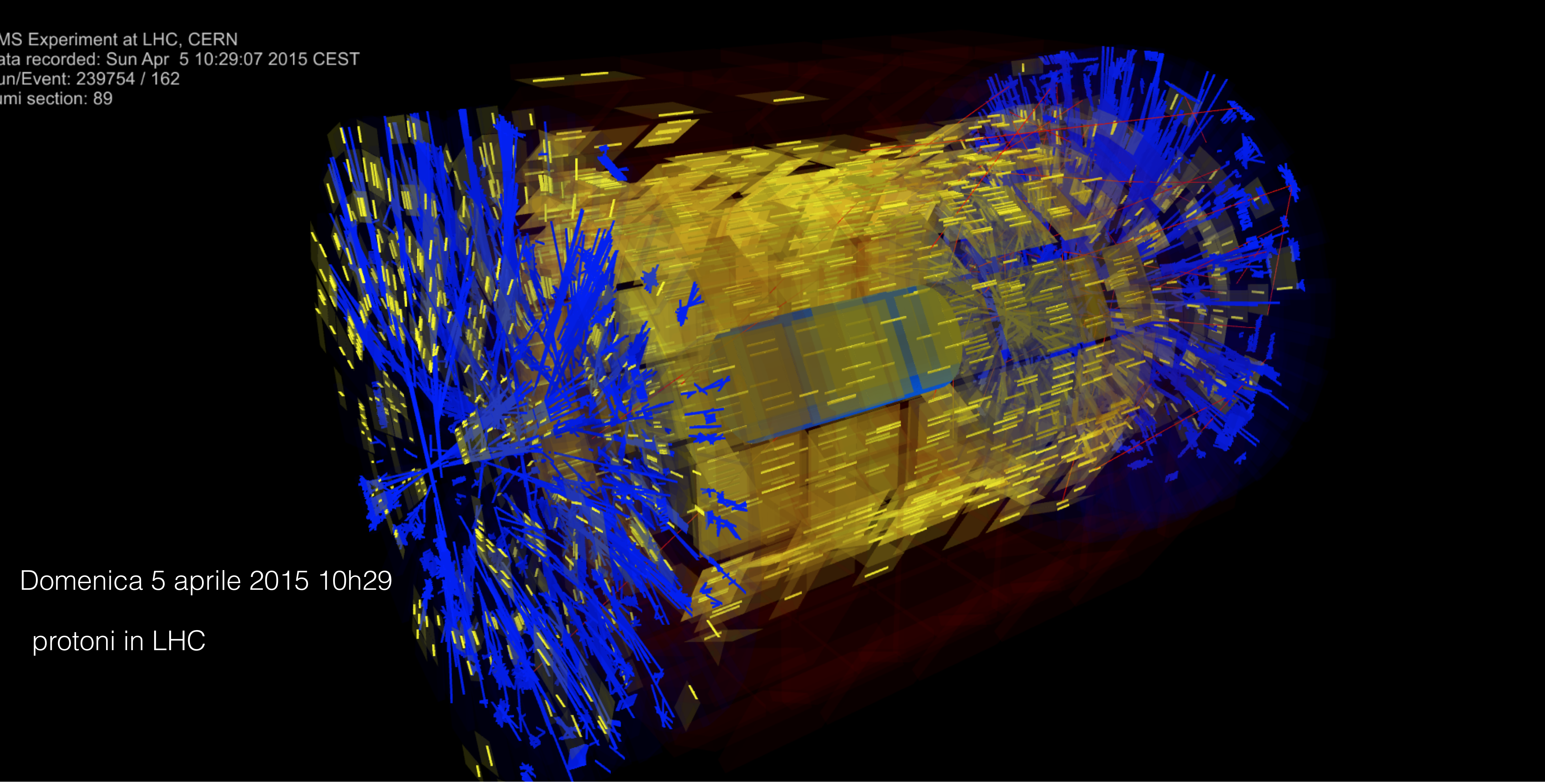
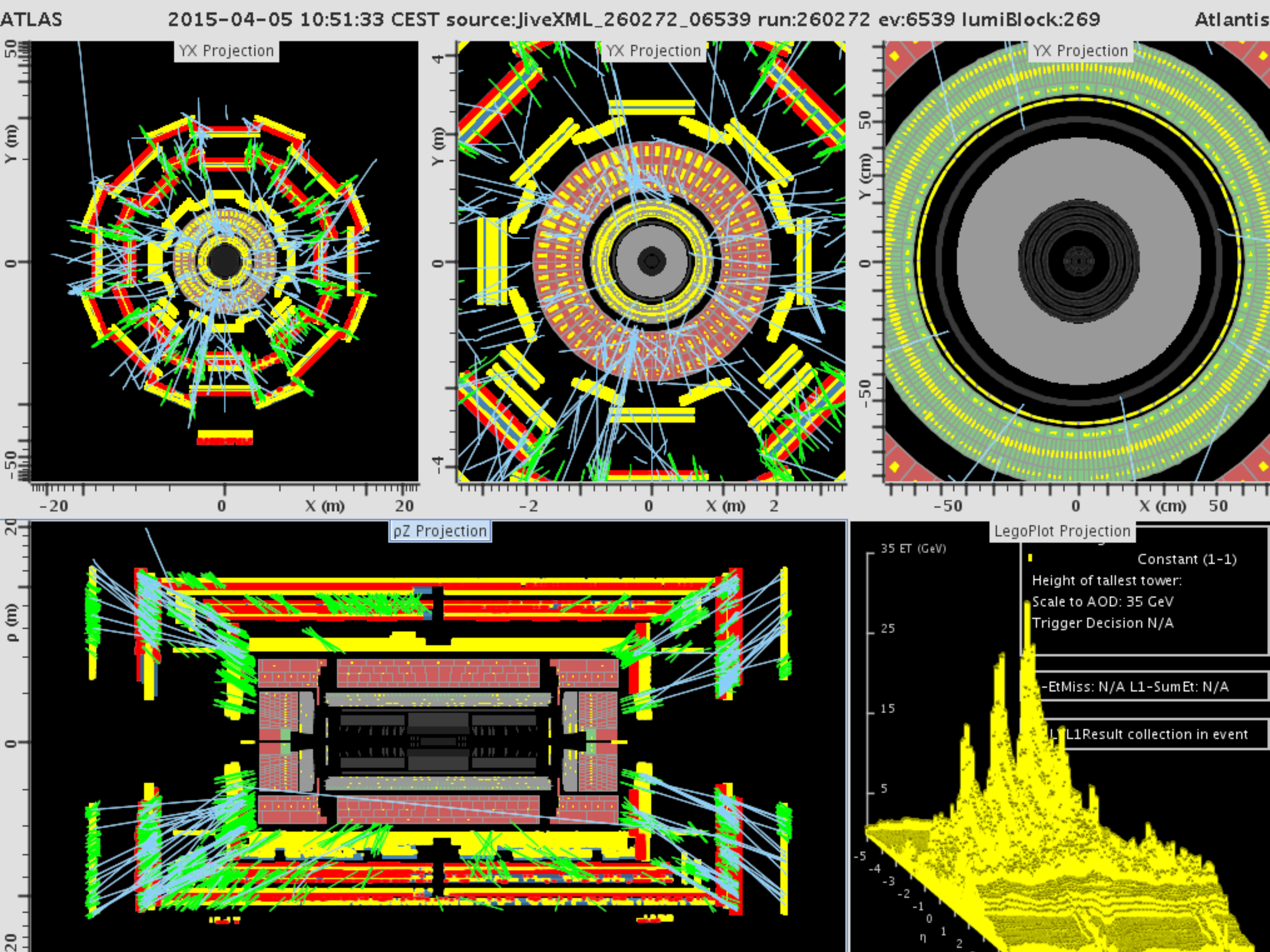


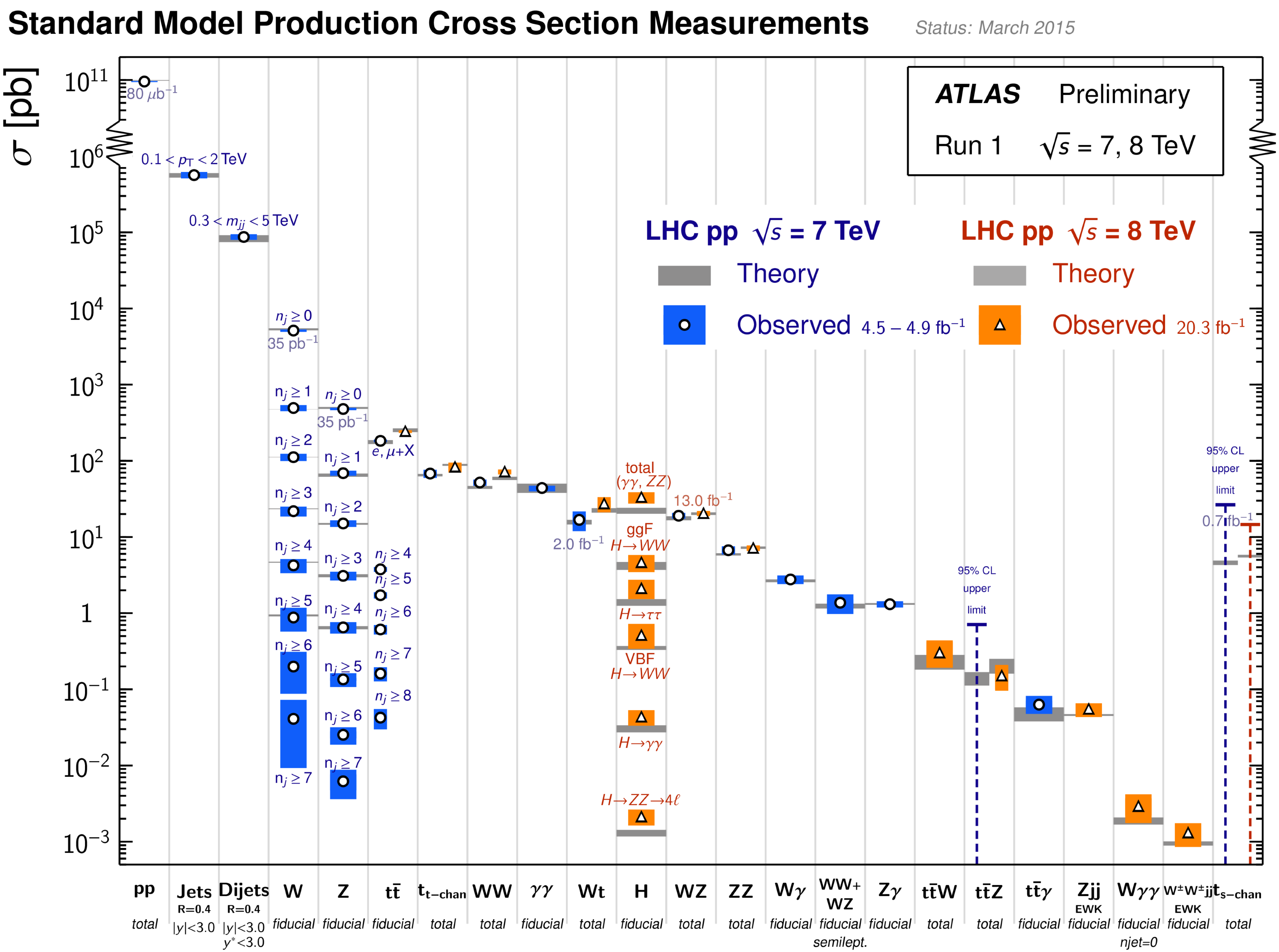
IFAE 2015 - 8 aprile - Roma

FISICA DELLE ALTE ENERGIE AI COLLISORI

Gigi Rolandi - CERN and Scuola Normale Superiore

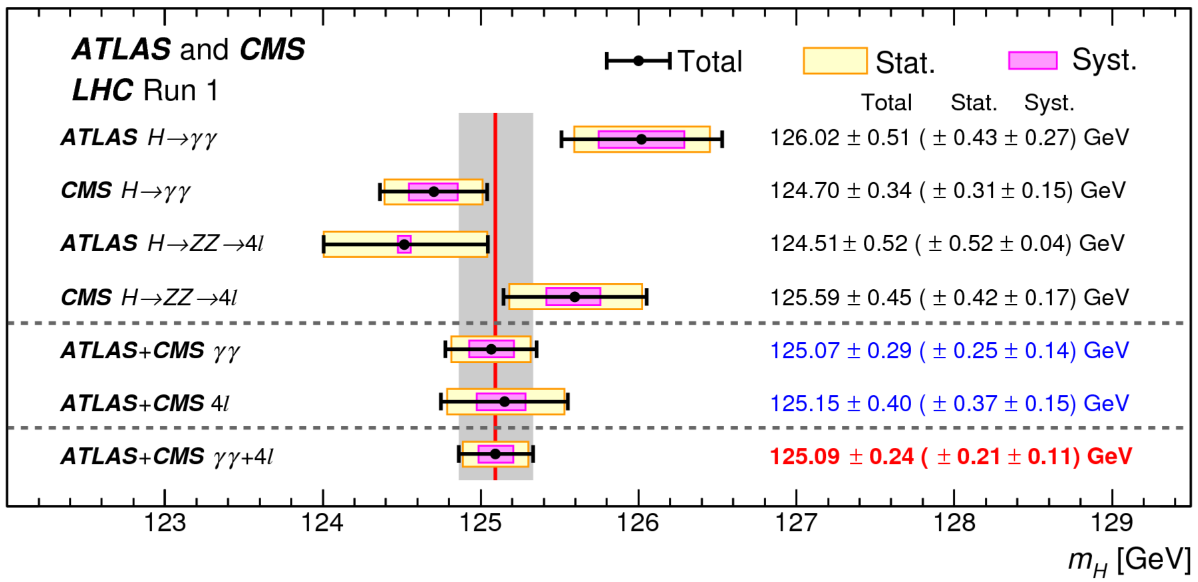

ATLAS
2015-04-05 10:51:33 CEST source:JiveXML_260272_06539 run:260272 ev:6539 lumiBlock:269
Atlantis
YX Projection
Y (m)
X (m)
-20
0
20
50
-50
YX Projection
-2
0
2
4
-4
YX Projection
Y (cm)
X (cm)
-50
0
50
ρZ Projection
ρ (m)
20
0
LegoPlot Projection
35 ET (GeV)
25
15
5
Constant (1-1)
Height of tallest tower:
Scale to AOD: 35 GeV
Trigger Decision N/A
-EtMiss: N/A L1-SumEt: N/A
L1Result collection in event
η

LHC Run 1

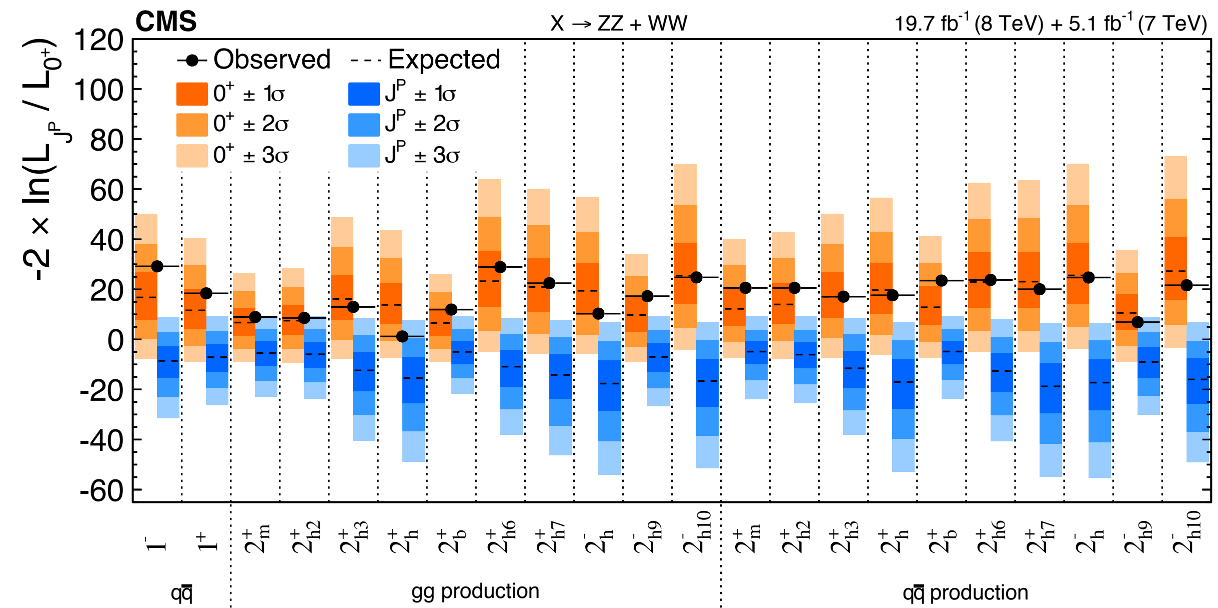


Standard Model Production Cross Section Measurements
Status: March 2015
σ [pb]
ATLAS Preliminary
Run 1 √s = 7, 8 TeV
LHC pp √s = 7 TeV
Theory
Observed 4.5 – 4.9 fb⁻¹
LHC pp √s = 8 TeV
Theory
Observed 20.3 fb⁻¹
80 μb⁻¹
0.1 < pT < 2 TeV
0.3 < mjj < 5 TeV
35 pb⁻¹
e, μ+X
total (γγ, ZZ)
ggF H→WW
H→ττ
VBF H→WW
H→γγ
H→ZZ→4ℓ
13.0 fb⁻¹
2.0 fb⁻¹
95% CL upper limit
0.7 fb⁻¹
pp total
Jets R=0.4 |y|<3.0
Dijets R=0.4 |y|<3.0 y*<3.0
W fiducial
Z fiducial
tt̄ fiducial
tt-chan total
WW total
γγ fiducial
Wt total
H fiducial
WZ total
ZZ total
Wγ fiducial
WW+WZ fiducial semilept.
Zγ fiducial
tt̄W total
tt̄Z total
tt̄γ fiducial
Zjj EWK fiducial
Wγγ fiducial njet=0
W±W±jj EWK fiducial
ts-chan total

