

Higgs Physics at Wakefield Colliders

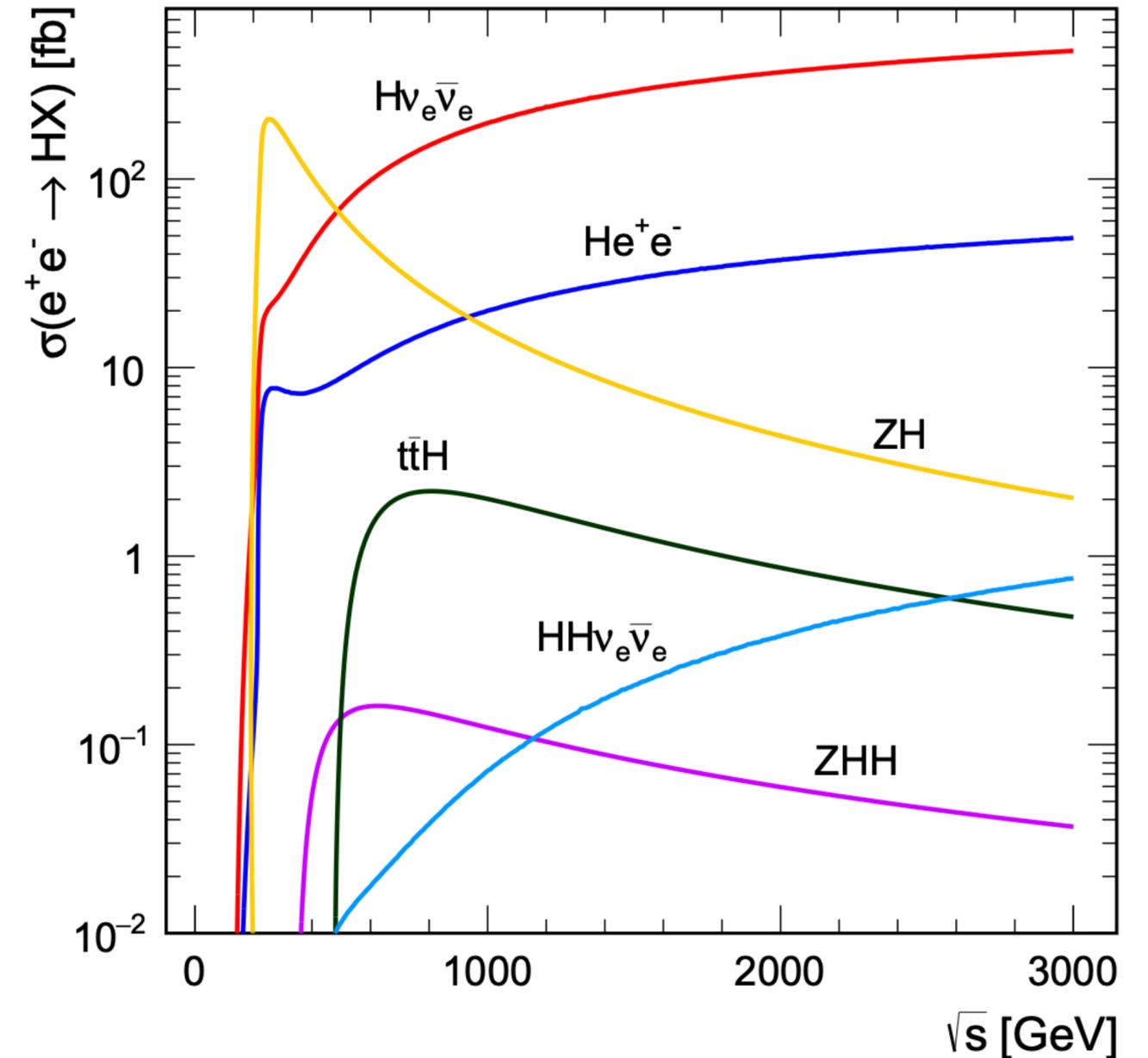
Kevin Langhoff

(In collaboration with Katie Fraser, Simon Knapen, Zoltan Ligeti, and Robert Szafron)

Potential Future Higgs Factories



- All aim at producing $\gtrsim 10^6$ Higgs bosons.
- Linear colliders can explore additional channels.
- Hope to follow with 10 TeV pCM collider.



[CLIC, 1608.07538]

Wakefield Colliders

10 TeV Wakefield Colliders are also Higgs Factories

Wakefield colliders have several challenges:

1. Accelerating positrons.
2. Beamstrahlung.

Which wakefield collider is best for Higgs physics?

- e^+e^- vs. e^-e^- ?
- Round vs. flat beams?

Should really be answered simultaneously.

How many Higgs bosons can we produce through each channel?

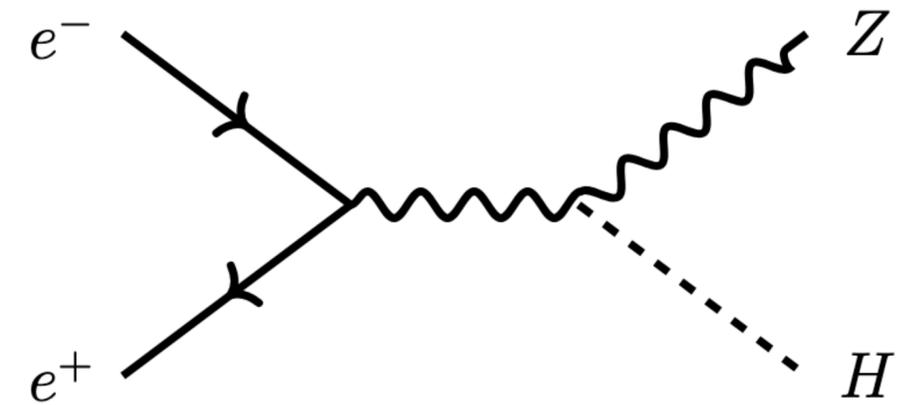
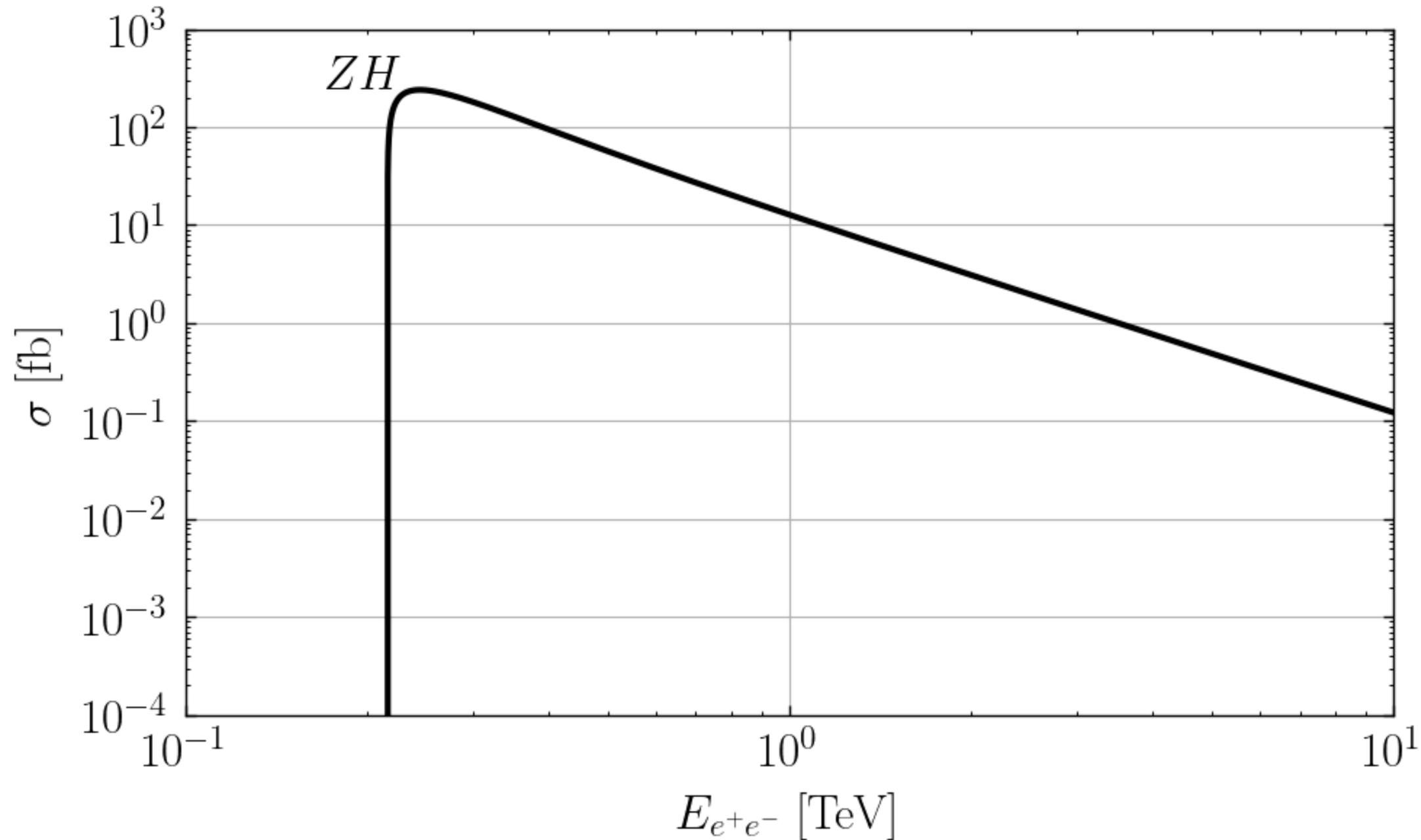
What detector features may a wakefield collider benefit from?

Question 1:

e^+e^- vs. e^-e^- at Zeroth Order

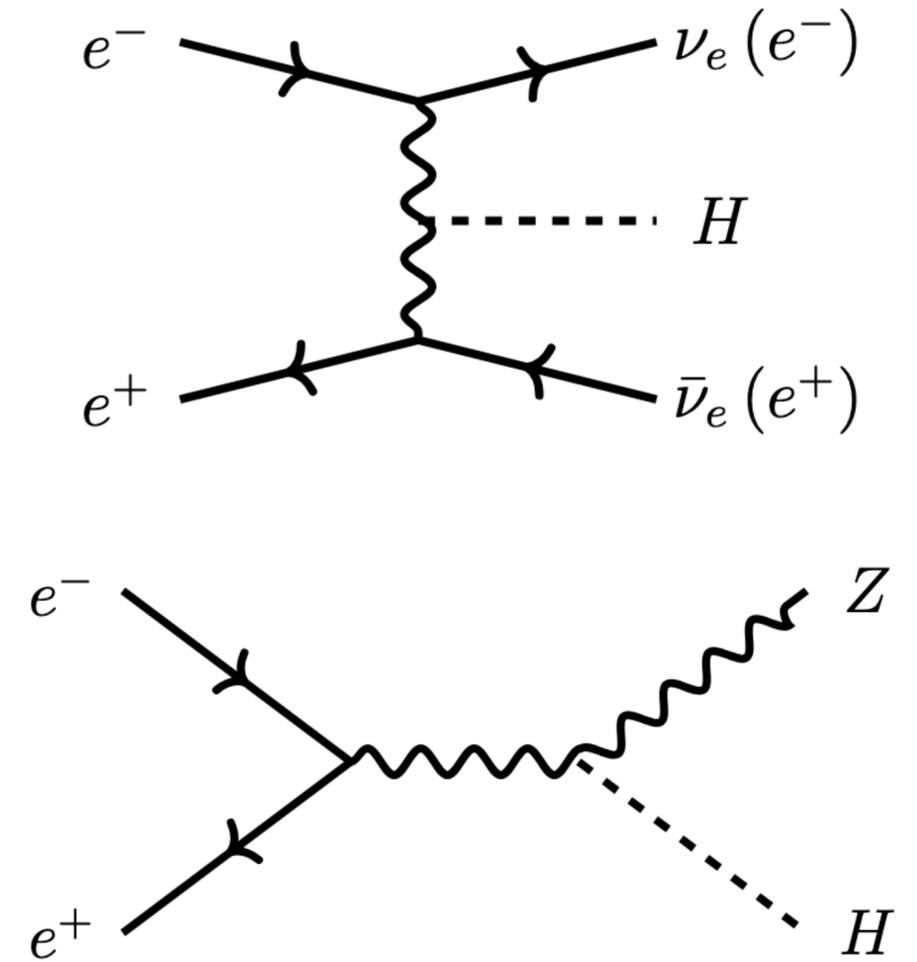
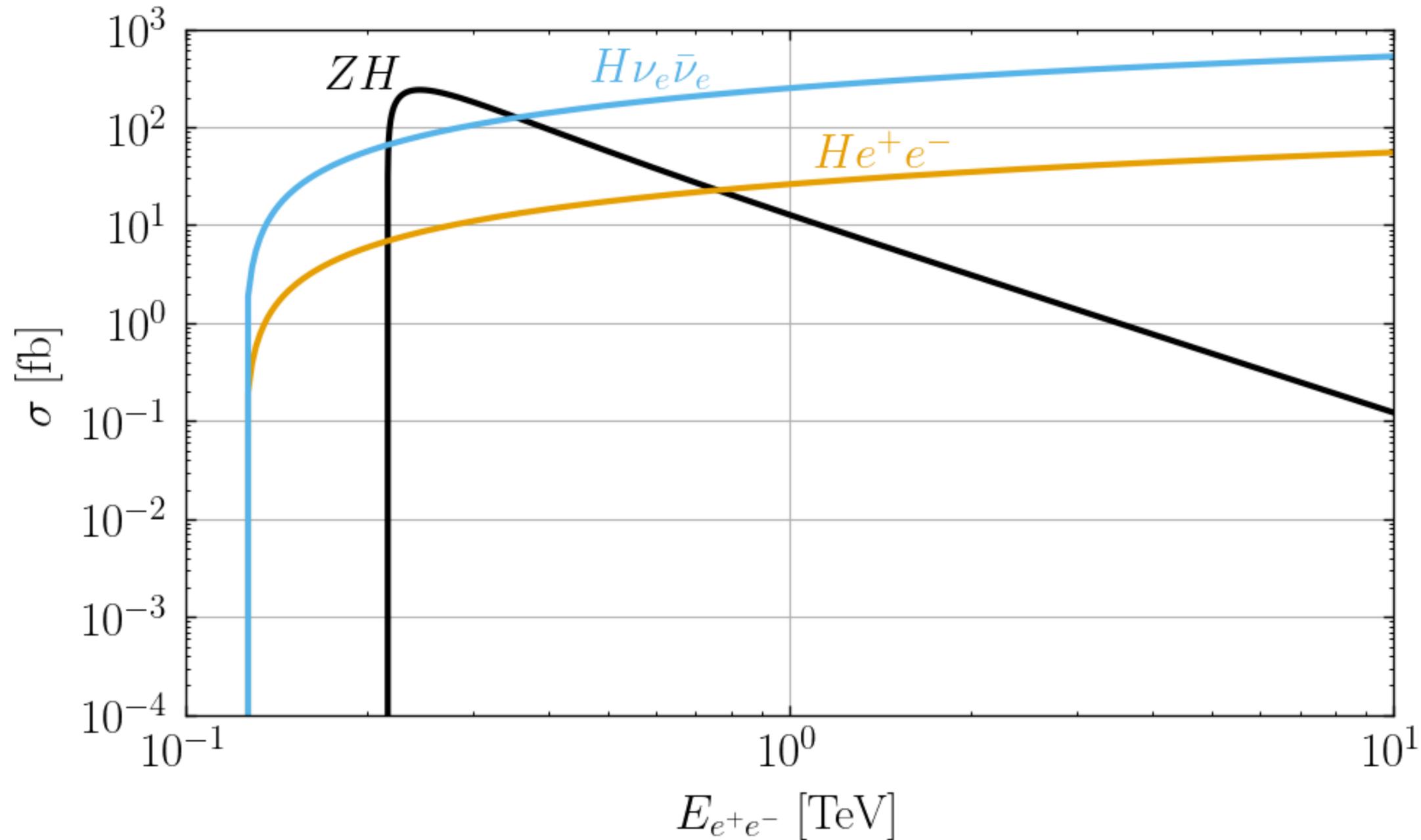
Higgs Production Cross Sections

