Optimization of data taking

Data taking scheme

1. Taking data at one point (just for m_W) √

2. Taking data at two points (both m_W and Γ_W) √

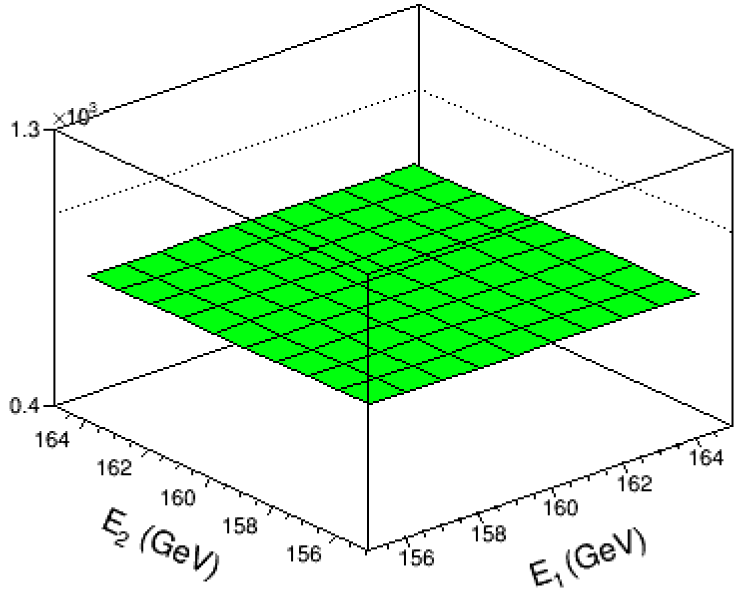
3. Taking data at three points (m_W , Γ_W and the correlated syst. uncertainties).

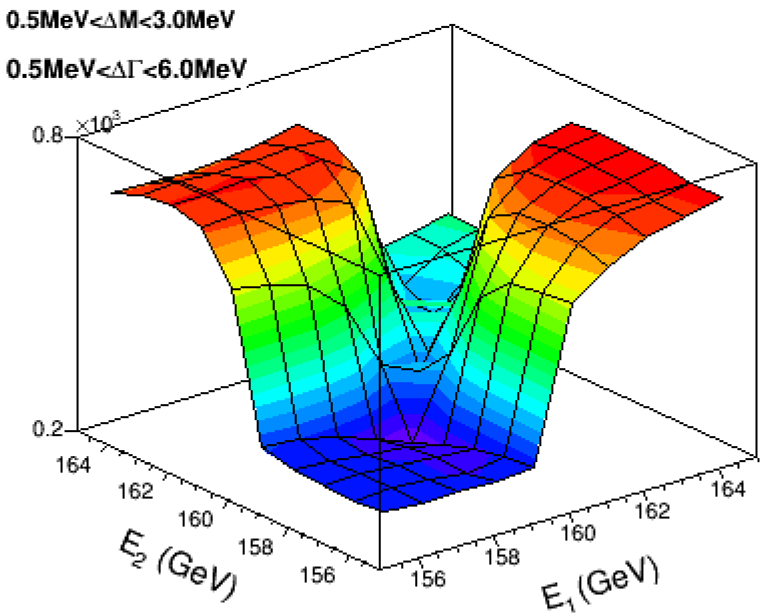
With $L = 3.2\ ab^{-1}, \epsilon P = 0.72$

Taking data at three point

1. Fit parameters: m_W, Γ_W, h(associated with σ_{sys}^{corr})
2. Scan parameters: $\mathrm{E}_1, \mathrm{E}_2, \mathrm{E}_3, \mathrm{F}_1, \mathrm{F}_2$($L$ normalization factors)
3. Scan procedure:
   A. $E_1, E_2, E_3 \in (154, 165)$GeV, $F_1, F_2 \in (0,1)$, $\Delta E_i = 1$, $\Delta F_i = 0.1$ (σ_{stat})
   B. $E_1 \in (154, 160), E_2, E_3 \in (160, 164), F_1 \in (0,0.5), F_2 \in (0, 1), \Delta F_2 = 0.2$ ($\sigma_{stat} + \sigma_{sys}^{corr}$)
   C. Get the $\Delta \mathrm{m_W}, \Delta\Gamma_W$ with optimization result from b($\sigma_{stat} + \sigma_{sys}^{corr} + \Delta E + \Delta E_{BS}$)

