Glue to light signal of a new particle

IBS-SNU joint workshop on particle physics & KimFest
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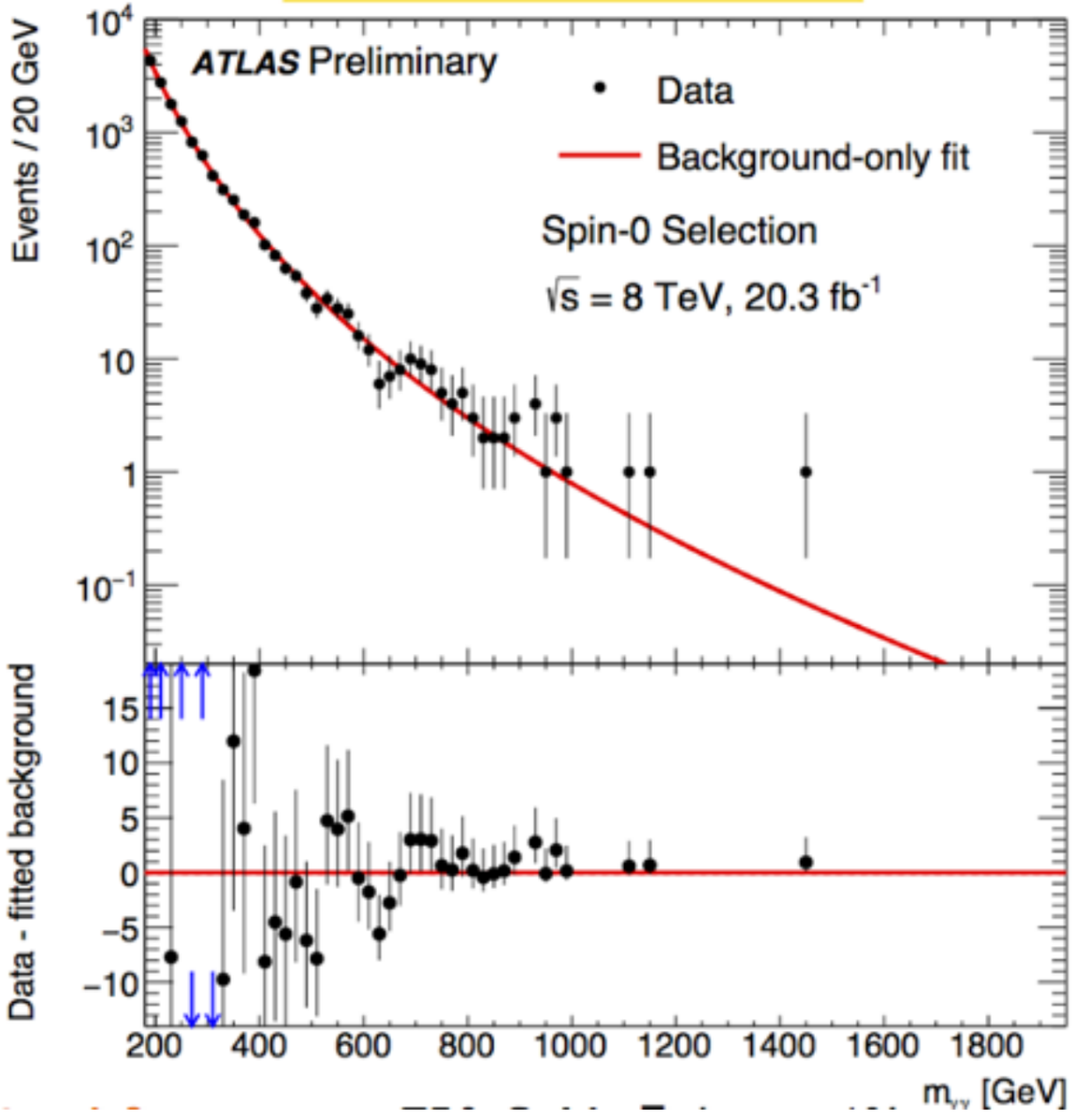
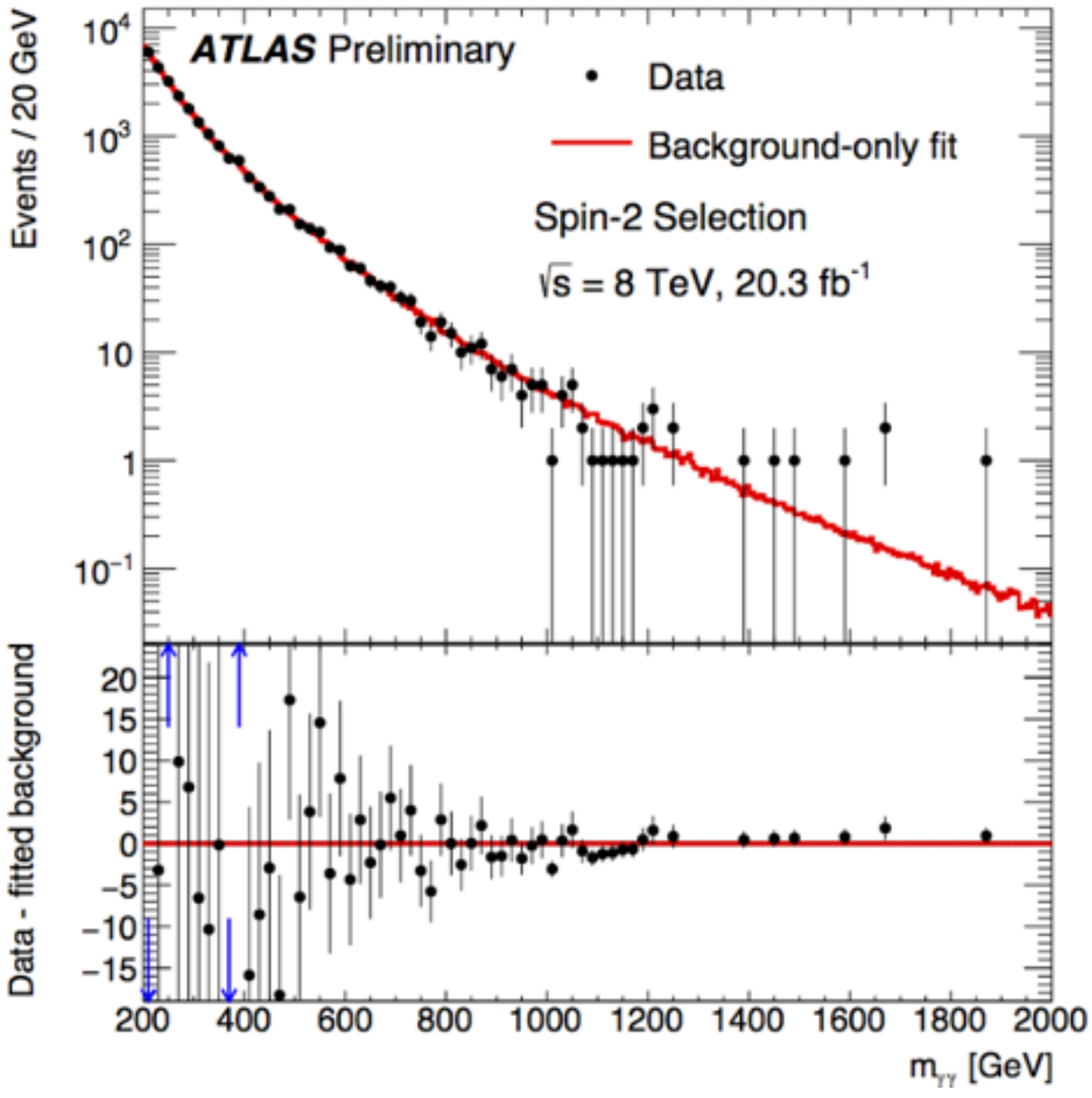
arXiv:1512.08221
replaced version on May 1
(resummation near the threshold added)

