HXSWG: FIDUCIAL CROSS SECTIONS
REPORT ON ACTIVITIES AND FUTURE PLANS

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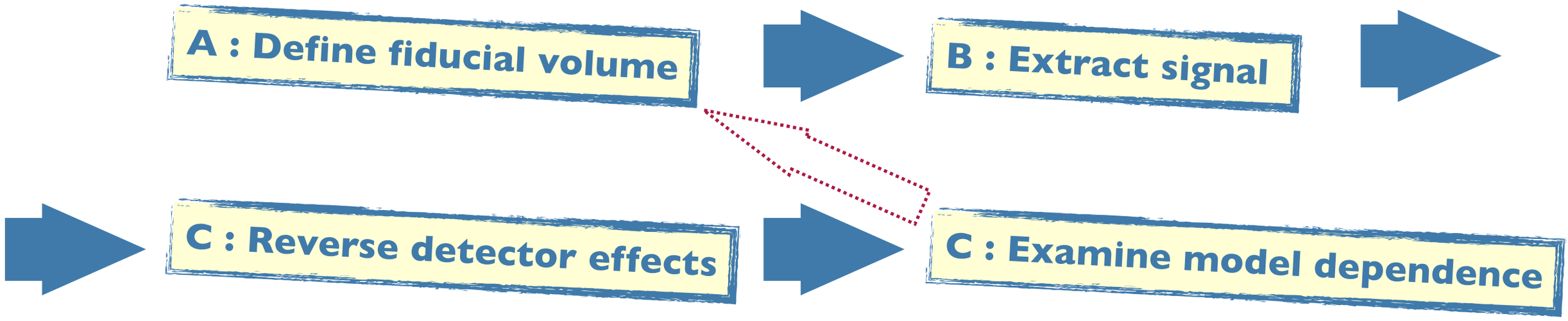
CERN, October 12, 2016

Preface

MOTIVATION:

- Fiducial XSs offer a **possibility to describe data in a nearly model independent** way
  - Maximise the applicability of LHC data to explore the **QCD effects** in the SM, and capture **BSM effects** in the Higgs boson physics.

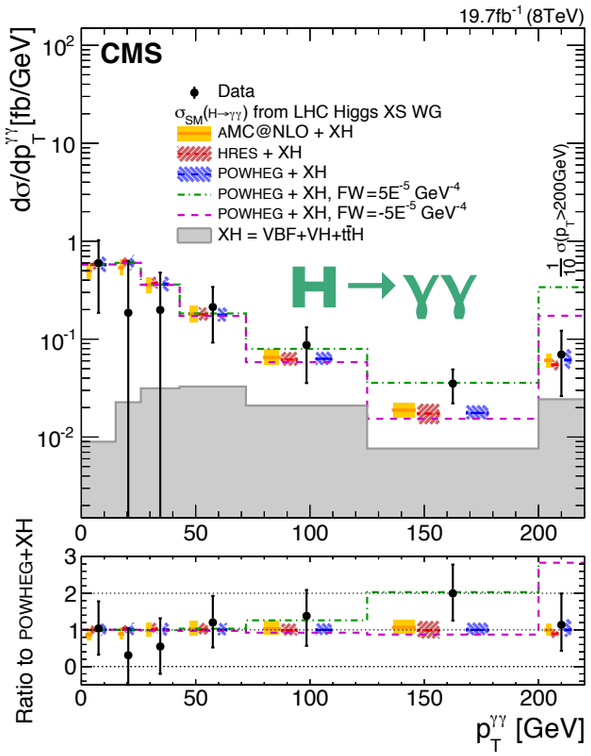


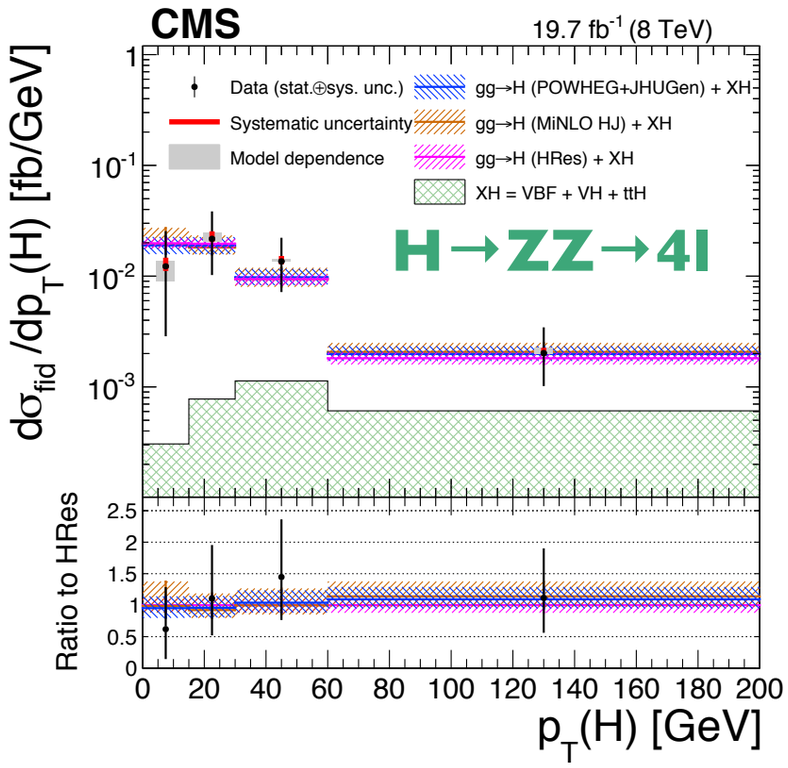
A FEW IMPORTANT ASPECTS:

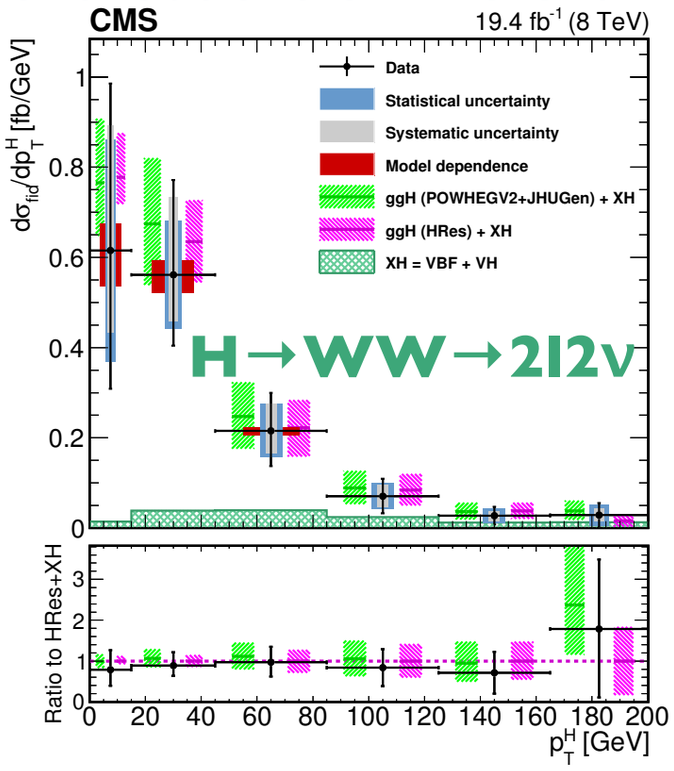
- **Model independence** of the measurements
  - Factorise theory uncertainties from experimental ones (no extrapolation)
- **Defined for a specific final state/decay mode**
  - Interesting by the theory community, deemed feasible by the experiments
  - Fiducial definitions require good theory control (perturbative, non-perturbative, uncertainties) and good experimental resolution

