Precise measurement of the Z resonance parameters at CEPC

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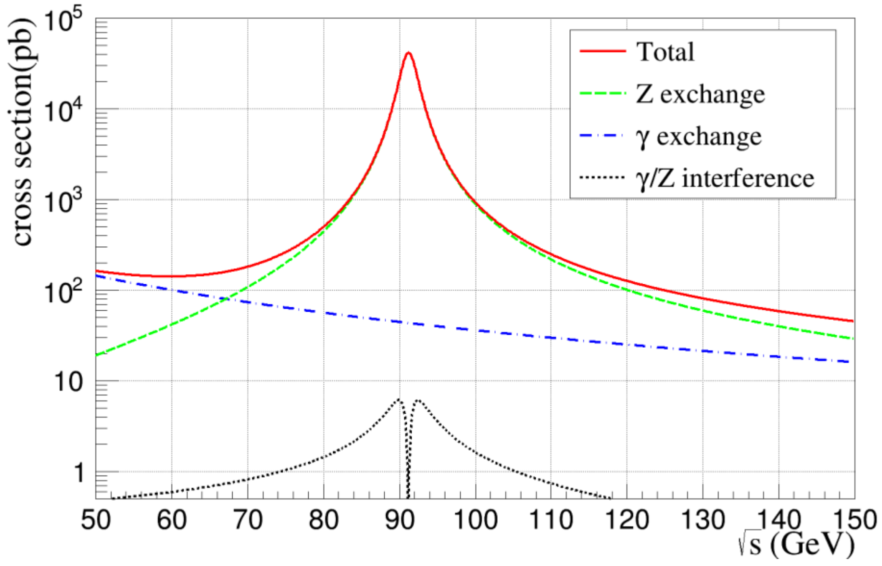
Outline

- Motivation
- Theoretical basis & Methodology
- Statistical and systematic uncertainties
- Data-taking strategy
- Summary & Outlook

Motivation

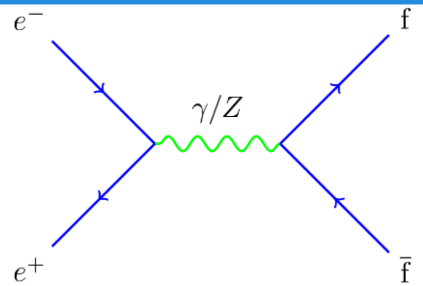
- Properties of Z boson are basic parameters of nature and could provide stringent tests of the Standard Model.
- Possible new particle or new physics beyond the SM might be revealed through the subtle changes of measured results.
- Develop data-taking strategies to make good use of the performance of future colliders (CEPC) & provide reference for CEPC design.



Theoretical basis & Methodology

Theoretical basis & Methodology

- Main process: $e^+e^- \to f\bar{f}$ at around 91 GeV



- In lowest order & neglecting fermion masses :

$$\frac{2s}{\pi N_c}\frac{d\sigma_{f\bar{f}}}{d\cos\theta} = \alpha^2 Q_f^2(1+\cos^2\theta)$$
$$+ 8\,\mathrm{Re}\left\{\alpha Q_f \chi^*(s)\left[\,C^s_{\gamma Z}(1+\cos^2\theta) + 2C^a_{\gamma Z}\cos\theta\,\right]\right\}$$
$$+ 16|\chi(s)|^2\left[\,C^s_{ZZ}(1+\cos^2\theta) + 8C^a_{ZZ}\cos\theta\,\right] ,$$

with

$$\chi(s) = \frac{G_F M_Z^2}{8\pi\sqrt{2}}\frac{s}{s - M_Z^2 + iM_Z\Gamma_Z} ,$$

$$C^s_{\gamma Z} = g_{Ve}g_{Vf} , \qquad C^a_{\gamma Z} = g_{Ae}g_{Af} ,$$
$$C^s_{ZZ} = (g^2_{Ve} + g^2_{Ae})(g^2_{Vf} + g^2_{Af}) , \qquad C^a_{ZZ} = g_{Ve}g_{Ae}g_{Vf}g_{Af} .$$

Ref: Eur.Phys.J.C 19 (2001) 587-651

Theoretical basis & Methodology

- Integrated over the full angular space：

  Z-exchange term：

$$\sigma_{f\bar{f}}^{Z} = \sigma_{f}^{0} \frac{s\Gamma_Z^2}{(s - M_Z^2)^2 + \Gamma_Z^2 M_Z^2},$$

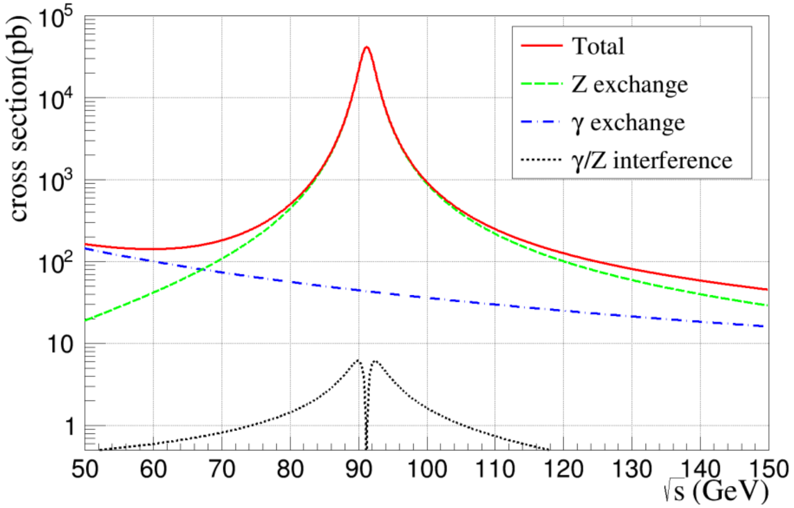
$$\sigma_{f}^{0} = \frac{12\pi}{M_Z^2}\frac{\Gamma_{ee}\Gamma_{ff}}{\Gamma_Z^2} = \frac{C_{ZZ}^{s} N_c}{6\pi}\left(\frac{M_Z^2 G_F}{\Gamma_Z}\right)^2$$

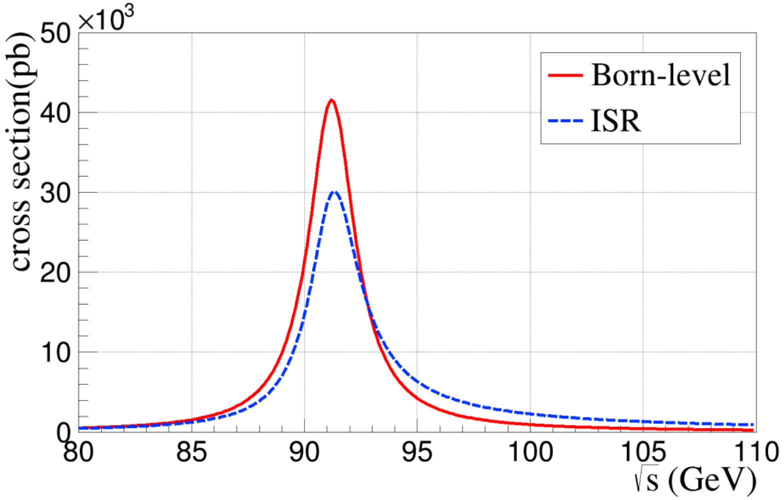
- Forward-backward asymmetry A_{FB}:

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

- ISR

$$\sigma_{f\bar{f}}^{obs}(s) = \int_0^{1-s_m/s} dx\,\sigma(s(1-x))F(x,s)$$





Theoretical basis & Methodology

- $\sigma_{\mathrm{f\bar{f}}} = \sigma_{\mathrm{f\bar{f}}}\,(M_Z, \Gamma_Z, \sigma^0_{\mathrm{had}}, C^{\mathrm{s}}_{\mathrm{ZZ}}, C^{\mathrm{s}}_{\gamma\mathrm{Z}})$, $A^{ll}_{\mathrm{FB}} = A_{\mathrm{FB}}(M_Z, \Gamma_Z, C^{\mathrm{s}}_{\mathrm{ZZ}}, C^{\mathrm{a}}_{\mathrm{ZZ}}, C^{\mathrm{s}}_{\gamma\mathrm{Z}}, C^{\mathrm{a}}_{\gamma\mathrm{Z}})$

- Parameter set: M_Z Γ_Z σ^0_{had} $C^{\mathrm{s}}_{\mathrm{ZZ}}$ $C^{\mathrm{a}}_{\mathrm{ZZ}}$ $C^{\mathrm{s}}_{\gamma\mathrm{Z}}$ $C^{\mathrm{a}}_{\gamma\mathrm{Z}}$

Ref: Eur.Phys.J.C 19 (2001) 587-651

- Parameters can be obtained by fitting the $N_{obs}(\sigma_{\mathrm{f\bar{f}}}, A^{ll}_{\mathrm{FB}})$ with the theoretical result.

- Focusing on uncertainties, we use toy Monte Carlo method to generate N_{obs} and perform χ^2 fits to get the uncertainties of measured parameters.

Statistical and systematic uncertainties

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Statistical and systematic uncertainties

- **Statistical uncertainties**
- For single data point:
- Cross-section :

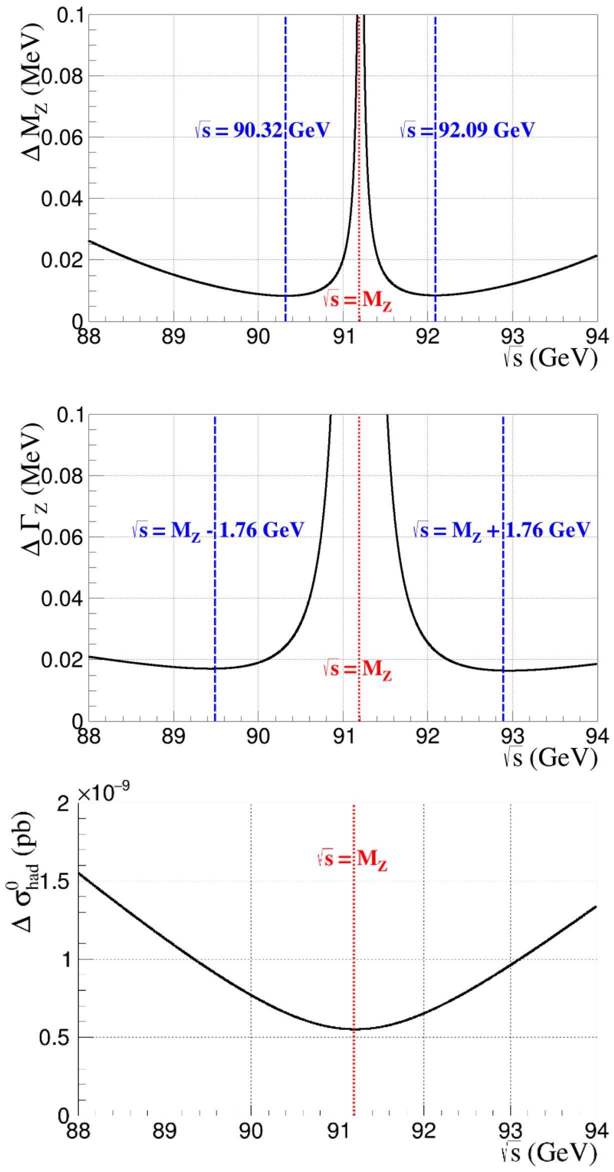
$$\sigma_{\mathrm{meas}} = \frac{N_{\mathrm{obs}} - N_{\mathrm{bkg}}}{\epsilon \mathcal{L}} = \frac{N_{\mathrm{meas}}}{\epsilon \mathcal{L}}$$

- N_{meas} subject to normal distribution

$$\Delta\sigma_{\mathrm{meas}}(\mathrm{stat}) = \frac{\sqrt{N_{\mathrm{meas}}}}{\epsilon \mathcal{L}}$$

- Statistical uncertainty of a parameter P:

$$\Delta P(\mathrm{stat}) = \left|\frac{\partial P}{\partial \sigma_{\mathrm{meas}}}\right| \Delta\sigma_{\mathrm{meas}}(\mathrm{stat}) = \left|\frac{\partial \sigma_{\mathrm{meas}}}{\partial P}\right|^{-1} \Delta\sigma_{\mathrm{meas}}(\mathrm{stat})$$



Statistical and systematic uncertainties

- **Statistical uncertainties**
- For two data points or more:
- The χ^2 defined as ($\xi = N$ or A_{FB}):

$$\chi^2 = \sum_i \frac{(\xi^i_{\mathrm{meas}} - \xi^i_{\mathrm{th}})^2}{\delta_i^2}$$