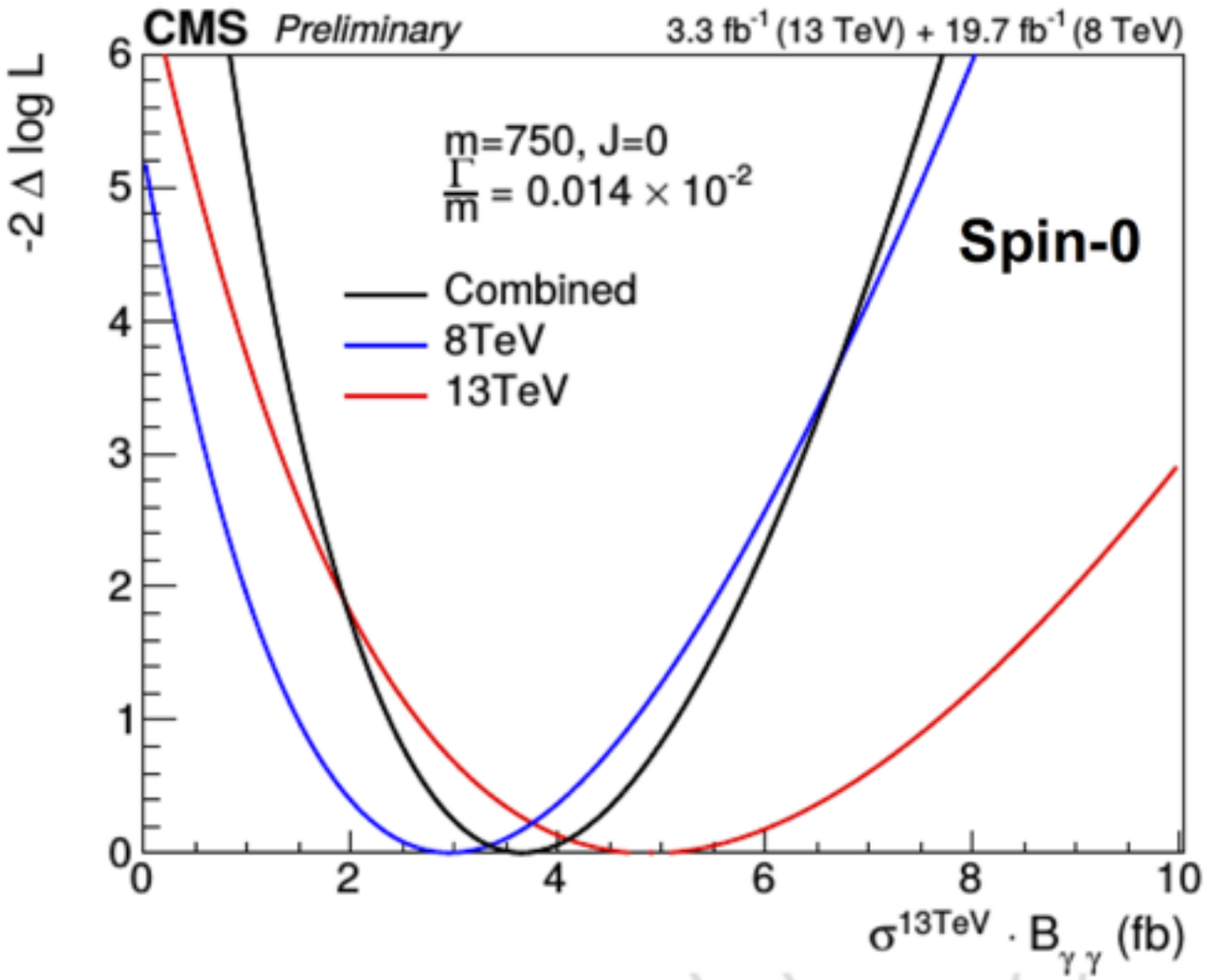
SPIN-0 ANALYSIS

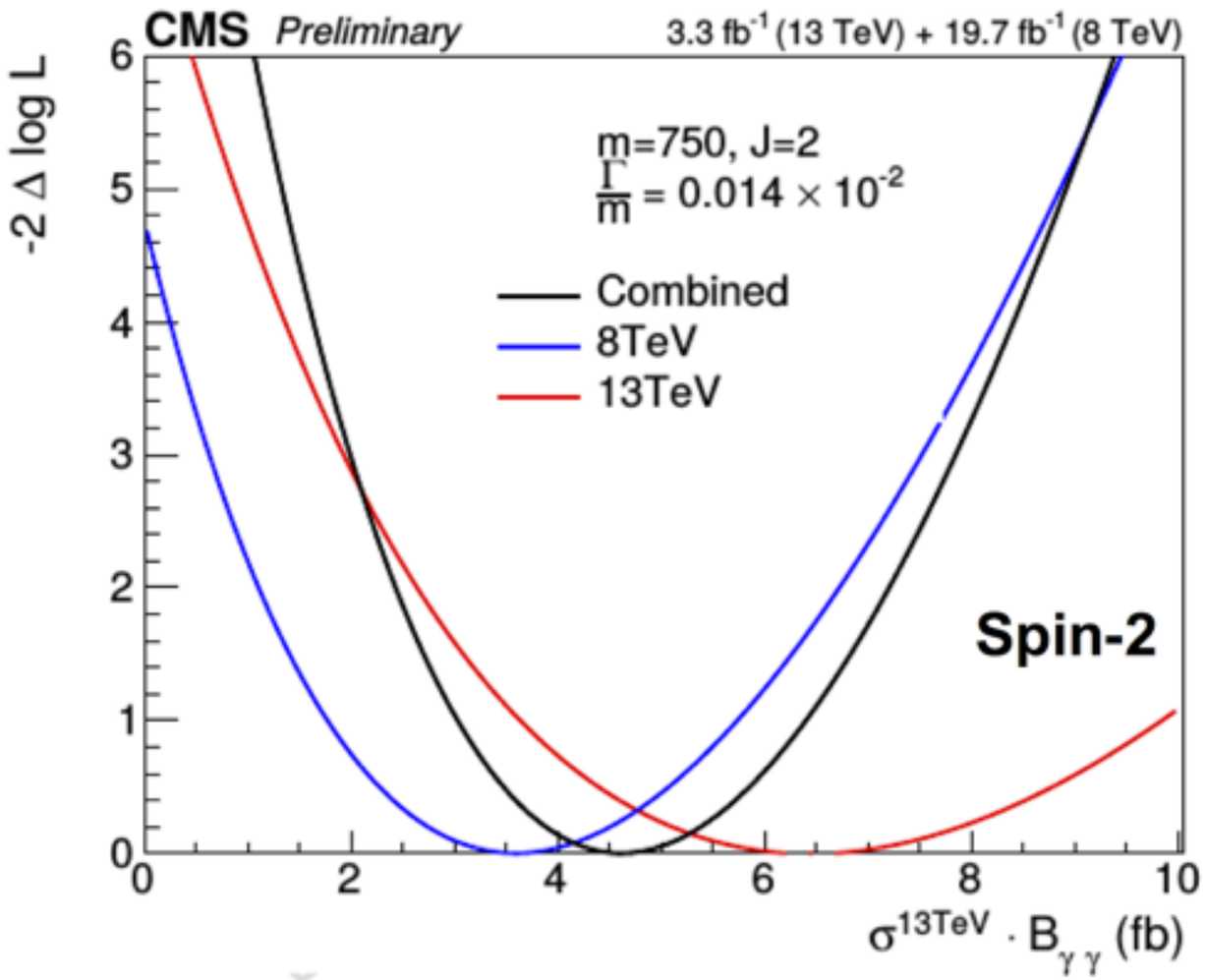


SPIN-2 ANALYSIS



Excess of events
from 700 ~ 800 GeV
(a few 10s events)





ATLAS : 4.7 sigma

CMS : 3.4 sigma

$$\Gamma(S \to gg) \sim 1 GeV$$

$$\Gamma(S \to \gamma\gamma) \sim 1 MeV$$

$$\sigma(gg \to S \to \gamma\gamma) \sim 5 \text{ fb}$$

$$\frac{\lambda}{M_S} \sim \frac{1}{300 \text{ GeV}}$$

Is it possible to have the width >> GeV?

Pros and Cons : Signal of New Physics?

Pro

: Diphoton channel is very clean
: Repetition of Higgs discovery
: Both in ATLAS and CMS

Con

: Excess is close to the event tail
: Not in ttbar, jj, ll
: So many 2 sigma bumps in CMS
: Strong coupling is necessary
(cross section*Br is too big)
: No motivated BSM can explain it

We have to wait till summer or the end of the year

Independently of the result, it would be a great opportunity for postdocs and students

