

Measurement of M_W with a Standard Candle

Part I

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OUTLINE

1. Introduction
2. Results for M_W
3. Conclusion

1. Introduction

General idea:

Optimise the use of the Z^0 boson in Drell–Yan-pair production processes as "*the standard reference candles*" for measuring the inclusive W^\pm - boson production processes.

[F. Fayette, W. Krasny, W. Płaczek *AS*, *Eur. Phys. J. C* 51, 607 (2007)]

The strategy allows to factorise and directly measure QCD effects which affect differently the W^\pm and Z^0 production processes.

- ▶ reduces significantly uncertainties in the partonic distribution functions while preserving their sensitivity to the SM parameters
- ▶ reduces by a factor of **10** the impact of systematic measurement errors, such as the energy scale and the measurement resolution.

Last MCnet meeting in Debrecen:

Florent Fayette's talk on W 's mass asymmetry.

[F. Fayette, W. Krasny, W. Płaczek *AS*, arXiv:0812.2571]

- *Cuts and statistics:*

- ▶ Cuts : $p_{T,l} > 20 \text{ GeV}$ & $|\eta_l| < 2.5$, where ($l = \{e, \mu\}$)
- ▶ Stat : 1 ATLAS year at low luminosity $10 \cdot \text{fb}^{-1}$
 - ▶ $\sigma_{W^+W^-}^{\text{cut}} \sim 18,8 \text{ nb} \Rightarrow 188 \times 10^6 W^+ \text{ and } W^-$
 - ▶ $\sigma_{Z^0}^{\text{cut}} \sim 2.1 \text{ nb} \Rightarrow 21 \times 10^6 Z^0$
- ▶ Charged lepton smearing : ATLAS Inner Detector

- *Systematics studies (the strongest effects in D0/CDF):*

- ▶ Experimental/Apparatus:
 - ▶ Energy Scale (ES): $p_{T,l} = (1 \pm \epsilon_s) \cdot p_{T,l, \text{truth}}$ and $\epsilon_s = \pm 0.5\%$ and $\pm 0.05\%$
 - ▶ Resolution Error (RE): 0.7 and 1.3 (wd. Gaussian smearing of track)
- ▶ Theoretical/Modeling:
 - ▶ PDF effects (errors) - CTEQ6.1 [J. Pumplin et al JHEP07, 012 (2002)]
 - ▶ Primordial k_T - QCD effects (Non-perturbative and higher order effects)
 - ▶ QED radiative corrections - not included yet - ZINHAC++ in progress.

- *Tools :*

- ▶ MC : WINHAC [W. Płaczek & S. Jadach, Eur. Phys. J. C 29 : 325-339, 2003]
- ▶ QCD effects incorporated from PYTHIA

[T. Sjostrand, S. Mrenna, and P. Skands, JHEP 05, 026 (2006)]

- The influence of effects both theoretical and experimental is extracted by performing binned χ^2 fits.

$$\chi_{\text{eff}}^2 \left(M_W^{\text{PDG}} \pm \Delta M_W \right) = \sum_i \frac{\left(N_i [M_W^{\text{PDG}} \pm \Delta M_W] - N_i^{\text{eff}} [M_W^{\text{PDG}}] \right)^2}{\sigma_{N_i}^2 + \sigma_{N_i^{\text{eff}}}^2}$$

where:

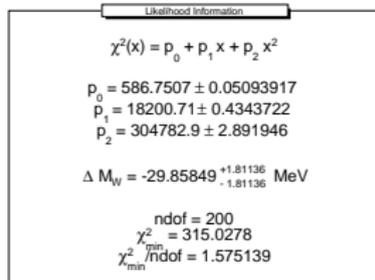
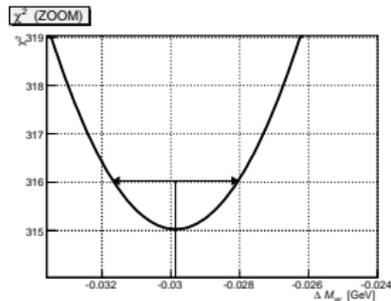
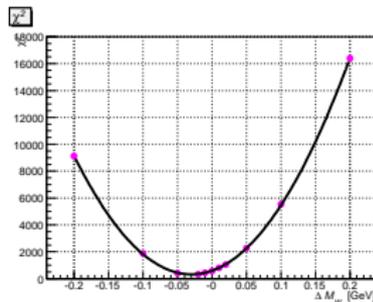
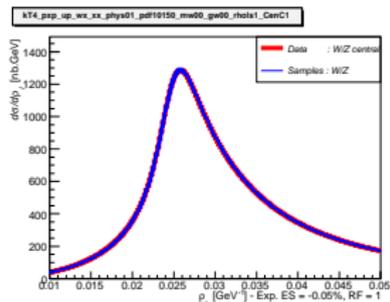
- ▶ N_i - the number of expected events in the template distribution in bin i
- ▶ N_i^{eff} - the number of expected events in the pseudo-data distribution in bin i
- ▶ **eff** = ES, RE, PDF min/max, kT
- After evaluation of all χ^2 for given **eff**, we fitted parabola, the position of its minimum estimates size of an **eff**, error (1σ) is calculated from the value $\chi^2 + 1$
- example in next slides.

2. Results for M_W studies

- **Assumption:** the masses of the W^+ and W^- bosons are the same ¹.
- **Present:**
 - ▶ $M_W = 80.413 \pm 0.048$ GeV [recent CDF]
- M_W & Γ_W measured in **hadronic** collisions via $W^\pm \rightarrow l^\pm \bar{\nu}_l$ ($l^\pm = \{e^\pm, \mu^\pm\}$)
 - ▶ $p_{T,l} \rightarrow l^\pm$
 - ▶ $m_{T,l\nu_l} \rightarrow l^\pm$ & $\bar{\nu}_l$ (\cancel{E}_T)
 - ▶ $\cancel{E}_T \rightarrow \bar{\nu}_l$
- “Standard method” during this talk \equiv , the method currently used in hadron colliders. (the plots: $\rho_l = 1/p_{T,l}$)

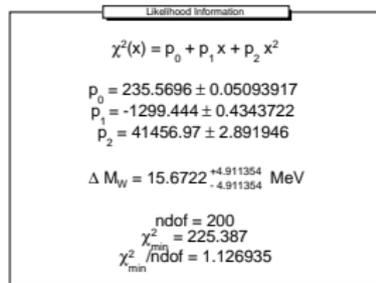
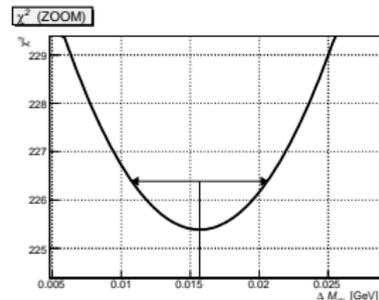
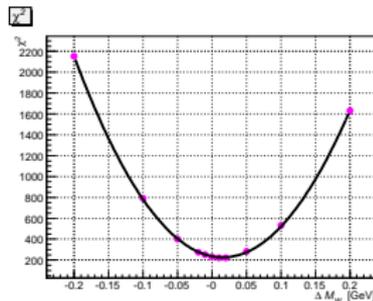
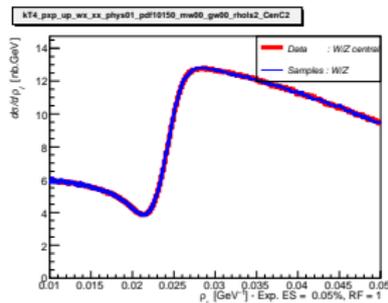
¹(see F. Fayette talk or [arXiv:0812.2571])