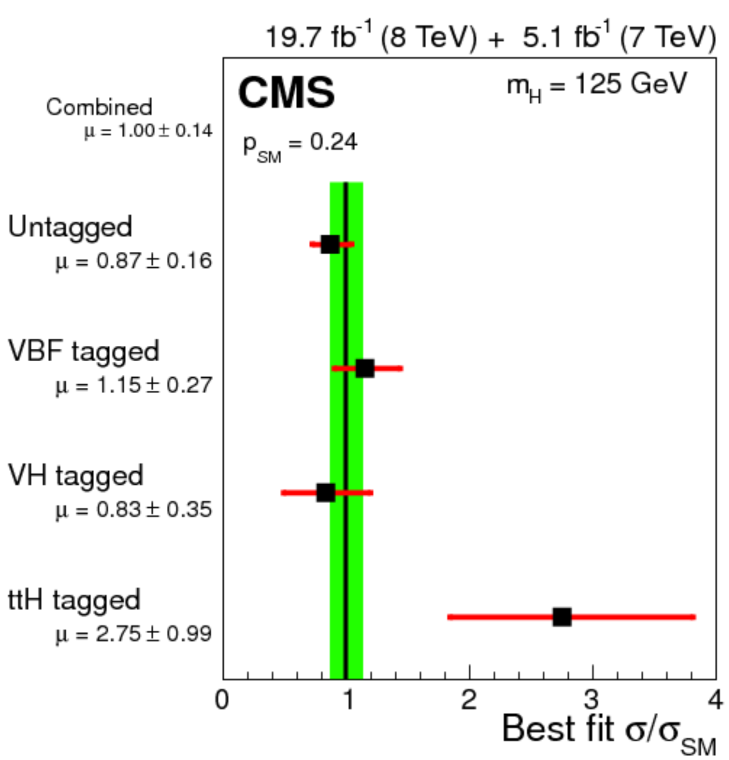
LHC Run 1: Higgs Boson properties

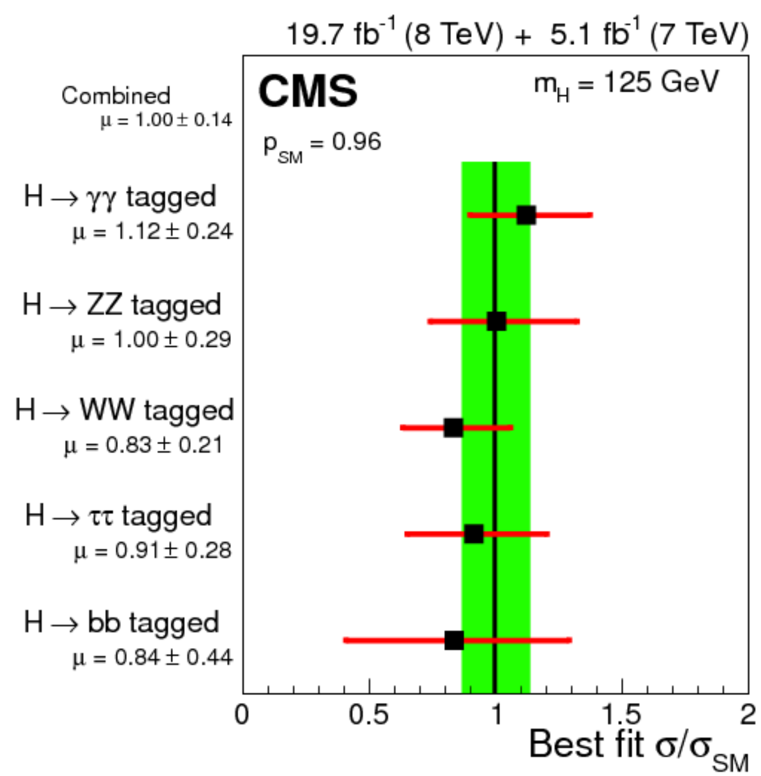


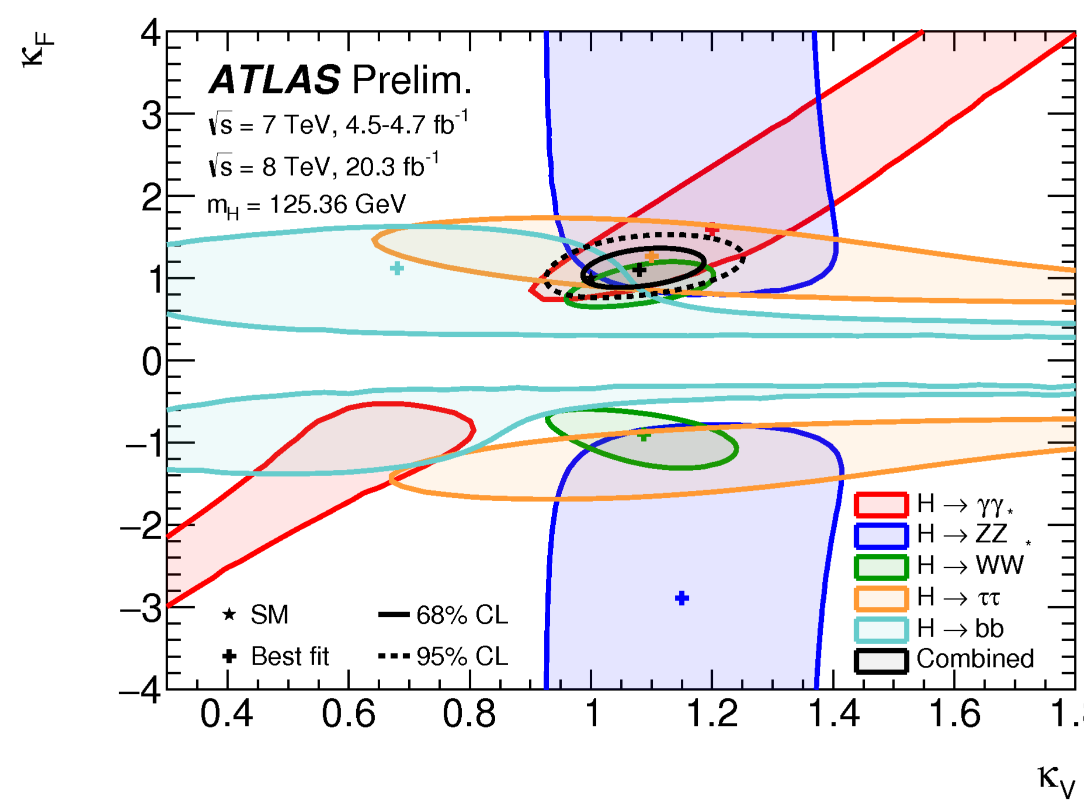
Mass known to 0.2%



J^P is 0^+

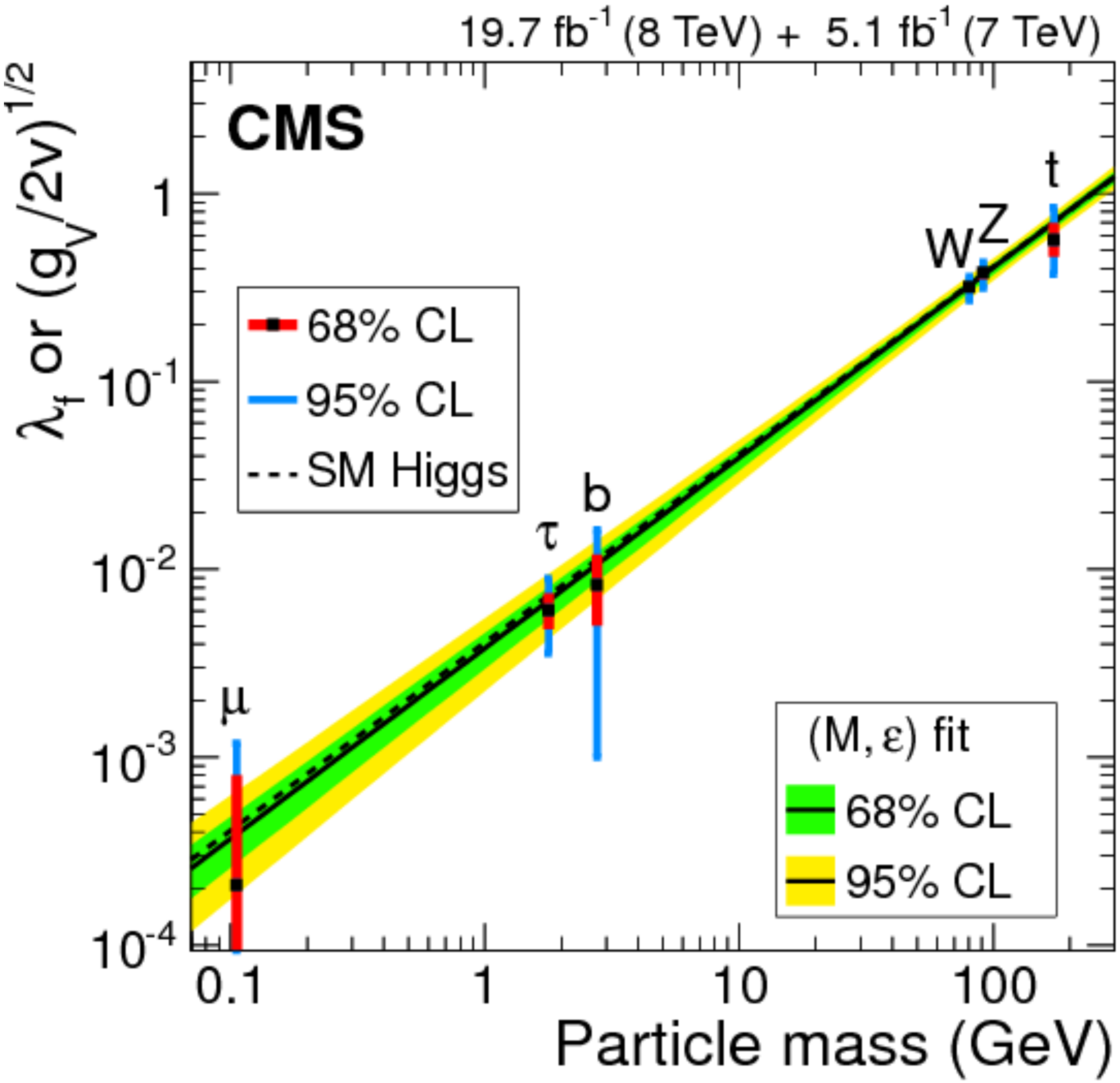






Couplings known to ~ 20%

After the discovery of the Higgs Boson:
Standard Model ——> Standard Theory

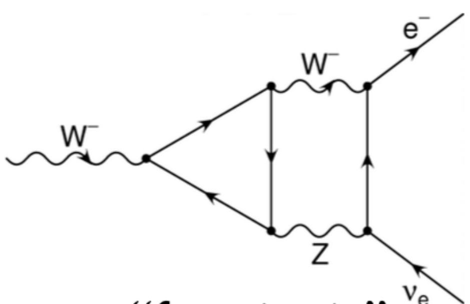


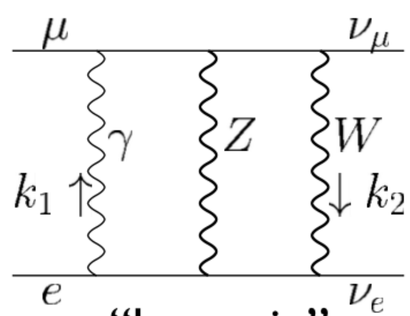
$$\lambda_{\mathrm{f}} \sim \kappa_{\mathrm{f}} m_{\mathrm{f}} / v$$

$$\sqrt{g_{\mathrm{V}} / (2v)} = \kappa_{\mathrm{V}}^{1/2} m_{\mathrm{V}} / v$$

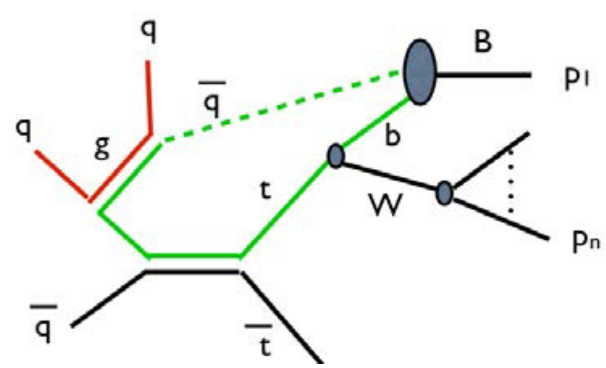
Global Electroweak FIT

Corrections calculated to 2 loops
EW precisions





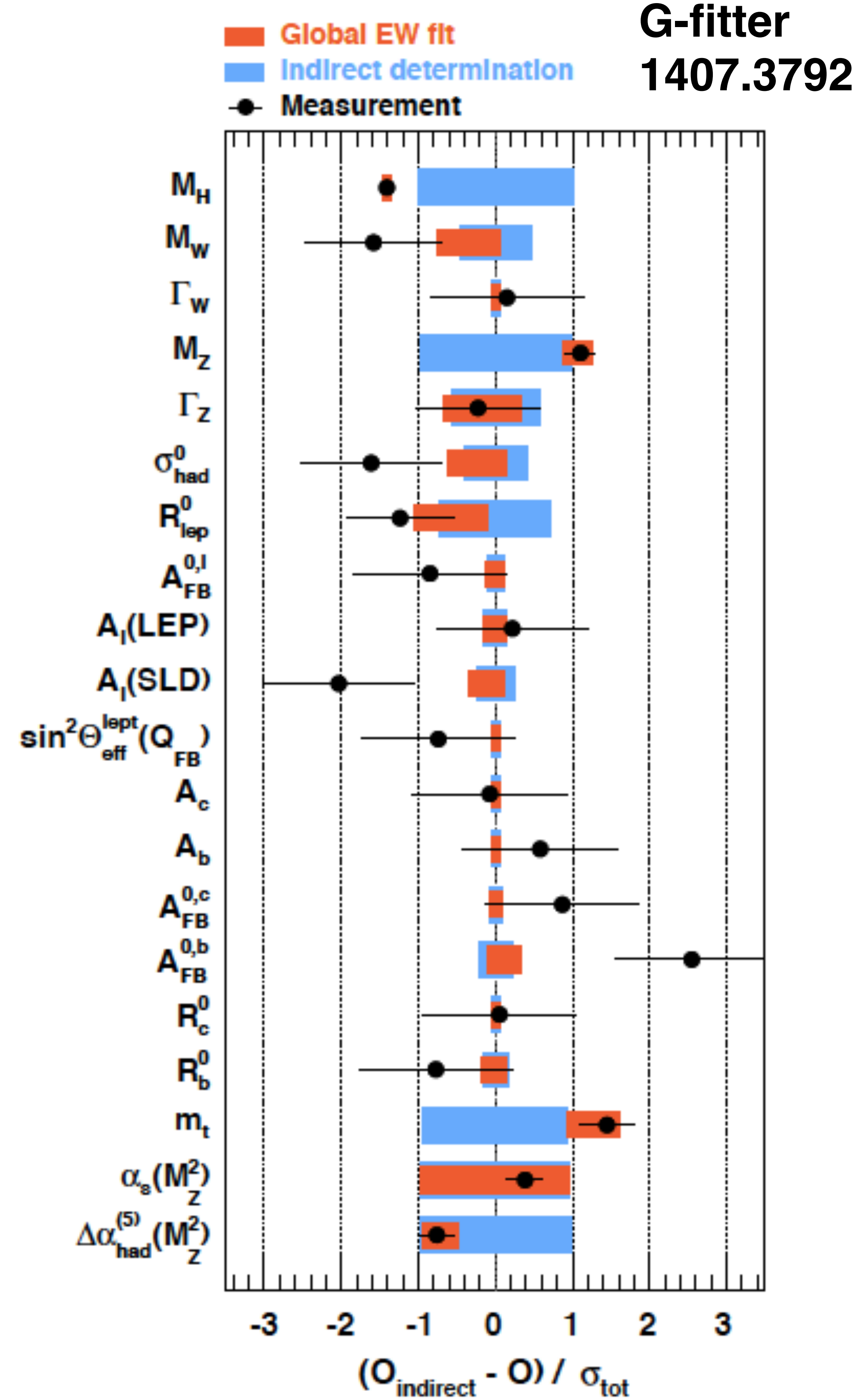
Includes 0.5 GeV top mass theoretical uncertainty



Improving M_W is high priority

$X^2/N_{dof}=17.8/14$ - 0.8σ

G-fitter
1407.3792



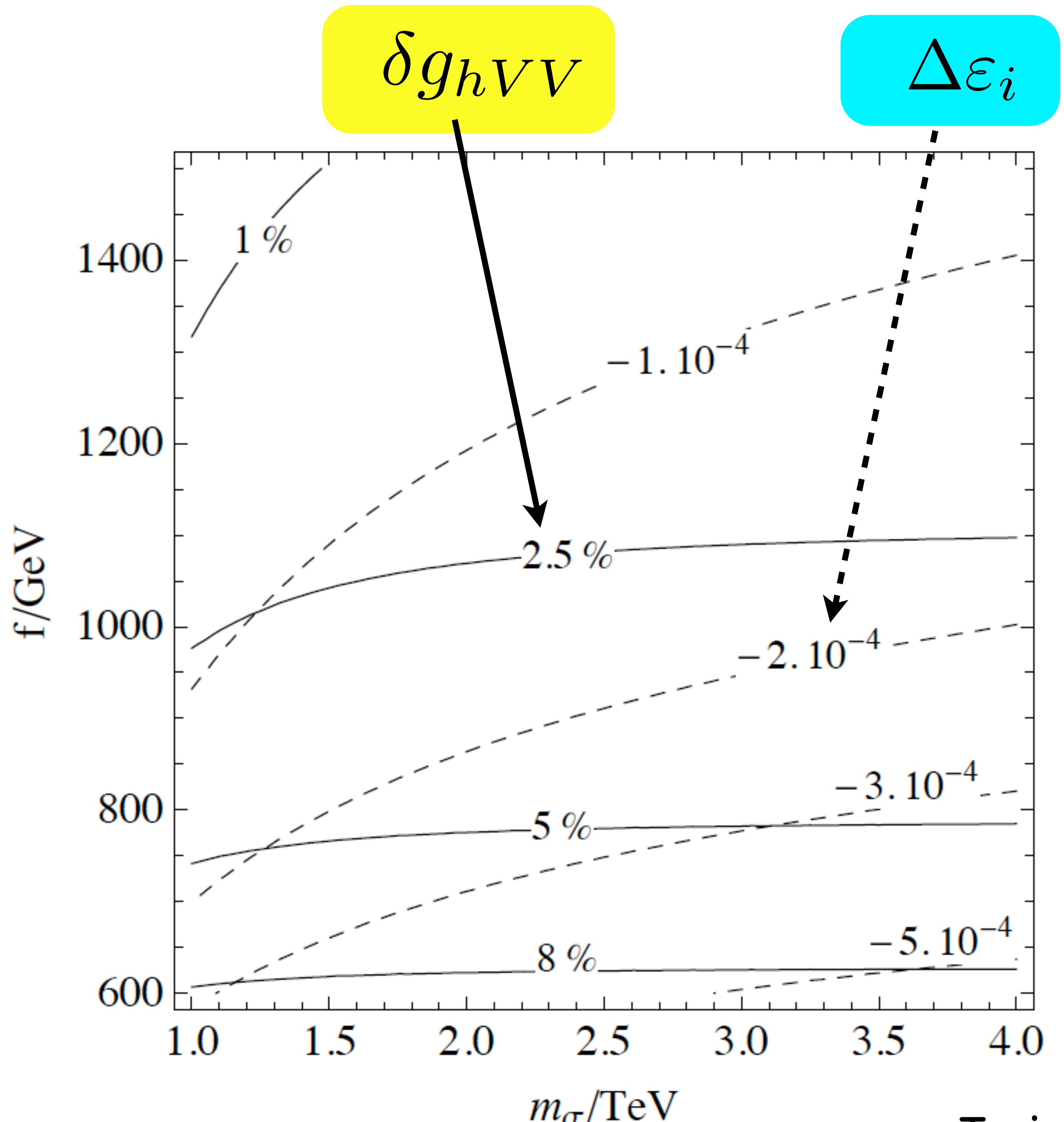
"Composite" Higgs boson ??

Barbieri Tesi 1311.7493

LHC14 after $300\ fb^{-1}$
$\delta g_{hVV} \approx 5\%$
(maybe down by a factor of 2 at HI-LHC if...)

