

# SM & collider physics overview

CERN Theory retreat Les Houches  
November 2015

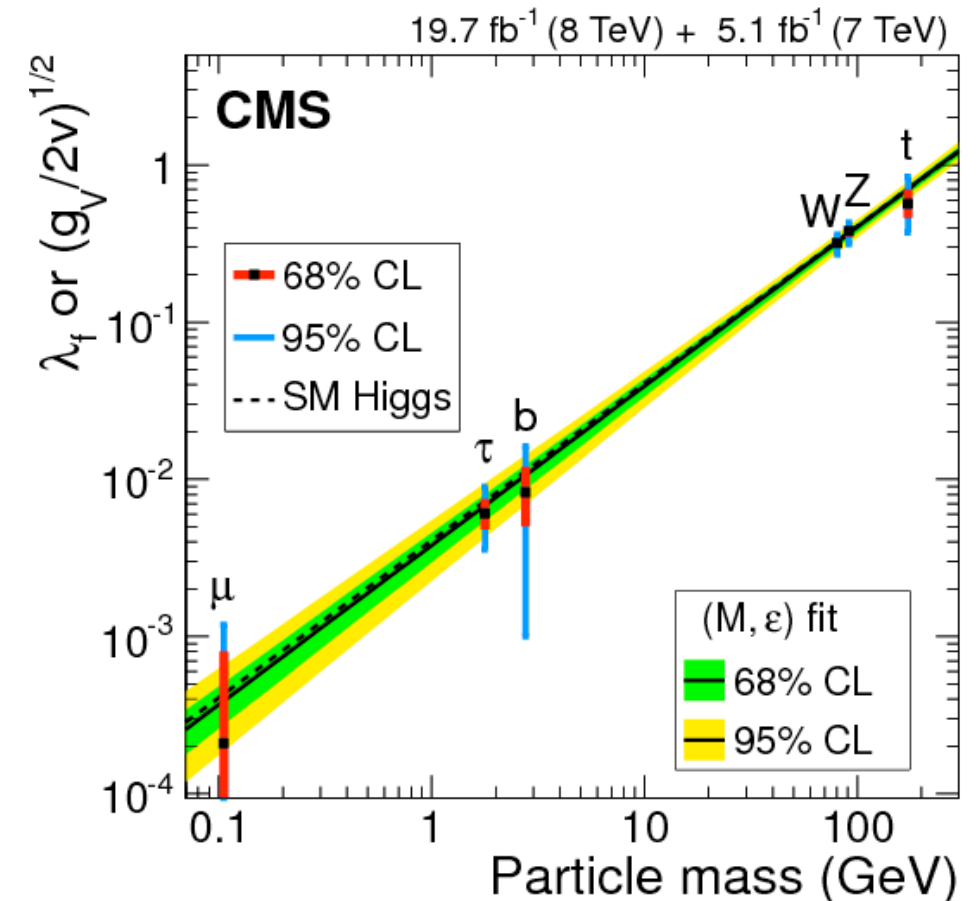


# Tribute to Run I

First studies of Higgs properties:

- consistent with  $J^{CP}=0^{++}$
- SM Yukawa couplings
- $m_H=125.09\pm 0.21(\text{stat.})\pm 0.11(\text{syst.})$  GeV

Looks very much like SM Higgs



Era of precision Higgs physics just started in Run II

While precise theoretical predictions were not crucial for the Higgs discovery, they are for precision measurements/setting limits/establishing deviations from SM

# New Physics in Run I?

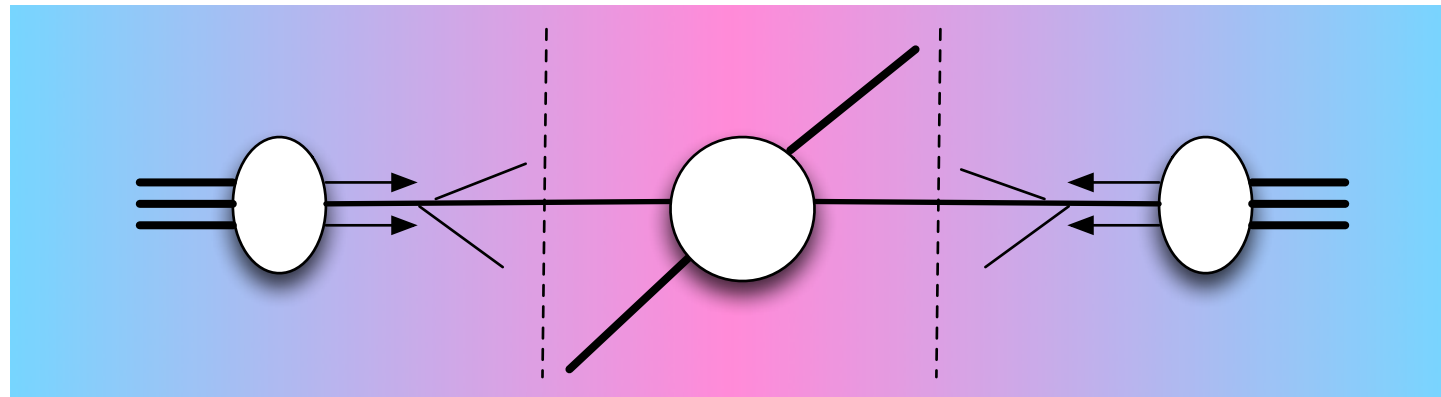
*Are there tensions between SM predictions and Run I LHC measurements (a.k.a. hints for New Physics)?*

