SiD ECal Simulation Study

Resolution vs. Longitudinal Segmentation

D. Austin, J. Barkeloo, J. Brau, J. Carlson, C. Potter, A. Steinhebel

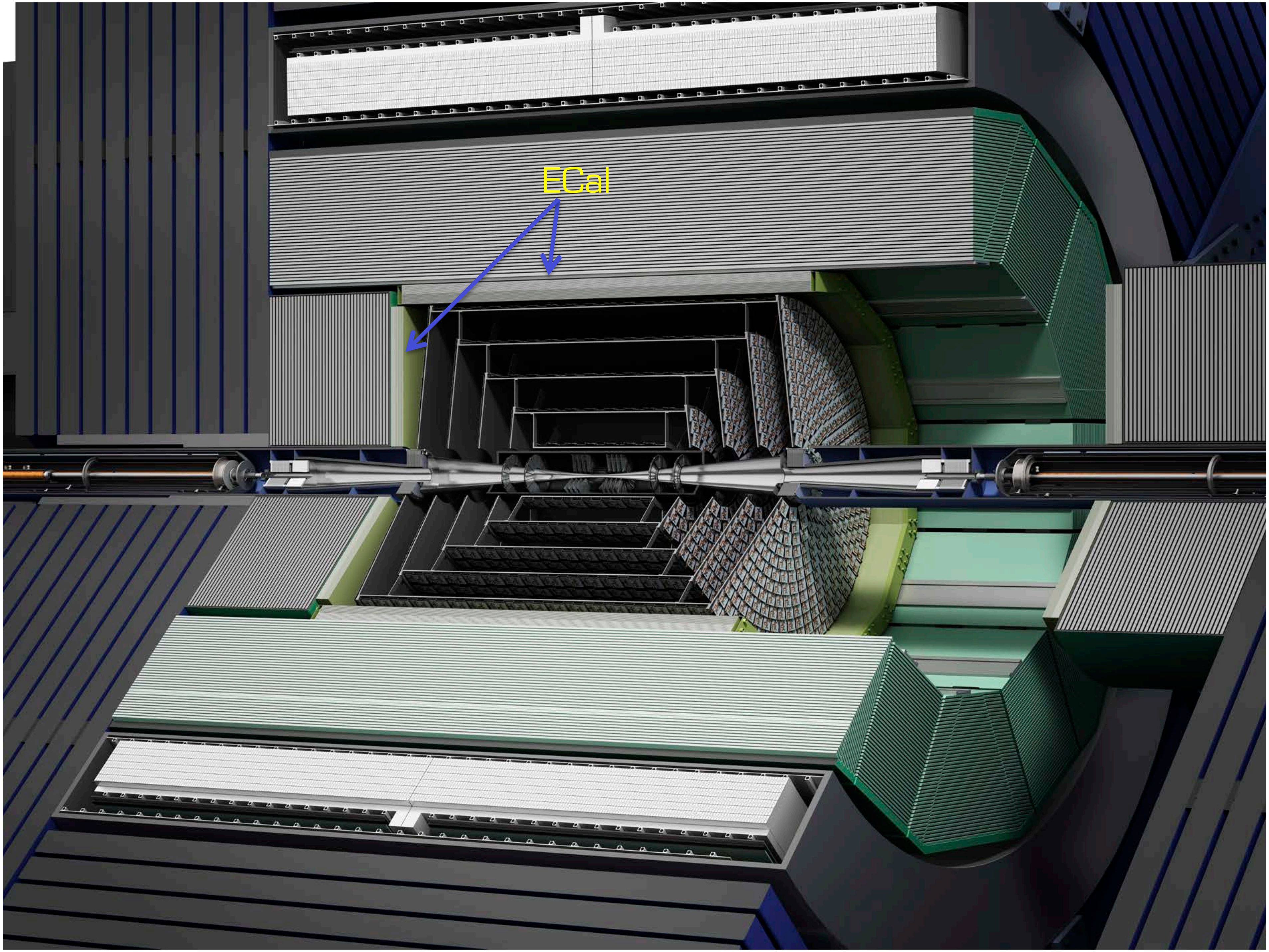
Physics Department, University of Oregon, Eugene, OR 97403

M. Breidenbach, D. Freytag

SLAC National Accelerator Center

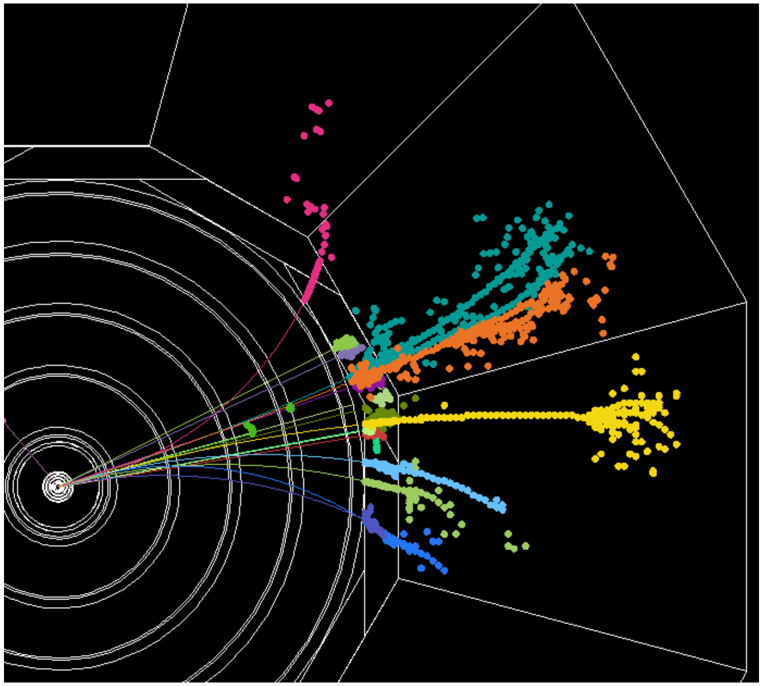
Outline

- Introduction
  - The SiD silicon-tungsten ECal design.
- Simulation tests.
  - Beam test data.
- SiD costs vs. number of silicon sampling layers.
- Fast resolution estimates for various sampling options.
  - Simplified sampling calorimeter model.
- Comparison of fast estimates with detailed Geant4.
- Testing resolution on Higgs -> reconstruction.


ECal

Calorimetry- Optimized for Particle Flow Cost constrained!

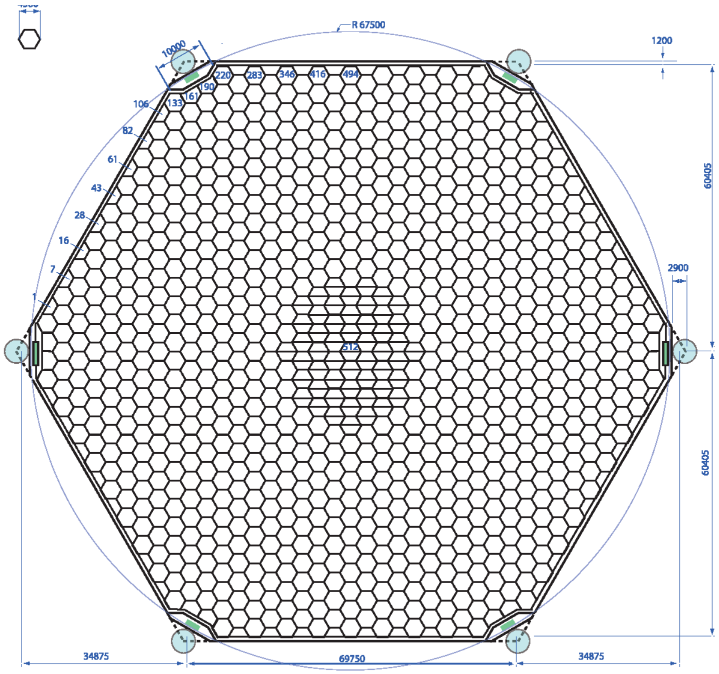
- SiD Silicon-Tungsten ECal
  - Tungsten absorber
  - 20 “thin”+10 “thick” layers
  - 20 x 0.64 X_0 + 10 x 1.3 X_0
  - Baseline Readout
    - 13 mm^2 silicon pads
    - KPiX 1024 channel system bump bonded directly to large Si Sensors



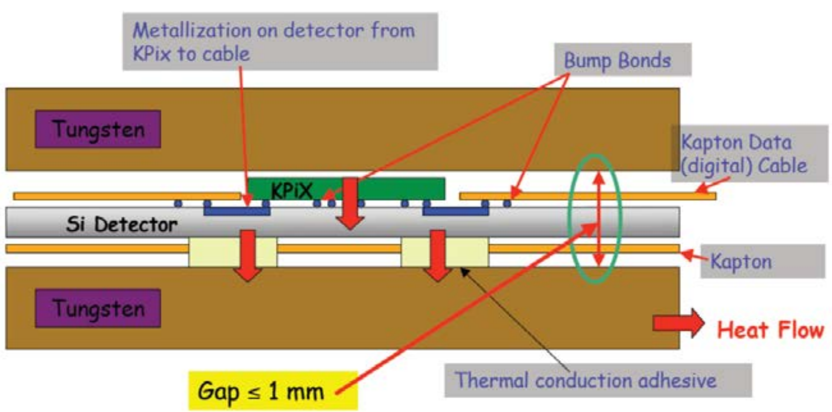
- SiD HCal
  - 40 layers steel absorber (4.5 λ)
  - Baseline readout
    - 3x3 cm scintillator w SiPM’s

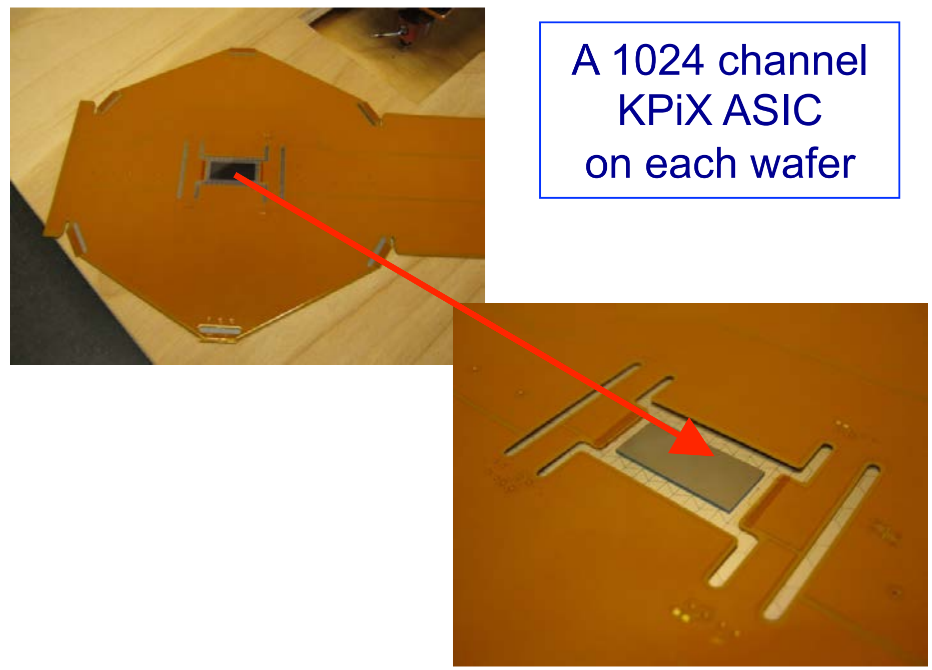
Particle flow significantly improves jets resolution by reducing contribution of hadron calorimeter resolution.

Silicon sensors and KPiX ASIC



- 6 inch wafers
- 1024 13 mm^2 pixels
- KPiX readout is bump-bonded directly to sensor

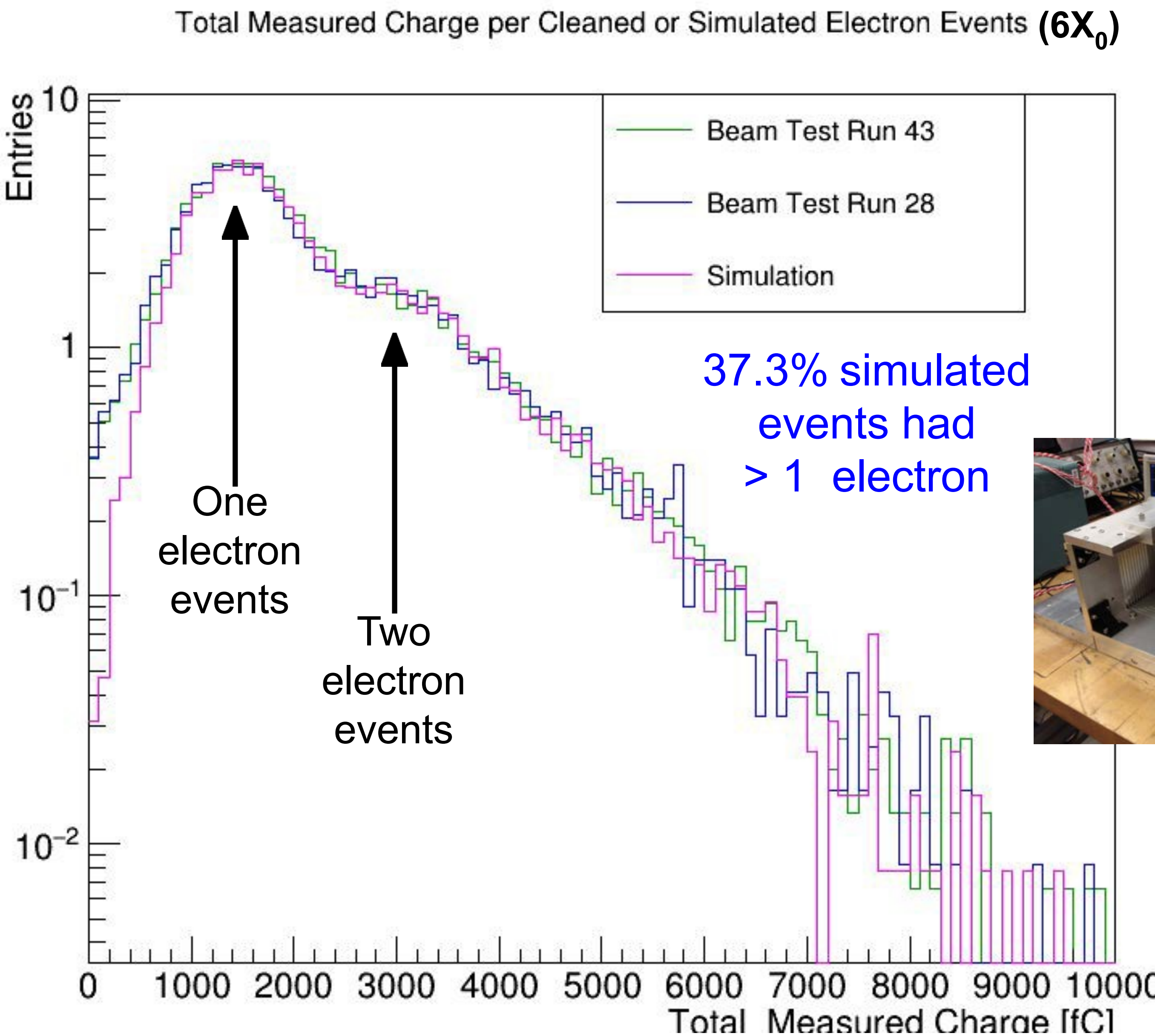




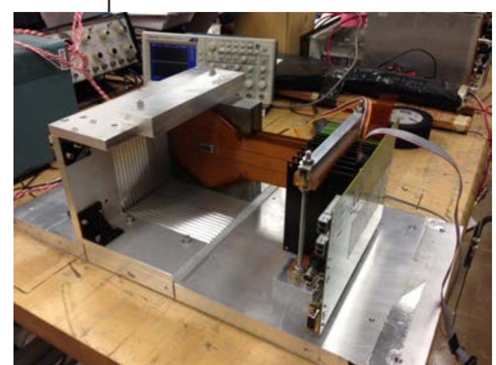
A 1024 channel KPiX ASIC on each wafer

Simulation vs. Test Beam Data

(12.1 GeV in 6 X_0)



