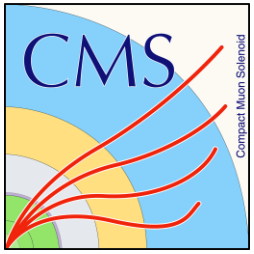
Search for the Higgs to dimuon decay in Run2 at the CMS experiment



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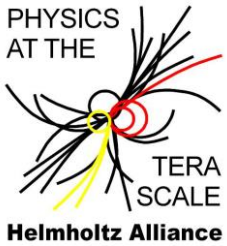


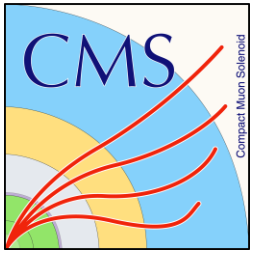
Oliver Rieger

University of Hamburg

22.11.2016

10^{th} Annual Meeting of the Helmholtz Alliance "Physics at the Terascale"

Search for the Higgs to dimuon decay in Run2 at the CMS experiment



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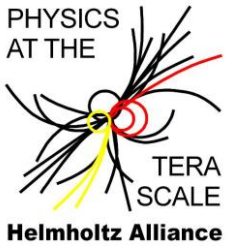
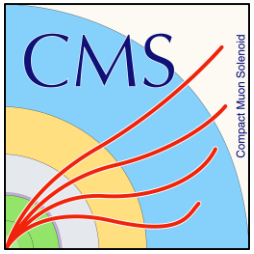


Helmholtz Alliance

Part ONE

… introduces concepts and results of the LHC *run1* analysis

Search for the Higgs to dimuon decay in Run2 at the CMS experiment



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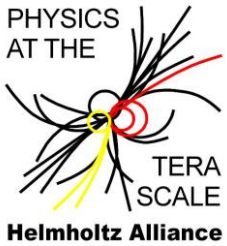


Part ONE

… introduces concepts and results of the LHC *run1* analysis

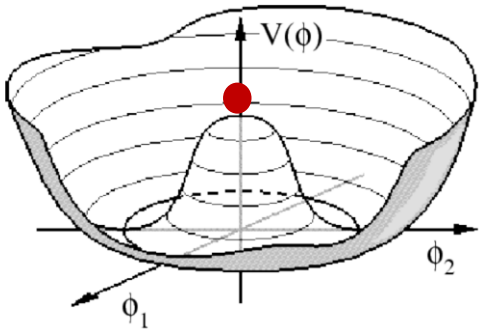
Part TWO

- Reloaded analysis at 13 TeV
- Ideas and improvements for LHC *run2* analysis

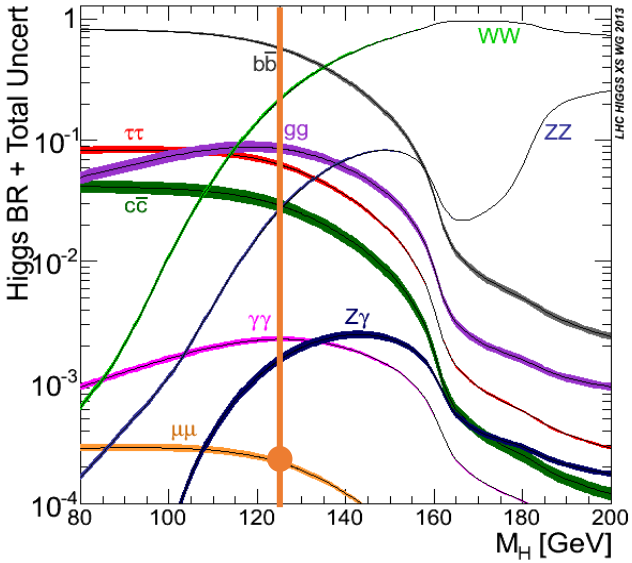
Higgs Physics

- **Higgs mechanism provides masses for gauge bosons and fermions**
- **Spontaneous symmetry breaking:**
  Non-zero vacuum expectation value
  → particles acquire a mass
- **Couplings proportional to particle mass**

$$\lambda_f \propto \frac{m_f}{v} \text{ and } \lambda_W^2 \propto gM_w$$



- bb (0.58)
- $\tau\tau$ (0.063)
- cc (0.029)
- $\mu\mu$ (0.00022)



- WW (0.21)
- gg (0.081)
- ZZ (0.026)
- $\gamma\gamma$ (0.0023)
- Z+γ (0.0015)

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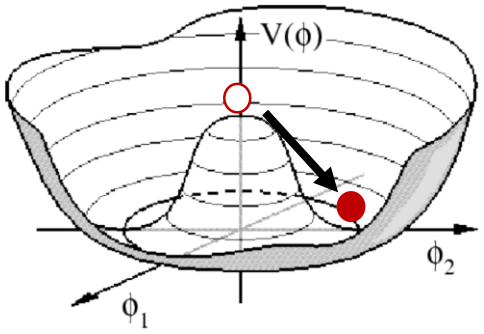

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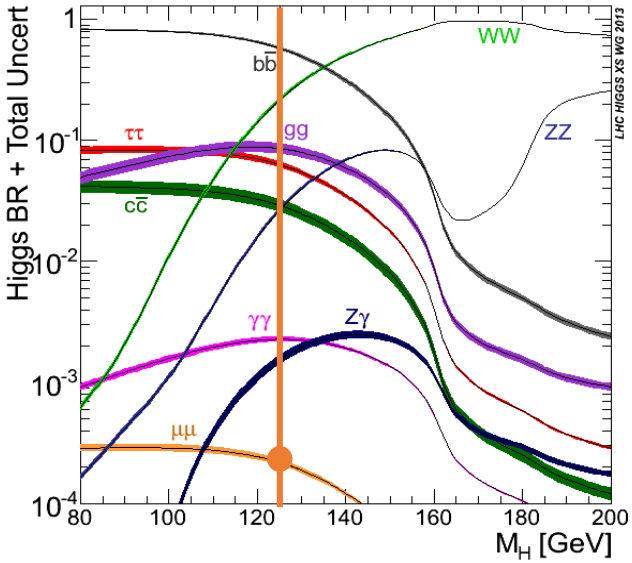

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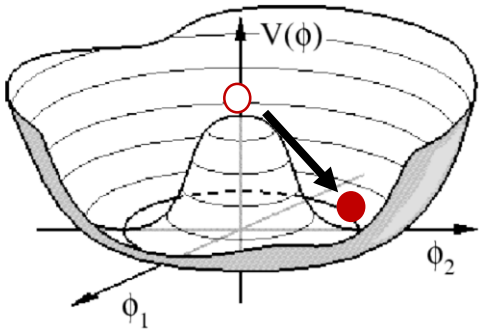

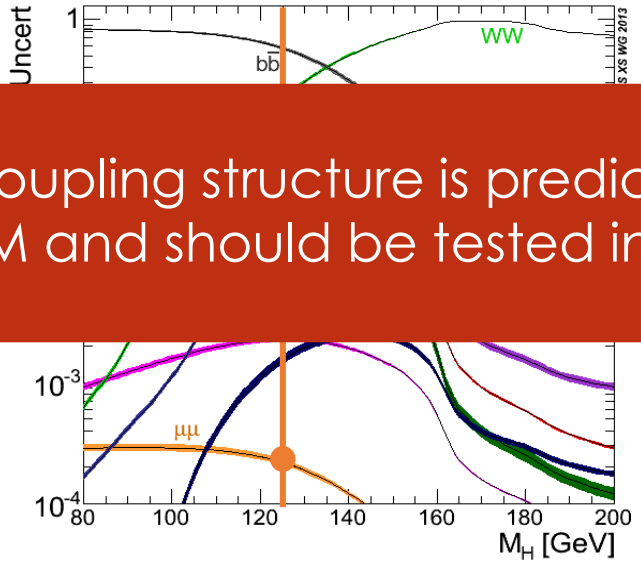

- bb (0.58
- $\tau\tau$ (0.06
- cc (0.02
- $\mu\mu$ (0.00022)

The coupling structure is predicted by the SM and should be tested in detail!

- (0.21)
- (0.081)
- 0.026)
- $\gamma\gamma$ (0.0023)
- Z+γ (0.0015)

Higgs Couplings

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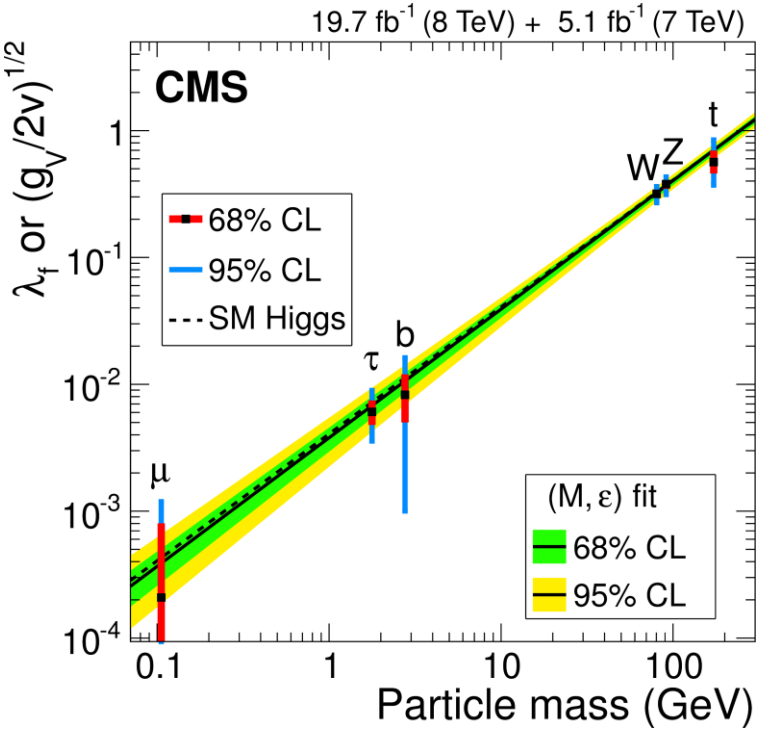
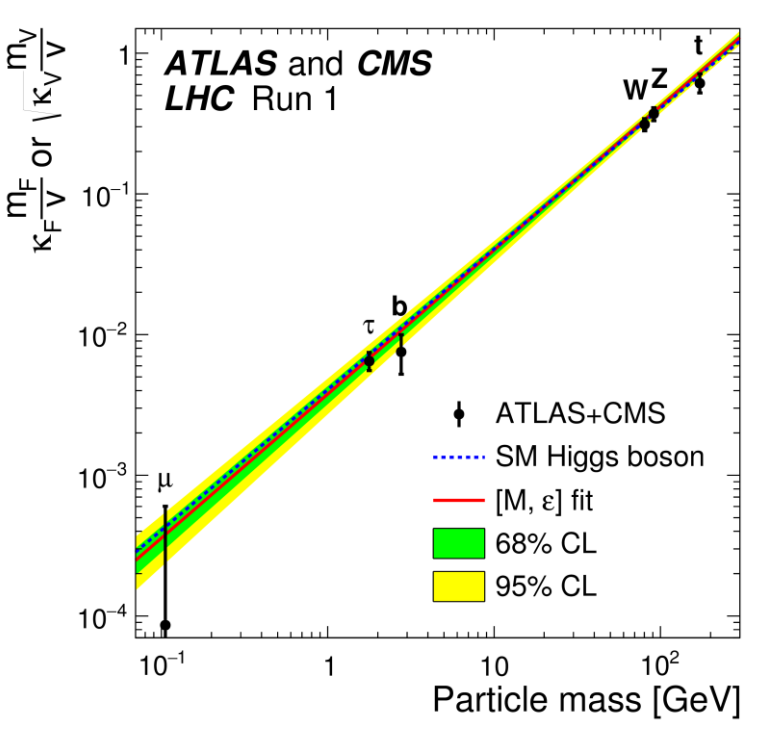
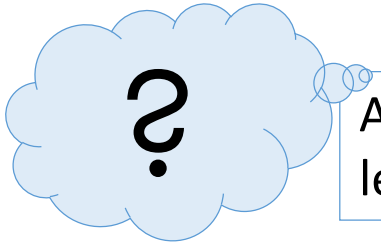
reduced coupling



and in combination with ATLAS



Higgs Couplings



Are we talking about the same mass generation mechanism for all lepton generations?

