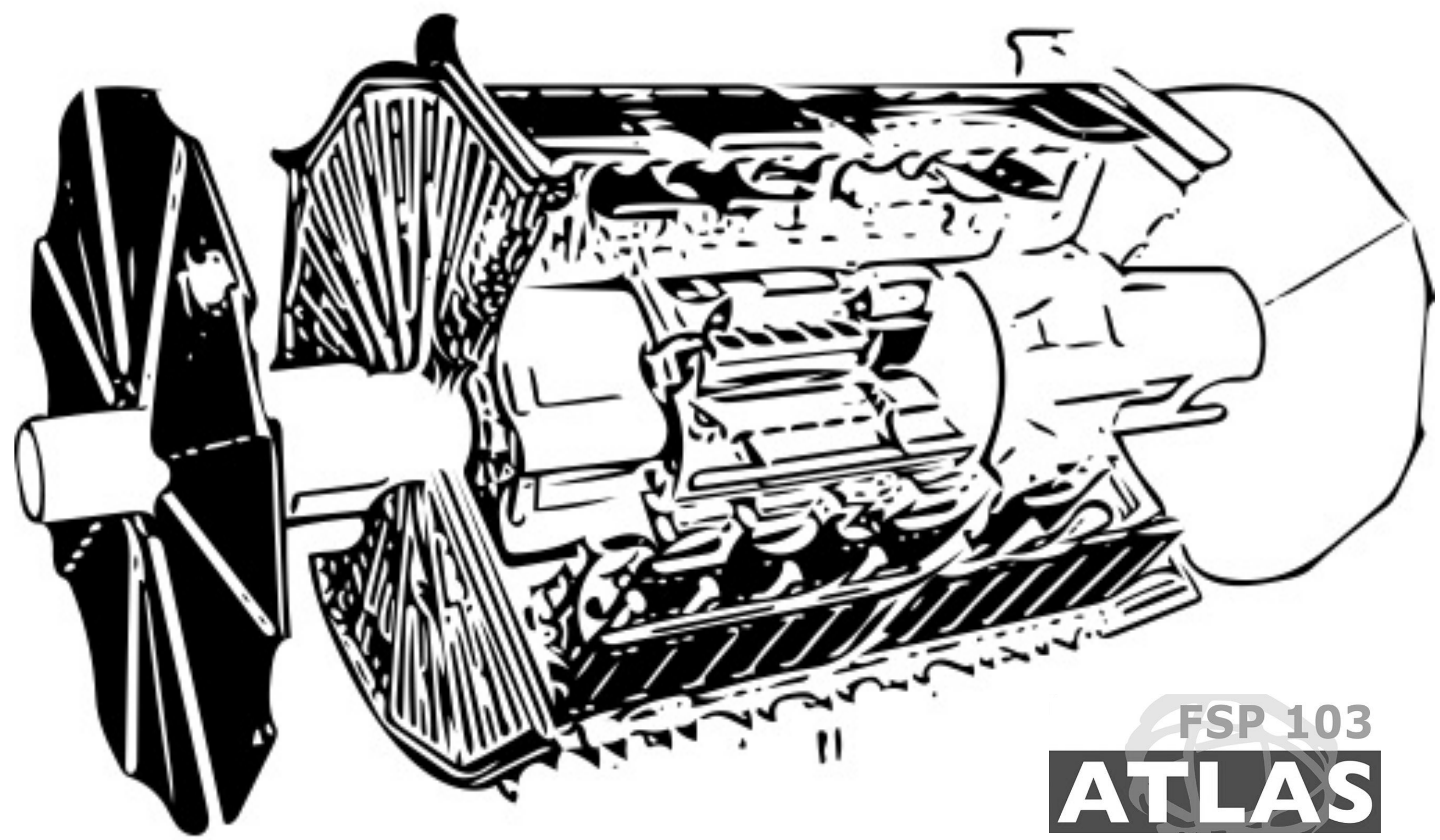
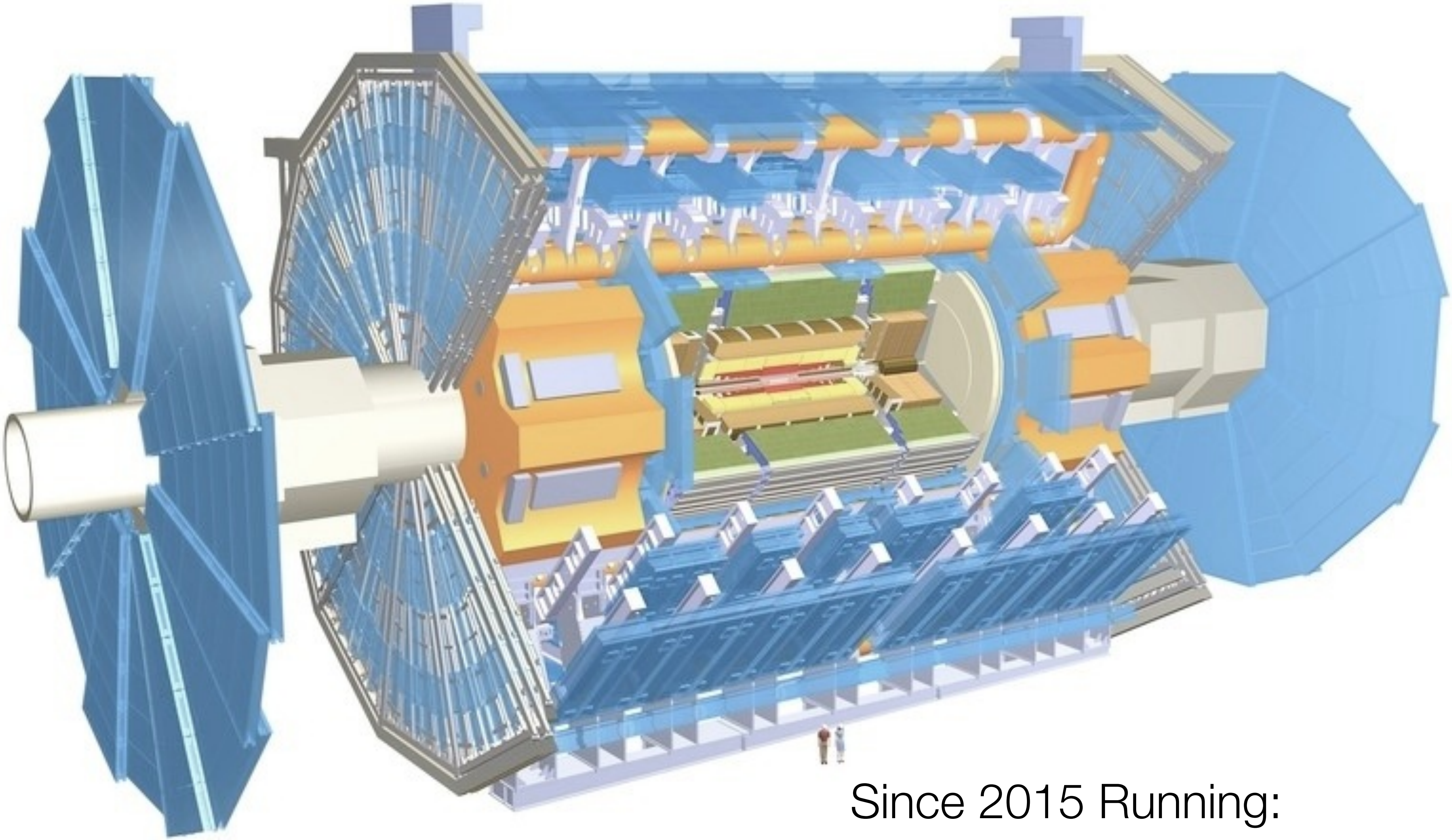
Recent News from ATLAS

Hans-Christian Schultz-Coulon
Kirchhoff-Institut für Physik

4th KSETA Plenary Workshop
Februar 2017



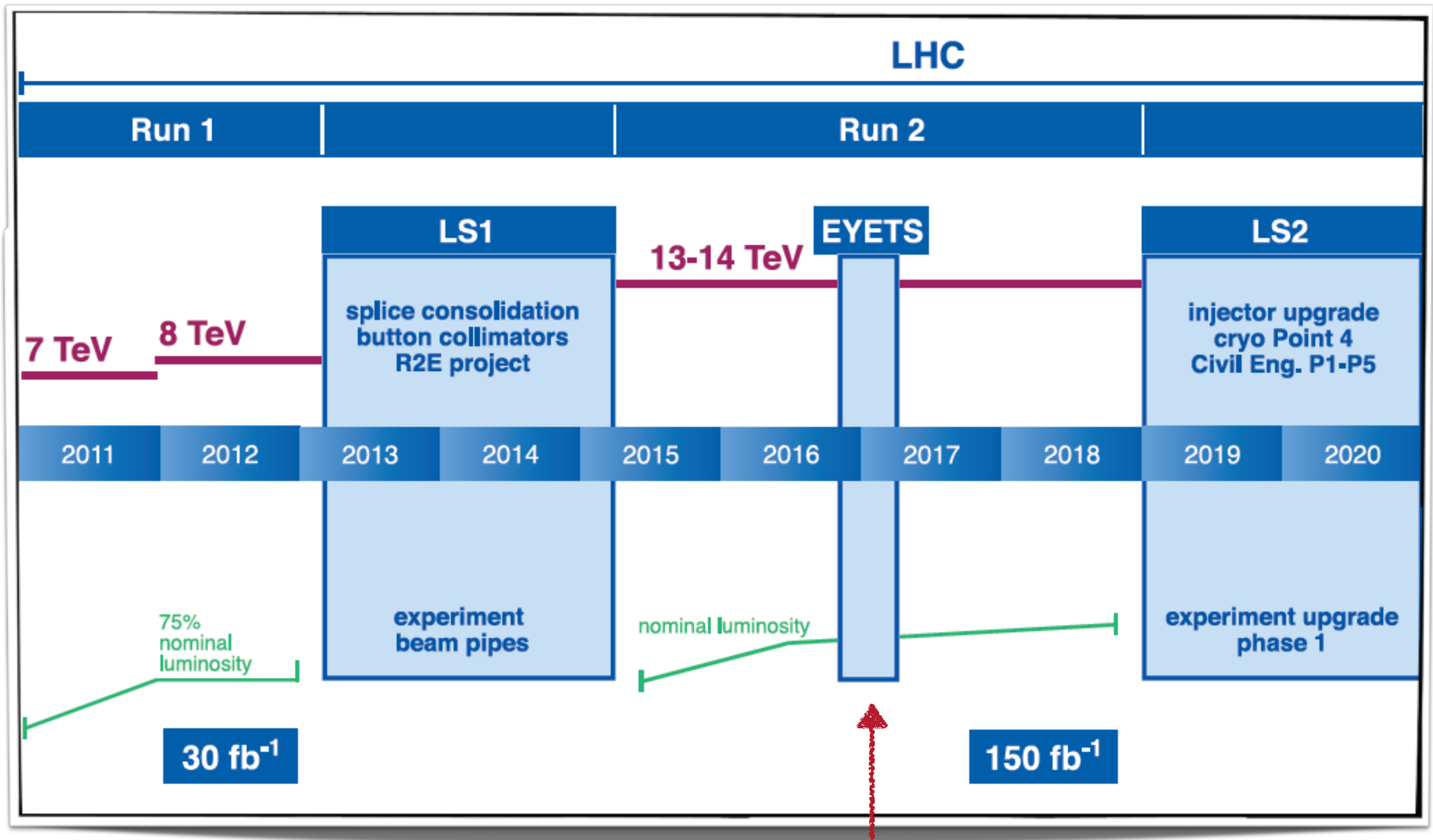
The ATLAS Experiment



Since 2015 Running:

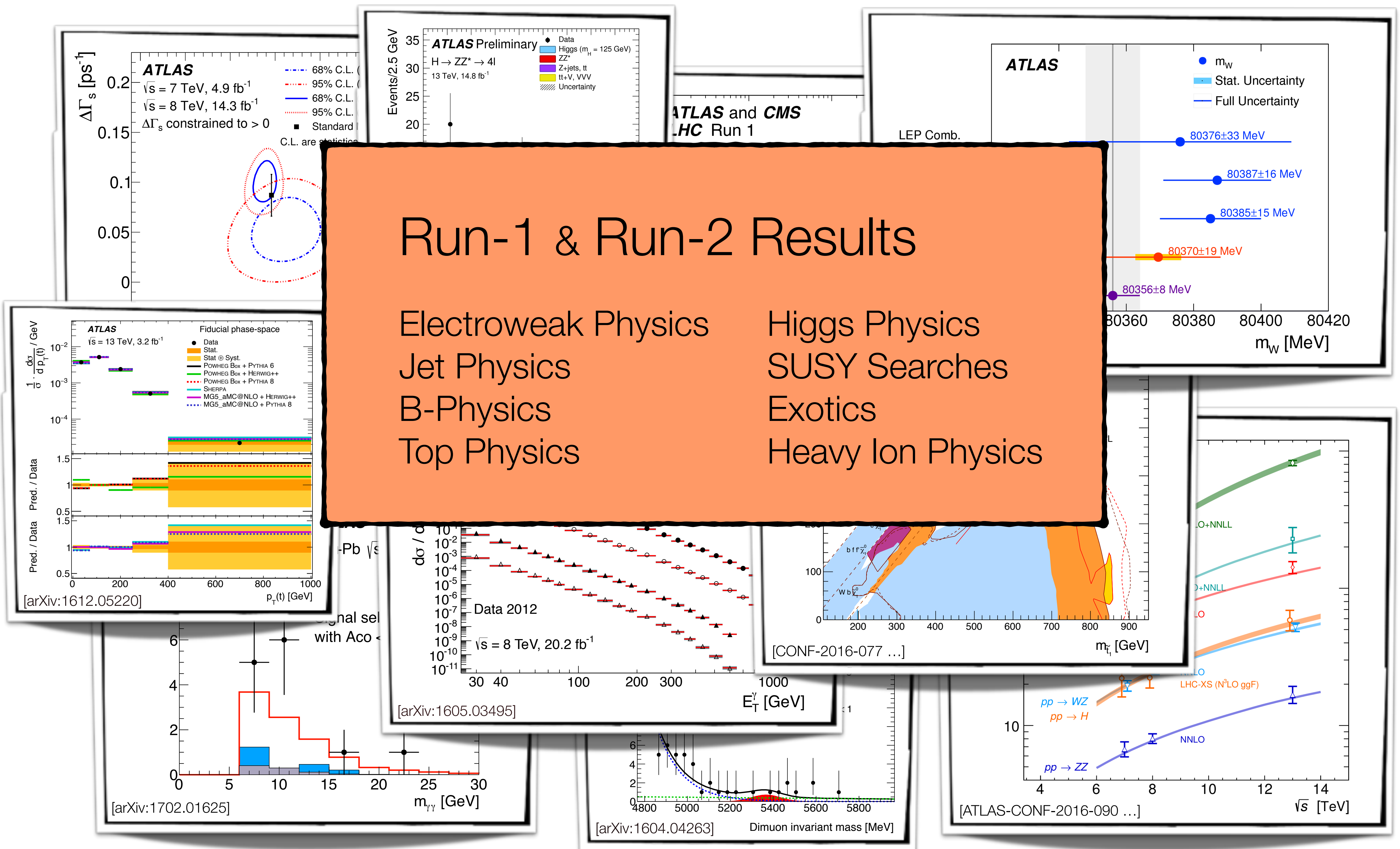
- New beam pipe; 4th pixel layer @ 3.3 cm (IBL)
- Improved Trigger/DAQ system; 100 kHz L1 rate
- …

LHC Schedule & Data Taking Periods

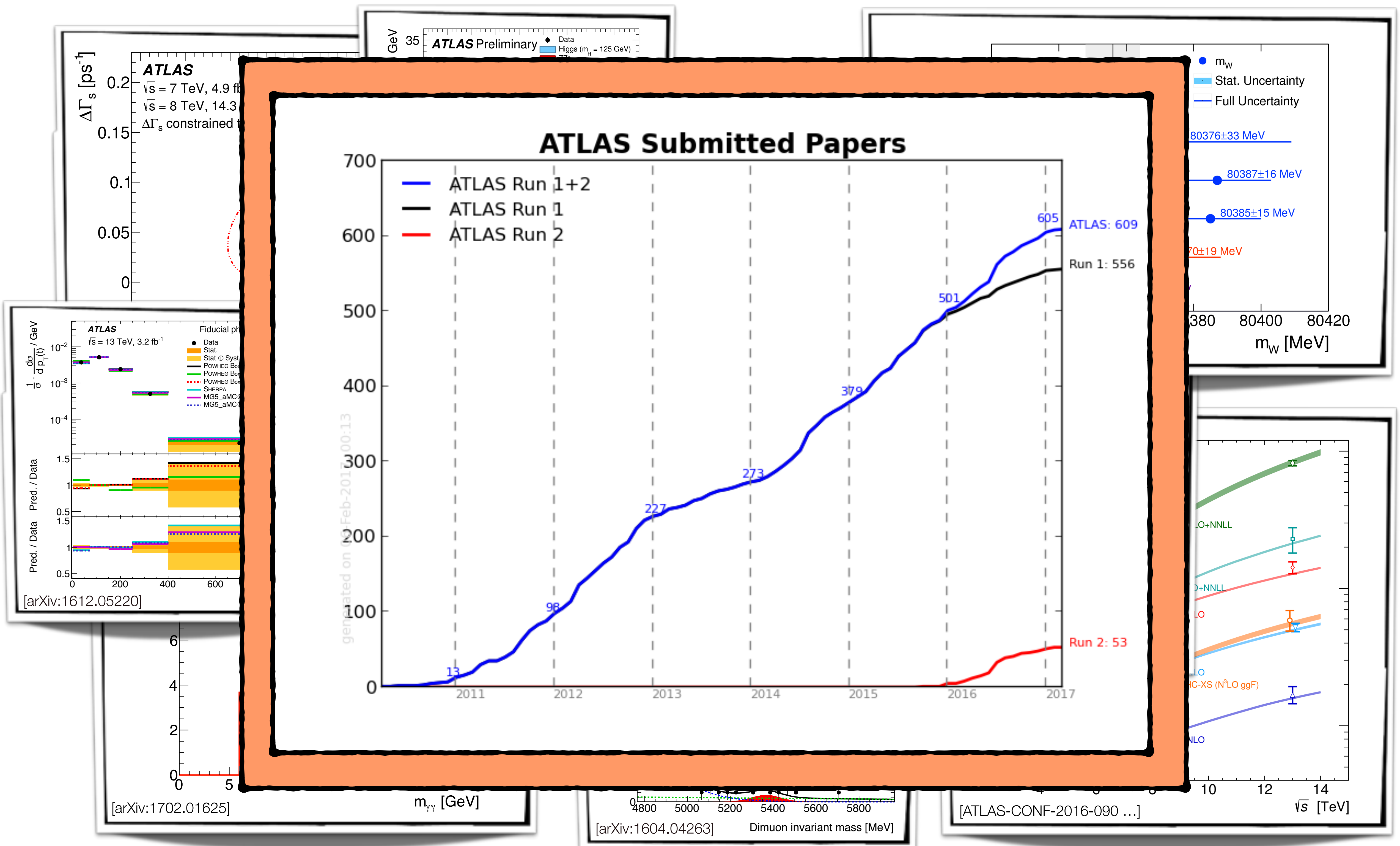


We are here …

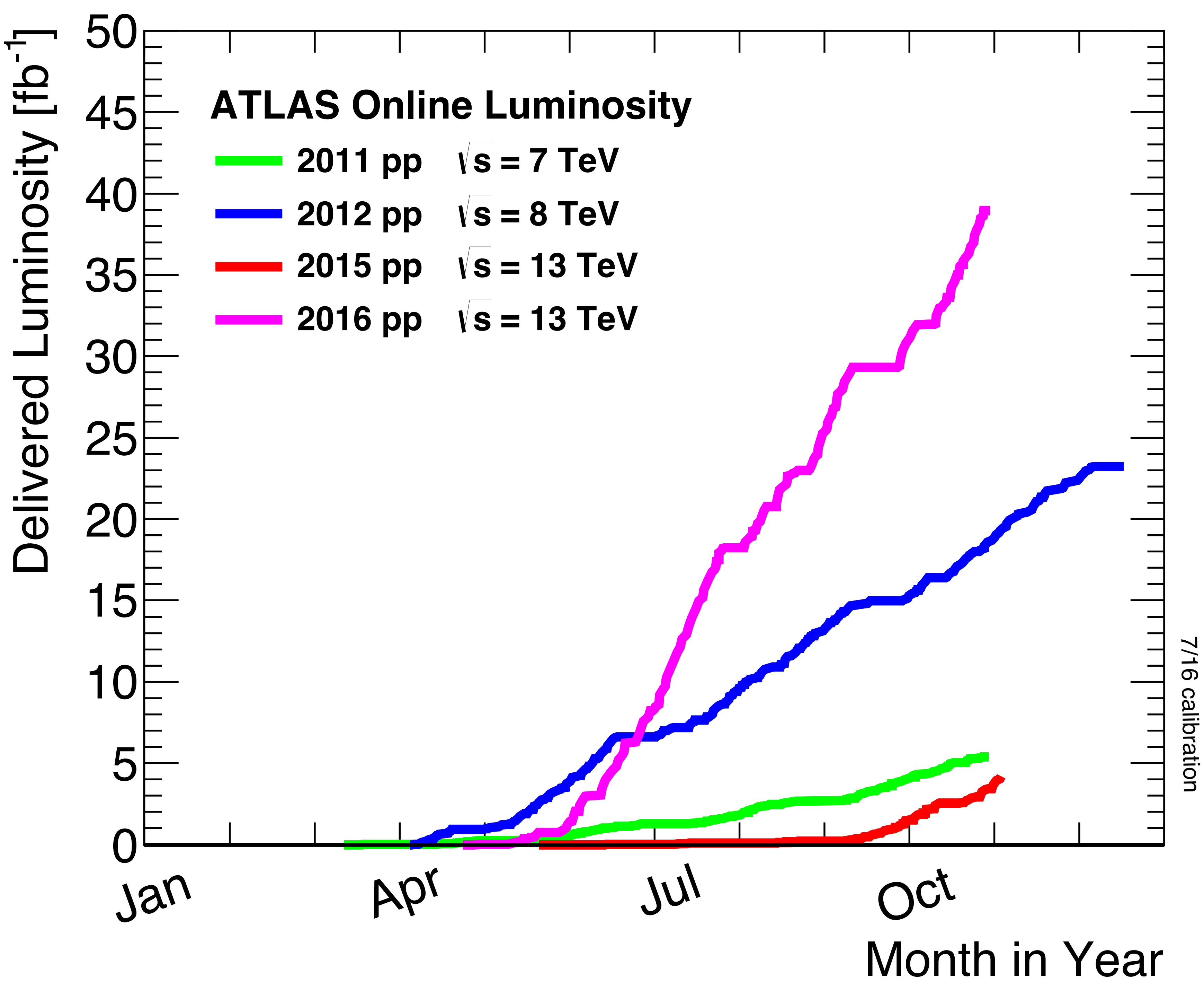
Recent ATLAS Result Collage



Recent ATLAS Result Collage



Run-2 Performance

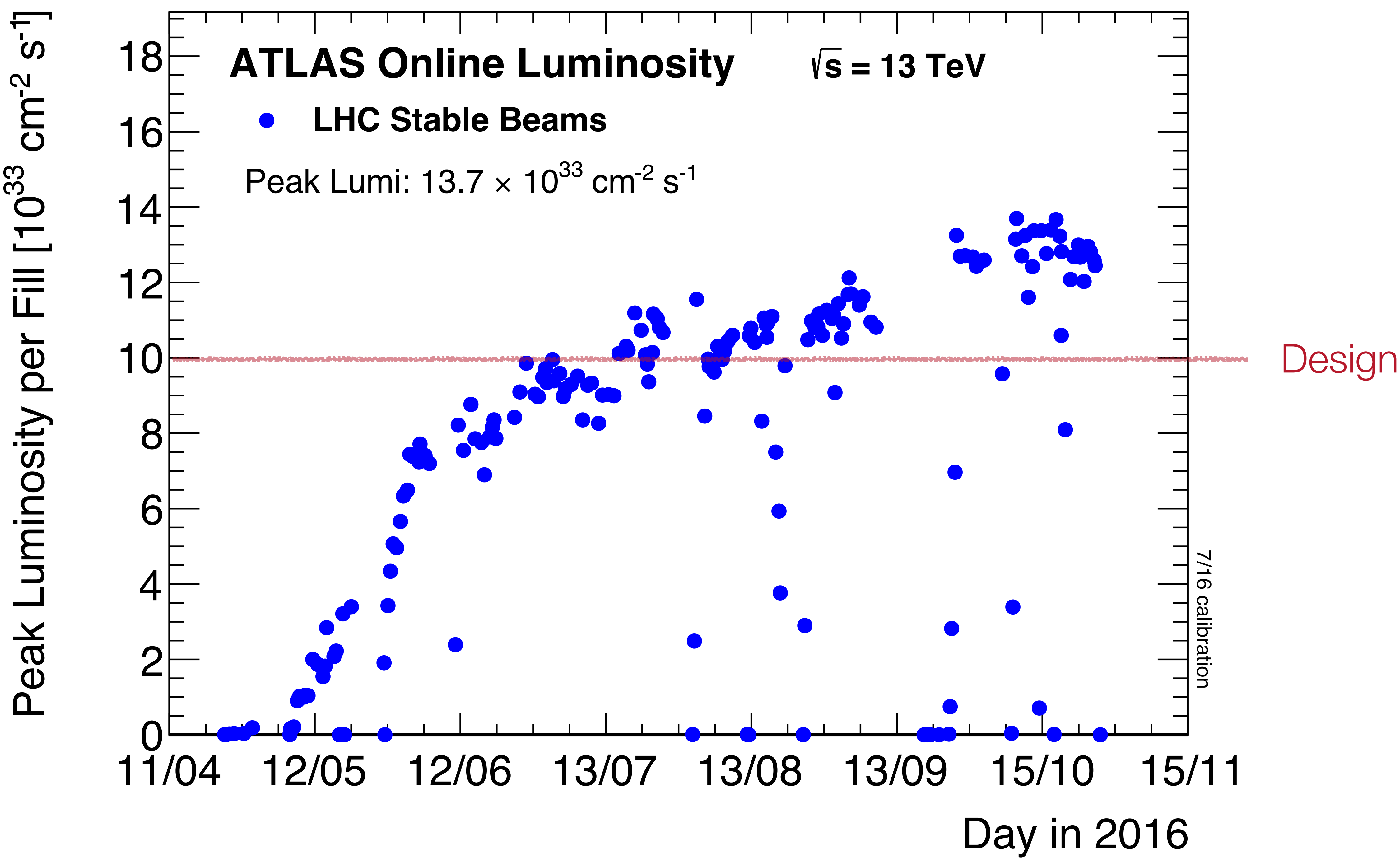


Luminosities:
[recorded]

2011: 5.1 pb^{-1}
2012: 21.3 pb^{-1}

2015: 3.9 pb^{-1}
2016: 36.0 pb^{-1}

Run-2 Performance

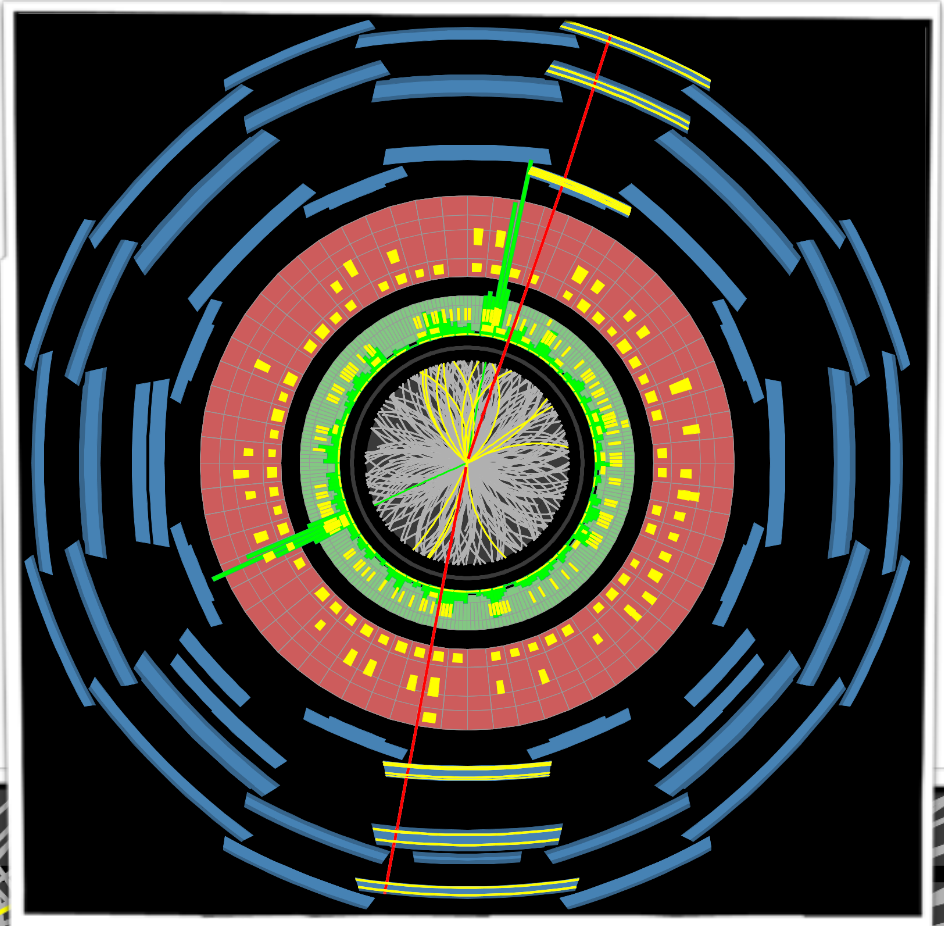


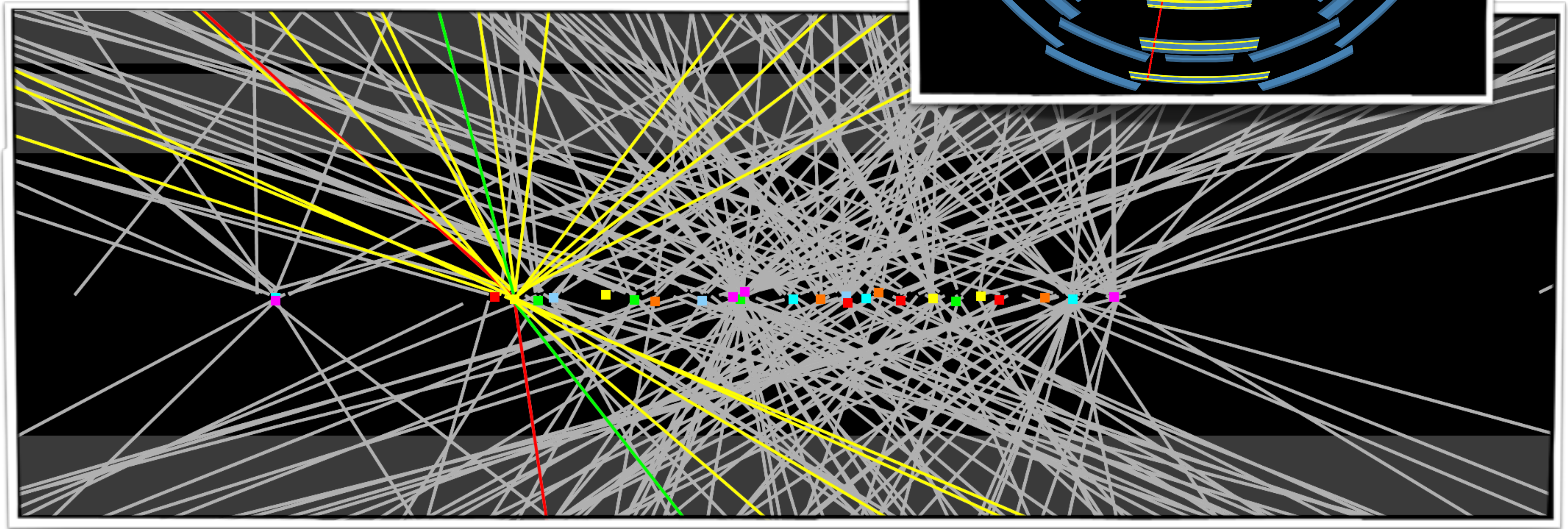
Run-2 Performance

ATLAS Event
with 25 pileup vertices

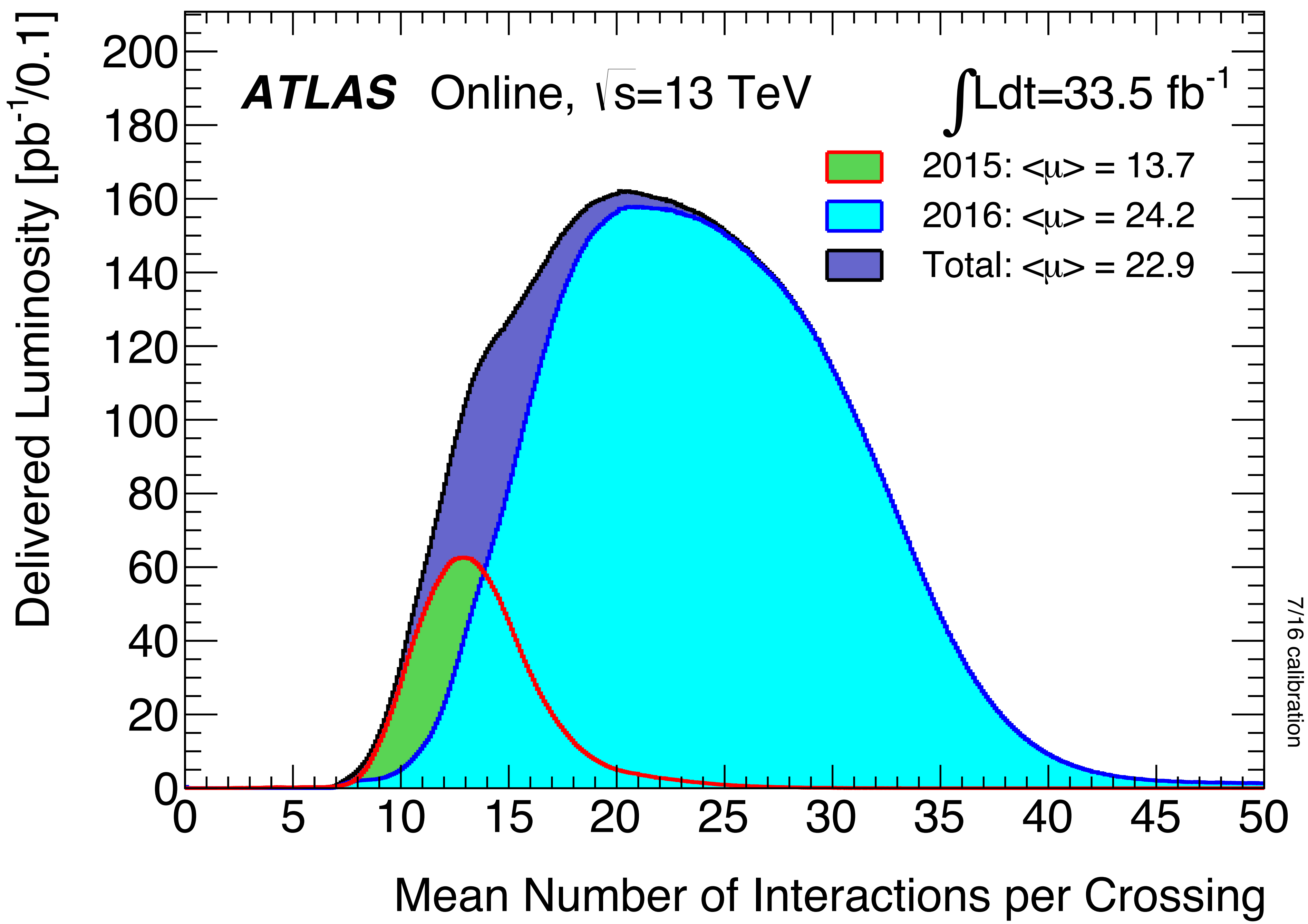
[√s = 13 TeV; 2016 Data]