37.3% simulated events had > 1 electron



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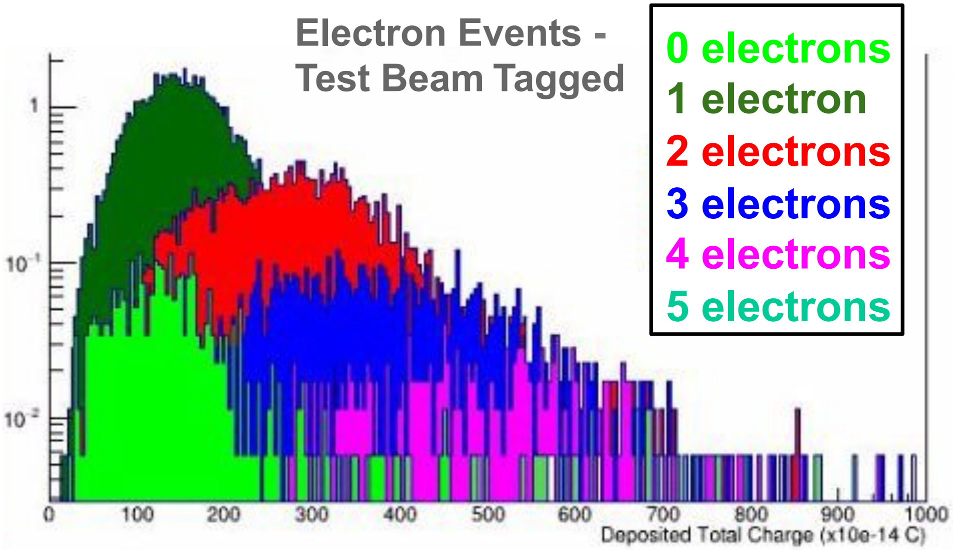
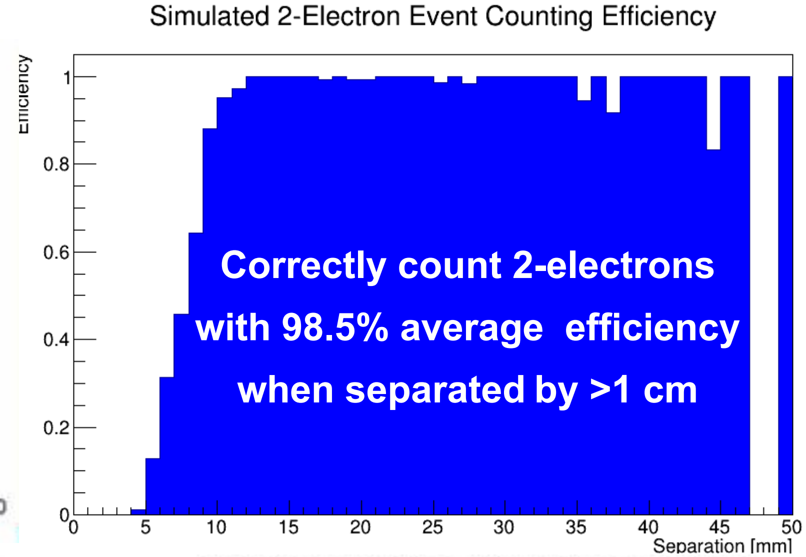
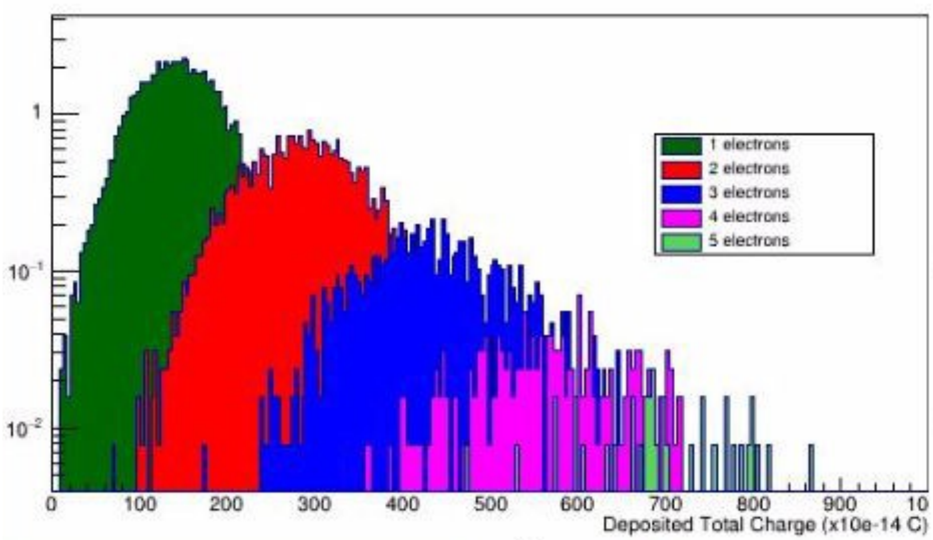
Test Beam Results
Counting 12.1 GeV Electrons in 6 X_0

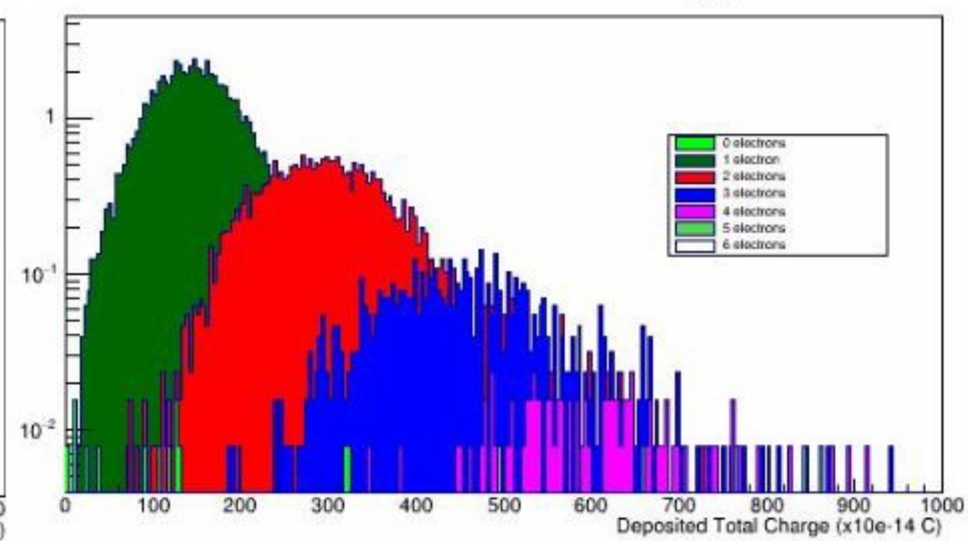




Electron Events -Simulation Truth



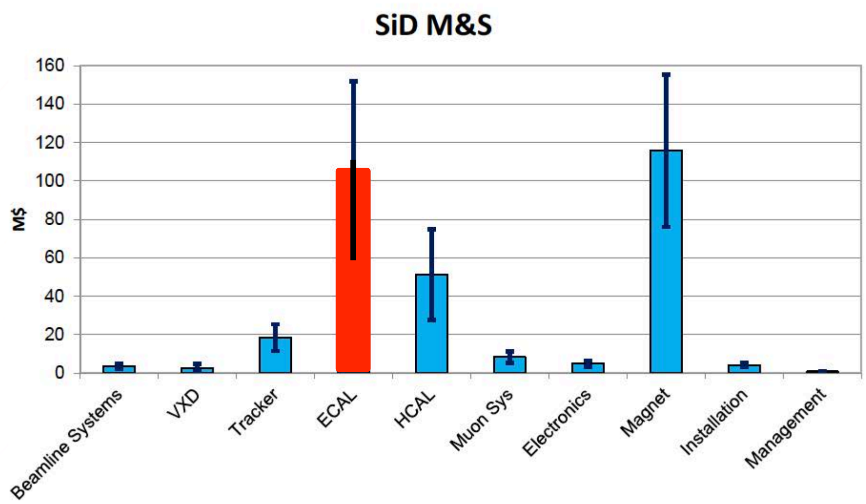
Electron Events -Simulation Tagged



SiD design is cost constrained!

From the TDR:

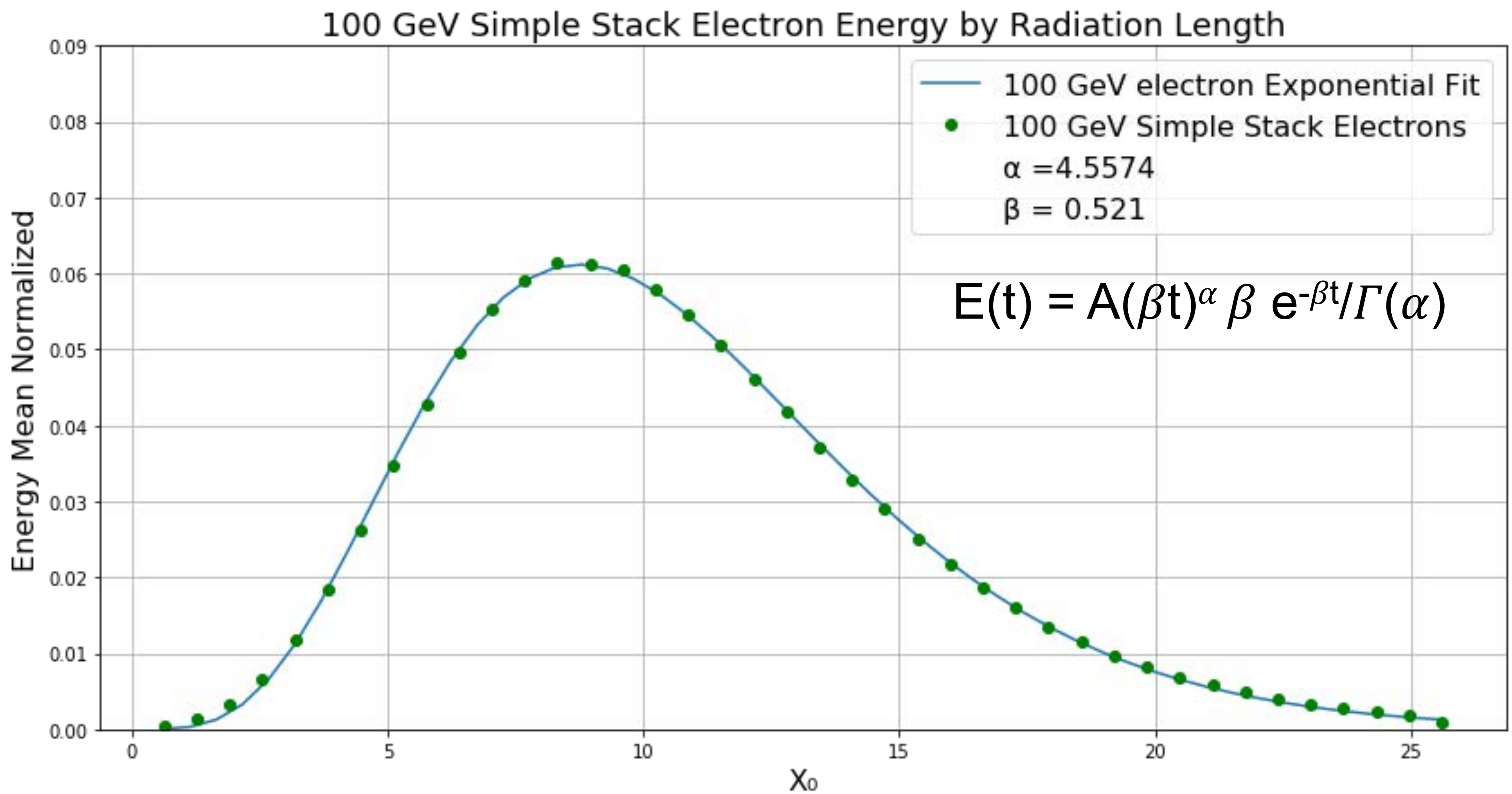
	M&S Base (M US-$)	M&S Contingency (M US-$)	Engineering (MY)	Technical (MY)	Admin (MY)
Beamline Systems	3.7	1.4	4.0	10.0	
VXD	2.8	2.0	8.0	13.2	
Tracker	18.5	7.0	24.0	53.2	
ECAL	104.8	47.1	13.0	288.0	
HCAL	51.2	23.6	13.0	28.1	
Muon System	8.3	3.0	5.0	22.1	
Electronics	4.9	1.6	44.1	41.7	
Magnet	115.7	39.7	28.3	11.8	
Installation	4.1	1.1	4.5	46.0	
Management	0.9	0.2	42.0	18.0	30.0
	314.9	126.7	186.0	532.1	30.0