At an e^+e^- h-factory
$\delta g_{hVV} < 1\%$

At TLEP
$\delta \varepsilon_i < 10^{-4}$

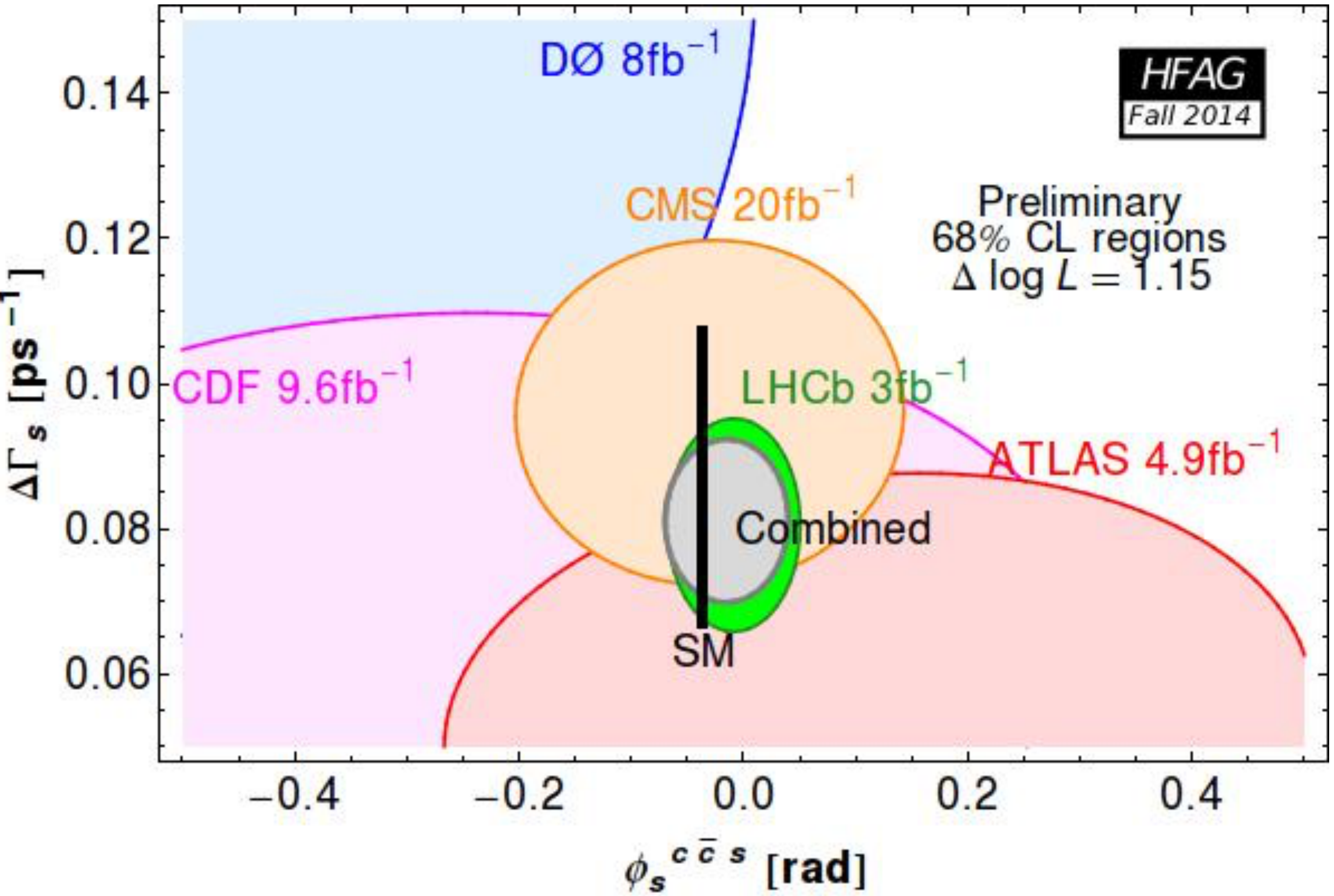


Tesi

Both types of precision tests highly motivated

Precision flavor physics

CP violation in the B_s system



$B^0_s \to J/\psi\, K^+K^-$

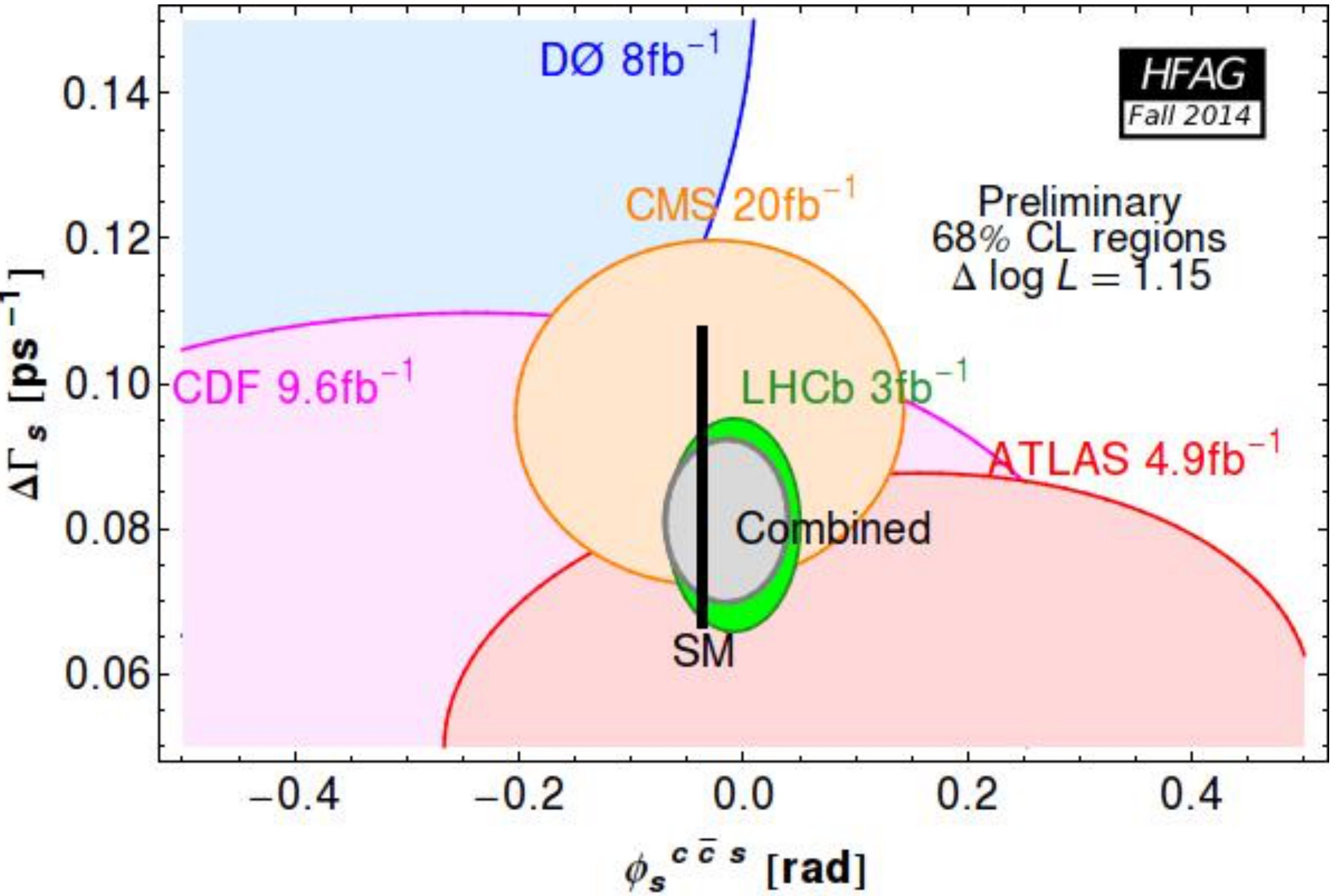
$\varphi_s = -\,0.058 \pm 0.049 \pm 0.006$ rad

$B^0_s \to J/\psi\, \pi^+\pi^-$

$\varphi^{\pi\pi}_s = +\,0.070 \pm 0.068 \pm 0.008$ rad

Precision flavor physics

CP violation in the B_s system

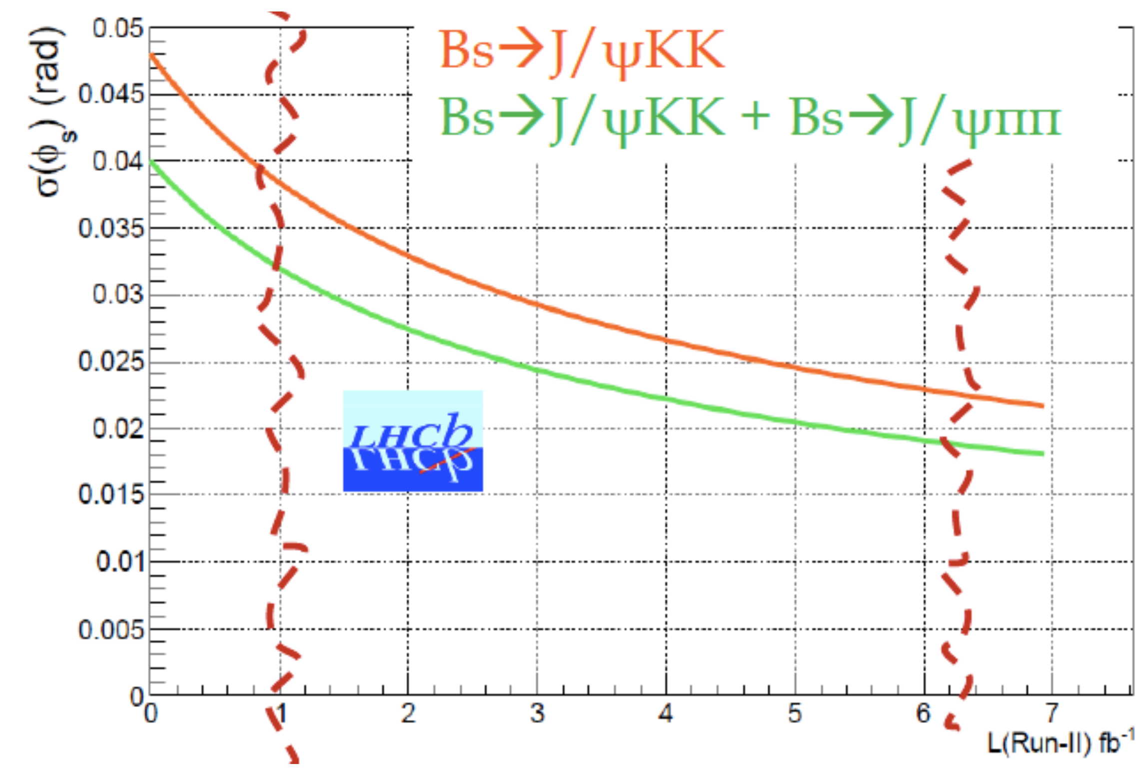


$B^0_s \to J/\psi\ K^+K^-$

$\varphi_s = -\ 0.058 \pm 0.049 \pm 0.006$ rad

$B^0_s \to J/\psi\ \pi^+\pi^-$

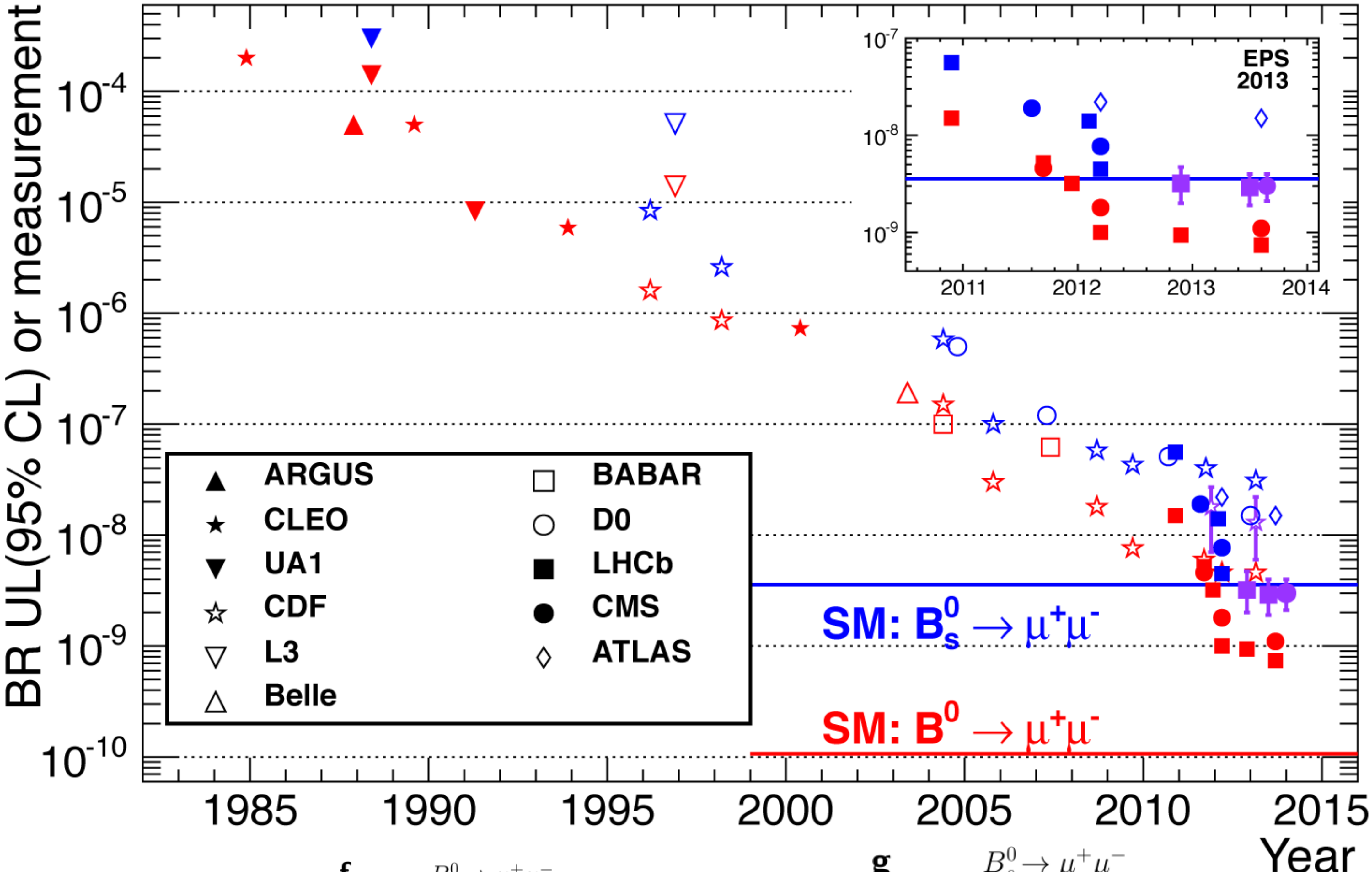
$\varphi^{\pi\pi}_s = +\ 0.070 \pm 0.068 \pm 0.008$ rad



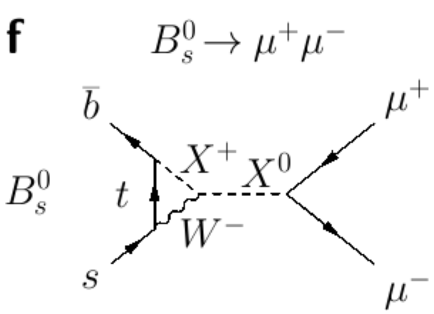
~ 2016

end of run II

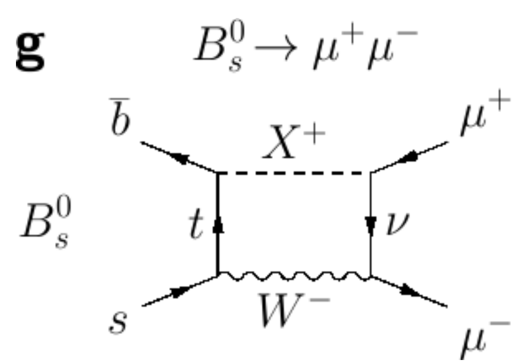
$B_{s,d}$ —> μμ


BR UL(95% CL) or measurement
Year
EPS 2013
ARGUS
CLEO
UA1
CDF
L3
Belle
BABAR
D0
LHCb
CMS
ATLAS
SM: $B_s^0 \to \mu^+\mu^-$
SM: $B^0 \to \mu^+\mu^-$

