

# ESR 15

## Mid-term report

Searching for  $tt+H (\rightarrow bb)$  with the matrix element method at CMS

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October 20, 2015



**ETH** *Zürich*

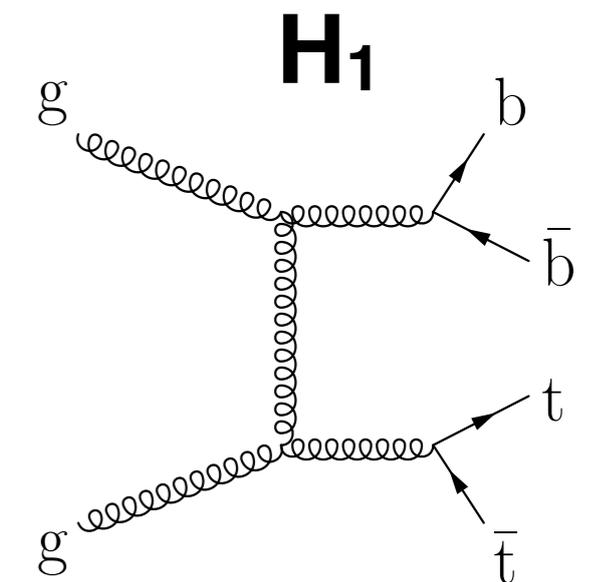
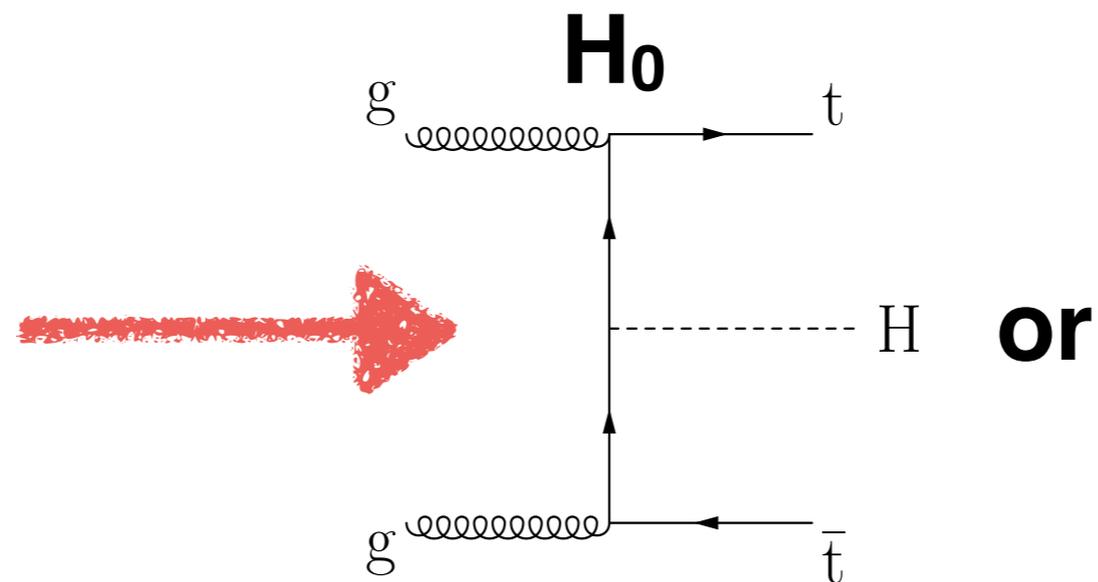
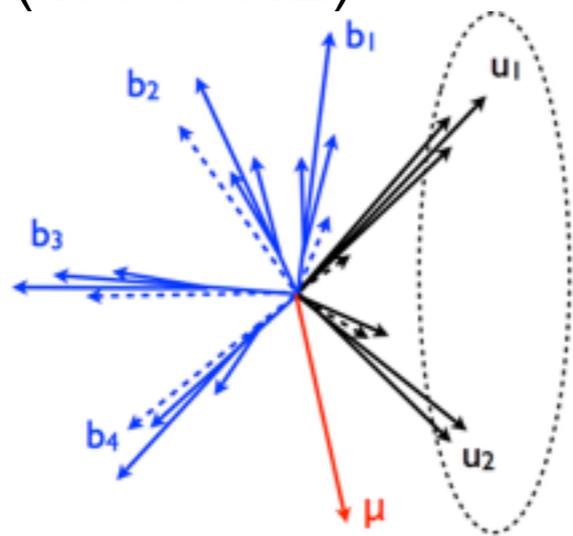
# My background

