MICHIGAN STATE UNIVERSITY

First look at 13 TeV data for the Exotic dilepton search using the ATLAS Detector.

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Theoretical Motivation

Many theories Beyond the Standard Model (BSM) predict new phenomena which give rise to dilepton final states, such as narrow resonances or broad non-resonant deviations from the SM in the dilepton invariant mass spectrum.

Z′

- Additional Spin-1 Gauge Boson.
- SSM: Simple extension to the SM invoking an additional heavy boson, with same couplings as Z.
- Also motivated by Grand Unified Theories (GUT), such as E_6. Depends on θ mixing of additional U(1) states.

$$\underbrace{E_6 \rightarrow SO(10) \times U(1)_\psi}_{\text{GUT Decomposition}} \rightarrow \underbrace{SU(5)}_{\text{SM Forces}} \times \underbrace{U(1)_\chi \times U(1)_\psi}_{\text{New Physics}}$$

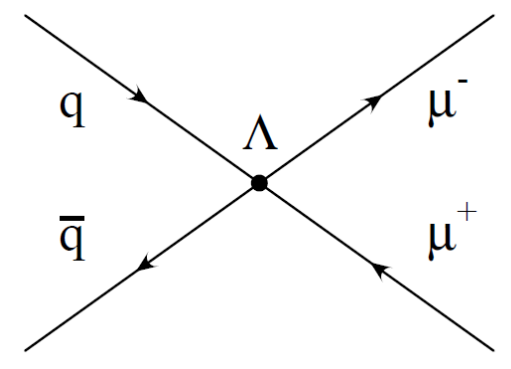
$$Z'(\theta) = Z'_\chi cos\theta + Z'_\psi sin\theta$$

- Six commonly motivated values for θ lead to different models with specific Z′ states named:

$$Z'_\psi \ , \ Z'_N \ , \ Z'_\eta \ , \ Z'_I \ , \ Z'_S \ , \ Z'_\chi$$

Contact Interactions (CI)

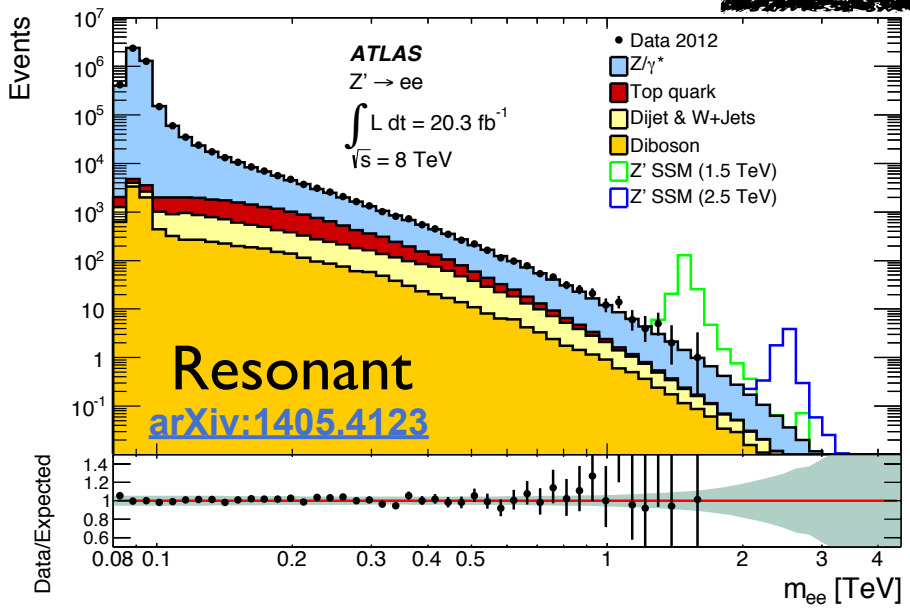
- q-ℓ compositeness, depending on energy scale, Λ.
- Broad excess over the SM invariant mass spectrum.

