JOINT INSTITUTE FOR NUCLEAR RESEARCH

СВ. КЛИМЕНТ ОХРИДСКИ

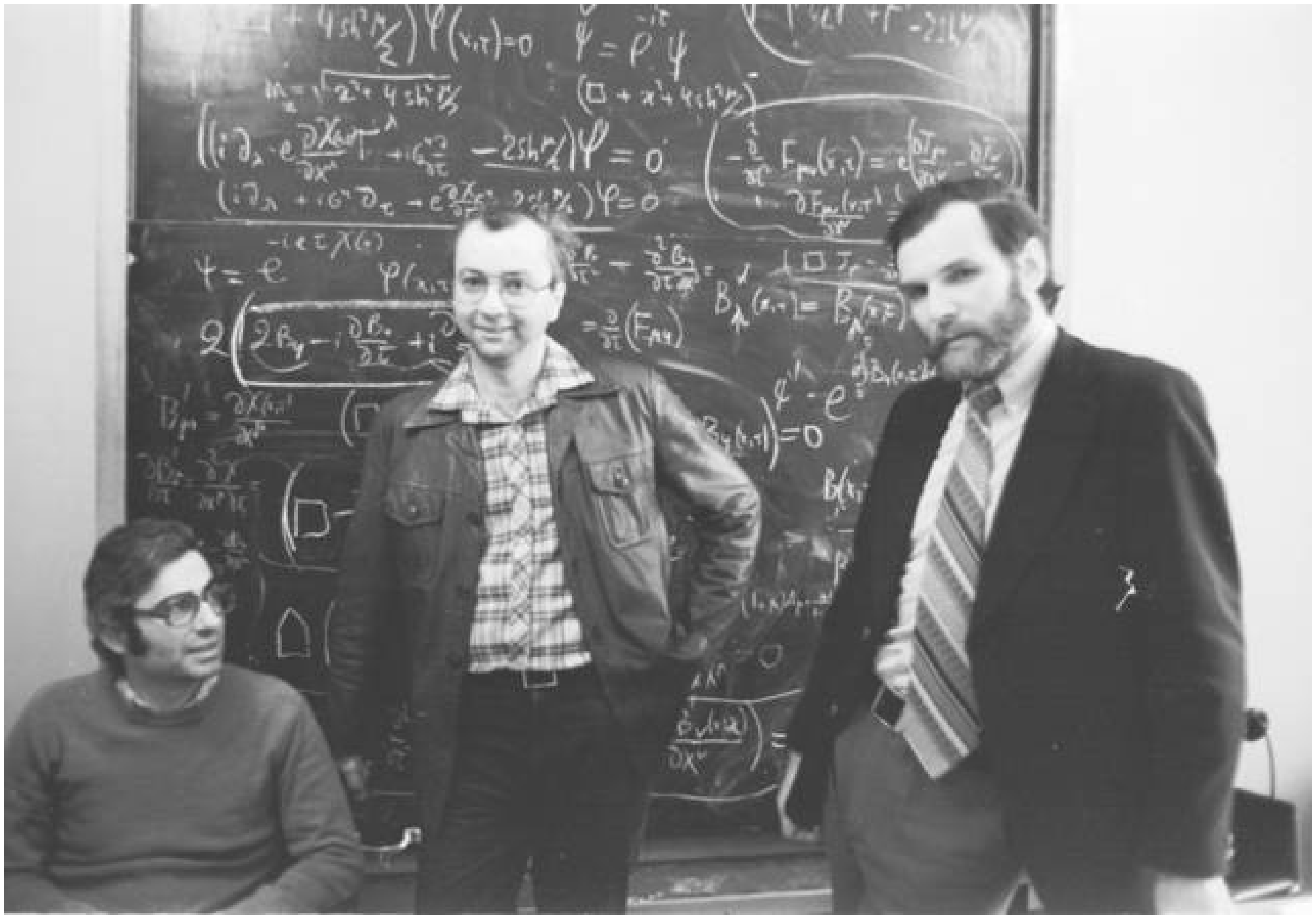
A boost for a whole life

Dedicated to the memory of my teacher Prof. Mateev

M.V. Chizhov

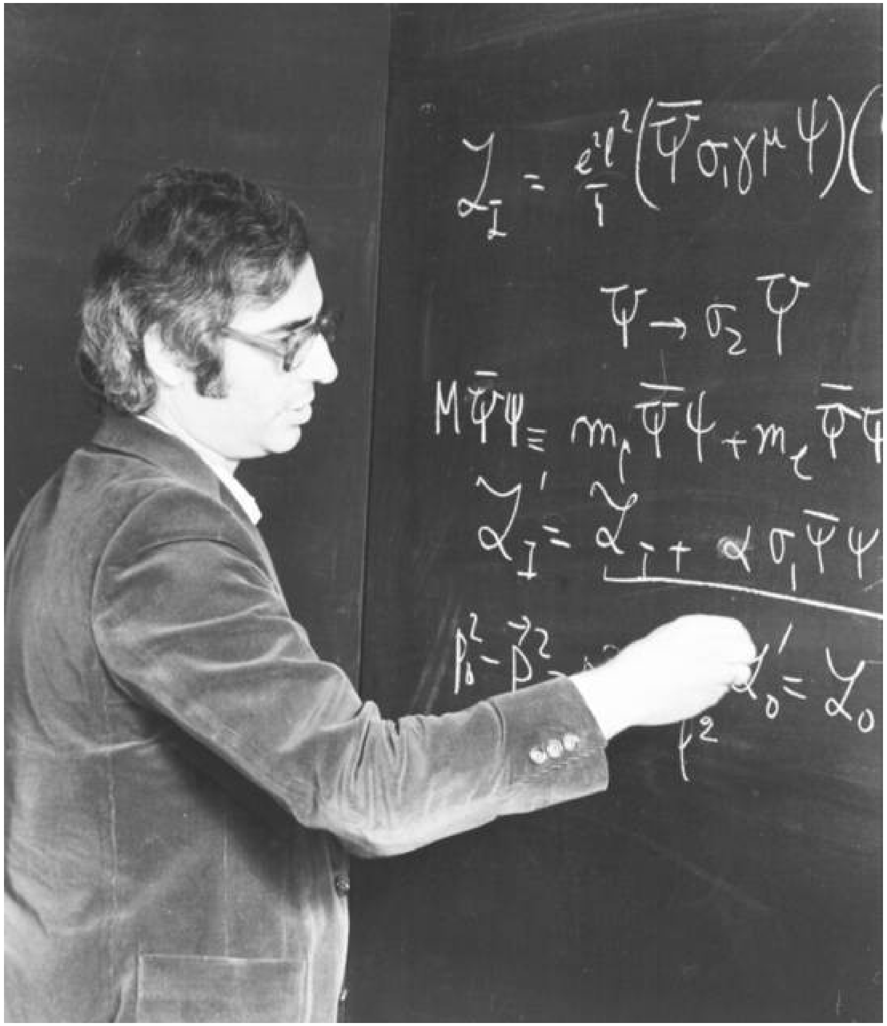
(Sofia University and JINR)

Beginning in Dubna …



ON THE MUON–ELECTRON MASS DIFFERENCE

V.G. Kadyshevskii, M.D. Mateev,
and M.V. Chizhov

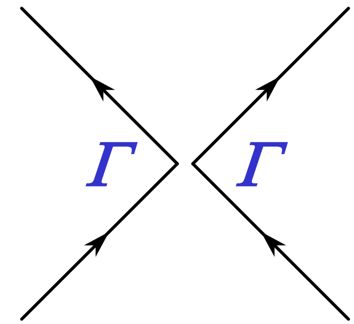


Heisenberg
Schwinger
Bogolyubov
Fröhlich
Thirring
Nambu – Jona-Lasinio
Vaks – Larkin
Arbuzov – Tavkhelidze – Faustov
Kirzhnits
Gross – Neveu

Joint Institute for Nuclear Research, Dubna. Translated from Teoreticheskaya i Matematicheskaya Fizika, Vol.45, No.3, pp.358-364, December, 1980. Original article submitted January 28, 1980.

Fundamental interaction

Heisenberg's four-fermion universal interaction



$$\mathscr{L}_I(x) = \frac{e^2 l^2}{4}[\bar{\Psi}(x)\sigma_1 \otimes \gamma^\mu \Psi(x)][\bar{\Psi}(x)\sigma_3 \otimes \gamma_\mu \Psi(x)]. \qquad (3.3)$$

$$\int d^4x\, \bar{\Psi}(x)\sigma_1 \otimes \gamma_\mu \Psi(x) \cdot \bar{\Psi}(x)\sigma_3 \otimes \gamma^\mu \Psi(x) = -\frac{1}{2}\int d^4x_1\, d^4x_2 [\Psi^{b_1}_{\beta_1}(x_1)\bar{\Psi}^{a_1}_{\alpha_1}(x_1)] K^{(a_1 b_1;\, a_2 b_2)}_{(\alpha_1\beta_1;\, \alpha_2\beta_2)}(x_1, x_2) \times$$

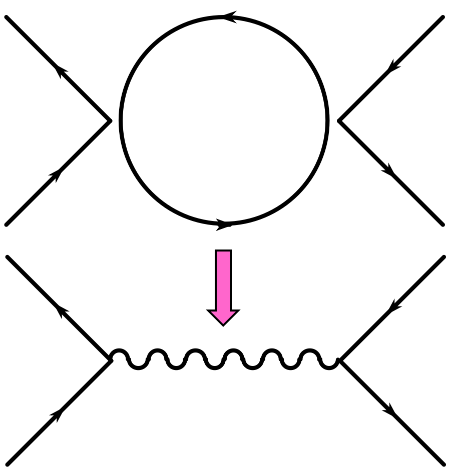
$$[\Psi^{b_2}_{\beta_2}(x_2)\bar{\Psi}^{a_2}_{\alpha_2}(x_2)] = -\frac{1}{2}\Psi_{B_1}\bar{\Psi}_{A_1} K_{A_1 B_1 A_2 B_2}\Psi_{B_2}\bar{\Psi}_{A_2} = -\frac{1}{2}(\Psi\bar{\Psi}, K\Psi\bar{\Psi}). \qquad (4.3)$$

