Introduction: Theoretical Issues

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(on behalf of the OCs – S.D., G.Passarino, C.Mariotti, R.Tanaka)

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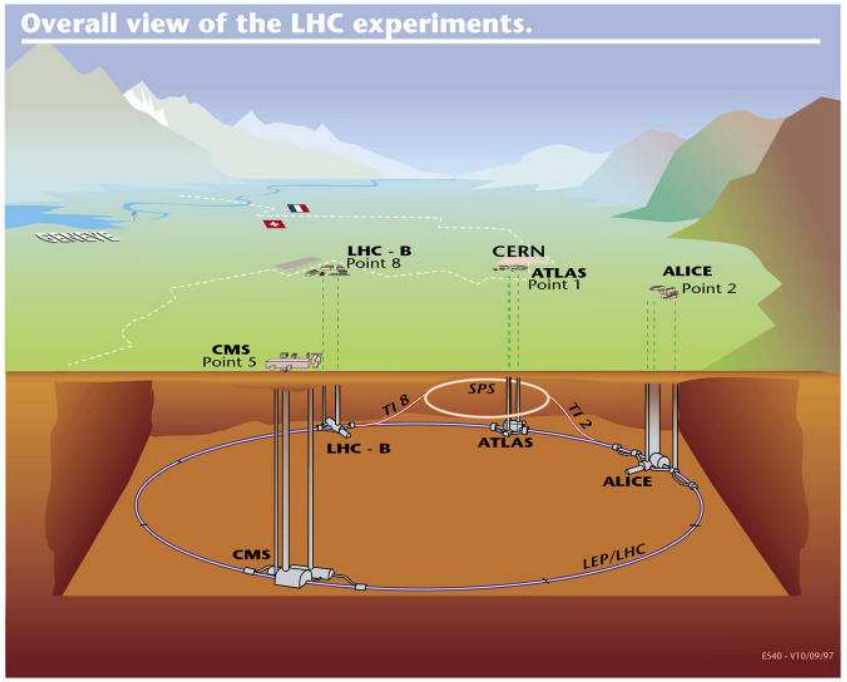
Motivation



2010: LHC @ $7\,\mathrm{TeV}$ rediscovers SM \ Higgs

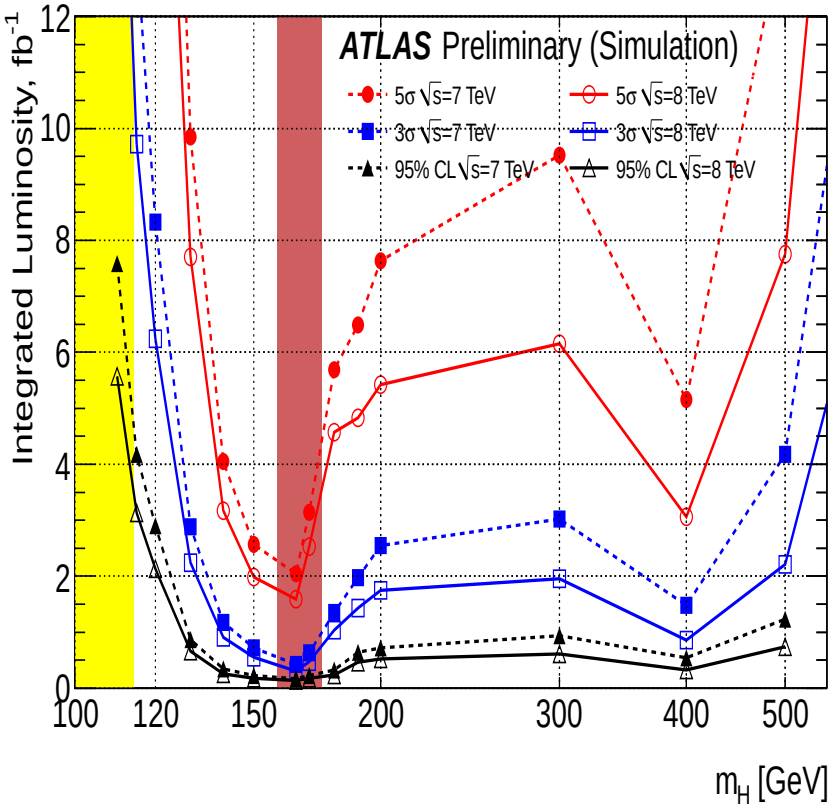
2011: LHC challenges the Higgs boson

- Moriond:
  $\mathrm{H} \to \gamma\gamma$: competitive with Tevatron
  $\mathrm{H} \to \tau\tau$: new exclusion limits in MSSM ($m_{\mathrm{h}}^{\mathrm{max}}$)
- Summer: extension of Tevatron exclusion (!?)
- end of 2011: $\mathcal{L} \sim 1\text{–}2\,\mathrm{fb}^{-1}$ on tape ?

