Measurement of the W boson mass: status and plans

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D0 France Meeting,
IPN Lyon, May 3-4, 2010

The Run IIb m(W) team

Stony Brook:

John Hobbs (Prof)
Bob McCarthy (Prof)
Rafael Lopes de Sa (grad student, started Oct 2009)
Daniel Boline (post-doc, started Feb 2010)

A small team, pretty “top-heavy”, 50 % IN2P3.

~~**Northwestern University:**~~

~~Heidi Schellman (Prof)~~
~~Sahal Yacoob (student, done)~~

gone – *c.f.* next slide

University of Mississippi:

Alex Melnitchouk (post-doc)

IPN Lyon:

Tibor Kurca (Sce Info)
Patrice Lebrun (CNRS)

LPSC Grenoble:

Hengne Li (post-doc)
Jan Stark (CNRS)

LAL:

Pierre Pétroff (CNRS)

REGION RHÔNE-ALPES

Sahal's PhD thesis

Defended yesterday, Mai 3rd 2010.

Co-advisors: Schellman/Stark.

Run IIb data only (*i.e.* no Run IIa) up to Summer 2009 shutdown, 4.4 fb^{-1} after data quality.

NORTHWESTERN UNIVERSITY

Measurement of the W Boson Mass in Proton-Antiproton collisions at a Center of Mass Energy of 1.96 TeV

A DISSERTATION

SUBMITTED TO THE GRADUATE SCHOOL
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

