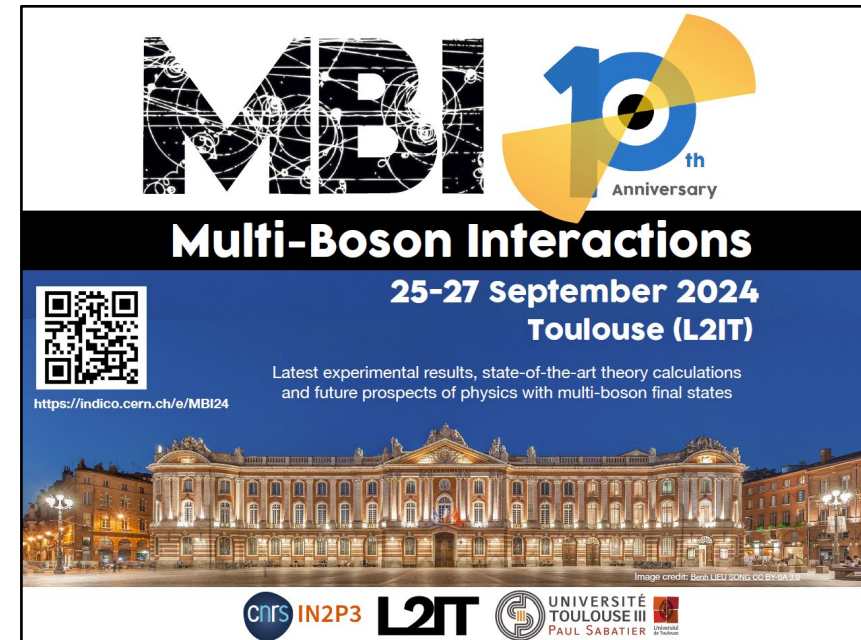
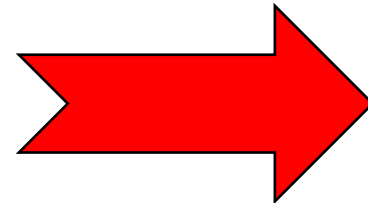
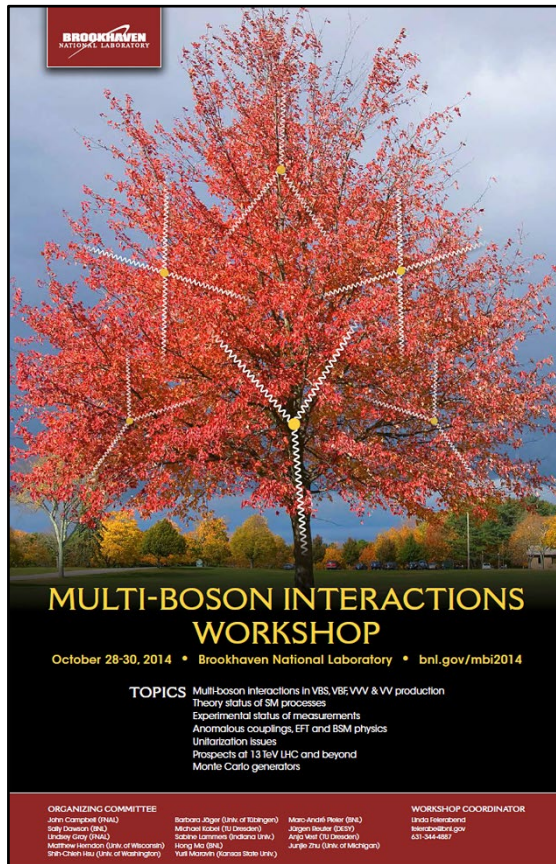


# Multi-Boson Interactions: The First 10 Years



Marc-André Pleier  
September 25 2024

# Pre-History of MBI

## Evolution at BNL:

- Two “US ATLAS BNL analysis jamborees” / year
  - ATLAS center for general analysis support/overview
- 2011: VV focus starts to emerge
- 2012: 1<sup>st</sup> “BNL Diboson VBF/VBS Jamboree”
  - Renamed jamboree to reflect its focus
  - Scope: ATLAS + theory
  - LOC: Dmitri Tsybychev, Hong Ma, Junjie Zhu
- 2013: 2<sup>nd</sup> BNL Diboson VBF/VBS Jamboree
  - LOC: Hong Ma, Junjie Zhu, MAP
  - 50% of talk time for discussion!
- 2014: Plan for “Multi-Boson Interactions workshop at BNL”
  - Initiated by Shih-Chieh Hsu, Hong Ma, Junjie Zhu, MAP
  - Scope: ATLAS, CMS (20/fb 2012 analyses) & theory

The screenshot shows the website for the BNL Diboson VBF/VBS Jamboree. The header is blue with the title "BNL Diboson VBF/VBS Jamboree". Below the header, there is a search bar and a navigation menu with options: Overview, Timetable, Contribution List, Author List, Registration, and Participant List. The main content area contains text about the event, including the dates (8-9 Jul 2013), the location (BNL Analysis Support Center), and a registration link. There are also sections for "My Conference" and "My Contributions" with details for the 2012 and 2013 events, including dates, times, and locations. A "There are no materials yet" message is visible in two places.

