The CMS Experiment – Selected Results

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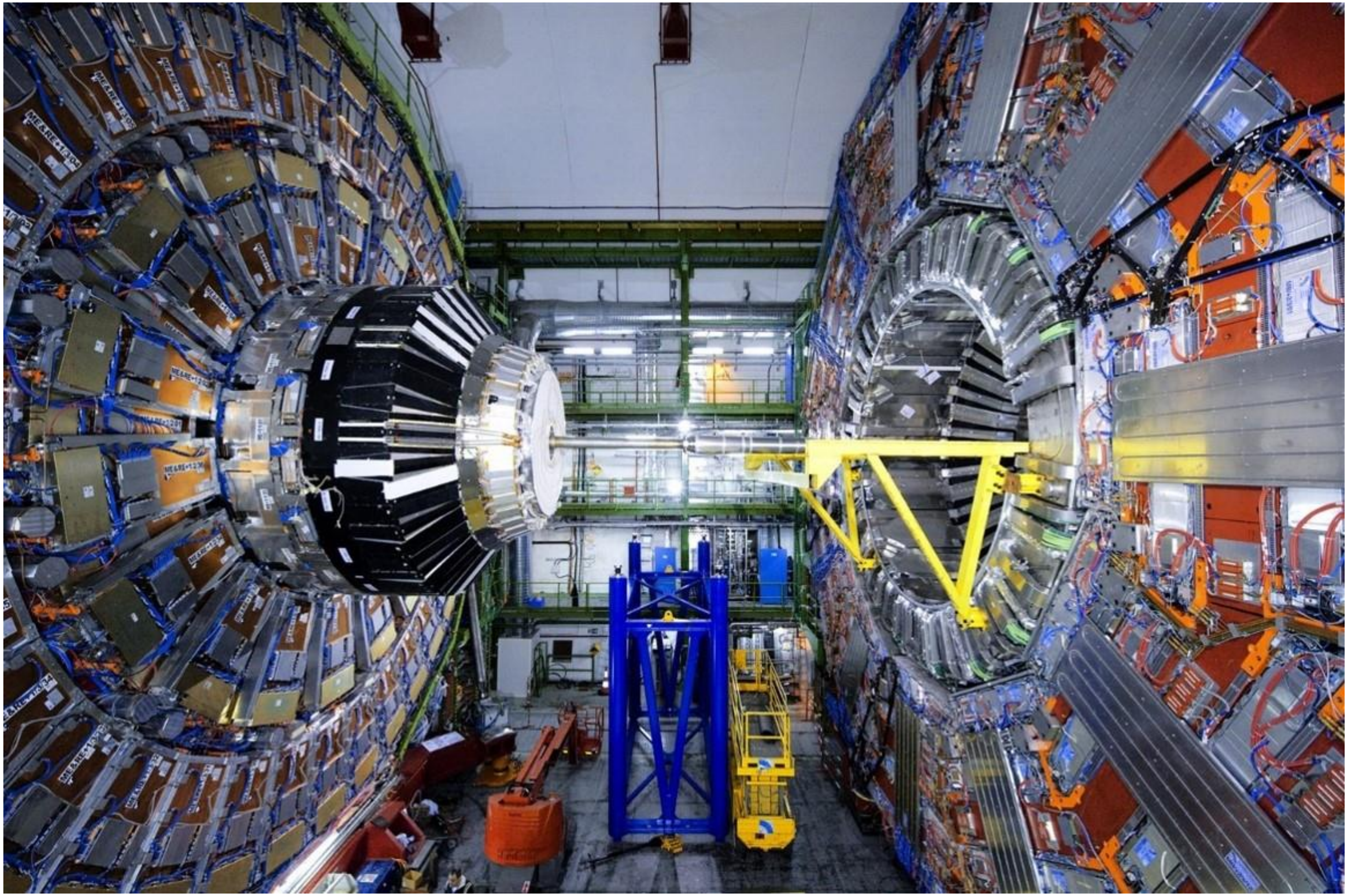
I had the pleasure to collaborate with Nicolai Shumeiko since more than 30 years within the FCAL R&D project and the CMS experiment

The CMS detector opened



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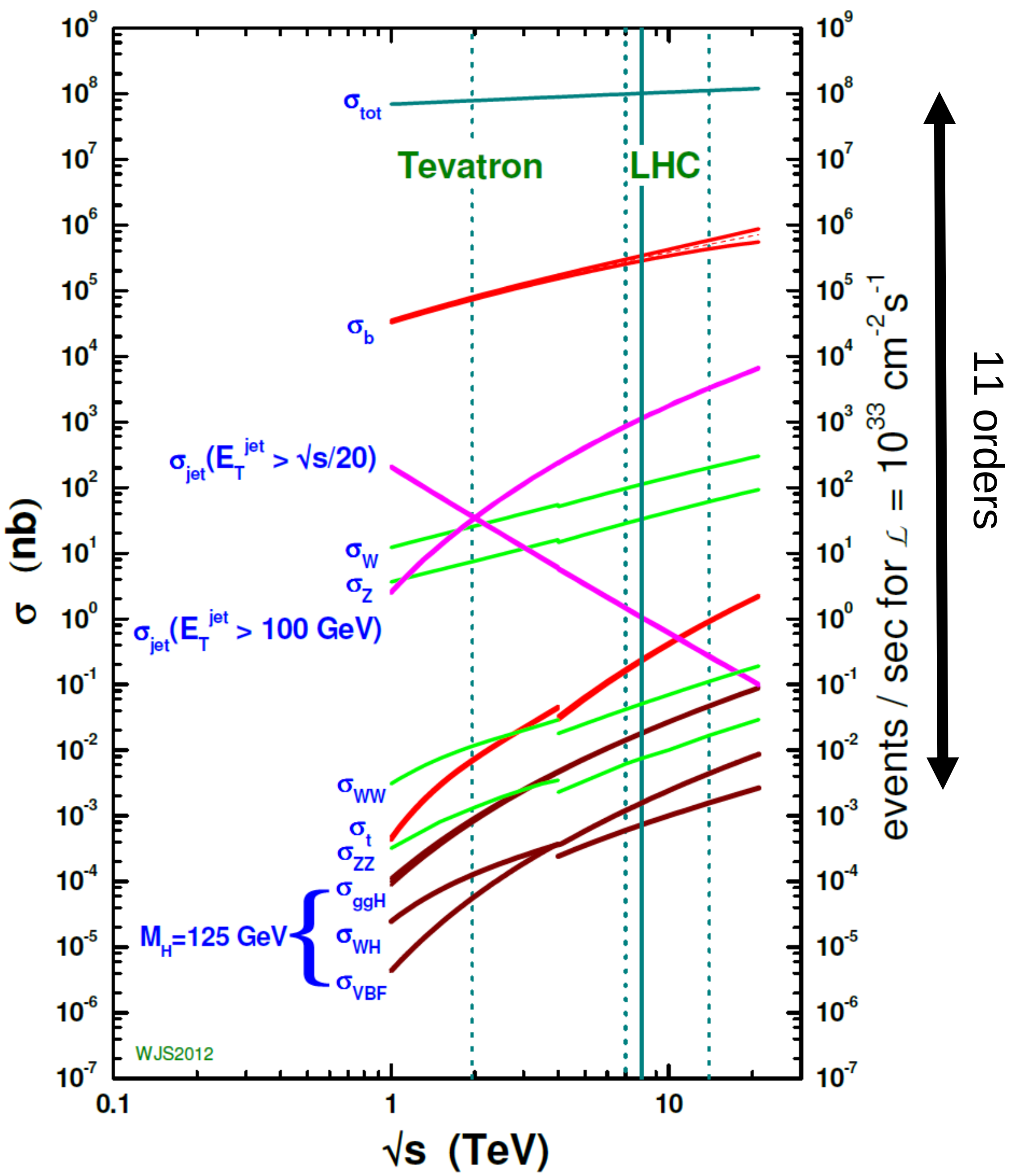
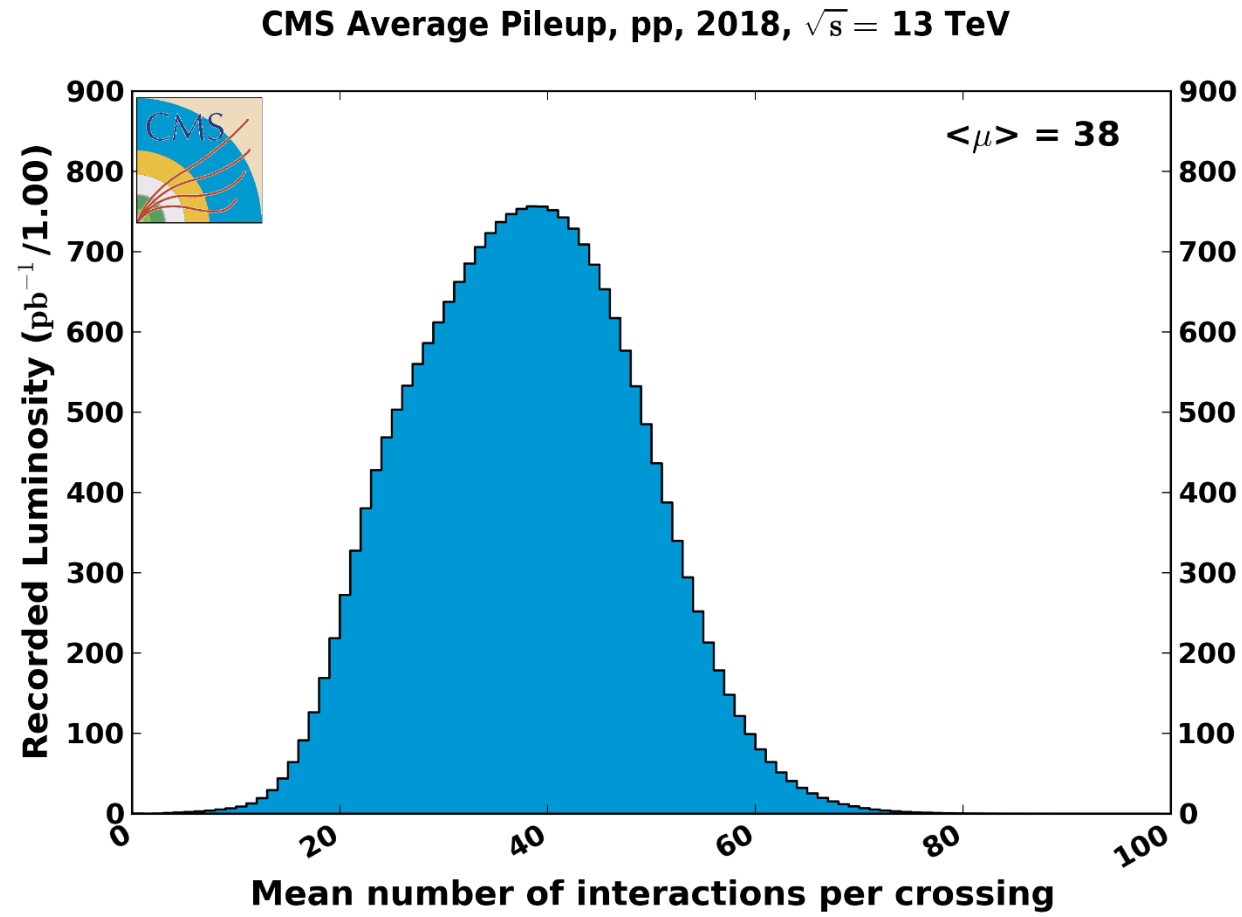
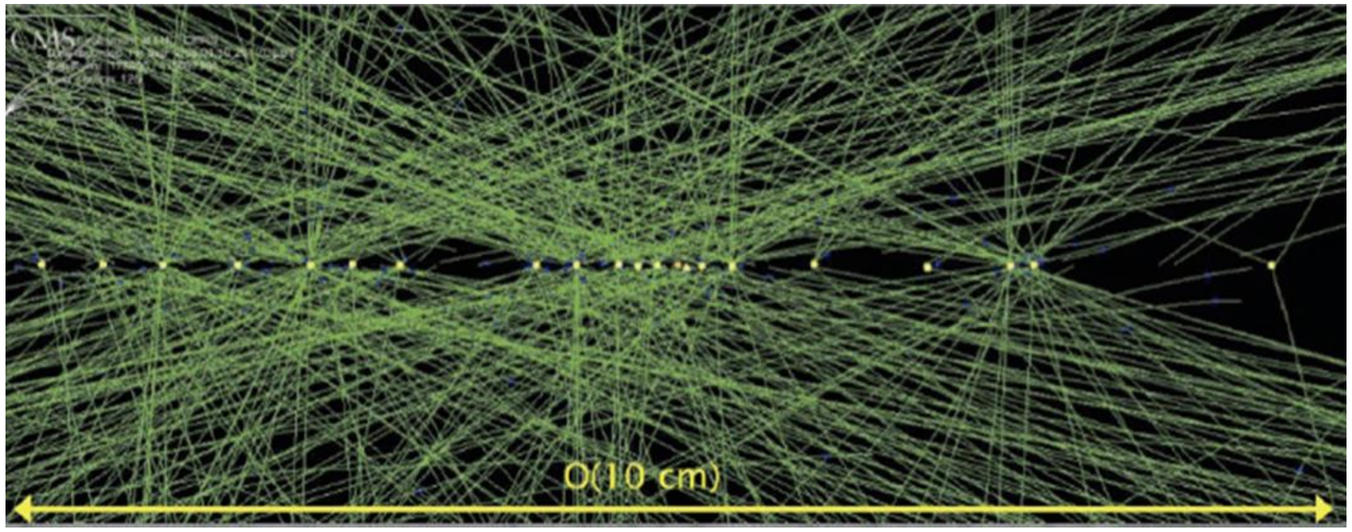
Physics at LHC is fighting with background

proton - (anti)proton cross sections

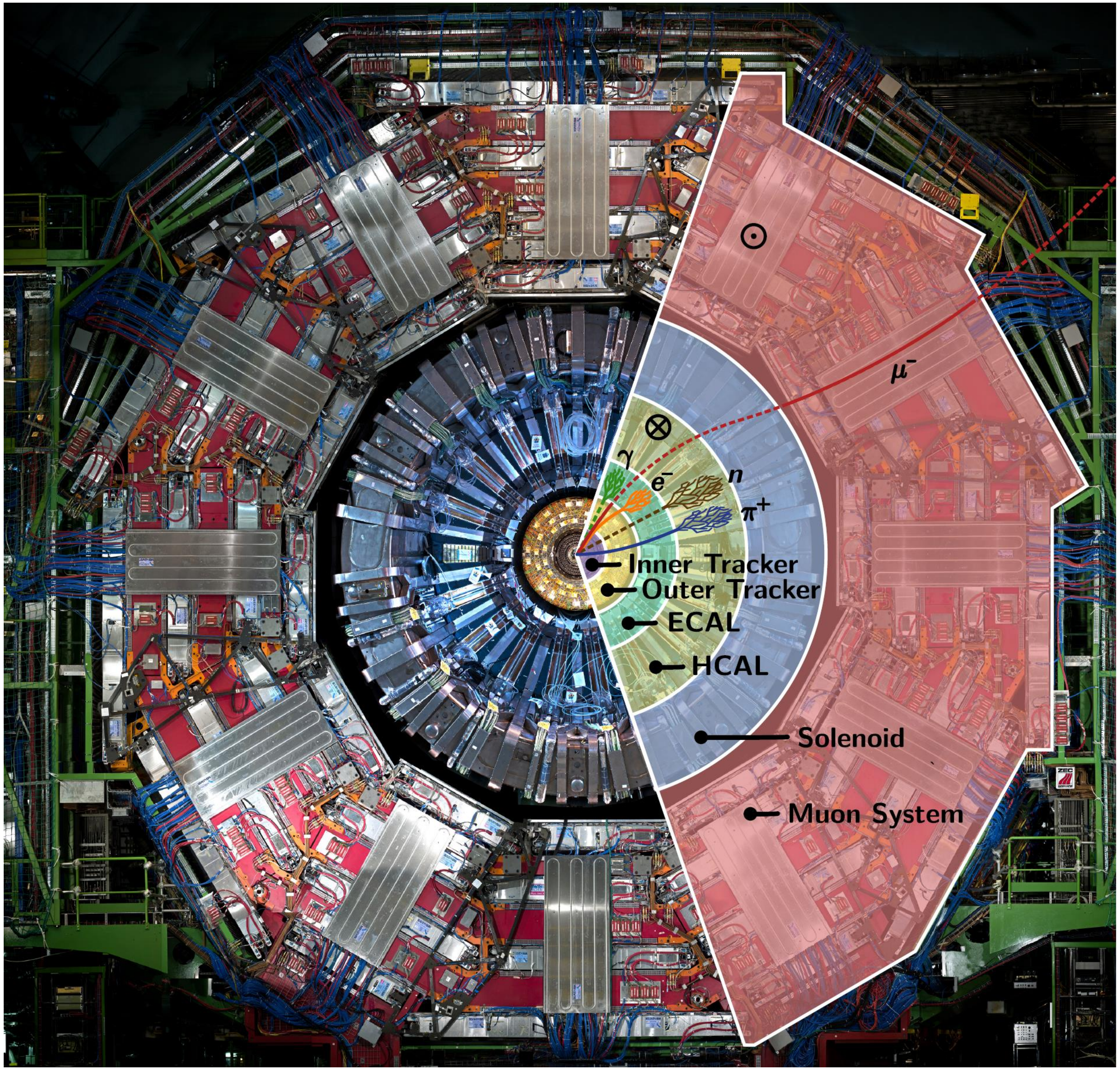


Physics background processes





Background events in the detector



B = 3.8 T

Full silicon tracker

coverage: $\eta < 2.5$

Resolution $\sigma(p_T/p_T) < 1\%$ (barrel)

$< 3\%$ (endcap)

($p_T < 100$ GeV)

Vertex reconstruction: $\sigma_{xy} = 10\ \mu m$

material budget: 0.4-1.8 X_0

ECAL

PbWO4 crystals, 24.7 – 25.8 X_0

σ_E/E = 1.5 – 5 % (for $Z \rightarrow ee$)