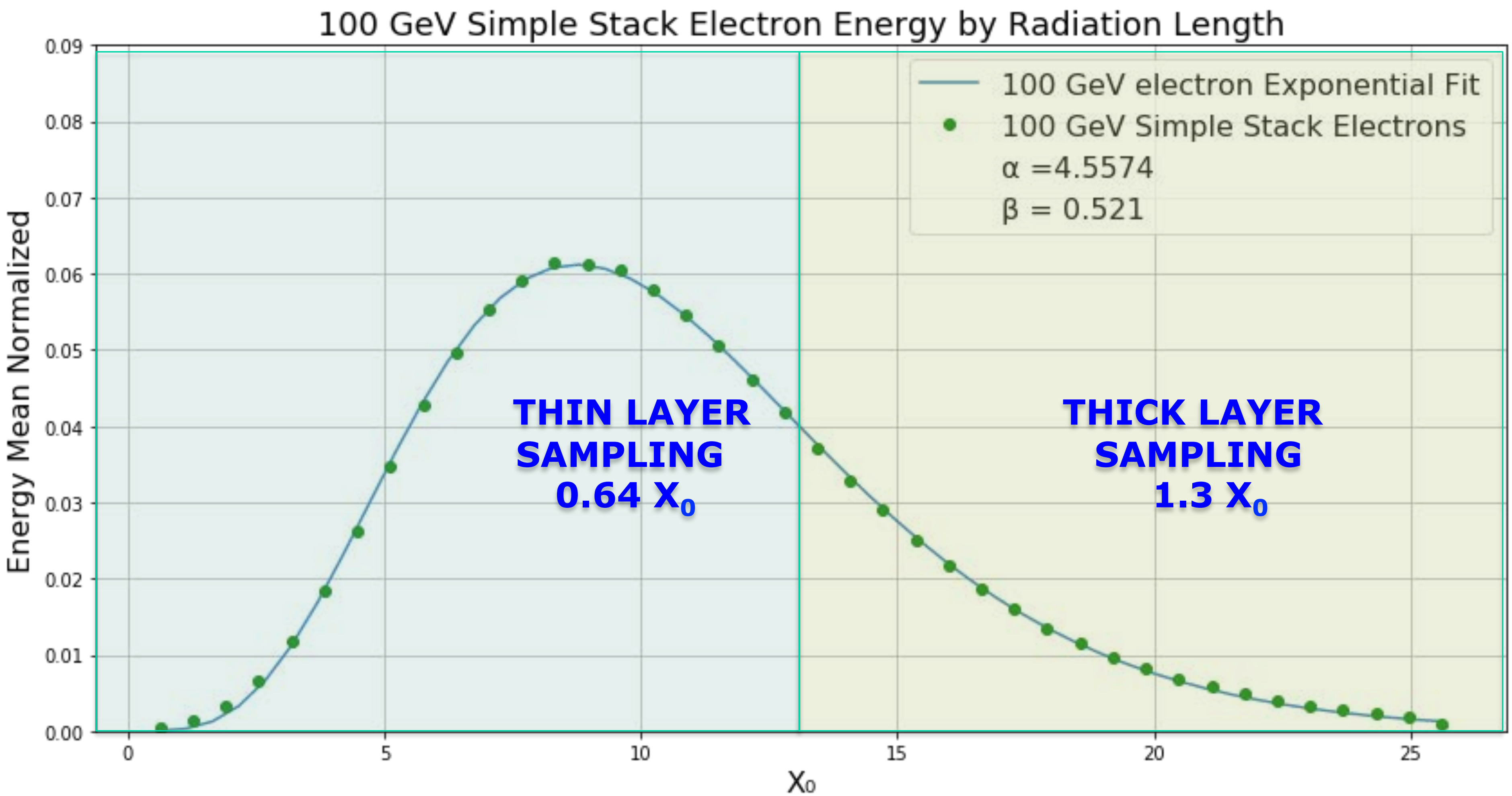
SiD ECal M&S Cost (incl. contingency) =

~33M$ + ~2.4M$ (no. of sampling layers)

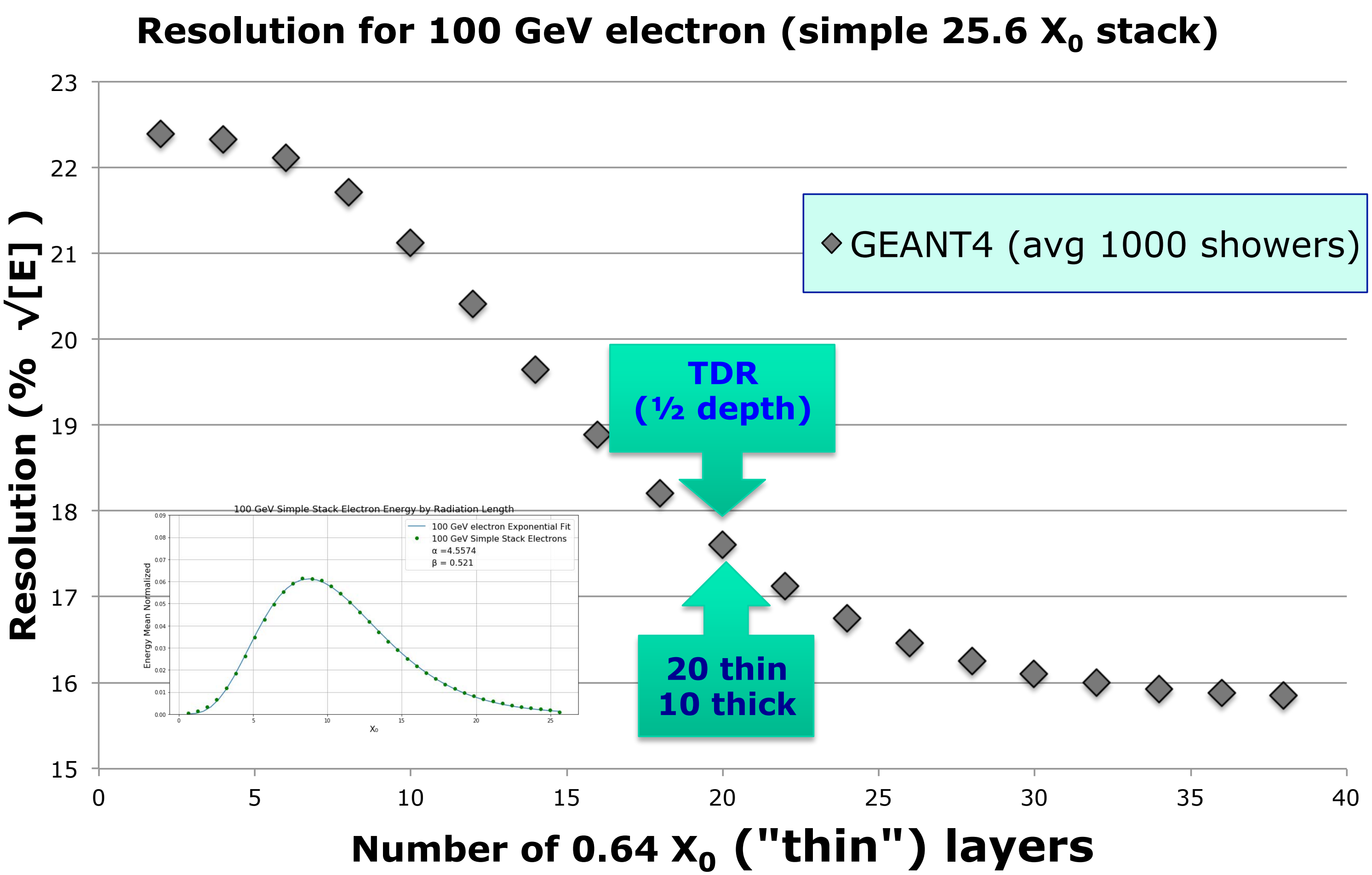
Study Geant4 model of simple stack



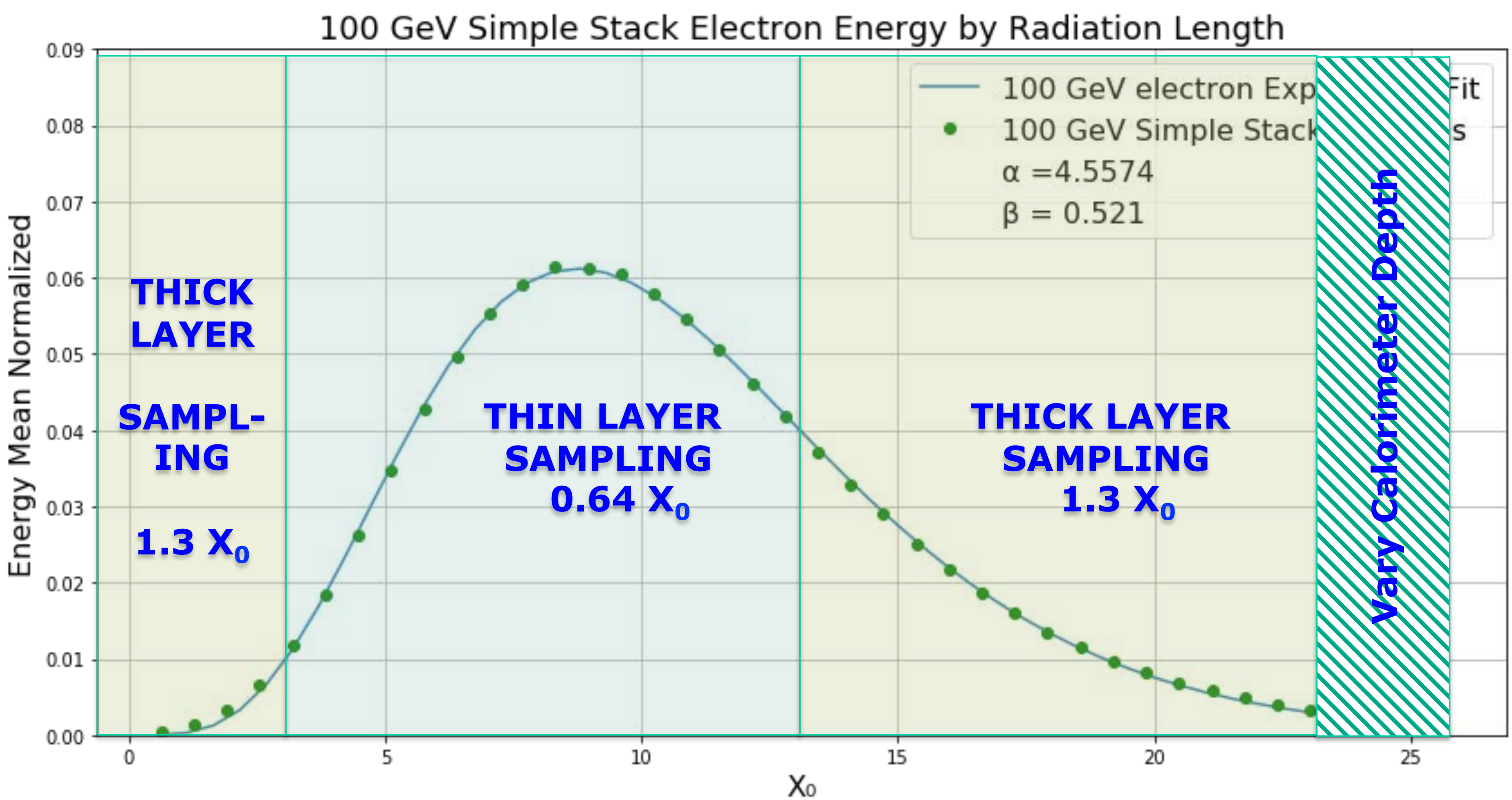
SiD Baseline

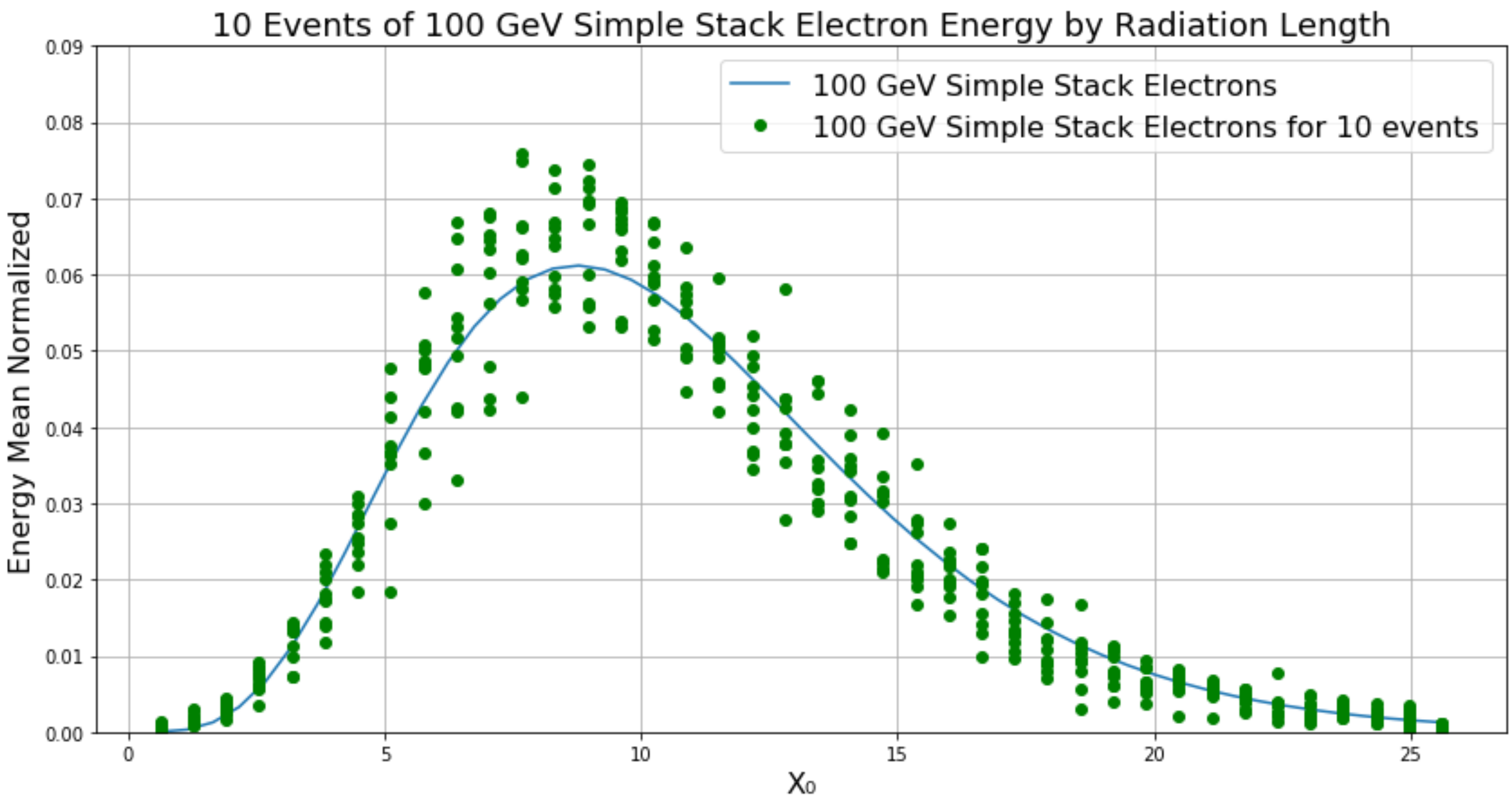


All thick (1.3 X_0) ⇔ All thin (0.64 X_0)



Study Different Sampling Options




10 Events of 100 GeV Simple Stack Electron Energy by Radiation Length
100 GeV Simple Stack Electrons
100 GeV Simple Stack Electrons for 10 events
Energy Mean Normalized
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
5
10
15
20
25
X0

Fast Resolution Model

Fluctuations in each layer proportional to sqrt(E in layer).