- From Estonia, June '14 MSc in physics (field theory).
- previously: SUSY, neutrino phenomenology, single top cross-section & polarization at CMS.
- CMS Fundamental Physics Scholar 2014 - 2015.
- HiggsTools (HT) ESR, PhD candidate @ ETH Zurich since Oct '14.
- Also involved in open source computing, scientific communication & CMS open data initiative.



# Top-higgs coupling

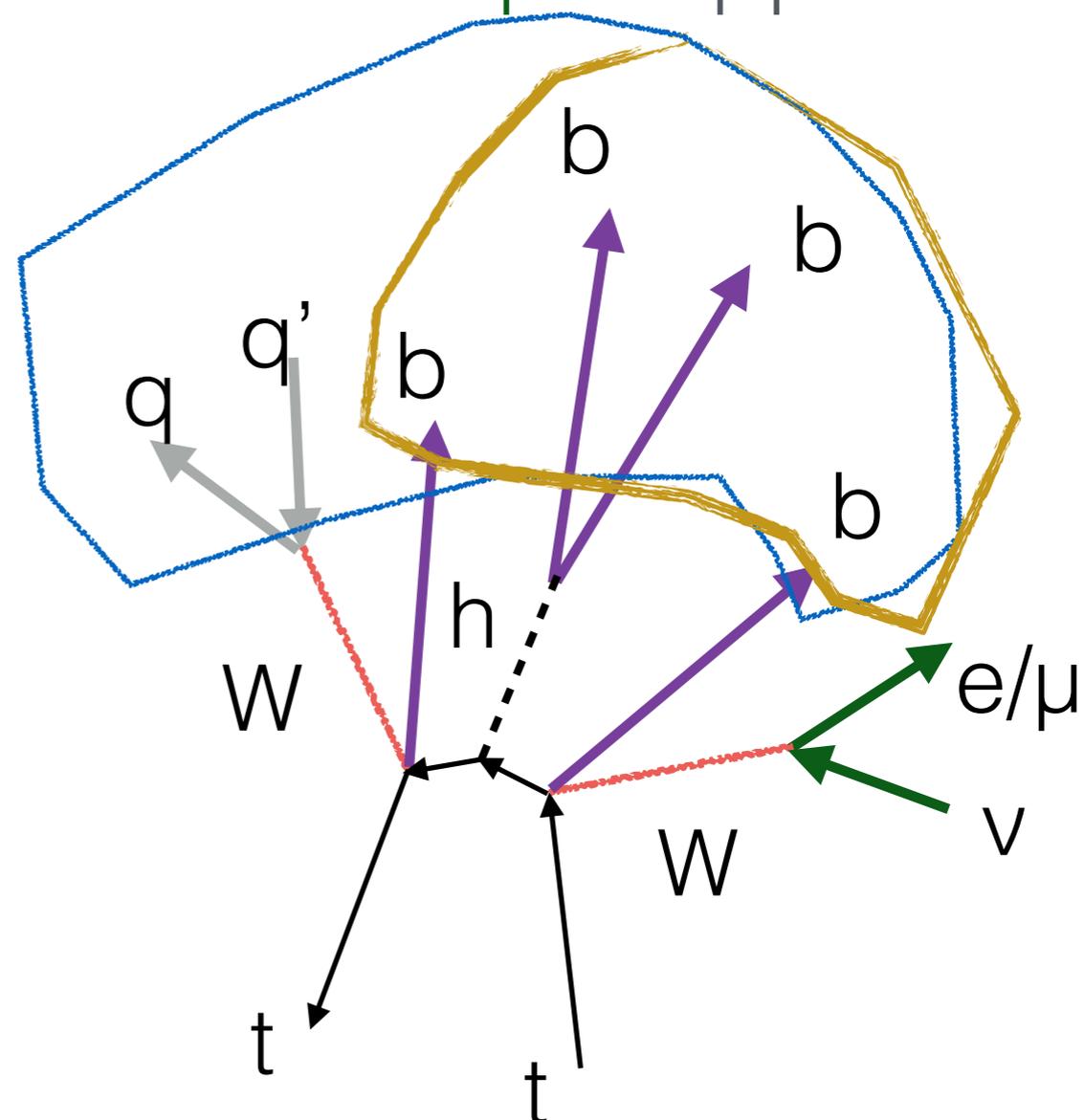
- Standard Model (SM) Yukawa theory:  $Y_t = \sqrt{2} m_t / v_{\text{ev}} \sim 1$ 
  - top mass  $\rightarrow$  coupling near unity. Top quark is a Higgs probe!
  - goal: observe & test compatibility with SM top pair associated Higgs (ttH) production in Run II.
- Higgs coupling measurements: ttH crucial input for coupling fits (**WP1 1.2**)



