Relazione fine II anno: XXXI Ciclo

"Search for resonances in muons decay with CMS at LHC"

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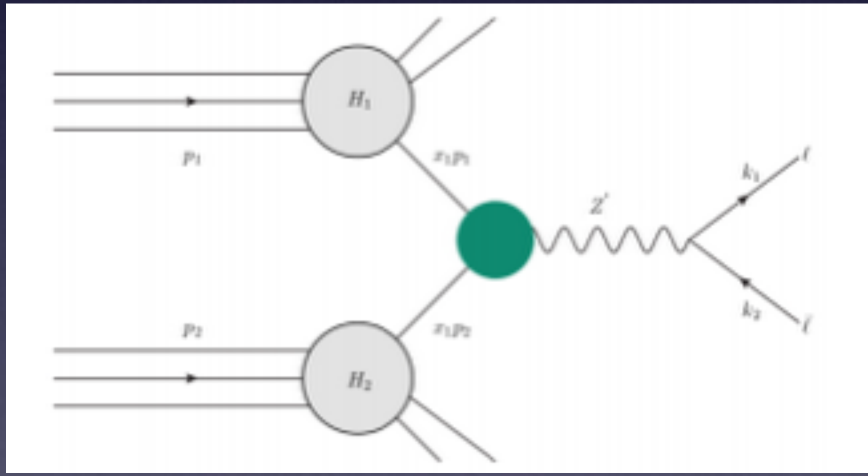
11/05/2017

Overview

- PhD project goal: search for resonances in dimuon channel:
  - ★ high mass resonances: Z’ and graviton
  - ★ medium mass resonance: Standard Model Higgs, 125 GeV
- School & conferences

Beyond Standard Model

- Many models developed beyond Standard Model:
  - ★ Supersymmetry (SUSY)
  - ★ Grand Unified Theory (GUT)
  - ★ Warped Extra Dimensions (WED)
- New bosons are introduced (mass > 1 TeV):
  - ★ Spin 1:
    - ✦ Z'_{SSM} with SM-like coupling
    - ✦ Z'_{ψ} GUT with E_6 group
  - ★ Spin 2:
    - ✦ Kaluza-Klein graviton



- **Updated analysis has been approved on the 2nd of November:**
  - **improved statistics (36.2 fb^{-1})**
  - **improved selection**

Muon selection

Resonance search in the dimuon channel: $\mu^+\mu^-$

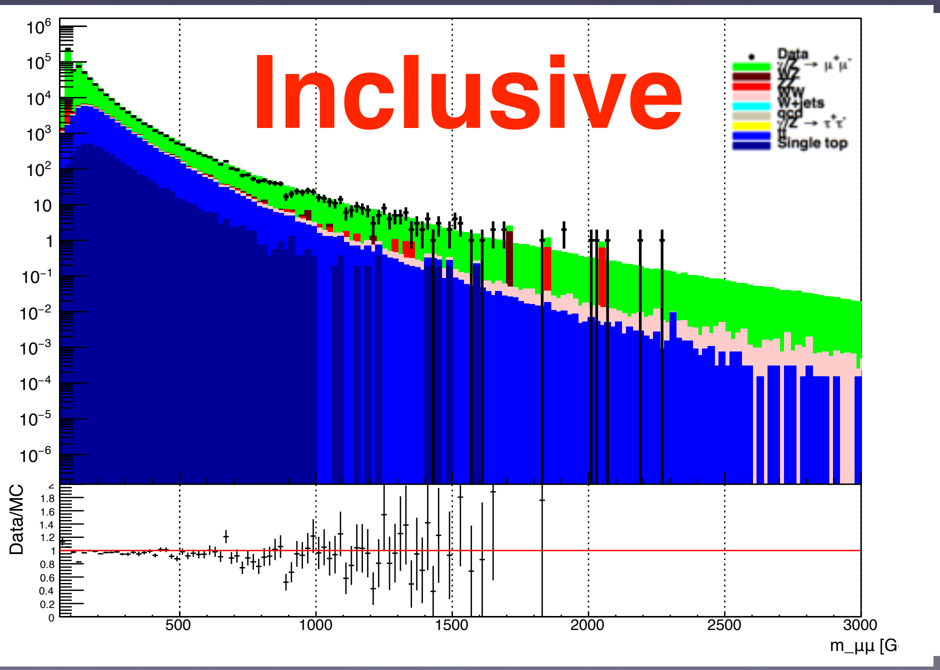
- Muon selection:
  - ★ At trigger level, muon candidates selected with traverse momentum (p_T) above 50 GeV
  - ★ Muons reconstructed associating tracks in the inner detector and in the muon system and considering a dedicated algorithm developed for high-p_T (~1 TeV) candidates.
  - ★ Offline reconstruction: $p_T > 53$ GeV and $|\eta| < 2.4$
  - ★ Dedicated high p_T muon selection and isolation.
- Dimuon selection:
  - ★ vertex constrain and comics rejection
  - ★ opposite charged
- Analysis split in two eta categories (improve sensitivity and isolate problems):
  - ★ Barrel - Barrel: both muons in the barrel (best mass resolution and momentum scale; small uncertainties)
  - ★ Barrel - Endcap & Endcap - Endcap (at least one muon in the endcap)

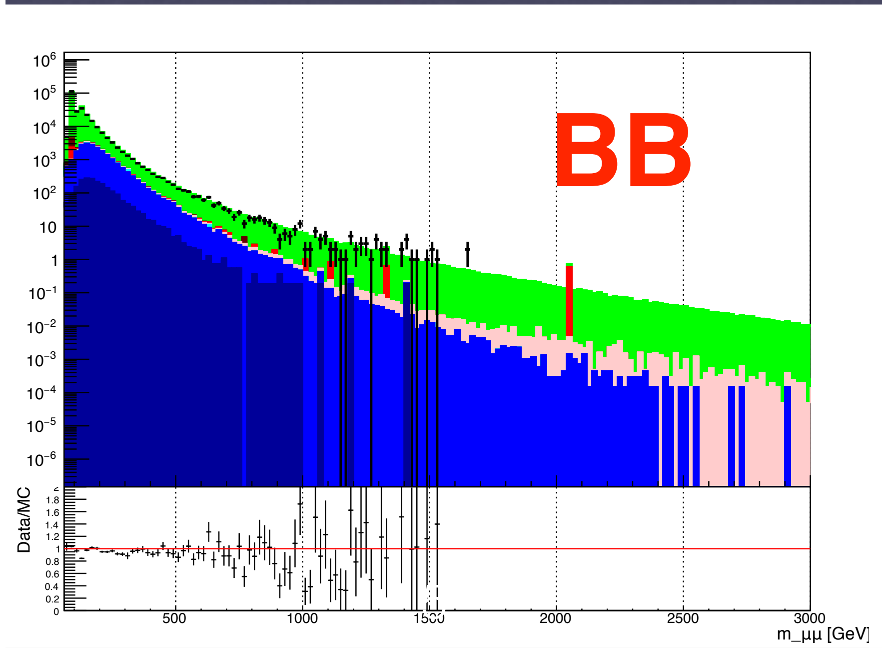
Background estimation

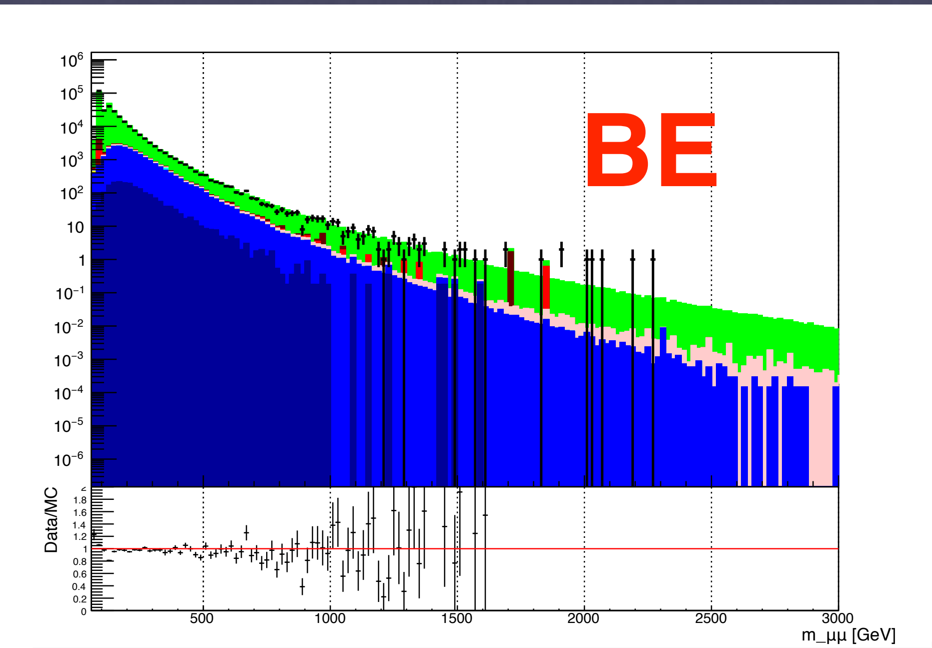
Accurate simulation and estimation of the background:

- Drell-Yan (DY) production (Z/γ^*) of $\mu^+\mu^-$ pairs: it is the dominant and irreducible SM background
- Top - antitop quark (ttbar), single top quark (tW), Drell-Yan $\tau^+\tau^-$ and diboson (WW, ZZ, WZ): two prompt leptons from different particles.