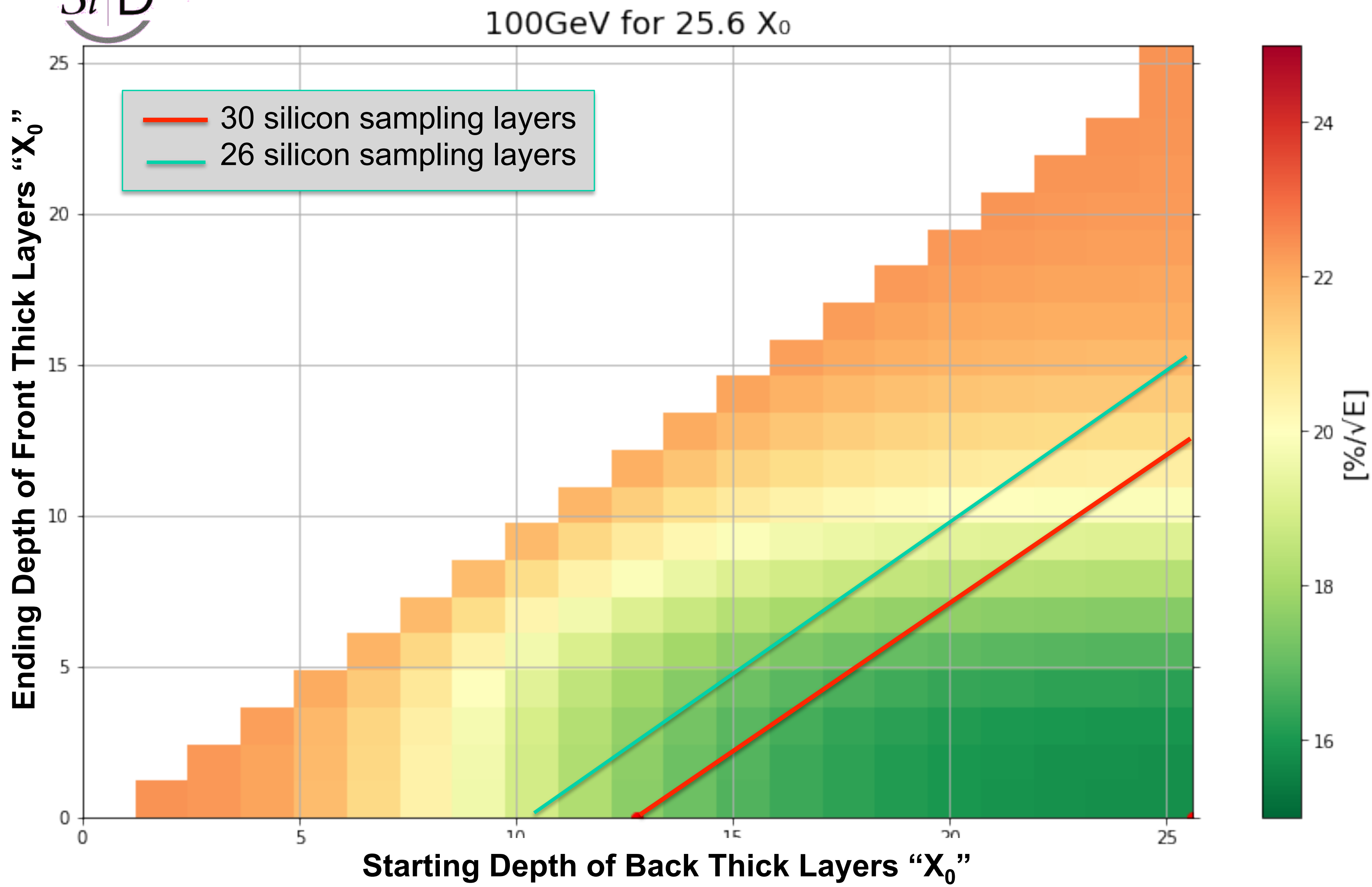
- Thick sampling gets 2 sqrt(E in layer)

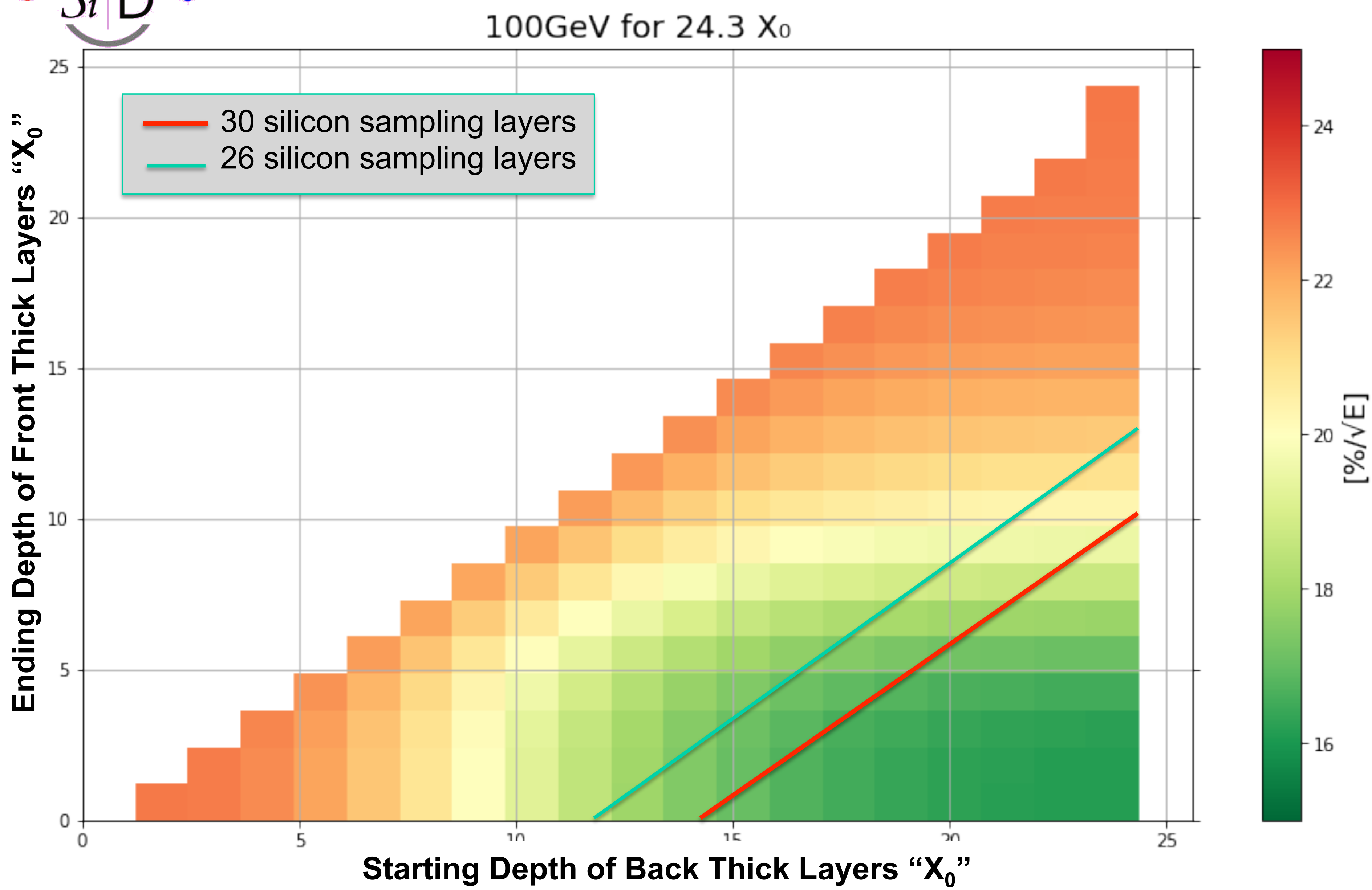
Fluctuation due to leakage proportional to sqrt(E lost) for truncated calorimeter.

Add two in quadrature.

Note – ignore layer to layer correlations.

- TO BE CHECKED WITH GEANT4


100GeV for 25.6 X0
30 silicon sampling layers
26 silicon sampling layers
Ending Depth of Front Thick Layers "X0"
Starting Depth of Back Thick Layers "X0"
[%/√E]
0
5
10
15
20
25
16
18
20
22
24


100GeV for 24.3 X_0
30 silicon sampling layers
26 silicon sampling layers
Ending Depth of Front Thick Layers "X_0"
Starting Depth of Back Thick Layers "X_0"
[%/√E]
0
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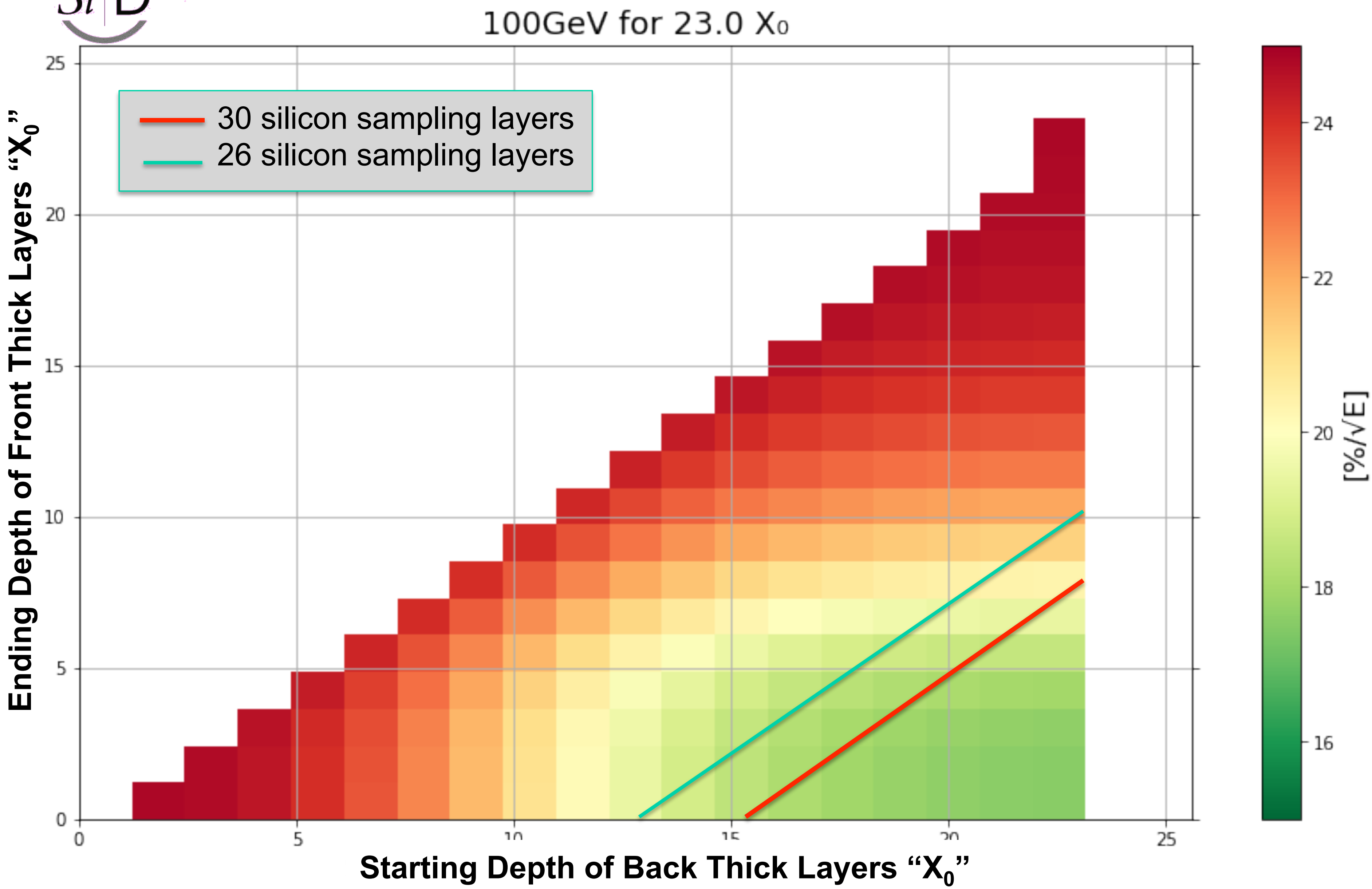

