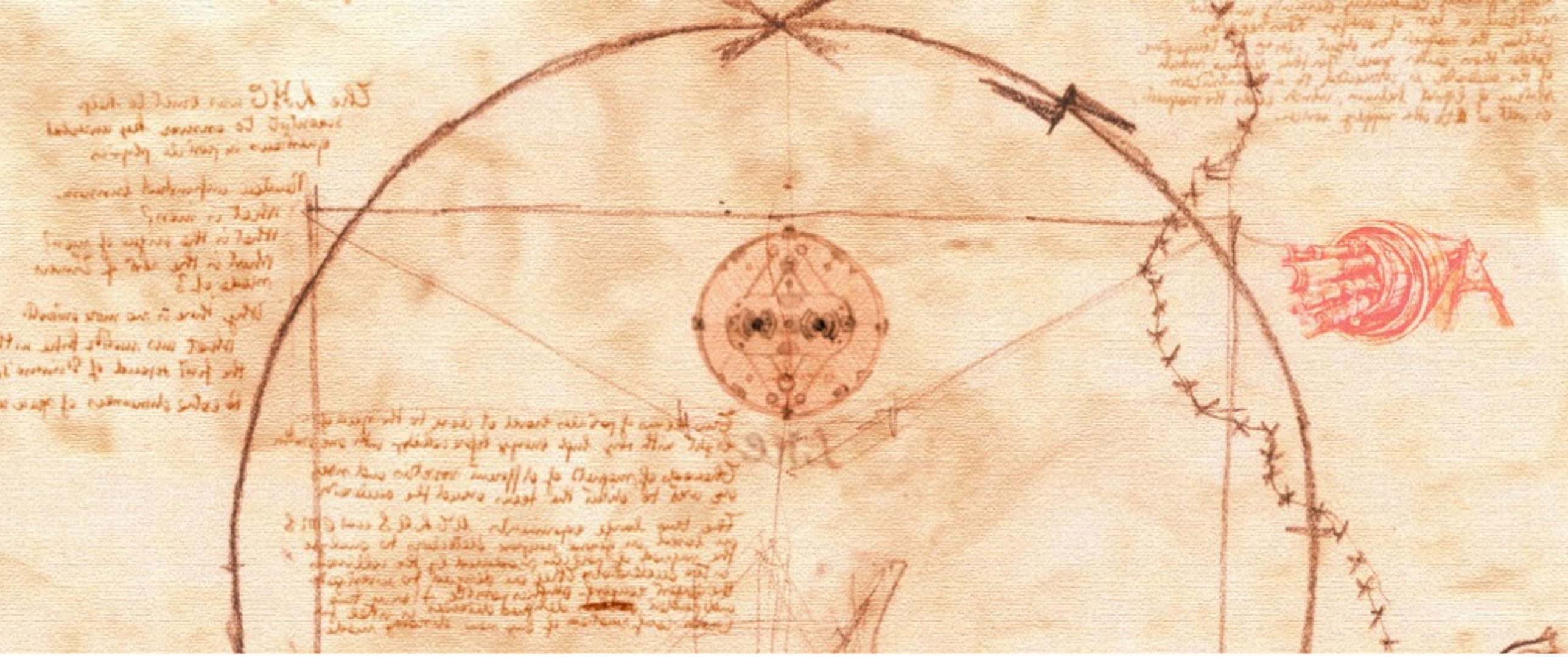
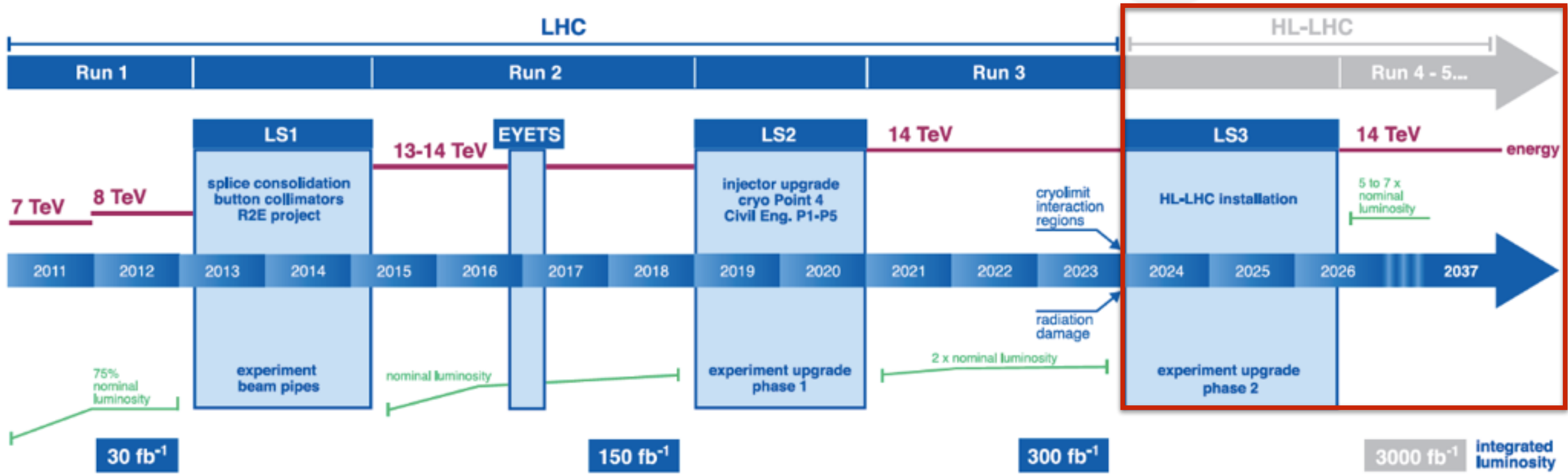