for the degree

DOCTOR OF PHILOSOPHY

Field of Physics and Astronomy

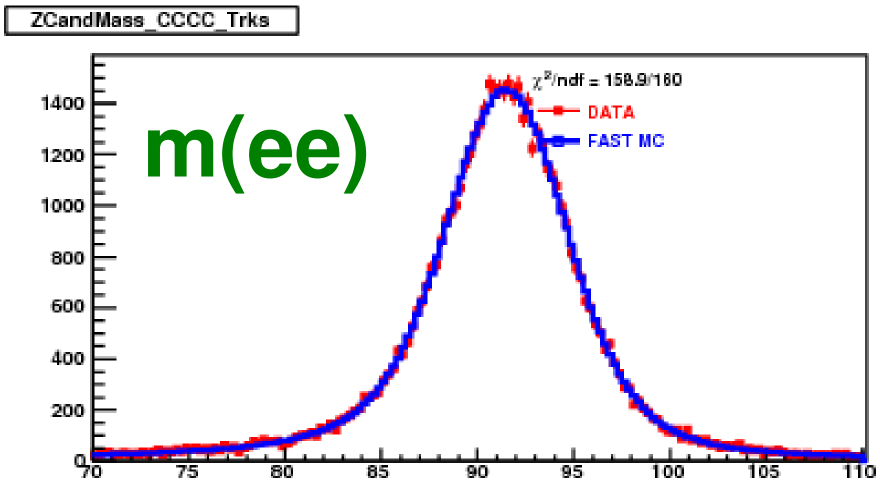
By

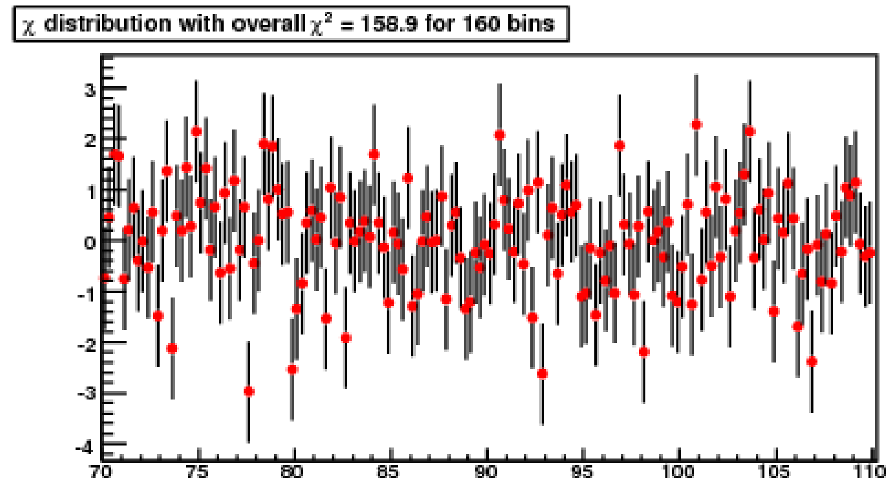
Sahal Yacoob

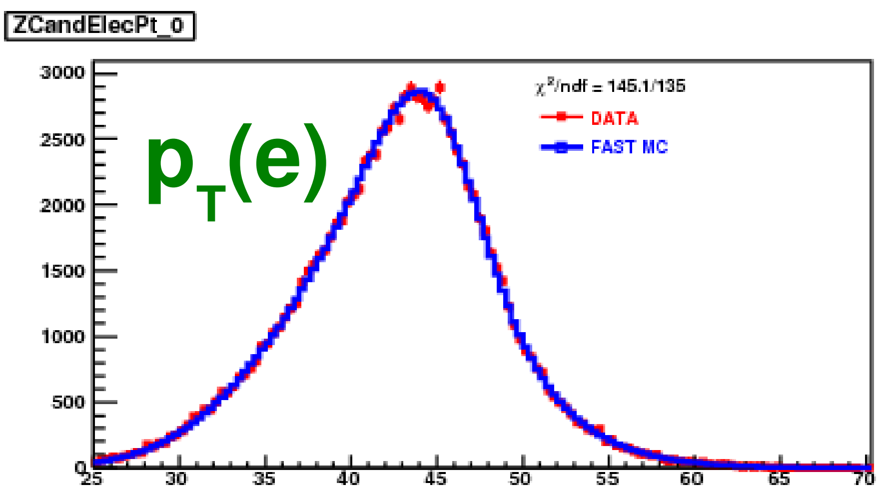
EVANSTON, ILLINOIS

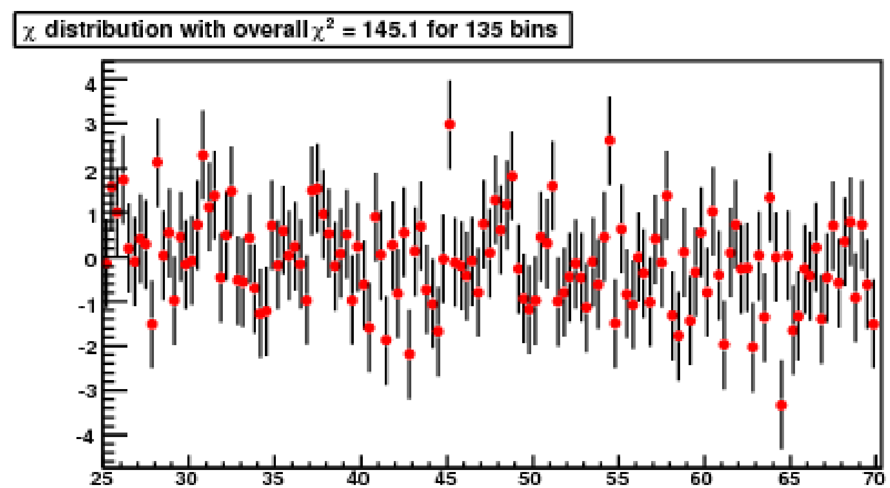
June 2010

