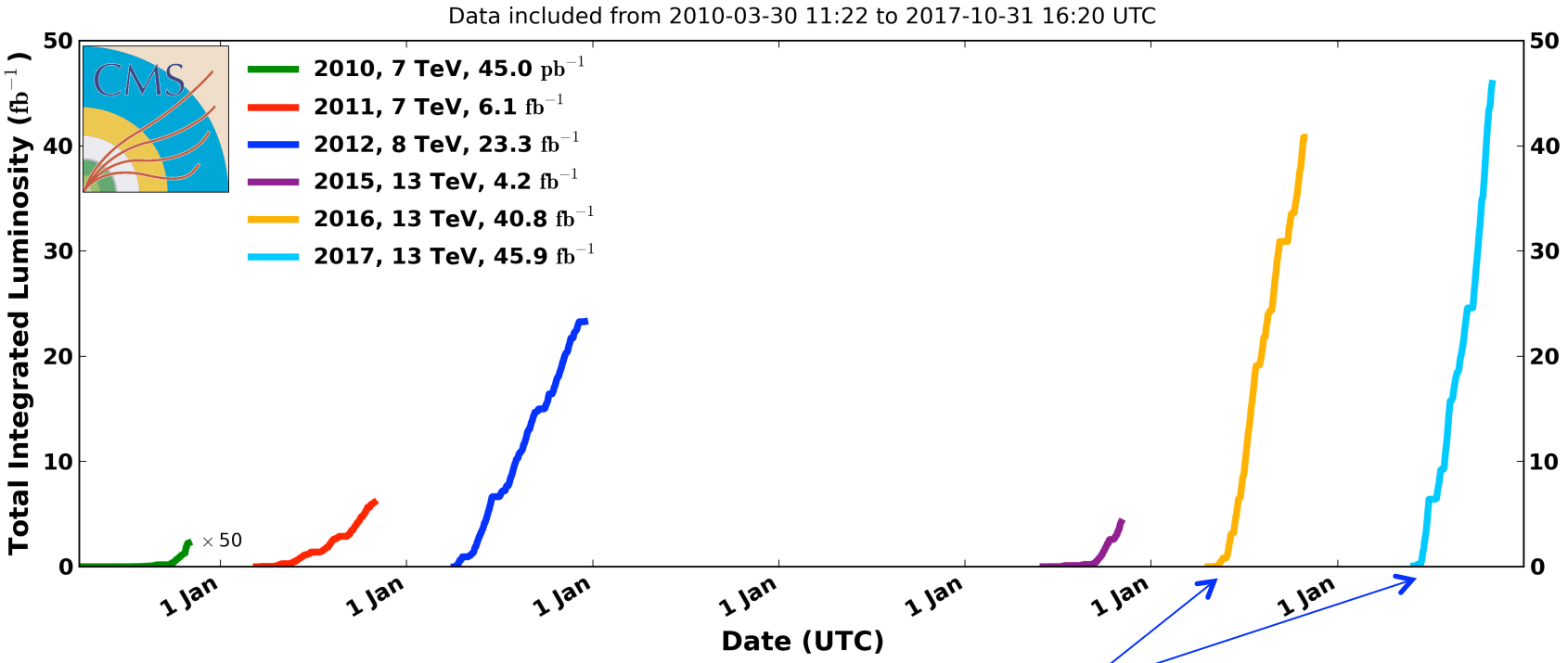
Status and plan of IHEP CMS physics analyses in ZZ channel

Mingshui Chen

国际创新海外团队, 院前沿重点项目
&所创新团队2017年联合年会

Nov. 03, 2017

CMS Run 2 data taking



Excellent machine & detector performance in Run 2:

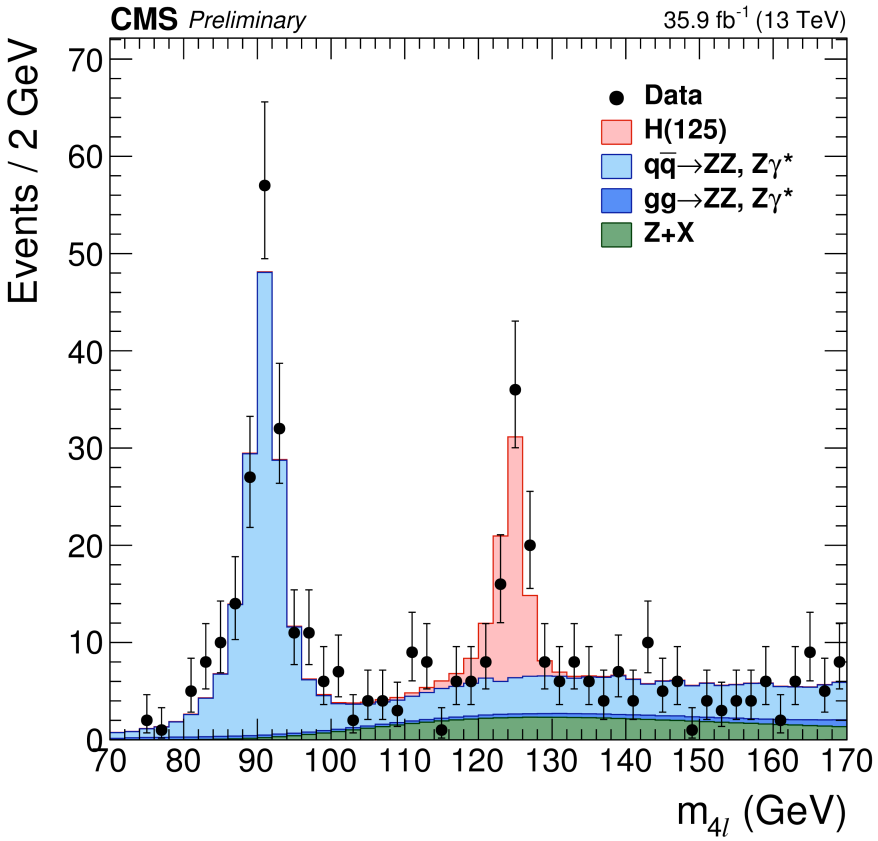
- 2016 delivered 41 fb^{-1} to CMS, **35.9 fb^{-1}** for physics analyses
- 2017 delivered >45 fb^{-1} to CMS, data taking efficiency ~92%
- Run II expected to deliver > **150 fb^{-1}**

