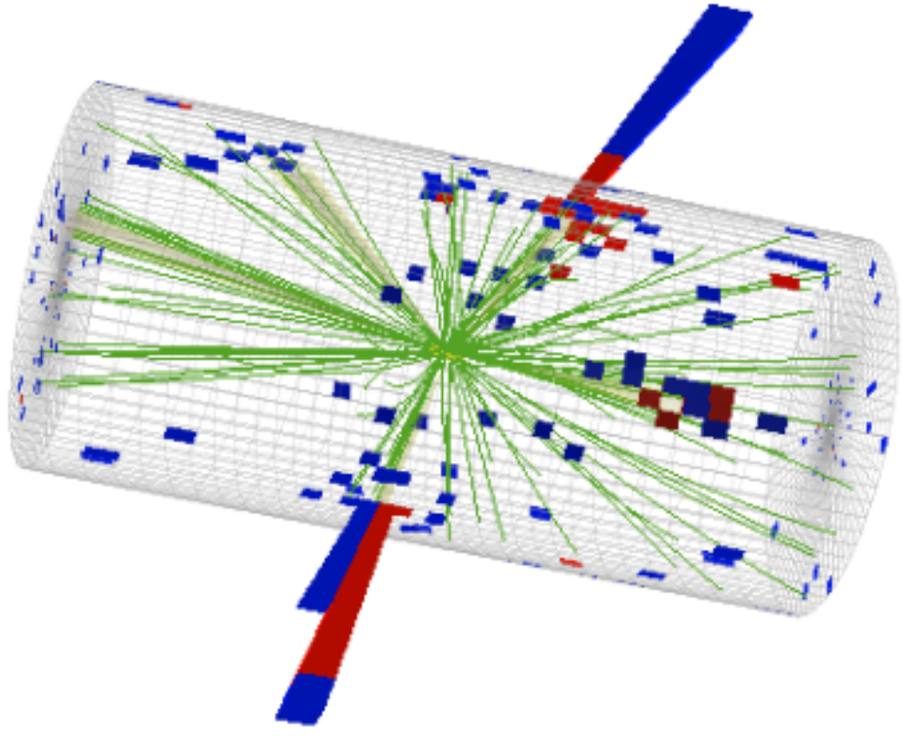
PHYSICS STATUS AND OUTLOOK

Shahram Rahatlou
CMS Italia, Piacenza, 30 Nov 2017



SAPIENZA UNIVERSITÀ DI ROMA

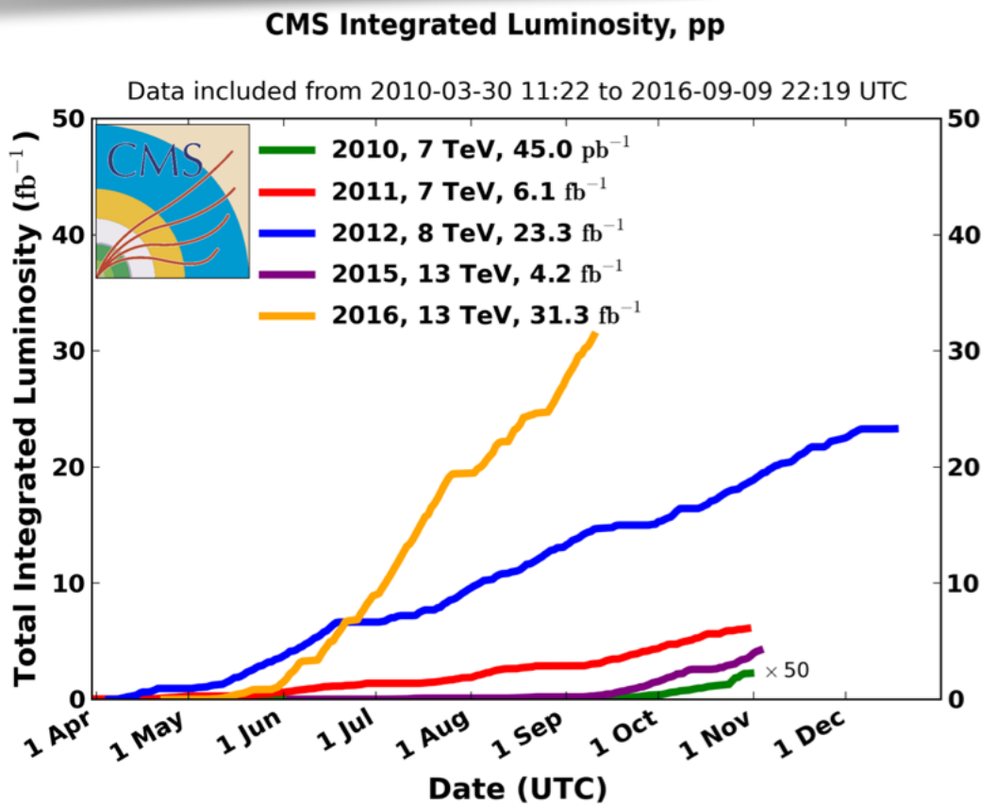
INFN Istituto Nazionale di Fisica Nucleare

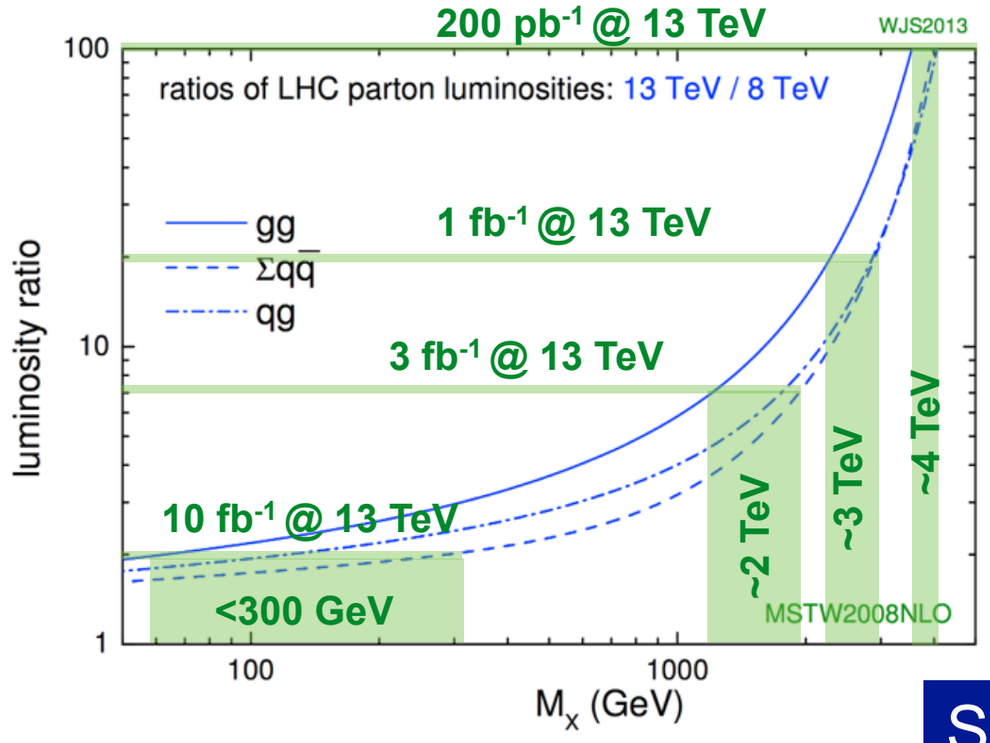
CERN

OUTLINE

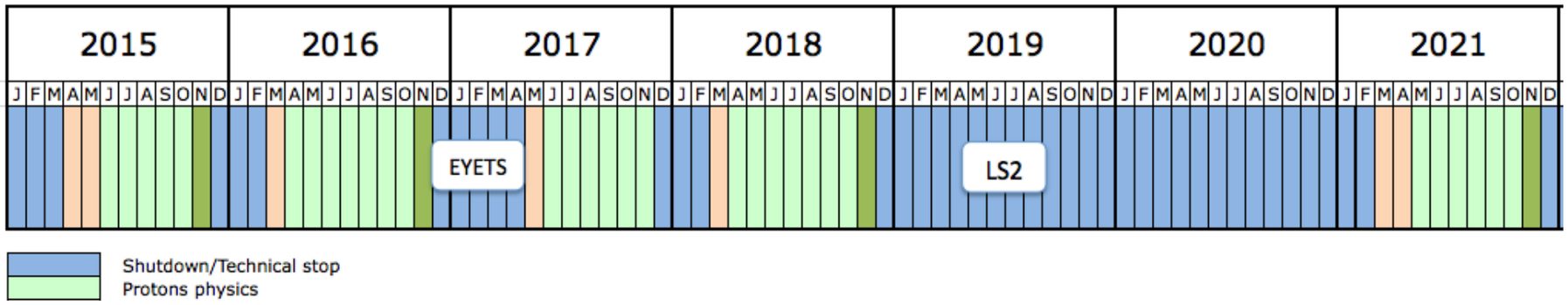
- Plan for 2017
- Highlights
- Publication strategy and status
- Prospects and challenges ahead

TRANSITION TO HIGH LUMINOSITY



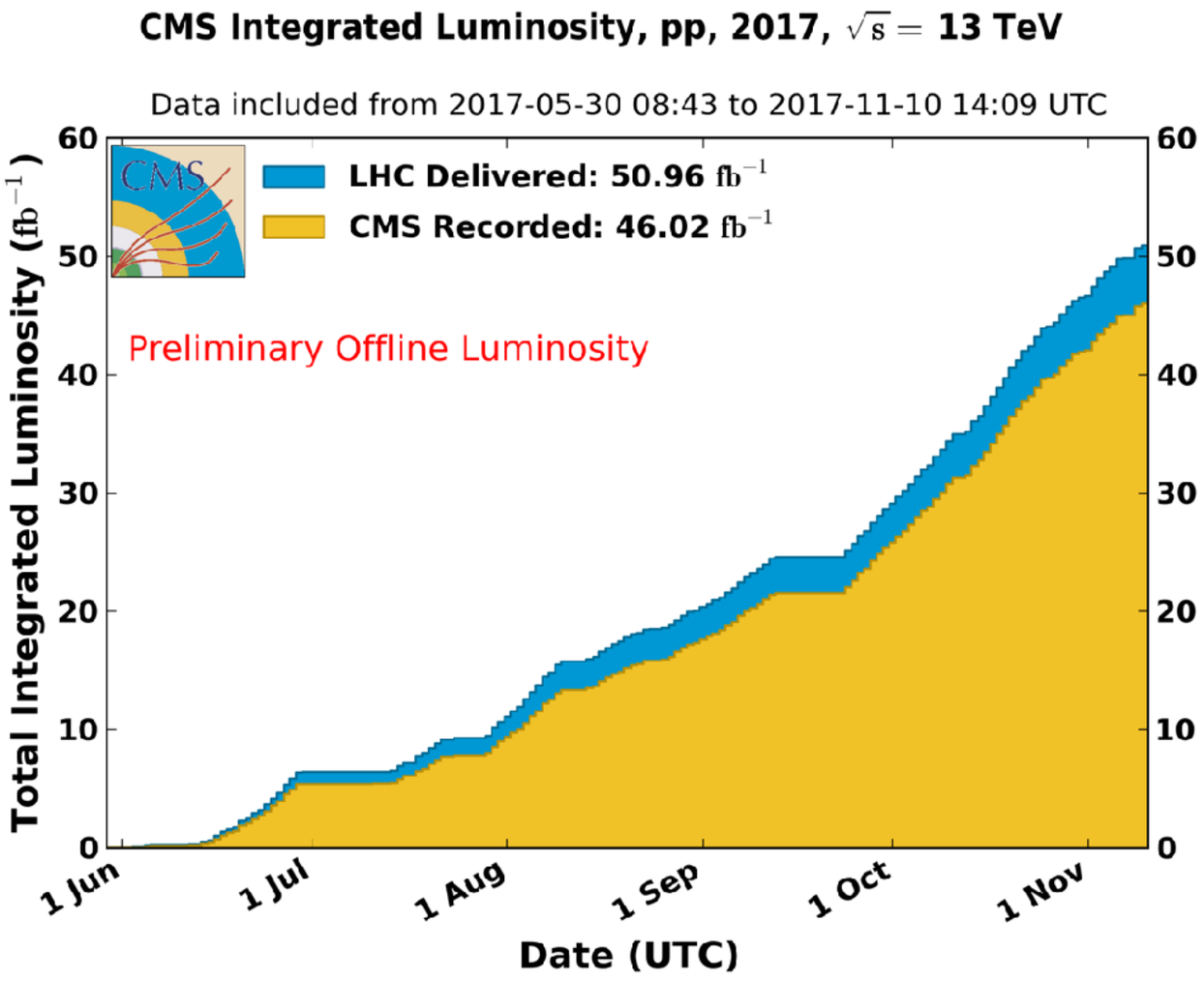


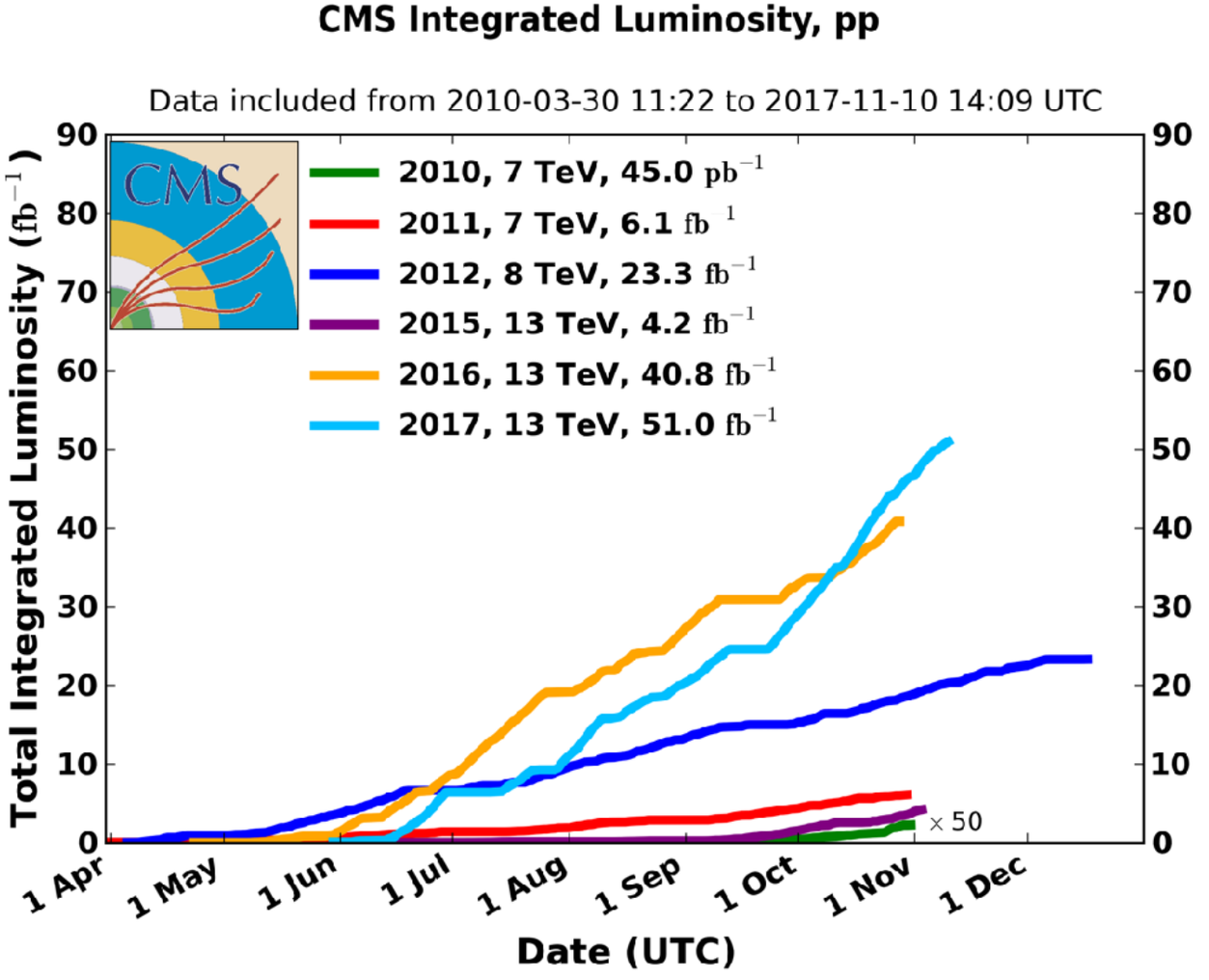
Sep 2016



- 2016 provided biggest jump in σ x Luminosity for a very long time
- Next two years will increment our sensitivity in rare decays and weak production
- EYETS provides opportunity to digest this jump and be ready for 2017 run
  - fluctuation will happen but our duty to use all data at our disposal
  - continuous reloading of everything every 6 months not healthy for long term

STELLAR PERFORMANCE BY LHC





- Exceeded promised delivery for 2017 despite unexpected problems
  - Expectations for 2018 could well exceed 60 fb^{-1}
  - Full Run 2 with 150 fb^{-1} presents opportunities and new challenges for analysis

STRATEGY FOR 2017

- Because of much larger statistics no physics case for quick re-loads of results every 6 months
  - very little gain for most searches
  - more challenging for tackling systematics in measurements
- Target publication quality results even for conferences not just half-baked (sometimes not correct) results for a PAS
  - PAS intended and used only as a conference note
  - paper should be near CWR in order to release PAS for a conference
- No last minute approvals before conferences
  - one week embargo on approvals and PAS (conference note) ready for release **before** the conference

