Extracting Electroweak Parameters from the Lineshape

By Rujuta Sane, Denis Siminiuc, Isabella Torres

Project Overview

Goal: Minimize the uncertainty on the Z-boson mass and width measurements by determining the optimal number of energy points and the amount of luminosity spent on peak.

Questions to consider:

- How spread out should the energy points be from the peak?
- How do we divide luminosity among the points?
- What are the present realistic uncertainties and their impact?
  - luminosity, center of mass, and the cross sections

Measuring the Z boson resonance

Cross section

$$\sigma(\sqrt{s}) = \frac{N_{\rm signal}}{\mathcal{L}} = \frac{N_{\rm selected} - N_{\rm background}}{\varepsilon A \mathcal{L}}$$

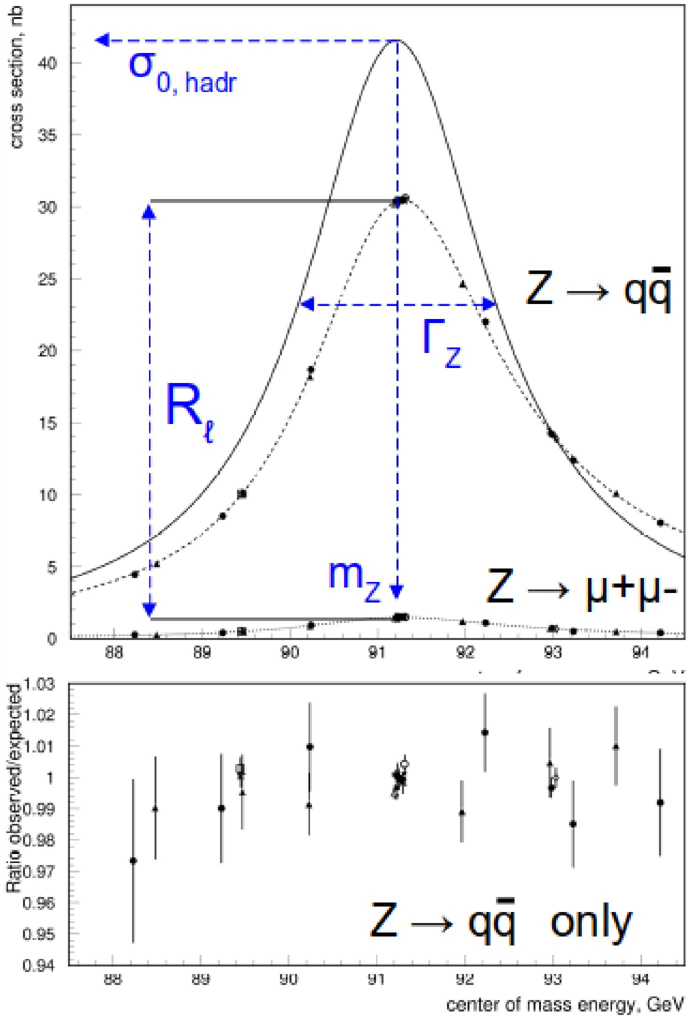
What can we extract?

- m_Z, Γ_Z, Hadronic peak cross section ($\sigma_{0,\ hadr}$)
- (Ratio of leptons (R_ℓ), Number of light neutrinos)

Hadronic final state has smallest uncertainties

- quarks have color charge
- will focus only on hadron cross sections

Typical LEP experiment



How did we do the fitting?

Revived the old L3 program to fit two-fermion data

- Various LEP theory programs are interfaced (TOPAZ0, ZFITTER, ALIBHABHA, MIBA, ….): ZFITTER is the only program used for the following studies
- Some weird old program names … PAW, KUIP, SIGMA and COMIS
- For verification the full L3 cross section and forward-backward asymmetry dataset was fit, including all details and the numbers in the last L3 paper were reproduced
- Thanks to Martin Grünewald who recovered the program from backups

We need to figure out how to do this for real with FCC data: Is Fortran making a come back?

