



Particle Physics Day 2016

[COLLABORATION](#)[DETECTOR](#)[PHYSICS](#)[ENGAGE WITH CMS](#)[UPDATES](#)[SEARCH](#)

CMS EMBARKS ON DATA COLLECTION AT 13 TEV



Mikko Voutilainen,
University of Helsinki and
Helsinki Institute of Physics

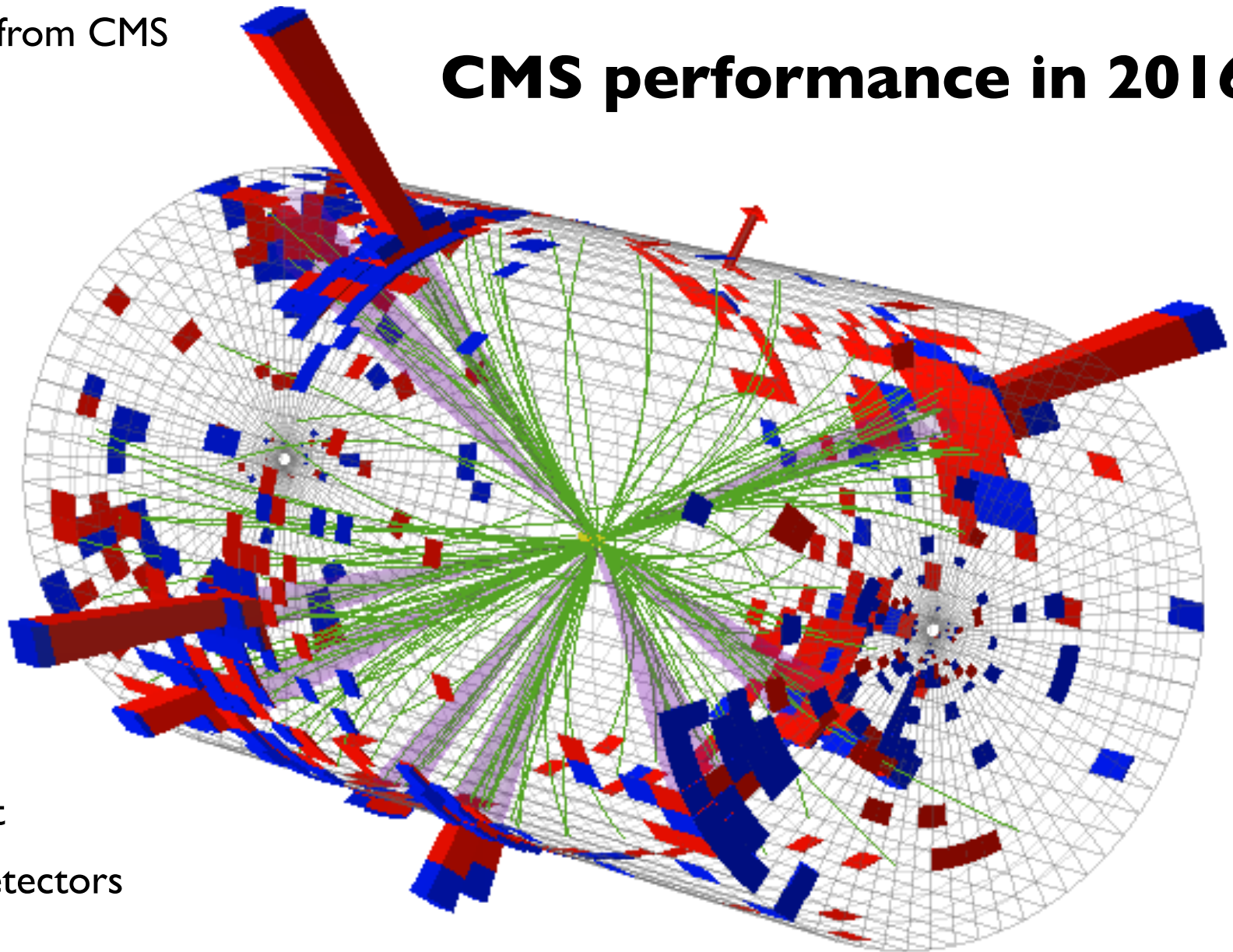


- LHC and detector performance in 2016
- ICHEP highlights from CMS
- Charged @ Lund
- Pixel upgrade
- Outlook

CMS performance in 2016



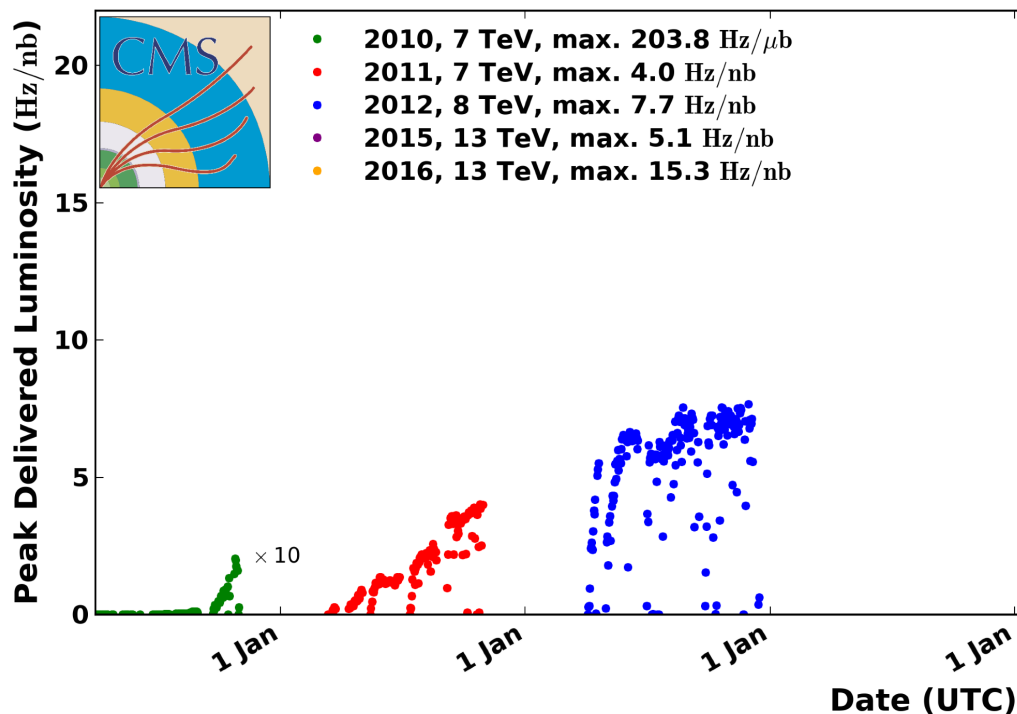
- Higgs
- Jet physics
- Tracker alignment
- Radiation hard detectors



- LHC went beyond design in 2016
 - design luminosity $1 \text{e}34$, pileup 25
 - actual max $1.4 \text{e}34$, peak pileup >40
- Remarkable availability on July 1—24 in period leading up to ICHEP (Aug 3–10)
 - we really, really wanted to find new physics

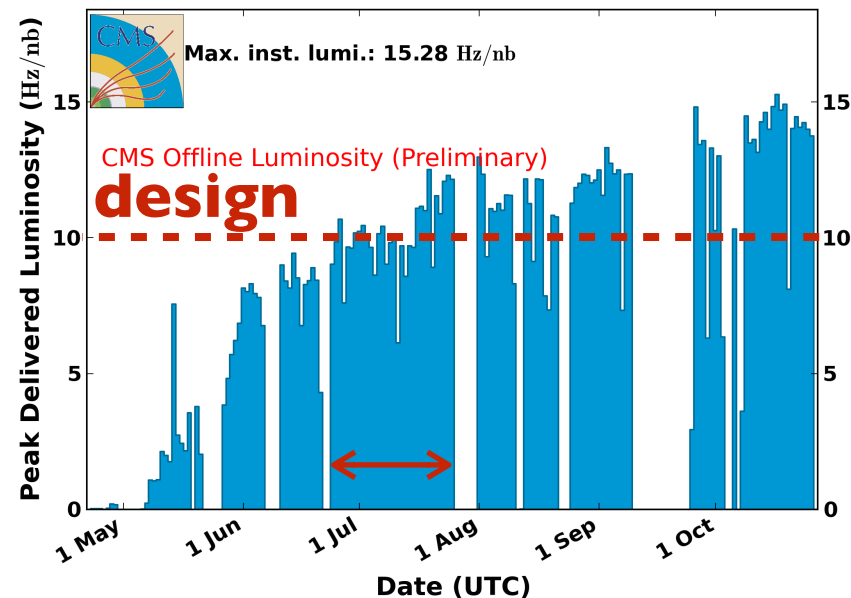
CMS Peak Luminosity Per Day, pp

Data included from 2010-03-30 11:22 to 2016-10-27 14:12 UTC

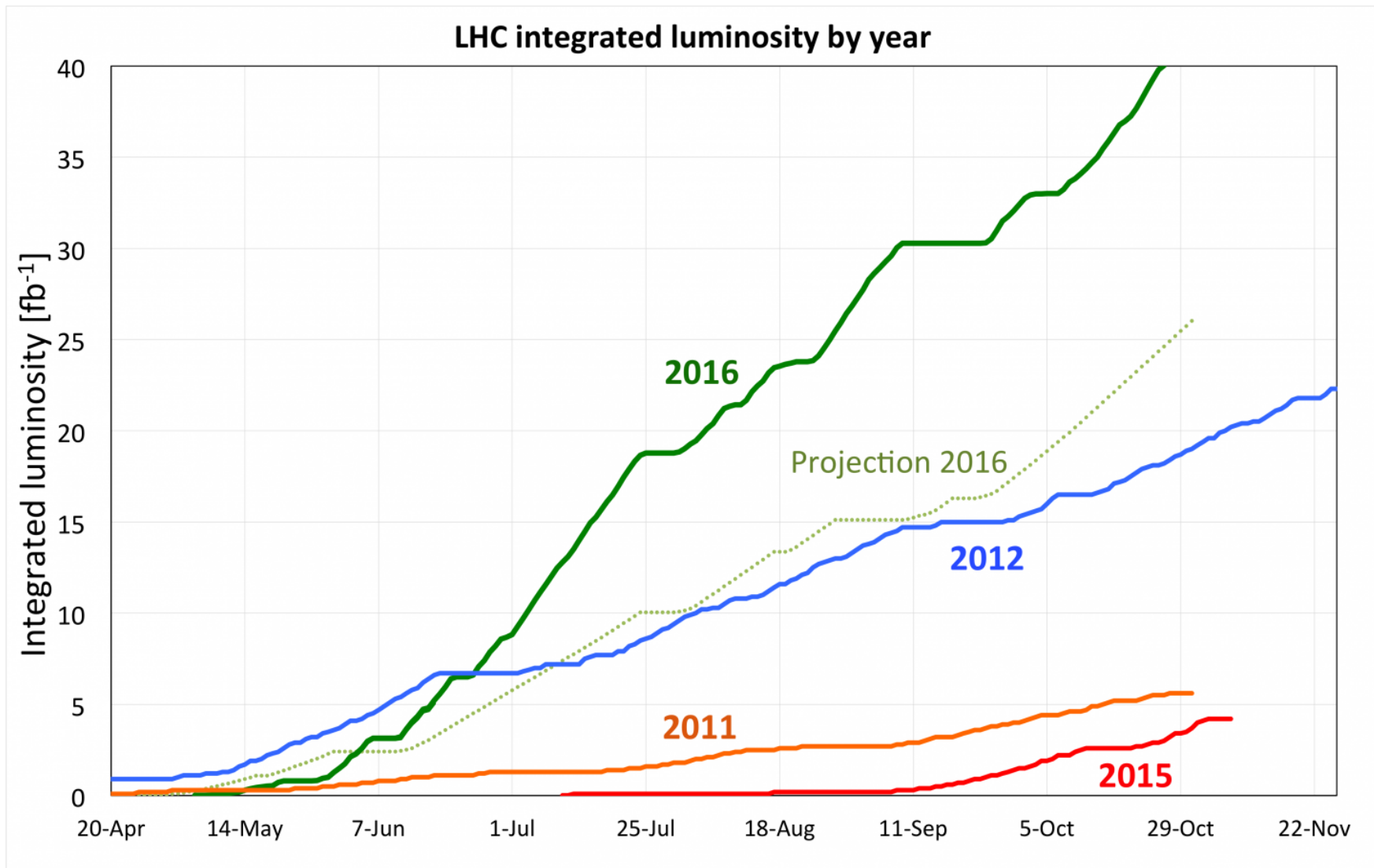


CMS Peak Luminosity Per Day, pp, 2016, $\sqrt{s} = 13 \text{ TeV}$

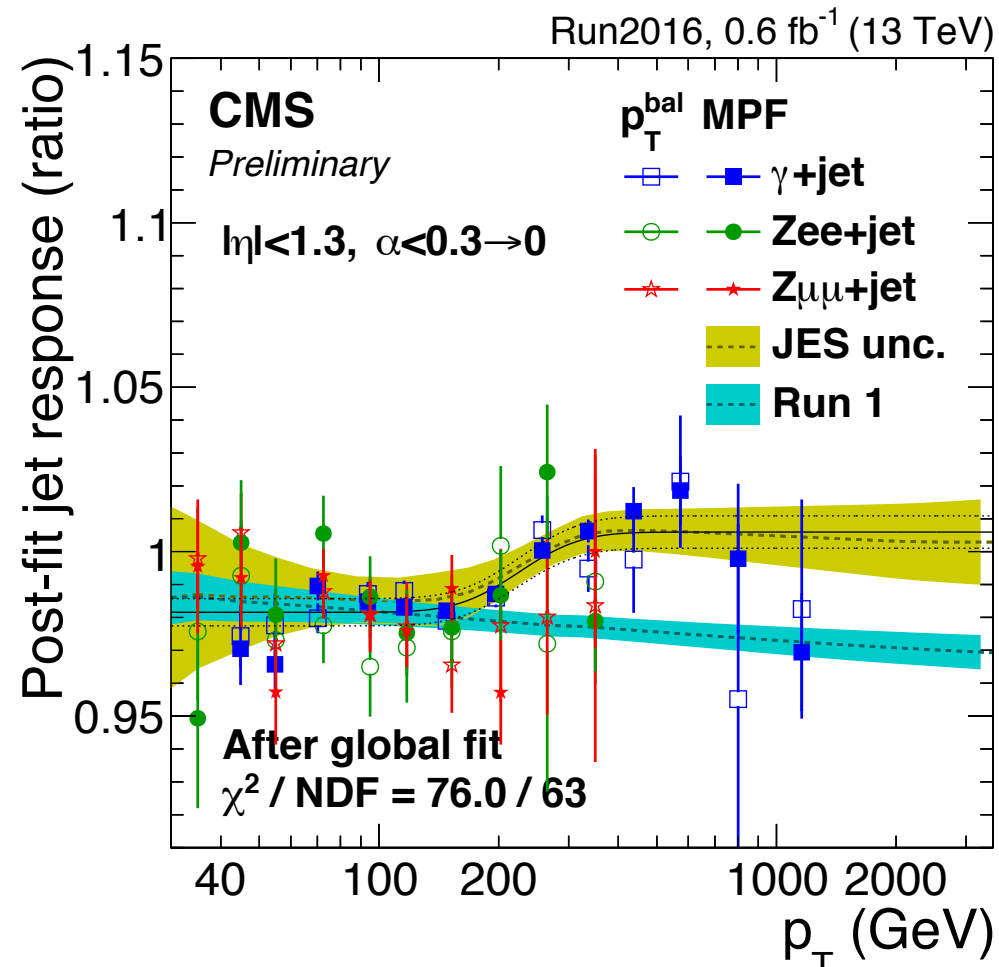
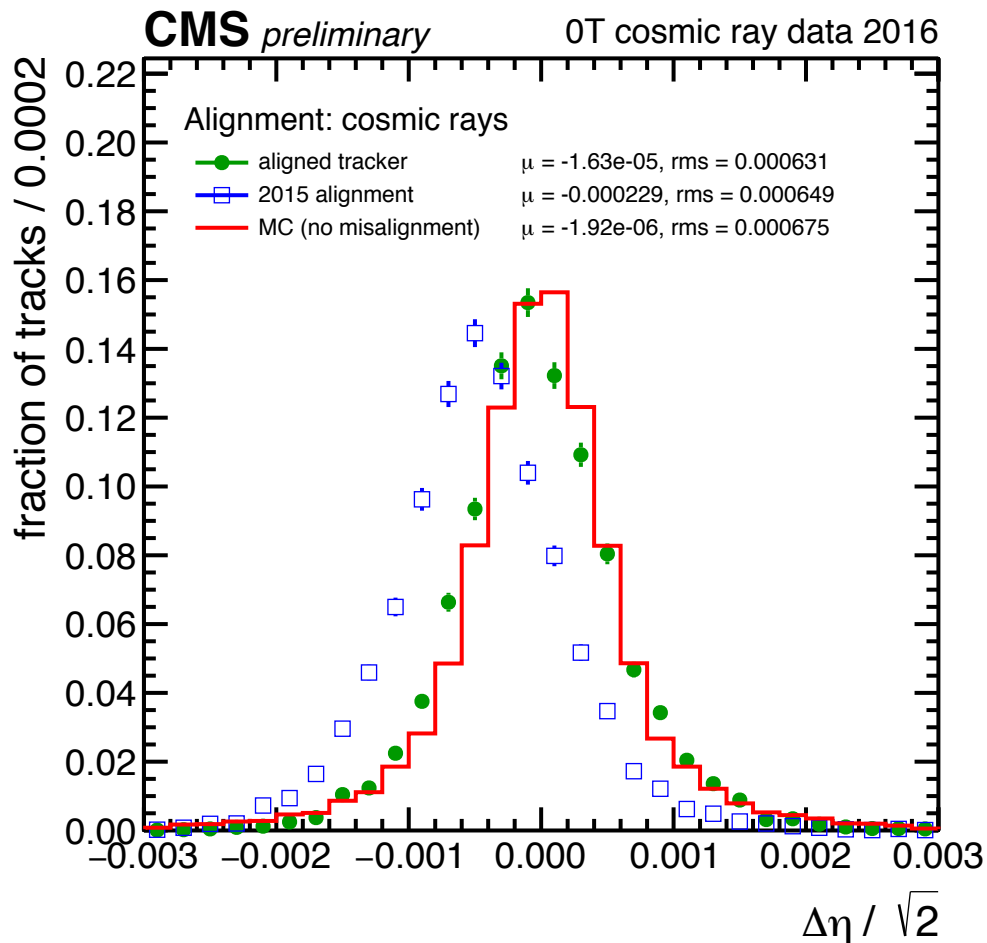
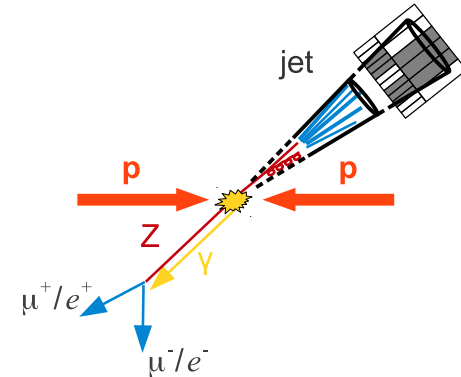
Data included from 2016-04-22 22:48 to 2016-10-27 14:12 UTC