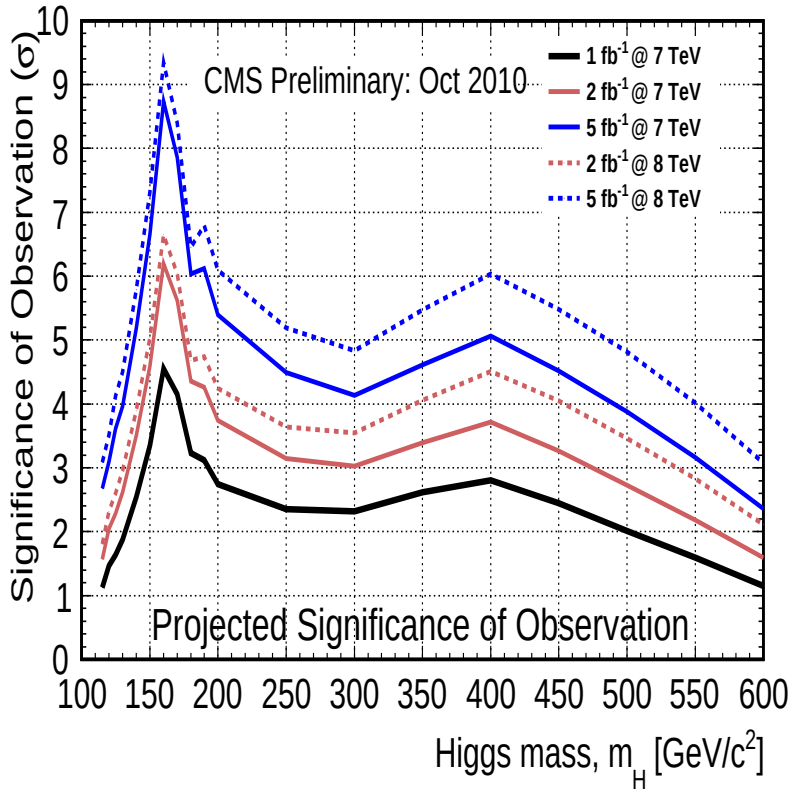
2012: sensitivity to SM Higgs boson in full mass range with $\mathcal{L} \sim$ some fb^{-1}

Prospects for the Higgs search at $7\,\mathrm{TeV}$ ($8\,\mathrm{TeV}$)

Required luminosity required for
95% CL exclusion, 3σ, or 5σ discovery:



Signal significance
for different luminosities (1, 2, $5\,\mathrm{fb}^{-1}$):



LHC Higgs Cross Section Group

The LHC Higgs XS group (ATLAS $\oplus$ CMS $\oplus$ LHCb $\oplus$ Theory)

- physics goals: cross-section predictions + related theory issues
  - ◇ theory update + agreement for XSs and BRs
  - ◇ concept of pseudo-observables (POs) for parameter extractions
  - ◇ SM and MSSM Higgs boson(s)
  - ◇ common input parameters and errors, including PDFs
  - ◇ background processes

$\hookrightarrow$ input / prescriptions / recommendations
for analyses and the LHC Higgs Combination Group

The LHC Higgs XS group (ATLAS $\oplus$ CMS $\oplus$ LHCb $\oplus$ Theory)

- physics goals: cross-section predictions + related theory issues
- 4 overall contacts

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

The LHC Higgs XS group (ATLAS ⊕ CMS ⊕ LHCb ⊕ Theory)

- physics goals: cross-section predictions + related theory issues
- 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)
10. Pseudo-observables	Michael Dührssen (CERN)	Marta Felcini (UCLA/IFCA)			Giampiero Passarino (Torino)

The LHC Higgs XS group (ATLAS ⊕ CMS ⊕ LHCb ⊕ Theory)

- physics goals: cross-section predictions + related theory issues
- 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)	

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- 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 LHC Higgs XS group (ATLAS $\oplus$ CMS $\oplus$ LHCb $\oplus$ Theory)

- physics goals: cross-section predictions + related theory issues
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Note:

- group is open for everybody to actively + constructively contribute
- for more up-to-date info see
  `https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections`