Standard Method - systematical effect - ES = 0.05 %



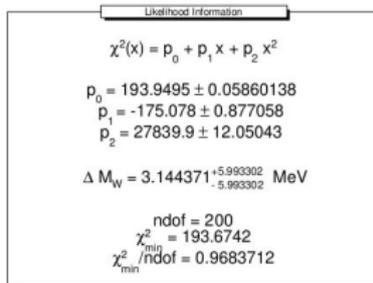
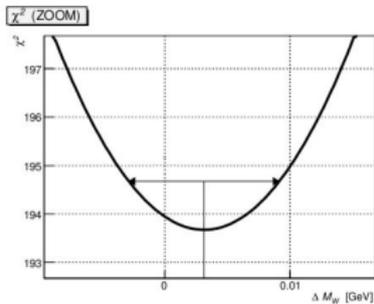
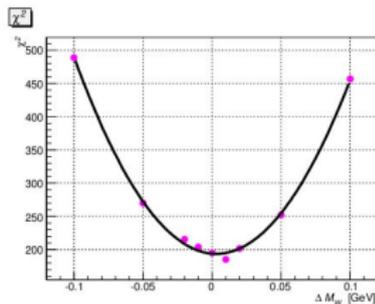
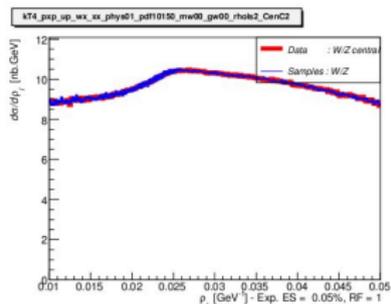
- The others systematical effects (RE, k_T , PDFs) are even bigger.

Simple Z - Candle - $R_{\text{simple}} = \frac{\rho_l^W}{\rho_l^Z}$ - systematical effect - ES = 0.05 %



- One of the lepton from the Z^0 boson is (randomly) removed from the charged

Z Candle - $R_{candle} = \frac{\rho_I^W(s_1, i_1)}{\rho_I^Z(s_2, i_2)}$ - systematical effect - ES = 0.05 %



- Description: $R_{candle} = \frac{\rho_l^W(s_1, i_1)}{\rho_l^Z(s_2, i_2)}$
 - ▶ s_1 and s_2 are CM-energy of the beam $\sqrt{s_1} = \frac{M_W}{M_Z} \sqrt{s_2}$.
 ⇒ the momentum fractions of the partons producing Z^0 and W s are equal
 - ▶ at the energy $\sqrt{s_1}$ the coil current has been rescaled down by the factor $\frac{M_W}{M_Z}$.
 ⇒ the distribution of the curvature radius (ρ_l) for charged leptons originating from the decays of the Z^0 and W are the same.

ΔM_W [MeV]	$ES = 0.05\%$	$ES = -0.05\%$	$RF = 0.7$	$RF = 1.3$	$\Delta kT = -1$ [GeV]	$\Delta kT = +1$ [GeV]
Standard	-29 ± 1.8	25 ± 1.8	14.1 ± 1.8	-22.8 ± 1.8	> 31	> 40
Simple Z Candle	-19 ± 4.91	15 ± 4.9	> 50	> 77	> 66	> 76
Z candle	0.4 ± 5.9	3.1 ± 5.9	6.6 ± 5.9	-3.7 ± 5.9	17.7 ± 6.11	-9.77 ± 6.0
$\chi^2/200$	1.01	0.96	0.99	1.06	1.20	1.19

- PDF effect are not presented but the mass shifts calculated using CTEQ6.1 [J. Pumplin et al JHEP07, 012 (2002)] method are also below statistical errors.
- The effect of $ES = 0.5\%$ for “Standard Method” is huge > 270 MeV, the Standard Candle method can reduce it to $\sim 15 \pm 6.0$ MeV with $\chi^2 = 0.95$, nbof= 200.

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STANDARD:

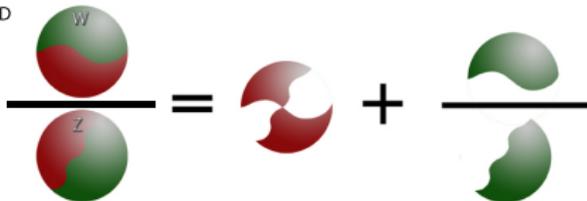


LEGEND:

- QED (precise controlled)
- QCD (imprecise controlled)