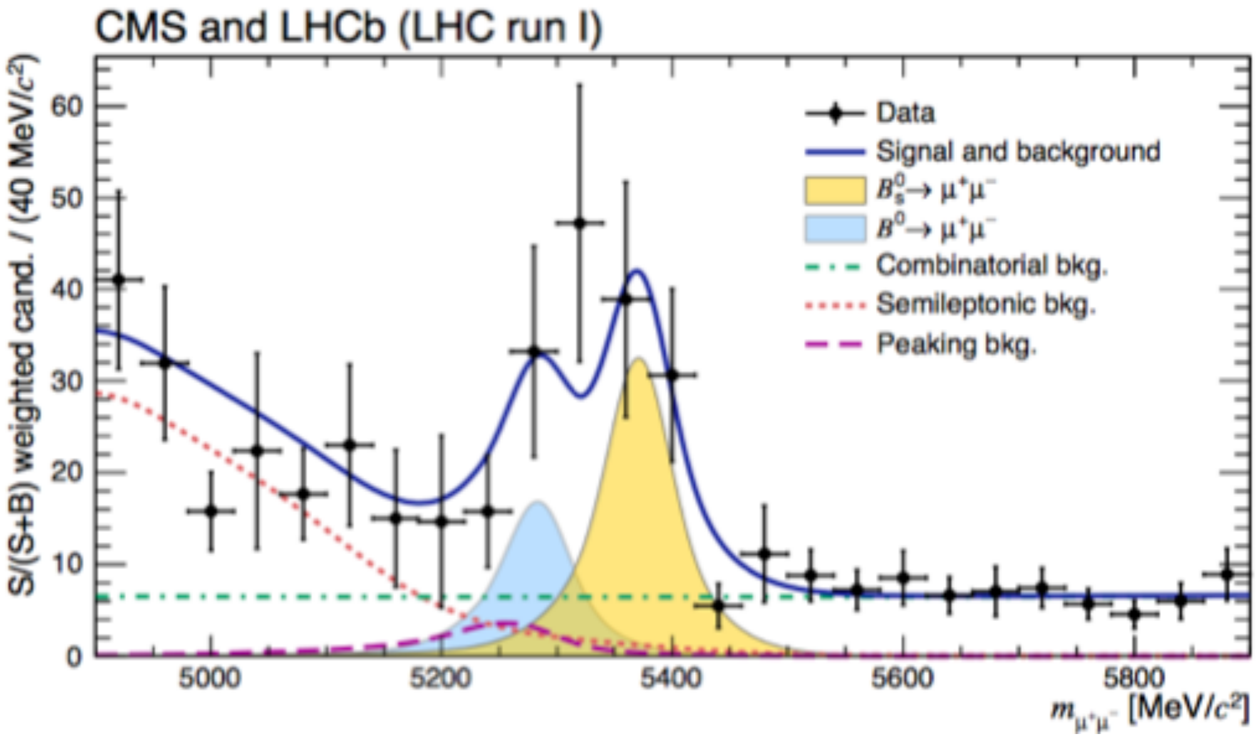
f

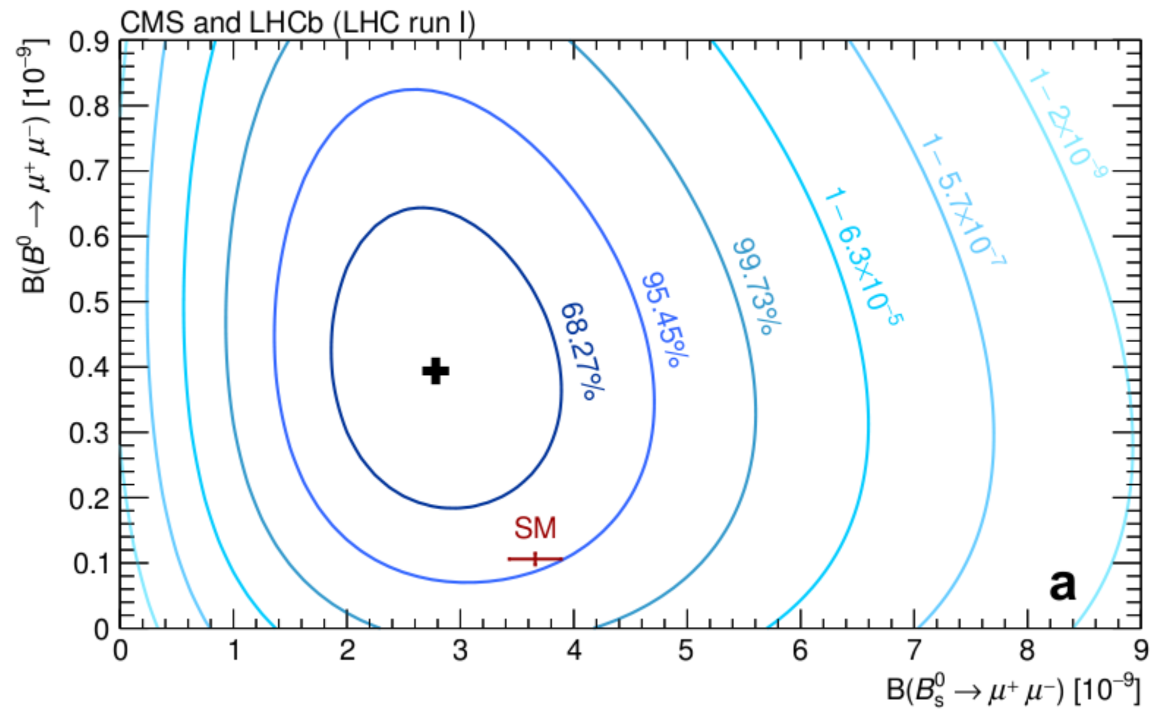

$B_s^0 \to \mu^+\mu^-$
$\bar{b}$
B_s^0
t
s
X^+
X^0
W^-
μ^+
μ^-

g


$B_s^0 \to \mu^+\mu^-$
$\bar{b}$
B_s^0
t
s
X^+
W^-
ν
μ^+
μ^-

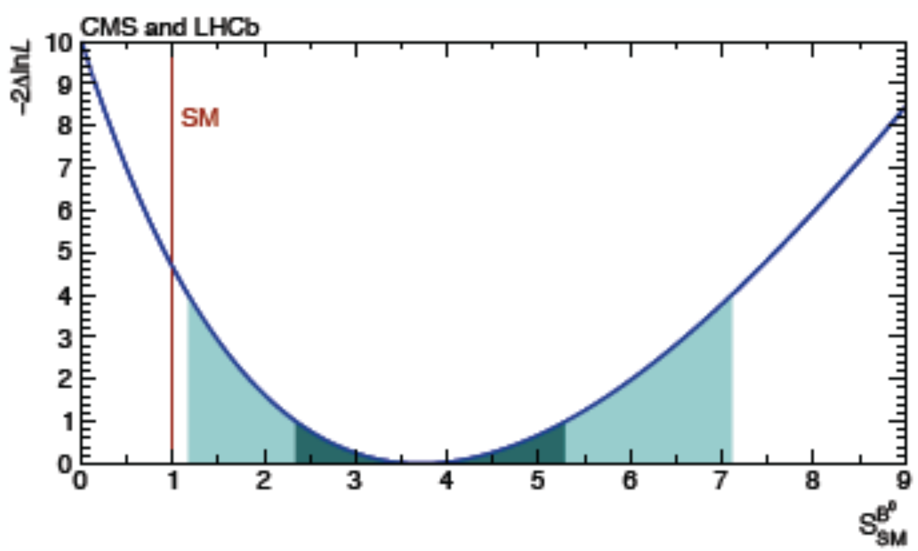
$B_{s,d}$ —> μμ

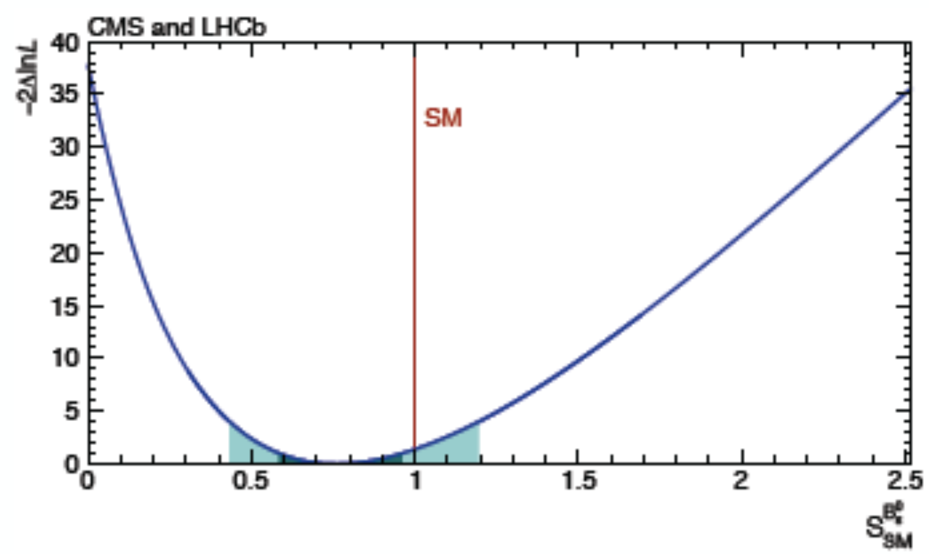




$\mathcal{BR}_d/\mathcal{BR}_d^{\mathcal{SM}}$

$\mathcal{BR}_s/\mathcal{BR}_s^{\mathcal{SM}}$

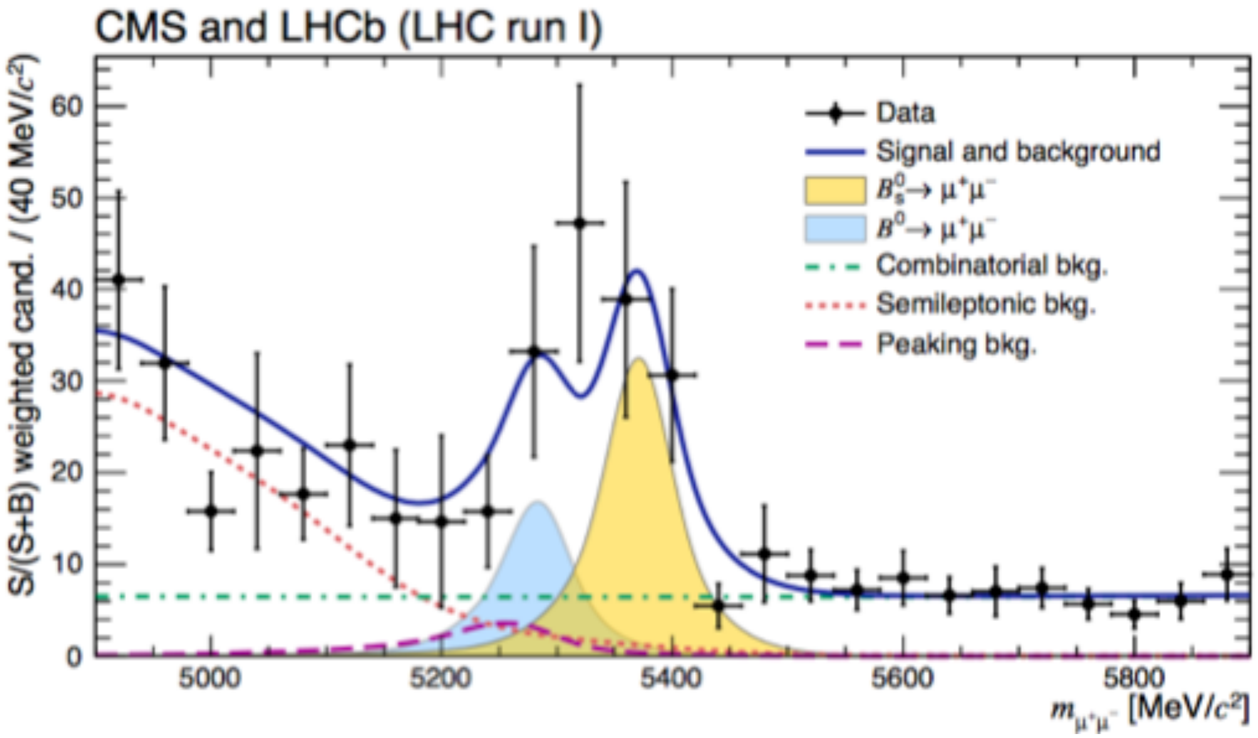


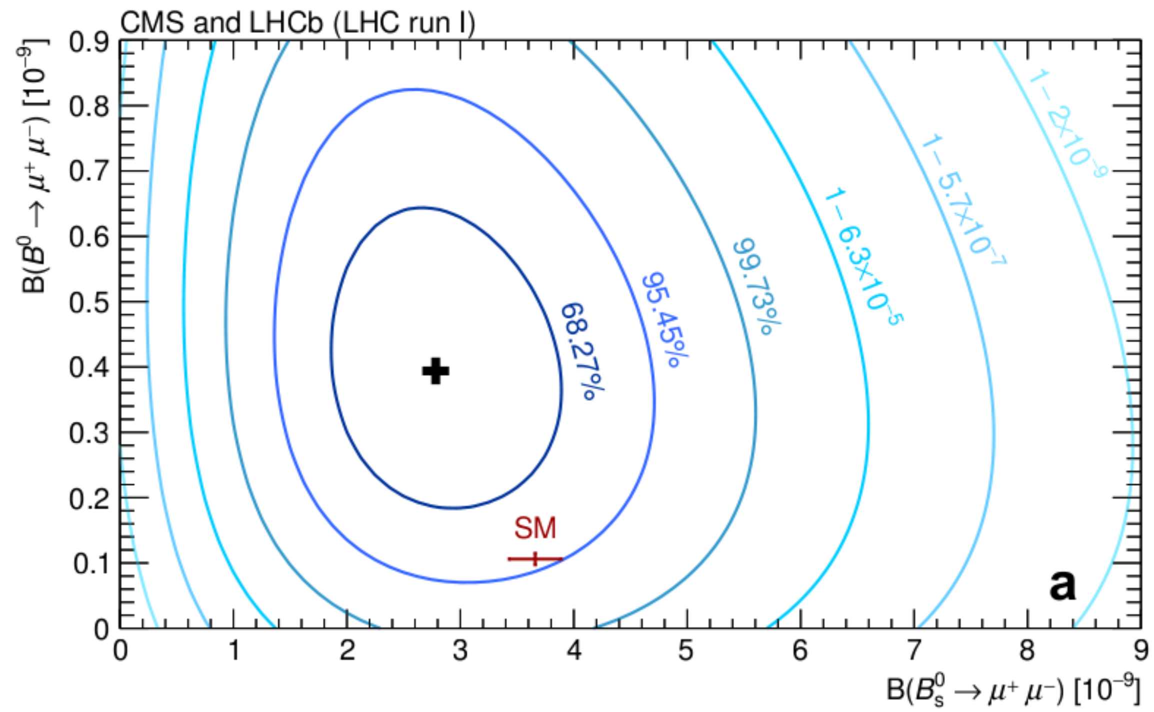


$$\mathcal{BR}_s/\mathcal{BR}_s^{\mathcal{SM}} = \left(0.76^{+0.20}_{-0.18}\right)$$

$$\mathcal{BR}_d/\mathcal{BR}_d^{\mathcal{SM}} = \left(\ 3.7^{+1.6}_{-1.4}\ \right)$$

$B_{s,d}$ —> μμ

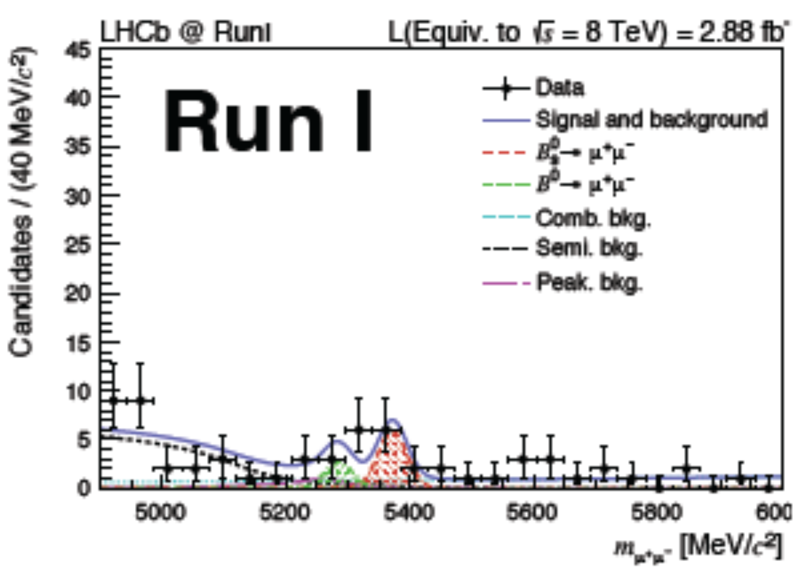


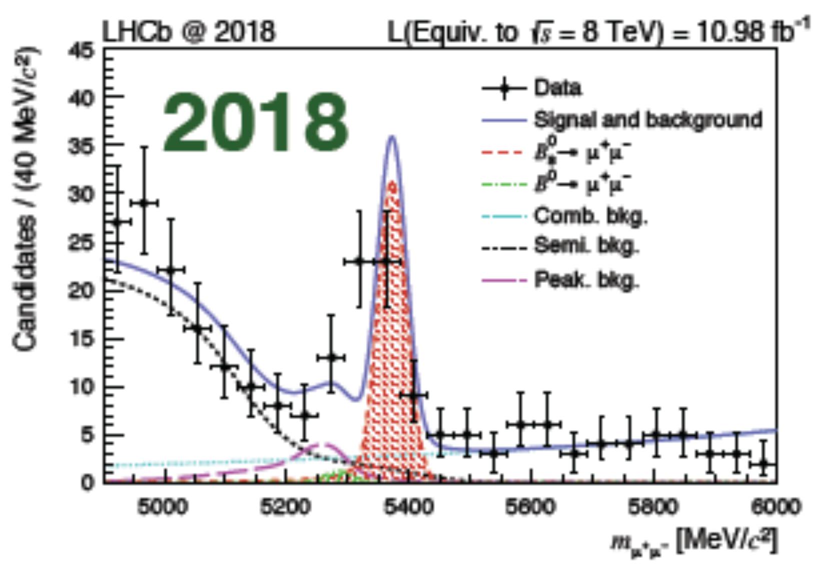


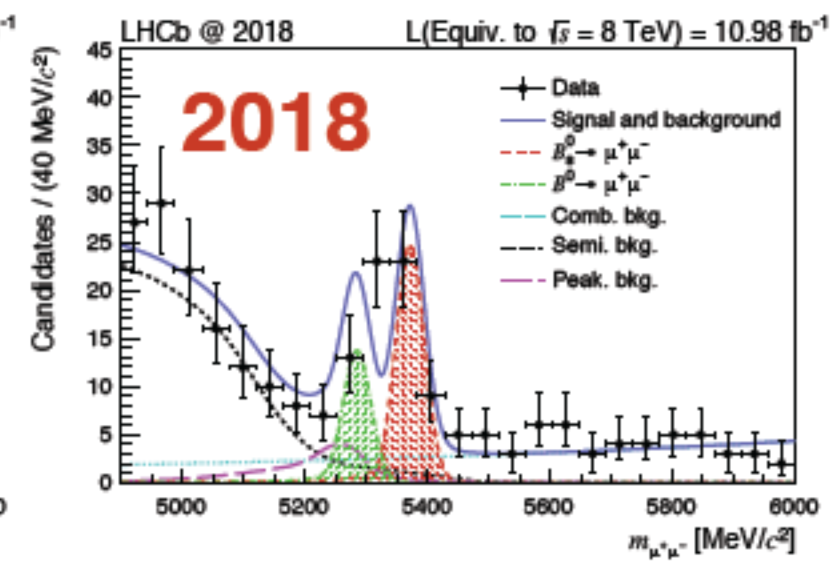
Siim Tolk

Scenario I:
With **SM** BR predictions

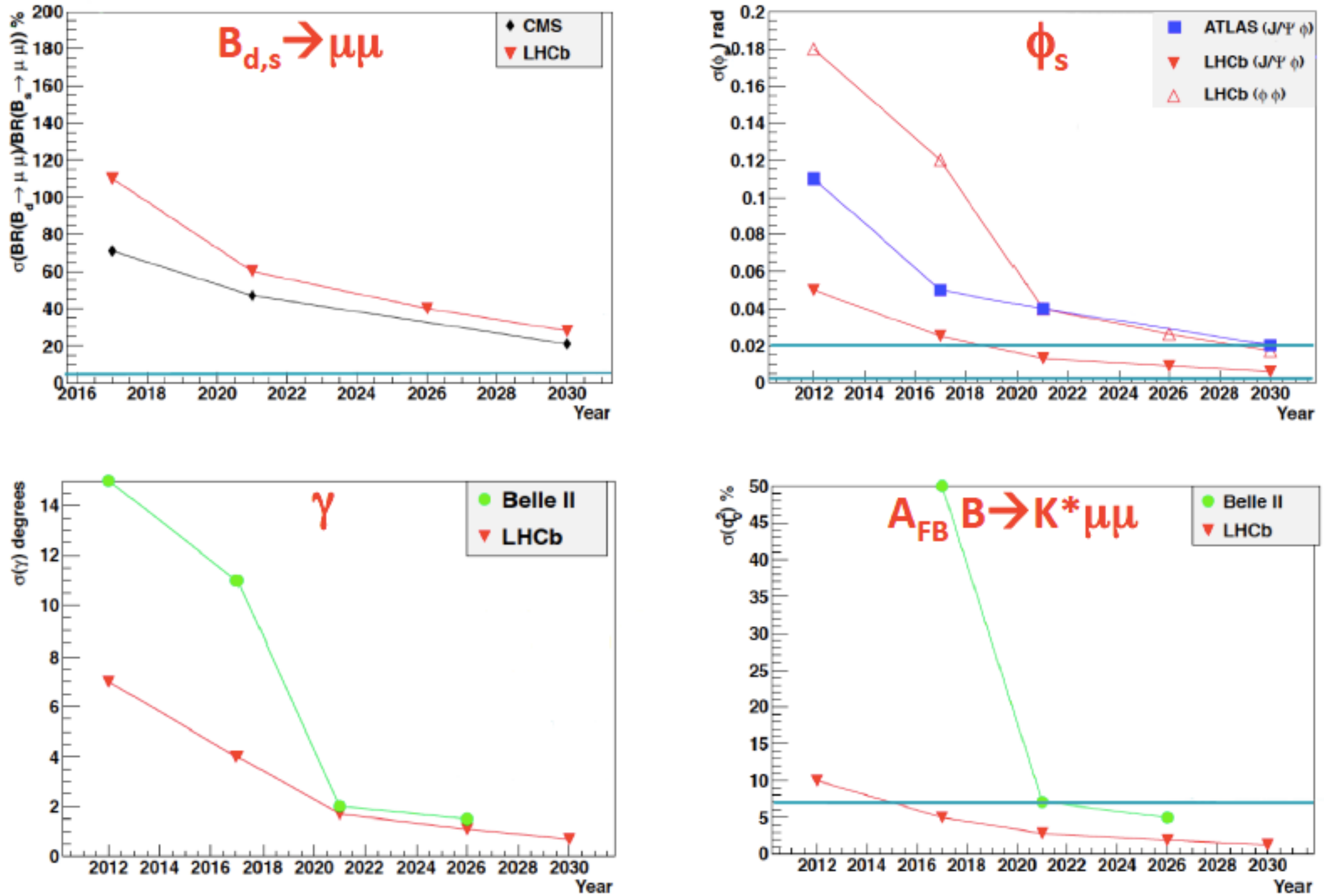
Scenario II:
With **measured** signal BR





