Discovery of the W-Boson

Oliver Dahme

University of Zurich

o.dahme@cern.ch

November 15, 2016

Postulate

- $q \rightarrow q + e^{\pm} + \nu$ mediated by 2 massive bosons
- should result in enhancement of: $q + \bar{q} \rightarrow e^{\pm} + \nu$ cross section
- M_W predicted at (82 ± 2.4) GeV$/c^2$

Detector

- $(7 \cdot 3.5 \cdot 3.5)m^3$ transverse dipole magnet with 0.7 T
- cylindric drift chamber, 3.5 m long and diameter of 2.3 m arround the interaction point
- yields a bubble-chamber picture of each $p\bar{p}$ interaction

Calorimeter		Angular coverage θ (deg)	Thickness: No. rad. lengths	Thickness: No. abs. lengths	Cell size: $\Delta\theta$ (deg)	Cell size: $\Delta\phi$ (deg)	Sampling step	Segmentation in depth	Resolution
barrel	EM: gondolas	25 –155	$26.4/\sin\theta$	$1.1/\sin\theta$	5	180	1.2 mm Pb 1.5 mm scint.	3.3/6.5/10.1/6.5 X_0	$0.15/\sqrt{E}$
	hadr.: c's	25 –155	–	$5.0/\sin\theta$	15	18	50 mm Fe 10 mm scint.	2.5/2.5 λ	$0.8/\sqrt{E}$
end-caps	EM: bouchons	5 – 25	$27/\cos\theta$	$1.1/\cos\theta$	20	11	4 mm Pb 6 mm scint.	4/7/9/7 X_0	$0.12/\sqrt{E_T}$
	hadr.: I's	155 –175	–	$7.1/\cos\theta$	5	10	50 mm Fe 10 mm scint.	3.5/3.5 λ	$0.8/\sqrt{E}$
calcom	EM	0.7– 5	30	1.2	4	45	3 mm Pb 3 mm scint.	4×7.5 X_0	$0.15/\sqrt{E}$
	hadr.	175 –179.3	–	10.2	–	–	40 mm Fe 8 mm scint.	6×1.7 λ	$0.8/\sqrt{E}$
very forward	EM	0.2– 0.7	24.5	1.0	0.5	90	3 mm Pb 6 mm scint.	5.7/5.3/5.8/7.7 X_0	$0.15/\sqrt{E}$
	hadr.	179.3–179.8	–	5.7	0.5	90	40 mm Fe 10 mm scint.	5×1.25 λ	$0.8/\sqrt{E}$

Figure: Calorimetry of the Experiment

Detection

- Electrons leave no track in the hadronic calorimeter (98%)
- Neutrinos by missing energy, due to a hermetic calorimetry down to 0.2^o
- muons by muon chamber arround the experiment

Data

- Data-taking in a 30-day period during Nov and Dez 1982
- minimum transvers energy of 10 GeV
- 3 triggers:
  1. jet trigger with 15 GeV in a localized region
  2. global transvers energy trigger with > 40 GeV
  3. muon trigger at least one penetrating track to the diamond (vertex)
- electrons have to be isolated
- energetic neutrinos required

Most important events

Main parameters of electron events with a large missing transverse energy.

Run, event		Properties of the electron track										Calorimeter information: Electromagnetic energy deposition					General event topology				
		E_T (GeV)	E (GeV)	p (GeV/c)	Δp a)	Q	dE/dx I/I_0	y b)	Track No.	Length (m)	Sagitta (mm)	Sample 1 (GeV)	Sample 2 (GeV)	Sample 3 (GeV)	Sample 4 (GeV)	E_{had} (GeV)	E_{tot} (GeV)	Missing E_T (GeV)	$\Delta\phi$ c) (deg.)	Charged tracks	$\sum\|E_T\|$ (GeV)
A	2958 1279	26	42	33.8	+6.3 −4.6	-	1.22 ±0.2	+1.1	36	1.36	1.7	4	35	3	0.2	0	278	24.4 ± 4.6	179	65	81
B	3522 214	17	46	47.5	+8.2 −6.1	-	1.37 ±0.16	+1.7	18	1.64	1.5	2	32	10	0.5	0	296	10.9 ± 4.0	219	49	60
C	3524 197	34	45	21.6	+21.8 −7.2	-	1.37 ±0.3	−0.8	26	1.25	2.11	1	30	14	0.2	0	367	41.3 ± 3.6	187	21	68
D	3610 760	38	40	33.4	+33.0 −11.1	-	1.64 ±0.34	+0.3	9	0.98	0.75	3	9	26	2.2	0.4	111	40.0 ± 2.0	181	10	47
E	3701 305	37	37	56.2	+121.3 −22.8	+	1.54 ±0.28	−0.1	12	0.95	0.4	1	18	17	0.9	0	363	35.5 ± 4.3	173	39	87
F	4017 838	37	70	53.1	+6.6 −5.3	-	1.30 ±0.26	+1.4	3	2.01	2.0	19	48	3	0.3	0	177	32.3 ± 2.4	179	14	49
G	3262 1108	40	40	6.7	+1.9 −1.2	-	1.23 ±0.28	0.0	21	0.85	3.0	2	22	15	0.9	0	218	33.4 ±2.9	172	21	63