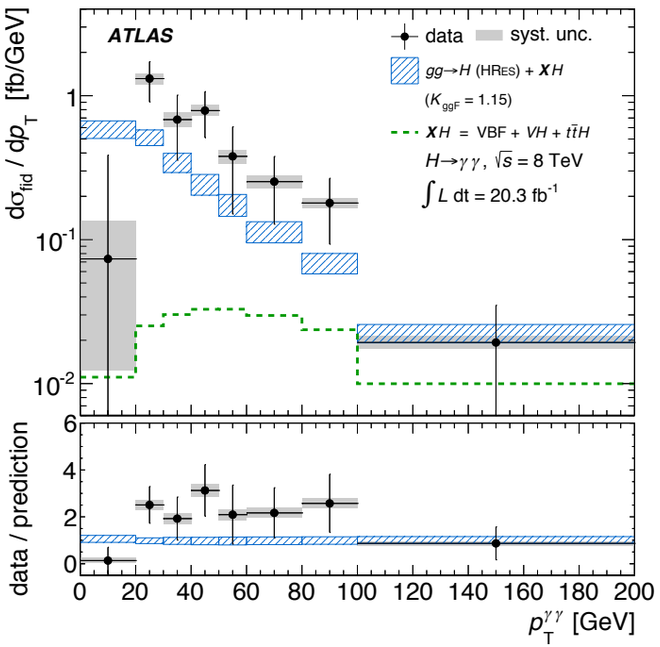
Run 1: Fiducial cross sections

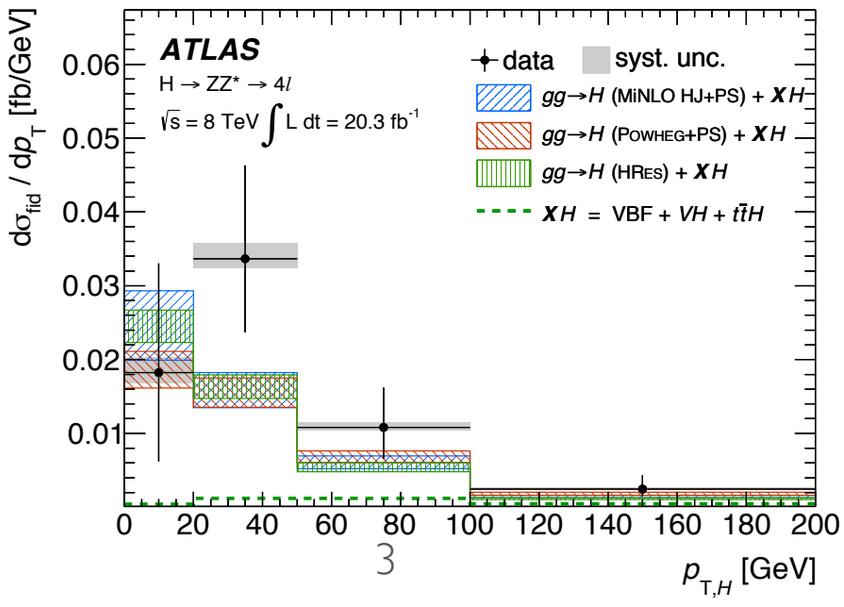
- **Inclusive and differential** fiducial XS @ 8 TeV in three channels:
  - Sensitive to modelling of hard quark and gluon radiation, relative contributions of different production modes, BSM effects in the loops, etc.