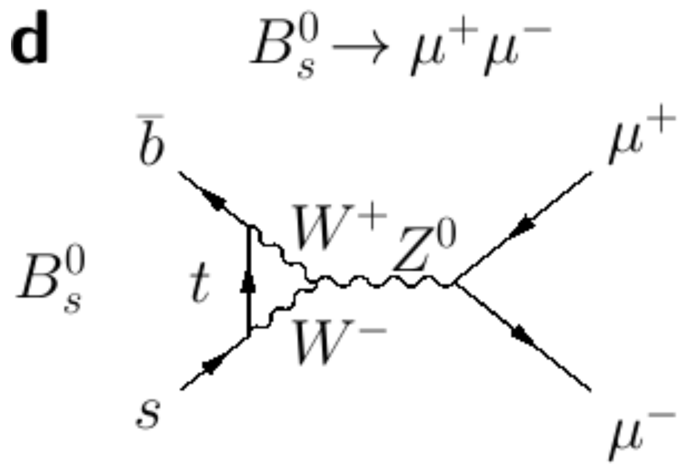


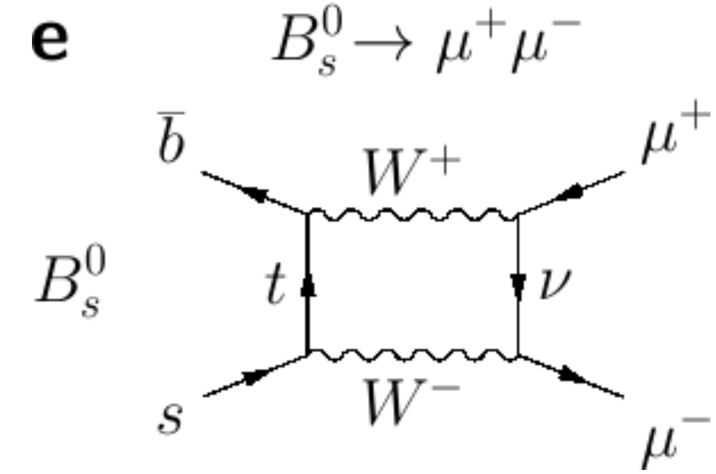
Ballistic program: Very nice prospects



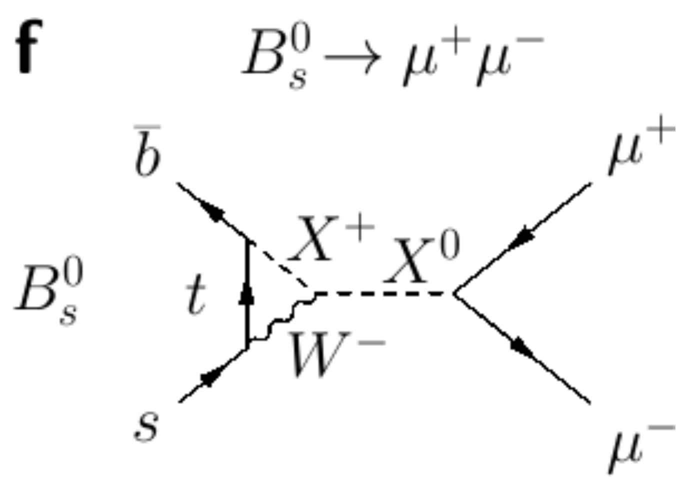
Vagnoni

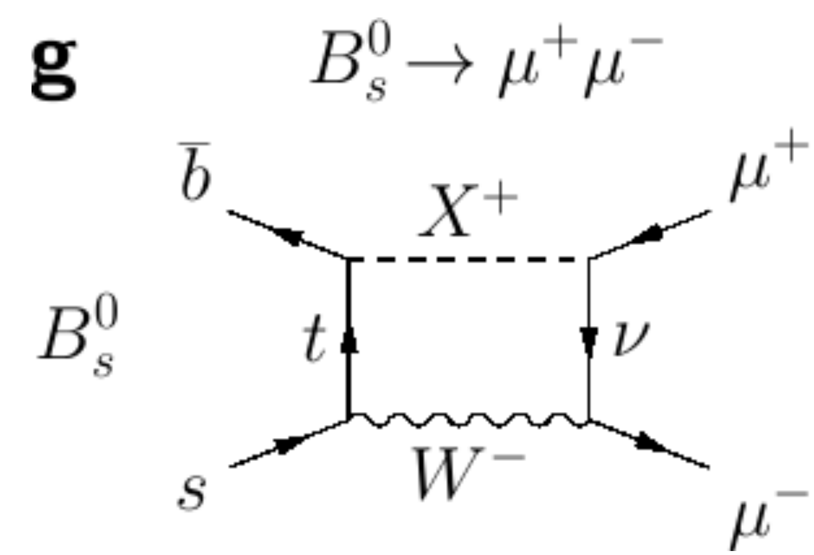
Presentation CNS1 Dec 2014



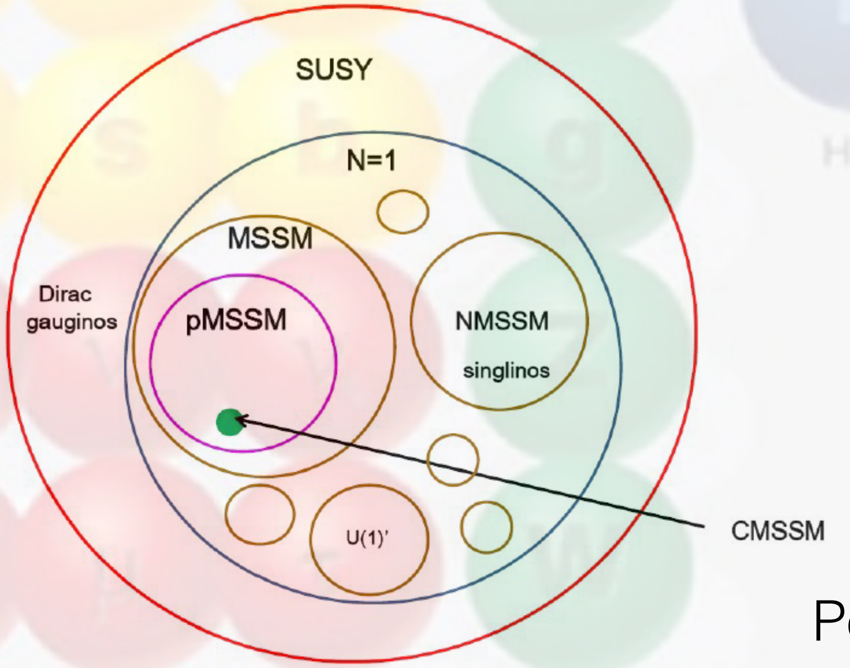


HOW COMPETITIVE with DIRECT SEARCHES ?





SUSY



Polesello

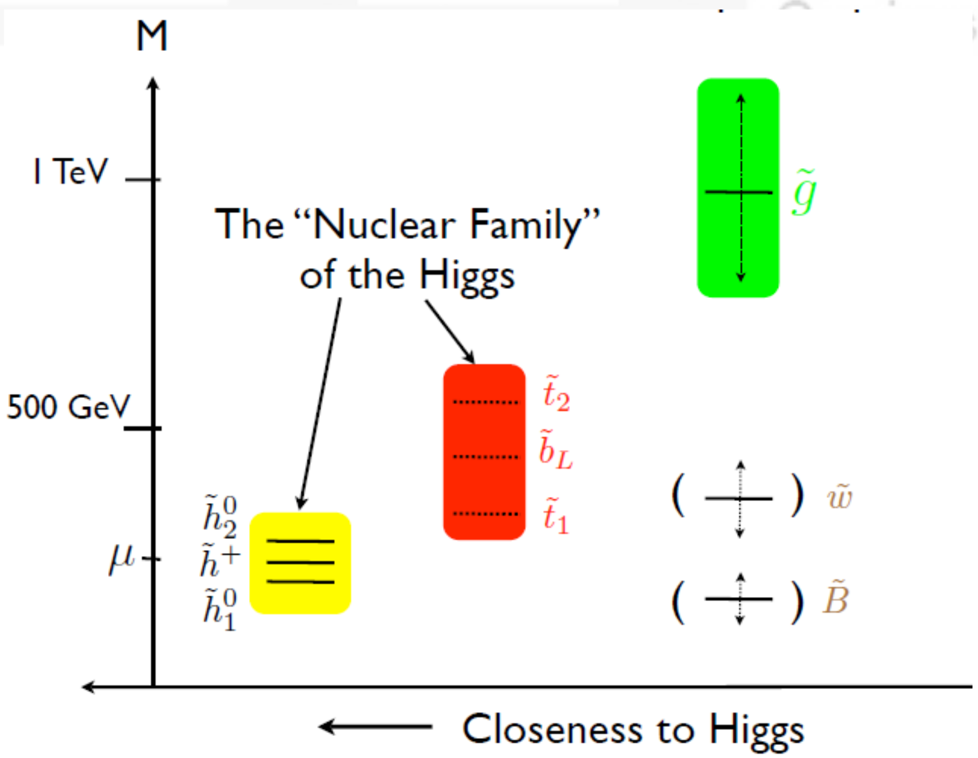
Sparticle masses from SUSY breaking not fixed by theory: large parameter space to saturate

Limiting to MSSM:

MSSM: ~109 parameters

pMSSM: 19 parameters

CMSSM: 4 parameters (+1 sign)



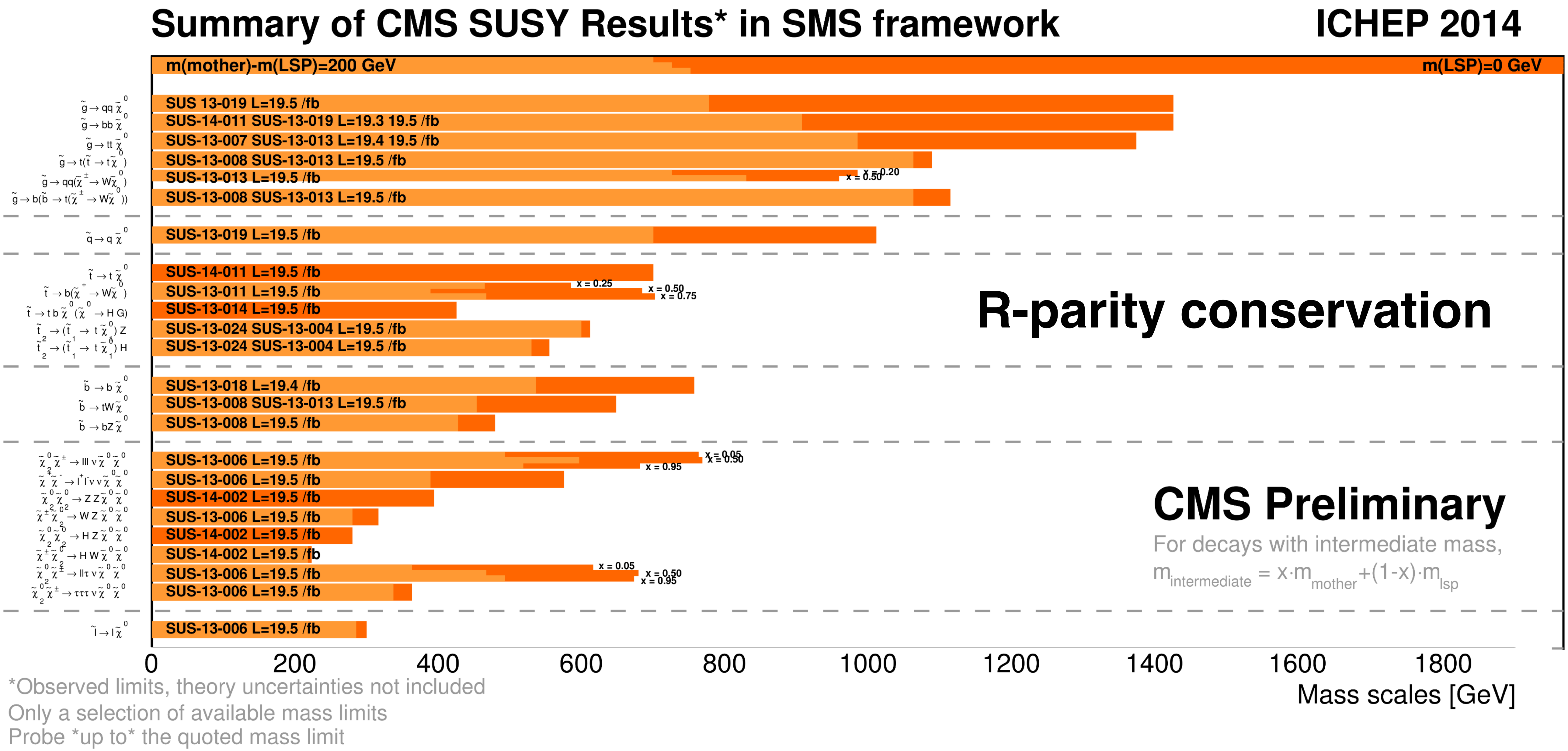
"small" fine tuning of the Higgs mass

Because of their radiative contribution to higgs mass, approximate upper limit:

Gluino ~ a few TeV

Stop ~ 1 TeV

Higgsino ~2-300 GeV



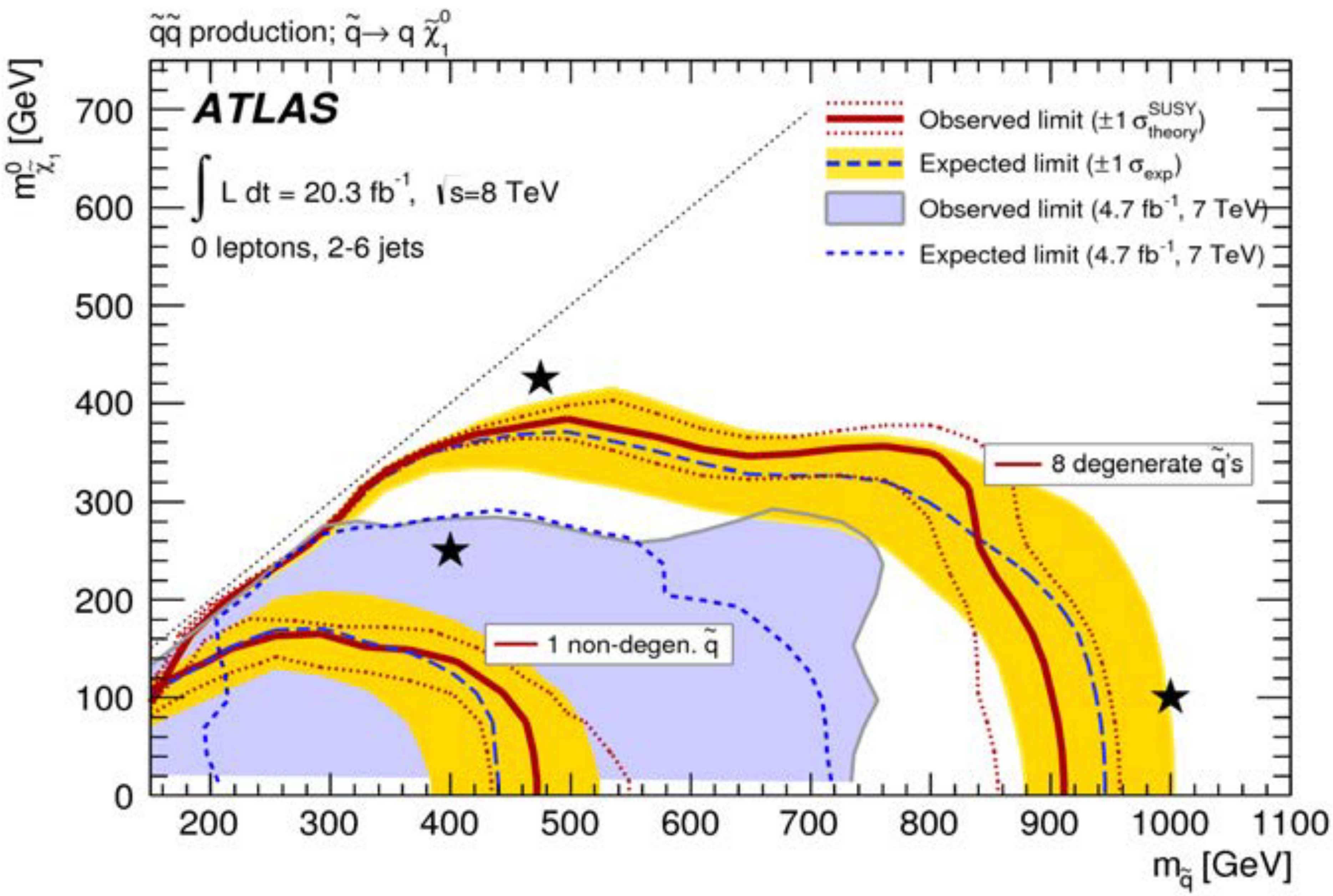
Main handle against SM is Missing Transverse Energy (MET) from undetected Lightest Supersymmetric Particle (LSP), assumed to be the lightest neutralino (chi01)

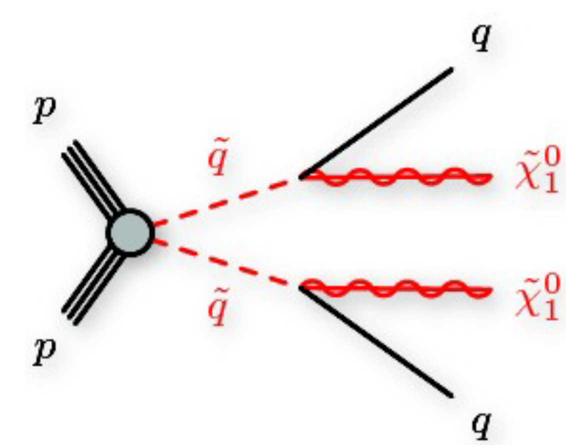
"Open" kinematics: two invisible particles in each event and no constraint on longitudinal boost of sparticle-sparticle system

Visible energy must be large enough to trigger !!

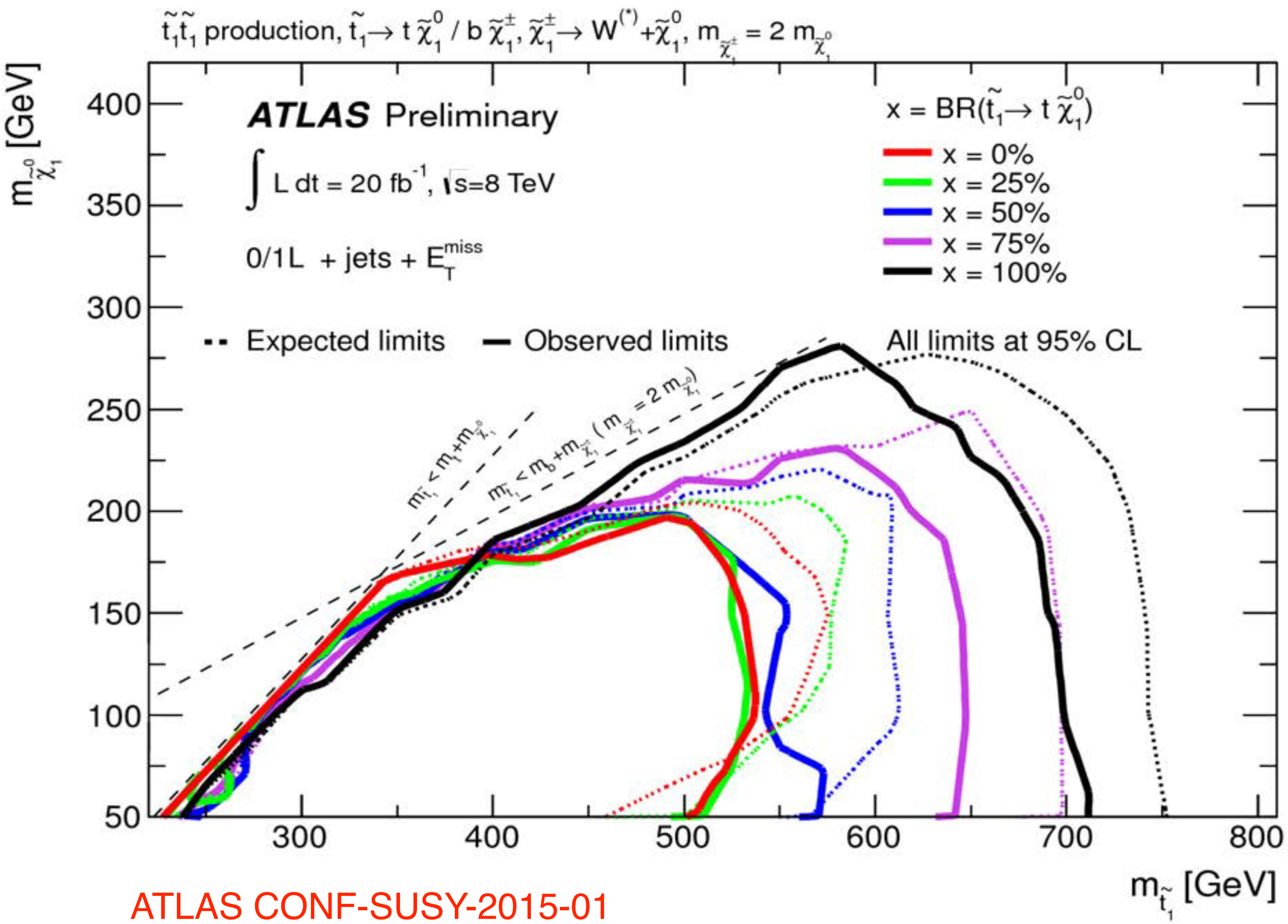
Simplified Models : good tool for analysis optimization and display