- Goal: reduce significant delays between preliminary PAS and paper
  - sometimes even >1 year
  - much reduced interest of community in our papers
    - Theorists and non-CMS members can cite our PAS and publish their great thoughts and ideas
    - By the time paper out with a year-old result, no interest
  - Provide real reward (paper) for young students and postdocs applying for jobs

PUBLICATIONS IN 2017

Citation summary results	CMS Citeable papers	CMS Published only	ATLAS Citeable papers	ATLAS Published only
Total number of papers analyzed:	115	115	76	76
Total number of citations:	1,941	1,941	1,269	1,269
Average citations per paper:	16.9	16.9	16.7	16.7
Breakdown of papers by citations:				
Renowned papers (500+)	0	0	0	0
Famous papers (250-499)	0	0	0	0
Very well-known papers (100-249)	1	1	2	2
Well-known papers (50-99)	6	6	3	3
Known papers (10-49)	55	55	30	30
Less known papers (1-9)	51	51	39	39
Unknown papers (0)	2	2	2	2
h_{HEP} index [?]	22	22	19	19

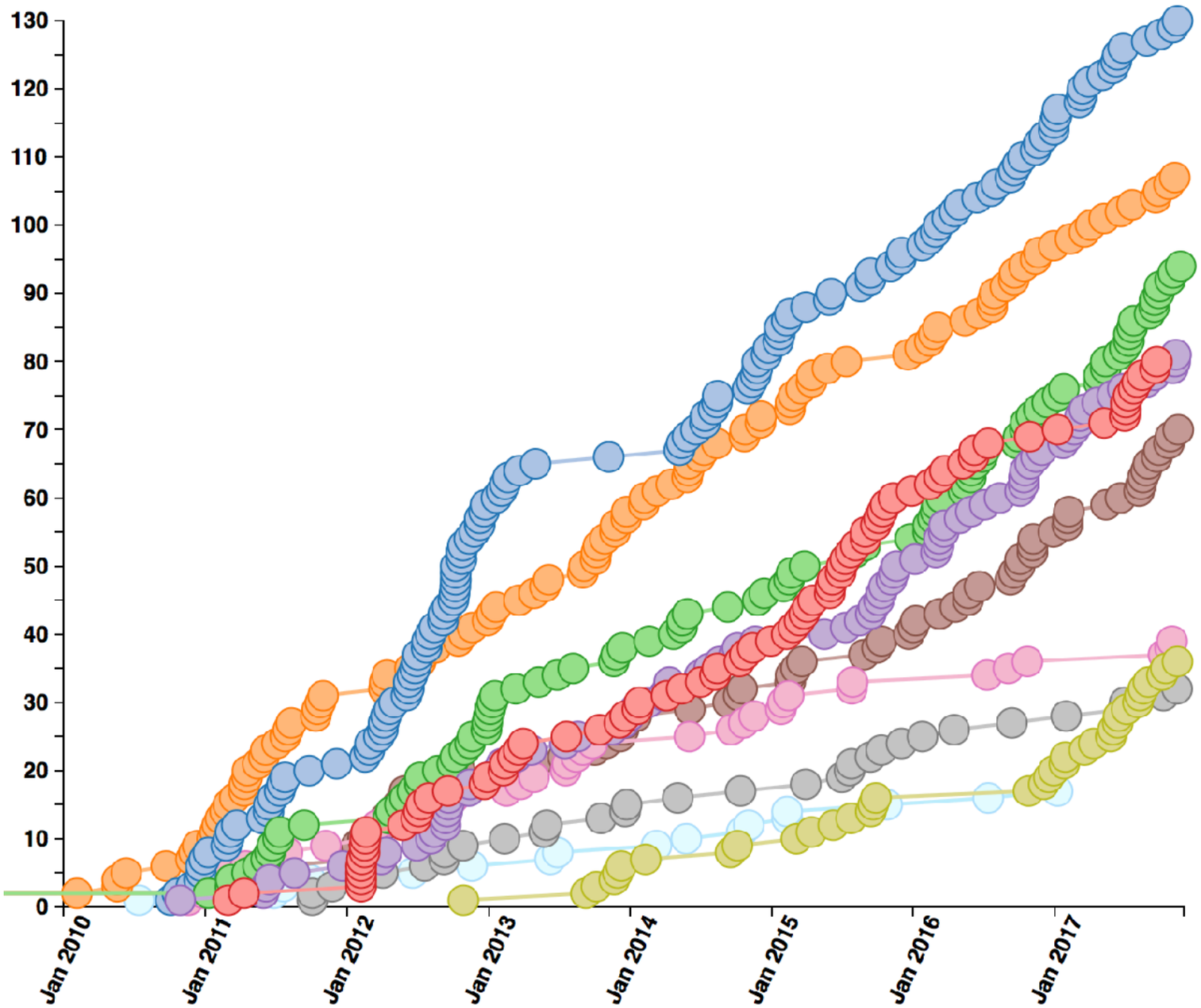
- Strategy to target publication-quality papers seems to pay off
  - Faster turn around between presentation at conferences and submission
  - Reduced delay between “a” preliminary result in PAS and paper
  - Advance the field with **papers** (**good for CMS and community**) not with PAS (only good for community)

PUBLICATION STATUS

Show all | Total | Exotica | Standard Model | Supersymmetry | Higgs | Top Physics

Heavy Ion | B Physics | Forward Physics | Beyond 2 Generations | Detector Performance

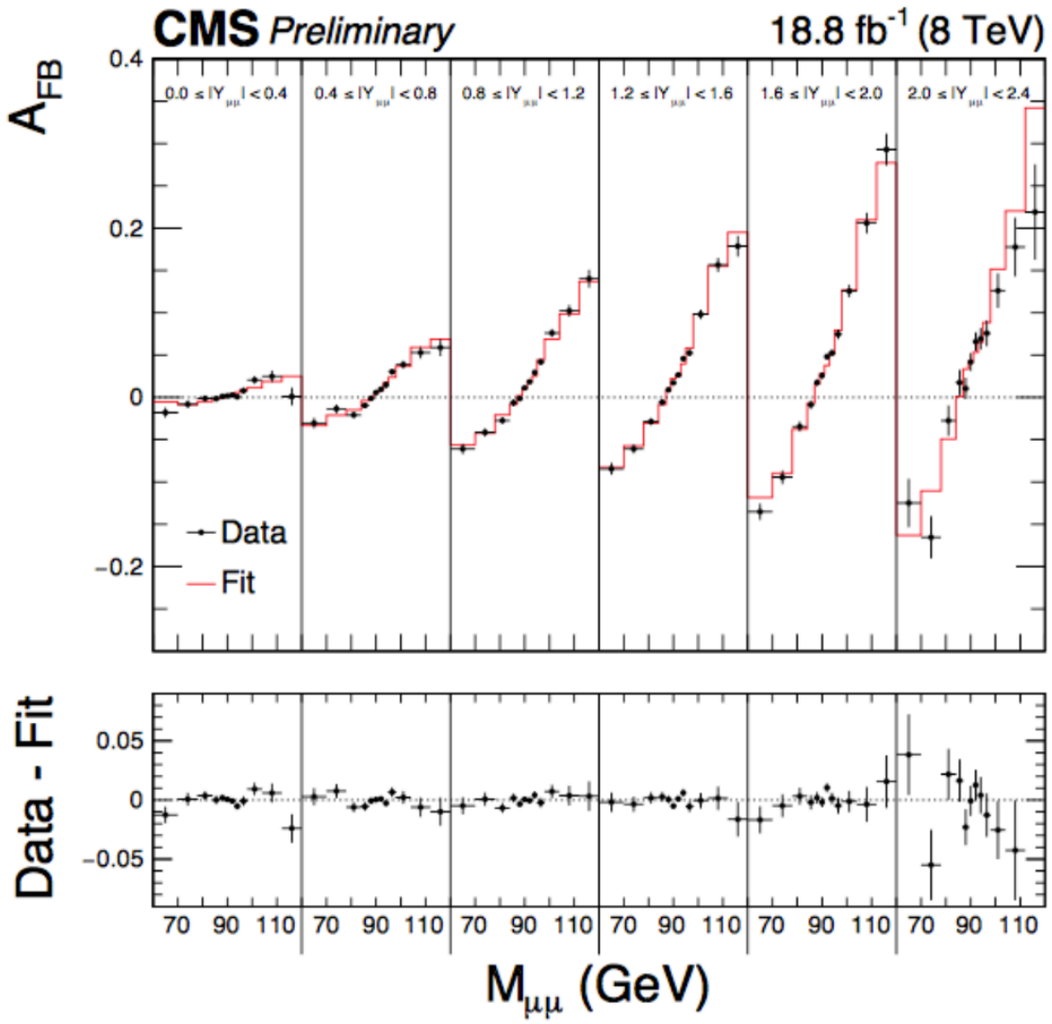
685 collider data papers submitted as of 2017-11-24

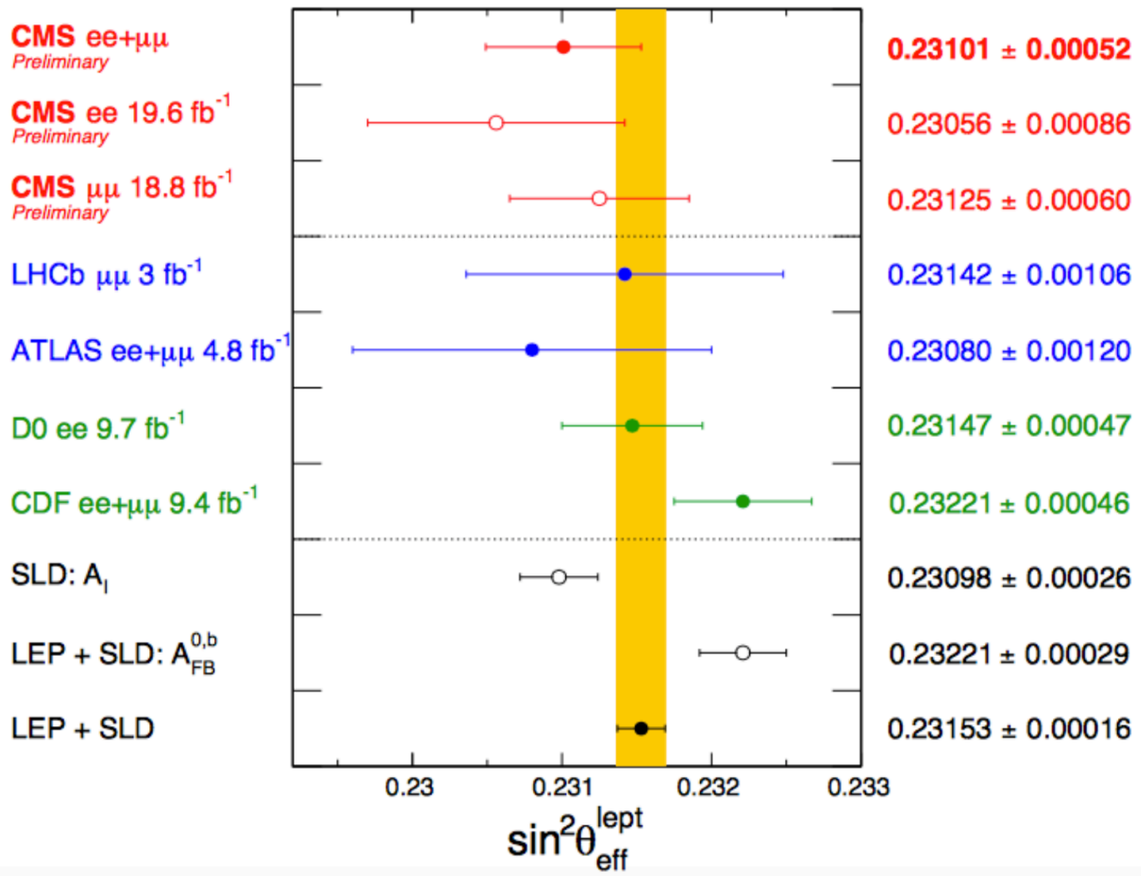


Some Highlights

Without spoiling too much next talks

EFFECTIVE WEAK MIXING ANGLE





$$\sin^2\theta_{\text{eff}}^{\text{lept}} = 0.23101 \pm 0.00036(\text{stat}) \pm 0.00018(\text{syst}) \pm 0.00016(\text{theory}) \pm 0.00030(\text{pdf})$$

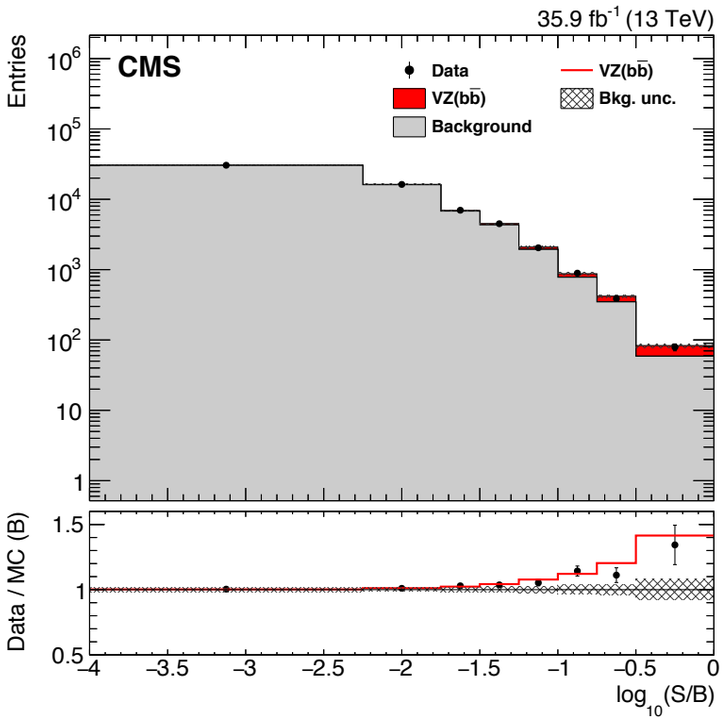
$$\sin^2\theta_{\text{eff}}^{\text{lept}} = 0.23101 \pm 0.00052.$$

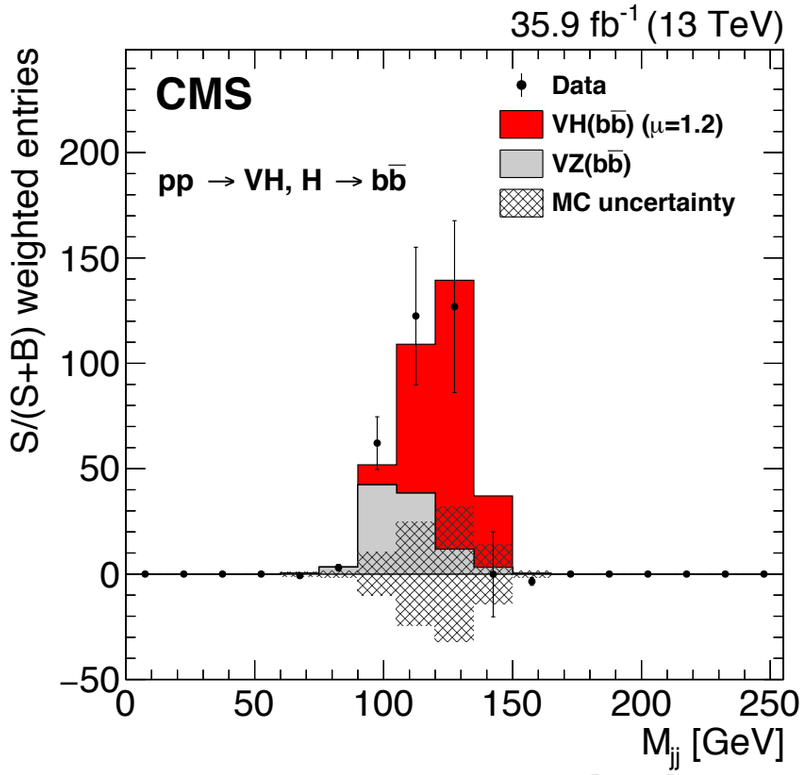
- Forward-backward asymmetry determined in bins of mass & rapidity
- Approaching Tevatron precision
  - will benefit from rest of run2 to push both statistics and systematics

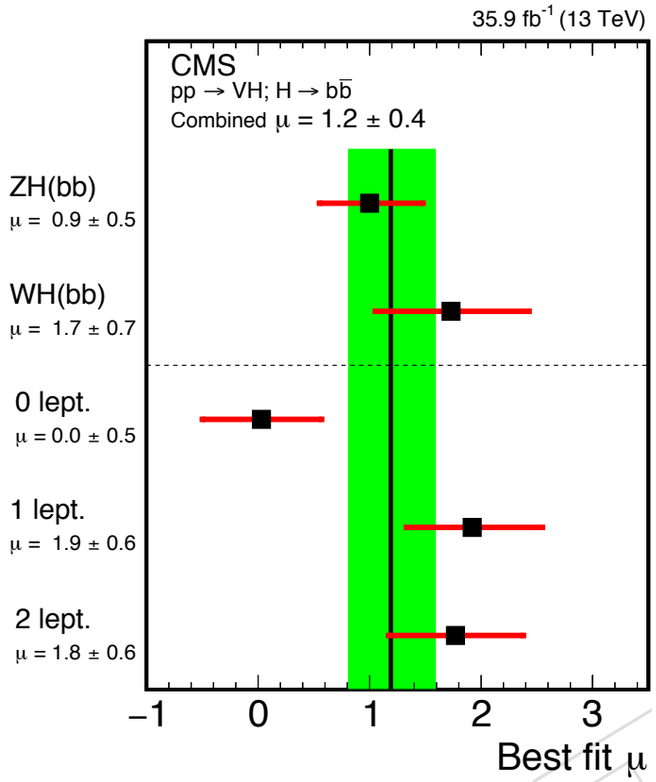
V + H → bb

HIG-16-044

- Presented at Lepton Photon
  - Paper submitted in September
  - ATLAS presented at EPS and submitted 2 days after our presentation at LP
- 3.3σ (2.8σ expected) at 13 TeV
  - ATLAS 3.5σ observed (3.0σ expected)
- 3.8σ (observed and expected) after combination with 8 TeV
  - ATLAS 3.6σ observed (4.0σ expected)