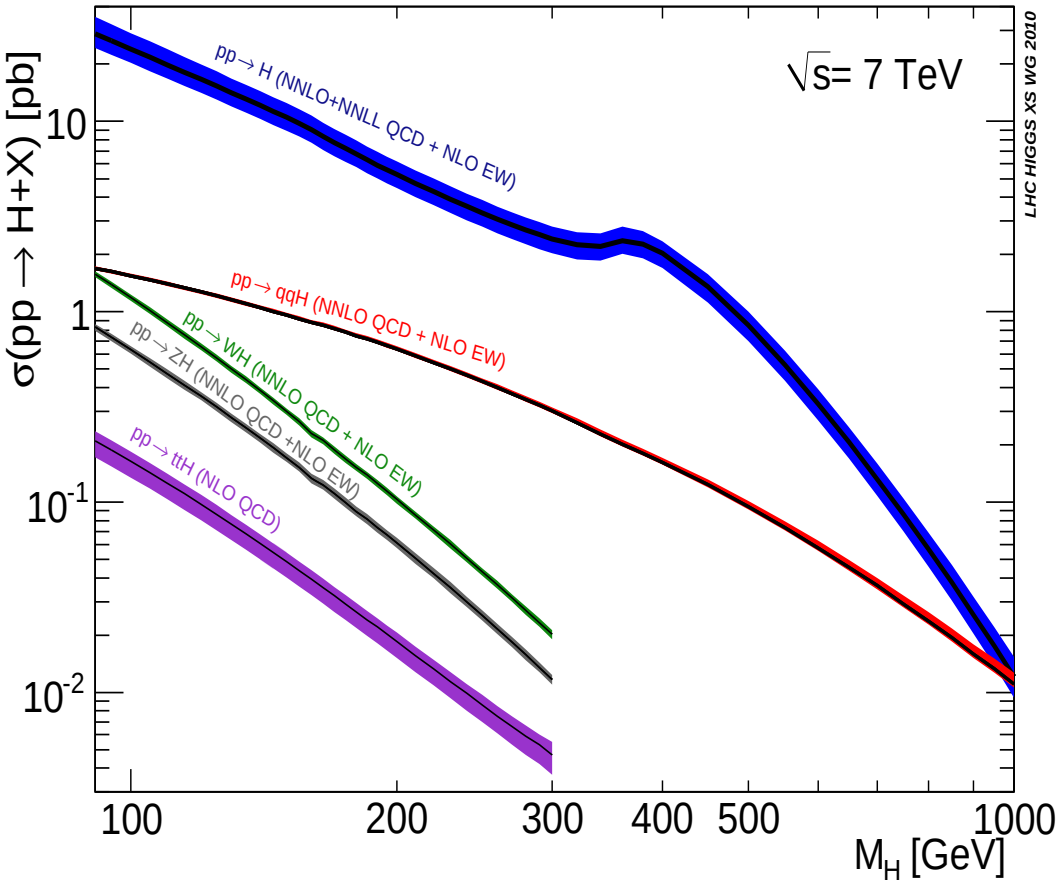
Achieved results

Major results achieved in 2010

↪ documented in Yellow Report CERN 2011-002 [arXiv:1101.0593]

- Common setup and input
- SM Higgs boson
  - ◇ total cross sections a la state-of-the-art for $\sqrt{s} = 7\,\mathrm{TeV}$ and $14\,\mathrm{TeV}$
  - ◇ theoretical and parametric uncertainties for XSs (PDF4LHC widely used)
  - ◇ BRs a la state-of-the-art with theoretical uncertainties
- MSSM Higgs bosons
  - ◇ description of state-of-the-art
  - ◇ numerics for $m_{\mathrm{h}}^{\mathrm{max}}$ scenario
- Selected issues:
  - ◇ PDFs
  - ◇ NLO Monte Carlos
  - ◇ Higgs pseudo-observables
  - ◇ parametric and theoretical uncertainties

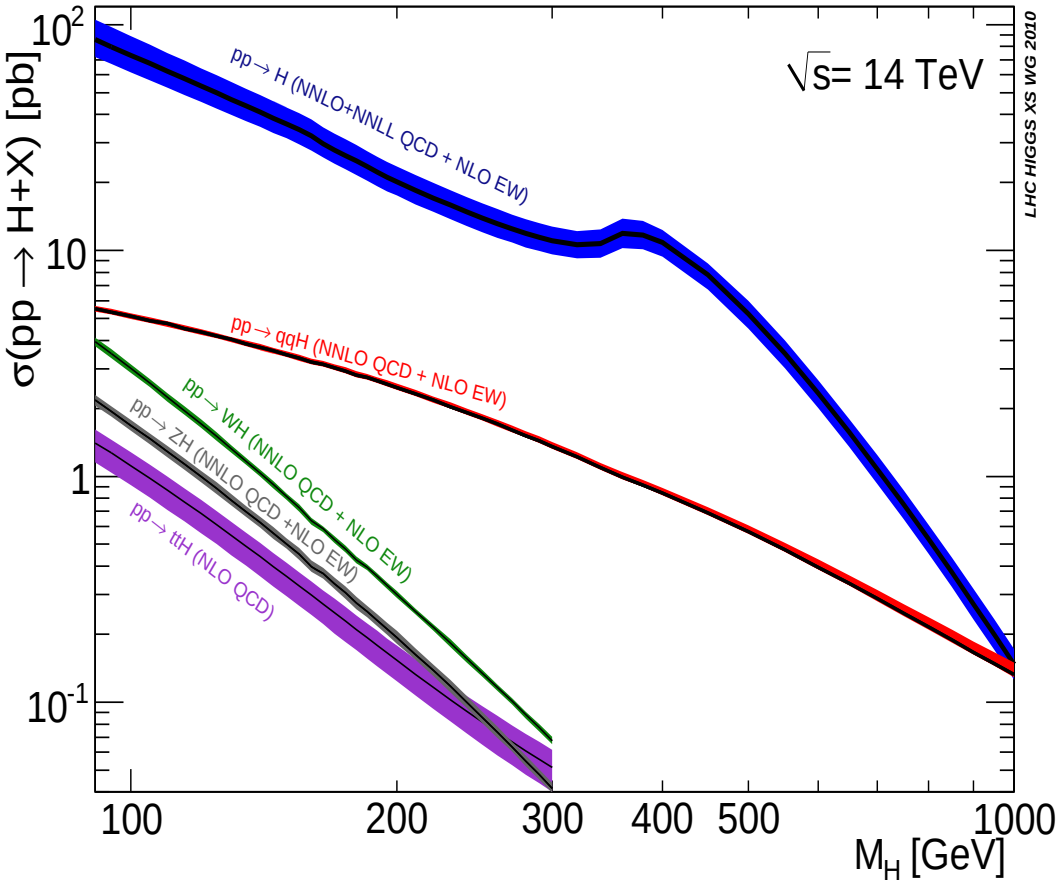
Updated SM Higgs XS predictions for the LHC at $\sqrt{s} = 7\,\mathrm{TeV}$



Rough numbers:

	M_{H}	Uncertainties scale	Uncertainties PDF4LHC	NLO/NNLO/NNLO+ QCD	NLO/NNLO/NNLO+ EW
ggF	$< 500\,\mathrm{GeV}$	$6-10\%$	$8-10\%$	$>100\%$	5%
VBF	$< 500\,\mathrm{GeV}$	1%	$2-7\%$	5%	5%
WH	$< 200\,\mathrm{GeV}$	1%	$3-4\%$	30%	$5-10\%$
ZH	$< 200\,\mathrm{GeV}$	$1-2\%$	$3-4\%$	40%	5%
ttH	$< 200\,\mathrm{GeV}$	10%	9%	5%	?

