Discussion on (Common) Fiducial Phase Space Definitions

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For the MB subgroup

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Motivation

- *Combination of results across experiments could increase the measurement precision, even considerably for certain phase spaces.*

- *Also desirable to have results from different experiments directly comparable.*

- *Therefore, it seems nature to think about defining common fiducial phase spaces, which experiments can directly measure inside or extrapolate their measurements to.*

- *This idea starts to become relevant now, as time comes for extensive strategic discussions, tunings and plans.*

Practice

- *We had relevant discussions in a couple of meetings this year [1, 2, 3, 4] and also some efforts in the past [1,2].*

- *It has become clearer that*
  - Fiducial PS definitions have not been so much different.
  - Small differences due to different detector acceptances and different conventions persist and are difficult to resolve.

- *A preliminary summary so far*
  - No necessity (possibility) to have experiments to measure in exactly the same fiducial PS.
  - Yet still try to discuss and eventually recommend on common fiducial PS definitions, which experiments can extrapolate their results to.
  - Important to make sure experiments will provide sufficient information concerning the extrapolation and future combinations.

- Discussions will continue post summer, eventually hope to have a good summary of studies and recommendations in the YR.

Prospect

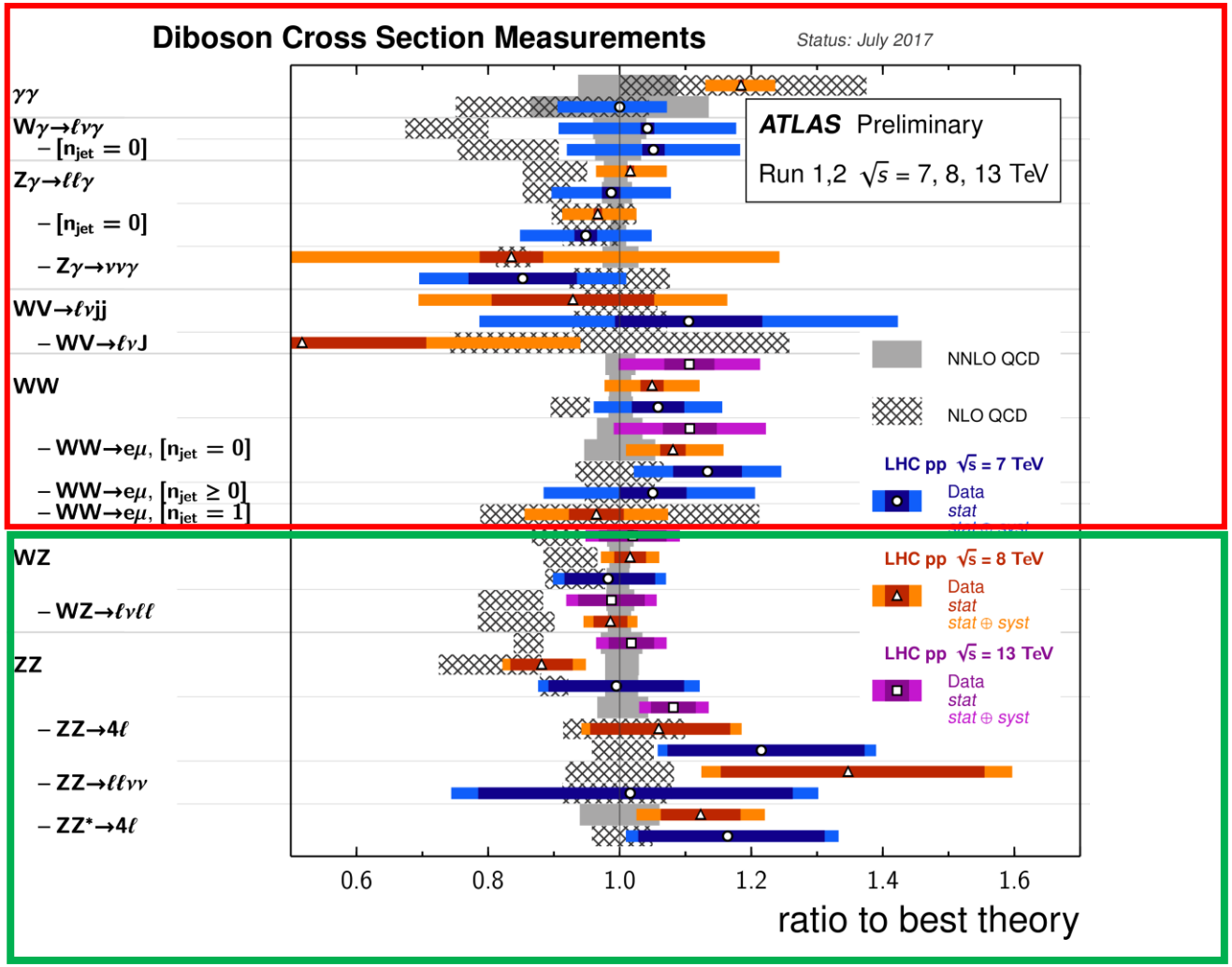
- *<u>For the measurements limited already by systematic uncertainties</u>, a combination of ATLAS and CMS measurement might not help much, as systematic uncertainties are not expected to cancel much.*

