

Exotic Searches at ATLAS

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Introduction and Outline

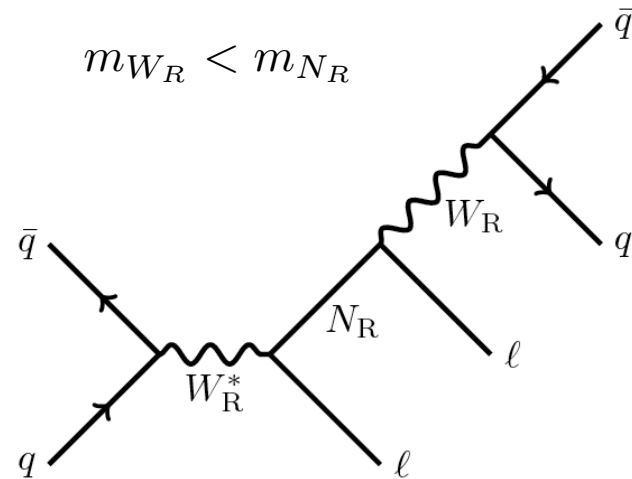
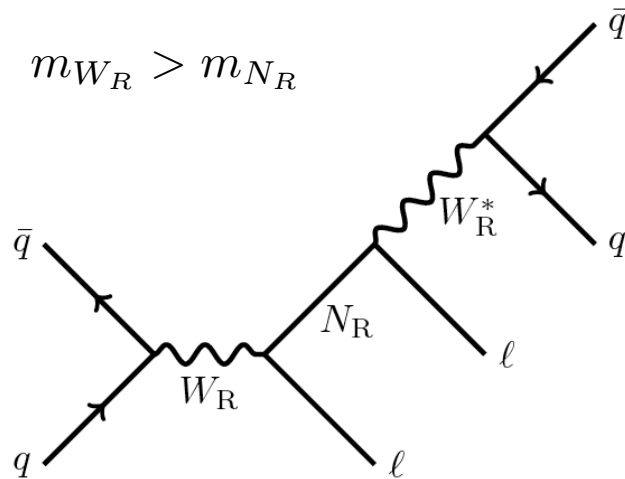
- Exotic physics at ATLAS:
 - ✓ Searches for new physics (NP) beyond the SM: Many well motivated theories
 - ✓ Many diverse & broad topics
 - Large overlap with SUSY searches
- Only a few selected results from ATLAS Analyses after summer 2018
 - ✓ Heavy neutrino + right-handed W
 - arXiv: 1809.11105 [hep-ex]
 - ✓ 4 Top production
 - arXiv: 1811.02305 [hep-ex]
 - ✓ Single Long-lived neutral particle
 - arXiv: 1811.02542 [hep-ex]
 - ✓ All based on 36.1fb^{-1} data at 13TeV pp collisions (149fb^{-1} recorded)
 - ✓ Not include SUSY, dark matter searches & BSM Higgs, Eg:
 - Invisible Higgs decays, arXiv: 1809.06682 [hep-ex]
 - BSM $H \rightarrow hh$ arXiv:1811.04671 [hep-ex]
- Focus on basic search strategy without too much technical details

An image of an iceberg floating in the ocean. The tip of the iceberg is visible above the water surface, while the much larger, submerged part is hidden below. The sky is blue with some clouds, and the water is a deep blue. The text is overlaid on the image.

Exotic searches in my talk:
A few selected new results
from ATLAS experiment

Many other and diverse searches for
exotic physics at ATLAS

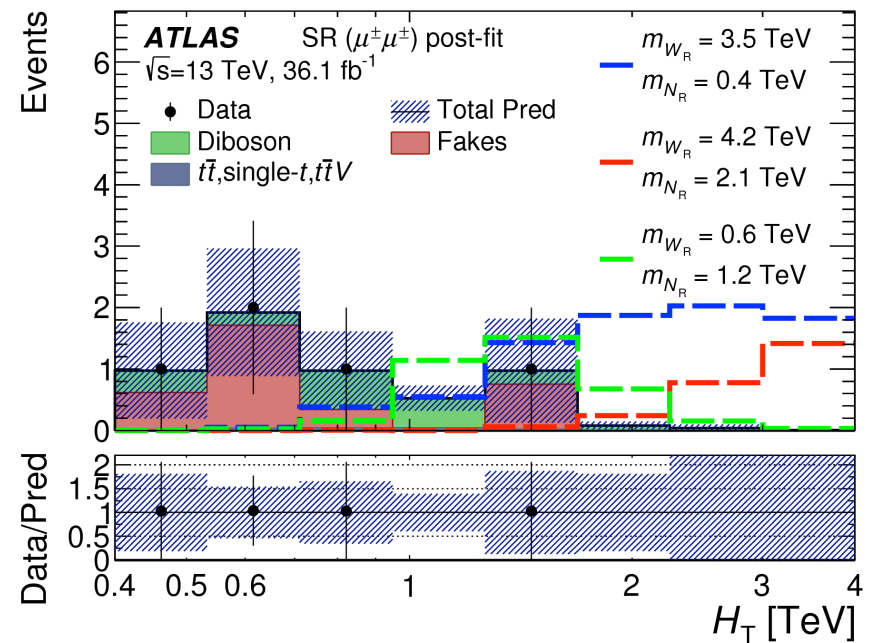
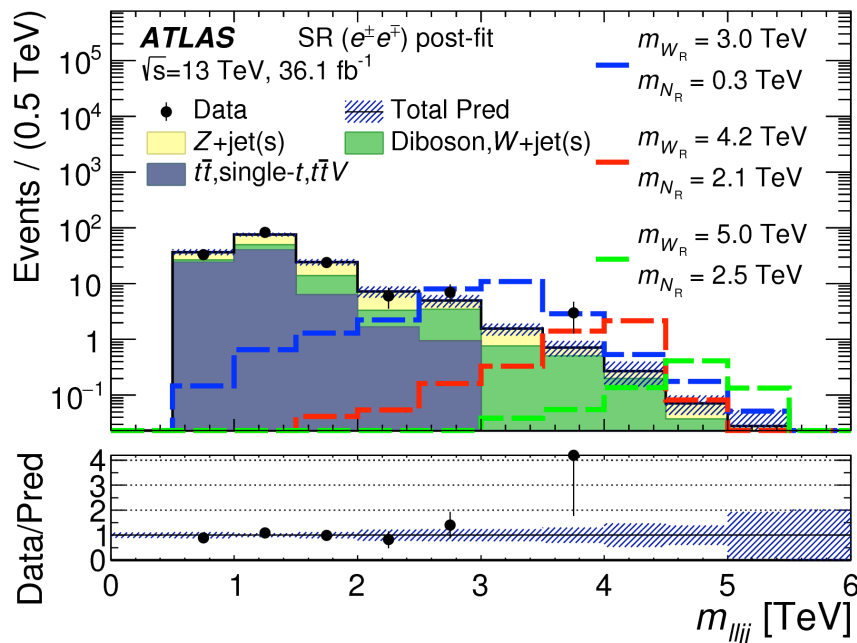
Heavy Neutrino and Right Handed W