First consider single Higgs production



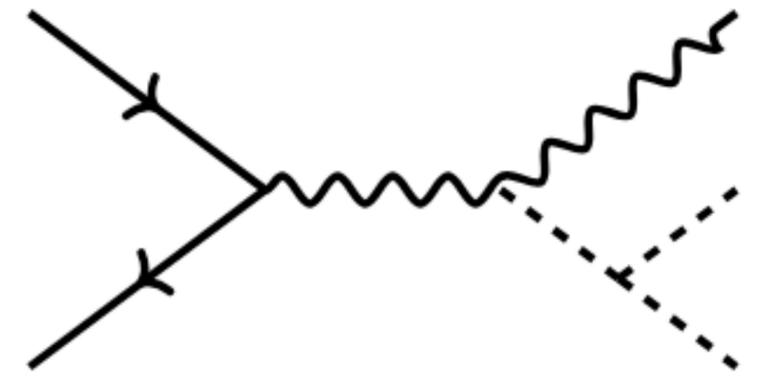
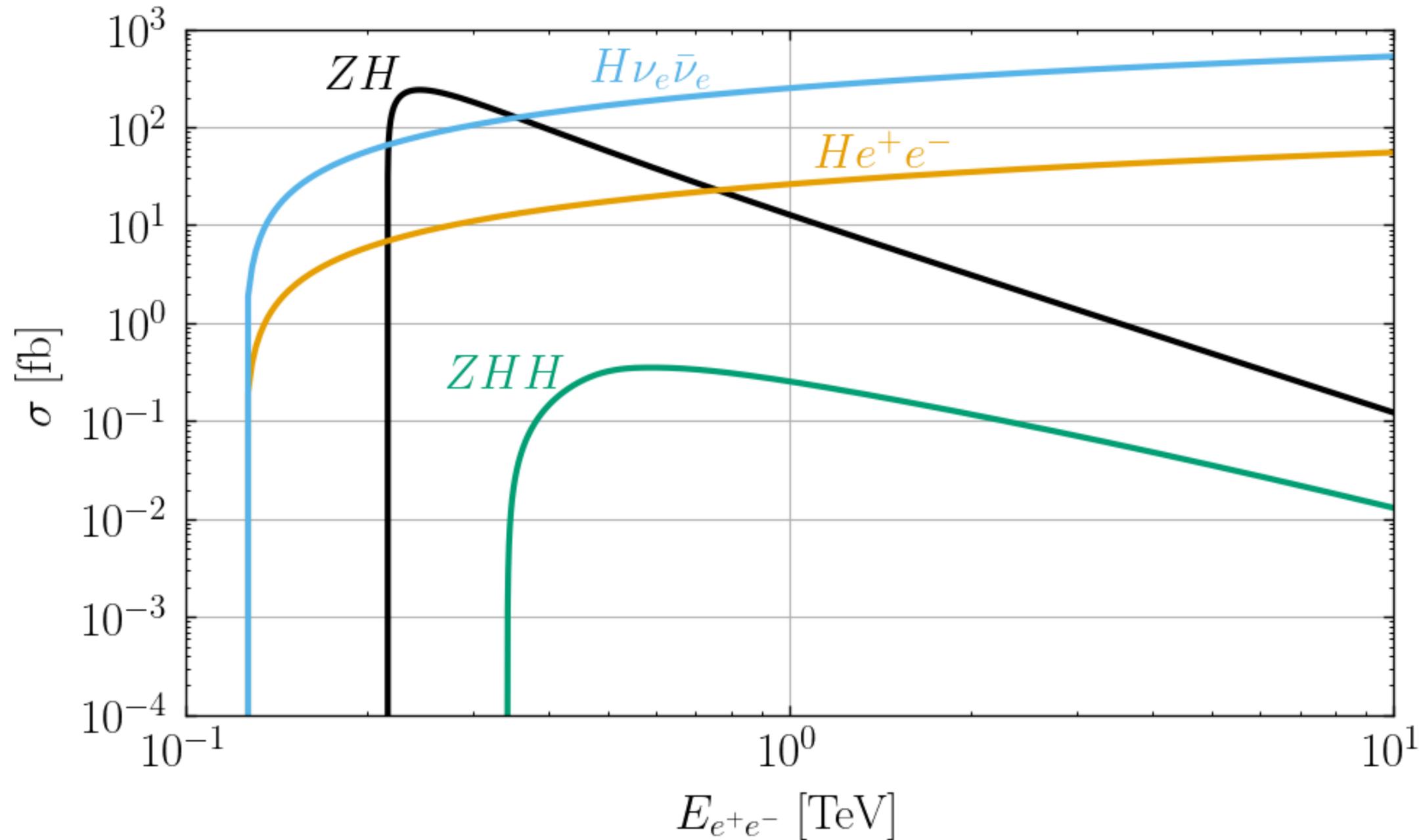
Higgs Production Cross Sections

First consider single Higgs production



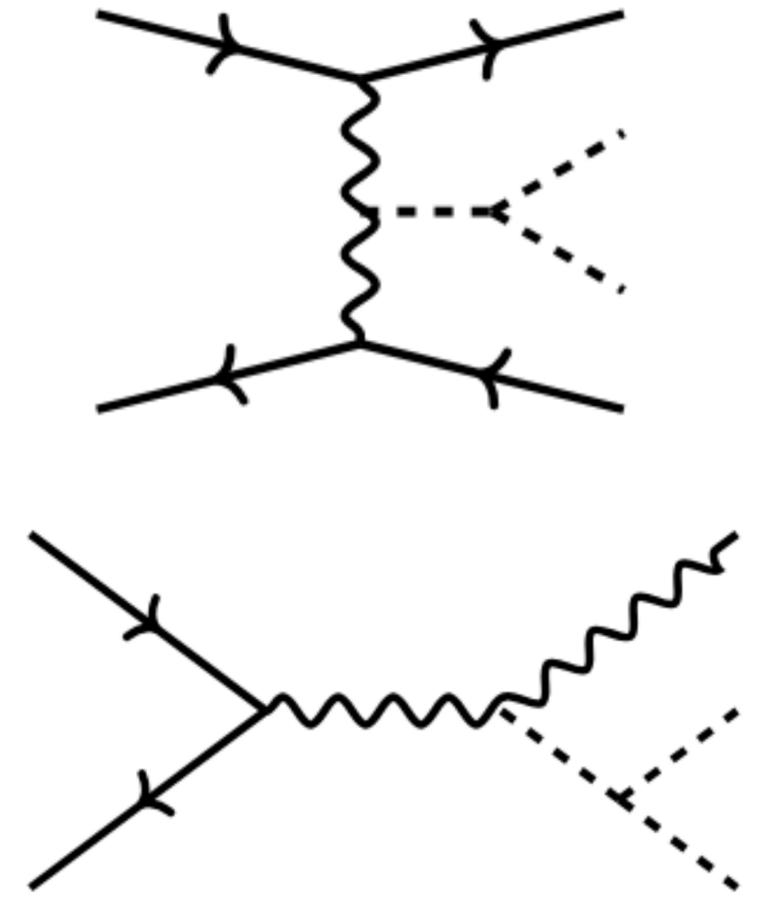
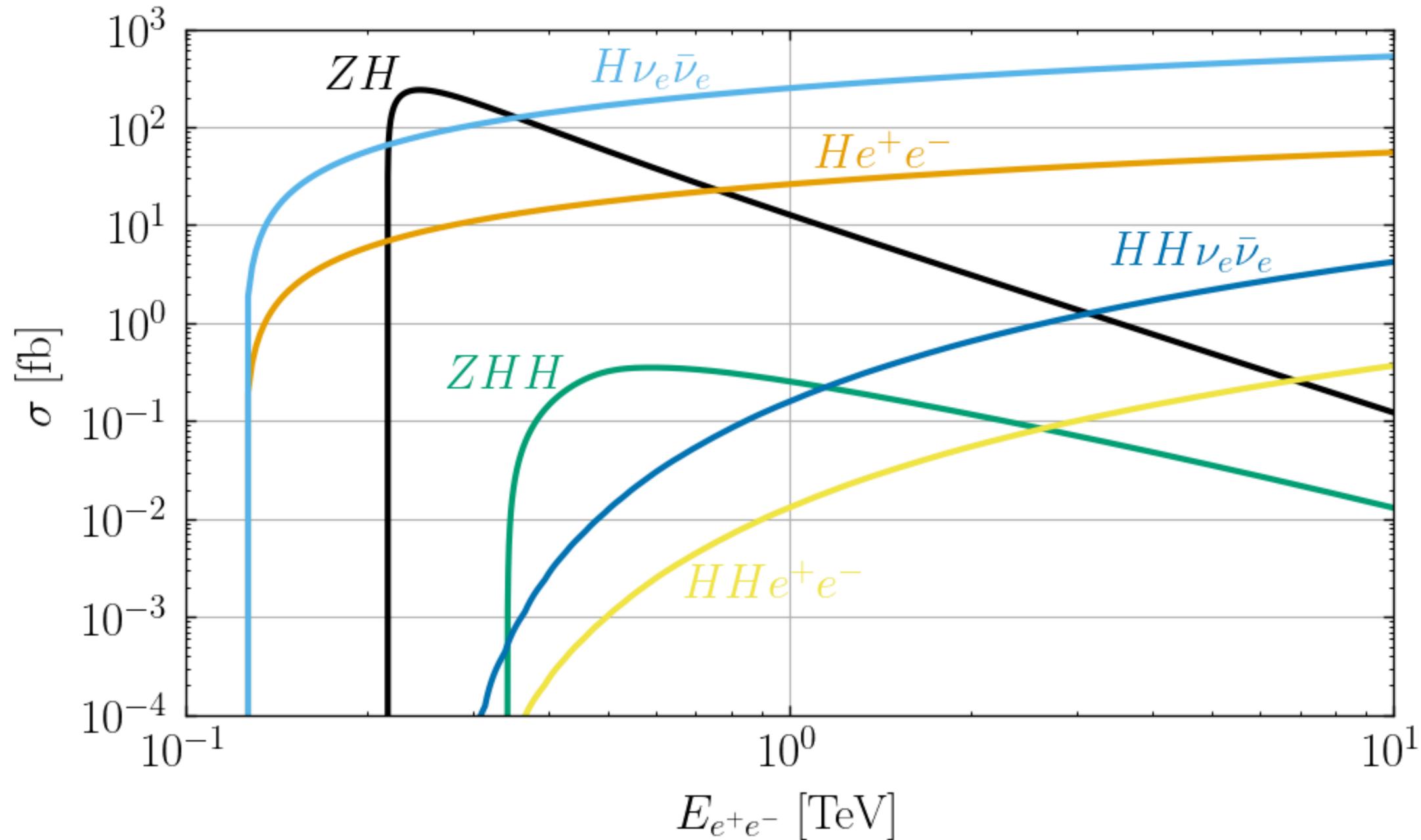
Higgs Production Cross Sections

