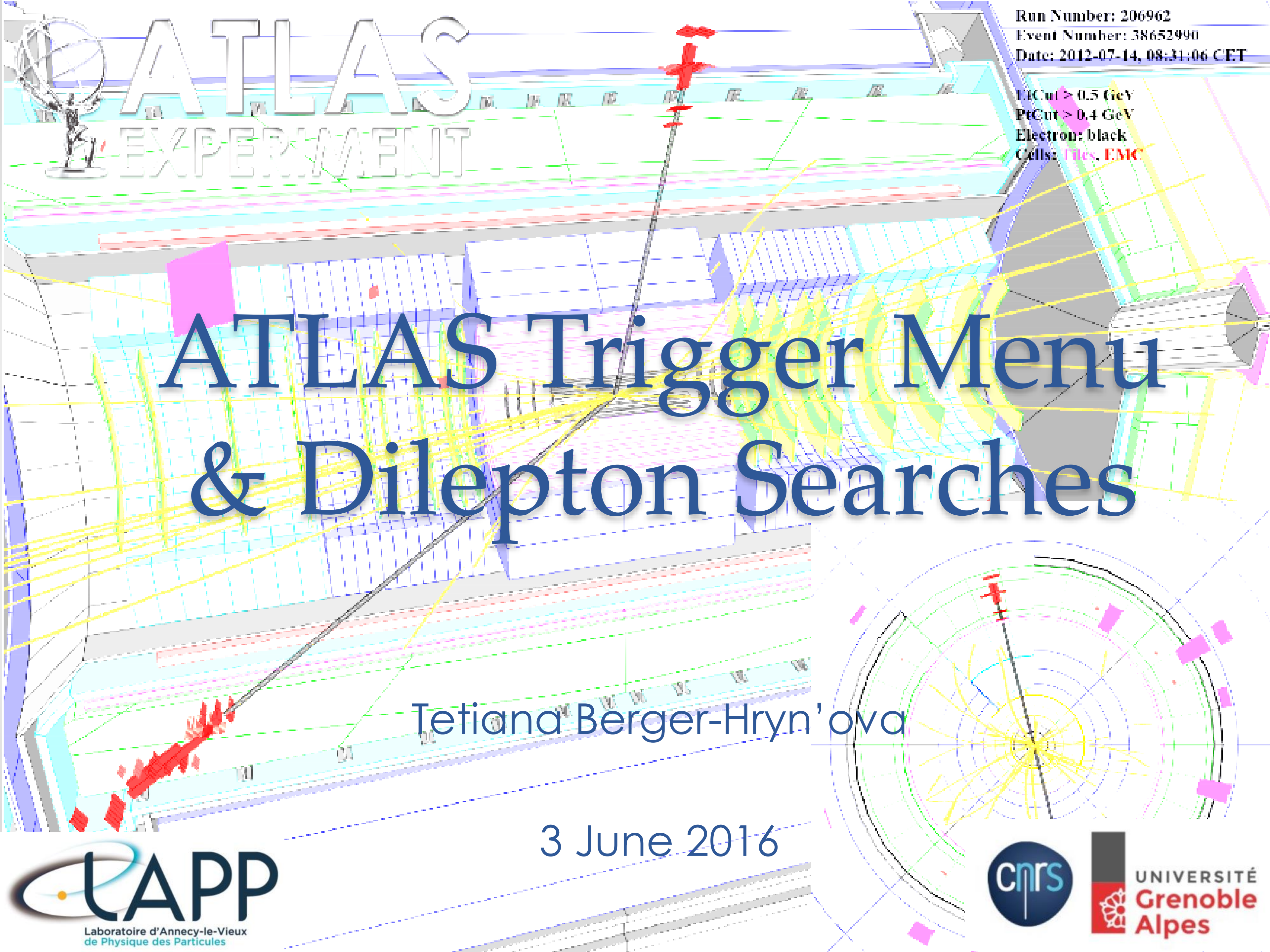
ATLAS Trigger Menu & Dilepton Searches



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3 June 2016

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My timeline on ATLAS

https://www.flickr.com/photos/primejunta/2518179985

2006-2009 Electron Triggers

2010-2012 Exotics Triggers

2013-2015 Trigger Menu for Run 2

2009-now Dilepton searches

My timeline on ATLAS

https://www.flickr.com/photos/primejunta/2518179985

2006-2009 Electron Triggers

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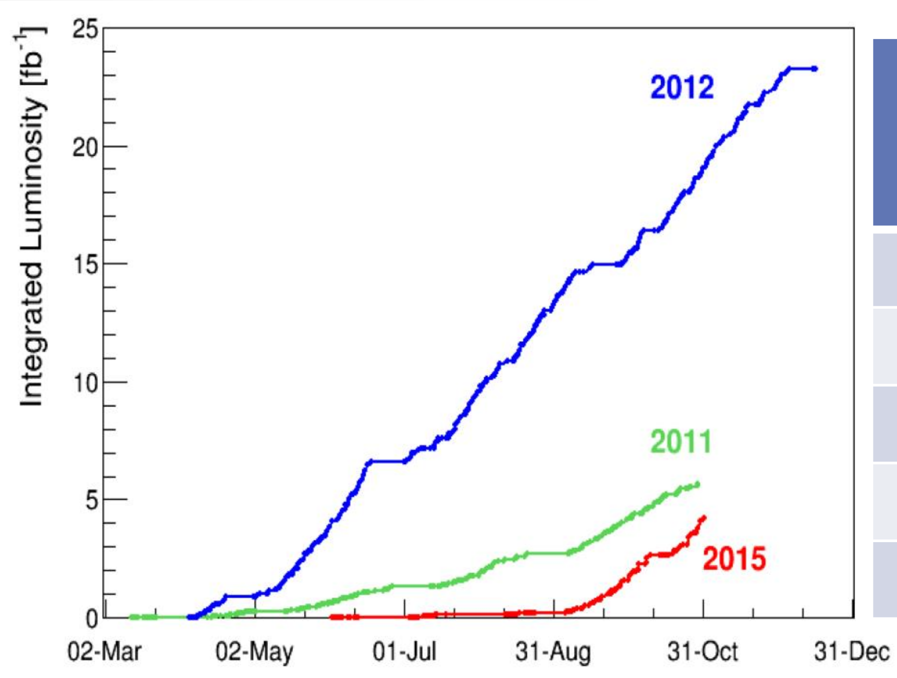
2013-2015 Trigger Menu for Run 2

2009-now Dilepton searches

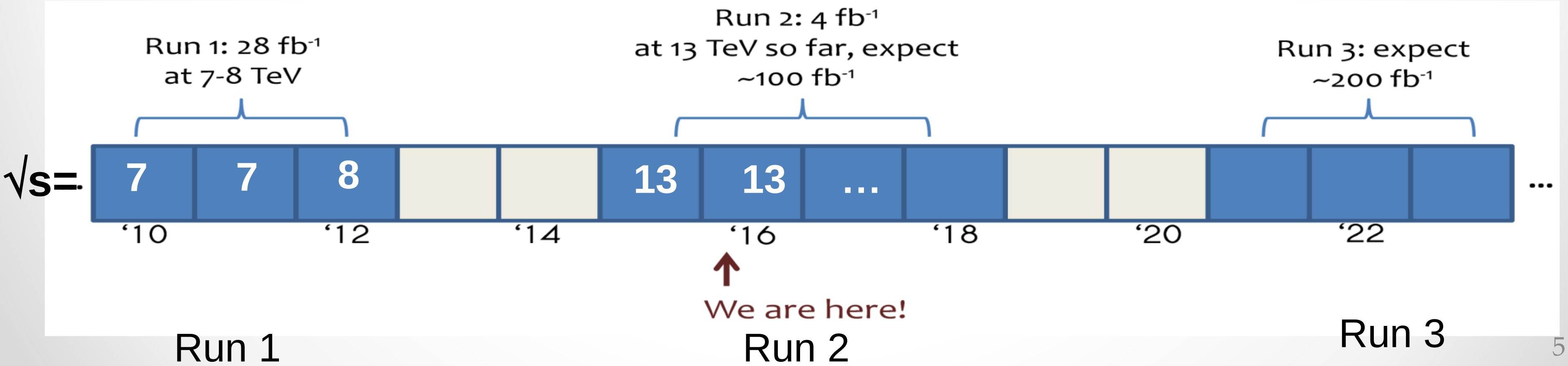
Heavy Ion data-taking is not discussed in this talk.

LHC timeline

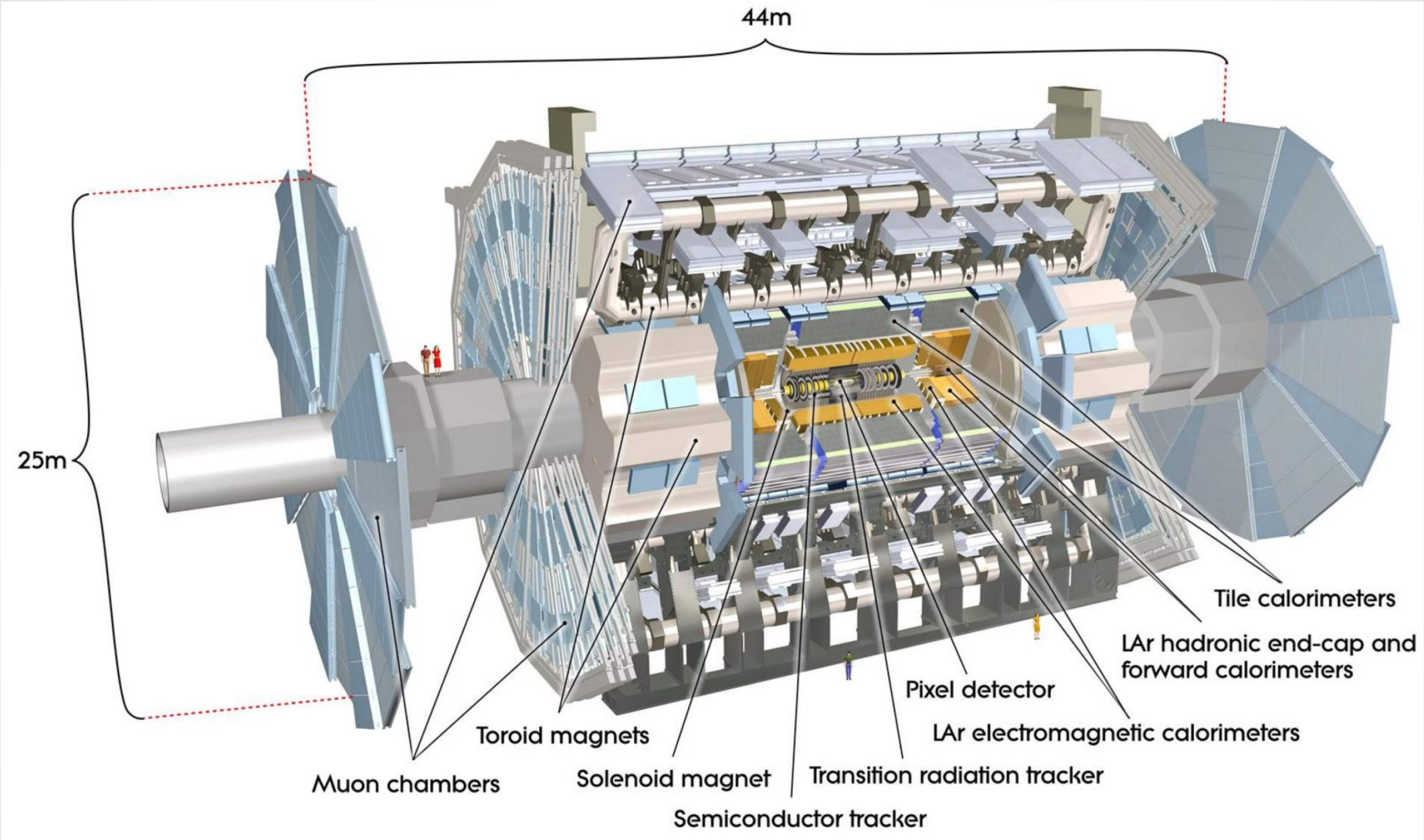


Year	Peak Lumi $10^{34}cm^{-2}s^{-1}$	Bunch Spacing	Pile-up*	Total Lumi [fb^{-1}]
Design	1	25	25	-
2011	0.37	50	9	5
2012	0.77	50	23	23
2015	0.5	25	14	4
2016*	*~1*	*25*	*43*	*25*

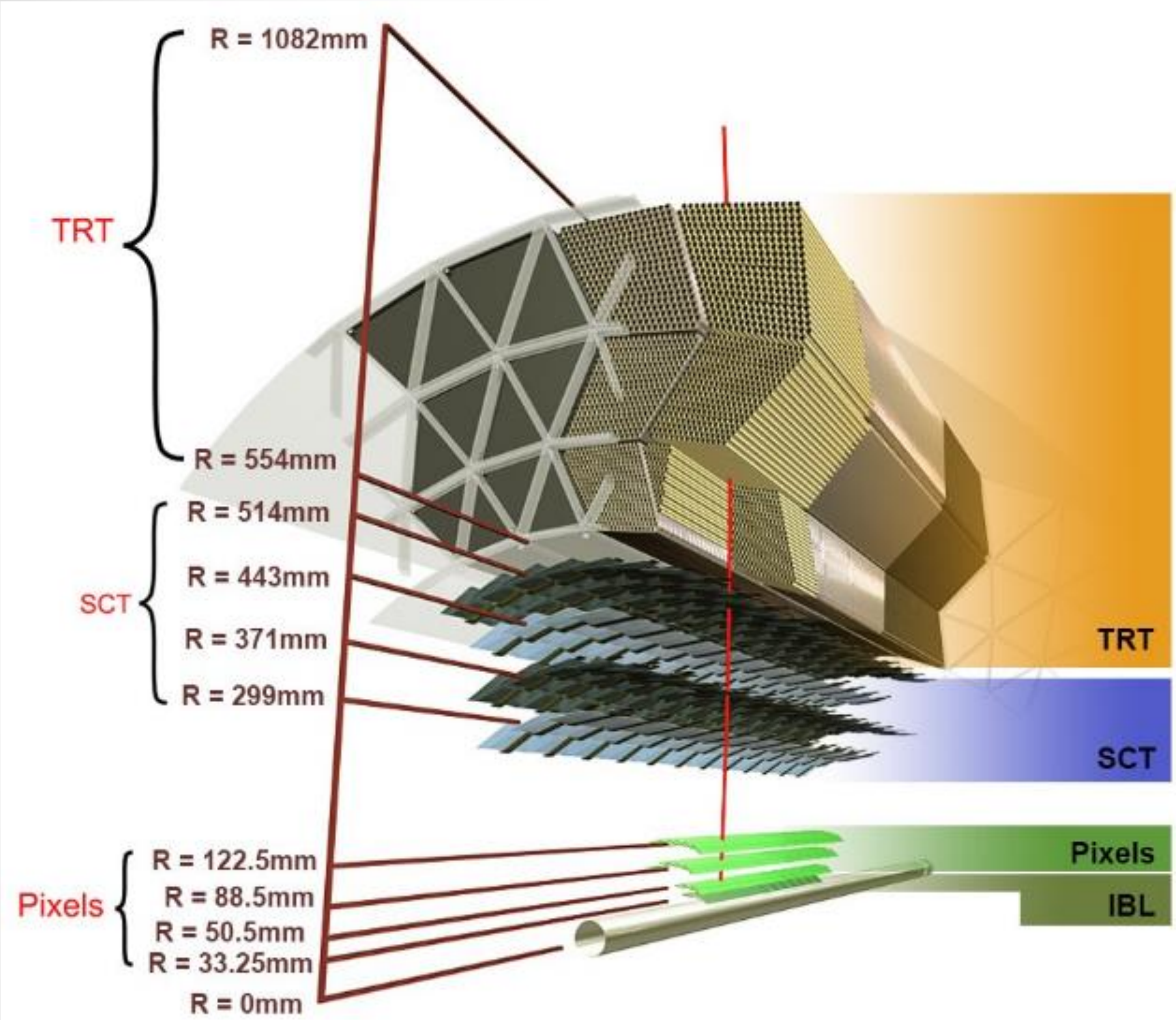
**expected values*



ATLAS Detector



Inner Detector



Transition Radiation Tracker (TRT): drift tubes with gas (Xe or Ar), 350 k channels, 36 measurement points

Semiconductor Tracker (SCT) Silicon, 6.2 M channels, 4 layers

Pixel Detector: Silicon, 92 M channels, 4 layers

Calorimeters

EM Calorimetry :
Liquid-Argon/Pb accordeon, $|\eta|<3.2$

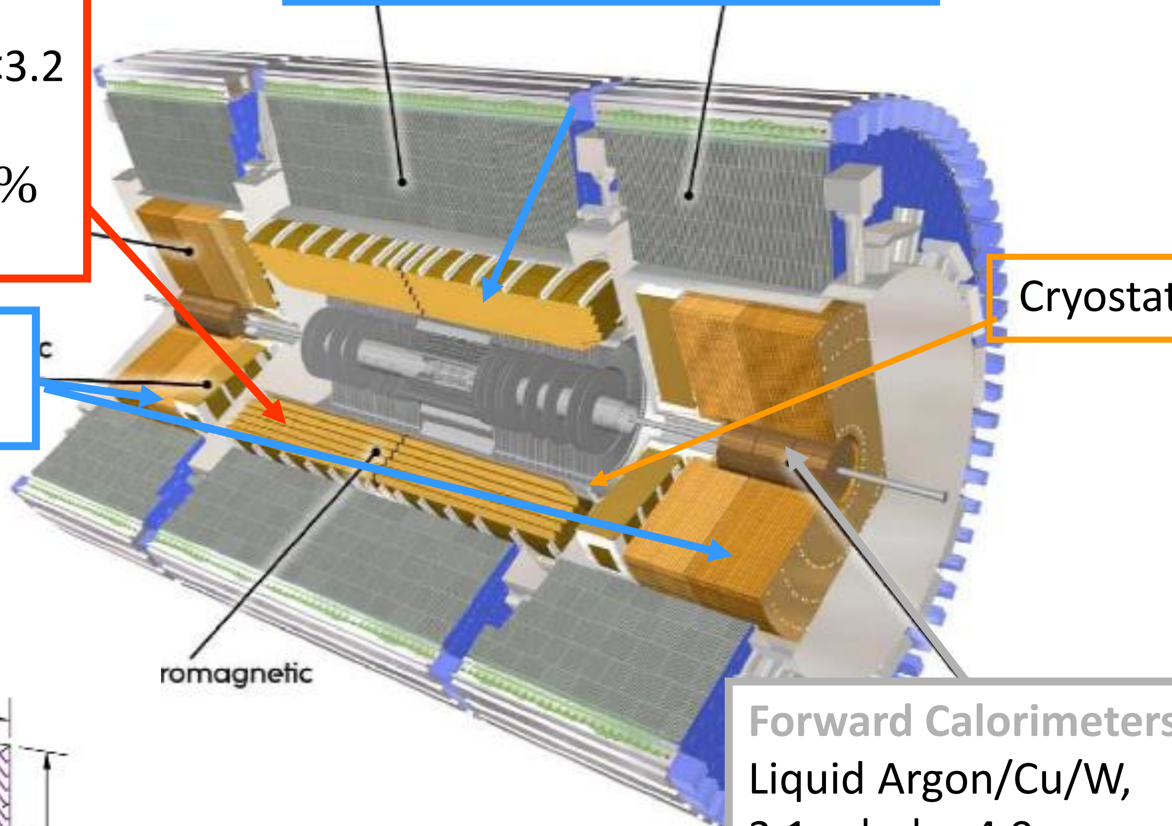
$$\left.\frac{\sigma(E)}{E}\right|_{e/\gamma} \cong \frac{10\%}{\sqrt{E/\mathrm{GeV}}} \oplus 0.7\%$$

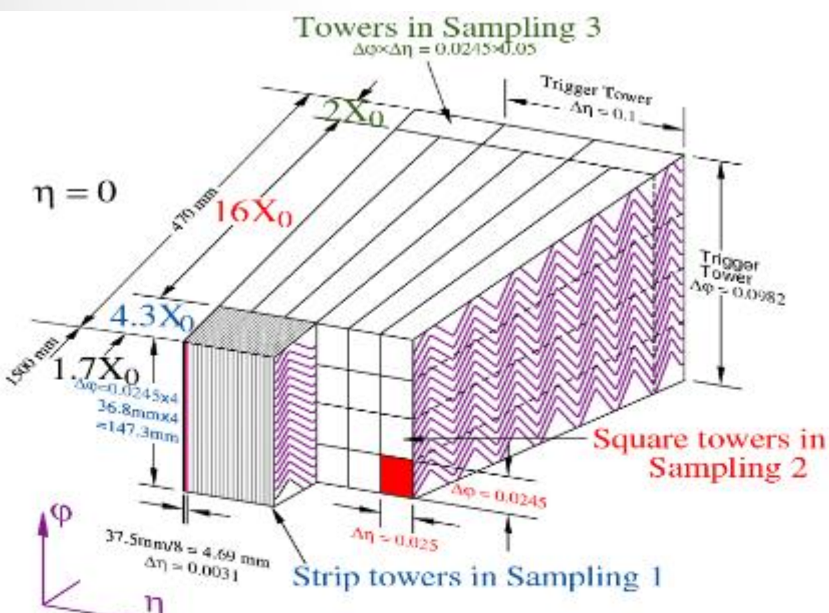
Hadronic End-cap:
Liquid Argon/Cu, $1.5 < |\eta| < 3.2$

Hadronic Barrel :
Scintillator/Fe, $|\eta| < 1.7$

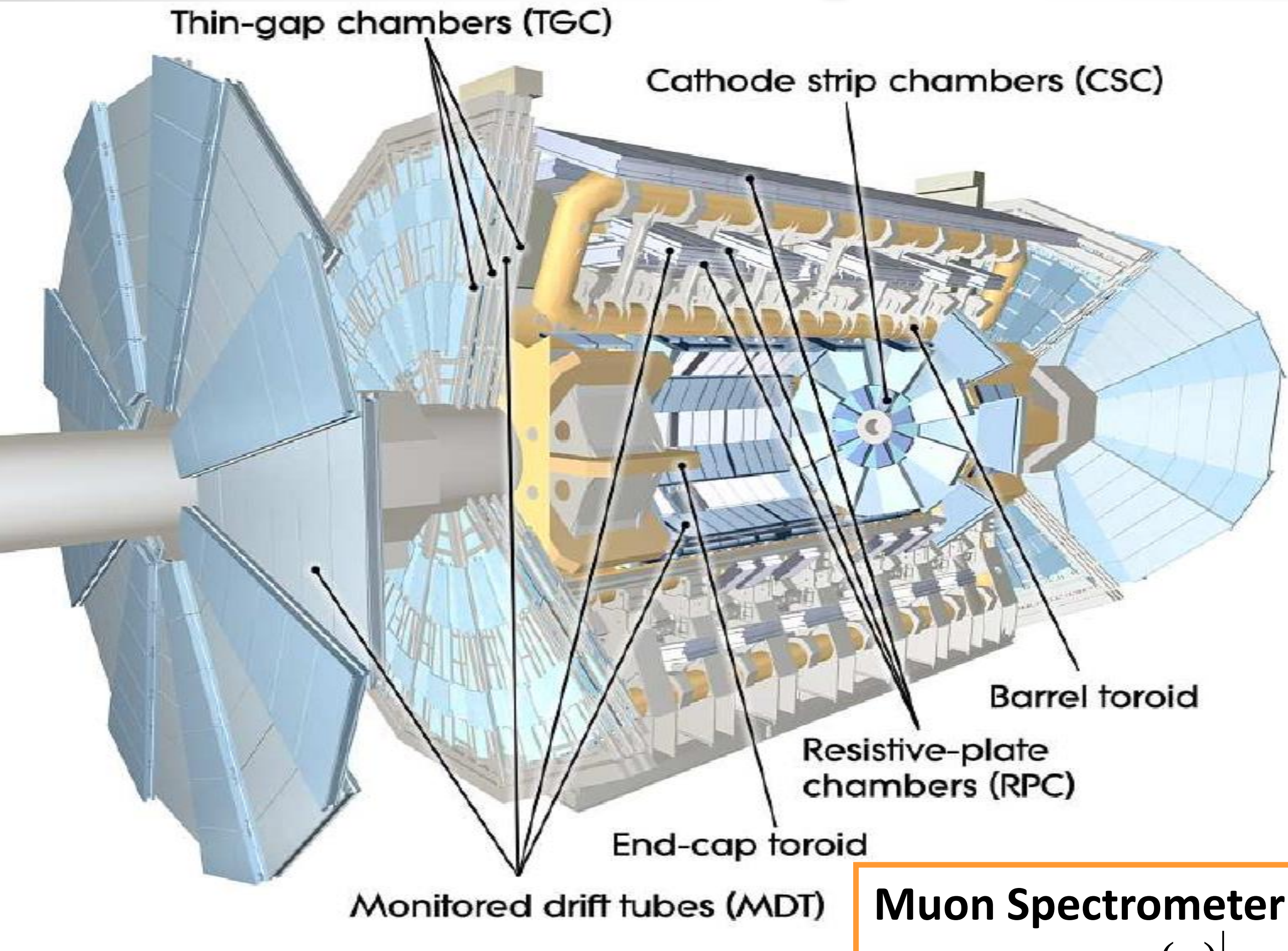
Cryostat

Forward Calorimeters:
Liquid Argon/Cu/W,
$3.1 < |\eta| < 4.9$





Muon Spectrometer

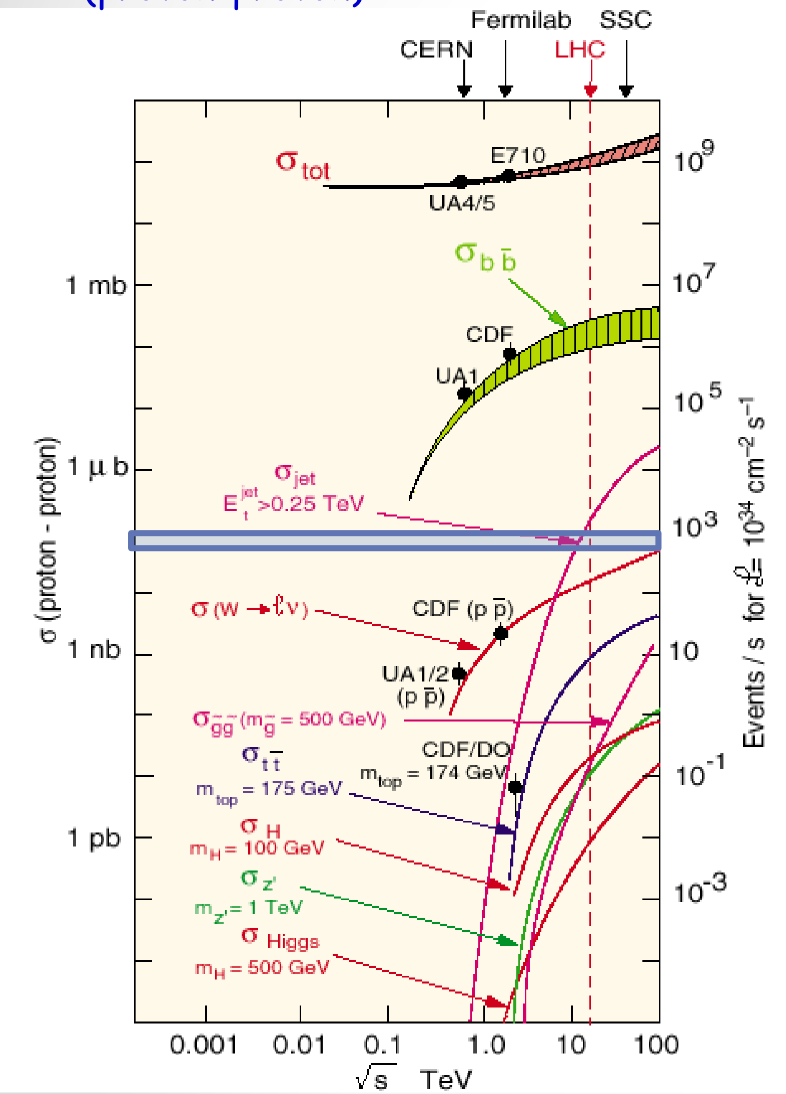


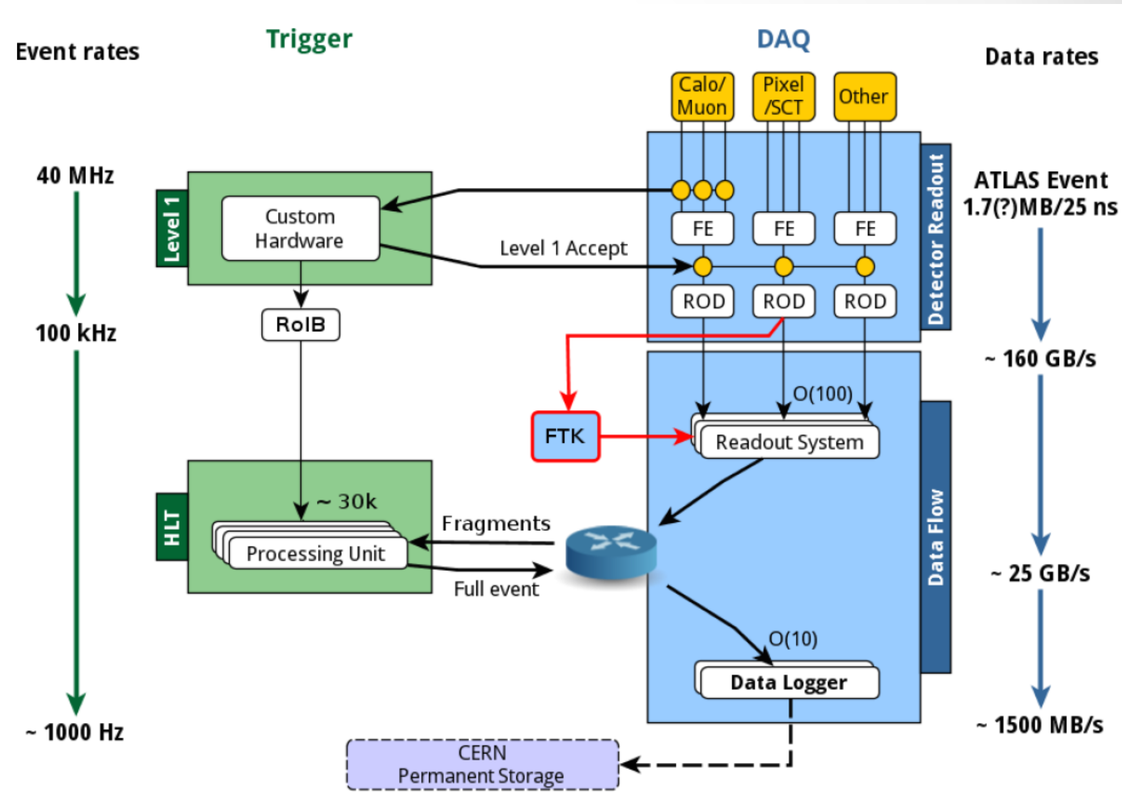
Muon Spectrometer : |η| < 2.7

- Standalone: $\left.\frac{\sigma(p)}{p}\right|_{\mu} \cong 3\%(100\,\text{GeV}) - 10\%(1\,\text{TeV})$
- Combined with inner tracker: $\left.\frac{\sigma(p)}{p}\right|_{\mu} \cong 2\%\ \ (p_T < 50\,\text{GeV})$

Trigger & DAQ

σ (proton-proton)

