WW Threshold scan runs and Z pole runs in CEPC

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Introduction

- Some discussion about CEPC Z pole running .
  - http://indico.ihep.ac.cn/event/7709/
  - Two possibility:
    - L=1.6 X 10^{35} $cm^{-2}s^{-1}$, solenoid field = 3T
    - L=3.2 X 1035 $cm^{-2}s^{-1}$, solenoid field = 2T
    - Two year running proposed by accelerator team
- WW threshold scan
  - Proposal from accelerator team
  - One year running, Total luminosity 3.2 ab^{-1}

WW threshold scan Vs luminosity

- WW threshold scan need to scan 3~5 mass points
  - Especially need to cover 158.5GeV, 161.2GeV, 162.4 GeV
- In CEPC Pre-CDR, we assume 0.5ab^{-1} for W threshold scan
  - W width measurement is totally limited by statistics
  - W mass measurement suffers a bit from statistics
- Assume we run one year WW threshold to collect 3.2 ab^{-1} data.
  - W width measurement is still limited by statistics, but much better than pre-CDR
- If running for two years with 6.4 fb^{-1}
  - W width measurement is not limited by statistics any more

Observable	Systematics	L=0.5 ab^{-1} (3 points scan, 0.16 ab^{-1} per run)	L=3.2 ab^{-1} (3 points scan, 1 ab^{-1} per run)	L=6.4 ab^{-1} (3 points scan, 2 ab^{-1} per run)	Major uncertainty
M_W	2 MeV	2 MeV	0.8 MeV	0.6 MeV	E beam cali. $\Delta E < 1$ MeV
Γ_W	2 MeV	6 MeV	2.4 MeV	1.7 MeV	Statistics

The parameters of CEPC

	Higgs	*W*	*Z*
Number of IPs	2		
Energy (GeV)	120	80	45.5
Circumference (km)	100		
SR loss/turn (GeV)	1.73	0.34	0.036
Half crossing angle (mrad)	16.5		
Piwinski angle	2.58	7.74	23.8
N_e/bunch (10^{10})	15	15	8.0
Bunch number (bunch spacing)	242 (0.68us)	1220 (0.27us)	12000 (25ns+10%gap)
Beam current (mA)	17.4	87.9	461
SR power /beam (MW)	30	30	16.5
Bending radius (km)	10.6		
Momentum compaction (10^{-5})	1.11		
β_{IP} x/y (m)	0.36/0.0015	0.36/0.0015	0.2/0.0015
Emittance x/y (nm)	1.21/0.0031	0.54/0.0016	0.17/0.004
Transverse σ_{IP} (um)	20.9/0.068	13.9/0.049	5.9/0.078
ξ_x/ξ_y/IP	0.031/0.109	0.013/0.12	0.0041/0.056
V_{RF} (GV)	2.17	0.47	0.1
f_{RF} (MHz) (harmonic)	650 (216816)		
Nature bunch length σ_z (mm)	2.72	2.98	2.42
Bunch length σ_z (mm)	3.26	6.53	8.5
HOM power/cavity (kw)	0.54 (2cell)	0.87(2cell)	1.94(2cell)
Energy spread (%)	0.1	0.066	0.038
Energy acceptance requirement (%)	1.35		
Energy acceptance by RF (%)	2.06	1.47	1.7
Photon number due to beamstrahlung	0.29	0.44	0.55
Lifetime _simulation (min)	100		
Lifetime (hour)	0.67 (40 min)	2	4
F (hour glass)	0.89	0.94	0.99
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	2.93	11.5	16.6

3T→2T

0.2/0.00
1

0.17/0.0015

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Z pole electroweak physics Vs lumiosity

- Assuming Z pole runs last for 180 days, Z cross section 60 nb
- $L=1e^{34}$, about 10^{10} Z

Observable	Systematics	$L=1e^{34}$ (stat unc.)	3T, $L=1.6e^{35}$ (stat unc.)	$L=3.2e^{35}$ (stat unc.)	Key
$M_{z,}$ Γ_Z	0.5 MeV	0.2MeV	0.05 MeV	0.035 MeV	E beam cali. $\Delta E < 500keV$
$R_l = \Gamma_h/\Gamma_l$	0.01%	0.01%	0.0025%	0.0018%	Statistics
R_b	0.05%	0.04%	0.01%	0.007%	Statistics + small Rin
A_{LR}	NA	NA	NA	NA	Beam polarization
$A_{FB}^{lept.}$	0.1%	0.08%	0.02%	0.014%	Forward acceptance