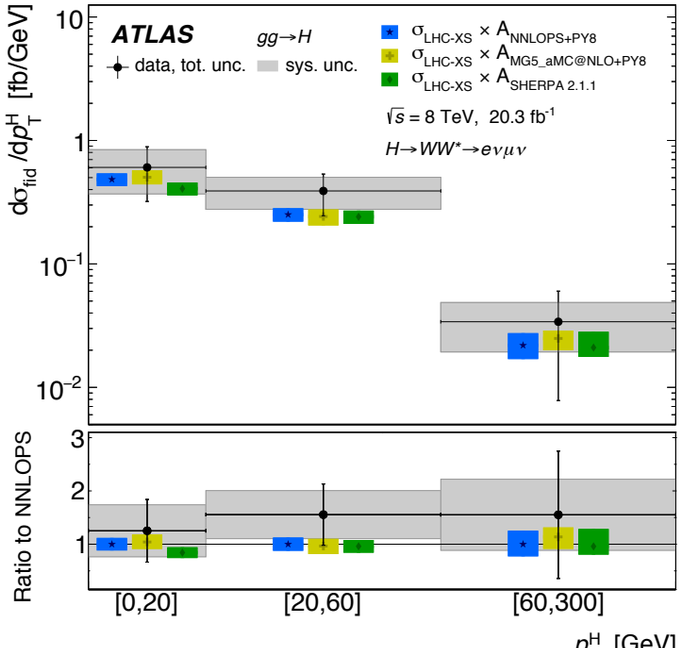






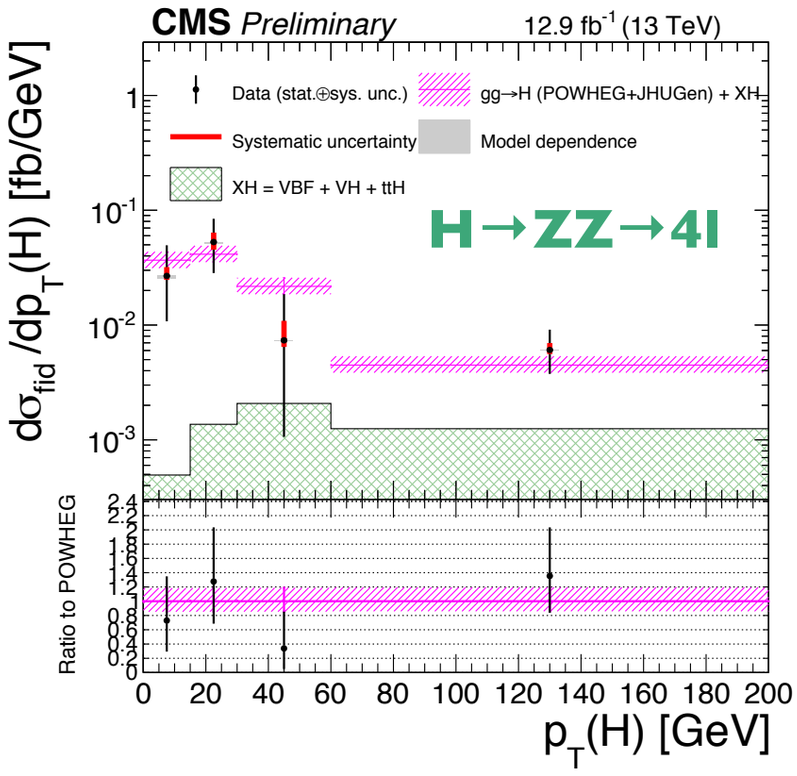


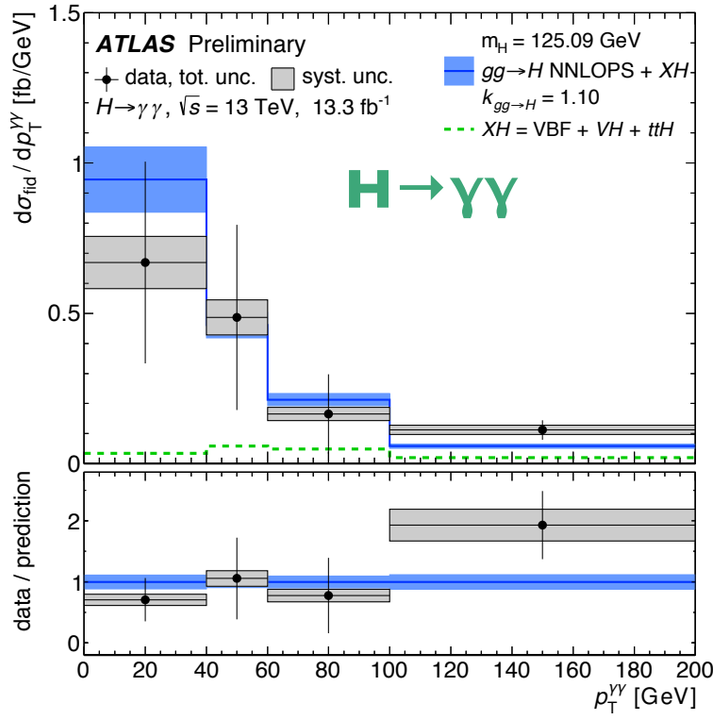




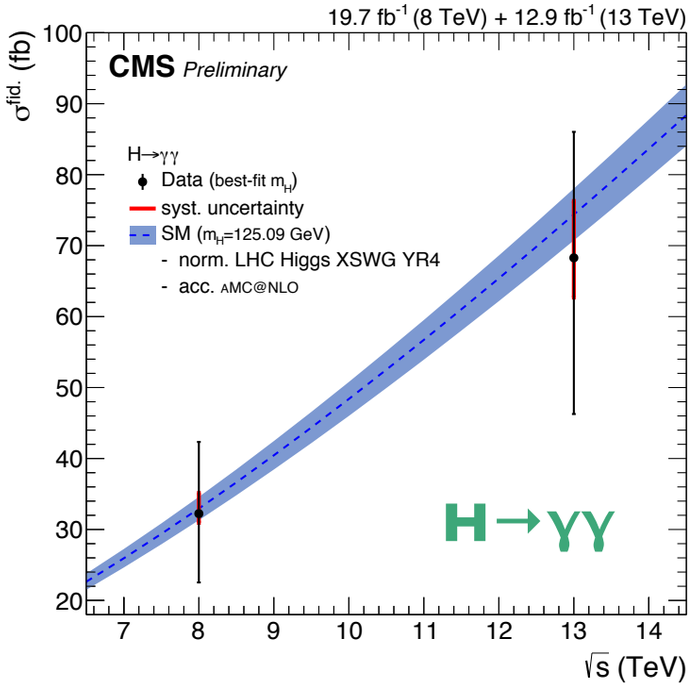
Beyond Run I

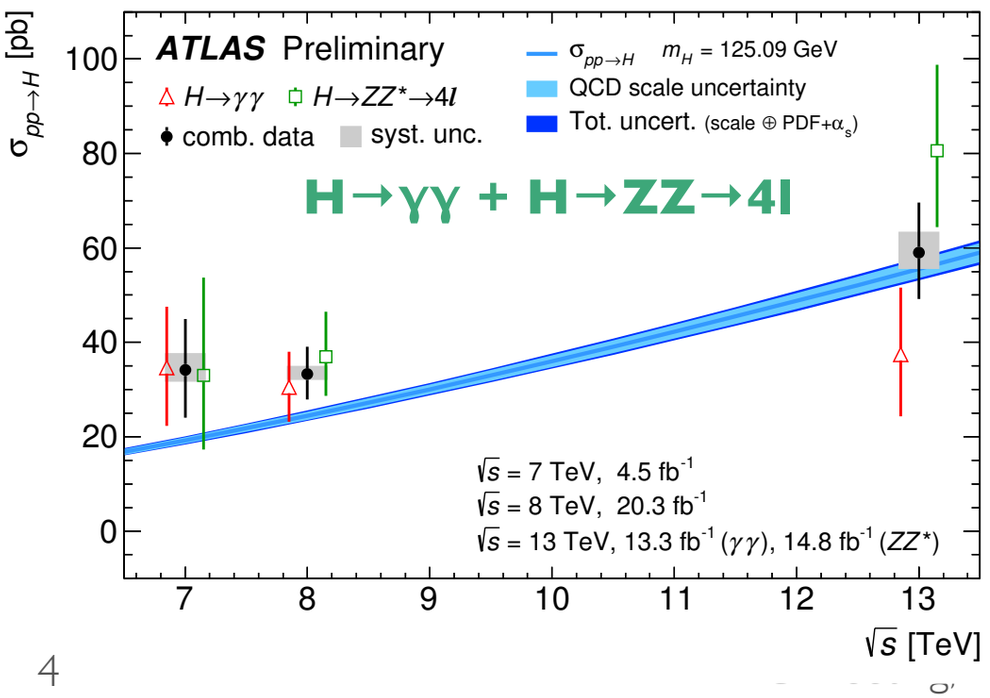
- **Present and near future**
  - **H→ZZ→4l** and **H→γγ** (**H→WW→2l2ν** soon): **inclusive + single-differential**





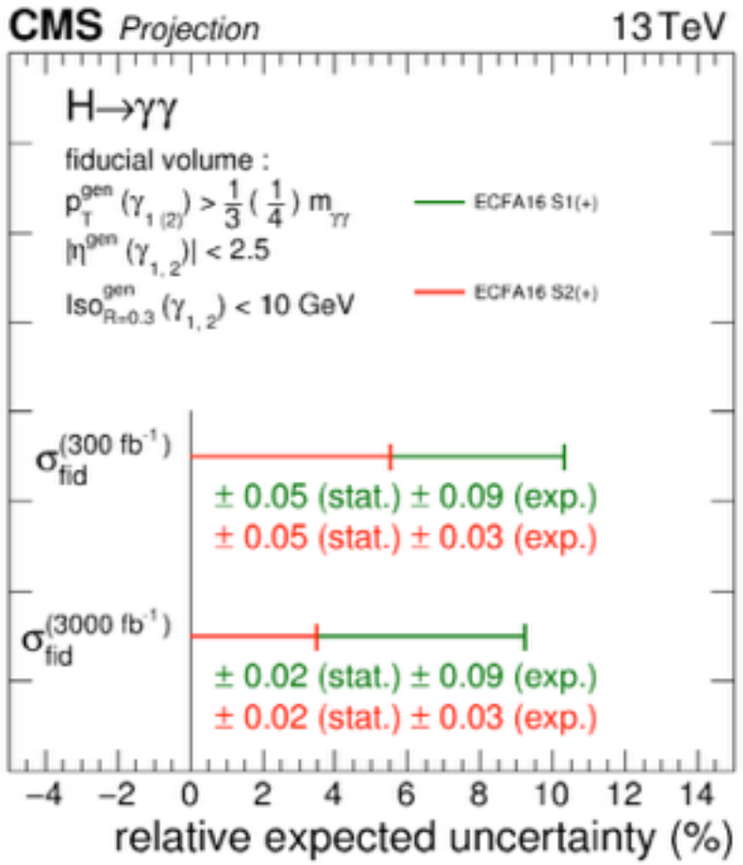
preliminary ICHEP'16 results

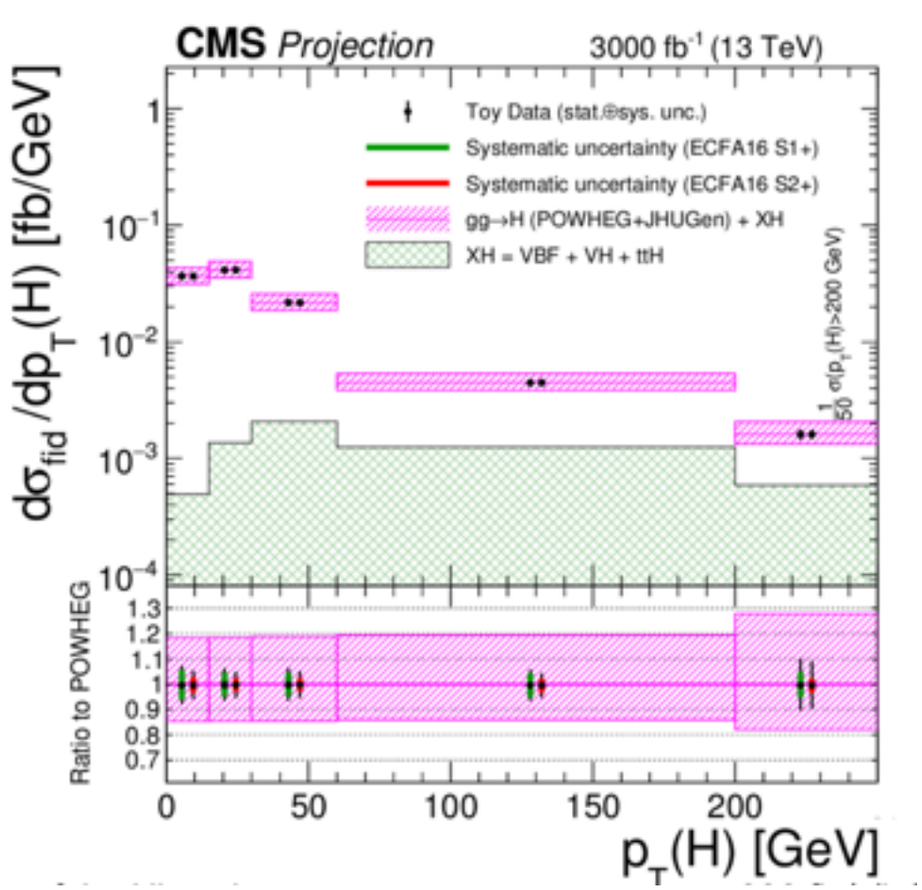




Beyond Run I

- **A bit further away future (e.g. ~2017)**
  - Double-differential measurements: **H→ZZ→4l** , **H→γγ** , (**H→WW→2l2ν**)
  - **H→bb**, **H→ττ** (after the observation has been established)
    - Caveats to consider: **MVA observables** in selection, **VBF/VH-enriched** measurement regions
- **High-luminosity Run (300-3000 fb^{-1}): preliminary projections**



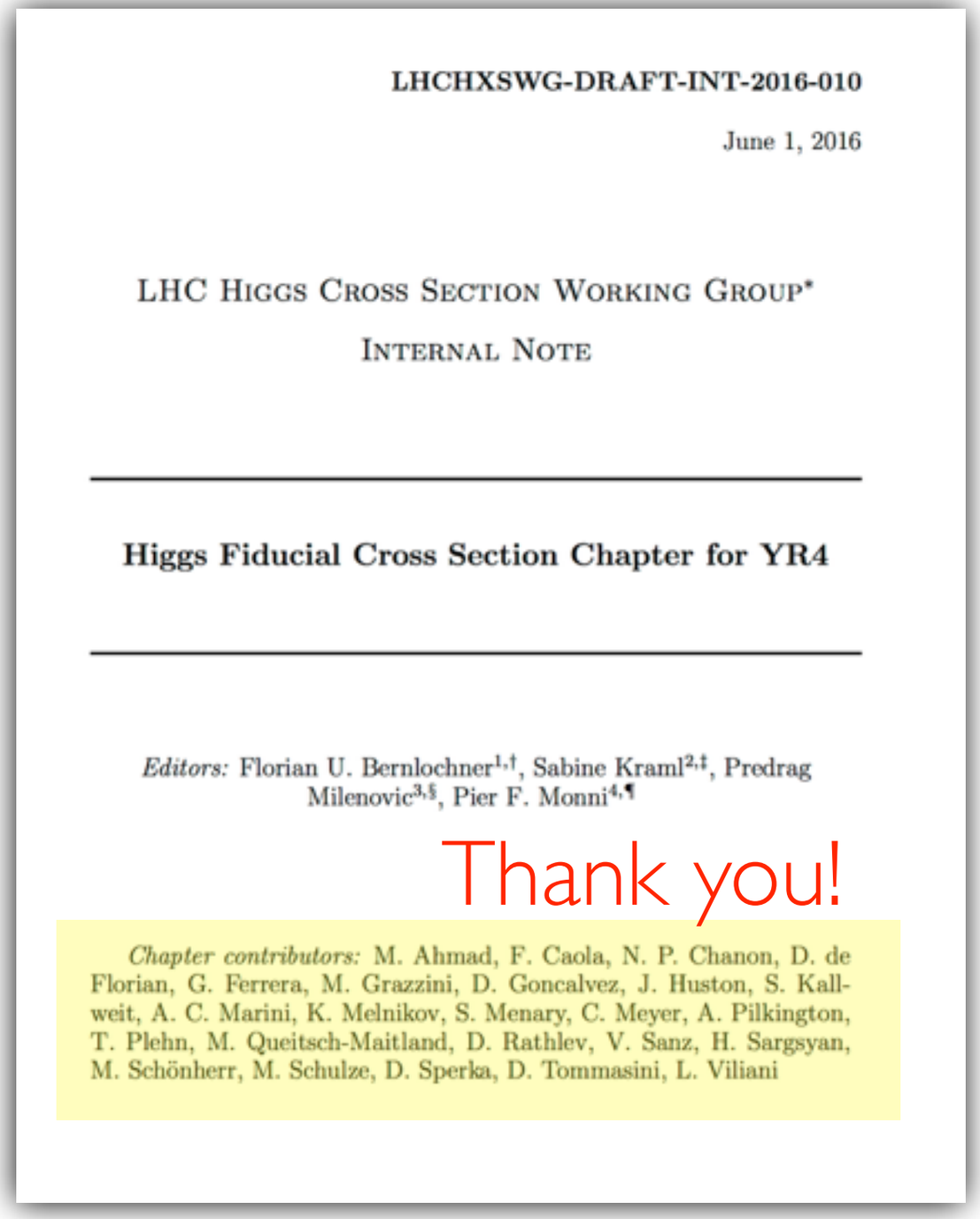


D. Sperka's talk

- Systematic (TH+EXP) uncertainties dominant at HL-LHC
  - Efforts on both sides required to best exploit the differential shapes