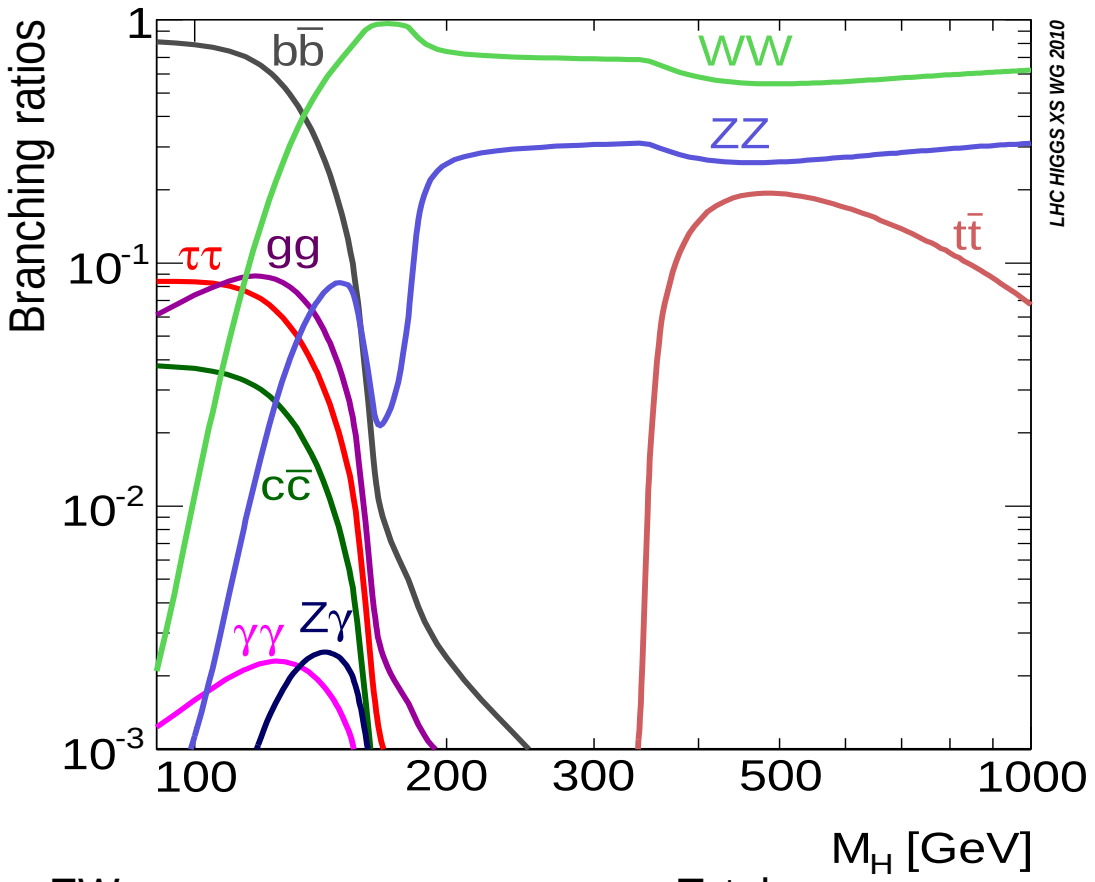
Updated SM Higgs XS predictions for the LHC at $\sqrt{s} = 14\,\mathrm{TeV}$



Rough numbers:

	M_H	Uncertainties scale	PDF4LHC	NLO/NNLO/NNLO+ QCD	EW
ggF	$< 500\,\mathrm{GeV}$	$6-14\%$	7%	$>100\%$	5%
VBF	$< 500\,\mathrm{GeV}$	1%	$3-4\%$	5%	5%
WH	$< 200\,\mathrm{GeV}$	1%	$3-4\%$	30%	$5-10\%$
ZH	$< 200\,\mathrm{GeV}$	$2-4\%$	$3-4\%$	45%	5%
ttH	$< 200\,\mathrm{GeV}$	10%	9%	$15-20\%$	?

BRs of the SM Higgs boson



Parametric uncertainty

↪ still in progress

Theoretical uncertainty:

Partial width	QCD	EW	Total
$\mathrm{H} \to \mathrm{bb/cc}$	~ 0.1–0.2%	~ 1–2% for $M_\mathrm{H} \lesssim 135\,\mathrm{GeV}$	~ 1–2%
$\mathrm{H} \to \tau\tau$		~ 1–2% for $M_\mathrm{H} \lesssim 135\,\mathrm{GeV}$	~ 1–2%
$\mathrm{H} \to \mathrm{tt}$	$\sim 5\%$	$\lesssim 2$–5% for $M_\mathrm{H} < 500\,\mathrm{GeV}$	$\sim 5\%$
$\mathrm{H} \to \mathrm{gg}$	$\sim 10\%$	$\sim 1\%$	$\sim 10\%$
$\mathrm{H} \to \gamma\gamma$	$< 1\%$	$< 1\%$	$\sim 1\%$
$\mathrm{H} \to \mathrm{WW/ZZ} \to 4f$	$< 0.5\%$	$\sim 0.5\%$ for $M_\mathrm{H} < 500\,\mathrm{GeV}$	$\sim 0.5\%$

