Search for new type resonances in dilepton LHC data

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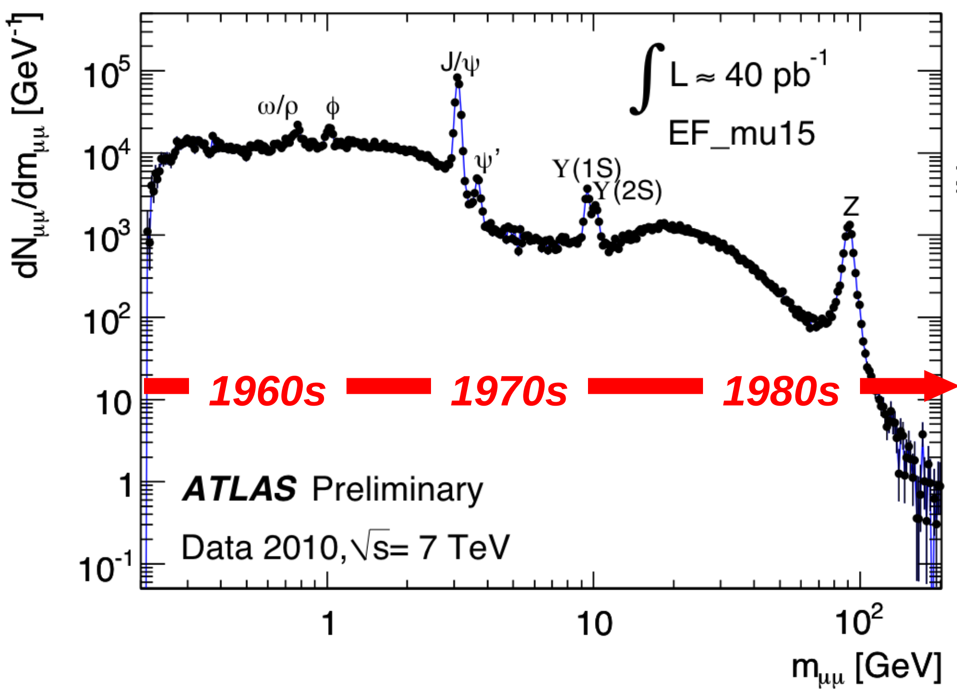
Di-Muon and Di-Electron Spectra

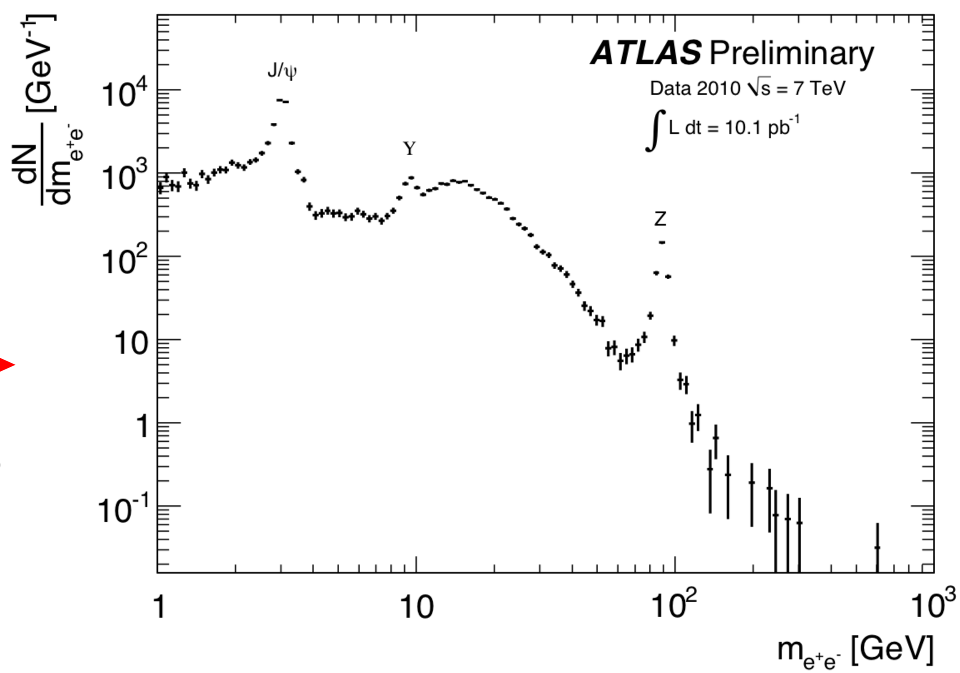
Di-Muon:

- Leading muon, p_T>15 GeV, second muon, p_T>2.5 GeV

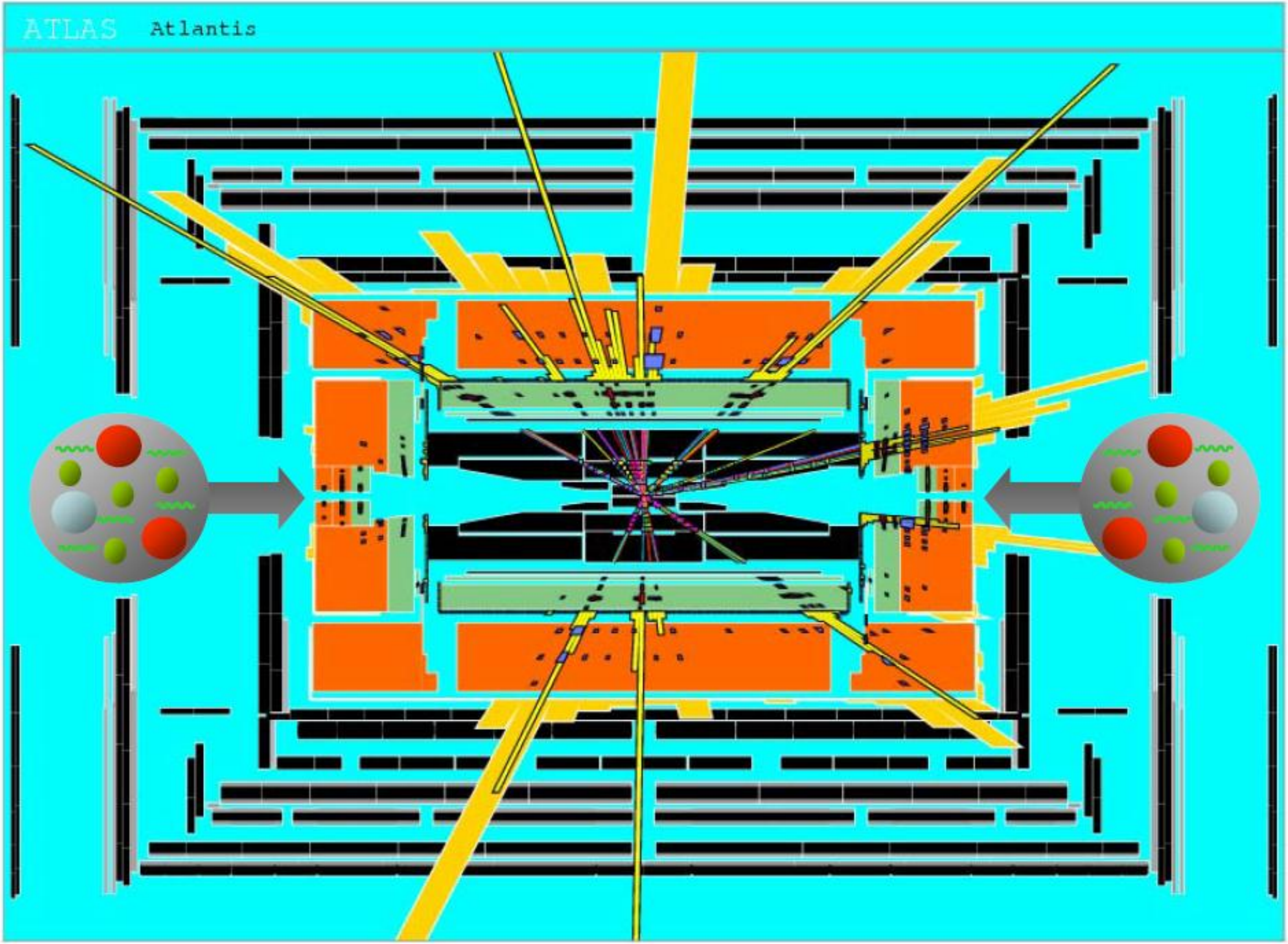
Di-electron:

- Data with 5 GeV E_T di-electron trigger (prescaled in later data)
- Trigger selection produces shoulder around 15 GeV

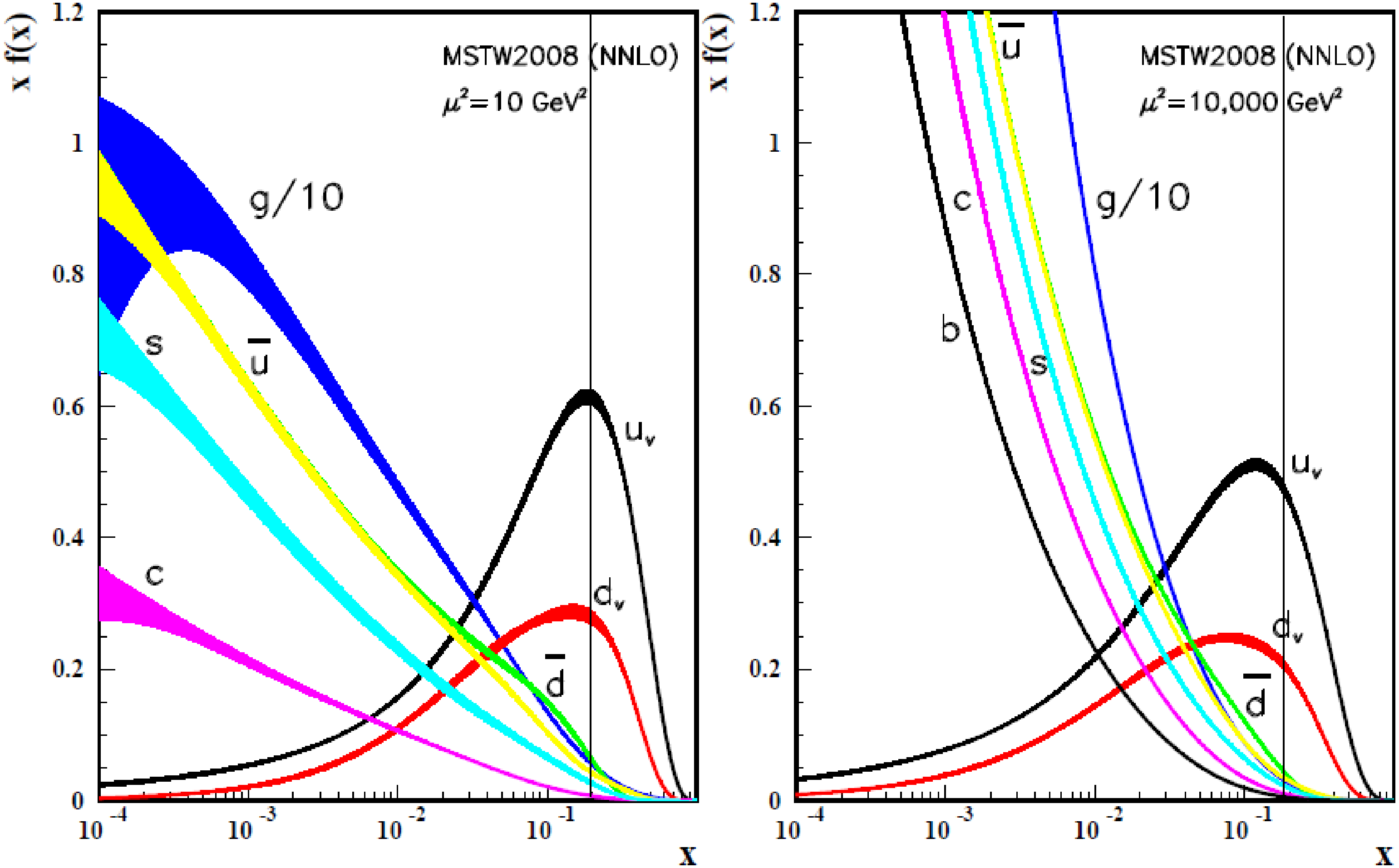




E_p =3.5 TeV is fixed!