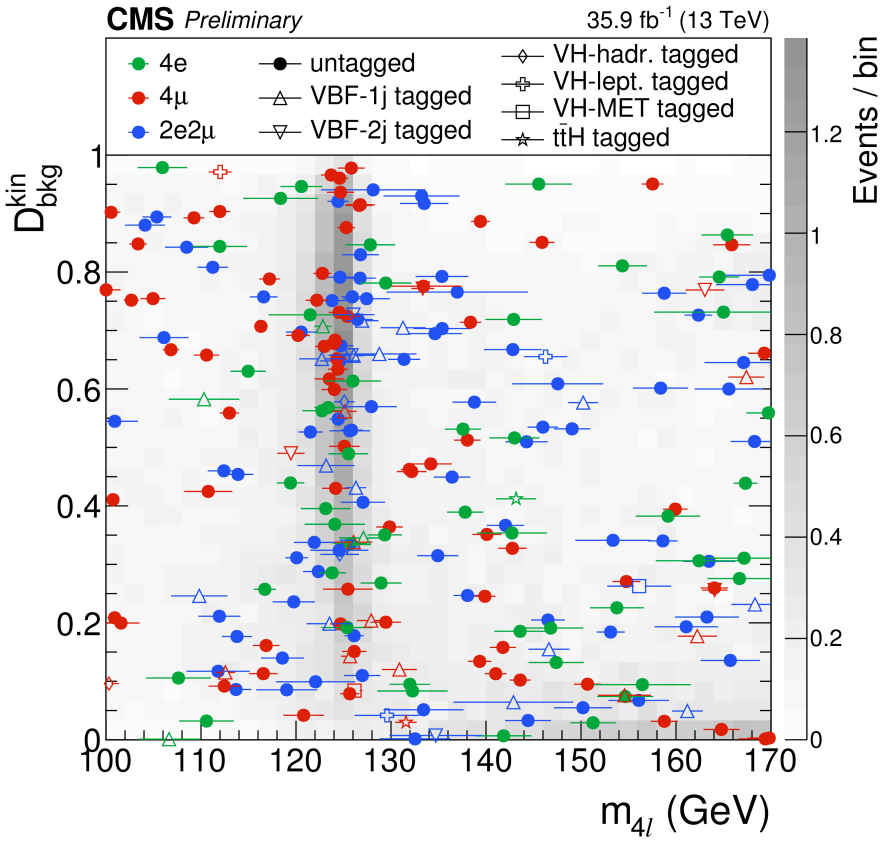
H→ZZ→4l

- For analysis HIG-16-041 based on full 2016 data, IHEP group mainly contribute to the Higgs mass and cross section measurements

- Several ideas successfully implemented
  - Z boson mass constraint
    - Improves the mass measurement sensitivity by ~8%
  - Simplified Template Cross Section
    - Step forwards to bridge experimental results and theory interpretations

m_H in H→ZZ→4l



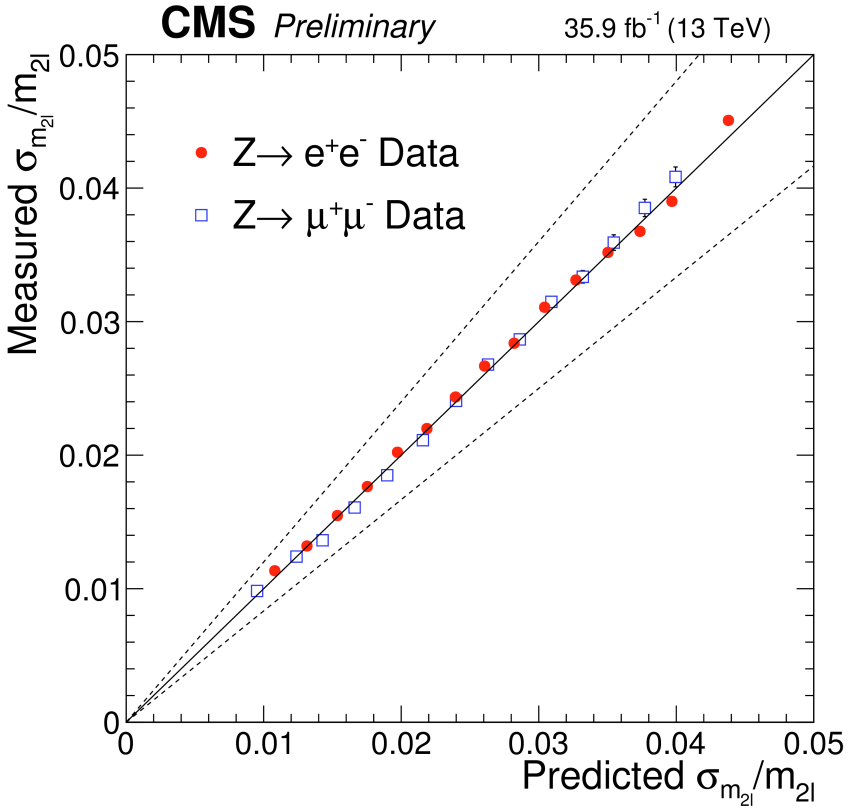


- Mass measurement with 3D likelihood fits
  - m4l, kinematic discriminant and per-event mass error

$$\mathcal{L}_{3D}^{m,\Gamma} \equiv \mathcal{L}_{3D}^{m,\Gamma}(m_{4\ell}, \mathcal{D}_{\rm m}, \mathcal{D}_{\rm bkg}^{\rm kin}) = \mathcal{P}(m_{4\ell}|m_{\rm H},\Gamma,\mathcal{D}_{\rm m})\mathcal{P}(\mathcal{D}_{\rm m}|m_{4\ell}) \times \mathcal{P}(\mathcal{D}_{\rm bkg}^{\rm kin}|m_{4\ell})$$

