Si Sensor Damage Test Beam

Pelle (w/ input from others obviously)

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Introduction

Real experts from UCSC gave talk in SVT meeting:

- https://confluence.slac.stanford.edu/display/hpsg/08.27.2013+Weekly
- Look there for additional details

Two components

- Readout chip damage (won't talk about it here; should be ok…)
- Breakdown of sensor strip implant capacitor

Spoiler

- Atlas studies show it's very hard to test behavior (beam loss scenarios are hard to produce in test)
- Vulnerability depends on *exact* details and specifications of the sensor
  - Bias "network", bias voltage, di-electric specifications on sensor, punch-through structures, implant resistance, etc.
- Vulnerability depends on *exact* charge deposition details:
  - Total charge, time evolution, spatial distribution, etc.

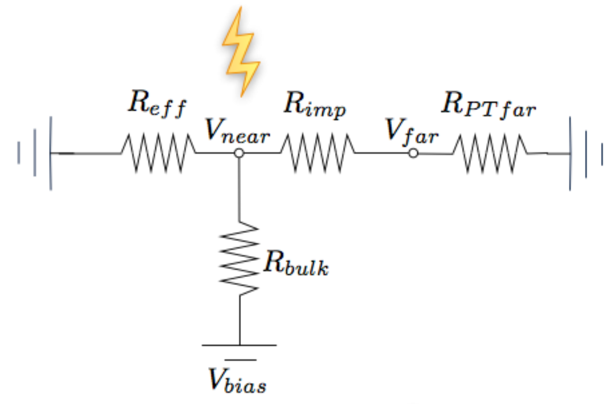
Implant Capacitor Damage

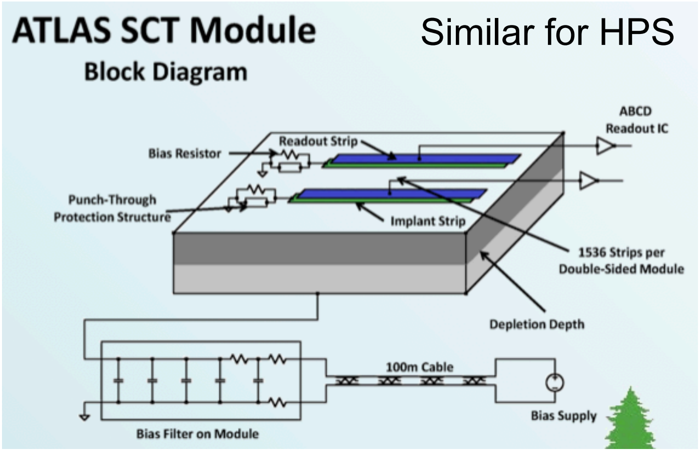
Large voltage on implant strip can permanently damage the coupling capacitor (rated for ~100V)

Operating at very high voltages (up to 1kV) increases risks

Large voltages on implant can occur if large charge deposition creates “ohmic path” in bulk (field breakdown)

- Implant voltage then depends on exact sensor design of:
  - Punch-through protection (on both sides)
  - Bias resistor
  - Strip implant resistance (incl. strip length)
  - Surface treatment and detailed geometry
- In addition, bias network will have an important impact on the circuit (may drop bias voltage which protects the implant voltage (depends on RC))

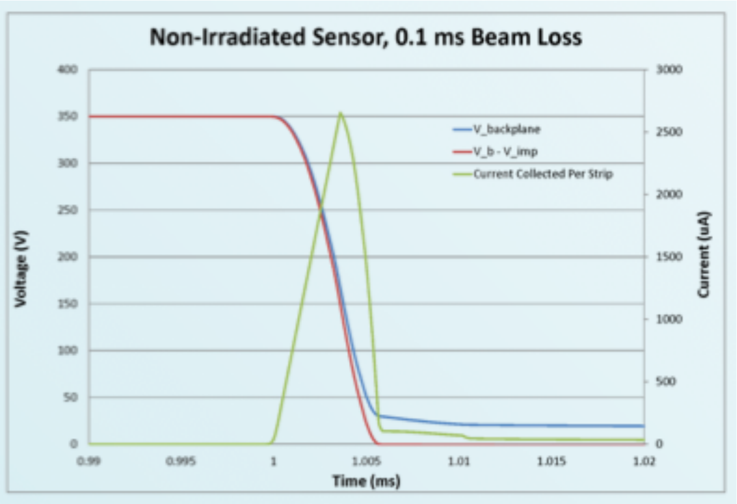


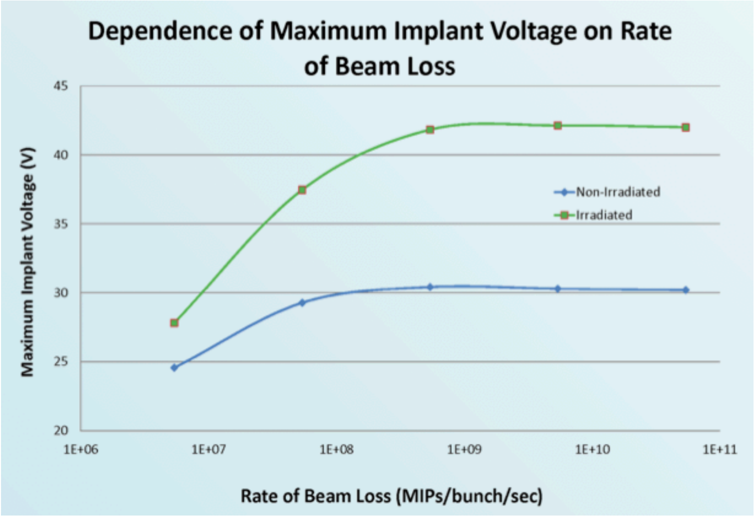


Implant Capacitor Damage (Atlas simulation)

