

# Higgs Summary

*Sven Heinemeyer, IFCA (CSIC–UC)*

Valencia, 11/2006

15 minutes (minus discussion time)  $\Rightarrow$  the usual apologies

- Status of the field
- Contributions in Valencia
- Discussions about parameters
- What is needed for the future

## Status of the field

Reality: ILC will start after the LHC

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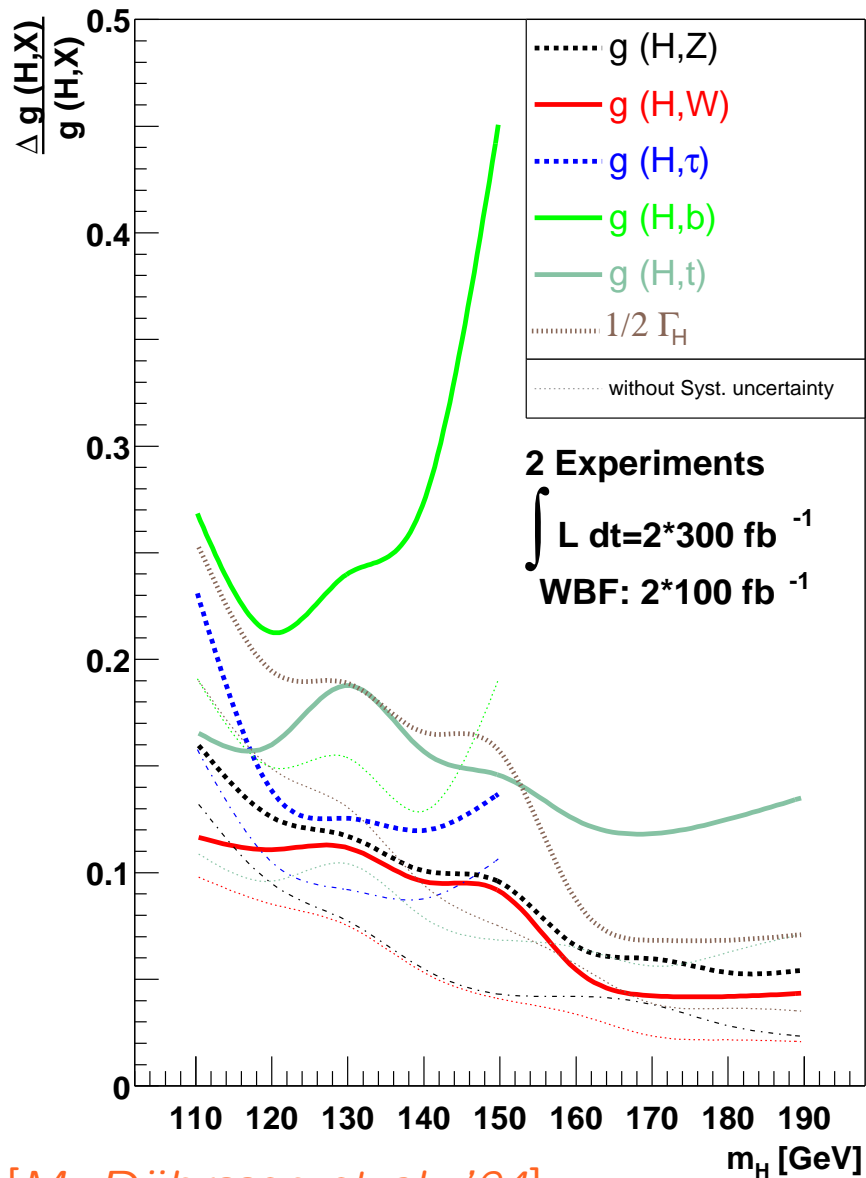
**A:** The ILC will add **precision**  $\Rightarrow$  The ILC delivers  $\oplus$  needs precision!

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Where are we in this respect? (Status? What is needed? Achievement?)

- Higgs
- Top/QCD
- LoopVerein
- SUSY
- New Physics at TeV, precision electroweak
- Cosmological connections

## The LHC will find a Higgs and measure its characteristics:



[M. Dürrssen et al. '04]

- mass:  $\delta M_h \approx 200 \text{ MeV}$
- couplings:  $(2 * 300 + 2 * 100) \text{ fb}^{-1}$  :  
typical accuracies of 20-30%  
for  $m_H \leq 150 \text{ GeV}$   
10% accuracies for  $HVV$  couplings  
above  $WW$  threshold

### Assumption:

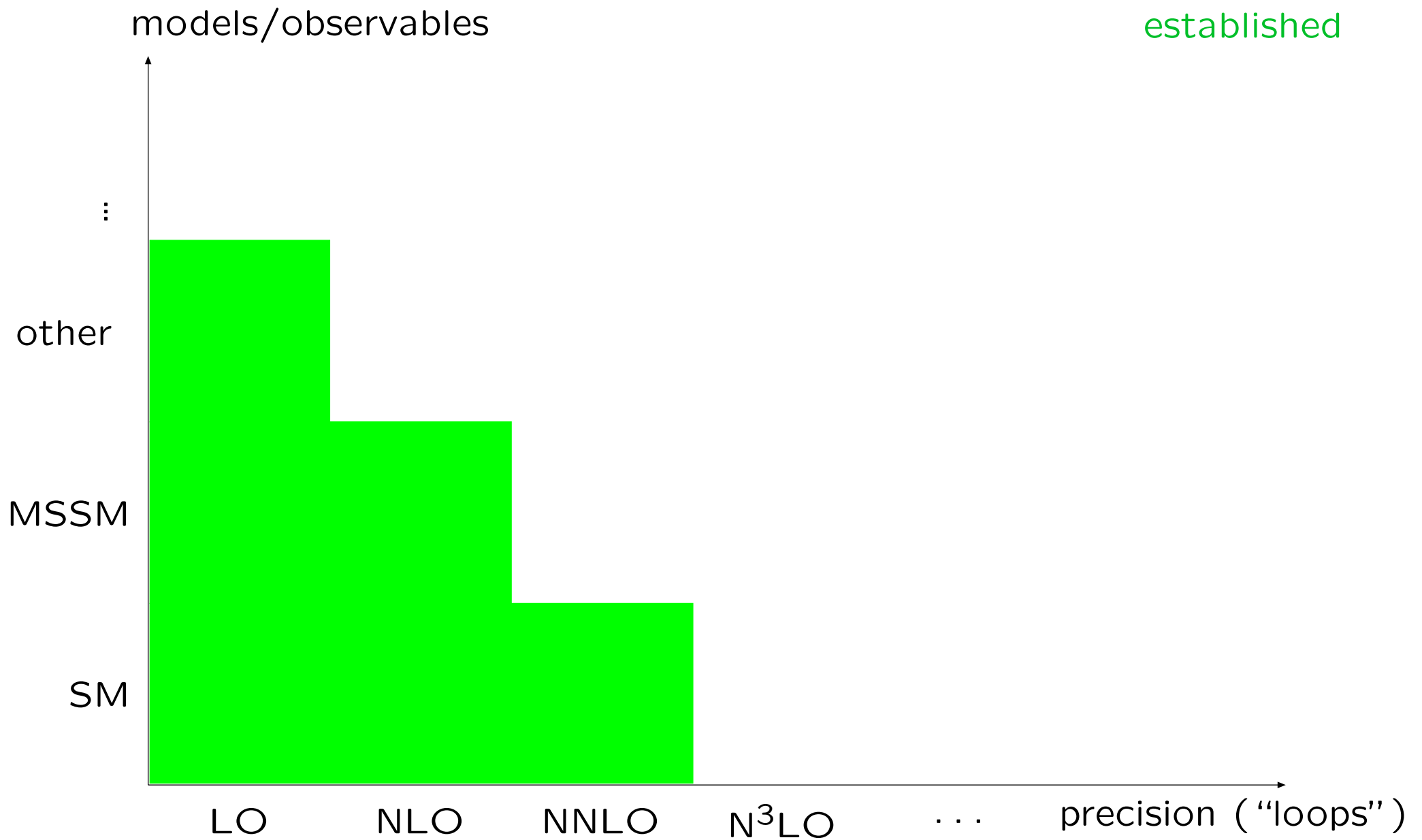
- $g_{HVV}^2 \leq g_{HVV,SM}^2 \times 1.05$
- SM rates for the Higgs

### Problems:

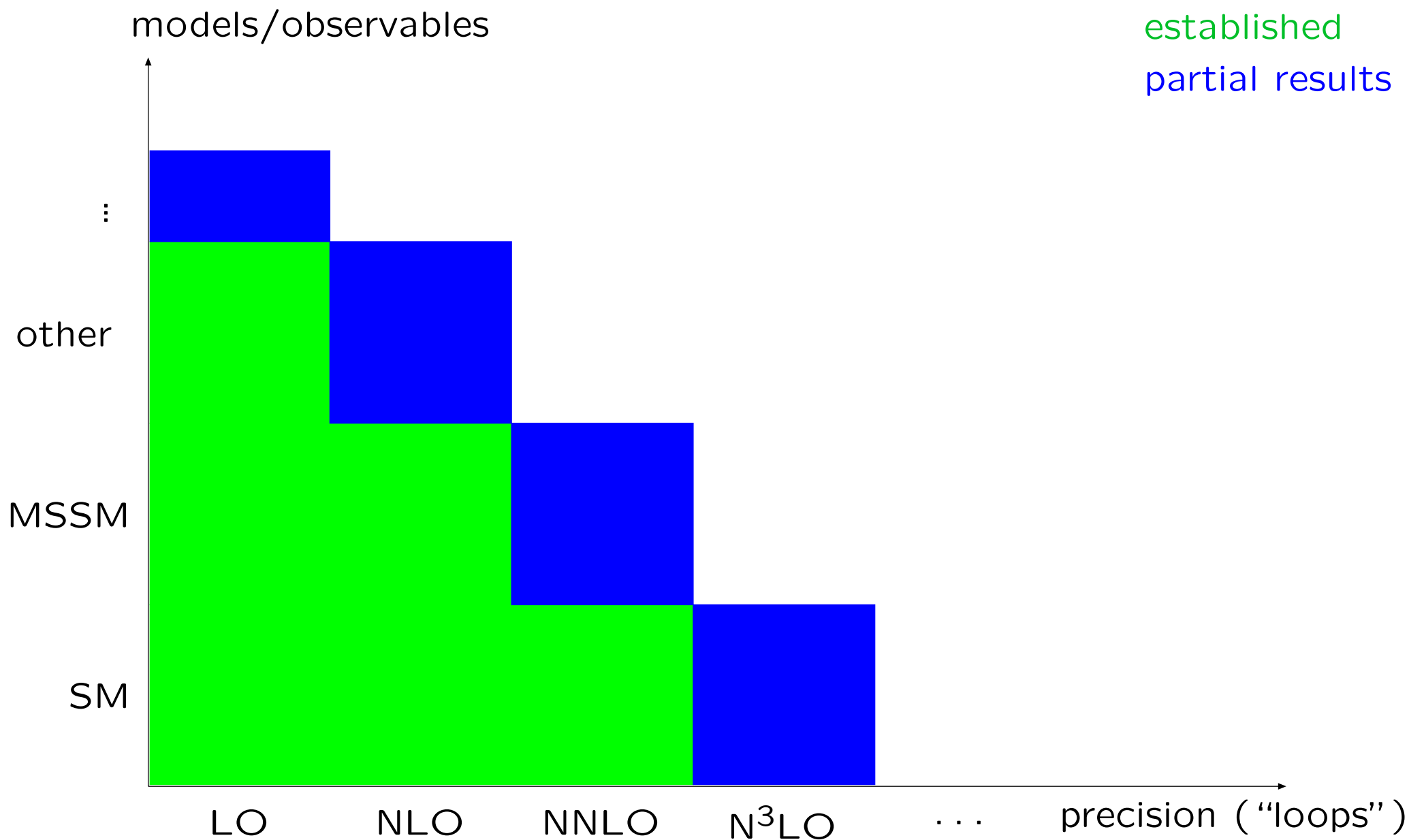
- valid in weakly interacting models
- rates much lower than in SM ??
- physics can/will hide in 5% margin
- self-couplings out of reach