Correction of per-event mass error

- Event by event mass error: lepton momentum error propagated to m4l
- Important for mass measurement when statistics are limited



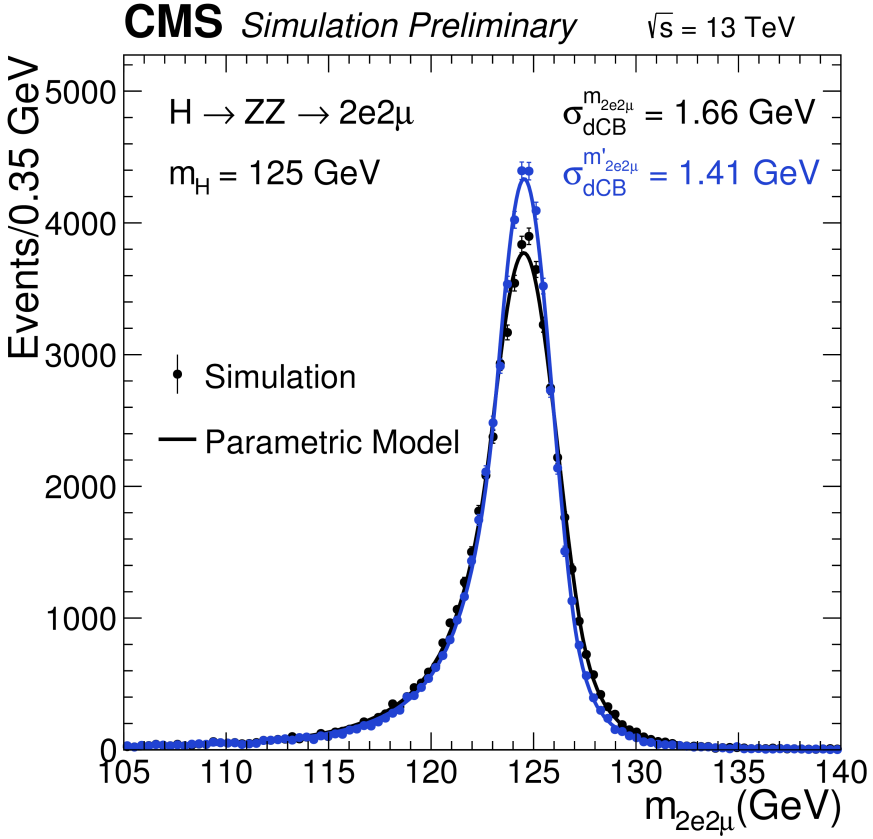
Huge effort on mass resolution validation by comparing measured mass resolution with the predicted dilepton mass resolution using the event-by-event mass uncertainty for Z→$\ell\ell$ events in data.

The dashed lines denote a ±20% region, used as the systematic uncertainty on the resolution.

Z mass constraint

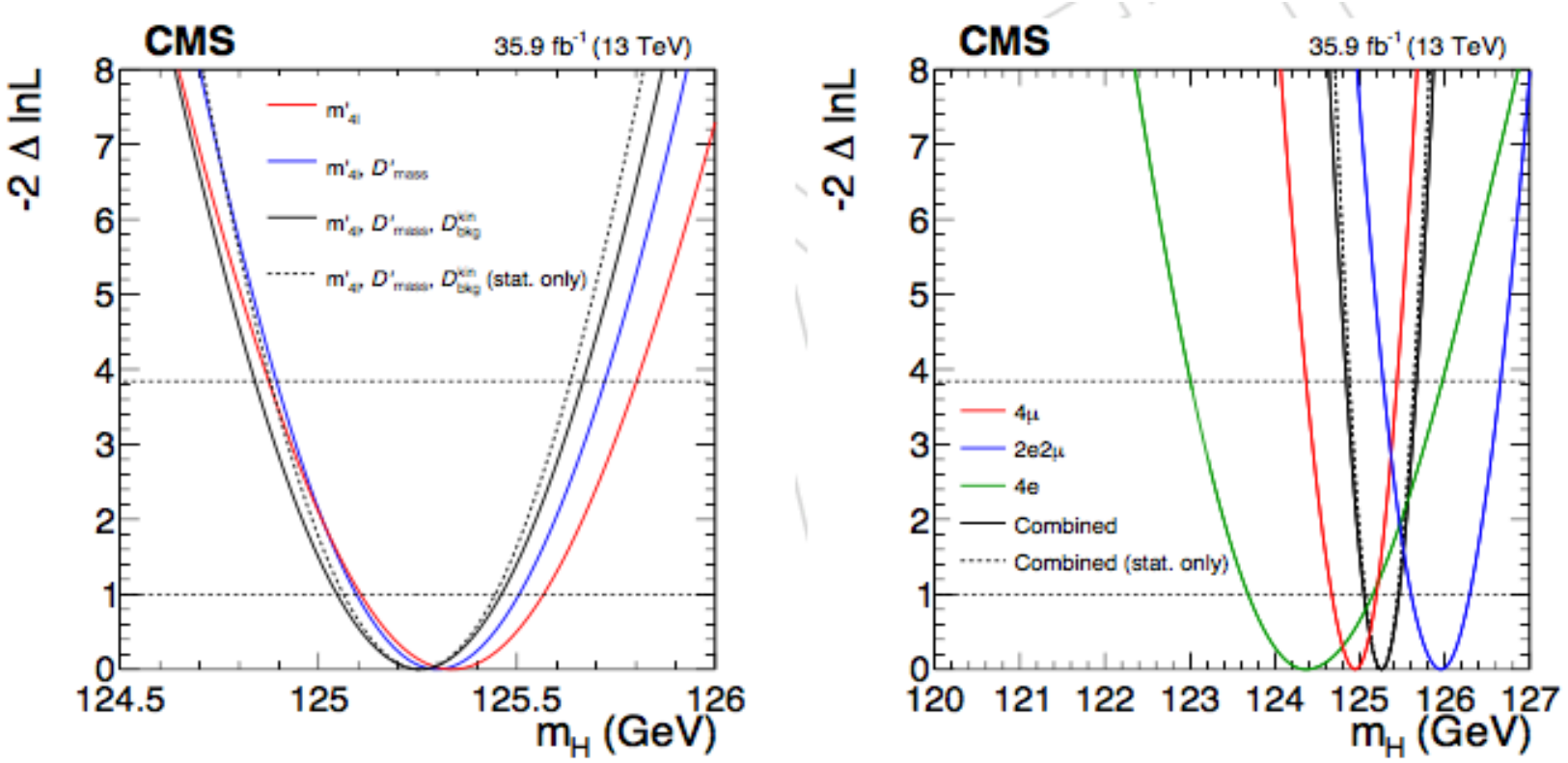
Improve mass resolution by performing kinematic fit on the intermediate Z resonance with mass constraint

