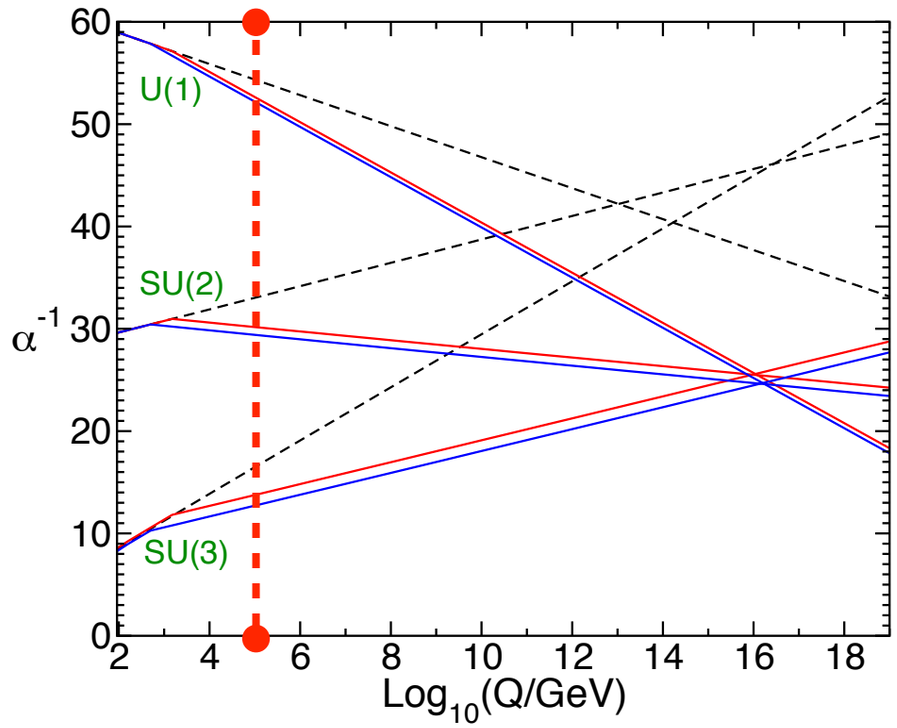
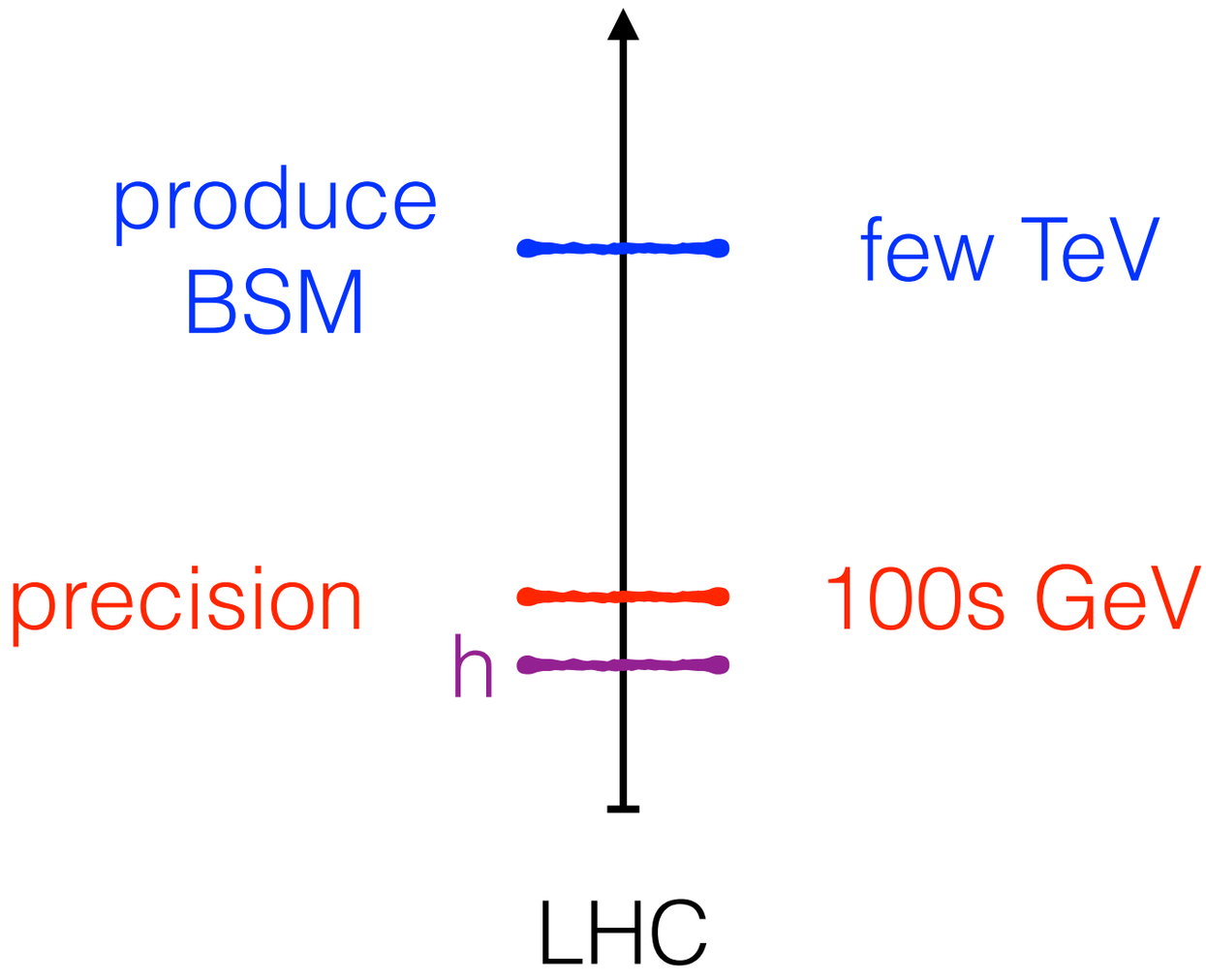
Running Weak Couplings at 100 TeV

Josh Ruderman
UC Berkeley
@CERN 2/10/14

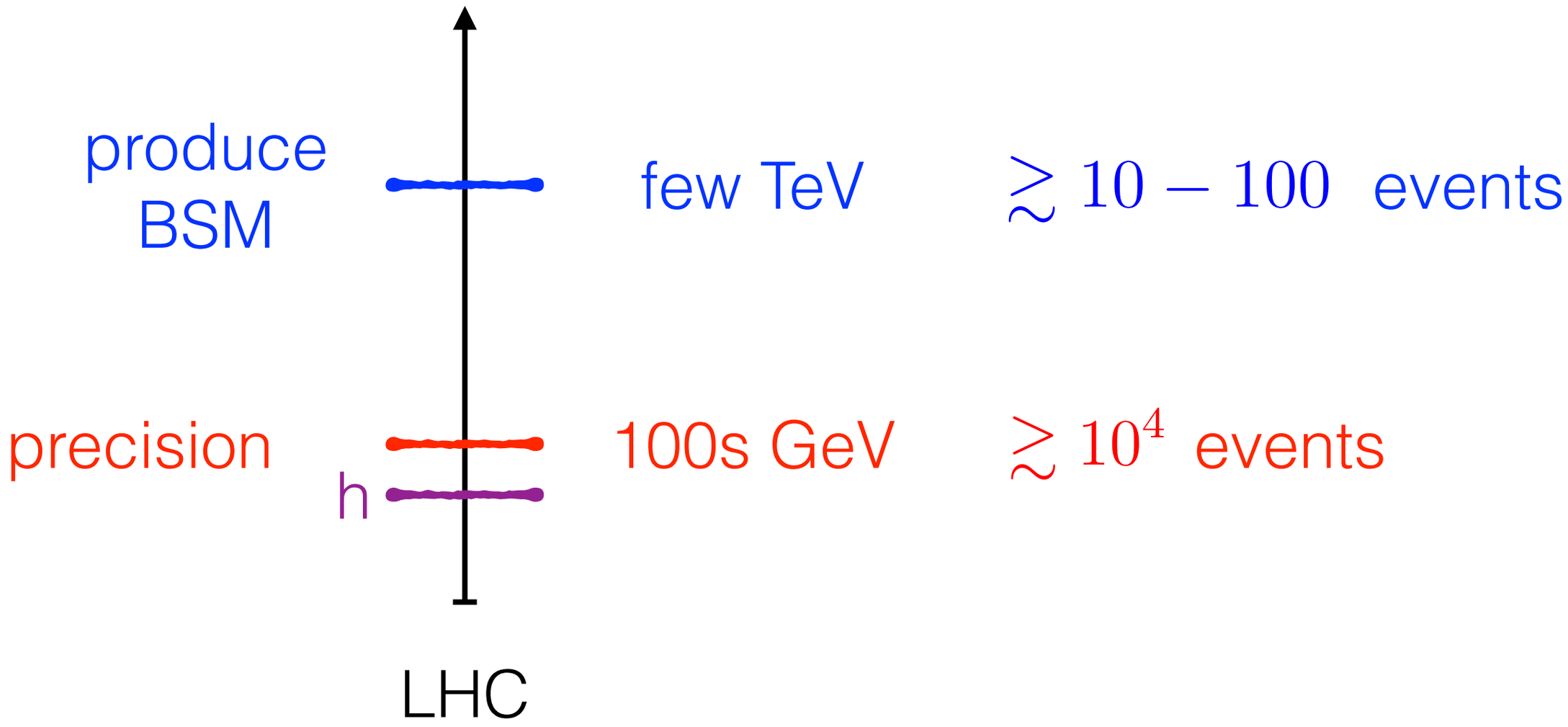


w/ Jamison Galloway and Jon Walsh

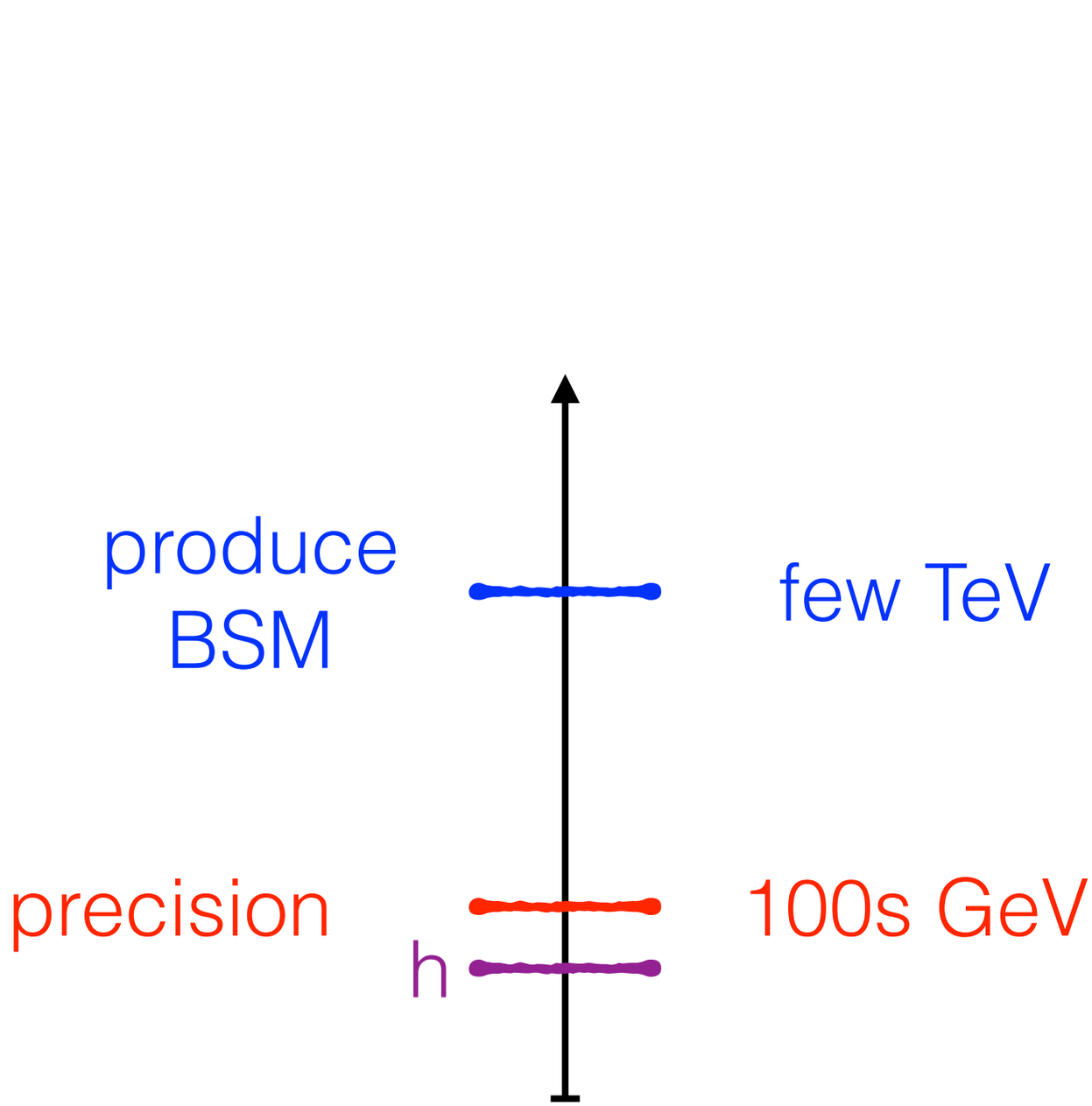
frontiers

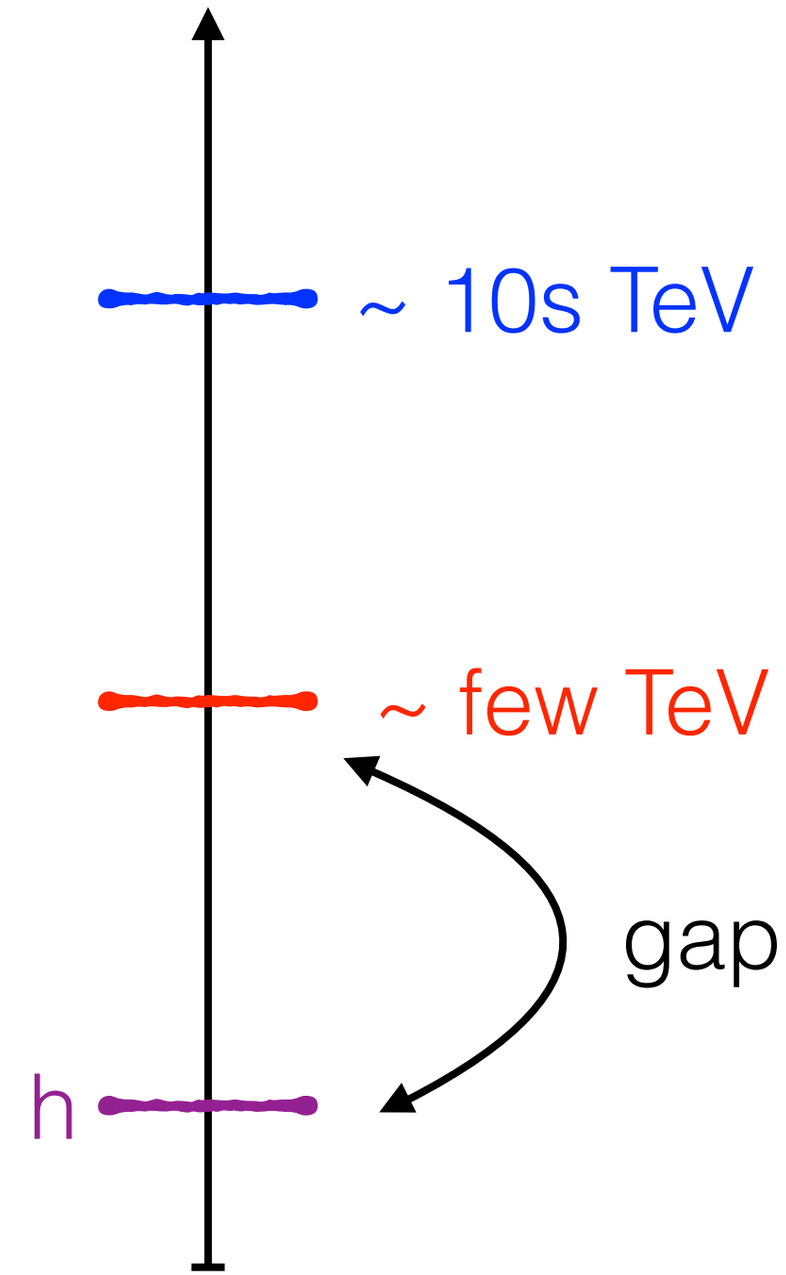


frontiers


produce
BSM
few TeV
$\gtrsim 10 - 100$ events
precision
100s GeV
$\gtrsim 10^4$ events
h
LHC

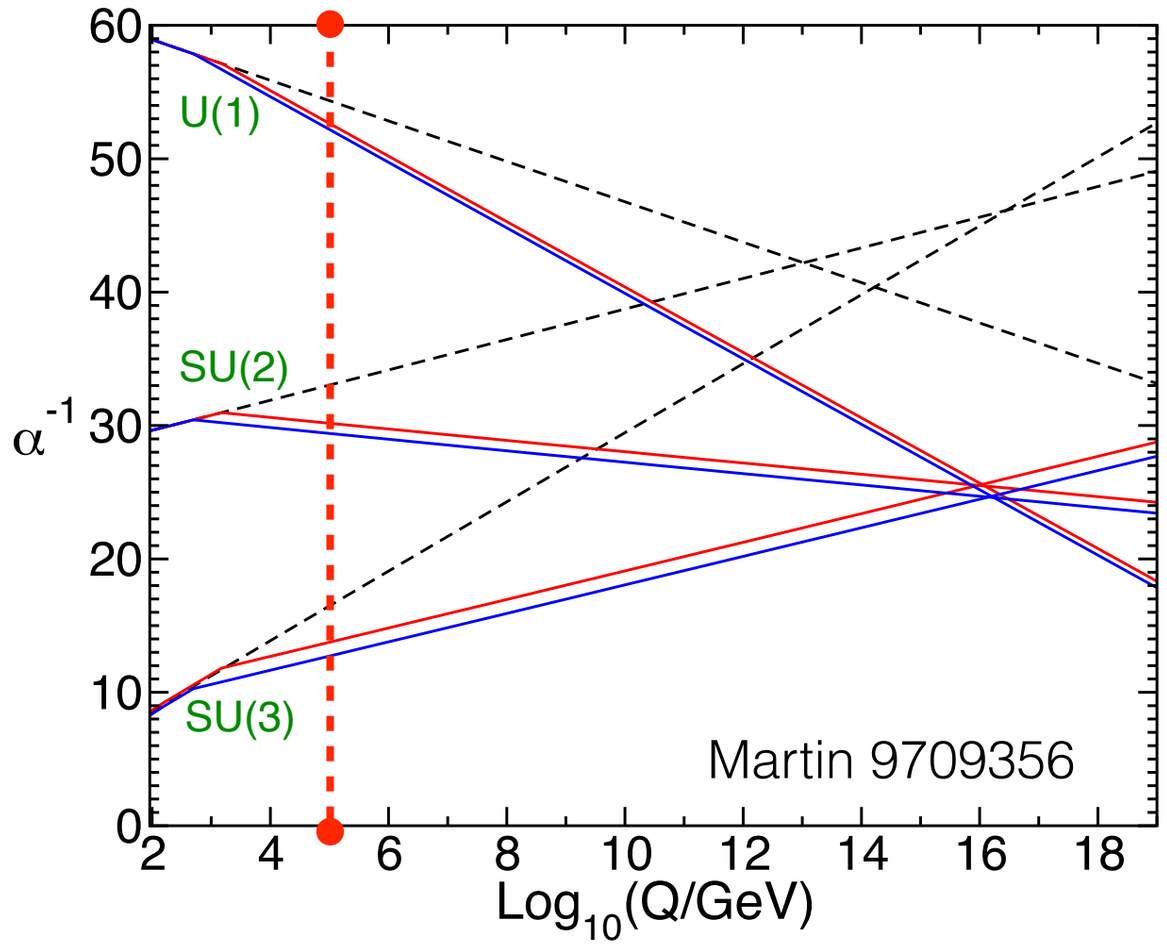
frontiers


produce
BSM
few TeV
precision
100s GeV
h
LHC


~ 10s TeV
~ few TeV
gap
h
100 TeV collider

gauge running

$$\frac{d}{dt} g_i = \frac{1}{(4\pi)^2} b_i \, g_i^3$$



SM

$$(b_1, b_2, b_3) = \left(\frac{41}{10}, -\frac{19}{6}, -7\right) \approx (4.1, -3.2, -7)$$