# Pre-History of MBI

## Evolution at BNL:

- Two “US ATLAS BNL analysis jamborees” / year
  - ATLAS center for general analysis support/overview
- 2011: VV focus starts to emerge
- 2012: 1<sup>st</sup> “BNL Diboson VBF/VBS Jamboree”
  - Renamed jamboree to reflect its focus
  - Scope: ATLAS + theory
  - LOC: Dmitri Tsybychev, Hong Ma, Junjie Zhu
- 2013: 2<sup>nd</sup> BNL Diboson VBF/VBS Jamboree
  - LOC: Hong Ma, Junjie Zhu, MAP
  - 50% of talk time for discussion!
- 2014: Plan for “Multi-Boson Interactions workshop at BNL”
  - Initiated by Shih-Chieh Hsu, Hong Ma, Junjie Zhu, MAP
  - Scope: ATLAS, CMS (20/fb 2012 analyses) & theory

## Meanwhile in Europe:



- Scope: processes sensitive to aQGC
- ATLAS, CMS & theory

# Pre-History of MBI

## Evolution at BNL:

- Two “US ATLAS BNL analysis jamborees” / year
  - ATLAS center for general analysis support/overview
- 2011: VV focus starts to emerge
- 2012: 1<sup>st</sup> “BNL Diboson VBF/VBS Jamboree”
  - Renamed jamboree to reflect its focus
  - Scope: ATLAS + theory
  - LOC: Dmitri Tsybychev, Hong Ma, Junjie Zhu
- 2013: 2<sup>nd</sup> BNL Diboson VBF/VBS Jamboree
  - LOC: Hong Ma, Junjie Zhu, MAP
  - 50% of talk time for discussion!
- 2014: Plan for ”Multi-Boson Interactions workshop at BNL”
  - Initiated by Shih-Chieh Hsu, Hong Ma, Junjie Zhu, MAP
  - Scope: ATLAS, CMS (20/fb 2012 analyses) & theory
  - Learned from nascent IAB (Barbara Jäger) about parallel effort in EU (Dresden follow-up workshop being planned)

## Meanwhile in Europe:



- Scope: processes sensitive to aQGC
- ATLAS, CMS & theory

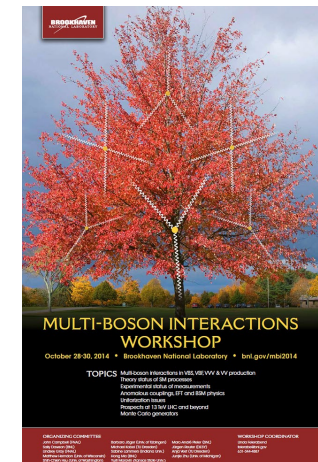
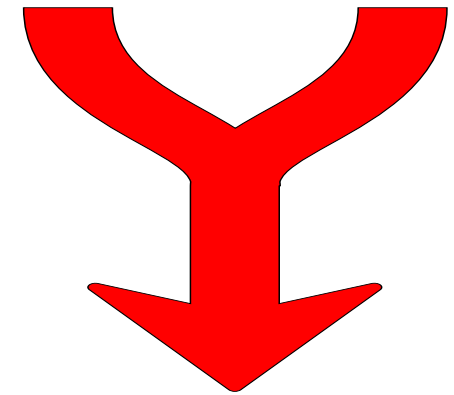
# MBI is born!

Both conferences had large overlap in scope  
=> decided to merge efforts!