Number of energy points
Cross Sections
Luminosity Ratio

→

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XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 EEEEEEE WWW       WWWW     A     PPPPPPP IIIII  CCCCCC
 EEEEEEE WW         WWW    AAA    PPP  PPP III  CCCC  CC
 EEE    WWW         WWW   AAAAA   PPP  PPP III CCC
 EEEEE  WWW    WWW  WWW AAA AAA   PPPPPPP  III CCC
 EEE     WWW WW WW WWW AAA   AAA PPP       III CCC
 EEEEEEE  WWWW   WWWW AAAAAAAAAAA PP       III  CCCC  CC
 EEEEEEE   WW     WW AAA       AAA P      IIIII  CCCCCC
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

→

Z-boson
mass/width
/hadronic peak

How good can the determination be?

Extract Pseudo Observables: m_Z, Γ_Z and $\sigma_{0,hadr}$; Inputs: hadronic cross sections, 5 points, 30/ab each

1. Start with statistical uncertainty on hadrons and the fully correlated systematic uncertainty as large as peak stat. uncertainty
2. Add stat. uncertainty on luminosity corresponding to 14 nb cross section
3. Add 10^{-4} syst. fully correlated, and another 10^{-5} uncorrelated (this might still improve)
4. Add 10 keV correlated uncertainty on ECMS
5. Or alternatively 100 keV correlated uncertainty on ECMS

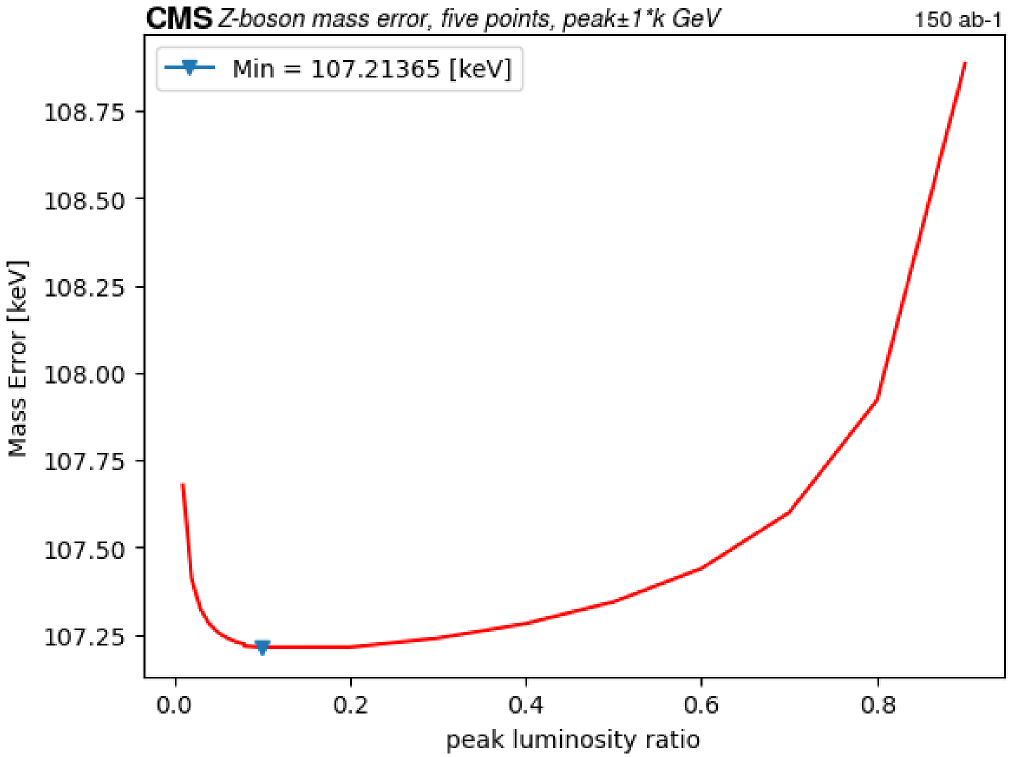
Setup	delta(m_Z)	delta(Γ_Z)	delta($\sigma_{0, hadr}$)
units	[keV]	[keV]	[pb]
1	1.2	3.4	0.0441
2	1.7	5.2	0.076
3	8.4	26	4.2
4	13	26	4.2
5	101	26	4.2

We find a best uncertainty of 1.2 keV as opposed to an uncertainty of 4 keV. commonly quoted. Why is that?

