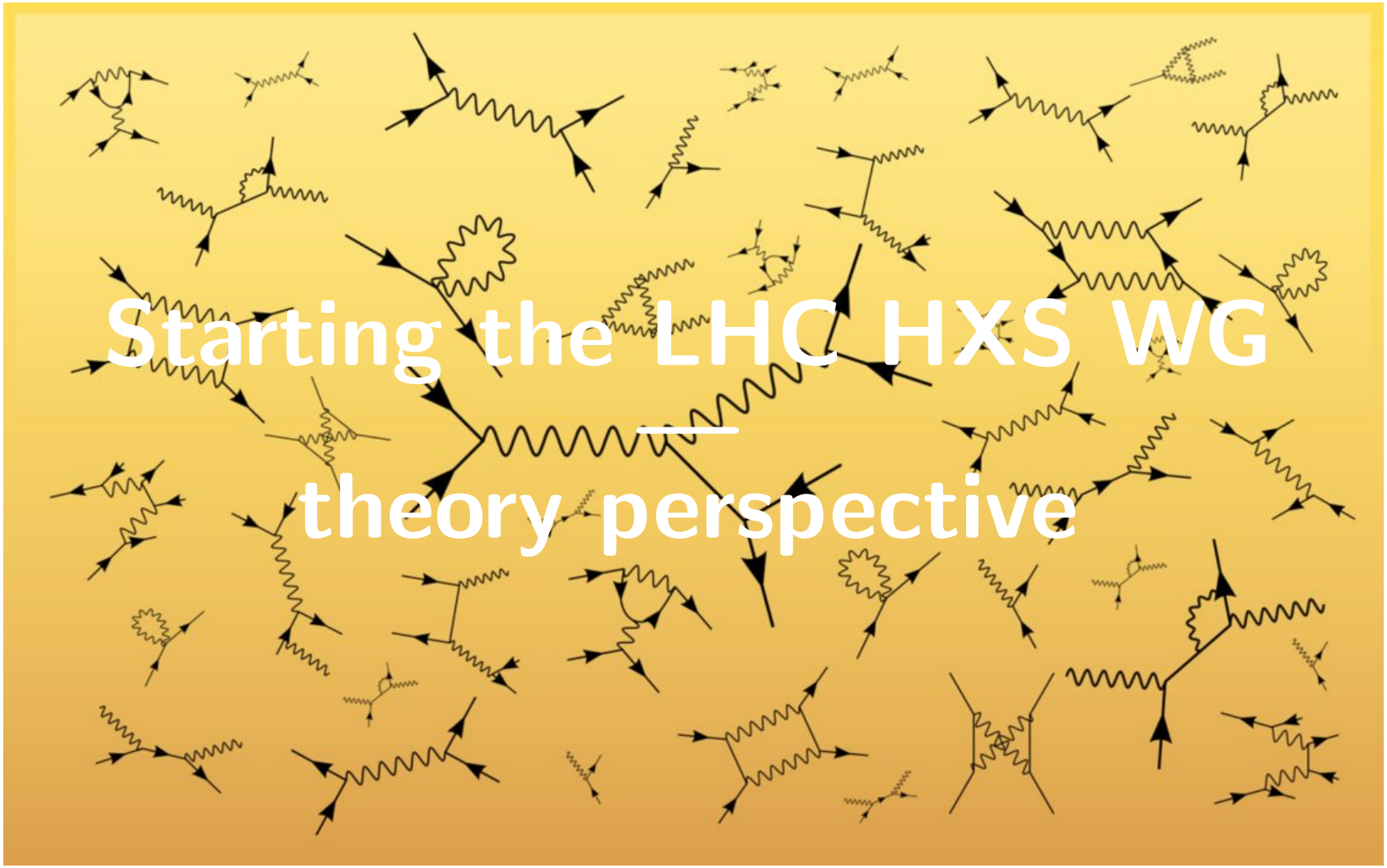


Starting the LHC HXS WG
— theory perspective

Stefan Dittmaier

universität freiburg

Table of contents

Table of contents

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

Initial structure of the group:

- 4 overall contacts

ATLAS	CMS	THEORY	
Reisaburo Tanaka (LAL)	Chiara Mariotti (Torino)	Stefan Dittmaier (Freiburg)	Giampiero Passarino (Torino)

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

Initial structure of the group:

- 4 overall contacts

ATLAS	CMS	THEORY	
Reisaburo Tanaka (LAL)	Chiara Mariotti (Torino)	Stefan Dittmaier (Freiburg)	Giampiero Passarino (Torino)

Chiara Mariotti
↪ charming diplomat

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

Initial structure of the group:

- 4 overall contacts

ATLAS	CMS	THEORY	
Reisaburo Tanaka (LAL)	Chiara Mariotti (Torino)	Stefan Dittmaier (Freiburg)	Giampiero Passarino (Torino)

Chiara Mariotti
↪ charming diplomat

Giampiero Passarino
↪ initiator and wise theorist

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

Initial structure of the group:

- 4 overall contacts

ATLAS	CMS	THEORY	
Reisaburo Tanaka (LAL)	Chiara Mariotti (Torino)	Stefan Dittmaier (Freiburg)	Giampiero Passarino (Torino)

Reisaburo Tanaka
↪ infinite energy

Chiara Mariotti
↪ charming diplomat

Giampiero Passarino
↪ initiator and wise theorist

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

Initial structure of the group:

- 4 overall contacts

ATLAS	CMS	THEORY	
Reisaburo Tanaka (LAL)	Chiara Mariotti (Torino)	Stefan Dittmaier (Freiburg)	Giampiero Passarino (Torino)

Reisaburo Tanaka
↪ infinite energy

Chiara Mariotti
↪ charming diplomat

... and me

Giampiero Passarino
↪ initiator and wise theorist

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

Initial structure of the group:

- 4 overall contacts

ATLAS	CMS	THEORY	
Reisaburo Tanaka (LAL)	Chiara Mariotti (Torino)	Stefan Dittmaier (Freiburg)	Giampiero Passarino (Torino)

Reisaburo Tanaka
↪ infinite energy

Chiara Mariotti
↪ charming diplomat

Giampiero Passarino
↪ initiator and wise theorist

... and me
↪ 2012 replaced by
Sven Heinemeyer

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

Initial structure of the group:

- 4 overall contacts

ATLAS	CMS	THEORY	
Reisaburo Tanaka (LAL)	Chiara Mariotti (Torino)	Stefan Dittmaier (Freiburg)	Giampiero Passarino (Torino)

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

Initial structure of the group:

- 4 overall contacts
- 10 subgroups on production modes and common issues

Group	ATLAS	CMS	LHCb	THEORY	
1. *ggF*	Jianming Qian (Michigan)	Fabian Stöckli (CERN)		Massimiliano Grazzini (Firenze)	Frank Petriello (Wisconsin)
2. *VBF*	Daniela Rebuzzi (Pavia) Sinead Farrington (Oxford)	Christoph Hackstein (Karlsruhe)		Ansgar Denner (Würzburg)	Carlo Oleari (Milano-Bicocca)
3. *WH/ZH*	Giacinto Piacquadio (CERN)	Jim Olsen (Princeton)	Clara Matteuzzi (Milano-Bicocca)	Stefan Dittmaier (Freiburg)	Robert Harlander (Wuppertal)
4. *ttH*	Chris Potter (Oregon)	Chris Neu (Virginia)		Laura Reina (Florida)	Michael Spira (PSI)
5. *MSSM neutral*	Markus Warsinsky (Freiburg)	Monica Vazquez Acosta (IC)		Michael Spira (PSI)	Georg Weiglein (DESY)
6. *MSSM charged*	Martin Flechl (Freiburg)	Sami Lehti (Helsinki)		Michael Krämer (Aachen)	Sven Heinemeyer (IFCA)
7. *PDF*	Joey Huston (Michigan State)	Kajari Mazumdar (TIFR)		Stefano Forte (Milano)	Robert Thorne (UCL)
8. *Branching ratios*	Daniela Rebuzzi (Pavia)	Ivica Puljak (Split)		Ansgar Denner (Würzburg)	Sven Heinemeyer (IFCA)
9. *NLO MC*	Jae Yu (Texas)	Marta Felcini (UCLA/IFCA)		Fabio Maltoni (Louvain)	Paolo Nason (Milano-Bicocca) Frank Krauss (Durham)
	Michael Dührssen	Marta Felcini			Giampiero