Current issues and agenda 2011

Continued work / pending homework

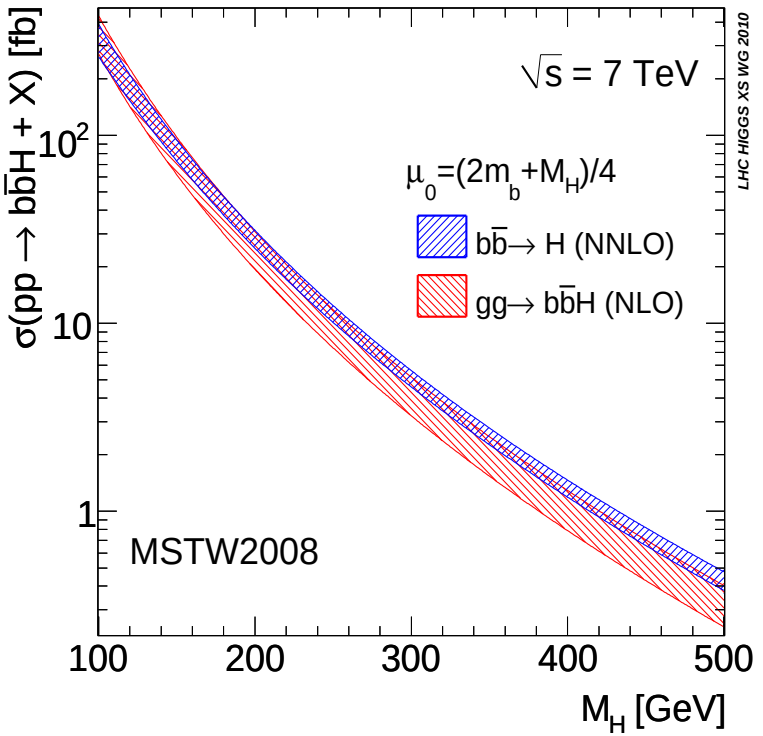
- parametric uncertainties of BRs and combination with THU
  ↪ new independent analysis (compare with Baglio/Djouadi arXiv:1012.0530)
- interpolation points for XS and BR predictions
  ↪ results for more M_{H} values via calculation / interpolation (if justified)
- reconcilation of 4FS and 5FS schemes for $\mathrm{pp} \to \mathrm{b\bar{b}H}$, etc.
  ↪ accepted proposal of “Santander Matching”:

Harlander, Krämer, Schumacher ’11

$$\sigma(\mathrm{b\bar{b}} \to \mathrm{H}{+}X) = \frac{1}{1+t}\left[\underbrace{\sigma^{\mathrm{4FS}}}_{\text{small } M_{\mathrm{H}}} + t\,\underbrace{\sigma^{\mathrm{5FS}}}_{\text{large } M_{\mathrm{H}}}\right]$$

$$t = \ln\frac{M_{\mathrm{H}}}{m_{\mathrm{b}}} - 2$$

For details see wiki page !



Specific final states

- combine production and decay tools for precision analyses
- dedicated subgroups formed for $\mathrm{H} \to \gamma\gamma, \mathrm{ZZ}^{(*)}, \mathrm{WW}^{(*)}, \tau\tau, \mathrm{bb}$ and $\mathrm{H}^{\pm}$