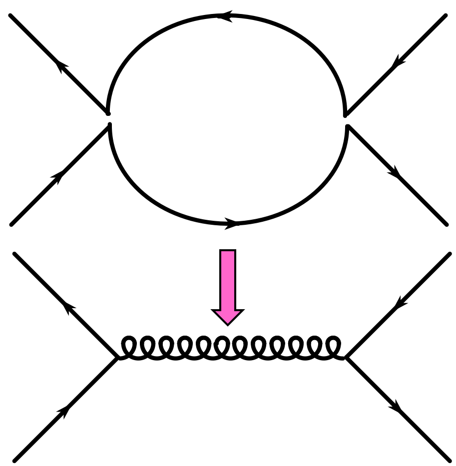
Mean-field approximation method

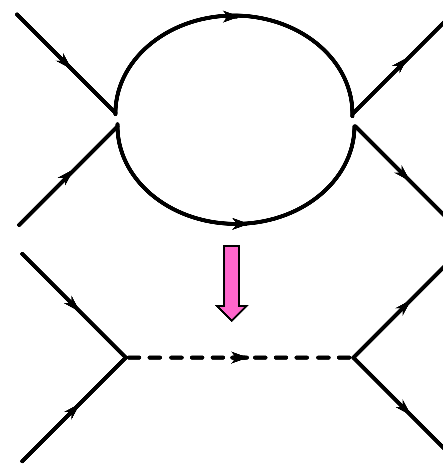
Hartree

Fock

Bogolyubov







ANOMALOUS EXPECTATION VALUES OF MULTICOMPONENT FIELDS

M. V. Chizhov   M. D. Mateev

$$\mathrm{Asym}(\lambda_0\overline{\Psi}\theta Q\Psi\ \overline{\Psi}\eta R\Psi)=\frac{\lambda_0}{4N}\overline{K}_{nm}{}^{ab}(\theta Q,\eta R)\ \frac{1}{2}\{\overline{\Psi}T_a\Gamma^n\overline{\Psi},\Psi T_b\Gamma^m\Psi\}+\frac{\lambda_0}{4N}K_{nm}{}^{ab}(\theta Q,\eta R)\ \frac{1}{2}[\overline{\Psi},T_a\Gamma^n\Psi]\ \frac{1}{2}[\overline{\Psi},T_b\Gamma^m\Psi],$$

$$\mathscr{K}=\begin{pmatrix} 3 & -4 & -6 & 4 & -1\\ -1 & 6 & 0 & 2 & 1\\ -1 & 0 & 6 & 0 & -1\\ 1 & 2 & 0 & 6 & -1\\ -1 & 4 & -6 & -4 & 3\end{pmatrix}, \tag{3.5a}$$

$$\overline{\mathscr{K}}=\begin{pmatrix} 1 & -4 & -6 & -4 & 1\\ -1 & 2 & 0 & -2 & 1\\ 1 & 4 & -6 & 4 & 1\end{pmatrix}. \tag{3.5b}$$

New Fierz identities for $\Psi\Psi$ and $\overline{\Psi}\overline{\Psi}$

Diquark excitations, color superconductivity…

Joint Institute for Nuclear Research, Dubna. Translated from Teoreticheskaya i Matematicheskaya Fizika, Vol. 51, No. 2, pp. 218-223, May, 1982. Original article submitted February 5, 1981.

Dynamical generation of composite particles

Higgs mechanism through $\Psi\Psi$ and $\bar{\Psi}\bar{\Psi}$ condensates

Volume 104B, number 6 PHYSICS LETTERS 17 September 1981

BOGOLUBOV'S SPONTANEOUS SYMMETRY-BREAKING MECHANISM AND THE HIGGS PHENOMENON

M.V. CHIZHOV
Joint Institute for Nuclear Research, Dubna, USSR

Received 18 June 1981

In the mean-field approximation the four-fermion (V–A)-theory is shown to have all the features of the abelian model with spontaneous symmetry breaking. In this model the coupling constants turn out to be the known functions of two parameters: the Yukawa coupling constant and the vacuum expectation value of the Higgs field.

E_6 as the minimal group for BSBM

Volume 113B, number 2 PHYSICS LETTERS 10 June 1982

A GRAND UNIFIED MODEL WITH BOGOLUBOV'S SYMMETRY BREAKING MECHANISM

M.V. CHIZHOV
Joint Institute for Nuclear Research, Dubna, USSR

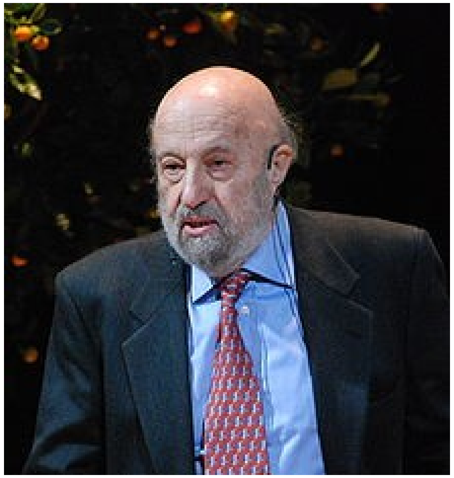
Received 22 December 1981
Revised manuscript received 15 March 1982

It is shown that E_6 is the *minimal group* in the E-chain of the Dynkin diagrams which allows the construction of a unified model of elementary particles in the framework of the *Bogolubov method* for dynamic symmetry breaking. The idea is based on the introduction of a fundamental self-coupled spinor field, the collective modes of which have the properties of gauge and Higgs particles. The hierarchy of fermion masses is discussed.

… continuation in Sofia

(and Pravetz)

Nambu – Jona-Lasinio extended model

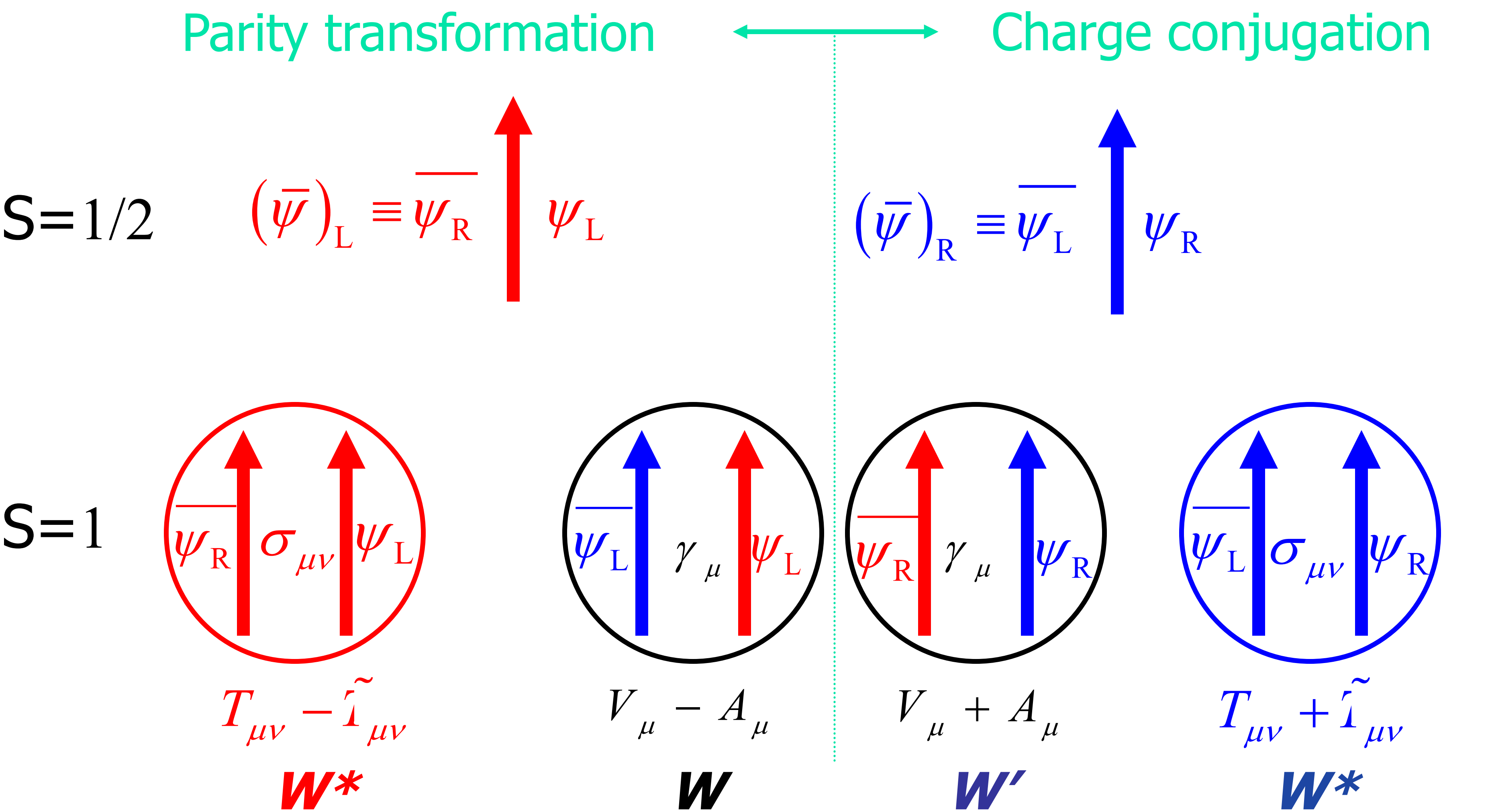


$$\mathcal{L} = \bar{\psi}\, \not{q}\, \psi + \frac{G_0}{2} \bar{\psi}(1+\gamma^5)\psi\, \bar{\psi}(1-\gamma^5)\psi$$

$$- \frac{G_V}{2}\left(\bar{\psi}\gamma_\mu\psi\right)^2 - \frac{G_A}{2}\left(\bar{\psi}\gamma_\mu\gamma^5\psi\right)^2$$

$$-\frac{G_T}{2}\bar{\psi}\sigma_{\mu\lambda}(1+\gamma^5)\psi \boxed{\frac{q^\mu q_\nu}{q^2}} \bar{\psi}\sigma^{\nu\lambda}(1-\gamma^5)\psi$$

Lorentz group representation



Mendeleev's table

TABELLE II

REIHEN	GRUPPE I. — R^2O	GRUPPE II. — RO	GRUPPE III. — R^2O^3	GRUPPE IV. RH^4 RO^2	GRUPPE V. RH^3 R^2O^5	GRUPPE VI. RH^2 RO^3	GRUPPE VII. RH R^2O^7	GRUPPE VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

Figure 2.5 Dmitri Mendeleev's 1872 periodic table. The spaces marked with blank lines represent elements that Mendeleev deduced existed but were unknown at the time, so he left places for them in the table. The symbols at the top of the columns (e.g., R^2O and RH^4) are molecular formulas written in the style of the 19th century.

Lorentz group representations

s \ χ	-2	-3/2	-1	-1/2	0	+1/2	+1	+3/2	+2
0					(0,0)				
1/2				(1/2,0)		(0,1/2)			
1			(1,0)		(1/2,1/2)		(0,1)		
3/2		(3/2,0)		(1,1/2)		(1/2,1)		(0,3/2)	
2	(2,0)		(3/2,1/2)		(1,1)		(1/2,3/2)		(0,2)

JETP Letters, Vol. 80, No. 2, 2004, pp. 73–77. From Pis'ma v Zhurnal Éksperimental'noĭ i Teoreticheskoĭ Fiziki, Vol. 80, No. 2, 2004, pp. 81–85.

