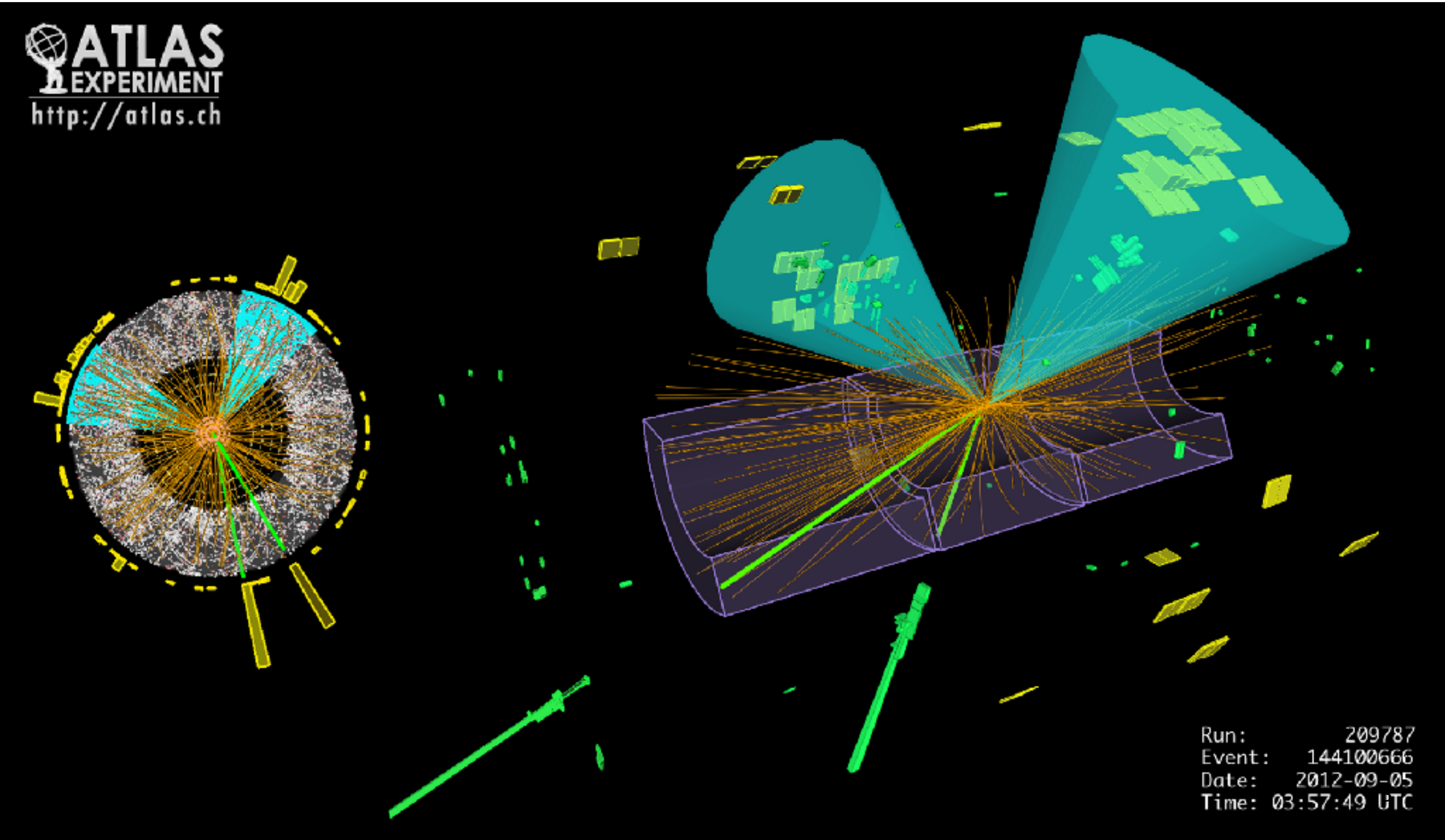
Missing Transverse Energy Reconstruction at the LHC : the ATLAS case

Paolo Francavilla - LPNHE
Dissecting the LHC results
LPNHE - Paris - 20/21 April 2017

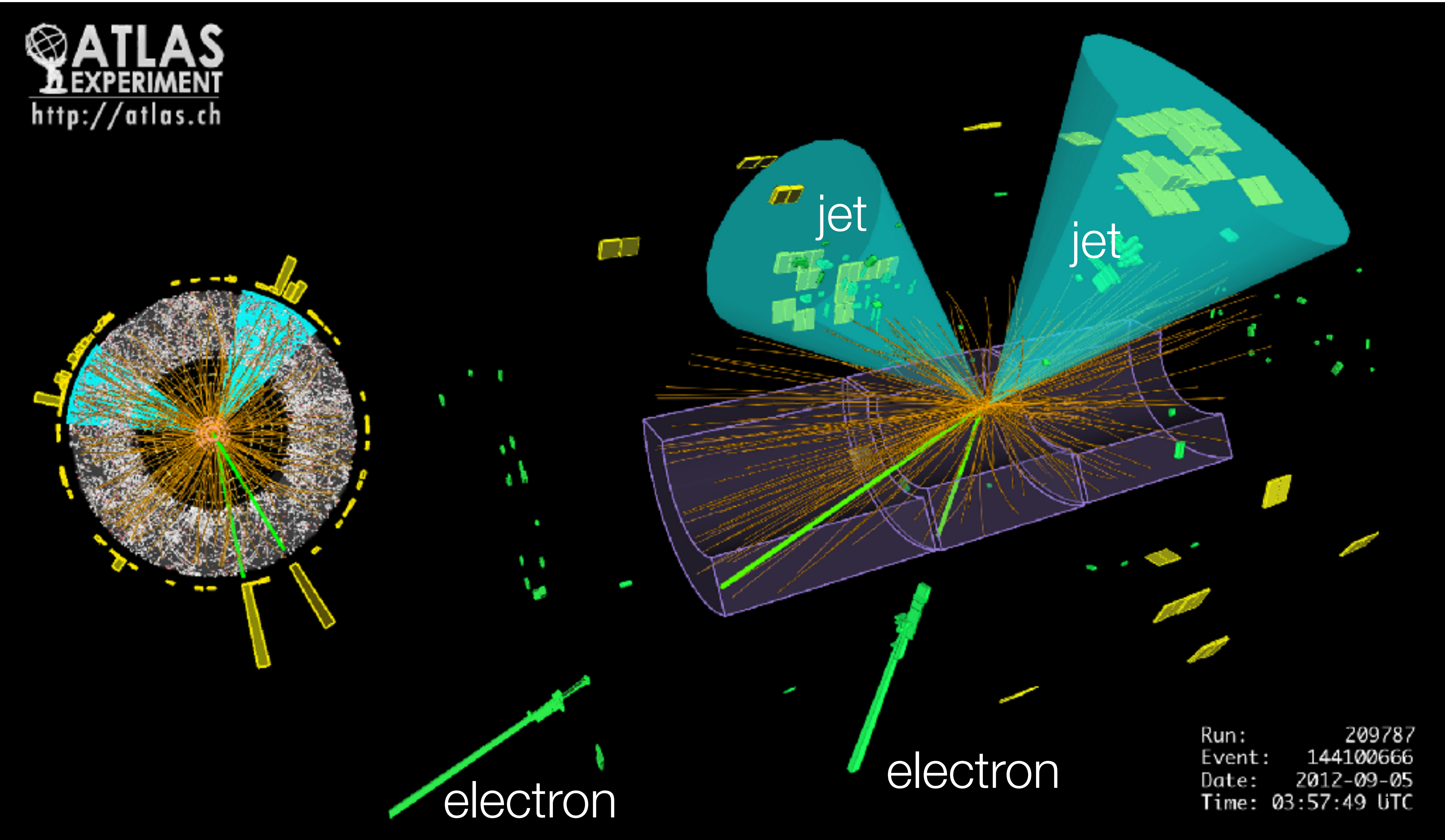
Since we are dissecting the LHC results…

- I will try to do my part, dissecting the MET
- aka: why we did not find (yet) an astonishing excess of events when we try to unbalance them.

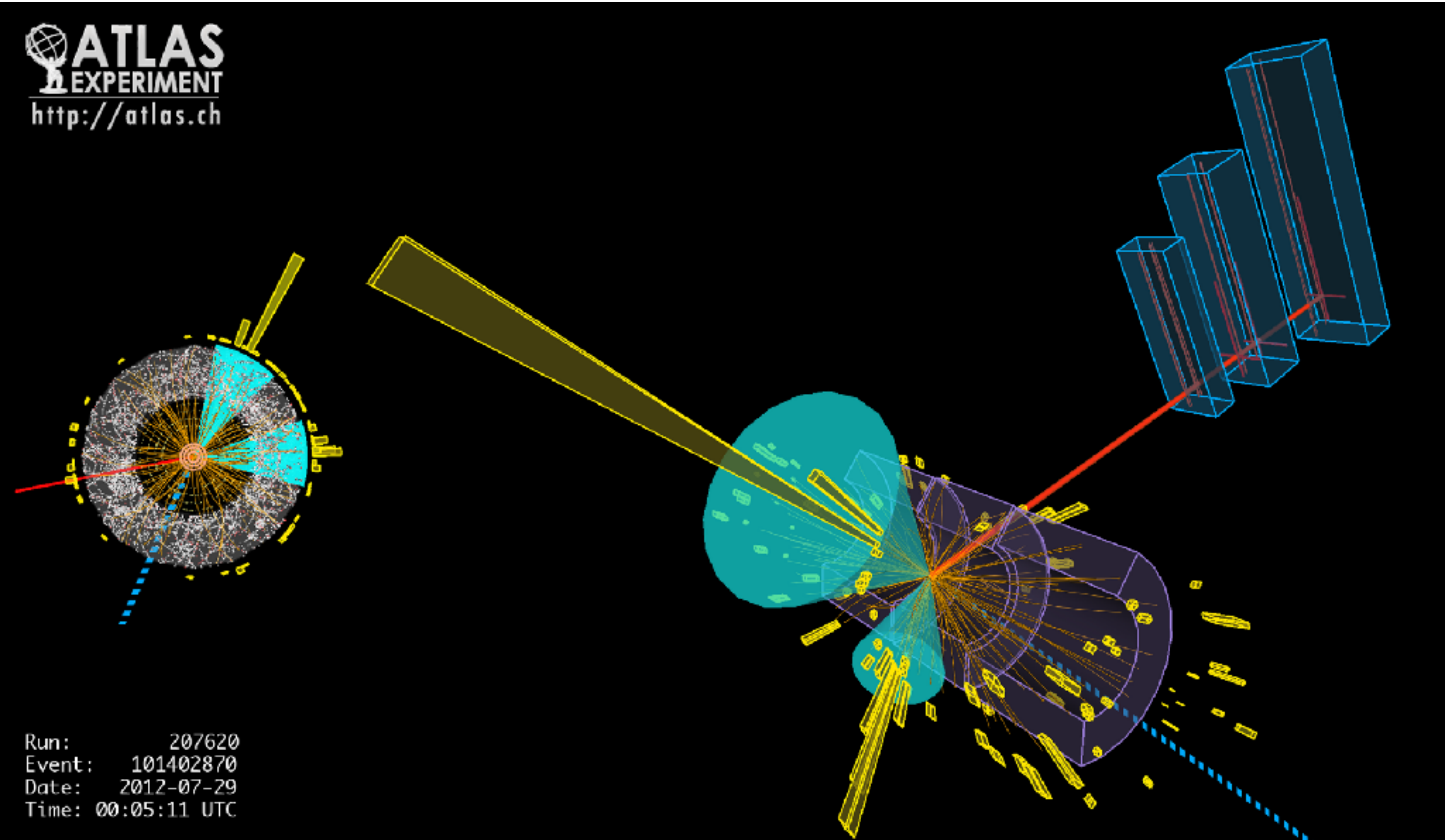
An event display…



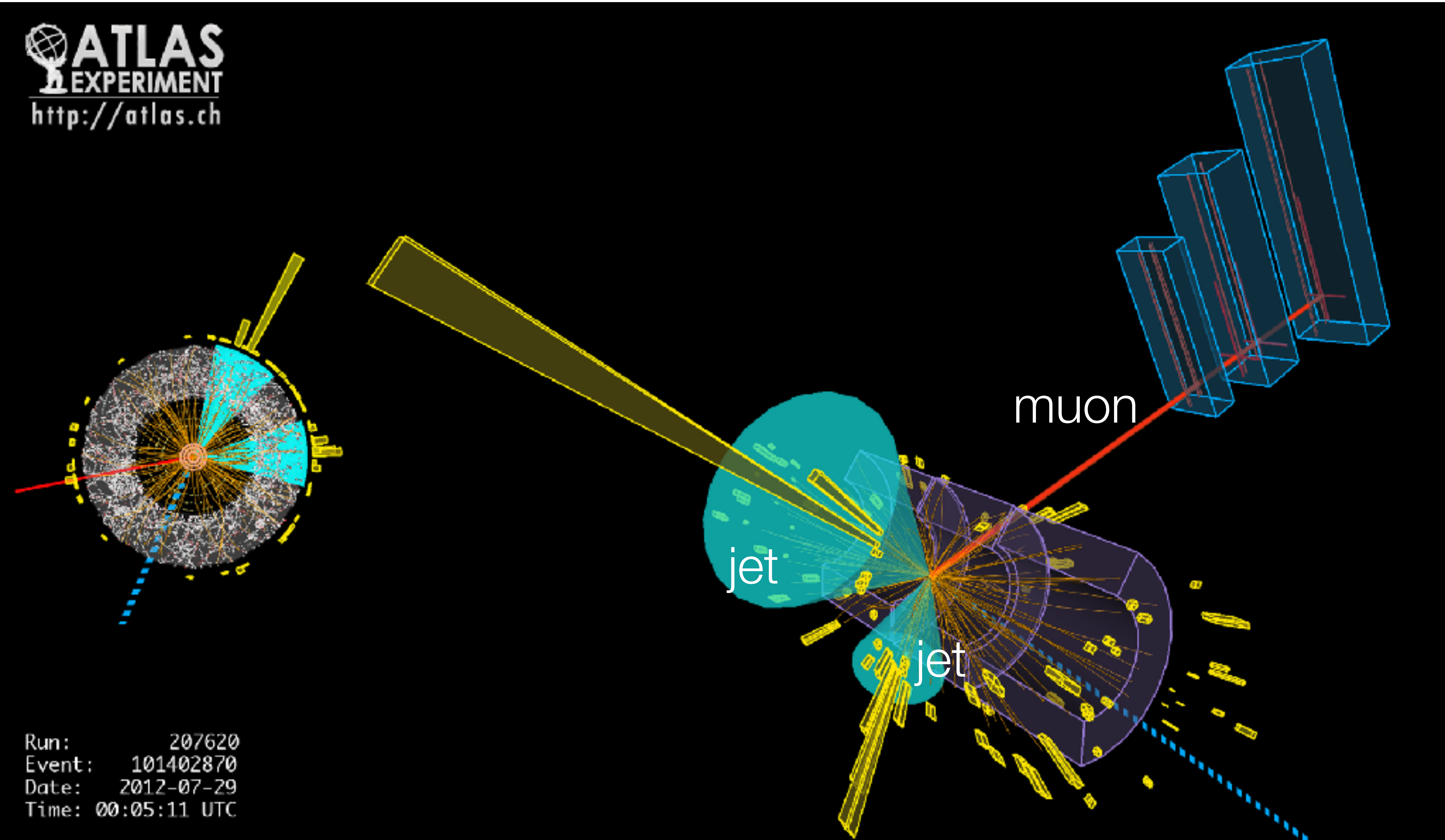
An event display…



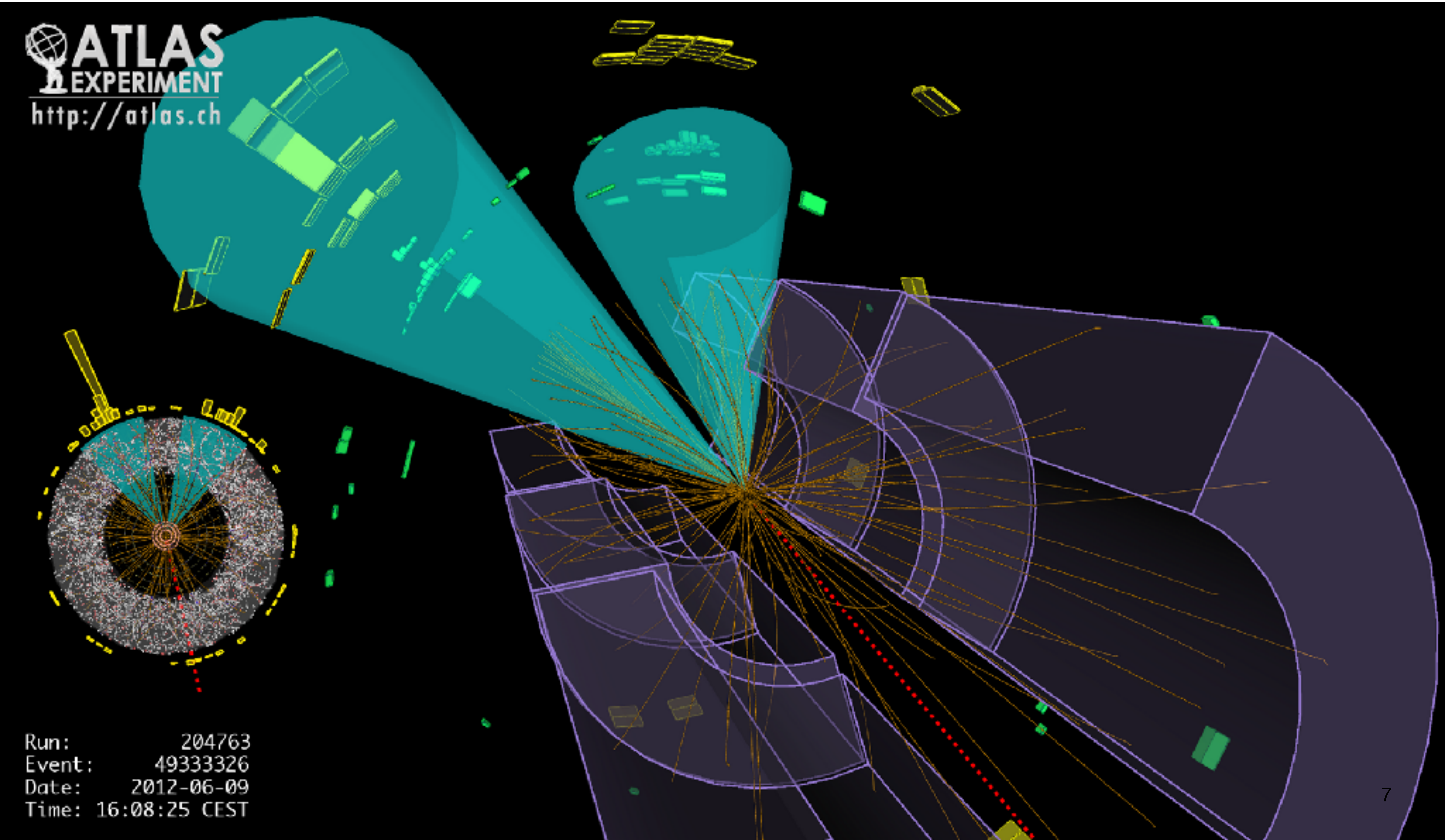
Another event display…



Another event display…



…and here the last!



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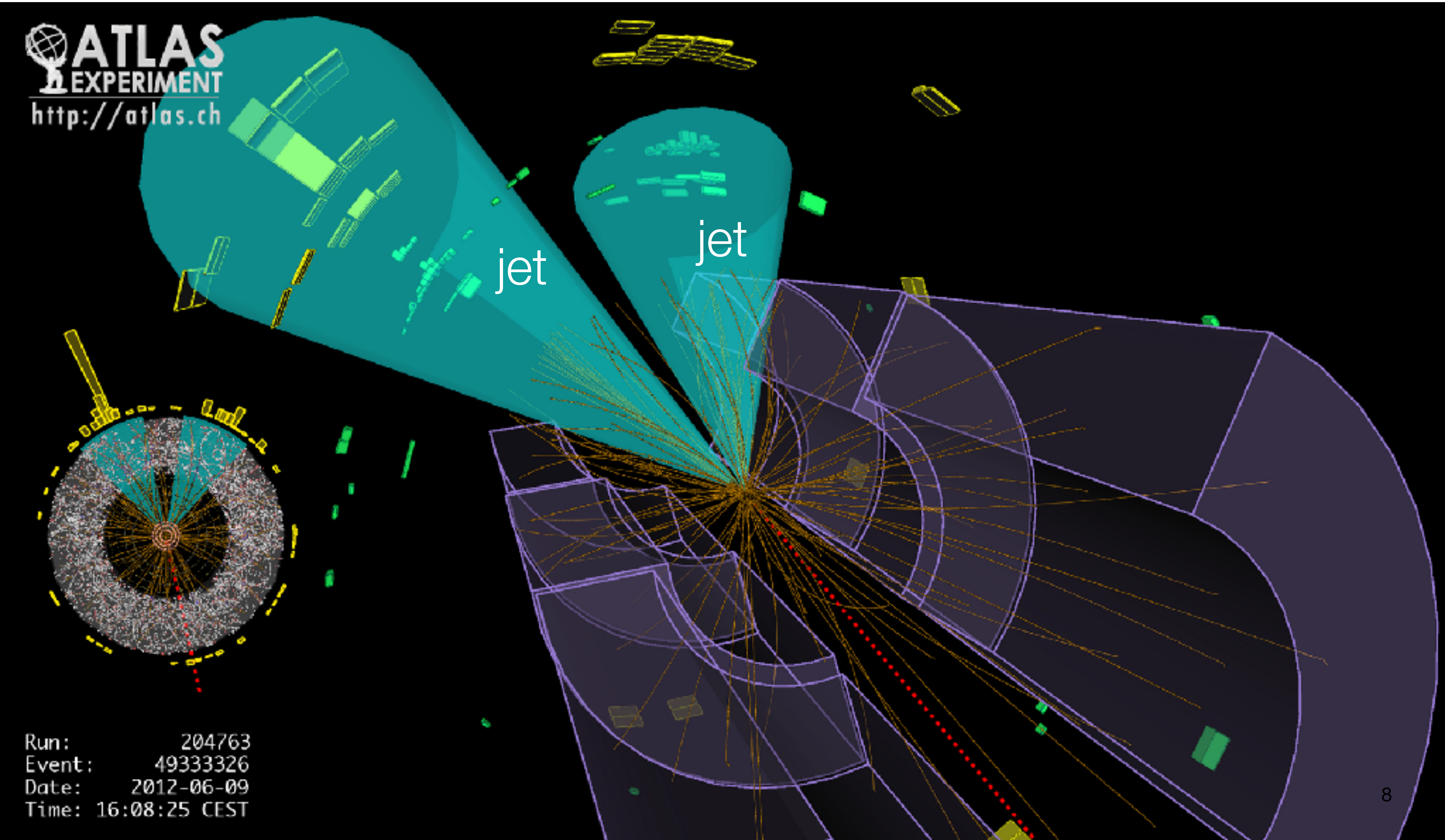

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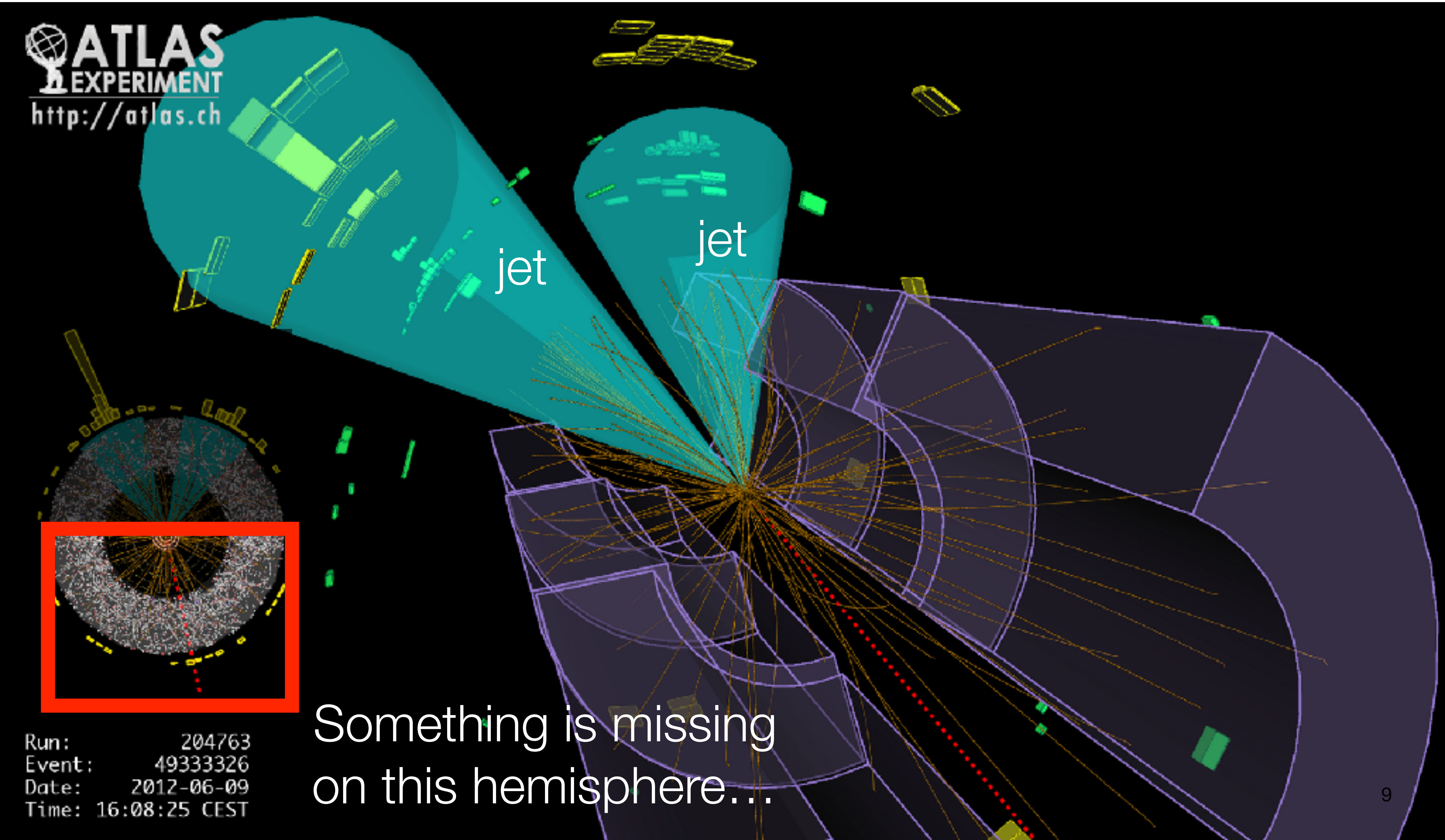
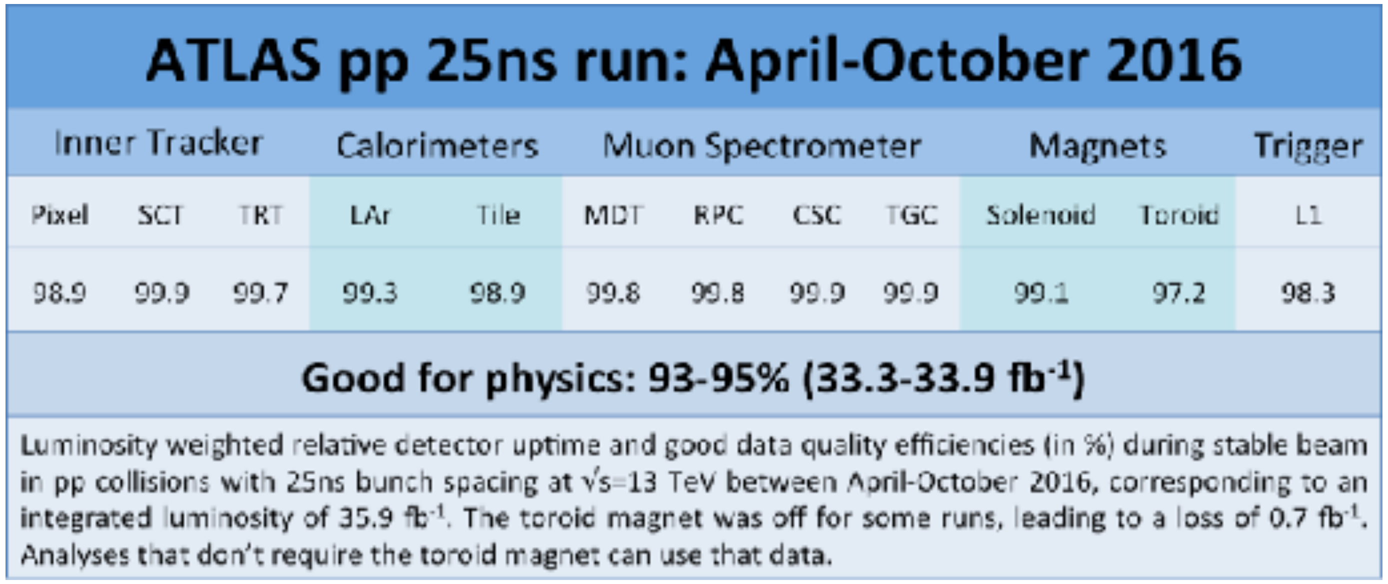


Something is missing
on this hemisphere…

Why?

- Problem (hole) with the detector? - Several check to make sure we are not encountering problematic issues



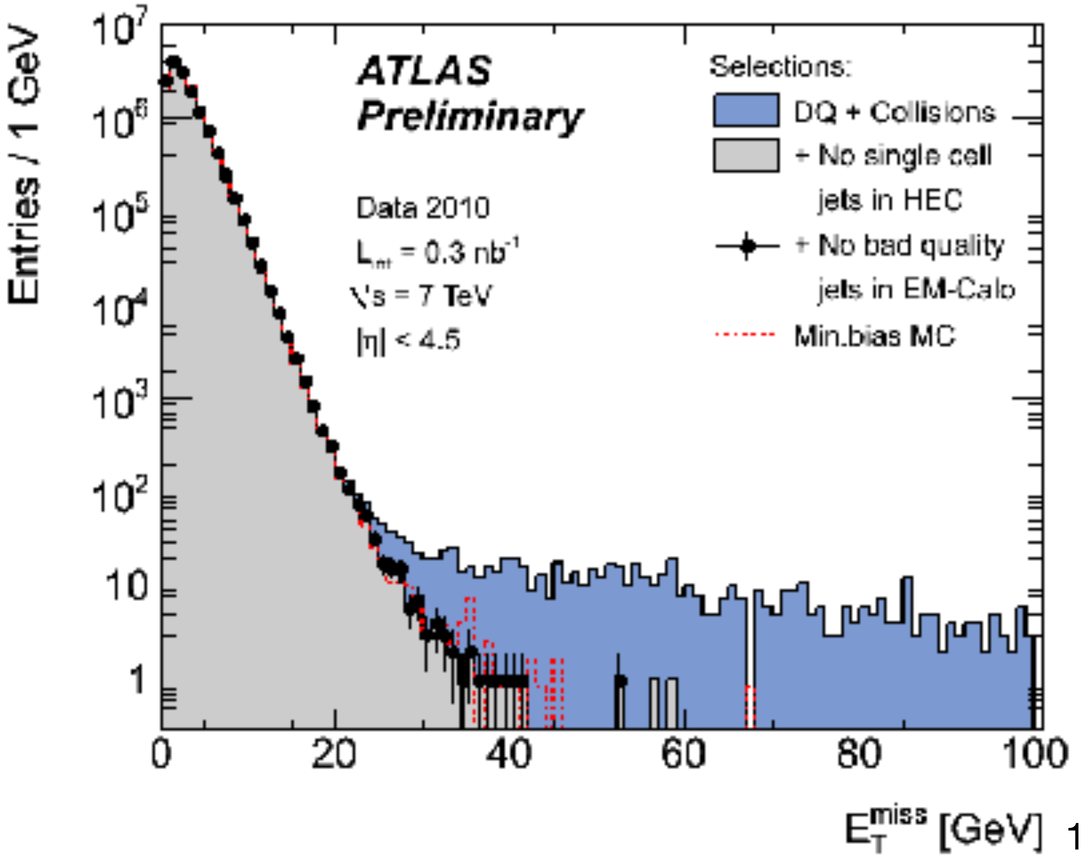
ATLAS pp 25ns run: April-October 2016

Inner Tracker			Calorimeters		Muon Spectrometer				Magnets		Trigger
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid	L1
98.9	99.9	99.7	99.3	98.9	99.8	99.8	99.9	99.9	99.1	97.2	98.3

Good for physics: 93-95% (33.3-33.9 fb^{-1})

Luminosity weighted relative detector uptime and good data quality efficiencies (in %) during stable beam in pp collisions with 25ns bunch spacing at $\sqrt{s}$=13 TeV between April-October 2016, corresponding to an integrated luminosity of 35.9 fb^{-1}. The toroid magnet was off for some runs, leading to a loss of 0.7 fb^{-1}. Analyses that don't require the toroid magnet can use that data.

- Only events in which all the detectors had good quality of data, and not bad jets, are used in analysis

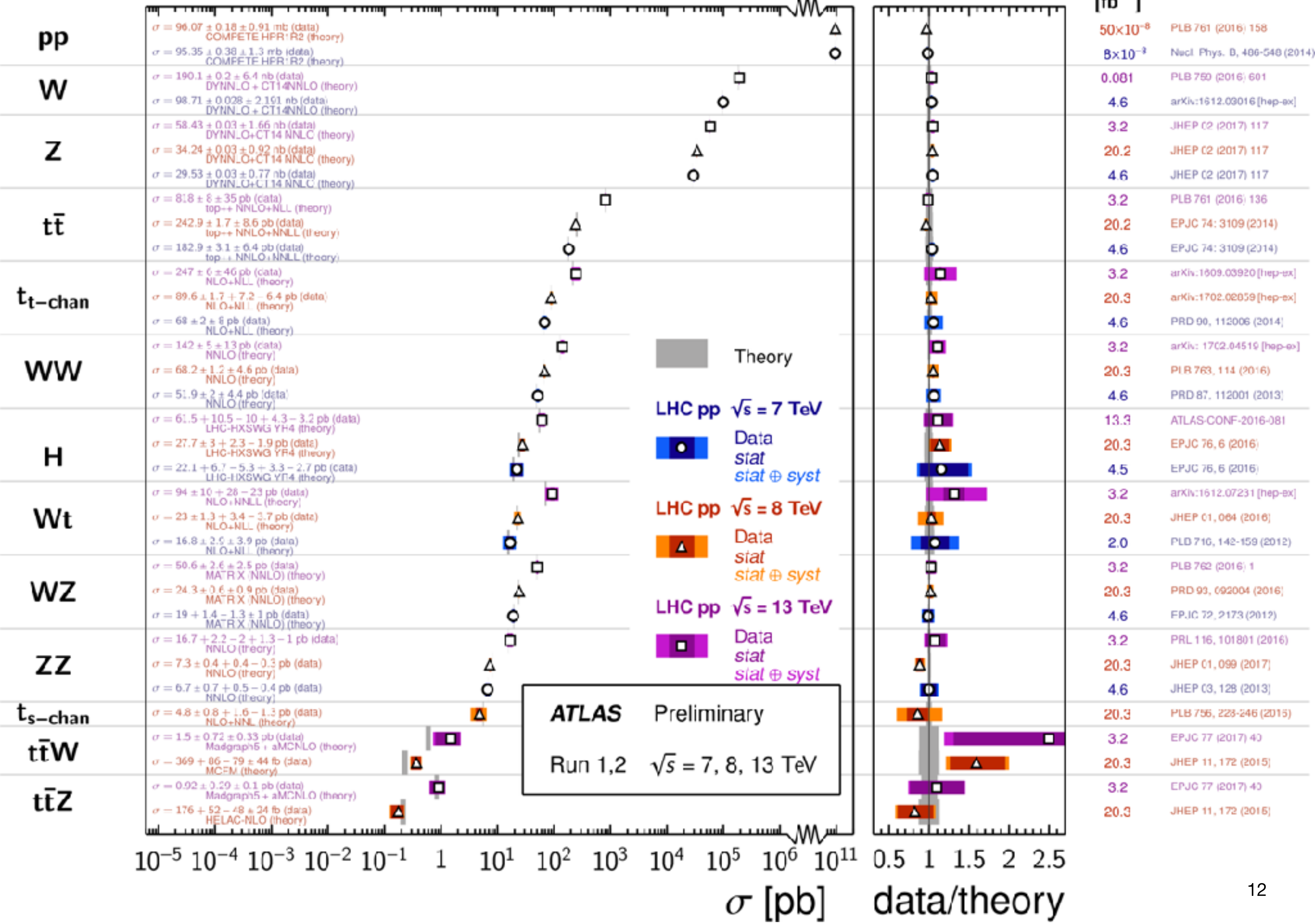


Why?

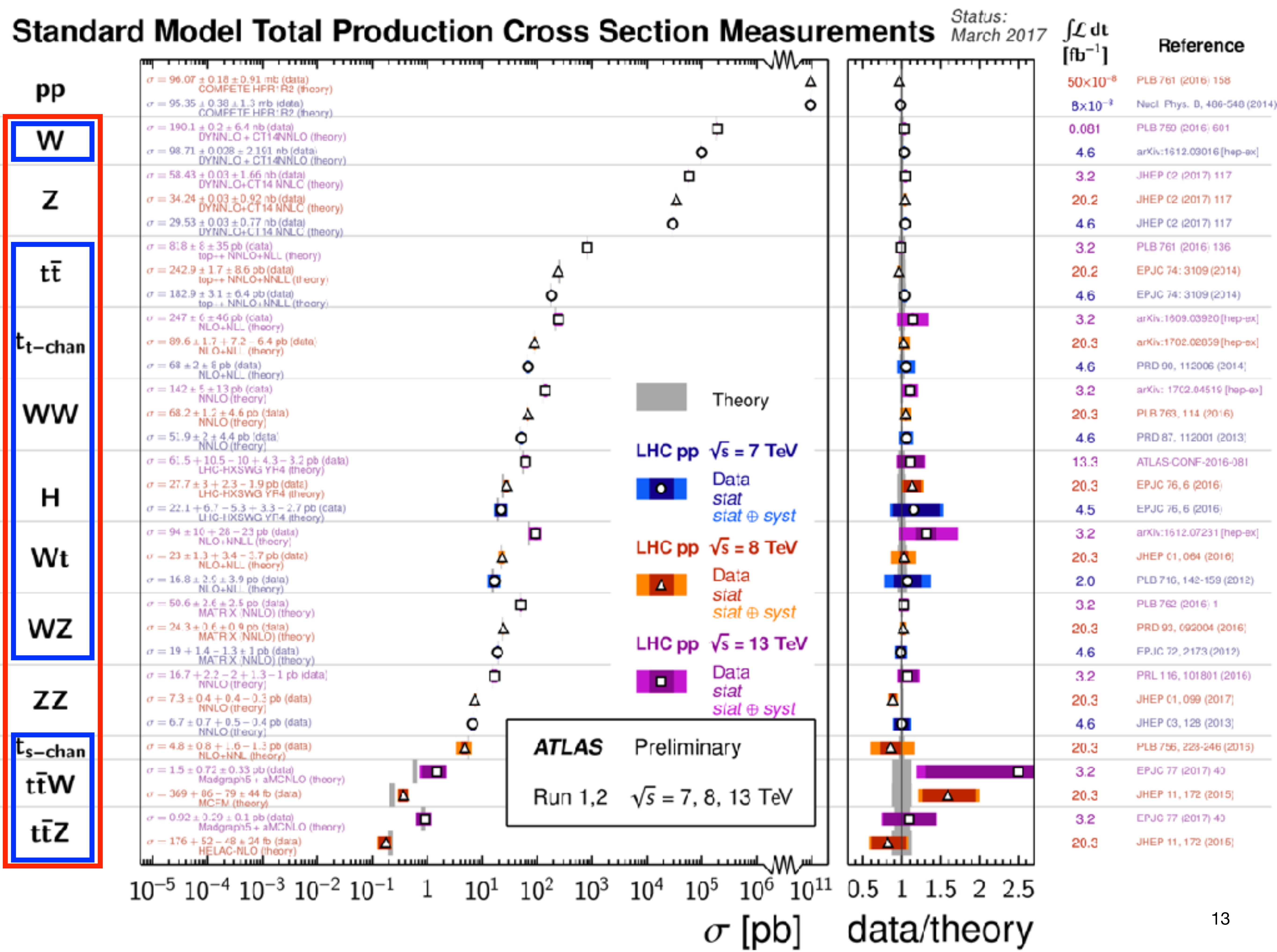
- **Physics origine: neutrinos produced by SM processes:**
- W(lv) in W+jets, di-boson, multi-boson, single top, ttbar+X, H(WW), WH, etc…
  - Note that BR(W→lv) ~ 32.4%
- Z(vv) in Z+jets, di-boson, multi-boson, H(ZZ), ZH, etc…
  - Note that BR(Z→vv) ~ 20%

Standard Model Total Production Cross Section Measurements

Status: March 2017



Standard Model Total Production Cross Section Measurements



Why?