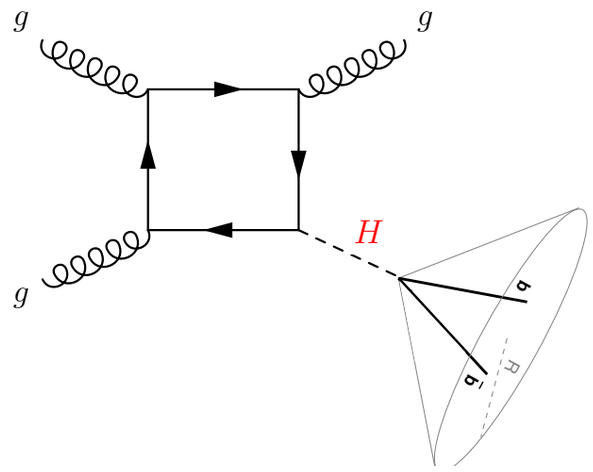


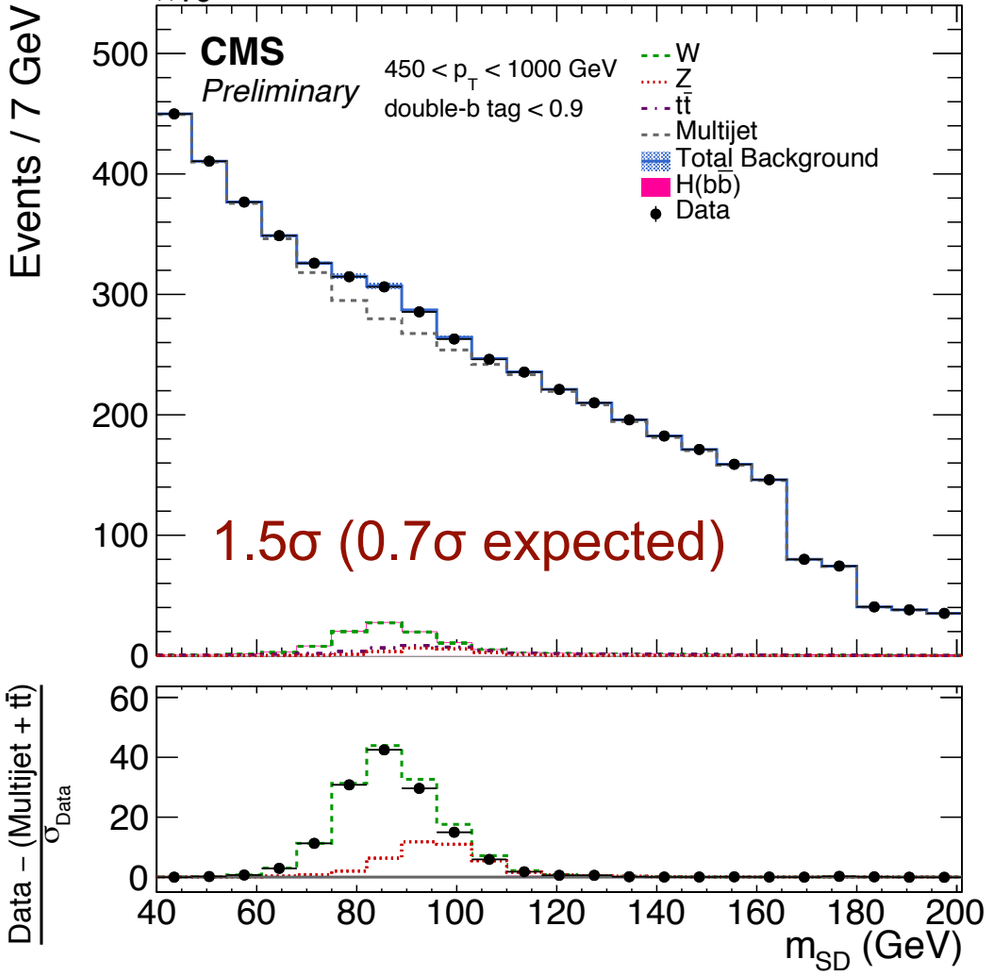


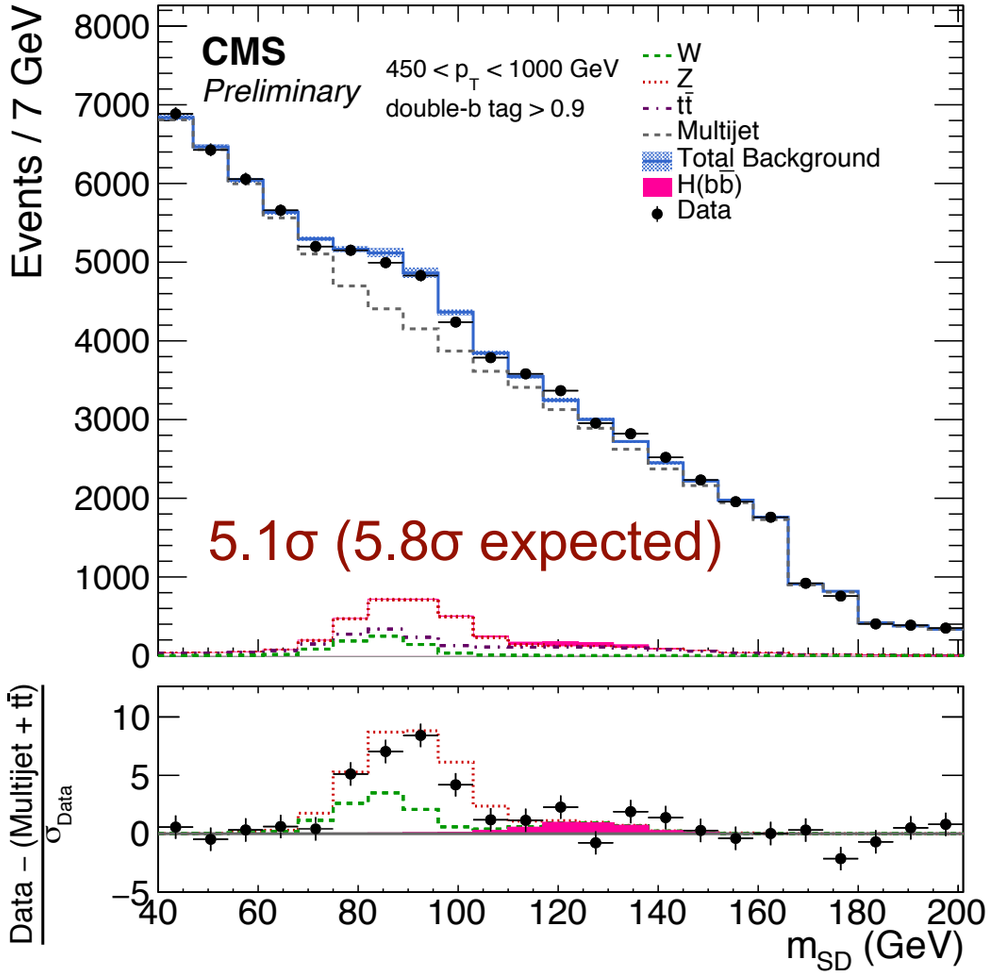
- ATLAS and CMS aiming for 5σ (possibly) with 2017 data
  - no combination before end of run2

BOOSTED Z/H → bb HIG-17-010

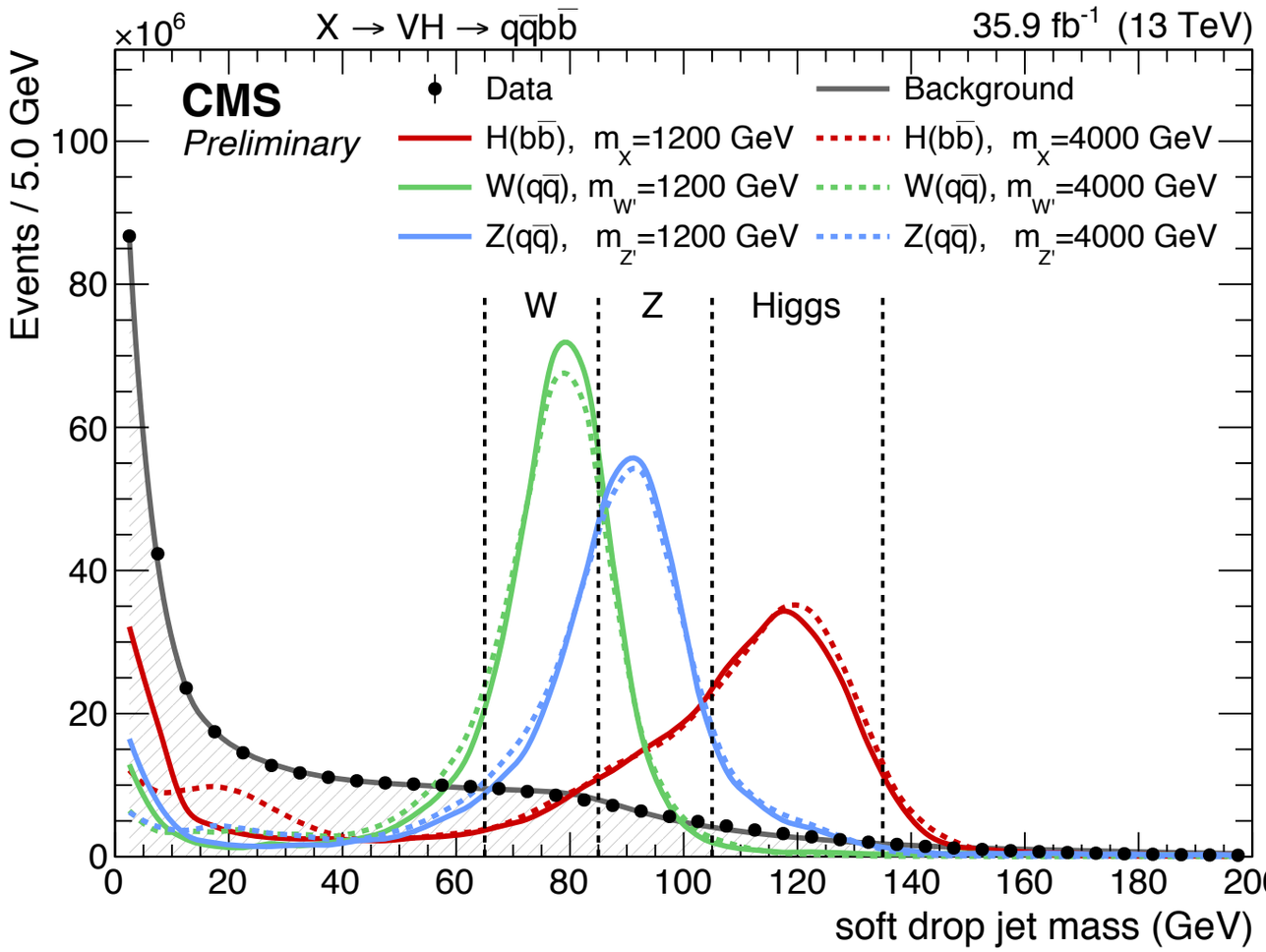
- Probing Higgs coupling at high momentum thanks to state-of-the-art techniques in boosted topology
  - Opens new possibilities for inclusive Higgs studies