100GeV for 23.0 X_0
30 silicon sampling layers
26 silicon sampling layers
Ending Depth of Front Thick Layers "X_0"
Starting Depth of Back Thick Layers "X_0"
[%/√E]
0
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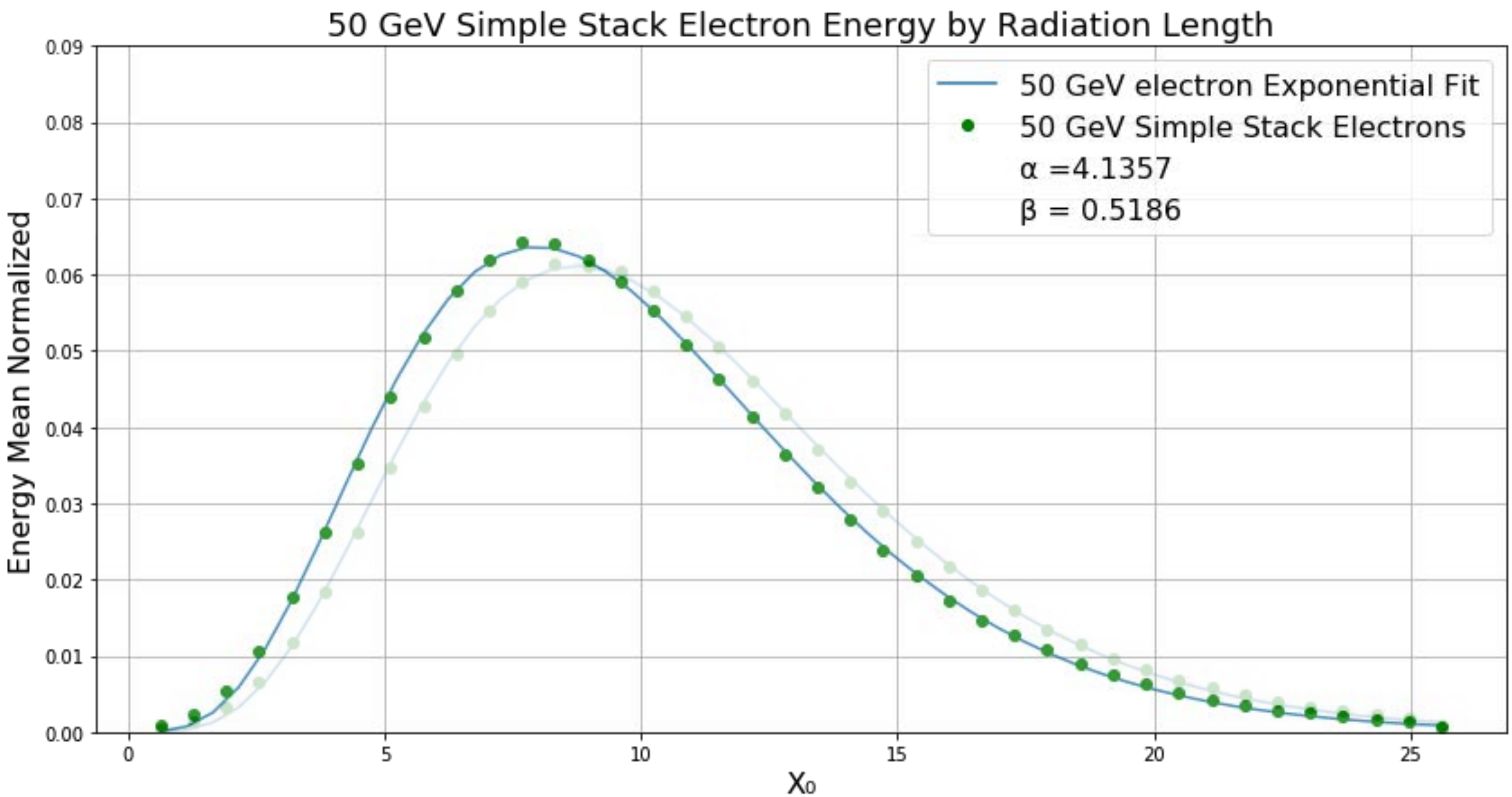
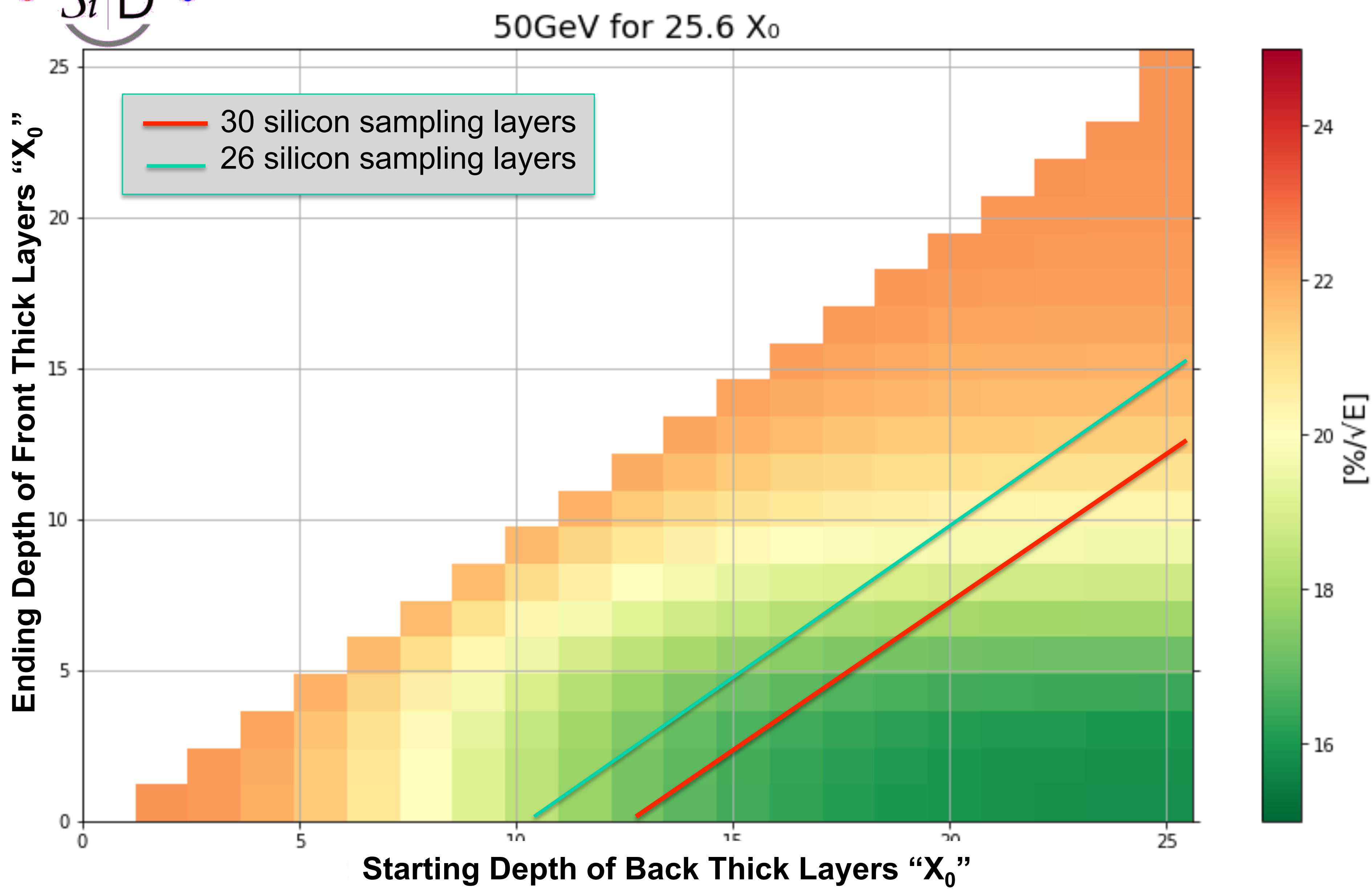

50 GeV Simple Stack Electron Energy by Radiation Length
Energy Mean Normalized
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0
5
10
15
20
25
X0
50 GeV electron Exponential Fit
50 GeV Simple Stack Electrons
α =4.1357
β = 0.5186


50GeV for 25.6 X₀
30 silicon sampling layers
26 silicon sampling layers
Ending Depth of Front Thick Layers "X0"
Starting Depth of Back Thick Layers "X0"
[%/√E]
0
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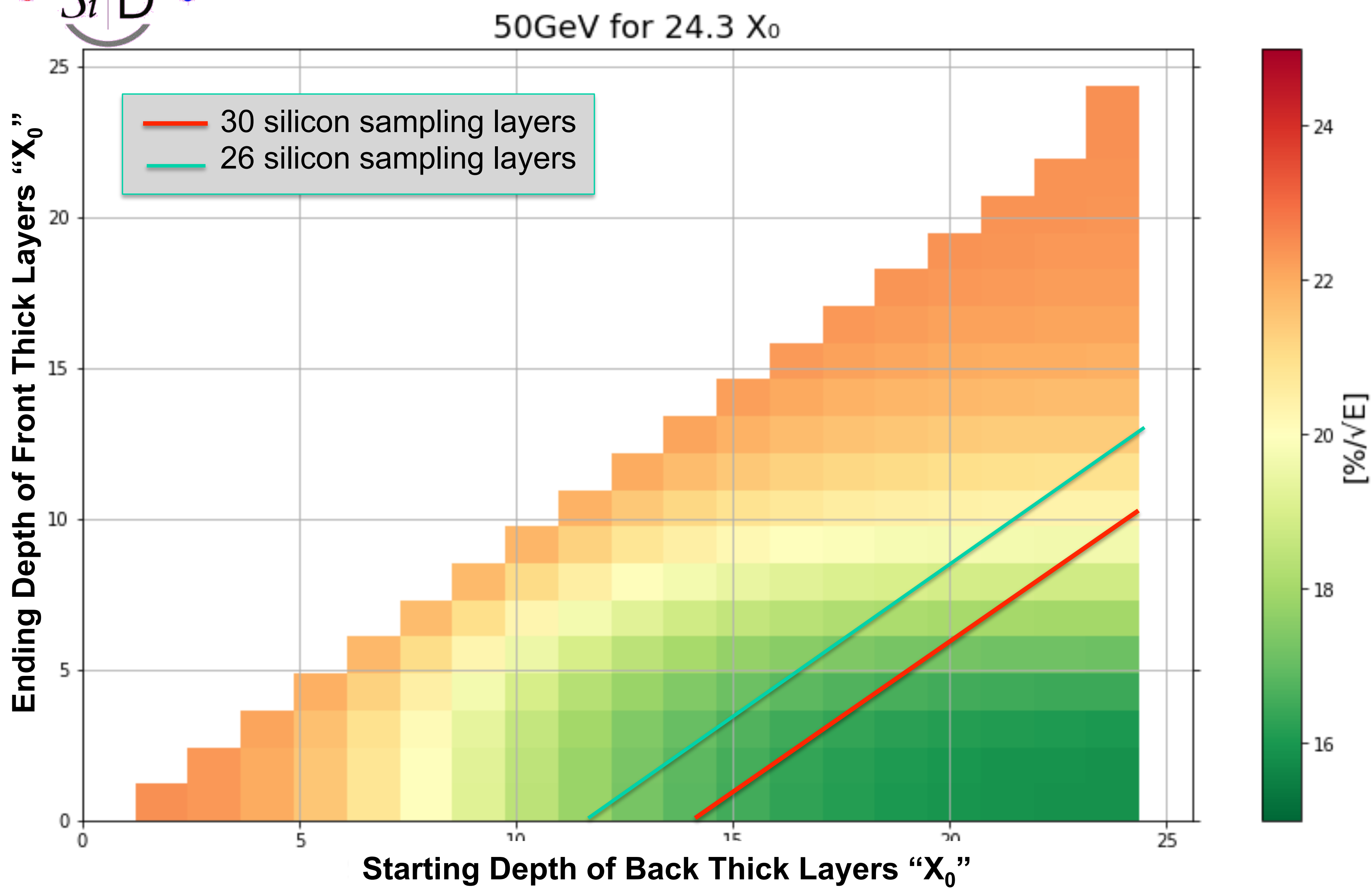

50GeV for 24.3 X₀
30 silicon sampling layers
26 silicon sampling layers
Ending Depth of Front Thick Layers "X₀"
Starting Depth of Back Thick Layers "X₀"
[%/√E]
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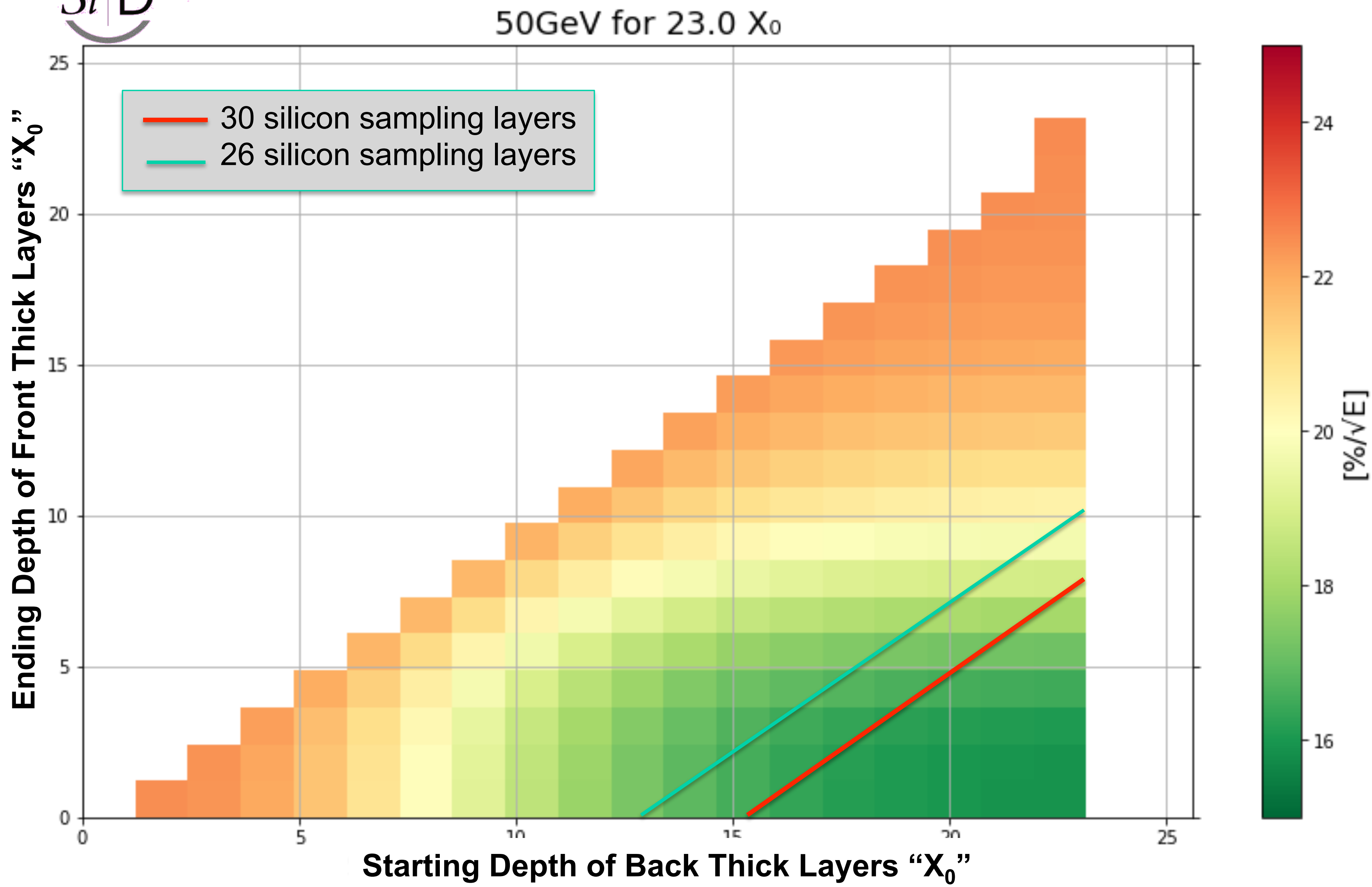