- From $1e^{34}$ to $1.6e^{35}$, large improvement in stat. uncertainty
- From $1.6e^{35}$ to $3.2\ e^{35}$, improvement is not big
- From 3T to 2T, Momentum resolution degraded to 50%, higher BkG. (no major impact)
- Key issue for Z pole physics, beam momentum systematics need to be smaller than 500keV
- Beam polarization is needed for beam momentum measurement and ALR

backup

Cross section Vs W mass or W width

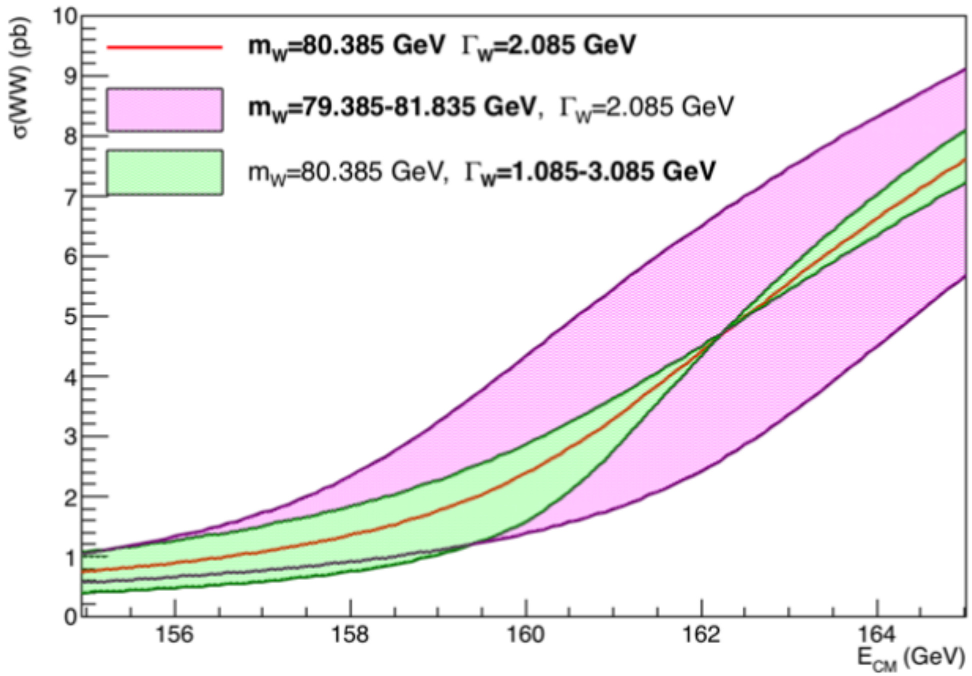

Figure 16. W-pair production cross section as a function of the e^+e^- collision energy E_{CM}. The central curve corresponds to the predictions obtained with $m_{\mathrm{W}} = 80.385$ GeV and $\Gamma_{\mathrm{W}} = 2.085$ GeV. Purple and green bands show the cross section curves obtained varying the W mass and width by ± 1 GeV.

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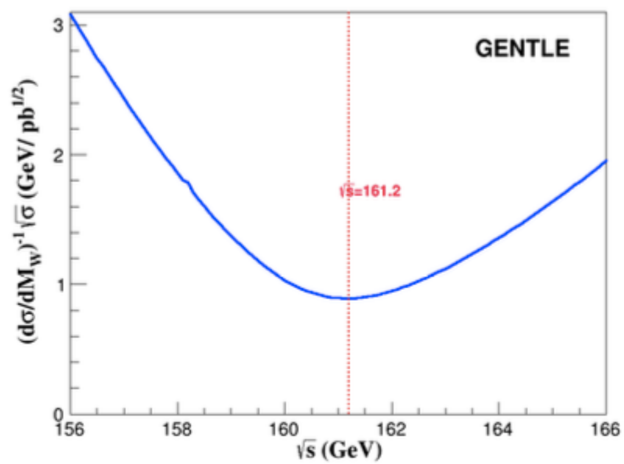
W mass stat uncertainty single energy point (500 fb^{-1})

$\Delta\sigma_{W^+W^-}, \Delta M_W, \Delta\Gamma_W$ (Stat.)