Vector Meson Couplings to Vector and Tensor Currents in Extended NJL Quark Model¶

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Center for Space Research and Technologies, Faculty of Physics, University of Sofia, 1164 Sofia, Bulgaria
Received May 14, 2004

A simple explanation of the dynamic properties of vector mesons is given in the framework of extended Nambu–Jona-Lasinio quark model. New mass relations among the hadron vector resonances are derived. The results of this approach are in good accordance with the QCD sum rules, the lattice calculations, and the experimental data. *© 2004 MAIK "Nauka/Interperiodica".*

PACS numbers: 12.39.Ki; 12.39.Fe; 14.40.Cs

Spin-1 states

Chiral representation

(Parity)

$$V_\mu + A_\mu$$

$$T_{\mu\nu} + \tilde{T}_{\mu\nu} \longleftrightarrow T_{\mu\nu} - \tilde{T}_{\mu\nu}$$

$$V_\mu - A_\mu$$

Polar-Axial representation

(J^{PC})

$V_\mu(1^{--})$ ⟷ *mixing* ⟷ $(1^{--})V_\mu^* \sim \partial^\nu T_{\mu\nu}$

$A_\mu(1^{++})$ $\quad$ $(1^{+-})A_\mu^* \sim \partial^\nu \tilde{T}_{\mu\nu}$

Spin-1 meson table

J^{PC} \ I	1	0	1/2
1^{--}	ρ, ρ'	$\omega, \omega'; \phi, \phi'$	K^*, K'^*
1^{++}	a_1	f_1	K_{a1}
1^{+-}	b_1	h_1	K_{b1}

Spin-1 hadron resonances

M.Chizhov, JETP Lett. **80** (2004) 73

$\rho(770)$ [j] $I^G(J^{PC}) = 1^+(1^{--})$

Mass $m = 775.5 \pm 0.4$ MeV
Full width $\Gamma = 149.4 \pm 1.0$ MeV

$$\bar{q}\gamma^\mu q \cdot V_\mu$$

mixing

$\rho(1450)$ [s] $I^G(J^{PC}) = 1^+(1^{--})$

Mass $m = 1459 \pm 11$ MeV [n] ($S = 3.4$)
Full width $\Gamma = 171 \pm 50$ MeV [n] ($S = 4.9$)

$$\bar{q}\sigma^{\mu\nu} q \cdot \left(\partial_\mu V_\nu^* - \partial_\nu V_\mu^*\right)$$

$a_1(1260)$ [m] $I^G(J^{PC}) = 1^-(1^{++})$

Mass $m = 1230 \pm 40$ MeV [n]
Full width $\Gamma = 250$ to 600 MeV

$$\bar{q}\gamma^\mu \gamma^5 q \cdot A_\mu$$

$b_1(1235)$ $I^G(J^{PC}) = 1^+(1^{+-})$

Mass $m = 1229.5 \pm 3.2$ MeV ($S = 1.6$)
Full width $\Gamma = 142 \pm 9$ MeV ($S = 1.2$)

$$\bar{q}\sigma^{\mu\nu}\gamma^5 q \cdot \left(\partial_\mu A_\nu^* - \partial_\nu A_\mu^*\right)$$

New mass relation

$$m_{a_1}^2 + m_{b_1}^2 = m_\rho^2 + m_{\rho'}^2$$

Weinberg's mass relation $m_{a_1}^2 = 2m_\rho^2$

$$m_{\rho'}^2 = m_\rho^2 + m_{b_1}^2 = \left(1453.8 \pm 3.0\ \mathrm{MeV}\right)^2$$

$$m_{\rho'}^{\mathrm{PDG}} = \left(1465 \pm 25\right)\ \mathrm{MeV}$$

Other new mass relations

$I^G = 1^+$: $$\frac{2(m_{\rho'} - m_{\rho})^2 + 3 m_{\rho'} m_{\rho}}{3(m_b)^2} = 0.96 \pm 0.03$$

$I^G = 0^-$: $$\frac{2(m_{\omega'} - m_{\omega})^2 + 3 m_{\omega'} m_{\omega}}{3(m_h)^2} = 1.01 \pm 0.07$$

$I^G = 0^-$: $h_1(s\bar{s})$? $m_h(m_{\phi'}, m_{\phi}) = (1415 \pm 13)$ MeV

Meson Summary Table

$f_0(1370)$ [k] $I^G(J^{PC}) = 0^+(0^{++})$

Mass m = 1200 to 1500 MeV
Full width Γ = 200 to 500 MeV

$f_1(1420)$ [n] $I^G(J^{PC}) = 0^+(1^{++})$

Mass $m = 1426.3 \pm 1.1$ MeV (S = 1.3)
Full width $\Gamma = 55.5 \pm 2.9$ MeV

$\omega(1420)$ [o] $I^G(J^{PC}) = 0^-(1^{--})$

Mass $m = 1419 \pm 31$ MeV
Full width $\Gamma = 174 \pm 60$ MeV

$\eta(1440)$ [p] $I^G(J^{PC}) = 0^+(0^{-+})$

Mass m = 1400 - 1470 MeV [m]
Full width Γ = 50 - 80 MeV [m]

$a_0(1450)$ $I^G(J^{PC}) = 1^-(0^{++})$

Mass $m = 1474 \pm 19$ MeV
Full width $\Gamma = 265 \pm 13$ MeV

$\rho(1450)$ [q] $I^G(J^{PC}) = 1^+(1^{--})$

Mass $m = 1465 \pm 25$ MeV [m]
Full width $\Gamma = 310 \pm 60$ MeV [m]

$f_0(1500)$ [r] $I^G(J^{PC}) = 0^+(0^{++})$

Mass $m = 1507 \pm 5$ MeV (S = 1.2)
Full width $\Gamma = 109 \pm 7$ MeV

$0^-(1^{+-})$

m = 1415 ± 13 MeV **?**

$h_1(1380)$ $I^G(J^{PC}) = ?^-(1^{+-})$

OMITTED FROM SUMMARY TABLE
Seen in partial-wave analysis of the $K\overline{K}\pi$ system. Needs confirmation.

$h_1(1380)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1386±19 OUR AVERAGE				
1440±60	ABELE	97H	CBAR	$\overline{p}p \to K^0_L K^0_S \pi^0 \pi^0$
1380±20	ASTON	88C	LASS	11 $K^- p \to K^0_S K^\pm \pi^\mp \Lambda$

"The making of the Standard model"

S. Weinberg, Eur. Phys. J. C **34** (2004) 5

"I supposed that the vector gauge boson of this theory (of the strong interactions) would be the ρ-meson, while the axial-vector gauge boson would be the a_1 meson."
"… but I was applying it to the wrong kind of interactions. The right place to apply these ideas was not the strong interactions, but to the weak and electromagnetic interactions."

Nature provides us with one more type of axial-vector bosons $\boldsymbol{b_1}$ and $\boldsymbol{h_1}$.
What is their role for the high energy physics?

Technicolor

techni-pion, techni-ρ, techni-ω …

What's esle?

π^0 $\quad I^G(J^{PC}) = 1^-(0^{-+})$

Mass $m = 134.9766 \pm 0.0006$ MeV $\quad (S = 1.1)$
$m_{\pi^\pm} - m_{\pi^0} = 4.5936 \pm 0.0005$ MeV
Mean life $\tau = (8.4 \pm 0.6) \times 10^{-17}$ s $\quad (S = 3.0)$
$c\tau = 25.1$ nm

$$\bar{q}\gamma^\mu q \cdot V_\mu$$

$$\bar{q}\gamma^\mu \gamma^5 q \cdot A_\mu$$

$\rho(770)$ [j] $\quad I^G(J^{PC}) = 1^+(1^{--})$

Mass $m = 775.49 \pm 0.34$ MeV
Full width $\Gamma = 149.1 \pm 0.8$ MeV
$\Gamma_{ee} = 7.04 \pm 0.06$ keV

$a_1(1260)$ [m] $\quad I^G(J^{PC}) = 1^-(1^{++})$

Mass $m = 1230 \pm 40$ MeV [n]
Full width $\Gamma = 250$ to 600 MeV

$\omega(782)$ $\quad I^G(J^{PC}) = 0^-(1^{--})$

Mass $m = 782.65 \pm 0.12$ MeV $\quad (S = 1.9)$
Full width $\Gamma = 8.49 \pm 0.08$ MeV
$\Gamma_{ee} = 0.60 \pm 0.02$ keV

$f_1(1285)$ $\quad I^G(J^{PC}) = 0^+(1^{++})$

Mass $m = 1281.8 \pm 0.6$ MeV $\quad (S = 1.6)$
Full width $\Gamma = 24.3 \pm 1.1$ MeV $\quad (S = 1.4)$

$$\bar{q}\sigma^{\mu\nu}\gamma^5 q \cdot \left(\partial_\mu A^*_\nu - \partial_\nu A^*_\mu\right)$$

? ? ?

Can we escape from SM prison?

Dark matter	Inflation	Gravitation	Baryon asymmetry	Hierarchy problem

SM slave

Motivation for SM extension

The main theoretical motivation for beyond the Standard Model physics around TeV energies (LHC) is provided by the Hierarchy Problem, an inexplicable the UltraViolet stability of the weak interaction scale ($M_{W,Z} = 10^2$ GeV) versus the Planck mass ($M_P = 10^{19}$ GeV),

WHY IS $M^2_{W,Z}/M^2_P = 10^{-34}$?

Introduction of new spin-1 bosons with the internal quantum numbers identical to the Standard Model Higgs doublet can help to solve by the Hierarchy Problem.

M. Chizhov and G. Dvali "Origin and Phenomenology of Weak-Doublet Spin-1 Bosons", arXiv:0908.0924

$$\begin{pmatrix} H^+ \\ H^0 \end{pmatrix} \leftrightarrow \begin{pmatrix} W^{*+}_\mu \\ Z^*_\mu \end{pmatrix}$$

We predict an existence of new excited chiral particles W* and Z* with new unique properties.

Z′, graviton and Z* angular distributions

Table 3.10. Angular distributions for the decay products of spin-1 and spin-2 resonances, considering only even terms in $\cos\theta^*$.

Channel	d-functions	Normalised density for $\cos\theta^*$
$q\bar{q} \to G^* \to f\bar{f}$	$\lvert d^2_{1,1}\rvert^2 + \lvert d^2_{1,-1}\rvert^2$	$P_q = \frac{5}{8}(1 - 3\cos^2\theta^* + 4\cos^4\theta^*)$
$gg \to G^* \to f\bar{f}$	$\lvert d^2_{2,1}\rvert^2 + \lvert d^2_{2,-1}\rvert^2$	$P_g = \frac{5}{8}(1 - \cos^4\theta^*)$
$q\bar{q} \to \gamma^*/Z^0/Z' \to f\bar{f}$	$\lvert d^1_{1,1}\rvert^2 + \lvert d^1_{1,-1}\rvert^2$	$P_1 = \frac{3}{8}(1 + \cos^2\theta^*)$
$d\bar{d} \to Z^* \to f\bar{f}$	$\lvert d^1_{0,0}\rvert^2$	$P_1^* = \frac{3}{2}\cos^2\theta^*$

3.3.6. Discriminating between different spin hypotheses

The fractions of generated events arising from these processes are denoted by ϵ_q, ϵ_g, and ϵ_1, respectively, with $\epsilon_q + \epsilon_g + \epsilon_1 = 1$. Then the form of the probability density $P(\cos\theta^*)$ is

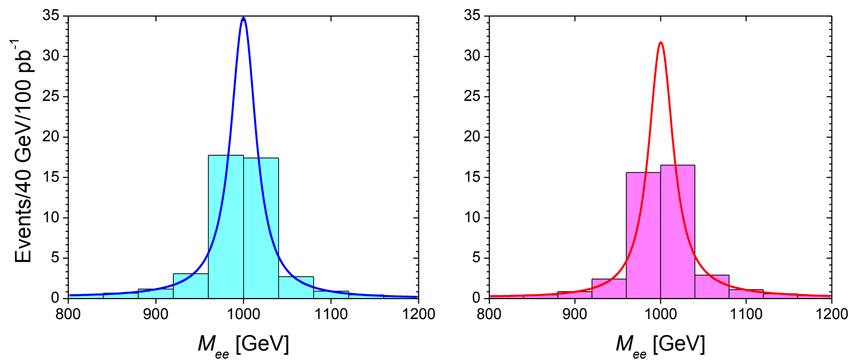
$$P(\cos\theta^*) = \epsilon_q P_q + \epsilon_g P_g + \epsilon_1 P_1. + \varepsilon_1^* P_1^* \qquad (3.24)$$

ATLAS is already looking for them!