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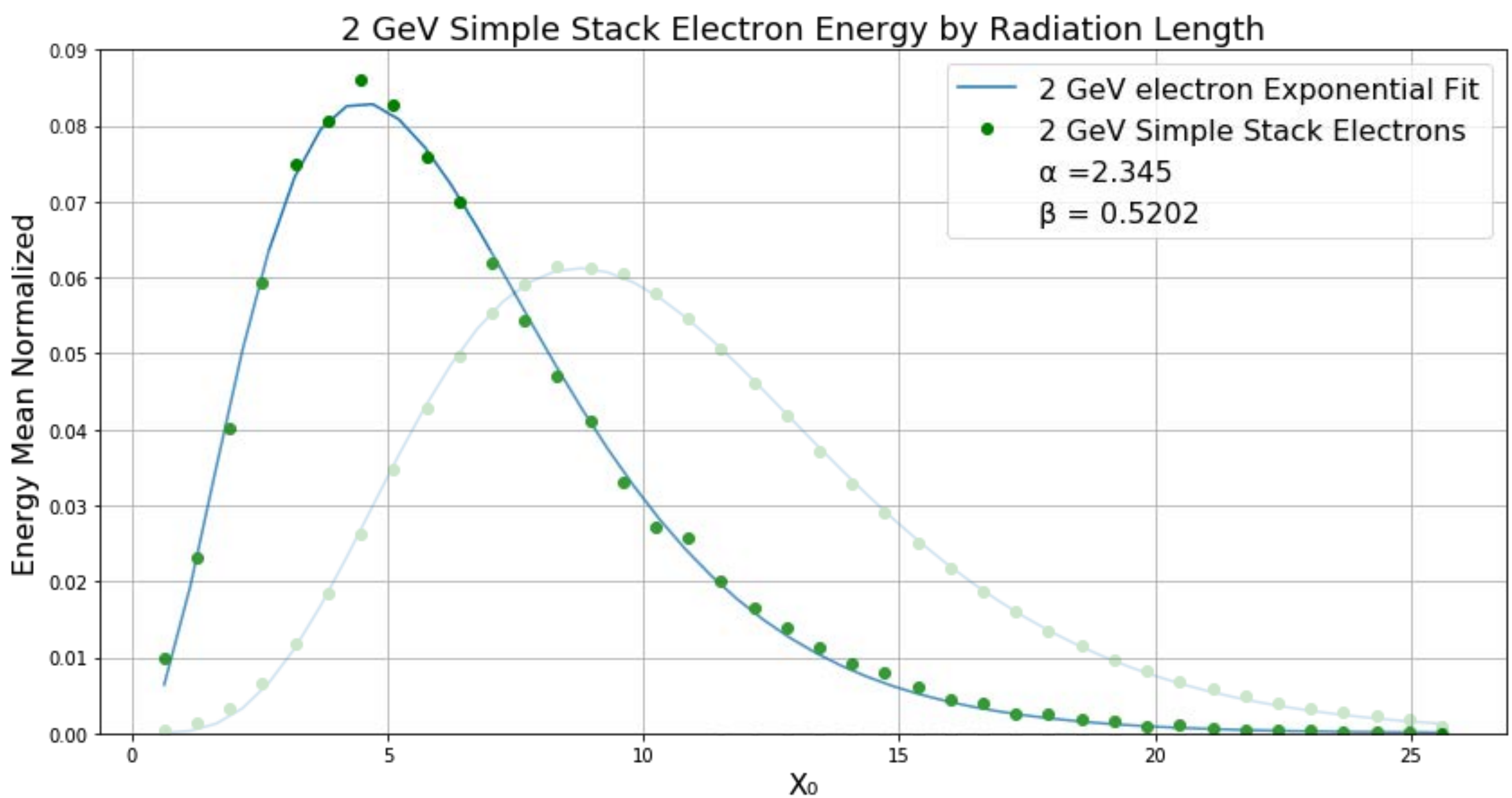
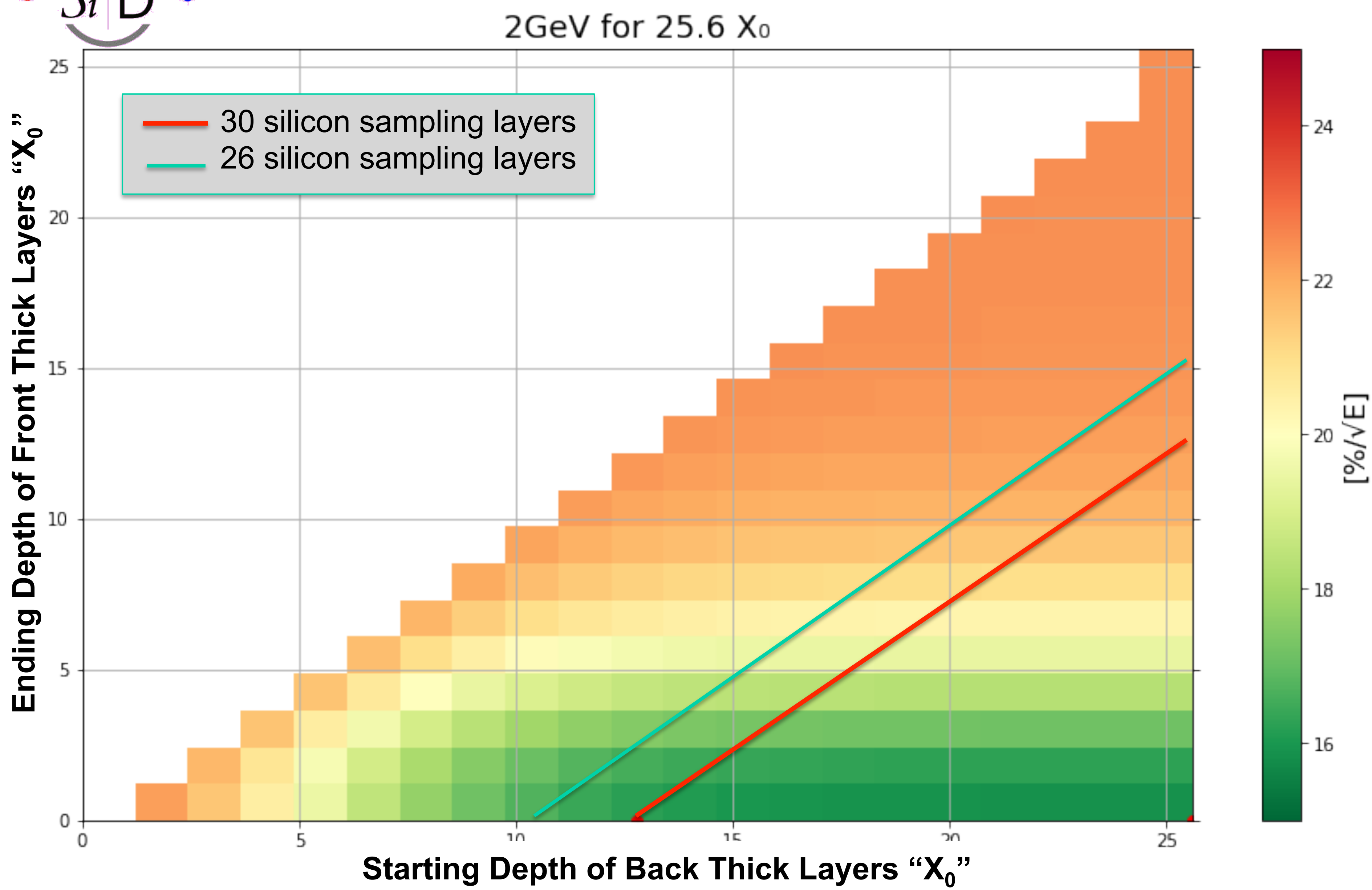

2 GeV Simple Stack Electron Energy by Radiation Length
2 GeV electron Exponential Fit
2 GeV Simple Stack Electrons
α =2.345
β = 0.5202
Energy Mean Normalized
X0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0
5
10
15
20
25