Higgs Couplings

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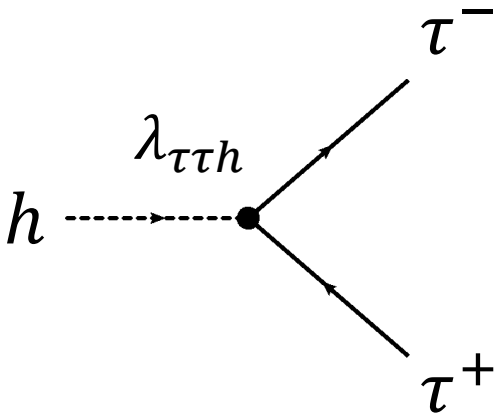
Are we talking about the same mass generation mechanism for all lepton generations?

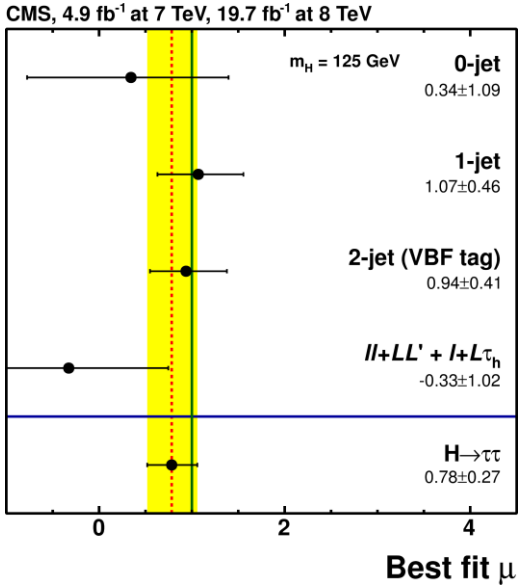


CMS-HIG-13-004

CERN-PH-EP/2014-001
2014/06/13

Evidence for the 125 GeV Higgs boson decaying to a pair of τ leptons

The CMS Collaboration*



Higgs Couplings

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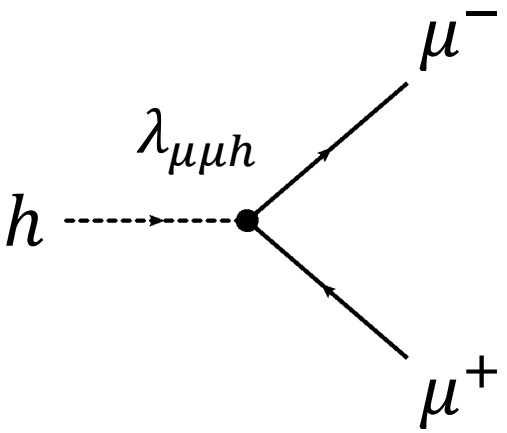
?

Are we talking about the same mass generation mechanism for all lepton generations?

$h \rightarrow \mu\mu$ gives us access to the 2^{nd} lepton generation coupling



!

$h \rightarrow \mu\mu$ could be a part of the answer!
(2^{nd} vs 3rd generation couplings)

Signal and Backgrounds

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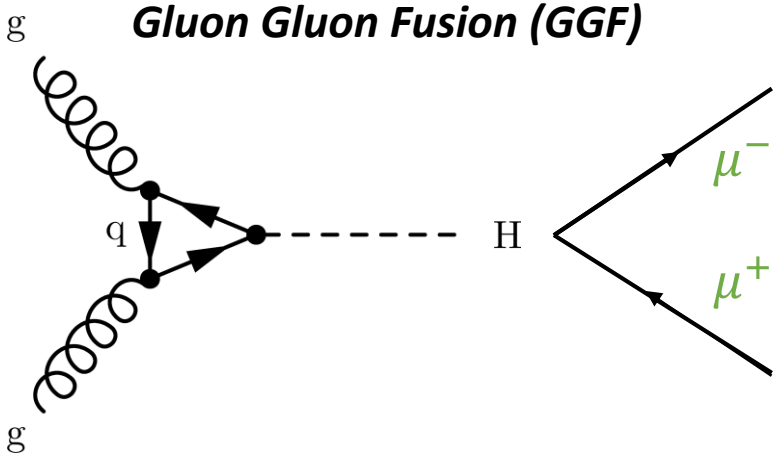
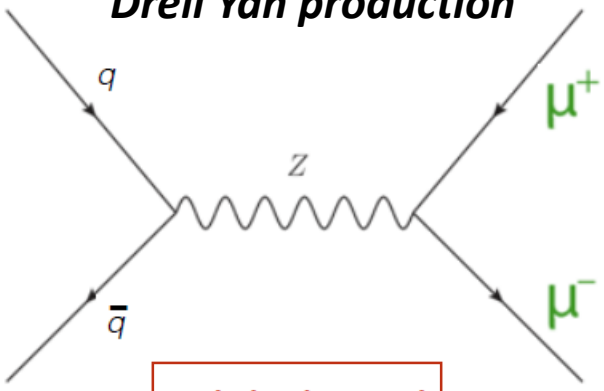
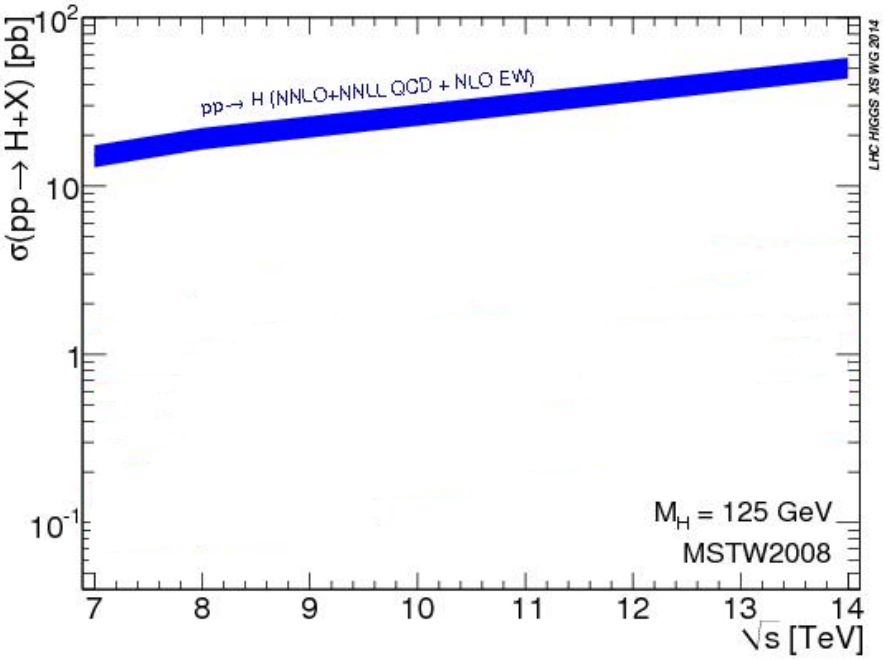
Gluon Gluon Fusion (GGF)