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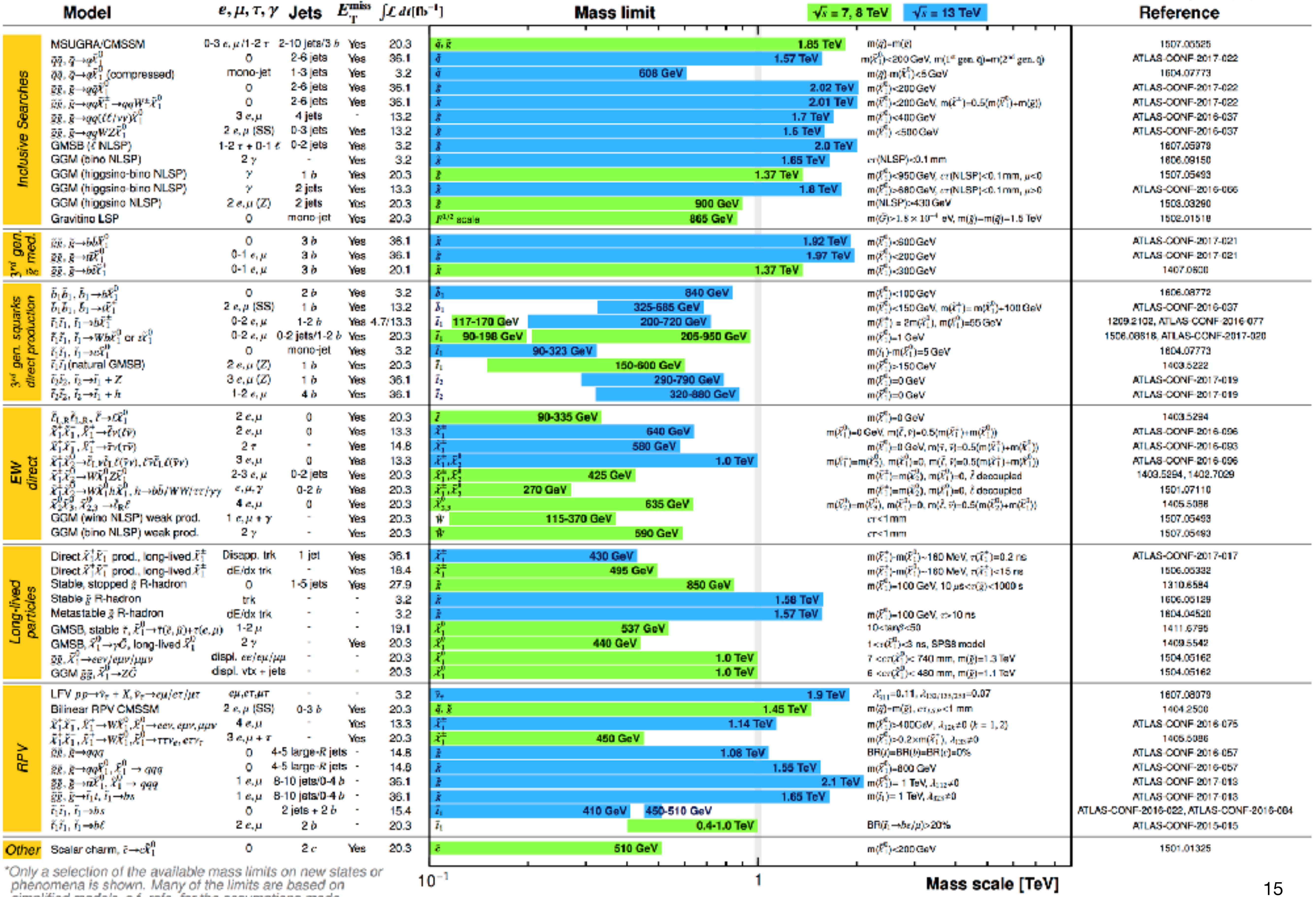
- W(lv) in W+jets, di-boson, multi-boson, single top, ttbar+X, H(WW), WH, etc…
  - Note that BR(W→lv) ~ 32.4%
- Z(vv) in Z+jets, di-boson, multi-boson, H(ZZ), ZH, etc…
  - Note that BR(Z→vv) ~ 20%
- **Physics origine: New physics with weakly interacting particles**
  - Dark Matter candidates
  - Lightest Supersymmetric Particles
  - etc etc…

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: March 2017

ATLAS Preliminary

$\sqrt{s}$ = 7, 8, 13 TeV



	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ /1-2 τ	2-10 jets/3 b	Yes	20.3	🟩 $\tilde{q}, \tilde{g}$ 1.85 TeV	$m(\tilde{q})=m(\tilde{g})$	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}^0_1$	0	2-6 jets	Yes	36.1	🟦 $\tilde{q}$ 1.57 TeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(1^{st}$ gen. $\tilde{q})=m(2^{nd}$ gen. $\tilde{q})$	ATLAS-CONF-2017-022
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}^0_1$ (compressed)	mono-jet	1-3 jets	Yes	3.2	🟦 $\tilde{q}$ 608 GeV	$m(\tilde{q})-m(\tilde{\chi}^0_1)$<5 GeV	1604.07773
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}^0_1$	0	2-6 jets	Yes	36.1	🟦 $\tilde{g}$ 2.02 TeV	$m(\tilde{\chi}^0_1)$<200 GeV	ATLAS-CONF-2017-022
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}^{\pm}_1\to qqW^{\pm}\tilde{\chi}^0_1$	0	2-6 jets	Yes	36.1	🟦 $\tilde{g}$ 2.01 TeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(\tilde{\chi}^{\pm})=0.5(m(\tilde{\chi}^0_1)+m(\tilde{g}))$	ATLAS-CONF-2017-022
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\nu\nu)\tilde{\chi}^0_1$	3 e,μ	4 jets	-	13.2	🟦 $\tilde{g}$ 1.7 TeV	$m(\tilde{\chi}^0_1)$<400 GeV	ATLAS-CONF-2016-037
	$\tilde{g}\tilde{g}, \tilde{g}\to qqWZ\tilde{\chi}^0_1$	2 e,μ (SS)	0-3 jets	Yes	13.2	🟦 $\tilde{g}$ 1.6 TeV	$m(\tilde{\chi}^0_1)$ <500 GeV	ATLAS-CONF-2016-037
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	3.2	🟦 $\tilde{g}$ 2.0 TeV		1607.05979
	GGM (bino NLSP)	2 γ	-	Yes	3.2	🟦 $\tilde{g}$ 1.65 TeV	$c\tau$(NLSP)<0.1 mm	1606.09150
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	🟩 $\tilde{g}$ 1.37 TeV	$m(\tilde{\chi}^0_1)$<950 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	13.3	🟦 $\tilde{g}$ 1.8 TeV	$m(\tilde{\chi}^0_1)$>680 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	ATLAS-CONF-2016-066
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	🟩 $\tilde{g}$ 900 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	🟩 $F^{1/2}$ scale 865 GeV	$m(\tilde{G})>1.8\times10^{-4}$ eV, $m(\tilde{g})=m(\tilde{q})=1.5$ TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{b}\tilde{\chi}^0_1$	0	3 b	Yes	36.1	🟦 $\tilde{g}$ 1.92 TeV	$m(\tilde{\chi}^0_1)$<600 GeV	ATLAS-CONF-2017-021
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0-1 e,μ	3 b	Yes	36.1	🟦 $\tilde{g}$ 1.97 TeV	$m(\tilde{\chi}^0_1)$<200 GeV	ATLAS-CONF-2017-021
	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{t}\tilde{\chi}^+_1$	0-1 e,μ	3 b	Yes	20.1	🟩 $\tilde{g}$ 1.37 TeV	$m(\tilde{\chi}^0_1)$<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}^0_1$	0	2 b	Yes	3.2	🟦 $\tilde{b}_1$ 840 GeV	$m(\tilde{\chi}^0_1)$<100 GeV	1606.08772
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}^{\pm}_1$	2 e,μ (SS)	1 b	Yes	13.2	🟦 $\tilde{b}_1$ 325-685 GeV	$m(\tilde{\chi}^0_1)$<150 GeV, $m(\tilde{\chi}^{\pm}_1)=m(\tilde{\chi}^0_1)$+100 GeV	ATLAS-CONF-2016-037
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}^{\pm}_1$	0-2 e,μ	1-2 b	Yes	4.7/13.3	$\tilde{t}_1$ 🟩 117-170 GeV 🟦 200-720 GeV	$m(\tilde{\chi}^{\pm}_1) = 2m(\tilde{\chi}^0_1)$, $m(\tilde{\chi}^0_1)$=55 GeV	1209.2102, ATLAS-CONF-2016-077
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}^0_1$ or $t\tilde{\chi}^0_1$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3	$\tilde{t}_1$ 🟩 90-198 GeV 🟩 205-950 GeV	$m(\tilde{\chi}^0_1)$=1 GeV	1506.08616, ATLAS-CONF-2017-020
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}^0_1$	0	mono-jet	Yes	3.2	🟦 $\tilde{t}_1$ 90-323 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}^0_1)$=5 GeV	1604.07773
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	🟩 $\tilde{t}_1$ 150-600 GeV	$m(\tilde{\chi}^0_1)$>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	36.1	🟦 $\tilde{t}_2$ 290-790 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2017-019
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+h$	1-2 e,μ	4 b	Yes	36.1	🟦 $\tilde{t}_2$ 320-880 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	ATLAS-CONF-2017-019
EW *direct*	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}^0_1$	2 e,μ	0	Yes	20.3	🟩 $\tilde{\ell}$ 90-335 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	1403.5294
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	13.3	🟦 $\tilde{\chi}^{\pm}_1$ 640 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^{\pm}_1)+m(\tilde{\chi}^0_1))$	ATLAS-CONF-2016-096
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	14.8	🟦 $\tilde{\chi}^{\pm}_1$ 580 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}^{\pm}_1)+m(\tilde{\chi}^0_1))$	ATLAS-CONF-2016-093
	$\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	13.3	🟦 $\tilde{\chi}^{\pm}_1,\tilde{\chi}^0_2$ 1.0 TeV	$m(\tilde{\chi}^{\pm}_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^{\pm}_1)+m(\tilde{\chi}^0_1))$	ATLAS-CONF-2016-096
	$\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1Z\tilde{\chi}^0_1$	2-3 e,μ	0-2 jets	Yes	20.3	🟩 $\tilde{\chi}^{\pm}_1,\tilde{\chi}^0_2$ 425 GeV	$m(\tilde{\chi}^{\pm}_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, $\tilde{\ell}$ decoupled	1403.5294, 1402.7029
	$\tilde{\chi}^{\pm}_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1h\tilde{\chi}^0_1, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	🟩 $\tilde{\chi}^{\pm}_1,\tilde{\chi}^0_2$ 270 GeV	$m(\tilde{\chi}^{\pm}_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, $\tilde{\ell}$ decoupled	1501.07110
	$\tilde{\chi}^0_2\tilde{\chi}^0_3, \tilde{\chi}^0_{2,3}\to\tilde{\ell}_R\ell$	4 e,μ	0	Yes	20.3	🟩 $\tilde{\chi}^0_{2,3}$ 635 GeV	$m(\tilde{\chi}^0_2)=m(\tilde{\chi}^0_3)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^0_2)+m(\tilde{\chi}^0_1))$	1405.5086
	GGM (wino NLSP) weak prod.	1 e,μ + γ	-	Yes	20.3	🟩 $\tilde{W}$ 115-370 GeV	$c\tau$<1 mm	1507.05493
	GGM (bino NLSP) weak prod.	2 γ	-	Yes	20.3	🟩 $\tilde{W}$ 590 GeV	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^{\pm}_1$	Disapp. trk	1 jet	Yes	36.1	🟦 $\tilde{\chi}^{\pm}_1$ 430 GeV	$m(\tilde{\chi}^{\pm}_1)-m(\tilde{\chi}^0_1)$~160 MeV, $\tau(\tilde{\chi}^{\pm}_1)$=0.2 ns	ATLAS-CONF-2017-017
	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^{\pm}_1$	dE/dx trk	-	Yes	18.4	🟩 $\tilde{\chi}^{\pm}_1$ 495 GeV	$m(\tilde{\chi}^{\pm}_1)-m(\tilde{\chi}^0_1)$~160 MeV, $\tau(\tilde{\chi}^{\pm}_1)$<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	🟩 $\tilde{g}$ 850 GeV	$m(\tilde{\chi}^0_1)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	3.2	🟦 $\tilde{g}$ 1.58 TeV		1606.05129
	Metastable $\tilde{g}$ R-hadron	dE/dx trk	-	-	3.2	🟦 $\tilde{g}$ 1.57 TeV	$m(\tilde{\chi}^0_1)$=100 GeV, τ>10 ns	1604.04520
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}^0_1\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	🟩 $\tilde{\chi}^0_1$ 537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde{\chi}^0_1\to\gamma\tilde{G}$, long-lived $\tilde{\chi}^0_1$	2 γ	-	Yes	20.3	🟩 $\tilde{\chi}^0_1$ 440 GeV	1<$\tau(\tilde{\chi}^0_1)$<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}^0_1\to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	🟩 $\tilde{\chi}^0_1$ 1.0 TeV	7 <$c\tau(\tilde{\chi}^0_1)$< 740 mm, $m(\tilde{g})$=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}^0_1\to Z\tilde{G}$	displ. vtx + jets	-	-	20.3	🟩 $\tilde{\chi}^0_1$ 1.0 TeV	6 <$c\tau(\tilde{\chi}^0_1)$< 480 mm, $m(\tilde{g})$=1.1 TeV	1504.05162
RPV	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	3.2	🟦 $\tilde{\nu}_\tau$ 1.9 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1607.08079
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	🟩 $\tilde{q}, \tilde{g}$ 1.45 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to ee\nu, e\mu\nu, \mu\mu\nu$	4 e,μ	-	Yes	13.3	🟦 $\tilde{\chi}^{\pm}_1$ 1.14 TeV	$m(\tilde{\chi}^0_1)$>400GeV, $\lambda_{12k}\neq0$ (k = 1, 2)	ATLAS-CONF-2016-075
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to\tau\tau\nu_e, e\tau\nu_\tau$	3 e,μ + τ	-	Yes	20.3	🟩 $\tilde{\chi}^{\pm}_1$ 450 GeV	$m(\tilde{\chi}^0_1)$>0.2×$m(\tilde{\chi}^{\pm}_1)$, $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\to qqq$	0	4-5 large-R jets	-	14.8	🟦 $\tilde{g}$ 1.08 TeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2016-057
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}^0_1, \tilde{\chi}^0_1\to qqq$	0	4-5 large-R jets	-	14.8	🟦 $\tilde{g}$ 1.55 TeV	$m(\tilde{\chi}^0_1)$=800 GeV	ATLAS-CONF-2016-057
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}^0_1, \tilde{\chi}^0_1\to qqq$	1 e,μ	8-10 jets/0-4 b	-	36.1	🟦 $\tilde{g}$ 2.1 TeV	$m(\tilde{\chi}^0_1)$= 1 TeV, $\lambda_{112}\neq0$	ATLAS-CONF-2017-013
	$\tilde{g}\tilde{g}, \tilde{g}\to\tilde{t}_1t, \tilde{t}_1\to bs$	1 e,μ	8-10 jets/0-4 b	-	36.1	🟦 $\tilde{g}$ 1.65 TeV	$m(\tilde{t}_1)$= 1 TeV, $\lambda_{323}\neq0$	ATLAS-CONF-2017-013
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$	0	2 jets + 2 b	-	15.4	$\tilde{t}_1$ 🟦 410 GeV 🟦 450-510 GeV		ATLAS-CONF-2016-022, ATLAS-CONF-2016-084
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$	2 e,μ	2 b	-	20.3	$\tilde{t}_1$ 🟩 0.4-1.0 TeV	BR($\tilde{t}_1\to be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}^0_1$	0	2 c	Yes	20.3	🟩 $\tilde{c}$ 510 GeV	$m(\tilde{\chi}^0_1)$<200 GeV	1501.01325

*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: March 2017

ATLAS Preliminary
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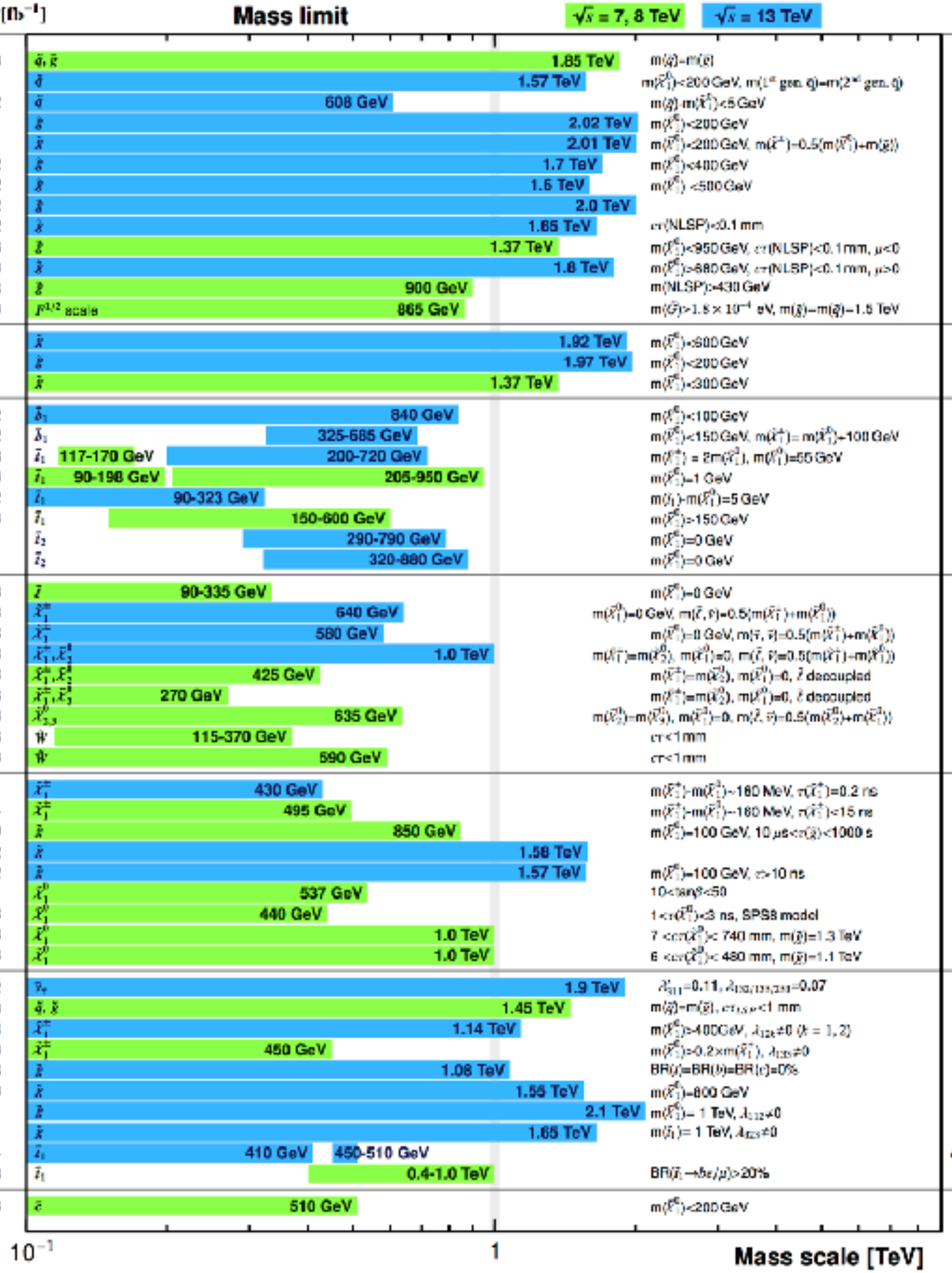


	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [fb^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e, μ /1-2 τ	2-10 jets/3 b	Yes	20.3	🟩 $\tilde{q}, \tilde{g}$ 1.85 TeV	m($\tilde{q}$)=m($\tilde{g}$)	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}^0_1$	0	2-6 jets	Yes	36.1	🟦 $\tilde{q}$ 1.57 TeV	m($\tilde{\chi}^0_1$)<200 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	ATLAS-CONF-2017-022
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}^0_1$ (compressed)	mono-jet	1-3 jets	Yes	3.2	🟦 $\tilde{q}$ 608 GeV	m($\tilde{q}$)-m($\tilde{\chi}^0_1$)<5 GeV	1604.07773
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}^0_1$	0	2-6 jets	Yes	36.1	🟦 $\tilde{g}$ 2.02 TeV	m($\tilde{\chi}^0_1$)<200 GeV	ATLAS-CONF-2017-022
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}^\pm_1\to qqW^\pm\tilde{\chi}^0_1$	0	2-6 jets	Yes	36.1	🟦 $\tilde{g}$ 2.01 TeV	m($\tilde{\chi}^0_1$)<200 GeV, m($\tilde{\chi}^\pm$)=0.5(m($\tilde{\chi}^0_1$)+m($\tilde{g}$))	ATLAS-CONF-2017-022
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\nu\nu)\tilde{\chi}^0_1$	3 e, μ	4 jets	-	13.2	🟦 $\tilde{g}$ 1.7 TeV	m($\tilde{\chi}^0_1$)<400 GeV	ATLAS-CONF-2016-037
	$\tilde{g}\tilde{g}, \tilde{g}\to qqWZ\tilde{\chi}^0_1$	2 e, μ (SS)	0-3 jets	Yes	13.2	🟦 $\tilde{g}$ 1.6 TeV	m($\tilde{\chi}^0_1$) <500 GeV	ATLAS-CONF-2016-037
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	3.2	🟦 $\tilde{g}$ 2.0 TeV		1607.05979
	GGM (bino NLSP)	2 γ	-	Yes	3.2	🟦 $\tilde{g}$ 1.65 TeV	$c\tau$(NLSP)<0.1 mm	1606.09150
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	🟩 $\tilde{g}$ 1.37 TeV	m($\tilde{\chi}^0_1$)<950 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	13.3	🟦 $\tilde{g}$ 1.8 TeV	m($\tilde{\chi}^0_1$)>680 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	ATLAS-CONF-2016-066
	GGM (higgsino NLSP)	2 e, μ (Z)	2 jets	Yes	20.3	🟩 $\tilde{g}$ 900 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	🟩 $F^{1/2}$ scale 865 GeV	m($\tilde{G}$)>1.8 × 10^{-4} eV, m($\tilde{g}$)=m($\tilde{q}$)=1.5 TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{b}\tilde{\chi}^0_1$	0	3 b	Yes	36.1	🟦 $\tilde{g}$ 1.92 TeV	m($\tilde{\chi}^0_1$)<600 GeV	ATLAS-CONF-2017-021
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0-1 e, μ	3 b	Yes	36.1	🟦 $\tilde{g}$ 1.97 TeV	m($\tilde{\chi}^0_1$)<200 GeV	ATLAS-CONF-2017-021
	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{t}\tilde{\chi}^+_1$	0-1 e, μ	3 b	Yes	20.1	🟩 $\tilde{g}$ 1.37 TeV	m($\tilde{\chi}^0_1$)<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}^0_1$	0	2 b	Yes	3.2	🟦 $\tilde{b}_1$ 840 GeV	m($\tilde{\chi}^0_1$)<100 GeV	1606.08772
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}^\pm_1$	2 e, μ (SS)	1 b	Yes	13.2	🟦 $\tilde{b}_1$ 325-685 GeV	m($\tilde{\chi}^0_1$)<150 GeV, m($\tilde{\chi}^\pm_1$)= m($\tilde{\chi}^0_1$)+100 GeV	ATLAS-CONF-2016-037
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}^\pm_1$	0-2 e, μ	1-2 b	Yes	4.7/13.3	🟩 $\tilde{t}_1$ 117-170 GeV 🟦 200-720 GeV	m($\tilde{\chi}^\pm_1$) = 2m($\tilde{\chi}^0_1$), m($\tilde{\chi}^0_1$)=55 GeV	1209.2102, ATLAS-CONF-2016-077
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}^0_1$ or $t\tilde{\chi}^0_1$	0-2 e, μ	0-2 jets/1-2 b	Yes	20.3	🟩 $\tilde{t}_1$ 90-198 GeV 🟩 205-950 GeV	m($\tilde{\chi}^0_1$)=1 GeV	1506.08616, ATLAS-CONF-2017-020
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}^0_1$	0	mono-jet	Yes	3.2	🟦 $\tilde{t}_1$ 90-323 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}^0_1$)=5 GeV	1604.07773
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3	🟩 $\tilde{t}_1$ 150-600 GeV	m($\tilde{\chi}^0_1$)>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	36.1	🟦 $\tilde{t}_2$ 290-790 GeV	m($\tilde{\chi}^0_1$)=0 GeV	ATLAS-CONF-2017-019
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + h$	1-2 e, μ	4 b	Yes	36.1	🟦 $\tilde{t}_2$ 320-880 GeV	m($\tilde{\chi}^0_1$)=0 GeV	ATLAS-CONF-2017-019
***EW* direct**	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}^0_1$	2 e, μ	0	Yes	20.3	🟩 $\tilde{\ell}$ 90-335 GeV	m($\tilde{\chi}^0_1$)=0 GeV	1403.5294
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	13.3	🟦 $\tilde{\chi}^\pm_1$ 640 GeV	m($\tilde{\chi}^0_1$)=0 GeV, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}^\pm_1$)+m($\tilde{\chi}^0_1$))	ATLAS-CONF-2016-096
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	14.8	🟦 $\tilde{\chi}^\pm_1$ 580 GeV	m($\tilde{\chi}^0_1$)=0 GeV, m($\tilde{\tau}, \tilde{\nu}$)=0.5(m($\tilde{\chi}^\pm_1$)+m($\tilde{\chi}^0_1$))	ATLAS-CONF-2016-093
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	13.3	🟦 $\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$ 1.0 TeV	m($\tilde{\chi}^\pm_1$)=m($\tilde{\chi}^0_2$), m($\tilde{\chi}^0_1$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}^\pm_1$)+m($\tilde{\chi}^0_1$))	ATLAS-CONF-2016-096
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1 Z\tilde{\chi}^0_1$	2-3 e, μ	0-2 jets	Yes	20.3	🟩 $\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$ 425 GeV	m($\tilde{\chi}^\pm_1$)=m($\tilde{\chi}^0_2$), m($\tilde{\chi}^0_1$)=0, $\tilde{\ell}$ decoupled	1403.5294, 1402.7029
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1 h\tilde{\chi}^0_1, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e, μ, γ	0-2 b	Yes	20.3	🟩 $\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$ 270 GeV	m($\tilde{\chi}^\pm_1$)=m($\tilde{\chi}^0_2$), m($\tilde{\chi}^0_1$)=0, $\tilde{\ell}$ decoupled	1501.07110
	$\tilde{\chi}^0_2\tilde{\chi}^0_3, \tilde{\chi}^0_{2,3}\to\tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3	🟩 $\tilde{\chi}^0_{2,3}$ 635 GeV	m($\tilde{\chi}^0_2$)=m($\tilde{\chi}^0_3$), m($\tilde{\chi}^0_1$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}^0_2$)+m($\tilde{\chi}^0_1$))	1405.5086
	GGM (wino NLSP) weak prod.	1 e, μ + γ	-	Yes	20.3	🟩 $\tilde{W}$ 115-370 GeV	$c\tau$<1 mm	1507.05493
	GGM (bino NLSP) weak prod.	2 γ	-	Yes	20.3	🟩 $\tilde{W}$ 590 GeV	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^\pm_1$	Disapp. trk	1 jet	Yes	36.1	🟦 $\tilde{\chi}^\pm_1$ 430 GeV	m($\tilde{\chi}^\pm_1$)-m($\tilde{\chi}^0_1$)~160 MeV, τ($\tilde{\chi}^\pm_1$)=0.2 ns	ATLAS-CONF-2017-017
	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^\pm_1$	dE/dx trk	-	Yes	18.4	🟩 $\tilde{\chi}^\pm_1$ 495 GeV	m($\tilde{\chi}^\pm_1$)-m($\tilde{\chi}^0_1$)~160 MeV, τ($\tilde{\chi}^\pm_1$)<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	🟩 $\tilde{g}$ 850 GeV	m($\tilde{\chi}^0_1$)=100 GeV, 10 μs<τ($\tilde{g}$)<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	3.2	🟦 $\tilde{g}$ 1.58 TeV		1606.05129
	Metastable $\tilde{g}$ R-hadron	dE/dx trk	-	-	3.2	🟦 $\tilde{g}$ 1.57 TeV	m($\tilde{\chi}^0_1$)=100 GeV, τ>10 ns	1604.04520
	GMSB, stable $\tilde{\tau}, \tilde{\chi}^0_1\to\tilde{\tau}(\tilde{e}, \tilde{\mu})+\tau(e, \mu)$	1-2 μ	-	-	19.1	🟩 $\tilde{\chi}^0_1$ 537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde{\chi}^0_1\to\gamma\tilde{G}$, long-lived $\tilde{\chi}^0_1$	2 γ	-	Yes	20.3	🟩 $\tilde{\chi}^0_1$ 440 GeV	1<τ($\tilde{\chi}^0_1$)<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}^0_1\to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	🟩 $\tilde{\chi}^0_1$ 1.0 TeV	7 <$c\tau$($\tilde{\chi}^0_1$)< 740 mm, m($\tilde{g}$)=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}^0_1\to Z\tilde{G}$	displ. vtx + jets	-	-	20.3	🟩 $\tilde{\chi}^0_1$ 1.0 TeV	6 <$c\tau$($\tilde{\chi}^0_1$)< 480 mm, m($\tilde{g}$)=1.1 TeV	1504.05162
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu, e\tau, \mu\tau$	-	-	3.2	🟦 $\tilde{\nu}_\tau$ 1.9 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1607.08079
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	🟩 $\tilde{q}, \tilde{g}$ 1.45 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to ee\nu, e\mu\nu, \mu\mu\nu$	4 e, μ	-	Yes	13.3	🟦 $\tilde{\chi}^\pm_1$ 1.14 TeV	m($\tilde{\chi}^0_1$)>400GeV, $\lambda_{12k}\neq 0$ (k = 1, 2)	ATLAS-CONF-2016-075
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to\tau\tau\nu_e, e\tau\nu_\tau$	3 e, μ + τ	-	Yes	20.3	🟩 $\tilde{\chi}^\pm_1$ 450 GeV	m($\tilde{\chi}^0_1$)>0.2×m($\tilde{\chi}^\pm_1$), $\lambda_{133}\neq 0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\to qqq$	0	4-5 large-R jets	-	14.8	🟦 $\tilde{g}$ 1.08 TeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2016-057
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}^0_1, \tilde{\chi}^0_1\to qqq$	0	4-5 large-R jets	-	14.8	🟦 $\tilde{g}$ 1.55 TeV	m($\tilde{\chi}^0_1$)=800 GeV	ATLAS-CONF-2016-057
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}^0_1, \tilde{\chi}^0_1\to qqq$	1 e, μ	8-10 jets/0-4 b	-	36.1	🟦 $\tilde{g}$ 2.1 TeV	m($\tilde{\chi}^0_1$)= 1 TeV, $\lambda_{112}\neq 0$	ATLAS-CONF-2017-013
	$\tilde{g}\tilde{g}, \tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	1 e, μ	8-10 jets/0-4 b	-	36.1	🟦 $\tilde{g}$ 1.65 TeV	m($\tilde{t}_1$)= 1 TeV, $\lambda_{323}\neq 0$	ATLAS-CONF-2017-013
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$	0	2 jets + 2 b	-	15.4	🟦 $\tilde{t}_1$ 410 GeV 🟦 450-510 GeV		ATLAS-CONF-2016-022, ATLAS-CONF-2016-084
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$	2 e, μ	2 b	-	20.3	🟩 $\tilde{t}_1$ 0.4-1.0 TeV	BR($\tilde{t}_1\to be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}^0_1$	0	2 c	Yes	20.3	🟩 $\tilde{c}$ 510 GeV	m($\tilde{\chi}^0_1$)<200 GeV	1501.01325

*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

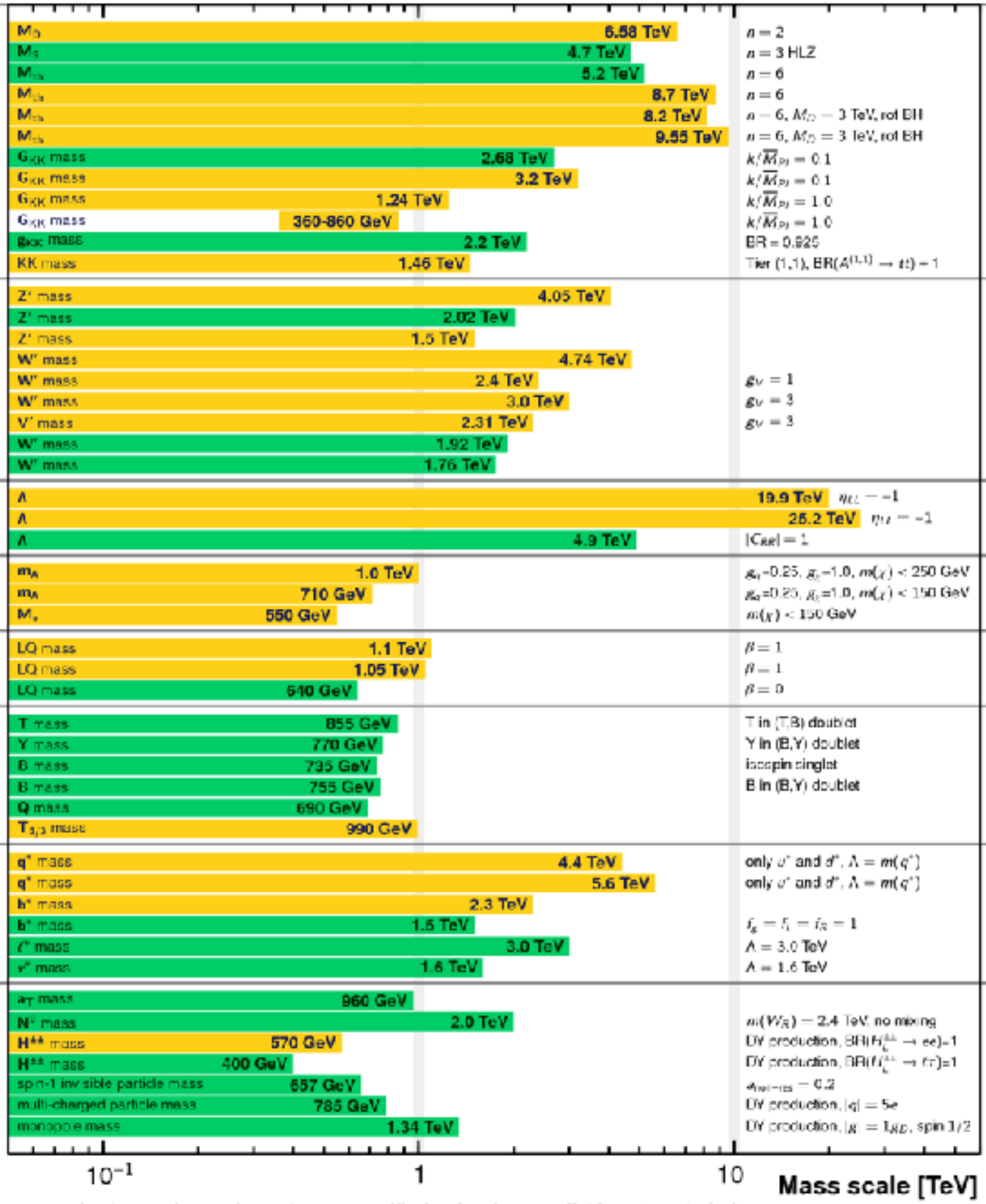
ATLAS Exotics Searches* - 95% CL Exclusion

Status: August 2016

ATLAS Preliminary

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

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



	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	≥ 1 j	Yes	3.2	🟨 M_D 6.58 TeV	$n = 2$	1604.07773
	ADD non-resonant $\ell\ell$	2 e, μ	–	–	20.3	🟩 M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	ADD QBH → ℓq	1 e, μ	1 j	–	20.3	🟩 M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	15.7	🟨 M_{th} 8.7 TeV	$n = 6$	ATLAS-CONF-2016-069
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	3.2	🟨 M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	🟨 M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \to \ell\ell$	2 e, μ	–	–	20.3	🟩 G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \to \gamma\gamma$	2 γ	–	–	3.2	🟨 G_{KK} mass 3.2 TeV	$k/\overline{M}_{Pl} = 0.1$	1606.03833
	Bulk RS $G_{KK} \to WW \to qq\ell\nu$	1 e, μ	1 J	Yes	13.2	🟨 G_{KK} mass 1.24 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-062
	Bulk RS $G_{KK} \to HH \to bbbb$	–	4 b	–	13.3	🟨 G_{KK} mass 360-860 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-049
	Bulk RS $g_{KK} \to tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	20.3	🟩 g_{KK} mass 2.2 TeV	BR = 0.925	1505.07018
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 4 j	Yes	3.2	🟨 KK mass 1.46 TeV	Tier (1,1), BR($A^{(1,1)} \to tt$) = 1	ATLAS-CONF-2016-013
Gauge bosons	SSM $Z' \to \ell\ell$	2 e, μ	–	–	13.3	🟨 Z' mass 4.05 TeV		ATLAS-CONF-2016-045
	SSM $Z' \to \tau\tau$	2 τ	–	–	19.5	🟩 Z' mass 2.02 TeV		1502.07177
	Leptophobic $Z' \to bb$	–	2 b	–	3.2	🟨 Z' mass 1.5 TeV		1603.08791
	SSM $W' \to \ell\nu$	1 e, μ	–	Yes	13.3	🟨 W' mass 4.74 TeV		ATLAS-CONF-2016-061
	HVT $W' \to WZ \to qq\nu\nu$ model A	0 e, μ	1 J	Yes	13.2	🟨 W' mass 2.4 TeV	$g_V = 1$	ATLAS-CONF-2016-082
	HVT $W' \to WZ \to qqqq$ model B	–	2 J	–	15.5	🟨 W' mass 3.0 TeV	$g_V = 3$	ATLAS-CONF-2016-055
	HVT $V' \to WH/ZH$ model B	multi-channel			3.2	🟨 V' mass 2.31 TeV	$g_V = 3$	1607.05621
	LRSM $W'_R \to tb$	1 e, μ	2 b, 0-1 j	Yes	20.3	🟩 W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \to tb$	0 e, μ	≥ 1 b, 1 J	–	20.3	🟩 W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	15.7	🟨 Λ 19.9 TeV	$\eta_{LL} = -1$	ATLAS-CONF-2016-069
	CI $\ell\ell qq$	2 e, μ	–	–	3.2	🟨 Λ 25.2 TeV	$\eta_{LL} = -1$	1607.03669
	CI $uutt$	2(SS)/≥3 e, μ	≥1 b, ≥1 j	Yes	20.3	🟩 Λ 4.9 TeV	$\lvert C_{RR} \rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	0 e, μ	≥ 1 j	Yes	3.2	🟨 m_A 1.0 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 250$ GeV	1604.07773
	Axial-vector mediator (Dirac DM)	0 e, μ, 1 γ	1 j	Yes	3.2	🟨 m_A 710 GeV	g_q=0.25, g_χ=1.0, $m(\chi) < 150$ GeV	1604.01306
	$ZZ_{\chi\chi}$ EFT (Dirac DM)	0 e, μ	1 J, ≤ 1 j	Yes	3.2	🟨 M_* 550 GeV	$m(\chi) < 150$ GeV	ATLAS-CONF-2015-080
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	🟨 LQ mass 1.1 TeV	$\beta = 1$	1605.06035
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	🟨 LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	1 e, μ	≥1 b, ≥3 j	Yes	20.3	🟩 LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \to Ht + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	🟩 T mass 855 GeV	T in (T,B) doublet	1505.04306
	VLQ $YY \to Wb + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	20.3	🟩 Y mass 770 GeV	Y in (B,Y) doublet	1505.04306
	VLQ $BB \to Hb + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	🟩 B mass 735 GeV	isospin singlet	1505.04306
	VLQ $BB \to Zb + X$	2/≥3 e, μ	≥2/≥1 b	–	20.3	🟩 B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $QQ \to WqWq$	1 e, μ	≥ 4 j	Yes	20.3	🟩 Q mass 690 GeV		1509.04261
	VLQ $T_{5/3} T_{5/3} \to WtWt$	2(SS)/≥3 e, μ	≥1 b, ≥1 j	Yes	3.2	🟨 $T_{5/3}$ mass 990 GeV		ATLAS-CONF-2016-032
Excited fermions	Excited quark $q^* \to q\gamma$	1 γ	1 j	–	3.2	🟨 q* mass 4.4 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1512.05910
	Excited quark $q^* \to qg$	–	2 j	–	15.7	🟨 q* mass 5.6 TeV	only u^* and d^*, $\Lambda = m(q^*)$	ATLAS-CONF-2016-069
	Excited quark $b^* \to bg$	–	1 b, 1 j	–	8.8	🟨 b* mass 2.3 TeV		ATLAS-CONF-2016-060
	Excited quark $b^* \to Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	🟩 b* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	🟩 ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	🟩 ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \to W\gamma$	1 e, μ, 1 γ	–	Yes	20.3	🟩 a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	2 e, μ	2 j	–	20.3	🟩 N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \to ee$	2 e (SS)	–	–	13.9	🟨 $H^{\pm\pm}$ mass 570 GeV	DY production, BR($H_L^{\pm\pm} \to ee$)=1	ATLAS-CONF-2016-051
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	3 e, μ, τ	–	–	20.3	🟩 $H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \to \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	1 e, μ	1 b	Yes	20.3	🟩 spin-1 invisible particle mass 657 GeV	$a_{non-res} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	🟩 multi-charged particle mass 785 GeV	DY production, $\lvert q \rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	🟩 monopole mass 1.34 TeV	DY production, $\lvert g \rvert = 1g_D$, spin 1/2	1509.08059

🟩 $\sqrt{s} = 8$ TeV

🟨 $\sqrt{s} = 13$ TeV

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*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).