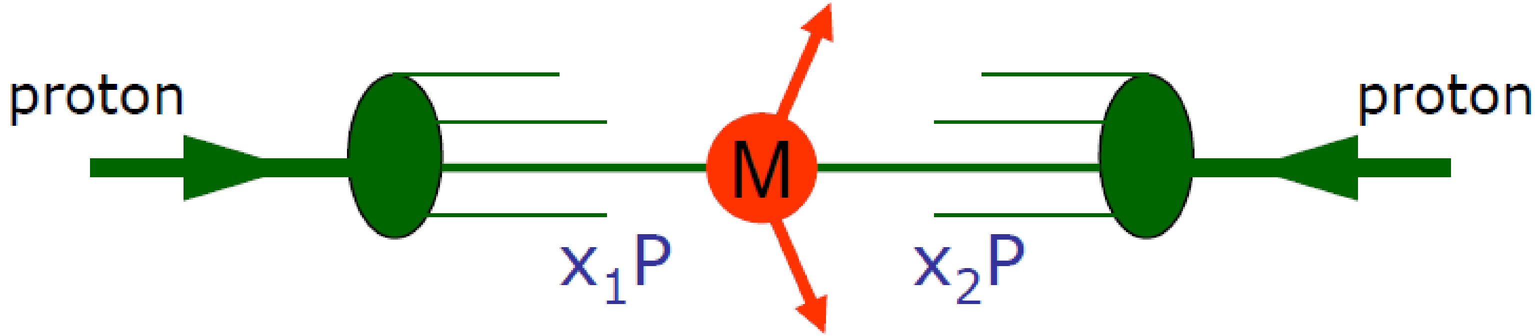

ATLAS
Atlantis

Parton Distribution Functions (PDFs)



x is the fraction of the proton's momentum carried by the selected quark.

Resonance production



$$q+\bar{q}\to Z^{*}\to \ell^{+}+\ell^{-}$$

collision energy: $\sqrt{s}=E_{\text{beam}}+E_{\text{beam}}$

patron momenta: $p_1=x_1E\left(1,0,0,1\right)$
$p_2=x_2E\left(1,0,0,-1\right)$

Mandelstam invariants: $\hat{t}=\left(p_1-\ell_1\right)^2,$

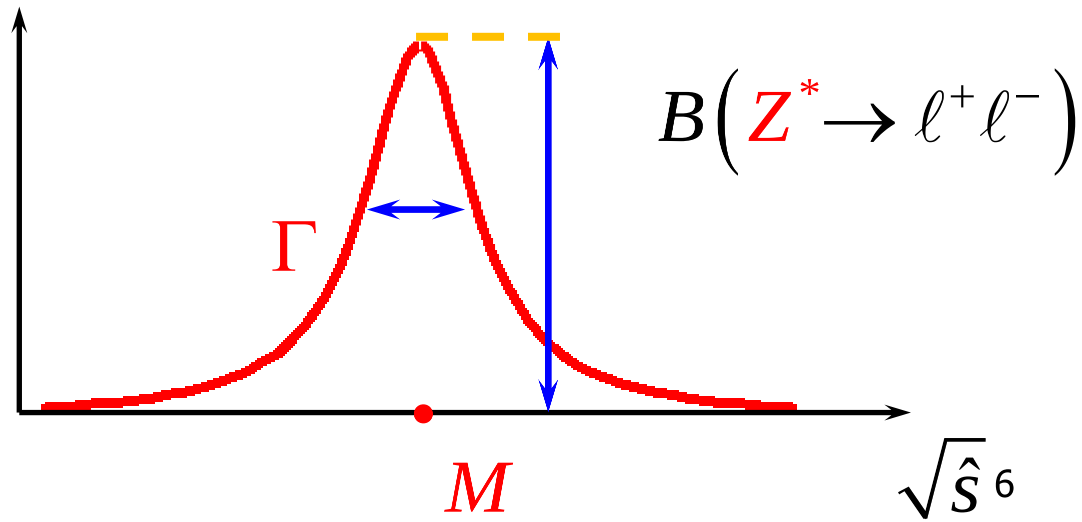
$\hat{u}=\left(p_1-\ell_2\right)^2,\ \hat{s}=\left(p_1+p_2\right)^2=x_1x_2s$

Cross section

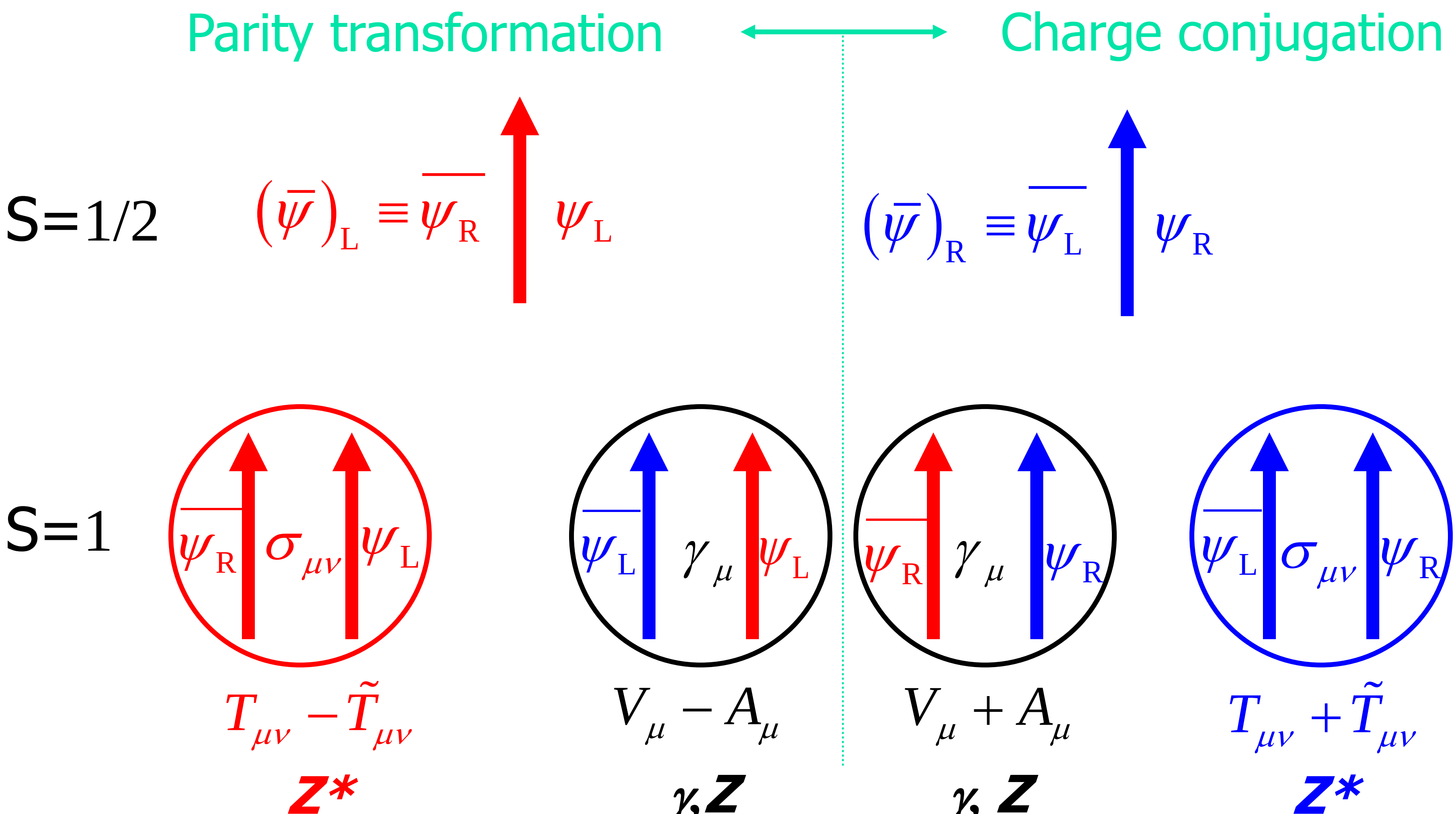
$$\sigma_{Z^*} B\left(Z^* \to \ell^+\ell^-\right) = \sum_{q,\bar{q}} \int_0^1 dx_1 \int_0^1 dx_2\, f_q\left(x_1,\mu^2\right) f_{\bar{q}}\left(x_2,\mu^2\right)$$

$$\times \quad \hat{\sigma}_{q\bar{q}\to Z^*}\left(\hat{s},\hat{t},\hat{u},M,\mu^2\right) B\left(Z^* \to \ell^+\ell^-\right)$$

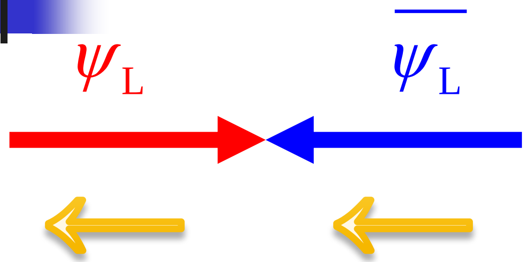
$$\to \frac{A\left(\hat{s},\hat{t},\hat{u}\right) B\left(Z^* \to \ell^+\ell^-\right)}{\left(\hat{s}-M^2\right)^2 + M^2\Gamma^2}$$



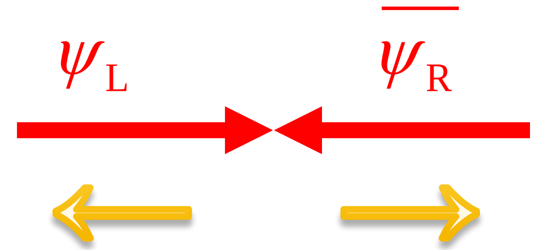
Spin-1 states



Minimal and anomalous couplings

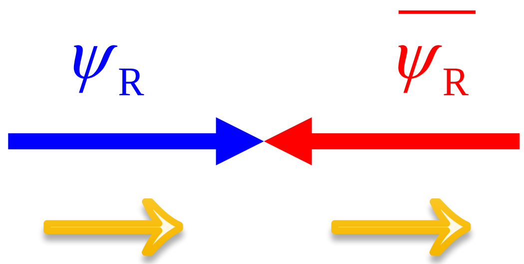


$$\overline{\psi_L}\gamma^\mu\psi_L\cdot\left(V_\mu - A_\mu\right)$$

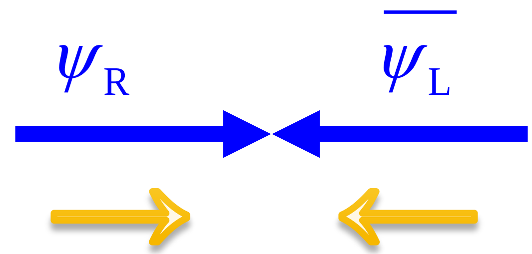


$$\overline{\psi_R}\sigma^{\mu\nu}\psi_L\cdot\left(T_{\mu\nu}-\tilde{T}_{\mu\nu}\right)\Rightarrow$$

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



$$\overline{\psi_R}\gamma^\mu\psi_R\cdot\left(V_\mu + A_\mu\right)$$



$$\overline{\psi_L}\sigma^{\mu\nu}\psi_R\cdot\left(T_{\mu\nu}+\tilde{T}_{\mu\nu}\right)\Rightarrow$$

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

Antisymmetric Tensor Fields (the massive case)

$$T_{\mu\nu} = \frac{1}{M}\left(\partial_\mu V_\nu^* - \partial_\nu V_\mu^*\right) - \frac{1}{2M}\varepsilon_{\mu\nu\alpha\beta}\left(\partial_\alpha A_\beta^* - \partial_\beta A_\alpha^*\right)$$

