


A Search for New Physics in the Dilepton Channel using the ATLAS Detector.

NPPD Conference in Glasgow
05/04/11





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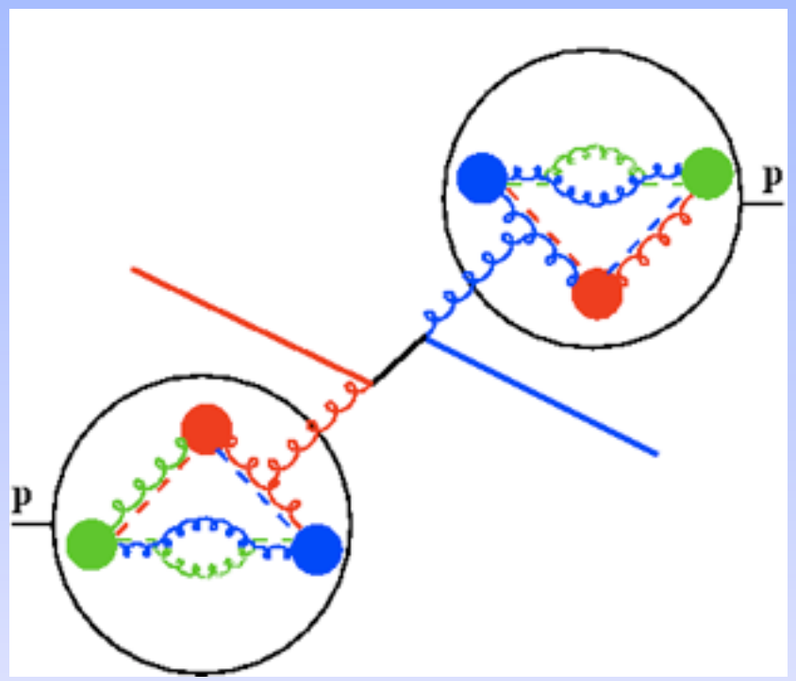
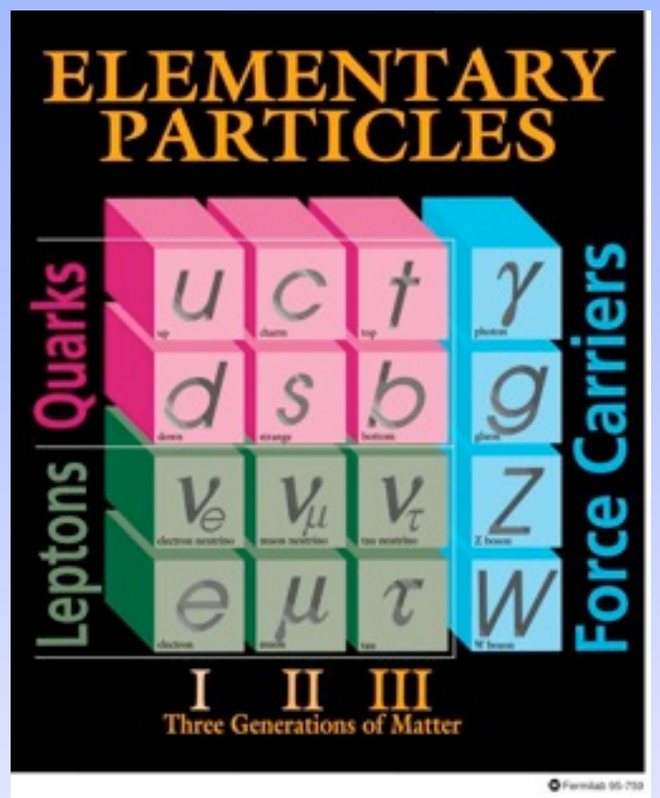
Contents

- Motivation for BSM Searches
- High Mass Dilepton Resonances (Z′/G)
- The ATLAS Detector
- Search Analysis
- 2010 Results
- The (Near) Future


The Standard Model

- The Standard Model of Particle Physics has had many successes...





Quantity
Mass of W boson
Mass of Z boson

Measured (GeV)	SM prediction (GeV)
80.398 ± 0.025	80.390 ± 0.018
91.1876 ± 0.0021	91.1874 ± 0.0021

Electroweak/QCD

Gluon, Top & Charm

W/Z Boson Masses

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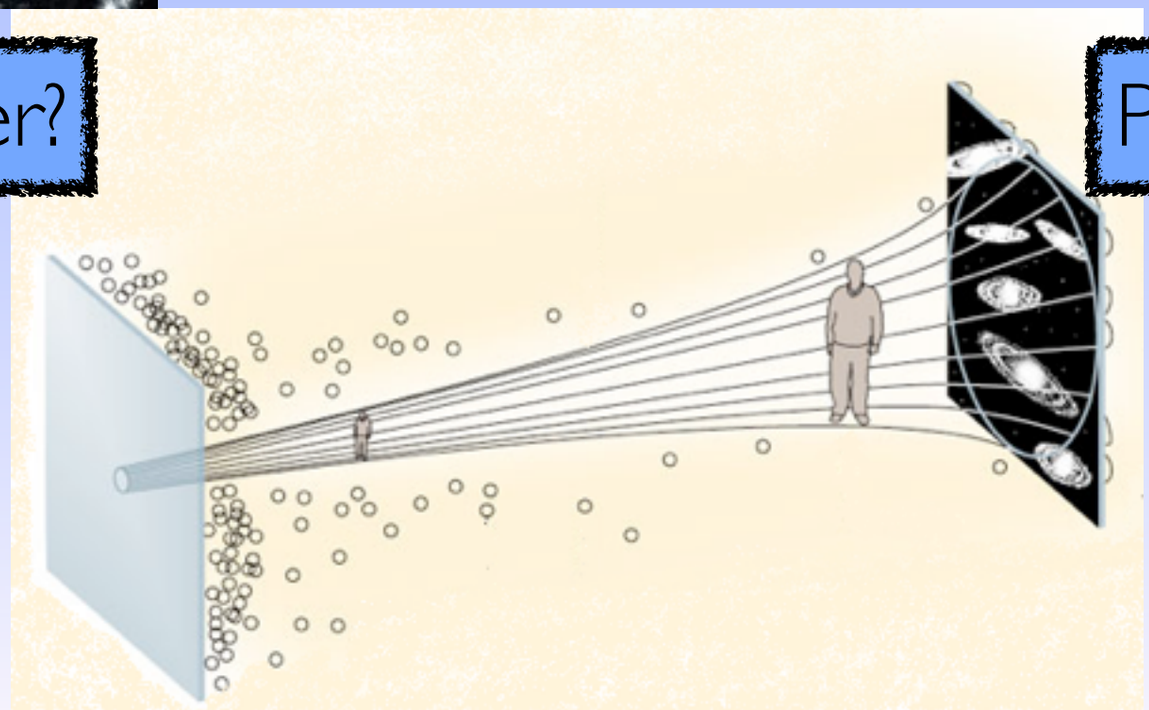
...But it also has its limitations...

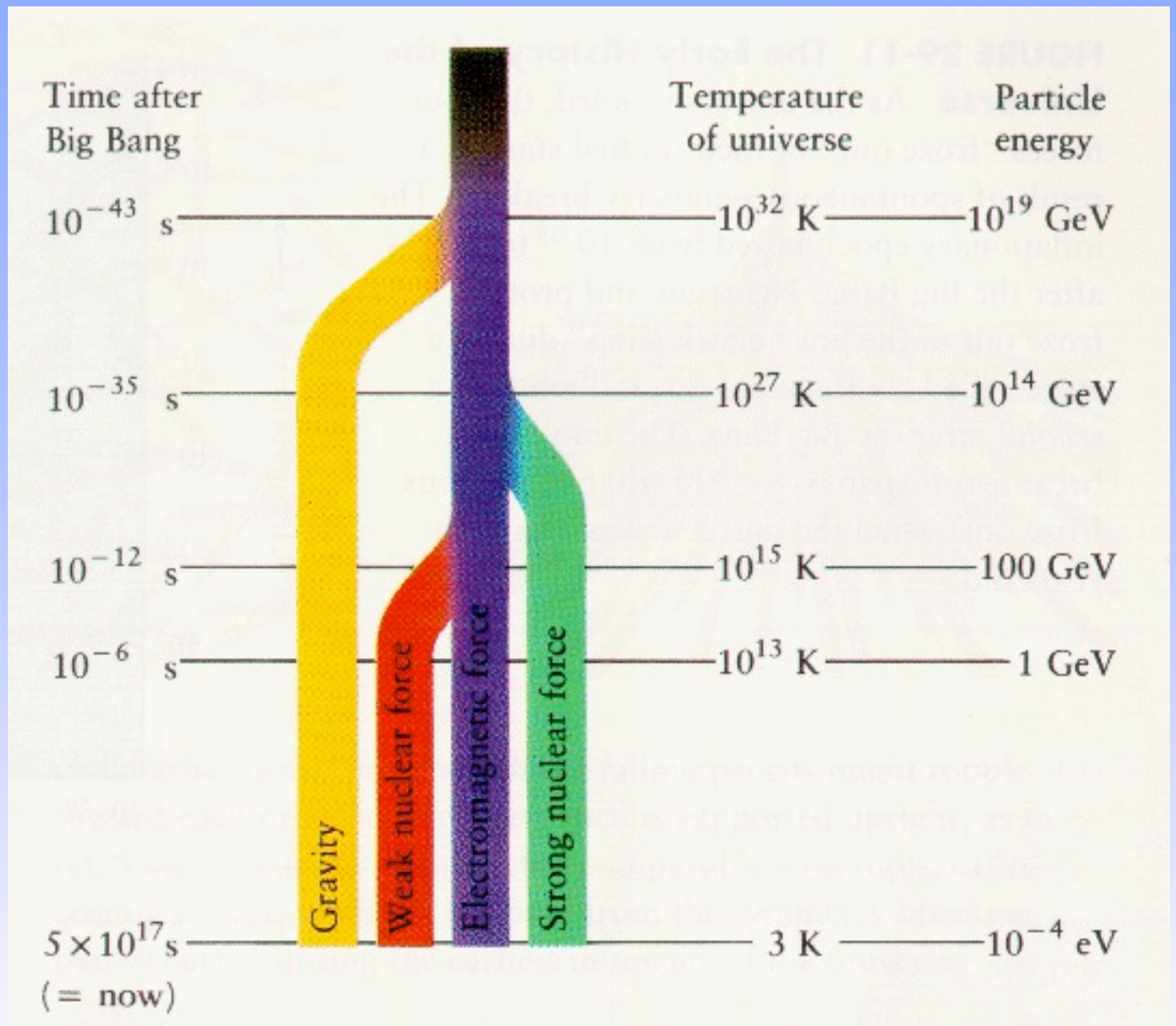
Gravity?

Cold Dark Matter?



Particle Masses?

...and we would like a Grand Unified Theory!