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

Initial structure of the group:

- 4 overall contacts
- 10 subgroups on production modes and common issues
- 6 "orthogonal" subgroups on decay channels (since 2011)

Group	ATLAS	CMS	LHCb
1. $\gamma\gamma$	Marumi Kado (LAL)	Susan Gascon-Shotkin (Lyon)	
2. ZZ*	Stathes Paganis (Sheffield)	Nicola De Filippis (Bari)	
3. WW*	Tiesheng Dai (Michigan)	Javier Cuevas (Oviedo)	
4. $\tau\tau$	Markus Schumacher (Freiburg)	Alexander Nikitenko (Imperial College)	
5. bb	Chris Potter (Oregon)	Jim Olsen (Princeton)	Clara Matteuzzi (Milano-Bicocca)
6. H+-	Martin Flechl (Freiburg)	Sami Lehti (Helsinki)	

LHC Higgs Cross Section Working Group – how it began

- initiated by Giampiero Passarino in 2009
- complicated negotiations with LHC collaborations ... politics
- Inauguration Workshop in Freiburg, April 2010
- regular workshops:

  CERN+Bari (2010), BNL+LAL (2011), CERN+CERN (2012), ...

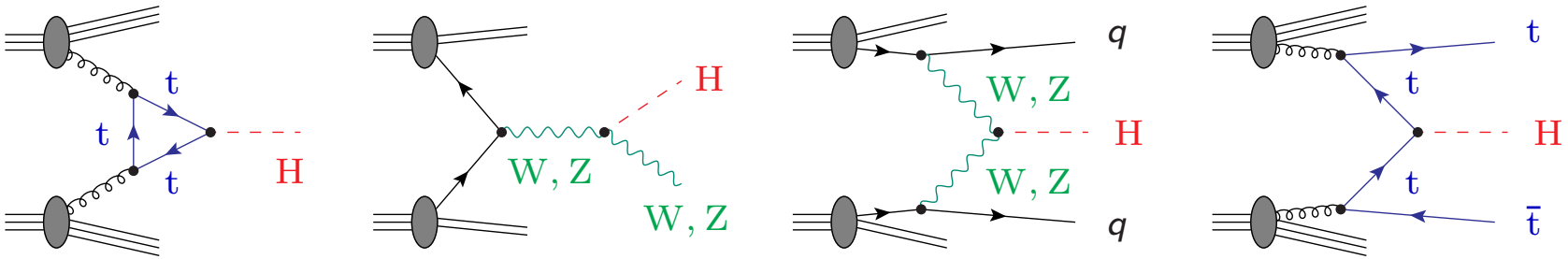
Initial structure of the group:

- 4 overall contacts
- 10 subgroups on production modes and common issues
- 6 "orthogonal" subgroups on decay channels (since 2011)
- ex-officio contact people