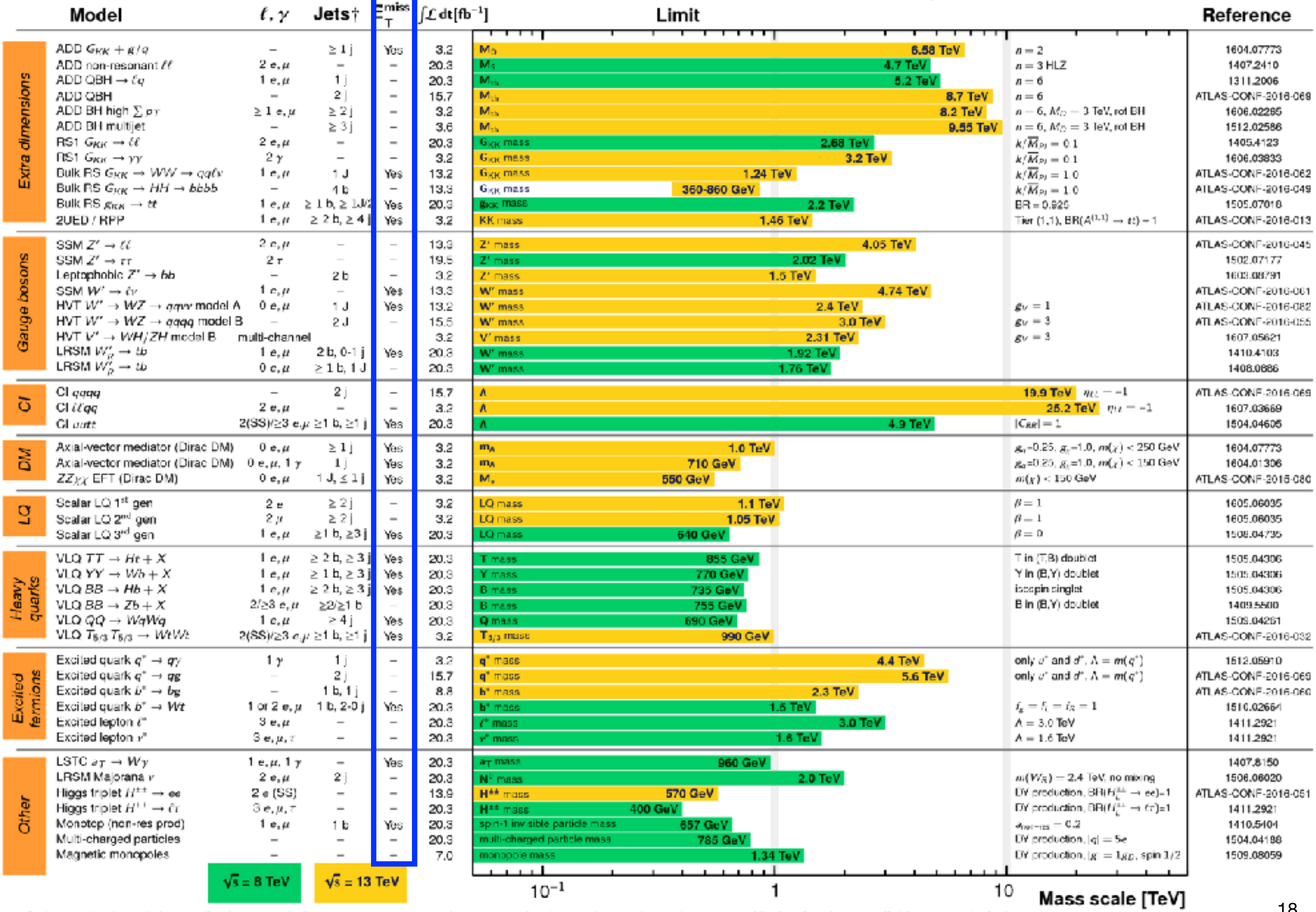
ATLAS Exotics Searches* - 95% CL Exclusion

Status: August 2016

ATLAS Preliminary

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

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



	Model	ℓ,γ	Jets†	E_T^{miss}	$\int\mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK}+g/q$	–	≥ 1 j	Yes	3.2	🟨 M_D 6.58 TeV	$n=2$	1604.07773
	ADD non-resonant $\ell\ell$	2 e,μ	–	–	20.3	🟩 M_S 4.7 TeV	$n=3$ HLZ	1407.2410
	ADD QBH $\to \ell q$	1 e,μ	1 j	–	20.3	🟩 M_{th} 5.2 TeV	$n=6$	1311.2006
	ADD QBH	–	2 j	–	15.7	🟨 M_{th} 8.7 TeV	$n=6$	ATLAS-CONF-2016-069
	ADD BH high $\sum p_T$	≥ 1 e,μ	≥ 2 j	–	3.2	🟨 M_{th} 8.2 TeV	$n=6$, $M_D=3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	🟨 M_{th} 9.55 TeV	$n=6$, $M_D=3$ TeV, rot BH	1512.02586
	RS1 $G_{KK}\to\ell\ell$	2 e,μ	–	–	20.3	🟩 G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl}=0.1$	1405.4123
	RS1 $G_{KK}\to\gamma\gamma$	2 γ	–	–	3.2	🟨 G_{KK} mass 3.2 TeV	$k/\overline{M}_{Pl}=0.1$	1606.03833
	Bulk RS $G_{KK}\to WW\to qq\ell\nu$	1 e,μ	1 J	Yes	13.2	🟨 G_{KK} mass 1.24 TeV	$k/\overline{M}_{Pl}=1.0$	ATLAS-CONF-2016-062
	Bulk RS $G_{KK}\to HH\to bbbb$	–	4 b	–	13.3	🟨 G_{KK} mass 360-860 GeV	$k/\overline{M}_{Pl}=1.0$	ATLAS-CONF-2016-049
	Bulk RS $g_{KK}\to tt$	1 e,μ	≥ 1 b, ≥ 1J/2j	Yes	20.3	🟩 g_{KK} mass 2.2 TeV	BR = 0.925	1505.07018
	2UED / RPP	1 e,μ	≥ 2 b, ≥ 4 j	Yes	3.2	🟨 KK mass 1.46 TeV	Tier (1,1), $BR(A^{(1,1)}\to tt)=1$	ATLAS-CONF-2016-013
Gauge bosons	SSM $Z'\to\ell\ell$	2 e,μ	–	–	13.3	🟨 Z' mass 4.05 TeV		ATLAS-CONF-2016-045
	SSM $Z'\to\tau\tau$	2 τ	–	–	19.5	🟩 Z' mass 2.02 TeV		1502.07177
	Leptophobic $Z'\to bb$	–	2 b	–	3.2	🟨 Z' mass 1.5 TeV		1603.08791
	SSM $W'\to\ell\nu$	1 e,μ	–	Yes	13.3	🟨 W' mass 4.74 TeV		ATLAS-CONF-2016-061
	HVT $W'\to WZ\to qq\nu\nu$ model A	0 e,μ	1 J	Yes	13.2	🟨 W' mass 2.4 TeV	$g_V=1$	ATLAS-CONF-2016-082
	HVT $W'\to WZ\to qqqq$ model B	–	2 J	–	15.5	🟨 W' mass 3.0 TeV	$g_V=3$	ATLAS-CONF-2016-055
	HVT $V'\to WH/ZH$ model B	multi-channel			3.2	🟨 V' mass 2.31 TeV	$g_V=3$	1607.05621
	LRSM $W'_R\to tb$	1 e,μ	2 b, 0-1 j	Yes	20.3	🟩 W' mass 1.92 TeV		1410.4103
	LRSM $W'_R\to tb$	0 e,μ	≥ 1 b, 1 J	–	20.3	🟩 W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	15.7	🟨 Λ 19.9 TeV	$\eta_{LL}=-1$	ATLAS-CONF-2016-069
	CI $\ell\ell qq$	2 e,μ	–	–	3.2	🟨 Λ 25.2 TeV	$\eta_{LL}=-1$	1607.03669
	CI $uutt$	2(SS)/≥3 e,μ	≥1 b, ≥1 j	Yes	20.3	🟩 Λ 4.9 TeV	$\lvert C_{RR}\rvert=1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	0 e,μ	≥ 1 j	Yes	3.2	🟨 m_A 1.0 TeV	g_q=0.25, g_χ=1.0, $m(\chi)$ < 250 GeV	1604.07773
	Axial-vector mediator (Dirac DM)	0 e,μ, 1 γ	1 j	Yes	3.2	🟨 m_A 710 GeV	g_q=0.25, g_χ=1.0, $m(\chi)$ < 150 GeV	1604.01306
	$ZZ_{\chi\chi}$ EFT (Dirac DM)	0 e,μ	1 J, ≤ 1 j	Yes	3.2	🟨 M_* 550 GeV	$m(\chi)$ < 150 GeV	ATLAS-CONF-2015-080
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	🟨 LQ mass 1.1 TeV	$\beta=1$	1605.06035
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	🟨 LQ mass 1.05 TeV	$\beta=1$	1605.06035
	Scalar LQ 3rd gen	1 e,μ	≥1 b, ≥3 j	Yes	20.3	🟩 LQ mass 640 GeV	$\beta=0$	1508.04735
Heavy quarks	VLQ $TT\to Ht+X$	1 e,μ	≥ 2 b, ≥ 3 j	Yes	20.3	🟩 T mass 855 GeV	T in (T,B) doublet	1505.04306
	VLQ $YY\to Wb+X$	1 e,μ	≥ 1 b, ≥ 3 j	Yes	20.3	🟩 Y mass 770 GeV	Y in (B,Y) doublet	1505.04306
	VLQ $BB\to Hb+X$	1 e,μ	≥ 2 b, ≥ 3 j	Yes	20.3	🟩 B mass 735 GeV	isospin singlet	1505.04306
	VLQ $BB\to Zb+X$	2/≥3 e,μ	≥2/≥1 b	–	20.3	🟩 B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $QQ\to WqWq$	1 e,μ	≥ 4 j	Yes	20.3	🟩 Q mass 690 GeV		1509.04261
	VLQ $T_{5/3}T_{5/3}\to WtWt$	2(SS)/≥3 e,μ	≥1 b, ≥1 j	Yes	3.2	🟨 $T_{5/3}$ mass 990 GeV		ATLAS-CONF-2016-032
Excited fermions	Excited quark $q^*\to q\gamma$	1 γ	1 j	–	3.2	🟨 q* mass 4.4 TeV	only u^* and d^*, $\Lambda=m(q^*)$	1512.05910
	Excited quark $q^*\to qg$	–	2 j	–	15.7	🟨 q* mass 5.6 TeV	only u^* and d^*, $\Lambda=m(q^*)$	ATLAS-CONF-2016-069
	Excited quark $b^*\to bg$	–	1 b, 1 j	–	8.8	🟨 b* mass 2.3 TeV		ATLAS-CONF-2016-060
	Excited quark $b^*\to Wt$	1 or 2 e,μ	1 b, 2-0 j	Yes	20.3	🟩 b* mass 1.5 TeV	$f_g=f_L=f_R=1$	1510.02664
	Excited lepton ℓ^*	3 e,μ	–	–	20.3	🟩 ℓ^* mass 3.0 TeV	$\Lambda=3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e,μ,τ	–	–	20.3	🟩 ν^* mass 1.6 TeV	$\Lambda=1.6$ TeV	1411.2921
Other	LSTC $a_T\to W\gamma$	1 e,μ, 1 γ	–	Yes	20.3	🟩 a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	2 e,μ	2 j	–	20.3	🟩 N^0 mass 2.0 TeV	$m(W_R)=2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm}\to ee$	2 e (SS)	–	–	13.9	🟨 $H^{\pm\pm}$ mass 570 GeV	DY production, $BR(H_L^{\pm\pm}\to ee)$=1	ATLAS-CONF-2016-051
	Higgs triplet $H^{\pm\pm}\to\ell\tau$	3 e,μ,τ	–	–	20.3	🟩 $H^{\pm\pm}$ mass 400 GeV	DY production, $BR(H_L^{\pm\pm}\to\ell\tau)$=1	1411.2921
	Monotop (non-res prod)	1 e,μ	1 b	Yes	20.3	🟩 spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}}=0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	🟩 multi-charged particle mass 785 GeV	DY production, $\lvert q\rvert=5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	🟩 monopole mass 1.34 TeV	DY production, $\lvert g\rvert=1g_D$, spin 1/2	1509.08059

🟩 $\sqrt{s}$ = 8 TeV

🟨 $\sqrt{s}$ = 13 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).

Well established idea…

as advertised at the Metropolitan Museum @ NYC

MET参观。看多元文化。ON

ET ОДИН МЕТ. МНОГО

UCHOS MUNDOS. أكثر من عالم.

ONE MET. MANY WORLDS

МНОГО МИРОВ. 来MET参

DOS. MET حف واحد. أكثر من عالم.

Building the MET: Well established assumptions and measurements

- How can we measure something that is not interacting with our detector?
  - **Measure all the rest, and impose the momentum conservation!**
  - **0**= Σ(**what we see**)+Σ(**what we do not see**)
    (bold meaning **2D vectors** in the plane transverse to the beam axis)
  - Σ(**what we do not see**)= - Σ(**what we see**) = **MET**

What do we see? - First qualitative try

- **Charge tracks:**
  Momentum of the charged particles thanks to the inner tracker **(e,μ,ch_had)**
  $|\eta|<2.5$, $p_T > 500$ MeV

- **Energy depositions in calorimeters:**
  Energy deposition due to charged **(e, ch_had)** and neutral particles **(γ,neu_had)**
  Muons deposit ~2 GeV in the calorimeter.
  $|\eta|<4.9$

- **Muon detector:**
  Muon momentum can be measured thanks to the combination of the inner tracker and the muon spectrometer.
  $|\eta|<2.7$ $p_T > 7$ GeV

- **First "naive" option:** Use the calorimeter, and refine the measurement adding information from the muon reconstruction when there are muons.
  At the end, was not this **one of** the benefits in having a calorimeter up to $|\eta|\sim 5$?

From the calorimeter to the objects

- We can use the calorimeter information as it is, maybe with some calibration to take into account the dead material in front of it, and the non-compensating nature of the detector,

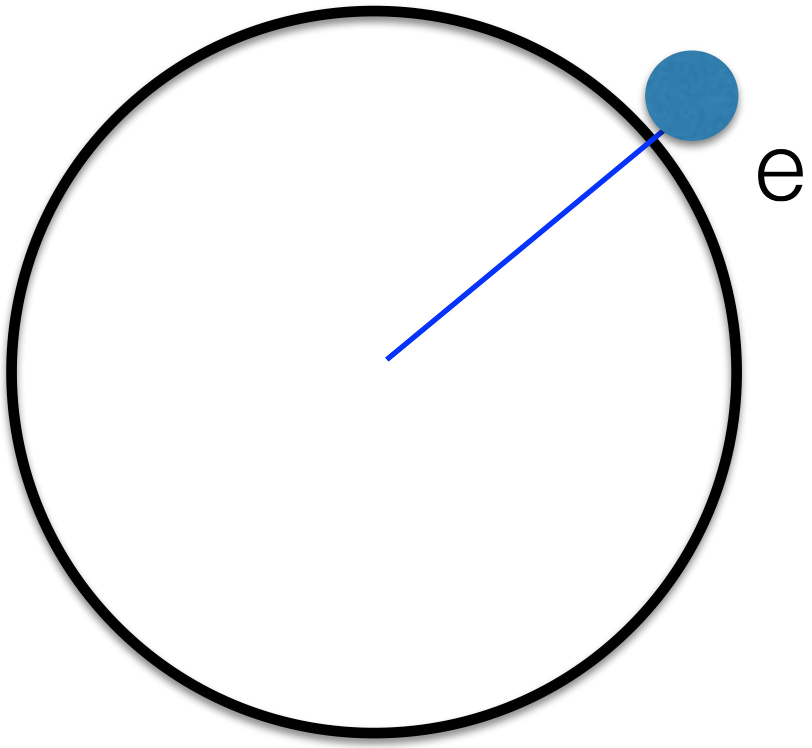
BUT:

- if we know that there are **e, γ, τ, jets** in our event, maybe **we can do better by using these objects**, and their dedicated calibration instead of the signals from the calorimeter
  → **Object based MET**

- additional benefit: we can inherits from each individual object its uncertainty.
  This allows a **consistent estimation and propagation of the errors.**

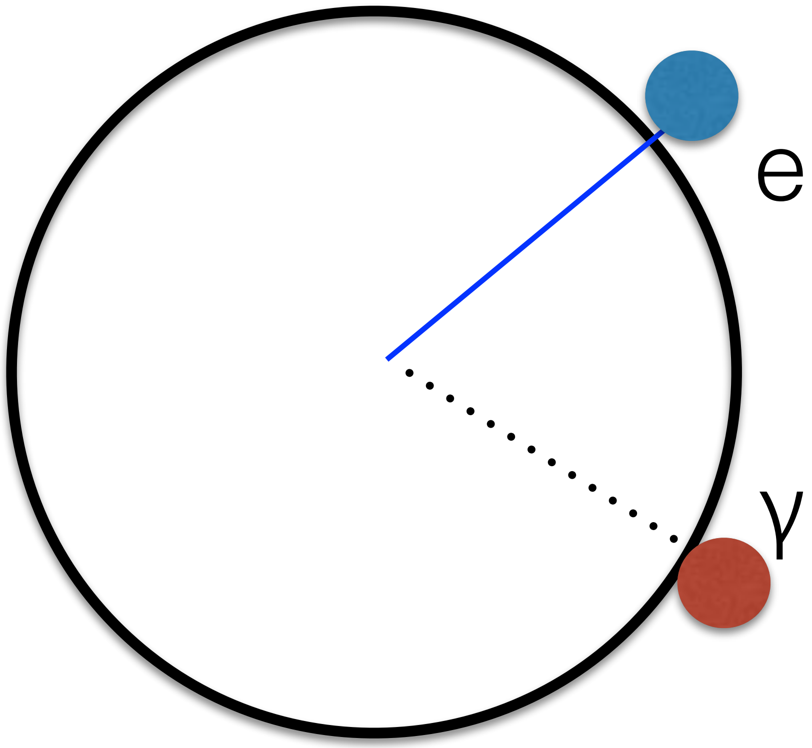
Building the MET

- Ingredients: $E_{x,y}^{miss} = \boxed{E_{x,y}^{miss,e}} + E_{x,y}^{miss,\gamma} + E_{x,y}^{miss,\tau} + E_{x,y}^{miss,jets} + E_{x,y}^{miss,\mu} + E_{x,y}^{miss,Soft\ Term}$
- Hard pT objects
  - **Electrons, p_T>10 GeV, |η|<2.47**
  - Photons,
  - Taus
  - Jets
  - Muons
- Rules to handle the overlap between objects
- Soft pT object
  - They are needed to “close” the event
- Vectorial sum on the all these on the transverse plane
  - Done!



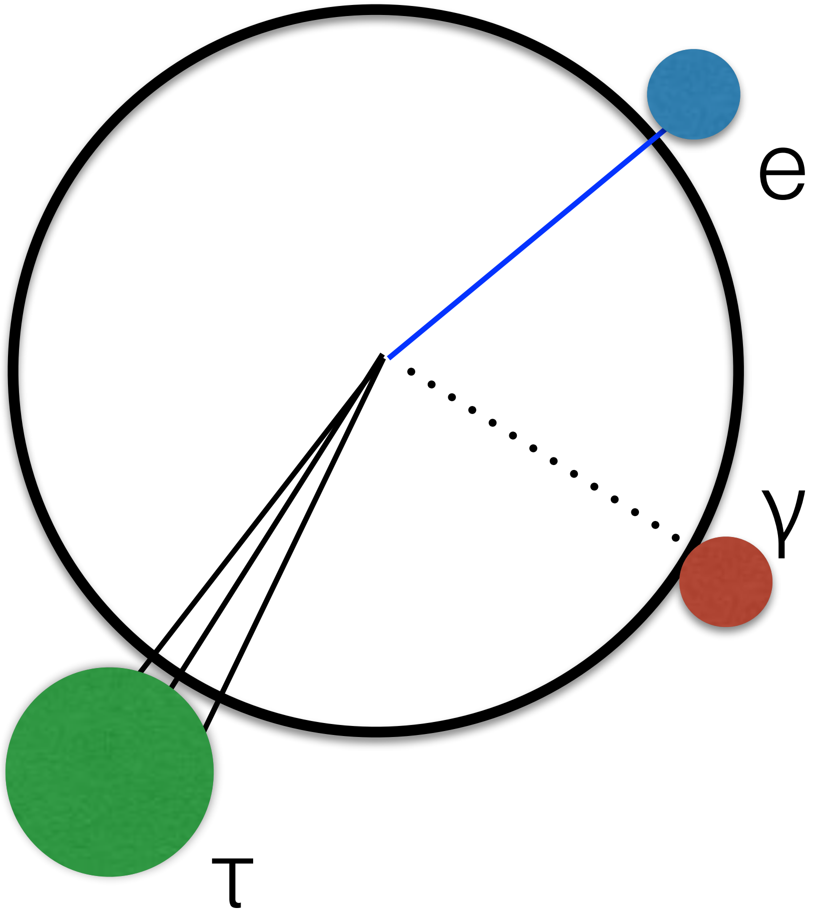
Building the MET

- Ingredients: $E_{x,y}^{miss} = E_{x,y}^{miss,e} + \boxed{E_{x,y}^{miss,\gamma}} + E_{x,y}^{miss,\tau} + E_{x,y}^{miss,jets} + E_{x,y}^{miss,\mu} + E_{x,y}^{miss,Soft\ Term}$
- Hard pT objects
  - Electrons,
  - **Photons, p_T>10 GeV**
  - Taus
  - Jets
  - Muons
- Rules to handle the overlap between objects
- Soft pT object
  - They are needed to “close” the event
- Vectorial sum on the all these on the transverse plane
  - Done!



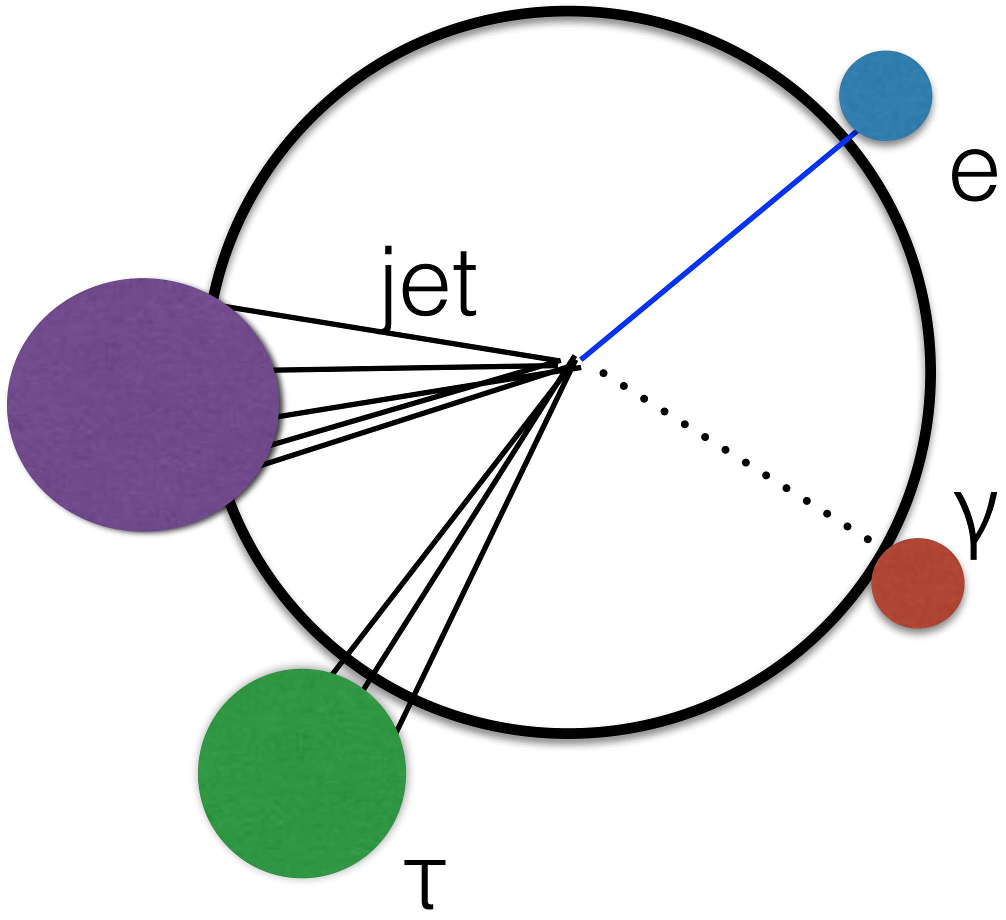
Building the MET

- Ingredients: $E_{x,y}^{miss} = E_{x,y}^{miss,e} + E_{x,y}^{miss,\gamma} + \boxed{E_{x,y}^{miss,\tau}} + E_{x,y}^{miss,jets} + E_{x,y}^{miss,\mu} + E_{x,y}^{miss,Soft\ Term}$
- Hard pT objects
  - Electrons,
  - Photons,
  - **Taus p_T>10 GeV, $|\eta|$<2.5**
  - Jets
  - Muons
- Rules to handle the overlap between objects
- Soft pT object
  - They are needed to “close” the event
- Vectorial sum on the all these on the transverse plane
  - Done!



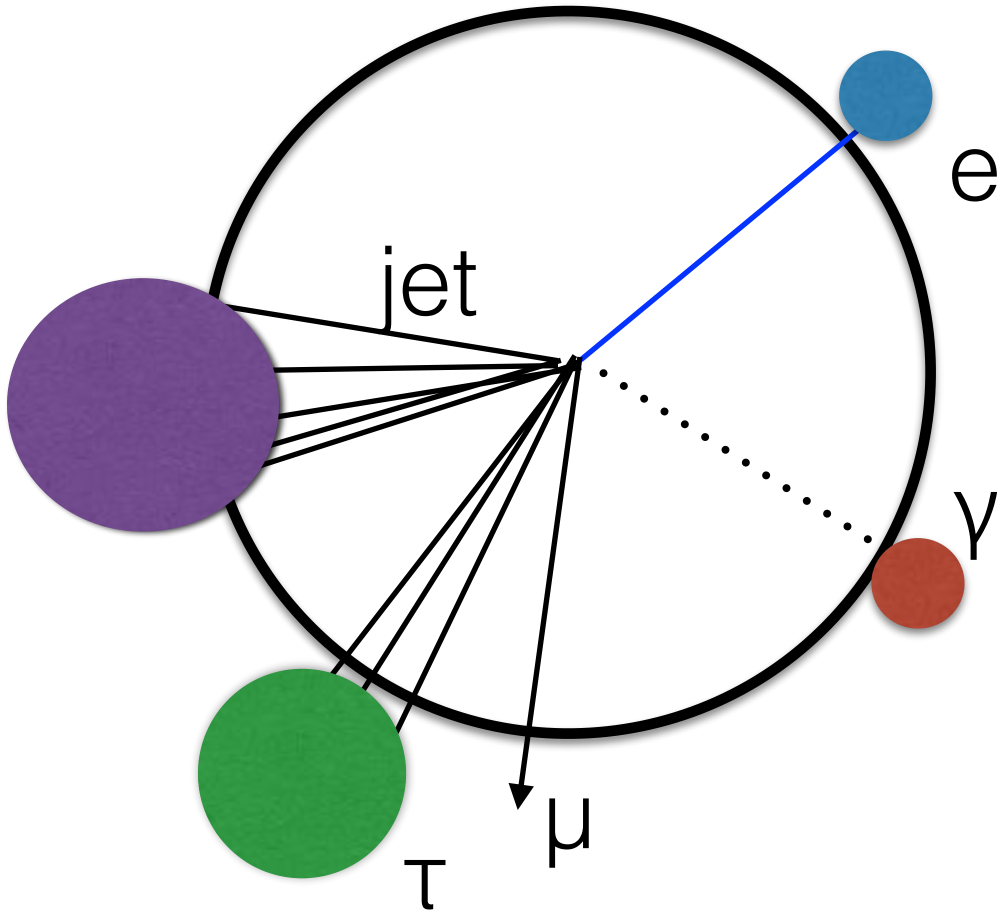
Building the MET

- Ingredients: $E_{x,y}^{miss} = E_{x,y}^{miss,e} + E_{x,y}^{miss,\gamma} + E_{x,y}^{miss,\tau} + \boxed{E_{x,y}^{miss,jets}} + E_{x,y}^{miss,\mu} + E_{x,y}^{miss,Soft\ Term}$
- Hard pT objects
    - Electrons,
    - Photons,
    - Taus
    - **Jets p_T>7 GeV**
    - Muons
- Rules to handle the overlap between objects
- Soft pT object
    - They are needed to “close” the event
- Vectorial sum on the all these on the transverse plane
    - Done!



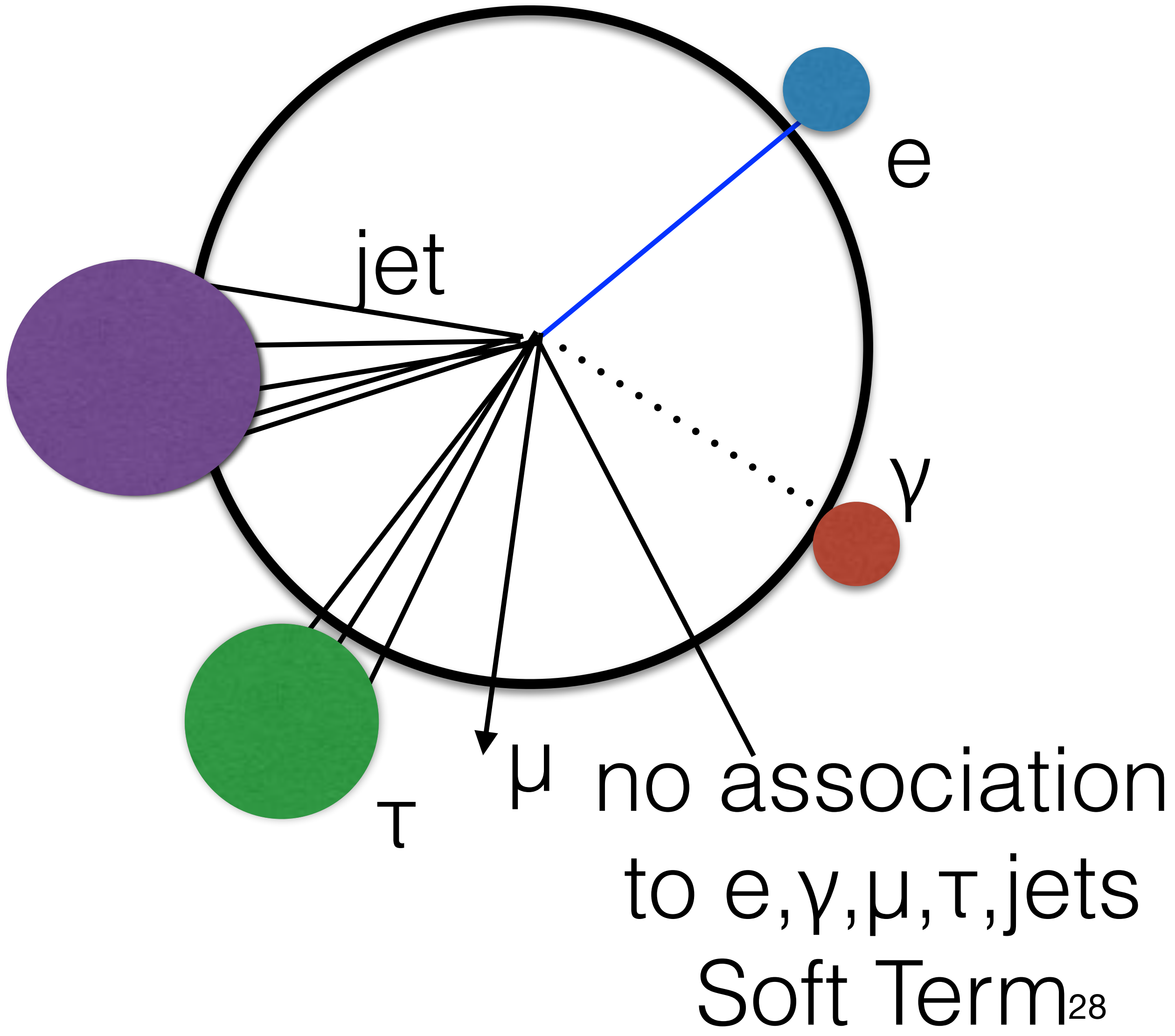
Building the MET

- Ingredients: $E_{x,y}^{miss} = E_{x,y}^{miss,e} + E_{x,y}^{miss,\gamma} + E_{x,y}^{miss,\tau} + E_{x,y}^{miss,jets} + \boxed{E_{x,y}^{miss,\mu}} + E_{x,y}^{miss,Soft\ Term}$
- Hard pT objects
  - Electrons,
  - Photons,
  - Taus
  - Jets
  - **Muons p_T>5 GeV, $|\eta|$<2.7**
- Rules to handle the overlap between objects
- Soft pT object
  - They are needed to “close” the event
- Vectorial sum on the all these on the transverse plane
  - Done!



Building the MET

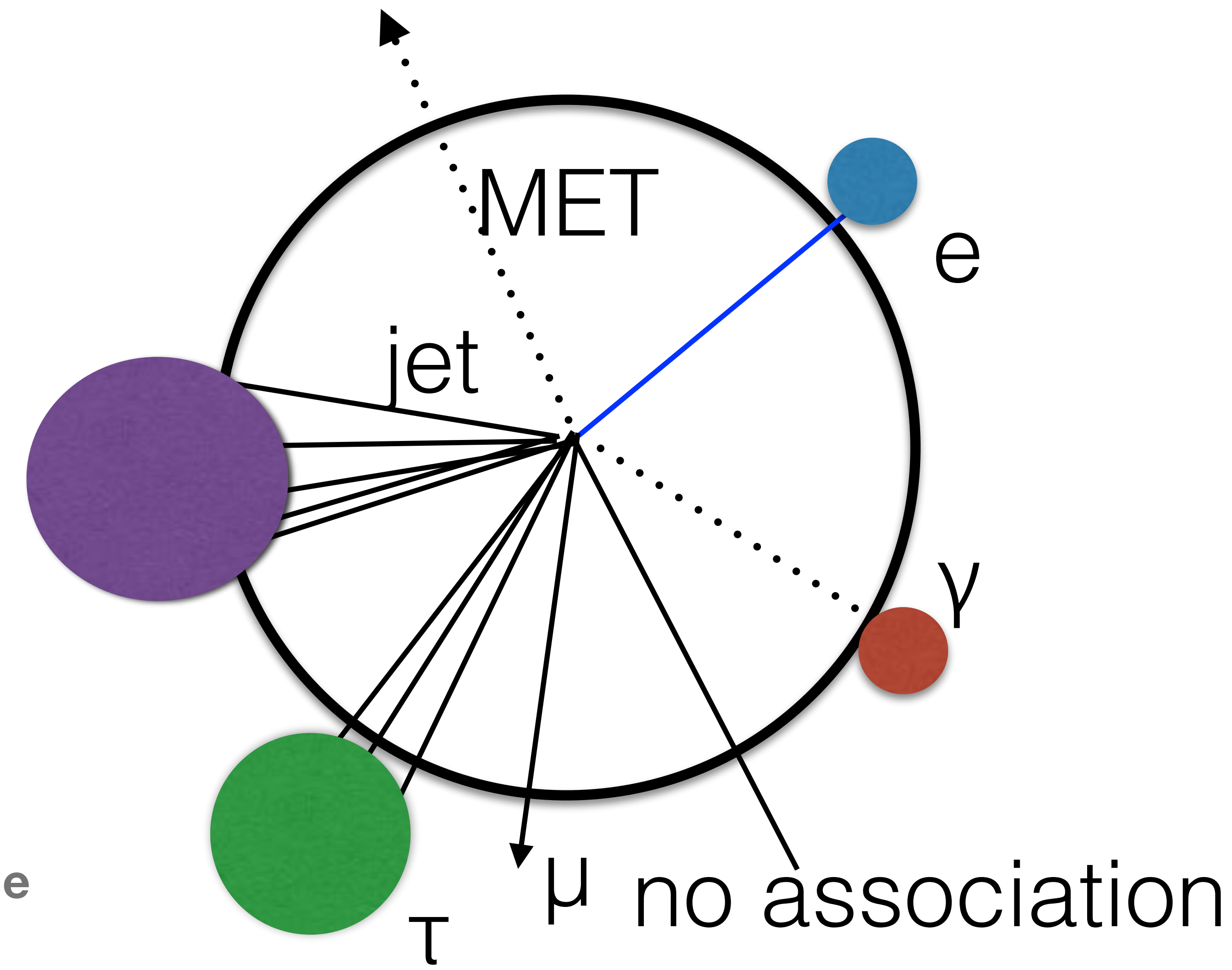
- Ingredients: $E_{x,y}^{miss} = E_{x,y}^{miss,e} + E_{x,y}^{miss,\gamma} + E_{x,y}^{miss,\tau} + E_{x,y}^{miss,jets} + E_{x,y}^{miss,\mu} + \boxed{E_{x,y}^{miss,Soft\ Term}}$
- Hard pT objects
  - Electrons,
  - Photons,
  - Taus
  - Jets
  - Muons
- Rules to handle the overlap between objects
- **Soft pT object ???**
  - They are needed to “close” the event
- Vectorial sum on the all these on the transverse plane
  - Done!



Building the MET

- Ingredients: $E_{x,y}^{miss} = E_{x,y}^{miss,e} + E_{x,y}^{miss,\gamma} + E_{x,y}^{miss,\tau} + E_{x,y}^{miss,jets} + E_{x,y}^{miss,\mu} + E_{x,y}^{miss,Soft\ Term}$
- Hard pT objects
  - Electrons,
  - Photons,
  - Taus
  - Jets
  - Muons
- Rules to handle the overlap between objects
- Soft pT object
  - They are needed to “close” the event
- **Vectorial sum on the all these on the transverse plane**
  - Done!

$E_{x,y}^{\text{Soft Term}} = \Sigma\, p_{x,y}$ what is left out from the hard objects



no association to e,γ,μ,τ,jets Soft Term

SoftTerm: How to measure it?

- **Which options do I have to measure the soft terms?**
- **Option 1: Depositions in the calorimeter**
  - **+ It has a good coverage in p_T and η**
  - **- it suffer from pile-up:**
    - deterioration in resolution:

      $d\sigma^{Reso}/d(NPV)$=0.5 - 1. GeV per addit. primary vertex
      for NPV=30:
      Resolution ~20-30 GeV just from pile-up effect on soft terms

SoftTerm: How to measure it?

- Which options do I have to measure the soft terms?
- **Option 2: Tracking**
  - **+ We can identify the primary vertex, and suppress any pile-up effect** (but we need to identify the right primary vertex)
  - **- it suffer from: missing the neutrals at low p_T + forward region**
  - MET resolution due to Soft Terms done with tracks: **8 GeV**.
  - **But we are slightly underestimating the Soft Term**.

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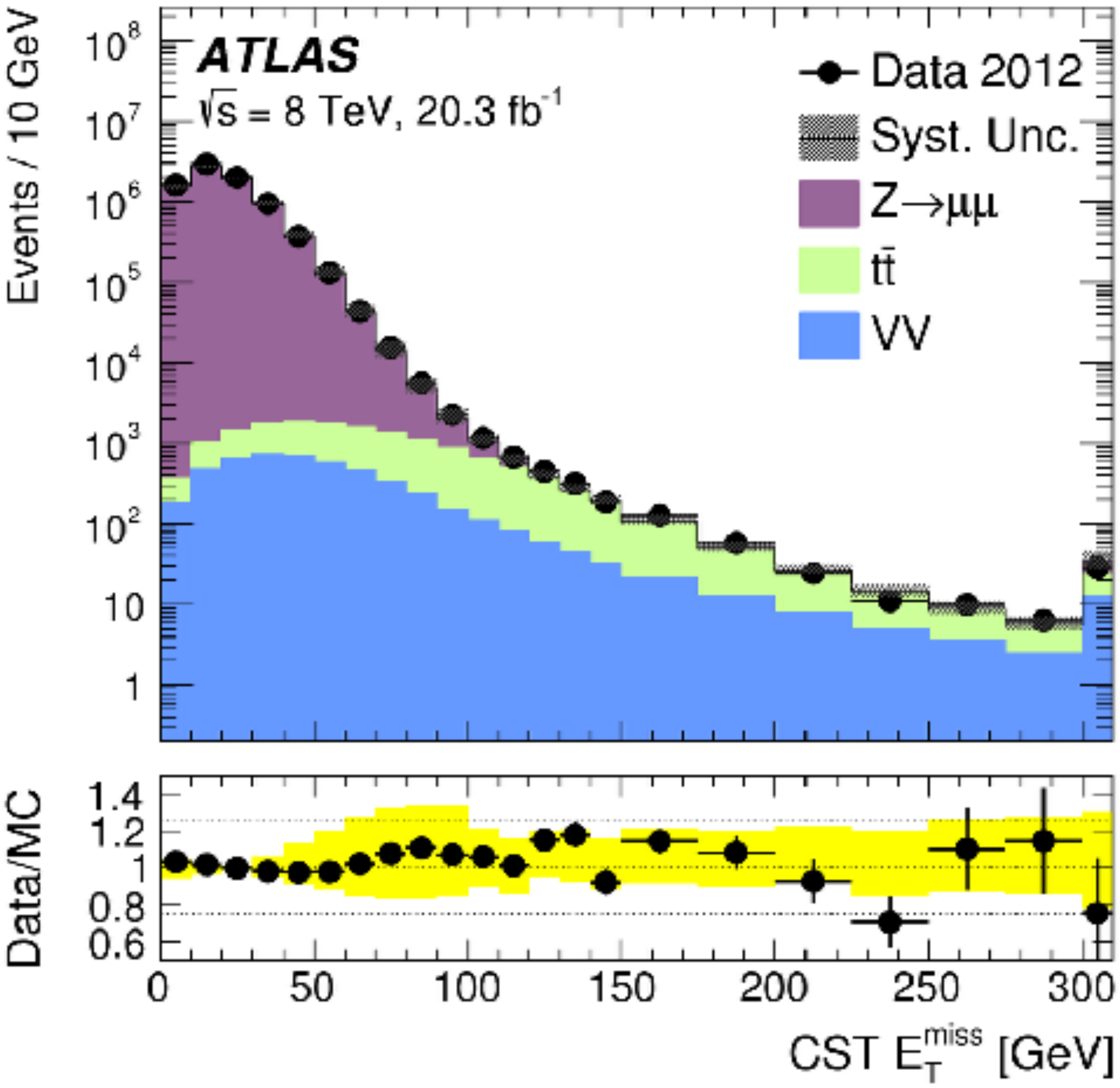
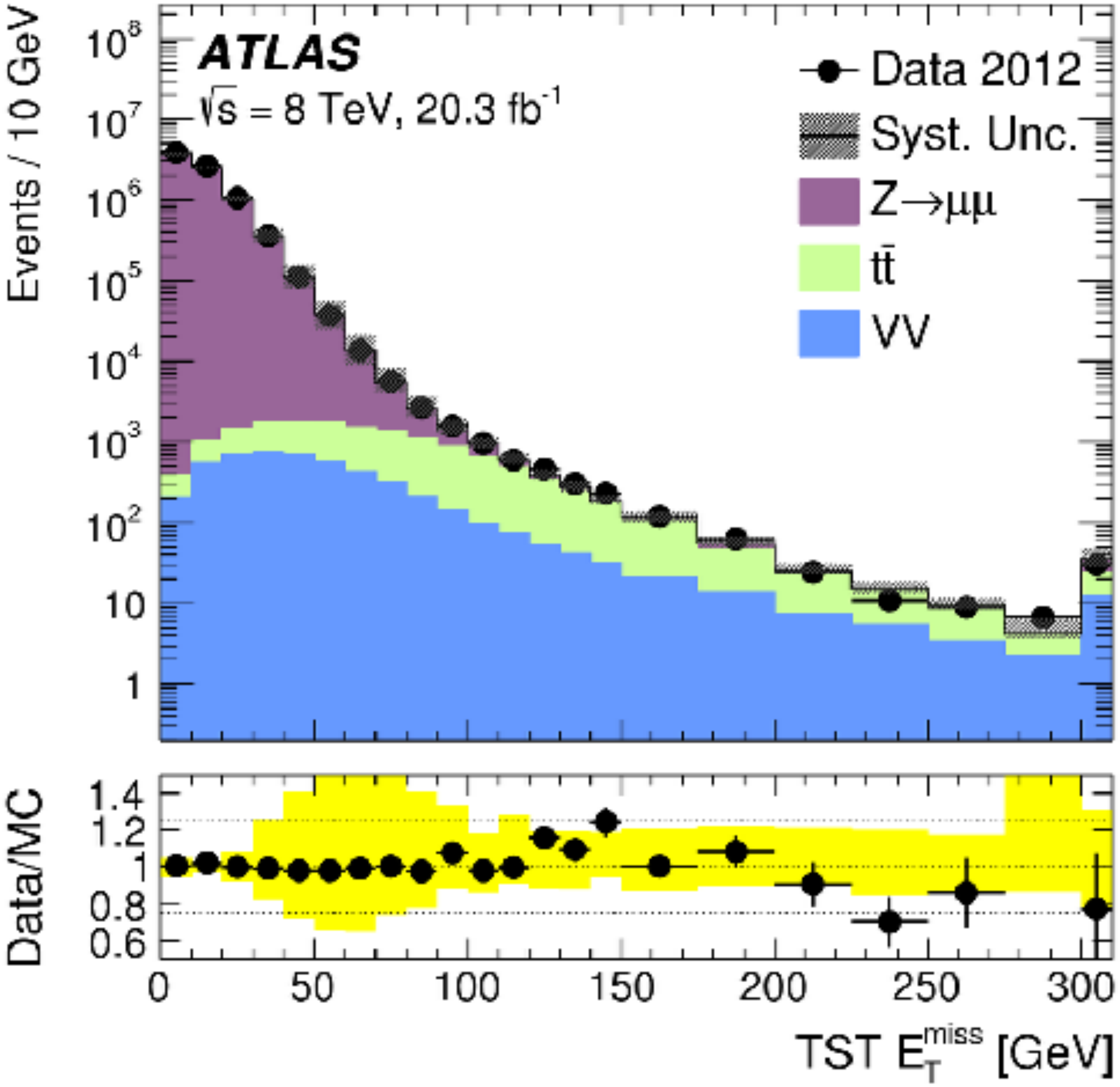
Measuring EtMiss where we expect no EtMiss