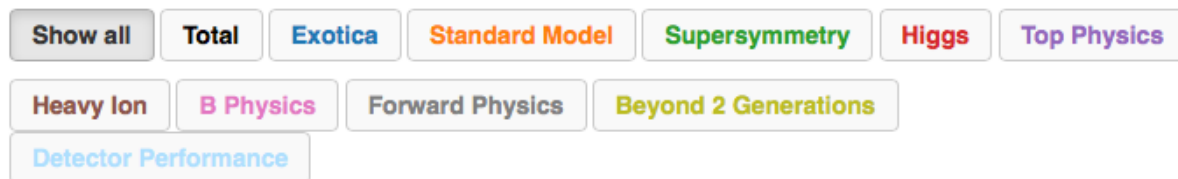
- Whopping 58% of time in stable beams during June 1st — Sep 8th
- LHC delivered ~50% more data in 2016 than expected (target 25 fb⁻¹, actual 41.4 fb⁻¹)
 - ▶ 36.5 fb⁻¹ golden for CMS (92.4% recorded, 95.3% certified as of highest quality)



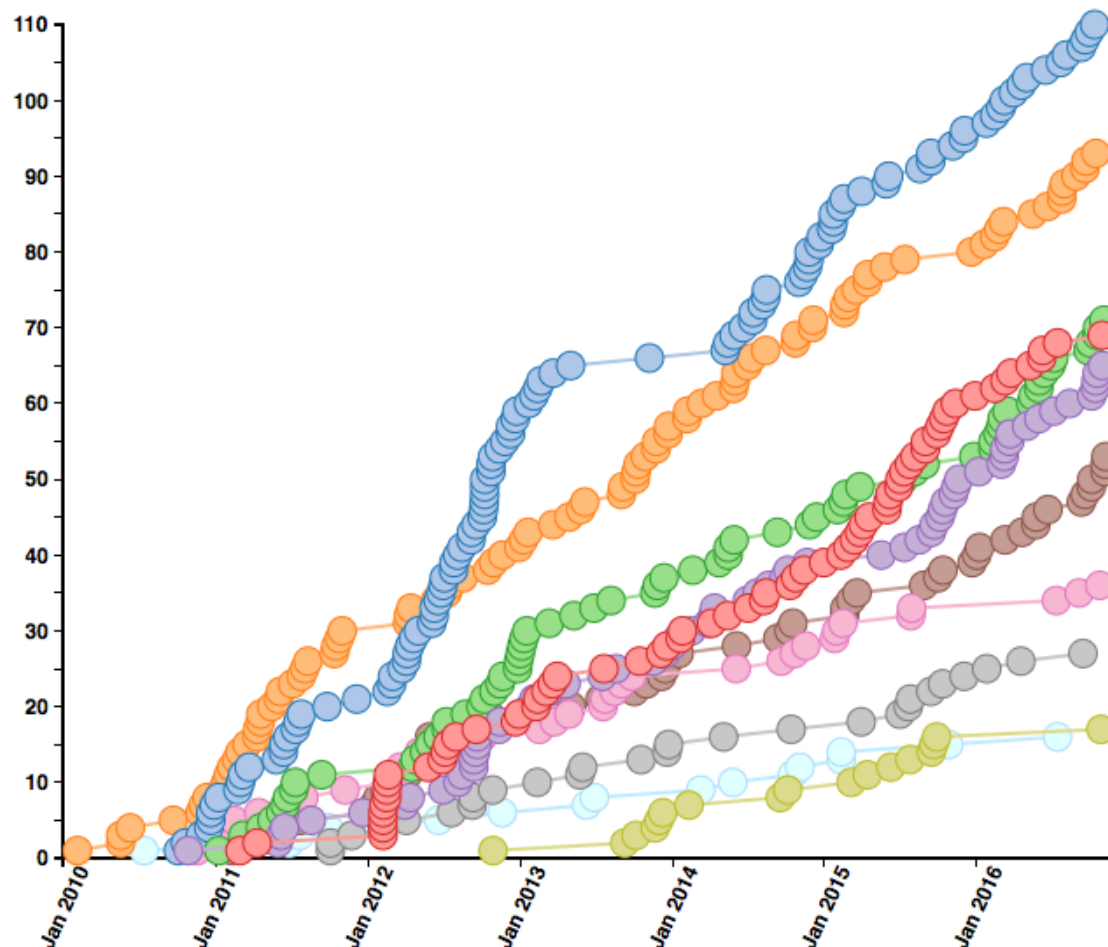
- No issues with magnet this year :)
- Early challenges with tracker dynamic inefficiency, now fixed
- Tracker alignment maintained with automatic updates per run
- Jet performance returning to Run I level or better



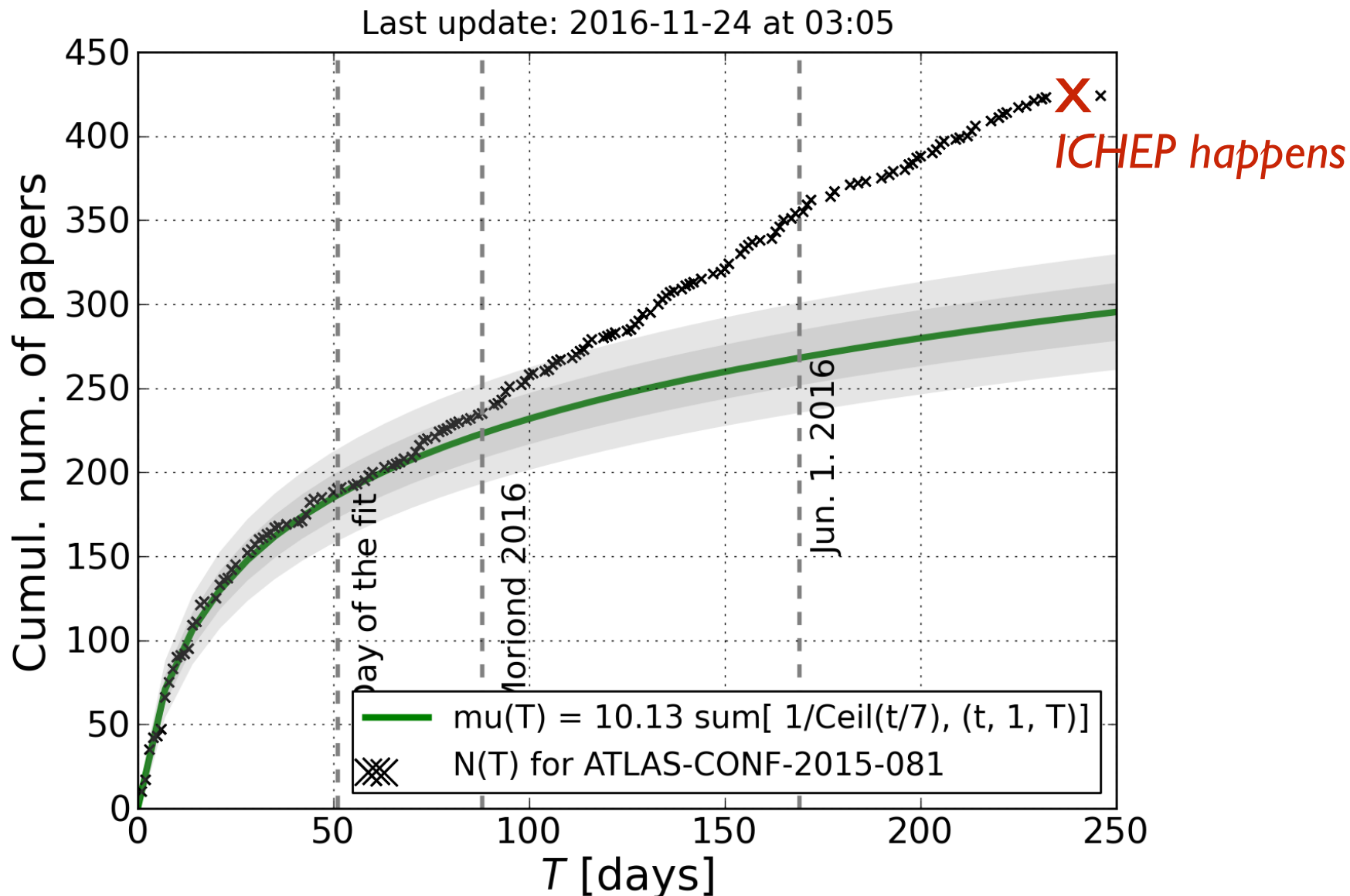
- Publication count >550
 - Higgs citations 6516
 - average 46.5 per paper
 - about ~150 since last PP days
- Jet calibration paper from 2011 as #4 with 844 citations
 - direct Finnish contribution; new paper submitted to JINST ([arxiv.org:1607.03663](https://arxiv.org/abs/1607.03663))
- Jet quenching in PbPb from 2011 as #9 with 533 citations
 - of interest to Finns
- Next up to renowned cat. is Higgs mass and couplings from 2015 as #11 with 466 citations
 - direct Finnish contribution; J. Heikkilä (as MSc student!)



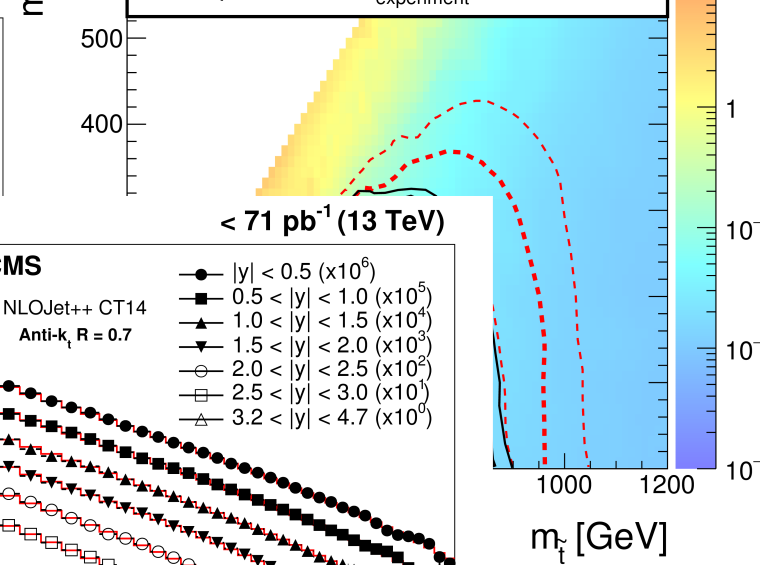
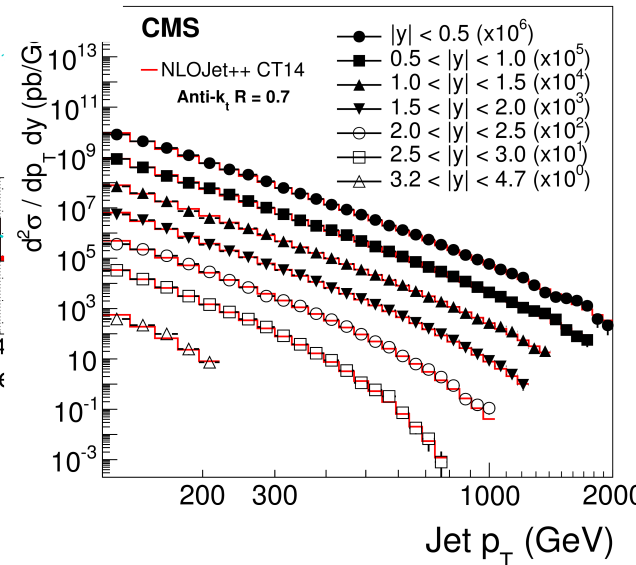
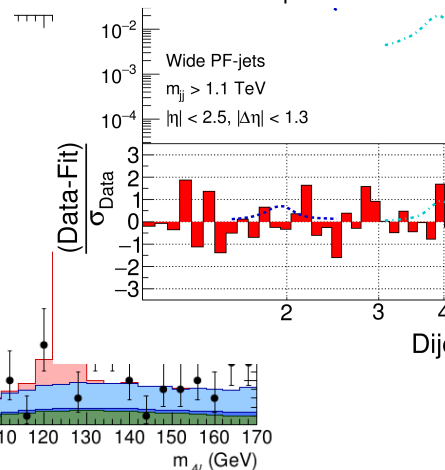
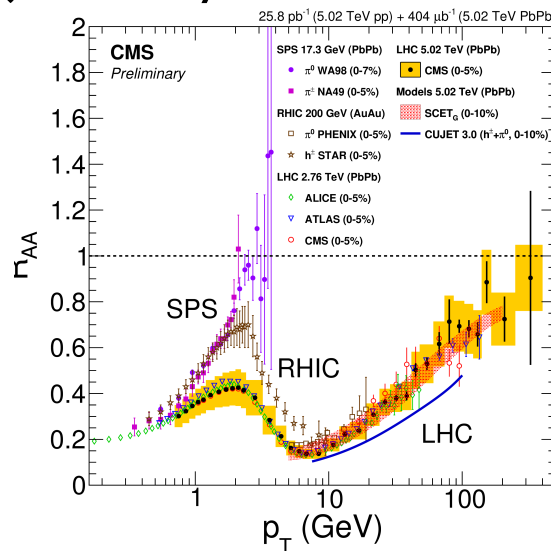
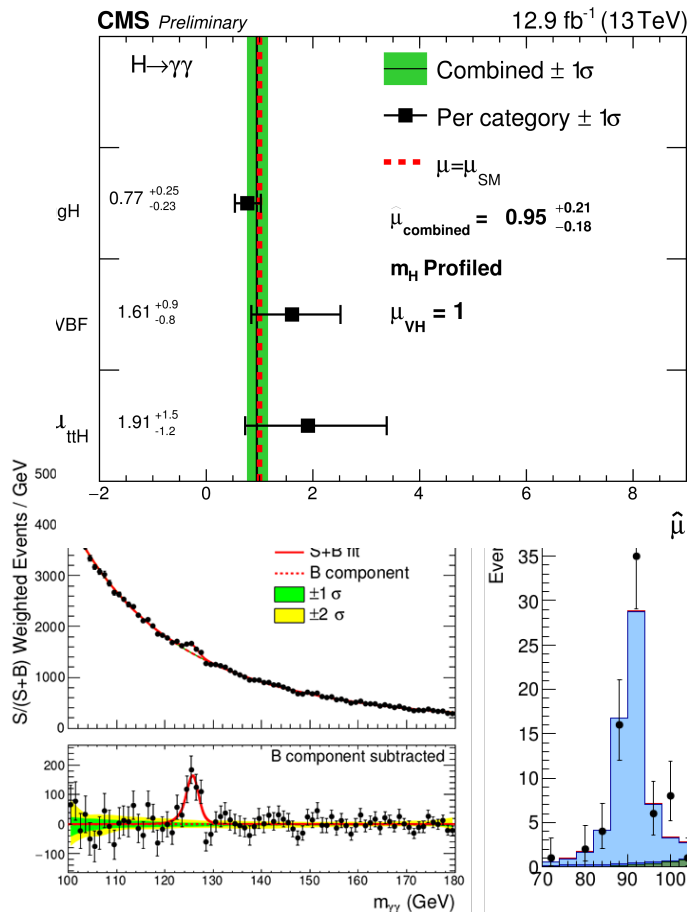
556 collider data papers submitted as of 2016-11-08