<u>Full sensor exposure</u> with linear beam loss (25ns "steps")

- Peak of ~0.5×10^6 MIPs/strip/25ns

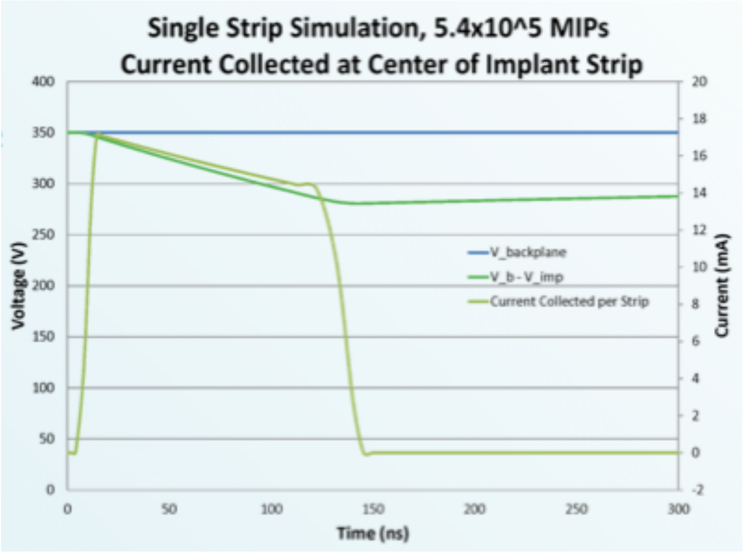




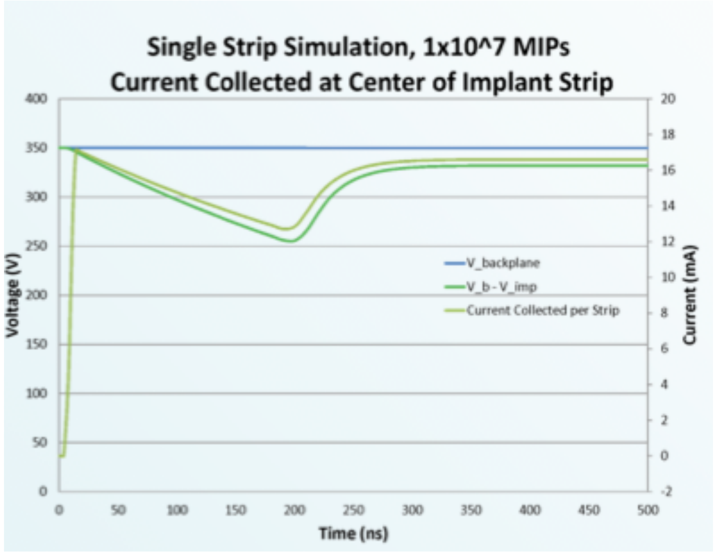
Backplane voltage drops (capacitance is depleted of charge)
Peak implant voltage is <50V
Rate of beam loss matters.

Implant Capacitor Damage (Atlas simulation)

Single strip exposure to single laser pulse



$V_{implant}$>70V



$V_{implant}$>90V

Backplane voltage do not protect for single strip exposure
Spatial distribution is important

Summary (again)

Predicting vulnerability for our sensors is hard

- Implant strip resistance not measured
- Punch through protection not measured
- Bias network would need to analyzed with different exposure scenarios

Exact beam loss scenario is important

- How many strips get hit simultaneously
- What is the time evolution (gradual exposure?)

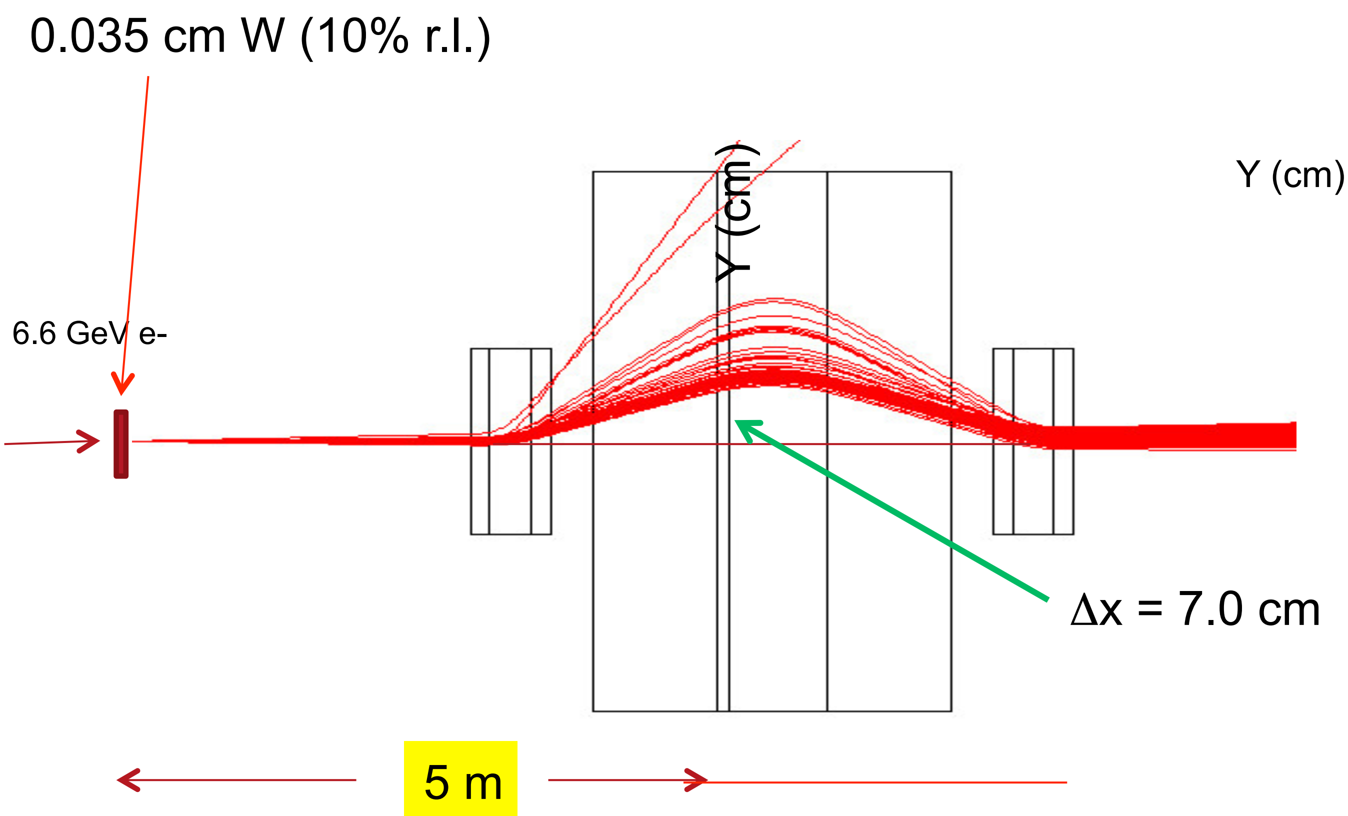
Conclusion is that we cannot say we are safe