- Covariance matrix calculated by MINUIT:

$$C = \begin{bmatrix}
\frac{\partial^2\chi^2}{\partial M_Z^2} & \frac{\partial^2\chi^2}{\partial M_Z \partial \Gamma_Z} & \frac{\partial^2\chi^2}{\partial M_Z \partial \sigma^0_{\mathrm{had}}} & \frac{\partial^2\chi^2}{\partial M_Z \partial C^{\mathrm{s}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial M_Z \partial C^{\mathrm{a}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial M_Z \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial M_Z \partial C^{\mathrm{s}}_{\gamma Z}} \\
\frac{\partial^2\chi^2}{\partial M_Z \partial \Gamma_Z} & \frac{\partial^2\chi^2}{\partial \Gamma_Z^2} & \frac{\partial^2\chi^2}{\partial \Gamma_Z \partial \sigma^0_{\mathrm{had}}} & \frac{\partial^2\chi^2}{\partial \Gamma_Z \partial C^{\mathrm{s}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial \Gamma_Z \partial C^{\mathrm{a}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial \Gamma_Z \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial \Gamma_Z \partial C^{\mathrm{s}}_{\gamma Z}} \\
\frac{\partial^2\chi^2}{\partial M_Z \partial \sigma^0_{\mathrm{had}}} & \frac{\partial^2\chi^2}{\partial \Gamma_Z \partial \sigma^0_{\mathrm{had}}} & \frac{\partial^2\chi^2}{\partial \sigma^{0\,2}_{\mathrm{had}}} & \frac{\partial^2\chi^2}{\partial \sigma^0_{\mathrm{had}} \partial C^{\mathrm{s}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial \sigma^0_{\mathrm{had}} \partial C^{\mathrm{a}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial \sigma^0_{\mathrm{had}} \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial \sigma^0_{\mathrm{had}} \partial C^{\mathrm{s}}_{\gamma Z}} \\
\frac{\partial^2\chi^2}{\partial M_Z \partial C^{\mathrm{s}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial \Gamma_Z \partial C^{\mathrm{s}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial \sigma^0_{\mathrm{had}} \partial C^{\mathrm{s}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{s}\,2}_{ZZ}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{s}}_{ZZ} \partial C^{\mathrm{a}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{s}}_{ZZ} \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{s}}_{ZZ} \partial C^{\mathrm{s}}_{\gamma Z}} \\
\frac{\partial^2\chi^2}{\partial M_Z \partial C^{\mathrm{a}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial \Gamma_Z \partial C^{\mathrm{a}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial \sigma^0_{\mathrm{had}} \partial C^{\mathrm{a}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{s}}_{ZZ} \partial C^{\mathrm{a}}_{ZZ}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{a}\,2}_{ZZ}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{a}}_{ZZ} \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{a}}_{ZZ} \partial C^{\mathrm{s}}_{\gamma Z}} \\
\frac{\partial^2\chi^2}{\partial M_Z \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial \Gamma_Z \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial \sigma^0_{\mathrm{had}} \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{s}}_{ZZ} \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{a}}_{ZZ} \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{a}\,2}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{a}}_{\gamma Z} \partial C^{\mathrm{s}}_{\gamma Z}} \\
\frac{\partial^2\chi^2}{\partial M_Z \partial C^{\mathrm{s}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial \Gamma_Z \partial C^{\mathrm{s}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial \sigma^0_{\mathrm{had}} \partial C^{\mathrm{s}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{s}}_{ZZ} \partial C^{\mathrm{a}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{a}}_{ZZ} \partial C^{\mathrm{s}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{a}}_{\gamma Z} \partial C^{\mathrm{s}}_{\gamma Z}} & \frac{\partial^2\chi^2}{\partial C^{\mathrm{s}\,2}_{\gamma Z}}
\end{bmatrix}^{-1}$$

Statistical and systematic uncertainties

- **Systematic uncertainties**
- Sources of systematic uncertainties that we have studied:

$$\sigma_E, \quad \Delta E, \quad \Delta\sigma_E, \quad \Delta L$$

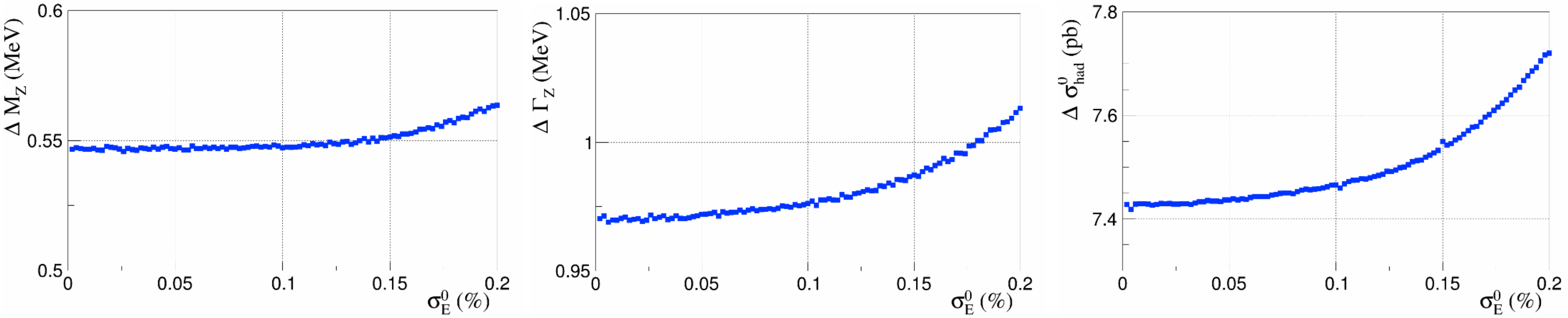
- σ_E beam energy spread :

$$\sigma_{\mathrm{f\bar{f}}}(E_0, \sigma_E^0) = \int \sigma_{\mathrm{f\bar{f}}}(E')G(E_0, \sigma_E^0)dE'$$

$$= \int \sigma_{\mathrm{f\bar{f}}}(E') \cdot \frac{1}{\sqrt{2\pi\sigma_E^0}} e^{\frac{-(E_0-E')^2}{2\sigma_E^{0\,2}}} dE'$$

Statistical and systematic uncertainties

- **Systematic uncertainties**
- σ_E beam energy spread :



Statistical and systematic uncertainties

- **Systematic uncertainties**
- Assume that E, σ_E subject to normal distribution:

$$\mathrm{E} = G(\mathrm{E}_0, \Delta \mathrm{E}) 、 \sigma_\mathrm{E} = G\left(\sigma_\mathrm{E}^0, \Delta\sigma_\mathrm{E}\right)$$

- Effect of ΔE, $\Delta\sigma_E$ can be considered by

$$\sigma_{\mathrm{f\bar{f}}}(E_0, \sigma_E^0) = \int \sigma_{\mathrm{f\bar{f}}}(E')G(E_0, \sigma_E^0)dE'$$