$$\mathcal{L}(\hat{p}_{\mathrm{T}}^{1}, \hat{p}_{\mathrm{T}}^{2} | p_{\mathrm{T}}^{1}, \sigma_{p_{\mathrm{T}}^{1}}, p_{\mathrm{T}}^{2}, \sigma_{p_{\mathrm{T}}^{2}}) = \mathrm{Gauss}(p_{\mathrm{T}}^{1} | \hat{p}_{\mathrm{T}}^{1}, \sigma_{p_{\mathrm{T}}^{1}}) \cdot \mathrm{Gauss}(p_{\mathrm{T}}^{2} | \hat{p}_{\mathrm{T}}^{2}, \sigma_{p_{\mathrm{T}}^{2}}) \cdot \mathcal{L}(m_{12} | m_{\mathrm{Z}}, m_{\mathrm{H}})$$



arXiv:1706.09936

Best m_H measurement to date



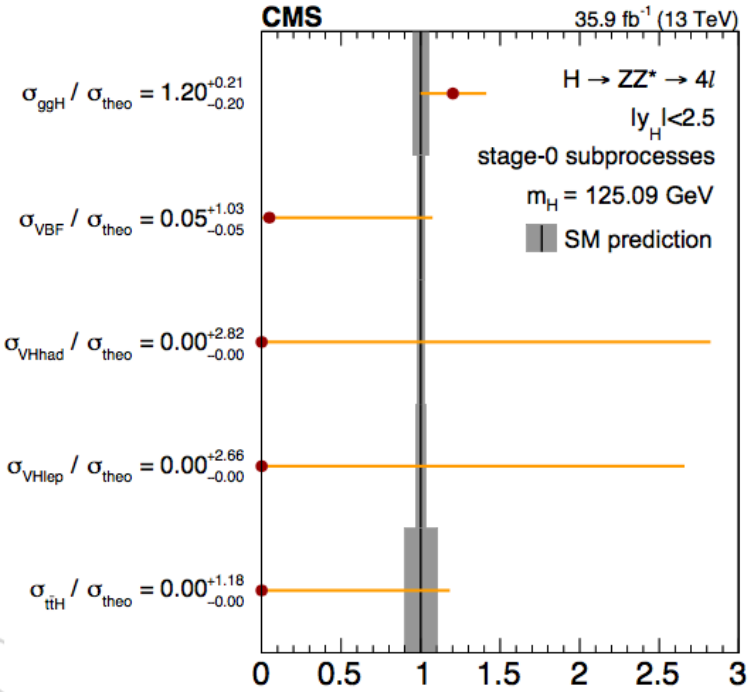
Mass (2016, 4L) : $125.26 \pm 0.20(stat) \pm 0.08(sys) Gev$

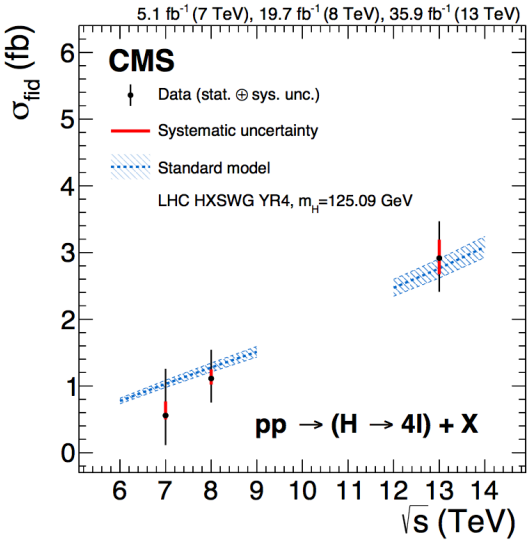
ATLAS + CMS:
Mass (Run 1, all): $125.09 \pm 0.21(stat) \pm 0.11(sys) Gev$

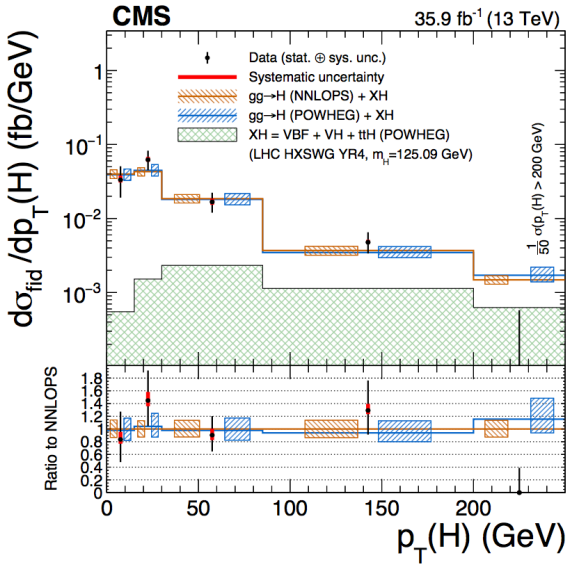
Best single measurement of Higgs mass!
Better than all modes, ATLAS and CMS from Run1!