6 = 3 + 3

$$V_\mu^* = \frac{1}{M}\partial_\nu T_{\mu\nu} \Rightarrow \left(\partial_\mu V_\mu^* \equiv 0\right); \quad A_\mu^* = \frac{\varepsilon_{\mu\nu\alpha\beta}}{2M}\partial_\nu T_{\alpha\beta} \Rightarrow \left(\partial_\mu A_\mu^* \equiv 0\right)$$

$$\frac{g}{2}\overline{\Psi_R}\sigma_{\mu\nu}\Psi_L \cdot (T_{\mu\nu} - \tilde{T}_{\mu\nu}) + \frac{g}{2}\overline{\Psi_L}\sigma_{\mu\nu}\Psi_R \cdot (T_{\mu\nu} + \tilde{T}_{\mu\nu}) =$$

$$= \frac{g}{M}\overline{\Psi}\sigma_{\mu\nu}\Psi\left(\partial_\mu V_\nu^* - \partial_\nu V_\mu^*\right) + i\frac{g}{M}\overline{\Psi}\sigma_{\mu\nu}\gamma^5\Psi\left(\partial_\mu A_\nu^* - \partial_\nu A_\mu^*\right)$$

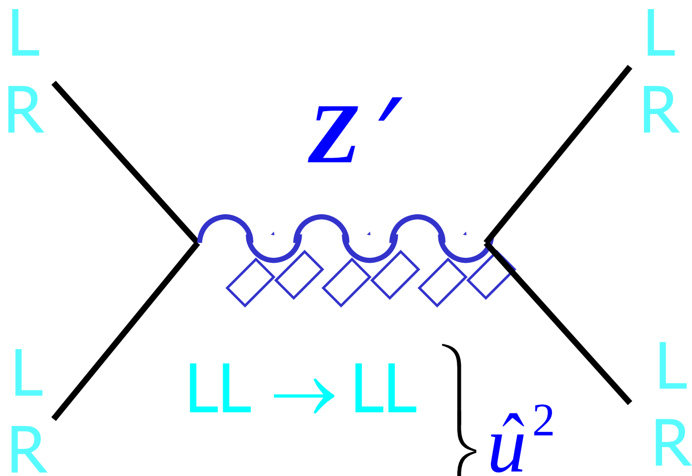
CP even — CP odd

Difference b/w Z′ and Z* couplings

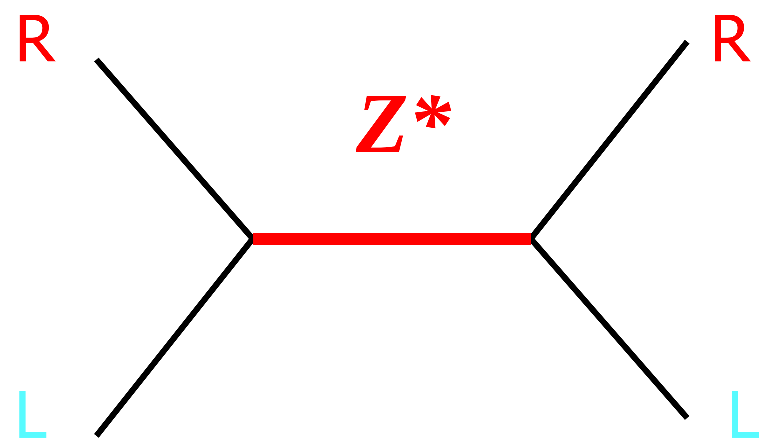
$$L_{Z'} = \bar{\psi}\,\gamma^{\mu}\left(g_V - g_A\gamma^5\right)\psi \cdot Z'_{\mu}$$

and

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



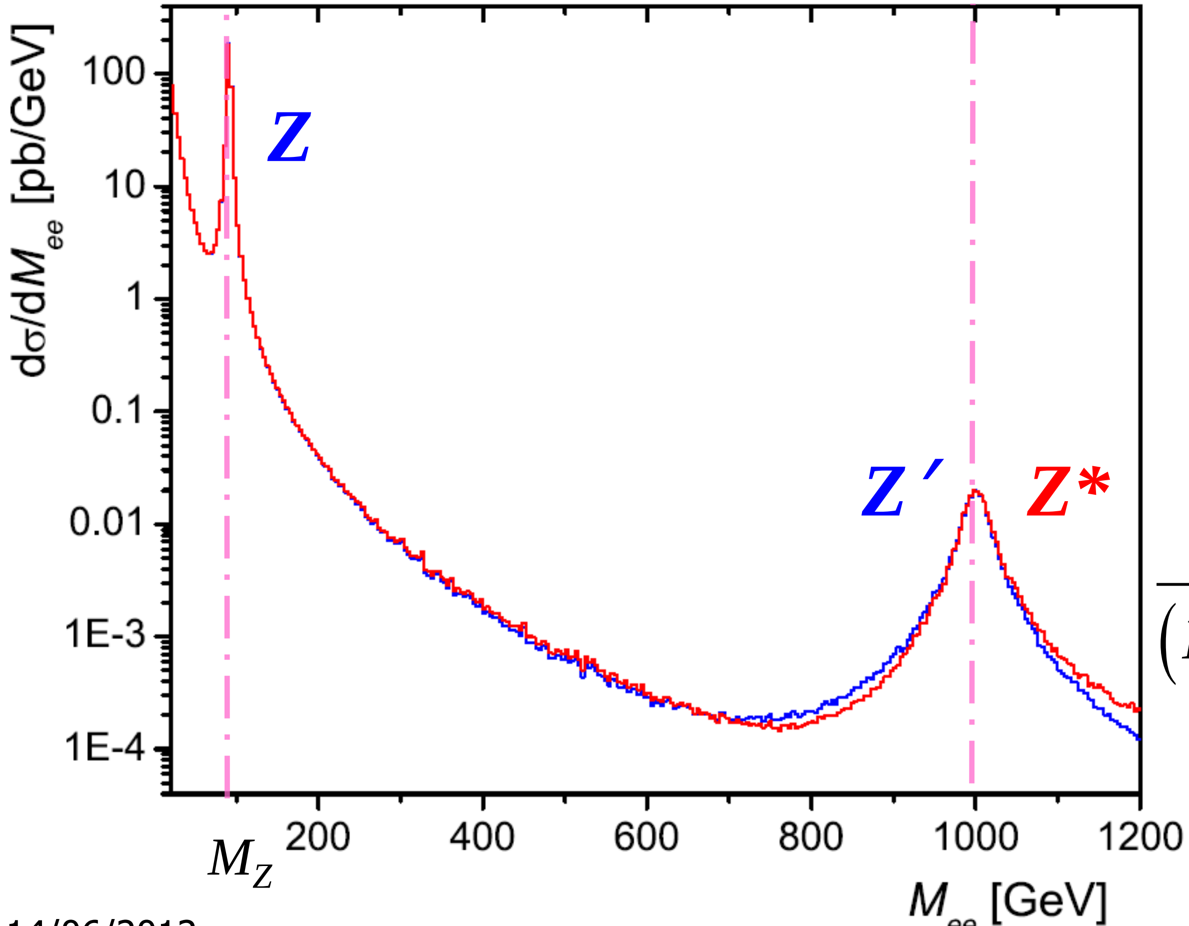
$$\frac{\left.\begin{matrix} LL \to LL \\ RR \to RR \end{matrix}\right\}\hat{u}^2 \quad \left.\begin{matrix} LL \to RR \\ RR \to LL \end{matrix}\right\}\hat{t}^2}{\left(\hat{s} - M^2\right)^2 + M^2\Gamma^2}$$



$$\frac{\left(\hat{u} - \hat{t}\right)^2}{\left(\hat{s} - M^2\right)^2 + M^2\Gamma^2}$$

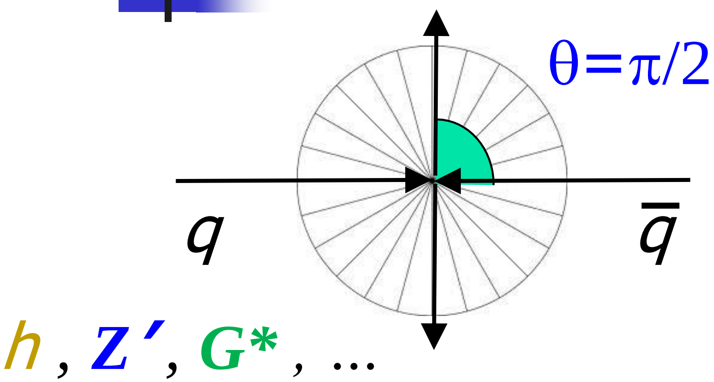
Invariant dilepton mass distributions

Several models predict new high mass neutral resonances that could decay into dilepton pairs(Z′, G, TC, KK, …)*

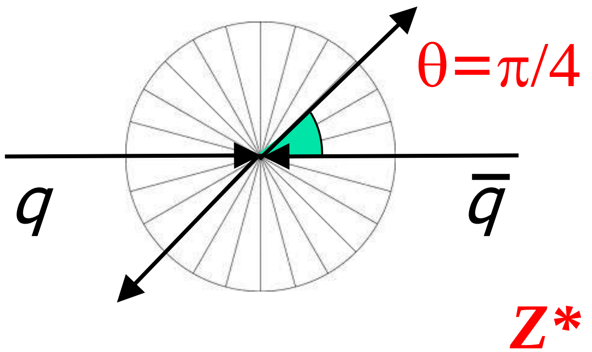


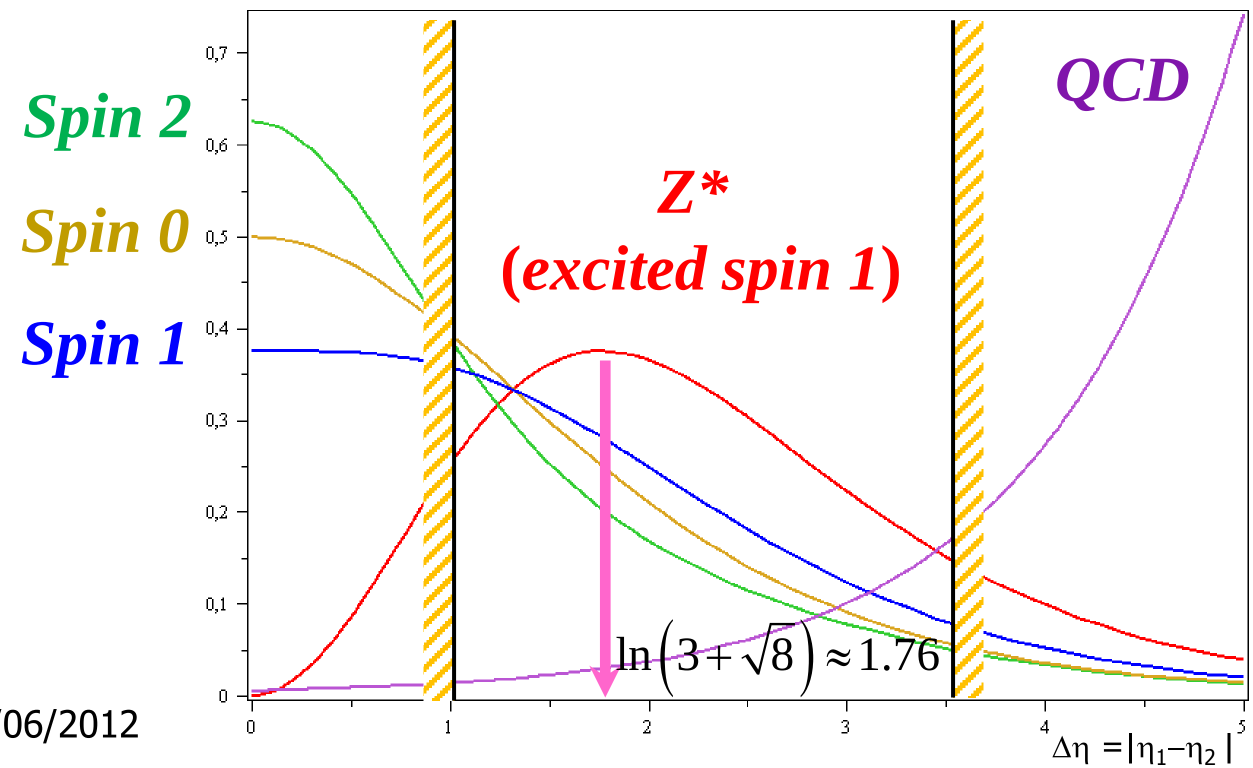
$$\frac{1}{\left(M_{\ell\ell}^2 - M_{\rm res}^2\right)^2 + M_{\rm res}^2\Gamma^2}$$

Angular distributions



$$\Delta\eta = \left| \ln \operatorname{tg}^2 \frac{\theta}{2} \right|$$





Z' and graviton 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

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

incomplete!

