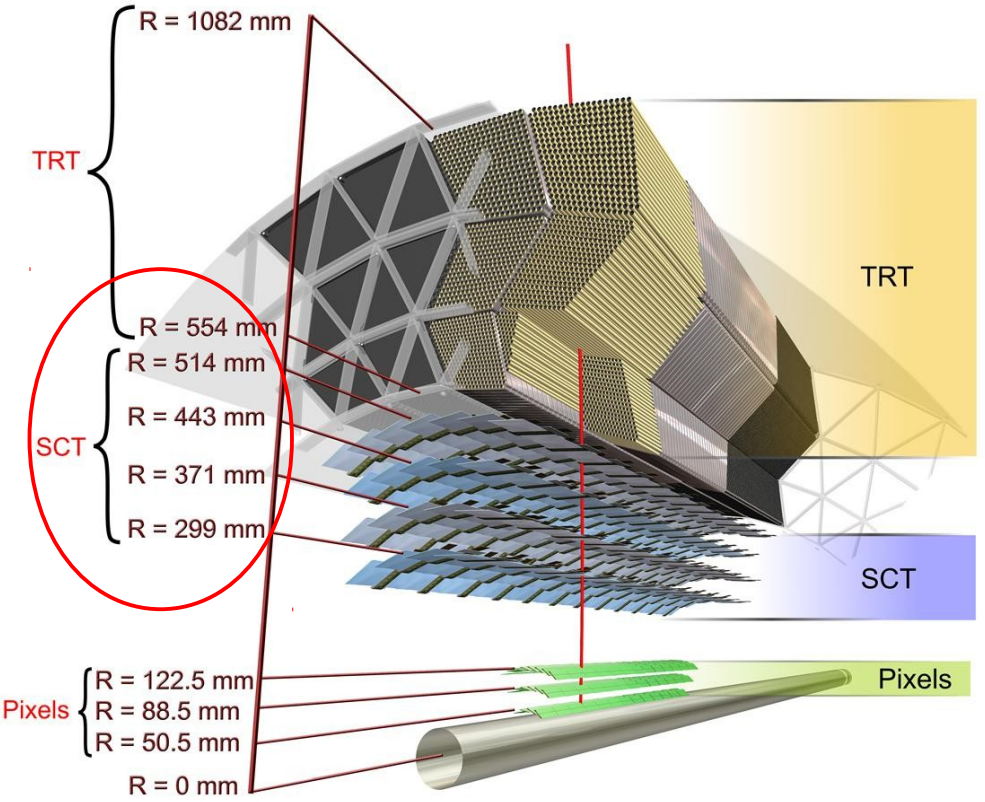
- 61 m² silicon
- 6.3 million readout channels
- 4088 modules
- 4 barrel layers
- 18 endcaps disks

ATLAS SCT detector

Semi-Conductor Tracker sensors:

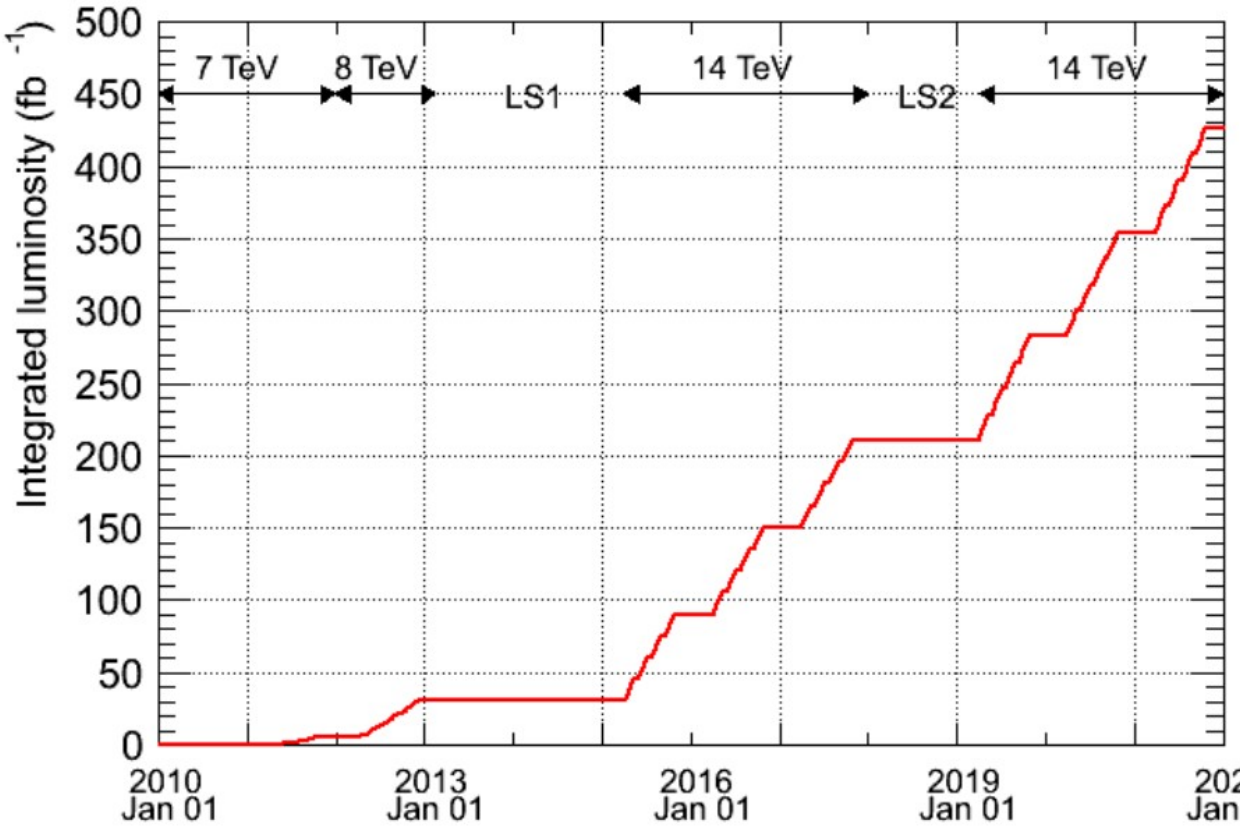
- Single sided p-on-n
- 285 μm thick
- Strip pitch: 80 μm (barrel), 57-94 μm (endcap)





