

Towards exclusive cross sections for $H \rightarrow ZZ$

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Outline

- ✧ Goals
- ✧ Event generators
- ✧ Plan for activities
 - ✧ signal
 - ✧ background
- ✧ Common cuts
- ✧ Manpower
- ✧ ...surprise

Goals

1) Evaluate **exclusive** cross section at **N(N)LO** and compare with LO for

H→ZZ signal in:

- ✧ 4l (including 2l2tau)
- ✧ 2l2jet (including b-jets)
- ✧ 2l2ν
- ✧ 2ν2b



No public results yet even if advanced studies have been done

Bkg:

- ✧ Zbb / Zcc (or more general Z+jets)
- ✧ tt
- ✧ ZZ/WZ

Why ?

- ✧ k-factors used to rescale the absolute cross section at N(N)LO don't take into account how the kinematical distributions change at NLO → differential k-factors
- ✧ extrapolation of background rate from signal to control region is affected by NLO vs LO difference and theoretical uncertainty
- ✧ what is the uncertainty related to PDF and QCD scale

2) Define common cuts agreed by experimentalists and theorists to evaluate cross section in the interesting phase space

Event generators

CMS and ATLAS

H→ZZ signal:

- ✧ PYTHIA LO
 - ✧ POWHEG NLO
 - ✧ MC@NLO
 - ✧ private code for helicity treatment and spin correlations
 - ✧ tauola is used for τ
- past/recent studies with MC@NLO/POWHEG demonstrate that there could be important differences in kinematical distribution and cross section values

Main background:

- ✧ PYTHIA LO
- ✧ MadGraph/MadEvent + PYTHIA LO
- ✧ Alpgen + PYTHIA LO
- ✧ Sherpa+PYTHIA LO
- ✧ GG2ZZ LO
- ✧ POWHEG NLO

MCFM is currently used to compute NLO absolute cross sections but clearly we need NLO generators for the background

Plan for activities: signal

- ✧ compare differential distributions at NNLO vs NLO
- ✧ compute differential k-factor depending on important observables (like p_T)
- ✧ compare results
 - ✧ at the level of leptons and partons
 - ✧ at level of reconstruction

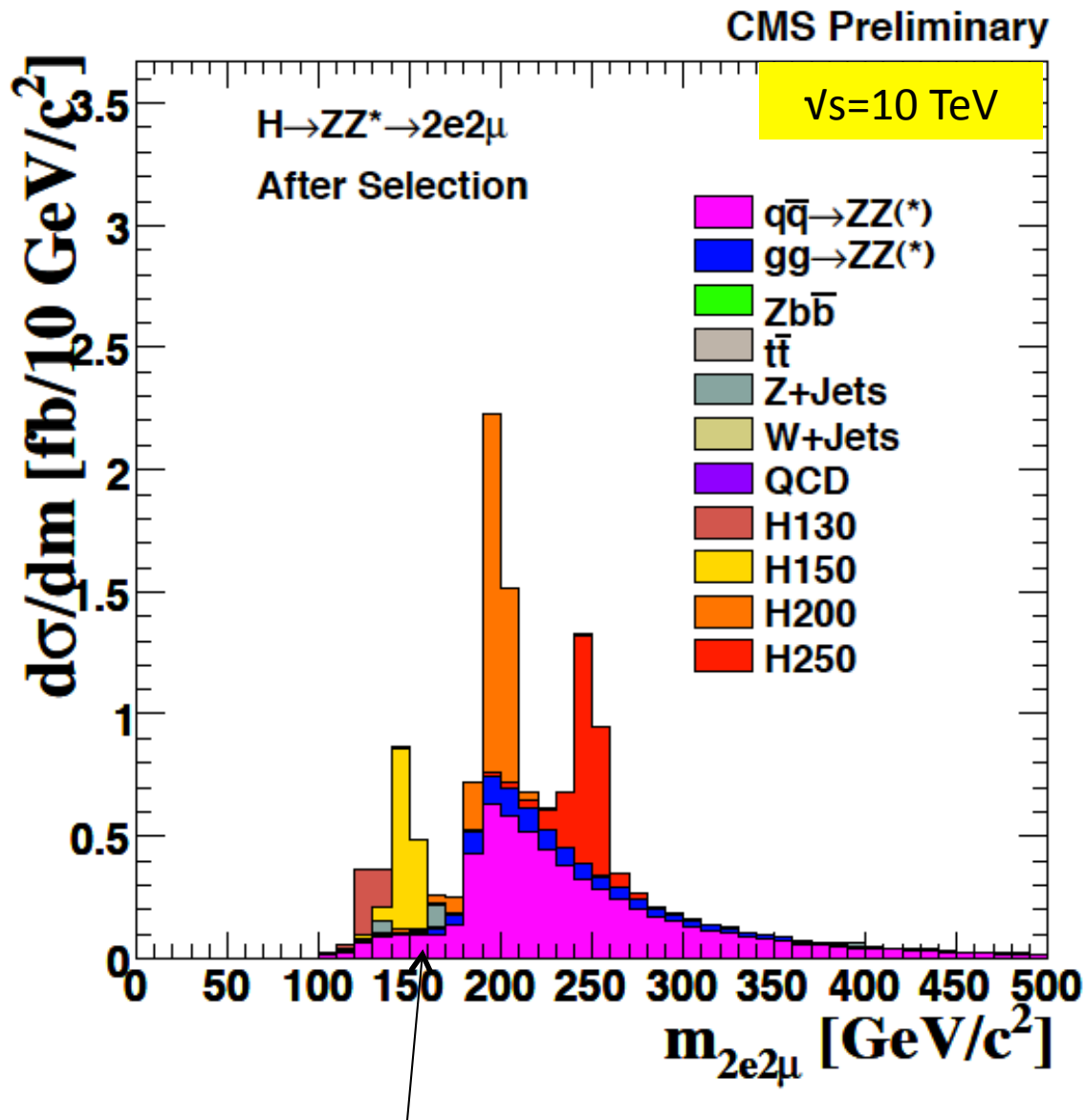
What is on going:

- ✧ **CMS** official production
 - POWHEG vs PYTHIA comparison already possible for $H \rightarrow WW$ but not yet for $H \rightarrow ZZ$ (time estimation for HZZ samples is one week)
 - MC@NLO vs PYTHIA comparison done in the past \rightarrow references
- ✧ **ATLAS**: POWHEG vs MC@NLO to be checked from past references

What we need:

- ✧ help from the authors of generator programs to do a meaningful comparison
- ✧ help from generator group from the technical point of view \rightarrow transversal meeting with ggZ and VBF subgroups going to be organized

Example CMS: 4l



Main
background:

- $qq \rightarrow ZZ$
- $gg \rightarrow ZZ$
- Zbb
- $t\bar{t}$

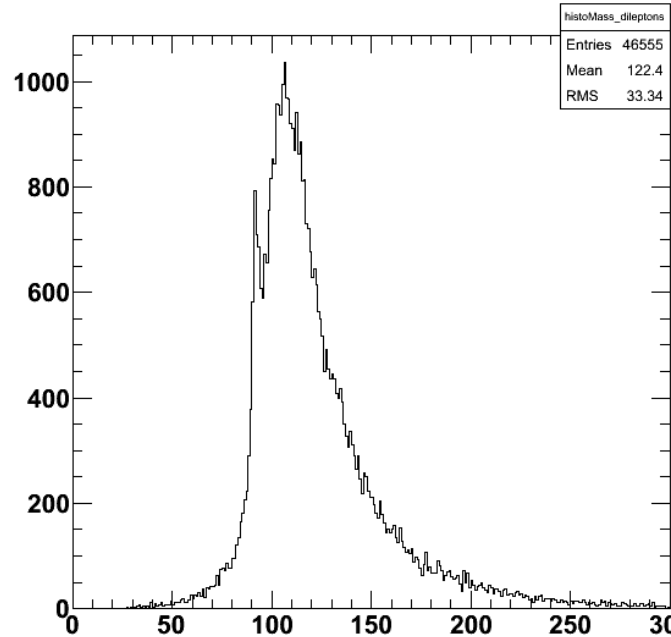
Plan for activities: bkg

- ✧ Comparison of few LO generators (MadGraph/AlpGen) and w.r.t NLO generators (POWHEG ?)
- ✧ Evaluation of shape and absolute and differential rate
- ✧ Definition of control region where the bkg is dominant while the signal is absent
- ✧ Extrapolation from control to signal region with MC expectation
- ✧ Definition of the uncertainty on bkg rate
- ✧ Possible normalization from Z

