

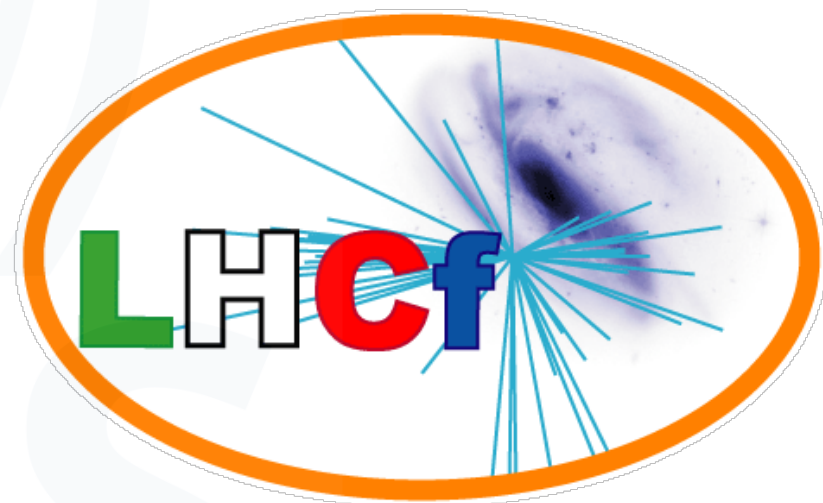
2016 ATLAS and LHCf overview

CERN Council Open Session

Federico Meloni



ATLAS
EXPERIMENT

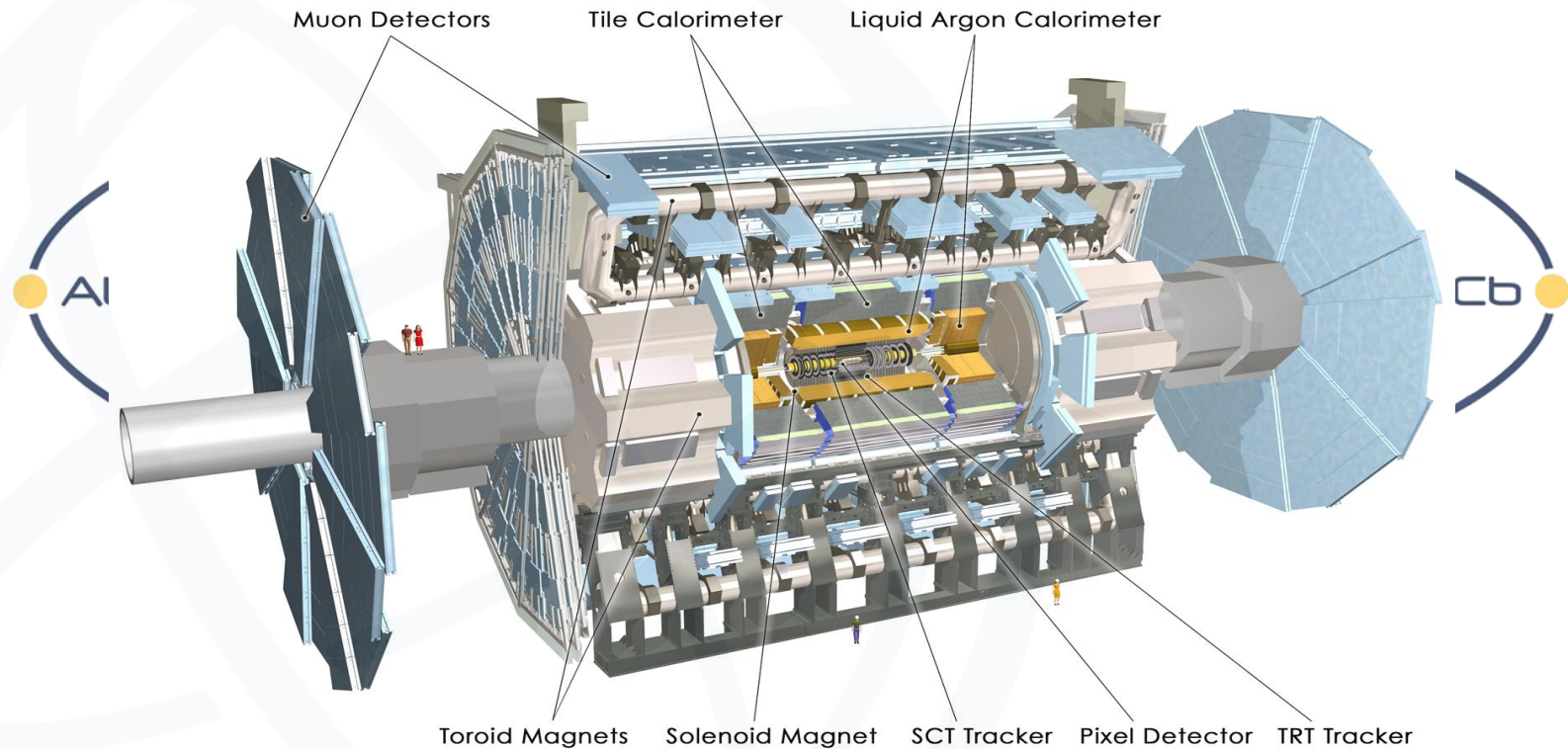


To the LHC and injector teams

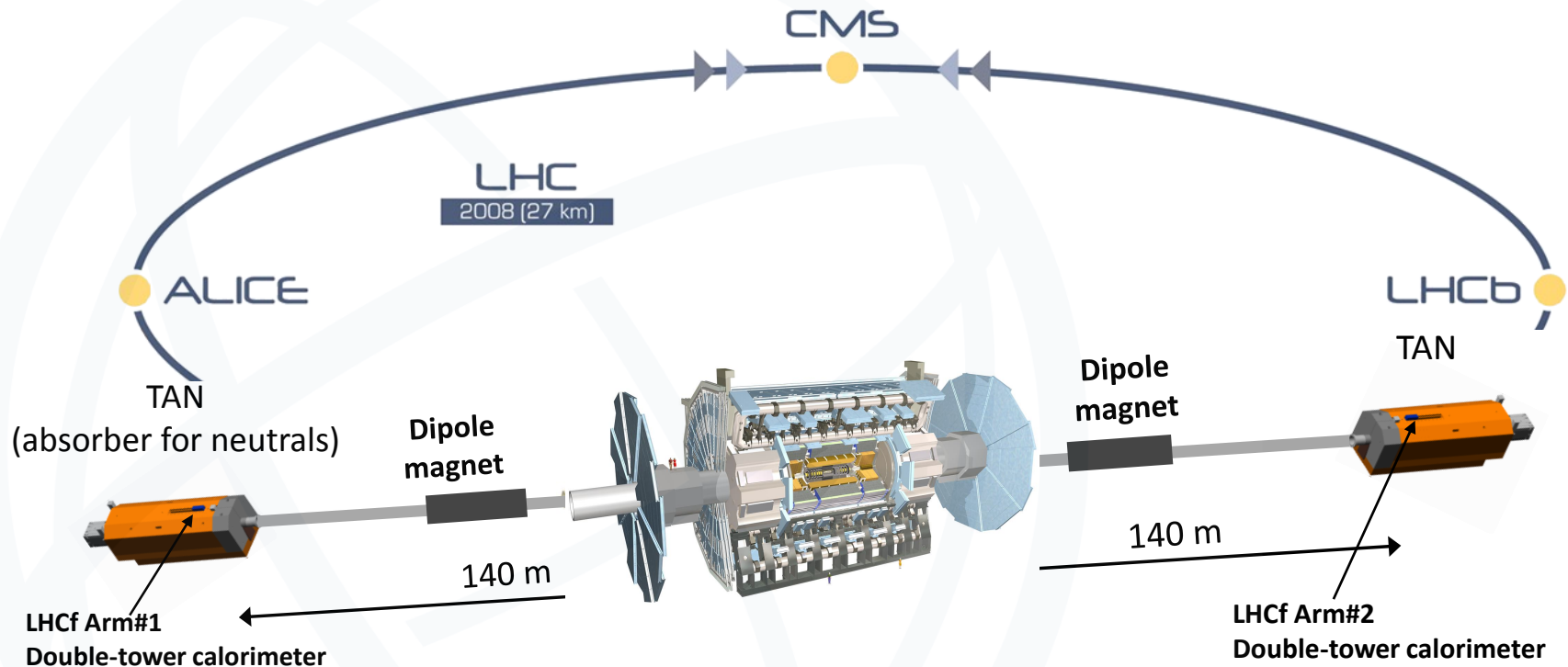


**Thanks a lot for the fantastic
dataset you delivered!**

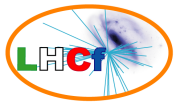
Physics around LHC Point 1



Physics around LHC Point 1

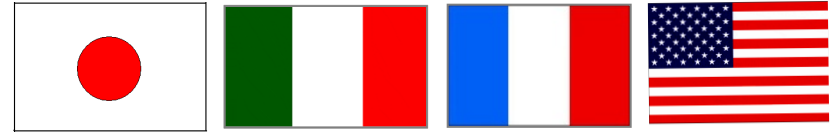


Two very different, but complementary experiments

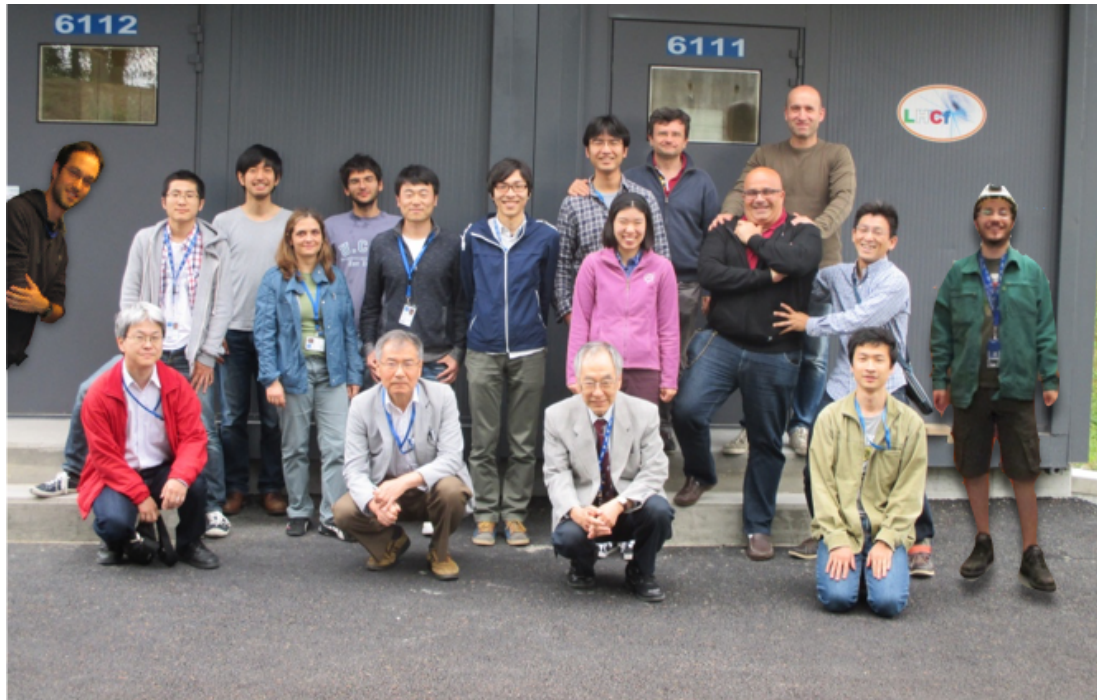


The LHCf Collaboration

O. Adriani, E.Berti, L.Bonechi, M.Bongi,
R.D'Alessandro, M.Haguenaer, Y.Itow, T.Iwata,
K.Kasahara, Y.Makino, K.Masuda, Y.Matsubara,
E.Matsubayashi, H.Menjo, Y.Muraki, P.Papini,
S.Ricciarini, T.Sako, K.Sato, N.Sakurai, Y.Shimitsu,
M.Shinoda, T.Suzuki, T.Tamura, A.Tiberio, S.Torii,
A.Tricomi, W.C.Turner, M.Ueno, K.Yoshida, Q.D.Zhou



4 countries
14 institutions
~10 students

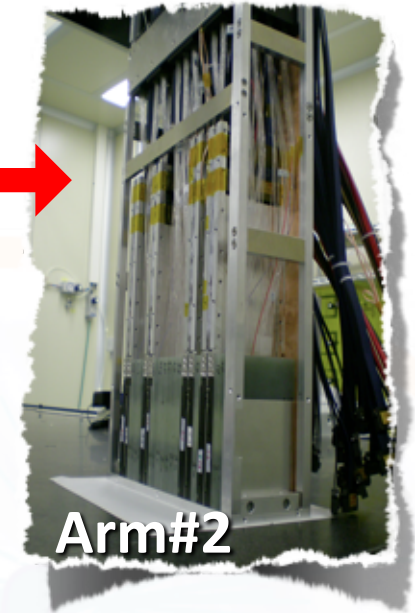
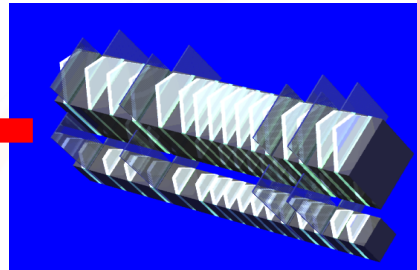
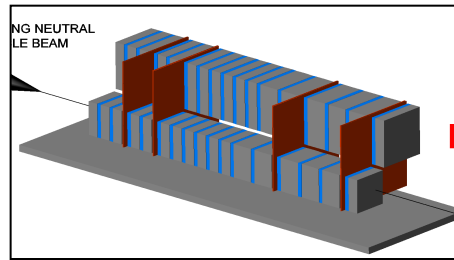


The LHCf detector

Position resolution: $< 200 \mu\text{m}$ (Arm1) and $40 \mu\text{m}$ (Arm2)
Energy resolution: $< 5\%$ for photons; 30% for neutrons
Pseudo-rapidity range: $\eta > 8.7$ @ zero crossing angle
 $\eta > 8.4$ @ $140 \mu\text{rad}$



Arm#1



Arm#2

Arm1 Detector

2cm x 2cm + 4cm x 4cm
 GSO tiles (e.m. calorimeter)
 4 X-Y tracking layers
(GSO bars)