On resonance search in dilepton events at the LHC

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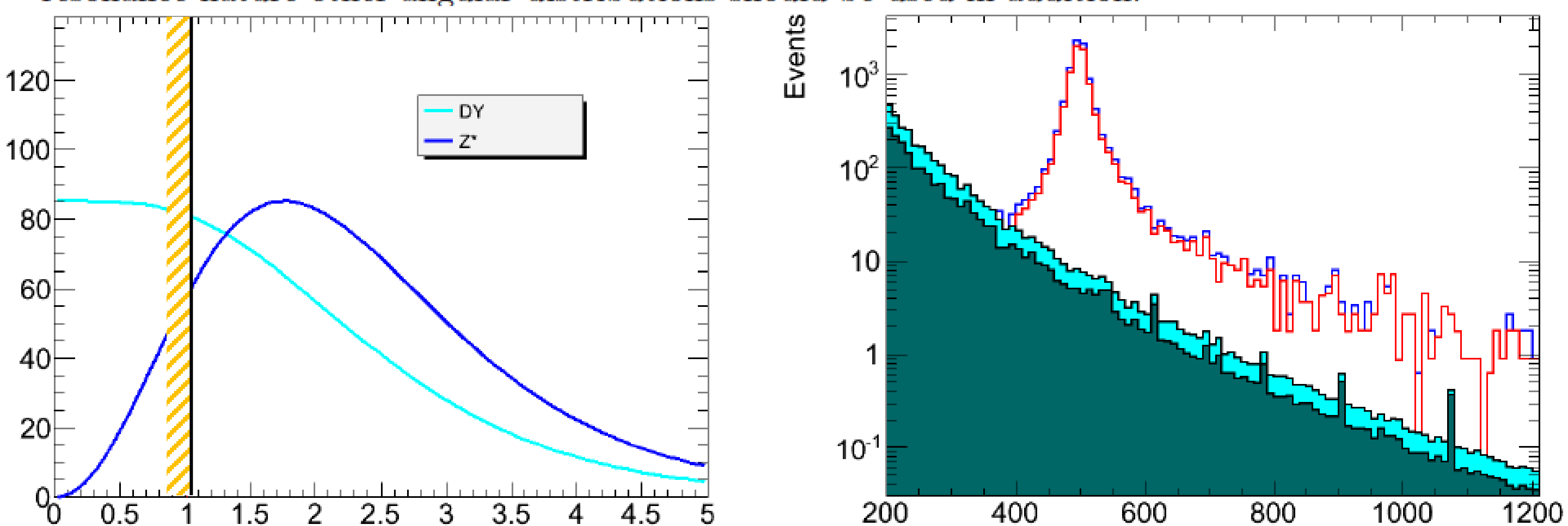
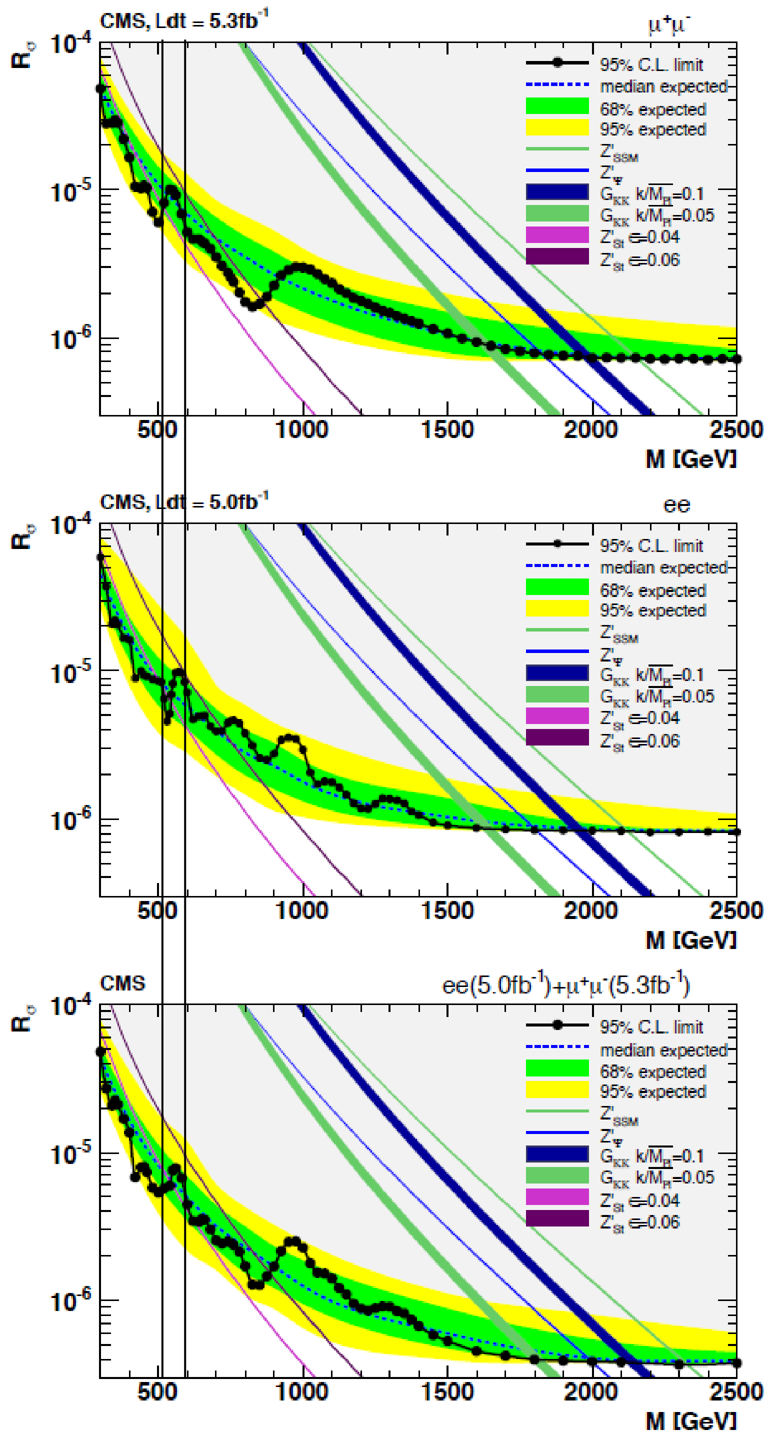
Joint Institute for Nuclear Research, 141980, Dubna, Russia
[2] *Centre for Space Research and Technologies,*
Faculty of Physics, Sofia University, 1164 Sofia, Bulgaria

The main distribution for a bump search is the dilepton invariant mass distribution with appropriated cut on an absolute value of pseudorapidity difference $\Delta\eta \equiv |\eta_1 - \eta_2|$ between the two leptons. The background from the Standard Model Drell–Yan process contributes mainly to the central pseudorapidity region $\Delta\eta \simeq 0$. By contrast, the excited bosons lead to a peak at $\Delta\eta \simeq 1.76$. We show that this property allows to enhance the significance of their bump search by means of new cut optimization. Nevertheless, in order to confirm an observation of the bump and reveal the resonance nature other angular distributions should be used in addition.



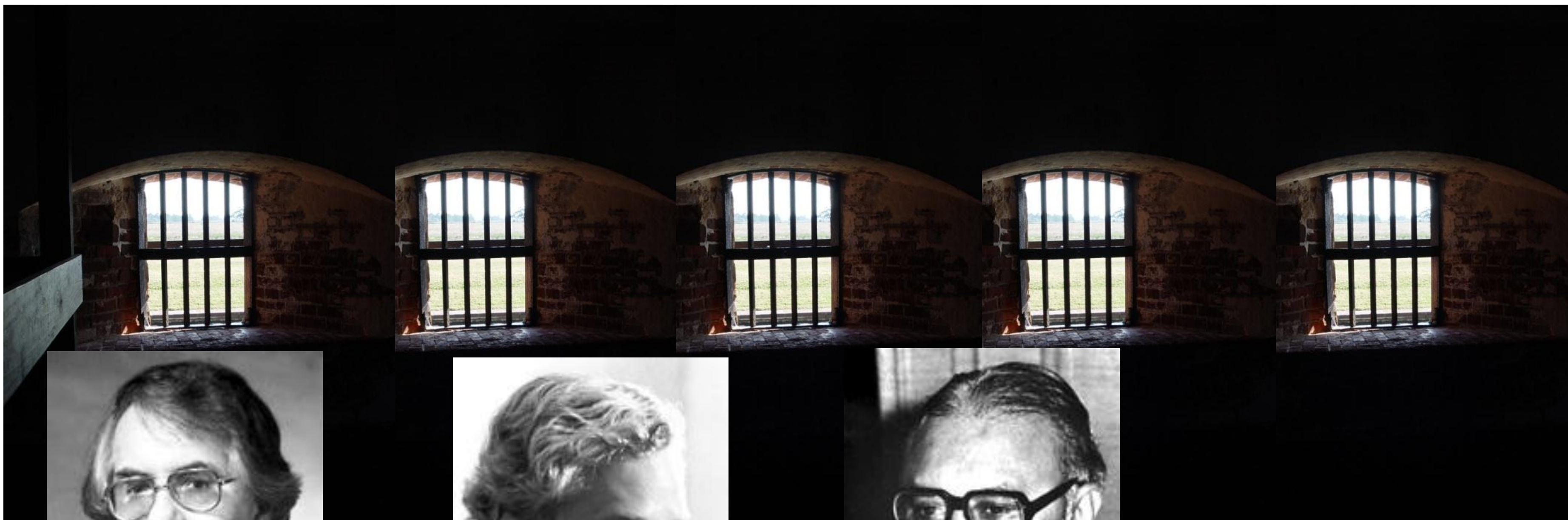
CMS: arXiv:1206.1849

It is interesting to know:
What is angular distributions for on-peak events?



Can we escape from SM prison?

Dark matter	Inflation	Gravitation	Baryon asymmetry	Hierarchy problem

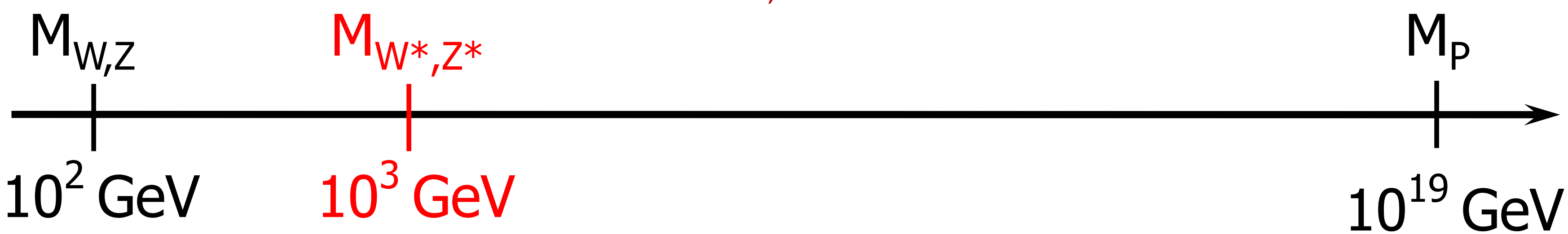


SM slave

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", Phys.Lett. B**703** (2011) 593-598; arXiv:0908.0924

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

1. SU(3) extension of SM

$SU(3) \supset SU(2)\times U(1)$ **$8=3+2+\bar{2}+1$**

$$\begin{pmatrix} \begin{matrix} W^3 & W^1+iW^2 \\ W^1-iW^2 & -W^3 \end{matrix} & \begin{matrix} Z^* \\ W^* \end{matrix} \\ \begin{matrix} \bar{Z}^* & \bar{W}^* \end{matrix} & B \end{pmatrix}$$

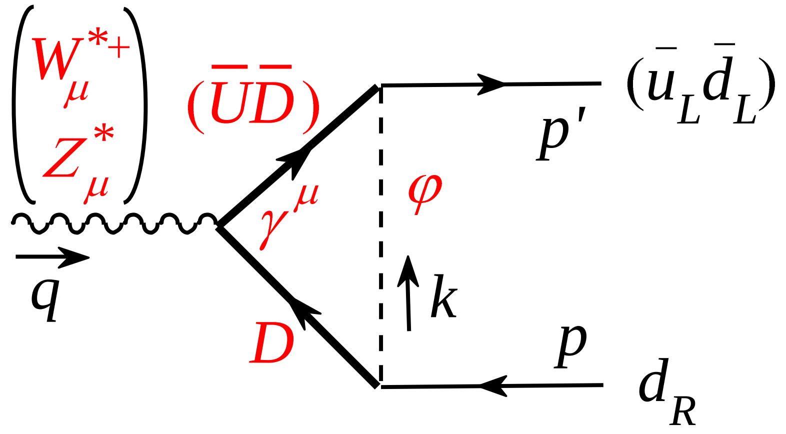
New vector bosons are transformed under fundamental representation of $\mathbf{SU(2)_L}$ (coset gauge bosons)

They belong to fragments **2** ($\bar{\mathbf{2}}$) and become massive during the spontaneous symmetry breaking SU(3) →SU(2)×U(1) by the two independent Higgs triplets $\mathbf{3_H=1_H+2_H}$ и $\mathbf{3'_H=1'_H+2'_H}$.
The lightness of the Higgs doublets is guaranteed, because they are related to the vectors by symmetry.