Assume 100% BR in both legs and the SUSY production cross-section

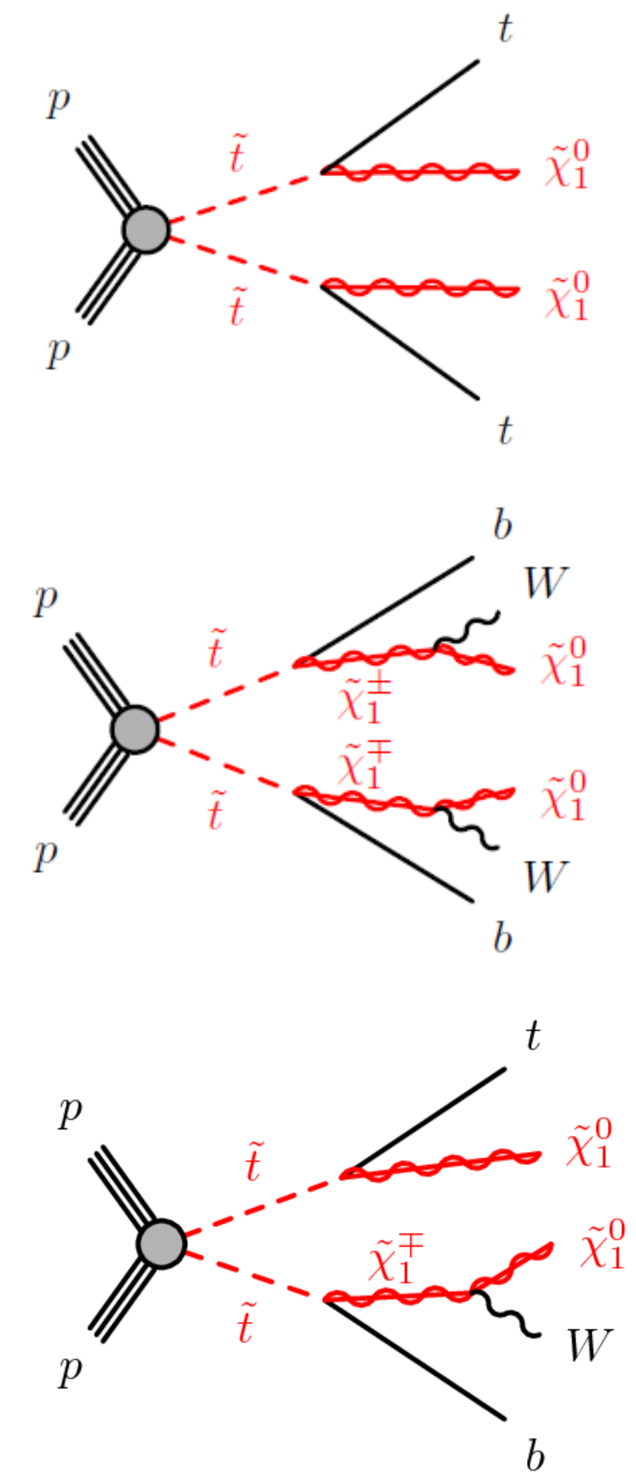




Branching ratio dependent stop limits



ATLAS CONF-SUSY-2015-01



Difficult regions ! Stop NLSP

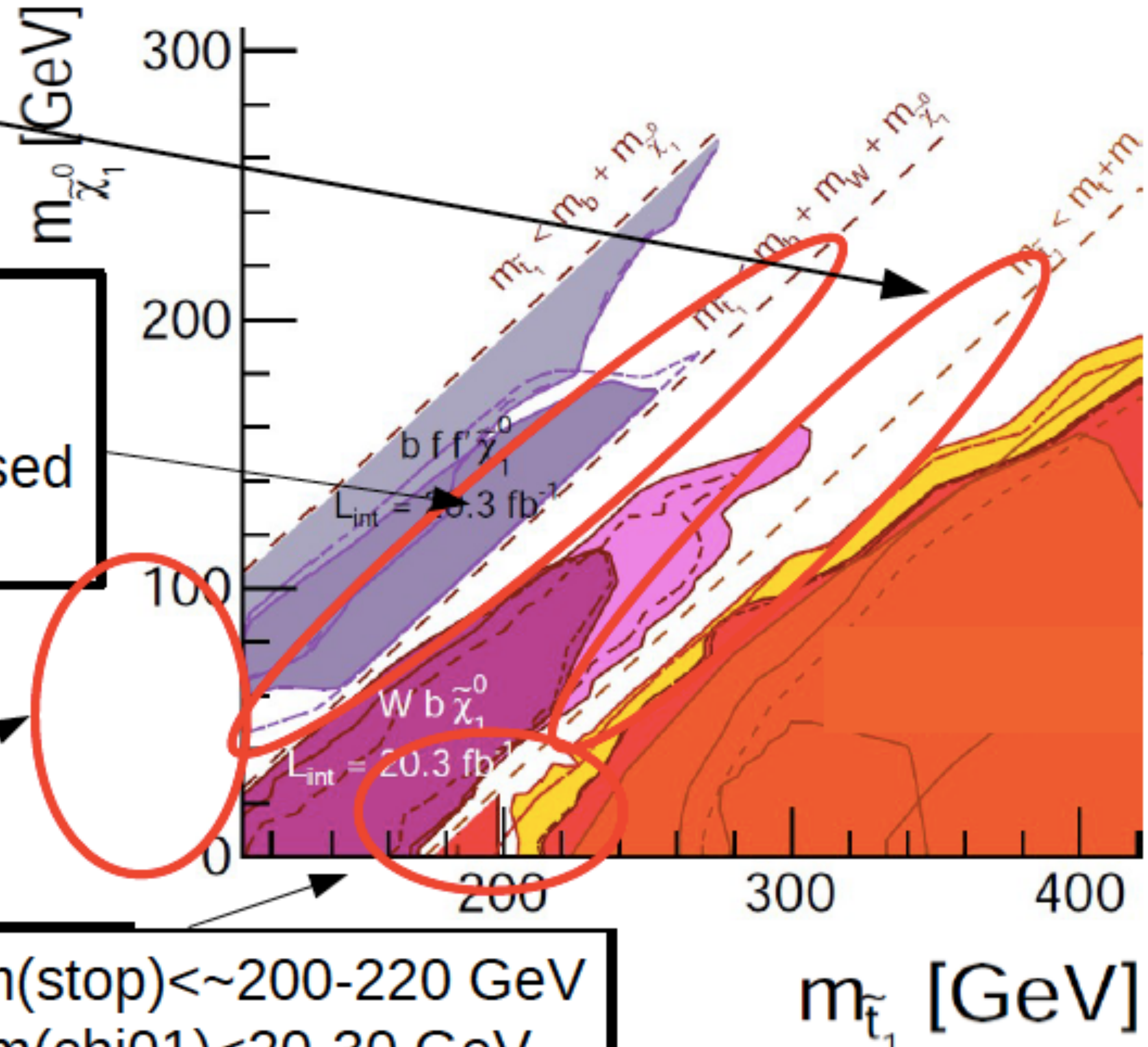
Polesello

Stop to charm (not shown) covers completely relevant region up to 200 GeV stop mass. Work in progress to verify whether stop excluded for any BR combination of stop → c chi01 and stop → bff'chi01

m(stop)>~250 GeV,
m(stop)-m(chi01)~m(t)

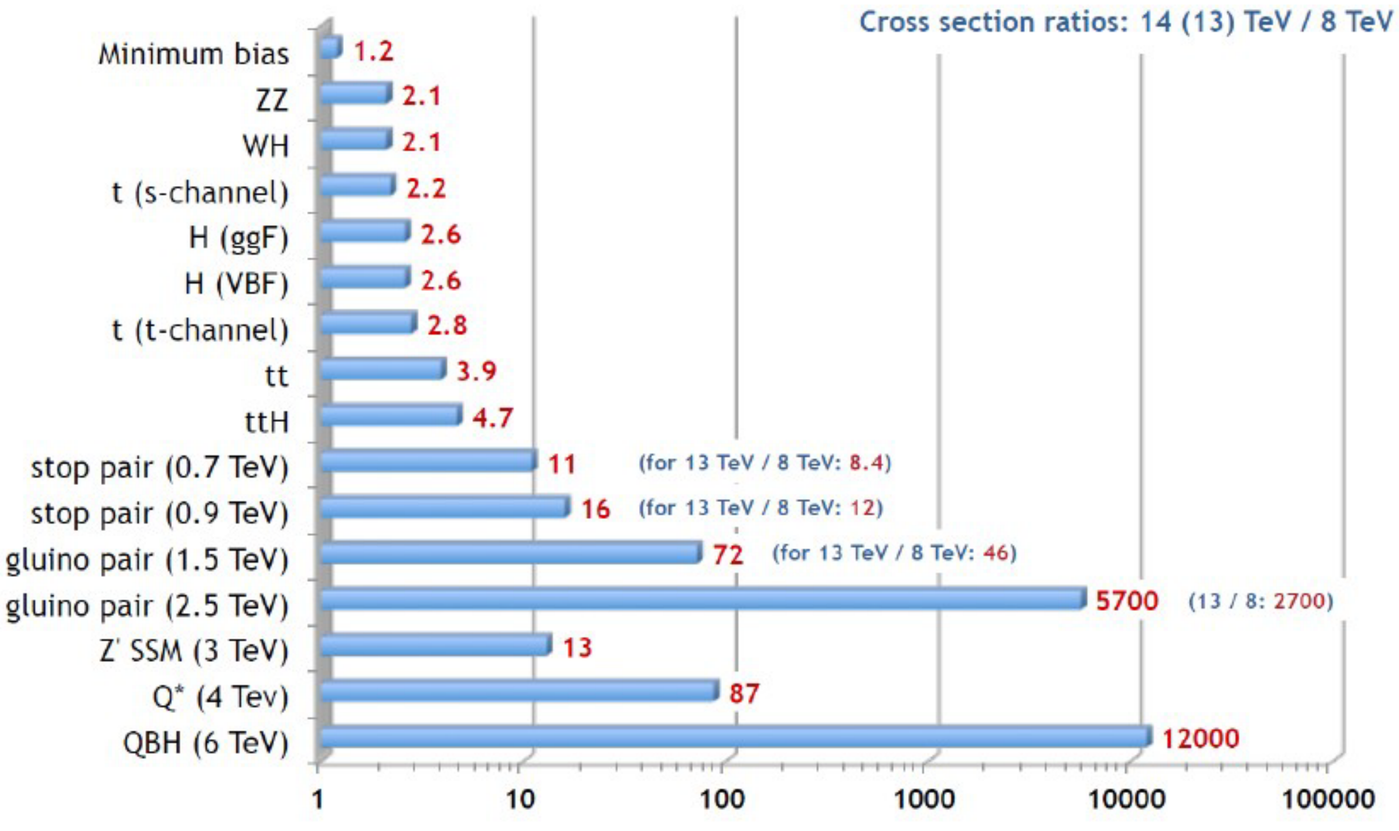
m(stop)-m(chi01)~m(W)
May be covered already with Run I data and dedicated MT2-based selection in 2-lepton channel?

m(stop)<100 GeV
Most likely OK,
Need to match LEP/Tevatron exclusions



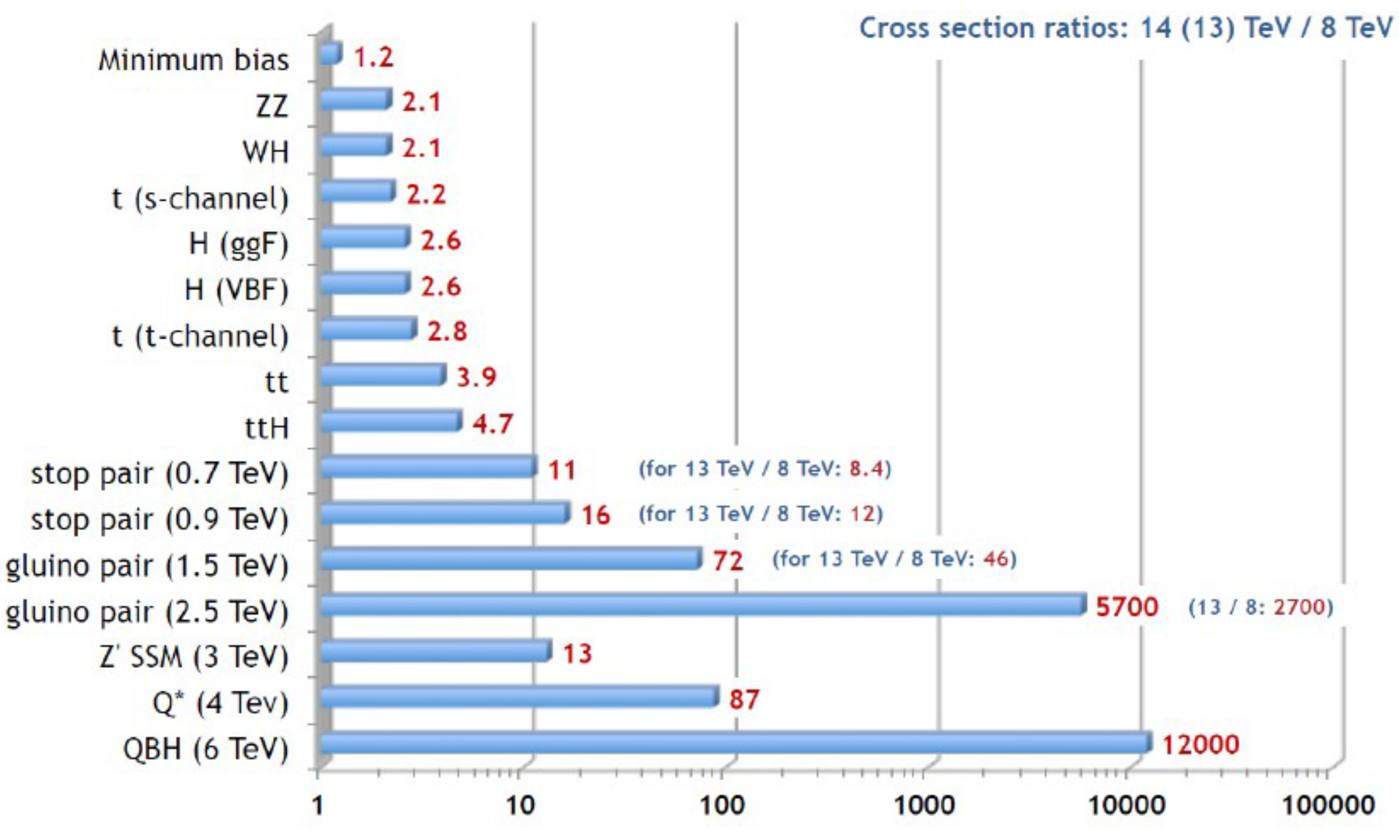
m(stop)<~200-220 GeV
m(chi01)<20-30 GeV

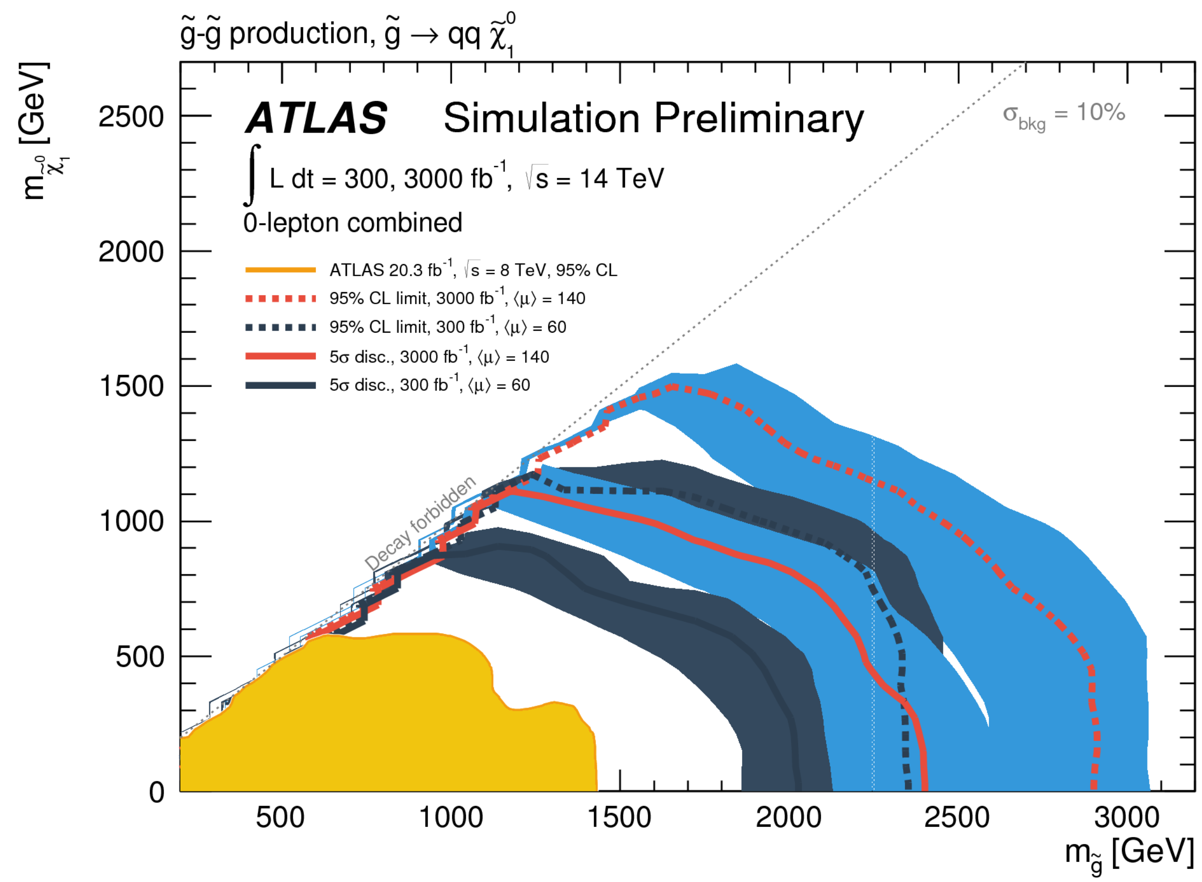
13 TEV !

