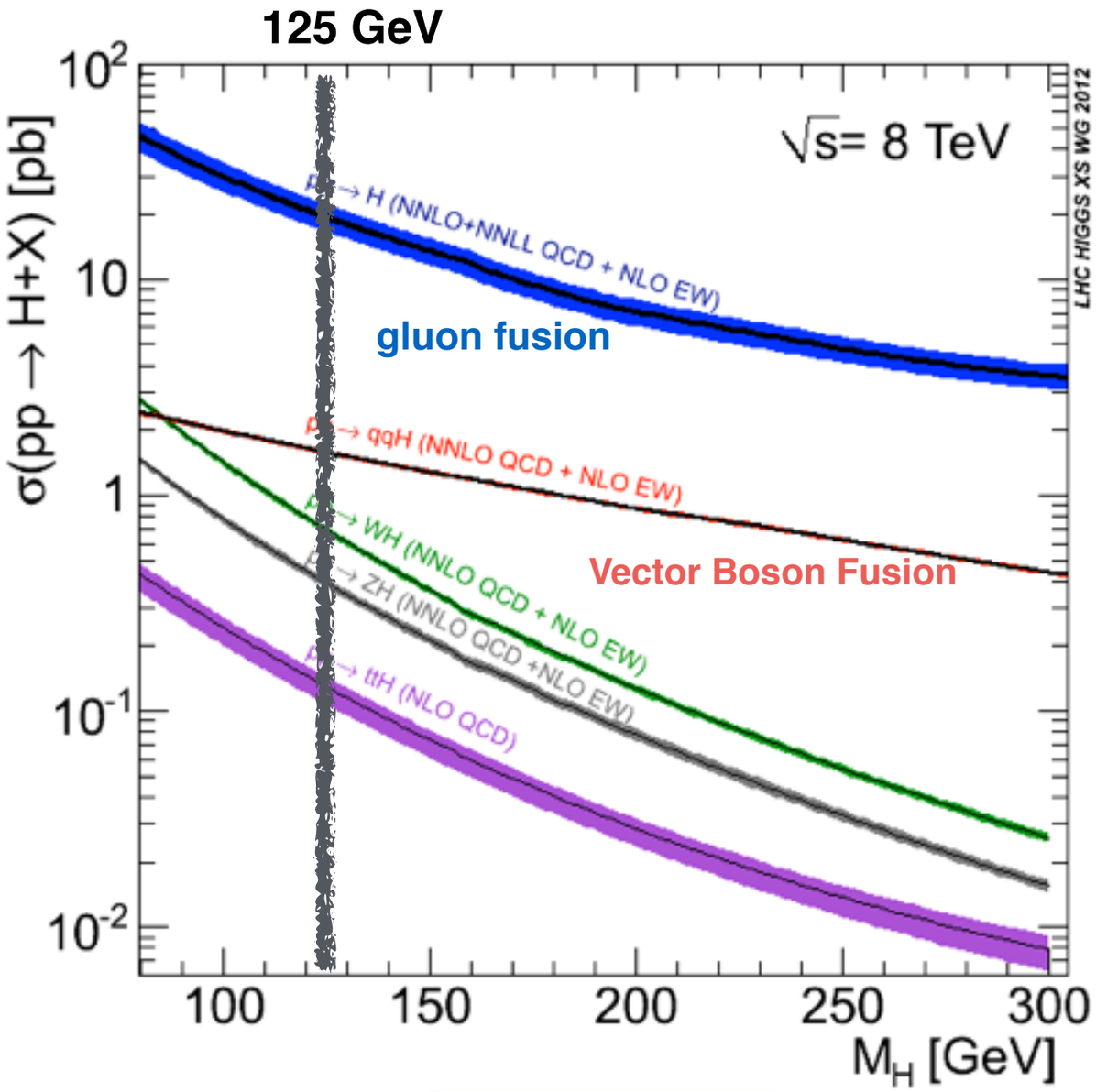
Search for SM and MSSM dimuon Higgs decay channel with CMS

12th April 2016

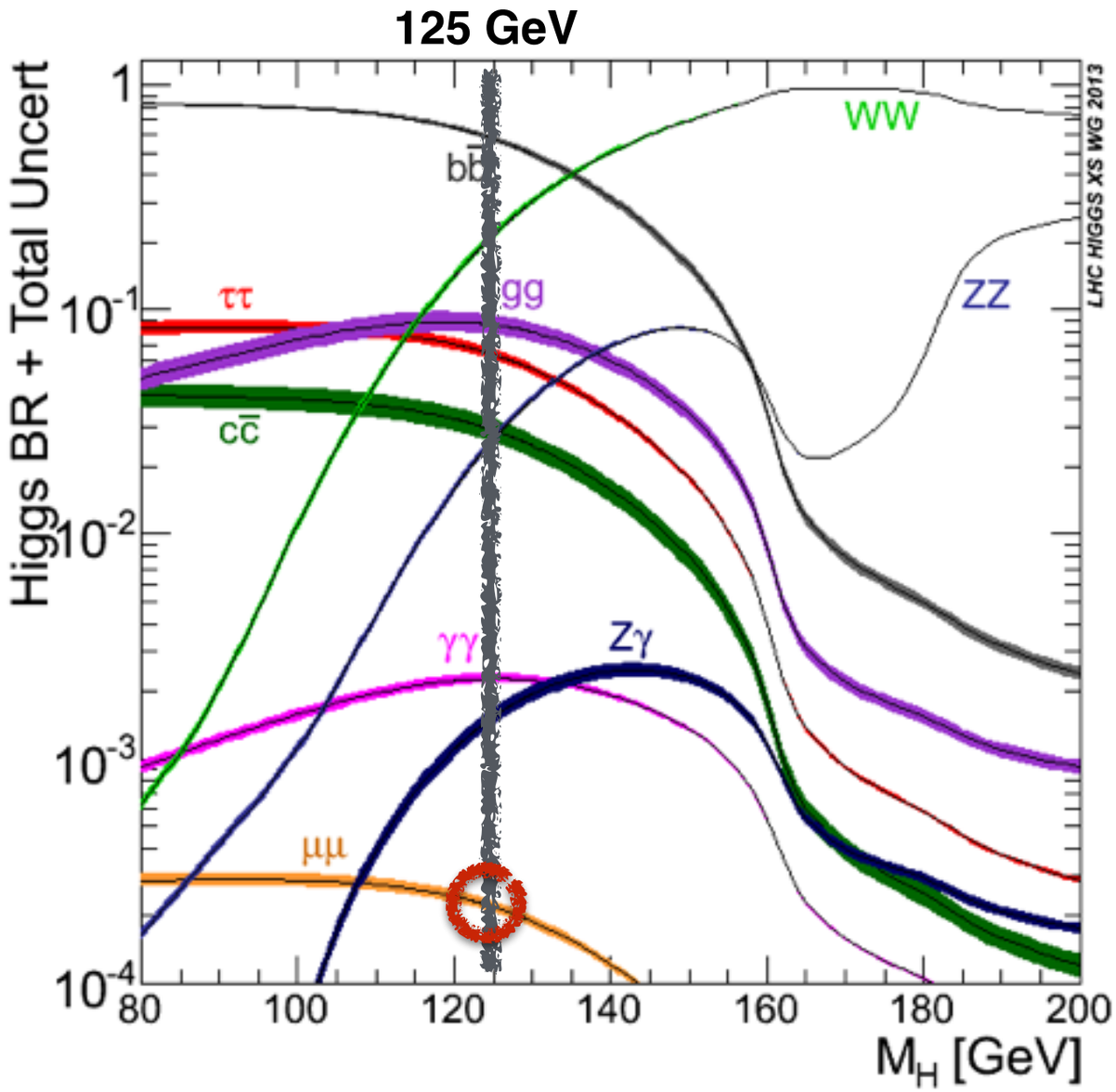
Adrian Perieanu

on behalf of the CMS Collaboration

Higgs production at LHC and its decays



* production

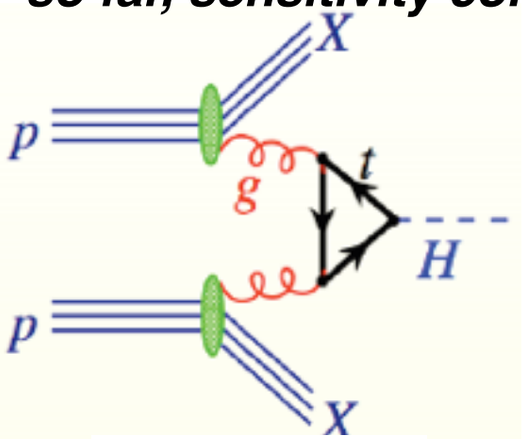


* decays

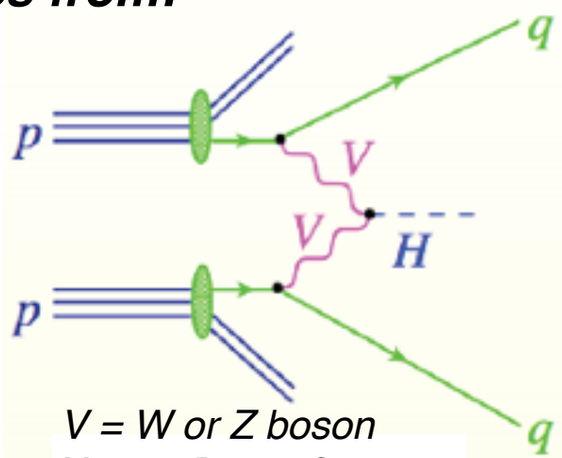
Higgs production at LHC and its decays

*** Higgs is produced at LHC mainly through the gluon fusion and Vector Boson fusion**

so far, sensitivity comes from:



gluon fusion



V = W or Z boson
Vector Boson fusion

Production Proces	Observed Significance (σ)	Expected Significance (σ)
VBF	5.4	4.7
Wh	2.4	2.7
Zh	2.3	2.9
V(W+Z)h	3.5	4.2
ttH	4.4	2.0

not yet "observed"

Measurements of the Higgs boson production and decay rates and constraints on its couplings from a combined ATLAS and CMS analysis of the LHC pp collision data at √s = 7 and 8 TeV

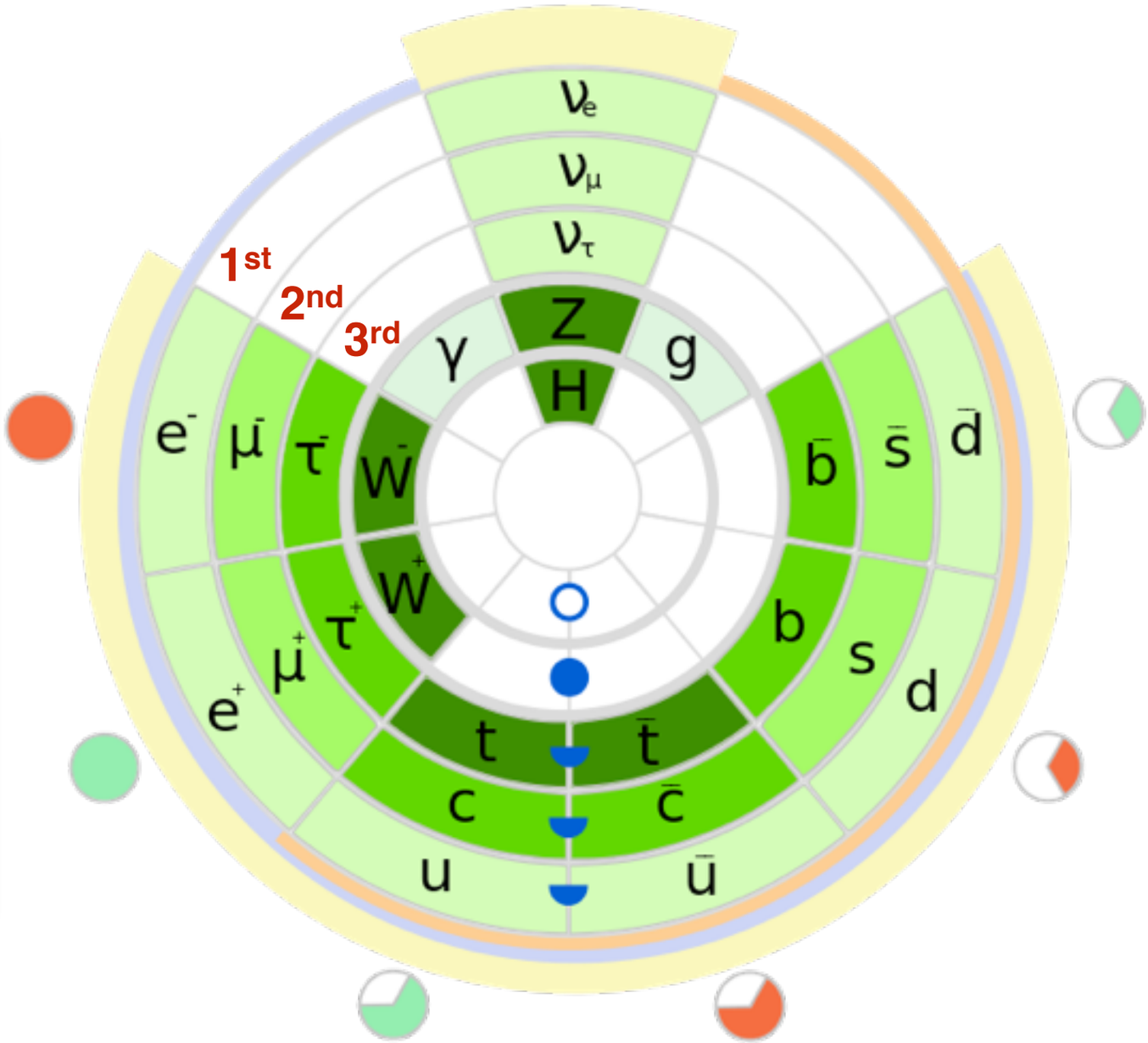
Higgs dimuon decay
- why is it interesting? -