Luminosity

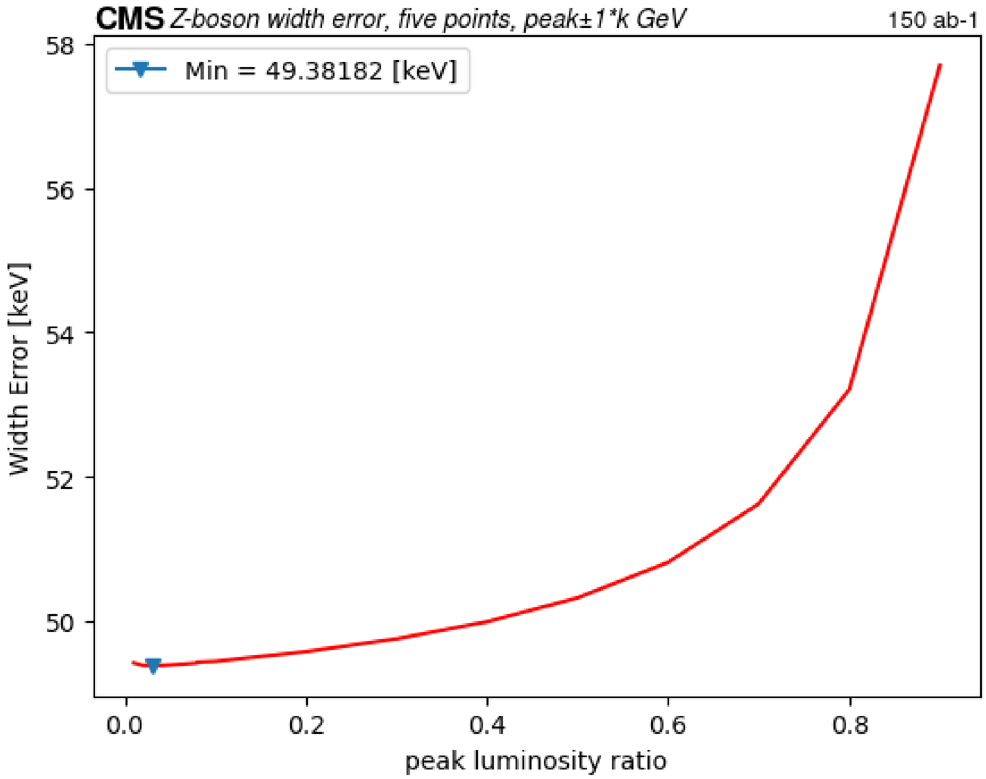
- In the program, we iterate over the luminosity ratios with increments of .10, from .10 to .90
  - The ratio is the amount of luminosity used on peak divided by the total luminosity (150 ab^-1)
- The purpose of this iteration was to find the optimal luminosity used on the peak that minimizes the uncertainties on the Z boson mass, width and the peak hadronic cross section measurements.

Minimum Z Mass Uncertainty



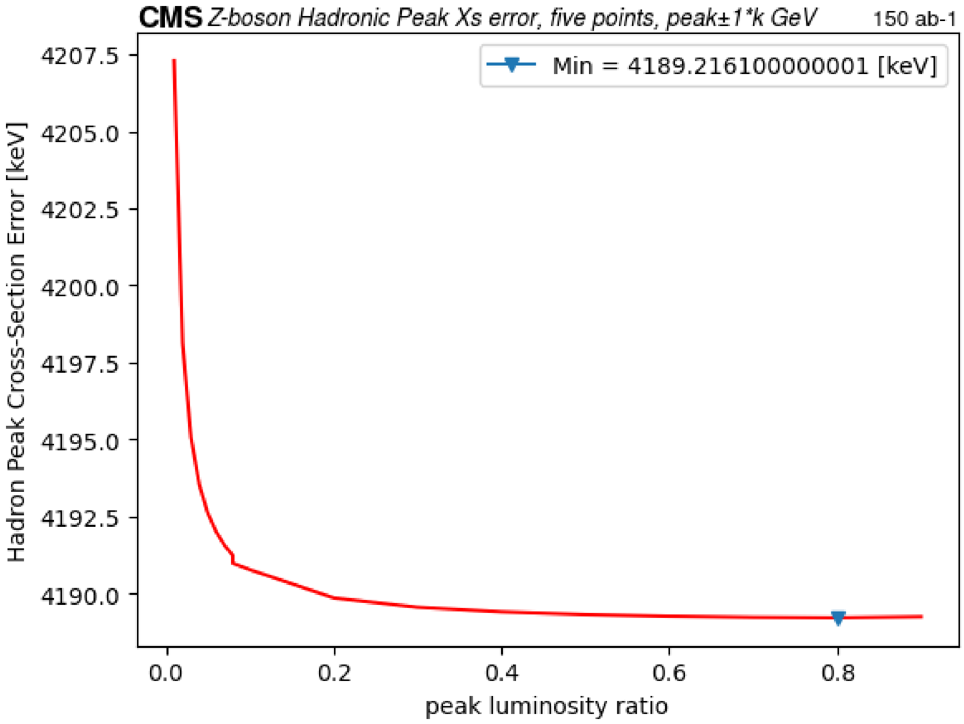
Z-boson mass uncertainty is minimized at peak luminosity ratio of about 0.1