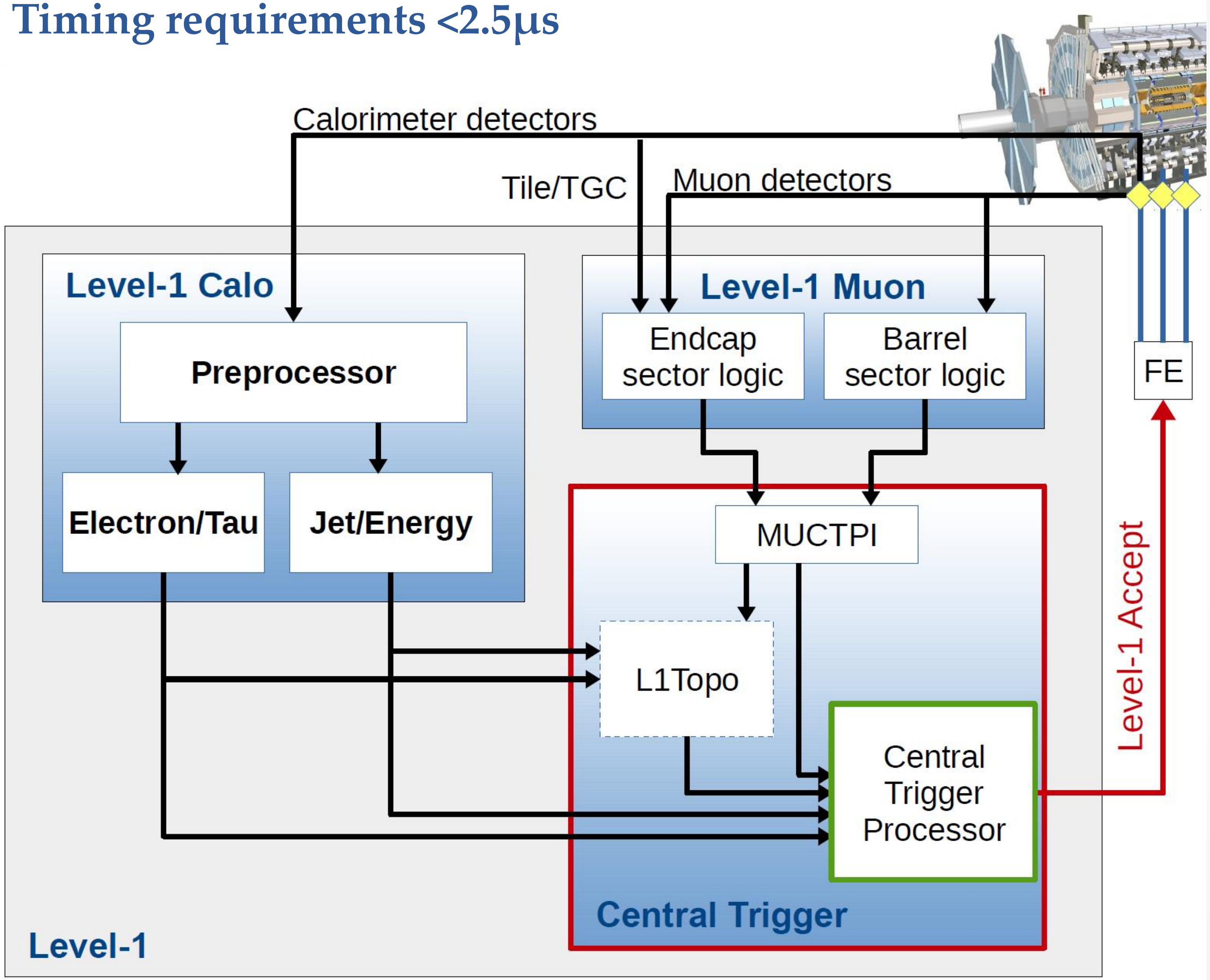




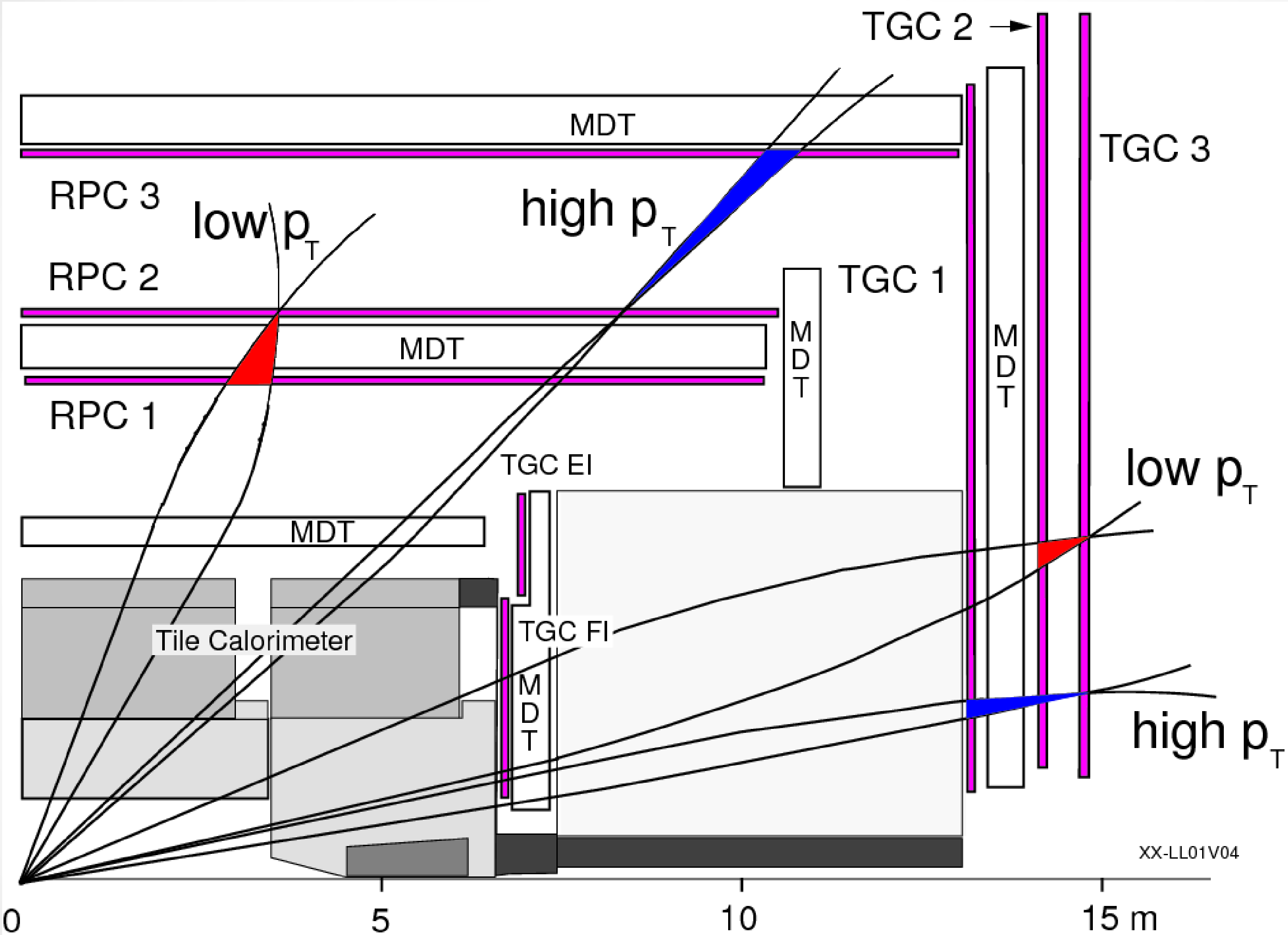
Trigger Menu
encodes configuration
of the trigger.

L1 Trigger Overview

Timing requirements <2.5μs

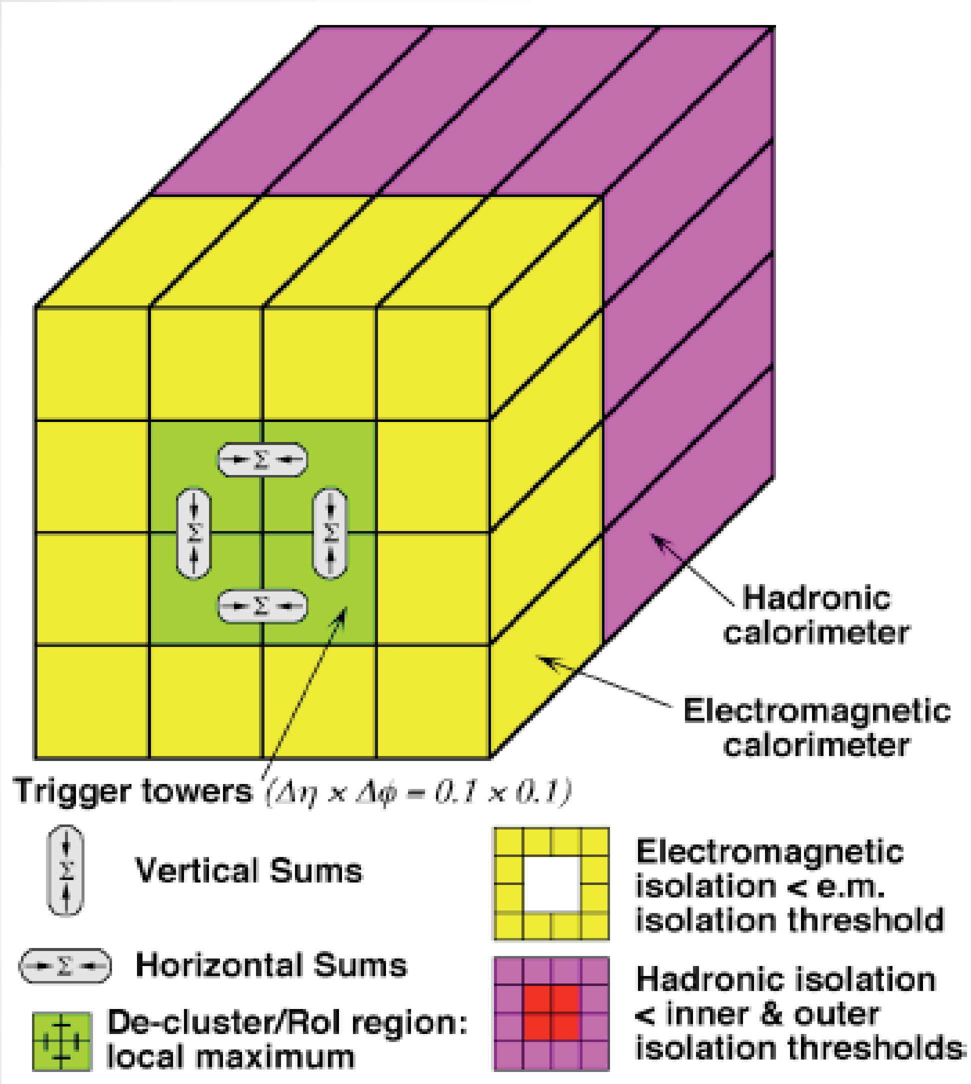


L1 Muon Trigger



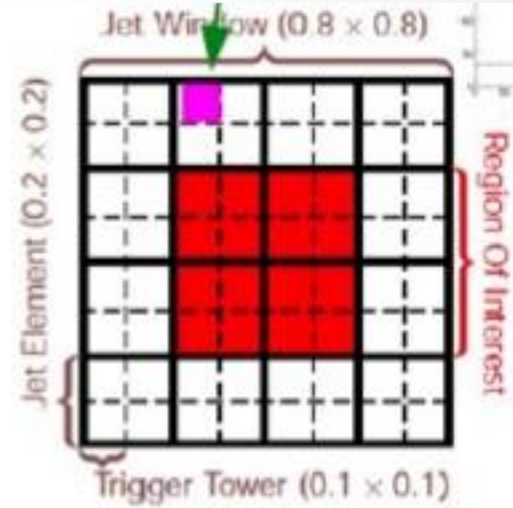
- coincidences in chamber layers
- widths determines p_T threshold (6 possibilities L1_MU)

L1 Calorimeter Trigger



"I"

"**H**"



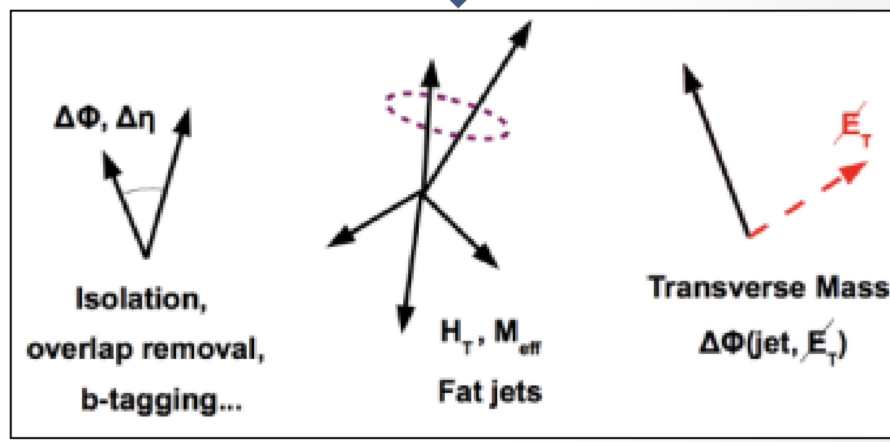
Objet	Type
Electron, Photon	**EM**
Tau	**TAU**
Jet	**J**
E_T^{Miss}	**XE, XS**
ΣE_T	**TE**

Threshold value (in GeV) can vary with η "V"

L1 Topo Trigger

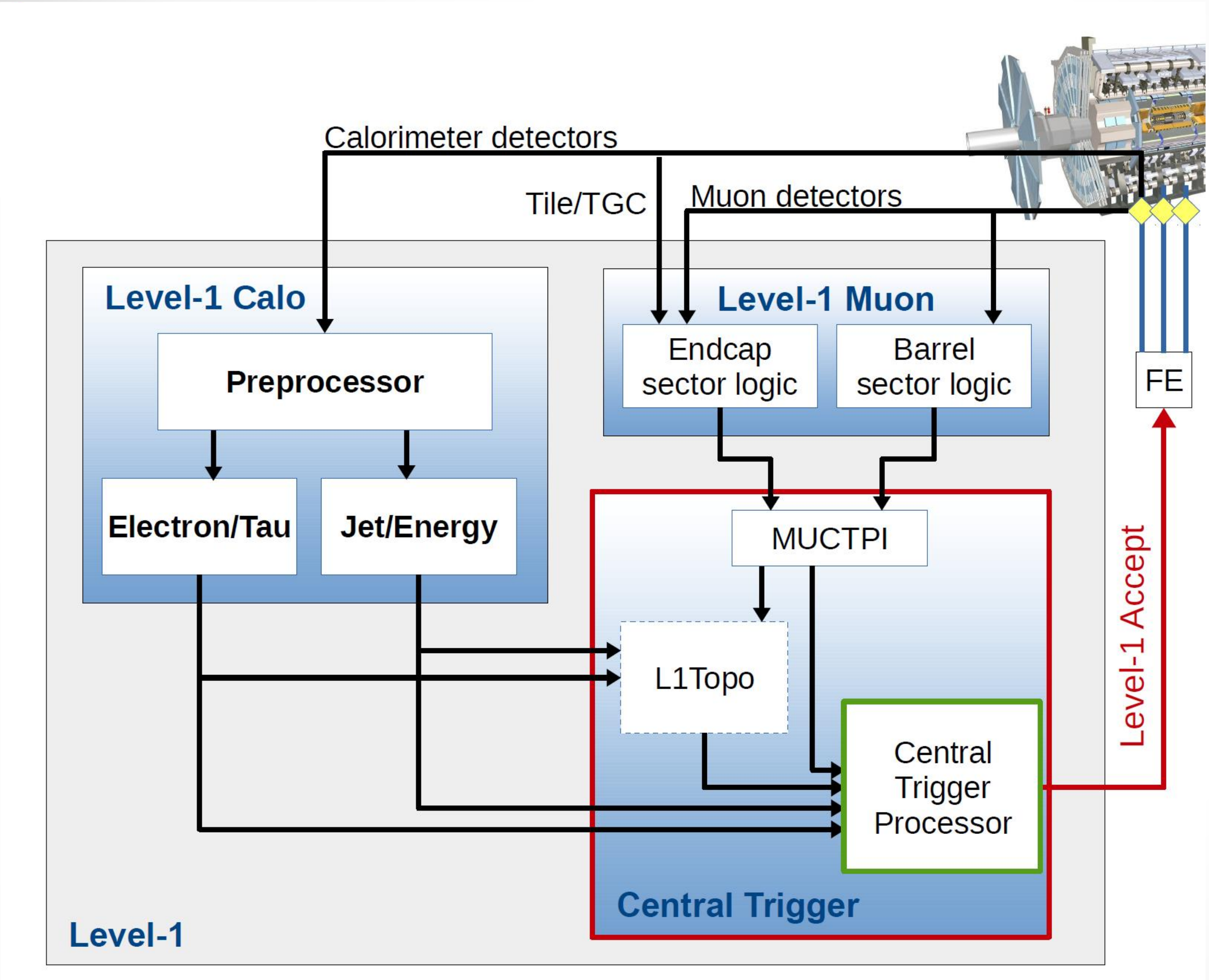
Input "Objects":
Muon, Missing E_T, EM,
Tau & Jet cluster
E_T/p_T, η, ϕ, & isolation.

All objects
sorted into lists:
"sorted" or
"abbreviated"



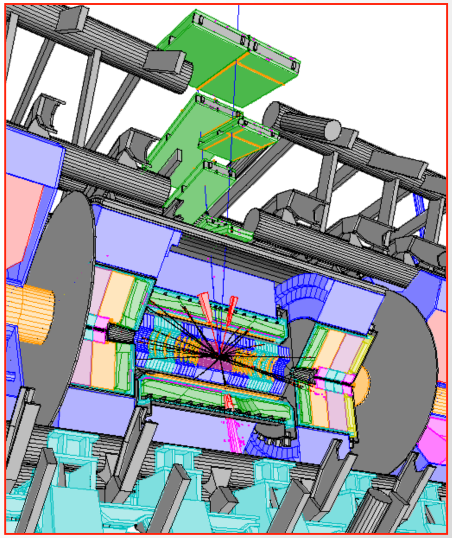
Up to 128 L1 Topo
trigger decisions possible

Central Trigger Processor



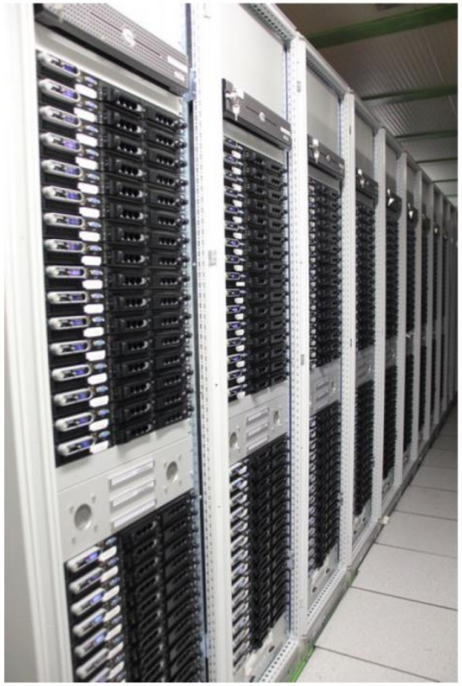
Multiplicities
Logical selection
Prescales
Bunch Crossing Identification
Trigger Type

Region of Interest:



High Level Trigger

<u>Typical HLT node:</u>
2x12-core Intel Xeon Haswell
→ 96 cores/box
48 GB RAM, 10Gb Ethernet
4 motherboards in 2U box

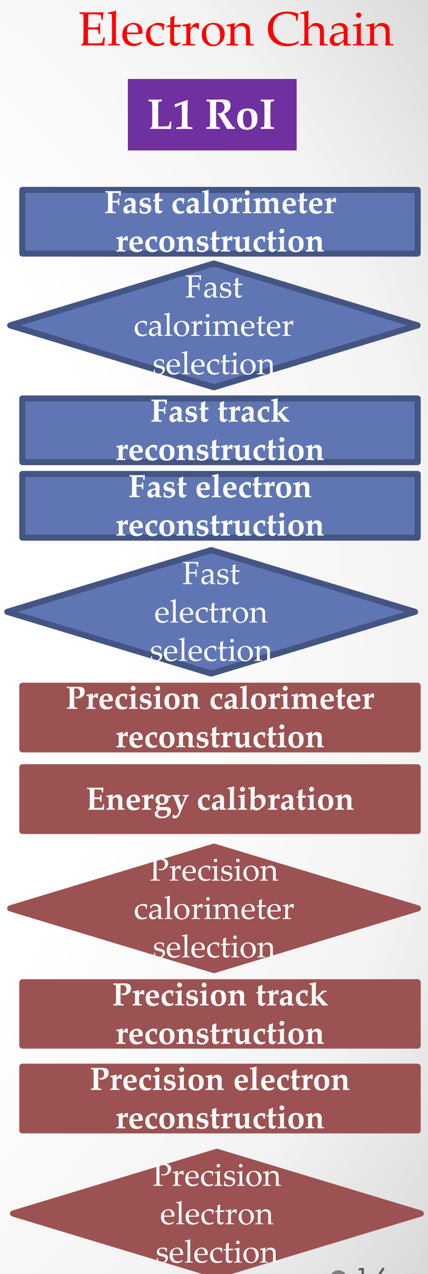


- Software running on large commercial PC farms
- Limitations
  - Size of the Farm:

Rate x Timing = CPU used

  - Total output rate **~1kHz**

Object	Notation
electron	e
photon	g
muon	mu
tau	tau
jet	j
b-jet	jet_b[TagType]
E_T^{Miss}	xe



Electrons

Electron Chain

L1 RoI

Fast calorimeter reconstruction

Fast calorimeter selection

Fast track reconstruction

Fast electron reconstruction

Fast electron selection

Precision calorimeter reconstruction

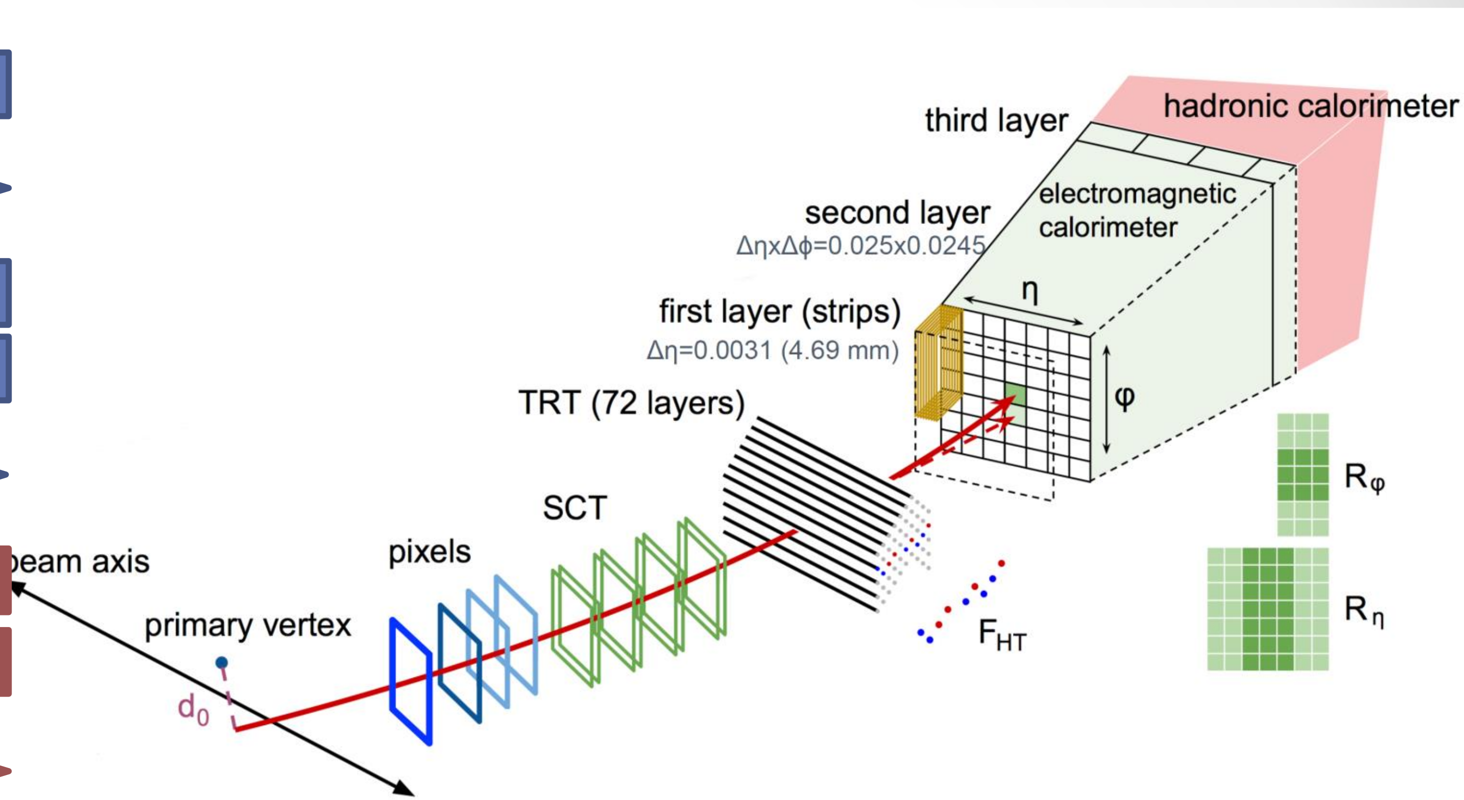
Energy calibration

Precision calorimeter selection

Precision track reconstruction

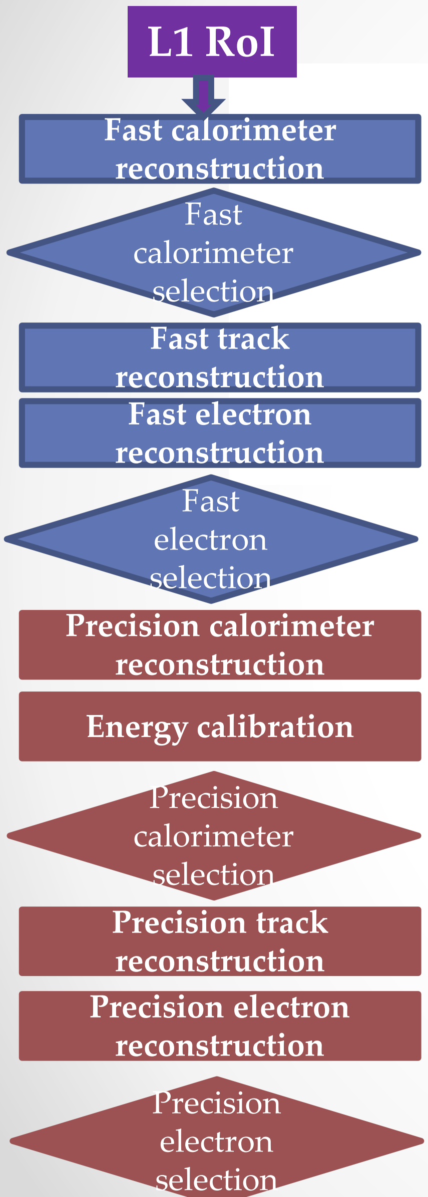
Precision electron reconstruction

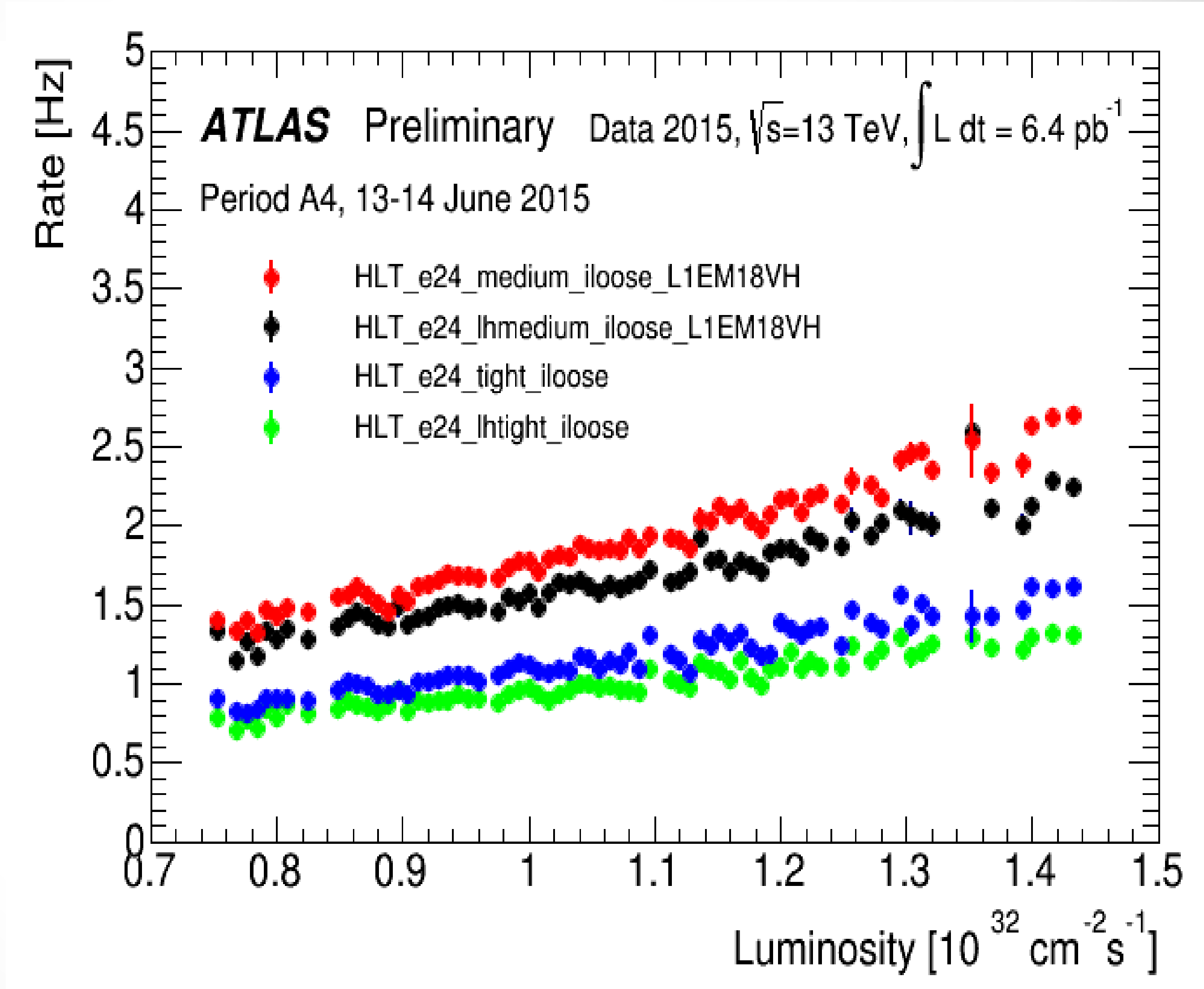
Precision electron selection



Electrons

Electron Chain





Electron Chain

1. L1 RoI
2. Fast calorimeter reconstruction
3. Fast calorimeter selection
4. Fast track reconstruction
5. Fast electron reconstruction
6. Fast electron selection
7. Precision calorimeter reconstruction
8. Energy calibration
9. Precision calorimeter selection
10. Precision track reconstruction
11. Precision electron reconstruction
12. Precision electron selection

Tau Chain

1. L1 RoI
2. Precision calorimeter reconstruction
3. Energy calibration
4. p_T cut
5. Fast track reconstruction Step 1
6. Fast track reconstruction Step 2
7. Cut on number of tracks
8. Precision track reconstruction
9. Precision tau reconstruction
10. Precision tau selection

Jet Chain

1. L1 RoI
2. Precision calorimeter reconstruction
3. Presicion jet reconstruction
4. Energy calibration
5. Precision jet selection