⇒ ILC comes in

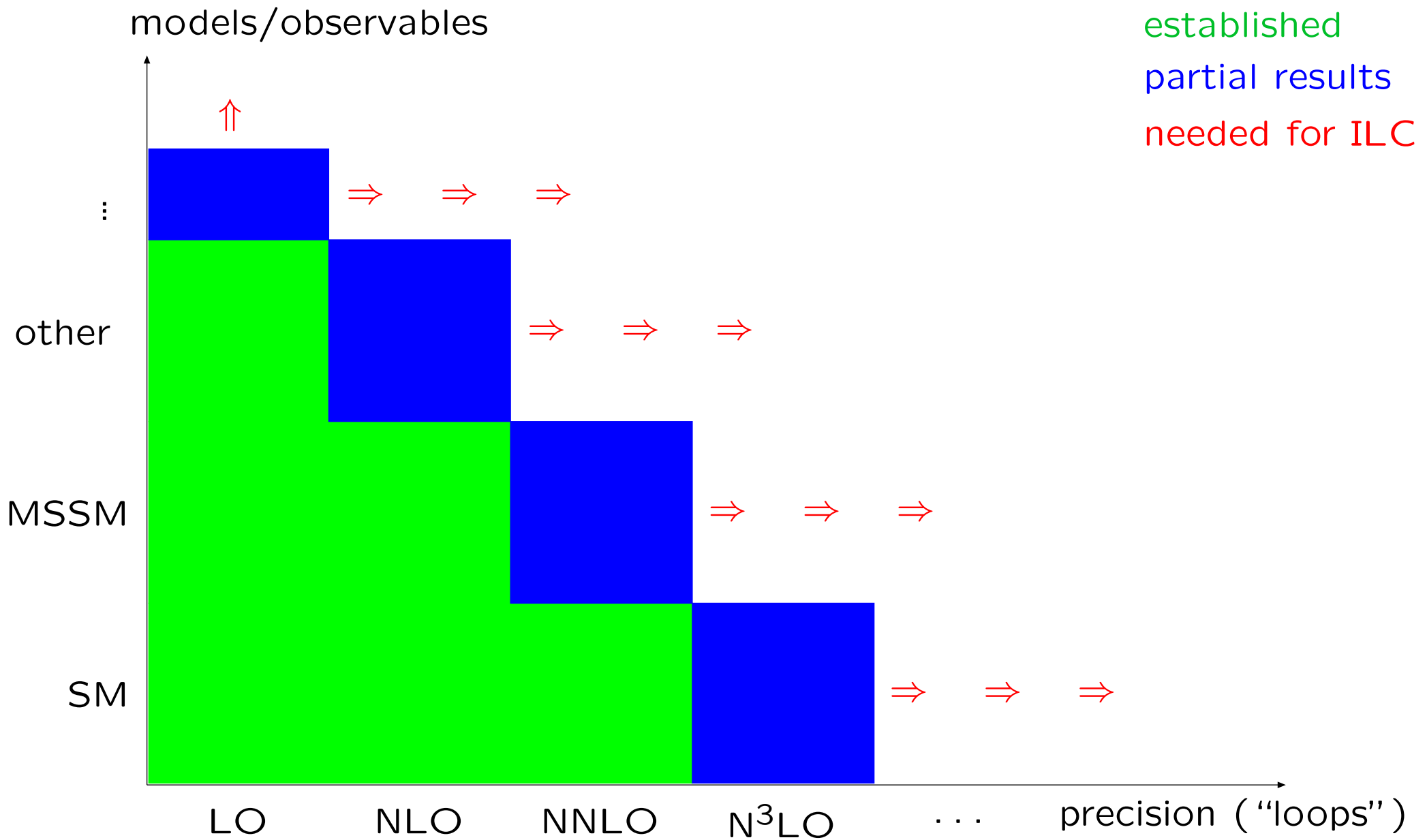
# Higgs: theory situation



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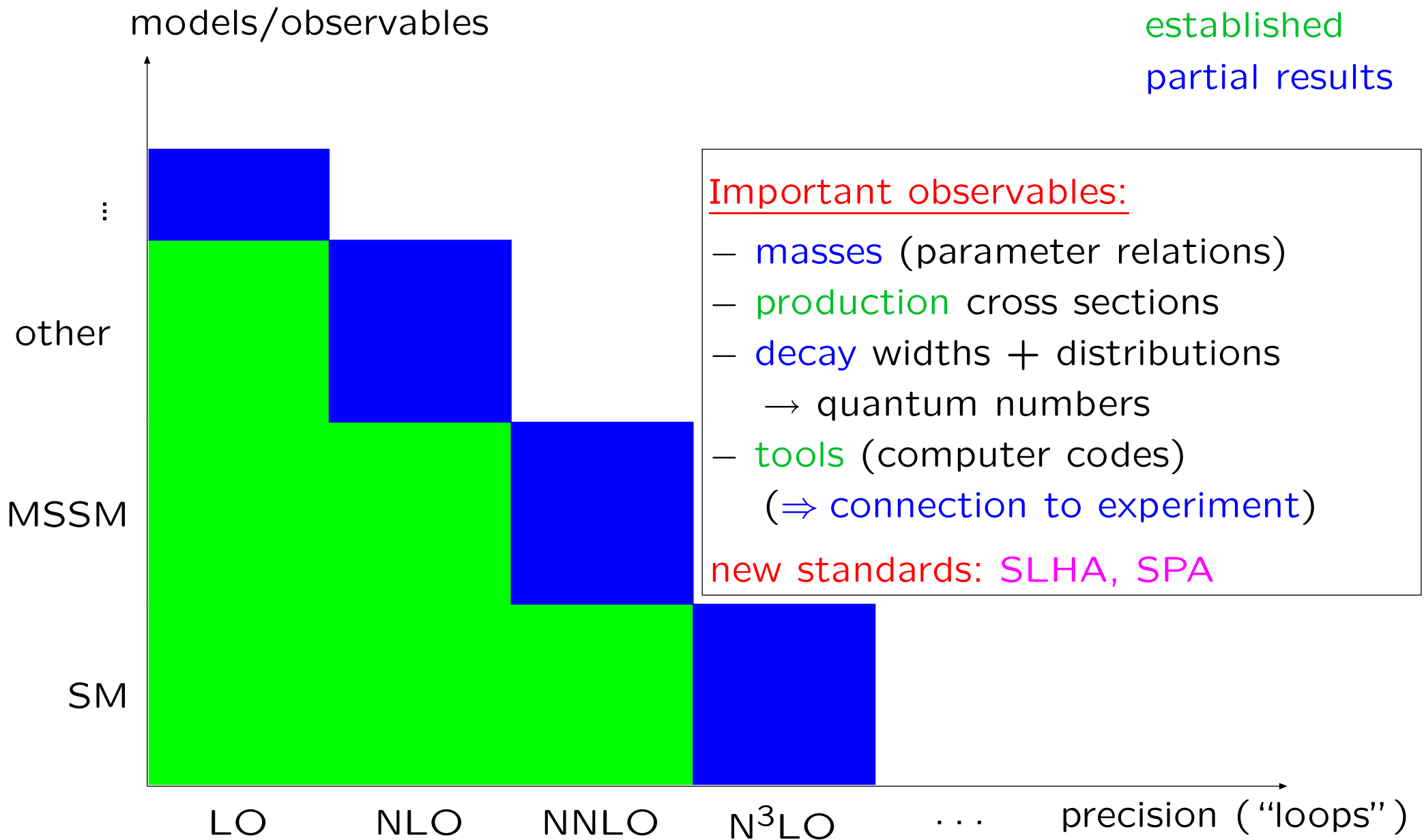


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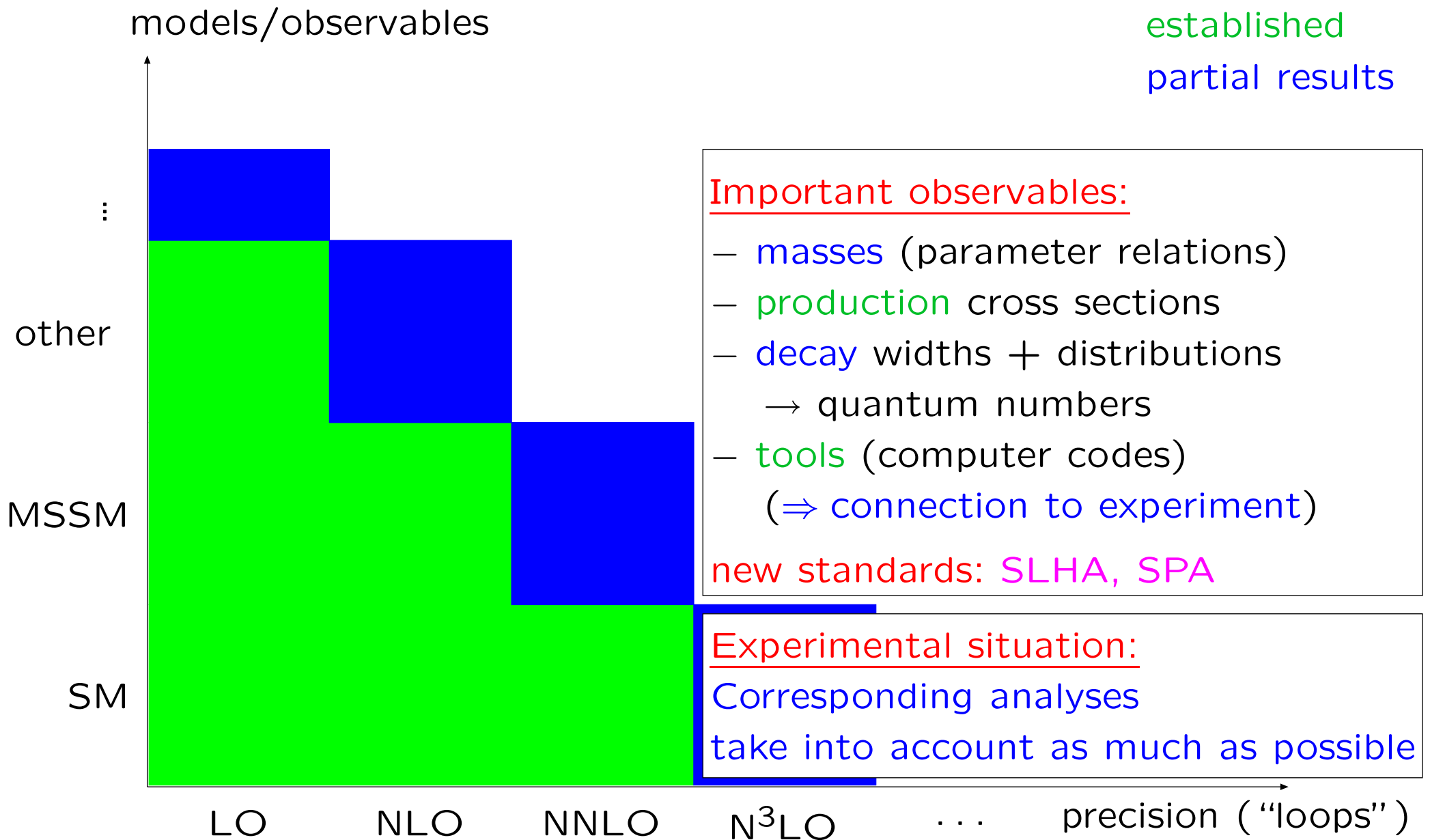