$$44 X_0$$

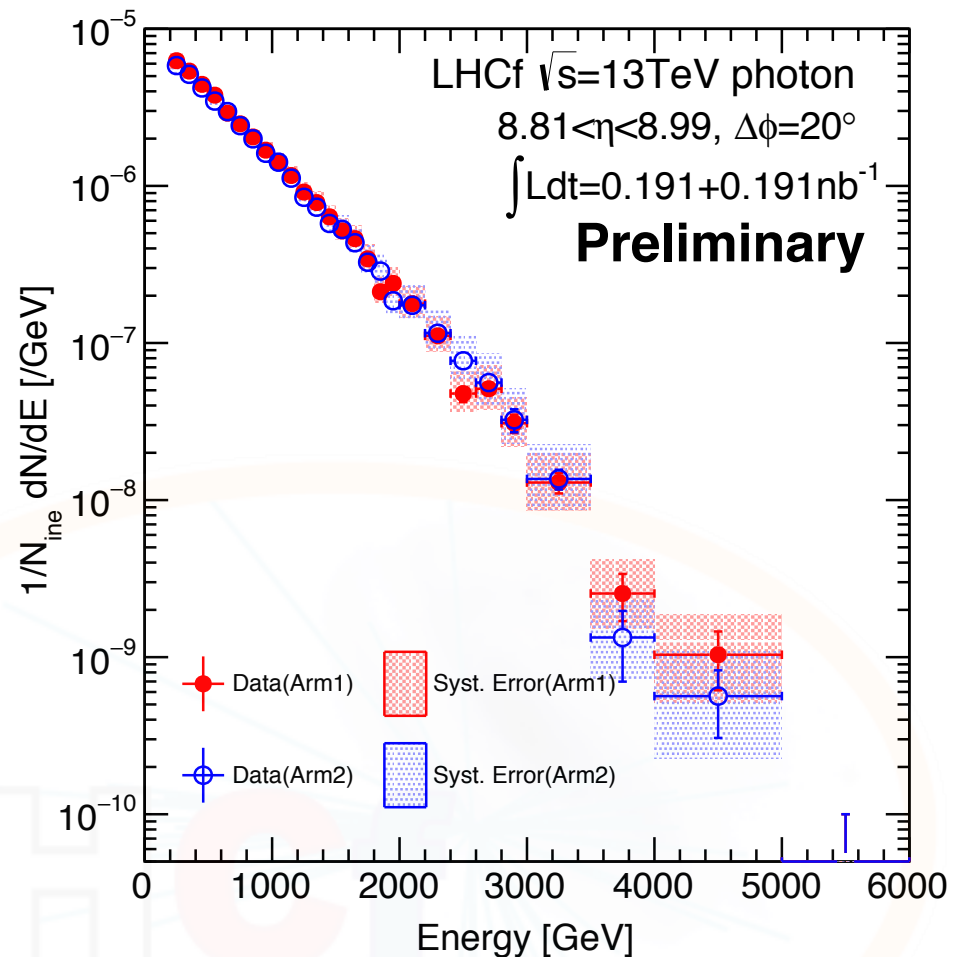
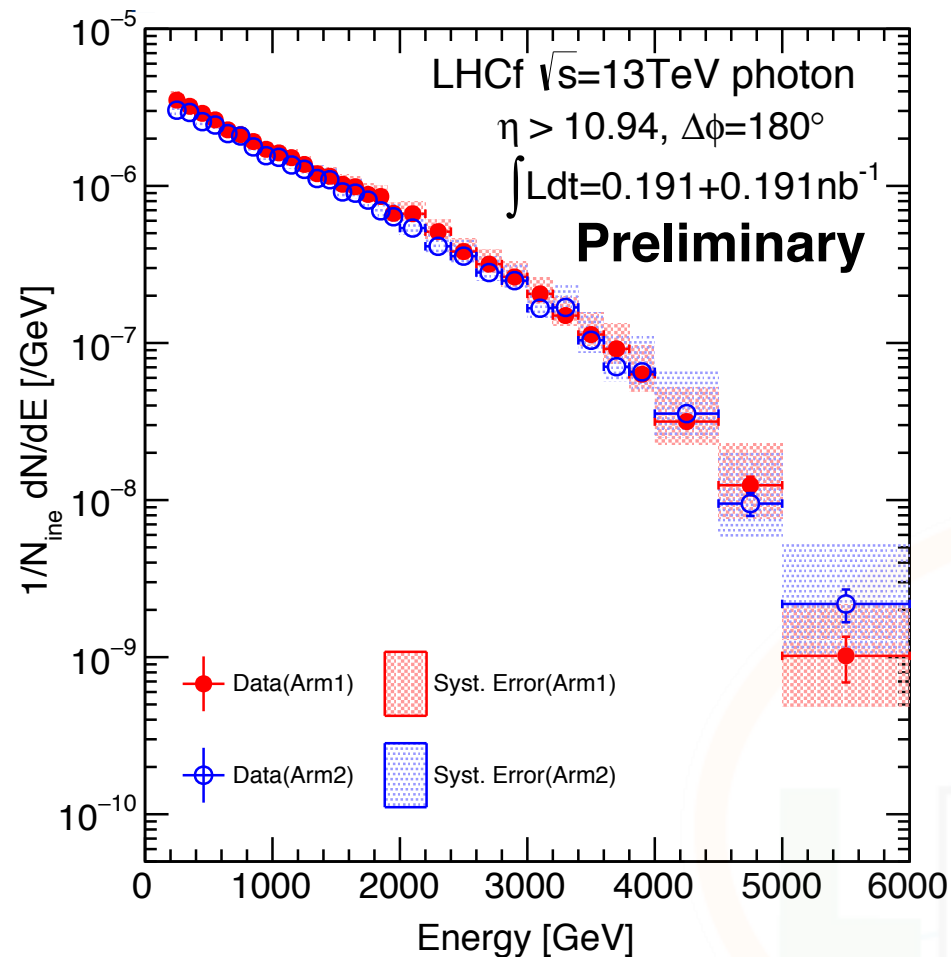
$$\sim 1.5 \lambda_{\text{int}}$$

Arm2 Detector

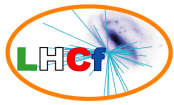
2.5cm x 2.5cm + 3.2cm x 3.2cm
 GSO tiles (e.m. calorimeter)
 4 X-Y tracking layers
(silicon microstrip)



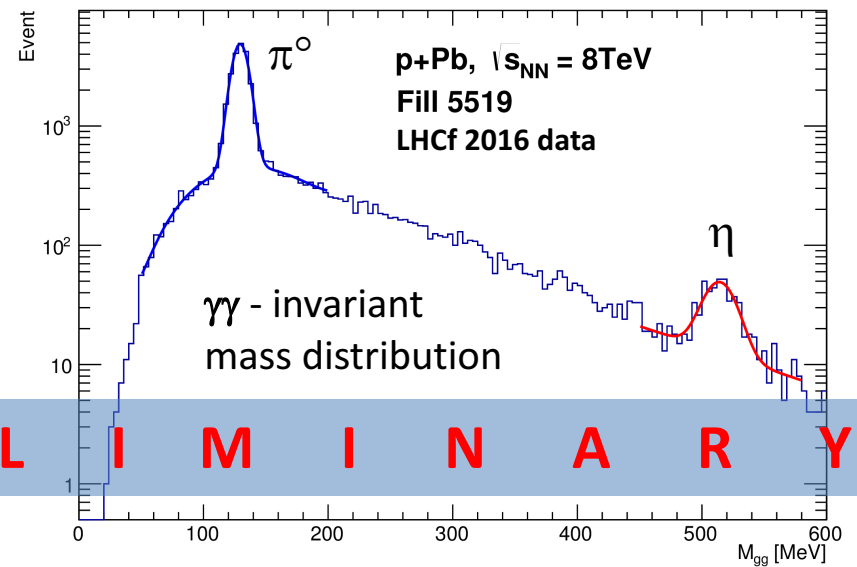
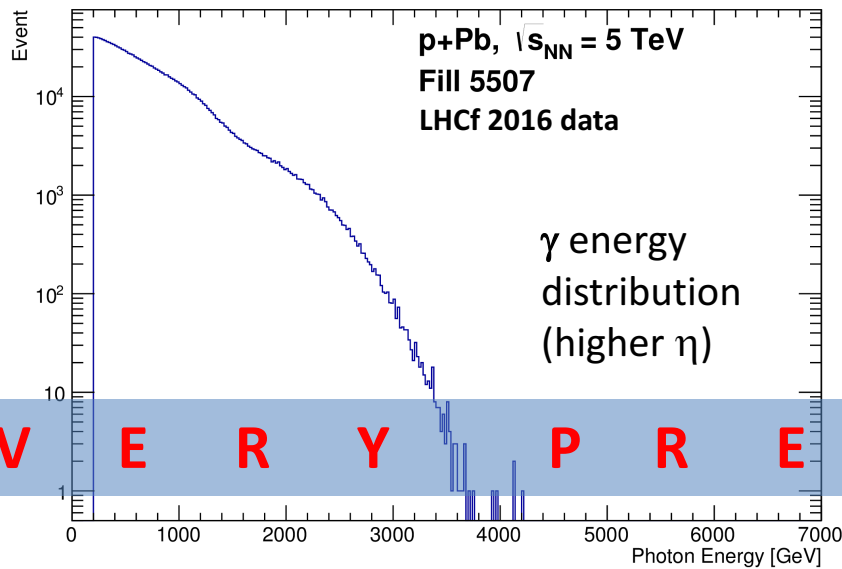
The LHCf performance



- **Arm1 and Arm2 spectra are consistent within the estimated systematics (mostly energy scale and multi-hit correction)**



The LHCf 2016 run



V E R Y P R E L I M I N A R Y

LHCf has taken data in combination with ATLAS

- Exploit the ATLAS tracker to separate the contributions from diffractive and non-diffractive collisions
- Various datasets (for $\sqrt{s_{pp}} = 13 \text{ TeV}$, $\sqrt{s_{pPb}} = 5 \text{ TeV}$ and $\sqrt{s_{pPb}} = 8 \text{ TeV}$) available for combined analysis

The LHCf Collaboration would like to thank the LHC Programme coordinators, the tunnel activities coordinator and all the people involved on the machine side for the final success of the 2016 run!!!

The ATLAS Collaboration

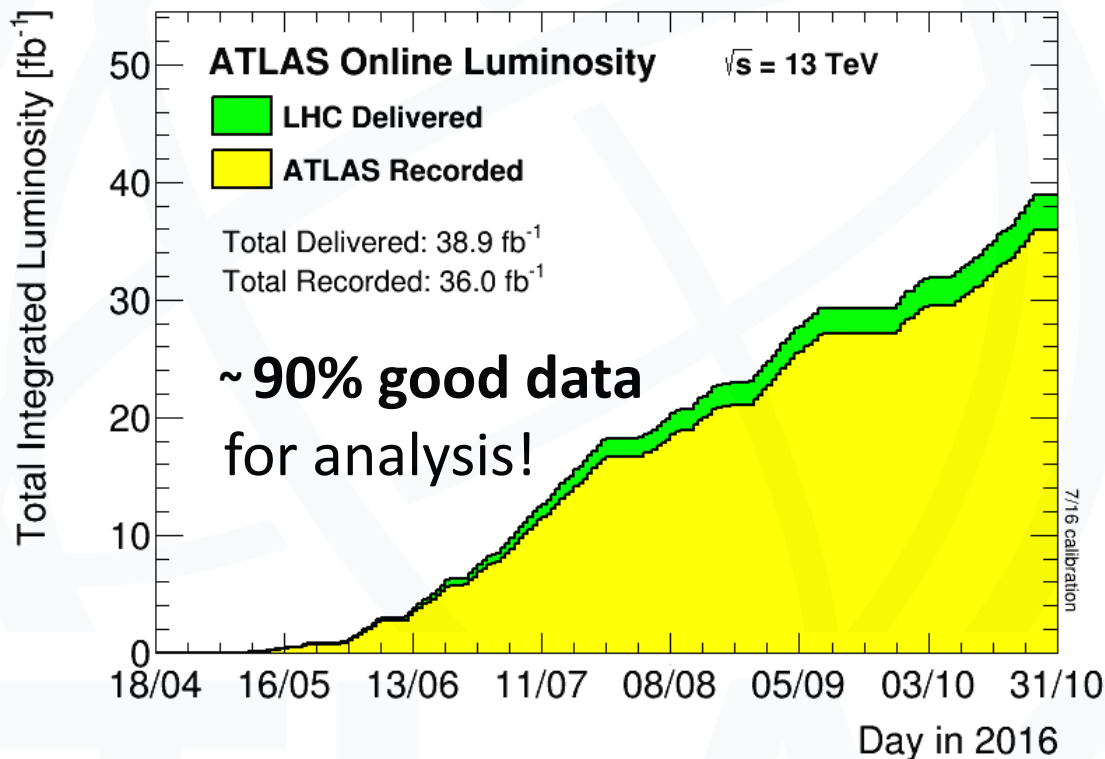
38 countries
182 institutions
>1000 students



The ATLAS data taking

ATLAS has performed very well in 2016!

- New systems commissioned and operational
- **>96% working channels** (pixels, cells...)

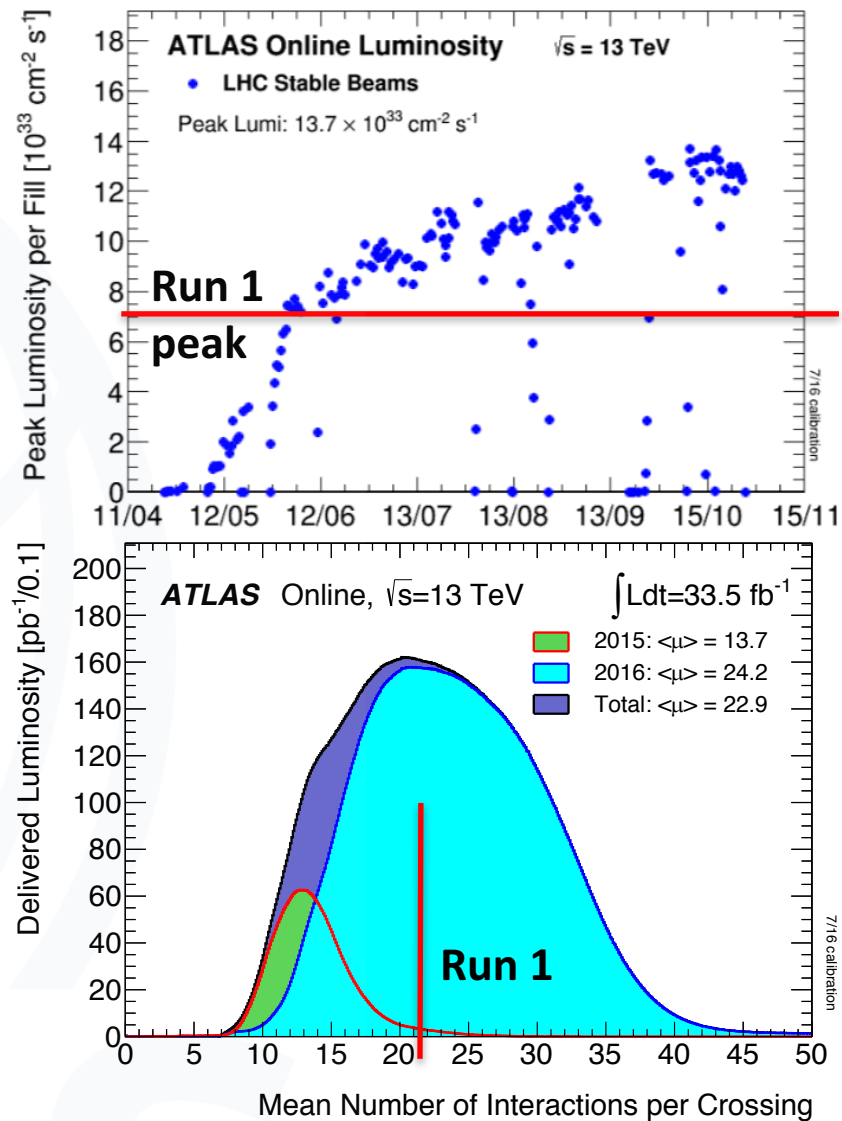


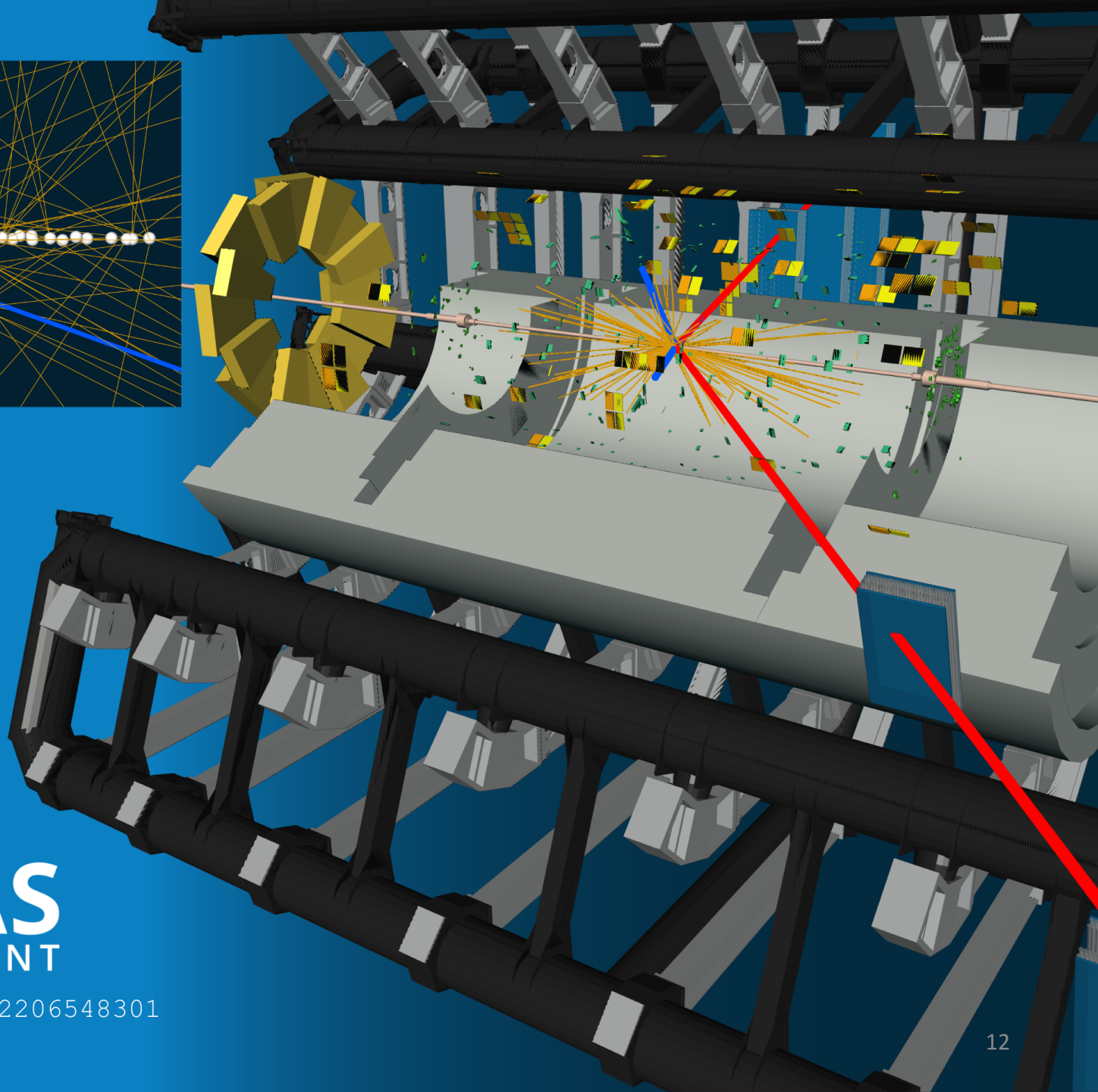
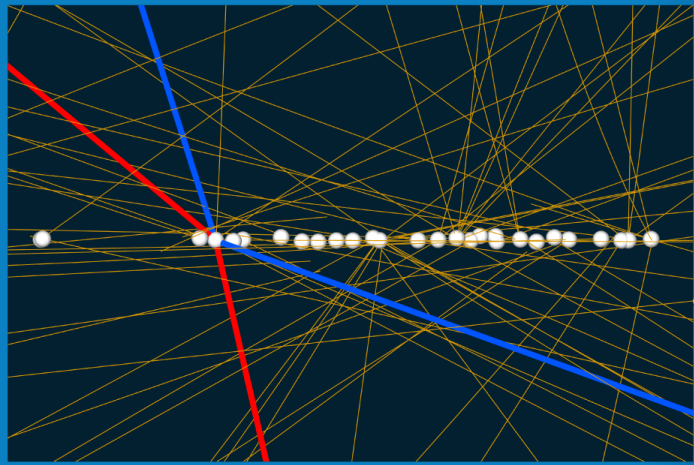
We have recorded more *pp* data in 2016 than in all the previous years combined!