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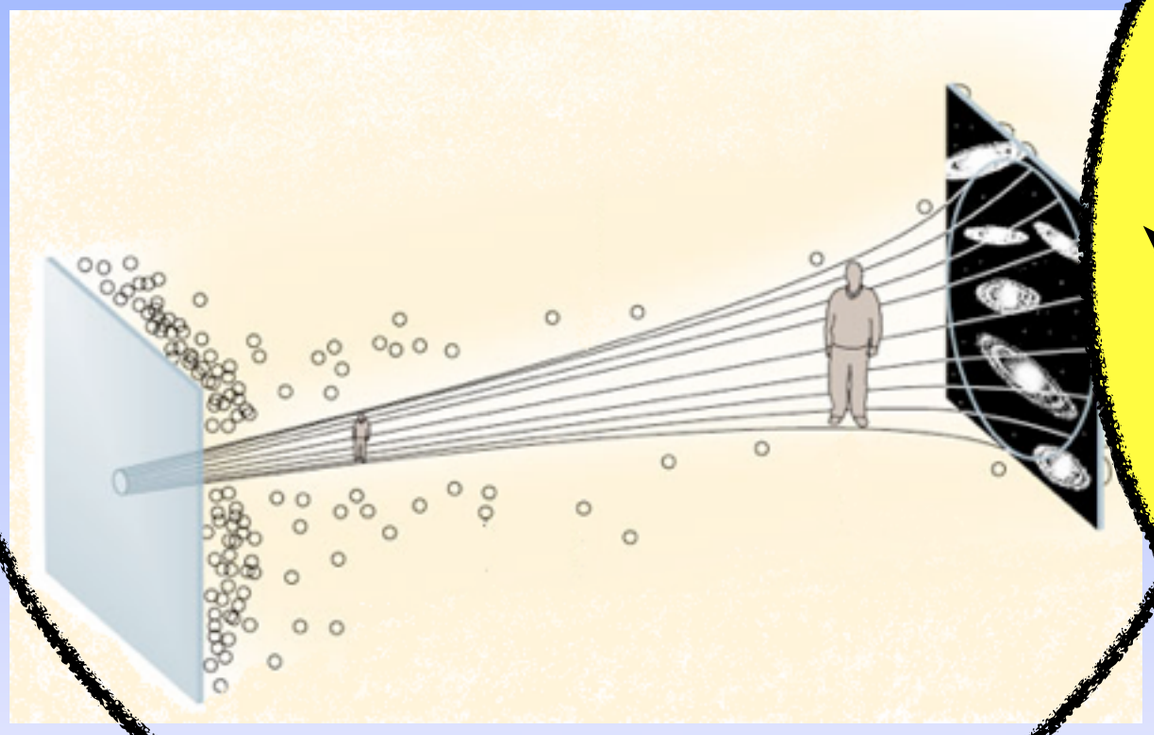
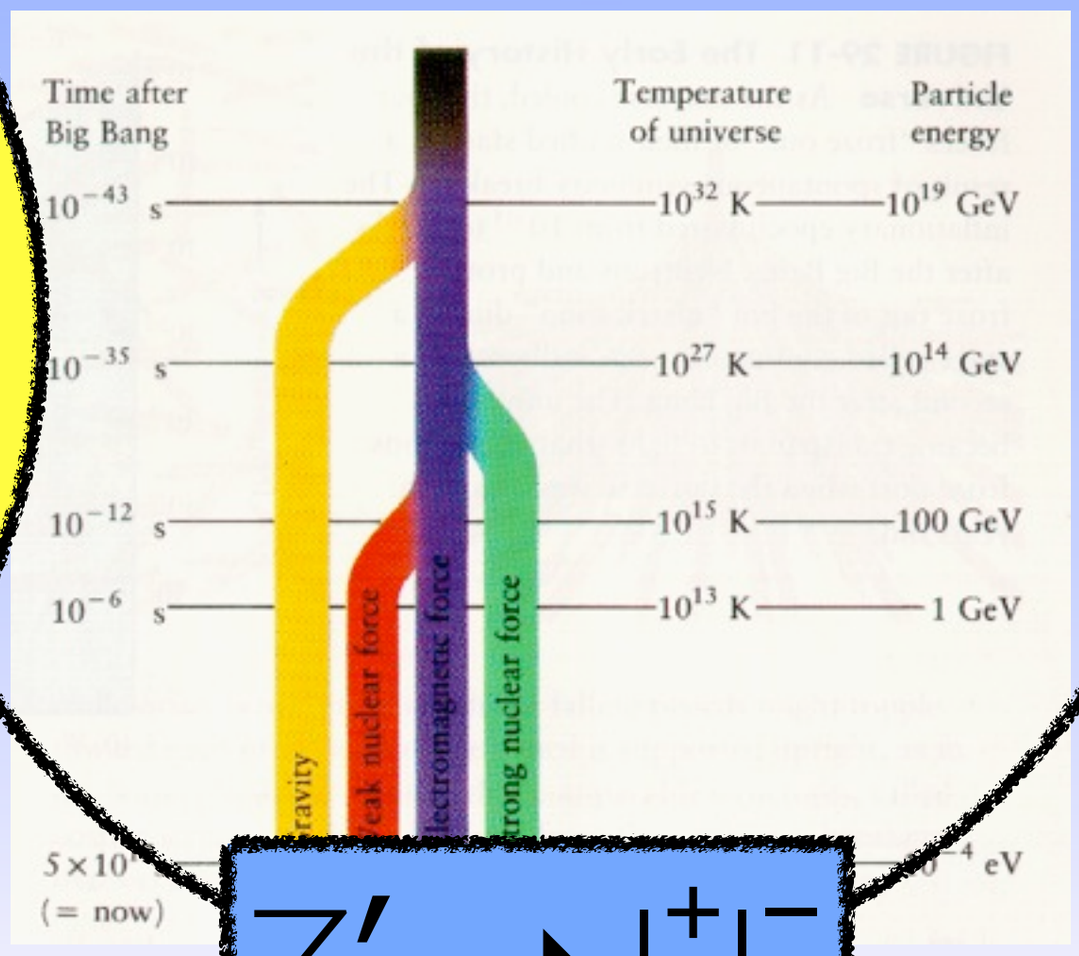
Today

Gravity/Hierarchy



$G \rightarrow l^+l^-$

GUT



$Z' \rightarrow l^+l^-$

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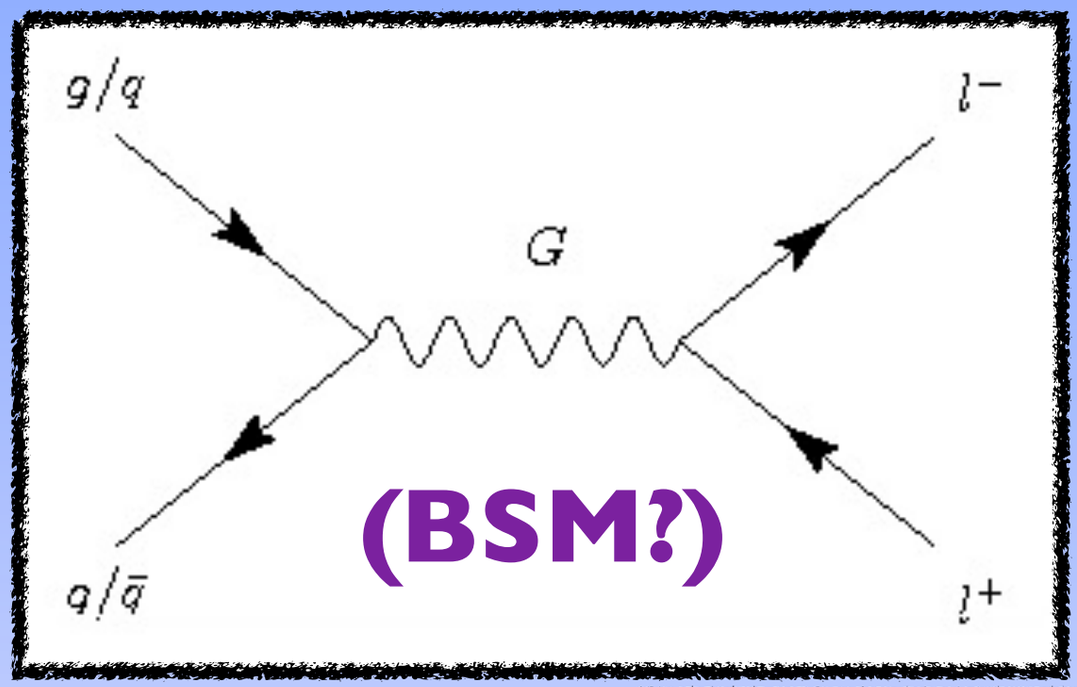
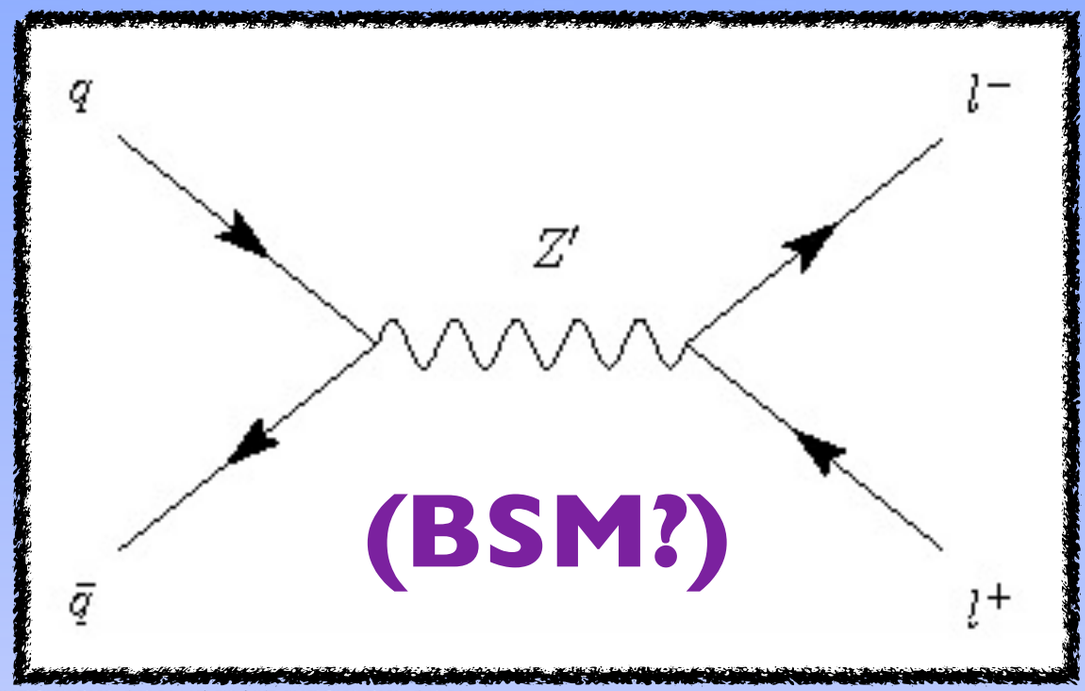
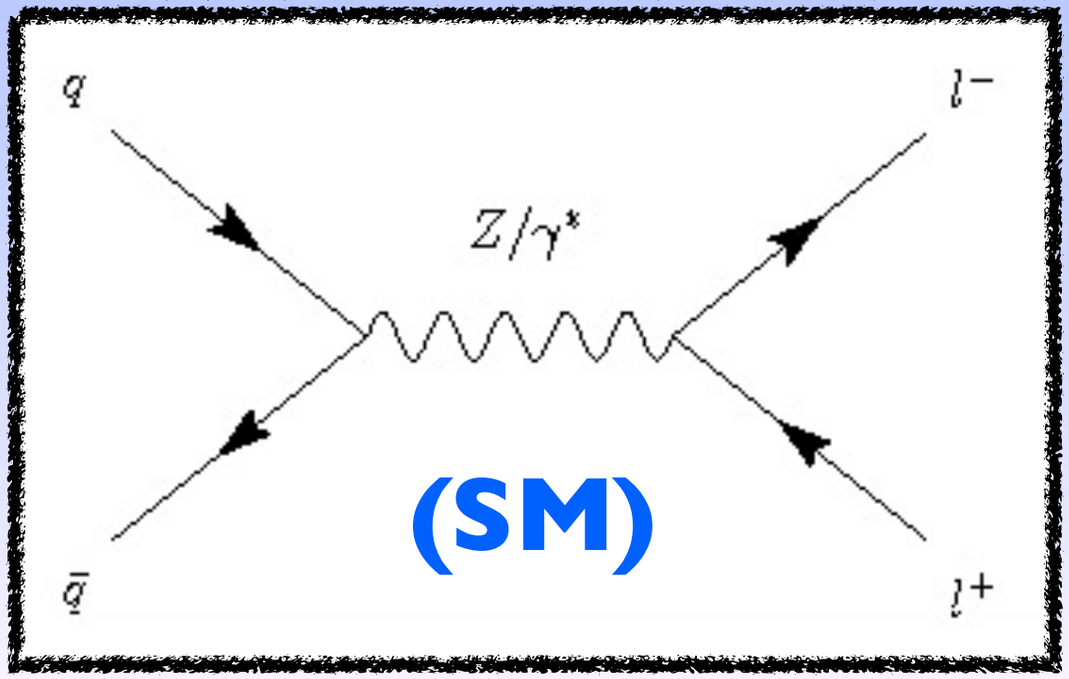
High Mass Dilepton Resonances