HCAL

scintillator brass, λ= 5.8 – 10.6

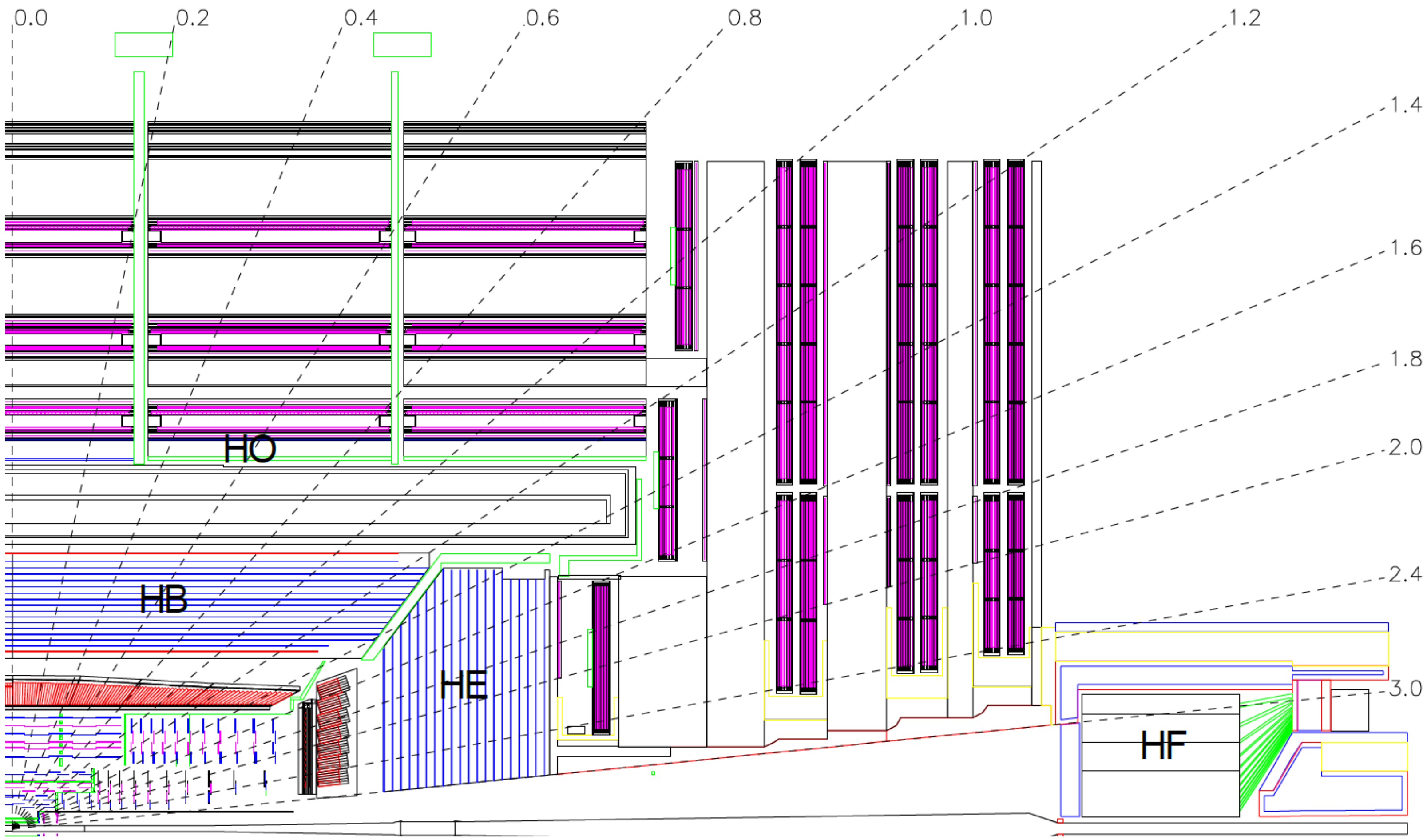
$\sigma_E/E = 84.7\% / \sqrt{E}$ for single particles

Muon system

Drift tubes and RPCs in the barrel

CSCs and RPCs in the endcup

Detector and trigger



two level trigger system

L1 40 MHz --> 100 kHz

calorimeters and muon chambers
L1 objects: muons, electrons, tau-leptons and jets, total and missing ET,
latency: 4µs

HLT 100 kHz → 1 kHz

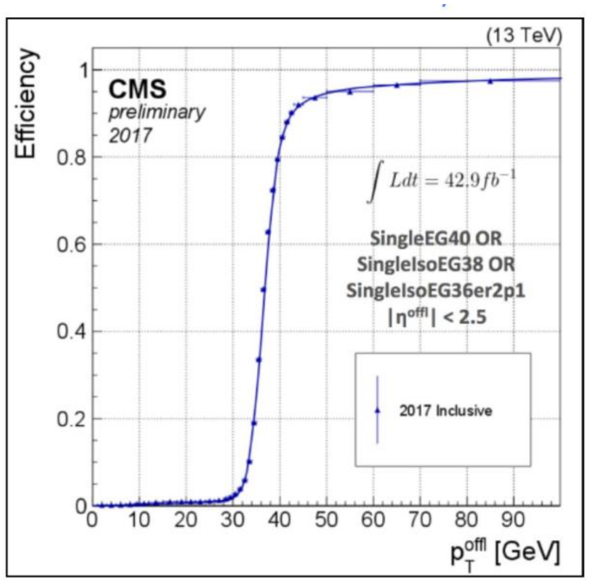
Computer farm, performing a fast reconstruction, including tracker +

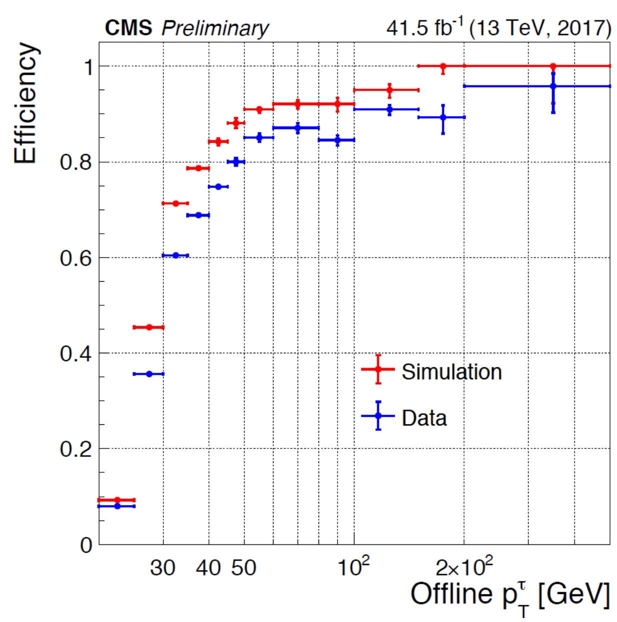
13000 CPU

latency: up to 175 ms

Eamples for the trigger performace

photon





τ-lepton

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Event reconstruction

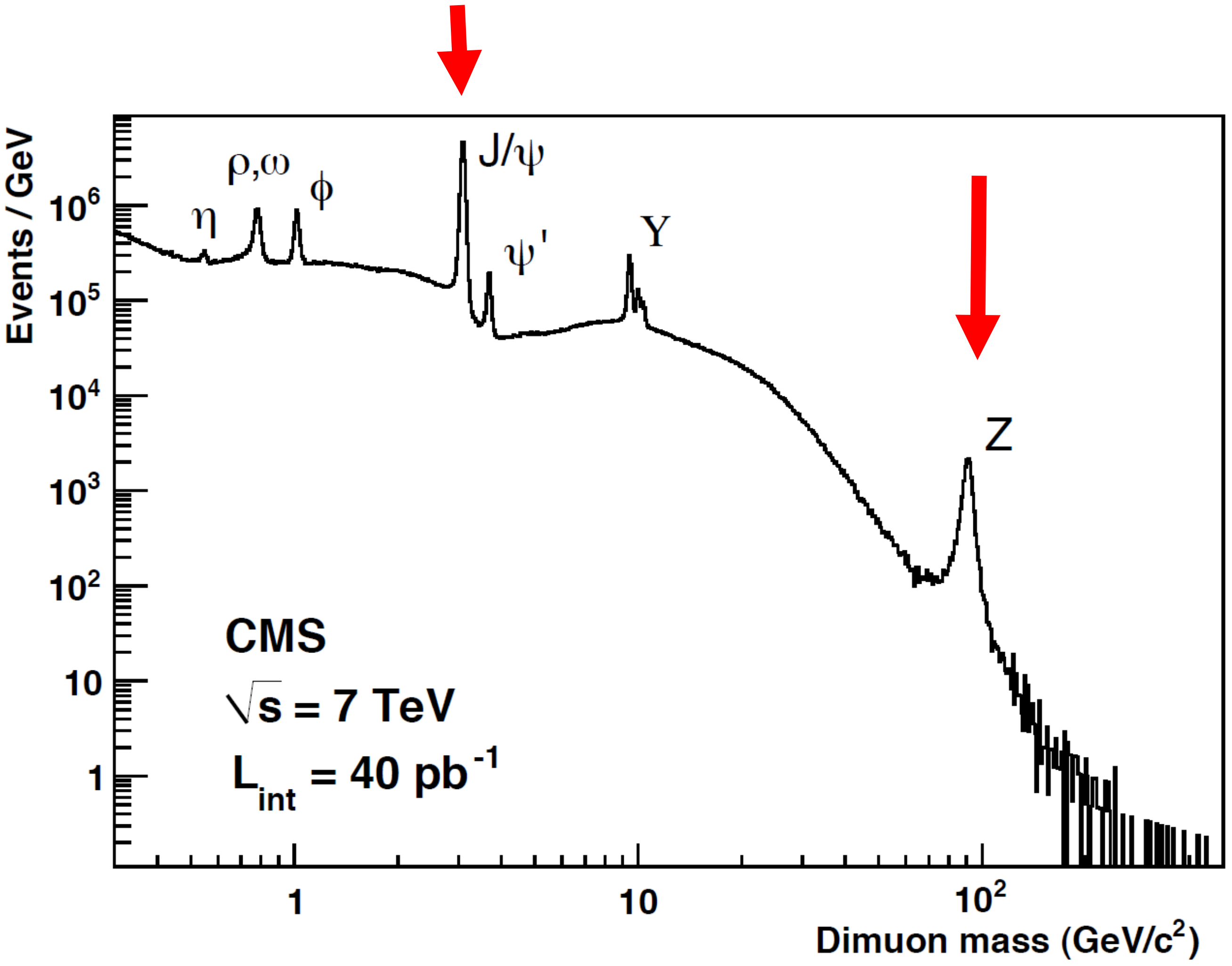
First track reconstruction, primary vertex determination (selected by the maximum sum of p_T^2 of associated tracks)

Formation of calorimetric clusters in ECAL and HCAL separately, being then subject of the particle flow algorithm

Muon momenta are measured in the tracker and, at sufficiently high energy, in the muon system separately and combined

b-hadrons are tagged using the combined secondary vertex (CSV) algorithm searching for secondary vertices and exploiting track impact parameters with respect to the primary vertex

Decays of of J/ψ and Z into a pair of leptons are used to calibrate energy and momentum scales for muons (tracks) and electrons (ECAL)

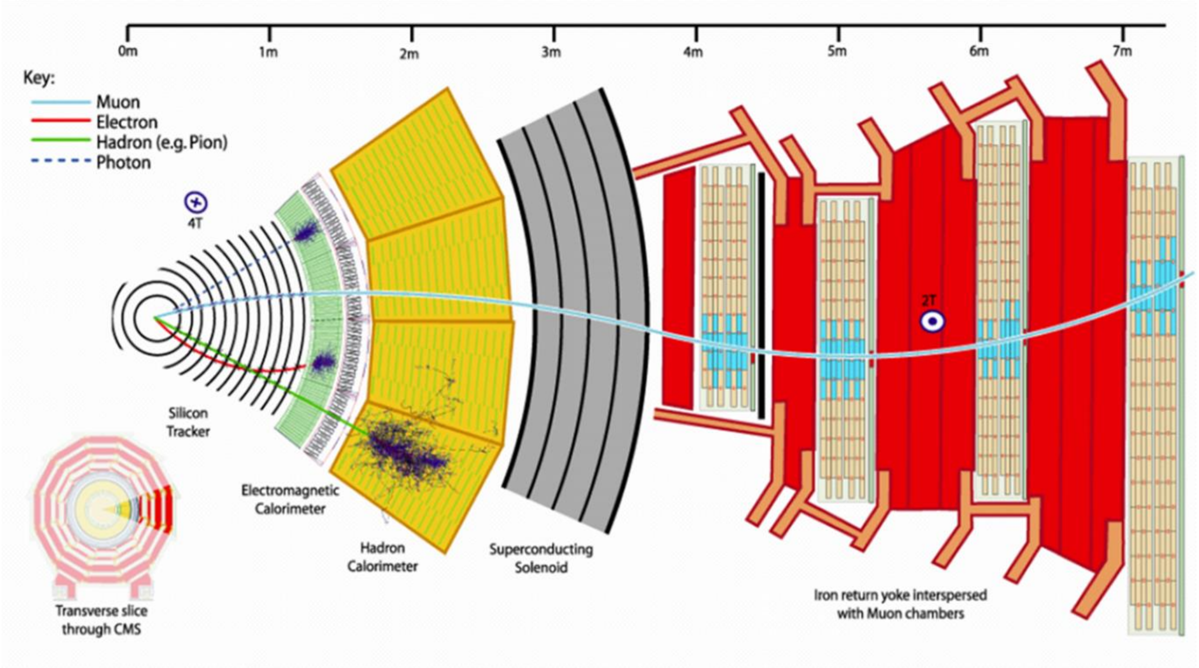


ParticleFlow Algorithm, PFA

tracks and clusters in the calorimeters are linked if spatially and energetically compatible

Test particle hypotheses:

1. Muons (matching of tracks in the tracker and muon chambers or tracks in the tracker and corresponding depositions in the calorimeters)
2. Electrons (multivariate discriminant based on shower shape, matched track quality and compatibility of track momentum with energy of the shower)
3. Isolated Photons
4. Charged hadrons
5. Neutral hadrons
6. Photons

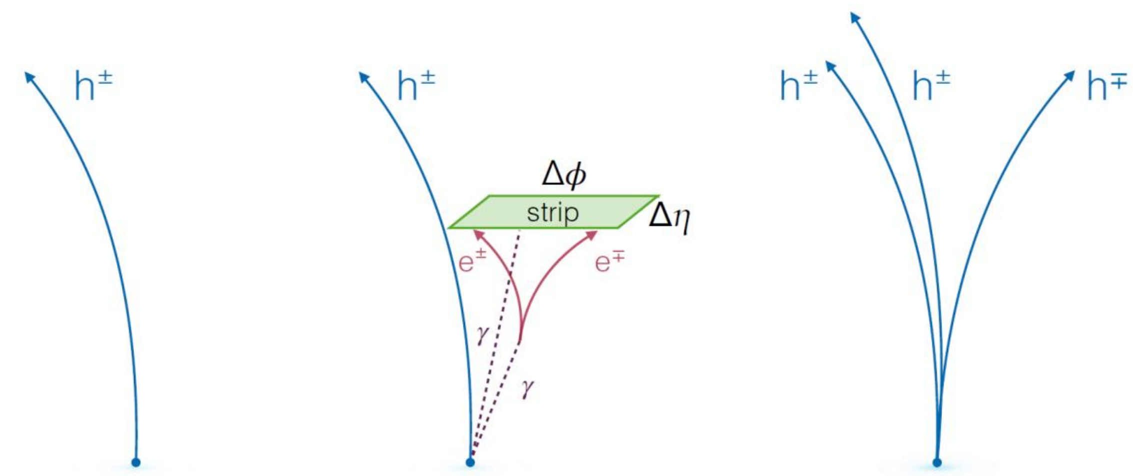


Reconstruction of higher level objects

- Jets (using the anti-k_T algorithm, with a cone $\Delta R=0.4$)
- Hadronically decaying tau-leptons, τ_h
- Missing transverse momentum

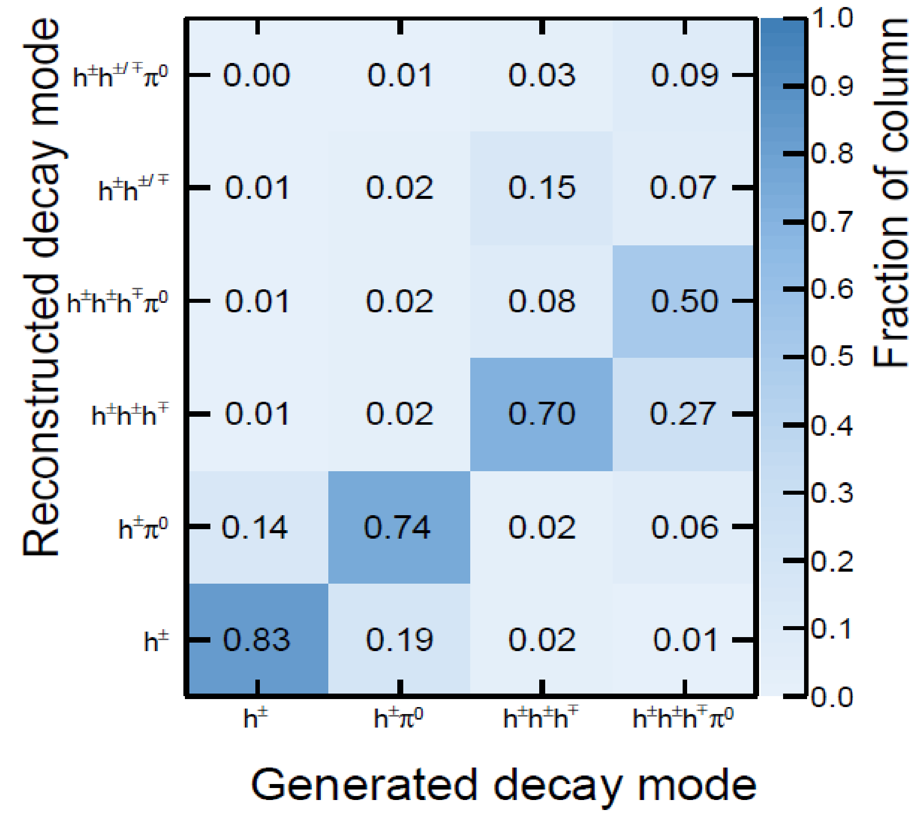
Jet energy corrections, including an offset due to depositions from min. bias interactions in the same or nearby bunch crossings

Reconstruction of hadronic τ-lepton decays



HPS (Hadron plus strips) algorithm

- jets with one or three ‚good tracks‘, originating from the primary vertex
- search for π^0 (includes photons and electrons/positrons from conversions in the tracker, p_T > 2.5 GeV)
- four momentum is the sum of tracks plus ‚strips‘
- require all constituents to be in a signal cone (ΔR p_T dependent)
- isolation creteria using th p_T sum of objects not being identified as t-lepton decay products within a cone $\Delta R = 0.5$
- impact parameter and decay length significances
- invariant mass compatible with ρ and a_1 for $\pi\pi^0$ and 3 pronc