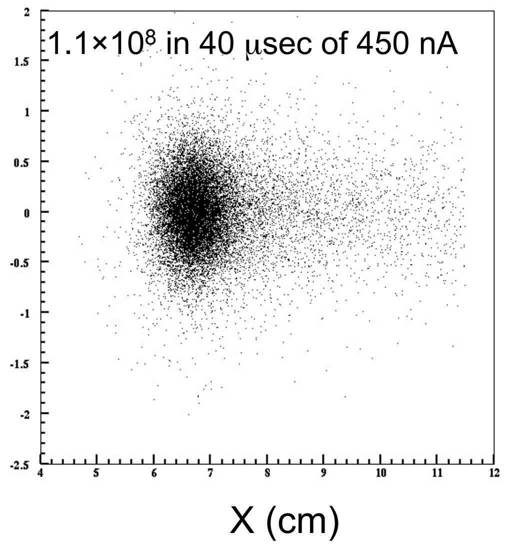
- Experts guess that most likely we are more vulnerable than Atlas (worse PTP distance, longer strips, potentially larger implant resistance)

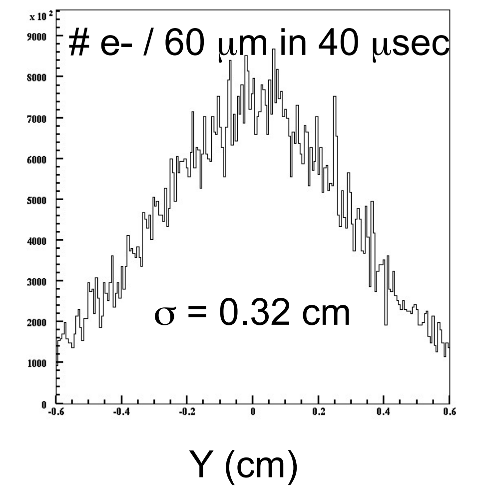
➔ We need to test our susceptibility

Looking at beam tests – these are only at the idea stage yet.
Who will help?

Collimator Scattering (Takashi)







Expect maximum of 8×10^5 electrons/ strip / 40usec
Spot size is ~0.32cm width
No time evolution – static for 40usec for this example (?)

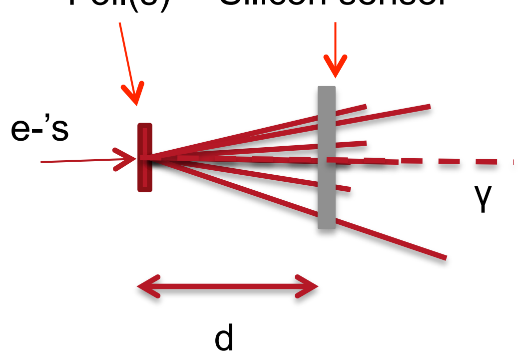
SLAC NLCTA (Next Linear Collider Test Accelerator)

Propose to use NLCTA
- Beam available this fall
- Tests in parallel to other experiments
- High enough intensity
- Much higher dQ/dt -> worst case scenario
- Easy access and setup

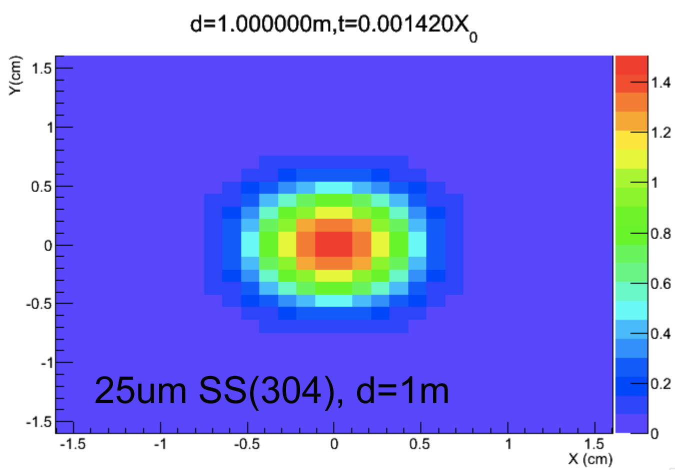
Vary intensity
- Foil thickness and # foils
- Distance from foil