Step A: E_1, E_2

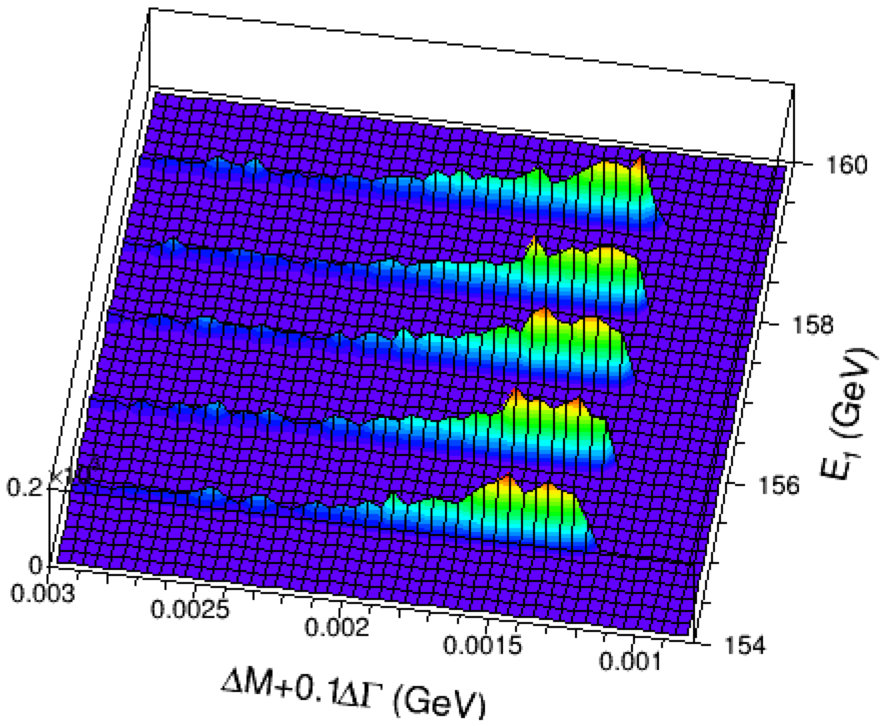


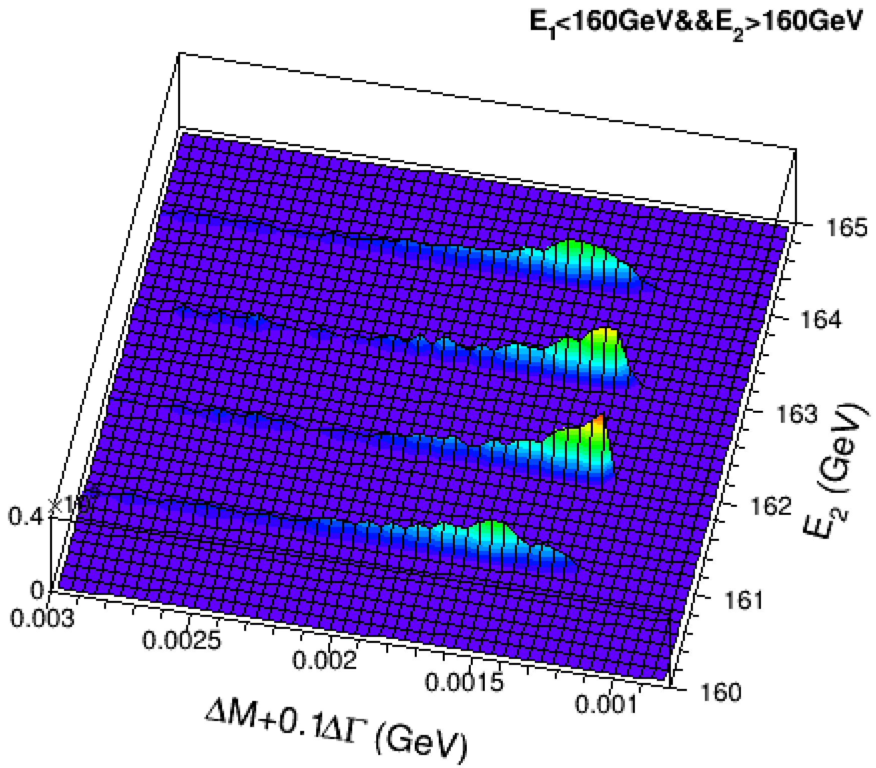


The z axis is the cumulation of the fit result. The edge of the distributions will affect the optimization results.

E_1<160, E_2>160 GeV is used in further optimization

Step A: E_1, E_2

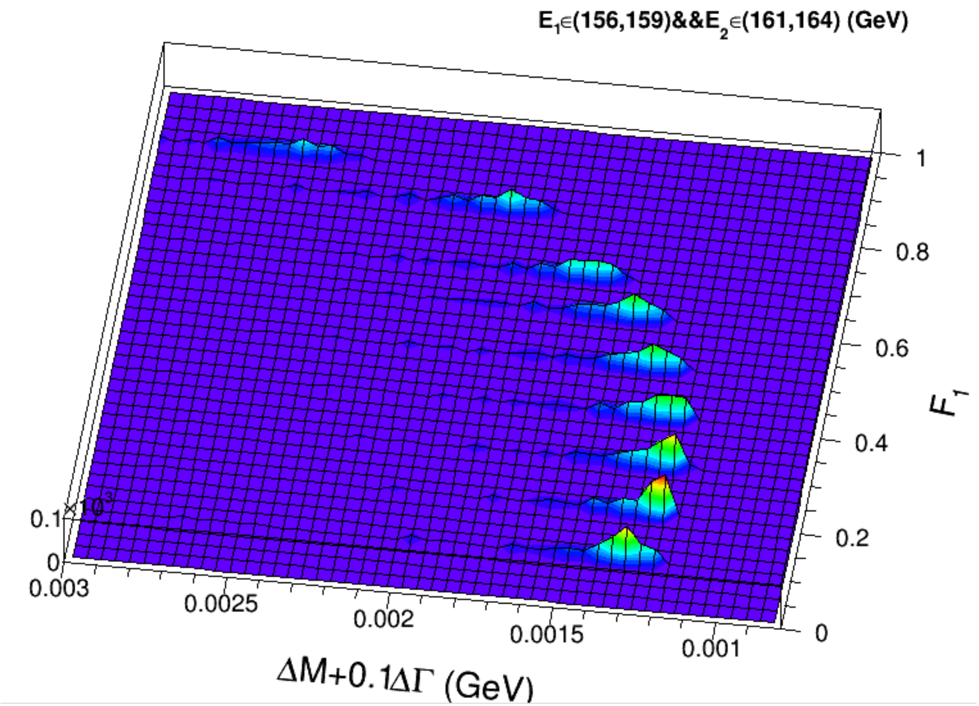




The optimal regions of E_1, E_2 are similar as two data points:

$E_1 \sim (157,158)$ GeV, $E_2 \sim (162, 163)$GeV

Step A: F_1



The optimal region of F_1 is similar as two data points: $F_1 \sim 0.3$

Step B

1. Use the rough results from step A, the requirements below are used:

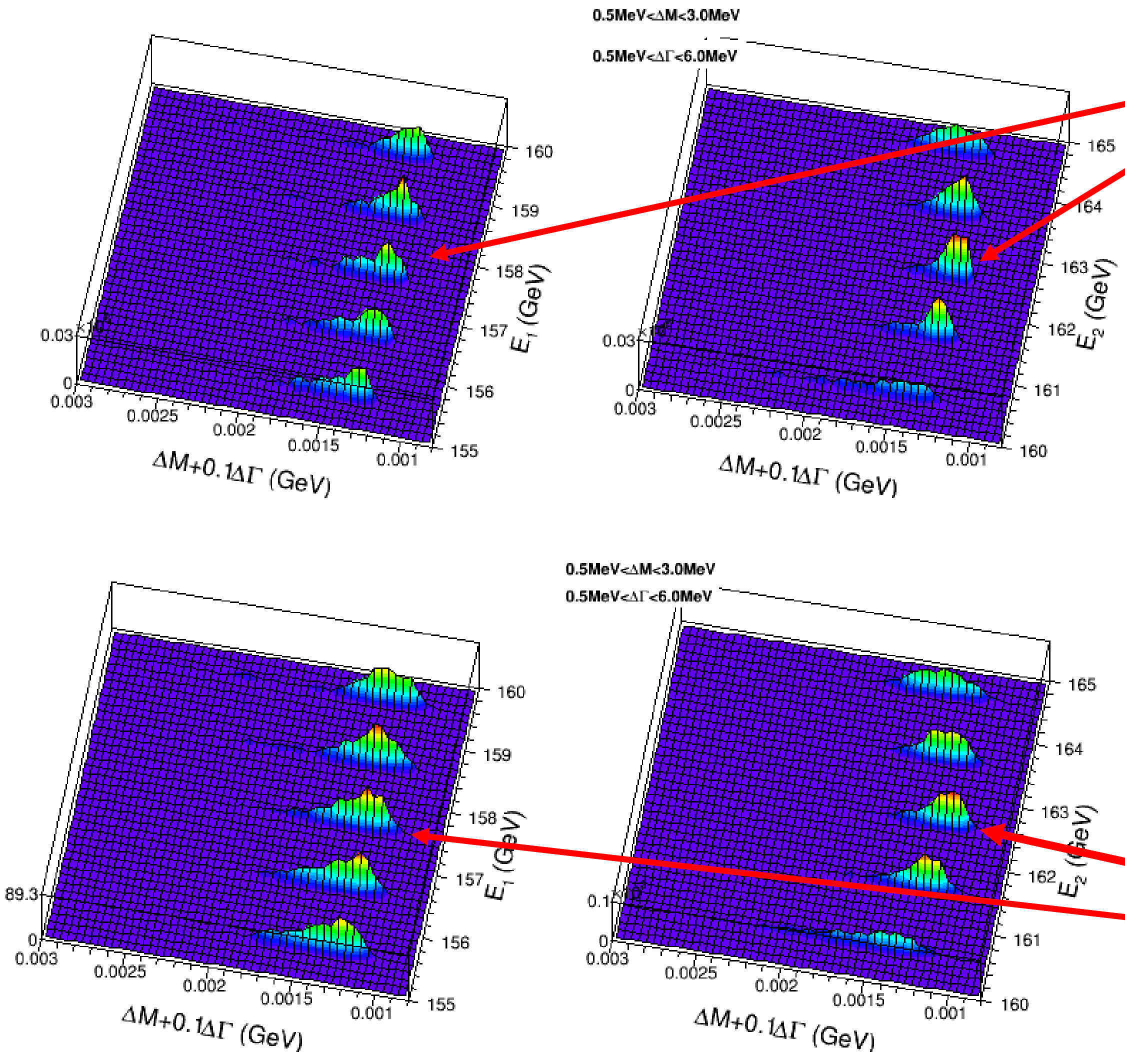
$$E_1 \in (155{,}160)$$
$$E_2 \in (160, 164)$$
$$E_3 \in (160, 164)$$
$$F_1 = 0.3, F_2 \in (0, 1)$$