MSSM

$$(b_1, b_2, b_3) = (6.6, 1, -3)$$

trade off

general

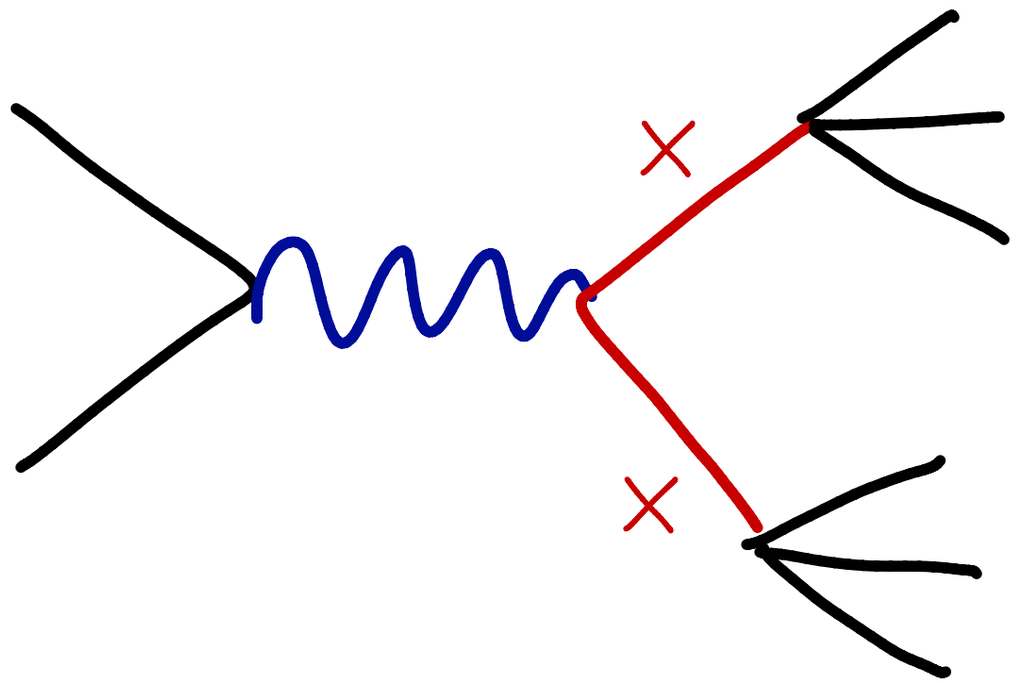
dedicated

trade off

general

dedicated

dedicated searches make assumptions about how the new states decay

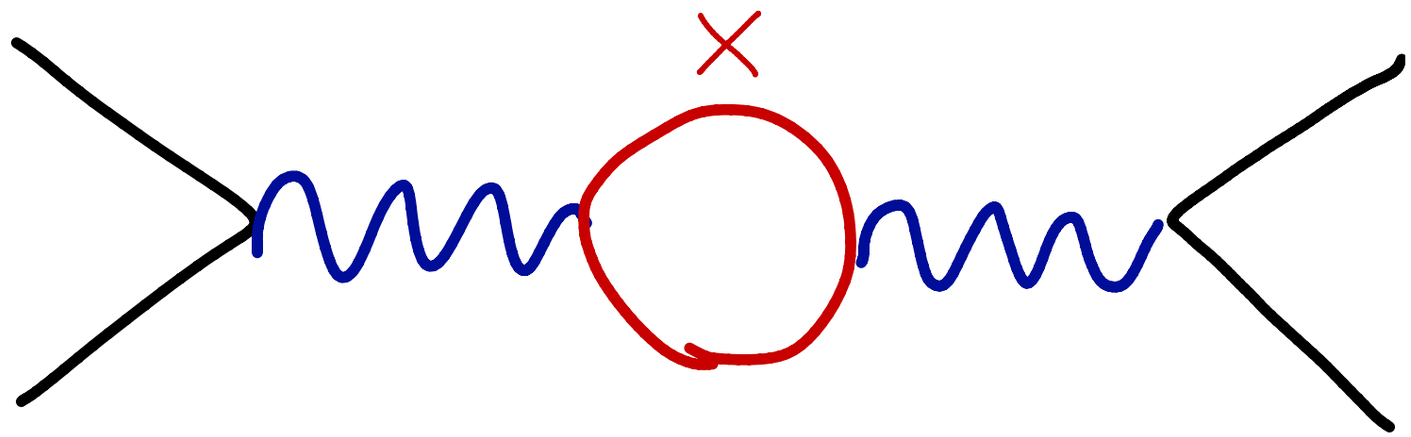


trade off

general

dedicated

general limits follow from closing the loop



plan

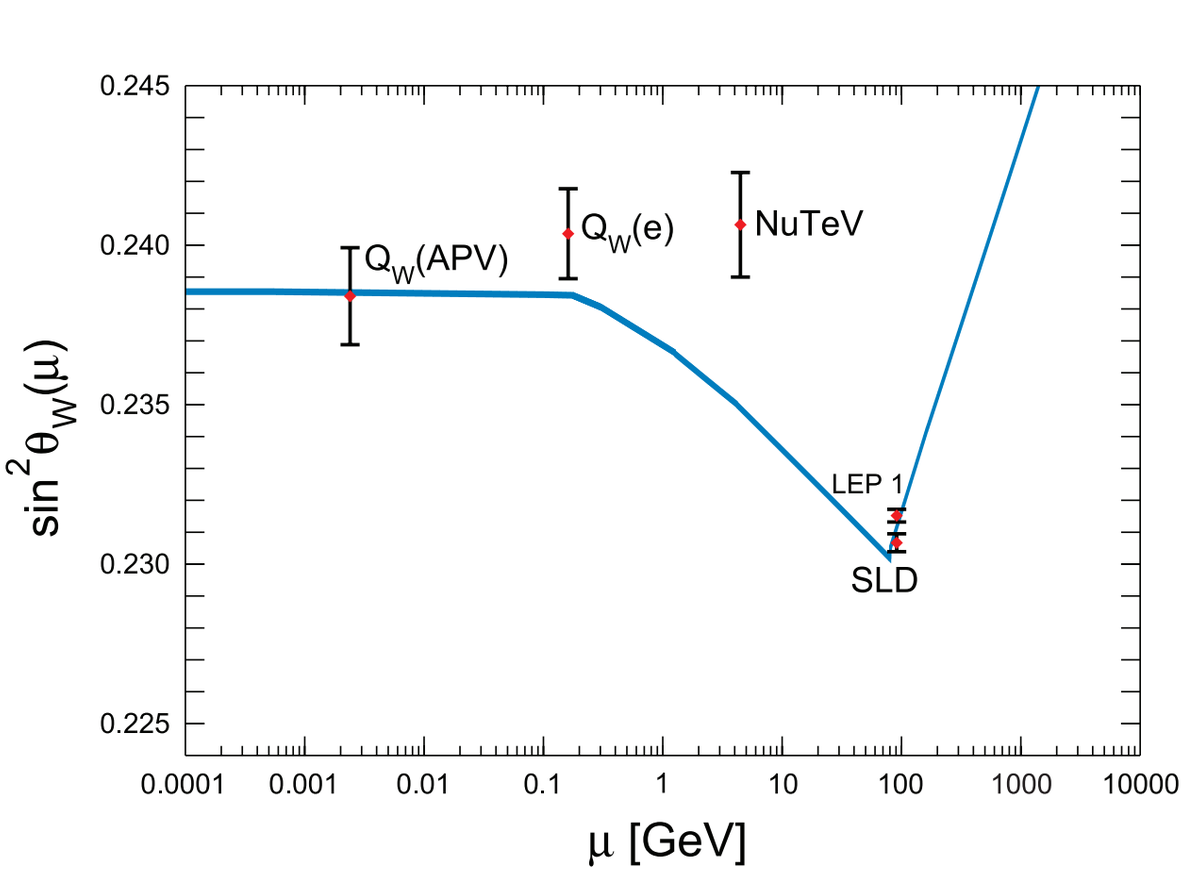
1. existing measurements
2. running weak primer
3. Drell-Yan at the LHC
4. Drell-Yan at 100 TeV

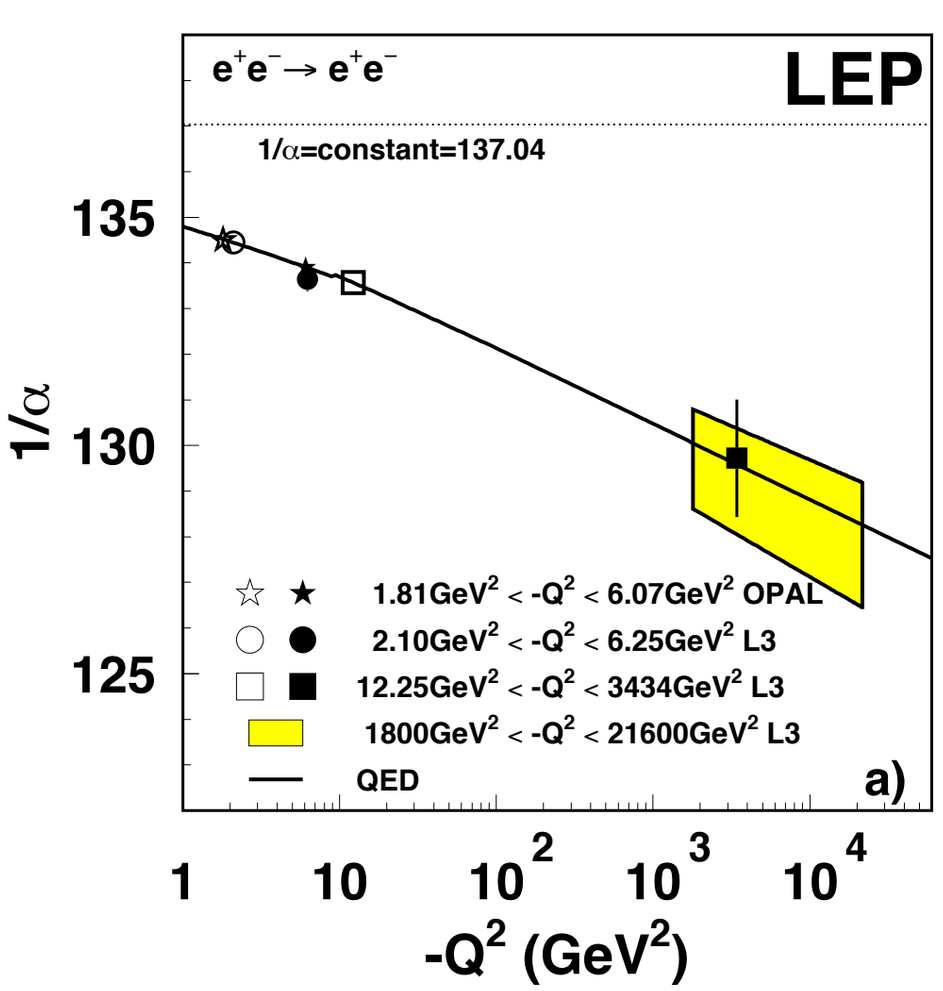
1. existing measurements

running weak couplings

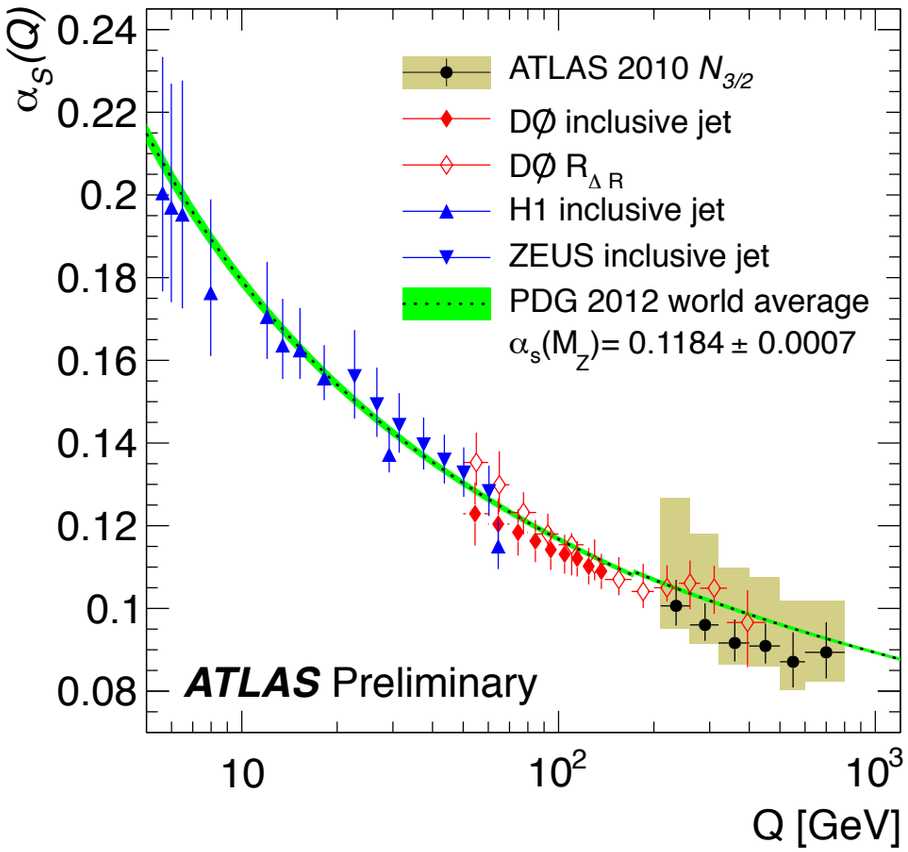
so far only measured in the broken regime:

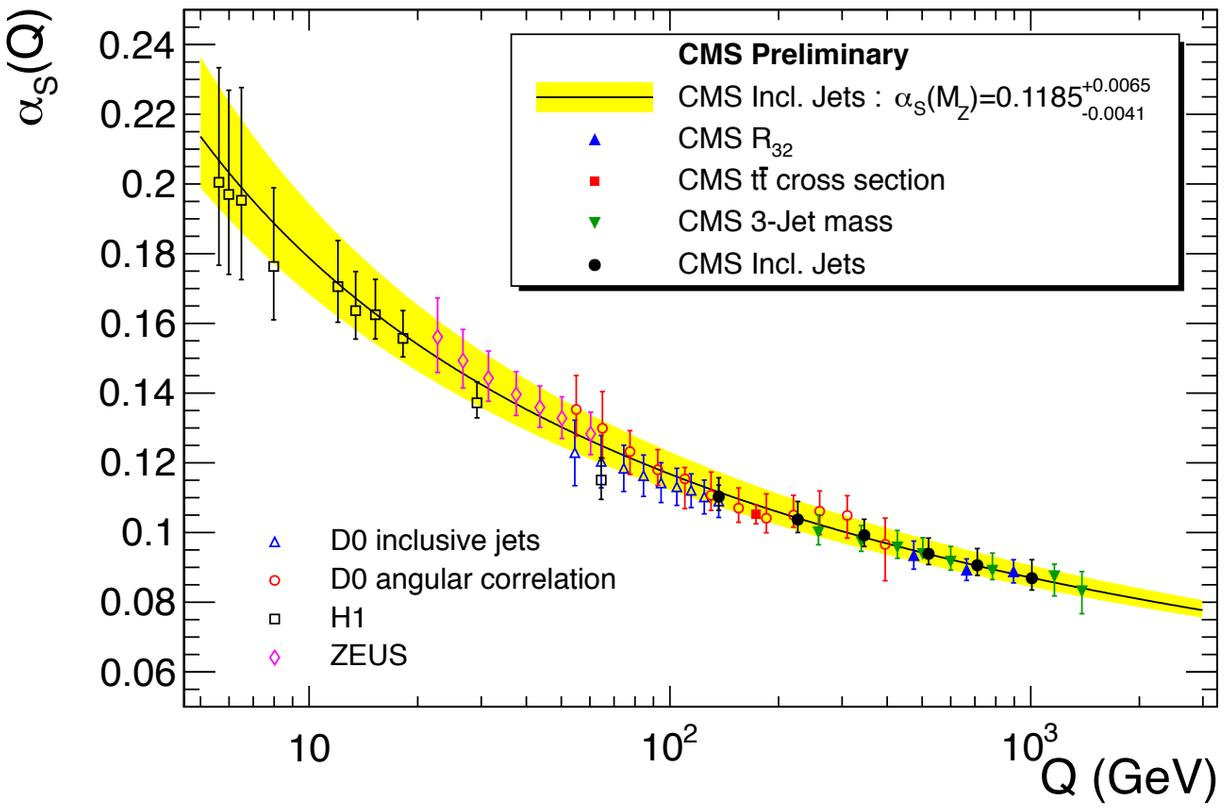
$$q^2 \lesssim m_Z^2$$





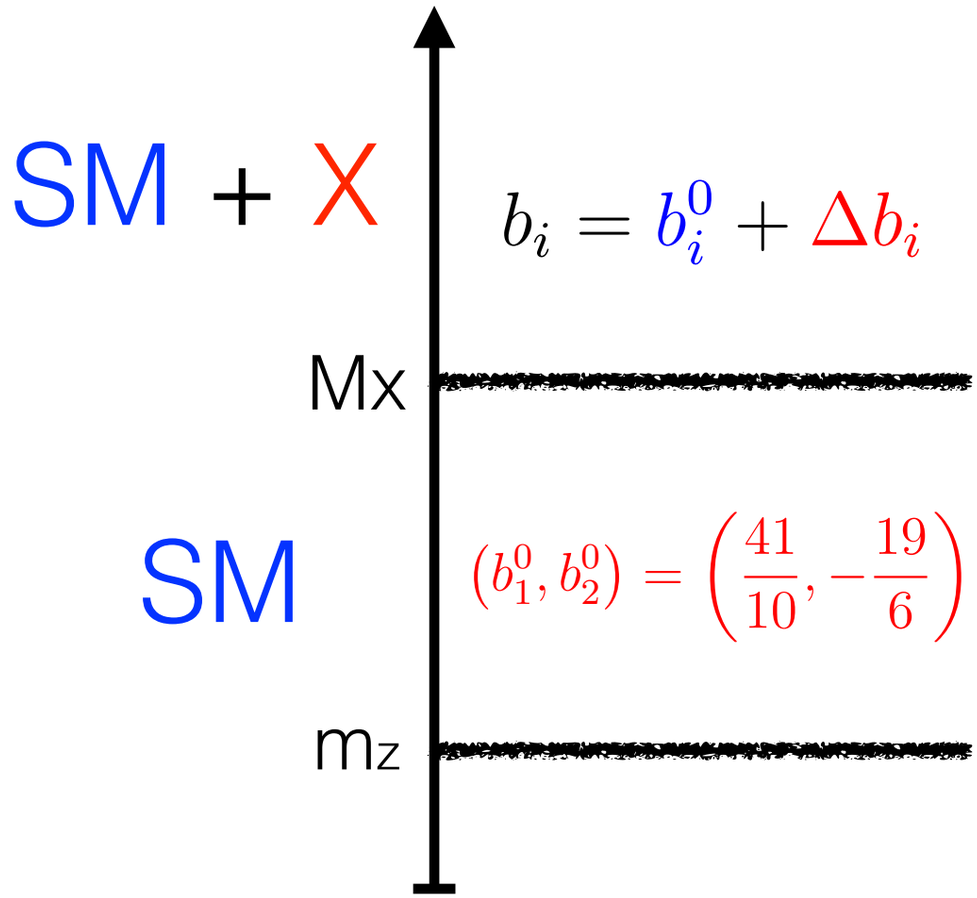
running strong coupling



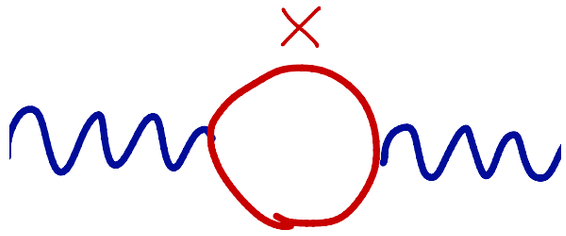


2. running weak primer

running weak couplings



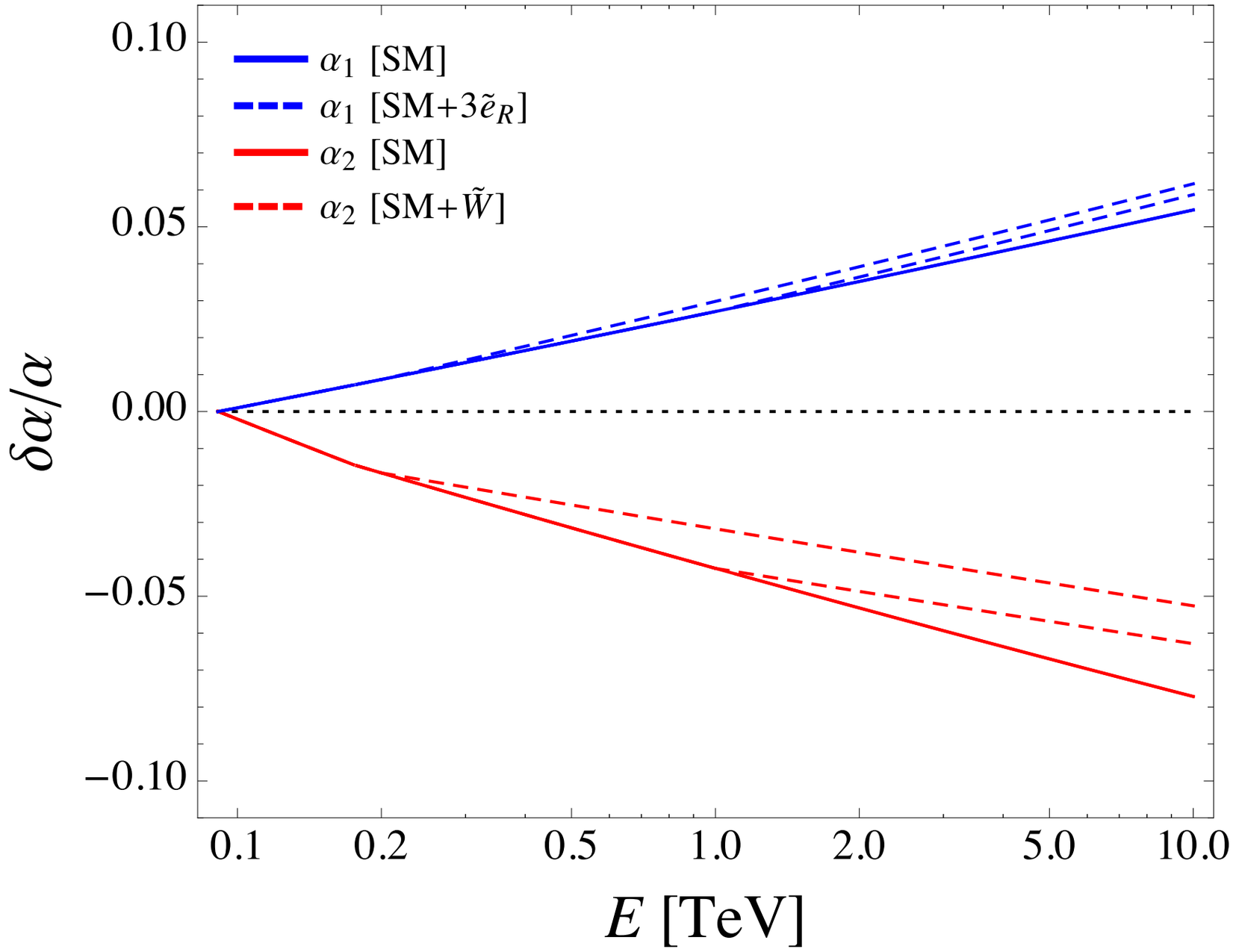
$$\frac{d}{dt} g_i = \frac{1}{(4\pi)^2} b_i \, g_i^3$$