- *<u>For those with sizable statistical uncertainties</u>, a combination will help to reach a better measurement precision which otherwise needs a new data-taking.*

- *<u>For measurements of differential distributions and less-populated search phase spaces</u>, which are currently limited by statistical uncertainties, a combination will be helpful*

- *<u>Bottom line</u>: two comparable and independent measurements provide an important cross-check*

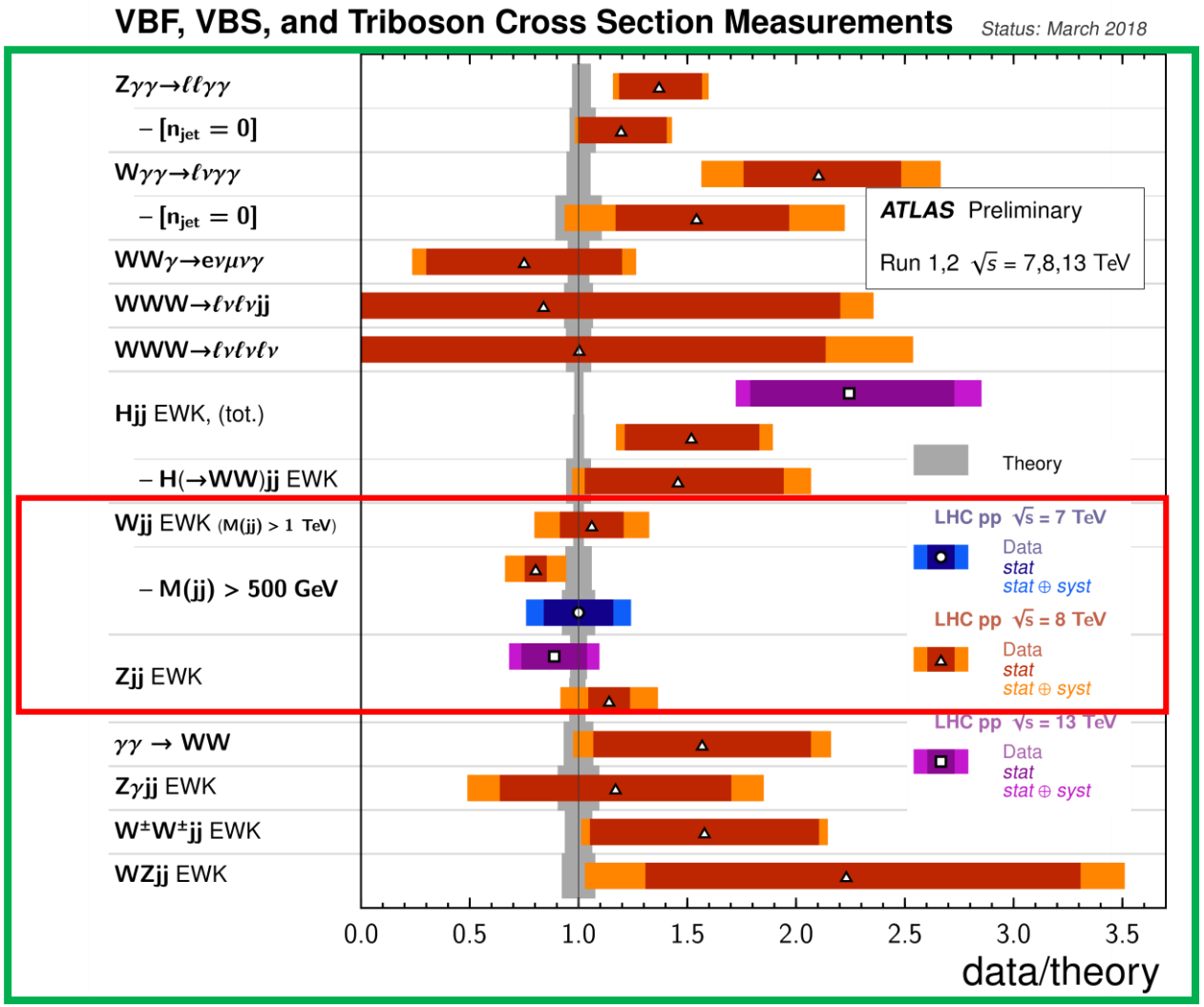
Precision with integrated σ



Systematics limited

Statistical uncertainty play roles

Precision with integrated σ



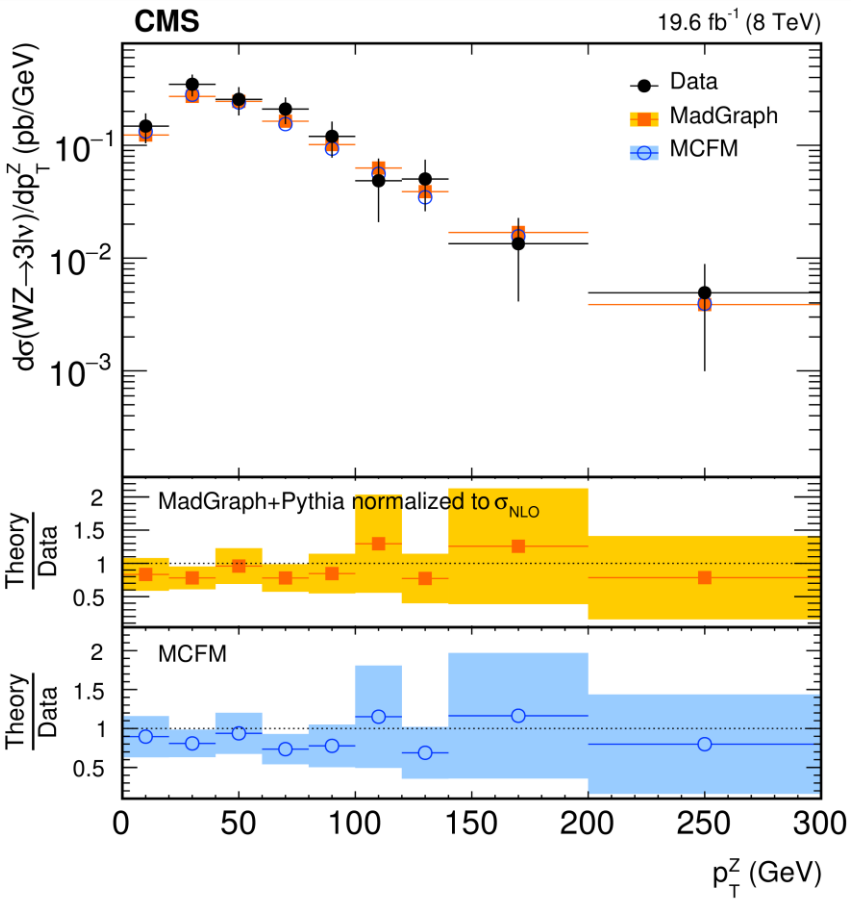
Statistical uncertainty dominating

Systematic uncertainties play critical roles

For some VBS and triboson channels, we are still seeking for individual observations, therefore not relevant for combination

