WG3: BSM @ HL-LHC & HE-LHC

Workshop on the physics of HL-LHC, and perspectives at HE-LHC
CERN - 30 October 2017

WG3 conveners

EX: Monica D'Onofrio (ATLAS), Keith Ulmer (CMS), Xabier Cid Vidal (LHCb)
TH: Patrick Fox, Riccardo Torre

Riccardo Torre
CERN, INFN Genova

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CERN

Plans for BSM WG3

- Monica D’Onofrio – Direct searches for new physics
- Keith Ulmer - Challenges and needs for BSM searches: experimental perspective
- Patrick Fox – Summary talk

- Supersymmetry (TH: Plehn, Krauss, Baer, EXP: Meloni, Della Porta)
- Long Lived Particles (TH: Curtin, EXP: Griso, Alimena, Sierra)
- Flavor (TH: Bishara, Greljo, You, EXP: De Aguiar Francisco, Klein)
- Higgs (TH: McCullough, EXP: Willocq, Hoepfner)
- SM EFT (TH: Farina, Wulzer)
- Dark Matter (TH: Haisch, Heisig, Westhoff, EXP: Magnan)
- Resonances, heavy fermions etc. (TH: Thamm, Barducci, Iyer, Ruiz, EXP: Chekanov)
- Axion-like particles (TH: Redigolo)
- Hidden sectors, Neutral naturalness (TH: Tesi, Sanchis Lozano, EXP: Borsato)

Some of these ideas will be discussed in the session “Discussion of submitted abstracts and other ideas” taking place on Wednesday at 12:00

All these and future studies will be collected in a Yellow Report to be submitted next year

(some of the) open questions

- Origin of the Higgs mechanism (Naturalness problem)
- Unification of forces
- Origin of matter/anti-matter asymmetry (Baryogenesis)
- Flavor (Yukawas, masses, flavor violation)
- Neutrino masses and mixings
- Strong CP problem
- Origin of Dark Matter/Dark Energy
- Inflation (why is our universe so homogeneous and isotropic)
- Gravity (quantum gravity, string theory)

Many of this question have or may have a relation with the electroweak scale

↓

We try to address them exploring these energies at colliders

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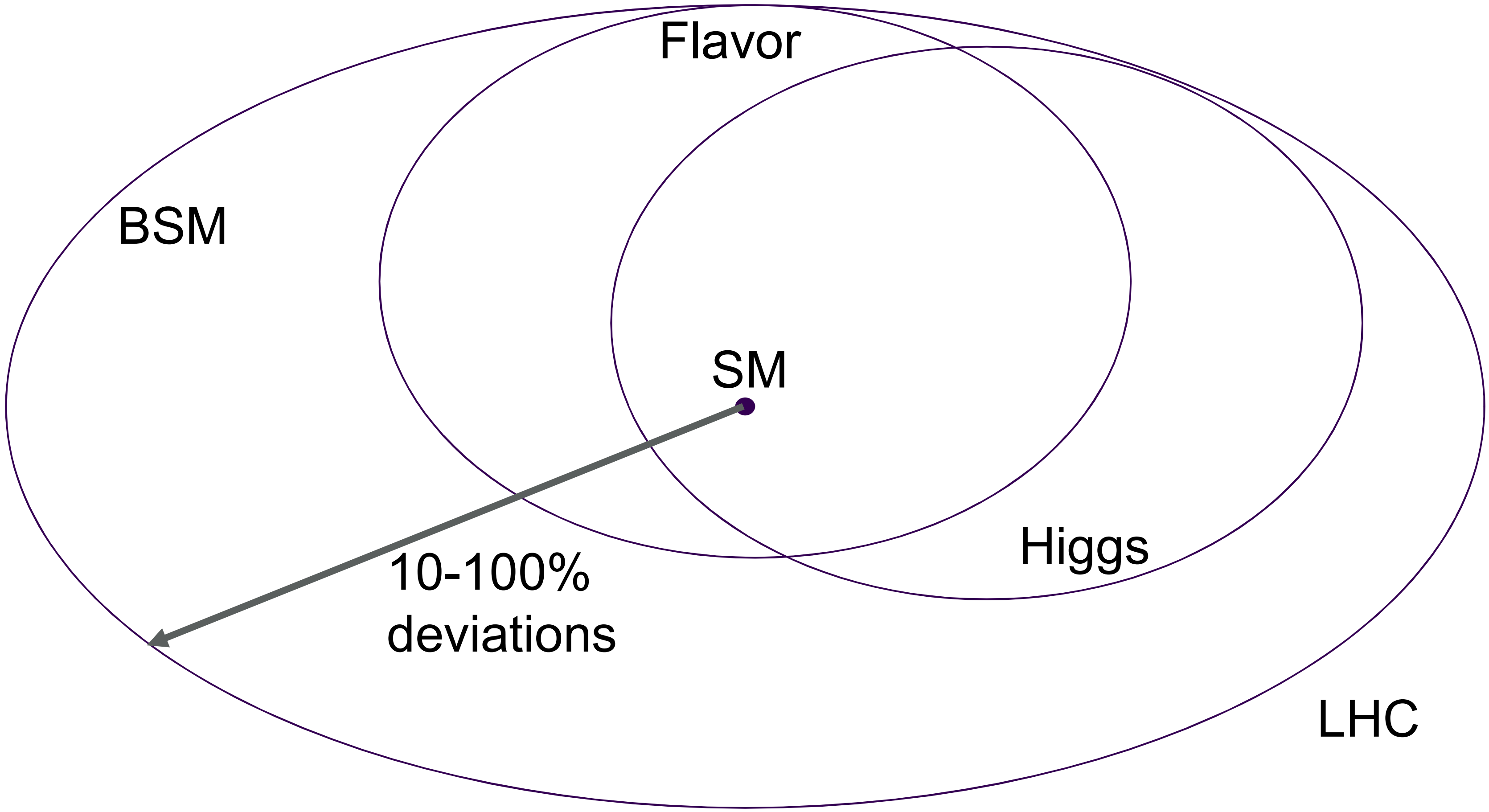
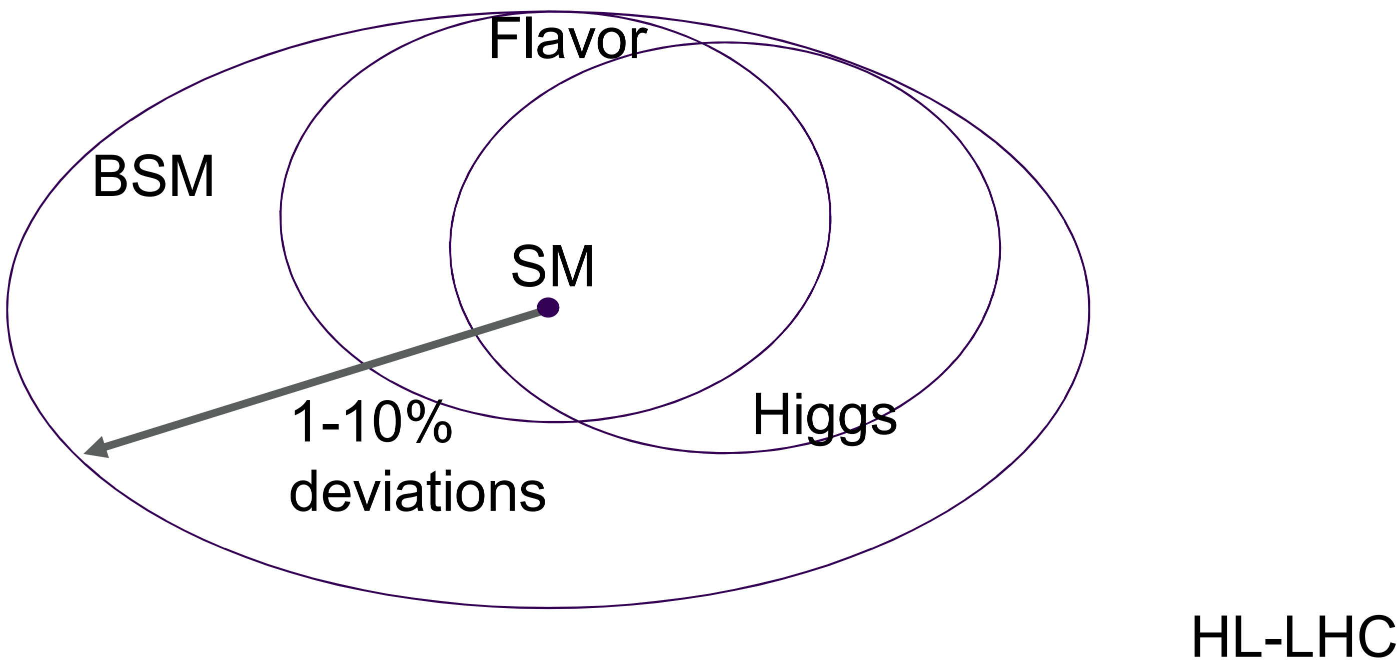
LHC is one of the biggest opportunities for the next >20-30 years to address these questions