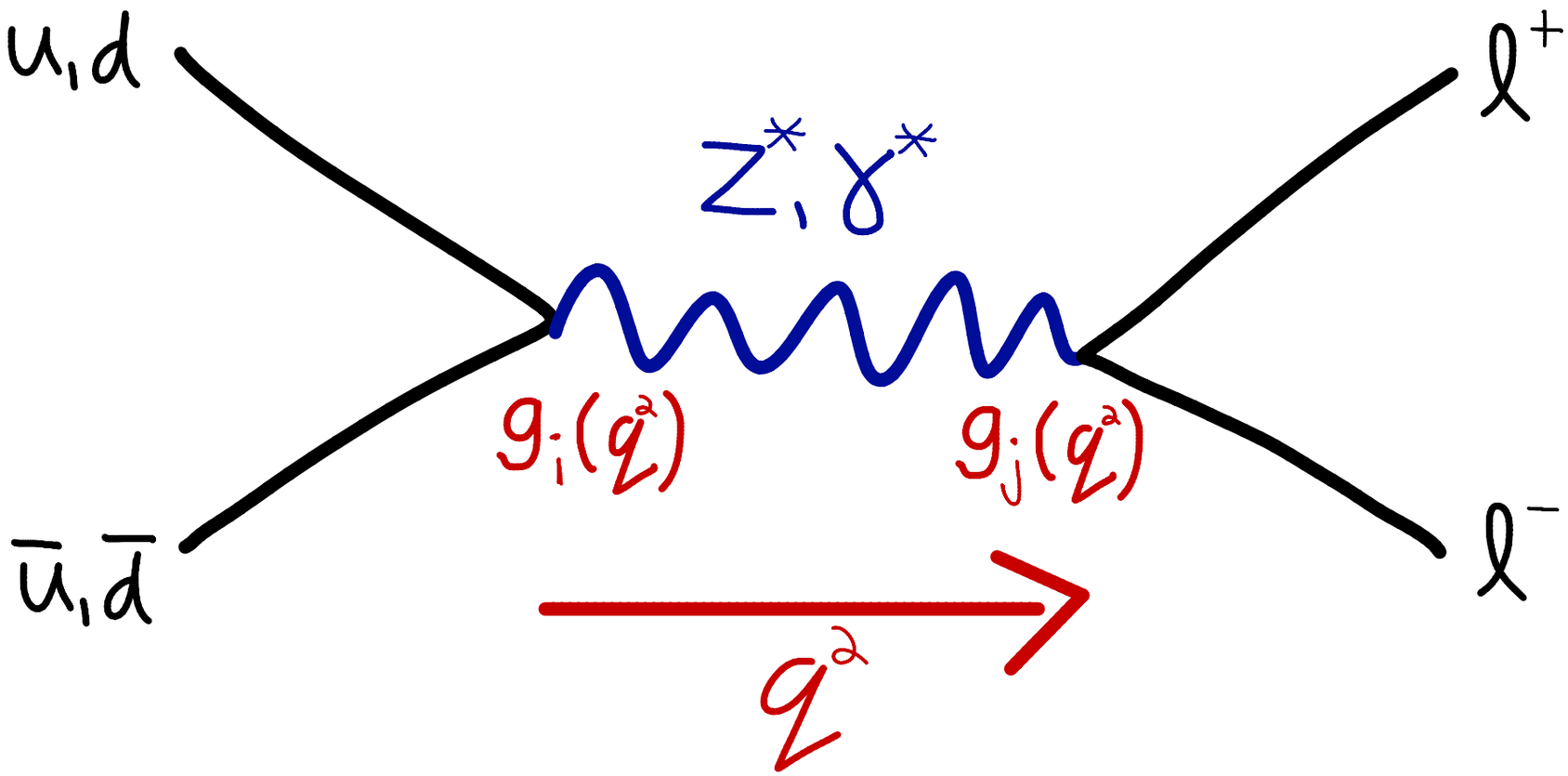
$$\Delta b_1 = \frac{2}{5} Y_i^2$$

	Δb_2
2	1/3 = 0.33
3	4/3 = 1.33
5	20/3 = 6.67
7	56/3 = 18.7

running weak couplings



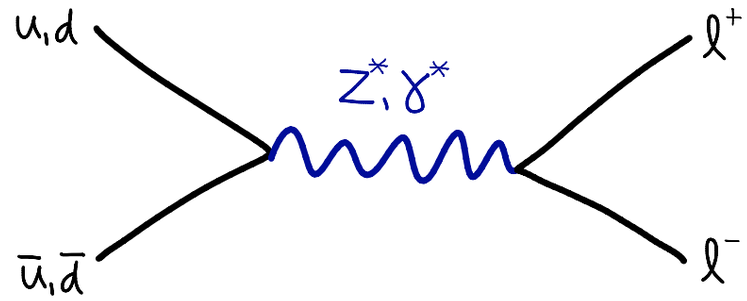
off-shell Drell-Yan

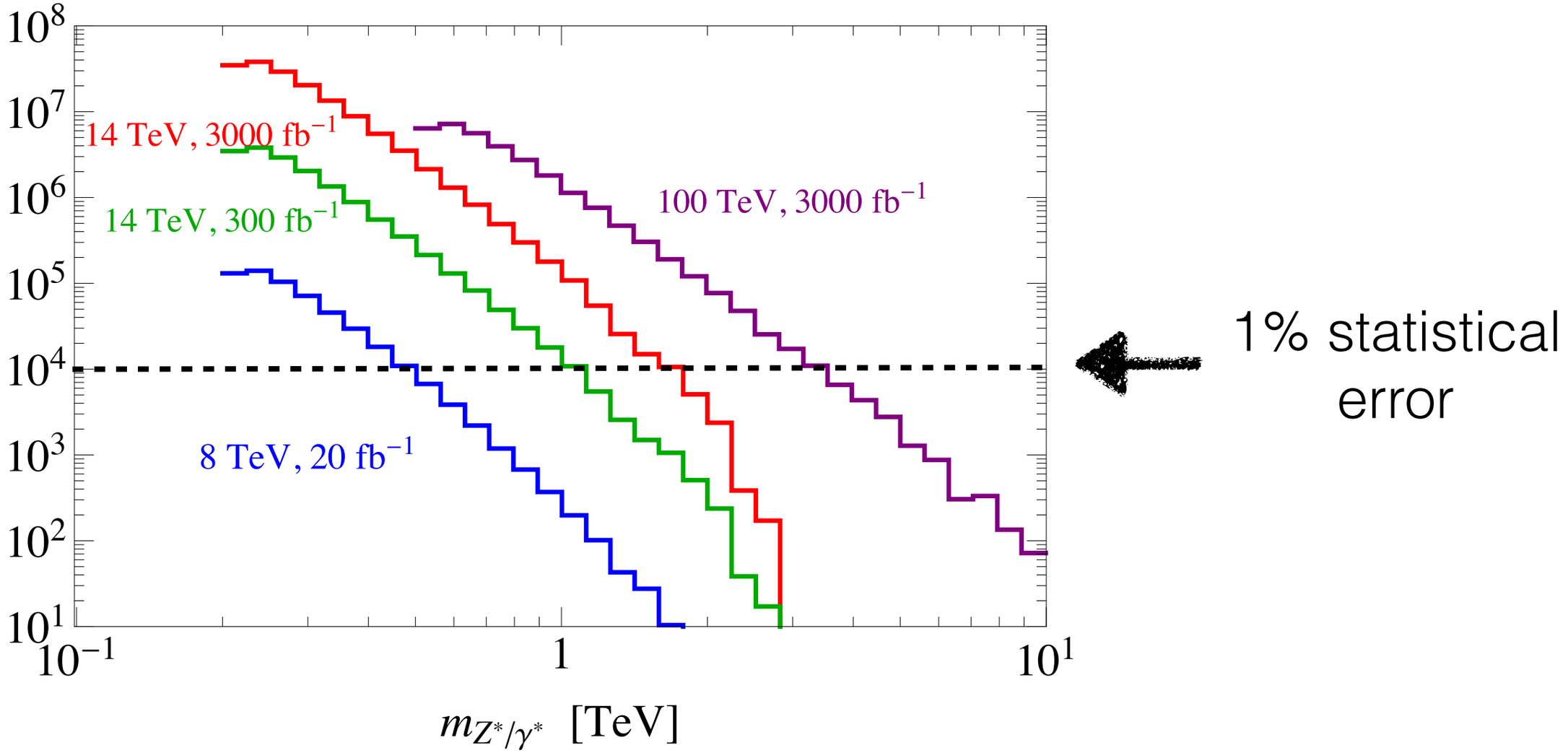


$$\frac{d\sigma}{dM} \propto \alpha_i(M)\,\alpha_j(M)$$

$$i,j = 1,2$$

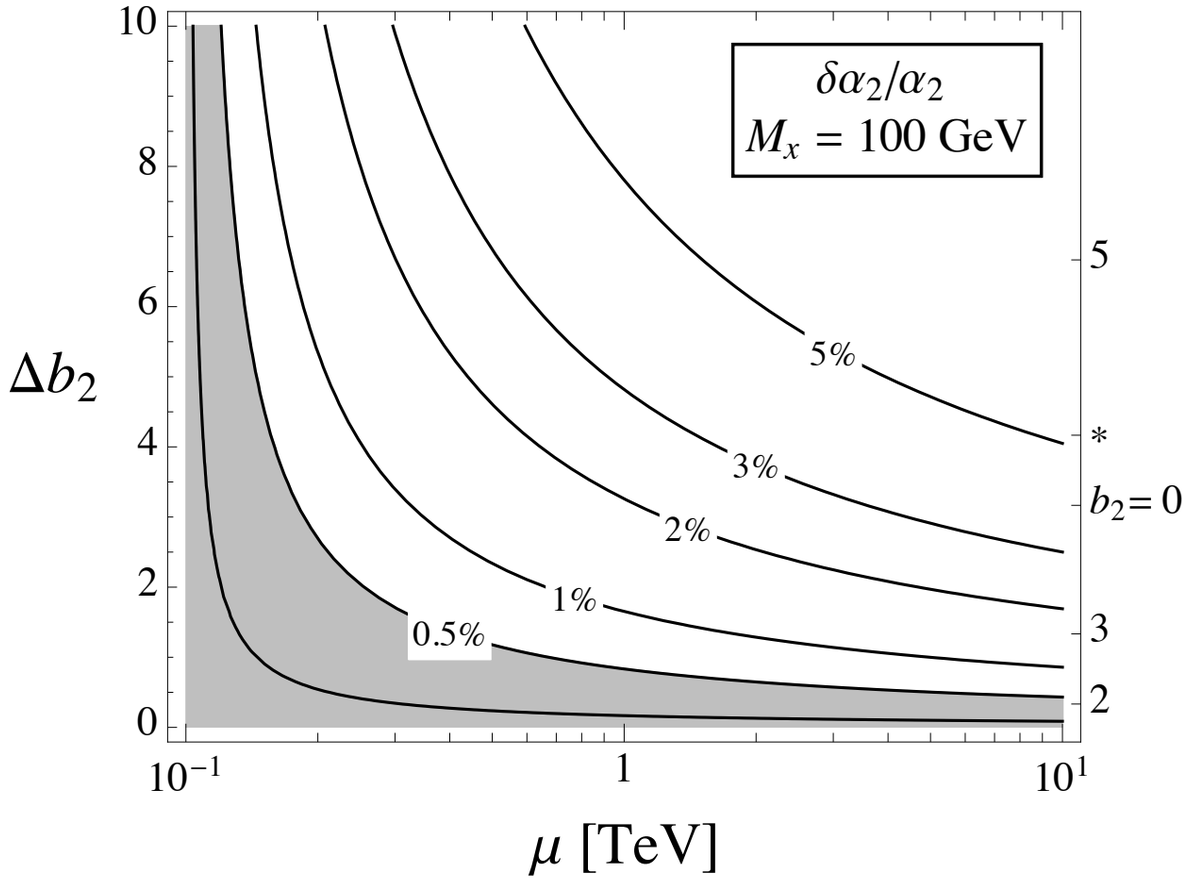
off-shell Drell-Yan

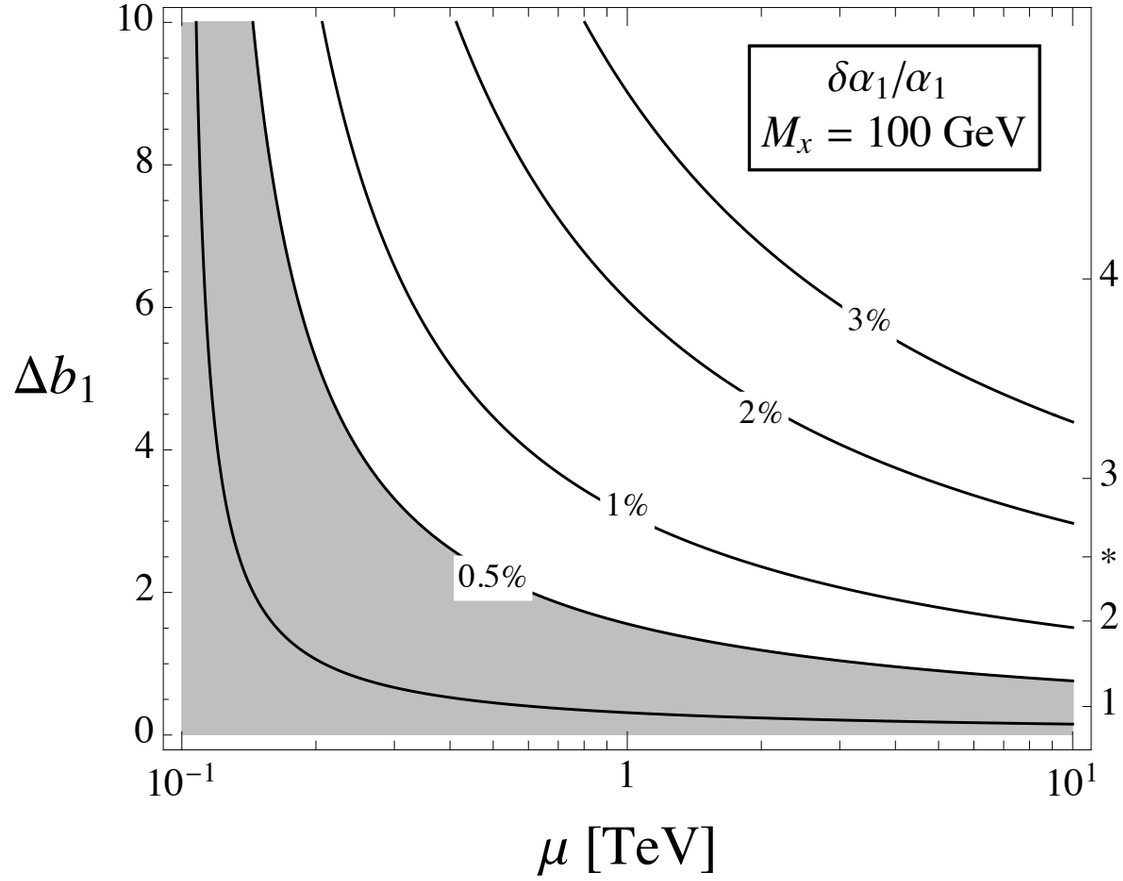




deviation from SM

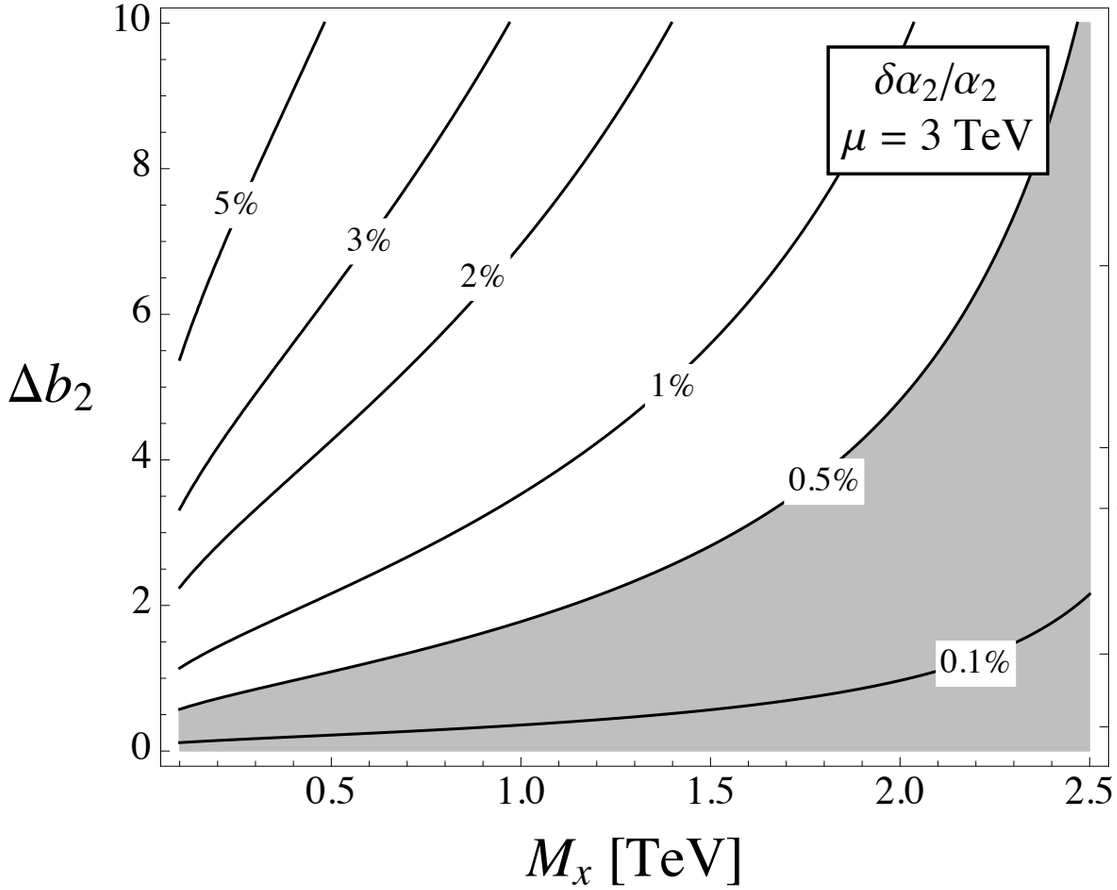
with new physics at 100 GeV

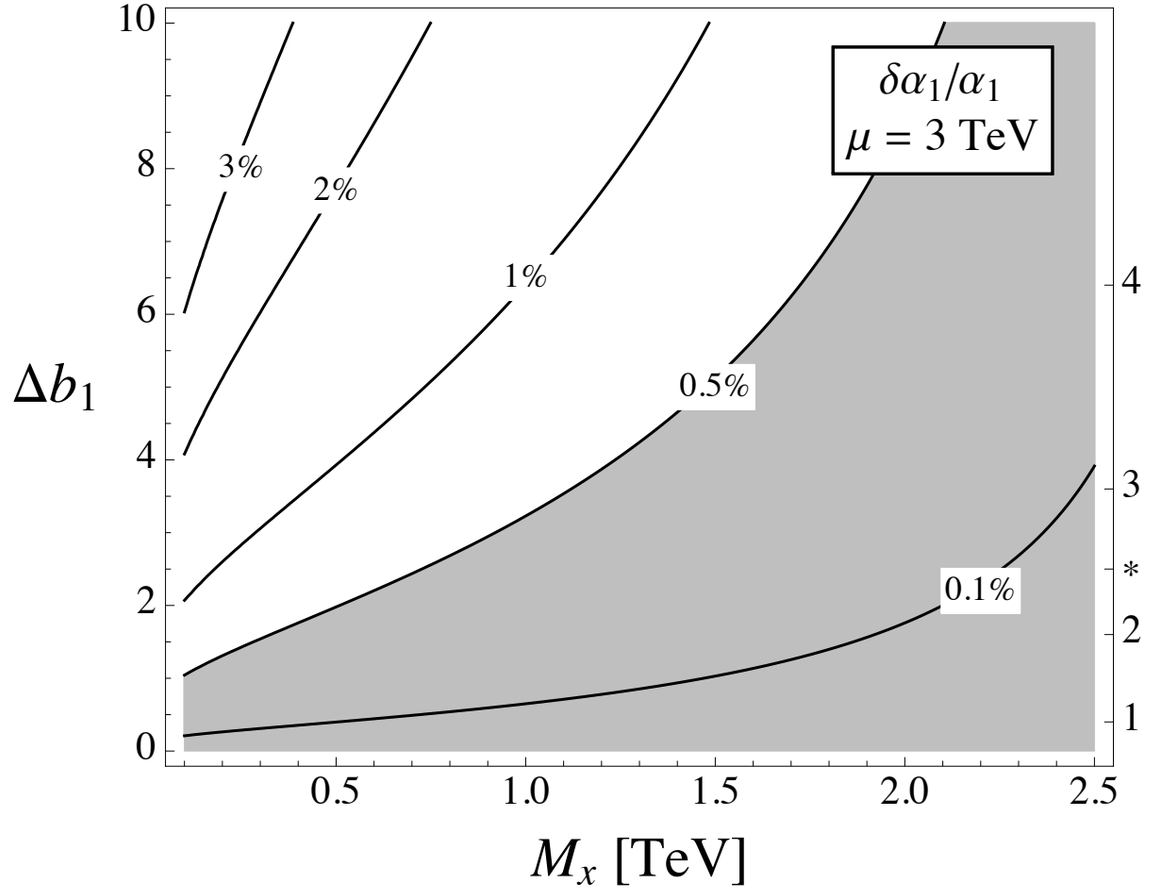




deviation from SM

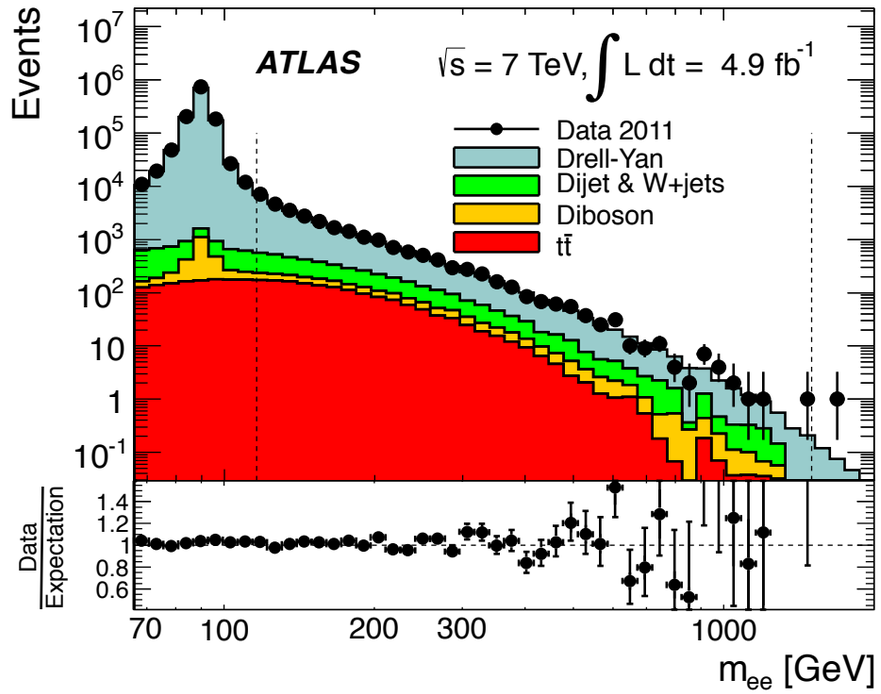
varying scale of new physics

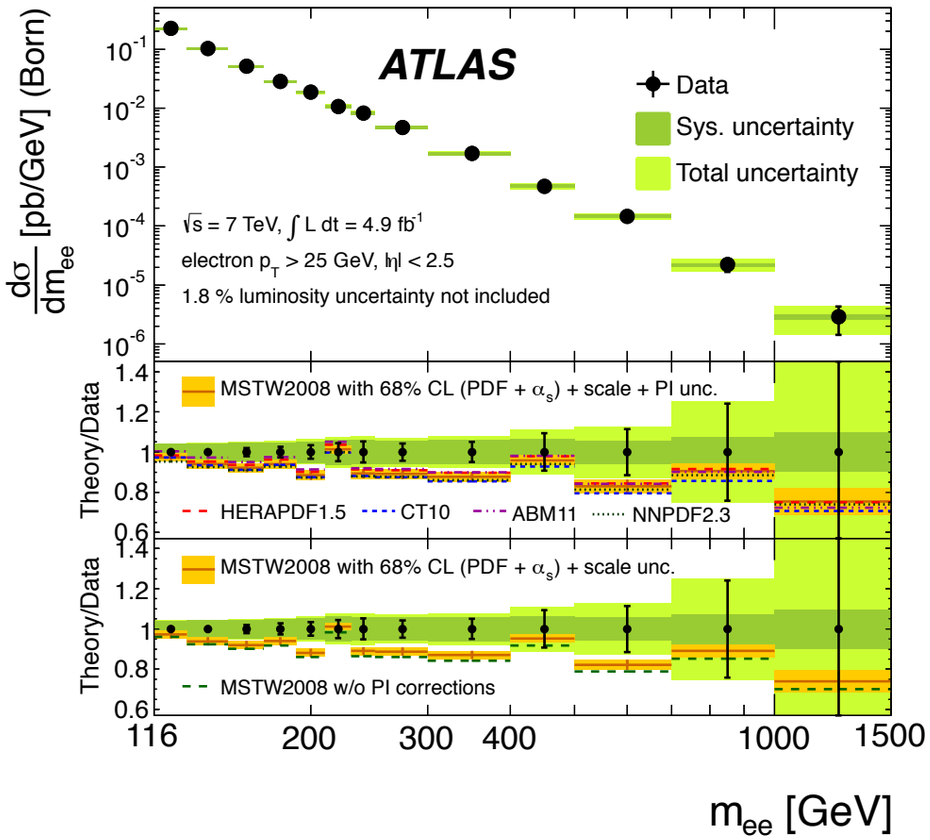


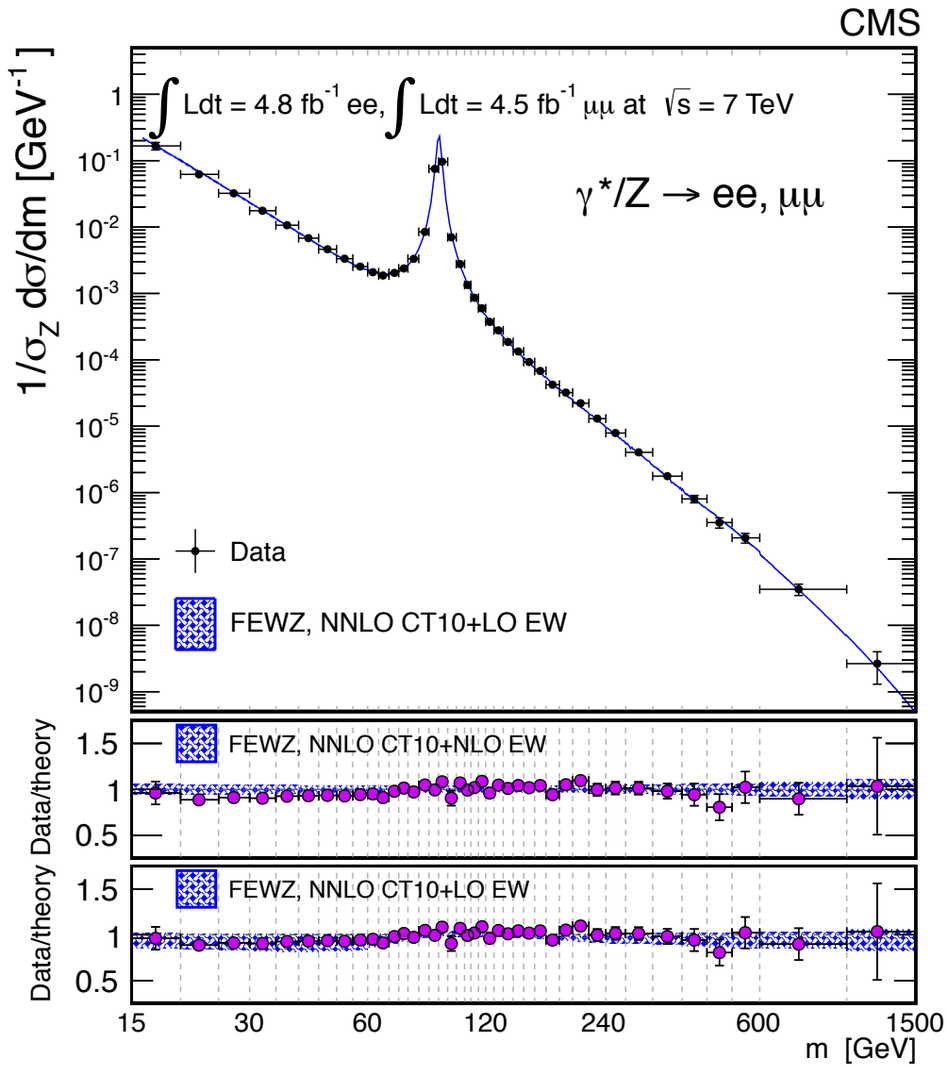


3. Drell-Yan at the LHC

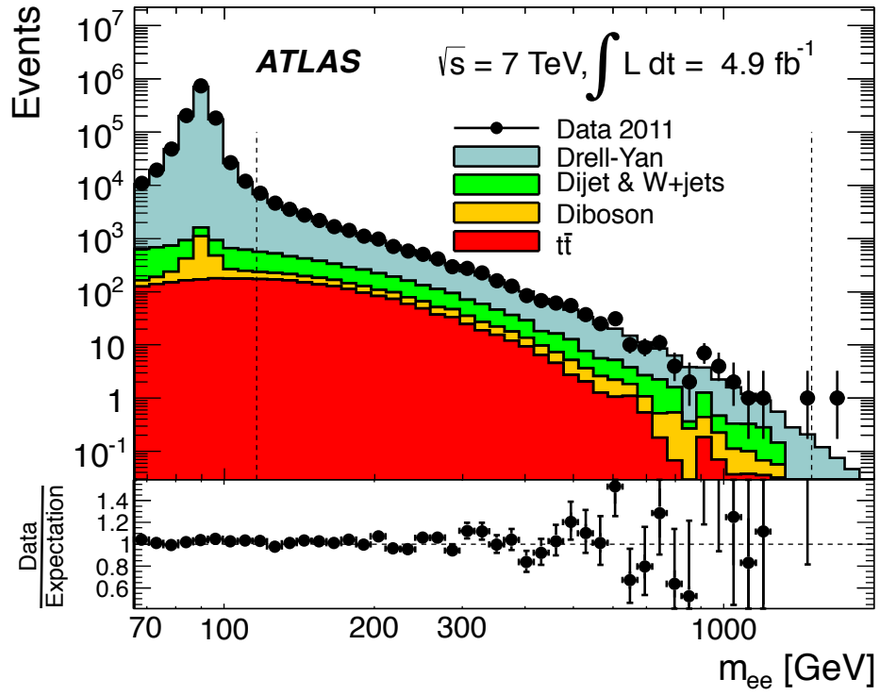
Drell-Yan measurements

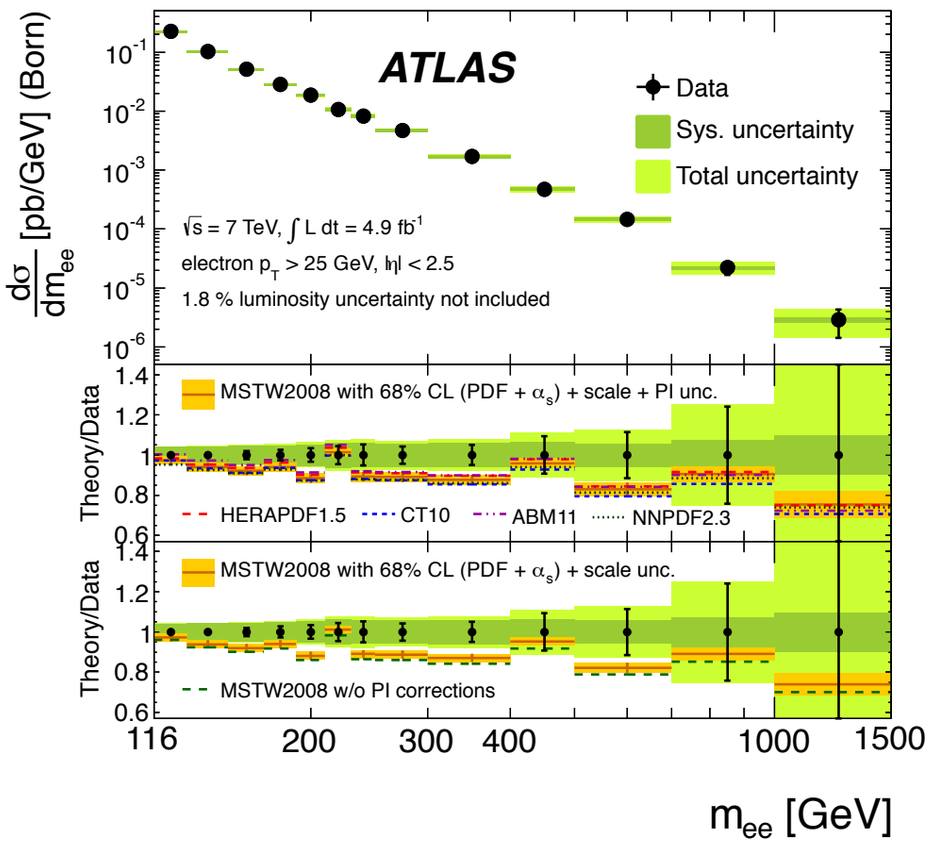