Z.G. Berezhiani & G.Dvali, Bull. Lebedev Phys. Inst. 5(1989)55; Kratk. Soobshch. Fiz. 5(1989)42;
G. Dvali, G.F. Giudice and A. Pomarol, Nucl. Phys. B478 (1996) 31;
G.R. Dvali, Phys. Lett. B 324 (1994) 59.

Standard Model symmetry $SU(2)_L \times U(1)_Y$

$$\frac{g}{\Lambda}\left(\bar{u}_L\ \bar{d}_L\right)\sigma^{\mu\nu}d_R\left[\partial_\mu\begin{pmatrix}W_\nu^{*+}\\ Z_\nu^{*}\end{pmatrix}-\partial_\nu\begin{pmatrix}W_\mu^{*+}\\ Z_\mu^{*}\end{pmatrix}\right]$$



2. Extra dimensions

Let us consider a doublet of the gauge fields in N-dimension Minkowski space. Then its the fifth and the subsequent components can play a role of the Higgs fields (so-called Gauge-Higgs unification)

$$\begin{pmatrix} W_M^{*+} \\ Z_M^{*} \end{pmatrix} = \begin{pmatrix} W_\mu^{*+}, H^+, \ \dots \\ Z_\mu^{*}\ \ , H^0, \ \dots \end{pmatrix}$$

N.S. Manton, Nucl. Phys. B 158 (1979) 141;
D.B. Fairlie, J. Phys. G 5 (1979) L55; Phys. Lett. B 82 (1979) 97.

The lightness of the Higgs doublets is guaranteed by the gauge symmetry. This symmetry is spontaneously broken by compactification. In this way the mass of the Higgs doublet is controlled by the compactification scale, as opposed to the high-dimensional cutoff of the theory.

$$\mathcal{L}_{(Z^*W^*)} = \frac{g_d}{\Lambda}\left(\bar{u}_L\ \bar{d}_L\right)\sigma^{\mu\nu}\, d_R \cdot \left[\partial_\mu \begin{pmatrix} W_\nu^{*+} \\ Z_\nu^{*} \end{pmatrix} - \partial_\nu \begin{pmatrix} W_\mu^{*+} \\ Z_\mu^{*} \end{pmatrix}\right]$$

$$+\frac{g_u}{\Lambda}\left(\bar{u}_L\ \bar{d}_L\right)\sigma^{\mu\nu}\, u_R \cdot \left[\partial_\mu \begin{pmatrix} \bar{Z}_\nu^{*} \\ -W_\nu^{*-} \end{pmatrix} - \partial_\nu \begin{pmatrix} \bar{Z}_\mu^{*} \\ -W_\mu^{*-} \end{pmatrix}\right] + \text{h.c.}$$

3. Technicolor

techni-π, techni-ρ, techni-ω …

What else?

π^0 $I^G(J^{PC}) = 1^-(0^{-+})$

Mass $m = 134.9766 \pm 0.0006$ MeV (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 (S = 3.0)
$c\tau = 25.1$ nm

$$\bar{q}\gamma^\mu q \cdot V_\mu \qquad s = 1 \quad \ell = 0$$

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

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

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

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

$h_1(1170)$ $I^G(J^{PC}) = 0^-(1^{+-})$

Mass $m = 1170 \pm 20$ MeV
Full width $\Gamma = 360 \pm 40$ MeV

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

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

techni-*a*, techni-*f*

$$\bar{q}\gamma^\mu\gamma^5 q \cdot A_\mu \qquad s = 1 \quad \ell = 1$$

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

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

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

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

techni-*b*, techni-*h*

$$\bar{q}\sigma^{\mu\nu}\gamma^5 q \cdot \left(\partial_\mu A^*_\nu - \partial_\nu A^*_\mu\right) \qquad s = 0 \quad \ell = 1$$

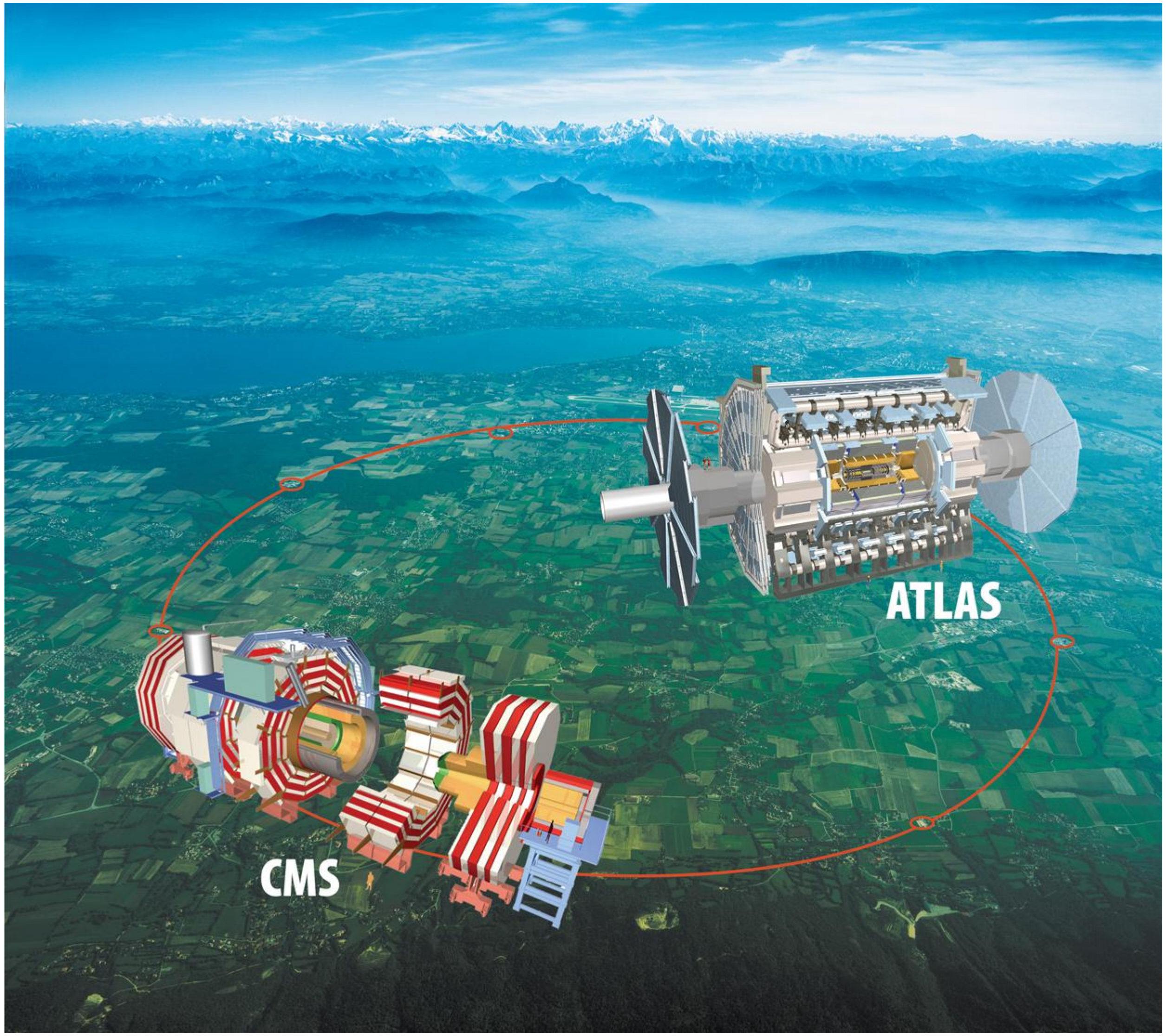
? ? ?

Low energy searches

- Muon decay $\mu \to e\, \nu_\mu\, \bar{\nu}_e$
- Radiative pion decay $\pi \to e\, \bar{\nu}_e \gamma$
- Neutron decay $n \to p\, e\, \bar{\nu}_e$
- Kaon decay $K \to \pi\, e\, \bar{\nu}_e$
- Lepton anomalous magnetic moment
- …

$$\text{suppressed by} \quad \frac{g^2}{\Lambda^2} \frac{q^2}{M_{Z*}^2 - q^2}$$

Large Hadron Collider



110th LHCC Meeting AGENDA OPEN Session (13-14 June 2012) - Mozilla Firefox

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110th LHCC Meeting AGENDA OPEN Session

chaired by Eckhard Elsen (Deutsches Elektronen-Synchrotron (DE))

from Wednesday, June 13, 2012 at **09:00** to Thursday, June 14, 2012 at **18:00** (Europe/Zurich)
at **CERN (500-1-001 - Main Auditorium)**

Description LIVE Webcast - All CERN staff and Users are welcome to attend Open Session - LIVE Webcast.

CLOSED Session meeting will take place in Georges Charpak Room F, 60-6-015 on **Wednesday 16h30 and Thursday 8h30**

Wednesday, June 13, 2012

09:00 - 16:05 Open Session

CERN Main Auditorium

09:00 **LHC Machine Status report** *20'*
Speaker: Steve Myers (CERN)
Material: Slides | Video in CDS

09:30 **ALICE Status Report** *30'*
Speaker: Dr. Andreas Morsch (CERN)
Material: Slides | Video in CDS