Using calorimeter clusters for the SoftTerms



Using tracks from PV for the SoftTerms



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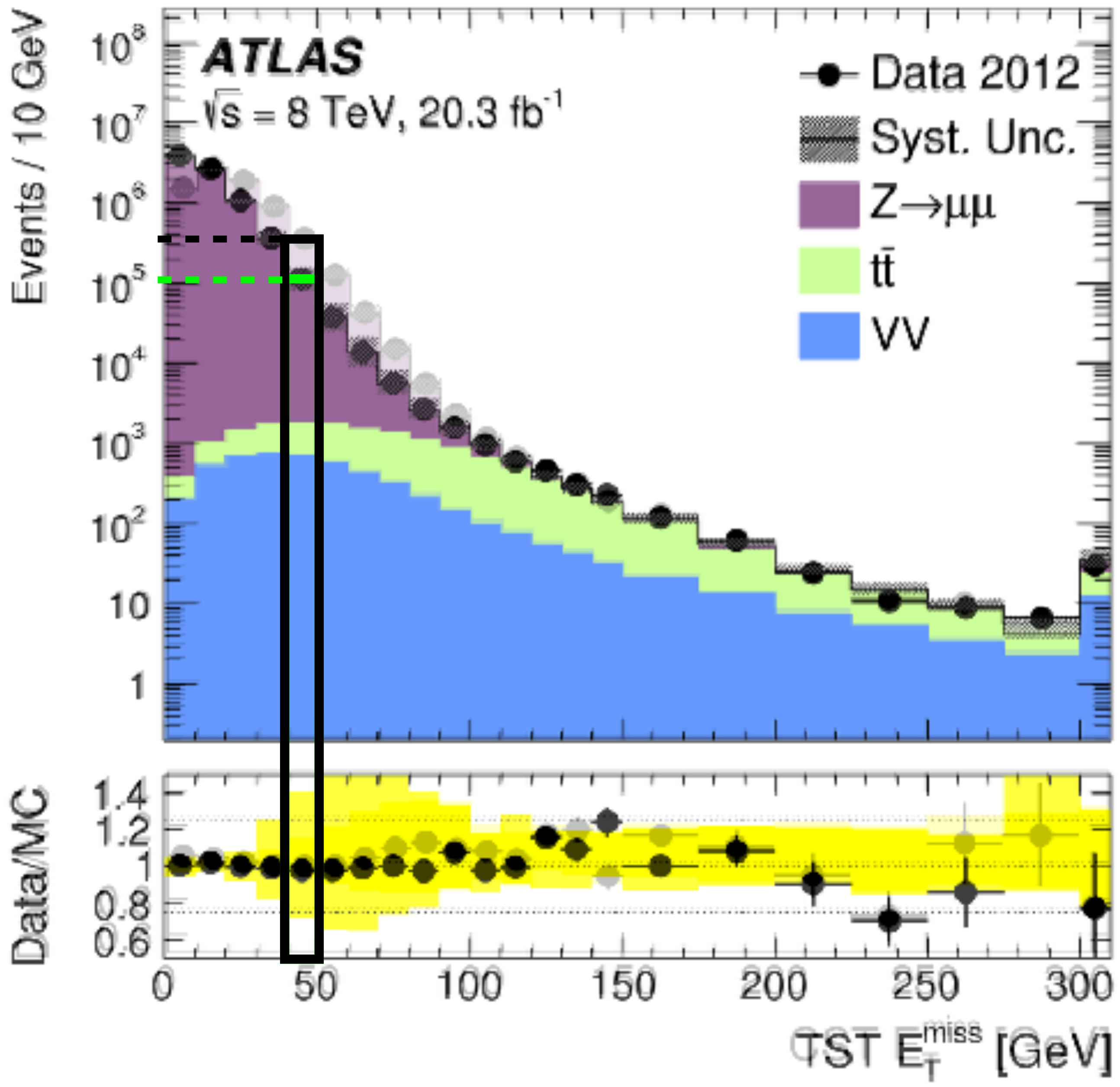
Measuring EtMiss where we expect no EtMiss

- Using the tracks from the primary vertex as soft terms seems to allow an improved resolution (lower MET values) in events with no real MET.
- By the end of the Run1 it become the new standard in ATLAS, and it is our default algorithm right now.
- BUT, we do not leave just of resolutions in events without EtMiss



Events with MET ~50 GeV diminished by ~ a factor 4

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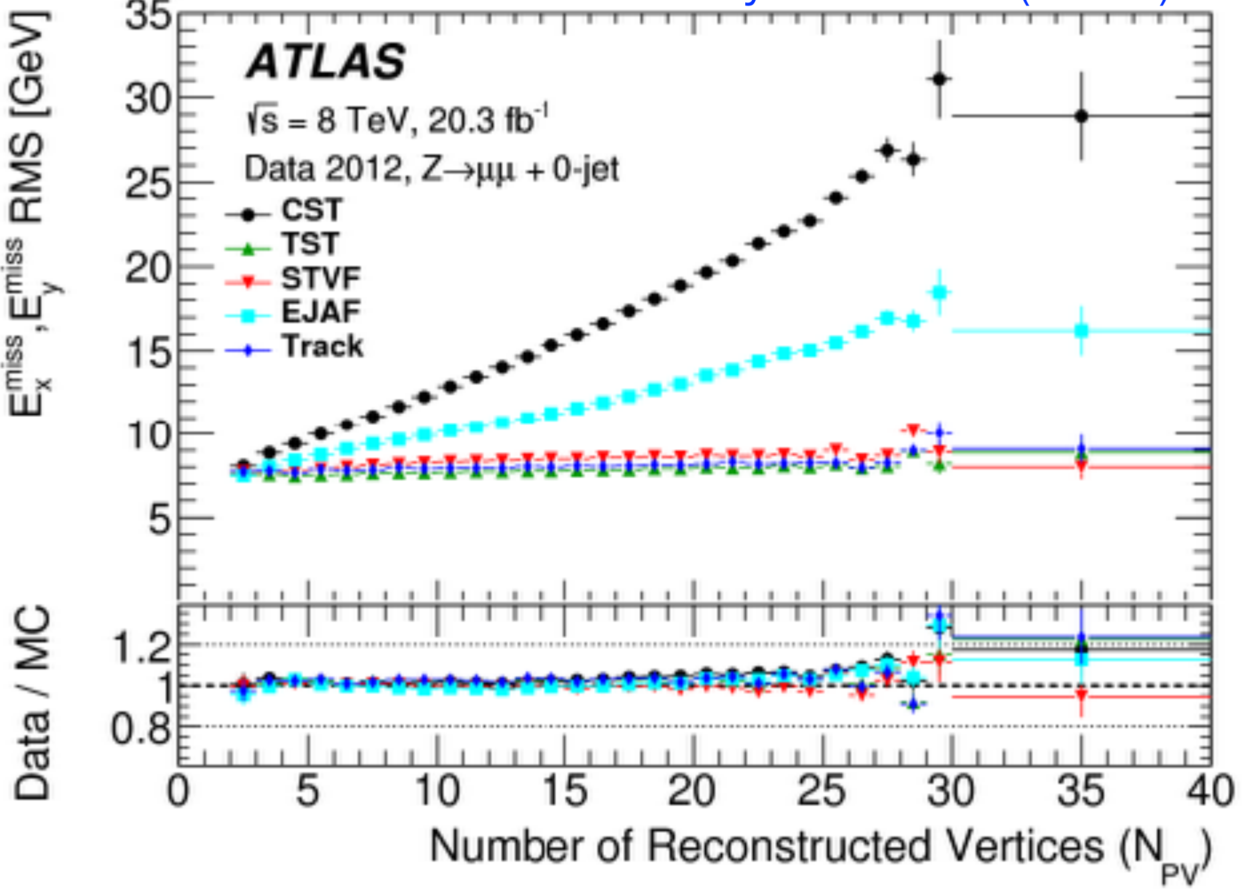
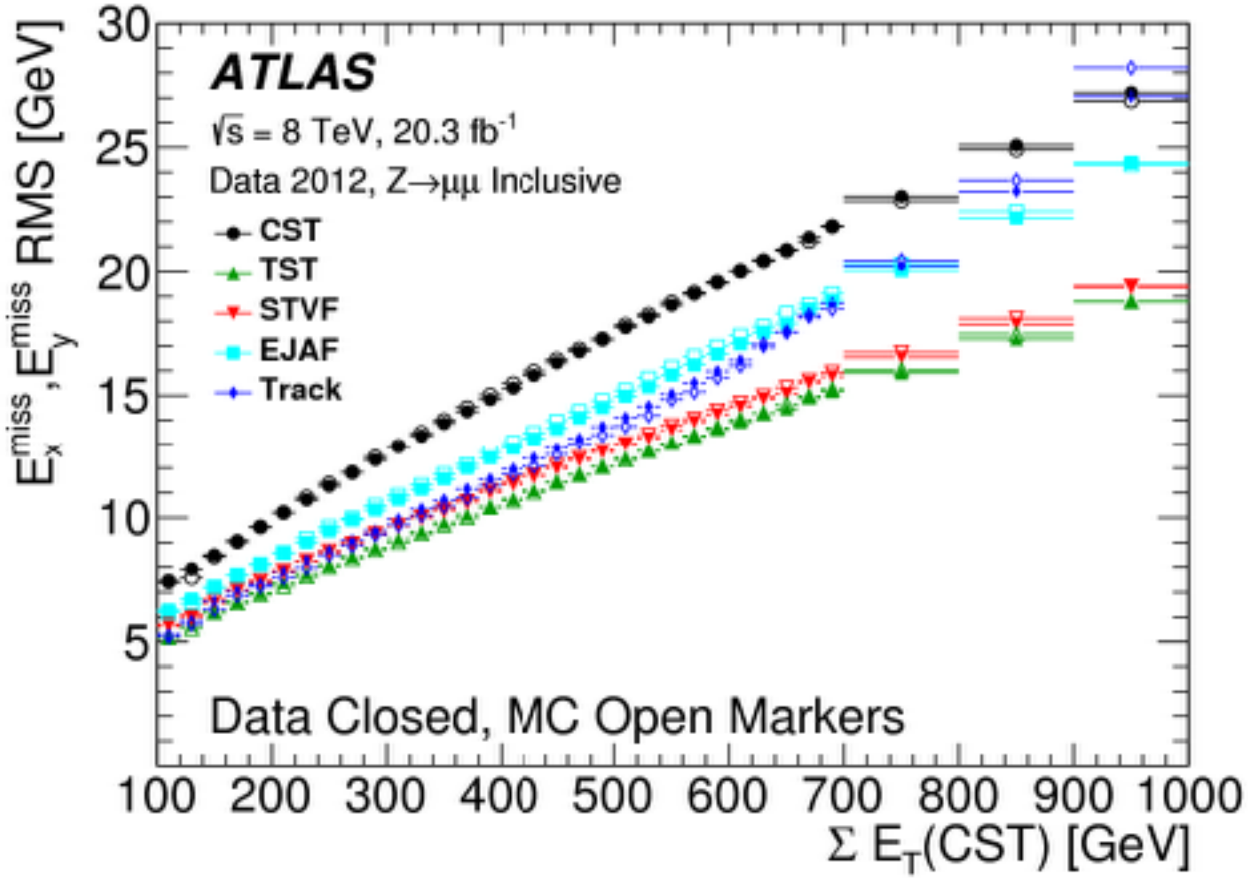
Measuring EtMiss where we expect no EtMiss

- Again resolution, and its dependence on pile-up and activity in the event
- ΣE_T(CST) is the scalar sum of the transverse energy, using calorimeter clusters for Soft Terms





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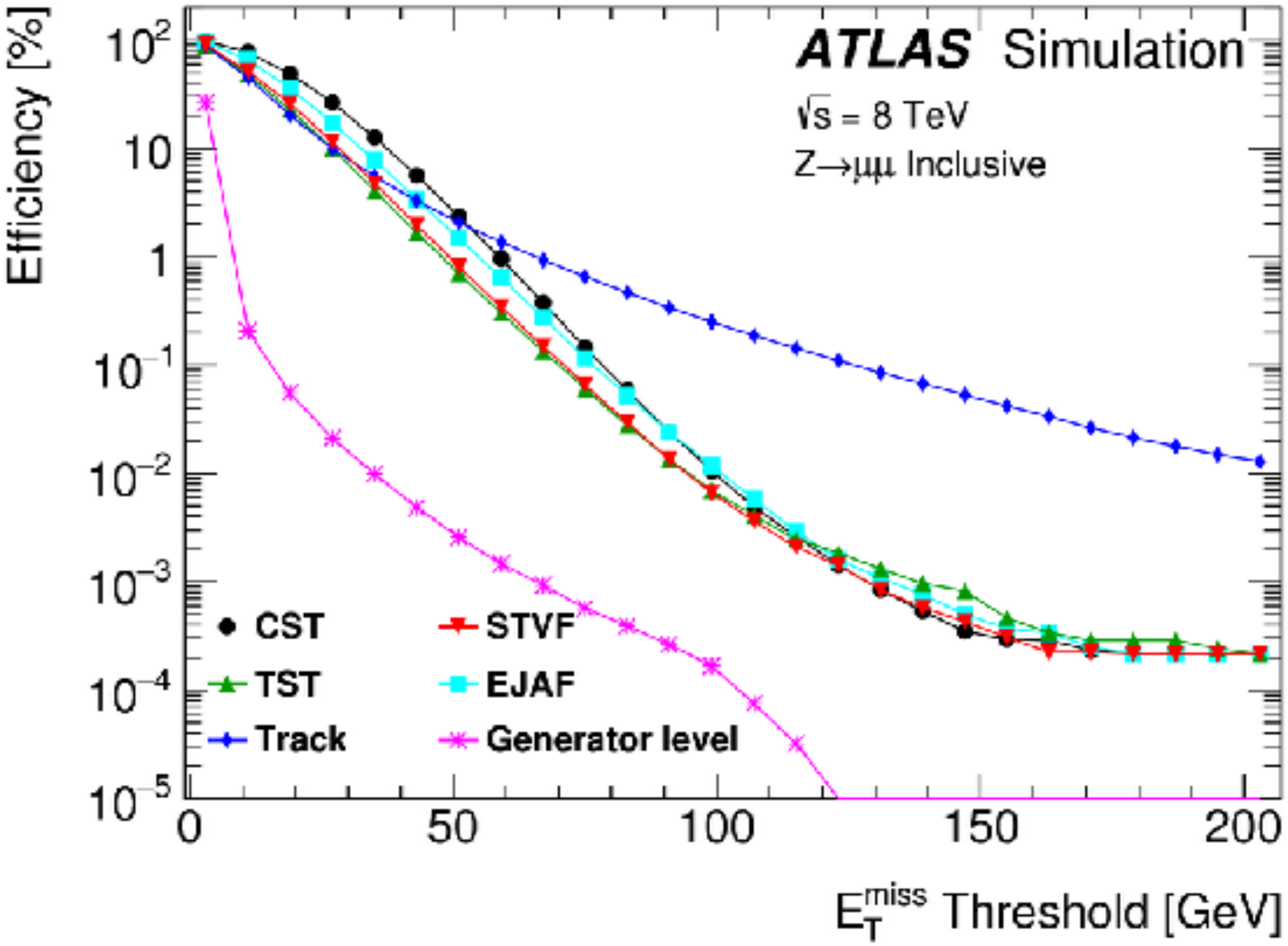
Measuring EtMiss where we expect no EtMiss

- But for searches are are interested in tails:
- **Step 0:** Make sure that we do not have problematic events (detector malfunctioning)
- **Step 1:** reduce as much as possible the tails in SM events where do not expect real MET
- Z+jets: reduction of a factor 10^5 for MET>120 GeV



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EtMiss Response

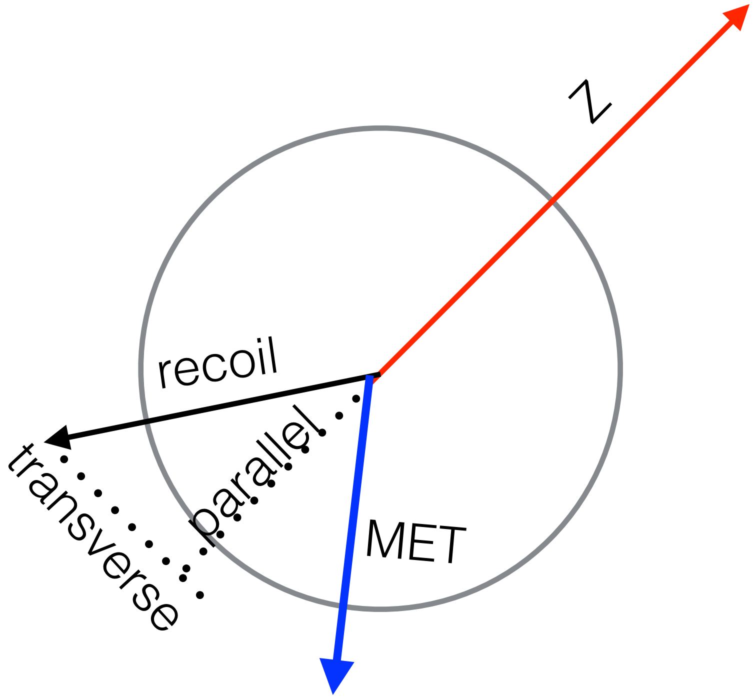
- In events with 0 truth MET, we expect the the MET to be average 0, irrespectively of the direction in which we project the MET.

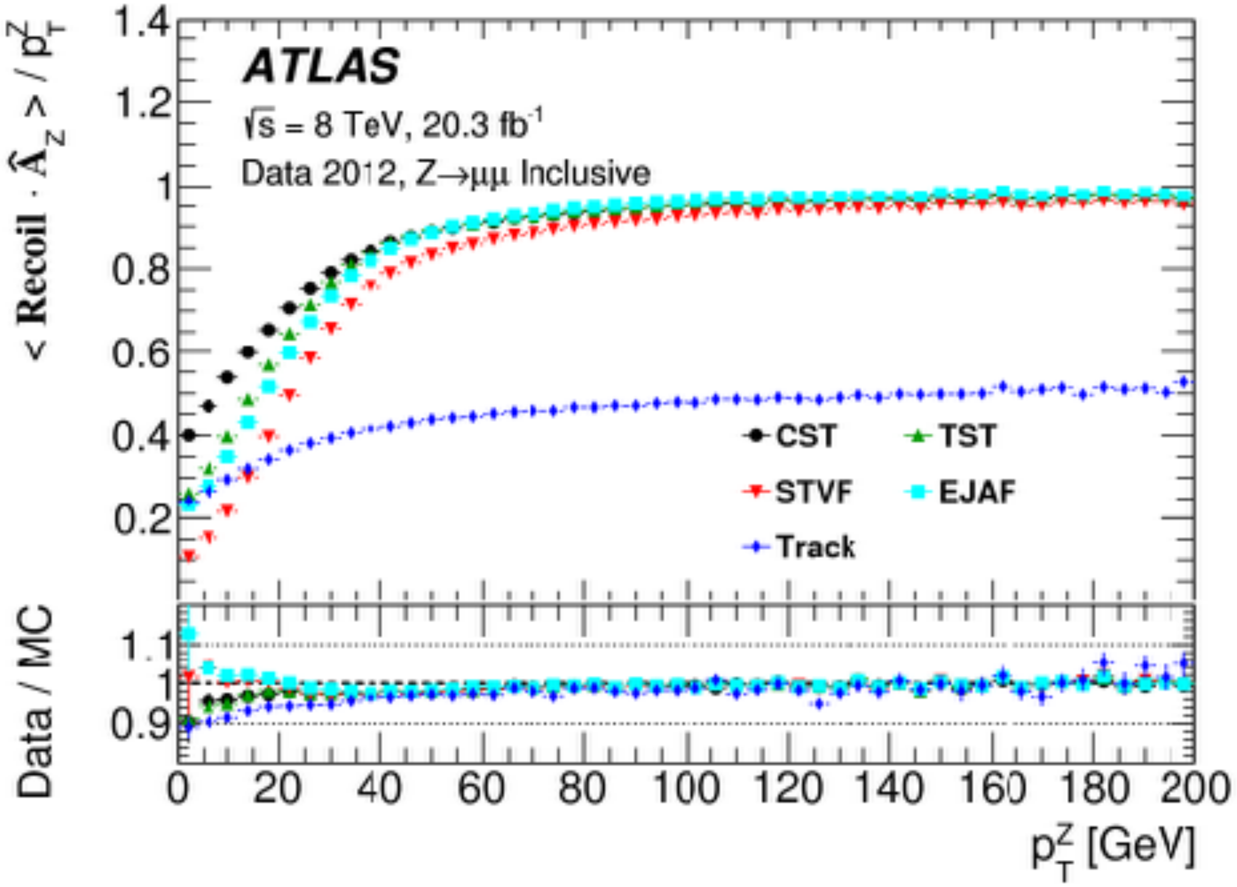
- This is what we see in x or y directions.

- In Z+jets we have another interesting directing to test: the Z direction.

- So doing <(**MET+p_T(Z)**) // **Z** > / p_T(Z) we expect 1 for a perfect response

- **MET+p_T(Z)** is the recoil of the Z boson





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- This is what we see in x or y directions.
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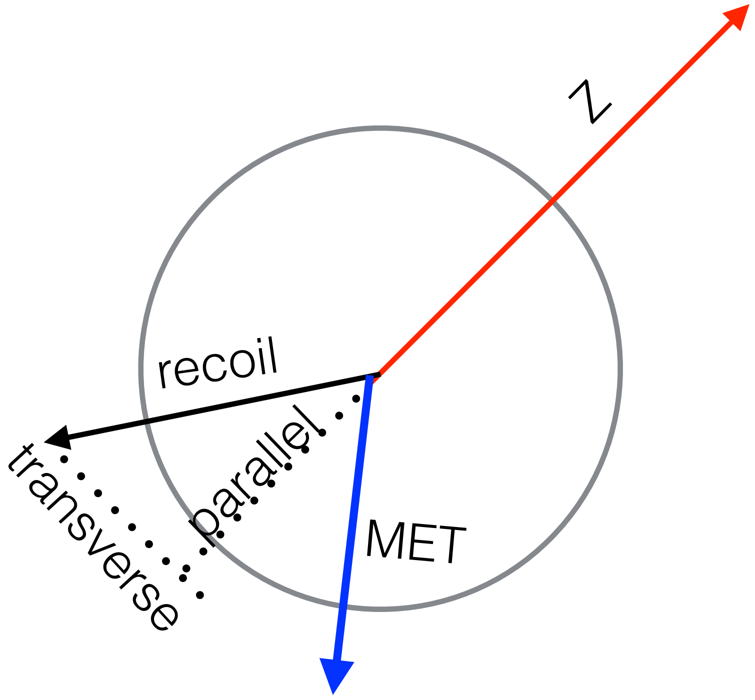

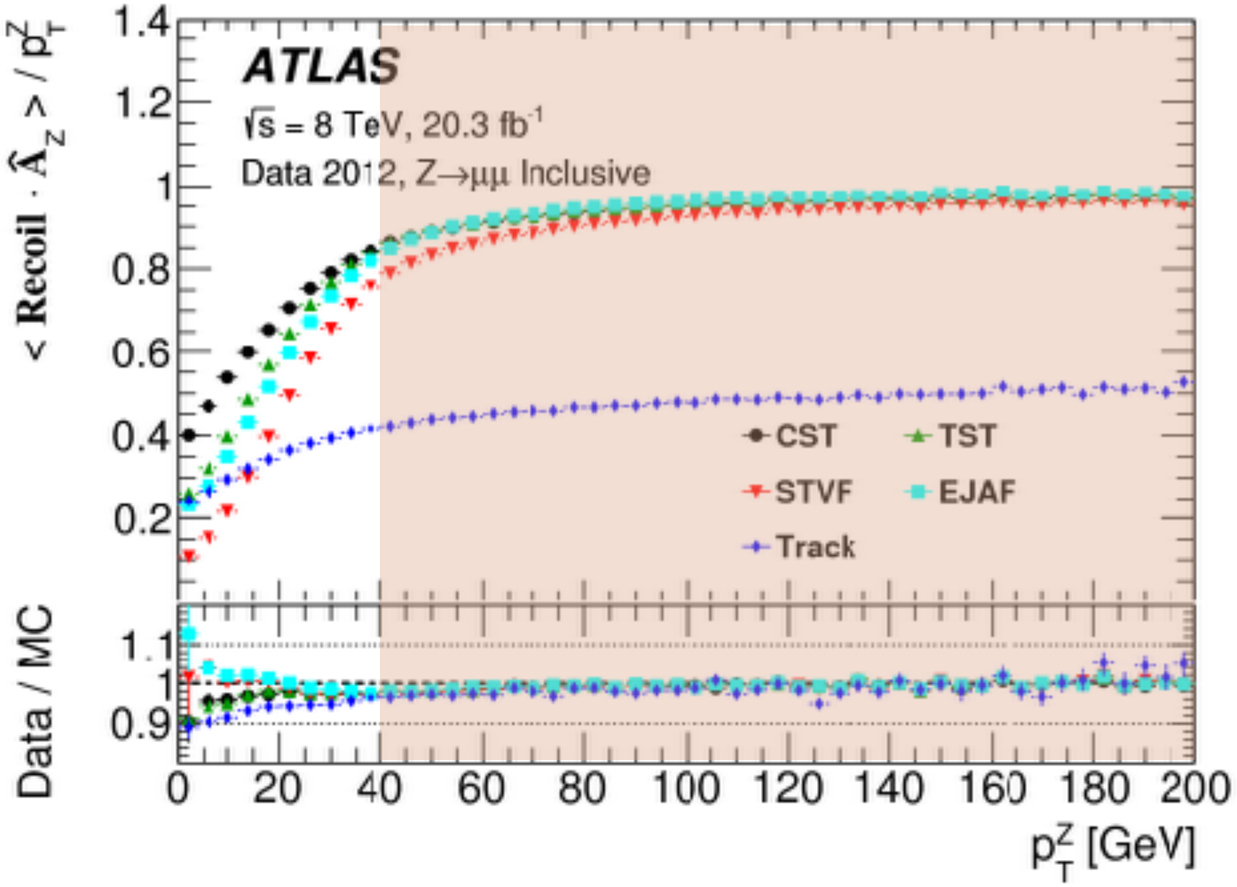

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EtMiss Response

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- In Z+jets we have another interesting directing to test: the Z direction.
- So doing <(**MET+p$_T$(Z)**) // **Z** > / p$_T$(Z) we expect 1 for a perfect response
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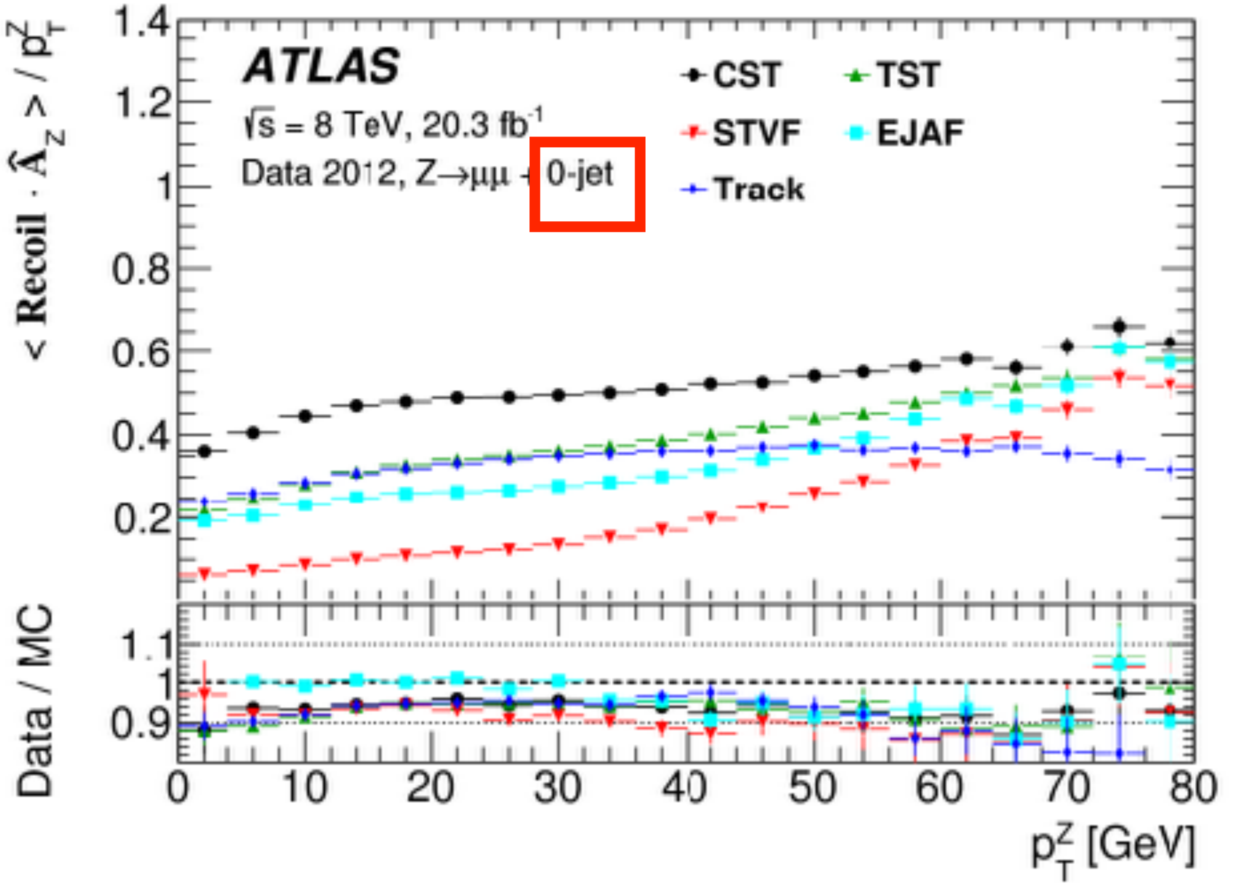

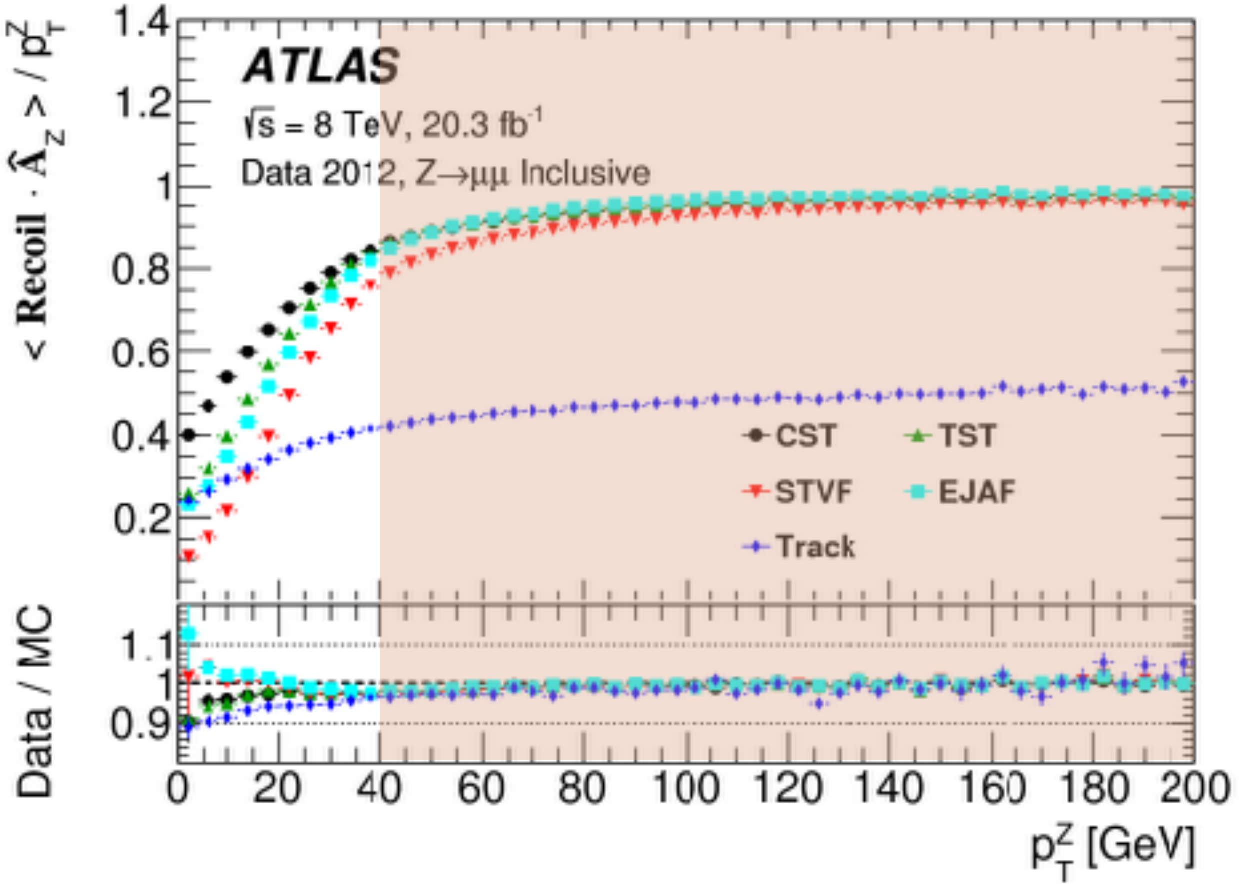

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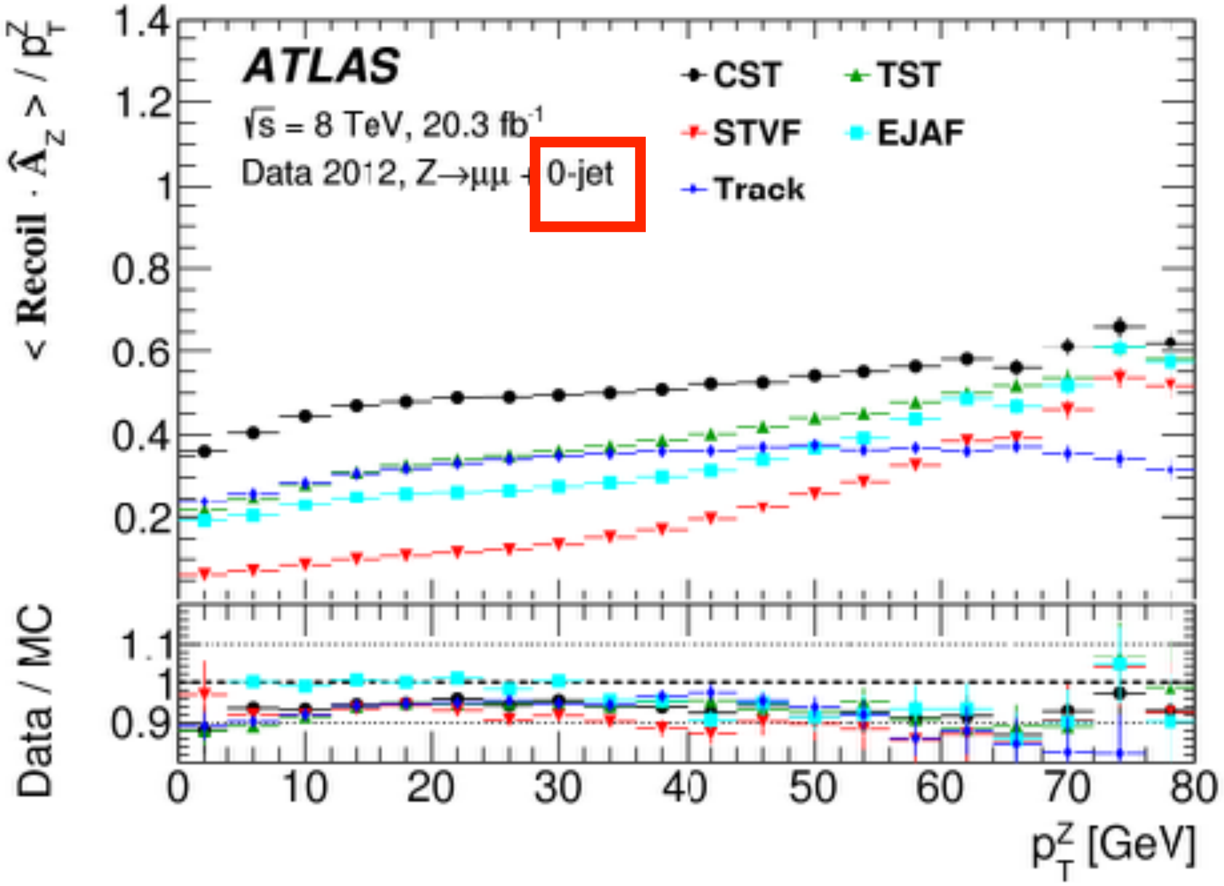
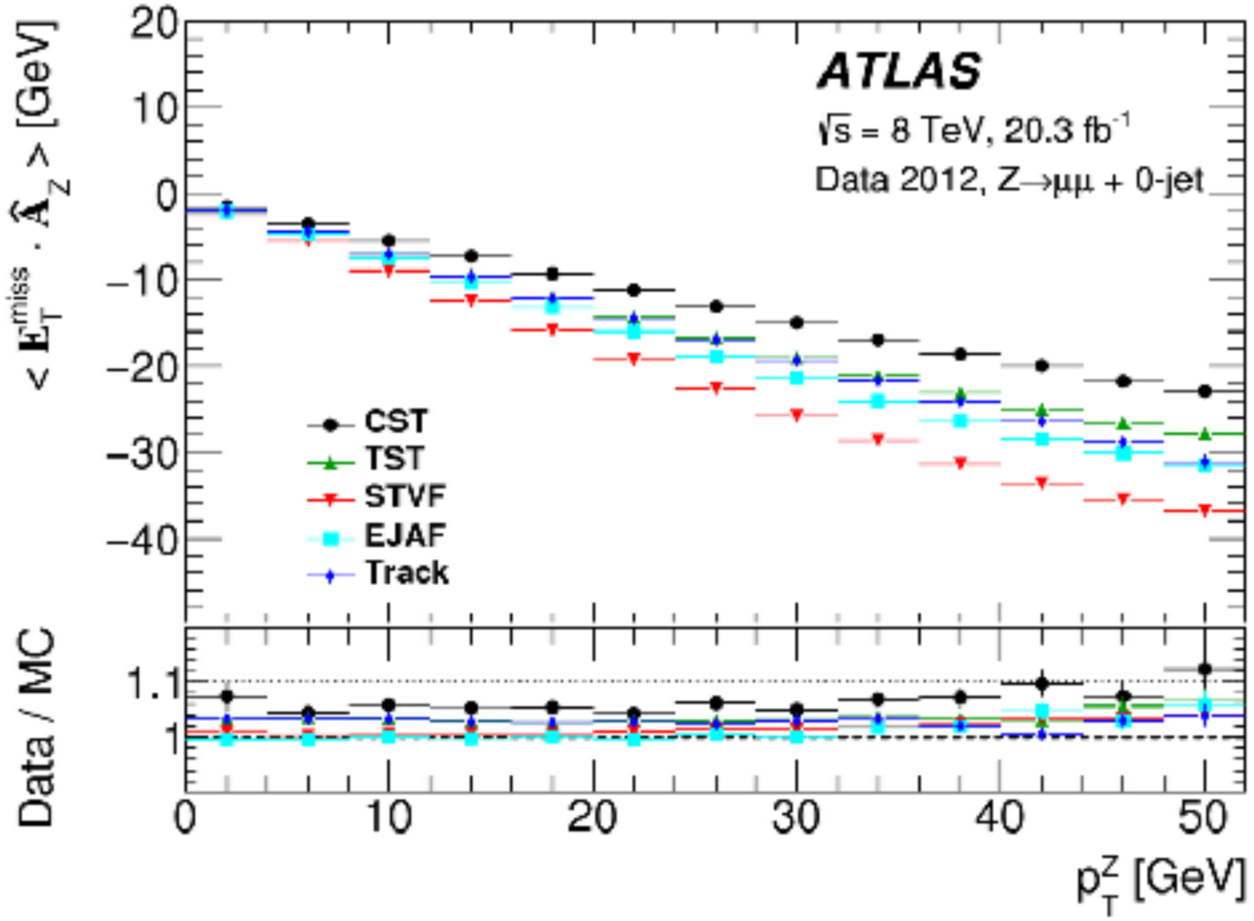
From EtMiss Response to Soft Term performance

- <(**MET**+**p_T(Z)**) // **Z** > / p_T(Z)

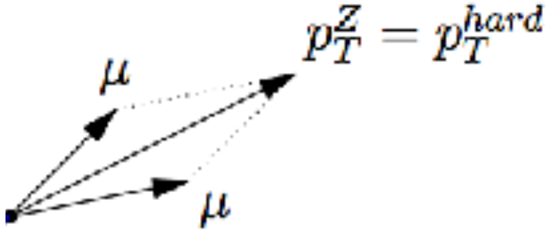


- <**MET** // **Z**>



From EtMiss Response to Soft Term performance

Z



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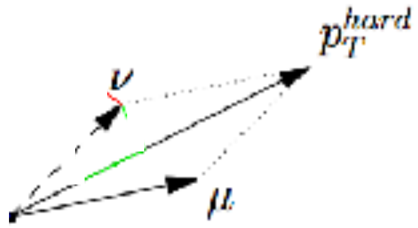
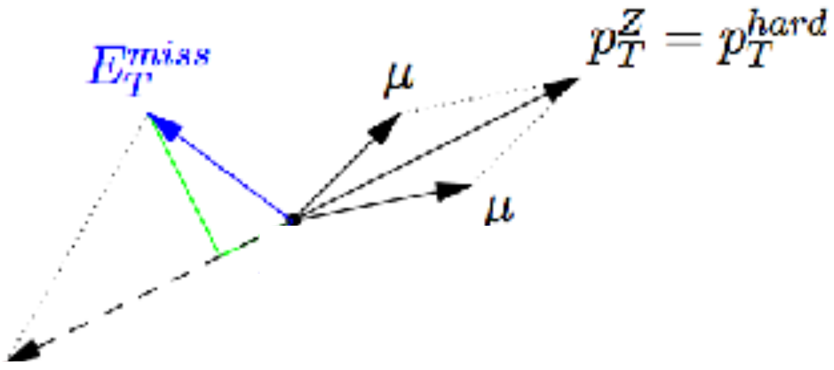
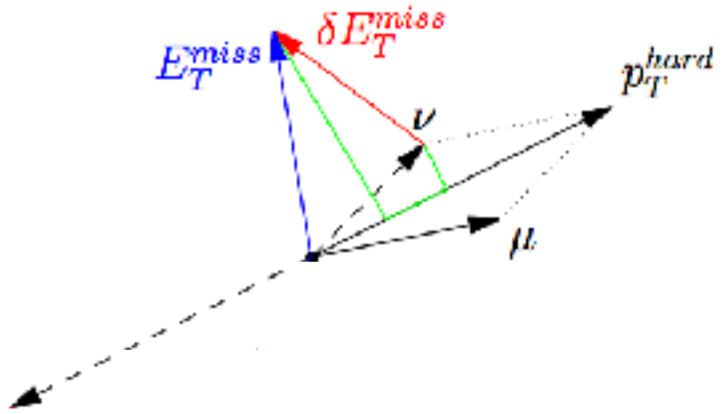