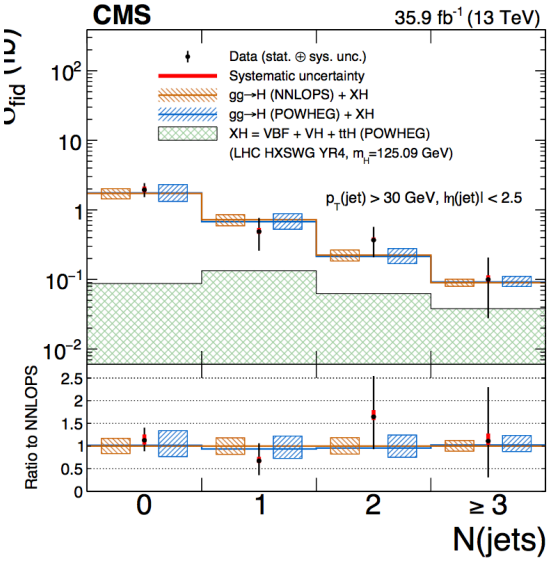
arXiv:1706.09936

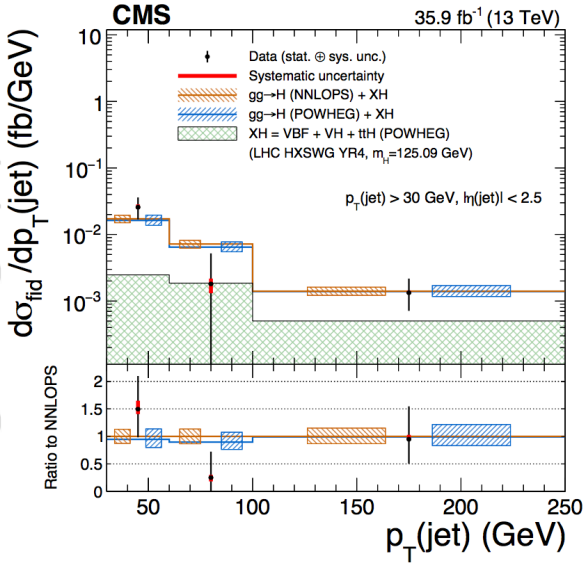
H->ZZ->4l: cross sections











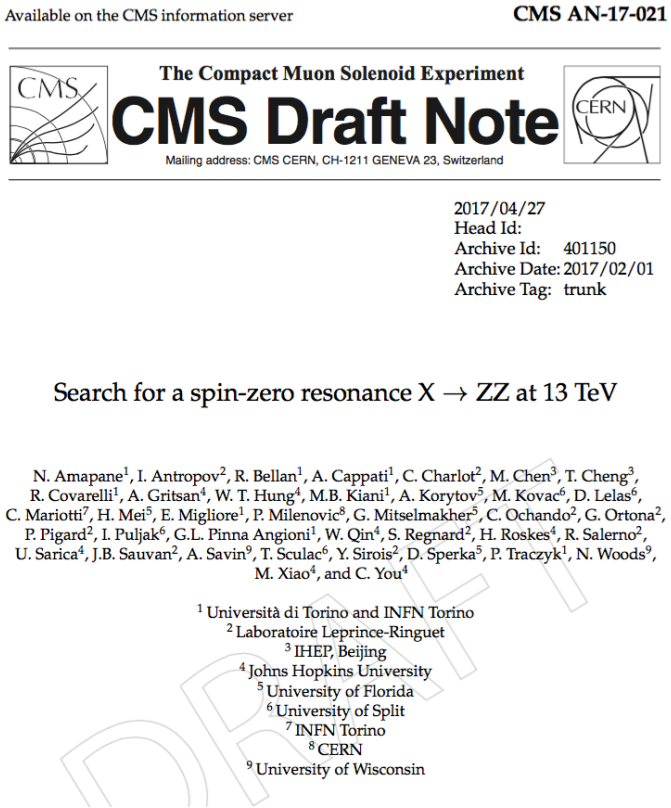
m_H measurement w.r.t. Z pole

- Originally a paper planned on extracting Higgs mass by using δ_m between m_Z and m_H, with PDG Z mass as reference
  - A new technique, thought to be able to reduce systematic uncertainty substantially
  - Lots of work done to understand various effects on small systematic uncertainties
- Due to the facts that lepton kinematics are different between Z (more soft leptons) and Higgs sources, also lepton scale uncertainties are pt-eta dependent

  --> hard/impossible to beat standard measurement
- Now the plan stopped, and we move on

High mass Higgs searches

- **HIG-16-034:** 2l2j based on 12.9 fb^{-1} 2016 partial data
- **HIG-17-012:** 2016 full data, approved, to be public soon
  - Combining 3 analyses targeting different final states: 4l, 2l2j, 2l2ν
  - IHEP contributed to 4l and 2l2j