* dimuon channel gives us access to the 2nd lepton generation coupling

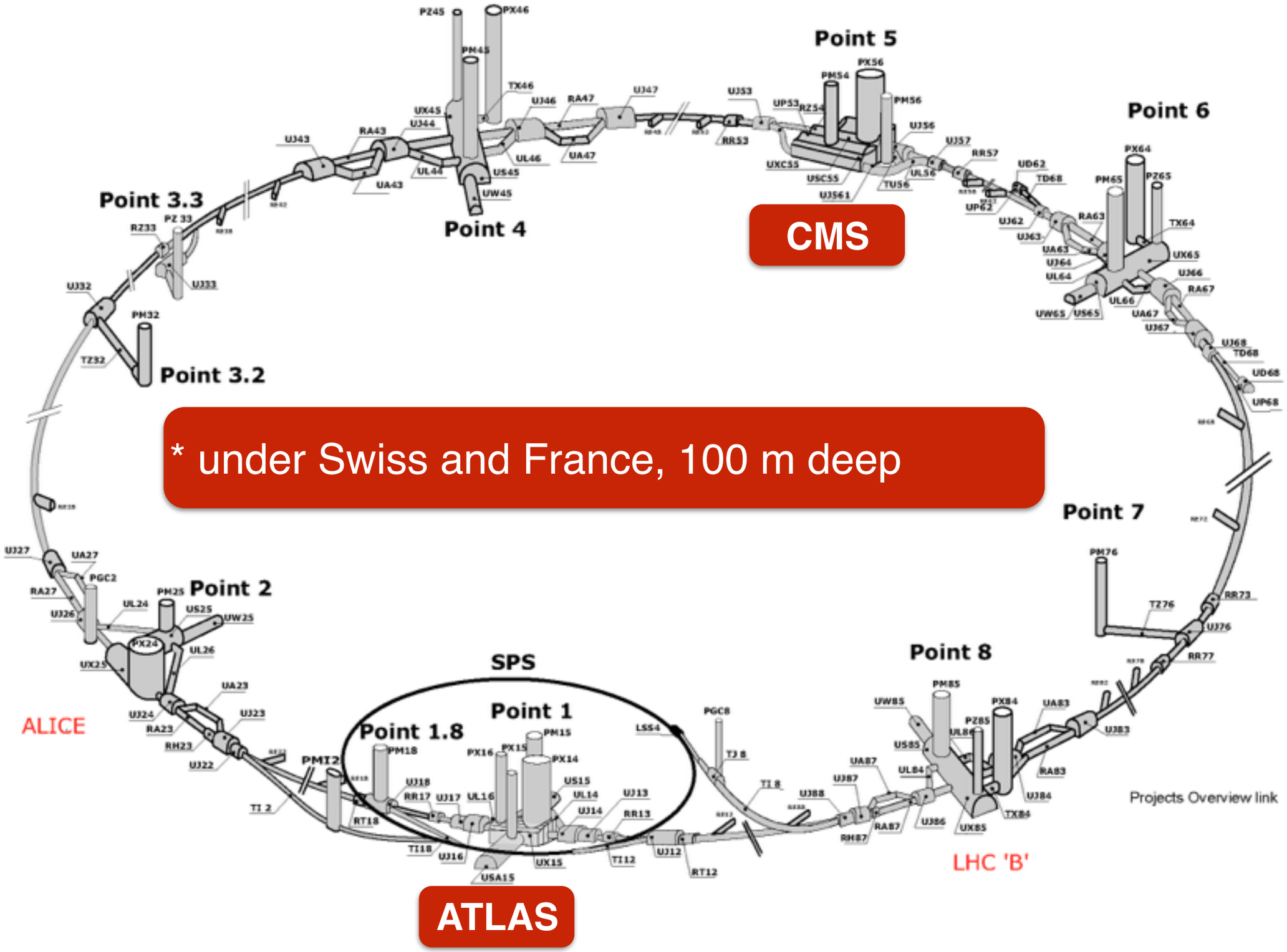
* allows ratio of 2nd and 3rd generation lepton couplings:

— are we talking about the same mass generation mechanism for the 2nd and 3rd generation lepton?

— what about the 2nd and 3rd generation quarks?

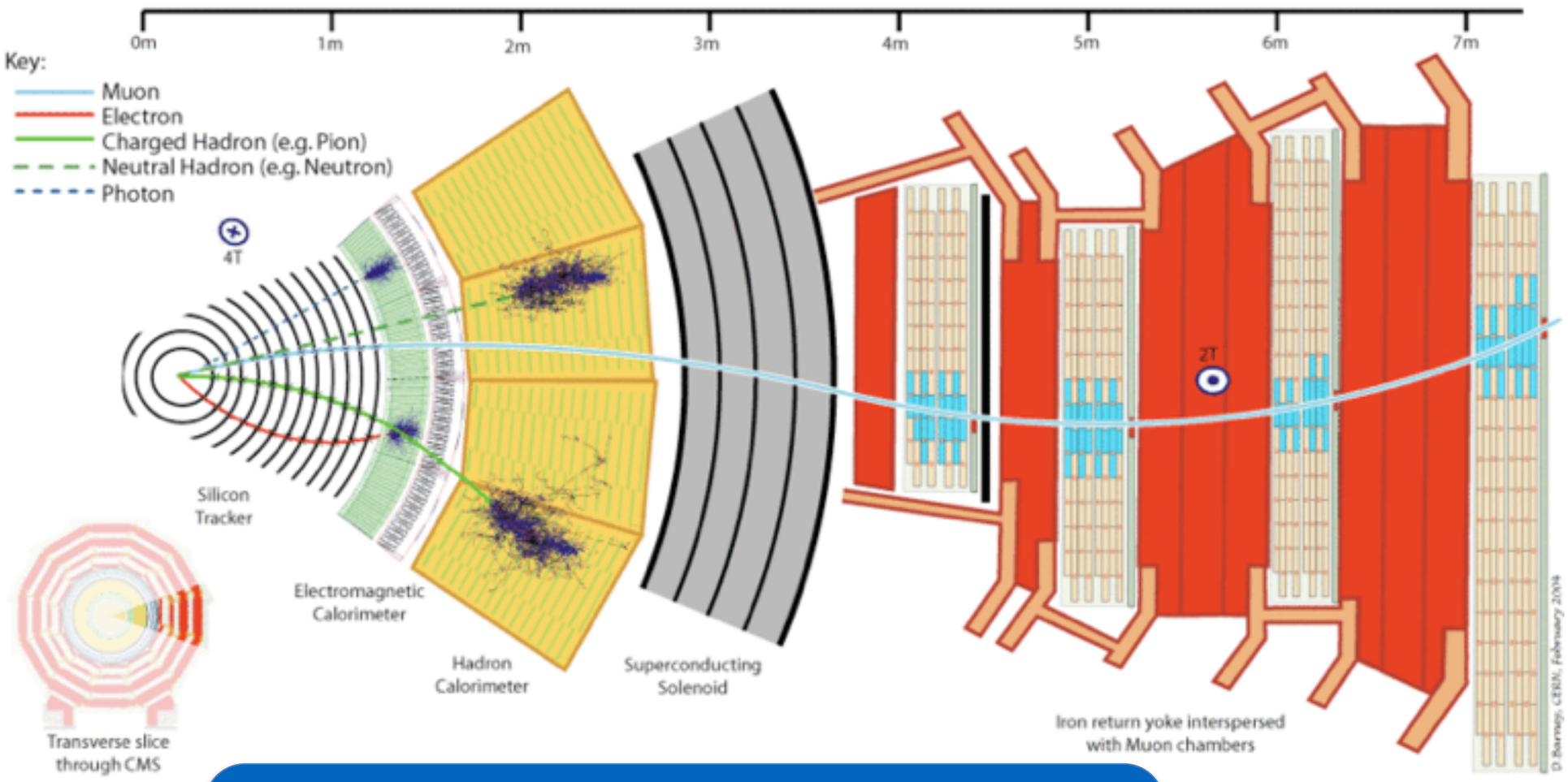


at the LHC


Point 5
Point 6
Point 4
Point 3.3
Point 3.2
Point 2
Point 7
Point 8
Point 1
Point 1.8
SPS
CMS
ATLAS
ALICE
LHC 'B'
* under Swiss and France, 100 m deep
Projects Overview link

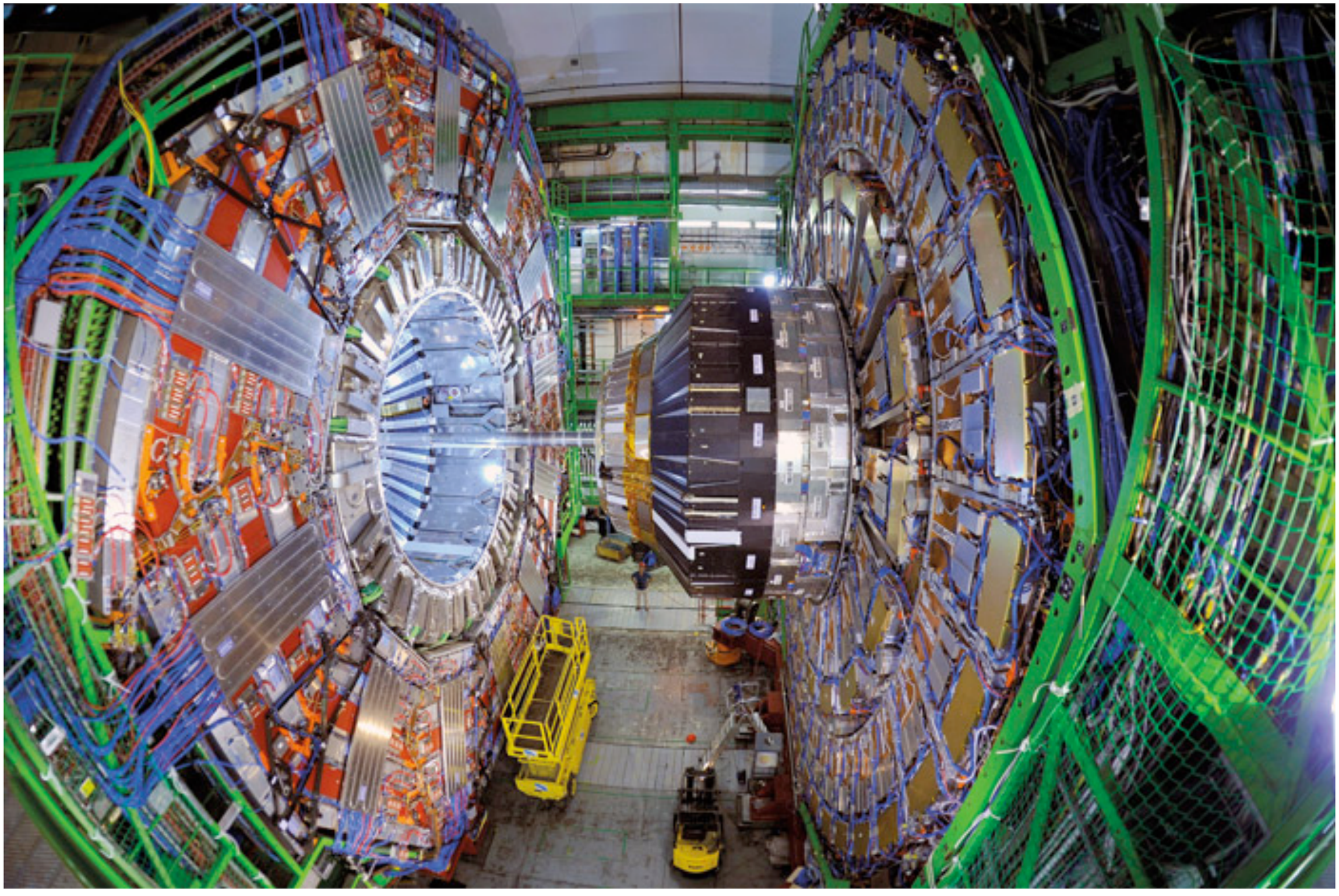
with the Compact Muon Solenoid

*** Muons in CMS:**
track segment reconstructed in the muon chambers matched with the track in silicon tracker (both ways)