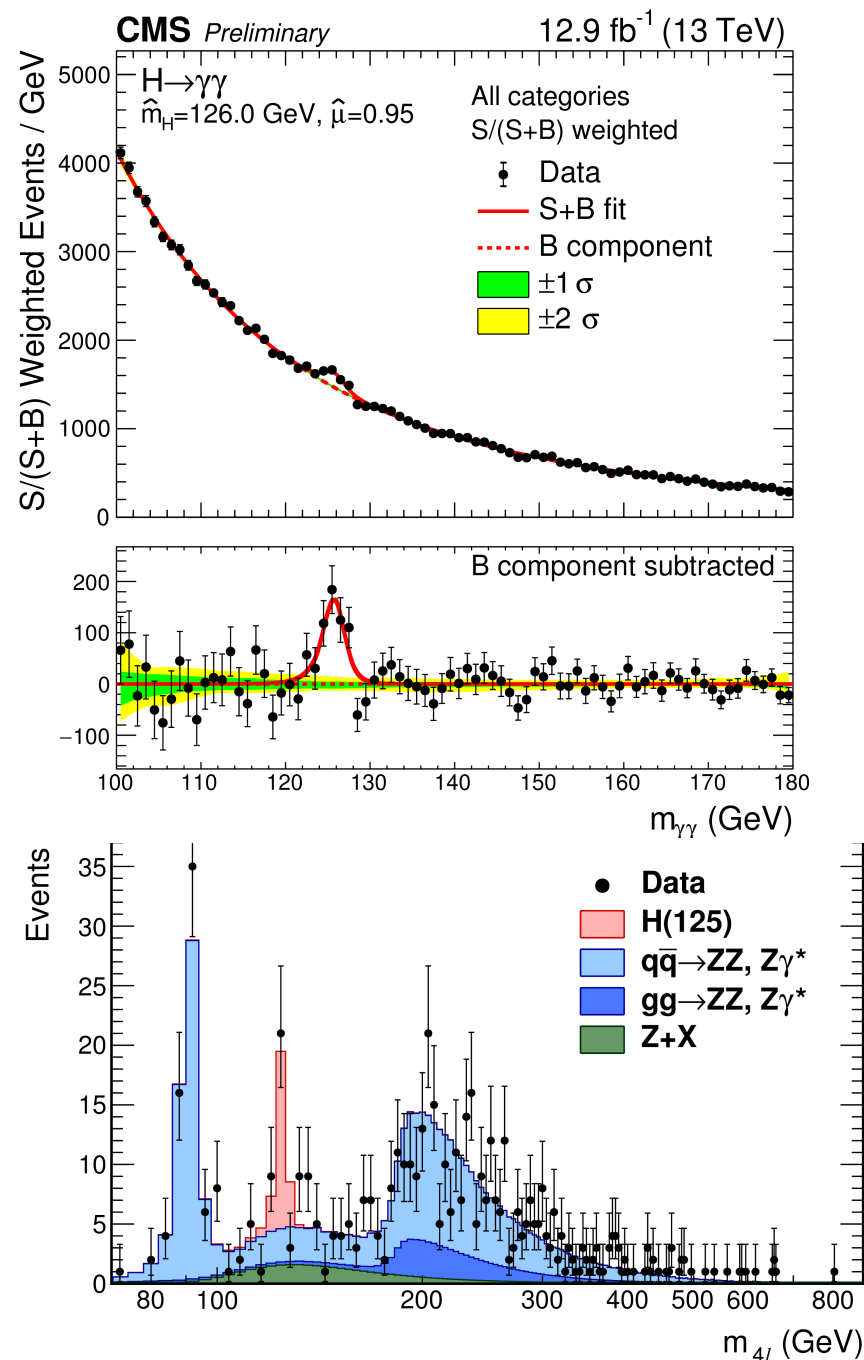


- CMS produced ~ 150 papers in past year, but killed **>400** on just $X \rightarrow \gamma\gamma$ (750) alone
 - we've been very efficient on shredding EXO and SUSY paper as well...

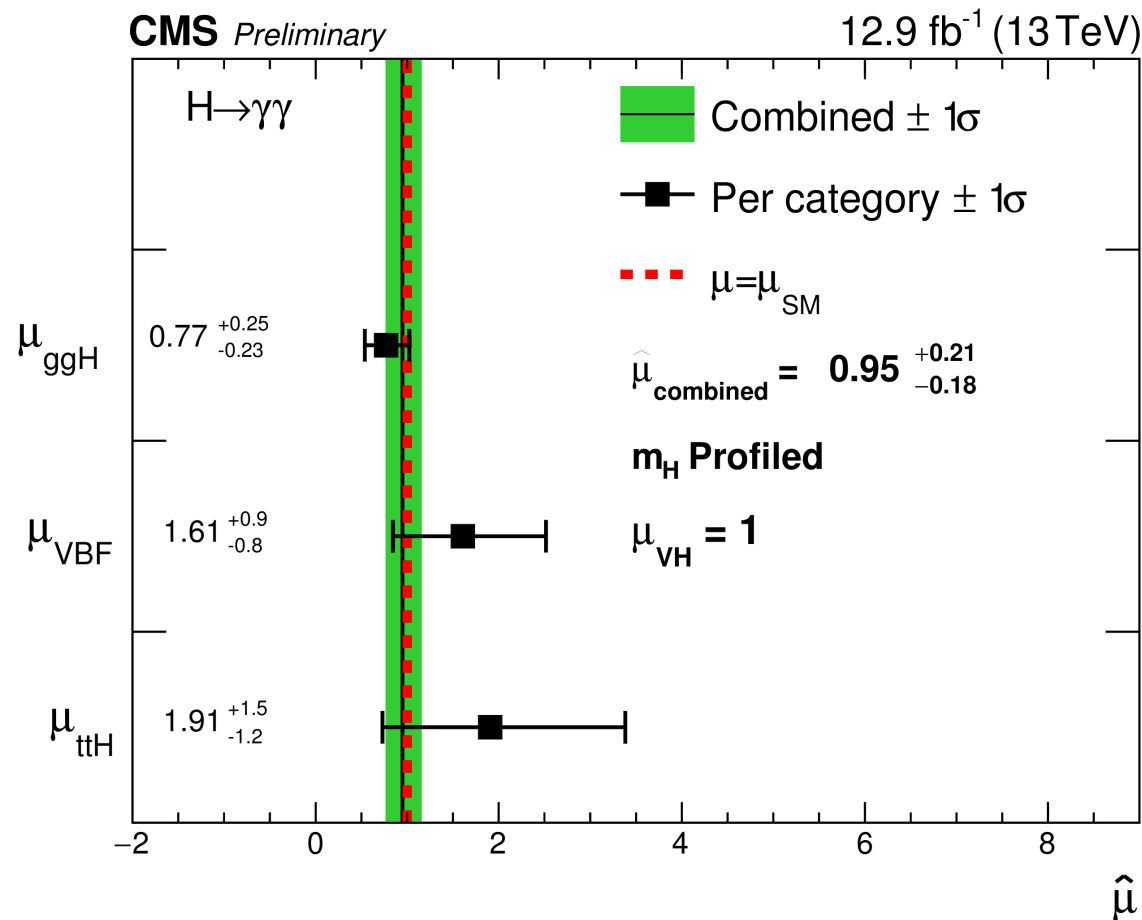


- Showdown of the year, with high expectations [[link](#)]
 ► ...and some severe disappointments
- Brief overview: Higgs re-discovery, ttH, digamma deficit, SUSY, EXO, dijet and inclusive jets, heavy ions

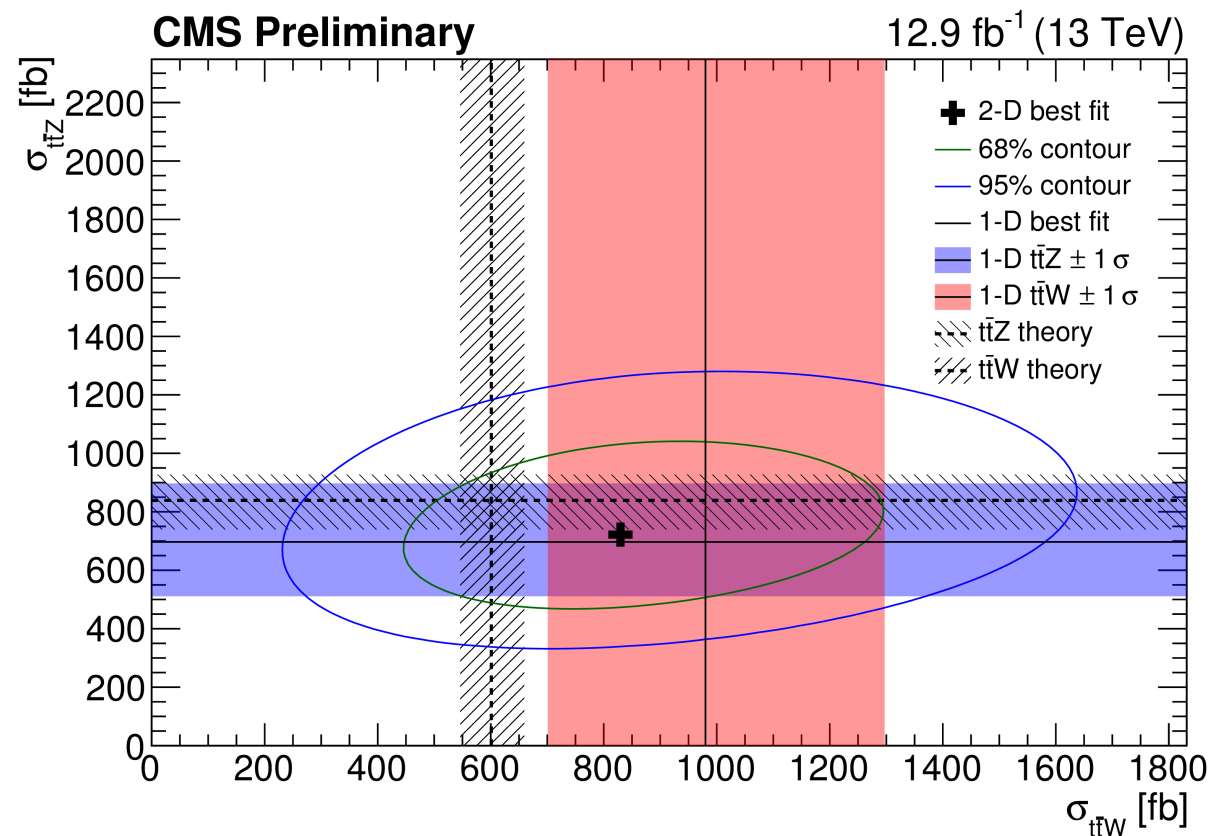
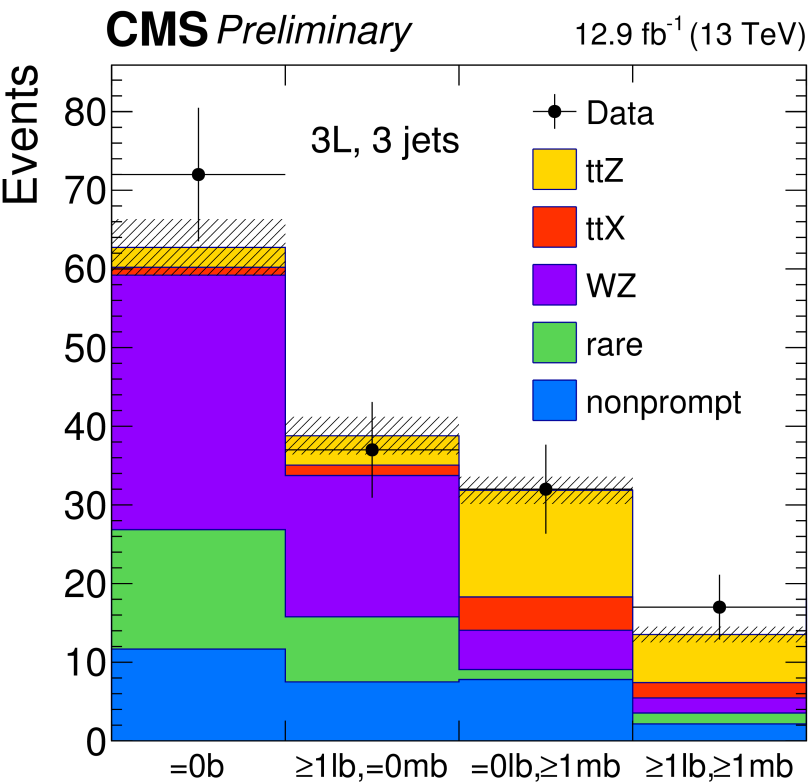
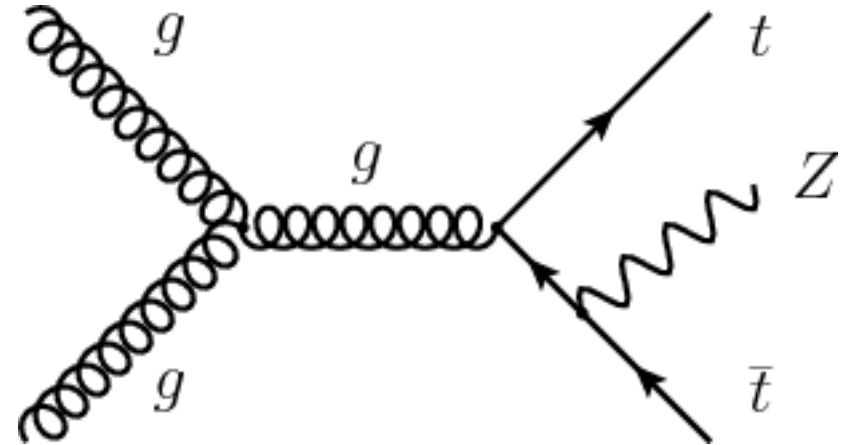




- Higgs is still there at 13 TeV
- Mass and couplings compatible with Run I
- Evidence for ttH mode starts to accumulate; critical for Higgs-top coupling
 - μ_{ttH} still above 1 as in Run I (1.4 σ for $\gamma\gamma, ZZ$)