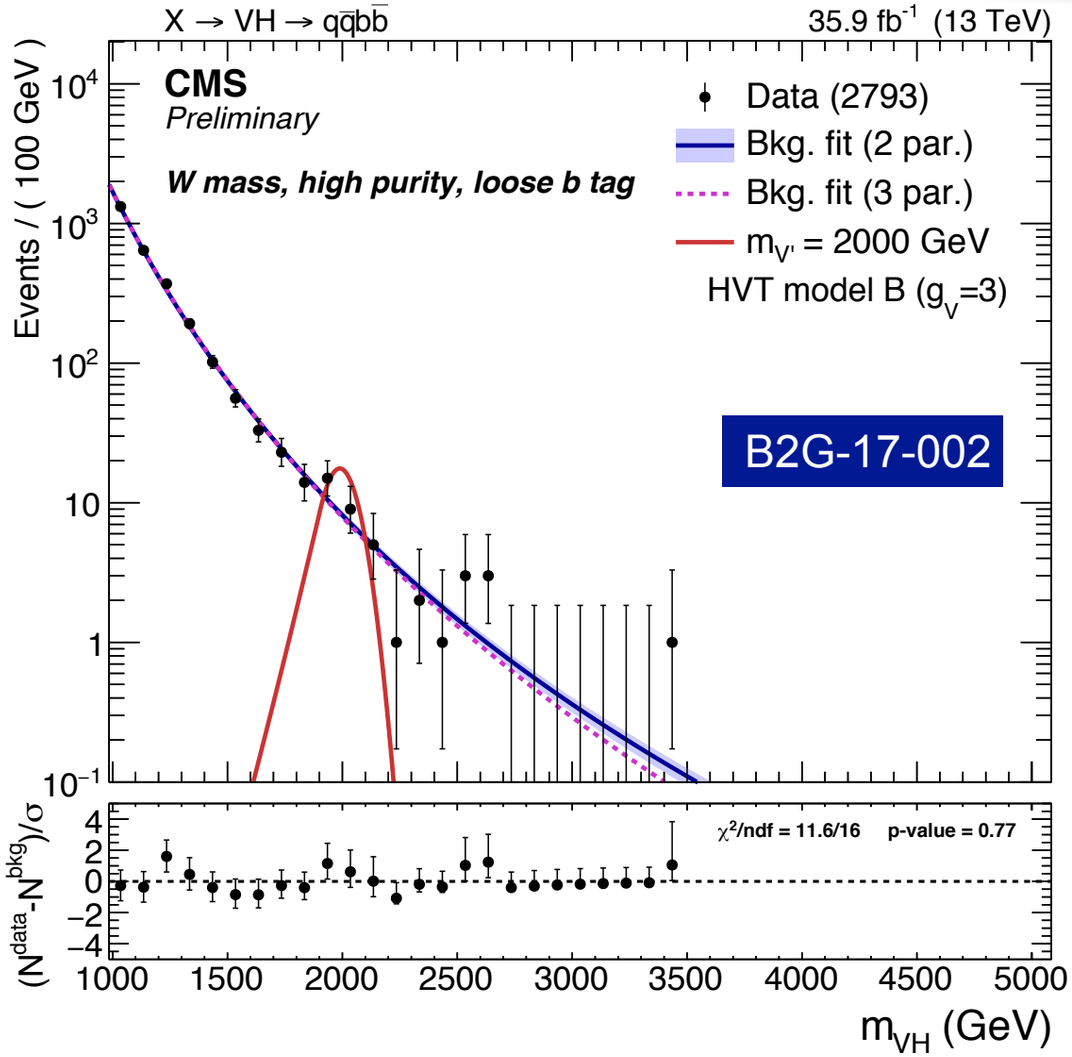






DI-BOSON SEARCHES

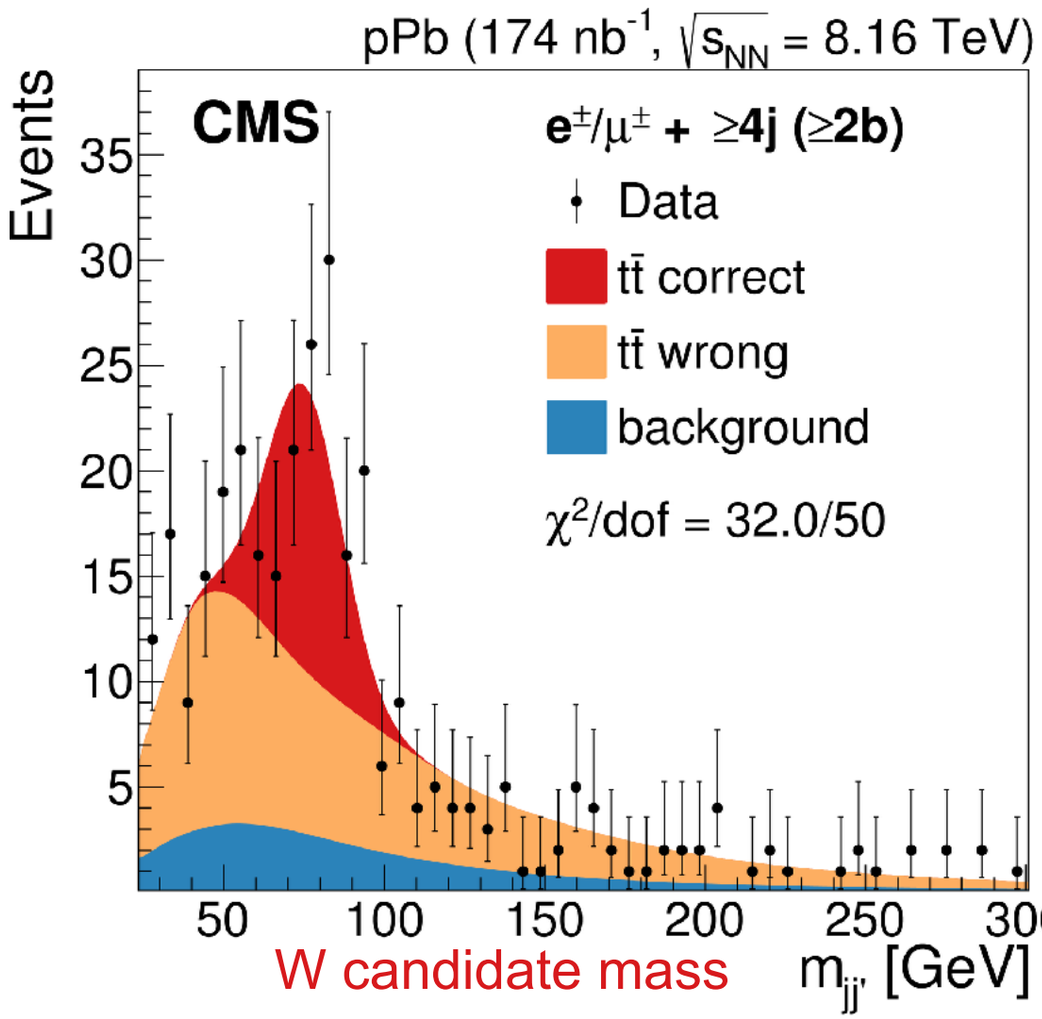


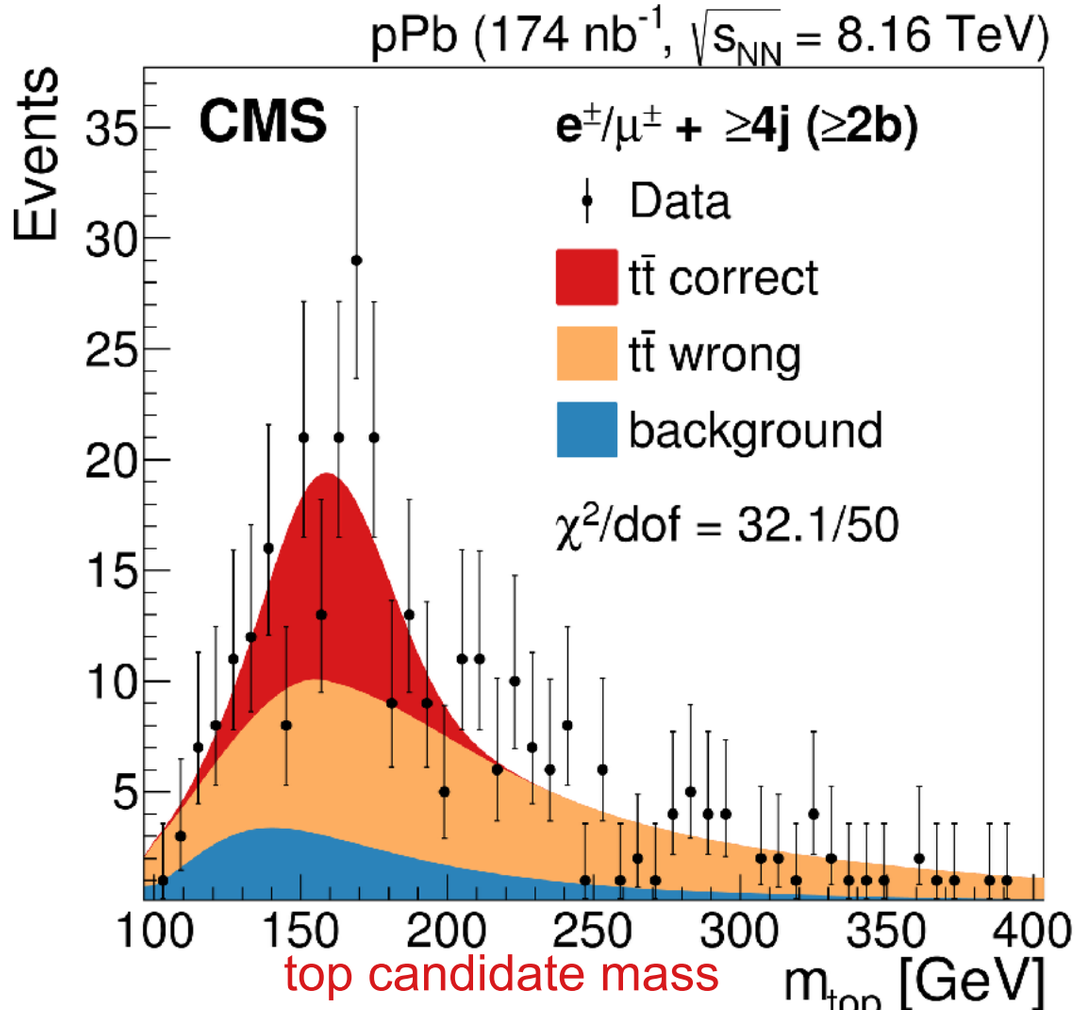


- Boosted topologies now used as standard tools for V-tagging and also Higgs-tagging
  - Workshop at CERN in December to explore boosted techniques also on SM Physics
- New results presented for VV, VH and HH (resonant and non-resonant)
  - CERN Seminar on Dec 5 during CMS week
- No new excess and no confirmation of old mild excesses

Top in Heavy Ions

- First observation of top quark production in proton-lead collisions!
  - showcased at TOP 2017 conference and paper submit at time of presentation

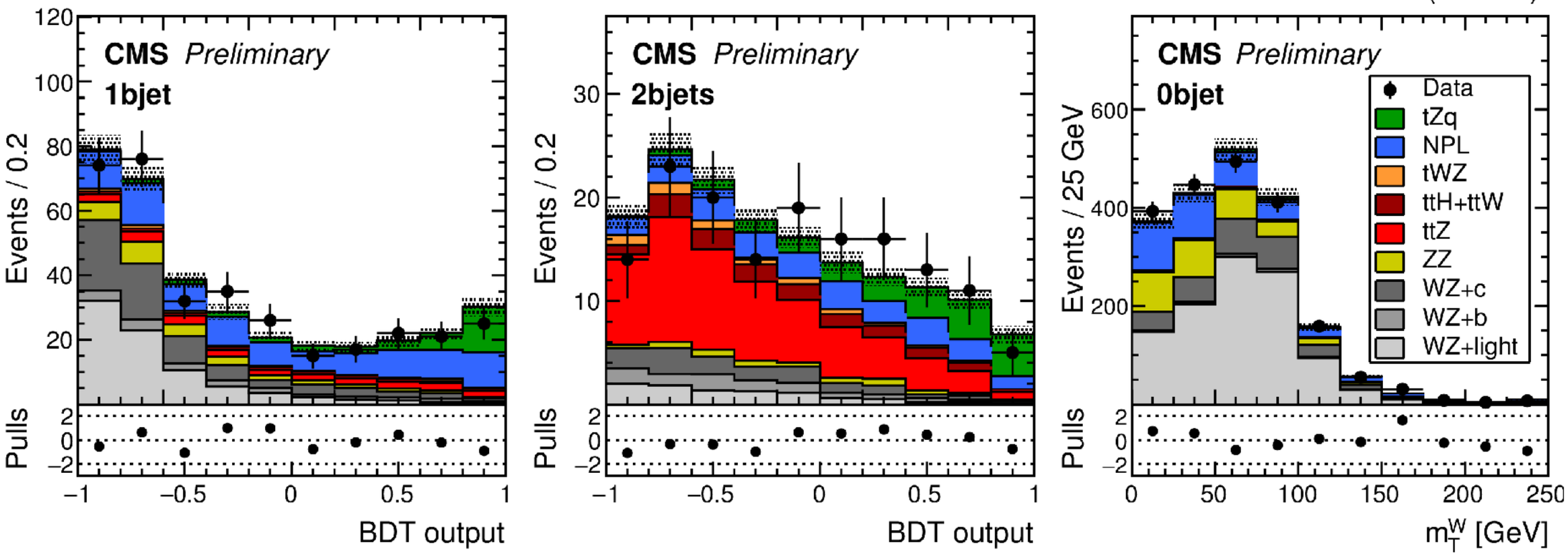




arxiv:1709.07411

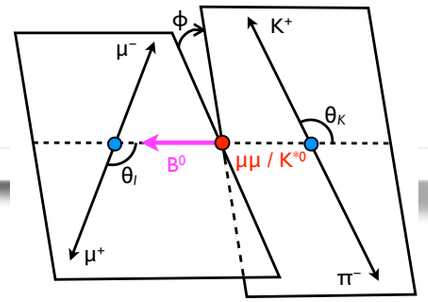
EVIDENCE FOR single top + Z

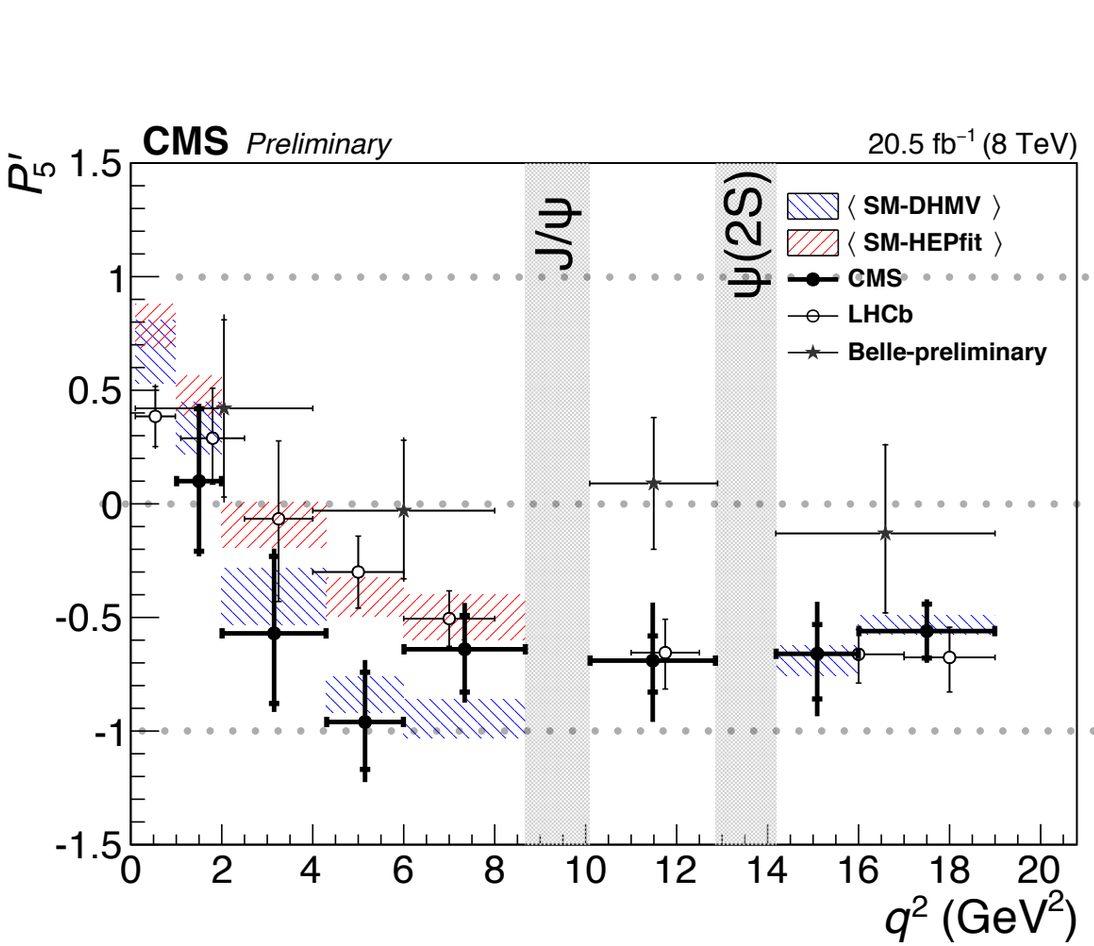
TOP-16-020

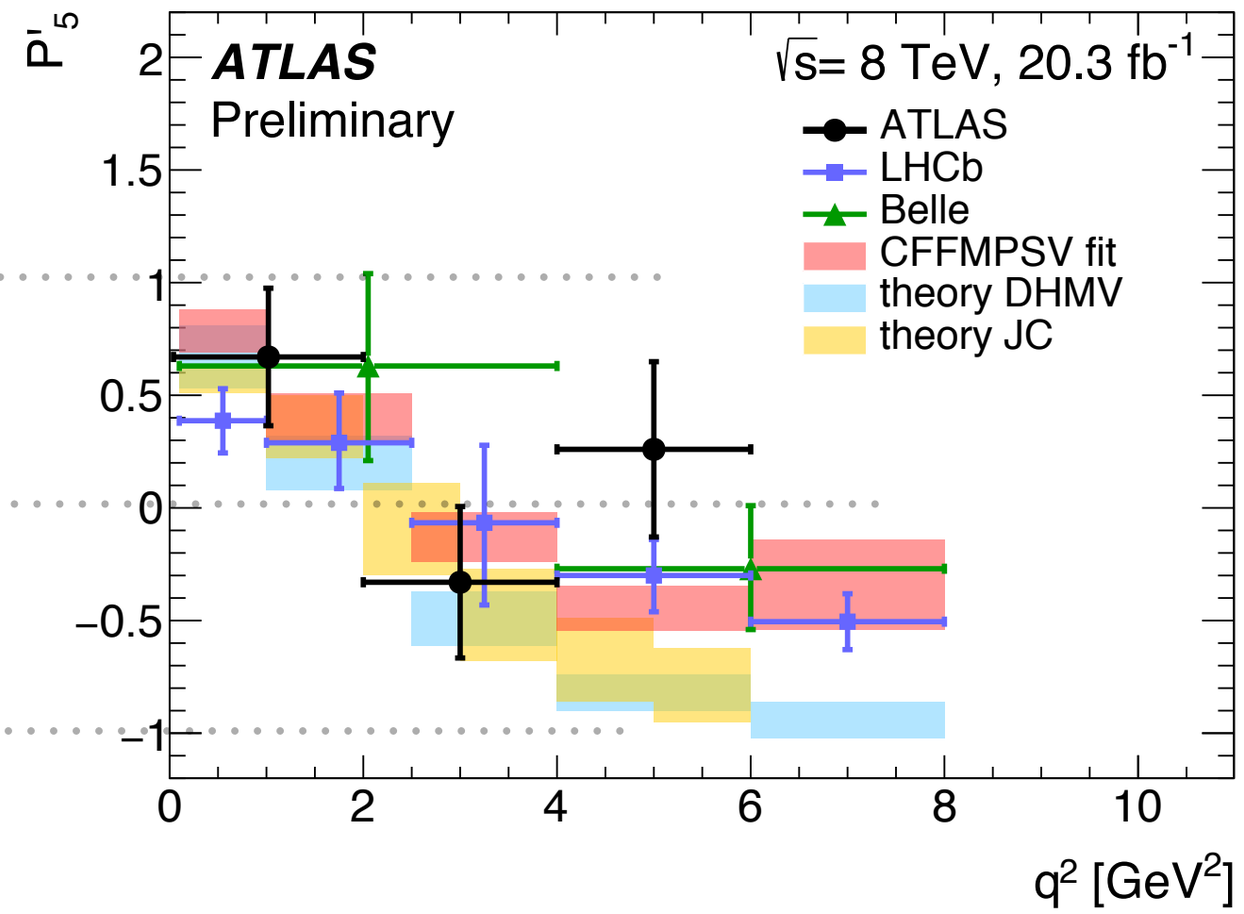


- Rare Standard Model process sensitive to FCNCs, tZ and WWZ triple coupling
  - presented at TOP 2017 and paper now in submission
  - Significance: 3.7σ observed with 3.1σ expected
  - ATLAS had shown results at EPS and submitted in September
    - Significance: 4.2σ observed with 5.4σ expected