Current data/MC agreement: $Z \rightarrow e\,e$



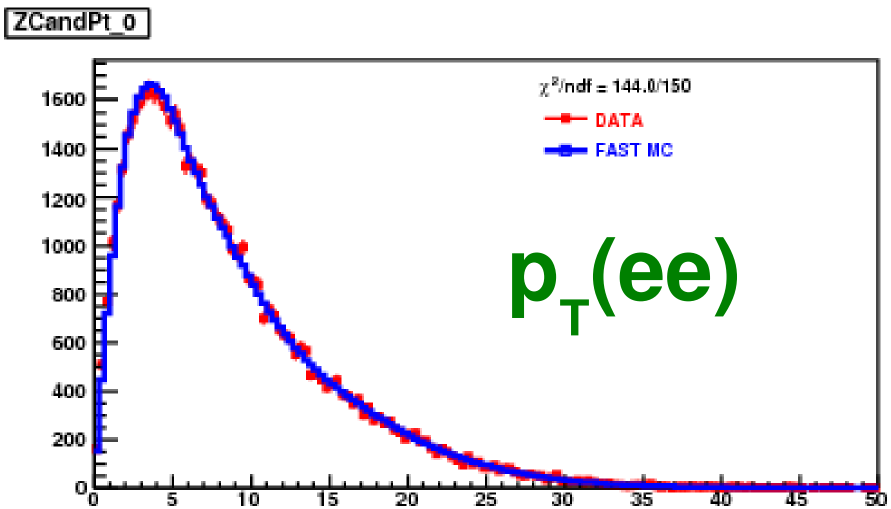


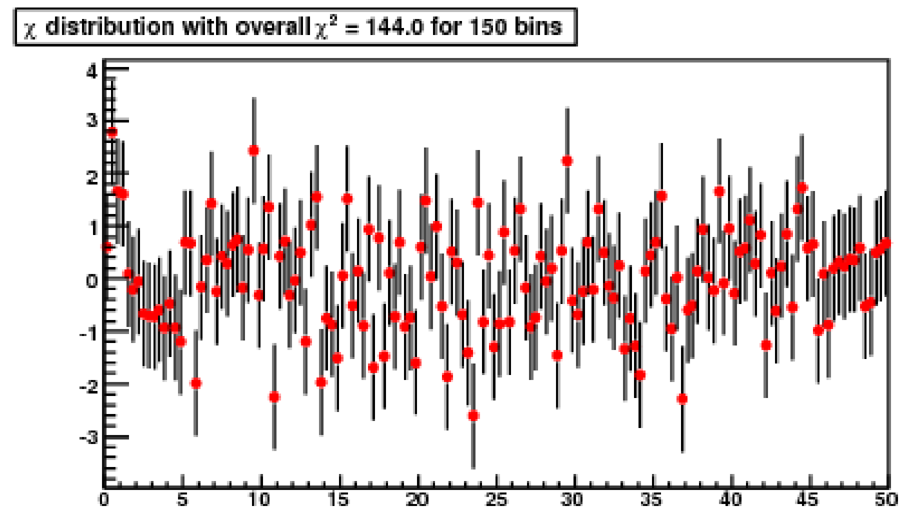


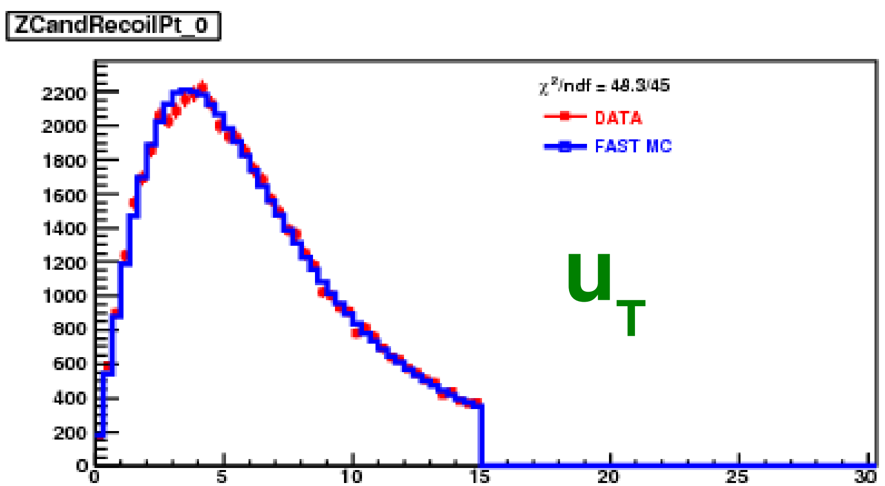


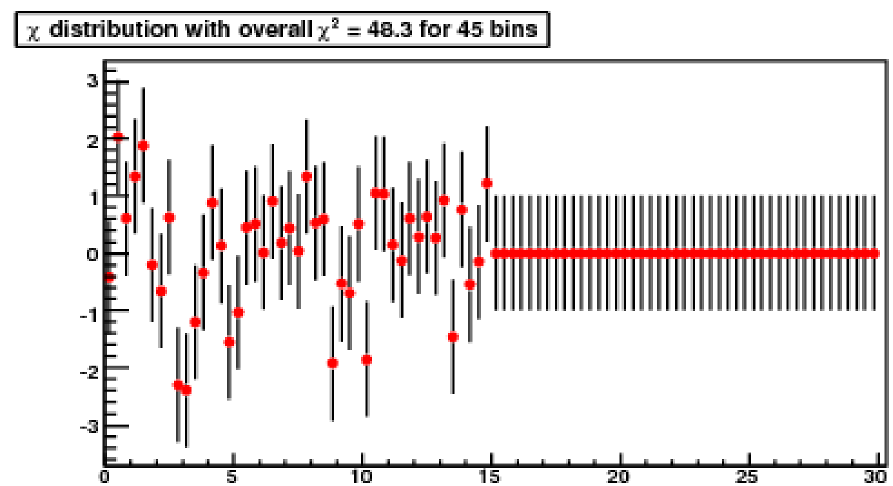
Good agreement between data and parameterised Monte Carlo.