Final detector calibration and alignment constants not available online:

allow for the lower precision in the trigger cuts

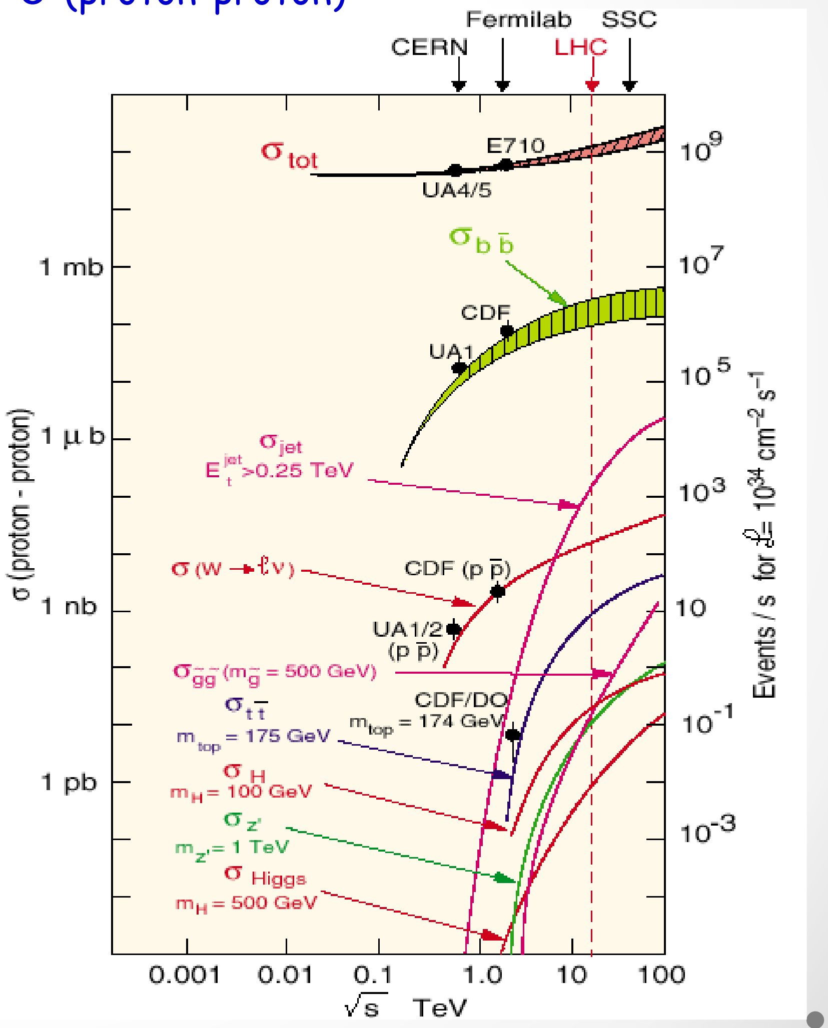
Muon Chain

1. L1 MU RoI
2. Fast muon track reconstruction
3. Fast muon track selection
4. Fast track reconstruction
5. Fast track selection
6. Matching
7. Precision muon reconstruction
8. Precision muon track selection
9. Precision track reconstruction
10. Precision track selection?
11. Precision muon reconstruction
12. Precision muon selection

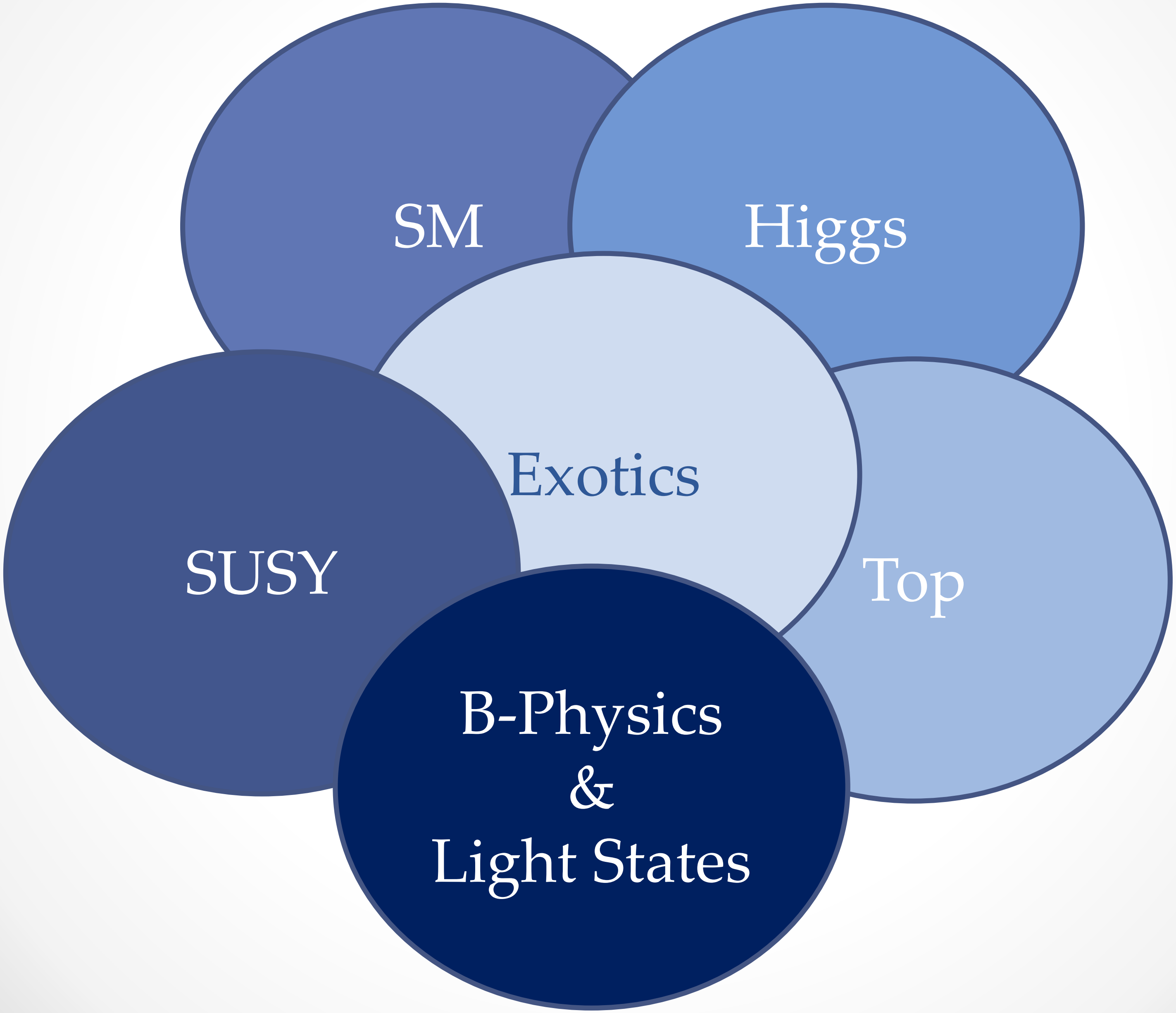
Trigger Menu = list of all triggers of interest

Luminosity dependent!

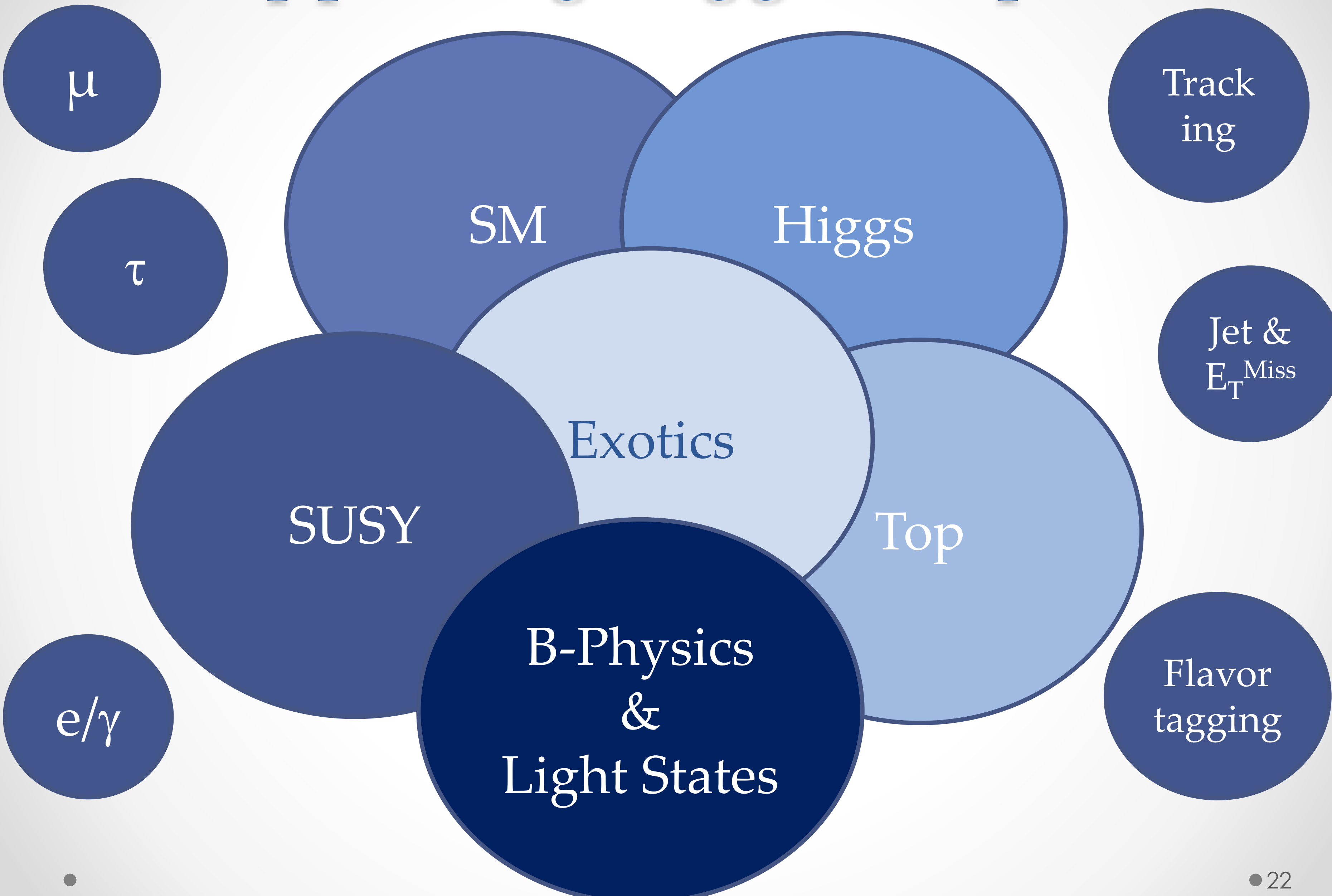
σ (proton-proton)



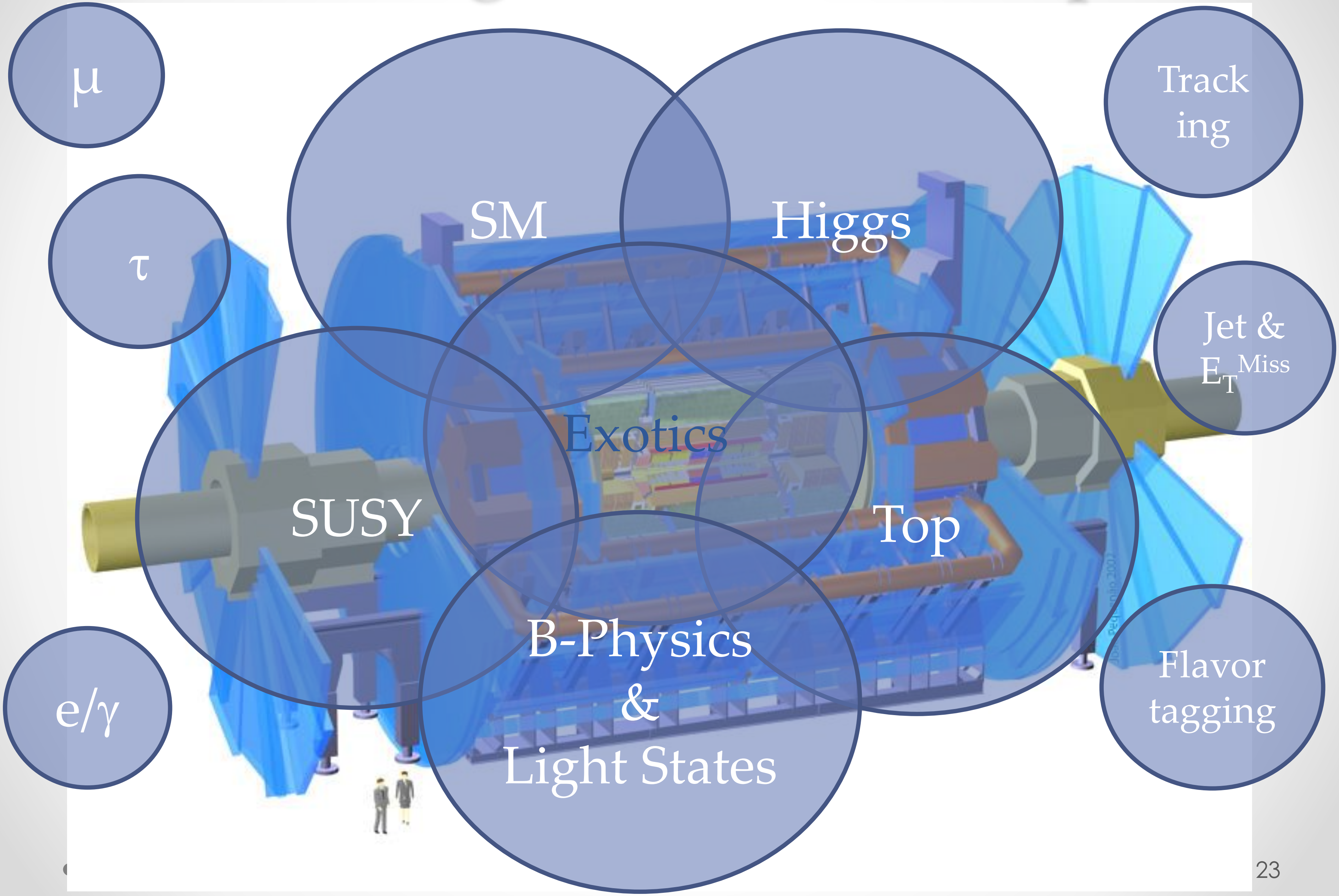
Physics Menu Priorities



Supporting triggers inputs



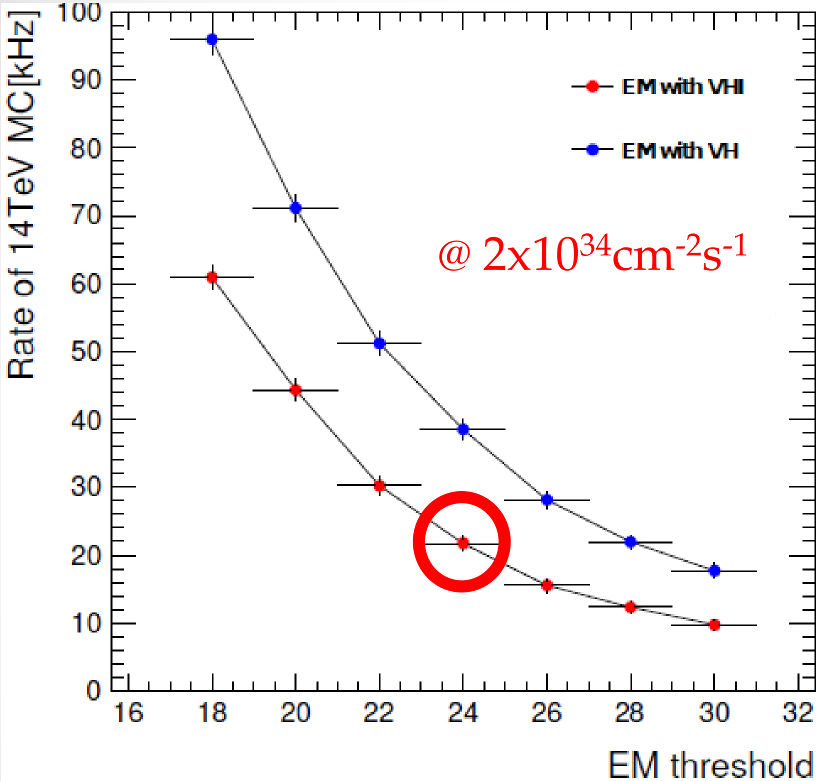
Monitoring, Calibration Inputs

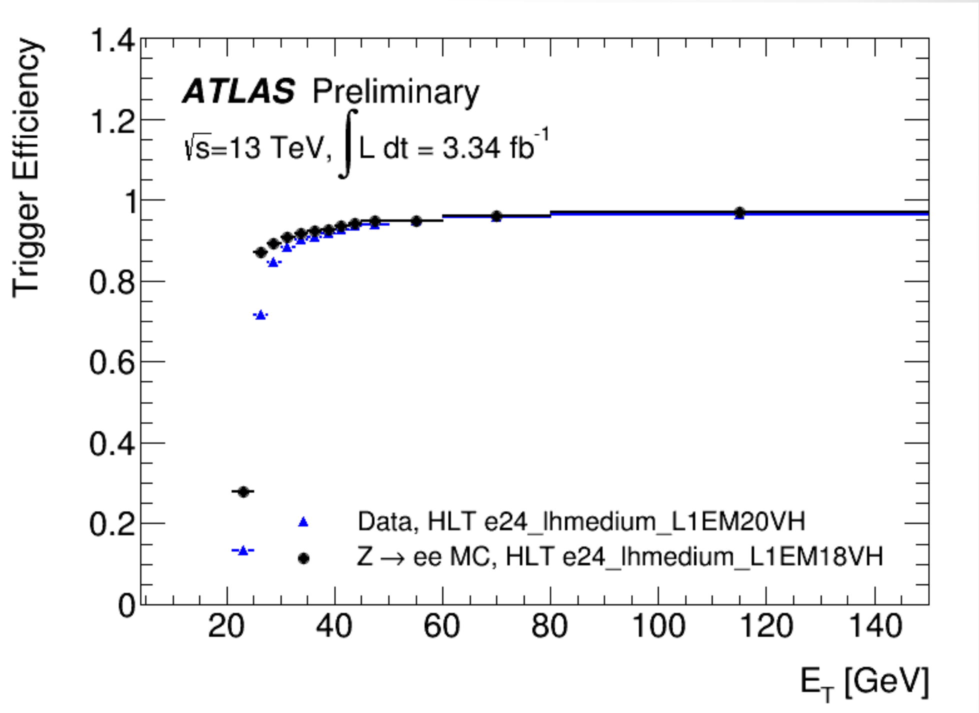


Physics Requests Summary

- Keep triggers as inclusive & simple as possible!
  - Single lepton (electron and muon triggers) below W
  - Single/di/tri-object triggers at thresholds as low as possible
- Topological, multi-object and dedicated triggers can be of huge benefit for certain analysis
- Menu should be stable throughout the Run 2

Single Electron Triggers

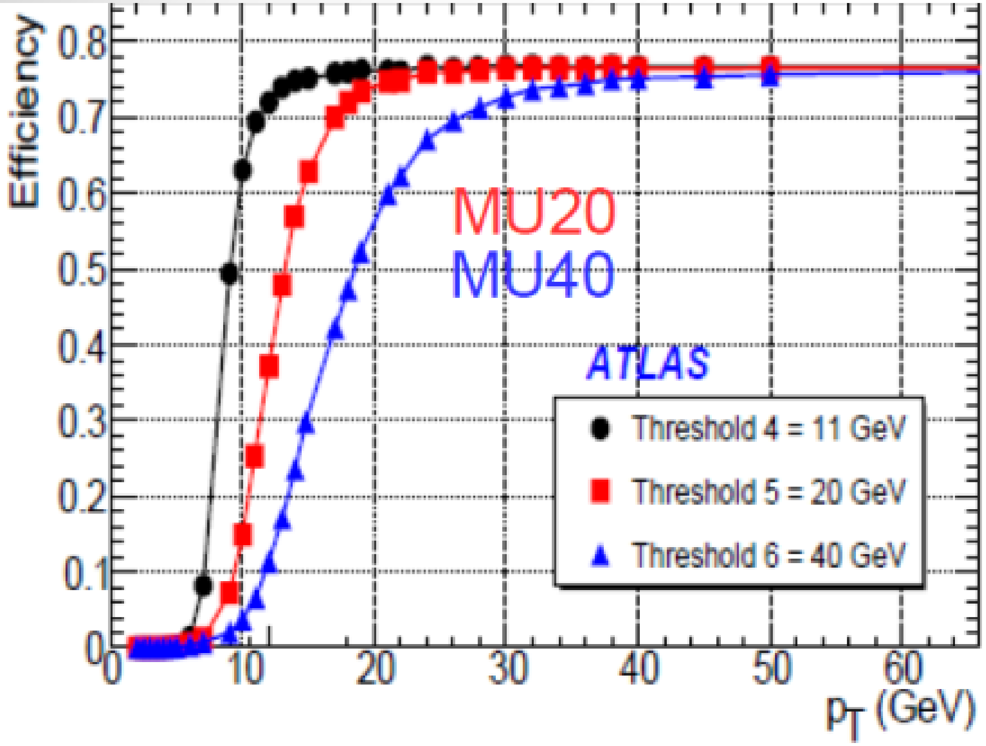


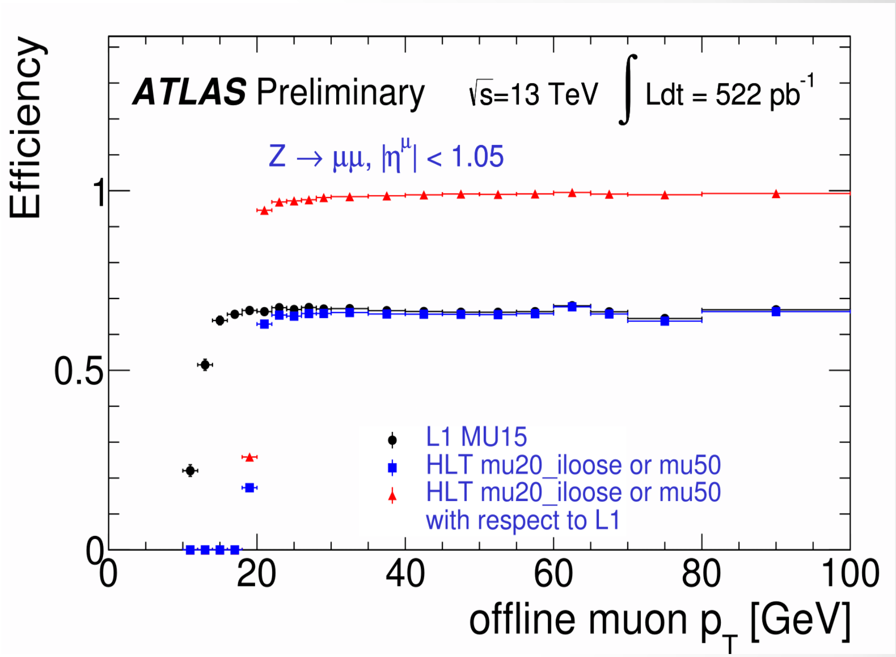


Level	0.5 10^{34}	1.0 10^{34}	1.5 10^{34}	2.0 10^{34}
L1	EM18VH *25kHz* EM20VH 18kHz	*EM20VHI ~20kHz*	*EM22VHI ~20kHz*	*EM24VHI ~20kHz*
HLT	e24_mediumlh (i?)	*e24_lhtight_ivarloose*	*e26_lhtight_i…*	*e28_lhtight_i…*

Numbers in italic are my estimate

Single Muon Triggers

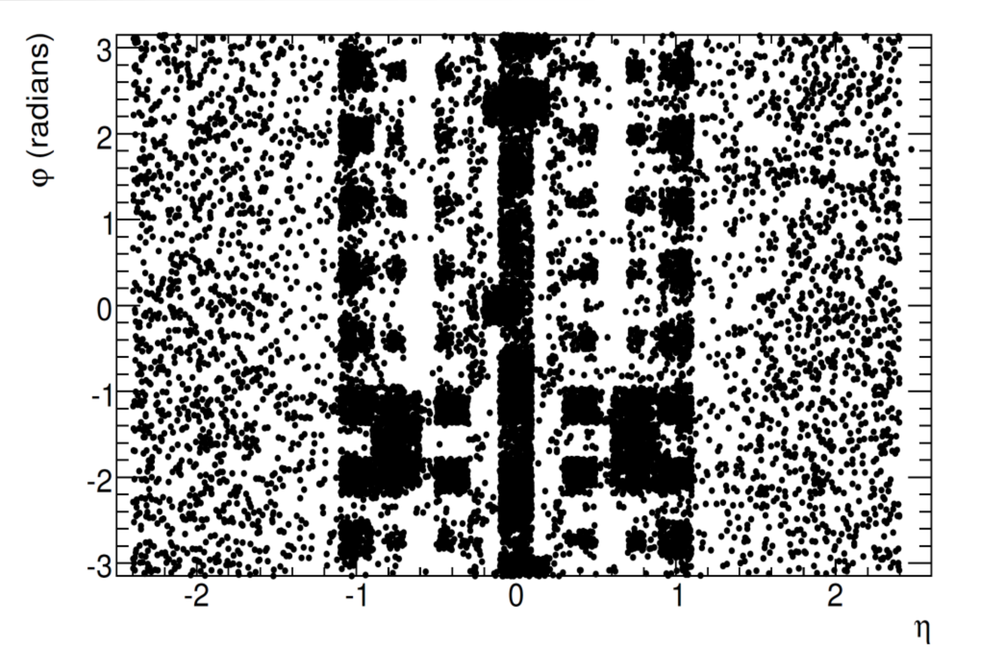


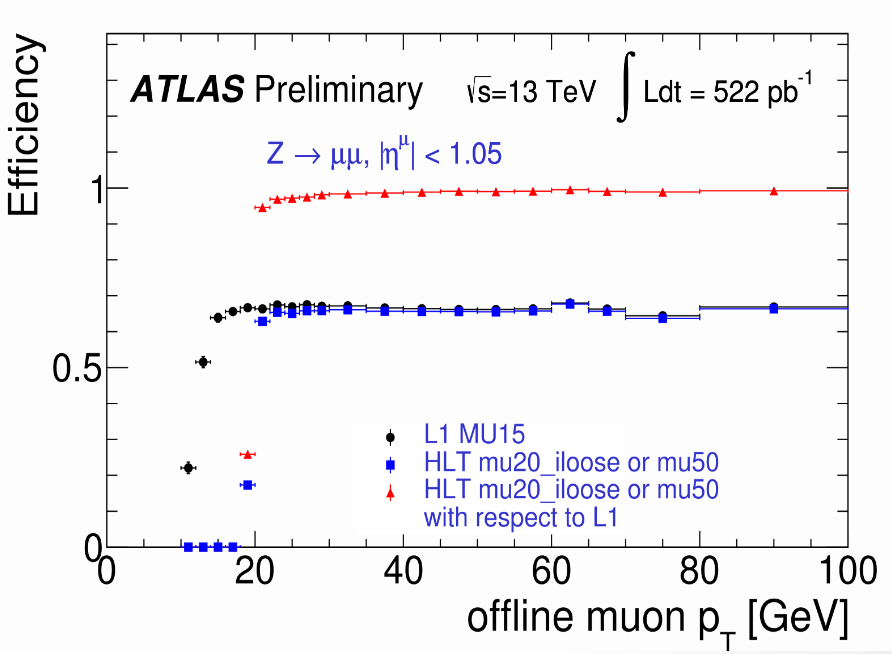


	0.5 10^{34}	1.0 10^{34}	1.5 10^{34}	2.0 10^{34}
L1	MU15 7kHz	*MU15 ~14kHz*	*MU20 ~14kHz*	*MU20 ~18kHz*
HLT	mu20i	*mu22i*	*mu24i*	*mu26i*

Numbers in italic are my estimate

Single Muon Triggers

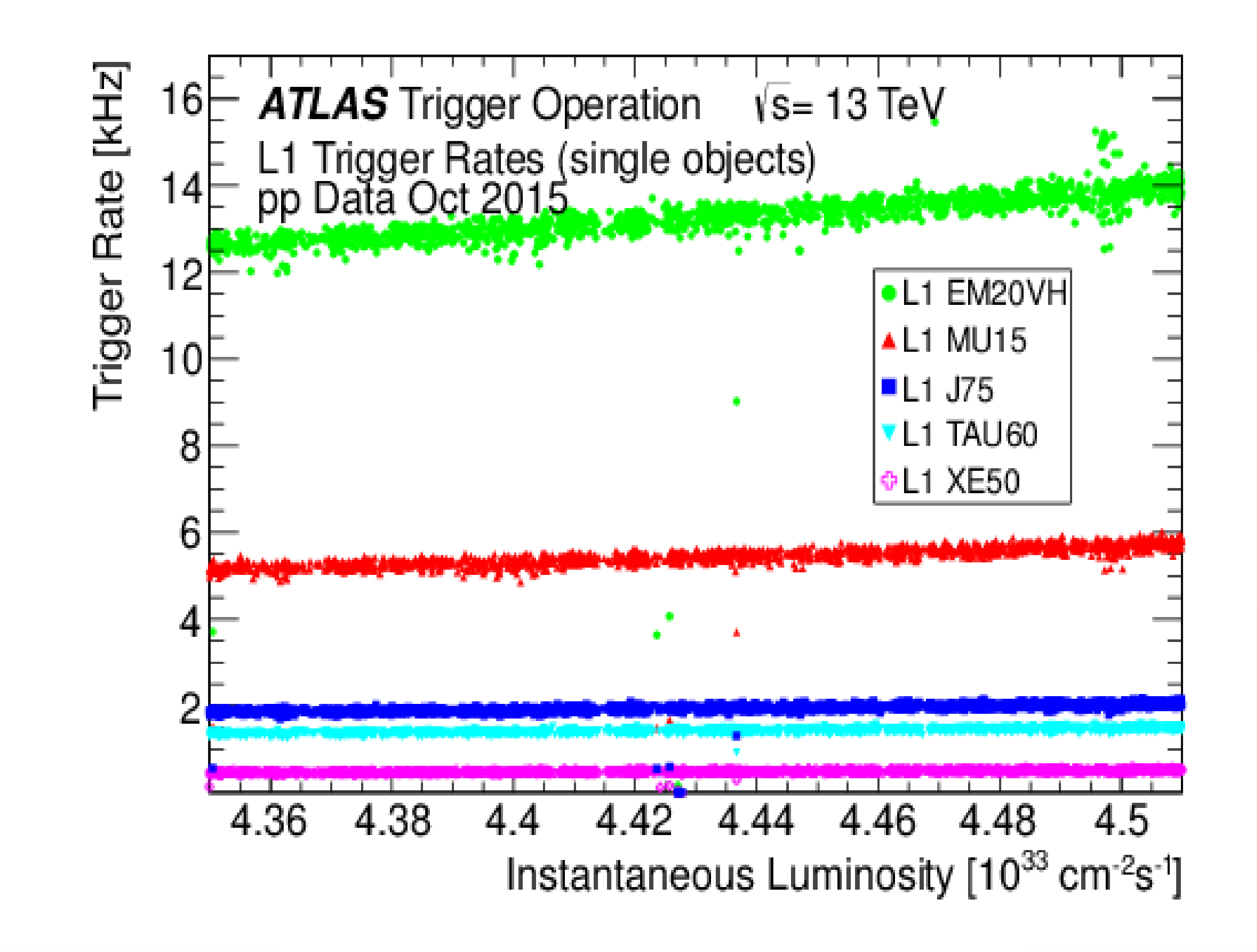




	0.5 10^{34}	1.0 10^{34}	1.5 10^{34}	2.0 10^{34}
L1	MU15 7kHz	*MU15 ~14kHz*	*MU20 ~14kHz*	*MU20 ~18kHz*
HLT	mu20i	*mu22i*	*mu24i*	*mu26i*