Bkg: Zbb – LO generators

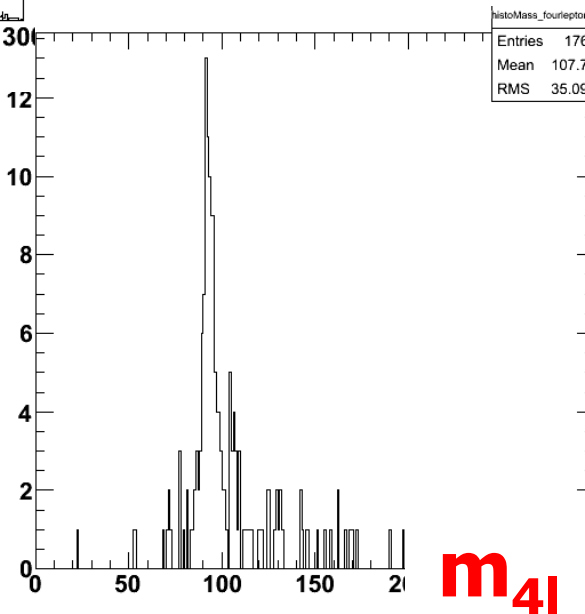
G. Singh

MadGraph Z(\rightarrow ll)bb (no jets) sample at 7 TeV

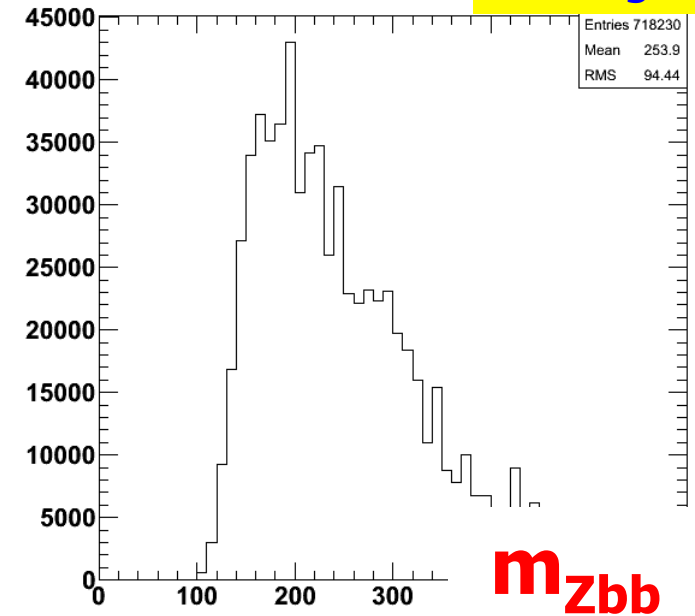


m_{4l}

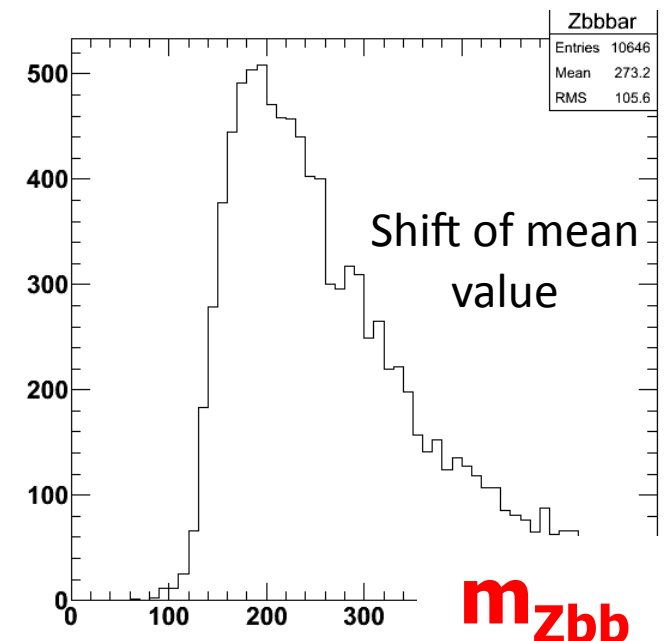
Alpgen Z(\rightarrow ll)bb (+2 jets) sample at 7 TeV



m_{4l}



m_{Zbb}



m_{Zbb}

Bkg: Zbb NLO

- ✧ no NLO generator used up to now for Zbb in CMS and ATLAS
- ✧ L. Reina, F. Cordero (arXiv:0906:1923 and arXiv:0809.3003) are working to integrate Zbbar diagrams in POWHEG → as soon as done we will ask for official production
- ✧ prediction could be wrong if Zbb at NLO give very different distributions with respect to LO → crucial point
- ✧ that will affect extrapolation from control to signal region

Absolute cross section at NLO are currently computed with MCFM
→ anyway this is not enough .