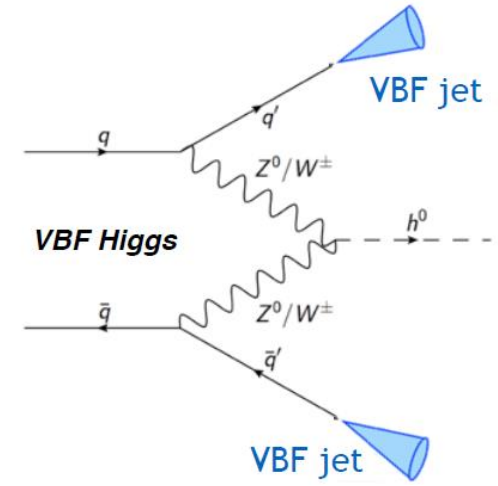
Drell Yan production



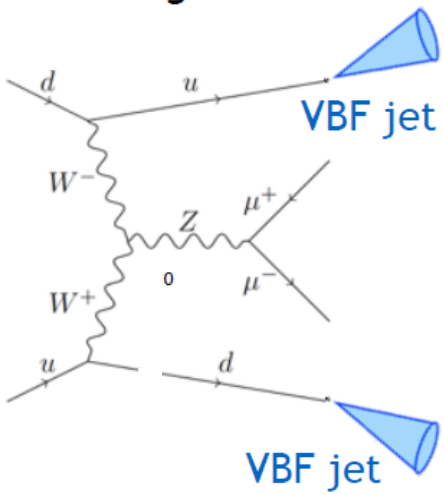
main background

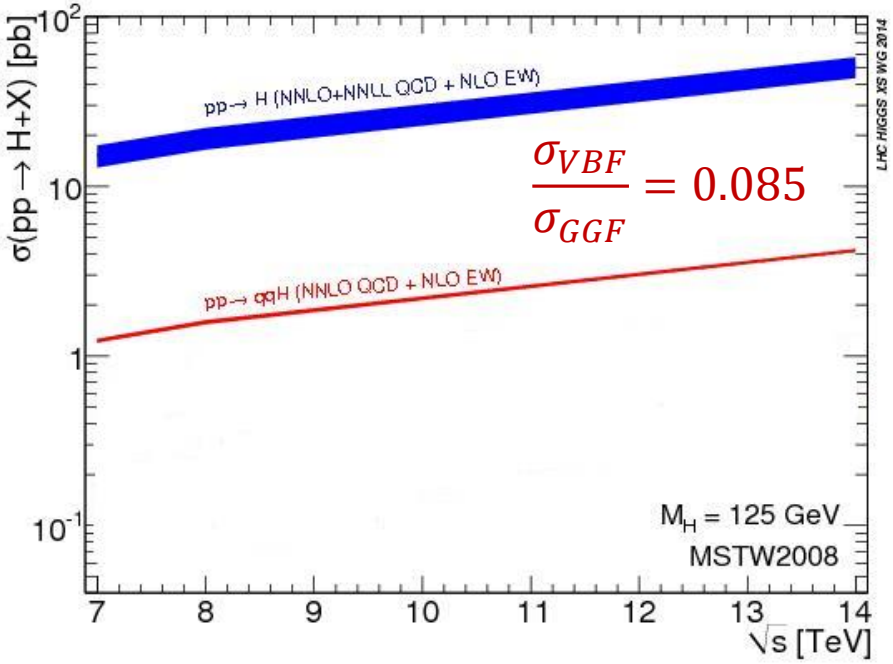


Signal and Backgrounds

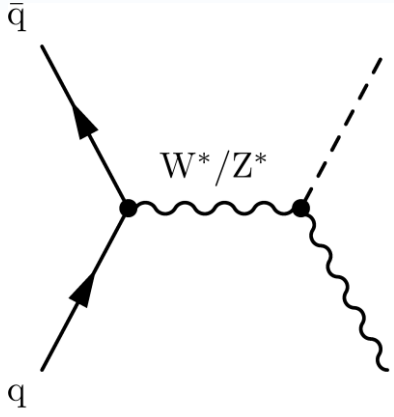


background VBF DY

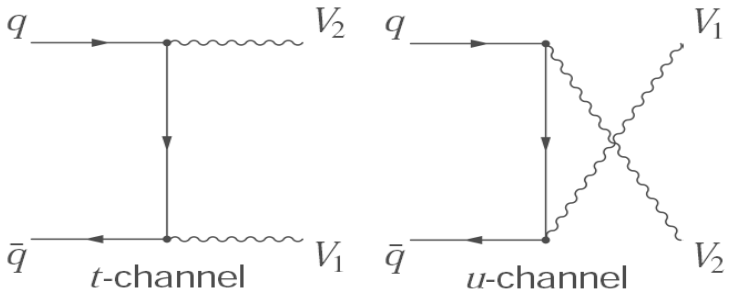


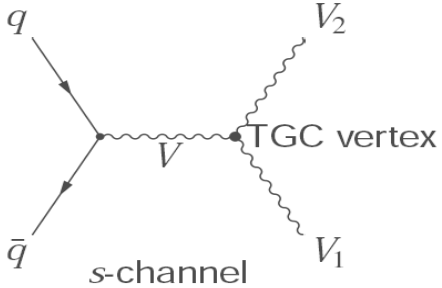


Signal and Backgrounds

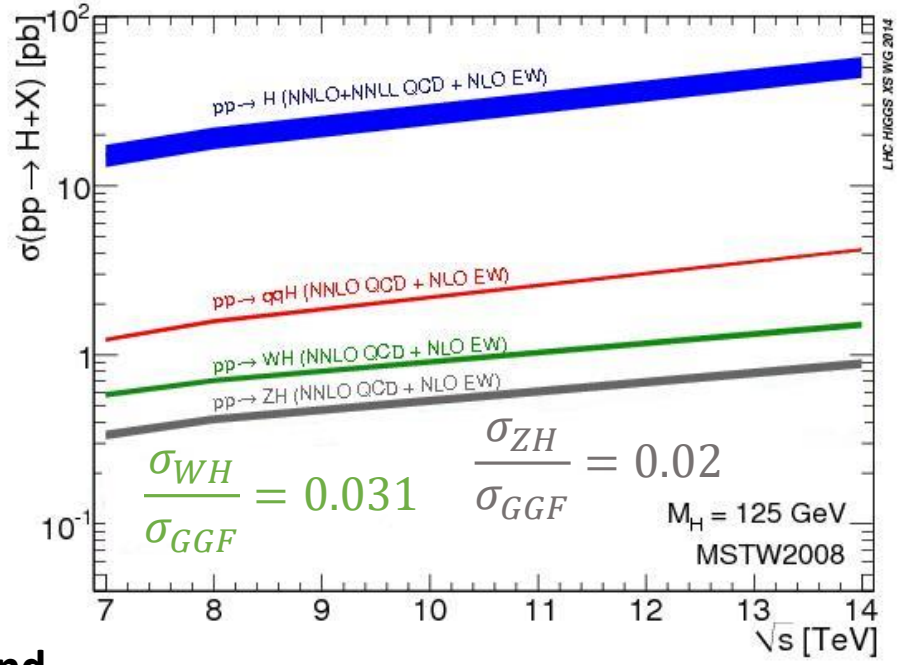


Higgs-Strahlung
(production in association with V)





Diboson background becomes important



Analysis Concepts

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Main Challenge

Very small branching fraction for $h \rightarrow \mu\mu$

- **Consider all Higgs production mechanisms**
  - → Target topologies with enhanced S/B
  - → Profit from the best muon p_T resolution
- **Good description of signal/background events**

Run I Analysis: Event Selection

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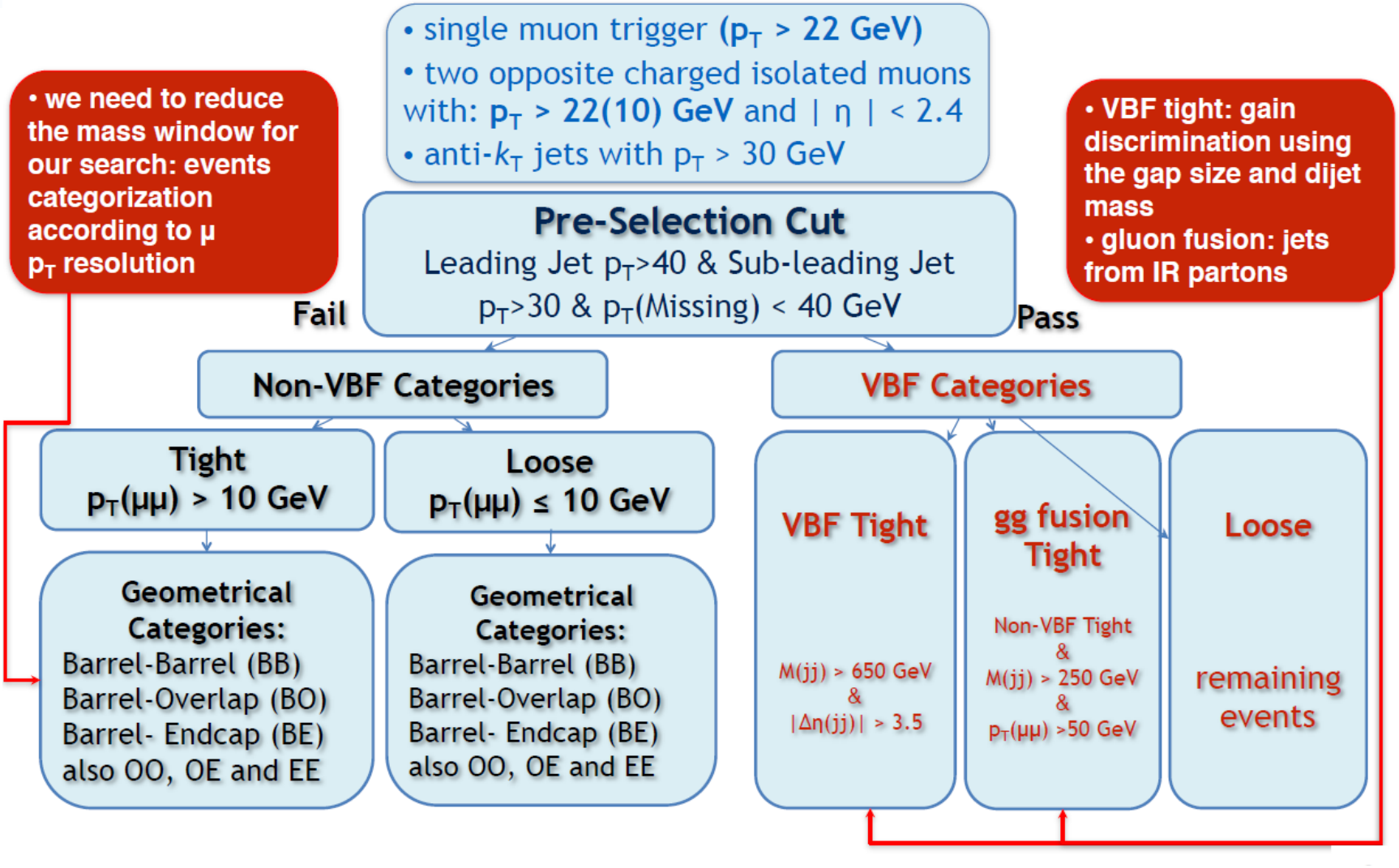
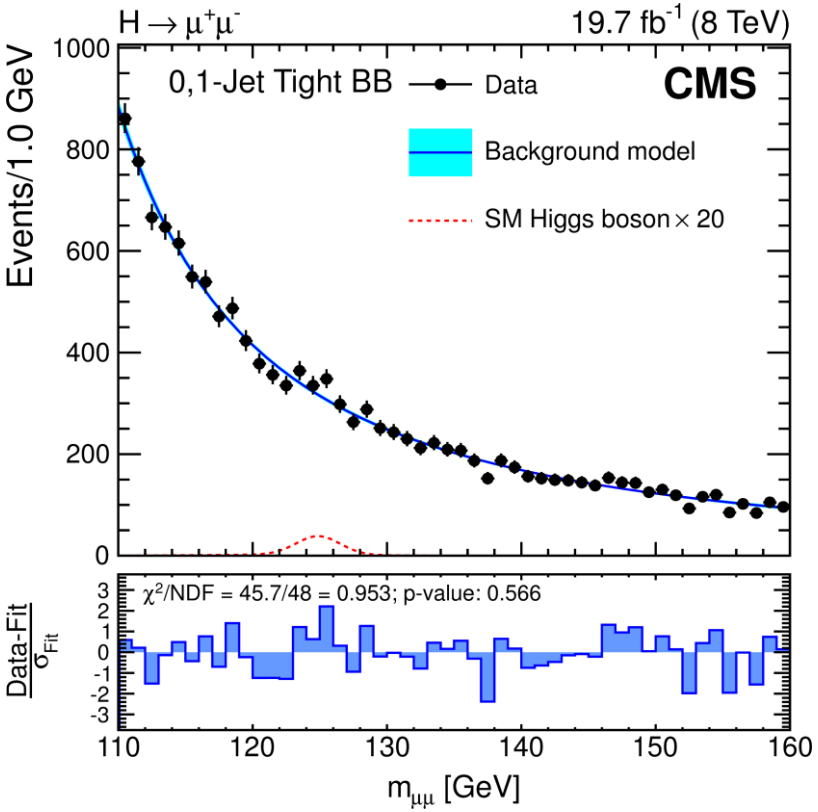
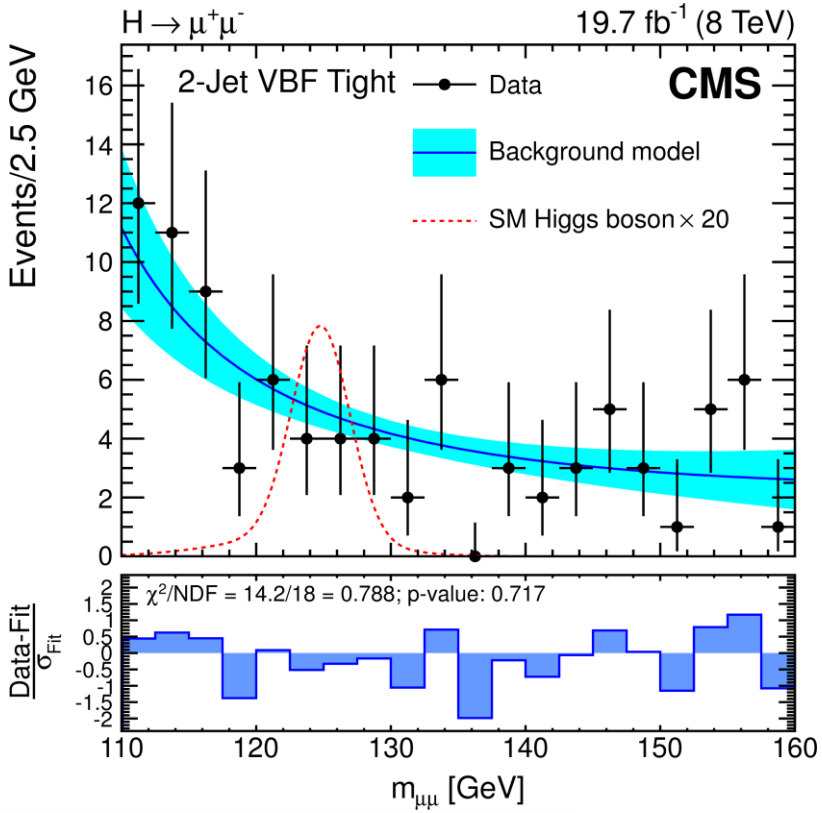