X-ray contribution should be small

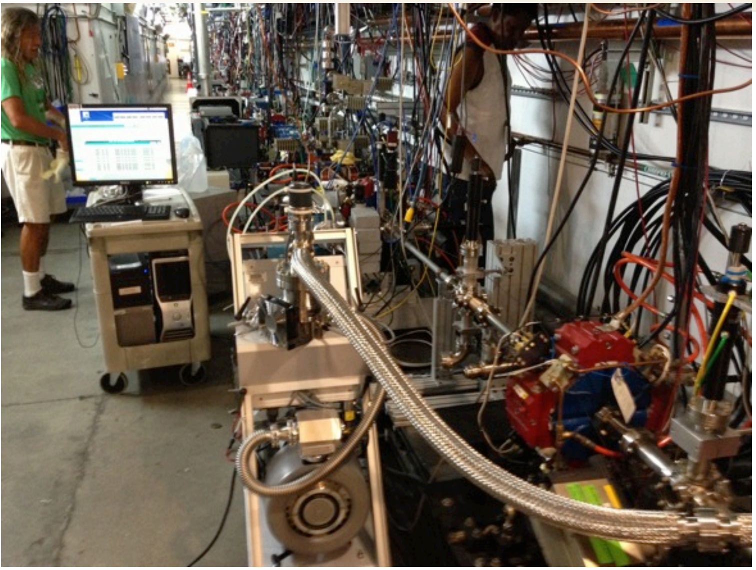
	NLCTA
Beam Type	e^-
Beam energy (MeV) (range)	120 60, 80-120
Repetition Rate (Hz) (range)	10 1-10
Bunch Intensity (E8) (range)	1.2 0.06-12
Bunch Length (s , mm) (range)	60
Beam Spot size ((s , mm) (range)	150 100-300
Comments/Notes	