Zbb control region: an example for 4l

Particularly important for low higgs mass searches

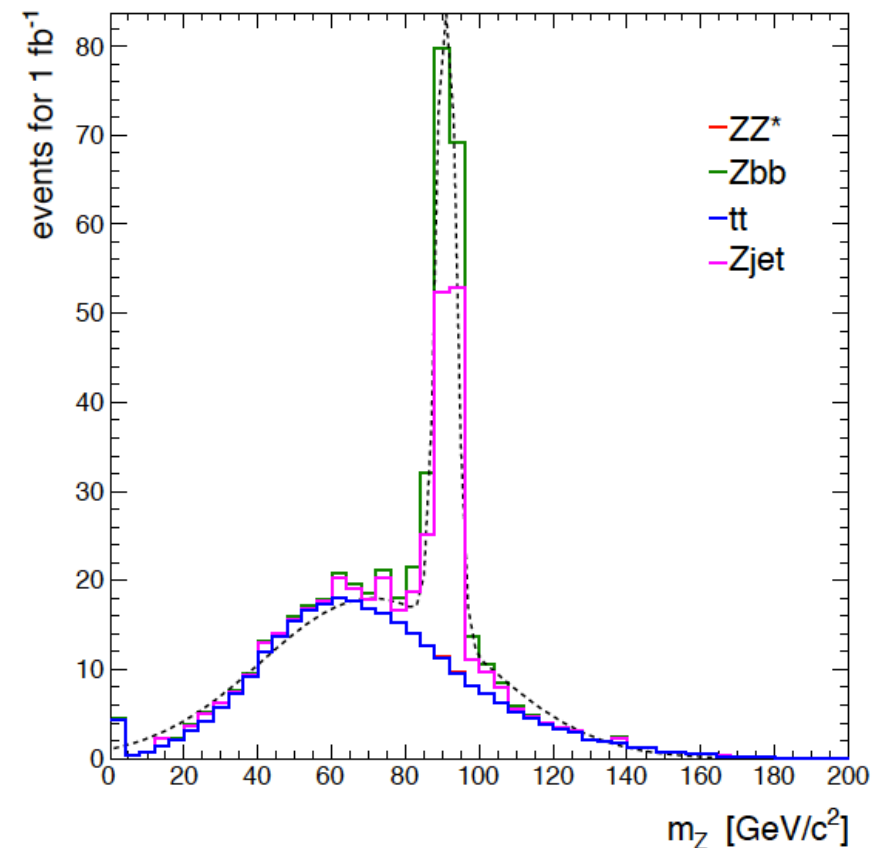
Control region defined by:

- m_{4l} of any four lepton combinations > 100 GeV
- $m_{Z^*} < 60$ GeV in order to suppress the ZZ and Higgs signal contribution.
- reverted isolation cut
- reverted constraint on impact parameter

The signal and the ZZ background are fully absent in **control** region.

Best fit predicts: 1 fb^{-1} luminosity:

- $t\bar{t} = 380 \pm 22$ events
- $Zbb (4\mu, 2e2\mu, 3\mu 1e) + Z+jets = 160 \pm 16$ events