Current data/MC agreement: Z → e e



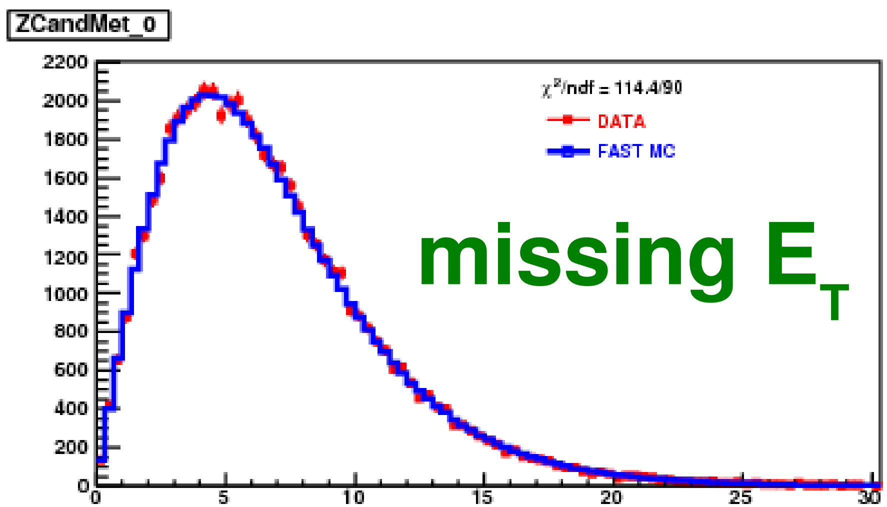


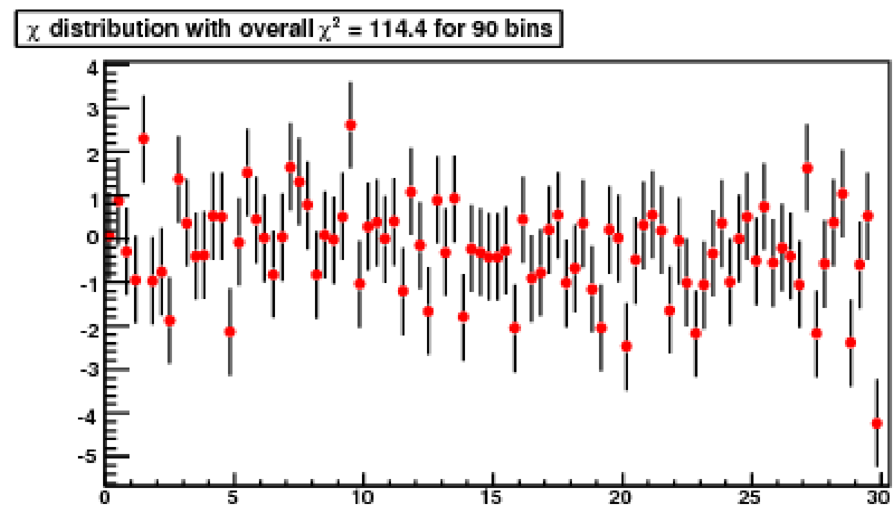


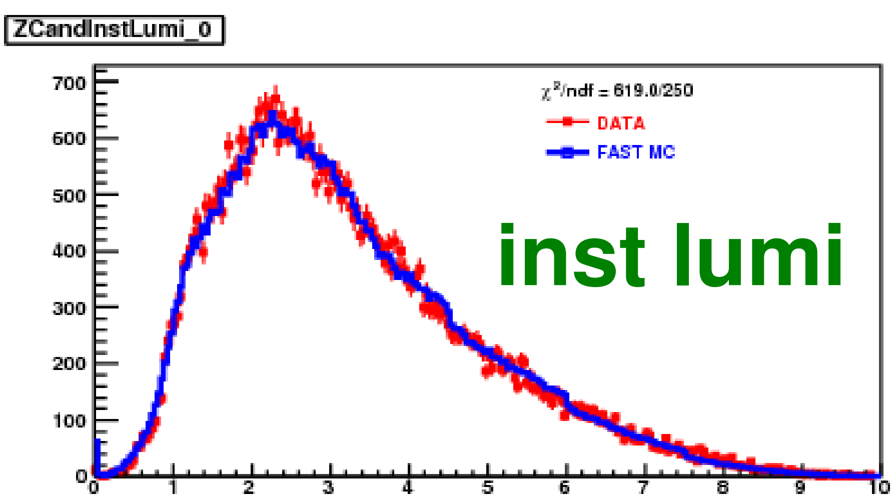


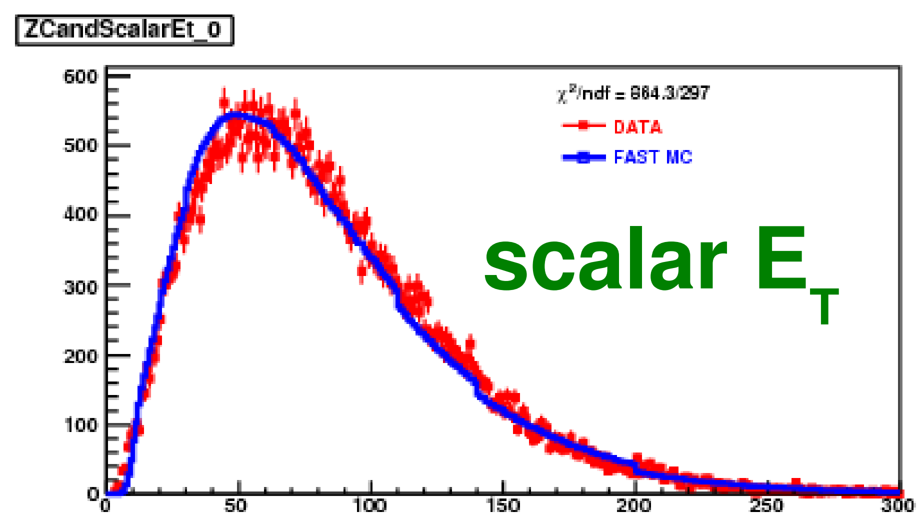
Good agreement between data and parameterised Monte Carlo.