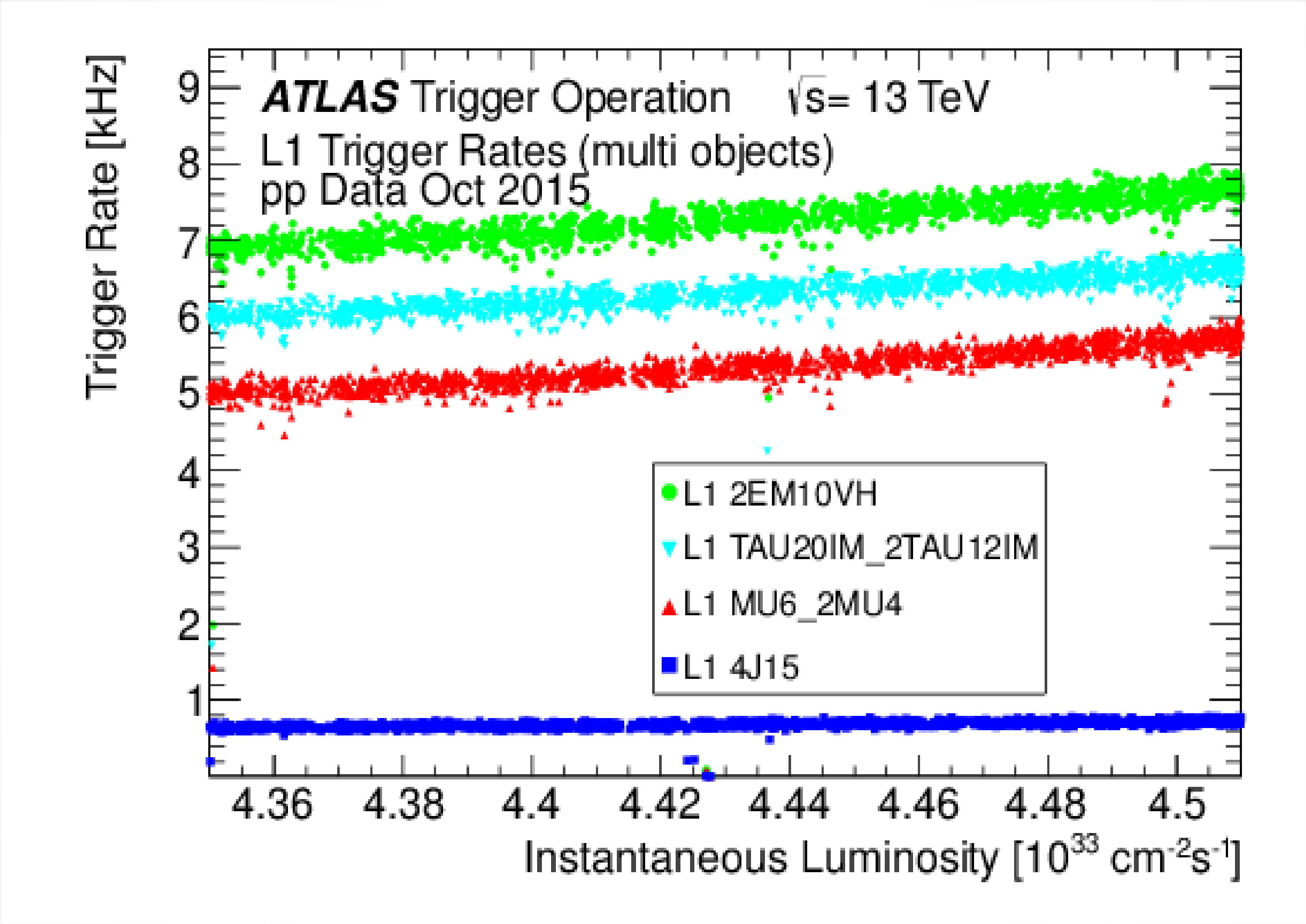
Numbers in italic are my estimate

More on L1: single objects



Maximum of 512 L1 Trigger Items (including 128 of L1Topo)

More on L1: multiobject

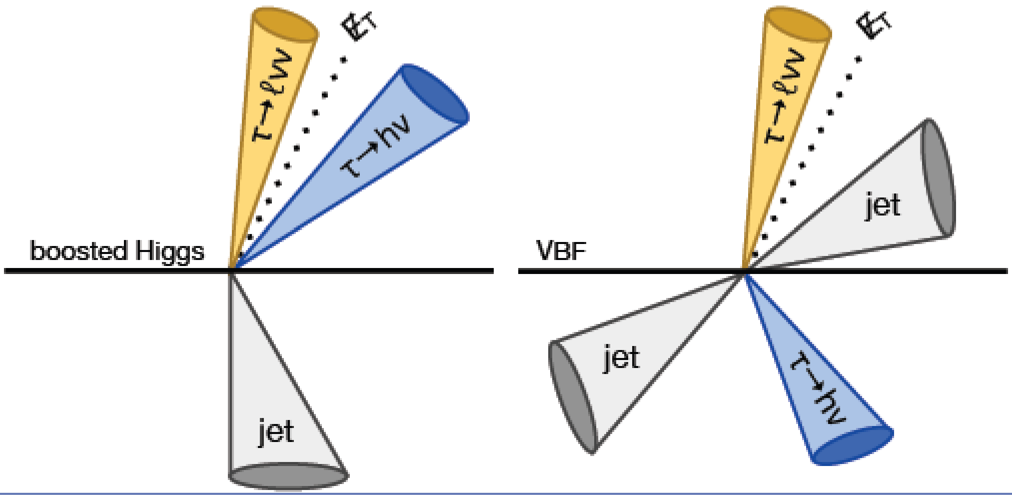


Maximum of 512 L1 Trigger Items (including 128 of L1Topo)

Tau Topologies for Run 2 L1 selection

SM H→$\tau_\ell\tau_h$

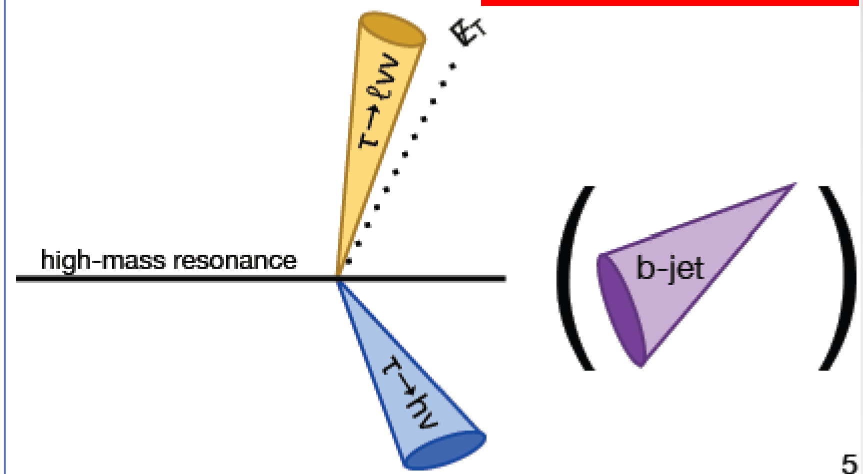
with jets; no MET requirement



MSSM H→$\tau_\ell\tau_h$

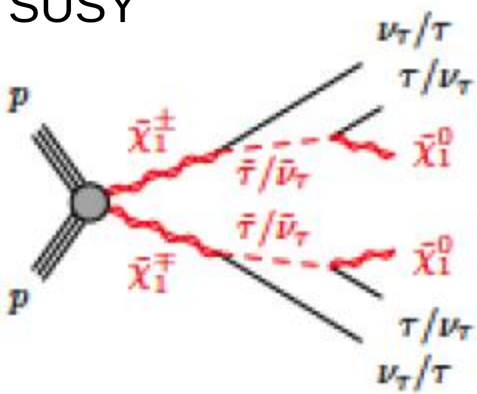
Z′→$\tau_\ell\tau_h$

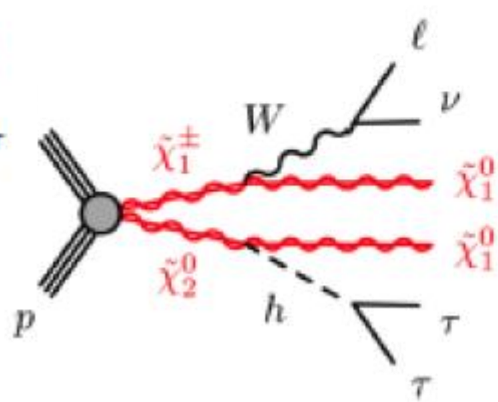
no jets, no MET requirement



SUSY

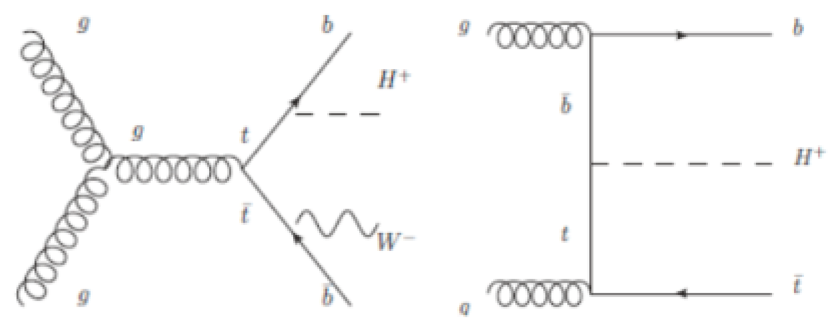
MET, no jet requirement



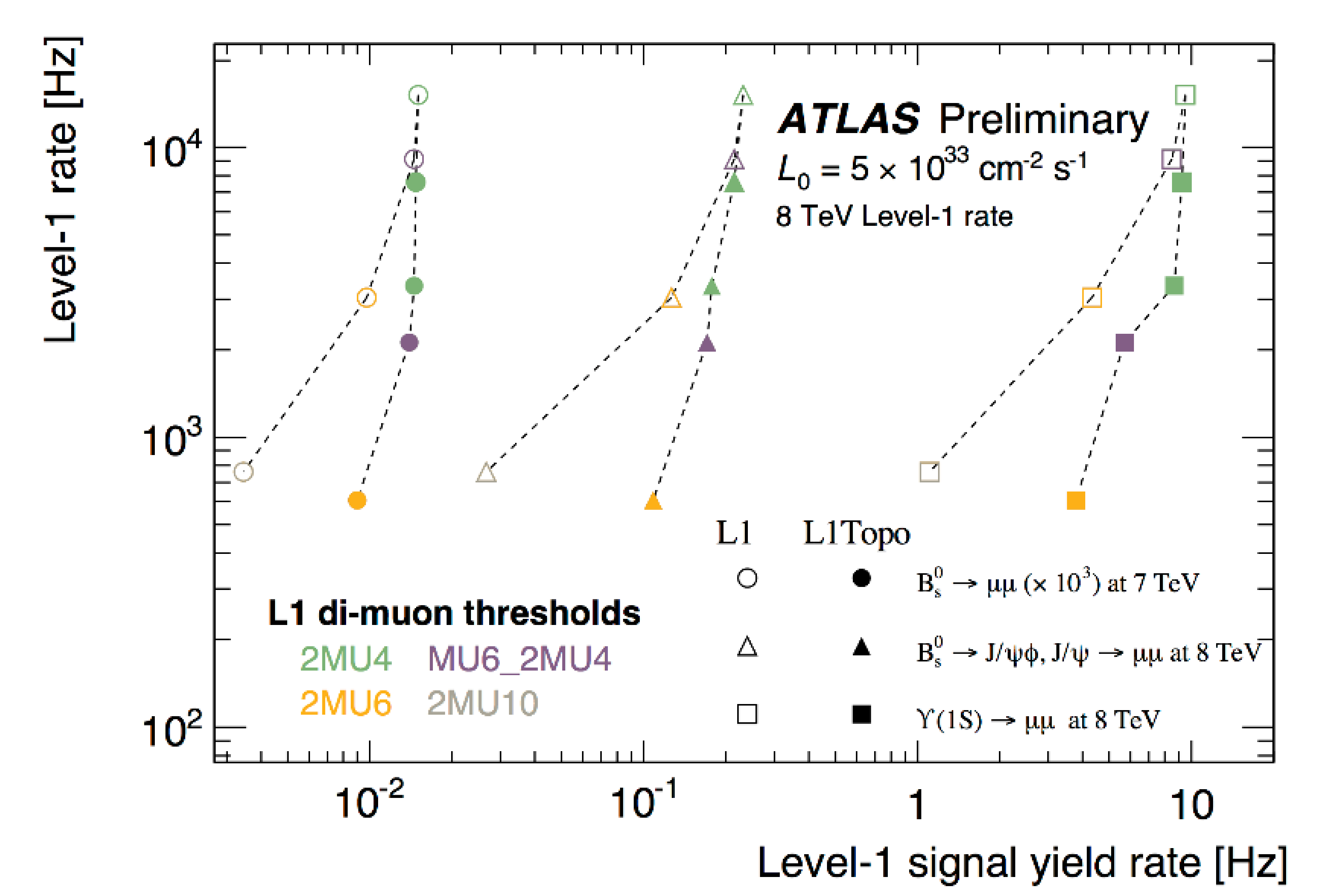


Charged Higgs

with MET, jet



B Physics triggers



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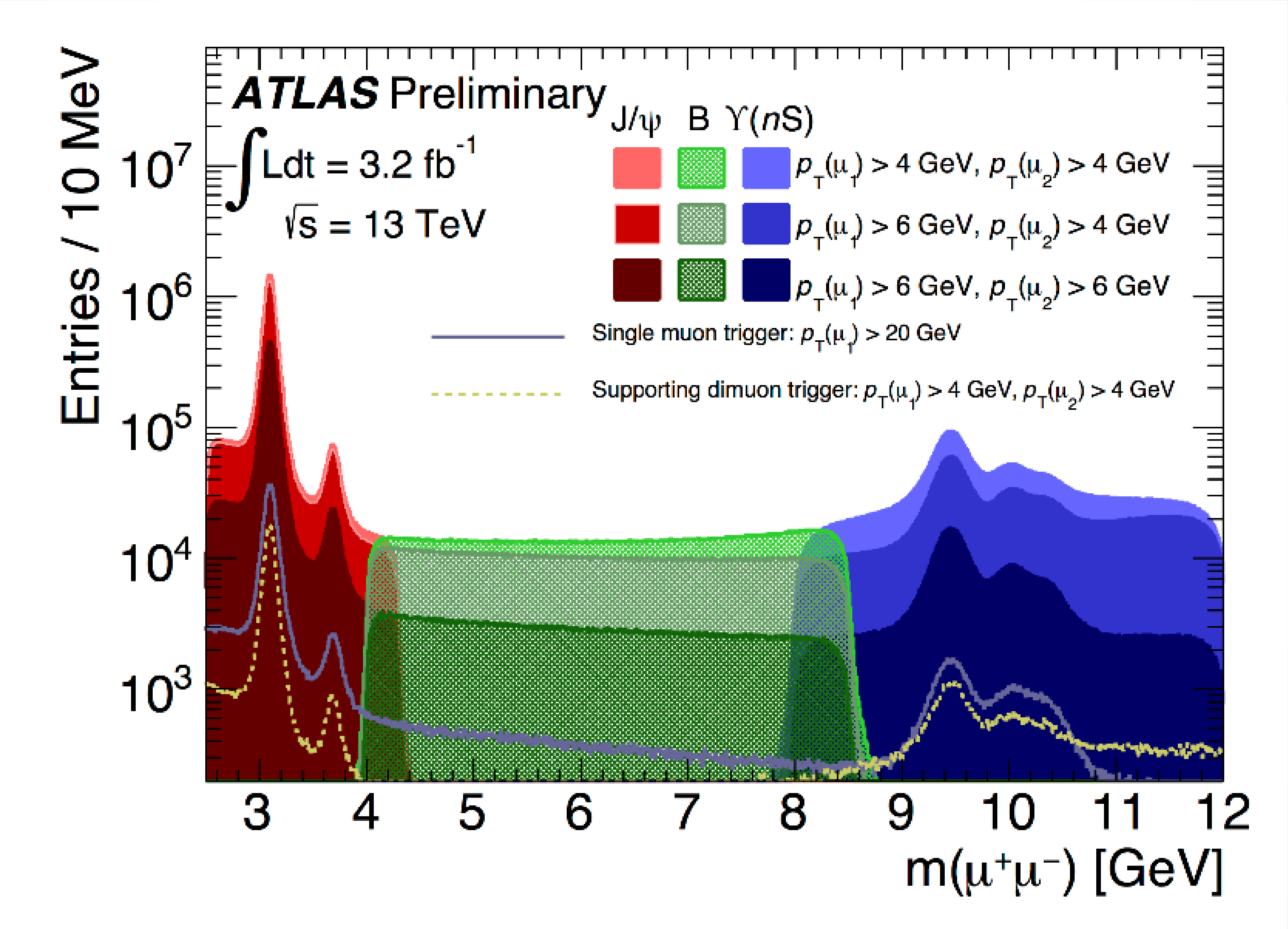
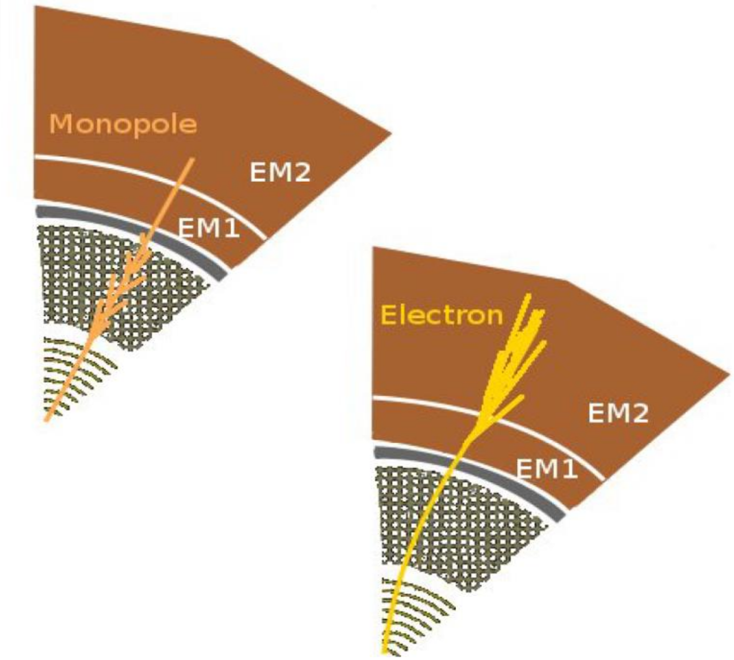


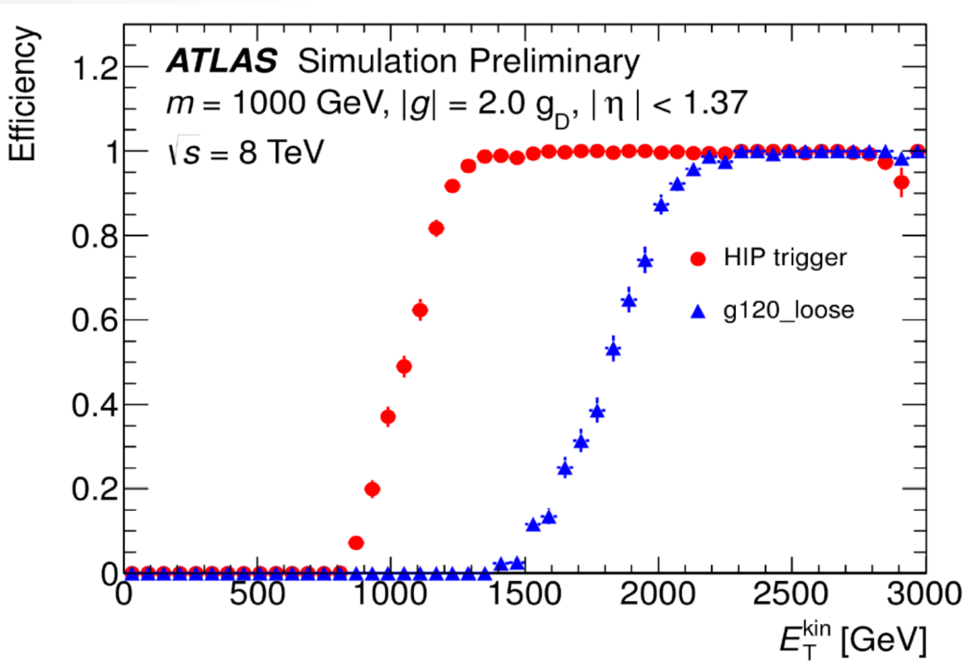
Thresholds for HLT primaries

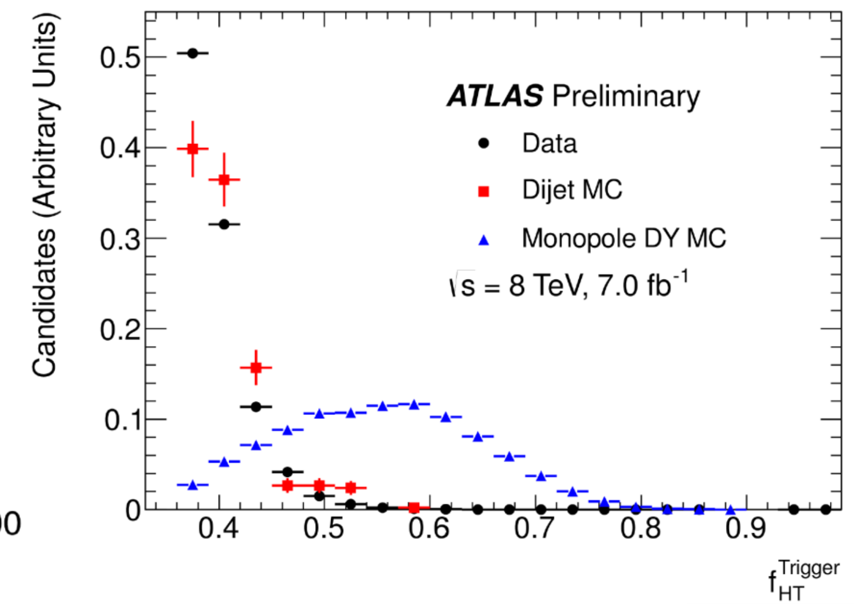
	e	mu	tau	g	j	b-jet
Single	24	20i, 50	80	120	360	225
Di-	2x12	2x10; 18&8	35, 25	35&25	n/a	150&50
Tri-	15&2x7	3x6; 17&2x4		3x15	3x175	n/a
Four					4x85	n/a
Five					5x60	n/a
Six					6x45	n/a

There are also combined triggers (e.g. mixed object types)

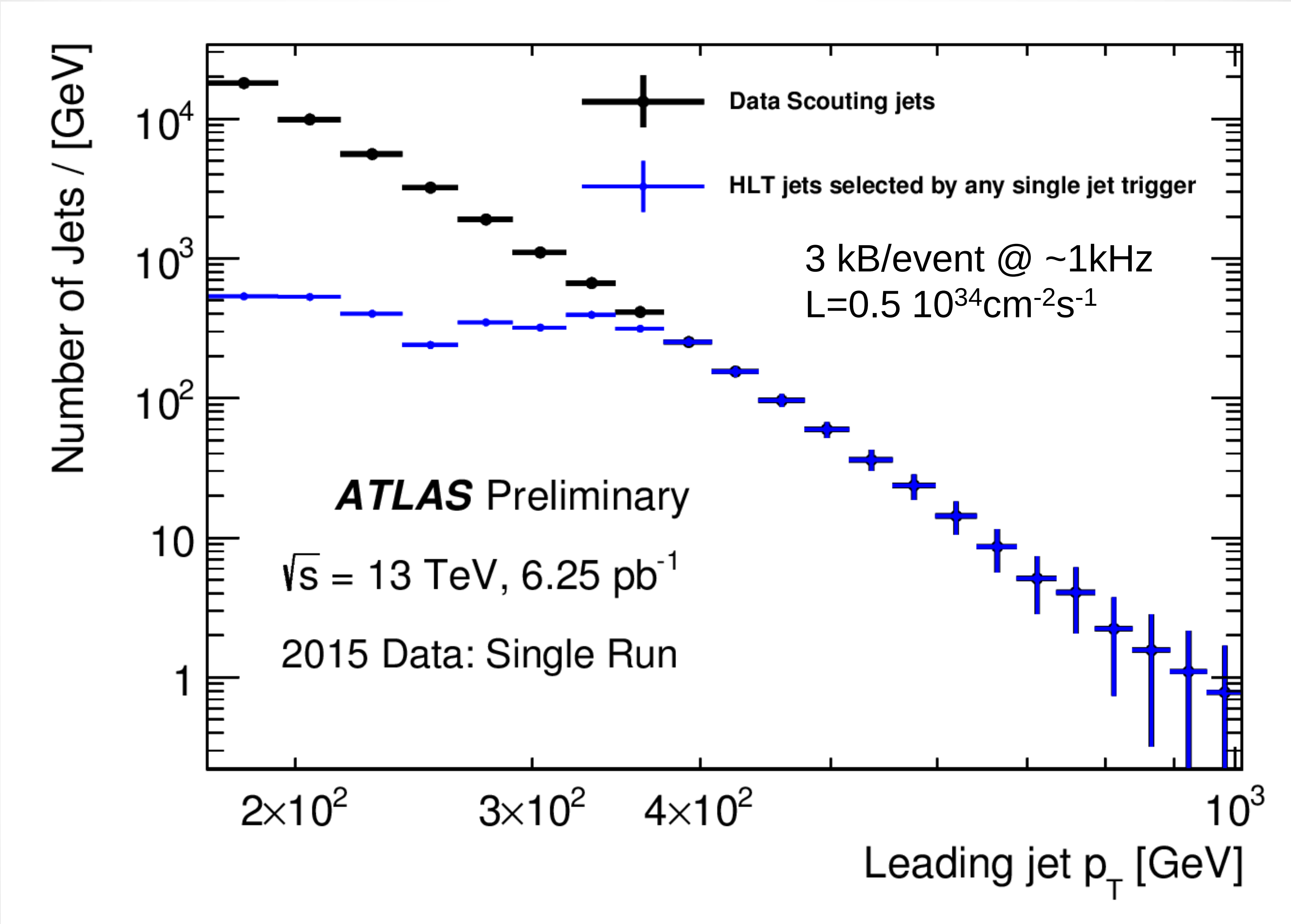
Dedicated Triggers: Highly Ionizing Particles





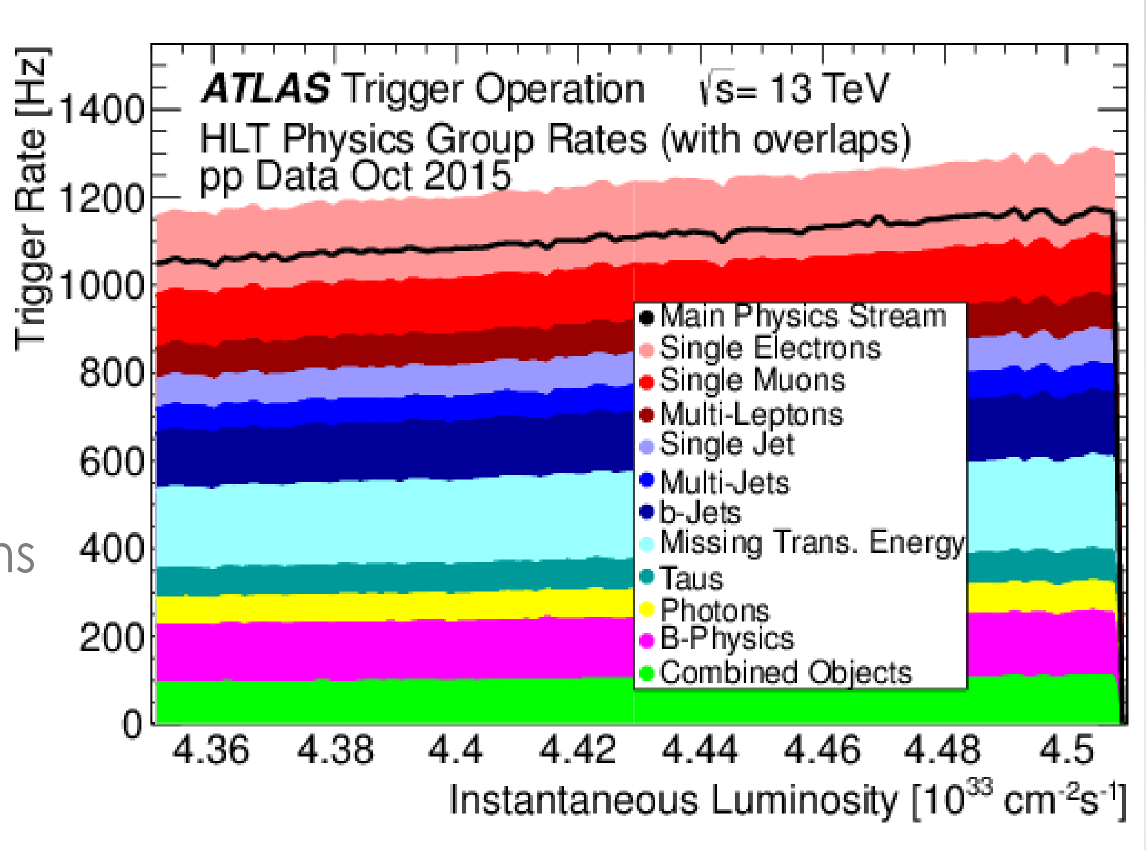


Trigger Level Analysis



Menu Content

- 400 L1 trigger items and 1500 HLT trigger chains
- Unprescaled primary triggers and backups for other lumi points
- Prescaled primary triggers (jets, photons)
- Alternative triggers including various algorithms or selections
- Support triggers for efficiency measurements, backgrounds studies etc.
- Triggers for calibration (partially built events)
- Triggers for monitoring
- Triggers for special runs



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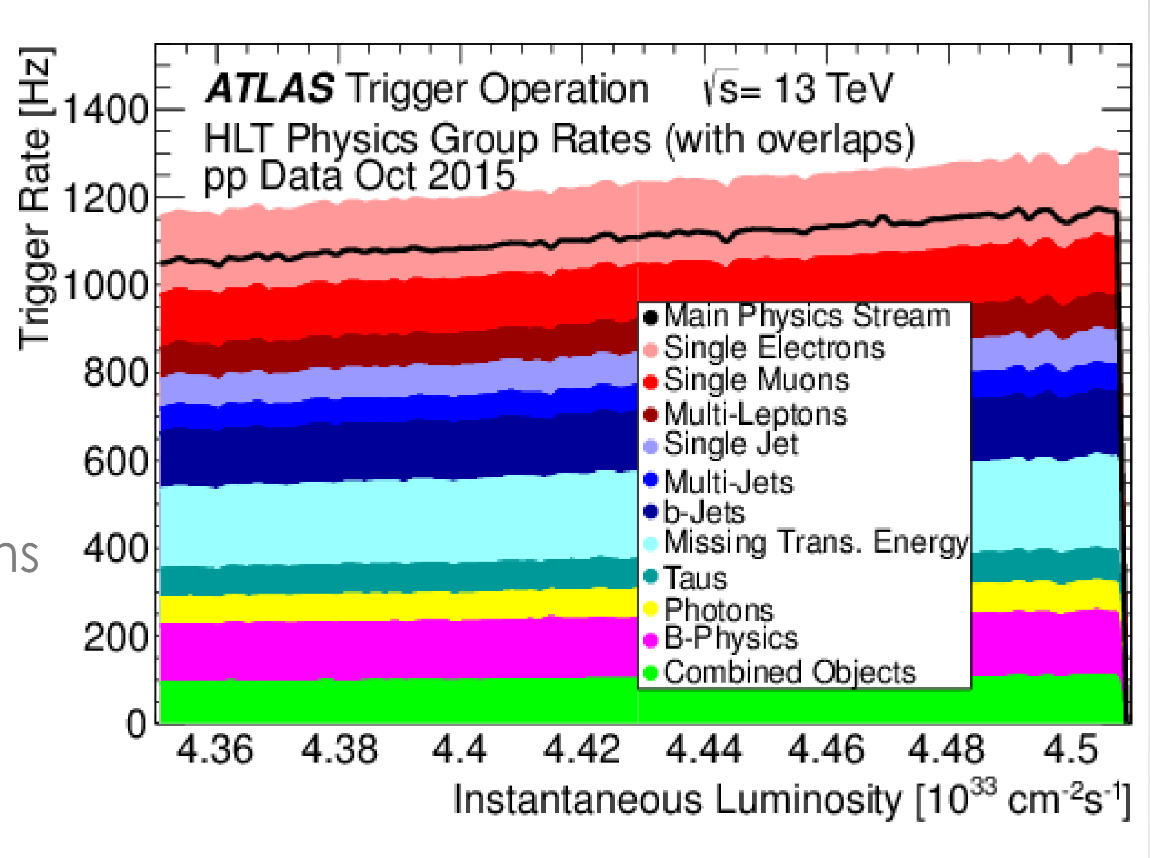


Trigger menu did its job in 2015 run.