Now consider Di-Higgs production



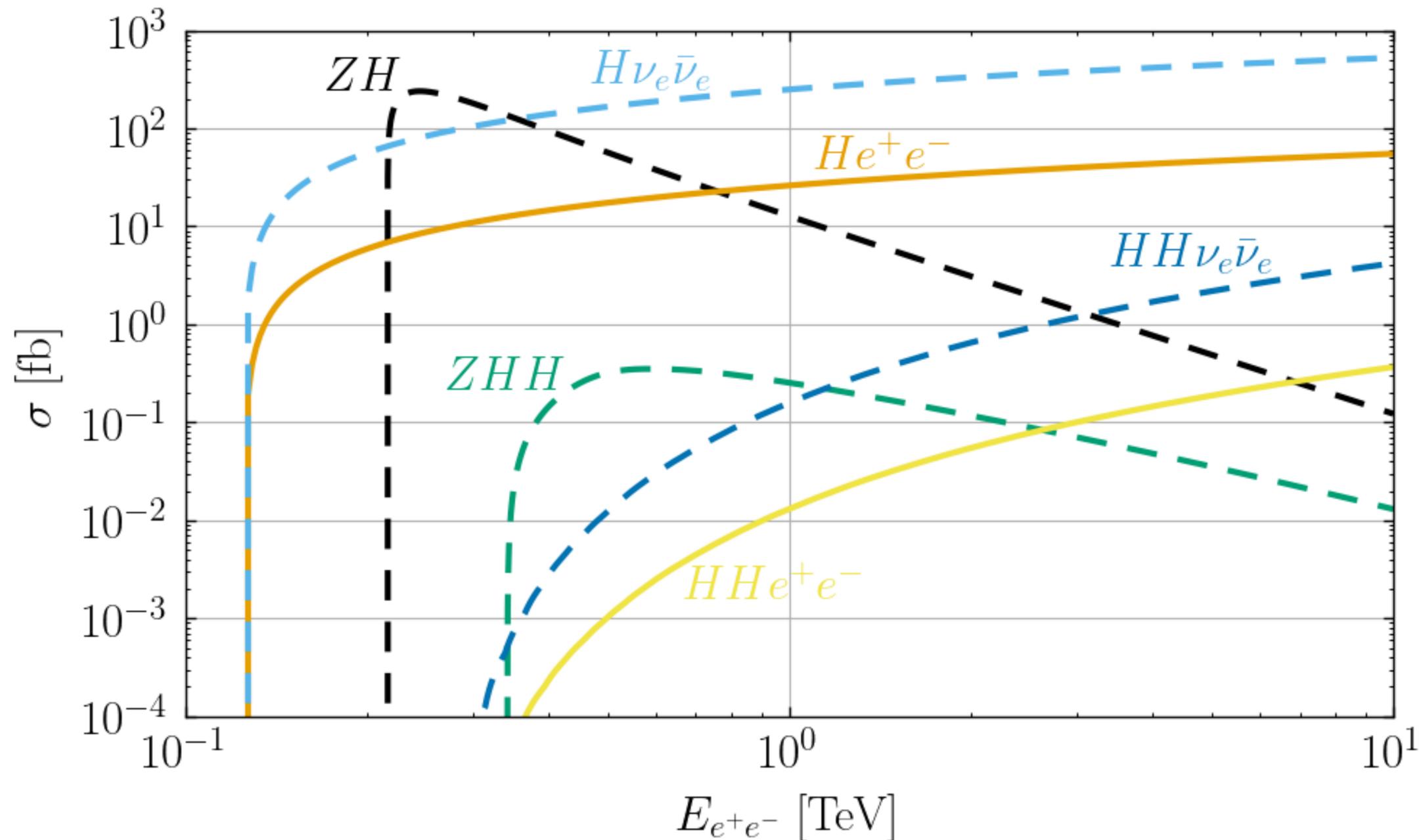
Higgs Production Cross Sections

Now consider Di-Higgs production



Higgs Production Cross Sections

We lose the dashed line channels for e^-e^- .

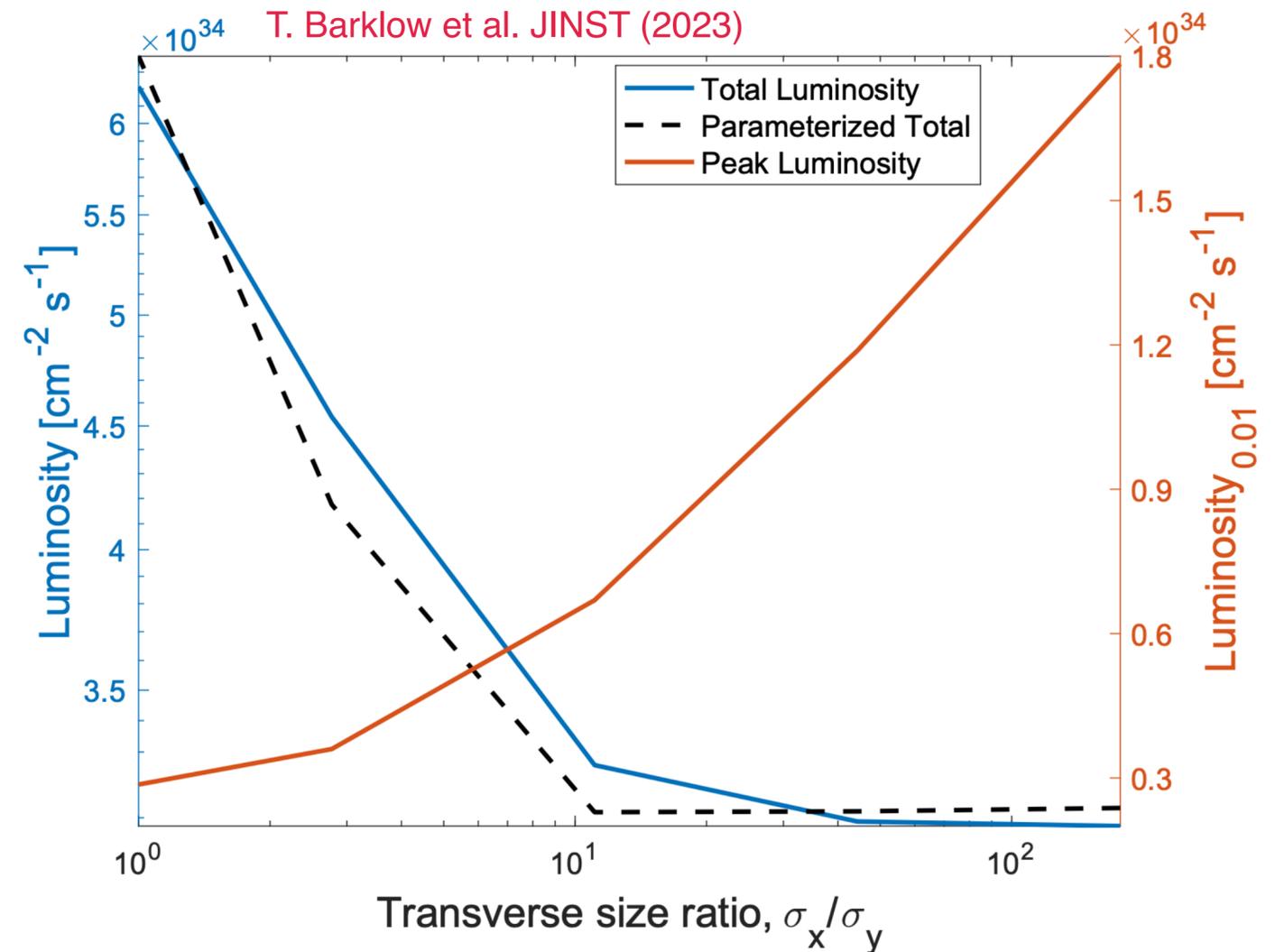
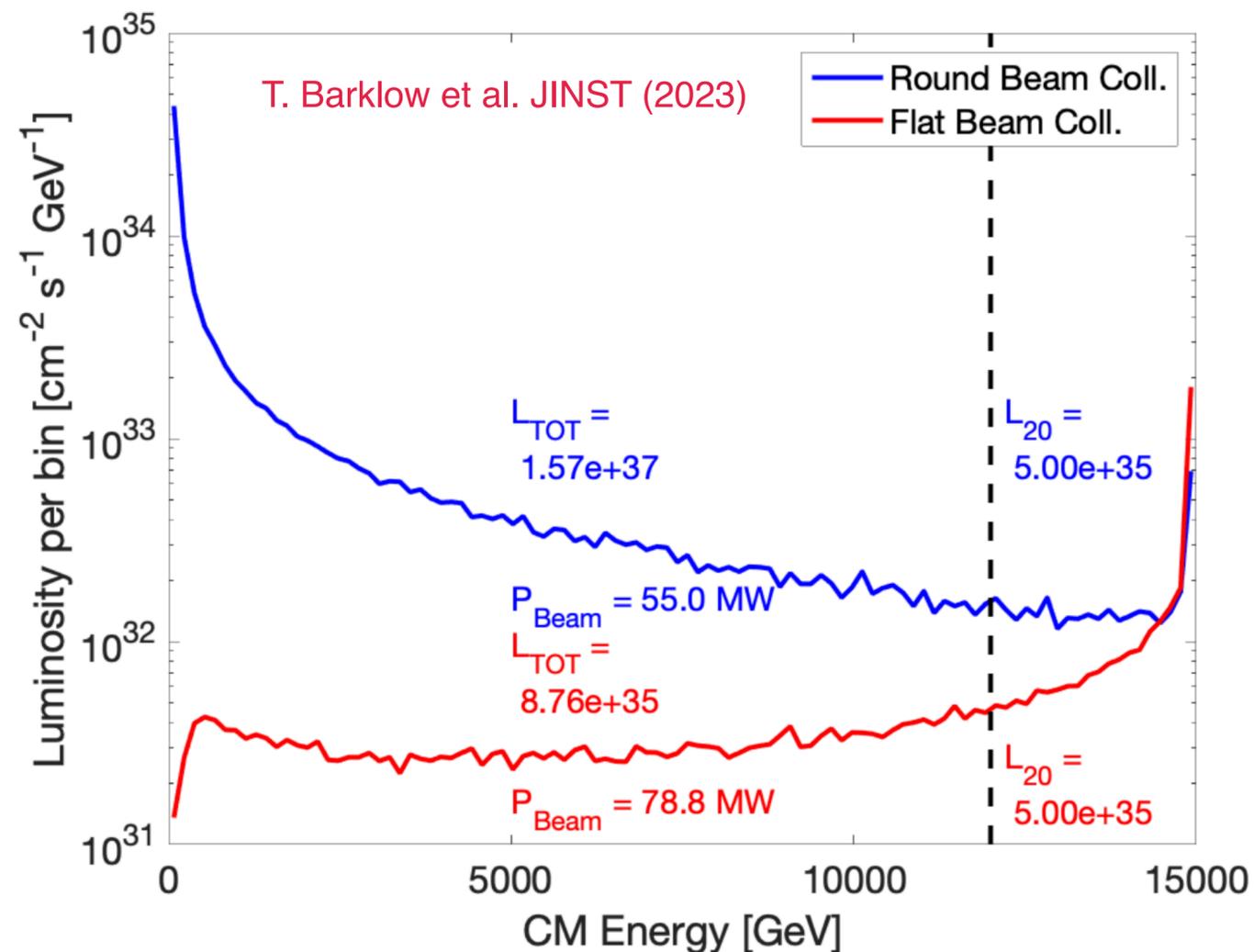


Naively implies
factor of 10 worse.