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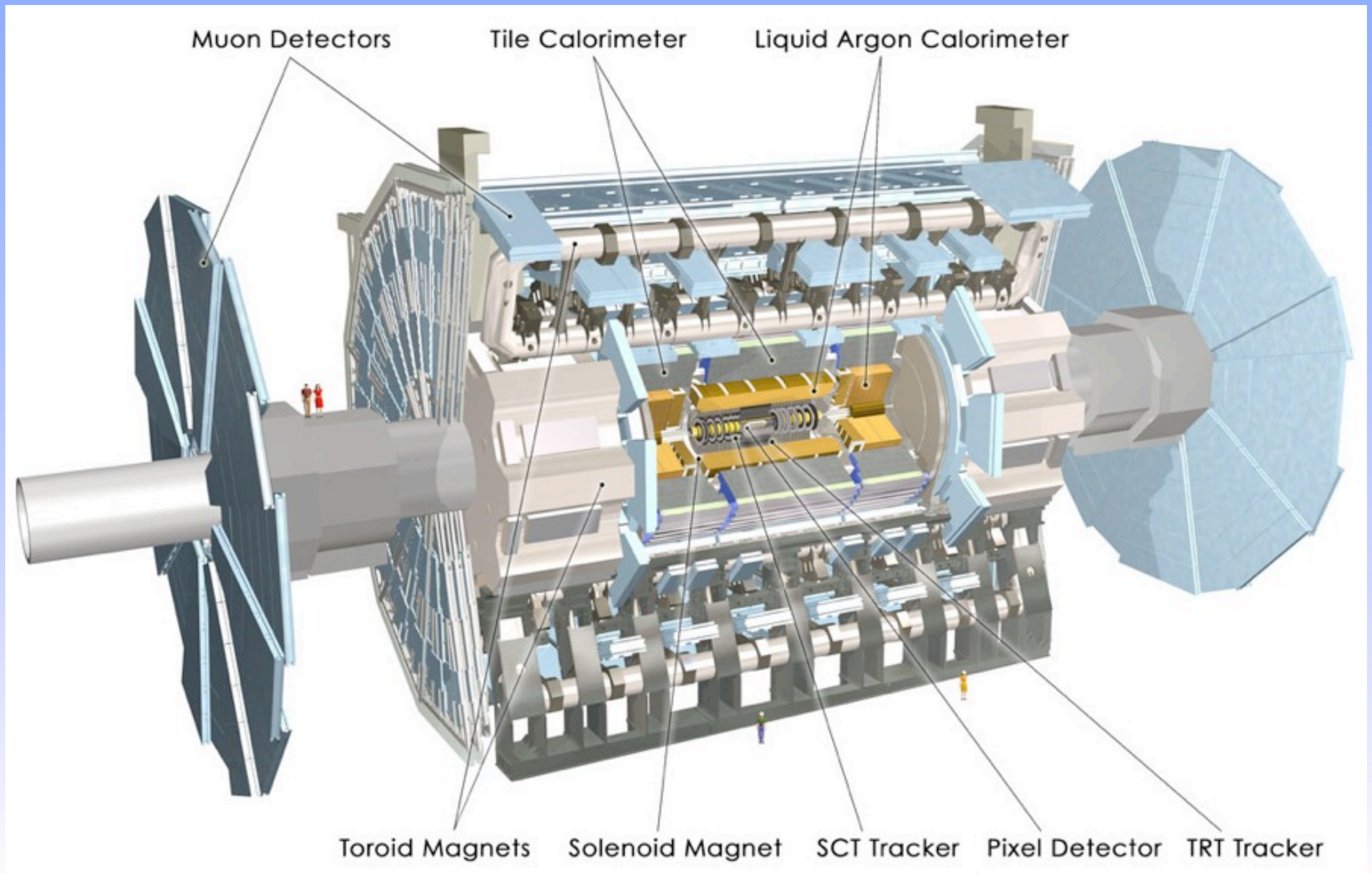
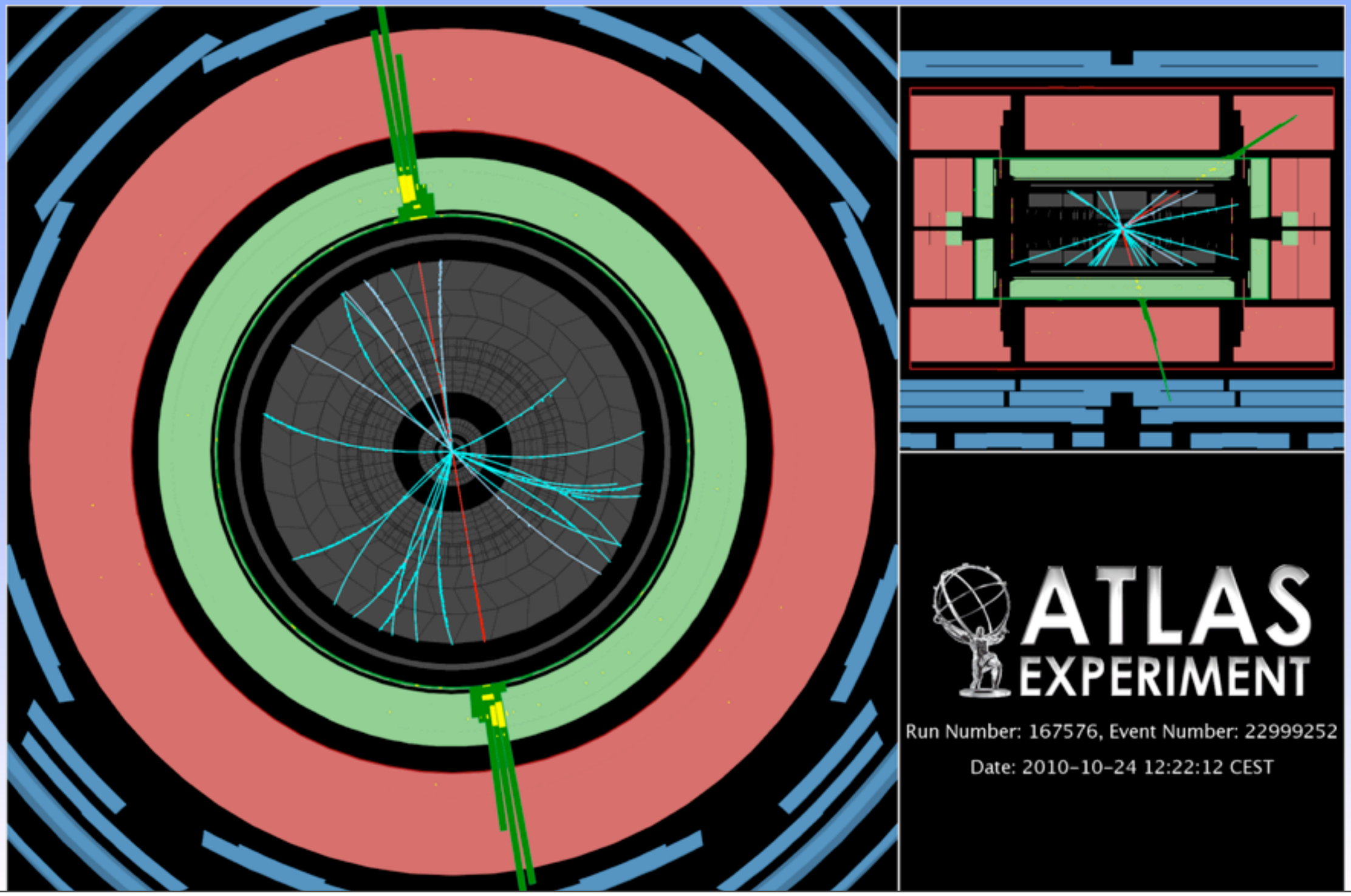
The ATLAS Detector