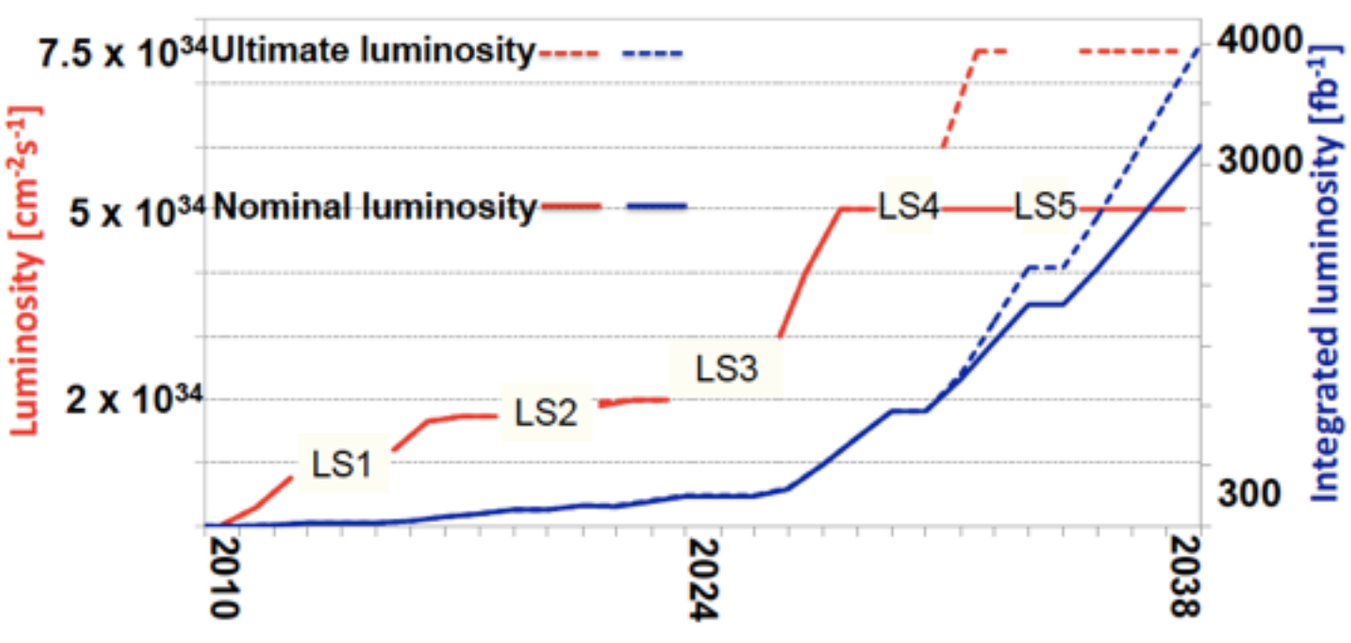


