GUINEA-PIG Simulations for HALHF

HALHF Monthly Accelerator Meeting 10.12.2025

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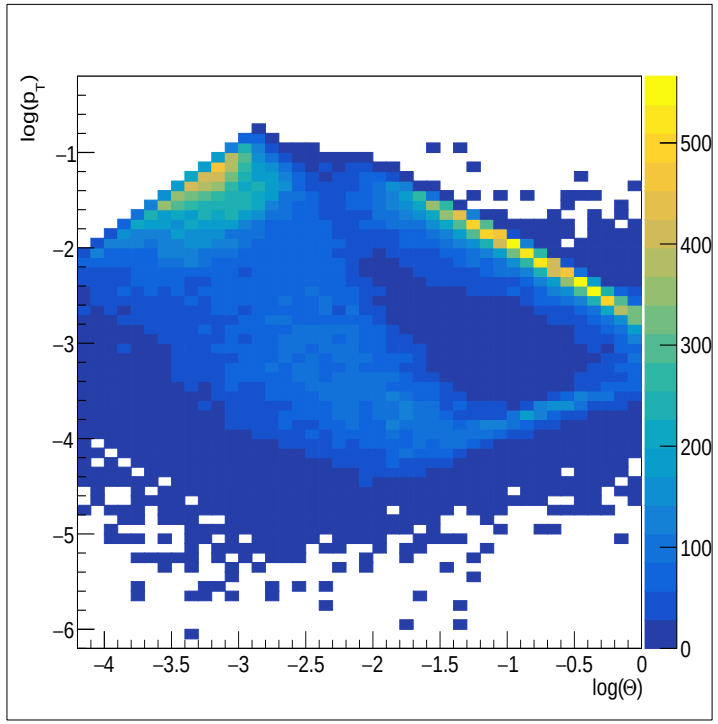
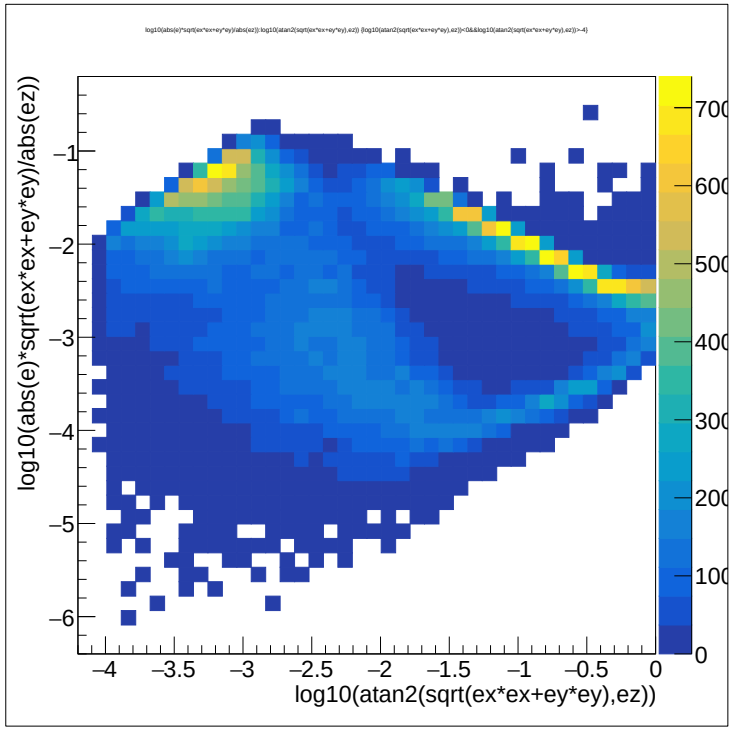
Validation of GUINEA-PIG

Using ILC 250 GeV Parameters

- Plotted the e+ and e- generated after one bunch crossing on a log(p_T) v/s log(Θ) plane.
- Obtained a good agreement between plots generated by me and Mikael (old setup).