The ATLAS Detector

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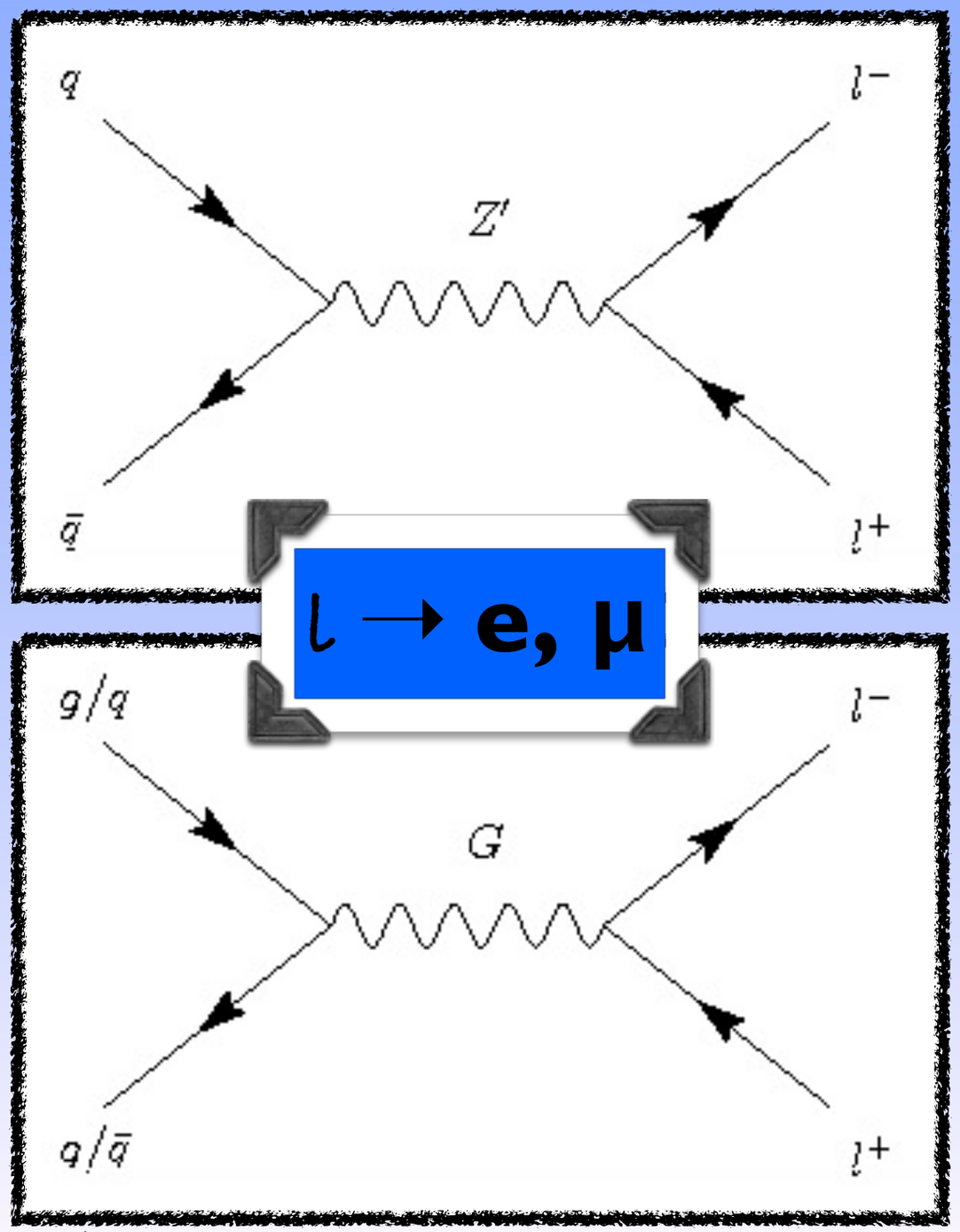
Dilepton Resonance Search

- Both processes decay to dileptons (**e**, **μ**, **τ**).
- Graviton can also decay to diphoton (P.Waller).
- Main analysis here will concentrate on e^+e^- channel, with dilepton combination at the end.

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Electron Analysis Cut Flow

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Cut Name	Comment
Good Run List	List of "Good" Luminosity Blocks in Data.
Primary Vertex	Check Vertices come from Interaction Point.
Trigger	Interested in High Energy Events.
Author	Reconstructed by Calo Seeds / Track Algorithm
η	Fiducial Cut, Excluding Crack between B&E.
P_T	Threshold Cut to avoid Low Energy QCD.
OTx	Exclude HV regions and Bad Calo Cells.
ID	Ensemble of Shower Shape Variable Cuts.
B-Layer	Require Pixel Layer Hit, if Expected.
Mass Window	Interested in High Invariant Mass Region.

* Full Details of Cut Flow in Backup Slides


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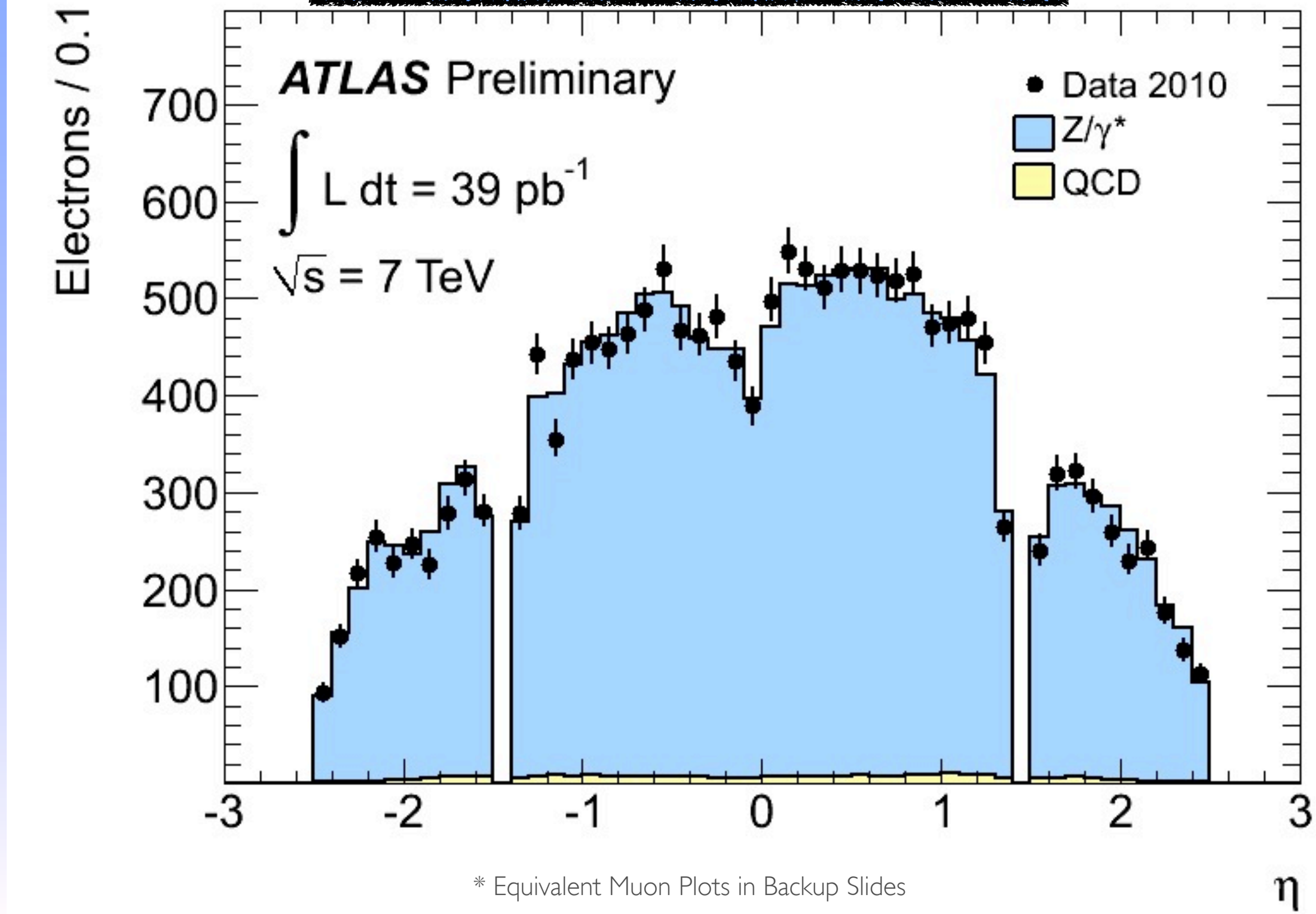
Electron Eta Spectrum



* Equivalent Muon Plots in Backup Slides

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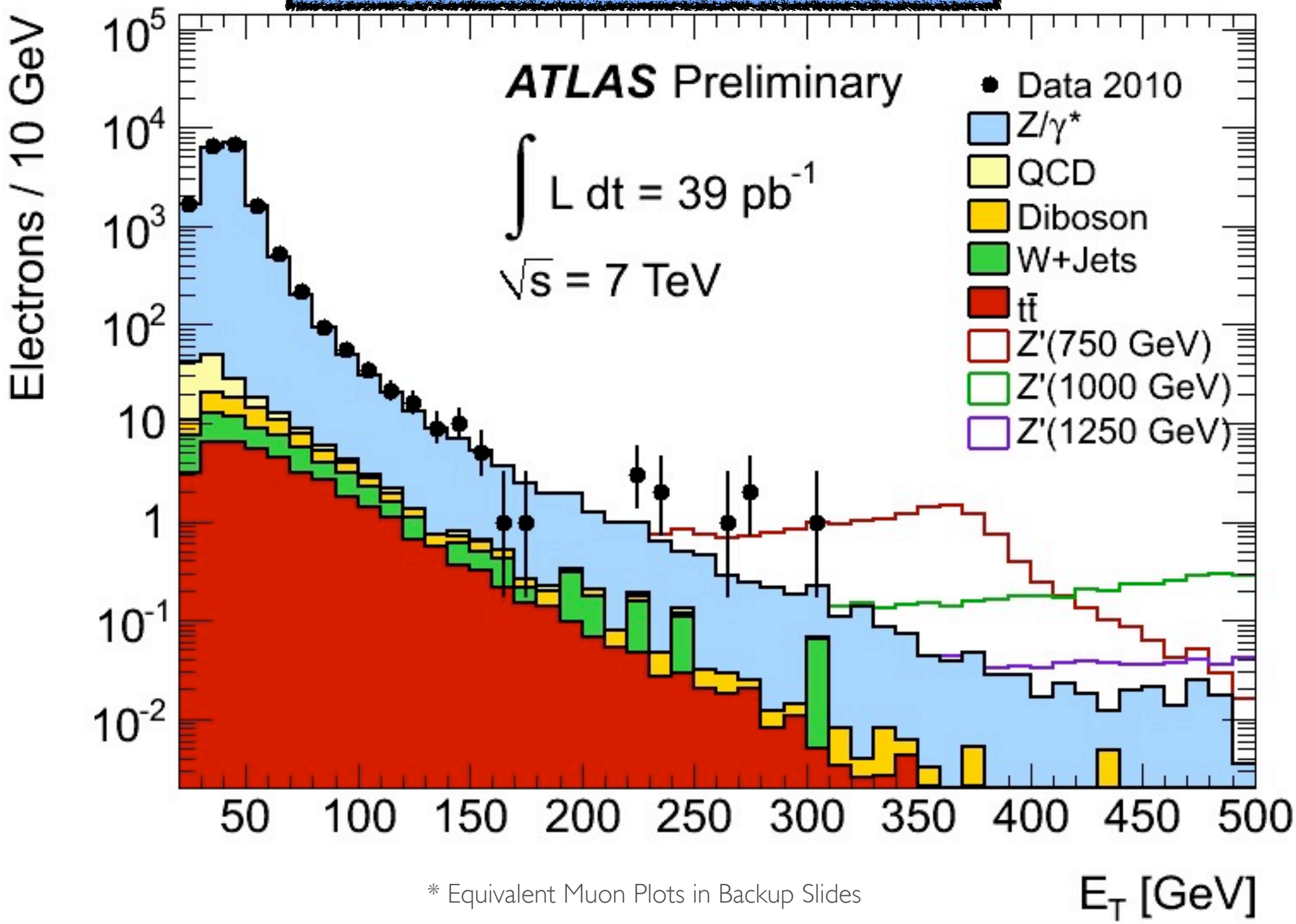
Electron E_t Spectrum