  These processes are estimated using Monte Carlo (MC) simulated events at the next-to-leading order (NLO) and corrected to the next-to-next-to-leading order (NNLO)
- W+jets, γ+jets and multijets: events in which at least one lepton candidate is a misidentified jet (small contribution); estimated from data.







Muon momentum scale

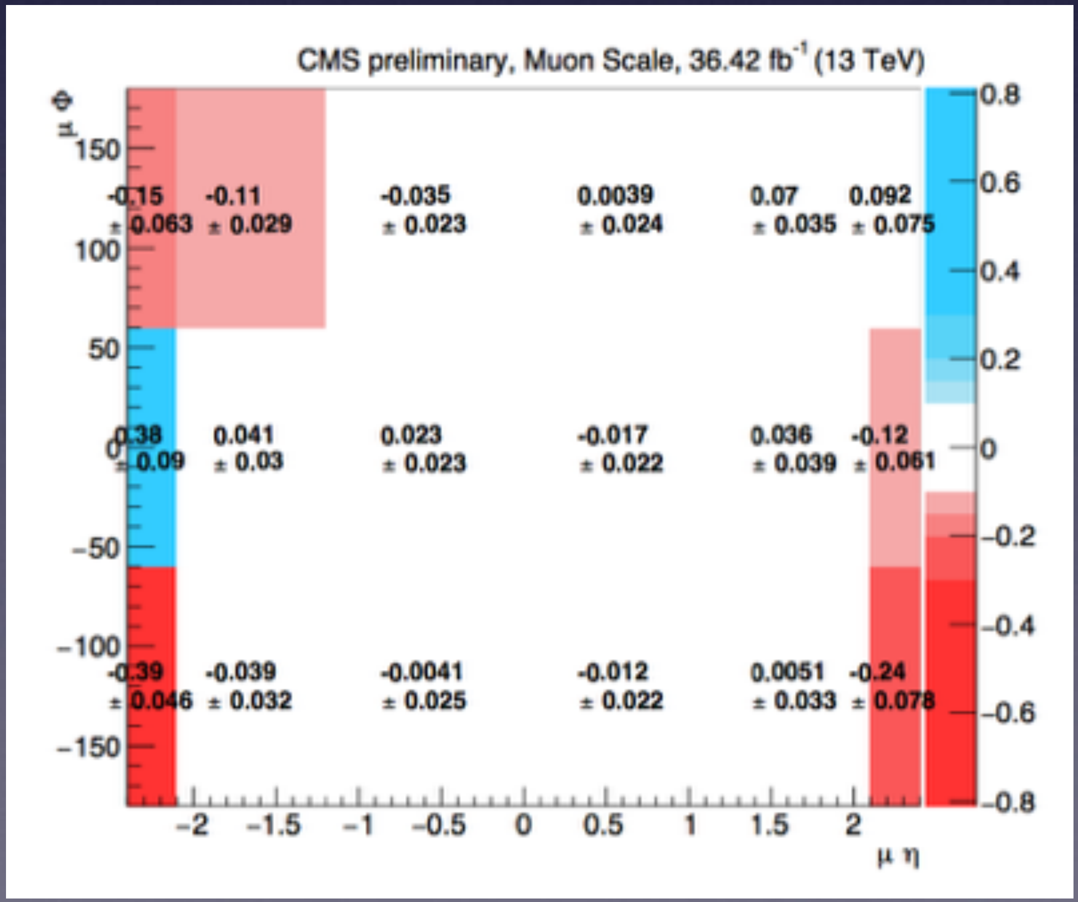
Muon momentum is sensitive to the detector alignment: large effect for high-p_T muons

Generalized end point method used to determine the momentum bias. Bias injected in simulated events in order to match the q/p_T distribution measured in data (as a function of η and ϕ).

Bias that minimize the differences in bins of η and ϕ *between simulation and data.*