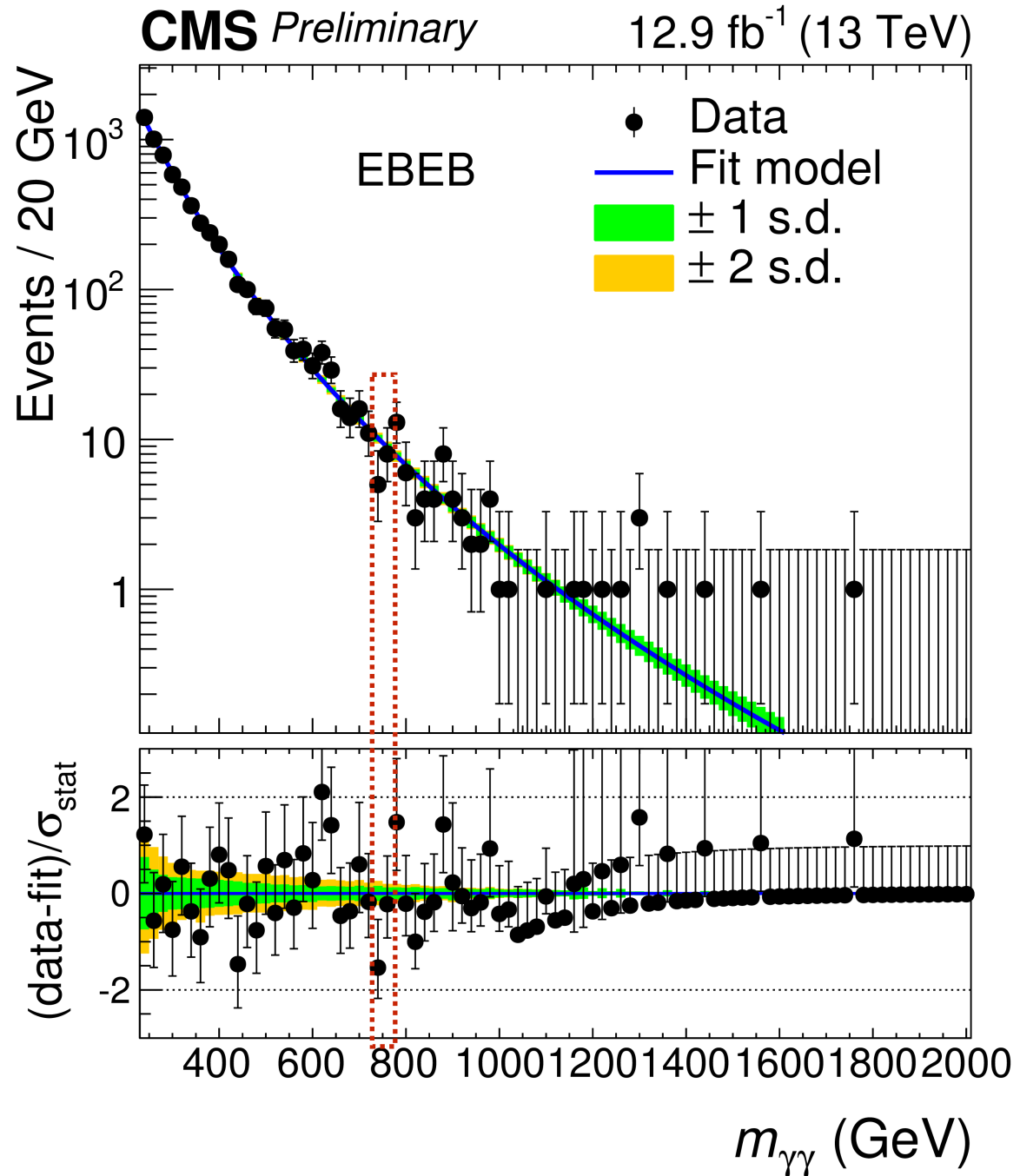
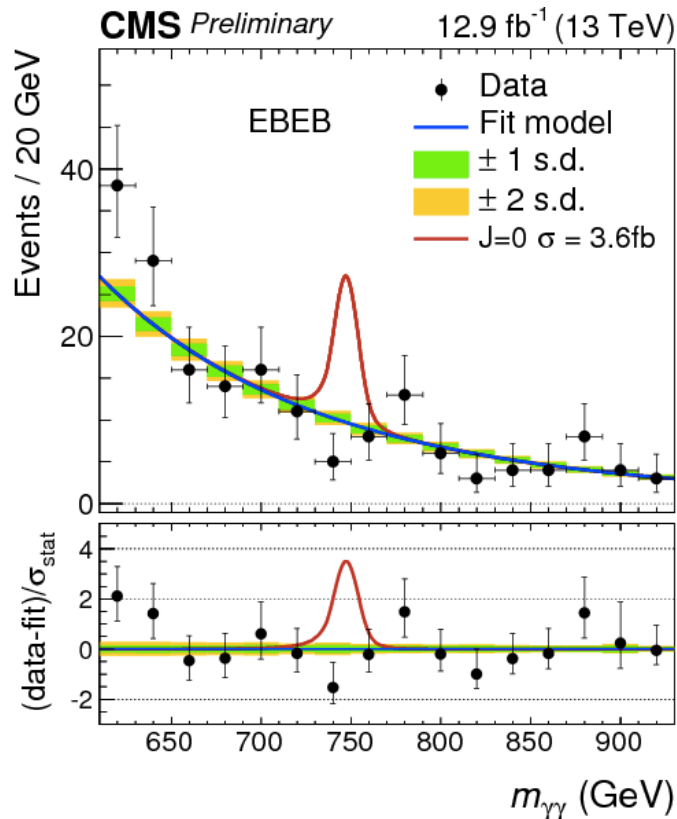


- Channels related to ttH , the ttZ and ttW coming in to view at 13 TeV
- ttZ has same production dynamics as ttH , similar kinematic scales ($m_Z \sim m_H$)
- ttZ most sensitive direct measurement of top- Z coupling

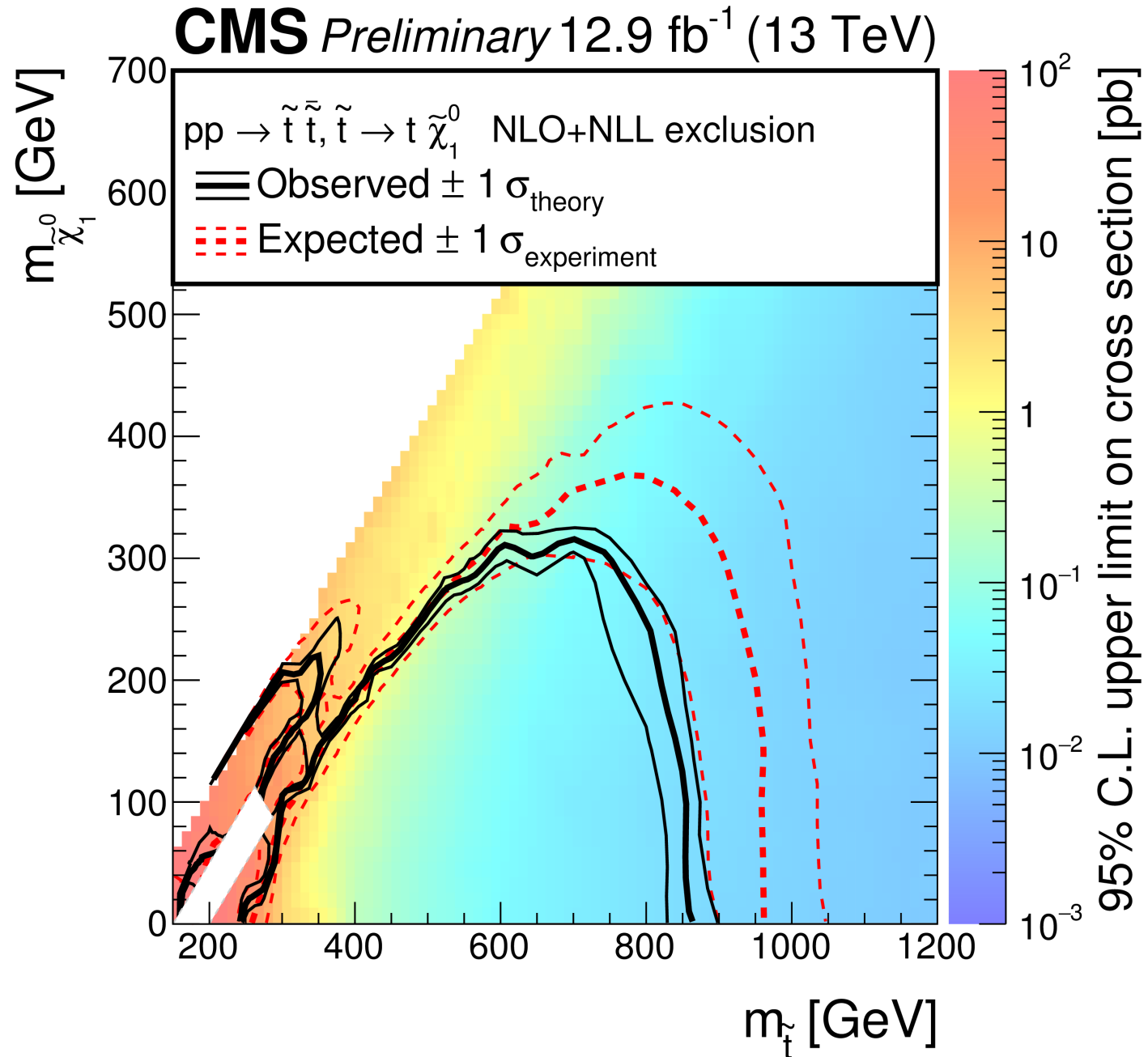


Di-gamma deficit

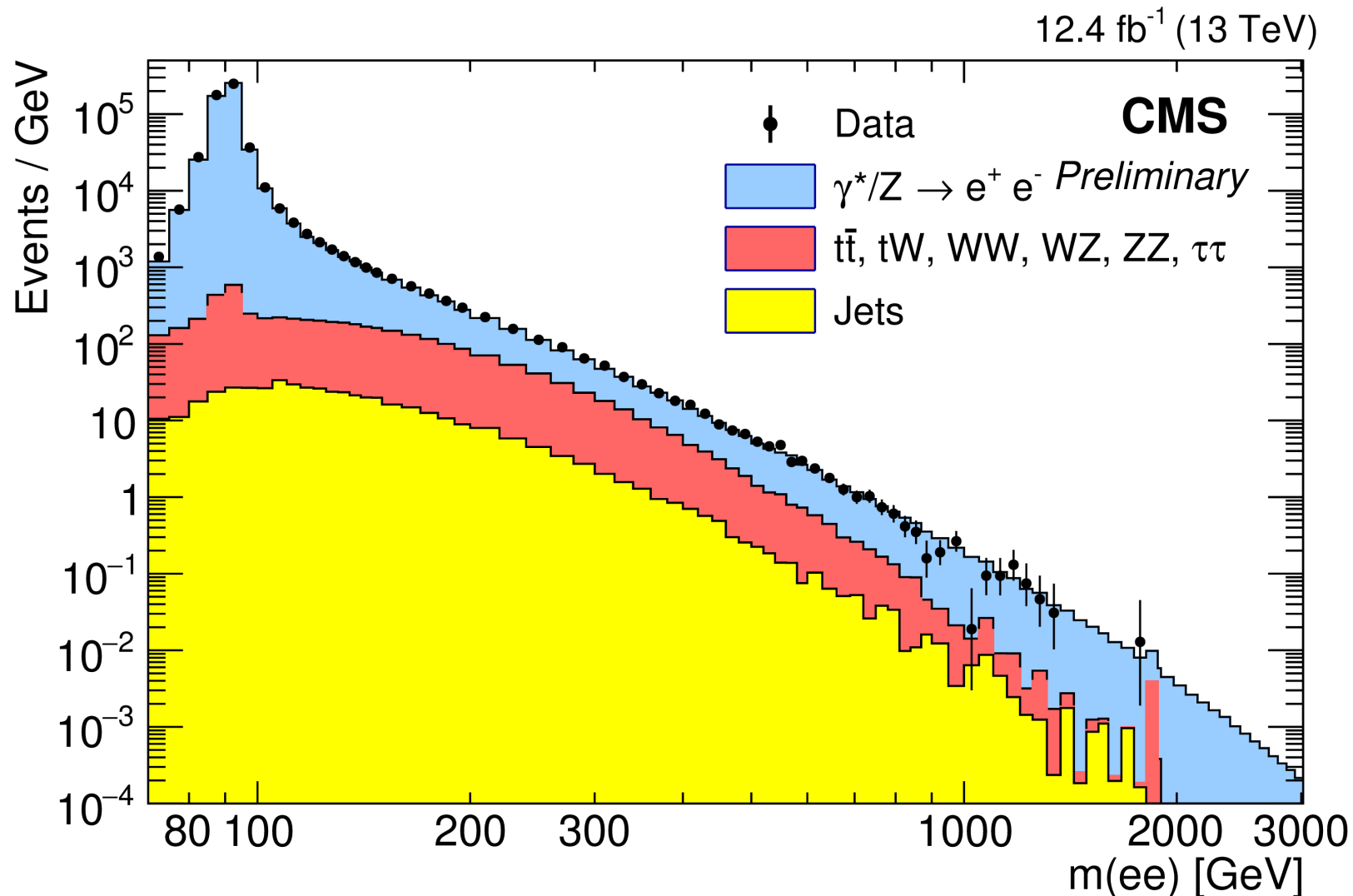
- No hint of a di-gamma resonance (as first indicated in Dec 2015 seminar by ATLAS)
- 750 GeV excess ruled out at a level of quite a few sigma with x3—4 times the data of 2015
- ▶ just to rub it in, there's a nice big **deficit** there at 750 GeV



- SUSY is hiding, as ever
- Limits increased by few hundred GeV at high mass
- In particular gluino and stop searches benefit from higher sqrt(s)
- New generation of SUSY analyses targeting complicated scenarios



- Dilepton resonance peaks have in the past caused some excitement within CMS
 - ▶ 2.9 TeV e^+e^- event in 2015 (DP-2015/039) was memorably almost 3σ by itself
 - ▶ 1 TeV “orange alert” in $ee+\mu\mu$ in early 2011
 - ▶ sadly, nothing to see here this year