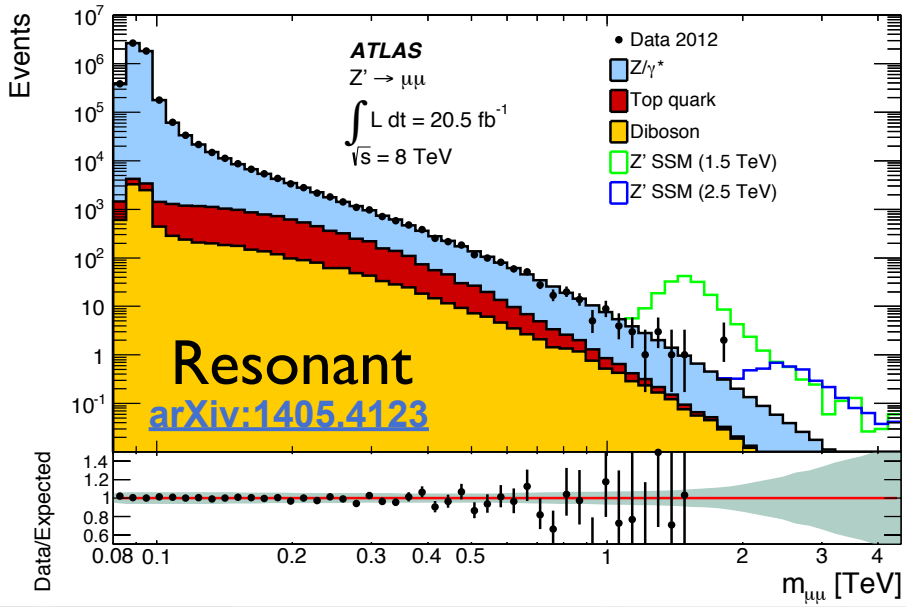


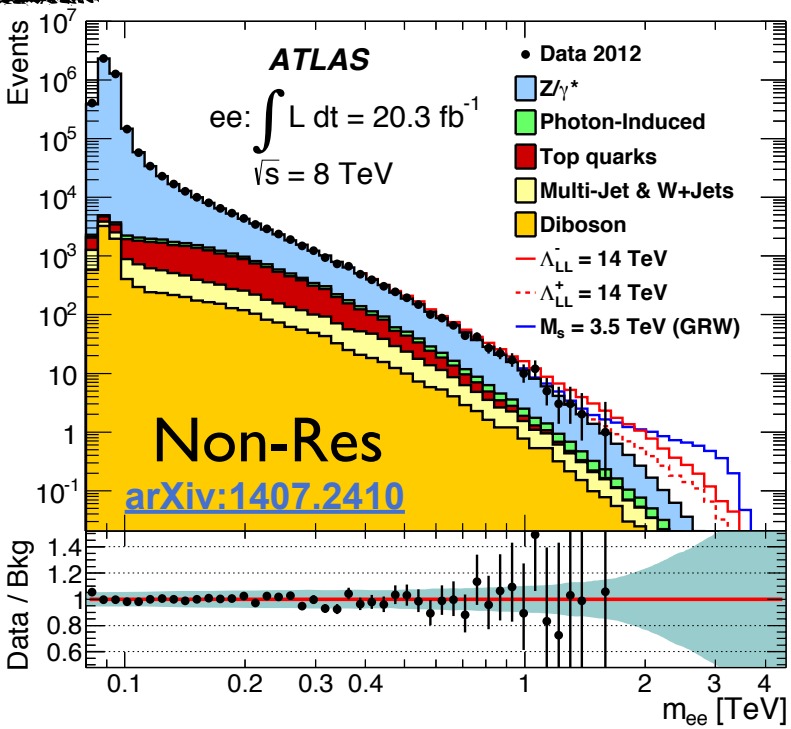
$$\frac{d\sigma}{dm_{\ell\ell}} = \frac{d\sigma_{DY}}{dm_{\ell\ell}} - \eta\frac{F_I}{\Lambda^2} + \frac{F_C}{\Lambda^4}$$

- Interaction describes a color and isospin singlet with couplings to L/R- handed fermion states.
- η_{XY} describes whether the interference is constructive (-), or destructive (+), and the couplings i.e. $\eta_{LL} = 1$, $\eta_{RR} = \eta_{LR} = 0$

Run-I Results







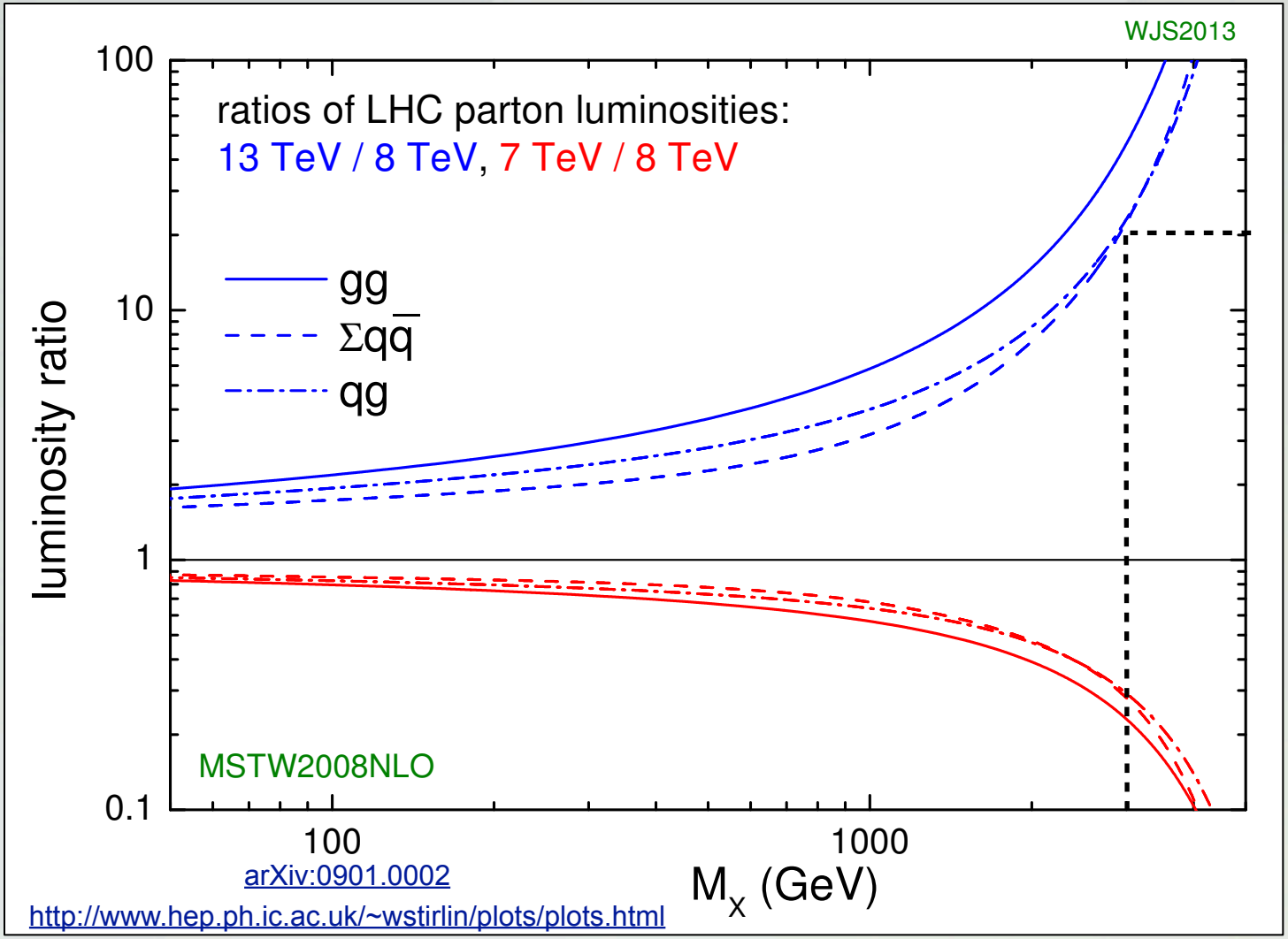
Model	Width [%]	Observed Limit [TeV]	Expected Limit [TeV]
Z'_{SSM}	3.0	2.90	2.87
Z'_{χ}	1.2	2.62	2.60
Z'_{ψ}	0.5	2.51	2.46
Z^*	3.4	2.85	2.82

Expected and observed lower limits on Λ [TeV]

Channel	Prior	Left-Left		Left-Right		Right-Right	
		Const.	Destr.	Const.	Destr.	Const.	Destr.
Exp: $\ell\ell$	$1/\Lambda^2$	21.4	14.7	24.8	18.5	21.0	15.0
Obs: $\ell\ell$		21.6	17.2	26.3	19.0	21.1	17.5
Exp: $\ell\ell$	$1/\Lambda^4$	19.1	13.8	23.1	17.6	19.1	14.2
Obs: $\ell\ell$		19.6	15.4	23.8	17.8	19.3	15.6

Run-2

With the increase from 8 TeV to 13 TeV in center-of-mass energy, provided by the LHC in Run-2, it is a very exciting time and opportunity to discover new physics!



qq Parton Luminosity Increases by a factor of ~20 at a mass of 3 TeV!