It can also stimulate some ideas

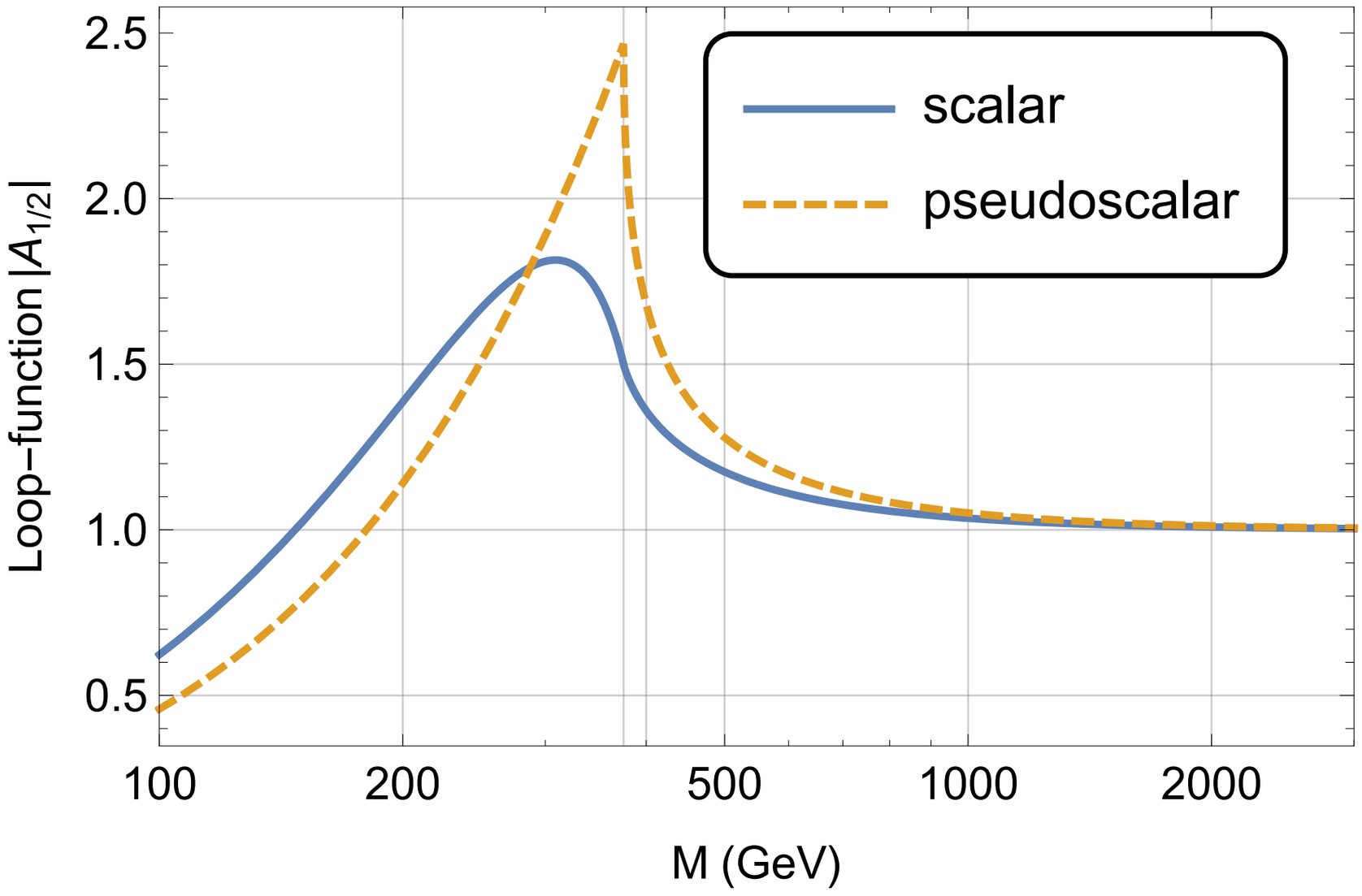
Physics of ambulance chasing

One success in 2012 Dec.
: precursor of Higgs discovery

Many other failures
: Many B physics anomalies
Tevatron W+dijet,
dimuon charge asymmetry,
top A_FB,
DAMA/LIBRA,
CoGeNT,
PAMELA,
140 GeV Higgs (WW*)
BICEP2

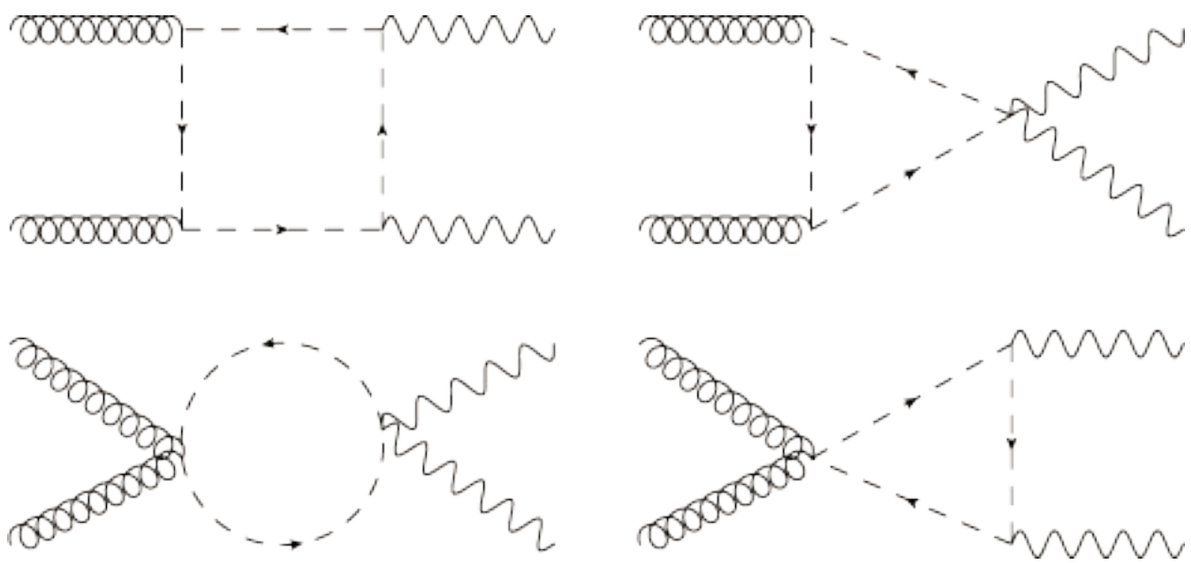
Model independent search strategy
for colored and charged (new) particles in diphoton channel at LHC.

diboson to scalar amplitude from 1512.07624

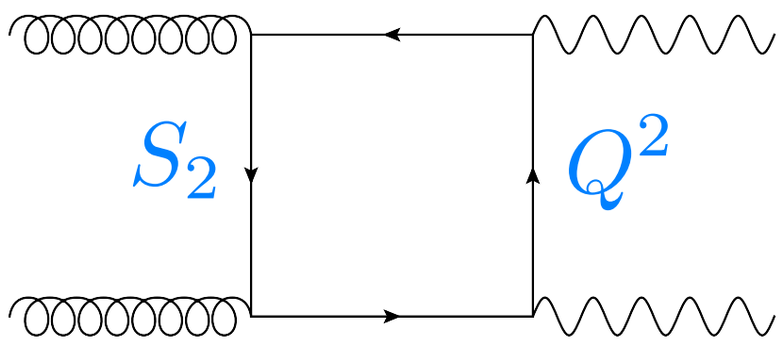


$gg \to \gamma\gamma$

Scalar



Fermion



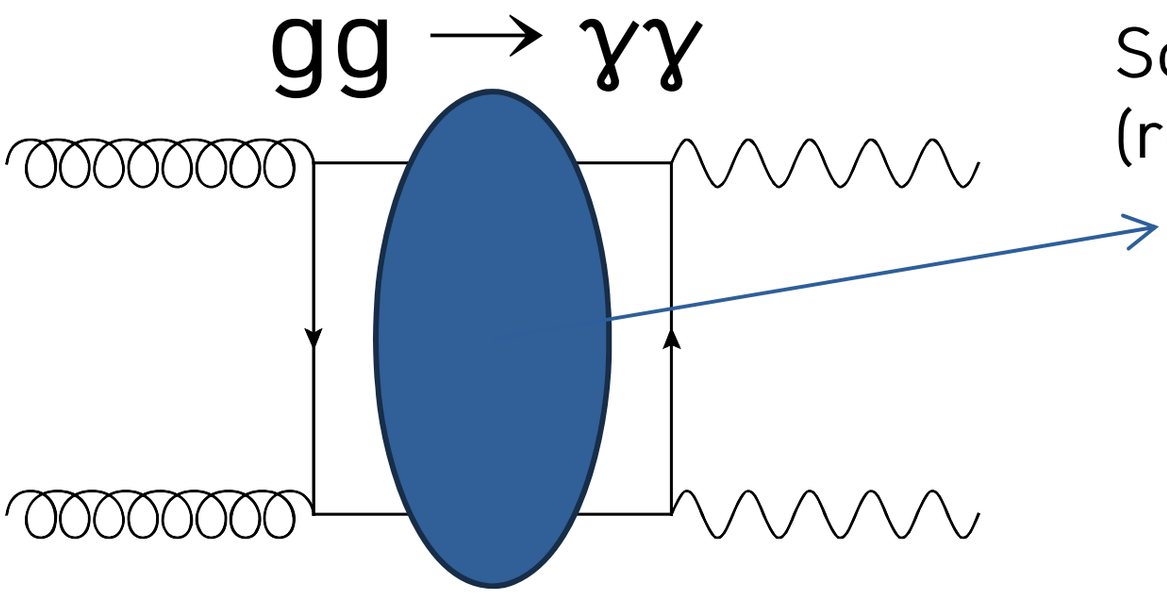
$$C = N S_2 Q^2$$

Any new colored/charged particle will contribute to the loop of $gg \to \gamma\gamma$