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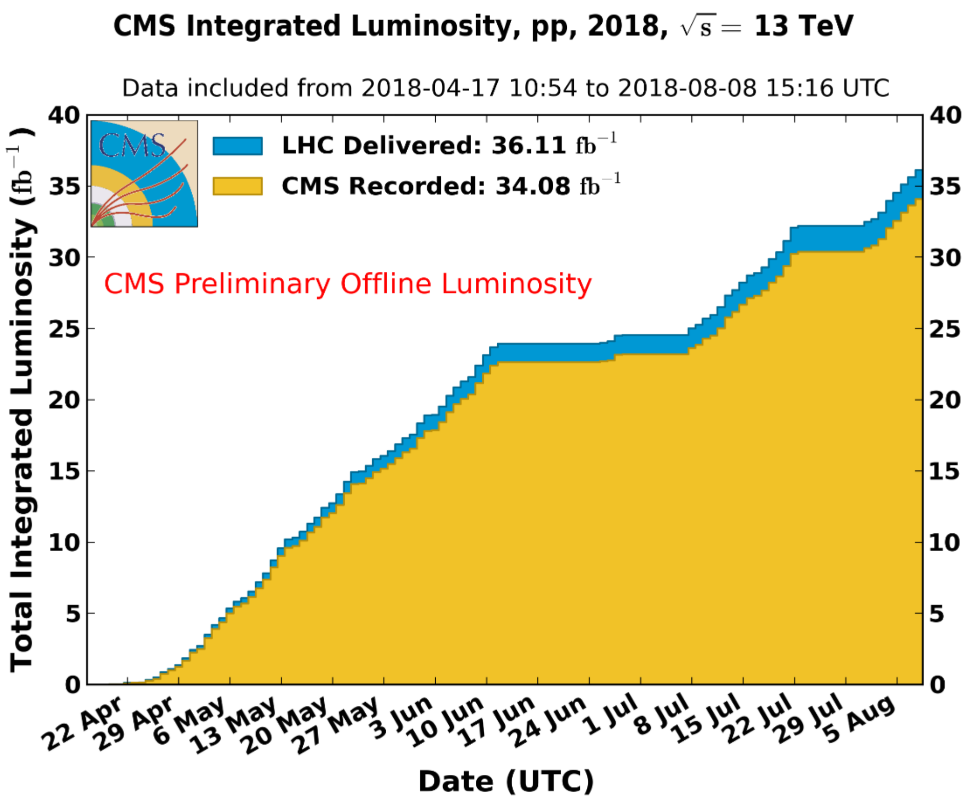
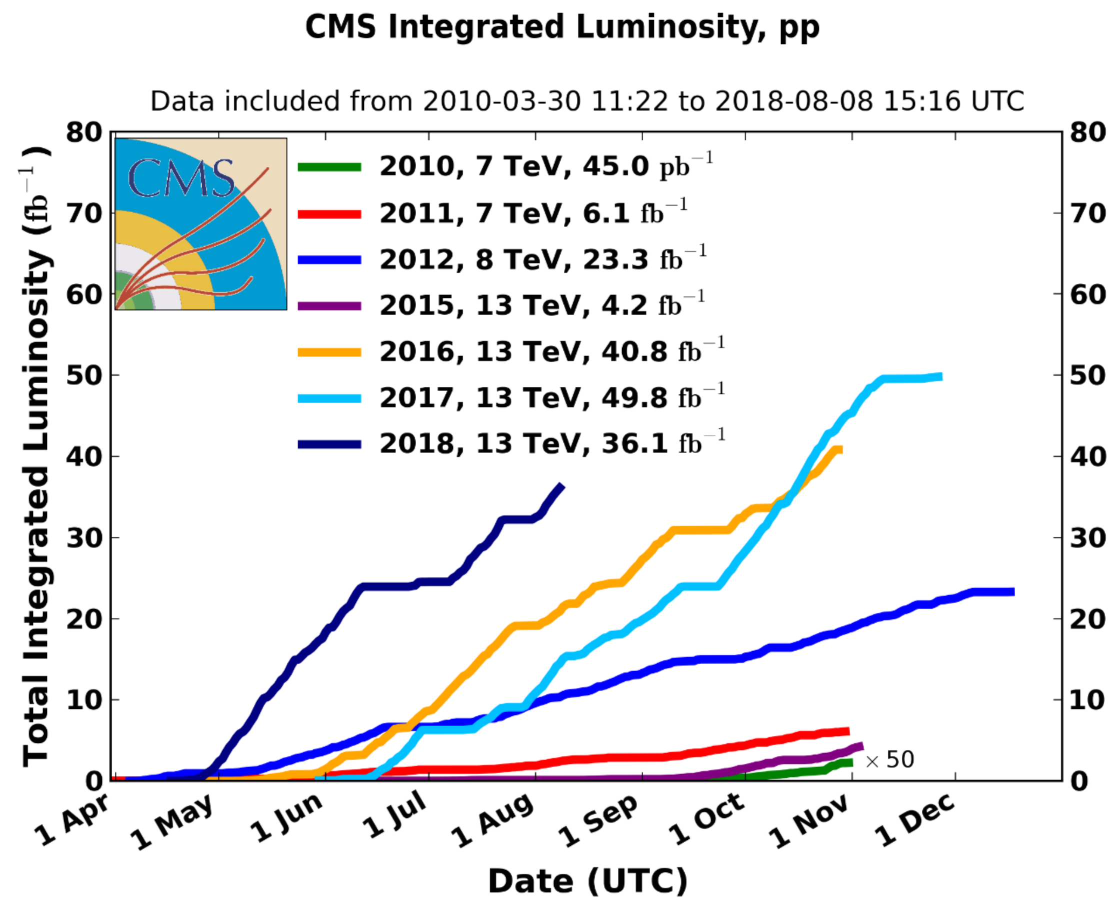
Luminosity 2018

Data taking efficiency: 95 %





Luminosity measurement

three independent on-line luminometer:

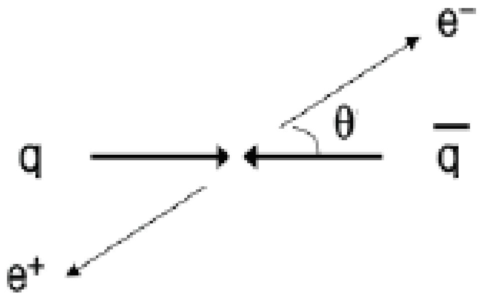
- Pixel luminosiy telescope
- Beam condition monitor BCM1F
- Hadron forward calorimeter HF

in 2017 also used for off-line luminosity measurement

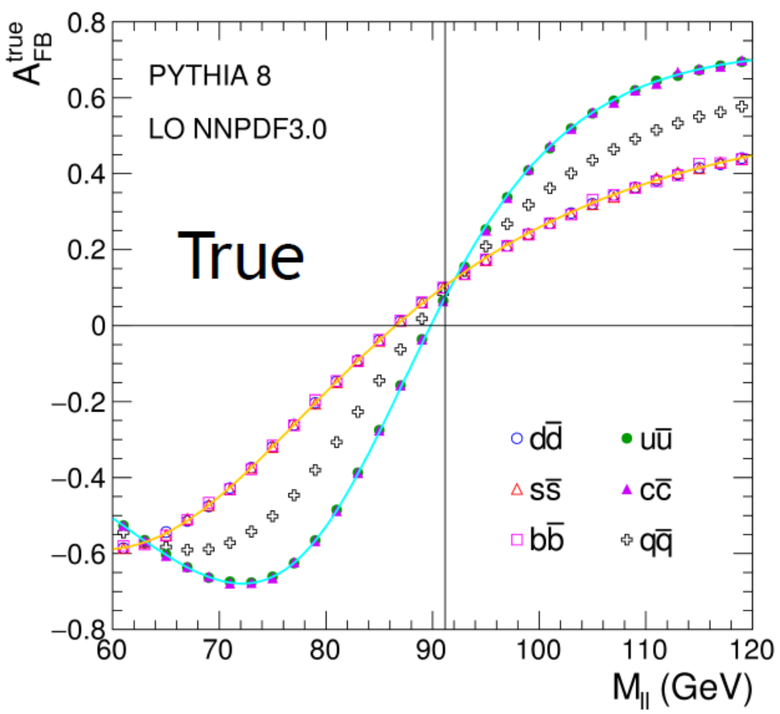
precision: 2.3 % (2017), 1.7% at low pile-up

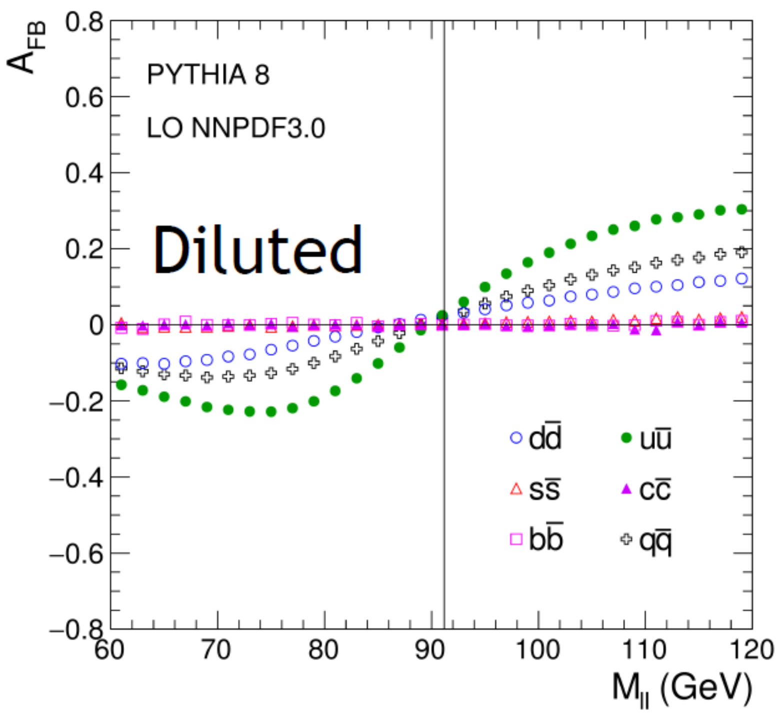
Weak mixing angle $\sin^2\theta_W$

$qq \rightarrow Z \rightarrow e^+e^-$ and $qq \rightarrow Z \rightarrow \mu^+\mu^-$ at 13 TeV, forward-backward asymmetry in the polar angle distribution of the negatively charged lepton with respect to the incoming quark

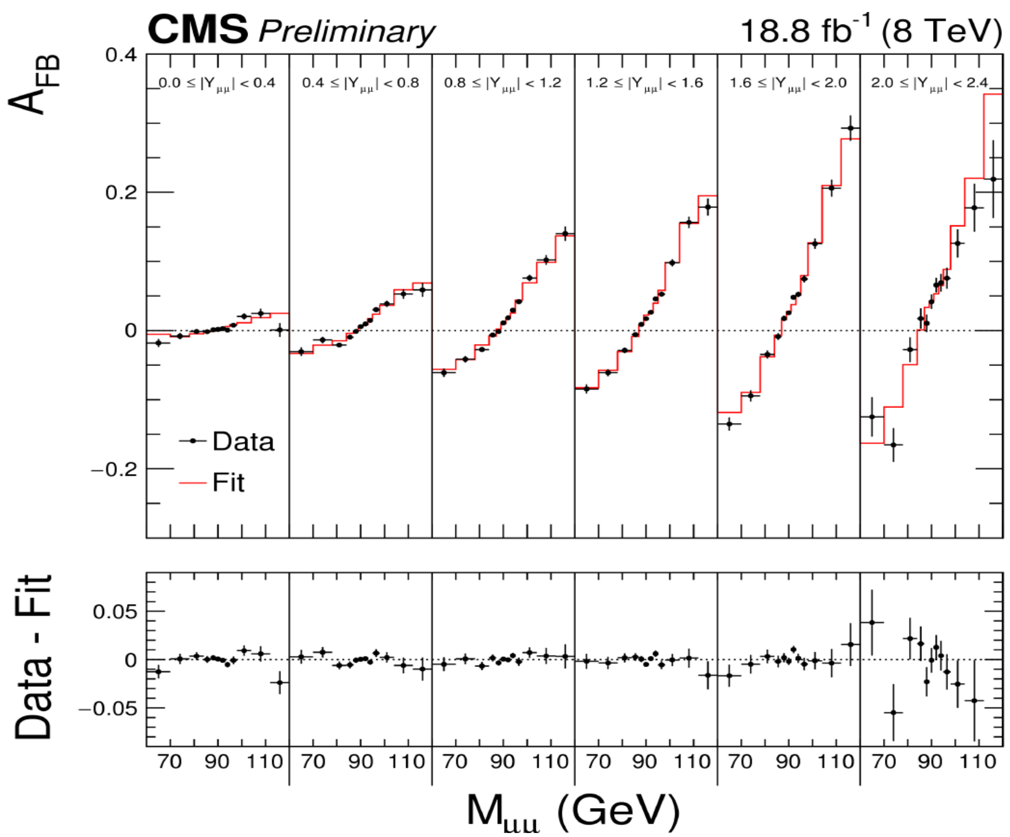


$A_{FB} = \dfrac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$, with σ_F and σ_B the cross sections for $\cos\theta > 0$ and $\cos\theta < 0$ in the Collins-Soper frame



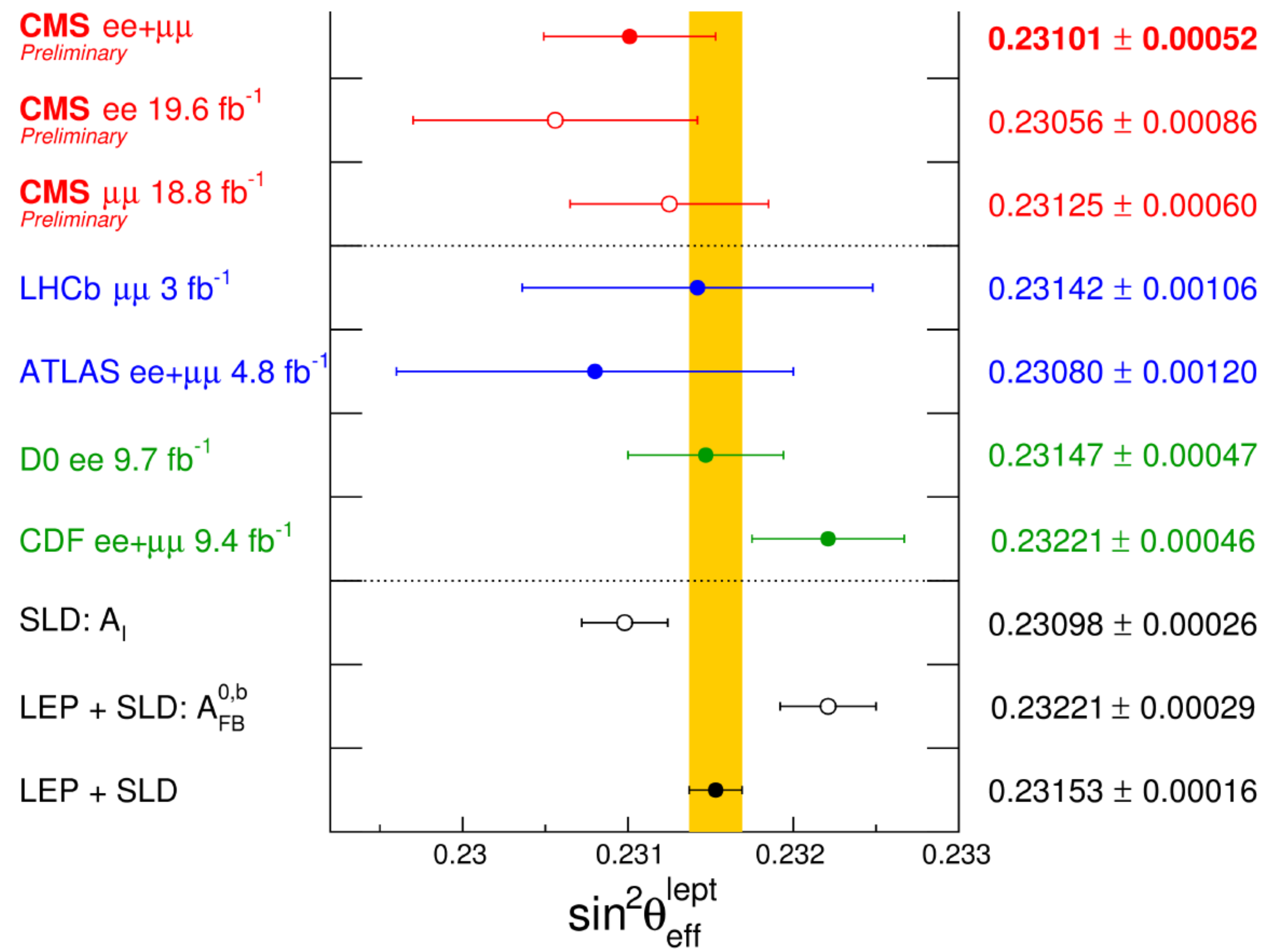


as quark direction the direction of the direction of the boost of the dilepton system is taken,
this is however not always true,
in addition A_{FB} depends on the PDFs



The dilution depends strongly on the rapitidy of the di-lepton system. $A_{FB} \sim 0$ at $\eta = 0$

A_{FB} measured in 6 bins of η and 12 bins of M_{ll}



Result

$\sin^2\theta_W$ = 0.23101±0.00036± 0.00018±0.00016±0.00030
(stat.) (syst.) (th.) (pdf)

$\sin^2\theta_W$ = 0.23101±0.00052

Statistical uncertainties still dominate,
but pdf uncertainties may become a problem soon

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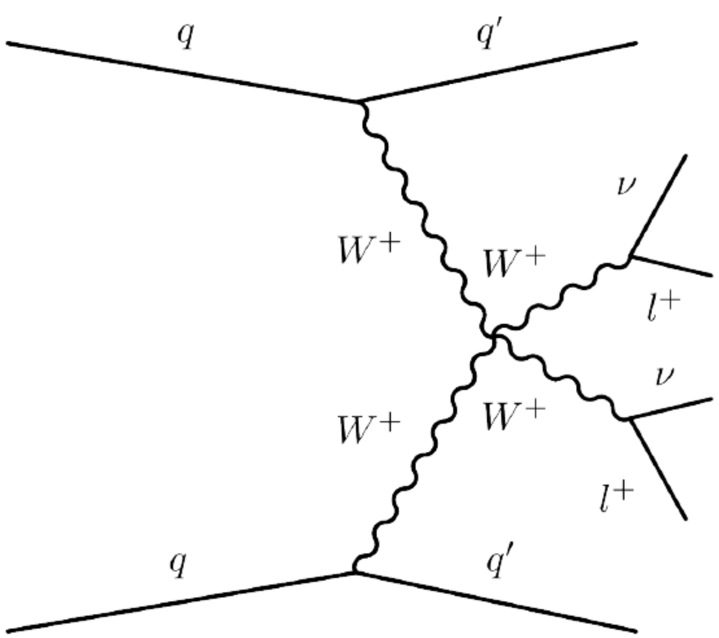
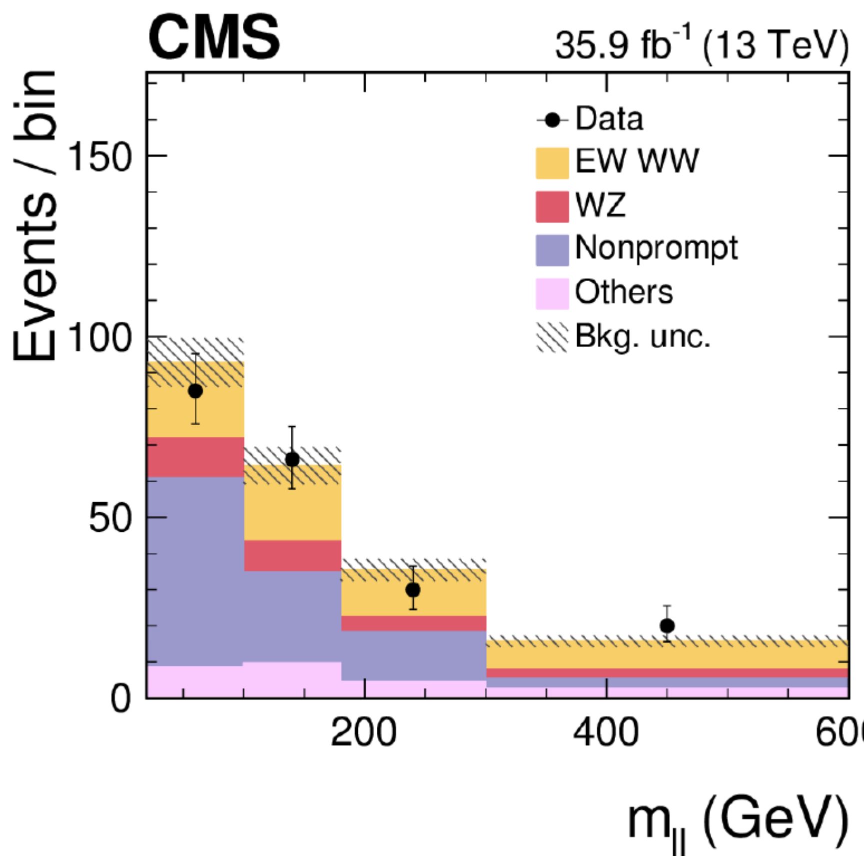
Gauge boson scattering, couplings and unitarity