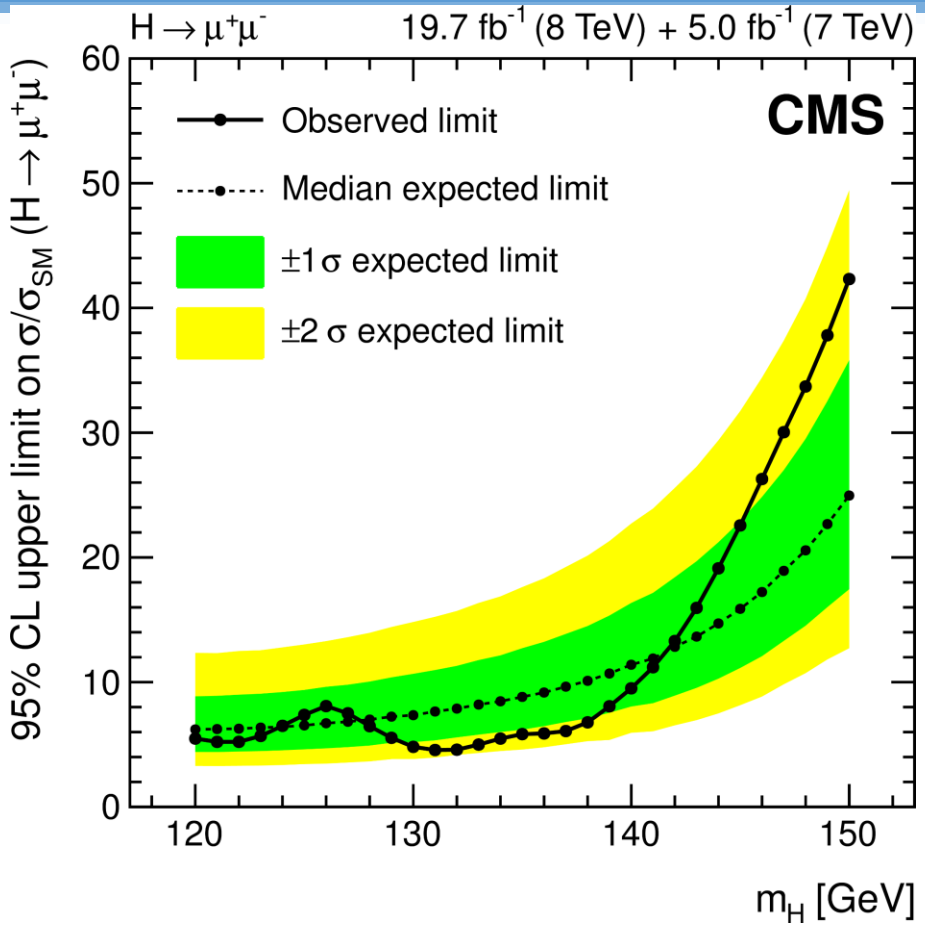
Run I Analysis: Results





$$f(m_{\mu\mu}) = \beta C_1 e^{-\lambda m_{\mu\mu}} \frac{1}{(m_{\mu\mu} - m_Z)^2 + \frac{\Gamma^2}{4}} + (1-\beta) C_2 e^{-\lambda m_{\mu\mu}} \frac{1}{m_{\mu\mu}^2}.$$

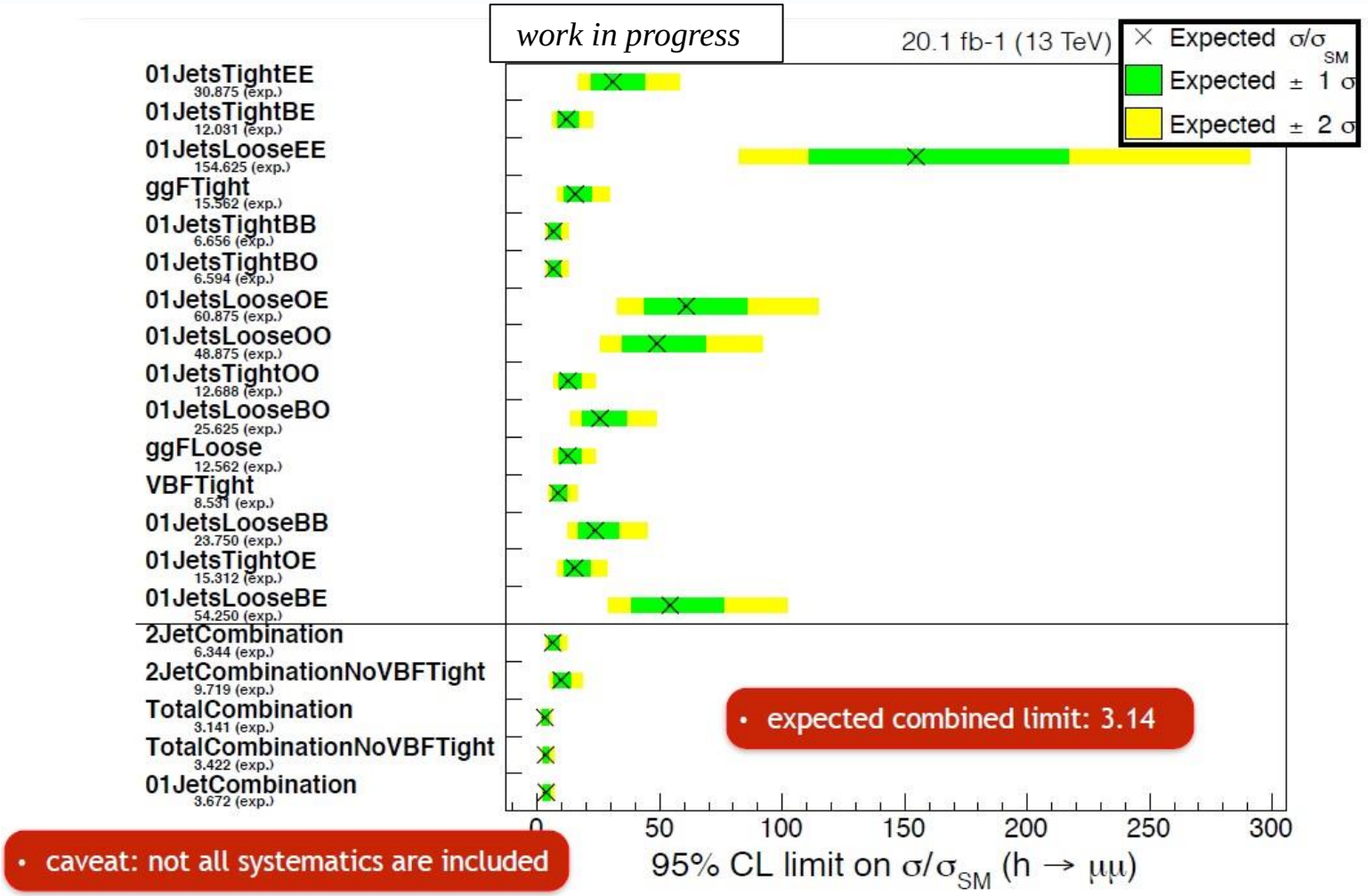
Run I Analysis: Results



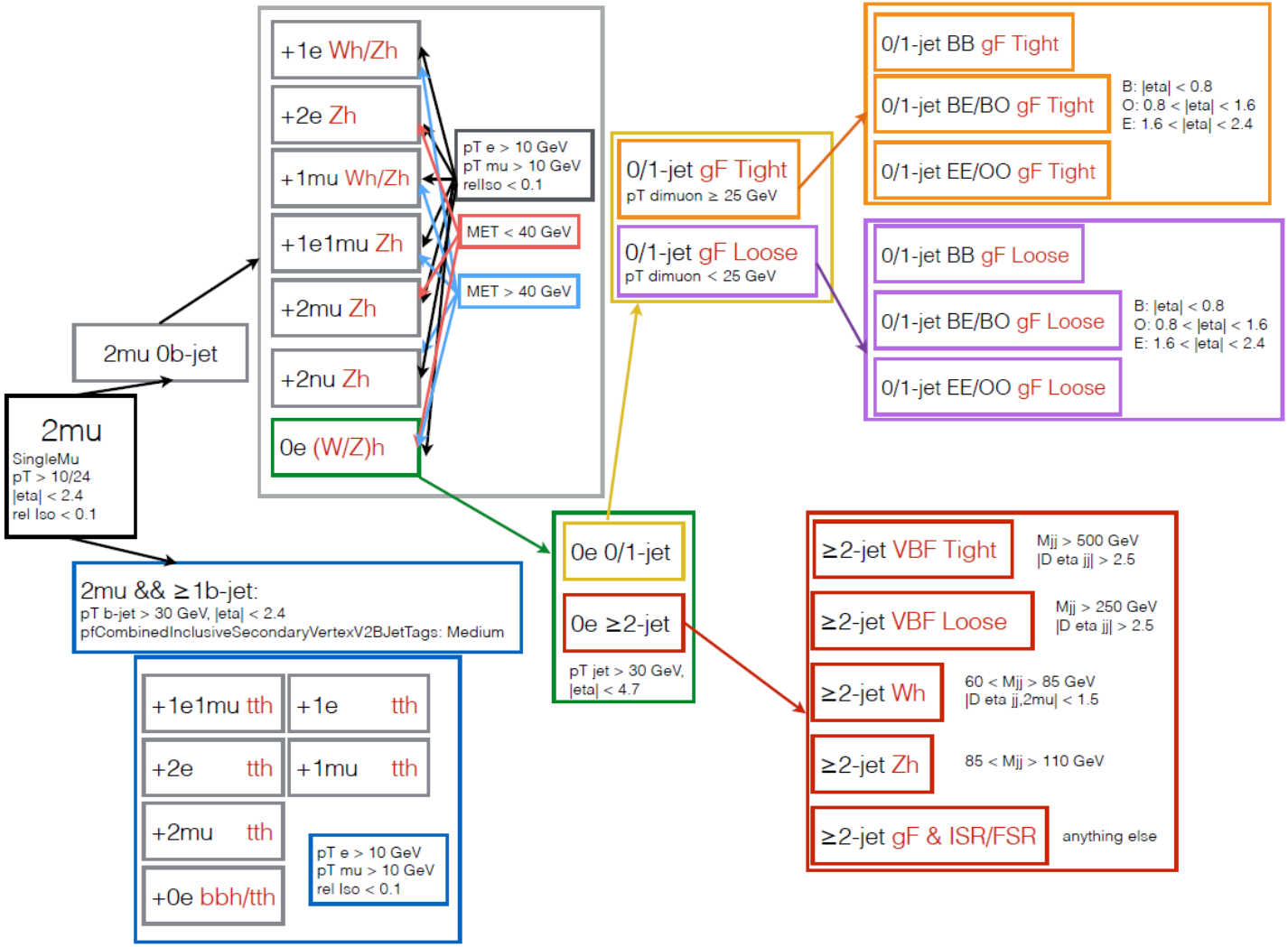
7.4 ($6.5^{+2.8}_{-1.9}$) observed (expected) 95% CL limit