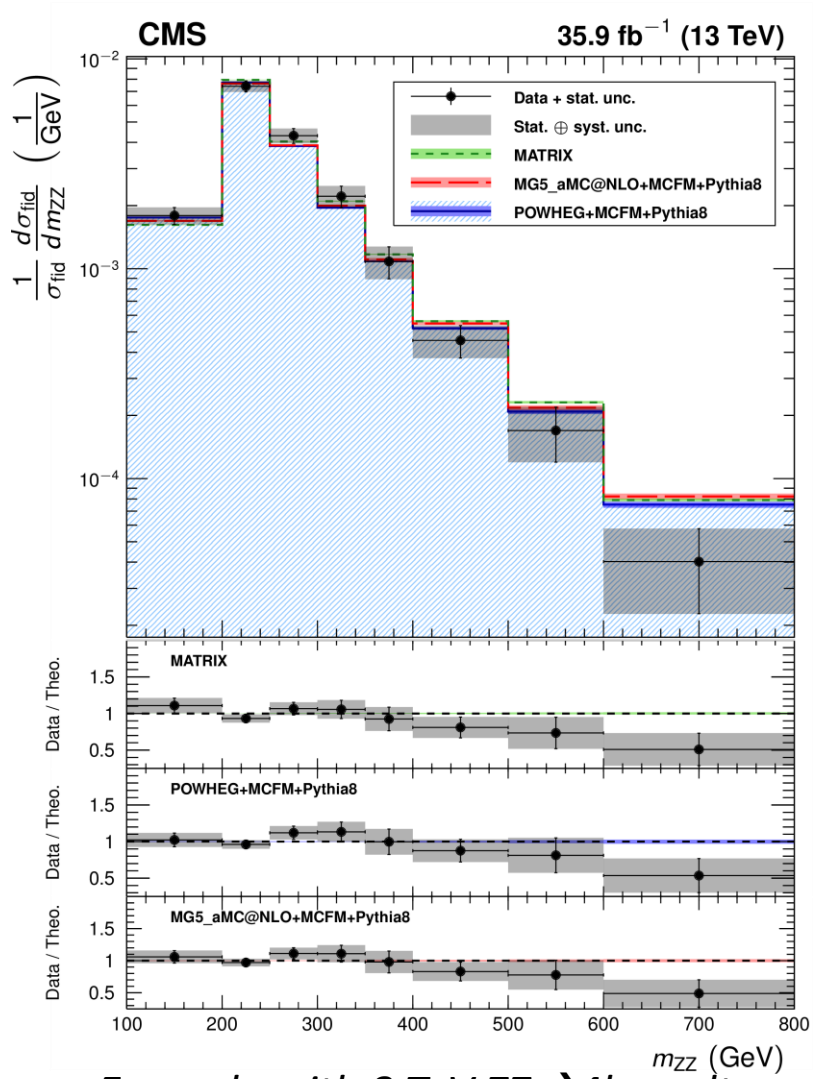
Precision with differential σ

Eur. Phys. J. C 77 (2017) 236



Example with 8 TeV WZ results

Eur. Phys. J. C 78 (2018) 165



Example with 8 TeV ZZ→4l results

An example with ZZ→4l

- *Fiducial PS definitions close but not identical*

From ATLAS: *Phys. Rev. D 97 (2018) 032005*

Type	Input or requirement
Leptons (e, μ)	Prompt Dressed with prompt photons within $\Delta R = 0.1$ (added to closest prompt lepton) $p_{\mathrm{T}} > 5\ GeV$ $\lvert\eta\rvert < 2.7$
Quadruplets	Two same-flavor opposite-charge lepton pairs Three leading-p_{T} leptons satisfy $p_{\mathrm{T}} > 20$ GeV, 15 GeV, 10 GeV
Events	Only quadruplet minimizing $\lvert m^a_{\ell\ell} - m_Z\rvert + \lvert m^b_{\ell\ell} - m_Z\rvert$ is considered Any same-flavor opposite-charge dilepton has mass $m_{\ell\ell} > 5$ GeV $\Delta R > 0.1$ (0.2) between all same-flavor (different-flavor) leptons Dileptons minimizing $\lvert m^a_{\ell\ell} - m_Z\rvert + \lvert m^b_{\ell\ell} - m_Z\rvert$ are taken as Z boson candidates Z boson candidates have mass 66 $GeV < m_{\ell\ell} <$ 116 GeV