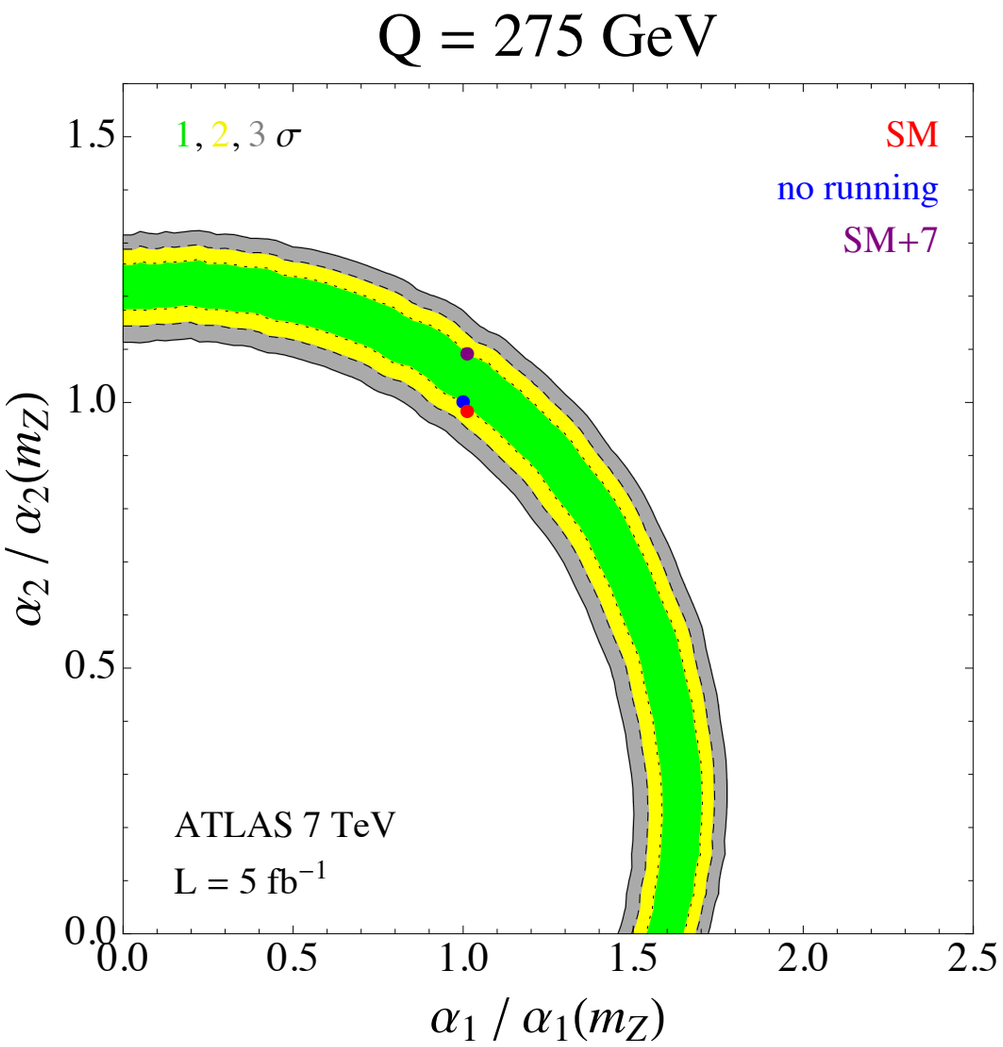
ATLAS Drell-Yan

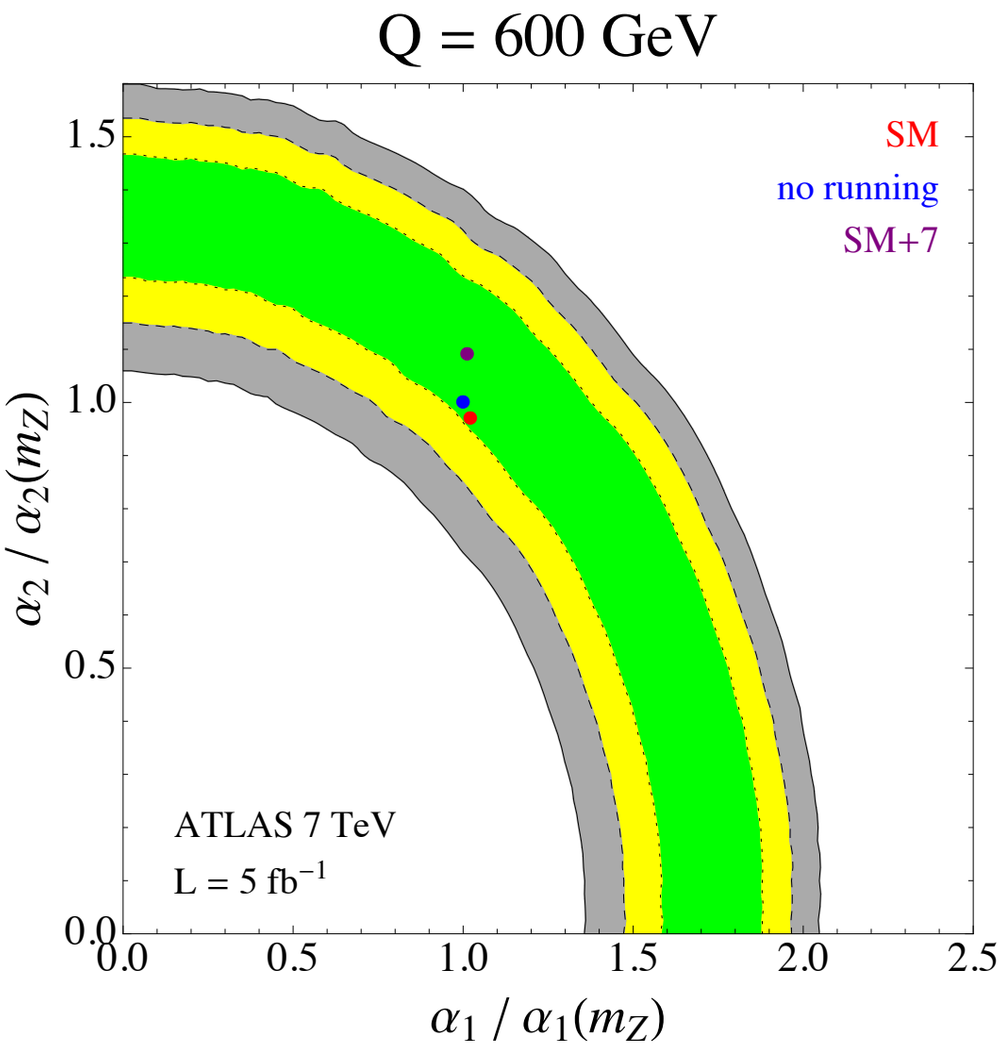




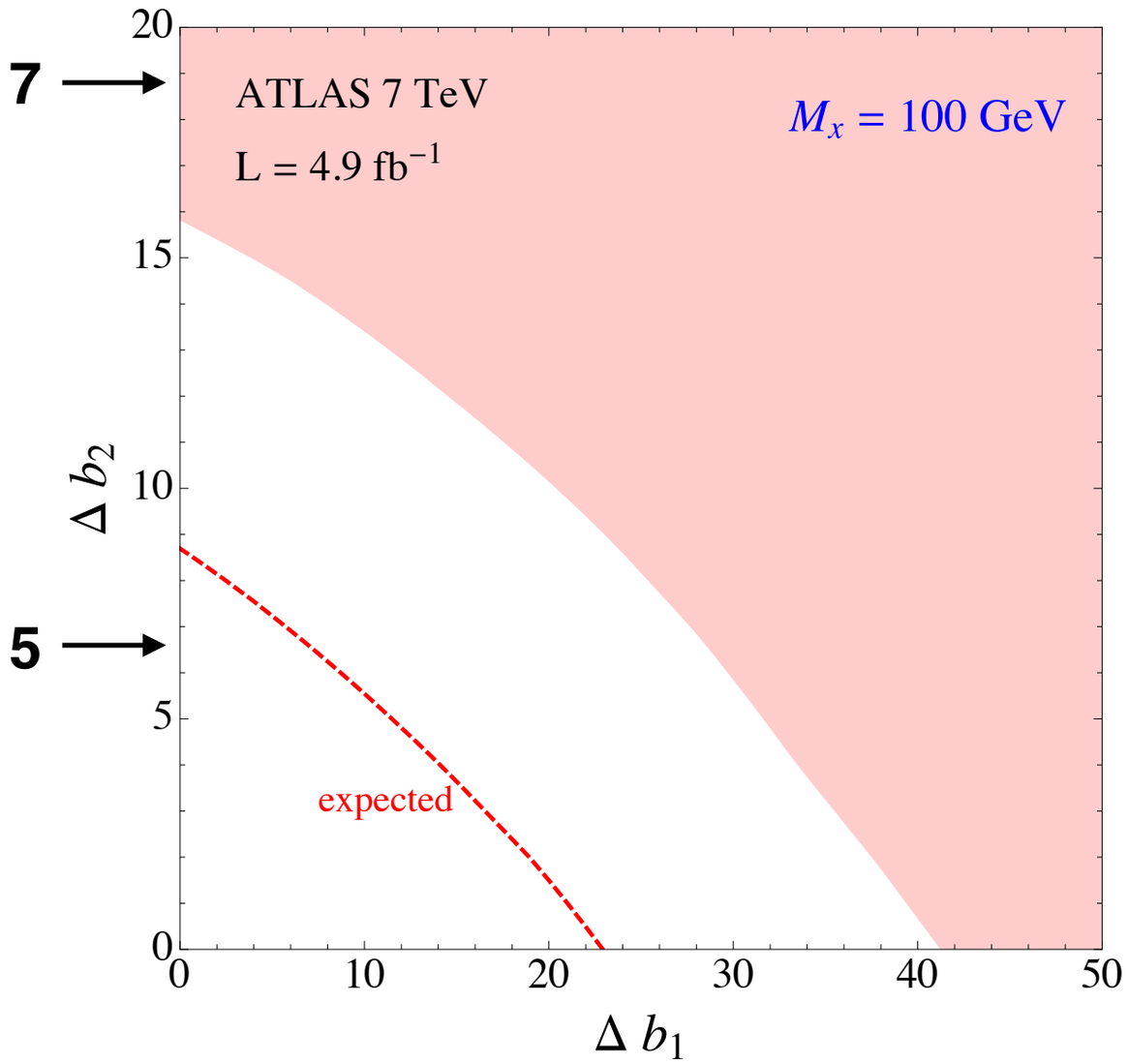
m_{ee} [GeV]	$\frac{d\sigma}{dm_{ee}}$(Born)	$\frac{d\sigma}{dm_{ee}}$(dressed)	Stat. err. [%]	Syst. err. [%]	uncorr. sys [%]
116–130	2.24×10^{-1}	2.15×10^{-1}	1.1	4.2	0.7
130–150	1.02×10^{-1}	9.84×10^{-2}	1.4	4.3	0.7
150–170	5.12×10^{-2}	4.93×10^{-2}	2.0	4.6	1.0
170–190	2.84×10^{-2}	2.76×10^{-2}	2.7	4.7	1.4
190–210	1.87×10^{-2}	1.82×10^{-2}	3.0	5.3	1.8
210–230	1.07×10^{-2}	1.04×10^{-2}	4.4	6.1	2.2
230–250	8.23×10^{-3}	7.98×10^{-3}	5.2	5.9	2.6
250–300	4.66×10^{-3}	4.52×10^{-3}	4.3	5.8	1.1
300–400	1.70×10^{-3}	1.65×10^{-3}	5.1	5.9	1.3
400–500	4.74×10^{-4}	4.58×10^{-4}	9.4	6.3	2.2
500–700	1.46×10^{-4}	1.41×10^{-4}	11	5.7	2.2
700–1000	2.21×10^{-5}	2.13×10^{-5}	24	7.5	4.0
1000–1500	2.88×10^{-6}	2.76×10^{-6}	50	9.8	7.6