The pile-up challenge

We acquired data following the LHC beyond the design specifications

- **Twice as high luminosity as in Run-1!**
- Improved understanding of the detector and mitigated challenges as luminosity increased

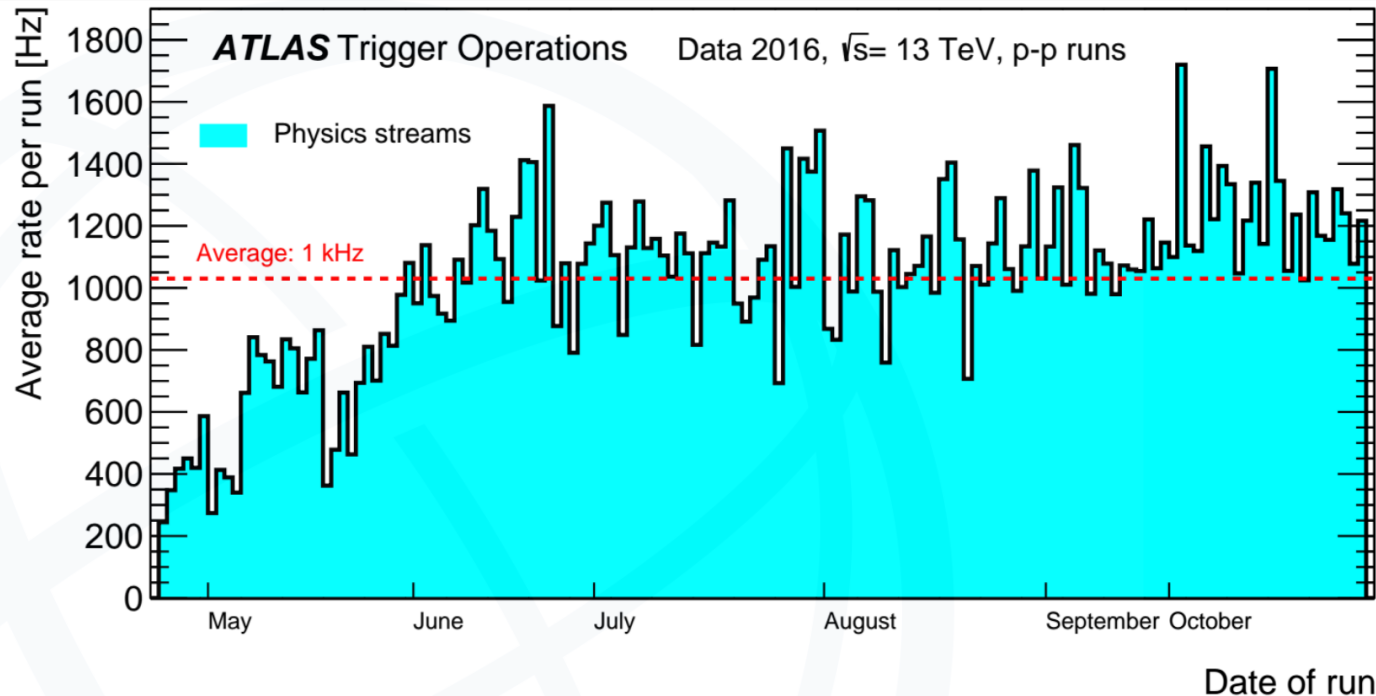




 **ATLAS**
EXPERIMENT

run: 304431 event: 2206548301
2016-07-25 07:01:07

Online event selection



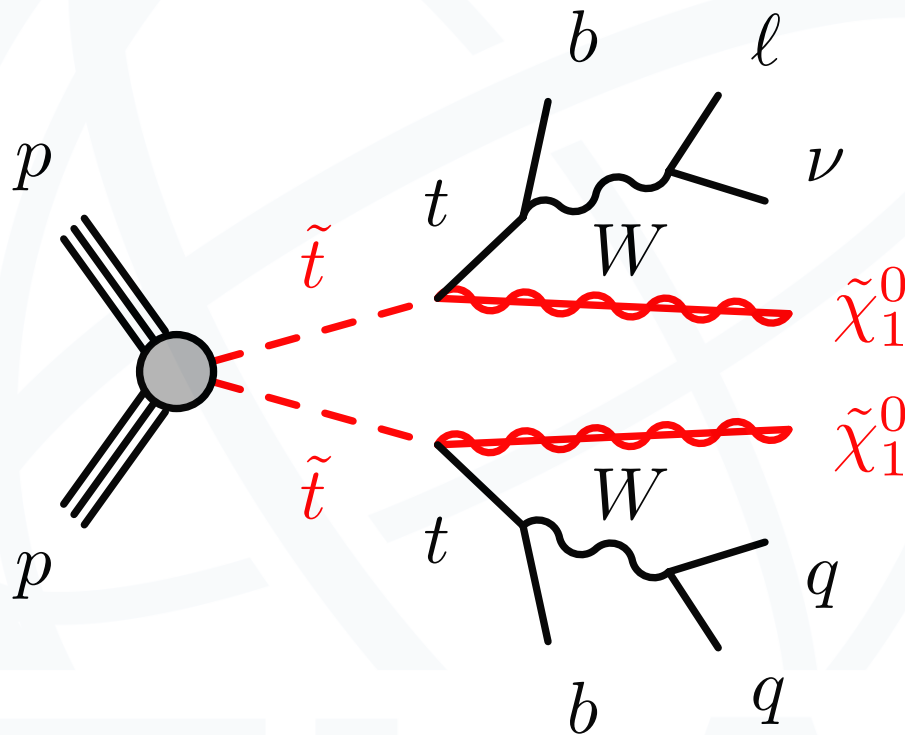
Online selections (triggers) nearly stable across the whole year despite the increasing luminosity

- **Coherent dataset across 2015 and 2016**

What to look for

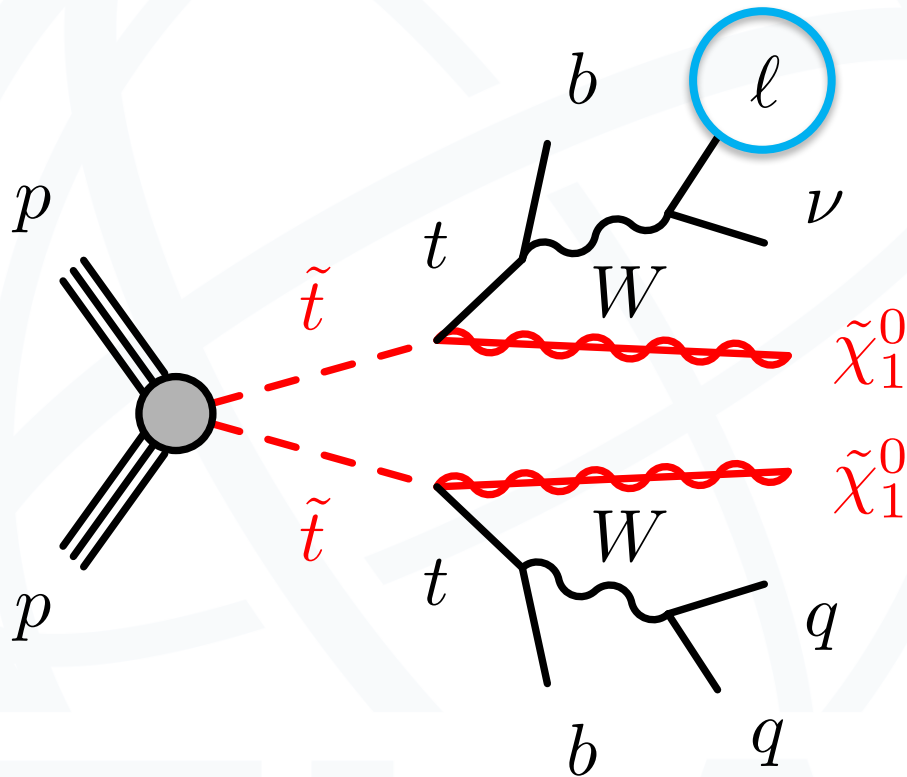
One of the main goals of the 13 TeV run is to look for new physics

- This often implies understanding complex topologies



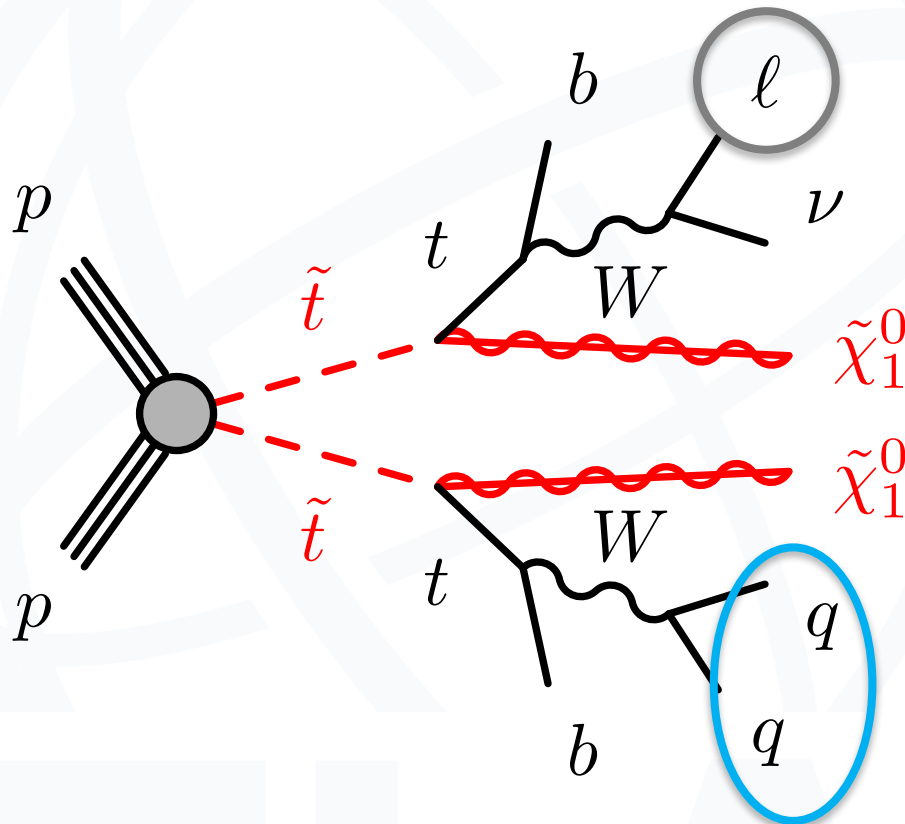
What to look for

Charged leptons!



What to look for

Charged leptons!

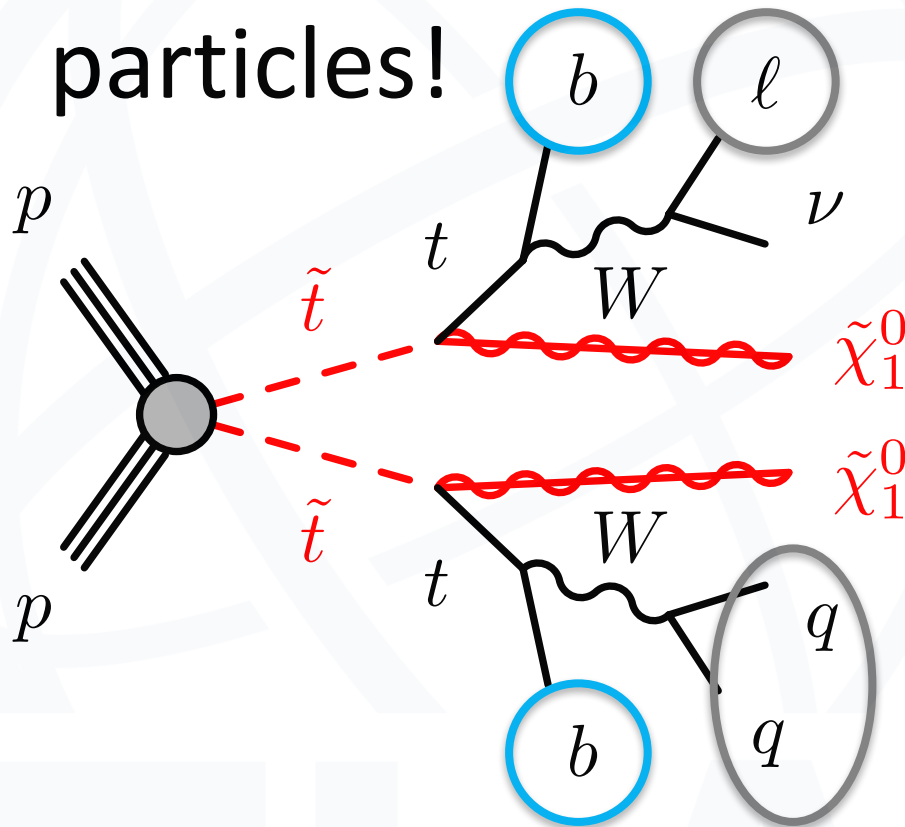


Jets!

What to look for

'Long lived' particles!

Charged leptons!

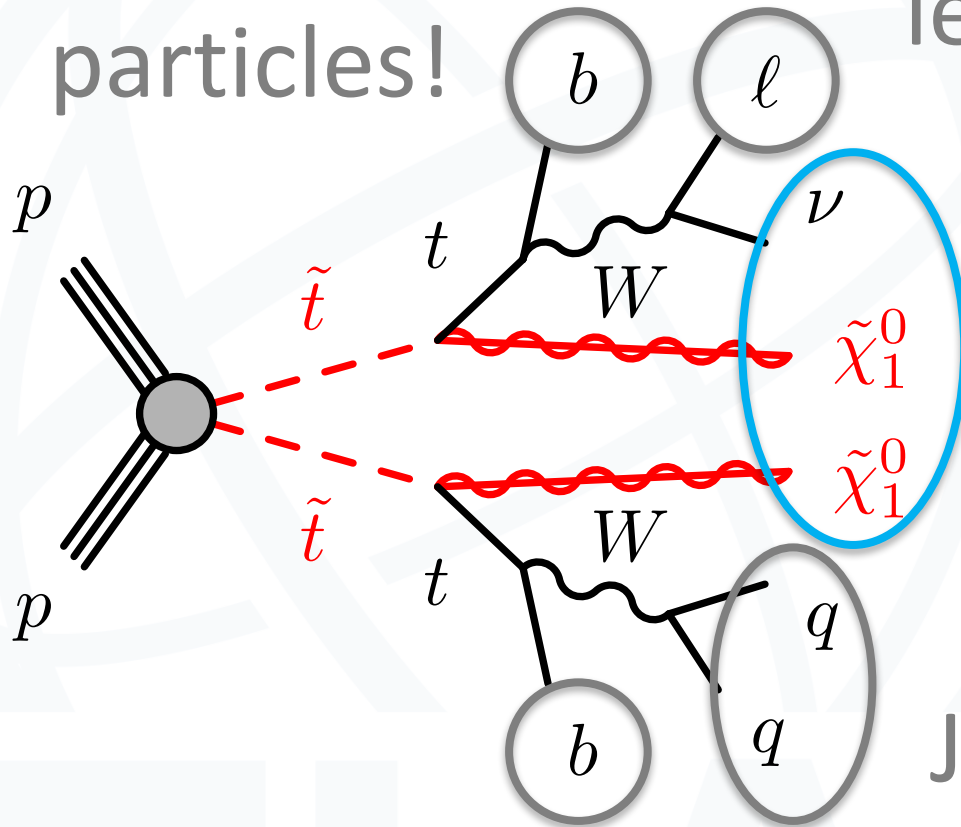


Jets!

What to look for

'Long lived' particles!

Charged leptons!

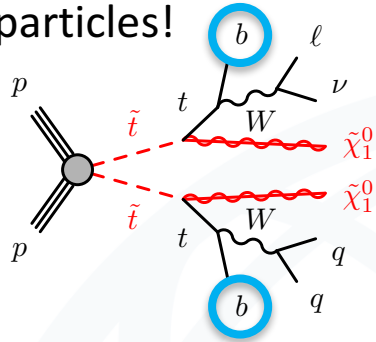


Invisible particles!

Jets!