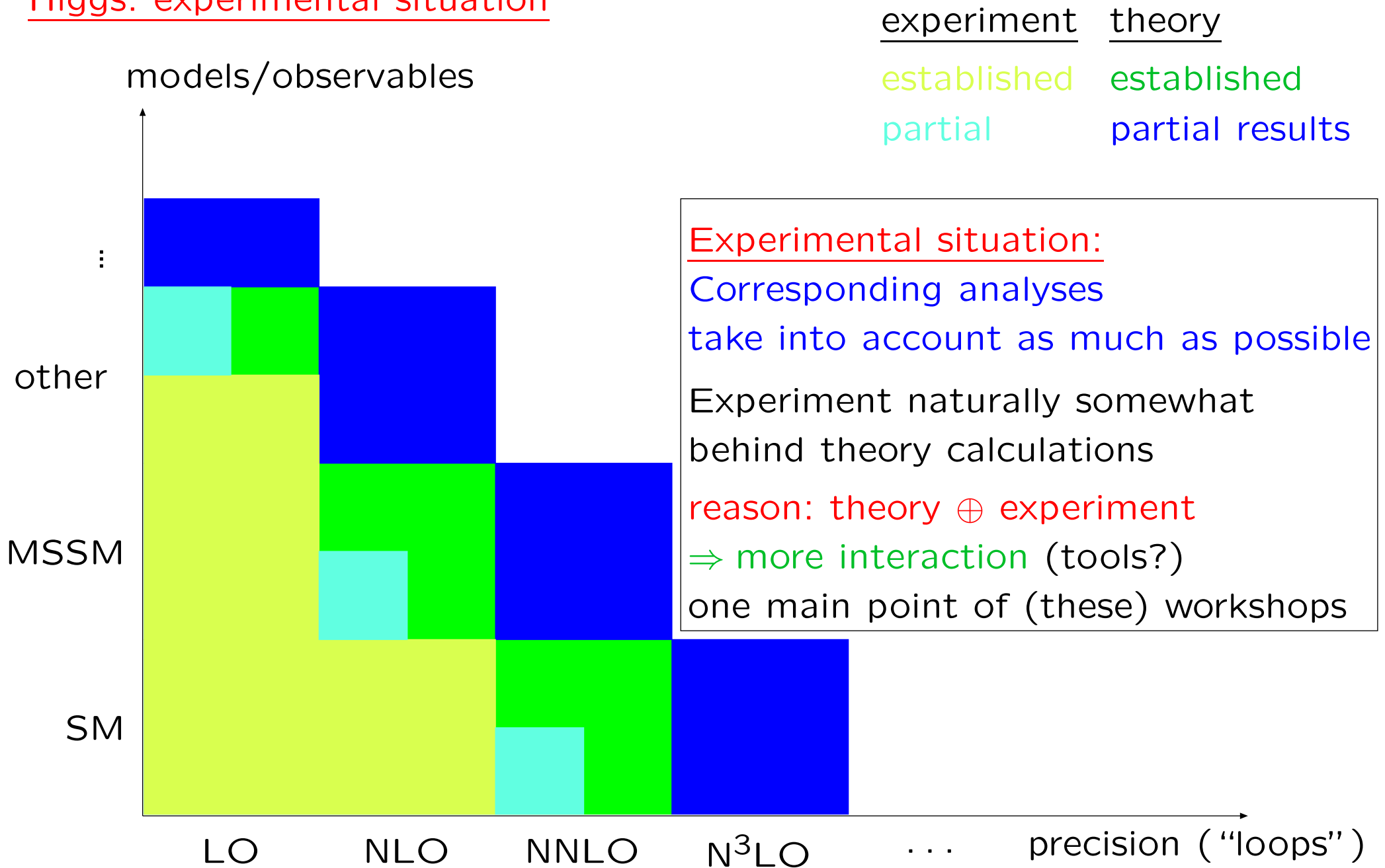
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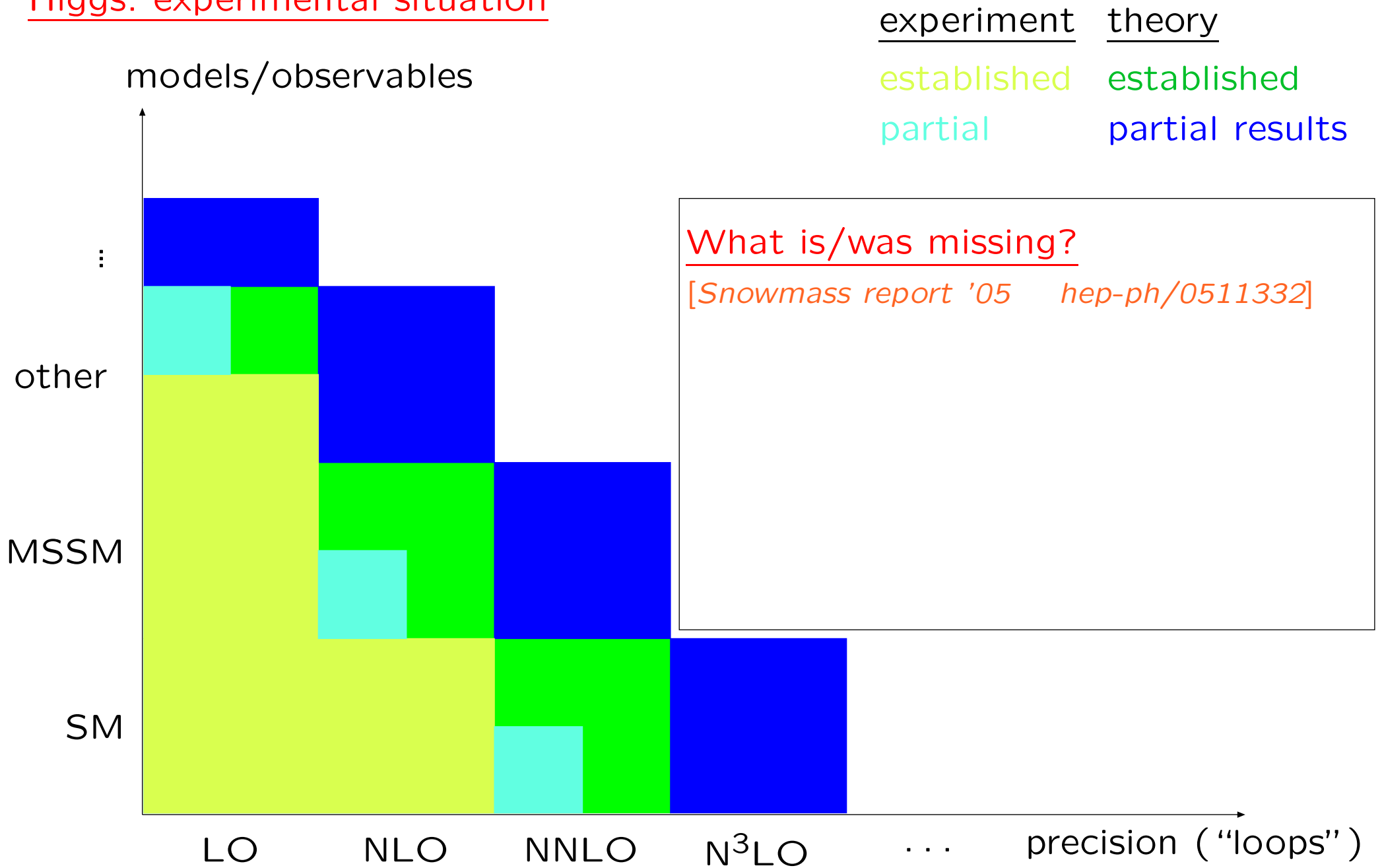
# Higgs: experimental situation