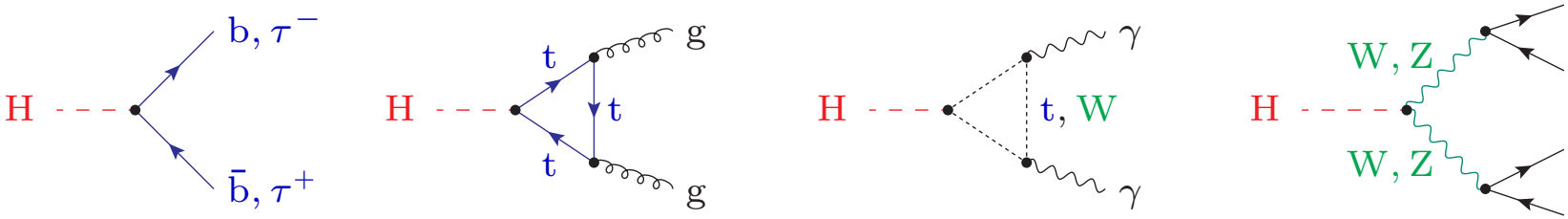
Group	ATLAS		CMS	
Higgs conveners	Bill Murray (RAL)	Sandra Kortner (MPI)	Andrey Korytov (Florida)	Vivek Sharma (UCSD)
MC Generator conveners	Claire Gwenlan (Oxford)	Peter Loch (Arizona)	Fabio Cossutti (Trieste)	Fabian Stöckli (CERN)
SM XS Task Force convener	Jon Butterworth (UCL)		Roberto Chierici (Lyon)	

The mission ...

Processes at hadron colliders ($\mathrm{p\bar{p}}/\mathrm{pp}$):



Decay channels for Higgs bosons of moderate mass ($M_{\mathrm{H}} \lesssim 300\,\mathrm{GeV}$):



Tasks:

- precise predictions in the SM and beyond for common input
- combination of production channels and decays
- uncertainty estimates
- appropriate (pseudo-)observables
- simulation tools

⇒ Working Group planned following the role model of LEP WGs

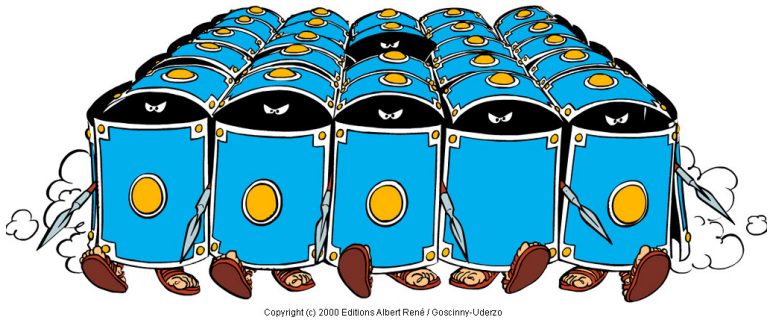
LHC XS WG – how it worked (in the beginning)

- weekly virtual meetings among the overall contacts

LHC XS WG – how it worked (in the beginning)

- weekly virtual meetings among the overall contacts
- continuous work by many participants

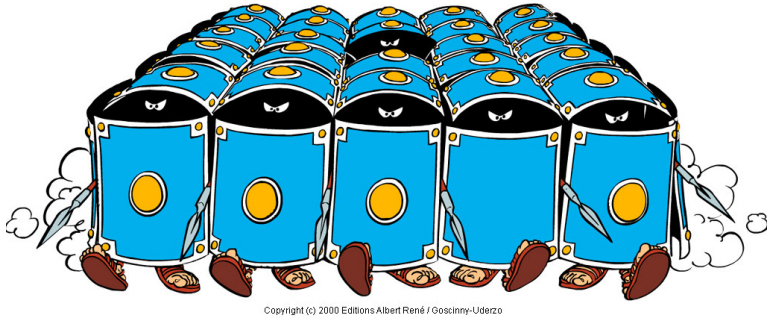
... planned like this



LHC XS WG – how it worked (in the beginning)

- weekly virtual meetings among the overall contacts
- continuous work by many participants

... planned like this

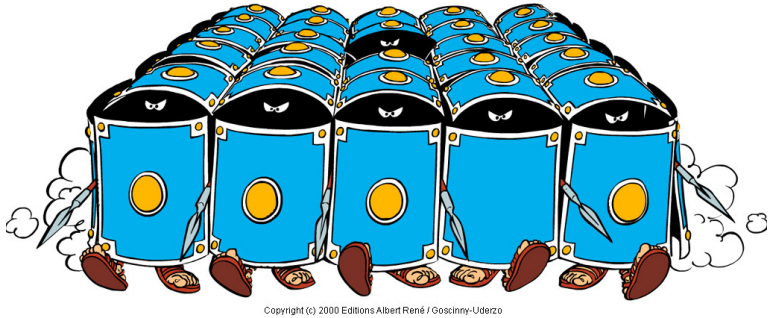


... sometimes working out like that

LHC XS WG – how it worked (in the beginning)