   the $\sigma_{sys}^{corr} = 2 \times 10^{-4}$ is considered in the fit.

2. For each specific fit, 200 samplings are used, $\sigma_{WW} \sim G(\sigma_{WW}^0, \sigma_{sys}^{corr})$

3. So we can get the direct fit results ($N_1 = N_{scan} \cdot 200$), and the results by fitting the distributions of m_W, Γ_W of each fit result ($N_2 = N_{scan}$).

Step B: E_1, E_2



Direct fit results

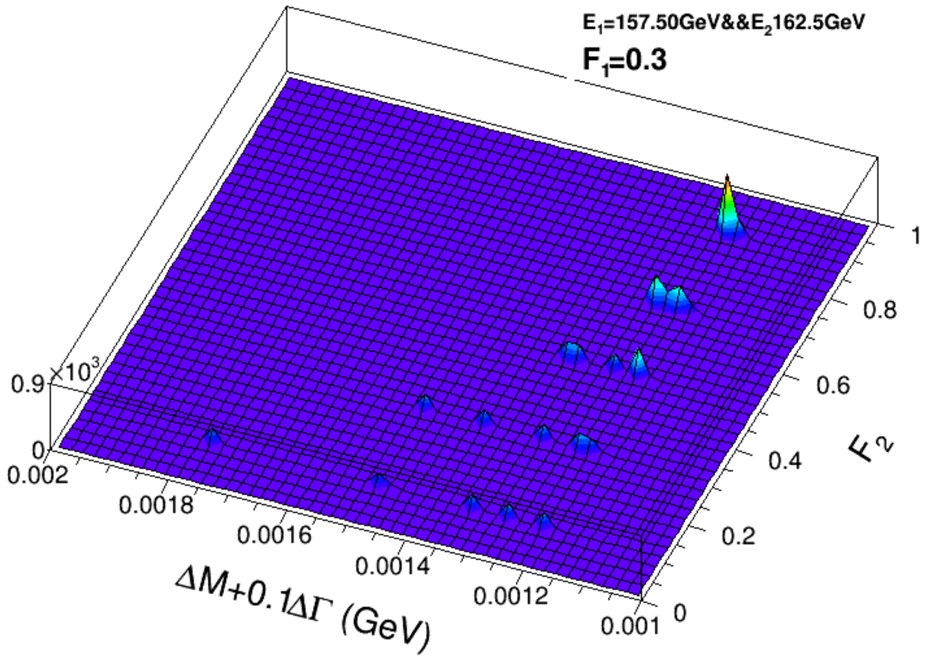
The optimal regions of E_1, E_2 from these two results are consistent and the results are similar as two data points:

$E_1 \sim 157.5$ GeV, $E_2 \sim 162.5$ GeV

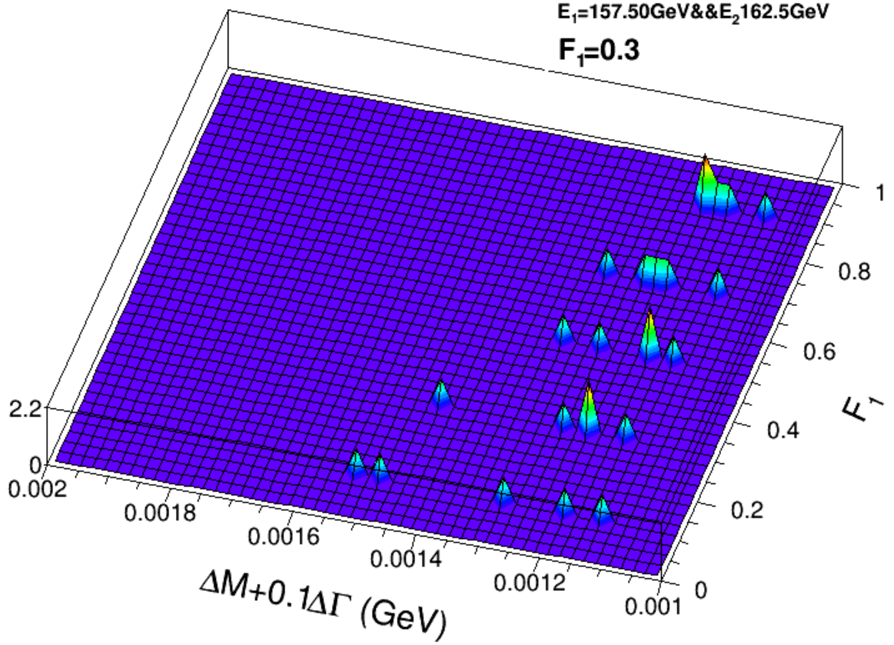
Fit the m_W, Γ_W of each fit results

Step B: F_2

Direct fit results



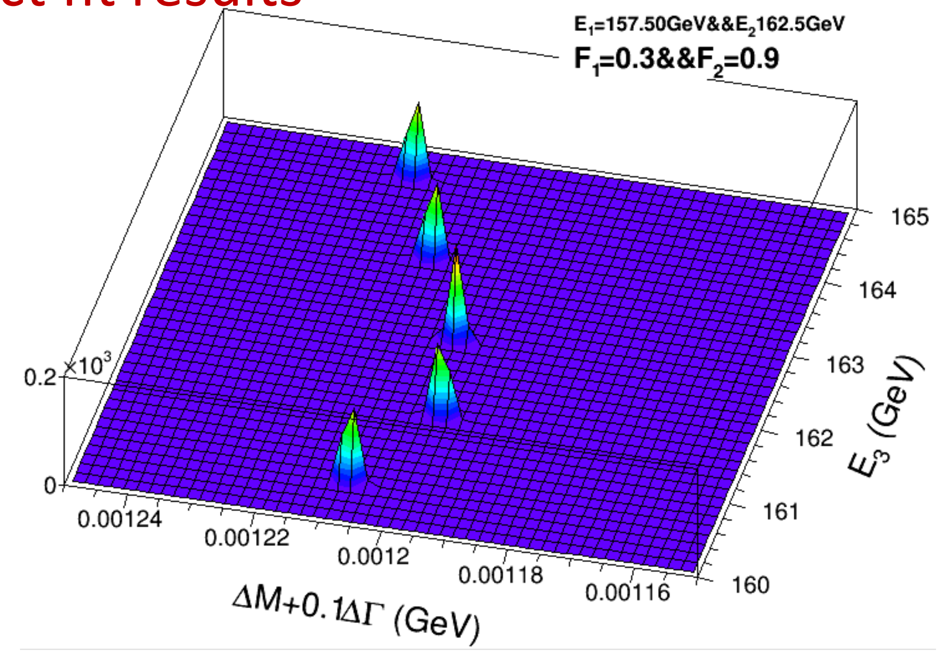
Fit the m_W, Γ_W of each fit results



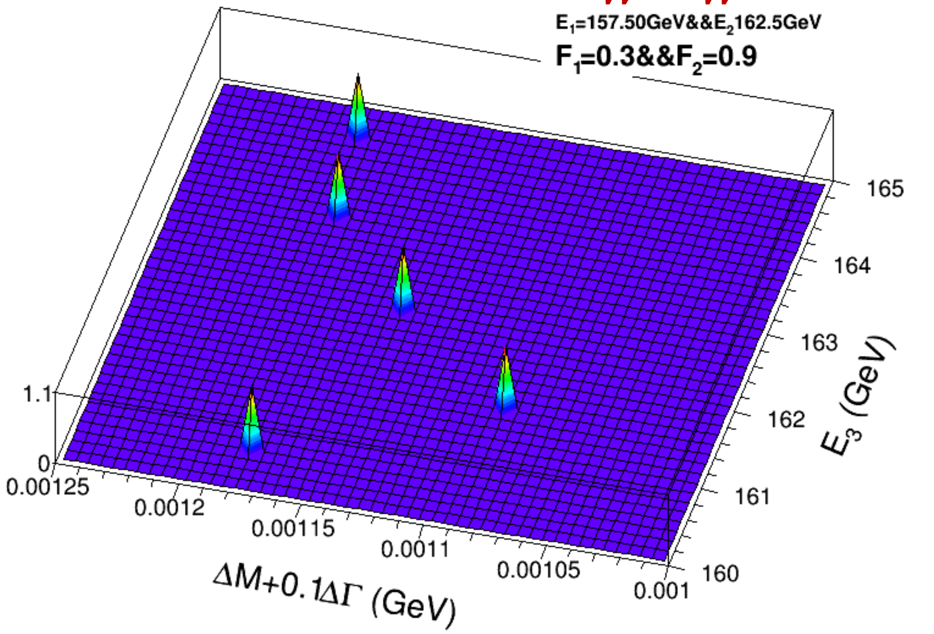
The $F_2 = 0.9$ is used in further study

Step B: E_3

Direct fit results



Fit the m_W, Γ_W of each fit results



The minimal result favors E_3~161.5 GeV

Step C

1. Use the rough results from step A, the requirements below are used:

E_1 =157.5, E_2 =162.5, $E_3 = 161.5, F_1 = 0.3, F_2 = 0.9$

$\sigma_{sys}^{corr} = 2 \times 10^{-4}$, ΔE=0.5 MeV, $\mathrm{E_{BS}}$=1.6× 10^{-3}, ΔE_{BS}=0.01

2. $\sigma_{WW} \sim G\left(\sigma_{WW}^0, \sigma_{sys}^{corr}\right), E \sim G\left(E_p^0, \Delta E\right) + G(E_m^0, \Delta E)$, the description about E_{BS} can be found in backup.

3. By 500 samplings, we fit the distributions of m_W, Γ_w, and the corresponding uncertainties are : Δm_W~1 MeV, $\Delta\Gamma_W$~2.8 MeV

Summary and next to do

1. With the configurations :

$$\boldsymbol{L = 3.2\ ab^{-1}, \epsilon P = 0.72}\ ,\ \sigma_{sys}^{corr} = 2 \times 10^{-4}$$

$$\Delta E\text{=0.5 MeV, } \mathrm{E_{BS}}\text{=}1.6\times 10^{-3},\ \Delta E_{BS}\text{=0.01}$$

If we taking data at:

a. One points: $\Delta \mathrm{m_W}$~0.9 MeV at 162.5 GeV

b. Two points: Δm_W~1.0 MeV, $\Delta\Gamma_W$~2.9 MeV (E_1=157.5, E_2=162.5GeV, F_1=0.3)

c. Three points: Δm_W~1.0 MeV, $\Delta\Gamma_W$~2.8 MeV (E_1=157.5, E_2=161.5, E_3=162.5GeV, F_1=0.3, F_2=0.1)

2. The more precise scan will be performed with the preliminary results.

Backup

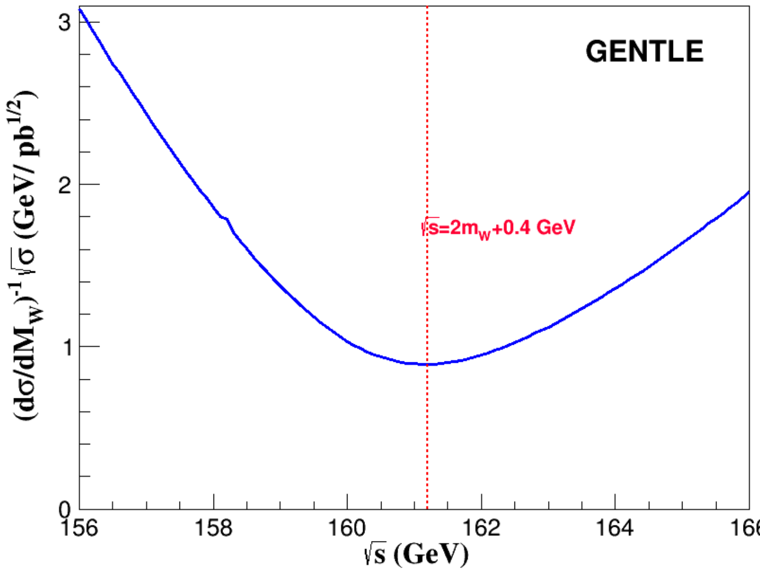
Taking data at one point (just for m_W)

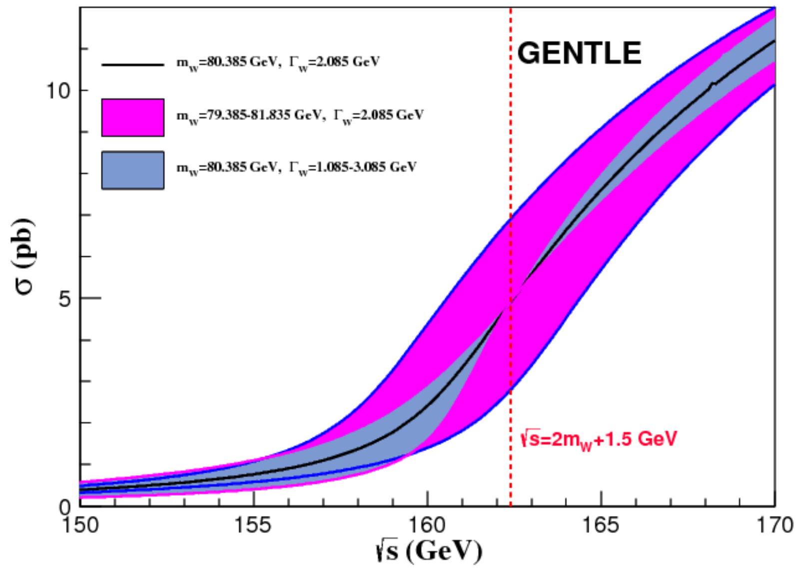
There are two special energy points for just measuring m_W:

1. The one where most statistical sensitivity to m_W:

$$\Delta m_W(\text{stat.}) = \left(\frac{d\sigma_{WW}}{dm_W}\right)^{-1} \frac{\sqrt{\sigma_{WW}}}{\sqrt{L\epsilon P}} \approx 0.59 \text{ MeV at } E\text{=161.2 GeV (with } \Delta\Gamma_W \text{ effect)}$$

2. The one where $\frac{\partial \sigma_{WW}}{\partial \Gamma_W} = 0$ at $E \approx 162.5$ GeV (Δm_W0.68 MeV, but no $\Delta\Gamma_W$ effect)





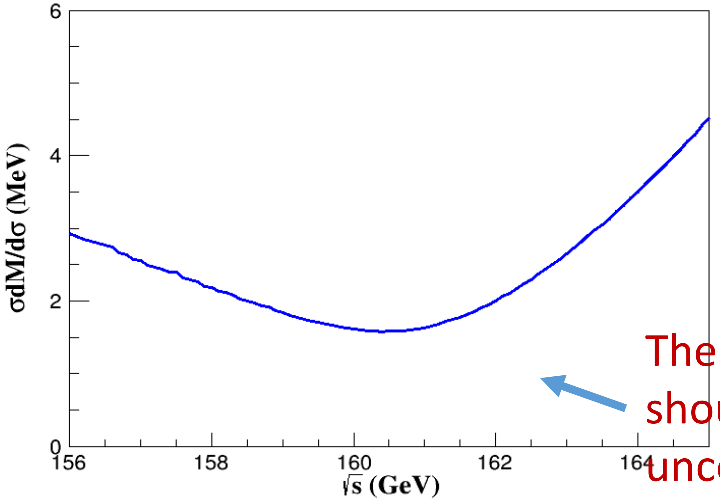
Systematic uncertainty for data taking at one point

$$N_{tot} = L \cdot \sigma_{WW}(E) \cdot \frac{\epsilon}{P}$$

$$\Delta m_W(\sigma_{WW}) = \frac{\partial m_W}{\partial \sigma_{WW}} \Delta\sigma_{WW}$$

$$\Delta m_W(\Gamma_W) = \frac{\partial m_W}{\partial \sigma_{WW}} \frac{\partial \sigma_{WW}}{\partial \Gamma_W} \Delta\Gamma_W \text{ ....}$$

$$\sigma^{sys}(corr.) = \sqrt{\Delta L^2 + \Delta\sigma_{WW}^2 + \Delta\epsilon^2 + \Delta P^2}$$

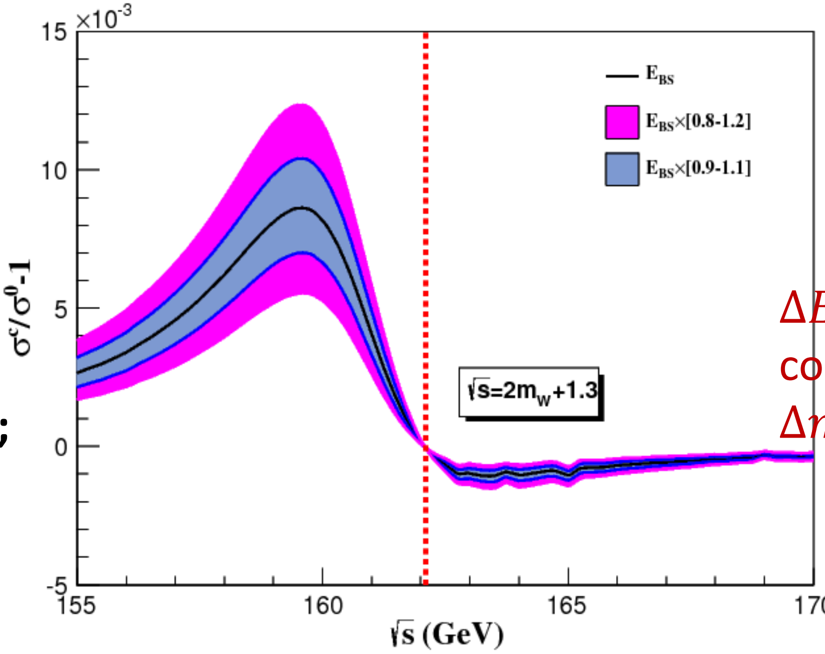


The value in this curve should times relative uncertainty!

With ΔL $(\Delta\sigma_{WW}, \Delta\epsilon, \Delta P)$<$10^{-4}$, σ^{sys}(corr.)<2×10^{-4}:

	$E = 161.2$ GeV	$E = 162.5$ GeV
σ^{sys}(corr.)	0.35	0.44
ΔE (0.5 MeV)	0.36	0.37
ΔE_{BS}(1%)	0.12	-
$\Delta\Gamma_W$ (42 MeV)	**8**	-

$\Delta m_W(tot)$~0.9 MeV, if taking data at 162.5 GeV;