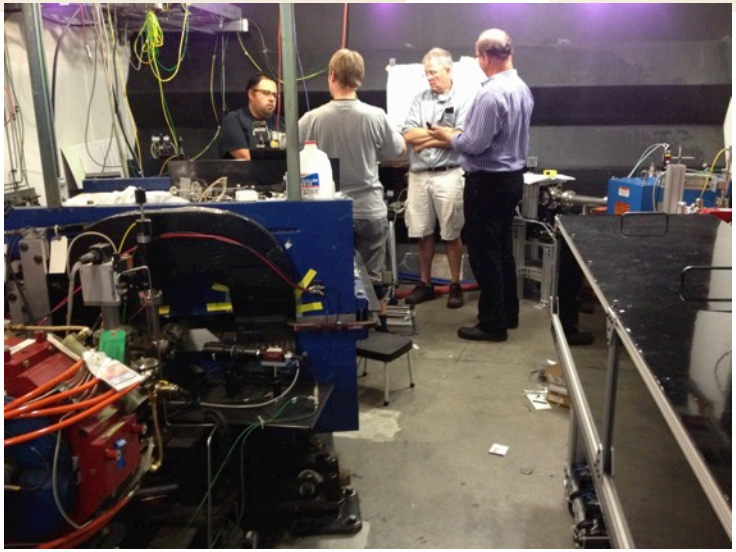


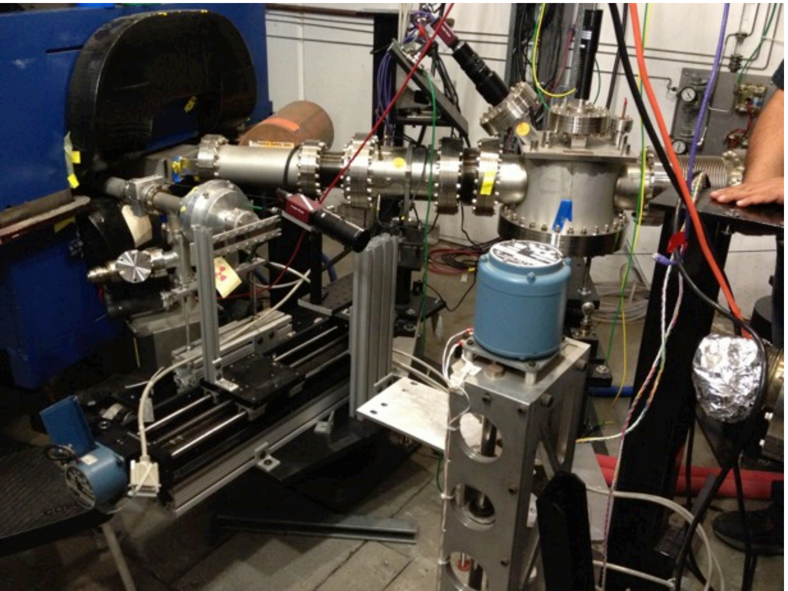
Beam spot + multiple scattering



NLCTA

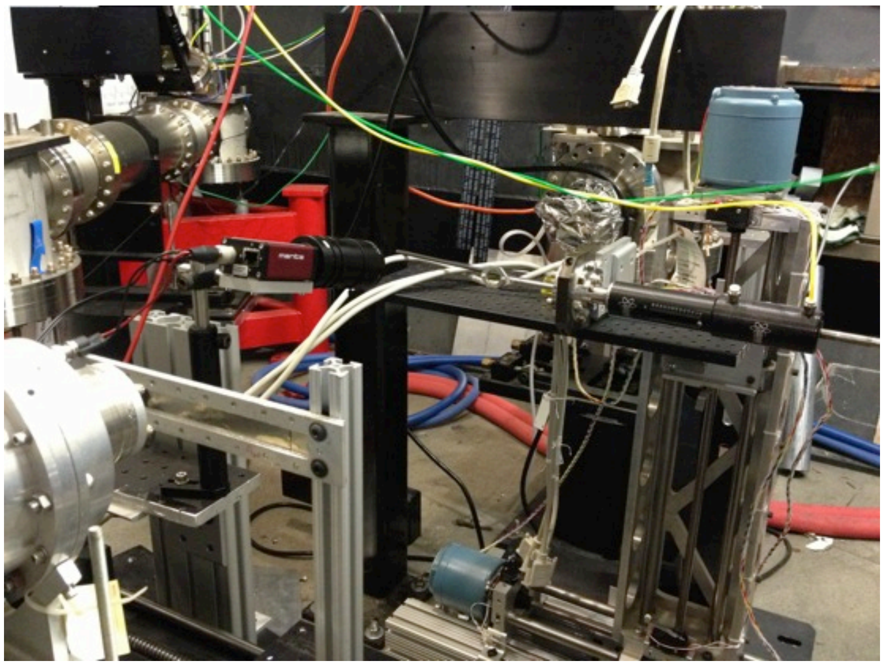


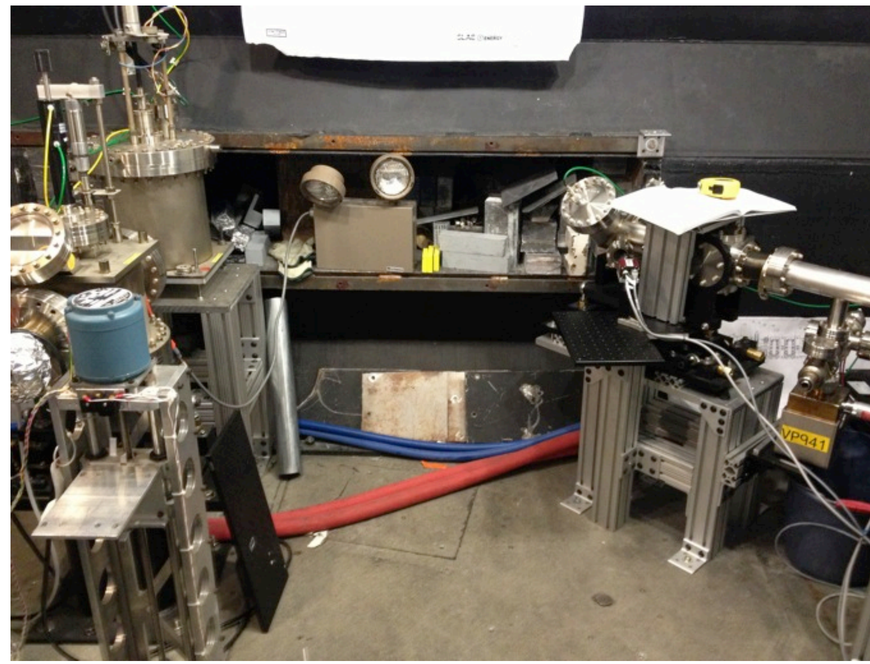




NLCTA

SLAC





NLCTA Setup

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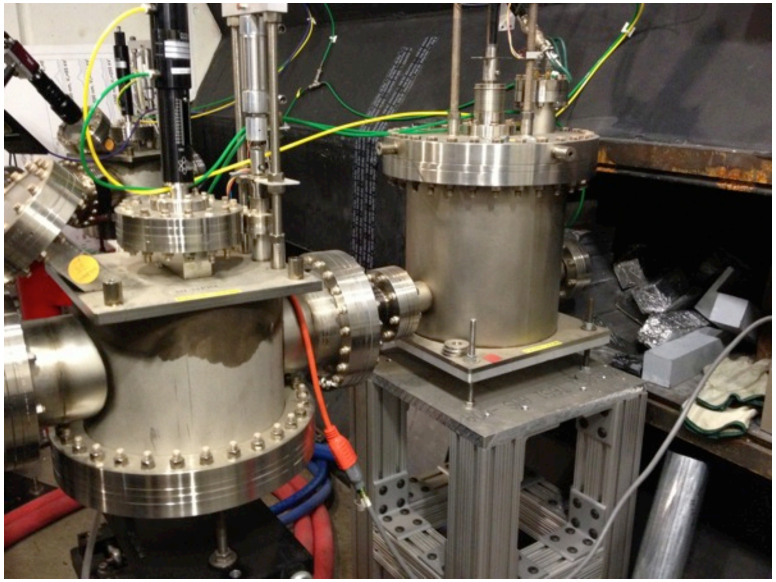
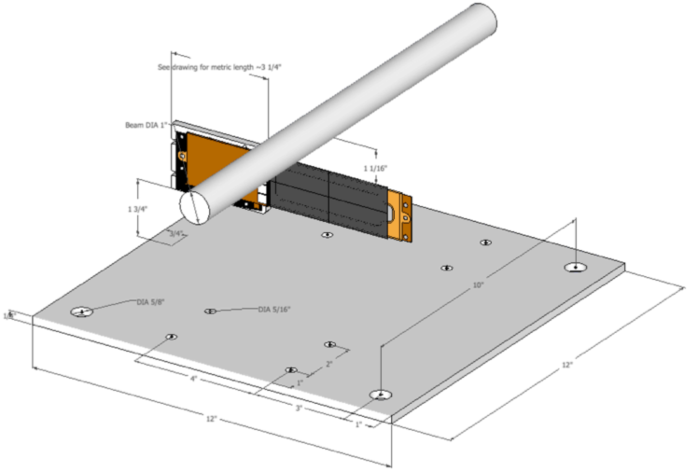