* Equivalent Muon Plots in Backup Slides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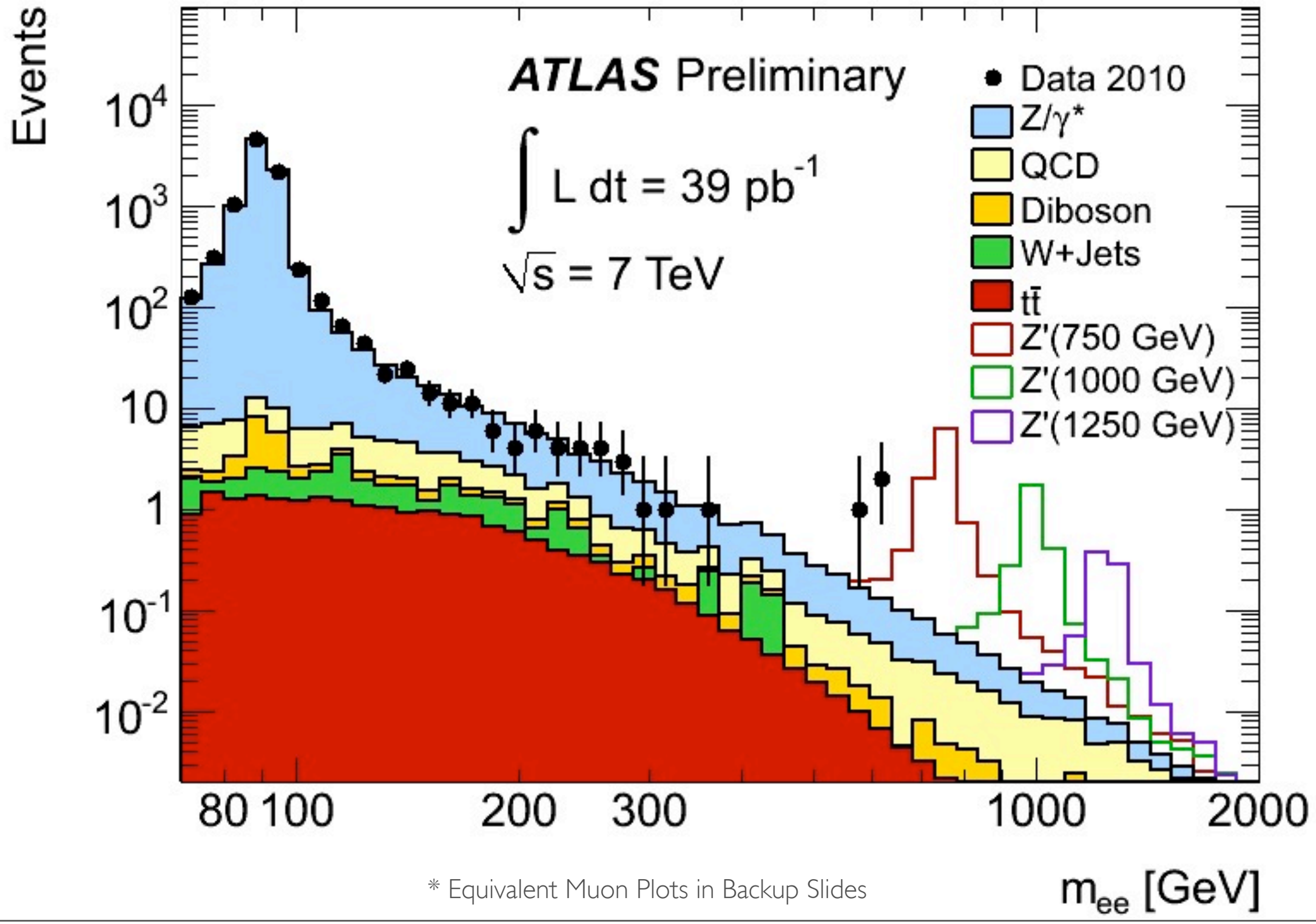
Dielectron Invariant Mass Spectrum



* Equivalent Muon Plots in Backup Slides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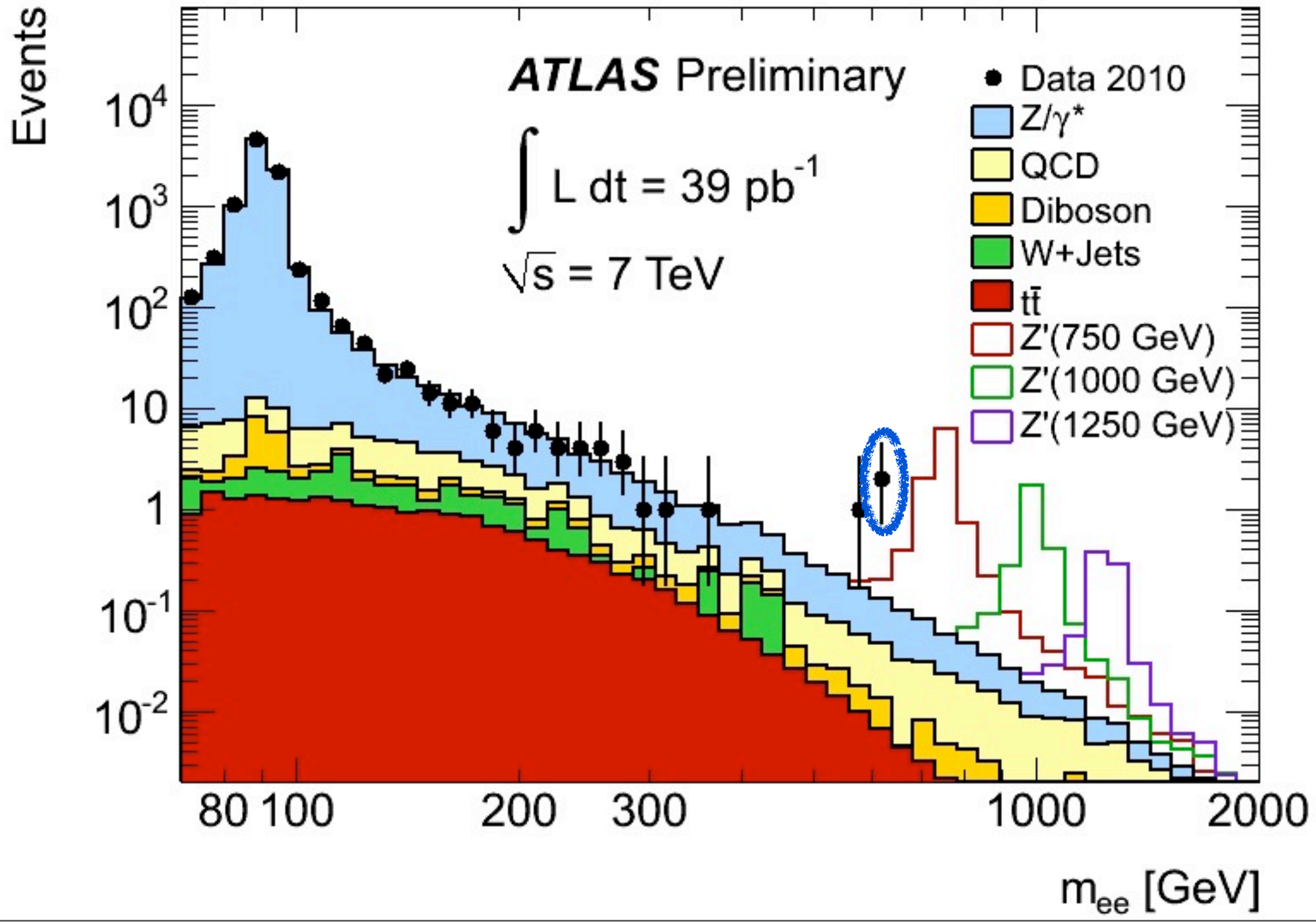
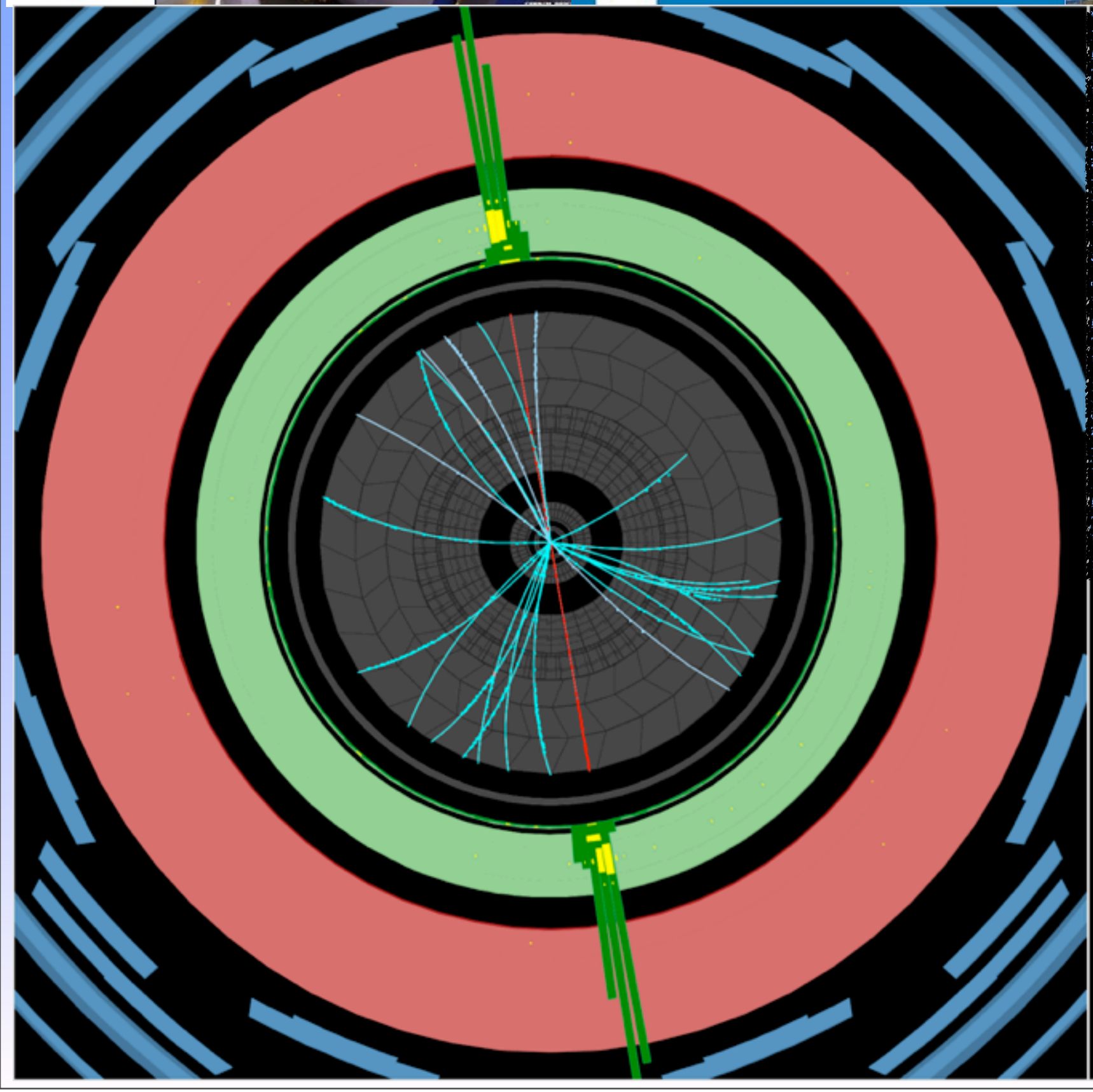
Dielectron Invariant Mass Spectrum