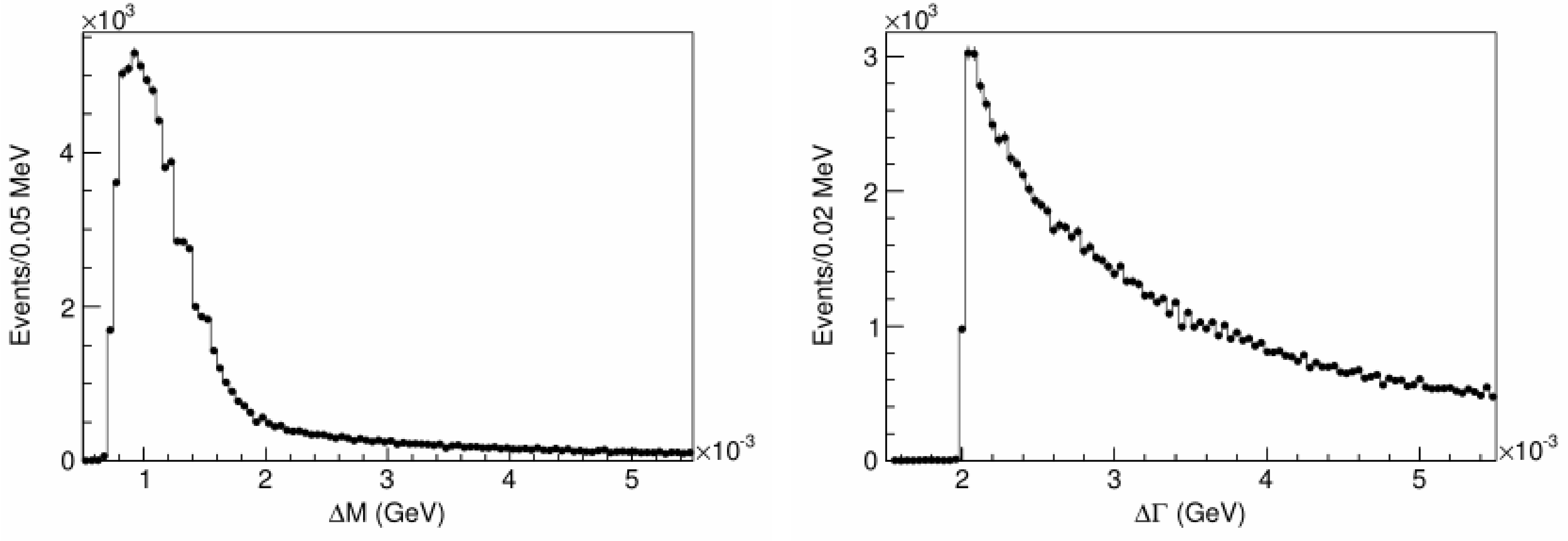


ΔE_{BS} does't contribute to Δm_W !

Taking data at two energy points

To measure both Δm_W and $\Delta\Gamma_W$, we scan the energies and the luminosity fraction of the two data points:

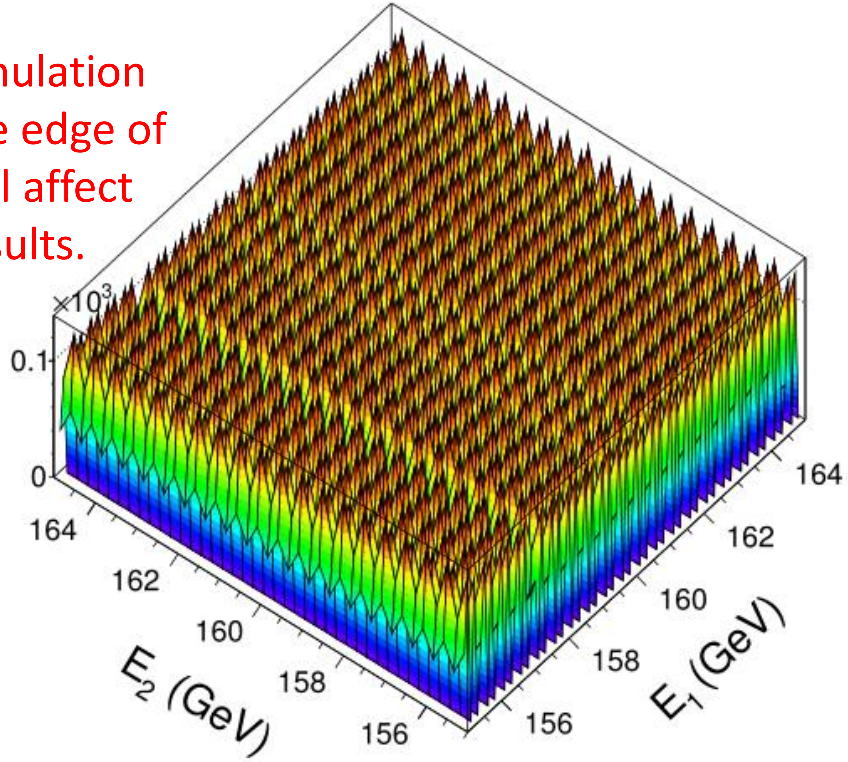
1. $E_1, E_2 \in [155,\ 165]$ GeV, $\Delta E = 0.1$ GeV
2. $F\ \left(\frac{L_1}{L_2}\right) \in (0, 1), \Delta F = 0.05$