NLCTA Beam Parameters

	ASTA	ESTB	FACET	NLCTA	XTA
Beam Type	e^-	e^-	e^-	e^-	e^-
Beam energy (MeV) (range)		2000-15,000	20,000	120 60, 80-120	80
Repetition Rate (Hz) (range)	60	5	10 1 - 30	10 1-10	10
Bunch Intensity (E8) (range)		20-250 or single particle	200 50-300	1.2 0.06-12	
Bunch Length (σ, μm) (range)		300	30 20-1000	60	
Beam Spot size ((σ, μm) (range)		30	30 20-200	150 100-300	
Comments/Notes		(1)			

NLCTA Simulation

Setup

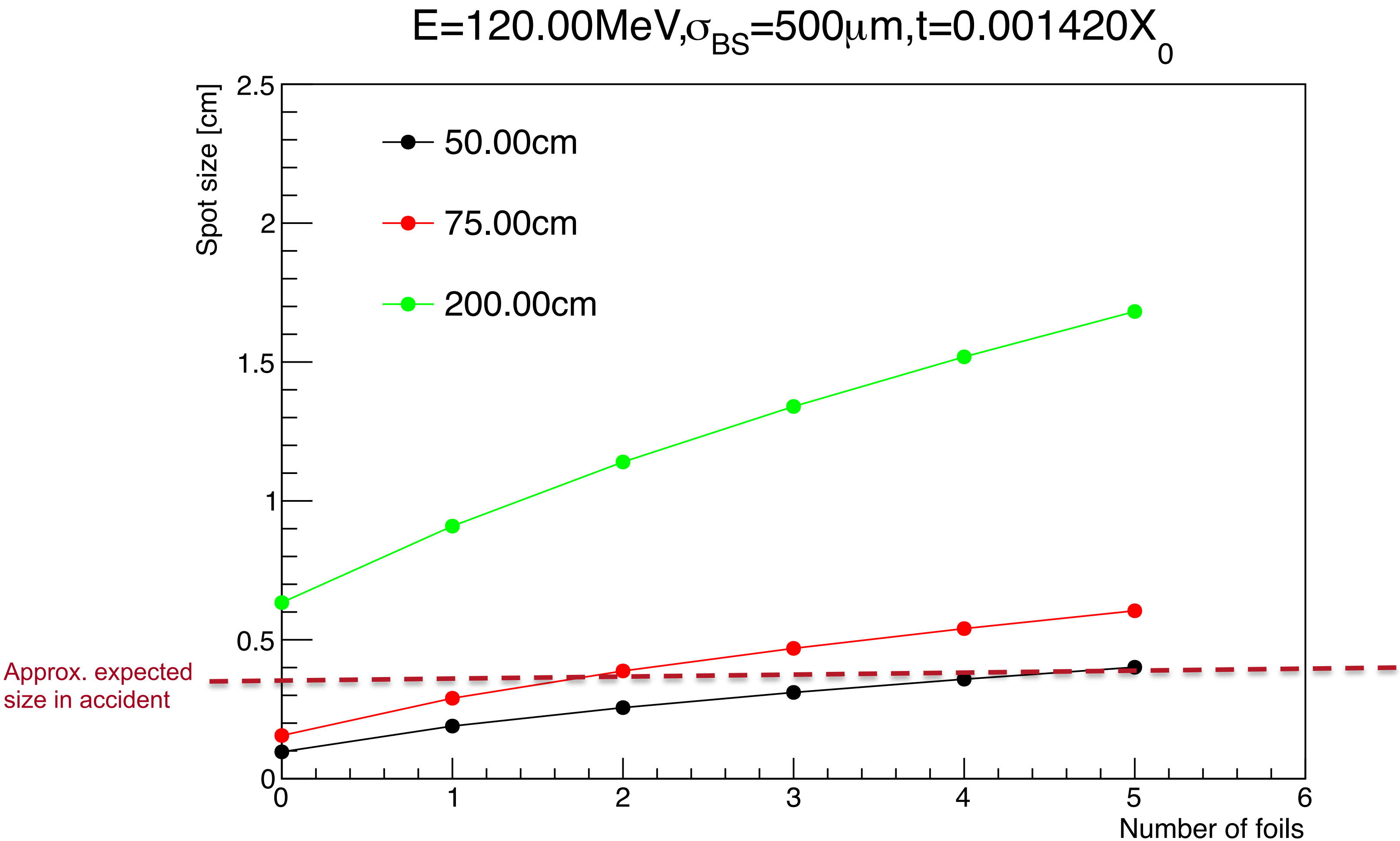
- 120 MeV electron beam
- 500um beam spot (estimate)
- 50um Be window, SS foils 25um thick
- 1” aperture not included (no real effect since spot is small)

“Gaussian” approximation

- Core multiple scattering description
- Foils and window on same “z”-position
- The effect from scattering in air is taken into account