H ➛ ZZ ➛ ee μμ candidate event

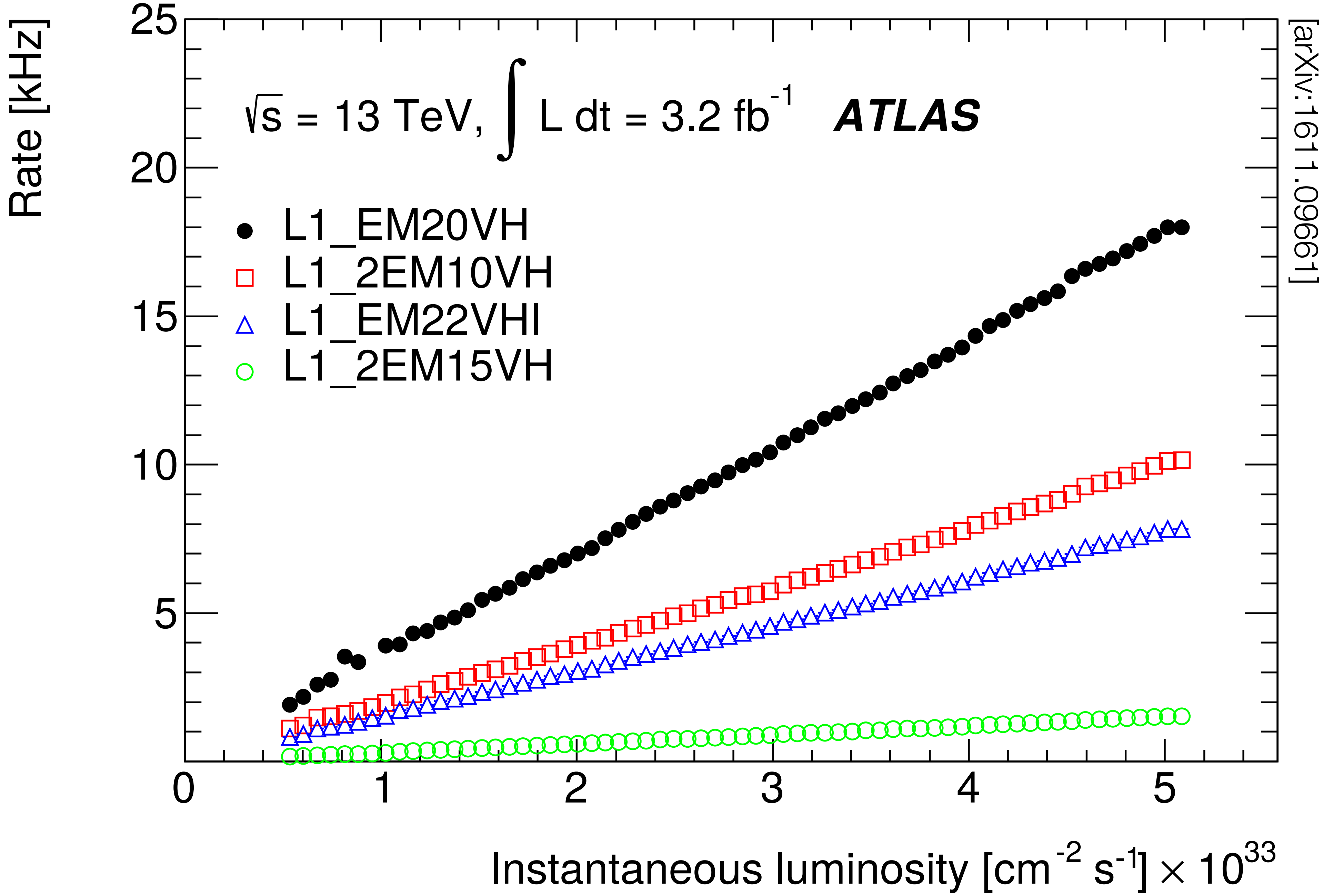




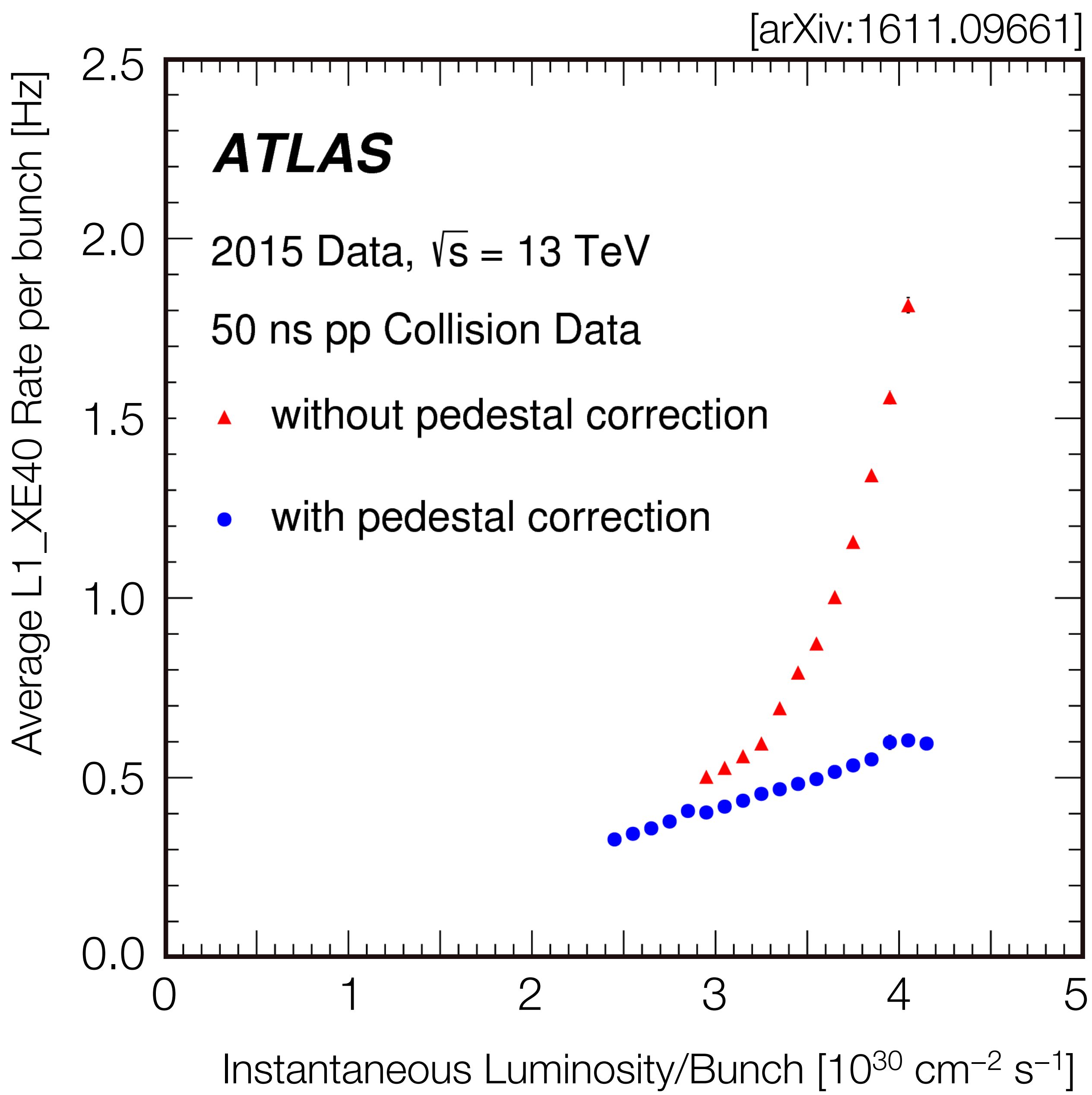
Run-2 Performance

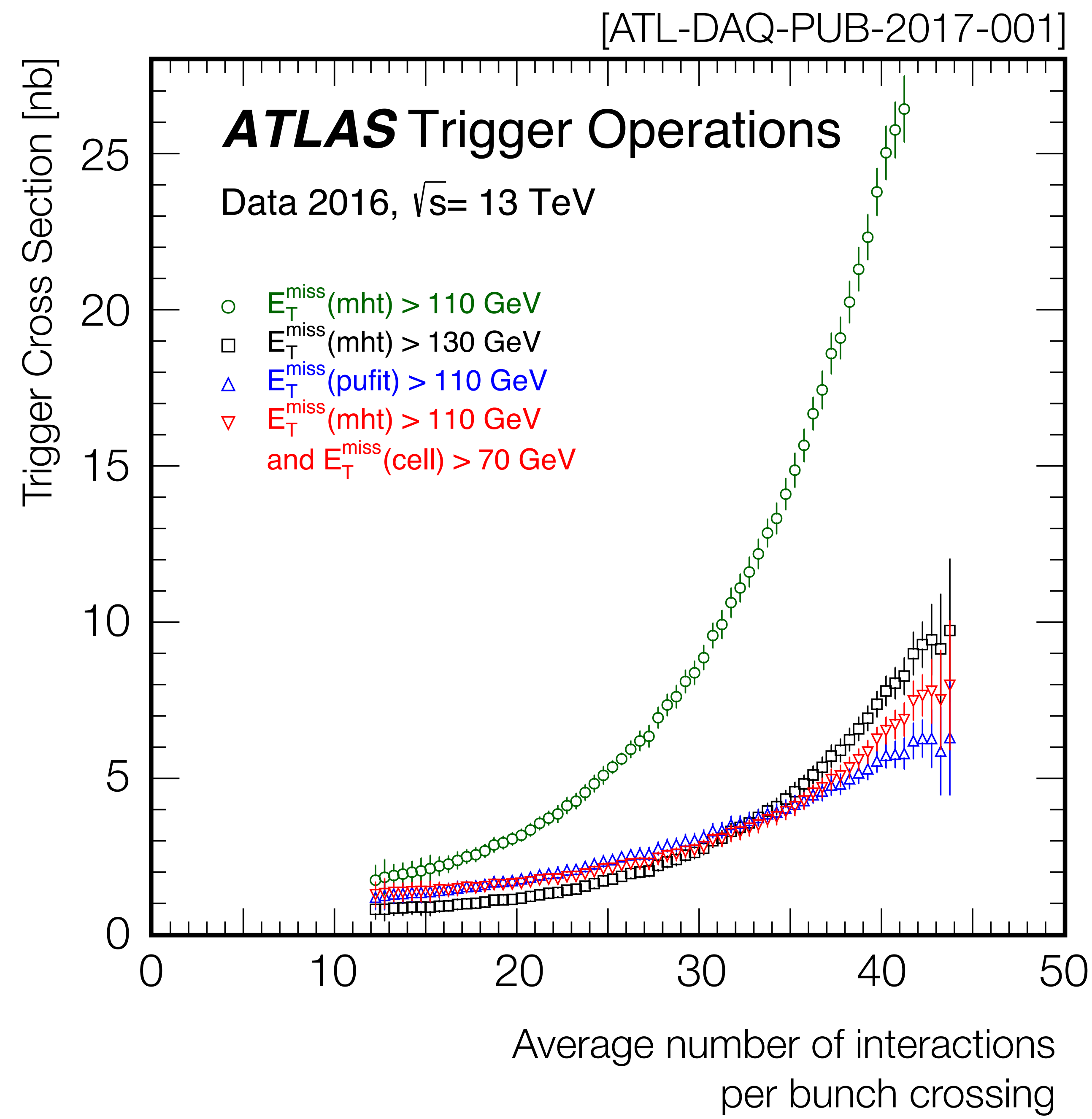


Rate and Pileup Mitigation at Trigger Level



Rate and Pileup Mitigation at Trigger Level



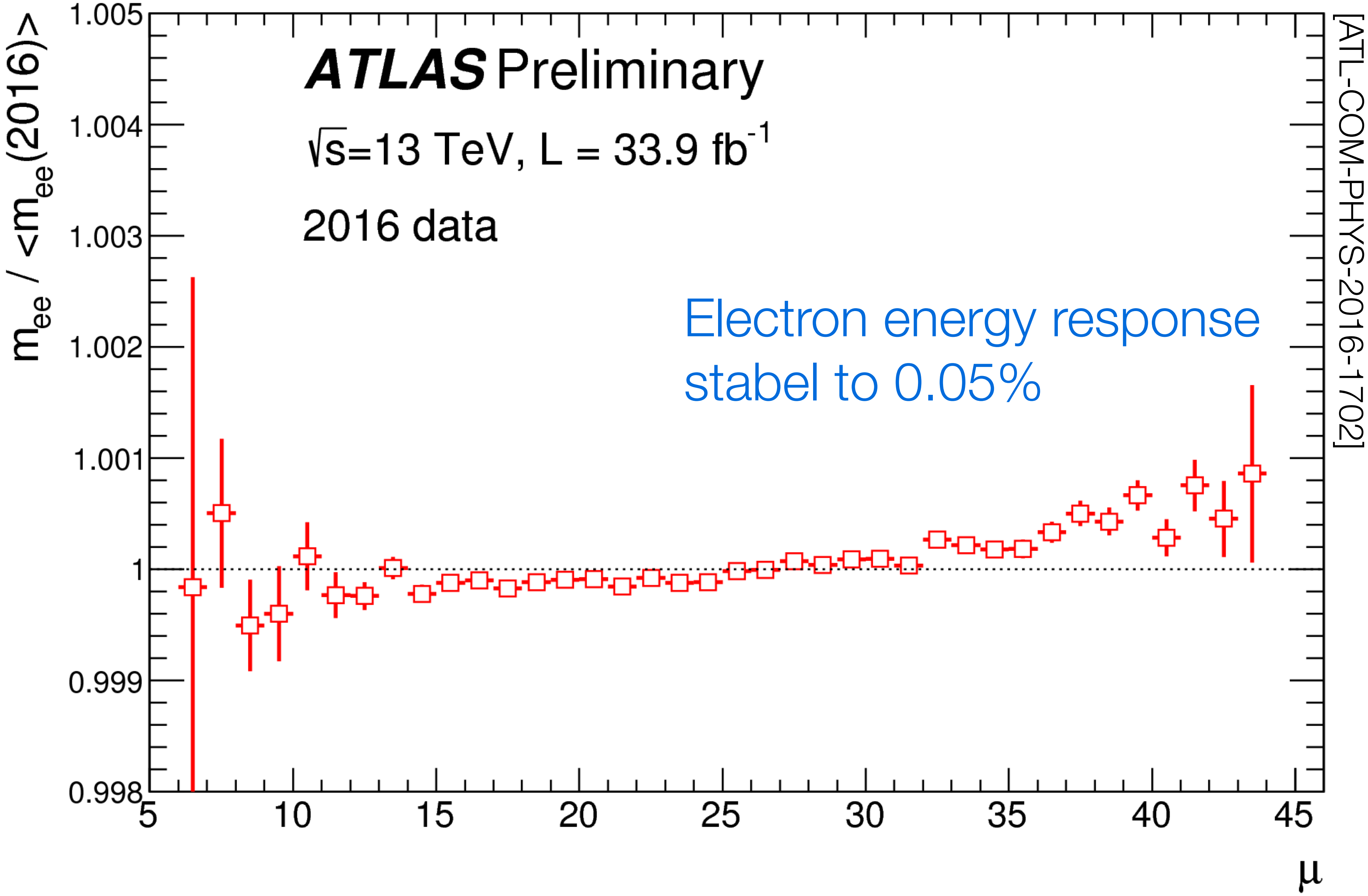


Rate reduction based on pileup corrections @ L1 & HLT

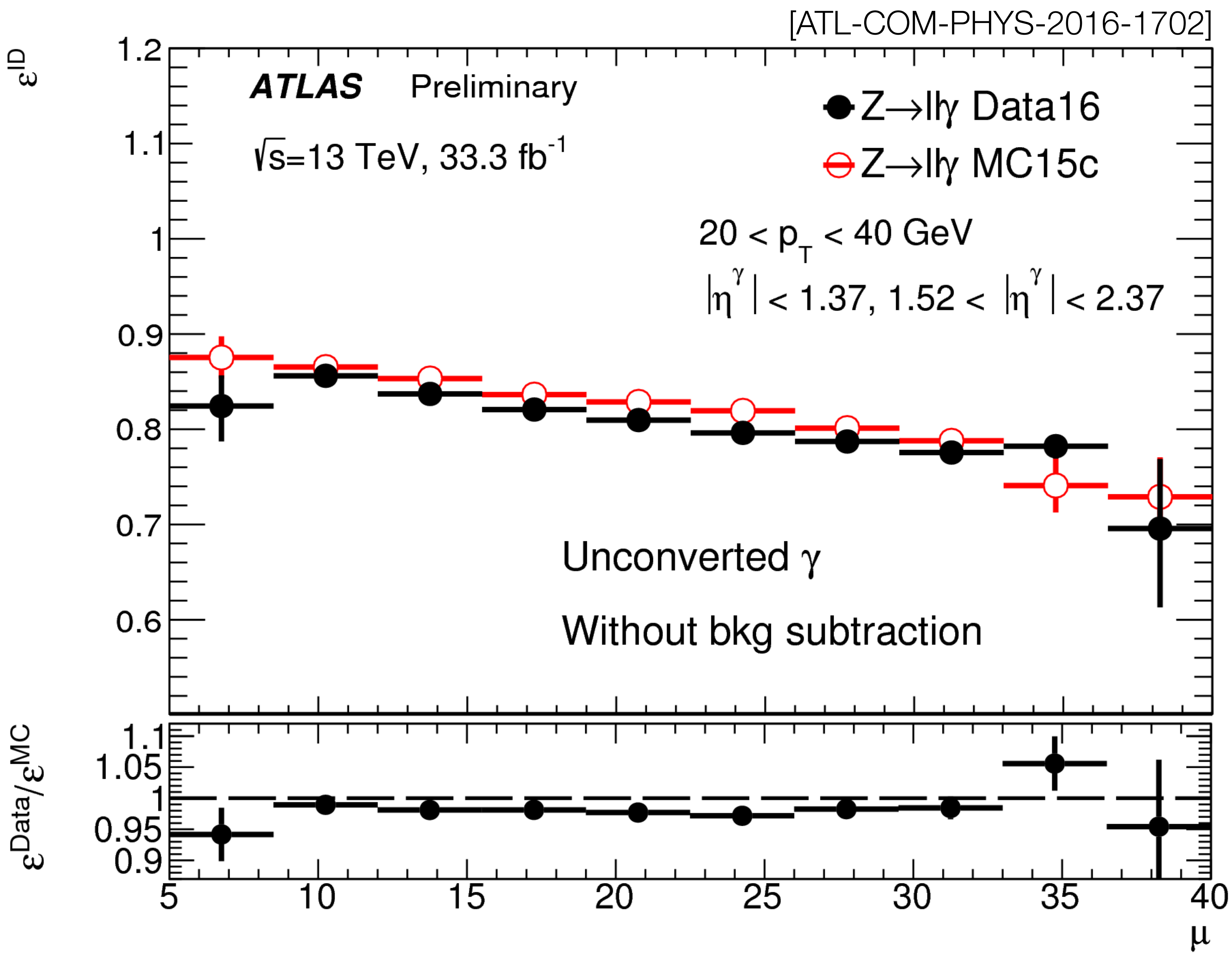
Pileup Stability

Reconstructed Z mass ($m_{Z\rightarrow ee}$) vs. μ;

normalized to the 2016 average $\langle m_{Z\rightarrow ee} \rangle$



Pileup Stability



Photon Identification Efficiency

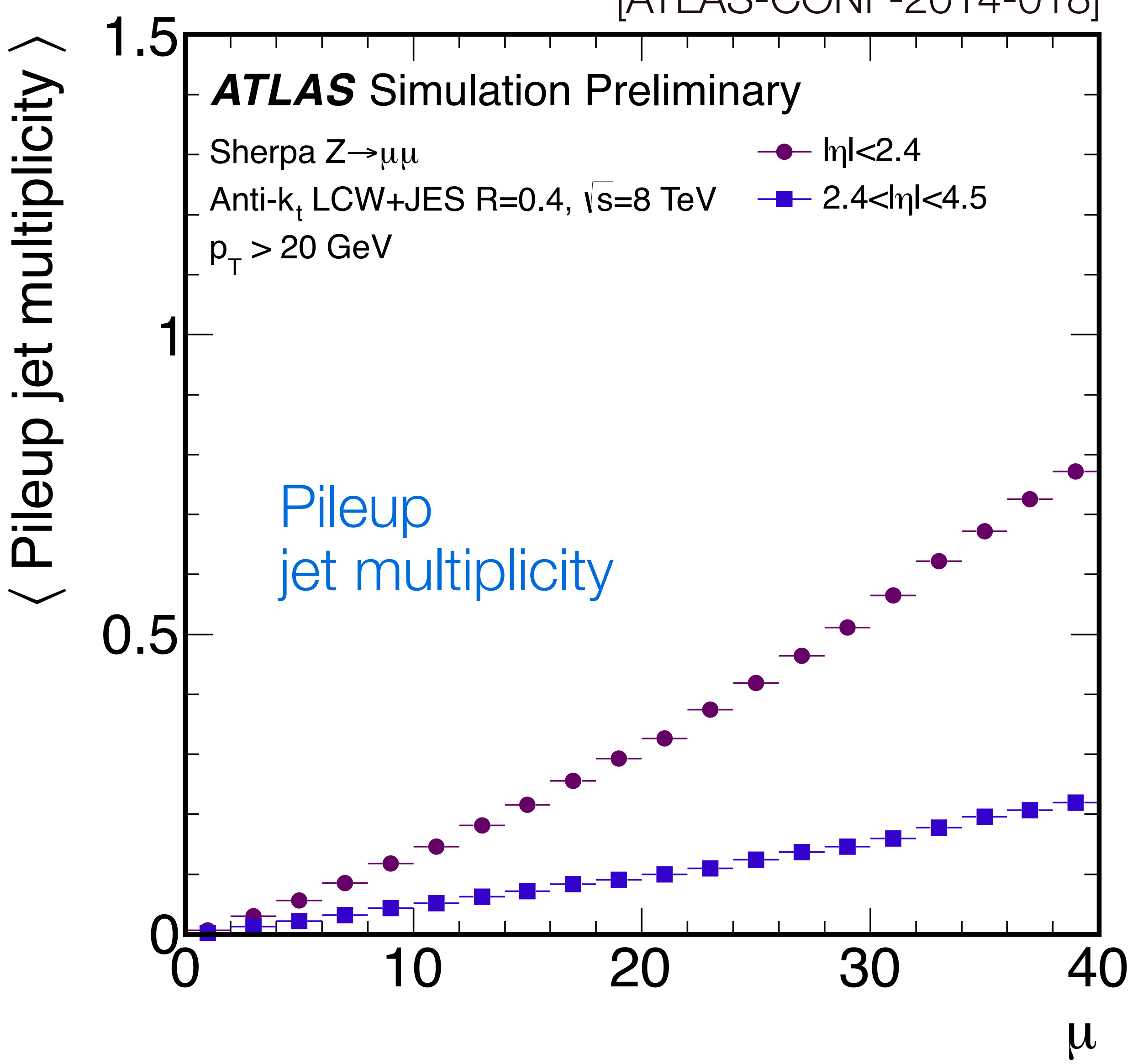
Zγ Events

Tight Photon ID

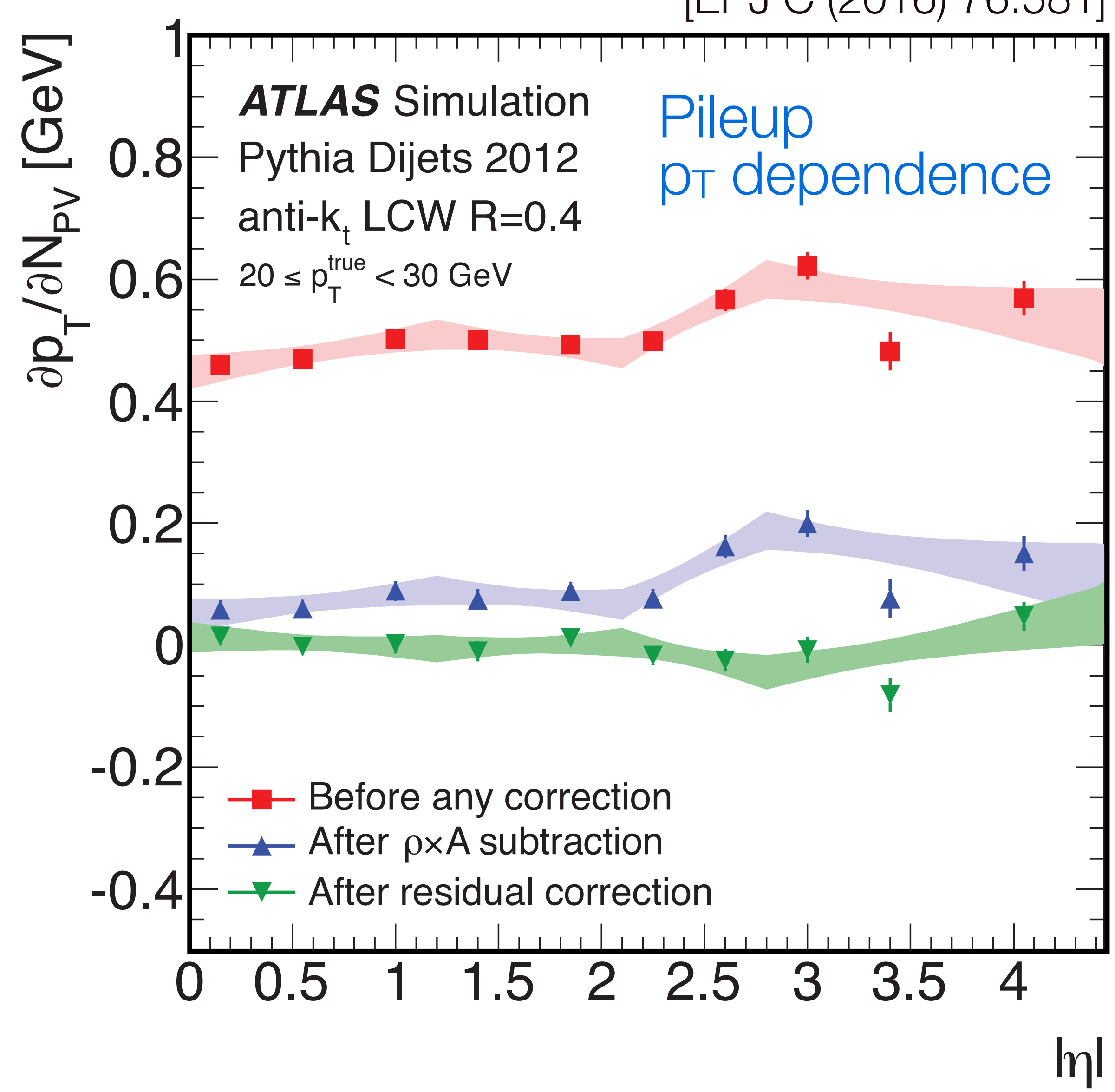
Jet Pileup Mitigation

Pileup affects hard-scatter jets and produces extra jets

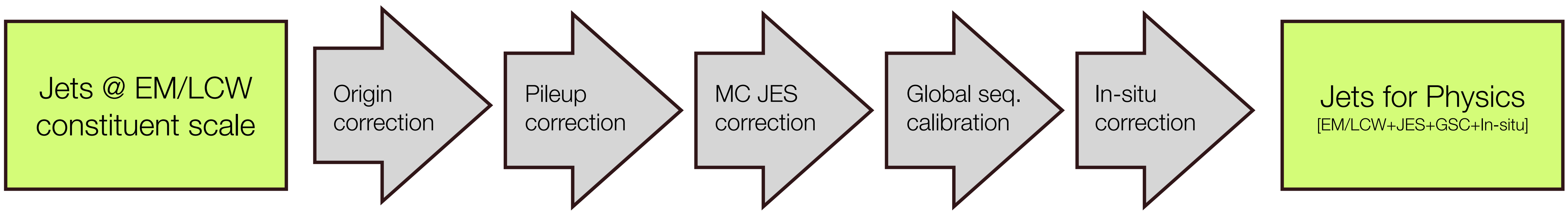
[ATLAS-CONF-2014-018]