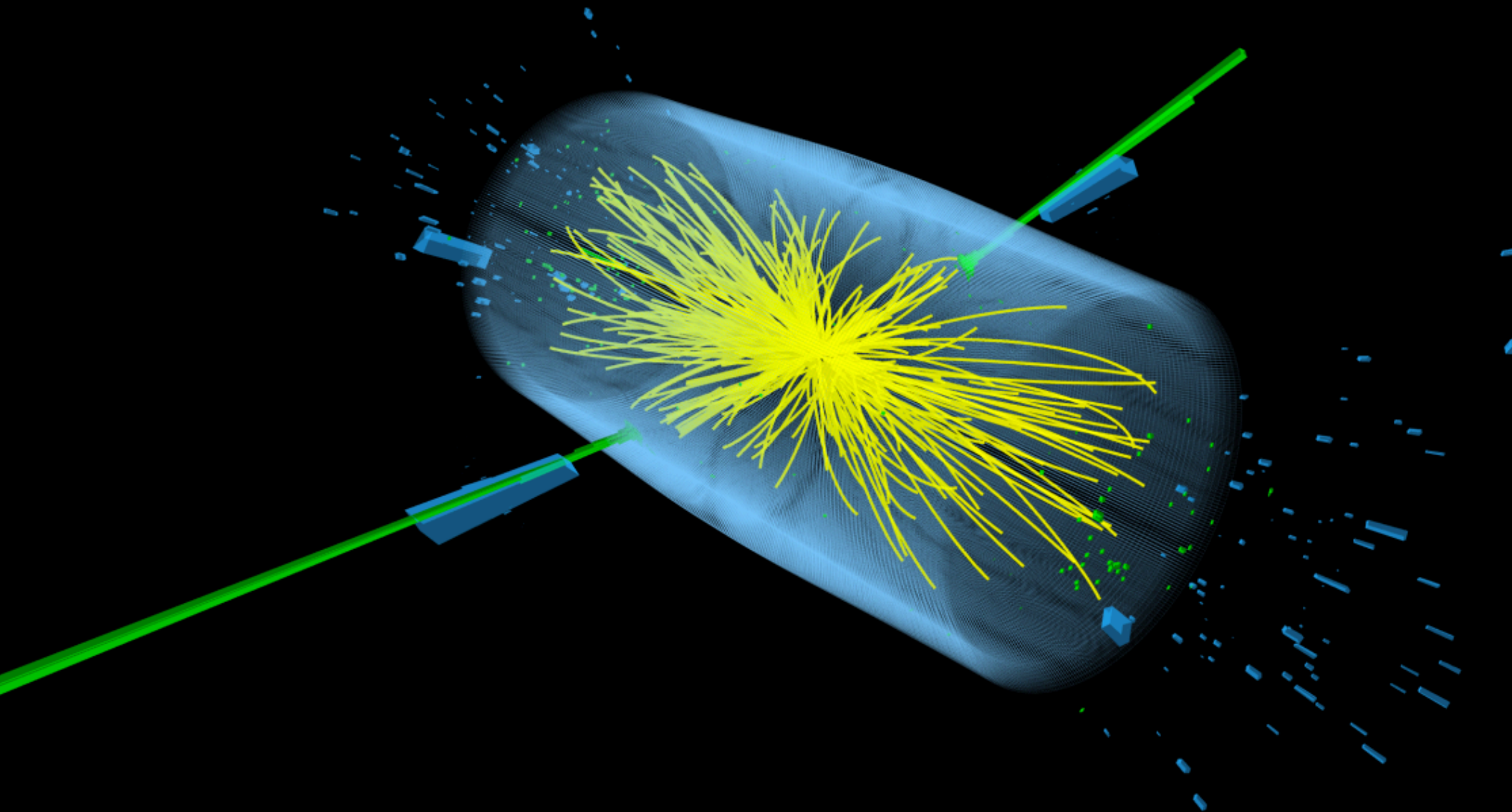


Dijet at 7.7 TeV

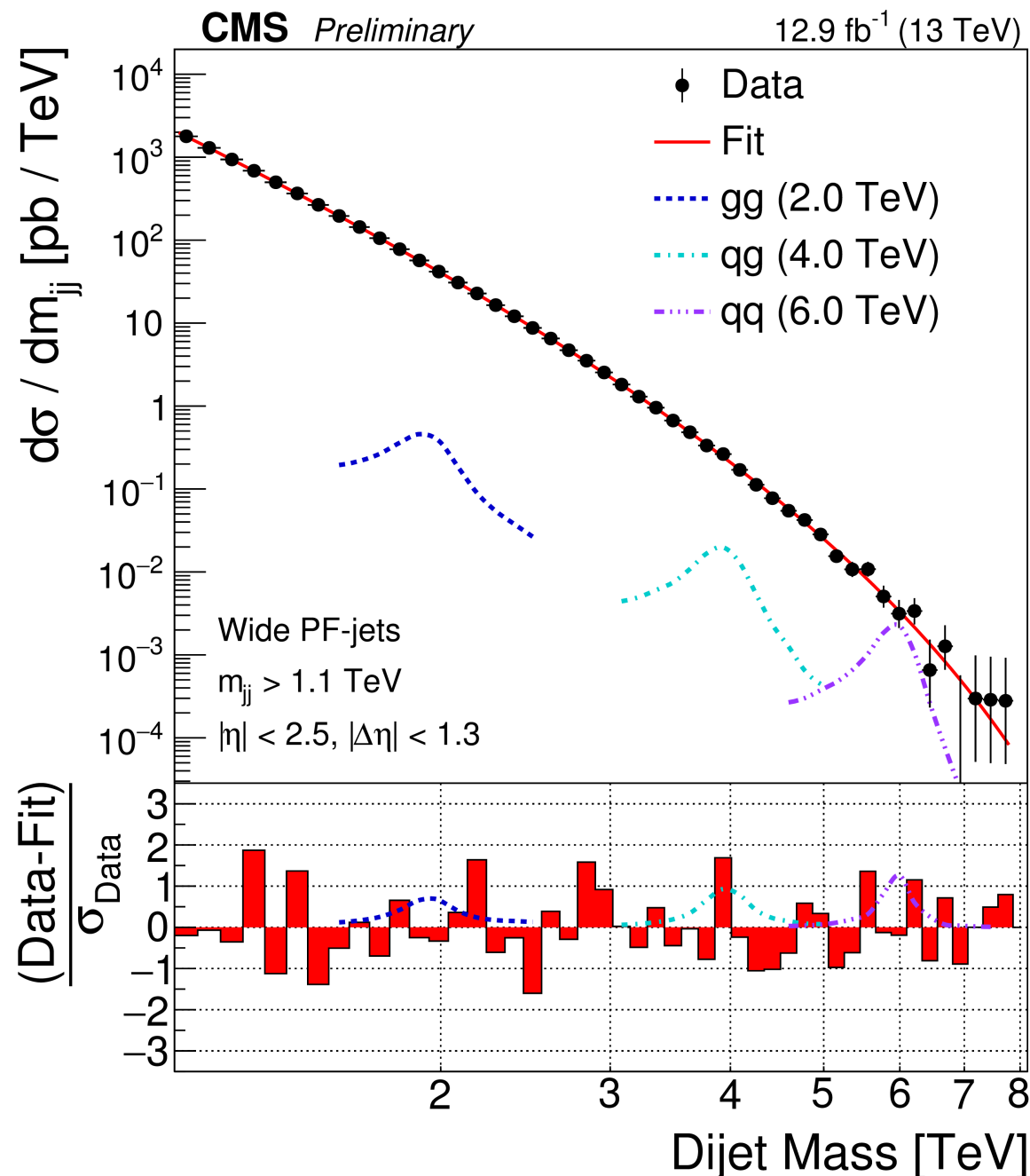
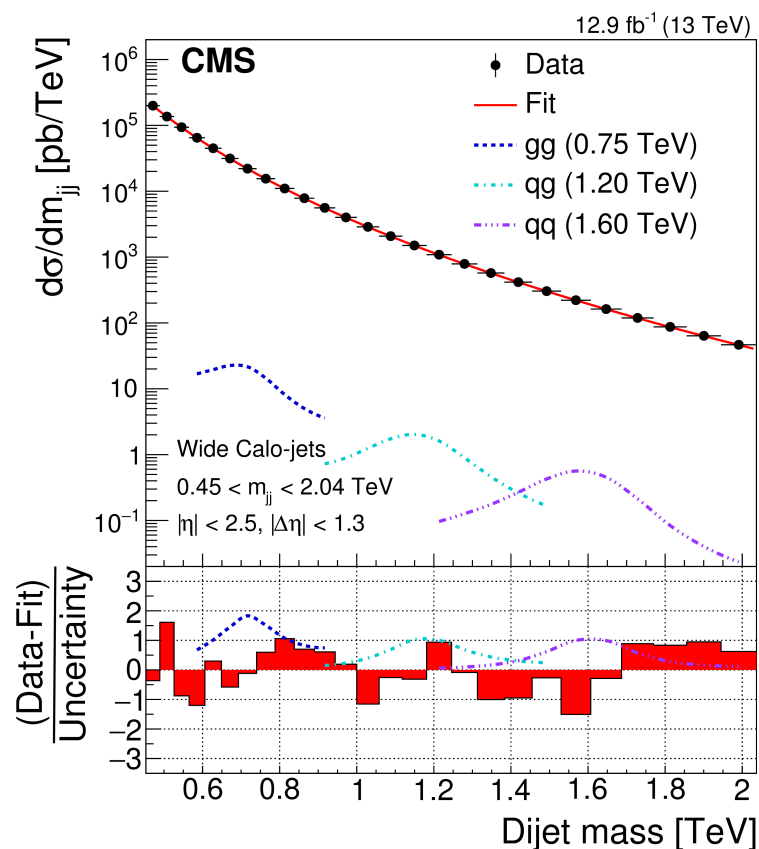
CMS Experiment at the LHC, CERN

Data recorded: 2016-May-11 21:40:47.974592 GMT

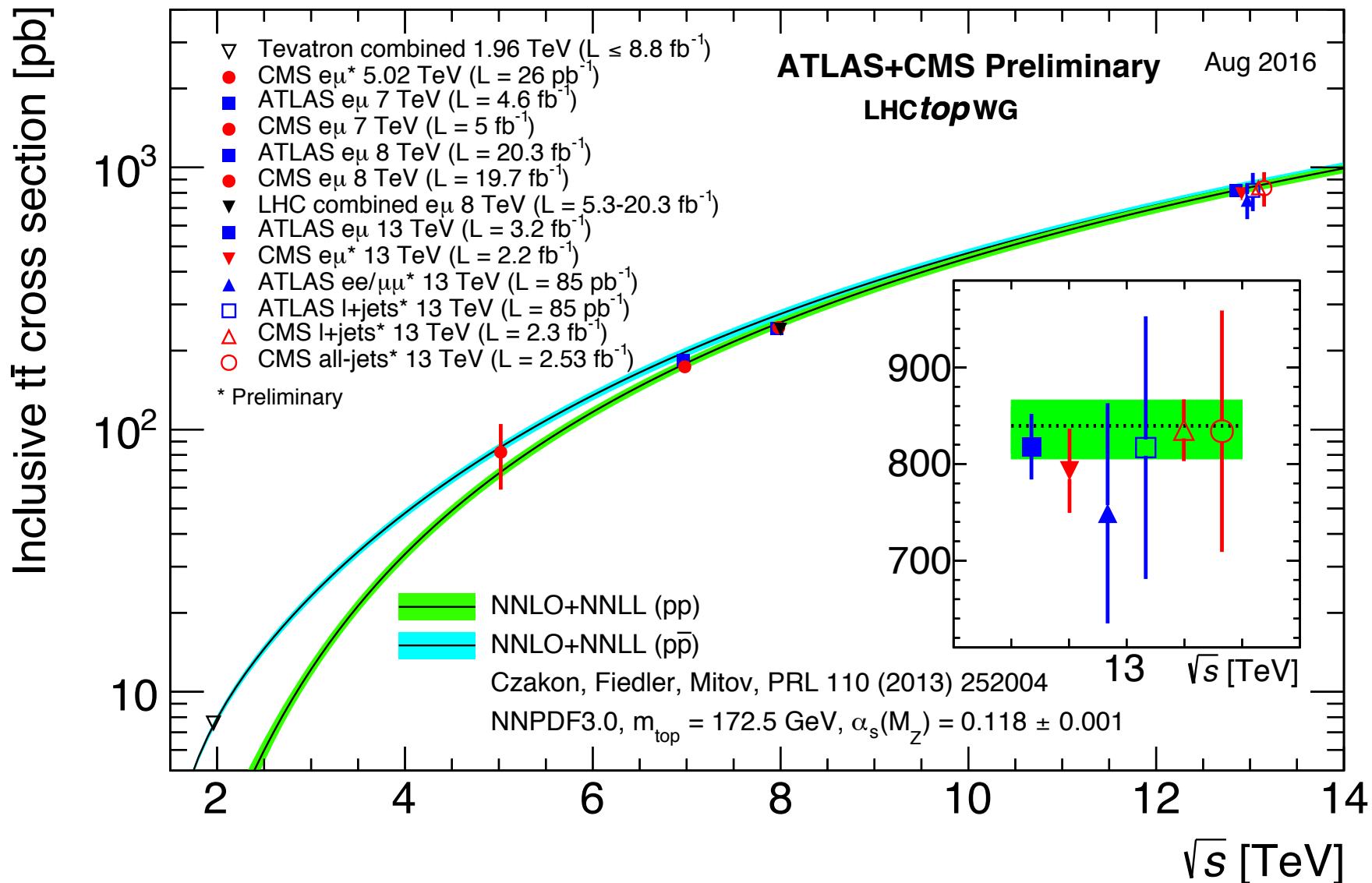
Run / Event / LS: 273158 / 238962455 / 150



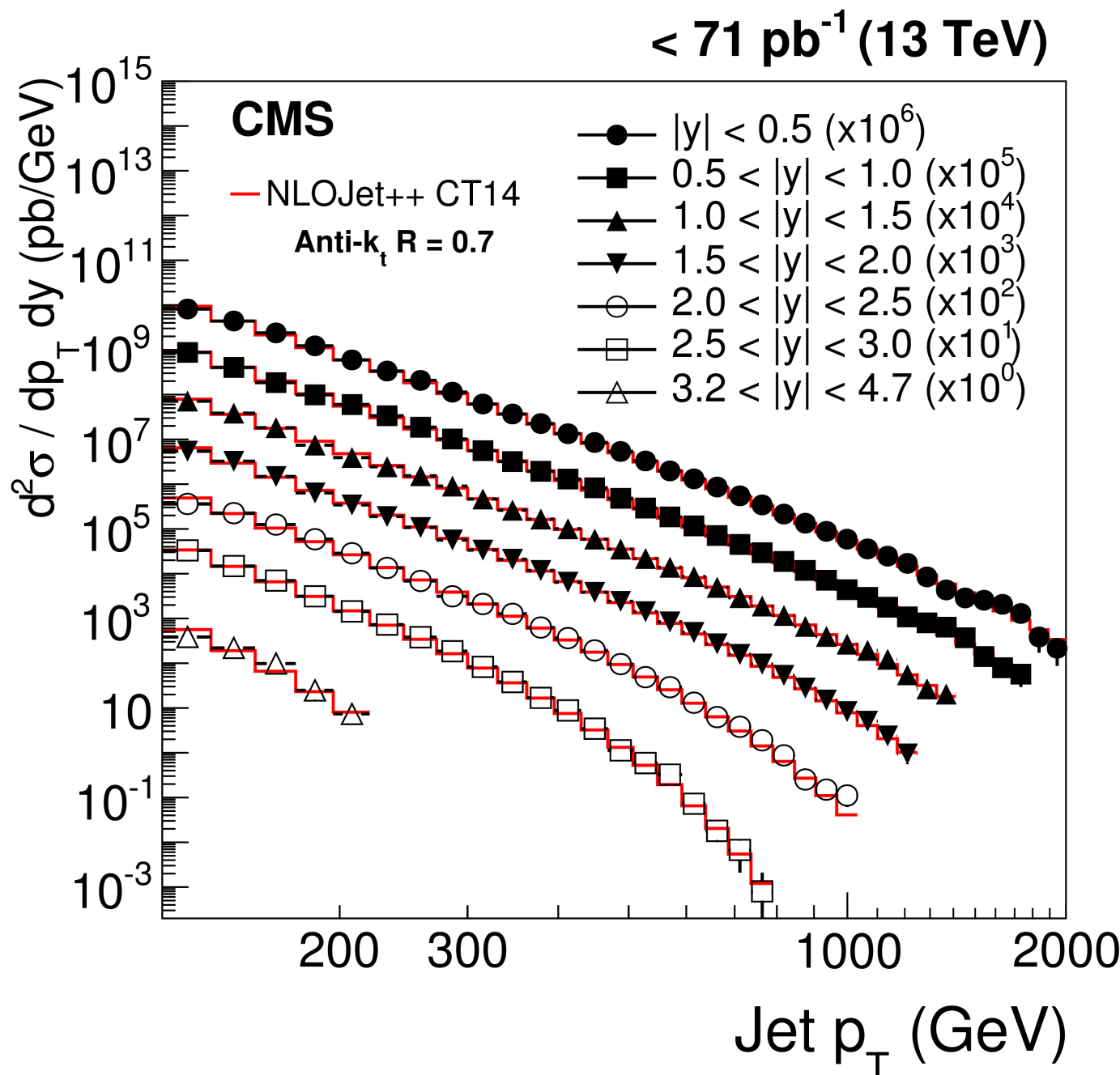
- Dijets extend to very highest masses
- Interesting bump at 2.8 TeV in Run I; also extended down to 500 GeV with trigger-level analysis
- Nothing here, but at least we did have a super-exciting spring

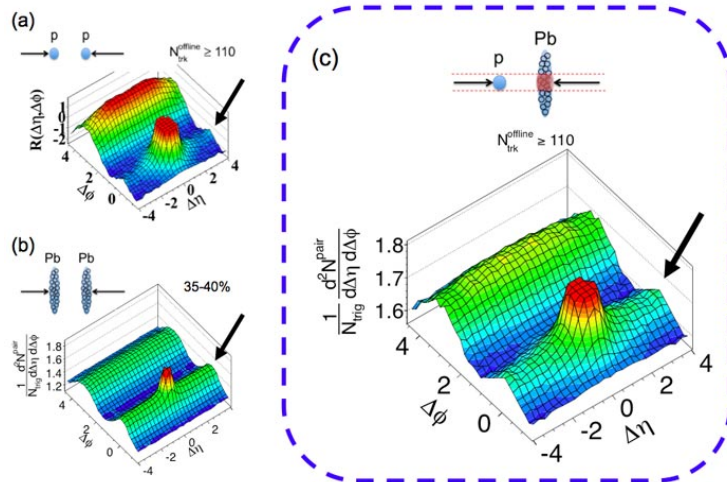


- LHC is a top factory, and $t\bar{t}$ cross section at 13 TeV now well established
 - measurements from CMS and ATLAS agree nicely

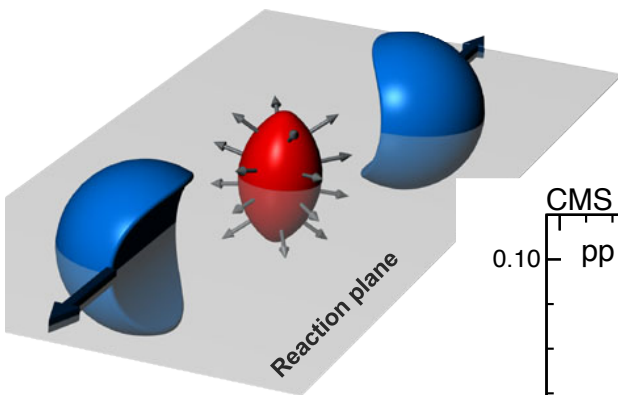


- First 13 TeV Standard Model Physics paper from CMS is inclusive jet cross section
 - rather quick (8 TeV paper of 2012 not yet published)
- Good agreement with NLO pQCD and Powheg (NLO+parton shower) for wide cones $R=0.7$
- For narrow cones $R=0.4$ NLO pQCD is left wanting, but Powheg still works well

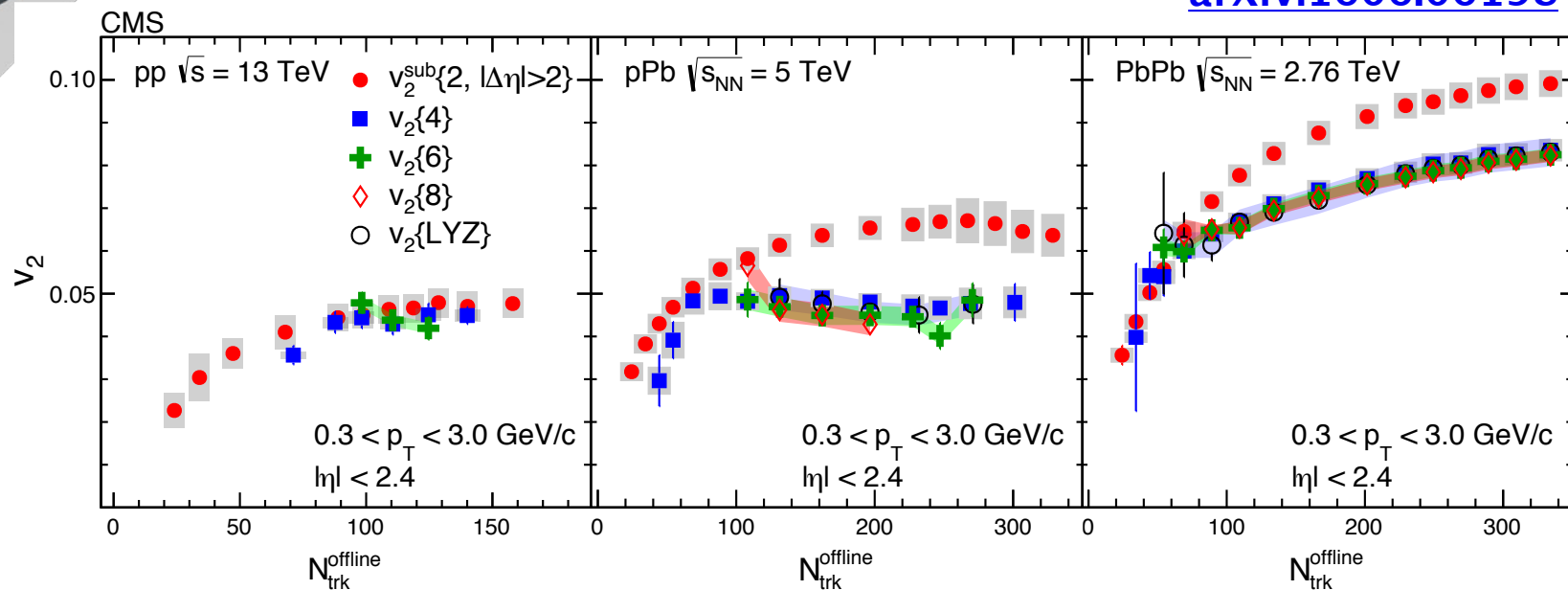




- Collective phenomena in pp confirmed in high multiplicity events at 13 TeV
 - aka “The Ridge”
- Enduring puzzle with striking similarities to collective phenomena in pPb and PbPb
 - v_2 is a measure of elliptic flow

