ECFA studies
Focus Topics on the Higgs Boson (wiki)

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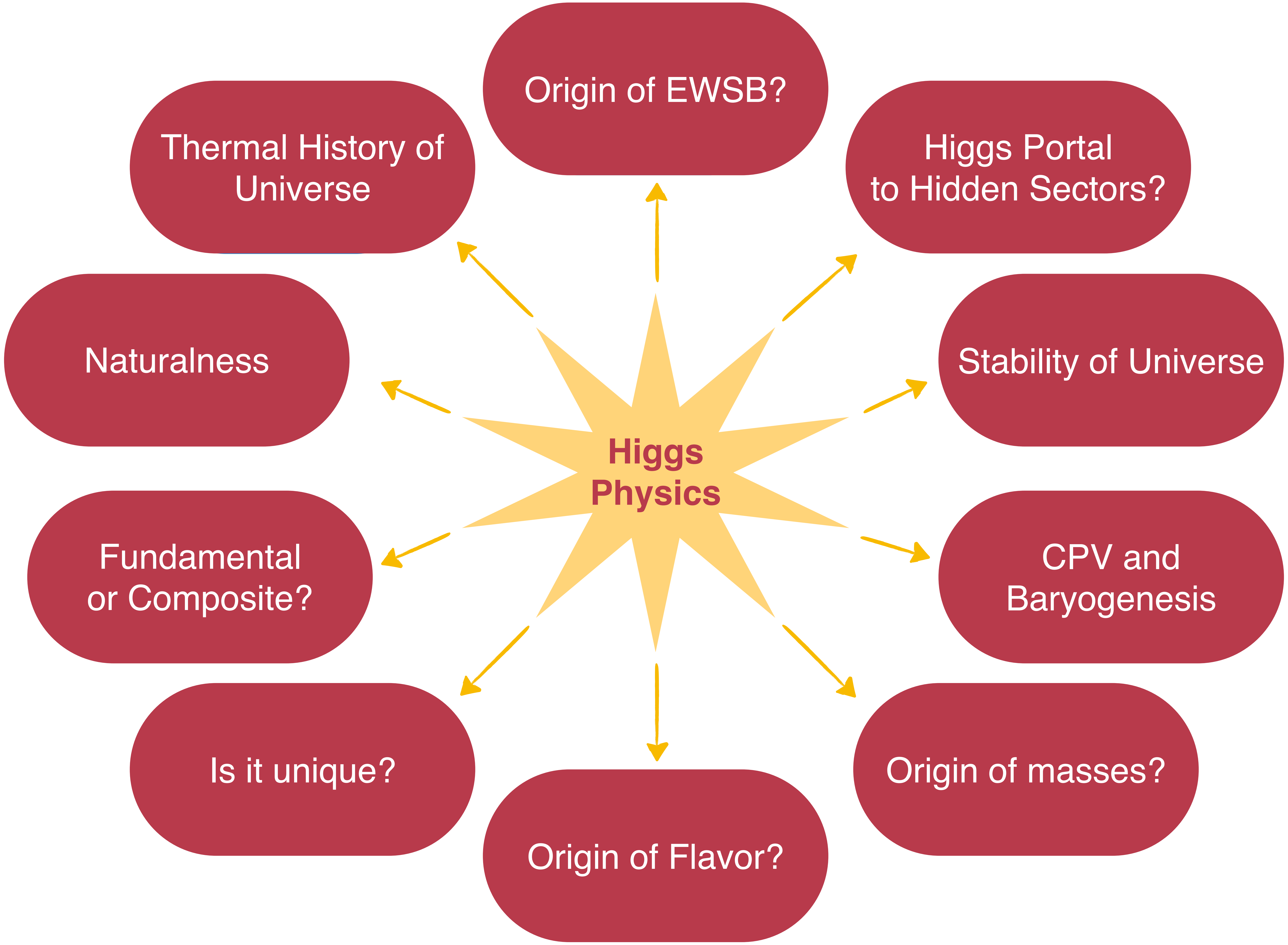
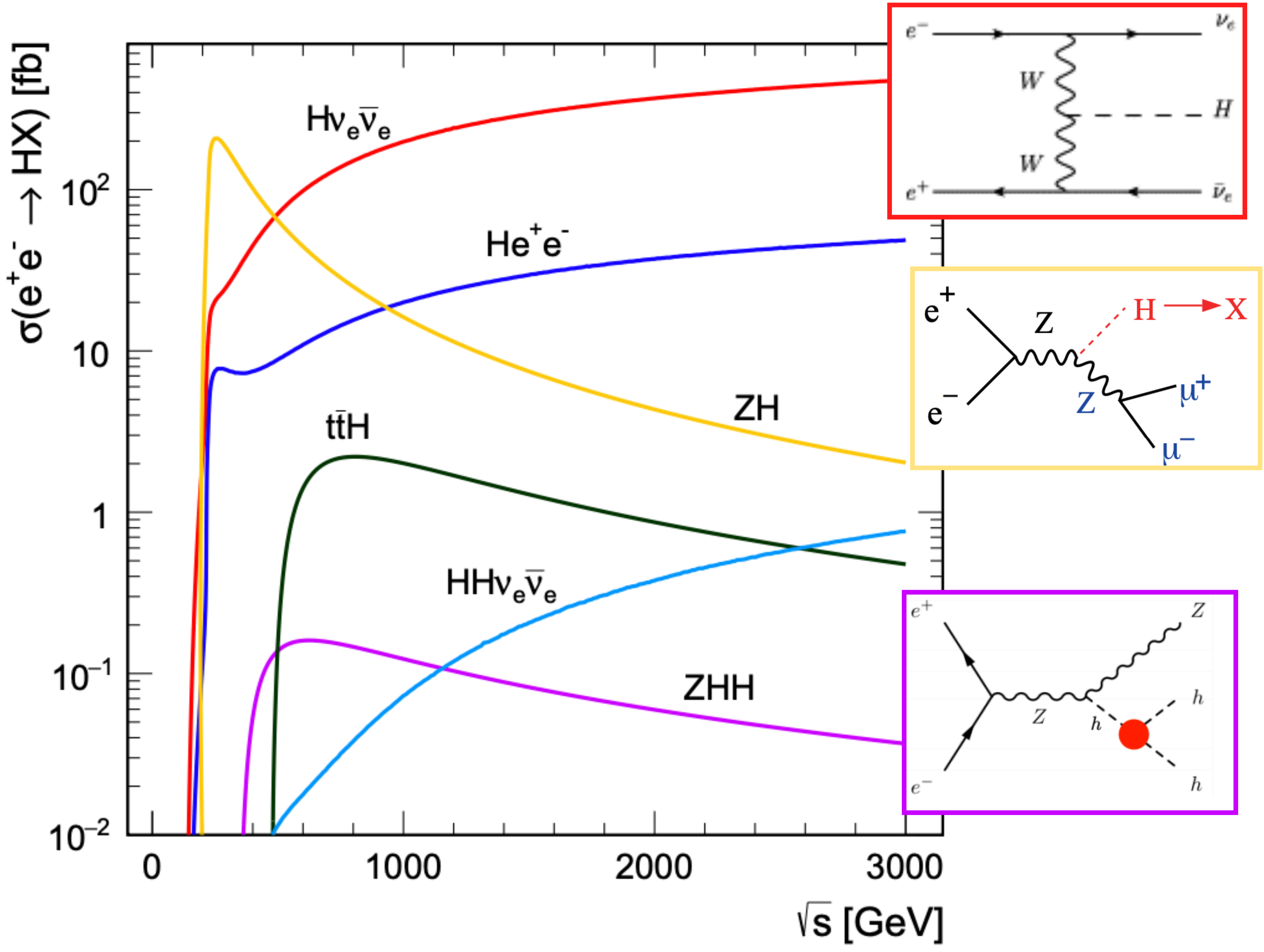


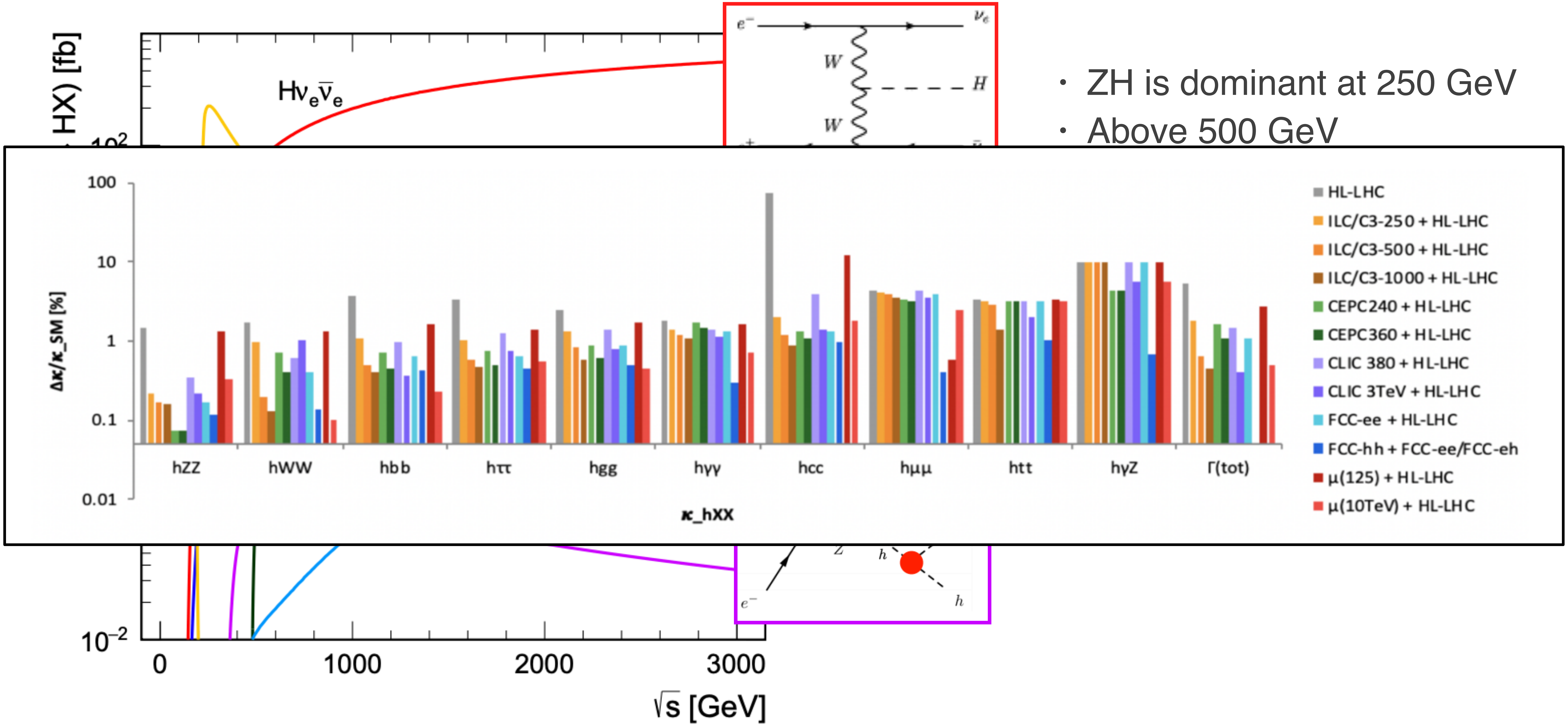
The Energy Frontier 2021 Snowmass Report

Higgs at e^+e^-



- ZH is dominant at 250 GeV
- Above 500 GeV
  - Hvv dominates
  - ttH opens up
  - **HH accessible with ZHH**

Higgs at e^+e^-



- ZH is dominant at 250 GeV
- Above 500 GeV

Outline

Focus topics for the ECFA study on Higgs / Top / EW factories

Table 1: Overview of focus topics and relevant centre-of-mass energies. Energies applicable to the considered topic are indicated with '✓'.

Topic		Lead group	Relevant $\sqrt{s}$ [GeV]				
			91	161	240–250	350–380	≥ 500
1	HtoSS	HTE			✓	✓	✓
2	ZHang	HTE (GLOB)			✓	✓	✓
3	Hself	GLOB			✓	✓	✓

Focus topics for the ECFA study on Higgs / Top / EW factories will provide further **detector design guidelines** (2401.07564)
Timeline: End of 2024 for the summary document

$H \to ss$, beyond EFT

1811.00017
1908.11376
2101.04119

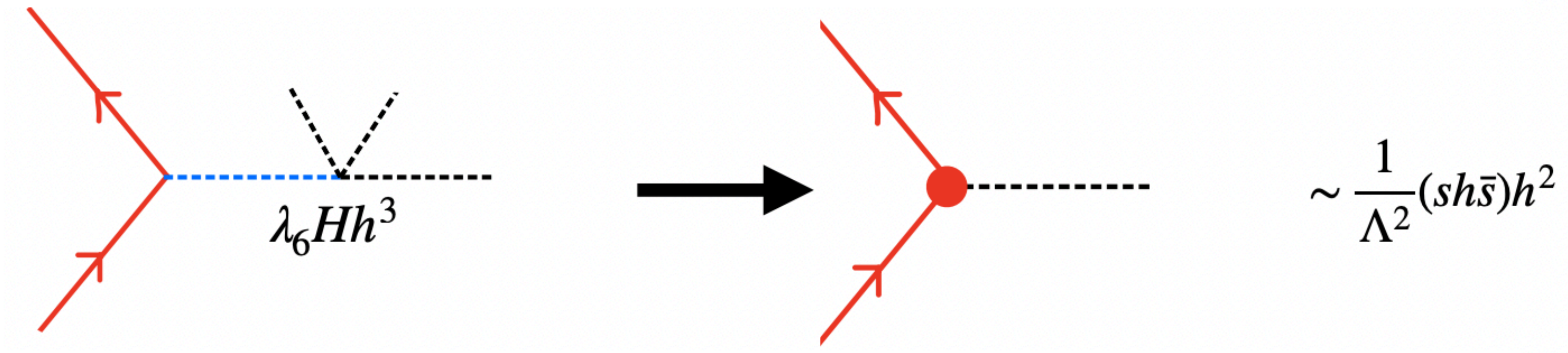
Higgs to strange coupling is an appealing signature to probe new physics

Is the Higgs the source for all flavor?

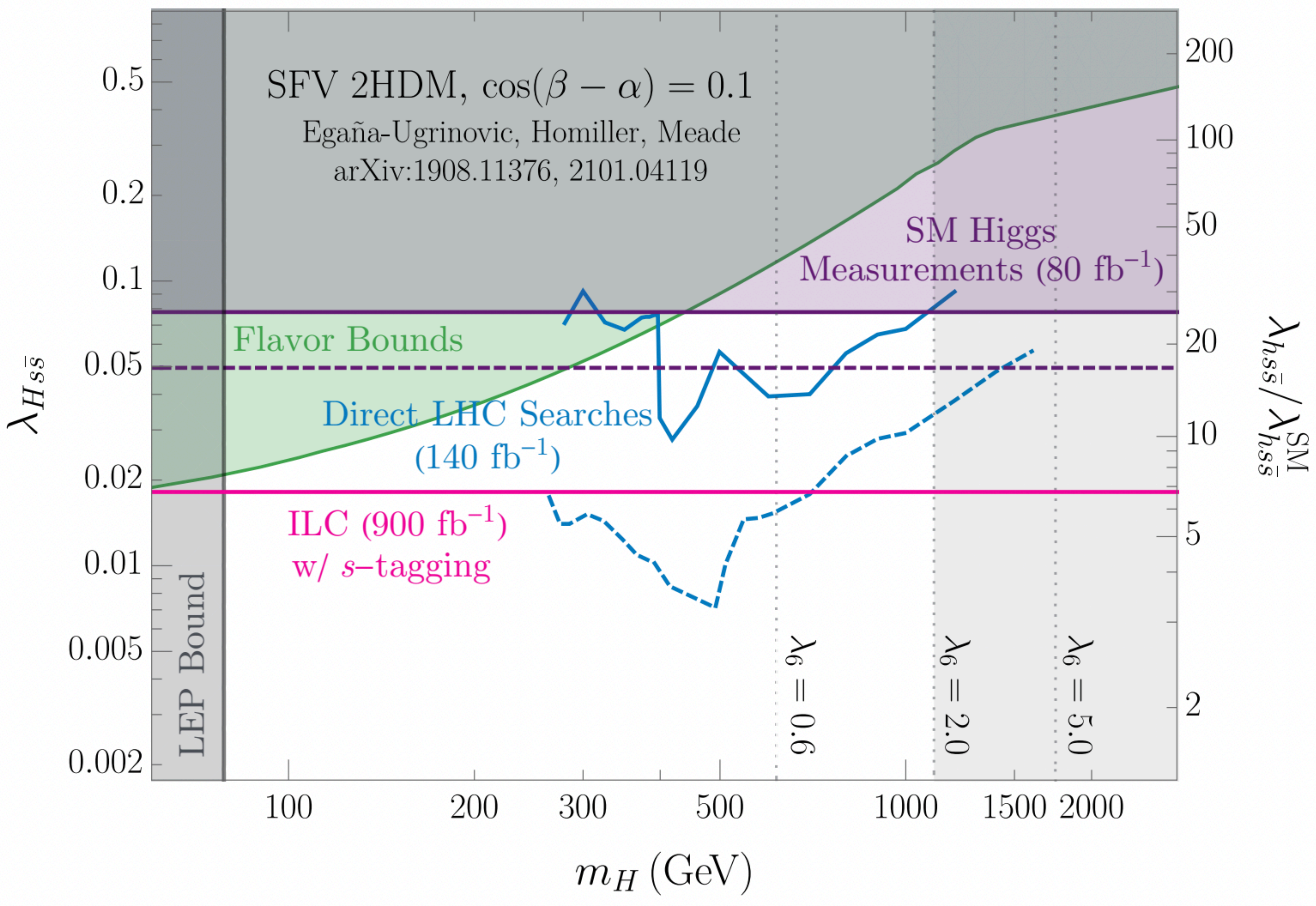
An option, **Spontaneous Flavor Violation**

New physics can couple in a strongly flavor dependent way if it is aligned in the down-type quark or up-type quark sectors

- It allows for large couplings of additional Higgs to strange/light quarks
- No flavor-changing neutral currents

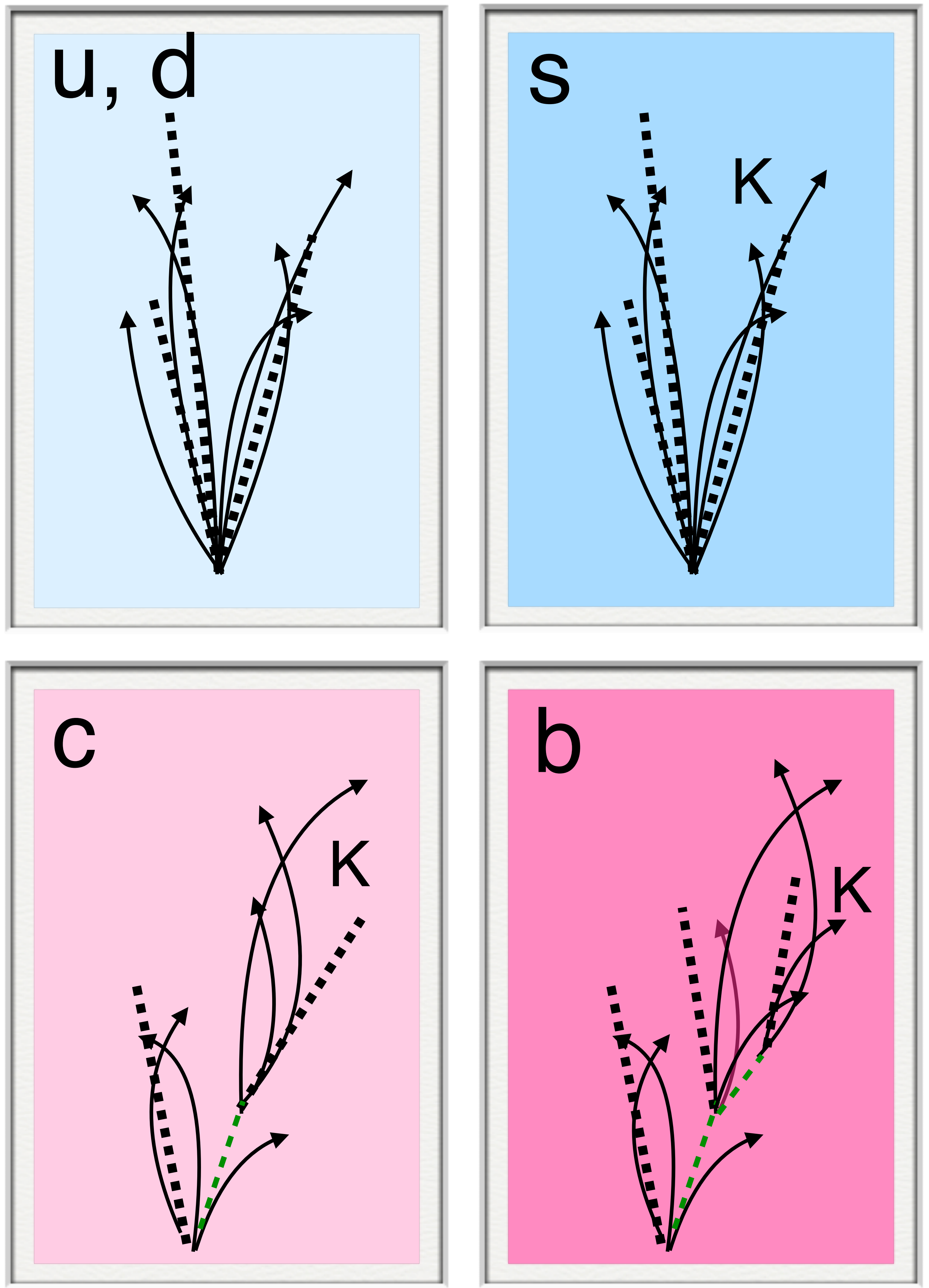


P. Meade, link



s-tagging

Tagging strange is a challenging but not impossible task for future detectors at e^+e^-



- As b,c, and s jets contain at least one strange hadron
- Strange quarks mostly hadronize to prompt kaons which carry a large fraction of the jet momentum
- Strange hadron reconstruction:
  - $K^{\pm}$ PID
  - K^0_L PF (neutral)
  - $K^0_S \rightarrow \pi^+\pi^-$ (~70%) / $\pi^0\pi^0$ (~30%)
  - $\Lambda^0 \rightarrow p\pi^-$ (~65%)

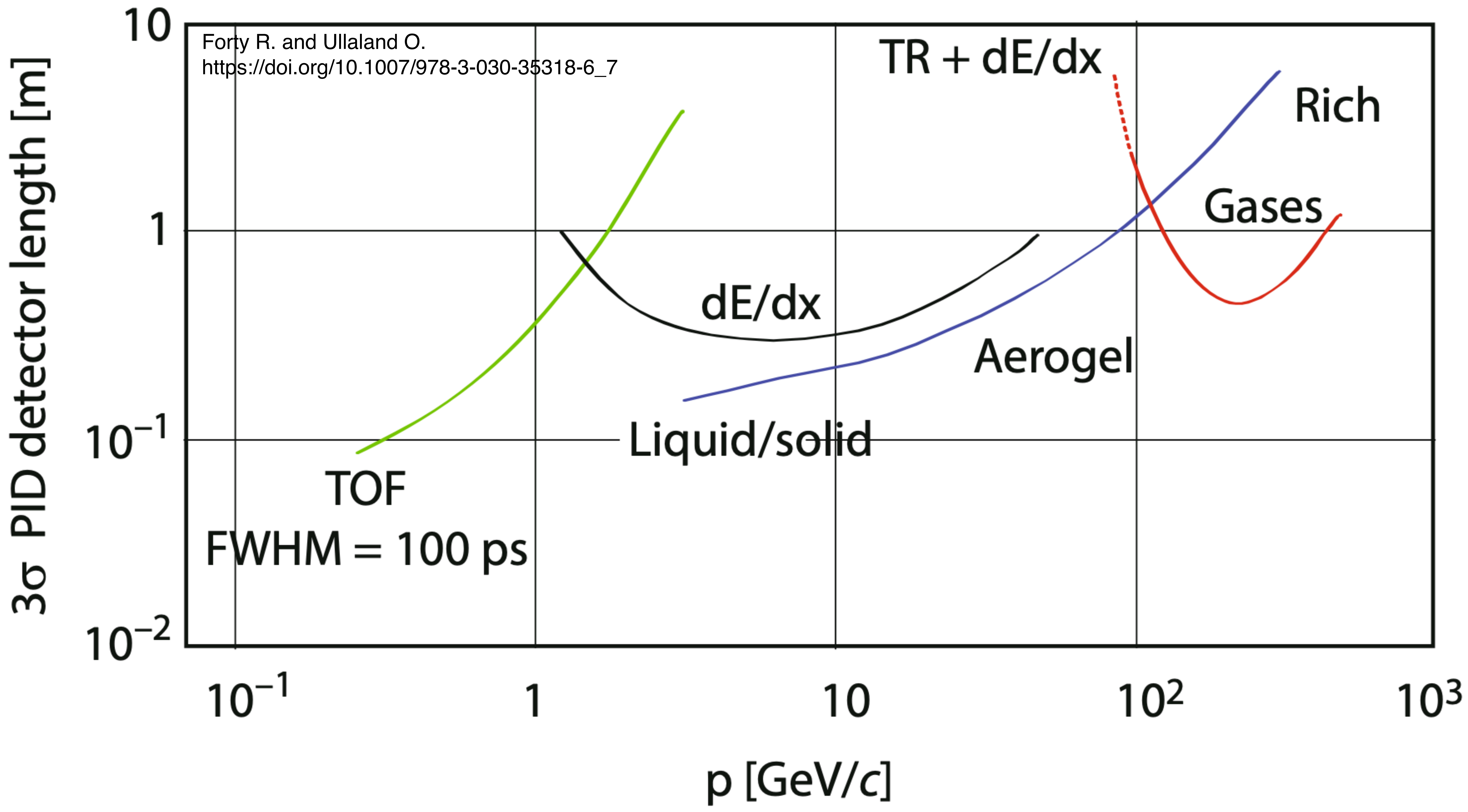
Distinctive two-prong vertices topology

Jet flavour	Number of secondary vertices (excluding V^0s)	Number of strange hadrons (e.g., $K^{\pm}$, $K^0_{L/S}$, and Λ^0)
Bottom	2	≥ 1
Charm	1	≥ 1
Strange	0	≥ 1
Light	0	0

1912.04601
e2019-900045-4

Particle ID for s-tagging

Combining different strategies for optimal PID performance across a wide p_T range