GUINEA-PIG New Setup

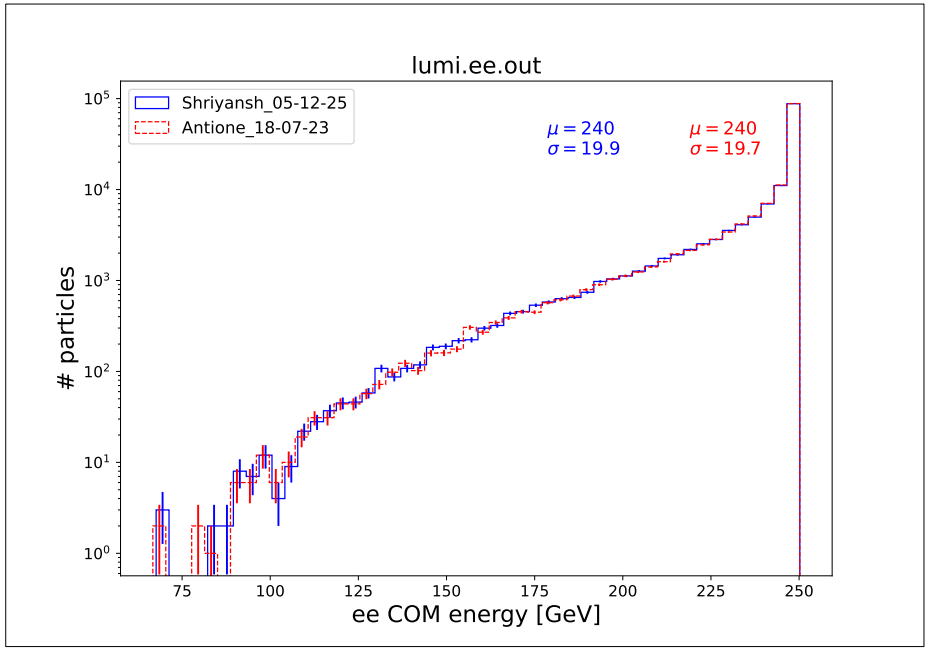


GUINEA-PIG Old Setup

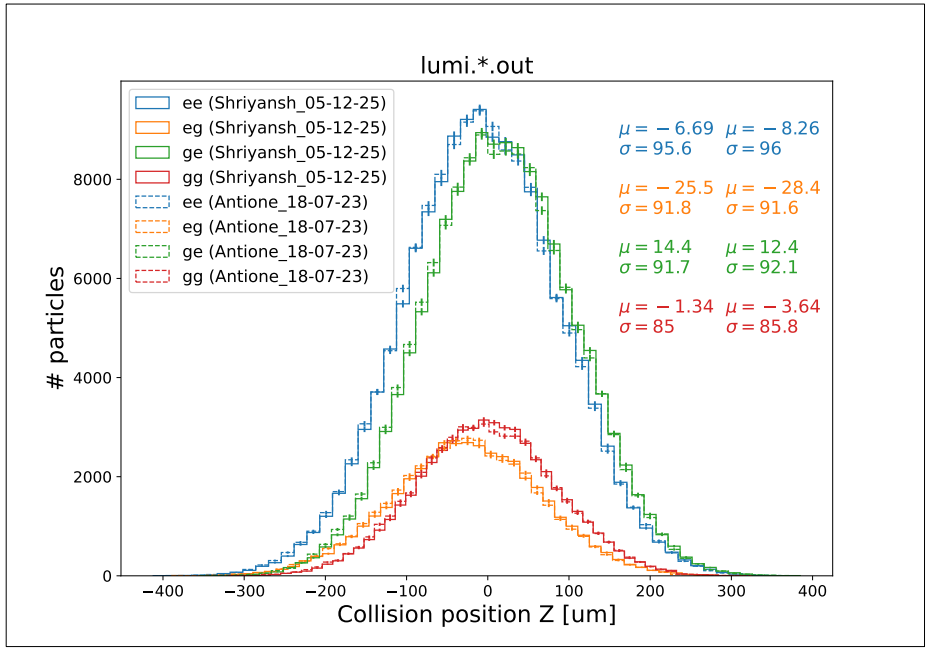
Validation of GUINEA-PIG

Using Old HALHF 250 GeV Parameters

- Plotted the energy spectrum and z-position luminosity spectrum.
- Obtained a good agreement between plots generated by me and Antoine (old setup).
- Successfully completed hand-over from Antoine.