- Left-right symmetric models: Keung-Senjanovic (KS) process
 - ✓ Assuming no mixing between flavors: two same flavor leptons (e,μ) + 2 jets final states
 - ✓ Heavy Dirac neutrino N_R : opposite signed leptons
 - ✓ Heavy Majorana neutrino N_R : 50% same (SS) and 50% opposite (OS) signed leptons
- Background in OS final state:
 - ✓ Dominated by SM top & Z+jets: estimated using MC
 - ✓ Small contribution from diboson and W+jets
- Background in SS final state:
 - ✓ SM diboson and SM Z+jets (for ee only due to charge misidentification)
 - Charge misidentification from control sample
 - ✓ Largest bg from fake leptons (~60%)
 - estimated using fake factors from data

Heavy Neutrino and Right Handed W

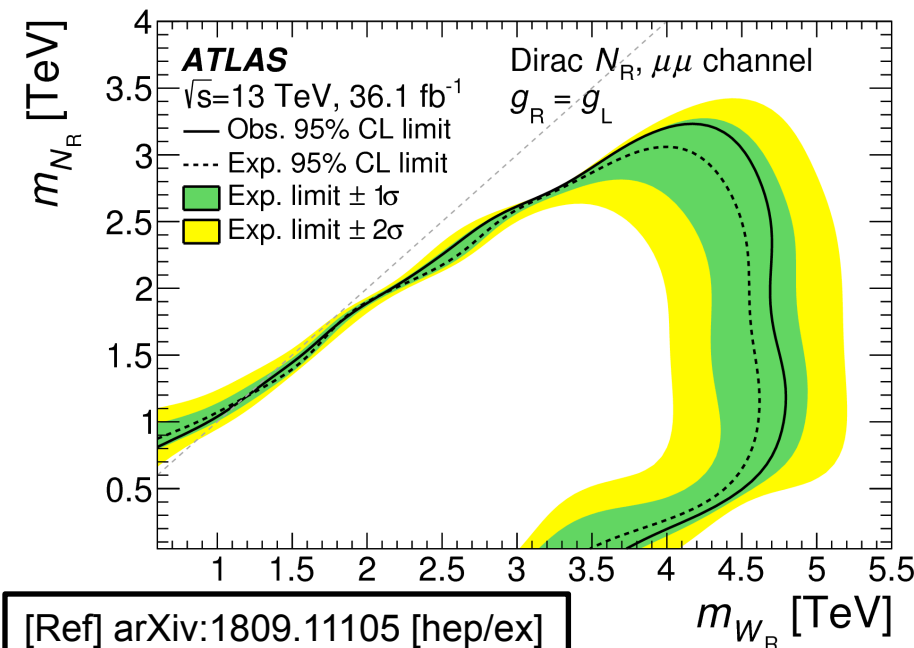
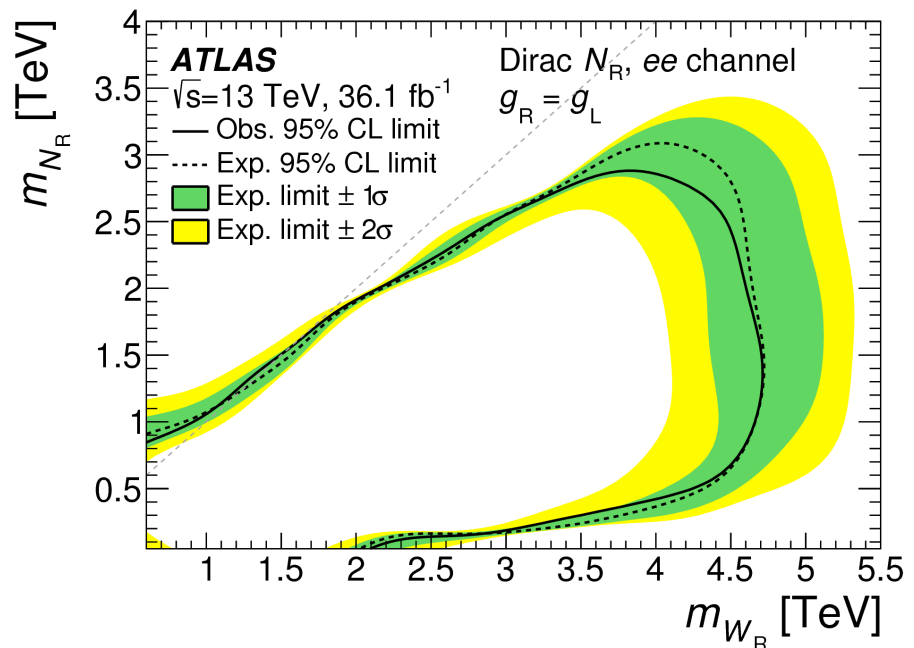
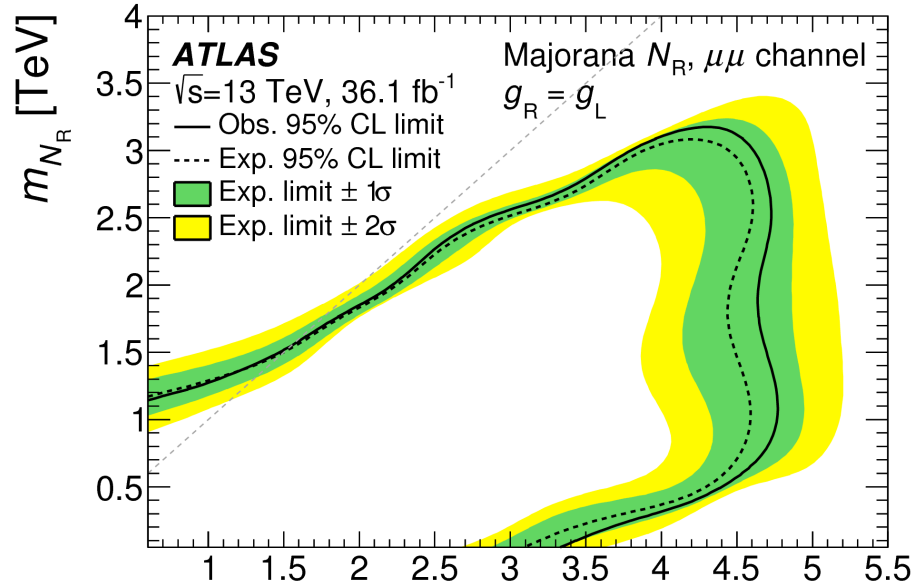
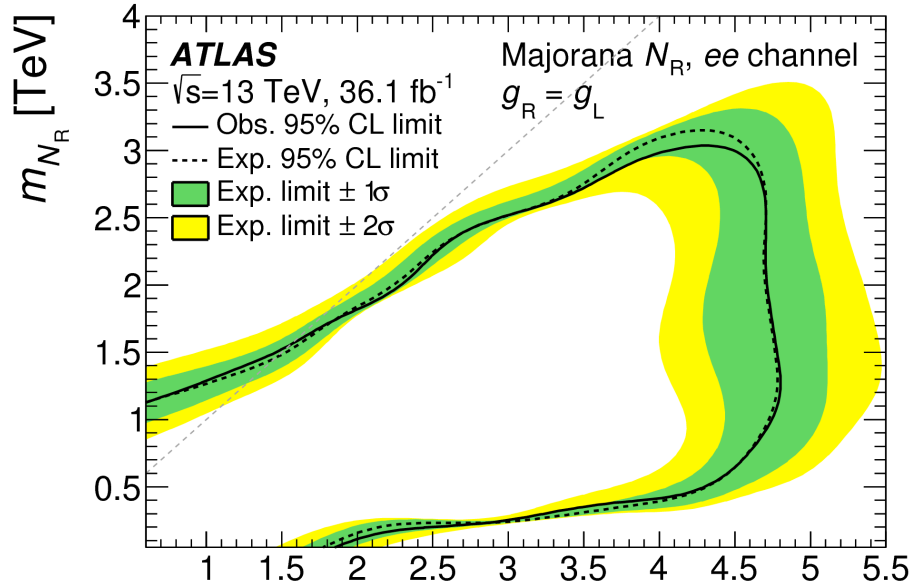
- Defined signal (SR) and control (CR) region:
 - ✓ Events in CR to constrain the background estimation
- Signal extraction: Simultaneous binned likelihood fits to various kinematic variables of selected events in the signal and control regions
 - ✓ Simultaneous fit to SS and OS events for Majorana neutrino scenario
- Systematic uncertainties taken into account as nuisance parameters in fits