Even more for qq/gg initiated processes (Graviton).

Signal & Background Processes

The backgrounds to a dilepton search come from:
Drell-Yan, Tops, Diboson, and Multi-Jet & W+Jets processes.

Process	Generator	Order	Parton Shower	PDF
$q\bar{q} \to Z/\gamma^* \to \ell^+\ell^-$	POWHEG [28]	NLO	PYTHIA 8.165 [30]	CT10 [29]
$t\bar{t} \to \ell X, Wt \to X$	POWHEG [28]	NLO	PYTHIA 6.400 [35]	CT10 [29]
$WW, WZ, ZZ \to \ell X/\ell\nu/\ell\ell$	SHERPA 2.1.1 [33]	NLO	SHERPA 2.1.1 [33]	CT10 [29]
$q\bar{q} \to Z/\gamma^* \to \ell^+\ell^-$	PYTHIA 8.165 [30]	LO	PYTHIA 8.165 [30]	NNPDF23LO [34]
$q\bar{q} \to Z' \to \ell^+\ell^-$	PYTHIA 8.165 [30]	LO	PYTHIA 8.165 [30]	NNPDF23LO [34]
CI: $q\bar{q} \to \ell^+\ell^-$	PYTHIA 8.165 [30]	LO	PYTHIA 8.165 [30]	NNPDF23LO [34]

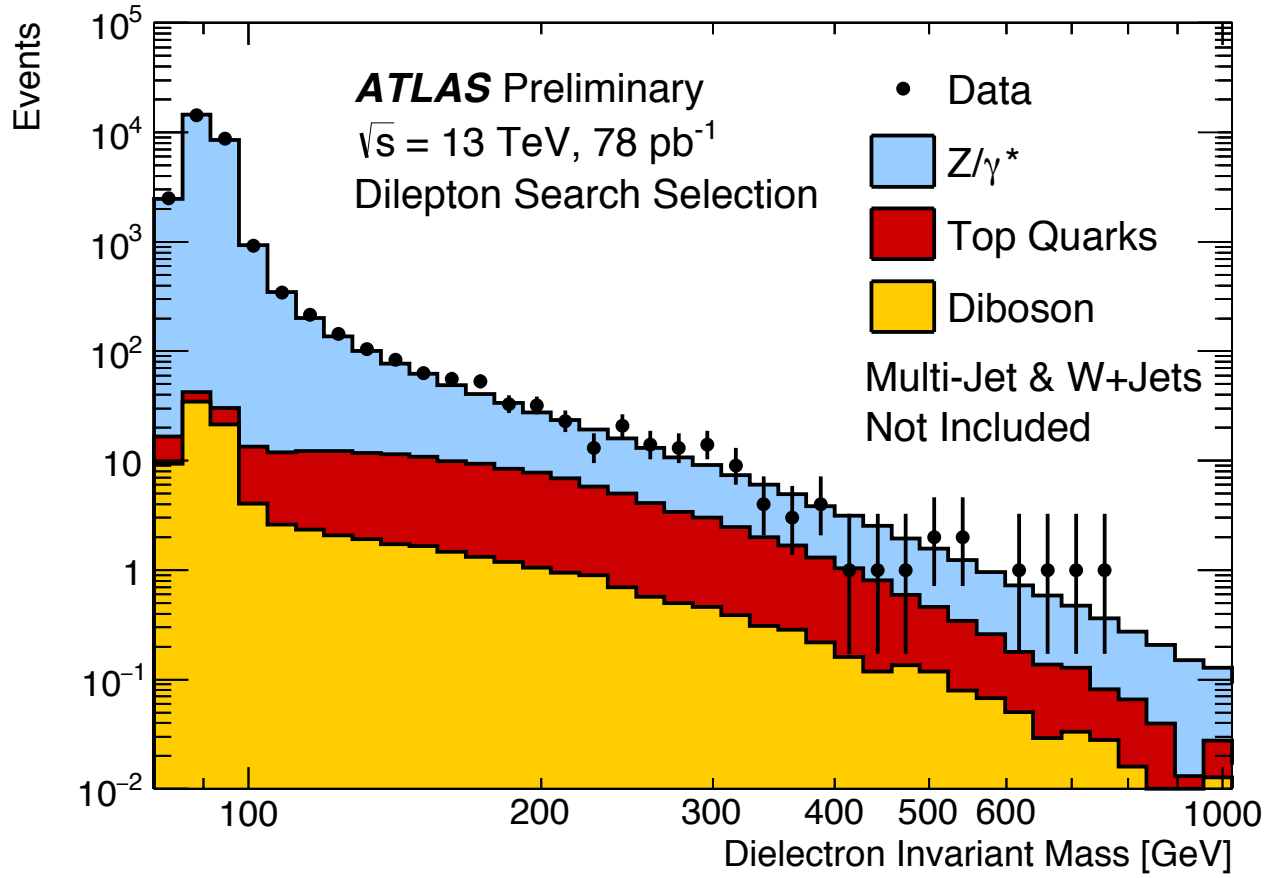
Most of these are estimated using Monte Carlo,
and corrected to NNLO where possible.

The Multi-Jet & W+Jets background, which is relevant in the electron channel, is estimated using a Data-Driven Method.

This contribution is expected to be small, and there are not enough statistics to produce an estimate in the plots shown today.