e+e- COM energy spectrum



Luminosity wrt z-position of collisions

HALHF Parameters used in GUINEA-PIG

arXiv:2503.23489 [physics.acc-ph]

Machine parameters	*Unit*	*Value (250 GeV)*		*Value (380 GeV)*		*Value (550 GeV)*	
Centre-of-mass energy	GeV	250		380		550	
Centre-of-mass boost		1.67		1.67		1.67	
Bunches per train		160		160		160	
Train repetition rate	Hz	100		100		100	
Average collision rate ❗	kHz	16		16		16	
Luminosity	$\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$	1.2×10^{34}		1.7×10^{34}		2.5×10^{34}	
Luminosity fraction in top 1%		63%		53%		46%	
Quantum parameter (Υ)		0.9		1.6		2.8	
Estimated total power usage	MW	106		154		218	
Total site length	km	4.9		6.5		8.4	
Colliding-beam parameters		e^-	e^+	e^-	e^+	e^-	e^+
Beam energy ✅	GeV	375	41.7	570	63.3	825	91.7
Bunch population ✅	10^{10}	1	3	1	3	1	3
Bunch length in linacs (rms)	μm	40	150	40	150	40	150
Bunch length at IP (rms) ✅	μm	150		150		150	
Energy spread (rms) ✅	%	0.15		0.15		0.15	
Horizontal emittance (norm.) ✅	μm	90	10	90	10	90	10
Vertical emittance (norm.) ✅	μm	0.32	0.035	0.32	0.035	0.32	0.035
IP horizontal beta function ✅	mm	3.3		3.3		3.3	
IP vertical beta function ✅	mm	0.1		0.1		0.1	
IP horizontal beam size (rms)	nm	636		519		429	
IP vertical beam size (rms)	nm	6.6		5.2		4.4	
Average beam power delivered	MW	9.6	3.2	14.6	4.9	21.1	7.0
Bunch separation	ns	16		16		16	
Average beam current	μA	26	77	26	77	26	77

New Parameters

B Foster et al 2023 New J. Phys. 25 093037

Machine parameters	*Unit*	*Value*	
Centre-of-mass energy	GeV	250	
Centre-of-mass boost		2.13	
Bunches per train		100	
Train repetition rate	Hz	100	
Average collision rate ❗	kHz	10	
Luminosity	$\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$	0.81×10^{34}	
Luminosity fraction in top 1%		57%	
Estimated total power usage	MW	100	
Colliding-beam parameters		e^-	e^+
Beam energy ✅	GeV	500	31.25
Bunch population ✅	10^{10}	1	4
Bunch length in linacs (rms)	μm	18	75
Bunch length at IP (rms) ✅	μm	75	
Energy spread (rms) ✅	%	0.15	
Horizontal emittance (norm.) ✅	μm	160	10
Vertical emittance (norm.) ✅	μm	0.56	0.035
IP horizontal beta function ✅	mm	3.3	
IP vertical beta function ✅	mm	0.1	
IP horizontal beam size (rms)	nm	729	
IP vertical beam size (rms)	nm	7.7	
Average beam power delivered	MW	8	2
Bunch separation	ns	80	
Average beam current	μA	16	64