Inv Mass: 617 GeV

Var	Ele 1	Ele 2
E_t (GeV)	279	276
Eta	1.22	0.28
Phi	1.74	-1.40
ID	Tight	Tight

ATLAS EXPERIMENT

Run Number: 167576, Event Number: 22999252

Date: 2010-10-24 12:22:12 CEST

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Limit Setting (2010 Dataset)

* Shown on this slide are Not Actual Limits.

- Bayesian Analysis based on Template Shape Fitting (Essentially a counting experiment in many (poisson) bins).

$$L(N_j, \theta_i \mid data) = \prod_{k=1}^{N_{bin}} \frac{N_k^{N_k^{obs}} e^{-N_k}}{N_k^{obs}!} \prod_{i=1}^{N_{sys}} G(\theta_i, 0, 1)$$

where, $$N_k = \sum_j N_j T_{jk}(1 + \theta_i \epsilon_{jik})$$

- N_k is the sum of expected signal (Z′/Graviton) events, N_{sig} & total background, N_{bkg} (N_Z + $N_{Diboson}$ + N_{QCD} + N_{TTbar} + N_{W+Jets}).

- G is a unit width Gaussian prior for nuisance parameters θ_i that control individual bin systematic variations ($\boldsymbol{\epsilon}_{ji}$) of the template shapes, T_{jk} in the likelihood function.

- We reduce the likelihood function by marginalisation, using MCMC implemented by the Bayesian Analysis Toolkit (BAT).

$$L'(N_{Z'}) = \int L(N_{Z'}, \theta_1, ..., \theta_N) d\theta_1, ..., d\theta_N$$

- Normalise sum of all backgrounds to the data in the mass window $70 < M_{ll} < 110$ GeV, effectively removing any dependency on integrated luminosity, as well as other mass-independent systematic uncertainties.

- Perform a raster scan using the likelihood function for fixed values of the resonance mass (0.13 - 1.5 TeV/c^2).

- In absence of a signal, we set an upper limit at 95% confidence level using the bayesian approach.


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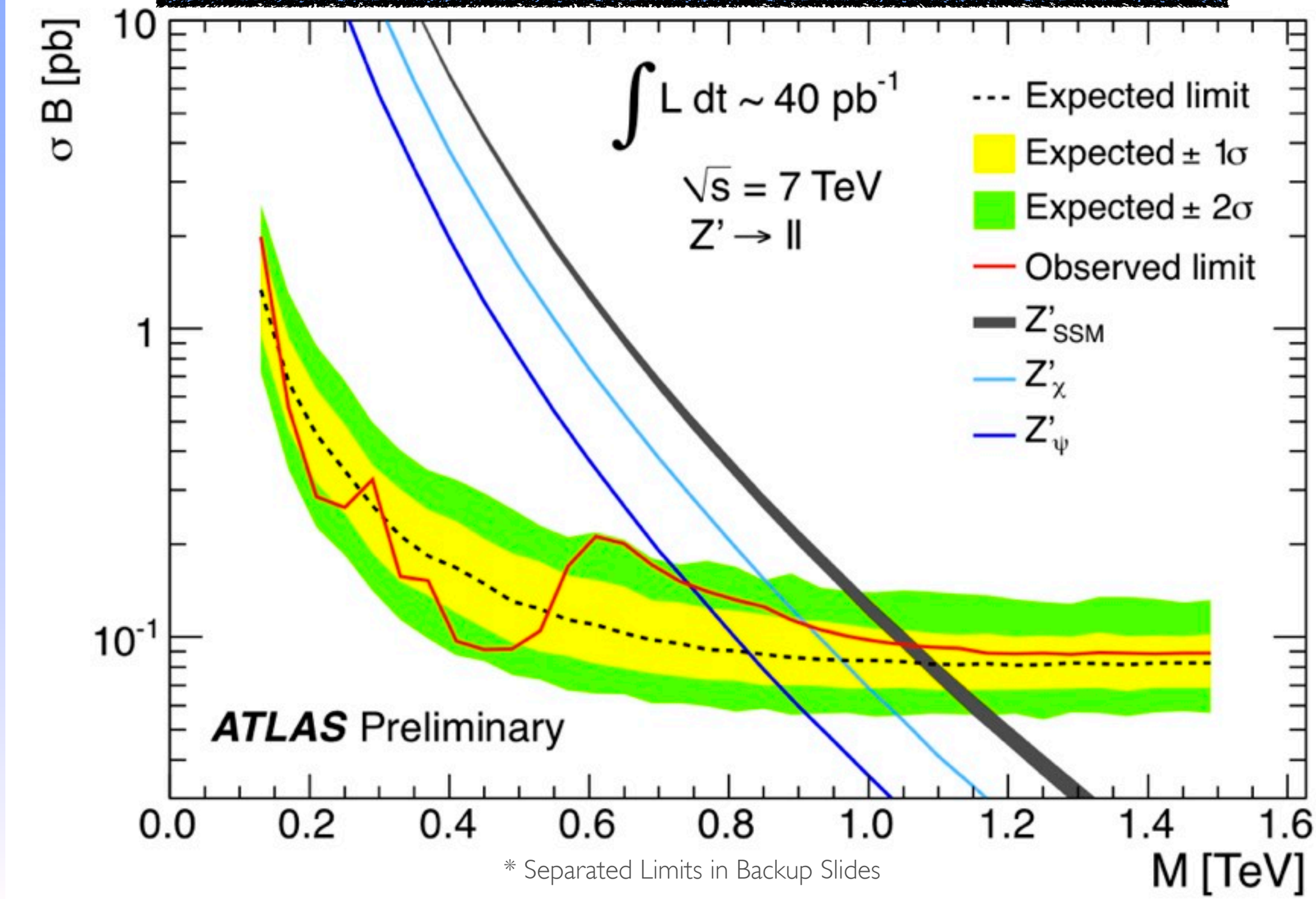
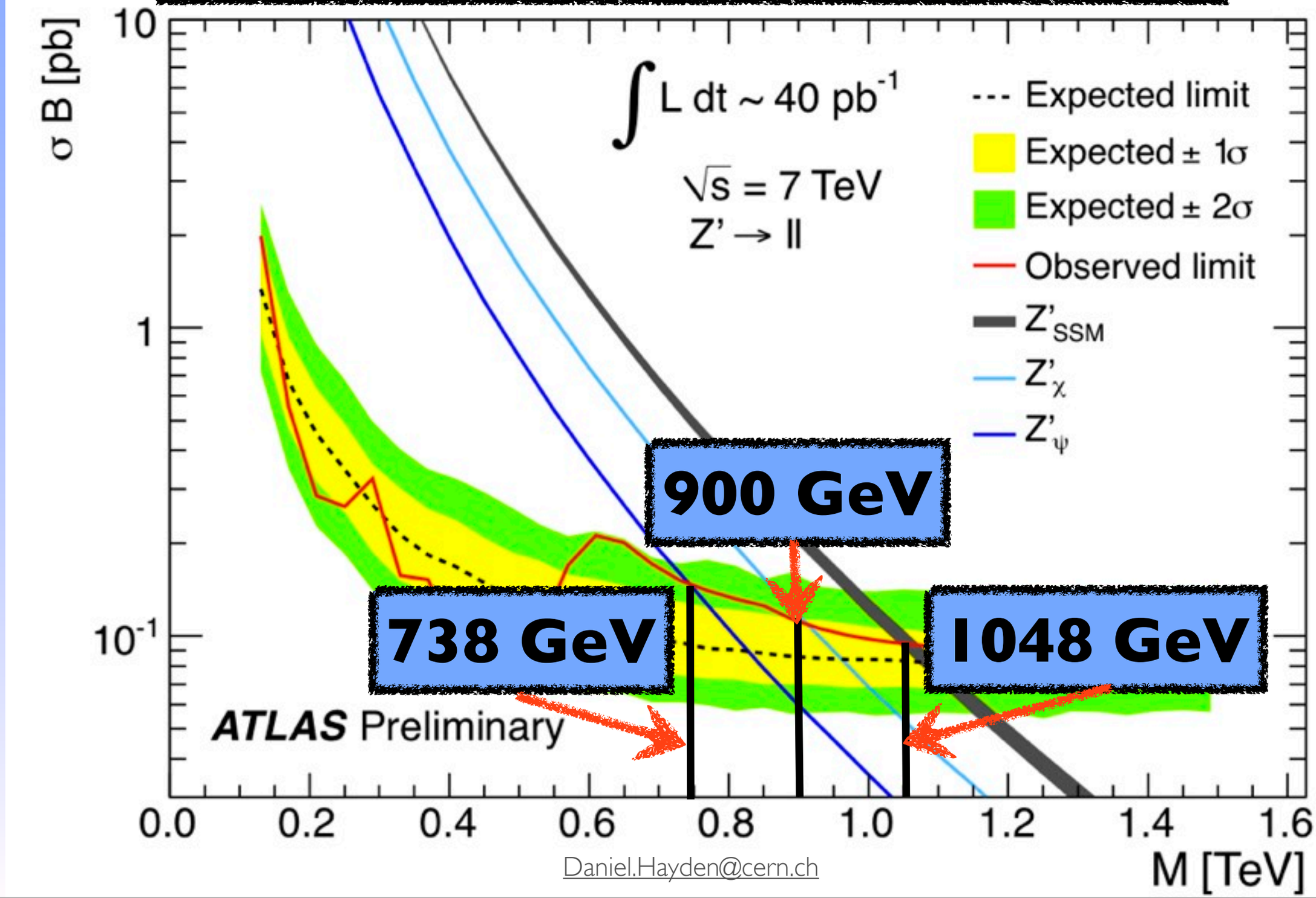
Combined Limit (e & μ)



* Separated Limits in Backup Slides


Combined Limit (e & μ)

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Combined Limit (e & μ)

ATLAS Preliminary

Mass Limits Z' (GeV/c^2)

Z' Model	Z'_{SM}	Z'_{η}	Z'_{χ}	Z'_{ψ}	Z'_{I}	Z'_{sec}	Z'_{N}
e^+e^- (39 pb^{-1})	957	633	829	604	779	807	626
$\mu^+\mu^-$ (40 pb^{-1})	834	645	702	720	736	662	659
$e^+e^- + \mu^+\mu^-$ (~40 pb^{-1})	1048	771	900	738	842	871	763

ATLAS Work in Progress

Mass Limits RS Graviton (GeV/c^2)

k/M_{Pl}	0.010	0.030	0.050	0.100
e^+e^- (39 pb^{-1})	385	599	701	926


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Conclusions

- Exciting time for BSM searches at the LHC!
- ATLAS now extending Tevatron Limits!