Theory landscape/WGs interplay



- There is clearly a strong interplay between SM (WG1), Higgs physics (WG2), BSM (WG3) and Flavor (WG4)
- We need to exploit this interplay as much as possible since we have common interests and a common goal: shrink the ellipses as much as possible and possibly find new physics

Theory landscape/WGs interplay



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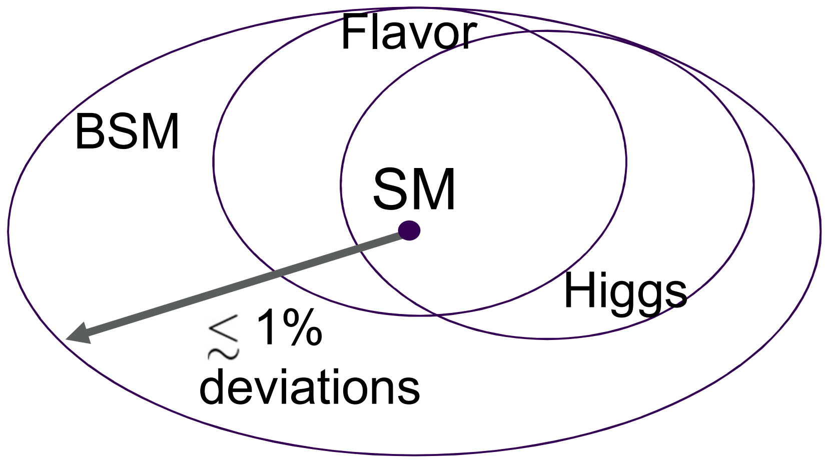