2GeV for 25.6 X₀
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Ending Depth of Front Thick Layers "X0"
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[%/√E]
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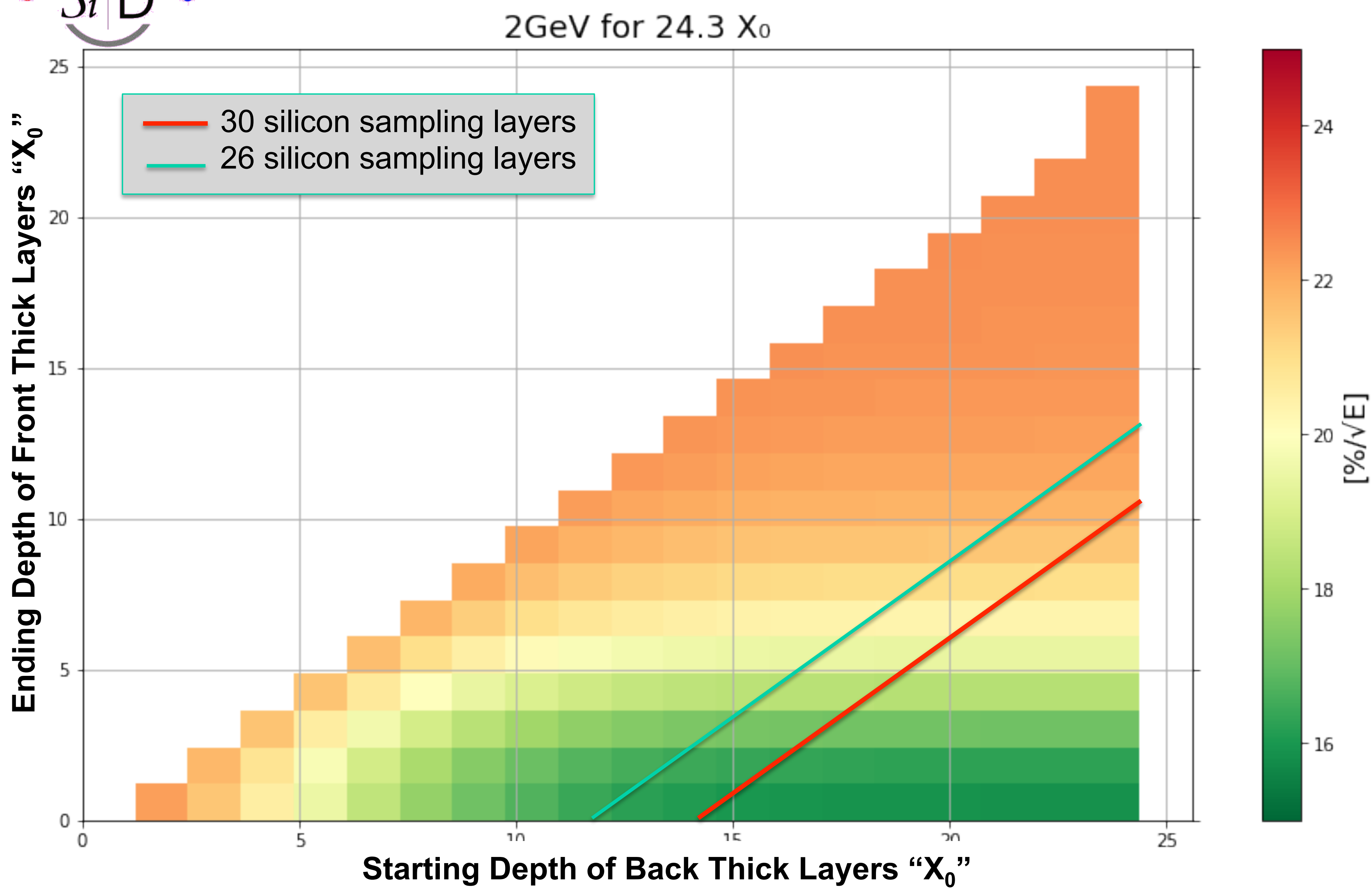
2GeV for 24.3 X0
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Ending Depth of Front Thick Layers "X0"
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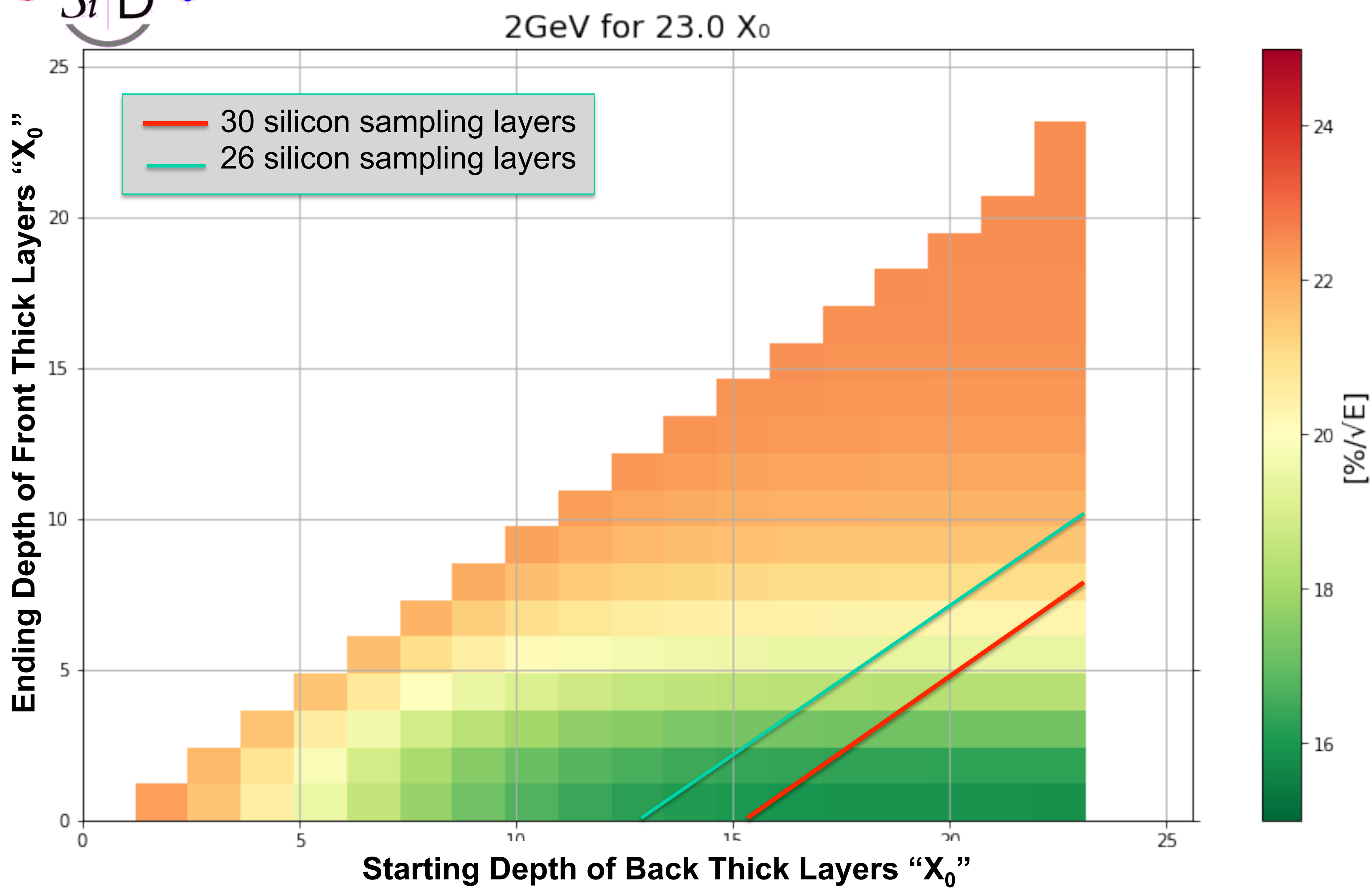
2GeV for 23.0 X0
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Starting Depth of Back Thick Layers "X0"
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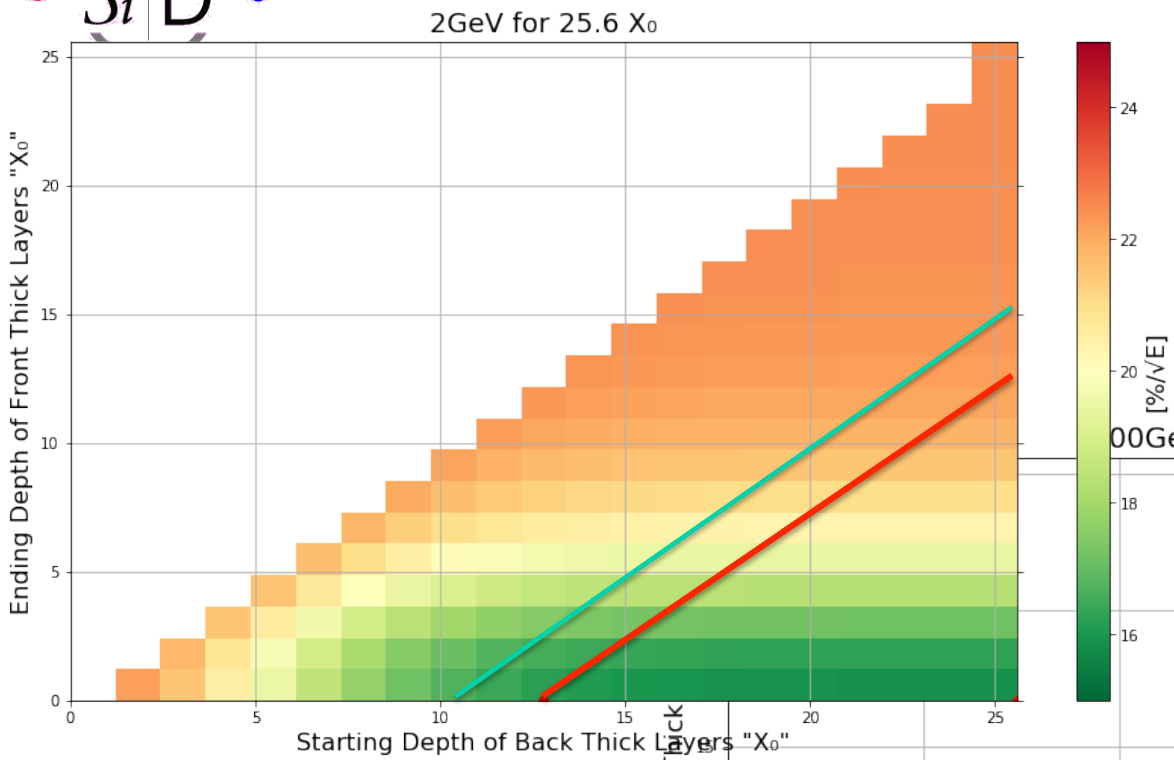
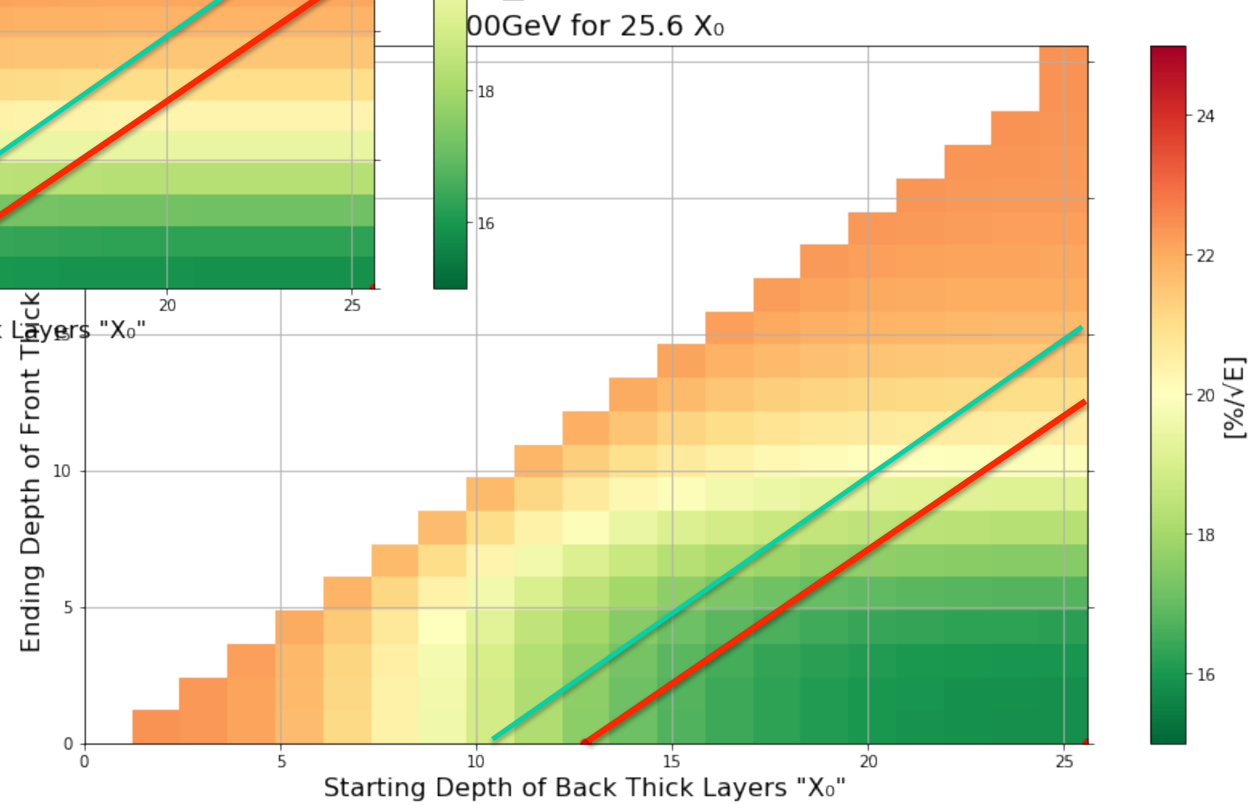
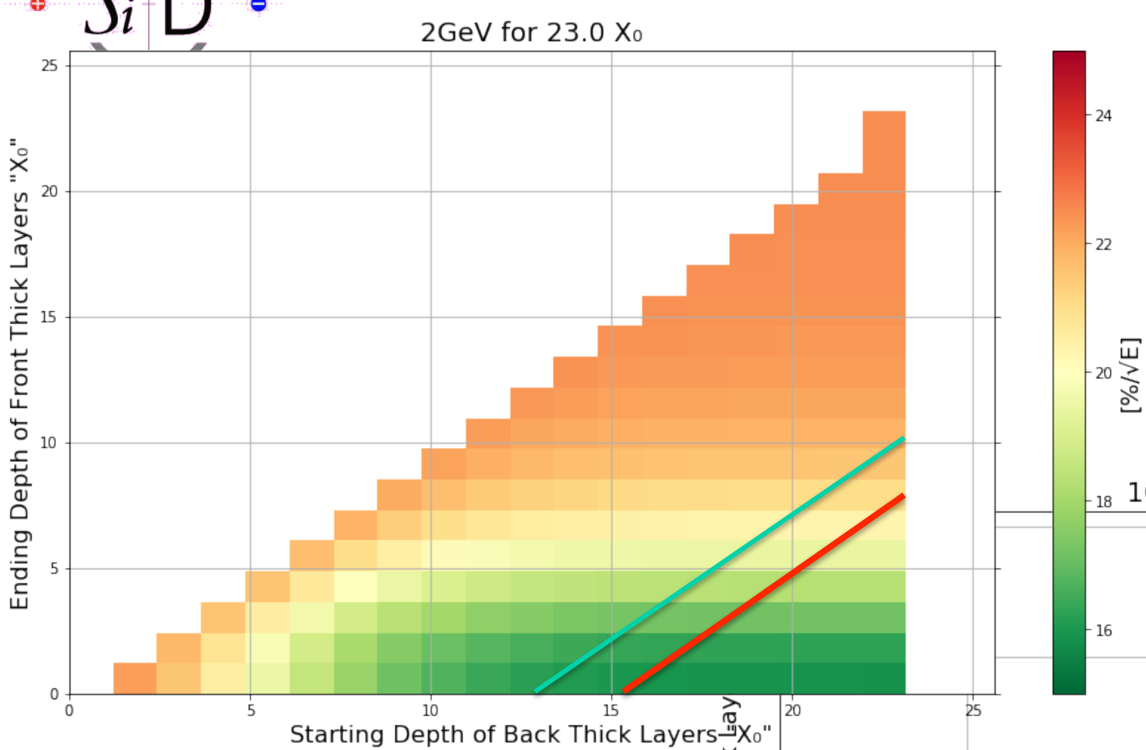

2GeV for 25.6 X_0
Ending Depth of Front Thick Layers "X_0"
Starting Depth of Back Thick Layers "X_0"
[%/√E]


00GeV for 25.6 X_0
Ending Depth of Front Thick
Starting Depth of Back Thick Layers "X_0"
[%/√E]