Fluences in the SCT detector

Expected fluences are calculated using FLUKA simulation



Fluence received in the innermost SCT Barrel layer (B3) [1 MeV n-eq / cm²]:

$\Phi \sim 10^{14}$

$\Phi \sim 7 \times 10^{13}$

$\Phi \sim 4 \times 10^{13}$

$\Phi \sim 3.8 \times 10^{12}$

Prediction taken from p.47 of P. Collier's talk at the ATLAS week on 2012.6.4

Fluences in the SCT detector

Detailed predicted values per layer:

Fluence per **pb-1** for **7 TeV** from **PHOJET1.12**

SCT barrel	radial position (cm)	1 MeV neq (x 10^8 cm^{-2})	Dose (Gy)
1	29.9	1.66	0.069
2	37.1	1.30	0.049
3	44.3	1.07	0.036
4	51.4	0.90	0.027

SCT endcap disk	Inner		Middle		Outer	
	1 MeV neq	Dose (Gy)	1 MeV neq	Dose (Gy)	1 MeV neq	Dose (Gy)
1	-		1.26	0.048	1.02	0.031
2	1.64	0.071	1.24	0.047	1.00	0.031
3	1.62	0.073	1.22	0.047	1.00	0.032
4	1.66	0.074	1.26	0.050	1.01	0.032
5	1.65	0.076	1.30	0.052	1.03	0.034
6	1.67	0.081	1.35	0.052	1.09	0.035
7	-		1.45	0.055	1.18	0.037
8	-		1.67	0.058	1.37	0.040
9	-		-		1.54	0.040

Fluence per **fb-1** for **14 TeV** from **PHOJET1.12**

SCT barrel	radial position (cm)	1 MeV neq (x 10^{11} cm^{-2})	Dose (Gy)
1	29.9	2.06	85.3
2	37.1	1.61	59.8
3	44.3	1.33	44.8
4	51.4	1.13	34.6

SCT endcap disk	Inner		Middle		Outer	
	1 MeV neq	Dose (Gy)	1 MeV neq	Dose (Gy)	1 MeV neq	Dose (Gy)
1	-		1.58	57.6	1.26	38.1
2	2.02	87.1	1.56	58.0	1.24	38.5
3	2.02	88.7	1.56	59.8	1.25	40.5
4	2.03	91.0	1.59	61.5	1.28	41.6
5	2.08	94.9	1.60	62.0	1.29	42.0
6	2.14	101.2	1.70	65.4	1.38	44.7
7	-		1.85	69.4	1.51	47.0
8	-		2.15	73.6	1.76	49.3
9	-		-		2.03	52.3