HE-LHC

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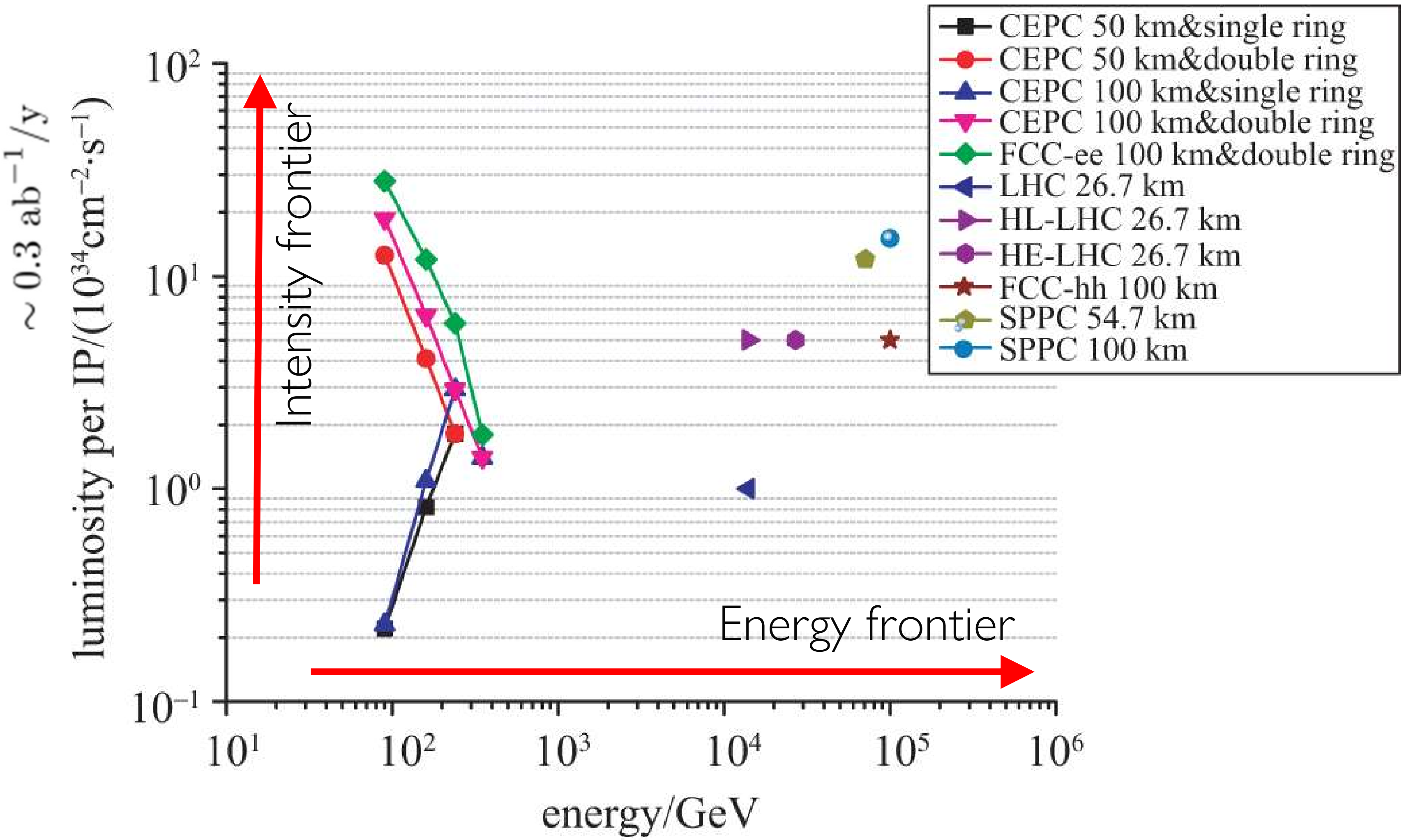
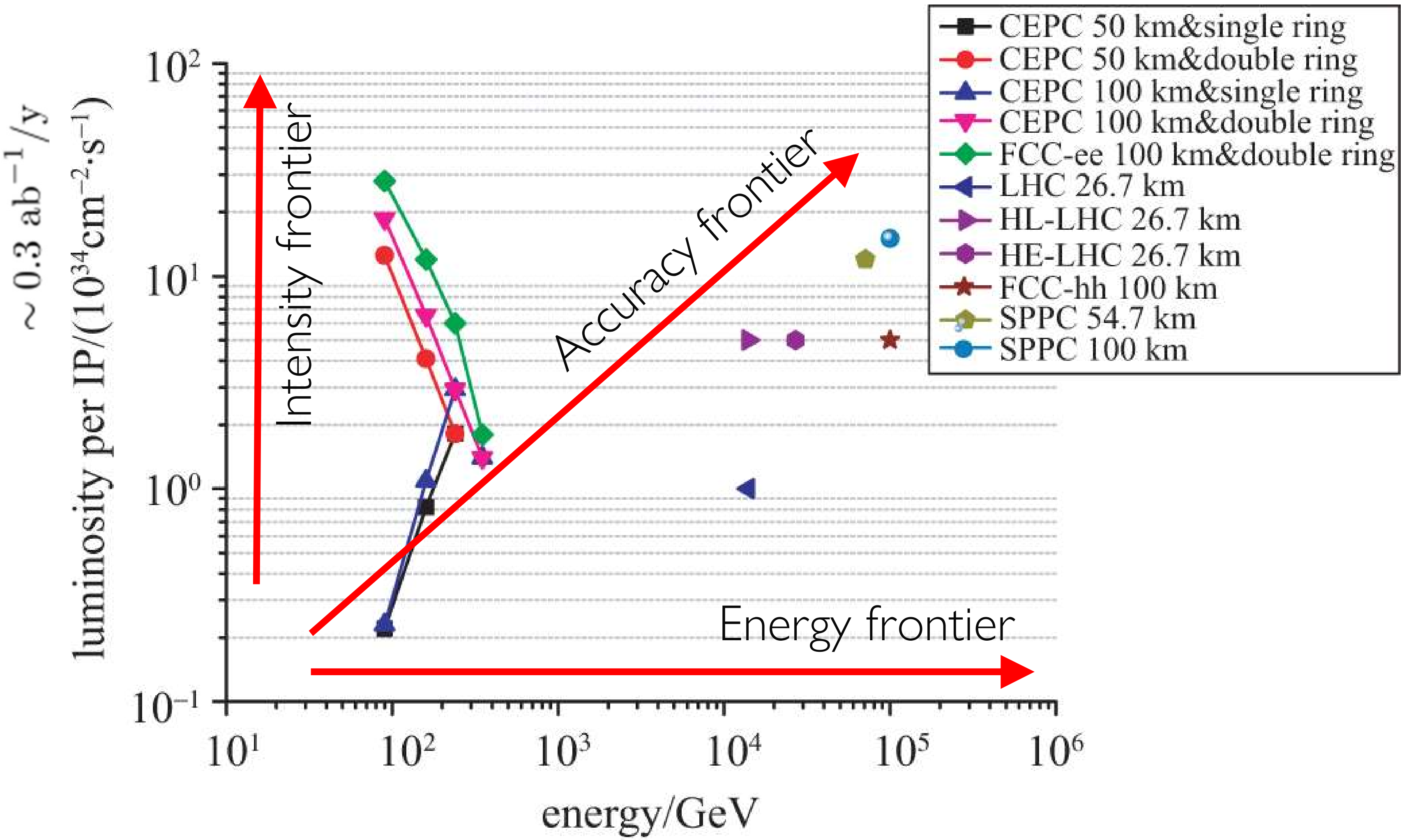
Energy, intensity, and accuracy frontiers