# WP3: analysis tools

- **WP3 1.3:** Matrix Element Method (MEM)
- **Analytical approach complements machine learning (ML)!**
  - Improved sensitivity in signal-rich regions with high jet/b-tag #
  - Competitive (~10-20% better) with dedicated machine learning
- **Key part of ttH data analysis @ CMS in LHC run II:** similar sensitivity to simulation-dependent ML.

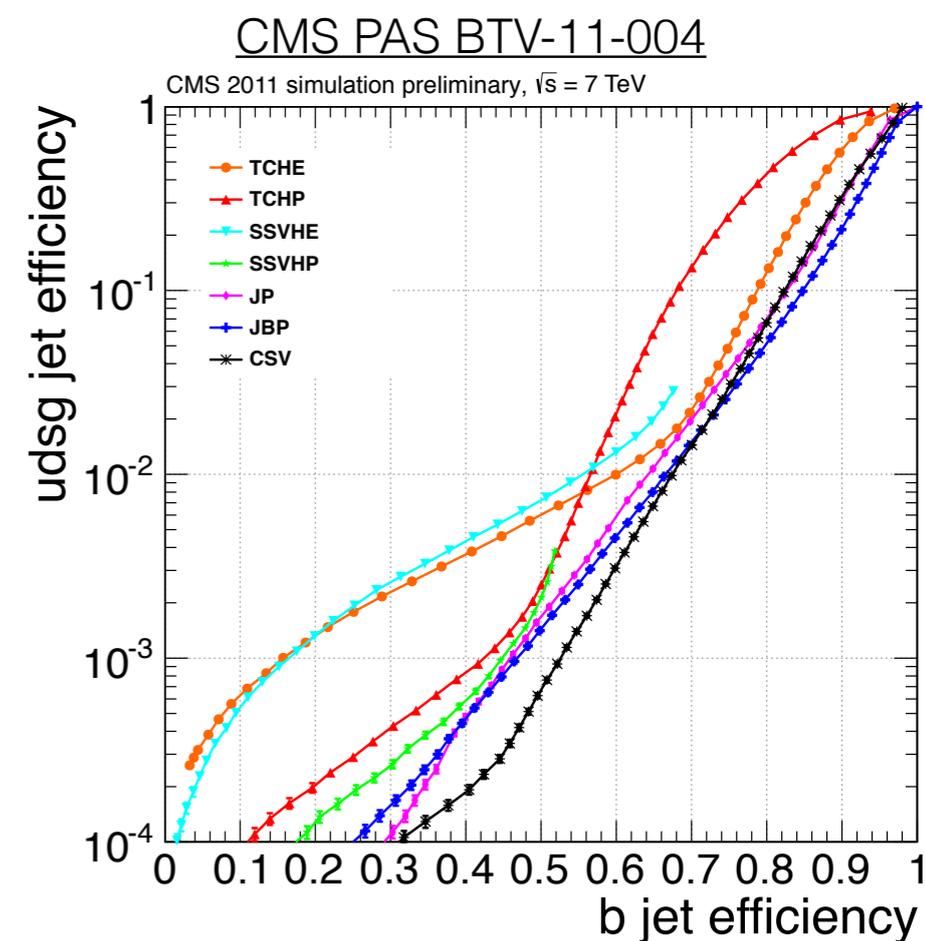
$pp \rightarrow ttH \rightarrow evb \ q q' b \ bb$   
 $\rightarrow \mu\nu b \ q q' b \ bb$