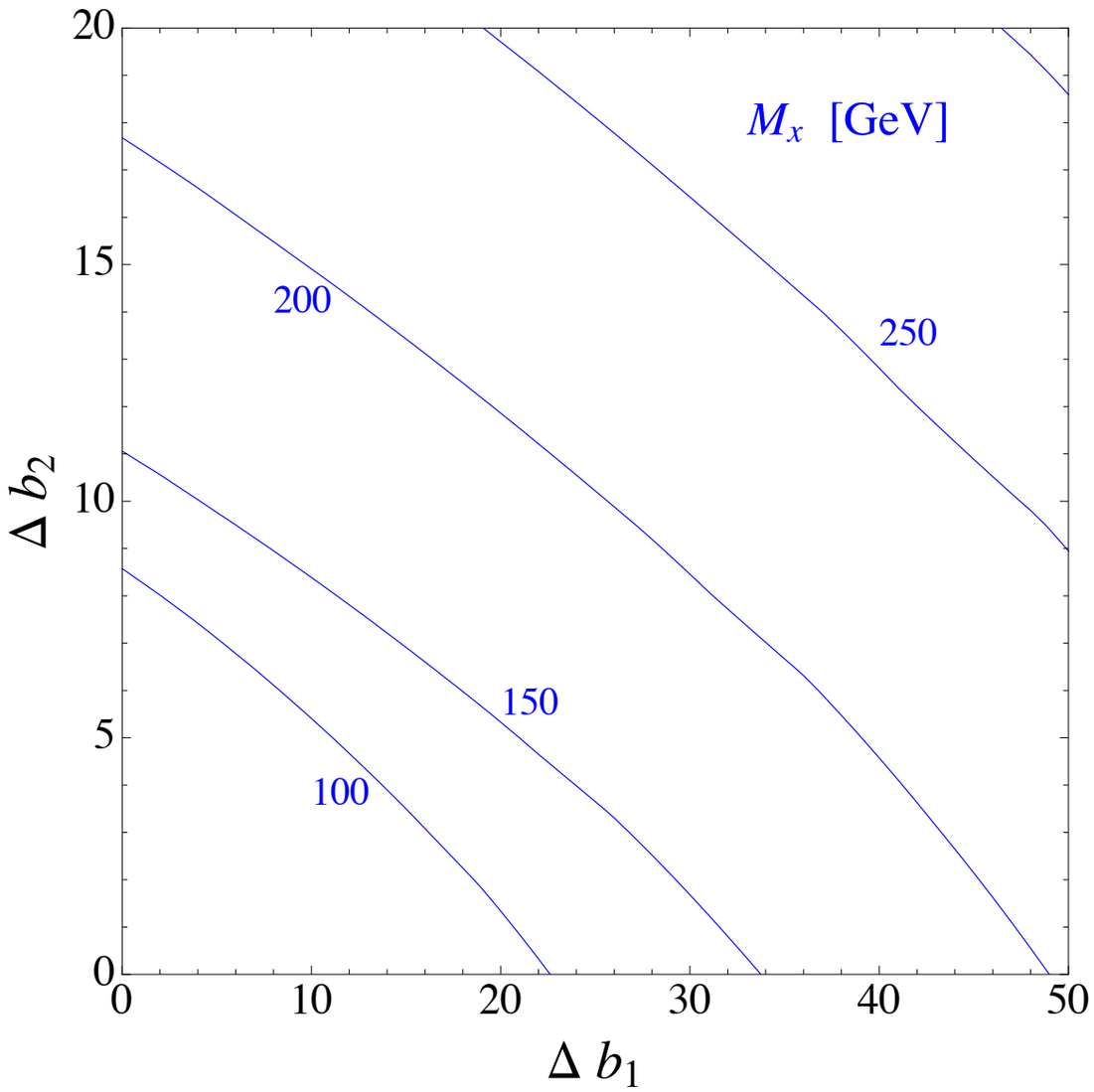
ATLAS Drell-Yan





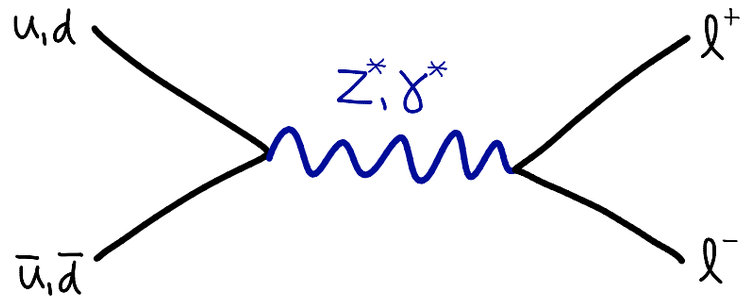
ATLAS Drell-Yan

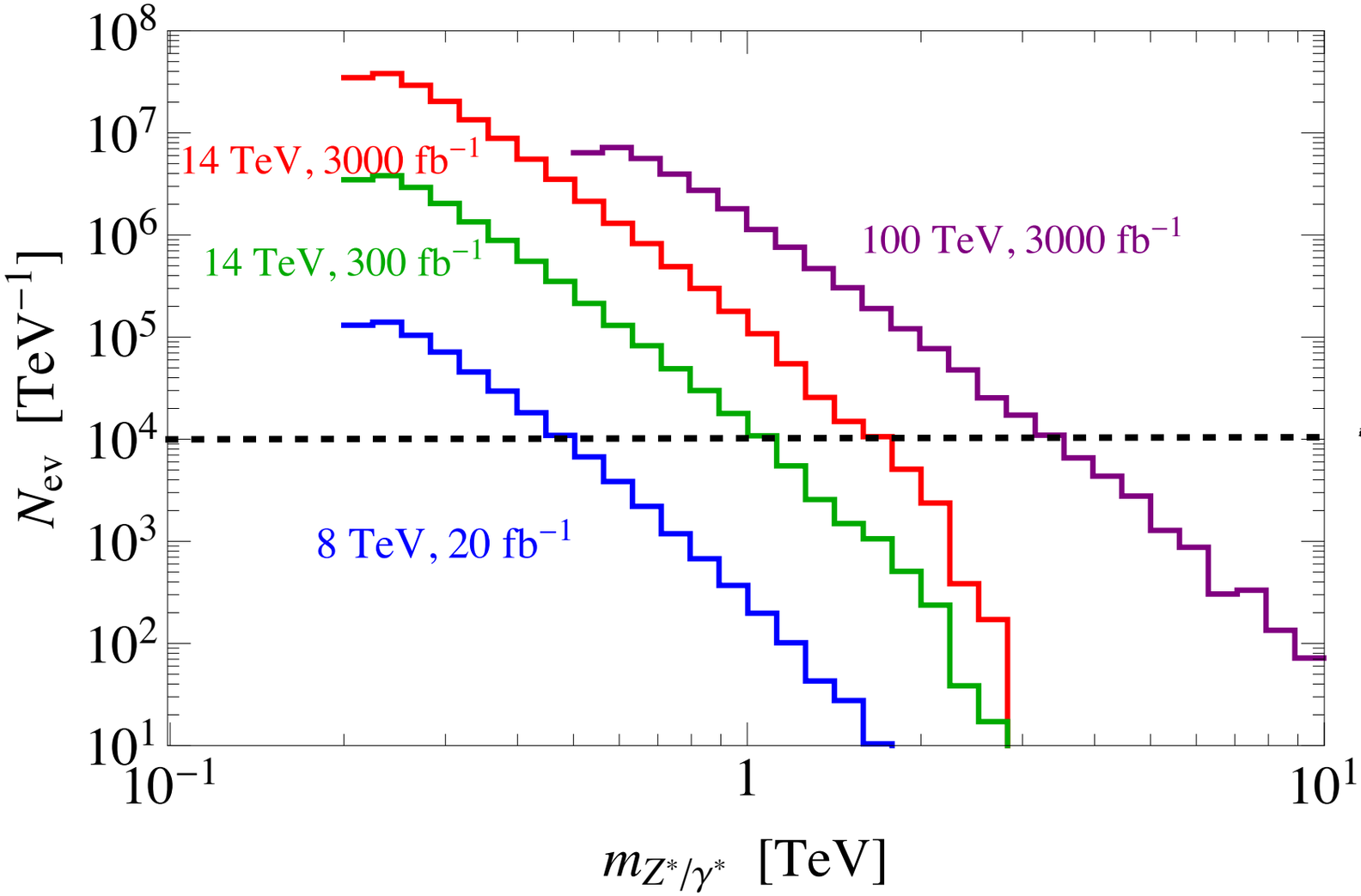




4. Drell-Yan at 100 TeV

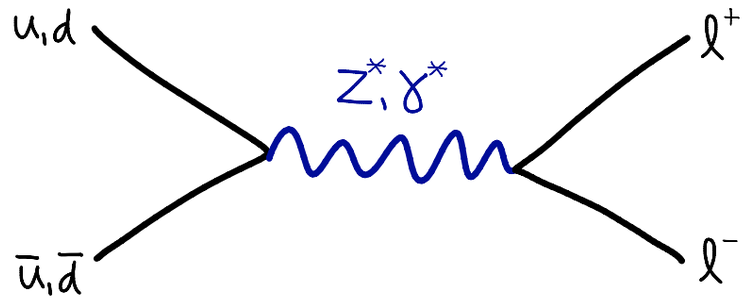
Drell-Yan at 100 TeV

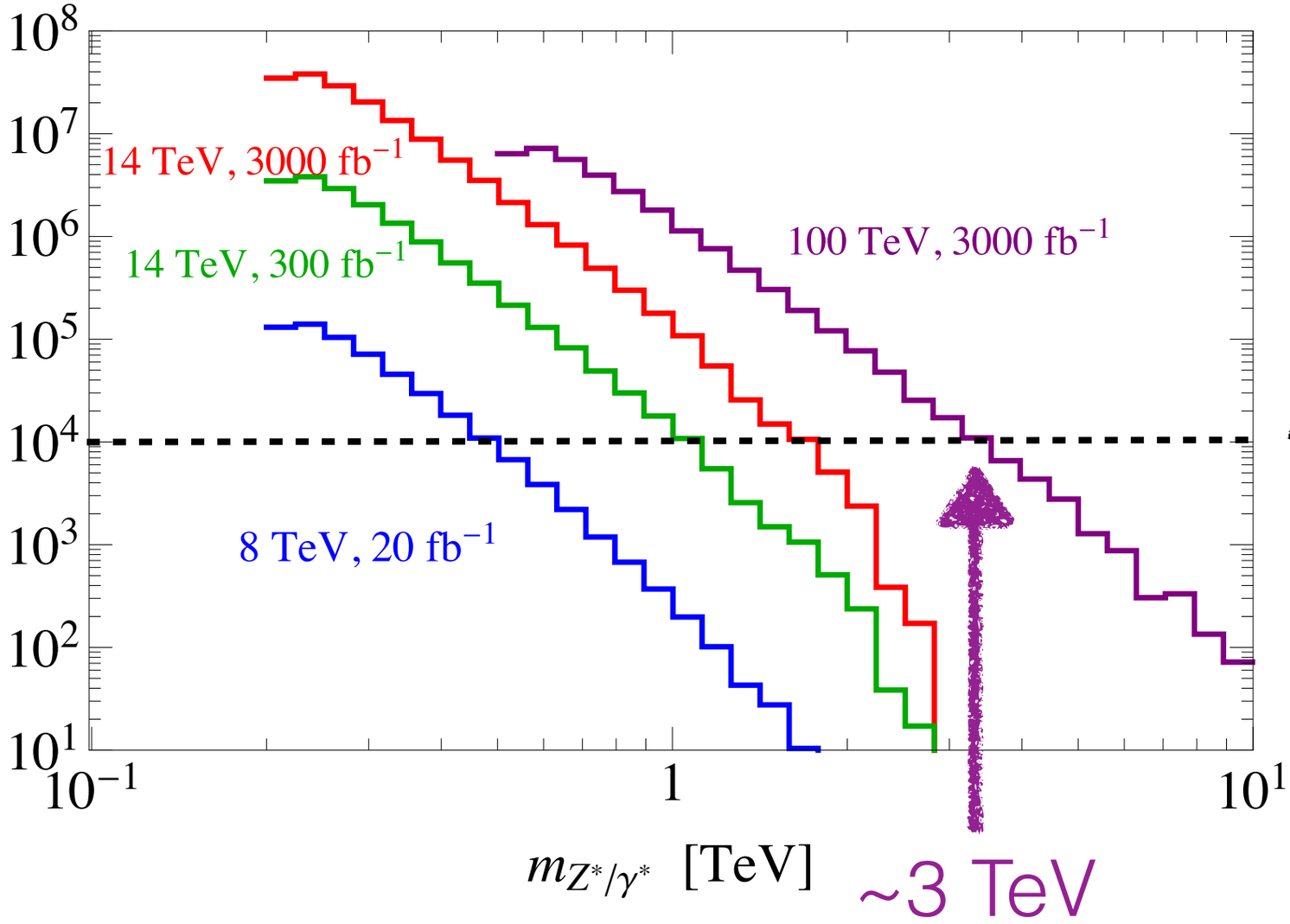




1% statistical error

Drell-Yan at 100 TeV

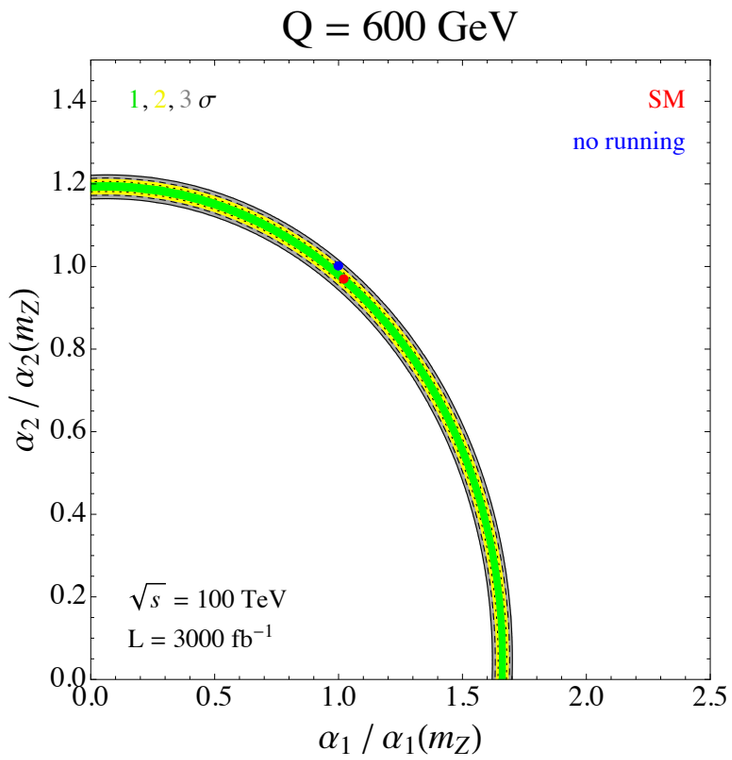


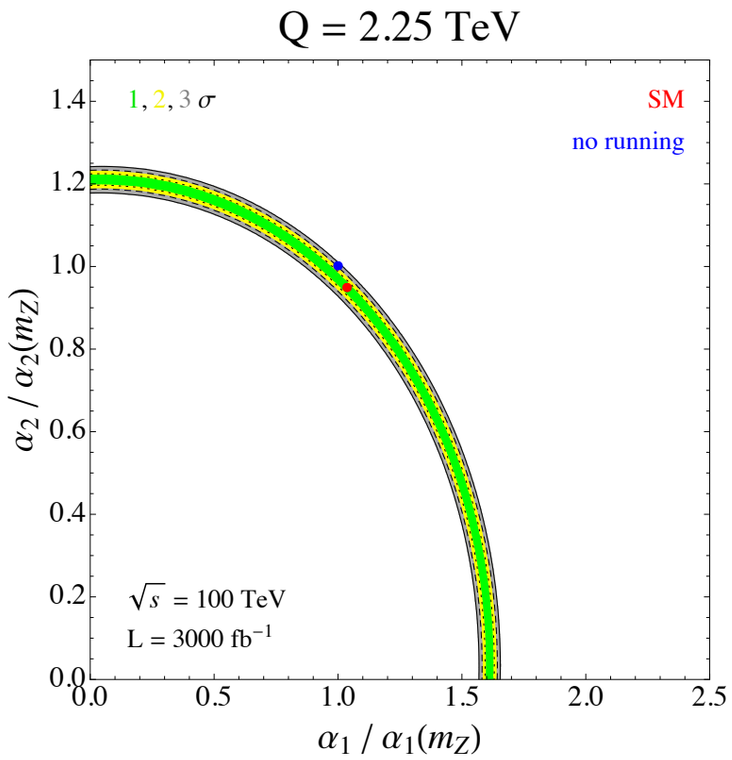


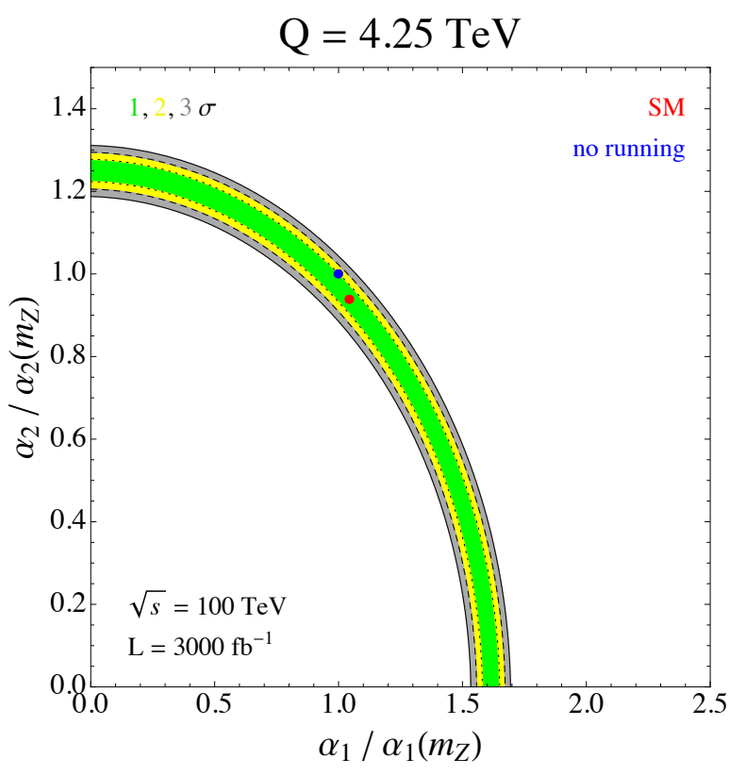
1% statistical error

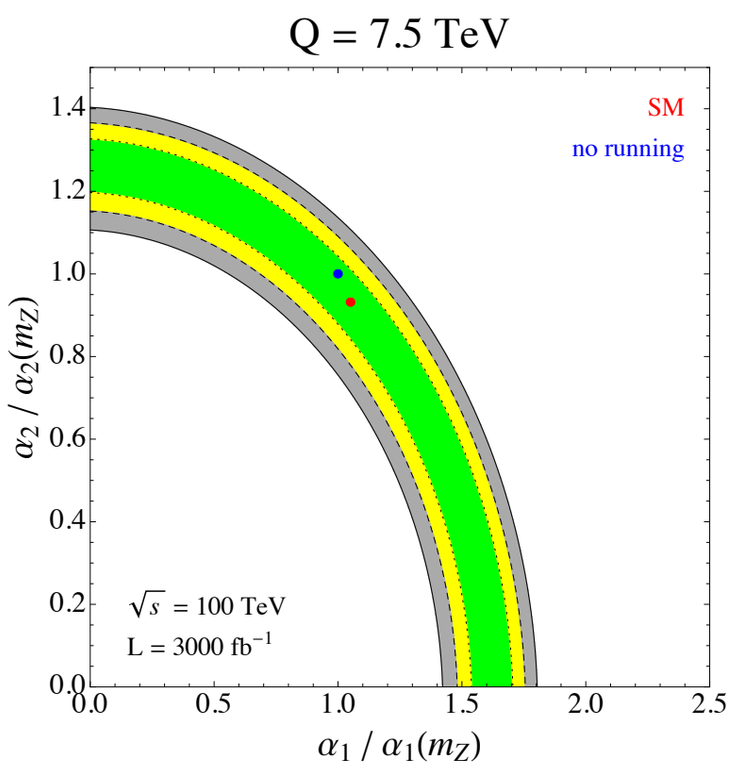
Drell-Yan at 100 TeV

assuming 1% uncorrelated sys:



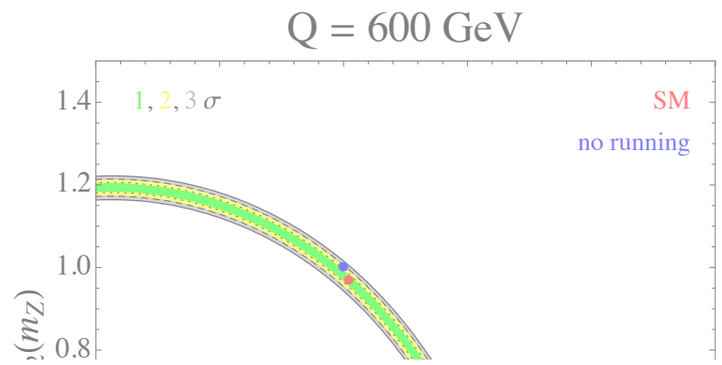


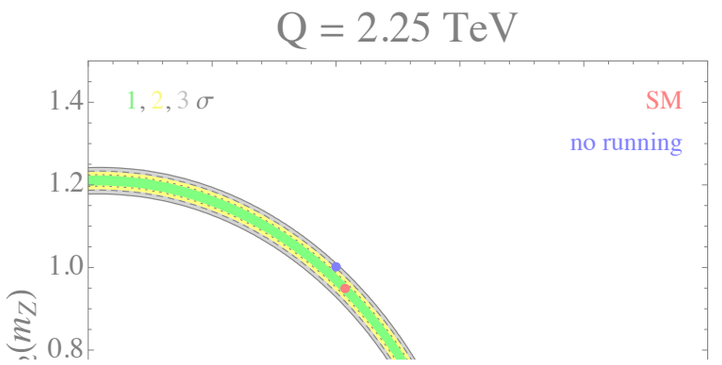


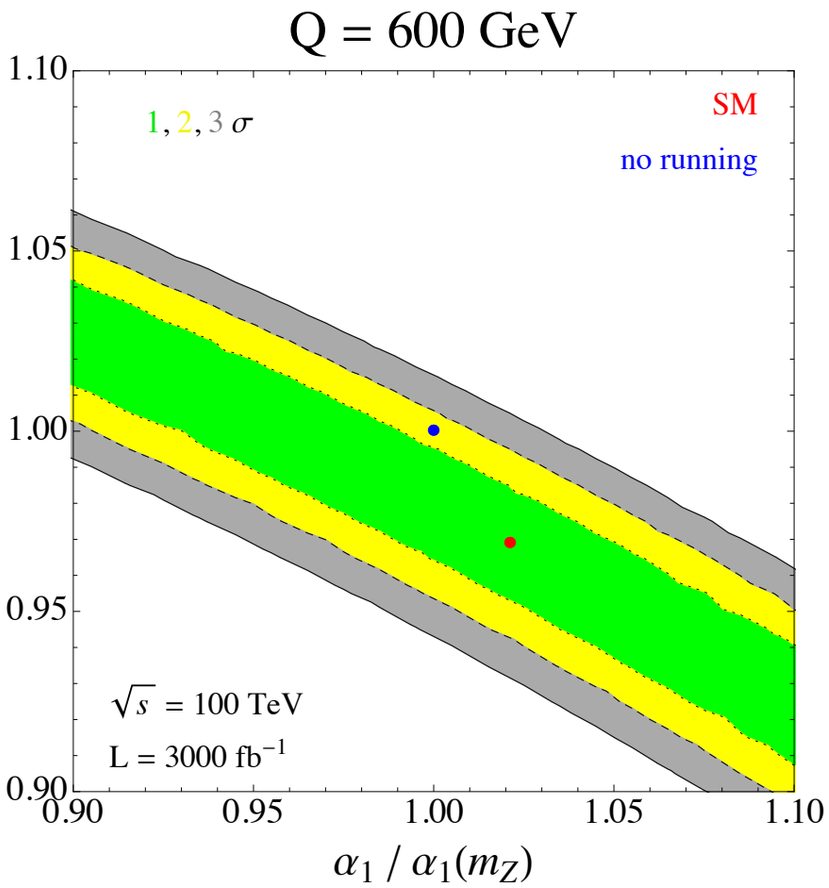


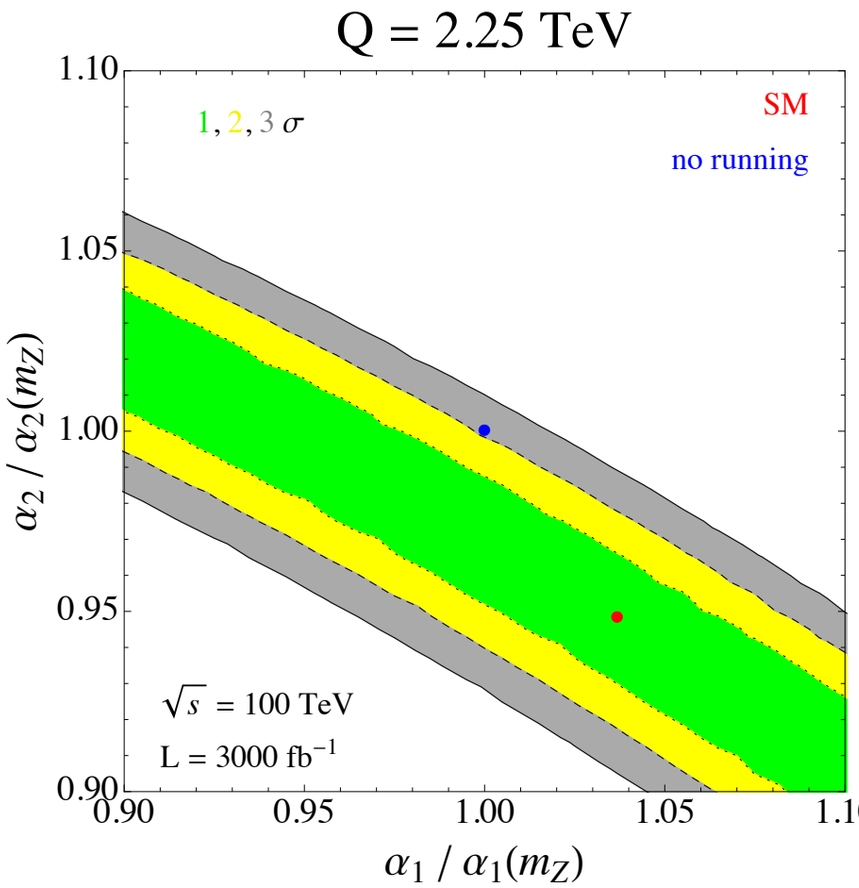
Drell-Yan at 100 TeV

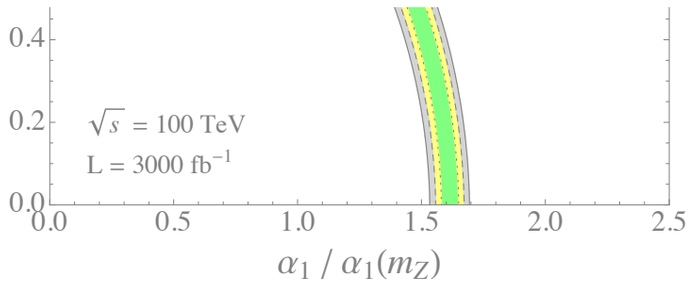
assuming 1% uncorrelated sys:

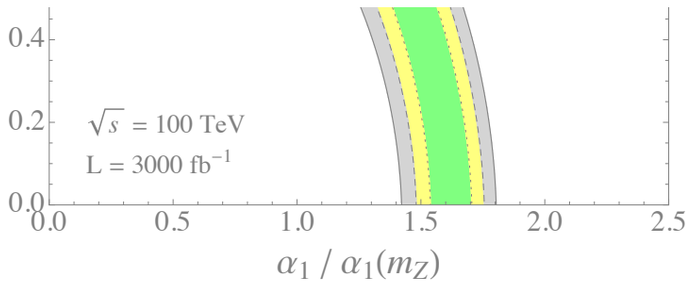






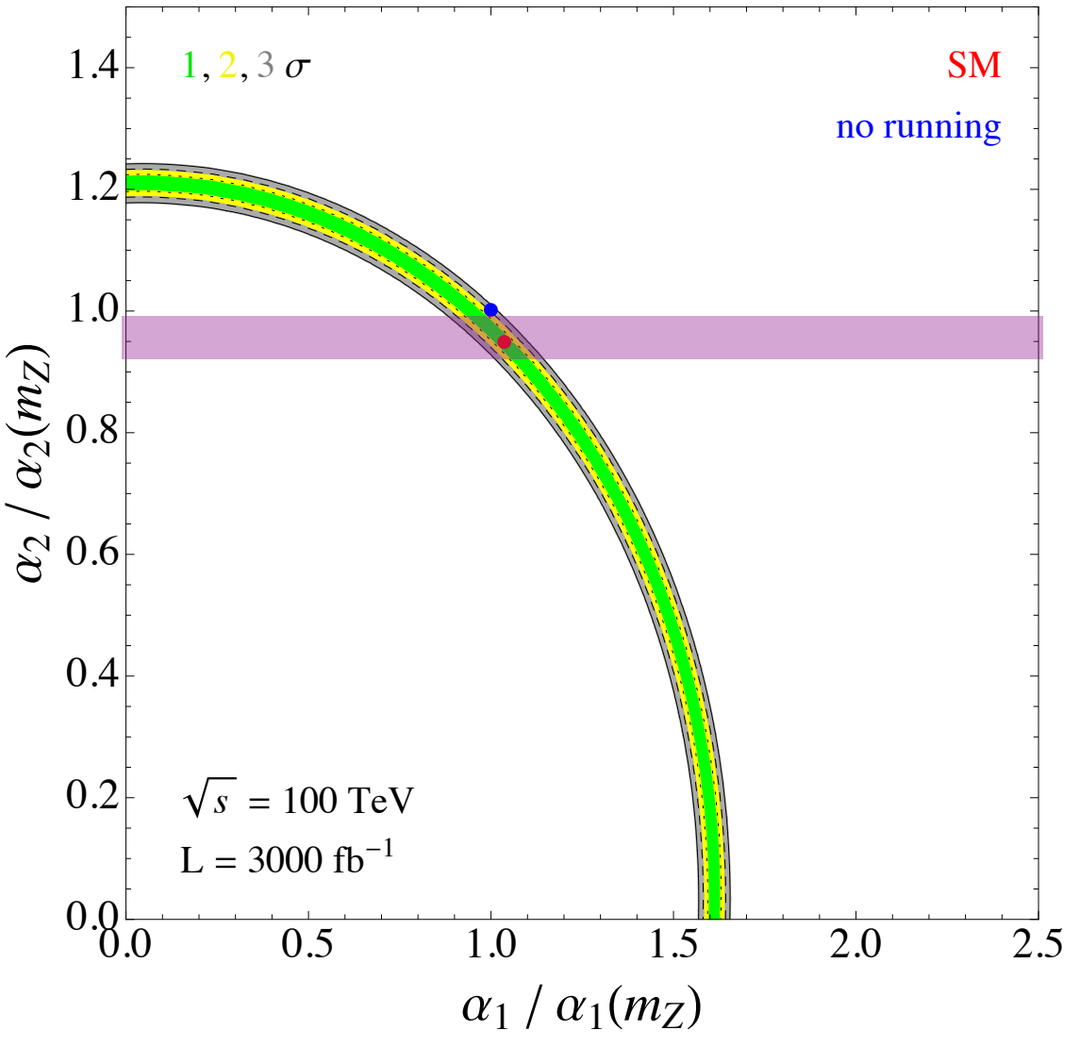


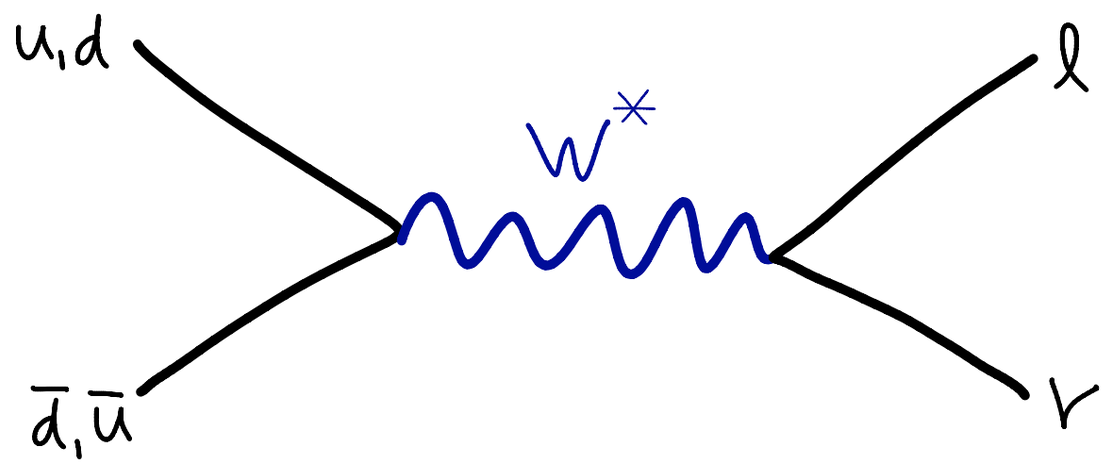




Drell-Yan at 100 TeV

should be possible to combine with W*:

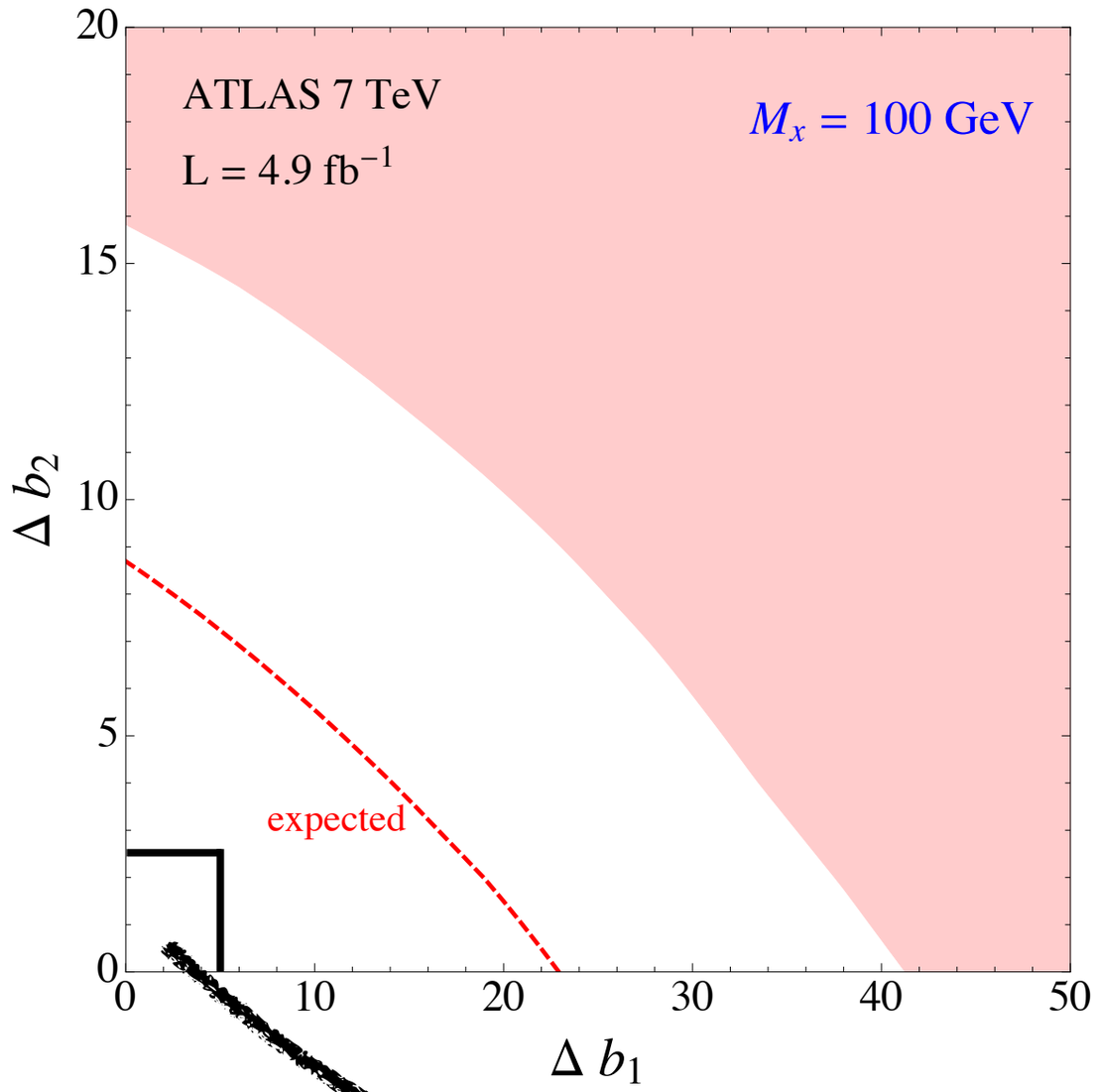




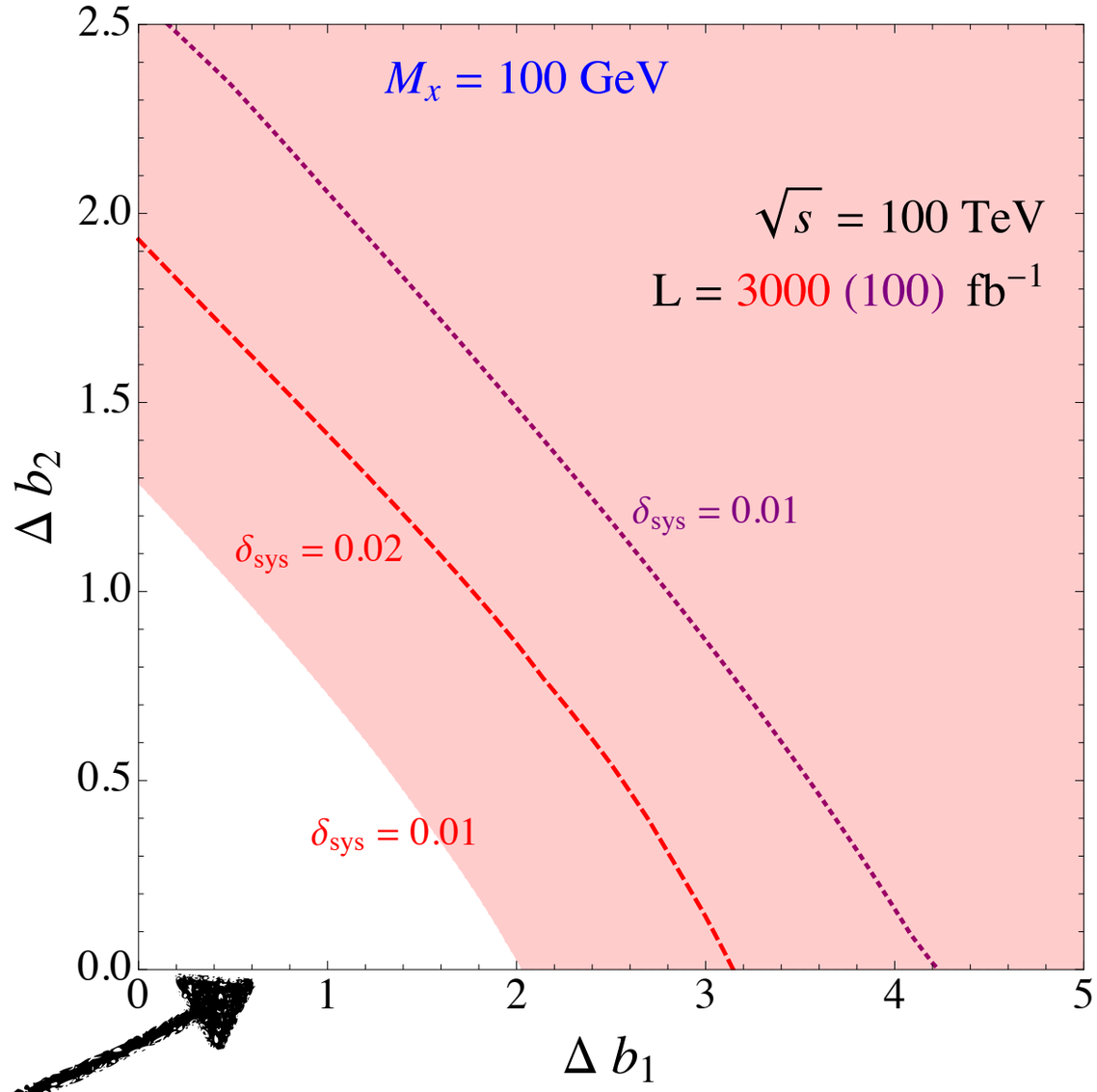
select events with high transverse mass

100 TeV limits

7 TeV

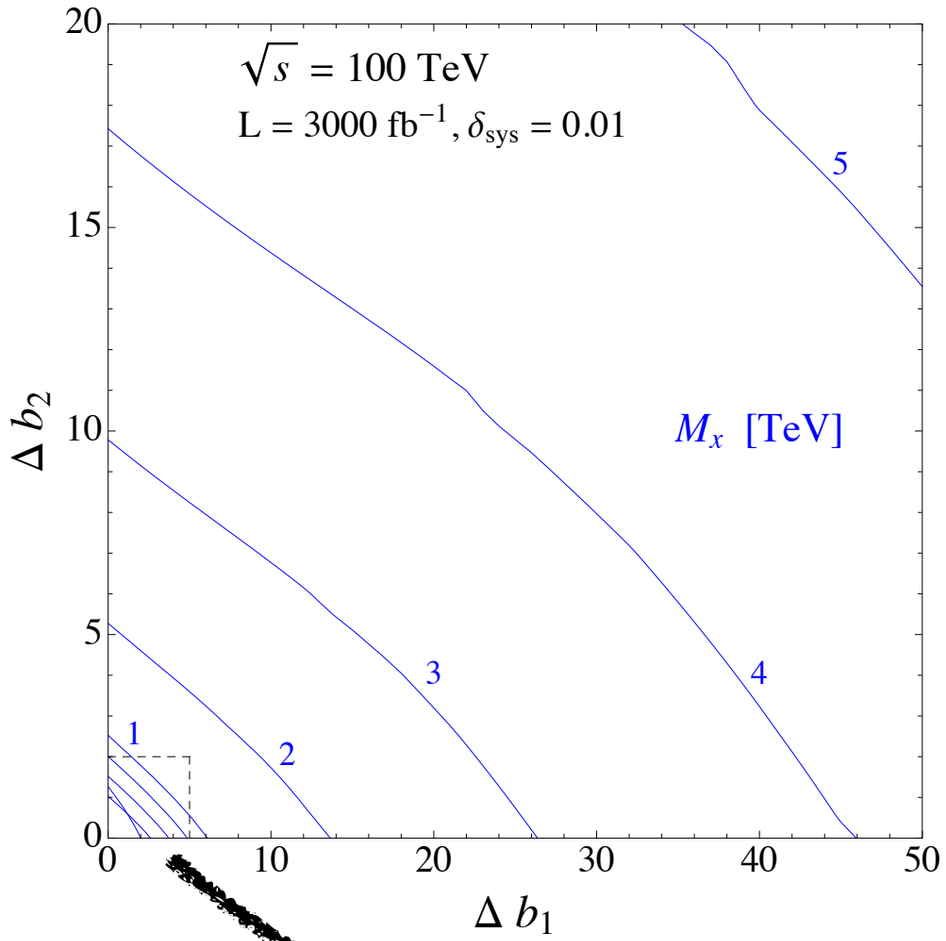


100 TeV

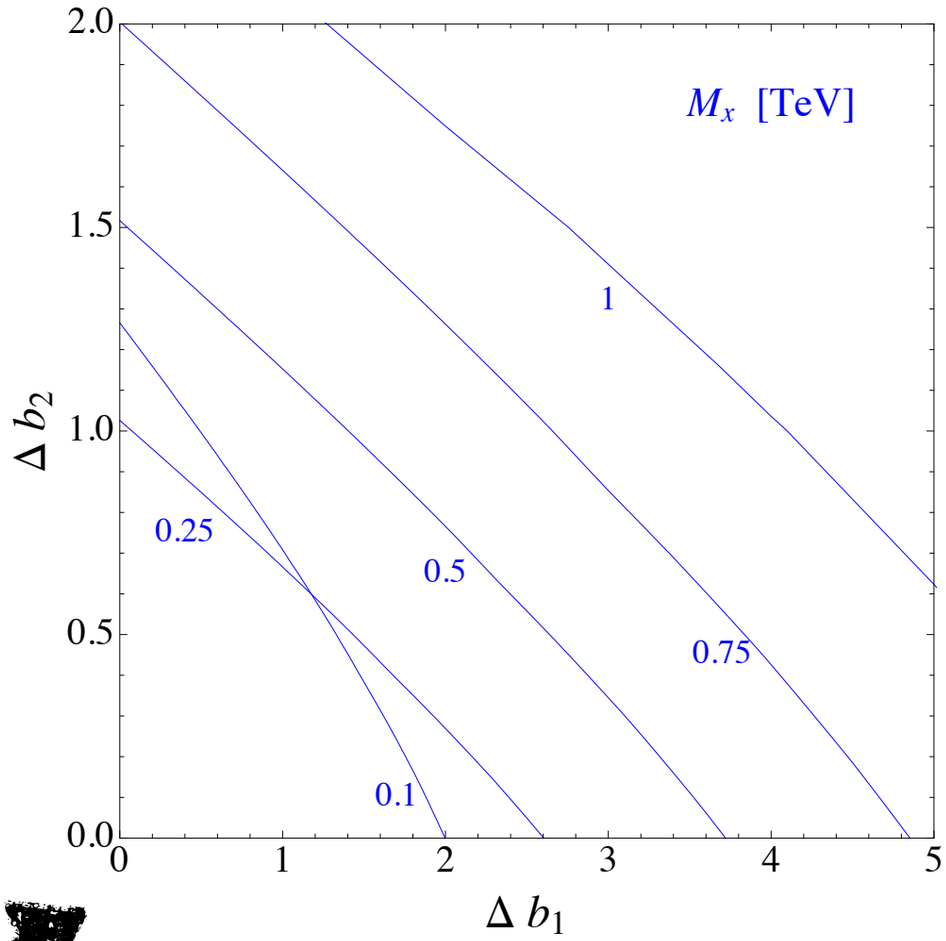


100 TeV limits

zoom out

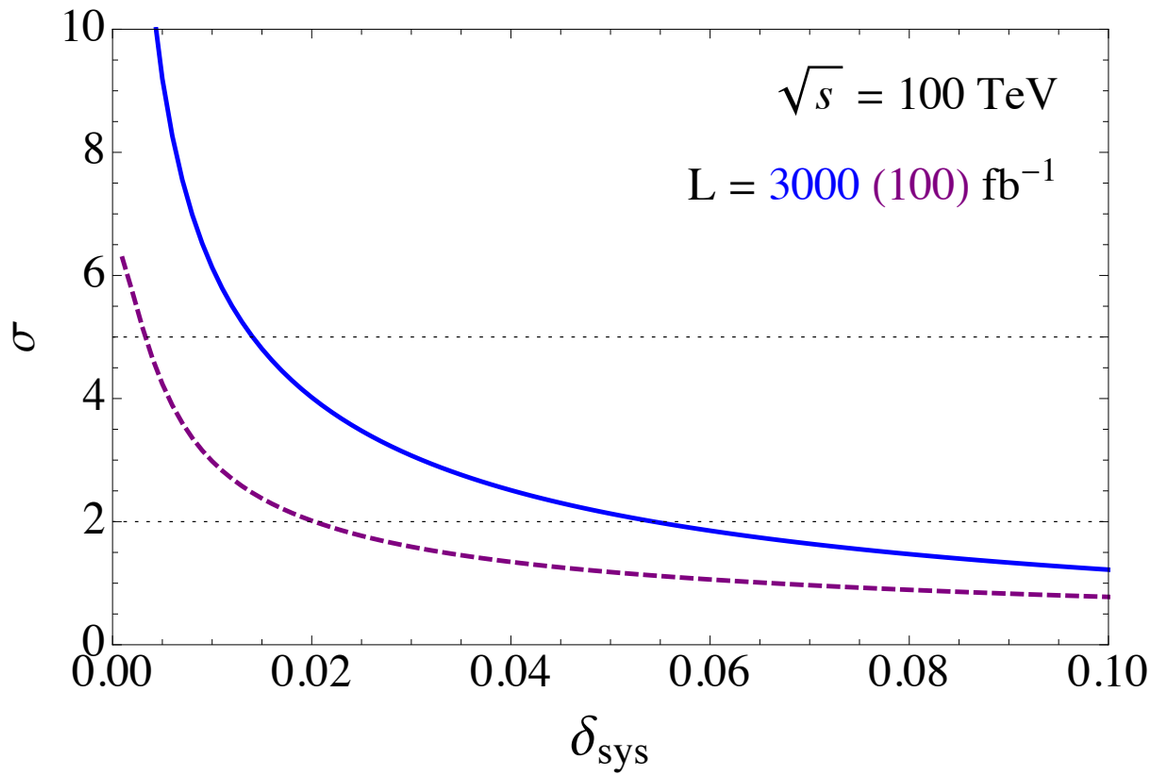


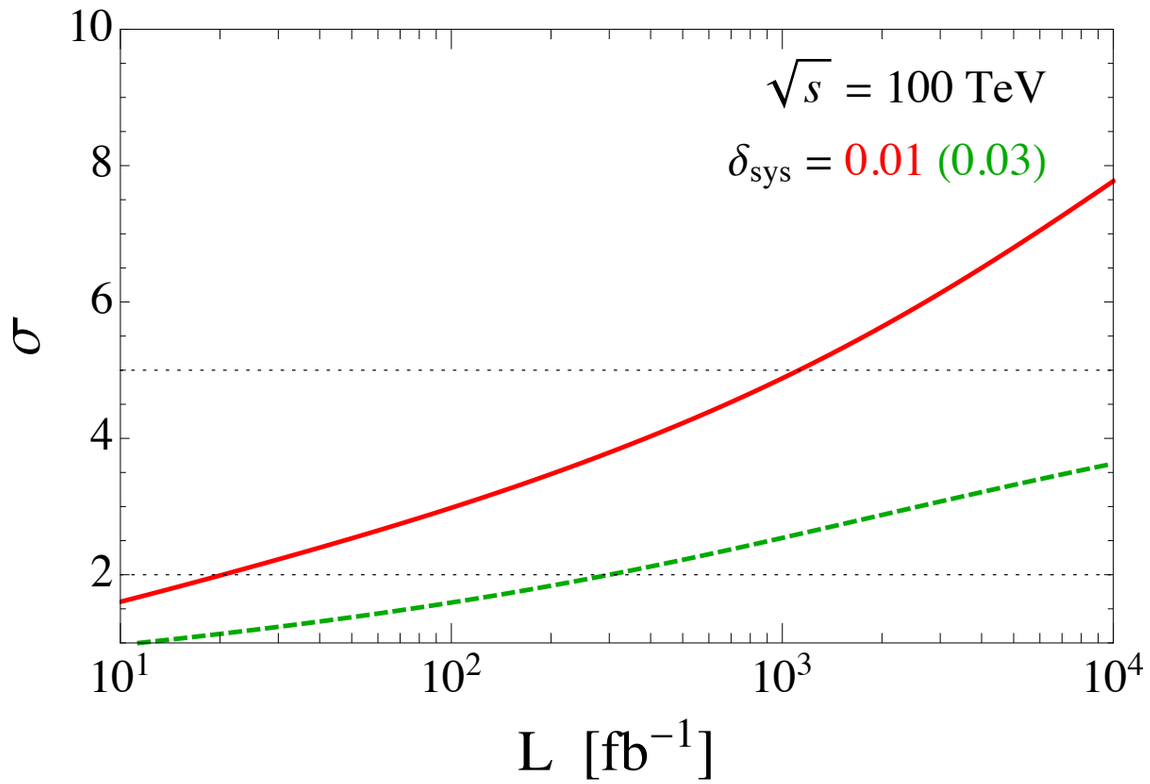
zoom in



measuring the sign of β_2

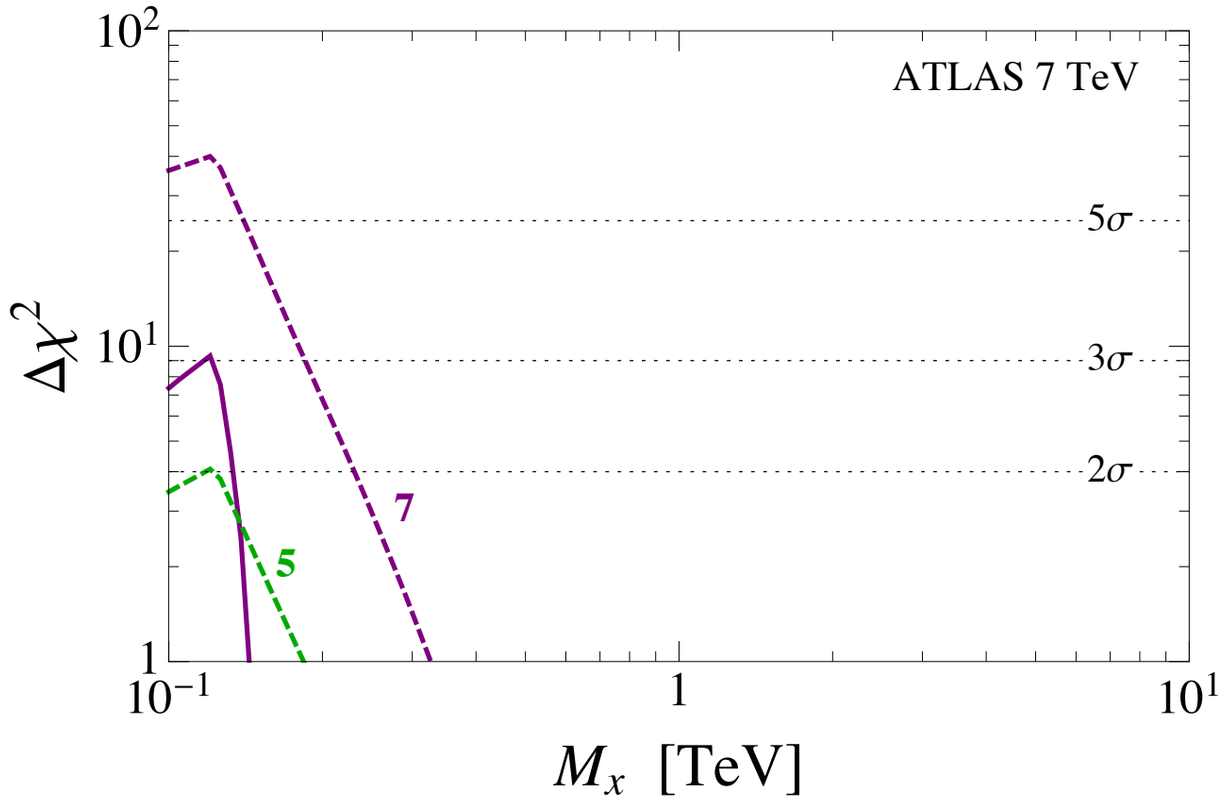
reject positive sign with significance:



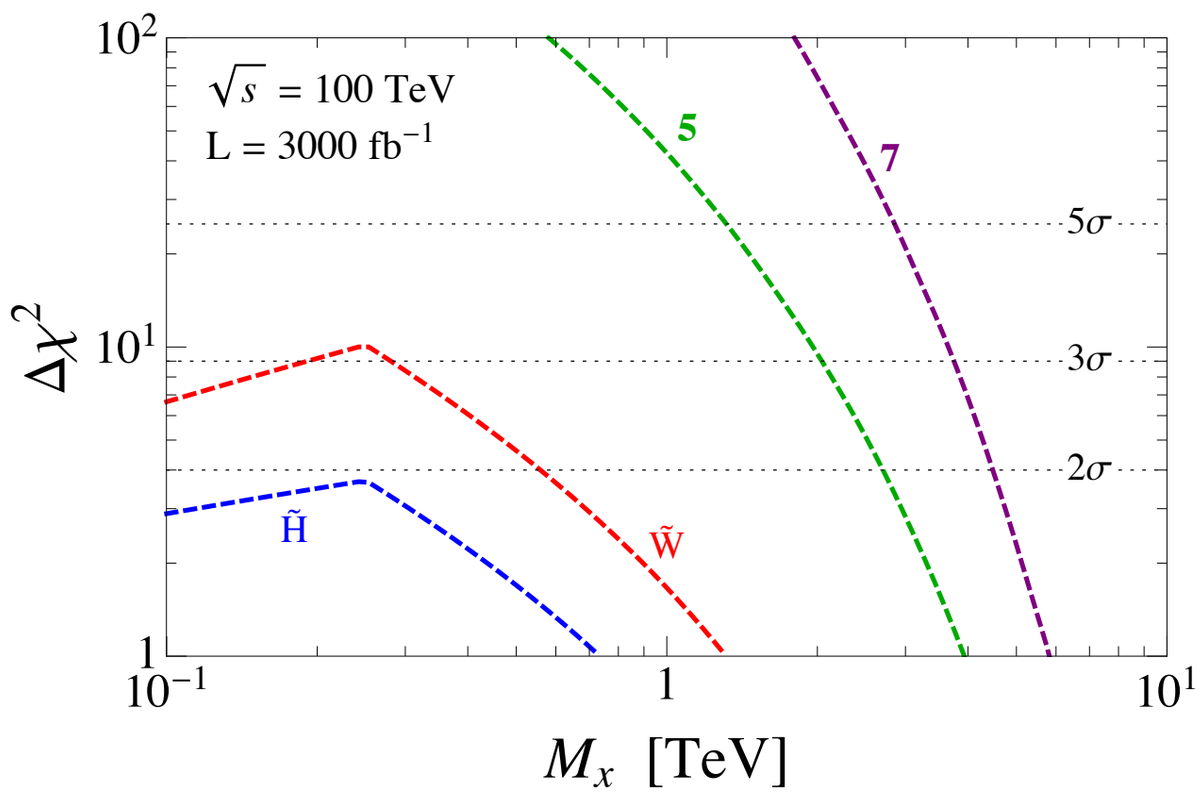


limits on specific particles

7 TeV

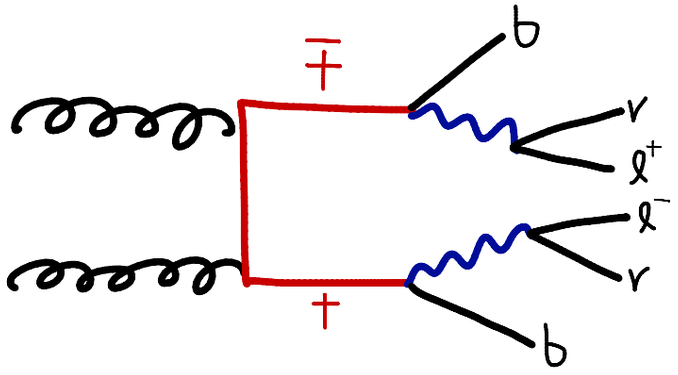


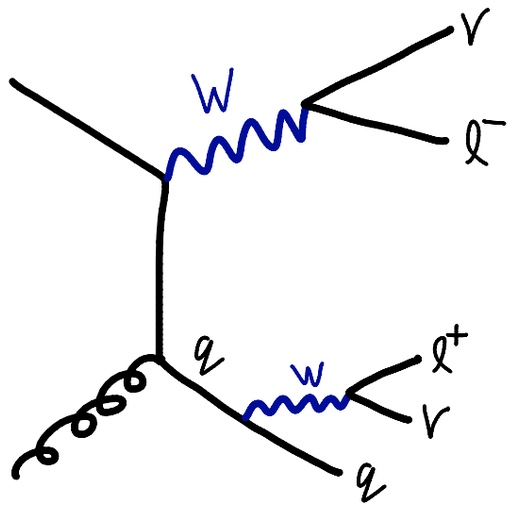
100 TeV



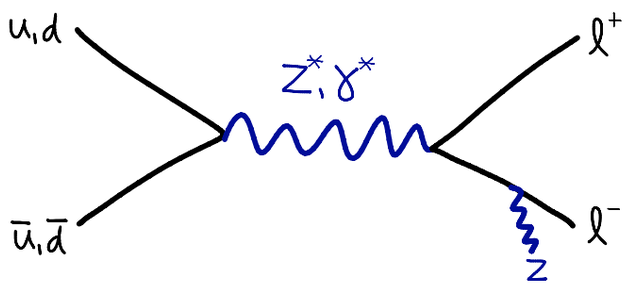
things to do

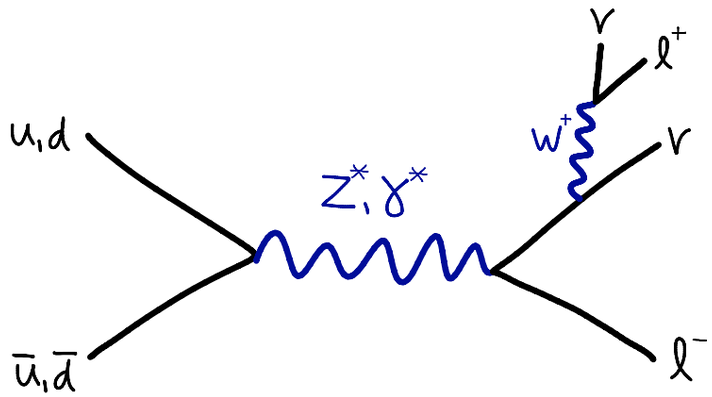
- determine cuts to suppress reducible backgrounds

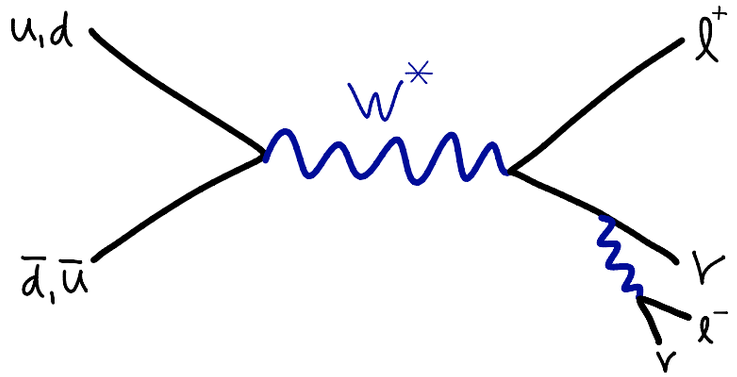




- EW radiation: veto or use as extra handle?

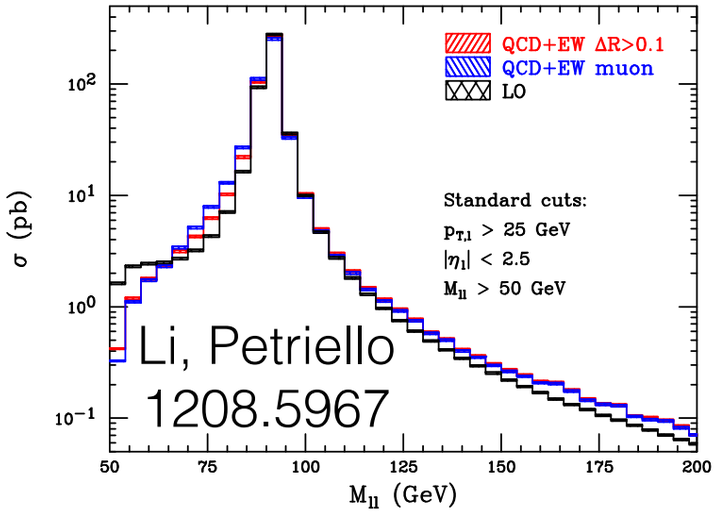


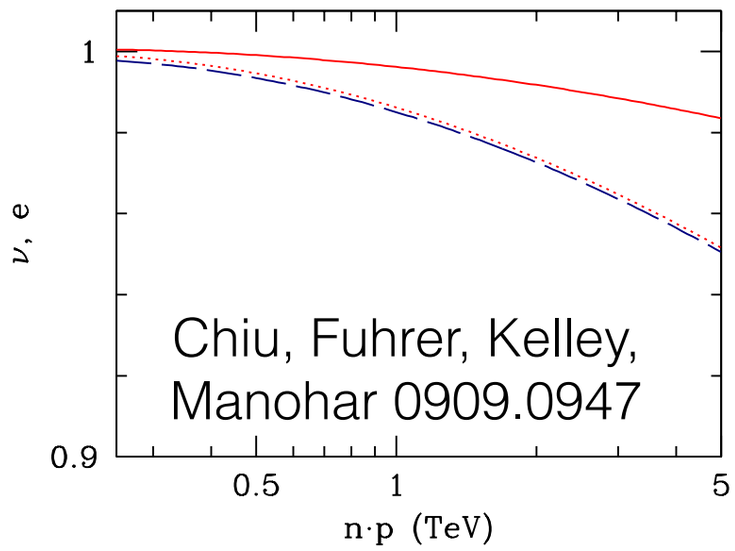




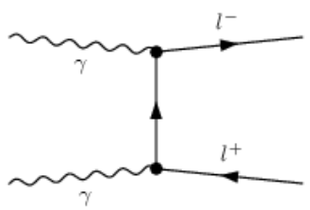
things to do

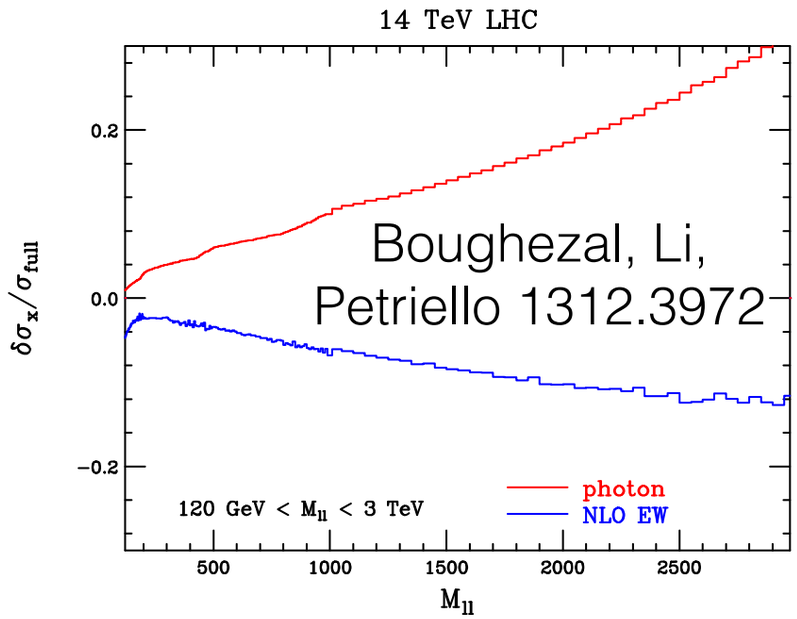
- include modified g1,g2 in NLO EW effects

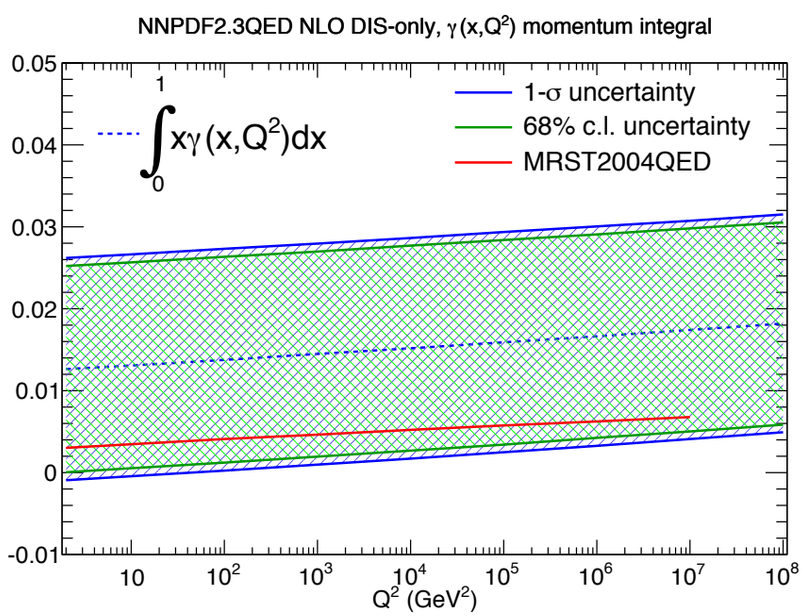




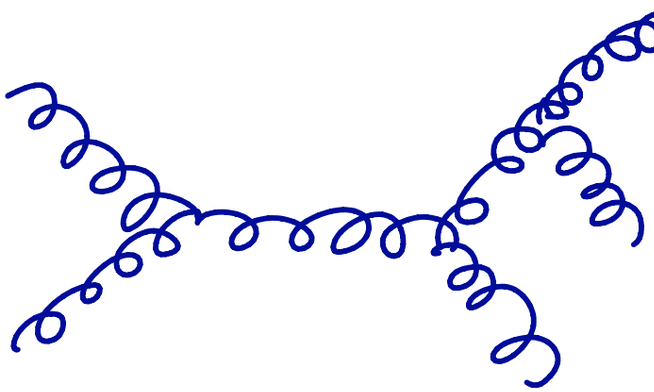
- improve understanding of photon PDF to tame uncertainty on photon-initiated Drell-Yan



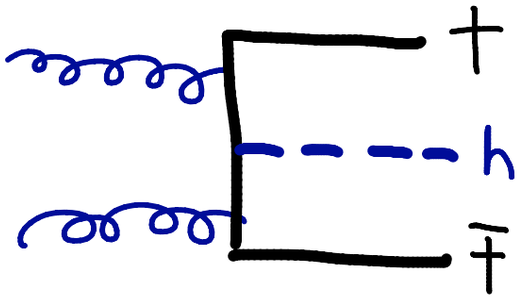




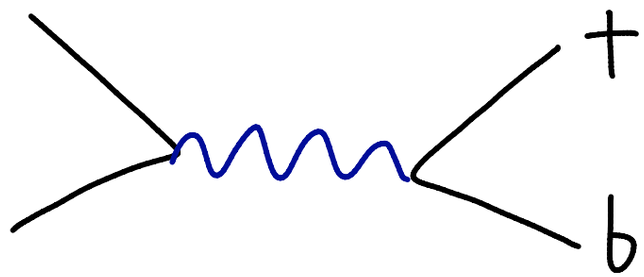
other running parameters?