Energy and intensity frontiers usually considered complementary, but orthogonal

Energy, intensity, and accuracy frontiers



Real interplay is given by the accuracy frontier, which is not orthogonal to them

Energy, intensity, and accuracy frontiers

Energy frontier: increase sensitivity to high mass (not necessary strongly coupled) new physics that can be produced on-shell

- Examples are heavy SUSY particles, resonances, top-partners, minimal DM, etc.

Intensity frontier: increase sensitivity light and weakly coupled new physics

(precision that does not necessary profit from increasing energy)

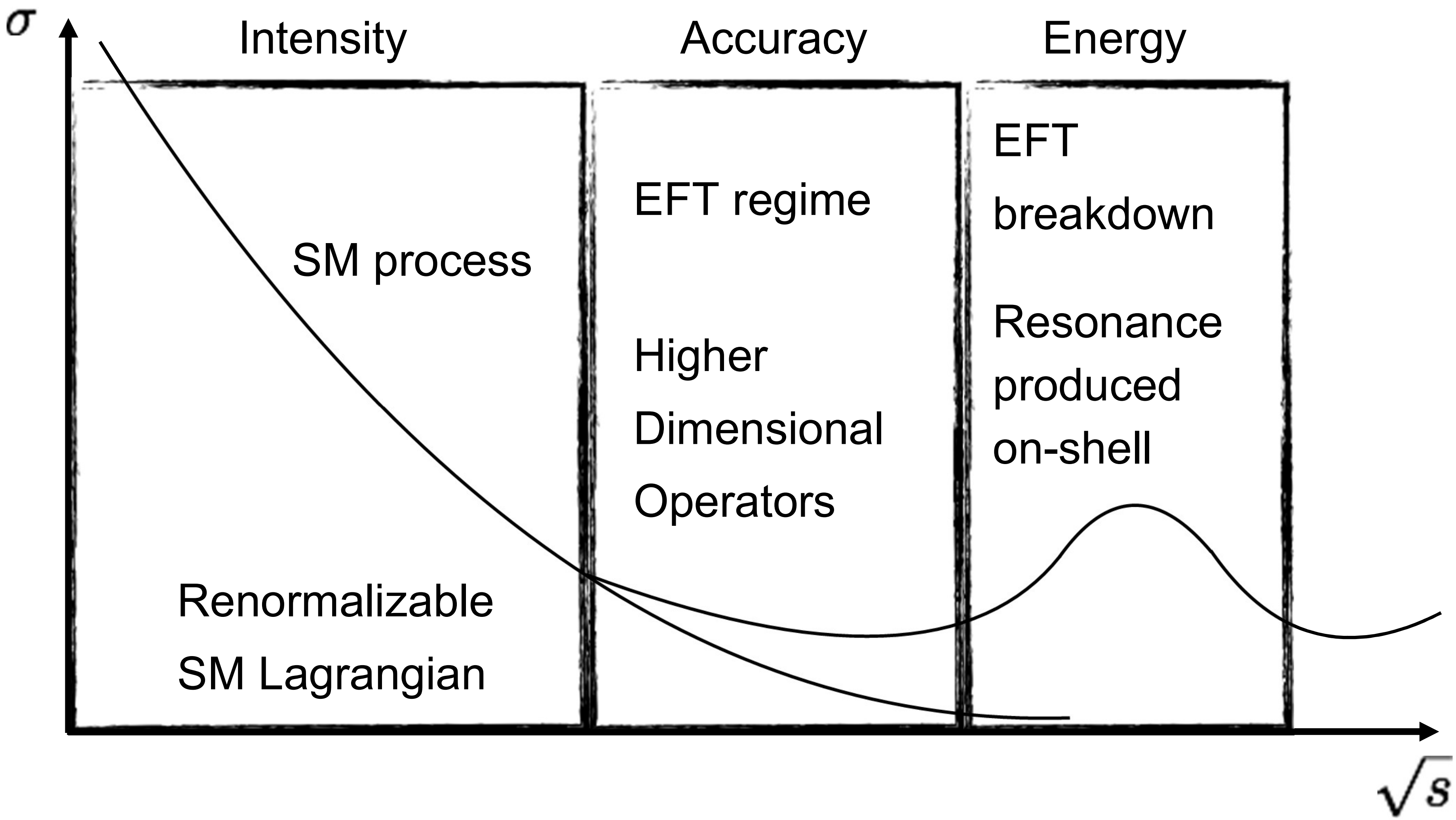
- Examples are Higgs couplings (including self coupling), TGCs, flavor observables, light and weakly coupled particles, weakly interacting DM, etc.