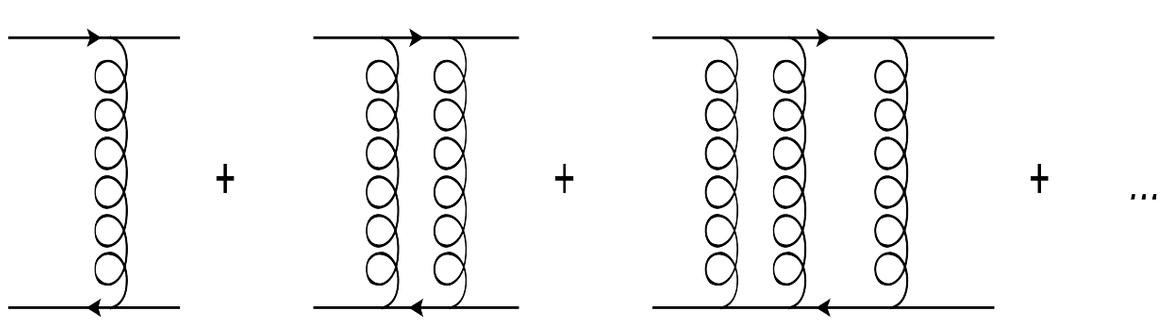
Near threshold

$$\frac{\alpha_s}{v} \qquad (\frac{\alpha_s}{v})^2 \qquad \ldots \qquad (\frac{\alpha_s}{v})^n$$

should be resummed



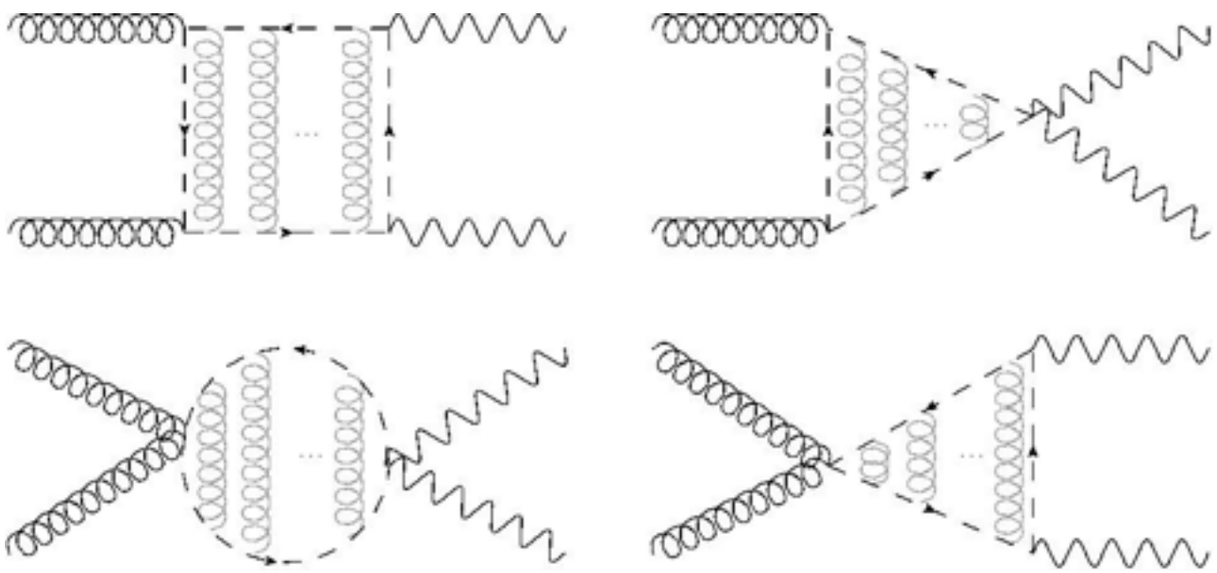
Sommerfeld enhancement near $m_{\gamma\gamma} = 2m_X$
(resummation of ladder diagrams)



$$v_{\min} = \sqrt{\frac{\Gamma_X}{M_X}}$$

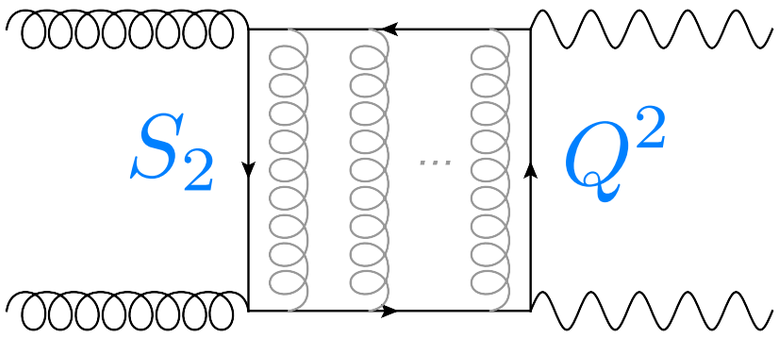
$gg \to \gamma\gamma$

Scalar



Fermion

Threshold resummation



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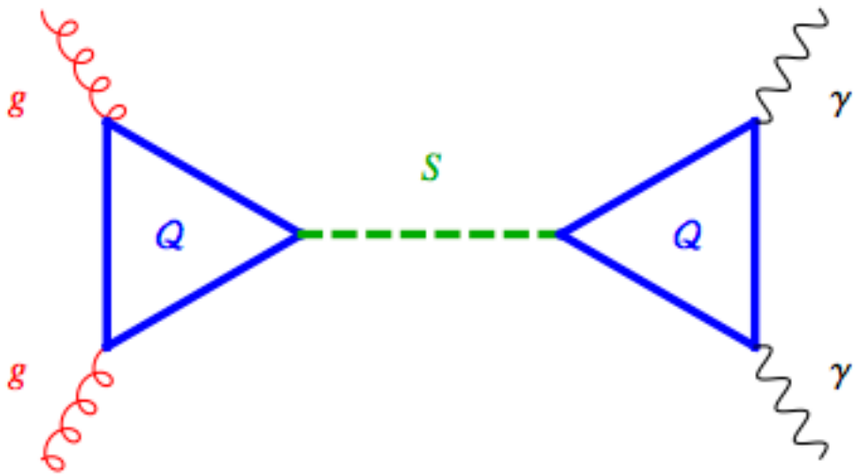
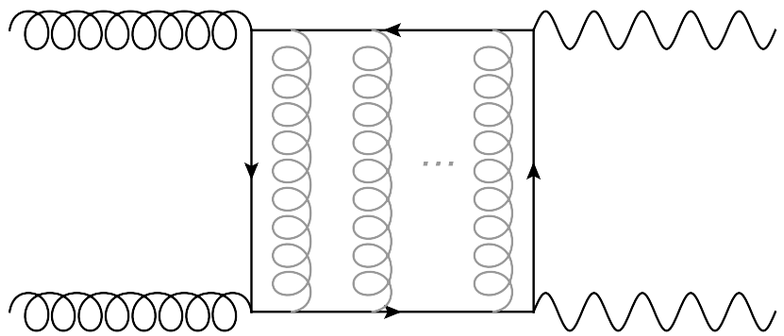
Any new colored/charged particle will contribute to the loop of $gg \to \gamma\gamma$





750onium

In the small width limit of the particle X,
the bound state production and decay applies