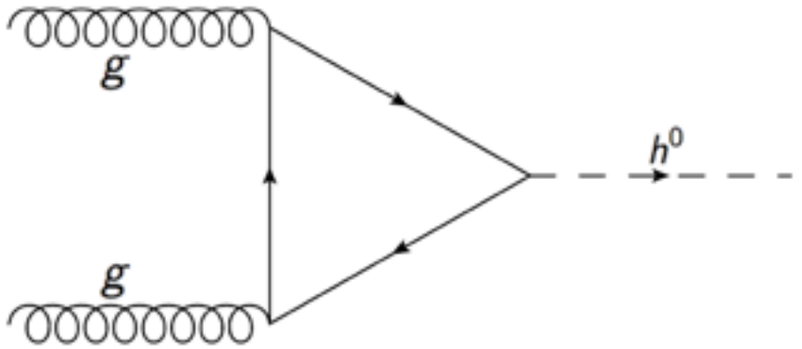
- **coverage:** $|\eta| < 2.4$, $\eta = -\ln[\tan(\theta/2)]$
- **transverse momentum resolution**:
$\sigma_{pT}/pT \approx 0.015\%\ pT \oplus 0.5\%$

during the shut down CMS

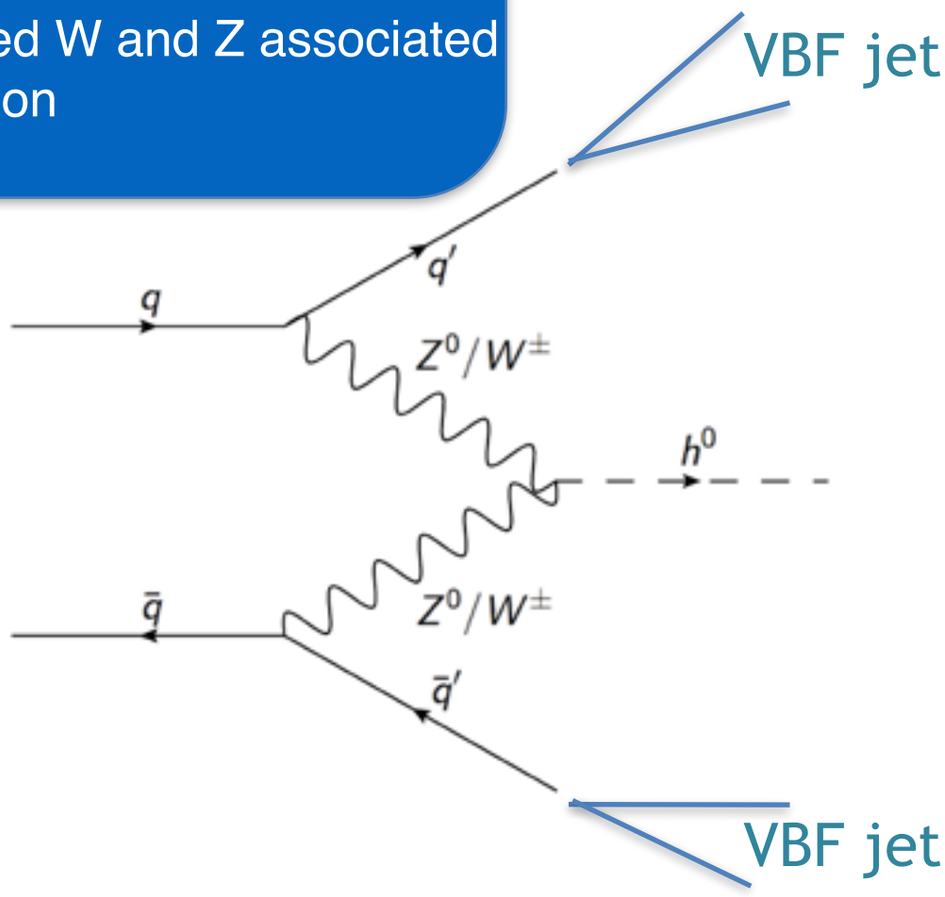


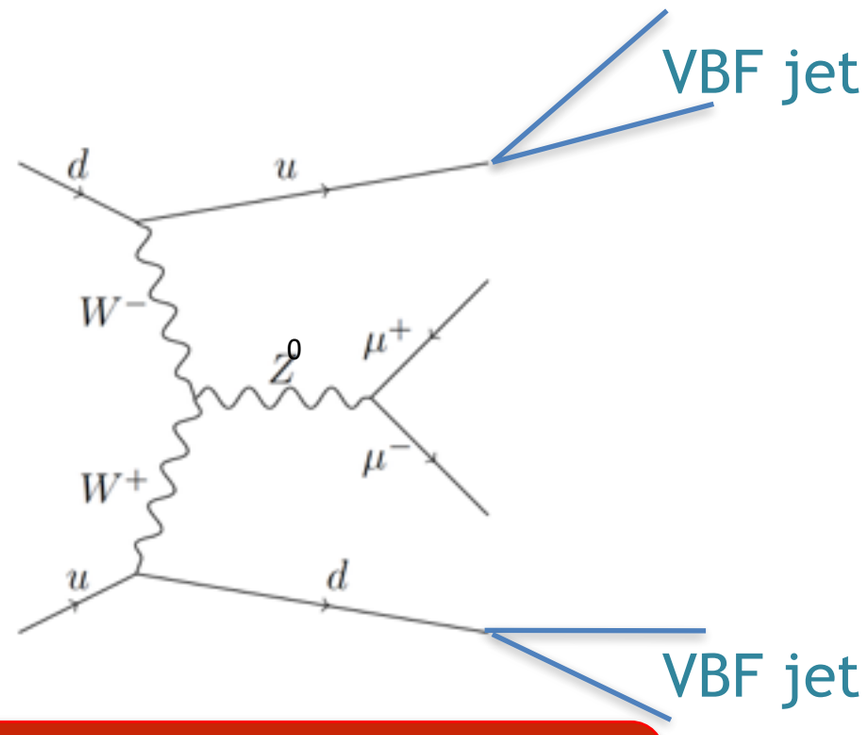
Higgs dimuon decay
— signal vs. background —

main signal production mechanisms:
- gluon fusion
- Vector-Boson fusion
- too low statistics for dedicated W and Z associated production



main background processes:
- Drell-Yan (irreducible background)
- tt pair
- WW
- WZ, ZZ, W + jets





- **discrimination against Drell-Yan is limited if we do not use the spin information – and we do not plan to use it until we see a signal**

Higgs dimuon decay: Run I analysis - event selection -

- single muon trigger (p_T > 24 GeV)
- two opposite charged isolated muons with: p_T > 25 GeV and | η | < 2.1
- anti-k_T jets with p_T > 30 GeV

• we need to reduce the mass window for our search: events categorization according to μ p_T resolution

• VBF tight: gain discrimination using the gap size and dijet mass
• gluon fusion: jets from IR partons

Pre-Selection Cut

Leading Jet p_T>40 & Sub-leading Jet p_T>30 & p_T(Missing) < 40 GeV

Fail → **Non-VBF Categories**

Tight
$p_T(\mu\mu)$ > 10 GeV

Geometrical Categories:
Barrel-Barrel (BB)
Barrel-Overlap (BO)
Barrel- Endcap (BE)
also OO, OE and EE

Loose
$p_T(\mu\mu)$ ≤ 10 GeV

Geometrical Categories:
Barrel-Barrel (BB)
Barrel-Overlap (BO)
Barrel- Endcap (BE)
also OO, OE and EE