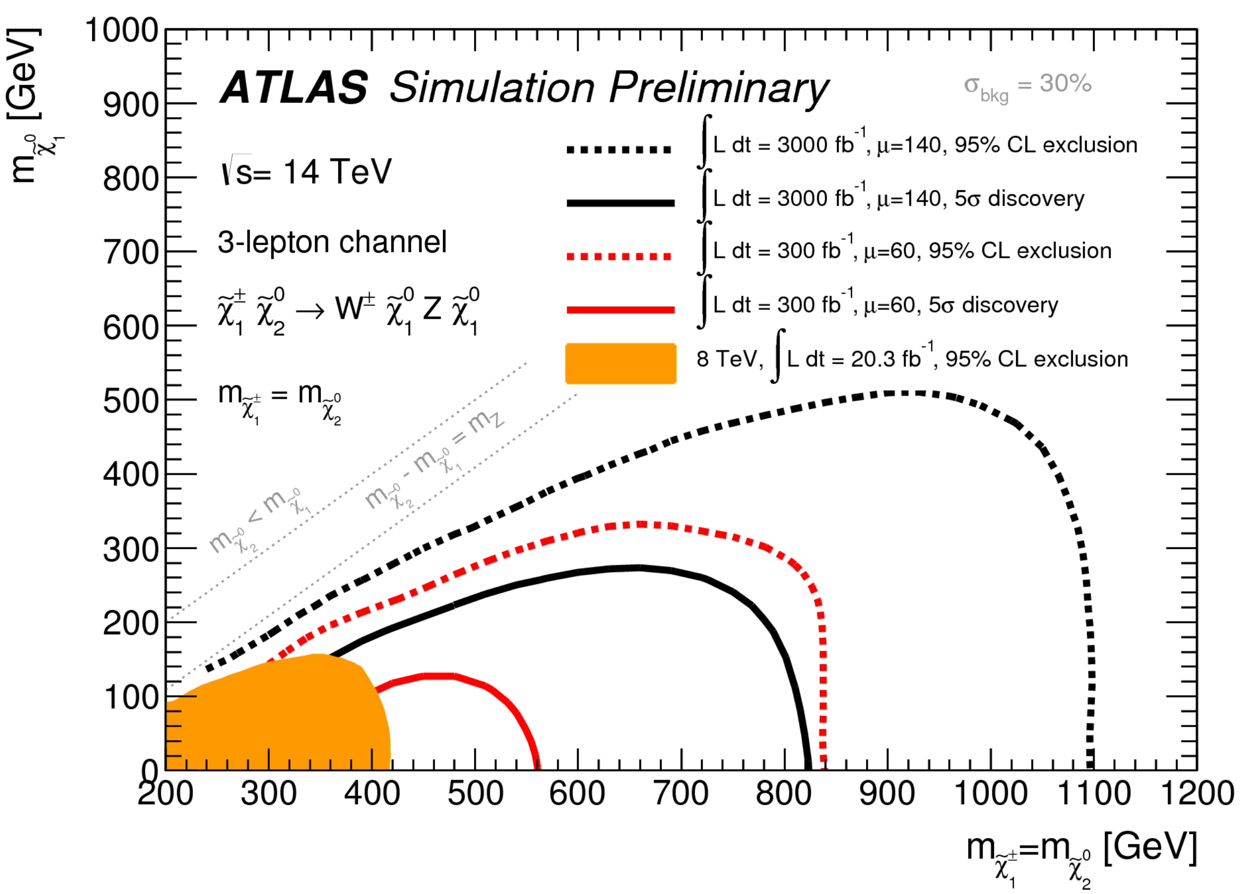


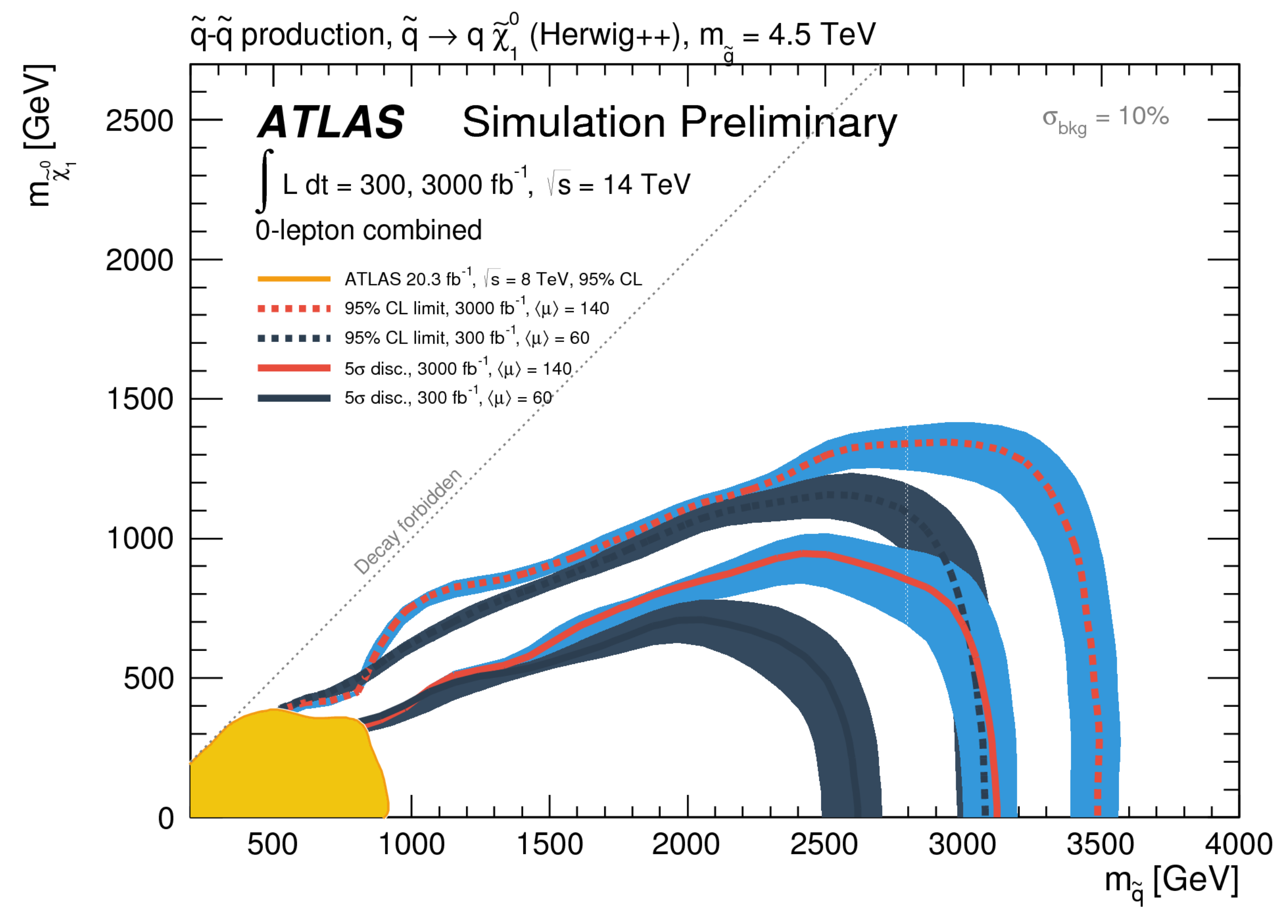
Cross section ratios: 14 (13) TeV / 8 TeV
Minimum bias
ZZ
WH
t (s-channel)
H (ggF)
H (VBF)
t (t-channel)
tt
ttH
stop pair (0.7 TeV)
stop pair (0.9 TeV)
gluino pair (1.5 TeV)
gluino pair (2.5 TeV)
Z' SSM (3 TeV)
Q* (4 Tev)
QBH (6 TeV)
1.2
2.1
2.1
2.2
2.6
2.6
2.8
3.9
4.7
11
(for 13 TeV / 8 TeV: 8.4)
16
(for 13 TeV / 8 TeV: 12)
72
(for 13 TeV / 8 TeV: 46)
5700
(13 / 8: 2700)
13
87
12000
1
10
100
1000
10000
100000

13 TEV !


Cross section ratios: 14 (13) TeV / 8 TeV
Minimum bias 1.2
ZZ 2.1
WH 2.1
t (s-channel) 2.2
H (ggF) 2.6
H (VBF) 2.6
t (t-channel) 2.8
tt 3.9
ttH 4.7
stop pair (0.7 TeV) 11 (for 13 TeV / 8 TeV: 8.4)
stop pair (0.9 TeV) 16 (for 13 TeV / 8 TeV: 12)
gluino pair (1.5 TeV) 72 (for 13 TeV / 8 TeV: 46)
gluino pair (2.5 TeV) 5700 (13 / 8: 2700)
Z' SSM (3 TeV) 13
Q* (4 Tev) 87
QBH (6 TeV) 12000
1
10
100
1000
10000
100000

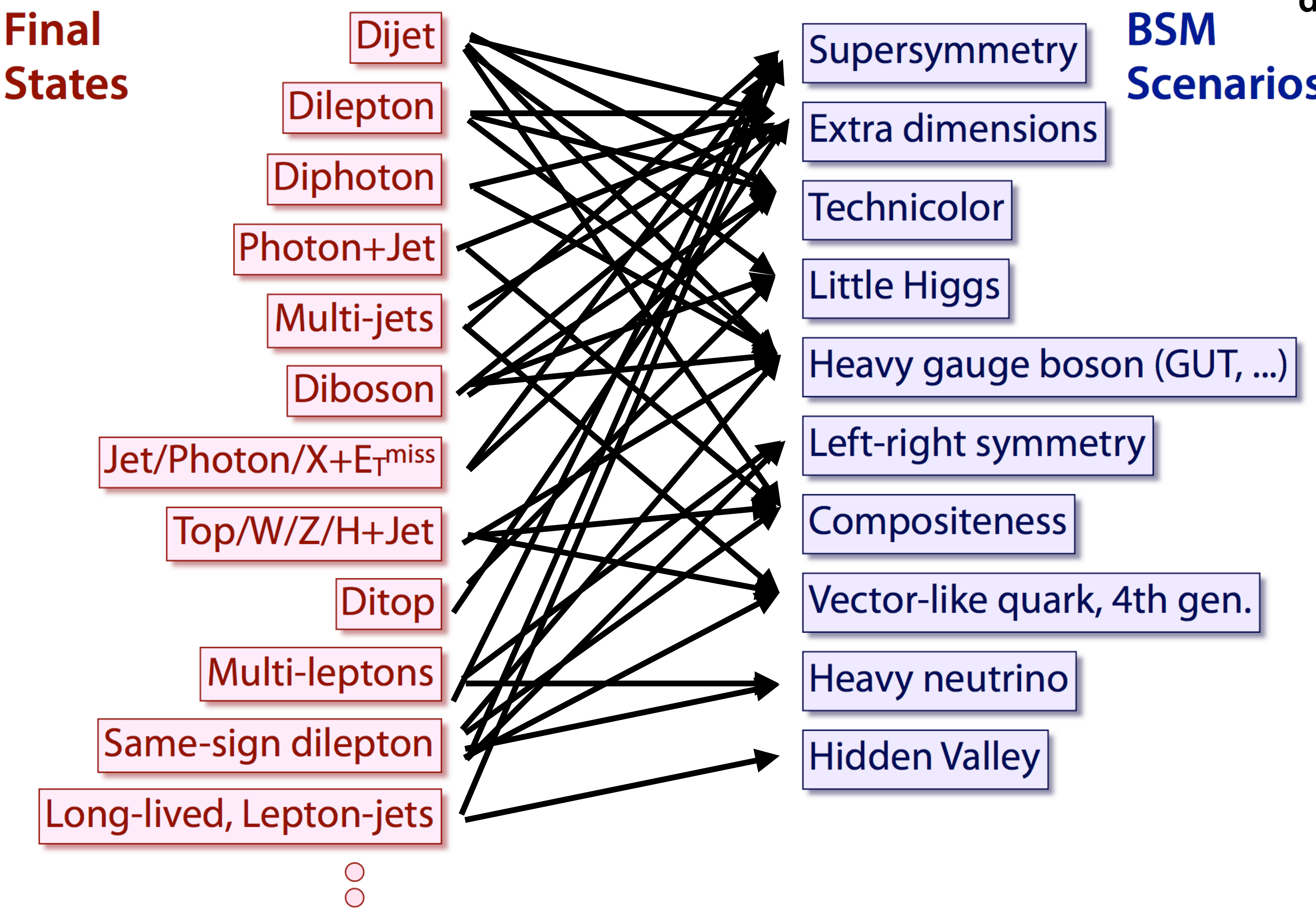

g̃-g̃ production, g̃ → qq χ̃⁰₁
ATLAS Simulation Preliminary
σbkg = 10%
∫ L dt = 300, 3000 fb⁻¹, √s = 14 TeV
0-lepton combined
ATLAS 20.3 fb⁻¹, √s = 8 TeV, 95% CL
95% CL limit, 3000 fb⁻¹, ⟨μ⟩ = 140
95% CL limit, 300 fb⁻¹, ⟨μ⟩ = 60
5σ disc., 3000 fb⁻¹, ⟨μ⟩ = 140
5σ disc., 300 fb⁻¹, ⟨μ⟩ = 60
Decay forbidden
m χ̃⁰₁ [GeV]
m g̃ [GeV]

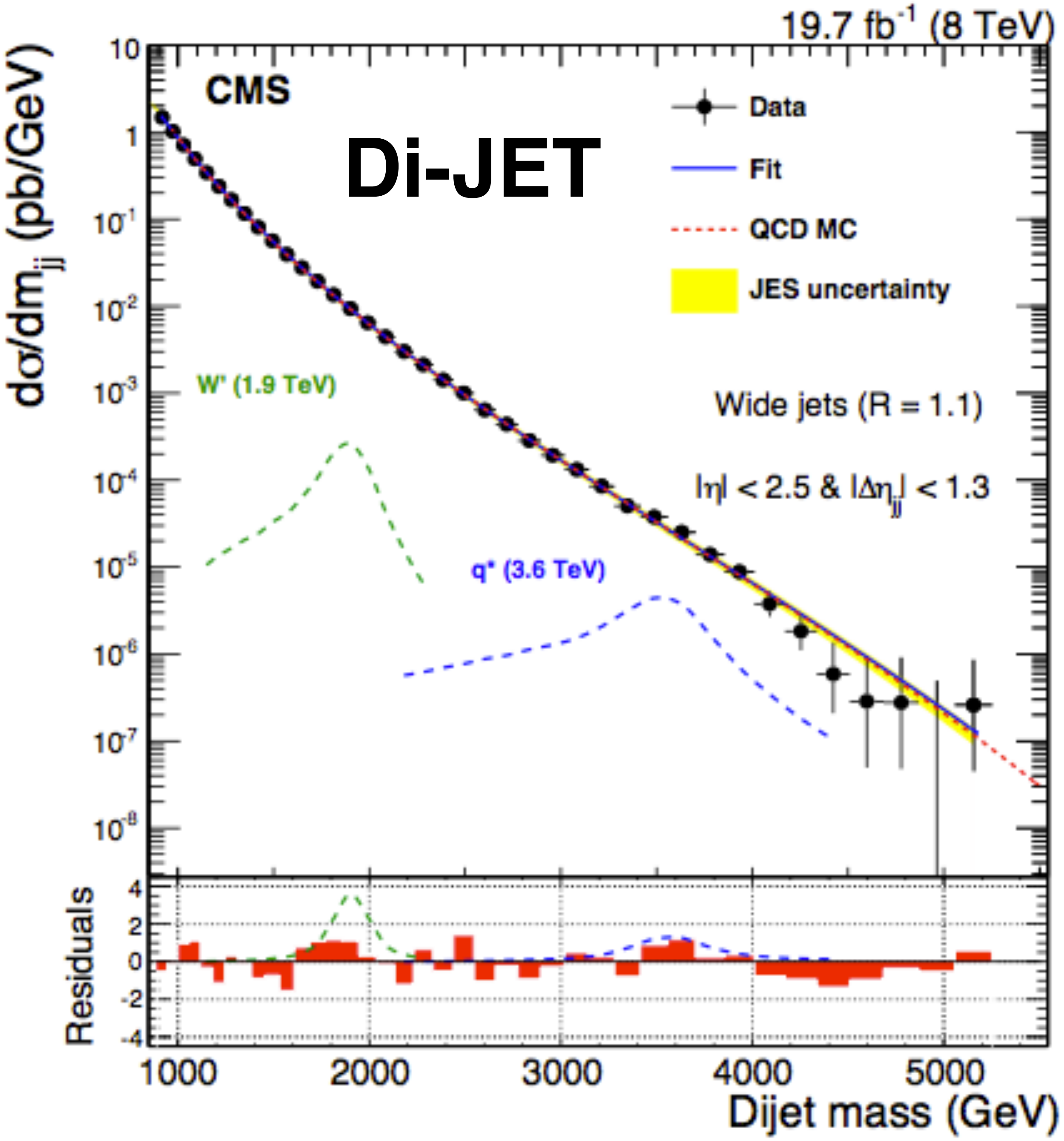

ATLAS Simulation Preliminary
σbkg = 30%
√s= 14 TeV
3-lepton channel
χ̃±₁ χ̃⁰₂ → W± χ̃⁰₁ Z χ̃⁰₁
m χ̃±₁ = m χ̃⁰₂
∫ L dt = 3000 fb⁻¹, μ=140, 95% CL exclusion
∫ L dt = 3000 fb⁻¹, μ=140, 5σ discovery
∫ L dt = 300 fb⁻¹, μ=60, 95% CL exclusion
∫ L dt = 300 fb⁻¹, μ=60, 5σ discovery
8 TeV, ∫ L dt = 20.3 fb⁻¹, 95% CL exclusion
m χ̃⁰₂ < m χ̃⁰₁
m χ̃⁰₂ - m χ̃⁰₁ = m Z
m χ̃⁰₁ [GeV]
m χ̃±₁=m χ̃⁰₂ [GeV]

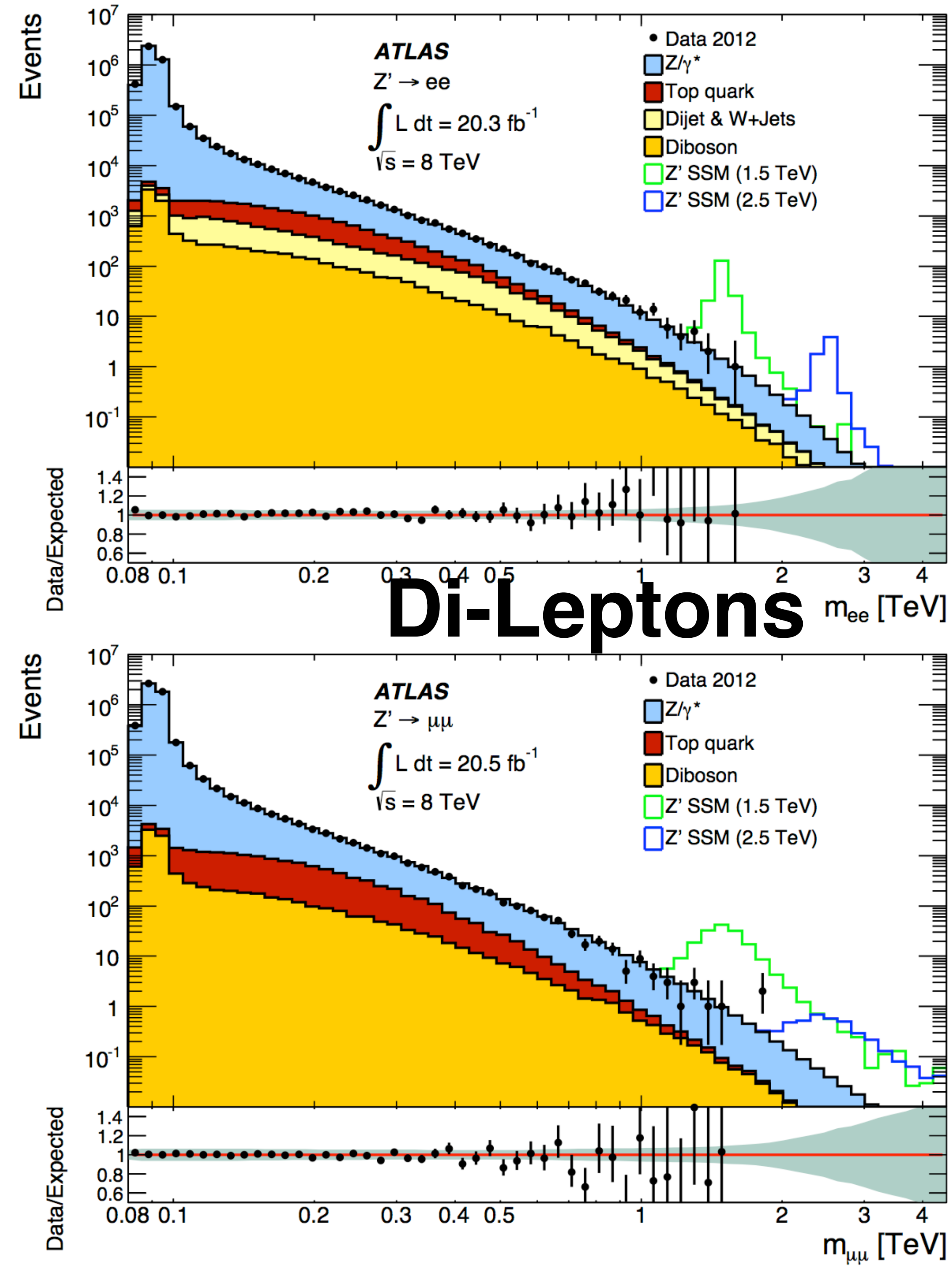

q̃-q̃ production, q̃ → q χ̃⁰₁ (Herwig++), m g̃ = 4.5 TeV
ATLAS Simulation Preliminary
σbkg = 10%
∫ L dt = 300, 3000 fb⁻¹, √s = 14 TeV
0-lepton combined
ATLAS 20.3 fb⁻¹, √s = 8 TeV, 95% CL
95% CL limit, 3000 fb⁻¹, ⟨μ⟩ = 140
95% CL limit, 300 fb⁻¹, ⟨μ⟩ = 60
5σ disc., 3000 fb⁻¹, ⟨μ⟩ = 140
5σ disc., 300 fb⁻¹, ⟨μ⟩ = 60
Decay forbidden
m χ̃⁰₁ [GeV]
m q̃ [GeV]

SEARCH FOR NEW RESONANCES

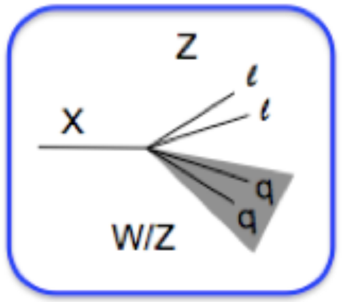
del Re

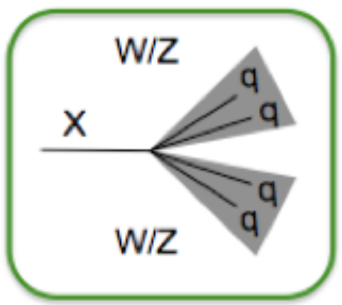


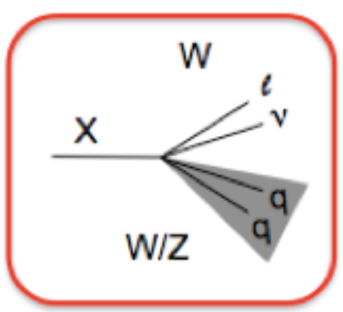

19.7 fb^{-1} (8 TeV)
CMS
Di-JET
Data
Fit
QCD MC
JES uncertainty
W' (1.9 TeV)
Wide jets (R = 1.1)
|η| < 2.5 & |Δη$_{jj}$| < 1.3
q* (3.6 TeV)
dσ/dm$_{jj}$ (pb/GeV)
Residuals
1000
2000
3000
4000
5000
Dijet mass (GeV)