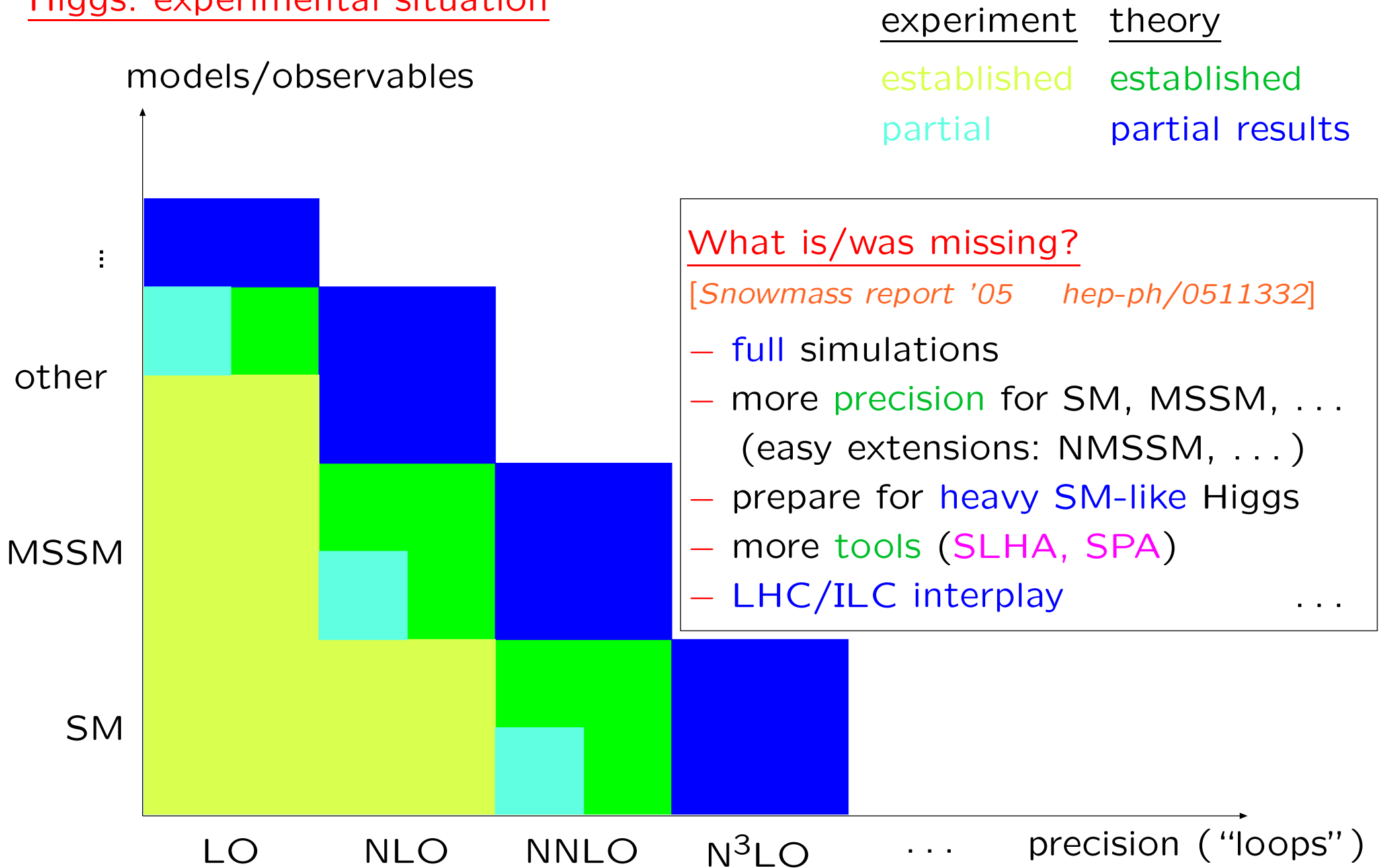
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What is/was missing?  
*[Snowmass report '05 hep-ph/0511332]*

- full simulations
- more precision for SM, MSSM, ...  
 (easy extensions: NMSSM, ...)
- prepare for heavy SM-like Higgs
- more tools (SLHA, SPA)
- LHC/ILC interplay ...