From EtMiss Response to Soft Term performance

Z

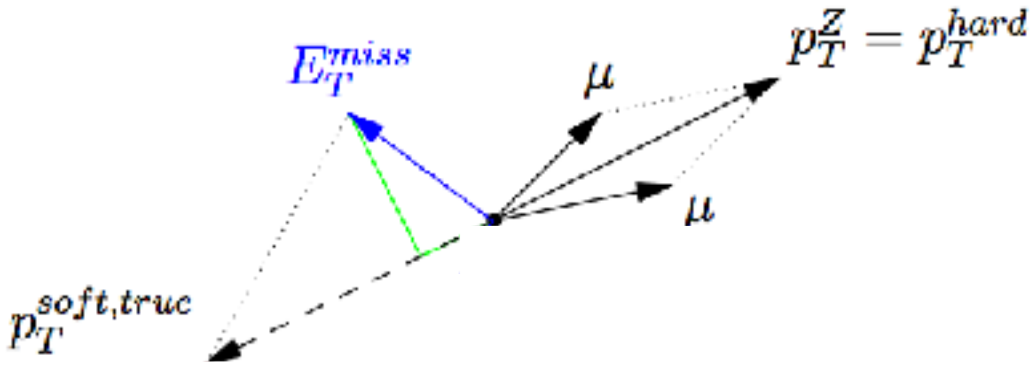


W

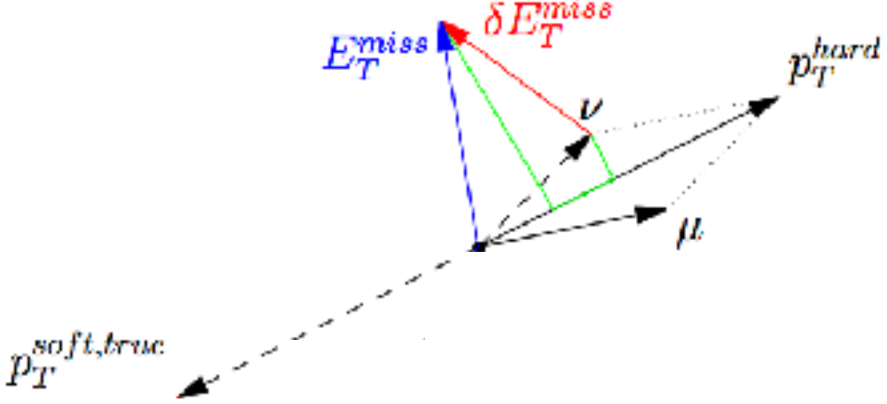


From EtMiss Response to Soft Term performance

Z

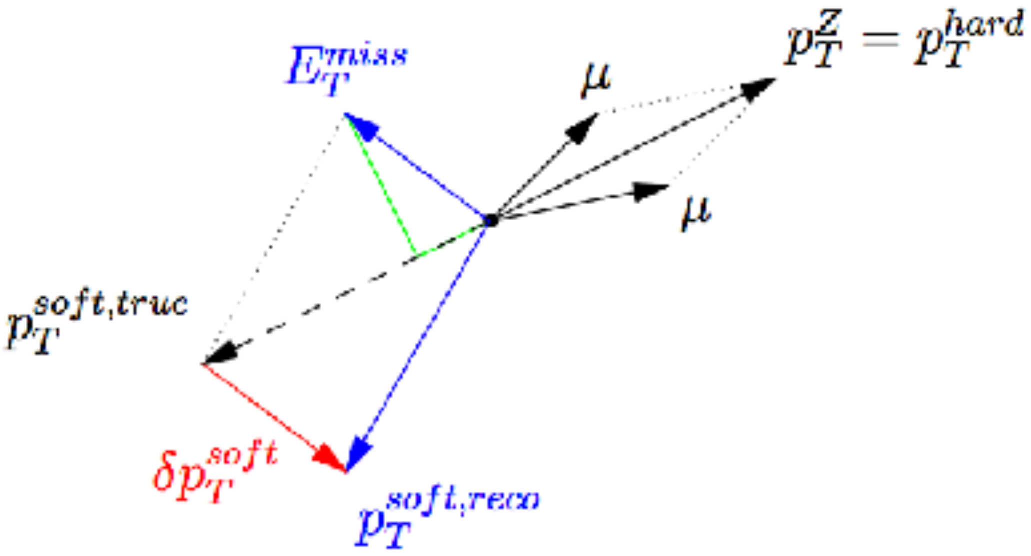


W

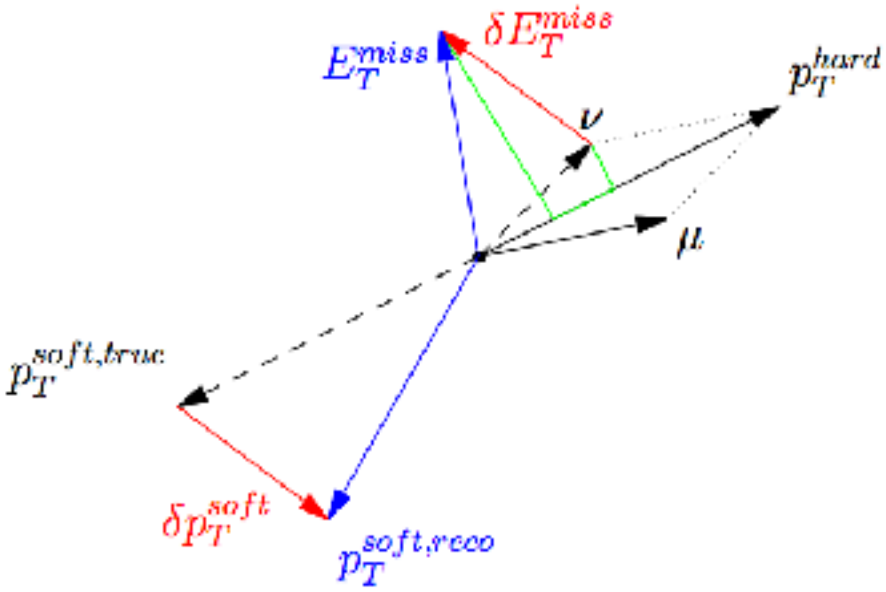


From EtMiss Response to Soft Term performance

Z



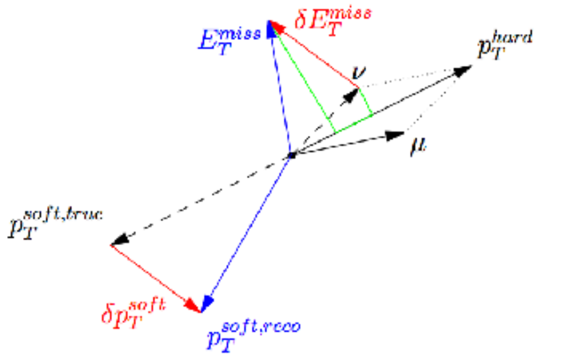
W

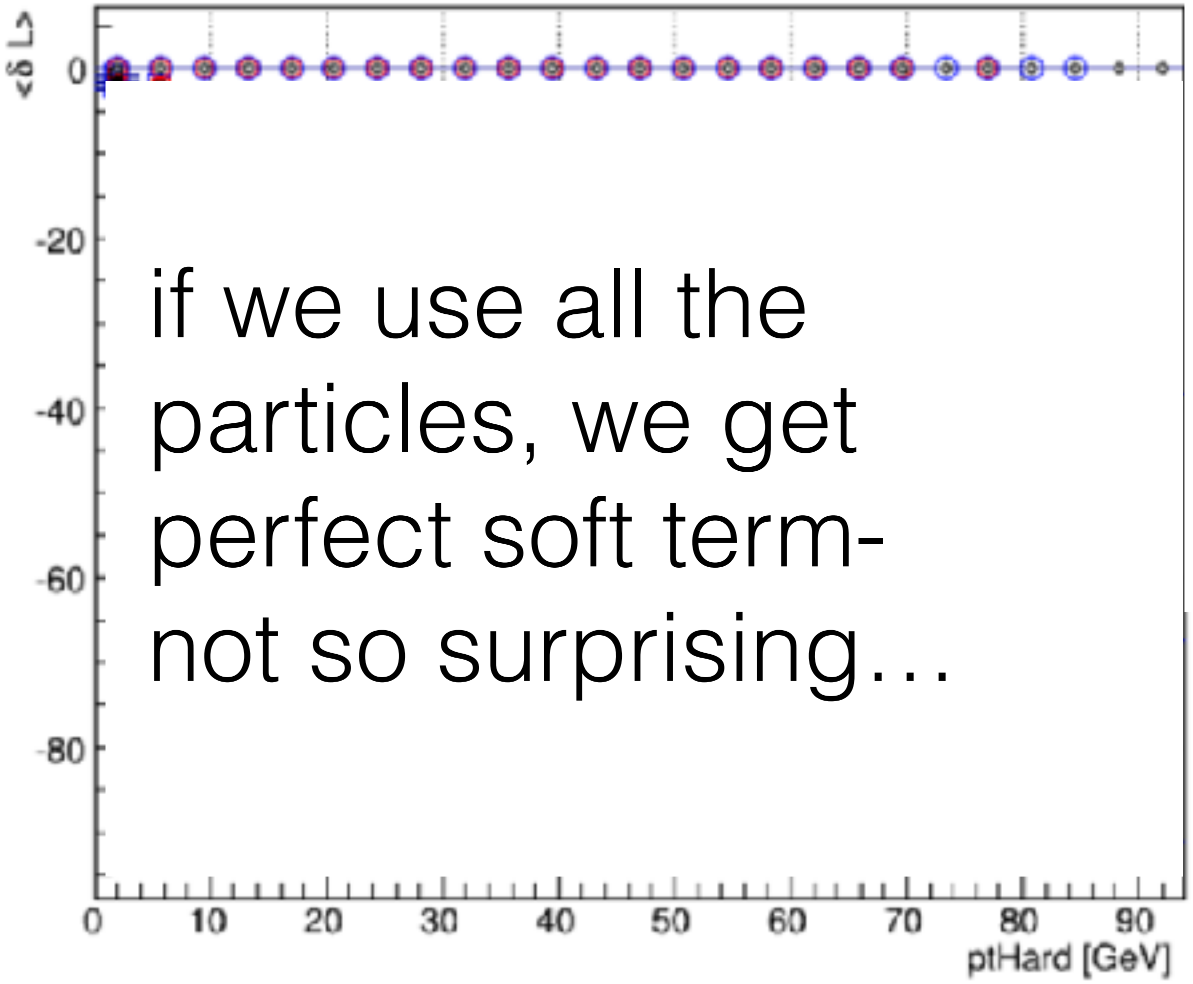


To get a feeling of the quality of the MET (and soft terms), one can project the δp_T^{soft} on the direction of the p_T^{hard}

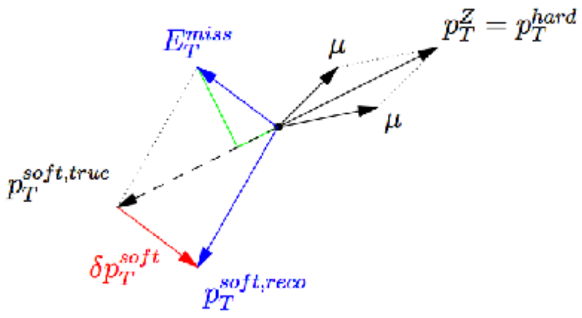
NOTE: $\delta E_T^{miss} = - \delta p_T^{soft}$

Soft Terms - Truth studies





if we use all the particles, we get perfect soft term- not so surprising…



Pythia8 private samples

Z+jets

W+Jets

TTBar

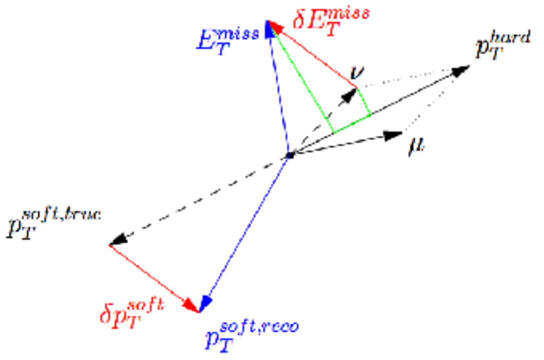
$<\delta L>=<\delta p_T^{soft} // p_T^{hard}>$

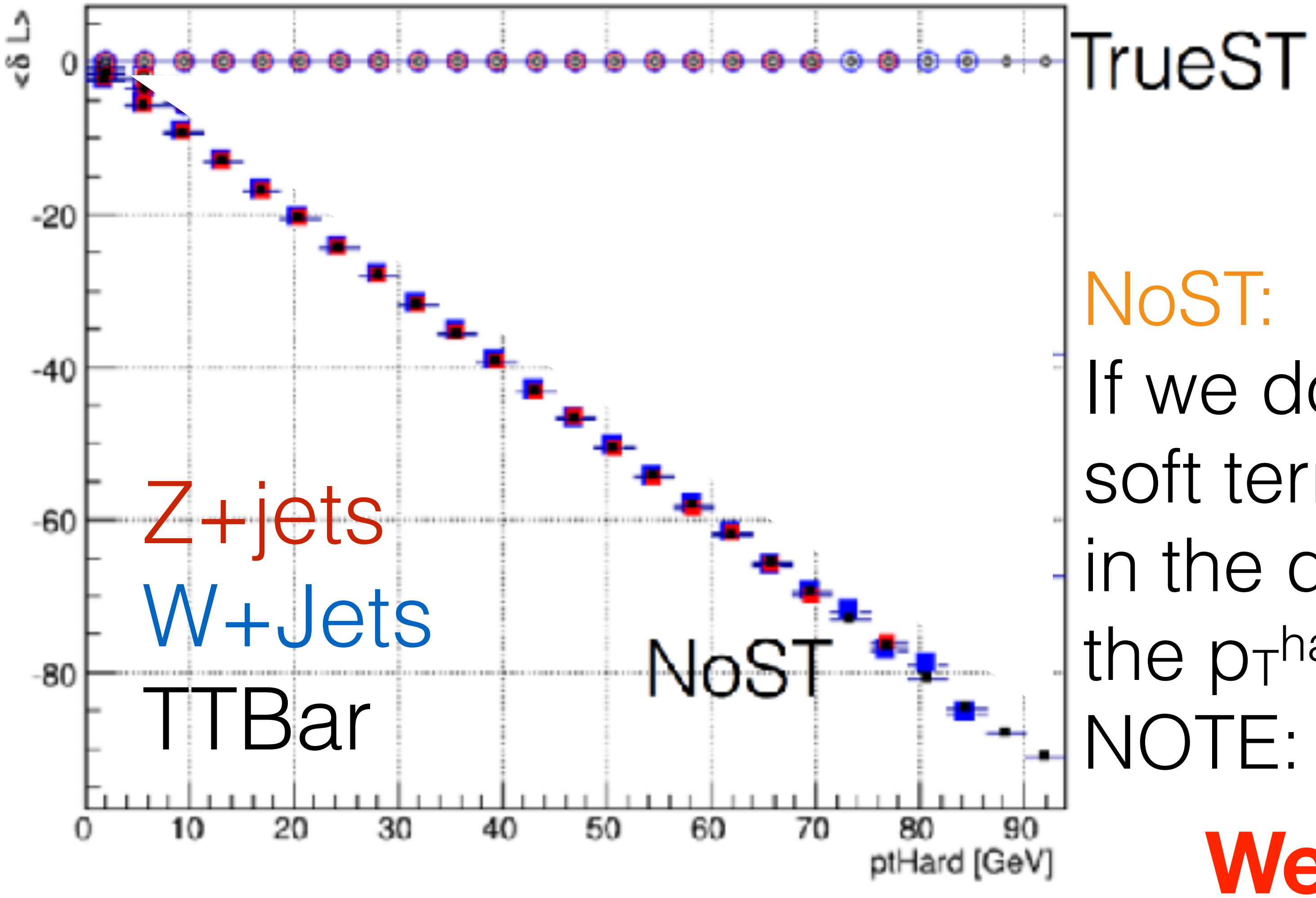
e, μ: pT>7 GeV and |η|<2.5

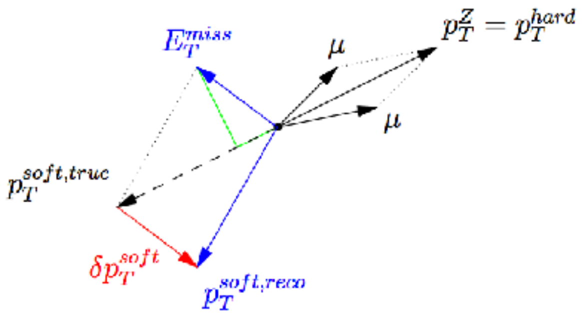
jets: anti-kt with R=0.4 with pT>20 GeV and |η|<5

All the rest enters in the Soft Term regime.

Soft Terms - Truth studies





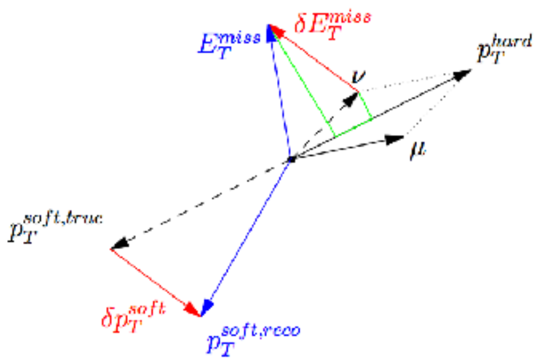


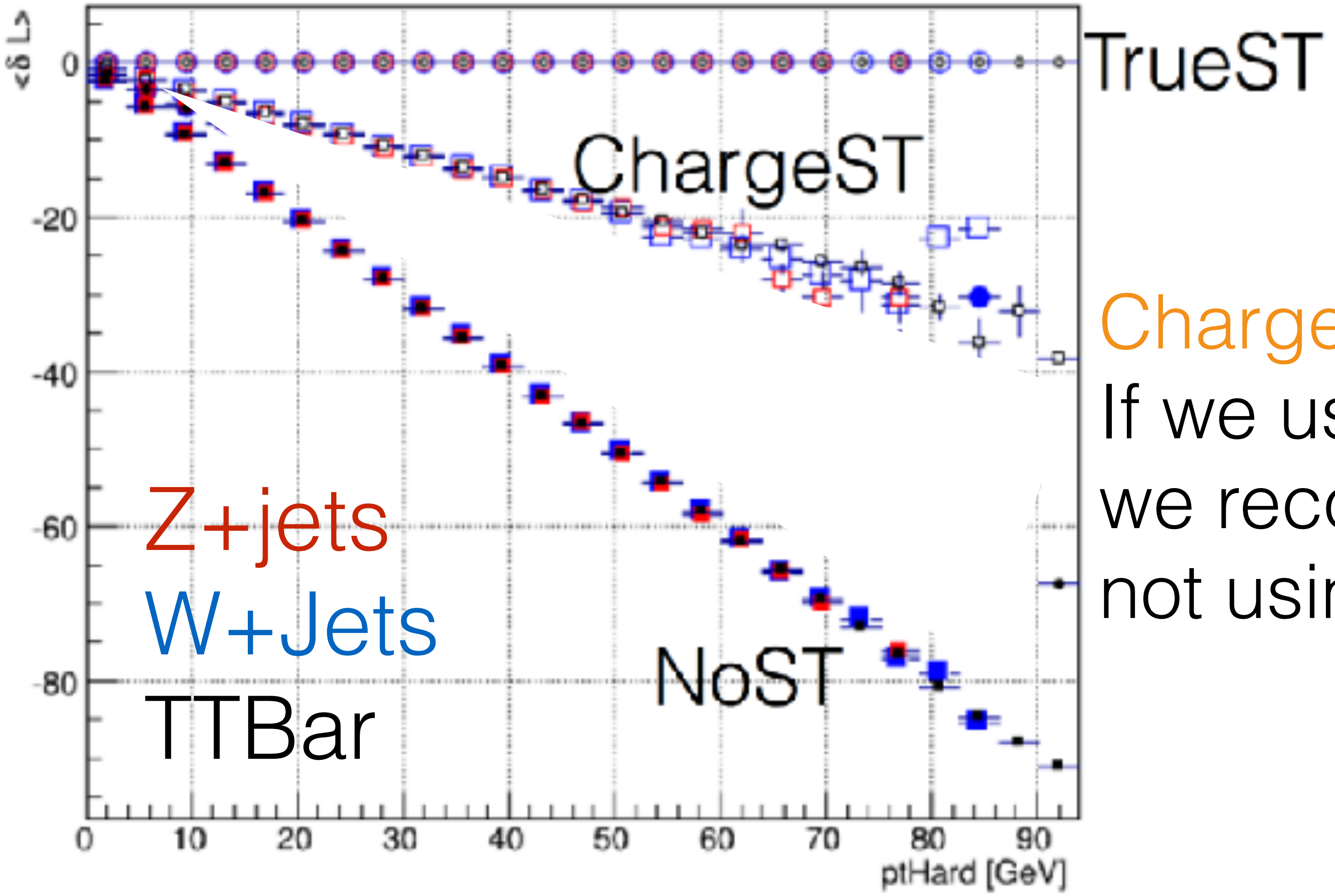
NoST:
If we do not use any soft term, we have a bias of the MET in the direction of the p_T^{hard} as big as the p_T^{hard}.
NOTE: $p_T^{hard}=p_T^{W/Z}$ for W/Z+jets

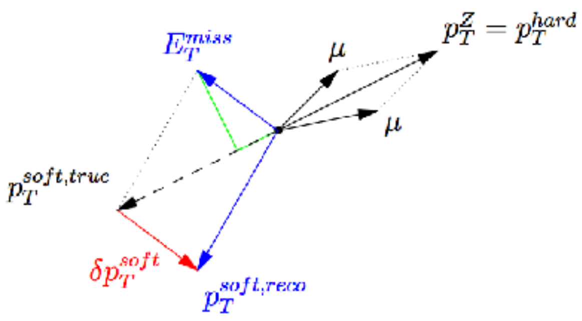
We need the soft terms!

Not a big difference between samples.

Soft Terms - Truth studies





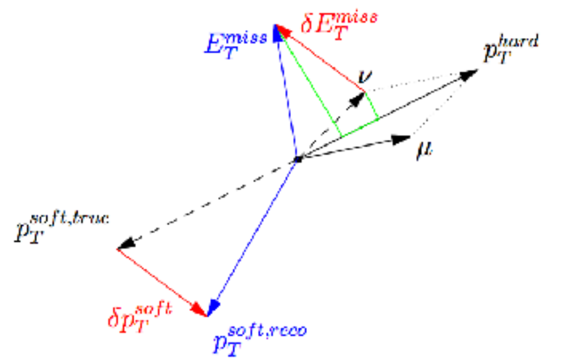


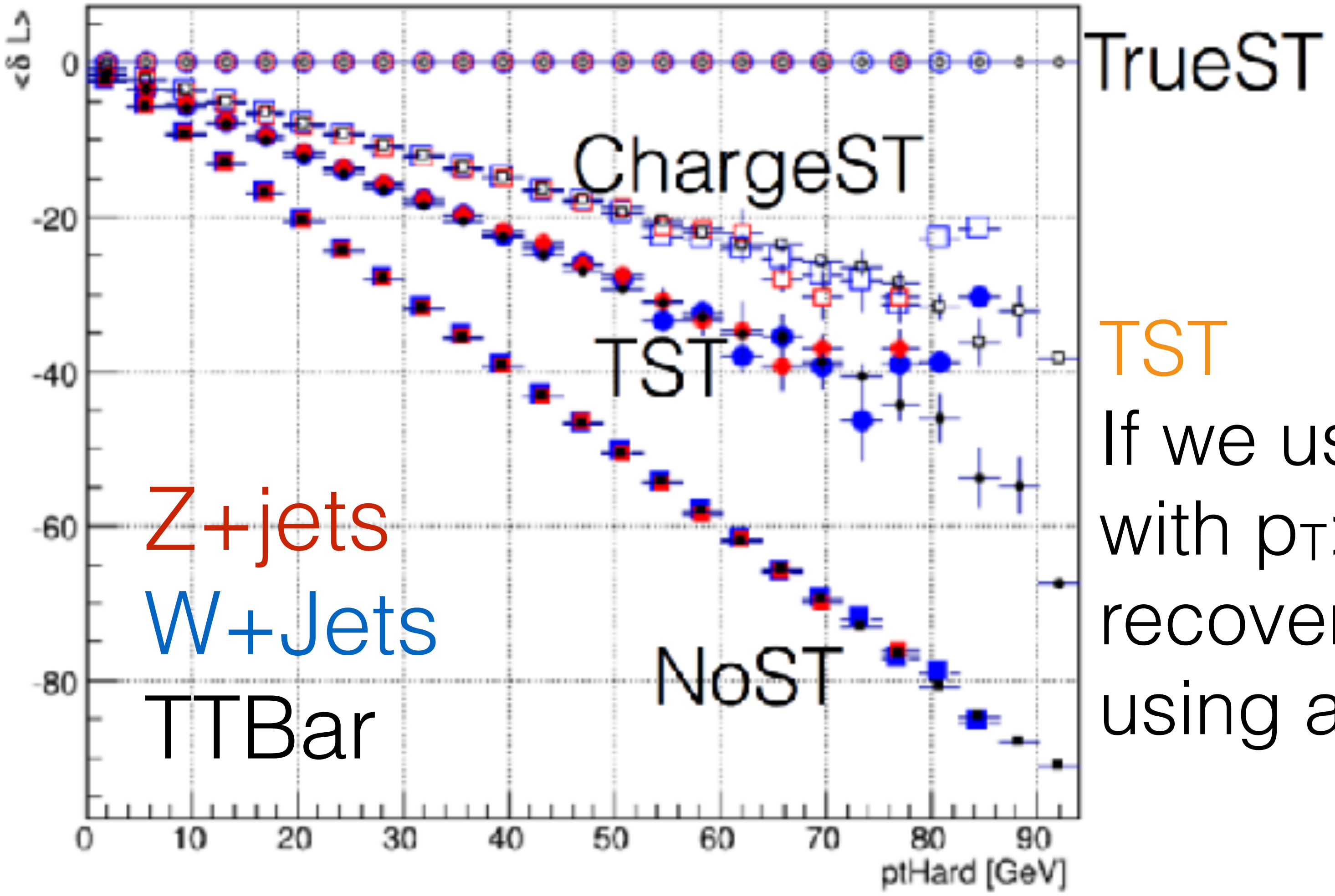
Charge ST

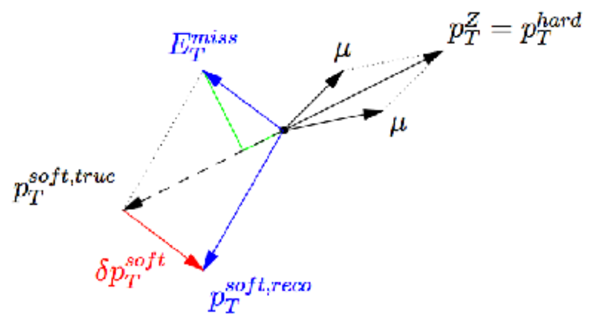
If we use only the charge particles, we recover ~ 60% of the bias from not using any soft term

Not a big difference between samples.

Soft Terms - Truth studies





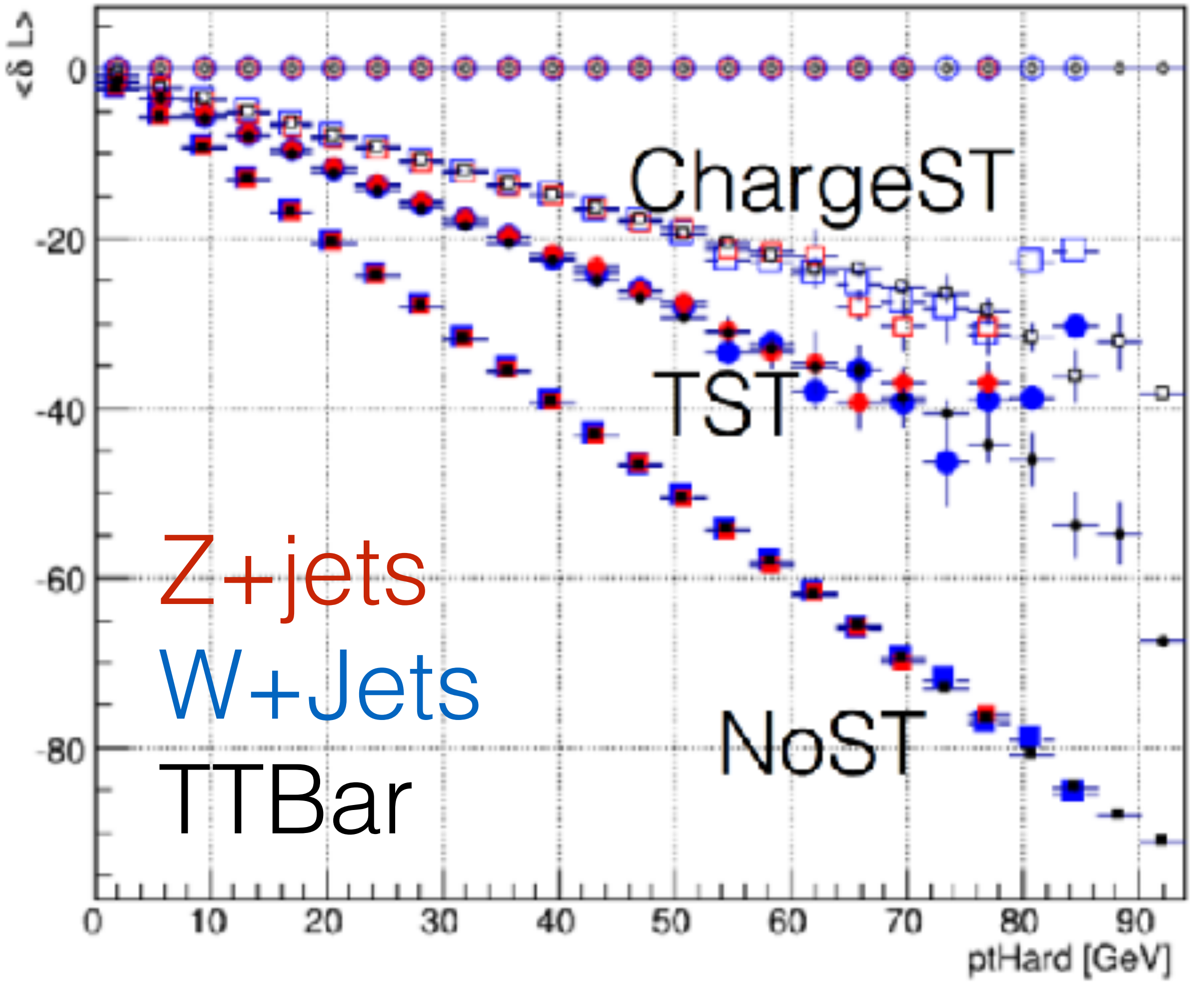


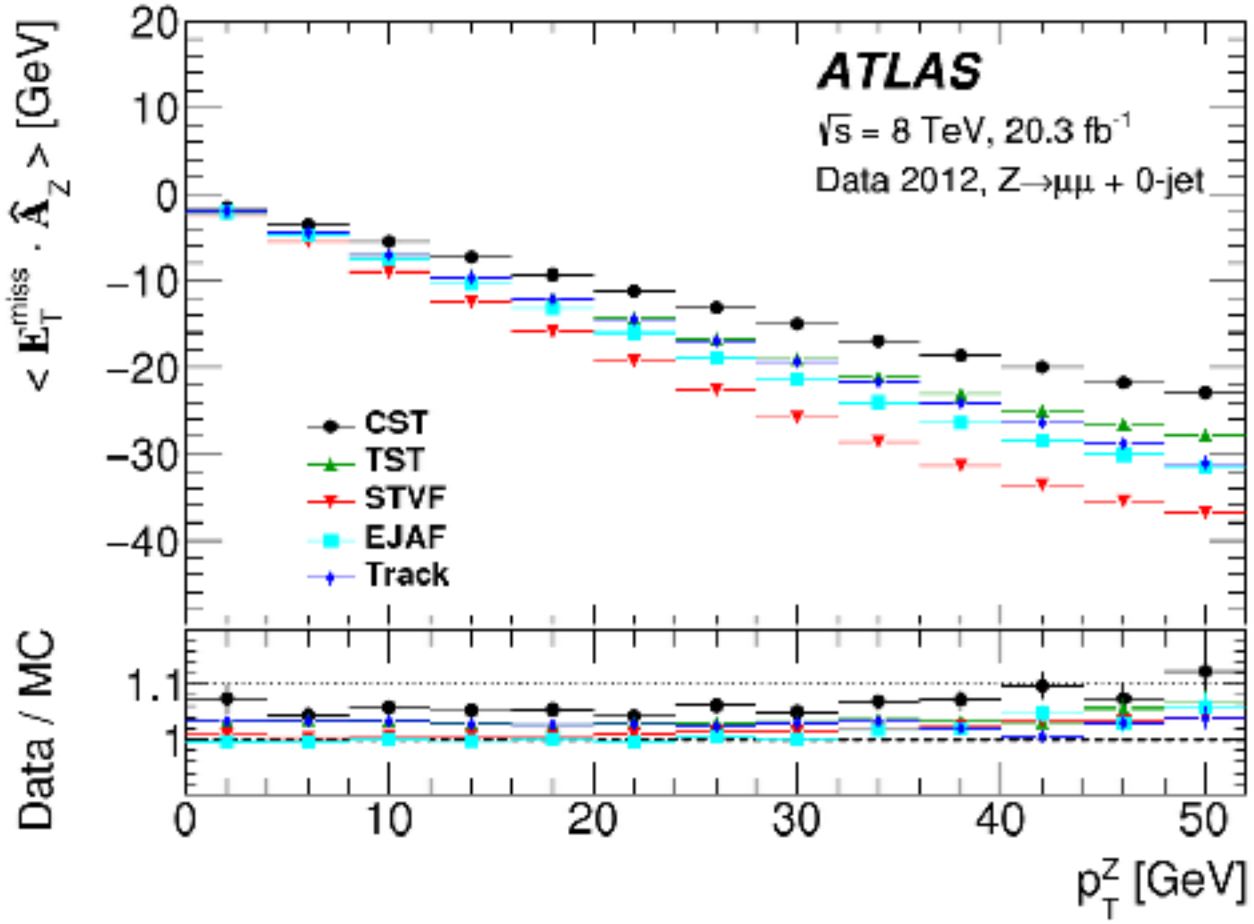
TST

If we use only the charge particles with p_T>0.5 GeV and |η|<2.5, we recover ~ 50% of the bias from not using any soft term

Not a big difference between samples.

Soft Terms - from truth studies to measurements





Calorimeter based Soft Terms have a better closure

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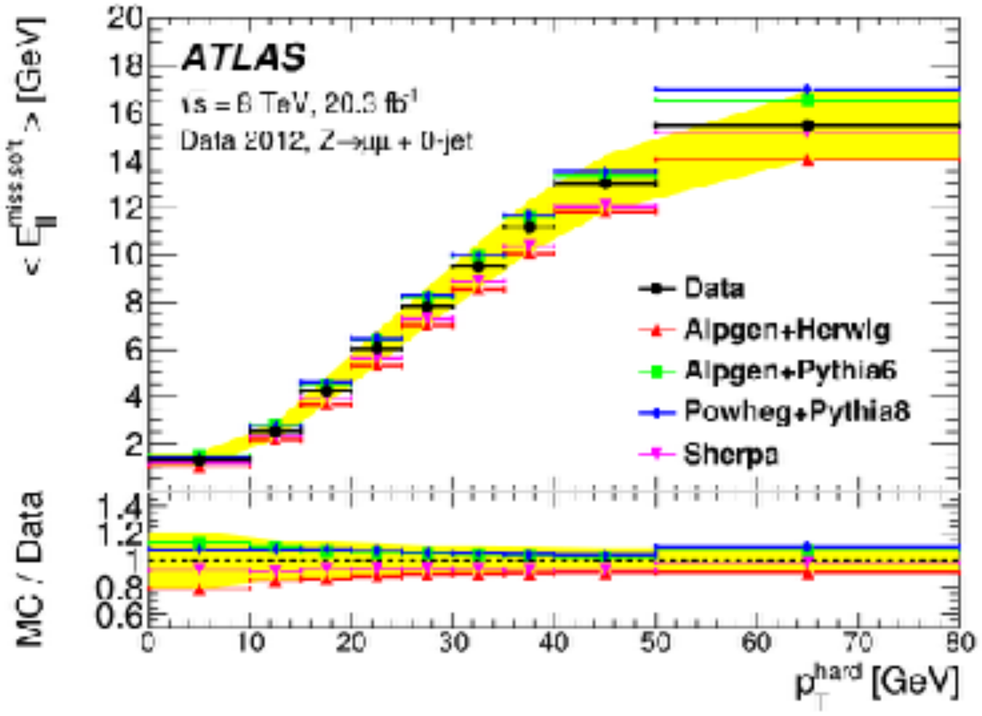
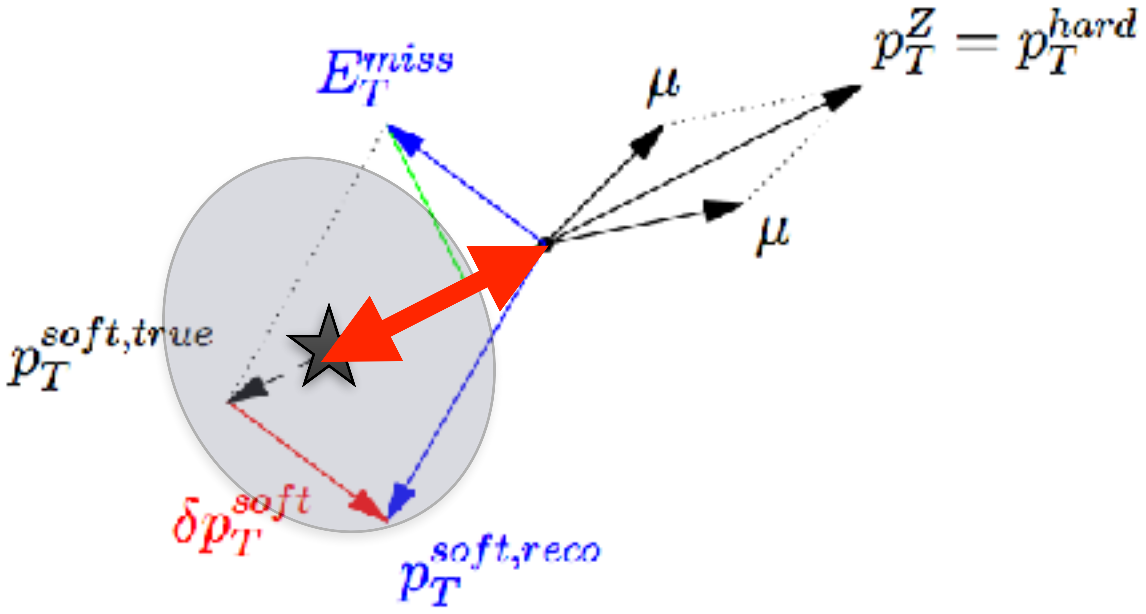
Systematics

Using this information to estimate the systematics





not strong dependence on sample, but some on generator-tune

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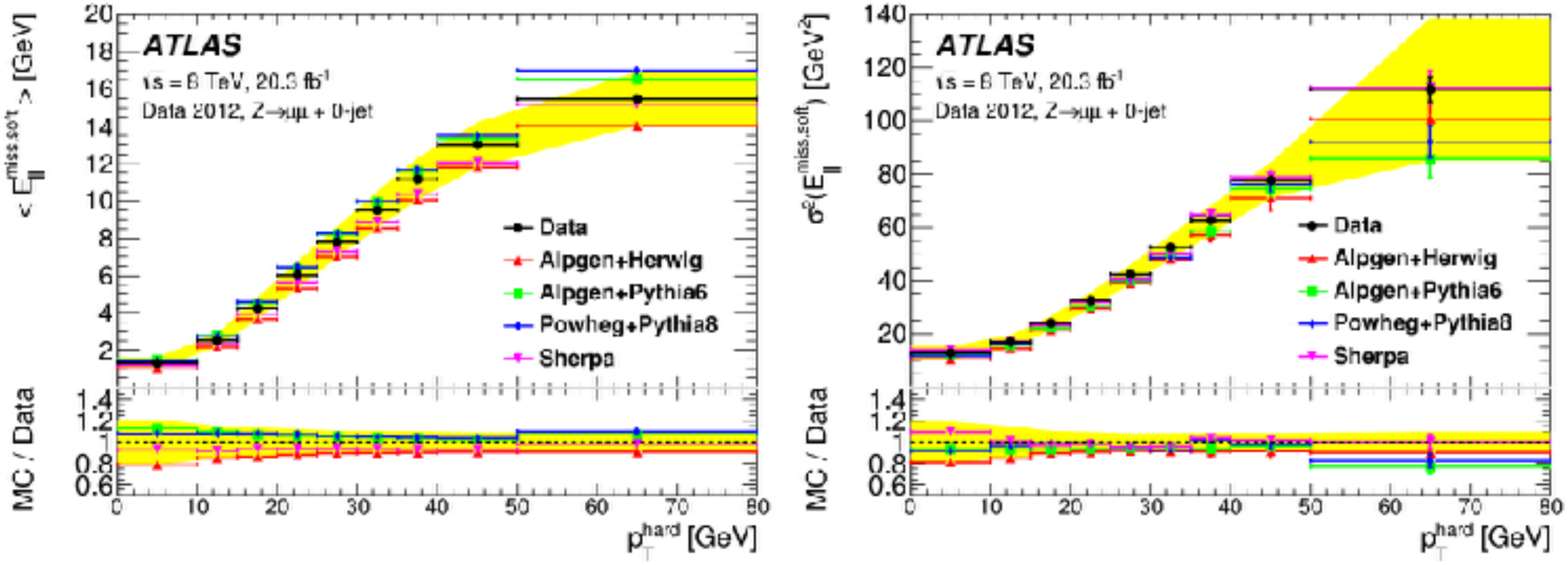
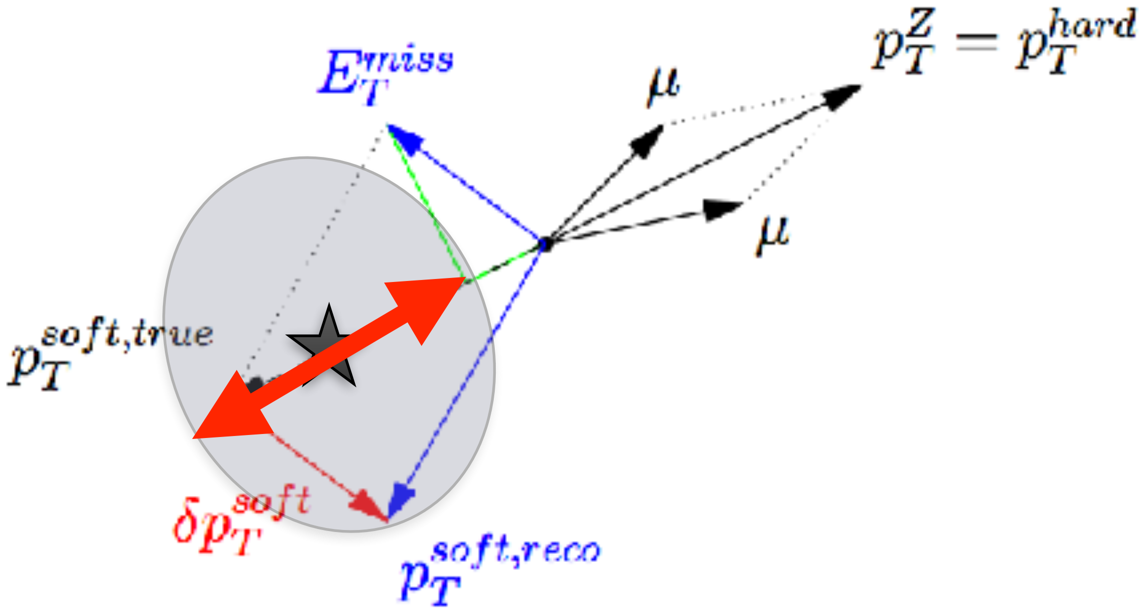
Soft Terms - from truth studies to measurements