Thanks to superb signal and background modeling only few ones and not easy to accommodate in NP scenarios, e.g.

- excess in total WW cross-section, both ATLAS and CMS
- ATLAS excess in diboson production at 2 TeV ( $3.4\sigma$ ), CMS also see anomalies, but below 2 TeV
- CMS anomaly in  $W_R$  search
- CMS two anomalies in di-leptoquark search
- top transverse momentum (high  $p_t$ )
- LHCb: B-meson anomalies ( $R_K$ ,  $P_5'$ , ...)
- decay of  $H \rightarrow \tau \mu$
- ...

If deviations from SM are to be seen “indirectly” we need very solid theoretical predictions

# Master formula



$$\frac{d\sigma_{pp \rightarrow \text{hadrons}}}{dX} = \sum_{a,b} \int dx_1 dx_2 f_a(x_1, \mu_F) f_b(x_2, \mu_F) \times \frac{d\hat{\sigma}_{ab \rightarrow \text{partons}}(\alpha_s(\mu_R), \mu_R, \mu_F)}{dX} + \mathcal{O}\left(\frac{\Lambda_{\text{QCD}}^n}{Q^n}\right)$$



PDFs: extracted from data, but evolution is perturbative



Partonic cross-sections: expansion in the coupling constant

# Ingredients for precision

According to this master formula, accurate predictions for hadronic cross-section require precise input for:

1. parton distribution functions (PDFs), the strong coupling constant  $\alpha_s$ , input parameters (masses, etc.)
2. partonic cross-sections, mostly computed via
  - fixed order, perturbative calculations (LO, NLO, NNLO ...)
  - all-order resummed perturbative calculations (NLL, NNLL ...)
  - parton shower event generators (include hadronization and Underlying Event modeling)

On top of this, particular attention must be paid to

3. process-specific issues, design of better observables

Main focus of the activity of our group on the above three points

# The group

- Staff



Duhr,  
Claude (LD)



Mangano,  
Michelangelo



Richardson,  
Peter (LD)



Salam,  
Gavin



Zanderighi,  
Giulia (LD)

- Associates



Haisch,  
Ulrich



Jenkins,  
Elizabeth



Manohar,  
Aneesh



Papadopoulos,  
Costas



Zapp,  
Korinna



# The group

- Fellows



Alioli,  
Simone



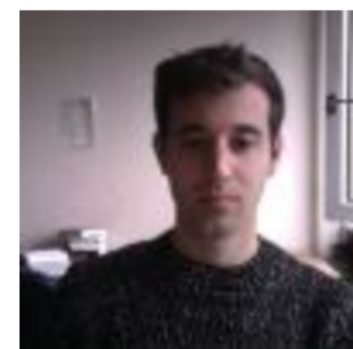
Caola,  
Fabrizio



Carrazza,  
Stefano



Luisoni,  
Gionata



Mistlberger,  
Bernhard



Papaefstathiou,  
Andreas



Procura,  
Massimiliano



Sapeta,  
Sebastian



Schulze,  
Markus



Shao,  
Hua-Sheng



Siodmok,  
Andrzej

[of which 3 on  
ERC grants + 2  
w. Marie Curie]

+ three students (Frederic Dryer, Stefan Richter, Stephen Webster) and many regular visitors (Djouadi, Frixione, Hurth, Jaeger, Nazila, Milhano, Piccinini ...)