P5’ IN K*μμ

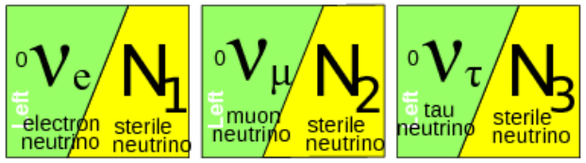


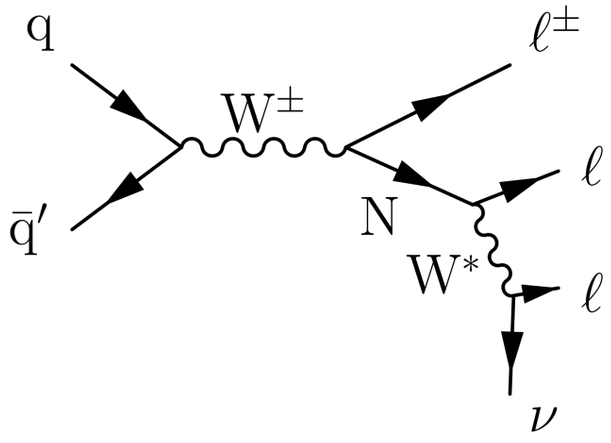


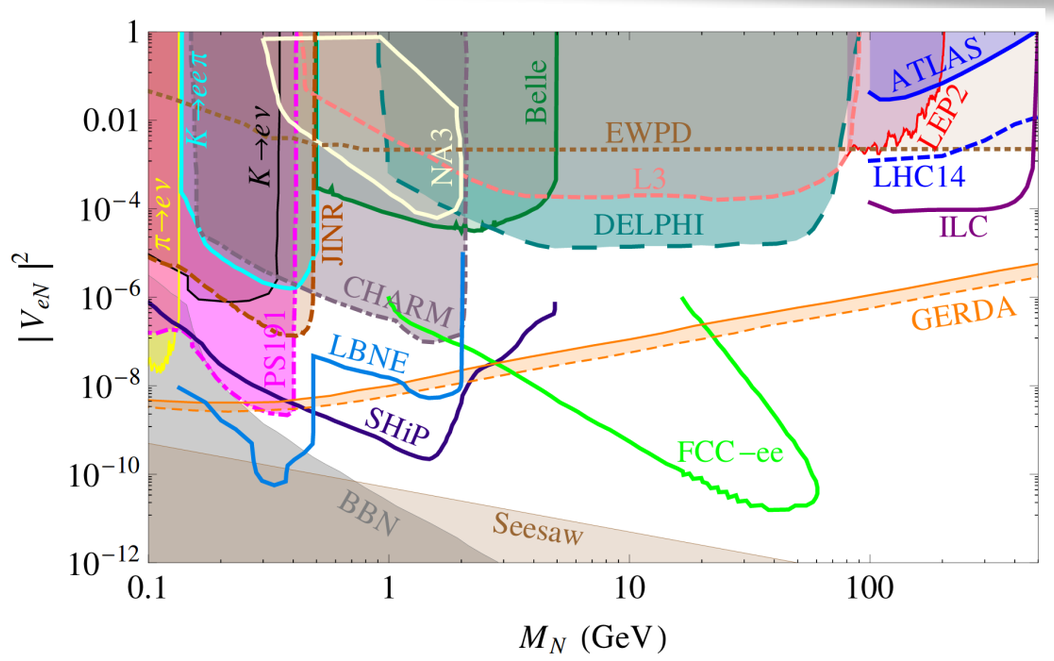


- Of great interest for community following hints of deviations in lepton flavour universality from LHCb
  - Uncertainties still large to draw conclusions
  - electron channel (unfortunately) not quite accessible in CMS
- Limited statistics at 13 TeV because of high thresholds in trigger
  - Work in progress towards updated measurement

HEAVY NEUTRAL LEPTONS

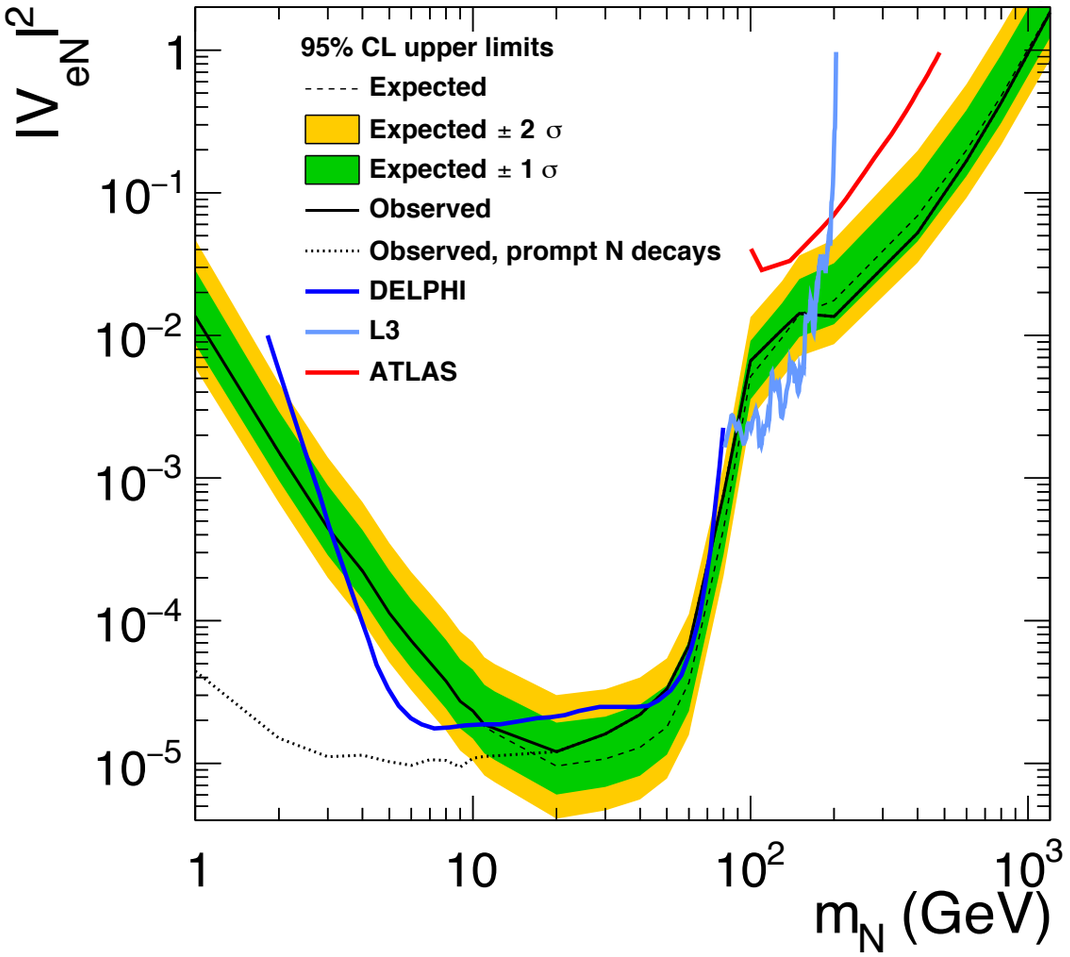






- Improved LEP limits below W mass
- First constraints for $m_N > 500$ GeV
- Strongest constraints from LHC
  - only probing prompt HNL decays so far
- Further improvement in progress
  - add long-lived particles to extending sensitivity at low mass

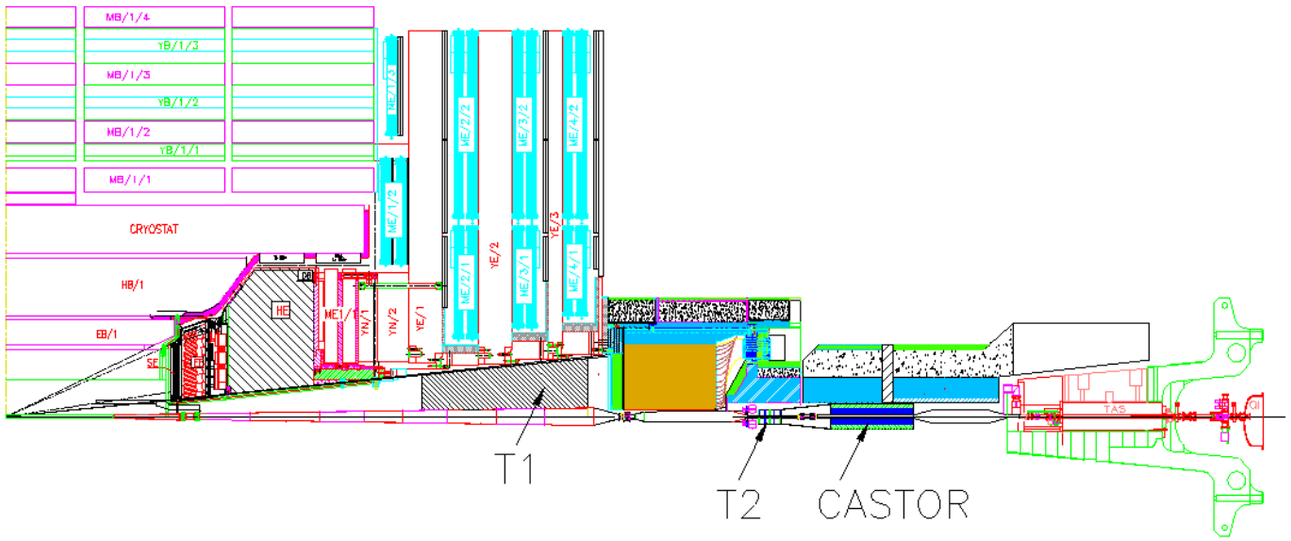
$$\tau \propto |V_{\ell N}|^{-2} \, m_N^{-5}$$



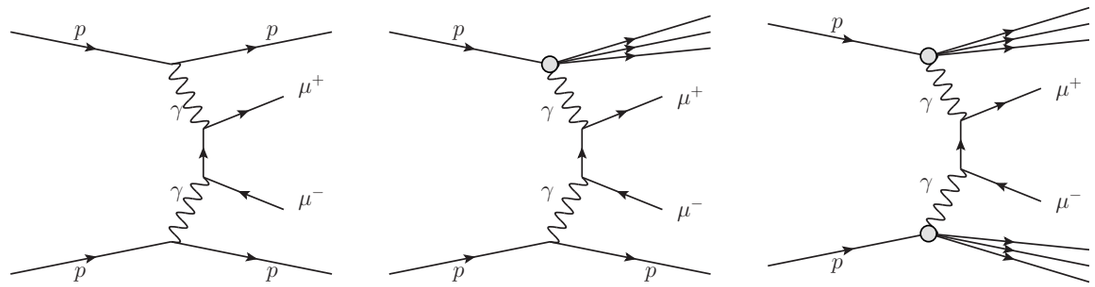
First Result with CT-PPS

- Evidence for central production of high mass di-muons

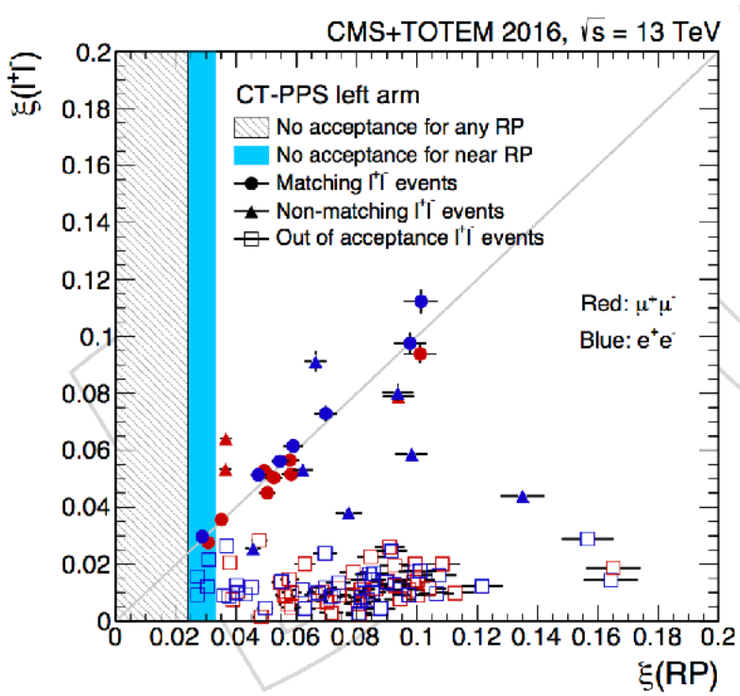
PPS-17-001

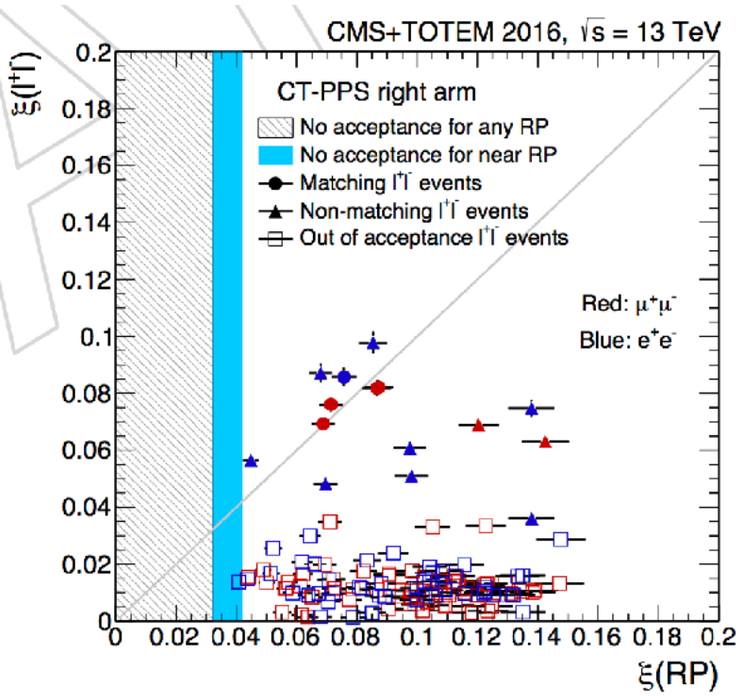


$$pp \rightarrow pl^+l^-p^{(*)}$$



- Excellent proof of principle and successful detector operation





$$\xi = \Delta p / p$$

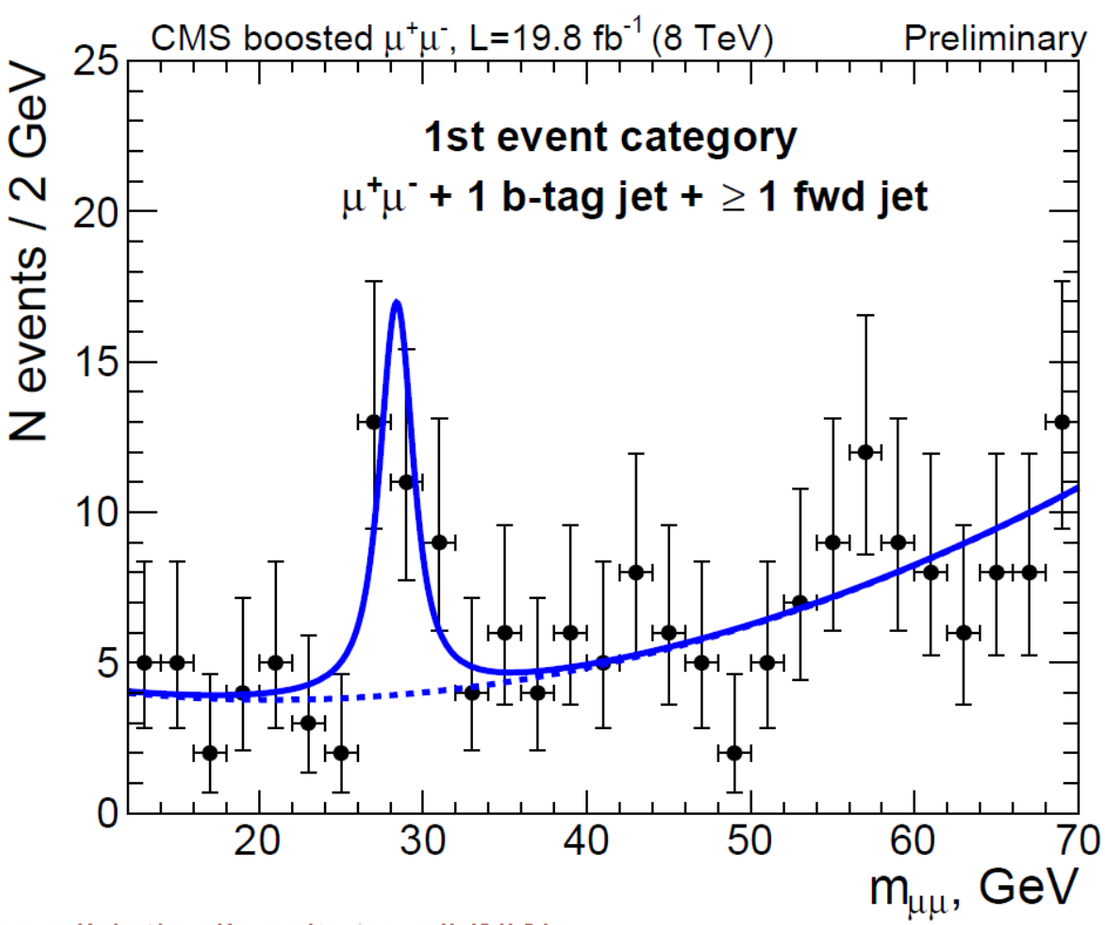
- Preliminary result with muons shown at EPS paper including also electrons now in CWR