# Higgs: contributions in Valencia

experiment

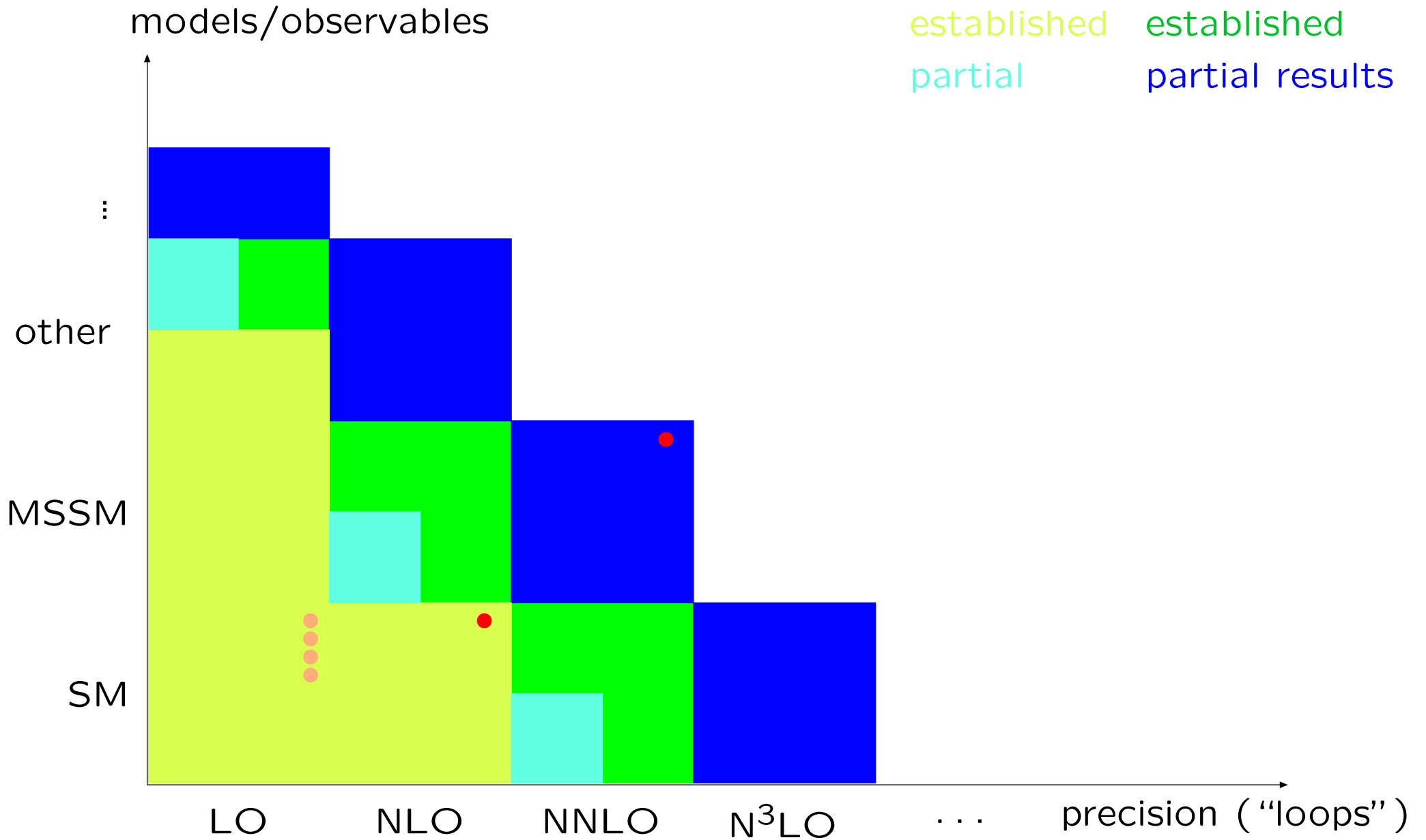
theory

established

established

partial

partial results



# SM Higgs from another angle: contributions in Valencia

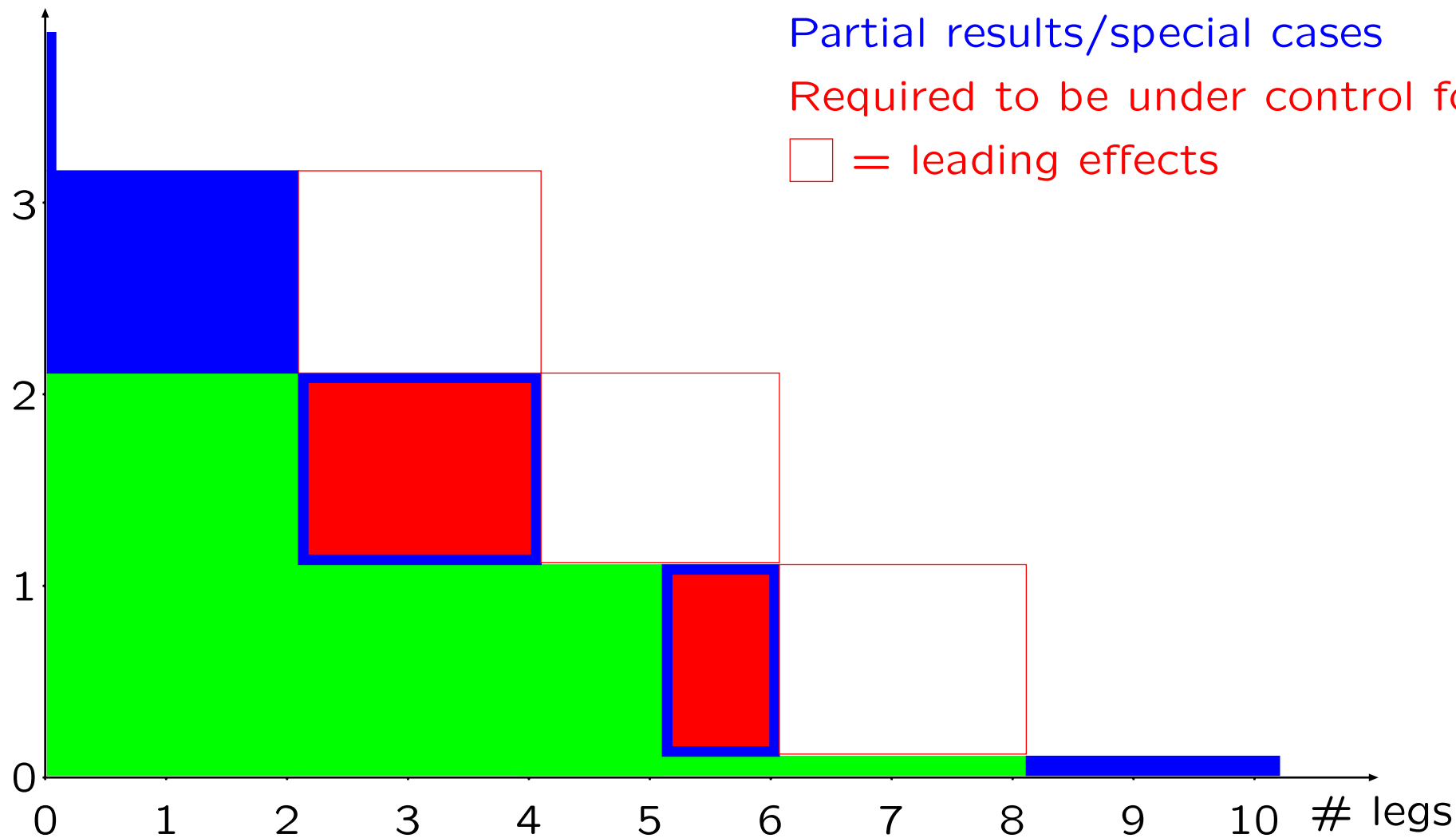
# loops

Technique well established

Partial results/special cases

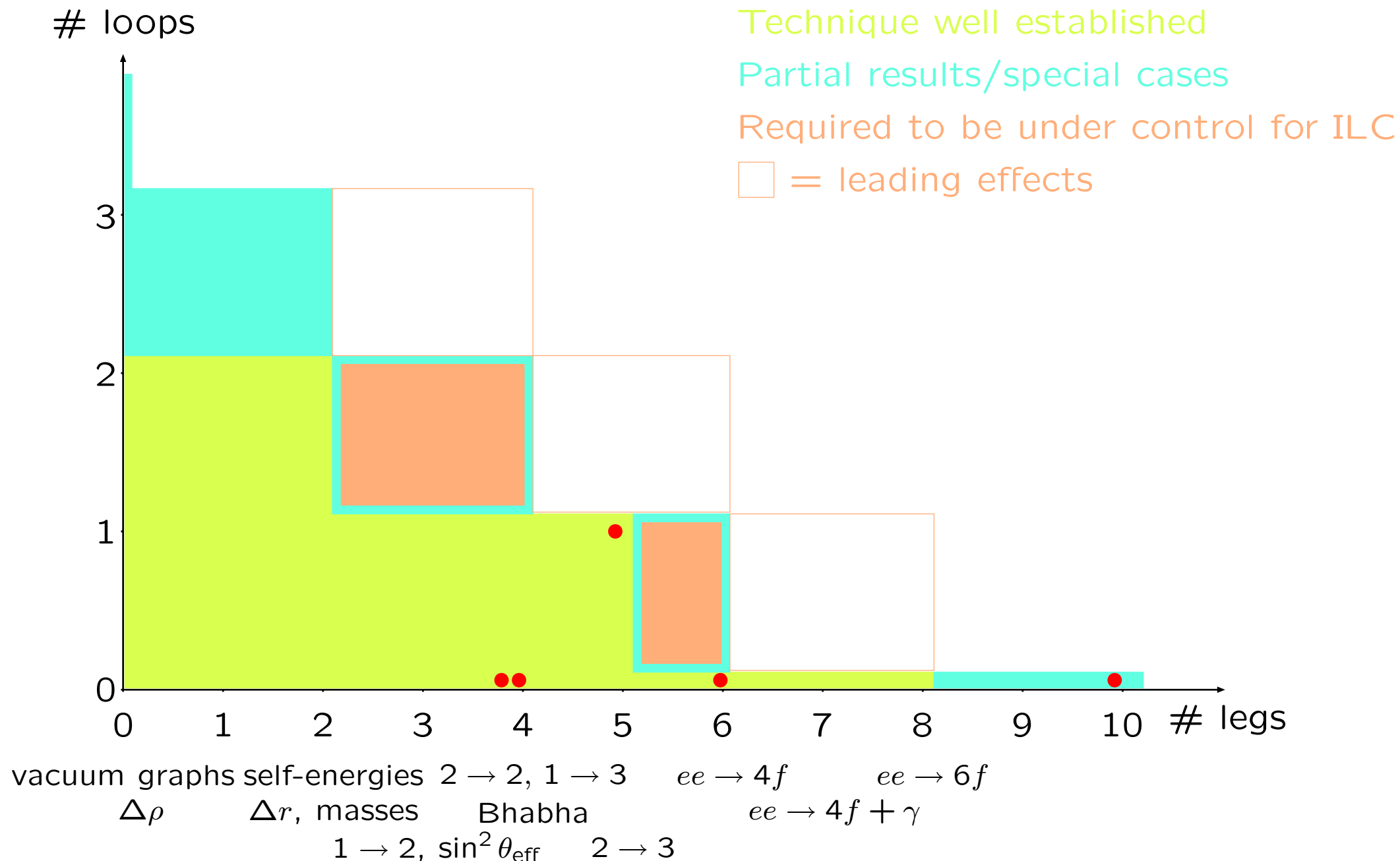
Required to be under control for ILC

□ = leading effects



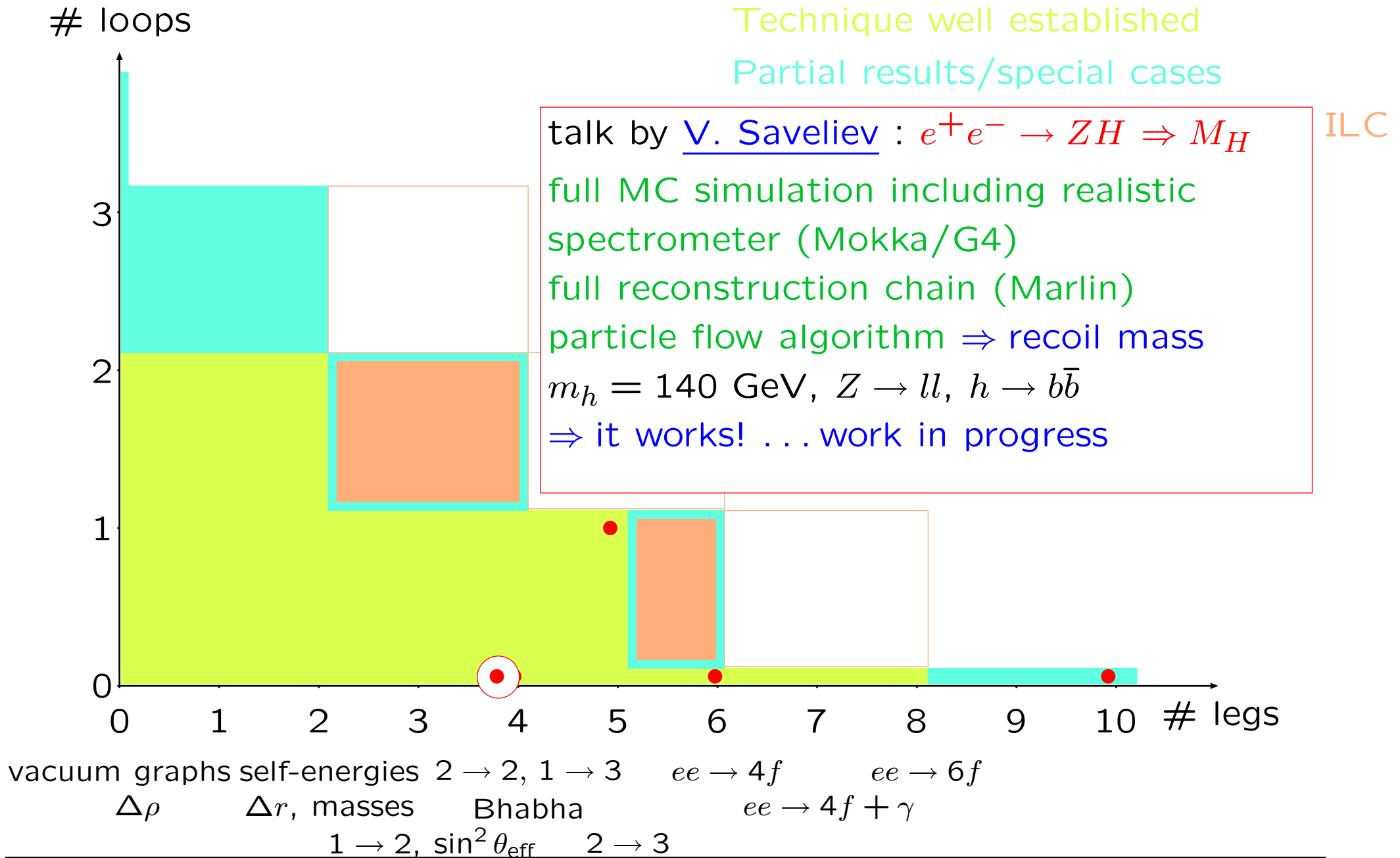
vacuum graphs  $\Delta\rho$  self-energies  $\Delta r$ , masses  $2 \rightarrow 2, 1 \rightarrow 3$  Bhabha  $1 \rightarrow 2, \sin^2 \theta_{\text{eff}}$   $2 \rightarrow 3$   $ee \rightarrow 4f$   $ee \rightarrow 4f + \gamma$   $ee \rightarrow 6f$

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# loops

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ILC

talk by [M. Ohlerich](#) :  $e^+e^- \rightarrow ZH \Rightarrow M_H$

[W. Lohmann, M. Ohlerich, A. Raspereza '06]

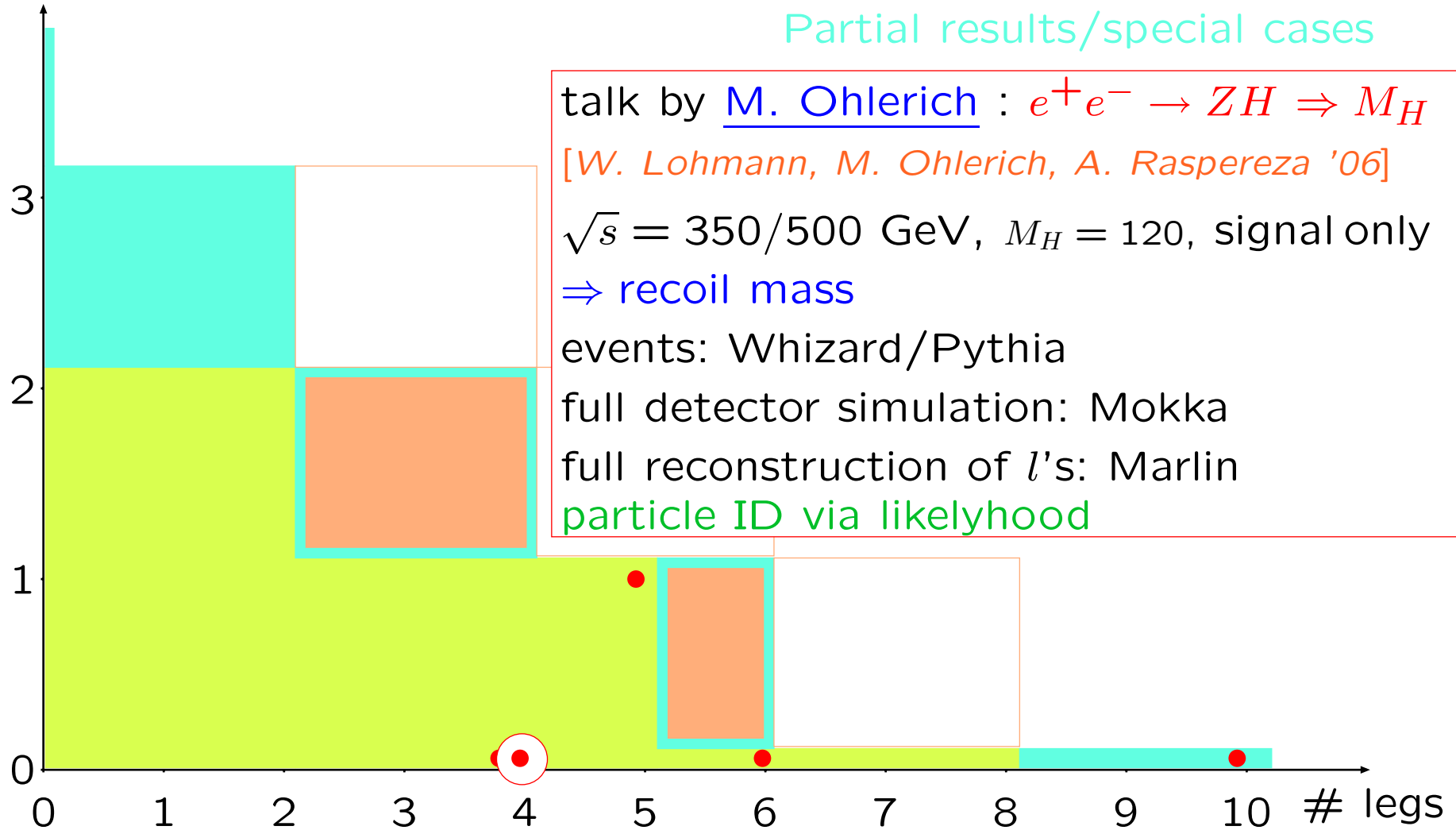
$\sqrt{s} = 350/500$  GeV,  $M_H = 120$ , signal only  
 $\Rightarrow$  recoil mass

events: Whizard/Pythia

full detector simulation: Mokka

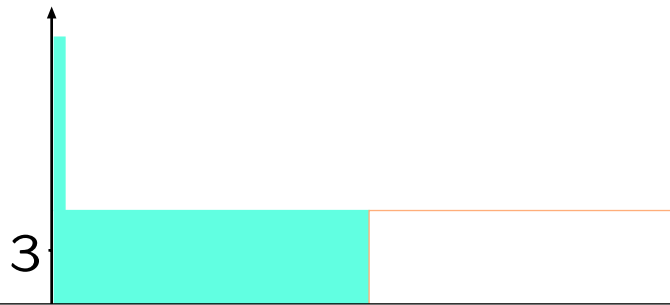
full reconstruction of  $l$ 's: Marlin

particle ID via likelihood



vacuum graphs  $\Delta\rho$  self-energies  $\Delta r$ , masses  $2 \rightarrow 2, 1 \rightarrow 3$  Bhabha  $1 \rightarrow 2, \sin^2 \theta_{\text{eff}}$   $2 \rightarrow 3$   $ee \rightarrow 4f$   $ee \rightarrow 4f + \gamma$   $ee \rightarrow 6f$