# Activities in the group

1. parton distribution functions (PDFs), the strong coupling constant  $\alpha_s$ , input parameters (masses, etc.)
- precise determination of “input” parameters Alioli, Caola, Carrazza, Haisch, Jenkins, Mangano, Manohar, Schulze, Salam, Siodmok ...
  - better modeling of PDFs (QED effects, threshold resummation, heavy flavour, generalised PDFs...), and their extraction Carazza, Manohar, Procura, Salam ...

# Activities in the group

## 2. partonic cross-sections

- matrix elements Mangano, Duhr, Papadopoulos ...
- NLO Costas, Luisoni, Papadopoulos, Schulze, GZ ...
- NNLO Caola, Duhr, Luisoni, Mistlberger, Papadopoulos, Schulze
- N3LO Duhr, Mistlberger
- parton shower (tuning, hadronization, MPI ...) Carrazza, Mangano, Papaefstathiou, Richardson, Siodmok ...
- NLO+parton shower (PS) Luisoni, Papadopoulos, Sapeta, Shao, Siodmok, Zapp and NNLO+PS Alioli, GZ
- EW corrections Jenkins, Mangano, Manhoar, Schulze, Shao
- resummations, approx higher orders (LoopSim...) Alioli, Caola, Luisoni, Salam, Sapeta, GZ ...

# Activities in the group

## 3. process-specific issues, design of better observables

- jets, boosted-objects, jet substructure Procura, Salam, Siodmok ...
- Higgs Caola, Duhr, Luisoni, Mangano, Manohar, Mistlberger, Papaefstathiou, Salam, Schulze, GZ
- top Alioli, Caola, Haisch, Mangano, Manohar, Schulze ...
- other heavy flavour Haisch, Jenkins, Manohar, Mangano, Procura...
- EFT Alioli, Haisch, Jenkins, Manohar, GZ
- hadron physics, quarkonium Shao
- form factors, chiral PT Jenkins, Manohar, Procura

# A diverse and rich group!

- **Good overlap** between the research of different members (a number of collaborations ongoing)
- Yet our group has **experts in all important pheno areas relevant for the LHC**, and accordingly close connections to experimental activities
- If you have any question on QCD or collider physics, at least one of us should be competent to answer it, or at least point to you the best experts in the field
- **Many codes delivered / maintained** for the benefit of ongoing experimental analysis (AlpGen, Apfel, APPLgrid, FastJet, Herwig, Hoppet, JetVHeto, LoopSim, Madgraph5\_aMC@NLO, NNPDF, POWHEG... )

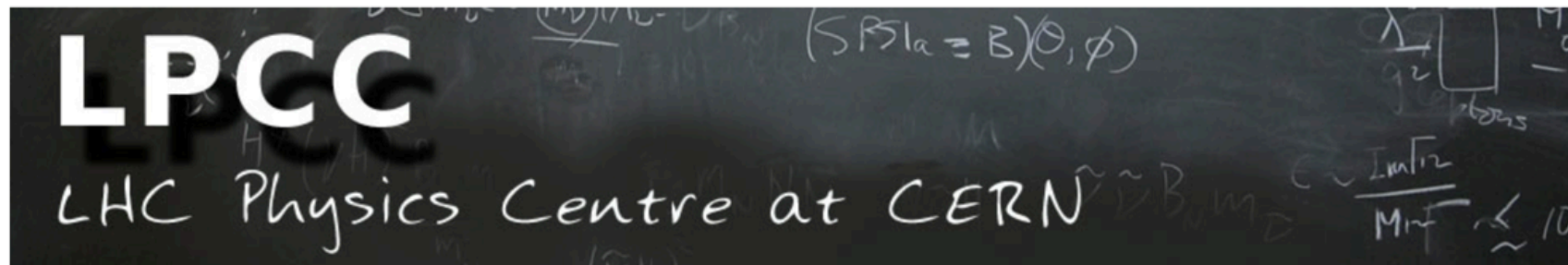
# A diverse and rich group!

- Also connections with
  - ▶ BSM Haisch, Jenkins, Mangano, Manohar, Salam, Schulze, Shao, Papaefstathiou, Procura, Richardson
  - ▶ Heavy Ions Mangano, Salam, Sapeta, Zapp
  - ▶ Formal developments Duhr, Mistlberger
  - ▶ Cosmology Jenkins, Manohar

# Group activities

- CERN-LHC seminar **Tuesday at 11** (not part of our TH activities, but good to go)
- Theory Colloquium on **Wednesday at 2** (organizers Papadodimas, Salam, Sibiryakov)
- Cross-collider talk **Thursdays at 11** (organizers Goertz + ...)
- QCD lunch **Friday at 12.45**
- Particle and Astro-particle Physics seminar **Friday at 2** (organizers Contino, Patella, Zanderighi)