- weekly virtual meetings among the overall contacts
- continuous work by many participants

... planned like this



... sometimes working out like that

- $\sim$ 2 plenary workshops per year
- Yellow Reports:

  YR1 (2011, 161p.) $\rightarrow$ YR2 (2012, 287p.) $\rightarrow$ YR3 (2013, 404p.) $\rightarrow$ YR4 (2017, 869p.) $\rightarrow$??

LHC XS WG – artist's painting from one of the workshops

LHC XS WG – artist's painting from one of the workshops

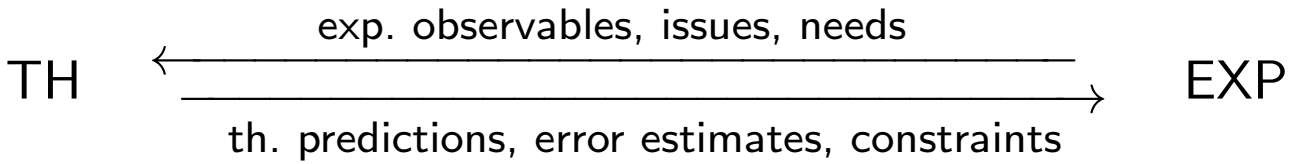
Back to the role model ...

Table of contents

The "LEP spirit" of the WG

Common approach is paramount:

- Subgroups lead by conveners to
  - identify most important physics issues
  - coordinate common effort to make progress
  - organize meetings to discuss progress and further directions
- Task forces within subgroups might concentrate on important topics leading to publications
- Common coherent contributions of subgroups to WG reports (YRs)
- Active collaborations between theorists and experimentalists:

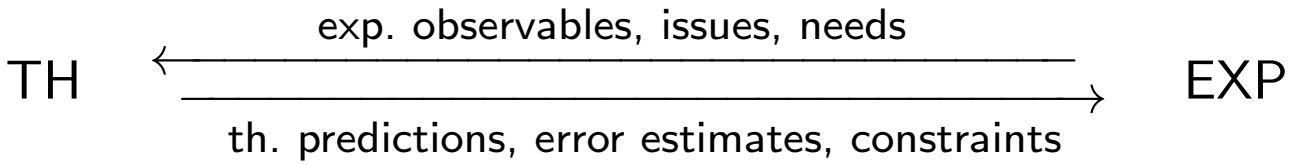


- New scientific contacts and collaborations emerge (also TH+EXP)

The "LEP spirit" of the WG

Common approach is paramount:

- Subgroups lead by conveners to
  - identify most important physics issues
  - coordinate common effort to make progress
  - organize meetings to discuss progress and further directions
- Task forces within subgroups might concentrate on important topics leading to publications
- Common coherent contributions of subgroups to WG reports (YRs)
- Active collaborations between theorists and experimentalists:



- New scientific contacts and collaborations emerge (also TH+EXP)

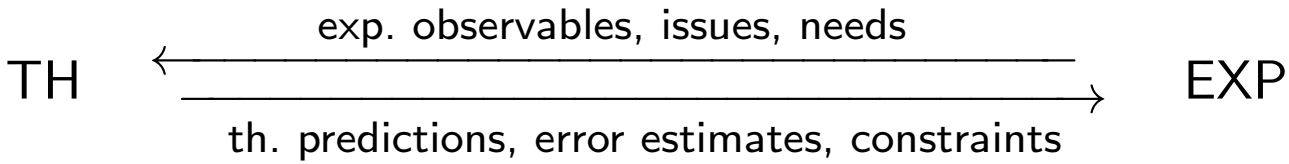
How it is NOT meant:

- Individuals or gangs work in isolation,
- on topics unrelated to the main theme of the subgroup,
- self-invite them to give talks at meetings,
- and abuse WG reports to propagate their work.