  $\hookrightarrow$ talks this afternoon

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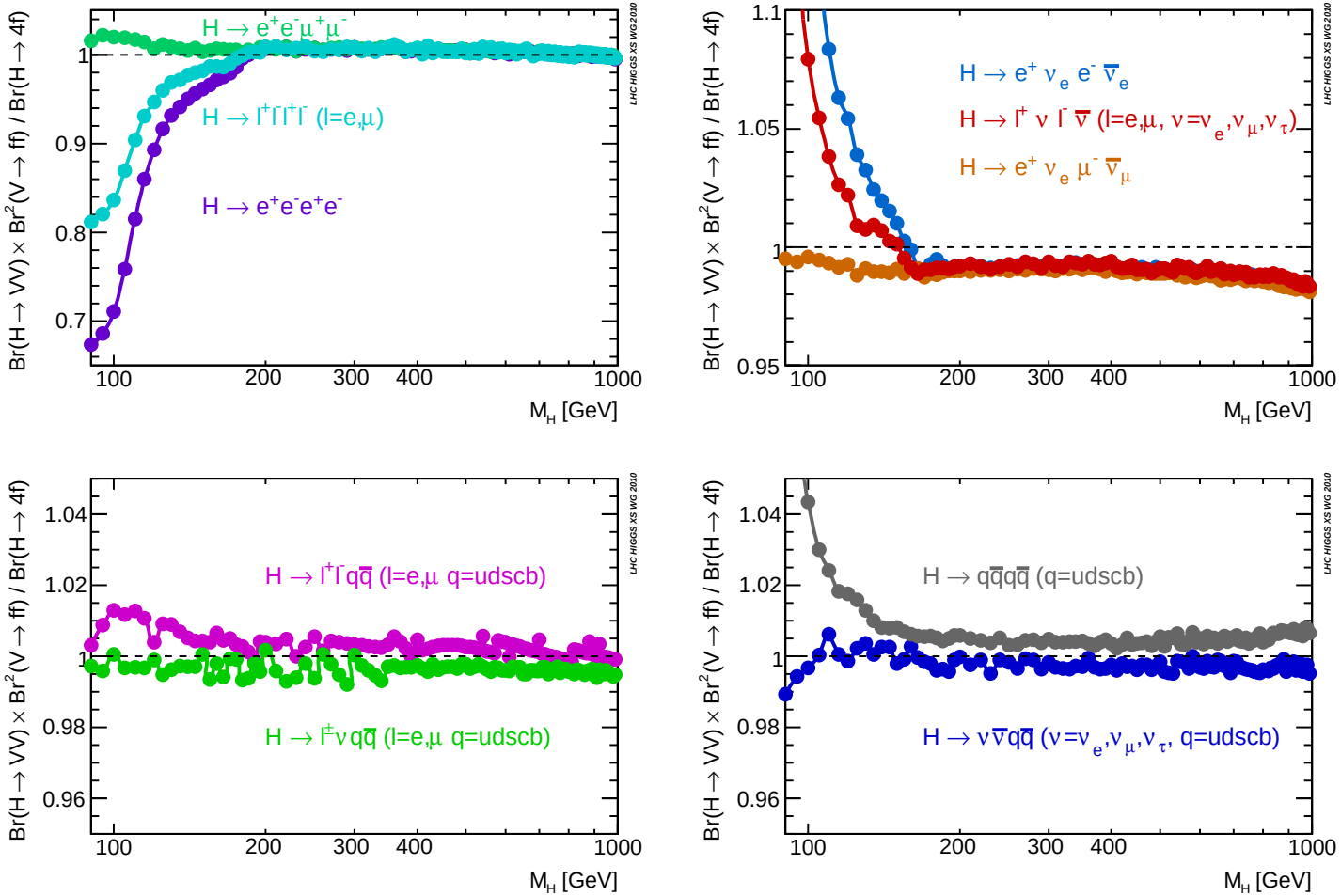
An example: interferences among different $\mathrm{H} \to 4f$ channels

Tanaka et al., see wiki page



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First background issues

- signal–background interference for $\mathrm{gg} \to$ heavy Higgs $\to \mathrm{WW}/\mathrm{ZZ} \to 4f$

  $\hookrightarrow$ talk by Giampiero
- WH/ZH background, e.g. via $\mathrm{pp} \to \mathrm{Wb\bar{b}}$, etc.
- more to come

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PDF activities

- more pragmatic/acceptable/reasonable PDF4LHC recipe ?
- update of PDF, PDF$\oplus\alpha_{\mathrm{s}}$ error correlations

$\hookrightarrow$ talk by Stefano

Issues in MSSM predictions

- Optimal combination of tools for XSs and BRs predictions

The controversial subject:

conservative LO improvements $\longleftrightarrow$ rescaled state-of-the-art SM predictions via effective MSSM couplings

- charged Higgs: combination of 4FS and 5FS a la Santander ?!
- ultimately: solid state-of-the-art predictions for $\mathrm{pp} \to \mathrm{b\bar{b}H}$ beyond ad hoc combinations of 4FS/5FS
- explicit results beyond $m_{\mathrm{h}}^{\mathrm{max}}$ scenario ?

$\rightarrow$ talks by Daniela, Sven

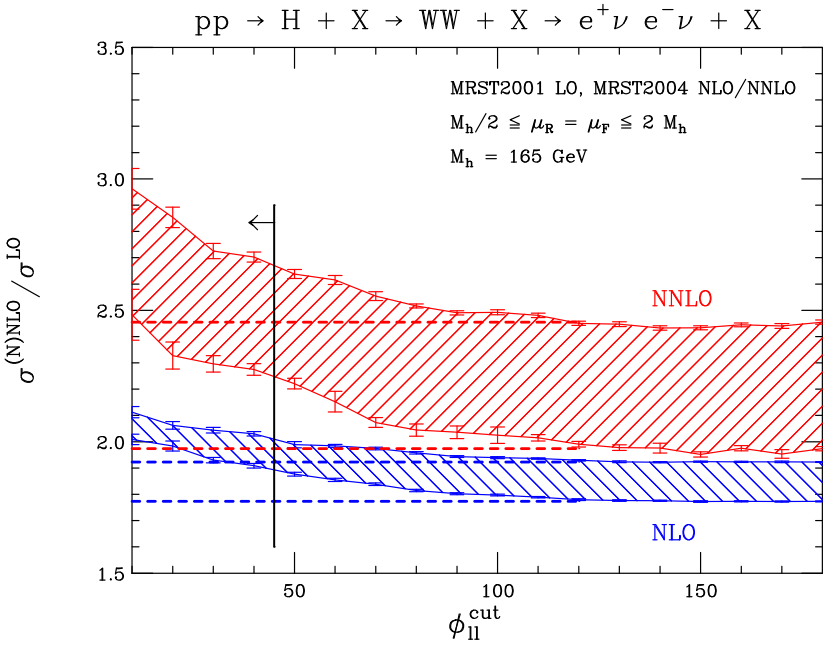
NLOMC activities

- determination of acceptance ε
- error assessment for $\sigma \times \varepsilon$
- comparison of results from different codes / code chains
  $\hookrightarrow$ unification of descriptions $\leftrightarrow$ spread as part of error ?!
- jet multiplicities (jet bin uncertainties)
- inclusion of corrections
- reweighting strategies
- strategy for combining Higgs results for summer conferences