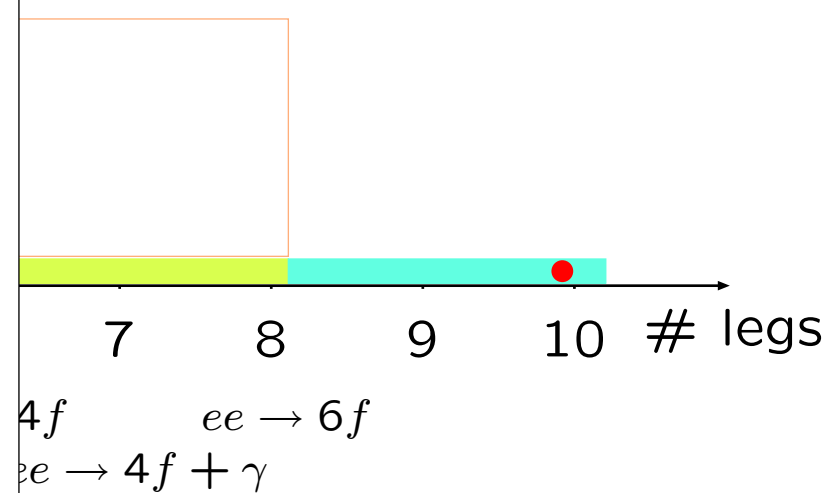
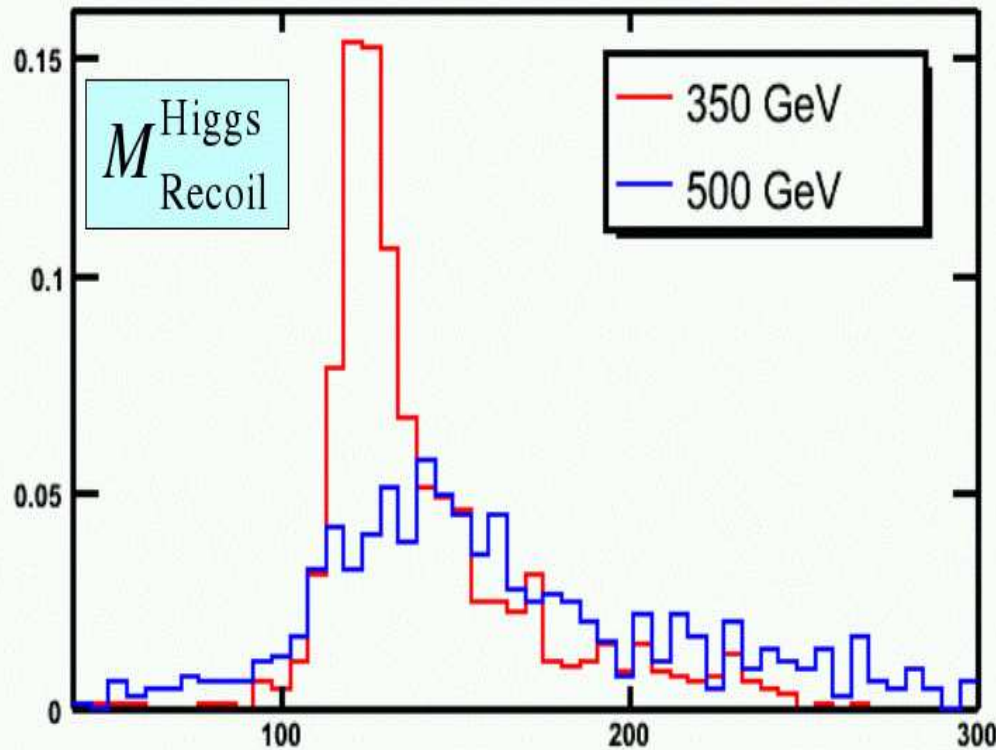
# loops



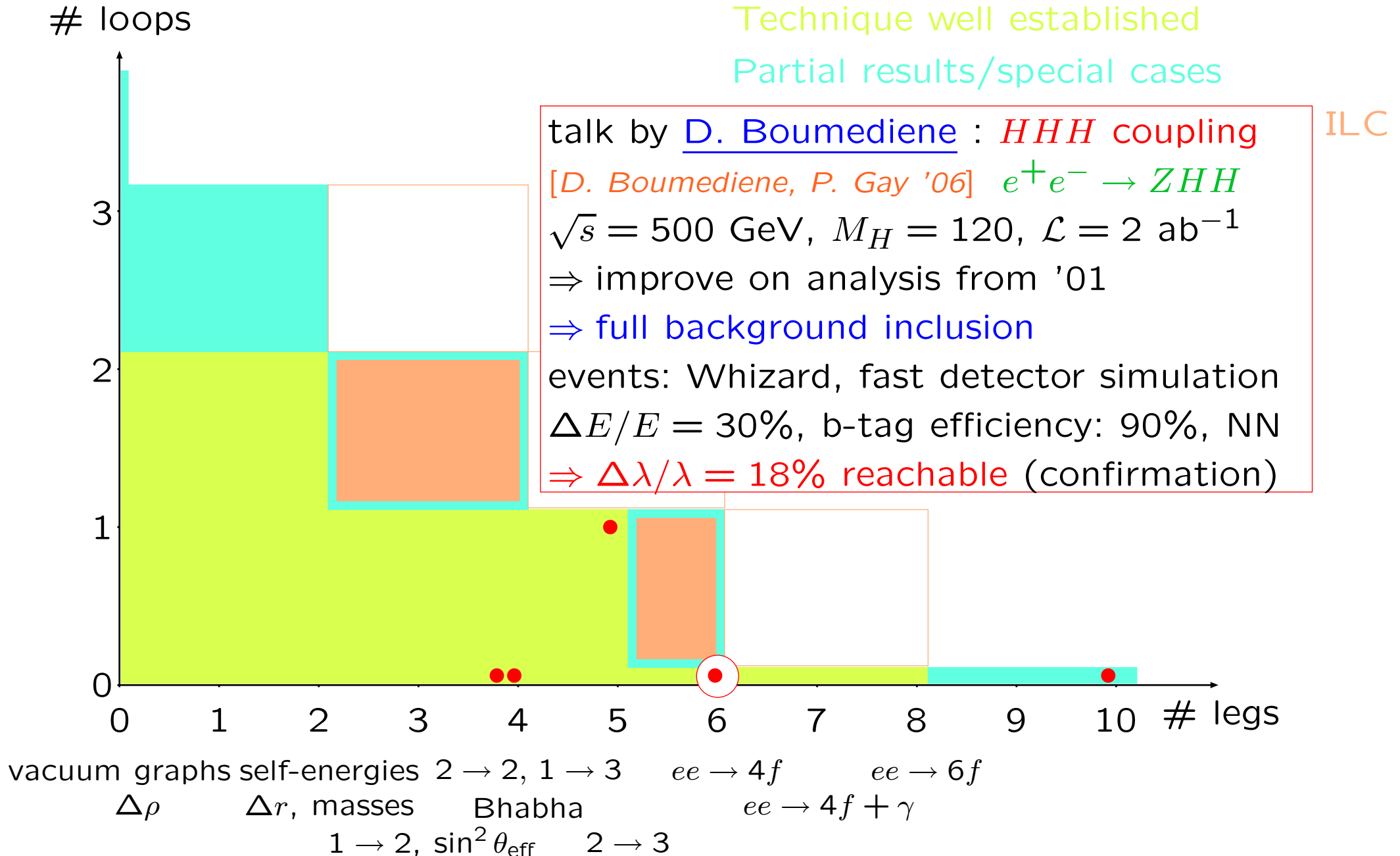
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Higgs recoil mass spectrum - full simulation & reconstruction



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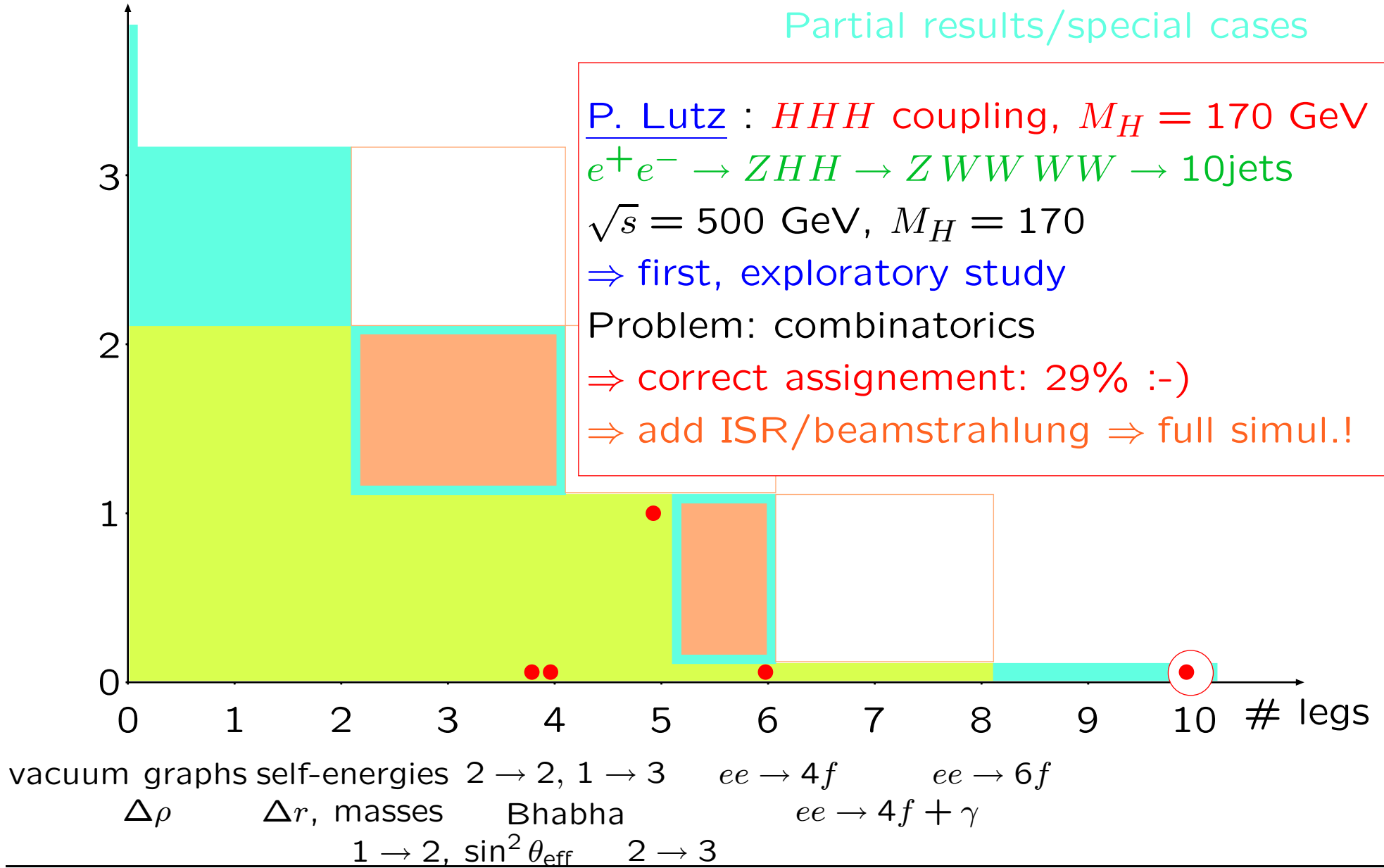
# loops