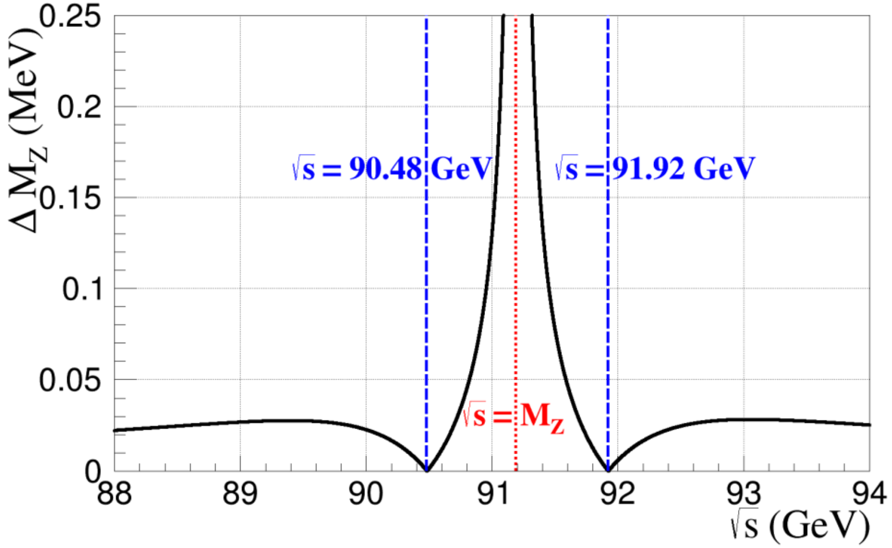
$$= \int \sigma_{\mathrm{f\bar{f}}}(E') \cdot \frac{1}{\sqrt{2\pi}\sigma_E^0} e^{\frac{-(E_0-E')^2}{2\sigma_E^{0\,2}}} dE'$$

$$\longrightarrow$$

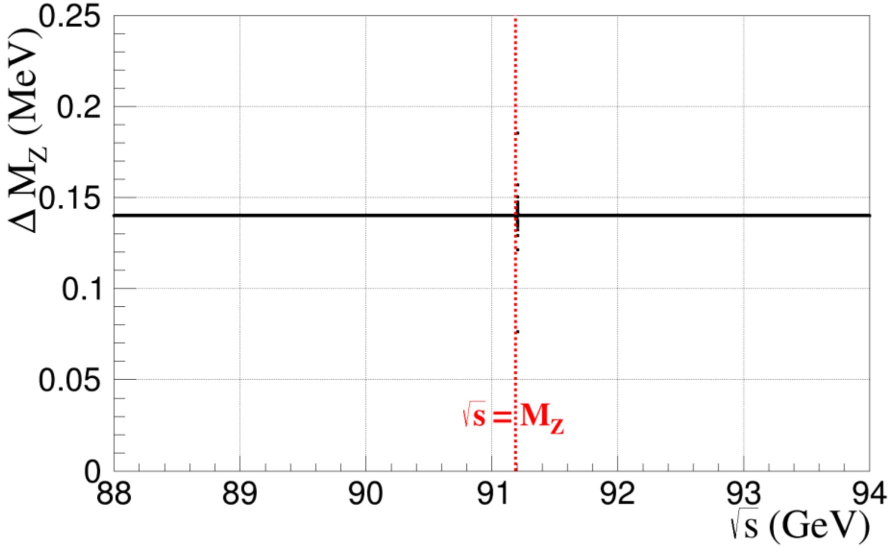
$$\sigma_{\mathrm{f\bar{f}}}(E, \sigma_E) = \int \sigma_{\mathrm{f\bar{f}}}(E') \cdot \frac{1}{\sqrt{2\pi}\sigma_E} e^{\frac{-(E-E')^2}{2\sigma_E{}^2}} dE'$$

Statistical and systematic uncertainties

- **Systematic uncertainties**
- Effect of ΔE, $\Delta\sigma_E$ on ΔM_Z



$\Delta \mathrm{E} = 0.14$ MeV



$\Delta\sigma_{\mathrm{E}} = 0.57$ MeV

Statistical and systematic uncertainties

- **Systematic uncertainties**
- ΔL Uncertainty of integrated luminosity
- $\Delta\sigma$ caused by ΔL

$$\sigma_{\text{meas}} = \frac{N_{\text{obs}} - N_{\text{bkg}}}{\epsilon \mathcal{L}} = \frac{N_{\text{meas}}}{\epsilon \mathcal{L}}$$

$$\Delta\sigma(\Delta\mathcal{L}) = \sigma_{\text{meas}} \Delta\mathcal{L}$$

- The uncertainty of a parameter P:

$$\Delta P(\Delta\mathcal{L}) = \left|\frac{\partial P}{\partial \sigma_{\text{f}\bar{\text{f}}}}\right| \Delta\sigma(\Delta\mathcal{L}) = \left|\frac{\partial P}{\partial \sigma_{\text{f}\bar{\text{f}}}}\right| \cdot \sigma_{\text{meas}} \Delta\mathcal{L}$$

- In the simulation

$$\sigma_{\text{meas}} = G(\sigma^0_{\text{meas}}, \sigma^0_{\text{meas}} \cdot \Delta\mathcal{L})$$

Data-taking strategy

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Data-taking strategy

- Global Determinant Parameter (GDP)
- For n parameters, it is defined as the determinant of the covariance matrix raised to the $\frac{1}{2n}$ power,

$$\mathrm{GDP} \equiv \sqrt[2n]{\det Cov}$$

- Here, GDP serve as an object parameter for optimization

Ref: J. High Energ. Phys. 2017, 14 (2017).

- To focus on uncertainties of M_Z Γ_Z σ^0_{had} , a transformation is needed:

$$C = VC_0V^T \qquad V = diag(5,\ 5,\ 3,\ 1,\ 1,\ 1,\ 1)$$

Data-taking strategy

- Energy points selection :

$\sqrt{s}$ (GeV)	$\mathcal{L}$	$\sqrt{s}$ (GeV)	$\mathcal{L}$	$\sqrt{s}$ (GeV)	$\mathcal{L}$
$E_1 = 84.6$	$\mathcal{L}_1$	$E_6 = 90.4$	$\mathcal{L}_6$	$E_{10} = 93.2$	$\mathcal{L}_{10}$
$E_2 = 85.6$	$\mathcal{L}_2$	$E_7 = 91.2$	$\mathcal{L}_7$	$E_{11} = 94.3$	$\mathcal{L}_{11}$
$E_3 = 87.9$	$\mathcal{L}_3$	$E_8 = 92.0$	$\mathcal{L}_8$	$E_{12} = 95.3$	$\mathcal{L}_{12}$
$E_4 = 88.7$	$\mathcal{L}_4$	$E_9 = 92.5$	$\mathcal{L}_9$	$E_{13} = 96.2$	$\mathcal{L}_{13}$
$E_5 = 89.9$	$\mathcal{L}_5$				