Cuts and corrections

Cut dependence of K factors:

- dependence often sizeable / large
- avoid large corrections
  ↪ perturbative stability !
- careful studies necessary

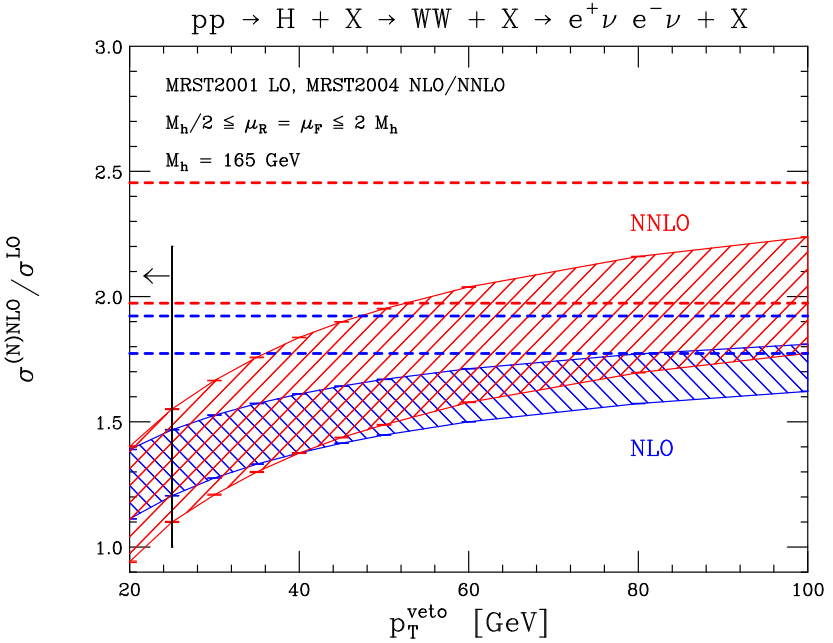


Anastasiou, Dissertori, Stoeckli '07

Jet vetoes:

- study usefulness
- impact on K often large
  ↪ stability issue important
- perturbative control via resummations ?
  ↪ Can Effective Field Theories help ?

→ talks by Alexander, Frank, Massimiliano



Differential distributions and corrections

- predictions with state-of-the-art corrections required
- study distortions induced by corrections

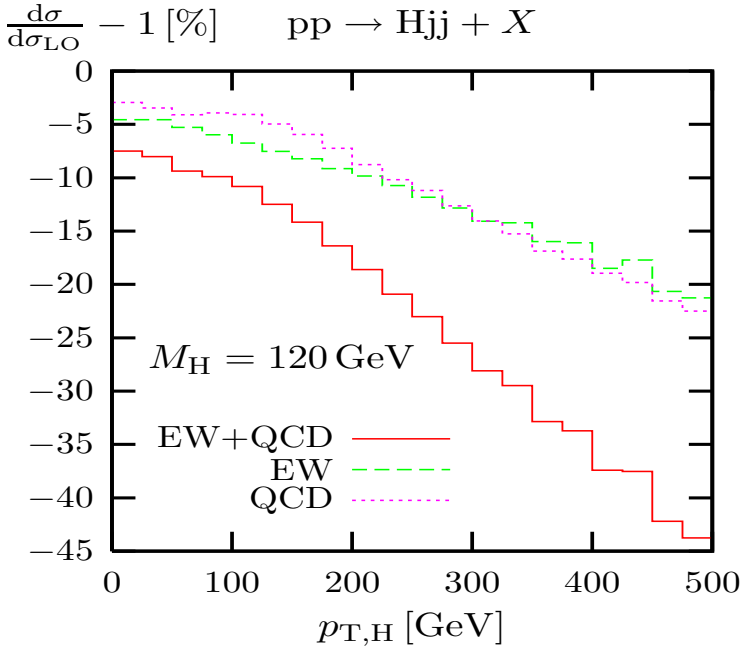
  Note: constant K factors only in “lucky cases” !

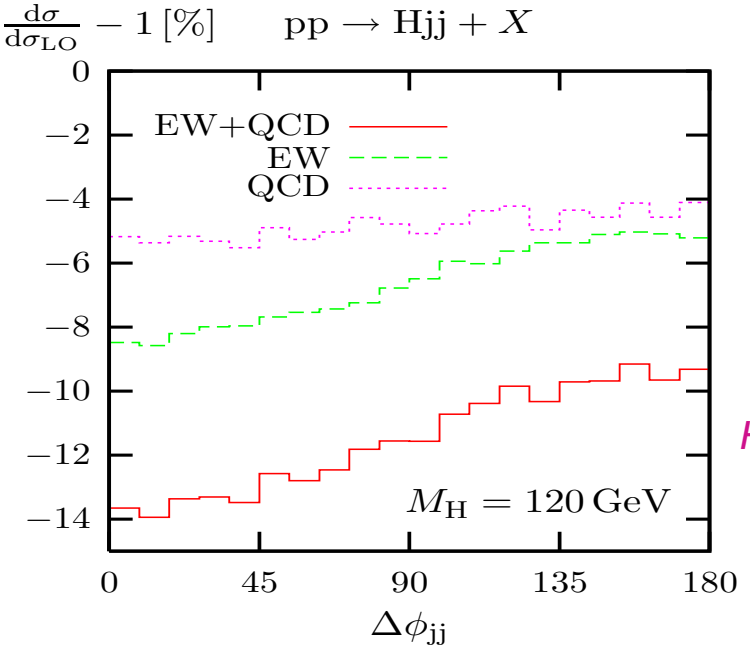
  ↪ Usually, if you flatten a specific distribution by tuning a dynamical scale, you distort another !
- error assessments for shapes of distributions → recipes and results