Question 2:

Round vs. Flat Beam

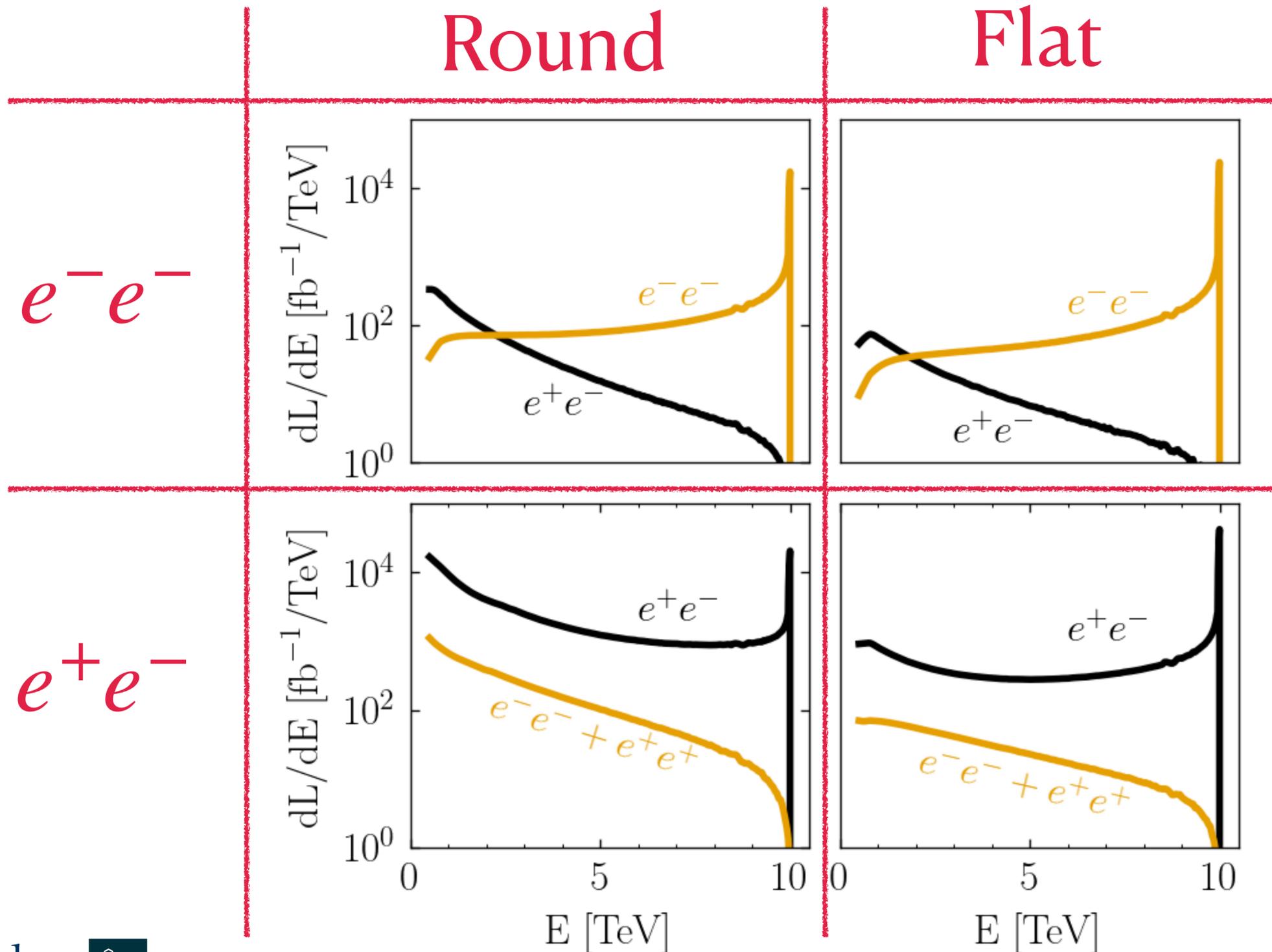
Luminosity Spectra



- Beamstrahlung leads to large low energy tails.
- The energy integrated luminosity actually increases!
- Tail can potentially be used to “scan” over energy.

Luminosity Spectra

Adapted from A. Fromenti, S. S. Bulanov, A. Huebl, R. Lehe, J. Osterhoff, C. Schroeder, J.L. Vay (in progress)



Beam parameters:

- Energy = 5 TeV
- $N_e/\text{beam} = 1.2 \times 10^9$
- $\sigma_z = 8.5 \mu\text{m}$

Flat beams:

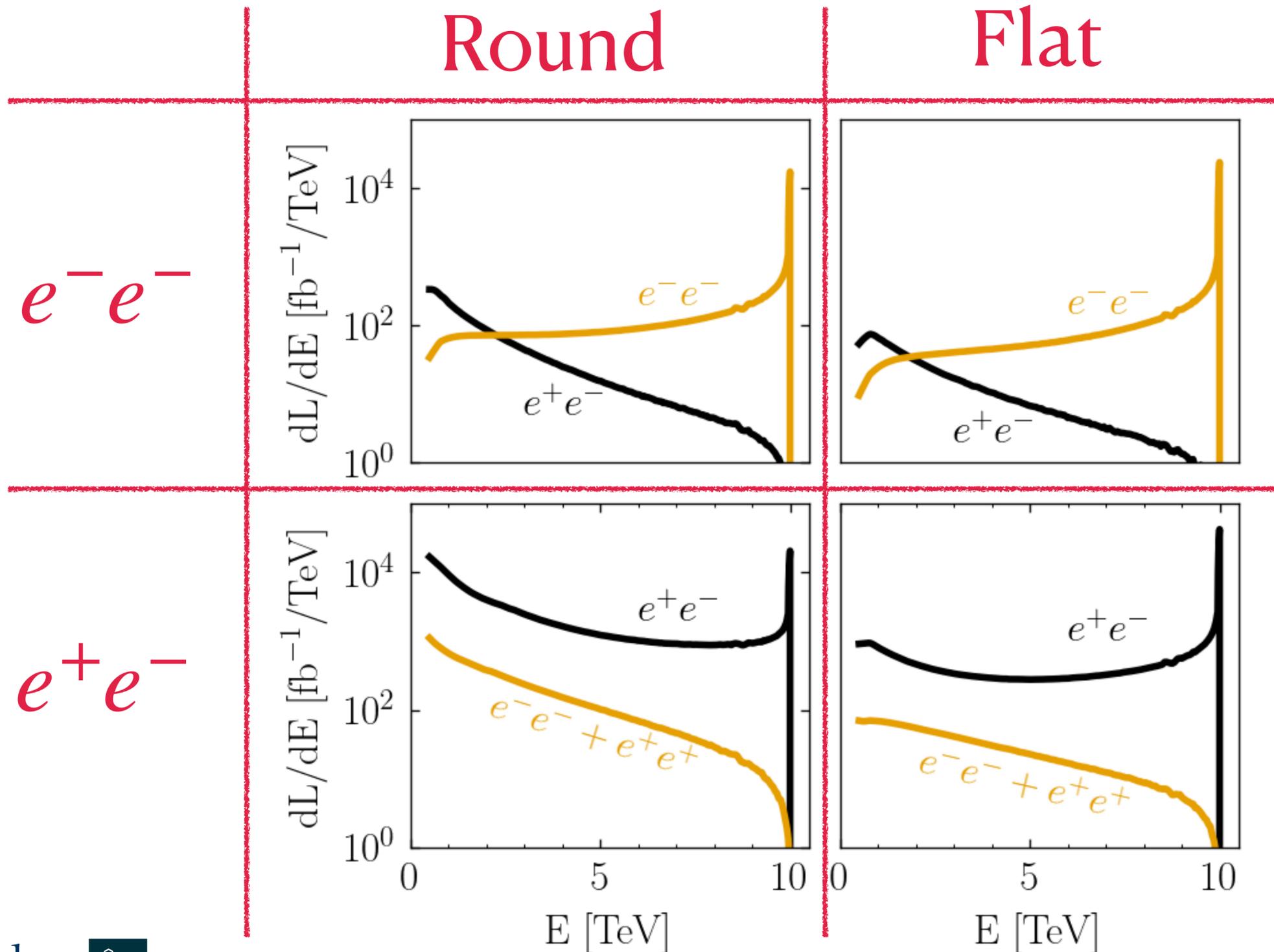
- $\sigma_x = 6 \text{ nm}, \sigma_y = 0.4 \text{ nm}$

Round beams:

- $\sigma_x = \sigma_y = 1.55 \text{ nm}$

Luminosity Spectra

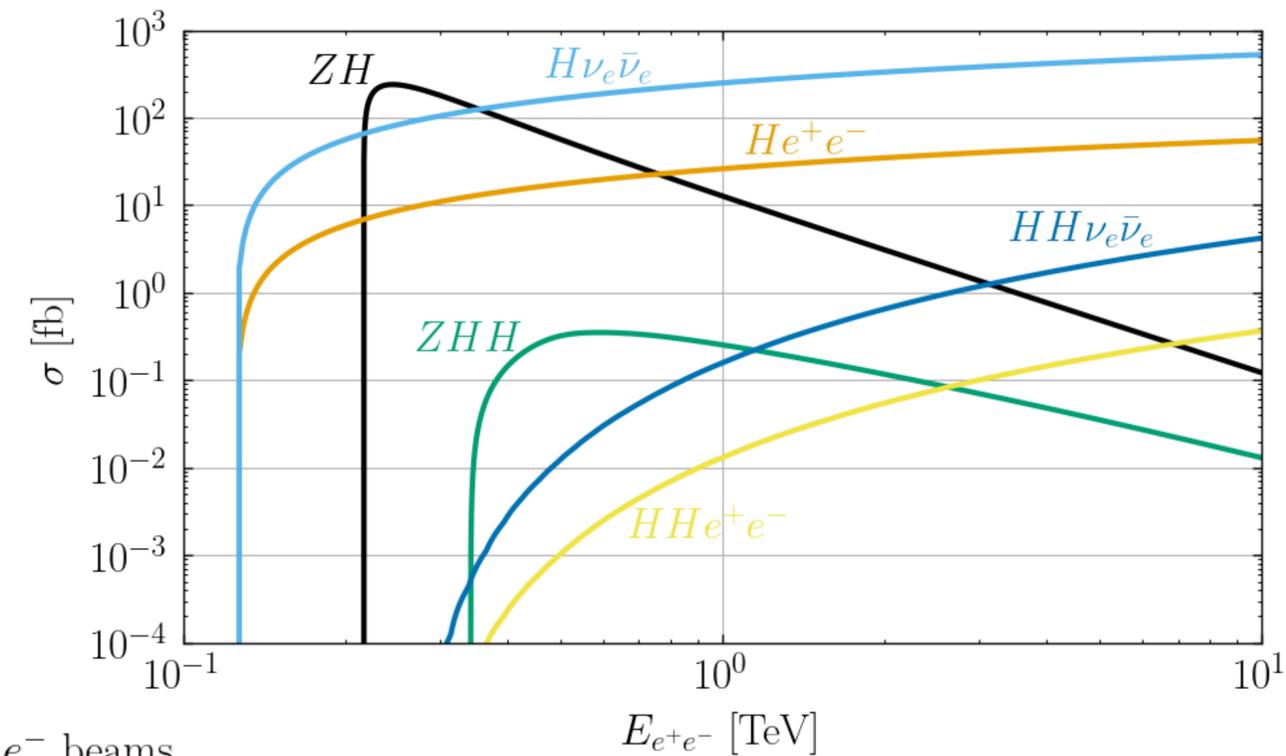
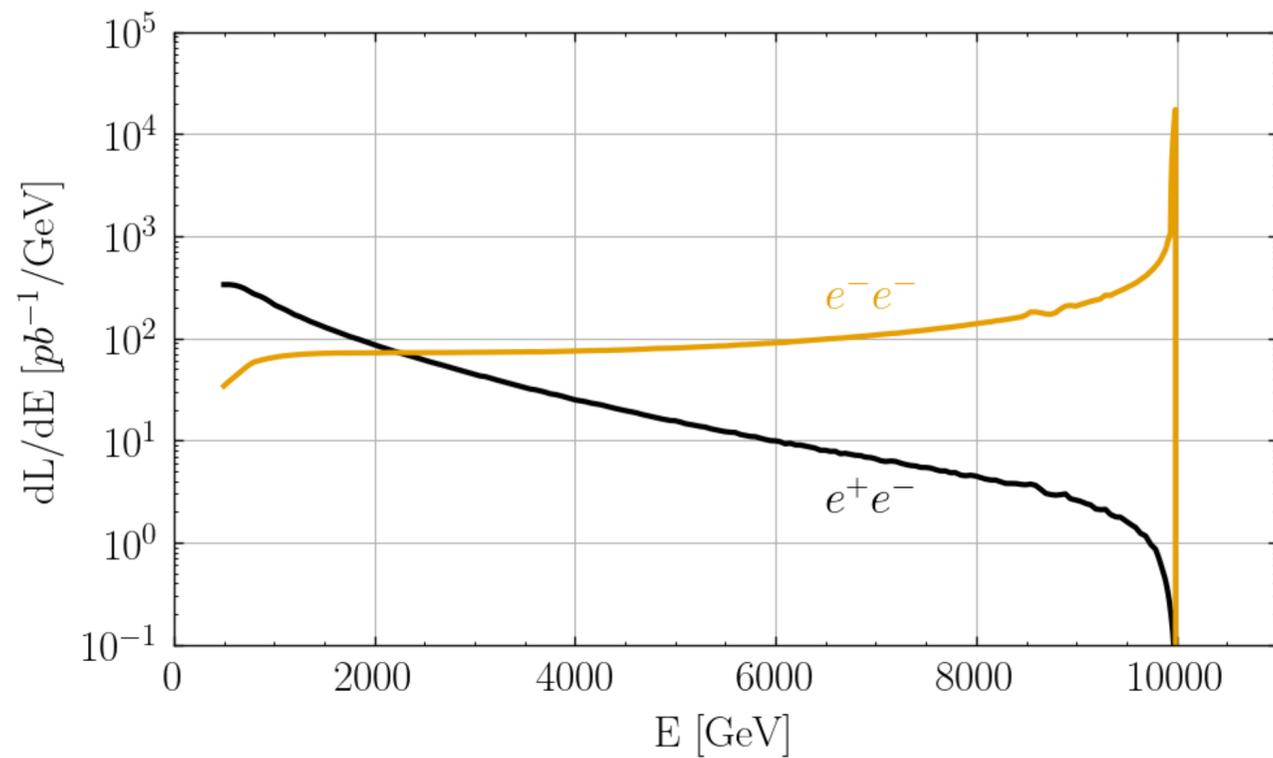
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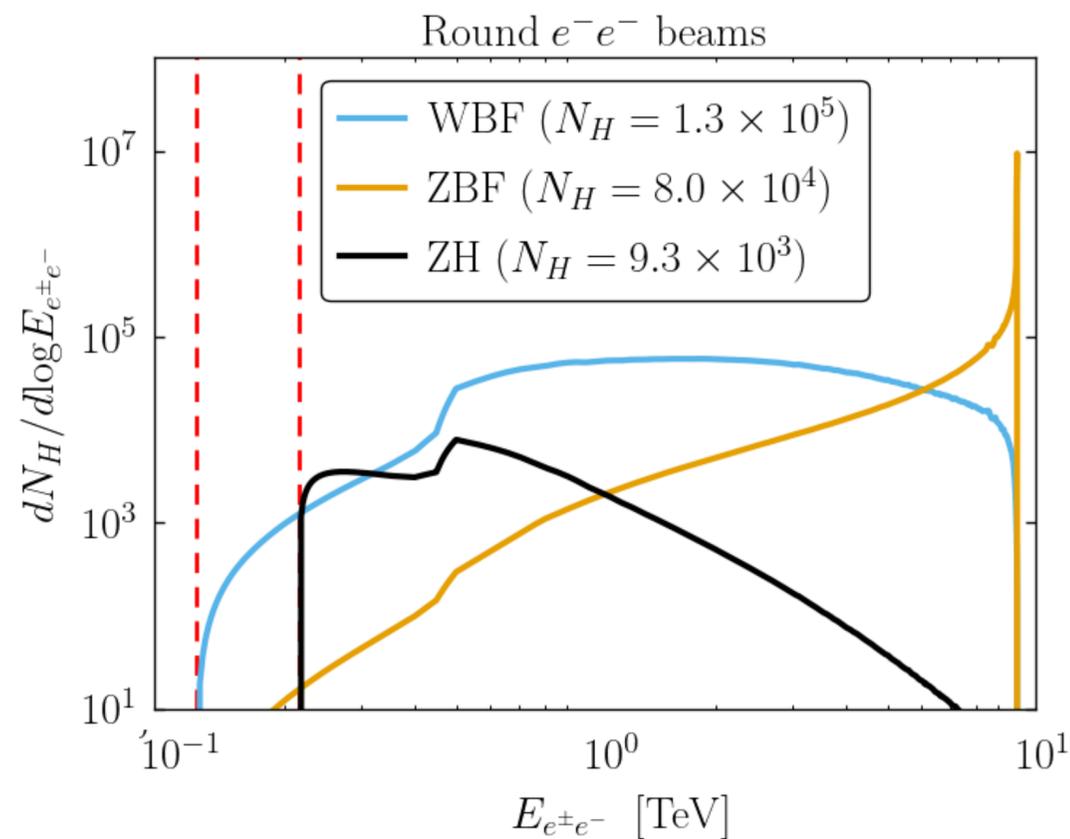
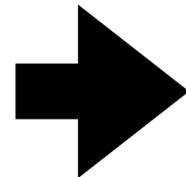
- Beamstrahlung has a stronger affect on e^+e^- tail.
- e^+e^- tail of e^-e^- beam isn't negligible.