https://twiki.cern.ch/twiki/bin/viewauth/Atlas/BenchmarkingAtTheLHC

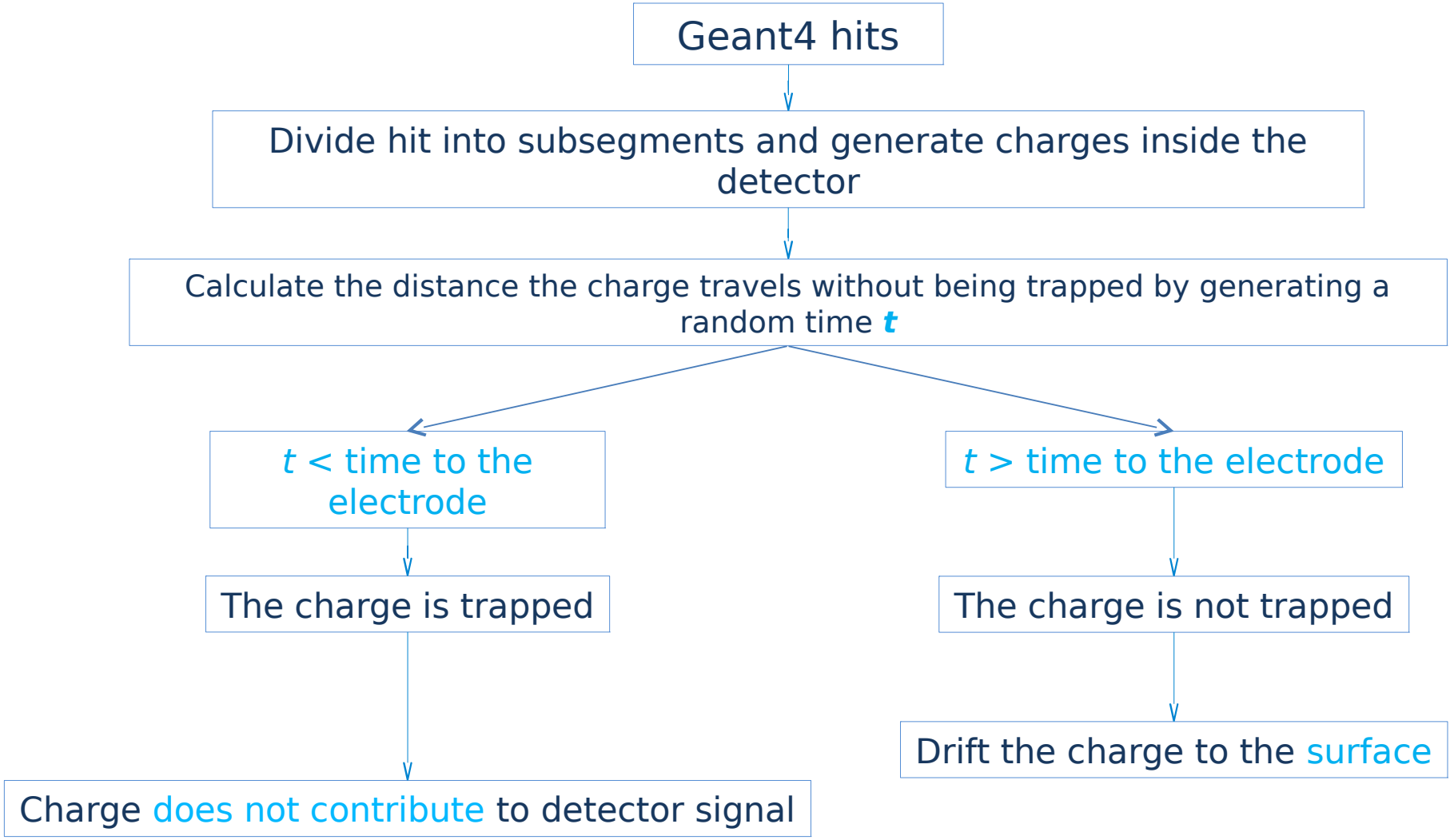
Thanks to T. Kondo and I. Dawson!