a) Including 200 μm systematic error. b) y is defined as positive in the direction of the outgoing $\bar{p}$.
c) Angle between electron and missing energy (neutrino).

Figure: The last 7 events after triggering and filtering

digital events

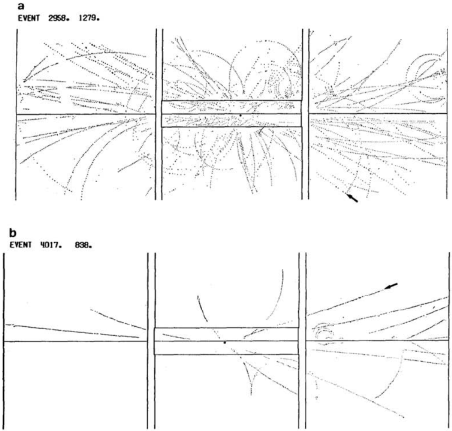

Fig. 6. The digitization from the central detector for the tracks in two of the events which have an identified, isolated, well-measured high-p_T electron: (a) high-multiplicity, 65 associated tracks; (b) low-multiplicity, 14 associated tracks.

relevant events

Transverse mass and transverse momentum of a W decaying into an electron and a neutrino computed from the events of table 2.

Run, event	$p_T^{(e)}$ of electron (GeV/c)	$p_T^{(\nu)}$ = missing E_T (GeV)	Transverse mass (GeV/c)^2	$p_T^{(W)} = \lvert p_T^{(e)} + p_T^{(\nu)} \rvert$ (GeV)
A 2958 1279	24 ± 0.6	24.4 ± 4.6	48.4 ± 4.6	0.6 ± 4.6
B 3522 214	17 ± 0.4	10.9 ± 4.0	26.5 ± 4.6	10.8 ± 4.0
C 3524 197	34 ± 0.8	41.3 ± 3.6	74.8 ± 3.4	8.6 ± 3.7
D 3610 760	38 ± 1.0	40.0 ± 2.0	78.0 ± 2.2	2.1 ± 2.2
E 3701 305	37 ± 1.0	35.5 ± 4.3	72.4 ± 4.5	4.7 ± 4.4
F 4017 838	36 ± 0.7	32.3 ± 2.4	68.2 ± 2.6	3.8 ± 2.5

Figure: candidates for W decay

Analysis

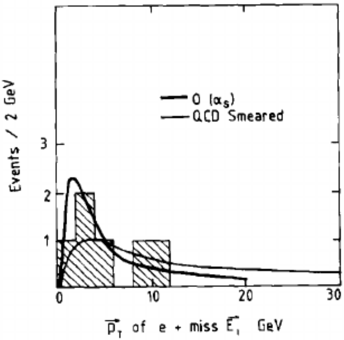

Fig. 10. The transverse momentum distribution of the W derived from our events, using the electron and missing-energy vectors. This is compared with the theoretical predictions of Halzen et al. [8] for W production without [$O(\alpha_s)$] and with QCD smearing.

- The fit lead to a $m_W = (81 \pm 5)\ \mathrm{GeV}/c^2$
- theory predicted $m_W = (82 \pm 2.4)\ \mathrm{GeV}/c^2$
- The result is in excellent agreement with the expactations

Questions?