How do these choices affect Higgs physics?

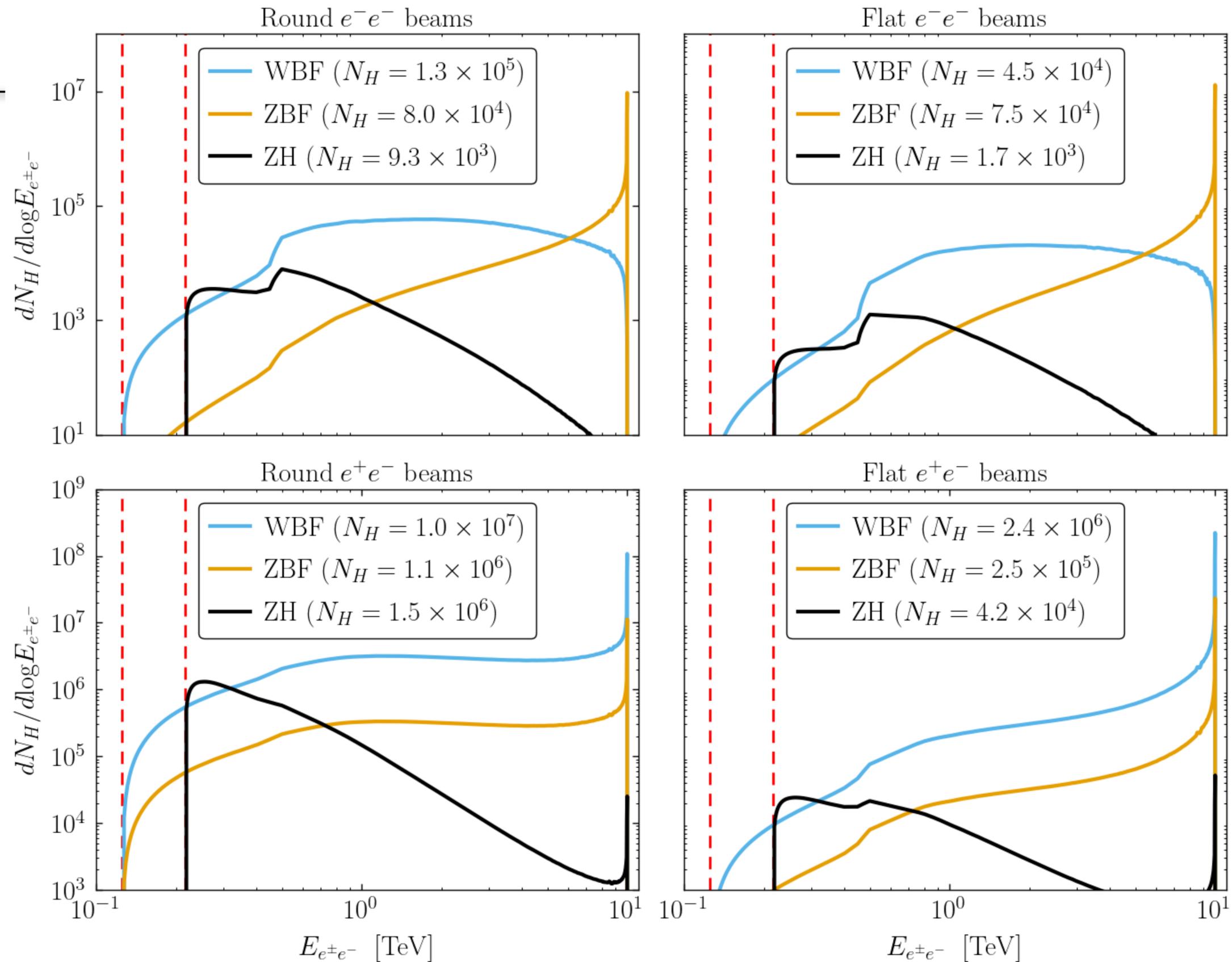
Including the Luminosity Spectra



Luminosity Spectra
+
Cross Sections

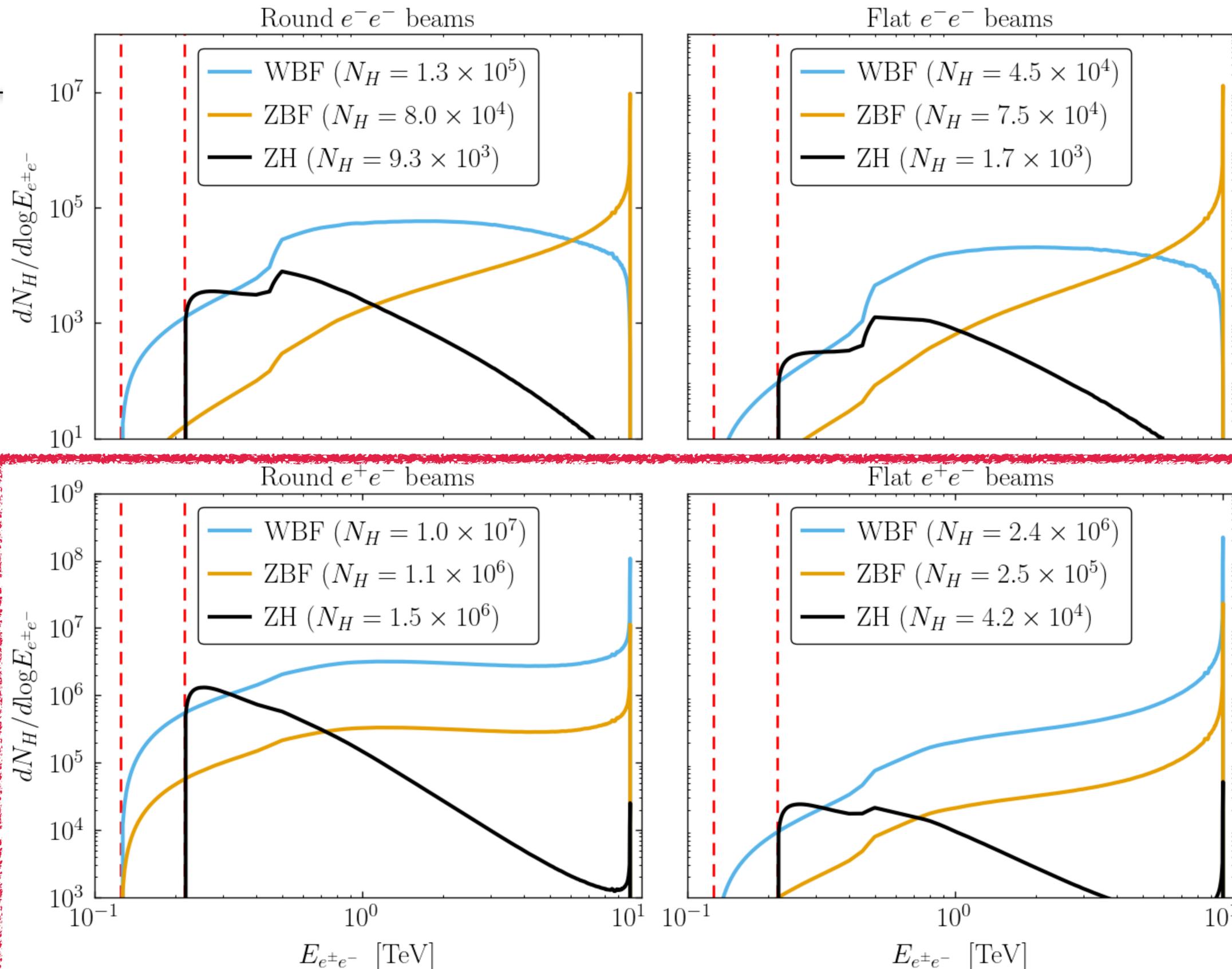


Single Higgs



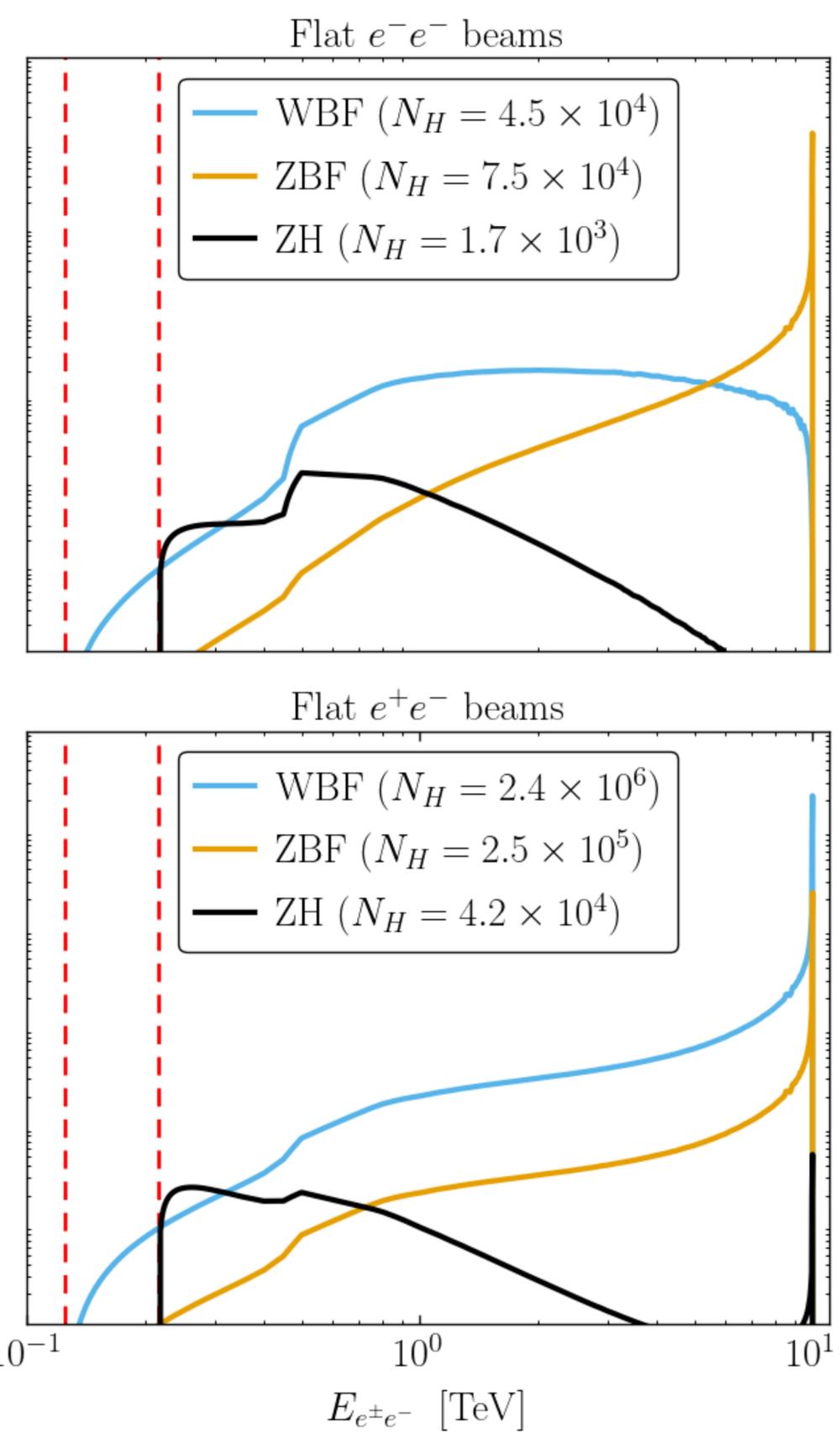
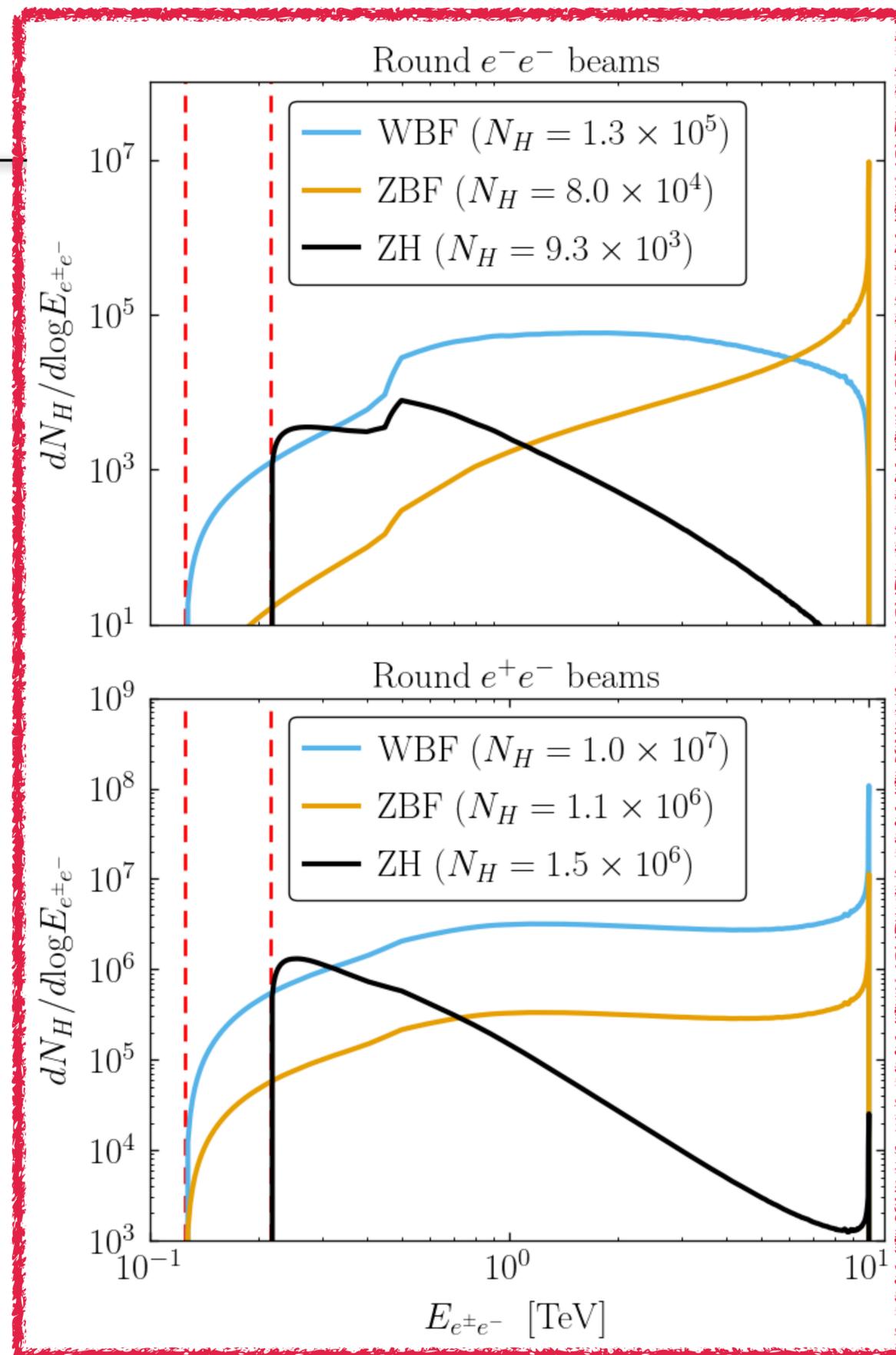
Single Higgs

e^+e^- benefits from W boson fusion and beamstrahlung.
(Factor of $\sim 50 - 100$)



Single Higgs

Round beams
benefit from
beamstrahlung.