$$\Gamma_X < \alpha^3(E_b) M_X$$

life time of X > formation time of the bound state

X should live long enough to form a bound state

Bohr radius

$$r_b = \frac{1}{M_X \alpha_S(E_b)}$$

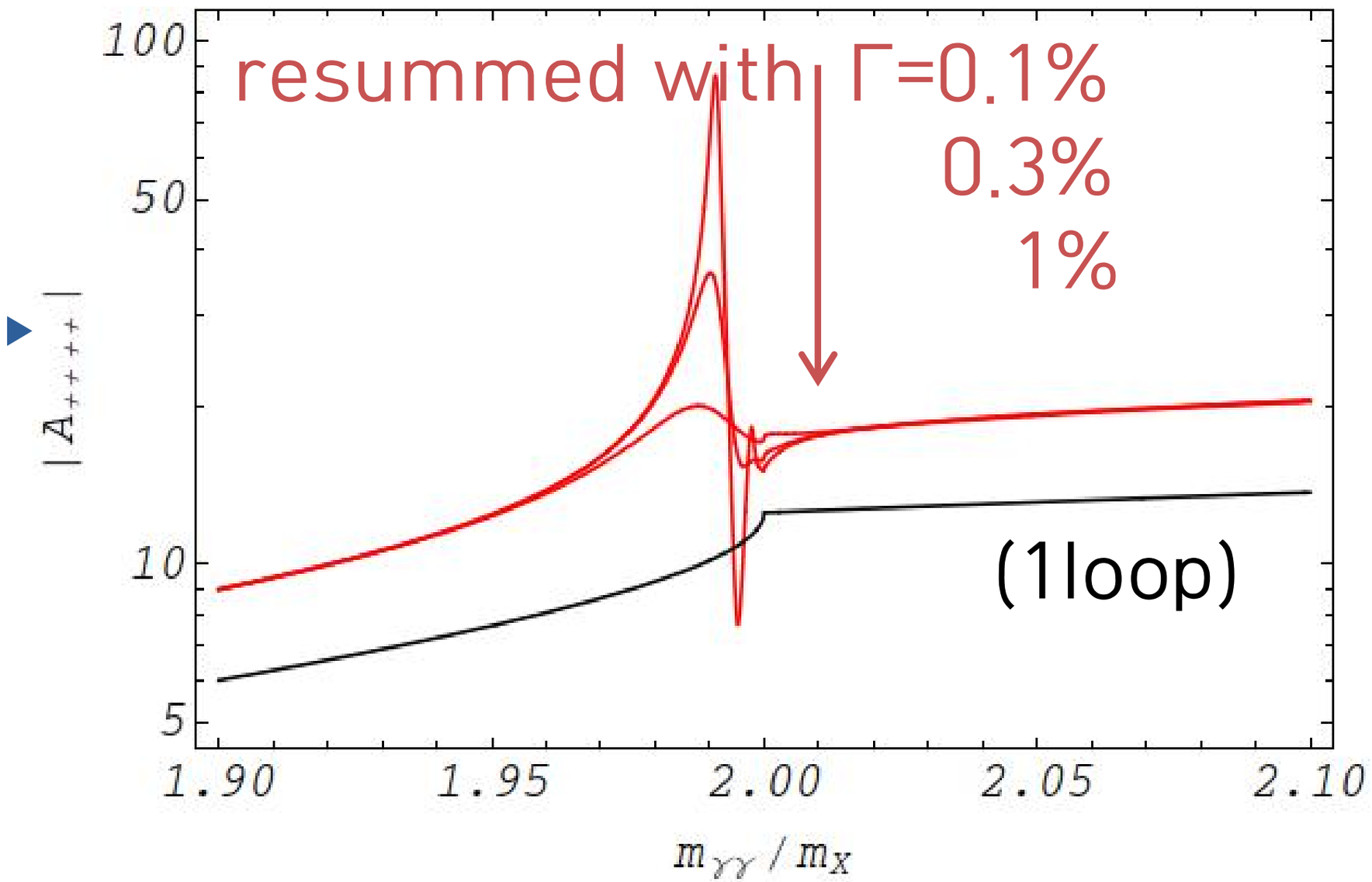
velocity

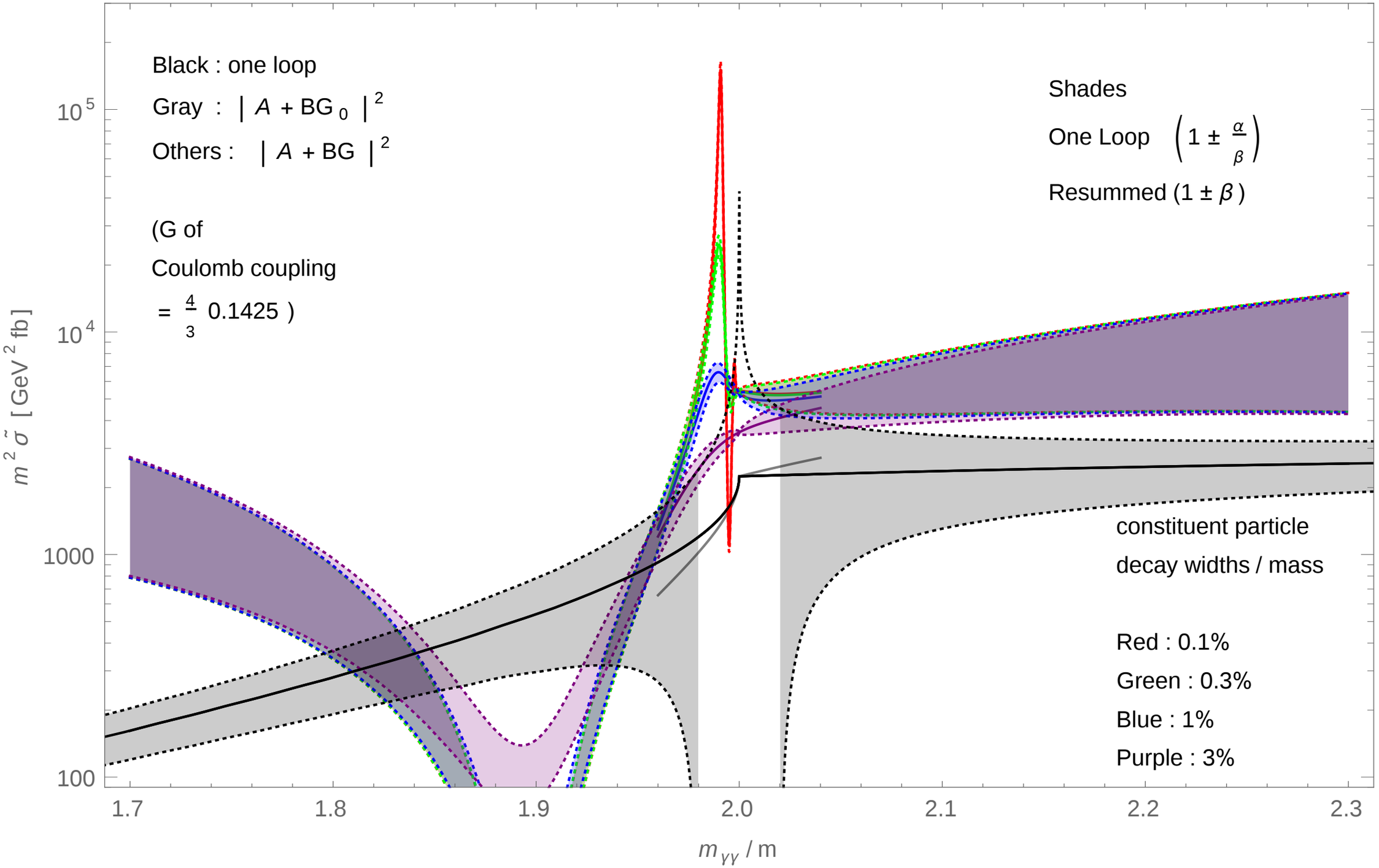
$$v = \alpha_S(E_b)$$

$$\left(\frac{\nabla^2}{m} + V(r) - E\right) G(\mathbf{r}, \mathbf{r}'; E) = \delta(\mathbf{r} - \mathbf{r}').$$

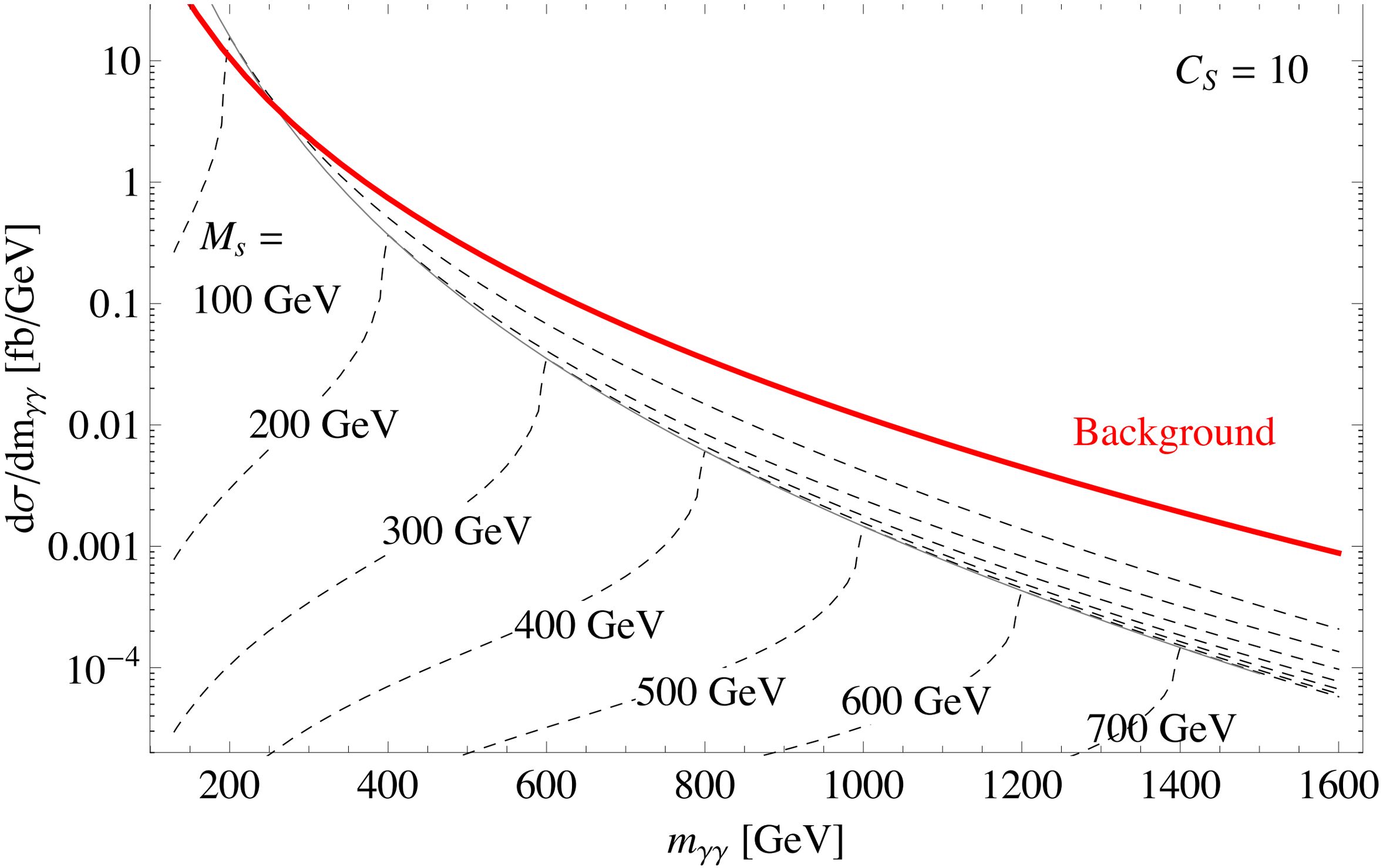
$$V(r) = -YC_2(X)\frac{\alpha_S(\bar{\mu})}{r}$$ (Y > 1 from QED resummation)

$$G(0,0;E) = \frac{m_X^2}{4\pi}\left(\sqrt{-\frac{E}{m_X} - i\epsilon} - YC_2(X)\alpha_S \ln\left(\frac{|YC_2(X)|\alpha_S}{2}\sqrt{-\frac{m_X}{E} + i\epsilon}\right) - \frac{2}{\sqrt{m_X}}\sum_{n=1}^{\infty}\frac{E_n}{\sqrt{(-E - i\epsilon)} - \text{sign}}\right.$$