Strategy is known for the rest of Run 2

My timeline on ATLAS

2006-2009 Electron Triggers

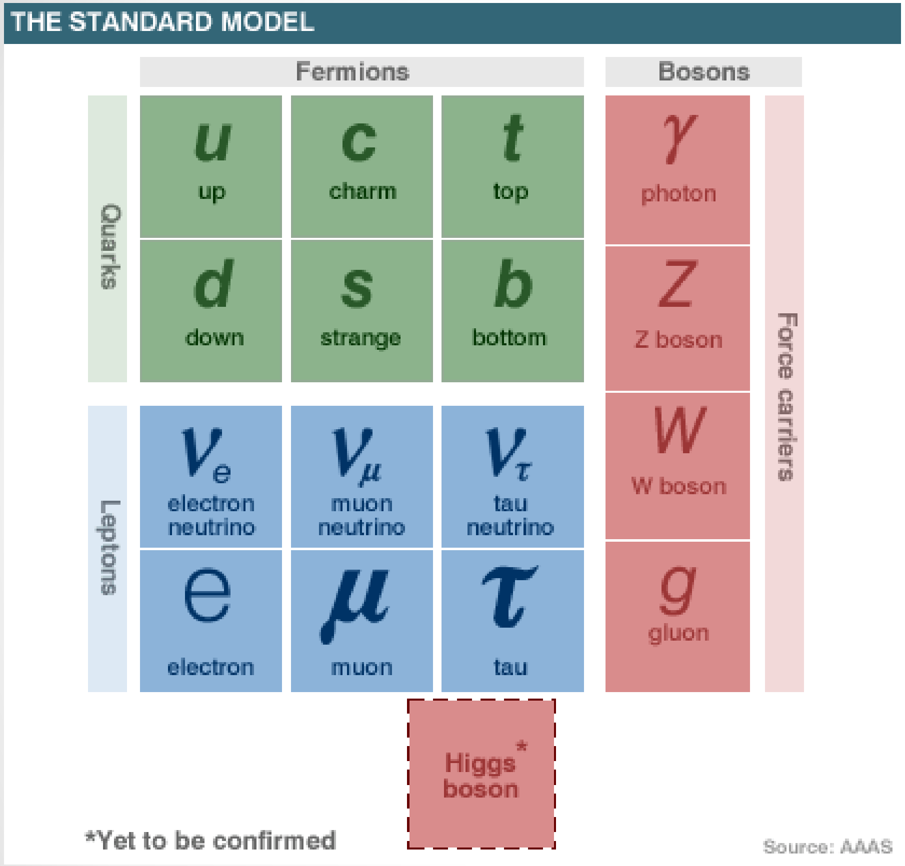
2010-2012 Exotics Triggers

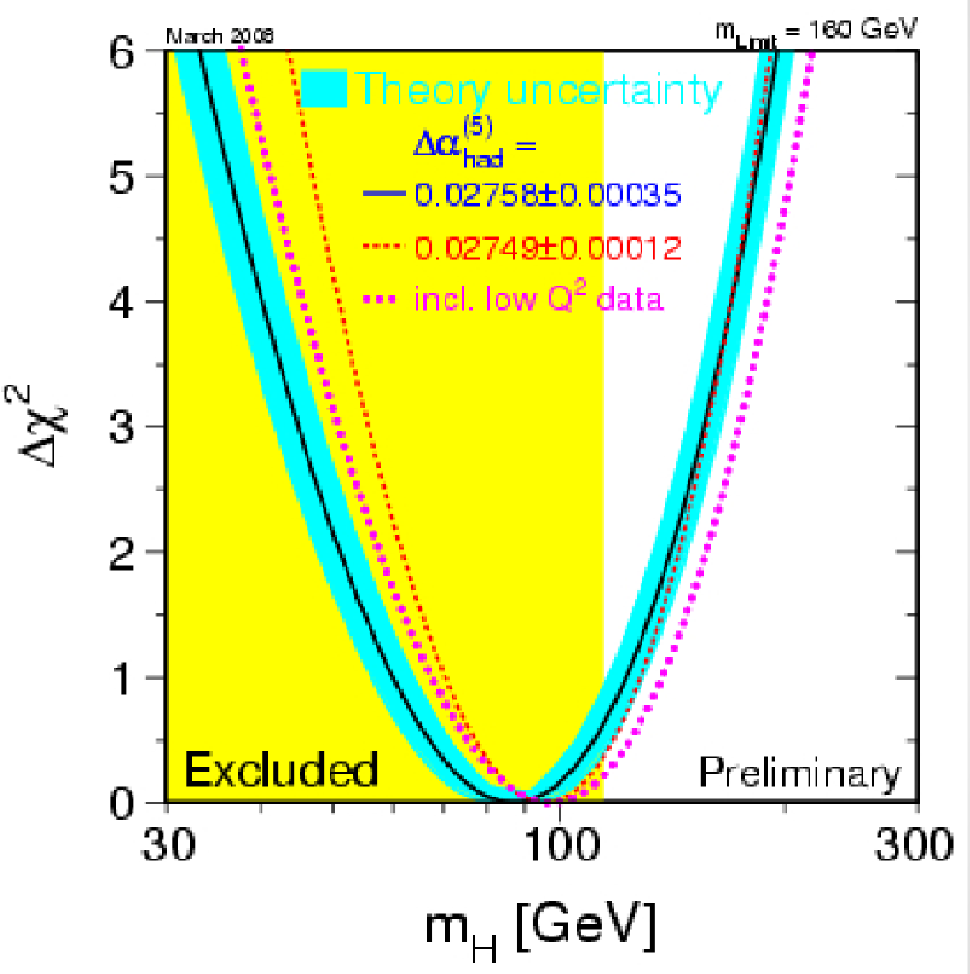
2013-2015 Trigger Menu for Run 2

2009-now Dilepton searches

https://www.flickr.com/photos/primejunta/2518179985

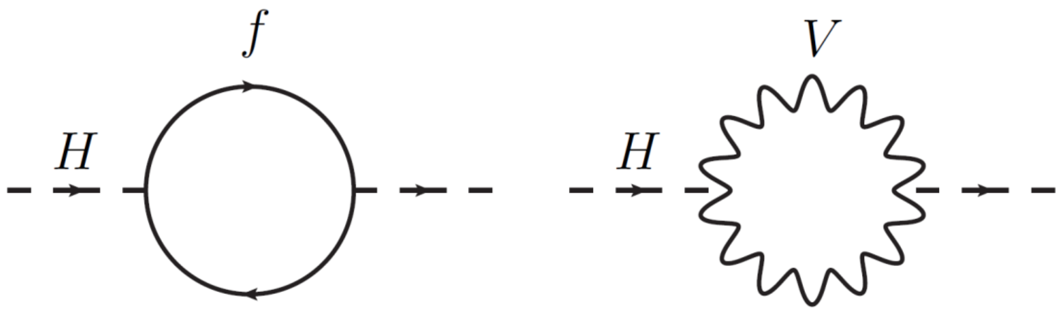
Before the start of LHC





Hierarchy problem of SM

- SM is an effective theory valid up to a cut off scale Λ_{SM}
- Radiative corrections to Higgs mass:



$$\Delta m_H^2 = -\frac{|y_f|^2}{16\pi^2}\left[2\Lambda^2 + \mathcal{O}\left(m_f^2 \ln\left(\frac{\Lambda}{m_f}\right)\right)\right]$$

Searches for Physics Beyond SM

Look for deviations from Standard Model predictions

Direct observation:
new resonant or
non-resonant structures

In-direct observation:
discrepancies in rates of rare processes,
couplings measurements, etc.

Experimental Approach: Exotic Search

Search for any deviations from Standard Model predictions

Direct observation:
new (e.g. Exotic) resonant or non-resonant structures

LOOK FOR SIGNATURES MADE OF BASIC OBJECTS

Jets, b-jets, E_T^{Miss}

Bosons (γ, W, Z)

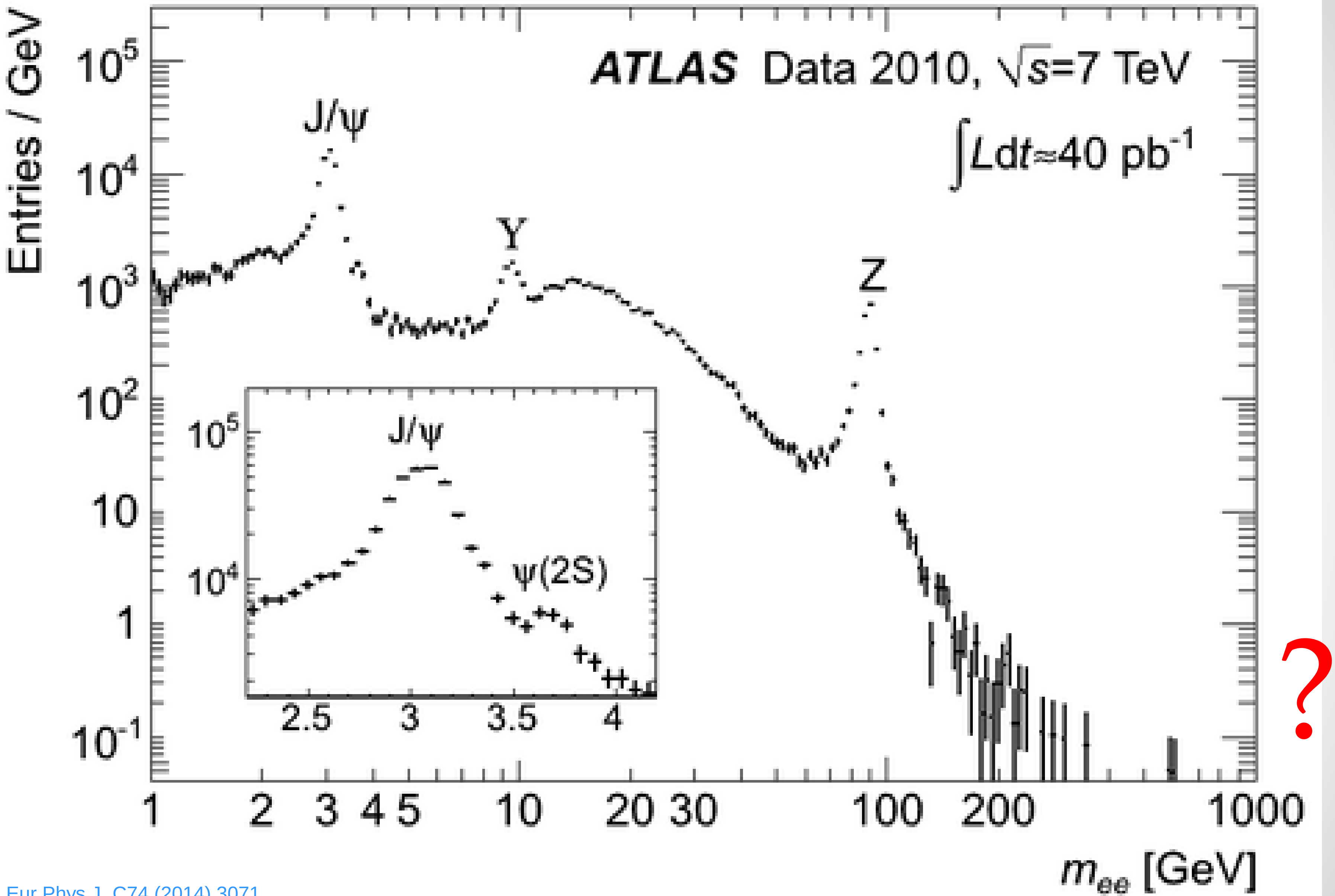
Leptons (e, μ, τ)

Unconventional Particles

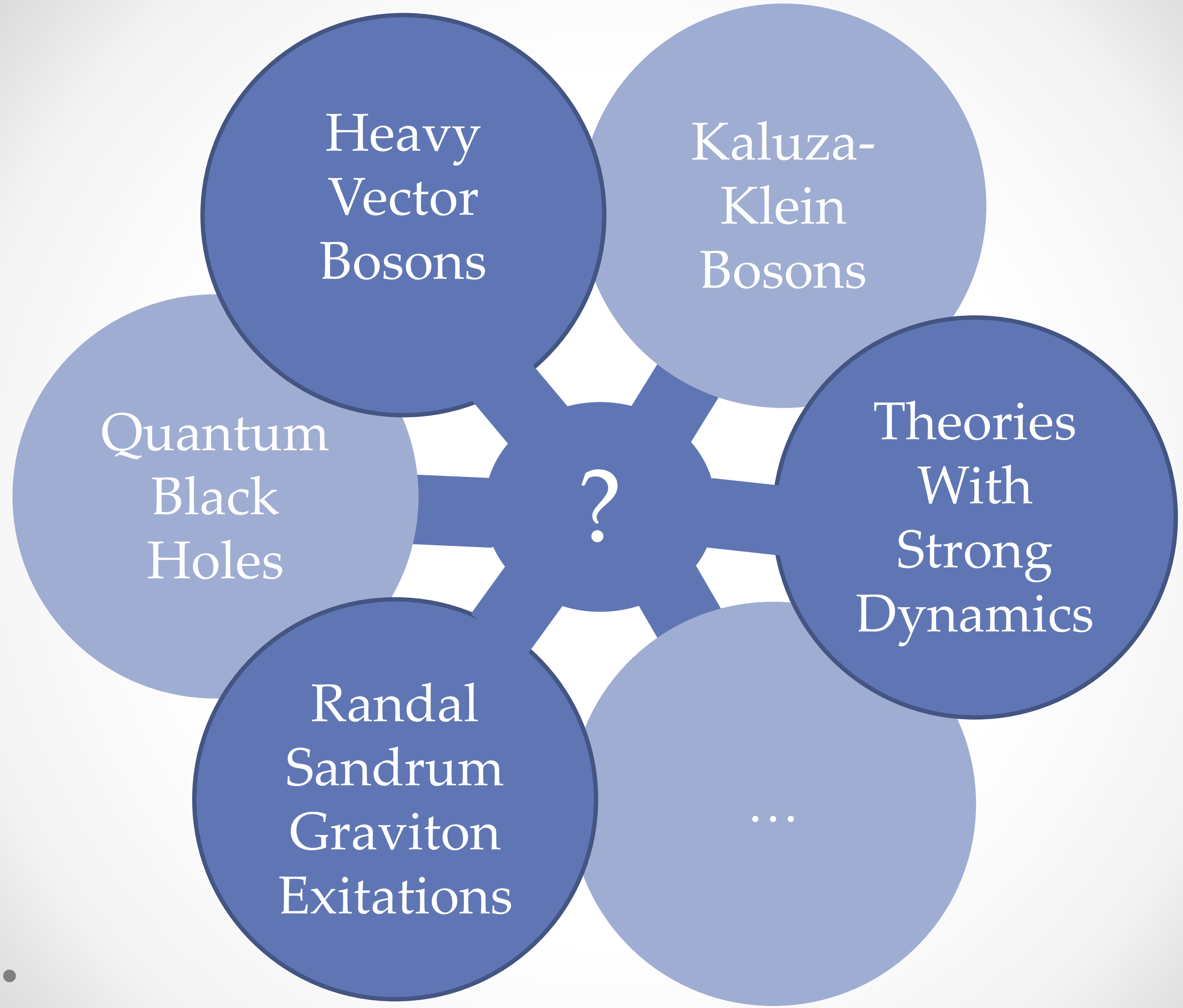
AS MANY SIGNATURES AS POSSIBLE

AS MODEL INDEPENDENT AS POSSIBLE

PROVIDE BENCHMARK MODEL RESULTS

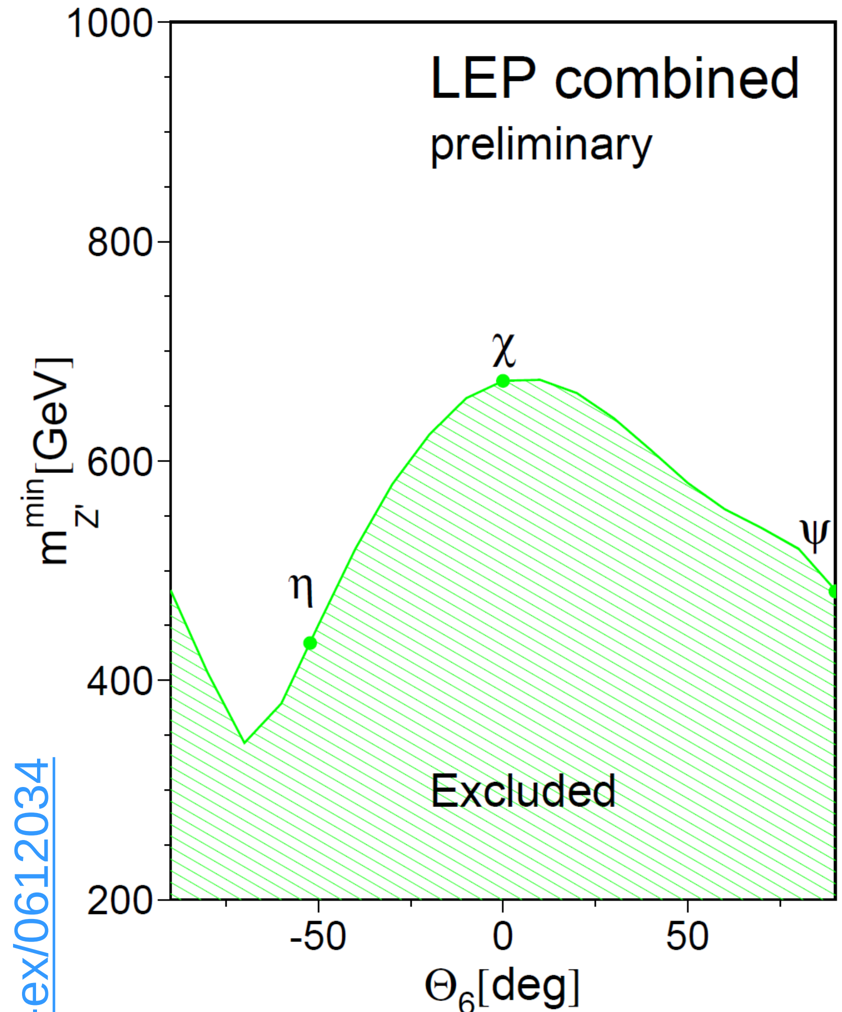


Eur.Phys.J. C74 (2014) 3071



Heavy Vector Bosons
Kaluza-Klein Bosons
Quantum Black Holes
?
Theories With Strong Dynamics
Randal Sandrum Graviton Exitations
…

Constraints from LEP



arXiv:hep-ex/0612034

- 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 E6. Depends on θ mixing of additional U(1) states.

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

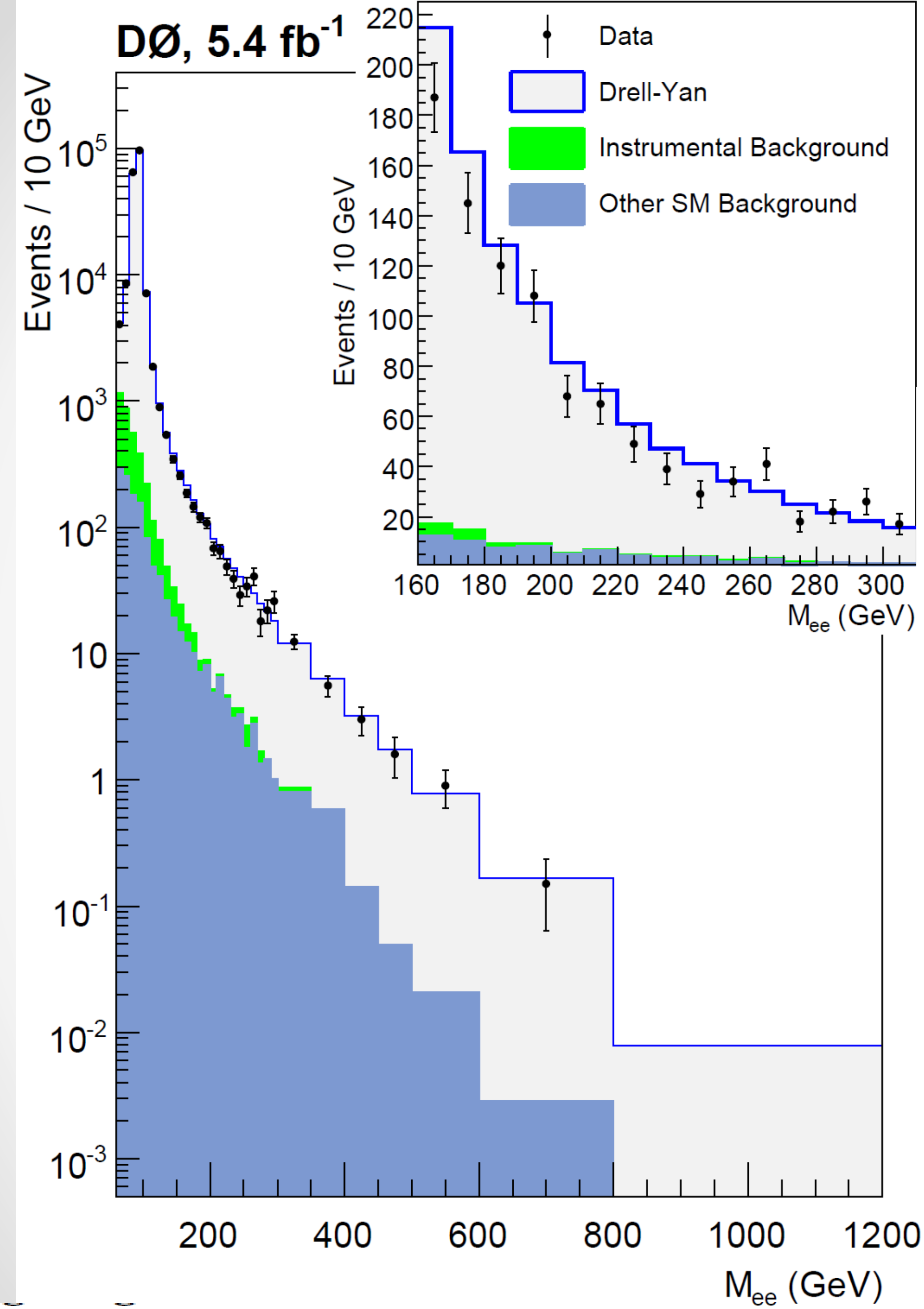
$$Z'(\theta) = Z'_\chi cos\theta + Z'_\psi sin\theta$$

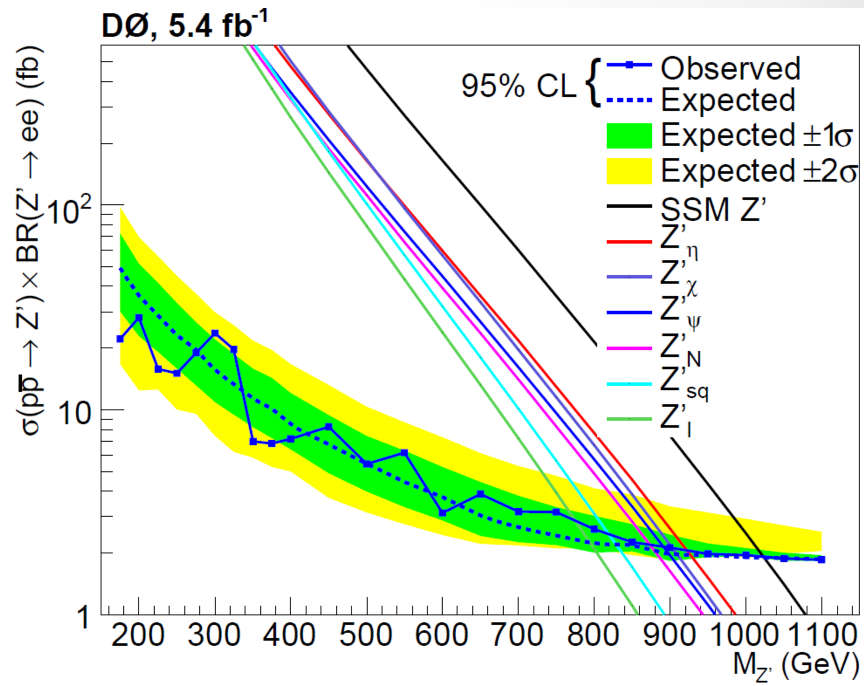
- Six commonly motivated values for θ lead to different models with specific Z′ states named:

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

Z' model	χ	ψ	η	L-R	SSM
$M_{Z'}^{limit}$ (GeV/c^2)	673	481	434	804	1787

Searches at TeVatron





Phys. Lett. B **695** (2011) 088,

Analysis Steps

Reconstruct and identify electrons & muons pairs

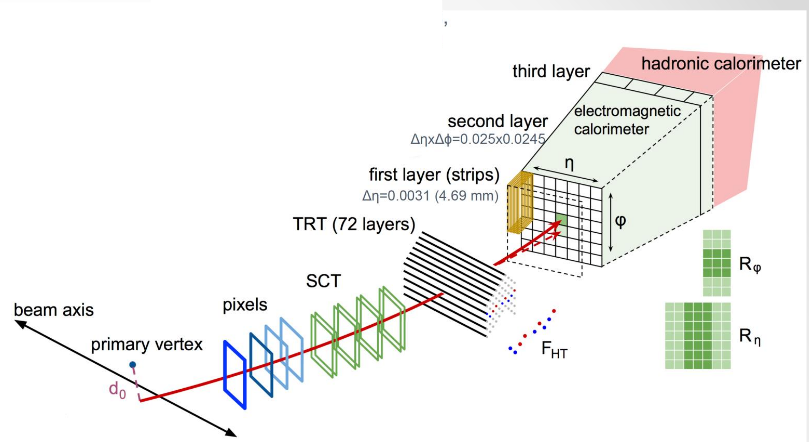
↓

Compare dilepton mass distributions in data with (the best possible) SM background expectation: excess?

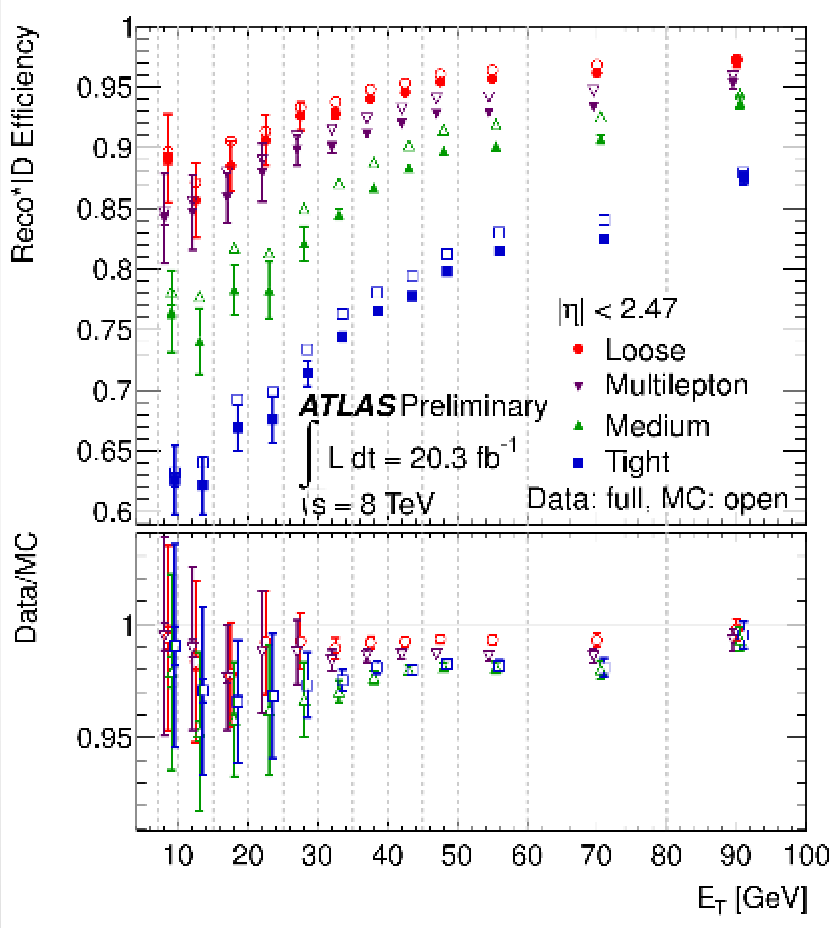
YES
Quantify,
study properties

NO
Set a limit in
a context of a
benchmark model

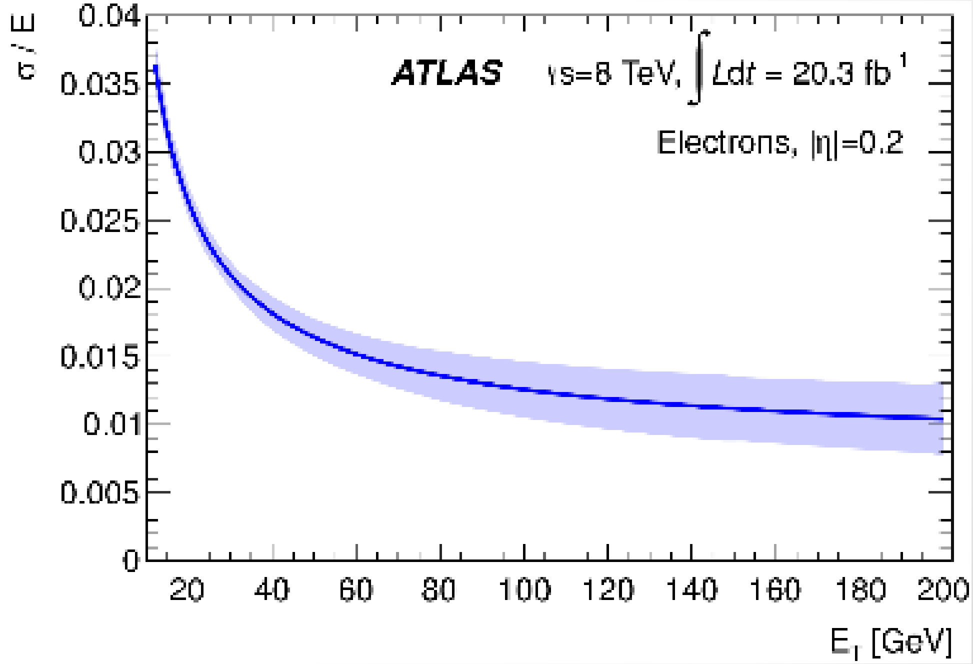
Electrons



third layer
hadronic calorimeter
second layer
Δη×Δϕ=0.025x0.0245
electromagnetic calorimeter
first layer (strips)
Δη=0.0031 (4.69 mm)
η
φ
TRT (72 layers)
SCT
pixels
beam axis
primary vertex
d0
FHT
Rφ
Rη