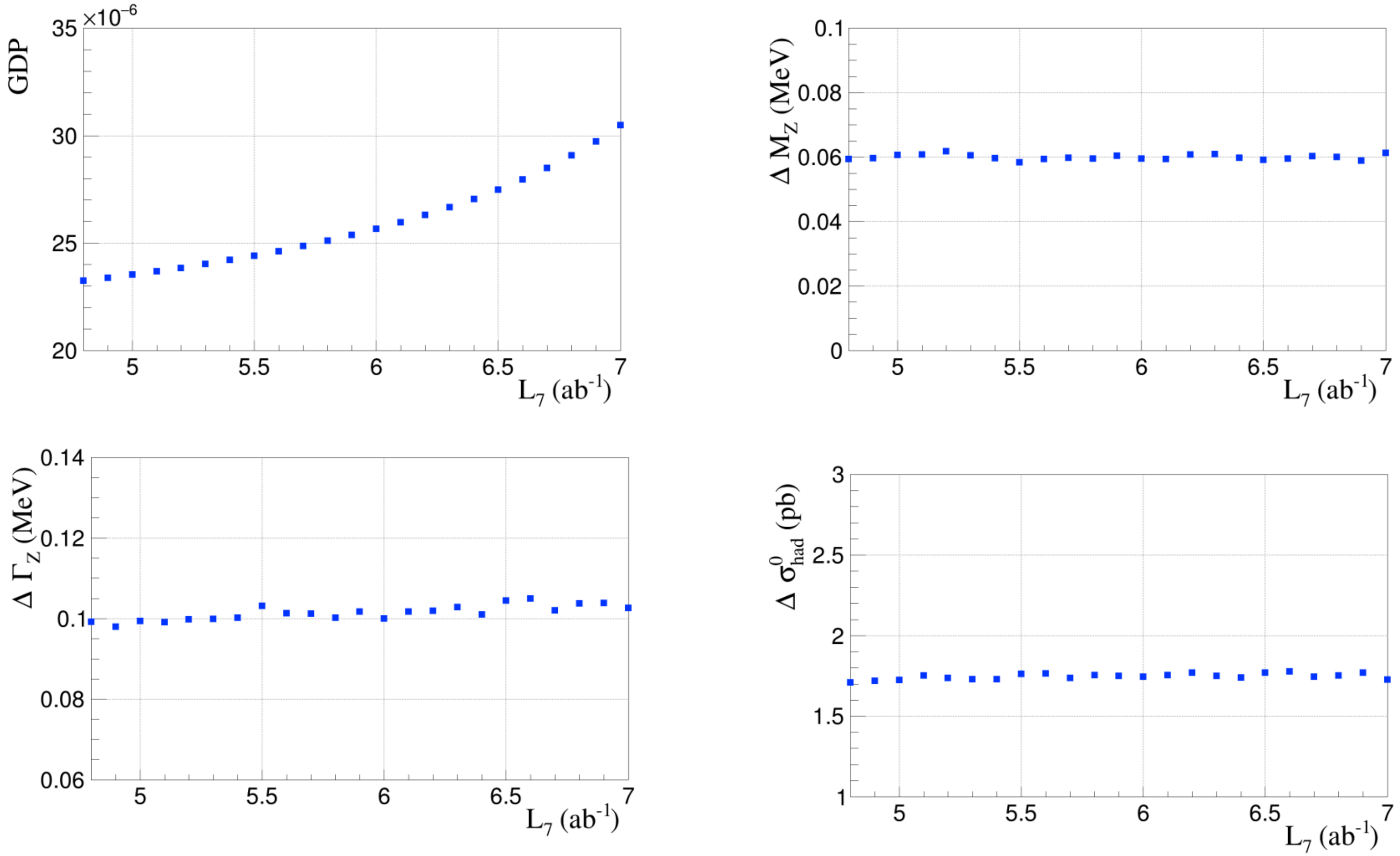
- Limitations for luminosity distribution :

➡ Total integrated luminosity $\mathcal{L} = 8\ \mathrm{ab}^{-1}$

➡ At $E_7 = 91.2\ \mathrm{GeV}$ (Z pole) $\mathcal{L}_7 \geq 60\% \cdot \mathcal{L}$

Data-taking strategy

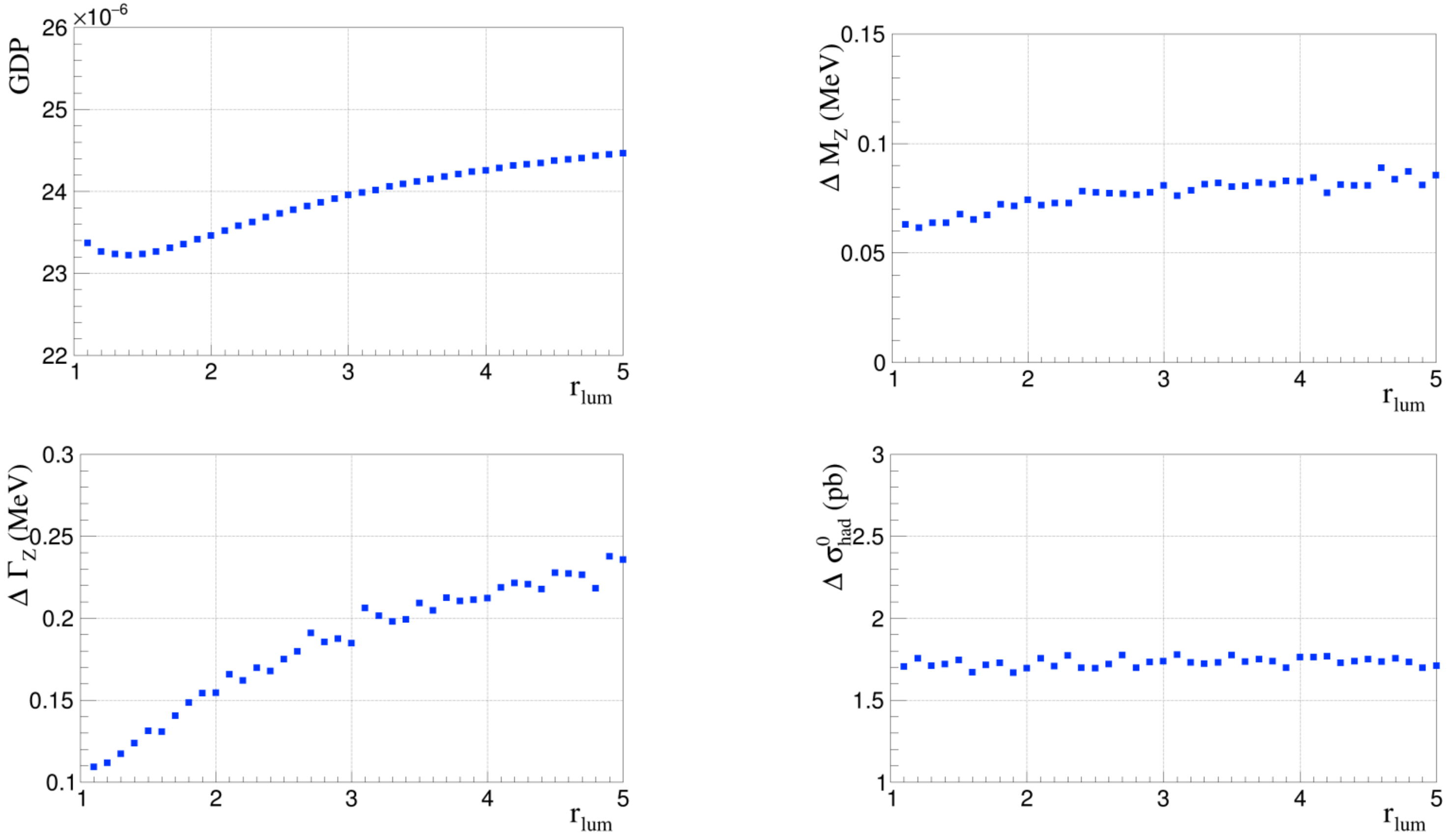
- **Luminosity scan on E_7 (Z pole)**



Data-taking strategy

- **Luminosity scan on off-peak energy points**
- Luminosity distribution is in the form of geometric series with common ratio r_{lum}

$$\mathcal{L}_1 : \mathcal{L}_2 : \mathcal{L}_3 : \mathcal{L}_4 : \mathcal{L}_5 : \mathcal{L}_6 = r_{\mathrm{lum}}^0 : r_{\mathrm{lum}}^1 : r_{\mathrm{lum}}^2 : r_{\mathrm{lum}}^3 : r_{\mathrm{lum}}^4 : r_{\mathrm{lum}}^5$$