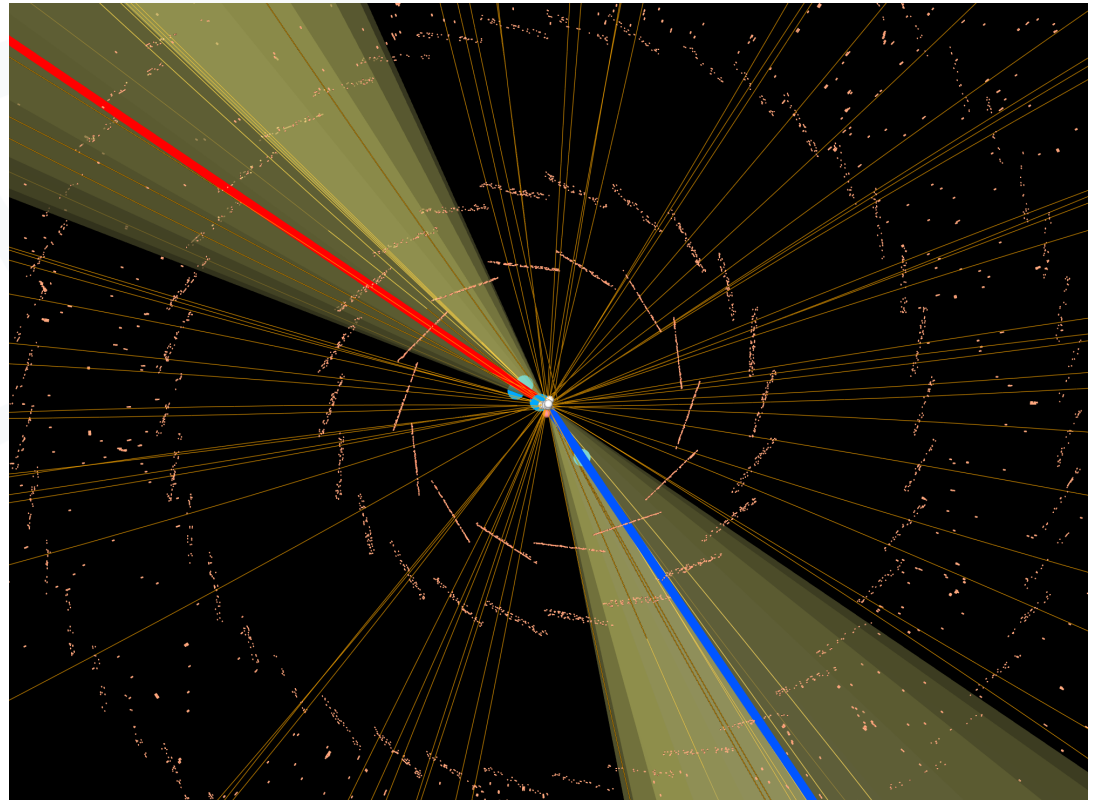
Flavour Tagging

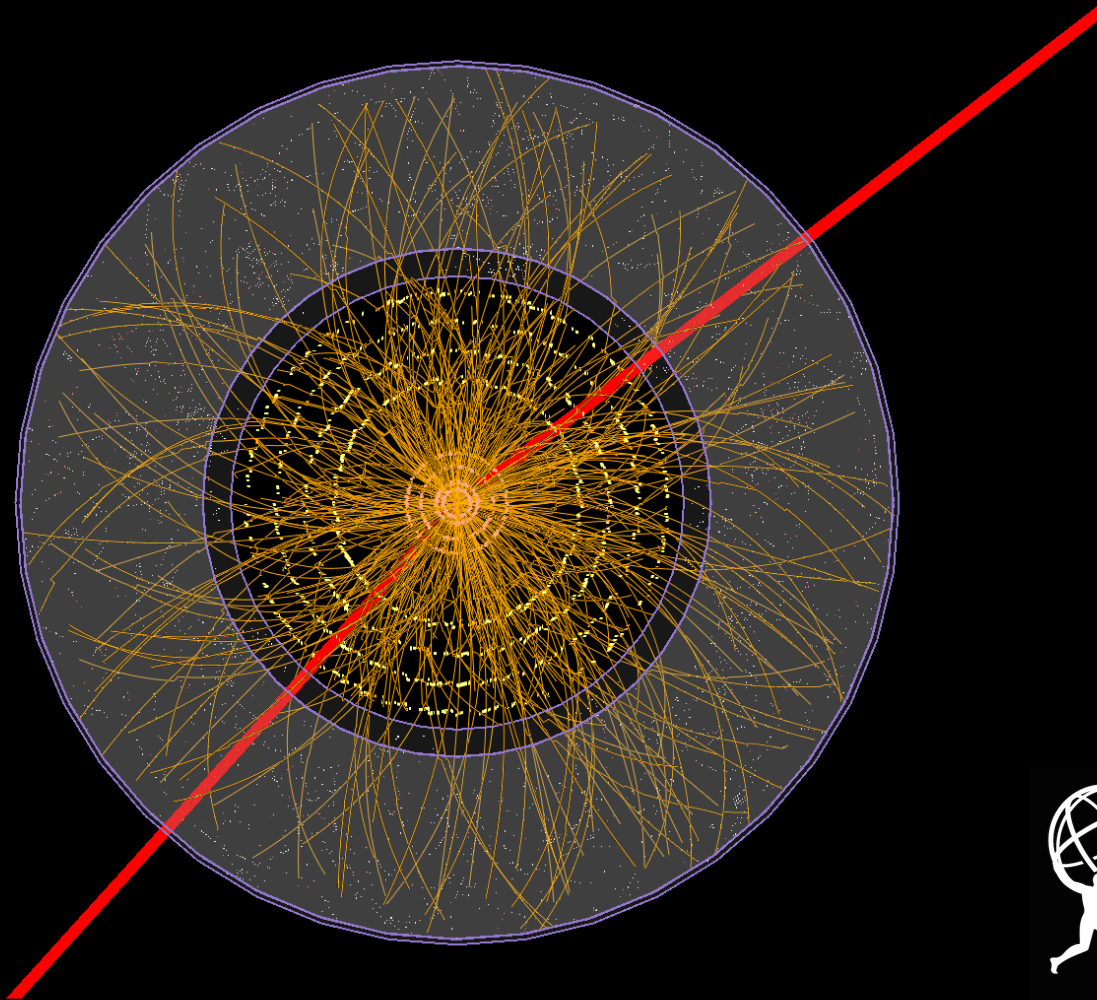
'Long lived'
particles!



Heavy flavour quarks form intermediate particles that travel away from the interaction before decaying.

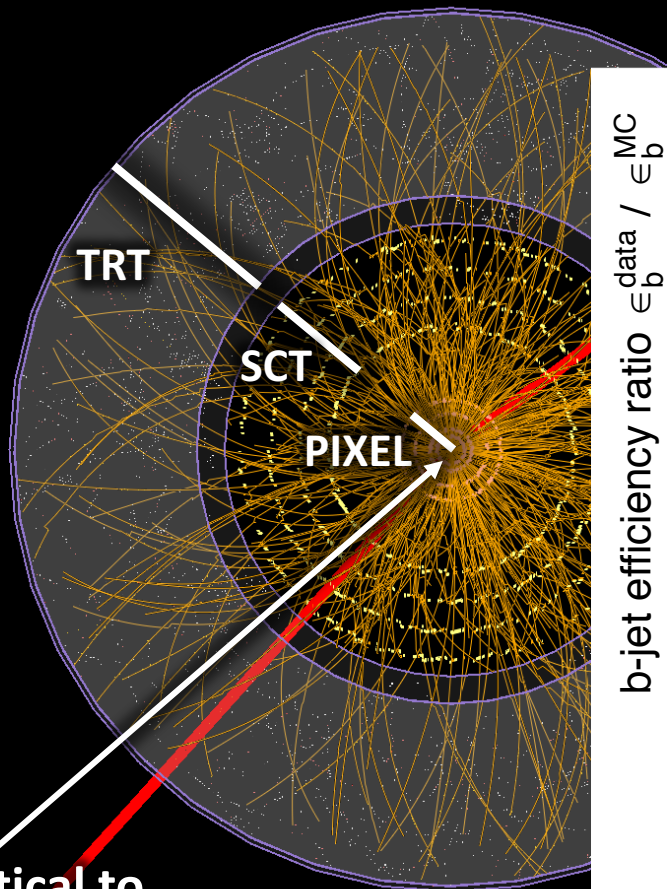
- We are able to identify them by looking for displaced vertices



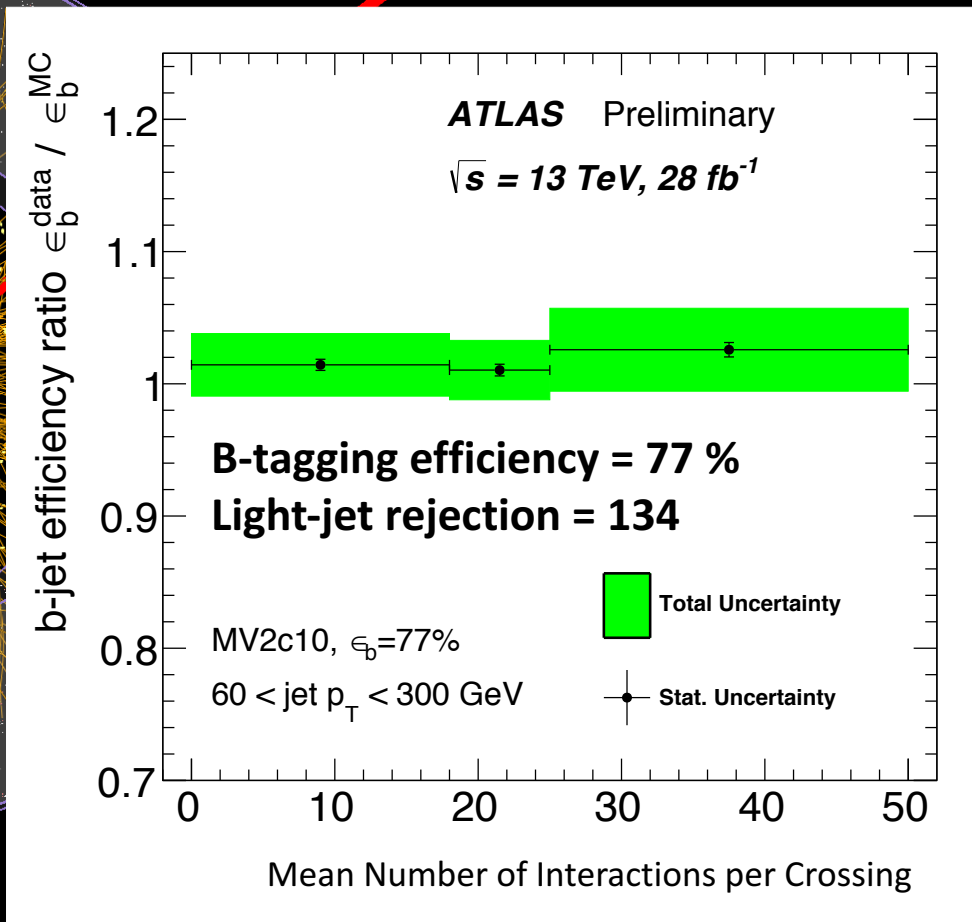


Run: 267638
Event: 242090708
2015-06-14 01:01:14 CEST

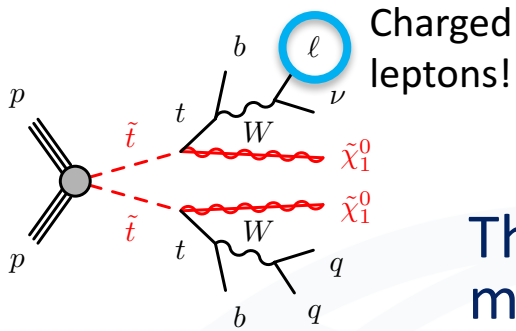
Flavour Tagging



IBL: critical to achieve this performance!

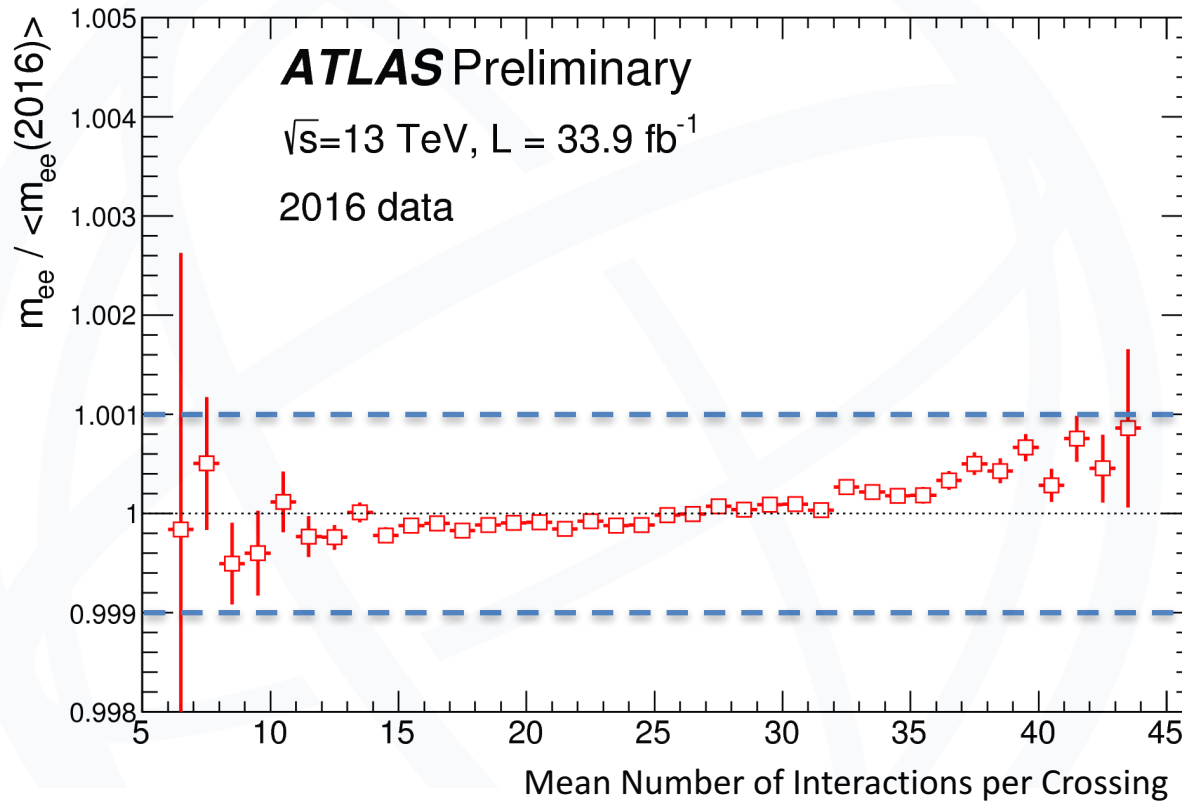


Identification efficiency robust against presence of additional interactions



Electrons

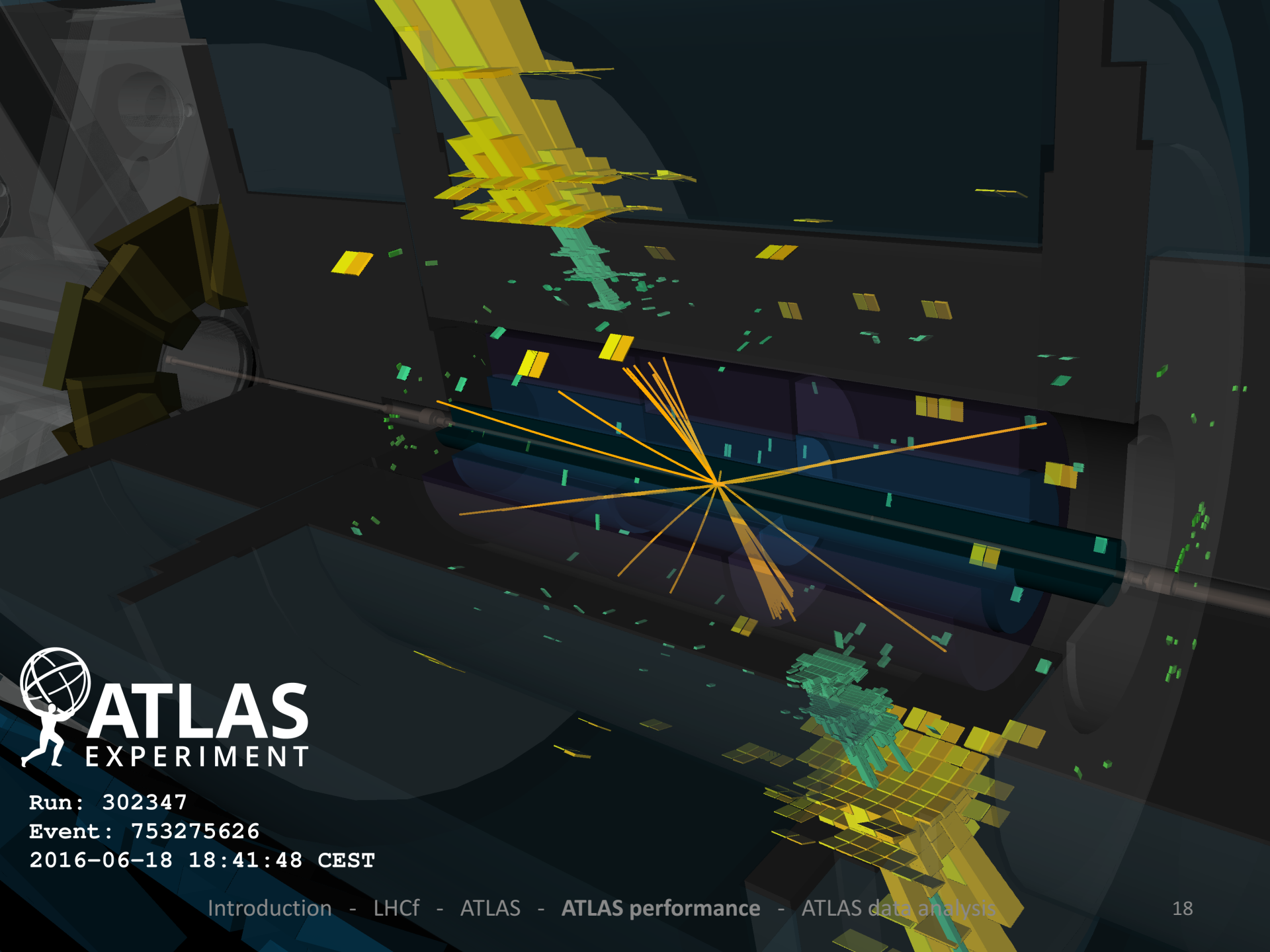
The leptonic decays of the Z boson are used to monitor the electron energy calibration.