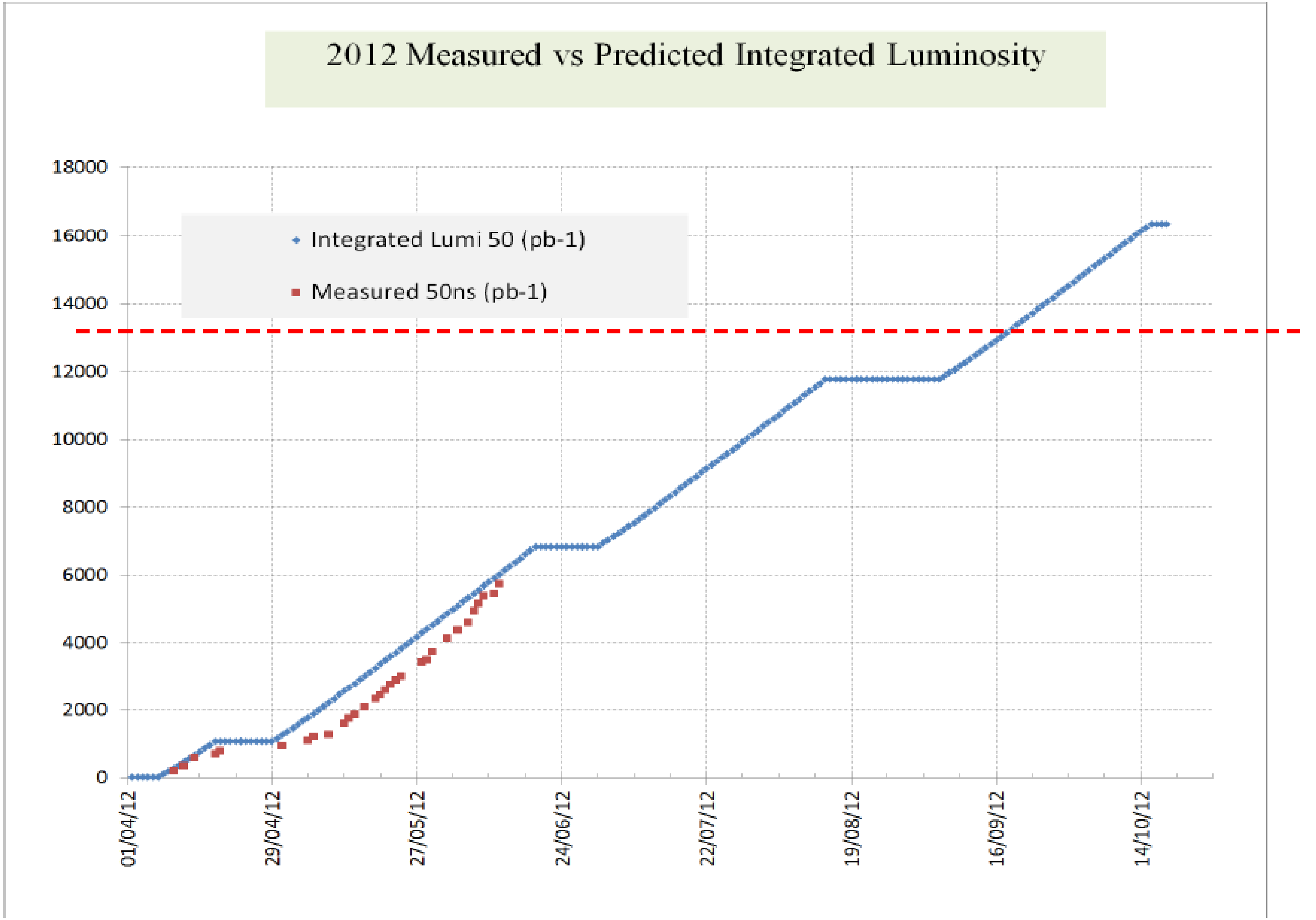
10:10 **LHCb Status Report** *30'*
Speaker: Diego Martinez Santos (CERN)
Material: Slides | Video in CDS

10:50 **Coffee Break** *20'*

11:10 **ATLAS Status Report** *30'*
Speaker: Klaus Monig (Deutsches Elektronen-Synchrotron (DE))
Material: Slides | Video in CDS

11:50 **CMS Status Report** *30'*
Speaker: Prof. Yves Sirois (Ecole Polytechnique (FR))
Material: Slides | Video in CDS

With Respect to estimates (as of Tuesday June 12)



Integrated luminosity needed for Discovery of Higgs

Year	fb-1	signal (in σ)	Beam Energy	
2011	5	2.5	3.5	
2012	15	5	3.5	Needed
2012	11.5	5	4.0	Needed
2012	13.3	5	4.0	addditional 15% for pile up and margin

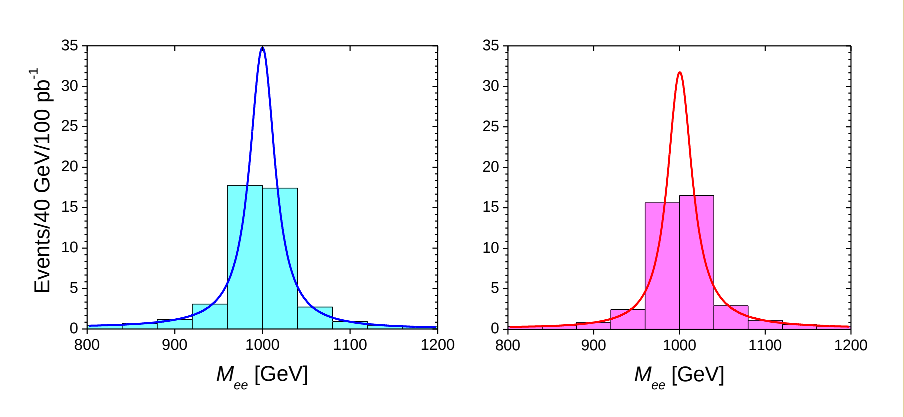
We predict an existence of new excited chiral particles W* and Z* with new unique properties.

ATLAS is already looking for them!

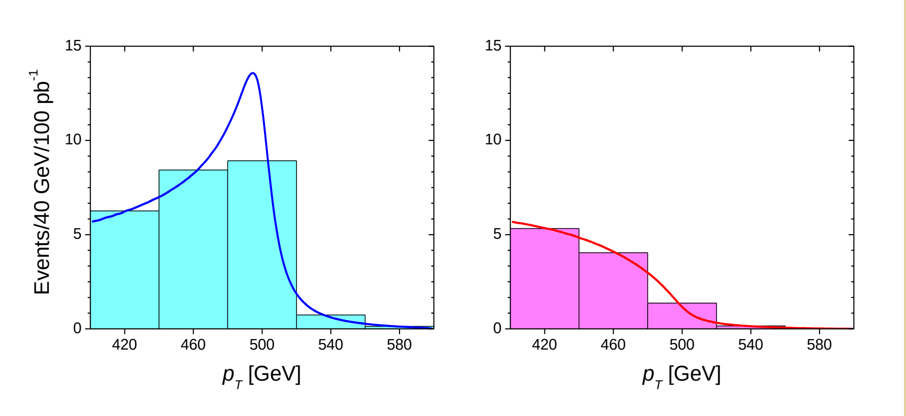
Theoretical comparision between Z′ and Z*

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

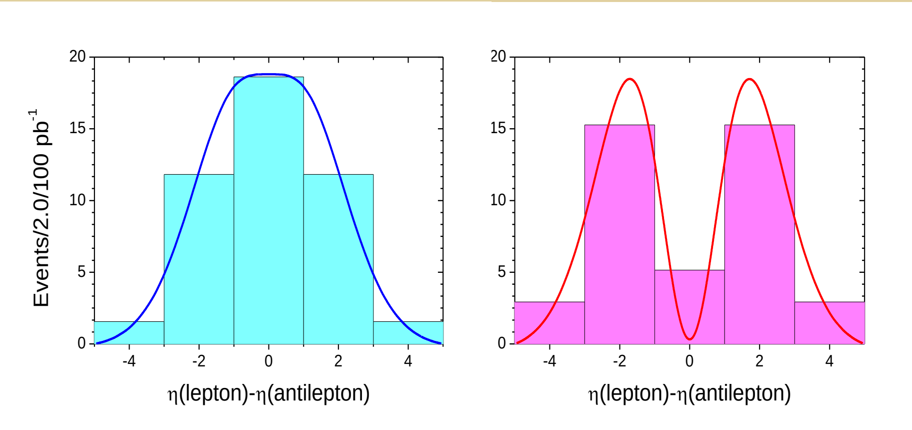
invariant mass



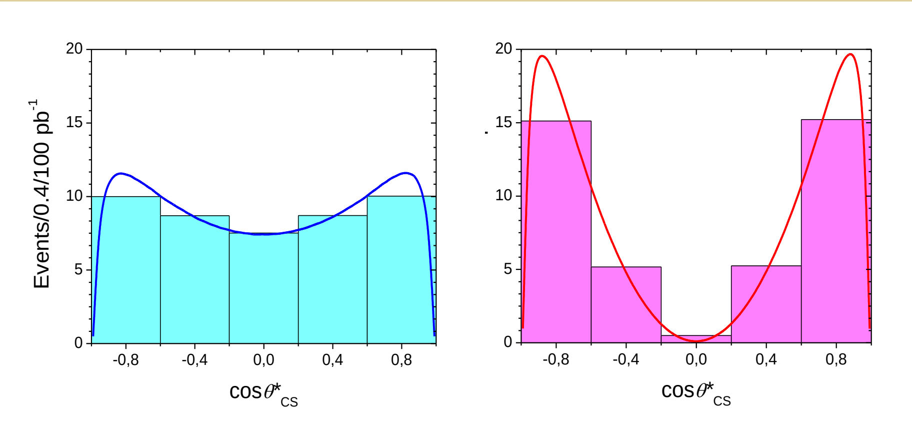
transverse momentum



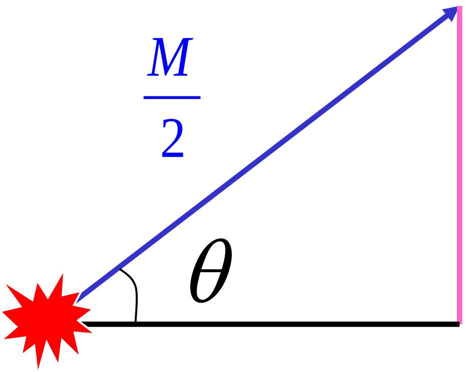
pseudorapidity difference



angular distribution



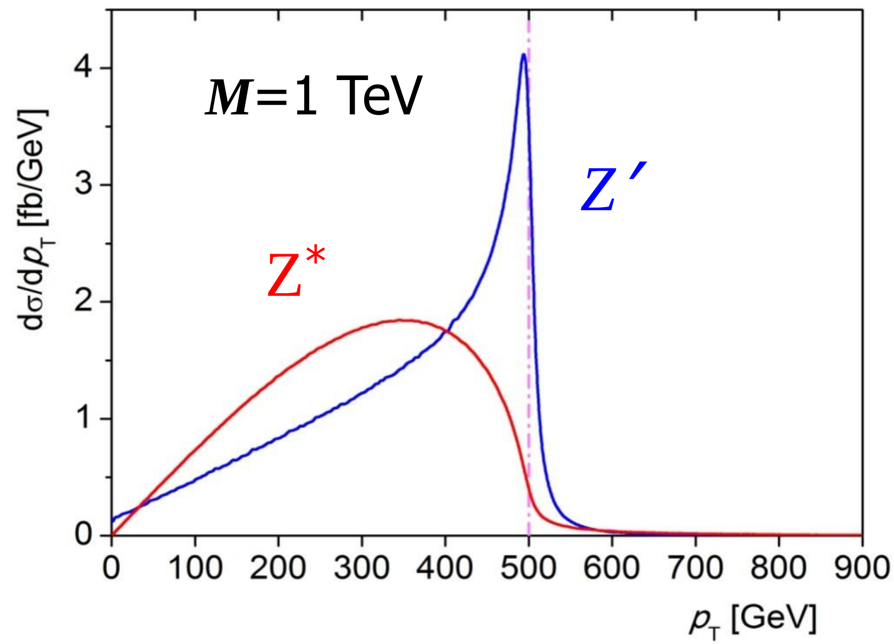
Jacobian factor for $\cos\theta \to p_{\mathrm{T}}$



$$p_{\mathrm{T}} = \frac{M}{2}\sin\theta$$

$$\frac{\mathrm{d}\cos\theta}{\mathrm{d}p_{\mathrm{T}}} = -\frac{2\sin\theta}{M\cos\theta}$$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}p_{\mathrm{T}}} = \left|\frac{\mathrm{d}\cos\theta}{\mathrm{d}p_{\mathrm{T}}}\right| \cdot \frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta} = \frac{2\sin\theta}{M\cos\theta} \cdot \frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta}$$



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

Vernon D. Barger, Roger J.N. Phillips
"Collider Physics"

wrong!