Fiducial XS for YR4

- Contributions are result of joint work and discussions between many CMS/ATLAS/TH colleagues



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June 1, 2016

LHC Higgs Cross Section Working Group*

Internal Note

Higgs Fiducial Cross Section Chapter for YR4

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Thank you!

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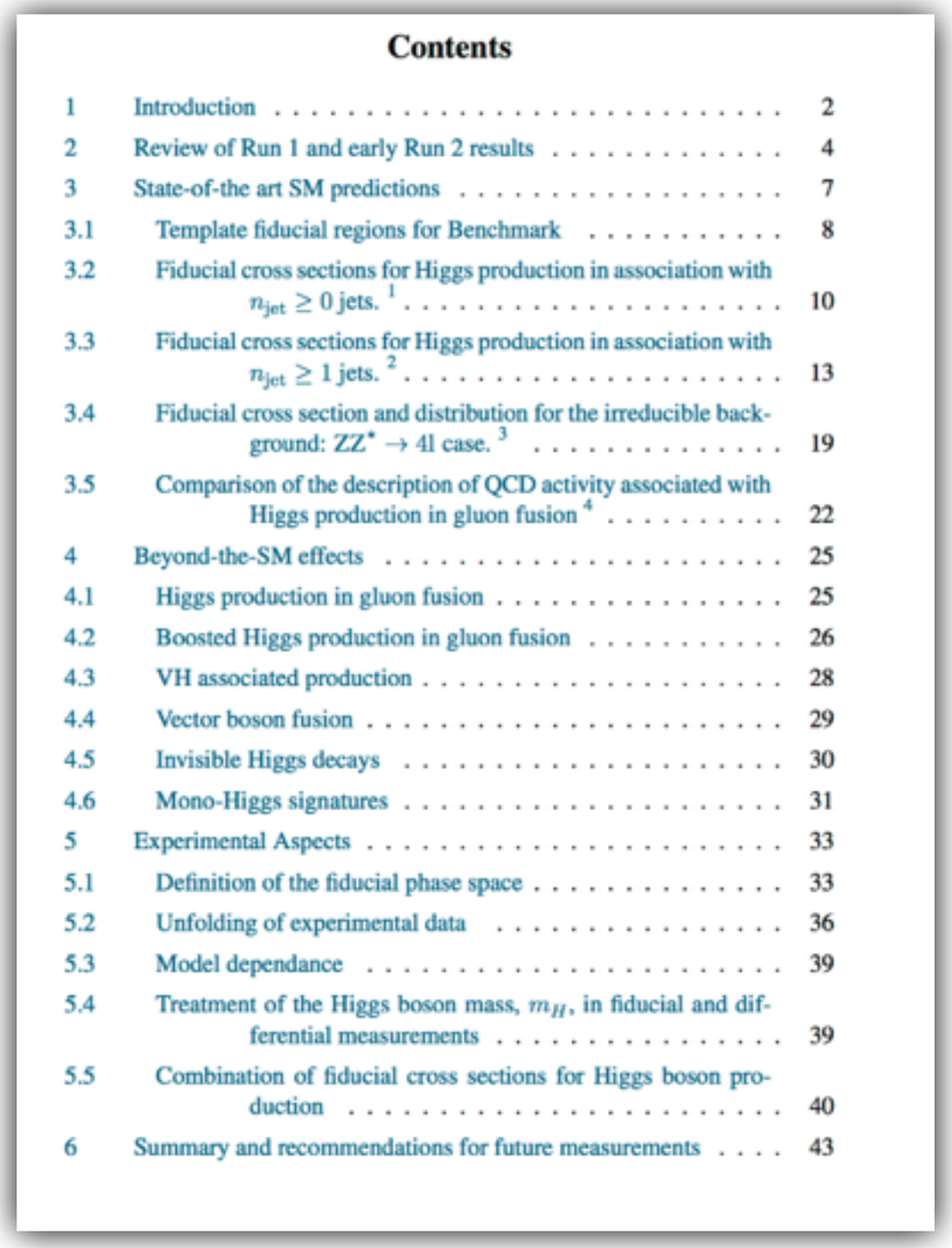

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Fiducial XS for YR4

- Output: set of recommendation and discussion of some of the relevant points to be pursued in future activity (many of which still subject of discussion)

- **Fiducial** definitions (particle-level objects);
  Harmonisation of fiducial objects definition and bin boundaries between experiments whenever possible

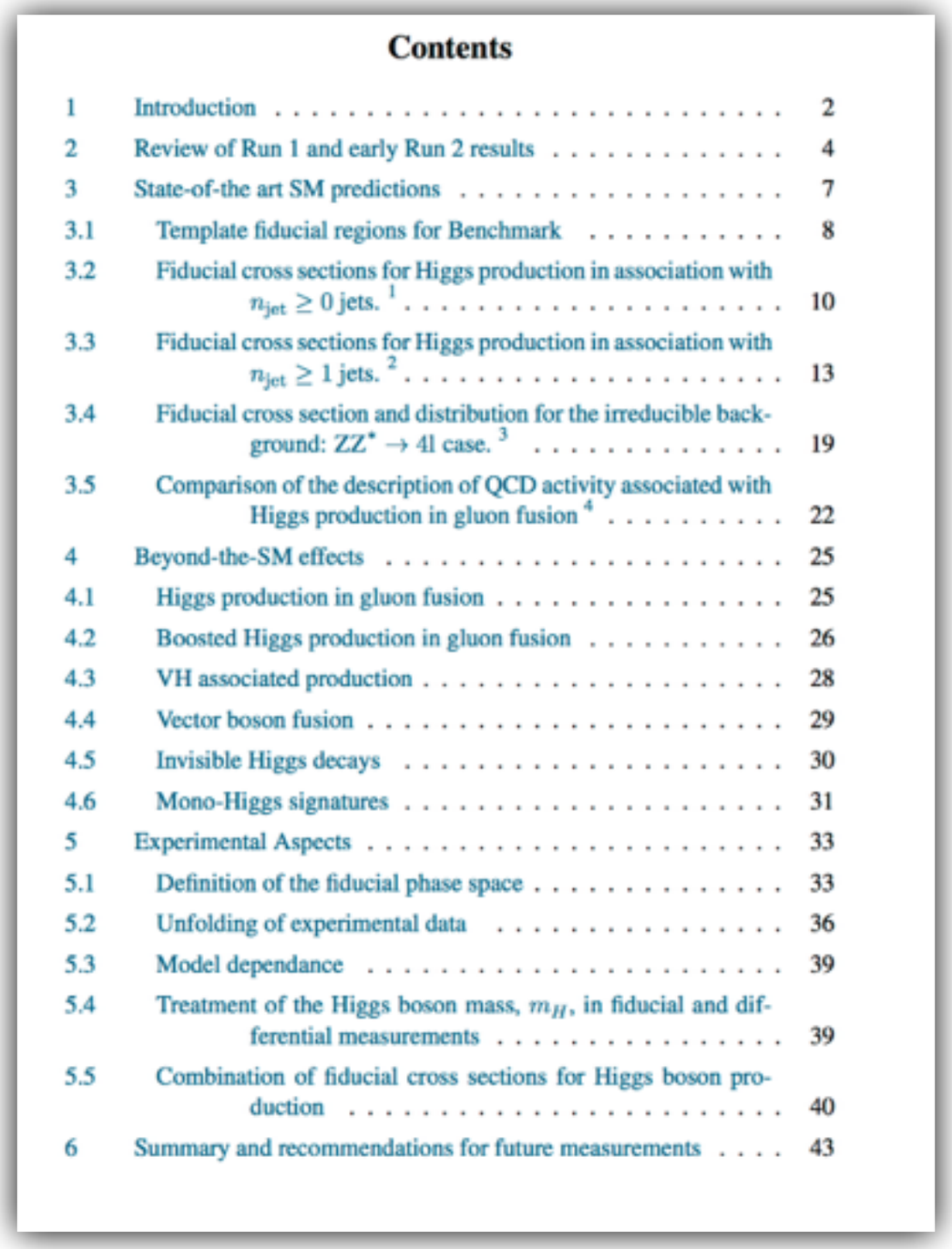
- **Preservation (presentation) of measurements.**
  (unfolding detector effects, flexibility for theory studies)