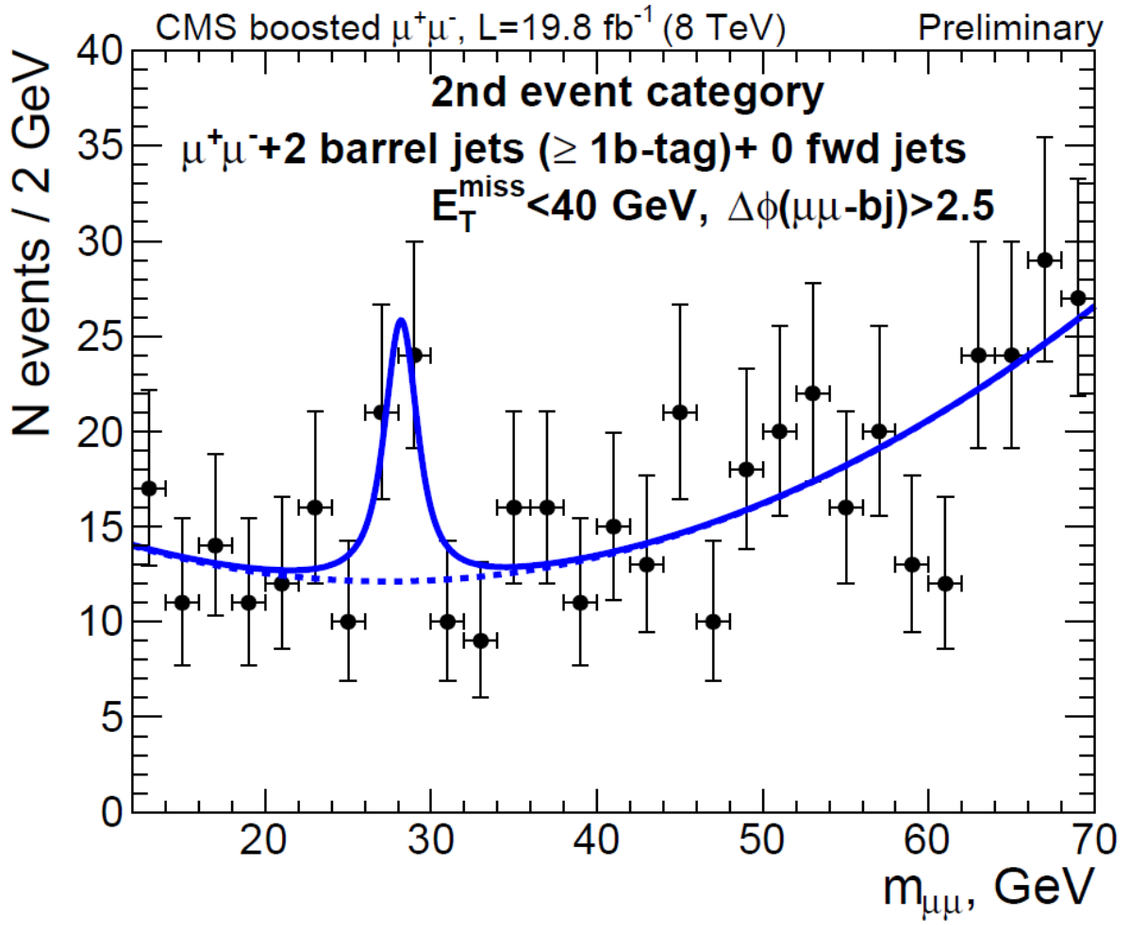
TEASERS

Low Mass μμ Search

HIG-16-017

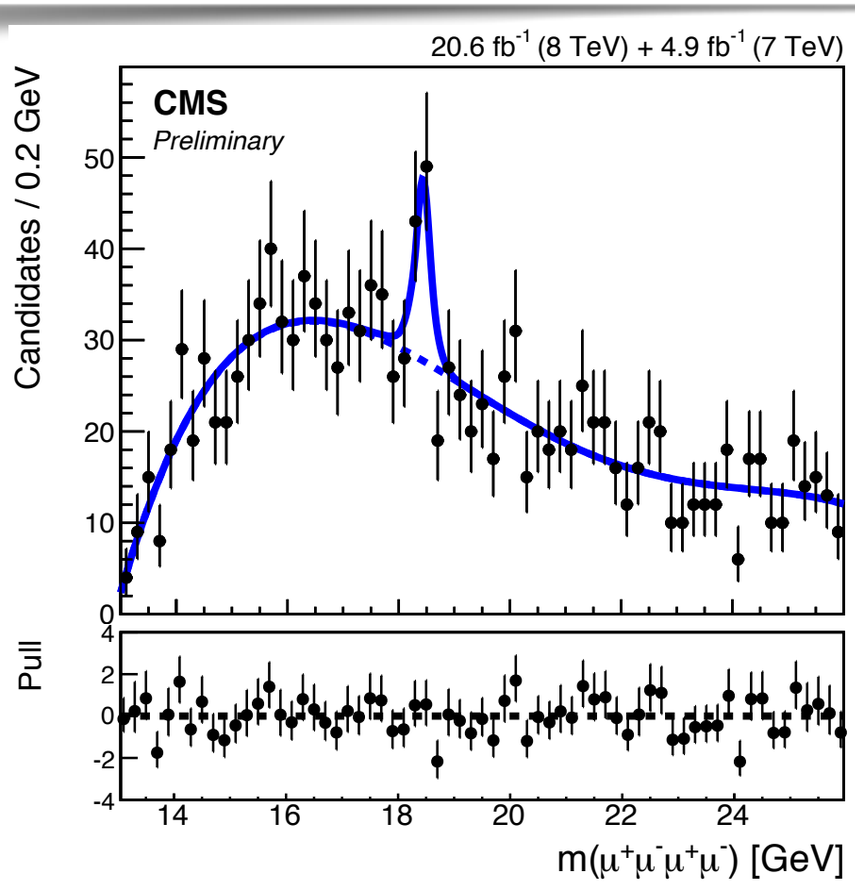
- Original analysis searching for light scalar in bbA(→μμ) final state
  - Motivated by theory papers in 2-Higgs-Doublet Model
  - bump in μμ mass with ***accidental*** requirements on muon pt
    - one b-jets in barrel and one forward jet
  - similar structure also with one b-jet in barrel and one other barrel jet
    - lower local significance
- ***Analysis of 13 TeV data approaching unblinding soon***

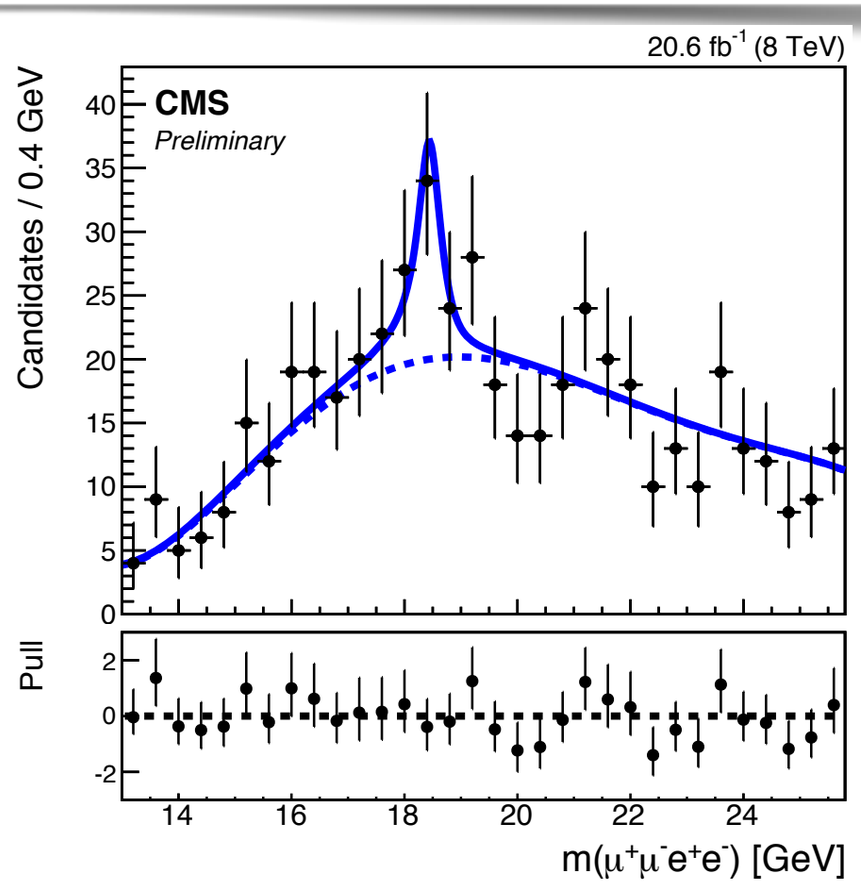




4-μ SEARCH

BPH-14-006



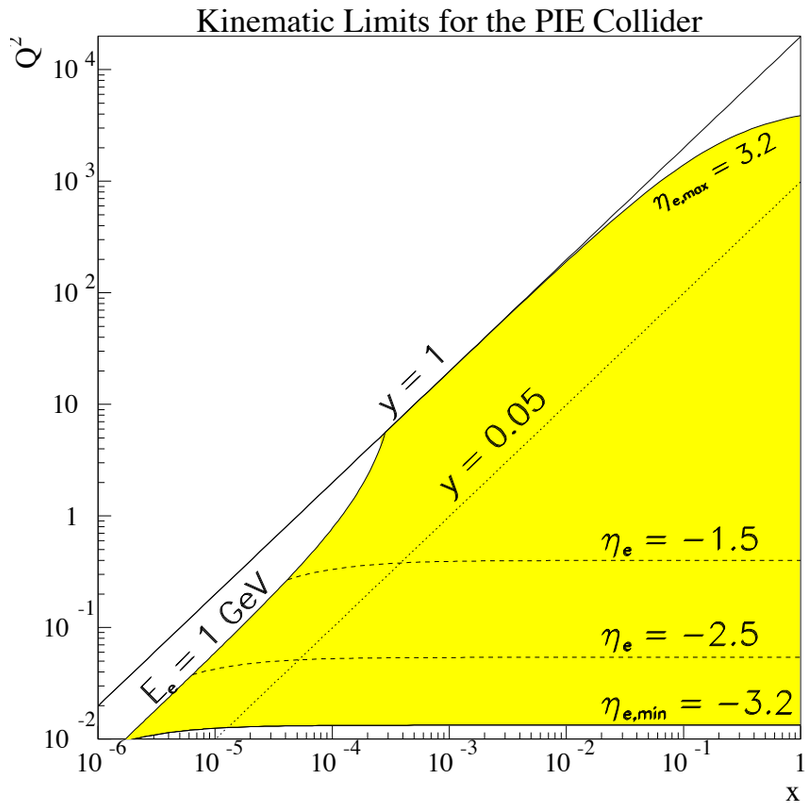


- Enhancement seen in a search motivated by theory papers on tetra-quarks and hidden valley
  - Extensive work by authors, conveners, and Carlo Battilana (thank you!) to address questions and concerns about trigger matching since October 2016
  - Cross check analysis, same selection but with independent tools, by a second team
  - Soon to be sent back to ARC for review
- At least 2 independent teams now looking at 13 TeV data
  - dedicated trigger deployed in last part of 2017 data
  - Aiming for a first result by Spring

CREATIVE PHYSICS

- Short but successful XeXe run in 2017 (40M min bias events)
  - Despite not being a desire of heavy ion group, excellent operation and 3 papers in preparation aiming for Spring
- Low pileup run
  - collected ~250 pb^{-1} at pile-up ~ 3
  - Targeting measurement of W pT at low momentum
  - includes triggers for auxiliary measurements of underlying events and QCD
    - See plenary presentation on motivations and first look at data next Thu

- electron-proton collisions at LHC! (see details, hep-ex/0405028)
  - partially stripped Pb ions against protons
  - center of mass energy ~ 200 GeV similar to HERA
    - no estimate yet of total luminosity
  - Useful for Parton Density Function measurements and probing (Q2,x) plane
    - Ongoing discussion in FSQ about acceptance in CMS barrel and trigger strategy



Room for Improvement

W Mass

- Steady but slow and limited progress after more than 1 year
  - List of tasks, deliverables, interested teams and their real commitments now available

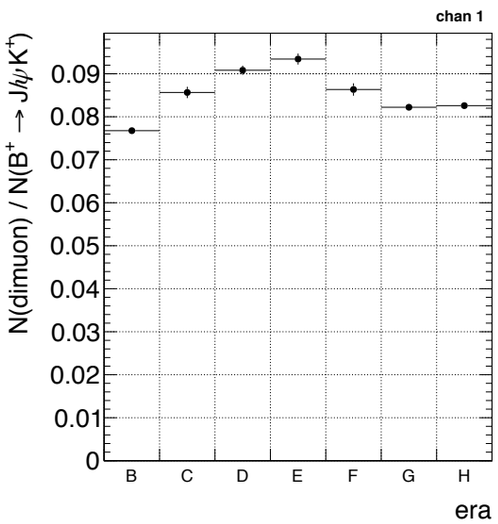
	W Helicity	W p_T	Z p_T	W Mass
Motivation	PDF's	QCD	QCD	W Mass
Lepton Cal.	Moderate	Minimal	Moderate	Ultimate
Recoil Cal.	Minimal	Ultimate	N/A	Ultimate
Phys. Modeling	Moderate	Moderate	Minimal	Ultimate
Bkg. Estimates	Moderate	Moderate	Minimal	Ultimate
Dataset	2016 (+2012)	2016 (+lowPU)	2012/2016	2012 or 2016
Timescale	Winter	Summer	Winter	Late 2018

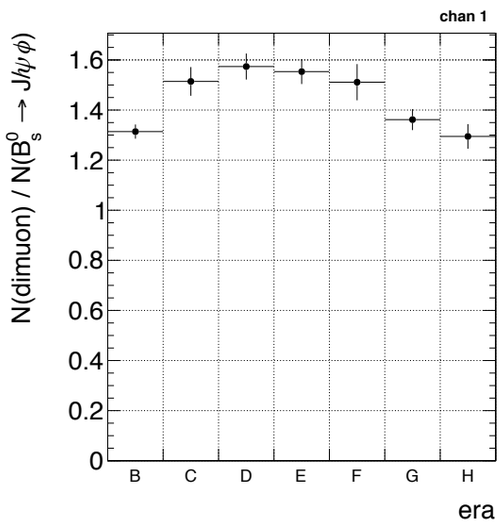
- Concerns about manpower while aiming for a better measurement than ATLAS
  - only 2 PhD students and one staff committed full-time to this project

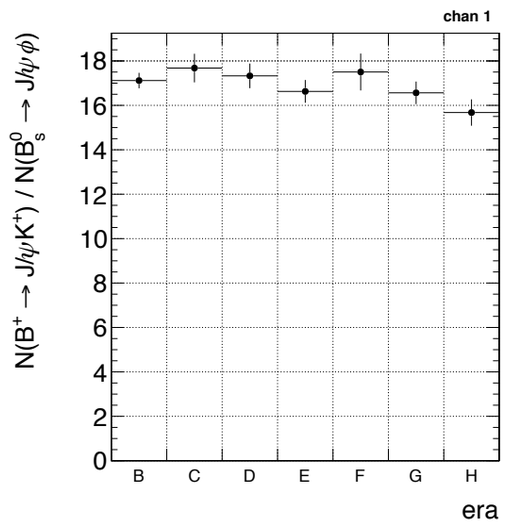
- CMS One-day workshop on W mass on Jan 31

$B_s \rightarrow \mu\mu$

- Extremely reduced manpower for a flagship measurement with very high scientific impact
  - Roughly 3 individuals fully focused on delivering analysis of 2016 data
- Analysis of 2016 data almost 1 year behind schedule
  - no look at data and its features in 2016
  - efforts started by end of 2016 and still on-going
- Several important issues have delayed this analysis
  - Yield instability for signal and control samples across 2016 eras
  - discrepancies in BDT output between data and MC still under investigation
    - cause related to flight distance significance selection but mitigation not found yet

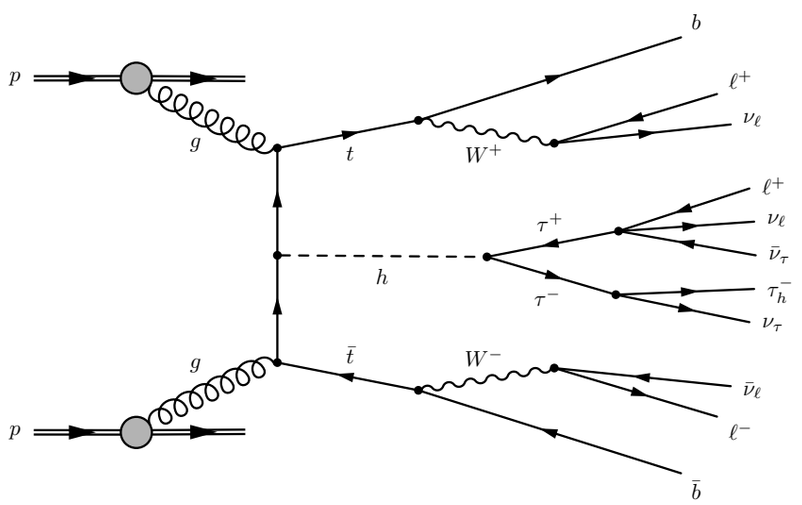


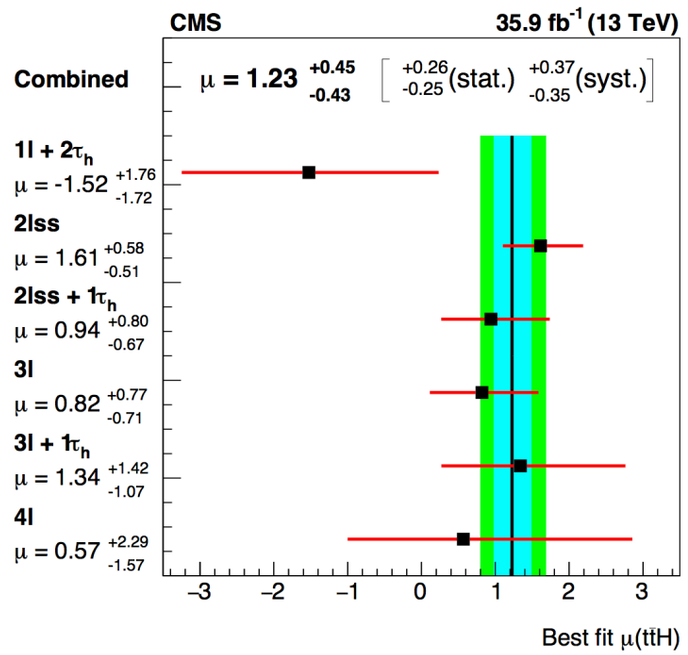


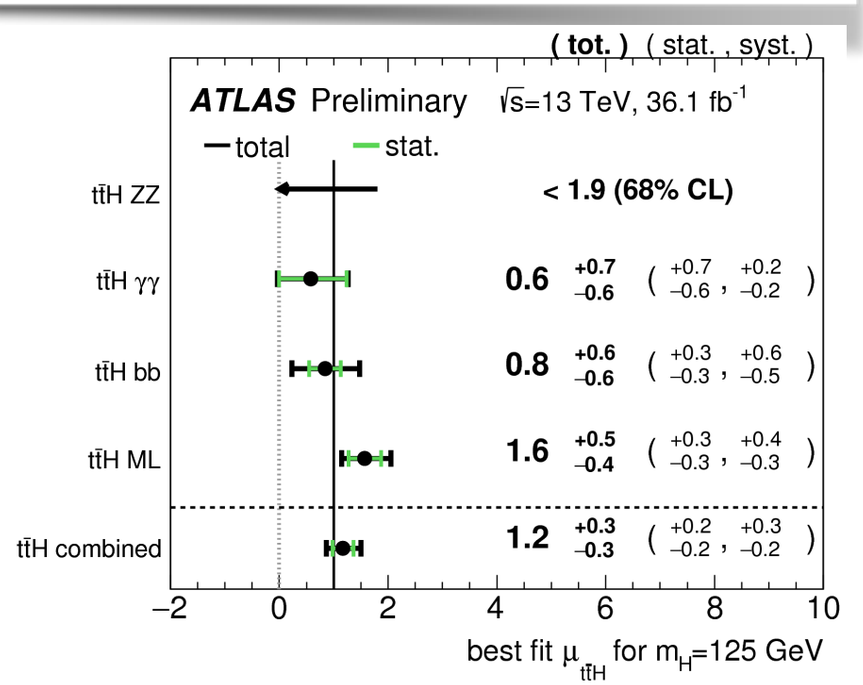


- *Delivery of this result on 2017 and 2018 data needs new blood and interested analysis teams - not just additional manpower*

ttH







- Individual results shown at Moriond 2017 for multilepton WW, ZZ, $\tau\tau$ and hadronic $\tau\tau$ Higgs decays
  - Ahead of ATLAS and of great impact for community
- Combination took several months
  - Observed significance of 3.2σ (2.8σ expected)
  - paper in CWR only in November
- ATLAS preliminary result presented in October
  - Observed significance of 4.2σ (3.8σ expected)
- Our result expected to be better and hopefully to be ready soon