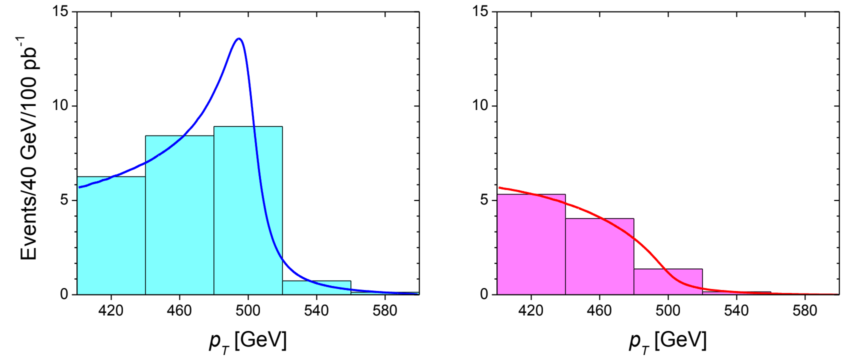
Theoretical comparision between Z′ and Z*

M. Chizhov, Disentangling between Z′ and Z* with first LHC data, arXiv:0807.5087

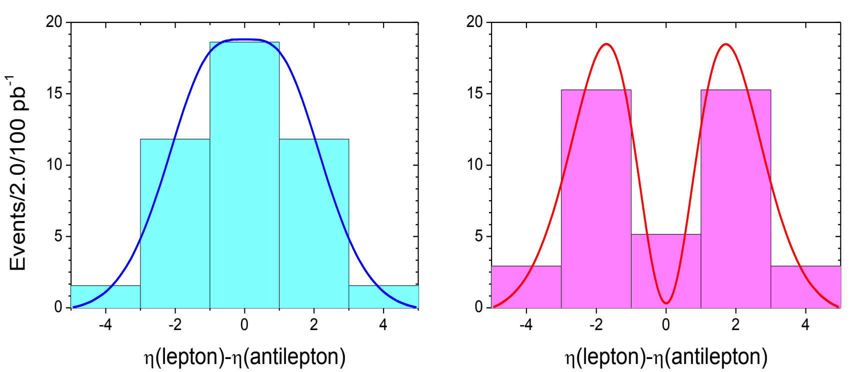
invariant mass



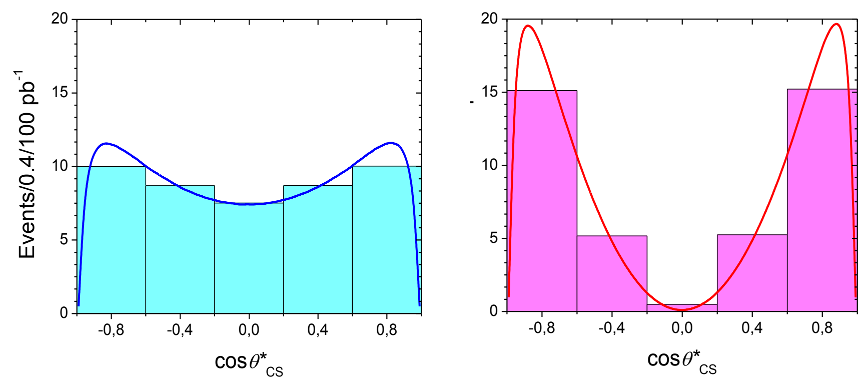
transverse momentum

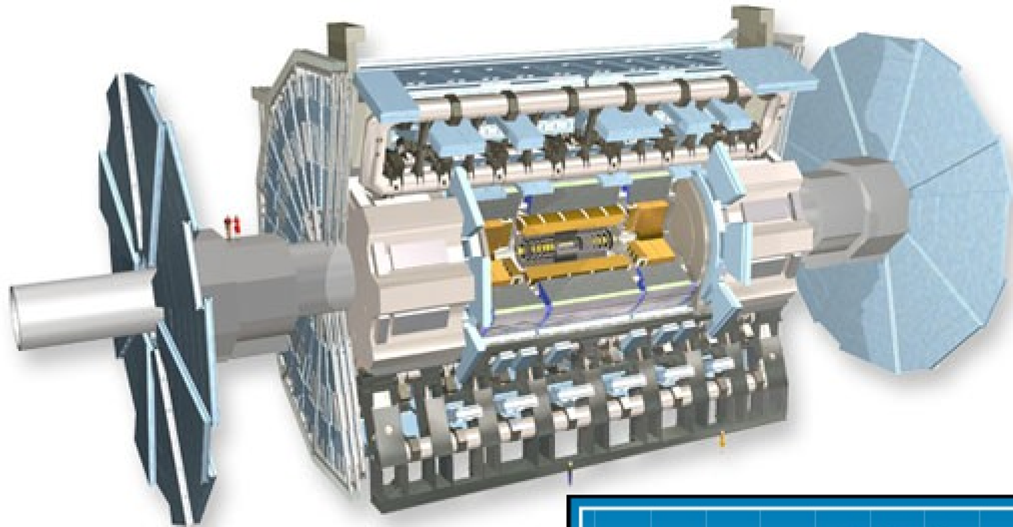


pseudorapidity difference

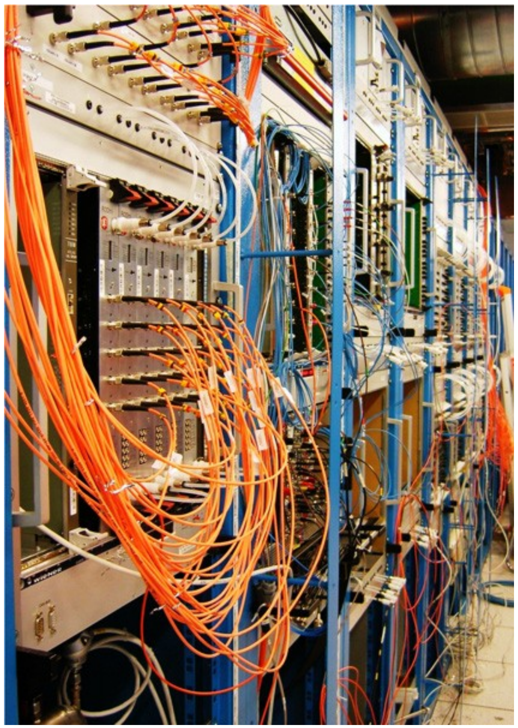


angular distribution





The ATLAS project is an international collaboration involving 38 countries, more than 3000 physicists and 1000 students from more than 174 universities and laboratories.



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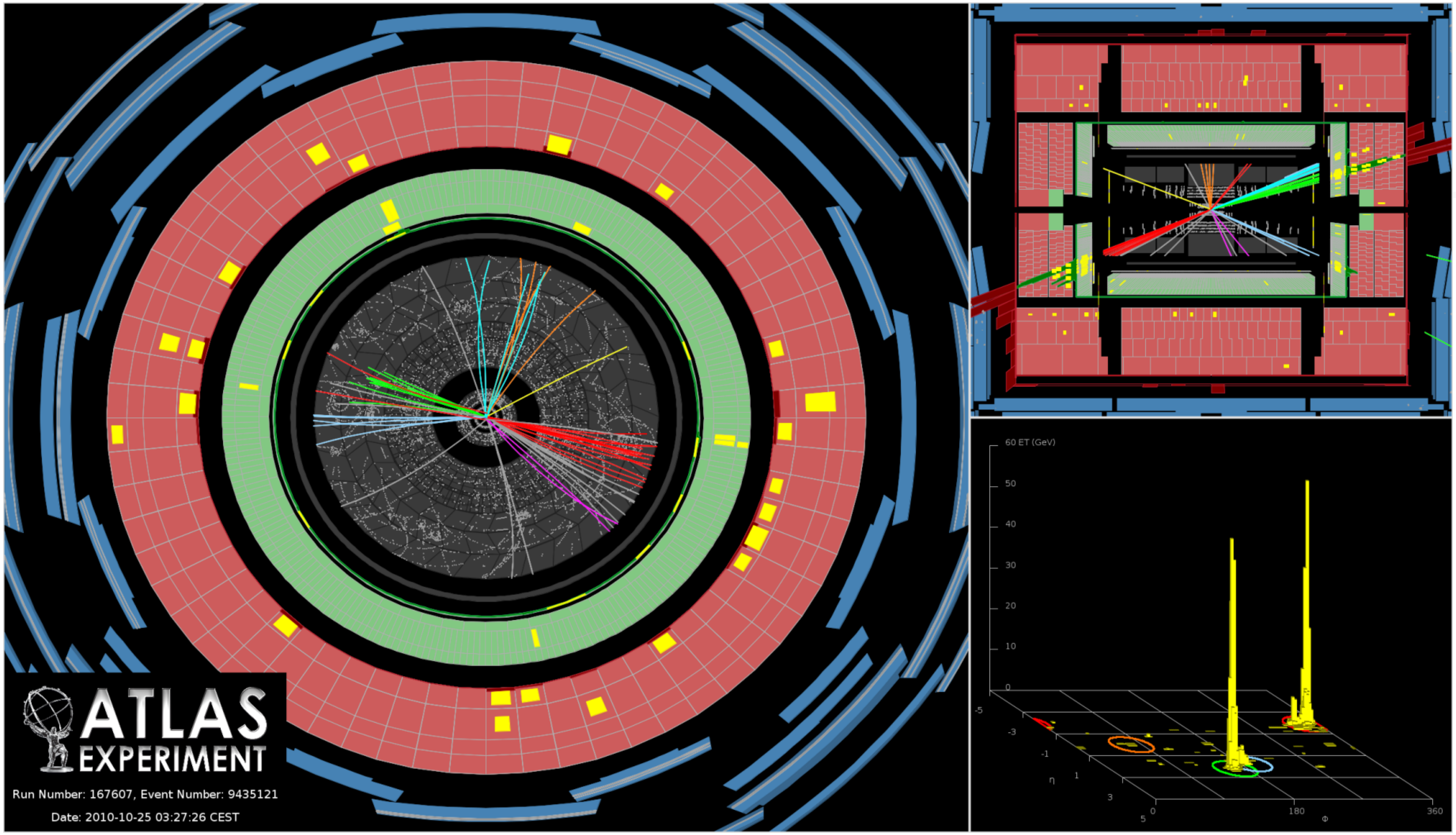
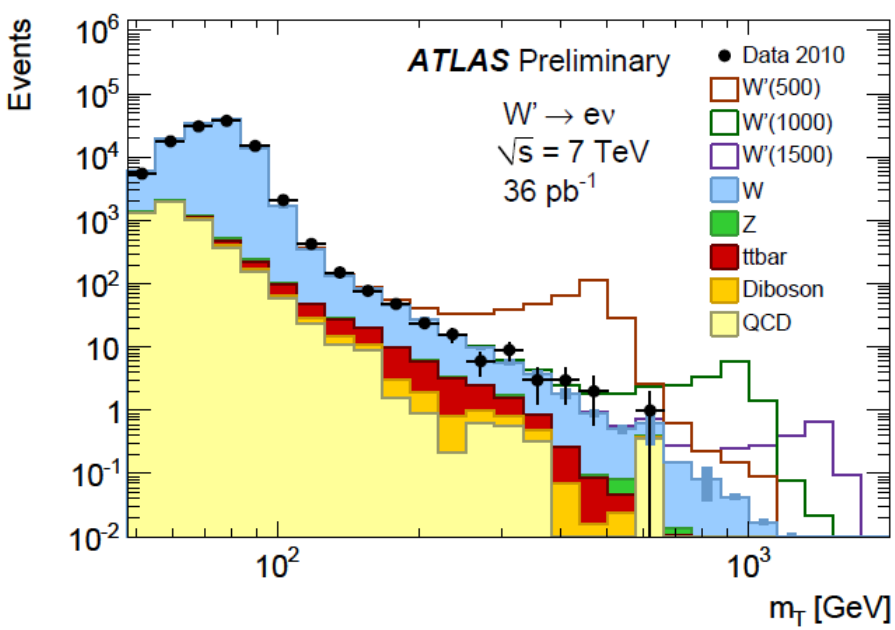