Accuracy frontier: increase sensitivity to heavy (possibly strongly coupled) new physics that cannot be produced on-shell

(precision that clearly profits from increasing energy)

- Examples are effective operators that lead at rates growing with the energy more than the SM, leading to deviations on the tails of distributions

New physics: a pictorial representation



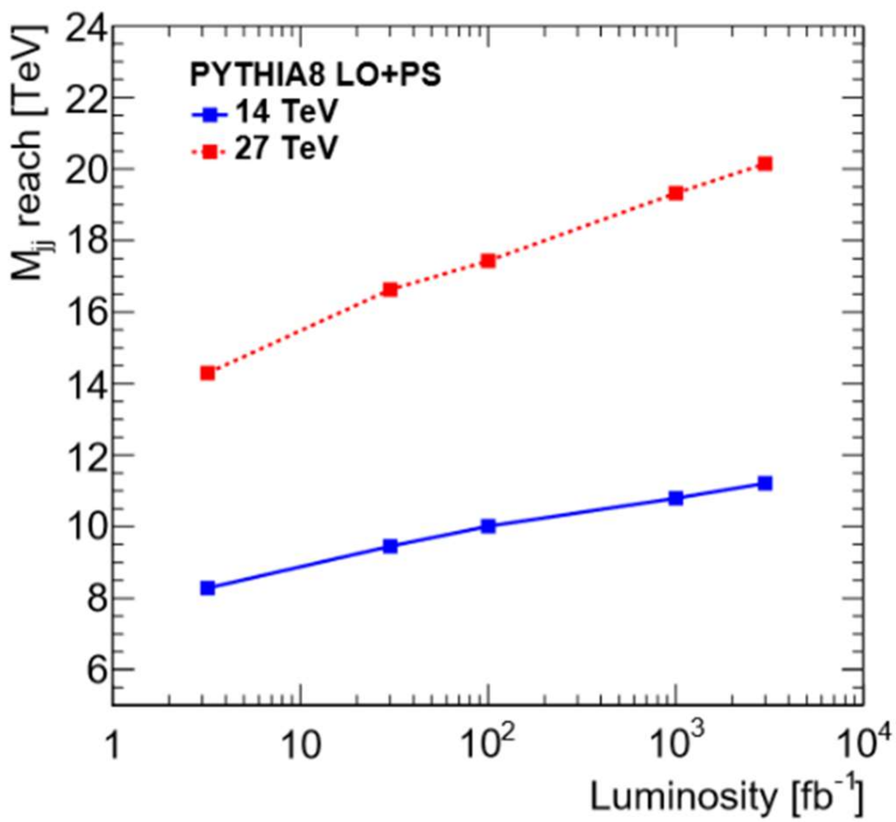
The strategy

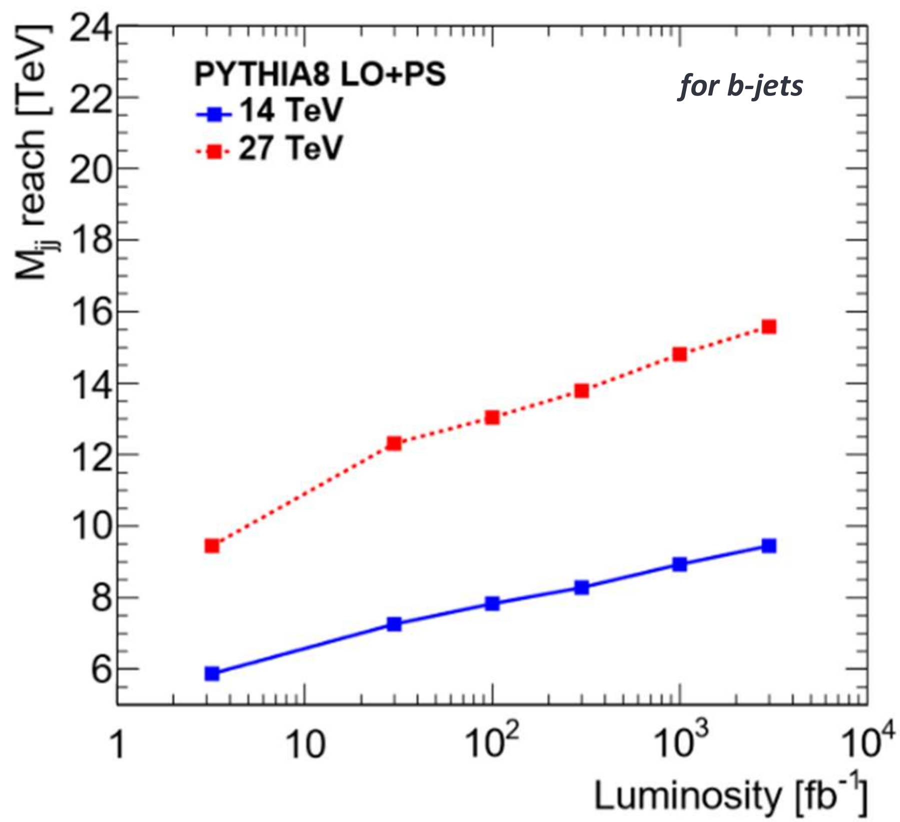
- HL-LHC is a great opportunity to address some of the questions mentioned above
- Experimentally challenging to tackle each possible scenario offering a solution to these questions
- Focus on relatively broad scenarios, with rather generic expectations
- Make use of consistent EFT approach when possible, i.e. new physics is heavy and/or strongly coupled (example: Composite models)
- For light and relatively weakly coupled new physics make use of simplified models that help keeping under control the number of parameters (example: natural SUSY simplified models, etc.)
- Also carry on specific “signature based” analysis with minimum theoretical bias: simple final states can be studied rather “model independently” and have impact on very different new physics models
- Important to think of new strategies that are optimized for HL-LHC and maybe have been overlooked because not optimal at LHC (examples: different triggers, more statistically convenient to look at final states with ISR, e.g. Higgs+j, etc.)
- In case of a deviation from the SM prediction one can start focusing on more specific BSM assumptions to identify the origin of the new physics
- In case of no deviation the constraint should be set in the most model independent way possible