Minimum Z Width Uncertainty



Z-boson width uncertainty is minimized at ~0.08 peak luminosity ratio.

Minimum Hadron Peak Cross Section Uncertainty



Hadronic peak cross section uncertainty is minimized at a peak luminosity of ~0.8

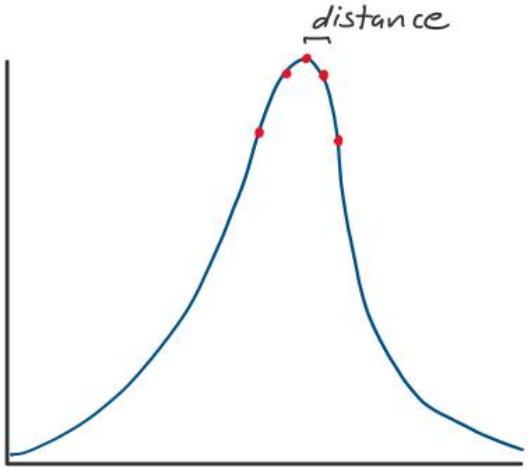
Point Distribution

In this study, we only fit the measurements using 5 points and varying their symmetric distances from the peak

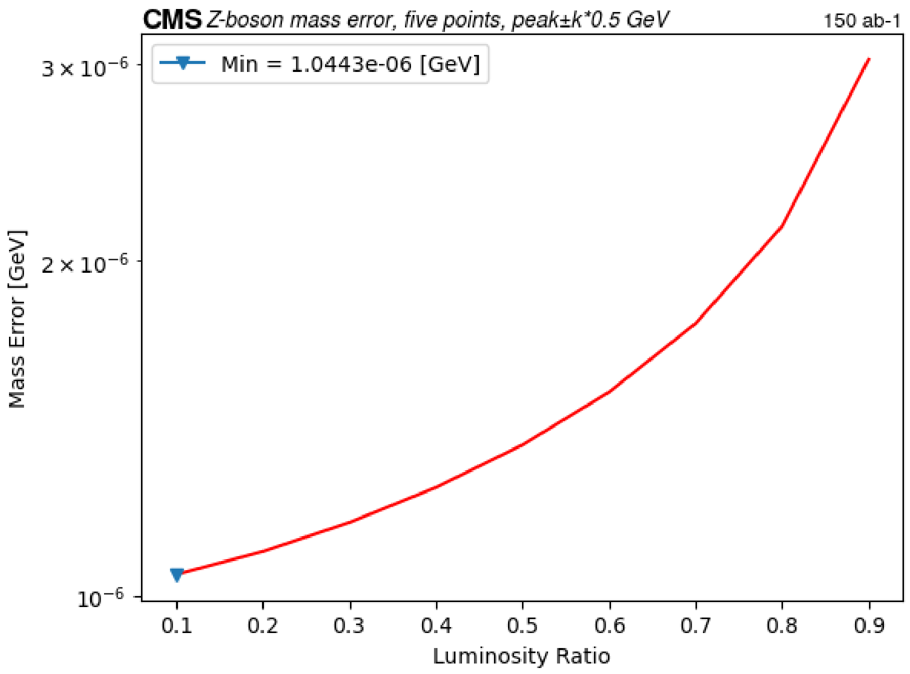
- We have selected 4 different set ups at distances of:

  0.2, 0.5, 1.0, and 2.0 GeV

- The findings were particularly interesting since no distance gave us more than one minimal error.