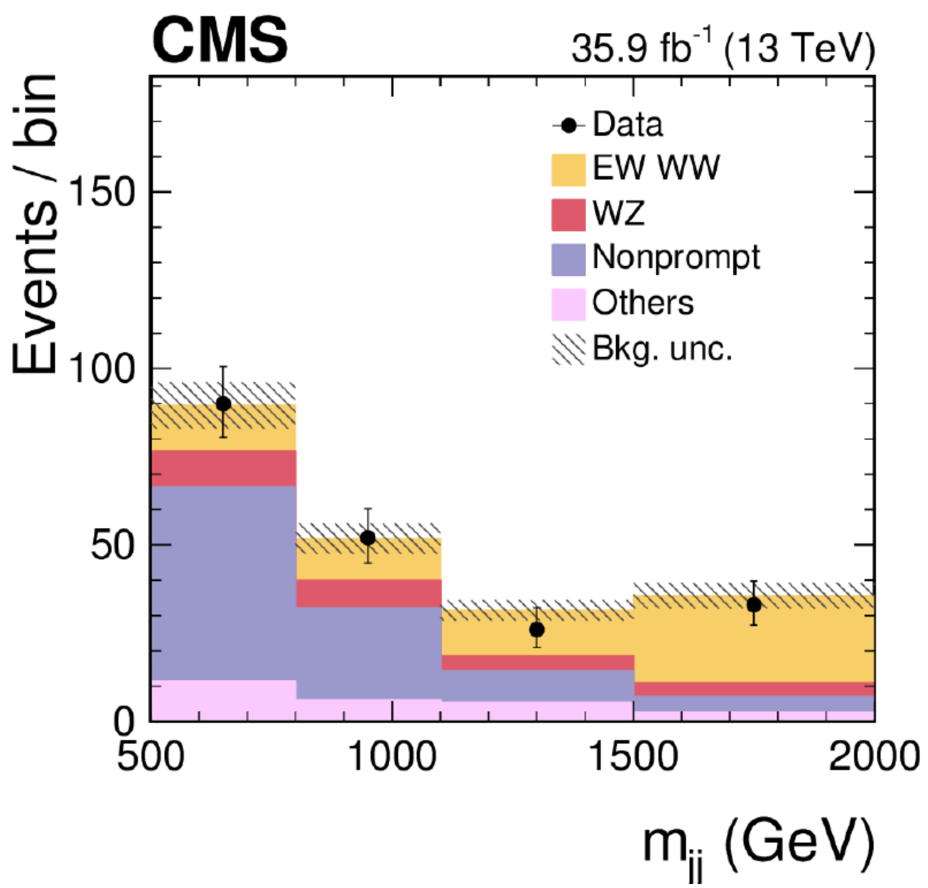


Signature:

- Two jets with large rapidity gap
- Two isolated leptons, same charge

First observation of same sign W production 5.5 (5.7 st. d.)





Fiducial cross section in agreement with the SM prediction of 4 fb

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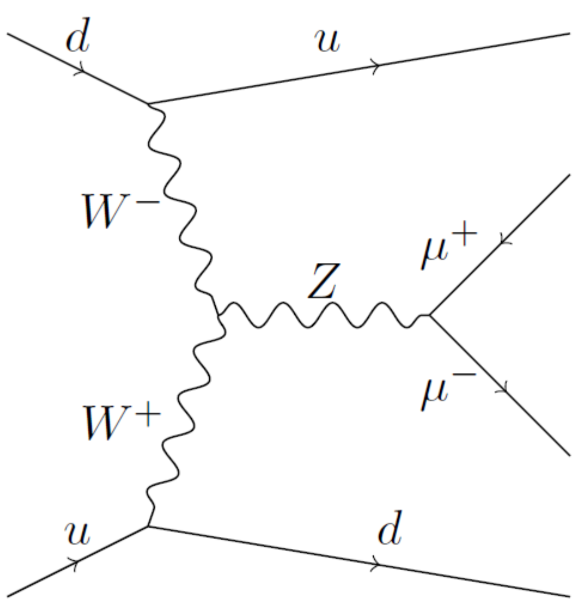
Gauge boson couplings



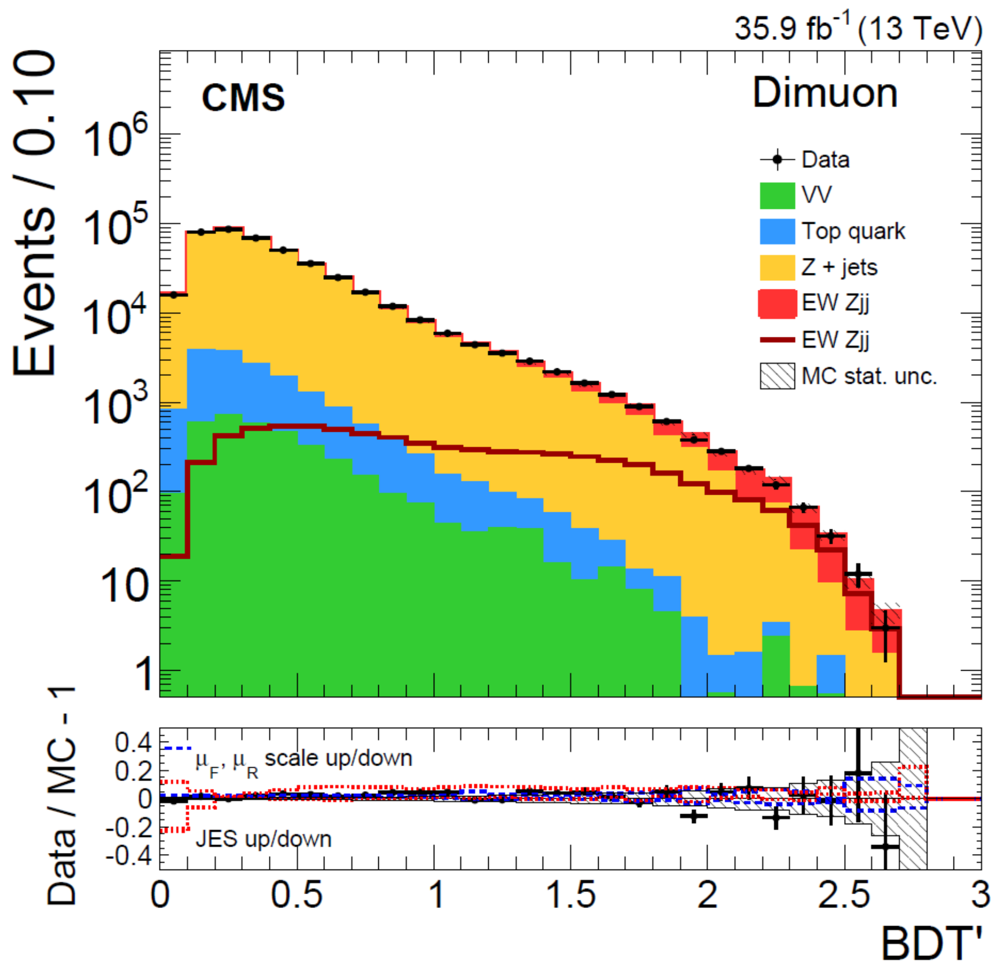
Search for anomalies

Signature:

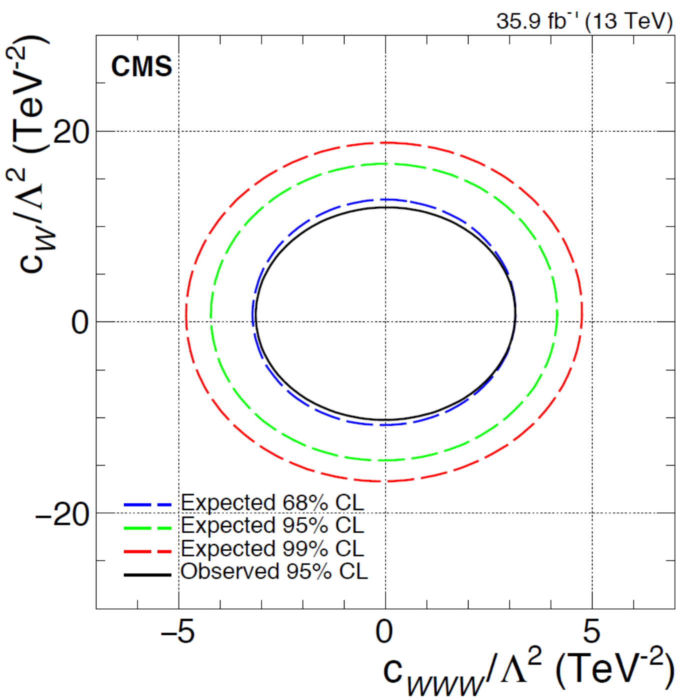
- Two jets with large rapidity gap
- Two isolated leptons, same flavor, opposite charge

Main background: DY with jets

σ = 552 ± 58 fb, SM expectation: 543±24 fb



search for anomalous couplings



$$\mathcal{O}_{WWW} = \frac{c_{WWW}}{\Lambda^2} W_{\mu\nu} W^{\nu\rho} W_\rho^\mu,$$

$$\mathcal{O}_W = \frac{c_W}{\Lambda^2} (D^\mu \Phi)^\dagger W_{\mu\nu} (D^\nu \Phi),$$

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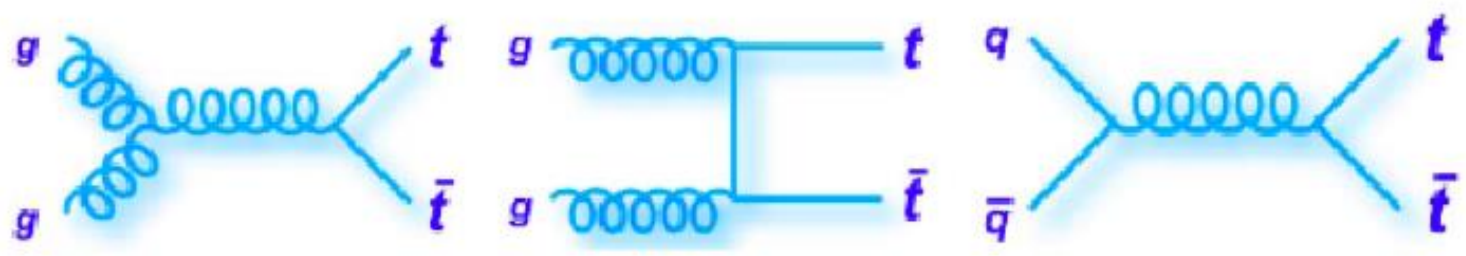
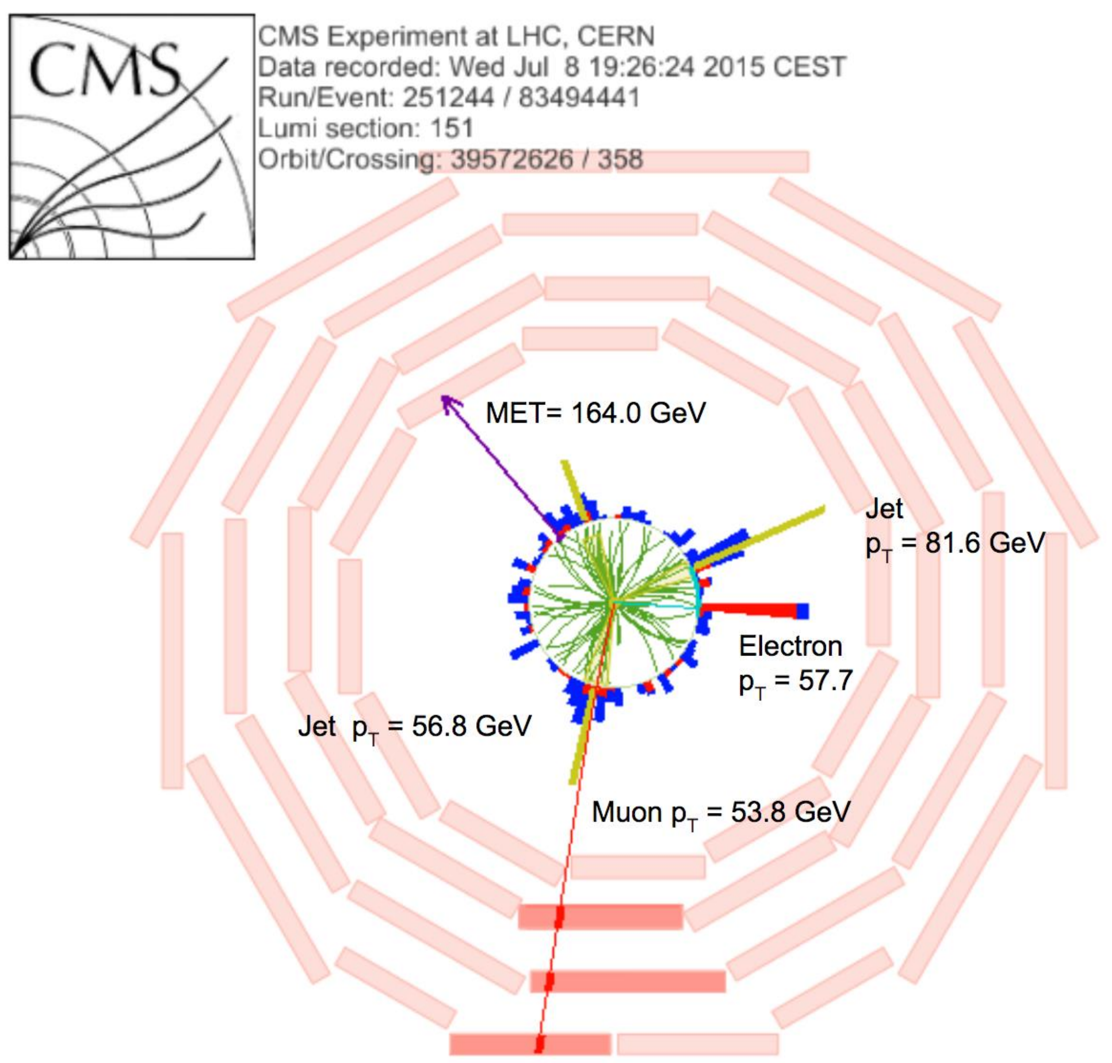
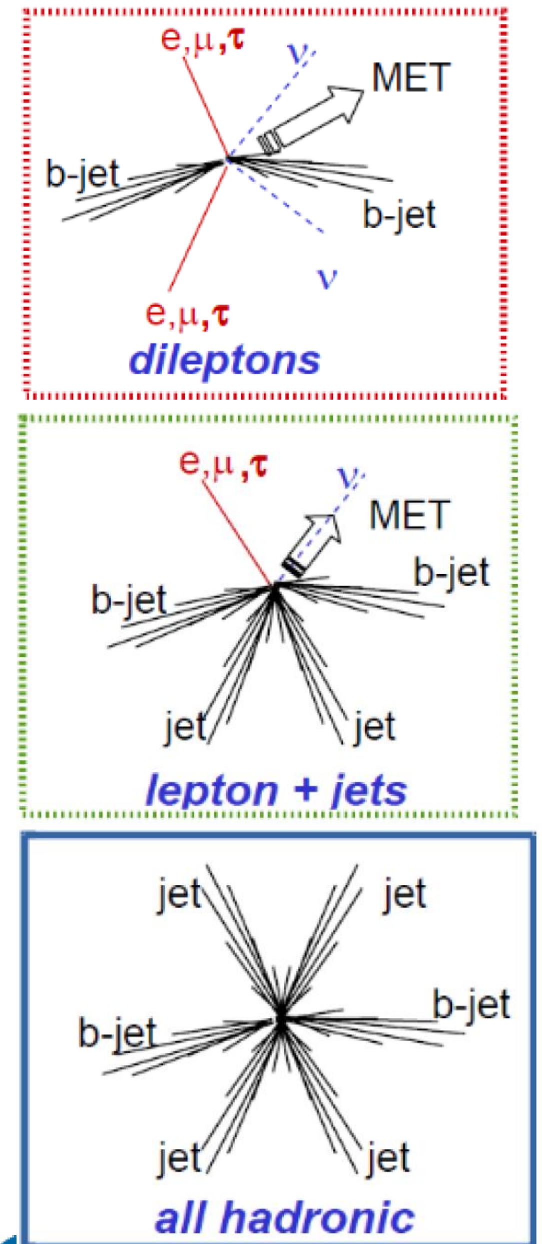
Top quark pair production



At 13 TeV 85 % via gluon fusion
decay almost 100% to bW
final state defined by W decay,