LCWS 2015 PANEL DISCUSSION

Markus Klute (MIT)

HL-LHC Higgs Potential



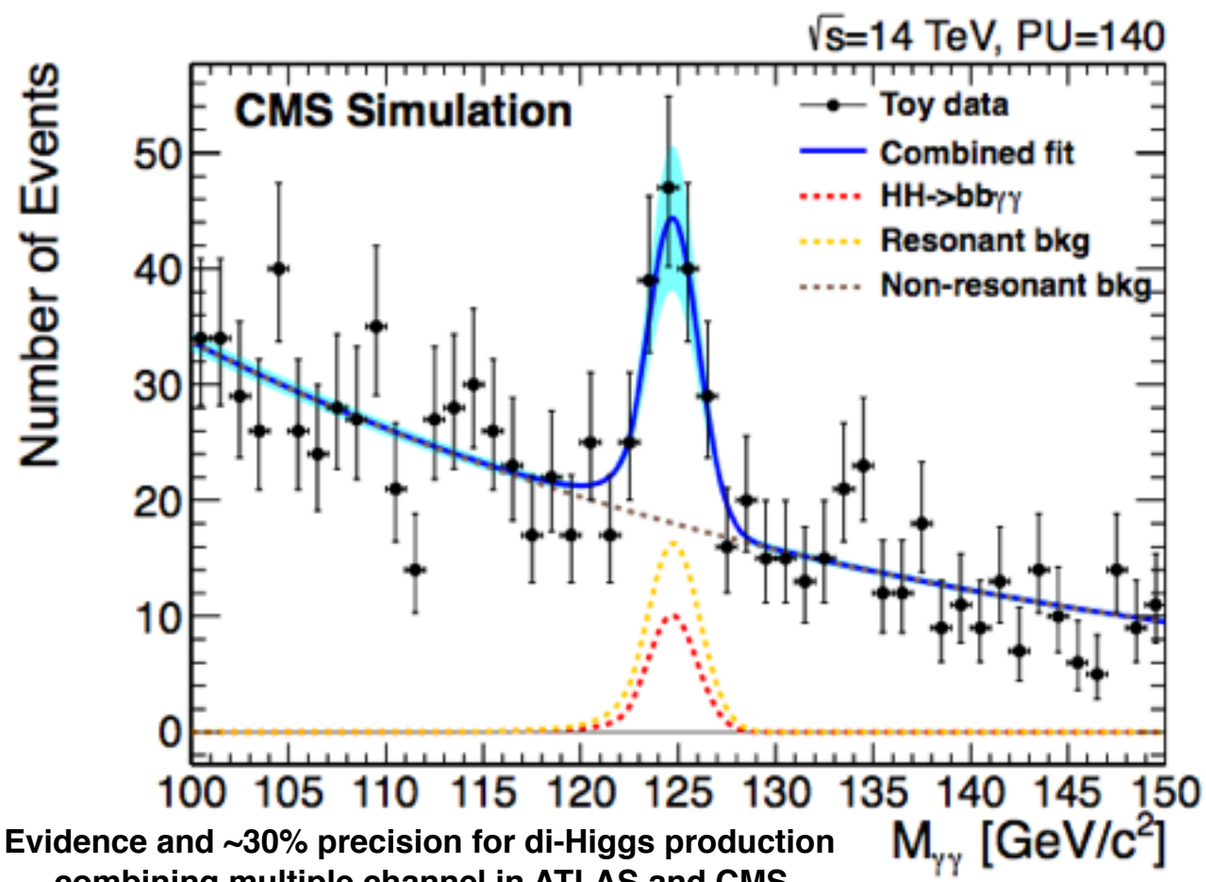


- ➡ **Precision measurements of SM parameters (including the Higgs boson)**
- ➡ **Sensitivity to rare SM & rare BSM processes**
- ➡ **Extension of discovery reach in high-mass region**
- ➡ **Determination of BSM parameter**

HL-LHC Higgs Potential

	$\Delta\kappa_\gamma$	$\Delta\kappa_W$	$\Delta\kappa_Z$	$\Delta\kappa_g$	$\Delta\kappa_b$	$\Delta\kappa_t$	$\Delta\kappa_\tau$	$\Delta\kappa_\mu$
Run I Combination	12	10	10	15	25	29	15	
CMS projection 300fb^{-1}, 14 TeV	5	4	4	6	10	14 **(9)**	6	23
CMS projection 3000fb^{-1}, 14 TeV	2	2	2	3	4	7 **(4)**	2	8 **(5)**

