Considerations on Z Running for Calibration

Graham W. Wilson

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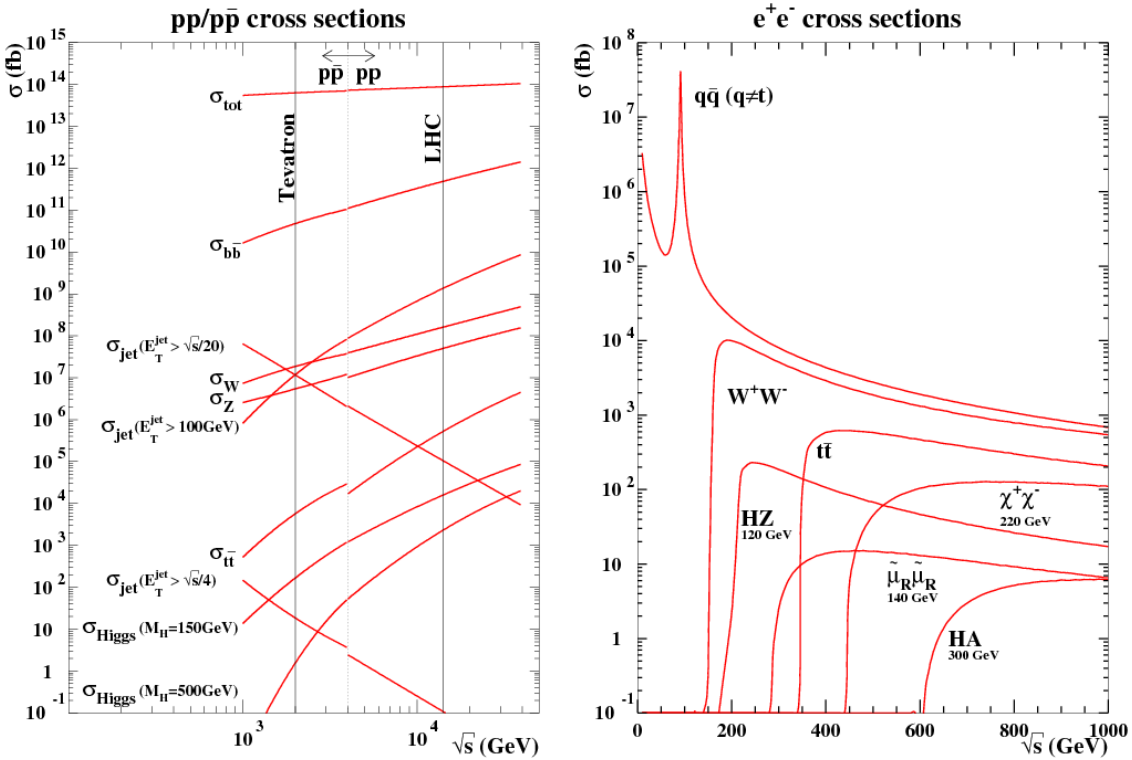

Introduction

See J. Timmermans talk at Oshu re Z calibration running (in references).

Calibration

A detector for ILC like ILD needs a plan for calibration and alignment. We assume that the ultimate detector precision will make extensive use of collision data. Data taking at the Z pole may be the most efficient for calibrating the detector. Needs to also be feasible for the accelerator.

Request from ILC parameters WG to ILD & SiD (March 2nd, 2016)

"The TDR version of the ILC is not easily operated at the Z and would likely need modification. Quantify and justify your needs.
Please specify your needs for Z pole calibration.
For which subdetectors is Z pole calibration essential and why? Which precision could be achieved without Z pole running?
If Z pole running is required, specify how often (once for commissioning, every year, every push-pull?) they are needed and with which integrated luminosity."