- two leptons of opposite charge
- one charged lepton and two jets
- four jets





Top-quark mass

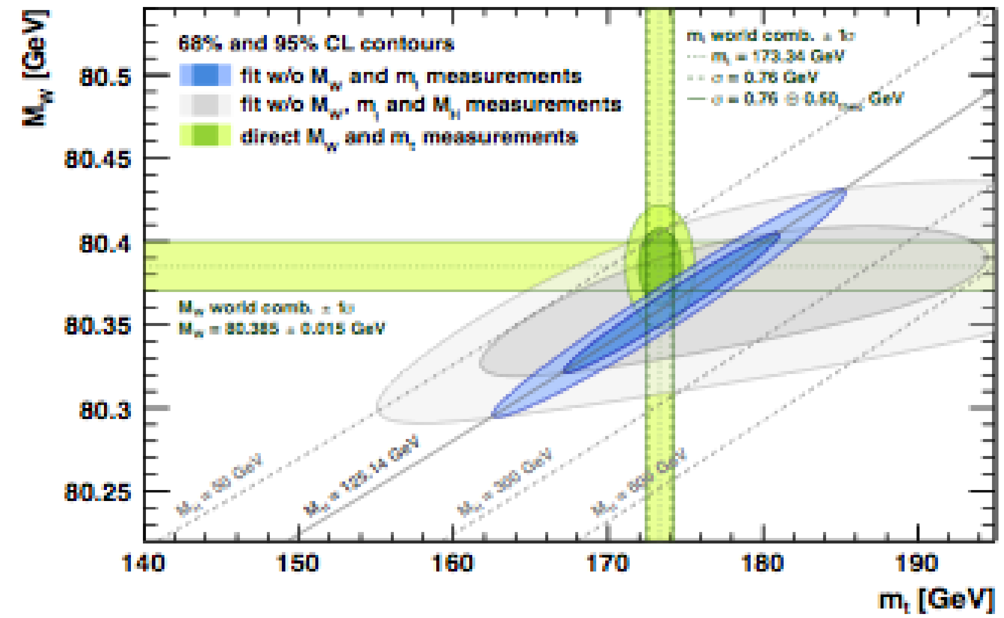
arXiv:1407.3792

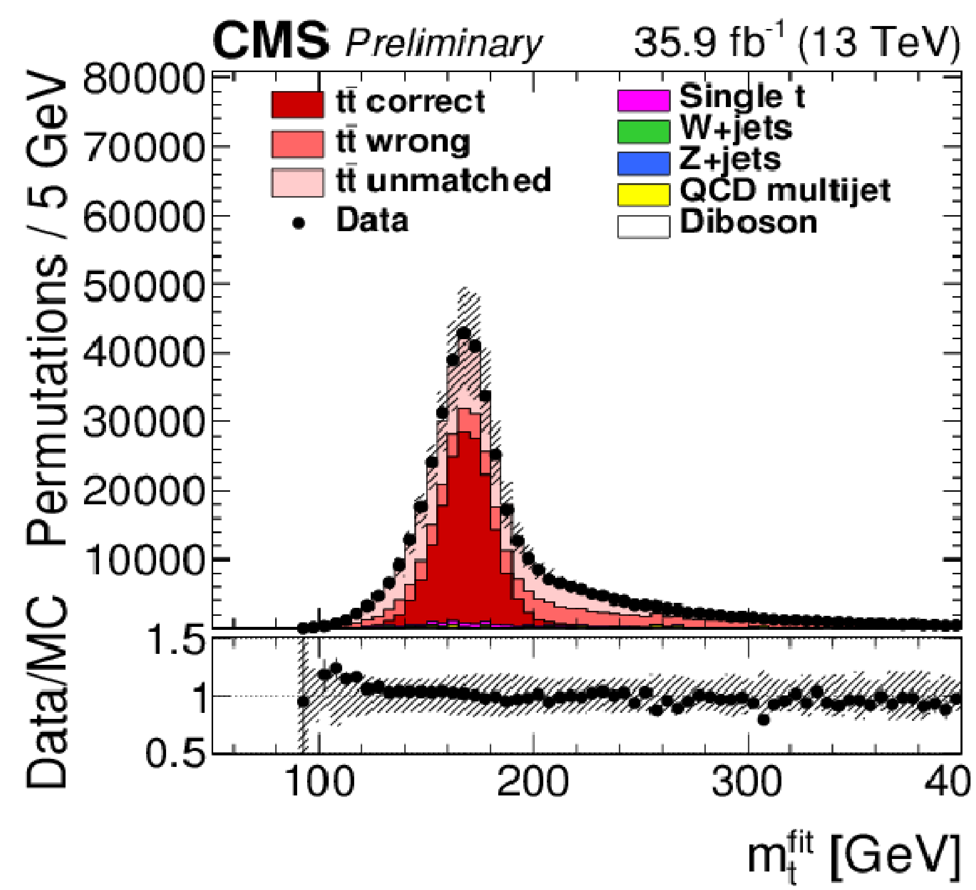
top-quark mass is a quantum number, essential for the internal consistency of the SM near the electroweak scale

reconstruction of the invariant mass from jets:

CMS Run 1
m_{top} = 172.44 ± 0.48 GeV

results at 13 TeV
m_{top} = 172.25 ± 0.62 GeV

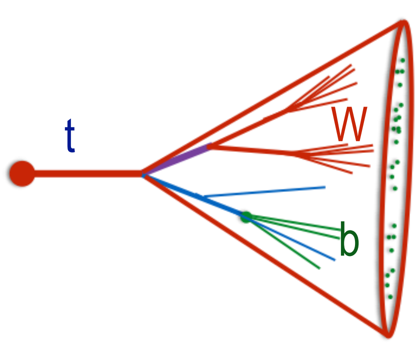


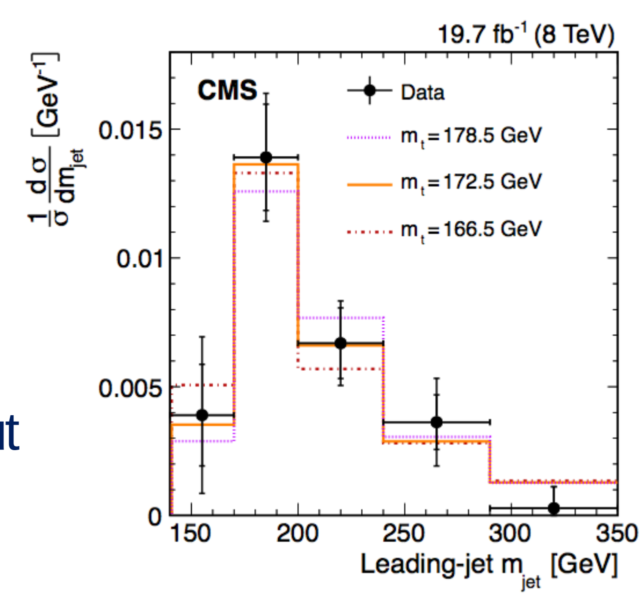


using boosted top quark jets

m_jet and different cross section measurements

$m_{top} = 170.8 \pm 6.0_{stat} \pm 2.8_{syst} \pm 4.6_{model} \pm 4.0_{theo}$ GeV





not yet competitive in precision but feasibility demonstrated

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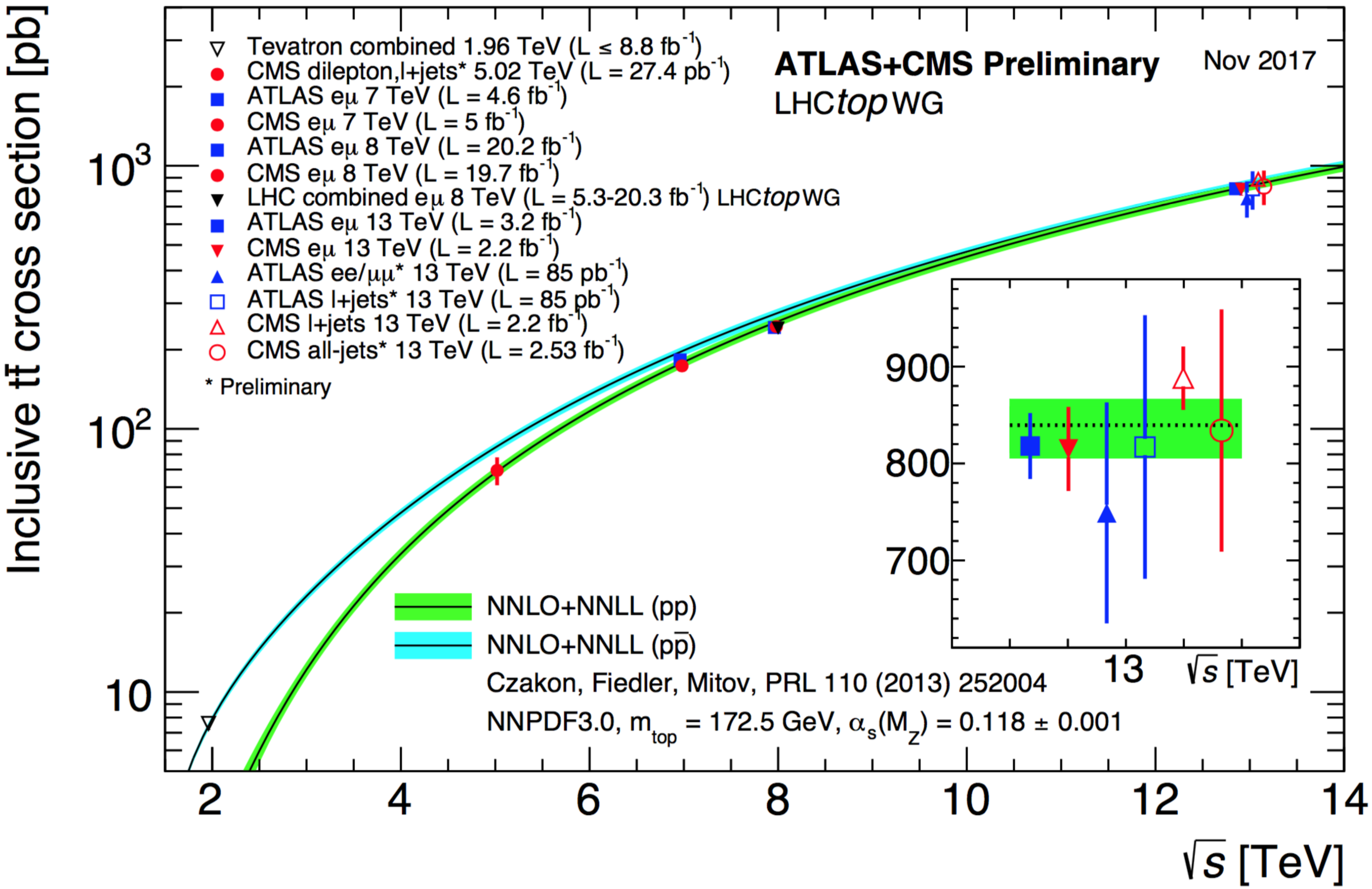
Precise NNLO and NNLL calculations done with an estimated precision of 5%

Measurements approached the same precision level !



t t final states with one W decaying in e or μ and the other in hadrons

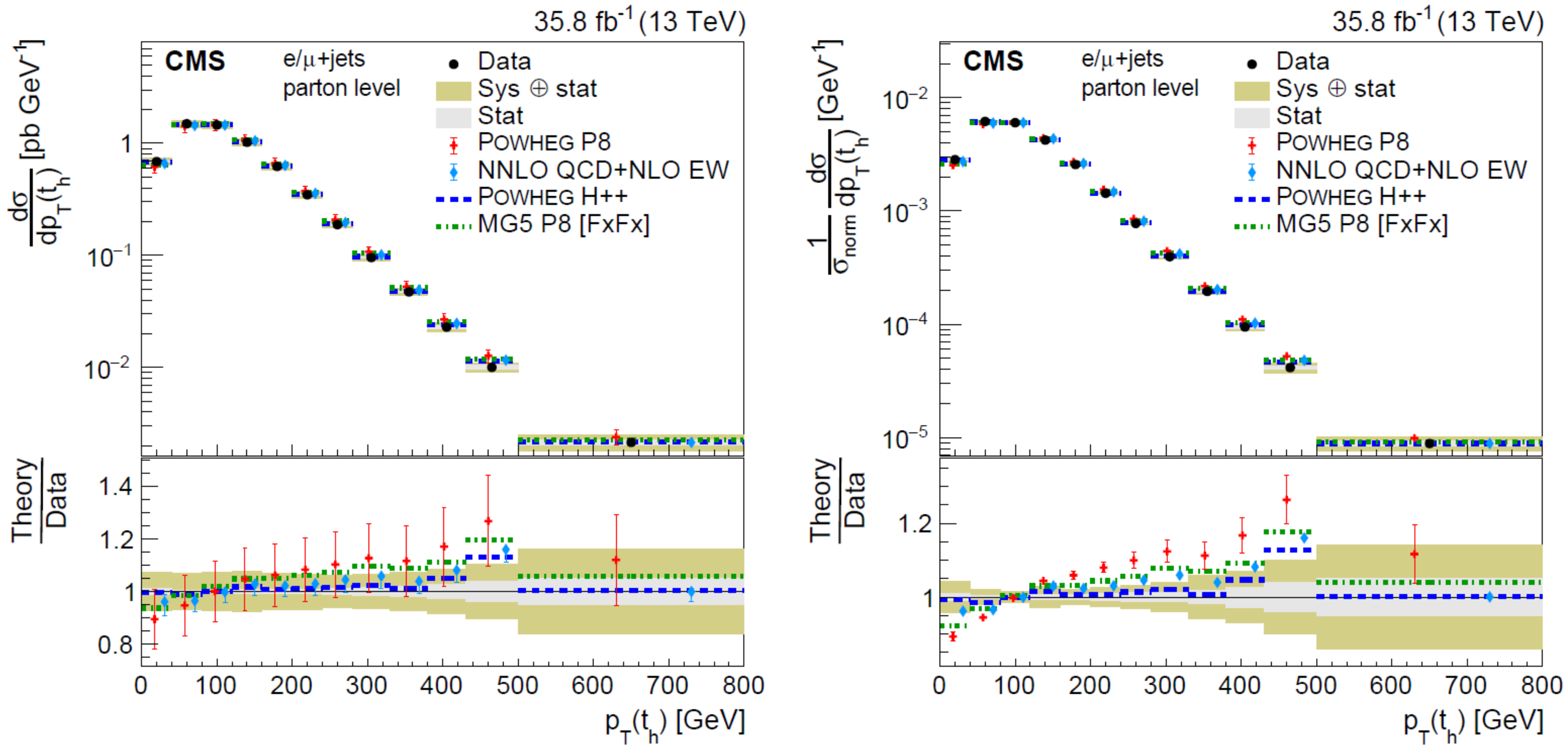
signature: two b-jets, two light quark jets and one isolated e or μ and missing p_T

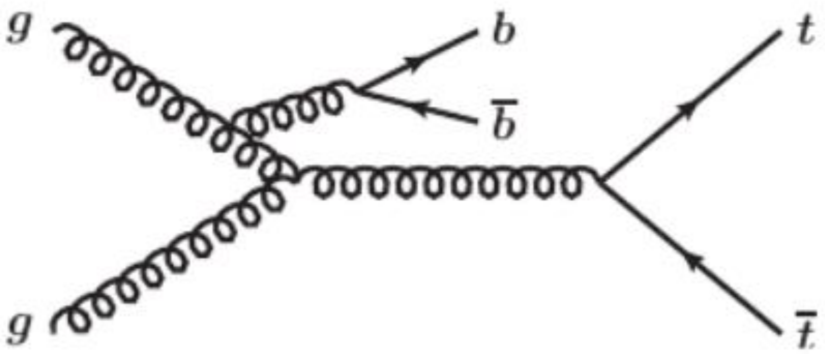
single and double differential distributions in p_T, η and m(tt)

most distributions are reasonably well described by theory (POWHEG+Pythia8, SHERPA when also theoretical uncertainties are considered)

exception:
top-quark p_T distribution measurement points to a softer spectrum,
being currently investigated

multiplicities and kinematic features of additional jets are modelled reasonably well by Pythia8 and POWHEG, SHERPA fails





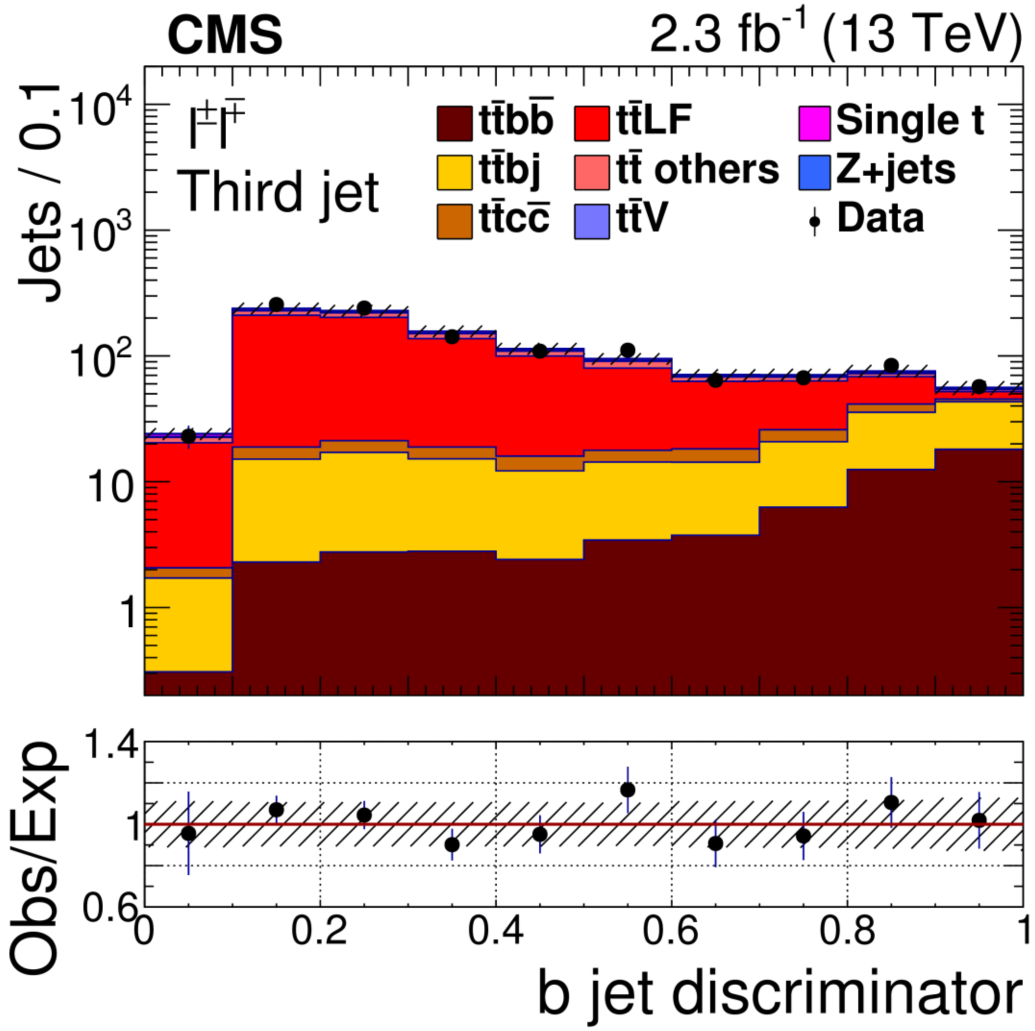
motivation:

- background for ttH and many searches
- Test of QCD

t t final states with two additional jets

signature:

- two isolated leptons with opposite charge
- $m(l^+l^-)$ > 12 GeV, same flavour leptons incompatible with Z decay
- at least four reconstructed jets with pT > 30 GeV, |η| > 2.4
- at least two b-jets,



method:
analyse 2D distributions of the b-jet discriminators of the 3-rd and 4-th jet, classification in b, c and light flavor jets

results:

σ(ttbb) = 4.0 ± 0.6 (stat) ± 1.3 (sys) pb

σ (ttqq) =184 ± 6 (stat) ± 33 (sys) pb

the ratio σ(ttbb)/σ(ttqq) is underestimated using POWHEG

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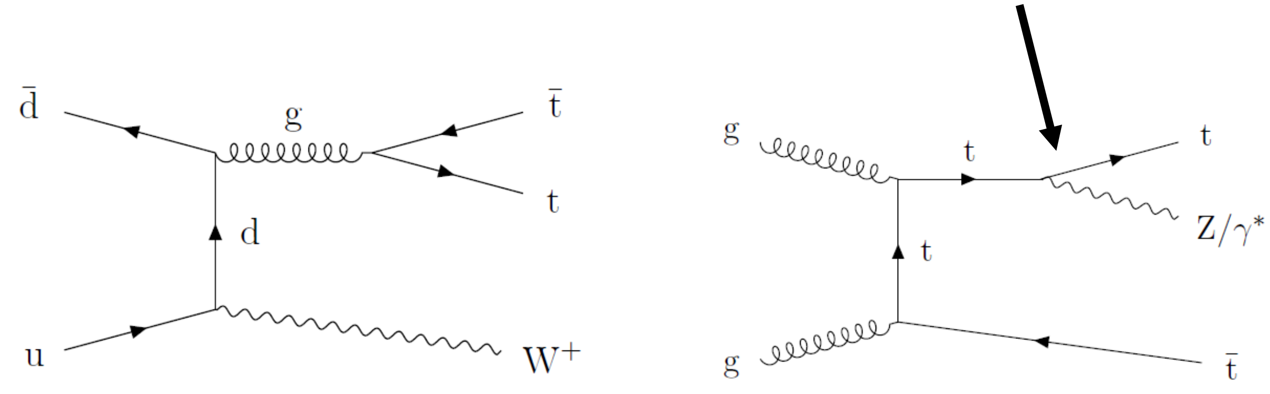
top couplings to the W/Z