Pass → **VBF Categories**

VBF Tight

M(jj) > 650 GeV
&
|Δη(jj)| > 3.5

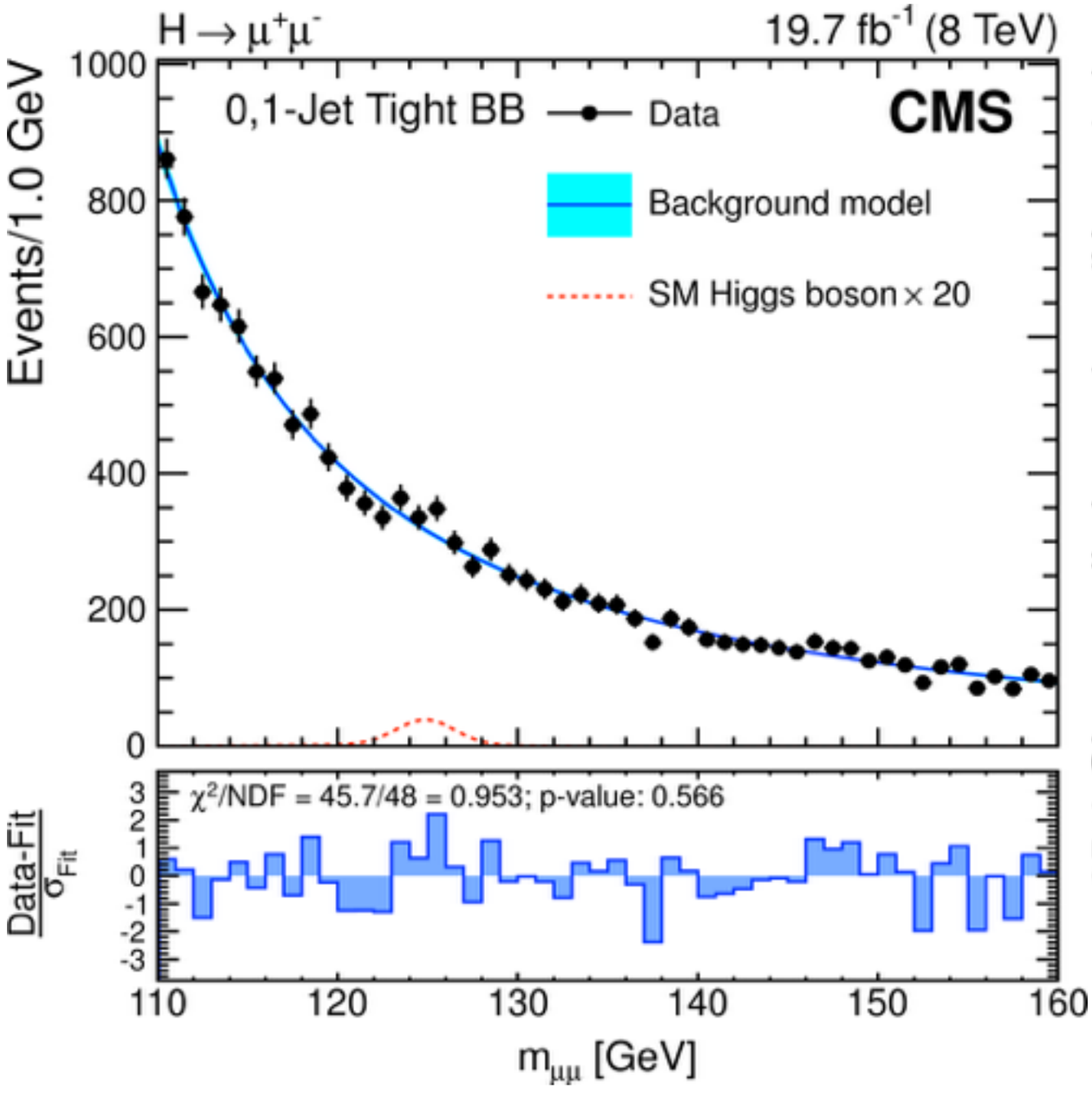
gg fusion Tight

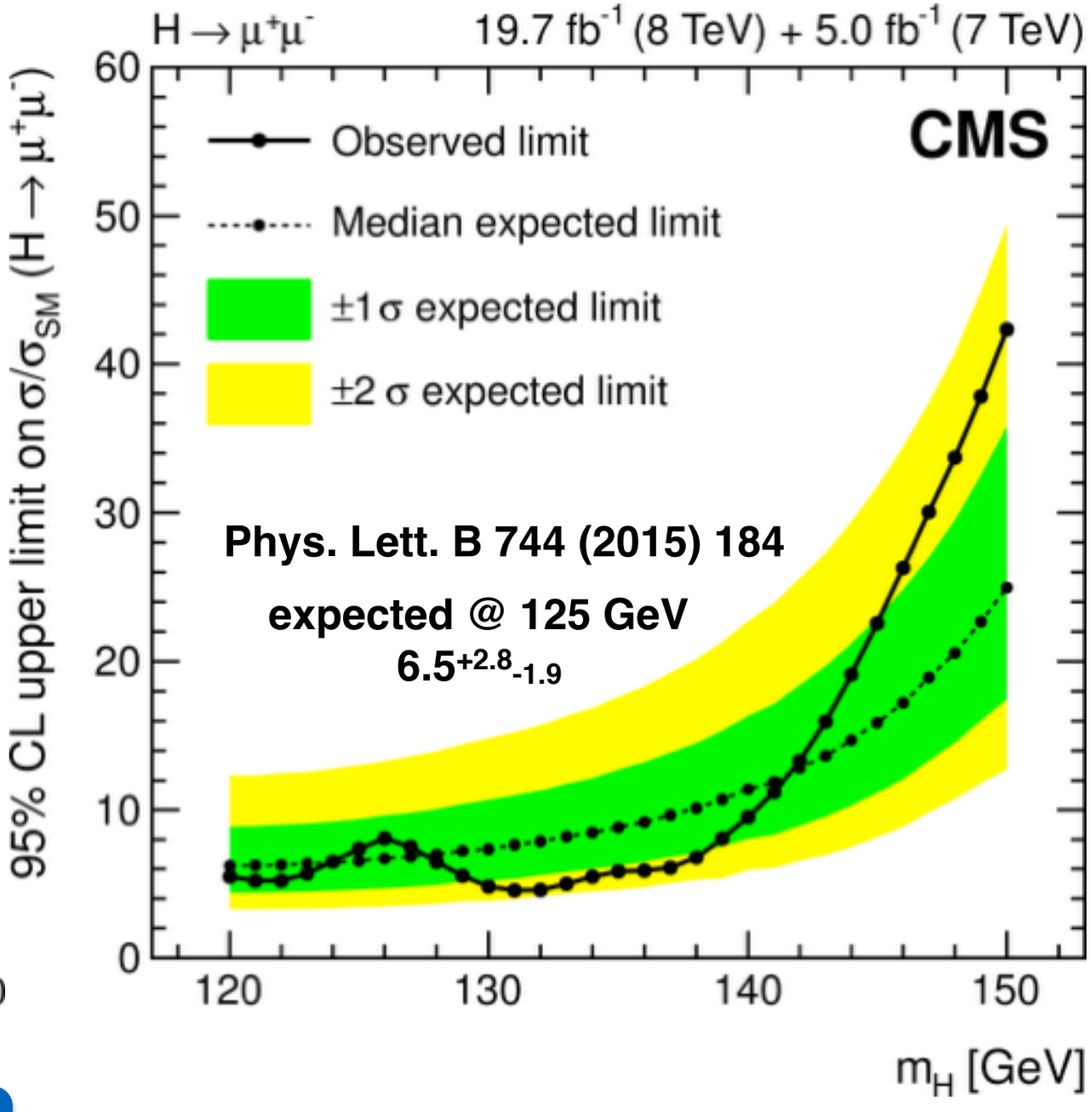
Non-VBF Tight
&
M(jj) > 250 GeV
&
$p_T(\mu\mu)$ >50 GeV

Loose

remaining events

“money”  plots



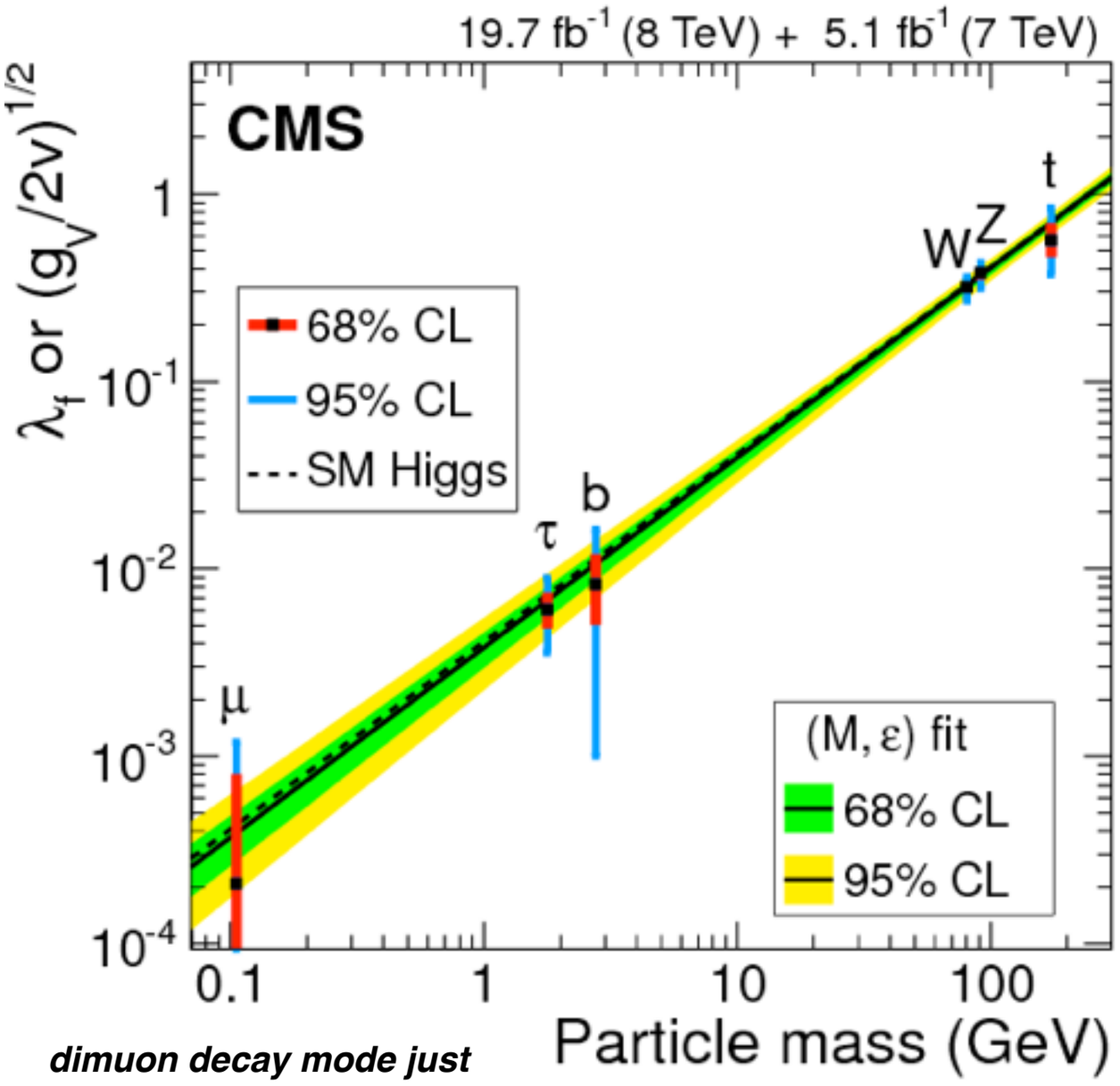


*** in Barrel region we have the best resolution regarding reconstruction**
*** this category and VBF are the most sensitive**

*** achieved sensitivity to SM**
*** fit bias gives to highest systematic uncertainty**

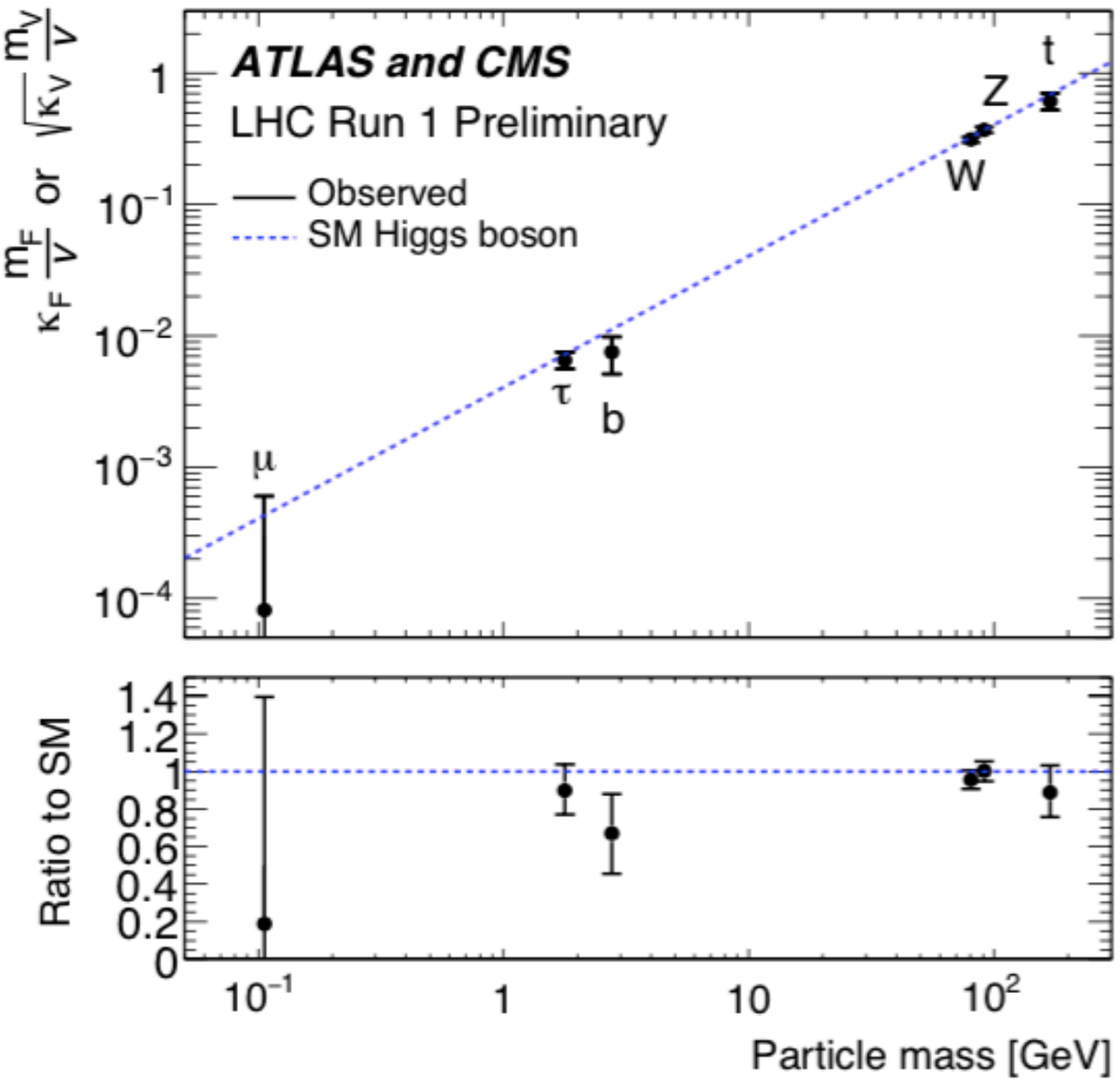
where is Higgs dimuon decay mode standing?