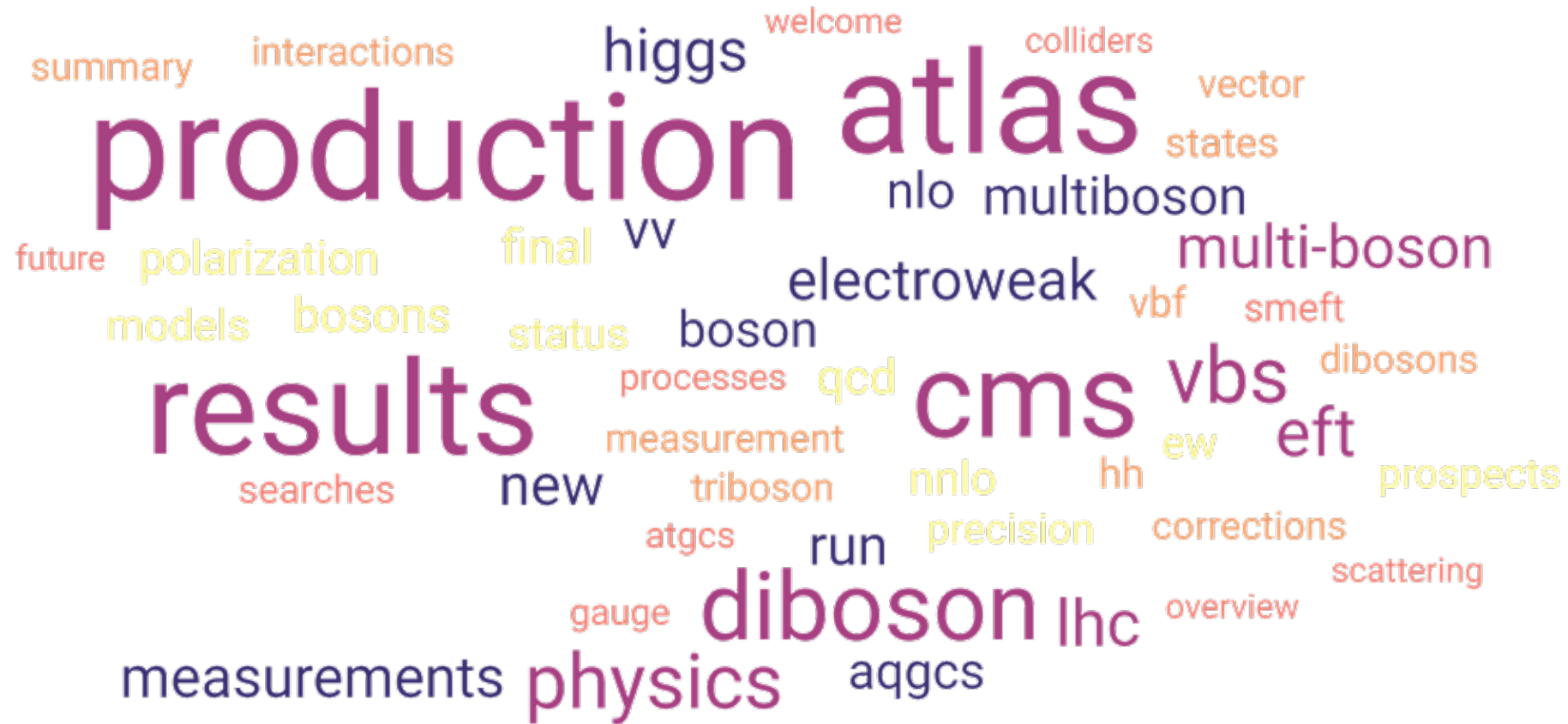
- Agreed on common organization committee (IAB)
- Decided the conference would alternate between EU and US
  - 2014: [BNL](#)
  - 2015: [DESY](#)
  - 2016: [Wisconsin](#)
  - 2017: [KIT](#) (Karlsruhe)
  - 2018: [Michigan](#)
  - 2019: [Thessaloniki](#)
  - 2020: pandemic skip
  - 2021: [Milan](#)
  - 2022: [Shanghai](#)
  - 2023: [UC San Diego](#)
  - 2024: [Toulouse](#)
- 50% theory and 50% experimental talks, trying to mix them thematically in sessions (no stove pipes!)
- Carefully selected speakers (only the best! 😊 )
- 2:1 talk:discussion time ratio (and we tend to use it all!)

“Multi-Boson Interactions”

“4-boson couplings and eweak symmetry breaking”