Reload Analysis at 13 TeV

Run II Analysis: Reloaded at 13 TeV



Run II Analysis: updated Event Selection



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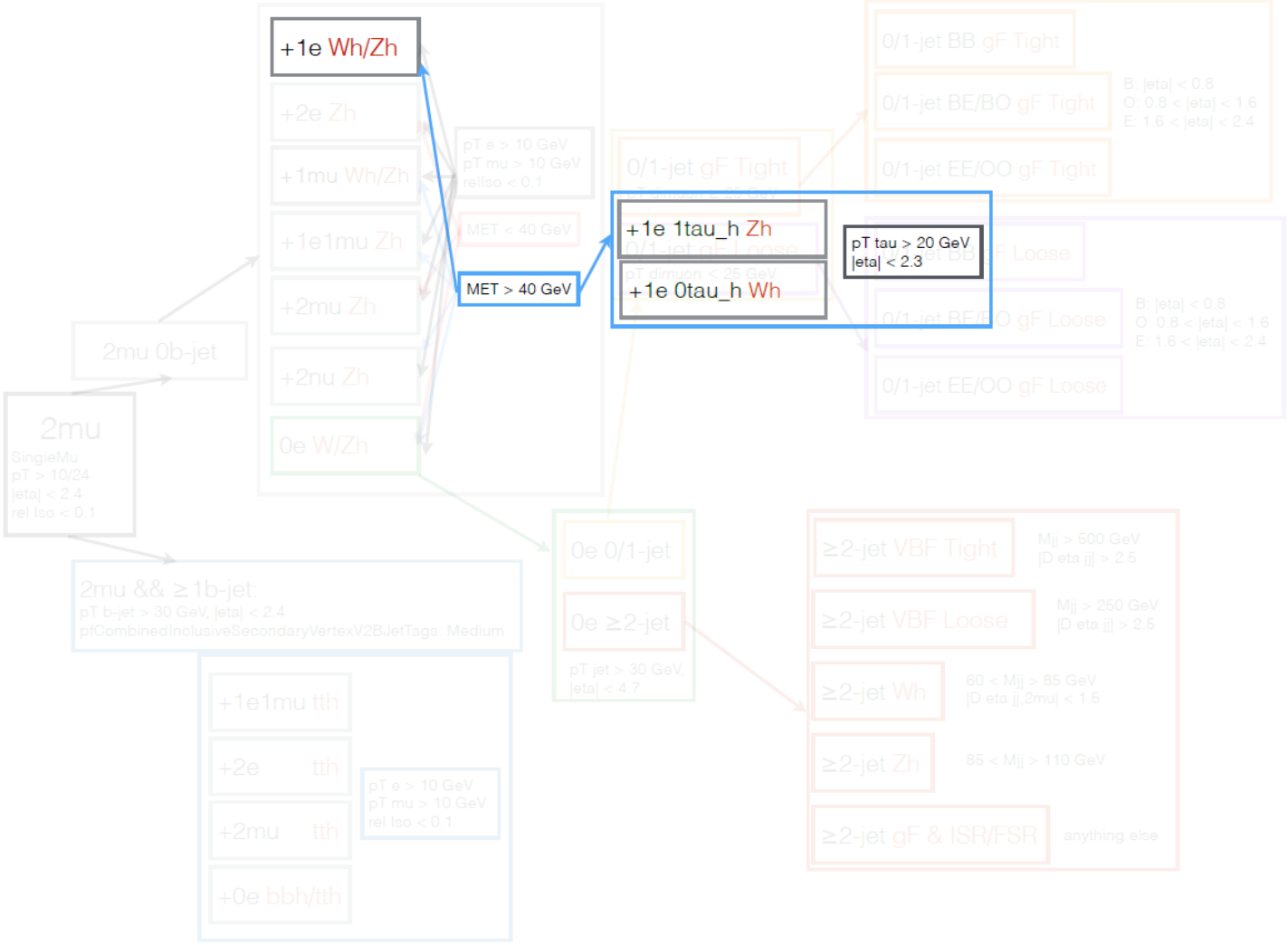

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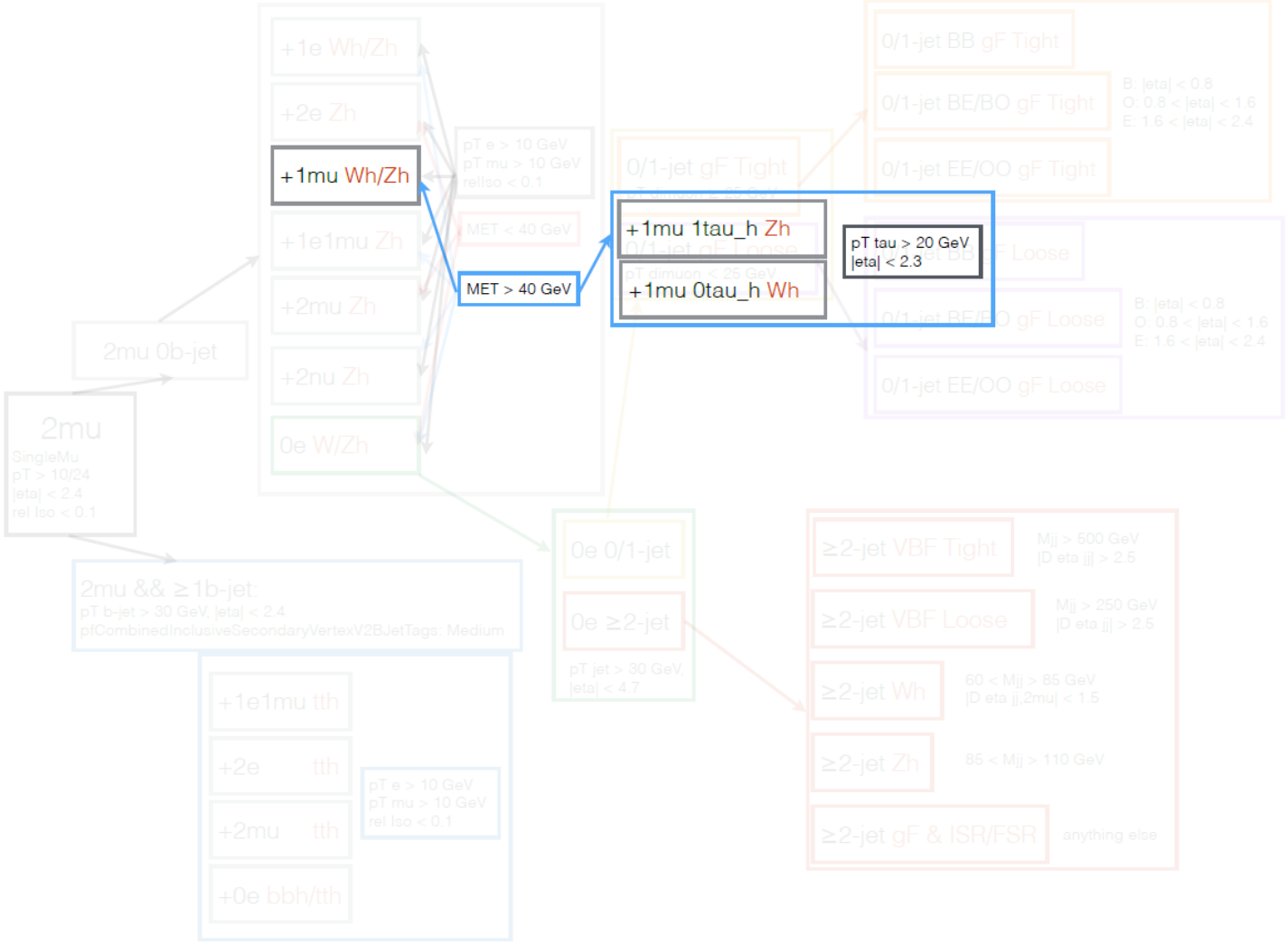

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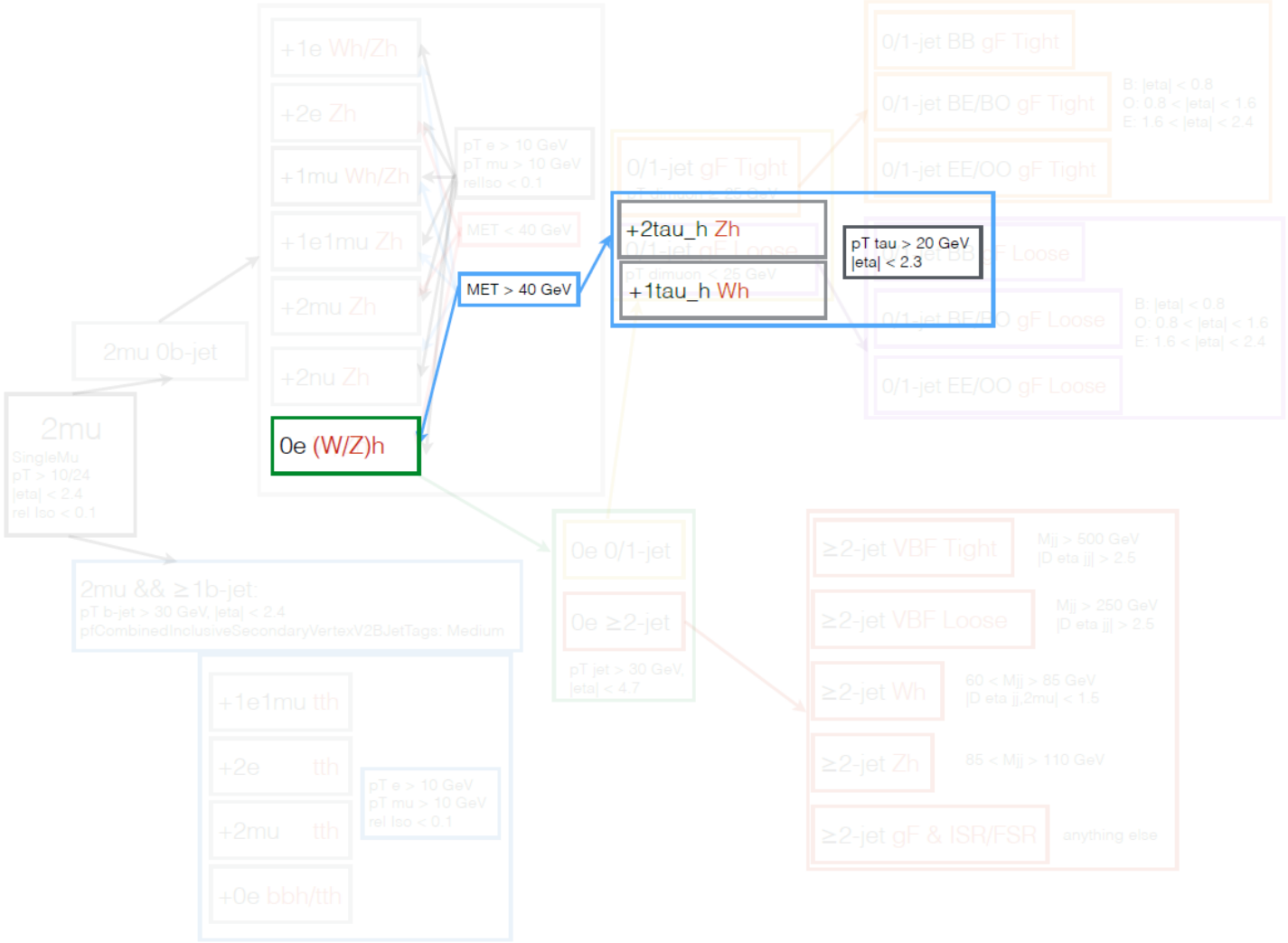