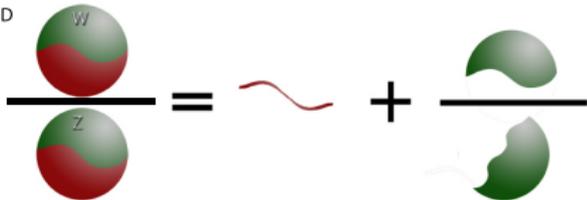
$$\rho_I^W = 1/p_{T,I}$$

STANDARD RATIO:



$$R_{\text{simple}} = \frac{\rho_I^W}{\rho_I^Z}$$

STANDARD CANDLE:



$$R_{\text{candle}} = \frac{\rho_I^W(s_1, i_1)}{\rho_I^Z(s_2, i_2)}$$

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$\chi^2/200$	1.01	0.96	0.99	1.06	1.20	1.19

ES = 0.5% for "Standard Method": > 270 MeV, the Z Candle method: $\sim 15 \pm 6.0$ MeV!! ($\chi^2 = 0.95$)

- The remaining QCD asymmetries:

which are reflected by the height values of the k_T in the Table we correct by C_{QCD} factor which can be measured rather than modeled using MC simulation.

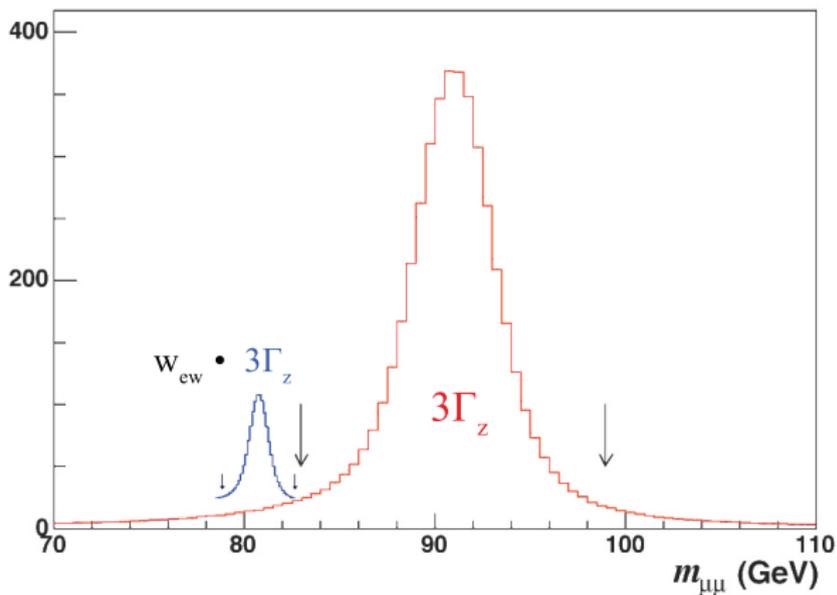
$$C_{QCD} = \frac{\int_{M_Z - 3\Gamma_Z}^{M_Z + 3\Gamma_Z} N^{l+l-}(s_2, i(s_2), M^{l+l-}) dM^{l+l-}}{\int_{M_W - 3\Gamma_W}^{M_W + 3\Gamma_W} f_{BW}(s^{l+l-}; M_W, \Gamma_W) w_{EW} N^{l+l-}(s_1, i(s_1), M^{l+l-}) dM^{l+l-}}$$

Each event having a reconstructed invariant mass in the latter region is weighted by the Breit–Wigner function

$$f_{BW}(s^{l+l-}; M_W, \Gamma_W) = \frac{1}{\pi} \frac{M_W \Gamma_W}{(s^{l+l-} - M_W^2)^2 + M_W^2 \Gamma_W^2},$$

where $s^{l+l-} = (M^{l+l-})^2$, and by the QCD-independent normalisation factor w_{EW} .

$$C_{QCD} = \frac{\int_{M_Z - 3\Gamma_Z}^{M_Z + 3\Gamma_Z} N^{l+l-}(s_2, i(s_2), M^{l+l-}) dM^{l+l-}}{\int_{M_W - 3\Gamma_W}^{M_W + 3\Gamma_W} f_{BW}(s^{l+l-}; M_W, \Gamma_W) w_{EW} N^{l+l-}(s_1, i(s_1), M^{l+l-}) dM^{l+l-}}$$