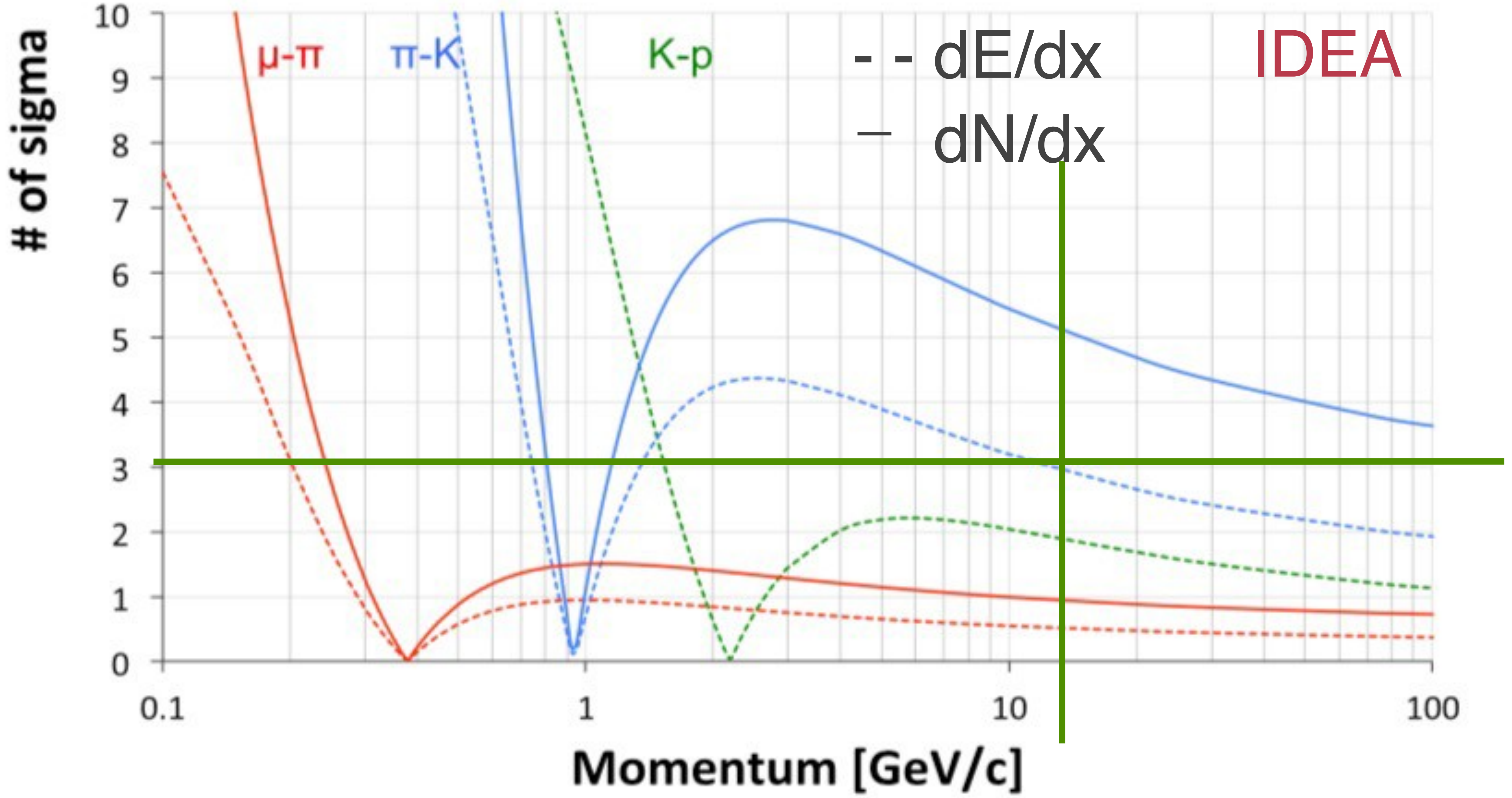


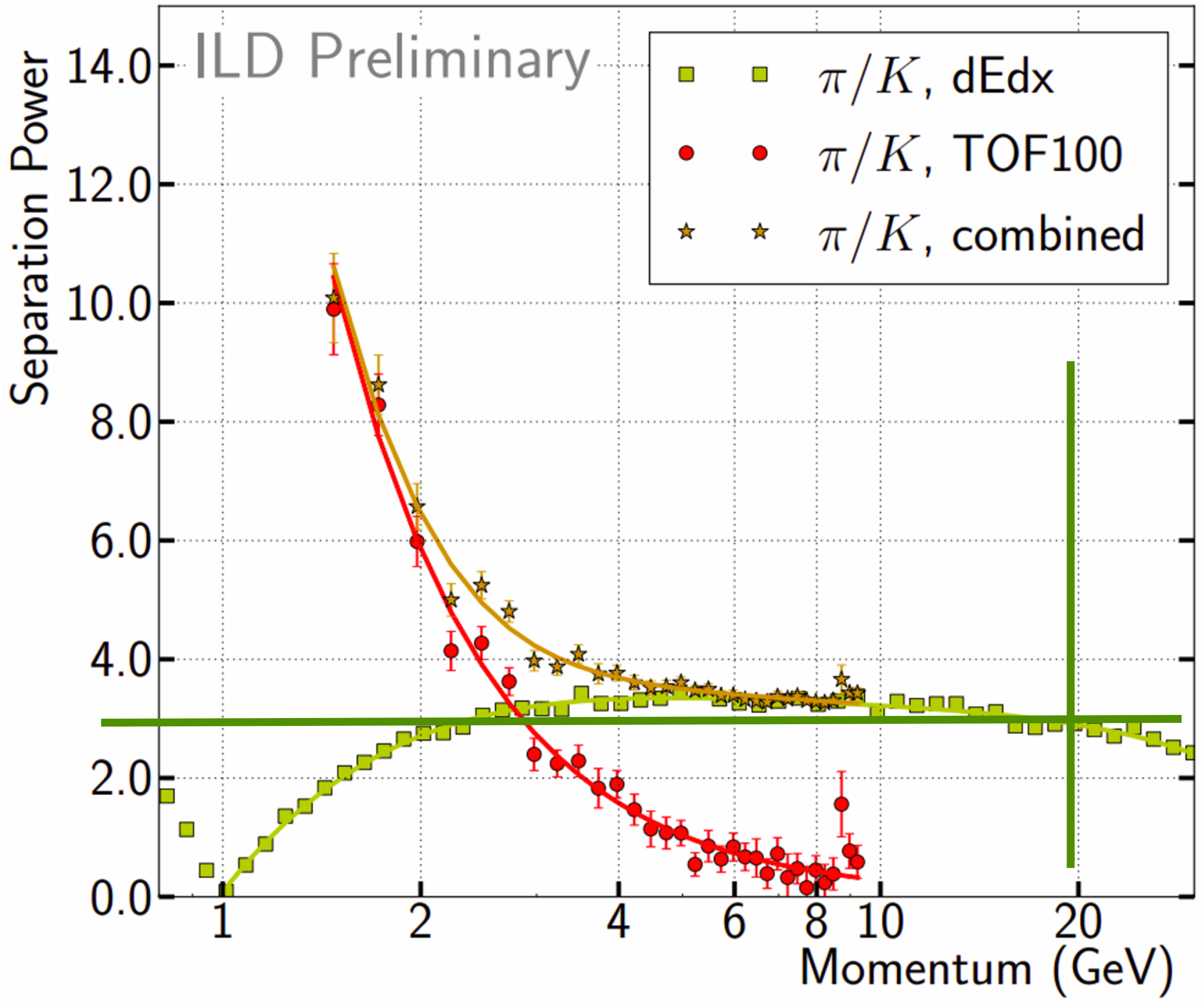
1912.04601
e2019-900045-4

Particle ID for s-tagging

Combining different strategies for optimal PID performance across a wide p_T range

- dE/dx from silicon (< 5 GeV) and large gaseous tracking detectors (< 30 GeV)
- < 5 GeV, time-of-flight (i.e. 100 ps from ECAL)

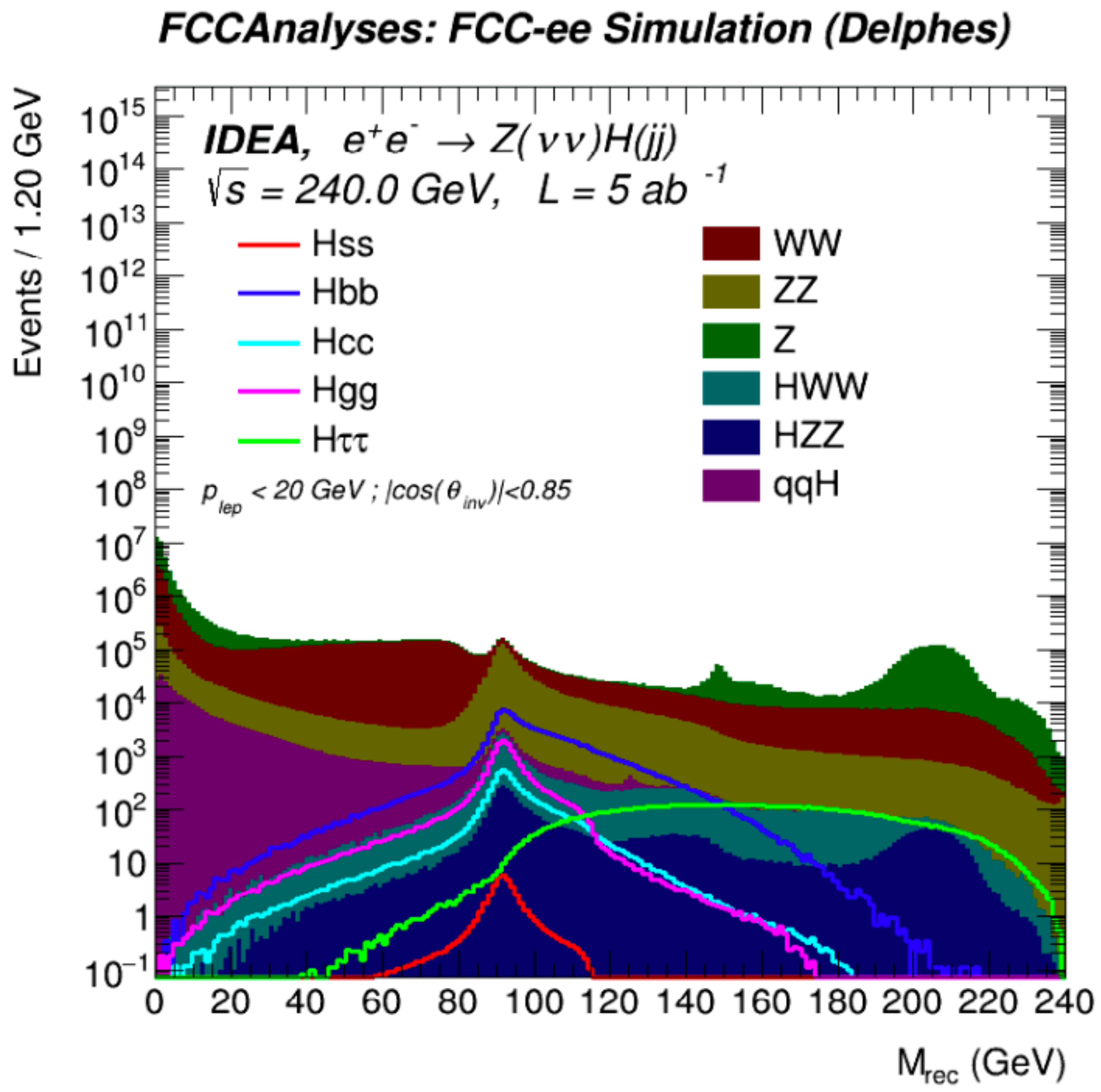


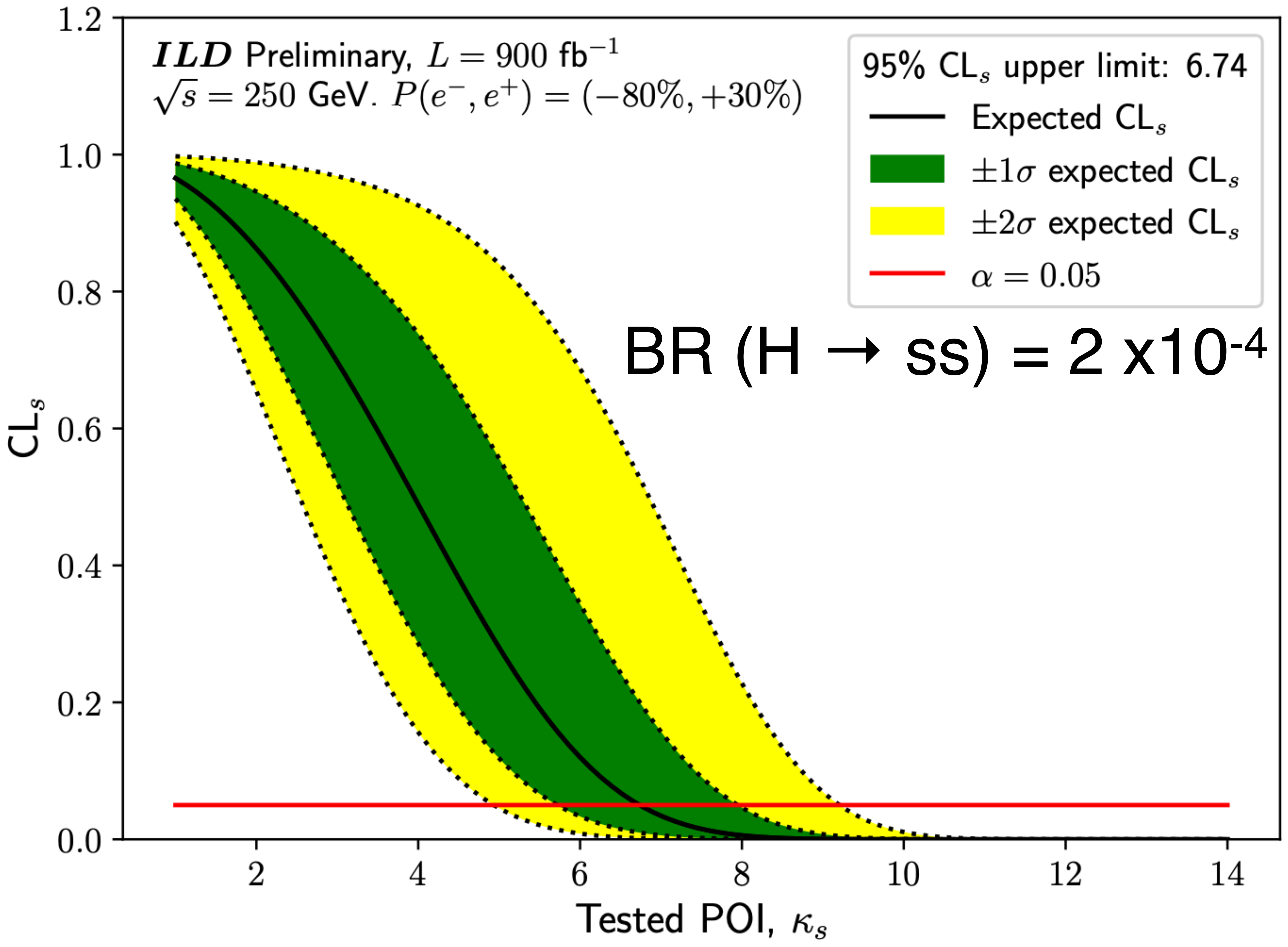


Constraints on s-coupling

Compatible results for both FCC and ILC like analyses

- ILD combined limit of $\kappa_s < 6.74$ at 95% CL with 900/fb at 250 GeV (i.e. half dataset)
  - No PID worsen the results by 8%
- FCC for Z(vv) only sets a limit of $\kappa_s < 1.3$ at 95% CL with 5/ab at 250 GeV and 2 IPs
  - No PID to PID with dN/dx → at fixed mistag, efficiency doubles



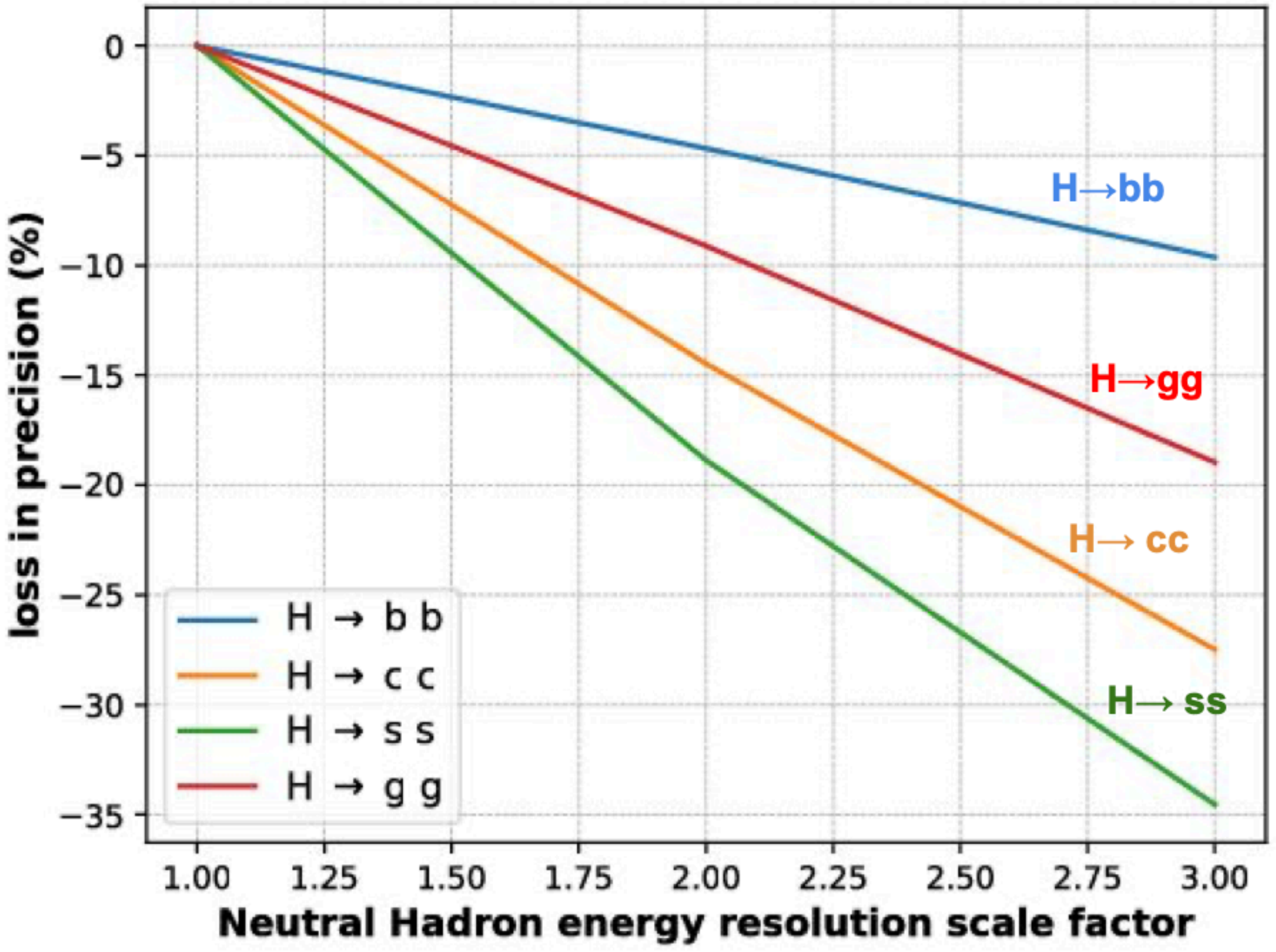


[arXiv:2203.07535](https://arxiv.org/abs/2203.07535)
L. Gouskos @FCC week

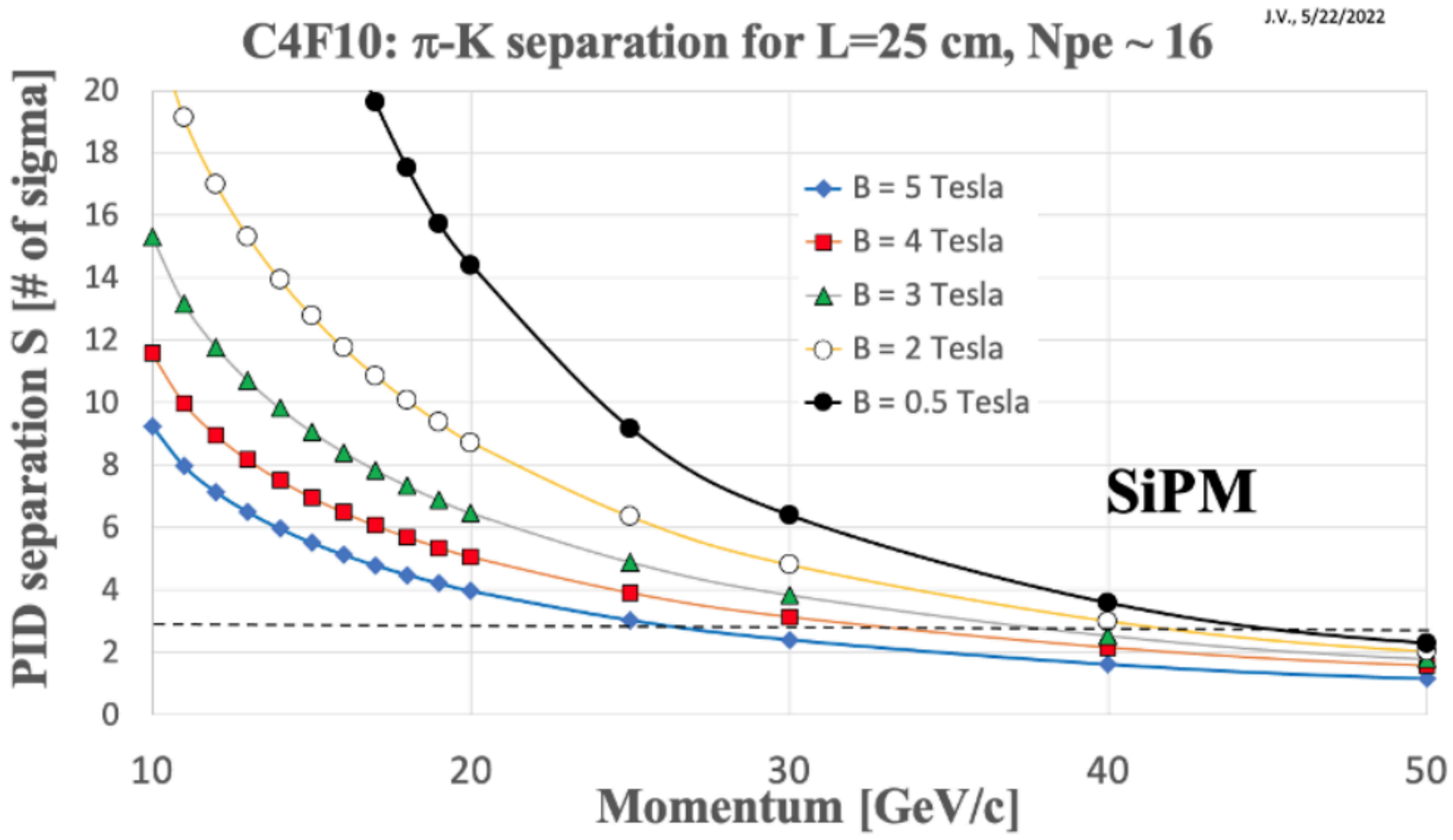
Lesson learned and moving forward

Use H → ss to inform detector design, while monitoring other benchmarks' performance

- Neutral Hadron energy resolution
- dE/dx and dN/dx: evaluate PID performance for H-strange coupling
- Timing resolution to be further investigated but less critical for s-tagging
- RHIC for improved reconstruction of $K^{+/-}$ at high momentum (< 30 GeV)



Compact RHIC



Goals of the H → ss focus study

s-tagging & PID would allow for a complete exploration of the 2nd generation Yukawa couplings

- map this into phenomenological targets
  - i.e. BSM models predicting deviations in h → ss, or h → cs
- refine the analysis for $e^+e^- \rightarrow Zh$ with h → ss (Z → X) at 240/250 GeV
  - higher center of mass energies still unexplored
- study detector benchmarks:
  - the complementarity in momentum reach of charged hadron ID from dN/dx, dE/dx, ToF, RICH
  - reconstruction of in-flight decays, $K^0_S \rightarrow \pi^+\pi^-$
  - strangeness-tagging and s/sbar separation
- ***Important to evaluate simultaneously other Higgs benchmarks***

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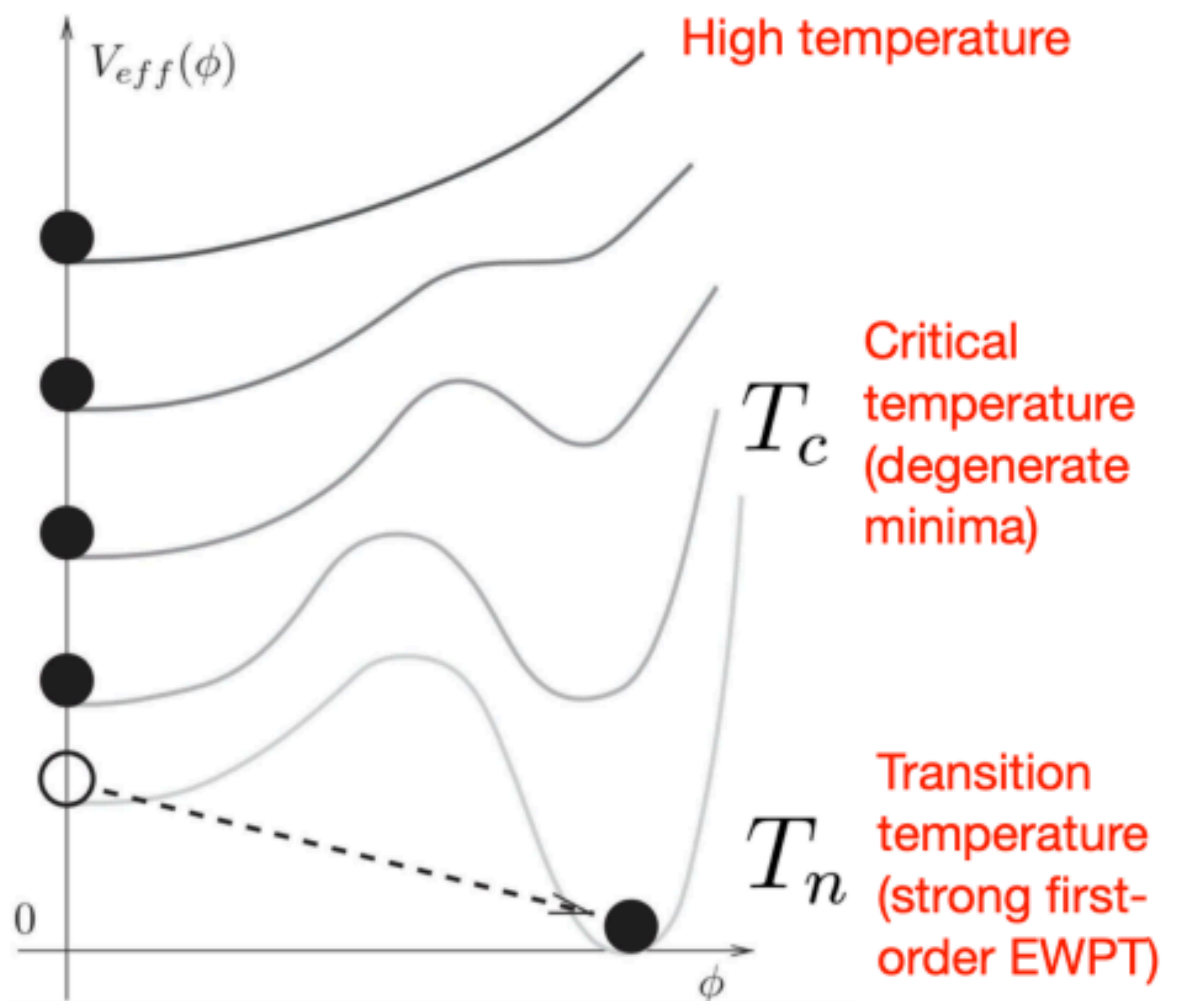
ZH Focus study

Talk at the ECFA workshop 2023

Are there additional sources for CP violation in Higgs sector?

- Higgs is not a pure CP-odd state, but experimentally it has not been demonstrated that it is a pure CP-even state either.
- Baryogenesis: creation of the asymmetry between matter and anti-matter in the universe requires a strong first-order electroweak phase transition (EWPT)
  - First-order EWPT does not work in the SM:
    - the amount of CP violation in the SM (induced by the CKM phase) is not sufficient to explain the observed asymmetry between matter and anti-matter in the universe
  - First-order EWPT can be realized in extended Higgs sectors and could give rise to detectable gravitational wave signal



arXiv:2205.07715
arXiv:2209.07510

Higgs CP properties

Most processes could be studied at an e+e- collider with the beam energy above the tth threshold.