(Factor of $\sim 2 - 4$)



Single Higgs

[CLIC, 1608.07538]

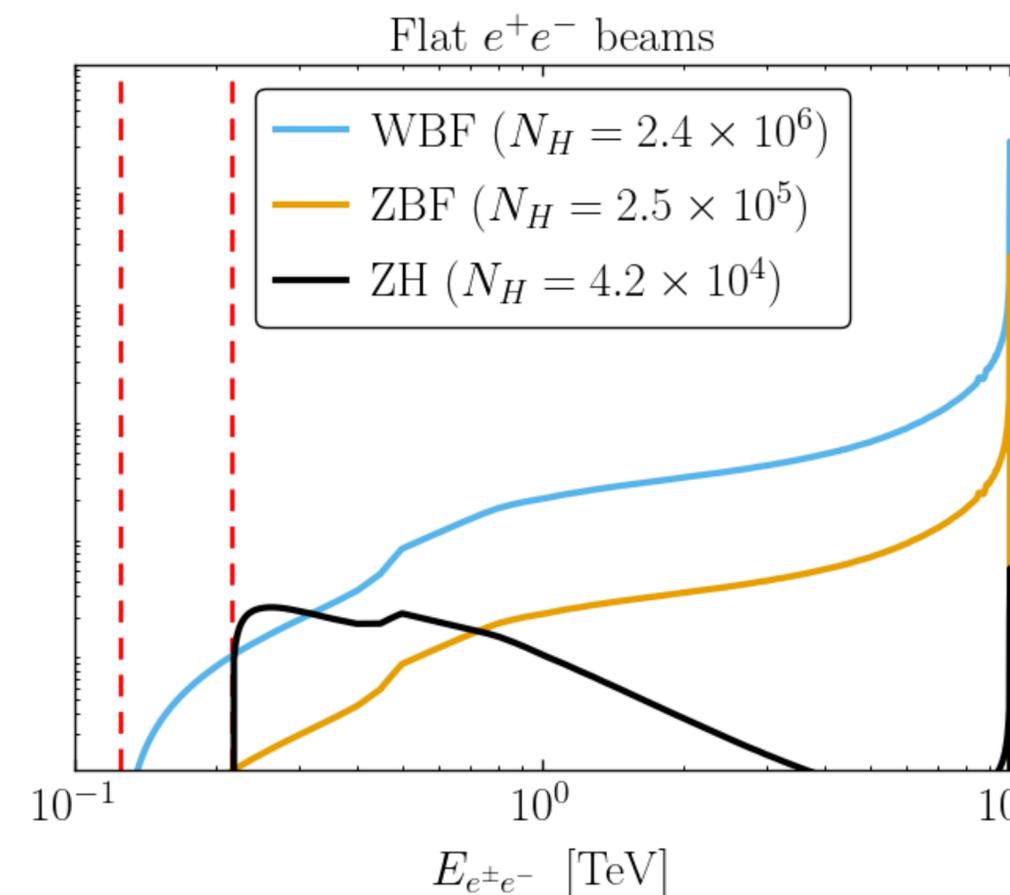
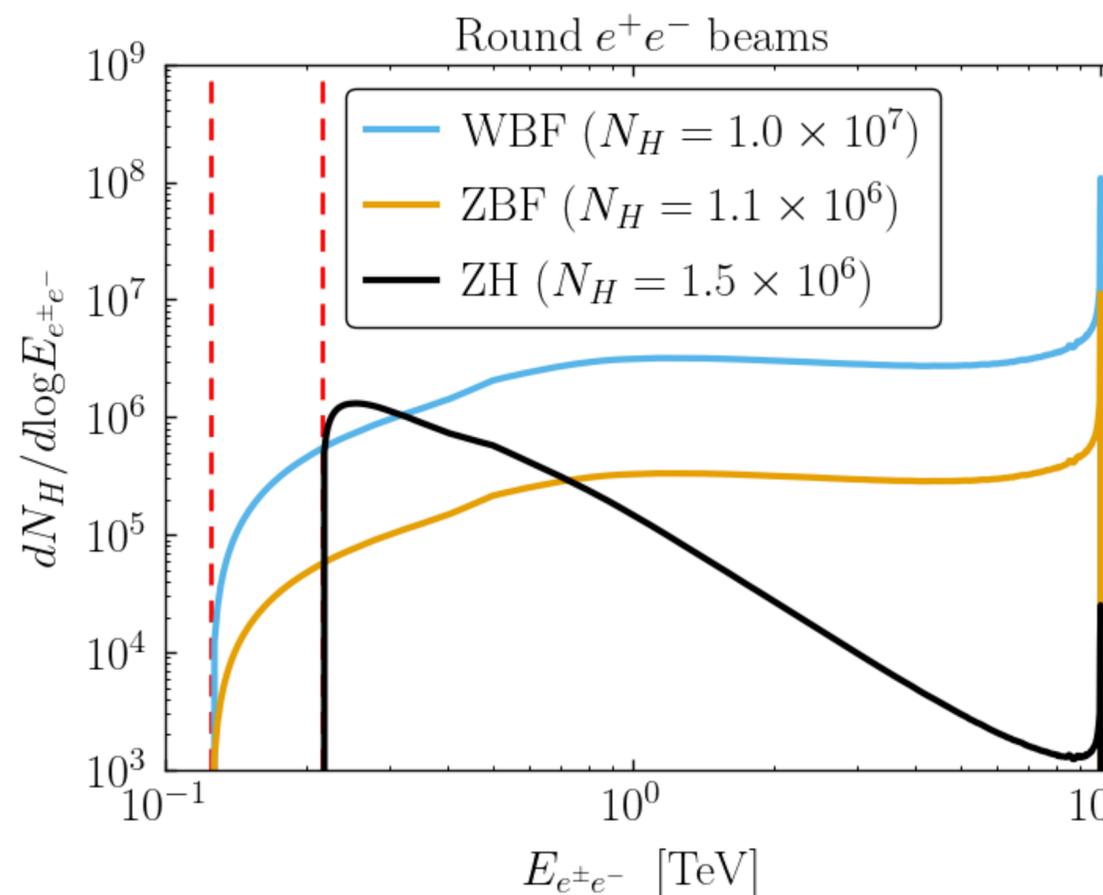
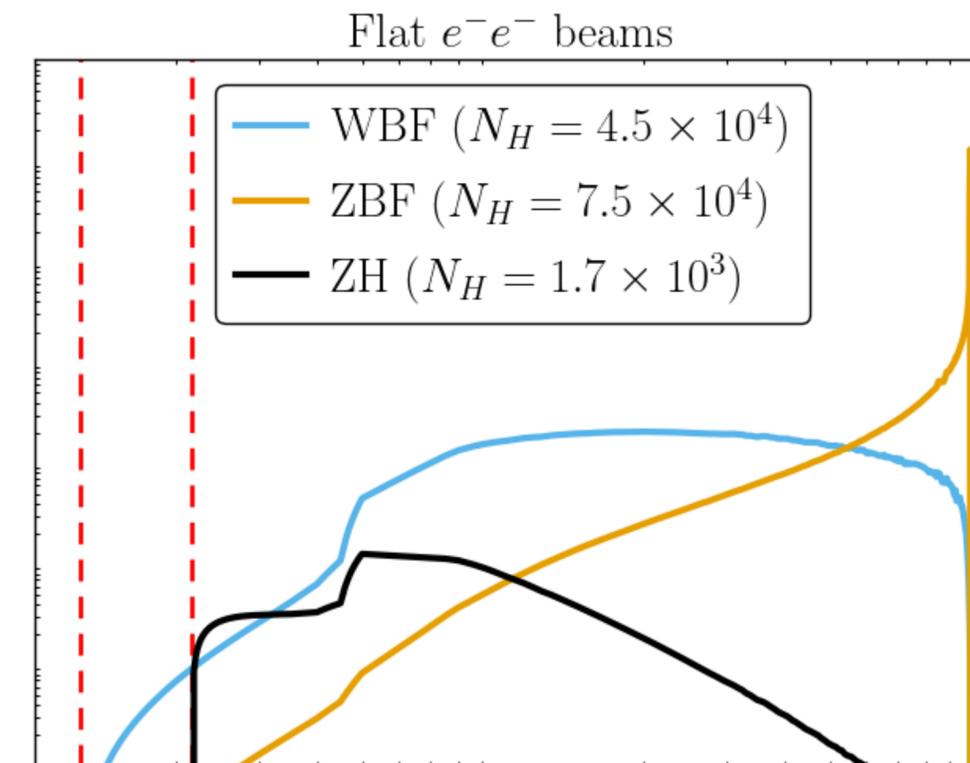
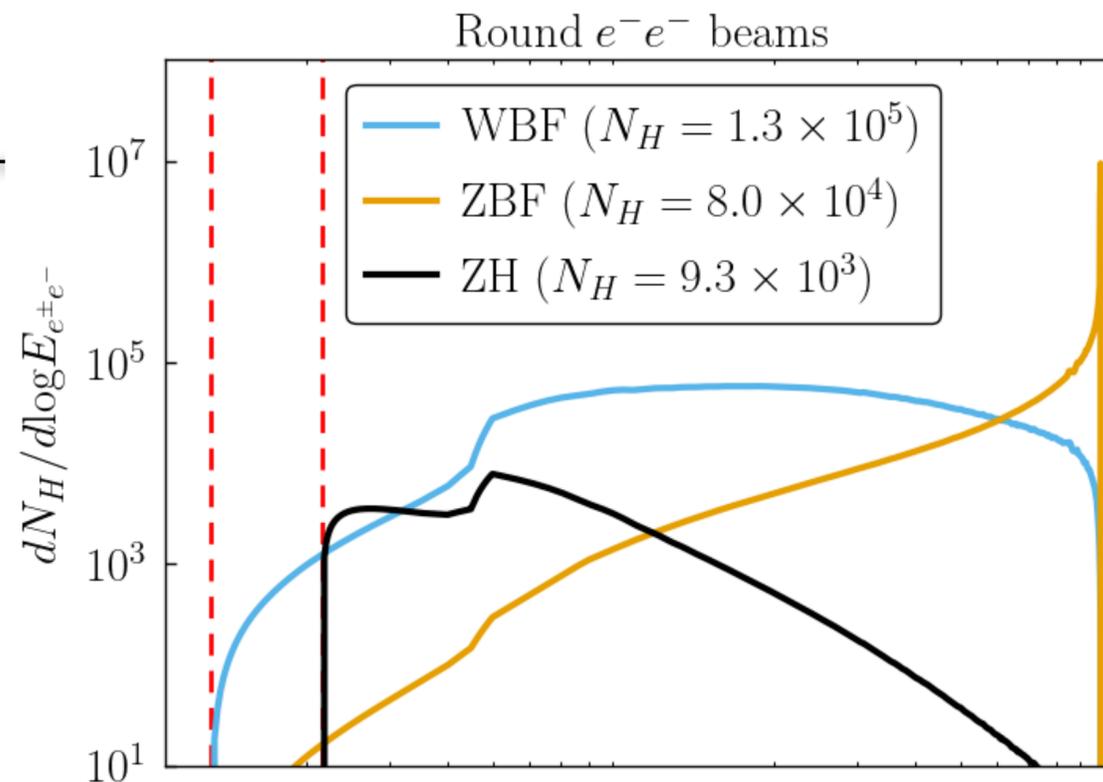
$\sqrt{s} =$	350 GeV	1.4 TeV	3 TeV
$\int \frac{d\mathcal{L}}{ds'} ds'$	500 fb ⁻¹	1.5 ab ⁻¹	2 ab ⁻¹
No. ZH events	68,000	20,000	11,000
No. H $\nu_e\bar{\nu}_e$ events	17,000	370,000	830,000
No. H e^+e^- events	3,700	37,000	84,000