2GeV for 23.0 X₀
Ending Depth of Front Thick Layers "X₀"
Starting Depth of Back Thick Layers "X₀"
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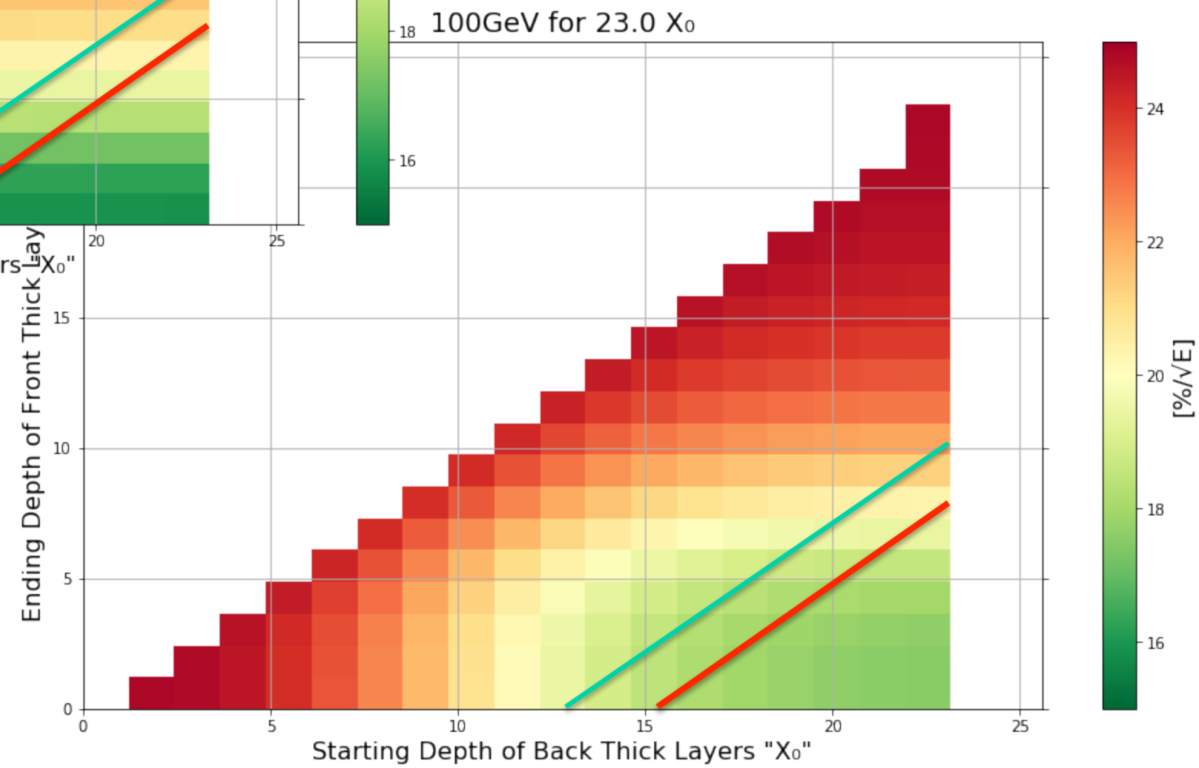
100GeV for 23.0 X₀
Ending Depth of Front Thick Lay
Starting Depth of Back Thick Layers "X₀"
[%/√E]
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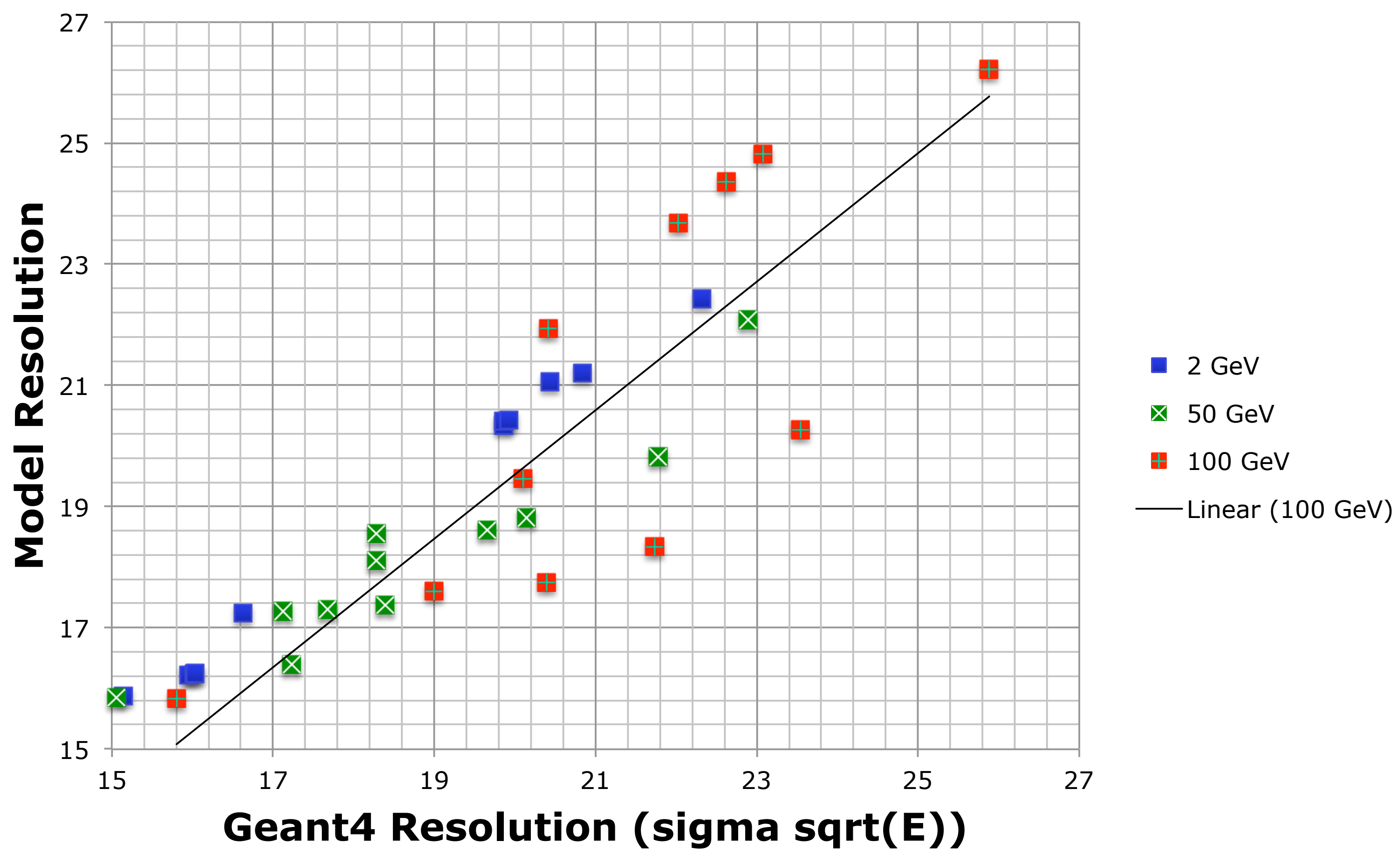
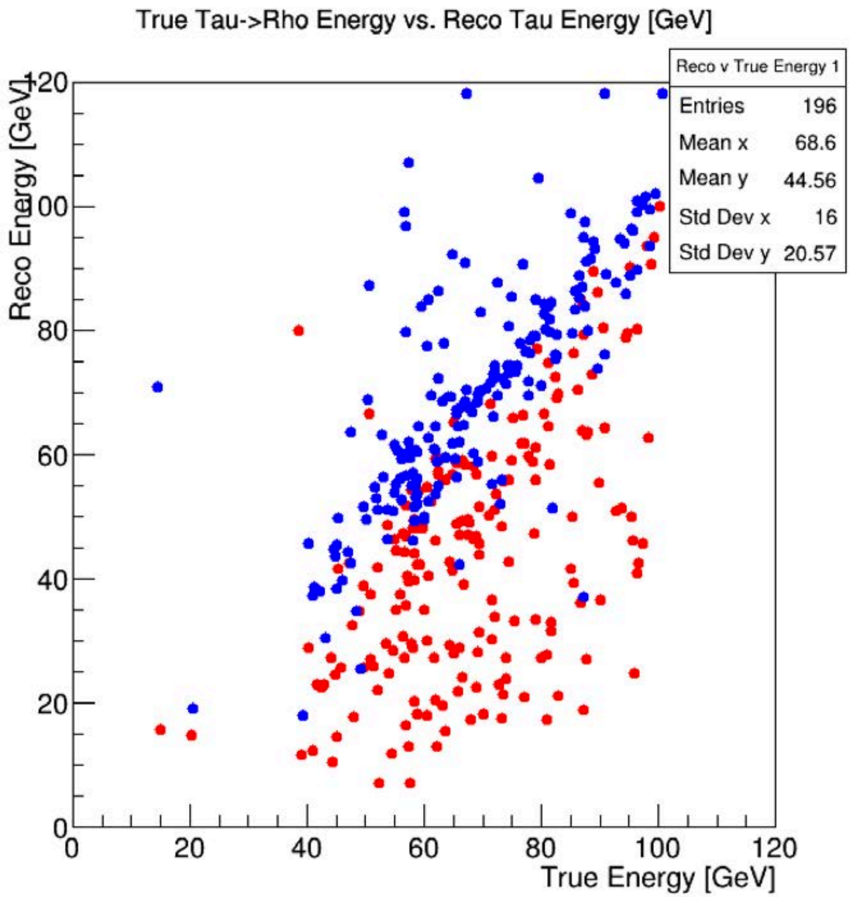
Geant4 check of fast model (arbitrary, wide variety of cases)



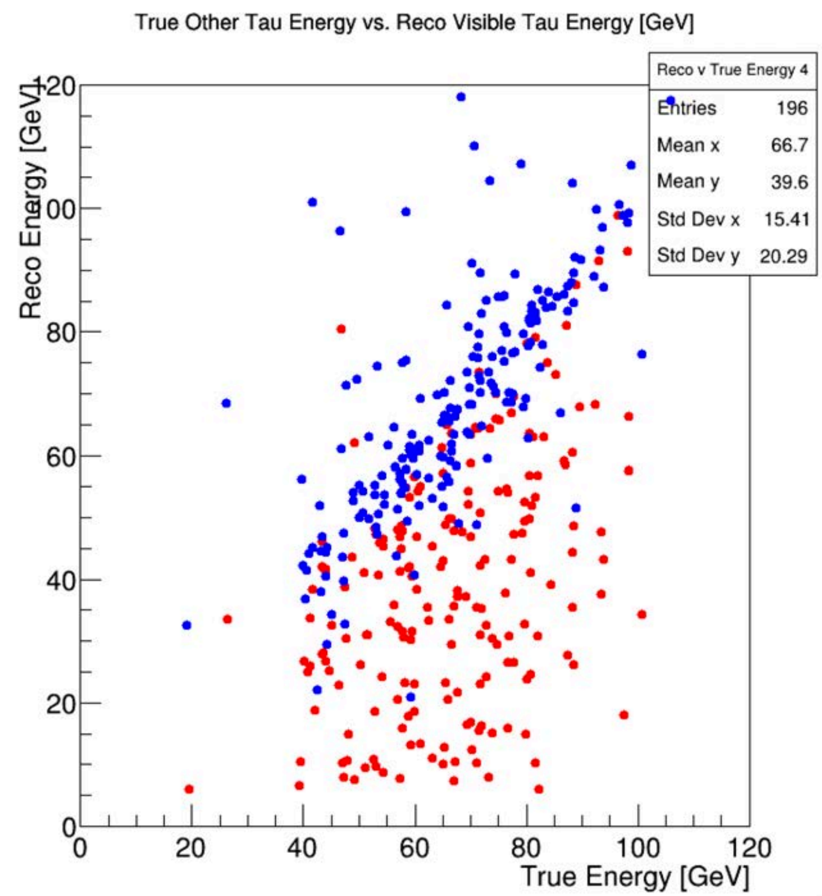
Still developing model.

Looking at Higgs decays to $\tau^\pm \rightarrow \rho^\pm \nu$ to measure physics impact (250 GeV)

Tagged $\tau^\pm \rightarrow \rho^\pm \ \nu \rightarrow \pi^\pm \pi^o \nu$



Second $\tau \rightarrow$ inclusive



Evaluation in progress.

Summary

- SiD ECal costs depend on the number of silicon sampling layers. Reducing number saves ~2.4 M$ /layer.
- Fast resolution estimates with simplified calorimeter model for various sampling options provide guidance on the impact of sampling choices on cost.
- Fast estimates have been compared to detailed Geant4 calculations and model will be refined.
- We plan to test the resolution impact on physics; one channel being studied is

  Higgs $\rightarrow \tau\,\tau$

  $\tau^{\pm} \rightarrow \rho^{\pm}\ \nu \rightarrow \pi^{\pm}\,\pi^{0}\,\nu$; other τ inclusive decay

- When simple stack is replaced by realistic SiD model resolution will degrade – but trends should be preserved.

Conclusion

- We have just started this investigation.
  - Intense effort by UO undergrads.
- Next steps:
  - Improve fast model to match Geant4 patterns.
  - Apply model options to physics studies.
  - Evaluate importance of energy resolution, energy linearity, transverse segmentation, trade-offs.
  - Consider other alternatives in longitudinal segmentation and calorimeter depth.
- Too early to draw conclusions but tools ready to understand the options.

Extra Material

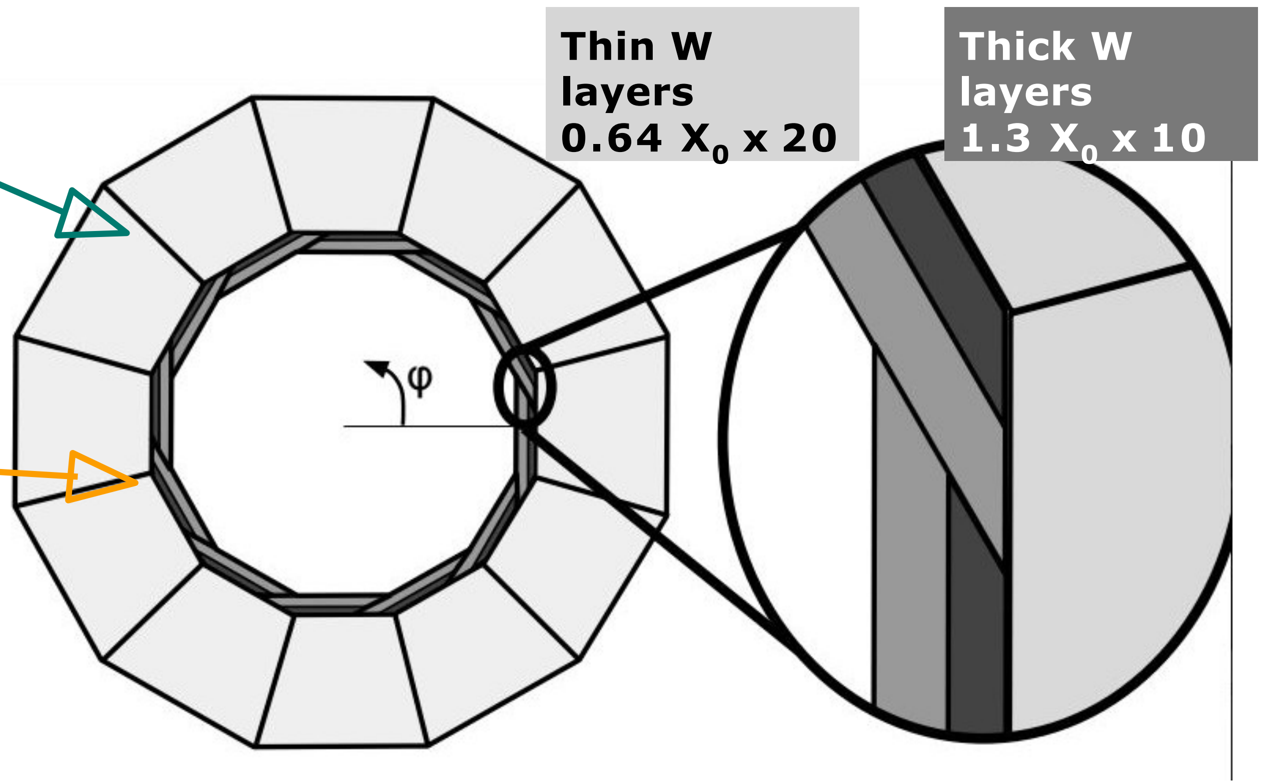
SiD Calorimeter Geometry

HCal

Scintillator
sampling
calorimeter
Steel/polystyrene

ECal

Solid state
sampling
calorimeter
Tungsten alloy/
silicon



Structure complicates shower measurement.