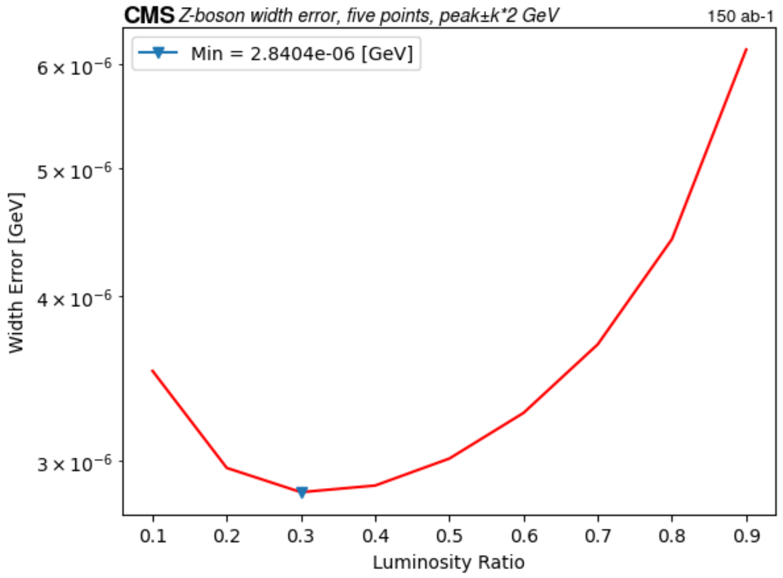


Minimal error for the mass



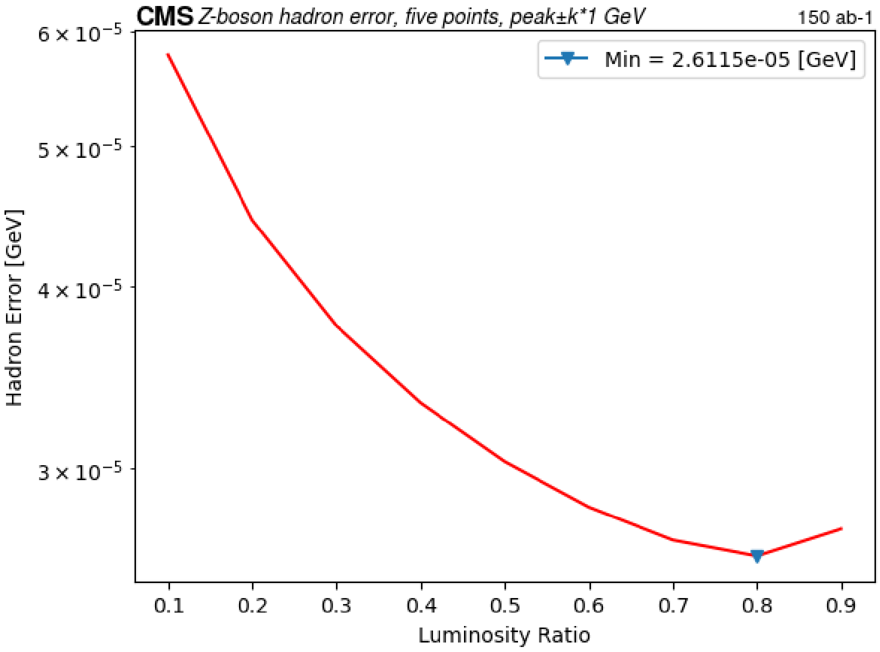
The minimal error for the measurement of the mass was found when the points are at a distance of 0.5 GeV from the peak.

Minimal error for the width



The minimal error for the measurement of the width was found when the points are at a distance of 2 GeV from the peak.

Minimal error for the Hadron peak cross-section



The minimal error for the measurement of the Hadron peak cross section was found when the points are at a distance of 1 GeV from the peak.

What next?

- Analyze effects of varying the distribution of the luminosity among the off-peak points
- Testing with 3 or 4 energy points instead of 5
- Run more trials at varying distances to better determine a more precise optimal distance between points

Thank you for your attention!

Any questions?

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