[EPJ C (2016) 76:581]



Jet Pileup Mitigation



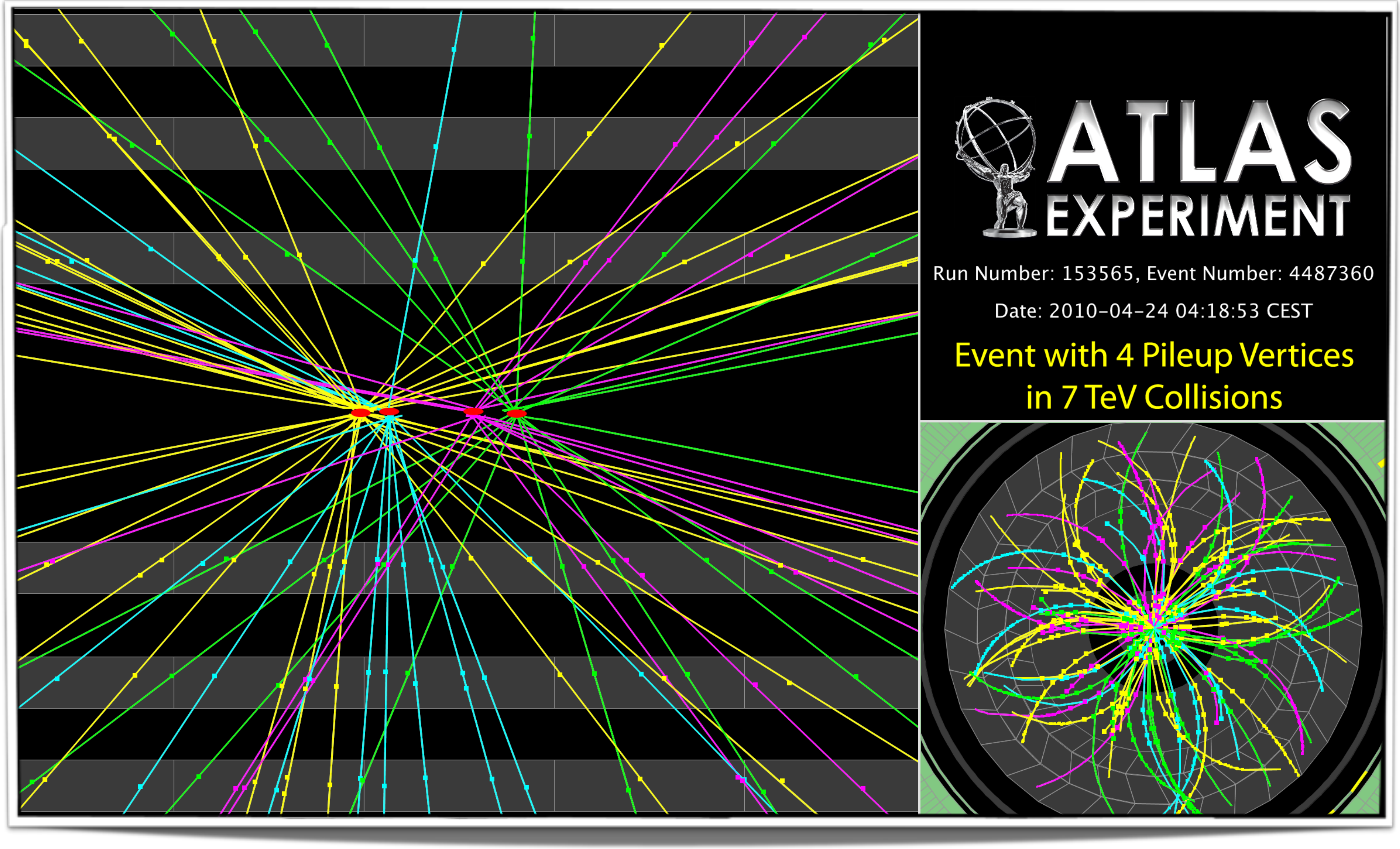
jet area based correction ($\rho \times A$)

residual correction ($\alpha \times (N_{PV} - 1) - \beta \times \langle \mu \rangle$)

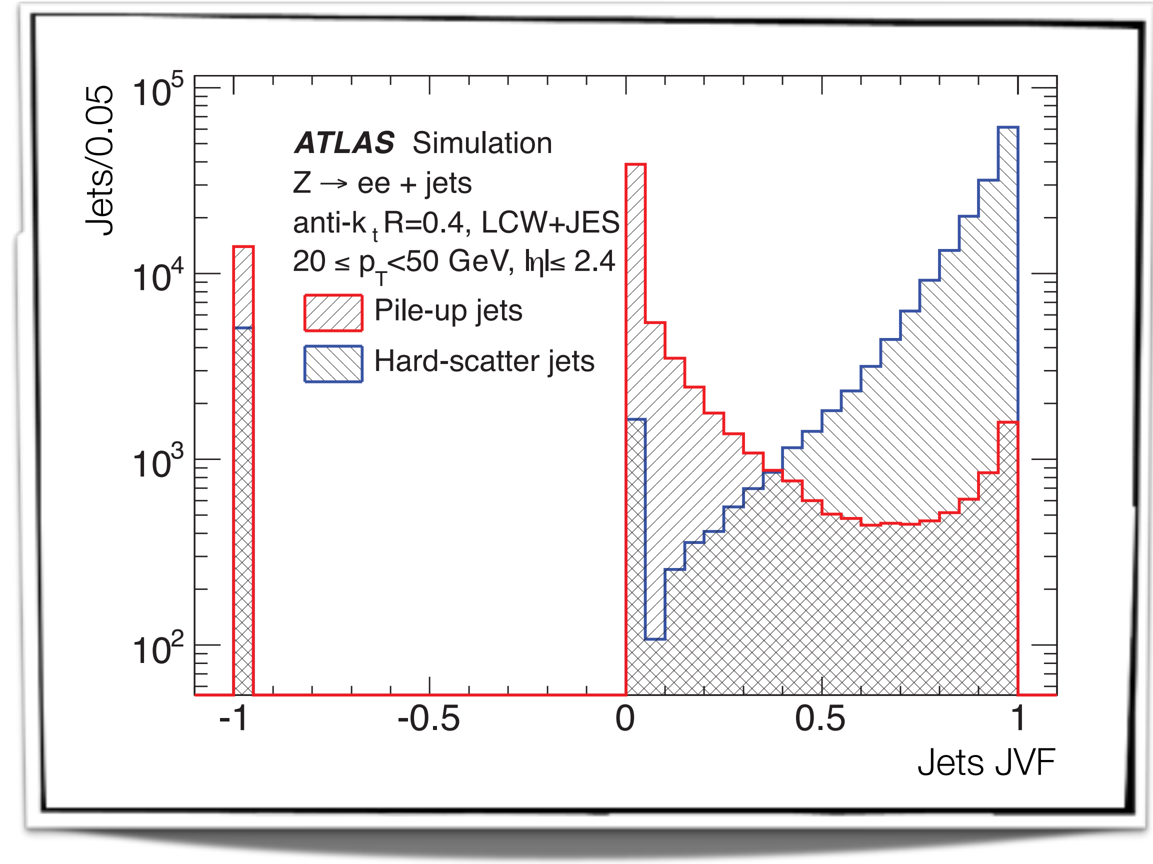
$$p_T^{\mathrm{corr}} = p_T^{\mathrm{EM}} - \rho \times A - \alpha \times (N_{PV} - 1) - \beta \times \langle \mu \rangle$$

- p_T^{EM}: p_T @ EM scale
- ρ: median pileup p_T density
- A: jet area
- α: from MC [η dependent]
- N_{PV}: number of primary vertices
- β: from MC [η dependent]
- $\langle \mu \rangle$: average number of interactions per bunch

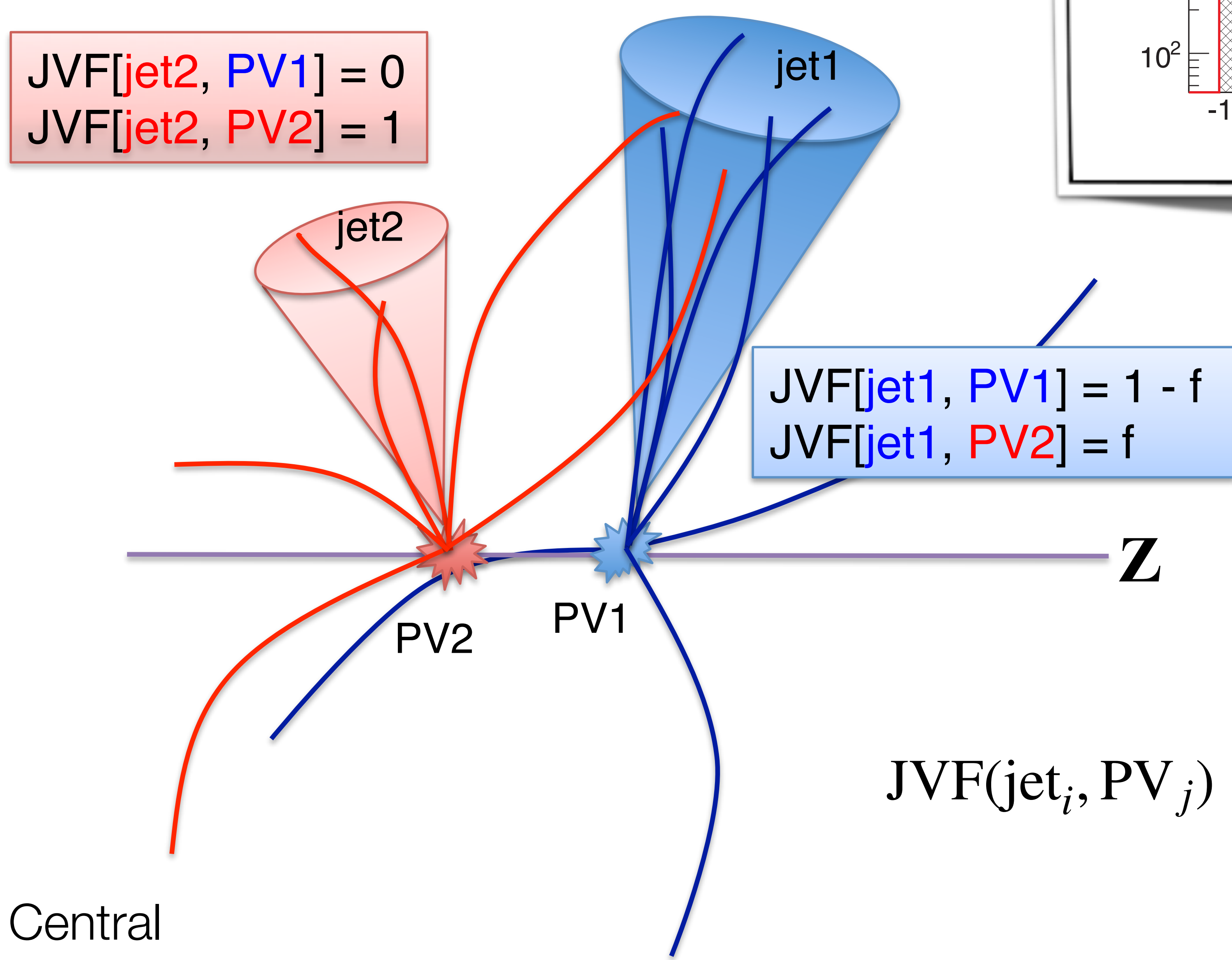
Jet Pileup Mitigation



Jet Pileup Mitigation



[EPJ C (2016) 76:581]

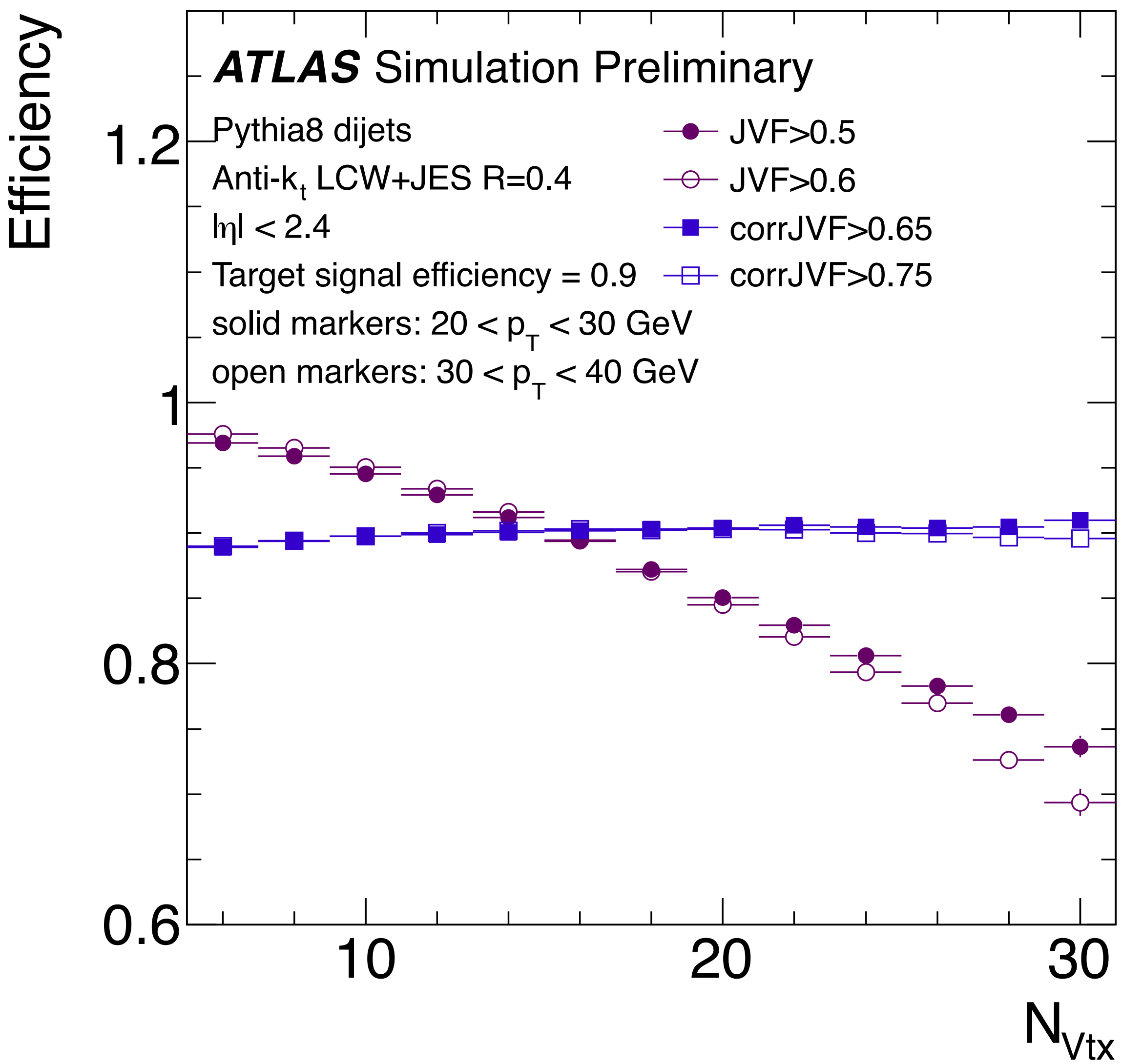


$$\mathrm{JVF}(\mathrm{jet}_i, \mathrm{PV}_j) = \frac{\sum_m p_\mathrm{T}(\mathrm{track}_m^{\mathrm{jet_i}}, \mathrm{PV}_j)}{\sum_n \sum_l p_\mathrm{T}(\mathrm{track}_l^{\mathrm{jet_i}}, \mathrm{PV}_n)},$$

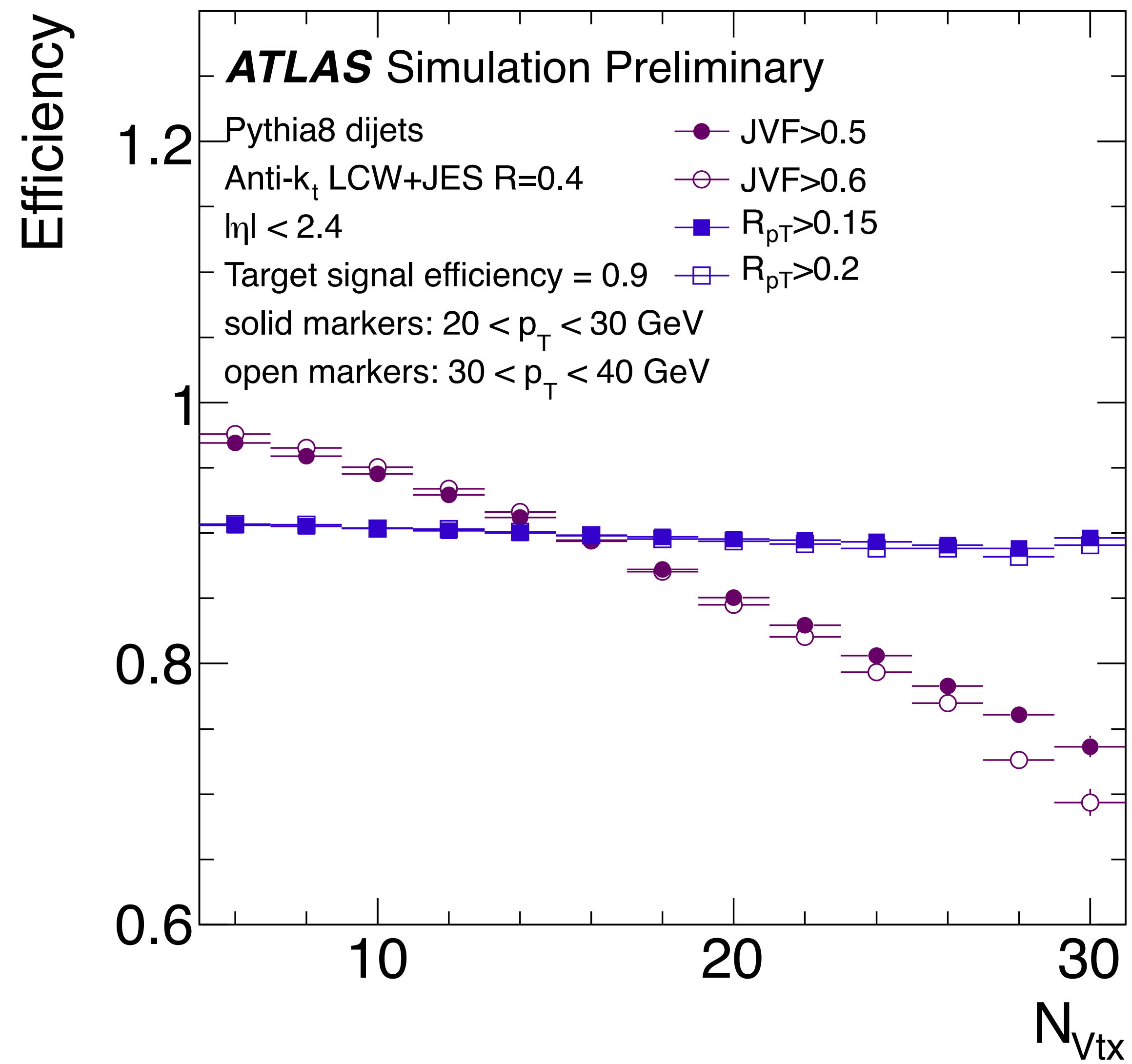
Central
Pileup Jet Suppression

Jet Pileup Mitigation

[ATLAS-CONF-2014-018]



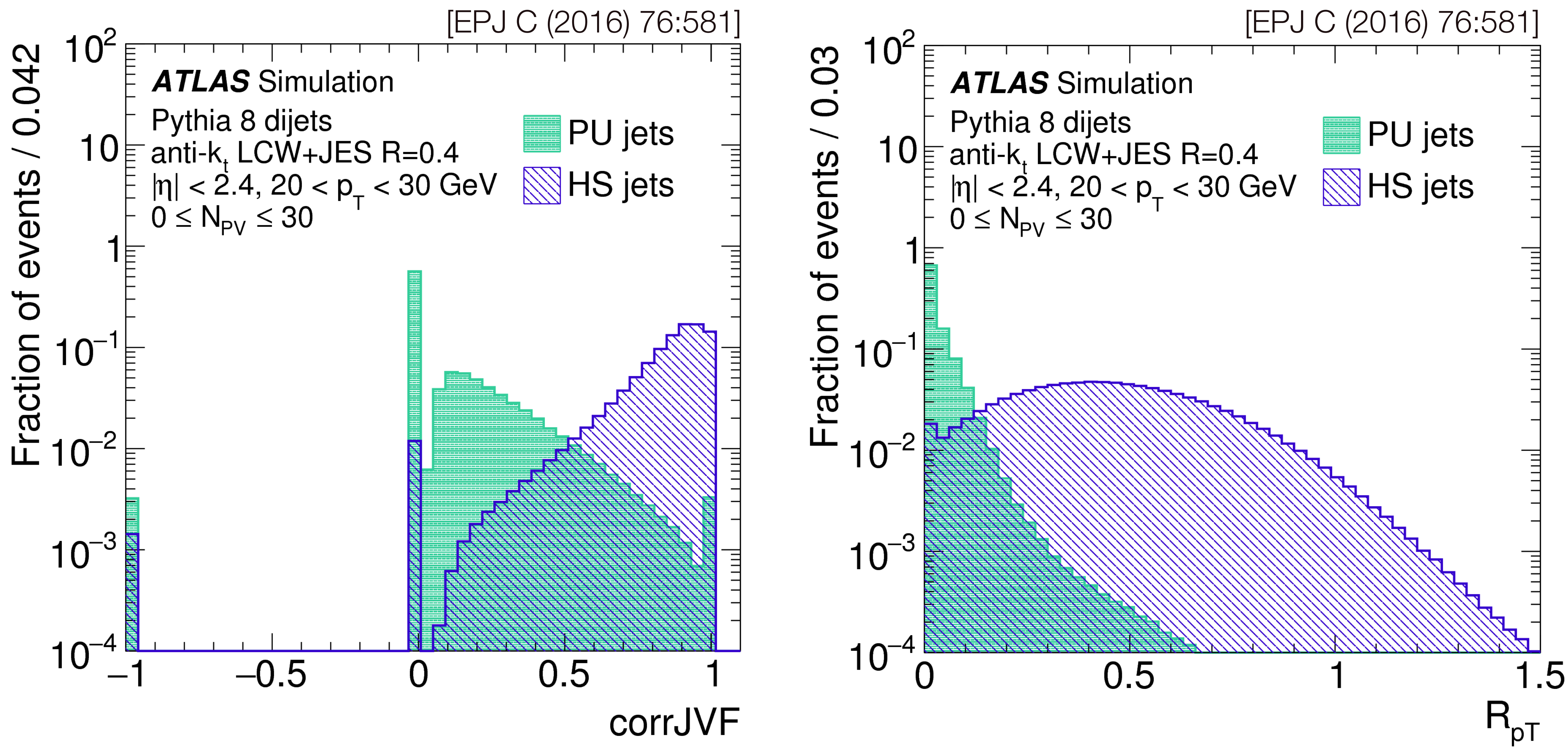
[ATLAS-CONF-2014-018]



$$\mathrm{corrJVF} = \frac{\sum_m p_{\mathrm{T},m}^{\mathrm{track}}(\mathrm{PV}_0)}{\sum_l p_{\mathrm{T},l}^{\mathrm{track}}(\mathrm{PV}_0) + \frac{\sum_{n\geq 1}\sum_l p_{\mathrm{T},l}^{\mathrm{track}}(\mathrm{PV}_n)}{(k\cdot n_{\mathrm{track}}^{\mathrm{PU}})}}$$

$$R_{p\mathrm{T}} = \frac{\sum_k p_{\mathrm{T}}^{\mathrm{trk}_k}(\mathrm{PV}_0)}{p_{\mathrm{T}}^{jet}}$$

Jet Pileup Mitigation



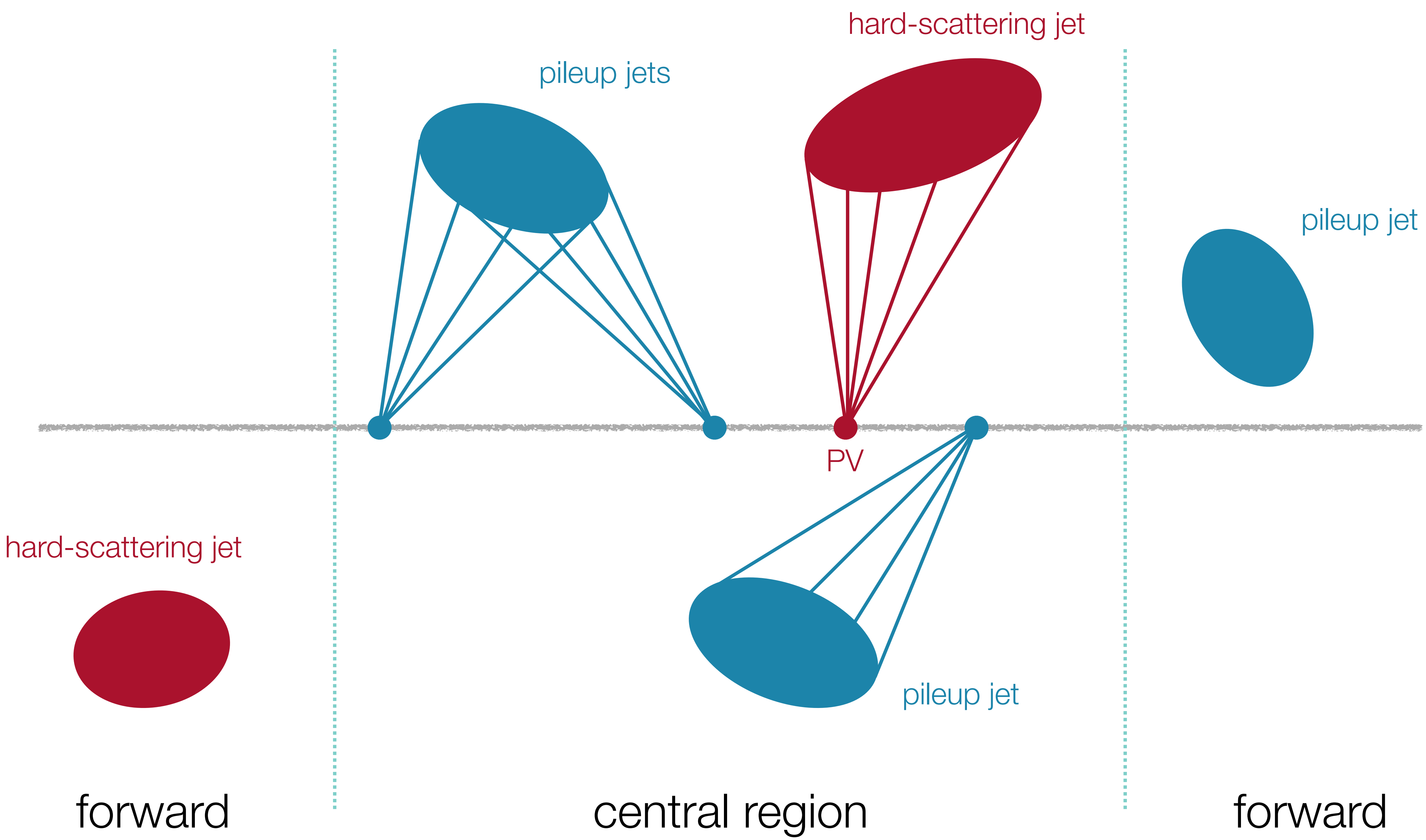
$$\mathrm{corrJVF} = \frac{\sum_m p_{\mathrm{T},m}^{\mathrm{track}}(\mathrm{PV}_0)}{\sum_l p_{\mathrm{T},l}^{\mathrm{track}}(\mathrm{PV}_0) + \frac{\sum_{n\geq 1}\sum_l p_{\mathrm{T},l}^{\mathrm{track}}(\mathrm{PV}_n)}{(k\cdot n_{\mathrm{track}}^{\mathrm{PU}})}}$$

$$R_{\mathrm{pT}} = \frac{\sum_k p_{\mathrm{T}}^{\mathrm{trk}_k}(\mathrm{PV}_0)}{p_{\mathrm{T}}^{jet}}$$

Jet Pileup Mitigation

[courtesy Matthew Klein]

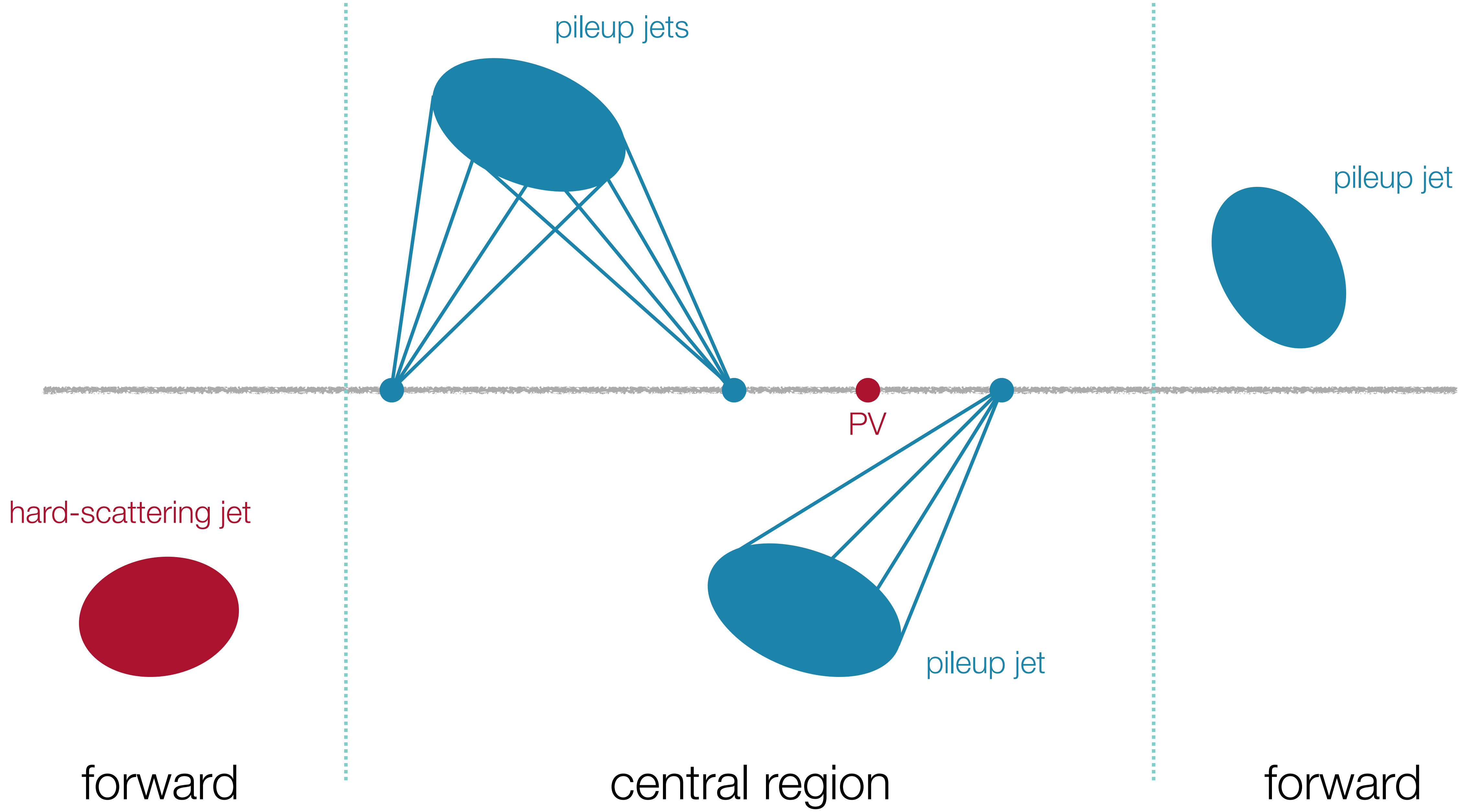
Initial Event



Jet Pileup Mitigation

[courtesy Matthew Klein]