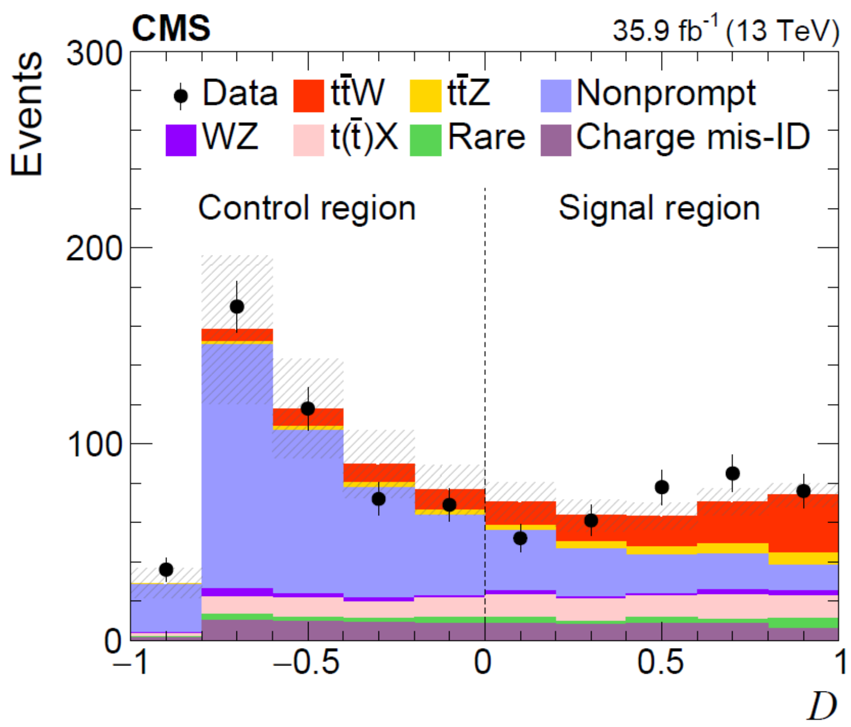
Contributing diagrams

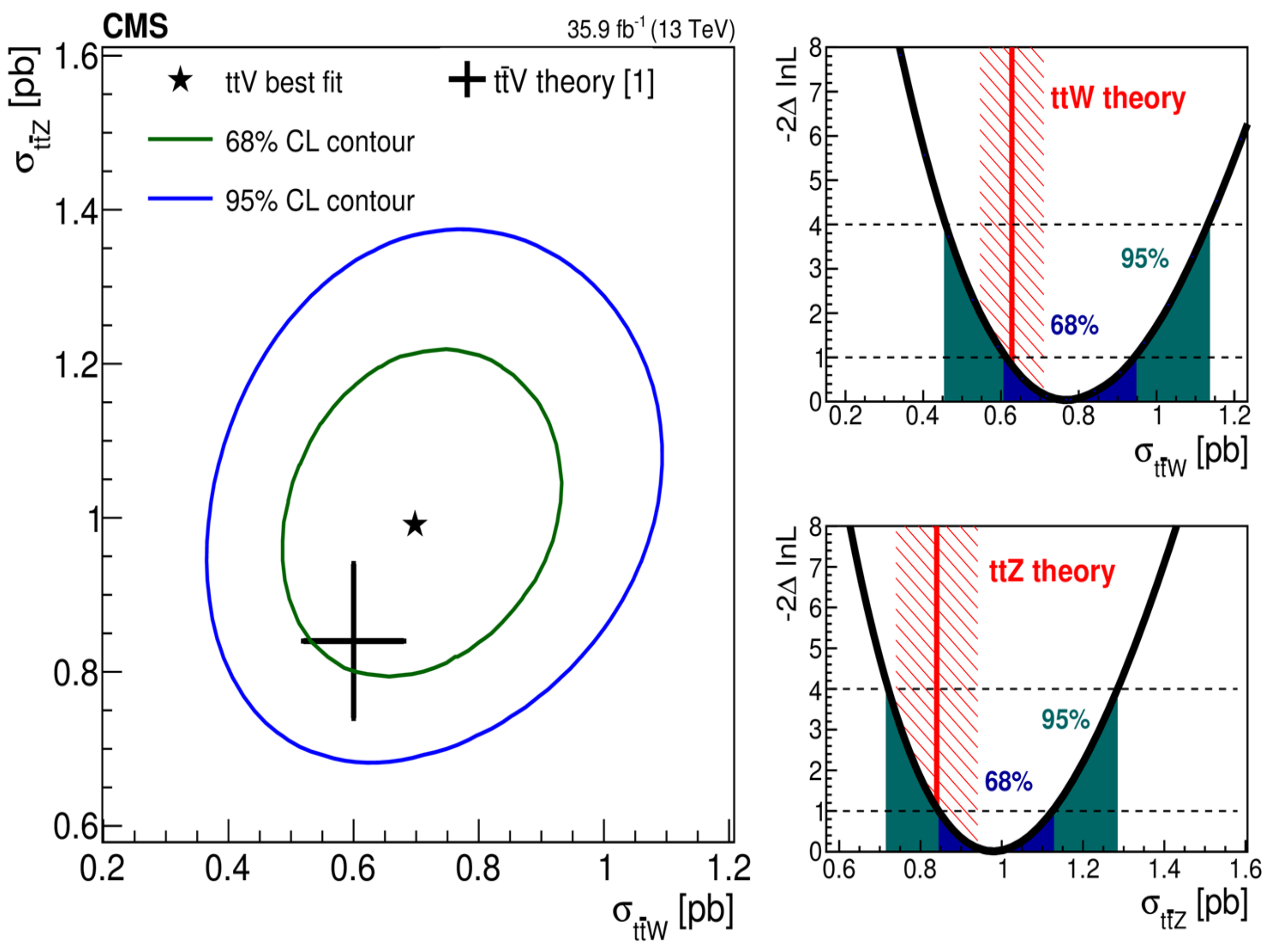
probe the ttZ coupling



ttZ and ttW productio observed with significance > 5σ

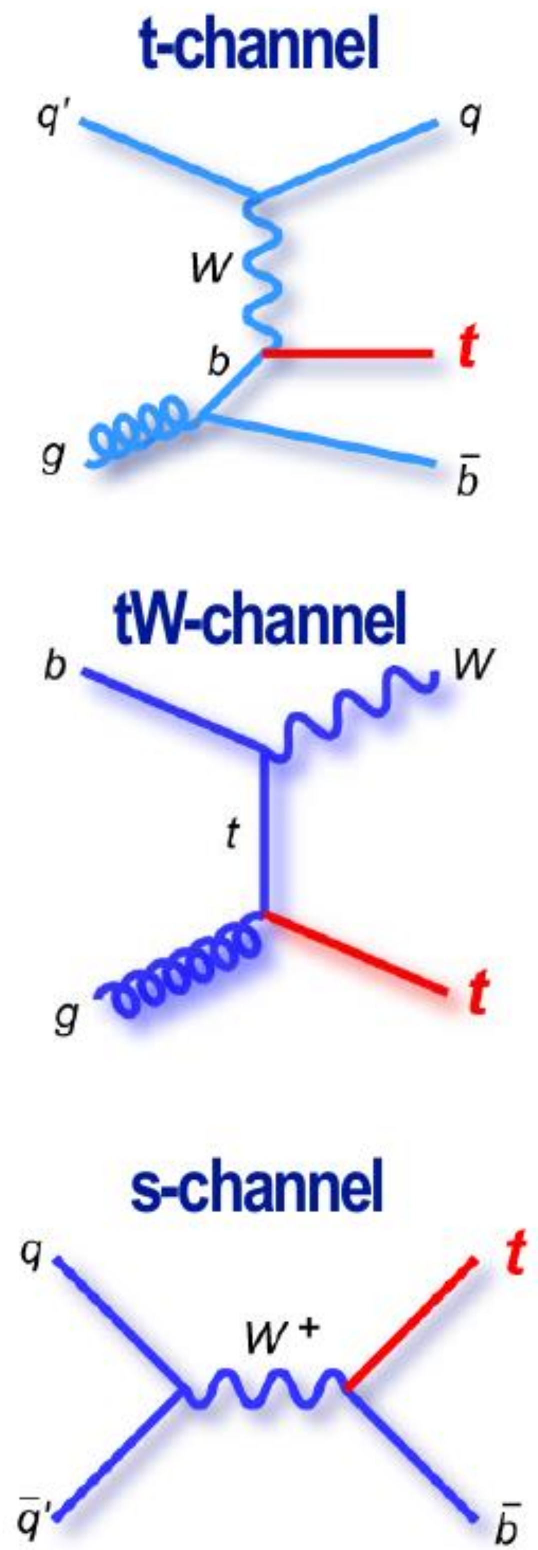
method:
analyse samples in bins of the number of leptons, where the fraction of ttW and ttZ is significantly different

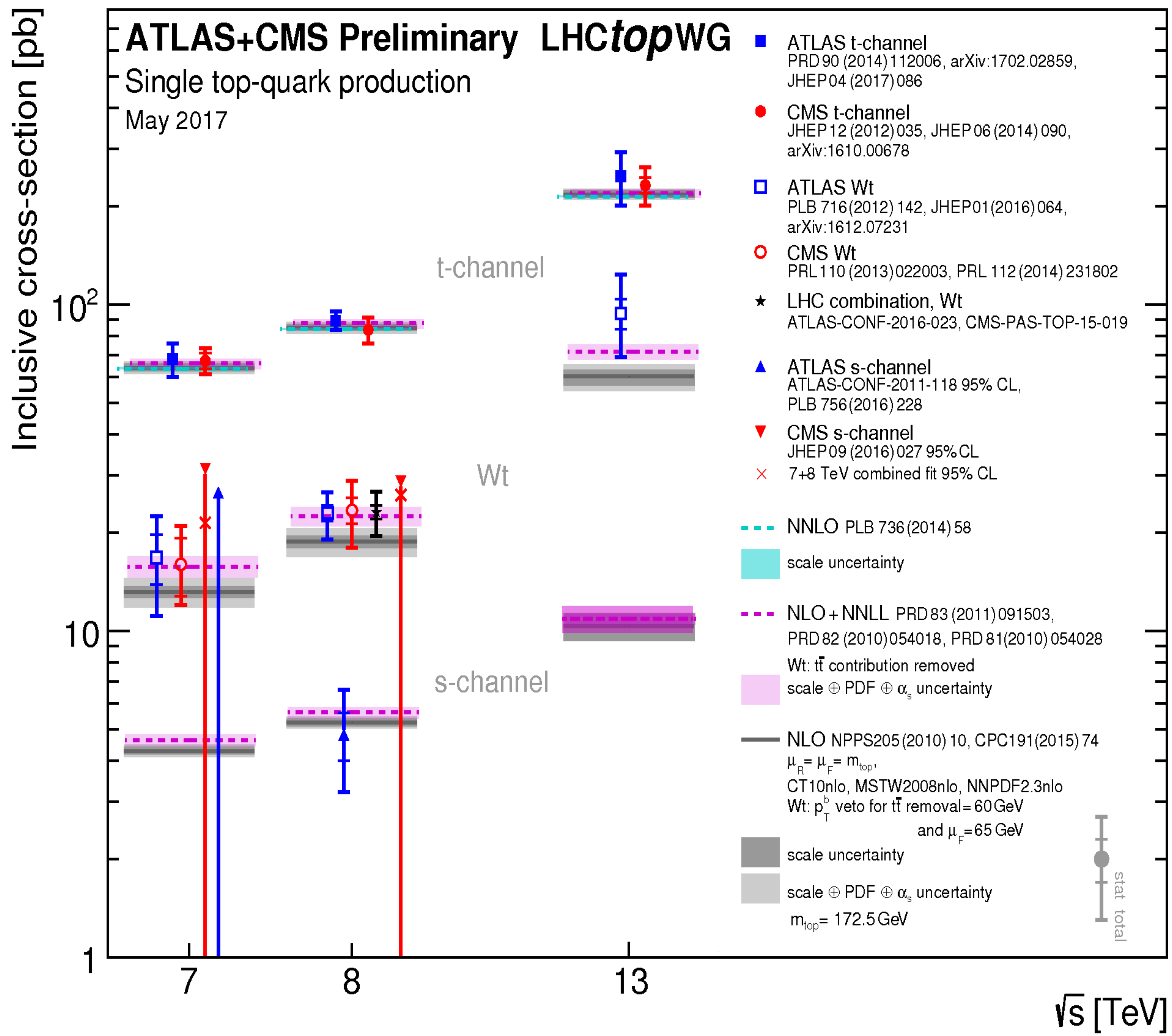




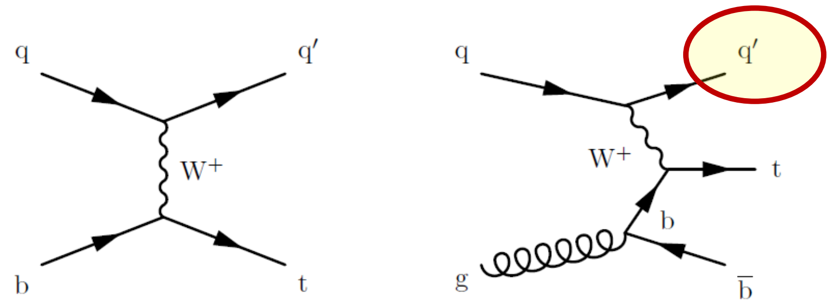
example: same-sign dilepton sample, ttW signal clearly visible

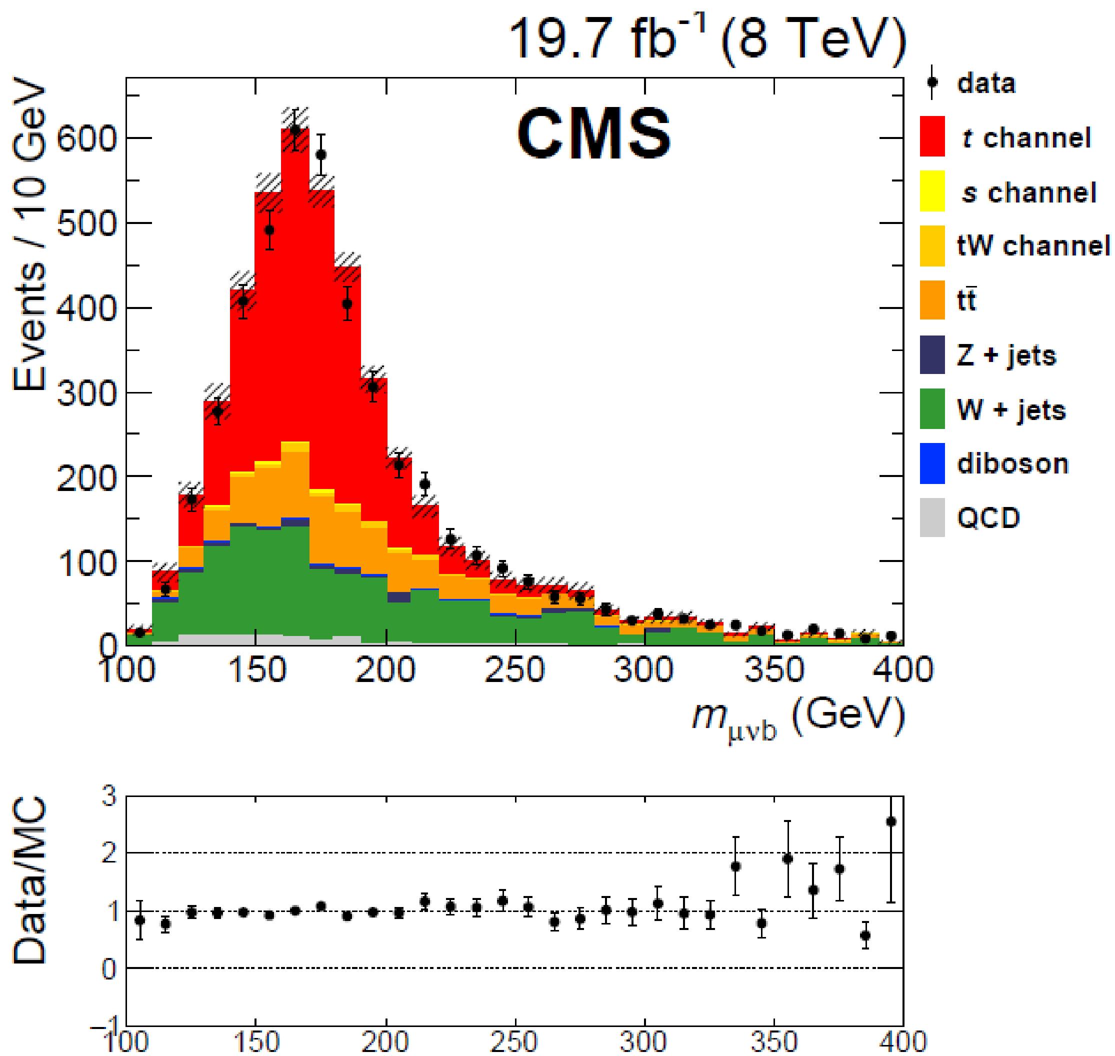
Single top production





Top-quark mass measurement in single top production





- new sample with partly uncorrelated systematic uncertainties
- m_{top} extraction differently affected by pertubative and non-pertubative effects

event topology:

- single isolated muon, p_T > 26 GeV
- momentum imbalance, p_{Tmiss} > 50 GeV
- central b-tagged jet
- one light-quark jet in the forward direction, $|\eta| > 2.5$
- Use only positive muons (larger top than anti-top) cross section

requirements:

Invariant mass of ($\mu\nu$) must be compatible with the W mass

t –channel signal and background from top-quark pair production modelled separately in the fit

$m_{top} = 172.95 \pm 0.77\ (\text{stat}) \pm^{97}_{93}\ (\text{syst})$ GeV

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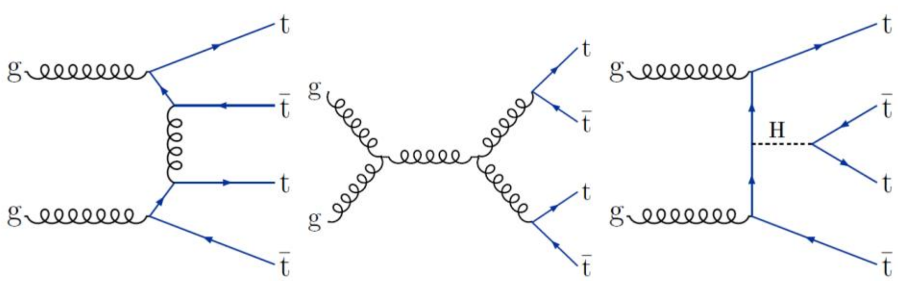
Four top-quark production

motivation: expected enhanced production in BSM models, like gluino pair production, 2Higgs doublets

SM production mechanisms

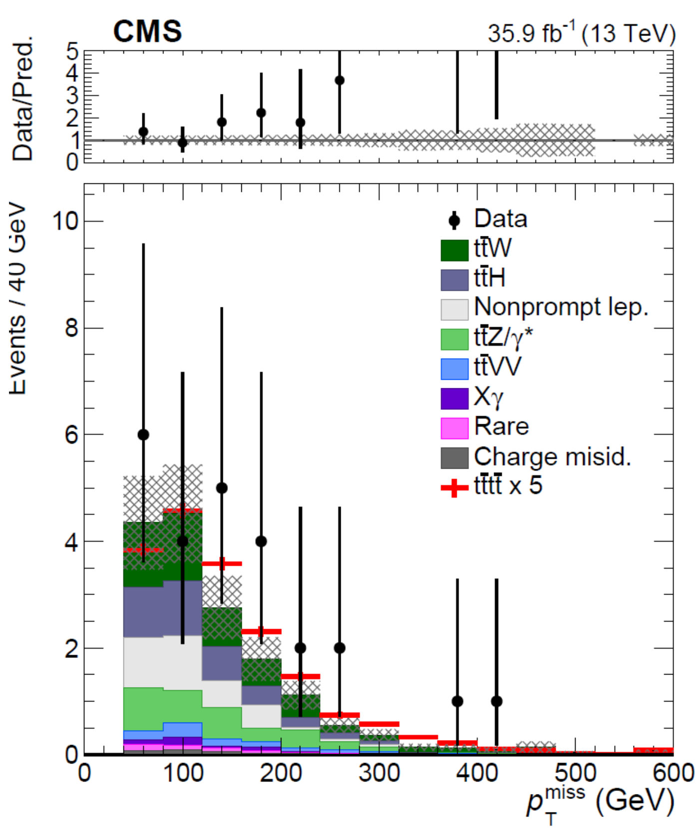


signature: two same-sign leptons or at least three leptons, jet multiplicity and b-quark jets

main background: tt + bosons

Physics background processes

N_ℓ	N_b	N_{jets}	Region
2	2	≤ 5	CRW
		6	SR1
		7	SR2
		≥ 8	SR3
	3	5, 6	SR4
		≥ 7	SR5
	≥ 4	≥ 5	SR6
≥ 3	2	≥ 5	SR7
	≥ 3	≥ 4	SR8
Inverted Z veto			CRZ



Result: σ(pp → tt tt X) = 16.9 (+13.8-11.4) fb

Assuming a Yukawa coupling different from SM the result can also be interpreted in terms of the limit:

$|y_t/y_t^{SM}| < 2.1$ at 95 % C.L.