Future e+e- colliders are expected to provide comparable sensitivity to HL-LHC in hff couplings, and potentially higher sensitivity in hZZ couplings.

CP-measurements in HZ and ZZ-fusion: **define CP-odd quantities and evaluate effect of polarization**

Collider	pp	pp	pp	e^+e^-	e^+e^-	e^+e^-	e^+e^-	$\gamma\gamma$	$\mu^+\mu^-$	$\mu^+\mu^-$	target
E (GeV)	14,000	14,000	100,000	250	350	500	1,000	125	125	≥ 500	(theory)
$\mathcal{L}$ (fb^{-1})	300	3,000	20,000	250	350	500	1,000	250			
HZZ/HWW	$4\cdot10^{-5}$	$2.5\cdot10^{-6}$	✓	$3.4\cdot10^{-4}$	$1.1\cdot10^{-4}$	$4\cdot10^{-5}$	$8\cdot10^{-6}$	✓	✓	✓	$< 10^{-5}$
$H\gamma\gamma$	–	0.50	✓	–	–	–	–	0.06	–	–	$< 10^{-2}$
$HZ\gamma$	–	~ 1	✓	–	–	–	–	–	–	–	$< 10^{-2}$
Hgg	0.12	0.011	✓	–	–	–	–	–	–	–	$< 10^{-2}$
$Ht\bar{t}$	0.24	0.05	✓	–	–	0.29	0.08	–	–	✓	$< 10^{-2}$
$H\tau\tau$	0.07	0.008	✓	0.01	0.01	0.02	0.06	✓	✓	✓	$< 10^{-2}$
$H\mu\mu$	–	–	–	–	–	–	–	–	✓	–	$< 10^{-2}$

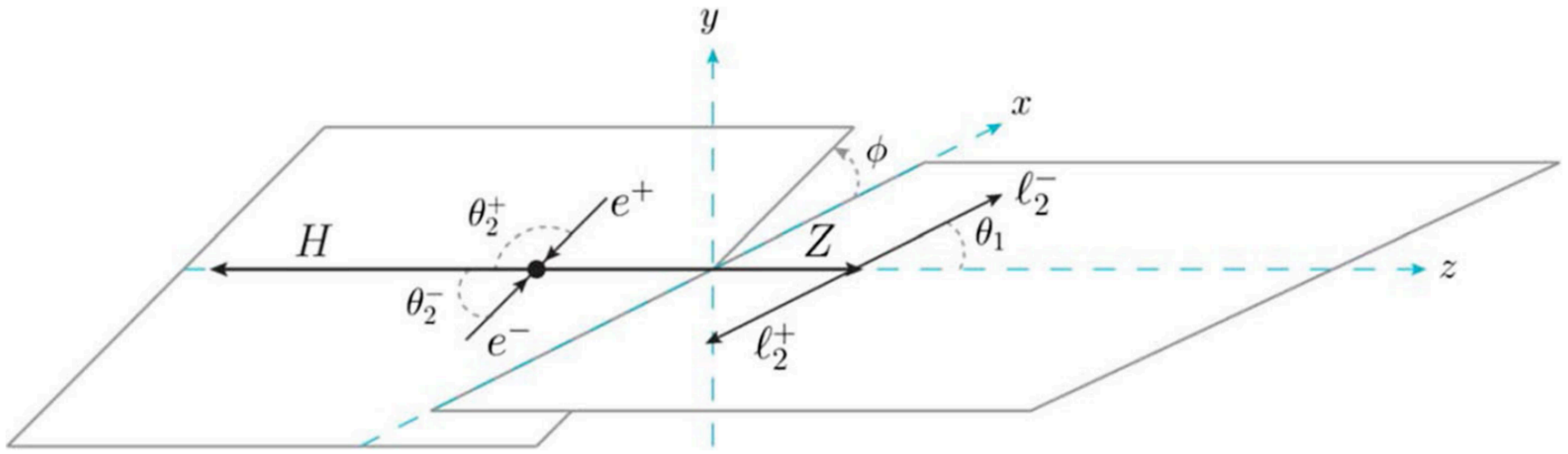
ZH CP studies

Talk at the ECFA workshop 2023

Studies of the CP properties of the Higgs boson require both high luminosities and energies from 250 GeV - 1 TeV

A possible to do list:

- **Phenomenology**:
  - Define CP-odd quantities in HZ, VV-fusion, HVV couplings, trilinear couplings
  - detailed model specific studies versus EFT studies,
  - optimal observables versus angular and kinematic observables,
  - Evaluate the impact of ISR and FSR
- **Simulations** : non-zero CPV mixing not yet included, detector-specific issues, full spin & polarization information, ISR, FSR
- **Reconstruction**:
  - τ reconstruction including polarization
  - q, qbar separation
  - angular reconstruction
  - (electron tracking) to small polar angles/ hermeticity
  - b-tagging efficiency uncertainty



Goals of the ZH focus study

Study CP-odd interactions and extend the sensitivity to a global SMEFT analysis to probe the Higgs self-coupling

- Use angular information or an optimal observable to improve sensitivity to the CP structure of the hZZ vertex
  - Towards a joint constraint on the CP-even and CP-odd components of the hZZ vertex using pseudo-observables or the SMEFT, rather than just the CP-odd fraction
- An expanded interpretation framework **connecting the SMEFT to specific model scenarios** could be used to clarify the coverage of an e+e- collider to the CP-odd interaction strengths that can explain the baryon asymmetry in the universe.
  - Perform a complete NLO analysis of the ZH process within the context of a global SMEFT analysis, including constraints from other measurements
  - Determine whether angular or other observables can target the **sensitivity to the self-coupling**, possibly in conjunction with ***different centre-of-mass energies and beam polarizations***
  - Extend the global SMEFT analysis to dimension-8 operators and all terms at order $1/\Lambda^4$: both CP-odd and CP-even operators contribute to many observables at this order

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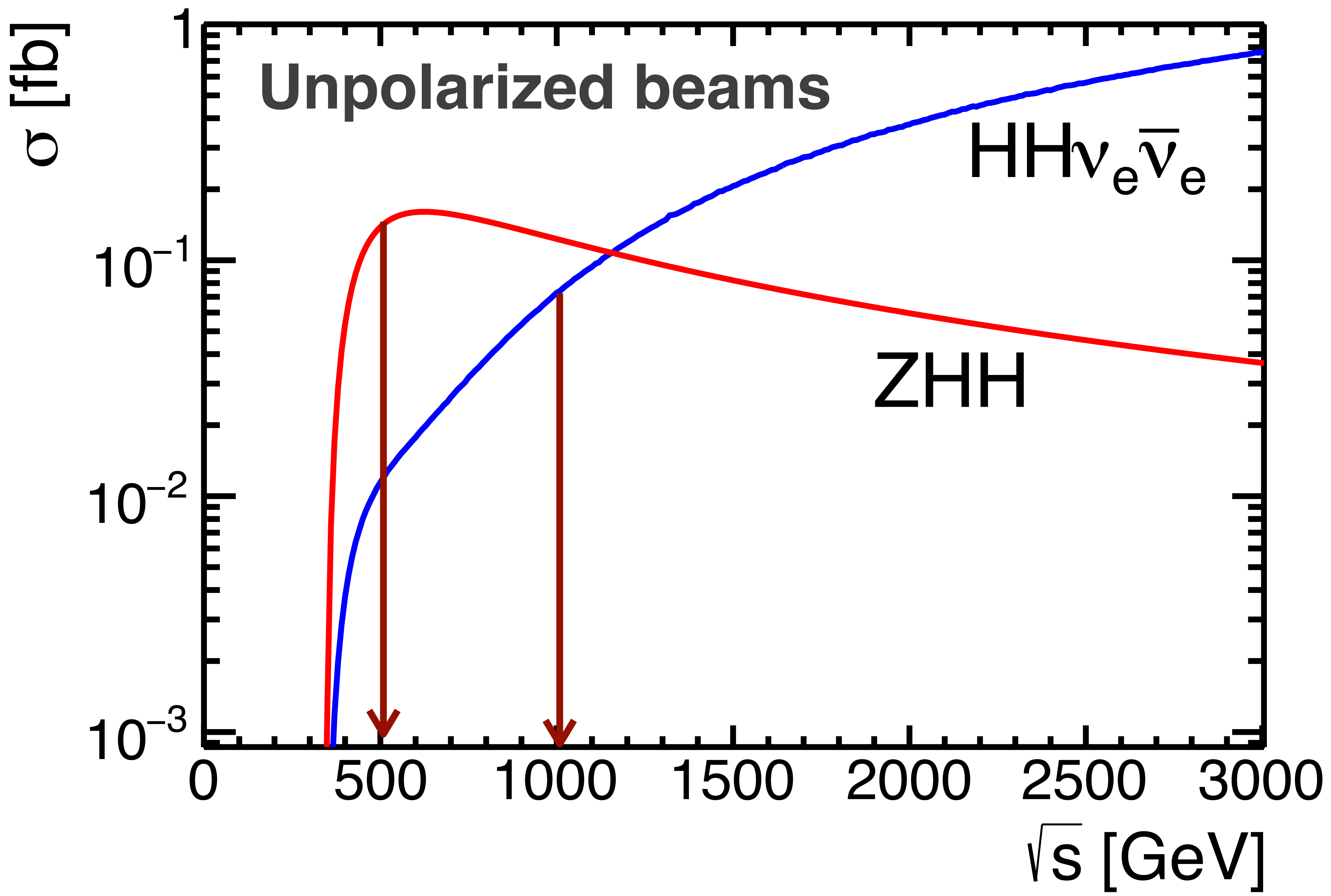
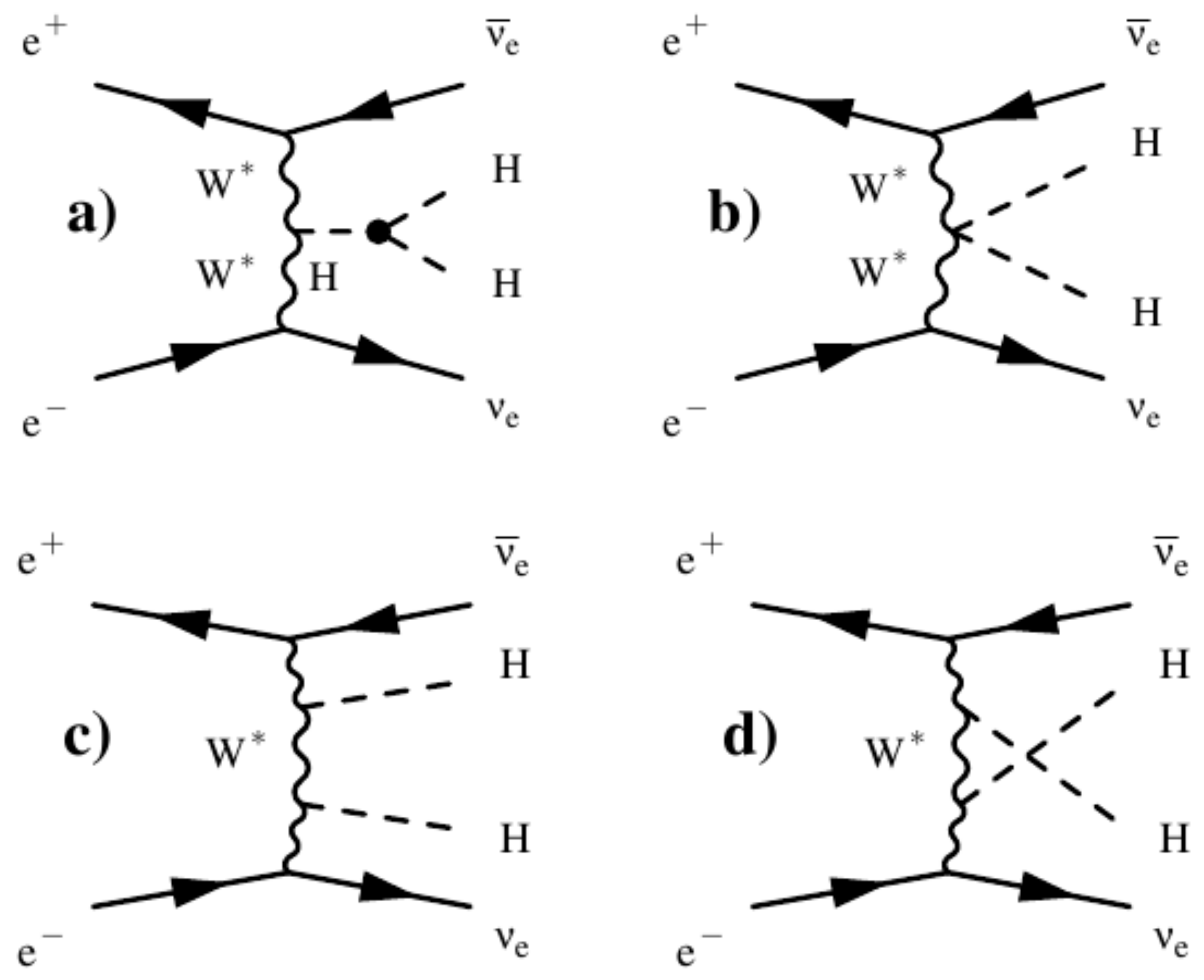
HH at future e^+e^- linear colliders

arXiv:1910.00012

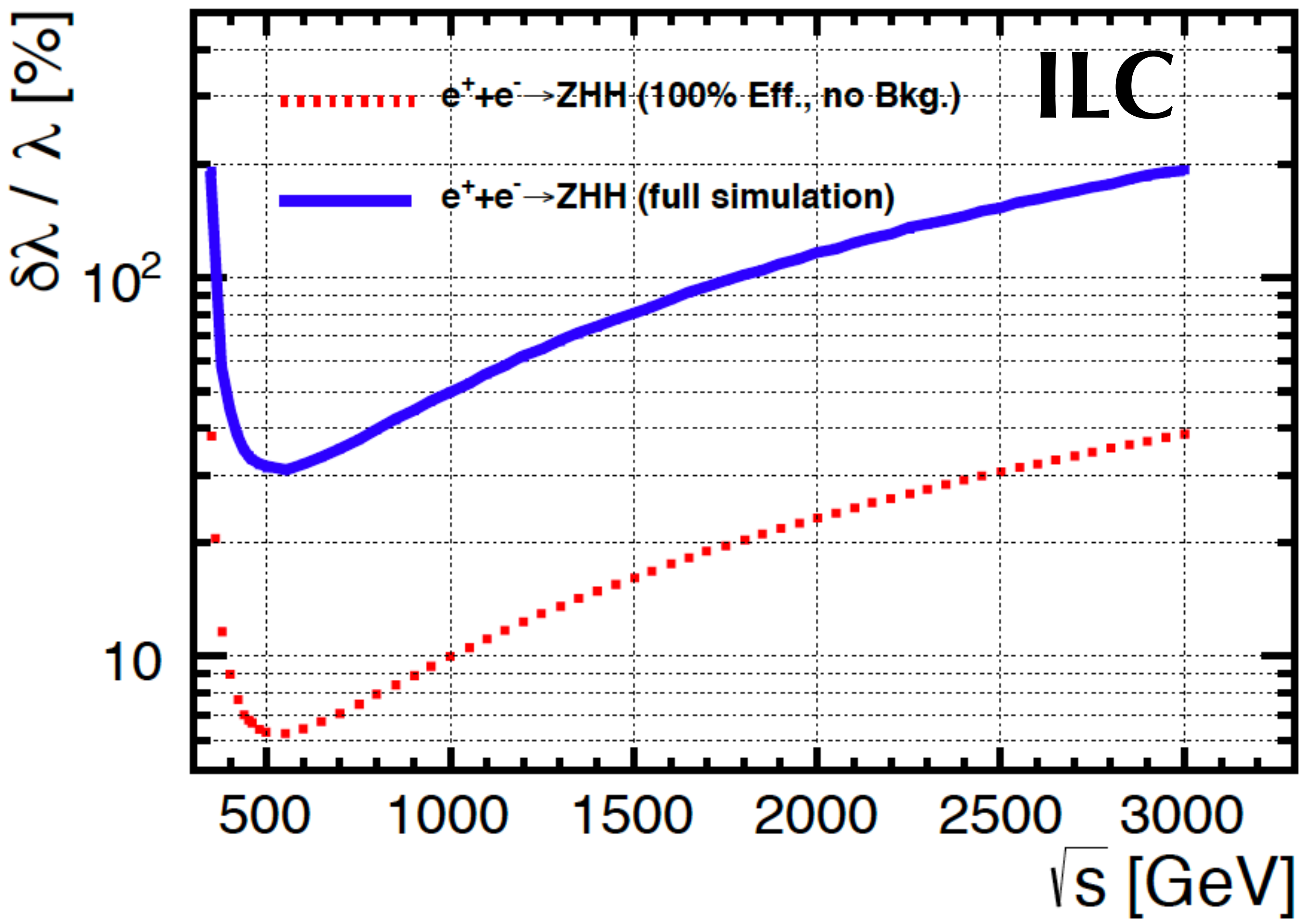


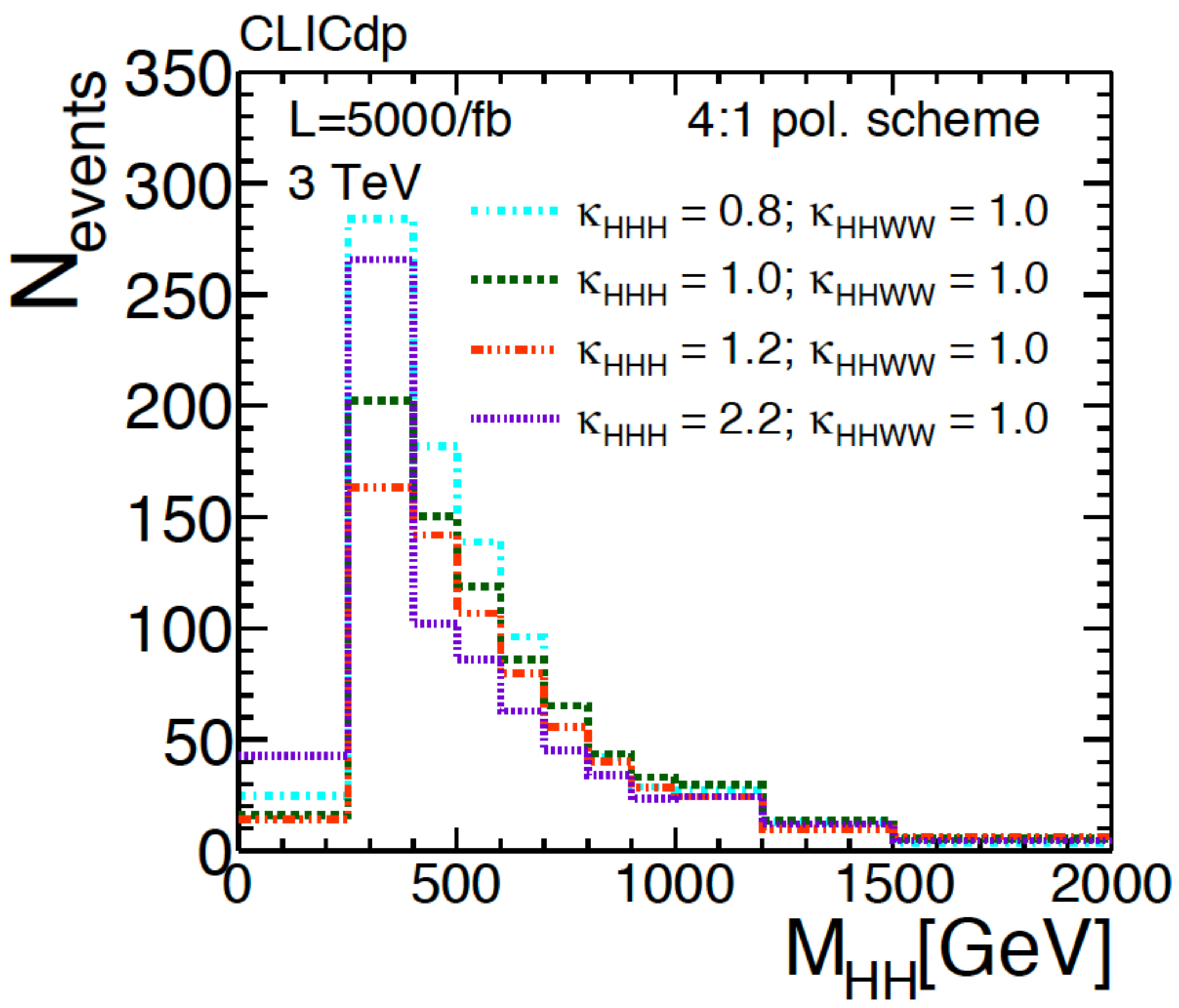


- The intrinsic precision (1% level) on single Higgs production processes is one of the main advantages of e^+e^- beams
- **HHvv** requires $e_L^- e_R^+$, the use of polarized beams could increase the cross-section by a factor ~2
- For both **ZHH** and **HHvv** processes there are diagrams involving the self-coupling in constructive/deconstructive interference with diagrams that do not contain this coupling.
  - No matter what is the sign of the deviation of the Higgs self-coupling from its SM value, one process is always enhanced

arXiv:1910.00012

Studying HH at e^+e^-





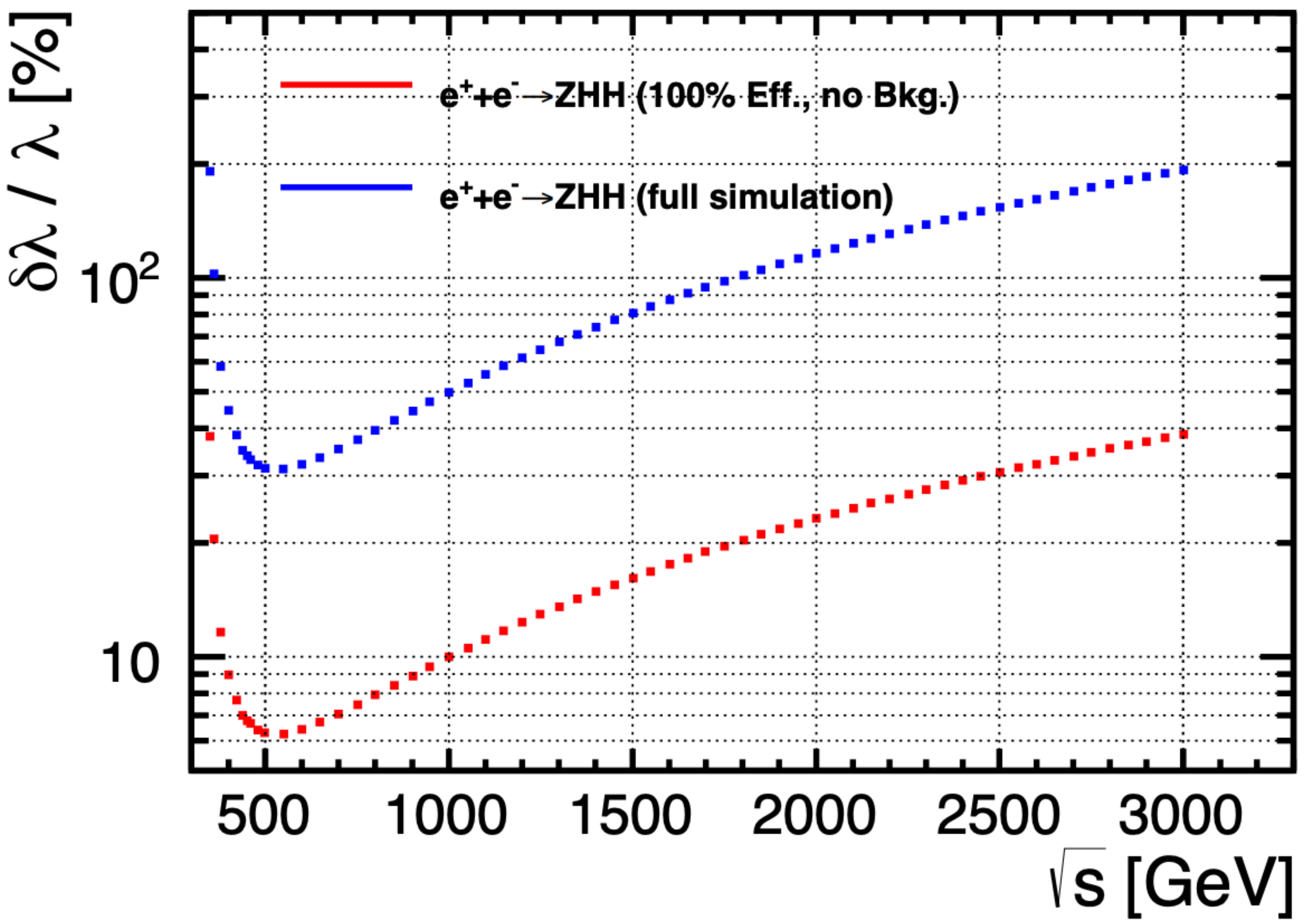
- Both the $b\bar{b}b\bar{b}$ and $b\bar{b}WW$ final states are considered with Z to leptons/neutrino/quarks
- For **ILC analyses** with an expected luminosity of 4/ab at 500 GeV, the combination of the various channels yield a precision of 16.8% on the HH total cross section which corresponds to an uncertainty of 27% on κ_λ coupling.
- For **CLIC studies** at 1.4 TeV, evidence for vvHH production is found with a significance of 3.6$\boldsymbol{\sigma}$, and the ZHH process can be observed at this stage with a significance of 5.9$\boldsymbol{\sigma}$
  - The ambiguity in the interpretation of the total cross-section results is resolved by measuring the HH invariant mass distribution in the vvHH process.

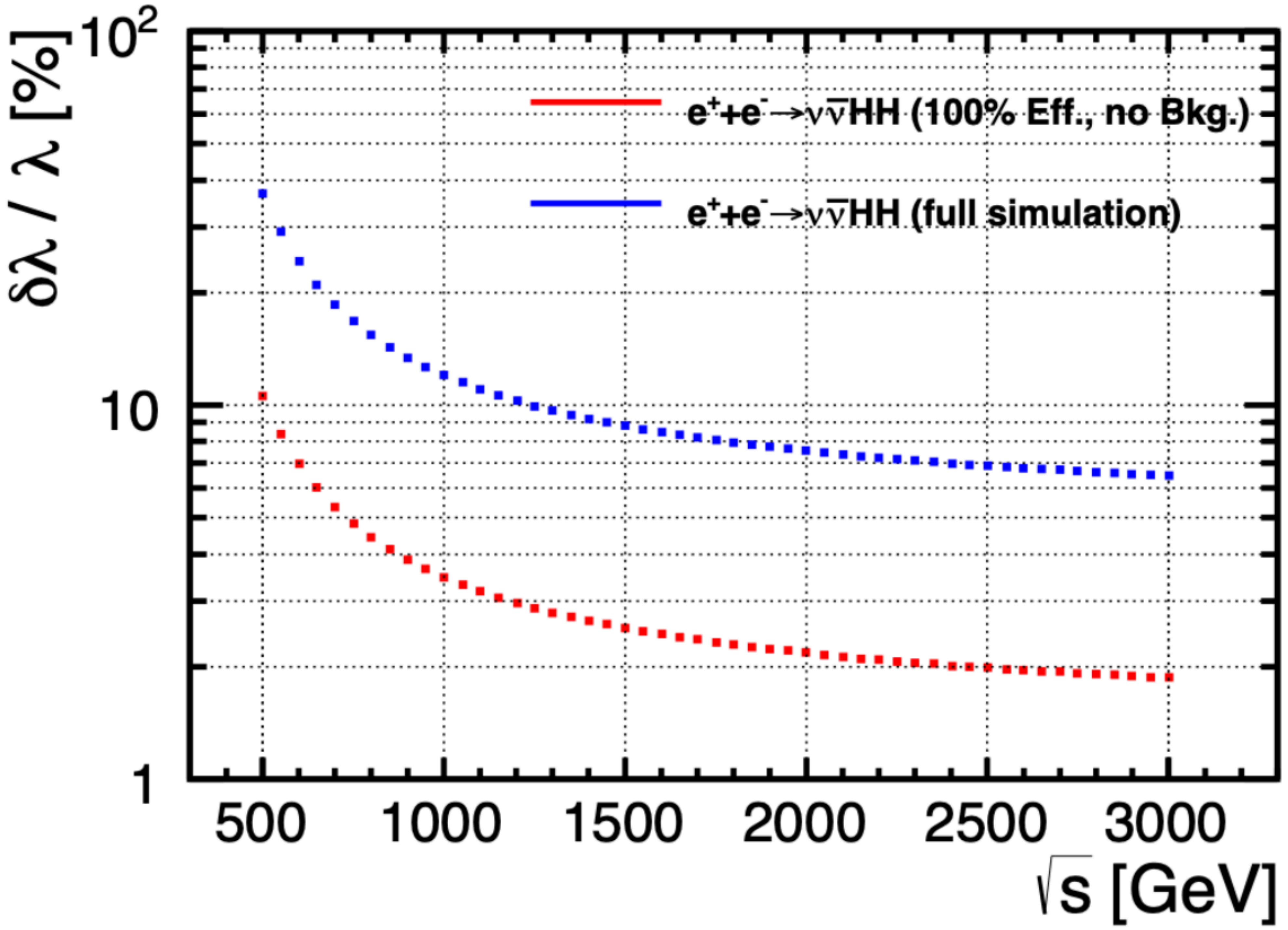
What is next for HH?