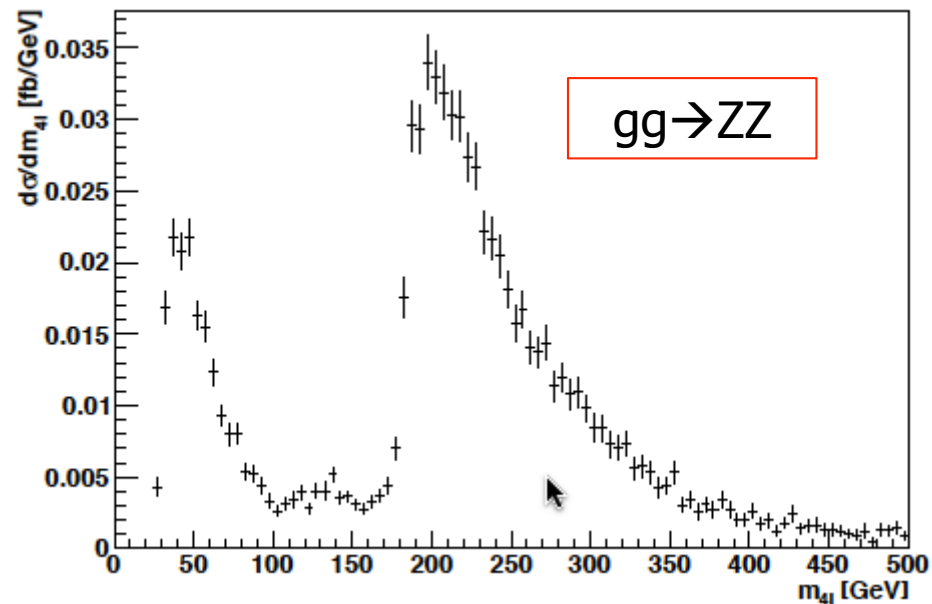
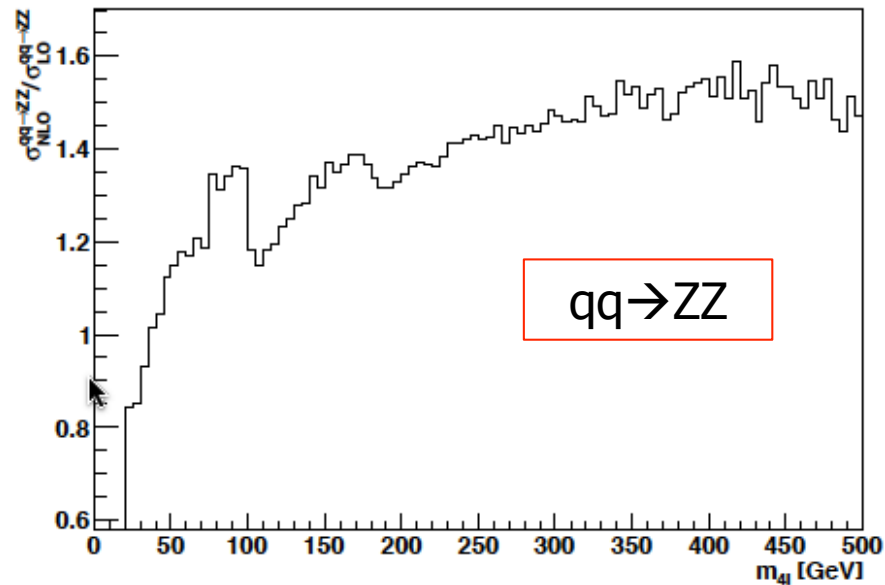
Bkg: $qq \rightarrow ZZ$ and $gg \rightarrow ZZ$

$\sqrt{s}=10$ TeV

MCFM:

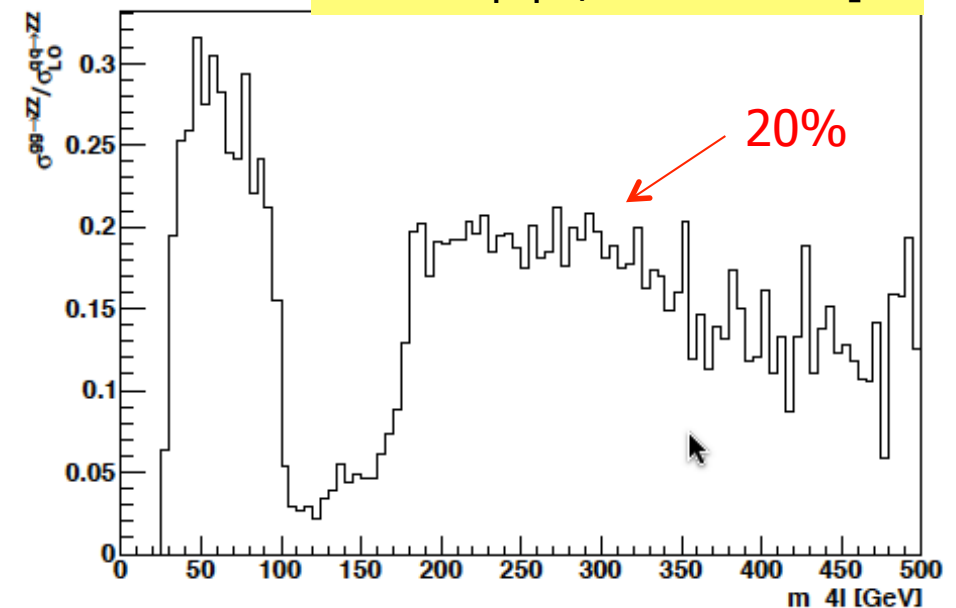
$\langle \text{K-factor} \rangle = 1.345$