$\alpha_3(\mu)$



$y_t(\mu)$



$V_{tb}(\mu)$

take away

- can measure running weak couplings using the shape of the Drell-Yan spectrum

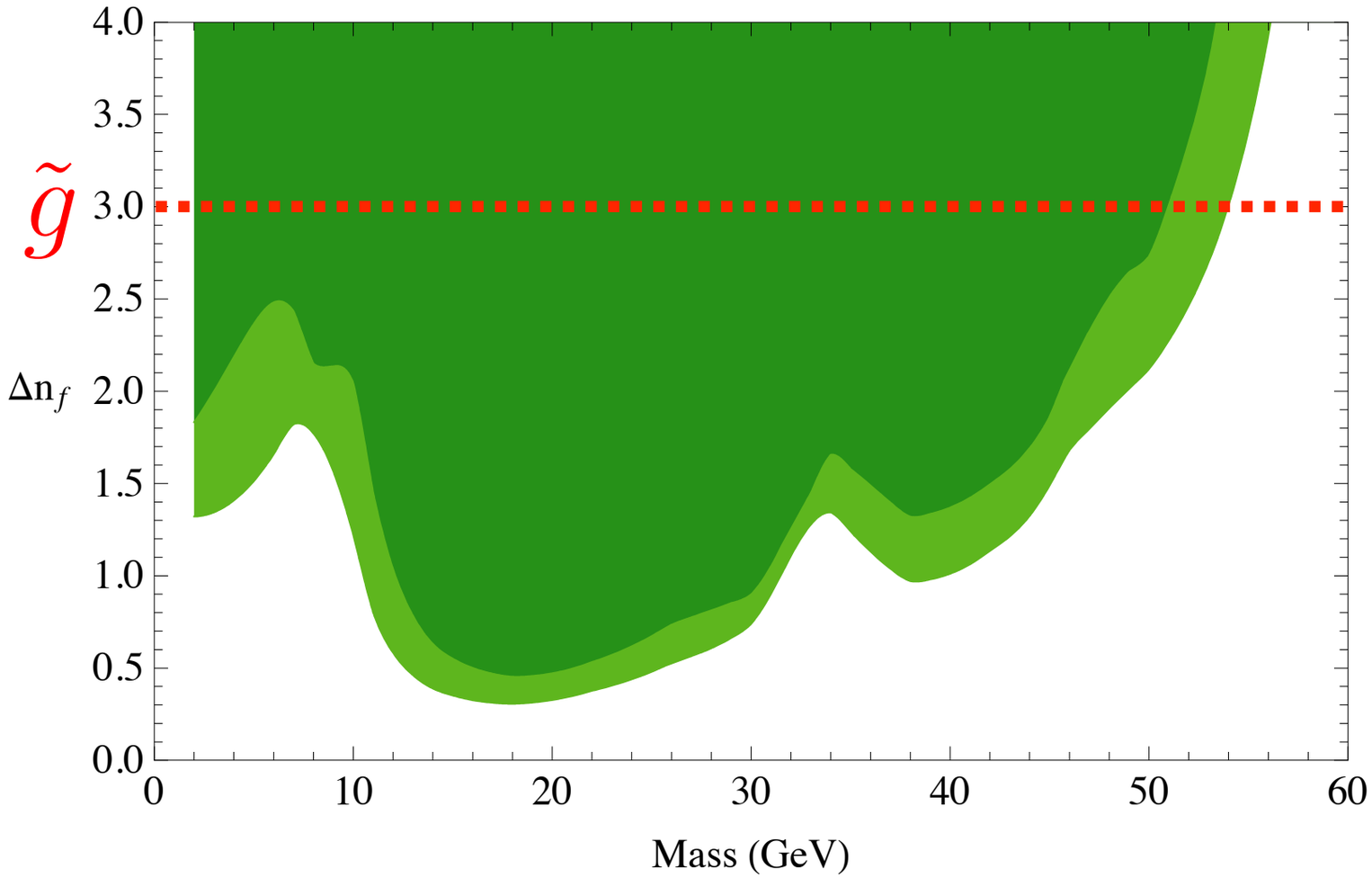
- proof-of-principle measurement possible now at the LHC

- can measure the sign of the g_2 beta function at a 100 TeV collider

- general limits on new weakly charged states await

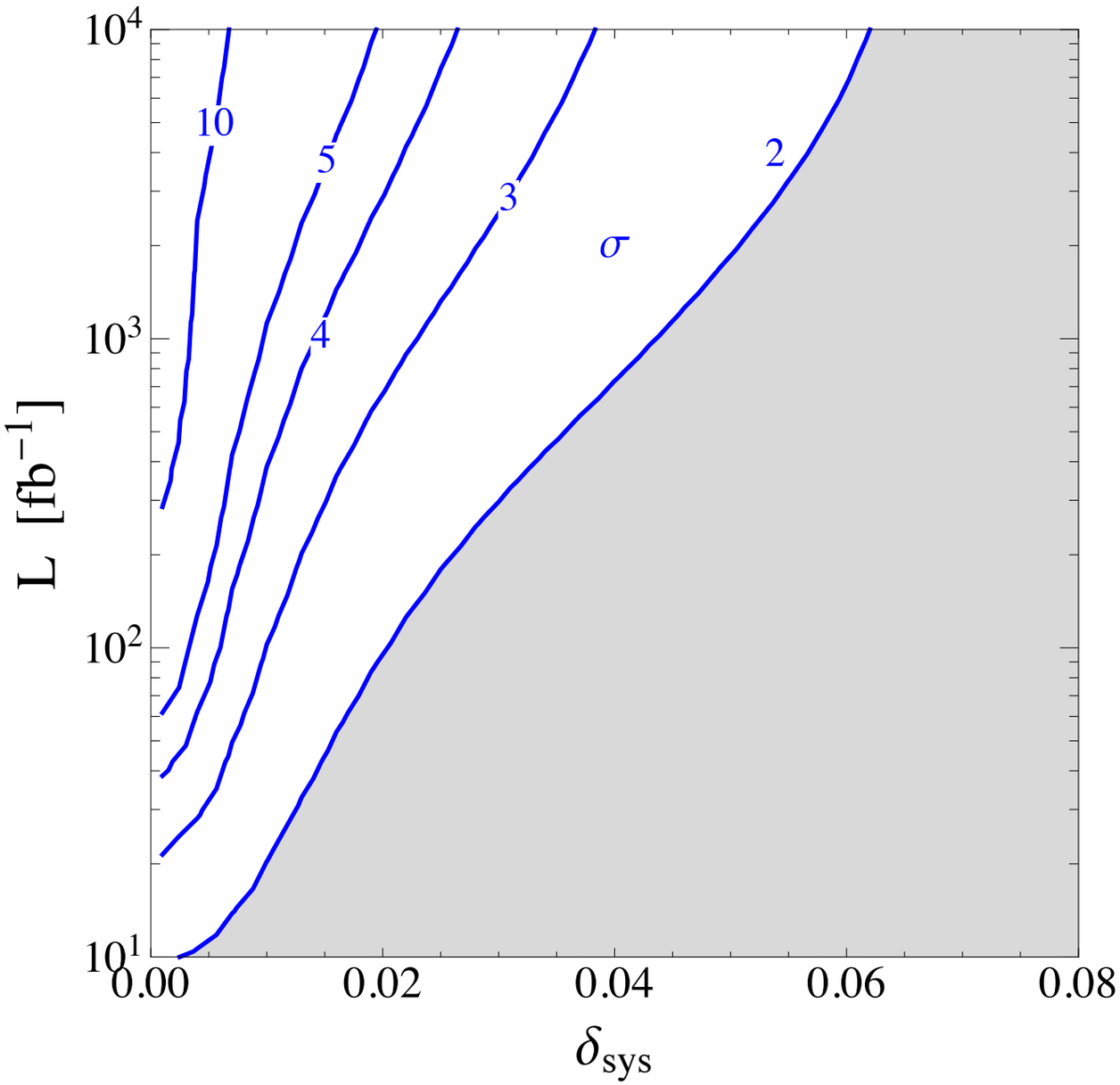
backup

LEP limit on gluino

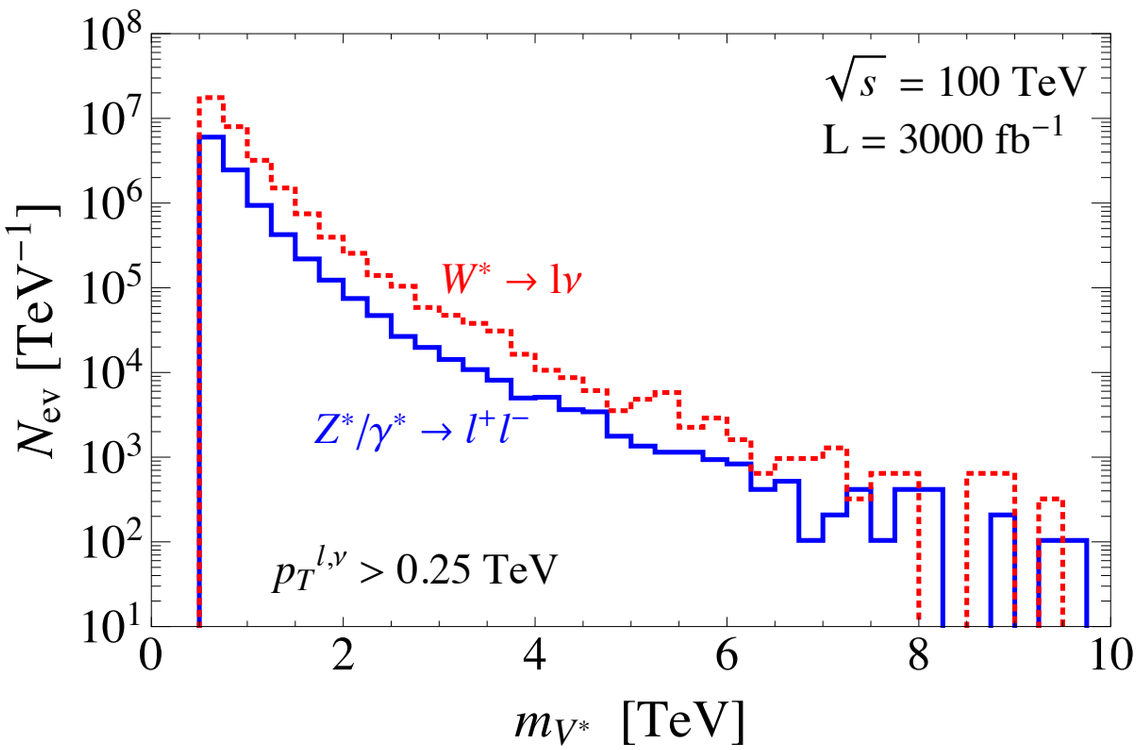


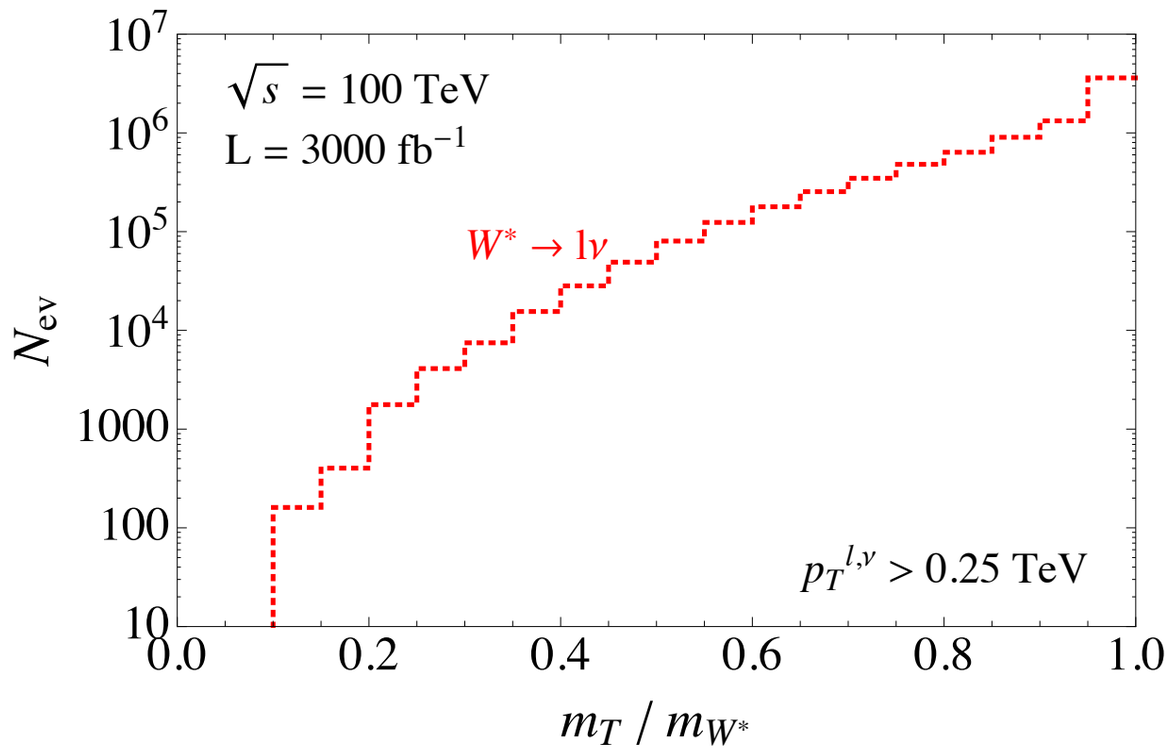
Kaplan and Schwartz 0804.2477

measuring the sign of β_2

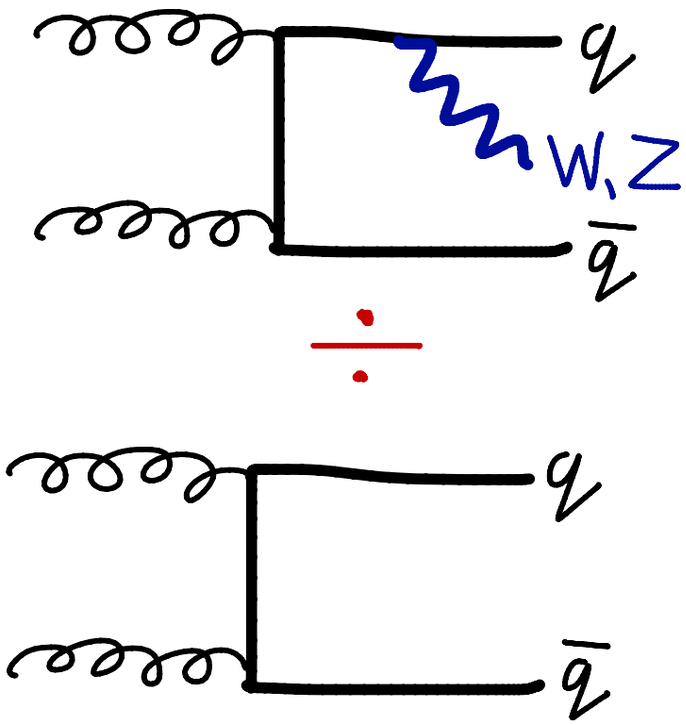


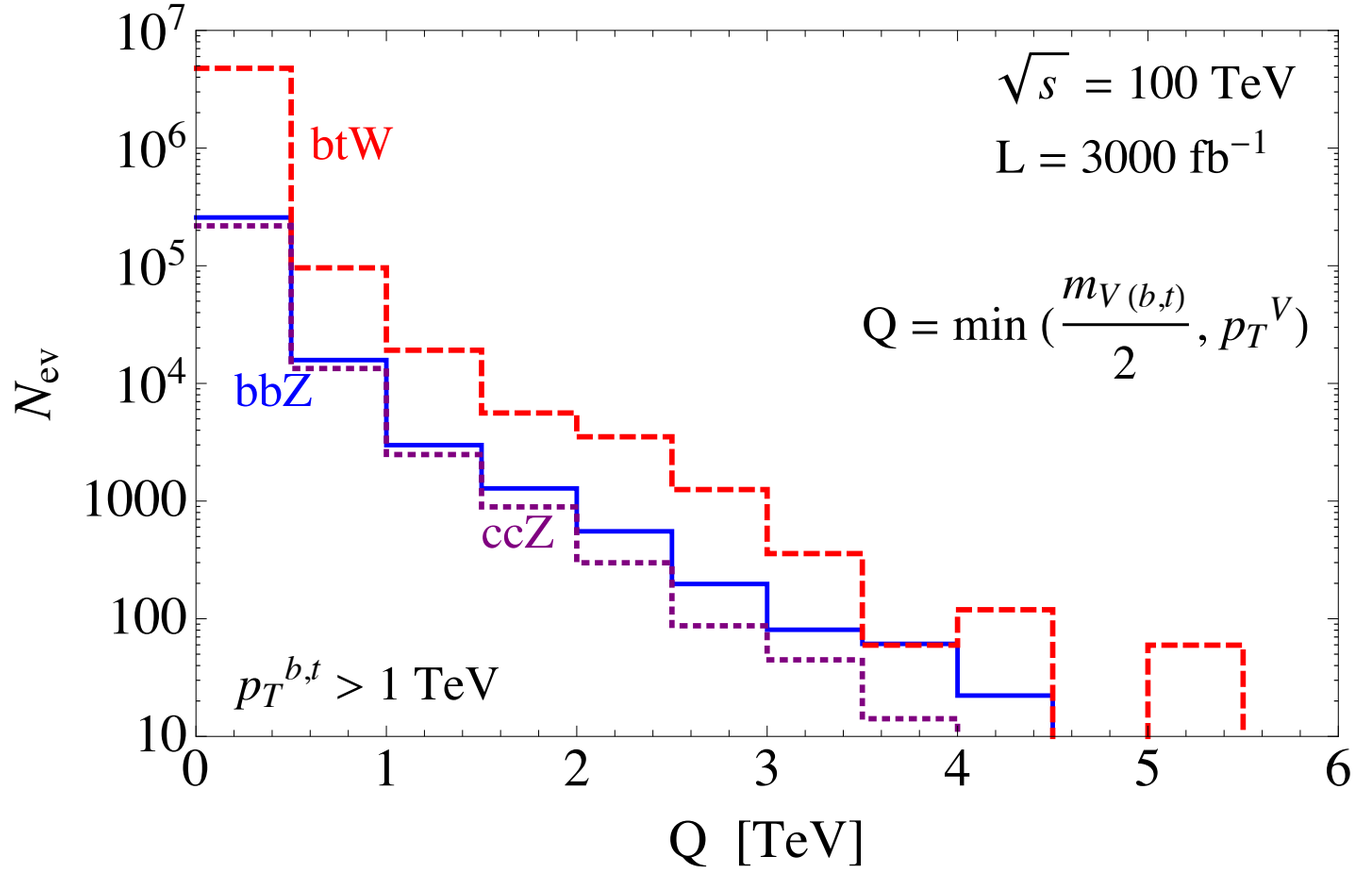
Drell-Yan


$\sqrt{s}$ = 100 TeV
L = 3000 fb^{-1}
$W^* \to l\nu$
$Z^*/\gamma^* \to l^+l^-$
$p_T{}^{l,\nu} > 0.25$ TeV
N_{ev} [TeV^{-1}]
m_{V^*} [TeV]


$\sqrt{s}$ = 100 TeV
L = 3000 fb^{-1}
$W^* \to l\nu$
$p_T{}^{l,\nu} > 0.25$ TeV
N_{ev}
m_T / m_{W^*}

EW radiation





high p_T vectors