Evaluate dependency as a function of CM and further analysis improvements

A lot of room for improvement by advanced analysis techniques:

flavor tagging, jet-clustering, kinematic fitting, matrix element method…





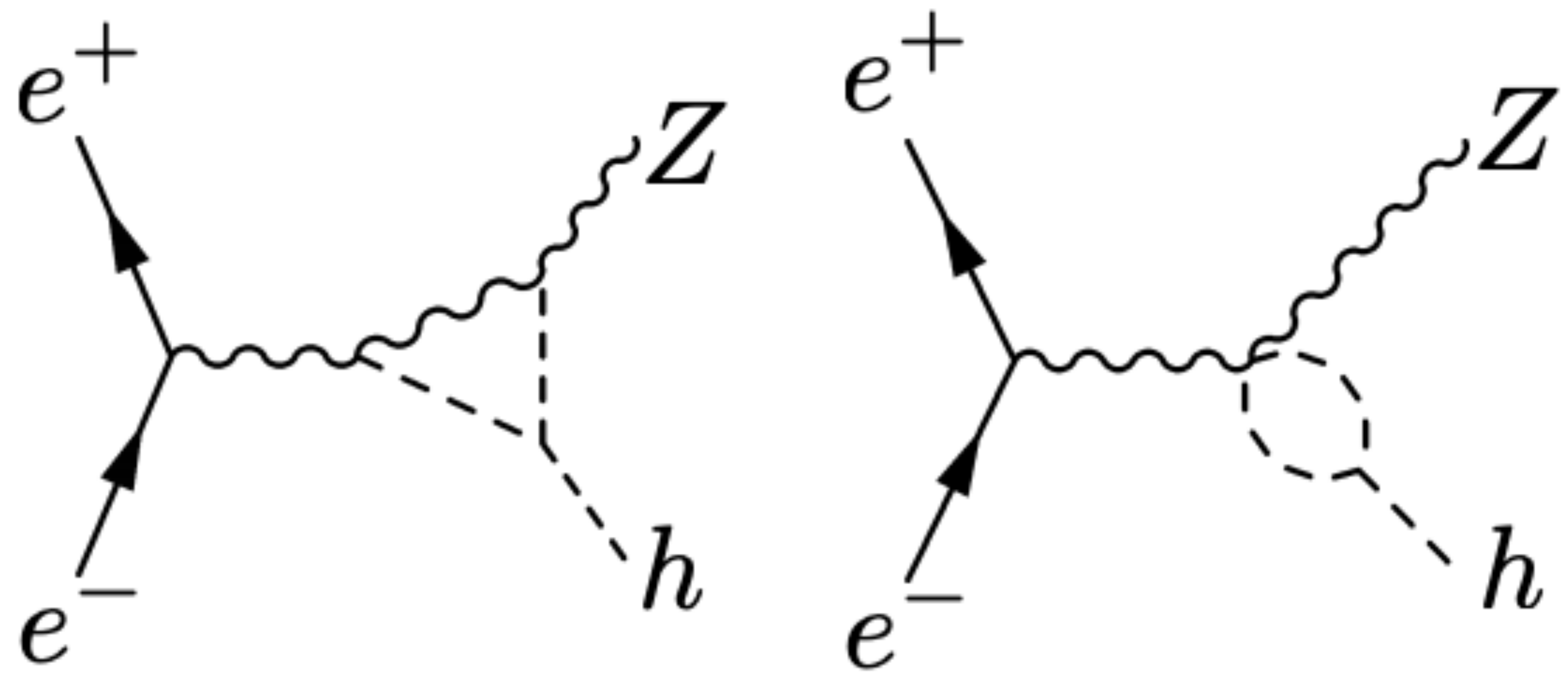
Review of ongoing studies for ZHH, Julie Torndal & Dimitris Ntounis (talk, arXiv)

arXiv:1312.3322
arXiv:1910.00012

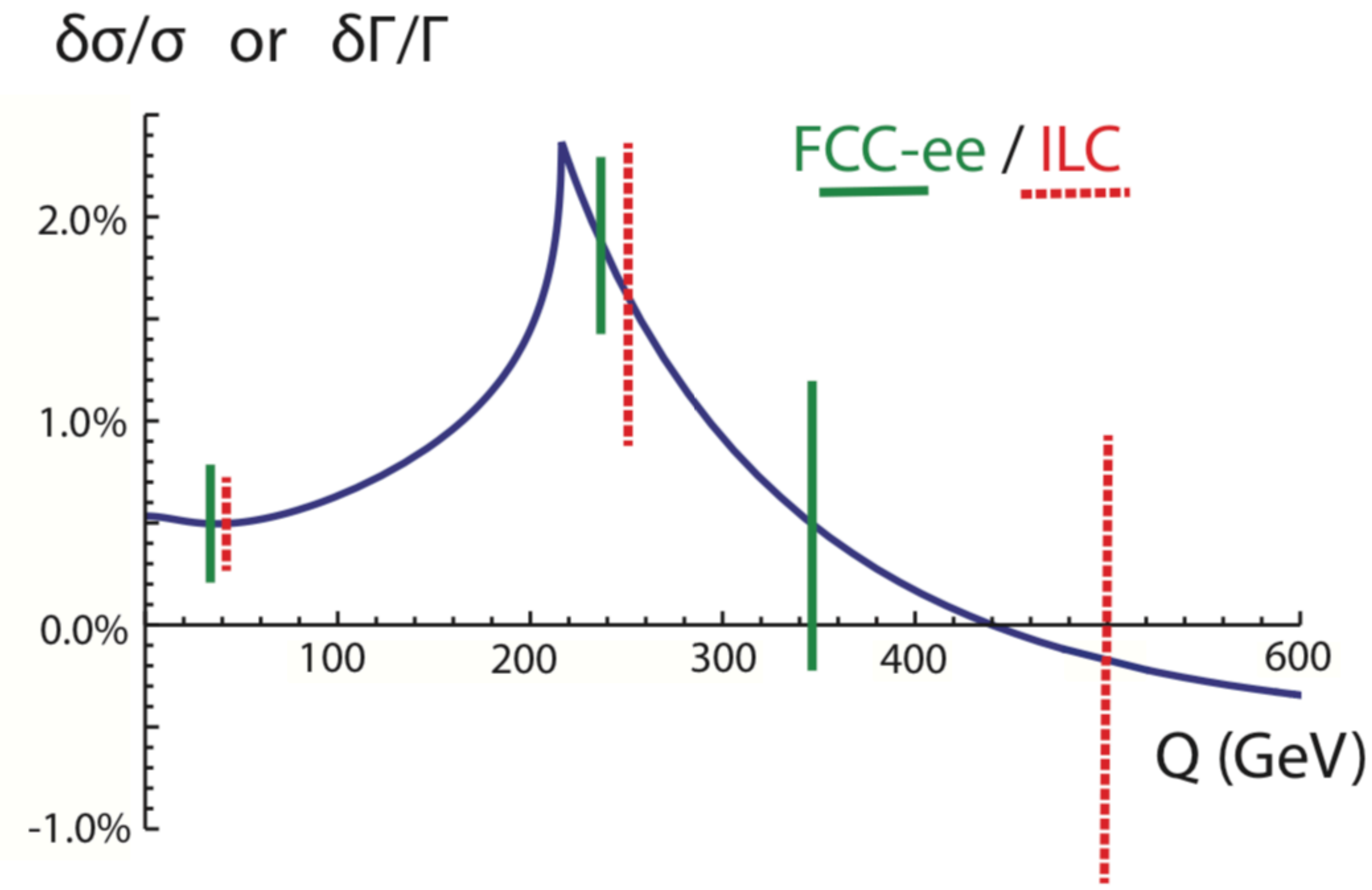
Self-coupling at e+e- with single Higgs

The self-coupling could be determined also through single Higgs processes

- Relative enhancement of the e+e− → ZH cross-section and the H→W+W− partial width
- Need multiple Q^2 to identify the effects due to the self-coupling



$$\delta_\sigma^{240} = 100\,(2\delta_Z + 0.014\delta_h)\,\%$$



New observables? Top-quark uncertainties? Which is the optimal energy scan?

The Higgs self-coupling at future colliders

From Snowmass22 update:

collider	Indirect-h	hh	combined
HL-LHC [68]	100-200%	50%	50%
ILC_{250}/C^3-250 [49, 50]	49%	–	49%
ILC_{500}/C^3-550 [49, 50]	38%	20%	20%
$CLIC_{380}$ [52]	50%	–	50%
$CLIC_{1500}$ [52]	49%	36%	29%
$CLIC_{3000}$ [52]	49%	9%	9%
FCC-ee [53]	33%	–	33%
FCC-ee (4 IPs) [53]	24%	–	24%
FCC-hh [69]	-	3.4-7.8%	3.4-7.8%
μ(3 TeV) [57]	-	15-30%	15-30%
μ(10 TeV) [57]	-	4%	4%

Not updated (yet) since the YR, although new projections available based on full Run 2 dataset

Goals of the HSelf focus studies

Talk at the ECFA workshop 2023

Target physics studies

Single Higgs observables at CM 250, 350/365 GeV:

- for indirect determination of κ_λ EFT approach ($\kappa_\lambda \approx 1$) vs. concrete models (κ_λ /= 1)
- for indirect determination of multi-Higgs interactions involving also extra Higgs bosons.
- Can these contributions be disentangled from the SM-like Higgs self-coupling?
- Study how differential measurements and energy scan can help lifting degeneracies

Double-Higgs observables at CM > 500 GeV:

- Evaluate how various algorithms can improve substantially di-Higgs cross section measurements
- Study the differential cross section in order to enhance the sensitivity to λ.

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Please contribute!

wiki

Last edited by **Patrick Koppenburg** 1 week ago

FocusTopics

The ECFA Higgs / Top / Electroweak Factory study has been set up to expand the e^+e^- community, bringing people together across the various e^+e^- projects to share expertise and tools and to work coherently on scientific and technical topics.

The focus topics are specific areas in which the ECFA study could reach significantly beyond the state-of-the-art understanding of the physics potential of future e^+e^- Higgs / top / EW factories. The topics do not aim to comprehensively map the physics program of a future Higgs factory. Instead, they should serve to:

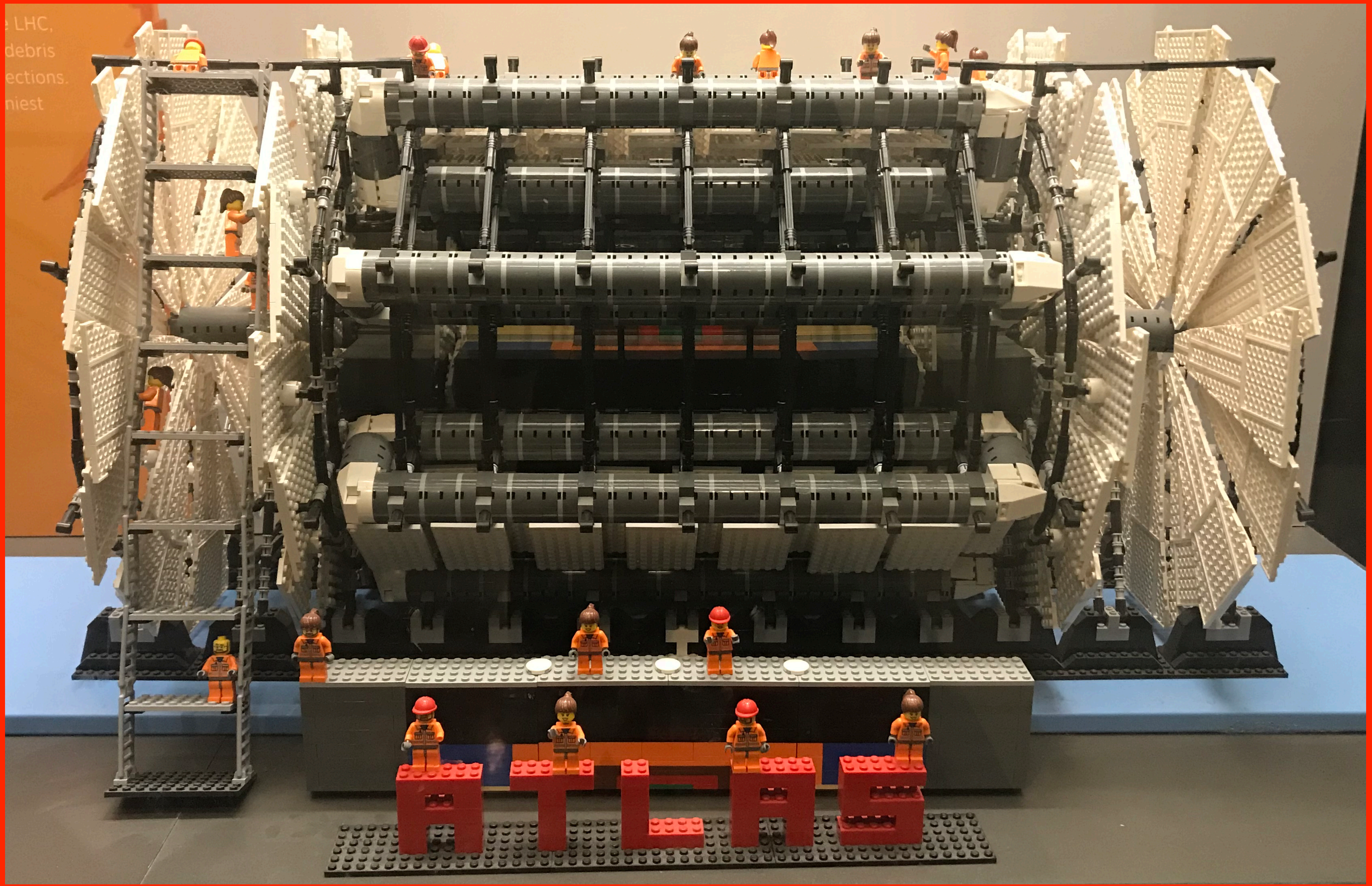
- complete the current overall picture where (most) necessary;
- give guidance to people who would like to contribute to the ECFA study;
- highlight processes particularly suitable for studying the interplay of the three working areas of the ECFA study: physics potential, analysis methods, and detector performance.

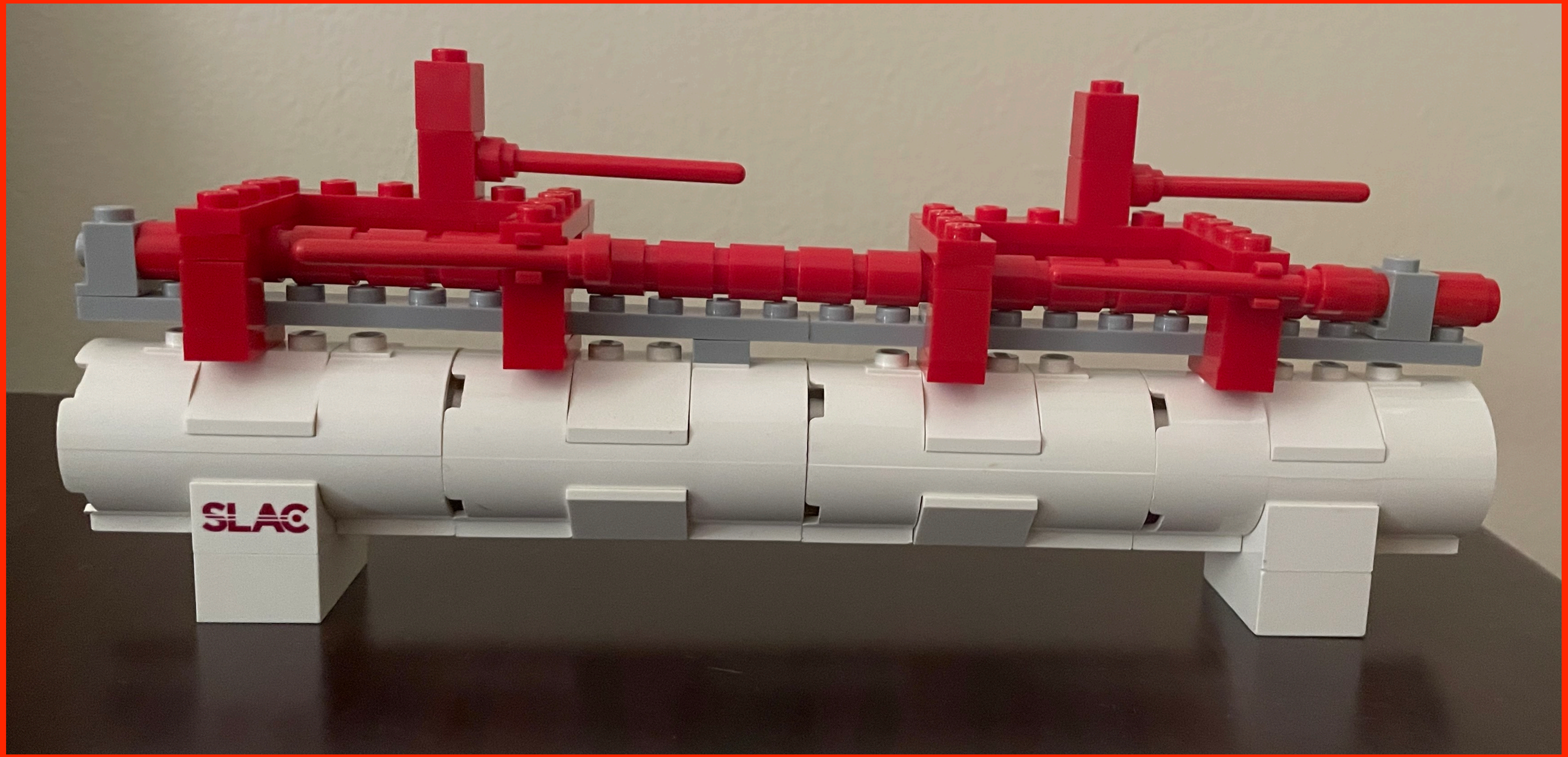
The topics can therefore act as a vehicle for new engagement and collaboration. They are intended as a basis that could be expanded later. The initiative should build on existing analysis tools and samples that can be shared among the projects and developed cooperatively, and it therefore highlights where existing examples, including analysis code and datasets, could be taken as a starting point, particularly by new entrants. All experimental simulation studies are strongly encouraged to use the KEY4HEP framework. This will translate into new tools usable by the whole community and thoroughly tested, and will improve already existing or interfaced tools.

Focus Topics index:

- HtoSS: $e^+e^- \to Zh$: $h \to ss$
- ZHang: ZH angular distributions and CP studies
- Hself: Determination of the Higgs self-coupling
- Wmass: Mass and width of the W boson
- WWdiff: Full studies of WW and evW
- TTthresh: Top threshold - detector-level studies of $e^+e^- \to t\bar{t}$
- LUMI: Precision luminosity measurement
- EXscalar: New exotic scalars
- LLPs: Long-lived particles
- EXtt: Exotic top decays
- CKMWW: CKM matrix elements with on-shell and boosted W decays
- BKtautau: $B^0 \to K^{0*}\tau^+\tau^-$
- TwoF: EW precision - 2-fermion final states
- BCfrag/Gsplit: Measurement of b- and c-fragmentation functions and hadronisation rates and measurement of gluon splitting to bb / cc

A document describing these topics in more detail has been submitted to arxiv:2401.07564, and is saved here.





thank you!

Self-coupling

Phys. Rev. D 90 (2014) 015001

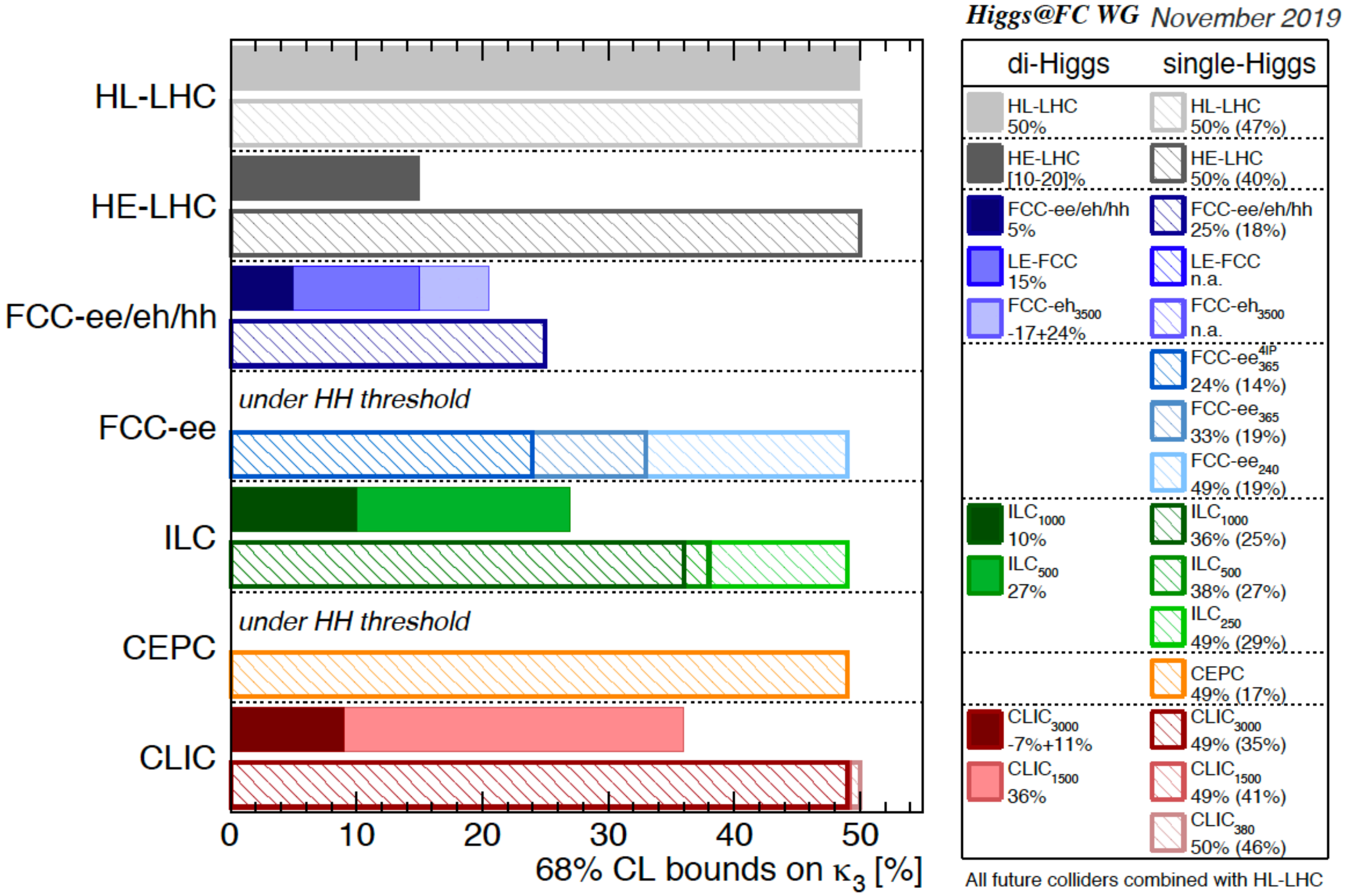
A combined framework to analyse single and double Higgs measurements

The use of e^+e^- beams offers two advantages when extracting the self-coupling from single Higgs production processes.

- intrinsic precision in single Higgs measurements that will be higher than at hadron colliders, reaching or exceeding the 1% level.
- a larger number of independent single Higgs observables that can be used to great effect in the interpretation of the measurements.

An e^+e^- Higgs factory at two different energies - at 250 and 365 GeV - would determine the trilinear coupling to about 40-60%.