Charge Trapping for SCT

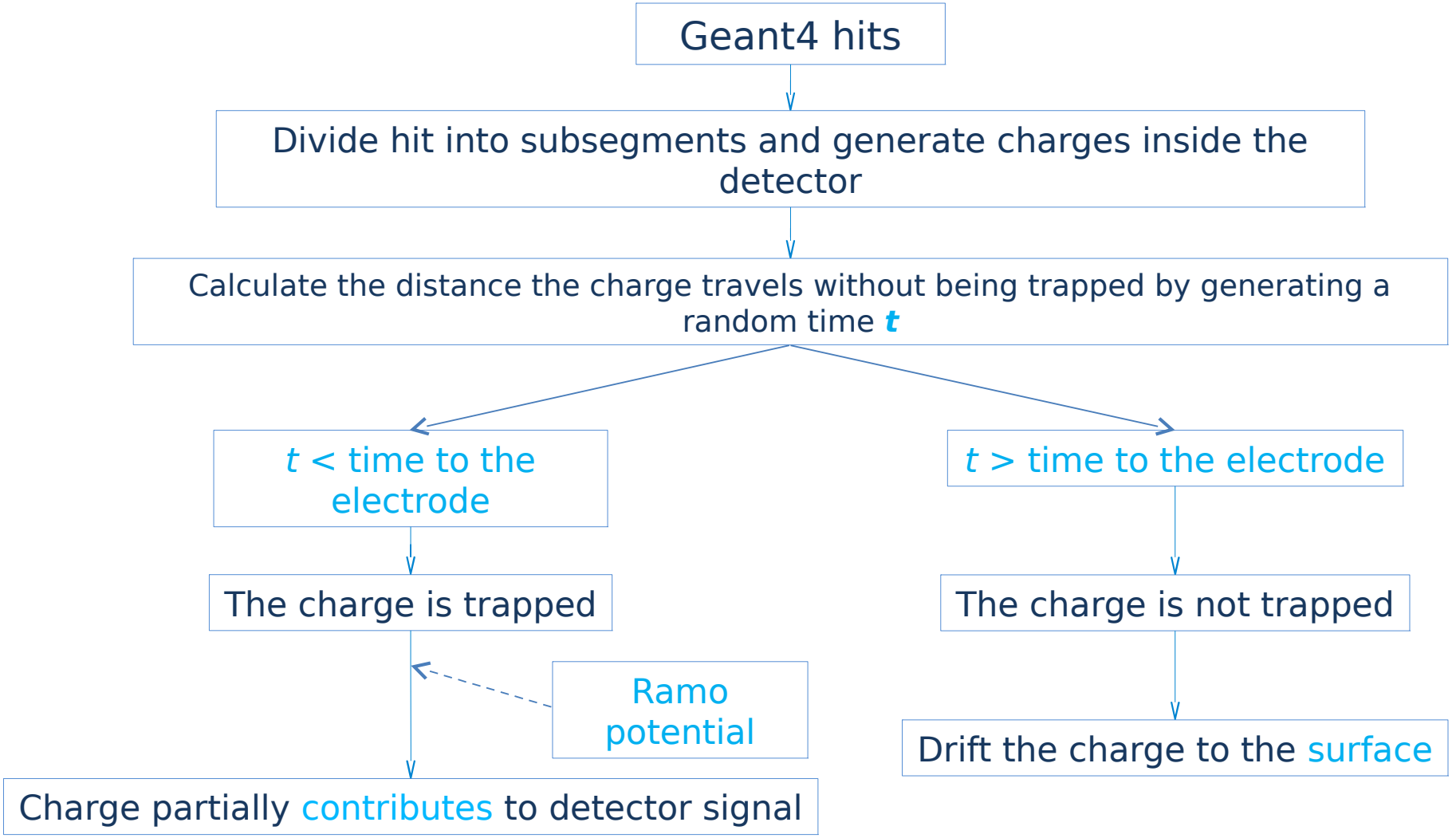
Study of charge trapping effect for SCT in the framework of ATLAS Full simulation (Athena):

implemented as an option into the current Athena framework for SCT simulation. This algorithm takes Geant4 hits and produces digits in the form of a Raw Data Object (RDO) which indicates the strips which have been hit.

How it is implemented



How it is implemented



How it is implemented

The random time that the free carrier can drift before being trapped are generated according to the following distribution:

$$t = -\tau log(u)$$

Where u is a random number between [0,1] and τ

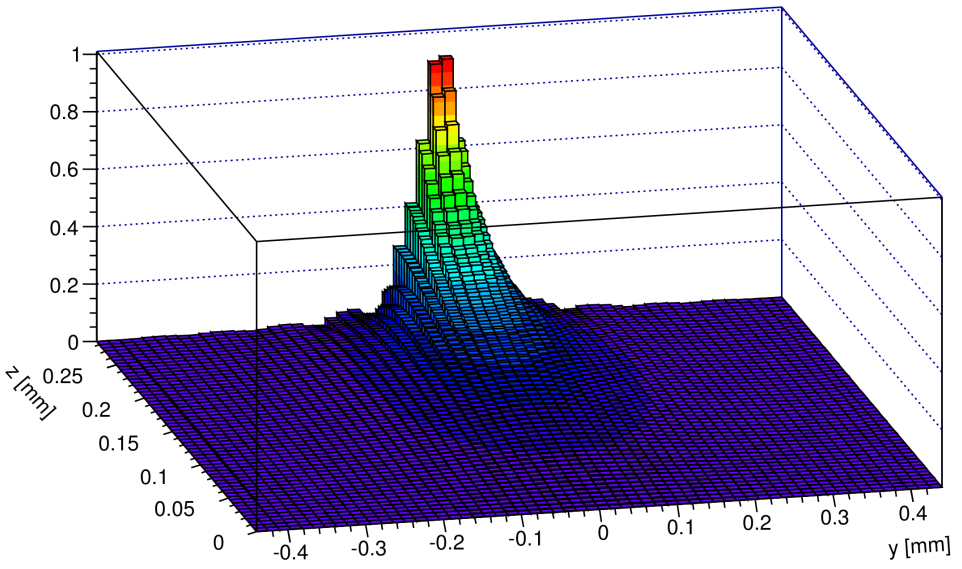
$$\frac{1}{\tau} = \beta\phi$$

With ϕ the fluence received so far and β the trapping constant

Ramo potential

In order to take into account the signal induced by the drift of free carriers that are trapped, a Ramo weighting potential map with the specific SCT detectors geometry was produced:

- Look up table
- y direction covers 5 strip length with steps of 5 μm
- z direction covers strip depth with steps of 2.5 μm



Preliminary results

- MC 14 TeV min. bias events are used, 100 events
- Fluence varied
- $\beta = 5.1 \cdot 10^{-16}\ cm^{-2}\ ns^{-1}$

  (O.Krasel, “Charge Collection in Irradiated Si Detectors”, Ph.D. Thesis, University of Dortmund (2004))
- T = -2° C

Fluences in the SCT detector

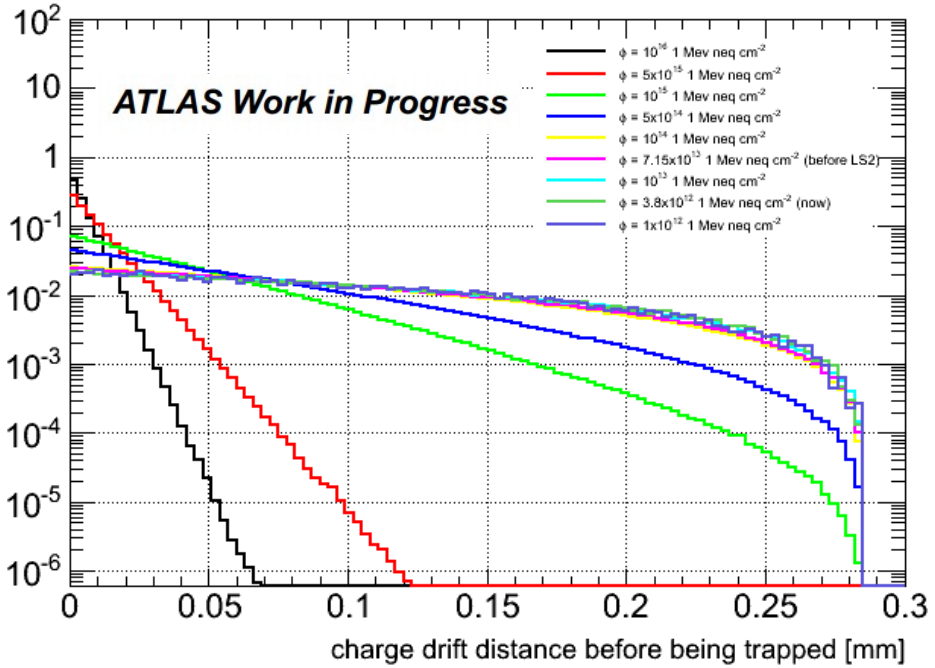
Results that will follow will focus our attention on the SCT

innermost barrel layer:

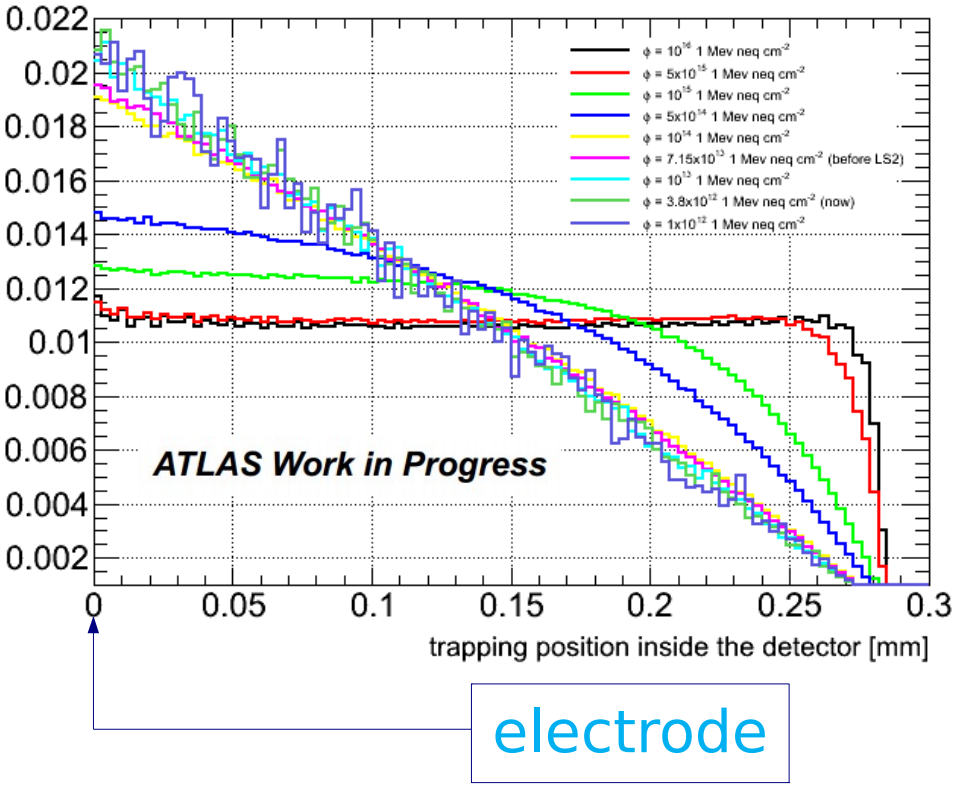
- Layer: B3
- Radius: 29.9 cm
- Modules 384
- T ~ -2° C