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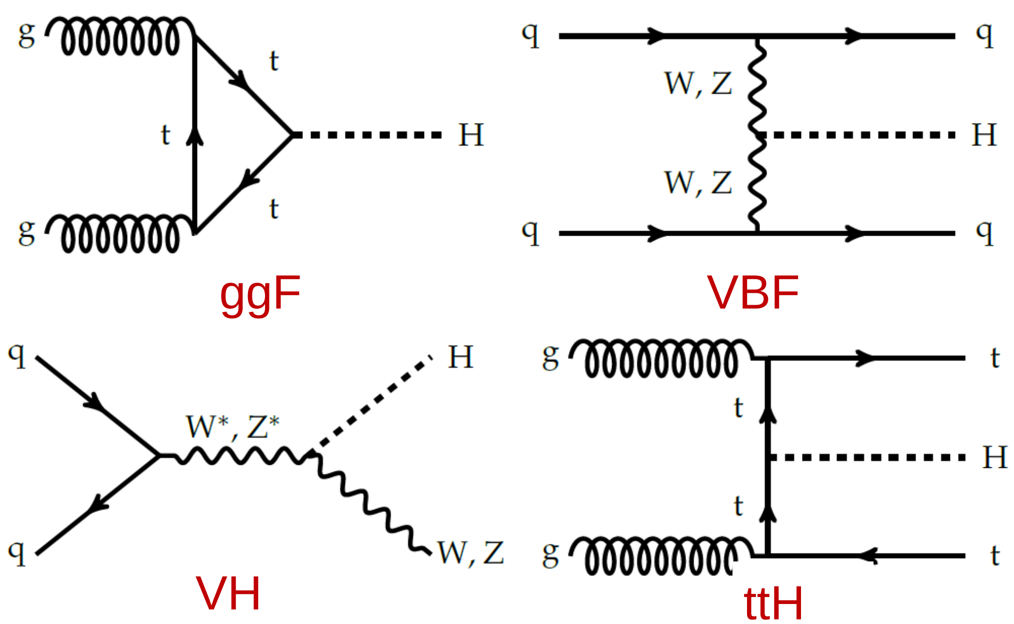
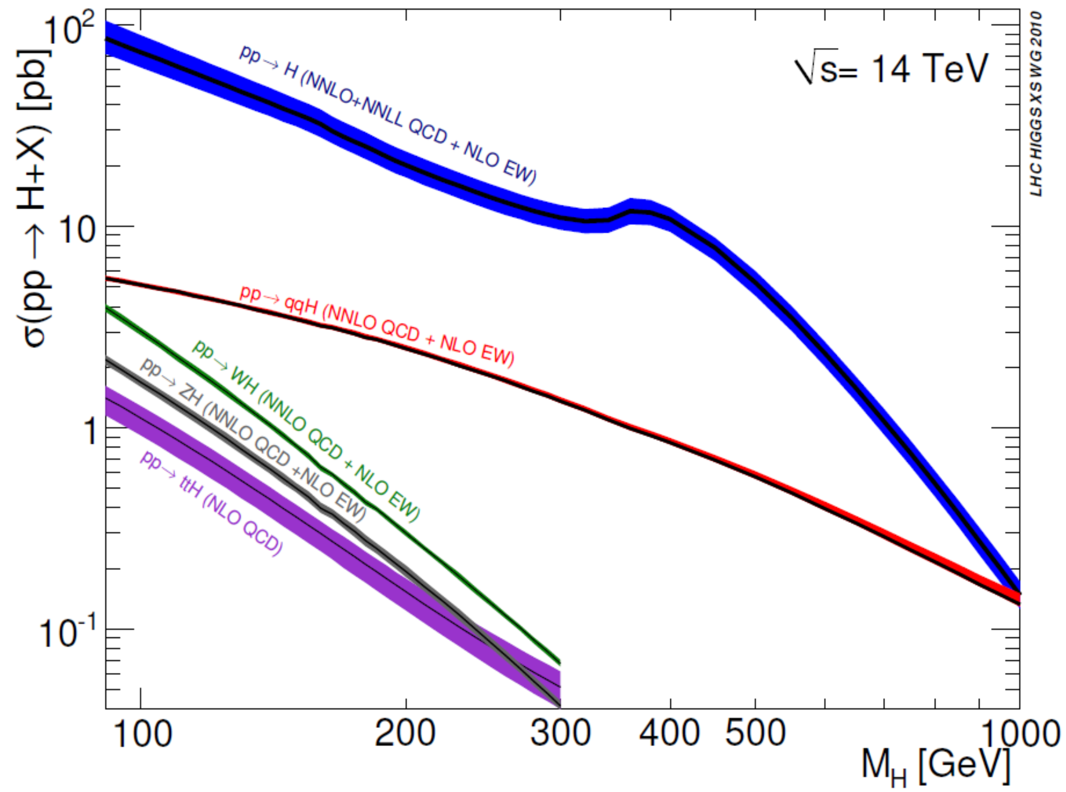
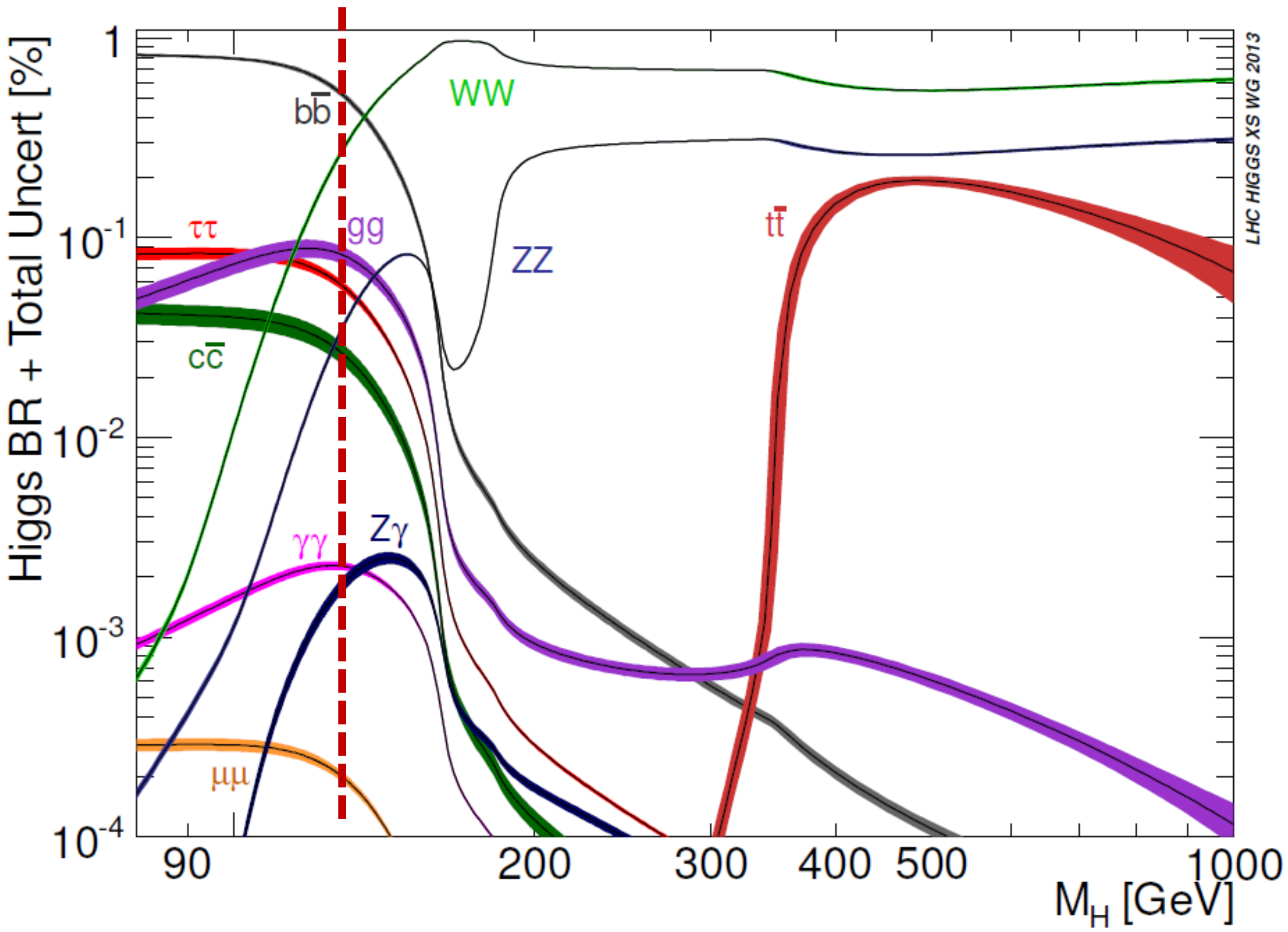
Higgs boson

production mechanisms





and decays



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Higgs boson at 13 TeV

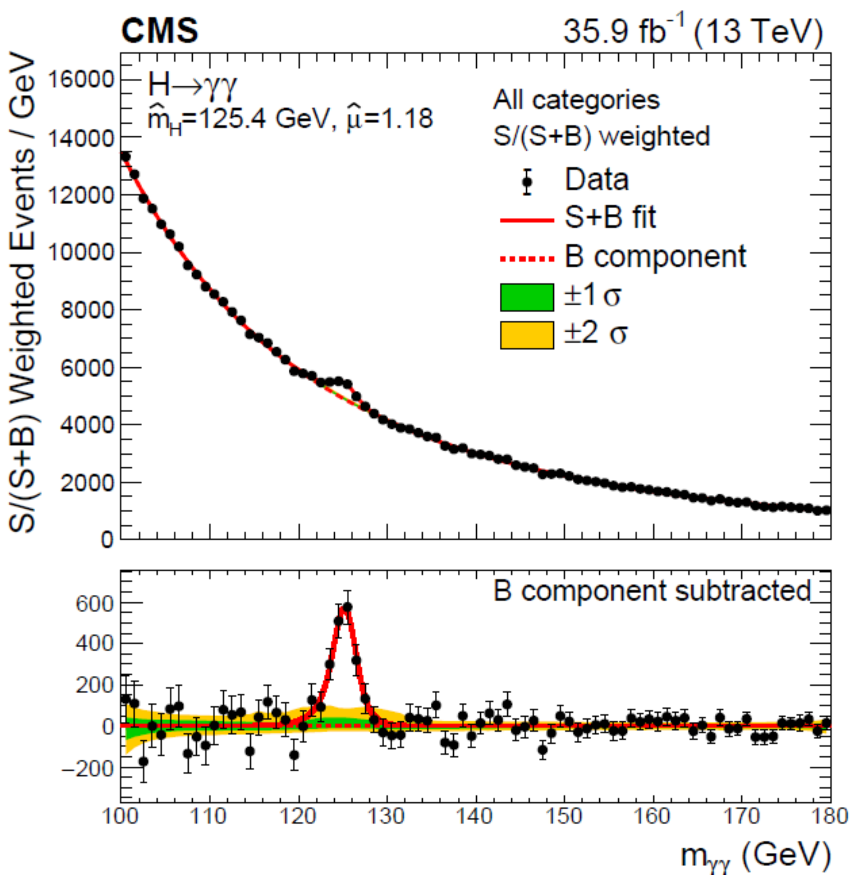
H → γγ excellent mass resolution, very low branching fraction

- preselection of events with two photons, $p_T^{(1)} > 30$ GeV and $p_T^{(2)} > 20$ GeV
- quality criteria on the shower shape, considering conversion, are applied
- events are categorised according to the expectations of the different production mechanism
- primary vertex identification

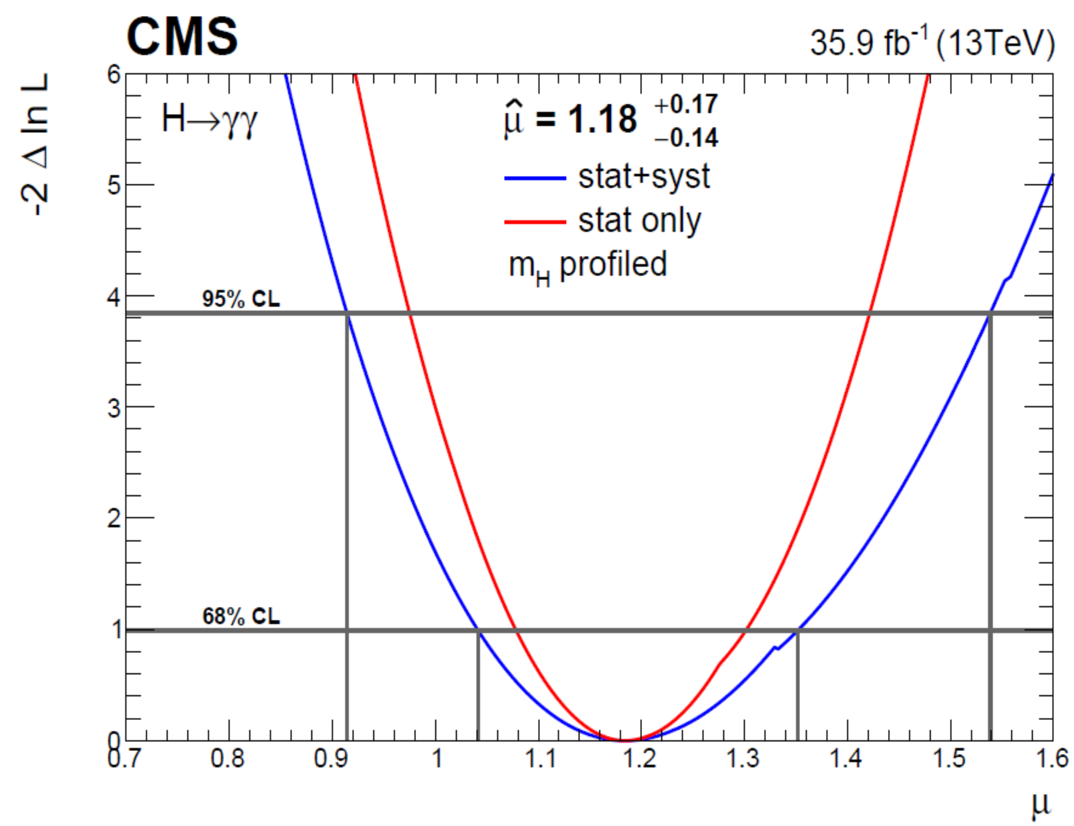
VBF: forward jets

tt H : electrons, muons,missing energy, b-quark jets

VH : decay producs from vector bosons



$$\widehat{m}_{\mathrm{H}} = 125.4 \pm 0.3\,\mathrm{GeV}$$



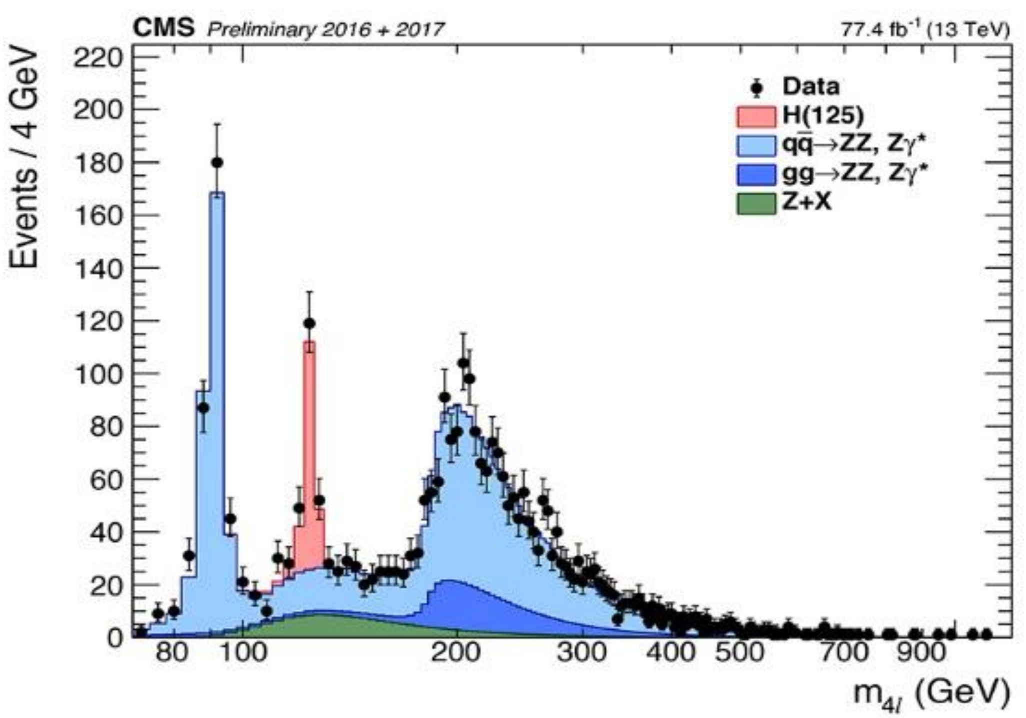
$$\hat{\mu} = 1.18^{+0.17}_{-0.14}$$

H → ZZ, excellent mass resolution, low branching fraction

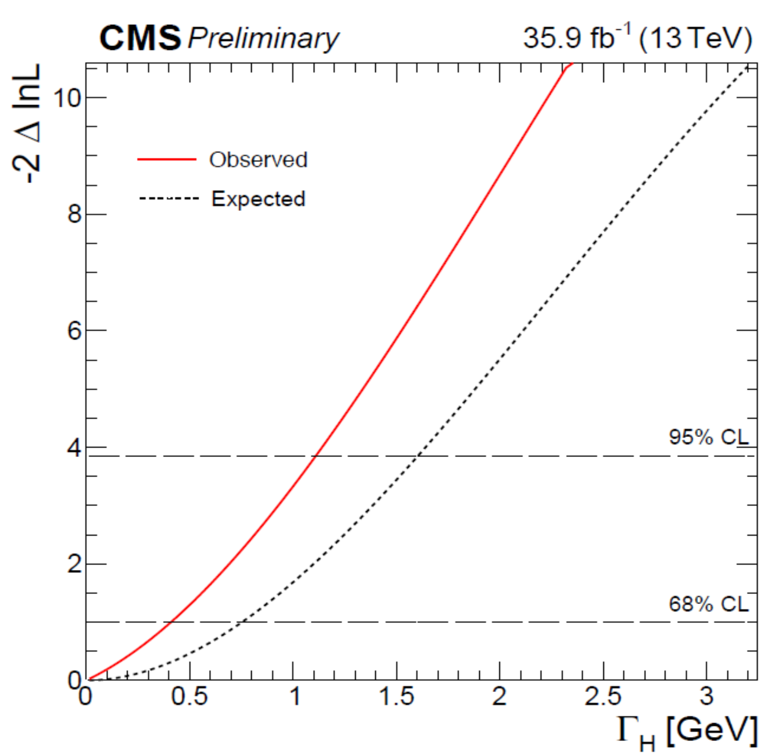
- events with four well defined isolated leptons
- muon and electron energy scale calibrated
- events are categorised according to the expectations of the different production mechanism