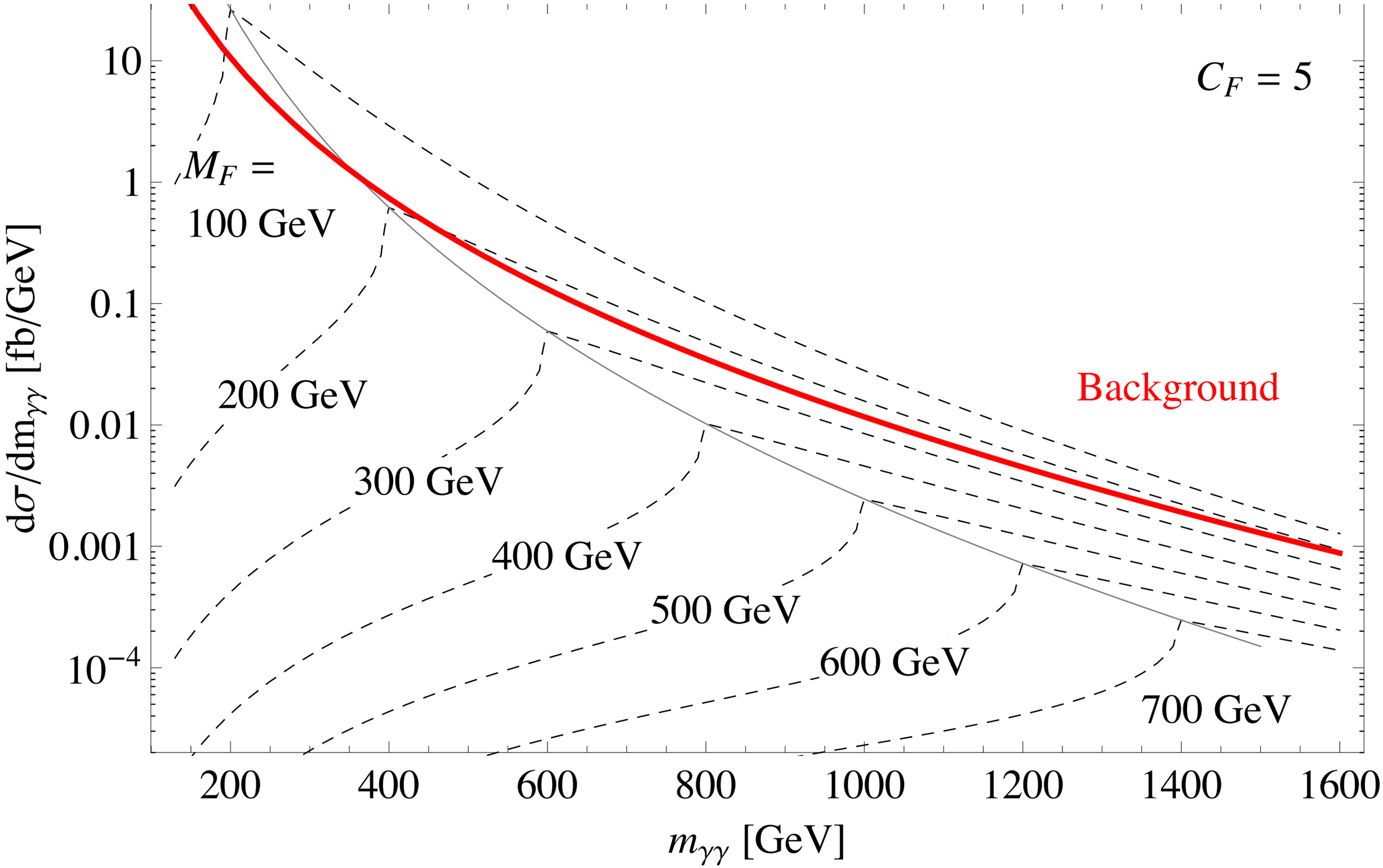

resummed with Γ=0.1%
0.3%
1%
(1loop)
100
50
10
5
1.90
1.95
2.00
2.05
2.10
$m_{\gamma\gamma} / m_X$
$|A_{++}|$


Black : one loop
Gray : | A + BG 0 | 2
Others : | A + BG | 2
(G of
Coulomb coupling
= 4/3 0.1425)
Shades
One Loop (1 ± α/β)
Resummed (1 ± β)
constituent particle
decay widths / mass
Red : 0.1%
Green : 0.3%
Blue : 1%
Purple : 3%
m 2 σ̃ [GeV 2 fb]
m γγ / m
10 5
10 4
1000
100
1.7
1.8
1.9
2.0
2.1
2.2
2.3

In the following analysis, selection efficiency is assumed to be 100%



Signal cross section as a function of the loop particle (scalar) mass



Signal cross section as a function of the loop particle (fermion) mass

Threshold resummation included

$C_S = 10$
$M_S = 365$ GeV
$\Gamma_S = 1\%\ M_S$

$(pp \to \gamma\gamma)$

$(gg \to \gamma\gamma)_{SM+X}$

$(gg \to \gamma\gamma)_{SM}$

$d\sigma/dm_{\gamma\gamma}$ [fb/GeV]

$m_{\gamma\gamma}$ [GeV]

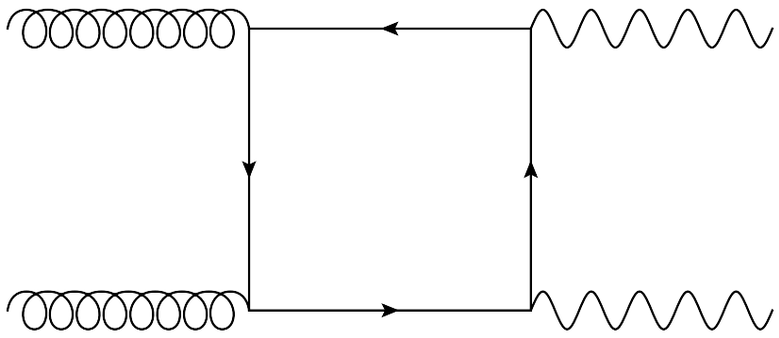
$C_F = 5$
$M_F = 365$ GeV
$\Gamma_F = 1\%\ M_F$

$(pp \to \gamma\gamma)$
$(gg \to \gamma\gamma)_{SM+X}$
$(gg \to \gamma\gamma)_{SM}$

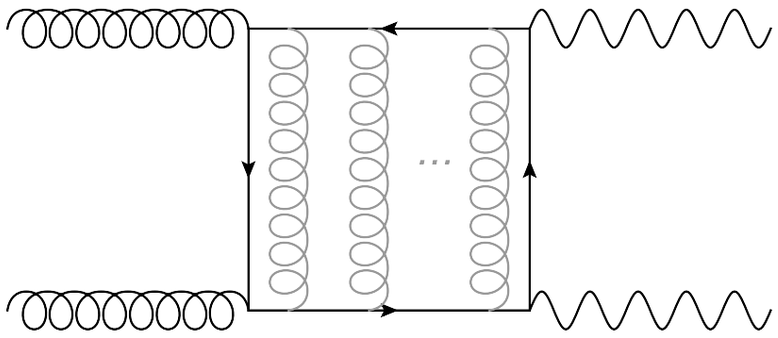
$d\sigma/dm_{\gamma\gamma}$ [fb/GeV]

$m_{\gamma\gamma}$ [GeV]