- **Higgs boson mass**: fixed vs. floating

- **Benchmarking/validation** of tools performance in a fiducial context

- **Model Dependence**

- **BSM**: Possibilities to define fiducial volumes that target specific models - high statistics required;
  use of fiducial cross sections in global BSM analysis (specific model, EFT) - statistical correlations



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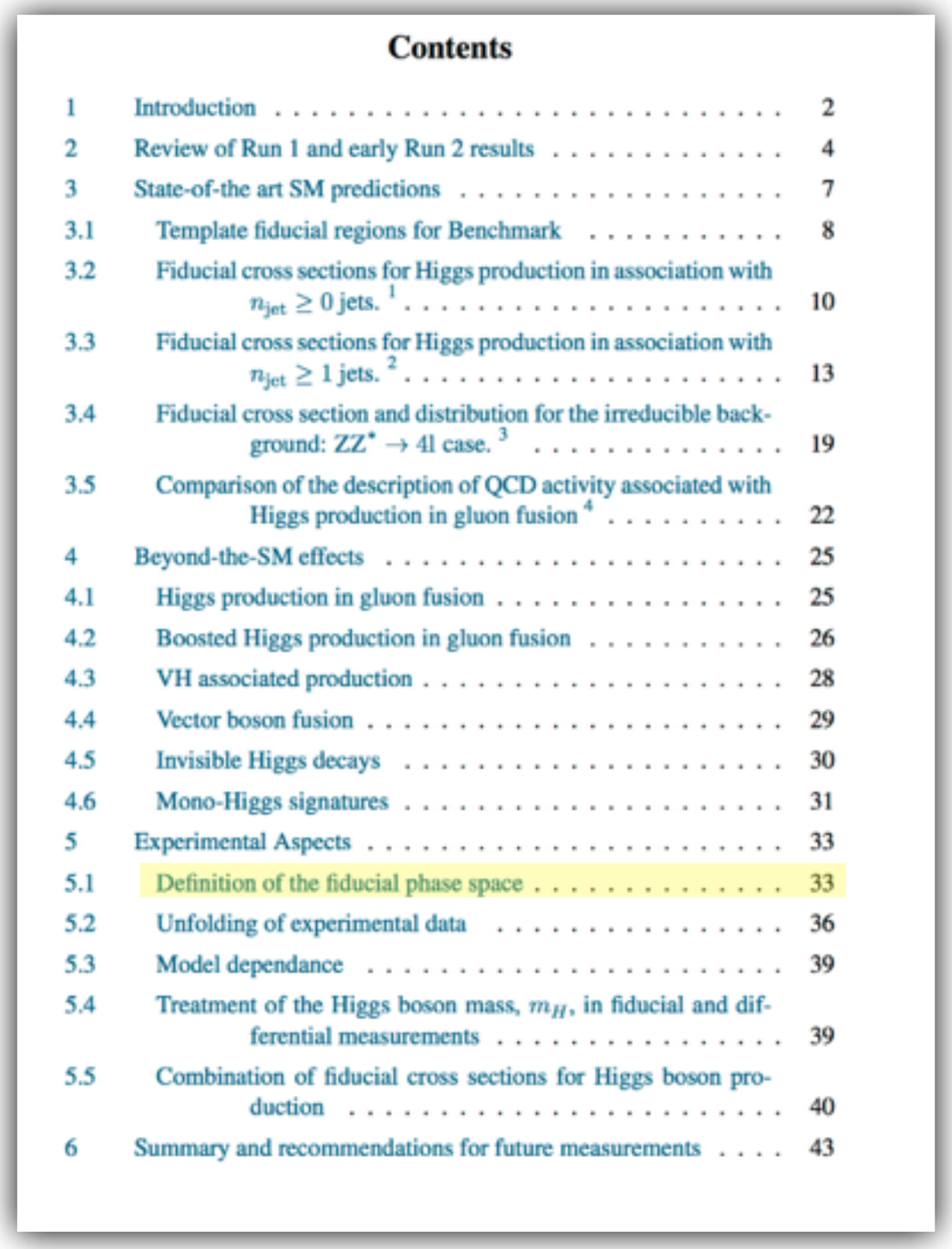

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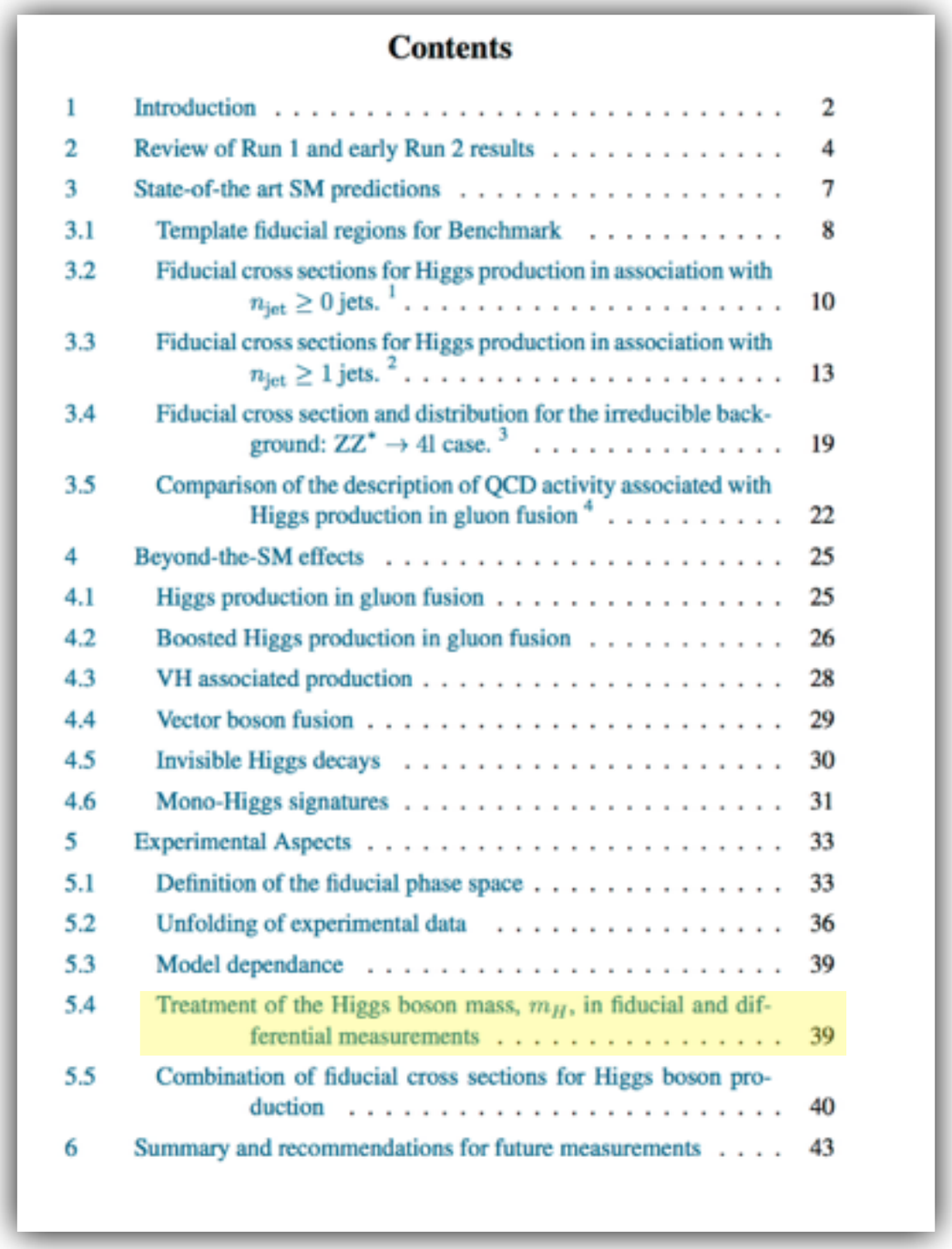