[Han et al, 2008.12204]

MuC10	WBF	ZBF
N_H	8.3×10^6	8.9×10^5

[FCC-hh CDR]

	gg→H	VBF	WH	ZH
N_{100}	24×10^9	2.1×10^9	4.6×10^8	3.3×10^8



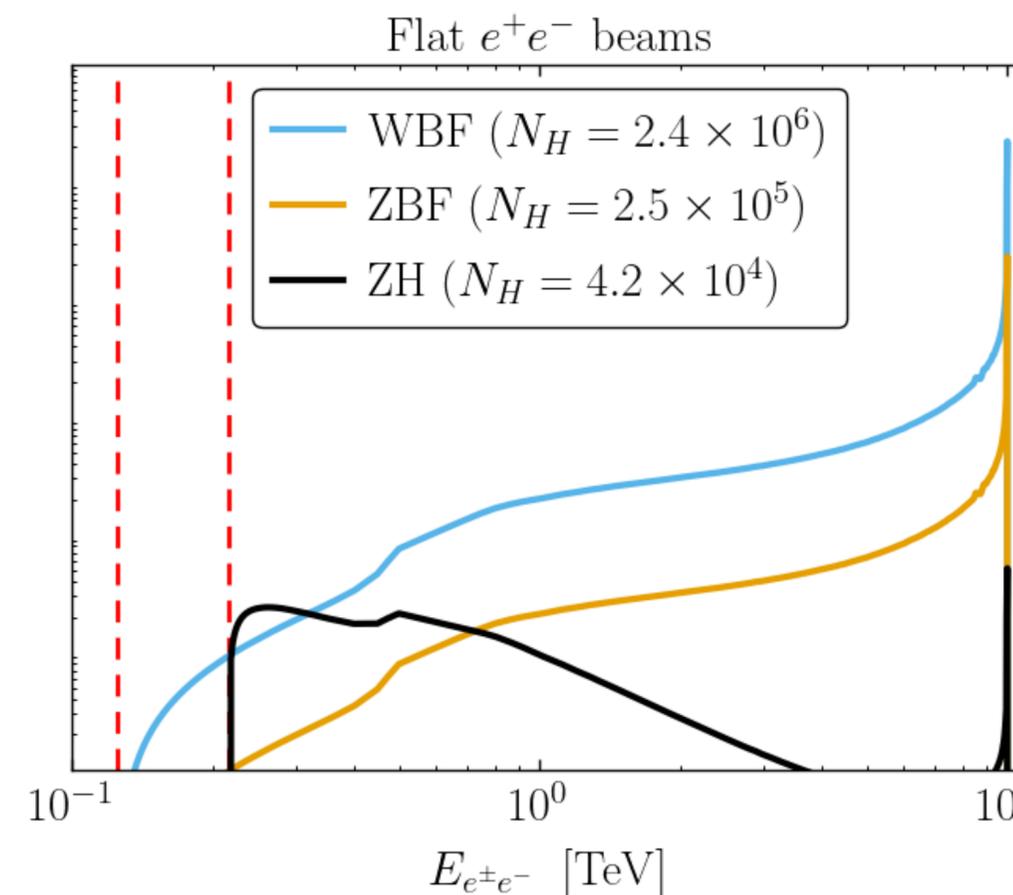
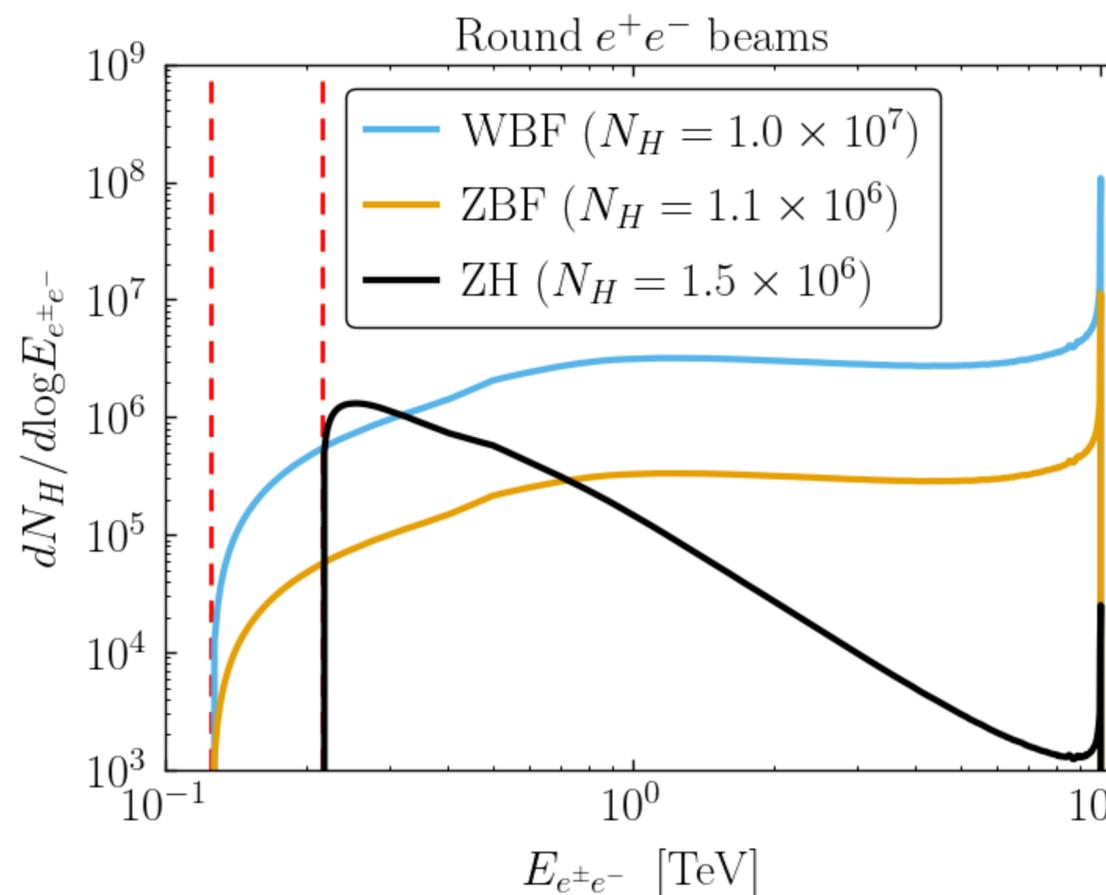
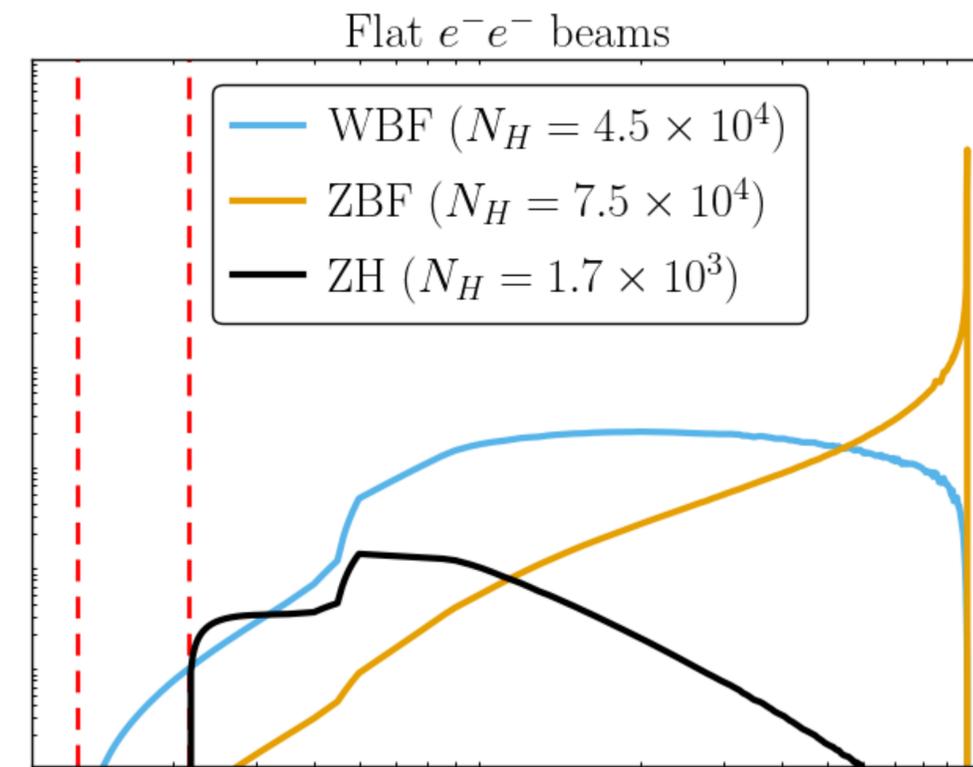
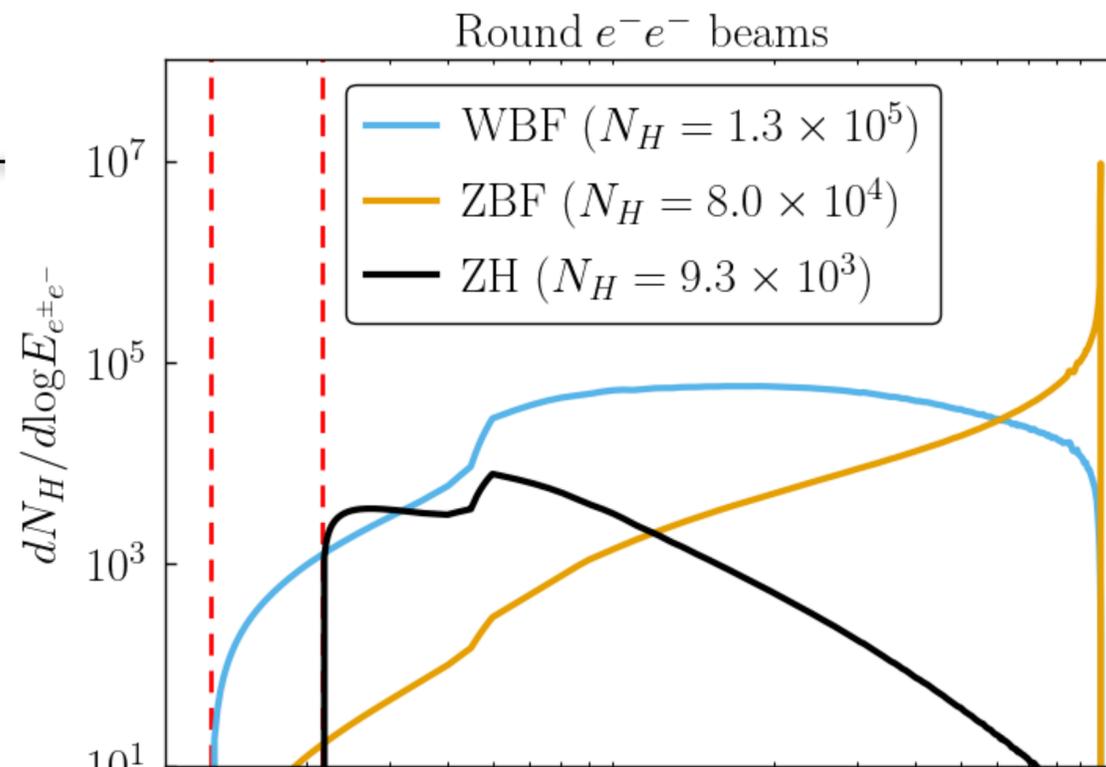
Single Higgs

Associated production not always negligible.