Using this information to estimate the systematics





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Soft Terms - from truth studies to measurements

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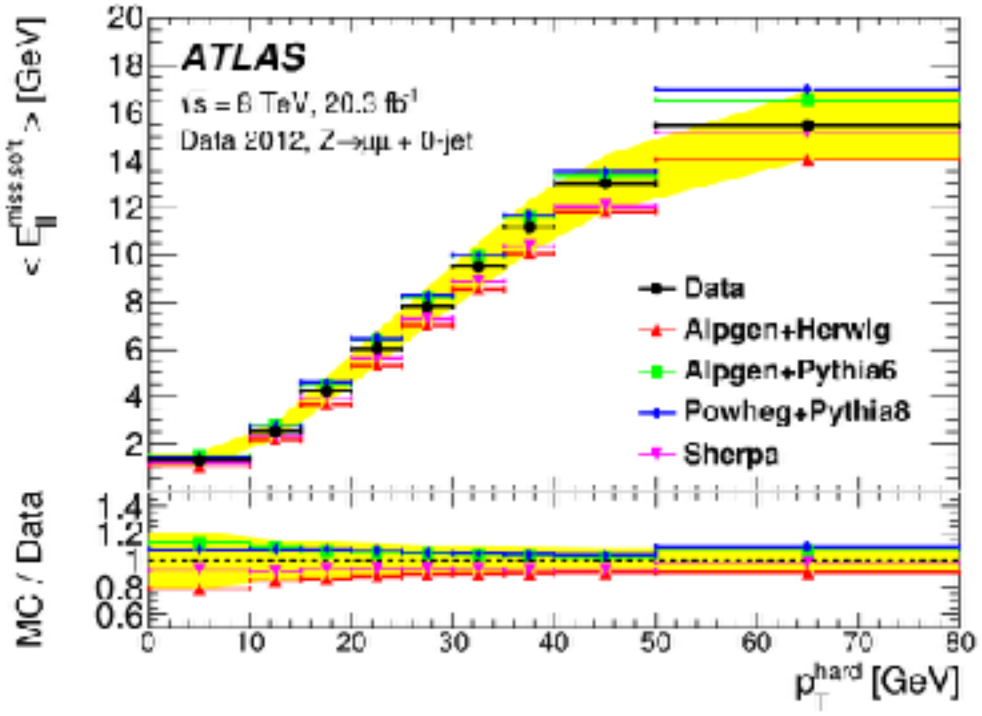

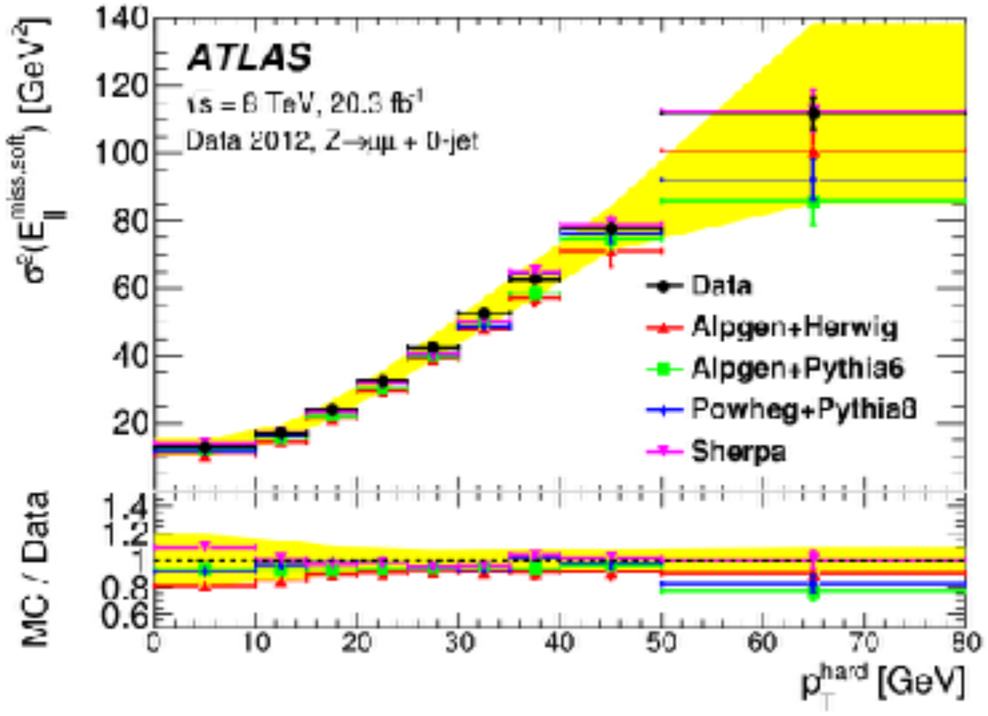

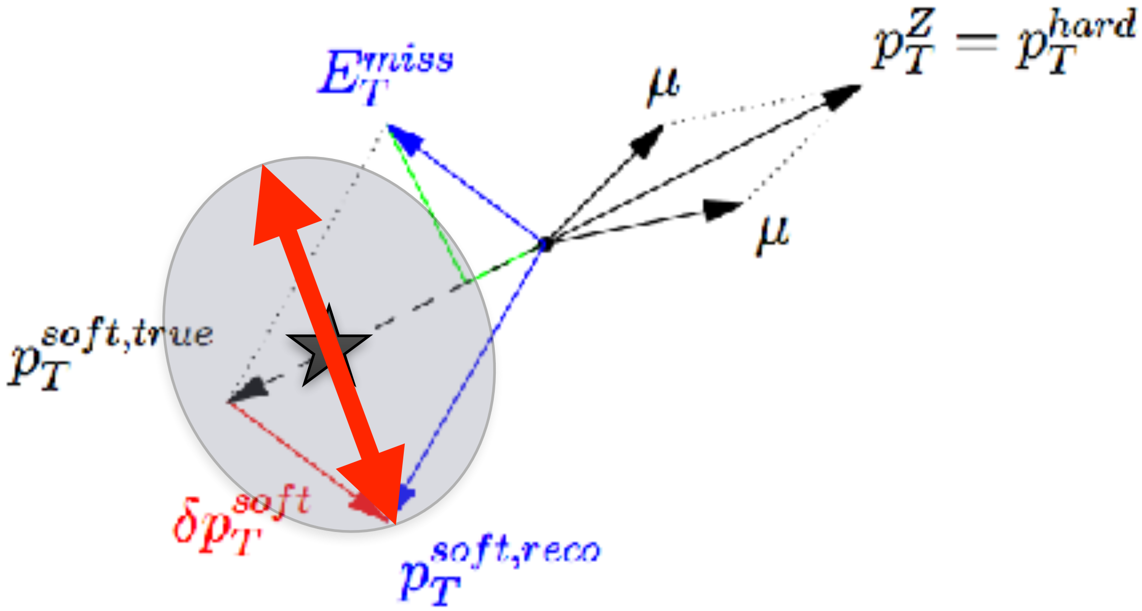

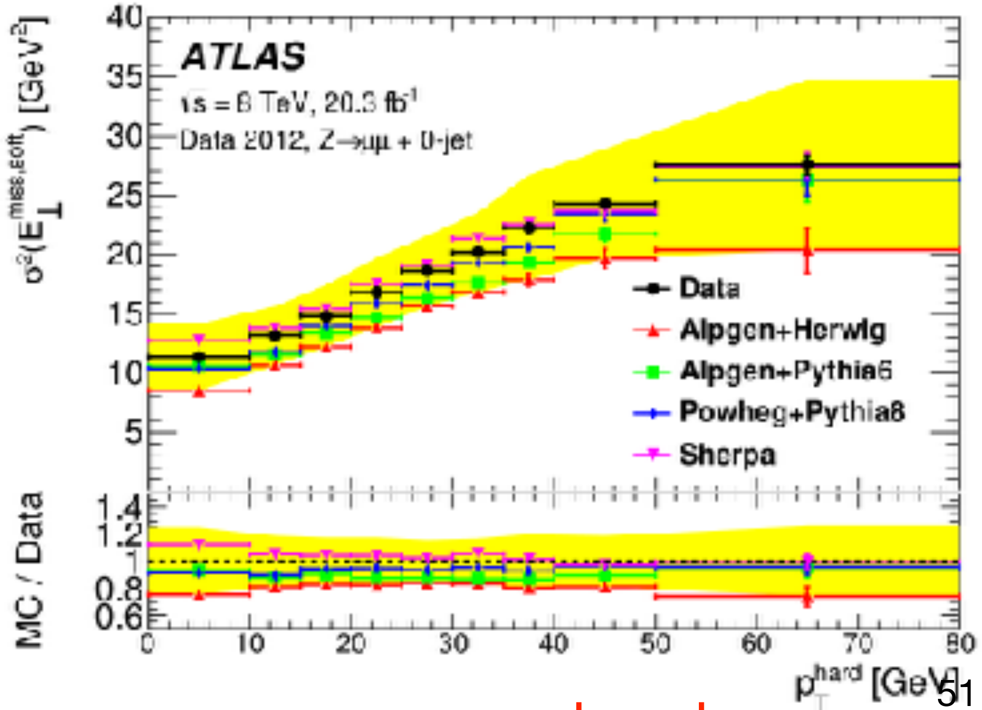

not strong dependence on sample, but some on generator-tune

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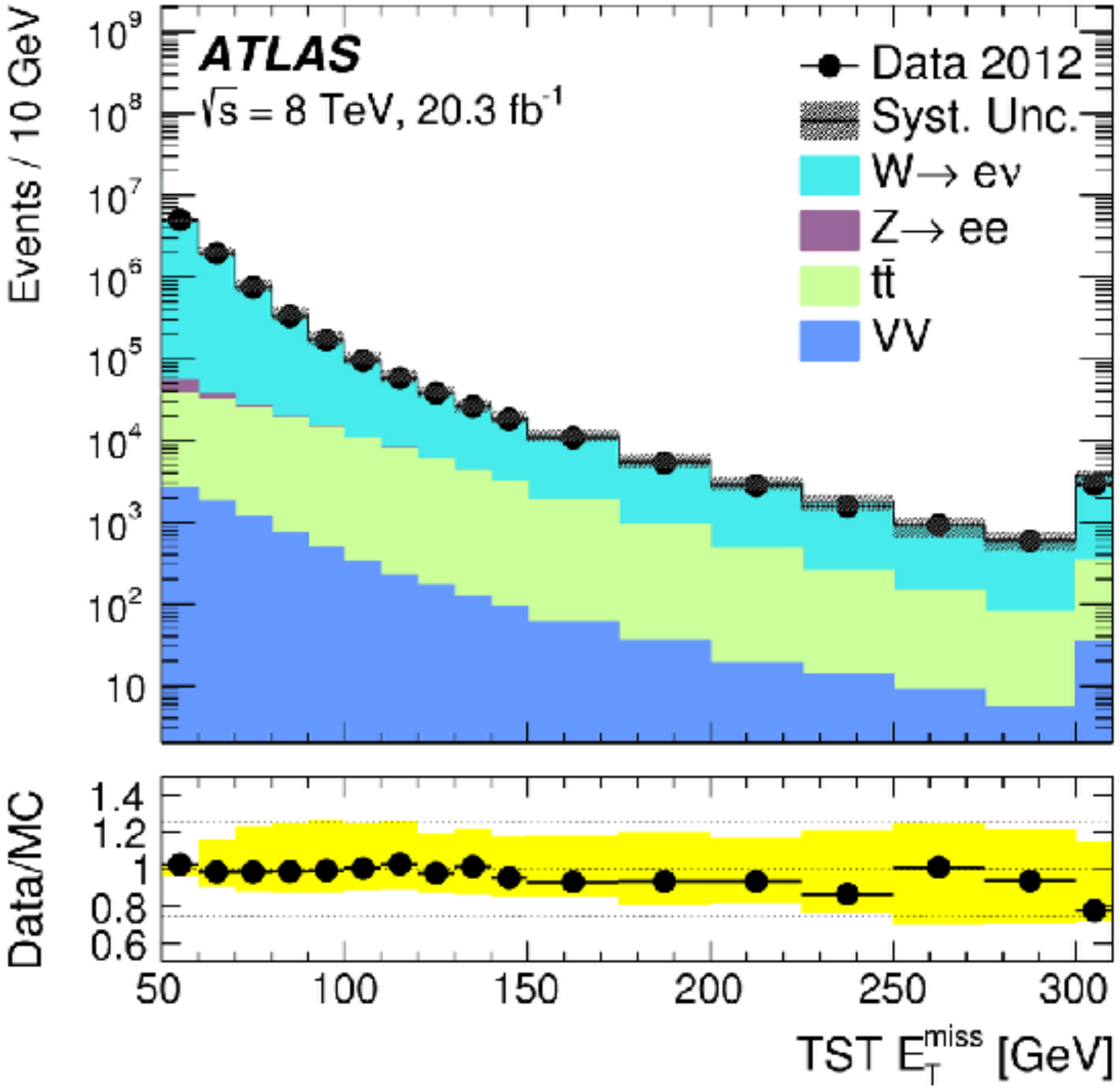
Measuring EtMiss
where we expect EtMiss

- **Z→μμ** is particularly interesting to measure how well we "close" the MET, but no “real" MET in it.

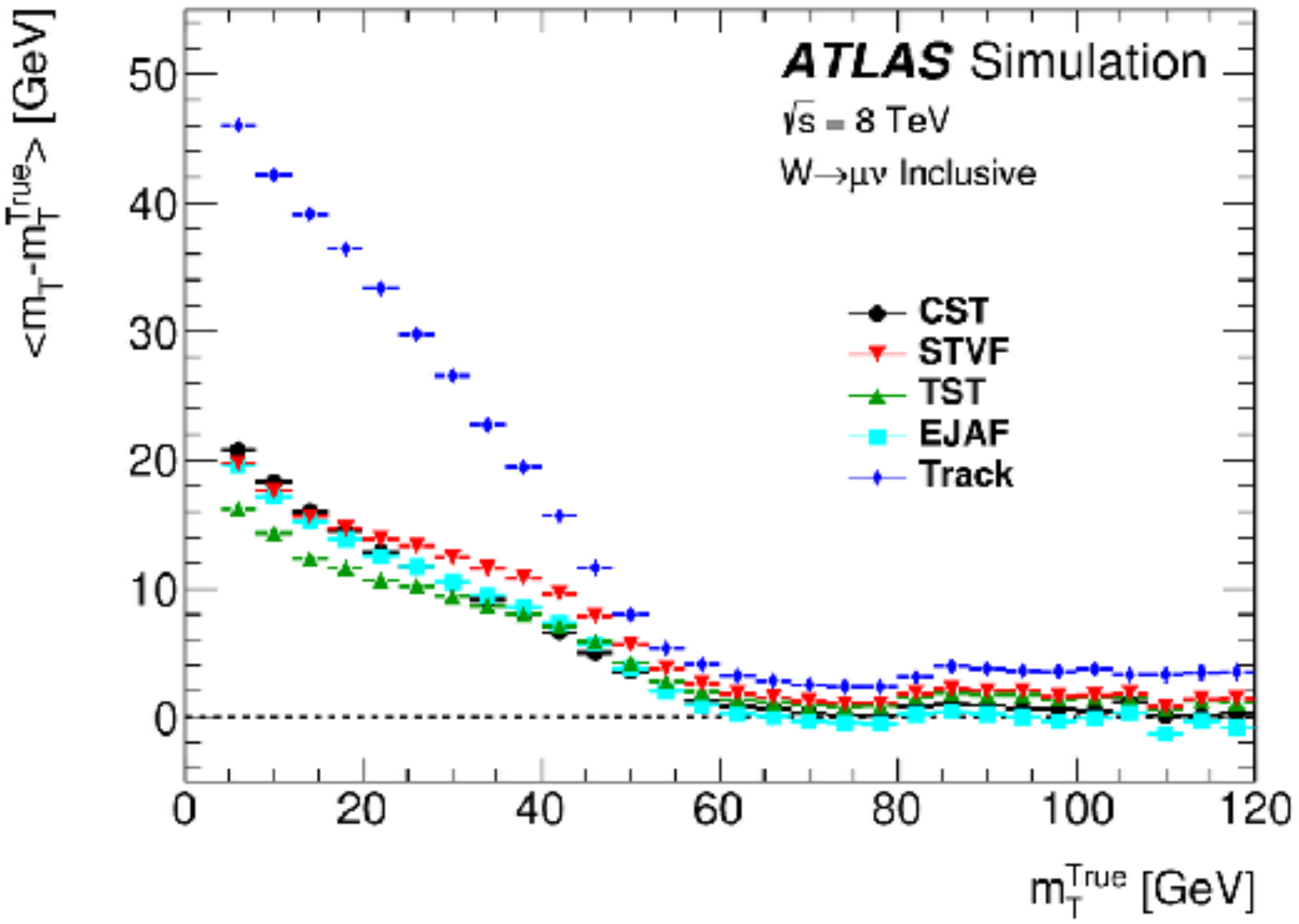
- Checking in events with real MET:

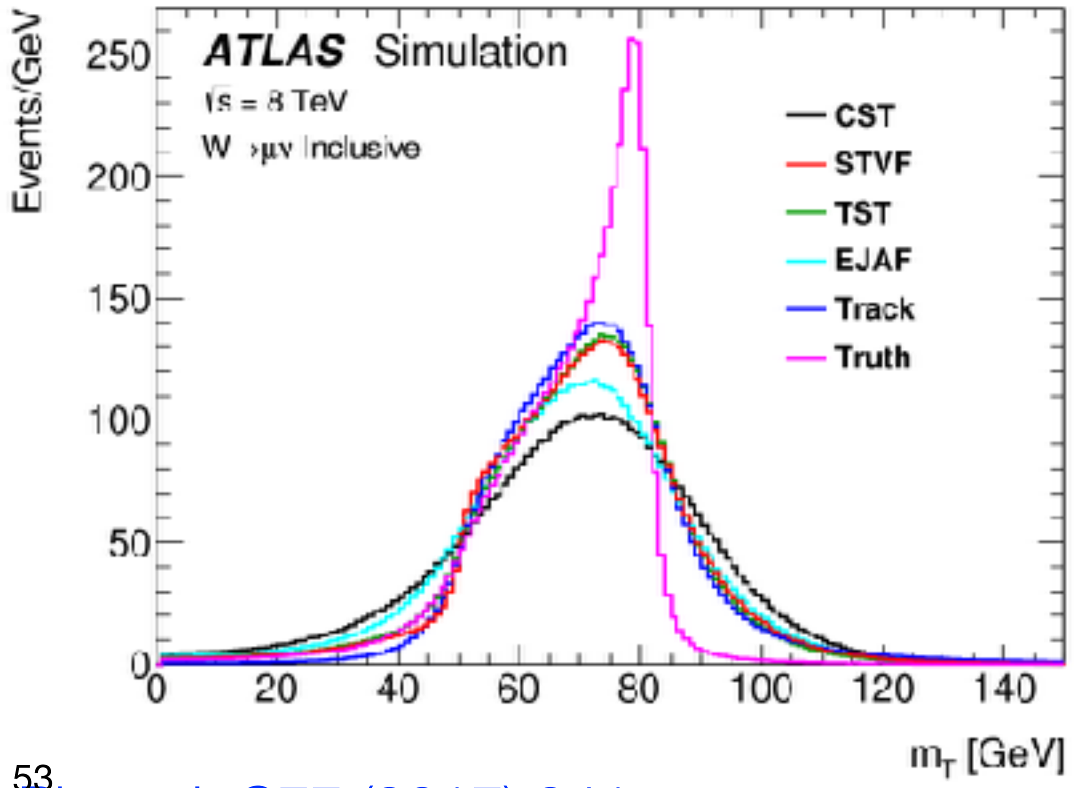
- **W+jets**

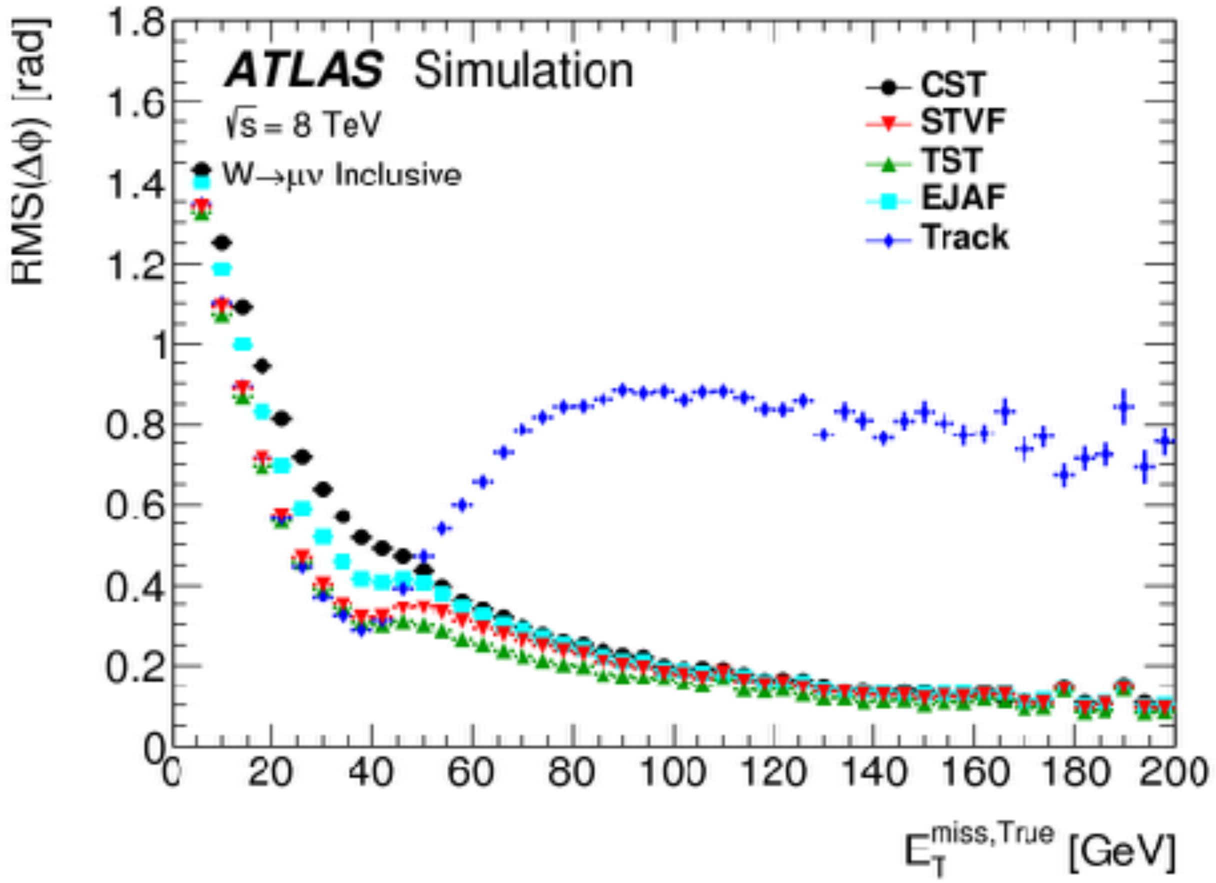


Measuring EtMiss where we expect EtMiss

- Even if we have some convolution of the resolution with the shape of the distribution of the particle level mT, we can check the linearity of our MET, and its angular resolution.







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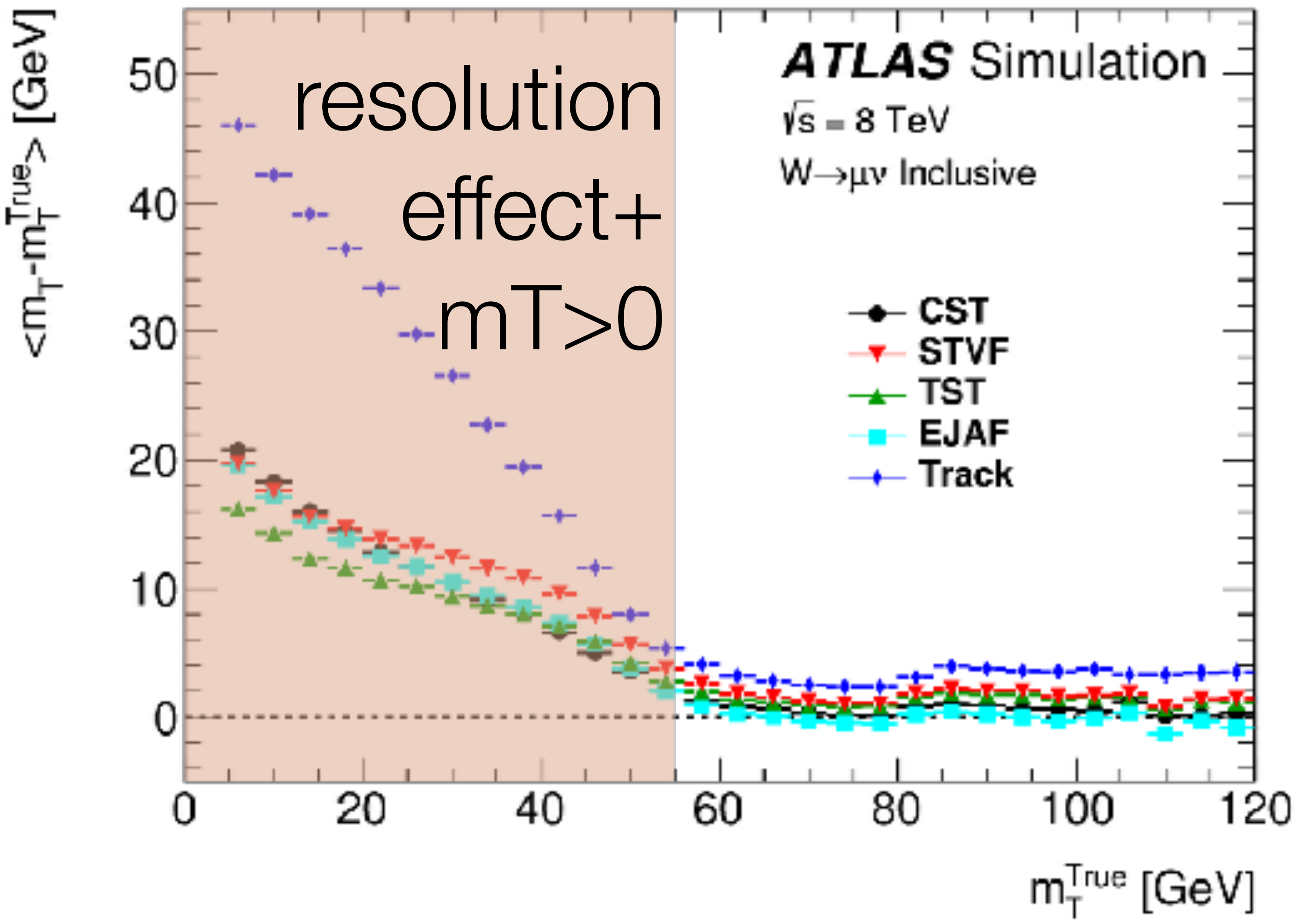
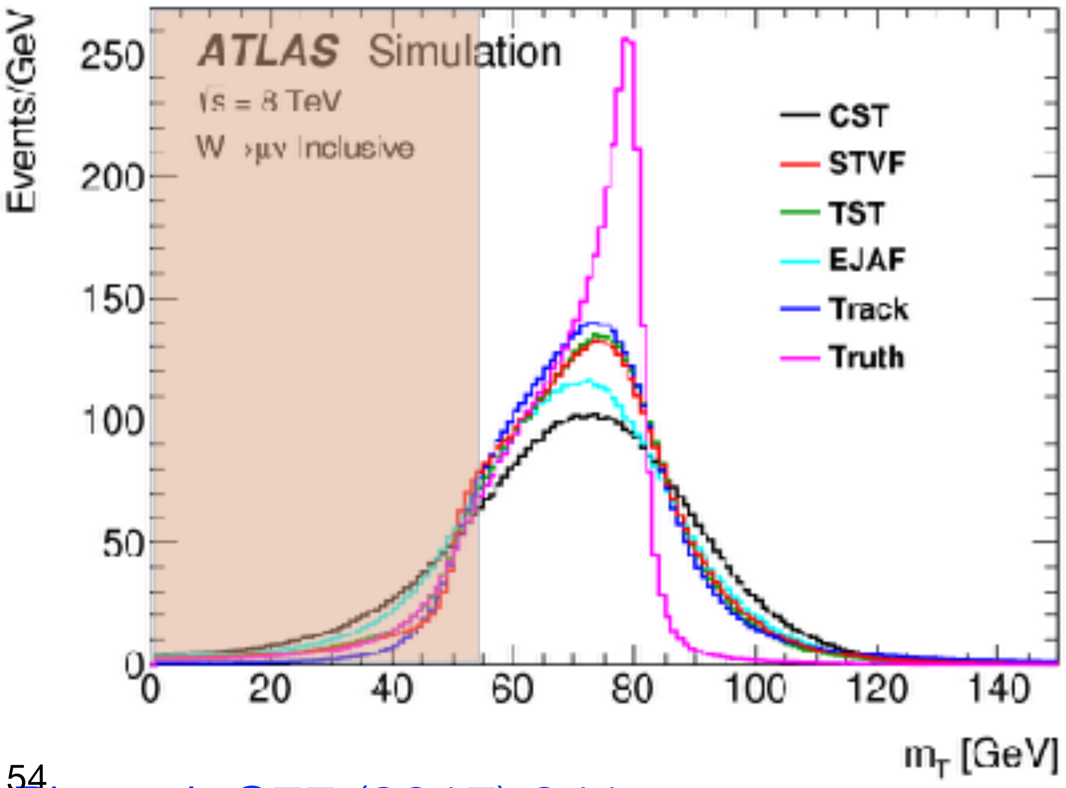
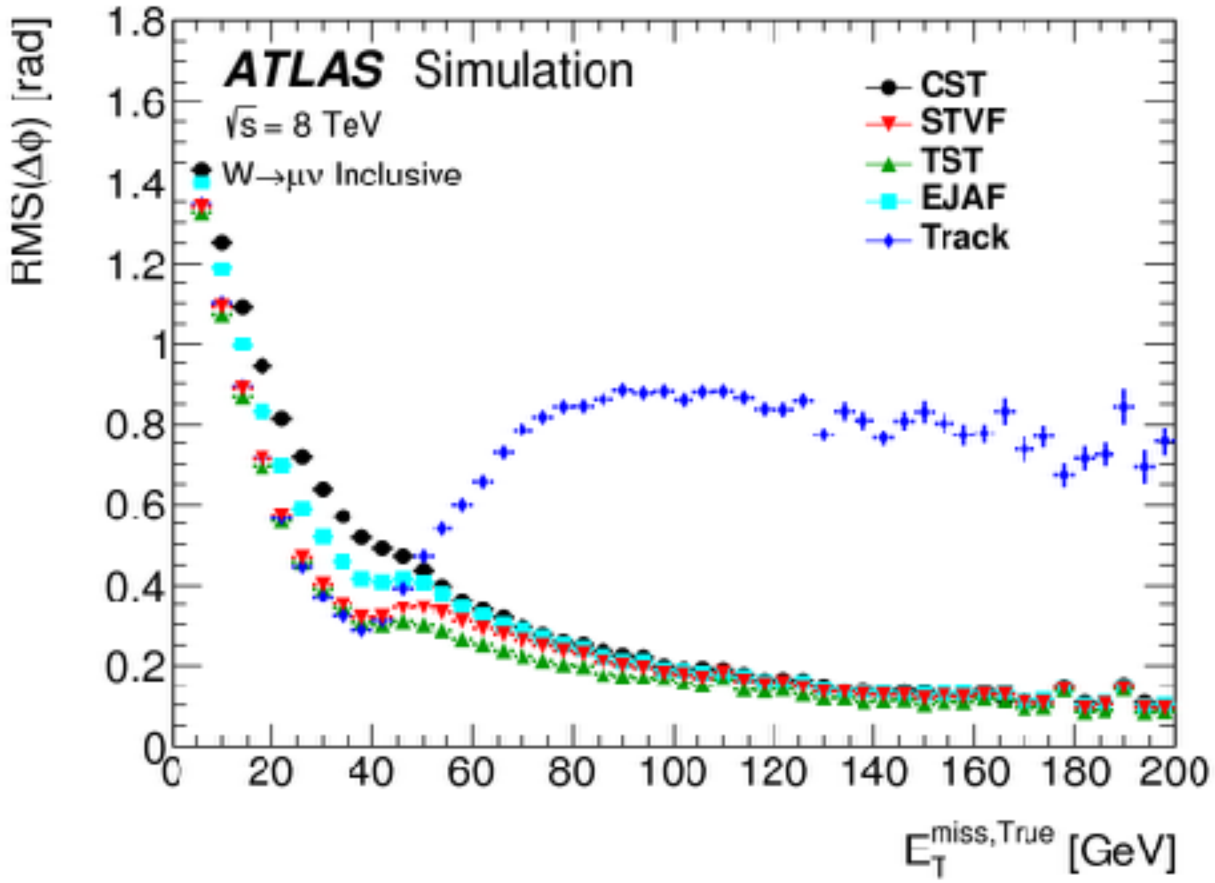


resolution effect+ mT>0





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Measuring EtMiss where we expect EtMiss

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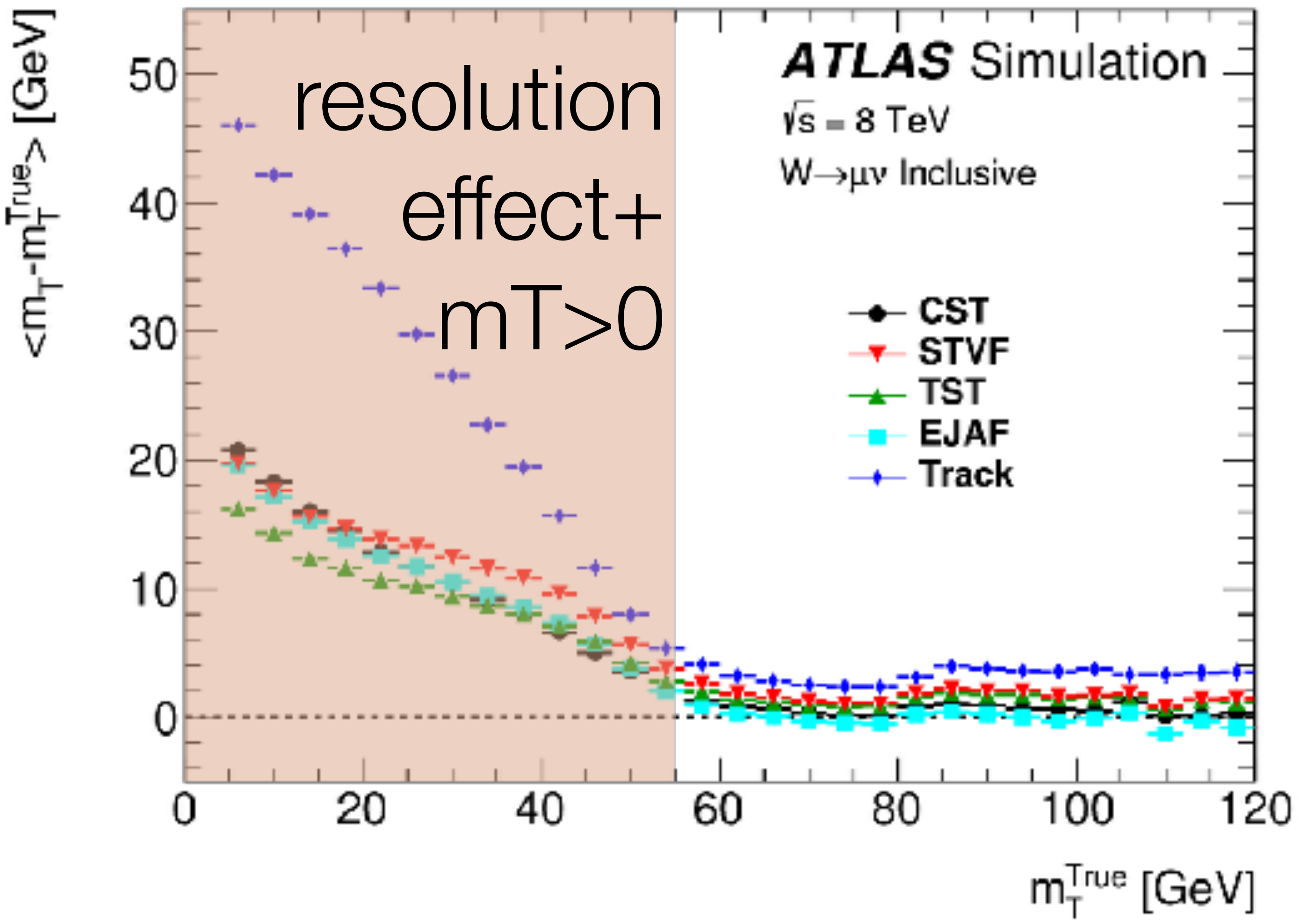

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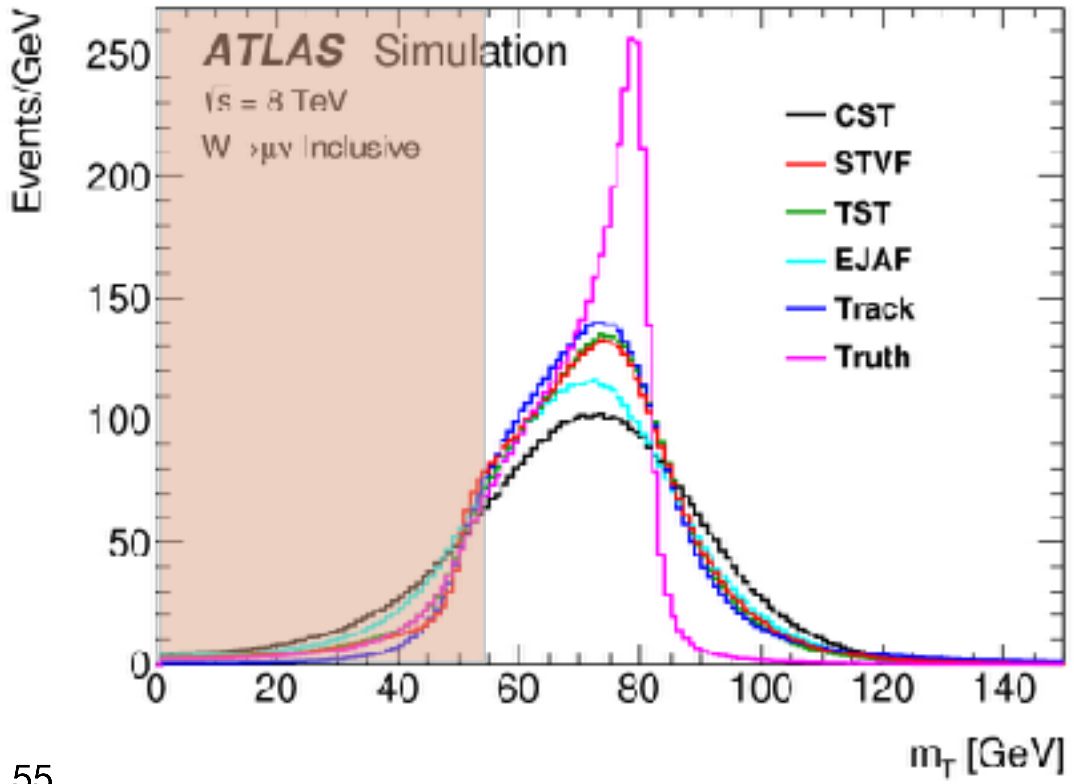