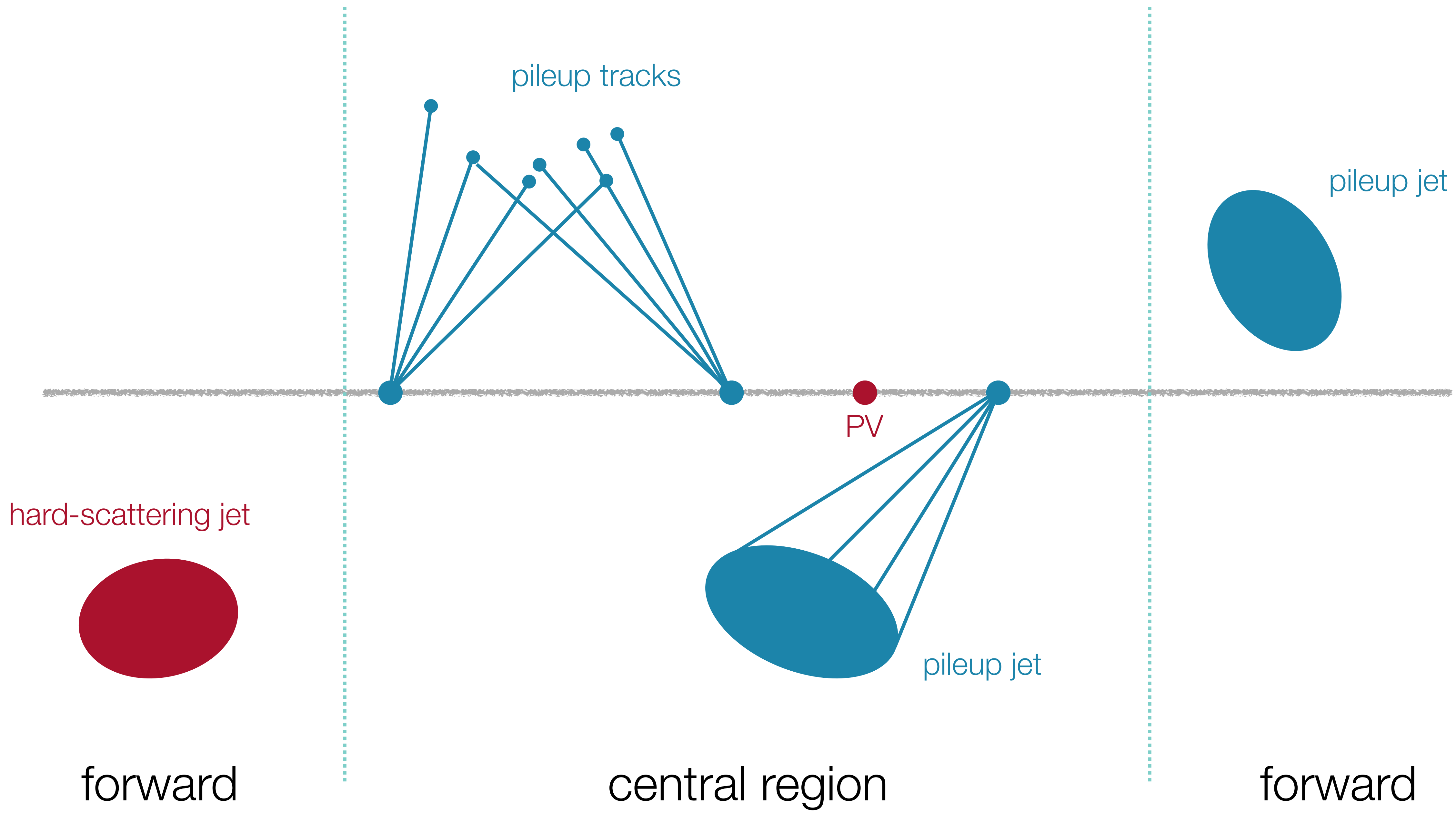
Discard central HS jets



Jet Pileup Mitigation

[courtesy Matthew Klein]

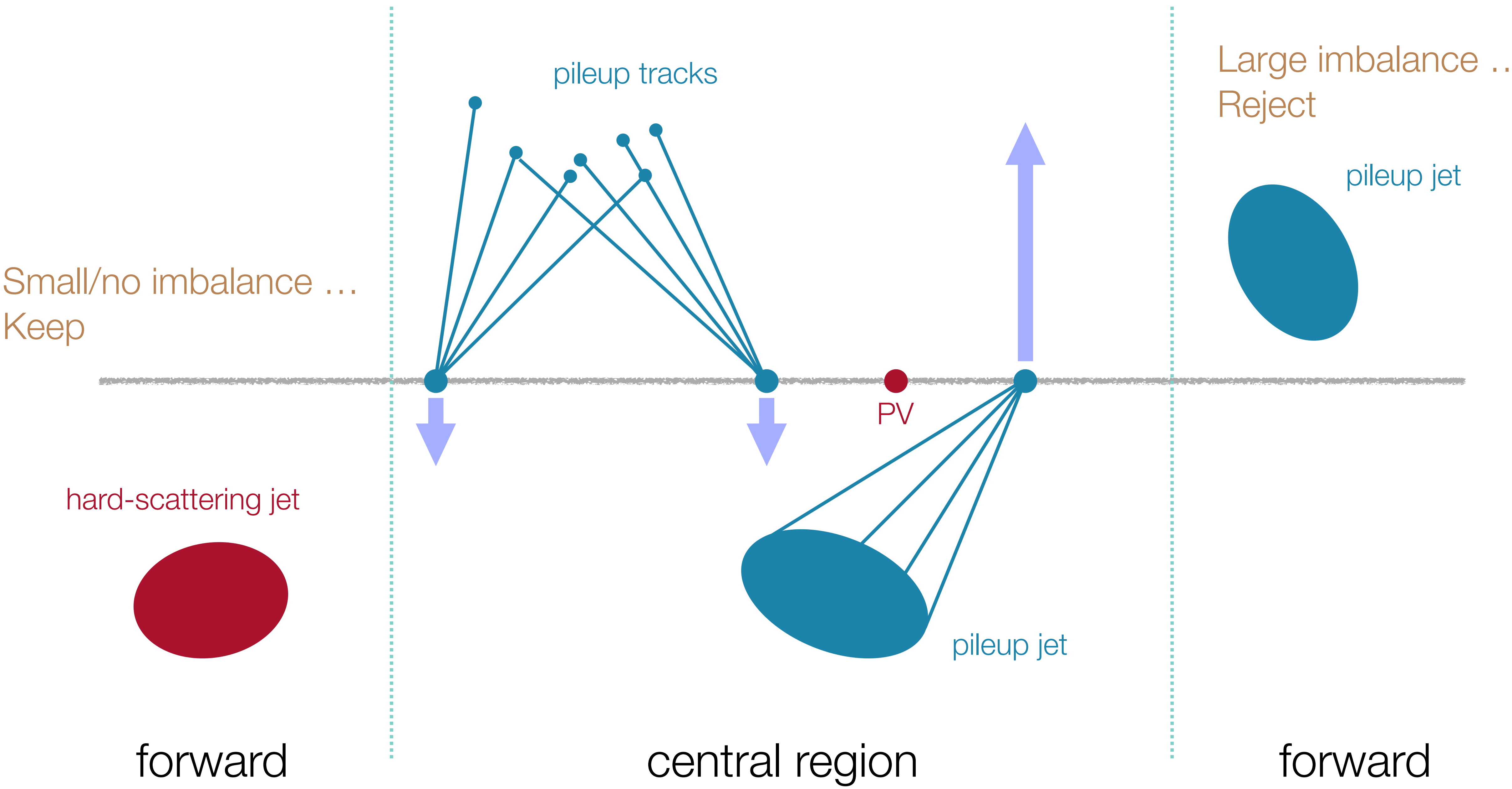
Stochastic jets: Use tracking



Jet Pileup Mitigation

[courtesy Matthew Klein]

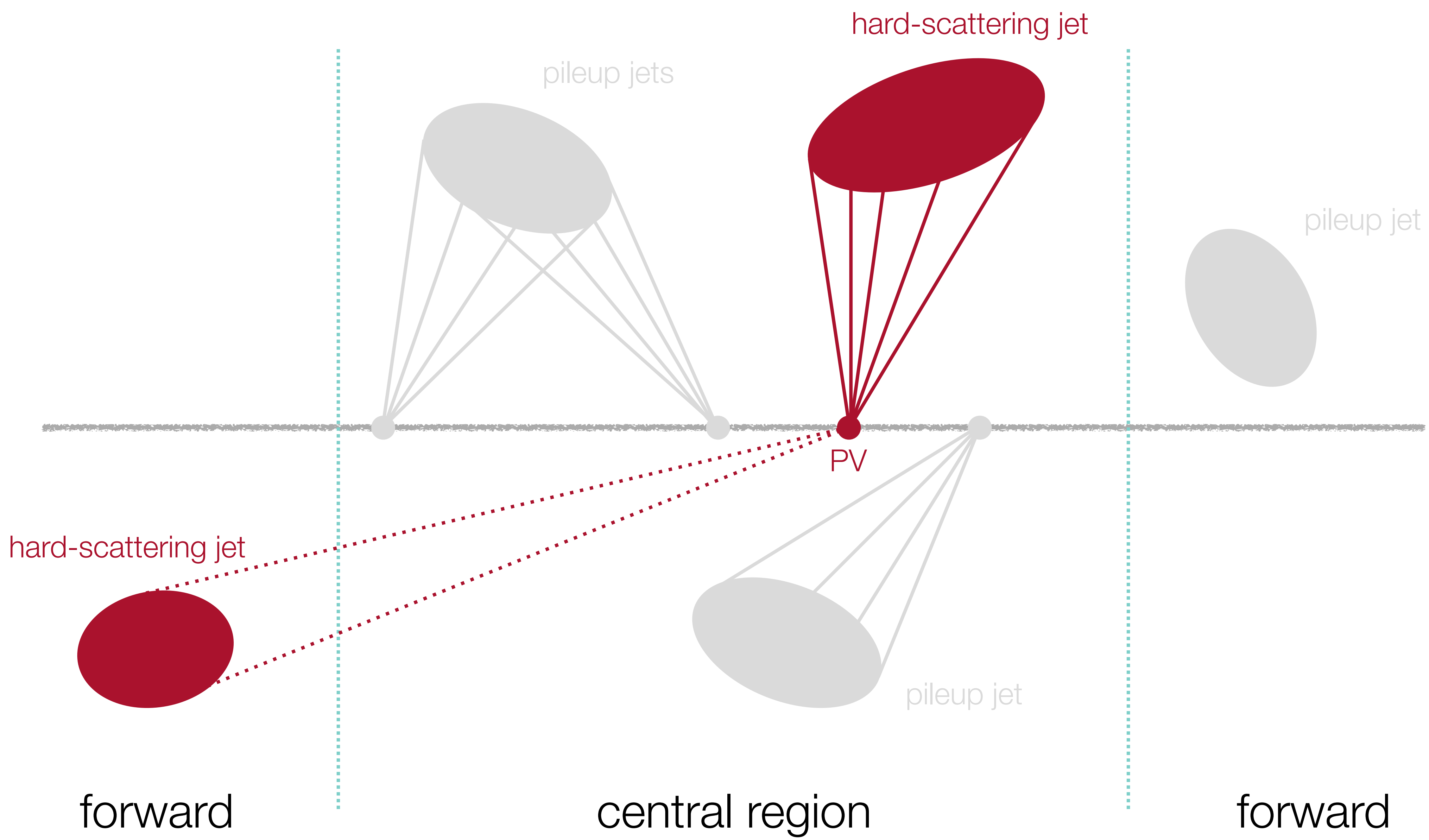
Calculate pileup vertex p_T-imbalance …



Jet Pileup Mitigation

[courtesy Matthew Klein]

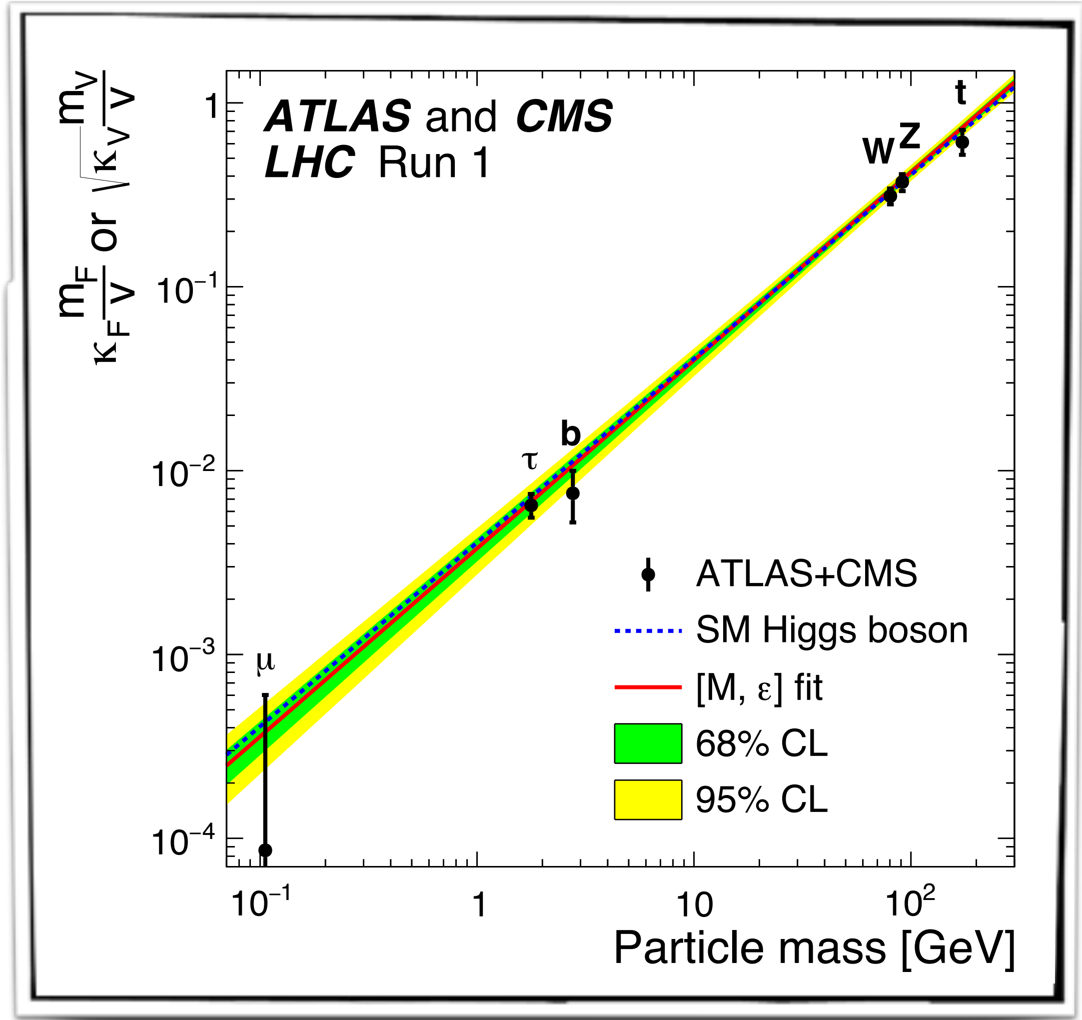
Final hard scattering event



Higgs Physics

Run-1 measurements:

- Higgs mass (precision: ±0.2%)
- Spin-parity of Higgs-Boson
- Production via gluon & vector-boson fusion
- Production with W and Z
- Decays to γγ, WW, ZZ, and ττ



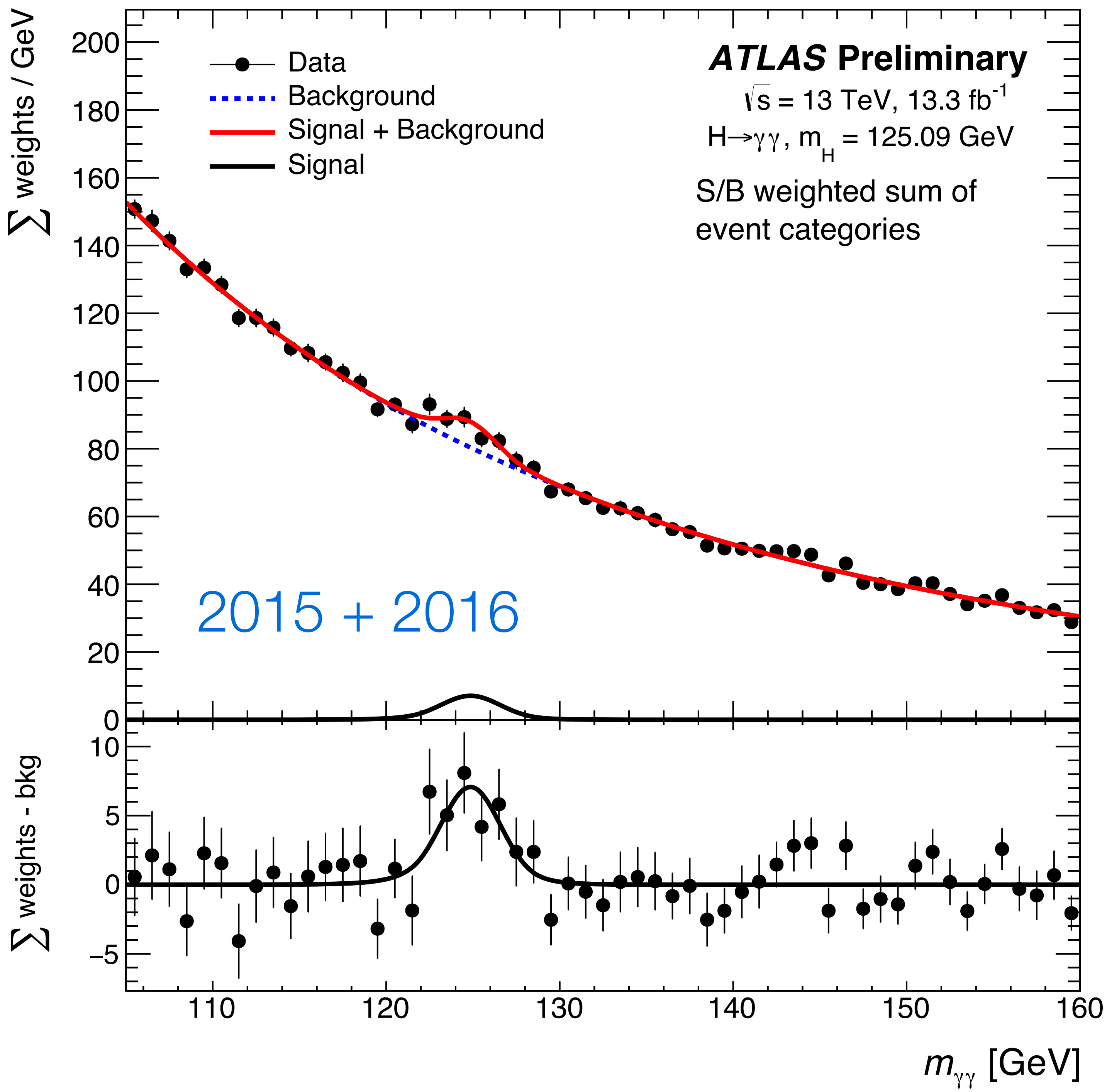
[JHEP 08 (2016) 045]

Run-2 priorities:

- Reestablish Run-1 measurements @ 13 TeV
- Refine measurements of couplings, mass, etc.
- Search for ttH production to probe ttH vertex directly
- Search for H → bb decays
- Search for rare decays
- Expand use of Higgs as tool to find new physics

Higgs Physics

[ATLAS-CONF-2016-067]



H ➤ γγ reestablished

$$\sigma_{\text{fid}} = 43.2 \pm 14.9\ (\text{stat.}) \pm 4.9\ (\text{syst.})$$

[SM prediction: $62.8\ ^{+3.4}_{-4.4}$ fb]

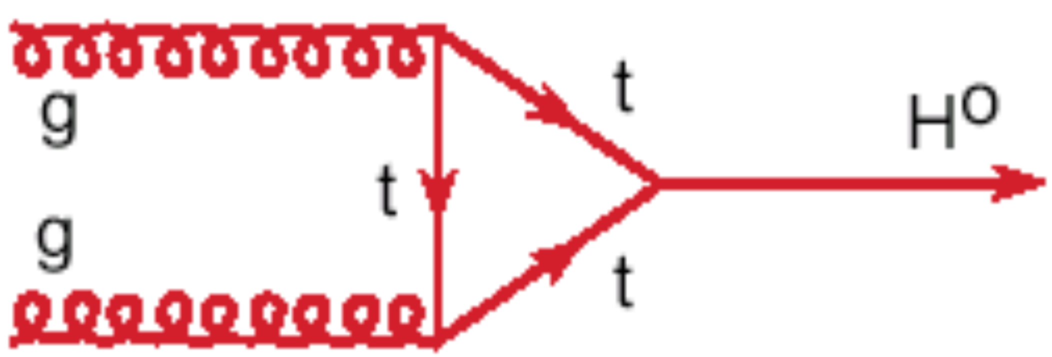
Event categories enhance sensitivity

and help to separate production modes

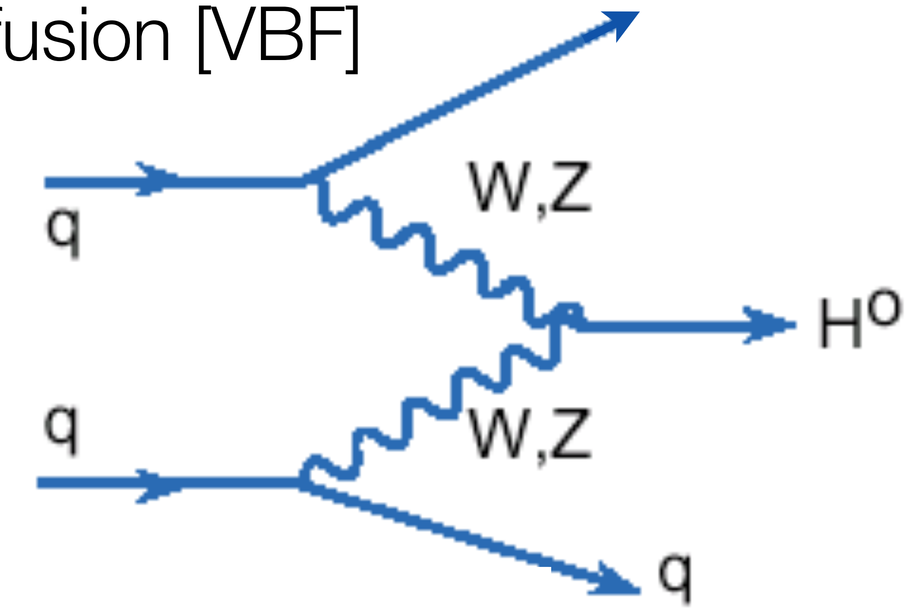
Higgs Physics

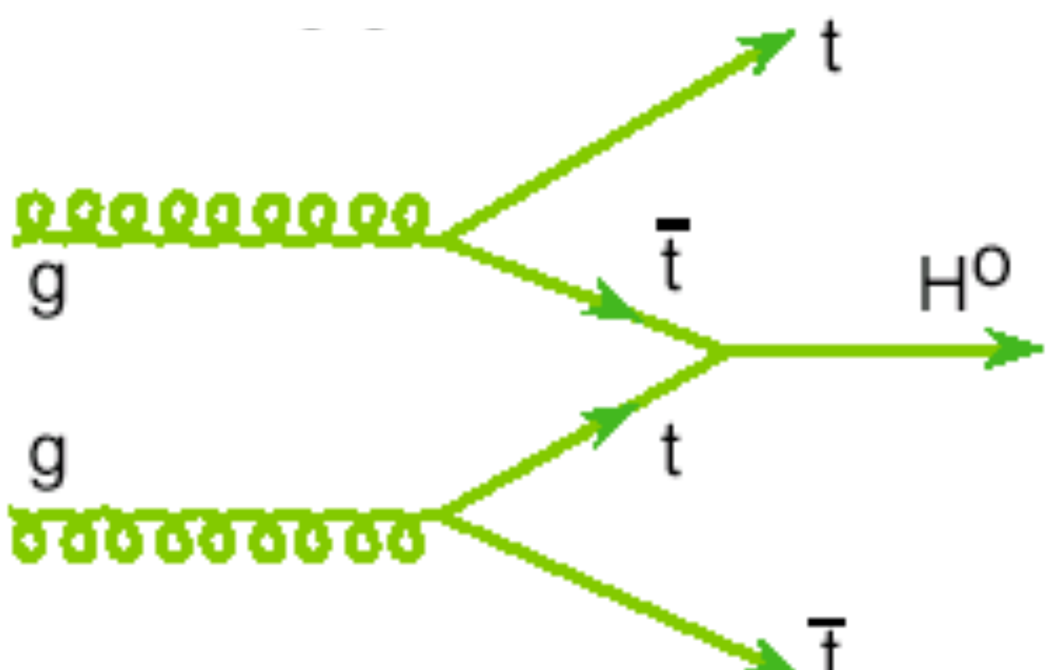
ATLAS
EXPERIMENT

Gluon fusion [ggH]

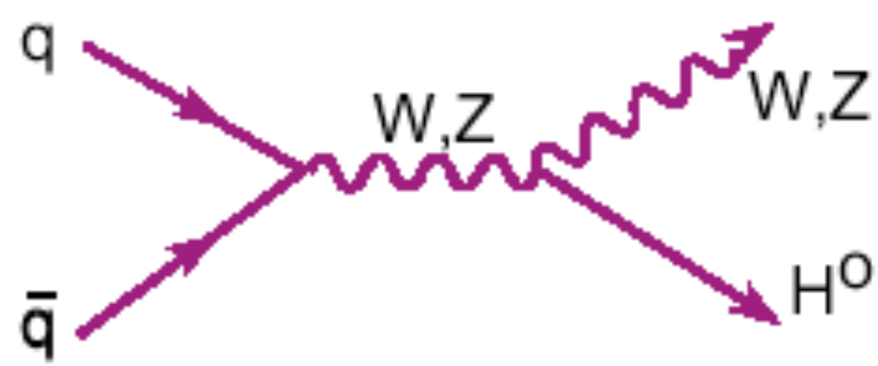


Vector
boson fusion [VBF]





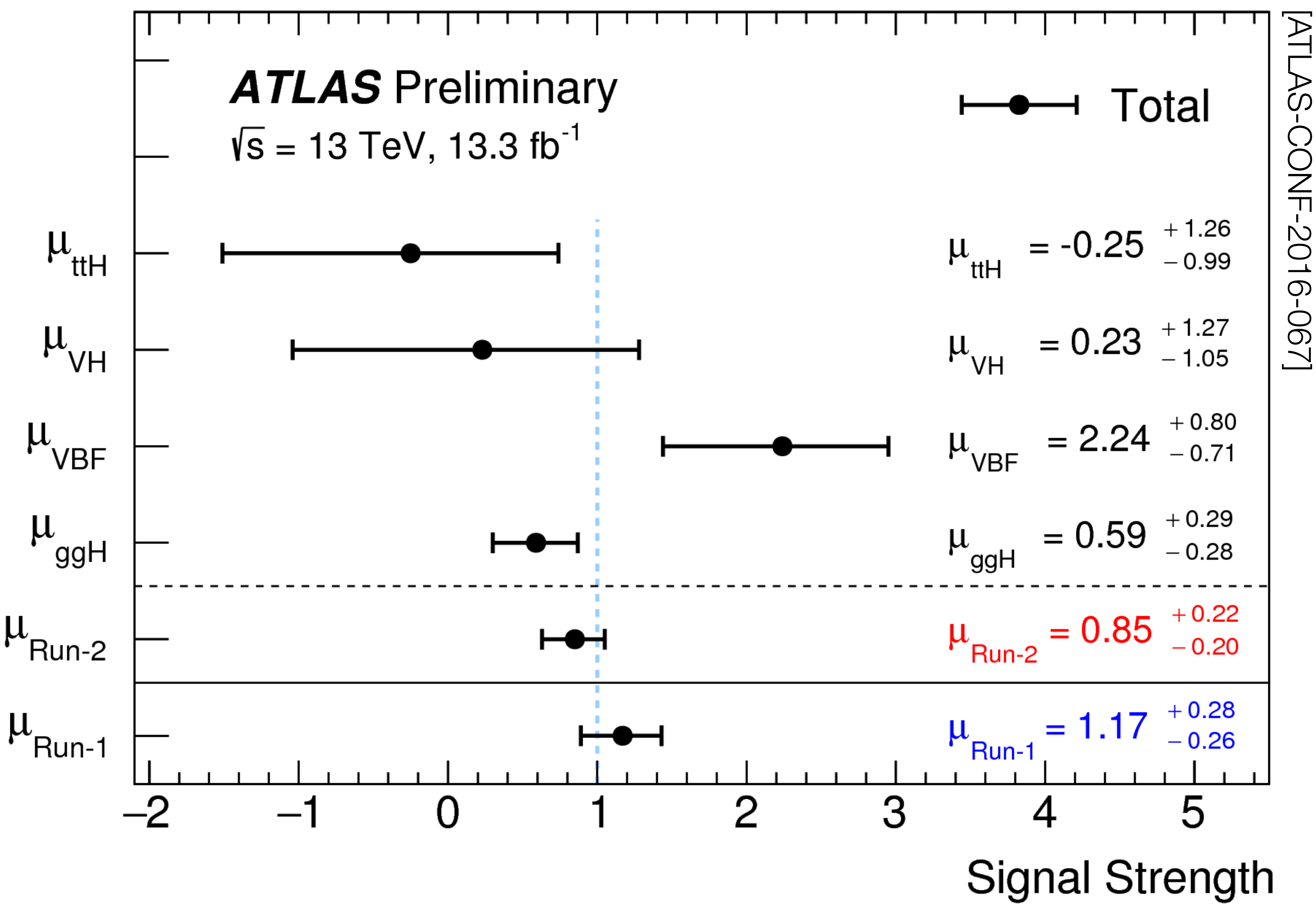
$t\bar{t}$-fusion [ttH]



Associated
production [VH]