**LPCC links**

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**EVENTS**

- [Forthcoming events](#)
- [Past events](#)

**LHC PUBLICATIONS**

**STUDENTS RESOURCES**

**MISC**

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**Useful links**

- [CERN](#)
- [LHC & expts](#)
- [LHC centres in other Labs](#)

**News**

**Forthcoming events**

**Next 2 weeks**

**Data Science @ LHC 2015 Workshop**

11/09/2015 || 09:00 => 11/13/2015 || 18:00

November 9-13, TH Auditorium. The field of data science produces advanced, innovative and creative methods for data analysis, pattern recognition and model inference. The Workshop will review the results from this field, and explore possible applications to the analysis of LHC data. The workshop will consist of plenary presentations, tutorials and hands-on hackathon type of machine-learning exercises as well as directed and undirected discussion and brainstorming sessions. Abstract submission is also possible, via the registration link at the Indico page:

<http://indico.cern.ch/event/395374/>

**Beyond 2 weeks**

**LHC Top WG**

11/17/2015 || 09:00 => 11/18/2015 || 18:00

Open meeting of the LHC top WG. CERN (see agenda for precise location). Registrations and agenda (tbd) on:

<https://indico.cern.ch/event/403826/>

**Status of LHC ops**

Latest [news](#)

LHC status, ["page 1"](#)

Current fill [luminosity](#)

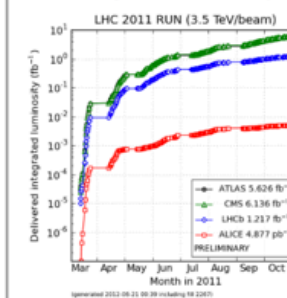
"Page-1", [tutorial](#)

Exp's status, ["page 3"](#)

LHC [weekly plan](#)

[LHC programme coordination](#)

LHC integrated luminosity [charts](#)



**Coming events at CERN**

[LPCC Workshops, 27/10, 9h](#) - PDF4LHC meeting by [De Roeck, Albert](#)

- Collects initiatives in support of the LHC physics program (workshops, LHC Physics Day, EE/PP/LPCC seminars, LPCC students lectures, LHC reports, theory tools used by experiments, and more...)
- Subscribe to LPCC News or sign up for WG mailing lists from <http://cern.ch/lpcc>
- Responsible: **Michelangelo Mangano**

# Myself

- Arrived at CERN in Jan 2014 (on leave from Oxford)
- Current research activity in very few words: improving theoretical accuracy of collider cross-sections to match current and upcoming experimental precision (NLO calculations, multi-jet merging with MiNLO, merging of NLO and NNLO and parton showers, resummed calculations, event-shapes, Higgs, finite-mass effects in Higgs production, Vector Boson Fusion ...)
- Involved in the **ESHEP** (E=European) and **CLASHEP** (CLA=CERN Latin-American) CERN schools. I might ask you to get involved, if so you should say “YES!” for at least three very good reasons ...
- Currently involved in the writeup of a report on Standard Model physics at a 100 TeV FCC

# QCD, EW and tools at 100 TeV

chaired by Michelangelo Mangano (CERN), Giulia Zanderighi (CERN)

from Wednesday, 7 October 2015 at 09:00 to Friday, 9 October 2015 at 18:30 (Europe/Zurich)

CERN ( 4-3-006 - TH Conference Room )

**Description** Meeting dedicated to a discussion of QCD and EW physics at 100 TeV, and on a review of theoretical tools (PDFs, MCs, etc) and their suitability for the modeling of 100 TeV pp collisions.

The material from the Workshop will provide input to the relative Chapter of the report on physics at 100 TeV, to be prepared in the context of the FCC study.

To subscribe to the mailing list for communications on the activities of the Future Hadron Collider group, go to

<http://simba3.web.cern.ch/simba3/SelfSubscription.aspx?groupName=fcc-experiments-hadron>

Information on accommodation, access to CERN and laptop registration is available from <http://lpcc.web.cern.ch/LPCC/index.php?page=visit>

Videoconference Rooms

 QCD\_\_EW\_and\_tools\_at\_100\_TeV

Join

Go to day ▾

Wednesday, 7 October 2015

09:00 - 09:15

Introduction 15'

Speakers: Michelangelo Mangano (CERN), Giulia Zanderighi (CERN)



FCC-SM.pdf



Intrp\_Wshop.pdf

- Very preliminary sketch of the structure of report available
- First draft of the report by end of the year
- Many of you involved, if you are not yet, and are interested in contributing get in touch with MLM or myself *now*