$p_T > 200$ GeV for $|\eta| < 2.1$

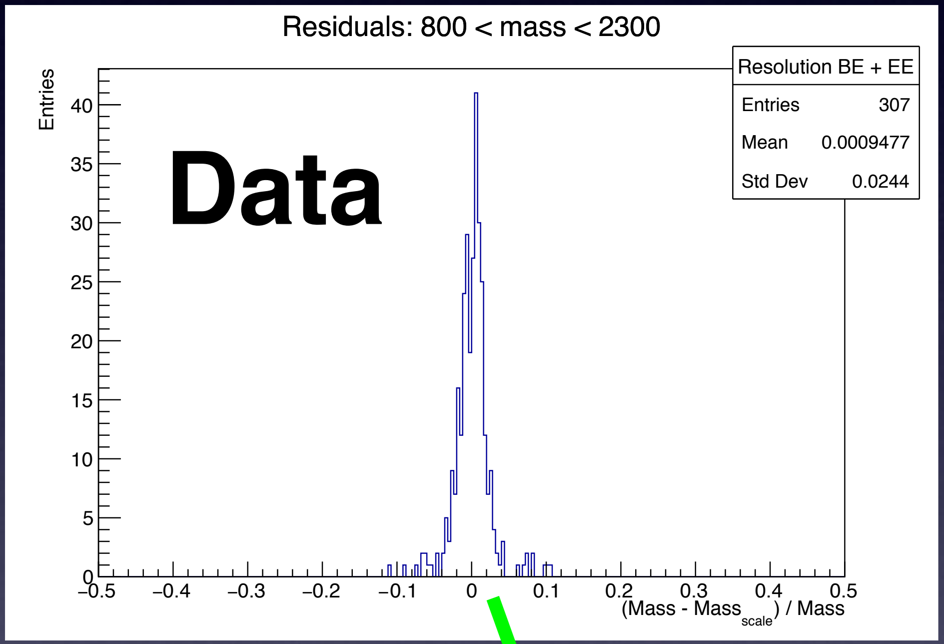
$p_T > 100$ GeV for $|\eta| > 2.1$

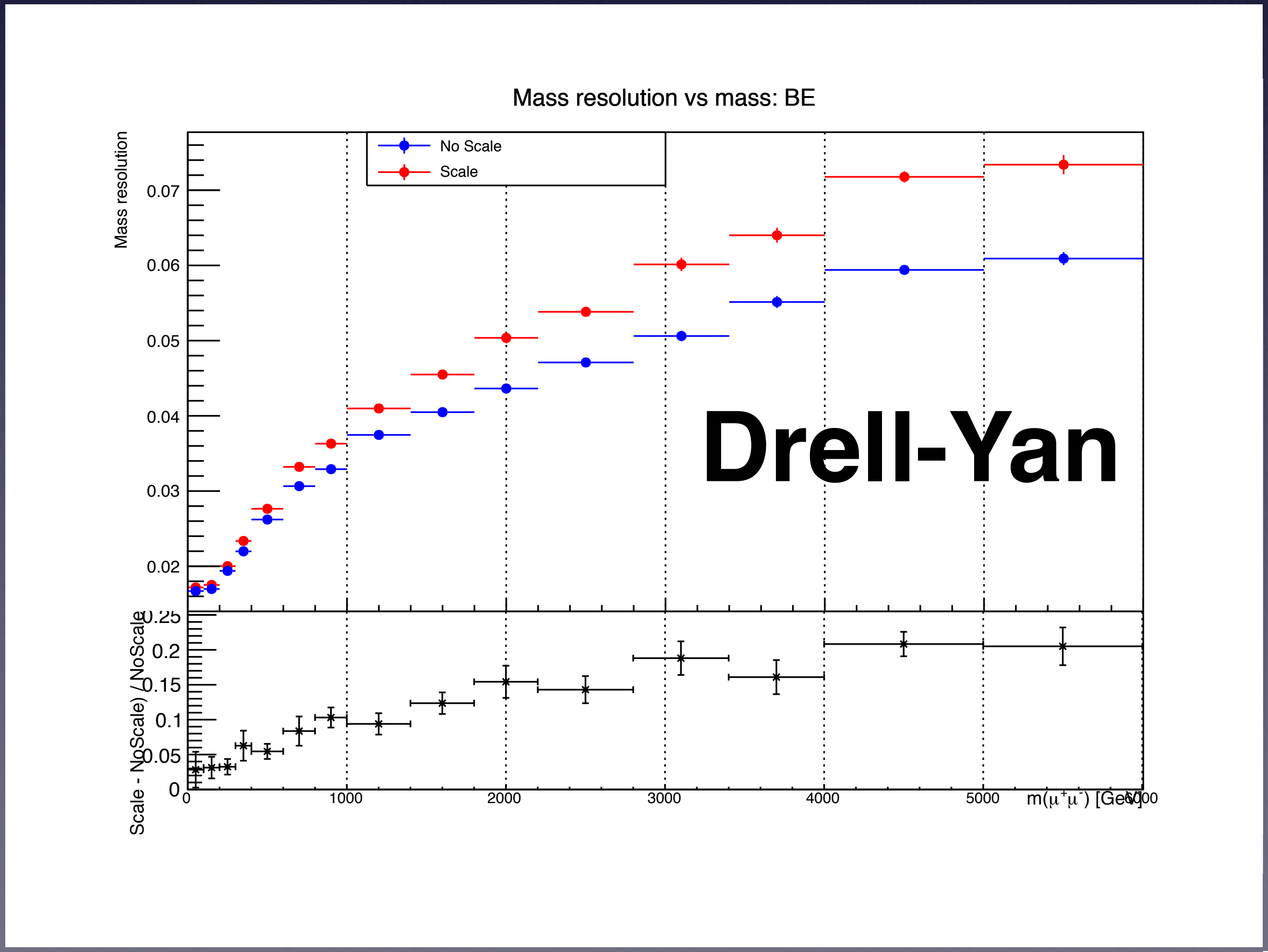


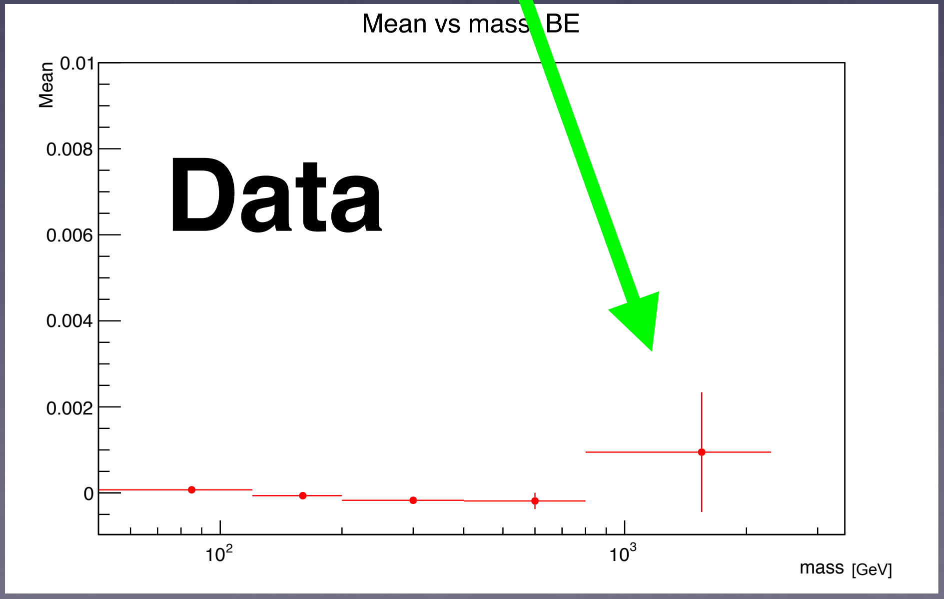
Muon momentum scale

To estimate the effect of the q/p_T bias to the dimuon mass:

- in simulation a bias is applied to each muon and shift is done according to a Gaussian
- in data a shift is applied to each muon