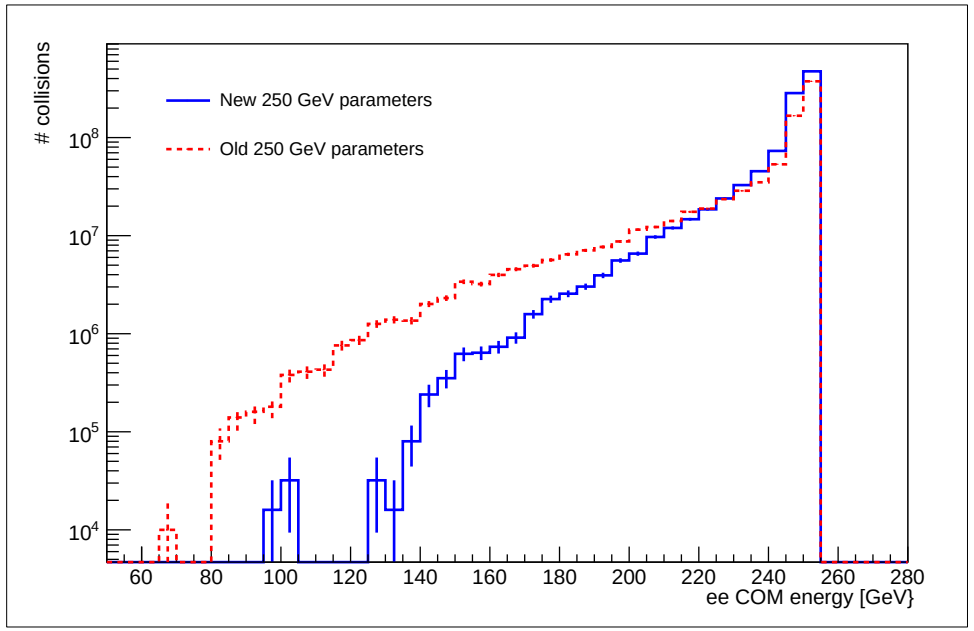
Old Parameters

Note: The collision rate of new parameters is different. So, have to scale the luminosity per bunch accordingly!

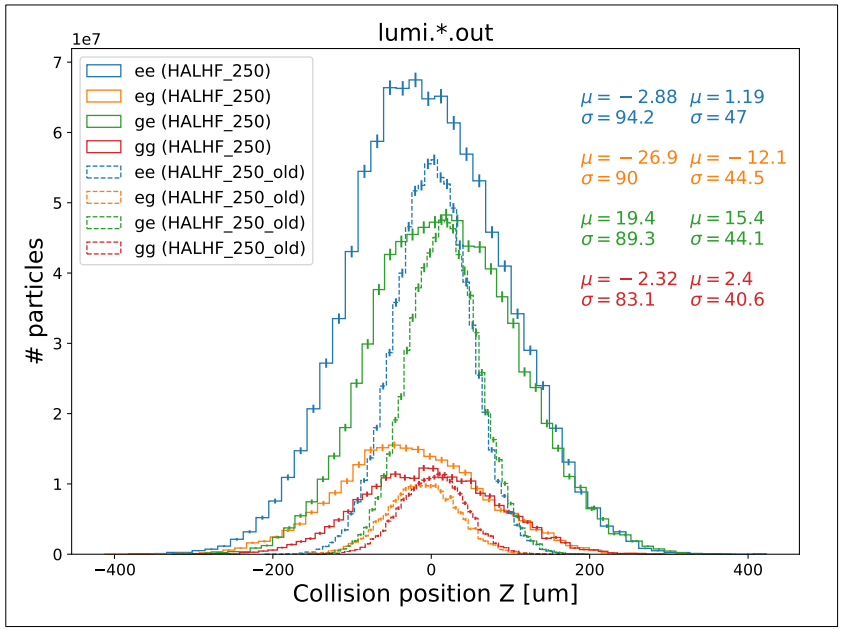
Comparison of old and new HALHF setups

Old v/s new 250 GeV parameters

- Plots scaled to collisions per second
- Newer setup gives:
  - Narrower energy spectrum
  - Wider z-distribution