- Based on the observation that the cross section for $e^+e^- \to ZH$ contains a radiative correction involving the self-coupling and it falls off rapidly at energies above 250 GeV
- Constraints on the self-coupling using its indirect effect on the HZZ and HWW vertices



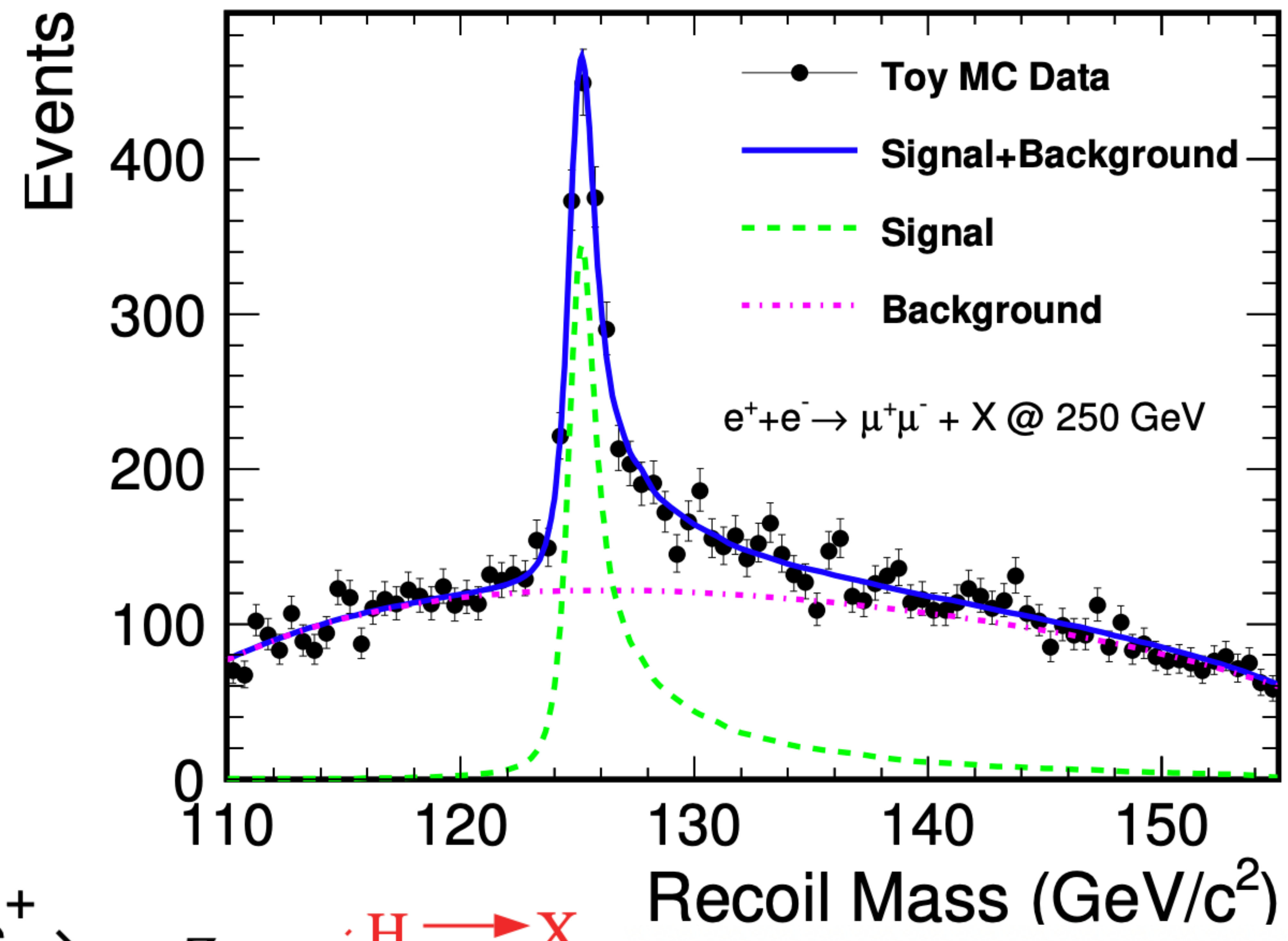
Physics requirements for detectors

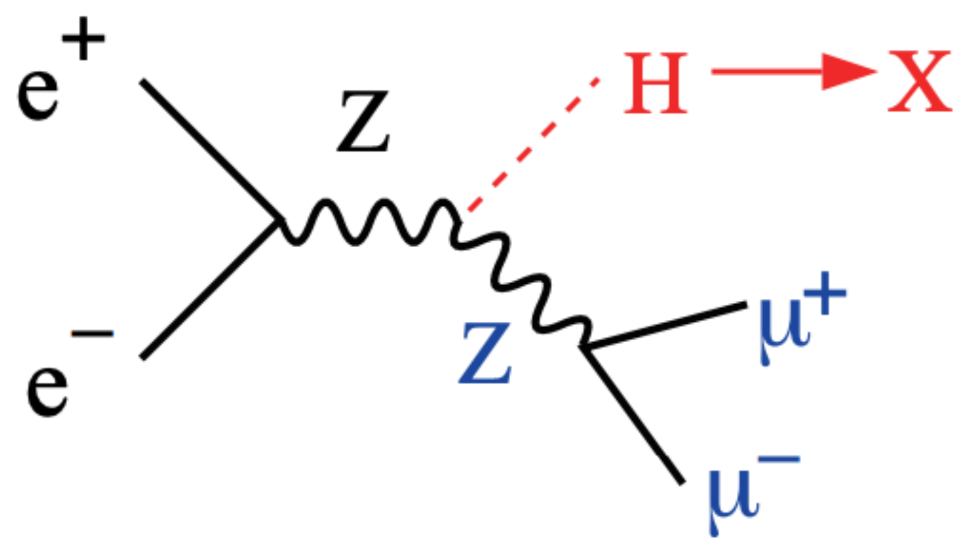
Precision challenges detectors

ZH process: Higgs recoil reconstructed from Z →$\mu\mu$
- Drives requirement on charged track momentum and jet resolutions
- Sets need for high field magnets and high precision / low mass trackers
- *Bunch time structure allows high precision trackers with very low X0 at linear lepton colliders*

Particle Flow reconstruction

Higgs → bb/cc decays: Flavor tagging & quark charge tagging at unprecedented level
- Drives requirement on charged track impact parameter resolution → low mass trackers near IP
- <0.3% X0 per layer (ideally 0.1% X0) for vertex detector
- Sensors will have to be less than 75 μm thick with at least 5 μm hit resolution (17-25μm pitch)





$$m^2_{recoil} = s + m^2_Z - 2 \cdot E_Z \cdot \sqrt{s}$$

arXiv:2003.01116

Physics requirements for detectors

Precision challenges detectors

ZH process: Higgs recoil reconstructed from Z →*μμ*
- ○ Drives requirement on charged track momentum and jet resolutions
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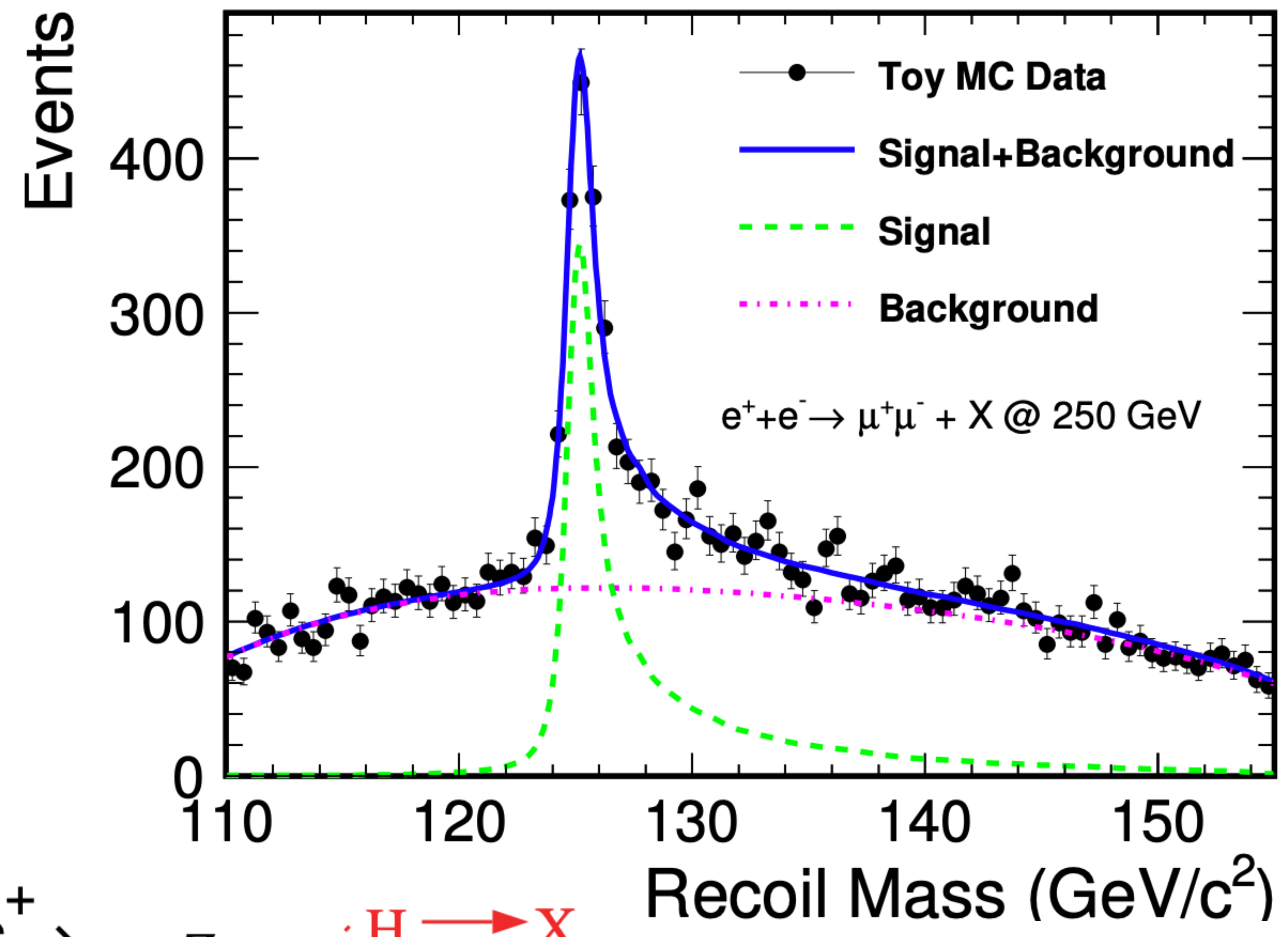
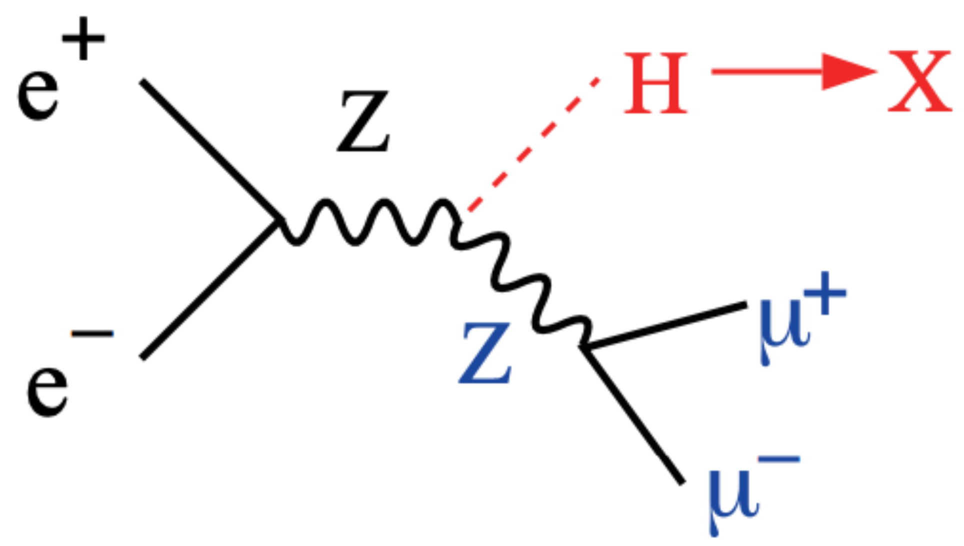




$$m^2_{recoil} = s + m^2_Z - 2 \cdot E_Z \cdot \sqrt{s}$$

Need new generation of ultra low mass vertex detectors with dedicated sensor designs

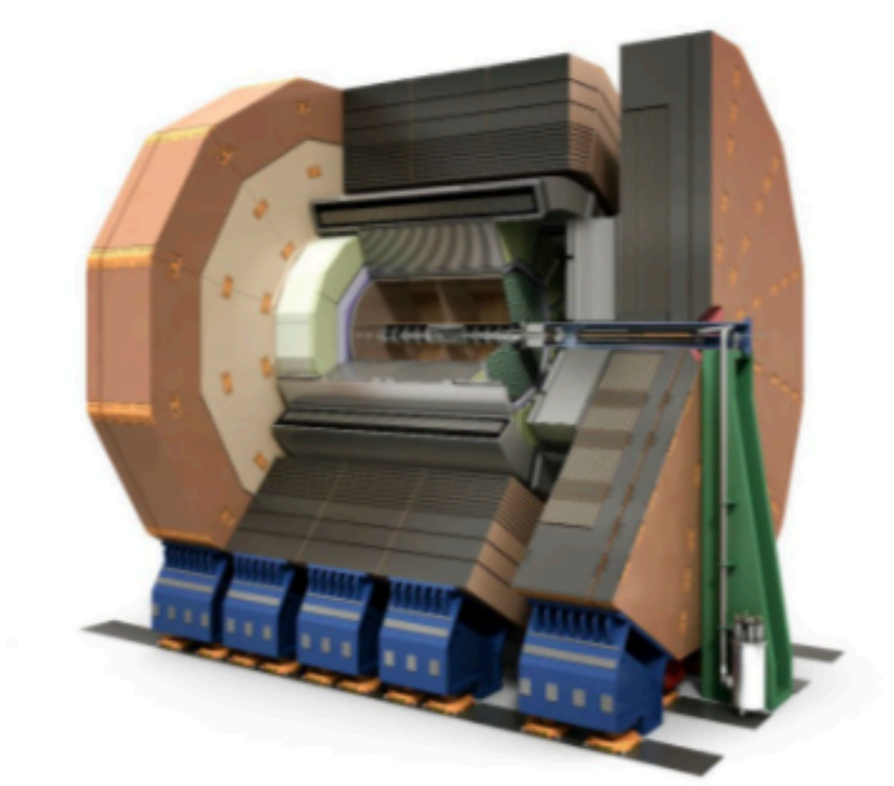
arXiv:2003.01116

Detectors at future e^+e^-

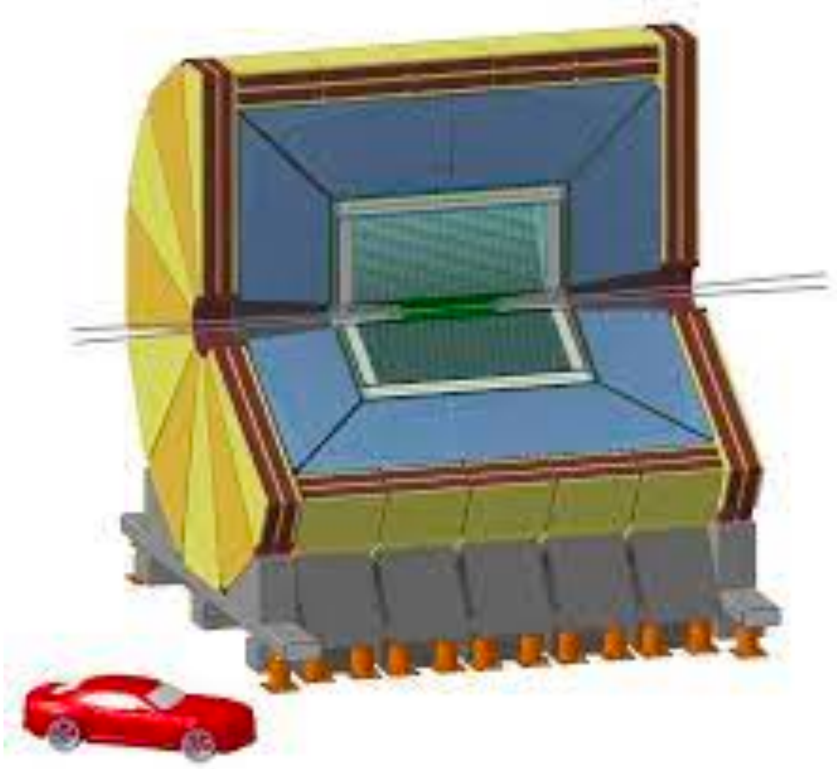
Stringent detector requirements from ZH reconstruction

Detector designs at e^+e^- colliders are converging to very similar strategies

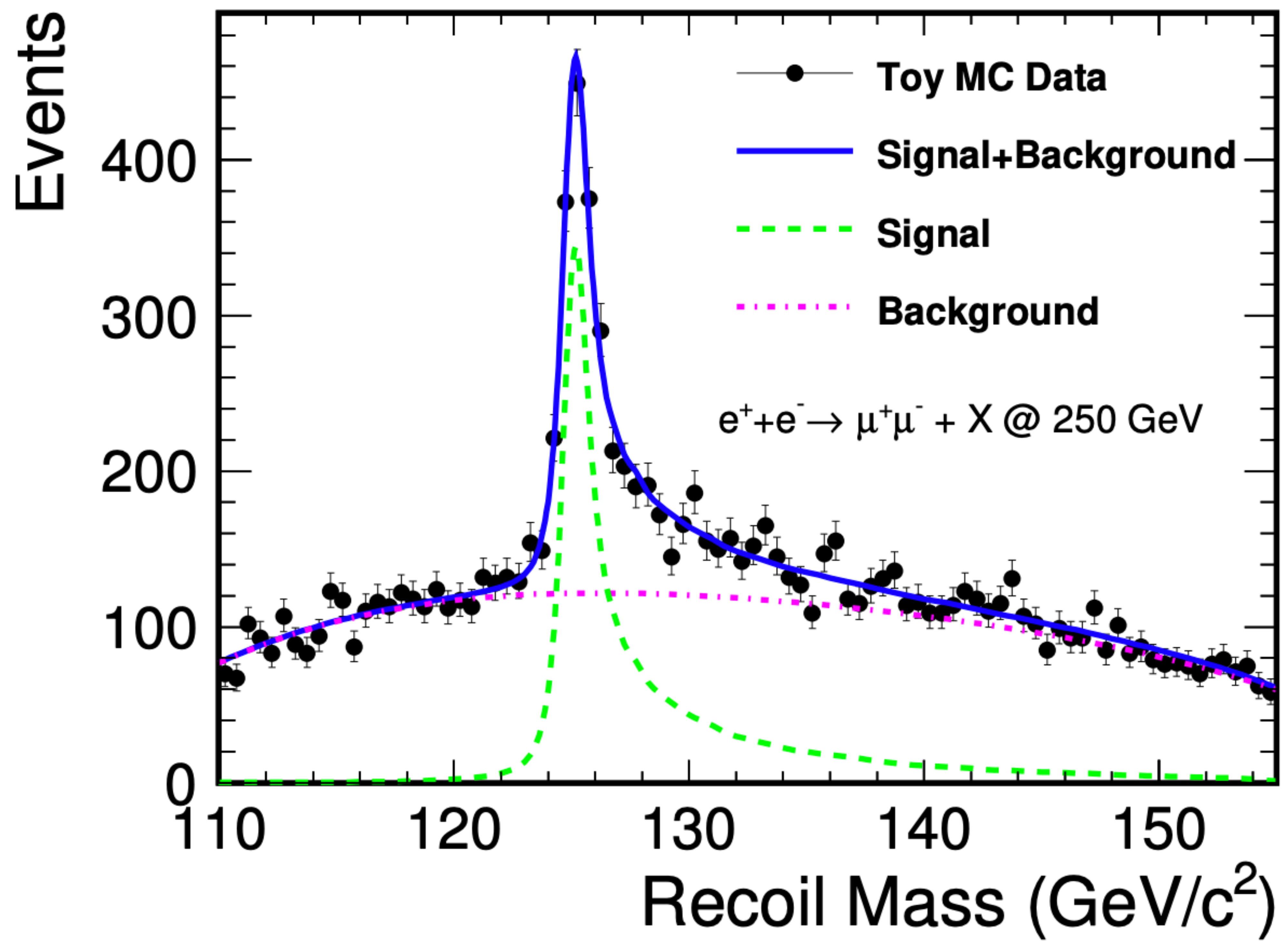
- Strong magnetic field 2-5 T
- (Ultra) low material budget tracker (<0.3% X0)
    - Close to the interaction region (10-25 mm)
- High granularity calorimetry
    - Particle Flow reconstruction → plays a big part in many designs

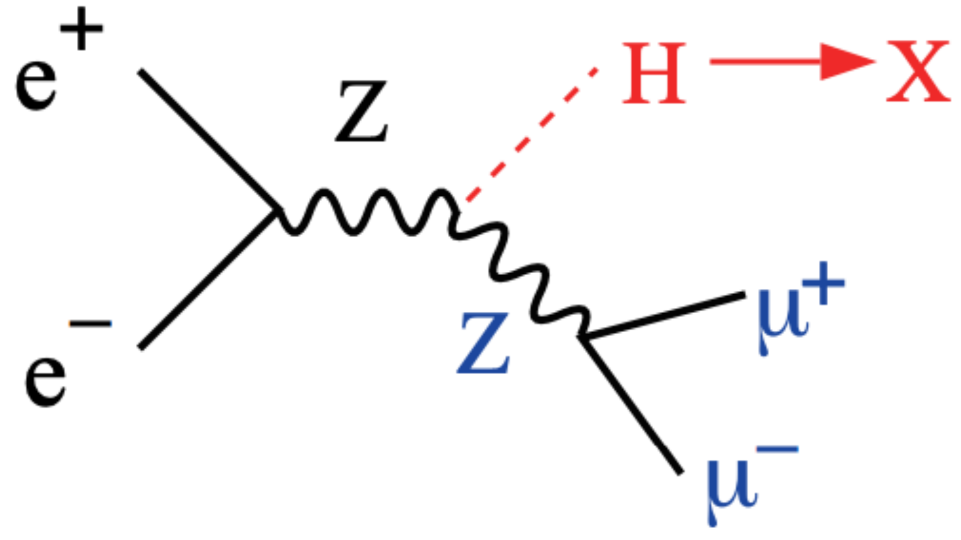


ILD



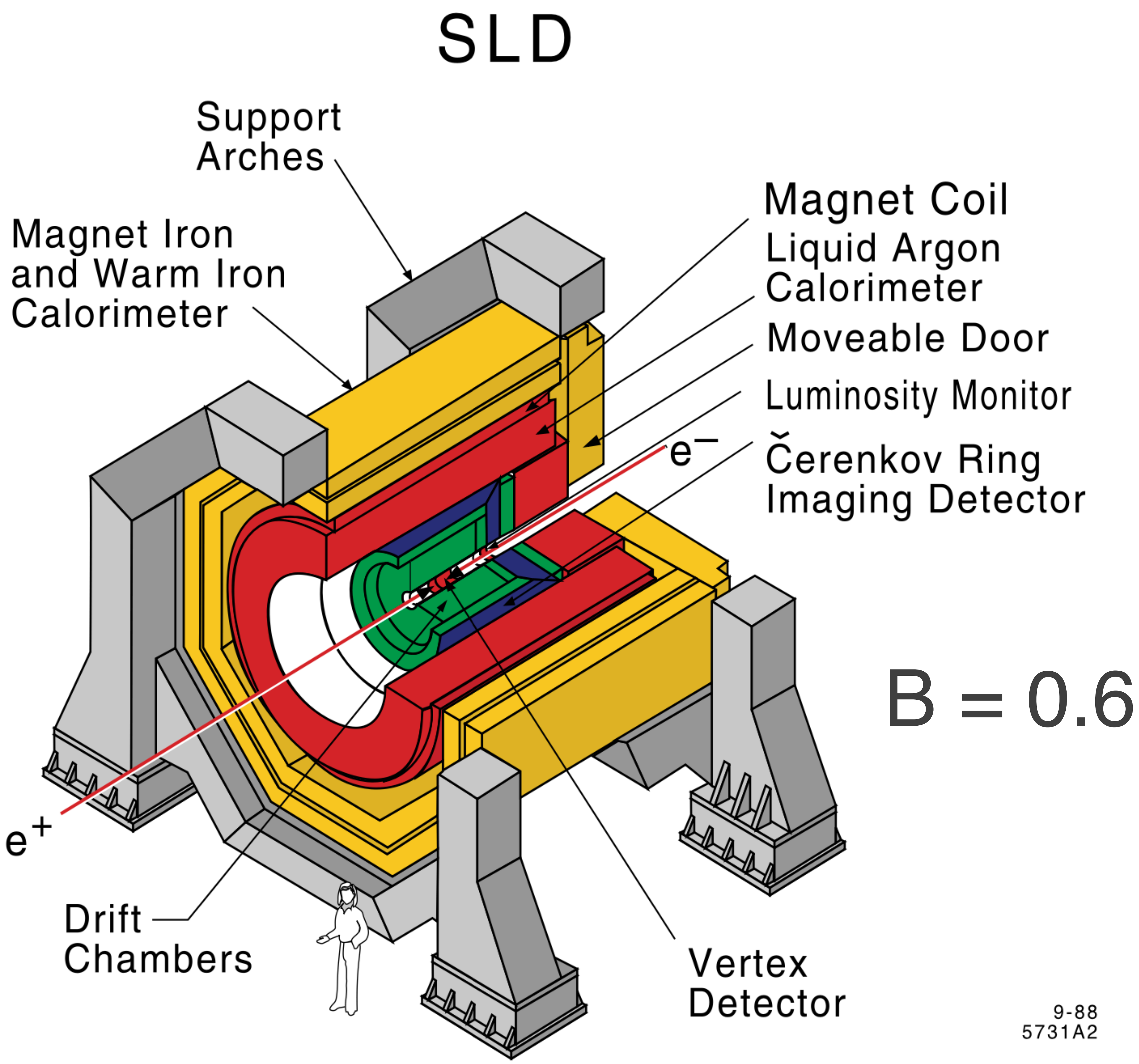
IDEA





s-tagging in the past

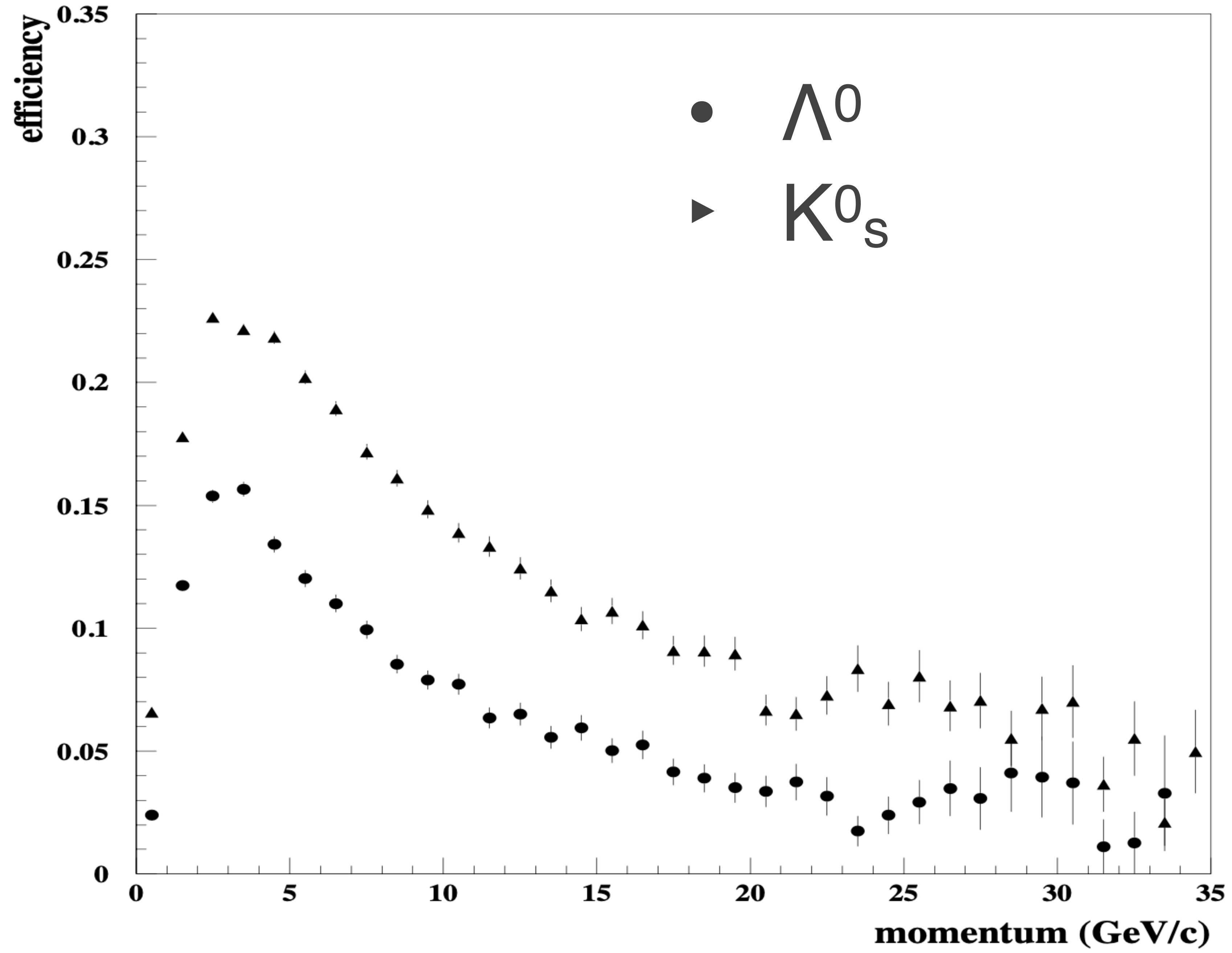
SLD at SLC (e+e- at the Z) measured asymmetry in $Z \rightarrow s\bar{s}$



B = 0.6 T

A Cherenkov Ring Imaging Detector combined with a drift chamber and vertex detector