Available on the CMS information server CMS AN-17-021

The Compact Muon Solenoid Experiment

CMS Draft Note

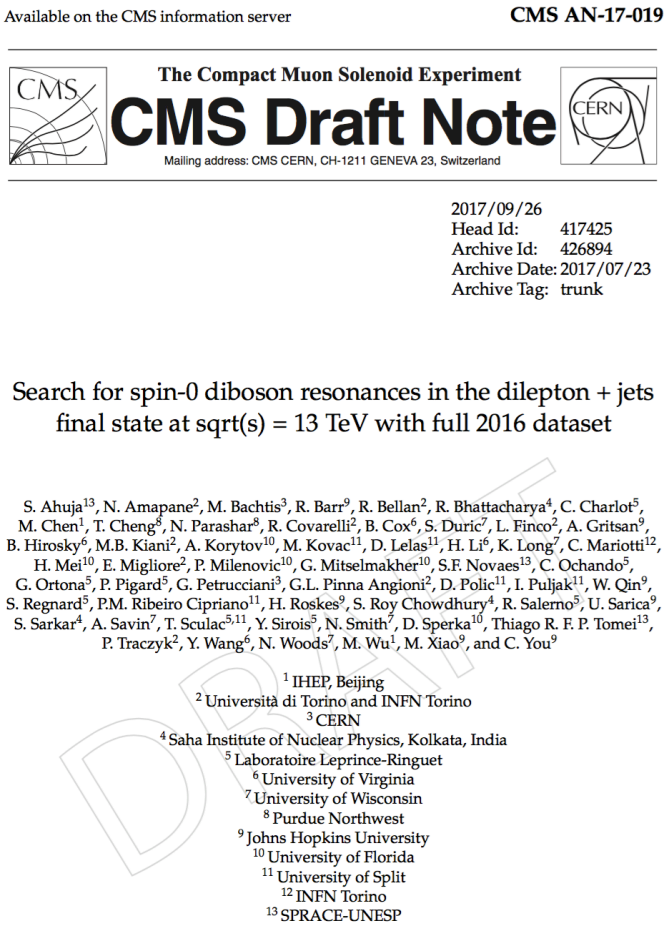
Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

2017/04/27
Head Id:
Archive Id: 401150
Archive Date: 2017/02/01
Archive Tag: trunk

Search for a spin-zero resonance X → ZZ at 13 TeV

N. Amapane[1], I. Antropov[2], R. Bellan[1], A. Cappati[1], C. Charlot[2], M. Chen[3], T. Cheng[3], R. Covarelli[1], A. Gritsan[4], W. T. Hung[4], M.B. Kiani[1], A. Korytov[5], M. Kovac[6], D. Lelas[6], C. Mariotti[7], H. Mei[5], E. Migliore[1], P. Milenovic[8], G. Mitselmakher[5], C. Ochando[2], G. Ortona[2], P. Pigard[2], I. Puljak[6], G.L. Pinna Angioni[1], W. Qin[4], S. Regnard[2], H. Roskes[4], R. Salerno[2], U. Sarica[4], J.B. Sauvan[2], A. Savin[9], T. Sculac[6], Y. Sirois[2], D. Sperka[5], P. Traczyk[1], N. Woods[9], M. Xiao[4], and C. You[4]

[1] Università di Torino and INFN Torino
[2] Laboratoire Leprince-Ringuet
[3] IHEP, Beijing
[4] Johns Hopkins University
[5] University of Florida
[6] University of Split
[7] INFN Torino
[8] CERN
[9] University of Wisconsin



Available on the CMS information server CMS AN-17-019

The Compact Muon Solenoid Experiment

CMS Draft Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

2017/09/26
Head Id: 417425
Archive Id: 426894
Archive Date: 2017/07/23
Archive Tag: trunk

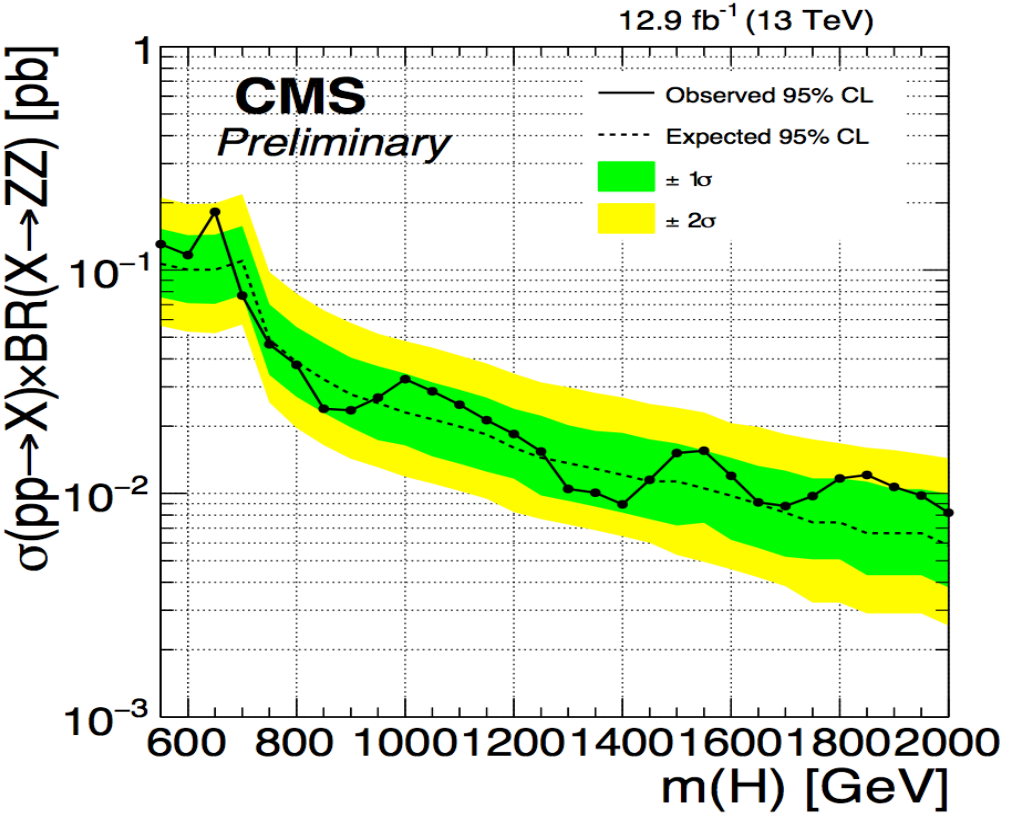
Search for spin-0 diboson resonances in the dilepton + jets final state at sqrt(s) = 13 TeV with full 2016 dataset