reduced coupling



dimuon decay mode just made it on the overview table - last place, but on the table

and combined with ATLAS



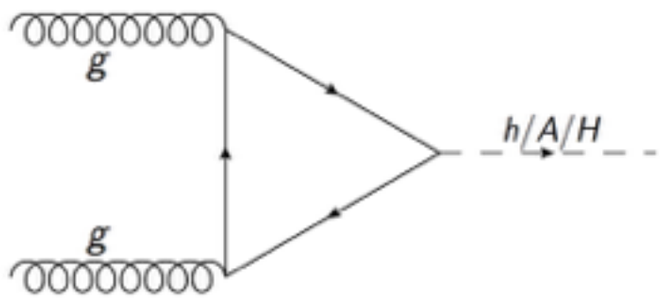
beyond SM

SM breaking via MSSM

MSSM: Φ^0 (h^0, H^0, A^0), $H^\pm$
- Higgs sector can be described by: tanß and m_A
- tanß = v_1/v_2 where v_1 and v_2 are vacuum expectation values

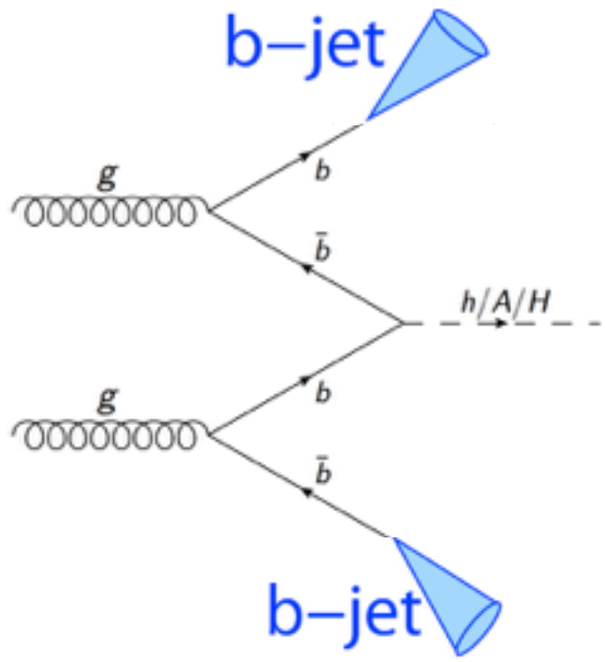
main signal production mechanisms:
- gluon-gluon fusion
- associated b-quark production

$$g^{MSSM}_{b\bar{b}\Phi} = \tan\beta \cdot g^{SM}_{b\bar{b}\Phi}$$

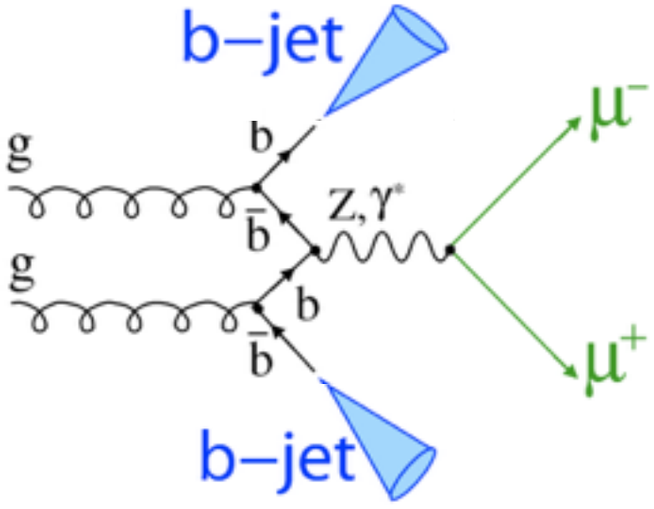


main background processes:
- VBF Drell-Yan (use b-tagging)
- bb Z/γ* (irreducible background)
- tt pair (use missing energy in transverse plane)
- WW (use b-tagging)
- WZ, ZZ

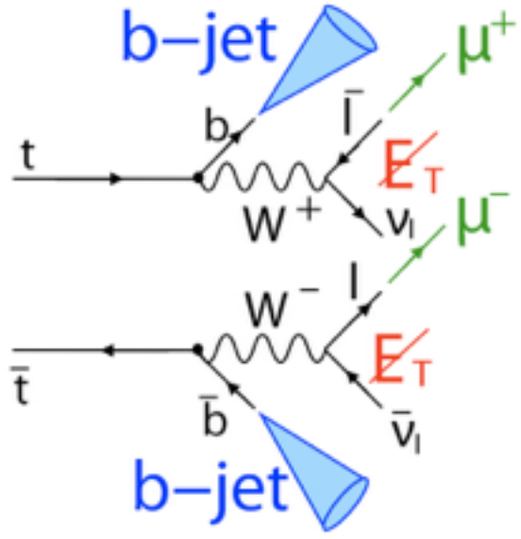
signal: associated b-quark production



background: $b\bar{b}$ Z/γ*



background tt

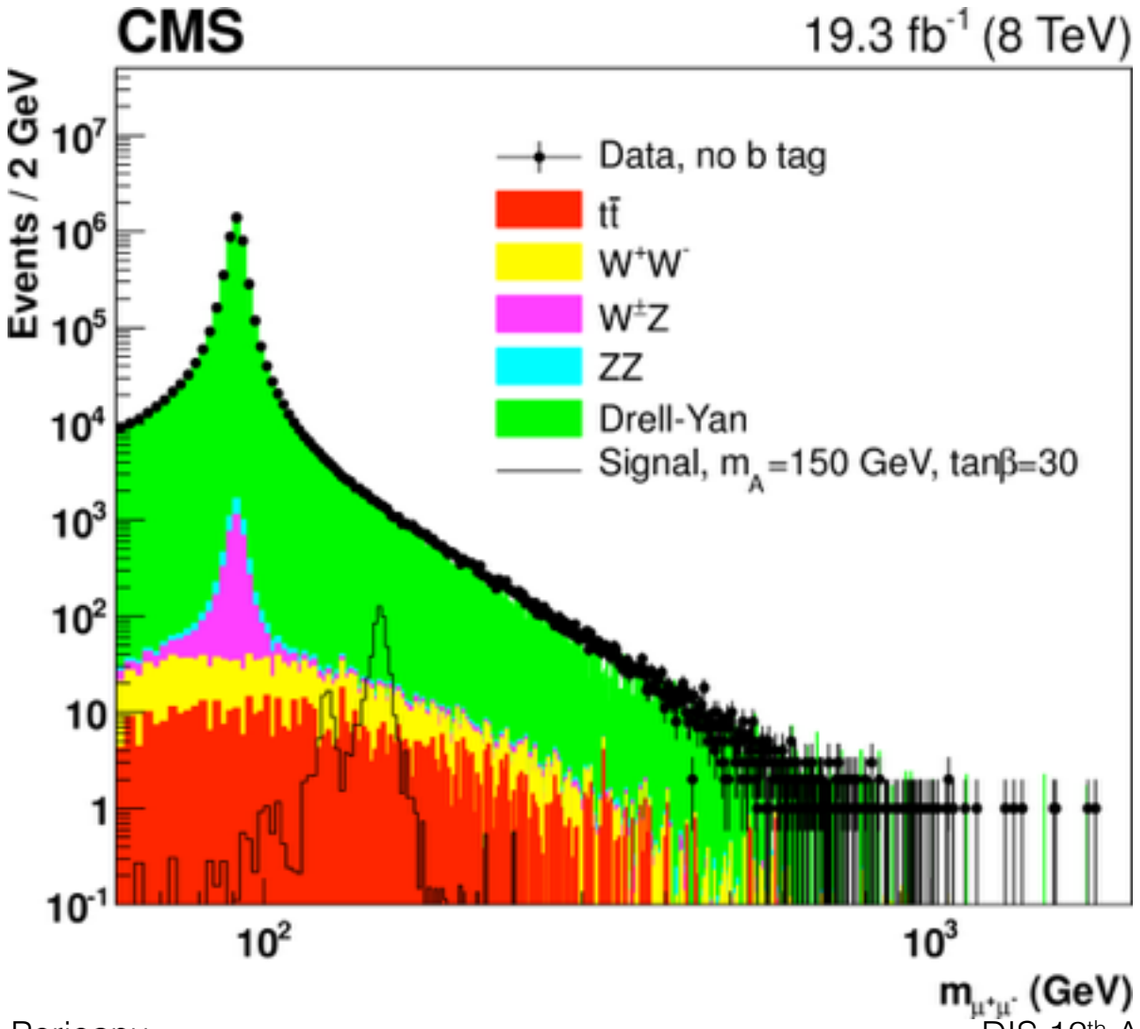


- better discrimination against Drell-Yan (relative to SM search)
- we do not use the spin information (not yet)

“money”  plots beyond SM

• when fitting, one needs to take into account the **expected double peak structure** shape which depends on **tanβ and m_A**

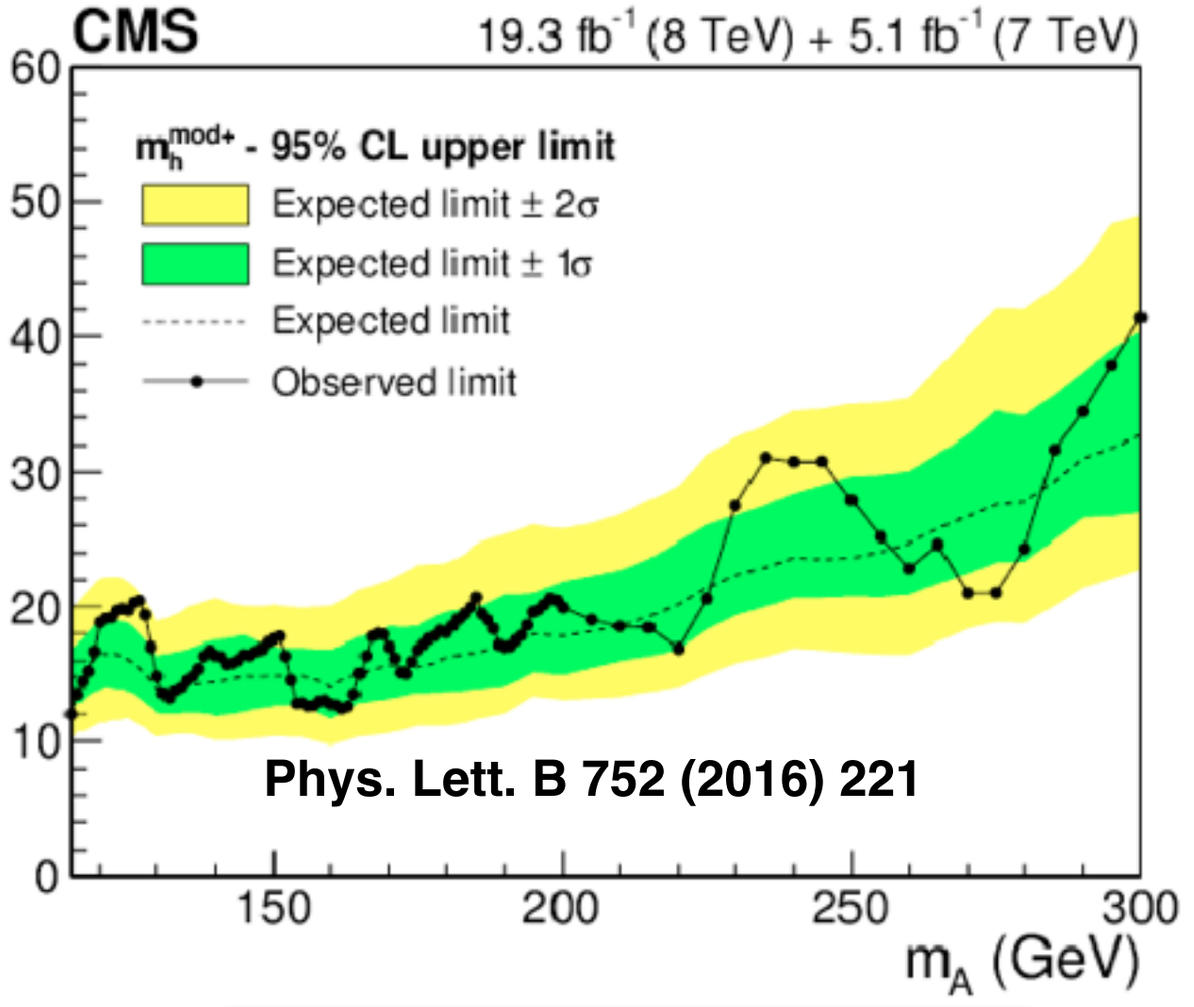
• dimuon channel has the needed mass resolution to distinguish between **h/H/A**