# Main results

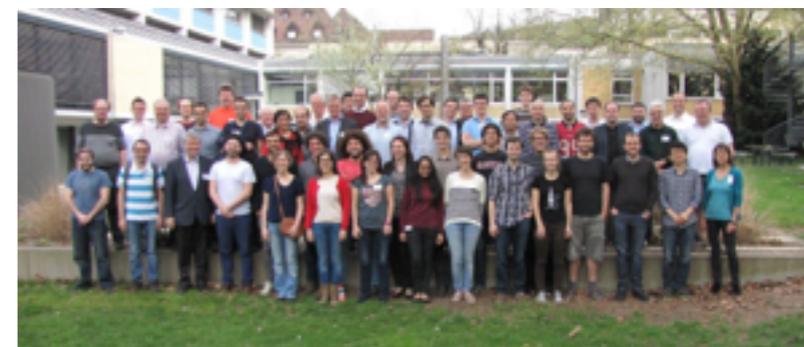
- Analysis of 8 TeV data published
  - [Eur. Phys. J. C 75 \(2015\) 251](#)
- Developed new **combined b-tagging** algorithm at CMS as authorship task.
- **ttH with MEM in run II:** new code, ready for data!
  - evaluated expected performance with main uncertainties for 2016 data
  - start of background validation & commissioning on 2015 data

Efficiency of finding b-jets can be combined!



# Training

- **CMS Data Analysis School** Dec '14: student & lecturer: lectures on Higgs physics, 3-day exercise session on analysis methods
- **Young Researchers Meeting** Feb. '15: collaboration & media training
- **Annual Meeting** April '15: research talks
- **Summer School** July '15: lectures (Effective Field Theory, ...)
- **workshop** on ttH polarization later this week...



# Conferences

- CMS 2nd single top workshop: t-channel angular properties
- HT ITN Annual Meeting: ttH(bb) with MEM
- ROOT CERN workshop: Julia: fast dynamic computing
- Higgs Couplings 2015

# Challenges

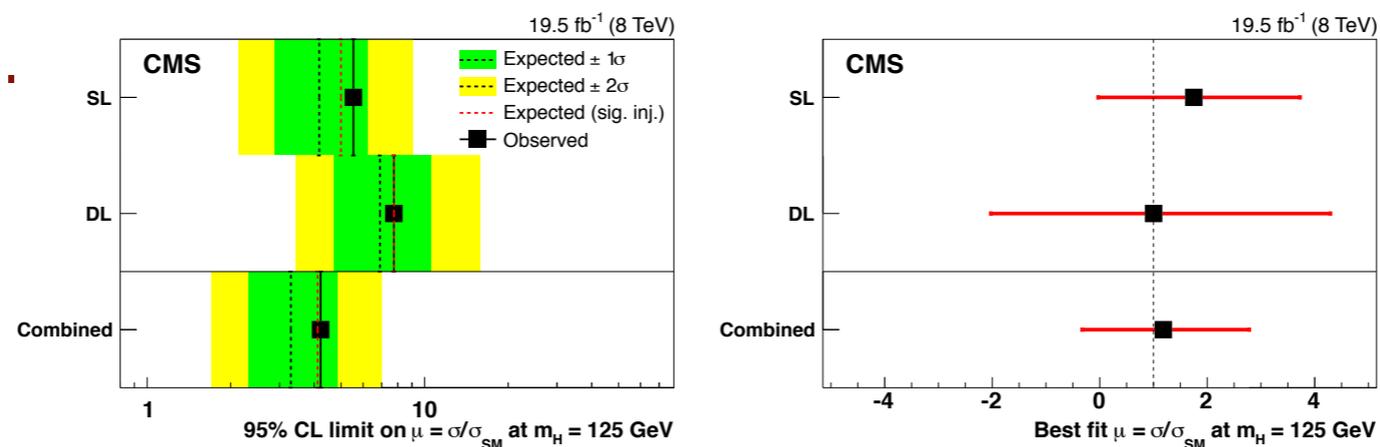
- tt+bb background modelling: constrain from data (with **M2.2.3**)
- Higher-order effects: MEM improvements under next-to-leading order (NLO) corrections (with **M3.2.1**)
- Inclusion of boosted objects in MEM (with **M3.1.3**)
- fast & flexible computation (with **all WP-s**)
  - MEM  $O(100)$  sec / event,  $\sim O(10^6)$  tt+jets events expected in 2015-2016,  $\sim O(10^{2..3})$  CPUs for 24h turn-over
- **Data taking at energy frontier**