H_T : scalar sum of p_T of selected lepton pairs and two most energetic jets

[Ref] arXiv:1809.11105 [hep/ex]

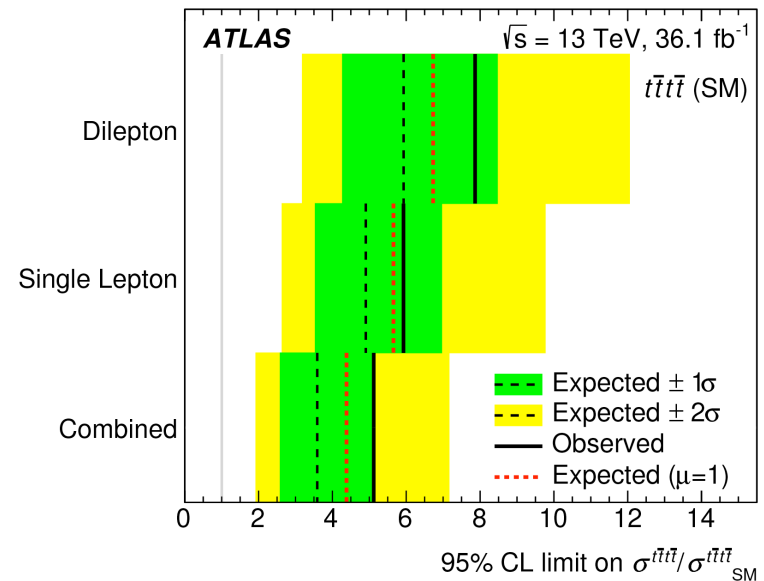
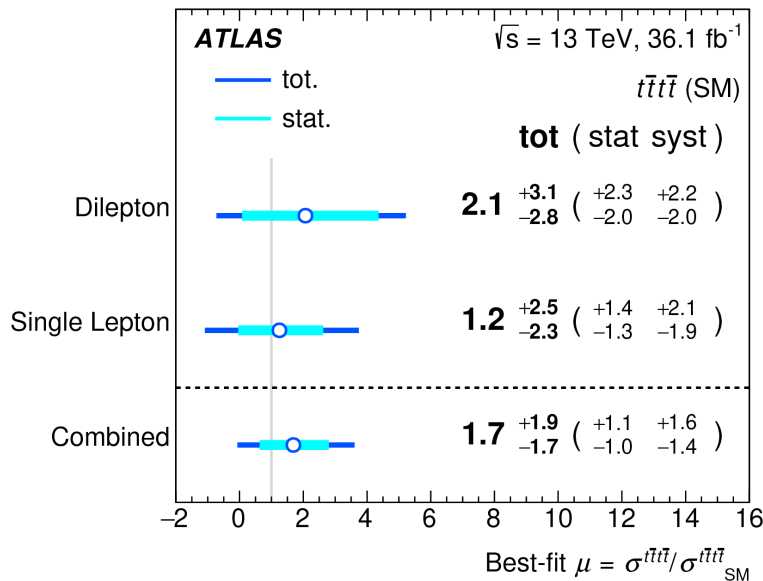
Heavy Neutrino and Right Handed W