Associated production will be boosted.

VBF largely not boosted.

Boost may be able to infer E_{CM} . Might be able to scan over all energies!



Di-Higgs

Di-Higgs also prefers round e^+e^- beams.

[CLIC, 1608.07538]

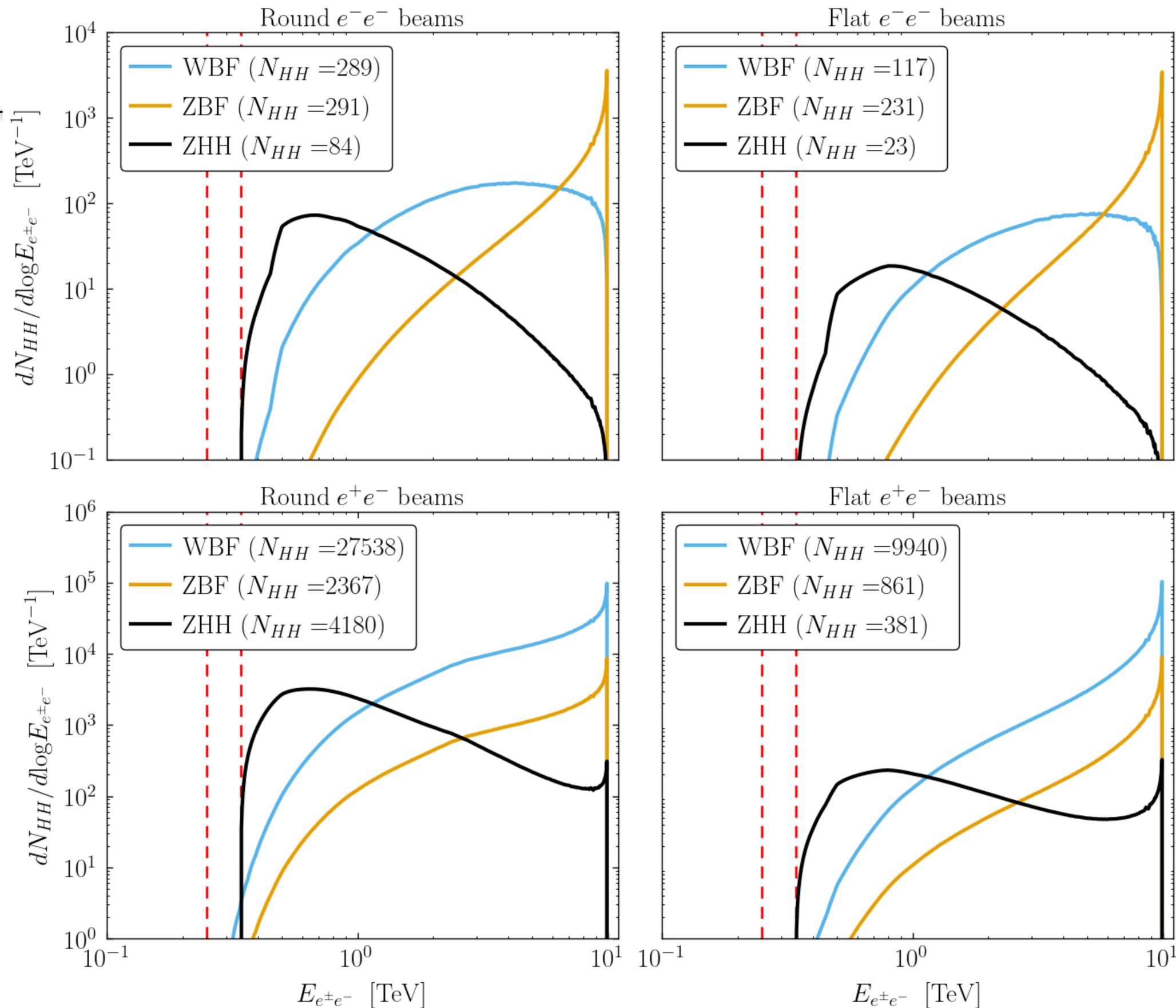
CLIC(3000)	WBF	ZBF
N_{HH}	$\sim 3 \times 10^3$	~ 150

[Han et al, 2008.12204]

MuC10	WBF	ZBF
N_{HH}	3×10^4	4×10^3

[FCC-hh CDR]

$$N_{HH} = 3.6 \times 10^7$$



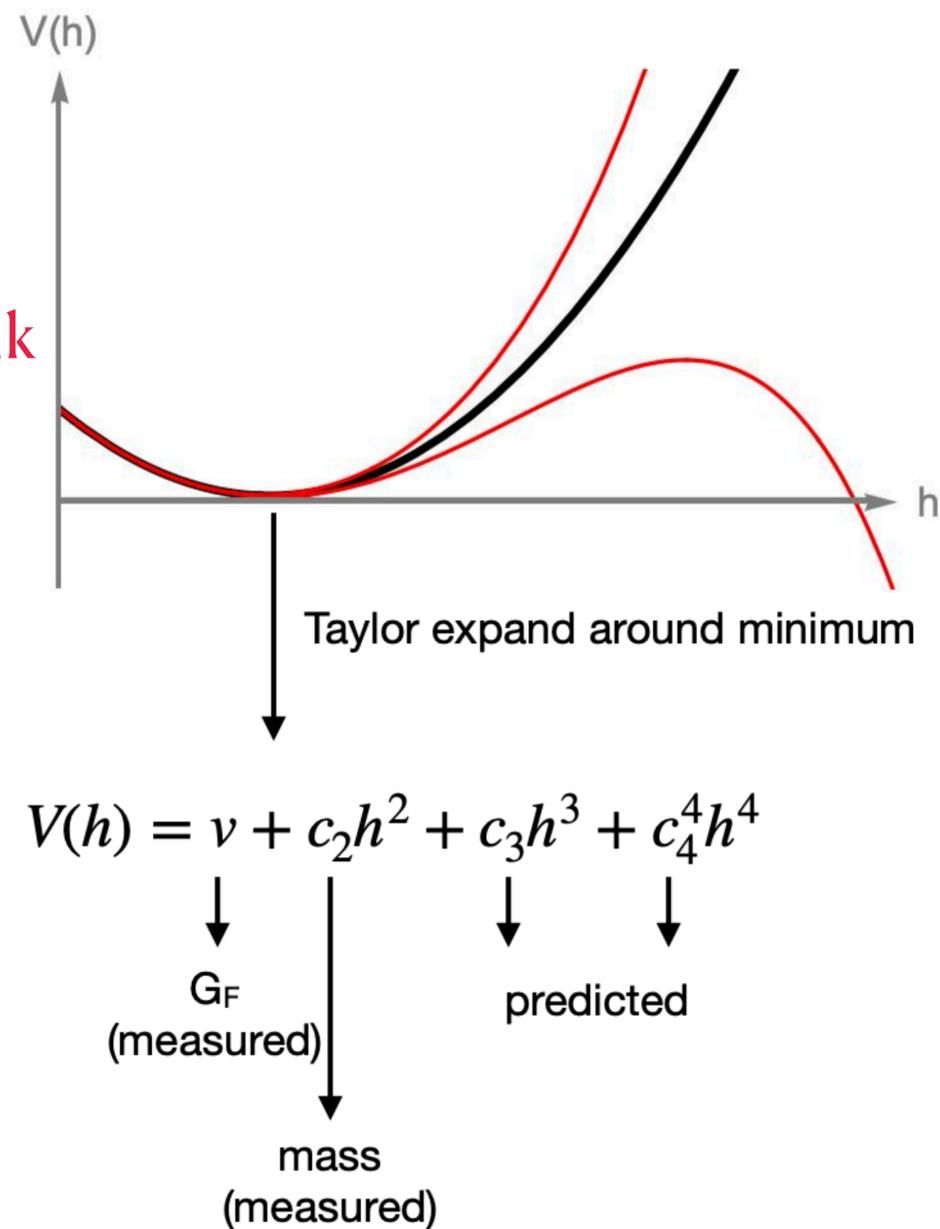
Question 3:

What Higgs physics can we learn?

Higgs Self Interaction is Directly Accessible

One example: The Higgs trilinear coupling

Simon's Talk



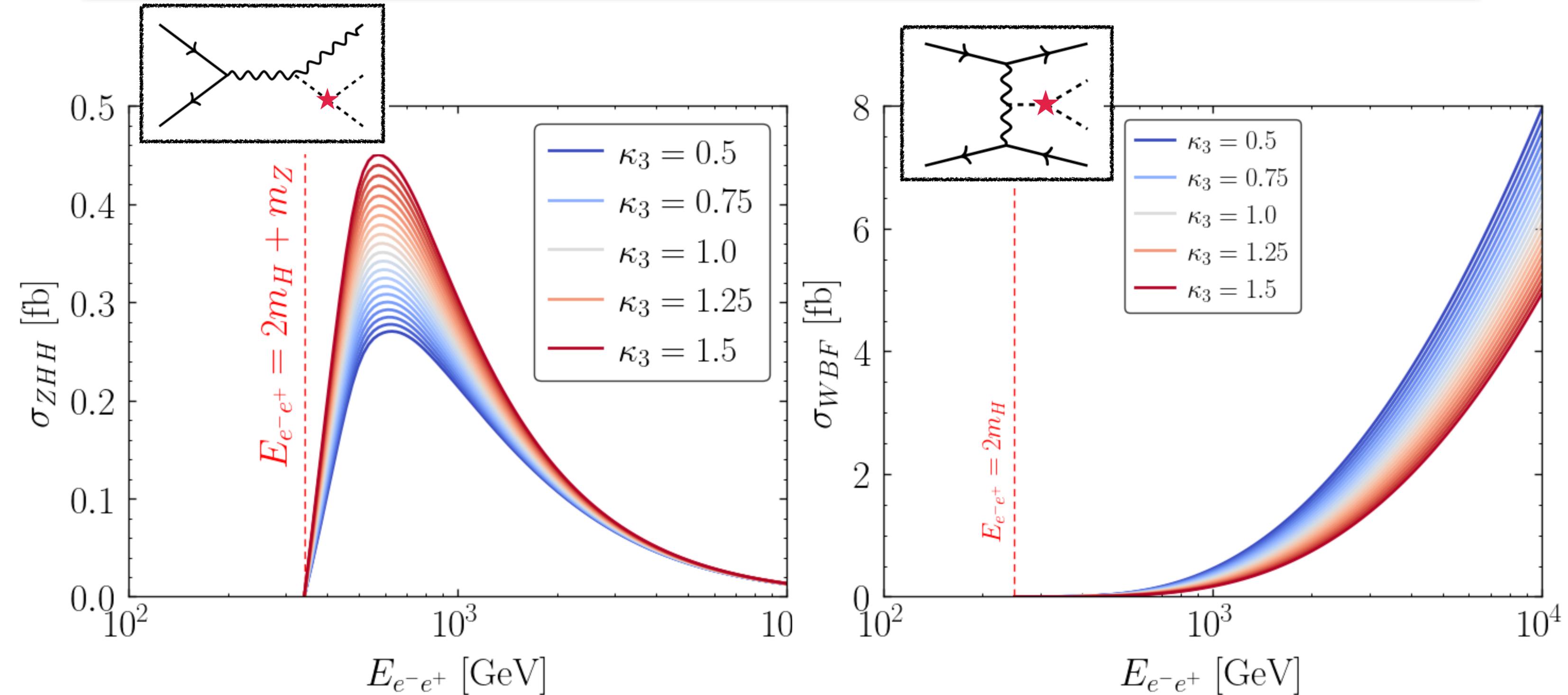
[Torndal and List, 2307.16515]

collider	indirect- h	direct- hh
HL-LHC	100-200%	50%
ILC250	-	-
ILC500	58%	20%*
ILC 500/1000	52%	10%*
CLIC380	-	-
CLIC1500	-	36%
CLIC 1500/3000	-	9%
FCC-ee 240	-	-
FCC-ee 240/365	44%	-
FCC-ee (4 IPs)	27%	-
FCC-hh	-	3.4-7.8%
MuC10	-	5.6 %



[Han et al, 2008.12204]

Higgs Self Interaction is Directly Accessible



Conclusion

- e^+e^- vs. e^-e^- ?

For Higgs physics, an e^+e^- is worth about a factor of 50 – 100 in lumi compared to an e^-e^- beam.

- Round vs. flat beams?

For Higgs physics, a round beam is worth about a factor of 2 – 4 in lumi compared to a flat beam.

An e^+e^- wakefield collider is exciting for precision Higgs measurements and is also capable of discovering new physics responsible for any deviation from SM predictions.

Thanks very much!