Technique well established

Partial results/special cases

ILC

P. Lutz :  $HHH$  coupling,  $M_H = 170$  GeV  
 $e^+e^- \rightarrow ZHH \rightarrow ZWW WW \rightarrow 10\text{jets}$   
 $\sqrt{s} = 500$  GeV,  $M_H = 170$   
 $\Rightarrow$  first, exploratory study  
 Problem: combinatorics  
 $\Rightarrow$  correct assignement: 29% :-)  
 $\Rightarrow$  add ISR/beamstrahlung  $\Rightarrow$  full simul.!



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Partial results/special cases

ILC

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[Bredenstein, Denner, Dittmaier, Weber '06]

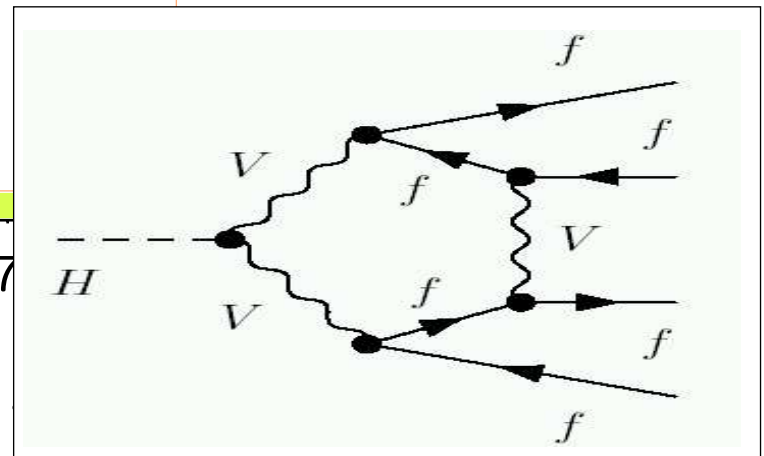
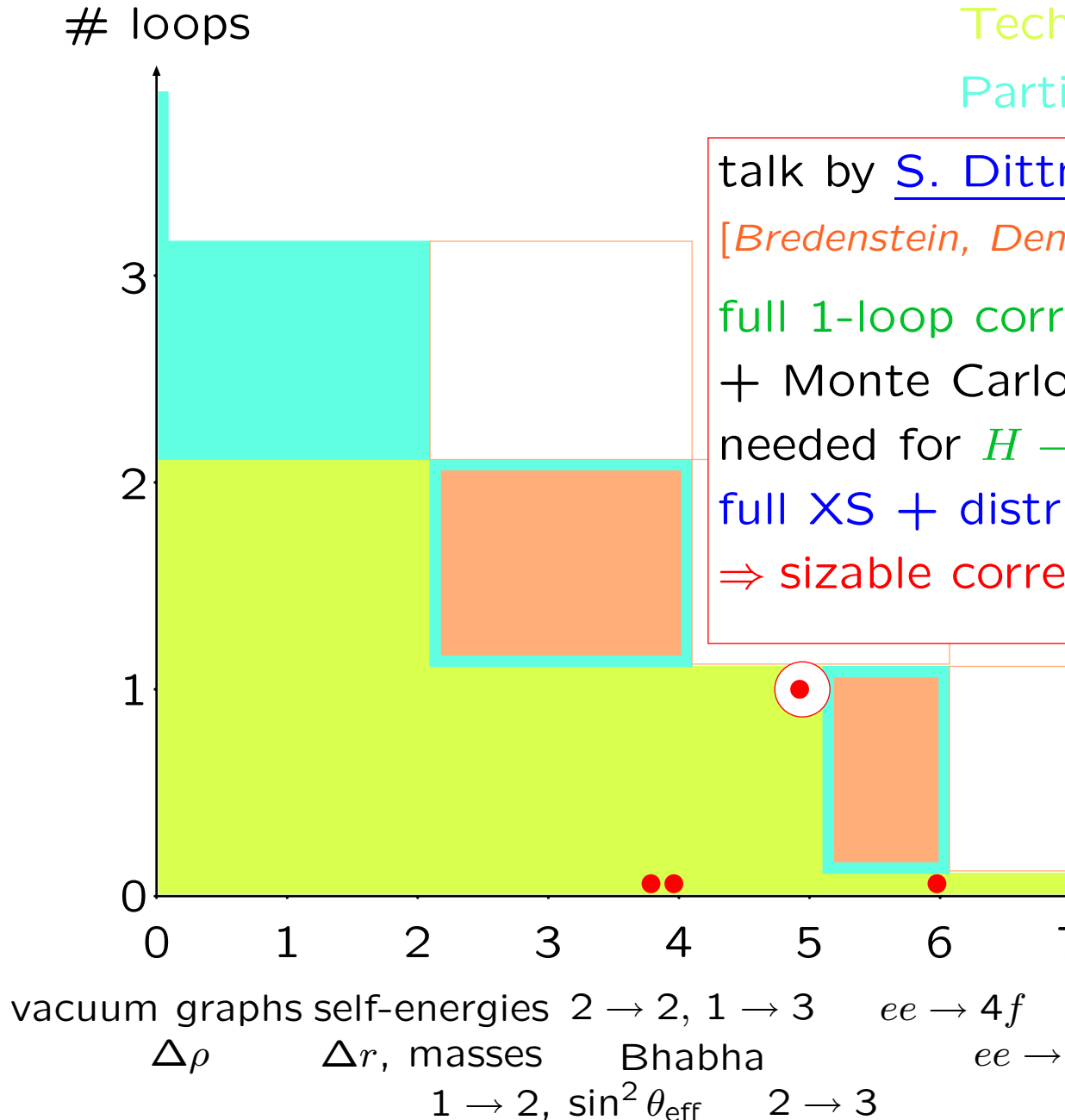
full 1-loop correction to  $1 \rightarrow 4$

+ Monte Carlo

needed for  $H \rightarrow VV^{(*)}$  analysis

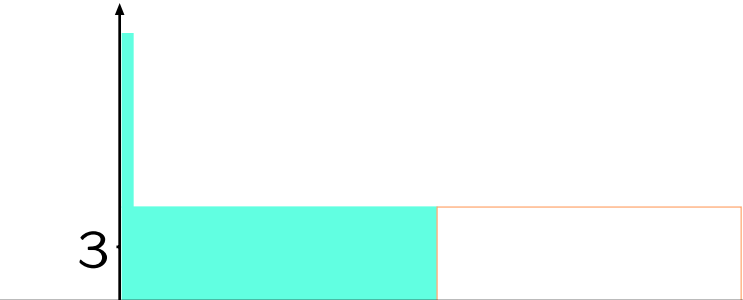
full XS + distributions

$\Rightarrow$  sizable corrections



# SM Higgs from another angle: contributions in Valencia

# loops



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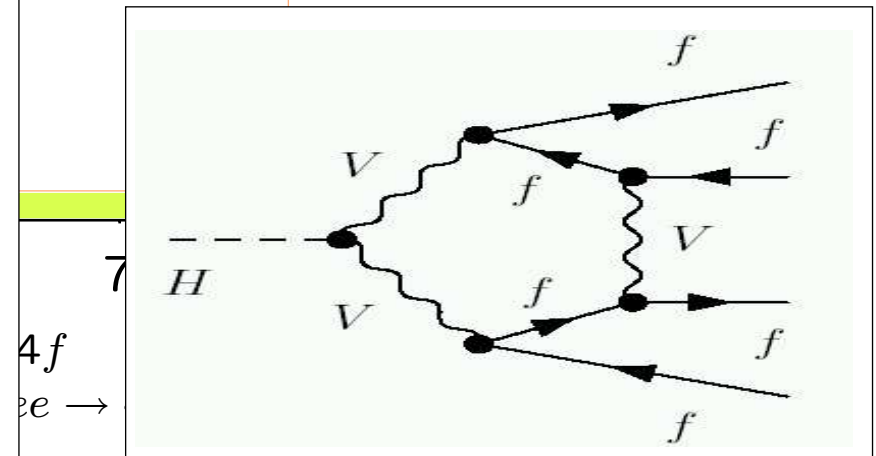
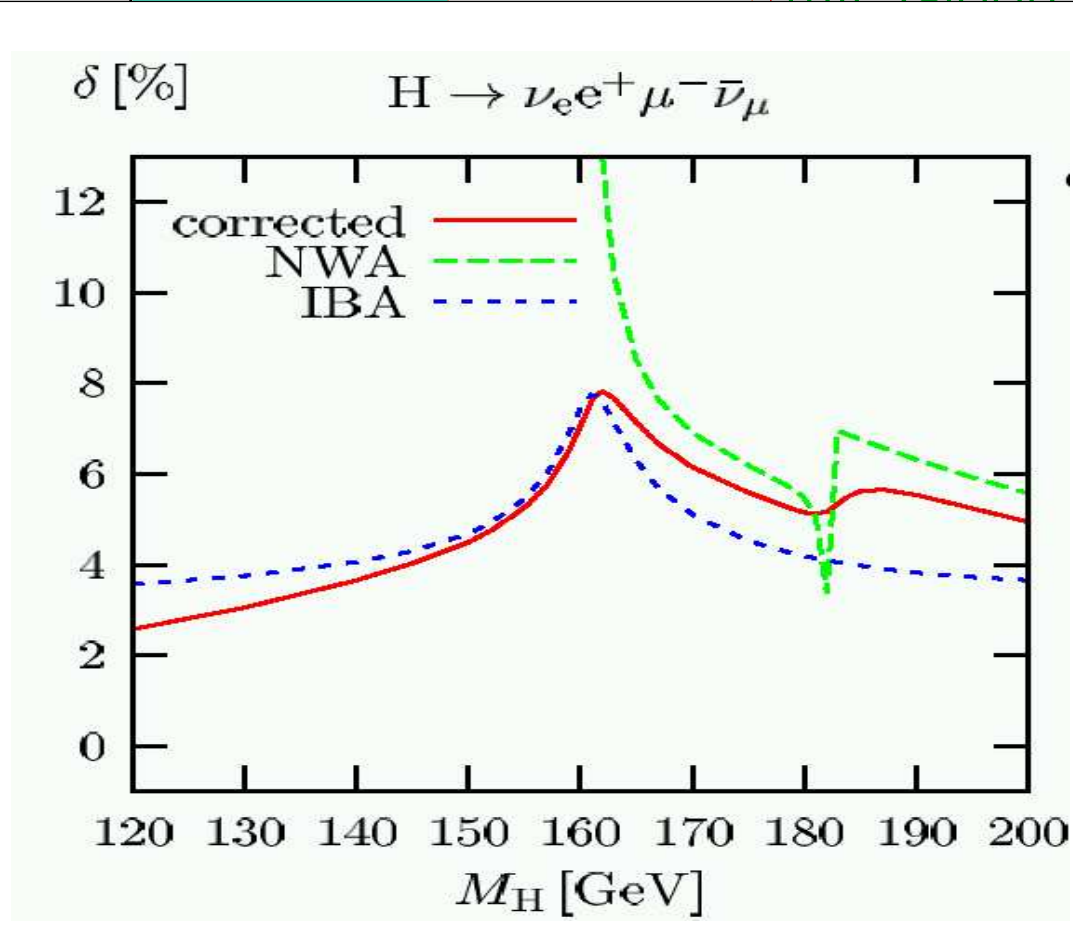
ILC