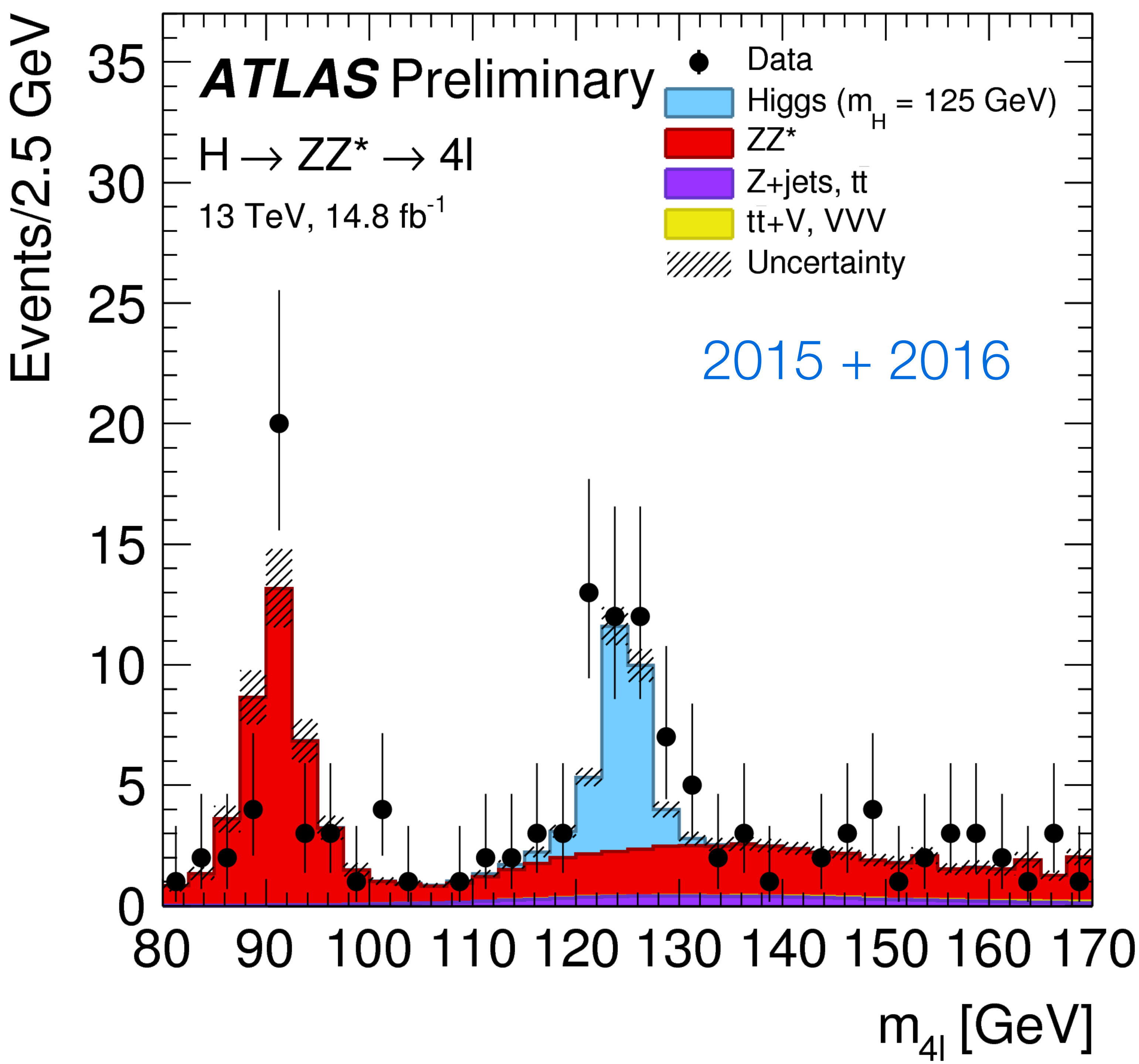
Higgs Physics

Signal strengths derived from H ➛ γγ



Higgs Physics

[ATLAS-CONF-2016-079]



H ➛ ZZ* ➛ 4 lept. re-observed

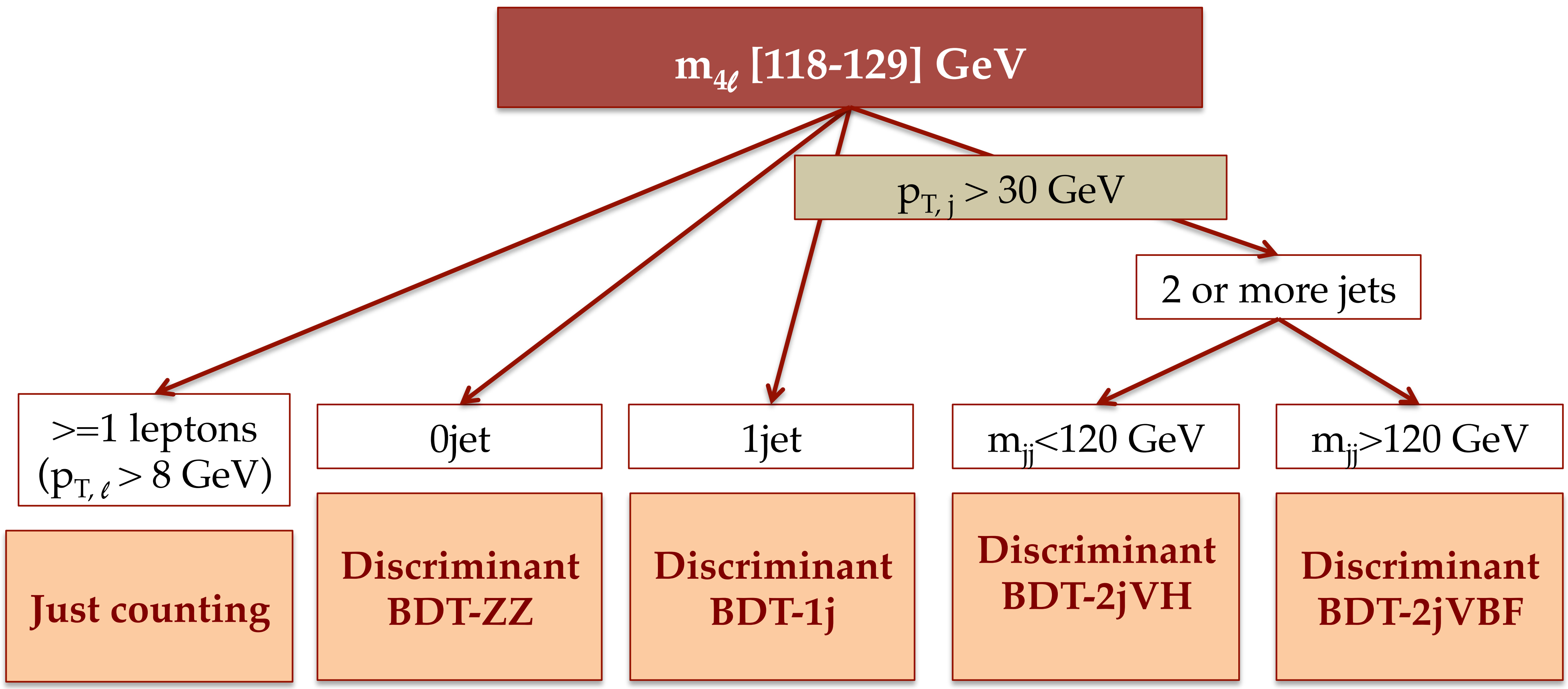
$$\sigma^{4\ell}_{\text{fid,sum}} = 4.48^{+1.01}_{-0.89}\ \text{fb}$$

[SM prediction: $3.07\ ^{+0.21}_{-0.25}\ \text{fb}$]
[1.6σ high]

Combine with H ➛ γγ results …

to obtain total cross section …

Higgs Physics



BDT_ZZ:
- $p_{T4\ell}$
- $\eta_{4\ell}$
- KD = $\log(ME_{HZZ}/ME_{ZZ})$

BDT_1jet:
- $p_{T,j}$
- η_j
- $\Delta R_{4\ell j}$

BDT_2jet_VH:
- $p_{T,j1}$
- $p_{T,j2}$
- η_{j1}
- $\Delta\eta_{jj}$
- $\Delta\eta_{4\ell jj}$
- m_{jj}
- $\min(\Delta R_{Zj})$

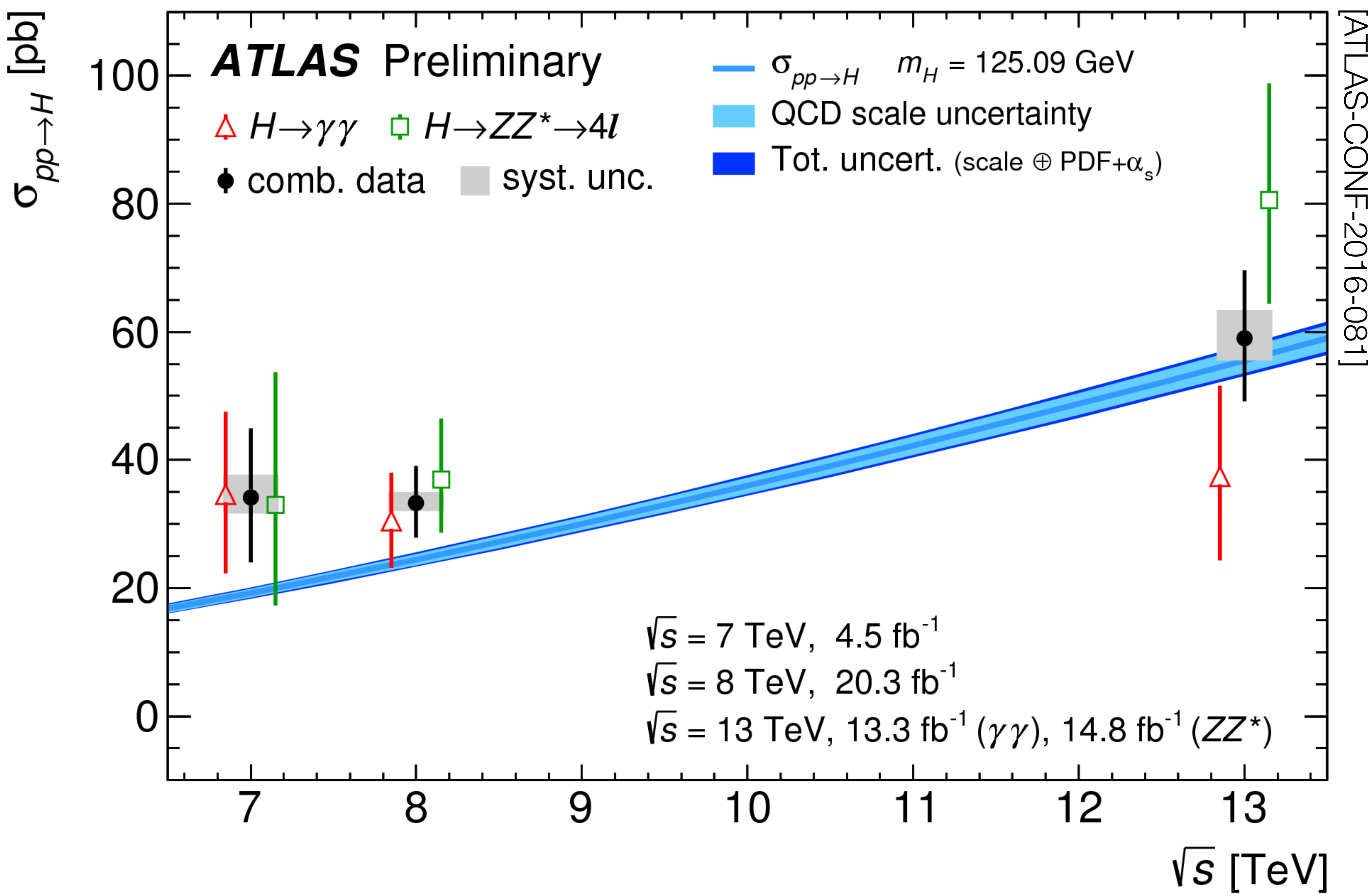
BDT_2jet_VBF:
- $p_{T,j1}$
- $p_{T,j2}$
- $p_{T,4\ell jj}$
- $\Delta\eta_{jj}$
- $\Delta\eta_{4\ell jj}$
- m_{jj}
- $\min(\Delta R_{Zj})$

$H \rightarrow ZZ^* \rightarrow$ 4 lept.

[ATLAS-CONF-2016-079]

Higgs Physics

Total pp ➛ H + X cross section @ √s = 7,8,13 TeV



Higgs Physics

ttH:

$\sigma(\ 8\ \text{TeV}) = 0.13$ pb
$\sigma(13\ \text{TeV}) = 0.5$ pb
$\times 4$

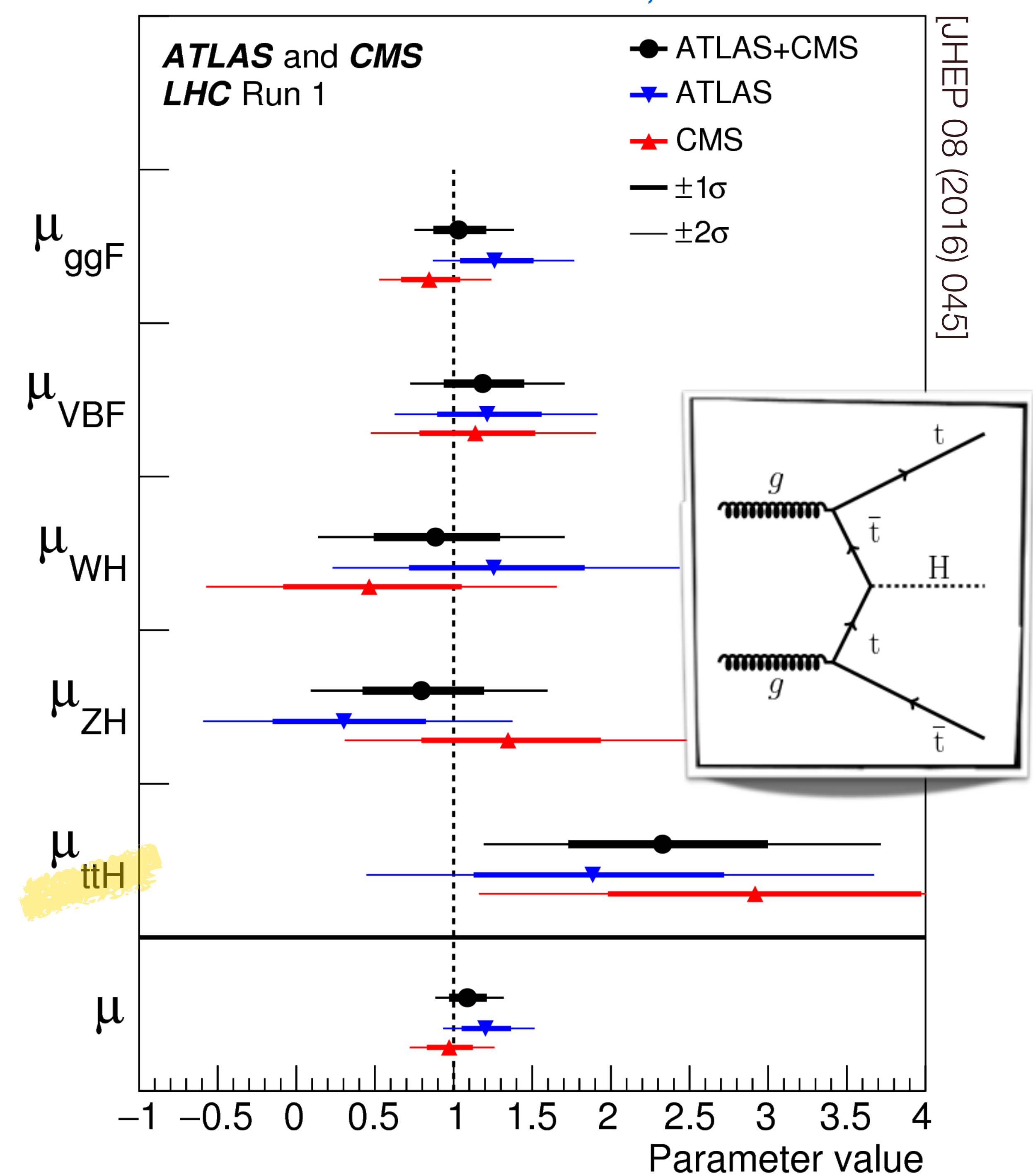
Combination
of three analyses:

- ttH, H ➛ bb
- ttH, multi-lepton final states
- ttH, H ➛ γγ, event categorization

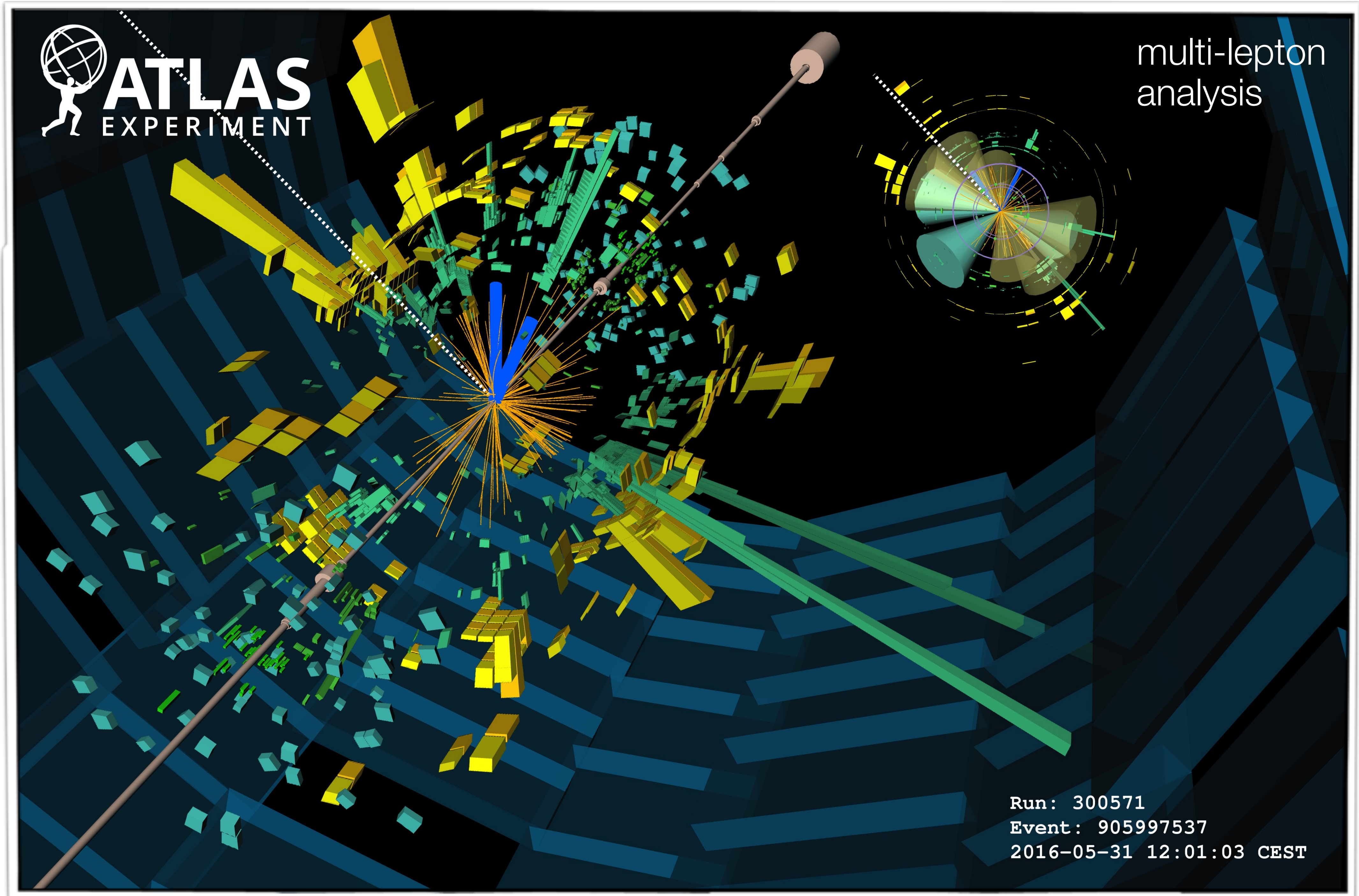
Combined significance:

- 4.4σ observed
- 2.0σ expected

Run 1; L ≈ 25 fb^{-1}



Higgs Physics



Higgs Physics

ttH

Multi-lepton analysis

Mainly targets:

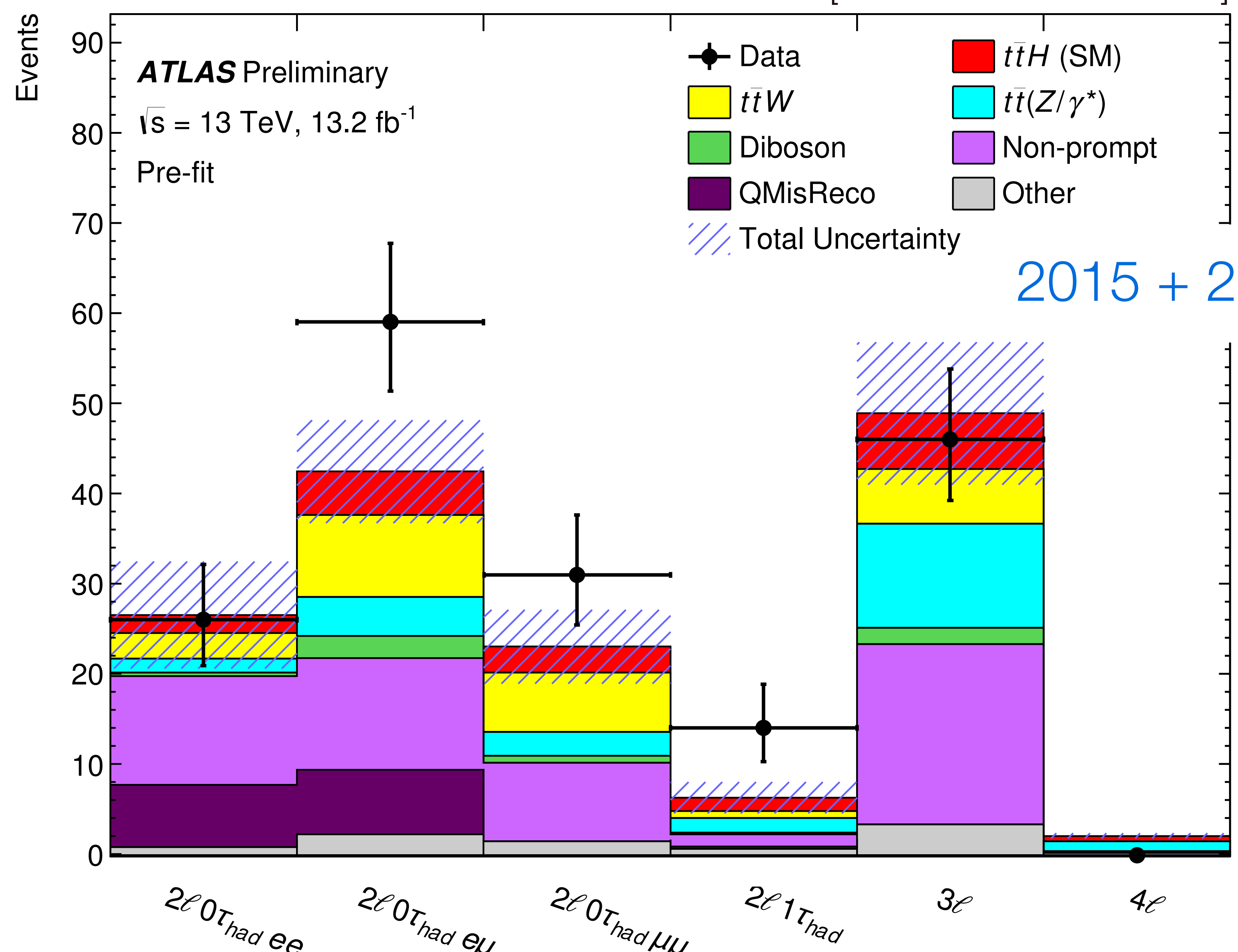
- H ➛ WW*
- H ➛ ττ

Strategy:

Target final states that cannot be produced in tt decays …

i.e.: 3 or more leptons
2 same-sign leptons

[ATLAS-CONF-2016-058]



2015 + 2016

Fit to data yields: $\mu_{ttH} = 2.5\,^{+1.3}_{-1.1}$

Higgs Physics

ttH

H ➛ bb decay

Complex final states:

- 1l + 6jets (4 b-jets)
- 2l + 4jets (4 b-jets)

Strategy:

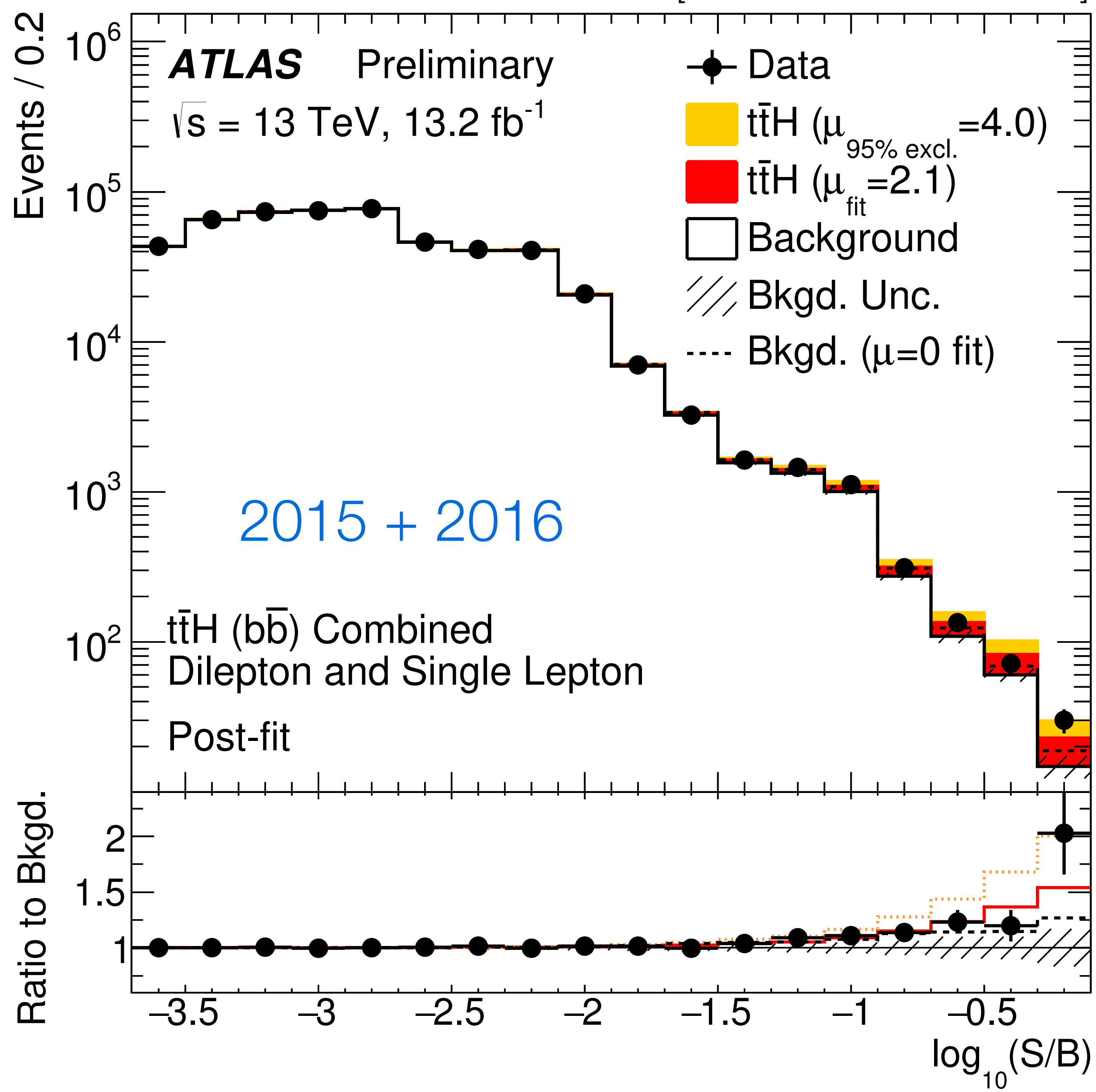
Use multiple selection regions to constrain background …

[Categorization by number of jets/b-jets]
[Challenge: estimation of tt+heavy flavor]

Two-stage MVA …

Fit to data yields: $\mu_{ttH} = 2.1^{+1.0}_{-0.9}$

[ATLAS-CONF-2016-080]