- Very well known reference mass (measured at LEP)

**LESS THAN
1/1000
VARIATION!**

- Impressive stability of electron energy calibration



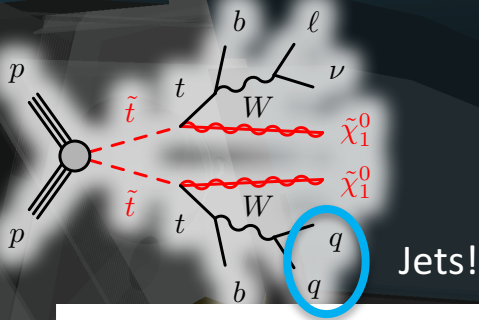
 **ATLAS**
EXPERIMENT

Run: 302347

Event: 753275626

2016-06-18 18:41:48 CEST

Jets

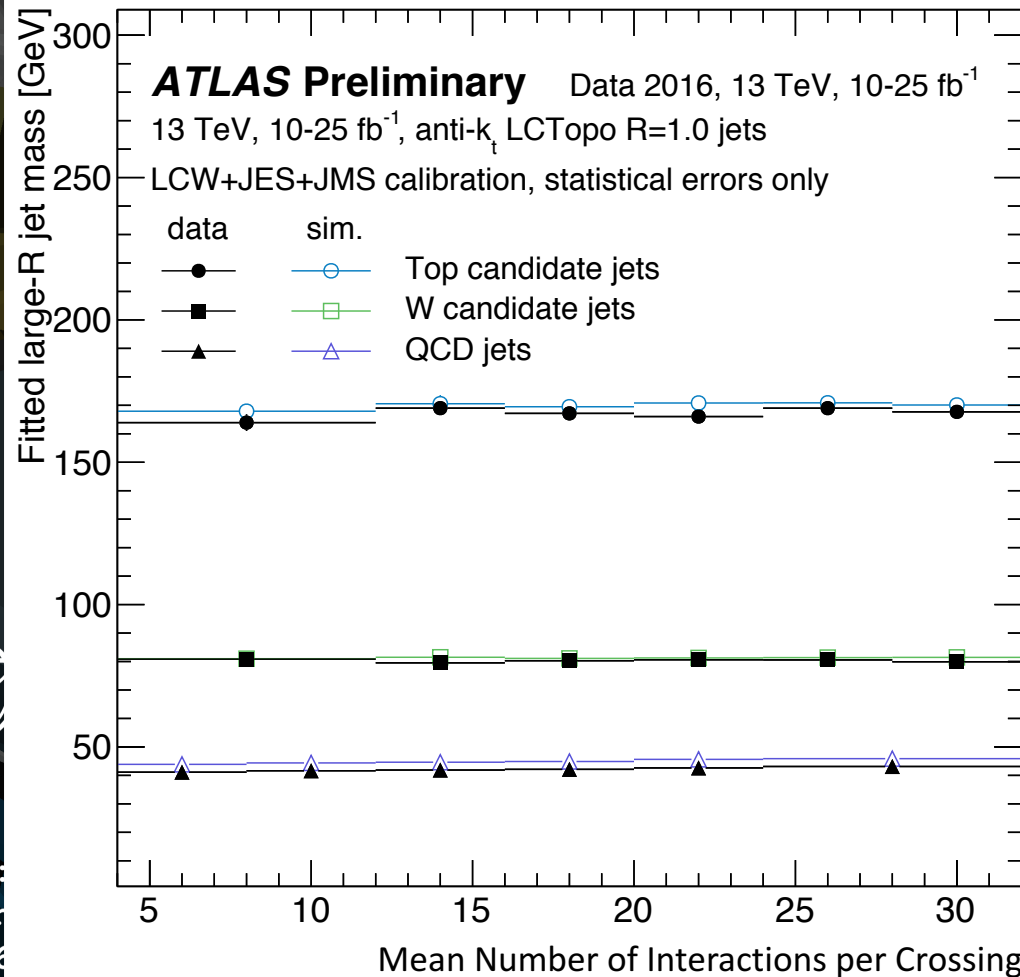


The decay products of highly energetic W bosons and top quarks tend to be close to each other.

- They can be reconstructed as a single jet

- We can measure the mass of these jets to monitor our calibration

- Impressive stability



Run :
 Ever
 2016

Run: 313136

Event: 723576997

2016-11-20 06:15:45 CEST

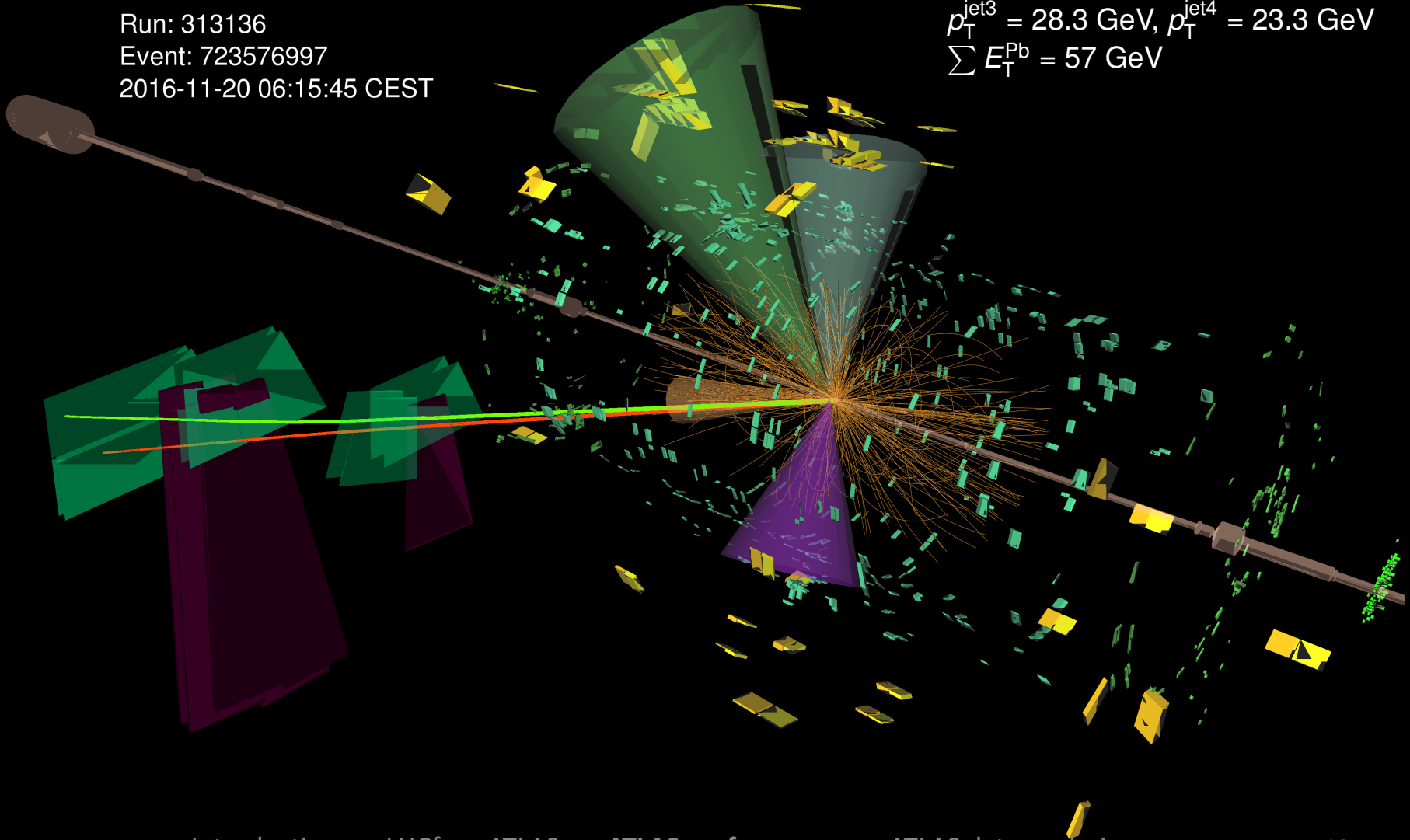
$p+Pb \sqrt{s_{NN}} = 8.16 \text{ TeV}$

$m^{\mu^+ \mu^-} = 3.09 \text{ GeV}, p_T^{\mu^+ \mu^-} = 50.9 \text{ GeV}$

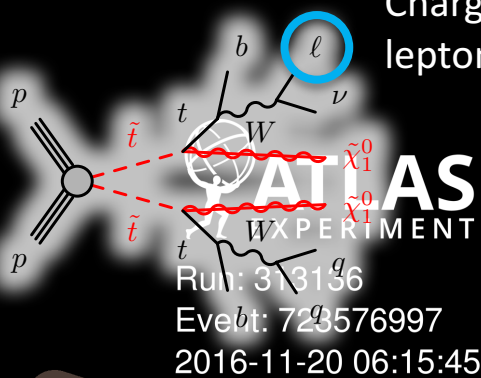
$p_T^{\text{jet1}} = 48.5 \text{ GeV}, p_T^{\text{jet2}} = 31.4 \text{ GeV}$

$p_T^{\text{jet3}} = 28.3 \text{ GeV}, p_T^{\text{jet4}} = 23.3 \text{ GeV}$

$\sum E_T^{\text{Pb}} = 57 \text{ GeV}$



Charged leptons!



Muons

$$p+Pb \sqrt{s_{NN}} = 8.16 \text{ TeV}$$

$$m^{\mu^+\mu^-} = 3.09 \text{ GeV}, p_T^{\mu^+\mu^-} = 50.9 \text{ GeV}$$

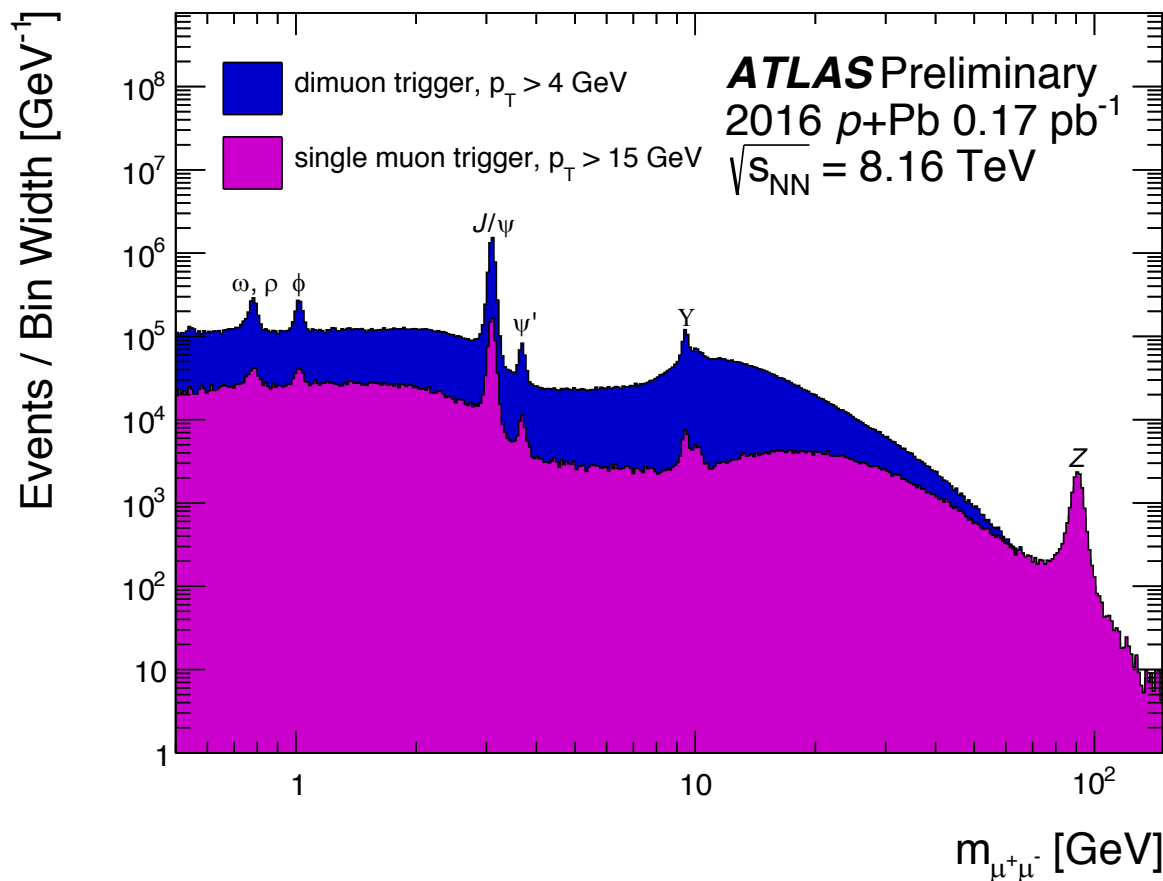
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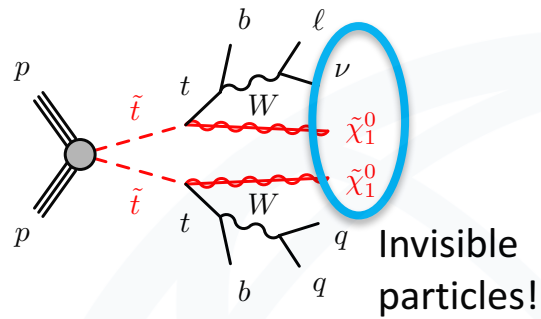
$$\sum E_T^{\text{Pb}} = 57 \text{ GeV}$$

Decades of particle physics, in heavy ion collisions.

- 2016 p+Pb data already being analysed!

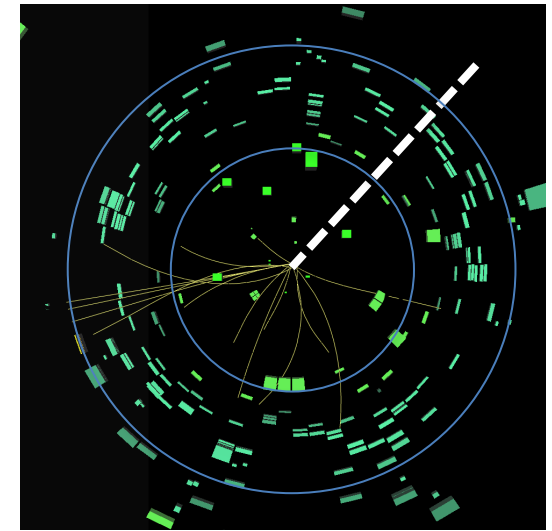
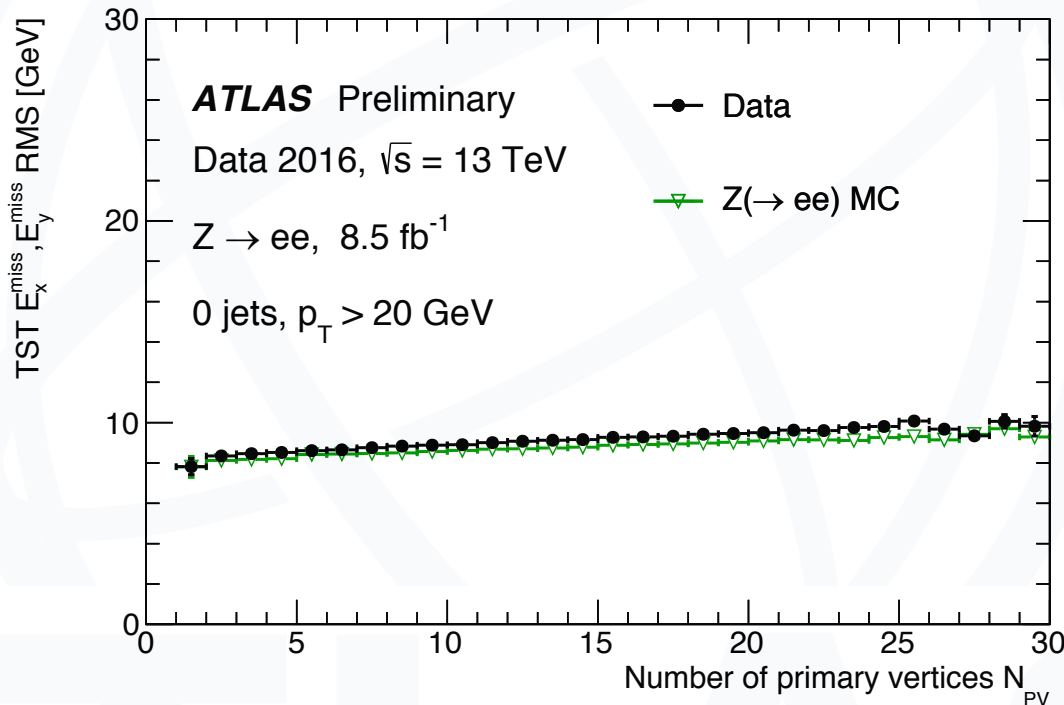


Missing Transverse Momentum



The momentum balance is known only in the transverse plane.