Energy frontier: An example

Di-jet resonances are a good benchmark to study how the reach on high mass resonances changes with luminosity/energy

Chekanov, Childers, Proudfoot, Wang, Frizzell, 1710.09484





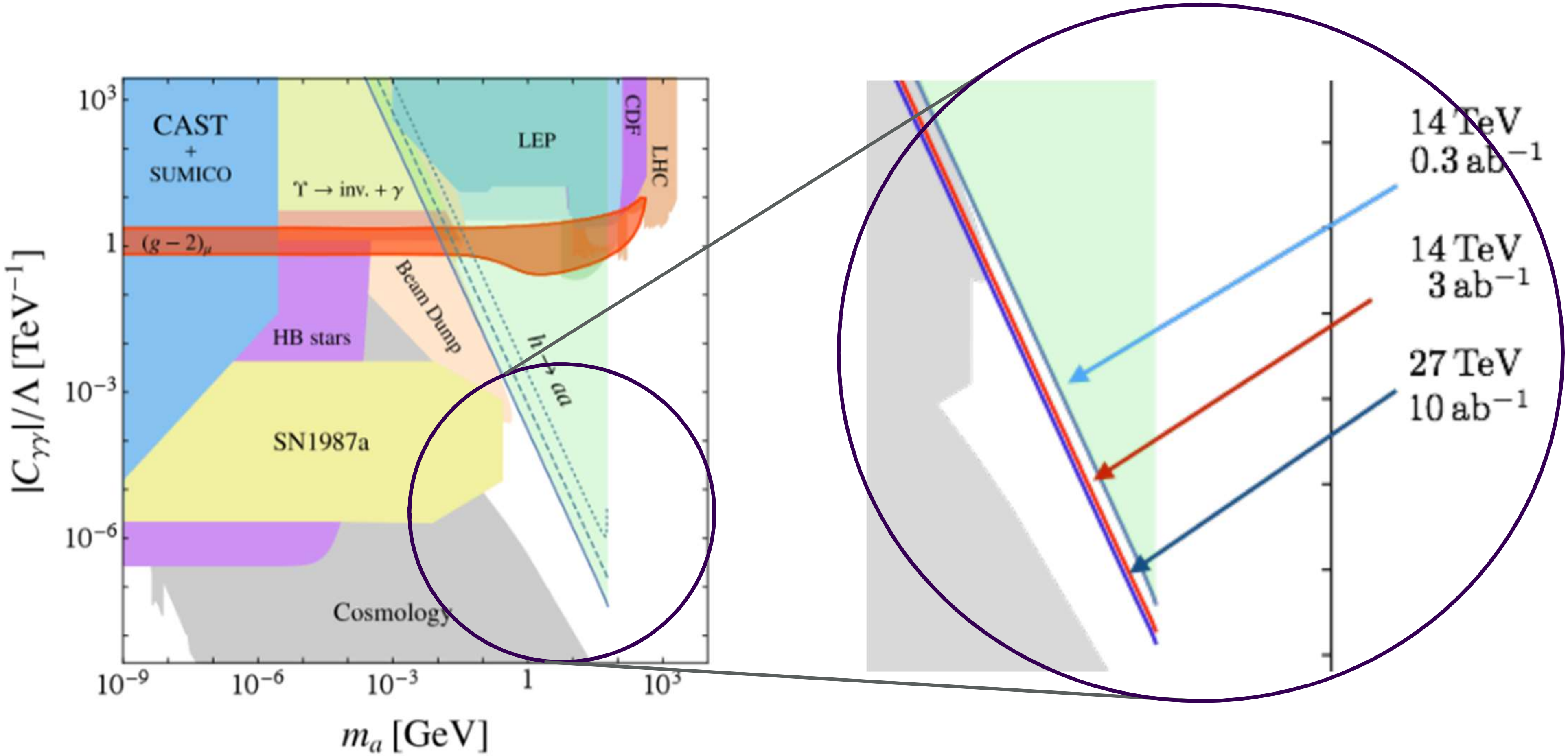
Reach defined as the invariant mass at which the relative statistical uncertainty becomes 100%