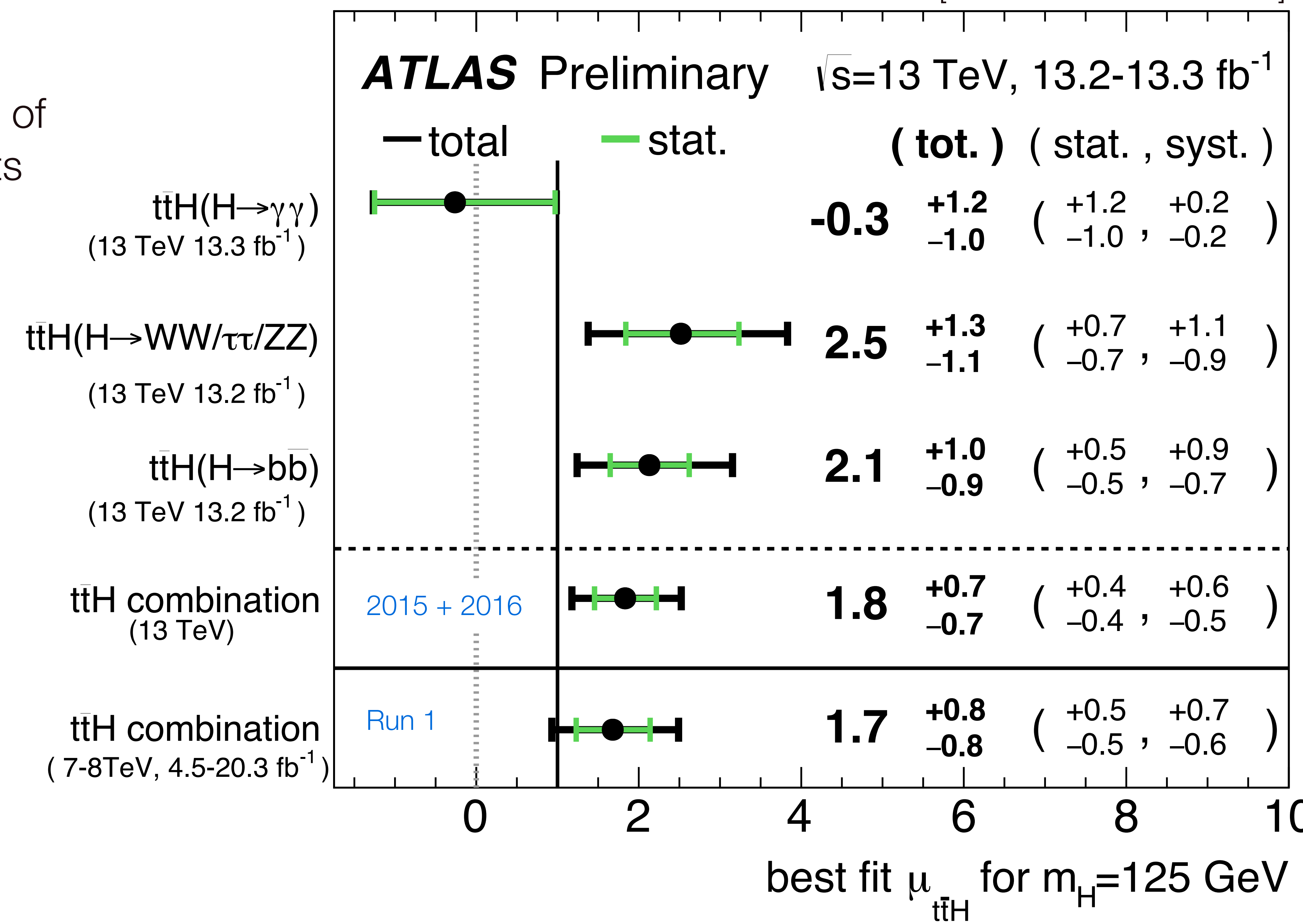


Higgs Physics

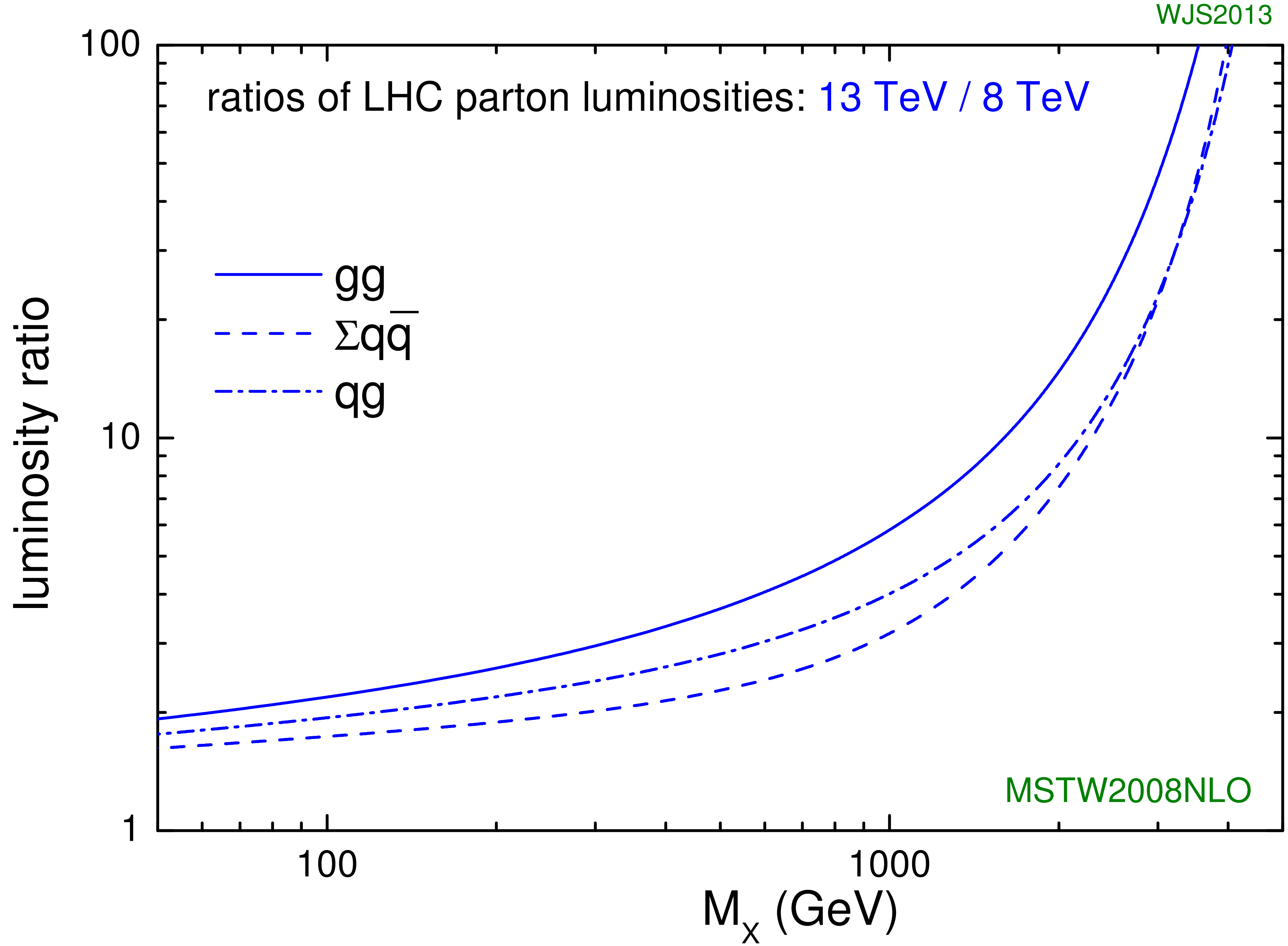
[ATLAS-CONF-2016-068]

ttH

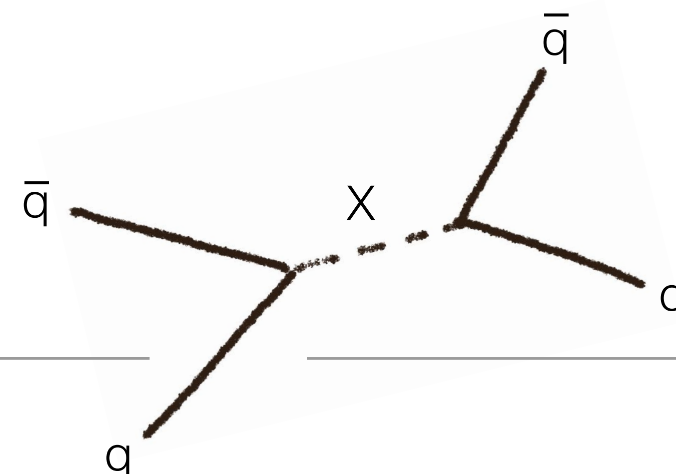
Combination of 13 TeV results



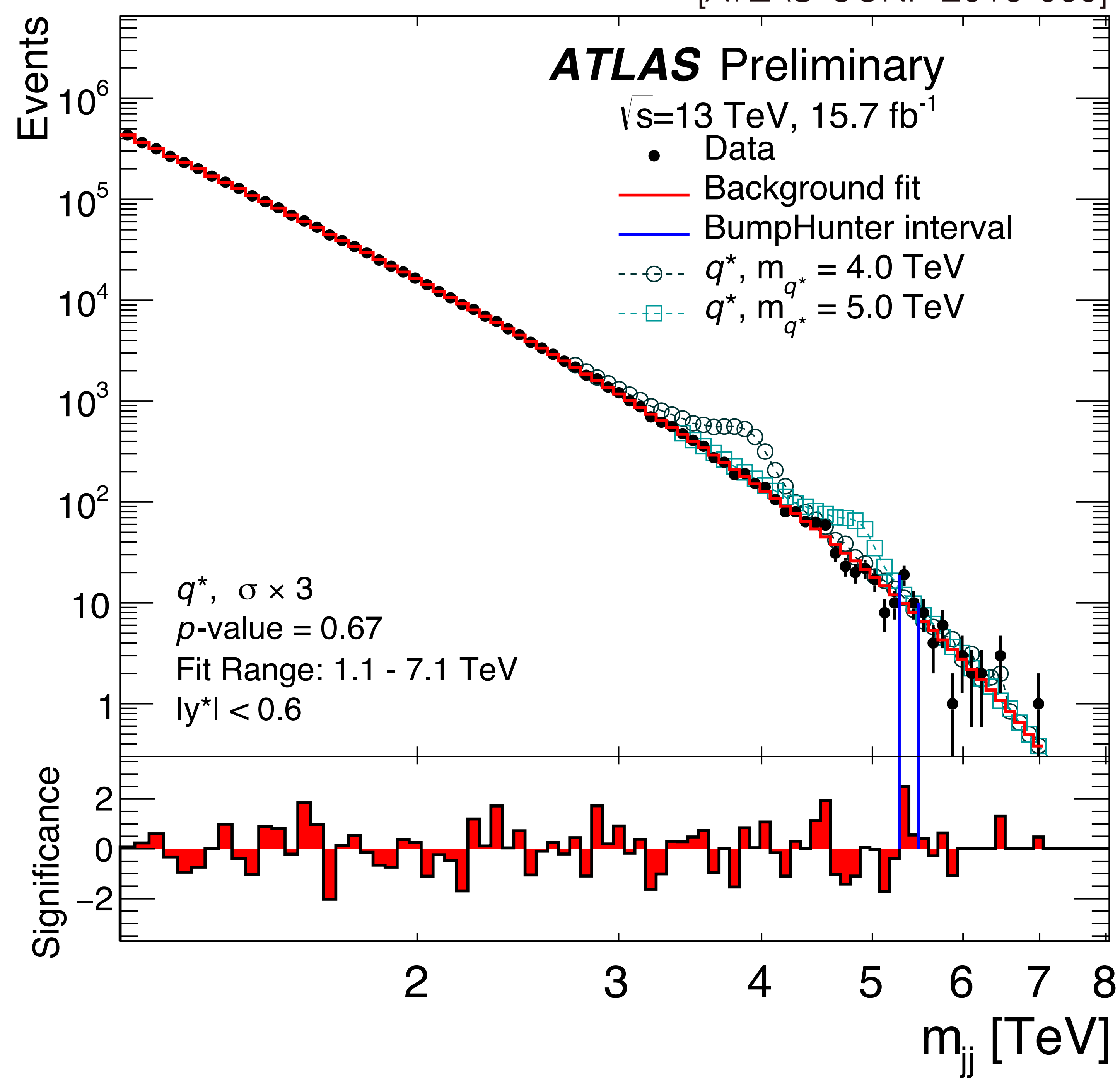
Searches for New Physics



Searches for New Physics



[ATLAS-CONF-2016-069]



Dijet searches
at high energy

2 ➛ 2 processes
well described by QCD …

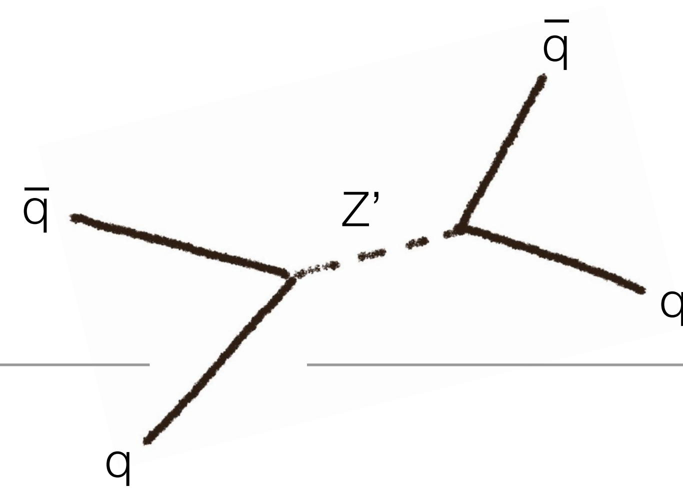
i.e.

any deviation from SM
implies new physics …

e.g.

quantum black holes	> 8.7 TeV
excited quarks	> 5.6 TeV
heavy SM-like W'	> 2.9 TeV
excited W* bosons	> 3.3 TeV
leptophobic Z'	
contact interactions	
…	

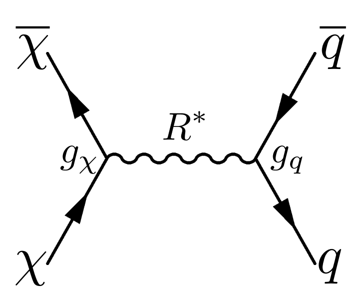
Searches for New Physics



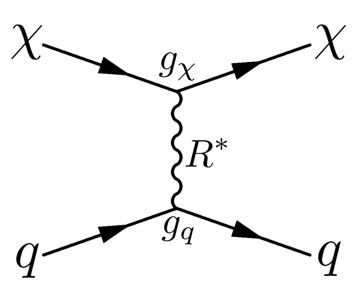
Dijet searches and dark matter

Consider

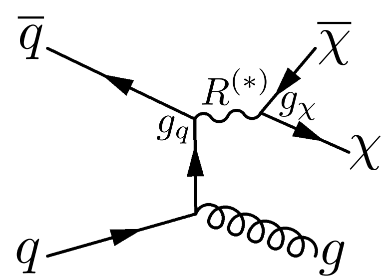
models with mediator R, e.g. Z', connecting SM & Dark Sector



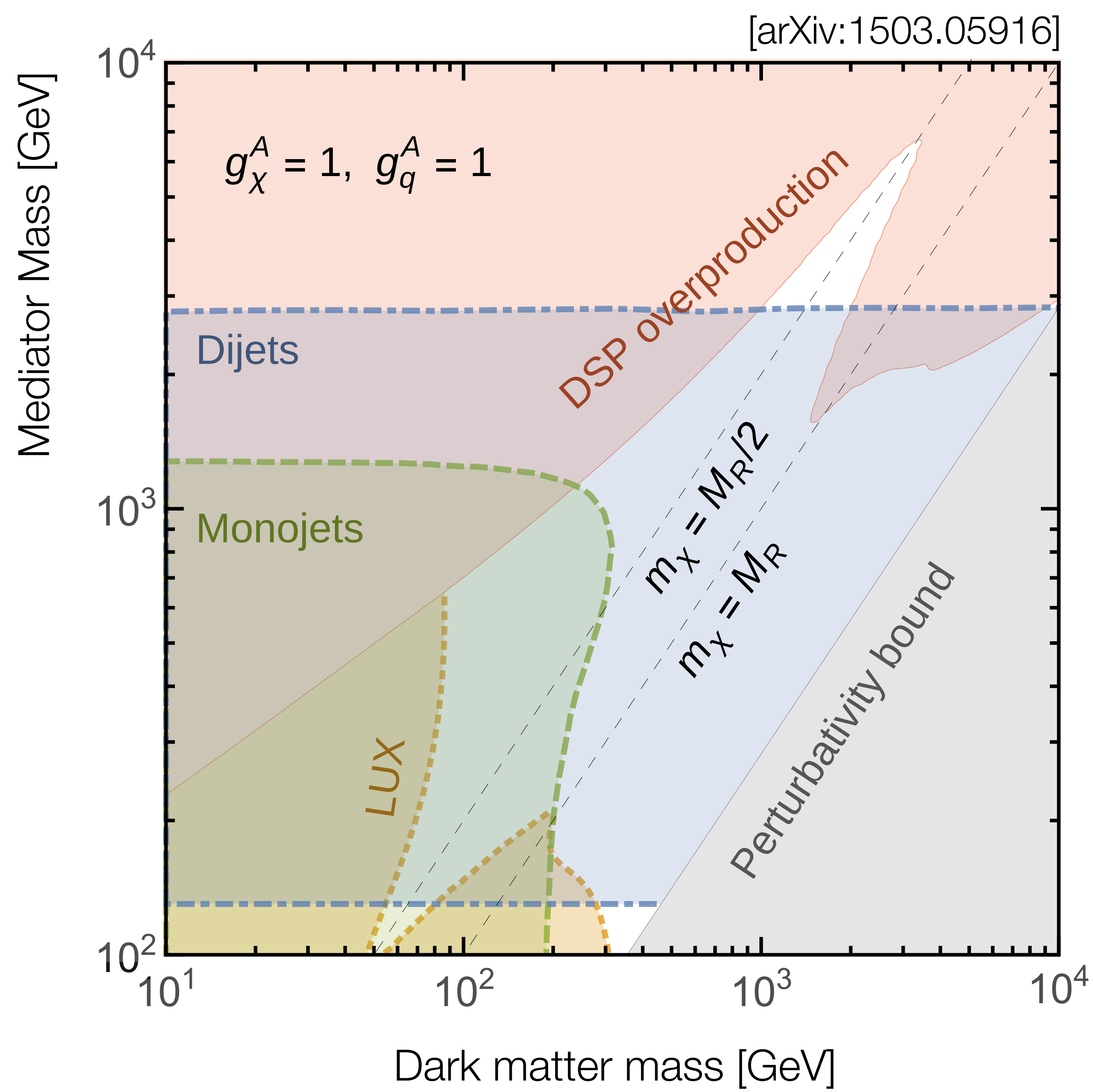
DM annihilation
DM production



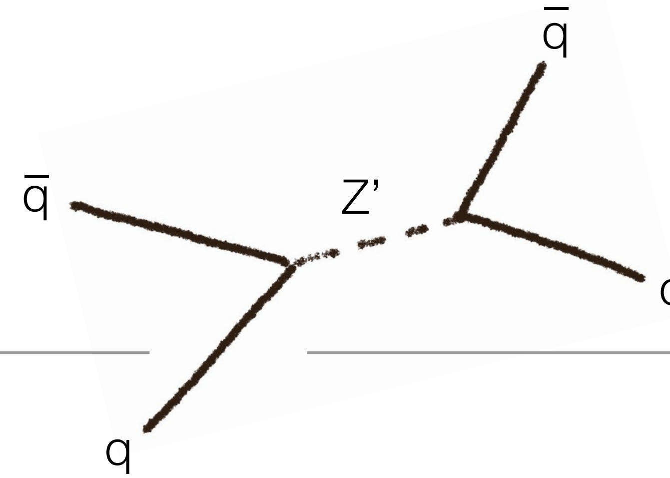
Direct detection



Monojet searches



Searches for New Physics

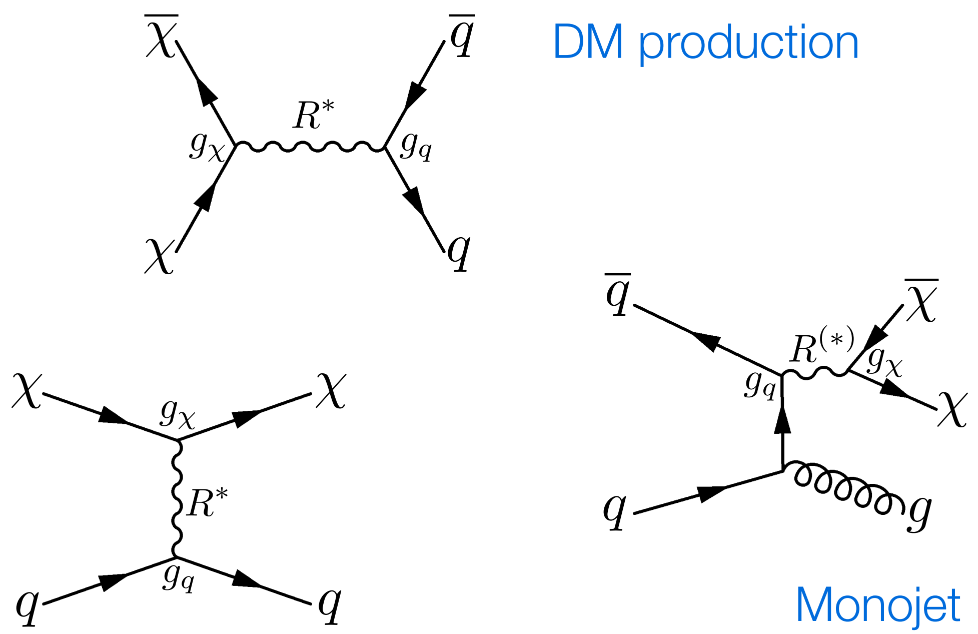


ATLAS
EXPERIMENT

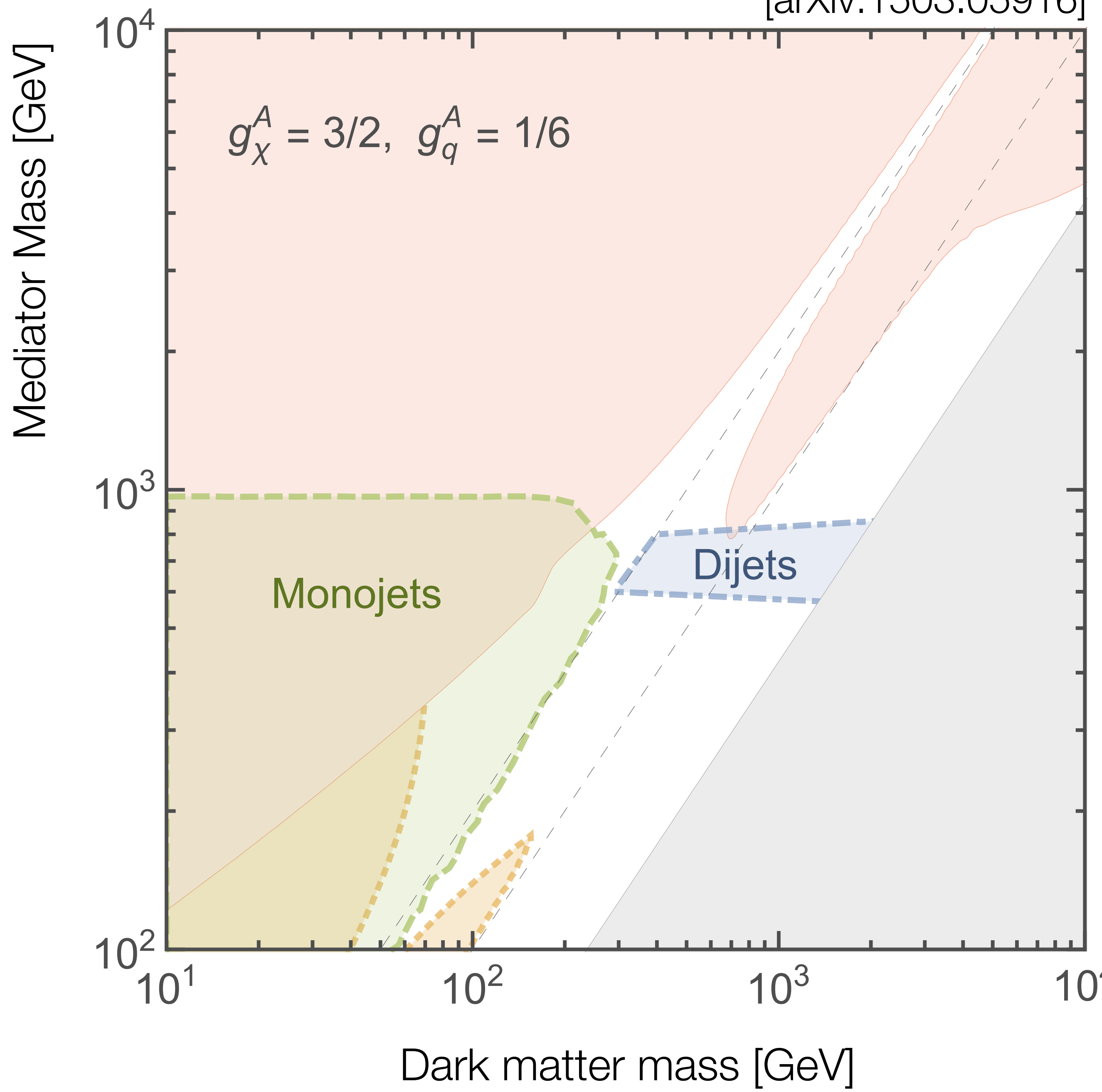
Dijet searches
and dark matter

Consider

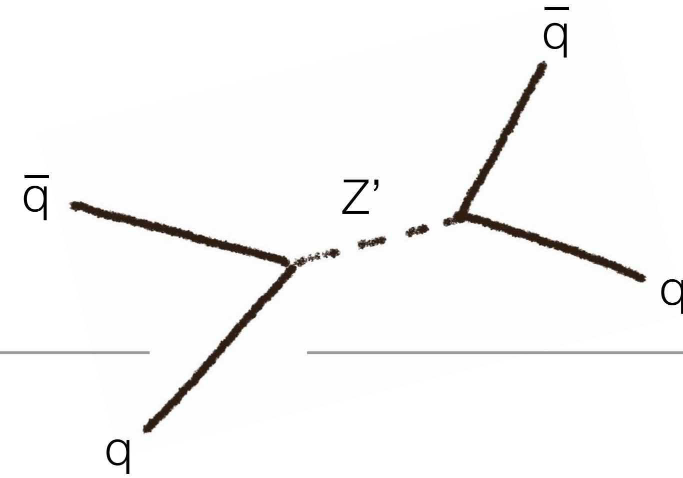
models with mediator R, e.g. Z', connecting SM & Dark Sector

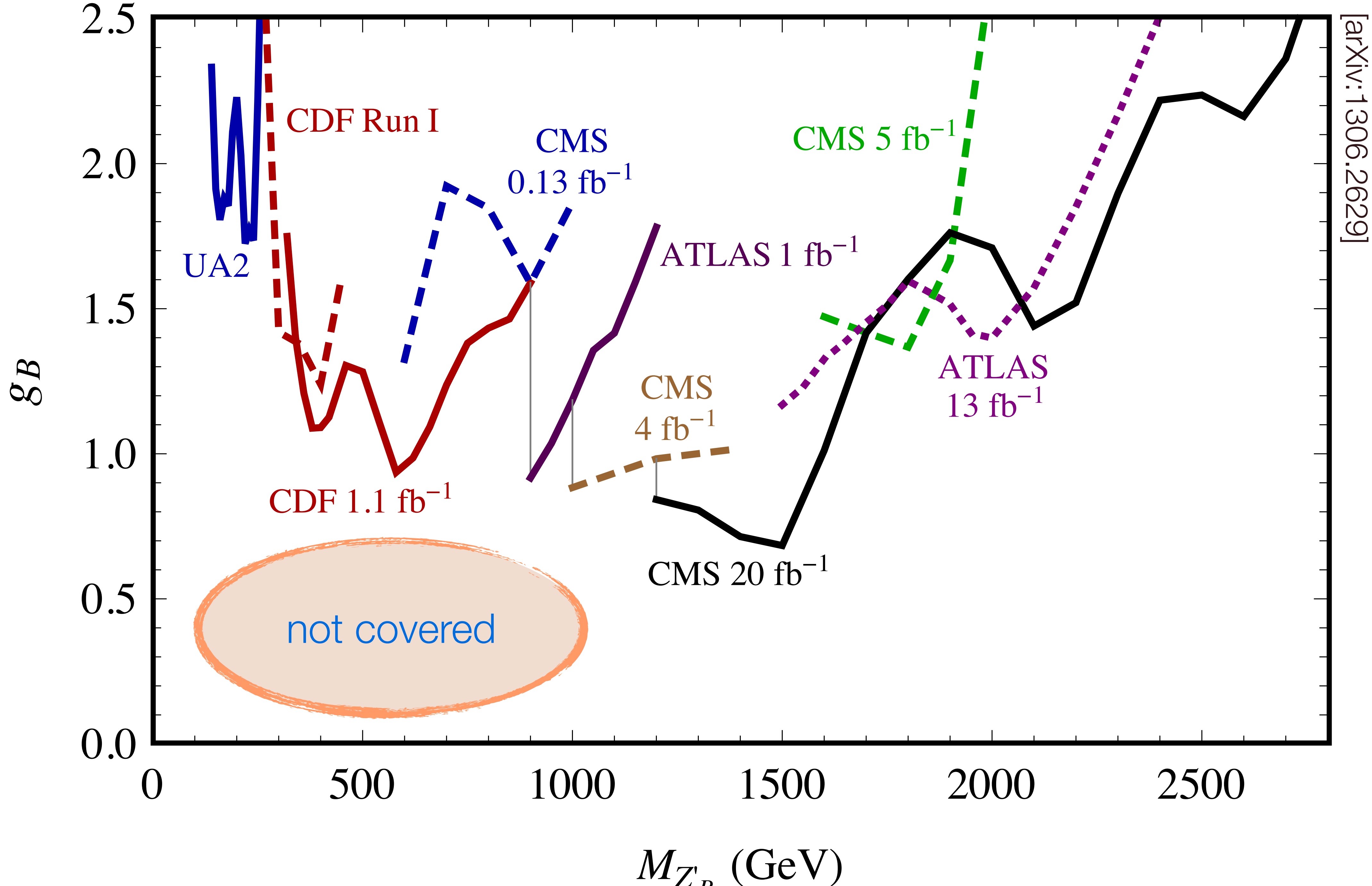


[arXiv:1503.05916]

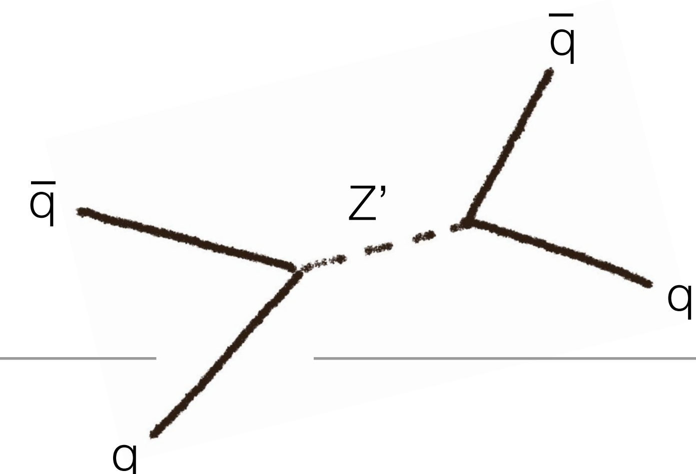


Searches for New Physics





Searches for New Physics



Dijet searches
at low energy

Trigger Object Level Analysis [aka TLA]

Problem:

Trigger limits statistics at low dijet mass …

Solution:

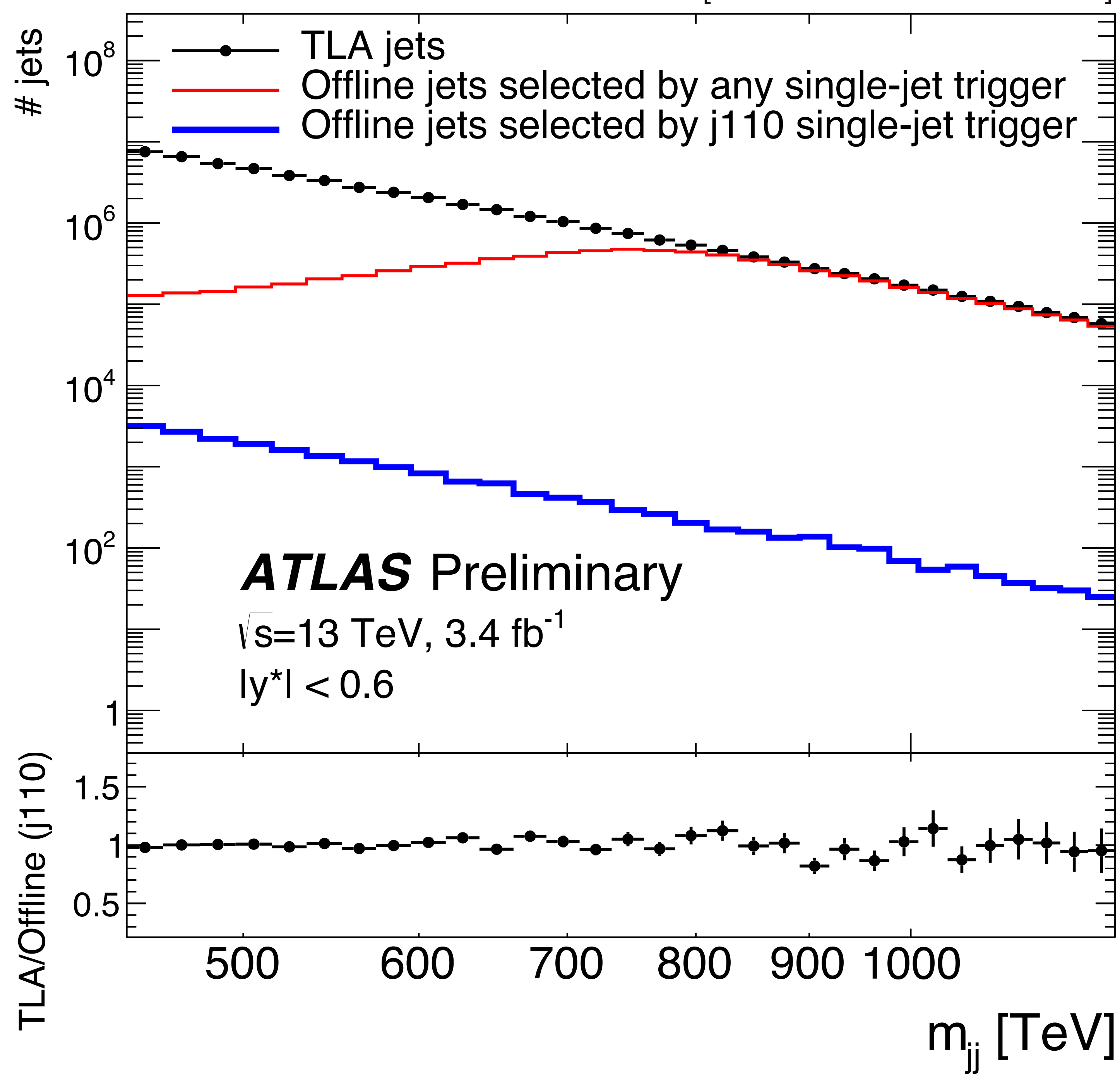
Partial event recording for low m_{jj} events…