# Strategies

- **tt+bb background**
  - multi-dimensional fit, exploit control regions in data (**M2.3.1**)
  - theory uncertainty on MEM discriminator (**M2.3.2**)
- **NLO discrimination power in MEM (M3.2.1-2)**
  - exploit extended hypotheses (tt+3jets)
  - n+1 parton process contribution in  $2 \rightarrow n$  processes

# Outlook

- First results with **13 TeV data in 2016 spring conferences**: object & background studies
- Expect  $\sim 75\text{-}100/\text{fb}$  data until 2017, expect to exceed Run I ttH sensitivity with  $\sim 5/\text{fb}$ !
- Improve jet flavour tagging algorithms.
- Combine with ttH fully-hadronic,  $H \rightarrow WW$ ,  $H \rightarrow \text{tautau}$  channels.



# Career development

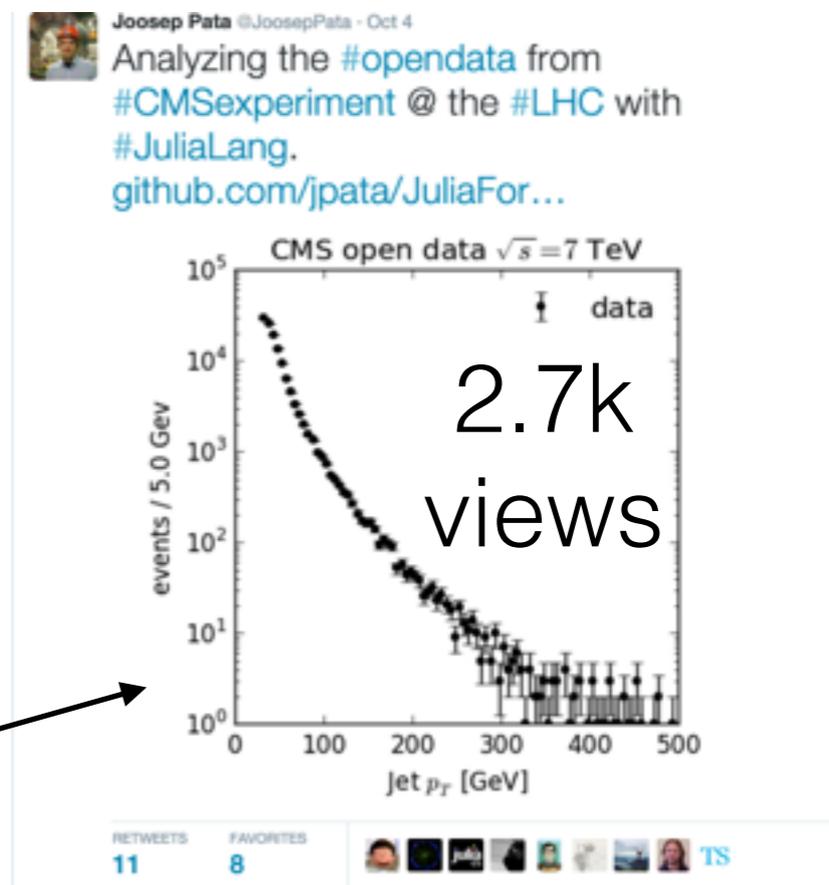
- Foster contacts in HEP community
  - Secondment at UZH (2015 winter): work on tt+bb background, NLO MEM
  - UDUR (2016 spring): NLO tools (Sherpa)
- Planned private secondment at Maple or Wolfram in Spring 2017

# Outreach activities

- 2 interviews for Estonian public broadcasting: 100k views (~10% of Estonian speaking population): 1, 2

 Popularizing data analysis with open tools (with CMS open data group).

 Educating public about CERN.