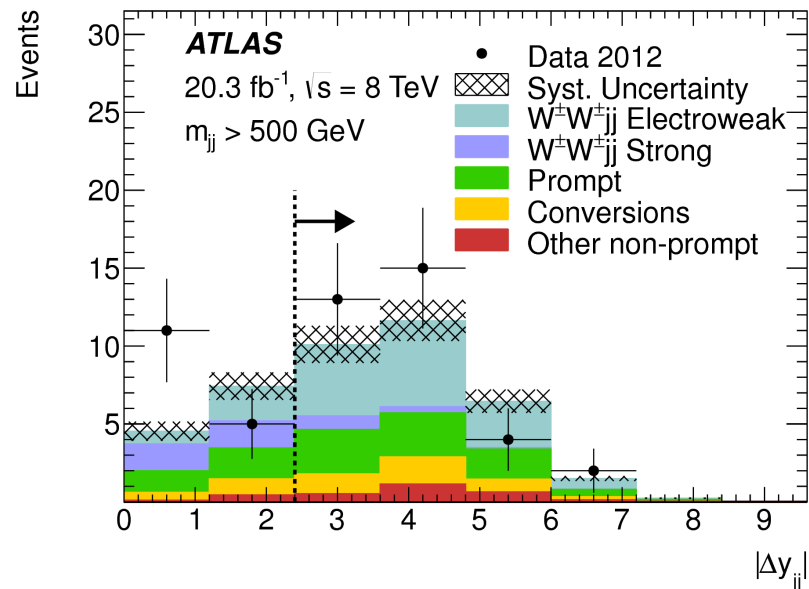


# 10 years MBI at a glance



# 10 years of progress!

[[Phys. Rev. Lett. 113 \(2014\) 141803](#)]



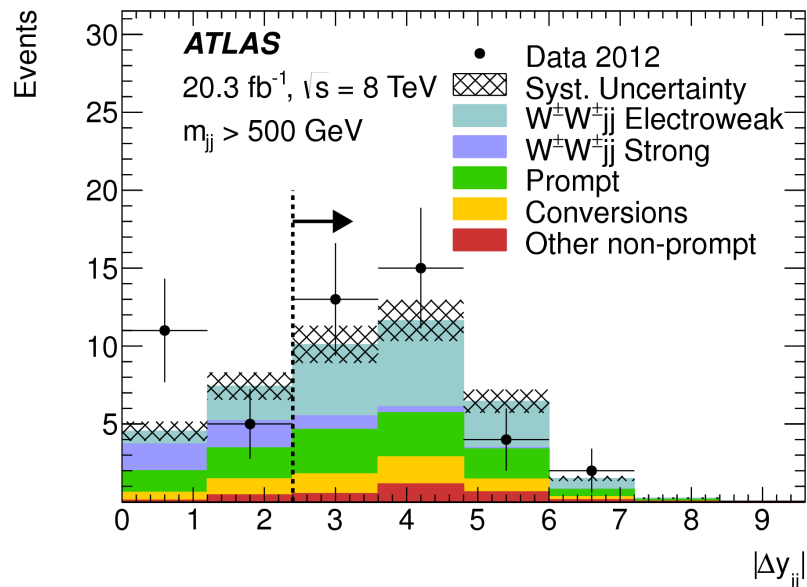
23 May 2014: evidence ( $3.6 \sigma$ ) for ewk

W<sup>±</sup>W<sup>±</sup>jj production,  $\sqrt{s} = 8$  TeV, 20.3 fb<sup>-1</sup>

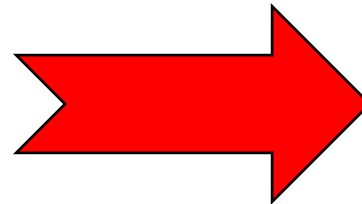
34 events in VBS region!

# 10 years of progress!

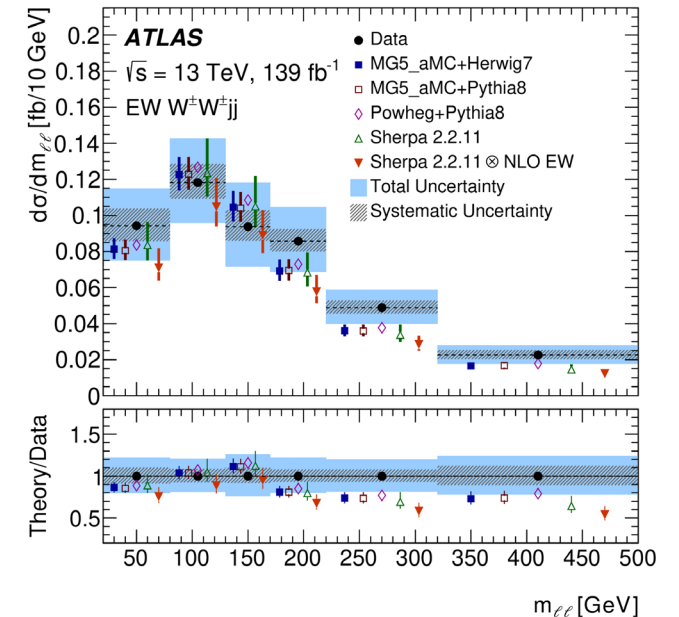
[Phys. Rev. Lett. 113 (2014) 141803]



23 May 2014: evidence ( $3.6 \sigma$ ) for ewk  
 $W^\pm W^\pm jj$  production,  $\sqrt{s} = 8 \text{ TeV}$ ,  $20.3 \text{ fb}^{-1}$   
 34 events in VBS region!