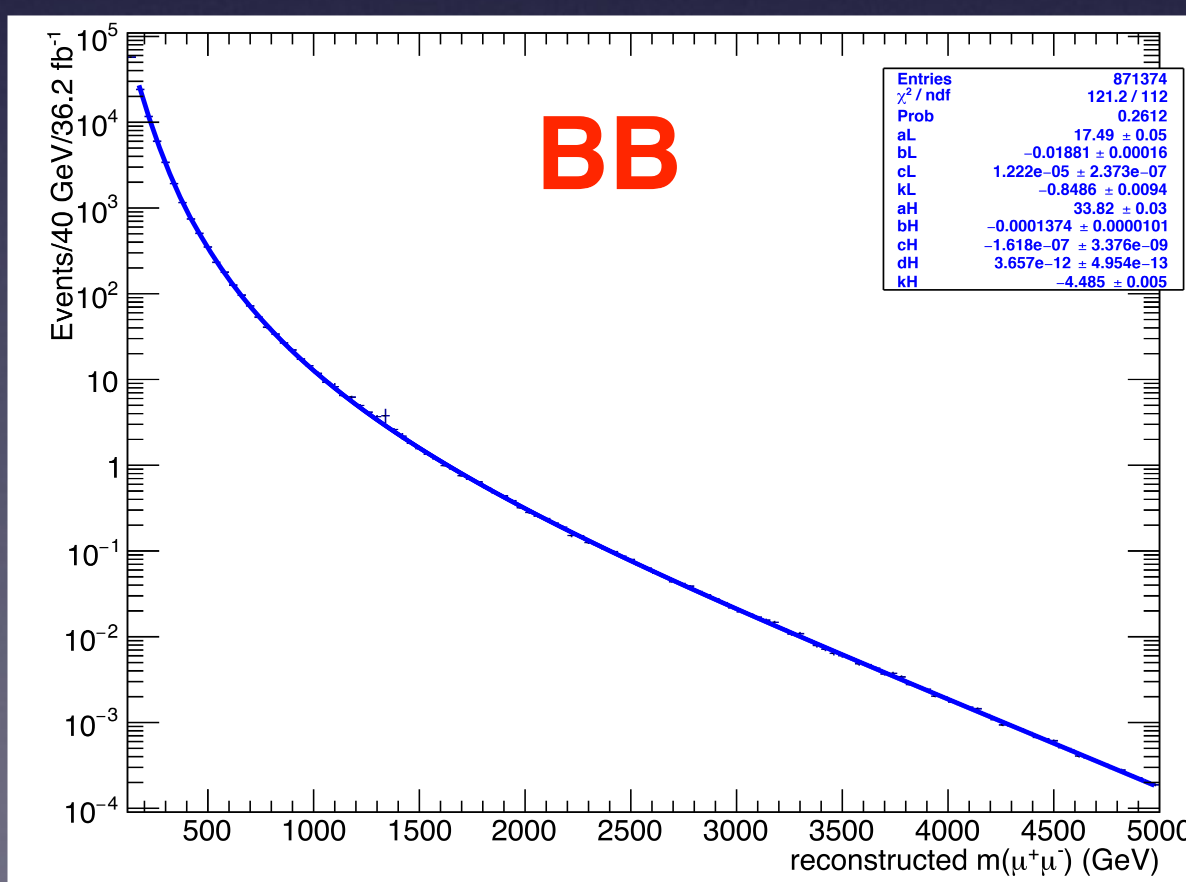


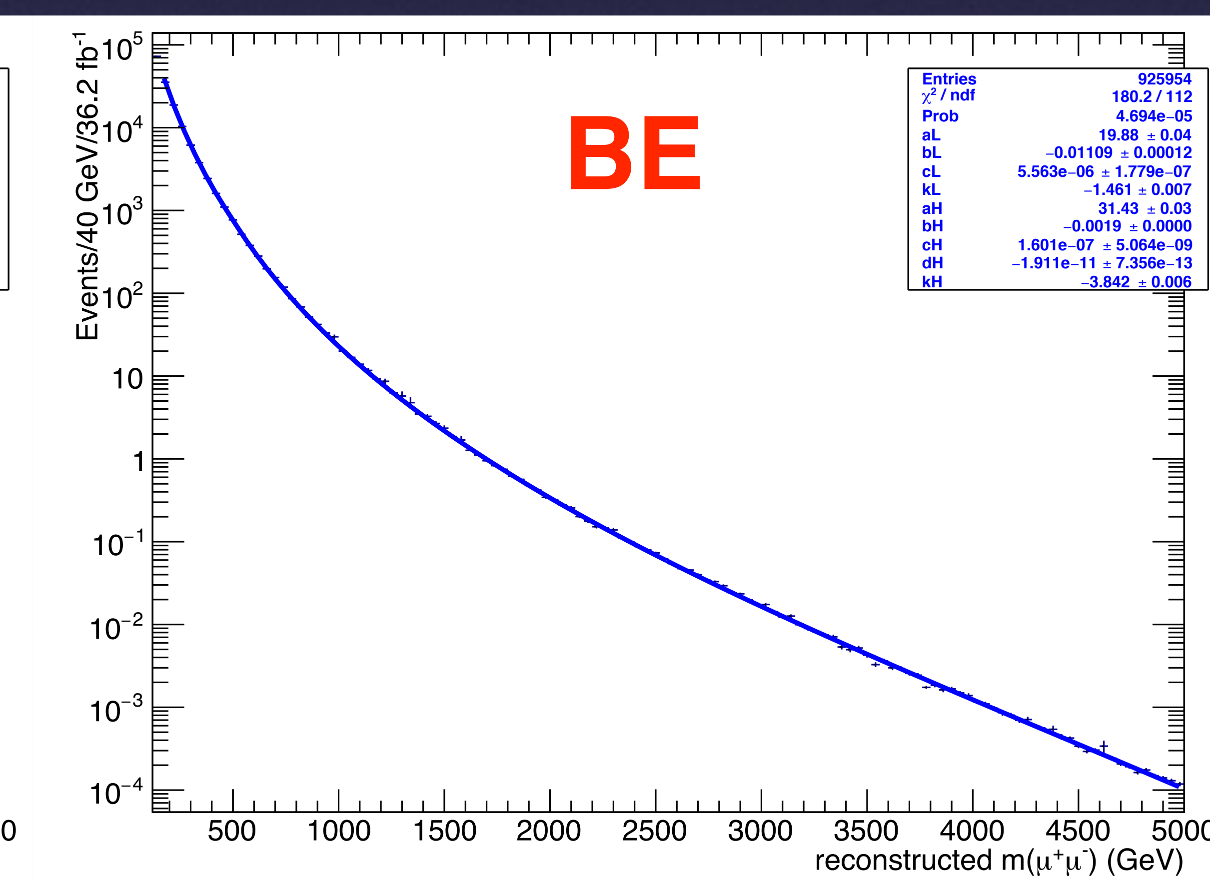


Dimuon mass distribution fit

- Fit the dimuon mass distribution in order to have probability density function for limit extrapolation.
- Fit in the mass range [150, 5000] GeV, split at 500 GeV

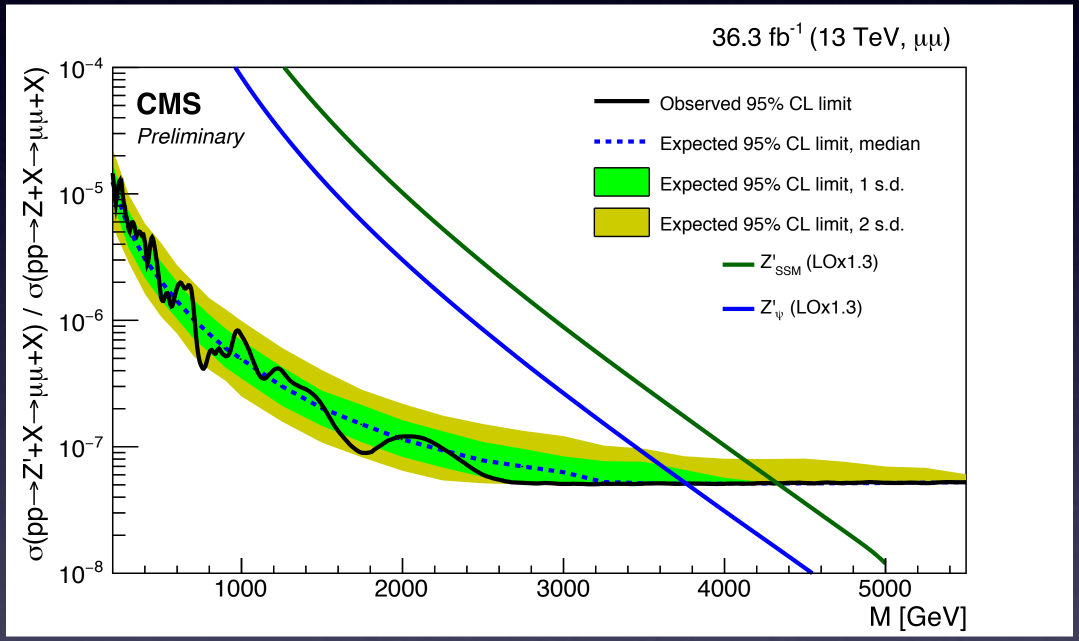
$$f_{bkg}(m|a_{L,H}, b_{L,H}, c_{L,H}, d, k_{L,H}) = \begin{cases} e^{a_L + b_L \times m + c_L \times m^2} \times m^{k_L}, & \text{if } m < 500 \text{ GeV} \\ e^{a_H + b_H \times m + c_H \times m^2 + d \times m^3} \times m^{k_H}, & \text{if } m > 500 \text{ GeV} \end{cases}$$

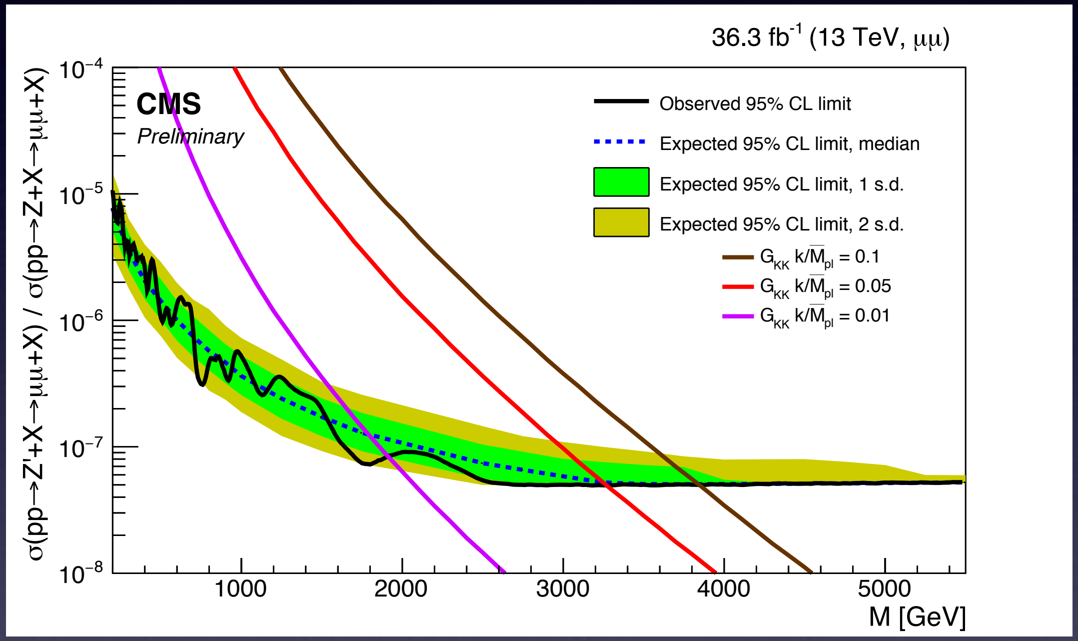




Limit

The limits are set on the parameter R_σ which is the ratio of the cross section for dilepton production through a Z' boson to the cross section for dilepton production through a Z boson.