2.7k views

13k views

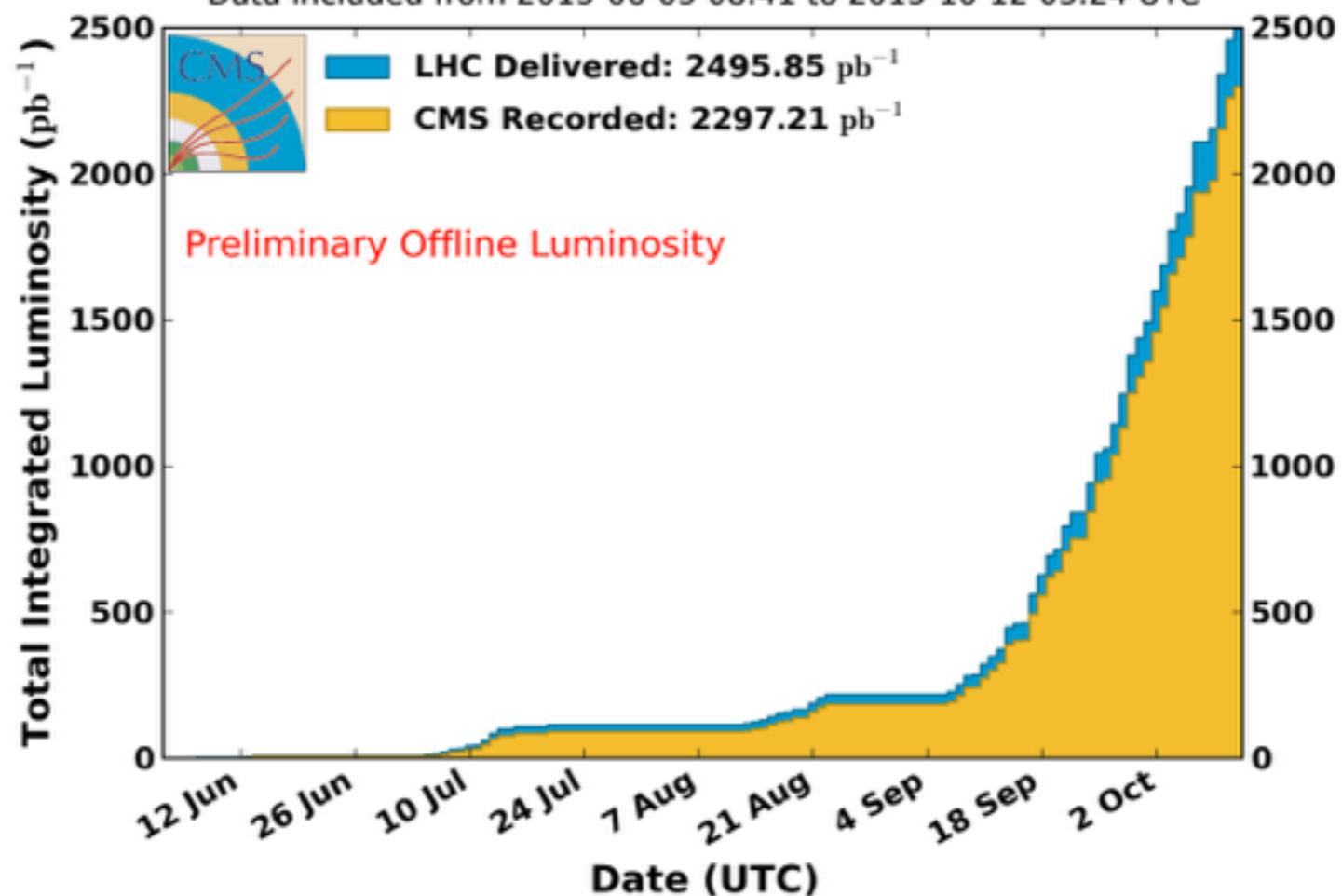
TIL that CERN has a page explaining the weirdest frequently asked questions: [press.web.cern.ch/backgrounders/...](https://press.web.cern.ch/backgrounders/)

Will CERN open a door to another dimension?  
CERN will not open a door to another dimension.

# Thank you!

CMS Integrated Luminosity, pp, 2015,  $\sqrt{s} = 13$  TeV

Data included from 2015-06-03 08:41 to 2015-10-12 03:24 UTC



# Exciting times ahead...