  Note: can be non-trivial, e.g., due to “non-local correlations” (PDFs, dyn. scales)

Examples from VBF:

Ciccolini, Denner, S.D. ’07





HAWK

Quick summary

- Homework: THU$\oplus$PU for BRs, more M_{H} points for interpolation
- New subgroup structure: dedicated task forces for specific final states
- Ongoing work:
  - ◇ background issues: signal$\oplus$bkg, $\mathrm{Wb\bar{b}}$
  - ◇ PDFs: updates, uncertainties
  - ◇ MSSM: Santander matching, combination of tools
  - ◇ NLOMC: $\sigma \times \varepsilon$, comparison of tools
  - ◇ cuts and distributions: issue of QCD$\oplus$EW corrections, jet vetoes

Main goals of the BNL workshop

- Discussion of current issues – preparation for summer conferences
- Communication between LHC and Tevatron Higgs groups (e.g. about errors)
- Plans for 2011 $\rightarrow$ final discussion

It’s a lot of work ...

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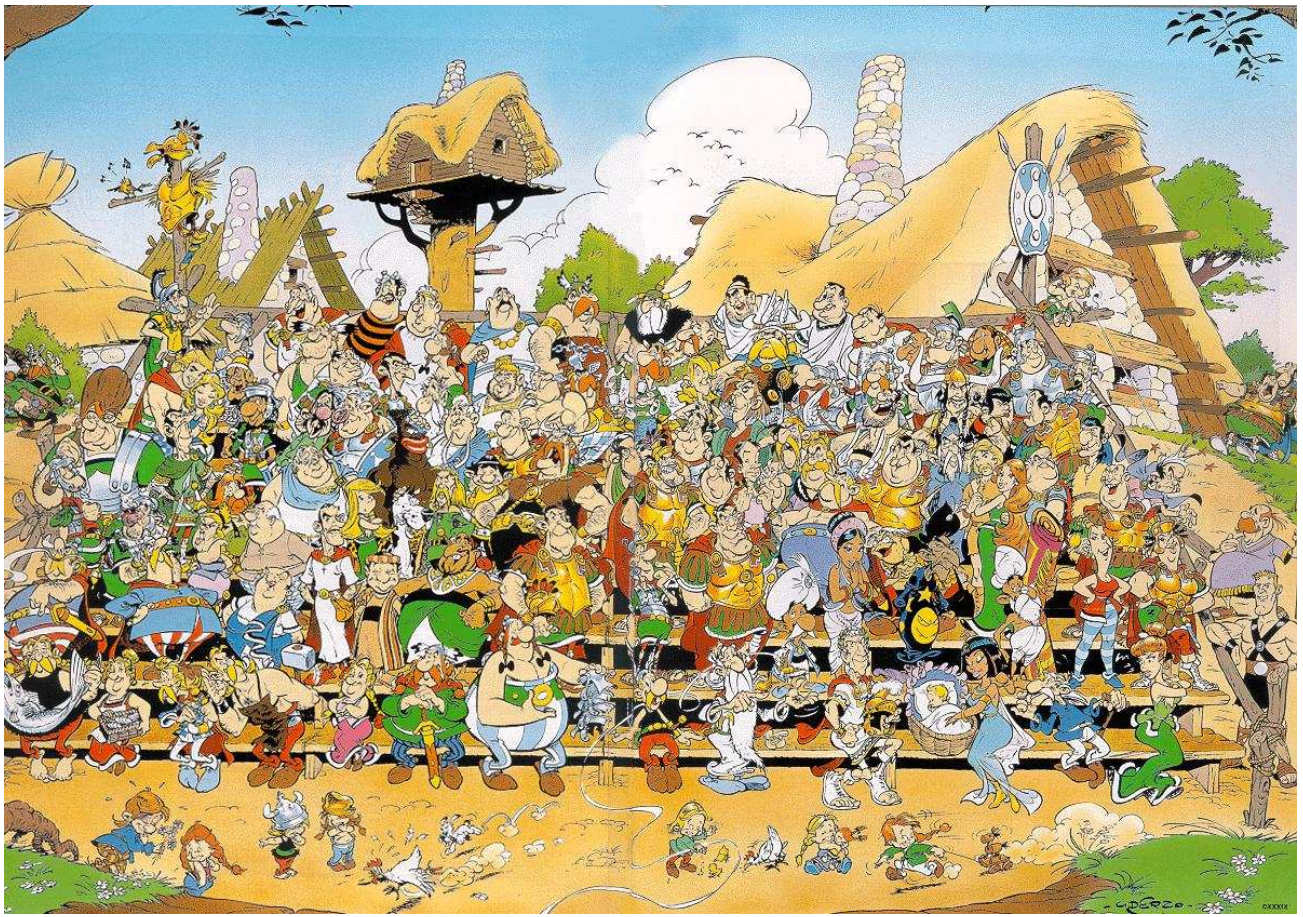

... but acting as a team we can make it !