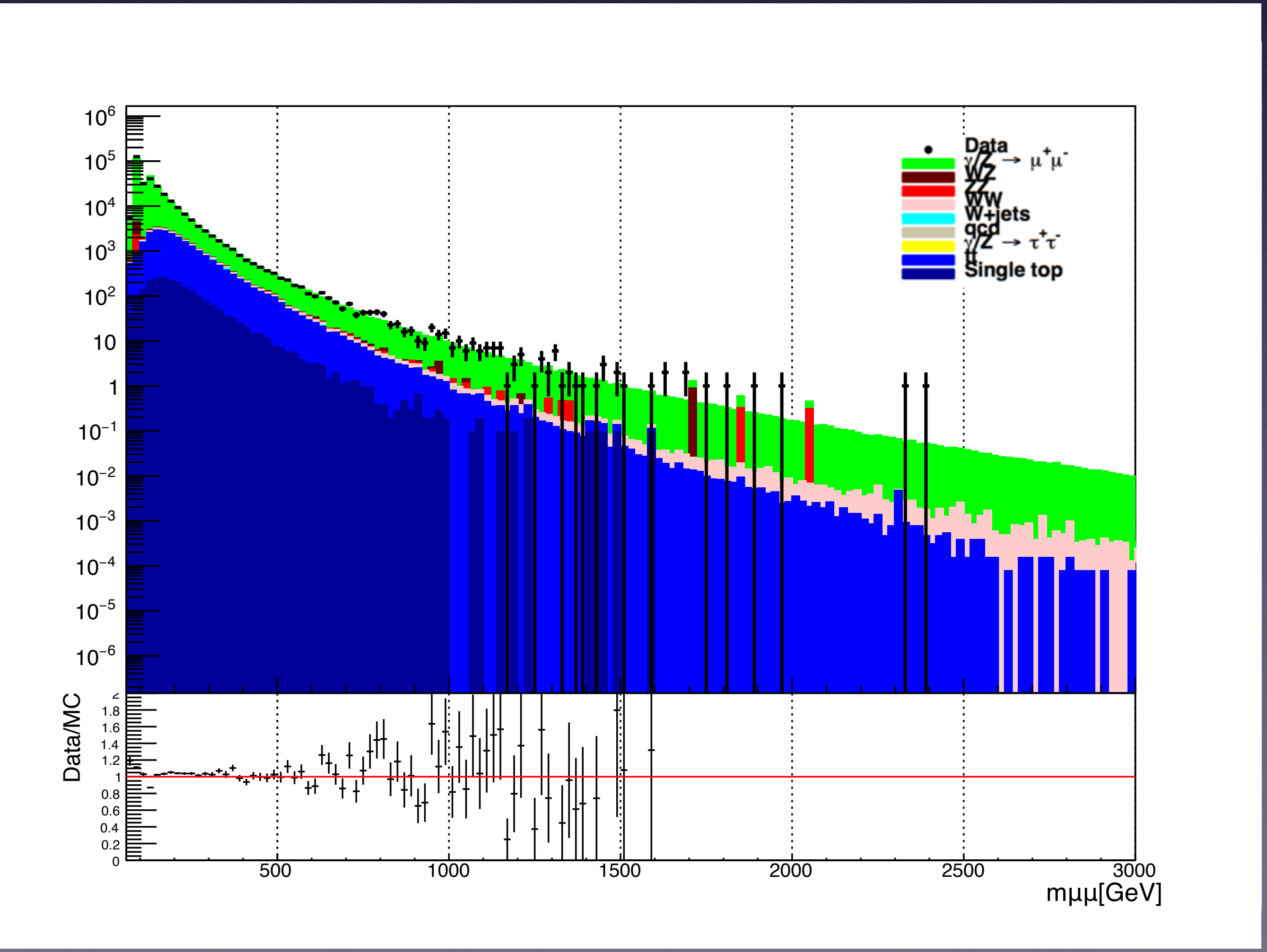


For the Z'_{SSM} particle and for the superstring inspired Z'_ψ particle, 95% confidence level lower mass limits are found to be 4.3 TeV (previous 4 TeV) and 3.75 TeV (3.5 TeV). The corresponding limits for Kaluza-Klein gravitons (G_{KK}) arising in the Randall - Sundrum model of extra dimensions depends on k/M_{Pl} and ranges from 1.9 TeV to 3.85 TeV.

Within Dark Matter searches, the existence of a mediator produced from proton collision decaying into leptons has been also tested for the first time.

First look at 2017 Data

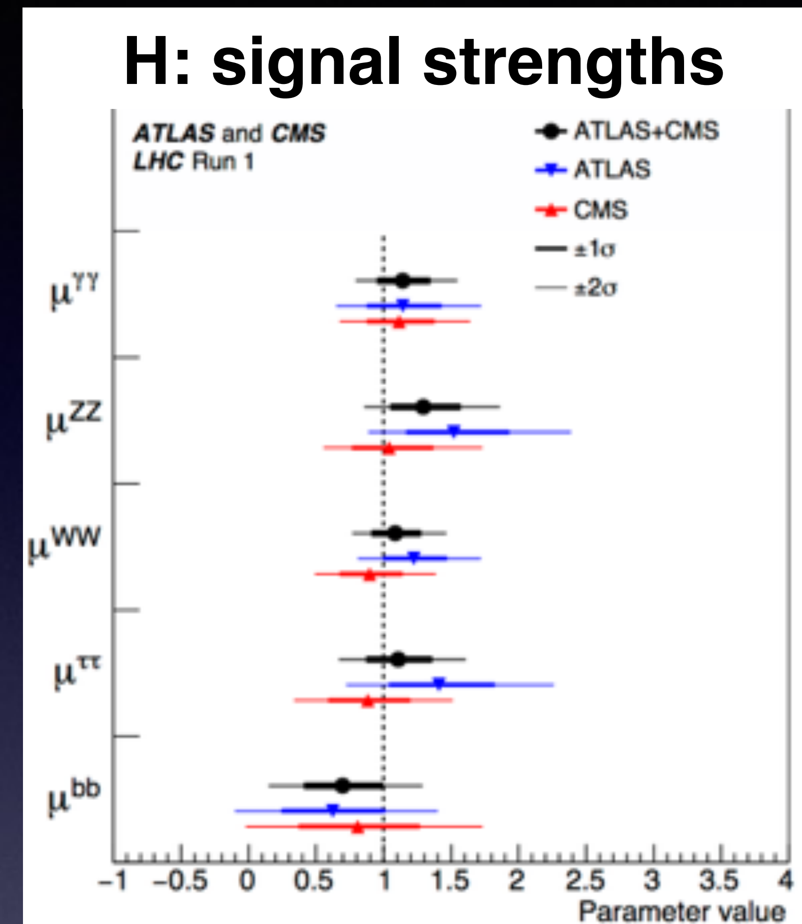
- 2016 MC Samples (2017 not yet available)
- 2017 Data: /SingleMuon/Run2017(B/C/D)-PromptReco-(v1/v2/v3)/MINIAOD
- JSON File
  - ★ Cert_294927-303825_13TeV_PromptReco_Collisions17_JSON_MuonPhys.txt
  - ★ 18.701 fb^{-1}

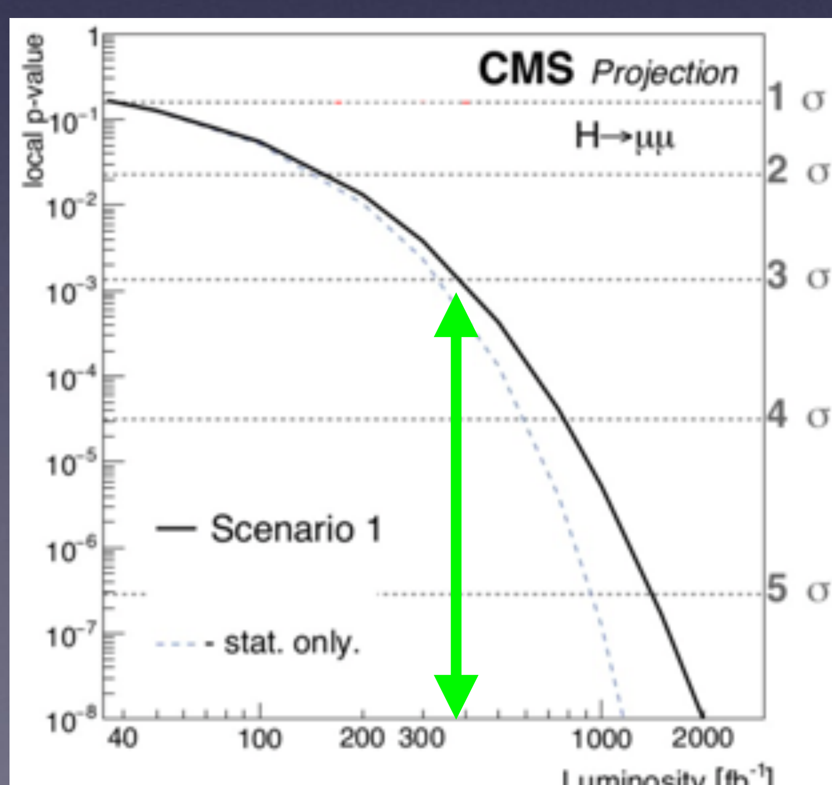


H—>μμ search

Standard Model Higgs search: H—>μμ

- It is a probe for:
  - ★ constraints on the proportionality of the couplings to fermions of different generations and of leptons with different masses
  - ★ lepton flavor-violating