Current data/MC agreement: $Z \rightarrow e\, e$



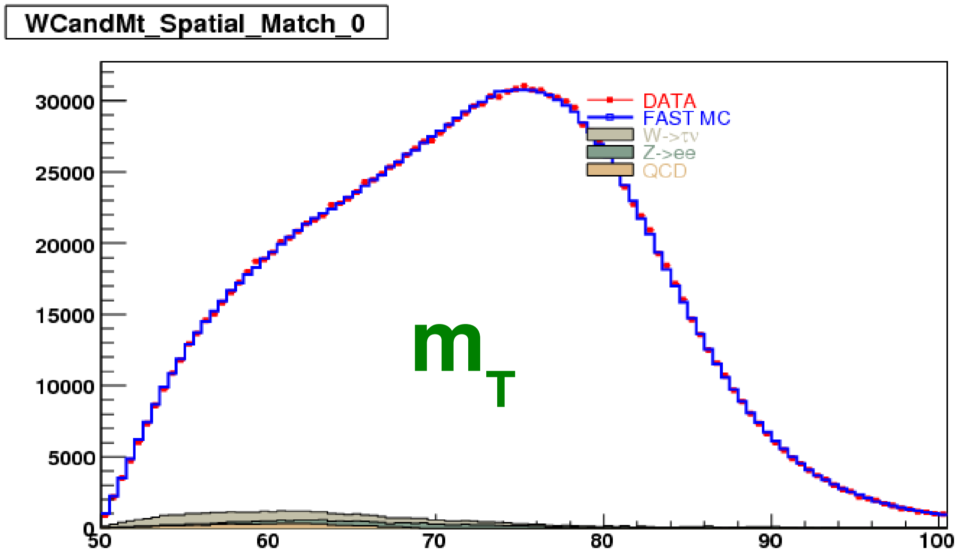


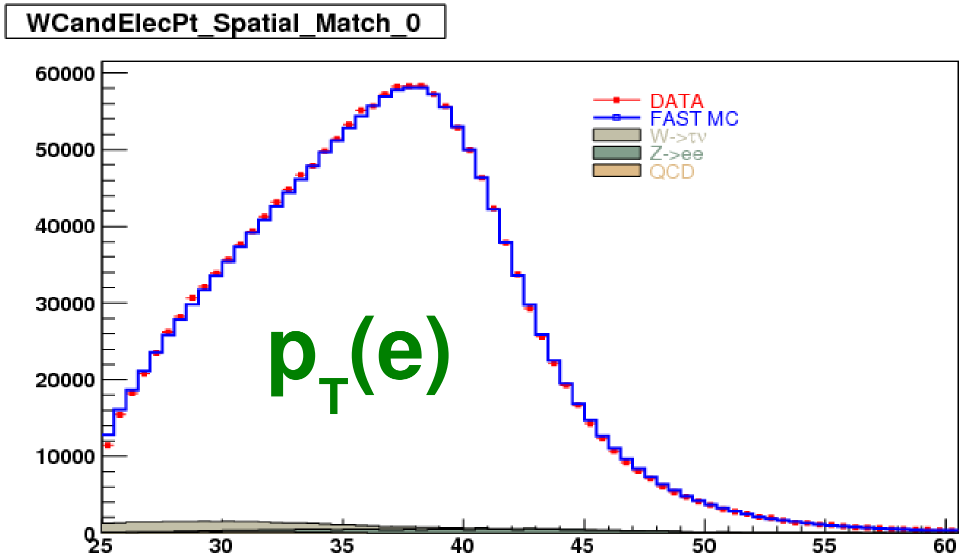


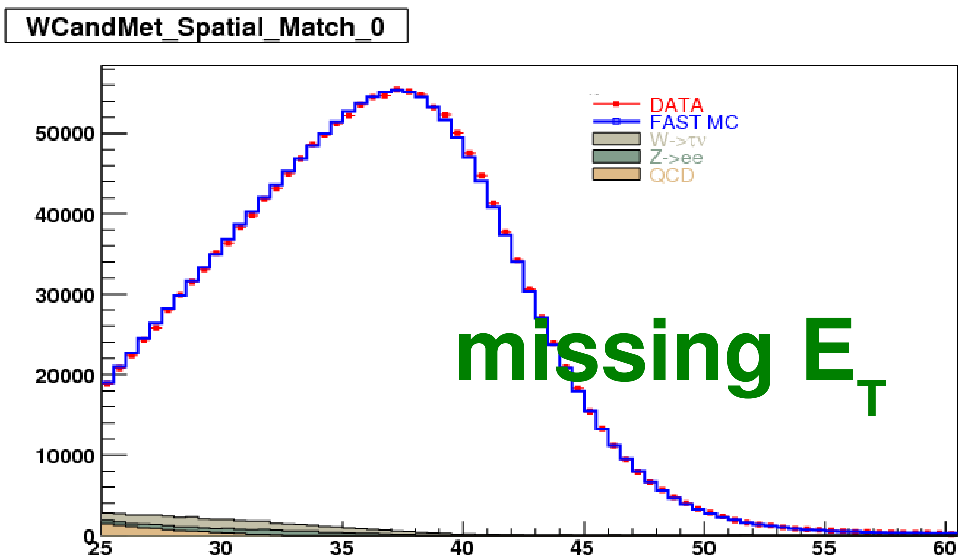


Good agreement between data and parameterised Monte Carlo.

Current data/MC agreement: $W \rightarrow e\,\nu$







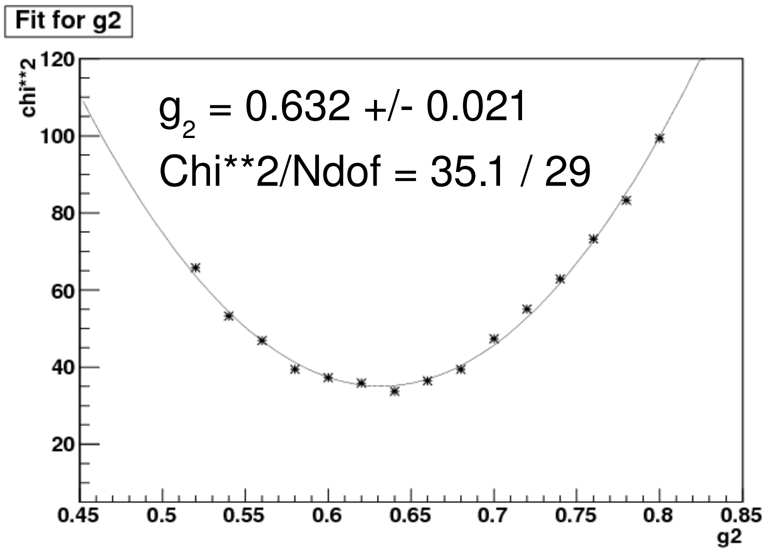
Agreement between data and parameterised Monte Carlo is not bad.