MSSM: Φ^0 **(**h^0, H^0, A^0), $H^\pm$

• Higgs sector can be described by: tanβ and m_A

• tanβ = v_1/v_2 where v_1 and v_2 are vacuum expectation values



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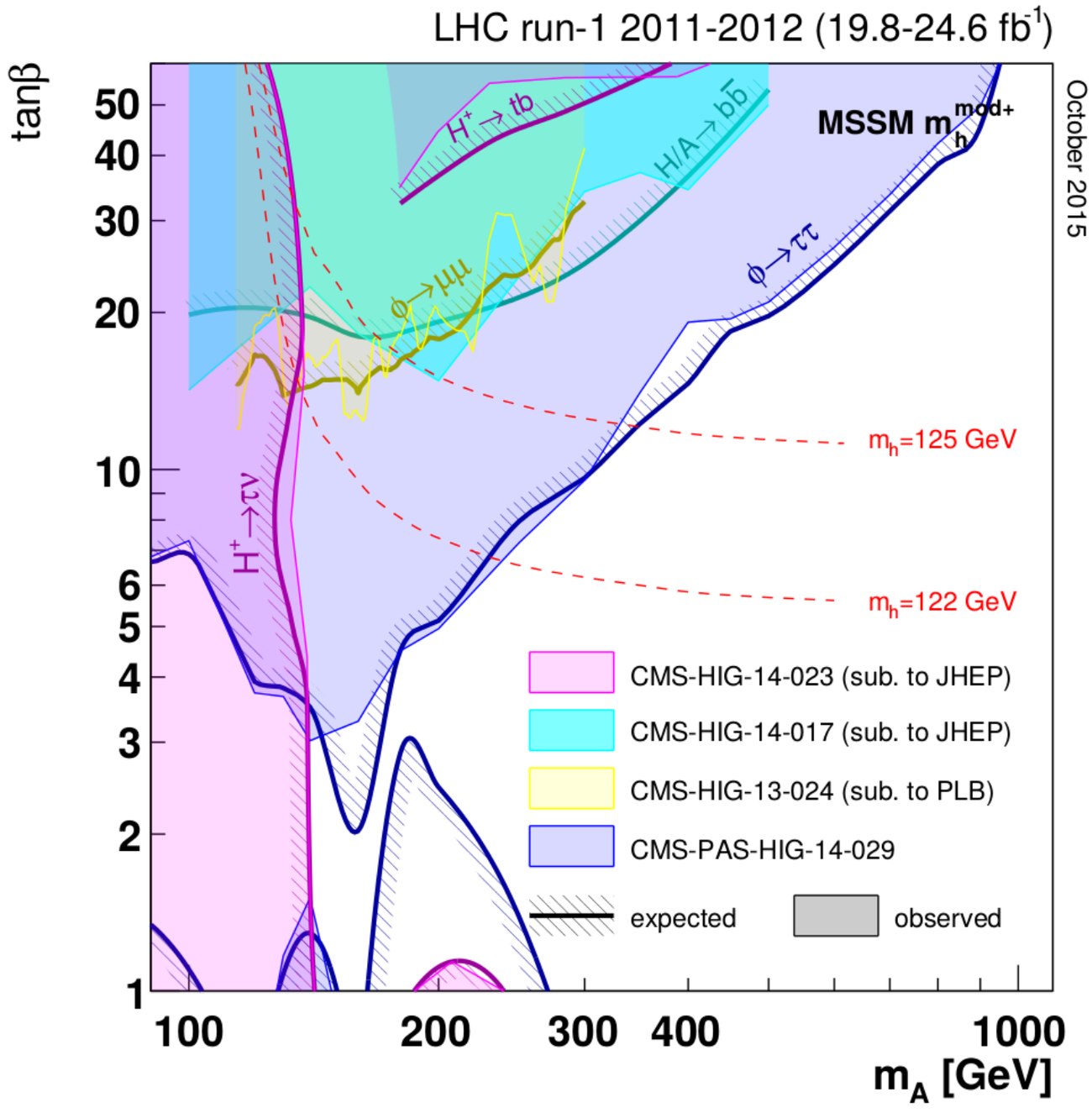
• we reached a sensitivity similar to the Higgs bb decay channel