[Ref] arXiv:1809.11105 [hep/ex]

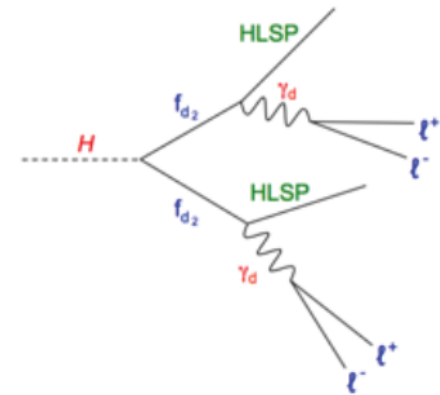
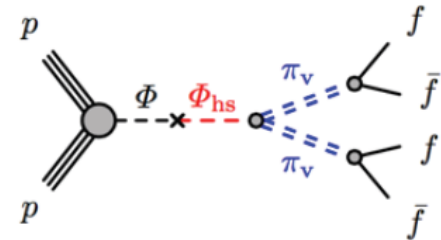
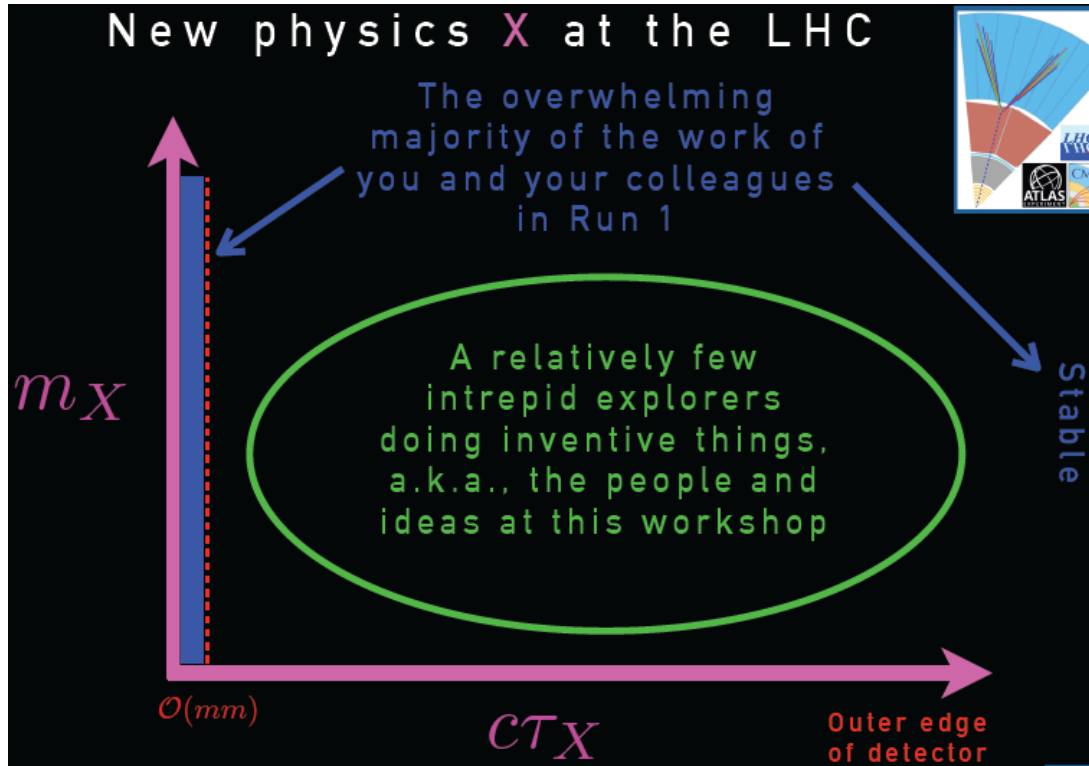
Four Top Quark Production

- SM 4 quark production ($\sigma \sim 9.2 \text{ fb}$), can be significantly enhanced by NP
- Final state: 1 or 2 W boson decay leptonically
 - ✓ Single or dilepton + MET
 - ✓ high multiplicity of jets & b-jets
 - ✓ Hadronic top candidates tagged with large-R jets
- Dominated by SM top+jets production
 - ✓ Based on b-jet fake probability: assuming no correlation with jet multiplicity
- Distinguish signal from background using H_T
 - ✓ H_T : scalar sum of the jet P_T
- See talk by Leonid Serkin at this workshop for details



[Ref] arXiv:1811.02305[hep/ex]

Long-lived Neutral Particles (LLP)



- Long lived neutral particles predicted by NP: Hidden/Dark sectors, SUSY
- Very unconventional experimental signatures, Eg:
 - Jets associated with vertex significant away from the collision point
 - Narrow jets with little energy deposition in the EM calorimeter, and no inner detector tracks
 - Lepton jet: collinear jet-like structure containing leptons/pions