Muon Momentum Corrections

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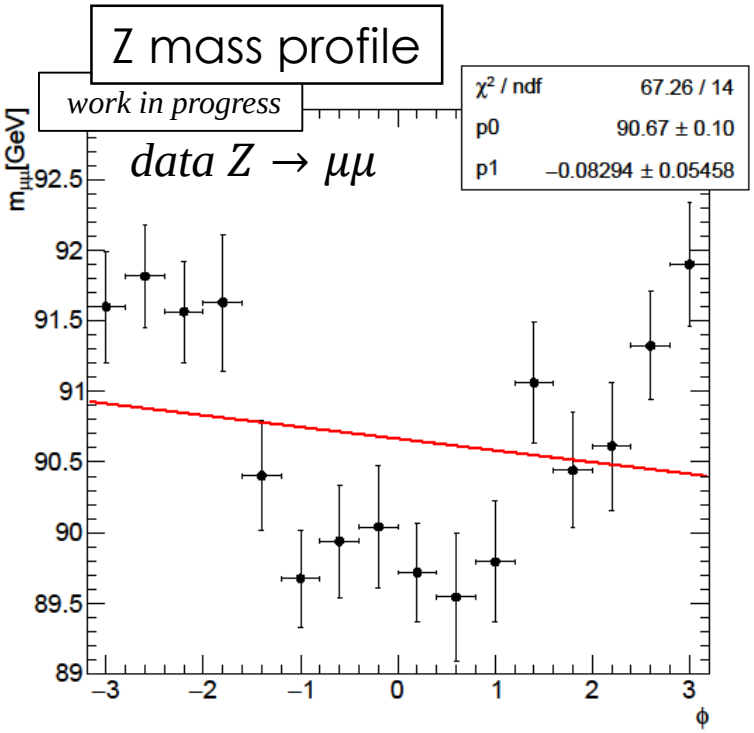
Remove the bias from:
- detector misalignments,
- reconstruction software,
- uncertainties in the magnetic field



'Rochester corrections'

$1/p_T$ correction binned in Q, η and ϕ
- $\left\langle \frac{1}{p_T} \right\rangle$ is used
- No correlation between μ^+ and μ^- assumed

Step 1

Z mass constrained correction
- Z mass peak is used for finer tuning of the corrections
- Independent from any physics modelling

Step 2

Reference for the method :
EPJC V72, 10.2194 (2012) (arXiv:1208.3710[hep-ex])

➢ μ^+: $-2.4 < \eta < -2.1$ (used muons: isolated, tight ID, p_T and η criteria)

Muon Momentum Corrections

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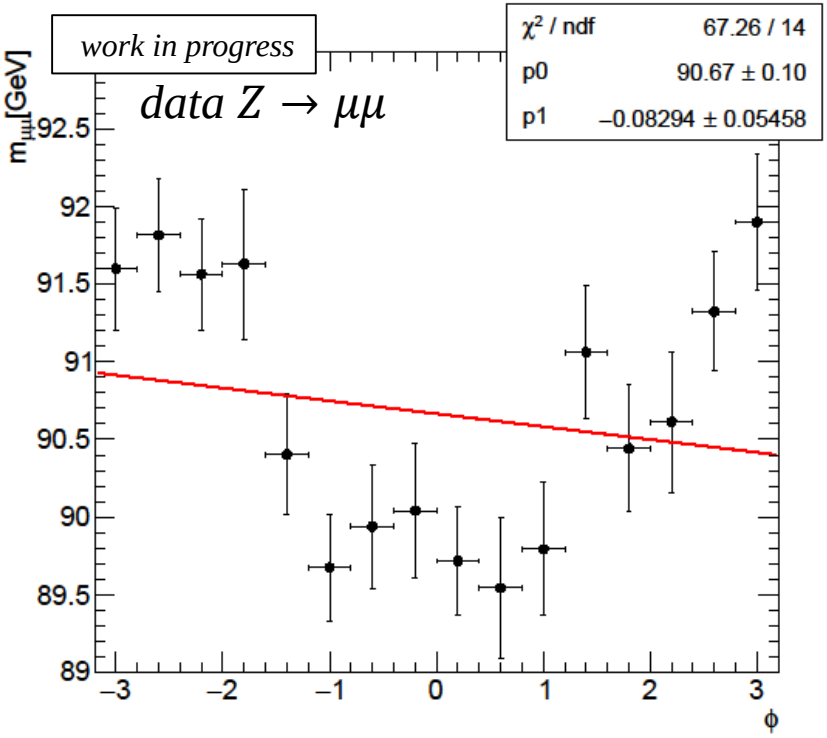
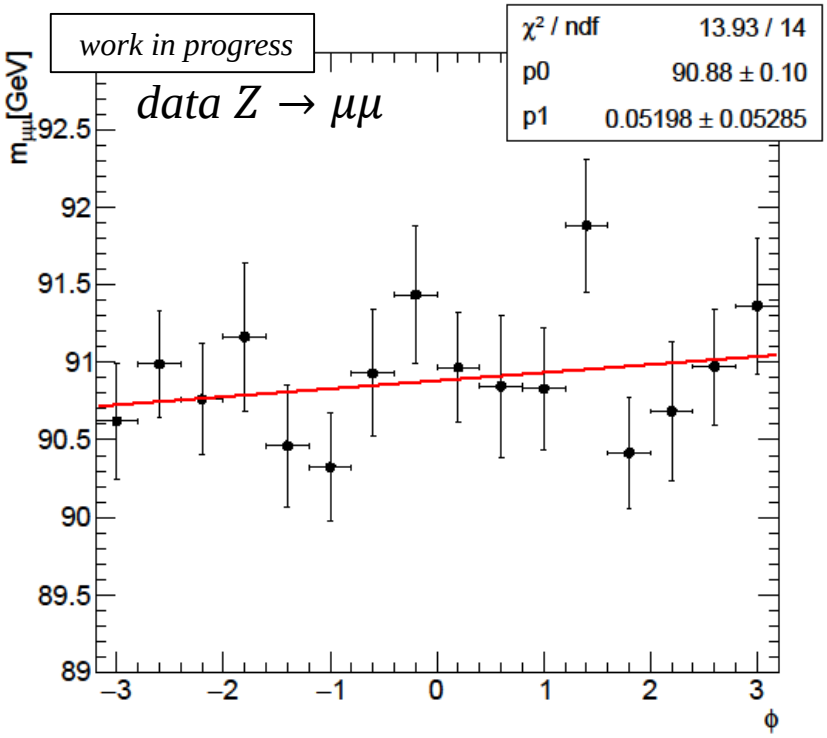
Before momentum correction



… and after correction



- This is mainly an effect in the high η region for data: μ^+: $-2.4 < \eta < -2.1$

Muon Momentum Corrections

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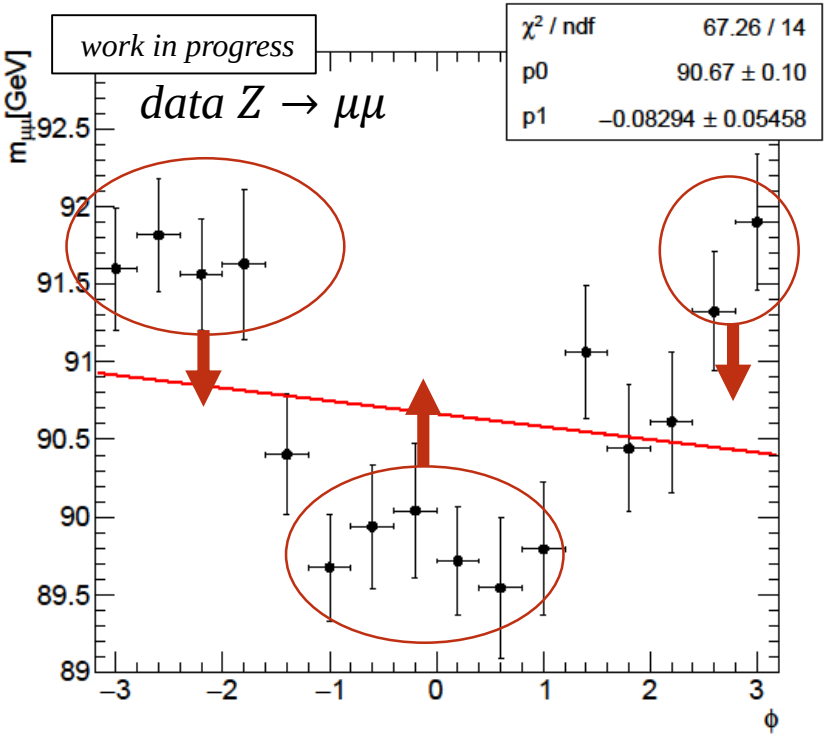
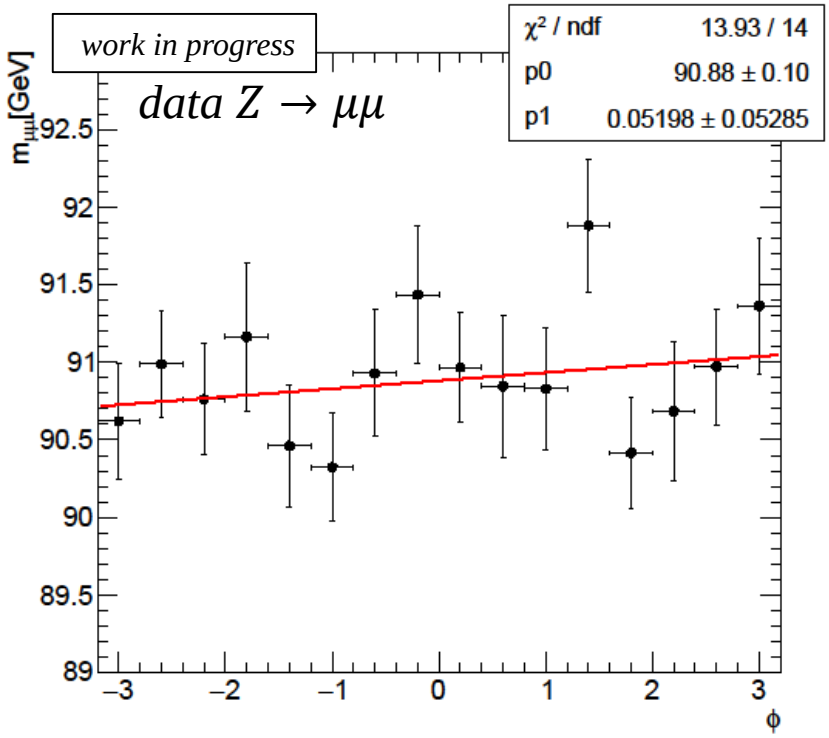
Before momentum correction