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

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

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

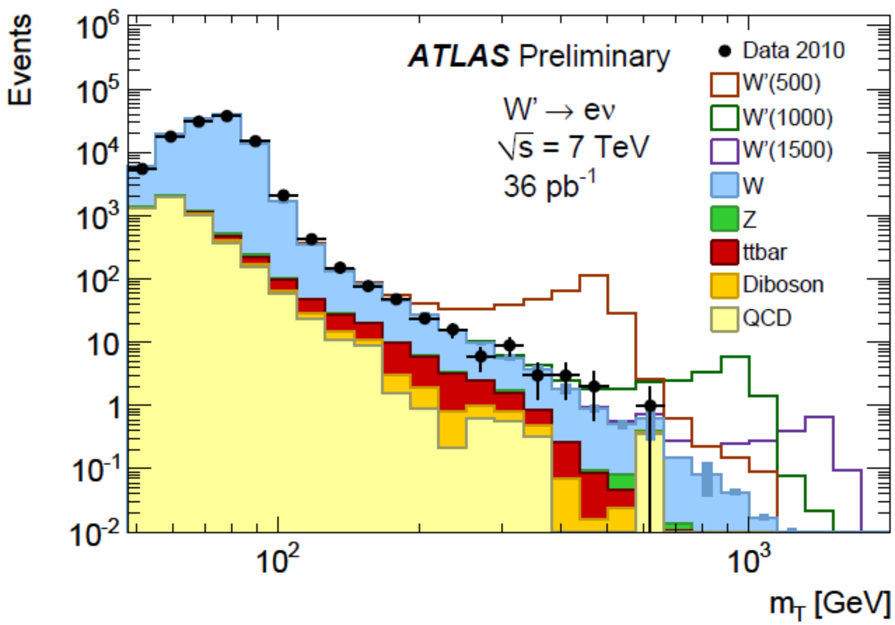
$$E_p = 980\ \mathrm{GeV},\ E_{\bar{p}} = 980\ \mathrm{GeV};\ \ E_{\mathrm{CM}} = 1960\ \mathrm{GeV}$$

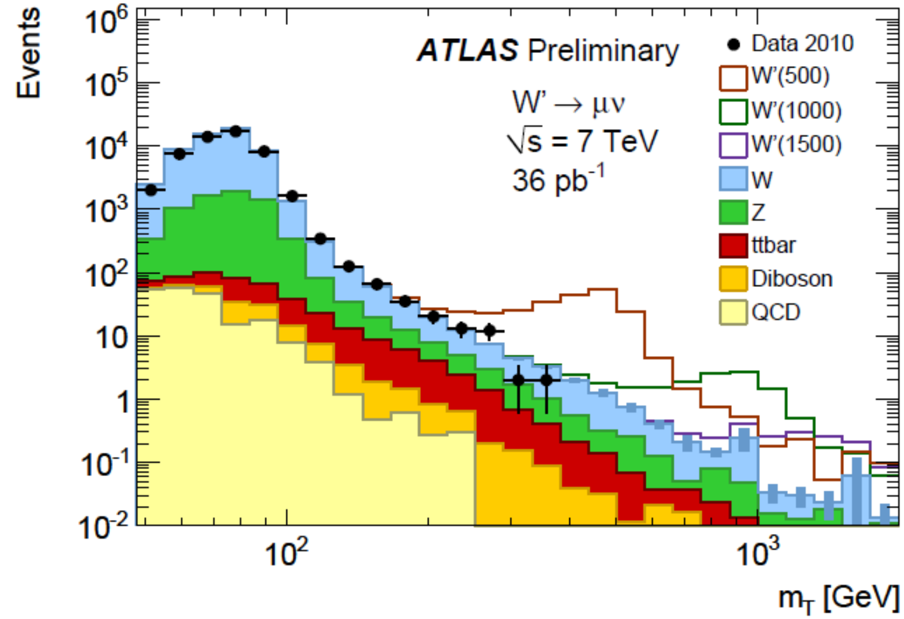
$$\rightarrow 1960\ \mathrm{GeV}/6 \approx 330\ \mathrm{GeV}$$

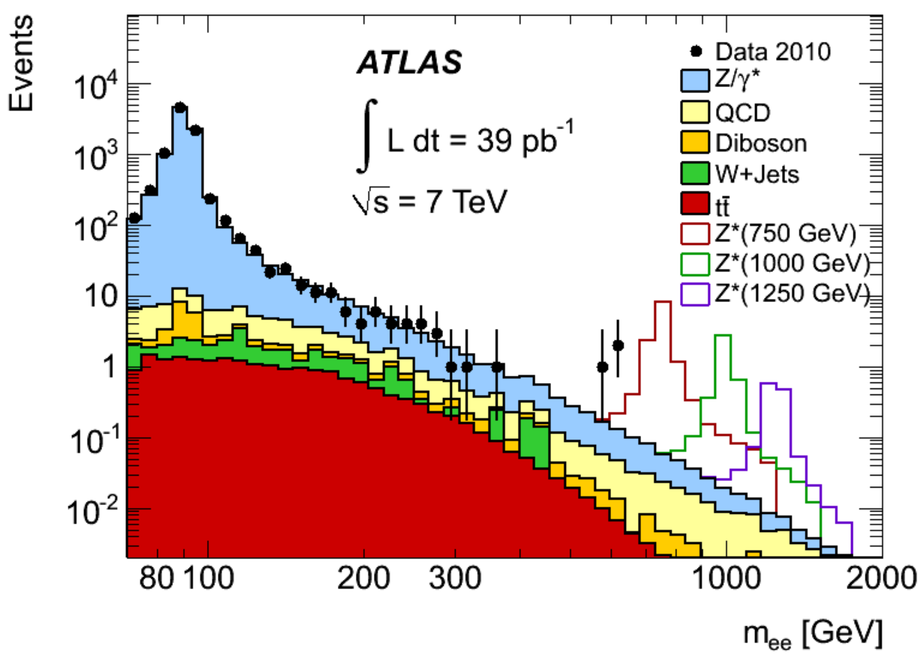
(LHC: 27 km)

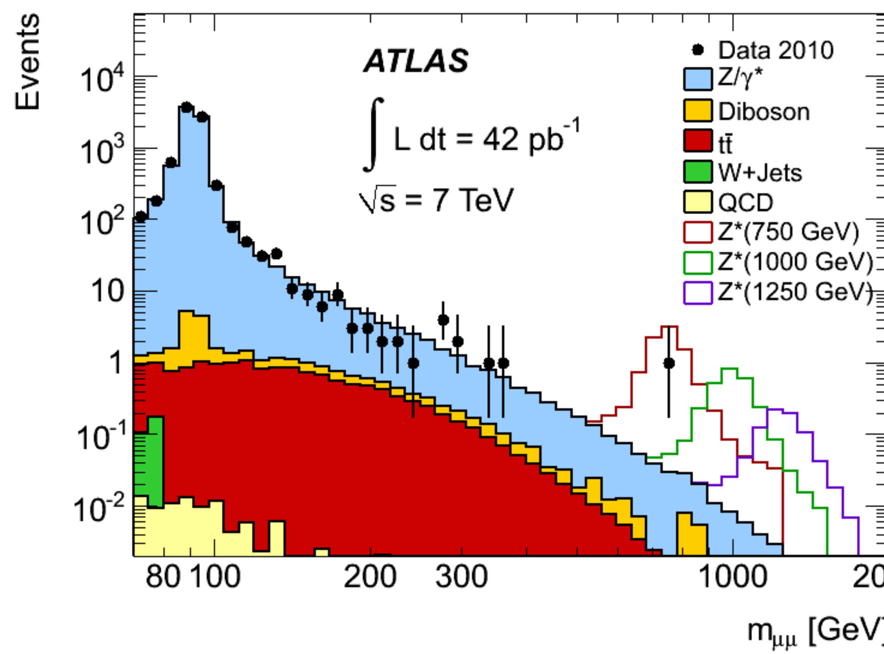
$$E_p = 7\,000\ (3500)\ \mathrm{GeV},\ E_p = 7\,000\ (3500)\ \mathrm{GeV};\ \ E_{\mathrm{CM}} = 14\,000\ (7000)\ \mathrm{GeV}$$

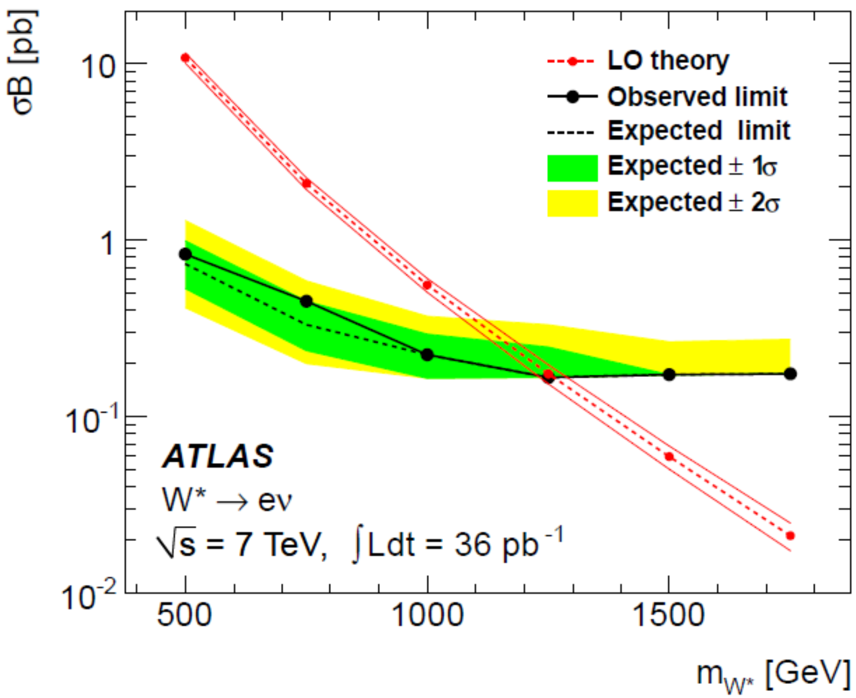
$$\rightarrow 14000\ (7000)\ \mathrm{GeV}/6 \approx 2\,330\ (1165)\ \mathrm{GeV}$$

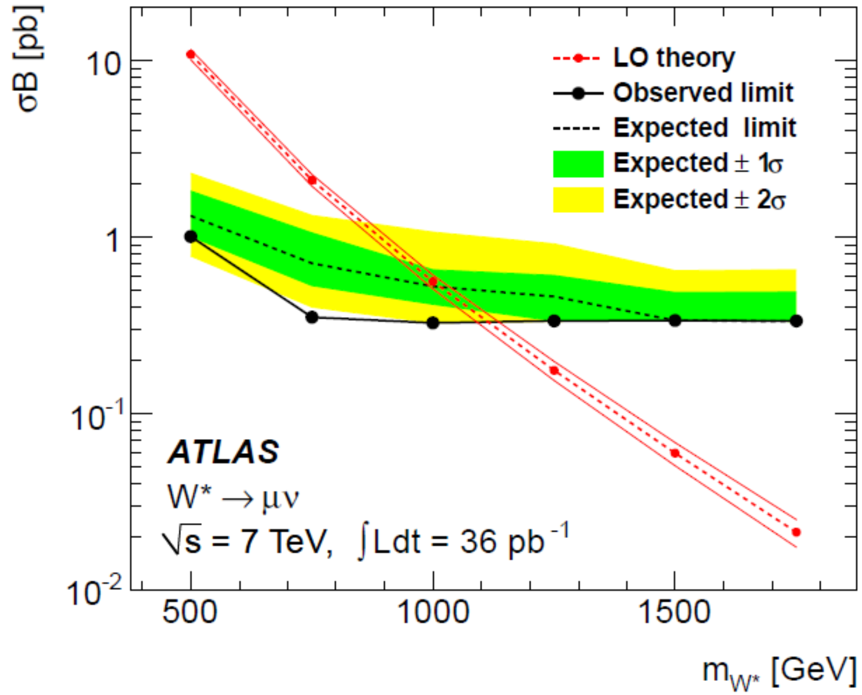

ATLAS Preliminary
W' → eν
√s = 7 TeV
36 pb-1
Data 2010
W'(500)
W'(1000)
W'(1500)
W
Z
ttbar
Diboson
QCD
Events
mT [GeV]