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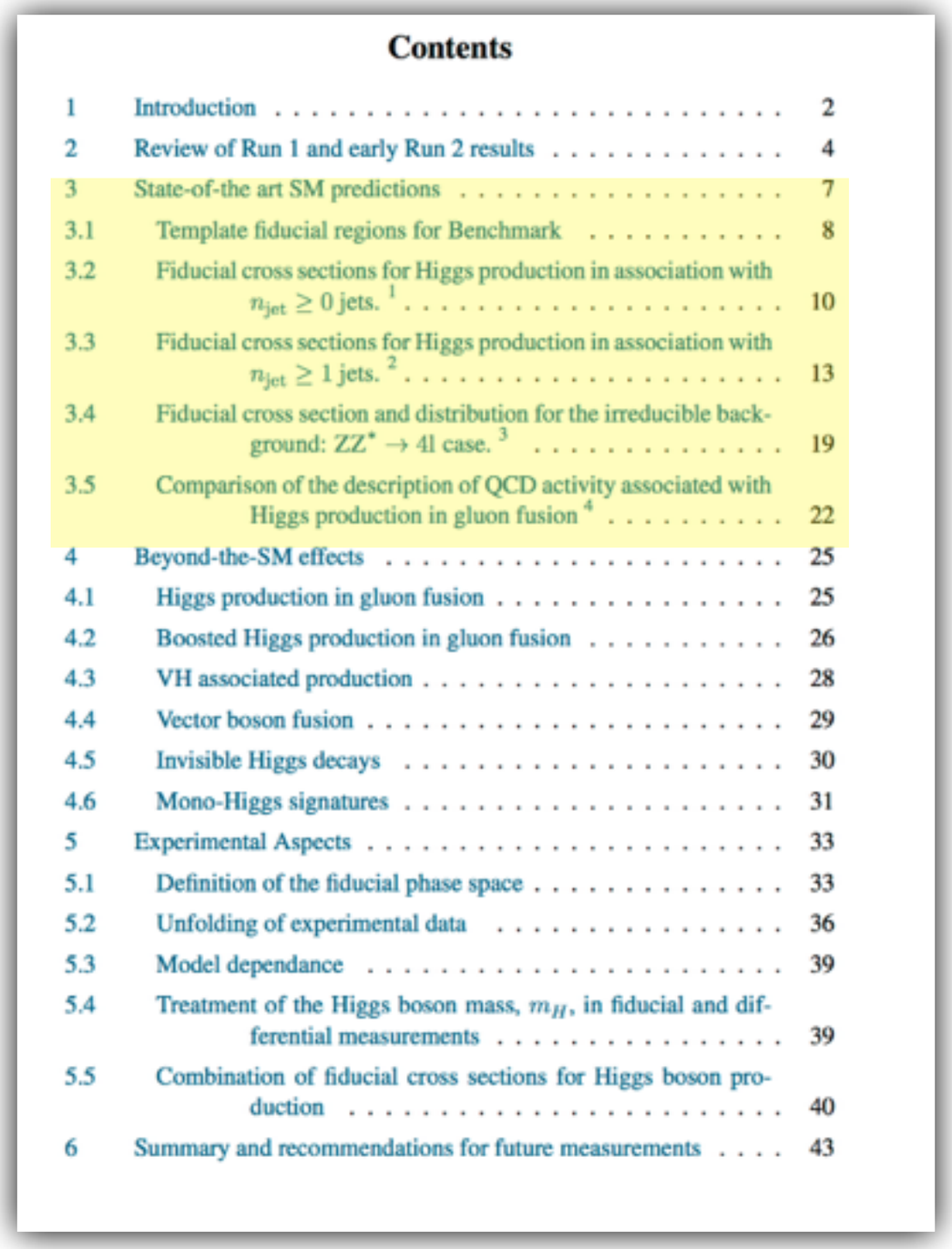

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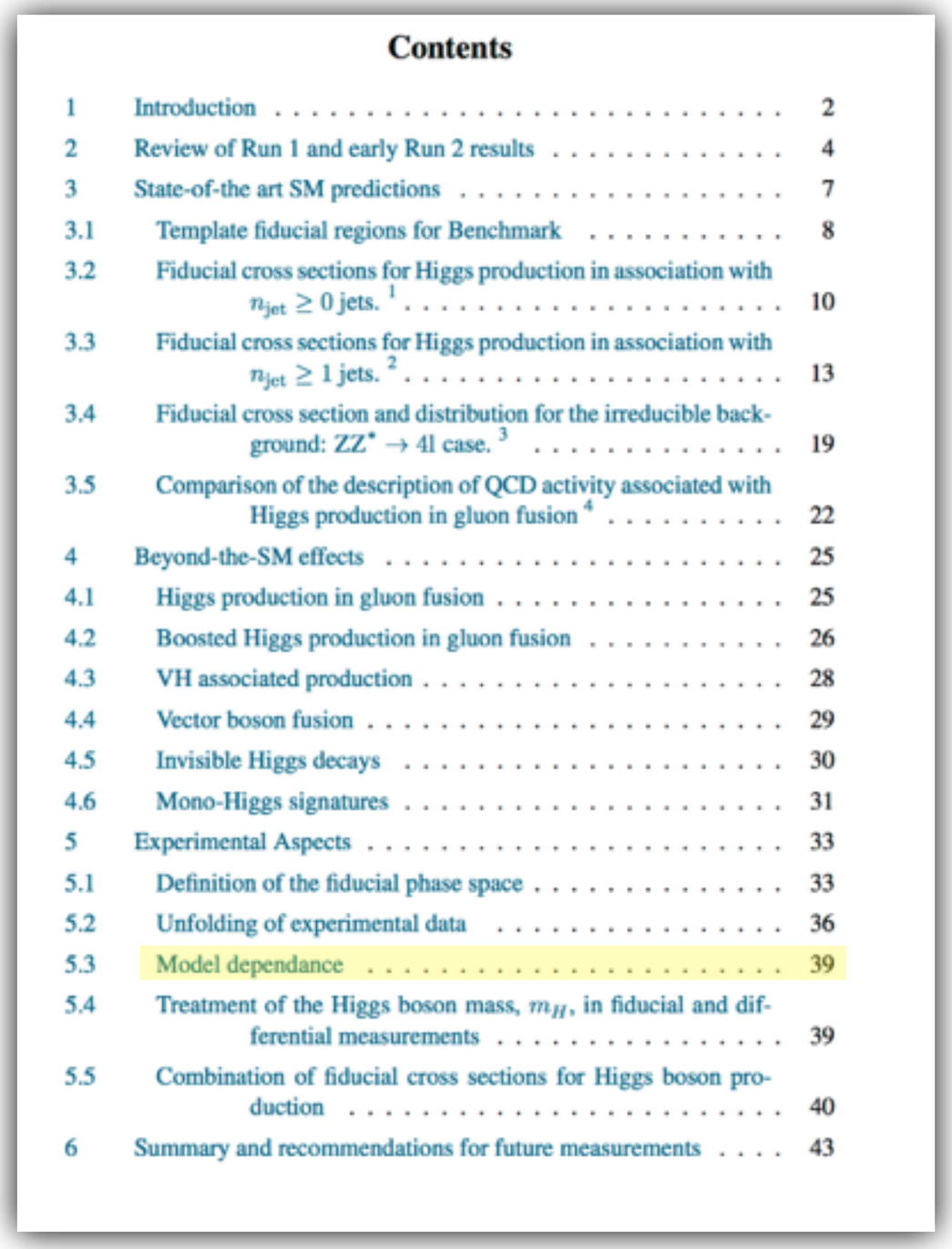

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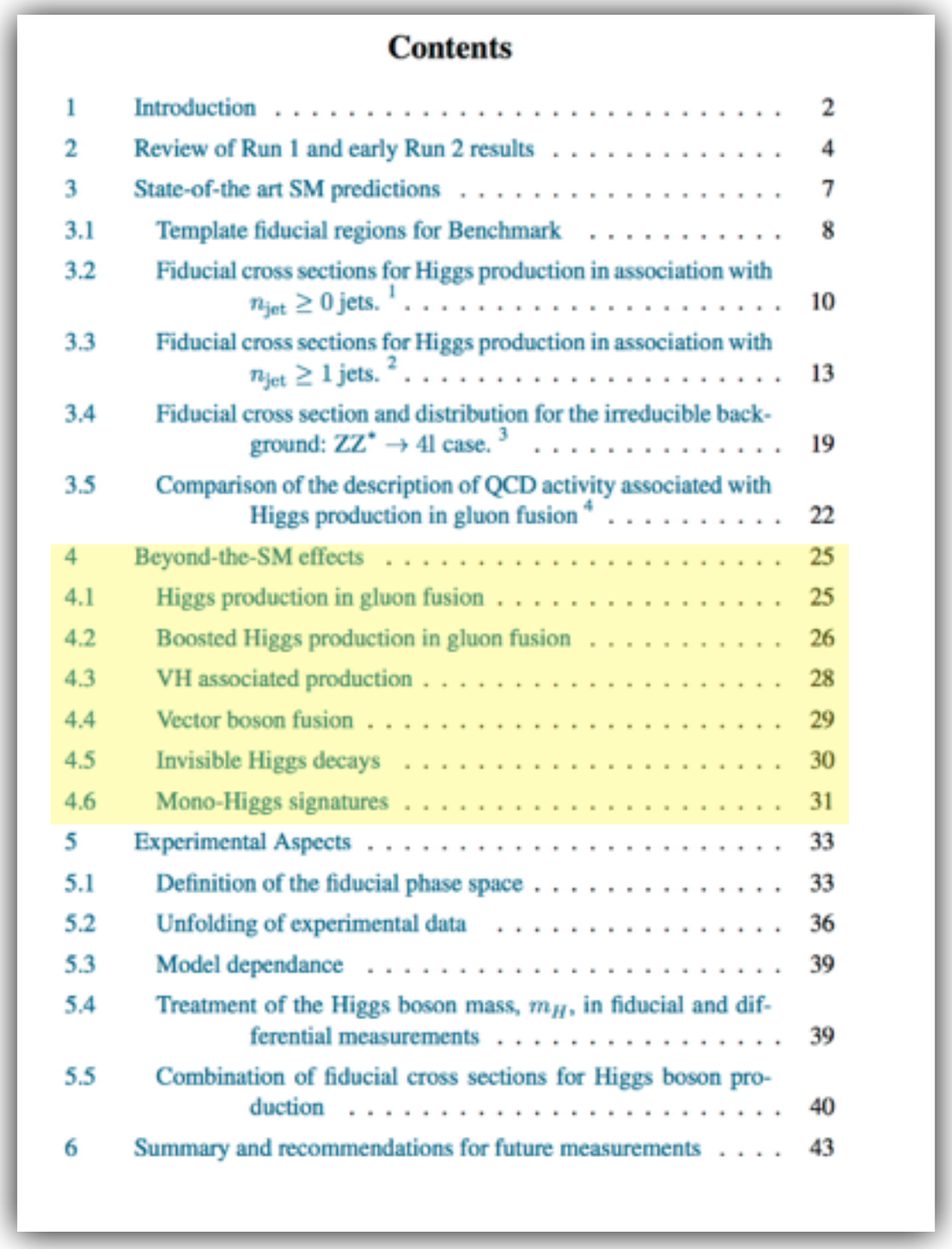