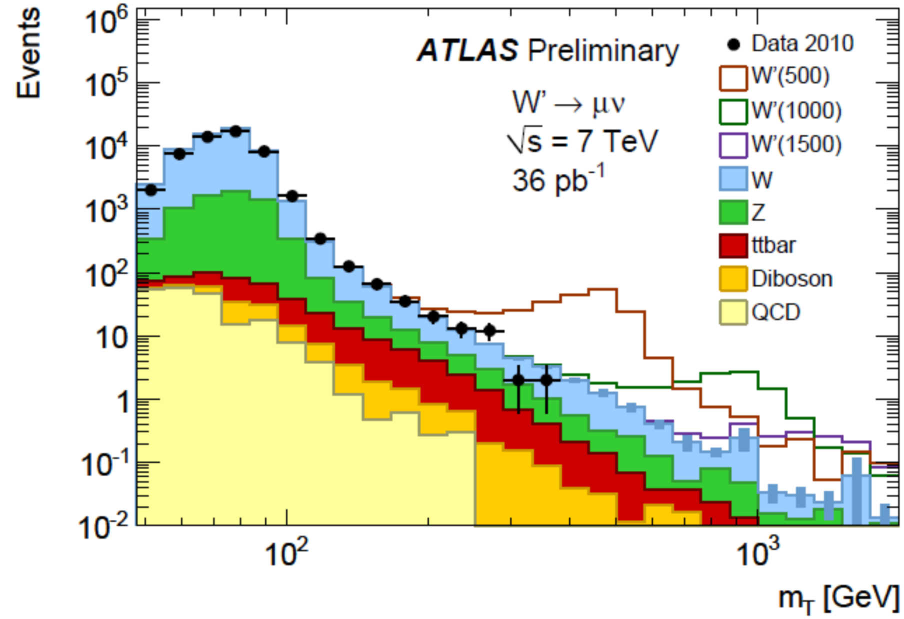
Event display of Run 167607, Event 9435121.
This shows the highest-mass dijet event collected during 2010, where the two leading jets in a forward-backward dijet system produce an invariant mass of 4.0 TeV. The two leading jets have (p_T, y) of (510 GeV, -1.9) and (510 GeV, 2.2), respectively. The missing E_T in the event is 31 GeV.

4 TeV ~ 50 zm (zeptometer = 10^{-21} m) !

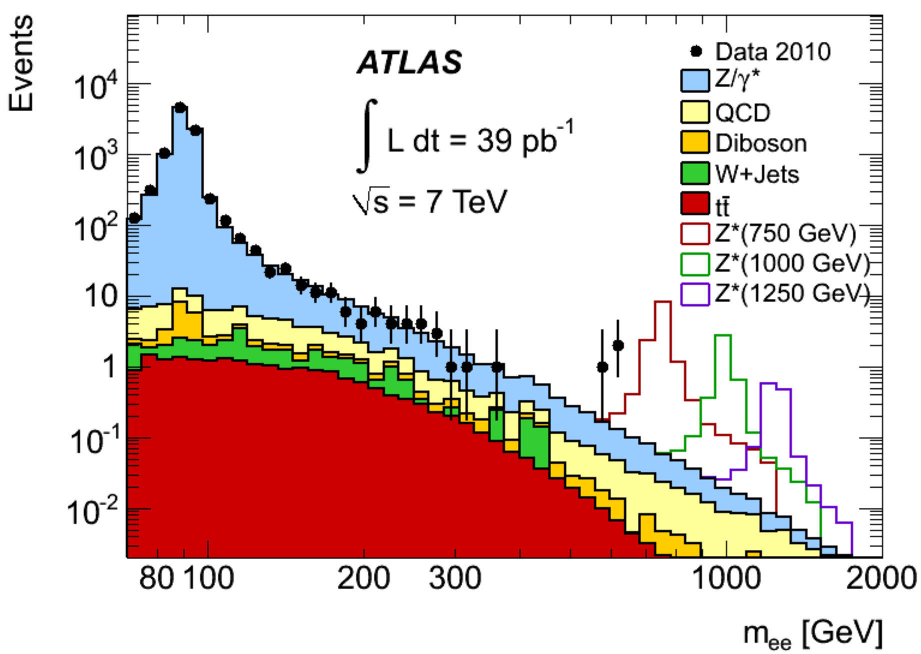
17,000 times smaller than the proton size!



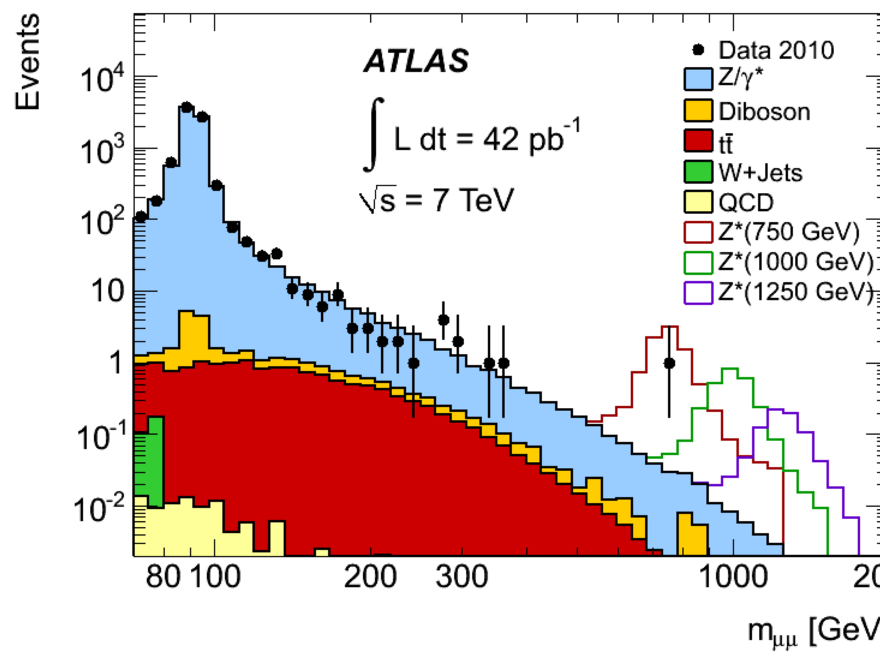
ATLAS Preliminary
W' → eν
√s = 7 TeV
36 pb-1
Data 2010
W'(500)
W'(1000)
W'(1500)
W
Z
ttbar
Diboson
QCD
Events
m_T [GeV]



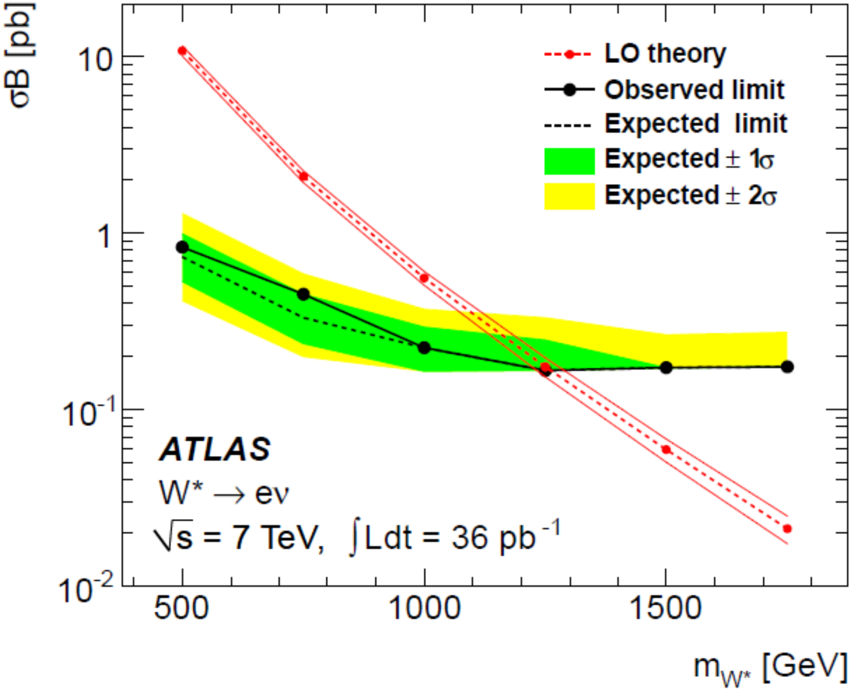
ATLAS Preliminary
W' → μν
√s = 7 TeV
36 pb-1
Data 2010
W'(500)
W'(1000)
W'(1500)
W
Z
ttbar
Diboson
QCD
Events
m_T [GeV]