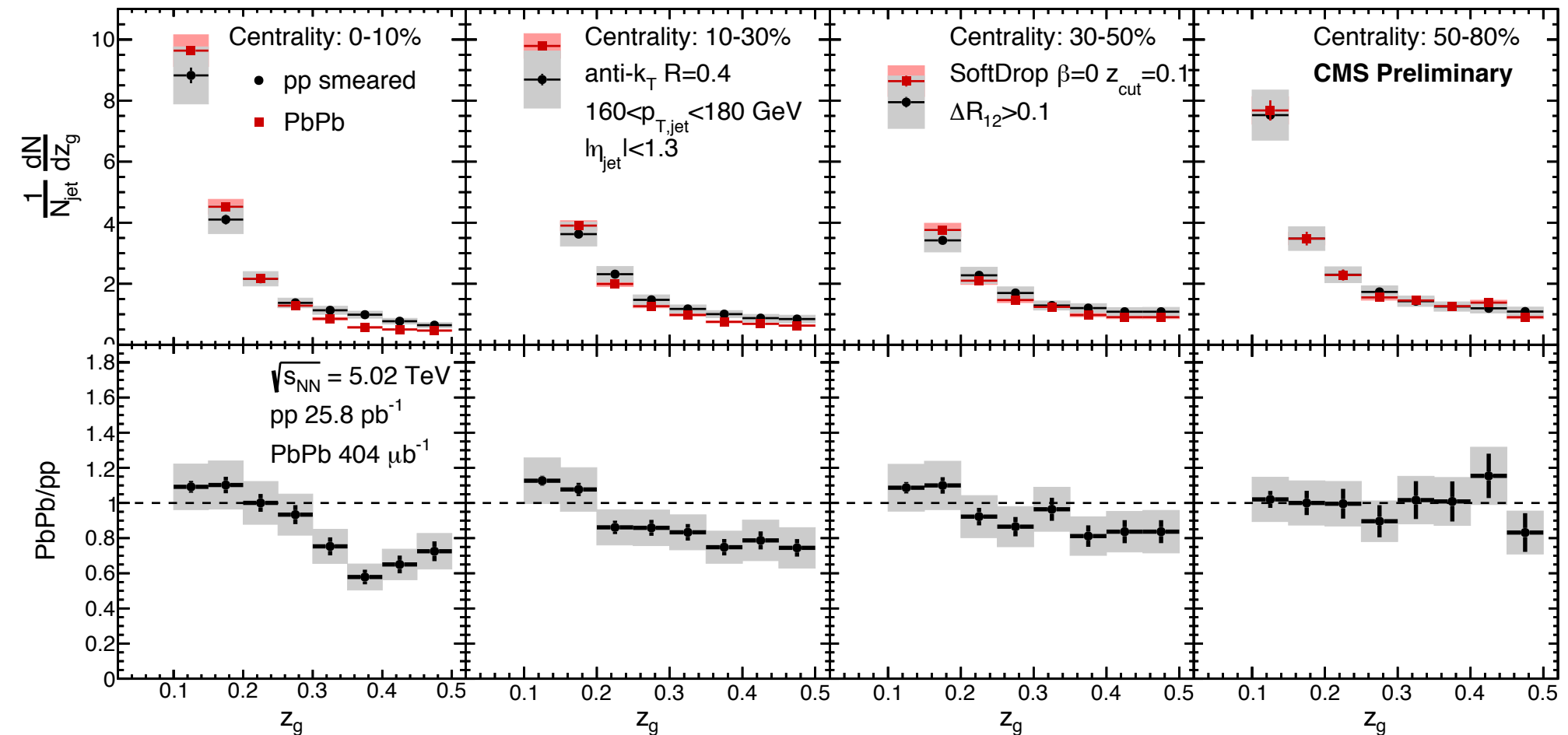
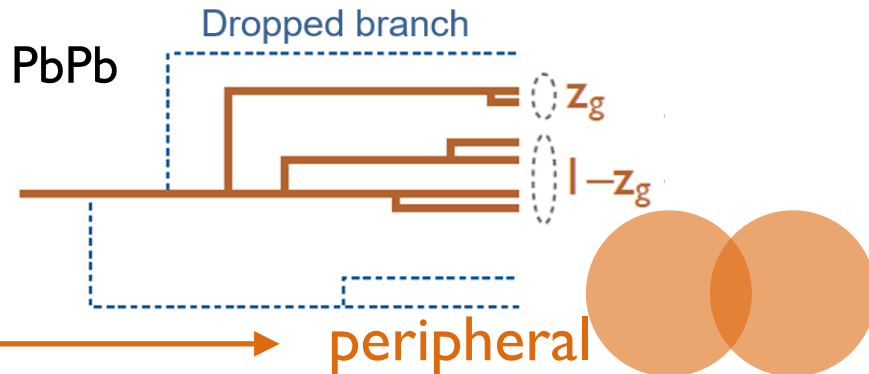


[arXiv:1606.06198](https://arxiv.org/abs/1606.06198)

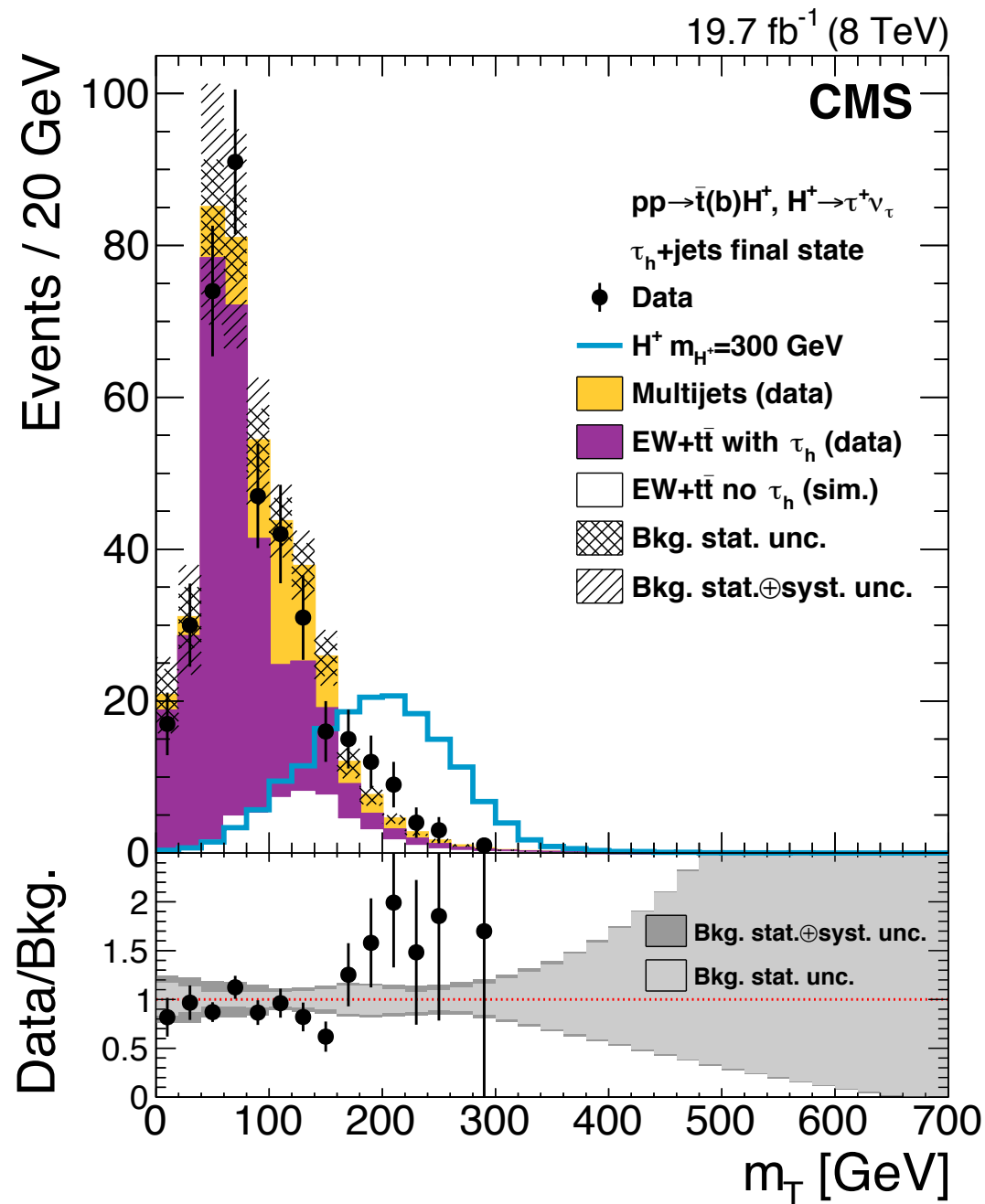
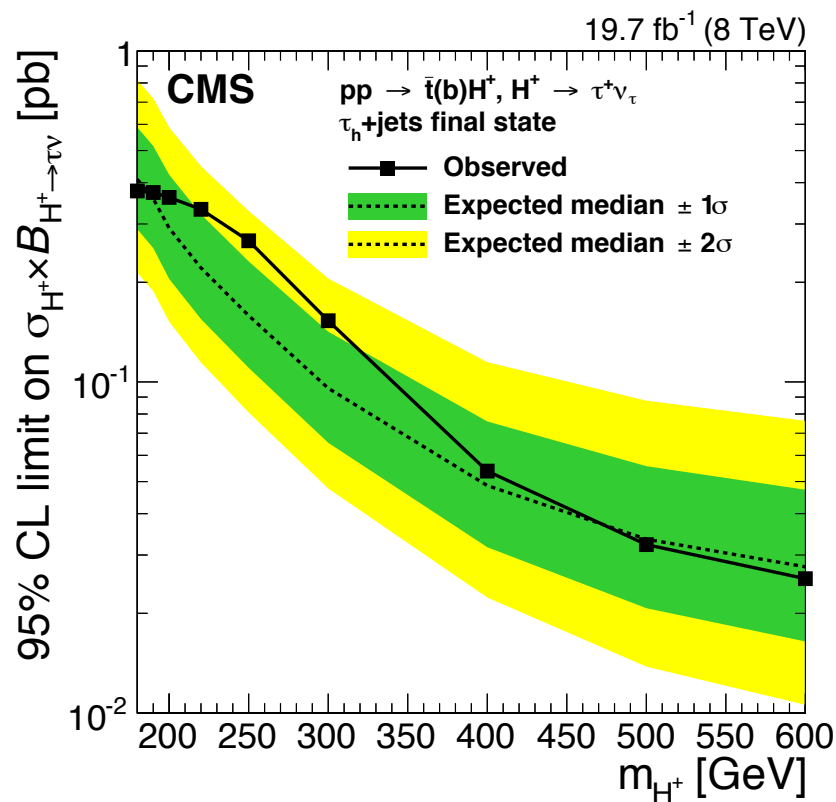


Jet splitting function

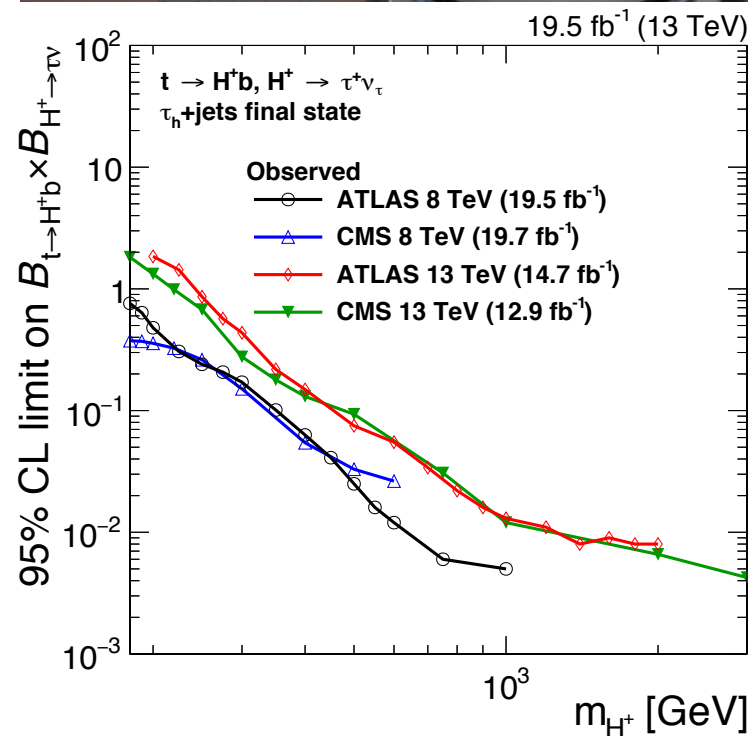
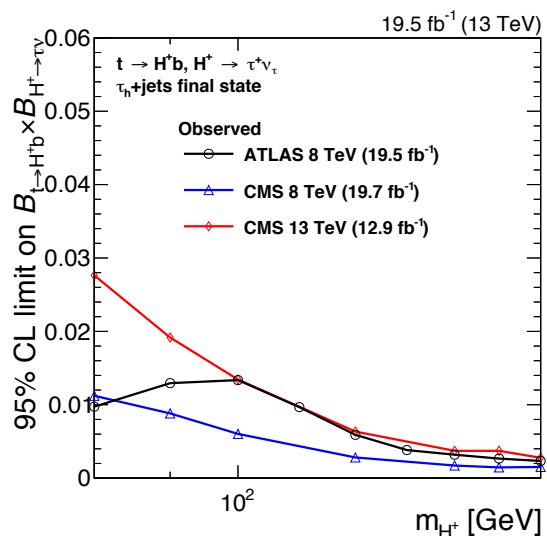
- First general fragmentation measurement in pp and PbPb
- More imbalanced subjet pairs in PbPb



- World best H^+ limits at $m_{H^+} < 400$ GeV
 - Long-time flagship analysis in Helsinki
- Collaboration with MIT in Run II
 - 13 TeV analysis sensitivity approaching Run I
 - exploring further improvements with neutral networks and machine learning

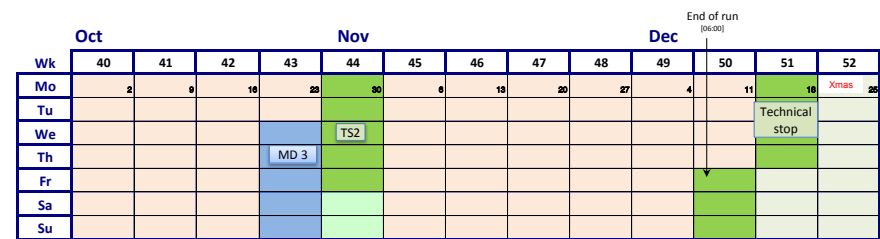
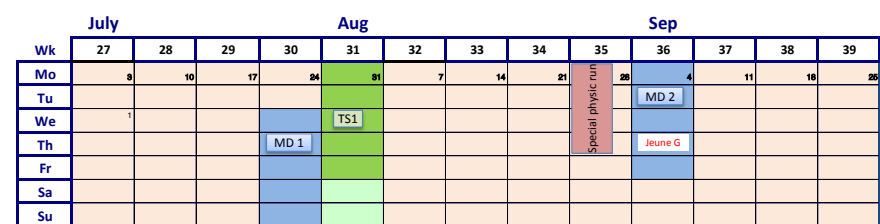
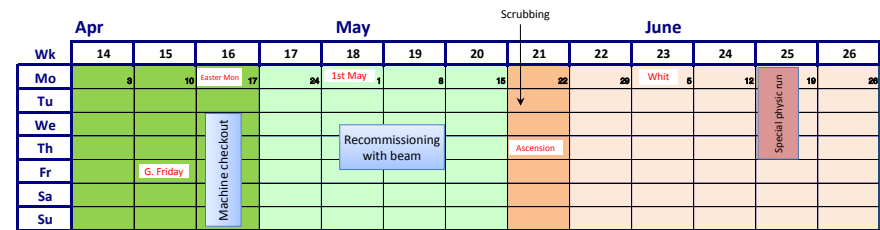