Preliminary results

Variables monitored:



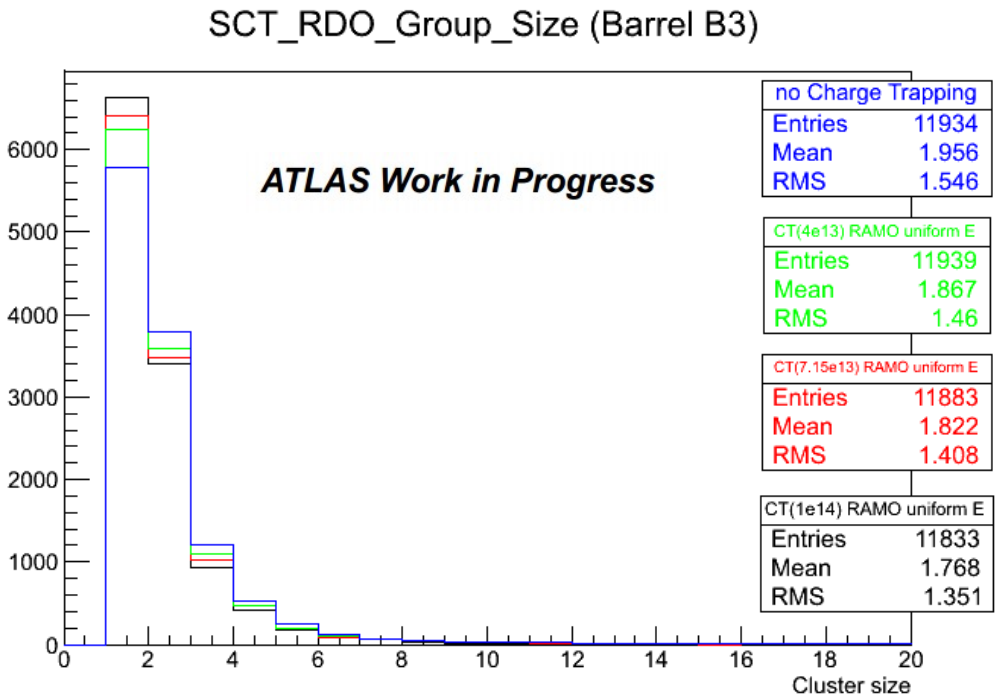
distance without being trapped



trapping position

Preliminary results

Looking at the cluster size for raw data and comparing SCT full simulation with and without charge trapping:



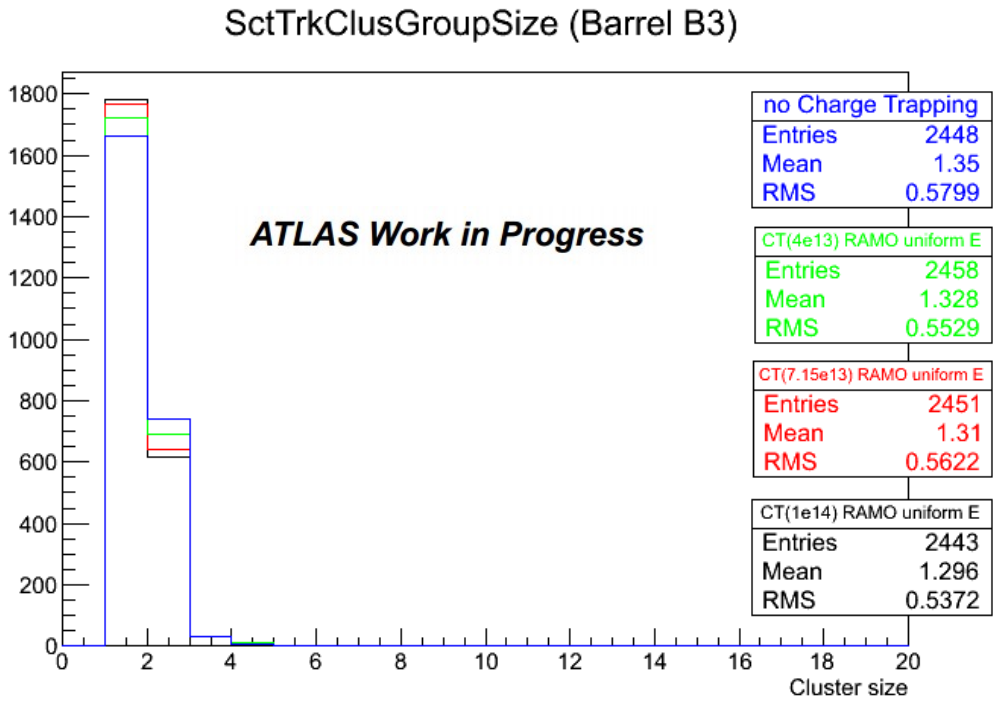
Fluence [1MeV neq/cm^2]	Mean cluster size	Difference with charge trapping
No charge trapping	1.956	
CT (4x10^{13})	1.867	-4.5%
CT (7x10^{13})	1.822	-6.8%
CT (1x10^{14})	1.768	-9.6%