The "LEP spirit" of the WG

Common approach is paramount:

- Subgroups lead by conveners to
  - identify most important physics issues
  - coordinate common effort to make progress
  - organize meetings to discuss progress and further directions
- Task forces within subgroups might concentrate on important topics leading to publications
- Common coherent contributions of subgroups to WG reports (YRs)
- Active collaborations between theorists and experimentalists:



- New scientific contacts and collaborations emerge (also TH+EXP)

How it is NOT meant:

- Individuals or ga
- e
- s
- a

Reality ≠ ideal world

... but the right attitude makes a difference!

oup,

ngs,

to propagate their work.

Potential issues and challenges: (more about real life)

- different views on different methods, approaches, results
  $\hookrightarrow$ actually natural+productive
- common progress versus personal interests
  $\hookrightarrow$ conveners/coordinators should enusure balance
- WG groups as "Yellow Reports" or journal publications?
  $\hookrightarrow$ controversal views ...
- LHC community $\gg$ LEP community
  $\hookrightarrow$ organisation more difficult
- LHC physics often more complex than LEP physics
  (PDFs, complicated reconstructions, hadronic junk, etc.)
  $\hookrightarrow$ WG structure more complex

Table of contents

Showcase examples from theory in the LHC HXS WG:

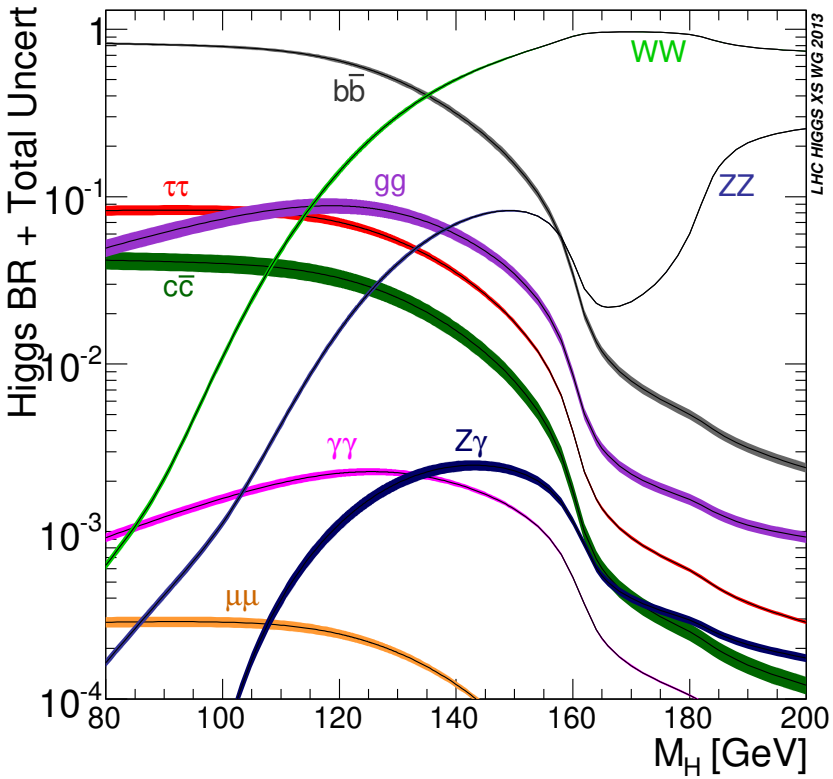
State-of-the-art predictions with error estimates on ...

Showcase examples from theory in the LHC HXS WG:

State-of-the-art predictions with error estimates on ...