Some technical improvements are needed to address residual issues:

- smooth electron efficiency model,,
- improved treatment of backgrounds,
- zero suppression in recoil model,
- ...

Know what needs to be done; some work, though.

Boson p_T distribution



Based on our Z -> e e sample, we find that the default ResBos (with g_2 = 0.68) predicts a boson p_T spectrum that is a tad too high. This result is in line with Mika's more exhaustive analysis.

When we look in more detail, then we see that the disagreement is exclusively in the part of the spectrum where the bosons are almost at rest.
Issue with things like "primordial k_T" rather than g_2 ??? Will follow up.

Mika Vesterinen, Terry Wyatt

MANCHESTER 1824

The University of Manchester

Cross checks with g2

- We can fit for g2 at folded (detector) level as a tool for internal consistency checks
  - E.g. electron/muon comparisons, and stability w.r.t. ϕ-gaps.
- Some 2-3 σ discrepancies
- Need to be careful about rapidity dependence: since ResBos gets it wrong, the g2 fits will depend on rapidity.
  - E.g. even within the 0 < |y| < 1 bin, 0/1-fiducial have broader rapidity distribution than 2-fiducial for ee, and the opposite for $\mu\mu$.

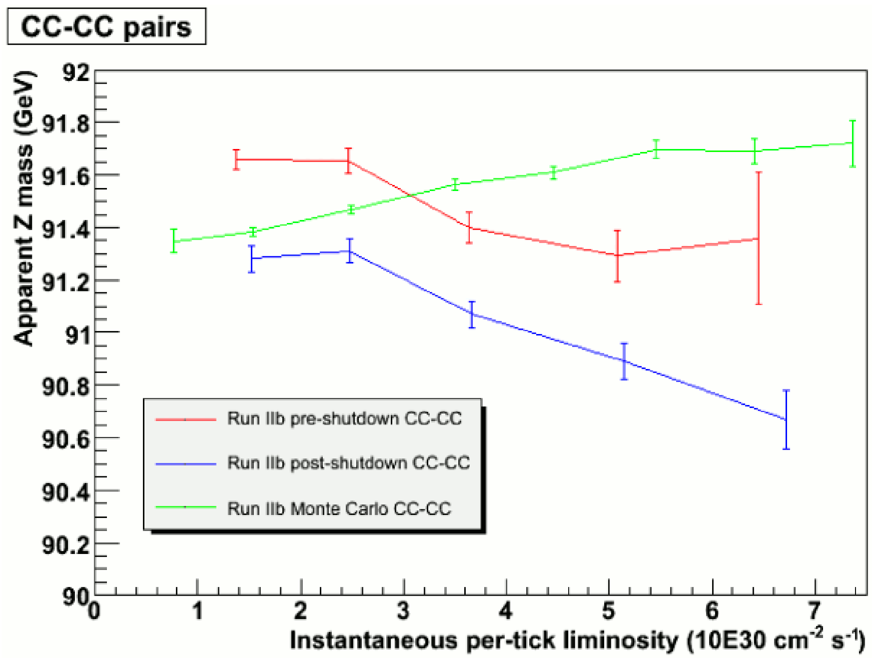
sample	0 < |y| < 1		1 < |y| < 2	
ee	0.647 ± 0.012	–	0.597 ± 0.018	–
$\mu\mu$	0.664 ± 0.011	+1.0σ	0.637 ± 0.020	+1.5σ
ee CCCC 2-fiducial	0.653 ± 0.016	–		
ee CCCC 1-fiducial	0.617 ± 0.030	-2.0σ		
ee CCCC 0-fiducial	0.461 ± 0.074	-2.6σ		
$\mu\mu$ 2-fiducial	0.638 ± 0.012	–	0.609 ± 0.023	–
$\mu\mu$ 1-fiducial	0.745 ± 0.034	+3.0σ	0.624 ± 0.067	+0.2σ
$\mu\mu$ 0-fiducial	0.714 ± 0.044	+1.7σ	0.839 ± 0.071	+3.2σ