u,d,s,c,b

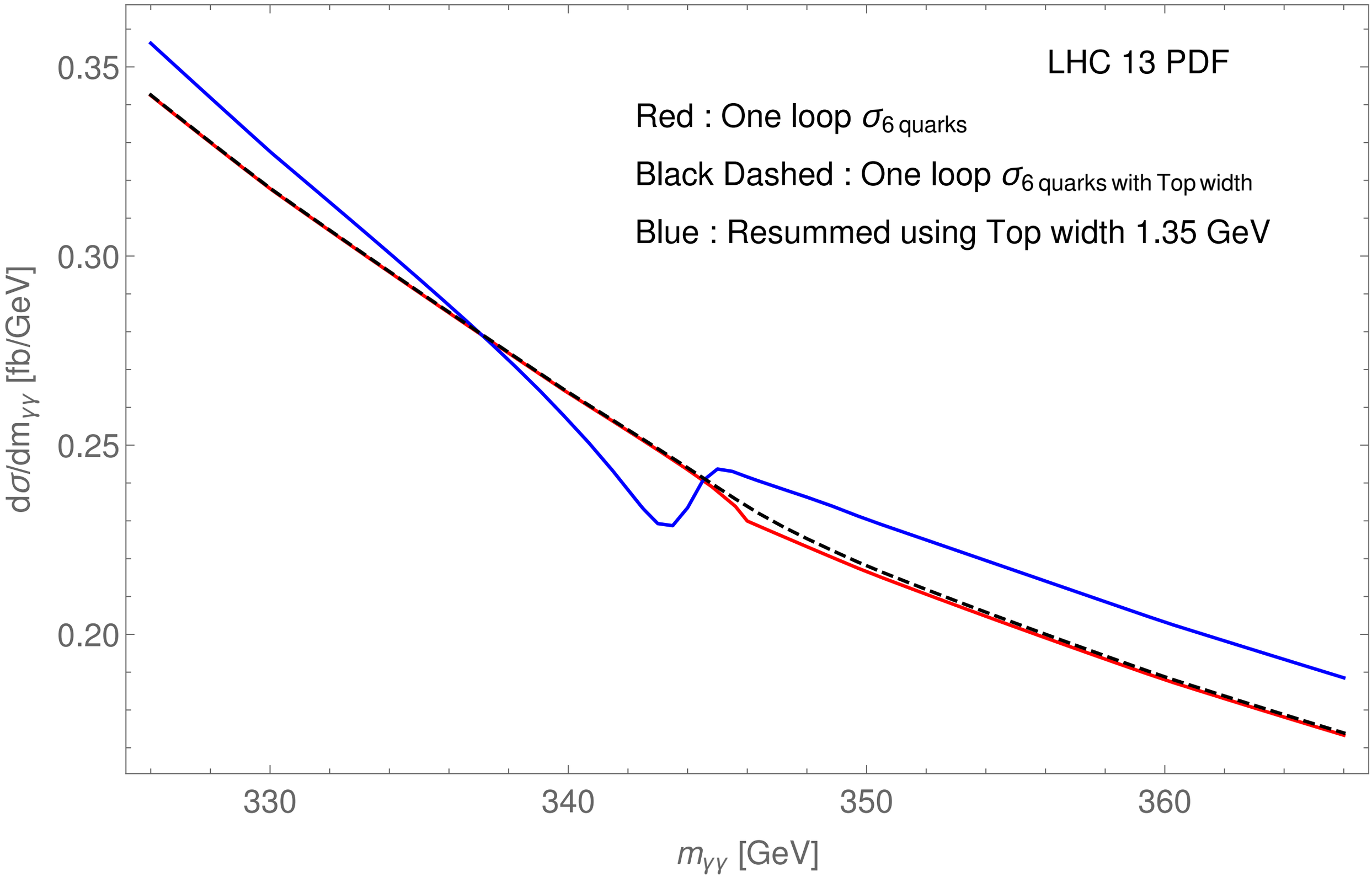


top

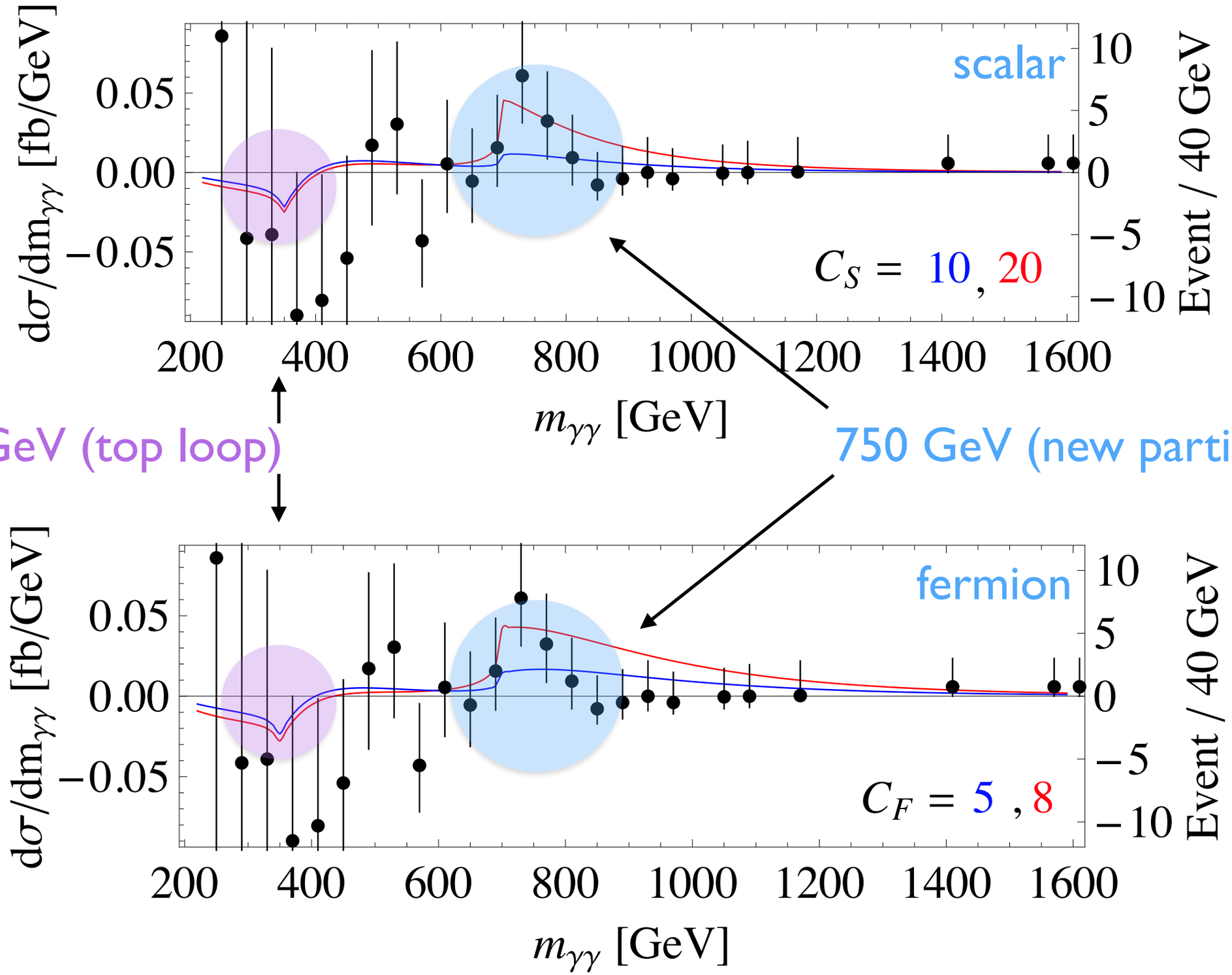


Top quark can show 2~3% effects
in diphoton invariant mass at 2m_t
from interference with 5 light quarks

Top threshold from diphoton



Resummation at the threshold NOT included

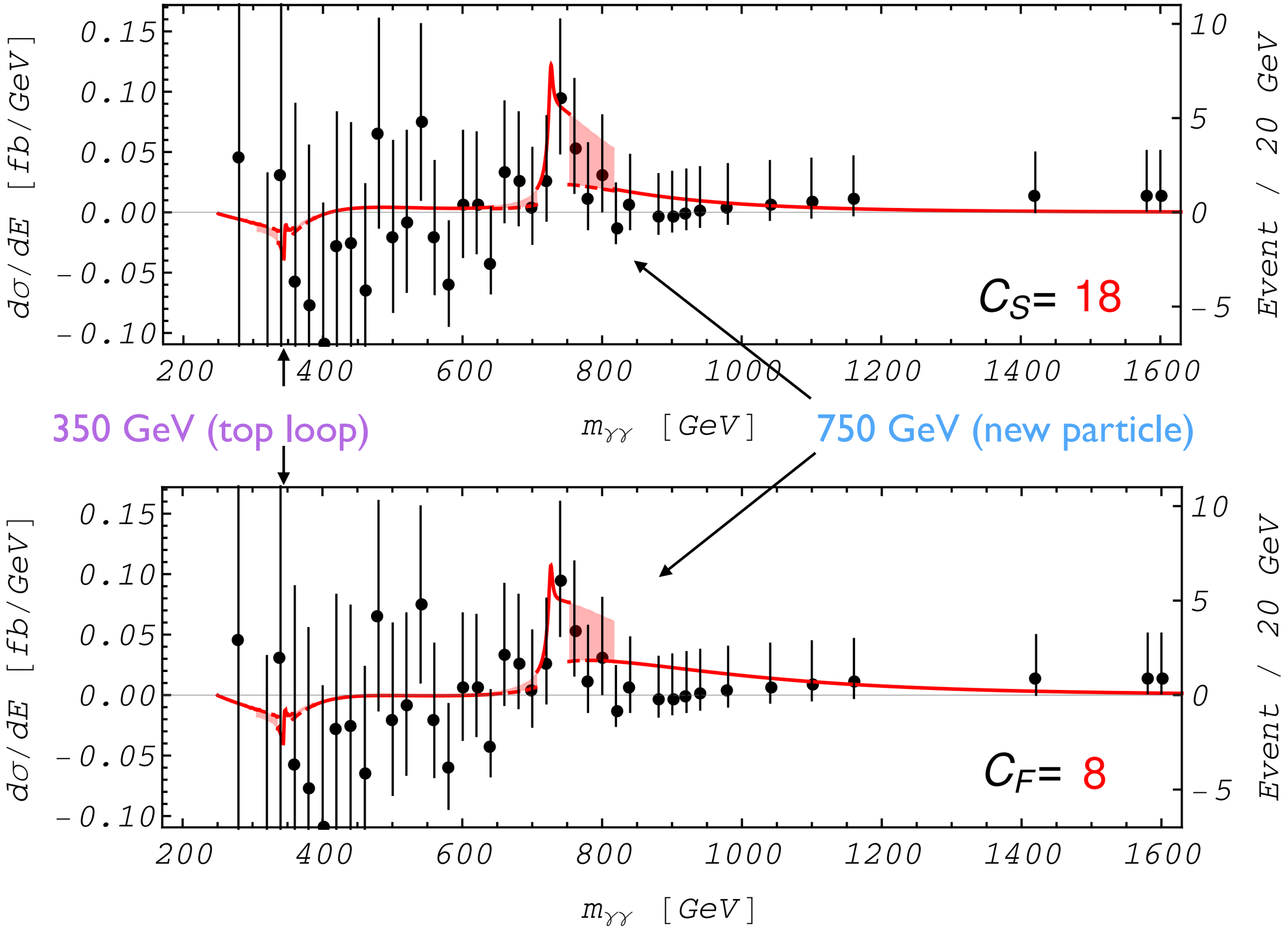


350 GeV (top loop)

750 GeV (new particle)

Best fit (red) and small color/charge (blue)