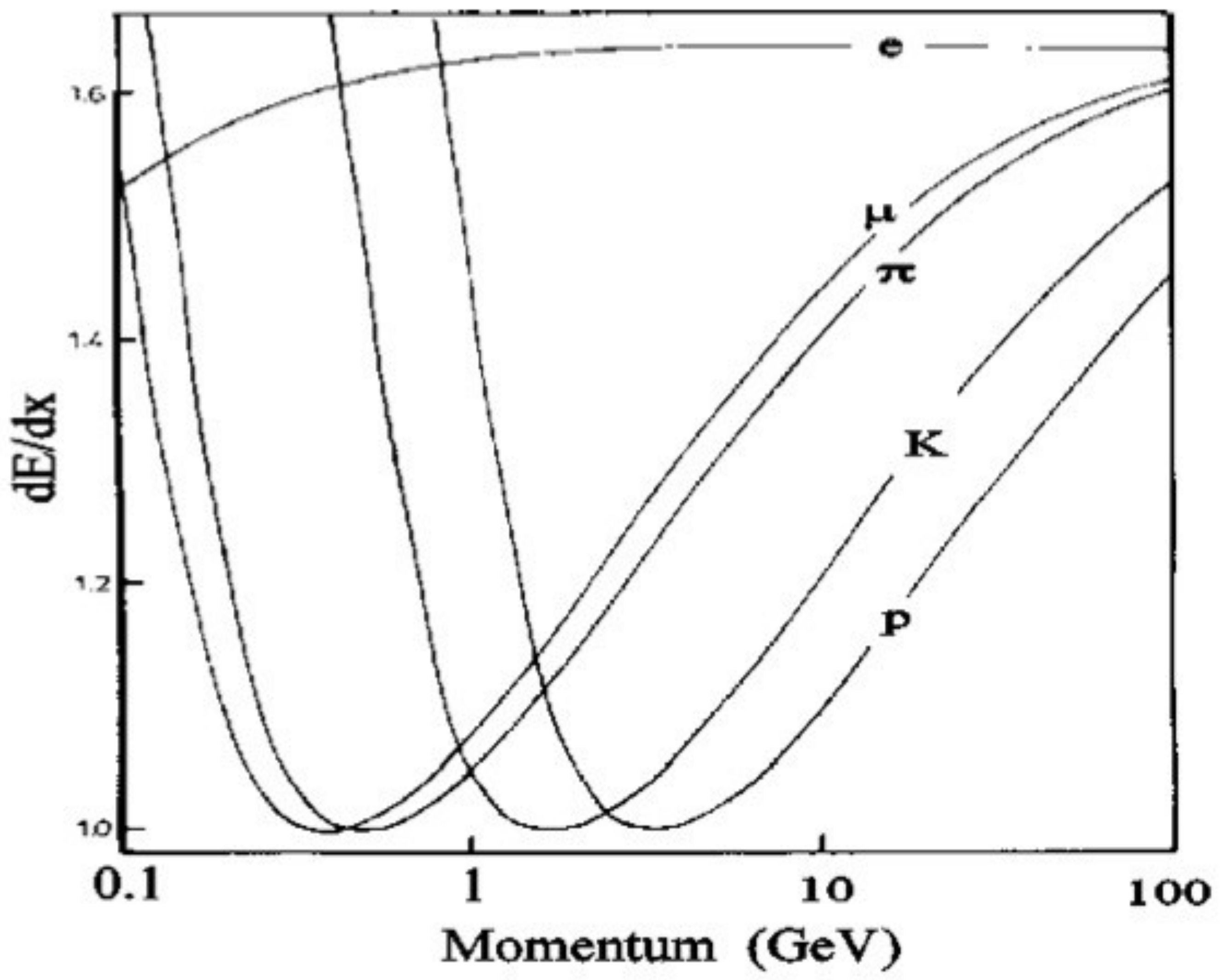
- CRID only available for $K^{\pm}$ with $p_T > 9$ GeV with a selection efficiency (purity) of 48% (91.5%)
- K^0_S efficiency (purity) of 24% (90.7 %)

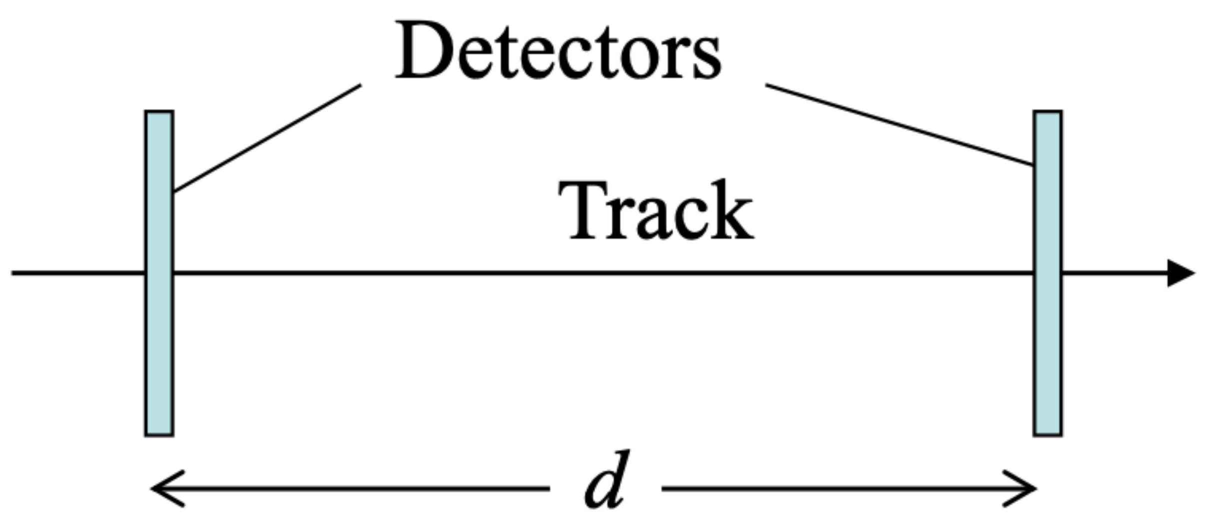


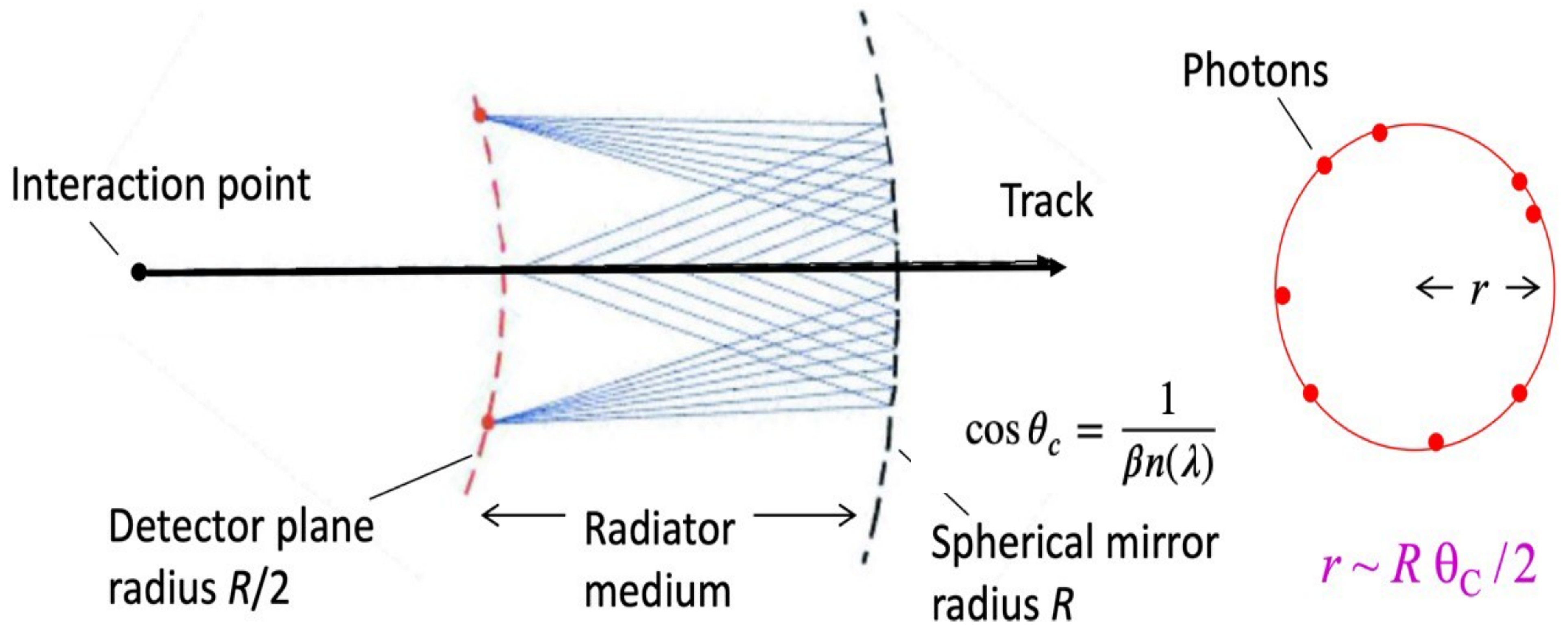
How to enhance s-tagging capabilities

Depending on the hadron energy, different technologies are available for 3σ π/K separation

dE/dx in silicon	Time-of-flight via Fast Timing in silicon envelopes or calorimetry	dE/dx in Time Projection or Drift Chambers	Ring Imaging Cherenkov Detectors
< 5 GeV	< 5 GeV	< 30 GeV (volume dependent)	O(10)GeV





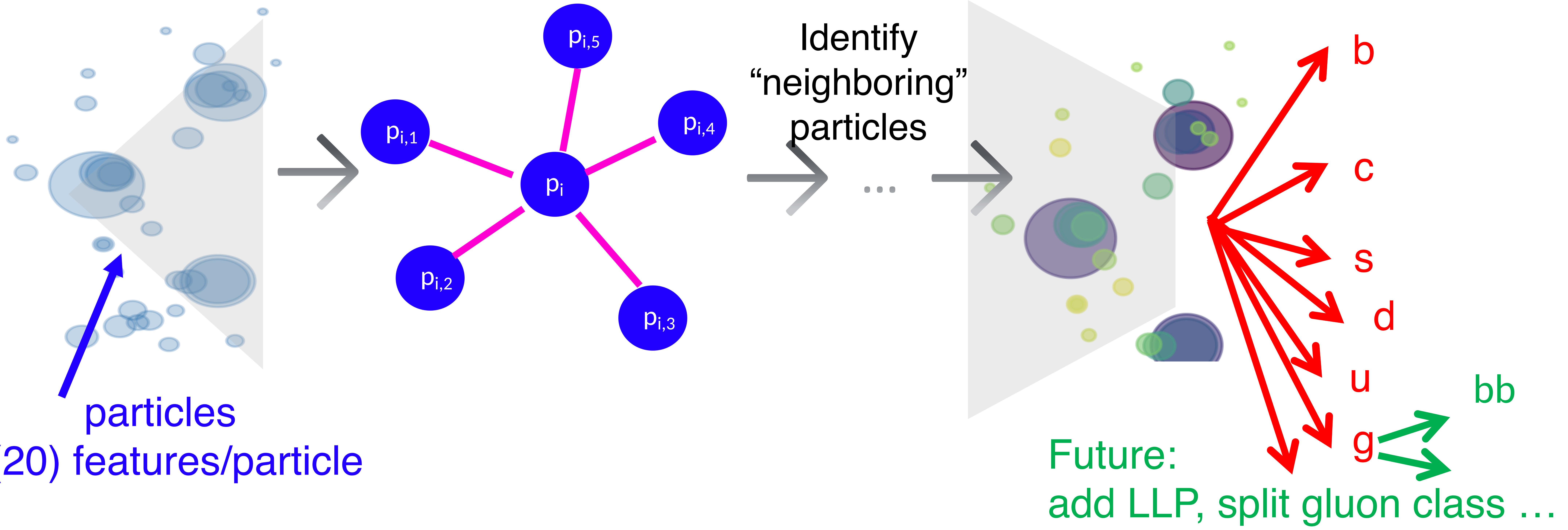


V. Cairo

PRD 101 056019 (2020)
EPJ C 82 646 (2022)

Particle cloud represented as a graph

Jet representation: Particle cloud i.e. unordered set of particles
Network architecture: Graph Neural Networks
Particles: vertices of graph; interactions b/w particles: edges of graph
Hierarchical learning approach: local → global structures



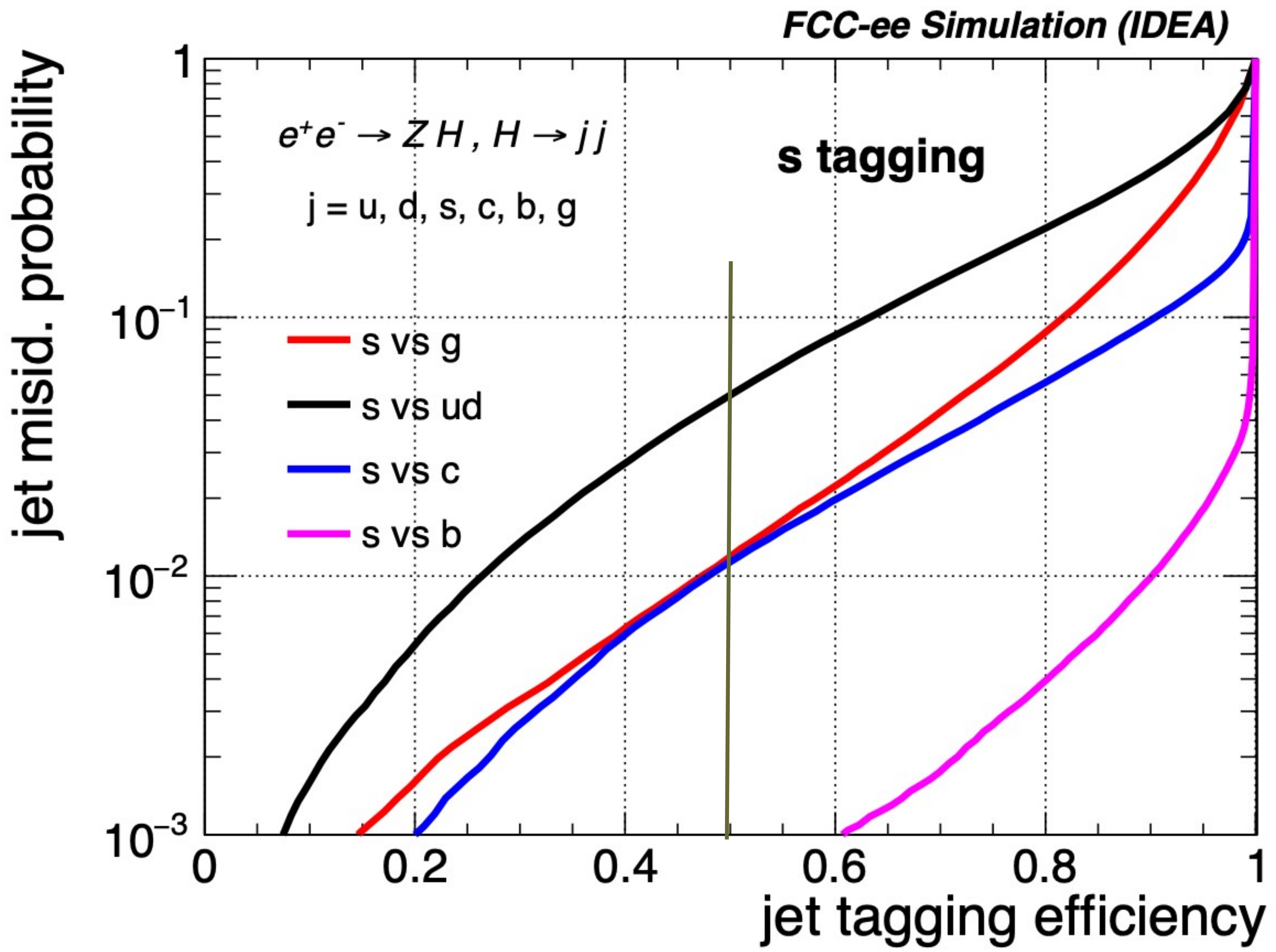
L. Gouskos

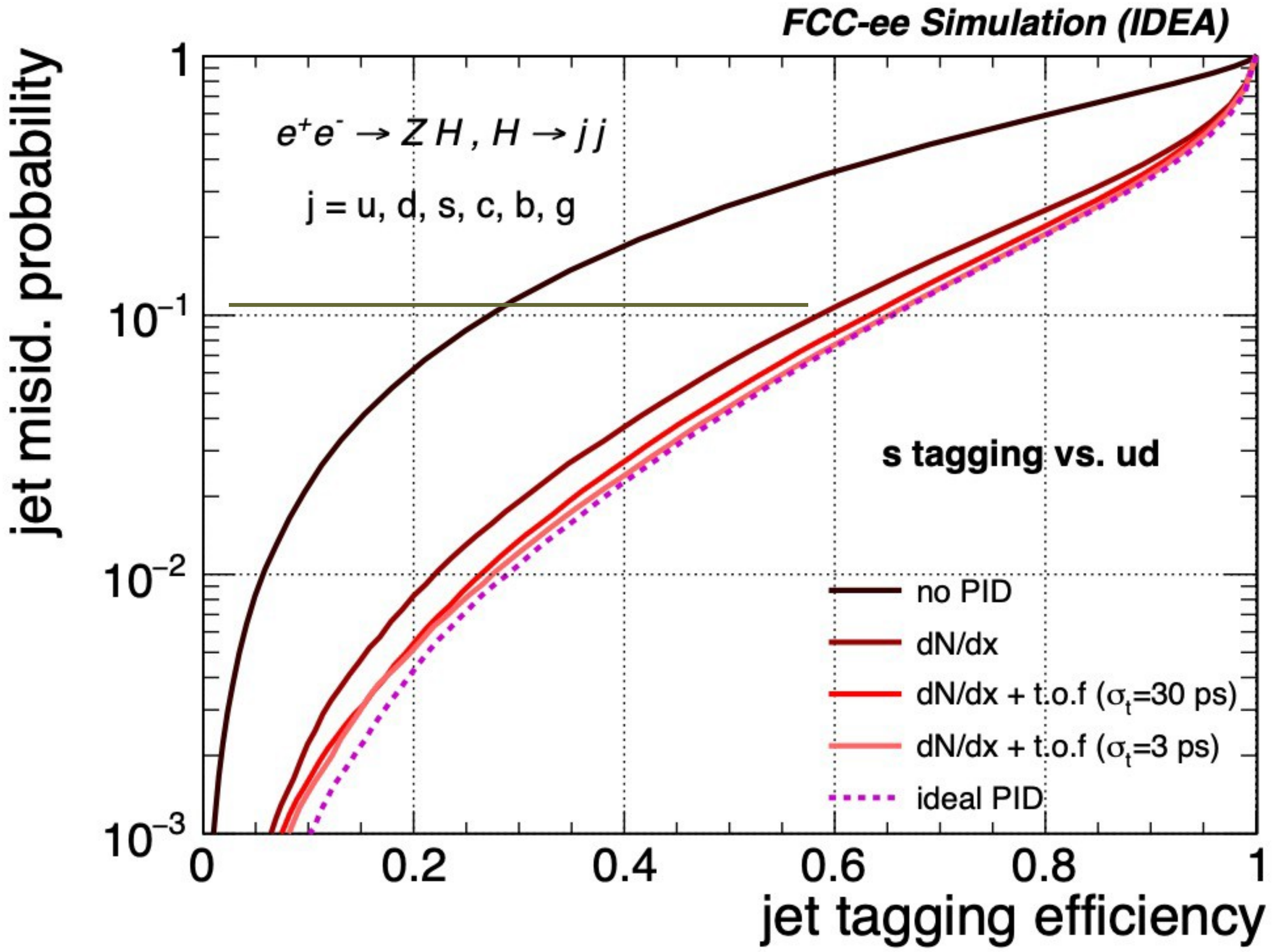
PRD 101 056019 (2020)
EPJ C 82 646 (2022)
L. Gouskos @FCC week

Strange tagging performance 1/2

IDEA-like detector and Particle cloud graph neural network (fast sim)

- Both TOF and dN/dx ($3\sigma < 30$ GeV) included as inputs
- No PID to PID with dN/dx → at fixed mistag, efficiency doubles



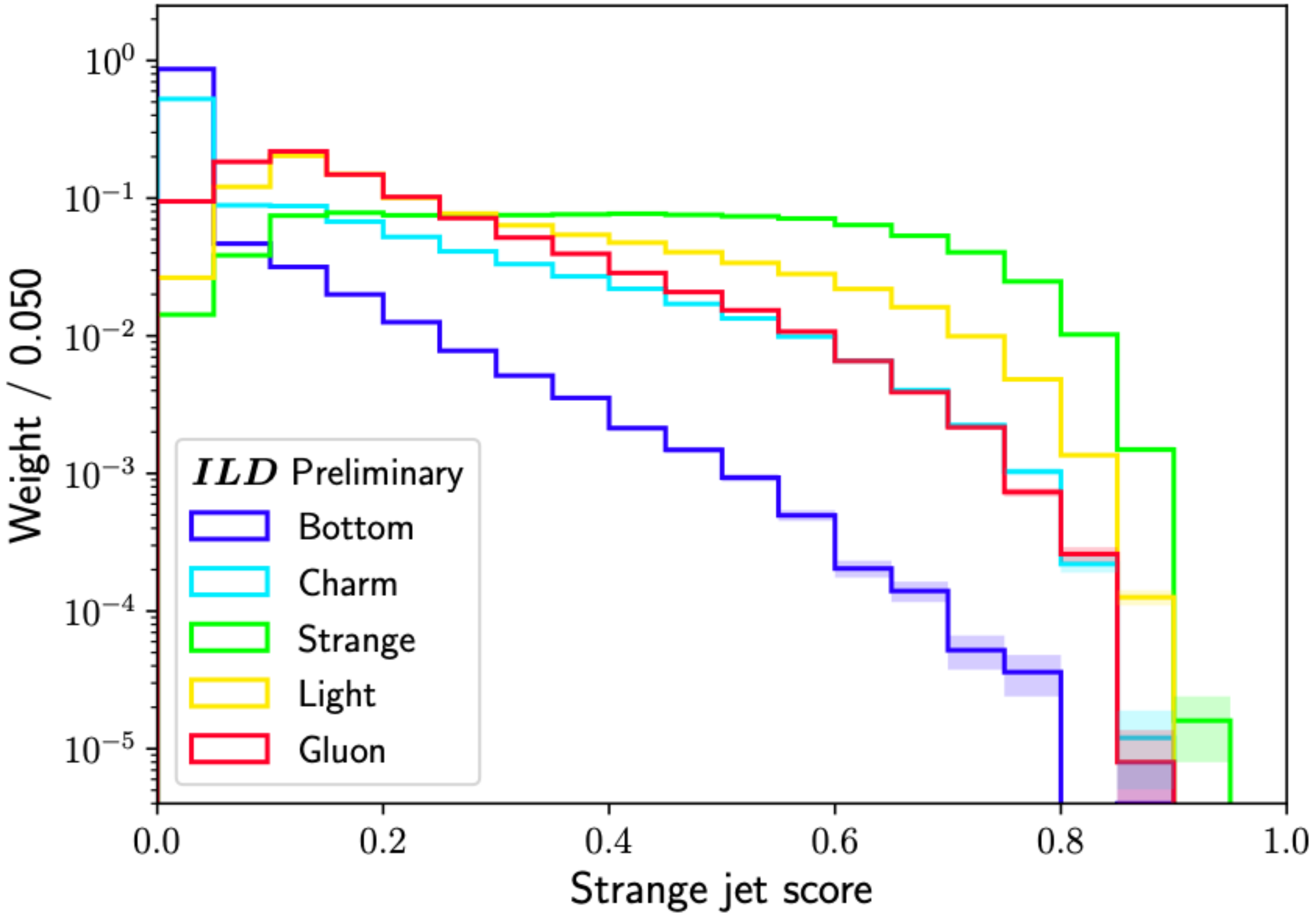


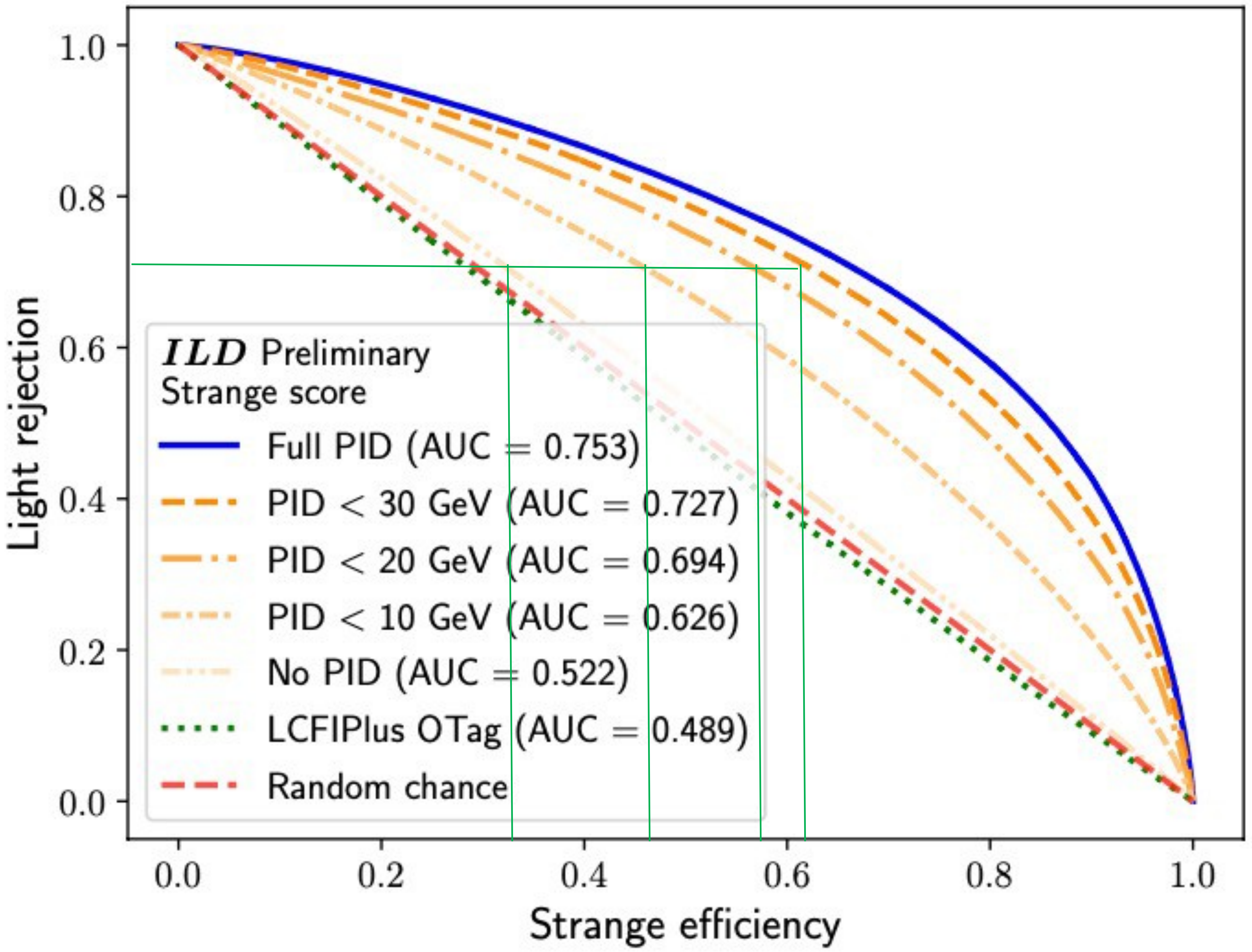
WP	Eff (s)	Mistag (g)	Mistag (ud)	Mistag (c)	Mistag (b)
Loose	90%	20%	40%	10%	1%
Medium	80%	9%	20%	6%	0.4%

Strange tagging performance 2/2

ILD-like detector with full simulation and Recurrent NN

- Includes PDG-based PID → assuming perfect detector capability
- At 50% s-tag efficiency, 90% background rejection
- No PID to PID < 10 (30) GeV → at fixed mistag, 1.5x (2x) efficiency