see also Chekanov in the Abstract/Discussion session

Intensity frontier: An example

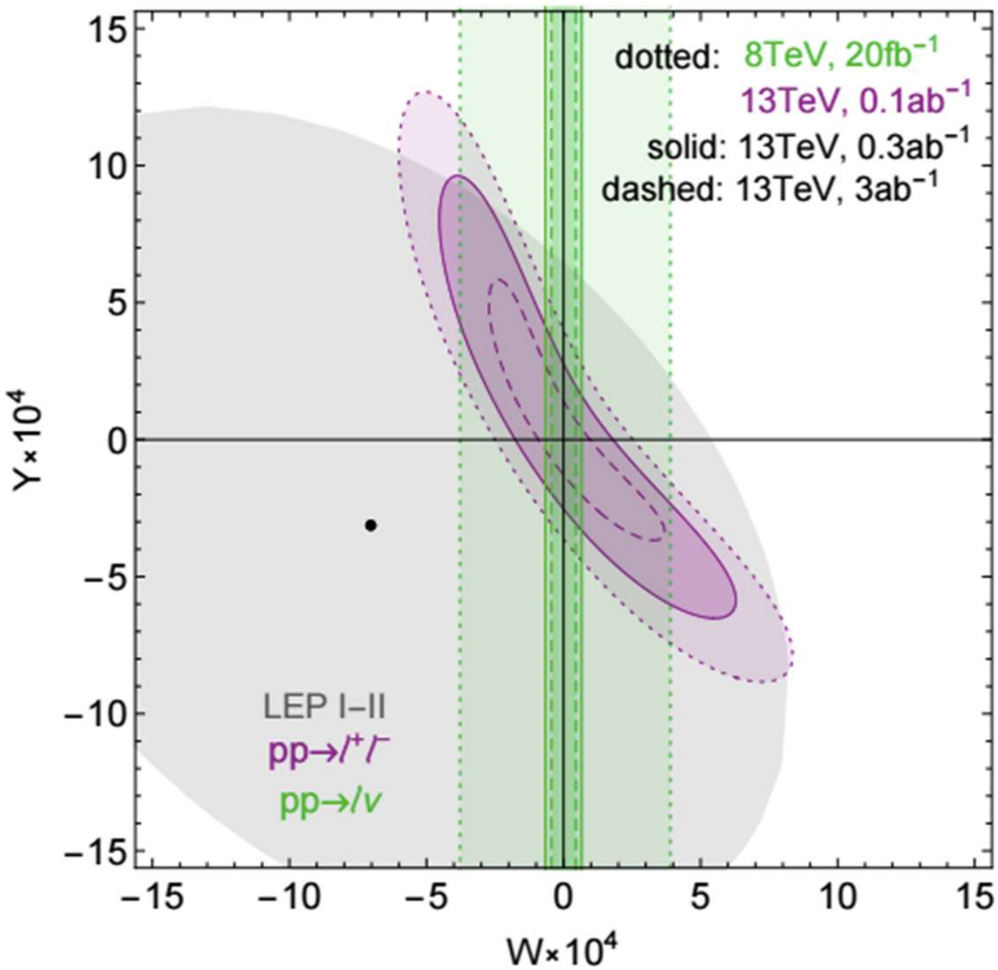
Axion-like-particles are one of the prototypical example of light and weakly coupled new physics

They couple to photons and can be produced in Higgs decays



Bauer, Neubert, Thamm, 1708.00443
see also Redigolo's talk

Accuracy frontier: An example



	universal form factor ($\mathcal{L}$)
W	$-\frac{\mathrm{W}}{4m_W^2}(D_\rho W^a_{\mu\nu})^2$
Y	$-\frac{\mathrm{Y}}{4m_W^2}(\partial_\rho B_{\mu\nu})^2$

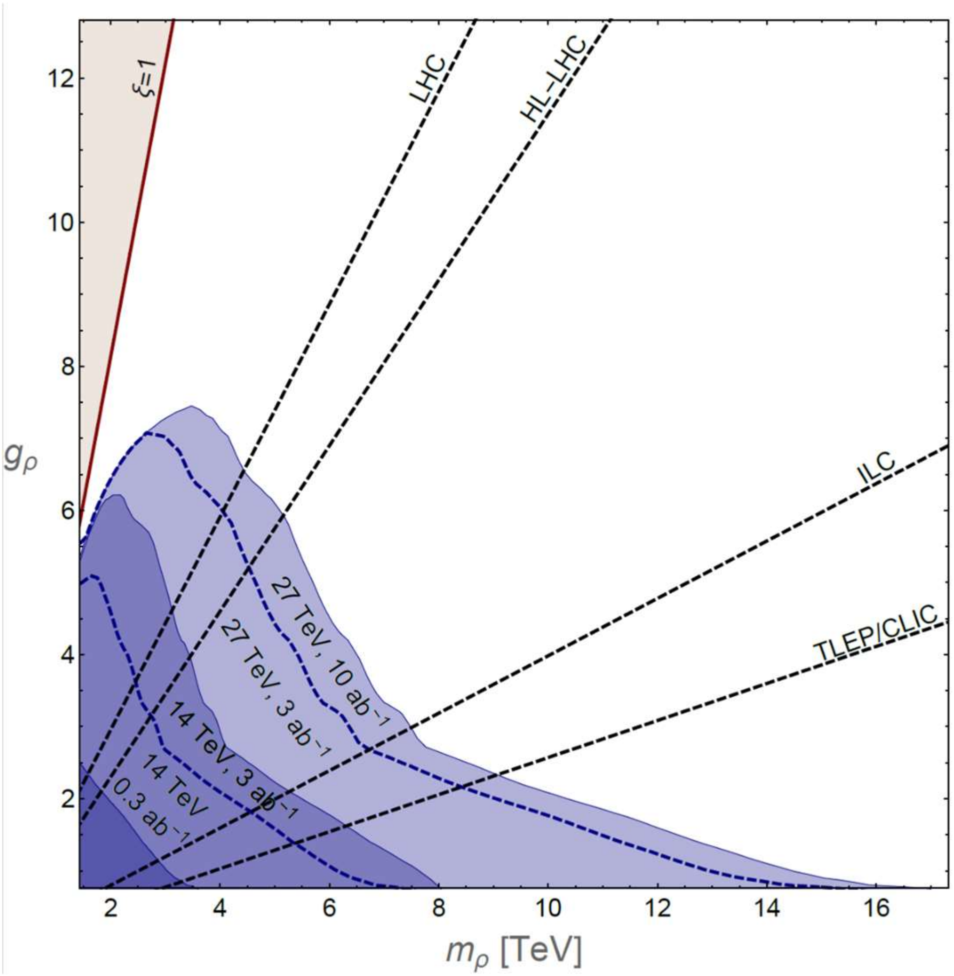
Farina, Panico, Pappadopulo, Ruderman, RT, Wulzer 1609.08157

see also Farina & Wulzer's talks

		LEP	ATLAS 8	CMS 8	LHC 13		100 TeV	ILC	TLEP	ILC 500 GeV
luminosity		$2\times10^7\,Z$	19.7 fb^{-1}	20.3 fb^{-1}	0.3 ab^{-1}	3 ab^{-1}	10 ab^{-1}	$10^9\,Z$	$10^{12}\,Z$	3 ab^{-1}
NC	W×10^4	[−19, 3]	[−3, 15]	[−5, 22]	±1.5	±0.8	±0.04	±3	±0.7	±0.3
	Y×10^4	[−17, 4]	[−4, 24]	[−7, 41]	±2.3	±1.2	±0.06	±4	±1	±0.2
CC	W×10^4	—	±3.9		±0.7	±0.45	±0.02	—	—	—