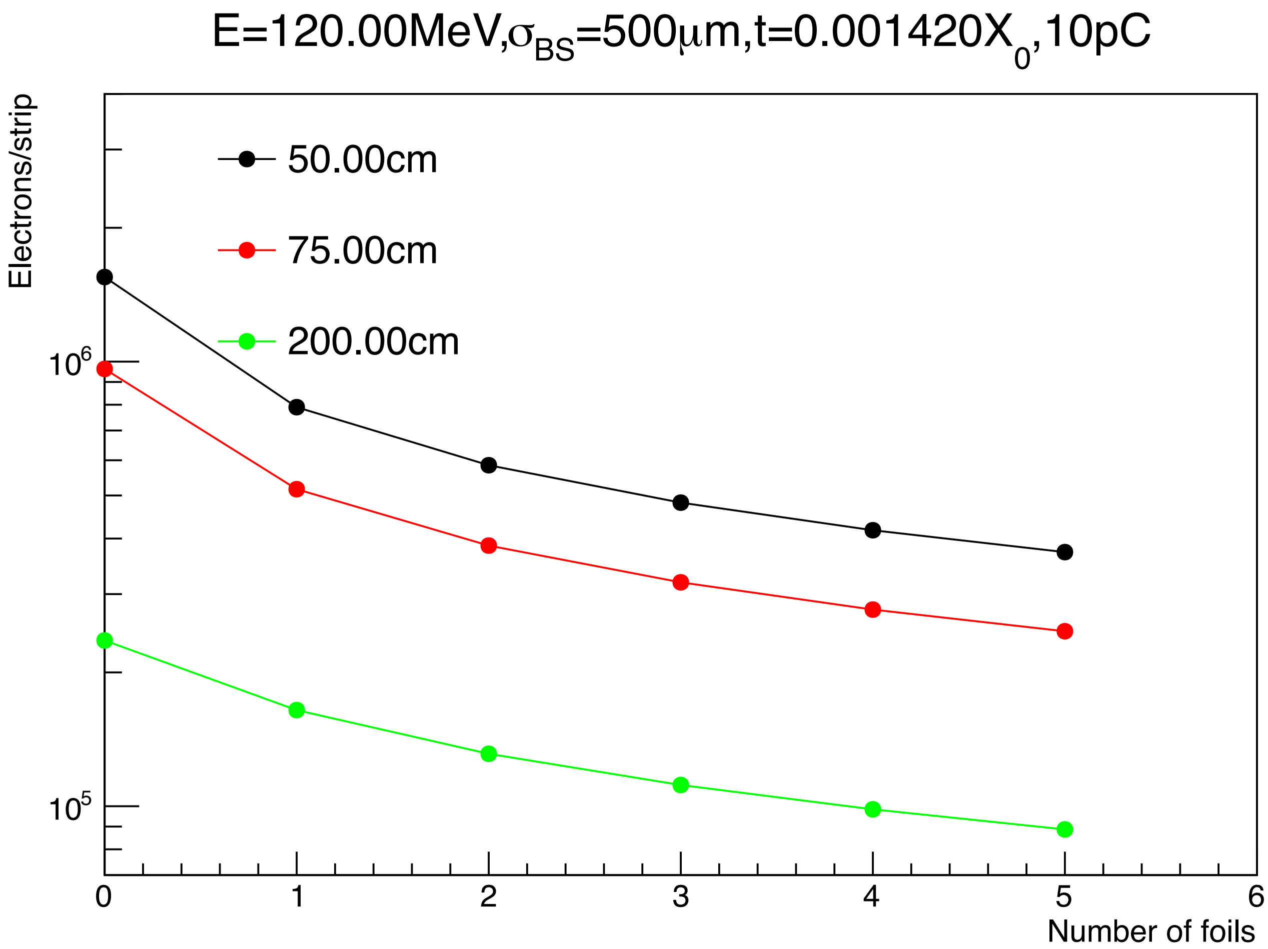
Cross-check with full EGS5 simulation

Beam spot



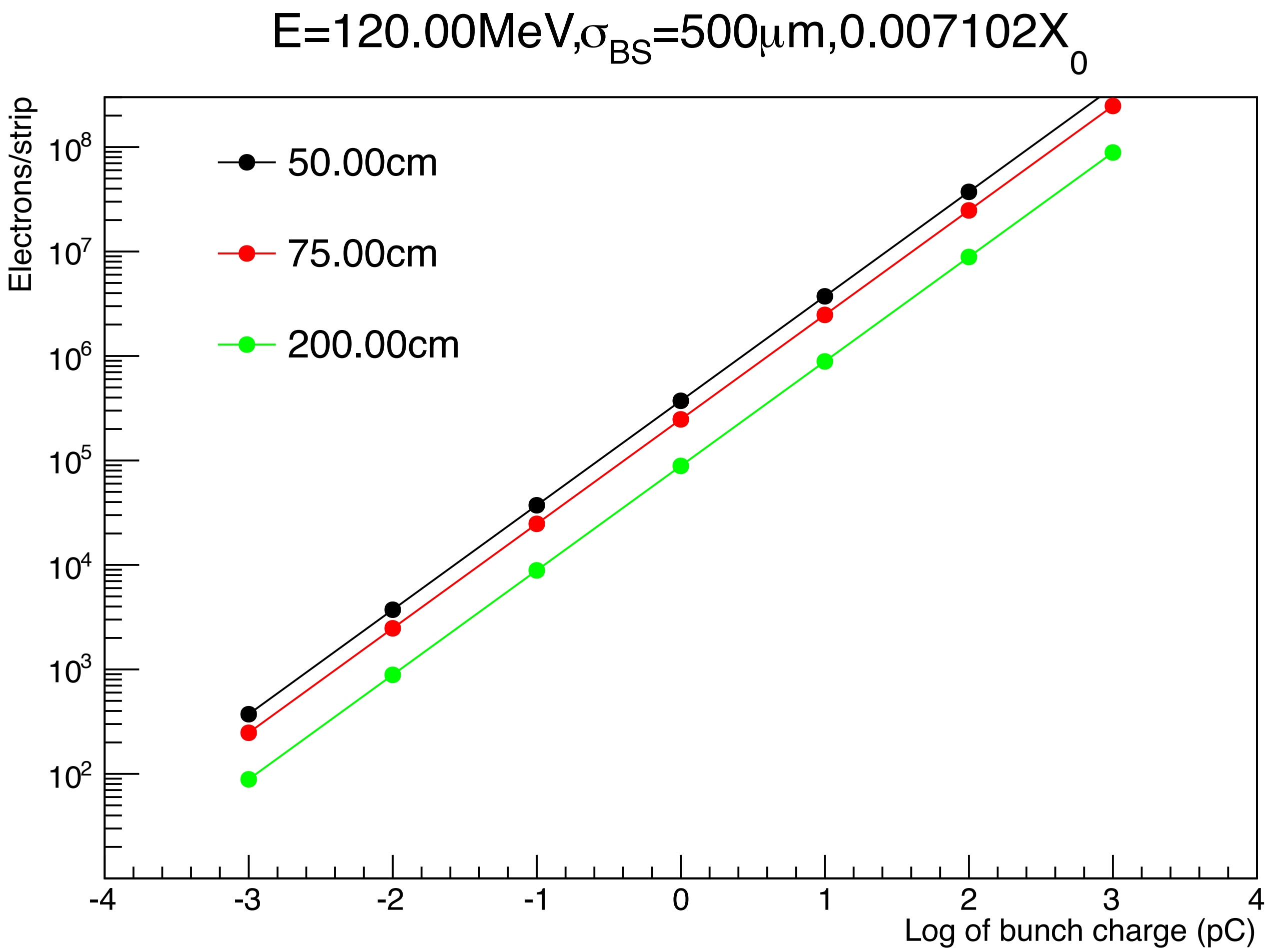
E=120.00MeV,σBS=500μm,t=0.001420X0
Spot size [cm]
2.5
2
1.5
1
0.5
0
50.00cm
75.00cm
200.00cm
0
1
2
3
4
5
6
Number of foils
Approx. expected size in accident