Notice the hit inefficiency caused by charge trapping that consists in a 0.8% efficiency reduction at Φ = 1x10^{14} [1MeV neq/cm^2]

Preliminary results

Looking at the cluster size for hits on track and comparing SCT full simulation with and without charge trapping:

Fluence [1MeV neq/cm^2]	Mean cluster size	Difference with charge trapping
No charge trapping	1.350	
CT (4x10^{13})	1.328	-1.6%
CT (7x10^{13})	1.310	-2.9%
CT (1x10^{14})	1.296	-4.0%



Summary

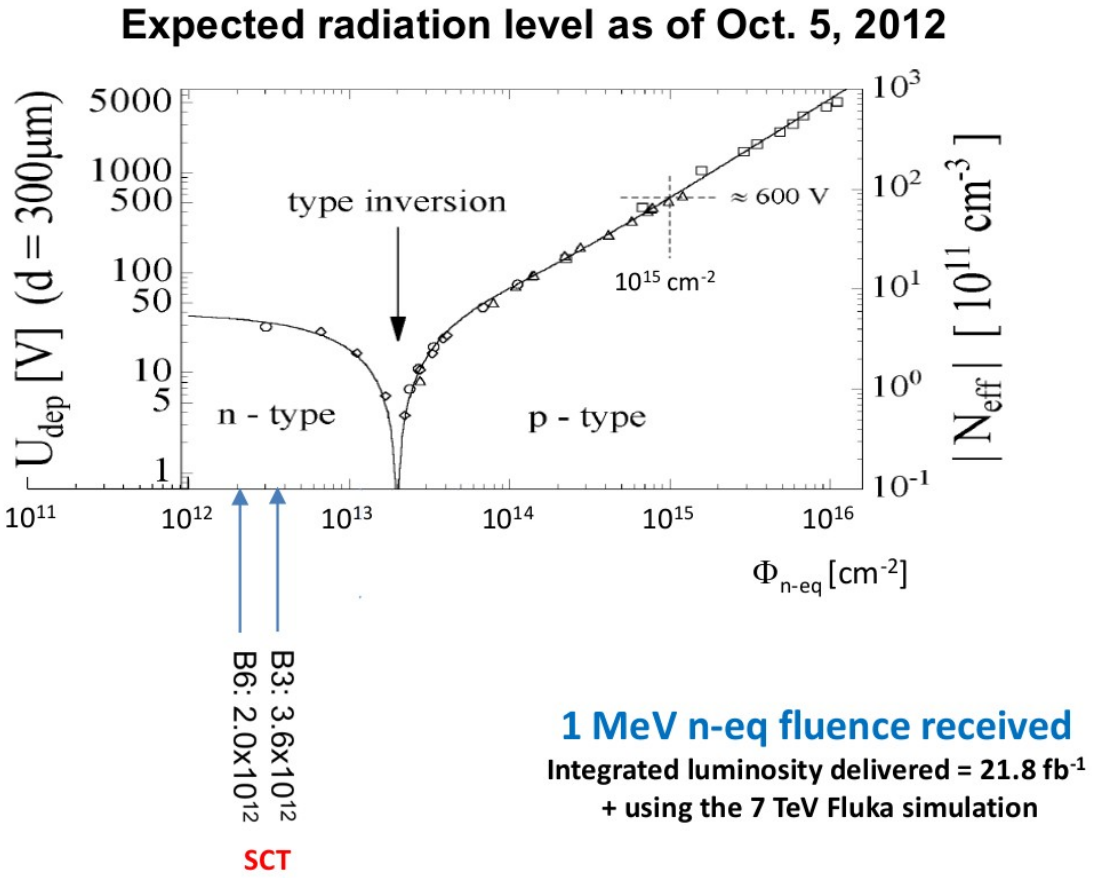
- First implementation of a radiation damage effect (charge trapping) in the full SCT simulation.
- Studied impact on cluster size and hit efficiency for different fluences.
- We focussed our attention to the SCT innermost barrel layer and to fluences up to 1xE14 [1 MeV neq/cm^2] which should correspond to the maximum fluence received after more than 430/fb. With a “simple model”, plots for cluster size for all cluster and for hits on track show a decrease of ~9% and ~4% respectively, of the mean cluster size.
- The hit inefficiency induced by charge trapping is ~0.8% for the fluence just mentioned.