Resummation at the threshold included

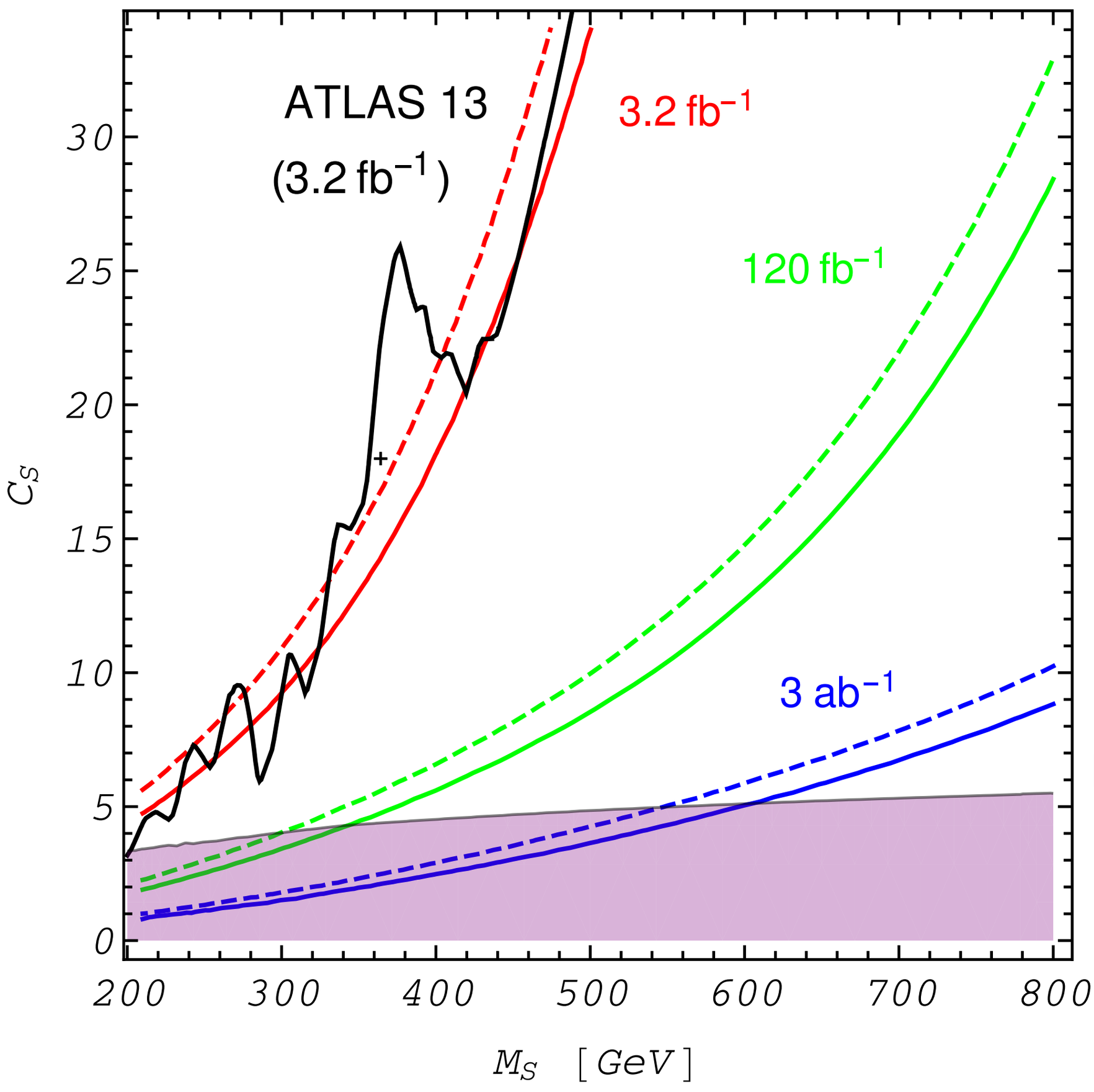


How to avoid direct detection?

$$X(375) \to Sj \to (jj)j$$

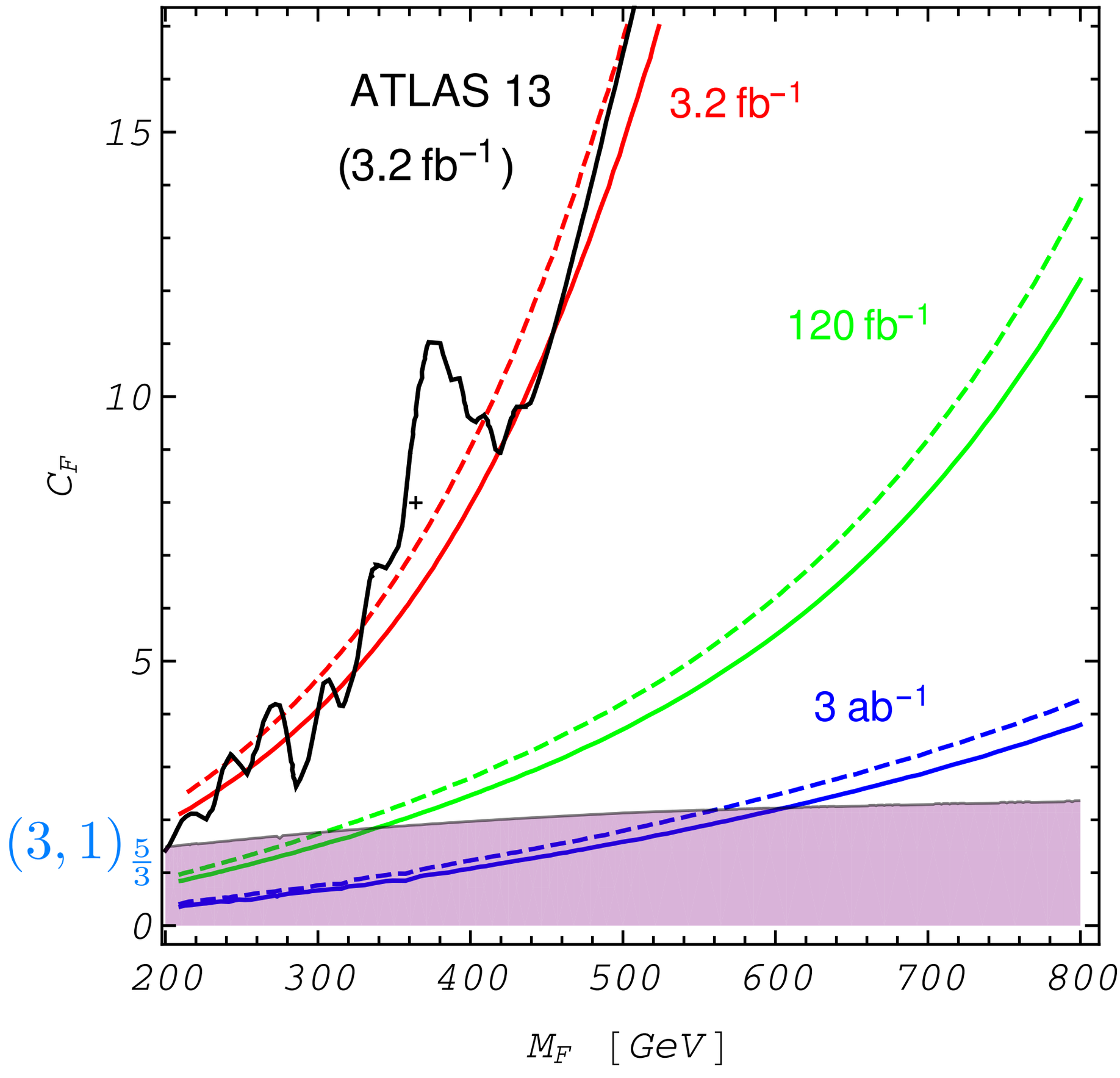
$$X(375) \to Sj \to S'jj \to (jj)jj$$

$$X(375) \to Sj \to S'jj$$



Interference is important

Upper limit on C (scalar) and expected upper limit



Interference is important

Upper limit on C (fermion) and expected upper limit

If 750 GeV excess survives at the end of this year,

If large width survives (> 0.1% m or GeV),

Jihn E. Kim's 70th

HAPPY BIRTHDAY!