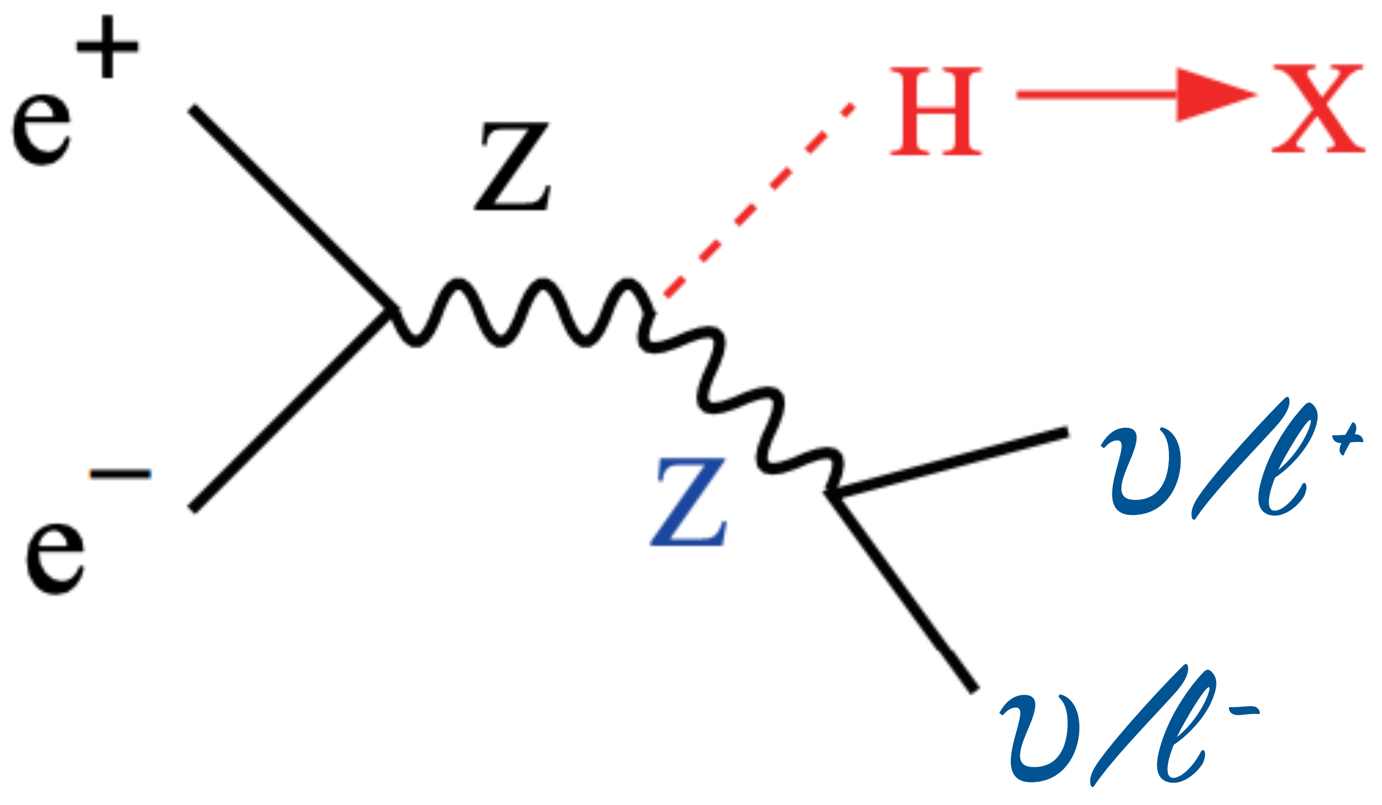


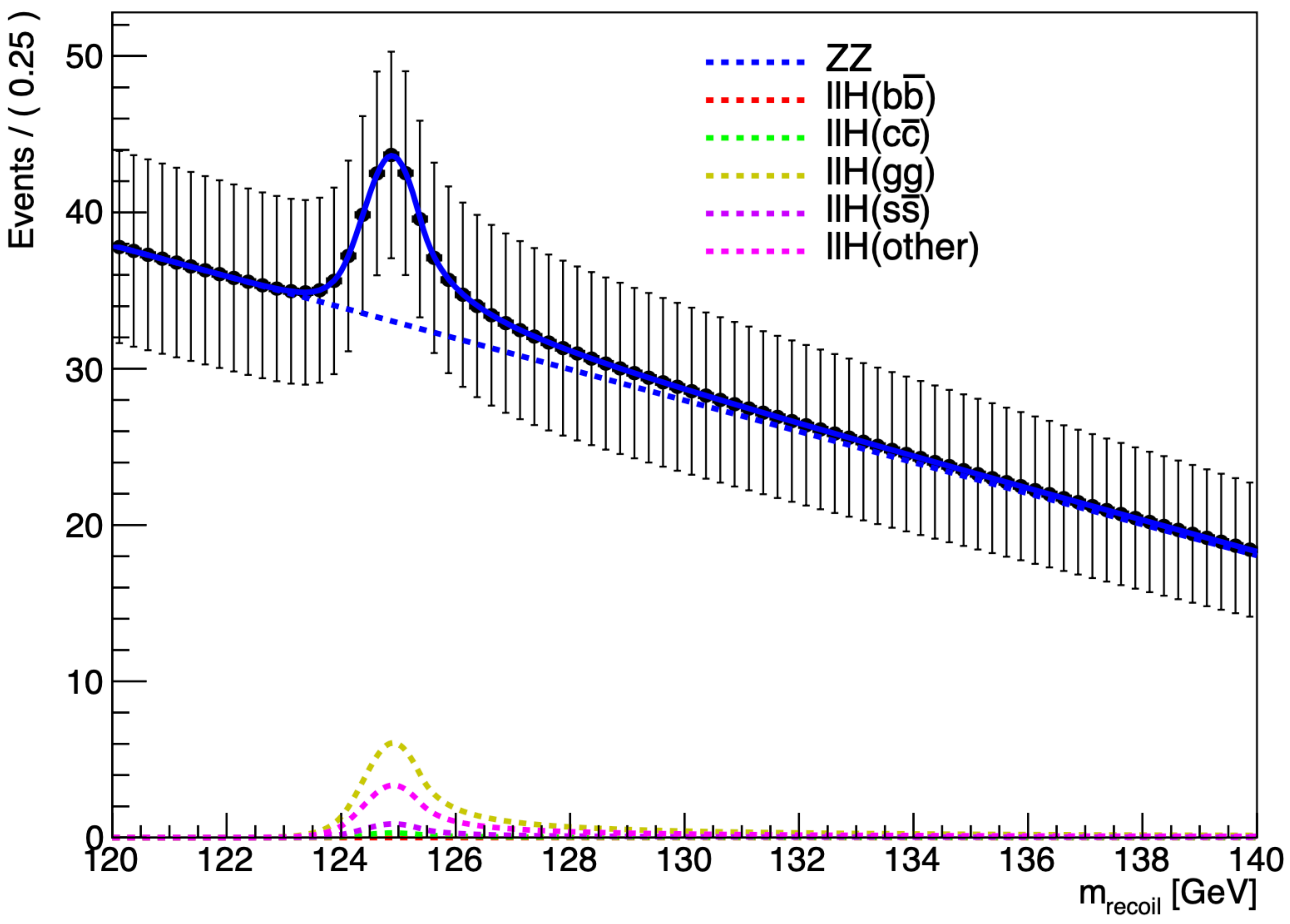


Analysis strategy to target H → ss

Exploit Z boson reconstruction in the ZH associated mode

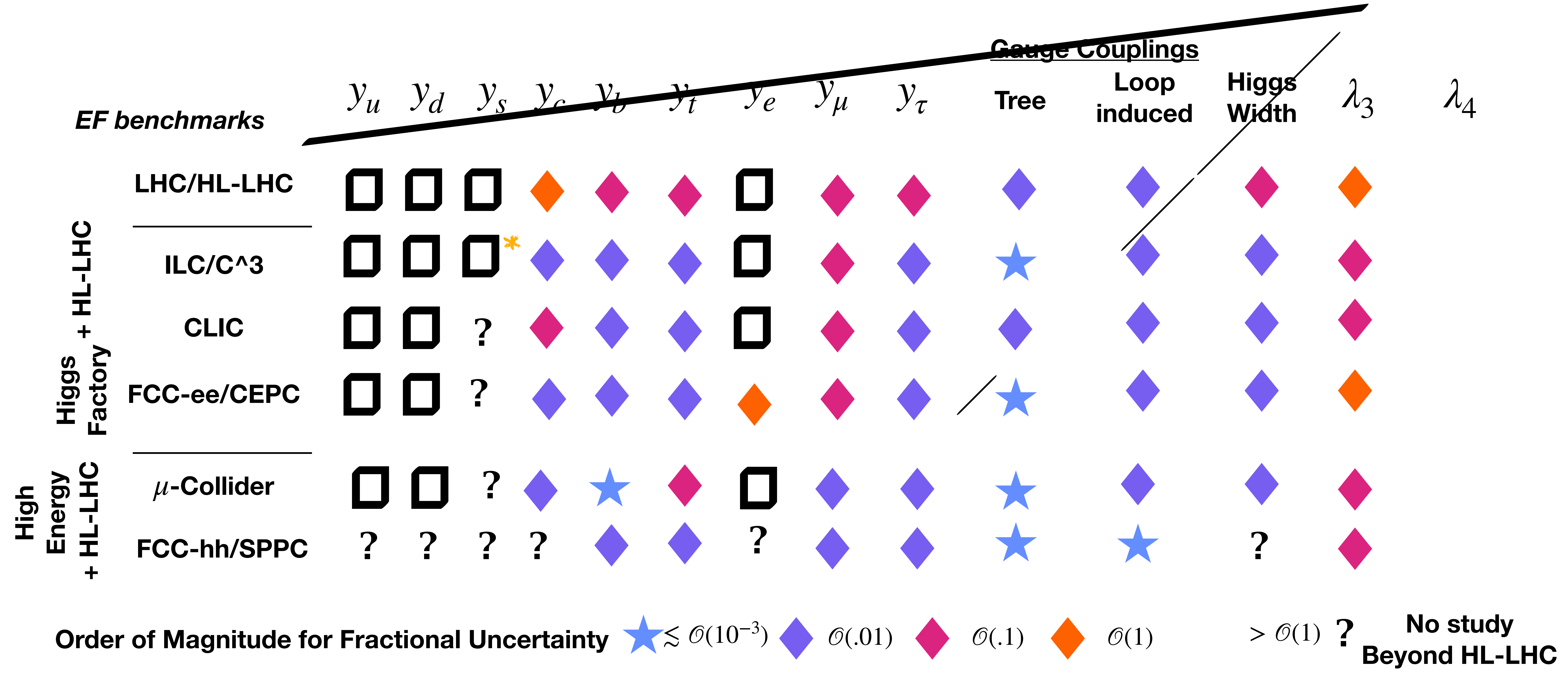
- At 250 GeV the total Zh cross section can be extracted independently of the Higgs boson's detailed properties by counting events with an identified Z boson
- Looking at 0 or 2 leptons Z decay modes



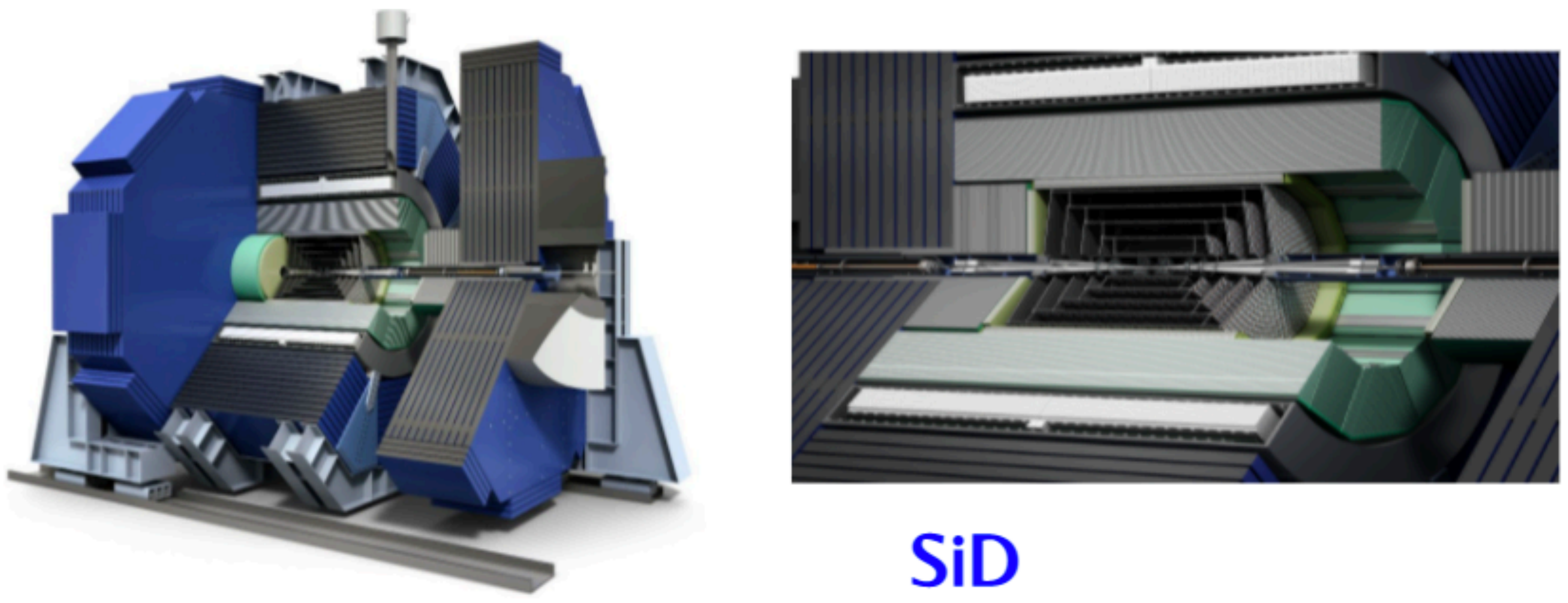


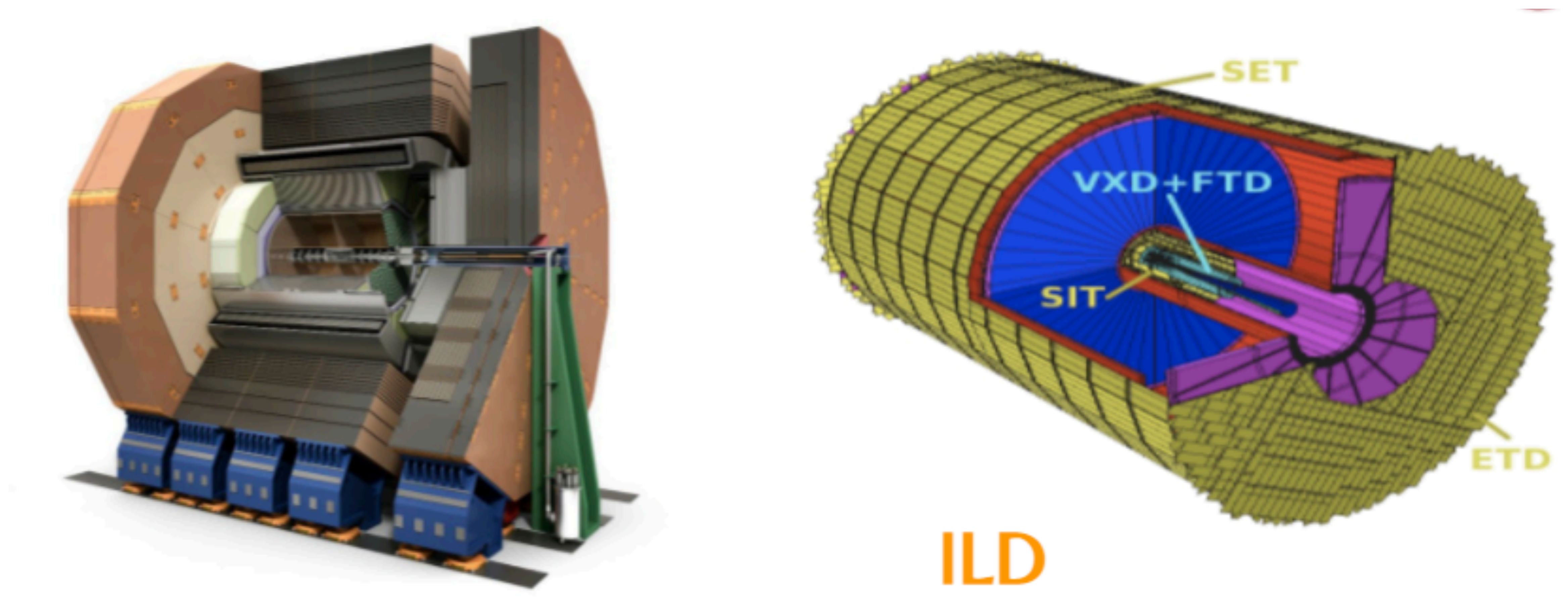
$$M_{\text{rec}} = \sqrt{(\sqrt{s} - E_Z)^2 - \vec{p}_Z^{\,2}}$$

Moving forward



Detectors design at lepton colliders





- Detector designs at e+e- colliders are converging to very similar strategies
  - Particle Flow reconstruction → plays a big part in many designs
- SiD like detector - Compact all silicon detector
- ILD like detector - Larger detector with Silicon+TPC tracker
  - Larger detector. Simulation and design work active in Europe / Japan
- IDEA detector - Using dual readout calorimeter, under study at CEPC/FCC-ee

ATLAS Twiki

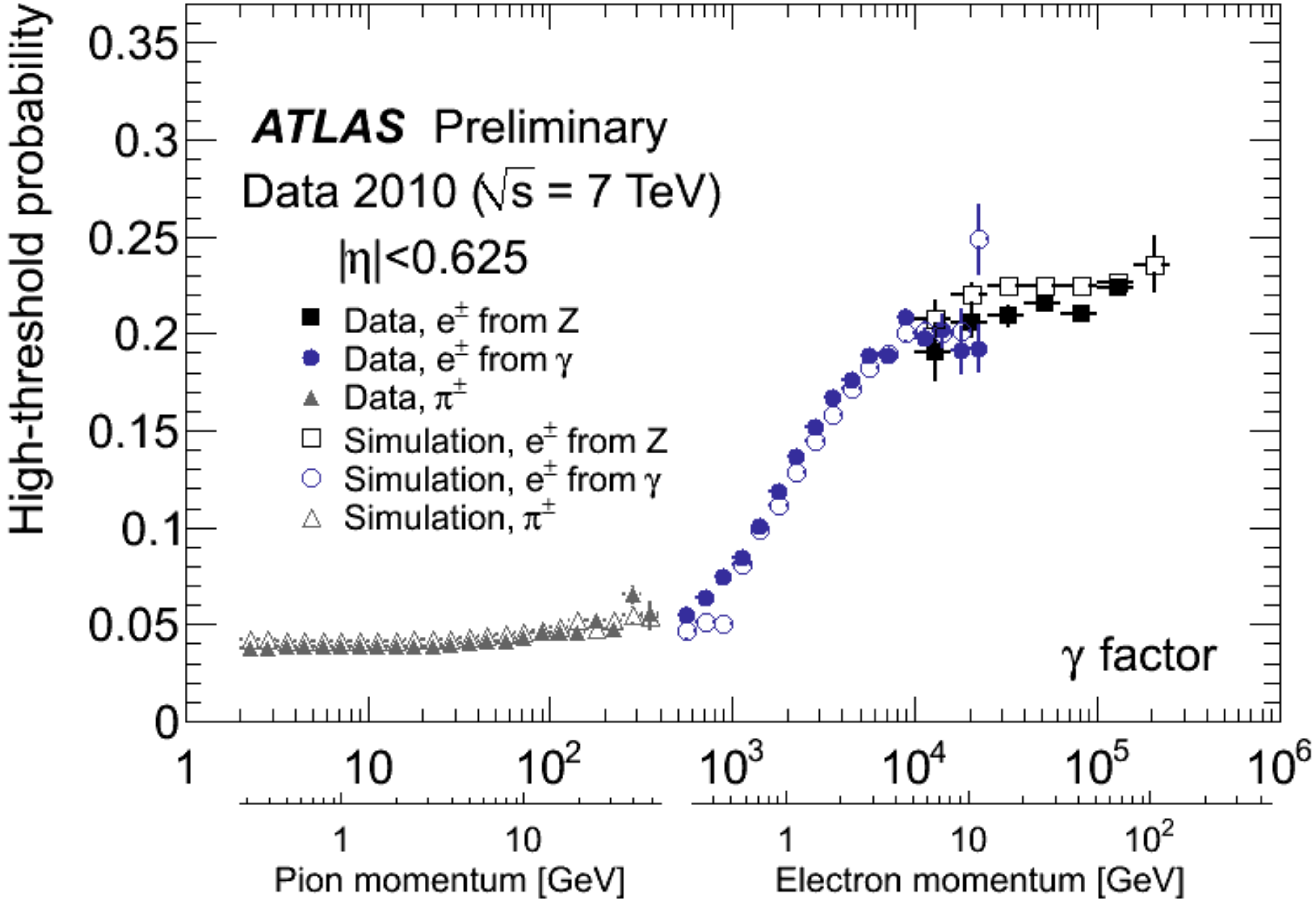
e/π separation with TR+dE/dx

e/π separation via detection of transition radiation photons

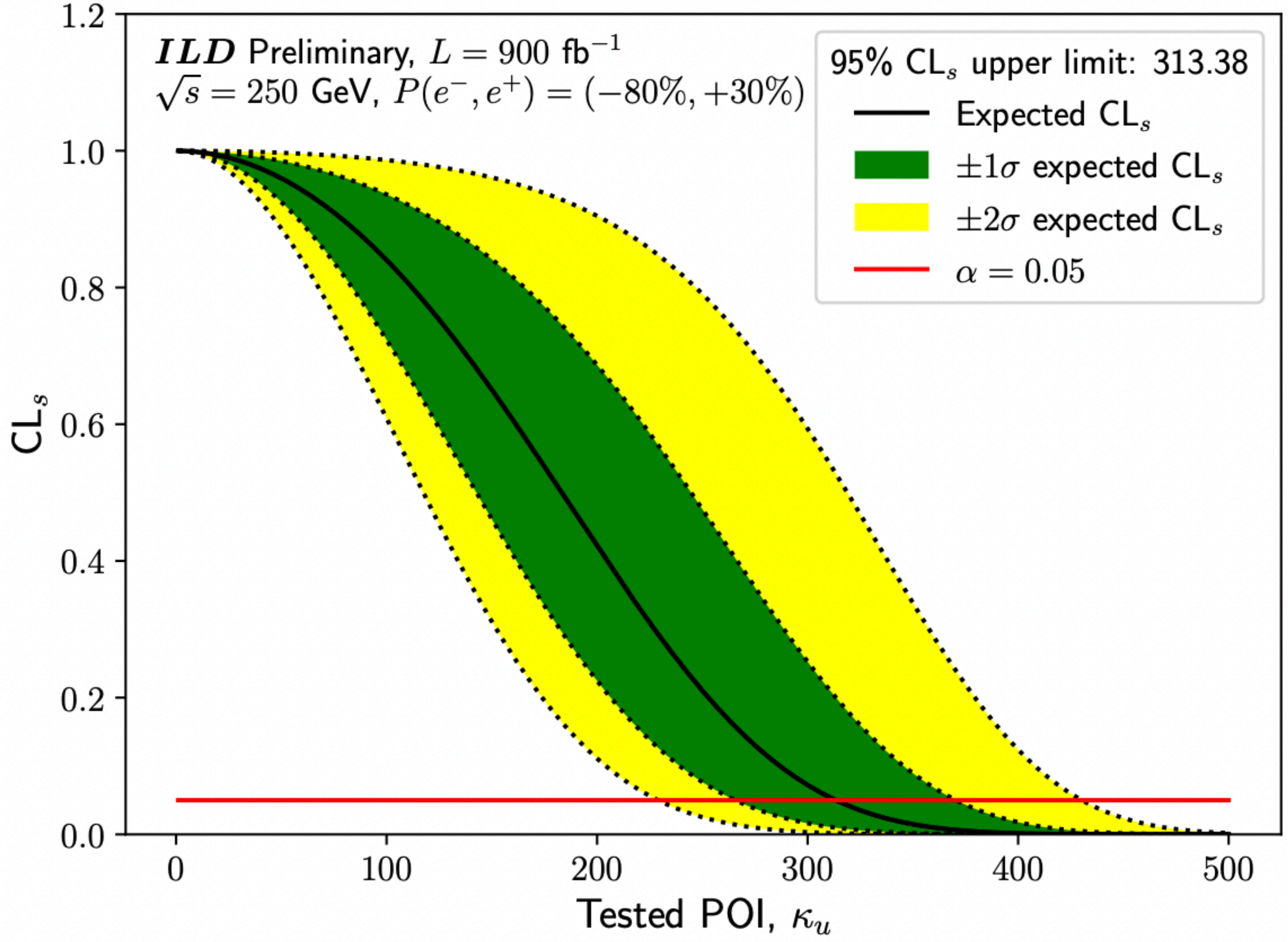
Transition radiation is emitted when a highly relativistic charged particle with a Lorentz factor $\gamma > 10^3$ traverses boundaries between materials of different dielectric constants.

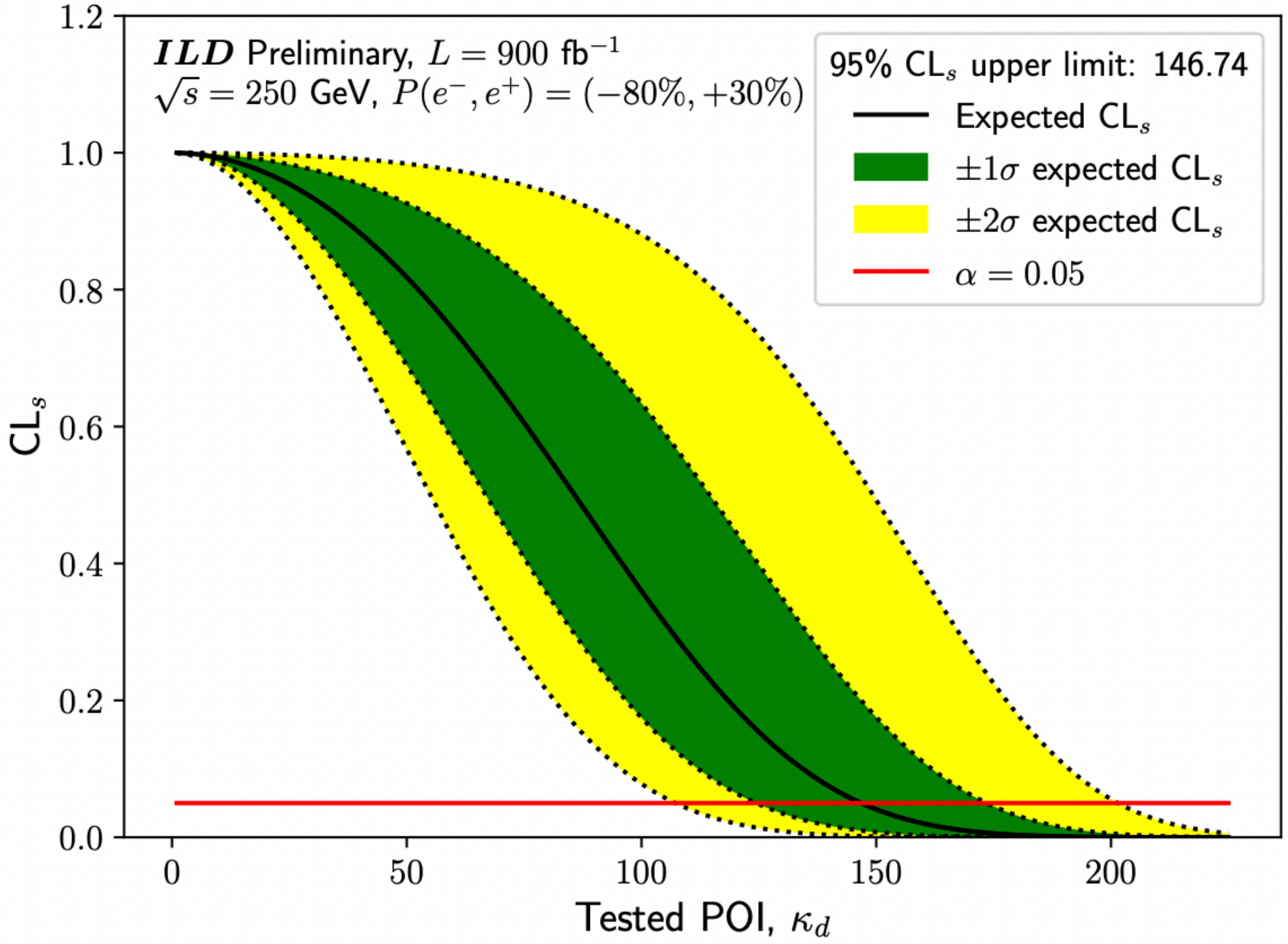
To achieve the best e/π separation, TR and dE/dx-based measurements are combined in a single likelihood function for a particle type.