- Crucial to detect invisible particles

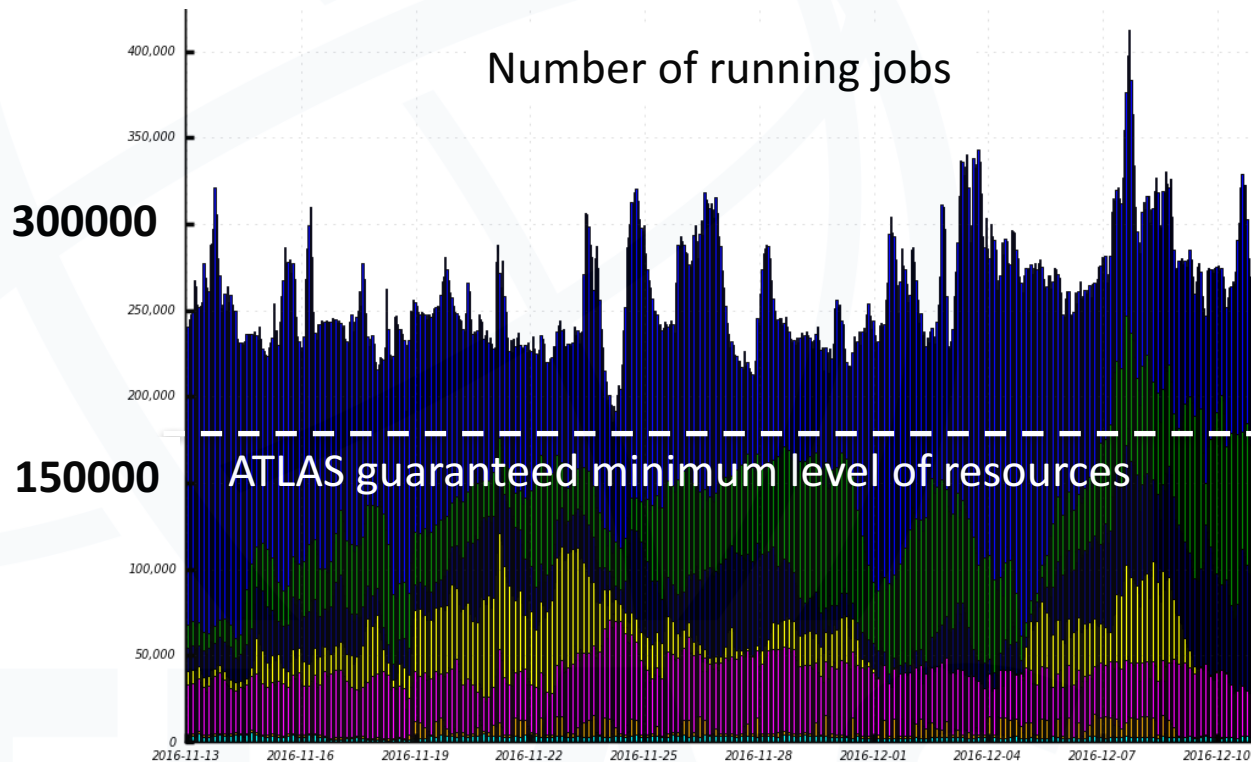


Combination of tracking and calorimetry to improve robustness.

Data Processing and Computing

Worldwide computing resources are crucial

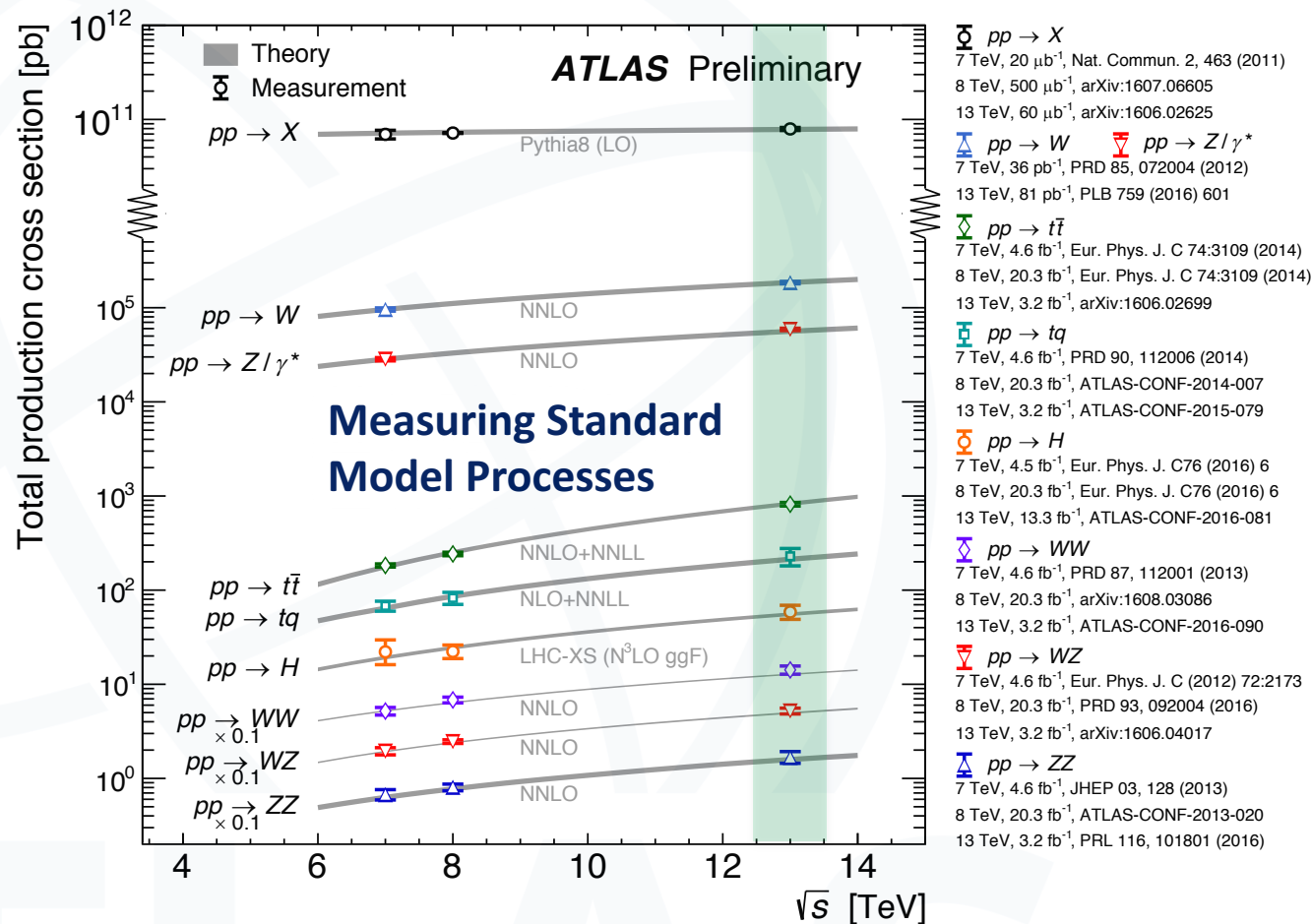
- The computing model continues to evolve: large simulation samples essential for detailed understanding of the data



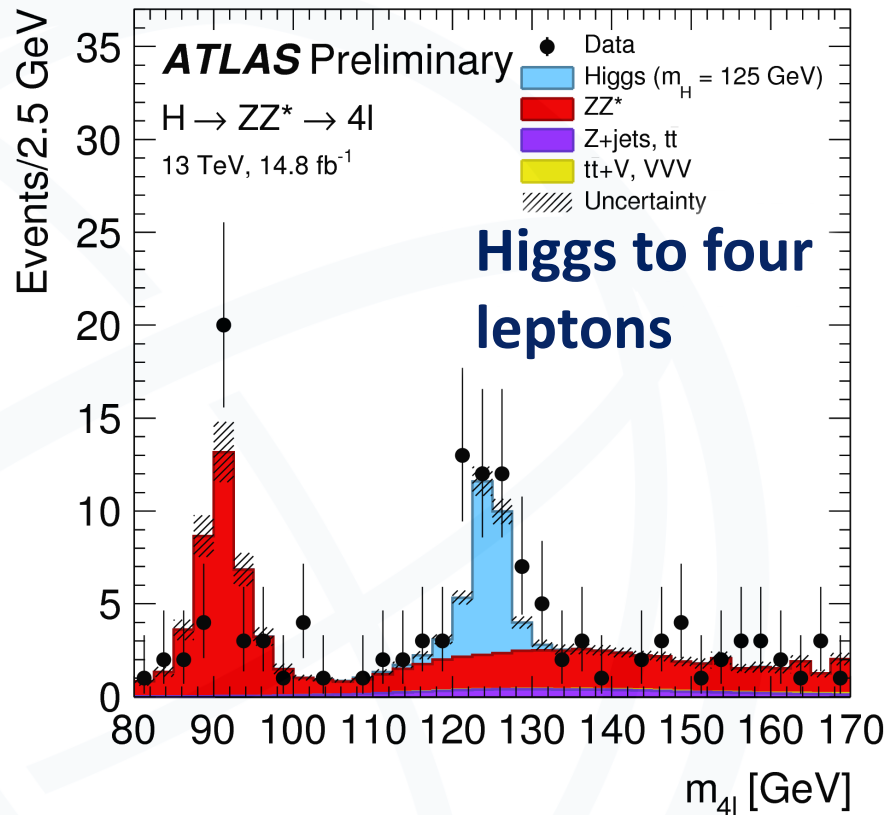
A 2016 milestone: ICHEP

Great achievement of the collaboration

- Results have been presented with data taken just two weeks before!

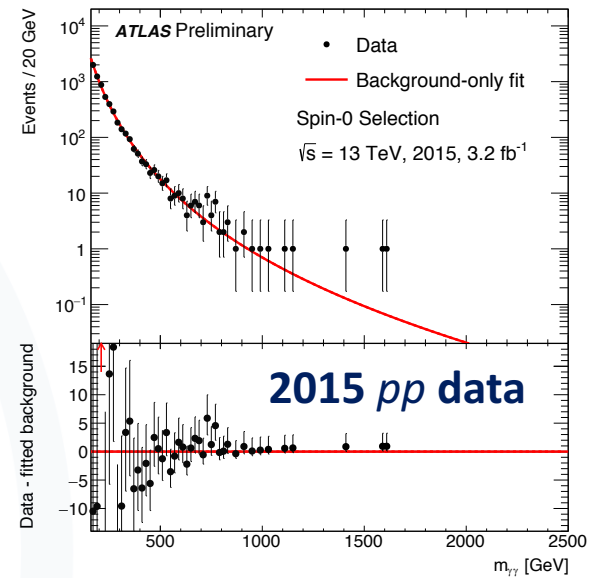
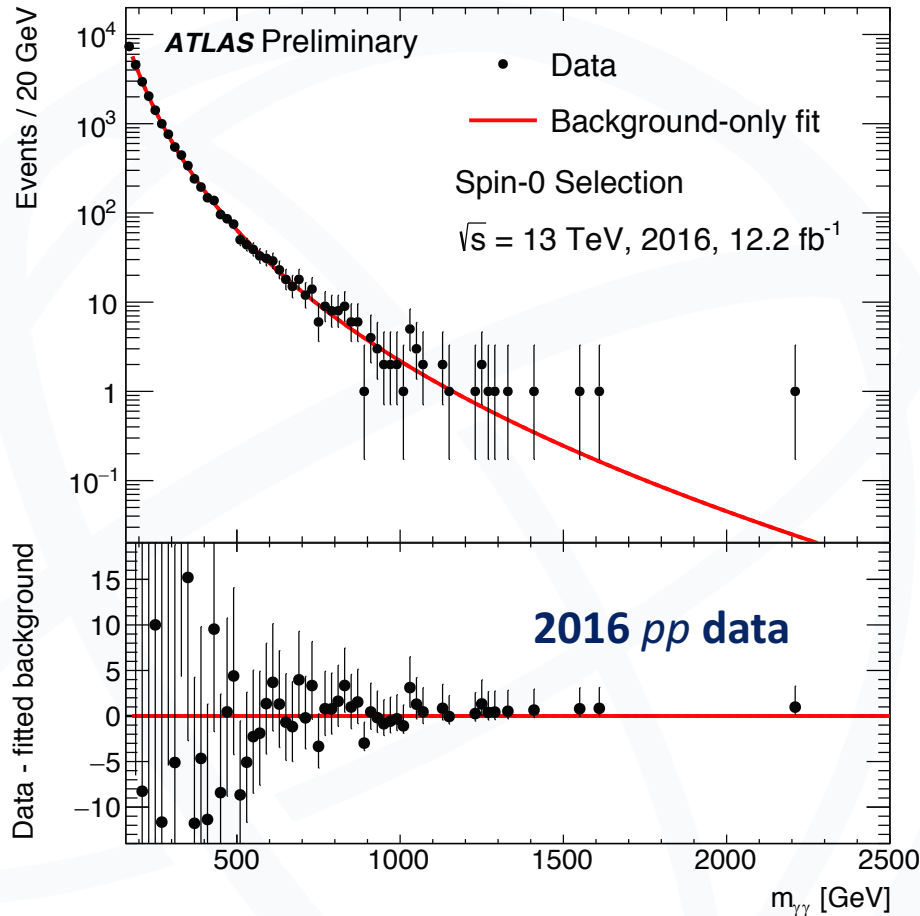


A 2016 milestone: ICHEP



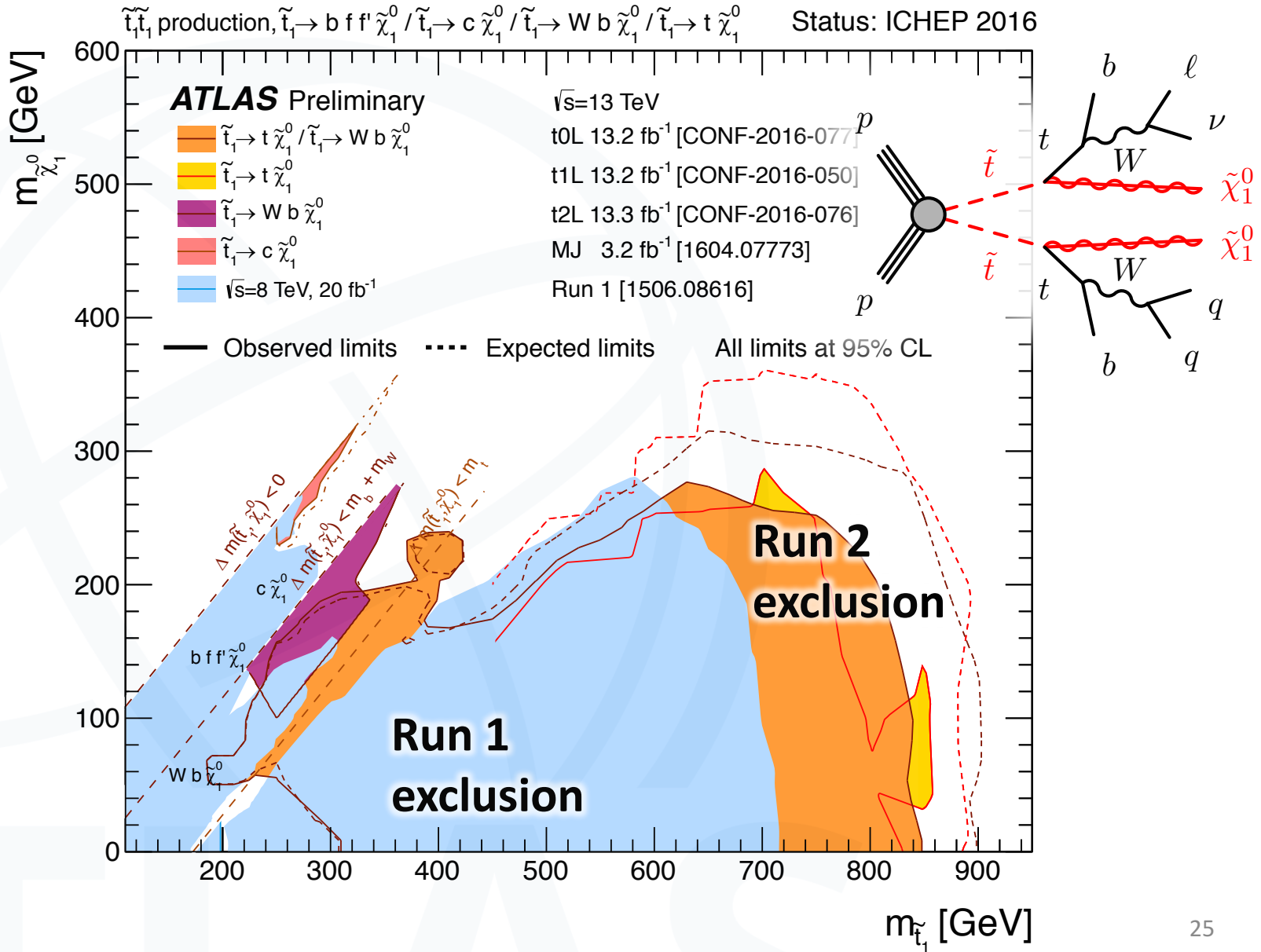
We have been able to fully re-establish the observations of Run 1 ...