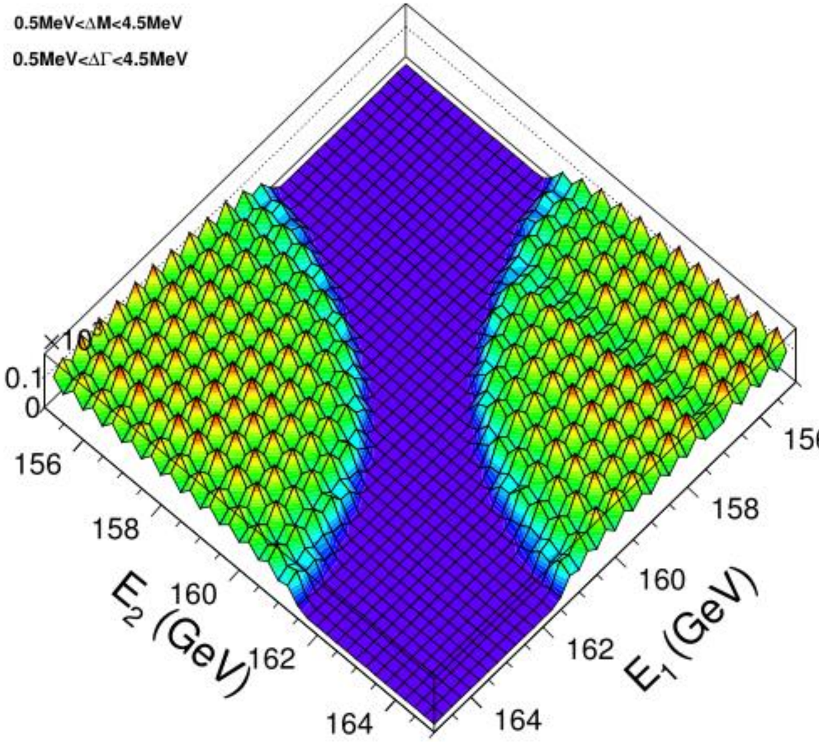


E_1, E_2

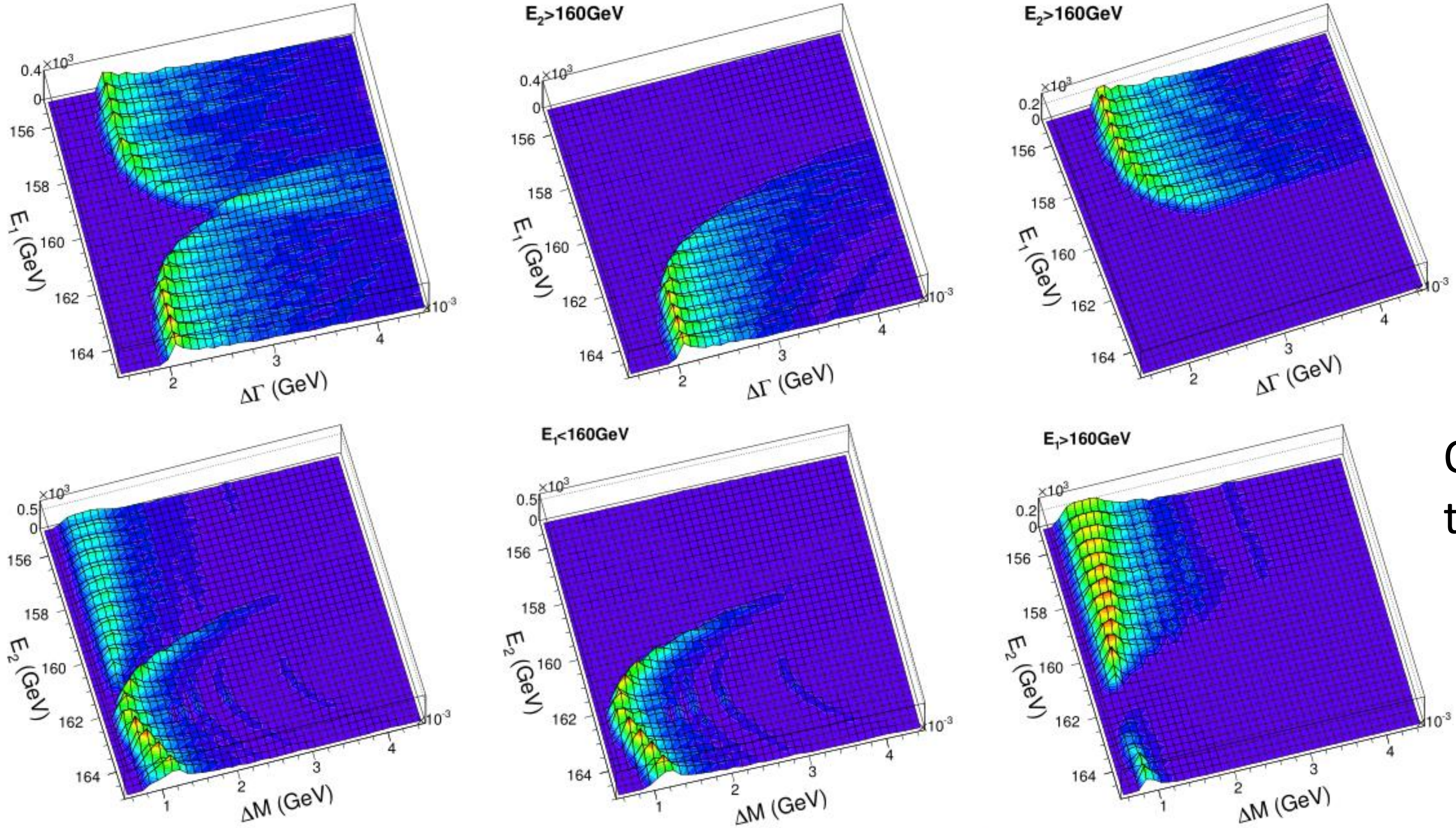
For further study, the two requirements are preformed: $\Delta m_W(\Delta\Gamma_W) \in (0.5, 4.5)$MeV, the scatter plot of E_1, E_2 is divided into two parts corresponding.

The z axis is the cumulation of the fit result. The edge of the distributions will affect the optimization results.





$\Delta m_W, \Delta\Gamma_W$ vs E_1, E_2



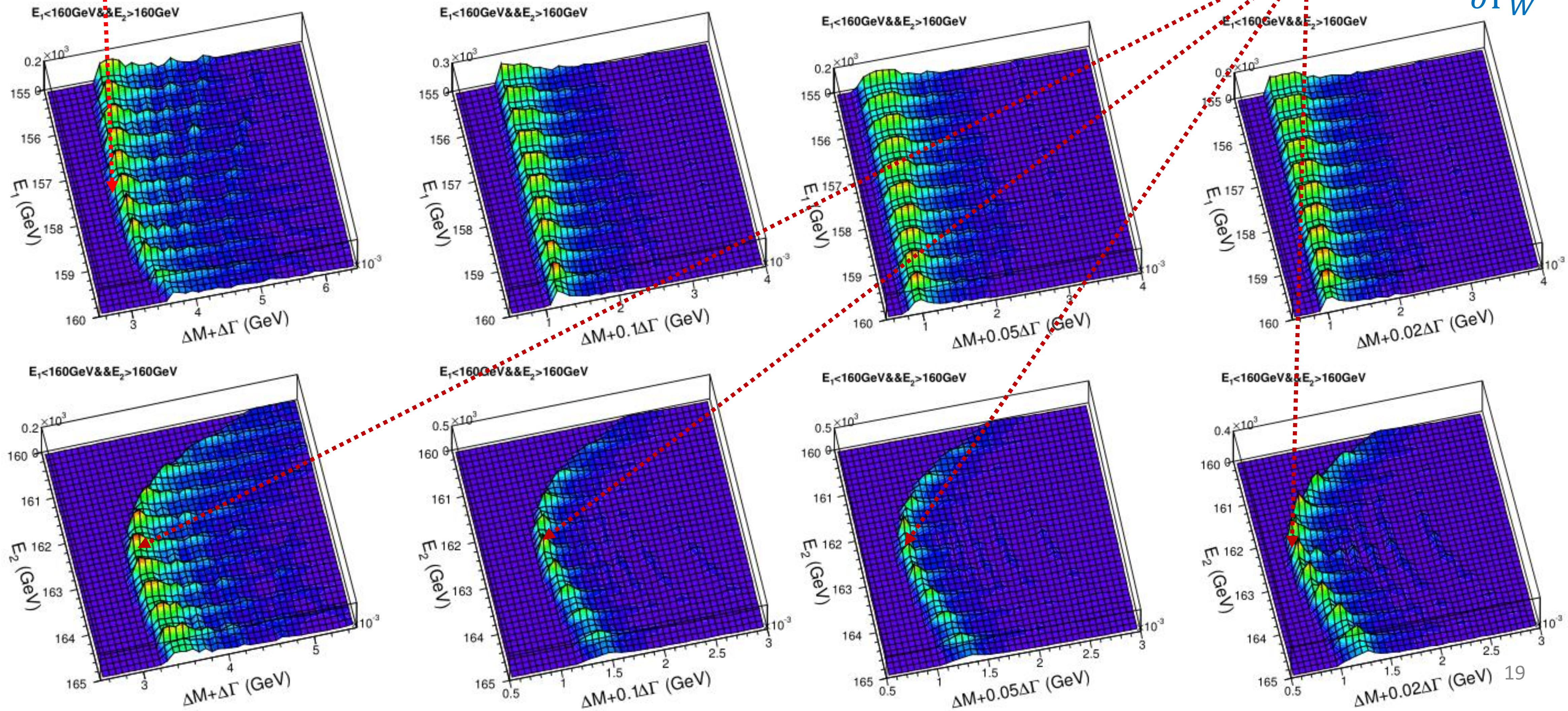
Both the energies of the two data points will affect $\Delta\Gamma_W$