- branching ratios

LHC Higgs XS WG '10–'13



Parametric + theoretical uncertainty:

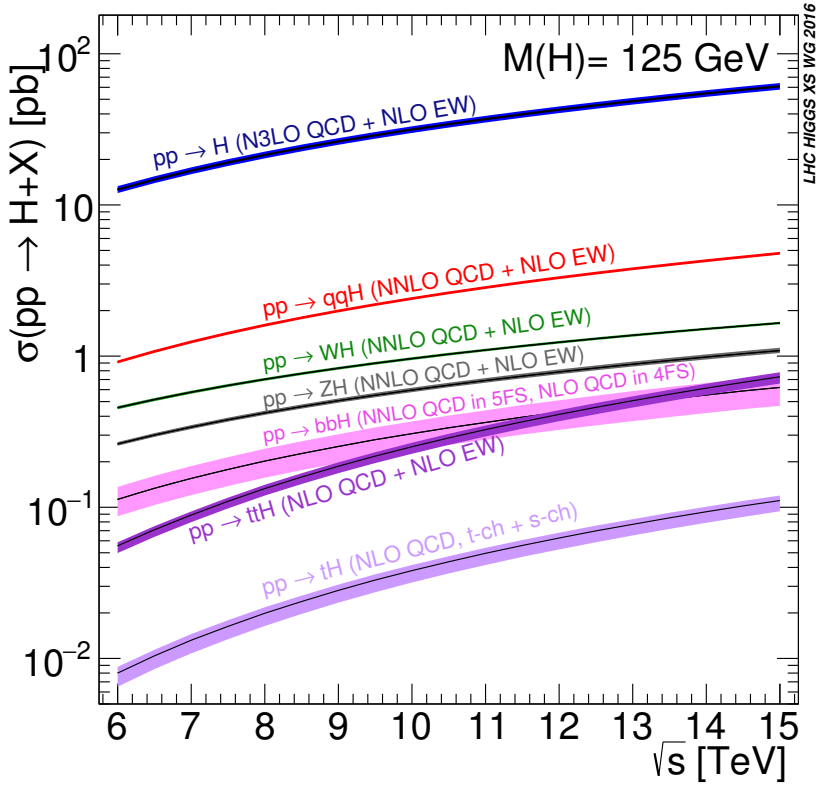
M_H[GeV]	H →	$b\bar{b}$	$\tau^+\tau^-$	$c\bar{c}$	gg	$\gamma\gamma$	WW	ZZ
120		3%	6%	12%	10%	5%	5%	5%
150		4%	3%	10%	8%	2%	1%	1%
200		5%	3%	10%	8%	2%	$< 0.1\%$	$< 0.1\%$

Showcase examples from theory in the LHC HXS WG:

State-of-the-art predictions with error estimates on ...

- branching ratios
- total XS

LHC Higgs XS WG '16



Rough numbers:

$M_H = 125\,\mathrm{GeV}$ $\sqrt{s} = 14\,\mathrm{TeV}$	Uncertainties theory	PDF4LHC	NLO/NNLO/NNNLO QCD	EW
ggF	6%	3%	>100%	5%
VBF	1%	2%	5%*	5%
WH	1%	2%	20%	7%
ZH	4%	2%	35%	5%
ttH	9%	4%	20%	1−2%