e+e- COM energy spectrum

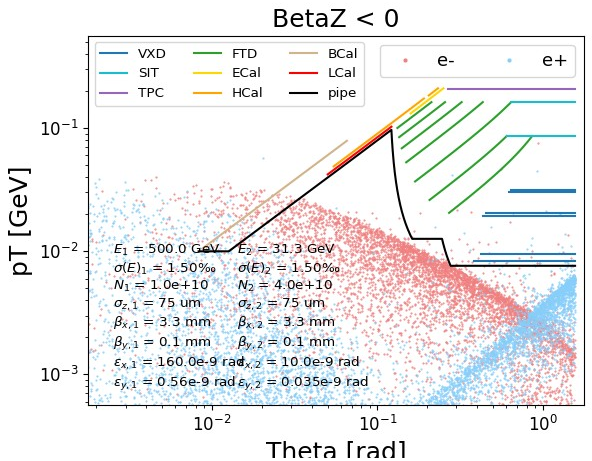


Luminosity wrt z-position of collisions

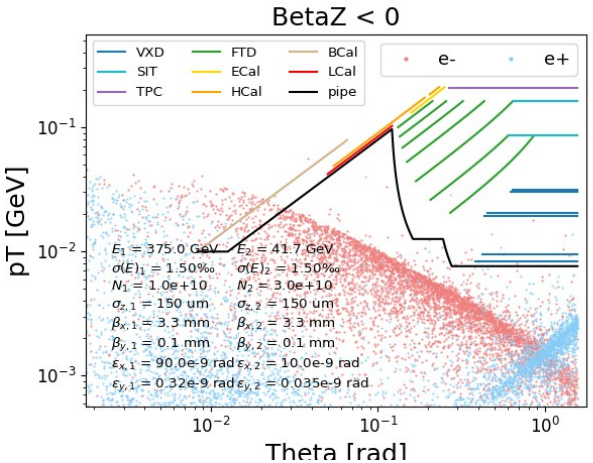
Comparison of old and new HALHF setups

Pairs produced in 1 bunch crossing (backward)

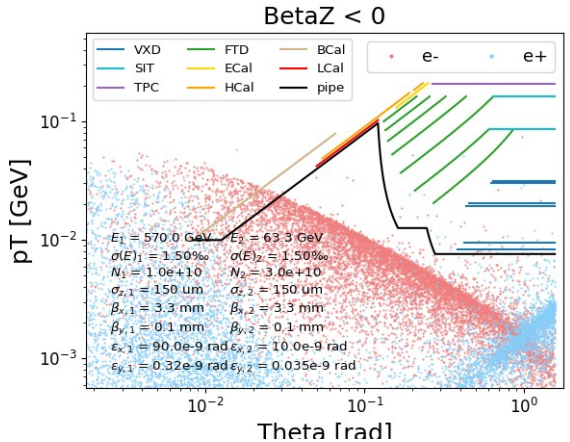
250 GeV (old)



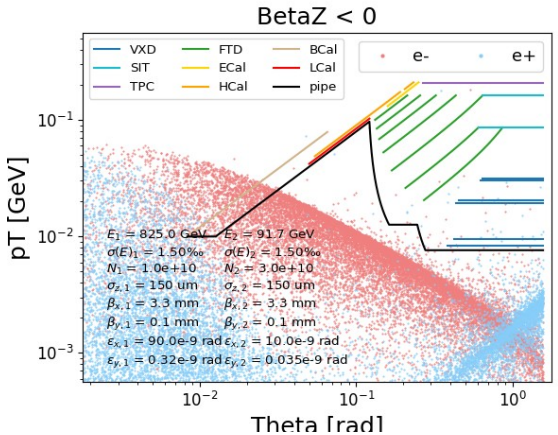
250 GeV (new)



380 GeV



550 GeV

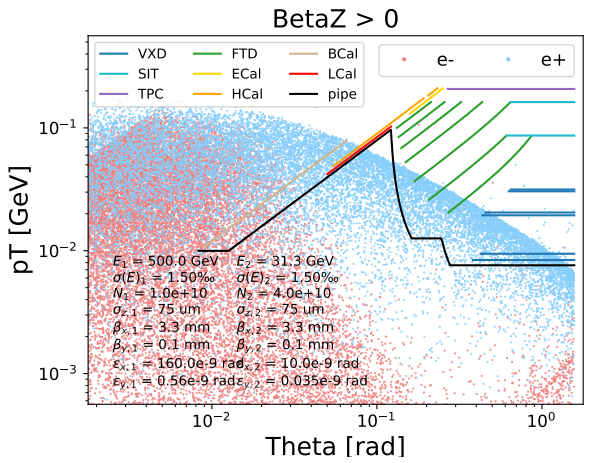


- The symmetric ILD@ILC detector is overlaid.
- No part of the detector affected.