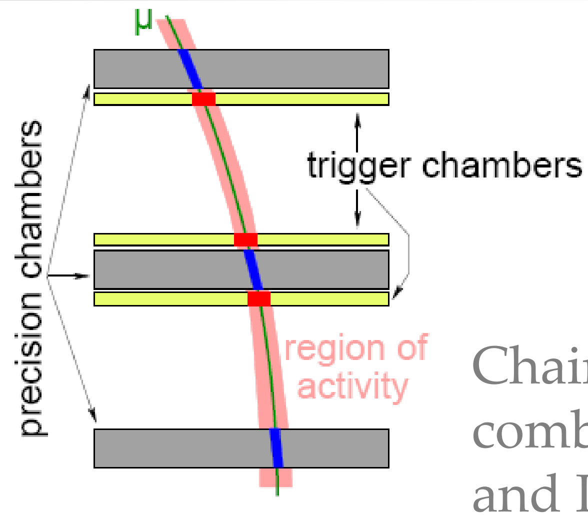


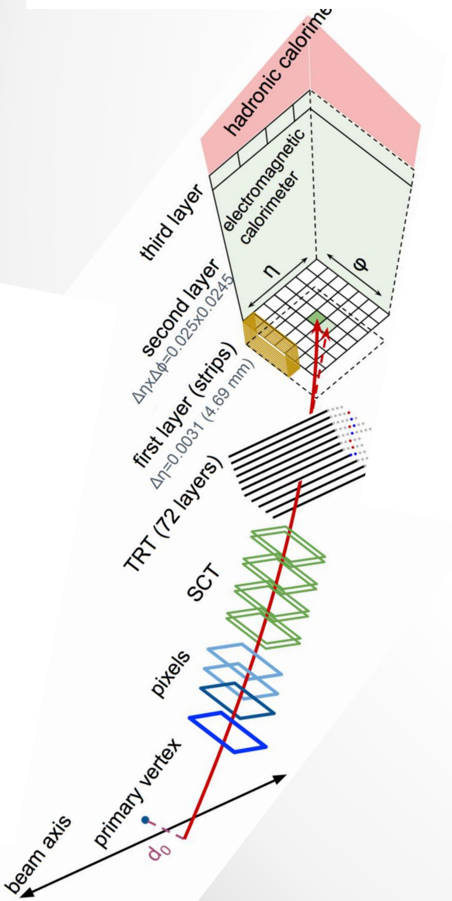
Reco*ID Efficiency
|η| < 2.47
Loose
Multilepton
Medium
Tight
ATLAS Preliminary
∫ L dt = 20.3 fb-1
√s = 8 TeV
Data: full, MC: open
Data/MC
ET [GeV]



σ / E
ATLAS
√s=8 TeV, ∫Ldt = 20.3 fb-1
Electrons, |η|=0.2
ET [GeV]

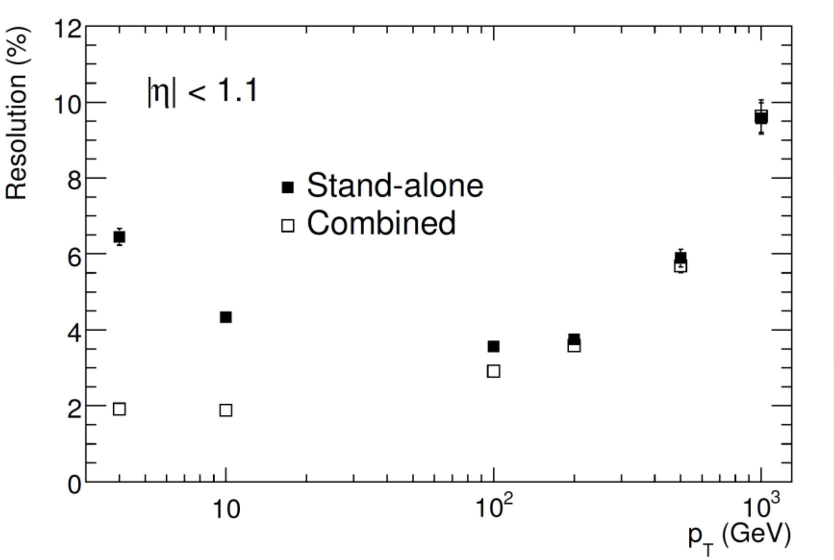
Muons

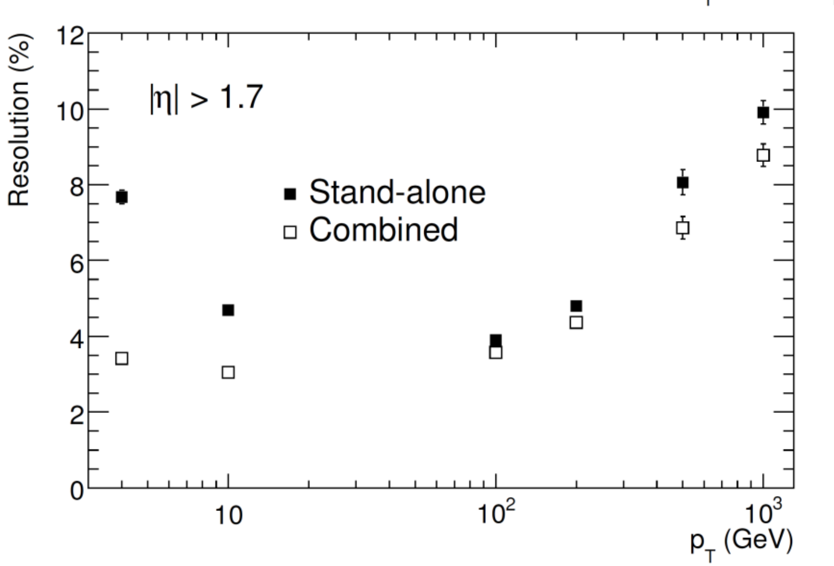




Chain 1: statistical combination of MS and ID tracks using their track parameter covariant matrices

Chain 2: global refit to hits in ID and MS





Analysis selection

Dielectron

- At least one primary vertex with more than two tracks
- Trigger on two EM calorimeter clusters with E_T>35(25) GeV
- $|\eta|<1.37$ or $1.52<|\eta|<2.47$
- Two electrons p_T > 40(30) GeV
- Medium identification requirements
- Isolation:

Leading: $\Sigma E_T(\Delta R<0.2)<0.05E_T+5\text{GeV}$;

Subleading: $\Sigma E_T(\Delta R<0.2)<0.022E_T+6\text{GeV}$

Dimuon

- At least one primary vertex with more than two tracks and $|z_{PV}|<200$mm
- Single muon trigger with p_T>25GeV (isolated) or >35GeV
- Two muons of opposite charge with p_T>25GeV
- High-quality inner detector track matched to high quality muon spectrometer track
- Also "Loose" channel ($|\eta|<1.015$) with less stringent requirements
- $d_0 < 0.2$ mm, $z_0 < 1$ mm
- Isolation: $\Sigma p_T(\Delta R<0.2)<0.05p_T$

Retain highest p_T same–flavor dilepton pair per event above 80 GeV

Analysis Steps

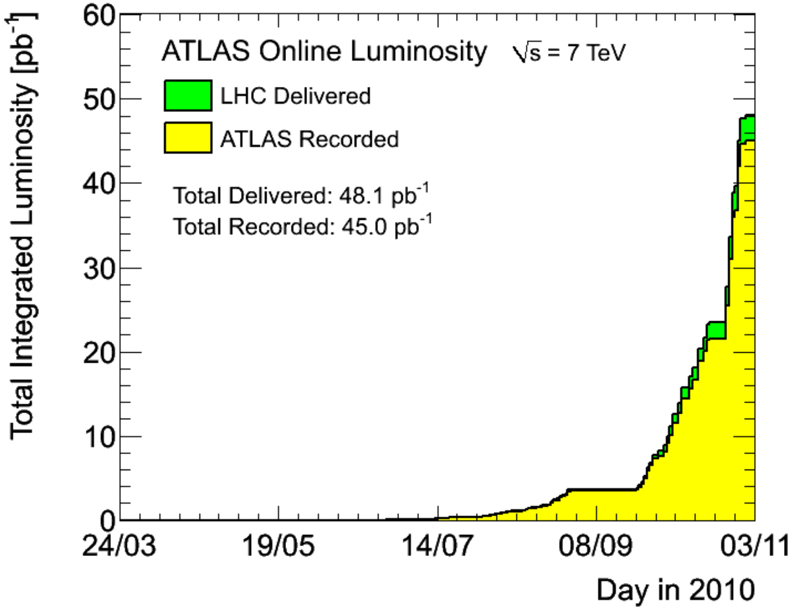
Reconstruct and identify electrons & muons pairs

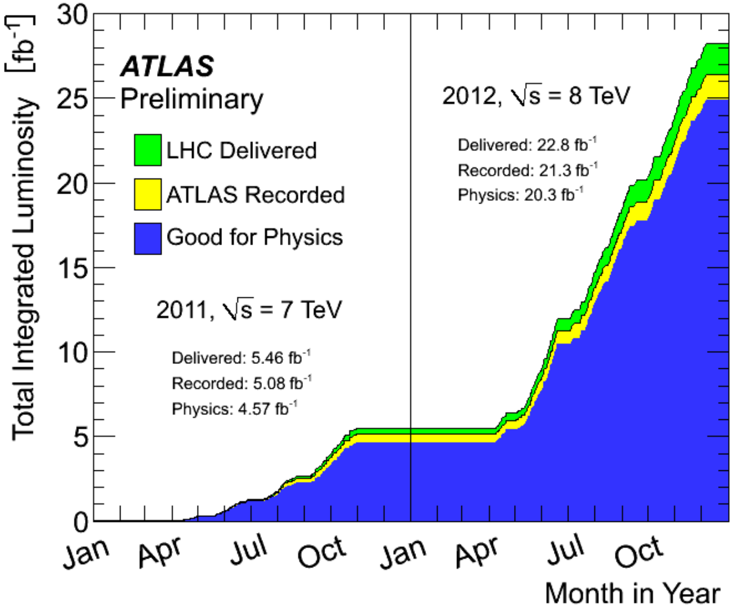
↓

Compare dilepton mass distributions in data with (the best possible) SM background expectation: excess?

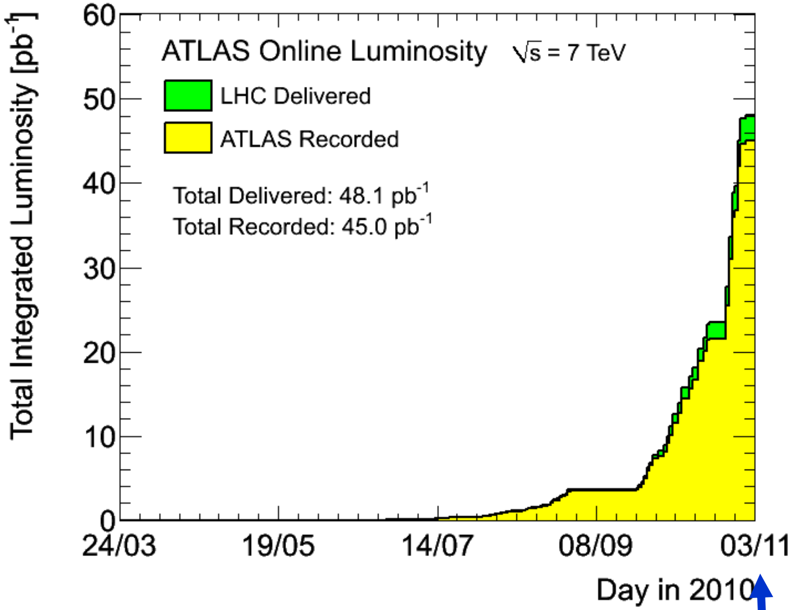
Process	Method
Drell-Yan	MC
Diboson	MC
ttbar	MC
Dijets & W+jets	Data-driven

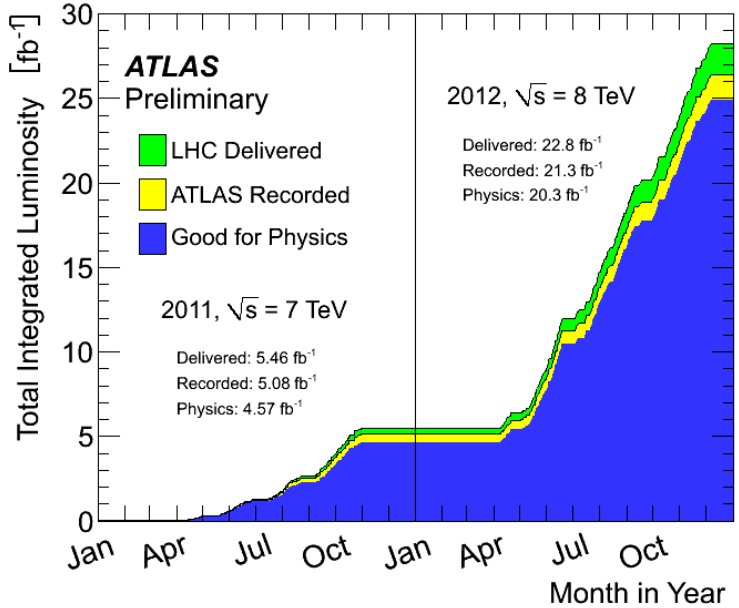
Run 1 Searches at ATLAS



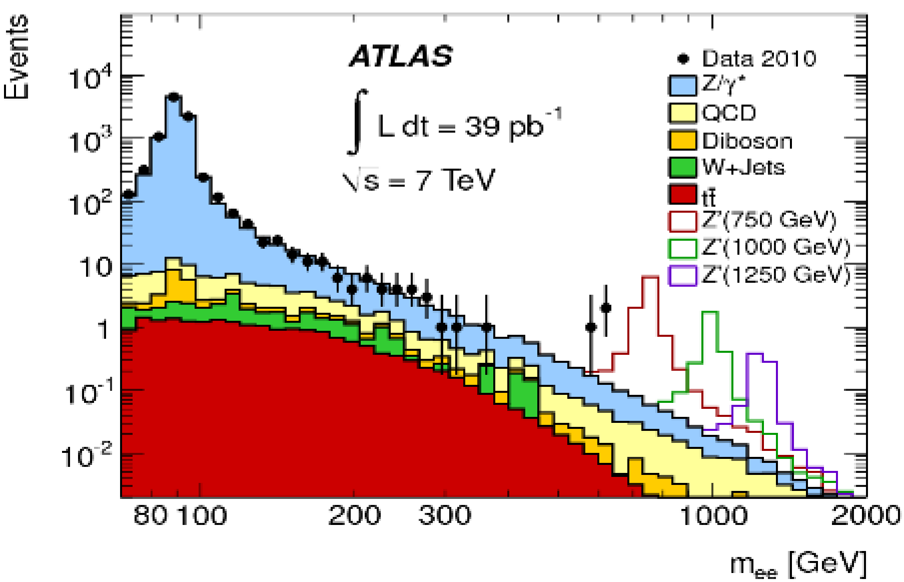


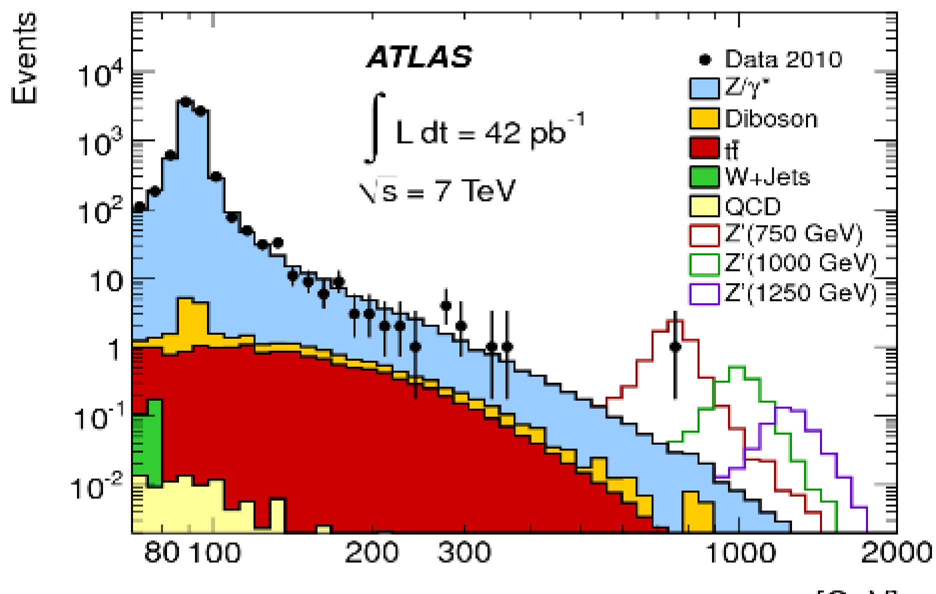
Run 1 Searches at ATLAS



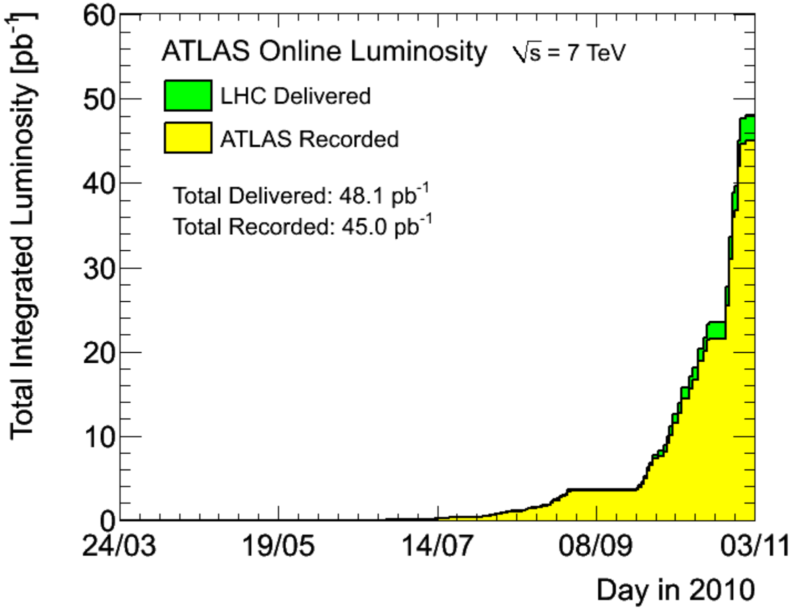


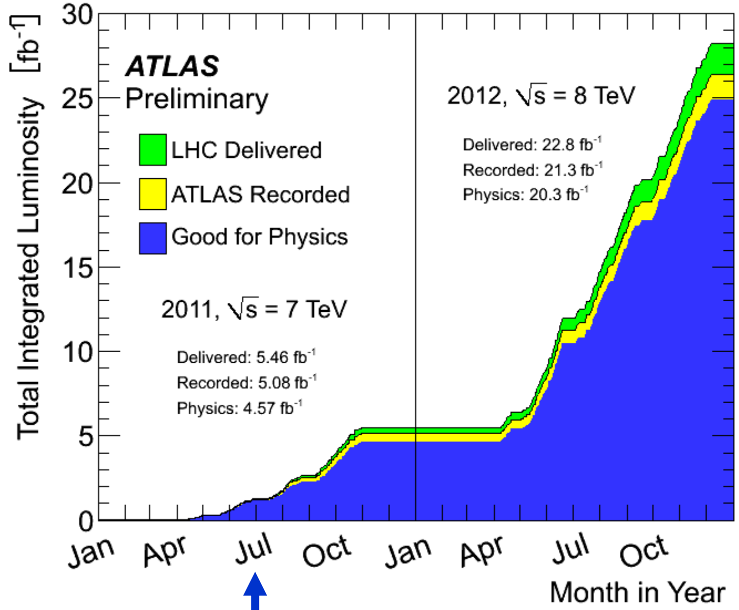
PLB 700 169(2011)



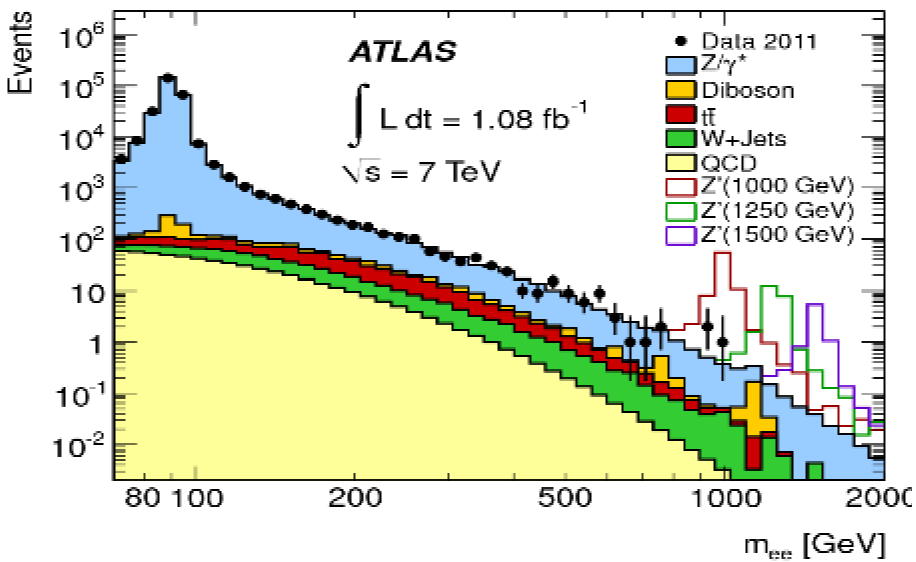


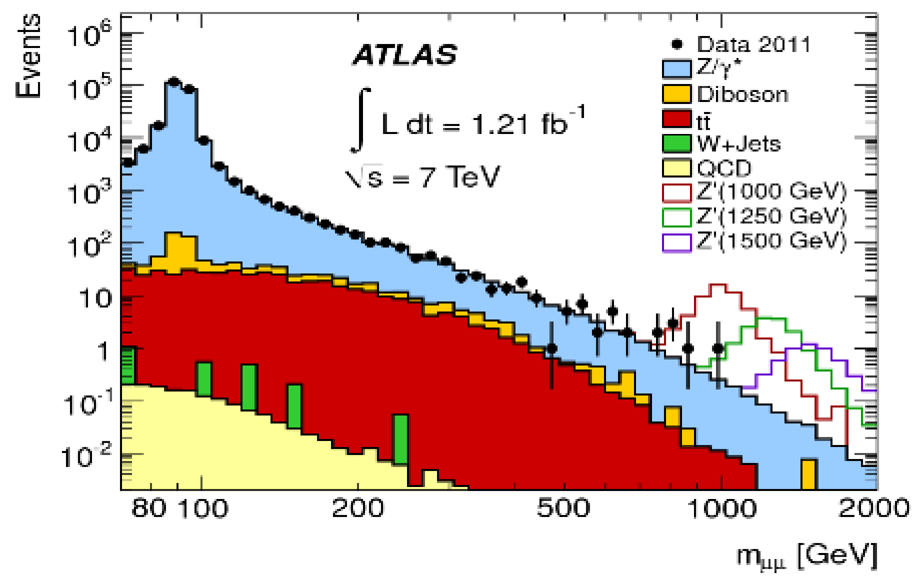
Run 1 Searches at ATLAS



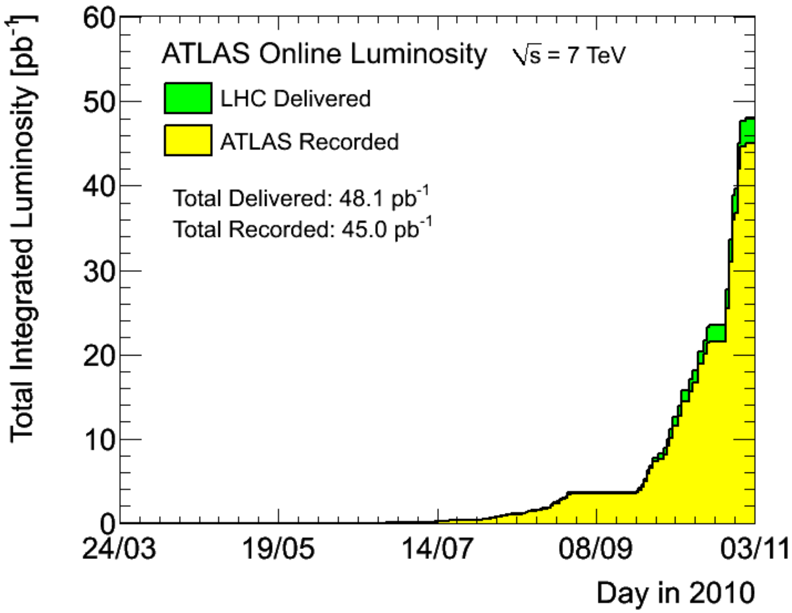


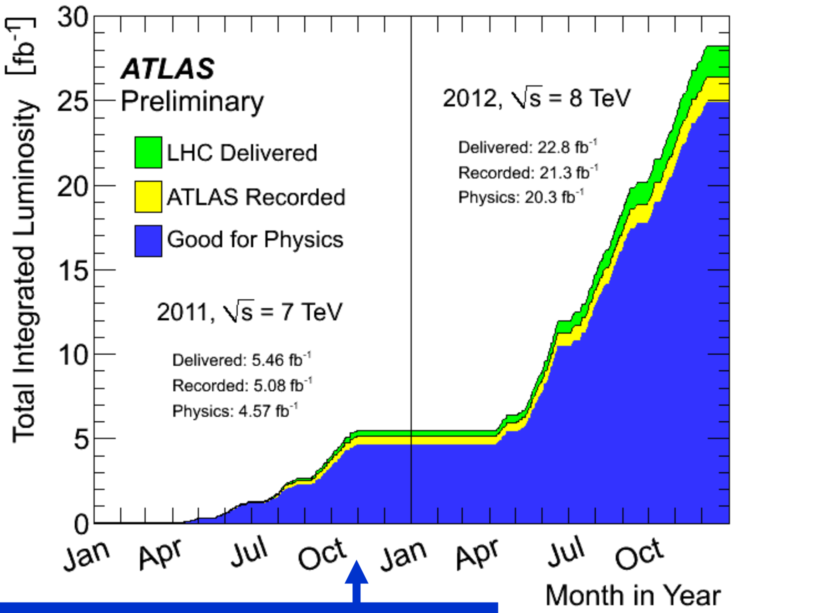
PRL107 202007 (2011)



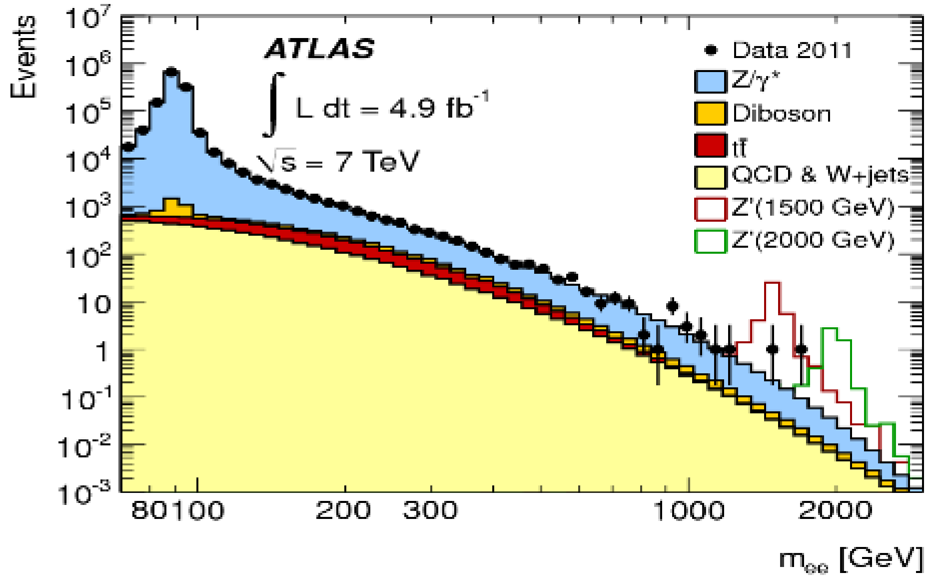


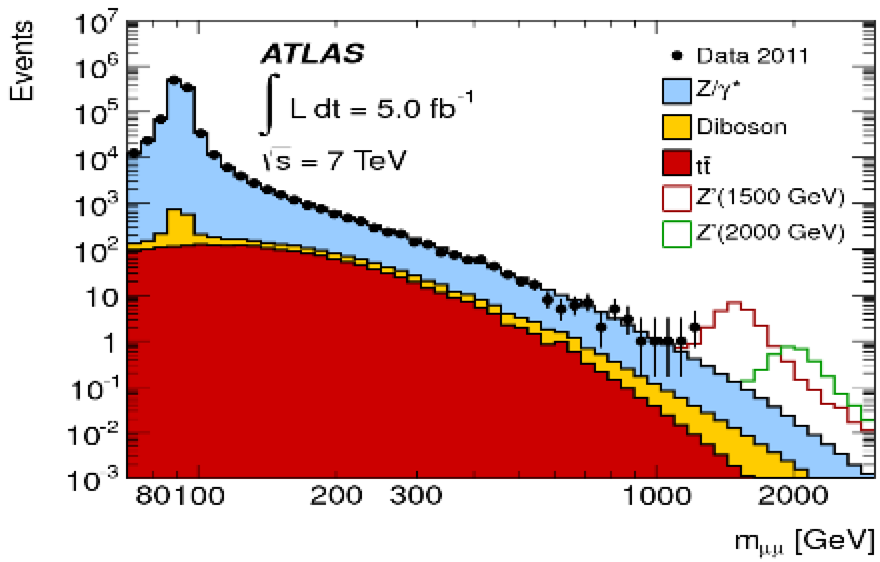
Run 1 Searches at ATLAS



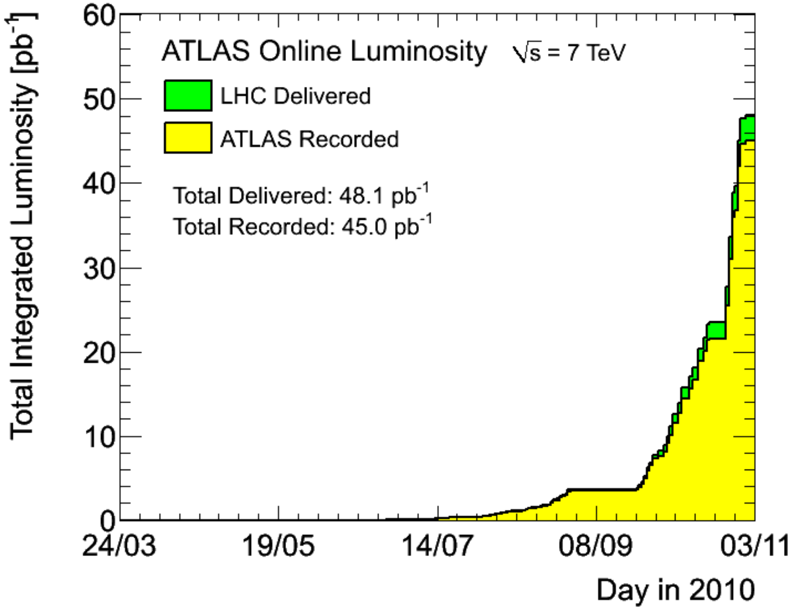


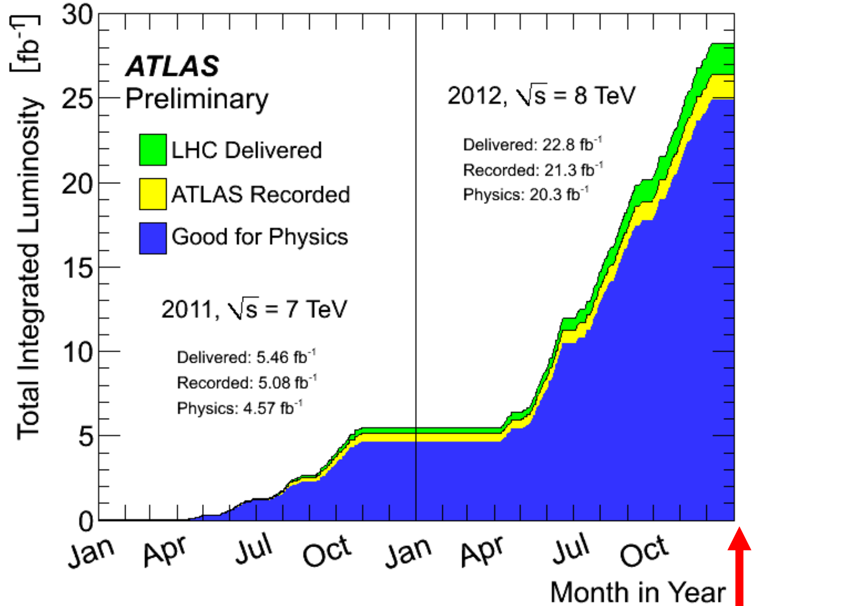
JHEP 1211 138 (2012)