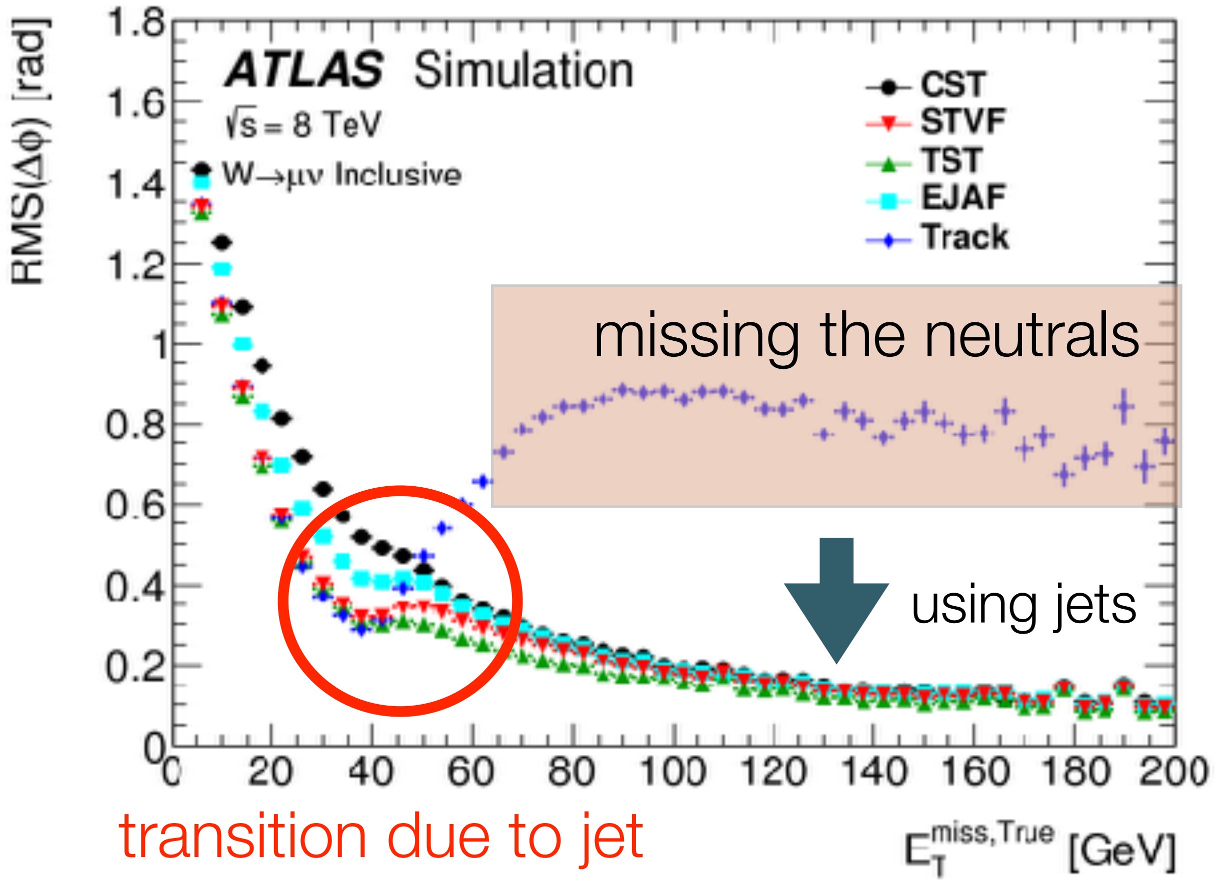

missing the neutrals

using jets

transition due to jet below threshold

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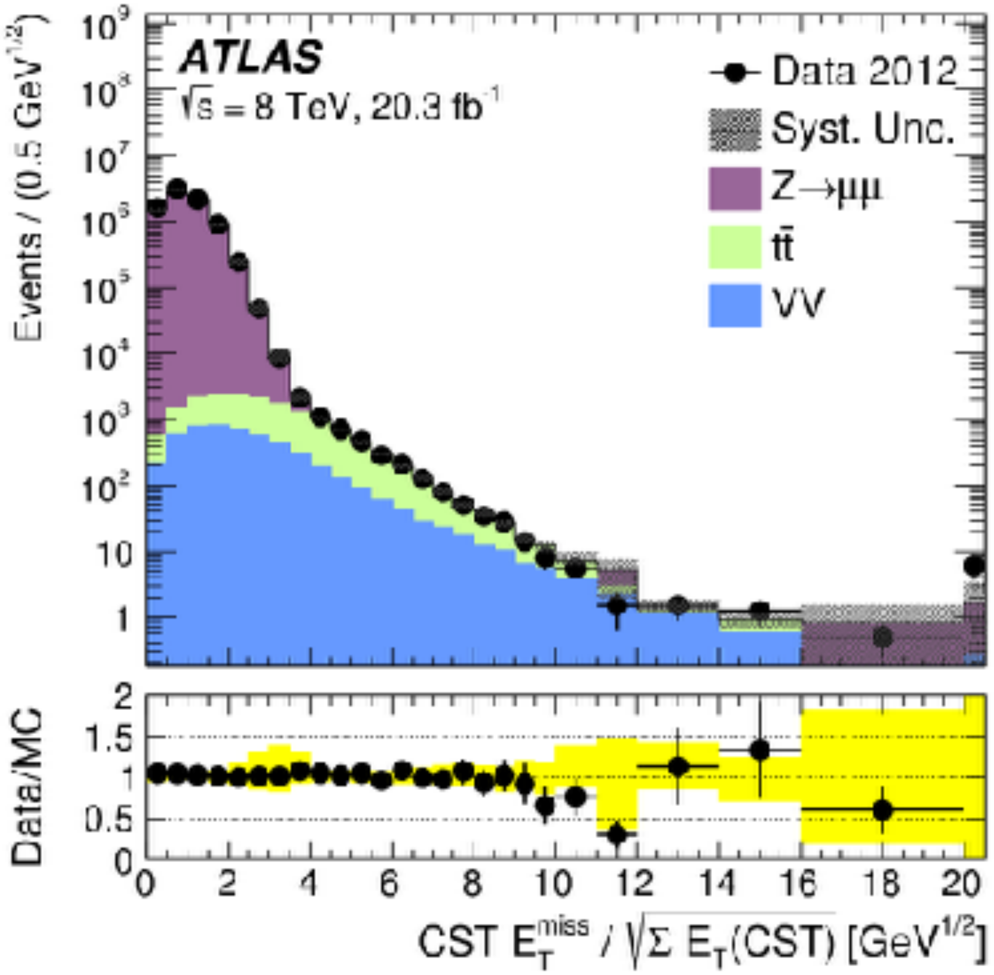
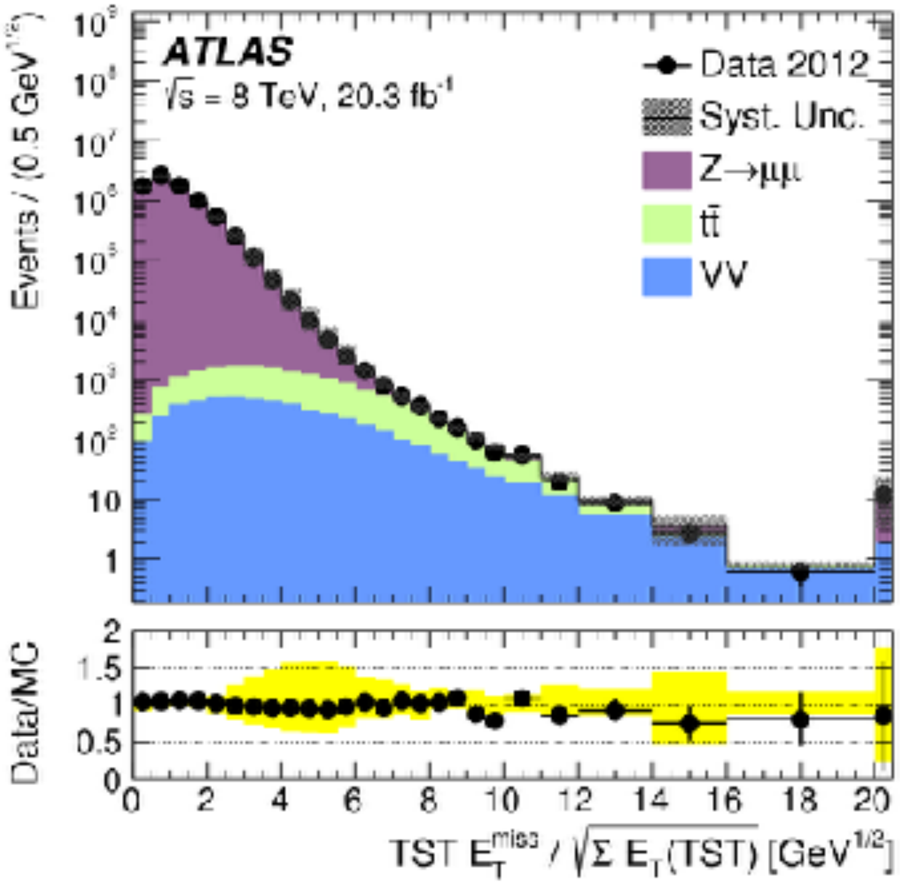
MET or not MET

- ATLAS adopted different definitions of MET significance
- All based on the assumption that

  $\sigma(\text{MET})$ is proportional to sqrt(ΣE_T)
- Good assumption for calorimeter based MET (stochastic fluctuations)

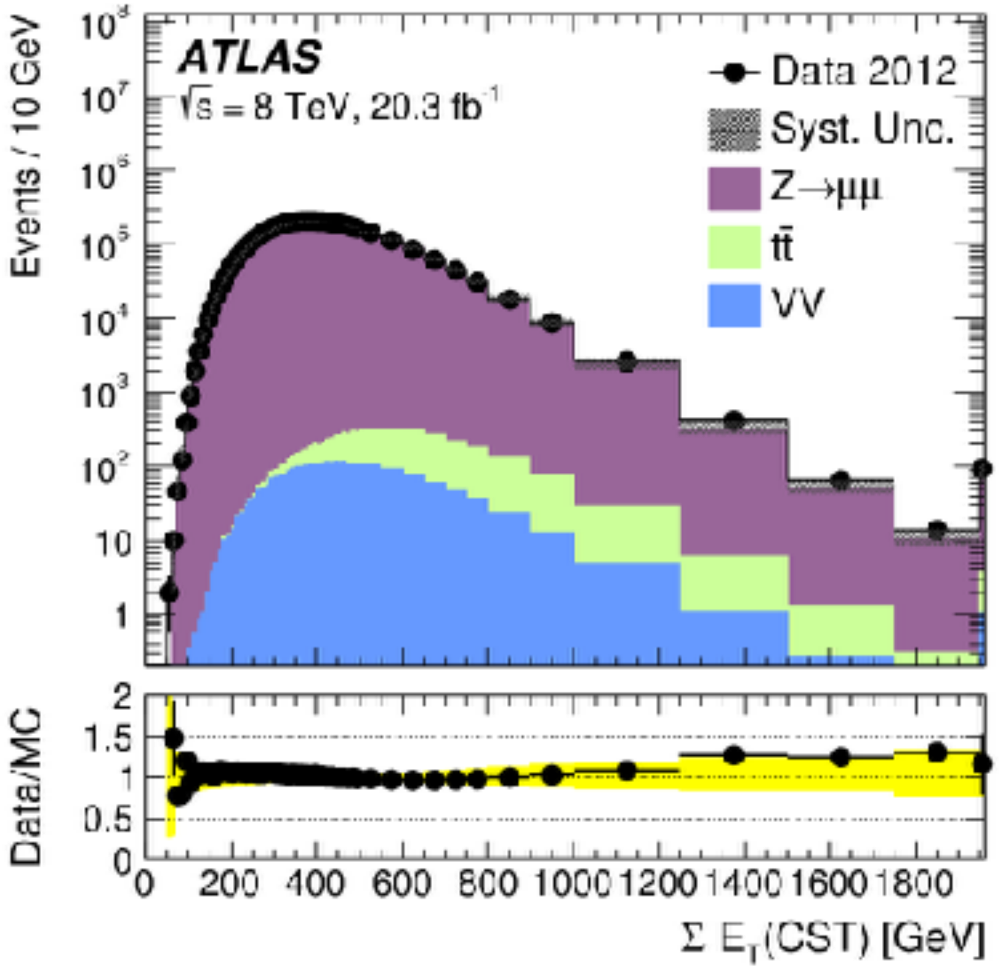


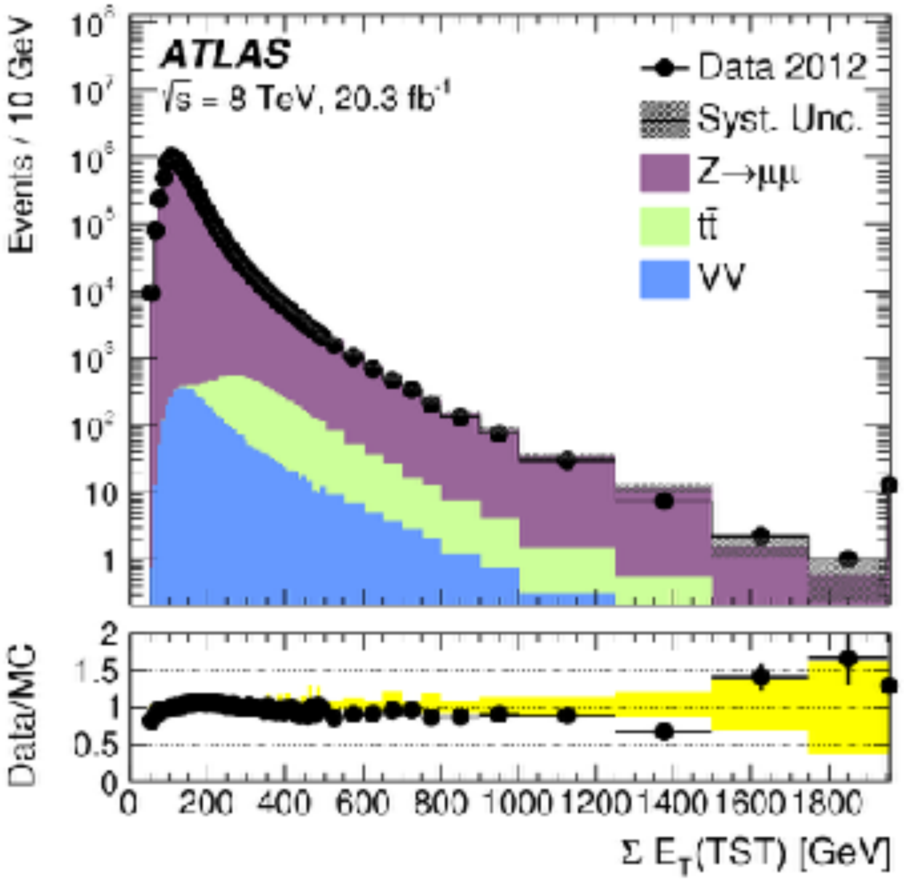


MET or not MET

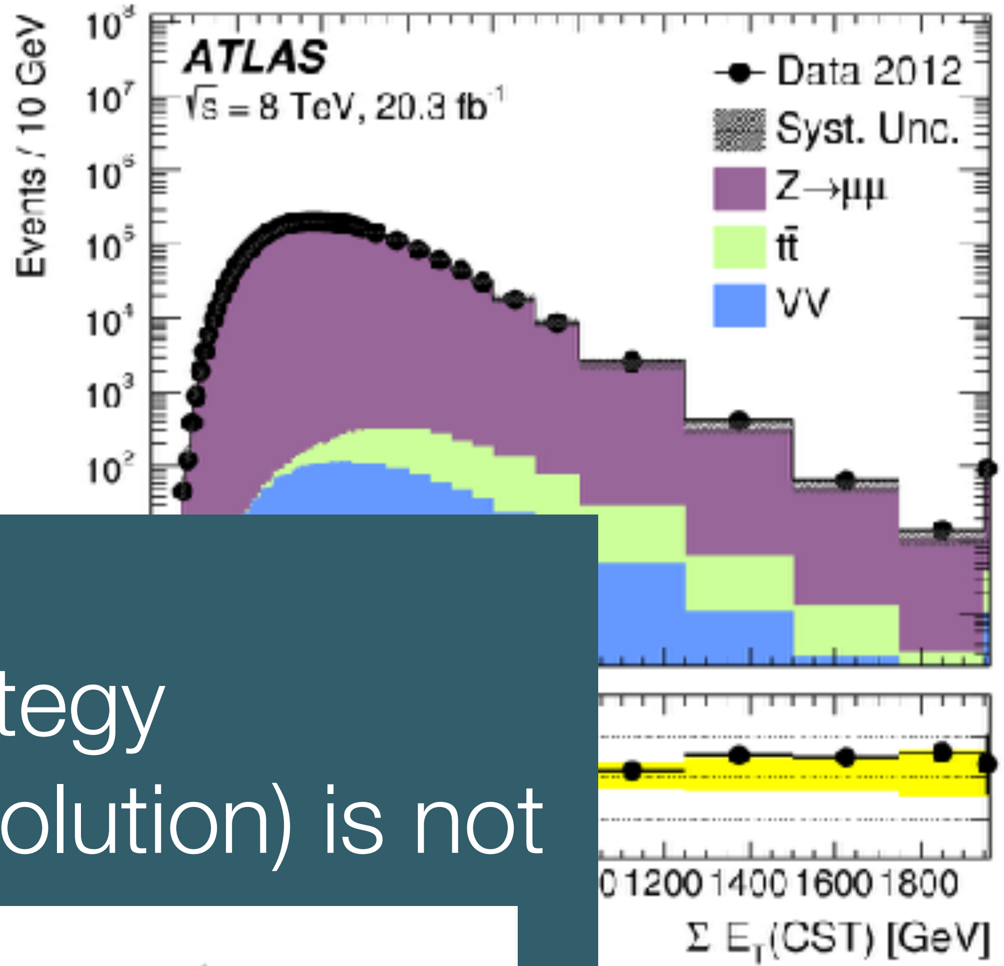
- ATLAS adopted different definitions of MET significance
- All based on the assumption that

  σ(MET) is proportional to sqrt(ΣE_T)
- Good assumption for calorimeter based MET (stochastic fluctuations)
- But ΣE_T(CST) and ΣE_T(TST)





MET or not MET

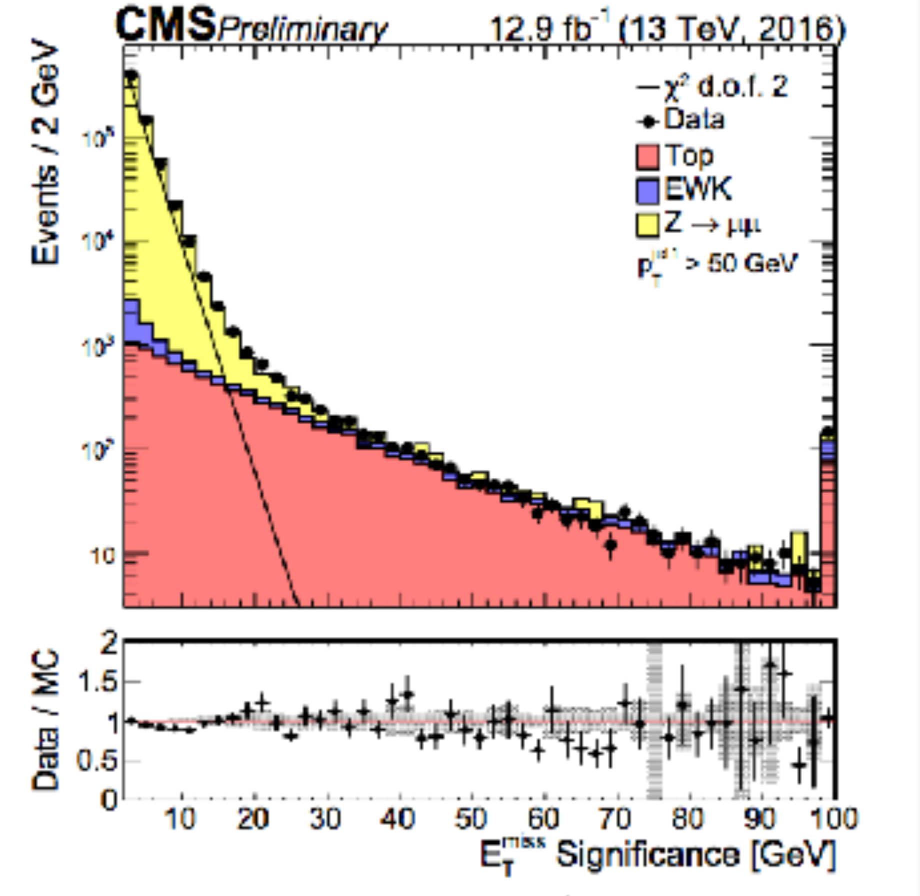


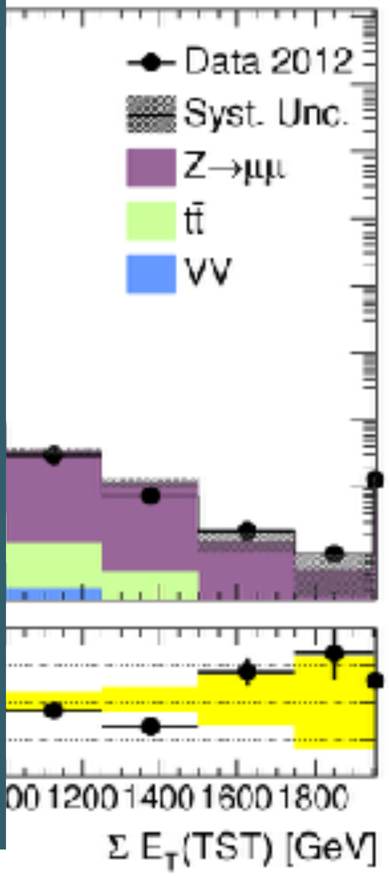
- ATLAS adopted different definiti
- All bas

  σ(MET
- Good calorim (stocha
- But ΣE

Can we go beyond this?
Probably adopting CMS strategy (propagating each object resolution) is not a bad idea…

CMS PAS JME-16-004

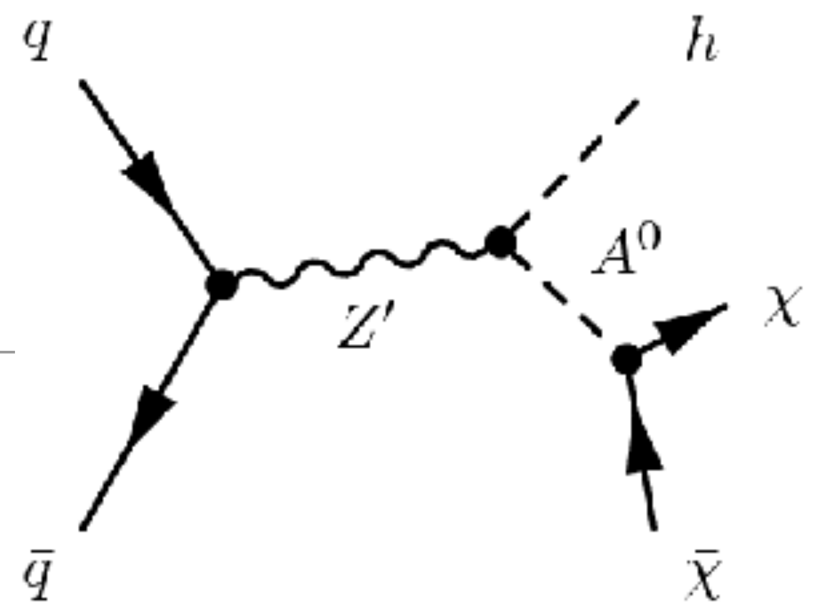




WHERE
WILL
THE MET
TAKE YOU?

ATLAS-CONF-2017-024

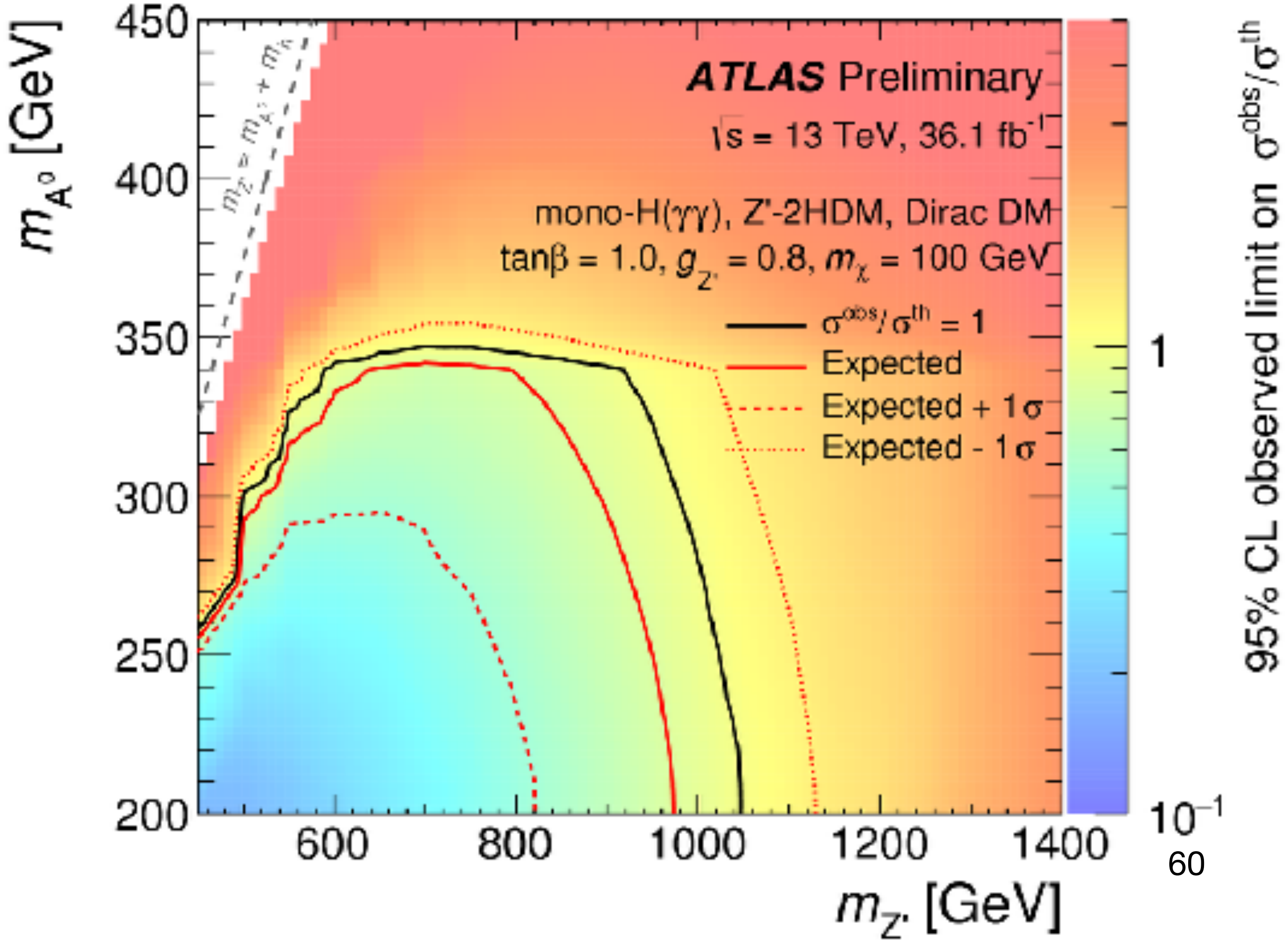
Model dependent limits



- We have seen in these days several analysis using MET to categorise events, or its shape to look for excesses.

- In most of the cases, these are interpreted in some model.

- Model dependent limits are provided, usually for "simplified" models, which can be re-interpreted in others.



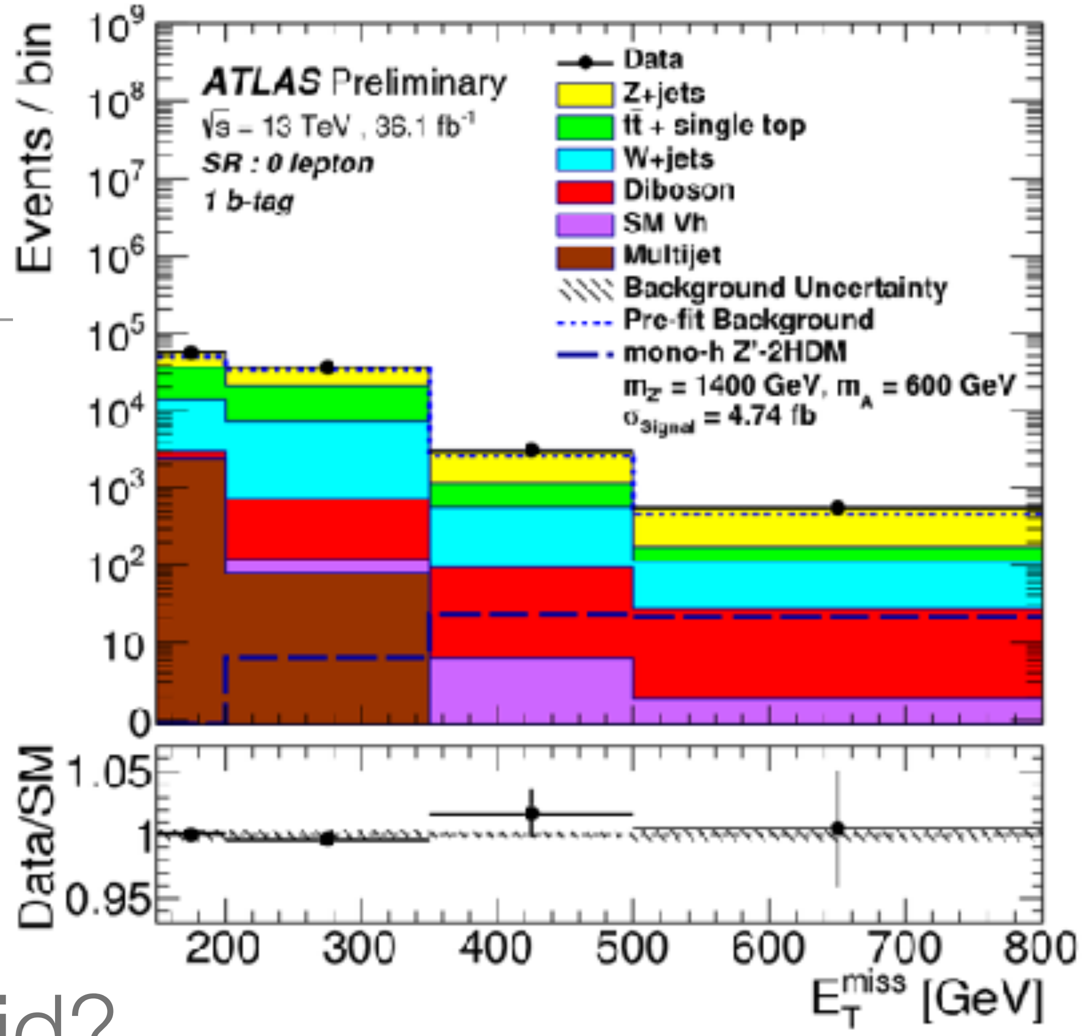
ATLAS-CONF-2017-028

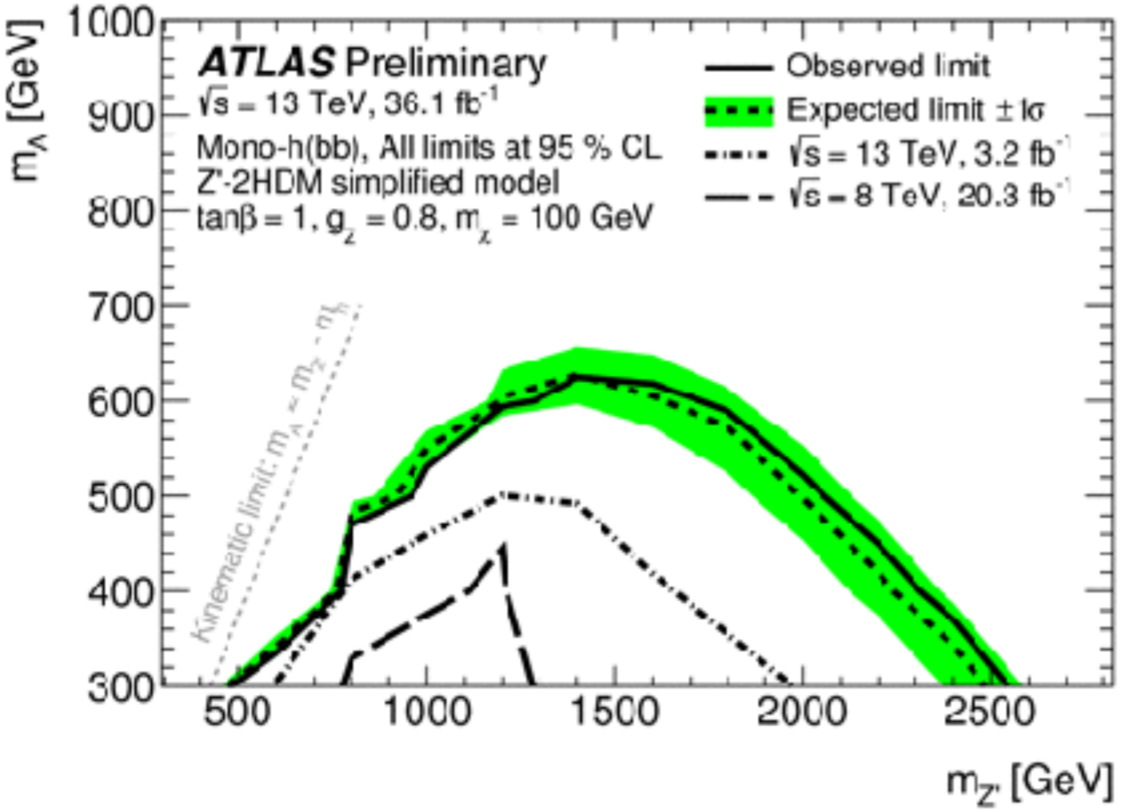
A bit more of information

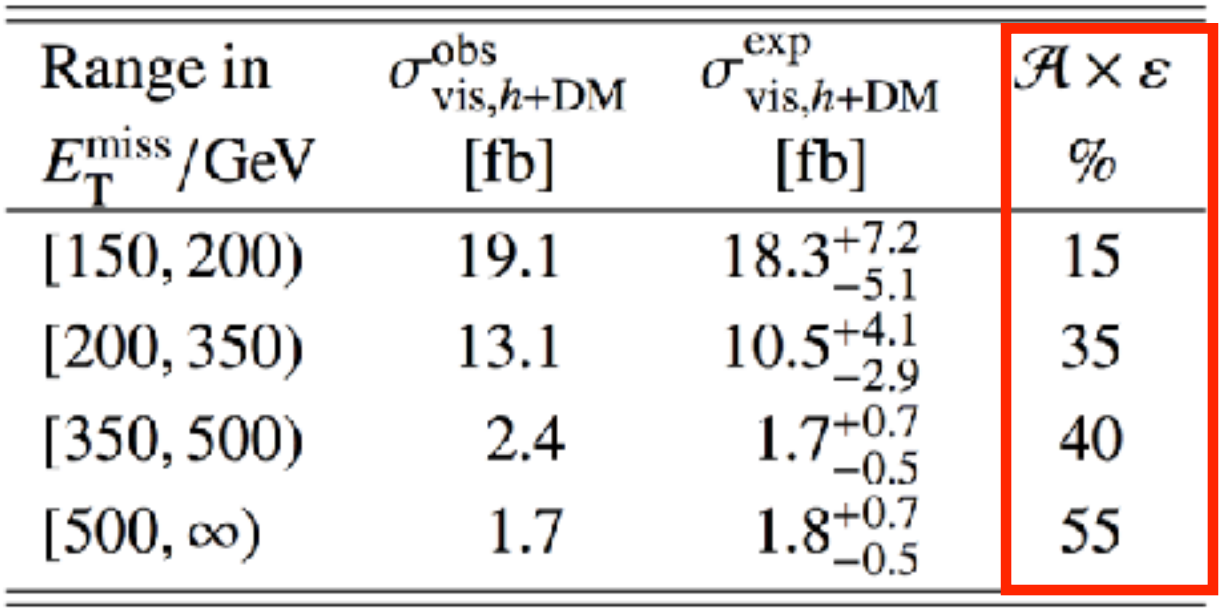
- Attempts to provide limits which are less model dependent.

  Limits in bins of MET.

  For which other models is this valid?







Range in $E_{\mathrm{T}}^{\mathrm{miss}}$/GeV	$\sigma^{\mathrm{obs}}_{\mathrm{vis},h+\mathrm{DM}}$ [fb]	$\sigma^{\mathrm{exp}}_{\mathrm{vis},h+\mathrm{DM}}$ [fb]	$\mathcal{A}\times\varepsilon$ %
[150, 200)	19.1	$18.3^{+7.2}_{-5.1}$	15
[200, 350)	13.1	$10.5^{+4.1}_{-2.9}$	35
[350, 500)	2.4	$1.7^{+0.7}_{-0.5}$	40
[500, ∞)	1.7	$1.8^{+0.7}_{-0.5}$	55

Tested for a wide range of (mZ', mA)

ATLAS-CONF-2017-028

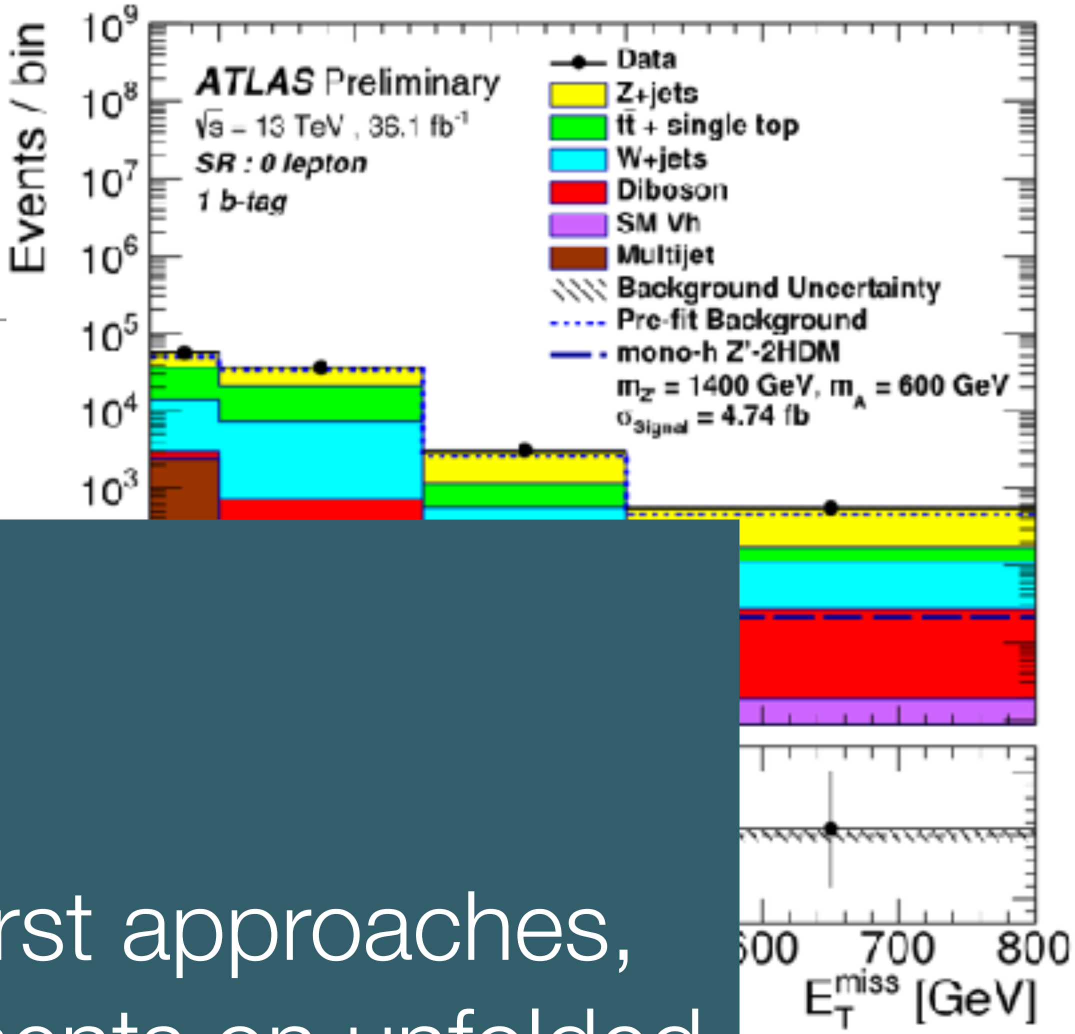
A bit more of information

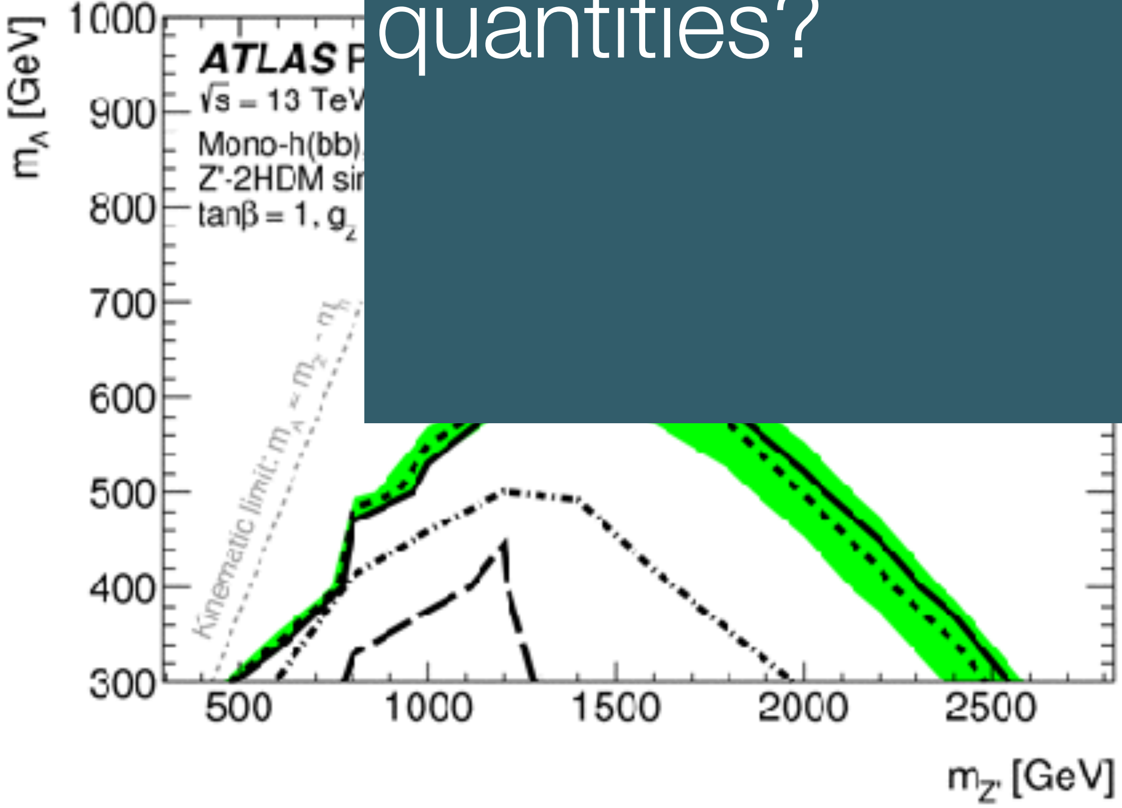
- Attempts to provide limits which

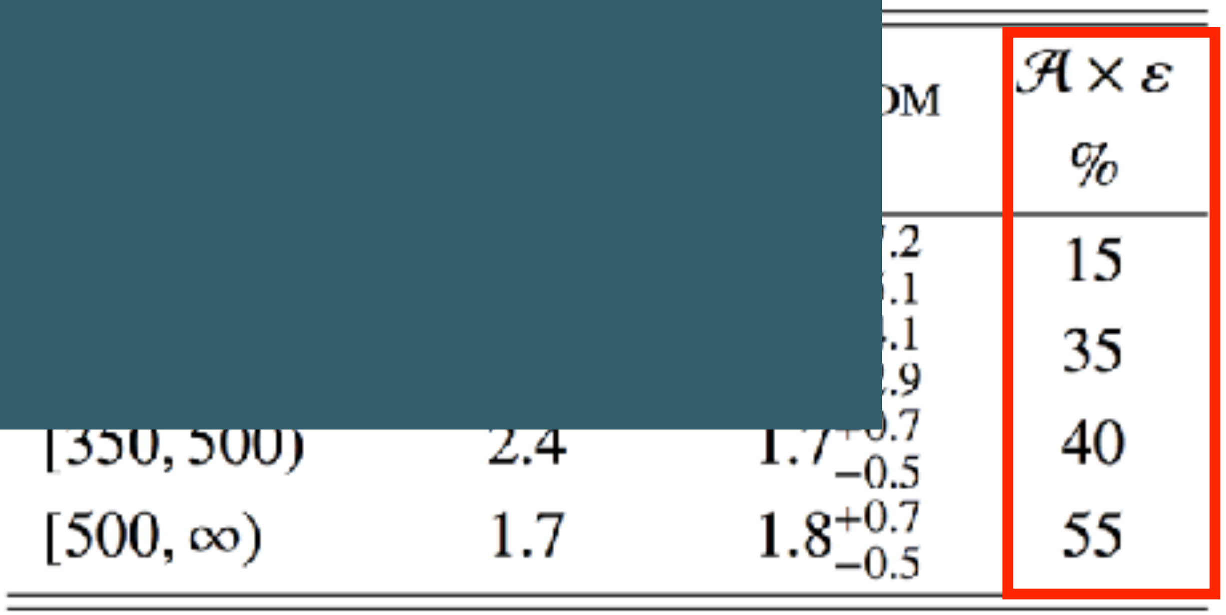
  Limits

  For wh

Can we go beyond these first approaches, defining limits or measurements on unfolded quantities?