What is contribution from $gg \rightarrow ZZ$
(roughly 15% at large $4l$ mass)



GG2ZZ:

T.Binoth, N.Kauer, P.Mertsch,
arXiv:hep-ph/0807.0024v1].



Bkg: ZZ control to signal region

✧ **Typical procedure** consists of choosing a **control region** outside the signal phase space and then verifying that the events rate changes according to the expectations from MC:

$$N_{ZZ}^{predicted}(\Delta m) = \rho(m_H) \cdot N_{CR}^{measured}$$

$$\rho(m_H) = \frac{N_{ZZ}^{theory}(\Delta m) \cdot \epsilon_{ZZ}}{N_{CR}^{theory} \cdot \epsilon_{CR}}$$

← From
MC

Which uncertainty on this factor ?

Question to be addressed in the LHC Higgs xsection group

✧ **Z → 2l to ZZ → 4l normalization:**

Open issues:

- ✧ **What is the physics justification ?** Similar diagrams for $qq \rightarrow ZZ$ and $qq \rightarrow Z$
- ✧ **Inclusive Z to ZZ is based on a** empirical MC function $f(m_{4l})$
- ✧ Is that valid also for $gg \rightarrow ZZ$??

We would need the help of theorists to progress on this topic

Common cuts for signal and background

Goal is: to provide theorists the phase space where to play to get the correct cross sections and theoretical estimates

Under discussion:

✧ common selection at the level of preselection or after full cuts (very low bkg except ZZ → big uncertainty)

→ we decided to prepare a “common” preselection to keep enough phase space for the signal and the background estimation

✧ Tight isolation to be included ?

→ we decided to not include because of dependence/sensitivity on experimental facts → somehow a very loose isolation could be quoted

→ Impact parameter related quantities too dependent on experimental issues

Common cuts: 4l case

Proposal: CMS and ATLAS:

- ✧ leptons with $p_T > 5$ GeV and $|\eta| < 2.5$
- ✧ ≥ 3 (4) leptons with $p_T > 5$
- ✧ ≥ 2 leptons with $p_T > 10$
- ✧ at least two l+l- pairs of identified leptons with opposite charge and matching flavour.
- ✧ at least two matching di-lepton pairs with $m_{2l} > 12$ GeV
- ✧ at least one 4-lepton combination with $m_{4l} > 100$ GeV
- ✧ $70 < m_{Z1} < 110$ GeV would be also added

Going to setup a team → manpower

CMS:


- ✧ myself
- ✧ one PHD from Bari (for ZZ/Zbb studies)
- ✧ one student from I. Puljak
- ✧ + we need a PostDOC with some experience with generators

ATLAS:

- ✧ Stathes
- ✧ Anthony Farnworth (PhD)
- ✧ reisaburo + somebody from the 4l team

We agreed to establish a **strong contact** with “**generator group**” experts within CMS and ATLAS