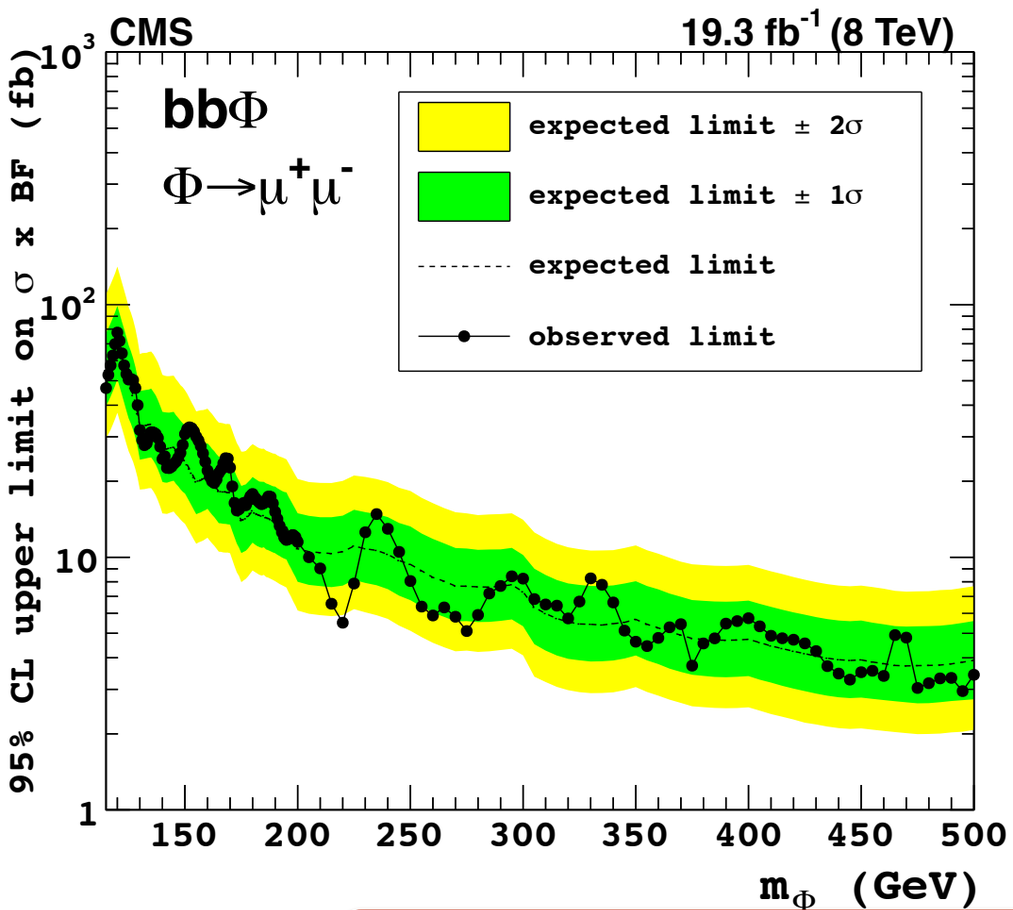
“money”  plots beyond SM

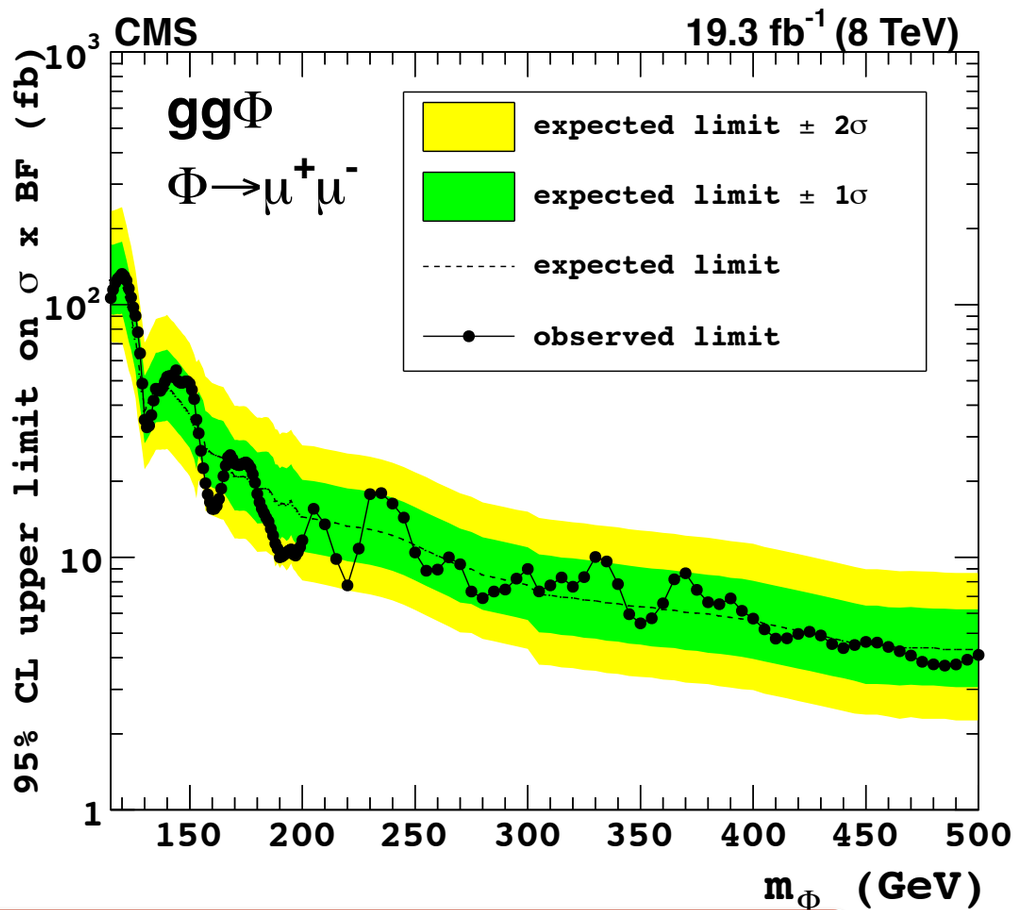


- **we reached a sensitivity similar to the Higgs bb decay channel**

“money”  plots beyond MSSM

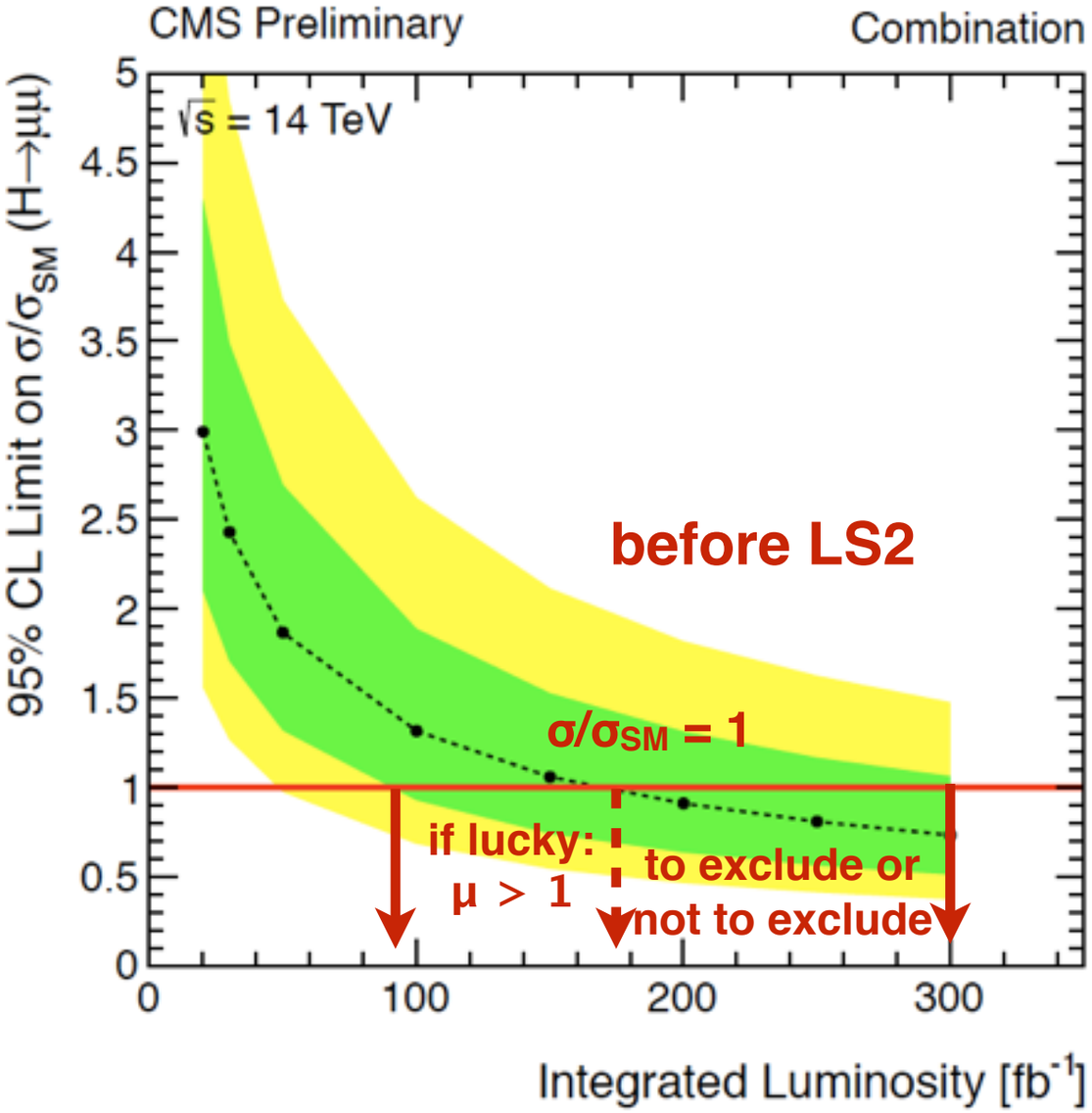
assumptions:
- Φ^0 produced entirely via bb associated production or only via gluon-gluon fusion
- single mass resonance search with detector efficiency obtained from A^0 at tanB = 20:
  - bias from kinematics is negligible
  - mass resolution much larger than the expected signal width

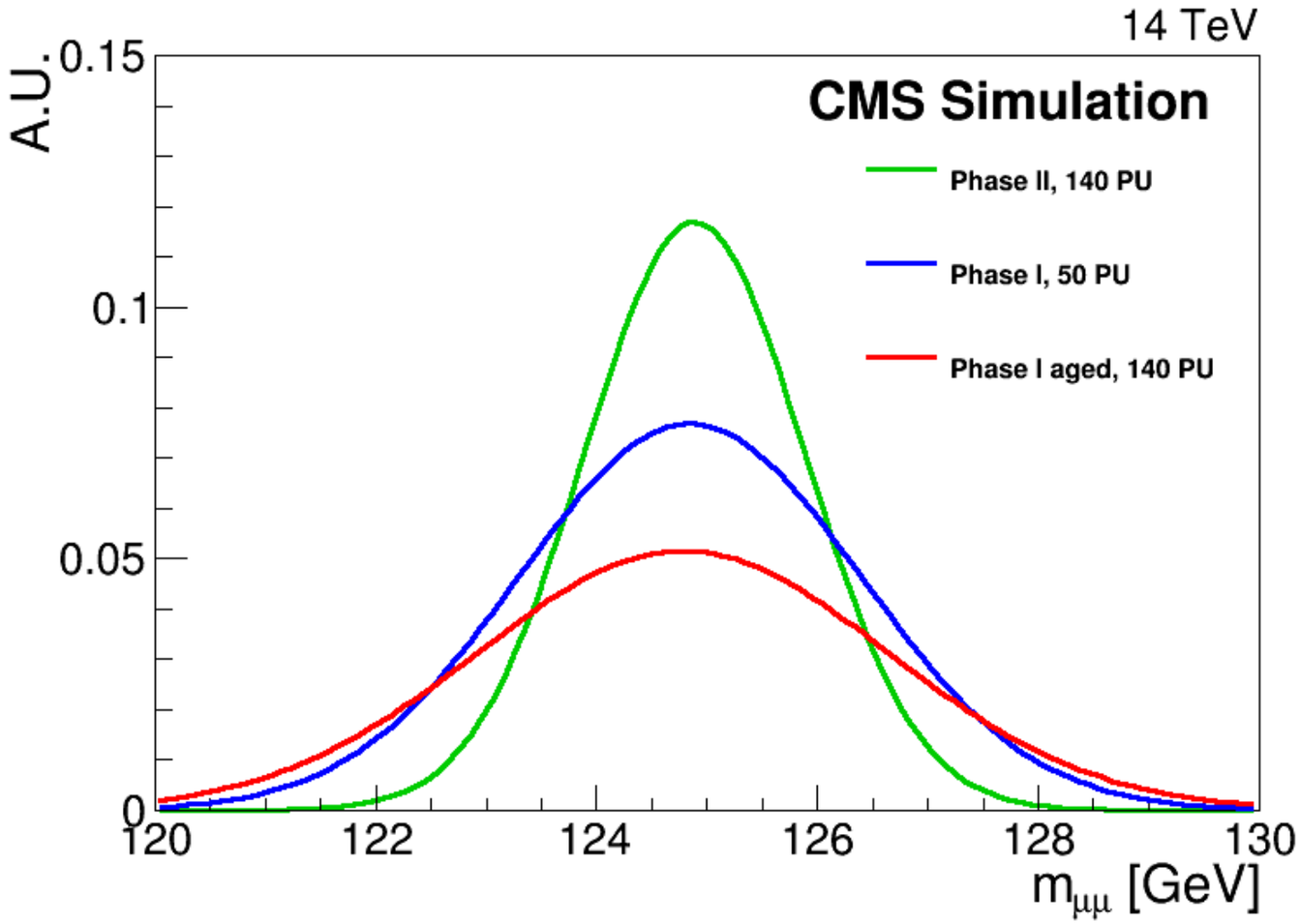




- **with 13/14 TeV data we can extend the mass range**

before the END… prospects for future — Higgs dimuon decay —





* SM sensitivity will be reached before LS2

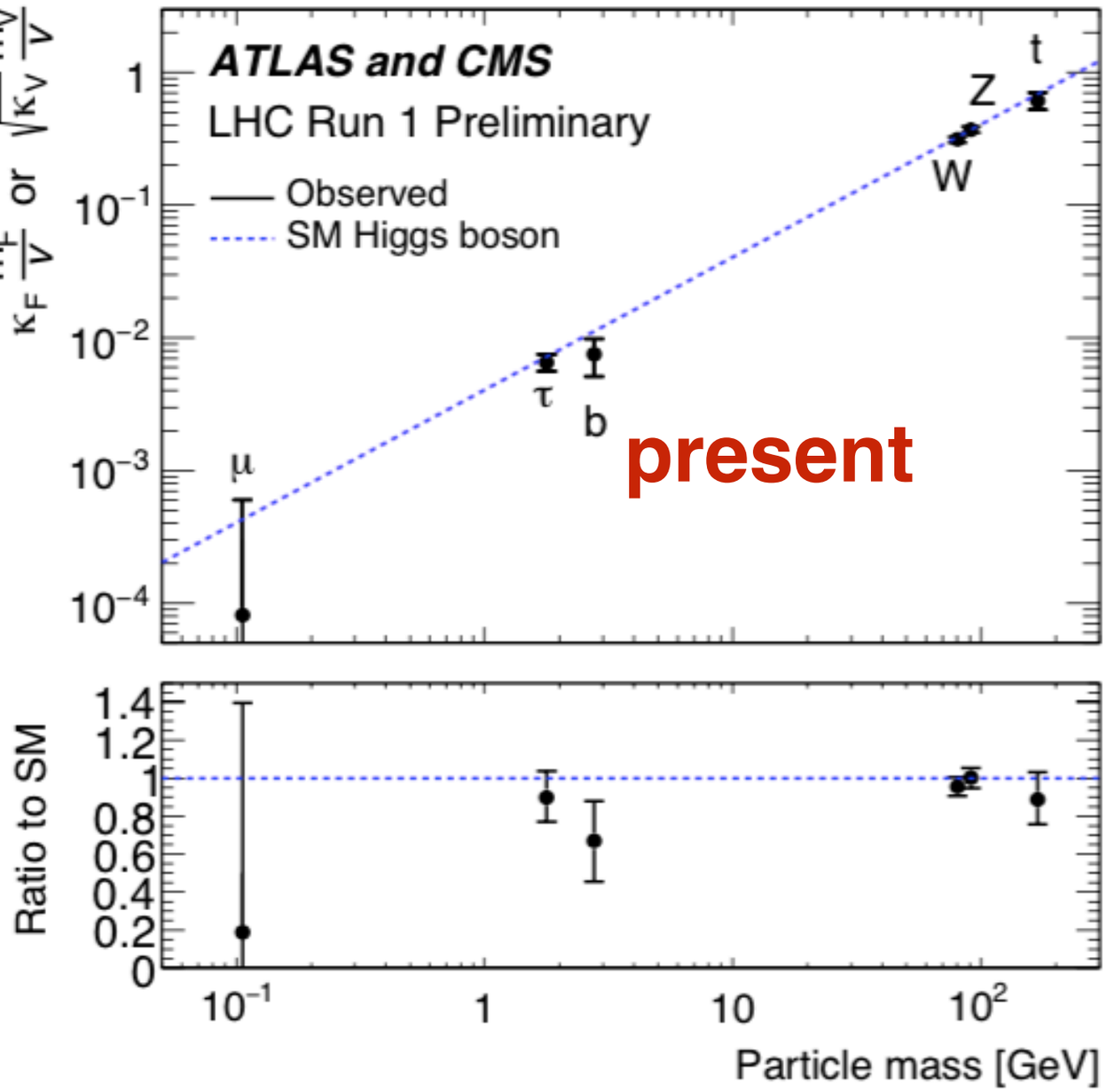
* observation (> 5σ) expected during HL-LHC