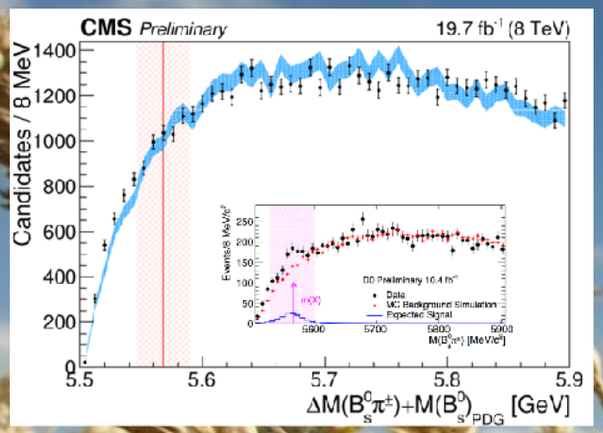
PHYSICS PLANNING MEETING

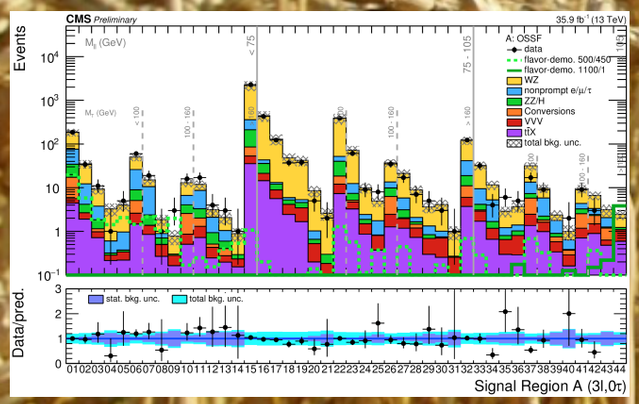
- Long term planning for physics with full 13 TeV data
  - Schedule and resources for MC production
  - Planning of re-processing with Offline & Computing and PPD
- Physics insights and inspiration for best use of data in next 5 years
- Statistics in 2017 and 2018 offer different prospects and opportunities for different physics groups
  - Some will need all the data
  - Some are already limited by statistics and could do with partial data
  - Some might have interesting plans which might never materialise due to personpower issues
- A first collaboration-wide discussion was held on October 26
  - Follow-up discussion at next Thursday Physics Plenary
- *Planning our physics goals and activities will continue with such regular meetings through 2018*

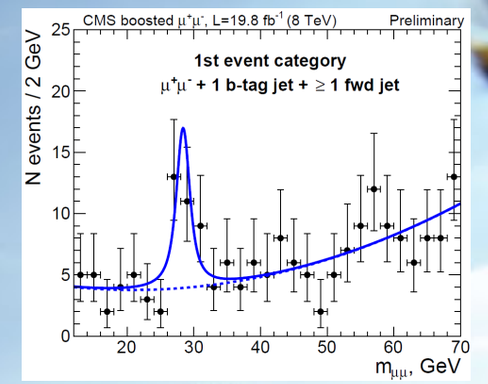
High Luminosity Program

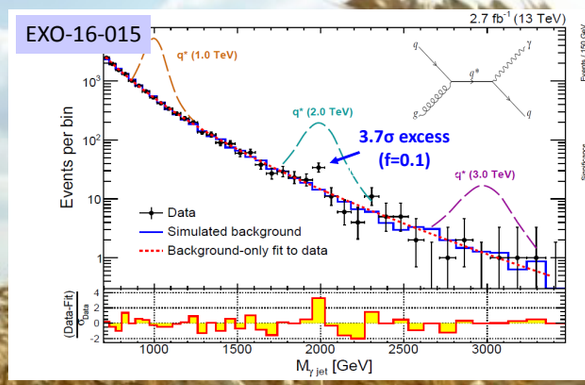
Hints and Fluctuations

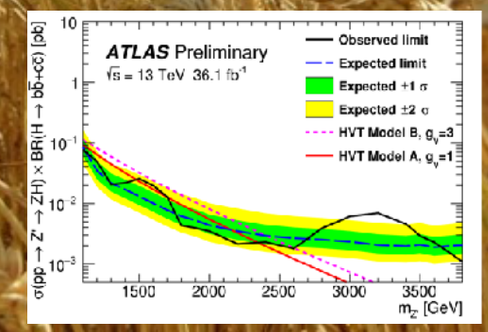
HINTS AND FLUCTUATIONS

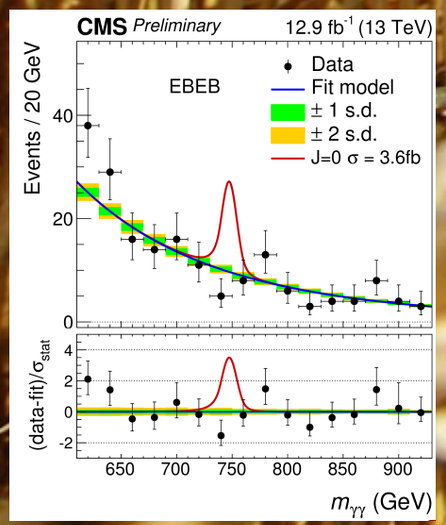


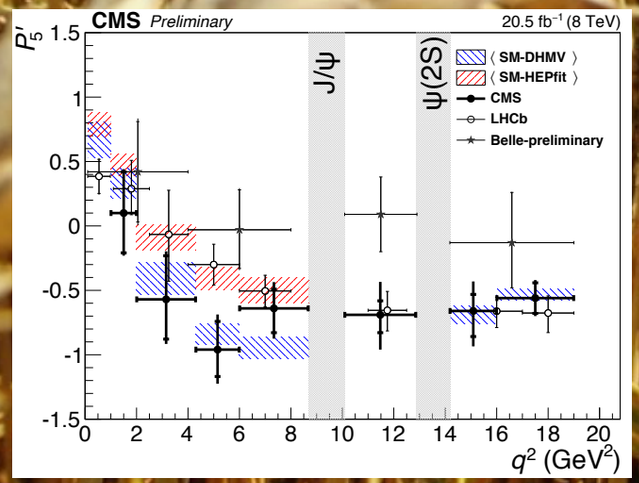


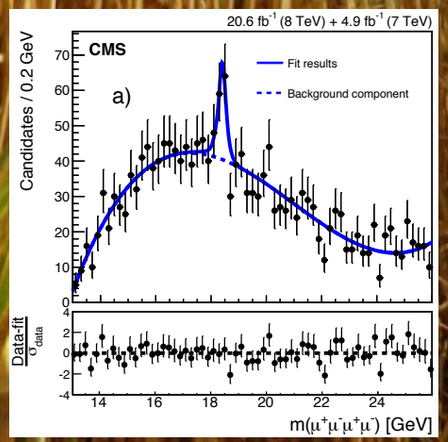


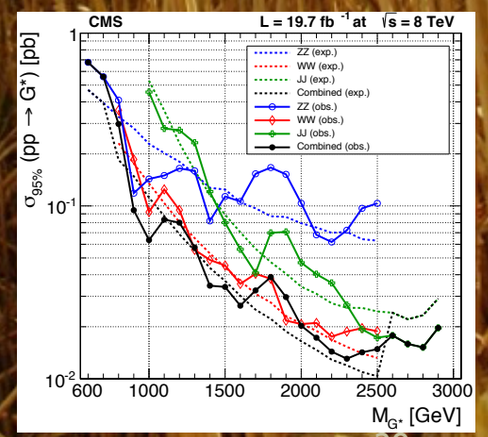












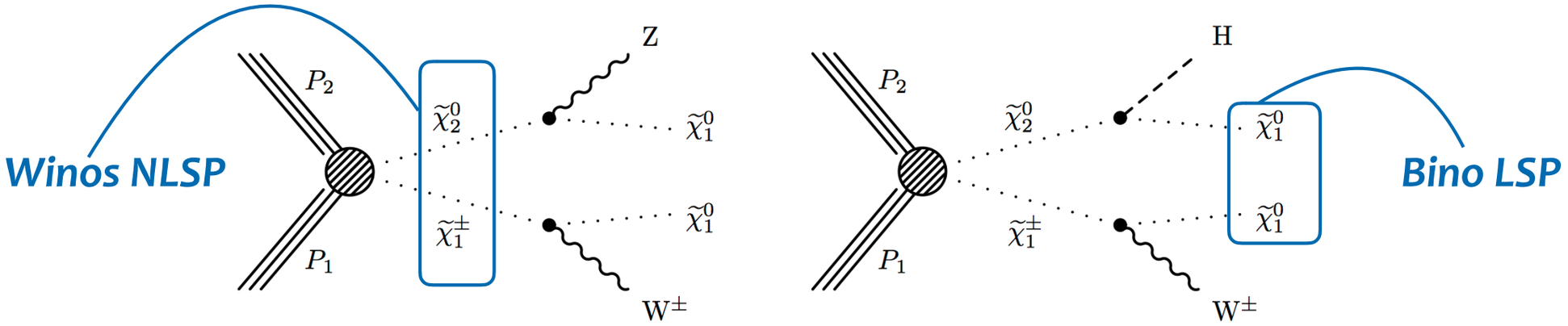
The Big Picture

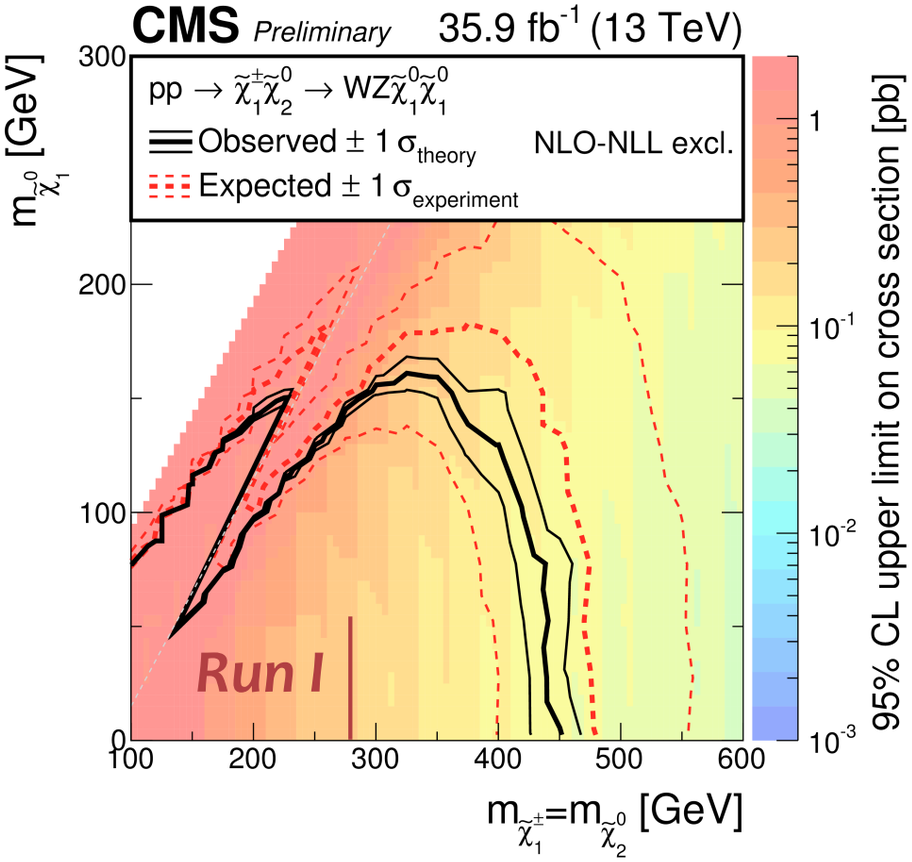
Concurrent and Complementary Efforts

- Multi-boson final states
  - Higgs
  - B2G
  - EXO
  - Standard Model
  - SUSY
- MET + X
  - EXO
  - SUSY
  - Top
- Long-lived objects
  - EXO
  - SUSY
  - Higgs
- Low mass objects
  - B Physics
  - Higgs exotic decays