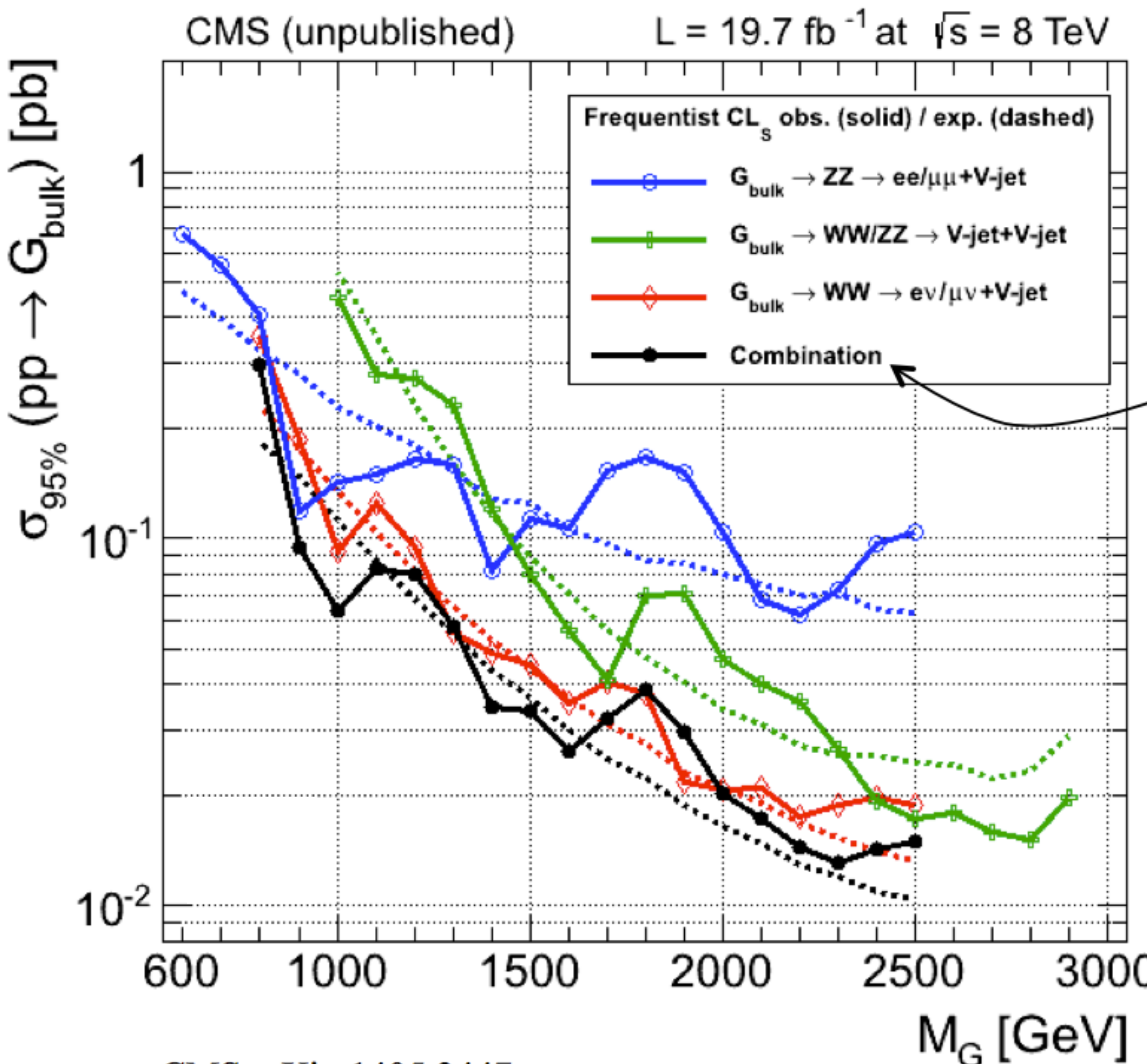

ATLAS
Z' → ee
∫L dt = 20.3 fb^{-1}
√s = 8 TeV
Data 2012
Z/γ*
Top quark
Dijet & W+Jets
Diboson
Z' SSM (1.5 TeV)
Z' SSM (2.5 TeV)
Events
Data/Expected
m$_{ee}$ [TeV]
Di-Leptons
ATLAS
Z' → μμ
∫L dt = 20.5 fb^{-1}
√s = 8 TeV
Data 2012
Z/γ*
Top quark
Diboson
Z' SSM (1.5 TeV)
Z' SSM (2.5 TeV)
Events
Data/Expected
m$_{μμ}$ [TeV]

Di-Bosons









CMS arXiv:1405.3447

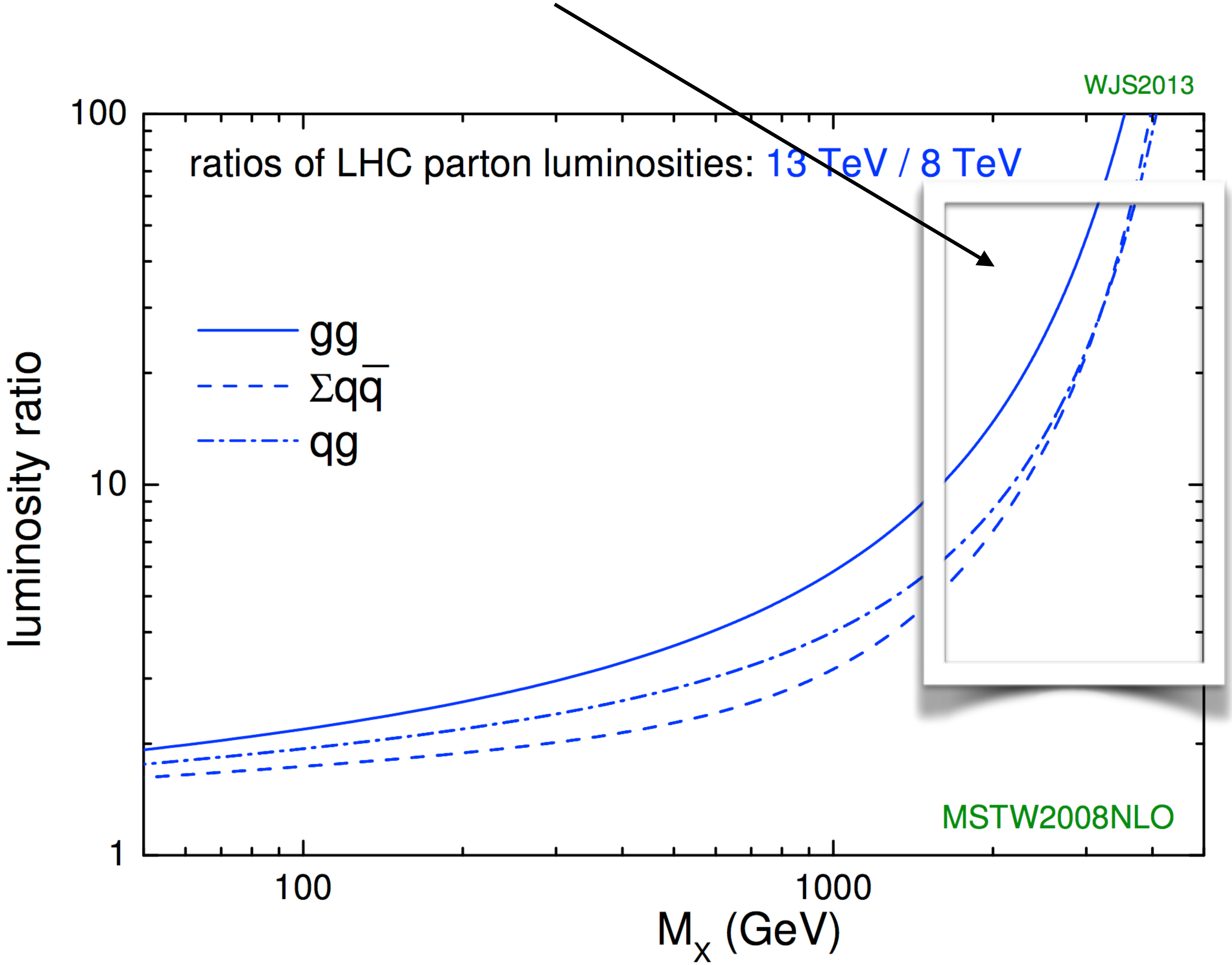
Bulk graviton (arXiv:hep-ph/0701186)

Combination assuming **BRs and efficiencies of narrow bulk graviton** model

Largest excess at M~1.8 TeV (<1.5σ)

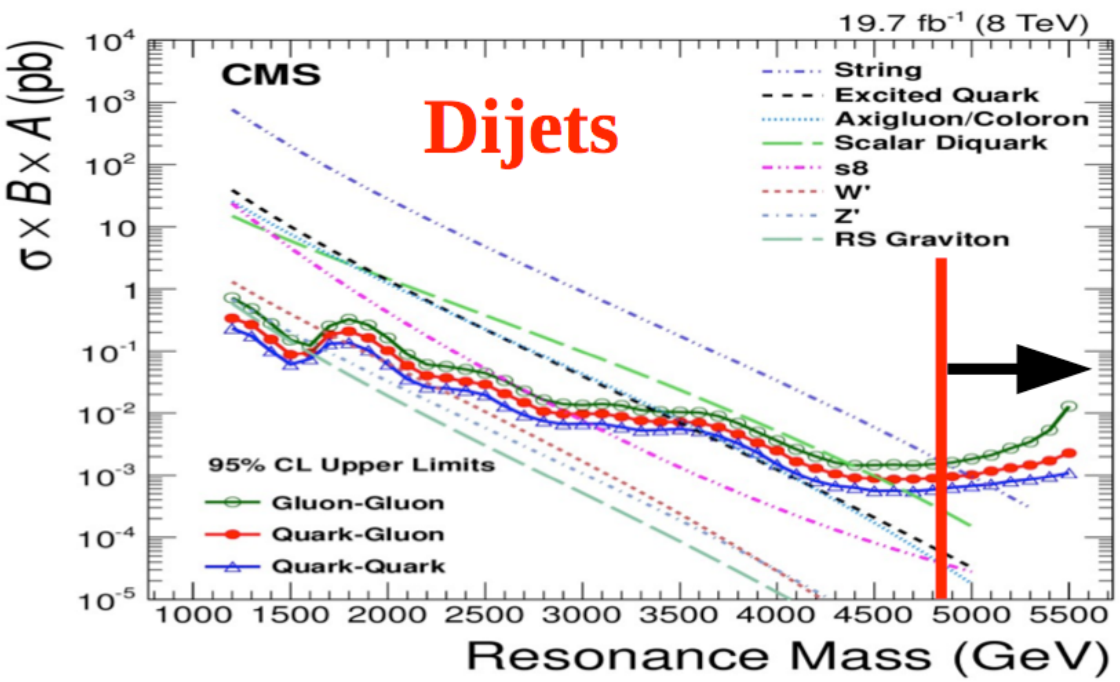
Parton Luminosity Ratio

- For high mass searches parton luminosity counts!
  - Huge ratio in the interesting (not yet excluded) region

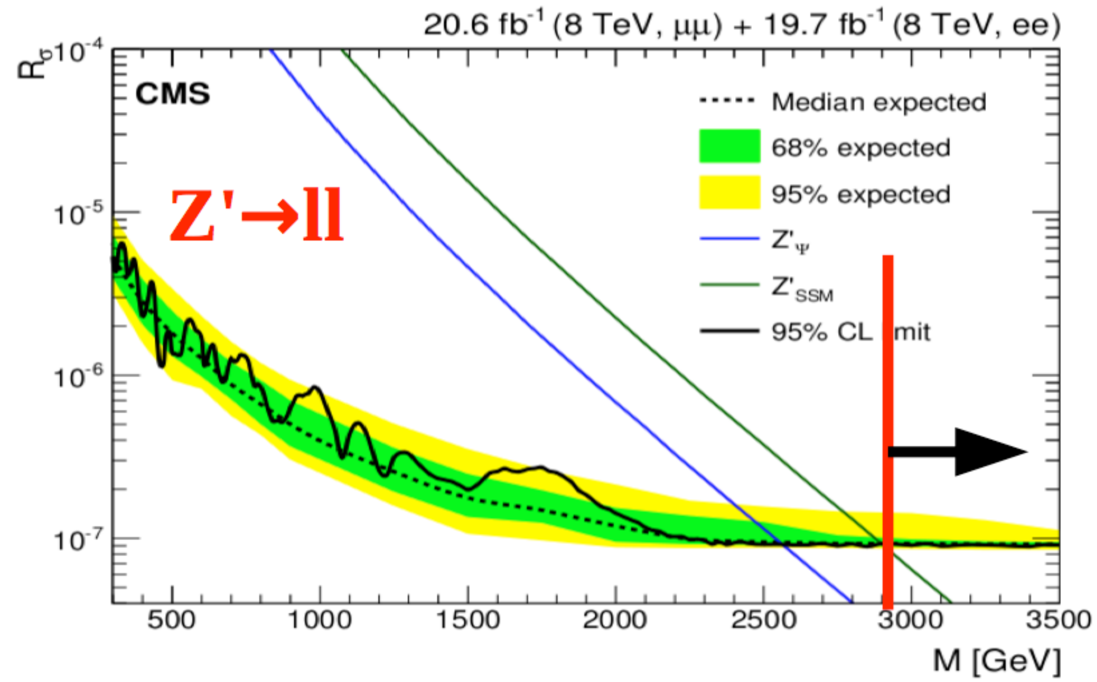


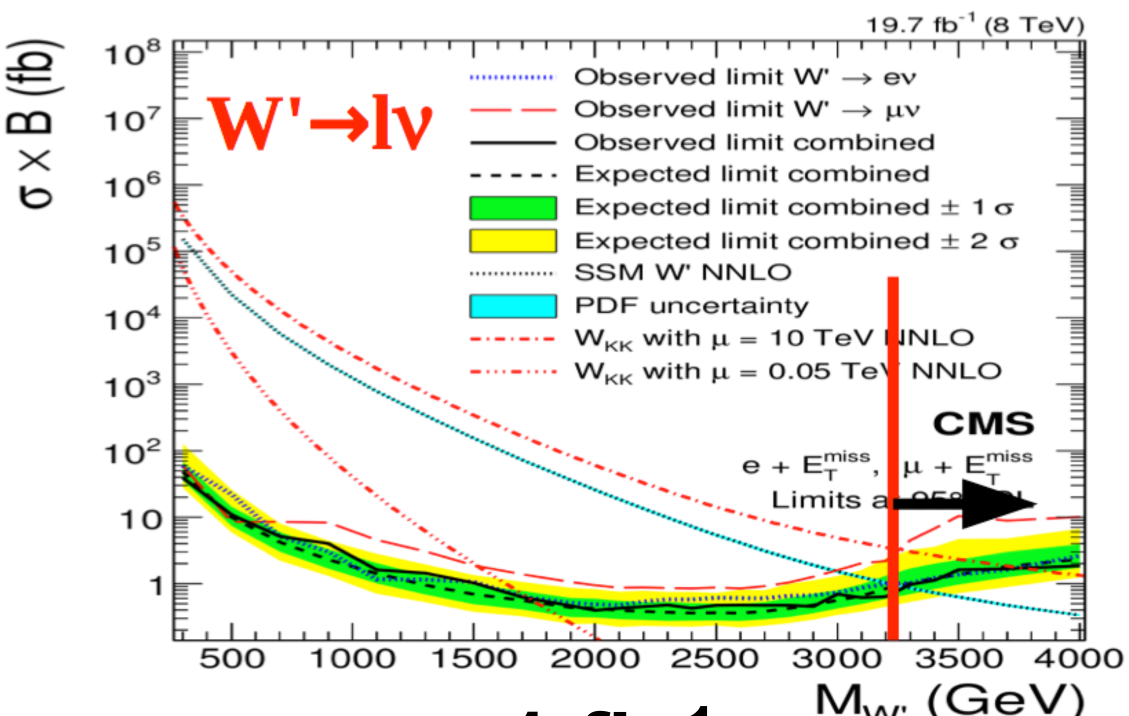
HOW MUCH LUMINOSITY?

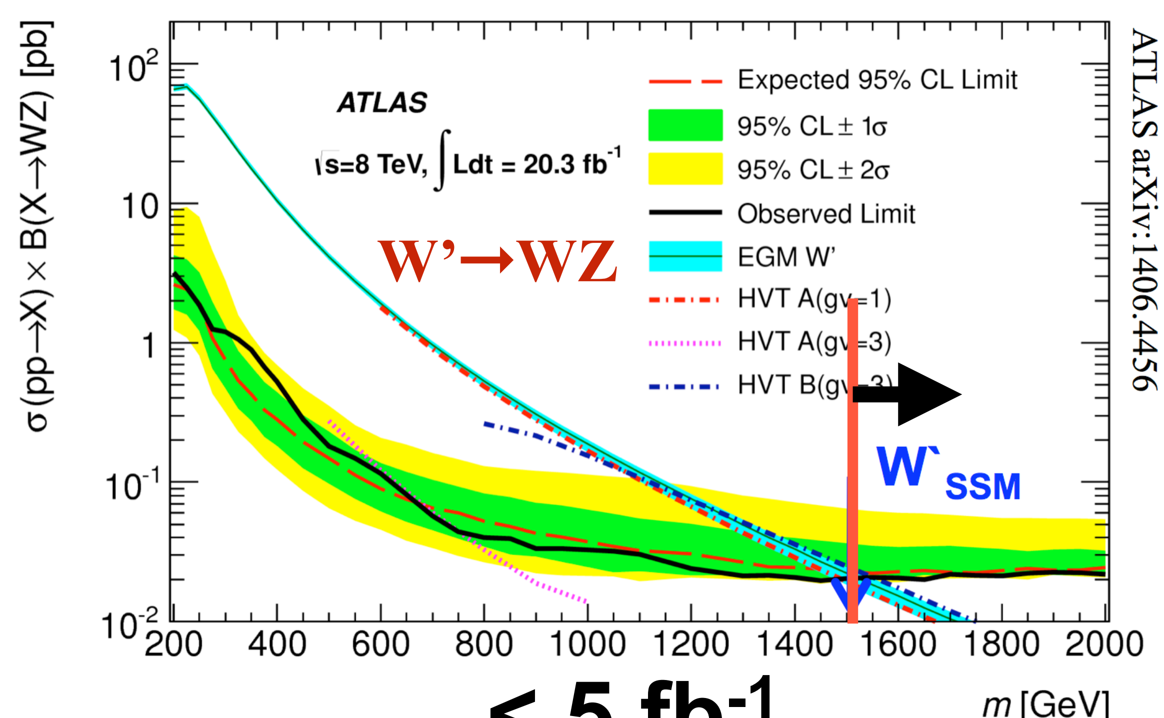
$100\ \mathrm{pb}^{-1}$



$1\ \mathrm{fb}^{-1}$







$1\ \mathrm{fb}^{-1}$

$< 5\ \mathrm{fb}^{-1}$

Conclusions

Not today. LHC starts in May at 13 TeV. The next 1-2 years will be crucial.

Results presented at Moriond 2016 could bring us much closer to the conclusion.*

* Alessandro Strumia Moriond EW 2015 Summary talk

Type	Observable	LHC Run 1	LHCb 2018	**LHCb upgrade**	Theory
B_s^0 mixing	$\phi_s(B_s^0 \to J/\psi\,\phi)$ (rad)	0.049	0.025	**0.009**	~ 0.003
	$\phi_s(B_s^0 \to J/\psi\ f_0(980))$ (rad)	0.068	0.035	**0.012**	~ 0.01
	$A_{\rm sl}(B_s^0)$ (10^{-3})	2.8	1.4	**0.5**	0.03
Gluonic penguin	$\phi_s^{\rm eff}(B_s^0 \to \phi\phi)$ (rad)	0.15	0.10	**0.018**	0.02
	$\phi_s^{\rm eff}(B_s^0 \to K^{*0}\bar{K}^{*0})$ (rad)	0.19	0.13	**0.023**	< 0.02
	$2\beta^{\rm eff}(B^0 \to \phi K_S^0)$ (rad)	0.30	0.20	**0.036**	0.02
Right-handed currents	$\phi_s^{\rm eff}(B_s^0 \to \phi\gamma)$ (rad)	0.20	0.13	**0.025**	< 0.01
	$\tau^{\rm eff}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	5%	3.2%	**0.6%**	0.2 %
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$	0.04	0.020	**0.007**	0.02
	$q_0^2\ A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$	10%	5%	**1.9%**	$\sim 7\%$
	$A_{\rm I}(K\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$	0.09	0.05	**0.017**	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	14%	7%	**2.4%**	$\sim 10\%$
Higgs penguin	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ (10^{-9})	1.0	0.5	**0.19**	0.3
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	220%	110%	**40%**	$\sim 5\,\%$
Unitarity triangle angles	$\gamma(B \to D^{(*)}K^{(*)})$	7°	4°	**0.9°**	negligible
	$\gamma(B_s^0 \to D_s^{\mp}K^{\pm})$	17°	11°	**2.0°**	negligible
	$\beta(B^0 \to J/\psi\,K_S^0)$	1.7°	0.8°	**0.31°**	negligible
Charm *CP* violation	$A_\Gamma(D^0 \to K^+K^-)$ (10^{-4})	3.4	2.2	**0.4**	–
	ΔA_{CP} (10^{-3})	0.8	0.5	**0.1**	–