Store:

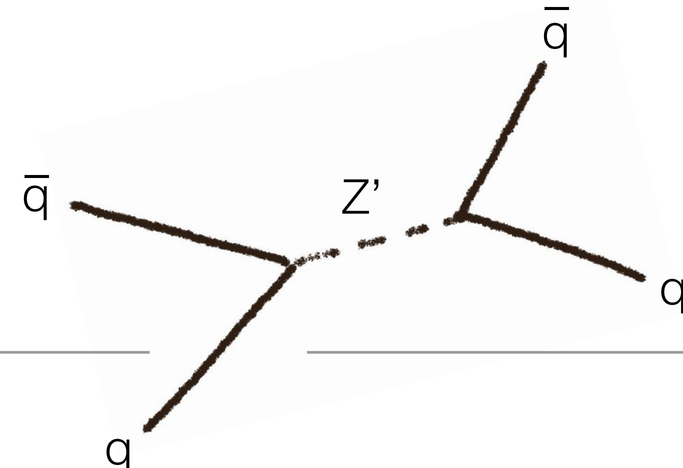
HLT information for jets with p_T> 20 GeV, seeded by L1_J100

[no calorimeter, no muon information]

[ATLAS-CONF-2016-030]



Searches for New Physics



Dijet searches
at low energy

Trigger Object Level
Analysis [aka TLA]

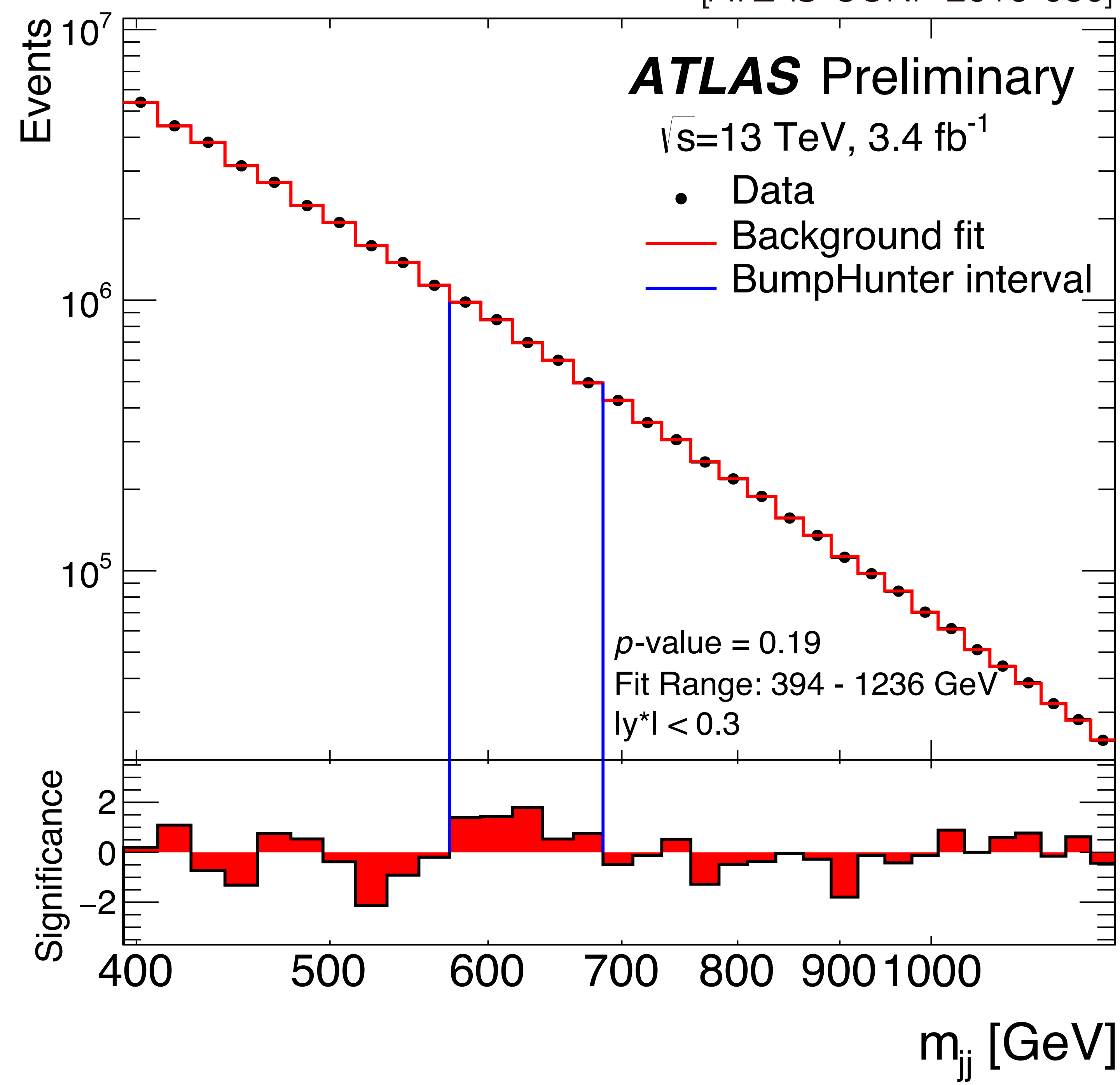
Measure:

Dijet mass spectrum
from 400 to 1000 GeV

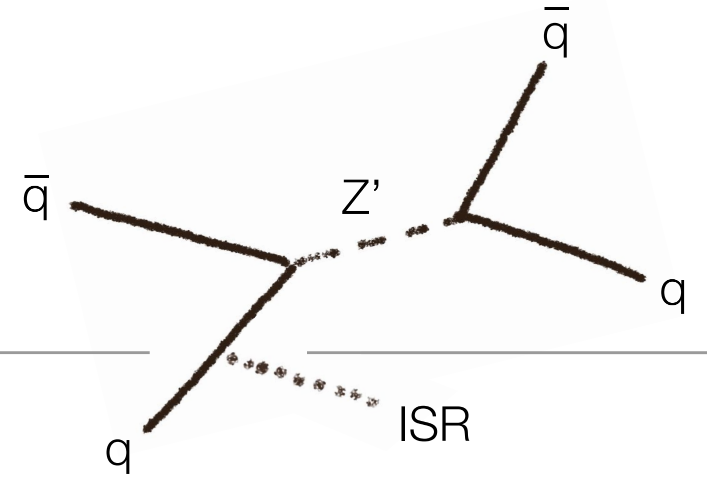
Search for localized excess
using BumpHunter

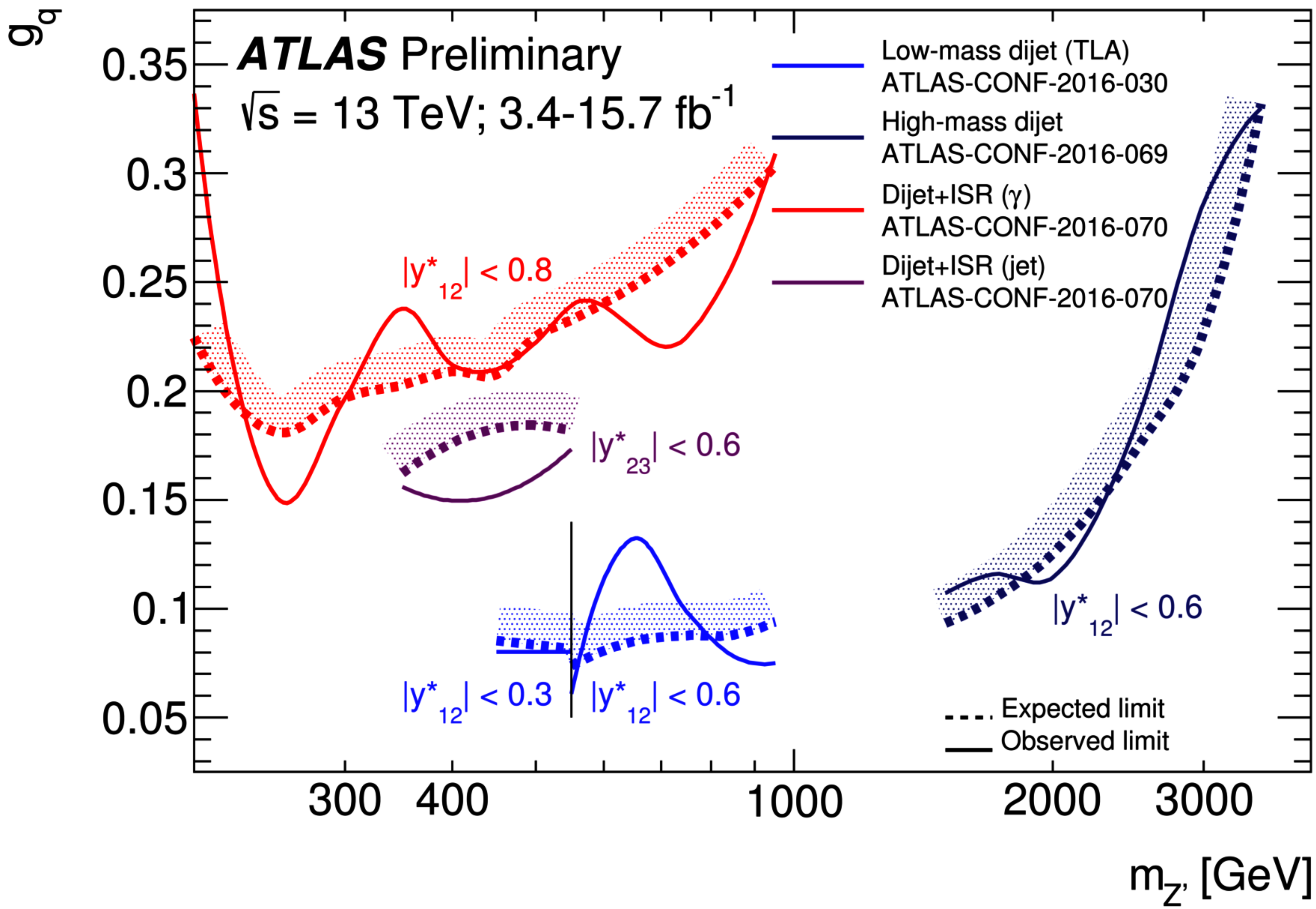
Analysis requires
dedicated jet calibration …

[ATLAS-CONF-2016-030]

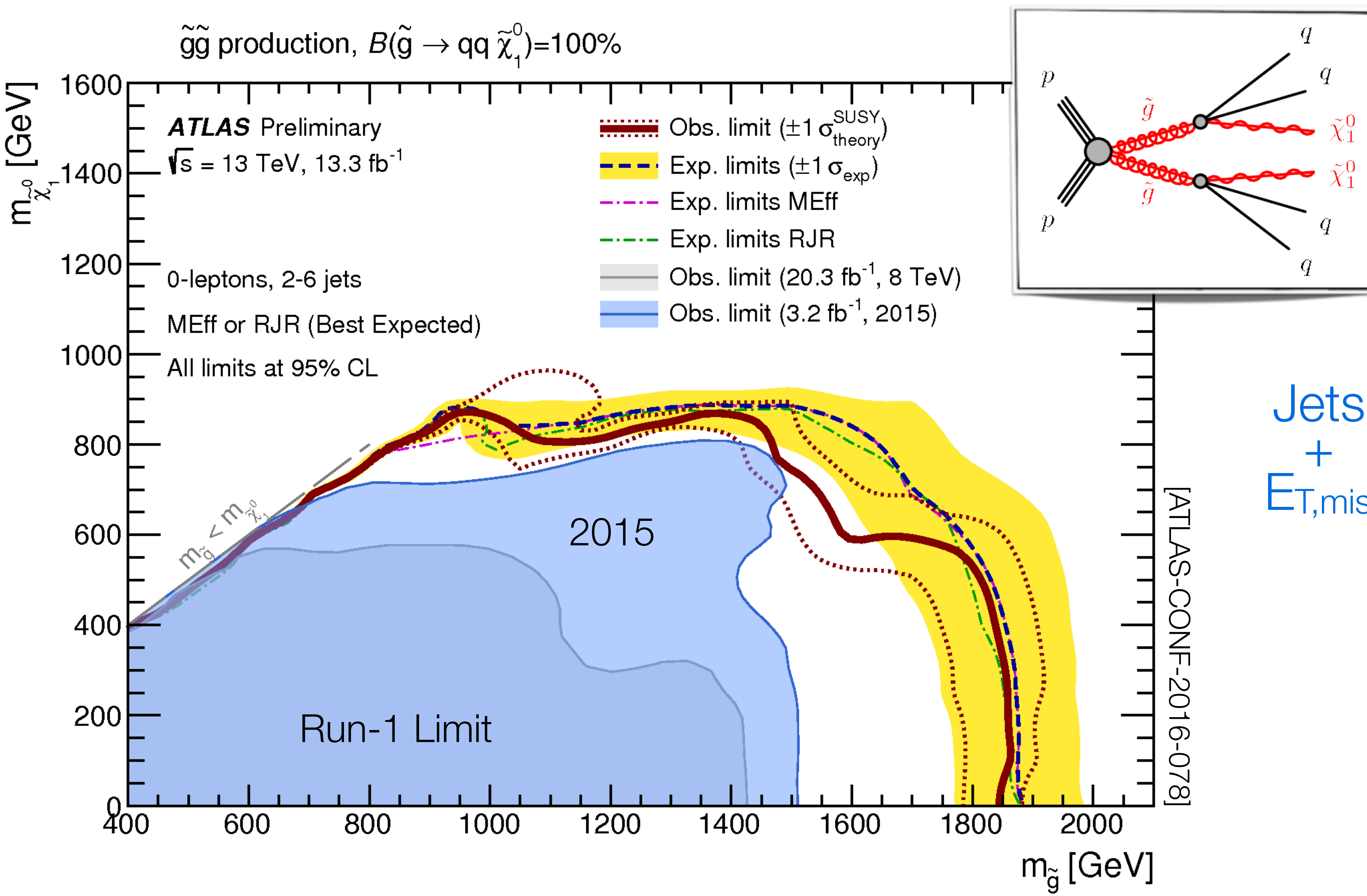


Searches for New Physics





Searches for New Physics – SUSY



Jets + $E_{T,miss}$

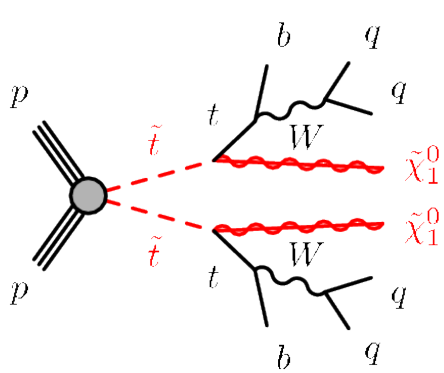
Searches for New Physics – SUSY

Stop Pair Production

No lepton …

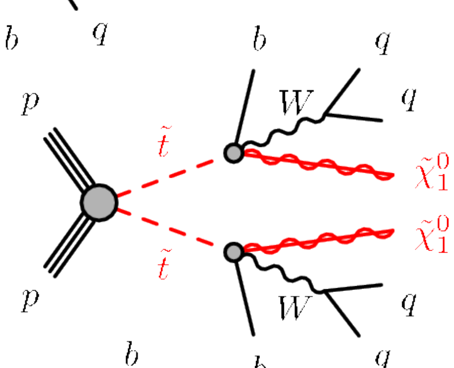
2 b-jet; ≥ 4 jets

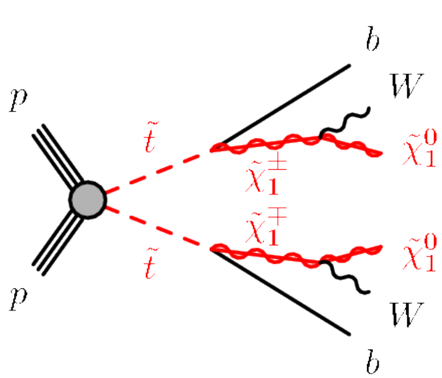
$E_{T,miss}$ > 250 GeV



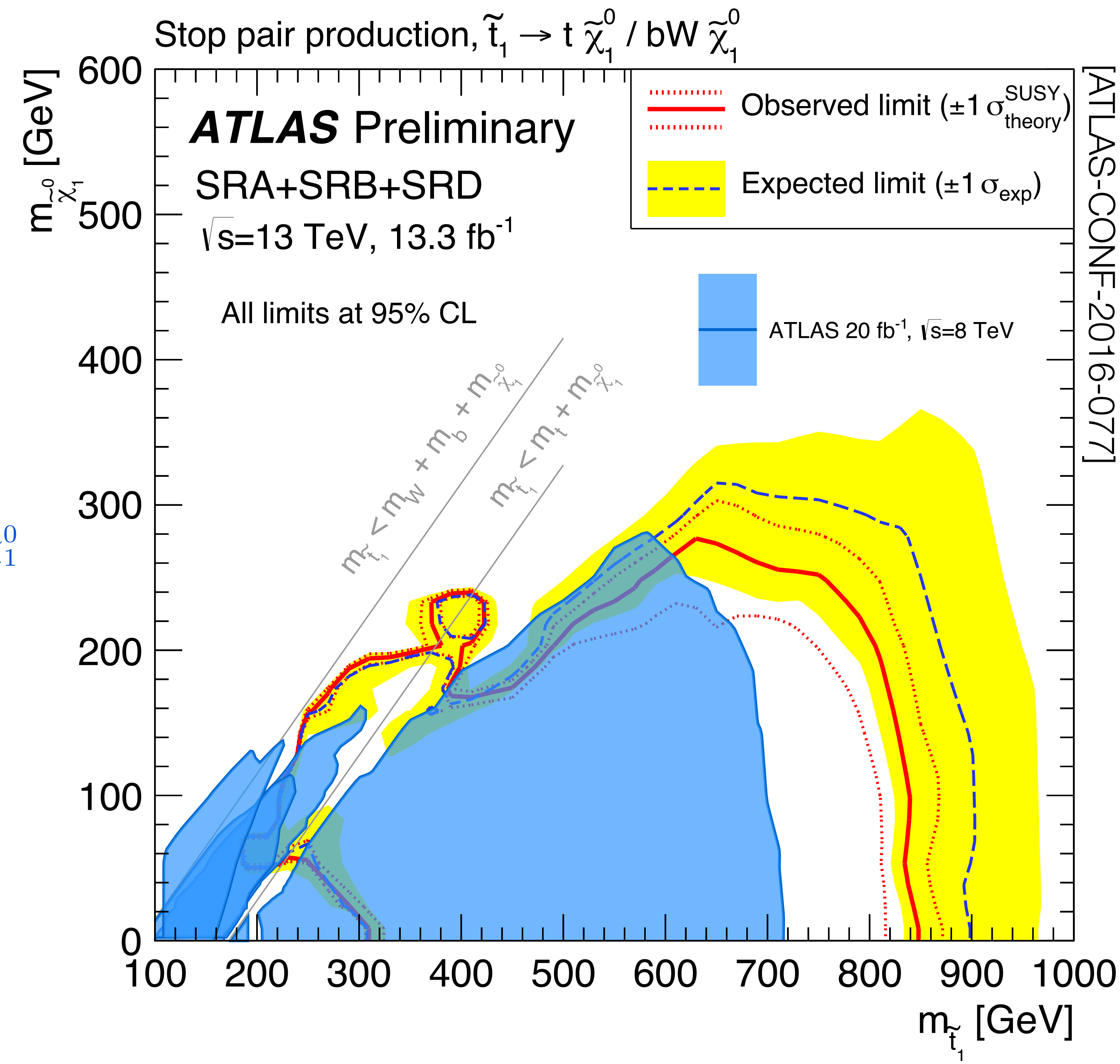
$\tilde{t} \to t + \chi_1^0$

$\tilde{t} \to W + b + \chi_1^0$





$\tilde{t} \to b + \chi_1^\pm$



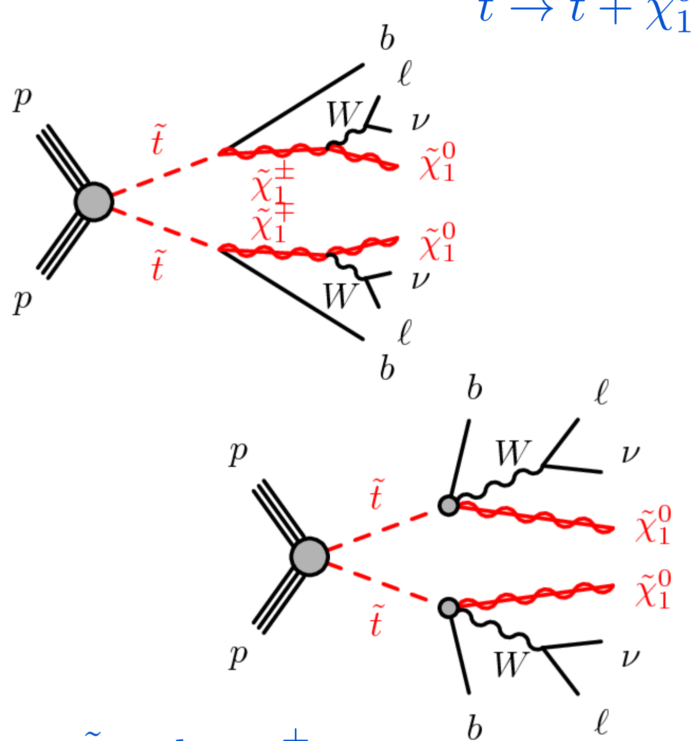
Searches for New Physics – SUSY

Stop Pair Production

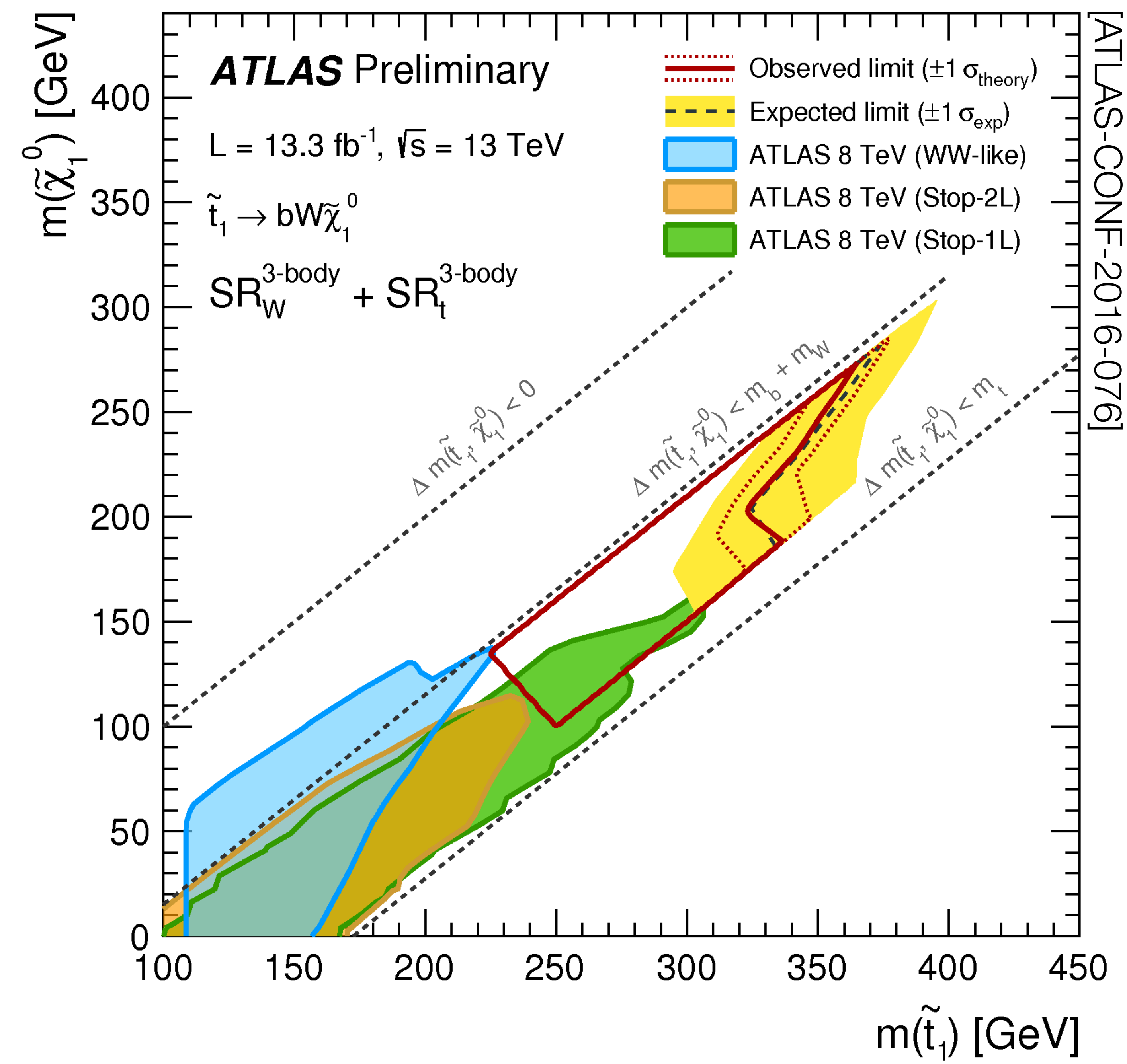
Two leptons …

Z-veto for same flavor
$E_{T,miss}$ > 200 GeV
$P_{T,l}$ > 20 GeV

$\tilde{t} \to t + \chi_1^0$



$\tilde{t} \to b + \chi_1^\pm$



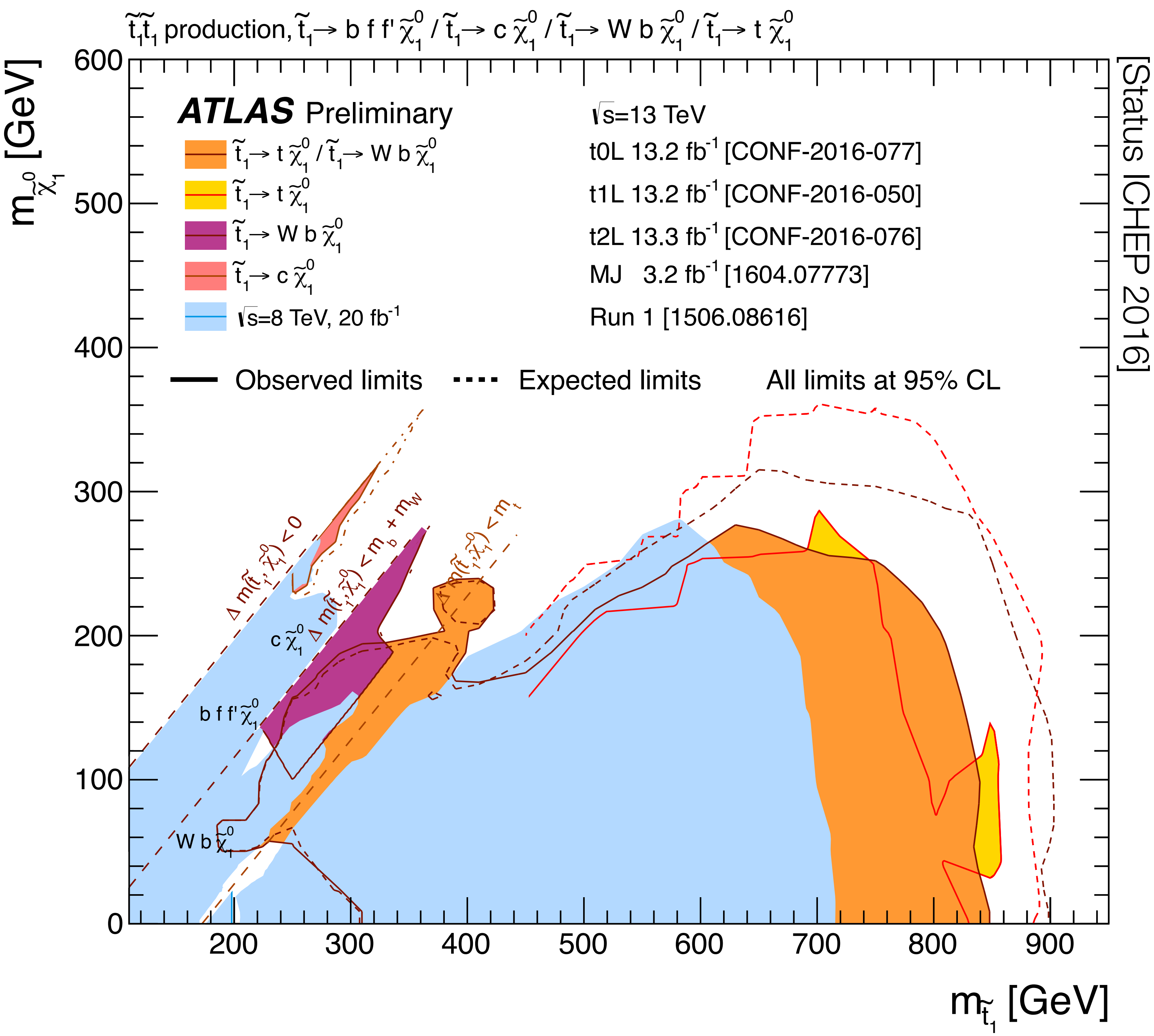
Searches for New Physics – SUSY

Stop Pair Production
Combination

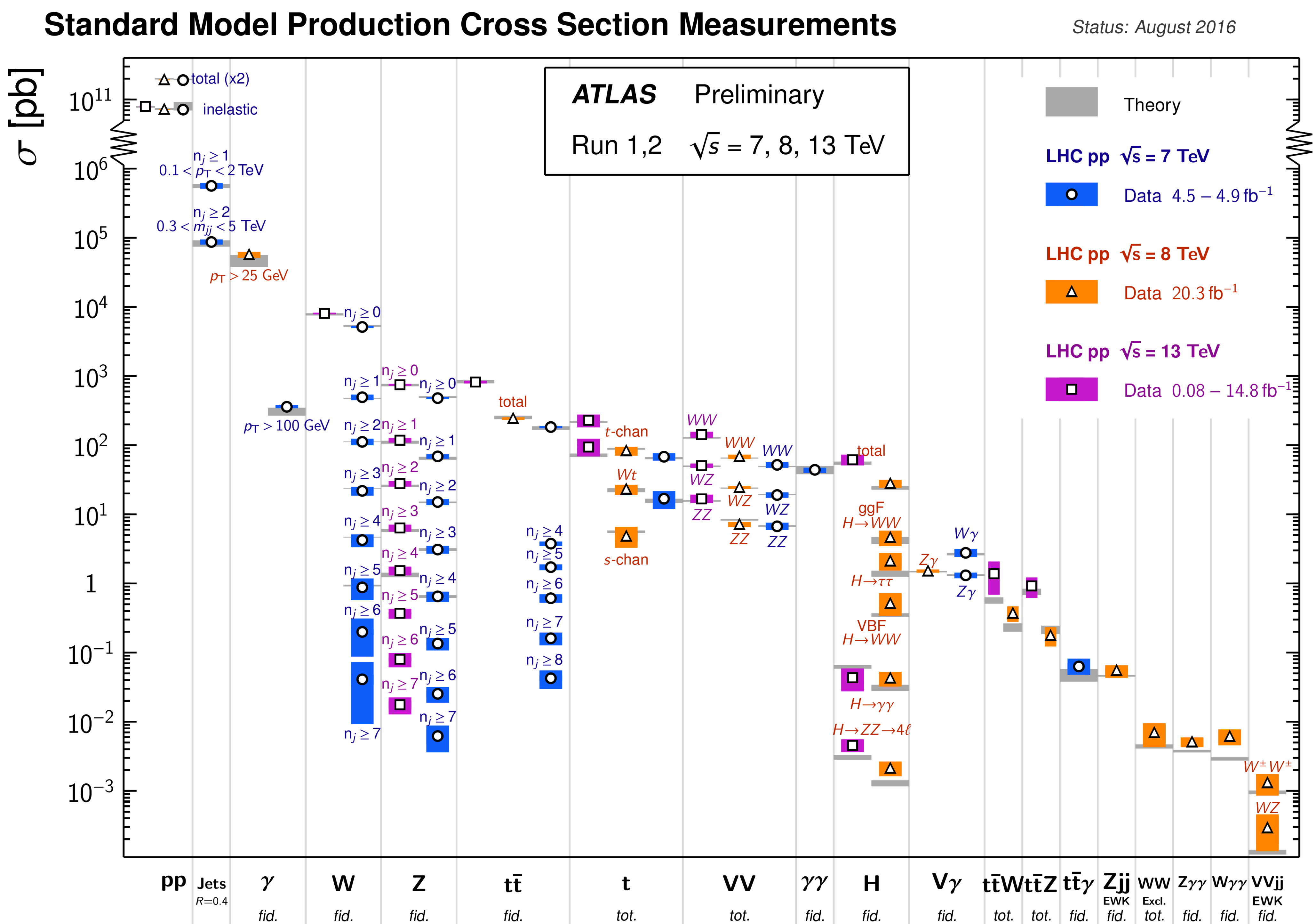
Overlay of different stop decay channels, mass hierarchies and decay scenarios