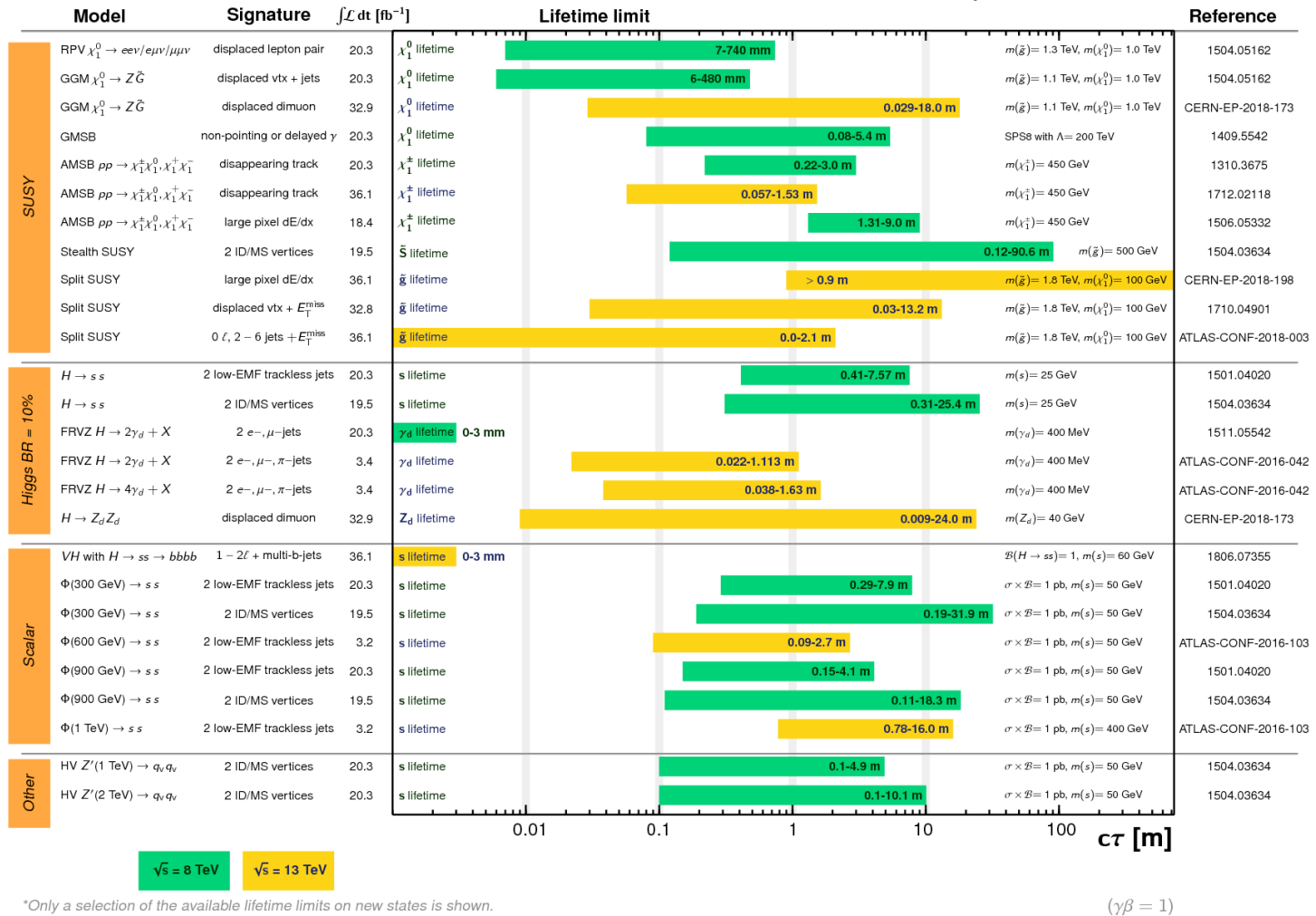
Searches for LLP at ATLAS

ATLAS Long-lived Particle Searches* - 95% CL Exclusion

Status: July 2018

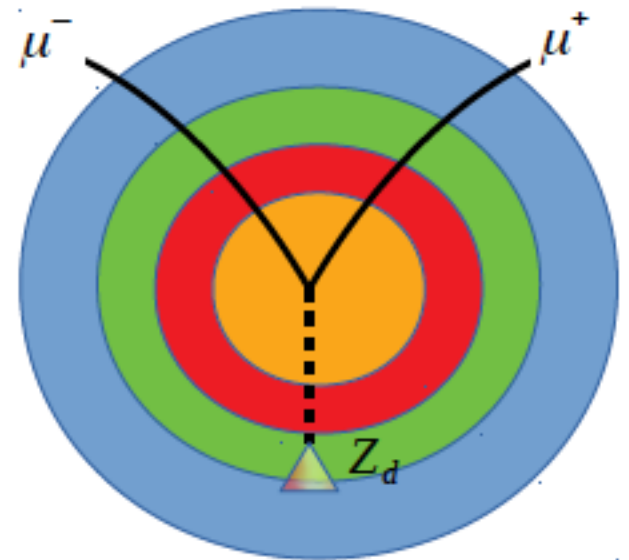
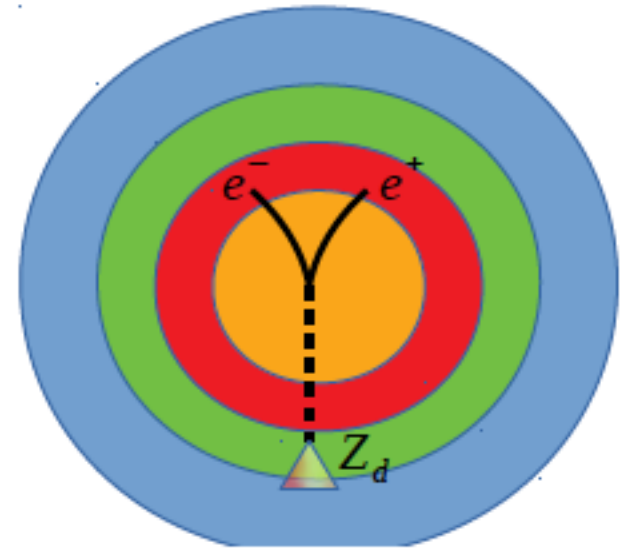
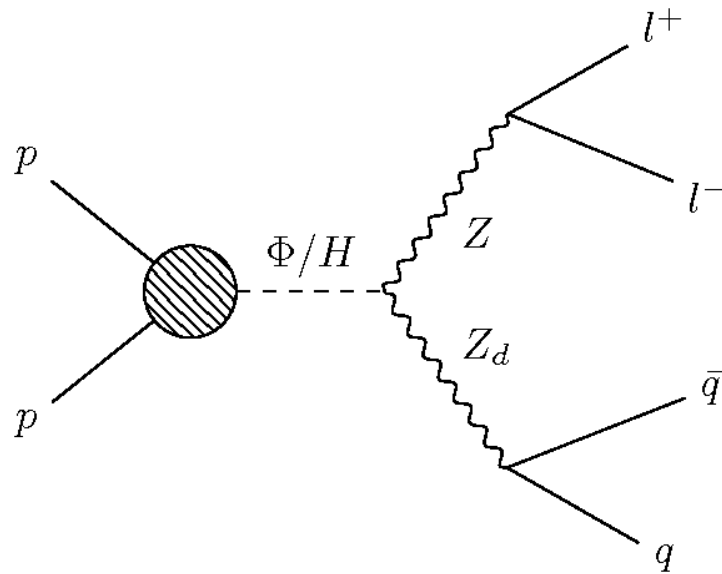
ATLAS Preliminary

$$\int \mathcal{L} dt = (3.2 - 36.1) \text{ fb}^{-1} \quad \sqrt{s} = 8, 13 \text{ TeV}$$