carlo

$H \rightarrow VV^{(*)}$  analysis

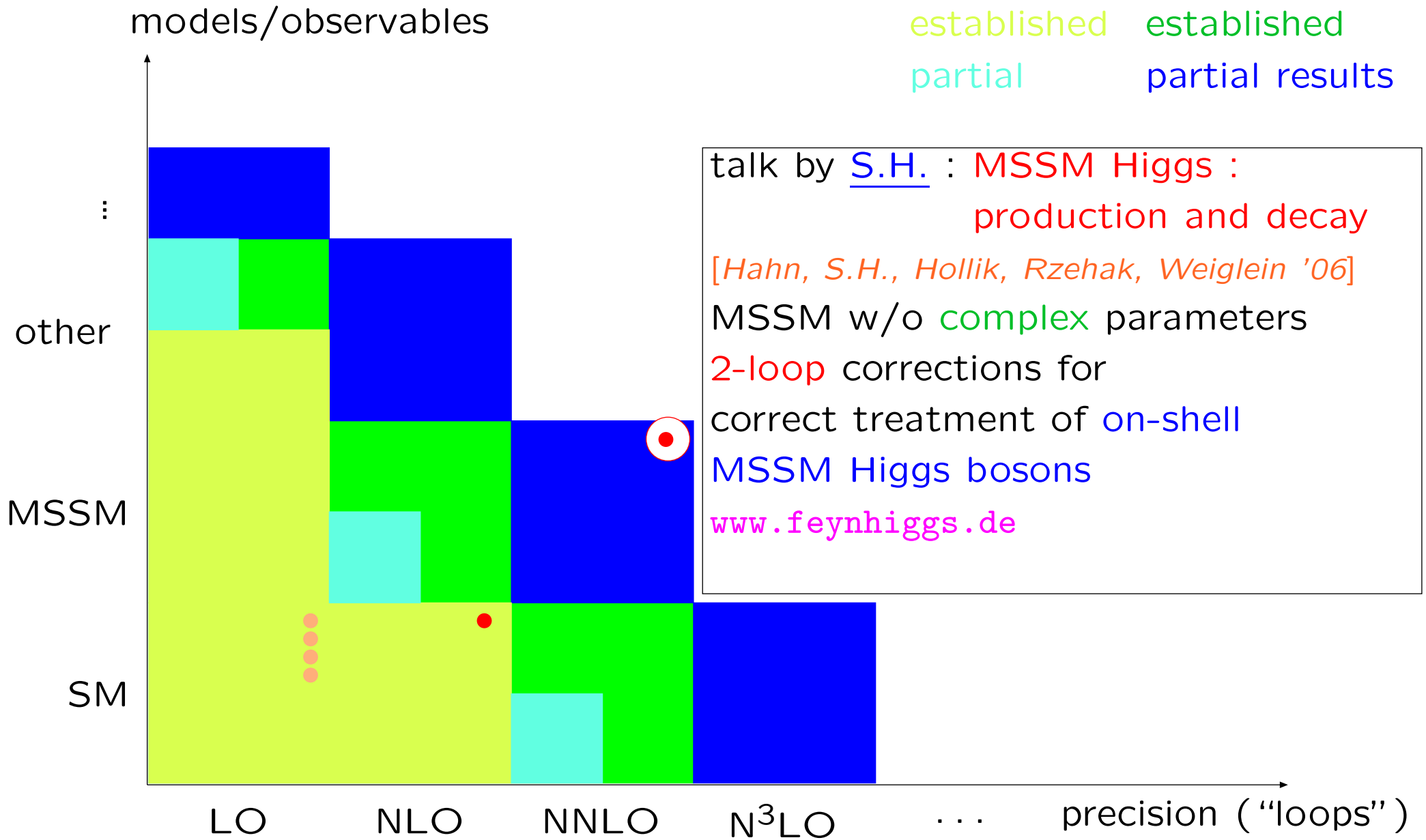
distributions

corrections



# Higgs: contributions in Valencia

experiment    theory  
 established    established  
 partial        partial results

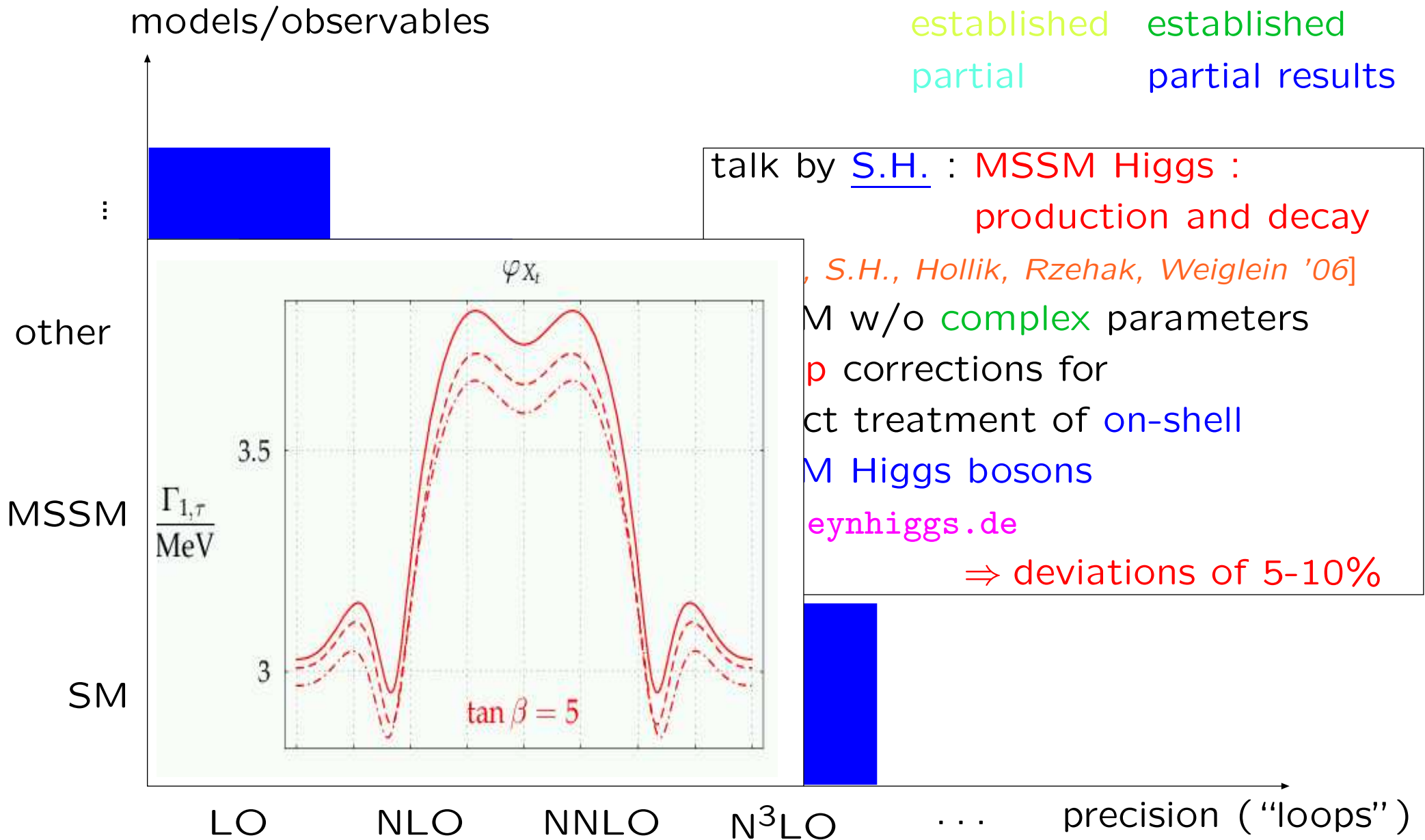


talk by [S.H.](#) : **MSSM Higgs** :  
    production and decay  
*[Hahn, S.H., Hollik, Rzehak, Weiglein '06]*  
 MSSM w/o **complex** parameters  
**2-loop** corrections for  
 correct treatment of **on-shell**  
 MSSM Higgs bosons  
[www.feynhiggs.de](http://www.feynhiggs.de)



# Higgs: contributions in Valencia

experiment    theory  
 established    established  
 partial        partial results



## Discussion about parameters:

F. Richard (with help from P. Bambade) tried to persuade us that

the optimal energy for Higgs measurements is the one with highest XS

$$\Rightarrow \sqrt{s} \approx M_H + 100 \text{ GeV}$$

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## Conclusions

- If  $M_H = 120 \text{ GeV}$ , there are many good reasons to run at  $\sim 220 \text{ GeV}$
- Spin determination
- Maximum cross section
- Best possible mass resolution
- We should therefore see what are the limitations on the Machine side

## Outlook

... no time left ...

There is progress in the right direction for “Higgs”,  
(sometimes one might wish for more activities)

Some goals can be met without problems, other are harder (as usual)  
and some are **very** difficult!

⇒ We must not stop in our efforts

⇒ We must support the people doing the really hard work

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⇒ We must support the people doing the really hard work

**If we continue with the hard work, physics will be ready  
for the ILC start**