A 2016 milestone: ICHEP



... and rule out some hints from 2015.

A 2016 milestone: ICHEP



A 2016 milestone: ICHEP

ATLAS Exotics Searches* - 95% CL Exclusion

Status: August 2016

1 TeV

$\int \mathcal{L} dt = (3.2 - 20.3) \text{ fb}^{-1}$

ATLAS Preliminary

$\sqrt{s} = 8, 13 \text{ TeV}$

Model	ℓ, γ	Jets [†]	E_T^{miss}	$\int \mathcal{L} dt [\text{fb}^{-1}]$	Limit	Reference
Extra dimensions	ADD $G_{KK} + g/q$	$\geq 1j$	Yes	3.2	M_D 6.58 TeV	$n = 2$ 1604.07773
	ADD non-resonant $\ell\ell$	$2 e, \mu$	-	20.3	M_S 4.7 TeV	$n = 3 \text{ HLZ}$ 1407.2410
	ADD QBH $\rightarrow \ell q$	$1 e, \mu$	$1j$	-	M_{th} 5.2 TeV	$n = 6$ 1311.2006
	ADD QBH	-	$2j$	-	M_{th} 8.7 TeV	$n = 6$ ATLAS-CONF-2016-069
	ADD BH high $\sum p_T$	$\geq 1 e, \mu$	$\geq 2j$	-	M_{th} 8.2 TeV	$n = 6, M_D = 3 \text{ TeV, rot BH}$ 1606.02265
	ADD BH multijet	-	$\geq 3j$	-	M_{th} 9.55 TeV	$n = 6, M_D = 3 \text{ TeV, rot BH}$ 1512.02586
	RS1 $G_{KK} \rightarrow \ell\ell$	$2 e, \mu$	-	-	$G_{KK} \text{ mass}$ 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$ 1405.4123
	RS1 $G_{KK} \rightarrow \gamma\gamma$	2γ	-	-	$G_{KK} \text{ mass}$ 3.2 TeV	$k/\overline{M}_{Pl} = 0.1$ 1606.03833
	Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\ell\nu$	$1 e, \mu$	$1J$	Yes	$G_{KK} \text{ mass}$ 1.24 TeV	$k/\overline{M}_{Pl} = 1.0$ ATLAS-CONF-2016-062
	Bulk RS $G_{KK} \rightarrow HH \rightarrow bbbb$	-	$4b$	-	$G_{KK} \text{ mass}$ 360-860 GeV	$k/\overline{M}_{Pl} = 1.0$ ATLAS-CONF-2016-049
Bulk RS $g_{KK} \rightarrow tt$	$1 e, \mu$	$\geq 1b, \geq 1J/2j$	Yes	$g_{KK} \text{ mass}$ 2.2 TeV	$BR = 0.925$ 1505.07018	
2UED / RPP	$1 e, \mu$	$\geq 2b, \geq 4j$	Yes	$KK \text{ mass}$ 1.5 TeV	Tier (1,1), $BR(A^{(1,1)} \rightarrow tt) = 1$ ATLAS-CONF-2016-013	
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	$2 e, \mu$	-	13.3	$Z' \text{ mass}$ 4.05 TeV	$g_V = 1$ ATLAS-CONF-2016-045
	SSM $Z' \rightarrow \tau\tau$	2τ	-	19.5	$Z' \text{ mass}$ 2.02 TeV	$g_V = 3$ 1502.07177
	Leptophobic $Z' \rightarrow bb$	-	$2b$	-	$Z' \text{ mass}$ 5 TeV	$g_V = 3$ 1603.08791
	SSM $W' \rightarrow \ell\nu$	$1 e, \mu$	-	Yes	$W' \text{ mass}$ 4.74 TeV	$g_V = 3$ ATLAS-CONF-2016-061
	HVT $W' \rightarrow WZ \rightarrow qq\nu\nu$ model A	$0 e, \mu$	$1J$	Yes	$W' \text{ mass}$ 2.4 TeV	ATLAS-CONF-2016-082
	HVT $W' \rightarrow WZ \rightarrow qqqq$ model B	-	$2J$	-	$W' \text{ mass}$ 3.0 TeV	ATLAS-CONF-2016-055
	HVT $V' \rightarrow WH/ZH$ model B	multi-channel	-	-	$V' \text{ mass}$ 2.31 TeV	1607.05621
LRSM $W'_R \rightarrow tb$	$1 e, \mu$	$2b, 0-1j$	Yes	$W'_R \text{ mass}$ 1.92 TeV	1410.4103	
LRSM $W'_R \rightarrow tb$	$0 e, \mu$	$\geq 1b, 1J$	-	$W'_R \text{ mass}$ 1.76 TeV	1408.0886	
CI	CI $qqqq$	-	$2j$	15.7	Λ 19.9 TeV	$\eta_{LL} = -1$ ATLAS-CONF-2016-069
	CI $\ell\ell qq$	$2 e, \mu$	-	3.2	Λ 25.2 TeV	$\eta_{LL} = -1$ 1607.03669
	CI $uu\tau\tau$	$2(SS)/\geq 3 e, \mu$	$\geq 1b, \geq 1j$	Yes	Λ 4.9 TeV	$ C_{RR} = 1$ 1504.04605
DM	Axial-vector mediator (Dirac DM)	$0 e, \mu$	$\geq 1j$	Yes	m_A 1.0 TeV	$g_q=0.25, g_\tau=1.0, m(\chi) < 250 \text{ GeV}$ 1604.07773
	Axial-vector mediator (Dirac DM)	$0 e, \mu, 1 \gamma$	$1j$	Yes	m_A 710 GeV	$g_q=0.25, g_\tau=1.0, m(\chi) < 150 \text{ GeV}$ 1604.01306
	$ZZ\chi\chi$ EFT (Dirac DM)	$0 e, \mu$	$1J, \leq 1j$	Yes	M_χ 550 GeV	$m(\chi) < 150 \text{ GeV}$ ATLAS-CONF-2015-080
LQ	Scalar LQ 1 st gen	$2 e$	$\geq 2j$	-	$LQ \text{ mass}$ 1.1 TeV	$\beta = 1$ 1605.06035
	Scalar LQ 2 nd gen	2μ	$\geq 2j$	-	$LQ \text{ mass}$ 1.05 TeV	$\beta = 1$ 1605.06035
	Scalar LQ 3 rd gen	$1 e, \mu$	$\geq 1b, \geq 3j$	Yes	$LQ \text{ mass}$ 640 GeV	$\beta = 0$ 1508.04735
Heavy quarks	VLQ $TT \rightarrow Ht + X$	$1 e, \mu$	$\geq 2b, \geq 3j$	Yes	$T \text{ mass}$ 855 GeV	T in (T,B) doublet 1505.04306
	VLQ $YY \rightarrow Wb + X$	$1 e, \mu$	$\geq 1b, \geq 3j$	Yes	$Y \text{ mass}$ 770 GeV	Y in (B,Y) doublet 1505.04306
	VLQ $BB \rightarrow Hb + X$	$1 e, \mu$	$\geq 2b, \geq 3j$	Yes	$B \text{ mass}$ 735 GeV	isospin singlet 1505.04306
	VLQ $BB \rightarrow Zb + X$	$2/\geq 3 e, \mu$	$\geq 2/\geq 1 b$	-	$B \text{ mass}$ 755 GeV	B in (B,Y) doublet 1409.5500
	VLQ $QQ \rightarrow WqWq$	$1 e, \mu$	$\geq 4j$	Yes	$Q \text{ mass}$ 690 GeV	1509.04261
VLQ $T_{5/3} T_{5/3} \rightarrow WtWt$	$2(SS)/\geq 3 e, \mu$	$\geq 1b, \geq 1j$	Yes	$T_{5/3} \text{ mass}$ 990 GeV	ATLAS-CONF-2016-032	
Excited fermions	Excited quark $q^* \rightarrow q\gamma$	1γ	$1j$	-	$q^* \text{ mass}$ 4.4 TeV	only u^* and d^* , $\Lambda = m(q^*)$ 1512.05910
	Excited quark $q^* \rightarrow qg$	-	$2j$	-	$q^* \text{ mass}$ 5.6 TeV	only u^* and d^* , $\Lambda = m(q^*)$ ATLAS-CONF-2016-069
	Excited quark $b^* \rightarrow bg$	-	$1b, 1j$	-	$b^* \text{ mass}$ 2.3 TeV	ATLAS-CONF-2016-060
	Excited quark $b^* \rightarrow Wt$	$1 \text{ or } 2 e, \mu$	$1b, 2-0j$	Yes	$b^* \text{ mass}$ 5 TeV	$f_g = f_t = f_b = 1$ 1510.02664
	Excited lepton ℓ^*	$3 e, \mu$	-	-	$\ell^* \text{ mass}$ 3.0 TeV	$\Lambda = 3.0 \text{ TeV}$ 1411.2921
	Excited lepton ν^*	$3 e, \mu, \tau$	-	-	$\nu^* \text{ mass}$ 1.6 TeV	$\Lambda = 1.6 \text{ TeV}$ 1411.2921
Other	LSTC $a_T \rightarrow W\gamma$	$1 e, \mu, 1 \gamma$	-	Yes	$a_T \text{ mass}$ 960 GeV	$m(W_R) = 2.4 \text{ TeV, no mixing}$ 1407.8150
	LRSM Majorana ν	$2 e, \mu$	$2j$	-	$N^0 \text{ mass}$ 2.0 TeV	$DY \text{ production, } BR(H_L^{\pm\pm} \rightarrow ee)=1$ 1506.06020
	Higgs triplet $H^{\pm\pm} \rightarrow ee$	$2 e (SS)$	-	-	$H^{\pm\pm} \text{ mass}$ 570 GeV	$DY \text{ production, } BR(H_L^{\pm\pm} \rightarrow \ell\tau)=1$ ATLAS-CONF-2016-051
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	$3 e, \mu, \tau$	-	-	$H^{\pm\pm} \text{ mass}$ 400 GeV	$a_{\text{non-res}} = 0.2$ 1411.2921
	Monotop (non-res prod)	$1 e, \mu$	$1b$	Yes	spin-1 invisible particle mass 657 GeV	$DY \text{ production, } q = 5e$ 1410.5404
	Multi-charged particles	-	-	-	multi-charged particle mass 785 GeV	$DY \text{ production, } g = 1g_D, \text{ spin } 1/2$ 1504.04188
	Magnetic monopoles	-	-	-	monopole mass 1.3 TeV	1509.08059

$\sqrt{s} = 8 \text{ TeV}$

$\sqrt{s} = 13 \text{ TeV}$

10^{-1}

1

10

Mass scale [TeV]

*Only a selection of the available mass limits on new states or phenomena is shown. Lower bounds are specified only when explicitly not excluded.

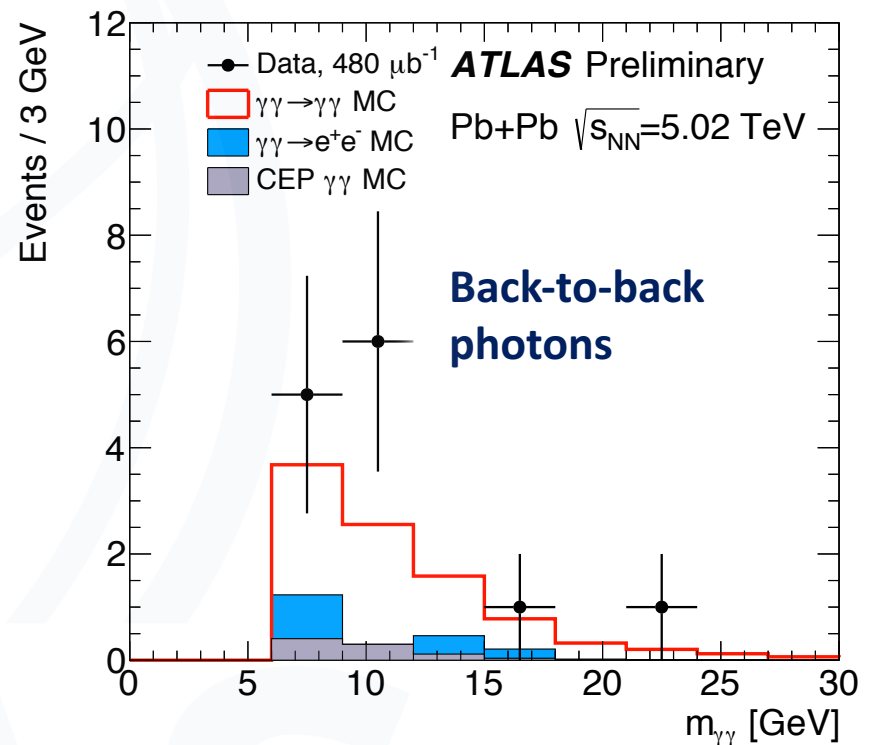
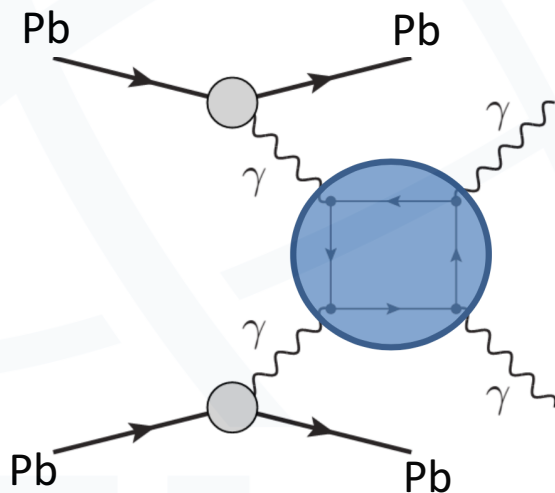
†Small-radius (large-radius) jets are denoted by the letter j (J).

Light-by-light scattering

Based on 2015 Pb-Pb data (5.02 TeV)

First evidence of quasi-elastic scattering of two photons at high energy!

- Use heavy ions as source due to their large electromagnetic field
- Relevant to precision QED physics!