Contents

Goal of the FXS group

Interface between theory and experiments:

- **Fiducial volumes**:
  - specific **definitions** follow experimental needs
  - **new observables** for fiducial measurements
  - Study of fiducial volumes for future **H→bb**, **H→ττ** measurements (unfolding of MVA, enriched in VBF/VH, etc.)
  - minimisation of **model dependence** and optimisation of sensitivity. Issues arise when definitions involve observables with poor resolution (important migration) or for which the SM theory modelling has sizeable uncertainties.
- **Validation of the used tools** and understanding of their uncertainties fundamental in extrapolation to a larger (or fully inclusive) phase space
  - Similar issues present for **Template/Simplified XS** studies

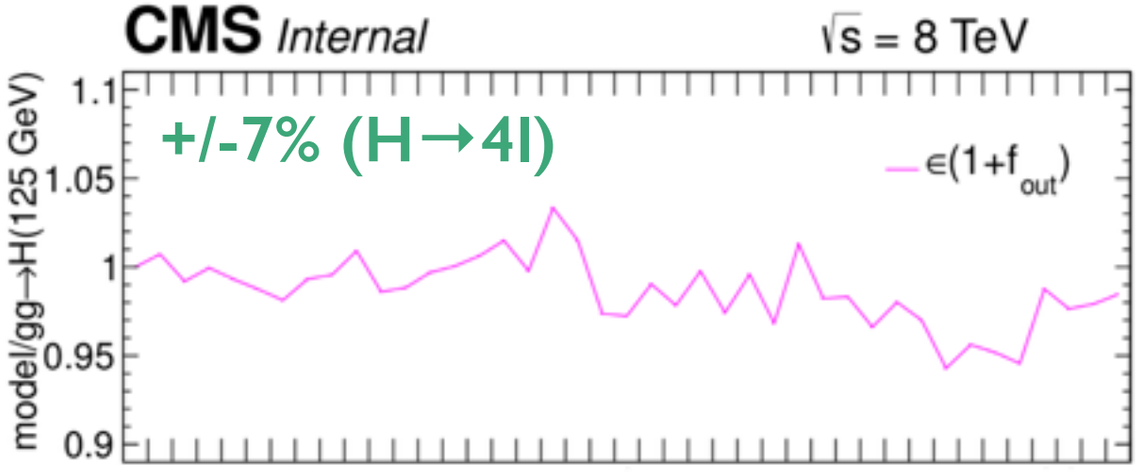
Similar activity in WG1 - close coordination natural/preferable:

- agree on what cuts/effects might be of interest in the benchmarking/tool validation activities
- coordination of benchmarking request for fiducial XS and shapes

Goal of the FXS group

Interface between theory and experiments:

- **Beyond the Standard Model physics:**
  - Definition of volumes requires **model independence** of unfolding procedure
  - In the near future fiducial volumes can be defined in order to **target specific effects/models**. Theorists are encouraged to propose specific suggestions
  - **New (fiducial) observables** sensitive to BSM effects, e.g. specific regions of differential distributions/kinematic regimes.



range of available alternative H models

Interaction with WG2 natural - already happening

close coordination with WG3 on these aspects preferable

Goal of the FXS group

Interface between theory and experiments:

- **Presentation (preservation) of the results:**
  - provide full set of **unfolded results w/ correlations** (as in Run I)
  - provide **exp. observations with parametrised detector response** (to be discussed in the near future)
  - use of **HEPDATA** and provide **RIVET** routines

Interface between experiments:

- **Harmonisation** of measurement procedures
  (fiducial object definitions, m(H) treatment, statistical/unfolding approaches)
- **Combination** of results
  (between the channels, between the experiments, agreement on bin boundaries)

Summary

- Fiducial cross sections offer a **nearly theory independent way** of characterising the high statistics channels (**H→γγ, H→ZZ→4l, H→WW→2l2ν,…**)
- **Several measurements of integrated and (single-)differential XS at 7, 8 and 13 TeV.** Important part of the future experimental programme

- A number of issues have been discussed in YR4. Future activities involve
  - TH:
    - **tools validation (PT and NPT corrections);**
    - **model dependence and study of BSM sensitivity**
  - EXP:
    - **presentation of data (unfolding/folding),**
    - **combination of results (channels+experiments),**
    - **harmonisation of procedures (e.g. Higgs mass treatment, bin boundaries)**

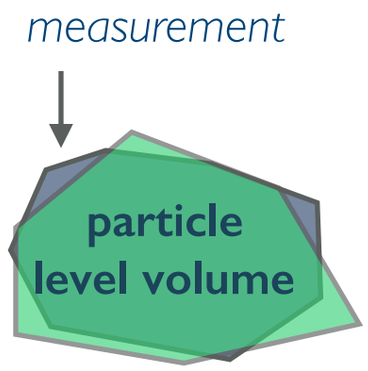
- For some of the activities it is natural to have an efficient interaction with other subgroups:
  - more effective studies for common/similar issues (avoids doubling the work)
  - open for discussion on how to interact across the subgroups

ADDITIONAL MATERIAL

Fiducial Cross Sections

- **Measurements typically follow these steps**

Step A: Find/design the fiducial volume close to the reconstructed volume to minimise the model dependence



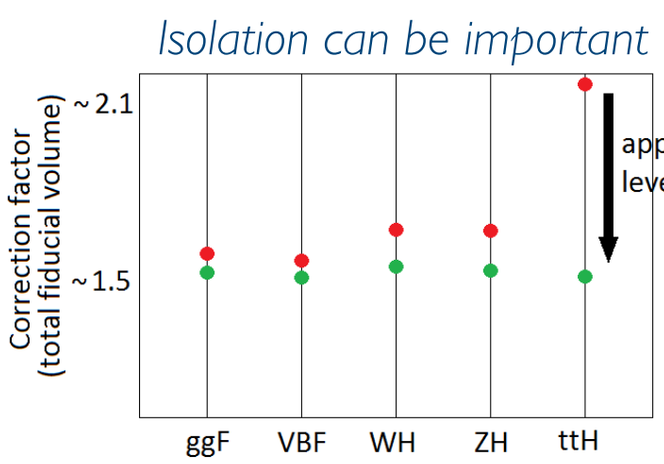
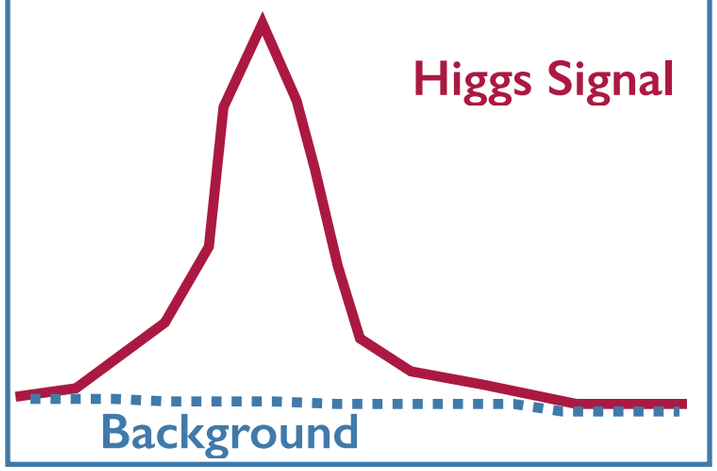


Diagram of real plot – nothing has been exaggerated but take exact points with pinch of salt

Step B: Measure signal yields by subtracting background



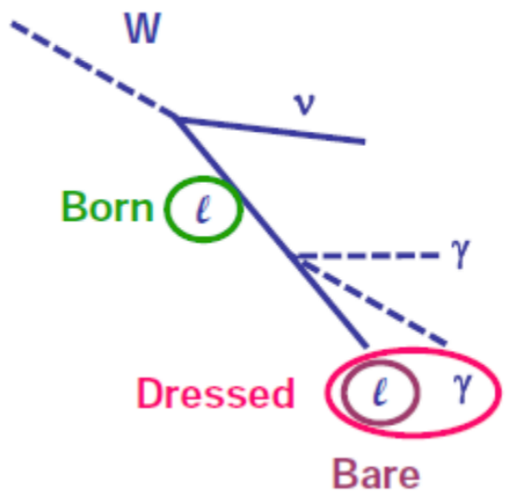
Step C: Reverse detector effects (migrations in and out the fiducial volume, migrations between bins of differential observables).

This is typically called '**unfolding**'.

Step D: Carefully evaluate the remaining model dependence from experimental and theoretical assumptions.

- **Steps B and C sometimes performed as one step (signal fit + unfolding)**

Important ingredients



FIDUCIAL DEFINITIONS:

- Definition of the **fiducial-level objects** (leptons, photons, jets)
- **Isolation requirement** plays an **important role**
- **Out-of-fiducial signal** contributions need special care
- **NOTE: Different kinematical cuts** in ATLAS/CMS (optimised to exploit detector potential).