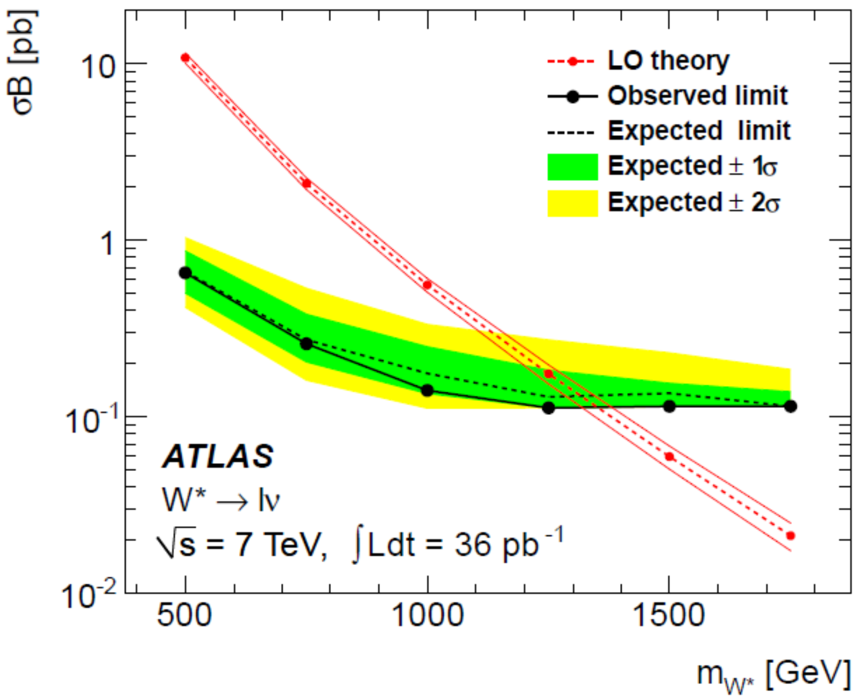

ATLAS Preliminary
W' → μν
√s = 7 TeV
36 pb-1
Data 2010
W'(500)
W'(1000)
W'(1500)
W
Z
ttbar
Diboson
QCD
Events
mT [GeV]


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
mee [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
mμμ [GeV]

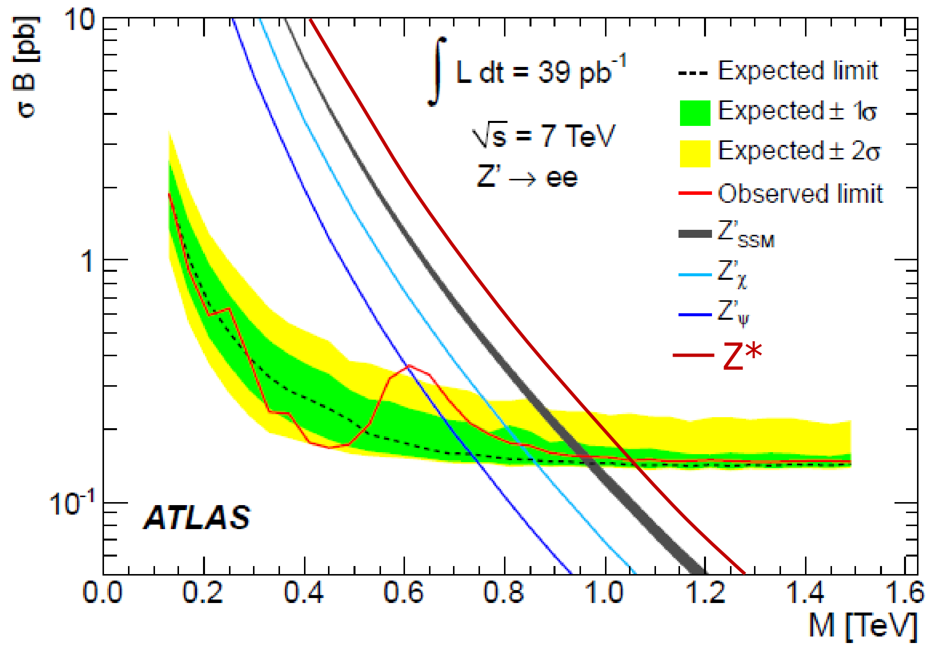


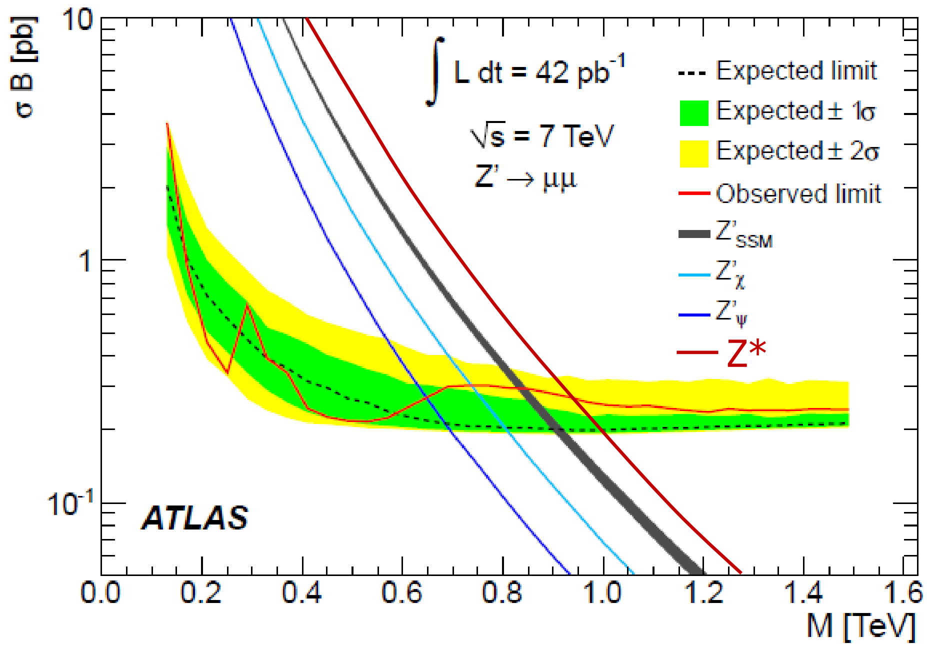


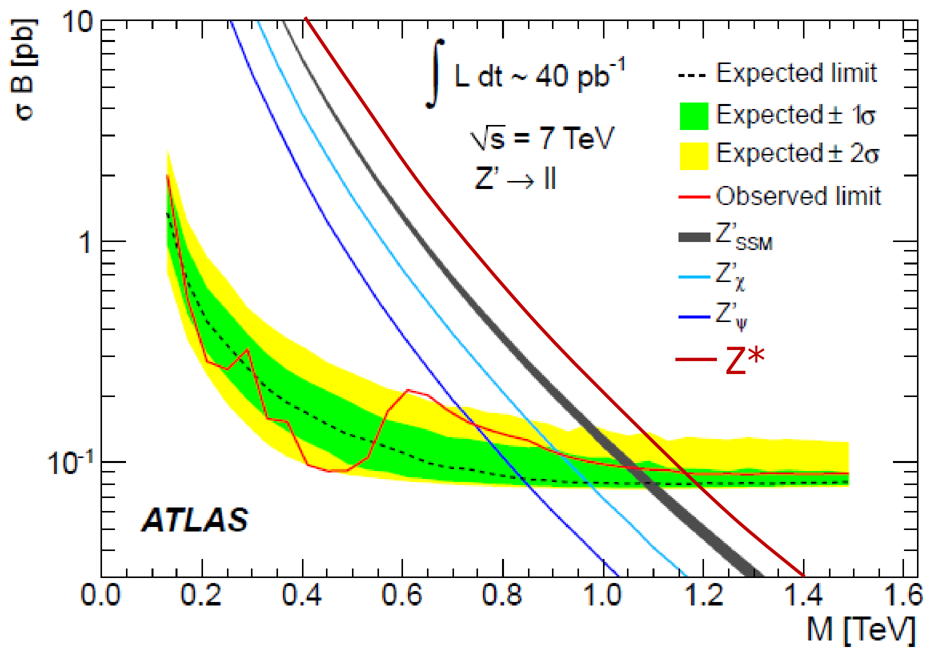


	Mass limit [GeV]			
	W'		W^*	
decay	Exp.	Obs.	Exp.	Obs.
$e\nu$	1370	1370	1260	1260
$\mu\nu$	1210	1290	1020	1120
both	1450	1490	1320	1350

The ATLAS Collaboration "Search for high-mass states with one lepton plus missing transverse momentum in proton-proton collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector", Phys. Lett. B**701** (2011) 50; arXiv:1103.1391







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

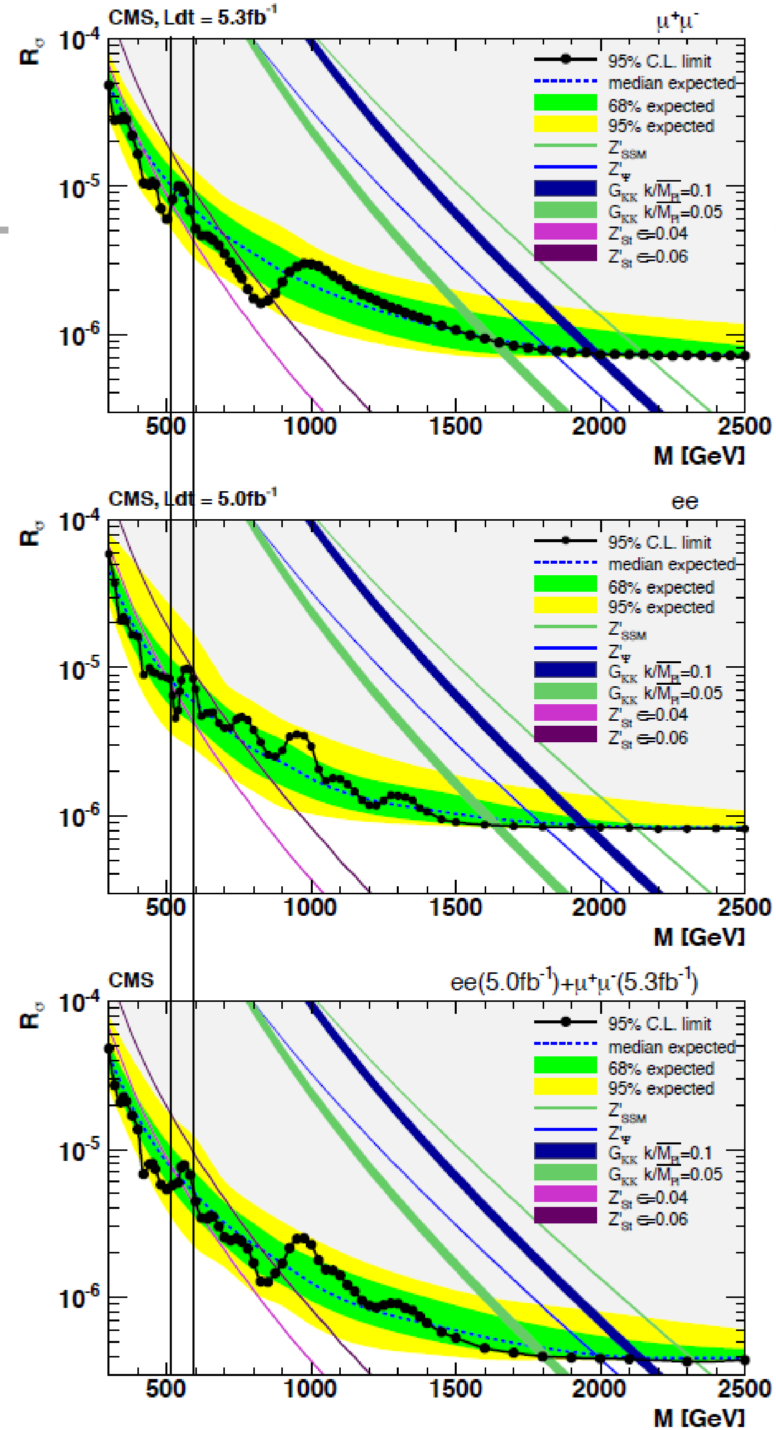
Model	Z'_ψ	Z'_N	Z'_η	Z'_I	Z'_S	Z'_χ
Mass limit [TeV]	0.738	0.763	0.771	0.842	0.871	0.900

	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", Phys. Lett. B**700** (2011) 163; arXiv:1103.6218

CMS: arXiv:1206.1849

I am very interested to know:
What is angular distributions
for the on-peak CMS events?



Thank you for your attention!