[JHEP 04 (2024) 026]

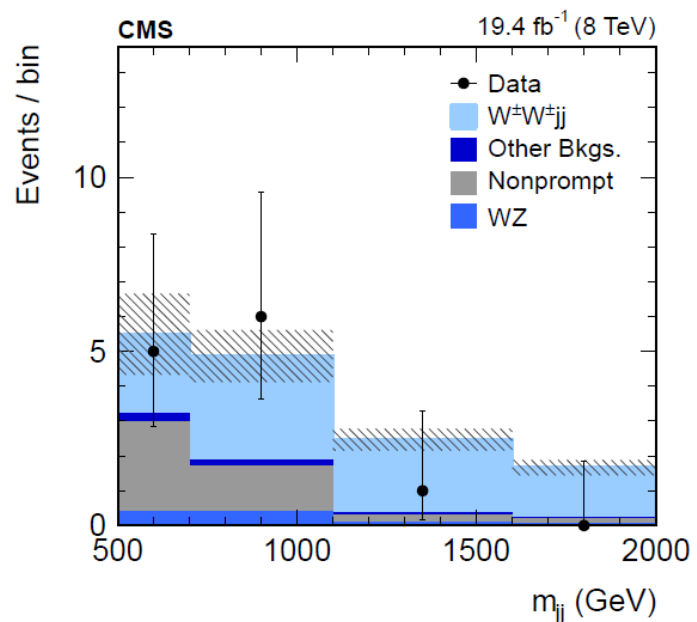


1 December 2023: differential cross sections for  
 ewk  $W^\pm W^\pm jj$  production,  $\sqrt{s} = 13 \text{ TeV}$ ,  $139 \text{ fb}^{-1}$   
 475 events in VBS region!



# 10 years of progress!

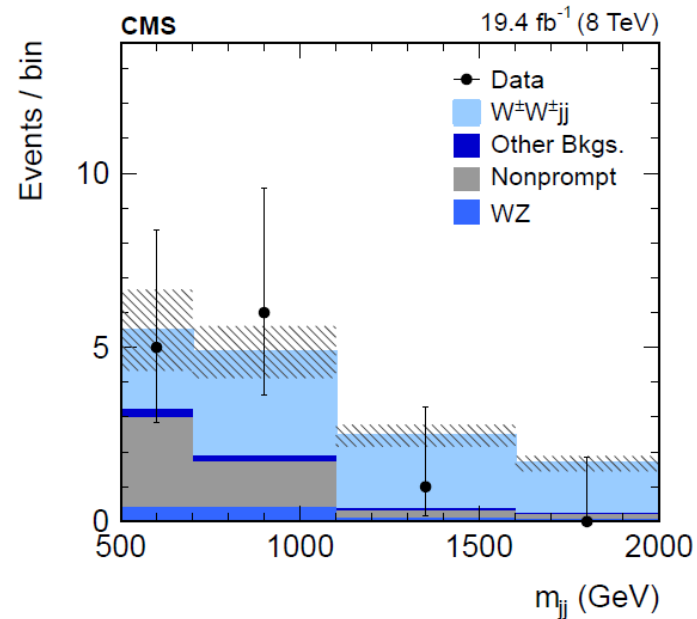
[[Phys. Rev. Lett. 114, 051801 \(2015\)](#)]



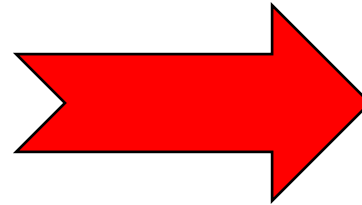
23 October 2014: expected evidence ( $3.1 \sigma$ ) for ewk  
 $W^\pm W^\pm jj$  production,  $\sqrt{s} = 8 \text{ TeV}$ ,  $19.4 \text{ fb}^{-1}$   
12 events in VBS region!

# 10 years of progress!

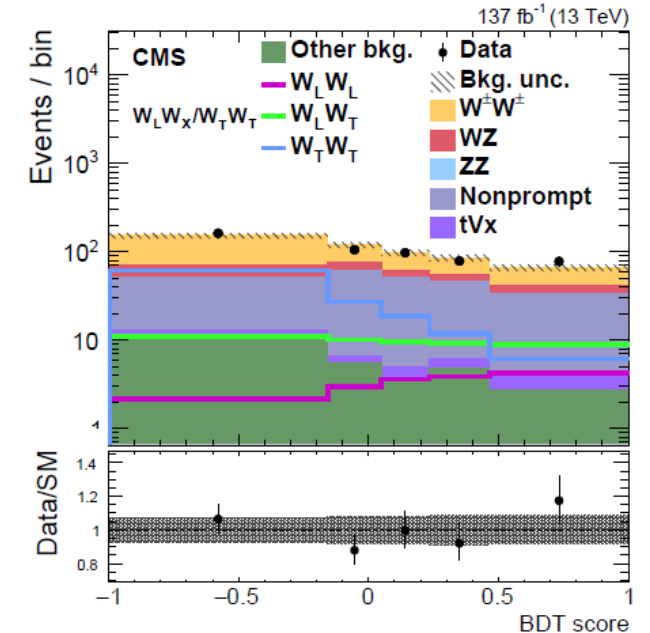
[[Phys. Rev. Lett. 114, 051801 \(2015\)](#)]