Event Selection

Electron Channel	Muon Channel
Event-Level Criteria	
Require low pT threshold, non-prescaled triggers.	
Perform event cleaning to remove “noisy” events.	
Require at least two electrons or muons in the event.	
Lepton-Level Criteria.	
$\lvert\eta\rvert < 2.47$, excluding crack region	$p_T > 30$ GeV
Remove electrons with bad calo clusters	High-p_T req. based on ID and MS hits
$E_T > 30$ GeV	d0 impact parameter requirement
d0 impact parameter requirement	z0 impact parameter requirement
e-identification = Likelihood “Medium”	Muon must be well isolated
Electron must be well Isolated	Opposite charge sign
Select Highest E_T/p_T Pair	
Dielectron Invariant Mass > 80 GeV	Dimuon Invariant Mass > 80 GeV



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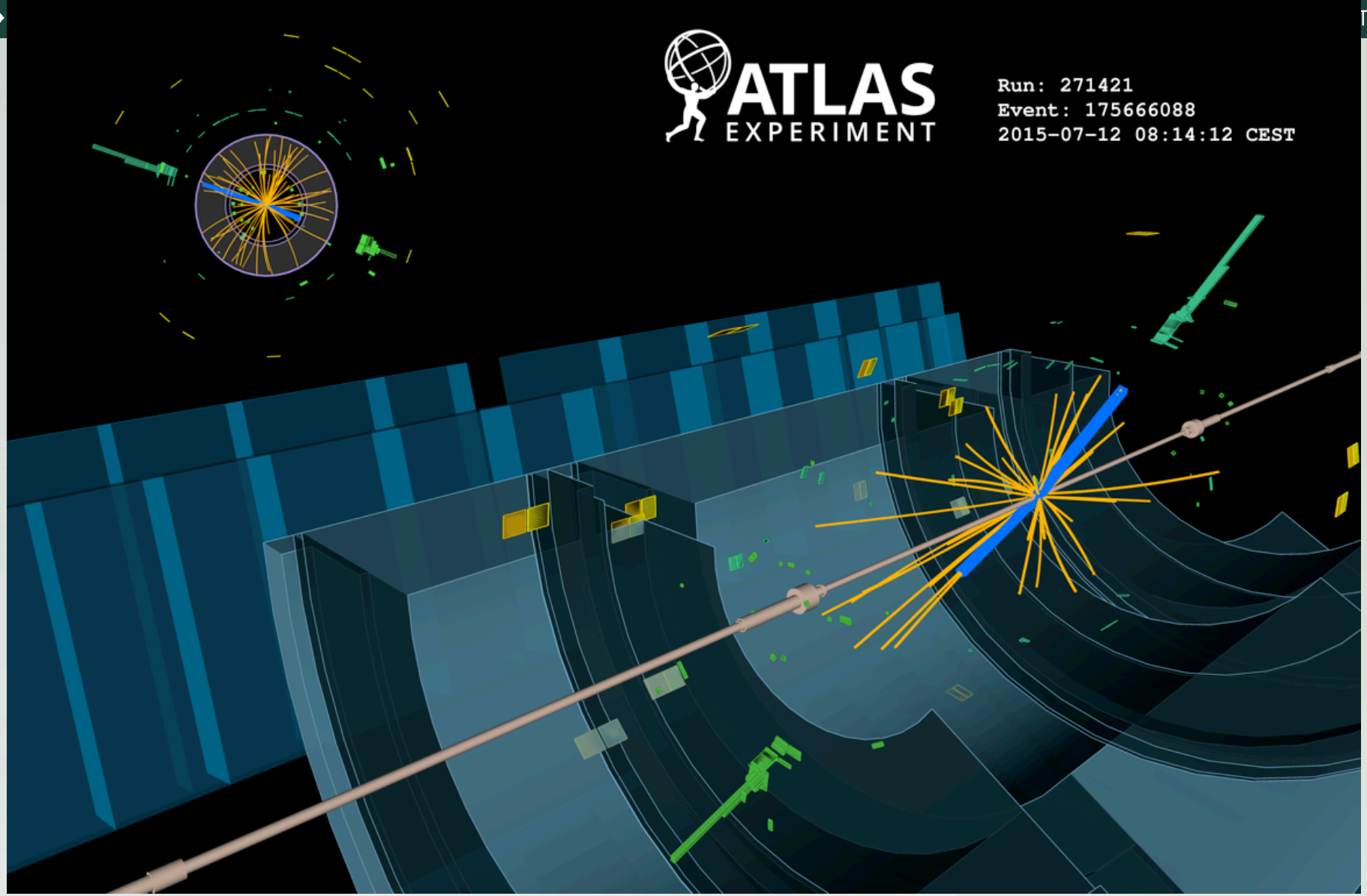
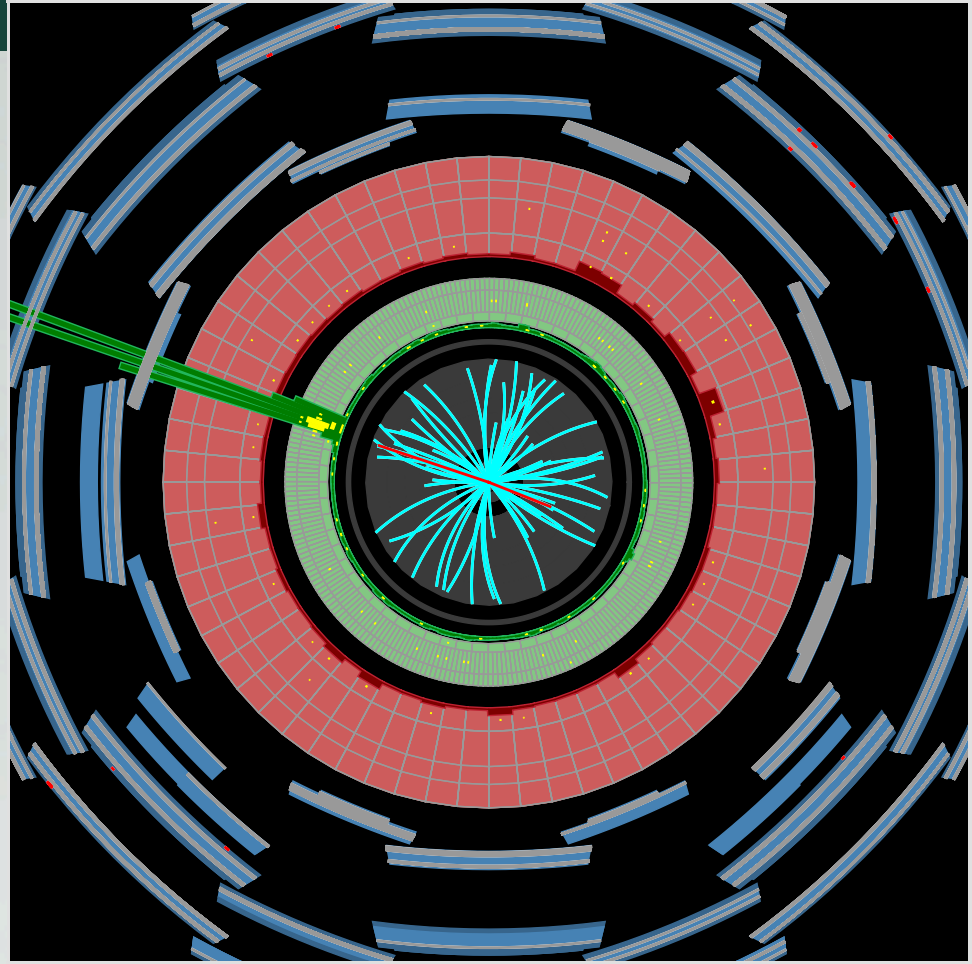
Dielectron invariant mass (m_{ee}) distribution after the dilepton search event selection, showing the stacked sum of all expected Monte Carlo backgrounds. The Data-Driven Multi-Jet & W+Jets background is not included, but is expected to be small. Events are selected which have two electrons with E_T greater than 30 GeV, $|\eta| < 2.47$ (also excluding the crack region), and are well isolated. The bin width is constant in $\log(m_{\ell\ell})$, and the Monte Carlo expectation is normalised to data in the invariant mass region 80–120 GeV. The previous search results at 8 TeV can be found at: arXiv:1405.4123.