M(H) HYPOTHESIS:

- Use **best-fit value measured by experiment(s)** for comparisons with theory (either **treat m(H) as a free parameter** and fit for it, or **fix m(H)** to best-fit value).

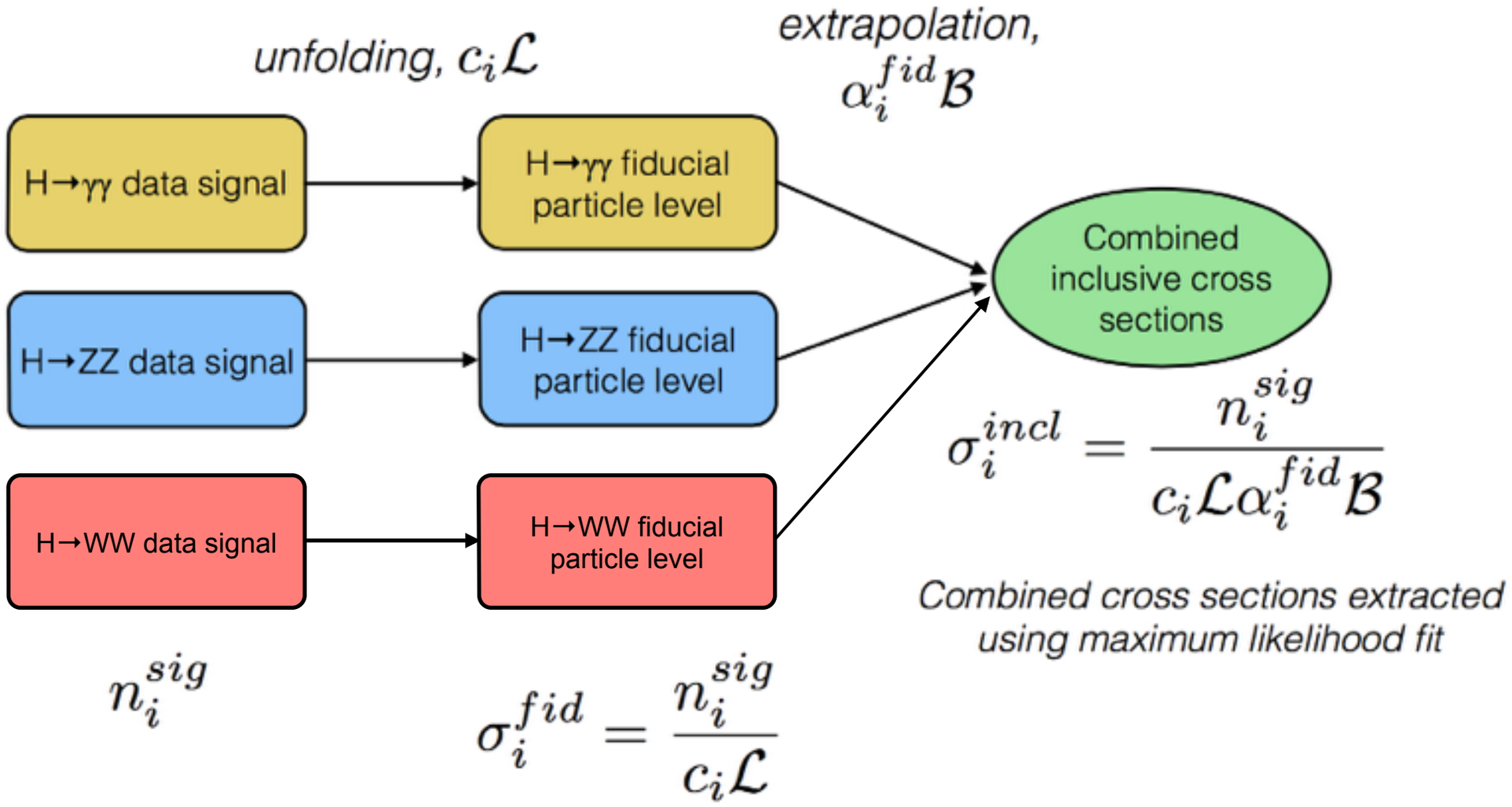
MODEL DEPENDENCE:

- Build response matrix and repeat the **unfolding procedure once per model**
  - **SM studies: vary production mode composition** (e.g. within experimental constraints)
  - **BSM studies:** consider a predefined **set of exotic models** (with/without exp. constraints)

Combination of measurements

Combination between decay channels (H→γγ, H→ZZ, H→WW, etc.):

- Perform the fit to **integrated/differential XS in the full phase space** (inherent assumption of the same source of decays)
- **Statistical precision** at the expense of model dependance due to extrapolation (quote a total XS, check the compatibility between the measurements).

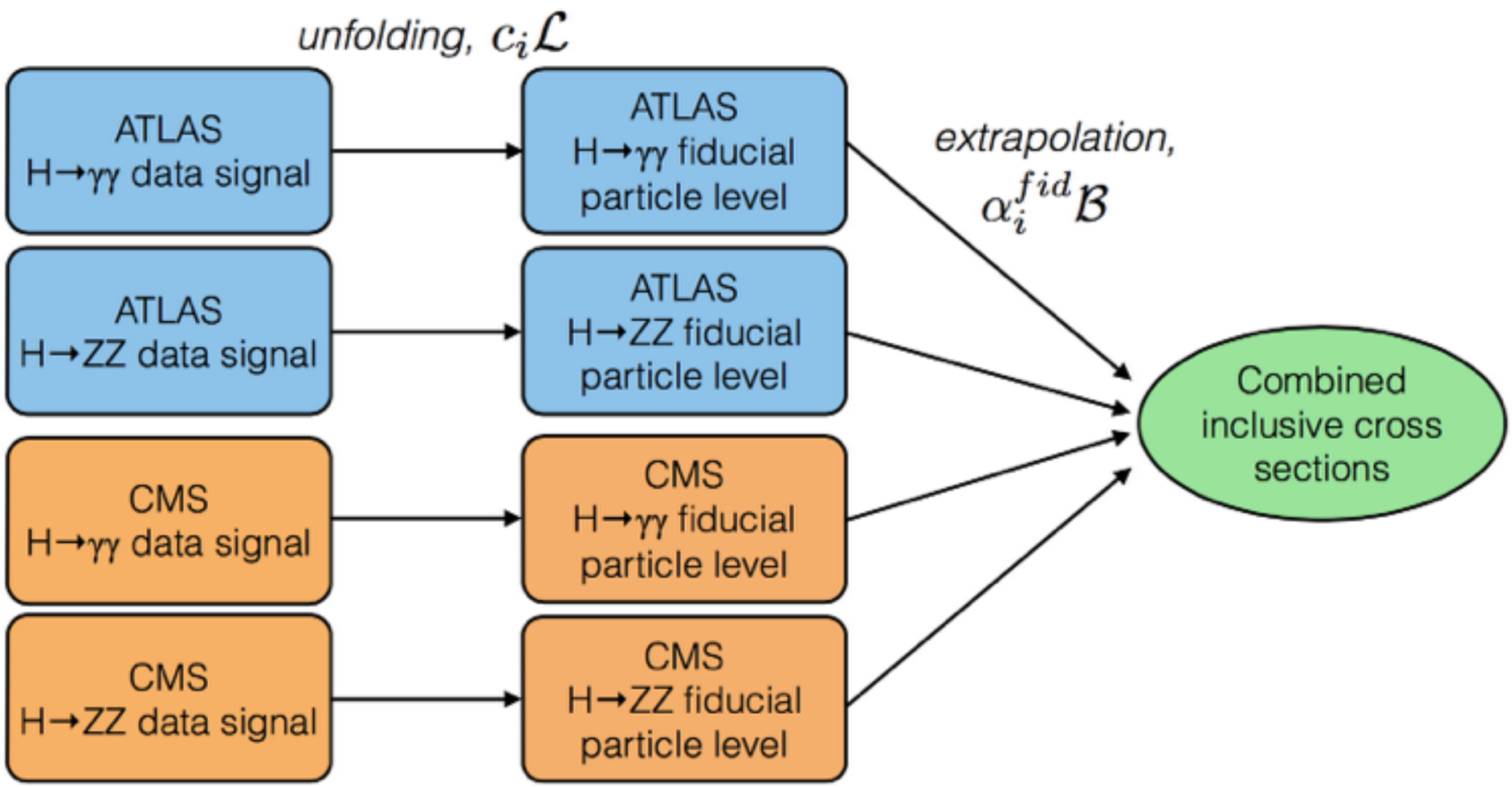


Combination of measurements

Combination between experiments:

- Potential to **combine inclusive and differential cross sections** (need harmonisation in fiducial objects, bin edges, unfolding, etc.)
- Choose **common fiducial** or **inclusive phase space?**
- Benefit form the HCG experience, start harmonisation in time

} still to be discussed



Fiducial requirements & observables with poor resolution

To be studied in each analysis:

- How to define the fiducial phase space when observables used to define the signal region have **poor experimental resolution** (missing E_T, jet p_T, etc.)?
  - Effects of migration of signal events can be large
  - Subtraction of non-fiducial signal events is model dependent
- Study if relaxing fiducial requirements can reduce model dependence.