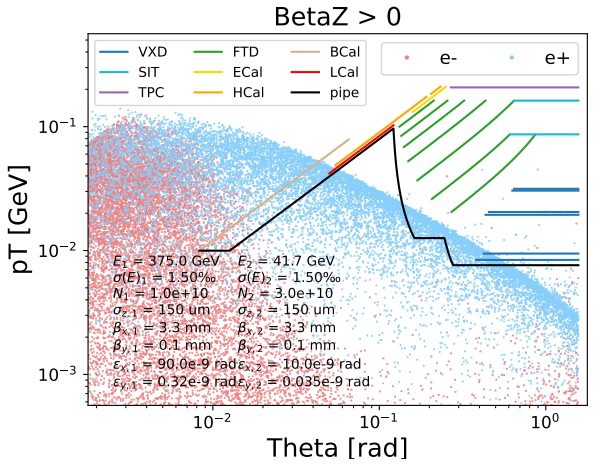
Comparison of old and new HALHF setups

Pairs produced in 1 bunch crossing (forward)

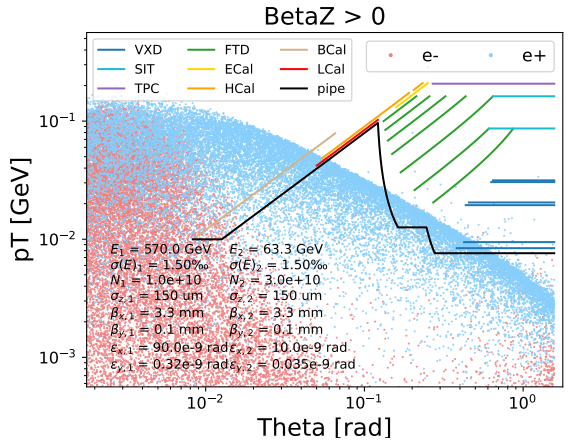
250 GeV (old)



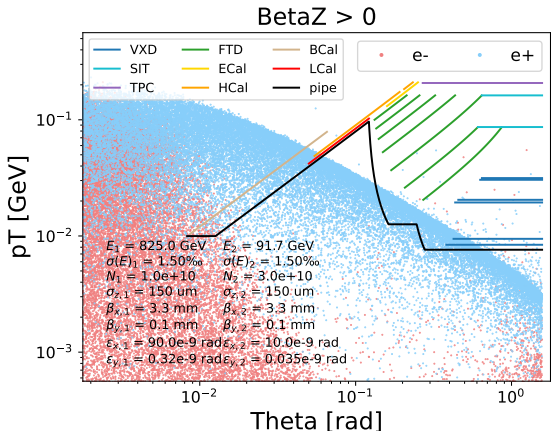
250 GeV (new)



380 GeV



550 GeV



- Much less part of the detector affected for newer parameters.
- Can use the narrower pair cone to adjust the asymmetric ILD@HALHF.

Luminosity Comparison

Luminosity (cm^{-2} s^{-1})	**250 GeV (old)**	**250 GeV (new)**	**380 GeV**	**550 GeV**
Simulation	$0.83 * 10^{34}$	$1.02 * 10^{34}$	$1.56 * 10^{34}$	$1.71 * 10^{34}$
Reference	$0.81 * 10^{34}$	$1.2 * 10^{34}$	$1.7 * 10^{34}$	$2.5 * 10^{34}$
Relative difference	2.5%	15%	8.2%	31.6%
Top 1% Luminosity				
Simulation	60%	68%	58%	51%
Reference	57%	63%	53%	46%

- Luminosities obtained from the simulation show some disagreement from the reference (especially newer parameters).
- Luminosity fraction in top 1% agrees with the reference.

Conclusion

- GUINEA-PIG up and running; reproduced ILC and old HALHF.
- New HALHF parameters give better luminosity spectrum and narrower pair cone → better for physics and detector.
- To clarify: Difference in the total luminosity in paper.
- Next:
  - Adjust SGV model for ILD@HALHF, re-do recoil analysis
  - Cross-check with CAIN/WarpX

Thank you