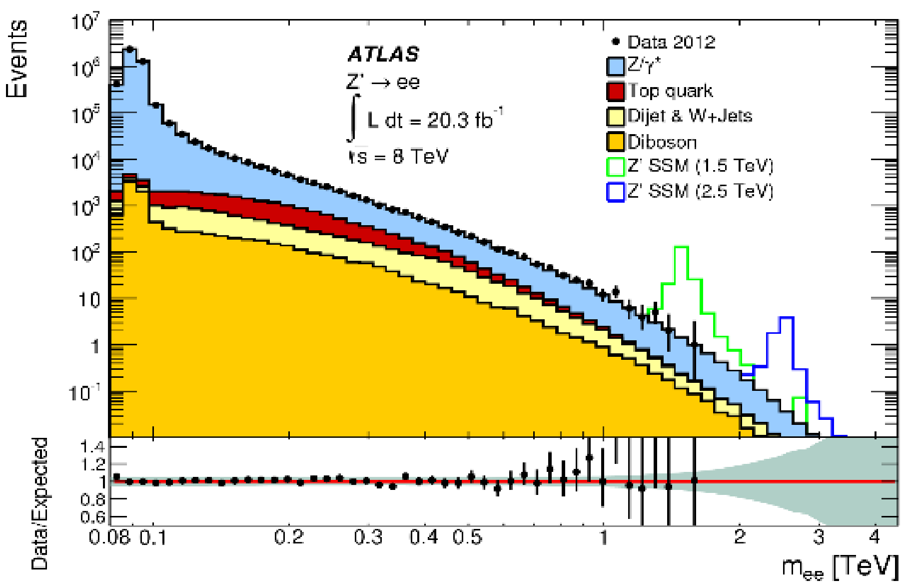


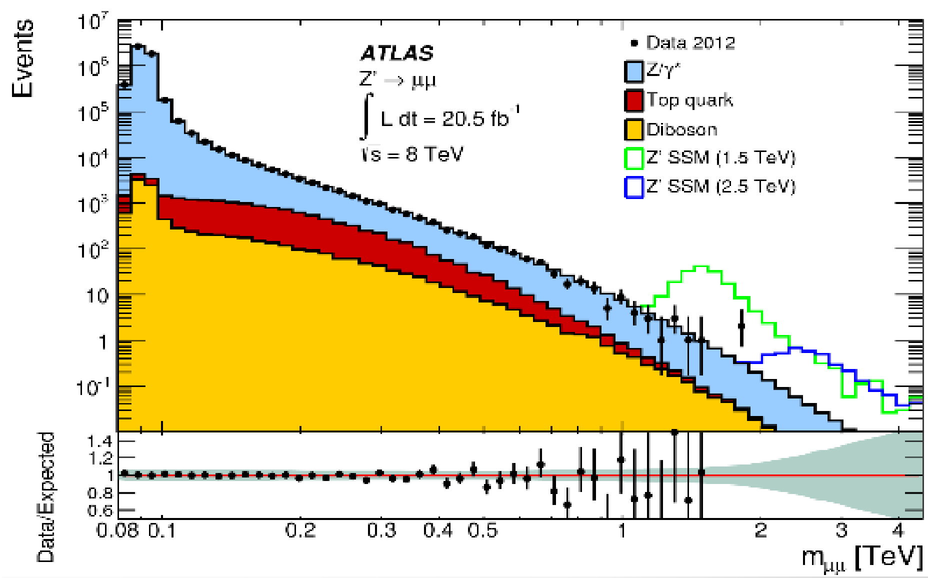
Run 1 Searches at ATLAS





PRD 90 052005 (2014)





Analysis Steps

Reconstruct and identify electrons & muons pairs

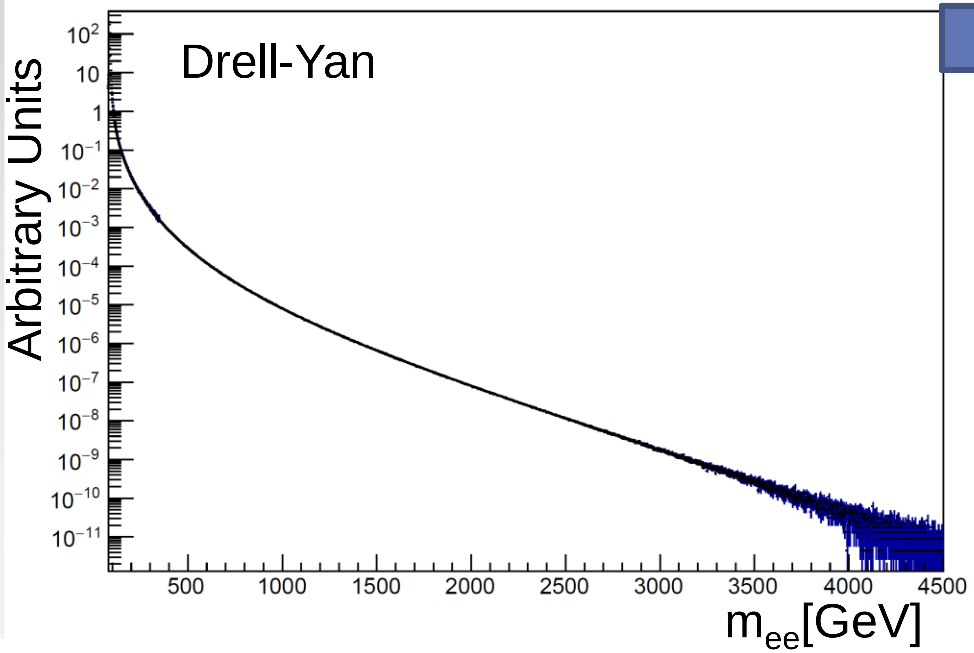
↓

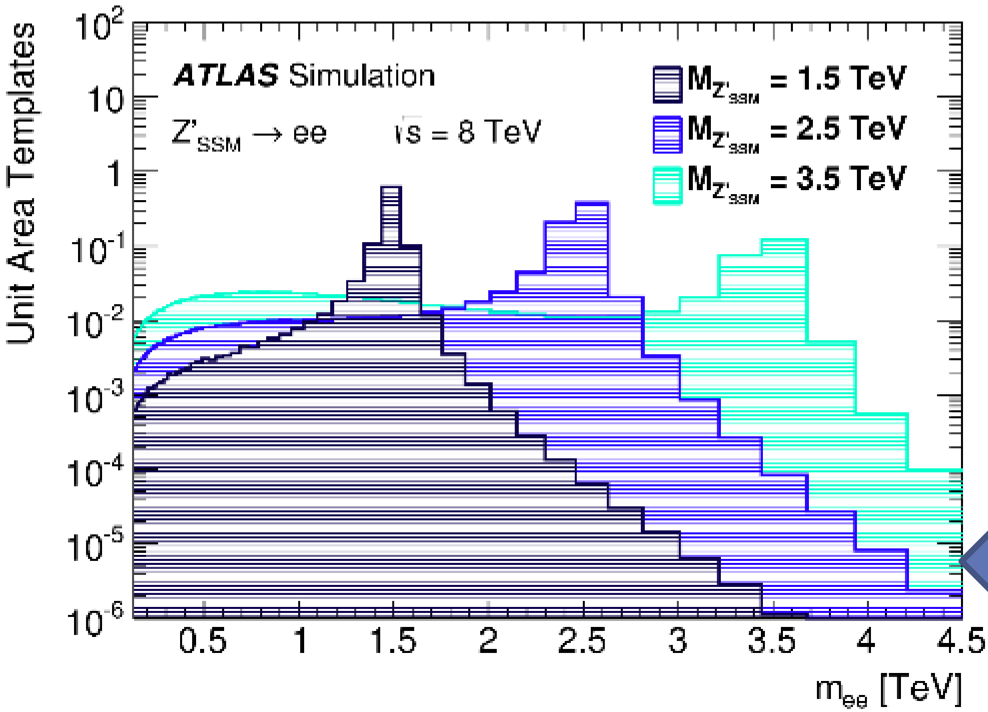
Compare dilepton mass distributions in data with (the best possible) SM background expectation: excess?

YES
Quantify,
study properties

NO
Set a limit in context of a benchmark model

Signal



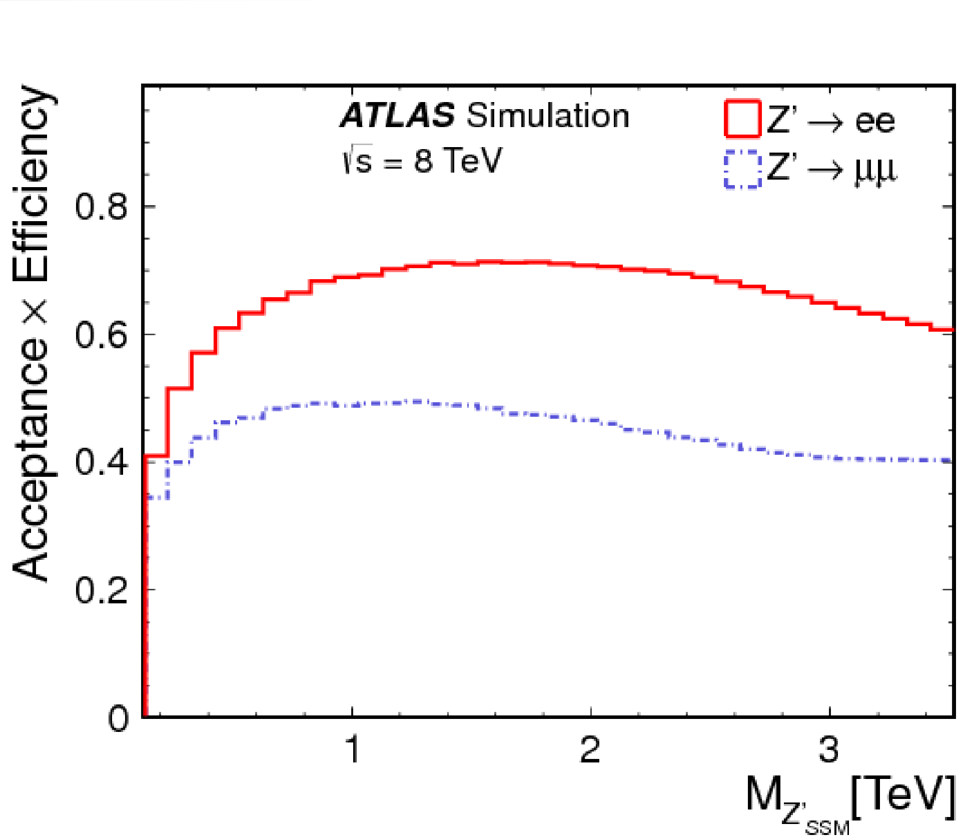


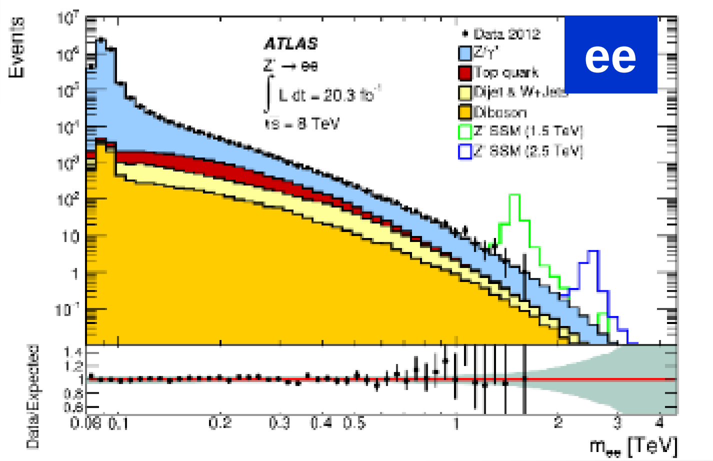
$$\mathscr{W}(m,q) = \frac{\sum_{i,j\in\{L,R\}} |A_{ij}(Z')|^2}{\sum_{i,j\in\{L,R\}} |A_{ij}(Z/\gamma^*)|^2}$$

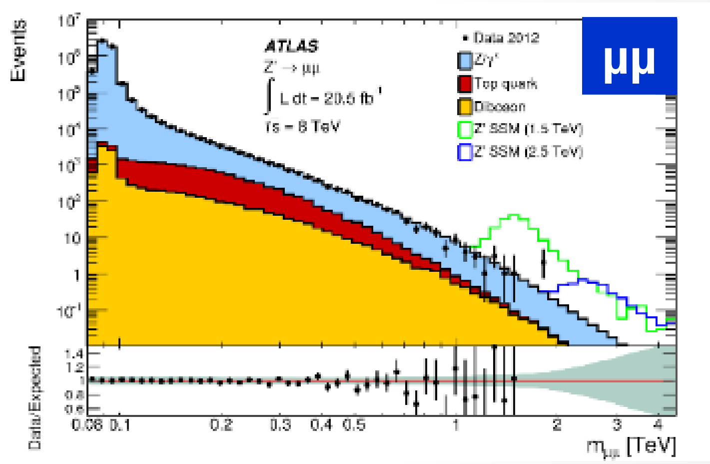
$$A_{ij}(Z') = g_{Z'}^2 \frac{g'_{qi} g'_{\mu j}}{m^2 - M_{Z'}^2 - iM_{Z'}\Gamma_{Z'}}$$

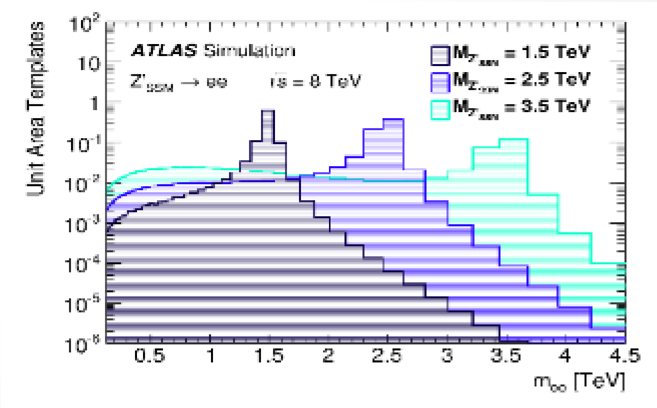
$$A_{ij} = g_{EM}^2 \frac{Q_q Q_\mu}{\hat{s}} + g_Z^2 \frac{g_{qi} g_{\mu j}}{\hat{s} - M_Z^2 - iM_Z\Gamma_Z}$$

Inputs to limit setting

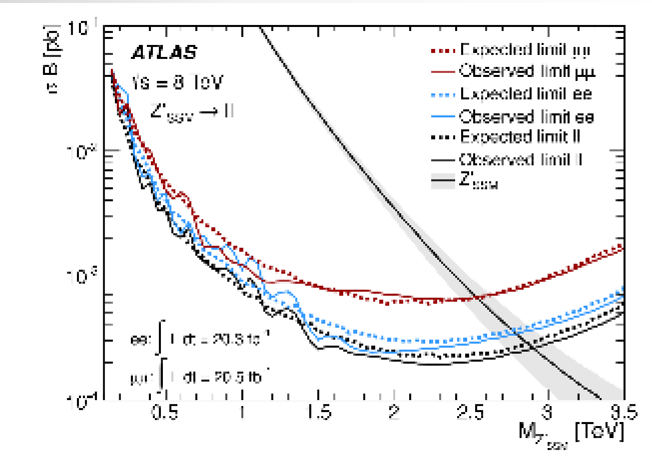




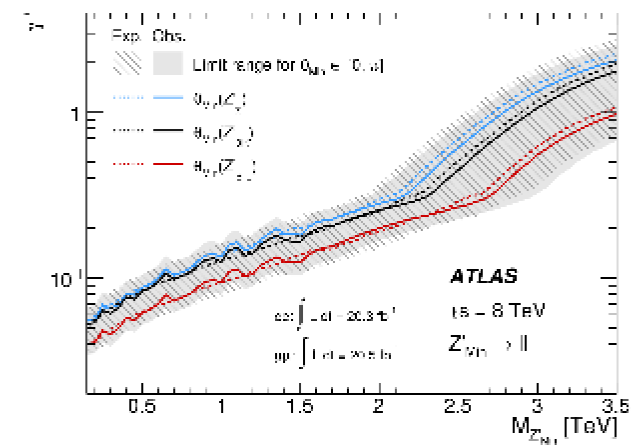




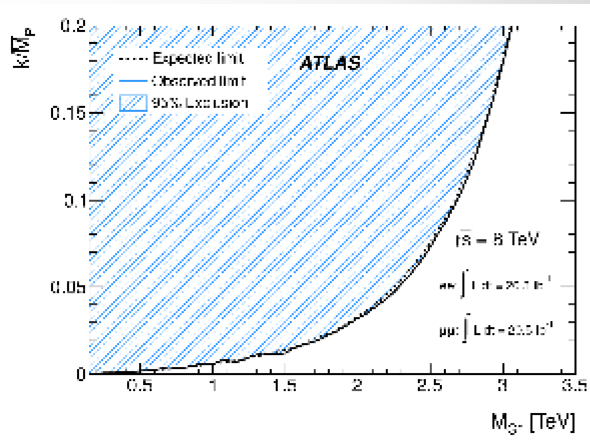
Limits



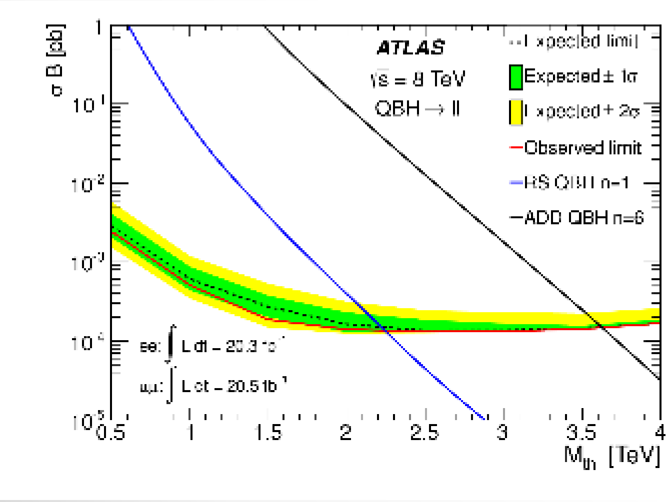
ATLAS
√s = 8 TeV
Expected limit μμ
Observed limit μμ
Expected limit ee
Observed limit ee
Expected limit ll
Observed limit ll
σ B [pb]
[TeV]



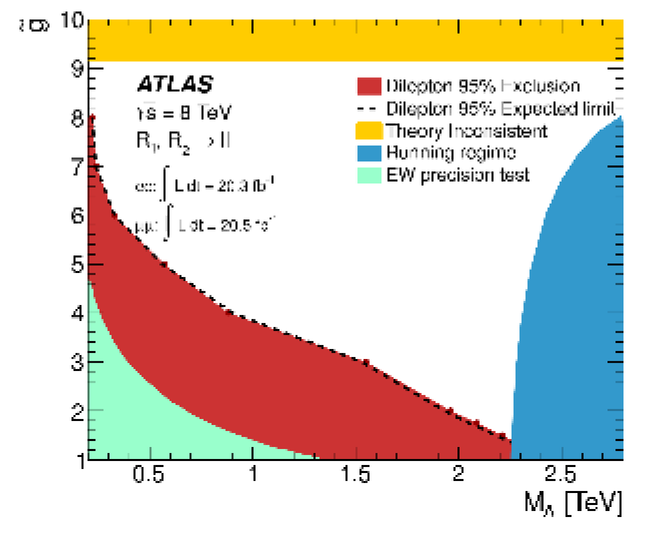
Exp. Obs.
ATLAS
√s = 8 TeV
[TeV]



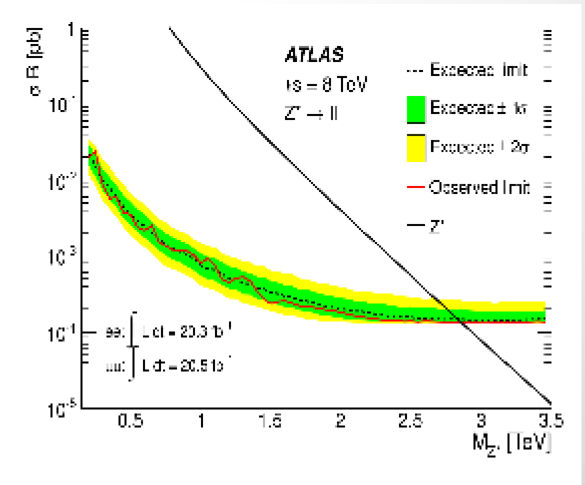
Expected limit
Observed limit
95% Exclusion
ATLAS
√s = 8 TeV
[TeV]



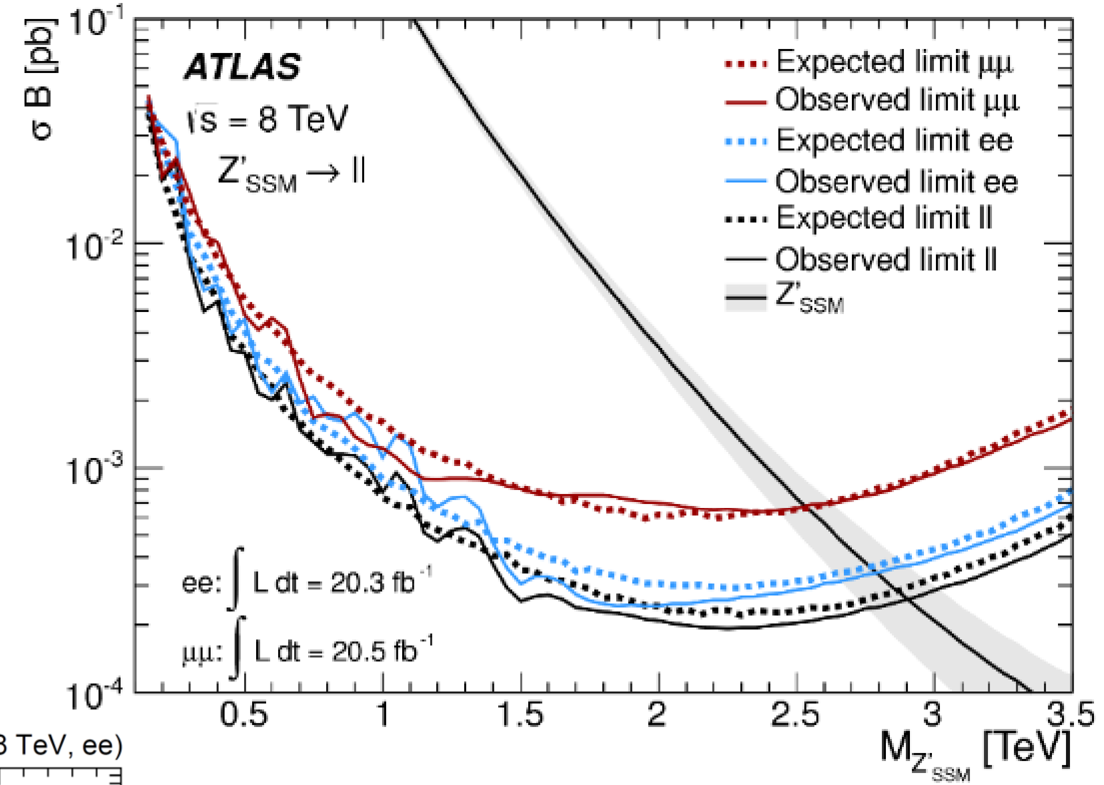
ATLAS
√s = 8 TeV
QBH → ll
Expected limit
Expected ± 1σ
Expected ± 2σ
Observed limit
RS QBH n=1
ADD QBH n=6
σ B [pb]
M_{th} [TeV]

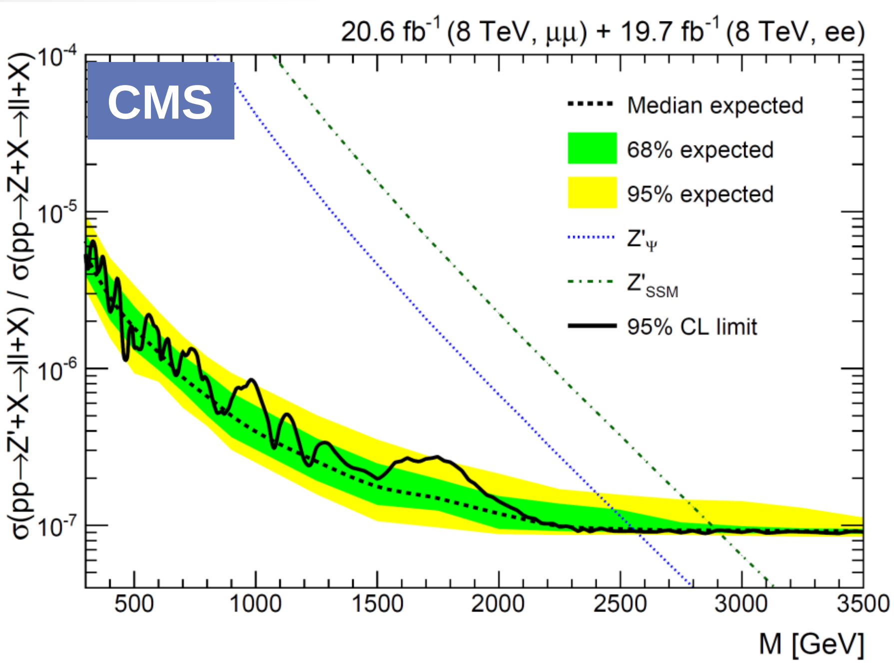


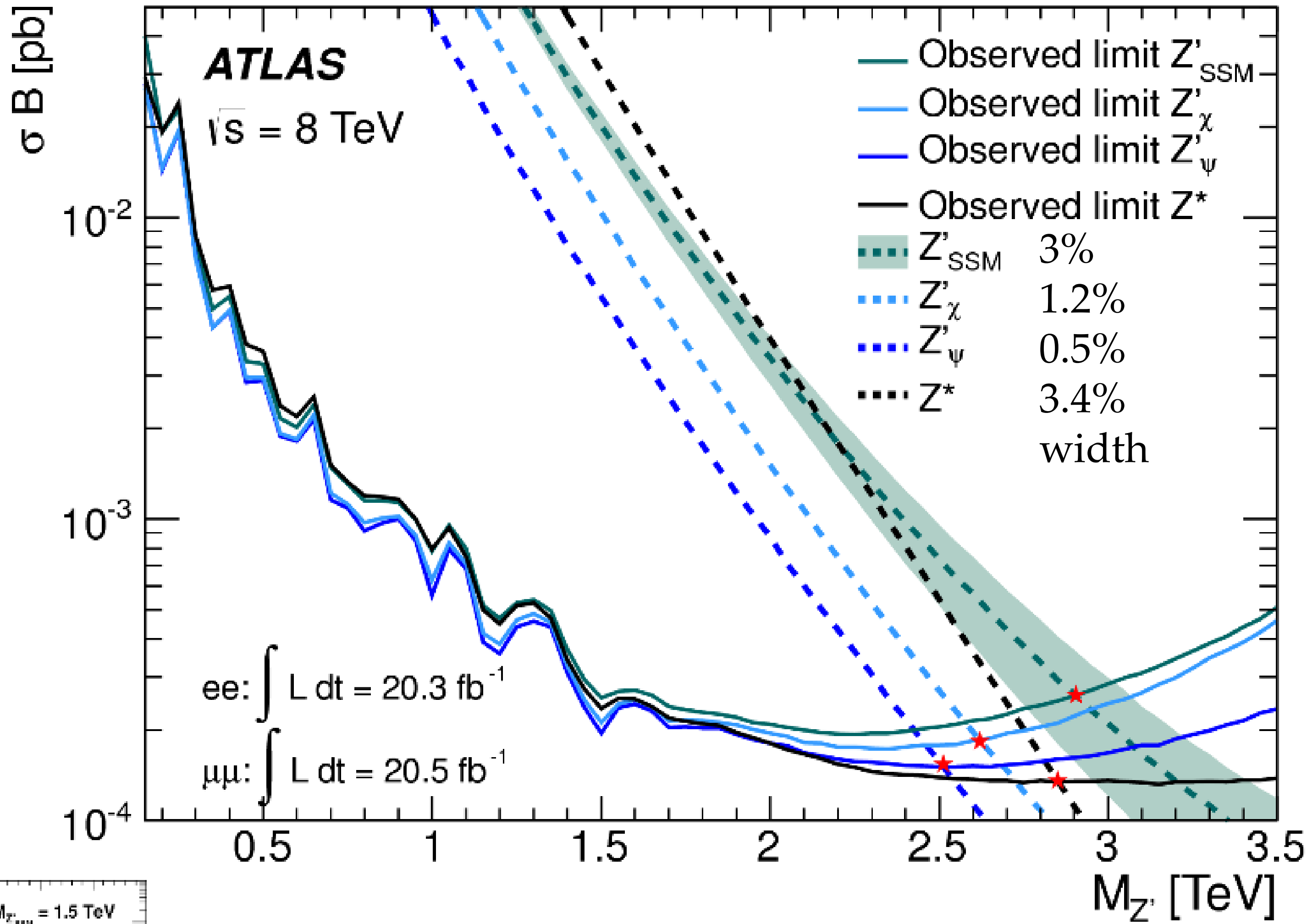
ATLAS
√s = 8 TeV
Dilepton 95% Exclusion
Dilepton 95% Expected limit
Theory Inconsistent
Running regime
EW precision test
M_Λ [TeV]

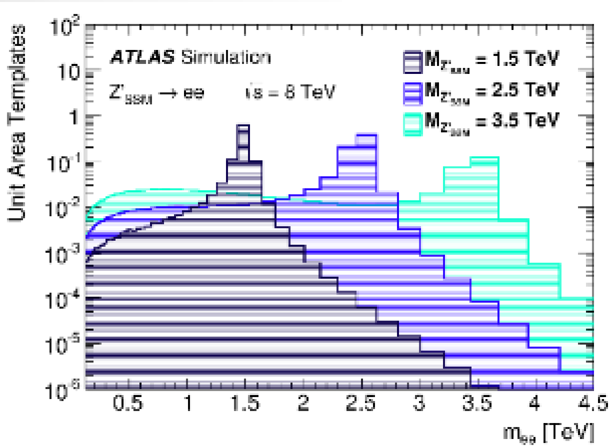


ATLAS
√s = 8 TeV
Observed limit
σ B [pb]
[TeV]


ATLAS
√s = 8 TeV
Z'SSM → ll
Expected limit μμ
Observed limit μμ
Expected limit ee
Observed limit ee
Expected limit ll
Observed limit ll
Z'SSM
ee: ∫ L dt = 20.3 fb-1
μμ: ∫ L dt = 20.5 fb-1
σ B [pb]
M Z'SSM [TeV]