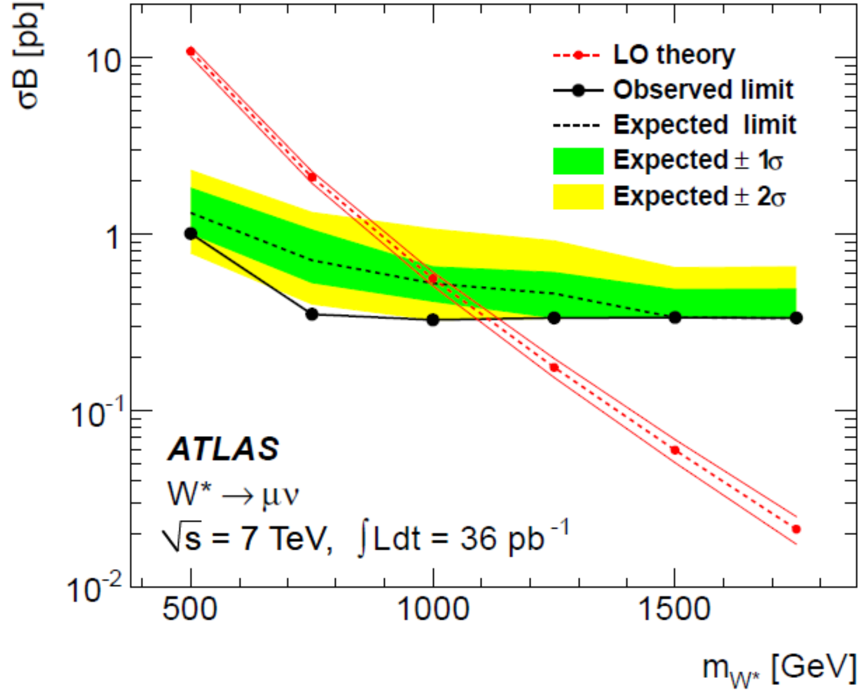


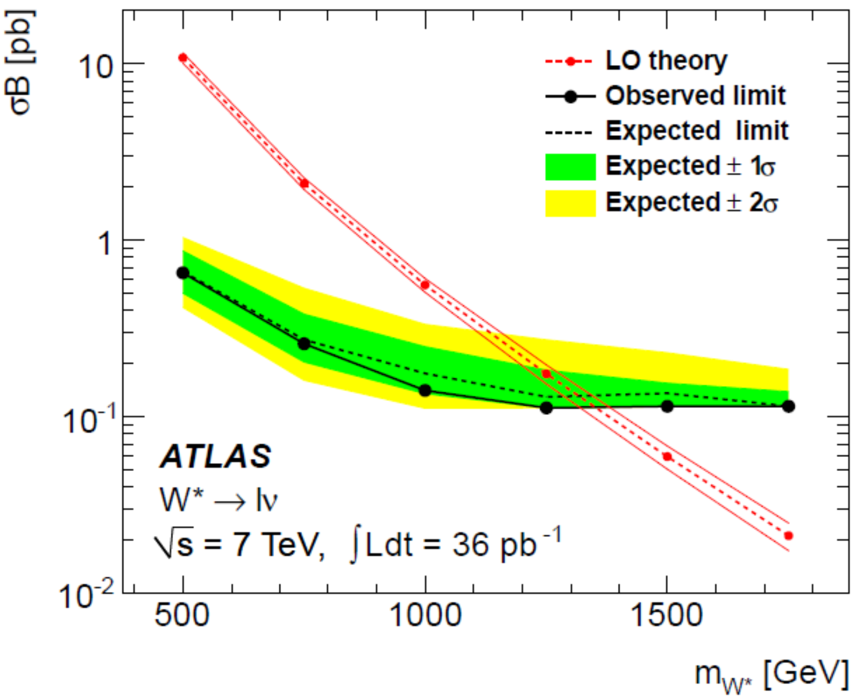
ATLAS
∫ L dt = 39 pb-1
√s = 7 TeV
Data 2010
Z/γ*
QCD
Diboson
W+Jets
tt̄
Z*(750 GeV)
Z*(1000 GeV)
Z*(1250 GeV)
Events
m_ee [GeV]



ATLAS
∫ L dt = 42 pb-1
√s = 7 TeV
Data 2010
Z/γ*
Diboson
tt̄
W+Jets
QCD
Z*(750 GeV)
Z*(1000 GeV)
Z*(1250 GeV)
Events
m_μμ [GeV]

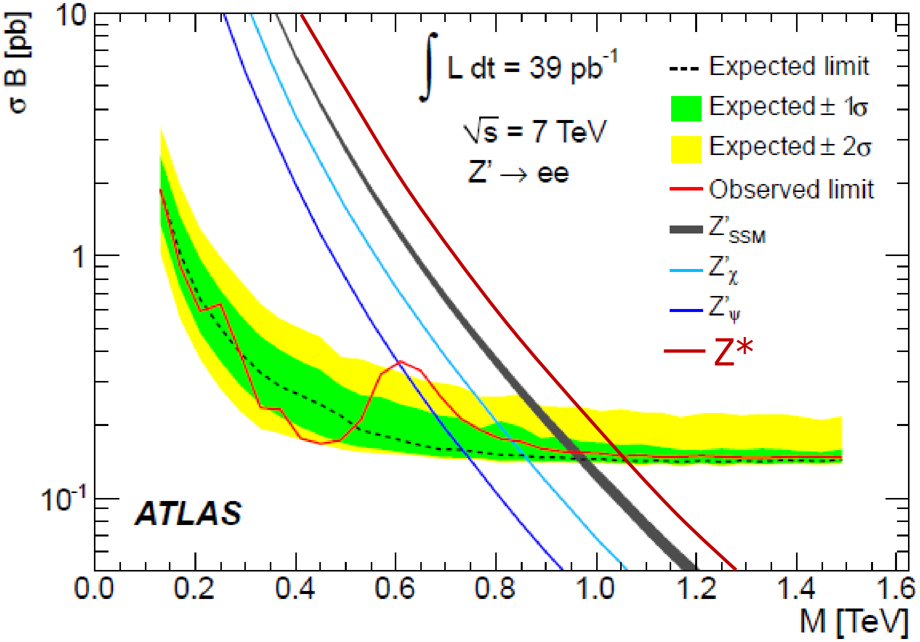


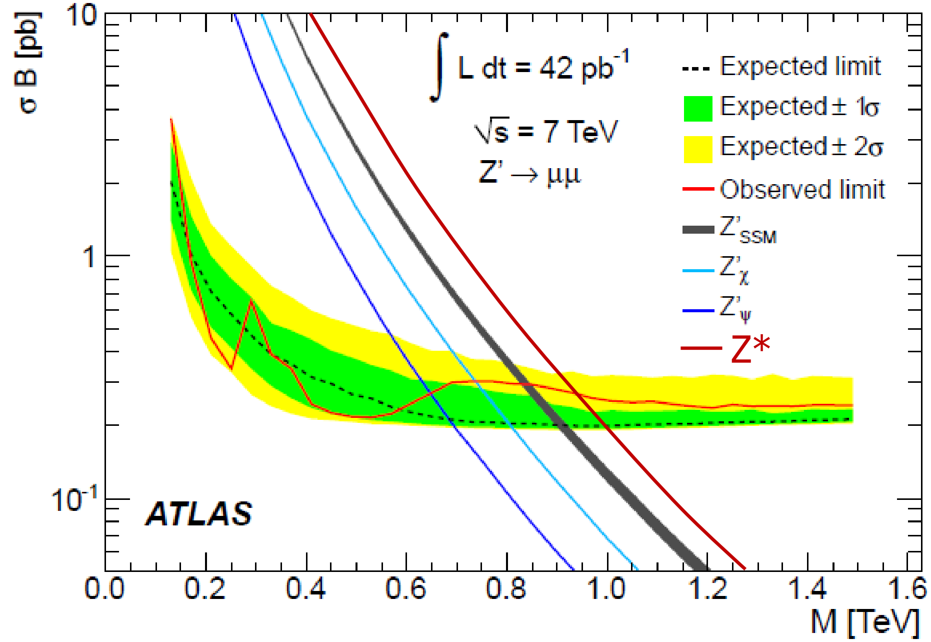


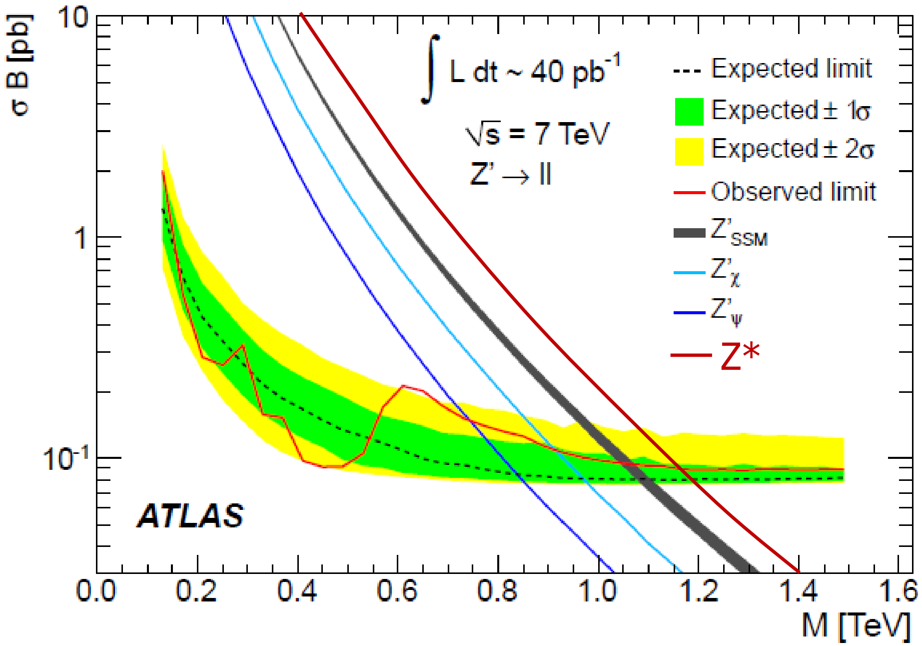


	Mass limit [GeV]			
	W'		W^*	
decay	Exp.	Obs.	Exp.	Obs.
$e\nu$	1370	1370	1260	1260
$\mu\nu$	1210	1290	1020	1120
both	1450	1490	1320	1350

The ATLAS Collaboration "Search for high-mass states with one lepton plus missing transverse momentum in proton-proton collisions at √s = 7 TeV with the ATLAS detector", arXiv:1103.1391, submitted to Physics Letter B