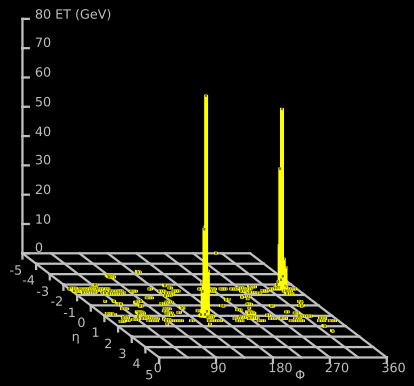
Highest dielectron invariant mass event. The highest momentum electron has an E_T of 189 GeV and an η of 1.08. The subleading electron has an E_T of 177 GeV and an η of -1.58. The invariant mass of the pair is 739 GeV.

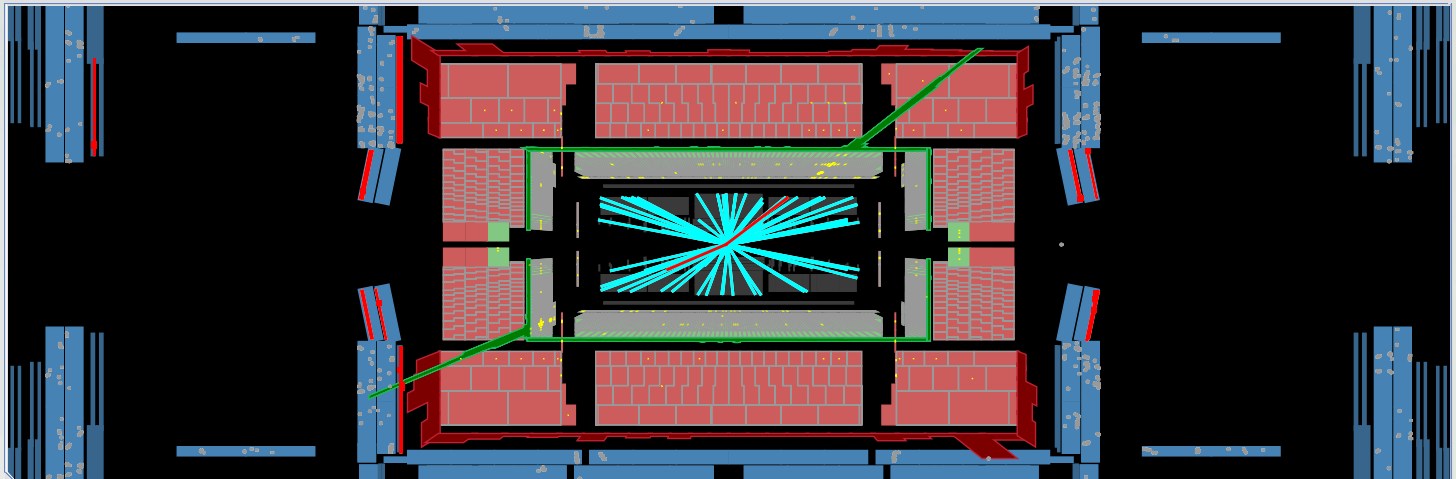


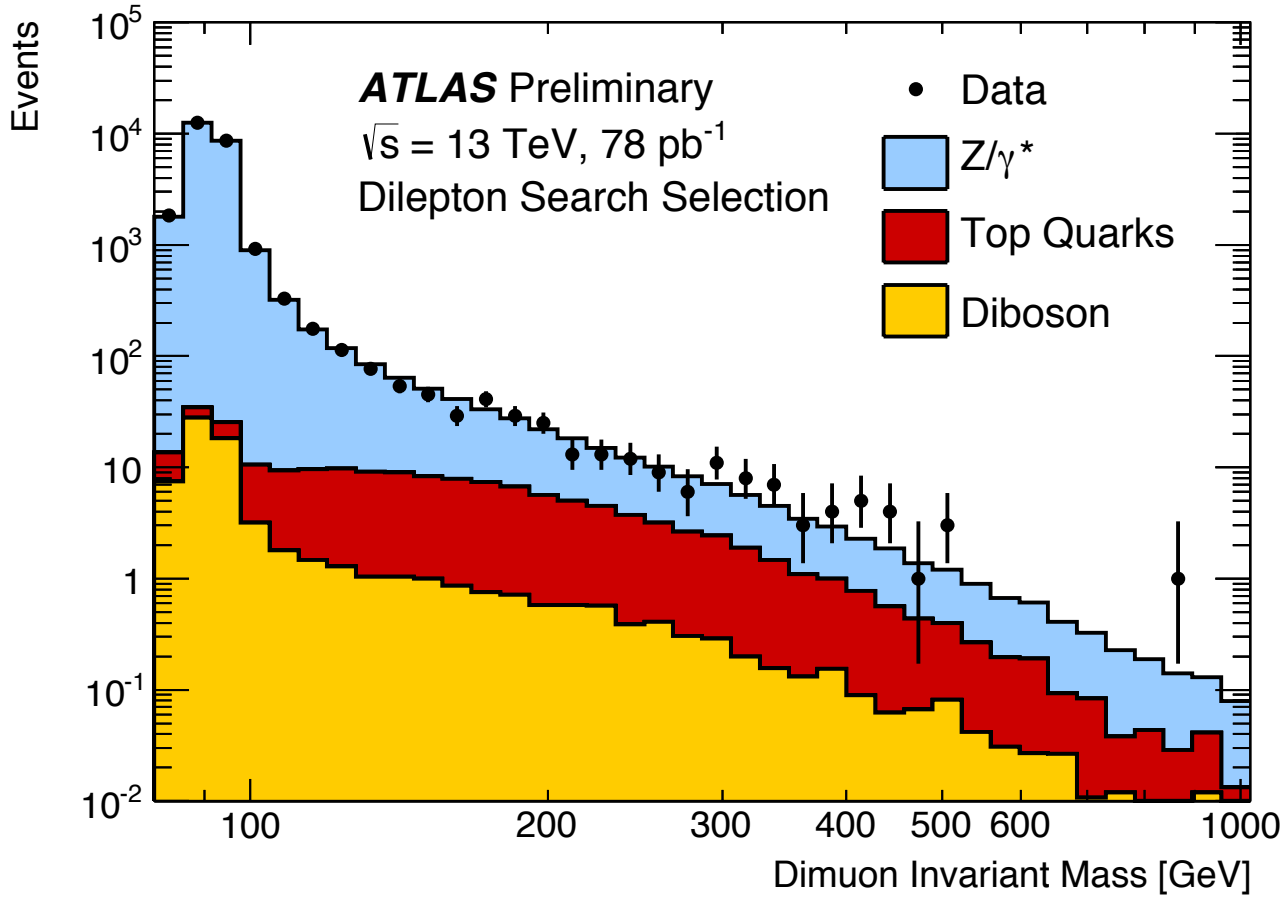
ATLAS EXPERIMENT