All searches are for pair production of LLP so far

Single LLP production with Z boson

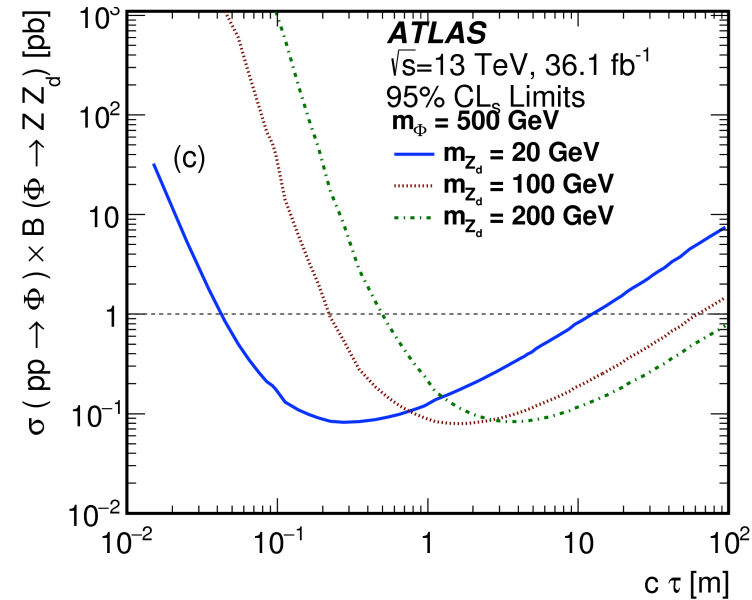
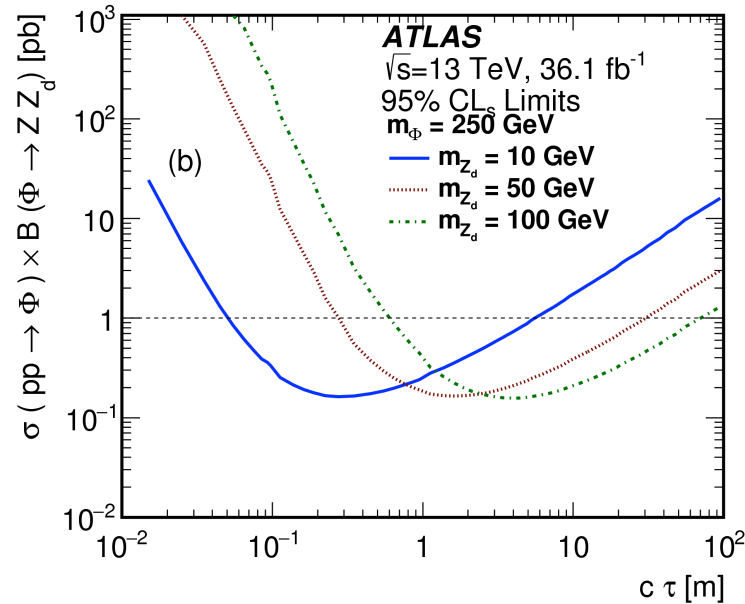
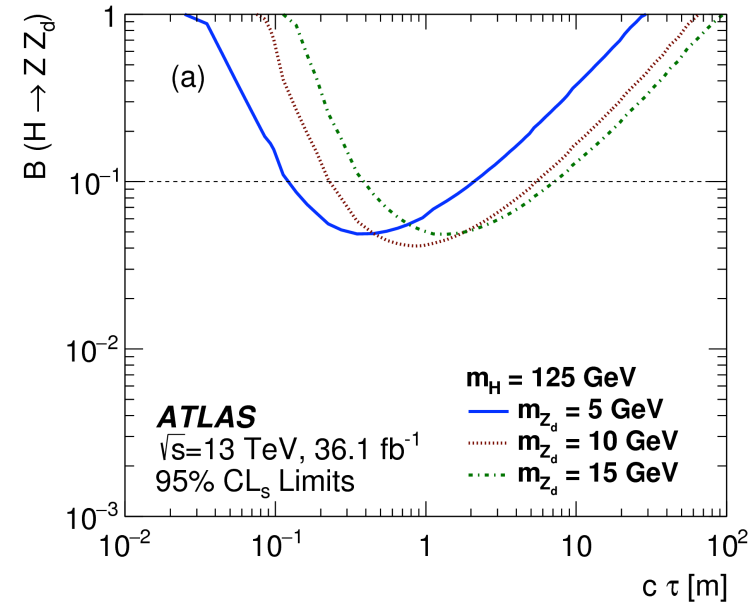


- Single production of LLP predicted in NP scenarios
- General search with a very unique experiment signature: Displaced jet
- Dominated bg from Z +jets (jet fakes LLP signal)
 - ✓ Data driven approach for bg estimate
 - ✓ Measuring fake jet fake probability using W +jets
- Counting experiment, different E_T cut for m_Φ
 - ✓ UL as a function of m_Φ , m_{Z_d} and lifetime of Z_d