Most challenging region: $m(\tilde{t}) \approx m(\tilde{\chi}^0)$

- reduced $E_{T,miss}$
- soft cascade particles



Standard Model Measurements



Standard Model Measurements – W Mass

W mass measurement …

Strategy:

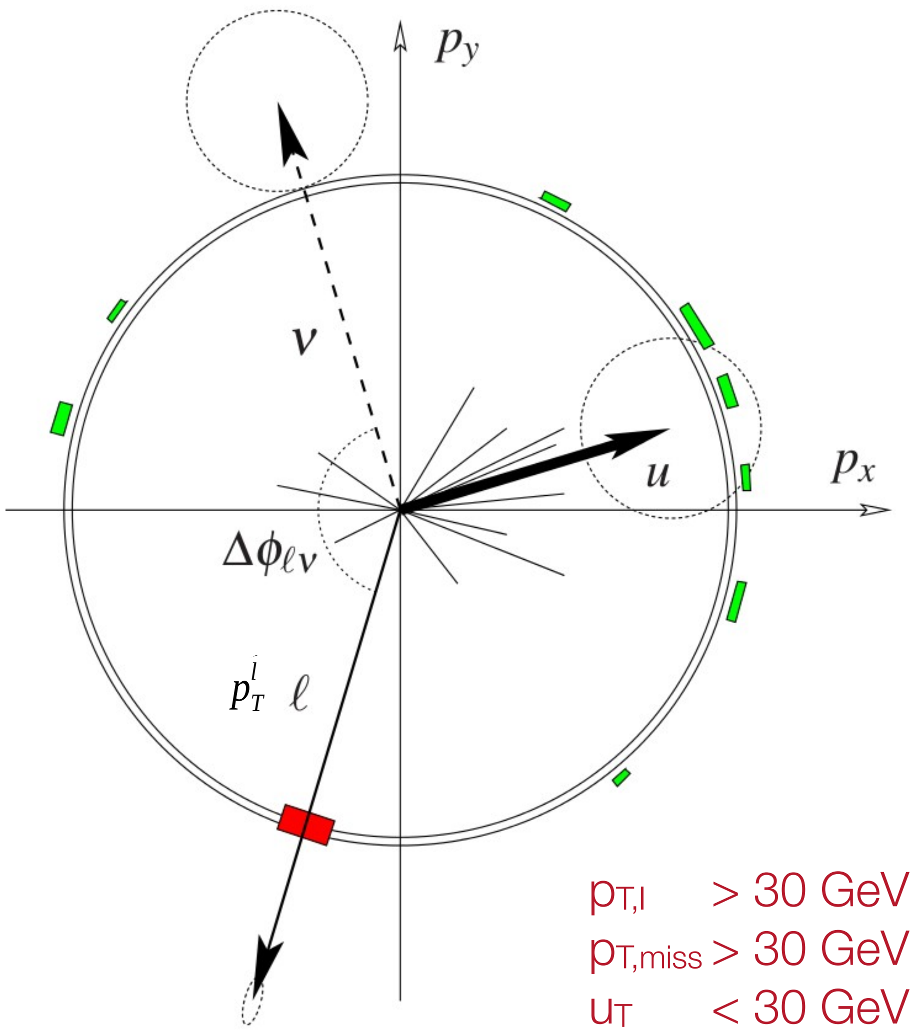
Select W-events with W decaying leptonically …

Signature: electron or muon; $E_{T,miss}$, $p_{T,miss}$
Recoil energy u_T measures p_T of W boson

Fit sensitive quantities …

transverse lepton momentum
missing transverse momentum
transverse mass

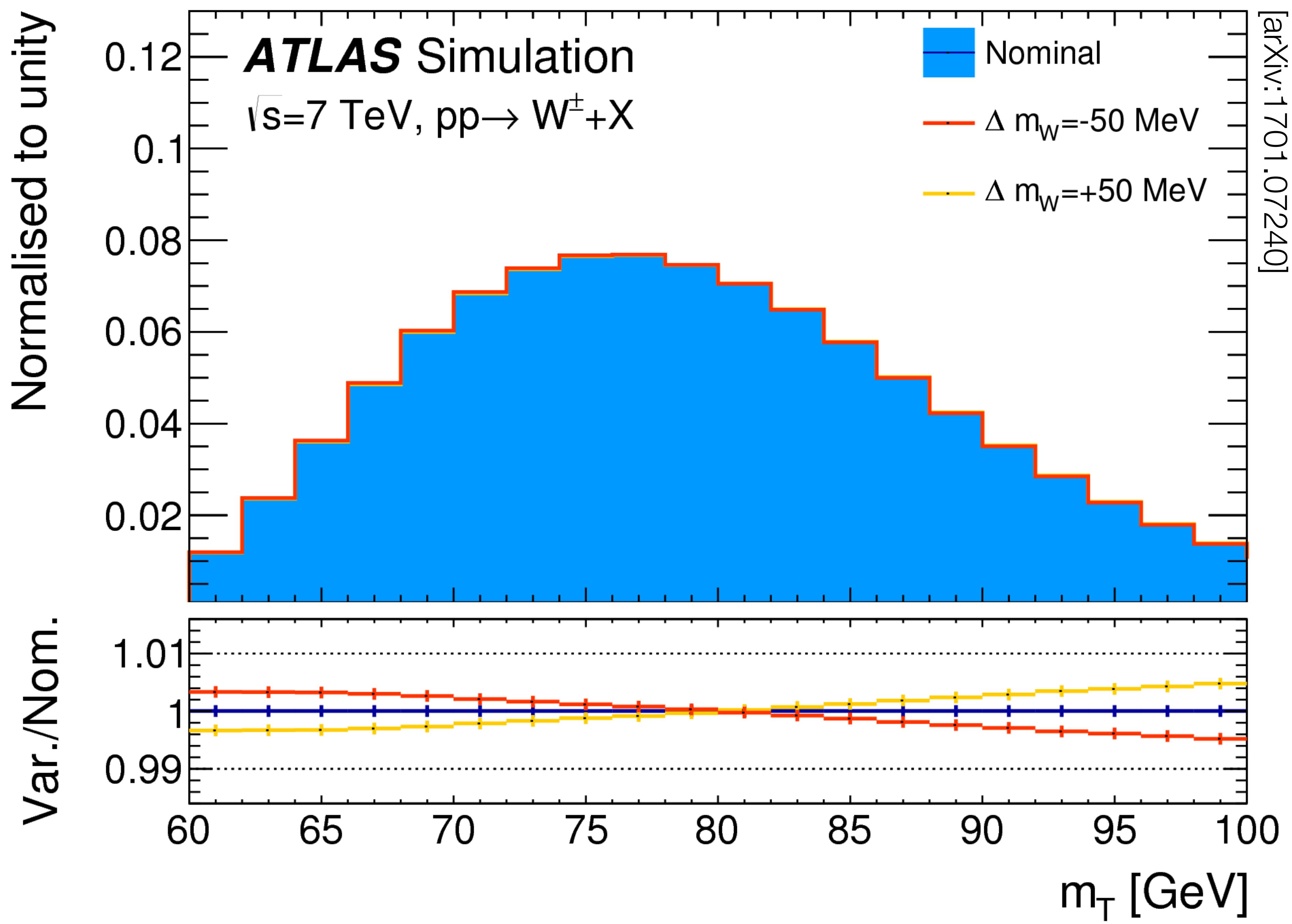
$$\vec{p}_T^{\,\ell}\,,\ \ \vec{p}_T^{\,\text{miss}} = -\left(\vec{p}_T^{\,\ell} + \vec{u}_T\right)\,,\ \ m_T = \sqrt{2p_T^\ell p_T^{\text{miss}}(1-\cos\Delta\phi)}$$



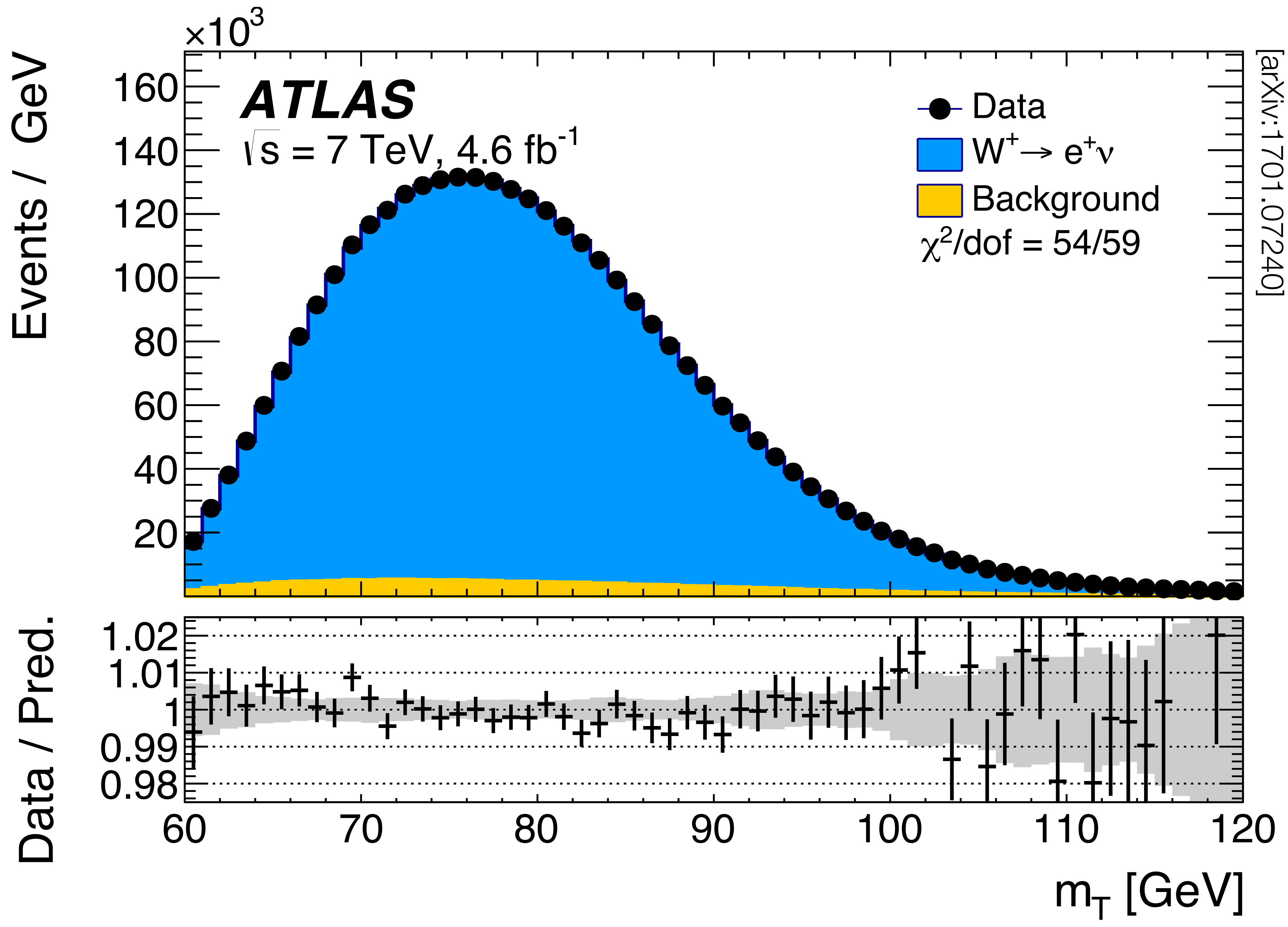
$p_{T,l}$ > 30 GeV
$p_{T,miss}$ > 30 GeV
u_T < 30 GeV
m_T > 60 GeV

Signal distributions constructed from Monte Carlo reweighting m_W …
W mass determination by χ^2-minimization …

Standard Model Measurements – W Mass

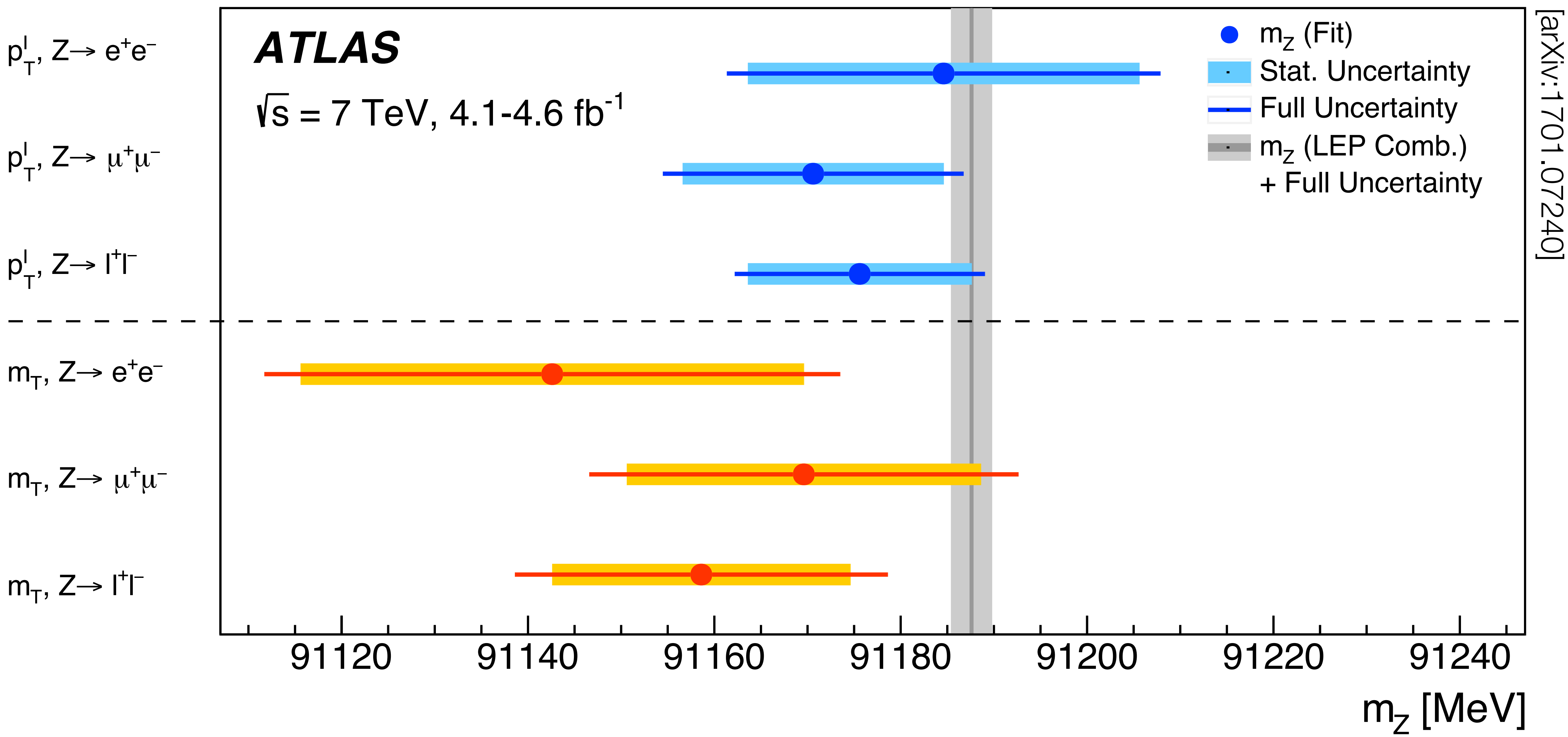


Standard Model Measurements – W Mass

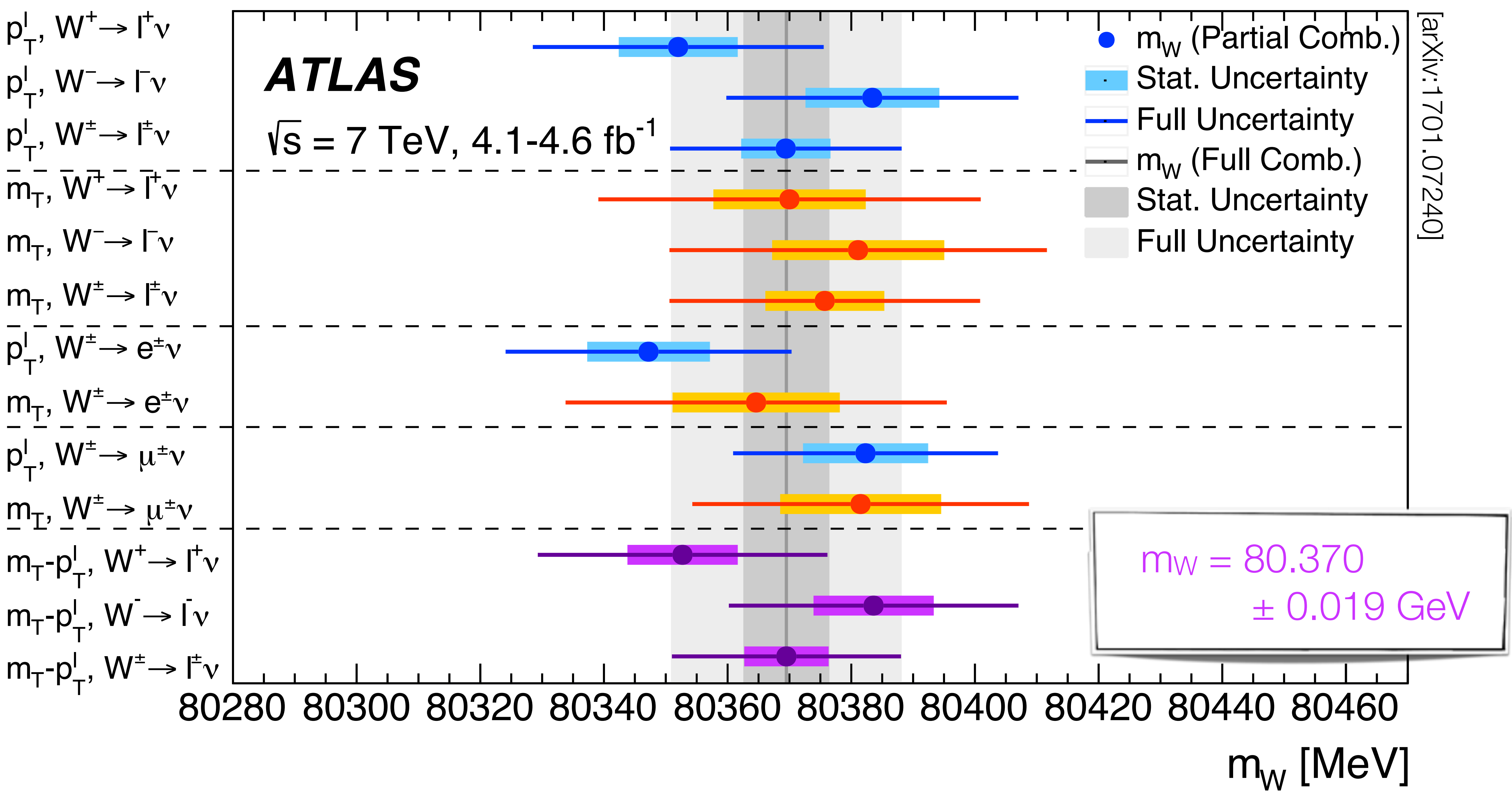


Standard Model Measurements – W Mass

Cross checks with Z events



Standard Model Measurements – W Mass



$$m_W = 80370 \pm 7\,(\text{stat.}) \pm 11\,(\text{exp. syst.}) \pm 14\,(\text{mod. syst.})\ \text{MeV}$$

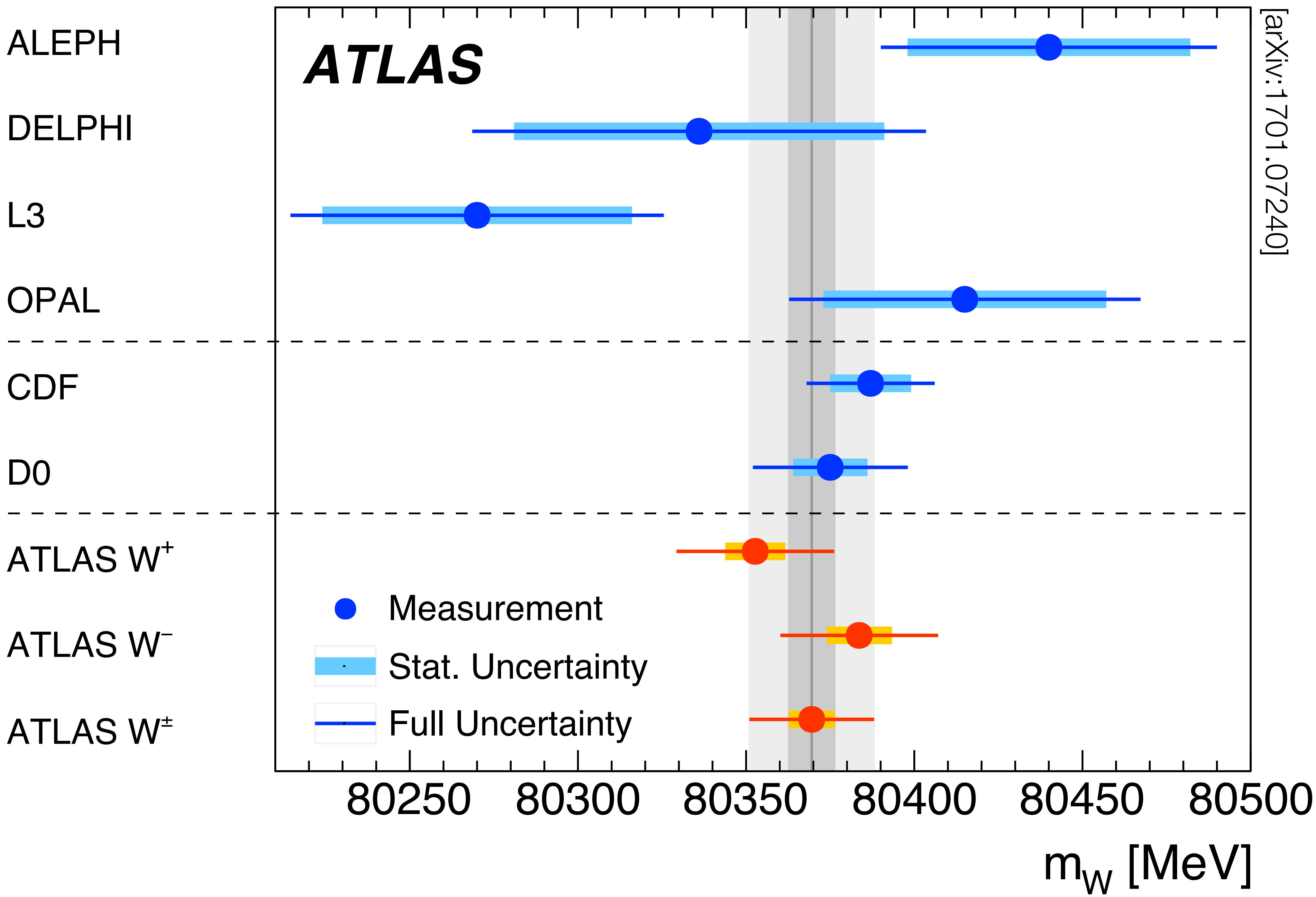
Standard Model Measurements – W Mass

ATLAS EXPERIMENT

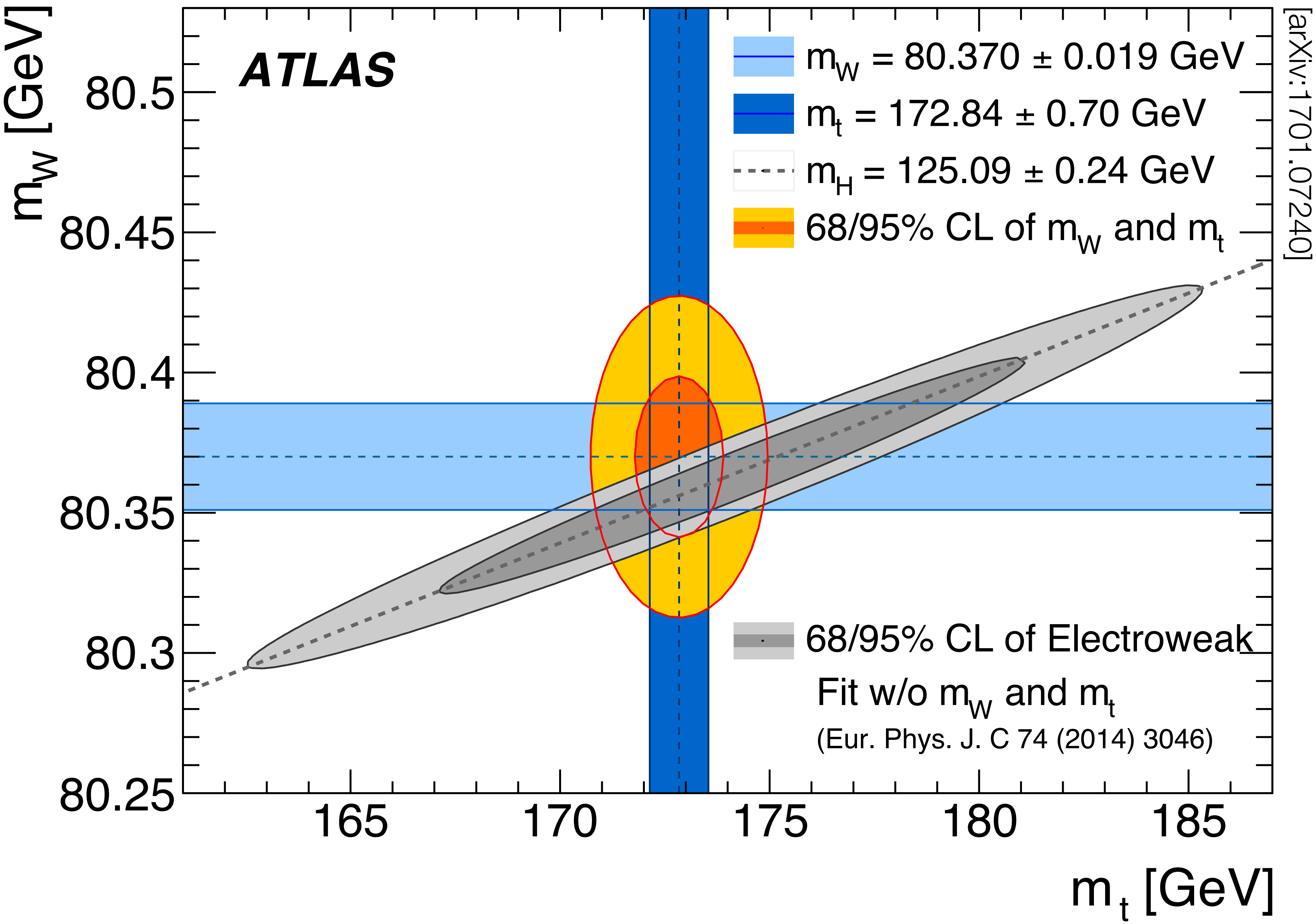
Combined categories	Value [MeV]	Stat. Unc.	Muon Unc.	Elec. Unc.	Recoil Unc.	Bckg. Unc.	QCD Unc.	EW Unc.	PDF Unc.	Total Unc.	χ^2/dof of Comb.
m_T, W^+, e-μ	80370.0	12.3	8.3	6.7	14.5	9.7	9.4	3.4	16.9	30.9	2/6
m_T, W^-, e-μ	80381.1	13.9	8.8	6.6	11.8	10.2	9.7	3.4	16.2	30.5	7/6
m_T, $W^\pm$, e-μ	80375.7	9.6	7.8	5.5	13.0	8.3	9.6	3.4	10.2	25.1	11/13
p_T^ℓ, W^+, e-μ	80352.0	9.6	6.5	8.4	2.5	5.2	8.3	5.7	14.5	23.5	5/6
p_T^ℓ, W^-, e-μ	80383.4	10.8	7.0	8.1	2.5	6.1	8.1	5.7	13.5	23.6	10/6
p_T^ℓ, $W^\pm$, e-μ	80369.4	7.2	6.3	6.7	2.5	4.6	8.3	5.7	9.0	18.7	19/13
p_T^ℓ, $W^\pm$, e	80347.2	9.9	0.0	14.8	2.6	5.7	8.2	5.3	8.9	23.1	4/5
m_T, $W^\pm$, e	80364.6	13.5	0.0	14.4	13.2	12.8	9.5	3.4	10.2	30.8	8/5
m_T-p_T^ℓ, W^+, e	80345.4	11.7	0.0	16.0	3.8	7.4	8.3	5.0	13.7	27.4	1/5
m_T-p_T^ℓ, W^-, e	80359.4	12.9	0.0	15.1	3.9	8.5	8.4	4.9	13.4	27.6	8/5
m_T-p_T^ℓ, $W^\pm$, e	80349.8	9.0	0.0	14.7	3.3	6.1	8.3	5.1	9.0	22.9	12/11
p_T^ℓ, $W^\pm$, μ	80382.3	10.1	10.7	0.0	2.5	3.9	8.4	6.0	10.7	21.4	7/7
m_T, $W^\pm$, μ	80381.5	13.0	11.6	0.0	13.0	6.0	9.6	3.4	11.2	27.2	3/7
m_T-p_T^ℓ, W^+, μ	80364.1	11.4	12.4	0.0	4.0	4.7	8.8	5.4	17.6	27.2	5/7
m_T-p_T^ℓ, W^-, μ	80398.6	12.0	13.0	0.0	4.1	5.7	8.4	5.3	16.8	27.4	3/7
m_T-p_T^ℓ, $W^\pm$, μ	80382.0	8.6	10.7	0.0	3.7	4.3	8.6	5.4	10.9	21.0	10/15
m_T-p_T^ℓ, W^+, e-μ	80352.7	8.9	6.6	8.2	3.1	5.5	8.4	5.4	14.6	23.4	7/13
m_T-p_T^ℓ, W^-, e-μ	80383.6	9.7	7.2	7.8	3.3	6.6	8.3	5.3	13.6	23.4	15/13
m_T-p_T^ℓ, $W^\pm$, e-μ	80369.5	6.8	6.6	6.4	2.9	4.5	8.3	5.5	9.2	18.5	29/27

[arXiv:1701.07240]

Standard Model Measurements – W Mass



Standard Model Measurements – W Mass



Final Remarks

Excellent Run 2 performance …

Enhanced detectors & trigger systems work well …

ATLAS coping well with increased pileup …

High precision analyses from Run 1 …

Wealth of results already from 13 TeV data …

Exploration of 2016 data in many topologies …

e.g. complex searches with multiple signal regions|
no significant excesses; some ~2-3σ effects

About 100 pb^{-1} data more to come until LS2.