Thank you!

Backup

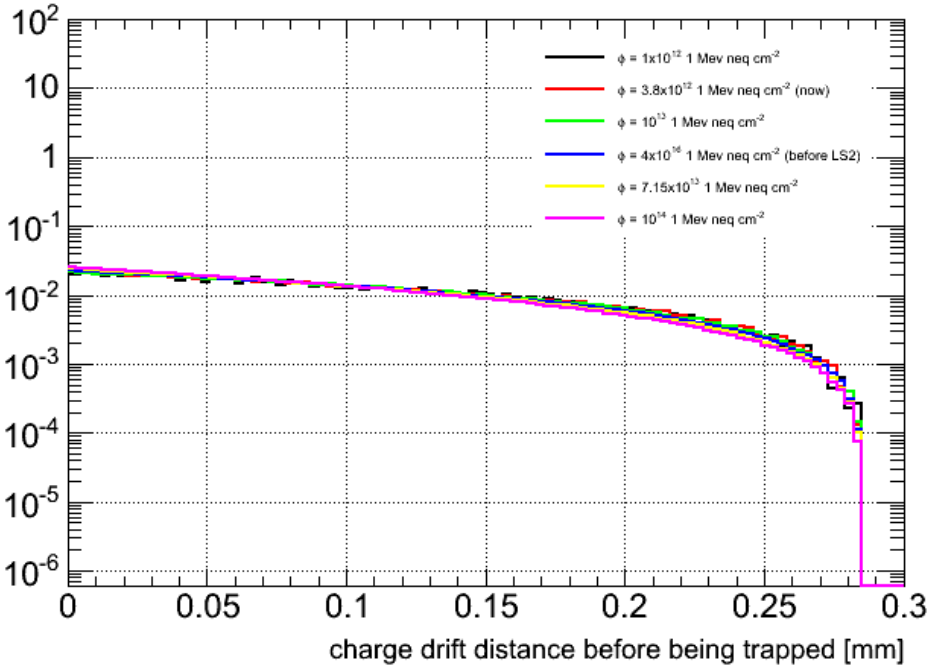
Fluences in the SCT detector

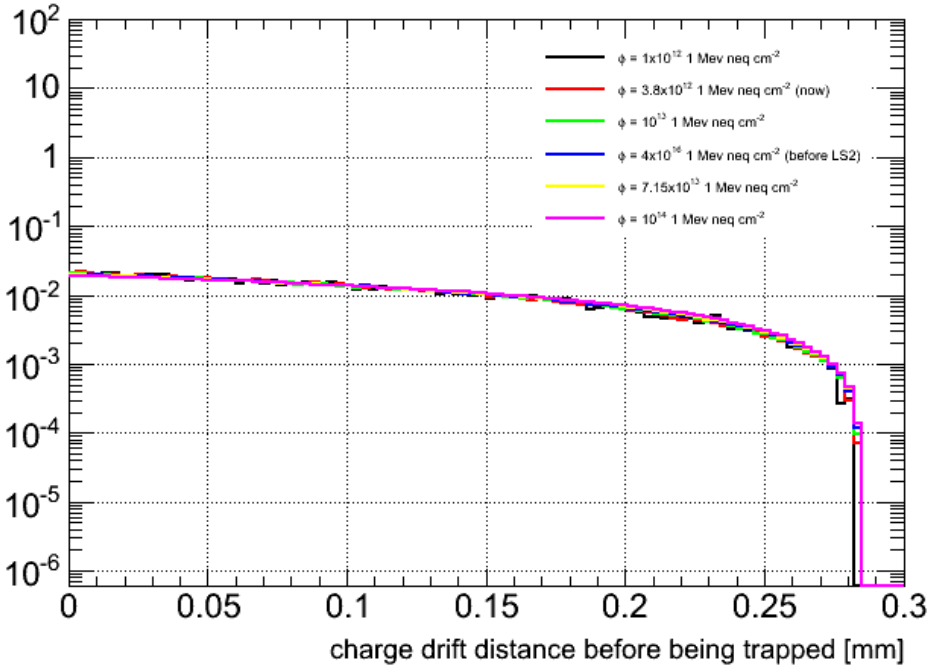
Expected fluences are calculated using FLUKA simulation



Preliminary results

Trapping position and trapping distance as a function of fluence





Preliminary results

Rate of free carrier that are trapped for different fluences

Fluence reiceived so far from B3 ~3.8xE12

fluence (cm^{-2})	Trapped charges (%)
1xE12	0.356
1xE13	3.468
1xE14	27.49
1xE15	80.98