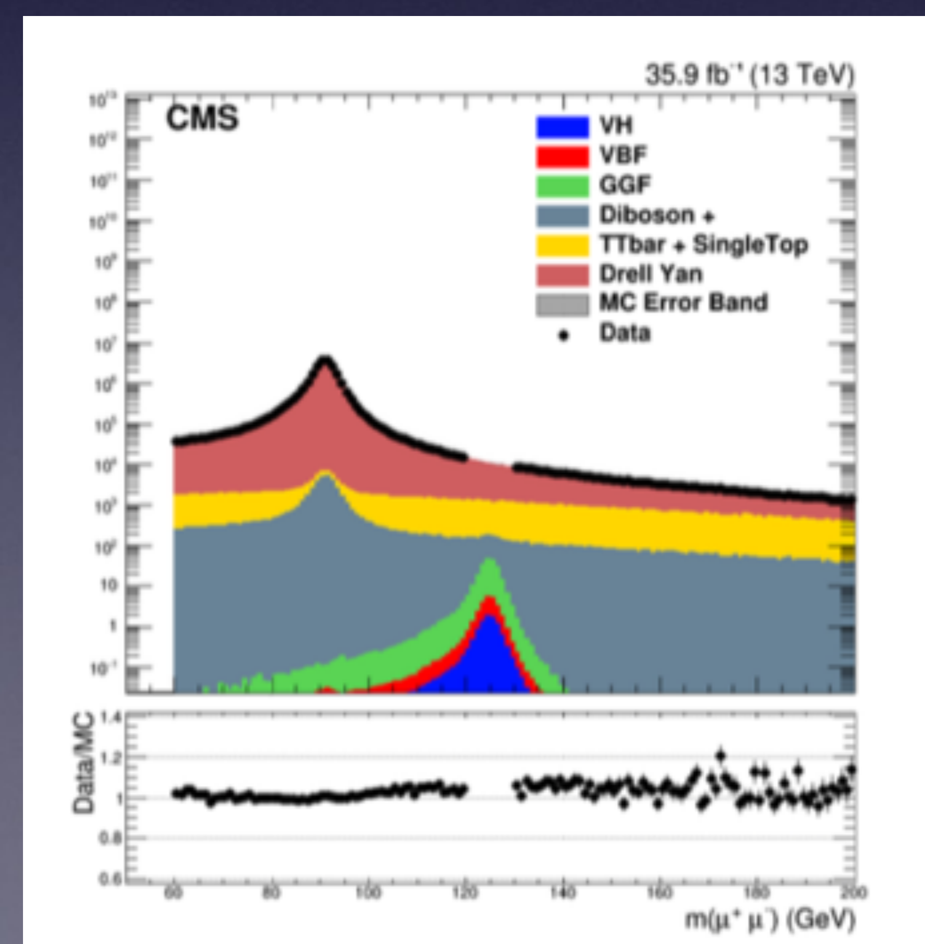
Decay channel	Branching ratio	Rel. uncertainty
$H \to \gamma\gamma$	2.27×10^{-3}	$^{+5.0\%}_{-4.9\%}$
$H \to ZZ$	2.62×10^{-2}	$^{+4.3\%}_{-4.1\%}$
$H \to W^+W^-$	2.14×10^{-1}	$^{+4.3\%}_{-4.2\%}$
$H \to \tau^+\tau^-$	6.27×10^{-2}	$^{+5.7\%}_{-5.7\%}$
$H \to b\bar{b}$	5.84×10^{-1}	$^{+3.2\%}_{-3.3\%}$
$H \to Z\gamma$	1.53×10^{-3}	$^{+9.0\%}_{-8.9\%}$
$H \to \mu^+\mu^-$	2.18×10^{-4}	$^{+6.0\%}_{-5.9\%}$

H—>μμ search

Cut based analysis in VBF and ggH channel:

- Muon selection:
  - ★ At trigger level, muon candidates selected p_T above 24 GeV
  - ★ Offline reconstruction: $p_T > 30$ GeV and $|\eta| < 2.4$
- Main backgrounds:
  - ★ Drell-Yan in μμ
  - ★ leptonic ttbar decay
- Recent results:

  $\mu_{OBS} = \sigma/\sigma_{SM} = 0.9 \pm 0.9$



VBF H—>μμ: new strategy

Innovative idea: use MVA distribution to improve limits

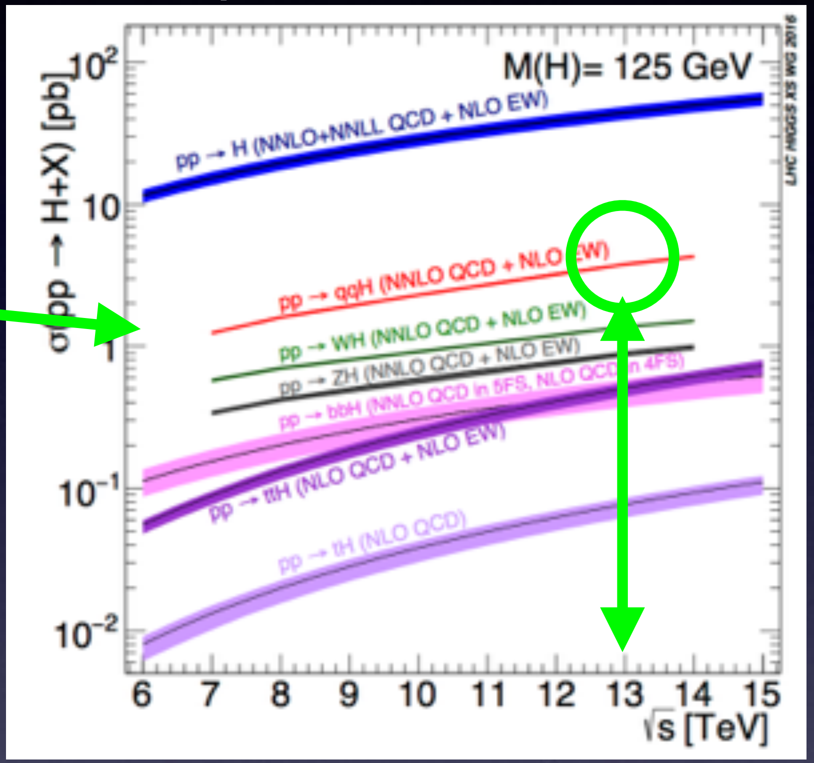
Looking at **only VBF** channel

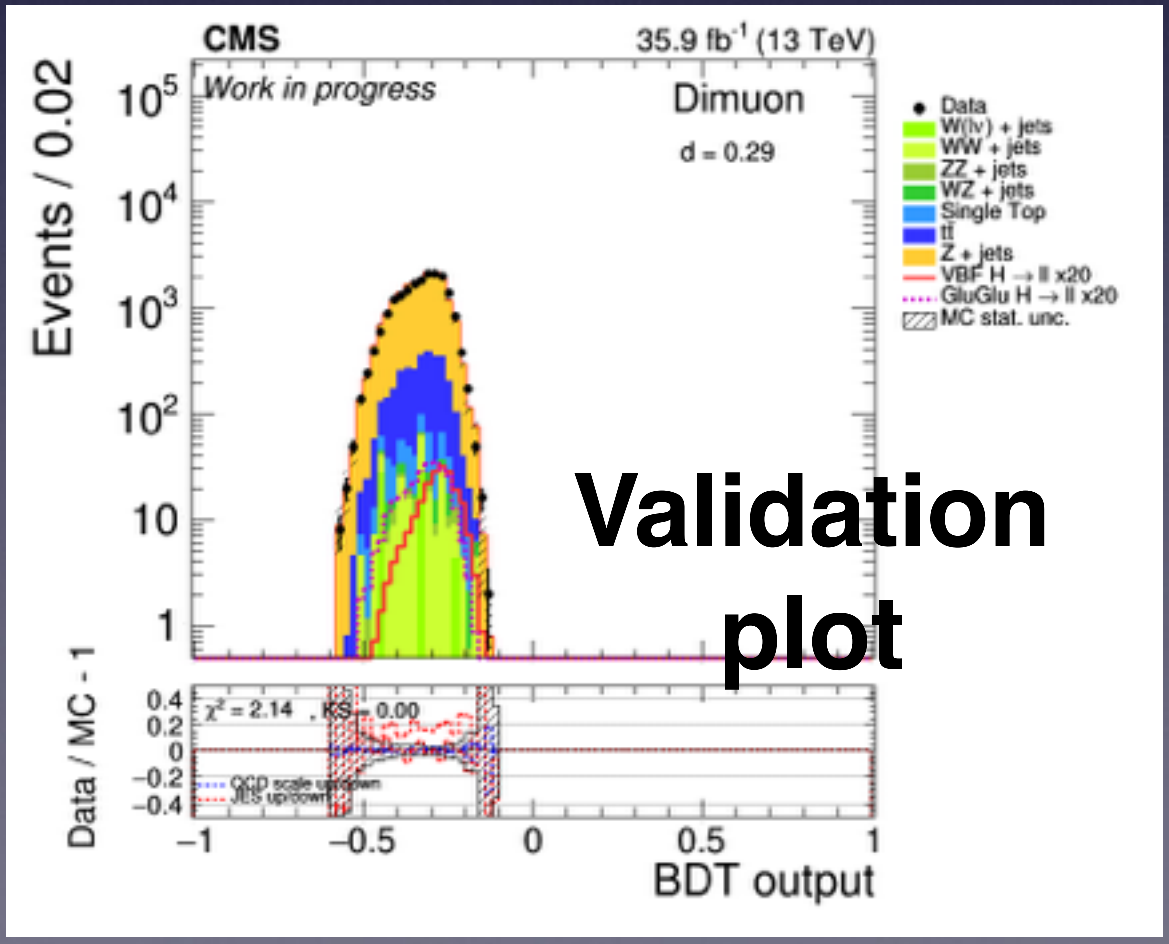
$\sigma_{VBF—>H}$ = 3.78 pb at 13 TeV

BR = 2.2 x 10^{-4}

2016 Data = 35.9 fb^{-1}

30 events expected





Future plans

- Analysis of 2017 data for high massive resonances search
- Analysis of 2016 and 2017 data for Standard Model Higgs search

School & Conferences

- **I won a position as CoAs starting from July (SimilFellow) for one year at CERN**
- **School**:
  - ★ CMSPhysics Object School, 4 - 8 September, Bari. (**as facilitator**) https://indico.cern.ch/event/615859/
  - ★ INFN School of Statistics 2017; 7 -11 May, Ischia. https://agenda.infn.it/conferenceDisplay.py?confId=12288
- **Conferences:**
  - ★ EPS-HEP2017: EPS Conference on High Energy Physics, 5-12 Jul 2017, Venice (Italy) http://eps-hep2017.eu
  - ★ IFAE2017: XVI Incontri di fisica delle alte energie, 19-21 Apr 2017, Trieste (Italy) https://agenda.infn.it/conferenceDisplay.py?confId=12289
  - ★ Posters@LHCC: Students' Poster Session at the 2017 Winter LHCC meeting, 22 Feb 2017, CERN, Geneva (Switzerland) https://indico.cern.ch/event/608530/

Thank you for your kind attention

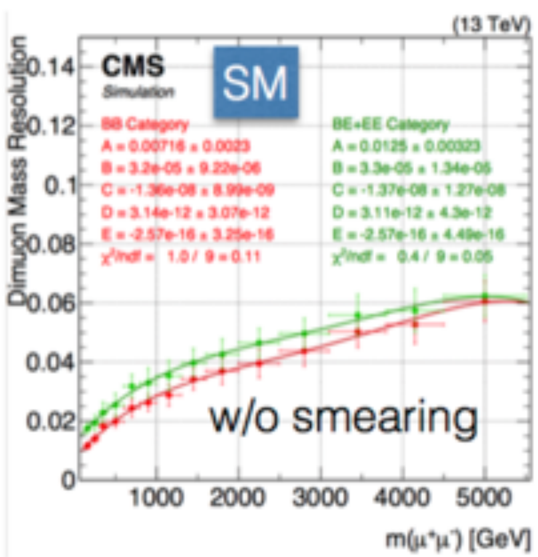
Backup

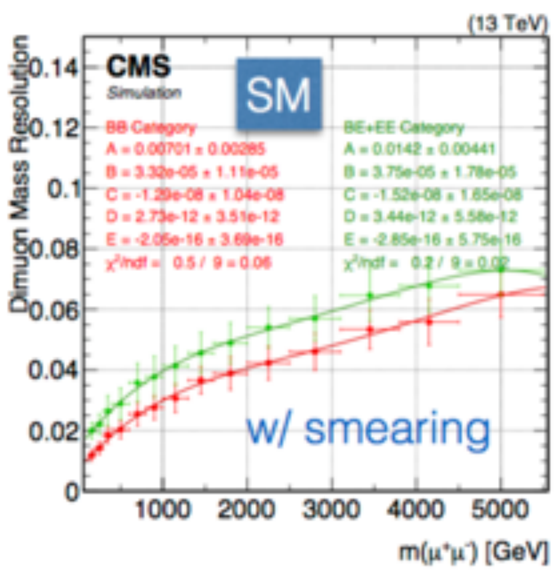
Systematic uncertainties

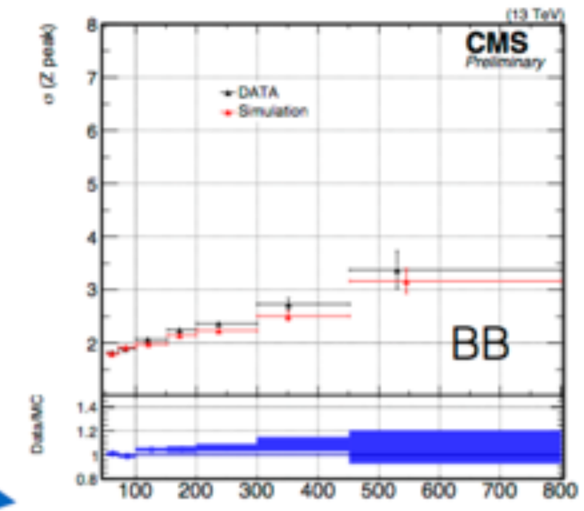
Source	Uncertainty (BB)	Uncertainty (non-BB)	Affects
Momentum Resolution	15%		Sig
Momentum Scale	1%	3%	Sig
Selection and Reconstruction	-1.5% (at 4 TeV)	-6.5% (at 4 TeV)	Sig+Bk
Trigger	0.3%	0.7%	Sig+Bk
Scale and Resolution (bkg shape)	8% (at 3 TeV)		Bkg
Non-DY Background	7%		Bkg
DY PDF (From AN-16-053)	6% (at 4 TeV)		Bkg
Jets	50%		Bkg
Z Normalisation	1%		Bkg

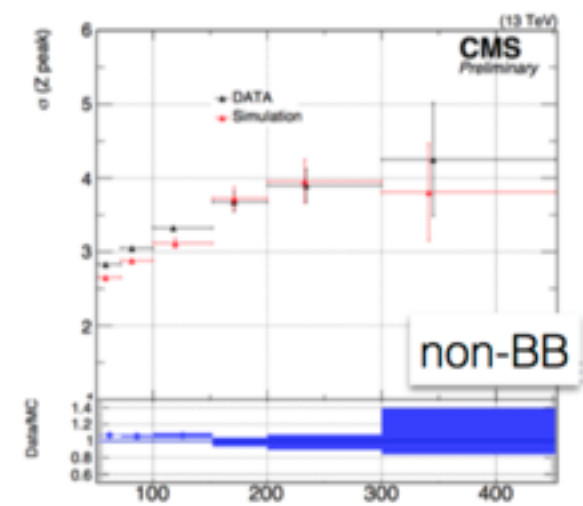
Momentum resolution

- The convolution of a BW+Cruijff function models the signal shape+experimental resolution
- Calculated as the residual of the mass at various mass points in DY MC
- The resolution in MC is smeared to match the resolution of boosted DY events measured in data
  - 10% barrel; 20% endcap









- A systematic uncertainty is calculated to be 15% by comparing the fit of the residual to that from a Crystal-Ball function

Analysis strategy

- We perform the statistical analysis on the ratio of the cross-sections:

Our signal yield depends on the detector resolution, estimated in MC and verified in data along with a sys. uncertainty; and the momentum scale which is estimated through injecting bias into MC to match data, along with a sys. uncertainty

$$R_\sigma = \frac{\sigma(\mathrm{pp} \to \mathrm{Z}' + \mathrm{X} \to \mu^+\mu^- + \mathrm{X})}{\sigma(\mathrm{pp} \to \mathrm{Z} + \mathrm{X} \to \mu^+\mu^- + \mathrm{X})} = \frac{N(\mathrm{Z}' \to \mu^+\mu^-)}{N(\mathrm{Z} \to \mu^+\mu^-)} \times \frac{A(\mathrm{Z} \to \mu^+\mu^-)}{A(\mathrm{Z}' \to \mu^+\mu^-)} \times \frac{\varepsilon(\mathrm{Z} \to \mu^+\mu^-)}{\varepsilon(\mathrm{Z}' \to \mu^+\mu^-)}$$

To increase the yield of Z bosons we use a prescaled trigger which has the same performance as our signal trigger in the plateau

The efficiency between the control region and signal region varies; we estimate the trigger, reconstruction and selection efficiency in the signal region along with a systematic uncertainty using TnP without mass restrictions