- CMS ahead at low mass

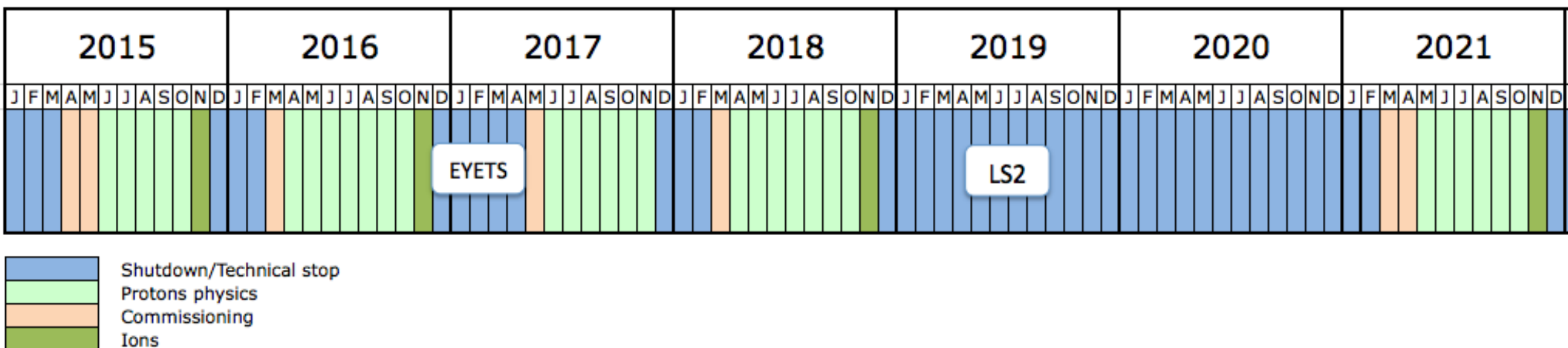


- ...but race is tight at high mass
- HIP+MIT could turn out winner

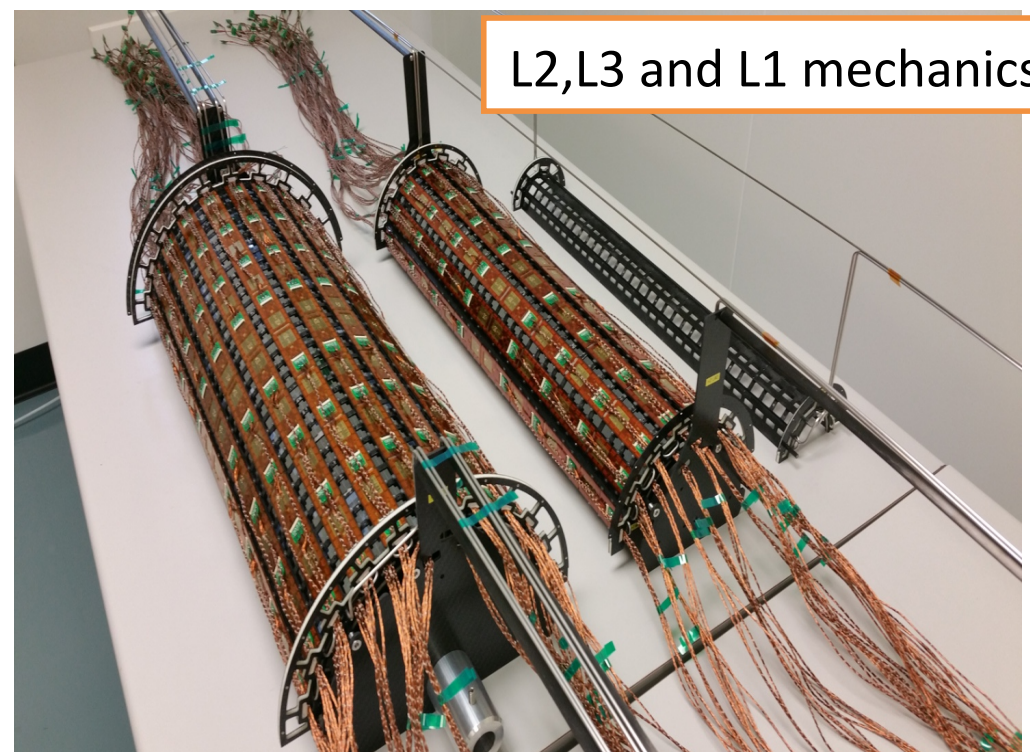
- Goal for 2017 and 2018 is 40—45 fb⁻¹
 - next ion run only end of 2018
- Could reach twice the design luminosity
- EYETS = Extended Year End Technical Stop
 - replace Pixel Detector
 - replace Endcap Hadron Calorimeter (HE) sensors
 - implement Hadron Forward (HF) split anode



4 fb⁻¹ 40 fb⁻¹ 40 fb⁻¹ 45 fb⁻¹

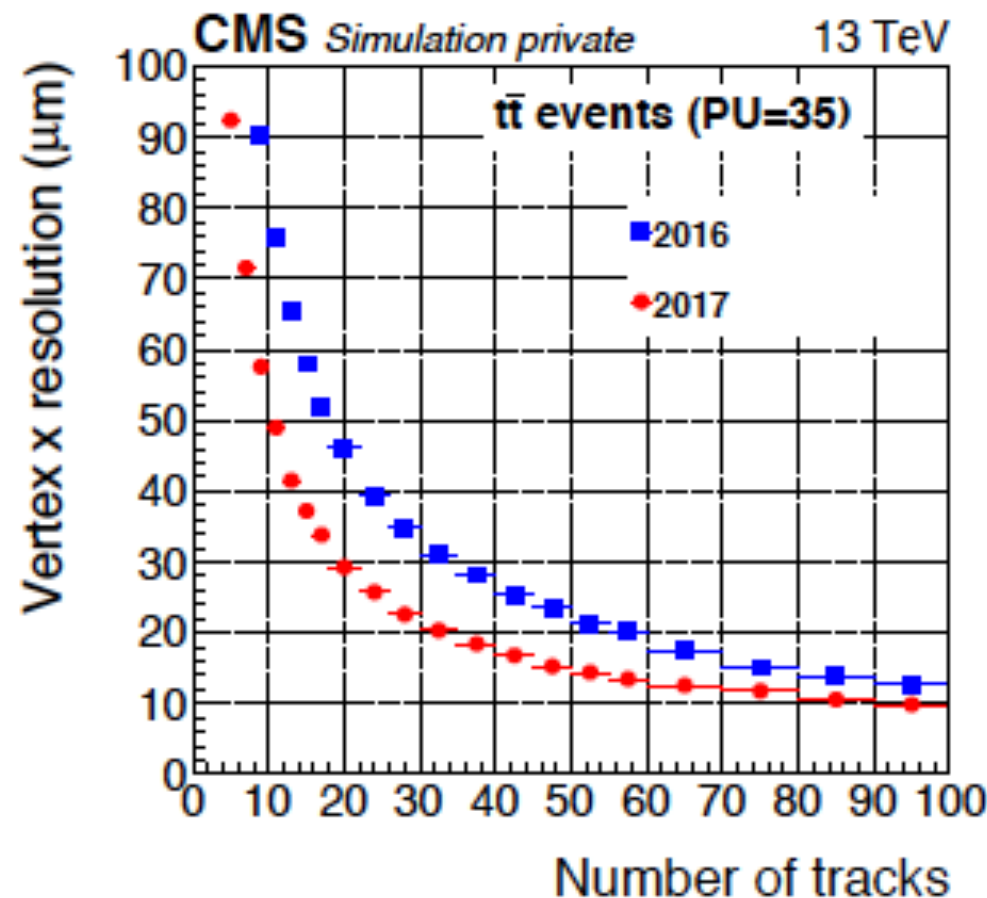
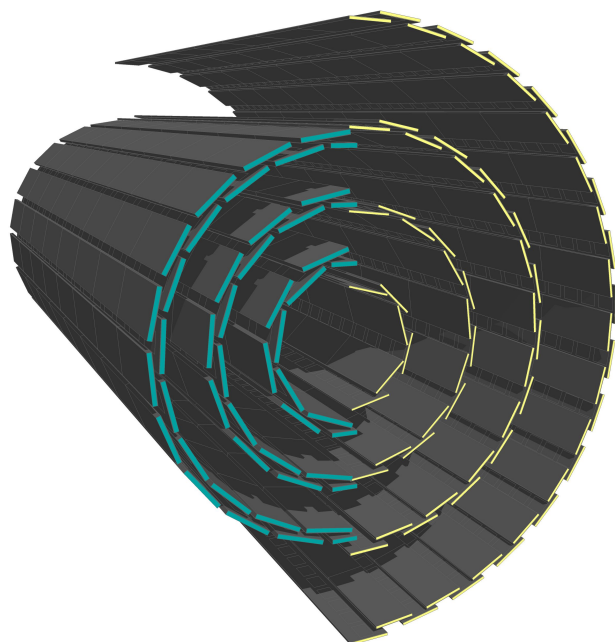


- Pixel phase I upgrade will start ~now
 - add extra layer closer to beam point (3- $\rightarrow$ 4)
 - more radiation hard
 - less material per layer



- Very nice improvements from additional pixel layer and less material
 - vertex resolution will help to distinguish signal from 50 PU within 5 cm beam spot
- Also very important improvements on reconstruction side to benefit from this
- CMS Achievement Award 2016:

Matti Kortelainen (CERN; postdoc):
“For his vital contributions to the performance of the CMS track reconstruction”



- Better resolution (20–40 %)

Time spent in tracking for $t\bar{t}$ event with pileup 35 is 3.7 s/event vs. 3.4 s/event now, but finds 15% more tracks.



CMS outlook

- Focus is shifting towards physics reach with 100 fb^{-1} by end of 2018
- Much extended new physics coverage, lots of potential for precision analyses
- Workshop in Helsinki for jets and missing-ET related plans in May
- December for Higgs planning (more in O. Lebedev's talk)

Helsinki Higgs Forum

14-16 December 2016, Helsinki, Finland

Organizing committee:

Oleg Lebedev (chair)
 Oskari Huittu (vice chair)
 Paula Eerola
 Kari Enqvist

Invited speakers include:

Abdelhak Djouadi (Orsay)
 Graham Ross (Oxford)
 Gustavo Branco (Lisbon)
 Stefano Moretti (Southampton)
 Marike Postma (NIKHEF)
 Sven-Olaf Moch (Hamburg)
 Martti Raidal (Tallinn)
 Christophe Grojean (DESY)
 Tiha Memvisek (Ljubljana)
 Ilman Plehn (Heidelberg)
 Arthur Hebecker (Heidelberg)
 Kimmo Kainulainen (Jyväskylä)
 Fatya Khooze (Durham)
 Howard Haber (Santa Cruz)*
 Bernd Kniehl (Hamburg)
 Per Osland (Bergen)
 José Espinosa (Barcelona)
 Arttu Rajantie (IC London)

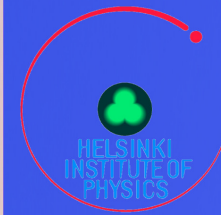
(* = to be confirmed)



Are we on the right track?

www.hip.fi/hhf

Credit: Sampsa Sulonen



HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Helsinki JetMET workshop: Physics at 100 fb^{-1}

10-12th May, 2017
in Helsinki, Finland

The LHC is set to collect over 100 fb^{-1} at 13 TeV by the end of Run 2 in 2018. This will allow unprecedented reach in searches of new physics and precision measurements.

This 4th JetMet workshop will review the status of the object performance with 2016 data, and plan for the ultimate precision reachable with full 100 fb^{-1} and with advanced tools and methods.

Registration and agenda:
www.hip.fi/jetmet100



International organising committee

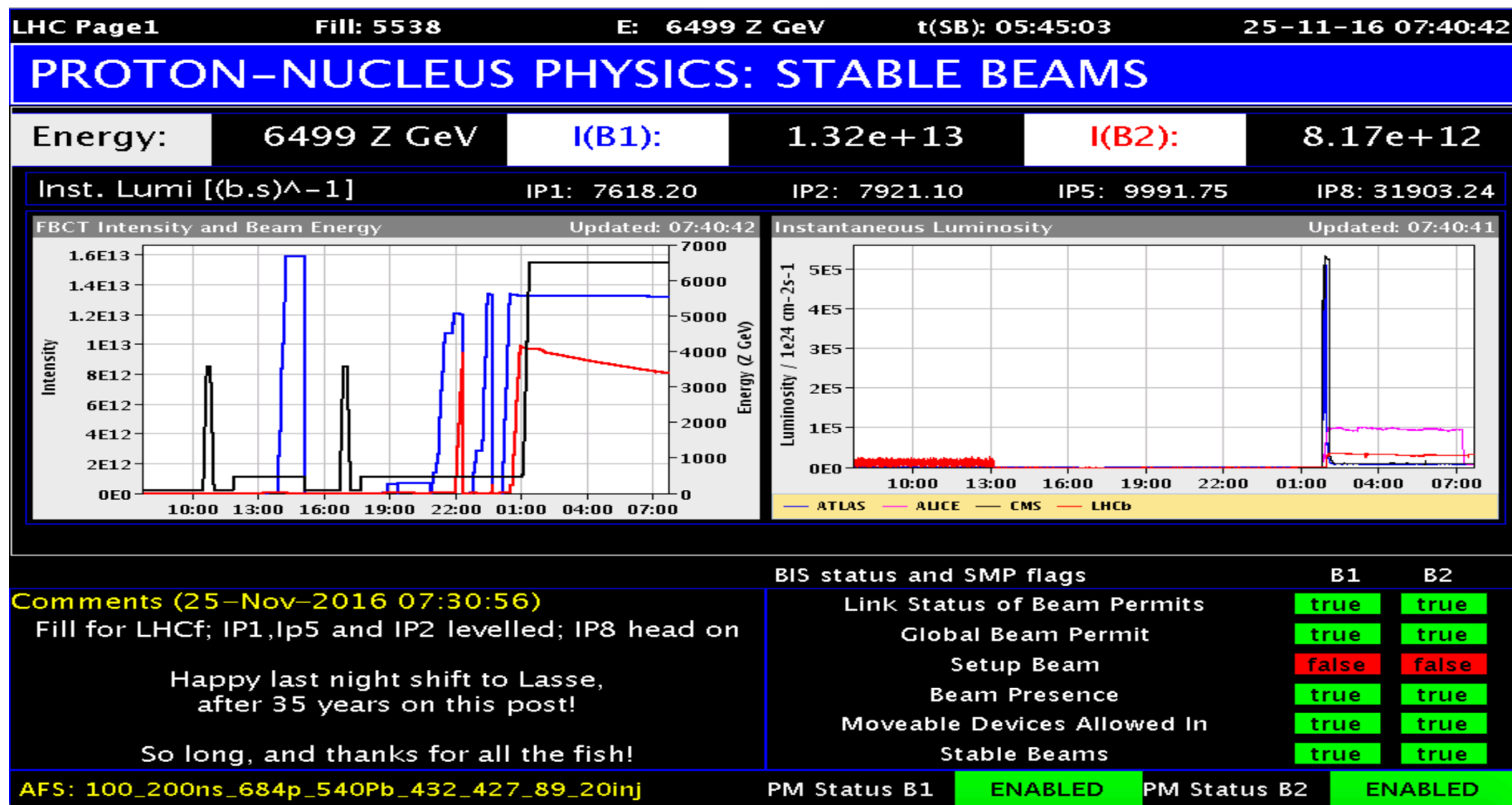
Henning Kirschenmann (CERN)
 Seema Sharma (IISER Pune)
 Robert Schoefbeck (Ghent U.)
 Mikko Voutilainen (Helsinki U.)