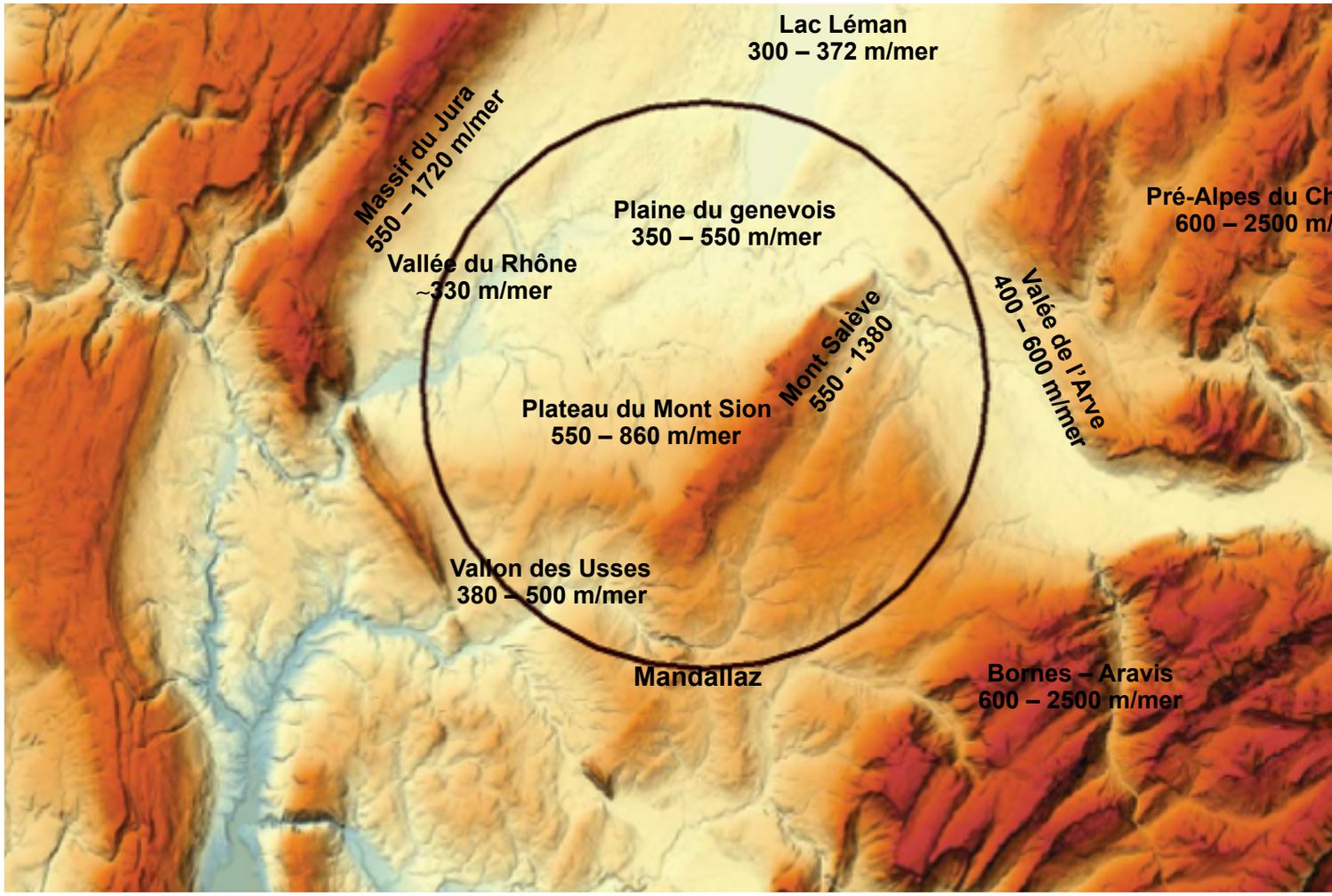
- ➡ Key question is the evolution systematic uncertainty
- ➡ Assumptions made on cross section uncertainties (PDF, N^{3}LO) already superseded
- ➡ Higgs program at the LHC extends far beyond coupling measurements



Evidence and ~30% precision for di-Higgs production combining multiple channel in ATLAS and CMS

Future Circular Collider Study

- ➡ **International FCC collaboration to study**
  - pp-collider (FCC-hh)
  - **e^+e^- collider (FCC-ee)**
  - p-e (FCC-he)
- ➡ 80-100 km infrastructure in Geneva area
- ➡ **Goal:** CDR and cost review by 2018
- ➡ Similar studies in China (50-70 km infrastructure)
  - pp-collider (SppS)
  - e^+e^- collider (CepC)