Vertical meeting with ggF and VBF subgroup ASAP



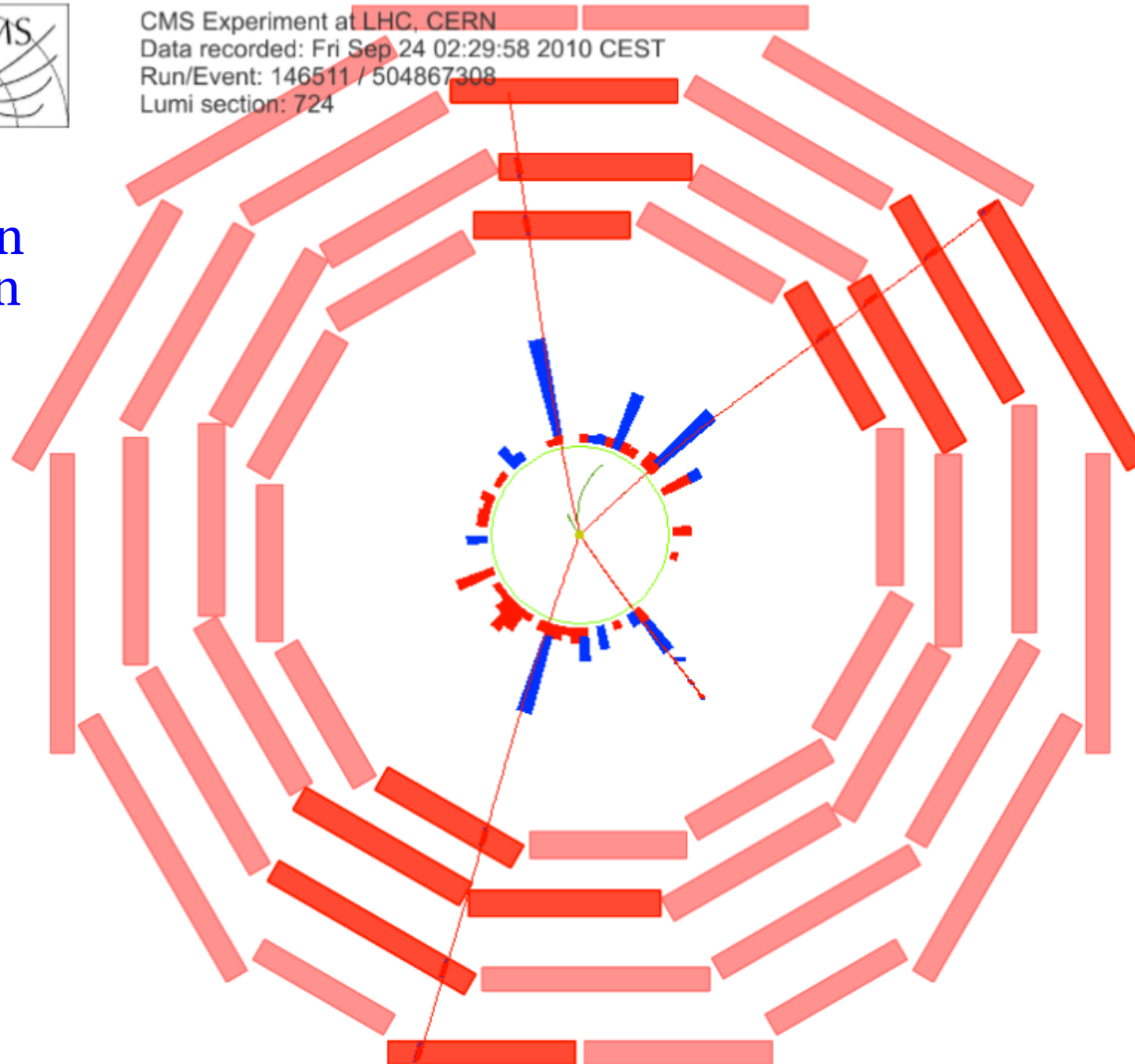
On the path to the Higgs in ZZ golden channels

Run=146511, event=504867308, lumis=724



CMS Experiment at LHC, CERN
Data recorded: Fri Sep 24 02:29:58 2010 CEST
Run/Event: 146511 / 504867308
Lumi section: 724

The **first** golden
 4μ candidate in
CMS



The first golden 4μ candidate in CMS

A first di-boson candidate in the ZZ channel was **observed** in CMS.

The event is observed in the 4mu channel with two pairs of opposite sign muons originating from a common primary vertex.

- ✓ The muons transverse momenta are **48.1, 43.4, 25.9, 19.6 GeV/c**.
- ✓ Two pairs of opposite sign muons separately have invariant masses compatible with a Z boson on a mass shell: **92.1** and **92.2 GeV/c²**
- ✓ The invariant mass of the 4mu is measured to be **201.7 GeV/c²**.
- ✓ The data analysed correspond to an integrated luminosity of about **20 pb⁻¹**
- ✓ The expected **ZZ→4l** rate is **0.20** for 20 pb⁻¹
- ✓ The probability to observe one 4l candidate is **16%**