The HT fraction is defined as the fraction of hits on track that exceed the high threshold (6-7 KeV)



Light Yukawa ?





Projected precision on λ as a function of $\sqrt{s}$

The impact of the centre-of-mass energy on the trilinear Higgs coupling measurement is studied by extrapolating the full simulation results done at 500 GeV and 1 TeV, done in a way that takes into account the sqrt(s) dependence both for the total cross-sections and the individual interference contributions.

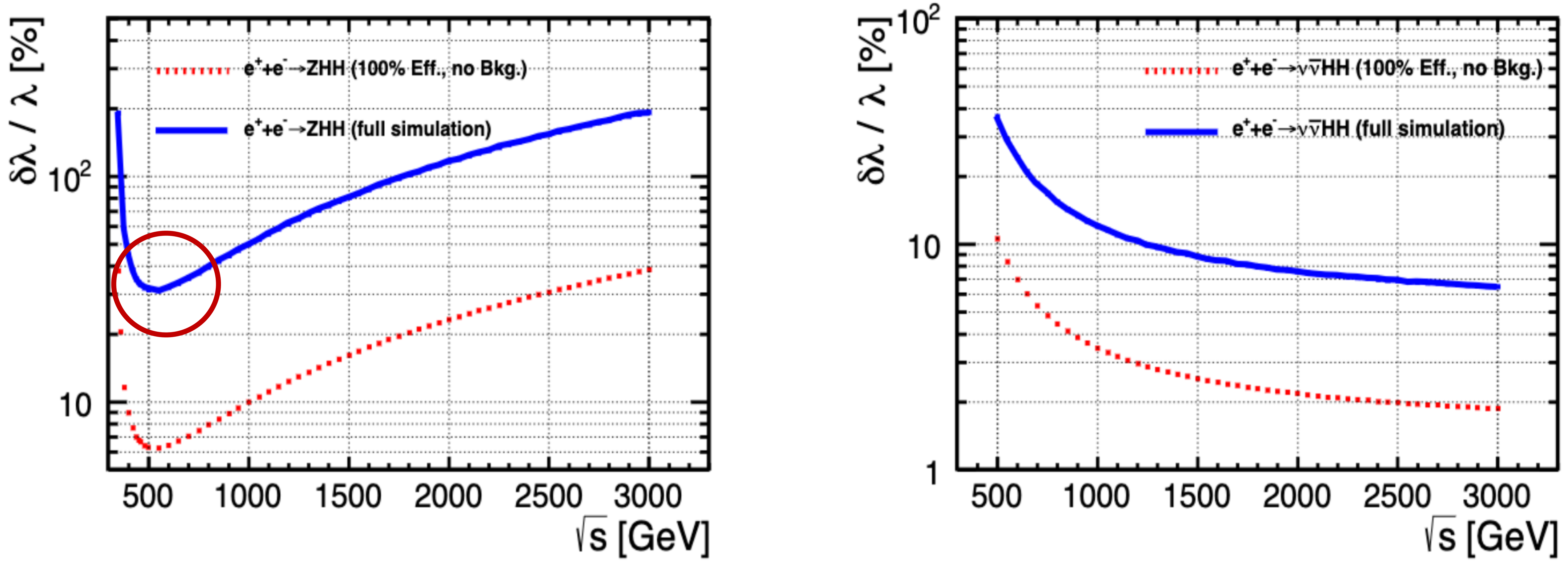
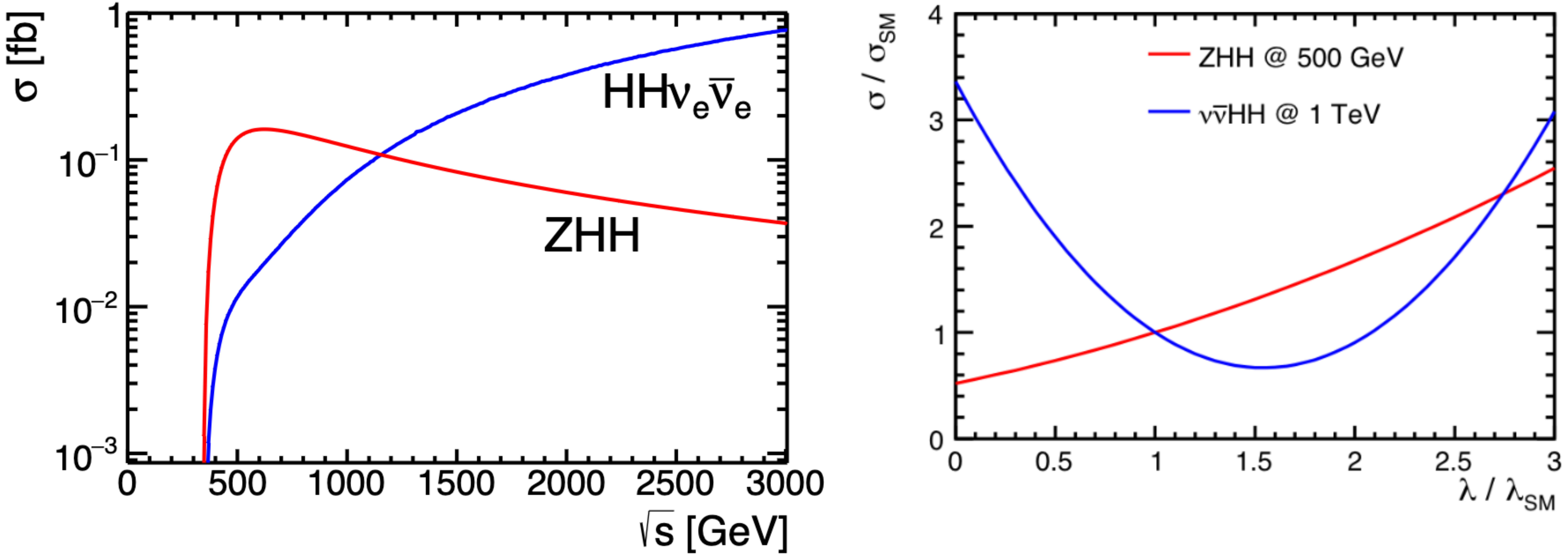


Figure 9.6: The expected precision of λ as a function of $\sqrt{s}$ for $e^+e^- \rightarrow ZHH$ (left) and for $e^+e^- \rightarrow \nu\bar{\nu}HH$ (right). The two lines in each plot correspond to the ideal situation using Monte Carlo truth (red/dotted) and the realistic situation (blue/solid) using current full-simulation analyses. The same integrated luminosities of 4 ab^{-1} is assumed at all values of $\sqrt{s}$.

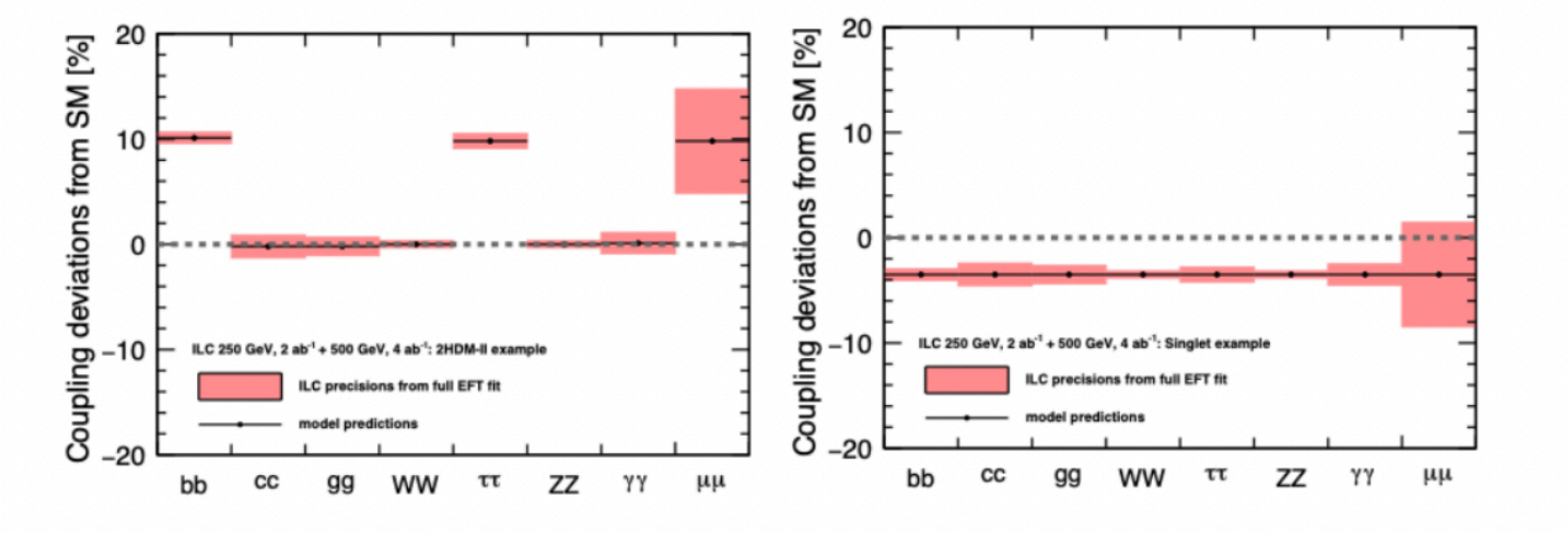
HH Cross Section Dependence on κ_λ



An example of complementarity

arXiv:2203.07622

Pattern of deviations associated with a particular parameter point in a 2HDM model is quite different from a singlet model



- 2HDM with a 600 GeV mass scale and a singlet with a 2.8 TeV scalar. Both of these are clearly out of the direct search reach of circular e+e– Higgs factories despite having the precision to test them via Higgs couplings
- High energy collisions would be then required to study such new particles

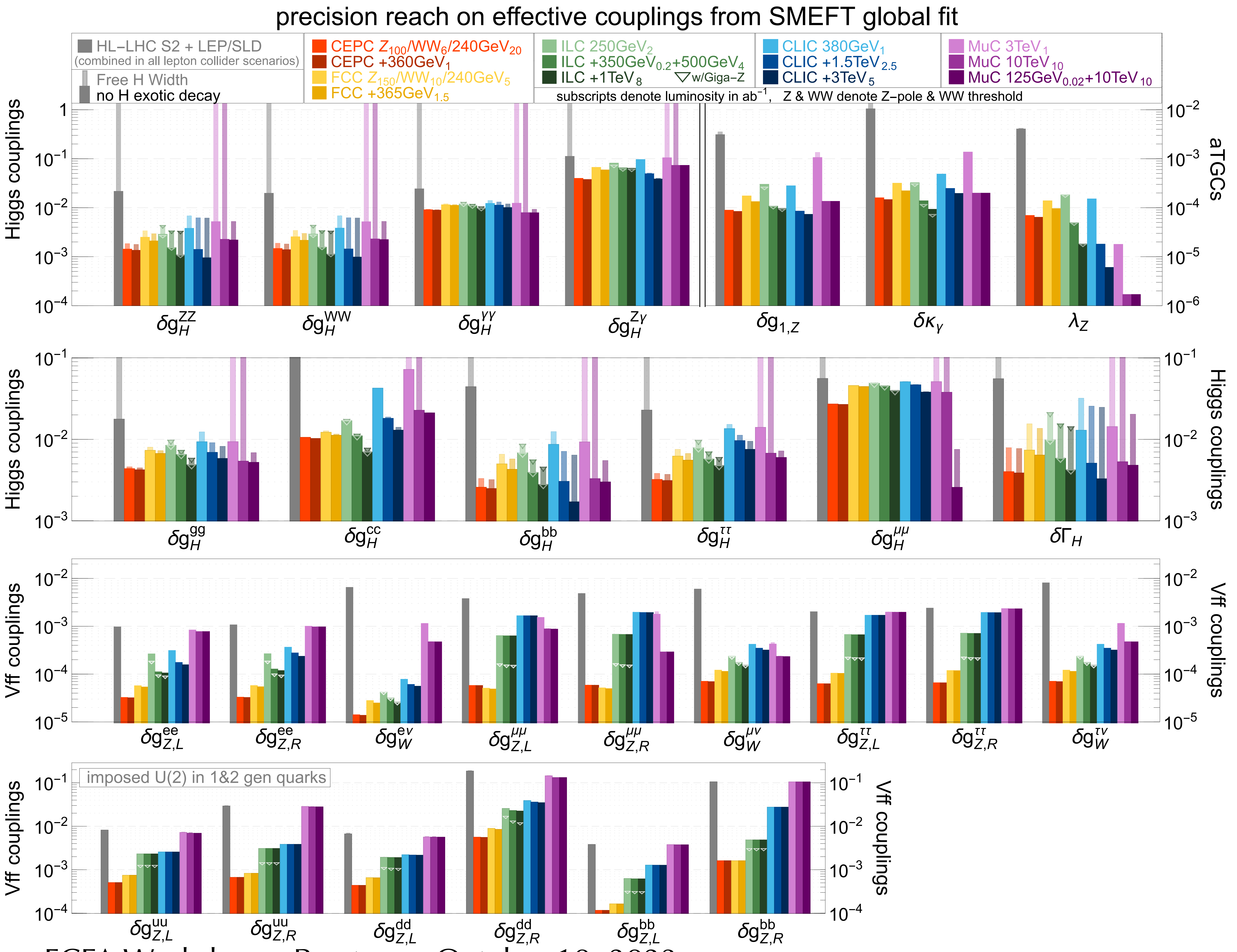
Various machines to consider

Collider	Type	$\sqrt{s}$	$\mathcal{P}[\%]$ e^-/e^+	$\mathcal{L}_{\text{int}}$ ab^{-1}
HL-LHC	pp	14 TeV		6
ILC and C^3	ee	250 GeV	$\pm 80/\pm 30$	2
c.o.m almost		350 GeV	$\pm 80/\pm 30$	0.2
similar		500 GeV	$\pm 80/\pm 30$	4
		1 TeV	$\pm 80/\pm 20$	8
CLIC	ee	380 GeV	$\pm 80/0$	1
CEPC	ee	M_Z		60
		$2M_W$		3.6
		240 GeV		20
		360 GeV		1
FCC-ee	ee	M_Z		150
		$2M_W$		10
		240 GeV		5
		$2\ M_{top}$		1.5
muon-collider (higgs)	$\mu\mu$	125 GeV		0.02

Collider	Type	$\sqrt{s}$	$\mathcal{P}[\%]$. e^-/e^+	$\mathcal{L}_{\text{int}}$ ab^{-1}
HE-LHC	pp	27 TeV		15
FCC-hh	pp	100 TeV		30
LHeC	ep	1.3 TeV		1
FCC-eh		3.5 TeV		2
CLIC	ee	1.5 TeV	$\pm 80/0$	2.5
		3.0 TeV	$\pm 80/0$	5
High energy muon-collider	$\mu\mu$	3 TeV		1
		10 TeV		10

Global fit results - from EF04

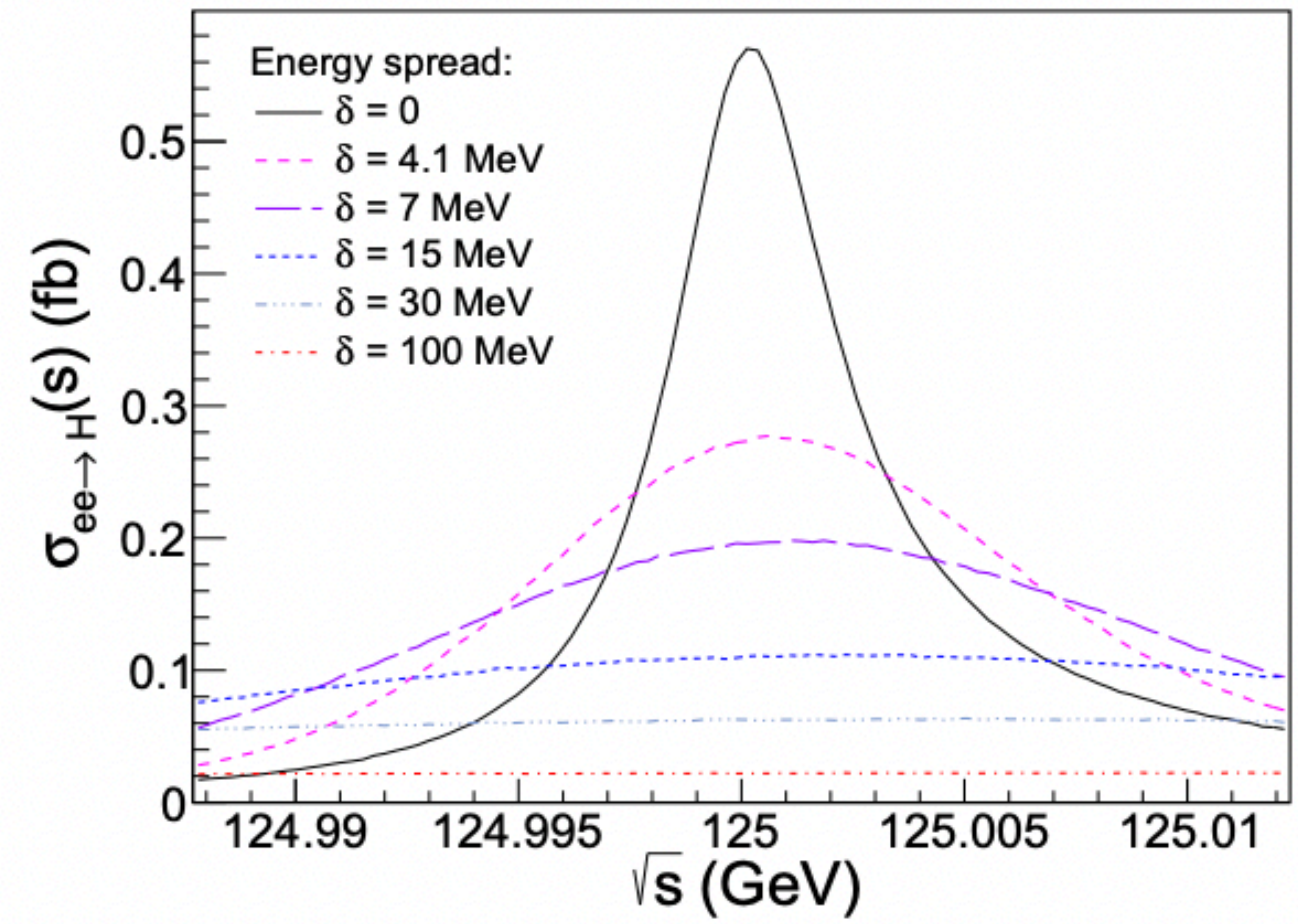
- Solid has no exotic Higgs decays, the light fits the width

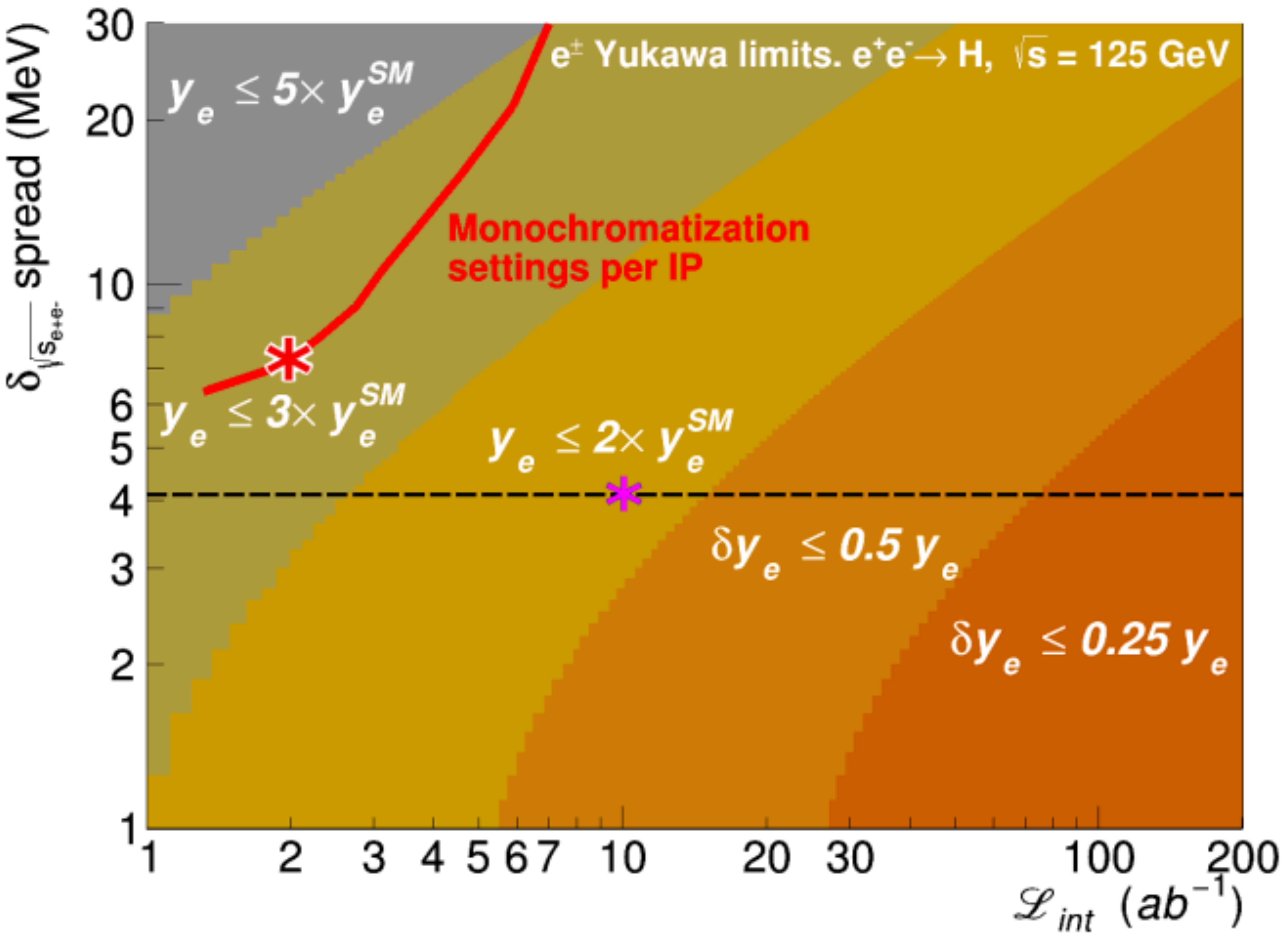


Higgs-electron Yukawa

Electron Yukawa at FCC-ee with a dedicated 4 years run at the Higgs mass

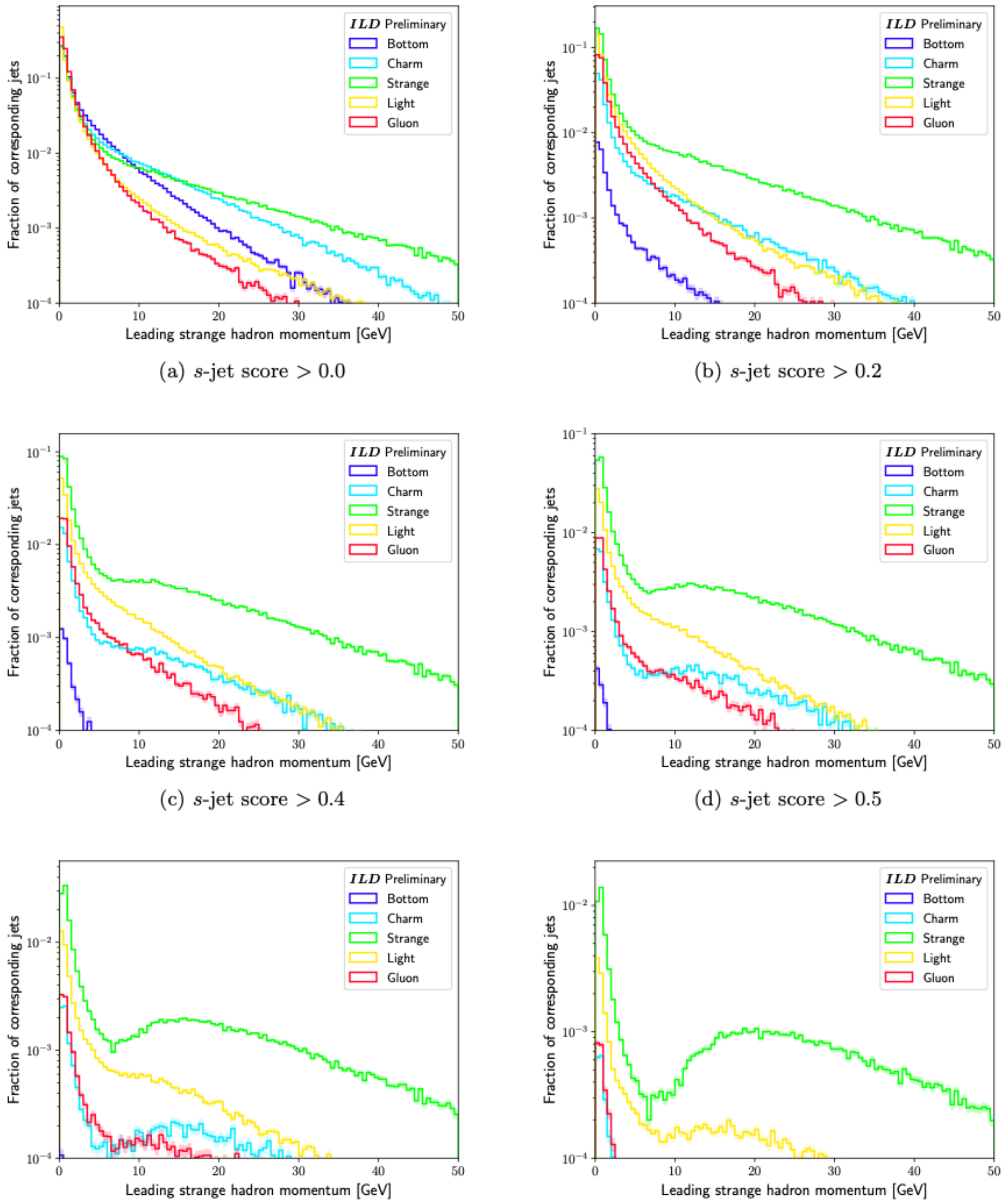
$\kappa_e < 1.6$ at 95% CL





Kaons in jets

Leading Kaons energy distribution



(a) s-jet score > 0.0

(b) s-jet score > 0.2

(c) s-jet score > 0.4

(d) s-jet score > 0.5

(e) s-jet score > 0.6

(f) s-jet score > 0.7