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Data-taking strategy

- A preliminary data-taking scheme：

$\sqrt{s}$ (GeV)	$\mathcal{L}$ (ab^{-1})	$\sqrt{s}$ (GeV)	$\mathcal{L}$ (ab^{-1})	$\sqrt{s}$ (GeV)	$\mathcal{L}$(ab^{-1})
$E_1 = 84.6$	$\mathcal{L}_1 = 0.09$	$E_6 = 90.4$	$\mathcal{L}_6 = 0.50$	$E_{10} = 93.2$	$\mathcal{L}_{10} = 0.25$
$E_2 = 85.6$	$\mathcal{L}_2 = 0.13$	$E_7 = 91.2$	$\mathcal{L}_7 = 5.00$	$E_{11} = 94.3$	$\mathcal{L}_{11} = 0.18$
$E_3 = 87.9$	$\mathcal{L}_3 = 0.18$	$E_8 = 92.0$	$\mathcal{L}_8 = 0.50$	$E_{12} = 95.3$	$\mathcal{L}_{12} = 0.13$
$E_4 = 88.7$	$\mathcal{L}_4 = 0.25$	$E_9 = 92.5$	$\mathcal{L}_9 = 0.35$	$E_{13} = 96.2$	$\mathcal{L}_{13} = 0.09$
$E_5 = 89.9$	$\mathcal{L}_5 = 0.35$				

- Uncertainties

Parameter	δ_{stat}	δ_{total}
M_Z (KeV)	7	66
Γ_Z (KeV)	13	126
σ^0_{had} (pb)	0.09	1.73

(ISR effect not considered due to technical problems)

Summary & Outlook

Summary & Outlook

- **Summary:**
- The precise measurement of Z boson resonance parameters is studied with simulation
- Statistical and some important systematic uncertainties are investigated
- A preliminary data-taking scheme is given

- **Outlook:**
- Take ISR effect & other radiative corrections into account
- A more comprehensive study on various sources of uncertainties
- New parameter sets with less members (e.g. $M_{\mathrm{Z}}, \Gamma_{\mathrm{Z}}, \sigma_{\mathrm{h}}^{0}, A_{\mathrm{FB}}^{0,l}, R_{l}$)
- More efficient way to perform optimization (e.g. genetic algorithm)

- **To be continued…**

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- Configurations:

Parameter	Value
M_Z (GeV)	91.1876 ± 0.0021
Γ_Z (GeV)	2.4952 ± 0.0023
BR_{ee} (%)	(3.3632 ± 0.0042)
BR_{had} (%)	(69.911 ± 0.056)
$\sin^2\theta_W$	0.23122(4)
$\mathcal{L}$ (ab^{-1})	8
ϵ	0.9
σ_E (%)	0.08
ΔE (MeV)	0.1
$\Delta\sigma_E$ (MeV)	0.4
$\Delta\mathcal{L}$(%)	0.05

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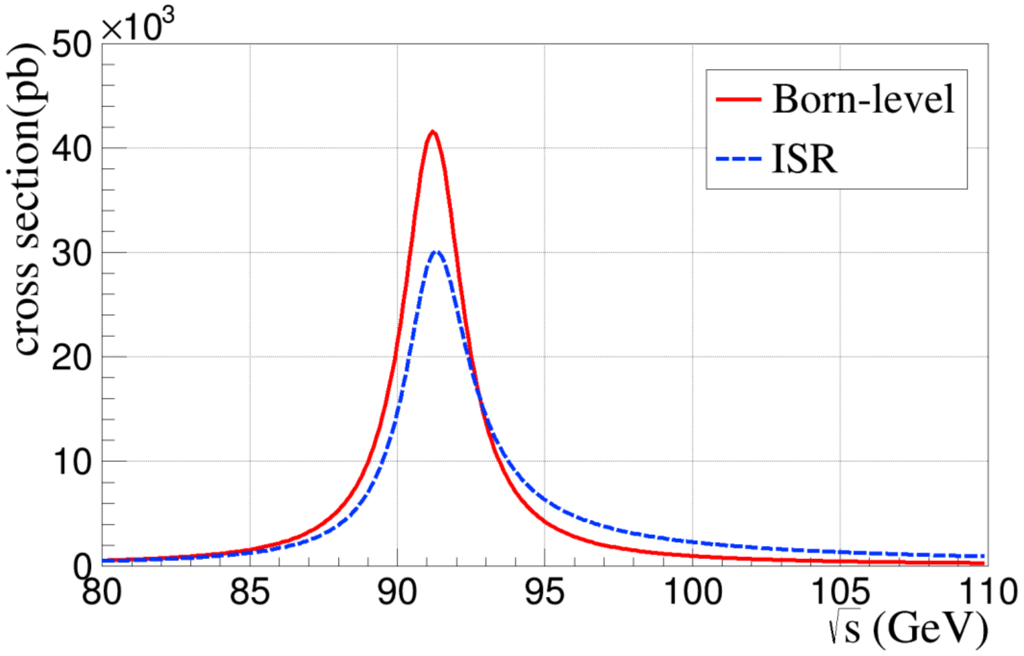
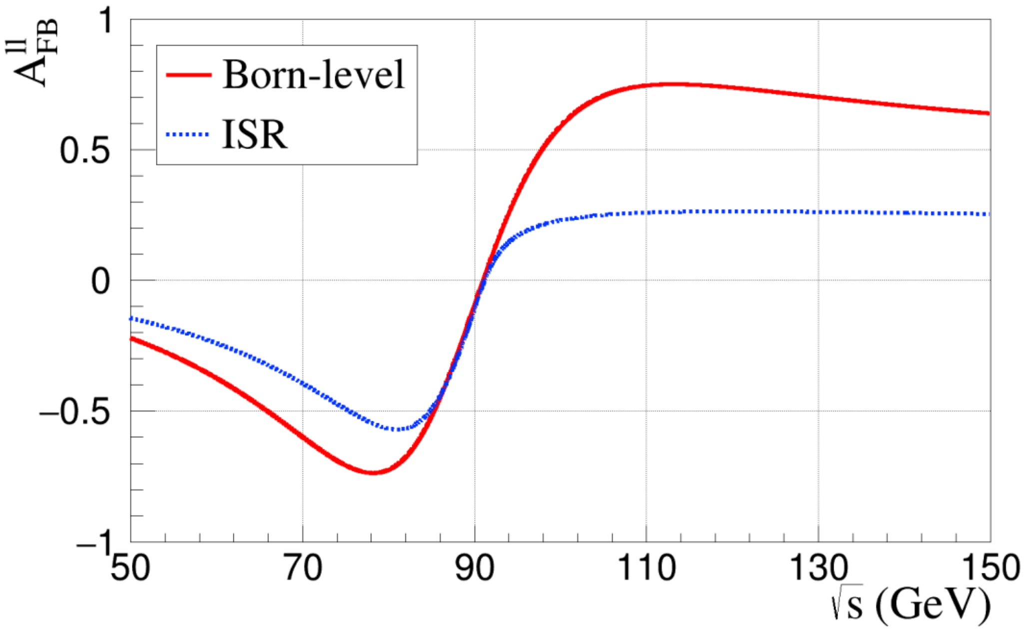
- ISR:



×10^3
50
40
30
20
10
0
cross section(pb)
Born-level
ISR
80
85
90
95
100
105
110
√s (GeV)



A^ll_FB
1
0.5
0
−0.5
−1
Born-level
ISR
50
70
90
110
130
150
√s (GeV)

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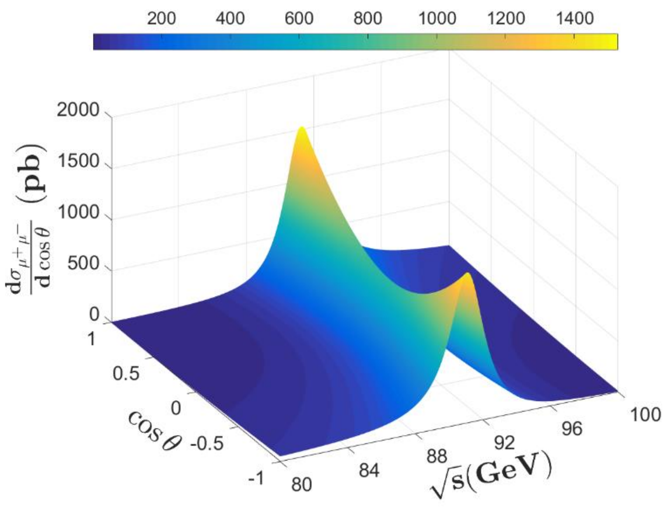

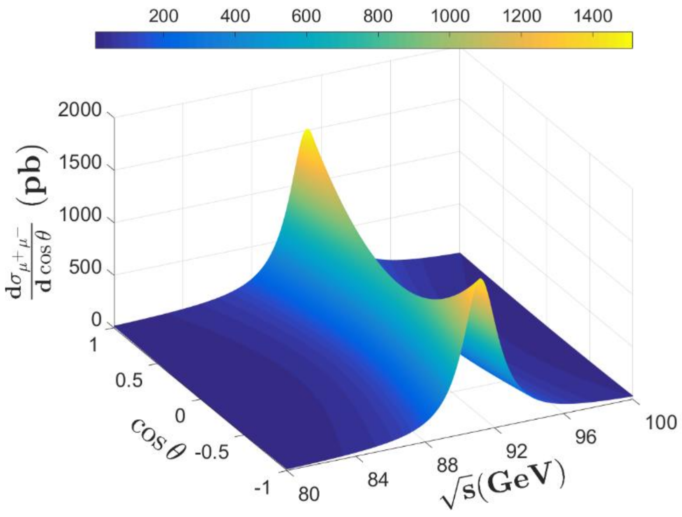

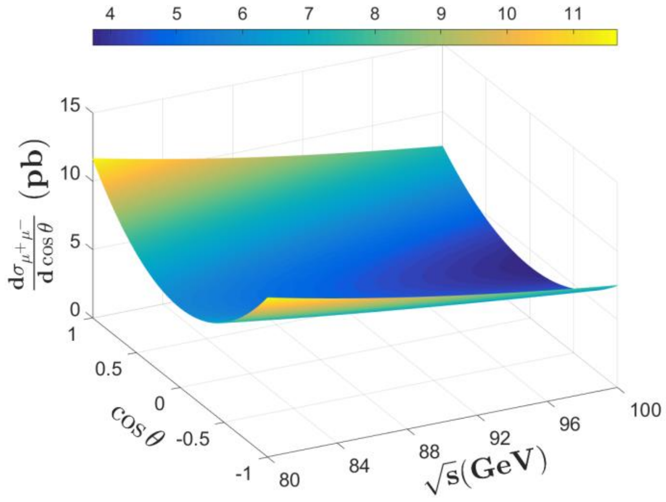

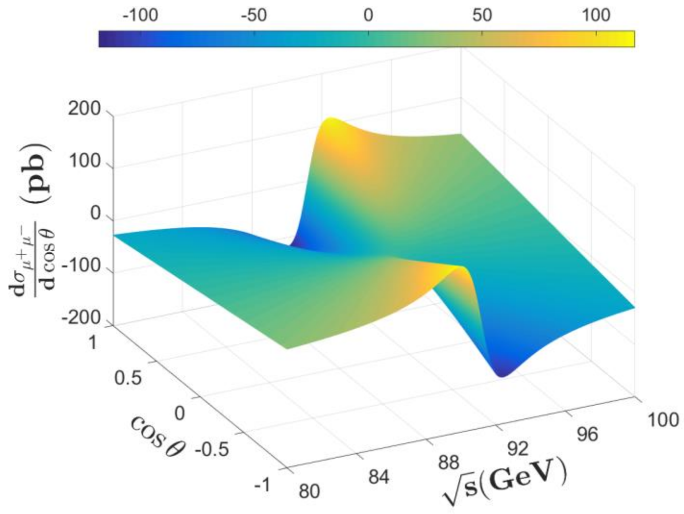

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- Analytical way to consider the effect of σ_E, ΔE, $\Delta\sigma_E$
- Taylor expansion of cross-section

$$\sigma_{f\bar{f}}(E) = \sigma_{f\bar{f}}(E_0) + \frac{d\sigma_{f\bar{f}}}{dE}(E-E_0) + \frac{1}{2}\frac{d^2\sigma_{f\bar{f}}}{dE^2}(E-E_0)^2 + \ldots + \frac{1}{n}\frac{d^n\sigma_{f\bar{f}}}{dE^n}(E-E_0)^n + \ldots$$

- Perform the convolution

$$\sigma_{f\bar{f}}(E_0,\sigma_E^0) = \int \sigma_{f\bar{f}}(E')G(E_0,\sigma_E^0)dE'$$

$$\sigma_{f\bar{f}}(E_0,\sigma_E^0) = \sigma_{f\bar{f}}(E_0) + \frac{1}{2}\frac{d^2\sigma_{f\bar{f}}}{dE^2}\sigma_E^{0\,2} + \frac{1}{8}\frac{d^4\sigma_{f\bar{f}}}{dE^4}\sigma_E^{0\,4} + \ldots.$$