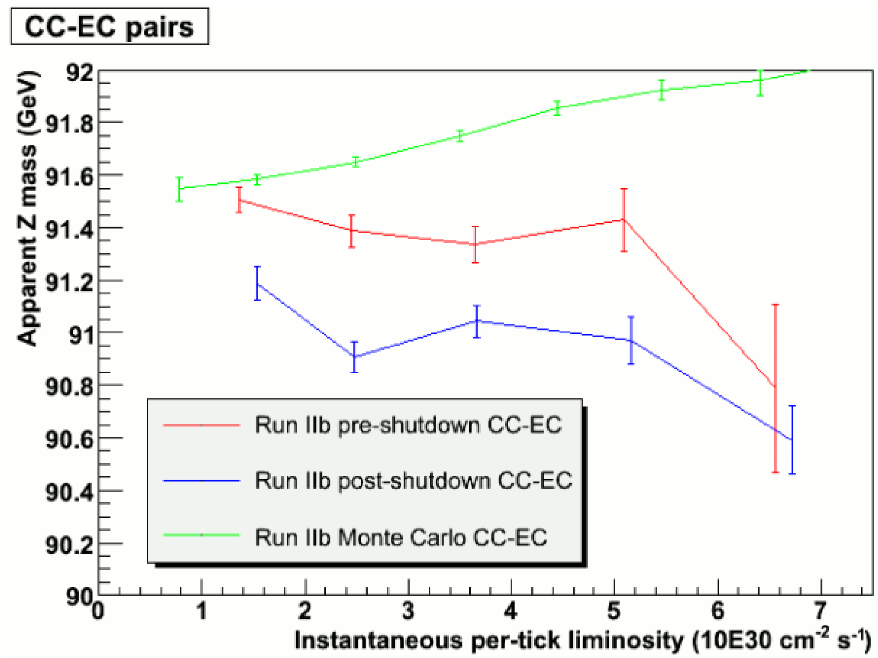
Monday, 19 April 2010 14

Inst-lumi-dependent CAL gains

Reminder: we have identified the issues that are conceptually new in Run IIb and we have solutions for them ...

Let's look at the position of the reconstructed Z -> e e mass peak as a function of instantaneous luminosity. We do this separately for CC-CC and CC-EC pairs. We look at Run IIb data (separately pre and post-Summer 2007 shutdown) and Monte Carlo with unsuppressed ZB overlay (Run IIb with correct lumi and time profile).





In the MC, the peak position moves to higher energies, as one would naively expect.
In the data, the peak position moves down (!).

Jan Stark, CALGO meeting, April 8th, 2009

Inst-lumi-dependent CAL gains

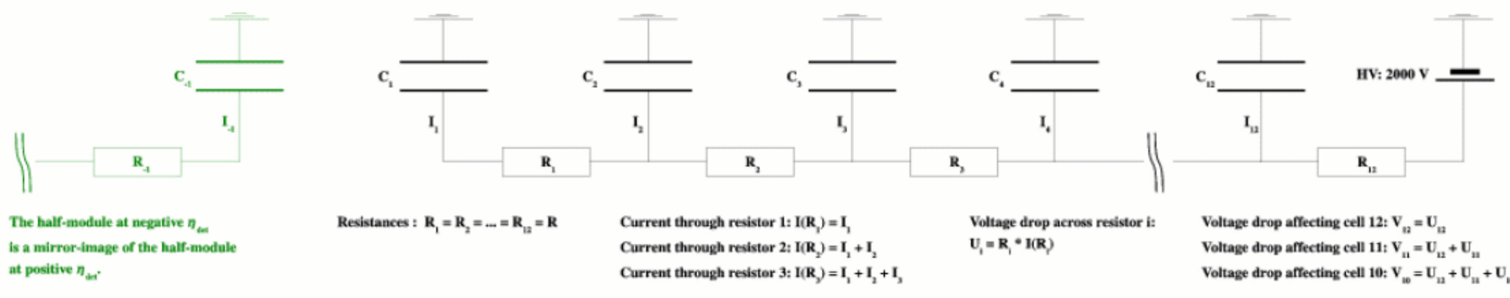
... but we fell behind in propagating our new models to the m(W) analysis; *e.g.* this one is still not included in the PMCS (fast simulation) that we are showing here.

Voltage drop across resistive coat

A schematic view of the CAL unit cell is shown on slide 12. The HV supply is connected to the resistive coat on the signal boards. In the CC this connection is made at the two outer edges of the module (at $|\eta_{det}| = 1.2$).

The ionisation current has to flow through the resistive coat. Since this coat has a high resistance, even small currents can lead to large voltage drops. This leads to a reduction in HV across the LAr gaps, and therefore to a reduction in electron drift speed and whence to a loss in signal.

Here we consider only the CC. The drawing below shows the “equivalent circuit” that we are using as a model of one LAr gap in any given CC layer.



The C_i represent the LAr gap along one readout cell at iphi = i. This is where the current is produced. It has to flow through the resistive coat (represented by the resistors) to the outer edge of the module where the HV is connected. The South part of the module is shown in black. The North part of the module is merely indicated in green. The largest single voltage drop occurs in R_{12}, but the gap that suffers the largest HV drop is C_1 – it is far away from the HV source and “feels” the voltage drop across all resistors.

For a given CAL layer, the value of R is calculated from the known sheet resistance of the resistive coat (about 40 MΩ/☐ according to the Run I NIM paper) and the known cell geometry: $R = 40\ M\Omega$ * [cell length] / [cell width]
where the [cell length] is measured along the beam axis and the [cell width] in the azimuthal direction: [cell width] $\simeq 2\pi r / 64$.

A high-resolution version of the drawing is available on the agenda server.