Run Number: 271421, Event Number: 175666088

Date: 2015-07-12 08:14:12 CEST







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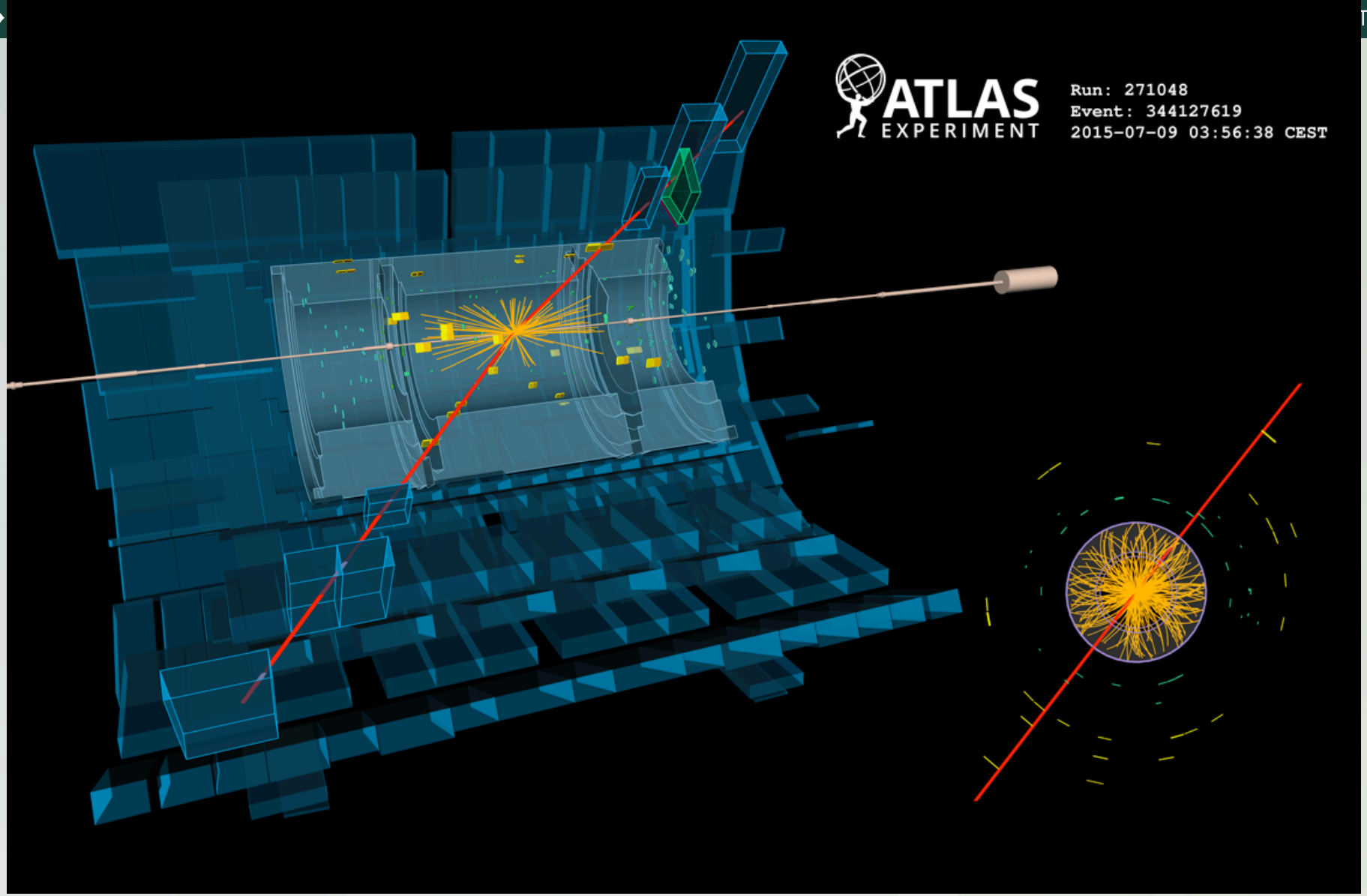
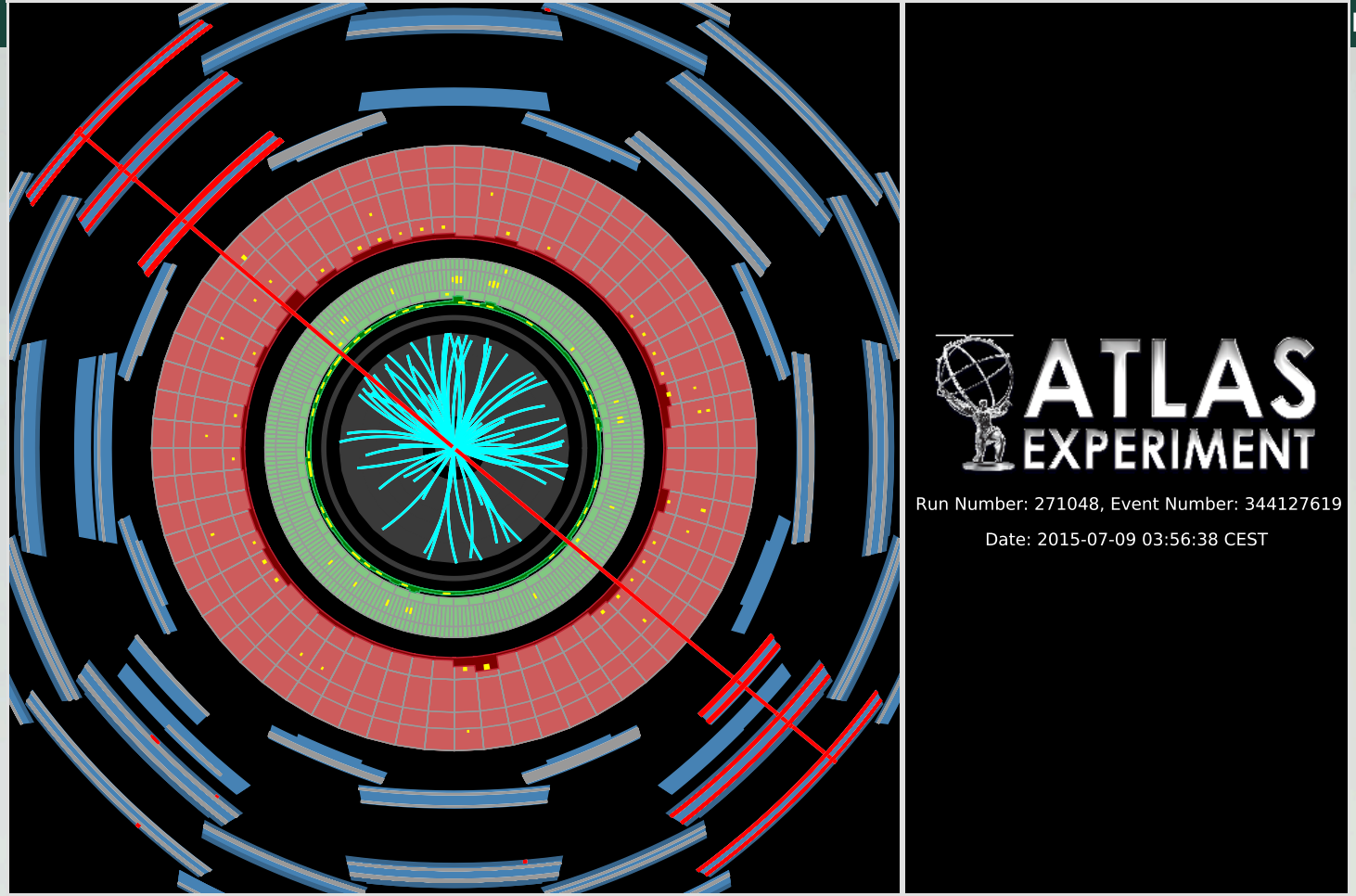
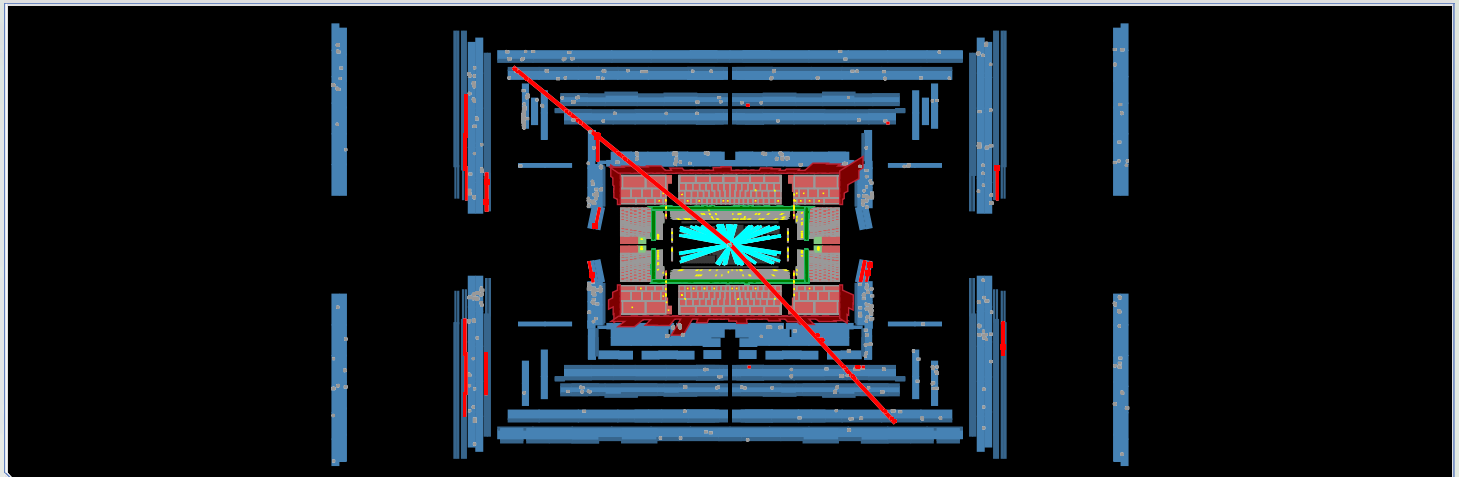
Dimuon invariant mass ($m_{\mu\mu}$) distribution after the dilepton search event selection, showing the stacked sum of all expected backgrounds. Events are selected which have two muons with p_T greater than 30 GeV, $|\eta| < 2.5$, and are well isolated. The bin width is constant in $\log(m_{\ell\ell})$, and the Monte Carlo expectation is normalised to data in the invariant mass region 80–120 GeV. The previous search results at 8 TeV can be found at: arXiv:1405.4123.