* NNNLO QCD available

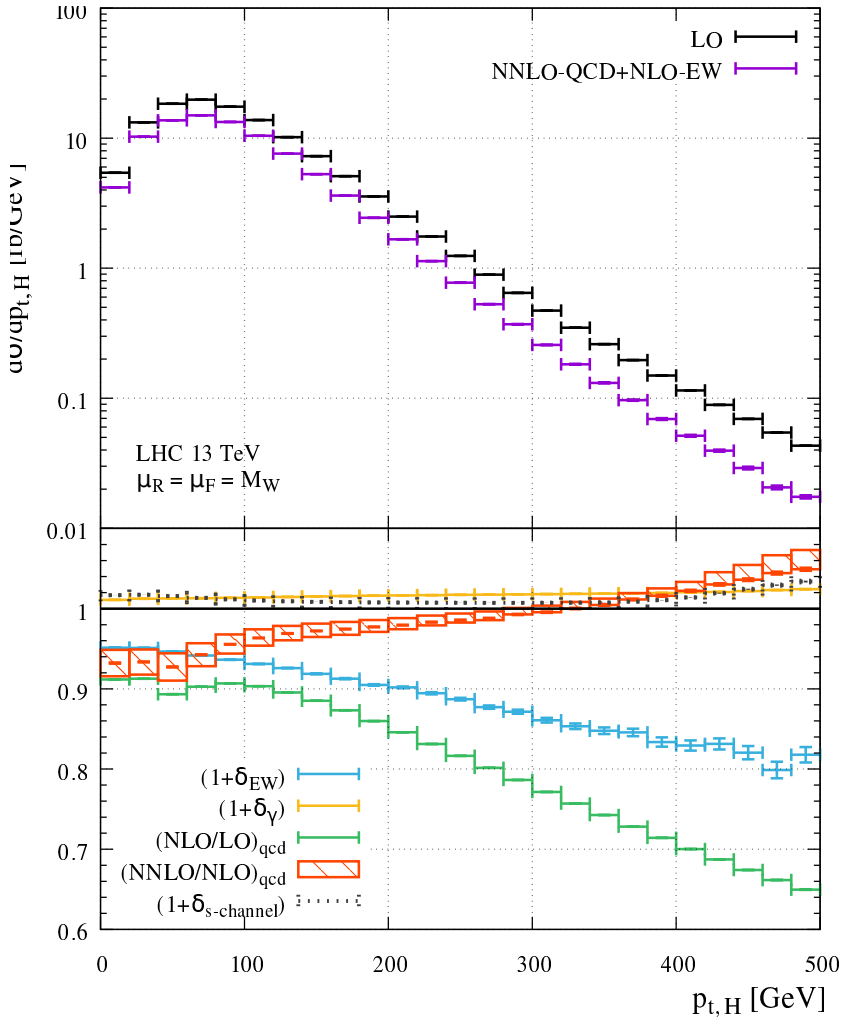
Showcase examples from theory in the LHC HXS WG:

State-of-the-art predictions with error estimates on ...

- branching ratios
- total XS
- differential XS

example: VBF XS

LHC Higgs XS WG '16



Features:

- scale uncertainty $\sim$ 1–2%
- (N)NLO QCD and NLO EW corrections $\sim$ 5–20%
- γ-induced and *s*-channel contributions $\sim$ 1.5%

Showcase examples from theory in the LHC HXS WG:

State-of-the-art predictions with error estimates on ...

- branching ratios
- total XS
- differential XS

Many more results on ...

- PDF interplay
- proposals for pseudo-observables
- predictions within effective field theories
- predictions within SM extensions
- ...

A concrete future challenge: consistent predictions within SM extensions

- common model parametrizations
- common input and input schemes
- common renormalization schemes
  $\hookrightarrow$ if not, model constraints & fits will not better than to $\sim 10\%$
- common treatment across all process classes in Higgs physics
- potential models:
  - Higgs singlet extension
  - THDM (various types)
  - models with Higgs triplets (e.g. Georgi–Machacek)
  - models with dark sectors

$\Rightarrow$ Close collaborations of several groups necessary!

Table of contents

Conclusions (somewhat personal)

The LHC H(XS) WG ...

- very successful in the past
- continuous restructurings adapted to new developments
  (physics of growing complexity, connections to neighbouring WG+fields, ...)
- organisational challenges
  (e.g. moving beyond the SM with an army + retinue)
- WG as important as ever

$\Rightarrow$ Show must go on!

Conclusions (somewhat personal)

The LHC H(XS) WG ...

- very successful in the past
- continuous restructurings adapted to new developments
  (physics of growing complexity, connections to neighbouring WG+fields, ...)
- organisational challenges
  (e.g. moving beyond the SM with an army + retinue)
- WG as important as ever

$\Rightarrow$ Show must go on!

Take long walks in the woods
for wise decisions?