23 October 2014: expected evidence ( $3.1 \sigma$ ) for ewk  $W^\pm W^\pm jj$  production,  $\sqrt{s} = 8 \text{ TeV}$ ,  $19.4 \text{ fb}^{-1}$   
12 events in VBS region!



[[Phys. Lett. B 812 \(2020\) 136018](#)]

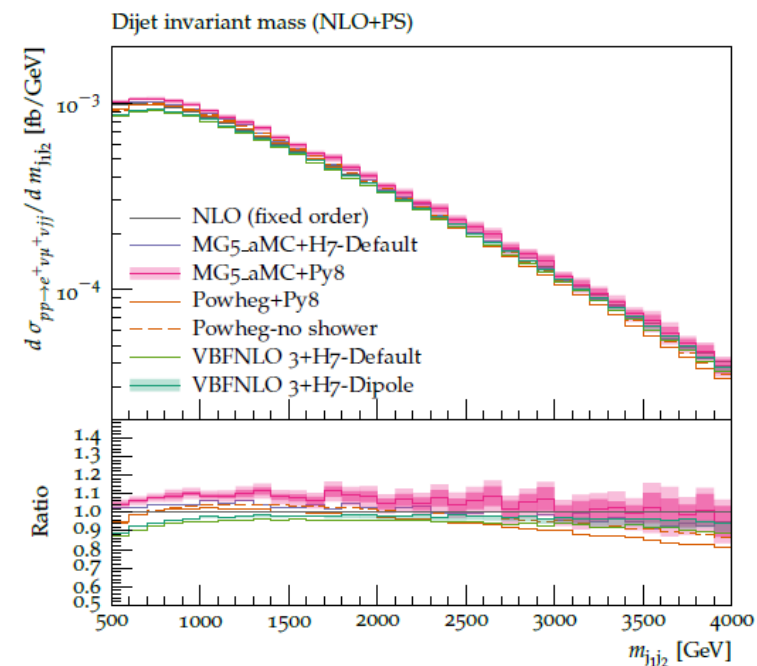
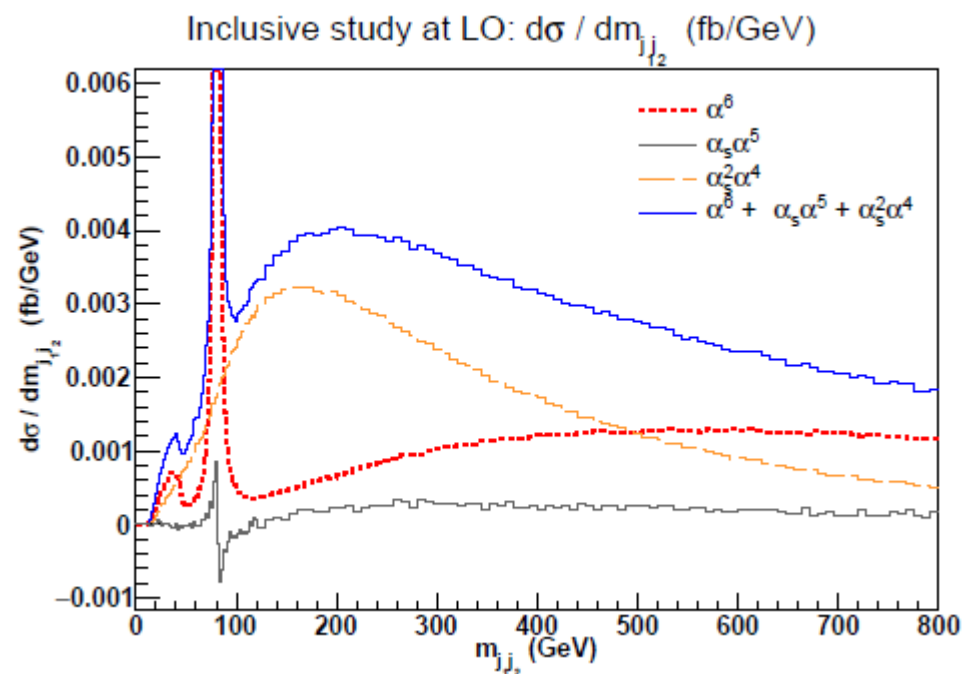


20 September 2020: expected evidence ( $3.1 \sigma$ ) for ewk  $W^\pm W^\pm jj$  production with at least one of the W bosons longitudinally polarized ( $W_L W_X$ ),  $\sqrt{s} = 13 \text{ TeV}$ ,  $137 \text{ fb}^{-1}$   
~200 signal events in VBS region!