S. Ahuja[13], N. Amapane[2], M. Bachtis[3], R. Barr[9], R. Bellan[2], R. Bhattacharya[4], C. Charlot[5], M. Chen[1], T. Cheng[8], N. Parashar[8], R. Covarelli[2], B. Cox[6], S. Duric[7], L. Finco[2], A. Gritsan[9], B. Hirosky[6], M.B. Kiani[2], A. Korytov[10], M. Kovac[11], D. Lelas[11], H. Li[6], K. Long[7], C. Mariotti[12], H. Mei[10], E. Migliore[2], P. Milenovic[10], G. Mitselmakher[10], S.F. Novaes[13], C. Ochando[5], G. Ortona[5], P. Pigard[5], G. Petrucciani[3], G.L. Pinna Angioni[2], D. Polic[11], I. Puljak[11], W. Qin[9], S. Regnard[5], P.M. Ribeiro Cipriano[11], H. Roskes[9], S. Roy Chowdhury[4], R. Salerno[5], U. Sarica[9], S. Sarkar[4], A. Savin[7], T. Sculac[5,11], Y. Sirois[5], N. Smith[7], D. Sperka[10], Thiago R. F. P. Tomei[13], P. Traczyk[2], Y. Wang[6], N. Woods[7], M. Wu[1], M. Xiao[9], and C. You[9]

[1] IHEP, Beijing
[2] Università di Torino and INFN Torino
[3] CERN
[4] Saha Institute of Nuclear Physics, Kolkata, India
[5] Laboratoire Leprince-Ringuet
[6] University of Virginia
[7] University of Wisconsin
[8] Purdue Northwest
[9] Johns Hopkins University
[10] University of Florida
[11] University of Split
[12] INFN Torino
[13] SPRACE-UNESP

HIG-16-034: 2l2j resonance search

- Tongguang Cheng is the editor & contact
- We also introduced Dijet kinematic fitting to improve the ZZ invariant mass resolution

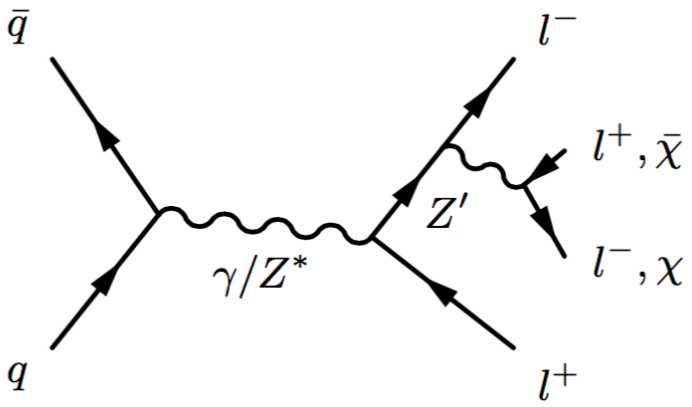


ongoing analysis

arXiv:1407.3001, 1505.04620, etc

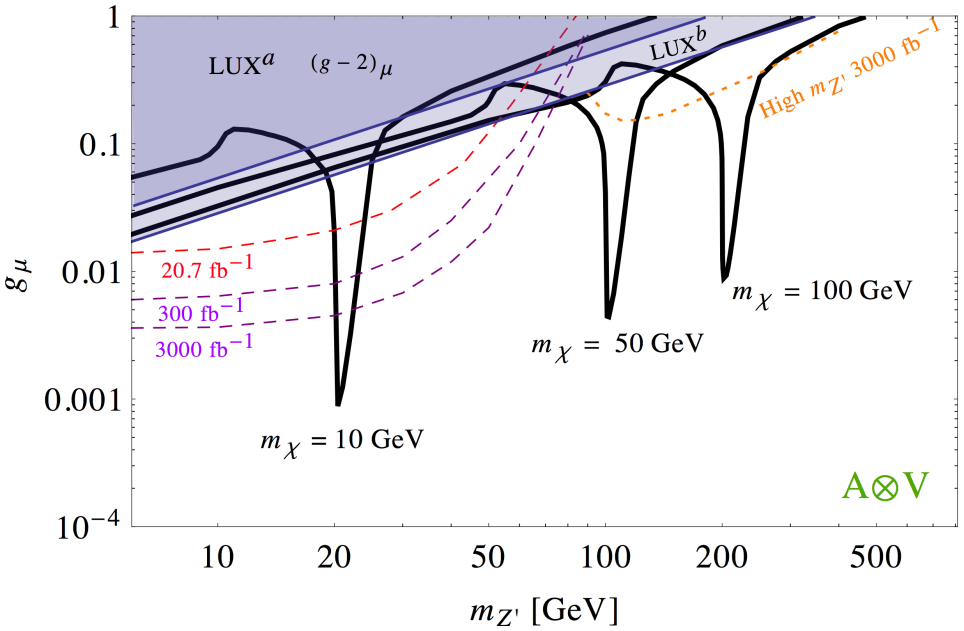
Low mass Z' bump hunting

- Leptophilic dark matter with Z' interaction
  - an alternate framework where direct DM-hadron interactions do not occur
  - instead the DM couples exclusively to SM leptons at tree level.