Jan Stark CAL gains vs. lumi, v2, July 4th, 2009 24

Current status: uncertainties

Systematic uncertainties:

Source	$\sigma(m_W)$ MeV M_t
Experimental	
Electron Energy Scale	14
Electron Energy Resolution Model	3
Electron Energy Nonlinearity	4
W and Z Electron energy loss difference	4
Recoil Model	<6
Electron Efficiencies	<5
Backgrounds	2
Experimental Total	
W production and decay model	
PDF	11
QED	7
Boson p_T	2
W model Total	13
Total	

Table 9.3. Systematic uncertainties on the W mass results in the transverse mass channel. The dominant systematic uncertainty comes from the electron energy scale, and this is determined by the statistical power of the Z event sample.

Statistical uncertainty: 13 MeV.

Reality check

This is an older projection that we like to show.
It is based on the 1 fb^{-1} Run IIa analysis:

source of uncertainties	1 fb-1	6 fb-1	10 fb-1	
Statistics	23	10	8	
Systematics				
Electron energy scale	34	14	11	
Electron resolution	2	2	2	
Electron energy offset	4	3	2	
Electron energy loss	4	3	2	
Recoil model	6	3	2	
Electron efficiencies	5	3	3	
Backgrounds	2	2	2	
Total Exp. systematics	35	16	13	
Theory				
PDF	9	6	4	
QED (ISR-FSR)	7	4	3	
Boson Pt	2	2	2	
Total Theory	12	8	5	
Total syst+theory	37	18	14	
(if theory unchanged)		20	17	
Grand total	44	21	16	(20)

(i.e. stat+syst+theory)

As discussed on the previous slide, we are on track for a 25 MeV uncertainty using 4.4 fb^{-1} of Run IIb data. Combined with the Run Iia result this gets you to 22 MeV for 5.4 fb^{-1}.

This is in line with the our projection for 6 fb^{-1},and we have not even started putting in our theory improvements !

Post 2010

This is an older projection that we like to show.
It is based on the 1 fb^{-1} Run IIa analysis:

source of uncertainties	1 fb-1	6 fb-1	10 fb-1
Statistics	23	10	8
Systematics			
Electron energy scale	34	14	11
Electron resolution	2	2	2
Electron energy offset	4	3	2
Electron energy loss	4	3	2
Recoil model	6	3	2
Electron efficiencies	5	3	3
Backgrounds	2	2	2
Total Exp. systematics	35	16	13
Theory			
PDF	9	6	4
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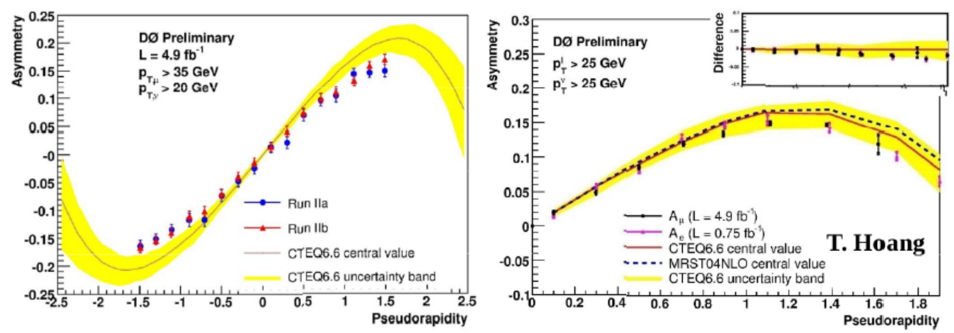
Total Theory	12	8	5
Total syst+theory	37	18	14
(if theory unchanged)		20	17
Grand total	44	21	16 (20)

(i.e. stat+syst+theory)

Given the considerations about uncertainties presented on the previous slides, and given the potential for Higgs constraints presented by Hengne, it clearly would make sense to continue the m(W) effort even after 2010. We expect 10 fb^{-1} analysable at the end of 2011, *i.e.* from the run that is already approved by the DOE.
Also, significant "theory" improvements are coming in from D0, *e.g.* PDF constraints from muon charge asymmetry.

Muon charge asymmetry

Approved as preliminary result for LP09



Since then:

- address comments from EB, add MSTW08 predictions
- plan to get this result published in the next few months
- work with theorists to make sure that the new CDF/D0 results get incorporated into new PDF sets on a reasonable timescale
  - first step: workshop with CDF to assess/quantify consistency of charge asymmetry measurements from CDF and D0 (more on next two slides)
  - second step: sitting down (workshops ?) with theorists

Jan Stark Conveners Meeting, November 13th, 2009 4

Summary

The Run IIb m(W) team: small, somewhat top-heavy, 50 % IN2P3.

Sahal's thesis, with a complete snapshot of the analysis, in an important milestone, just like Tim Andeen's thesis was in Run IIa.

Basics are under control; have good PMCS/data agreement for Z -> e e.
A lot more technical work needs to be done to incorporate everything that we have learned into the the analysis and complete it.

My usual comment is still valid: “the analysis will be ready when it is ready.” Expect sometime in 2010.

Looks like we get uncertainties that are in line with our expectations/projections.

Given the uncertainties and the potential for indirect constraints on the Higgs, it would make sense to continue the m(W) effort even after 2010.