Single LLP production with Z boson

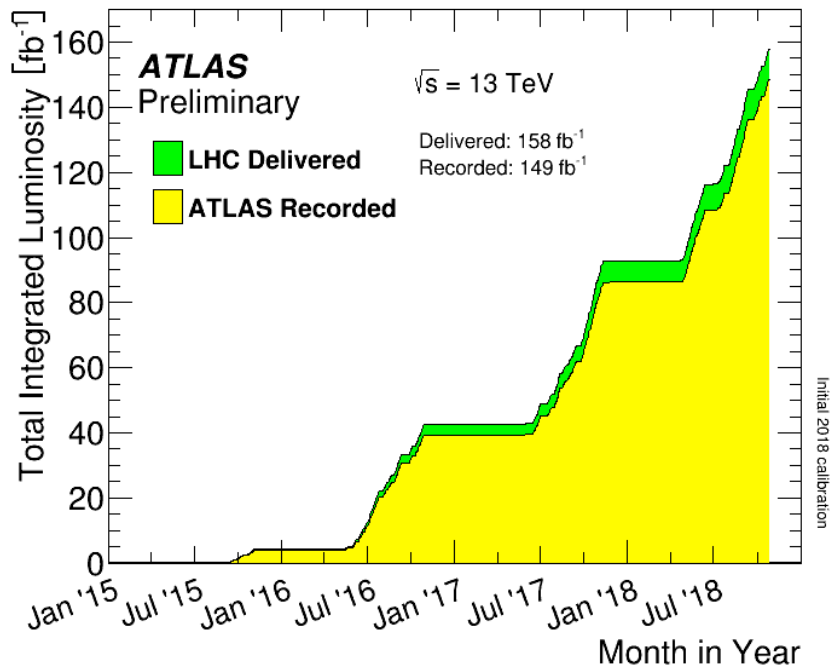
Minimum jet E_T	40 GeV	60 GeV	80 GeV
Background	175 \pm 22	33.0 \pm 4.4	13.2 \pm 3.5
Data	158	35	16
Expected UL	65	17	10
Observed UL	50	18	13

[Ref] arXiv:1811.02542 [hep/ex]



Conclusion

- Very broad and rich exotic physics program at ATLAS
 - ✓ Only a few selected new results were reported here
 - ✓ Start to probe many possible new particles/NP scenario at TeV scale
 - ✓ Strong constraint for some NP scenario
- Current results still dominated by statistical limitation
 - ✓ Expect significantly better physics reach with more data (HL-LHC)



ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

Status: July 2018

$\sqrt{s} dt = (3.2 - 79.8) \text{ fb}^{-1}$

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

Model	ℓ, γ	Jets [†]	E_{miss}^T	$\sqrt{s} dt [\text{fb}^{-1}]$	Limit	Reference
Extra dimensions	ADD $G_{\mu\nu} + g/\rho$	0 e, μ	1-4	Yes	36.1	M_{Pl} 7.7 TeV
	ADD non-resonant $\gamma\gamma$	2 e, μ	-	-	36.7	M_{Pl} 8.6 TeV
	ADD GBH	-	2j	-	37.0	M_{Pl} 8.9 TeV
	ADD BH high Σp_T	$\geq 1 e, \mu$	$\geq 2j$	-	3.2	M_{Pl} 8.2 TeV
	ADD BH multiplet	-	$\geq 3j$	-	3.6	M_{Pl} 9.55 TeV
	RS1 $G_{\mu\nu} \rightarrow \gamma\gamma$	2 e, μ	-	-	36.7	G_{UV} mass 4.1 TeV
	Bulk RS $G_{\mu\nu} \rightarrow WW/ZZ$	multi-channel	-	-	36.1	G_{UV} mass 2.3 TeV
	Bulk RS $G_{\mu\nu} \rightarrow tt$	1 e, μ	$\geq 1 b, \geq 1 \text{ JJ}$	Yes	36.1	$f/m = 15\%$ 1.8 TeV
	ZUED / RPP	1 e, μ	$\geq 2 b, \geq 3j$	Yes	36.1	KK mass 1.8 TeV
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	2 e, μ	-	-	36.1	Z' mass 2.42 TeV
	SSM $Z' \rightarrow \tau\tau$	2 e, μ	-	-	36.1	Z' mass 2.1 TeV
	Leptophobic $Z' \rightarrow bb$	1 e, μ	$\geq 1 b, \geq 1 \text{ JJ}$	Yes	36.1	Z' mass 3.0 TeV
	SSM $W' \rightarrow \ell\nu$	1 e, μ	-	Yes	79.8	W' mass 5.8 TeV
	SSM $W' \rightarrow \tau\nu$	1 e, μ	-	Yes	36.1	W' mass 3.7 TeV
	HVT $V' \rightarrow WW/ZZ$ model B	0 e, μ	2J	-	79.8	V' mass 4.15 TeV
	HVT $V' \rightarrow WW/ZZ$ model B	multi-channel	-	-	36.1	V' mass 2.93 TeV
	LRSM $W'_2 \rightarrow \nu\nu$	multi-channel	-	-	36.1	W' mass 3.25 TeV
CI	CI $qqqq$	-	2j	-	37.0	A 21.8 TeV ζ_{CI}
	CI $\ell\ell qq$	2 e, μ	-	-	36.1	A 40.6 TeV ζ_{CI}
	CI $\ell\ell\ell\ell$	$\geq 1 e, \mu$	$\geq 1 b, \geq 1j$	Yes	36.1	A 2.57 TeV
DM	Axial vector mediator (Dirac DM)	0 e, μ	1-4	Yes	36.1	m_{DM} 1.55 TeV
	Colored scalar mediator (Dirac DM)	0 e, μ	1-4	Yes	36.1	m_{DM} 1.67 TeV
	VV_{ij} EFT (Dirac DM)	0 e, μ	1, 4, $\geq 3j$	Yes	3.2	700 GeV
LO	Scalar LO 1 st gen	2 e, μ	$\geq 2j$	-	3.2	LO mass 1.1 TeV
	Scalar LO 2 nd gen	1 e, μ	$\geq 2j$	-	3.2	LO mass 1.05 TeV
	Scalar LO 3 rd gen	1 e, μ	$\geq 1 b, \geq 3j$	Yes	20.3	LO mass 640 GeV
Excited fermion-heavy quarks	VLO $7T \rightarrow Wj/Zj/Wb + X$	multi-channel	-	-	36.1	T mass 1.37 TeV
	VLO $6B \rightarrow Wj/Zb + X$	multi-channel	-	-	36.1	B mass 1.34 TeV
	VLO $T_{13} T_{13} T_{13} \rightarrow Wt + X$	$2(SS)/23 e, \mu, \tau, \geq 1j$	Yes	36.1	T_{13} mass 1.64 TeV	
	VLO $Y \rightarrow Wb + X$	1 e, μ, τ	$\geq 1 b, \geq 1j$	Yes	3.2	Y mass 1.44 TeV
	VLO $Q \rightarrow Hb + X$	0 e, μ, τ, γ	$\geq 1 b, \geq 1j$	Yes	79.8	Q mass 1.21 TeV
	VLO $QQ \rightarrow Wb + X$	1 e, μ, τ	$\geq 4j$	Yes	20.3	Q mass 690 GeV
Excited fermion-lepton	Excited quark $q^* \rightarrow q\gamma$	-	2j	-	37.0	q^* mass 6.0 TeV
	Excited quark $q^* \rightarrow qg$	1 e, μ, τ	1j	-	36.7	q^* mass 5.3 TeV
	Excited quark $b^* \rightarrow b\gamma$	-	1 b, 1j	-	36.1	b^* mass 2.6 TeV
	Excited lepton ℓ^*	3 e, μ, τ	-	-	20.3	ℓ^* mass 3.8 TeV
	Excited lepton ν^*	3 e, μ, τ	-	-	20.3	ν^* mass 1.8 TeV
Other	Type III Seesaw	1 e, μ, τ	$\geq 2j$	Yes	79.8	N^c mass 500 GeV
	LRSM Majorana ν	2 e, μ, τ	2j	-	20.3	N^c mass 870 GeV
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$	2, 3, 4 e, μ, τ, γ (SS)	-	-	36.1	$H^{\pm\pm}$ mass 400 GeV
	Higgs triplet $H^{\pm\pm} \rightarrow \tau\tau$	3 e, μ, τ	-	-	20.3	$H^{\pm\pm}$ mass 400 GeV
	Monotop (non-res prod)	1 e, μ, τ	1 b	Yes	20.3	g_{top} (1/1000) particle mass 657 GeV
	Multi-charged particles	20.3	-	-	20.3	monocharged particle mass 785 GeV
	Magnetic monopoles	-	-	-	7.0	monopole mass 1.34 TeV