Interplay: an example

- In a broad framework, and under certain assumptions, one can study the interplay of different collider configurations like HL-LHC, HE-LHC
- Contrary to expectation it's not always true that more energy is better



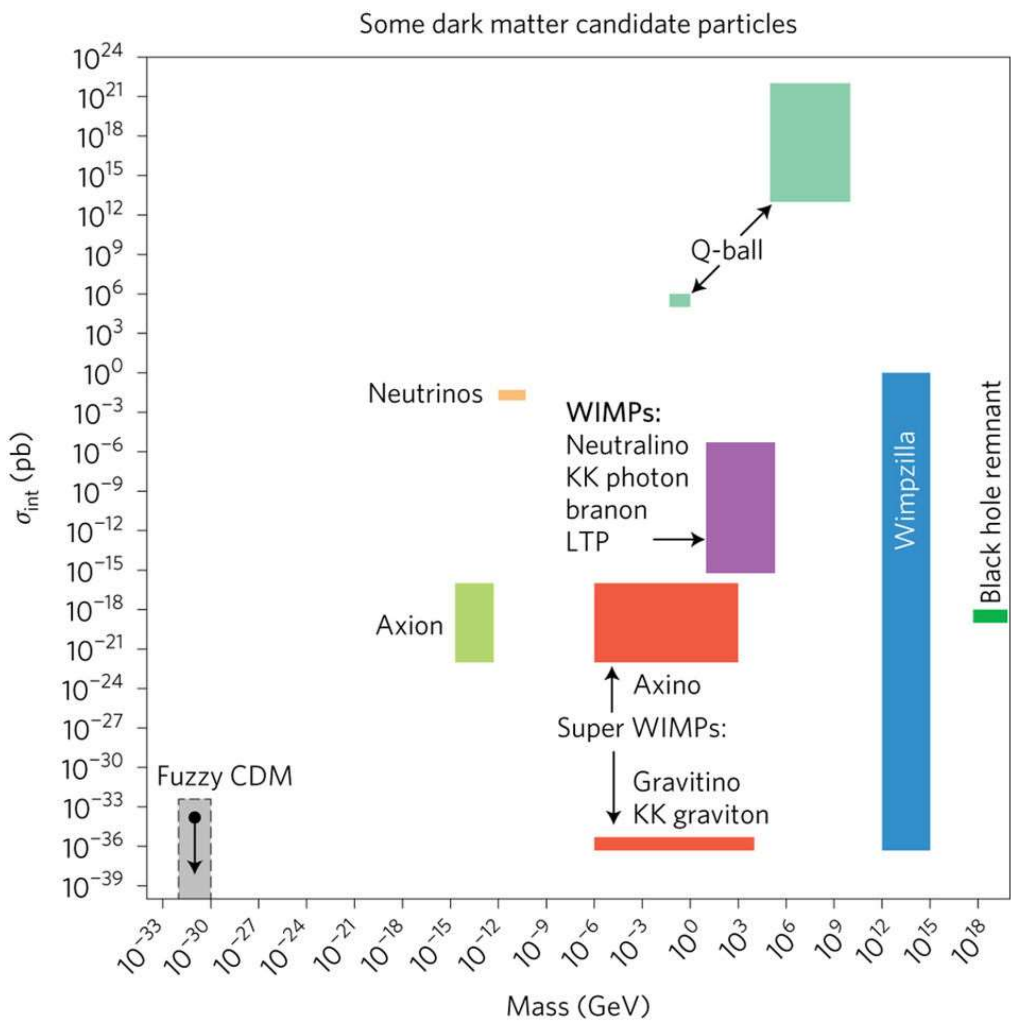
- Generic expectations: Higgs coupling modifications, contributions to EWPT, vector resonances (fermionic resonances are more model dependent)
- In a two-parameter plane can compare reach from direct and indirect searches at HL/HE-LHC
- Would be interesting to know the reach on ξ from HE-LHC

Thamm, RT, Wulzer, 1502.01701

see also Thamm's talks

The unknown: an example

- The biggest unknown is Dark Matter
- Even within the WIMP framework it could span several orders of magnitude in mass and coupling



- The LHC has access to part of the whole DM parameter space
- However this is one of the most important problems in physics and the LHC should not miss its opportunity to explore it
- Typical example of high-risk/hi-gain research

see D'Onofrio, Haisch, Heisig, Magnan and Westhoff's talks

Conclusions

- HL-LHC is a great opportunity that we should not miss
- New exploration can be characterized by three directions: Intensity, Energy, Accuracy frontiers
- Many results in all these directions are going to be presented during this Workshop
- BSM working group covers a very broad spectrum of possible new physics, possibly related with some of the most important open problems in HEP
- Synergy/Interplay with Higgs and Flavor working groups
- HE-LHC would represent the natural evolution of HL-LHC to explore a scale parametrically higher than the LHC
- Already a lot of activity in the WG, but new people and ideas are welcome to contribute to the WG activity and to the forthcoming report

THANK YOU