From CMS: *Eur. Phys. J. C 78 (2018) 165*

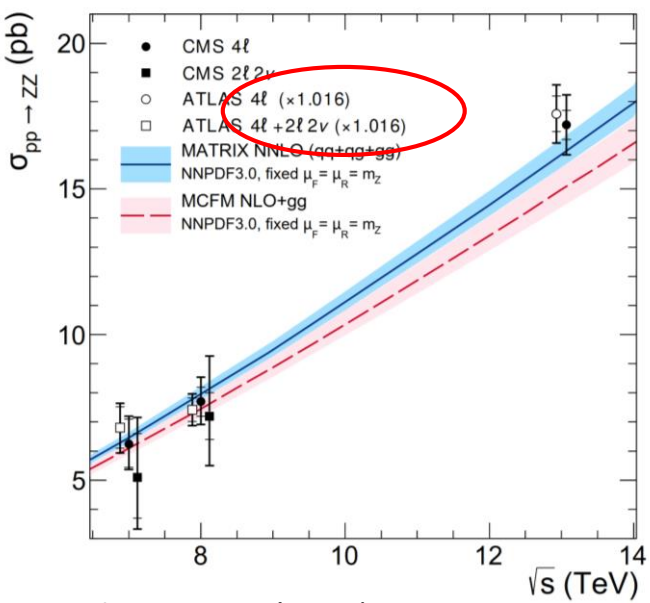
Cross section measurement	Fiducial requirements
Common requirements	$p_{\mathrm{T}}^{\ell_1} > 20\,\mathrm{GeV}$, $p_{\mathrm{T}}^{\ell_2} > 10\,\mathrm{GeV}$, $p_{\mathrm{T}}^{\ell_{3,4}} > 5\,\mathrm{GeV}$, $\lvert\eta^\ell\rvert < 2.5$, $m_{\ell\ell} > 4\,\mathrm{GeV}$ (any opposite-sign same-flavor pair)
$\mathrm{Z} \to 4\ell$	$m_{\mathrm{Z}_1} > 40\,\mathrm{GeV}$ $80 < m_{4\ell} < 100\,\mathrm{GeV}$
$\mathrm{ZZ} \to 4\ell$	$60 < (m_{\mathrm{Z}_1}, m_{\mathrm{Z}_2}) < 120\,\mathrm{GeV}$

Similar fiducial PS definitions, with small differences on

- lepton pT
- Z boson pairing
- mass window cuts

An example with ZZ→4l

- *Factors can be derived from simulation to extrapolate from one PS to the other. For example, the total PS only differed by the mass window [60-120] v.s. [66-116] GeV, and one was able to compare the total σ measurements with a small extrapolation factor*



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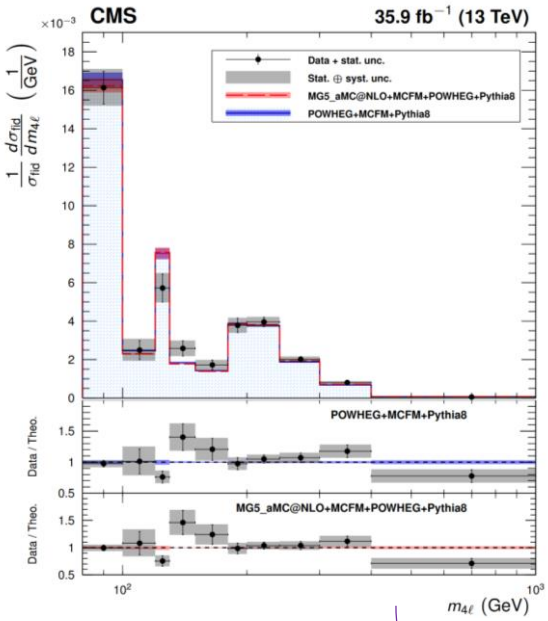
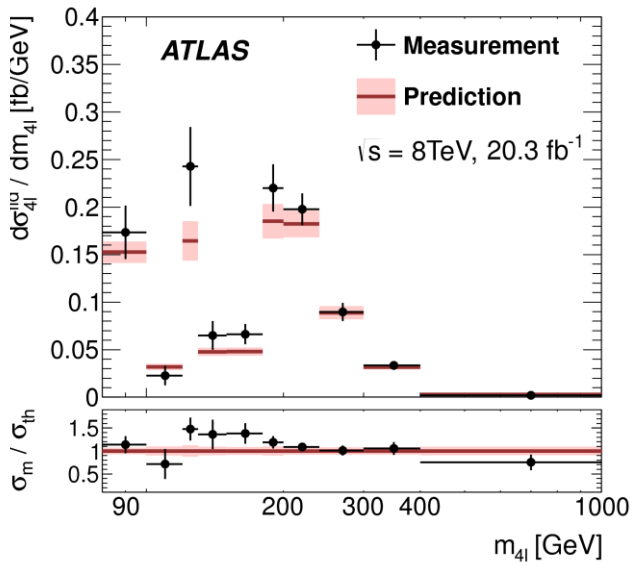