- With $\mathcal{L} = 500$ fb^{-1}, $\epsilon = 0.8$, $P = 0.9$:
  $\Delta M_W = (\frac{\partial\sigma_{W^+W^-}}{\partial M_W})^{-1} \times \sqrt{\frac{\sigma_{W^+W^-}}{\mathcal{L}\epsilon P}} \approx 1.5$MeV.

From Peixun and Gang



Max stat. sensitivity at $\sqrt{s} \sim 2m_W + 0.4$ GeV

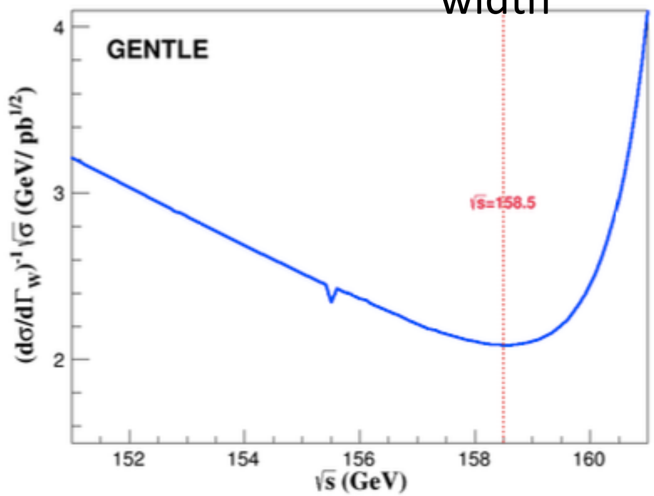
W width stat uncertainty single energy point (500 fb^{-1})

$\Delta\sigma_{W^+W^-}, \Delta M_W, \Delta\Gamma_W$ (Stat.)

- With $\mathcal{L} = 500\ fb^{-1}$, $\epsilon = 0.8$, $P = 0.9$:
  $\Delta\Gamma_W = (\frac{\partial\sigma_{W^+W^-}}{\partial\Gamma_W})^{-1} \times \sqrt{\frac{\sigma_{W^+W^-}}{\mathcal{L}\epsilon P}} \approx 3.5$ MeV.