Strip hits



E=120.00MeV,σBS=500μm,t=0.001420X0,10pC
Electrons/strip
50.00cm
75.00cm
200.00cm
10^6
10^5
0
1
2
3
4
5
6
Number of foils

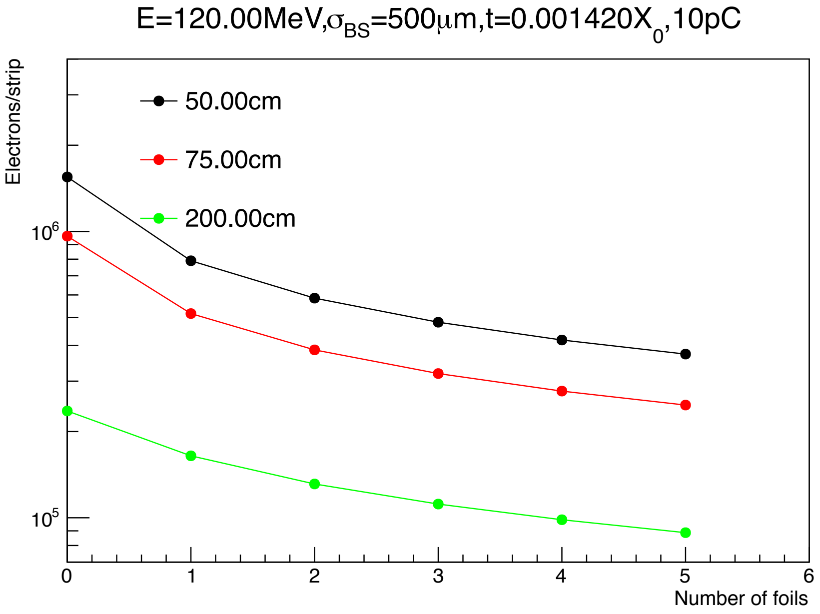
Strip hits

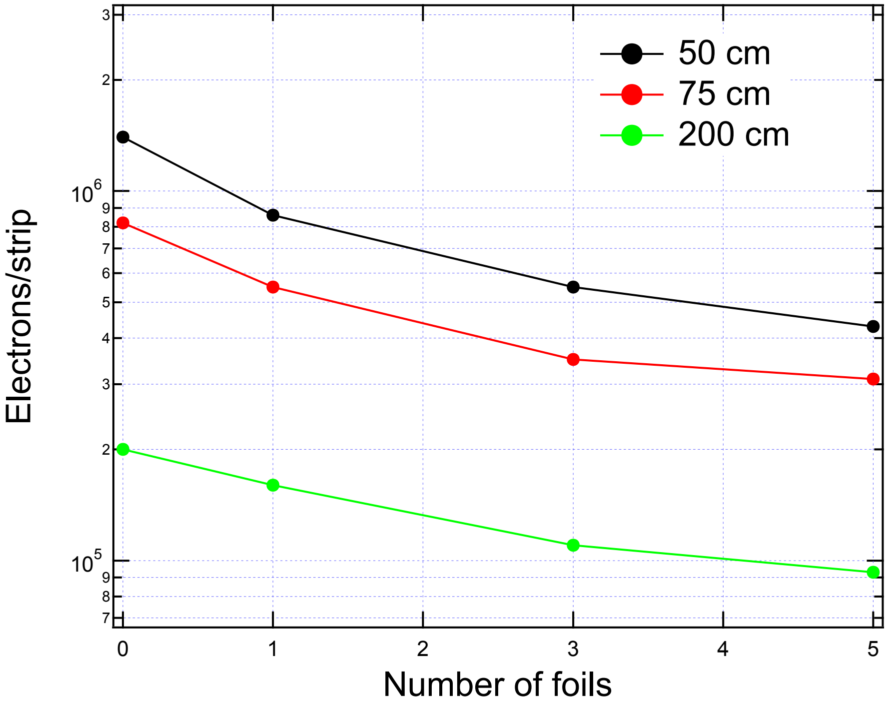


E=120.00MeV,σBS=500μm,0.007102X0
Electrons/strip
10^8
10^7
10^6
10^5
10^4
10^3
10^2
50.00cm
75.00cm
200.00cm
-4
-3
-2
-1
0
1
2
3
4
Log of bunch charge (pC)

EGS5 Full simulation

Agreement to within 20-50%





EGS5 Full simulation – X-rays

200cm Air + 5 foils