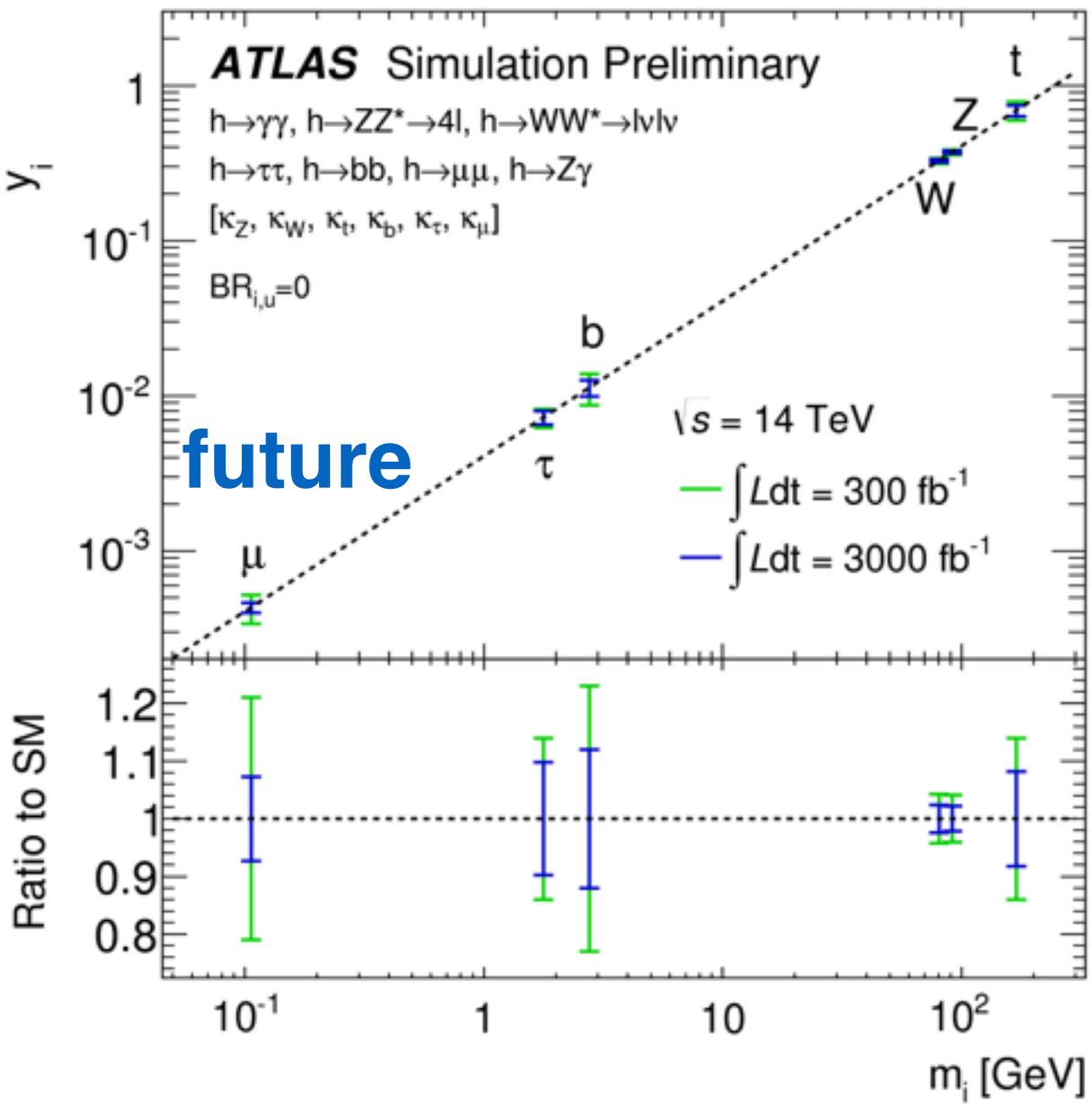
* new detectors design will make possible to improve dimuon mass resolution considerably

hopefully some of us will still try to answer the questions mentioned before

Higgs couplings after 3000 fb^{-1}

— where would we like to go —





we'll remain biased by the SM expectation for some while

backup

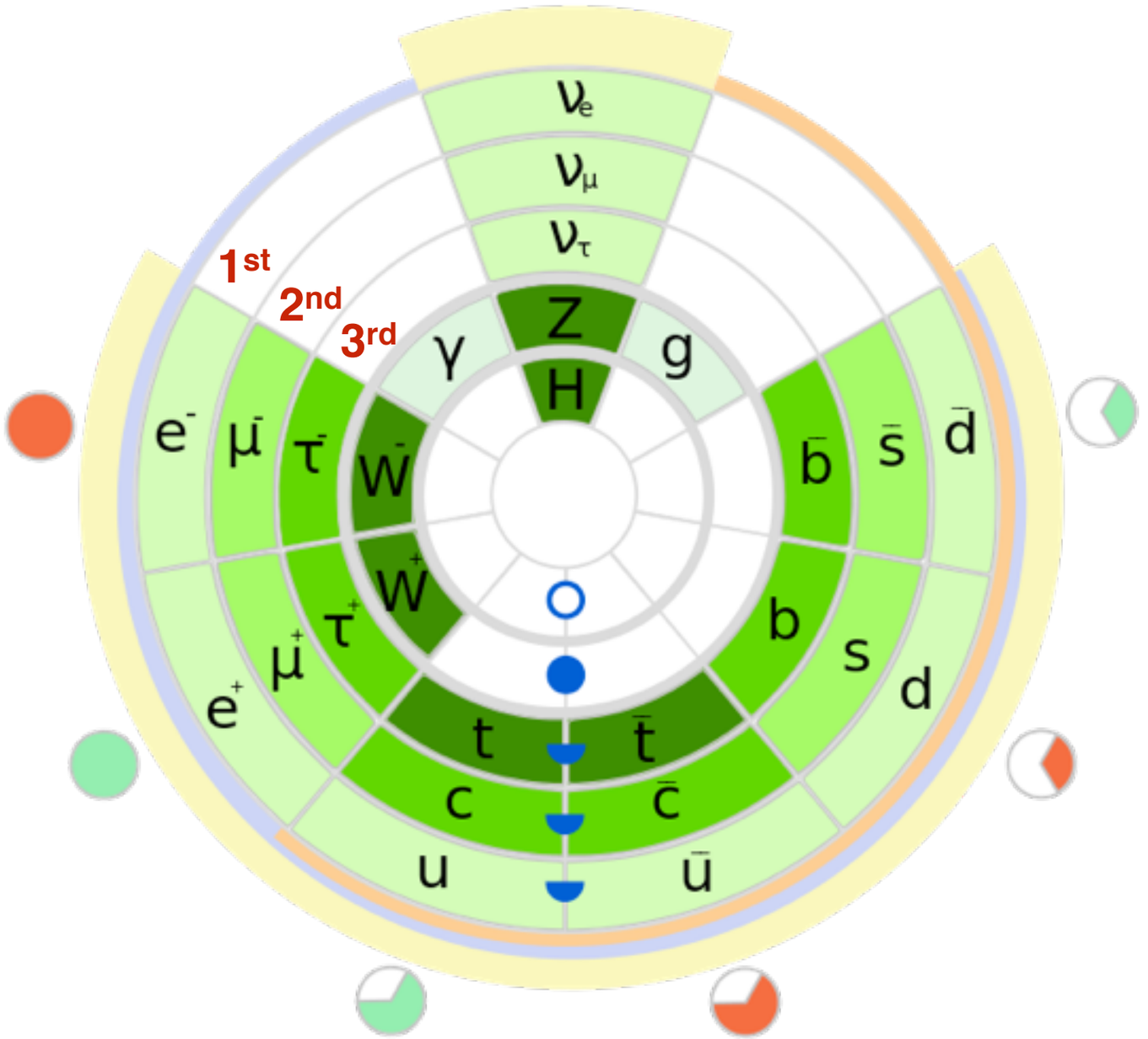
Higgs dimuon decay
- why is it interesting? -

* dimuon channel gives us access to the 2nd lepton generation coupling

* allows ratio of 2nd and 3rd generation lepton couplings:

— are we talking about the same mass generation mechanism for the 2nd and 3rd generation lepton?

— what about the 2nd and 3rd generation quarks?



Spin (small blue circles in the middle):
ring: 0
circle: 1
semicircle: 1/2

Mass:
- more than 80 GeV/c^2
- 1-5 GeV/c^2
- 90-110 MeV/c^2
- less than 16 MeV/c^2
- Massless

Participation in interactions:
- Weak force (note: only particles with non-zero mass are here)
- Electromagnetic force
- Strong force

Charge (external circles):
- positive
- negative

full circle: 1 or -1 respectively
2/3 circle: 2/3 or -2/3 respectively
1/3 circle: 1/3 or -1/3 respectively

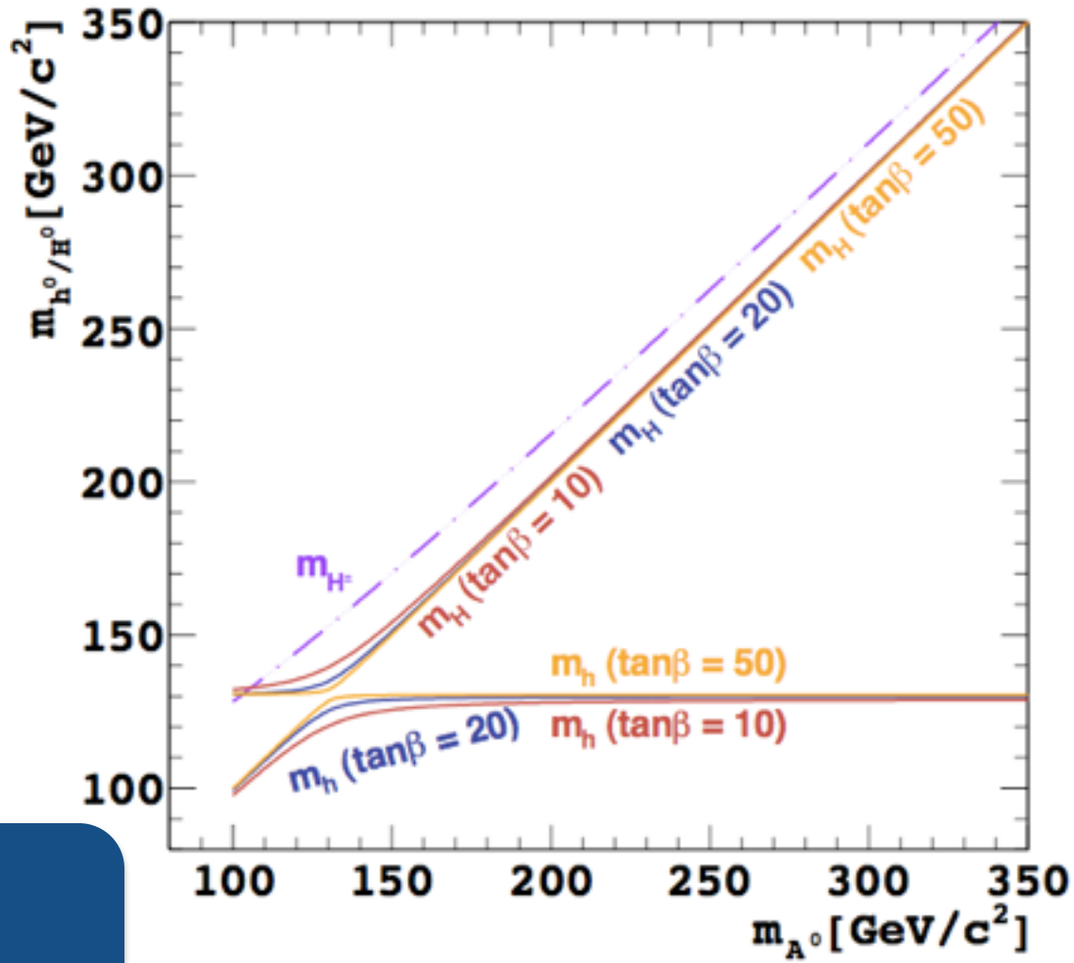
MSSM

constrained MSSM (phenomenological MSSM):

- all soft SUSY-breaking parameters are real
- no new source of CP-violation
- no FCNC at tree level
- soft SUSY-breaking masses and trilinear couplings of the 1st and 2nd sfermion generations are the same at low energy

- free parameters: reduced from 104 SUSY breaking terms to 22

- in most MSSM there is no soft SUSY-breaking scenario (mSUGRA, AMSB, GMSB, …) considered



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- Higgs sector can be described by: tanß and m_A
- tanß = v_1/v_2 where v_1 and v_2 are vacuum expectation values

- A^0 (CP odd): m_A
- $H^\pm$: $m_H=(m_A^2+m_W^2)^{1/2}$

- h^0, H^0 (CP even):

$$m_{H,h}=\left\{1/2\left\{m_A^2+m_Z^2 \pm \left[(m_A^2+m_Z^2)^2 - 4m_A^2m_Z^2\cos^2 2\beta\right]^{1/2}\right\}\right\}^{1/2}$$

m_h mod+ and mod – scenarios: not excluded as m_h max
M. Carena *et al.* http://arxiv.org/pdf/1302.7033v1.pdf