From Peixun and Gang

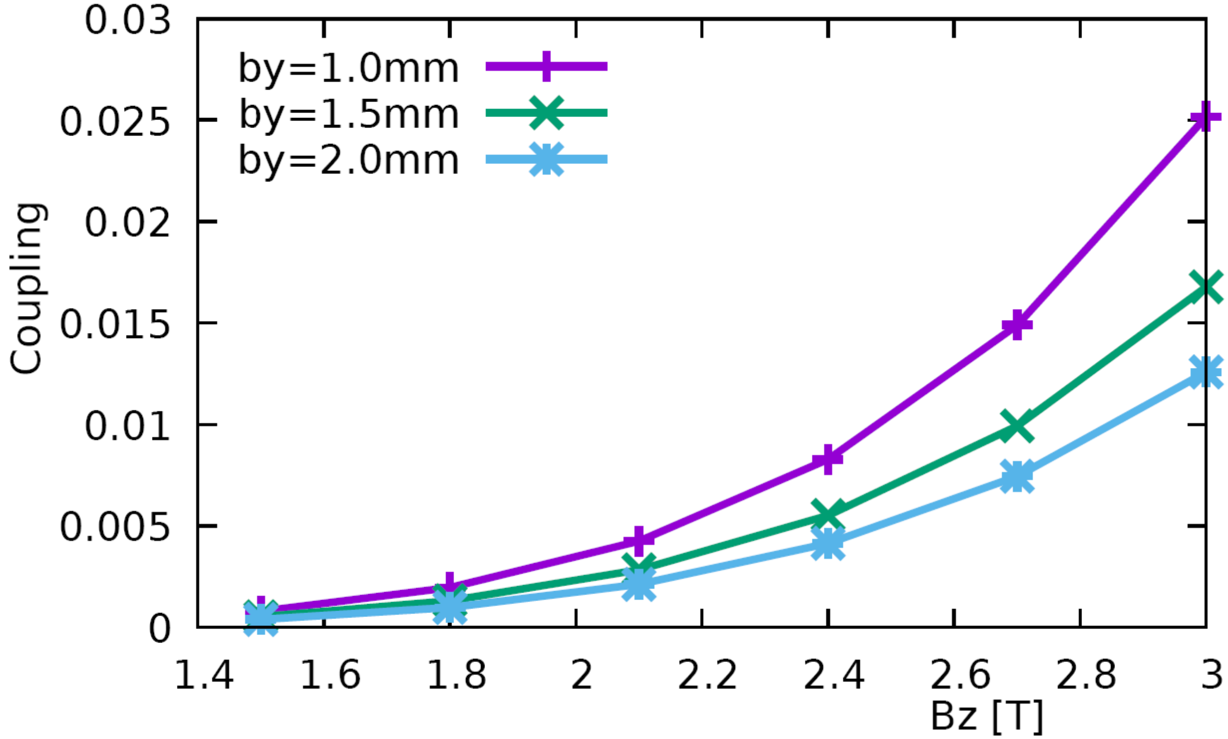
width



Max stat. sensitivity at $\sqrt{s} \sim 2m_W - 3.3$ GeV

Start from detector solenoid 3.0T

From Chenghui



β_y* Vs. coupling @ Z

Limitation of the luminosity improvement by reducing the β_y*

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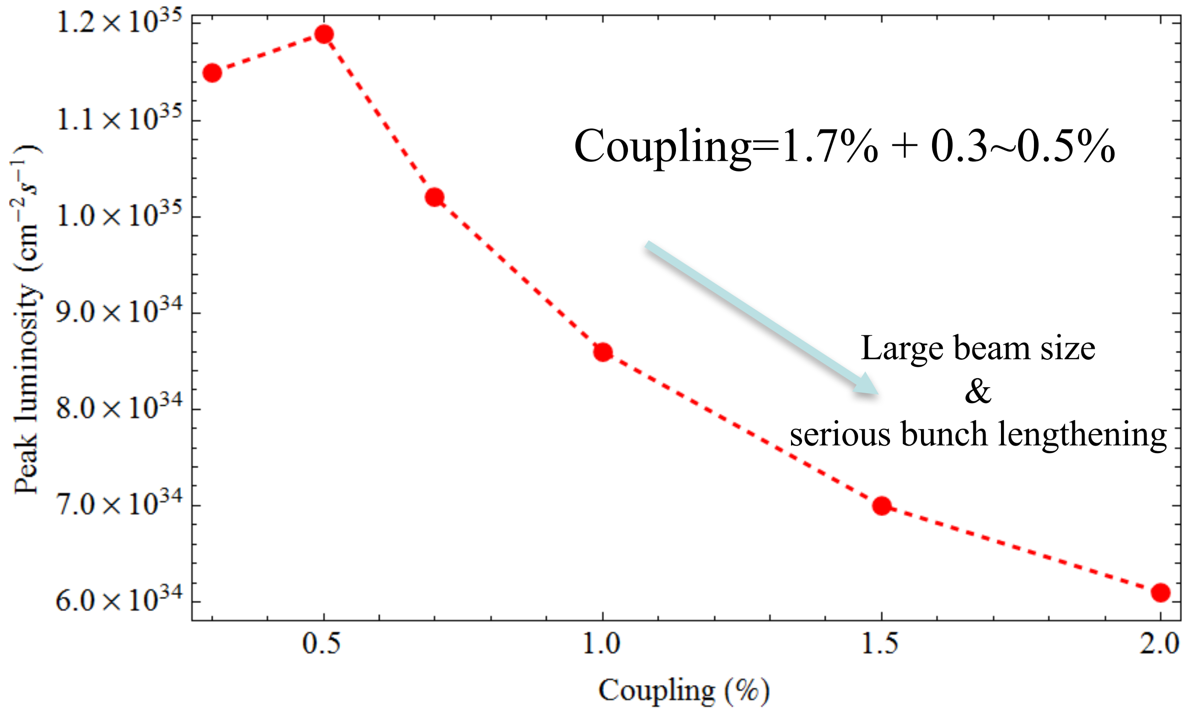
Start from detector solenoid 3.0T



From Chenghui

Coupling Vs. Luminosity @ Z

For **the 2Cell cavity** operation, if the coupling lose control **$L \approx L_0/2 \sim L_0/4$**