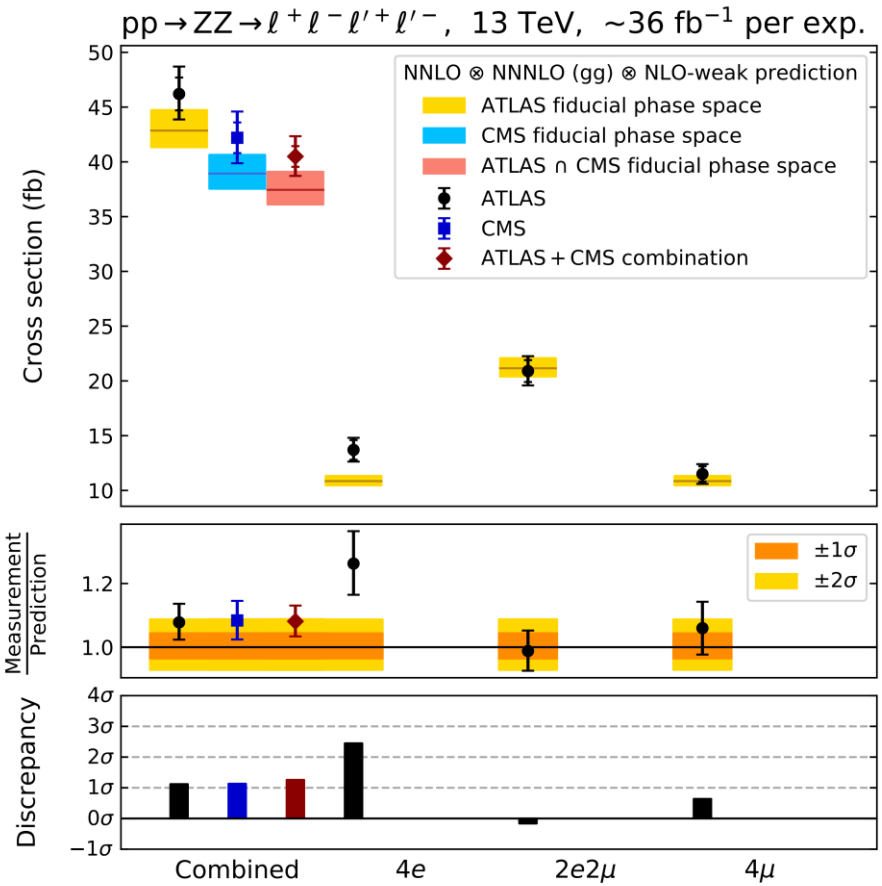
Physics Letters B 753 (2016) 552-572



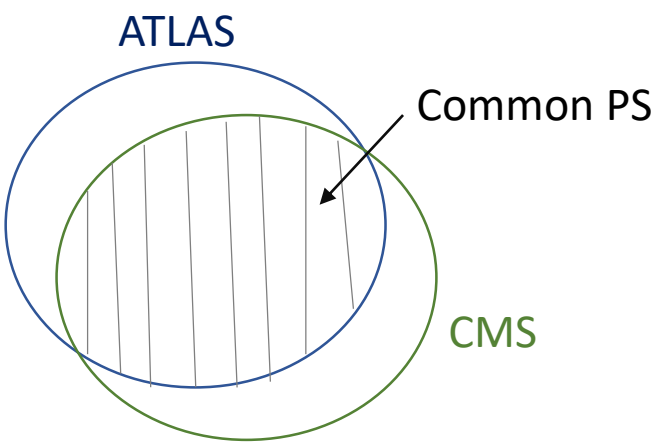
Identical binning (although not identical PS) was achieved as a result of LHC EW group discussion

An example with ZZ→4l

- *A possible strategy for common fiducial phase space definition*



by Stefan Richter



- Common PS could be smaller/larger, and an intersection was used for the plot
- To combine differential measurements, need to care about binning boundaries

Measurements shall provide …

- *A check list*
  - *Exact definition of fiducial PS*
  - *Rivert Routine (highly recommended)*
  - *Results presented in HepData or other common formats*
  - *Detailed information concerning uncertainties*
    - *<u>Essential to have</u>*
      - ✓ *separated statistical and systematic uncertainties*
      - ✓ *covariance matrices for both statistical and systematic components*
    - *<u>Ideal to also have (not much necessary for cross-experiment combination and theory-experiment comparison)</u>*
      - ✓ *separated uncertainties per source*
      - ✓ *covariance matrices per uncertainty source, or with correlation information*
      - ✓ *or ultimately, make the input histograms available*

Summary & Discussion

- *A set of slides prepared to summarize the discussion on common fiducial PS definitions in the multiboson subgroup*
- *A practical approach has been defined*
- *Wish to continue the discussion in upcoming months and summarize the recommendations in the YR*
- *Any suggestions welcomed!*