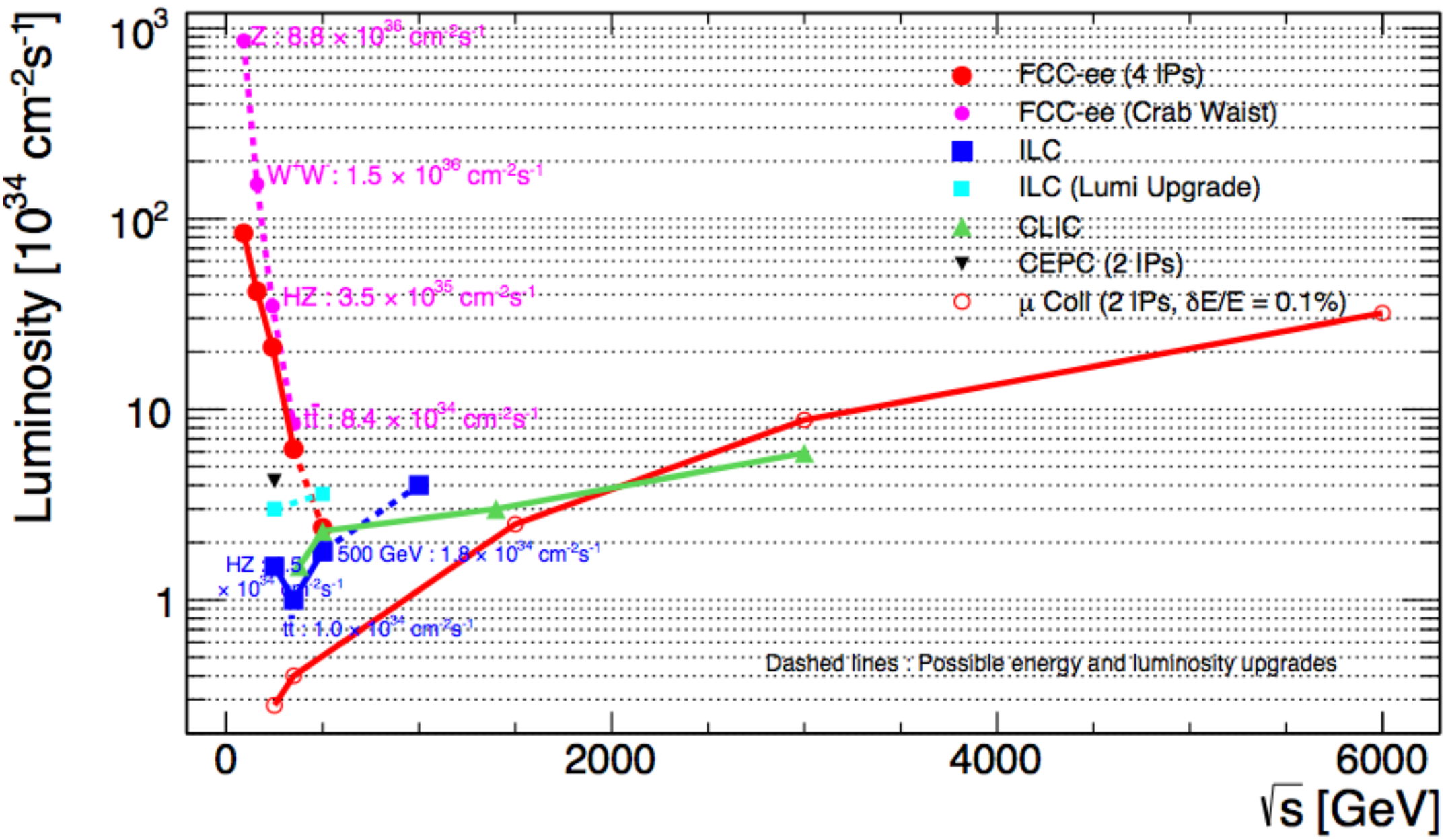


FCC-ee

$\sqrt{s}$ (GeV)	90	160	240	350	350+
$\mathscr{L}$(ab^{-1}/year)	86.0	15.2	3.5	1.0	1.0
Events/year	3.6×10^{12}	6.1×10^{7}	7.0×10^{5}	4.2×10^{5}	2.5×10^{4}
Event type	Z	WW	HZ	$t\bar{t}$	WW $\rightarrow$ H
Years	0.3 (2.5)	1	3	0.5	3