The (Near) Future

- 3-10 fb^{-1} of Data expected in 2011 (~100x2010!)
- Possible Graviton three channel combination result for the summer conferences: e^+e^- / $\mu^+\mu^-$ / $\gamma\gamma$

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Backup Slides

Theory


Z'

The Standard Model Gauge Bosons:

$$SU(3) \times SU(2) \times U(1)$$

Strong Force (8 Gluons)	Weak Force ($W\pm, Z^0$)	Electromagnetic (γ)

Several GUT's allow this scheme to be extended, the simplest of which is the SSM (Sequential Standard Model):

$$SU(3) \times SU(2) \times U(1) \times U(1)'$$

SM x Extra U(1) → Z'

... A better extension = LRM (Left-Right Symmetric Model):

$$SO(10) \rightarrow SU(3) \times SU(2)_L \times SU(2)_R \times U(1)_{B-L}$$

(8 Gluons)	($W\pm, Z^0$)	($W'\pm, Z'$)	(γ)


The RS Graviton

Hierarchy Problem:

Interaction	Strong	E/M	Weak	Gravity
Coupling	1	1×10^{-2}	1×10^{-6}	1×10^{-39}

... Or more specifically:

How can the Planck Mass ($\sim 10^{19}$ GeV/c^2) be so large compared to the Electroweak Scale ($\sim 10^{2}$ GeV/c^2), without needing a theory that involves "Fine Tuning".

A Few Possibilities:

Super Symmetry Extra Dimensions


The RS Graviton

Hierarchy Problem:

Interaction	Strong	E/M	Weak	Gravity
Coupling	1	1×10^{-2}	1×10^{-6}	1×10^{-39}

... Or more specifically:

How can the Planck Mass ($\sim10^{19}$ GeV/c^2) be so large compared to the Electroweak Scale ($\sim10^{2}$ GeV/c^2), without needing a theory that involves "Fine Tuning".

A Few Possibilities:

Super Symmetry

Extra Dimensions

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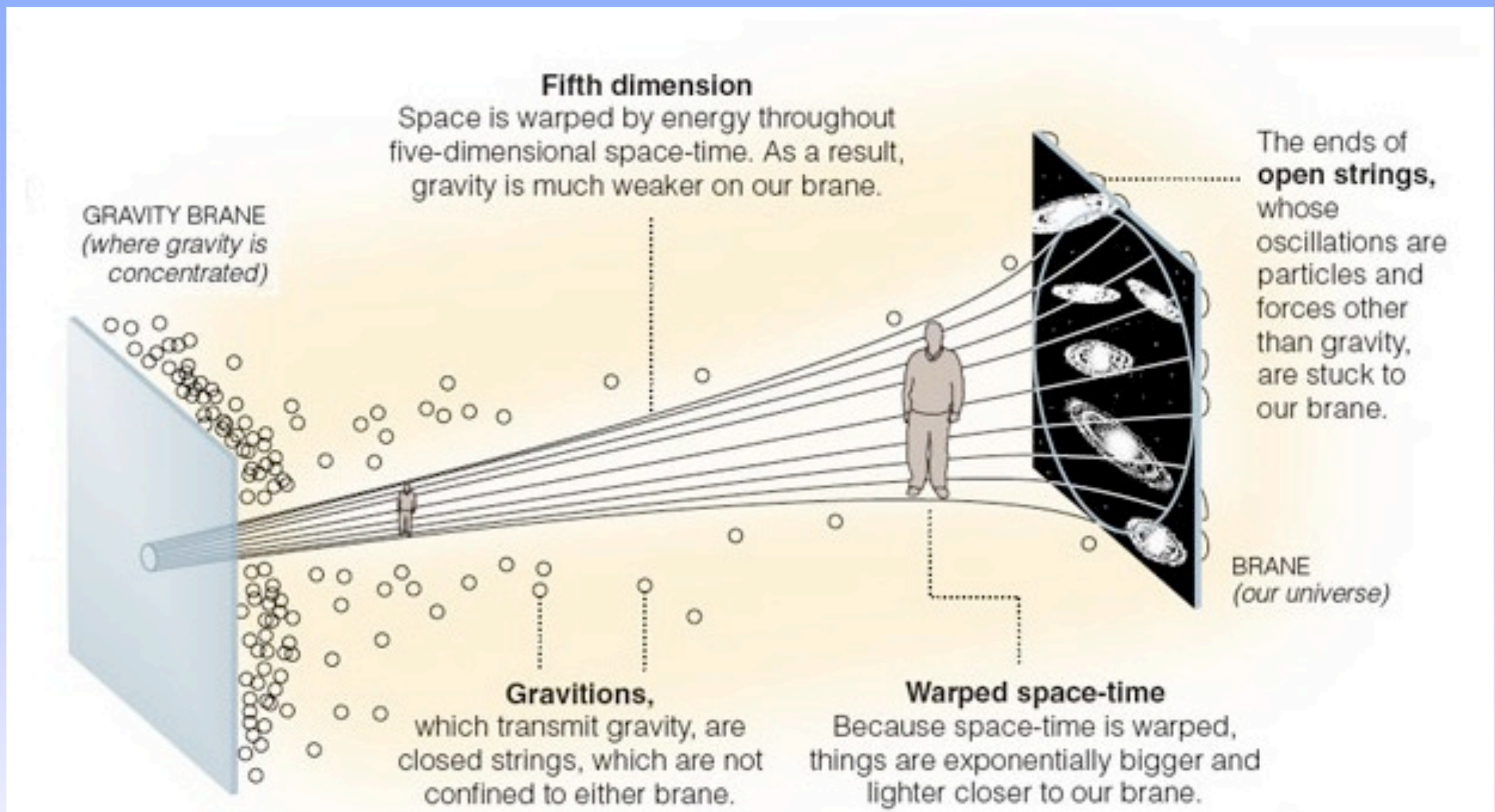
The Graviton

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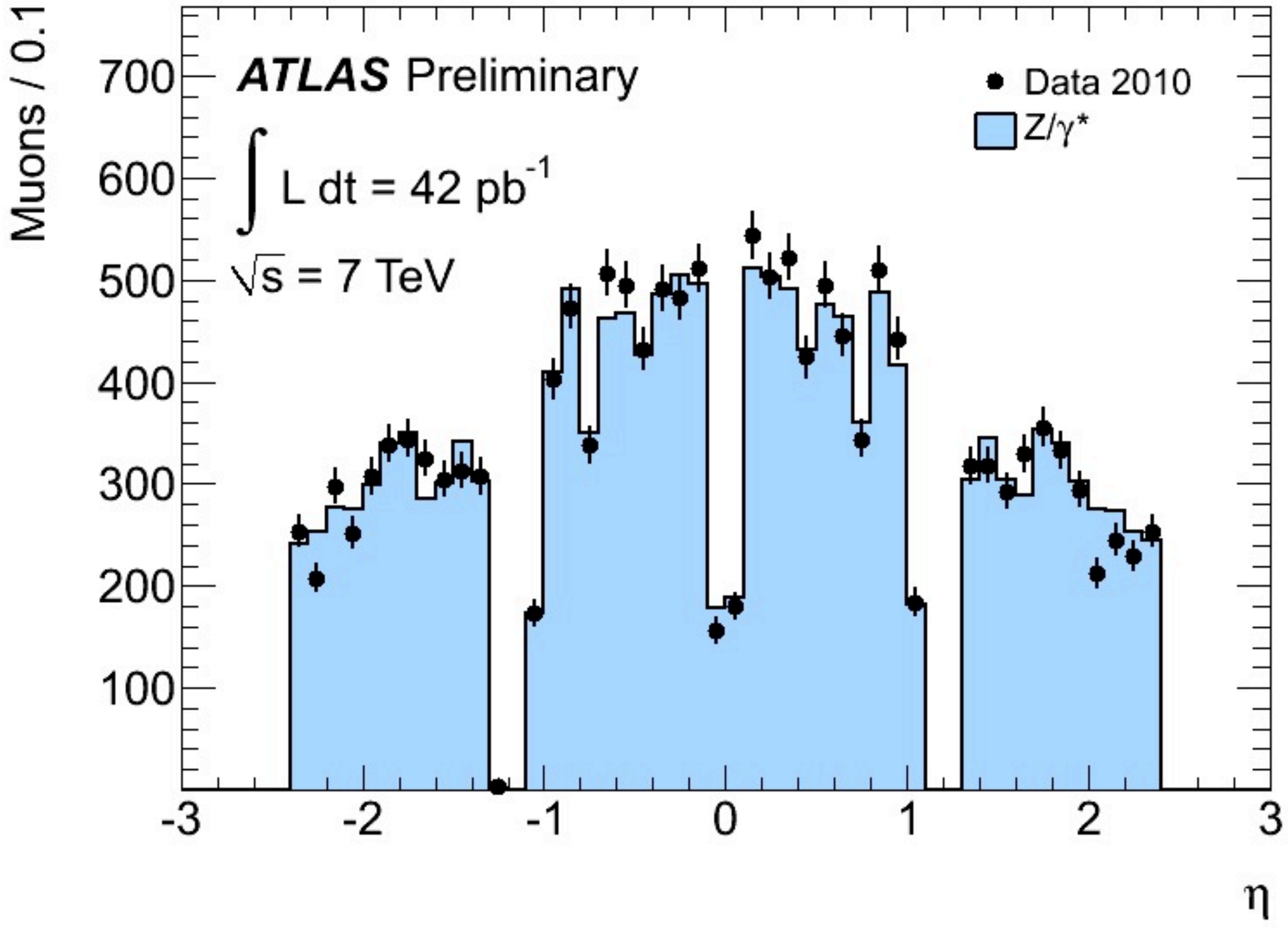
Detailed Cut Flow


Cut Name	Value (For Data)	Comment
Total # Events	N/A	Number of Events Recorded by ATLAS.
GRL	E/Gamma	List of "Good" Luminosity Blocks in Data.
Primary Vertex	At Least 1, with nTracks > 2	Vertices coming from the interaction point.
Trigger	L1_EM14 (<F), EF_e20_loose (≥F)	Interested in High Energy Events.
Author	1 or 3	1 ⇒ Reconstructed by Calo Seeds 3 ⇒ +Reconstructed by Track Algorithm
η	$\lvert\eta\rvert$ < 2.47, no crack: 1.37 > $\lvert\eta\rvert$ > 1.52	Fiducial Cut, Excluding Crack between B&E.
P_T	P_T > 25 GeV	Threshold to avoid low energy QCD.
OTx	Used Generated OTx Maps	Exclude HV regions and Bad Calo Cells.
ID	isEM == Medium	Ensemble of Variable Cuts (i.e. HadLeak).
B-Layer	Require B-Layer Hit, if Expected	B-Layer ⇒ First Layer of the Pixel Detector.
Mass Window	Invariant Mass ≥ 70 GeV	Interested in High Invariant Mass Region.