Some arguments related to Z calibration running

General

- Quick commissioning with Z
- Z provides high statistics for reducing systematic effects
- Reasonably high luminosity needed to make Z running time efficient. Likely 10^{32} or higher.
- ILC experiments order of magnitude more demanding in precision than LHC - but rate of calibration events is much, much smaller.
- Precedent. Was considered a reasonable use of beam time at LEP.

ILC Specifics

- Push-pull. Need more frequent alignment.
- Power-pulsing. Small live-time for cosmics. How much? 2%? Increase?
- Precision beam energy not available from machine (in contrast to LEP).
- No hardware trigger. May also be an issue for cosmics. Rate? Overburden?
- Potential seismic activity.
- Prefer not to use radionuclide based calibration strategies.

What do we mean by calibration

Calibration Types

- Inter-calibration. Channel-to-channel relative calibration. Eg AHCAL cells.
- Alignment (example, CMS 200,000 parameters ...)
- Absolute energy and momentum scales
- B-field measurements
- E, B-field effects / distortions
- Gas parameters (mixture, T, P, dE/dx)
- Monitoring of long-term calibration/alignment
- Fragmentation tuning
- Others ?

What Particles?

- What constitutes a useful calibration particle?
- Tracking: charged particle with $p > 5$ GeV?
- High energy muon. But maybe not too high ? $10 < p < 100$ GeV ??
- Maybe - whatever we can get.

Quantify

Define $\rho_Z(\sqrt{s}) = \sigma(m_Z)/\sigma(\sqrt{s})$

Cross-sections and ratios

$\sqrt{s}$	$\sigma(\mu\mu)$ (pb)	$\sigma(q\bar{q})$ (pb)	$\rho_Z(\mu\mu)$	$\rho_Z(q\bar{q})$
91.2	1580	30500	1.0	1.0
250	4.99	50.1	316	609
350	2.57	24.8	614	1230
500	1.30	12.6	1210	2420
1000	0.386	3.64	4080	8370

Event rate, $dN/dt = \sigma\mathcal{L}$.
Assuming γ scaling of the luminosity, the hadronic event rate at the Z is 440 times higher than at $\sqrt{s} = 500$ GeV.
Essentially a calibration that may need more than one year at $\sqrt{s} = 500$ GeV for statistics can be done in one day at $\sqrt{s} = m_Z$ **IF** the machine is designed properly.

Details

Total number of events for calibration (at 91 GeV and high energy), given running time T, and time-fraction f, devoted to Z.

$$N(\sqrt{s}; f) = (\rho(\sqrt{s}) f \; L_Z + (1 - f) L_{\sqrt{s}}) \sigma_{\sqrt{s}} T$$

Z calibration only makes sense when the first term is the largest, but f had better not be much greater than a few %. Note $L(500)$ is 1.8e34.
Define gamma factor, (γ scaling is $\alpha = 1$)

$$g(\sqrt{s}; \alpha) = (m_Z/\sqrt{s})^{\alpha}$$

Note

1. Z data angular distribution explores efficiently the full solid angle.
2. Other processes like gamma-gamma collisions may be quite effective for high-energy calibration.

How to proceed

Propose Two-Track Response

1. Reply soon - making the case for efficent Z pole calibration data-taking being essential. Encourage work on the accelerator design.
2. Initiate more mature and longer term quantitative studies of calibration and alignment in coordination with detector and physics studies.

Steps so far

1. Draft reply document being worked on.
2. Assembles various arguments.
3. Some estimates exist and need to be reviewed/revisited.

Input welcome

1. Your input on this is very welcome
2. We will discuss in more detail in ILD meeting at Santander

References I

- ILC Parameters Joint Working Group (T. Barklow, J. Brau, K. Fujii, J.List, N.Walker, K. Yokoya), "Request to ILD and SiD to specify their need for Z pole calibration", March 2, 2016.
- CMS Collab., "Alignment of the CMS tracker with LHC and cosmic ray data", JINST 9 (2014) P06009
- J. Timmermans, Talk at ILD meeting in Oshu, 2014. `https://agenda.linearcollider.org/event/6360`

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