… and after correction



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Muon Momentum Corrections

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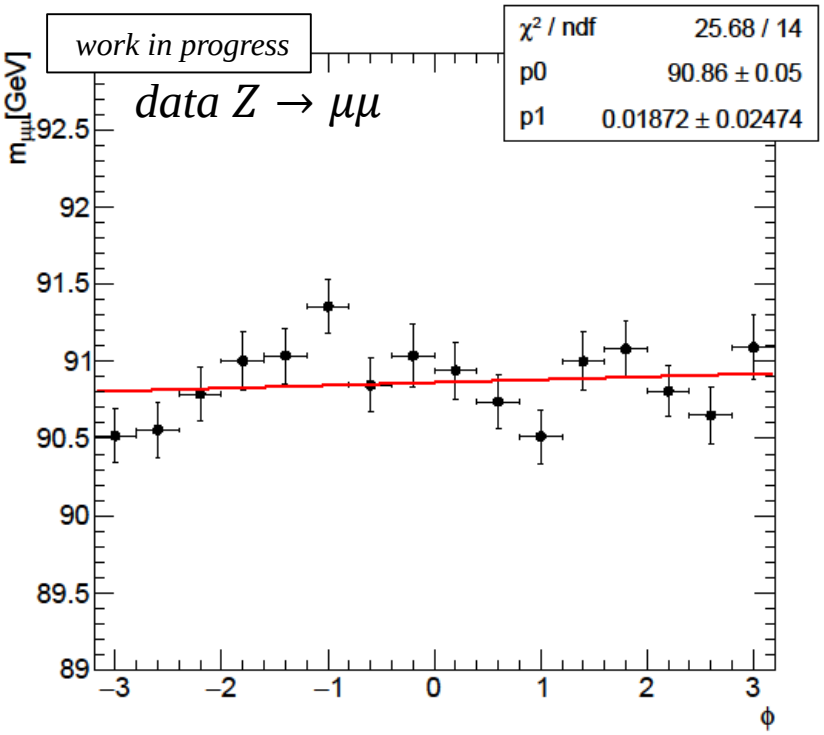
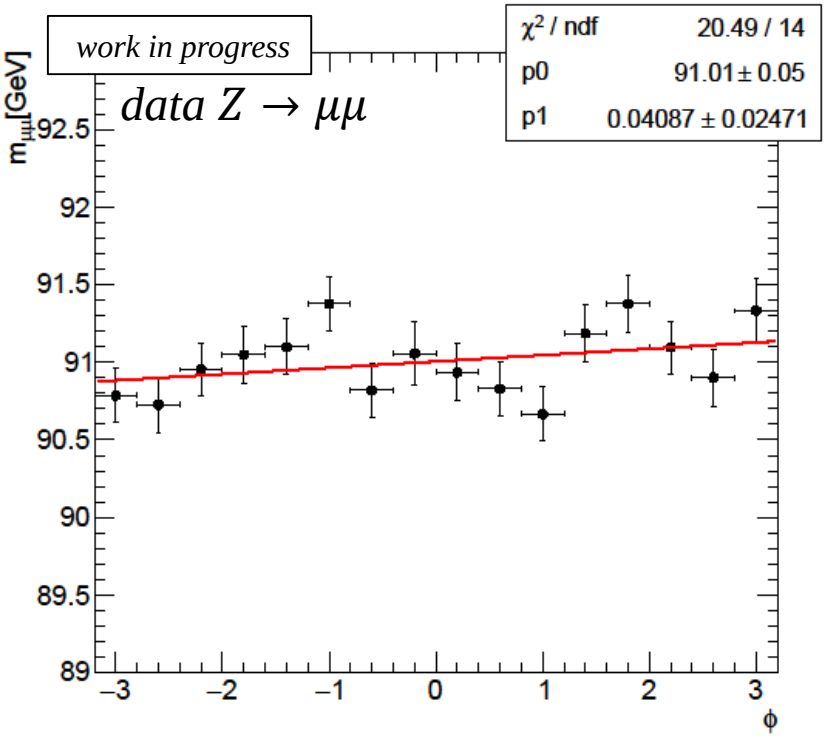
Before momentum correction



… and after correction



- Much smaller effect in the central region of the detector: $\mu^+: -\mathbf{0.7} < \boldsymbol{\eta} < \mathbf{0}$

Muon Momentum Corrections

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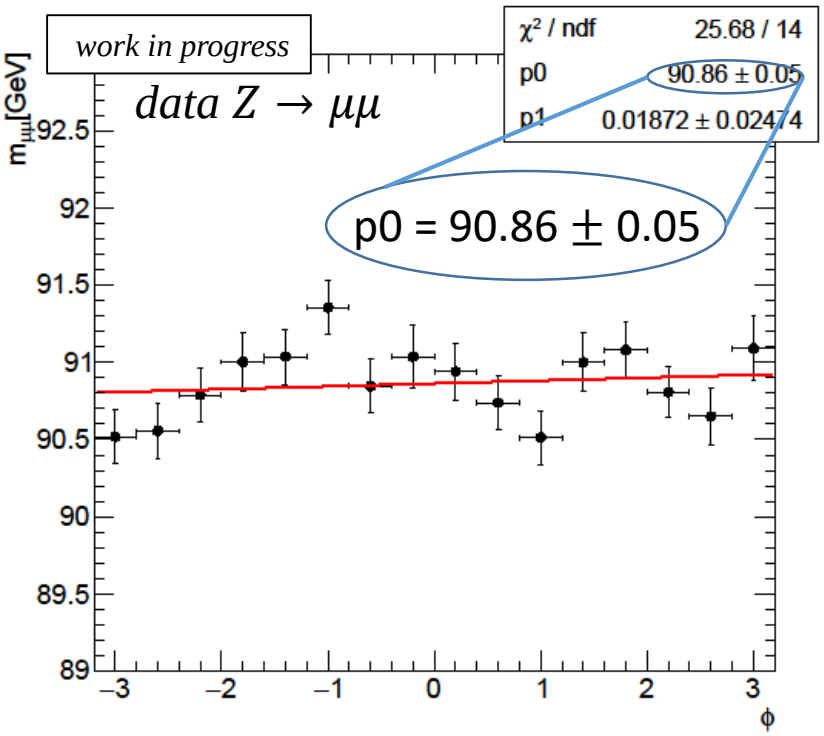
Before momentum correction



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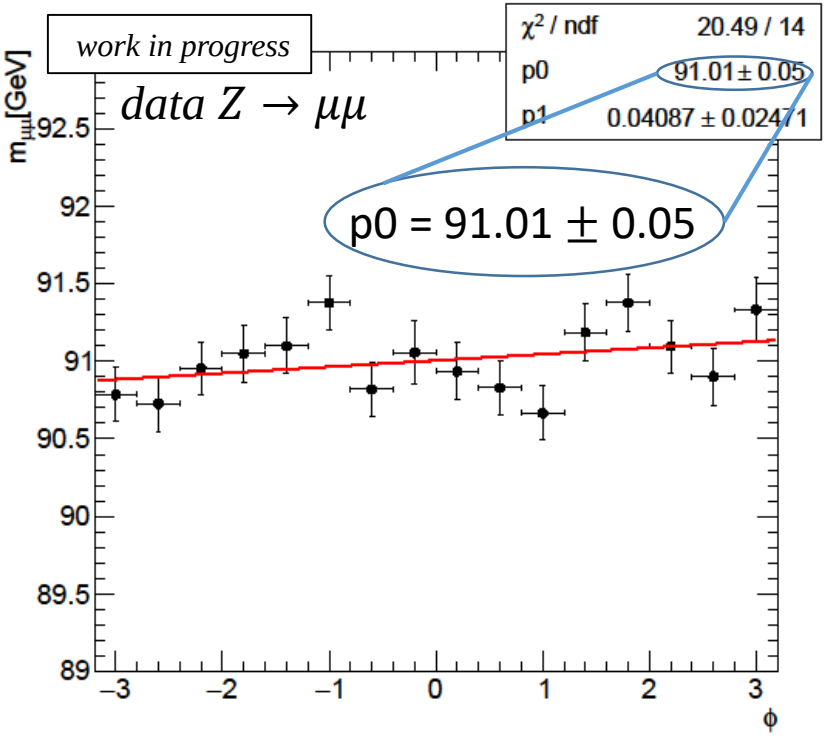

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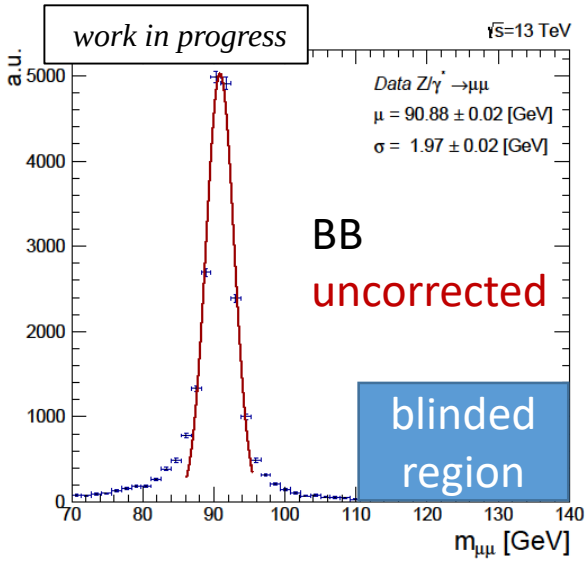
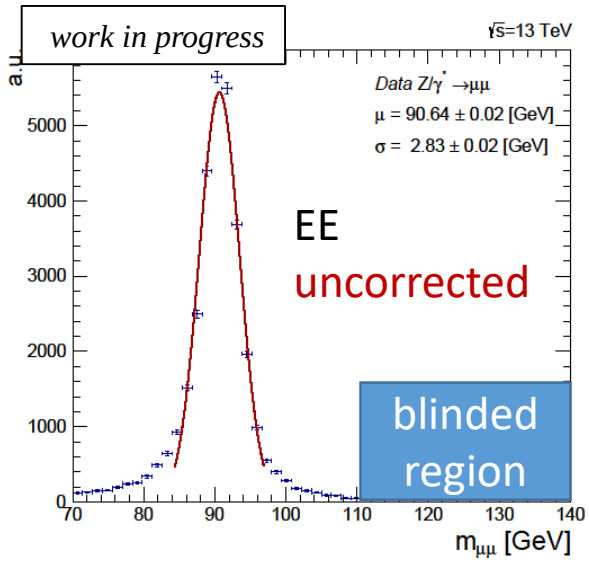
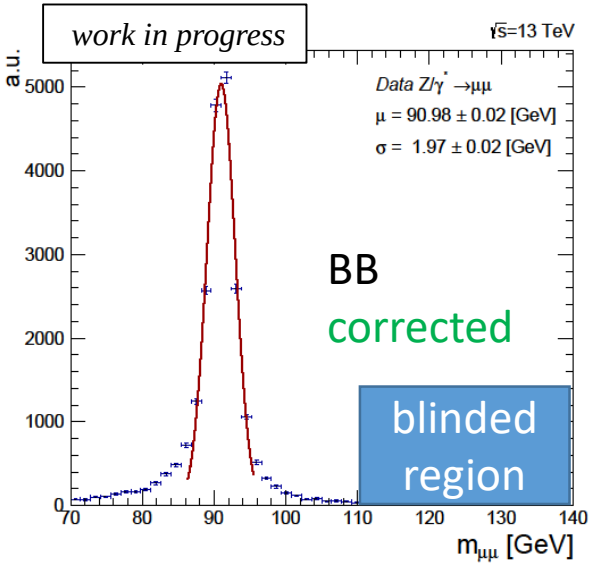
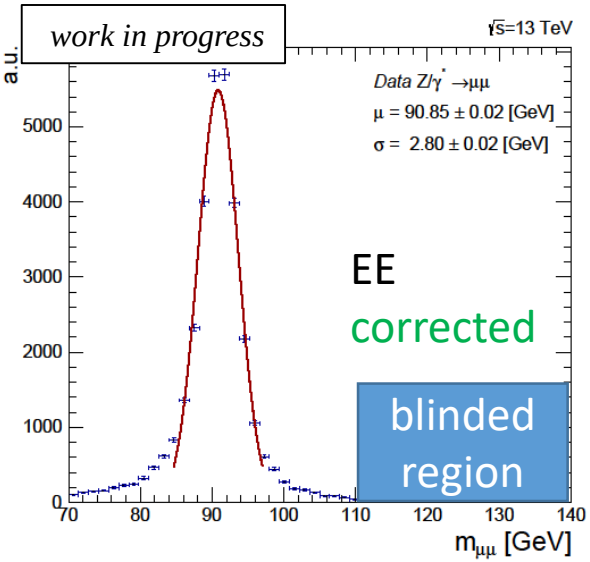
Muon Momentum Corrections