Future Lepton Collider

- ➡ **Luminosity and energy drive the physics program**
- ➡ Polarization can enrich the physics potential



Higgs Coupling Summary

Uncertainties	HL-LHC*	μ-	CLIC	ILC**	CEPC	FCC-ee
m_H [MeV]	40	0.06	40	30	5.5	8
Γ_H [MeV]	-	0.17	0.16	0.16	0.12	0.04
g_{HZZ} [%]	2.0	-	1.0	0.6	0.25	0.15
g_{HWW} [%]	2.0	2.2	1.0	0.8	1.2	0.2
g_{Hbb} [%]	4.0	2.3	1.0	1.5	1.3	0.4
$g_{H\tau\tau}$ [%]	2.0	5	2.0	1.9	1.4	0.5
$g_{H\gamma\gamma}$ [%]	2.0	10	6.0	7.8	4.7	1.5
g_{Hcc} [%]	-	-	2.0	2.7	1.7	0.7
g_{Hgg} [%]	3.0	-	2.0	2.3	1.5	0.8
g_{Htt} [%]	4.0	-	4.5	18	-	-
$g_{H\mu\mu}$ [%]	4.0	2.1	8.0	20	8.6	6.2
g_{HHH} [%]	30	-	24	-	-	-

* Estimate for two HL-LHC experiments

** ILC lumi upgrade improves precision by factor 2

For ~10y operation. Lots of "!,*,?"

Every number comes with her own story.

Communicating the science

Uncertaintie	HL-LHC*	μ-	CLIC	ILC	CEPC	FCC-ee
m_H [MeV]	40	0.06	40	15	5.5	8
Γ_H [MeV]	-	0.17	0.16	0.08	0.12	0.04
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g_{Hbb} [%]	4.0	2.3	1.0	0.7	1.3	0.4
$g_{H\tau\tau}$ [%]	2.0	5	2.0	0.8	1.4	0.5
$g_{H\gamma\gamma}$ [%]	2.0	10	6.0	3.3	4.7	1.5
g_{Hcc} [%]	-	-	2.0	1.2	1.7	0.7
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g_{Htt} [%]	4.0	-	4.5	3	-	-
$g_{H\mu\mu}$ [%]	4.0	2.1	8.0	9	8.6	6.2
g_{HHH} [%]	30	-	24	30	-	-

Readiness of the project

Ultimate potential of facility

Testing self-consistency

	Present precision		TLEP stat Syst Precision	TLEP key	Challenge
M_Z [MeV]	91187.5 ±2.1	Z Line shape scan	0.005 MeV <±0.1 MeV	E_cal	QED corrections
Γ_Z [MeV]	2495.2 ±2.3	Z Line shape scan	0.008 MeV <±0.1 MeV	E_cal	QED corrections
R_l	20.767 ± 0.025	Z Peak	0.0001 ± 0.002 - 0.0002	Statistics	QED corrections
N_ν	2.984 ±0.008	Z Peak Z+γ(161 GeV)	0.00008 ±0.004 0.0004-0.001	->lumi meast Statistics	**QED corrections to Bhabha scat.**
R_b	0.21629 ±0.00066	Z Peak	0.000003 ±0.000020 - 60	Statistics, small IP	Hemisphere correlations
A_{LR}	0.1514 ±0.0022	Z peak, polarized	±0.000015	4 bunch scheme	Design experiment
M_W [MeV]	80385 ± 15	Threshold (161 GeV)	0.3 MeV <1 MeV	E_cal & Statistics	QED corections
M_{top} [MeV]	173200 ± 900	Threshold scan	10 MeV	E_cal & Statistics	Theory limit at 100 MeV?

Requires a significant theory program

Conclusion

- **Physics goals of future lepton collider**
  - Testing self-consistency of the SM - indirect search for new physics
  - Higgs, top, and EW precision measurements
  - Sensitivity for low mass and EW new physics
- **Exploration of Higgs Physics at the LHC on its way**
  - HL-LHC will set a high bar for Higgs physics
  - Potential limited by systematic uncertainties with possibility for improvements
- **Circular collider potential**
  - Edge on luminosity at lower energies (relevant for Higgs and top physics)
  - Pave the path for future hadron collider