		DM	$\mathcal{A} \times \varepsilon$ %
			15
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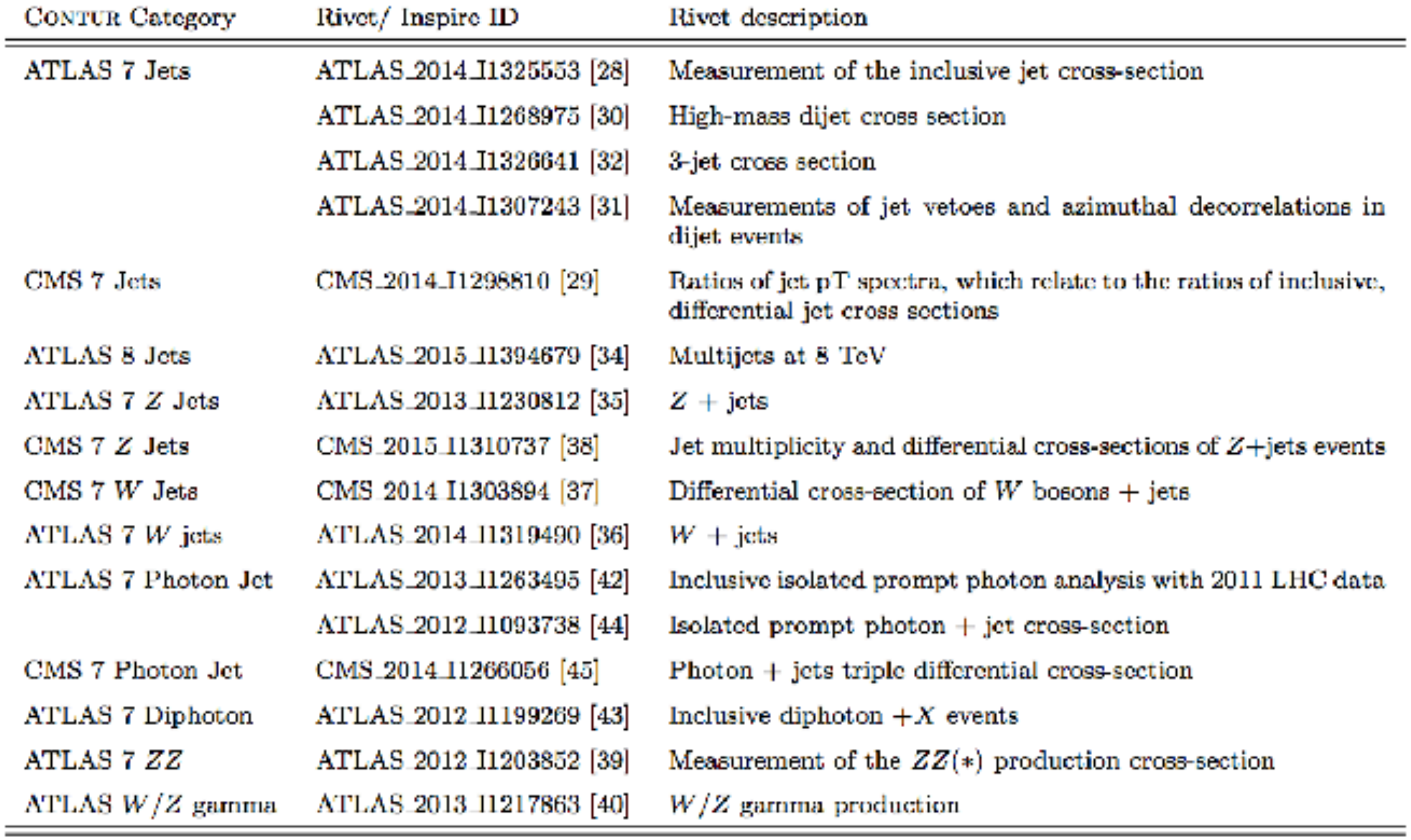
Tested for a wide range of (mZ', mA)

1606.05296

Unfolded measurements

- Unfolded measurements can provide very useful information on excluded phase space for searches.
- An example: 7 TeV ATLAS dijet cross section measurement, used to put limits on contact interaction.
- Another example: Butterworth et al. (1606.05296)



CONTUR Category	Rivet/ Inspire ID	Rivet description
ATLAS 7 Jets	ATLAS_2014_I1325553 [28]	Measurement of the inclusive jet cross-section
	ATLAS_2014_I1268975 [30]	High-mass dijet cross section
	ATLAS_2014_I1326641 [32]	3-jet cross section
	ATLAS_2014_I1307243 [31]	Measurements of jet vetoes and azimuthal decorrelations in dijet events
CMS 7 Jets	CMS_2014_I1298810 [29]	Ratios of jet pT spectra, which relate to the ratios of inclusive, differential jet cross sections
ATLAS 8 Jets	ATLAS_2015_I1394679 [34]	Multijets at 8 TeV
ATLAS 7 Z Jets	ATLAS_2013_I1230812 [35]	Z + jets
CMS 7 Z Jets	CMS_2015_I1310737 [38]	Jet multiplicity and differential cross-sections of Z+jets events
CMS 7 W Jets	CMS_2014_I1303894 [37]	Differential cross-section of W bosons + jets
ATLAS 7 W jets	ATLAS_2014_I1319490 [36]	W + jets
ATLAS 7 Photon Jet	ATLAS_2013_I1263495 [42]	Inclusive isolated prompt photon analysis with 2011 LHC data
	ATLAS_2012_I1093738 [44]	Isolated prompt photon + jet cross-section
CMS 7 Photon Jet	CMS_2014_I1266056 [45]	Photon + jets triple differential cross-section
ATLAS 7 Diphoton	ATLAS_2012_I1199269 [43]	Inclusive diphoton $+X$ events
ATLAS 7 ZZ	ATLAS_2012_I1203852 [39]	Measurement of the $ZZ(*)$ production cross-section
ATLAS W/Z gamma	ATLAS_2013_I1217863 [40]	W/Z gamma production

1606.05296

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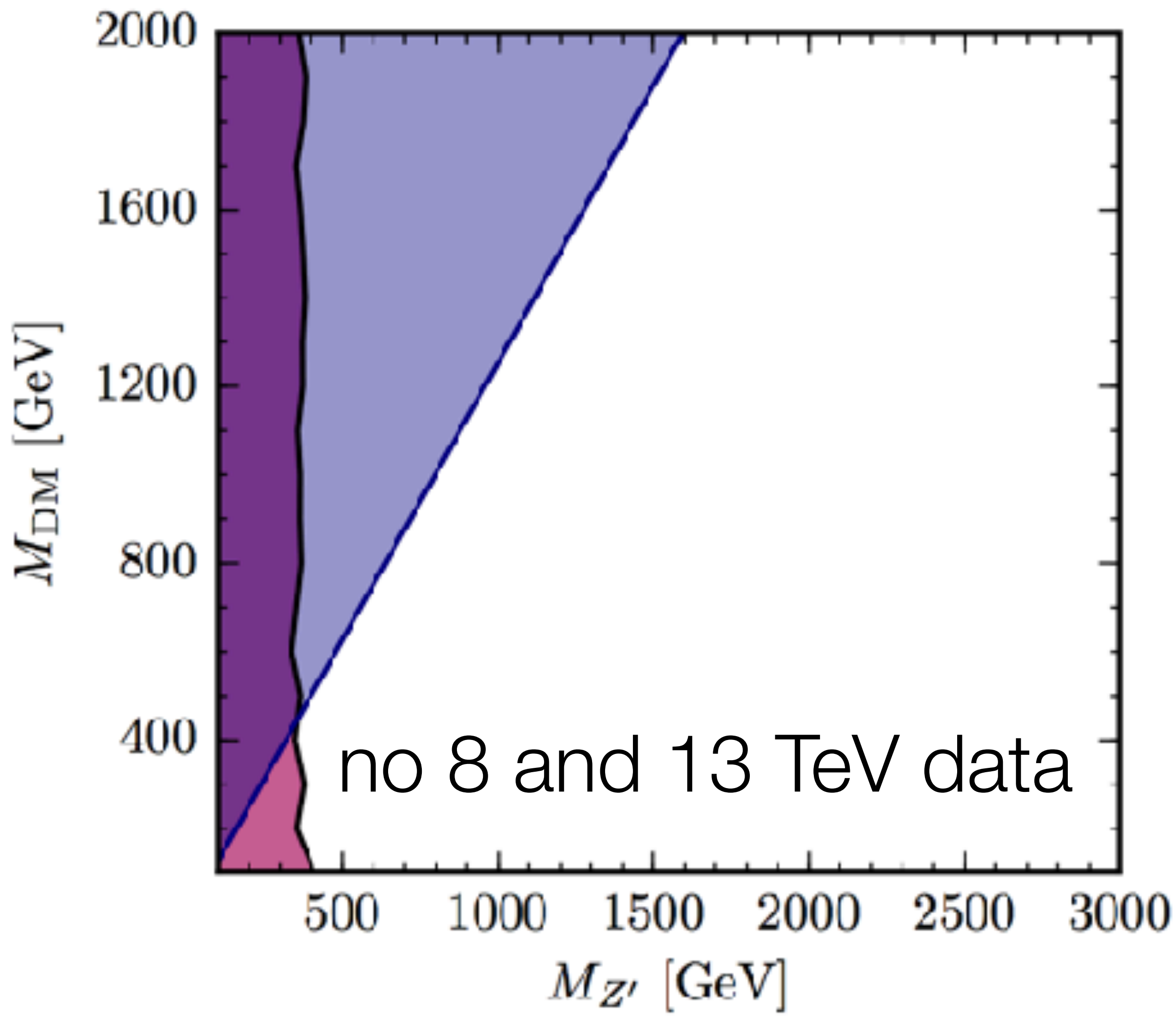
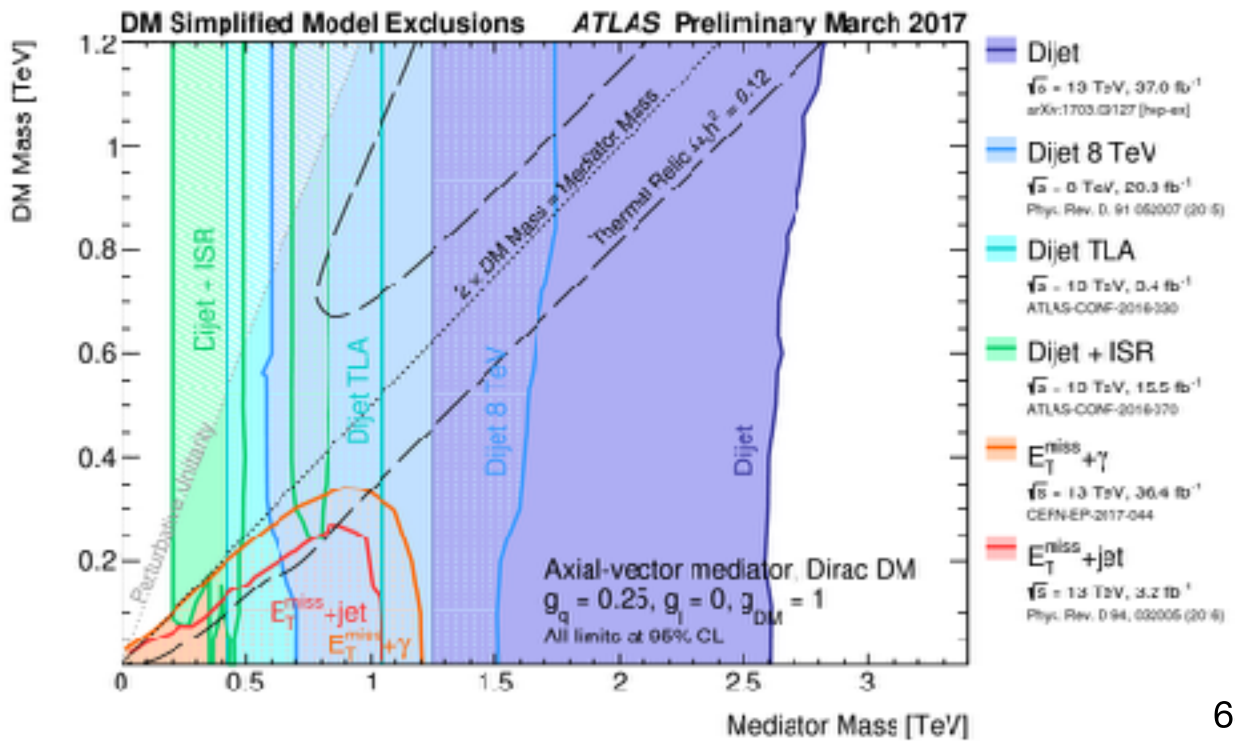


no 8 and 13 TeV data

(a) $g_q = 0.25$ and $g_{\rm DM} = 1$

for sure, searches are (usually)faster than measurements…



Unfolded measurements

- No unfolded measurement of MET distributions
  - Is it doable?
- MET is a complex variable, but we are getting more and more experience and understanding on it
- Is it worth doing it?
  - If yes, what can we measure? SM background with “equivalent" final state? how easy would be to use it?

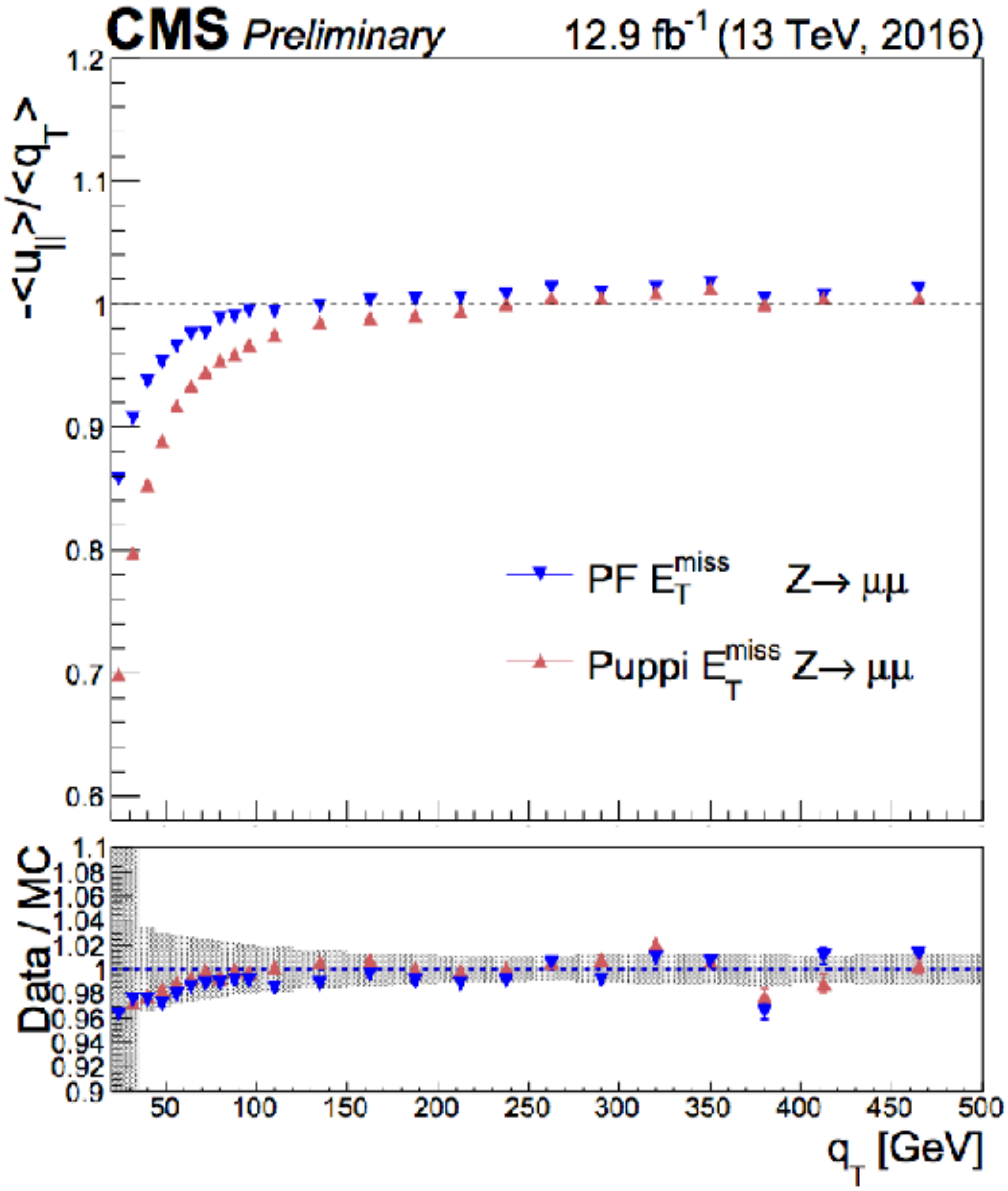
Conclusions

- A lot of progresses in MET definition since the LHC first collisions
  - (and for the moment we managed to avoid big wrong tails - spoiling our searches and measurements)
- MET used in several different ways, and several different final states, from precision measurements to searches, to removal of hard to model backgrounds.

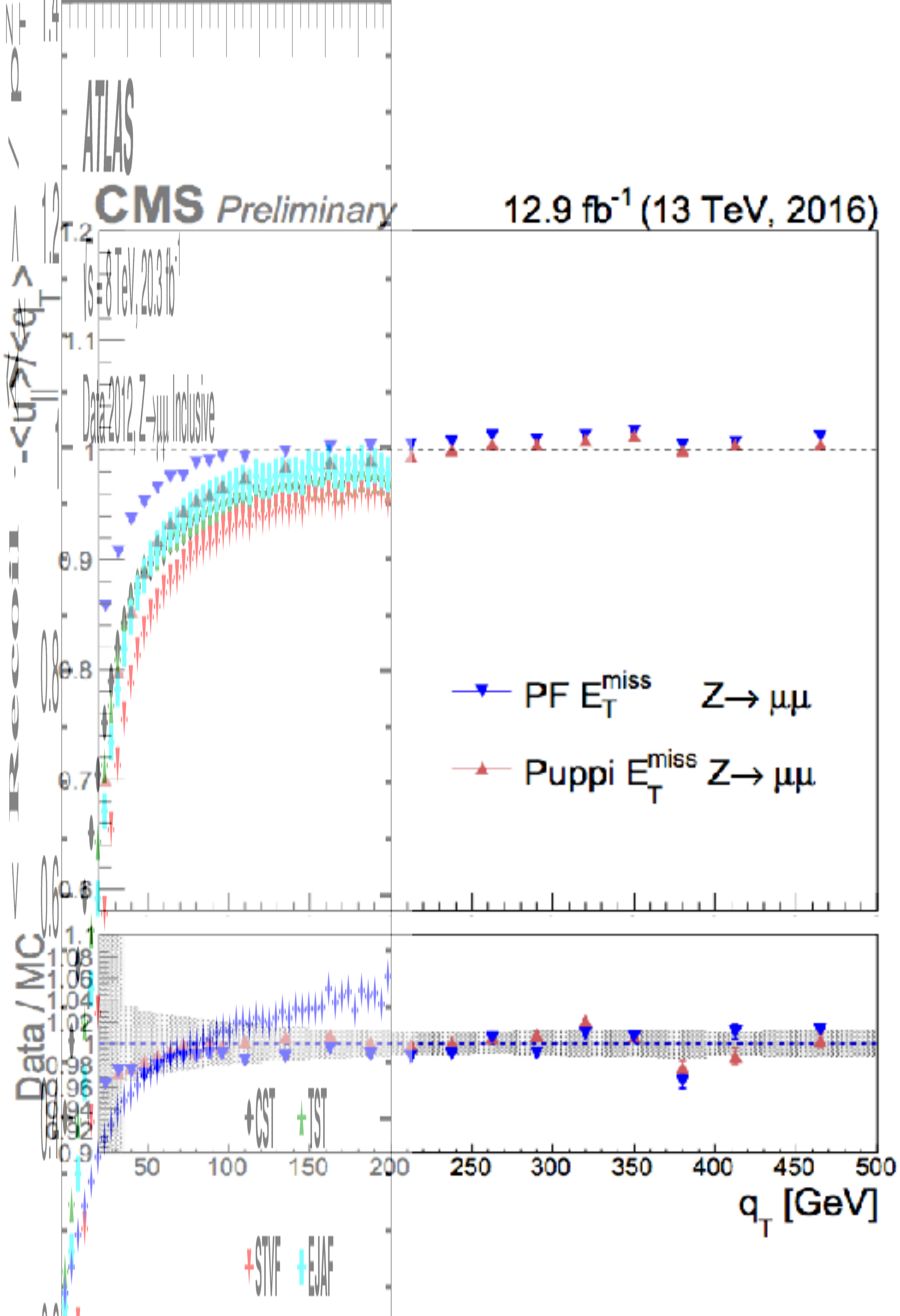
CMS

- CMS using PFlow objects to build the MET

- PU suppressed MET (PUPPI).

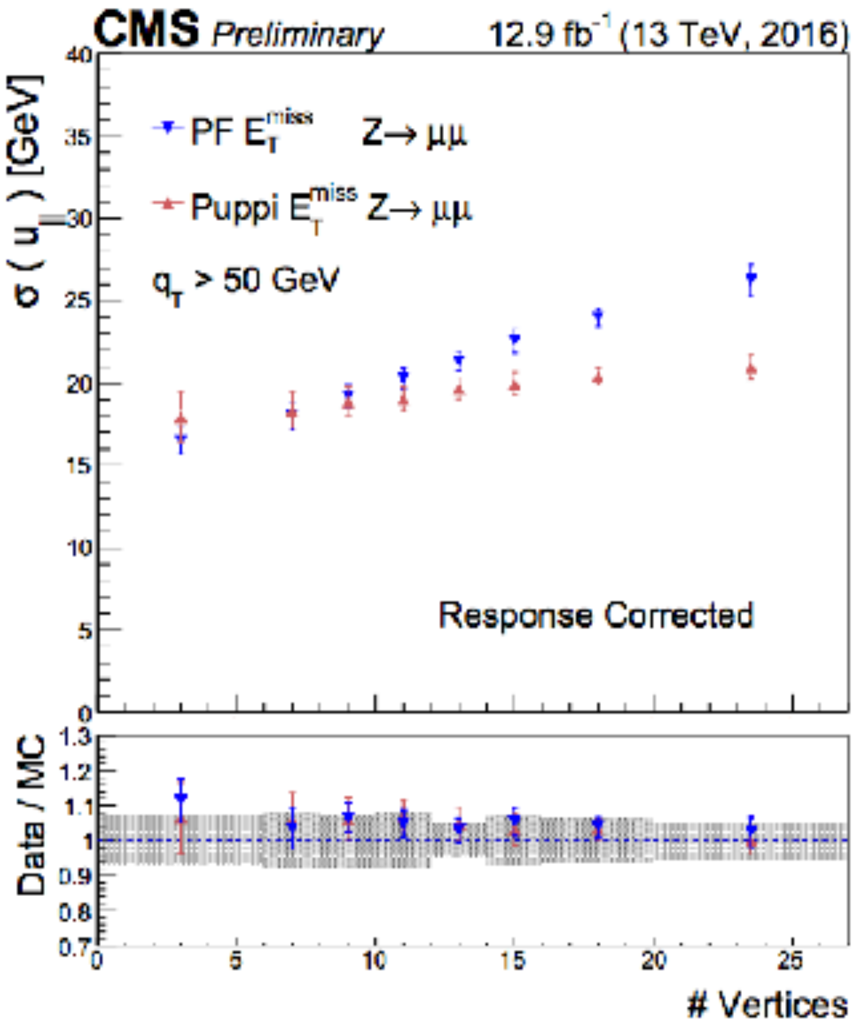


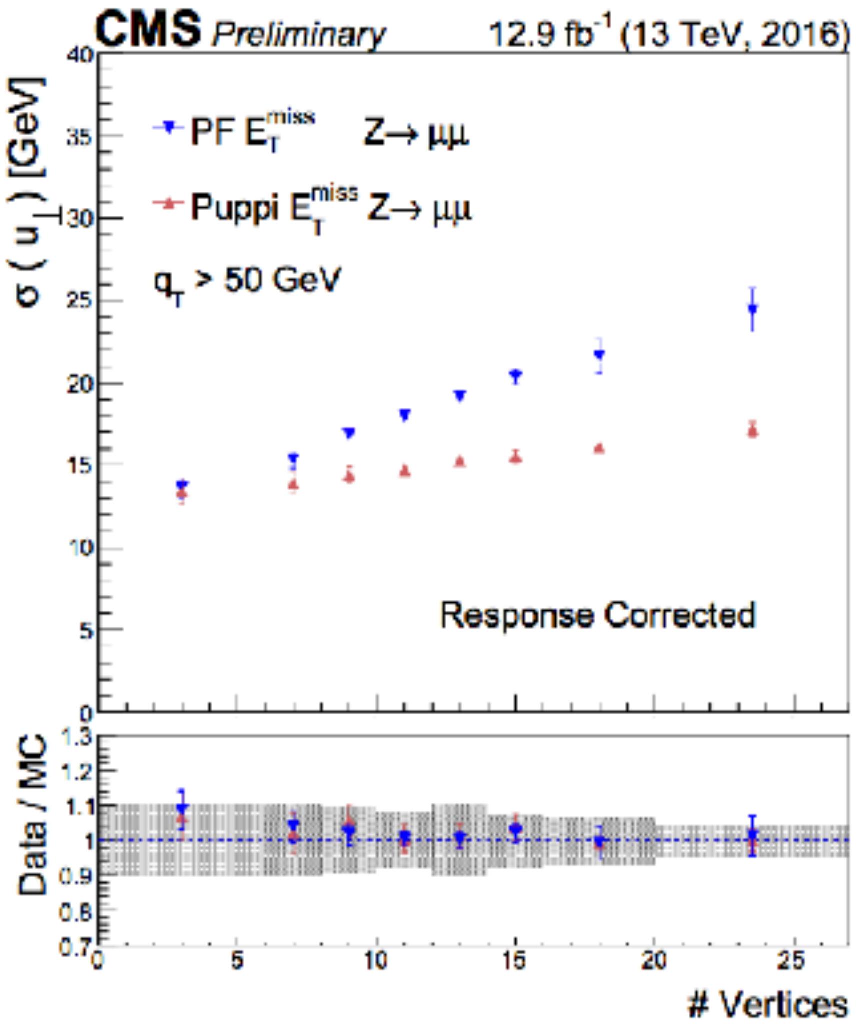
CMS


ATLAS
√s = 8 TeV, 20.3 fb⁻¹
Data 2012, Z→μμ Inclusive
CST
TST
STVF
EJAF
CMS Preliminary
12.9 fb⁻¹ (13 TeV, 2016)
-<u∥>/<q_T>
PF E_T^miss Z→ μμ
Puppi E_T^miss Z→ μμ
1.2
1.1
1
0.9
0.8
0.7
0.6
Data / MC
1.1
1
0.9
50
100
150
200
250
300
350
400
450
500
q_T [GeV]

CMS

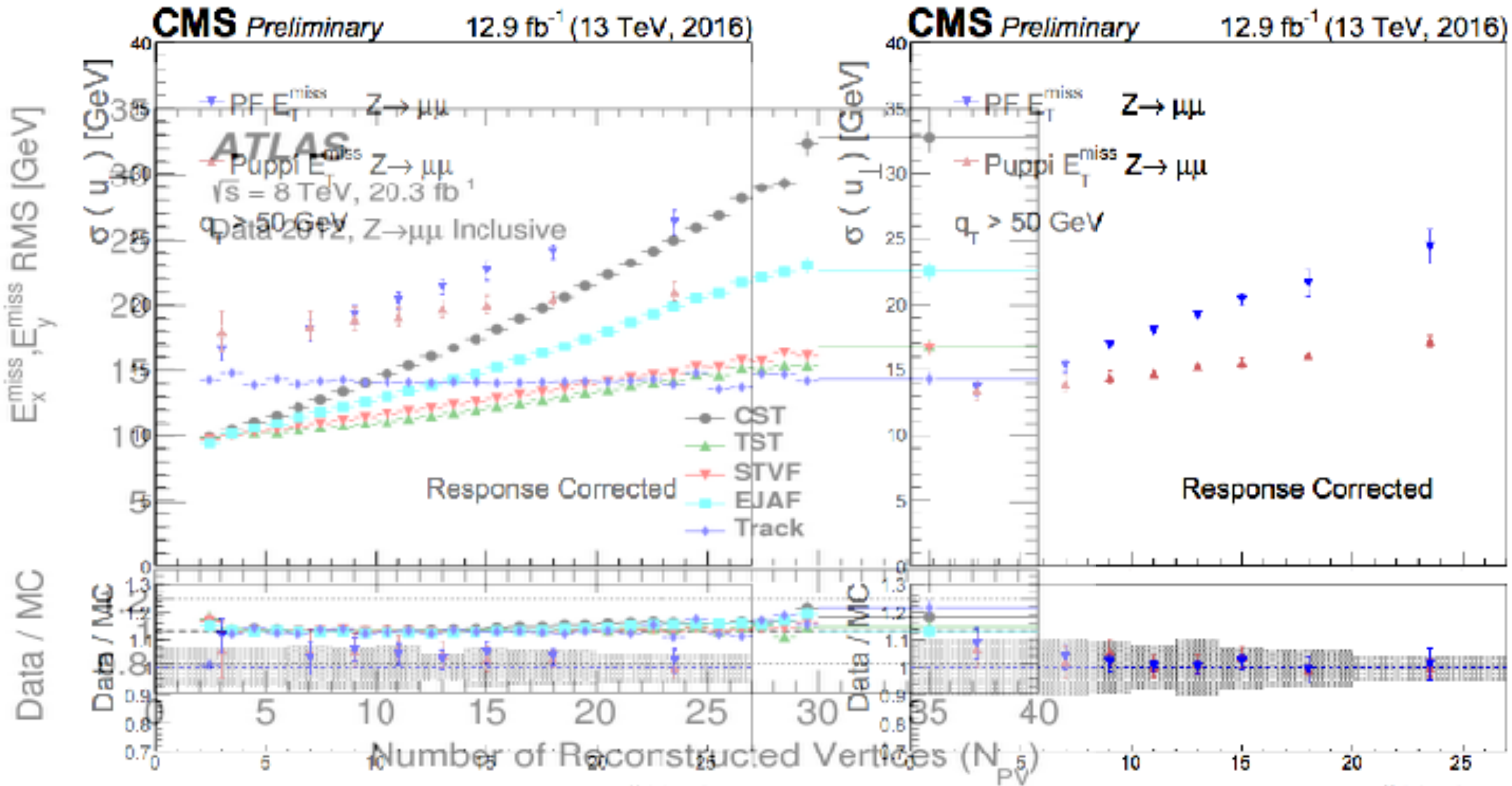
- as far as I understand, these are the resolution, after taking out the "bias"

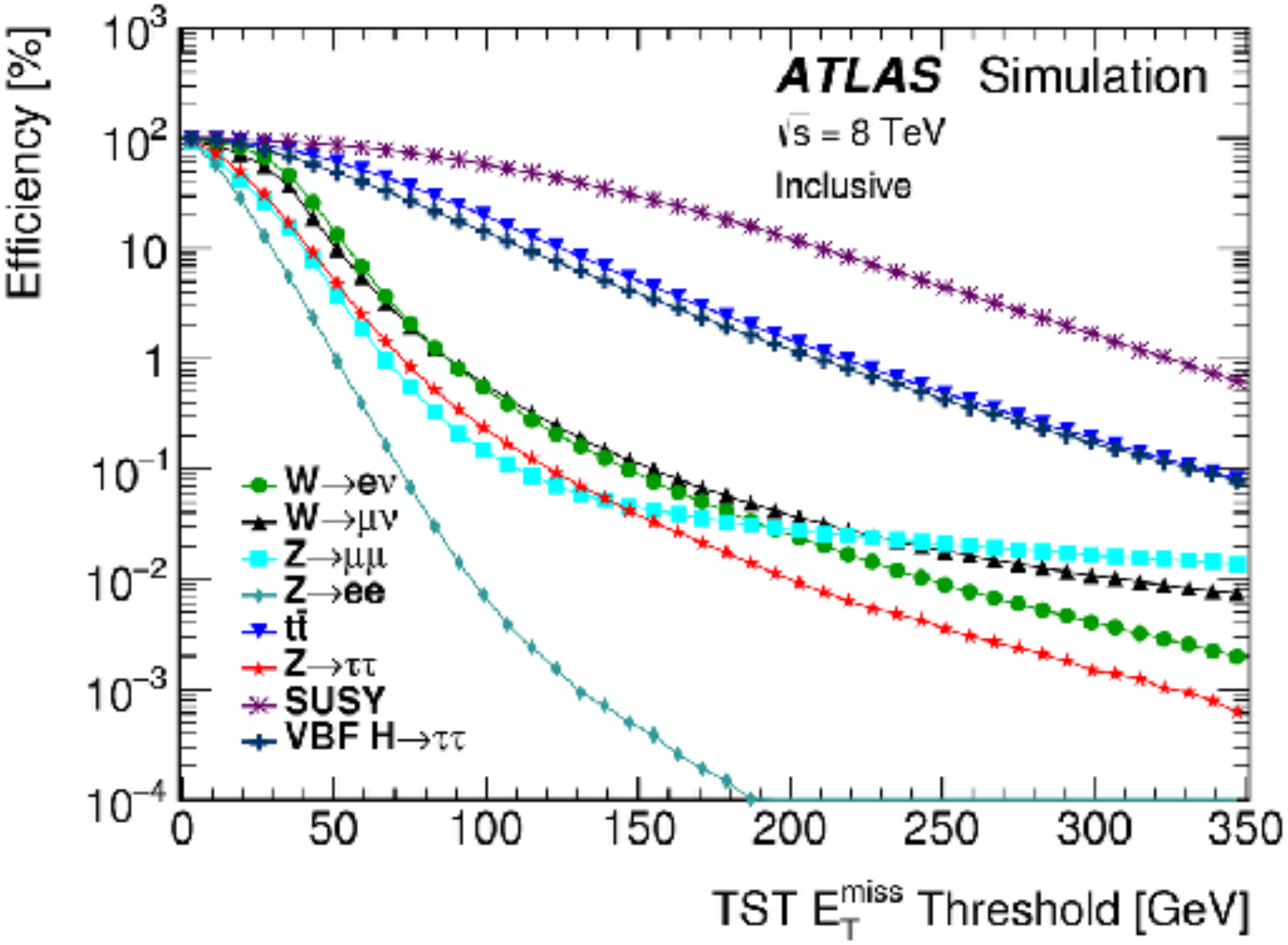


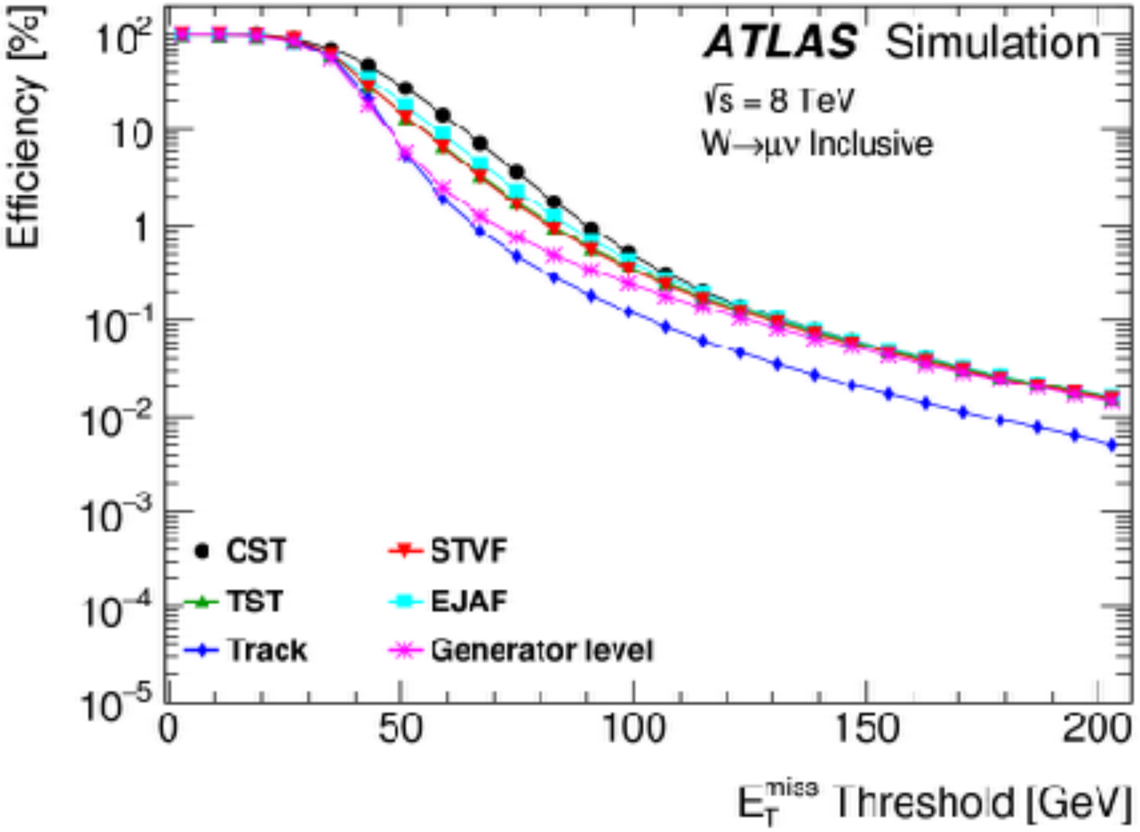


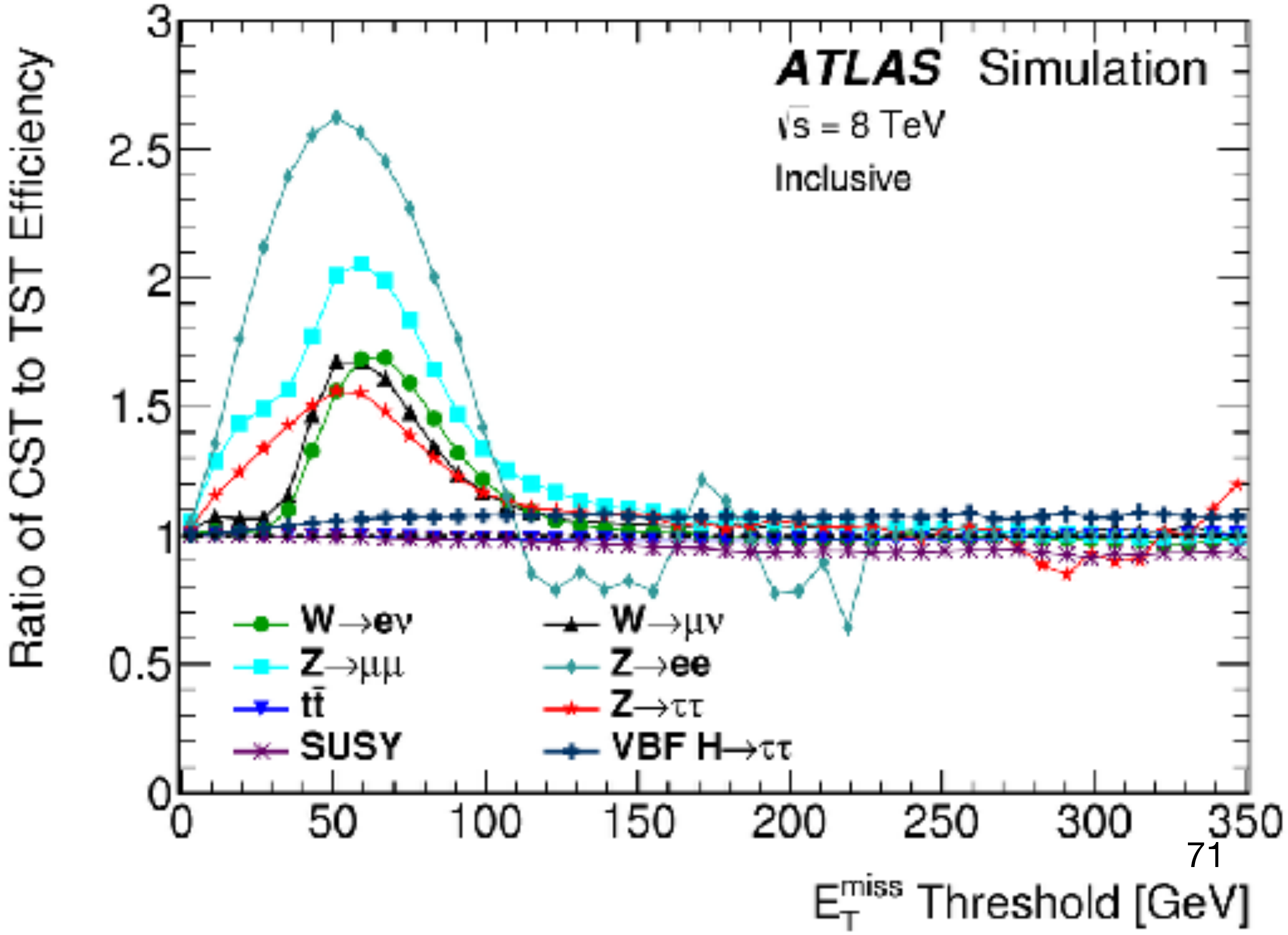
CMS

- as far as I understand, these are the resolution, after taking out the "bias"




ATLAS Simulation
$\sqrt{s}$ = 8 TeV
Inclusive
Efficiency [%]
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
50
100
150
200
250
300
350
TST E_T^{miss} Threshold [GeV]
$W \rightarrow e\nu$
$W \rightarrow \mu\nu$
$Z \rightarrow \mu\mu$
$Z \rightarrow ee$
$t\bar{t}$
$Z \rightarrow \tau\tau$
SUSY
VBF $H \rightarrow \tau\tau$


ATLAS Simulation
$\sqrt{s}$ = 8 TeV
$W \rightarrow \mu\nu$ Inclusive
Efficiency [%]
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
50
100
150
200
E_T^{miss} Threshold [GeV]
CST
TST
Track
STVF
EJAF
Generator level


ATLAS Simulation
$\sqrt{s}$ = 8 TeV
Inclusive
Ratio of CST to TST Efficiency
3
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
350
E_T^{miss} Threshold [GeV]
$W \rightarrow e\nu$
$W \rightarrow \mu\nu$
$Z \rightarrow \mu\mu$
$Z \rightarrow ee$
$t\bar{t}$
$Z \rightarrow \tau\tau$
SUSY
VBF $H \rightarrow \tau\tau$