Results for “Z candle” with C_{QCD} factor:

ΔM_W [MeV]	$ES = 0.05\%$	$ES = -0.05\%$	$RF = 0.7$	$RF = 1.3$	$\Delta kT = +1$ [GeV]	$\Delta kT = -1$ [GeV]
Z candle	0.4 ± 5.9	3.1 ± 5.9	6.6 ± 5.9	-3.7 ± 5.9	17.7 ± 6.11	-9.77 ± 6.0
Z candle, C_{QCD}	-2.6 ± 6.2	1.0 ± 6.0	3.3 ± 5.9	-6.3 ± 6.3	-0.6 ± 6.0	-3.8 ± 6.1
χ^2/ndof	1.1	1.0	1.0	1.2	1.2	1.3

even larger shifts of K_T are also in the statistical errors:

ΔM_W [MeV]	$\Delta kT = -4$	$\Delta kT = -2$	$\Delta kT = -1$	$\Delta kT = 1$	$\Delta kT = 2$	$\Delta kT = 4$ [GeV]
Z candle C_{QCD}	14.6 ± 6.1	5.6 ± 6.0	-0.6 ± 6.0	-3.8 ± 6.1	-6.8 ± 6.2	-26.7 ± 6.3
χ^2/ndof	1.3	1.4	1.2	1.3	1.1	1.5



Then using `PYTHIA`² we opened

Pandora's box...



but this is the next part of this story
soon on your arXiv mirror!:)

²and WINHAC + ZINHAC



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Description of the project

ZINHAC will be a Monte Carlo event generator written in C++ for Drell-Yan processes in proton-proton, proton-antiproton and nucleus-nucleus collisions. It features multiphoton radiation in Z-boson decays within the Yennie-Frautschi-Suura (YFS) exclusive exponentiation scheme and the O(α_s) electroweak radiative corrections for Z decays. Implementation of the total O(α_s) electroweak radiative corrections to the full neutral-current Drell-Yan process is under way in the collaboration with the SAIC group. A similar event generator for the W-boson production, called WINWAC, is available [here](#). Our group also works on constrained MC algorithms for the QCD ISR parton shower that could be applied to Drell-Yan processes see, e.g. [arXiv:0703281](#).

Related Talks and Publications

- "Z-boson as "the standard candle" for high precision W-boson physics at LHC" [arXiv](#)
- "Measurement of $M_{\nu^+ \nu^-} = M_W$ at LHC" [arXiv](#)
- "W-boson mass measurement at LHC" - available soon.

Help and User Guides

1. FAQ
2. Bug reporting / tracking Anyone can view the list of bug tickets: click View Tickets in the titlebar. To submit new bug reports, however, you will first need to register with the ZINHAC authors. Send a preferred login and password to andrzej.sladnink@cern.ch. Please do not send a password that you use for anything important; the current login mechanism transmits it in clear text. After registration, you can use your login name to file new bug reports. First, click on Login in the title bar, then New Ticket. To get email updates about progress on your ticket, specify an email address in the Settings.

Download

1. SVN repository

Zakończono

two students: **Kamil Sobol** and **Piotr Stecko**

3. Conclusion

Conclusion:

- We considered the main systematic errors which were the most important in previous measurements of W mass

ΔM_W [MeV]	$ES = 0.05\%$	$ES = -0.05\%$	$RF = 0.7$	$RF = 1.3$	$\Delta kT = -1$ [GeV]	$\Delta kT = +1$ [GeV]
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χ^2/ndof	1.1	1.0	1.0	1.2	1.2	1.3
Standard	-29 ± 1.8	25 ± 1.8	14.1 ± 1.8	-22.8 ± 1.8	> 31	> 40
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- the results are mainly constrained by statistical errors but studies were preform for one year of low luminosity 10fb^{-1} run.
- the next part shows very interesting results (soon o arXiv).
- all this tricks are feasible at LHC (maybe in the mature stage ...)

Thank you for the attention!