Limits

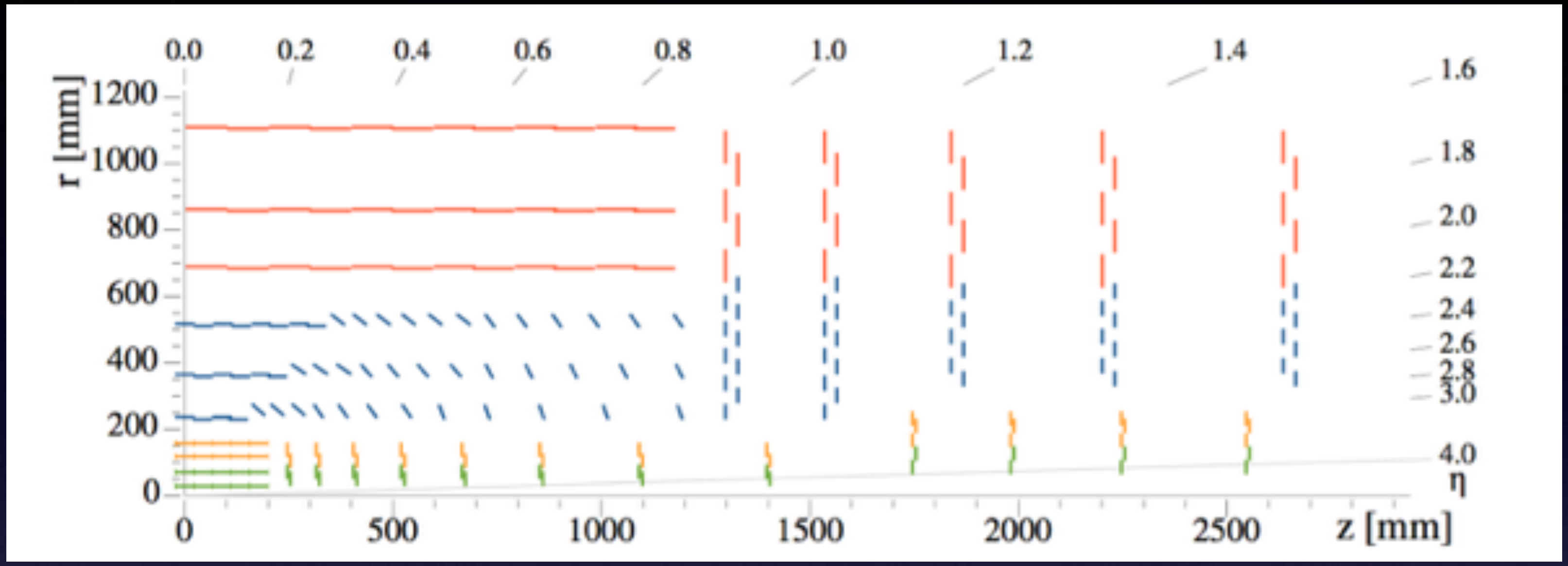
$$\mathcal{L}(\mathbf{m}|\boldsymbol{\theta},\boldsymbol{\nu}) = \frac{\mu^N e^{-\mu}}{N!} \cdot \prod_{i=1}^{N} \left(\frac{\mu_{sig}(\boldsymbol{\theta},\boldsymbol{\nu})}{\mu} f_{sig}(m_i|\boldsymbol{\theta},\boldsymbol{\nu}) + \frac{\mu_{bkg}(\boldsymbol{\theta},\boldsymbol{\nu})}{\mu} f_{bkg}(m_i|\boldsymbol{\theta},\boldsymbol{\nu}) \right)$$

The Poisson mean of the signal yield is $\mu_S = R_\sigma \, \mu_Z \, R_\varepsilon$, where:

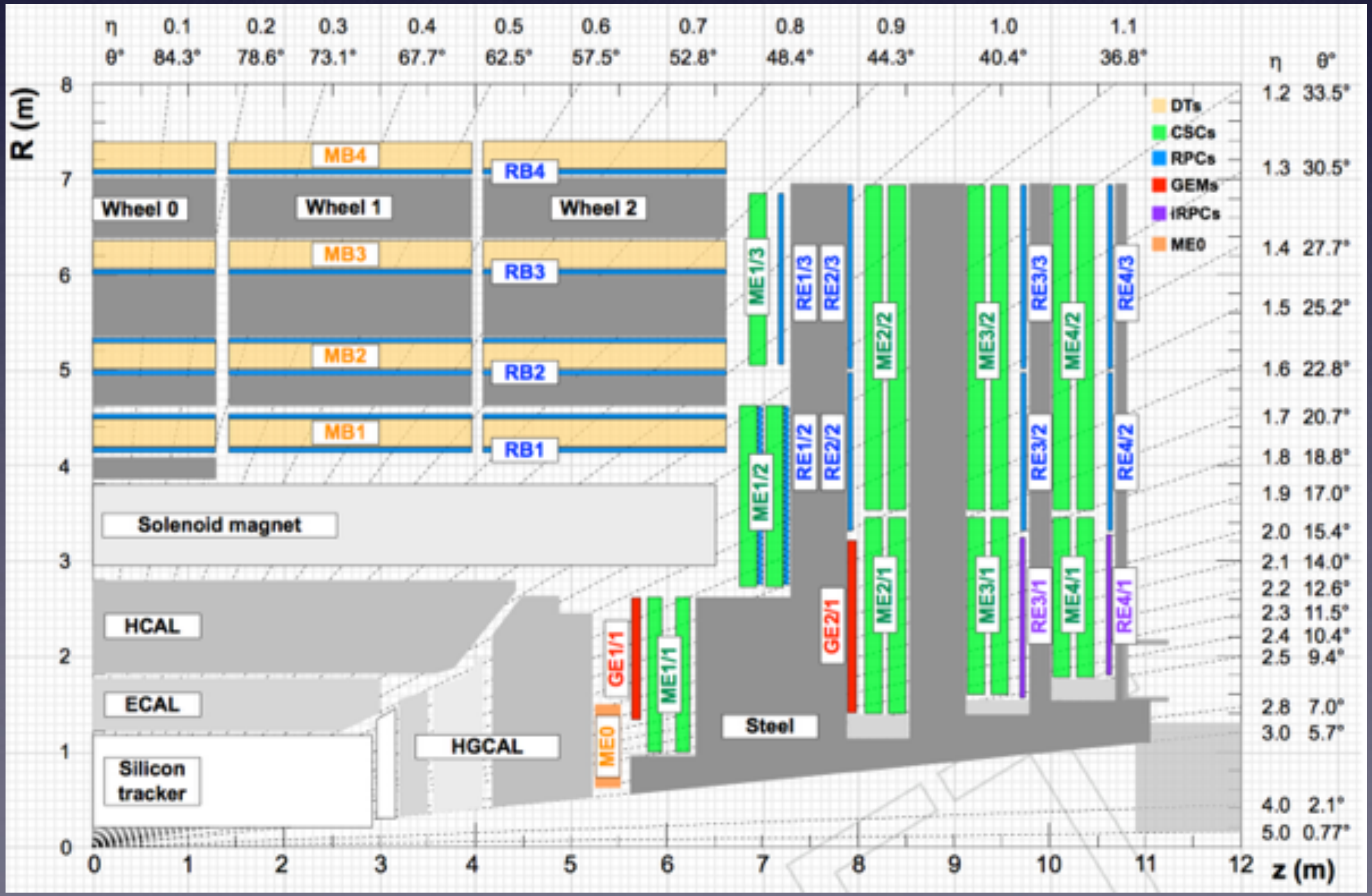
- R_ε is the ratio of the selection efficiency times detector acceptance for the Z' decay relative to that for the Z boson decay
- μ_Z is the Poisson mean of the number of *Z* > *ll* events.

To obtain the limit for a dilepton mass point, the amplitude of the background shape function is constrained using data within a mass window ±6 times the mass resolution about the mass point. The observed limits are robust and do not significantly change for reasonable variations in the limit-setting procedure (mass intervals, background shape).

CMS Phase-II



r [mm]
z [mm]
η
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
4.0



R (m)
z (m)
DTs
CSCs
RPCs
GEMs
iRPCs
ME0
Wheel 0
Wheel 1
Wheel 2
MB1
MB2
MB3
MB4
RB1
RB2
RB3
RB4
Solenoid magnet
HCAL
ECAL
Silicon tracker
HGCAL
Steel
ME0
GE1/1
ME1/1
ME1/2
ME1/3
RE1/2
RE1/3
RE2/2
RE2/3
GE2/1
ME2/1
ME2/2
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