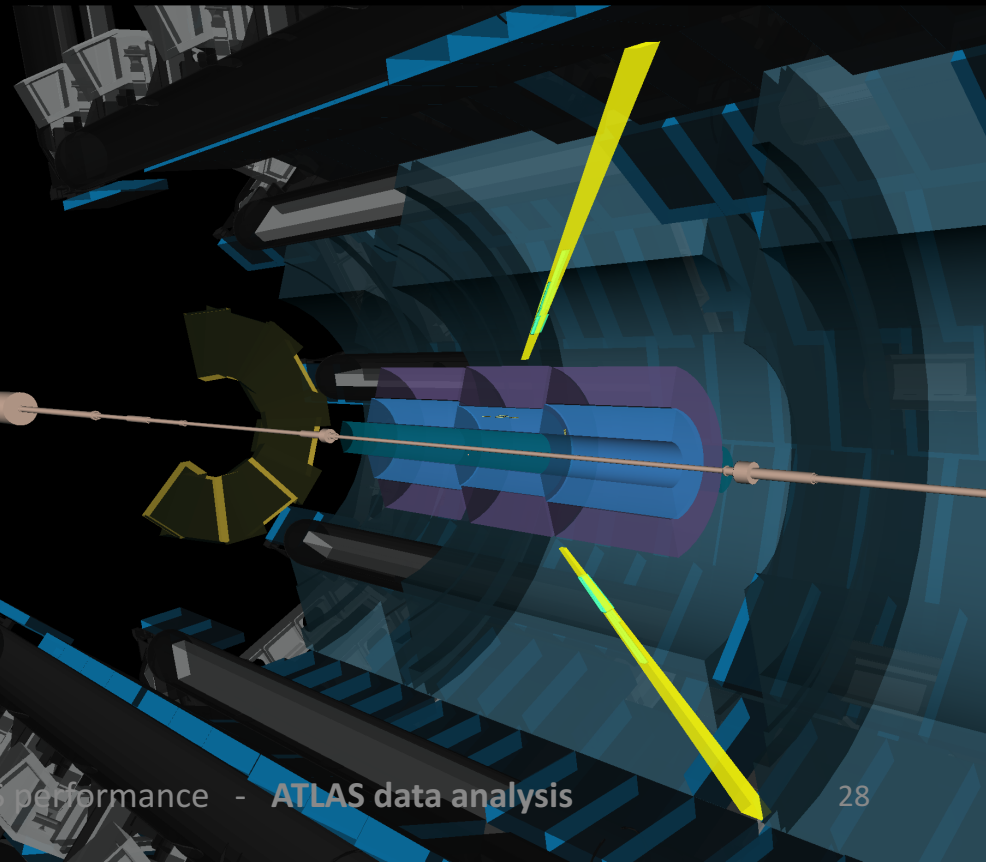
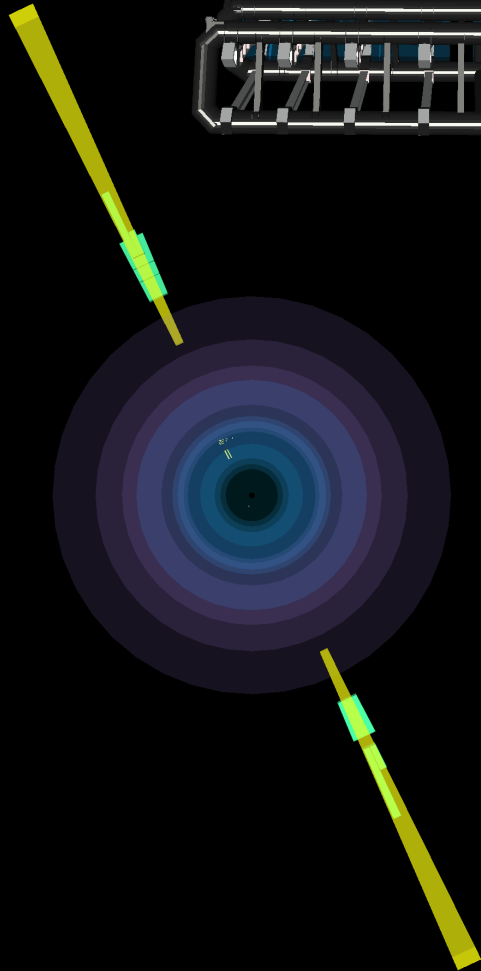
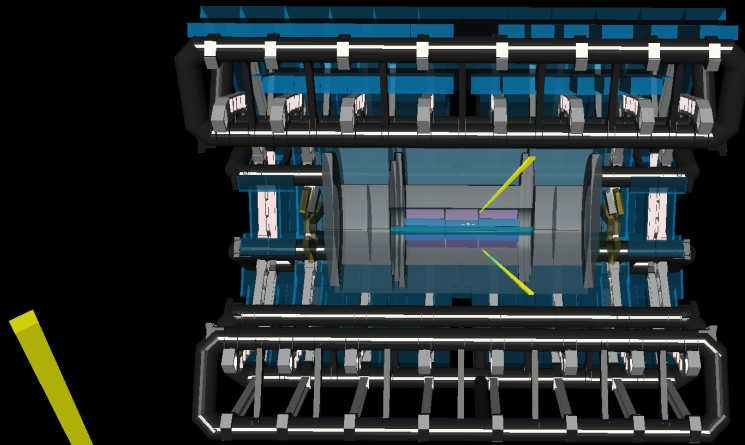


ATLAS-CONF-2016-111

Run: 287931

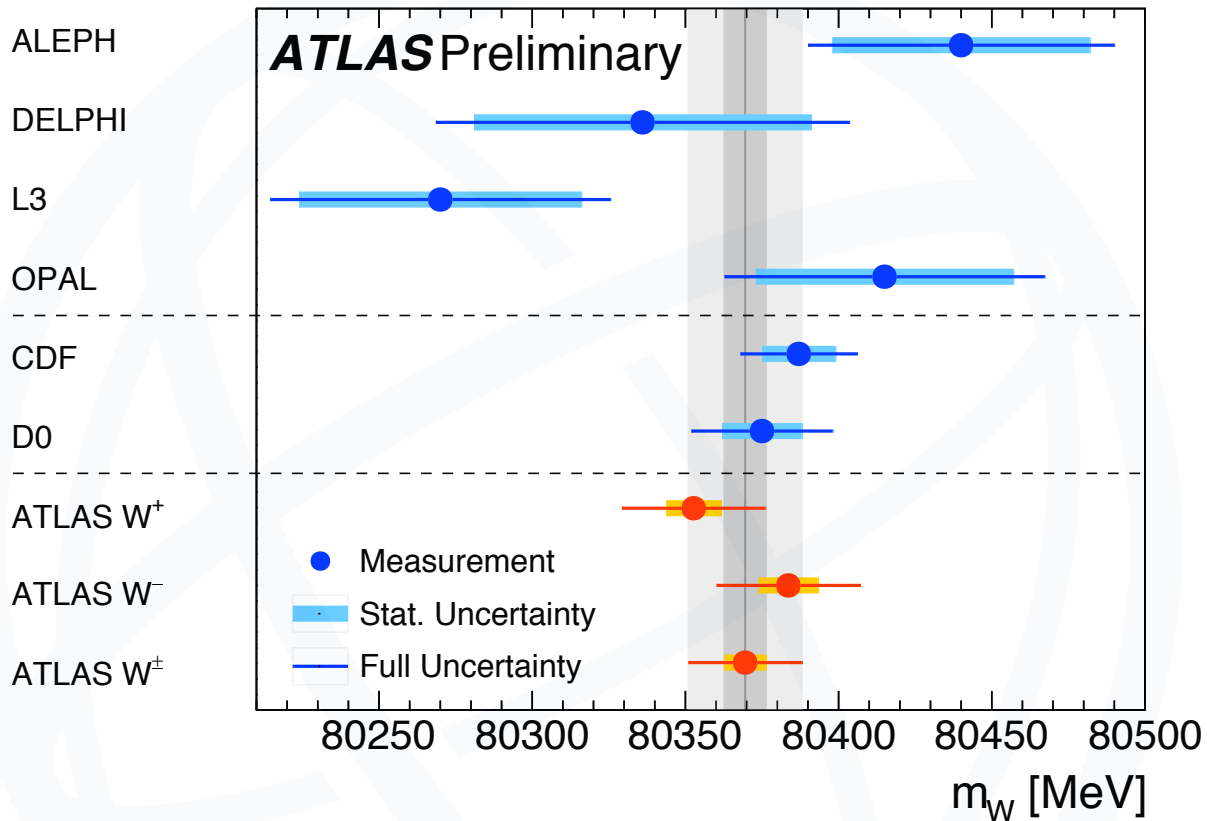
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2015-12-13 09:51:07 CEST



Measurement of the W -boson mass

ATLAS-CONF-2016-113

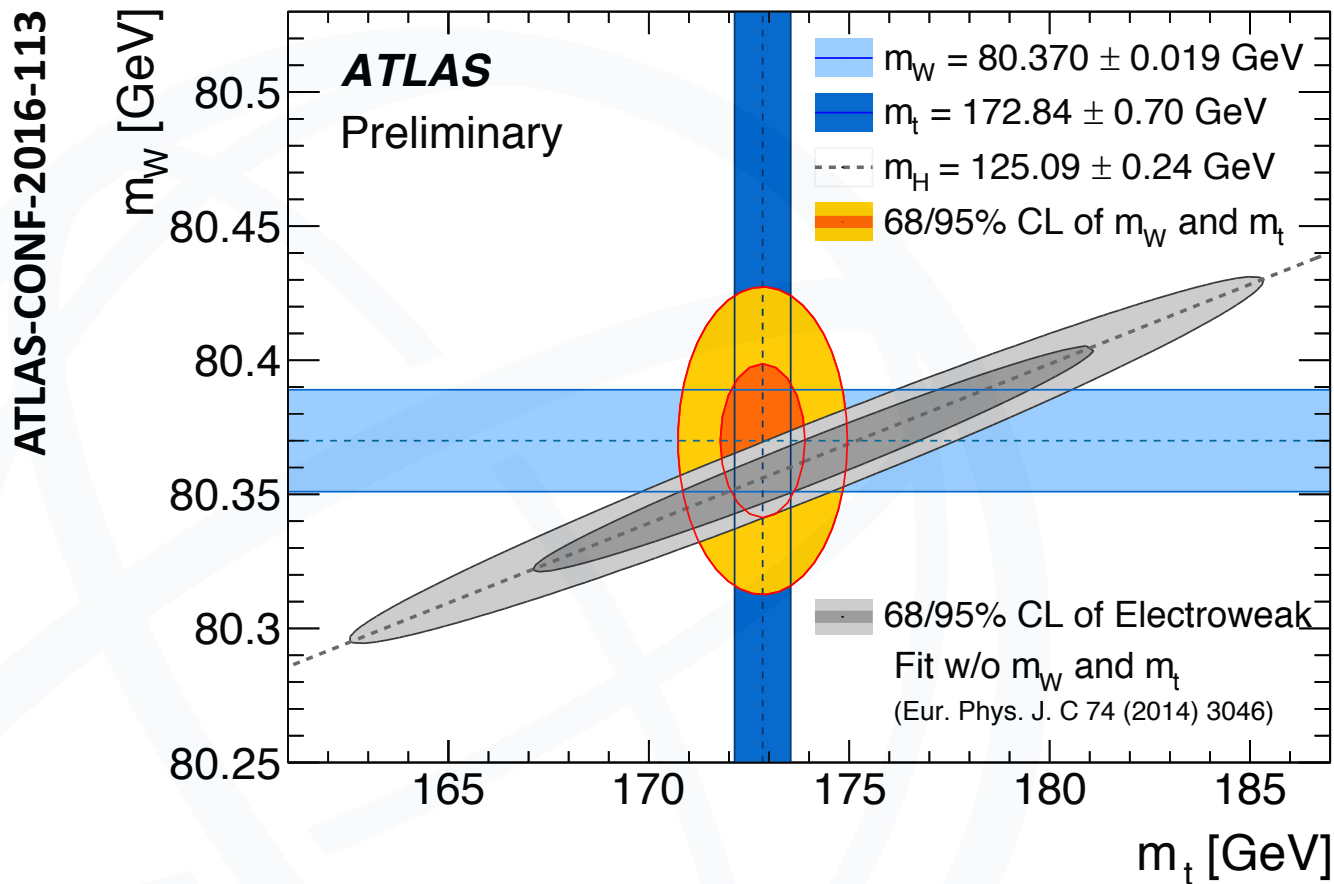


Just released result,
based on 7 TeV data

- **Precision comparable with the currently leading measurements performed by the CDF and D0 collaborations**

$$\begin{aligned} m_W &= 80370 \pm 7 \text{ MeV (stat.)} \pm 11 \text{ MeV (exp. syst.)} \pm 14 \text{ MeV (mod. syst.)} \\ &= 80370 \pm 19 \text{ MeV} \end{aligned}$$

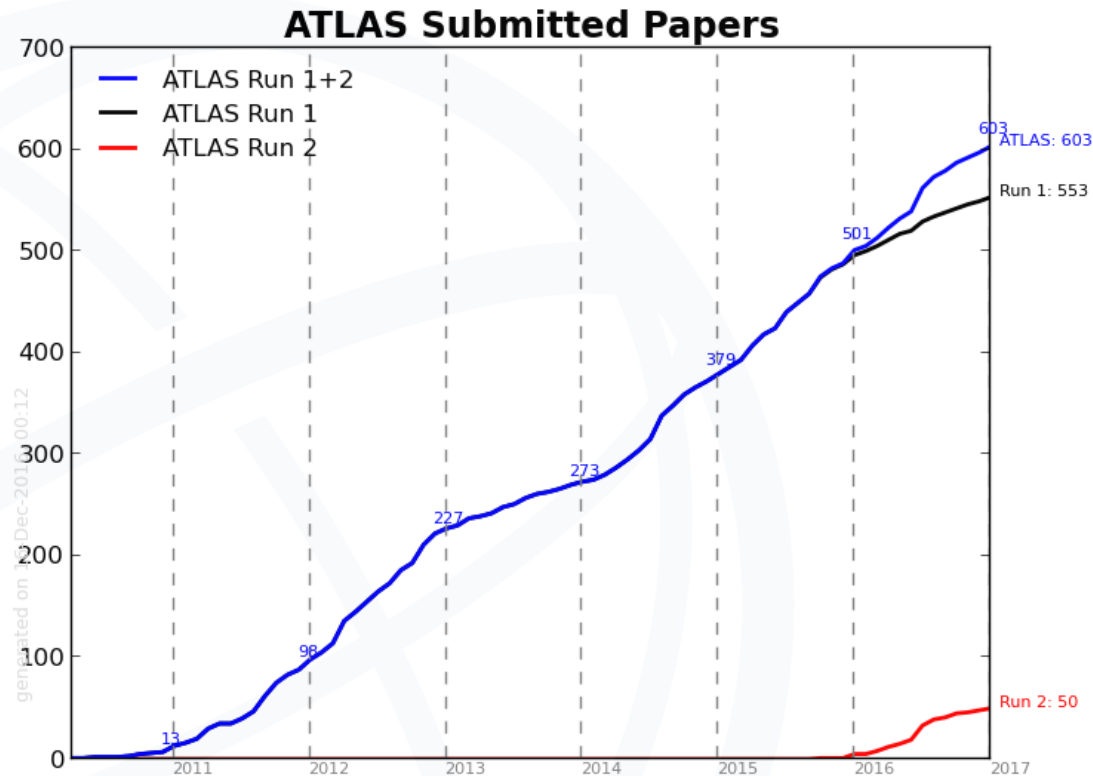
Measurement of the W -boson mass



In the Standard Model, m_W , m_t and m_H are related to each other

- **Measuring them precisely provides an important consistency test**

ATLAS publication status



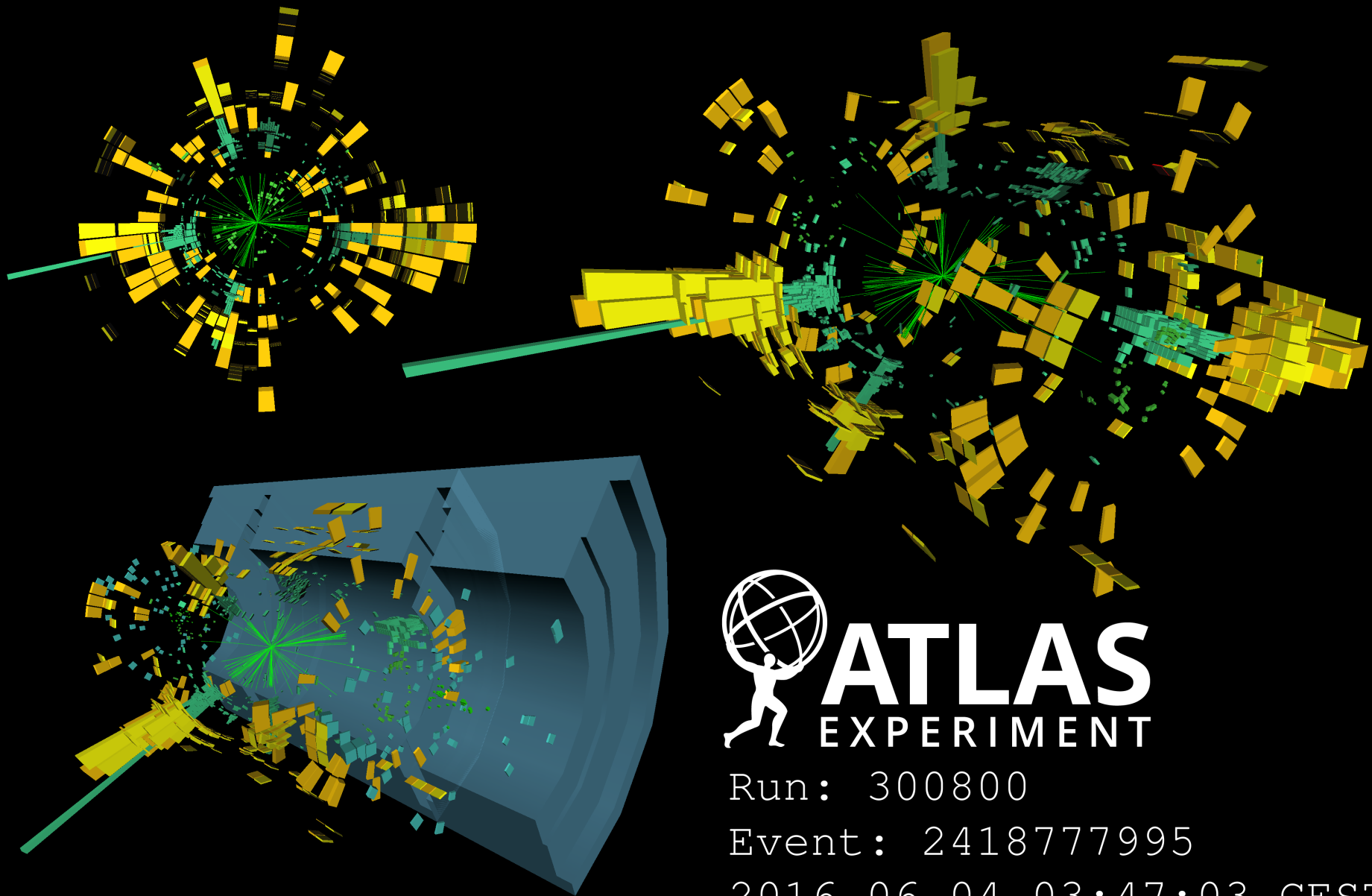
553 Run 1 and **49** Run 2 papers and counting...

Looking forward to more



Thanks to collaborating nations and funding agencies!

Thanks for your attention



ATLAS
EXPERIMENT

Run: 300800

Event: 2418777995

2016-06-04 03:47:03 CEST