- Analysis in Z->4l channel
  - Exploring our existing expertise
  - bump hunt in the dilepton invariant mass spectrum with 4l forming a Z

- Very preliminary results seem promising



Plan

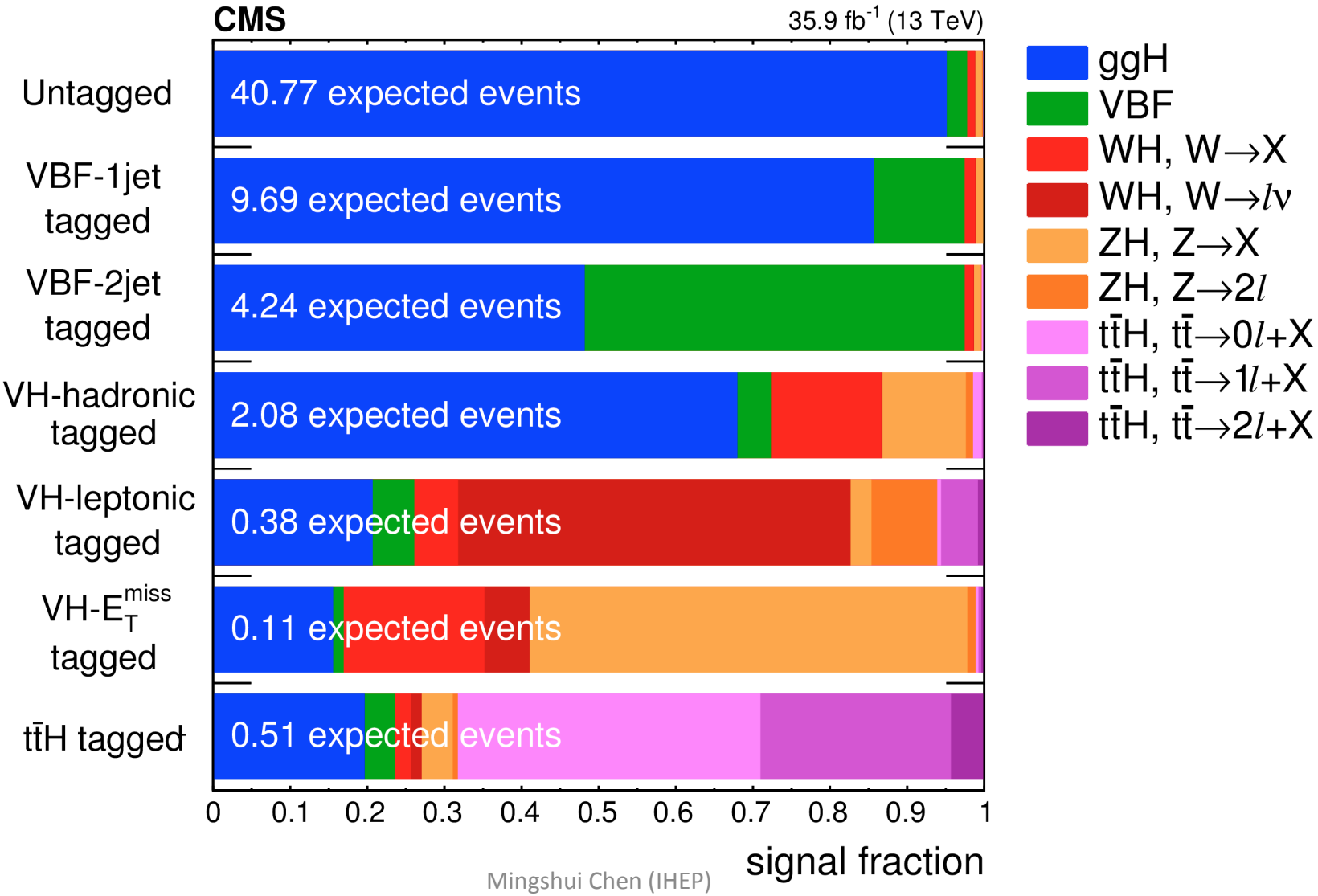
- With full Run II data, we committed to the following analyses with 4l state, by the end of 2020
  - Higgs mass and width measurement
  - Higgs total and diff. xs measurements
  - Higgs anomalous coupling search
  - High mass resonance search in 4l
  - Z->4l BR and diff. cross section measurement in SMP group
  - In addition, we also committed to High mass resonance search in 2l2v
- Clearly lack of person-power to cover all topics
  - current manpower: Mingshui + Ahmad + Tahir
  - from next July new student Chenguang Zhang will join in
  - seek funding to recruit more persons

back up

m_H with different fits

No $m(Z_1)$ constraint	3D: $\mathcal{L}(m_{4\ell}, \mathcal{D}_{\rm mass}, \mathcal{D}^{\rm kin}_{\rm bkg})$	2D: $\mathcal{L}(m_{4\ell}, \mathcal{D}_{\rm mass})$	1D: $\mathcal{L}(m_{4\ell})$
Expected $m_{\rm H}$ uncertainty change	+8.1%	+11%	+21%
Observed $m_{\rm H}$ (GeV)	125.28±0.22	125.36±0.24	125.39±0.25
With $m(Z_1)$ constraint	3D: $\mathcal{L}(m'_{4\ell}, \mathcal{D}'_{\rm mass}, \mathcal{D}^{\rm kin}_{\rm bkg})$	2D: $\mathcal{L}(m'_{4\ell}, \mathcal{D}'_{\rm mass})$	1D: $\mathcal{L}(m'_{4\ell})$
Expected $m_{\rm H}$ uncertainty change	—	+3.2%	+11%
Observed $m_{\rm H}$ (GeV)	125.26±0.21	125.30±0.21	125.34±0.23

H4l event categorization



Full mass spectrum of m_{4l}