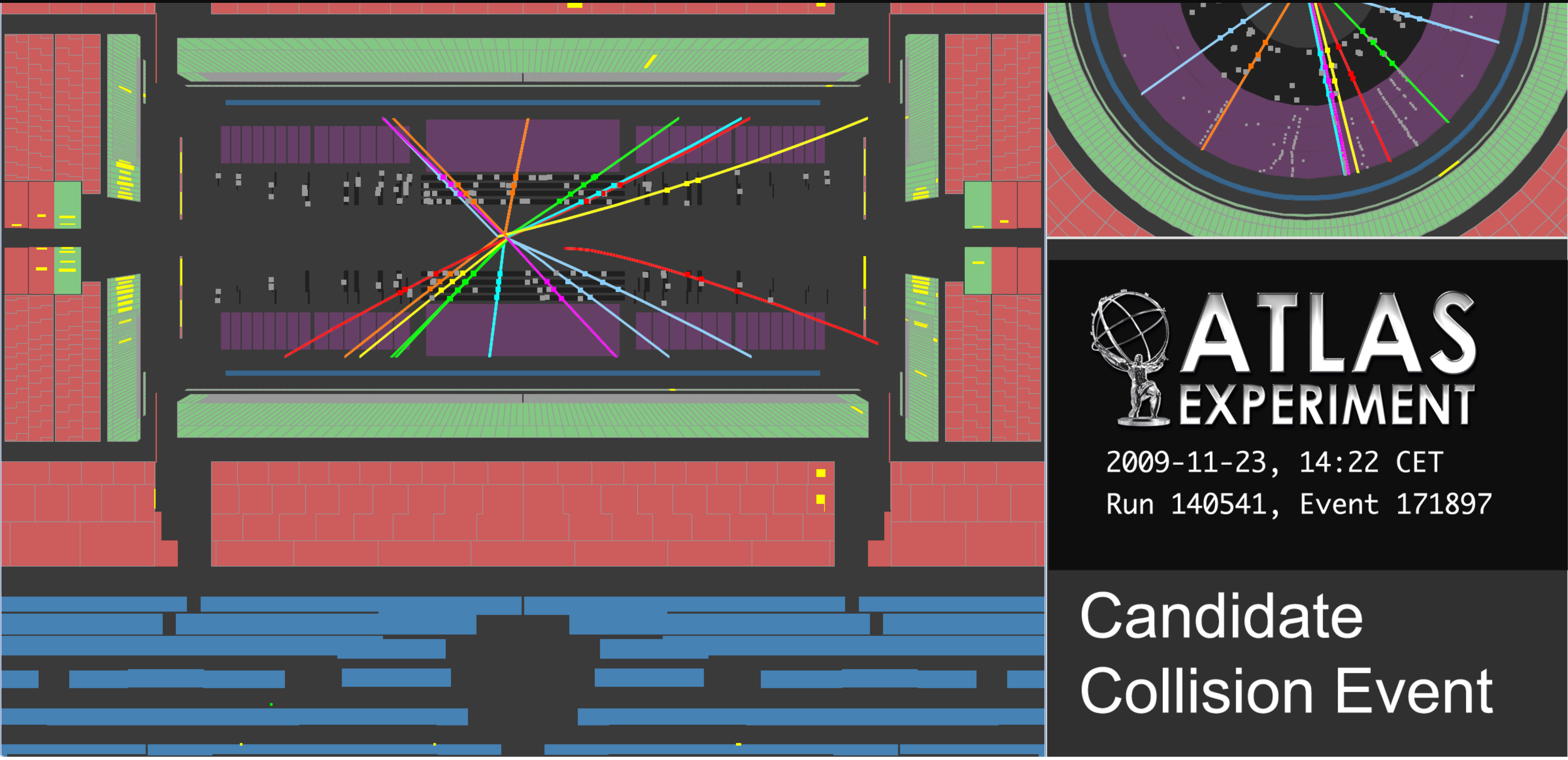
	Observed limit		Expected limit	
	mass [TeV]	σB [pb]	mass [TeV]	σB [pb]
$Z'_{\rm SSM} \to e^+e^-$	0.957	0.155	0.967	0.145
$Z'_{\rm SSM} \to \mu^+\mu^-$	0.834	0.297	0.900	0.201
$Z'_{\rm SSM} \to \ell^+\ell^-$	1.048	0.094	1.088	0.081

Model	Z'_ψ	$Z'_{\rm N}$	Z'_η	Z'_I	$Z'_{\rm S}$	Z'_χ
Mass limit [TeV]	0.738	0.763	0.771	0.842	0.871	0.900

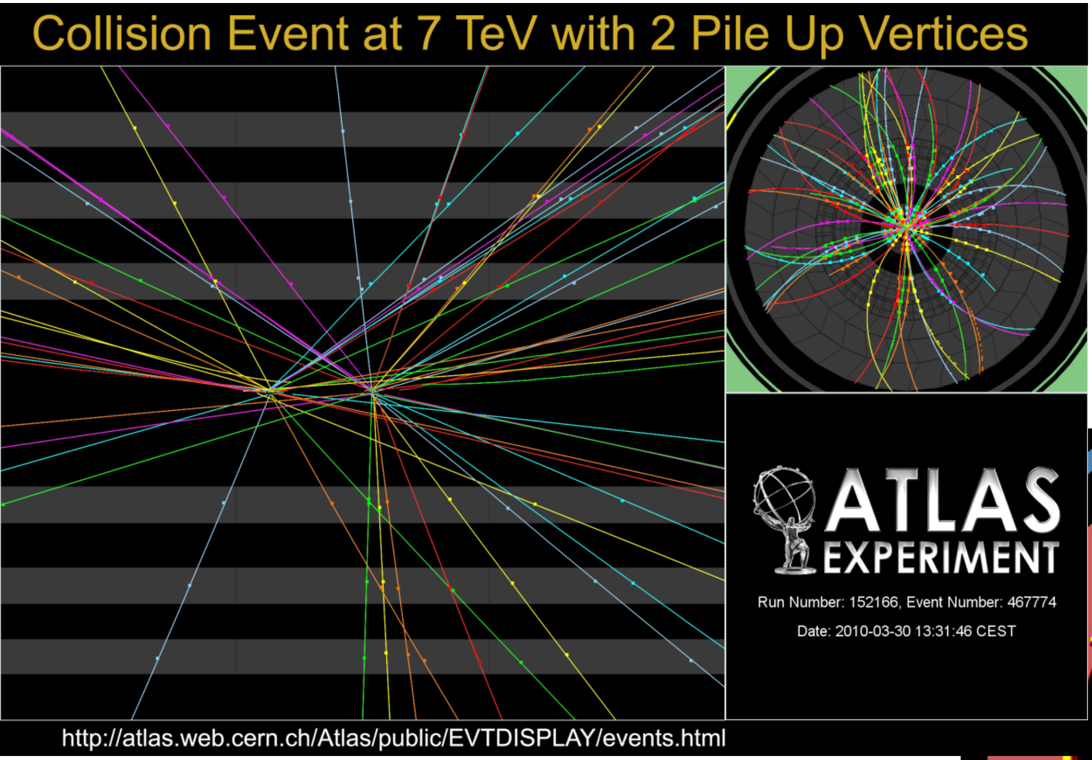
	Observed limit		Expected limit	
	mass [TeV]	σB [pb]	mass [TeV]	σB [pb]
$Z^* \to e^+e^-$	1.058	0.149	1.062	0.143
$Z^* \to \mu^+\mu^-$	0.946	0.265	0.995	0.199
$Z^* \to \ell^+\ell^-$	1.152	0.089	1.185	0.080

The ATLAS Collaboration "Search for high mass dilepton resonances in *pp* collisions at √s=7 TeV with the ATLAS experiment", arXiv:1103.6218, submitted to Physics Letter B

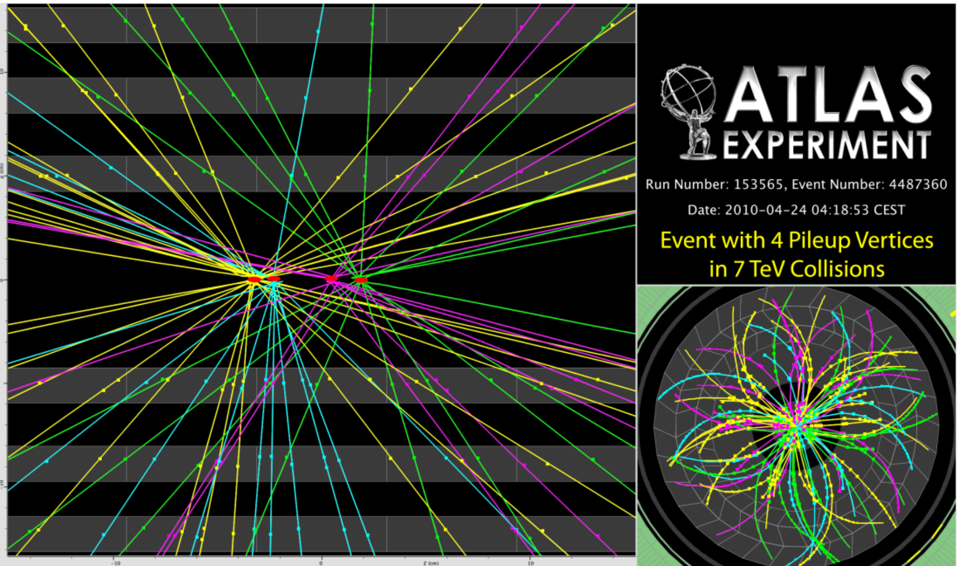
We were lucky - shortly after colliding beams were announced, at 14:22 an interesting event appeared on our screens



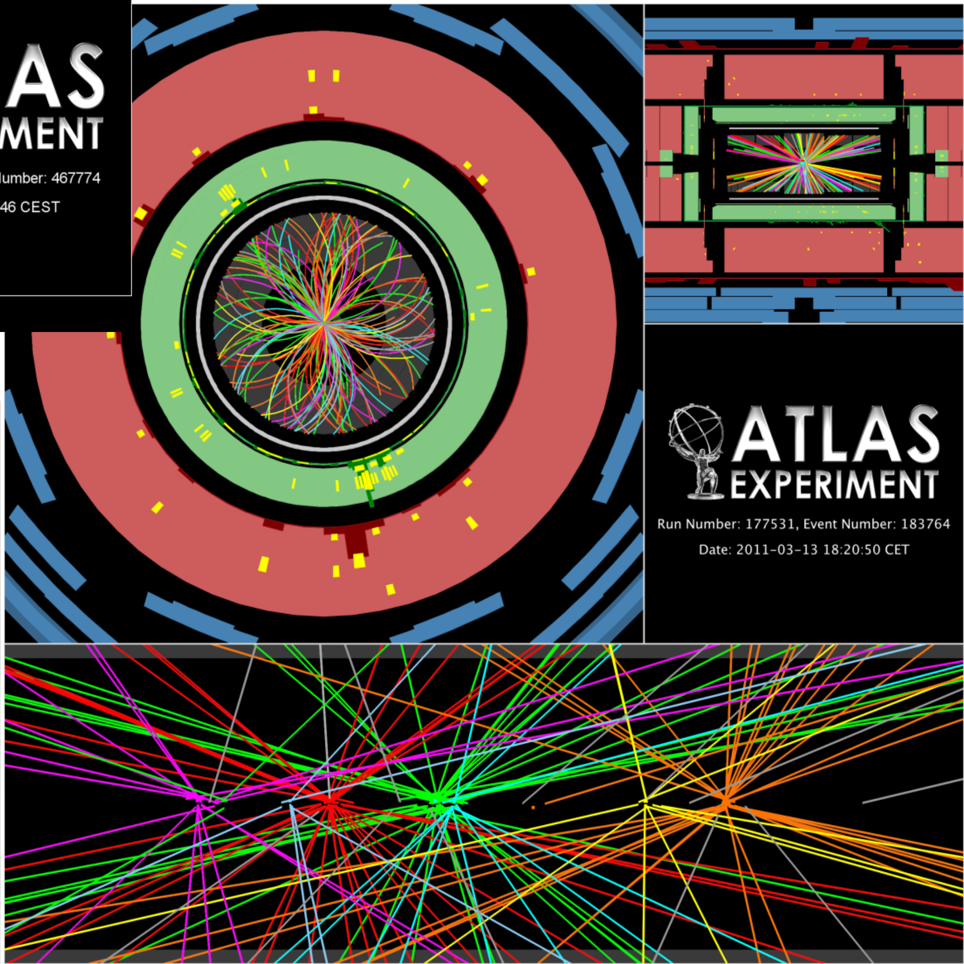
Pile Up!