- Uncertainty caused by σ_E^0

$$\Delta\sigma_{f\bar{f}}(E_0,\sigma_E^0) = \frac{1}{2}\frac{d^2\sigma_{f\bar{f}}}{dE^2}\sigma_E^{0\,2}$$

$$\Delta P(\sigma_E^0) = \left|\frac{\partial P}{\partial\sigma_{f\bar{f}}}\Delta\sigma_{f\bar{f}}(E_0,\sigma_E^0)\right| = \left|\frac{\partial P}{\partial\sigma_{f\bar{f}}}\cdot\frac{1}{2}\frac{d^2\sigma_{f\bar{f}}}{dE^2}\sigma_E^{0\,2}\right|$$

- Uncertainty caused by ΔE

$$\Delta P(\Delta E) = \left|\frac{\partial P}{\partial\sigma_{f\bar{f}}}\cdot\frac{\partial\sigma_{f\bar{f}}}{\partial E}\right|\Delta E$$

- Uncertainty caused by $\Delta\sigma_E$

$$\Delta P(\Delta\sigma_E) = \left|\frac{\partial P}{\partial\sigma_{f\bar{f}}}\cdot\frac{\partial\sigma_{f\bar{f}}}{\partial\sigma_E}\right|\Delta\sigma_E = \left|\frac{\partial P}{\partial\sigma_{f\bar{f}}}\cdot\frac{d^2\sigma_{f\bar{f}}}{dE^2}\sigma_E^0\right|\Delta\sigma_E$$

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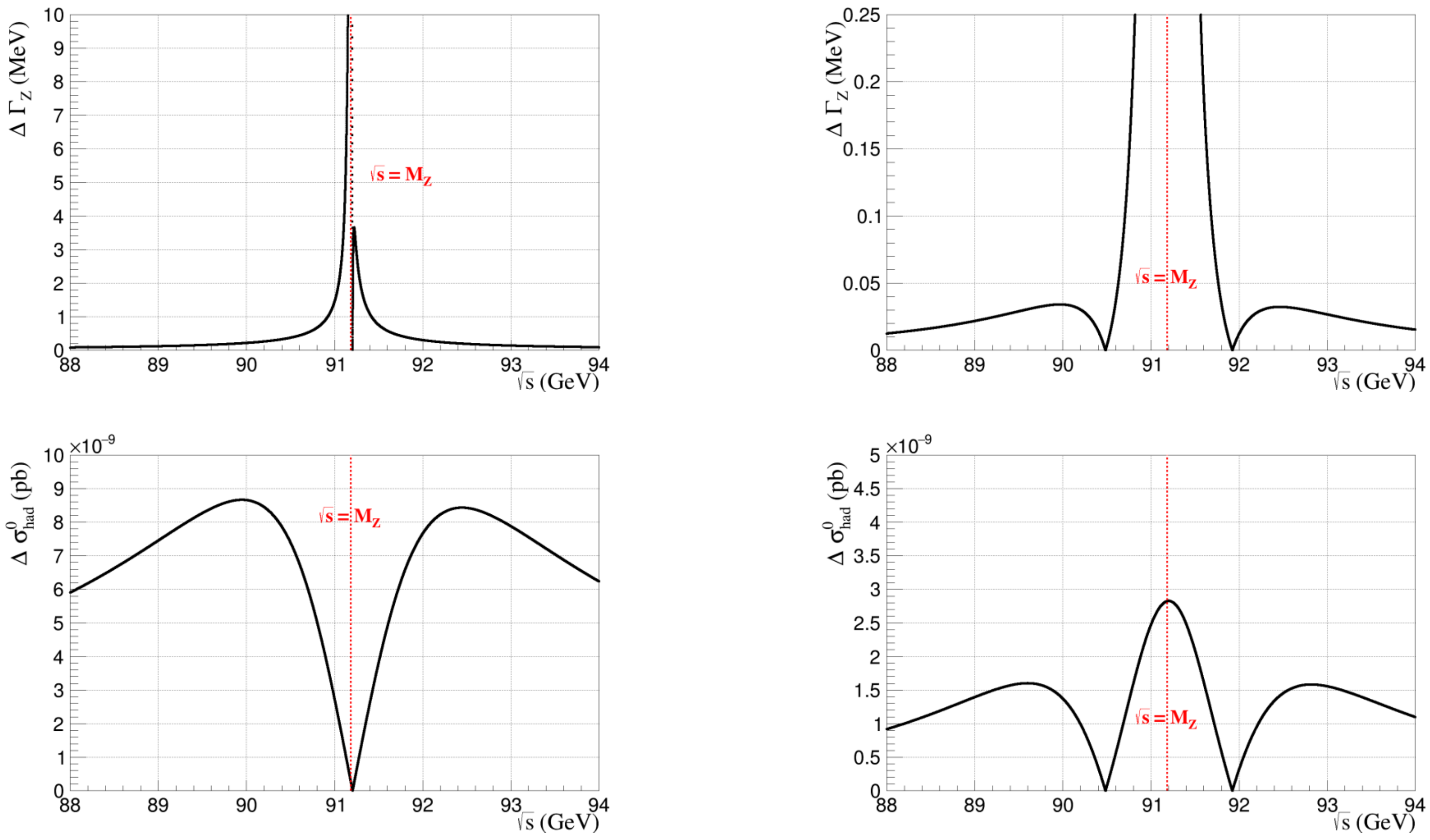

$\Delta E = 0.14\ \mathrm{MeV}$ $\Delta\sigma_E = 0.57\ \mathrm{MeV}$

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M_Z Γ_Z σ^0_{had} $C^{\mathrm{s}}_{\mathrm{ZZ}}$ $C^{\mathrm{a}}_{\mathrm{ZZ}}$ $C^{\mathrm{s}}_{\gamma\mathrm{Z}}$ $C^{\mathrm{a}}_{\gamma\mathrm{Z}}$

PARAMETER CORRELATION COEFFICIENTS

NO.	GLOBAL	1	2	3	4	5	6	7
1	0.29059	1.000	-0.080	0.028	-0.094	0.141	0.001	-0.226
2	0.85195	-0.080	1.000	-0.349	0.846	0.025	0.151	0.005
3	0.34935	0.028	-0.349	1.000	-0.295	-0.009	-0.053	-0.002
4	0.84771	-0.094	0.846	-0.295	1.000	0.028	0.179	-0.003
5	0.17363	0.141	0.025	-0.009	0.028	1.000	-0.024	0.054
6	0.19692	0.001	0.151	-0.053	0.179	-0.024	1.000	-0.079
7	0.25487	-0.226	0.005	-0.002	-0.003	0.054	-0.079	1.000