Cut Name	Value (For Monte Carlo)	Comment
Total # Events	N/A	Number of Events Recorded by ATLAS.
~~GRL~~	~~E/Gamma~~	~~List of "Good" Luminosity Blocks in Data.~~
Primary Vertex	At Least 1, with nTracks > 2	Vertices coming from the interaction point.
~~Trigger~~	~~L1_EM14 (<F), EF_e20_loose (≥F)~~	~~Interested in High Energy Events.~~
Author	1 or 3	1 ⇒ Reconstructed by Calo Seeds 3 ⇒ +Reconstructed by Track Algorithm
η	$\lvert\eta\rvert < 2.47$, no crack: $1.37 > \lvert\eta\rvert > 1.52$	Fiducial Cut, Excluding Crack between B&E.
P_T	$P_T > 25$ GeV	Threshold to avoid low energy QCD.
OTx	Use Luminosity Averaged OTx Map	Exclude HV regions and Bad Calo Cells.
ID	isEM == Medium	Ensemble of Variable Cuts (i.e. HadLeak).
B-Layer	Require B-Layer Hit, if Expected	B-Layer ⇒ First Layer of the Pixel Detector.
Mass Window	Invariant Mass ≥ 70 GeV	Interested in High Invariant Mass Region.

Muon Plots


ATLAS Preliminary
∫ L dt = 42 pb-1
√s = 7 TeV
Data 2010
Z/γ*
Muons / 0.1
700
600
500
400
300
200
100
-3
-2
-1
0
1
2
3
η

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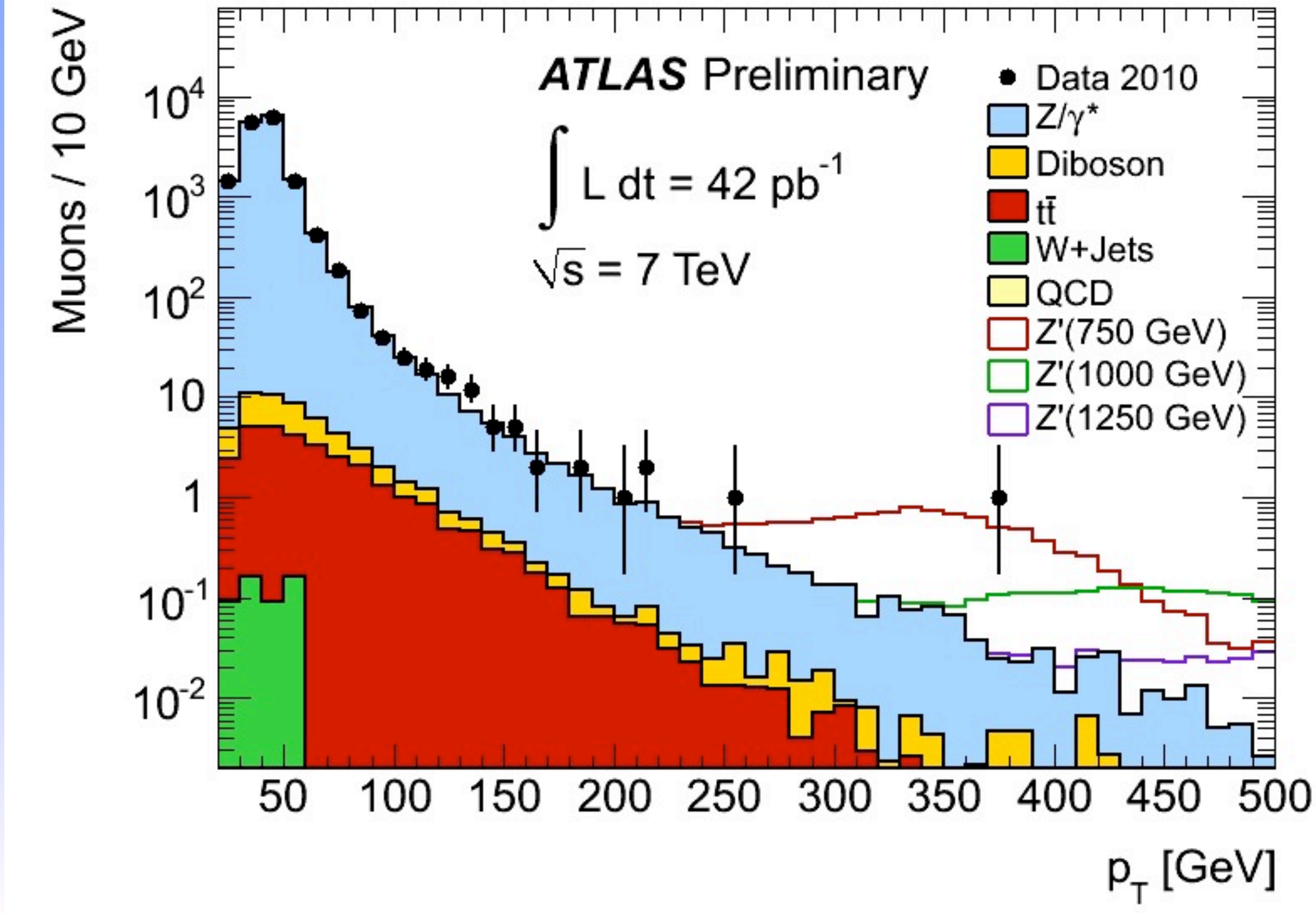


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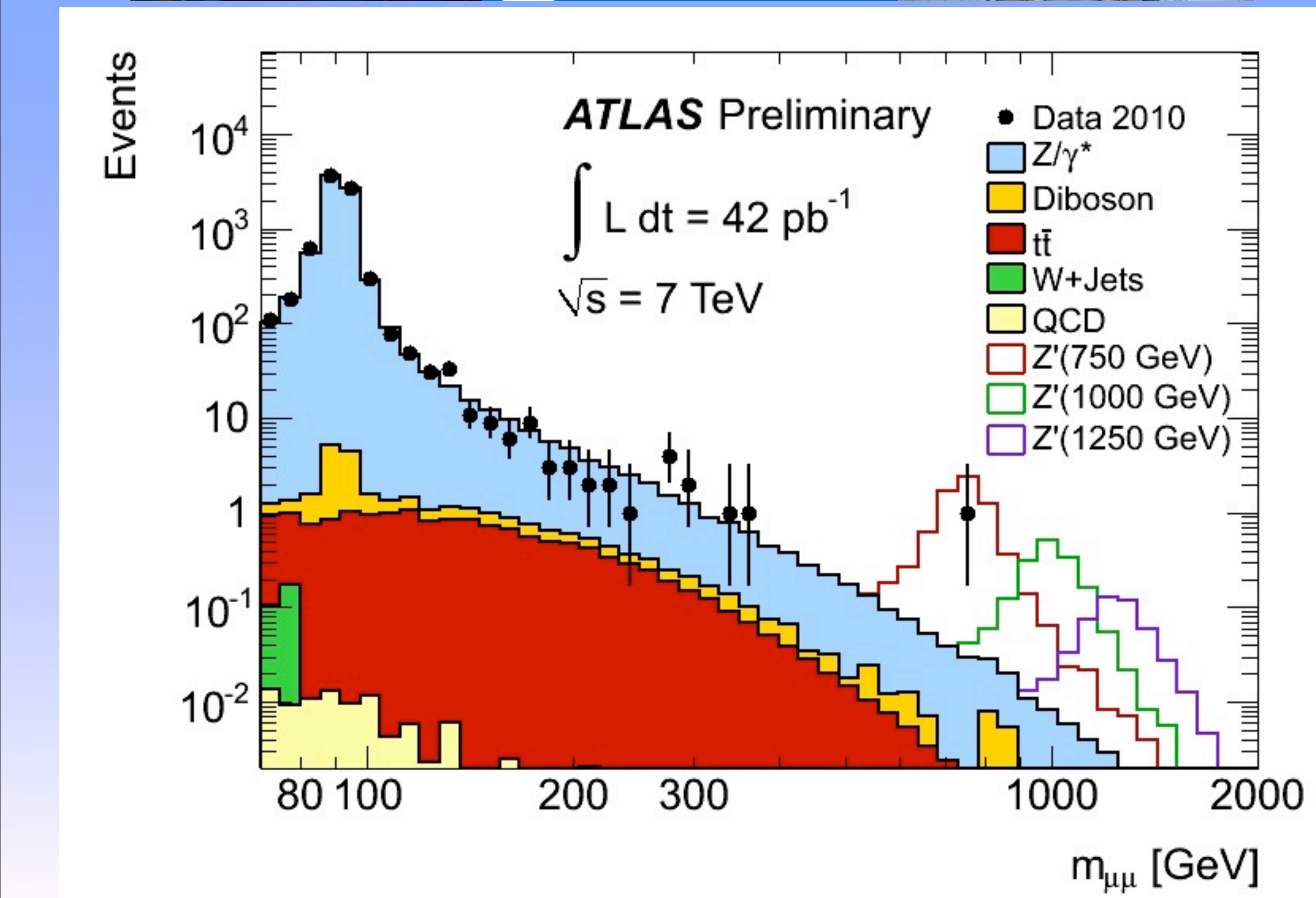
Events
ATLAS Preliminary
∫ L dt = 42 pb-1
√s = 7 TeV
Data 2010
Z/γ*
Diboson
tt̄
W+Jets
QCD
Z'(750 GeV)
Z'(1000 GeV)
Z'(1250 GeV)
10^4
10^3
10^2
10
1
10^-1
10^-2
80 100
200
300
1000
2000
mμμ [GeV]

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Separate Limits


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$\int L\,dt = 39\ pb^{-1}$

$\sqrt{s} = 7$ TeV

$Z' \rightarrow ee$

--- Expected limit

Expected ± 1σ

Expected ± 2σ

Observed limit

Z'_{SSM}

Z'_{χ}

Z'_{ψ}

ATLAS Preliminary

σ B [pb]

M [TeV]

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High Mass Muon Event Display

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ATLAS EXPERIMENT

Run Number: 166198
Event Number: 17169487
Date: 2010-10-04, 20:20:19 CET

Cells: Tiles, EMC