Collision Event at 7 TeV with 2 Pile Up Vertices
ATLAS EXPERIMENT
Run Number: 152166, Event Number: 467774
Date: 2010-03-30 13:31:46 CEST
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html



ATLAS EXPERIMENT
Run Number: 153565, Event Number: 4487360
Date: 2010-04-24 04:18:53 CEST
Event with 4 Pileup Vertices
in 7 TeV Collisions



ATLAS EXPERIMENT
Run Number: 177531, Event Number: 183764
Date: 2011-03-13 18:20:50 CET

Production of new chiral particles

stay tuned ...

IL NUOVO CIMENTO Vol. 87 A, N. 3 1 Giugno 1985

Quantum Field Theory and a New Universal High-Energy Scale.

II. - Gauge Vector Fields.

M. V. Chizhov, A. D. Donkov (*), R. M. Ibadov (**)
V. G. Kadyshevsky and M. D. Mateev (*)

Joint Institute for Nuclear Research
Laboratory of Theoretical Physics, Dubna, U.S.S.R.

IL NUOVO CIMENTO Vol. 87 A, N. 4 21 Giugno 1985

Quantum Field Theory and a New Universal High-Energy Scale.

III. - Dirac Fields.

M. V. Chizhov, A. D. Donkov, R. M. Ibadov (*)
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Joint Institute for Nuclear Research, Dubna, U.S.S.R.

Excited particles (compositeness)

$$\mathcal{L}_{\psi^*} = \frac{g}{\Lambda} \bar{\psi}^* \sigma^{\mu\nu} \psi \cdot \left(\partial_\mu Z_\nu - \partial_\nu Z_\mu \right)$$

Searches for excited fermions ψ^* have been performed at LEP, HERA and the Tevatron, and are also planned for the CMS and ATLAS experiments at the LHC.

ψ^* why not Z^*?

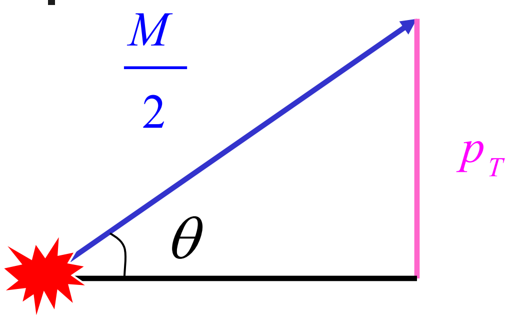
$$\mathcal{L}_{Z^*} = \frac{g}{\Lambda} \bar{\psi} \sigma^{\mu\nu} \psi \cdot \left(\partial_\mu Z^*_\nu - \partial_\nu Z^*_\mu \right)$$

M. C., V. A. Bednyakov, and J. A. Budagov, Proposal for chiral bosons search at LHC via their unique new signature, *Phys. Atom. Nucl.* **71** (2008) 2096; arXiv:0801.4235

Z^* has different interactions than Z'!

$$\mathcal{L}_{Z'} = \bar{\psi} \gamma^\mu \left(g_V + g_A \gamma^5 \right) \psi \cdot Z'_\mu$$

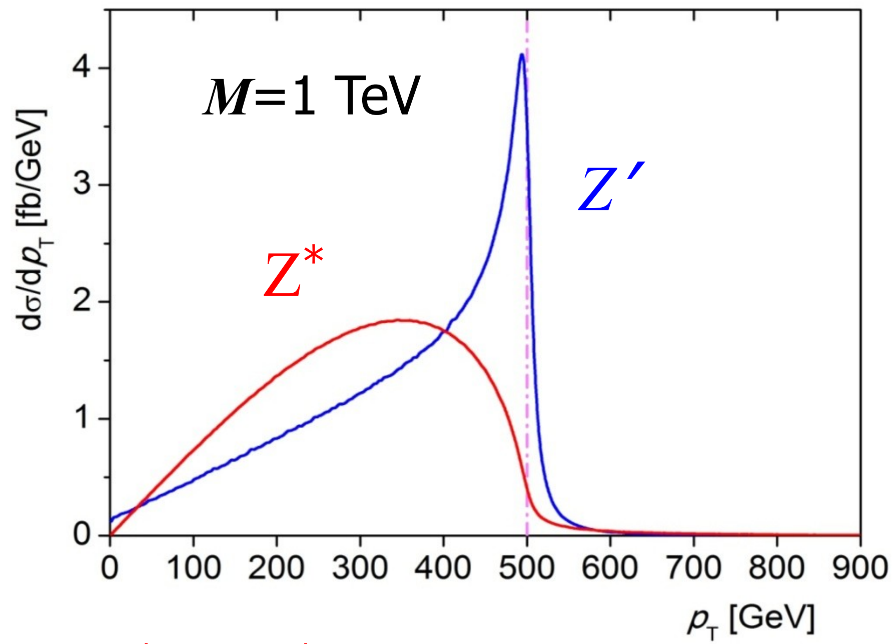
Jacobian factor for $\cos\theta \to p_T$



$$p_L = \frac{M}{2}\cos\theta$$

$$\cos\theta = \sqrt{1 - \frac{4p_T^2}{M^2}};$$

$$\frac{d\cos\theta}{d p_T^2} = -\frac{2}{M^2\cos\theta};$$



$$\frac{d\sigma}{dp_T^2} = \left|\frac{d\cos\theta}{dp_T^2}\right| \cdot \frac{d\sigma}{d\cos\theta} = \frac{2}{M^2\cos\theta} \cdot \frac{d\sigma}{d\cos\theta}$$

"The divergence at $\theta = \pi/2$ which is the upper endpoint $p_T \approx M/2$ of the p_T distribution stem from the Jacobian factor and is known as a *Jacobian peak* ; it is characteristic of **all** two-body decays …"

w r o n g ! V. Barger "Collider physics"

Hadron colliders

or search for heavy bosons beyond $W^{\pm}$ and Z

A hadron collider is the discovery machine. The production mechanism for new bosons at a hadron collider is $q\bar{q}$ annihilation. A presence of partons with a broad range of different momenta allows to flush the whole energetically accessible region, roughly, up to

$$M = \sqrt{x_1 x_2} E_{CM} \approx \bar{x} E_{CM} \leq \frac{E_{CM}}{6} \quad \left(\bar{x} \approx \frac{1}{2} \times \frac{1}{3} \right) \quad \text{(rule of thumb)}$$

$p\overset{(-)}{p}$ colliders (Tevatron: 6.3 km)

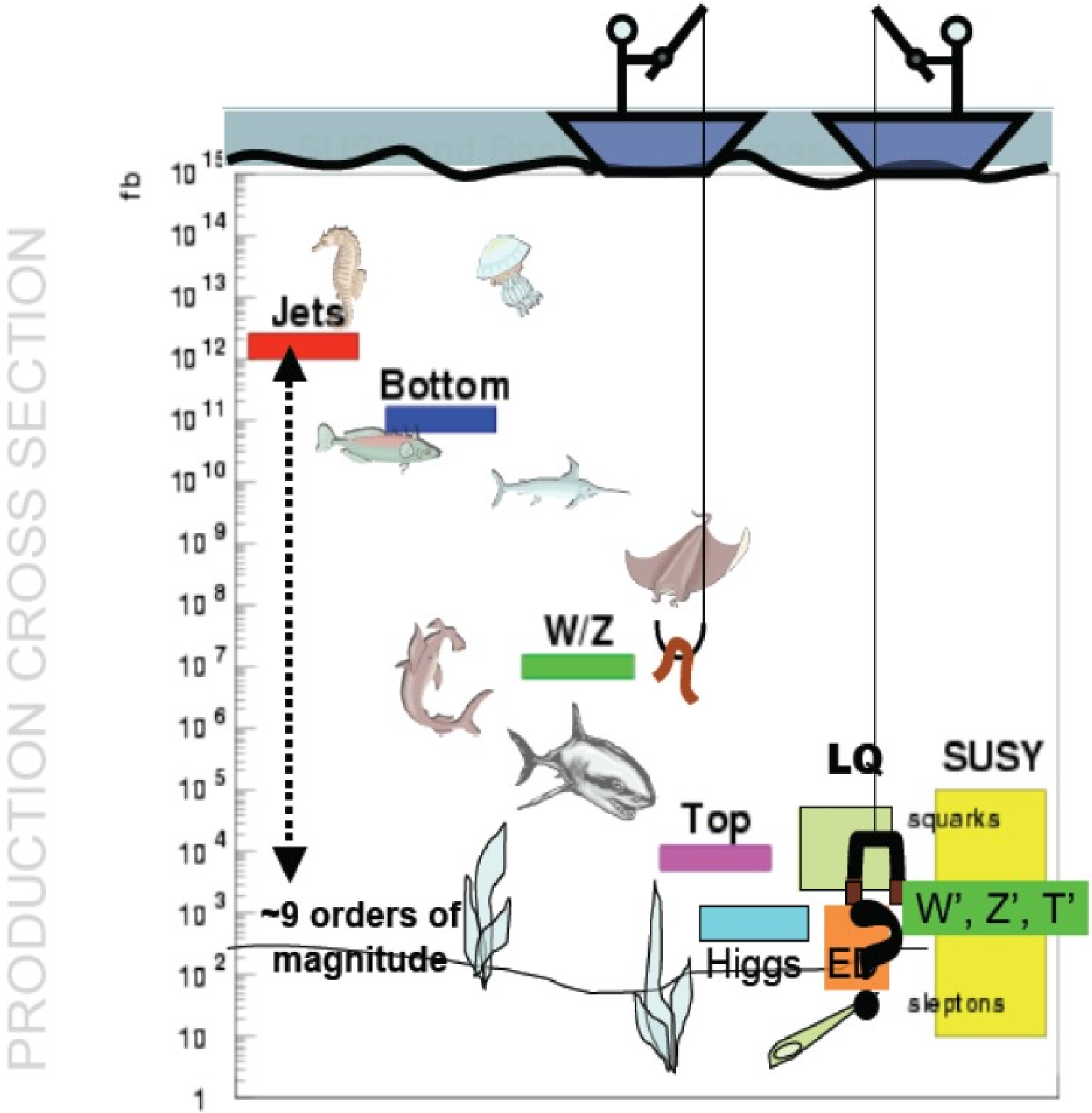
$$E_p = 980 \text{ GeV}, E_{\bar{p}} = 980 \text{ GeV}; \; E_{CM} = 1960 \text{ GeV}$$

$$\rightarrow 1960 \text{ GeV}/6 \approx 330 \text{ GeV}$$

(LHC: 27 km)

$$E_p = 7\,000 \; (3500) \text{ GeV}, E_p = 7\,000 \; (3500) \text{ GeV}; \; E_{CM} = 14\,000 \; (7000) \text{ GeV}$$

$$\rightarrow 14000 \; (7000) \text{ GeV}/6 \approx 2\,330 \; (1165) \text{ GeV}$$



From Aurelio Juste talk

proton - (anti)proton cross sections