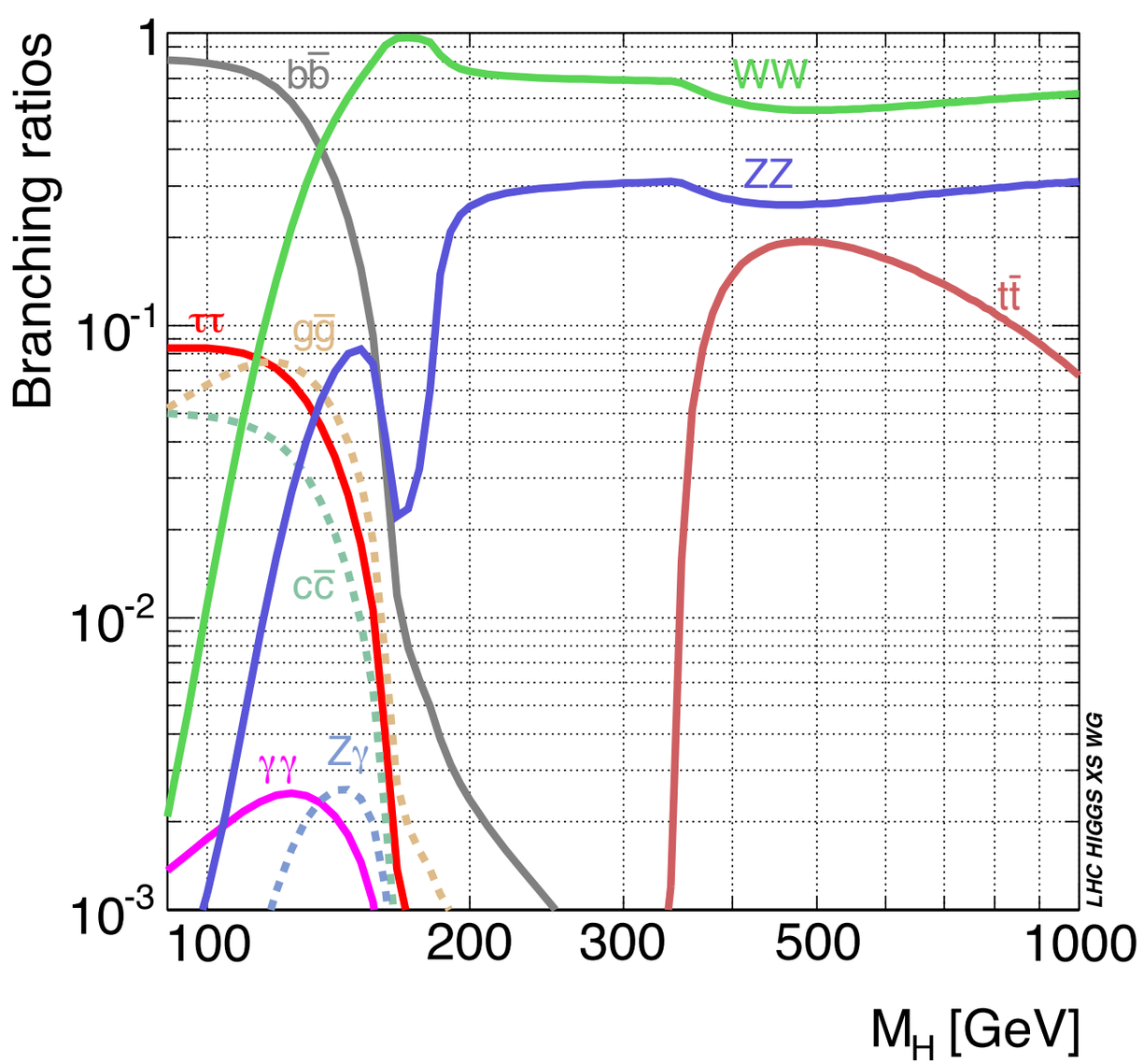
SUSY AND STANDARD MODEL

Winos, heavy sleptons



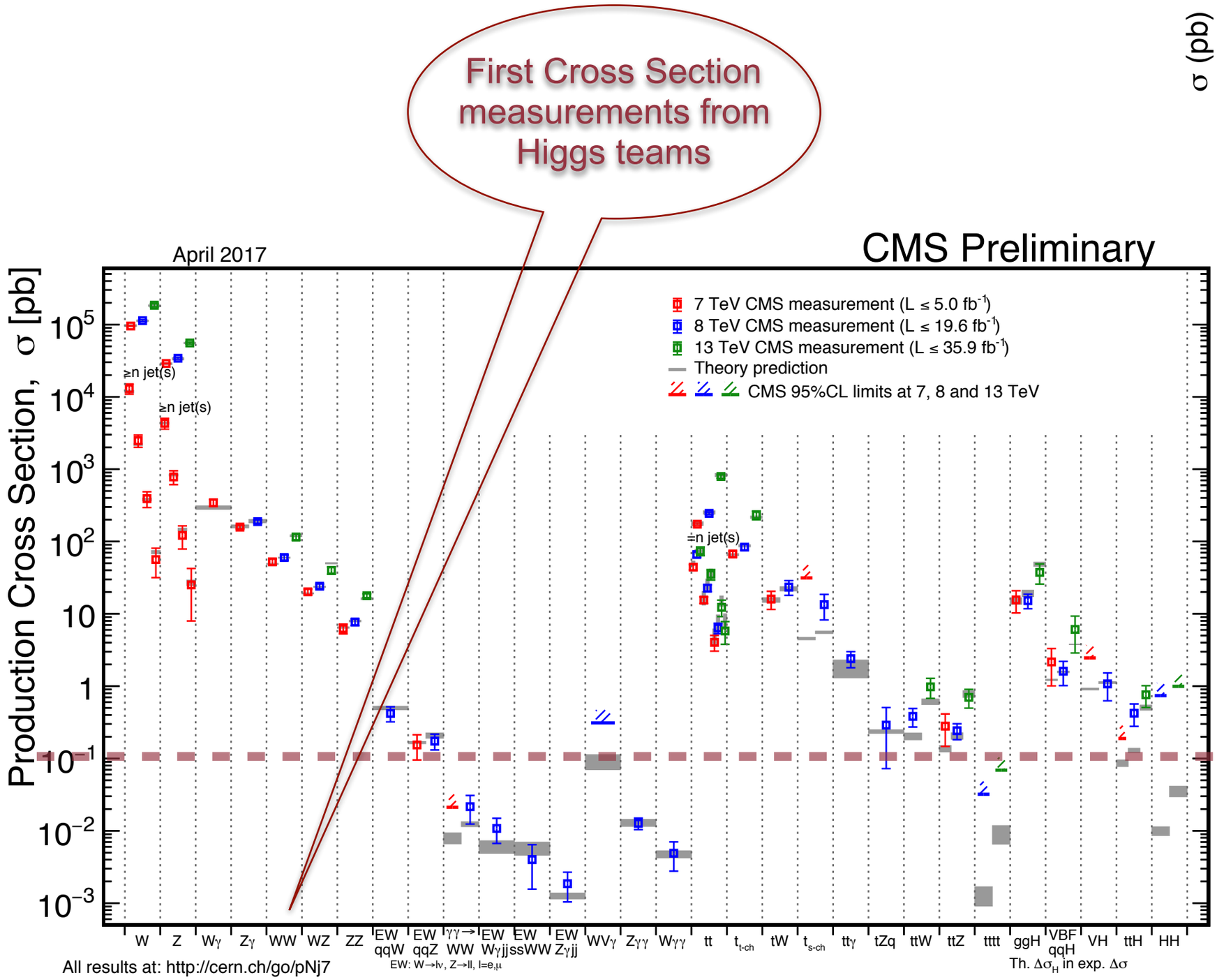


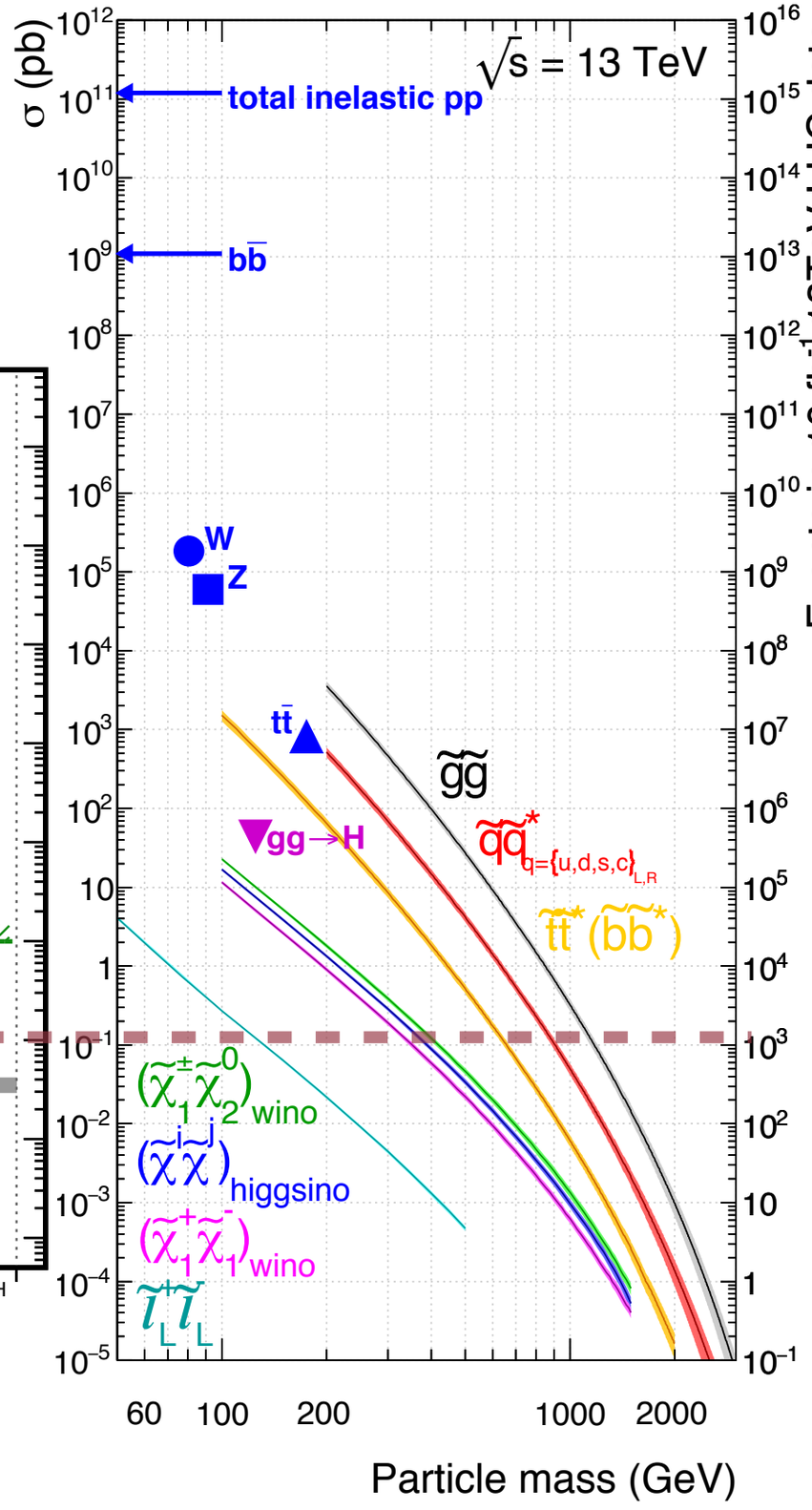
3ℓ(e,μ) with OSSF pair



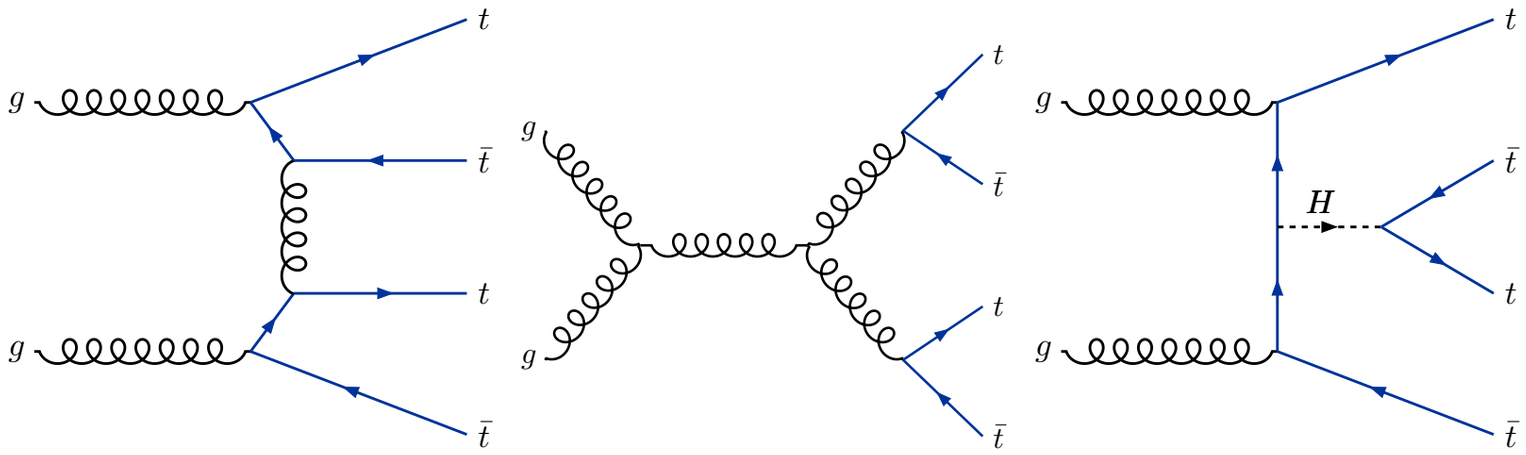
CROSSING GROUP BOUNDARIES

First Cross Section measurements from Higgs teams

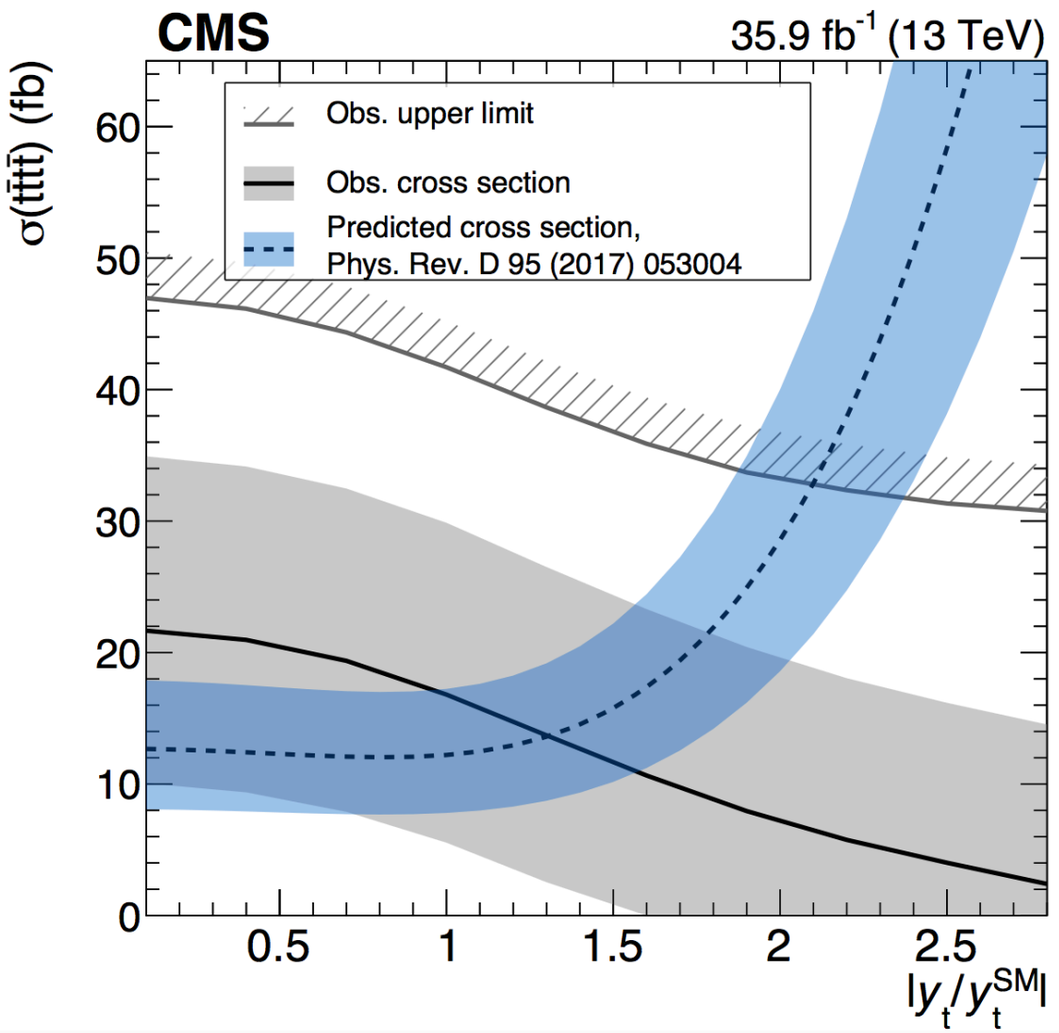




tttt



- Rare SM process with cross section ~ 10 fb
  - Sensitive to ttH coupling
  - enhancement in many BSM models
- 1.6σ significance compatible with SM
- Work in progress on 2017 data already
- Same team also targeting WWW production



PHYSICS DESIDERATA IN 2018

- Observation of H → bb decay
  - In 2017, CMS alone established H → $\tau\tau$
- Observation of ttH production
  - review underway for hadronic ttH(bb) and combination with ttH multi leptons with 2016 data
  - addition of 2017 data might be decisive
- New measurement of B_s → μμ and probing B_d → μμ
  - at least with 2016 data while monitoring quality of 2018 data
- Updated measurement of P5' in B_d → K*μμ
- Preliminary measurement of W mass

OUTLOOK

- Challenges and successes of 2017 exposed some of our fragilities
  - Partition of (not only) human resources across three projects
    - Running and operation of current CMS detector
    - Analysis of data in real time and production of solid scientific results
    - R&D of future CMS detector and its construction

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  - comprehensive feedback from analysis teams only in mid November
    - Unavailability of MC samples and stable data conditions did not help
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    - larger dataset in 2018 and 70 fb^{-1} of well understood data in hand for analysis
    - Upgrade of HCAL endcap in YETS 2017 could add another difficulty on top of existing challenges

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    - Upgrade of HCAL endcap in YETS 2017 could add another difficulty on top of existing challenges
- Democratic trigger budget for all groups might be revised
  - Consider alternative strategies by pre-scaling some triggers instead of all triggers at high luminosity (aka levelling)
  - First ideas to be discussed at Trigger Workshop on Dec 11

Extra

DESIDERATA FOR 2017 DATA

RE-RECO OF 2017 DATA

- Main use of 2017 data for late 2017 and Winter 2018
  - Legacy 2016 rereco + 2017 Prompt reco

O&C 29 Mar 2017

- Reprocess data when sufficient detector understanding to provide good (better) prompt reco
  - Expect about 10/fb by mid July
- Update Prompt Reco (PR) with improvements and fixes as early as possible
  - No delay in deployment of new calibrations and alignment
  - No issue with on-going analyses needing stability
- Prompt reco of 2017 data could be used for physics publications
  - 30/fb of PR with performance comparable to Sep rereco good for all searches
- When?
  - September with data availability no later than October
    - assuming PR as good as re-reco
  - legacy re-reco of 2017 only later if new issues arise or for uniformity

Unexpected problems with pixel did not help

Realistically this might be happening just now at the end of data taking

Delay of ~ 2.5 month WRT this plan a major concern

- We were aware new detector(s) might presented surprises
  - unfortunately situation much worse than expected
- Timely use of 2017 data basically impossible for Winter 2018
  - Later (wrt 2016) availability of MC and data
  - unique problems of the detector
  - Larger and more diverse data collected in 2017

DESIDERATA FOR 2017 MC

SIMULATION

O&C 29 Mar 2017

- Produce sufficient MC to allow detector commissioning and performance studies with early data
  - No massive MC production before July
  - target generic processes good for general performance and standard model plots
  - Copious MC samples only when

Unfortunately this happened too later (after summer) even for POG studies

- Bulk of MC production for physics after commissioning with early data
  - trigger menu finalized
  - issues and features in data understood

We might have achieved this but late availability is a serious concern