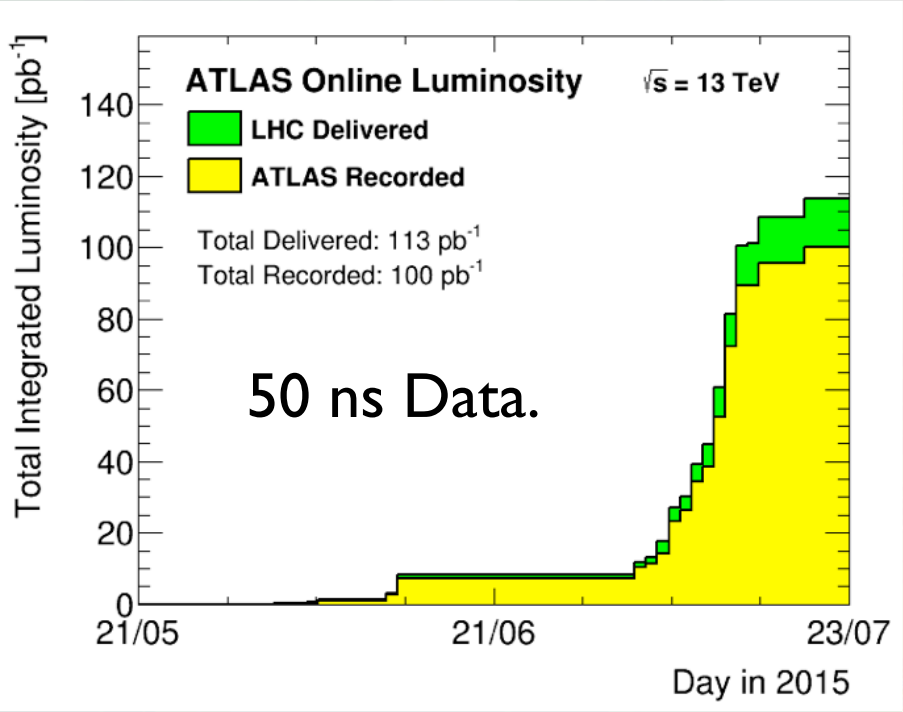
Highest dimuon invariant mass event. The highest momentum muon has a p_T of 305 GeV and an η of -1.03. The subleading muon has a p_T of 300 GeV and an η of 0.82. The invariant mass of the pair is 881 GeV.


ATLAS
EXPERIMENT
Run Number: 271048, Event Number: 344127619
Date: 2015-07-09 03:56:38 CEST



Conclusion and Plans

- We have presented a first look at 13 TeV data using 78 /pb of integrated luminosity, when applying the dilepton search event selection for Run-2.
- Data/MC agreement looks good with the current dataset, and we estimate that ~2-3 /fb are needed to exceed our Run-I sensitivity.
- Focus on being ready for a discovery, we're not starting in limit setting mode!



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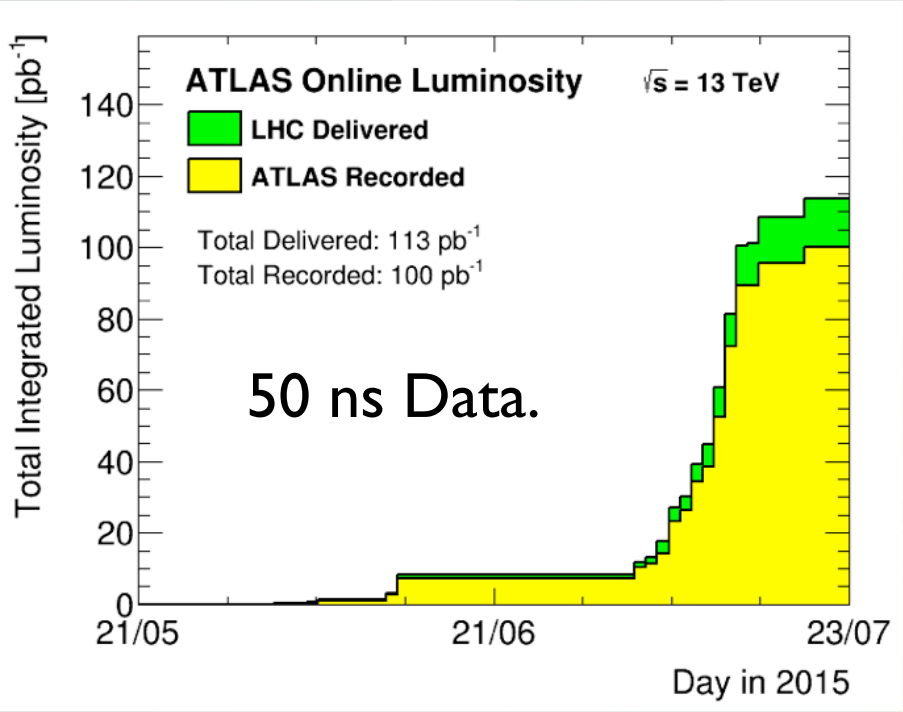
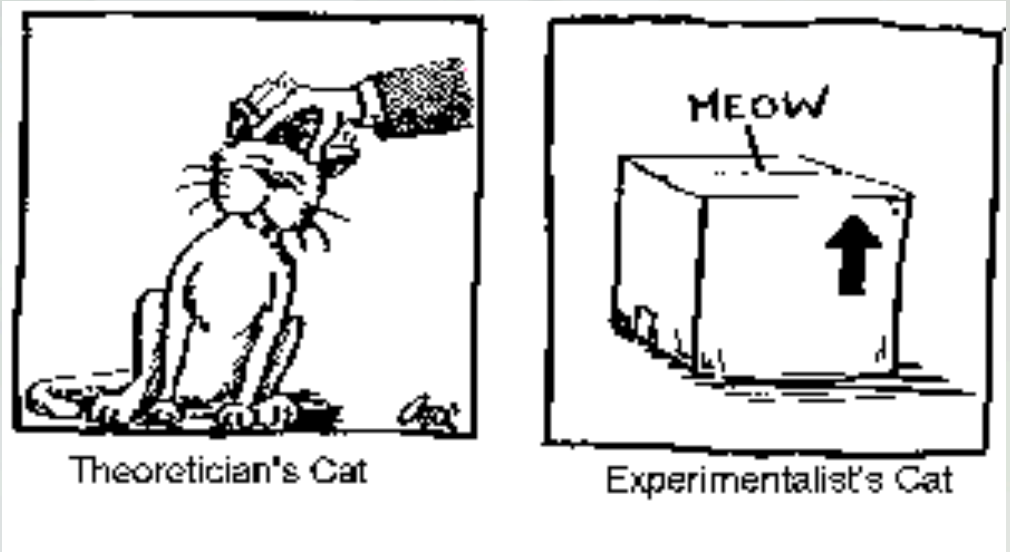


Backup



Link to Public Result:

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/EXOT-2015-001/