*Only a selection of the available mass limits on new states or phenomena is shown.
[†]Small-radius (large-radius) jets are denoted by the letter j (\bar{j}).

Backup

The ATLAS Detector

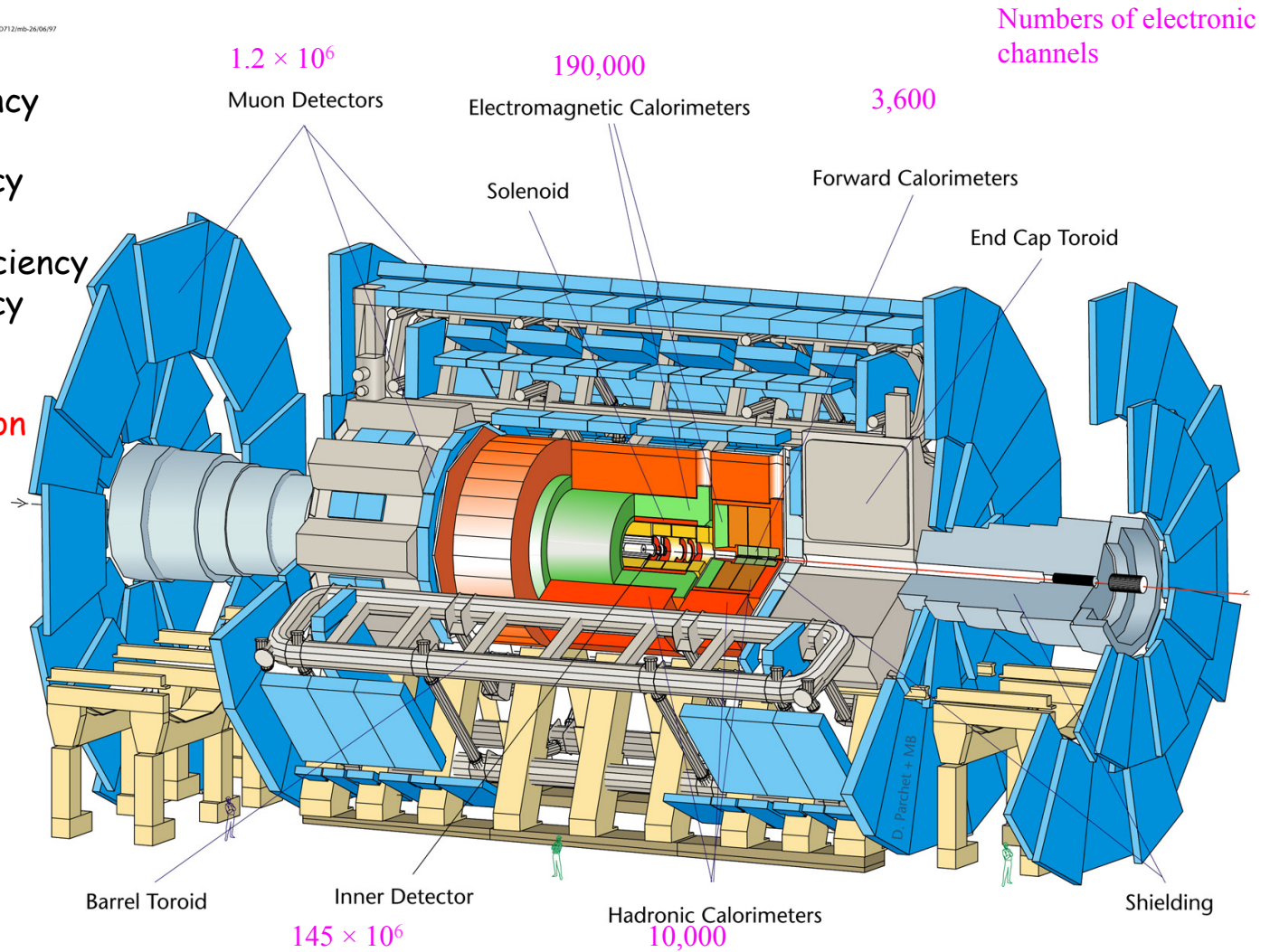
0712mb-26/06/97

e: ~75 - 90% efficiency

muon: ~90% efficiency

b tagging: ~57% efficiency
 ~ 0.2% fake efficiency
 from light jets

Efficiency & resolution
 depends on the
 selection criteria



46 m long, Overall weight: 7000 Tons

Excellent reconstruction efficiency and resolution:
 Electron, muon, track, jets, b-tagging & missing transverse energy