# 10 years of progress!

[[Eur.Phys.J. C78 \(2018\) no.8, 671](#)]

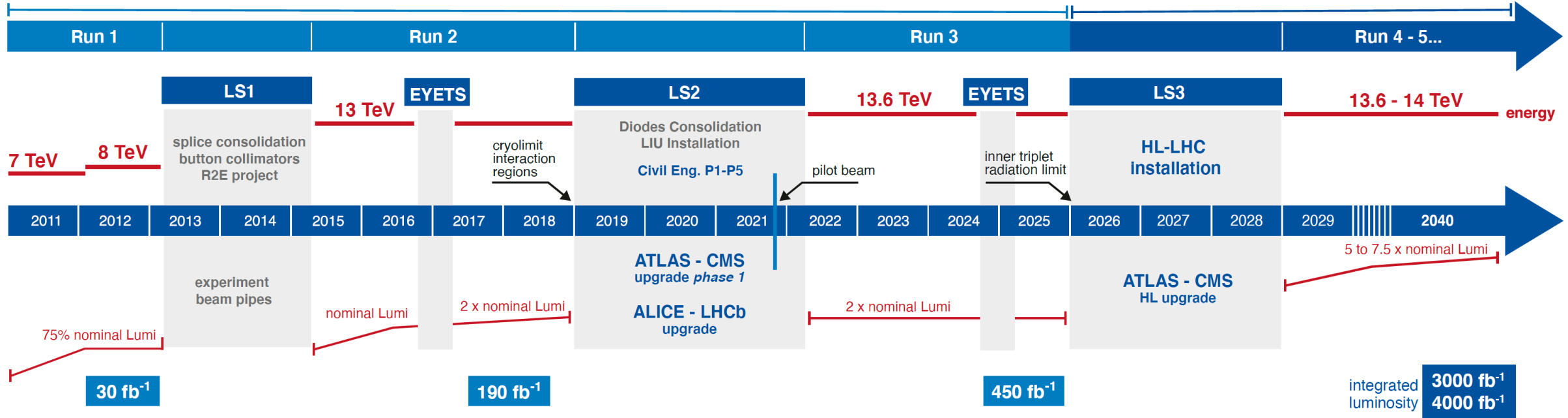
Development of precision predictions and automated tools within VBSscan COST action (now succeeded by COMETA):



# LHC Run Plan

LHC

HL-LHC



## HL-LHC TECHNICAL EQUIPMENT:



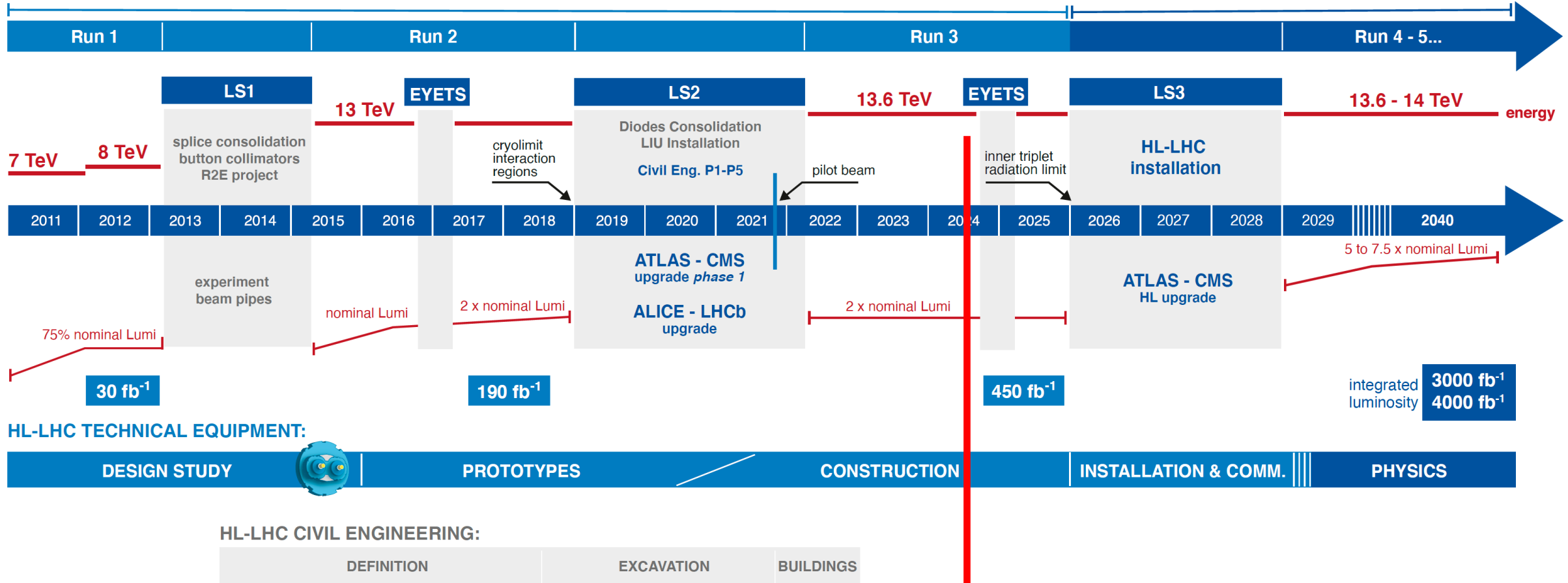
## HL-LHC CIVIL ENGINEERING:



# LHC Run Plan

LHC

HL-LHC



~10% of overall planned dataset taken so far – preparing for high-lumi

# Thank you!

## **IAB over the years:**

Ilaria Brivio (U Bologna), John Campbell (FNAL), Roberto Covarelli (U Turin), Sally Dawson (BNL), Lindsey Gray (FNAL), Christophe Grojean (DESY), Tao Han (U Pittsburgh), Matthew Herndon (U Wisconsin), Shih-Chieh Hsu (U Washington), Barbara Jäger (U Tübingen), Michael Kobel (TU Dresden), Sabine Lammers (Indiana U), Ian Lewis (U. of Kansas), Hong Ma (BNL), Joany Manjarres (L2IT), Yurii Maravin (Kansas State U), Marc-André Pleier (BNL), Jürgen Reuter (DESY), Anja Vest (TU Dresden), Doreen Wackerroth (SUNY Buffalo), Junjie Zhu (U Michigan)

## **LOCs and their secretariats over the years:**

Sally Dawson (BNL) Howard Gordon (BNL) Hong Ma (BNL) Marc-André Pleier (BNL) Christophe Grojean (DESY) Michael Kobel (TU Dresden) Kristin Lohwasser (DESY) Isabell Melzer-Pellmann (DESY) Jürgen Reuter (DESY, chair) Peter Schleper (U Hamburg) Thomas Schoerner-Sadenius (DESY) Anja Vest (TU Dresden) Matthew Herndon (UW Madison) Sridhara Dasu (UW Madison) Wesley Smith (UW Madison) Matthias Mozer (KIT) Thomas Müller (KIT) Günter Quast (KIT) Michael Rauch (KIT) Marco Sekulla (KIT) Dieter Zeppenfeld (KIT) Aaron Pierce (U Michigan) Jianming Qian (U Michigan) James Wells (U Michigan) Bing Zhou (U Michigan) Junjie Zhu (U Michigan) Chariclia Petridou (U Thessaloniki) Kostas Kordas (U Thessaloniki) Dimos Sampsonidis (U Thessaloniki) Spiros Tzamarias (U Thessaloniki) Vitaliano Ciulli (Milan) Roberto Covarelli (Milan) Raquel Gomez (Milan) Pietro Govoni (Milan) Andrea Massironi (Milan) Carlo Oleari (Milan) Marco Zaro (Milan) Jun GUO (SJTU) Hongjian HE (SJTU & TDLI) Xiaogang HE (TDLI & SJTU) Kim Siang KHAW (TDLI & SJTU) Bing LI (SDU) Liang LI (SJTU) Qiang LI (PKU) Shu LI (TDLI & SJTU) Kun LIU (TDLI & SJTU) Yanwen LIU (USTC) Michael RAMSEY-MUSOLF (TDLI & SJTU) Yusheng WU (USTC) Lailin XU (USTC) Haijun YANG (SJTU & TDLI) R. Sekhar Chivukulua (UC San Diego) Javier Duarte (UC San Diego) Frank Würthwein (UC San Diego) Alexis Vallier (L2IT) Anna Tegetmeier (L2IT) Catherine Biscarat (L2IT) Jan Stark (L2IT) Jeanette Thibaut (L2IT) Joany Manjarres (L2IT) Jocelyne Gauthier (L2IT) Sijing Zhang (L2IT)

## **Our speakers and attendees bringing each workshop to life!**