Local organising committee

Joona Havukainen
 Jaana Heikkilä
 Tapio Lampén
 Santeri Laurila
 Tomas Lindén
 Juska Pekkanen
 Hannu Siikonen
 Mikko Voutilainen



- “Jos et lottoa, et voi voittoa” (if you don’t play the lottery, you can’t win)
- No jackpot this year, but we’ll keep trying; eyes on 100 fb^{-1} !
- Lots of new results already out by ICHEP, lots more coming for Moriond 2017 and beyond
 - pPb run still on-going for those interested in heavy ions



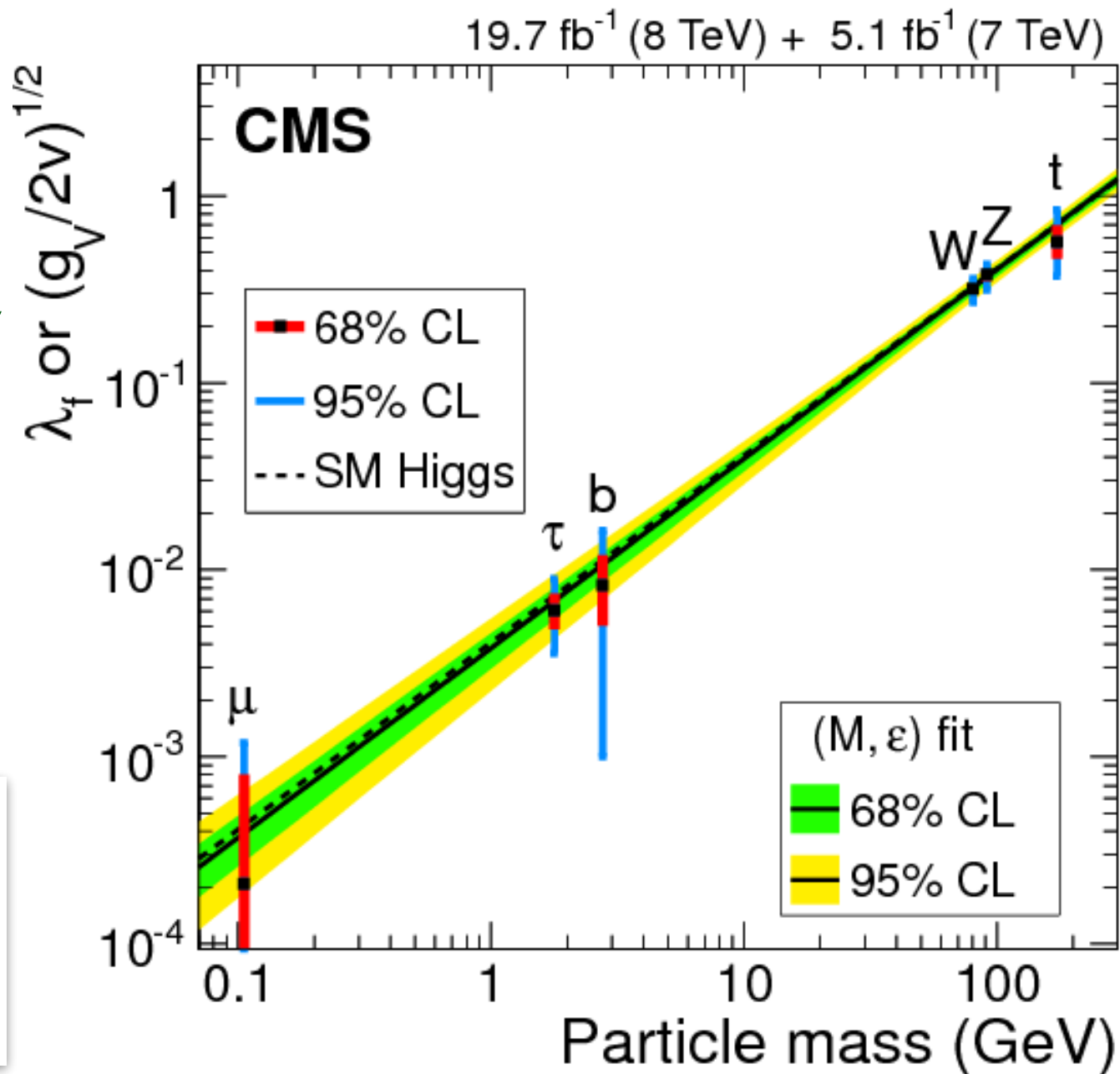
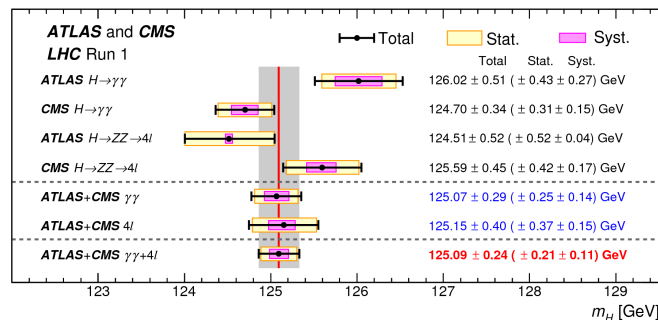
Backup slides

Mikko Voutilainen,
University of Helsinki and
Helsinki Institute of Physics

- ‘a’ Higgs boson, last missing piece of Standard Model
- Couplings to SM particles agree with expectations
- Mass measurement from combination with ATLAS:
 $m_H = 126.09 \pm 0.24$ GeV

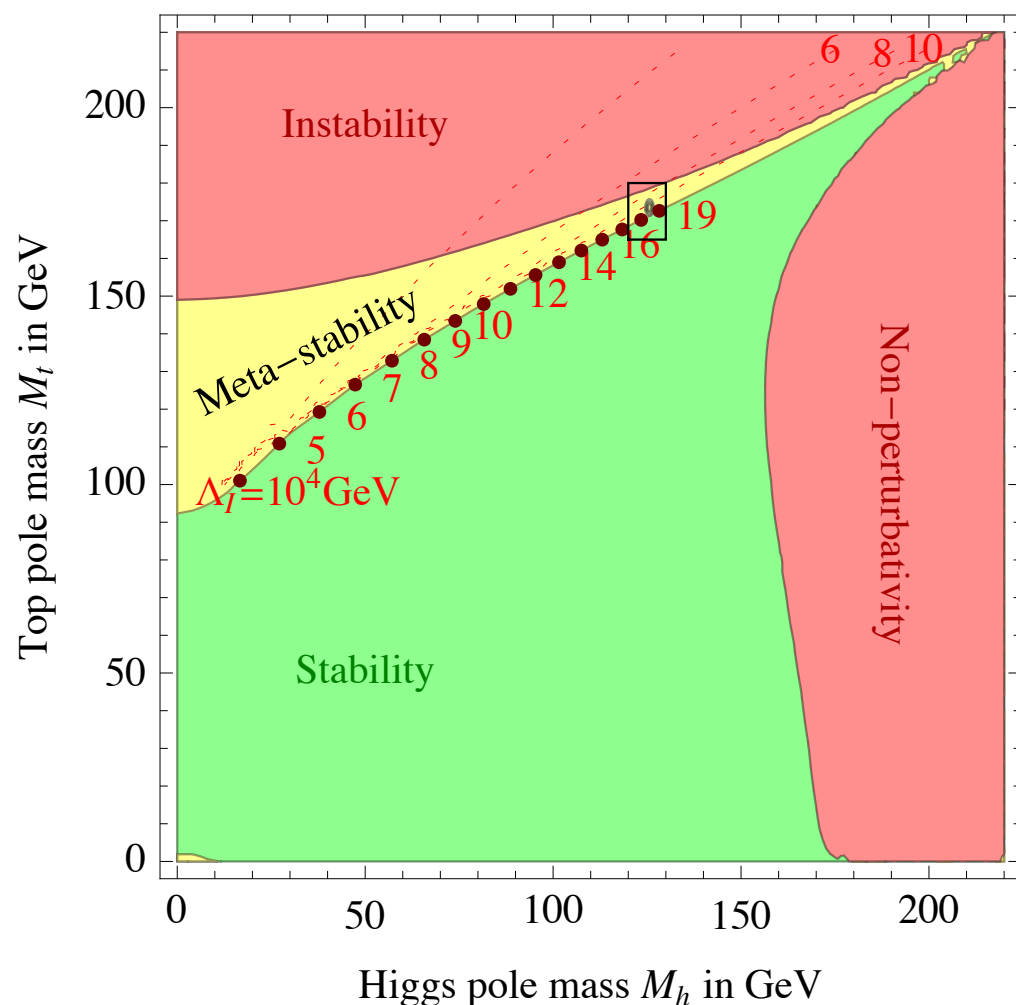


- For Higgs properties with combined CMS+ATLAS data, see talk by Jaana Heikkilä

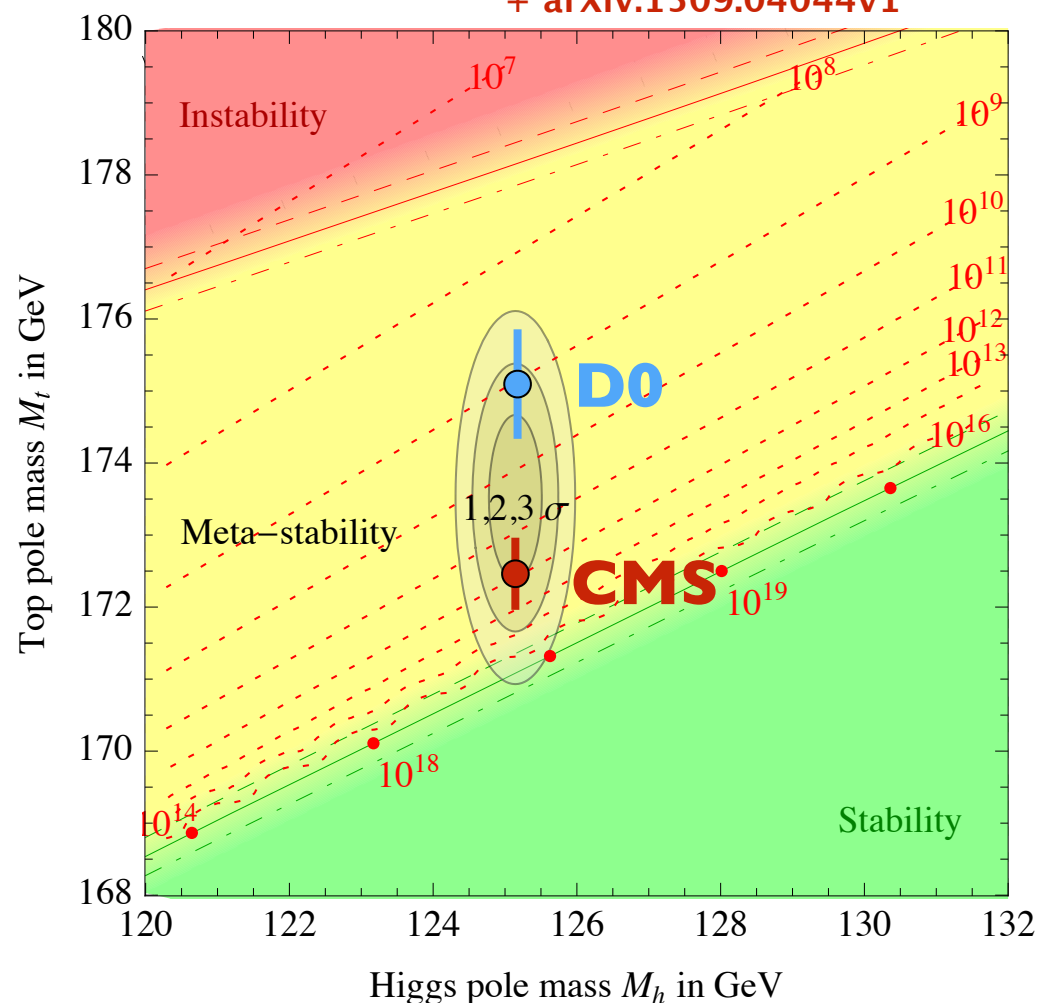


- The enduring puzzle from LHC Run I is the apparent metastability of SM vacuum
 - But, calculations only hold if no new particles between here and Planck scale
- Tension between LHC (CMS) and Tevatron (D0) lepton+jets also needs to be resolved

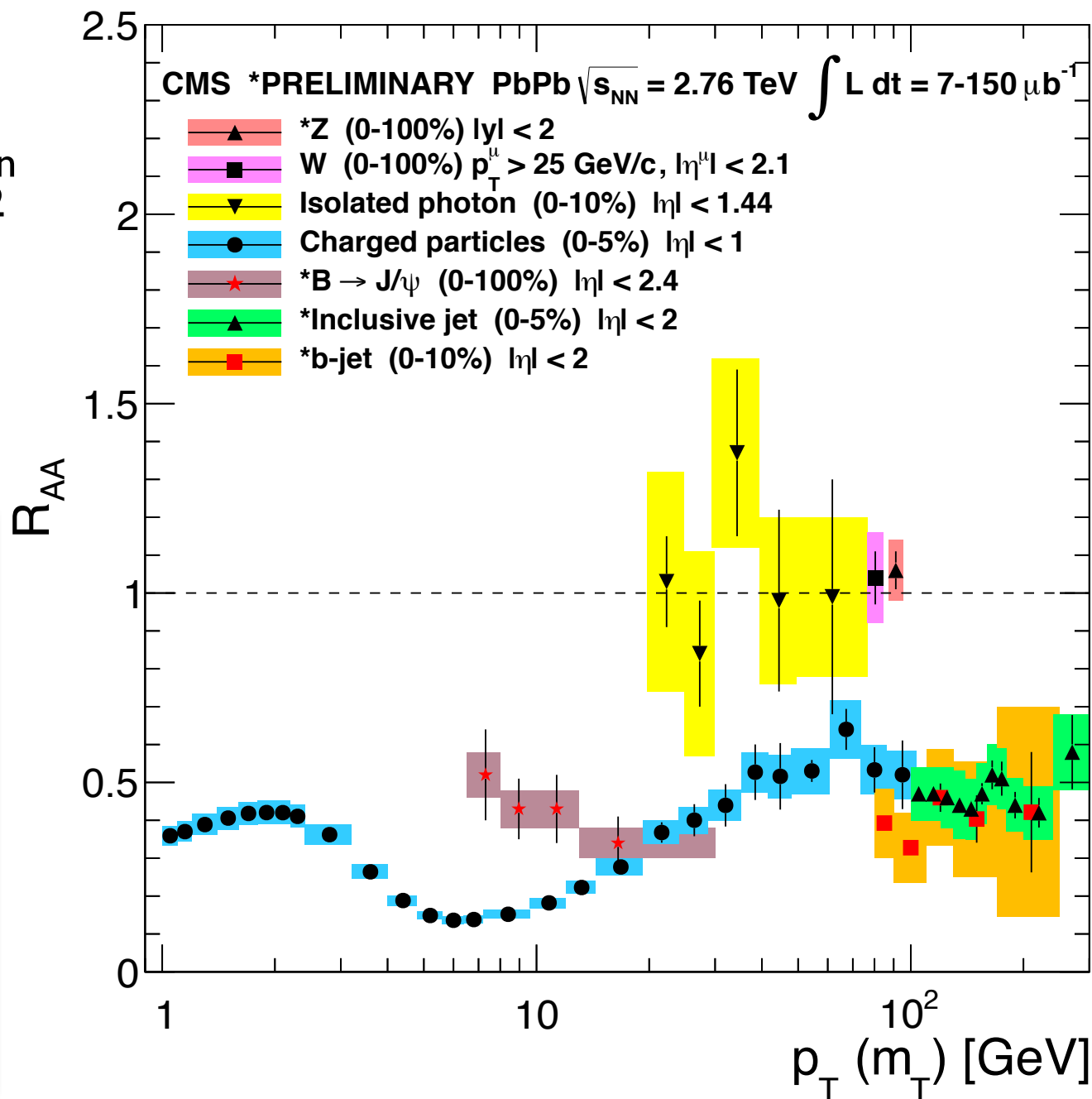
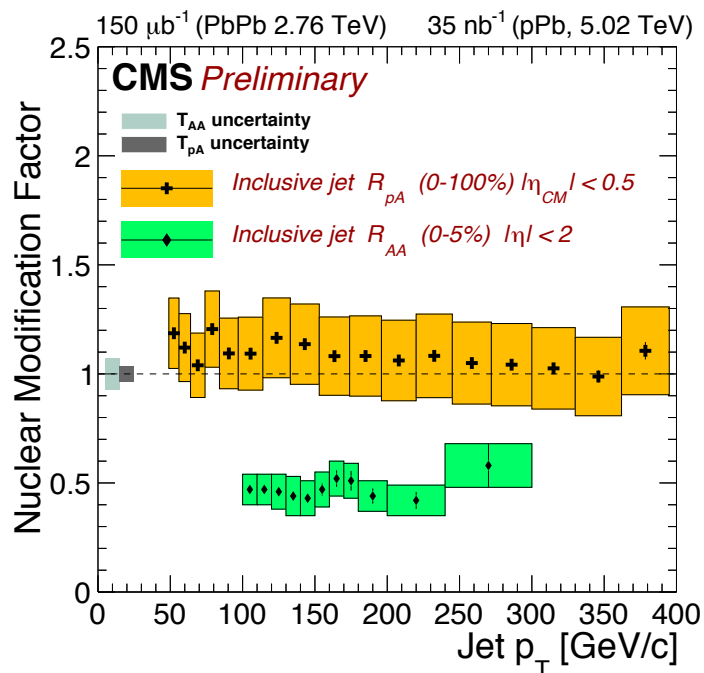
arXiv:1307.3536v4



arXiv:1307.3536v4 + arXiv:1407.2682v2
+ arXiv:1509.04044v1



- Big discovery: dijet quenching
 - **Q**uark **G**luon **P**lasma (is liquid)
- Nuclear modification factors in **PbPb** collisions (R_{AA}) in 2012
 - **hot** nuclear matter effects
- Reference **pPb** in 2013 (R_{pA})
 - **cold** nuclear matter effects



- Energy increased from 8 to **13 TeV**
 - **Parton luminosities** up from $\times 10$ at 1.5 TeV to $> \times 100$ above 3.5 TeV
 - **(much) more gain at higher masses M_x**
- Collision spacing from 50 ns to 25 ns
 - doubles collision rate
 - reco updated to fit overlapping pulses
- Pileup from 21 (2012) to 34 (2015 target)
 - challenge, but not a problem up to 40-50