20.6 fb-1 (8 TeV, μμ) + 19.7 fb-1 (8 TeV, ee)
CMS
Median expected
68% expected
95% expected
Z'ψ
Z'SSM
95% CL limit
σ(pp→Z'+X→ll+X) / σ(pp→Z+X→ll+X)
M [GeV]


ATLAS
√s = 8 TeV
Observed limit Z'SSM
Observed limit Z'χ
Observed limit Z'ψ
Observed limit Z*
Z'SSM 3%
Z'χ 1.2%
Z'ψ 0.5%
Z* 3.4%
width
ee: ∫ L dt = 20.3 fb-1
μμ: ∫ L dt = 20.5 fb-1
σ B [pb]
MZ' [TeV]


ATLAS Simulation
Z'SSM → ee
√s = 8 TeV
MZ'SSM = 1.5 TeV
MZ'SSM = 2.5 TeV
MZ'SSM = 3.5 TeV
Unit Area Templates
mee [TeV]

General Extension of SM: Effective Theory

Extra vectors: quantum numbers

Hadrophobic · Fermiophobic

Color	1					8		
Isospin	1		2	3		1		3
Hypercharge	0	1	$-\frac{3}{2}$	0	1	0	1	0
Symbol	$\mathcal{B}$	$\mathcal{B}^1$	$\mathcal{L}$	$\mathcal{W}$	$\mathcal{W}^1$	$\mathcal{G}$	$\mathcal{G}^1$	$\mathcal{H}$
Charges	0	± 1	$\pm 1, 2$	$0, \pm 1$	$\pm 1, 2$	0	± 1	$0, \pm 1$

Leptoquarks · Leptophobic

Color	3					$\bar{6}$	
Isospin	1		2		3	2	
Hypercharge	$\frac{2}{3}$	$\frac{5}{3}$	$\frac{1}{6}$	$-\frac{5}{6}$	$\frac{2}{3}$	$\frac{1}{6}$	$-\frac{5}{6}$
Symbol	$\mathcal{U}^2$	$\mathcal{U}^5$	$\mathcal{Q}^1$	$\mathcal{Q}^5$	$\mathcal{X}$	$\mathcal{Y}^1$	$\mathcal{Y}^5$
Charges	$\pm\frac{2}{3}$	$\pm\frac{5}{3}$	$\pm\frac{1}{3}, \frac{2}{3}$	$\pm\frac{1}{3}, \frac{4}{3}$	$\pm\frac{1}{3}, \frac{2}{3}, \frac{5}{3}$	$\pm\frac{1}{3}, \frac{2}{3}$	$\pm\frac{1}{3}, \frac{4}{3}$

5

Vector Bosons decaying to Leptons

Singlet $\mathcal{B}$ → Z′

(Universal, Neglecting mixing with Z)

$$M,\ g_l,\ g_e,\ g_q,\ g_u,\ g_d$$

$$c_{u,d} = \left({g_q}^2 + {g_{u,d}}^2\right) \frac{{g_l}^2 + {g_e}^2}{3\left(2{g_l}^2 + {g_e}^2 + 6{g_q}^2 + 3{g_u}^2 + 3{g_d}^2\right)}$$

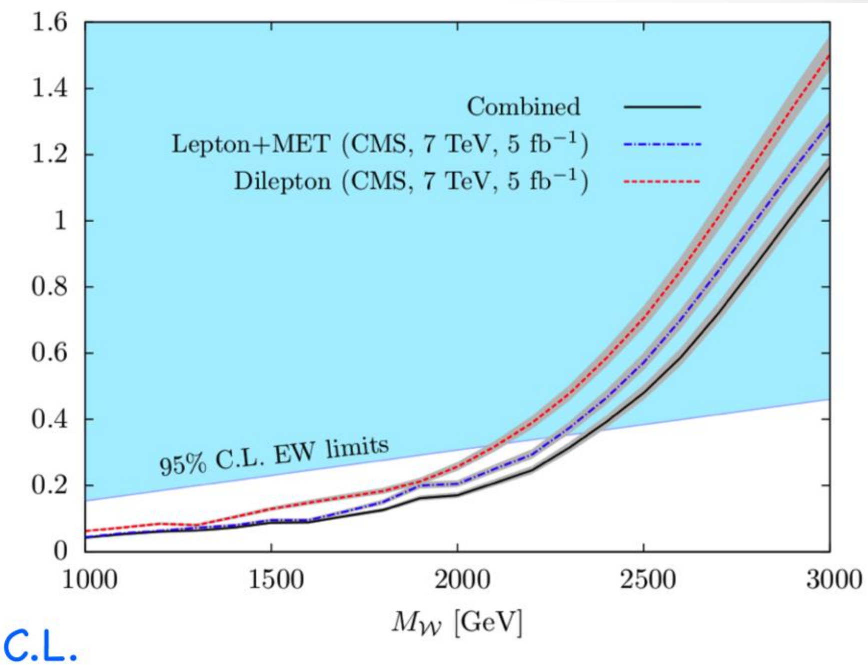
Triplet $\mathcal{W}$ → Z′, W′

(Universal, Neglecting mixing with Z,W)

$$M,\ g_l,\ g_q$$

$$c_u = c_d = \frac{\tilde{g}^2}{96}$$

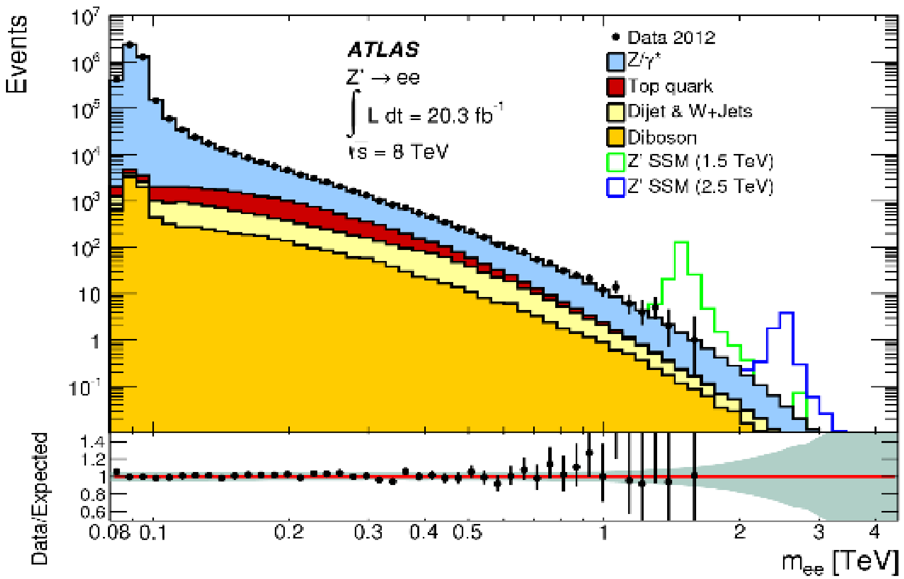
$$\tilde{g} = \frac{2 g_q g_l}{\sqrt{3{g_q}^2 + {g_l}^2}}$$

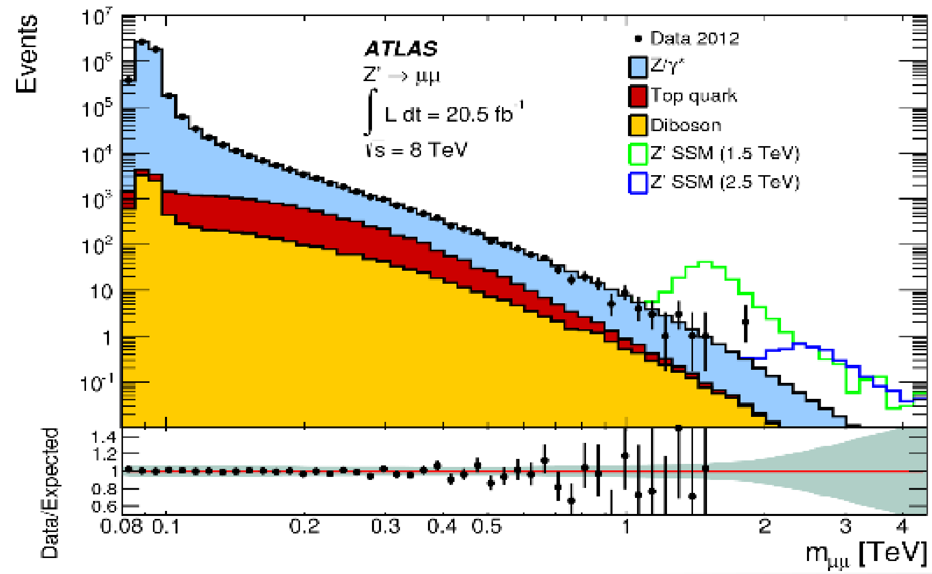


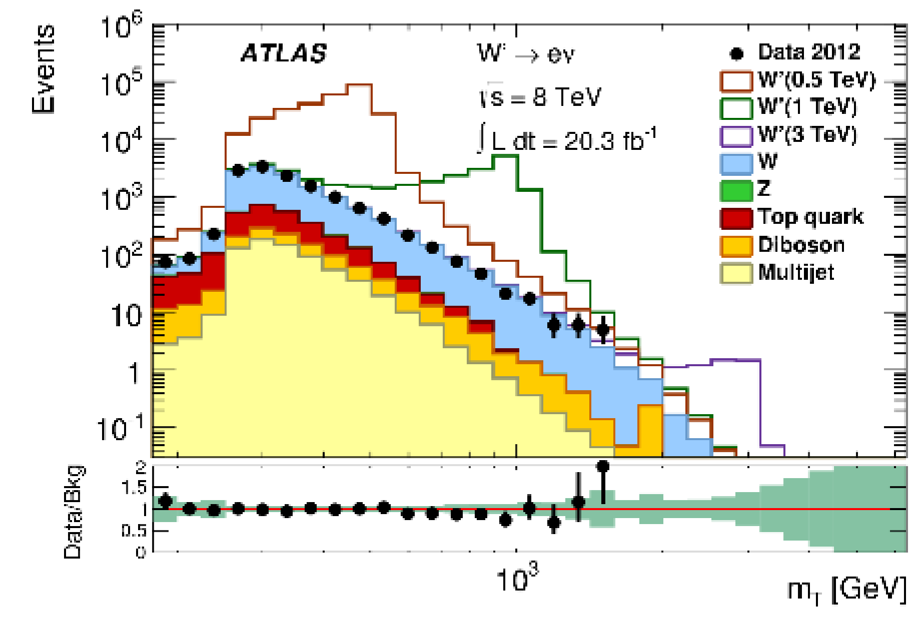
95% C.L.

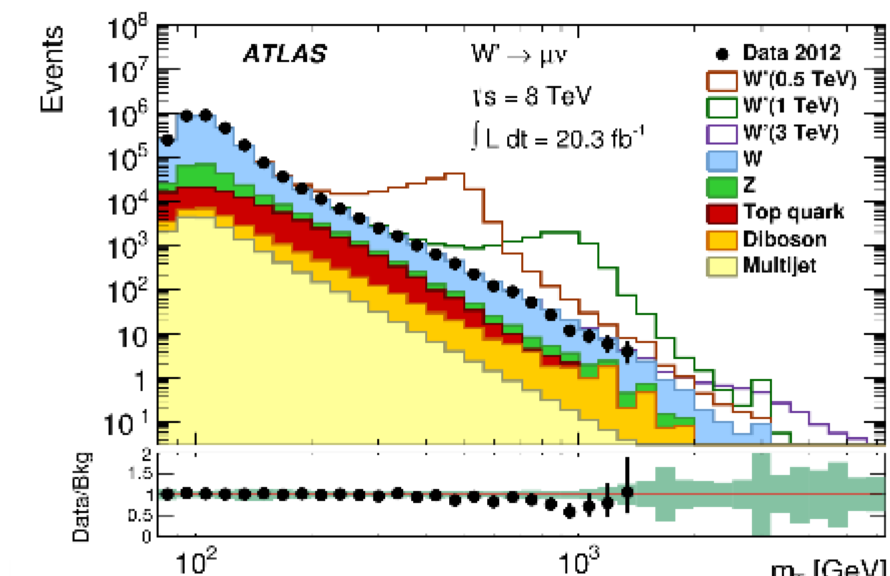
J.DeBlas et. al.JHEP01(2013)166

W'/Z' Run 1 combination?









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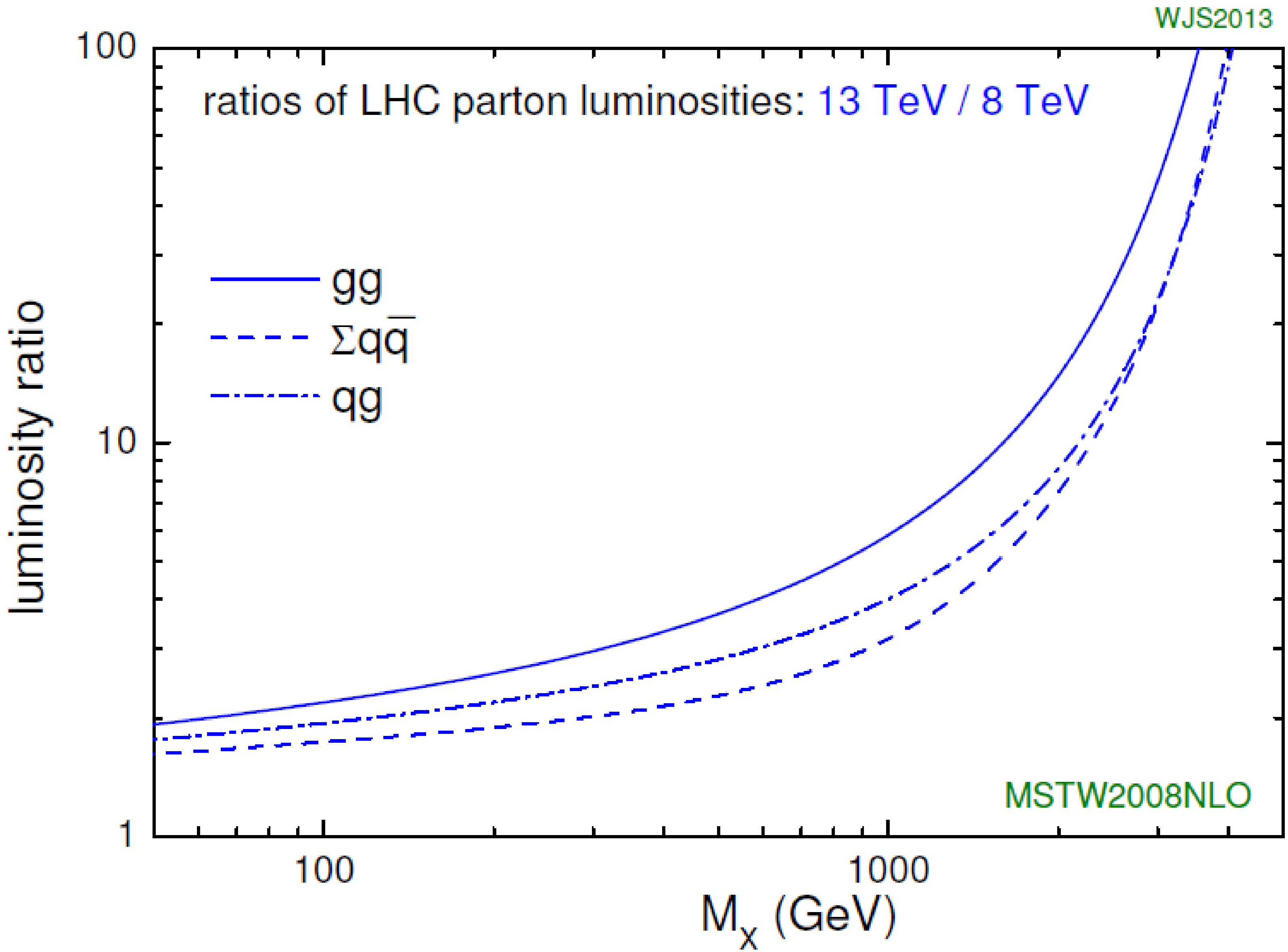
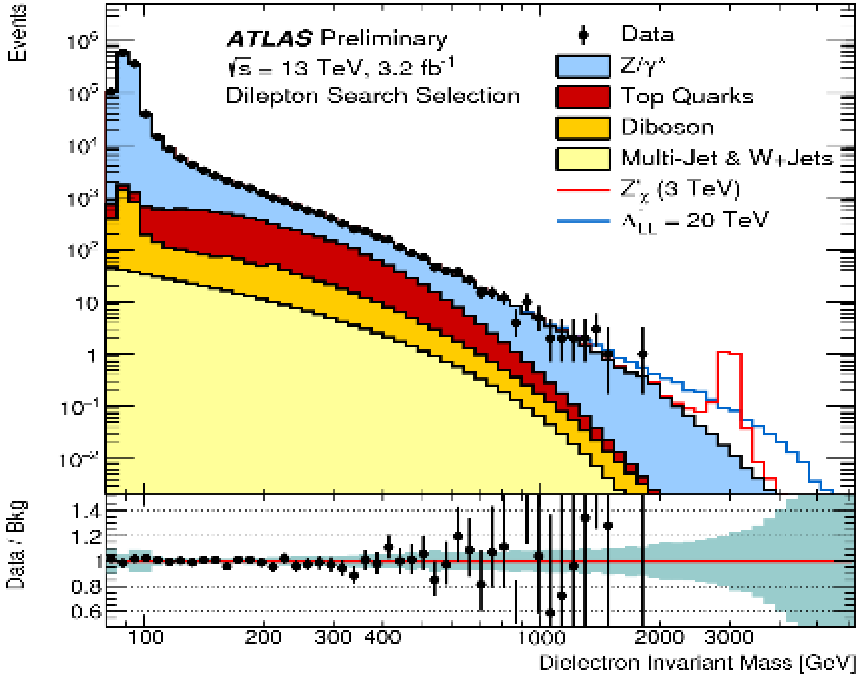
Heavy Vector Triplet combinations

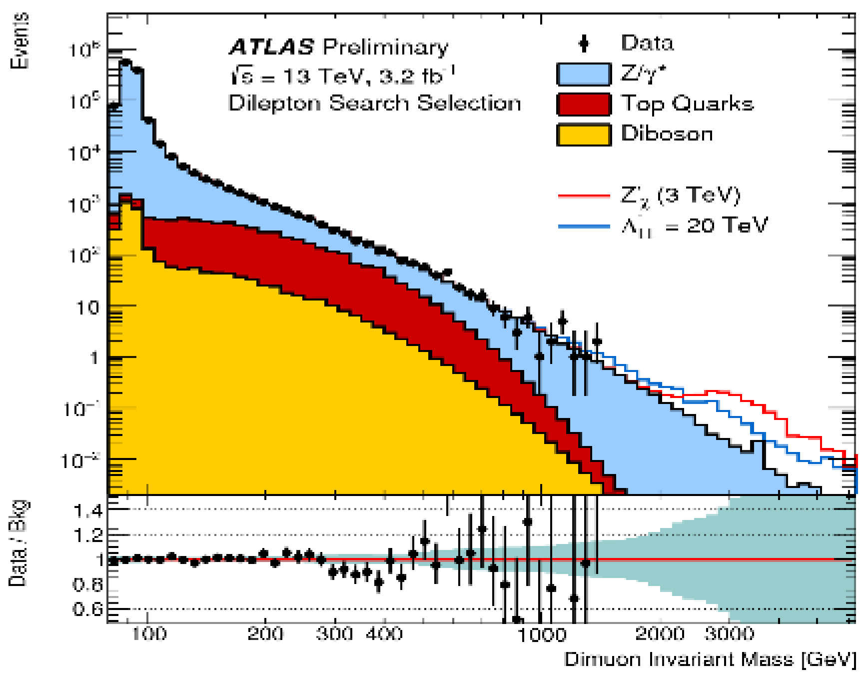
Channel	$V^0 \in (\mathbf{1},\mathbf{3})_{\mathbf{1}}$	$V^+ \in (\mathbf{1},\mathbf{3})_{\mathbf{1}}$	$V^0 \in (\mathbf{1},\mathbf{1})_{\mathbf{0}}$ $\in \mathbf{3}$ of $SU(2)_R$	$V^+ \in (\mathbf{1},\mathbf{1})_{\mathbf{1}}$ $\in \mathbf{3}$ of $SU(2)_R$
ll	□	×	□□	×
$l\nu$	×	□	×	×
$l\nu_R$	×	×	×	□□
jj	□	□	□□	□□
tb	×	□	×	□□
tt	□	×	□□	×
WW	□	×	□□	×
ZZ	×	×	×	×
Zh	□	×	□□	×
WZ	×	□	×	□□
Wh	×	□	×	□□
$W\gamma$	×	□	×	□□
hh	×	×	×	×

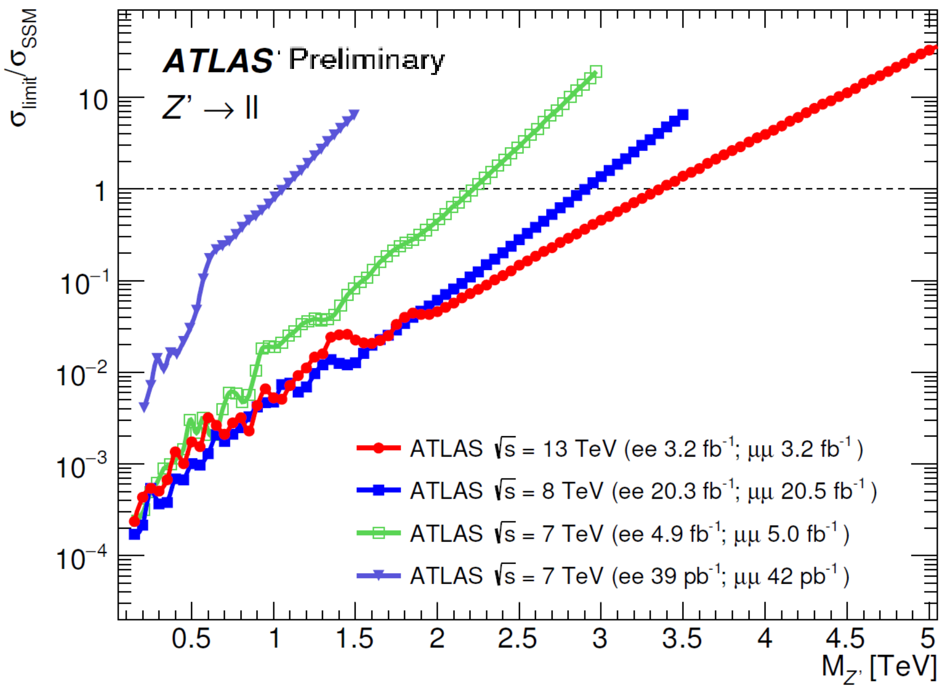
arXiv:1402.4431v2

A few words about LHC Run 2

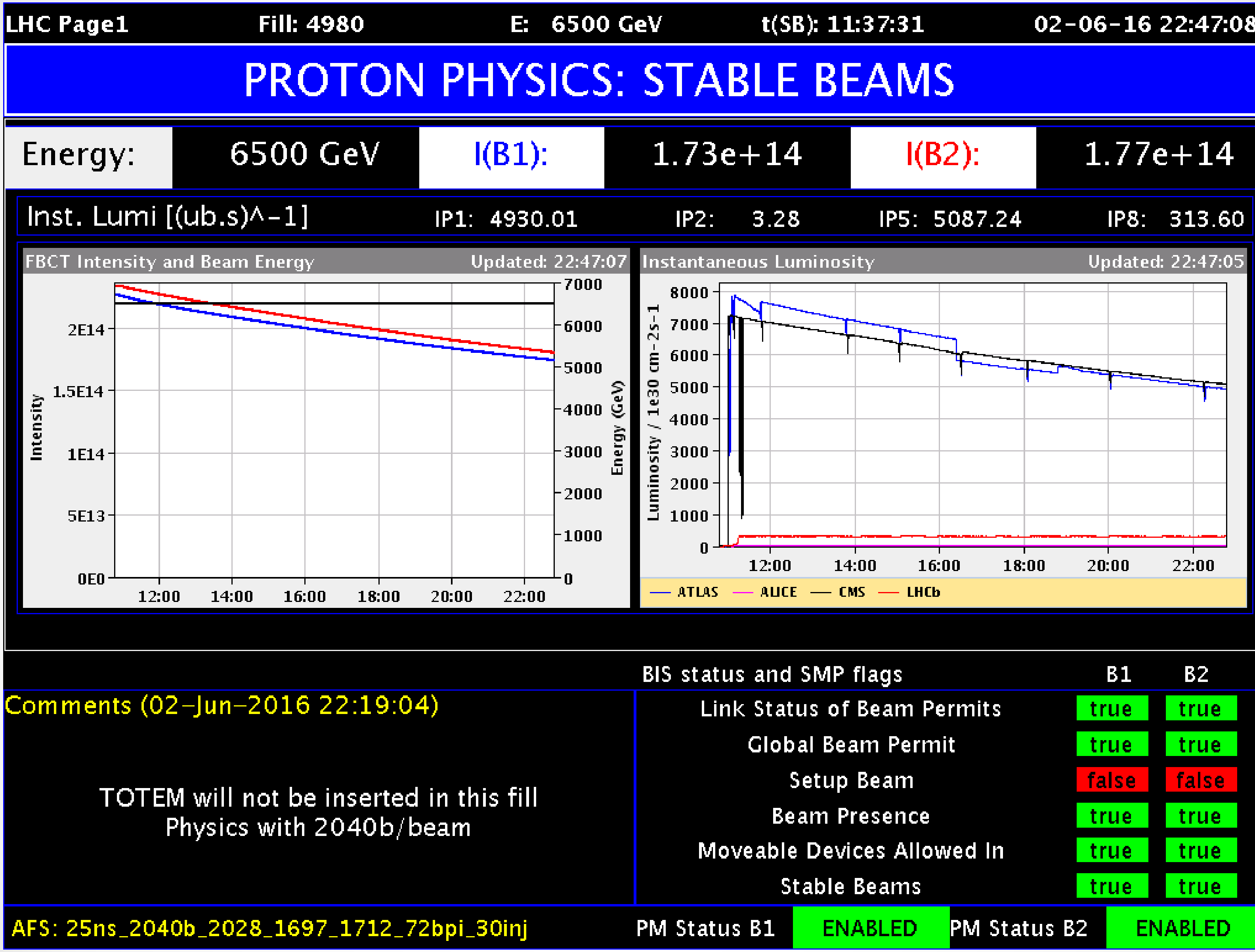



ATLAS Preliminary
√s = 13 TeV, 3.2 fb⁻¹
Dilepton Search Selection
Data
Z/γ*
Top Quarks
Diboson
Multi-Jet & W+Jets
Z'χ (3 TeV)
ΛLL = 20 TeV
Events
Data / Bkg
Dielectron Invariant Mass [GeV]


ATLAS Preliminary
√s = 13 TeV, 3.2 fb⁻¹
Dilepton Search Selection
Data
Z/γ*
Top Quarks
Diboson
Z'χ (3 TeV)
ΛLL = 20 TeV
Events
Data / Bkg
Dimuon Invariant Mass [GeV]

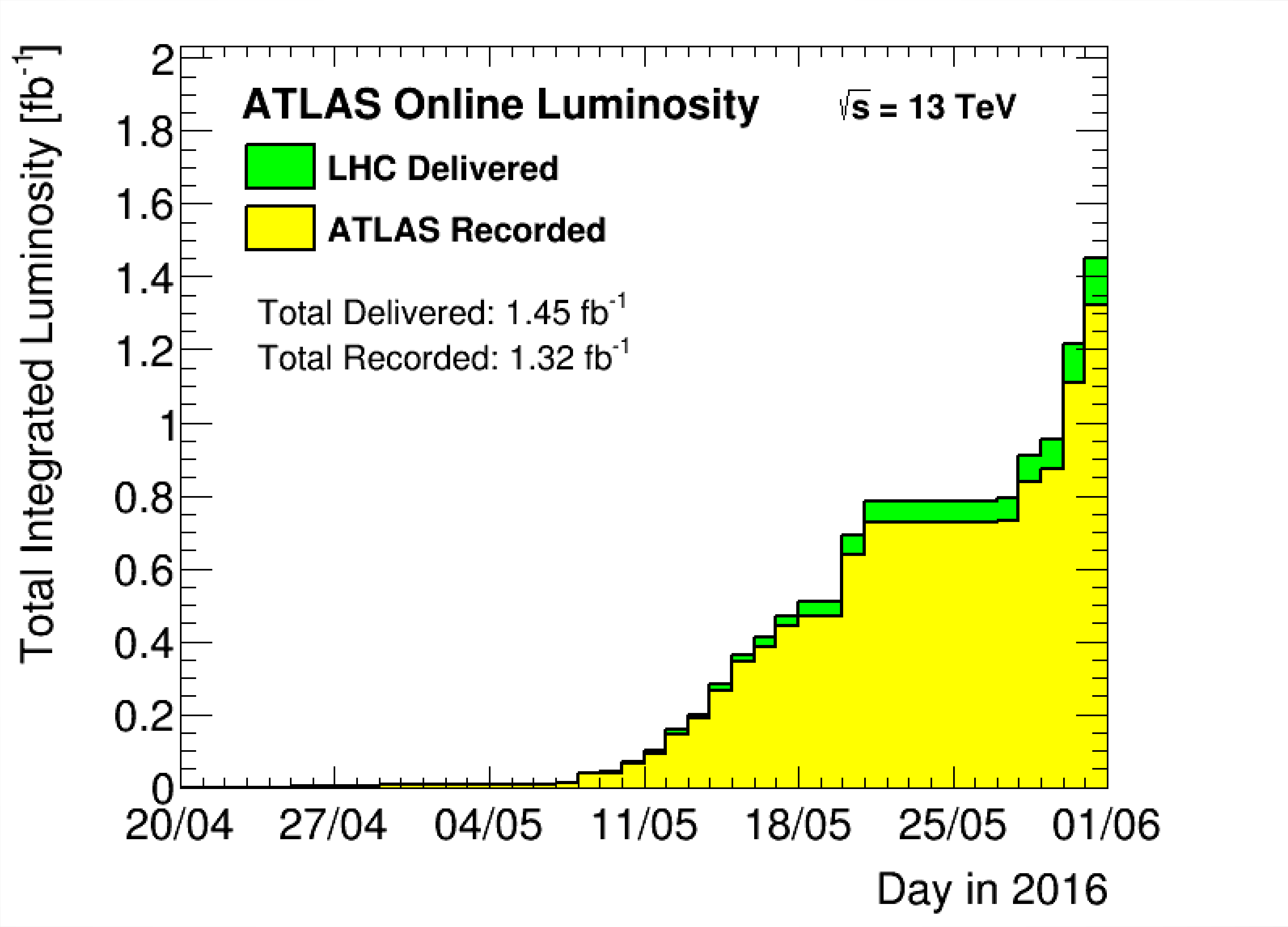

ATLAS Preliminary
Z' → ll
σlimit/σSSM
ATLAS √s = 13 TeV (ee 3.2 fb⁻¹; μμ 3.2 fb⁻¹)
ATLAS √s = 8 TeV (ee 20.3 fb⁻¹; μμ 20.5 fb⁻¹)
ATLAS √s = 7 TeV (ee 4.9 fb⁻¹; μμ 5.0 fb⁻¹)
ATLAS √s = 7 TeV (ee 39 pb⁻¹; μμ 42 pb⁻¹)
MZ' [TeV]

“Now”



The LHC has achieved a peak luminosity of 7.9 $10^{33}cm^{-2}s^{-1}$

“Now”


ATLAS Online Luminosity
√s = 13 TeV
LHC Delivered
ATLAS Recorded
Total Delivered: 1.45 fb⁻¹
Total Recorded: 1.32 fb⁻¹
Total Integrated Luminosity [fb⁻¹]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
20/04
27/04
04/05
11/05
18/05
25/05
01/06
Day in 2016