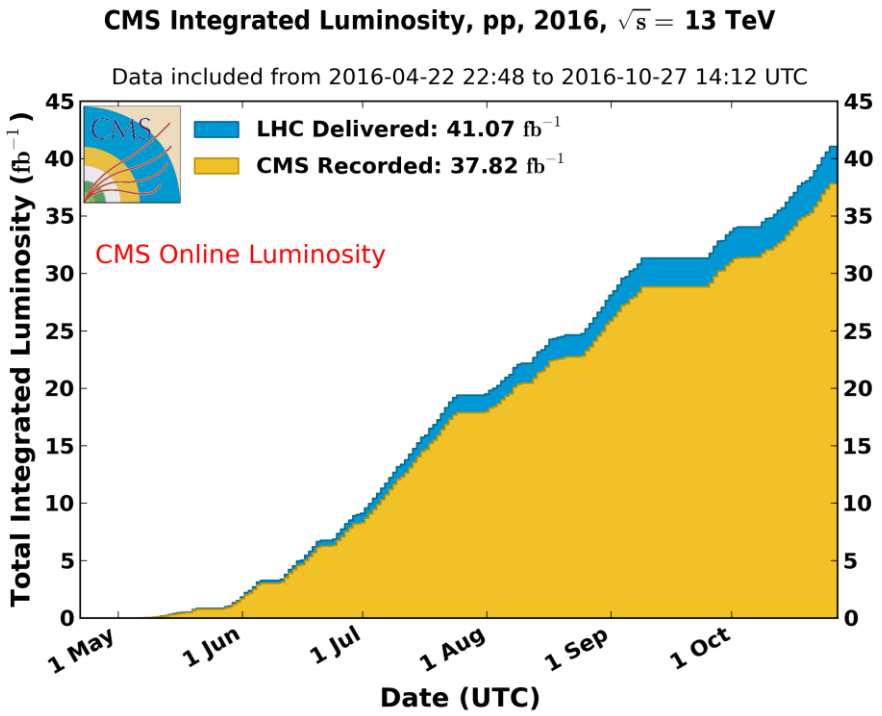
Estimation of scale and resolution by an iterative Gaussian fit

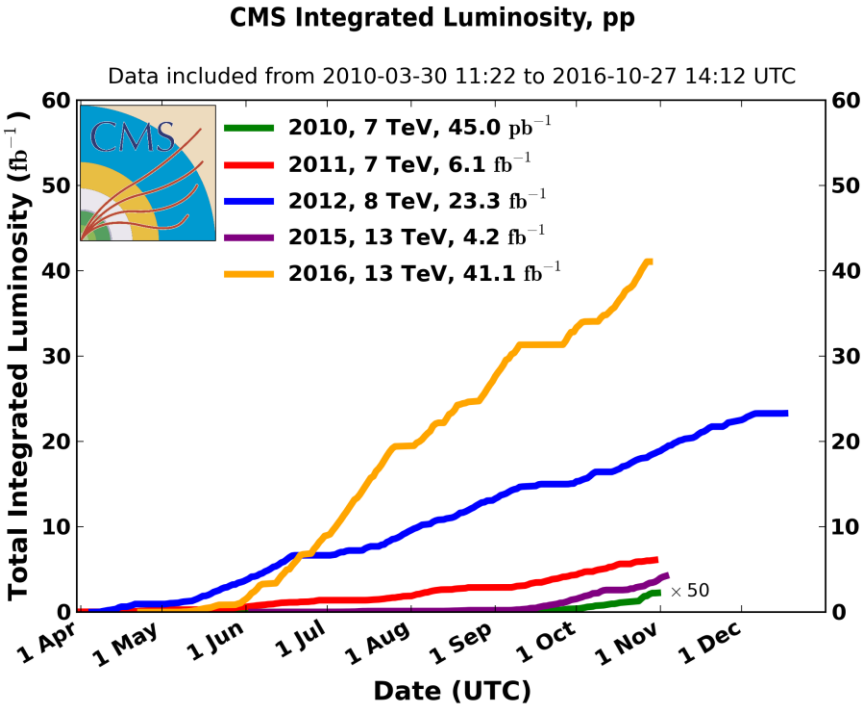
- **BB**: improvement of the Z mass scale
  $\mu(GeV)$: $90.88^{+0.02}_{-0.02}$ vs $90.98^{+0.02}_{-0.02}$
- **EE**: improvement of scale and resolution
  $\mu(GeV)$: $90.64^{+0.02}_{-0.02}$ vs $90.85^{+0.02}_{-0.02}$
  $\sigma(GeV)$: $2.83^{+0.02}_{-0.02}$ vs $2.80^{+0.02}_{-0.02}$

Outlook:

- Data/MC comparison
- MC studies $h \rightarrow \mu\mu$
  DY $\rightarrow \mu\mu$

A look into the future…





A look into the future…

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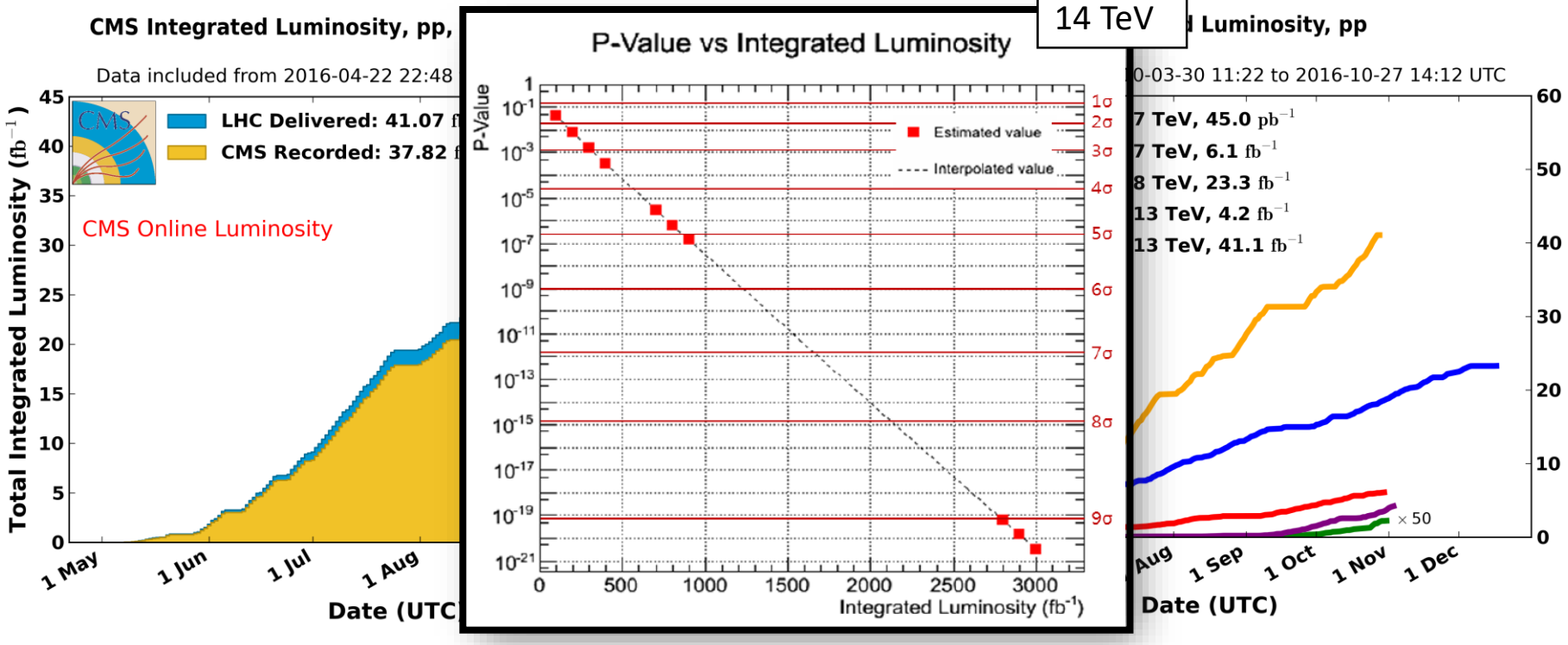
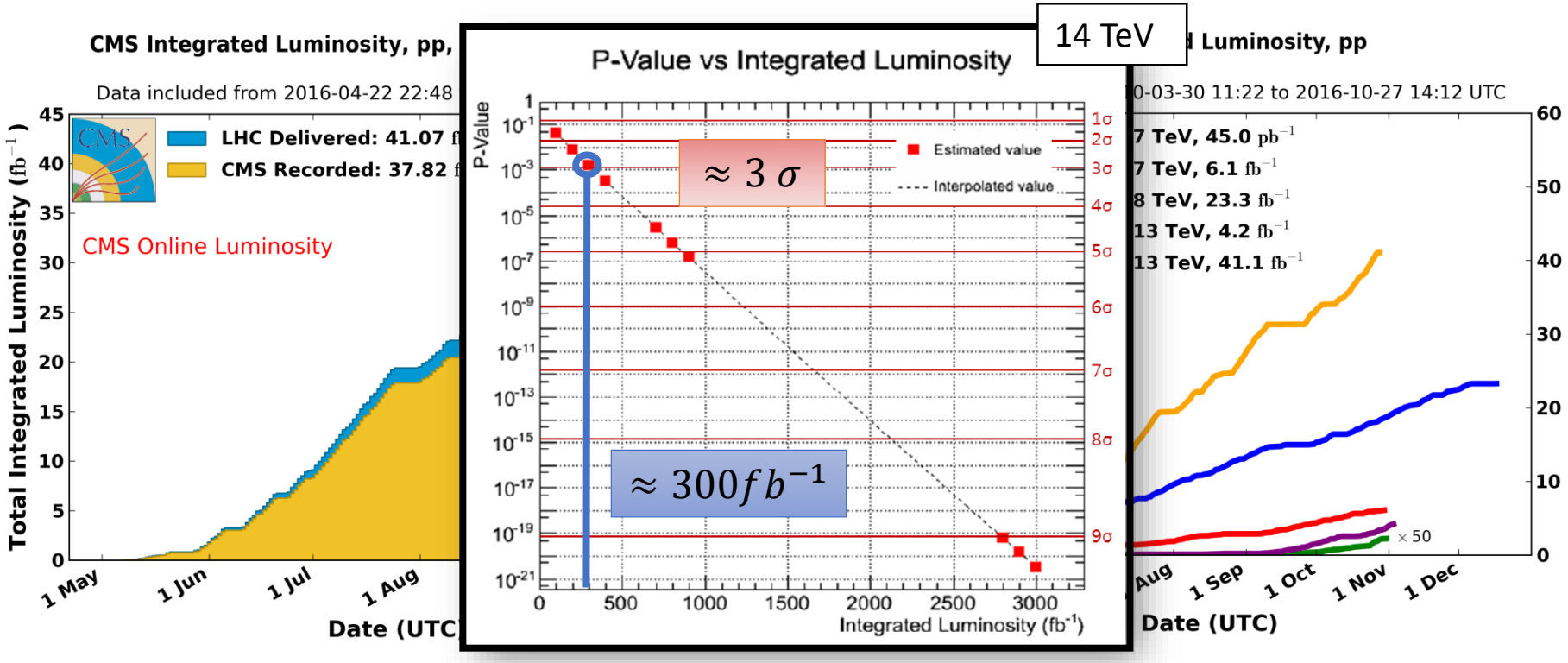


A look into the future…



- Evidence could become feasible after LHC run2

Conclusion

- Summary of the LHC *run1* analysis
  - 7,4 ($6{,}5^{+2{,}8}_{-1{,}9}$) observed (expected) 95% CL limit on $\frac{\sigma}{\sigma_{SM}}$
- $h \to \mu\mu$ evidence could become feasible ($L_{int} = 300\ \mathrm{fb}^{-1}$)
- Overview of challenges, plans and ideas for LHC *run2*
- First look into muon momentum corrections and their improvements on $Z \to \mu\mu$
- More to come for Moriond 2017