Only the one above threshold affect Δm_W

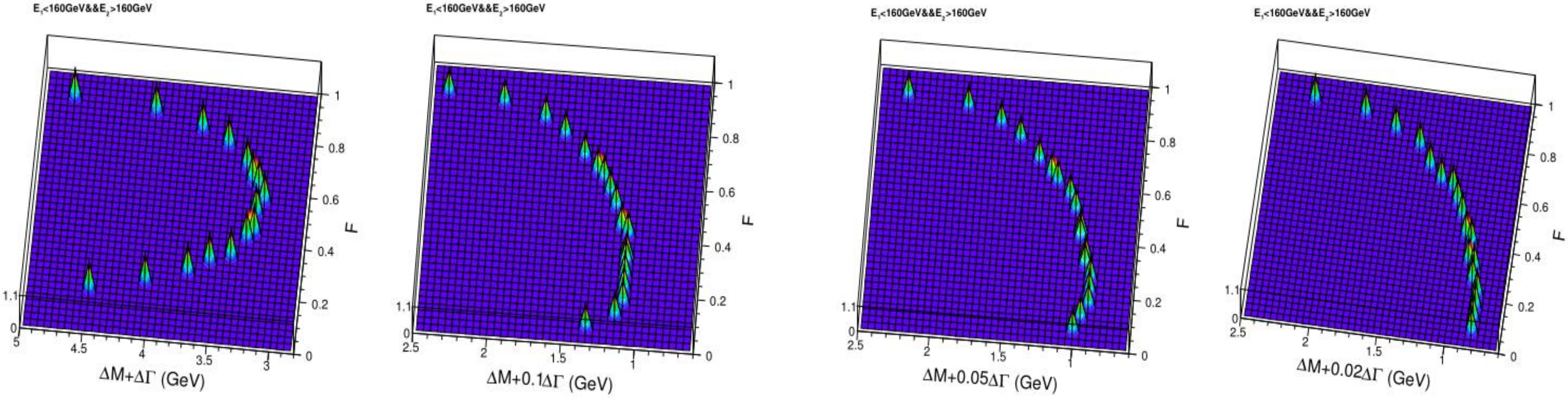
$(\Delta m_W + A \cdot \Delta\Gamma_W)$ vs E_1

E_1~157.5 GeV

E_2~162.5 GeV, around $\frac{\partial\sigma_{WW}}{\partial\Gamma_W}$=0



$(\Delta m_W + A \cdot \Delta\Gamma_W)$ vs F



Systematic uncertainty for data taking at two point

With : E_1=157.5GeV, E_2=162.5 GeV, σ^{sys}(corr.) = 2×10^{-4}(relative)

ΔE_{BS}=1.6×10^{-3}(relative), ΔE=0.5 MeV

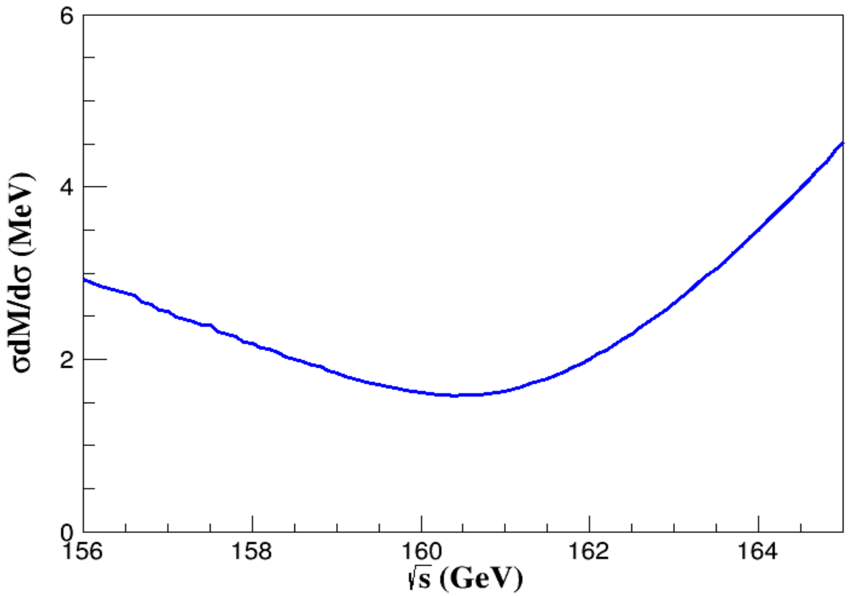
Just the quadratic sum without the ΔE_{BS}

F	Δm_W (Mev)						$\Delta\Gamma_W$ (MeV)					
	Stat.	Sys.				Total	Stat.	Sys.				Total
		σ(corr.)	ΔE	ΔE_{BS}	σ_{tot}^{sys}			σ(corr.)	ΔE	ΔE_{BS}	σ_{tot}^{sys}	
0.1	0.71	0.47	0.35	-		0.92	4.6	0.31	0.52	0.43	0.74	4.7
0.15	0.73	0.47	0.37	-		0.94	3.7	0.28	0.52	0.55	0.8	3.8
0.2	0.76	0.45	0.37	-		0.96	3.3	0.26	0.52	0.60	0.84	3.4
0.25	0.78	0.46	0.37	-		0.98	3.0	0.23	0.51	0.76	0.94	3.1
0.3	0.81	0.48	0.38	-		1.02	2.7	0.22	0.54	0.88	1.06	2.9

$$\boldsymbol{\sigma^{sys}}\textbf{(corr.) (}\sqrt{\Delta L^2 + \Delta\sigma_{WW}^2 + \Delta\epsilon^2 + \Delta P^2}\textbf{)}$$

Considering the σ^{sys}(corr.), the σ_{WW} becomes: $\sigma_{WW} \sim G(\sigma_{WW}^0, \sigma^{sys}(\text{corr.}))$

We simulate data with σ_{WW}, and use σ_{WW}^0 in fit.



σ^{sys}(corr.) = 2×10^{-4}(relative). By 500 samplings, the results are shown below (the uncertainty of each value is $1.5 - 2.0 \times 10^{-5}$)

F	0.1	0.15	0.2	0.25	0.3
Δm_W(MeV)	0.47	0.47	0.45	0.46	0.48
$\Delta\Gamma_W$(MeV)	0.31	0.28	0.26	0.23	0.22

ΔE

With the ΔE, the total energy becomes:

$$E = G(E_p, \Delta E) + G(E_m + \Delta E)$$

With ΔE=0.5 MeV and 500 samplings:

F	0.1	0.15	0.2	0.25	0.3
Δm_W(MeV)	0.35	0.37	0.37	0.37	0.38
$\Delta\Gamma_W$(MeV)	0.52	0.52	0.52	0.51	0.54

Uncertainty of each value is $0.6 - 1 \times 10^{-5}$

ΔE_{BS}

With the ΔE_{BS}, the σ_{WW} becomes:

$$\sigma_{WW}(E) = \int_0^{\infty} \sigma(E') \times G(E, E') dE'$$

$$= \int_{E-6\sqrt{2}E_{BS}}^{E+6\sqrt{2}E_{BS}} \sigma(E') \times \frac{1}{\sqrt{2\pi}\sqrt{2}E_{BS}} e^{\frac{-(E-E')^2}{2\left(\sqrt{2\pi E_{BS}}\right)^2}} dE'$$

For simulation $E_{BS} = E_{BS}^0 + \Delta\mathrm{E}_{\mathrm{BS}}$, and E_{BS}^0 for fit.