VBF: two or more jets, limited b-tag
VH : two or more jets, no b-tag, or one more lepton, or one more lepton pair of opposite sign and same flavour
tt H : at least four jets, at least one b-quark jet or one asdditional lepton

mass measurement



width measurement (105 < m_{4l} < 140 GeV)



$$\mu = 1.06^{+0.15}_{-0.13}, \qquad \Gamma_H < 1.10 \text{ GeV}$$

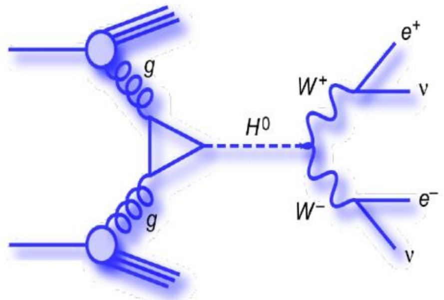
$$m_H = 125.26 \pm 0.20(\text{stat.}) \pm 0.08(\text{sys.}) \text{ GeV}$$ (only 2016)

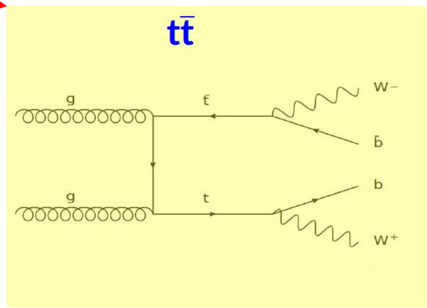
H → WW, WW → 2l 2ν, resonable branching fraction, very low mass resolution

Topology: two isolated leptons of opposite charge, missing momentum

No b-tagged jets

Main backgrounds: tt and WW production





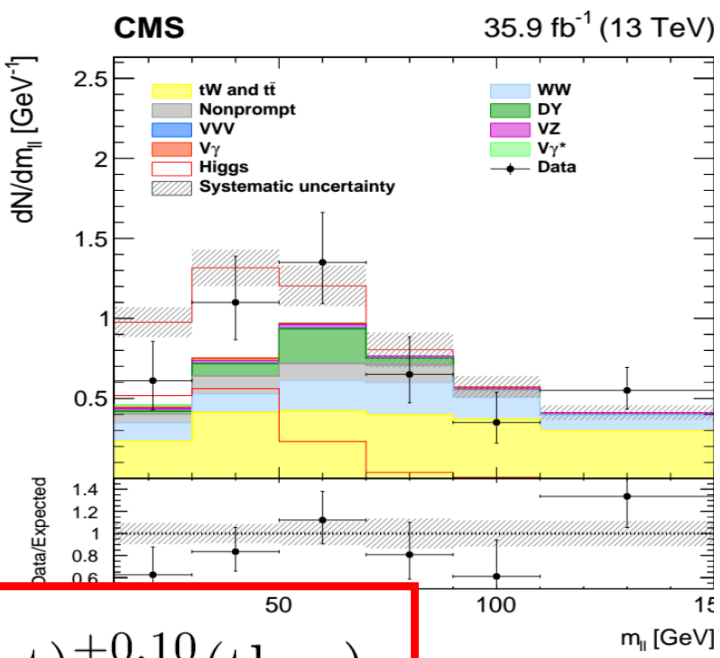
Discriminating quantities: m_{ll} and m_T , , $m_T^2 = 2p_T^{\ell\ell} E_T^{\rm miss}(1-\cos\Delta\phi(\ell\ell, \vec{E}_T^{\rm miss}))$

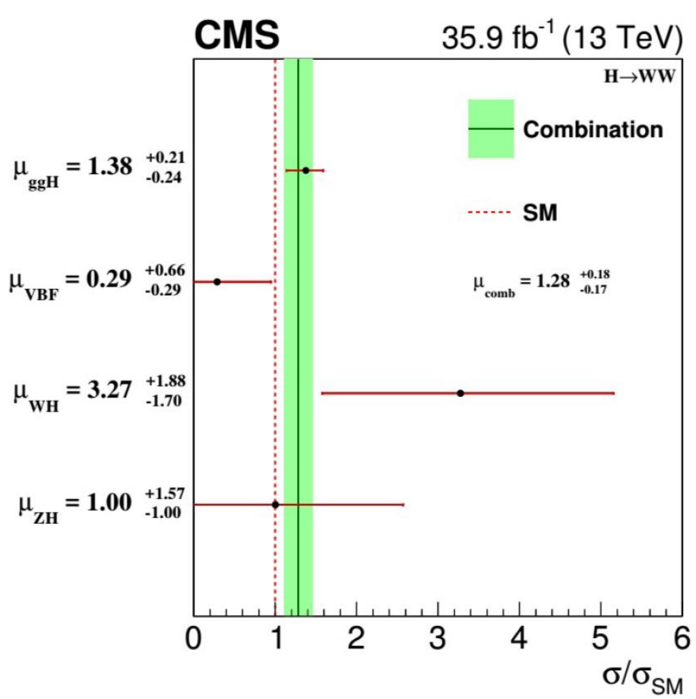
m_{ll} small, spin correlations!

tt : estimated from simulation, dedicated side-band region to control normalisation and t- quark p_T distribution

W+ jets : shape from MC, control samples used for adjustment

multi-jet production: fully data driven using control samples with same-sign loosely identified leptons





$$\mu = 1.28^{+0.18}_{-0.17} = 1.28 \pm 0.10(\rm stat) \pm 0.11(\rm syst)^{+0.10}_{-0.07}(\rm theo)$$
$$\rm Significance = 9.1\sigma(7.1\sigma\ exp)$$

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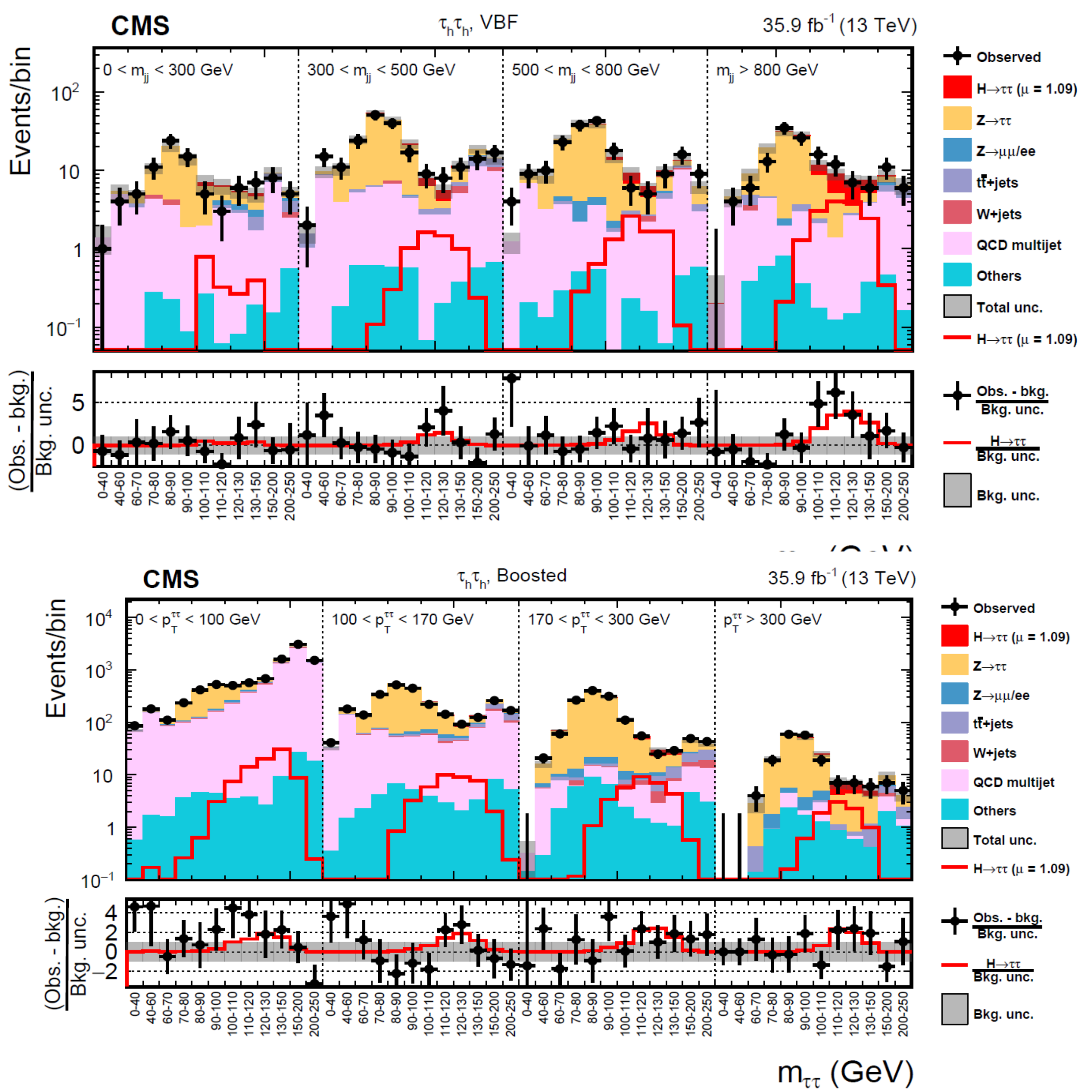
Higgs boson at 13 TeV

H → ττ, reasonable branching fraction and mass resolution

direct measurement of the Yukawa coupling !

hadronic τ decays must have one or three tracks, charge of three tracks must be ±1
isolation criteria are applied
challenge: discrimination from slim hadronic jets, BDT used, p_T dependend

used ττ decays: $(e\tau_h)$, $(\mu\tau_h)$, $(e\mu)$, $(\tau_h\tau_h)$



event categorisation: zero jet, VBF, boosted
background treatment

Z→ ττ: estimated with simulation, corrrected using Z → μμ control region

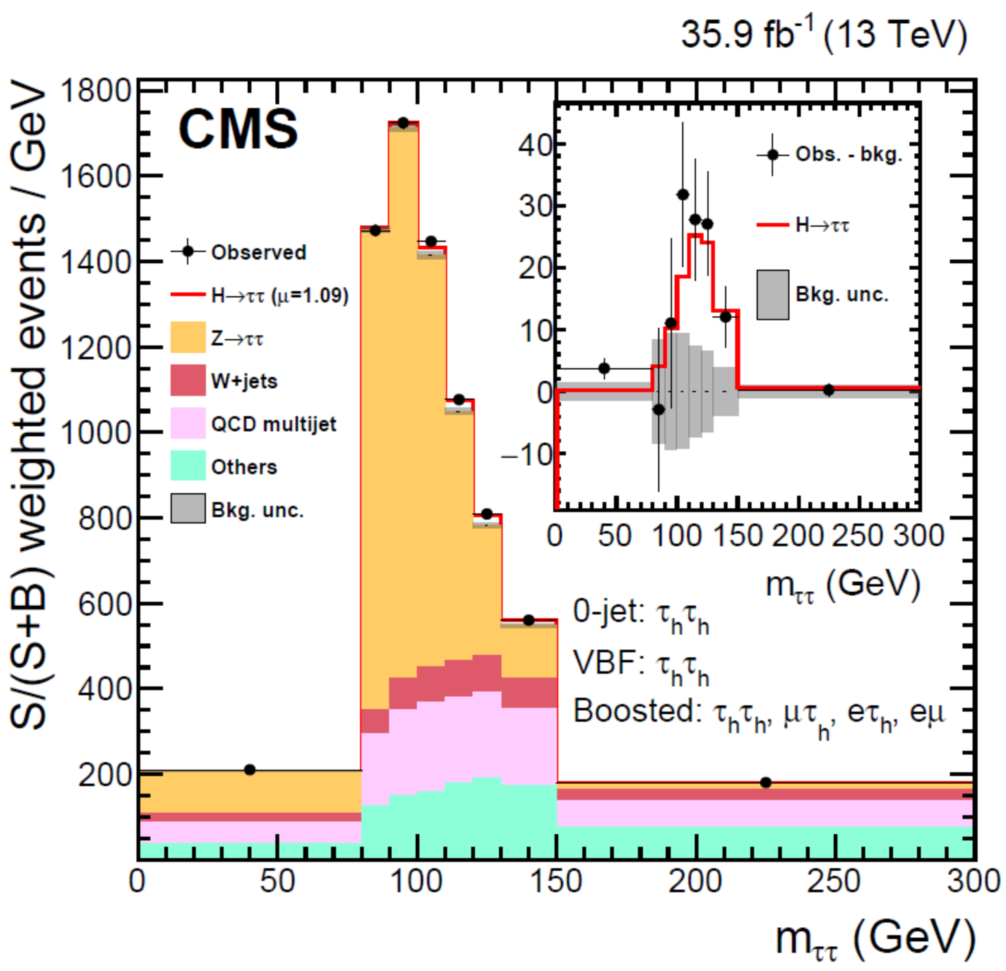
tt : estimated from simulation, dedicated side-band region to control normalisation and t- quark p_T distribution

W+ jets : shape from MC, control samples used for adjustment

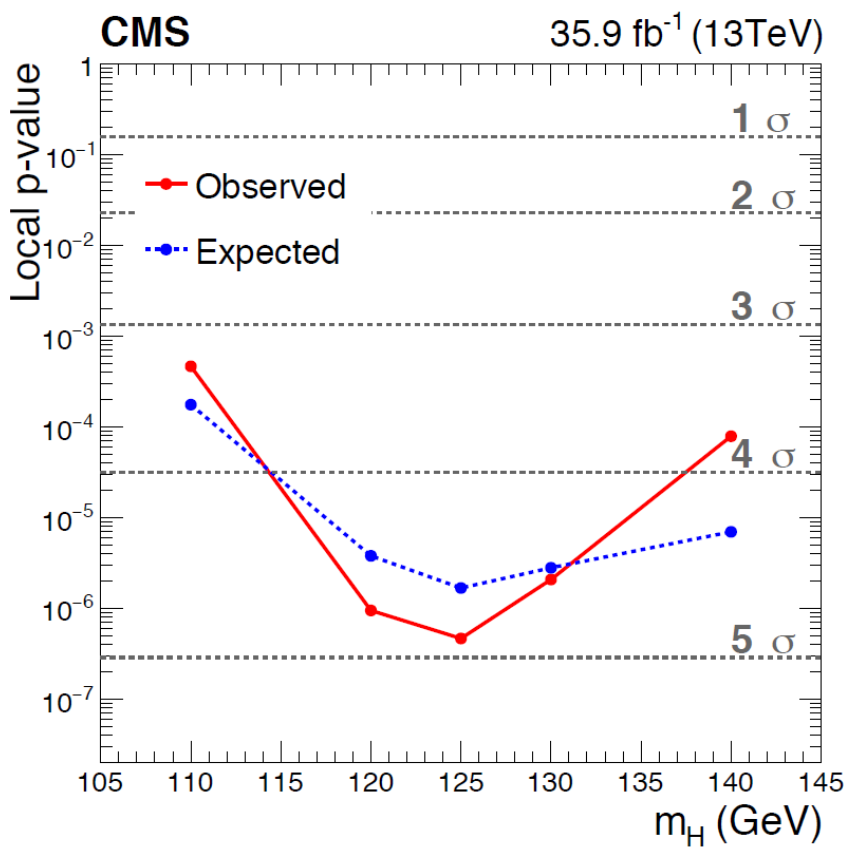
multi-jet production: fully data driven using control samples with same-sign loosely identified leptons

H → ττ

the signal strength is obtained from a simultaneous for of 2D distributions in all categories and final states, including the contol regions of tt, W+jets and multi-jet production.



events weighted with S/(S+B) as a function of the di-τ mass



local p-value as a function of the mass hypothesis of the Higgs boson

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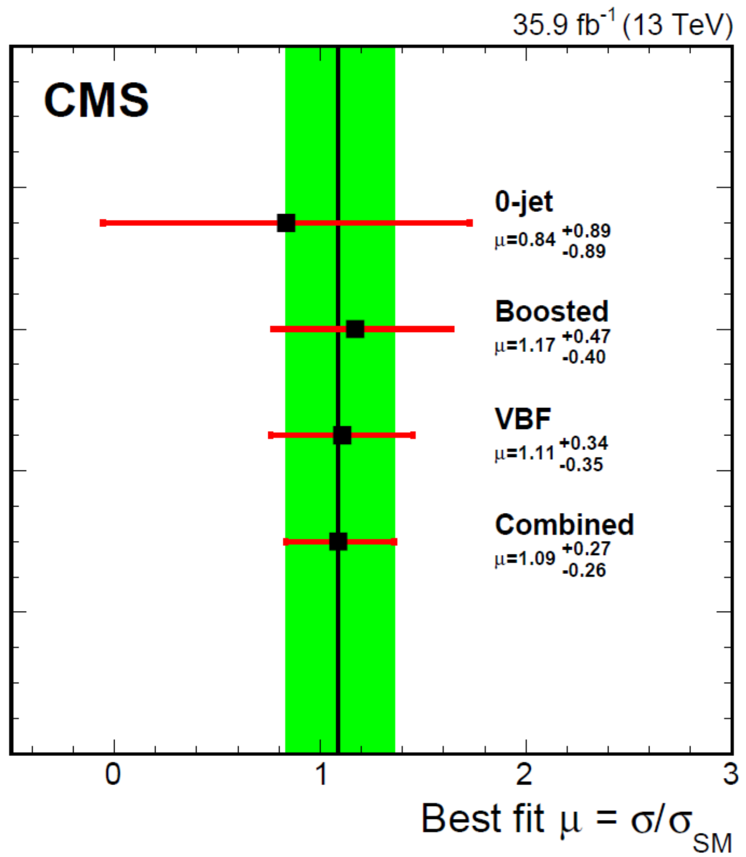
$H \rightarrow \tau\tau$

observed significance: σ = 4.9 s.d.
expected σ = 4.7 s.d.

signal strength: μ = 1.09 ± 0.26.



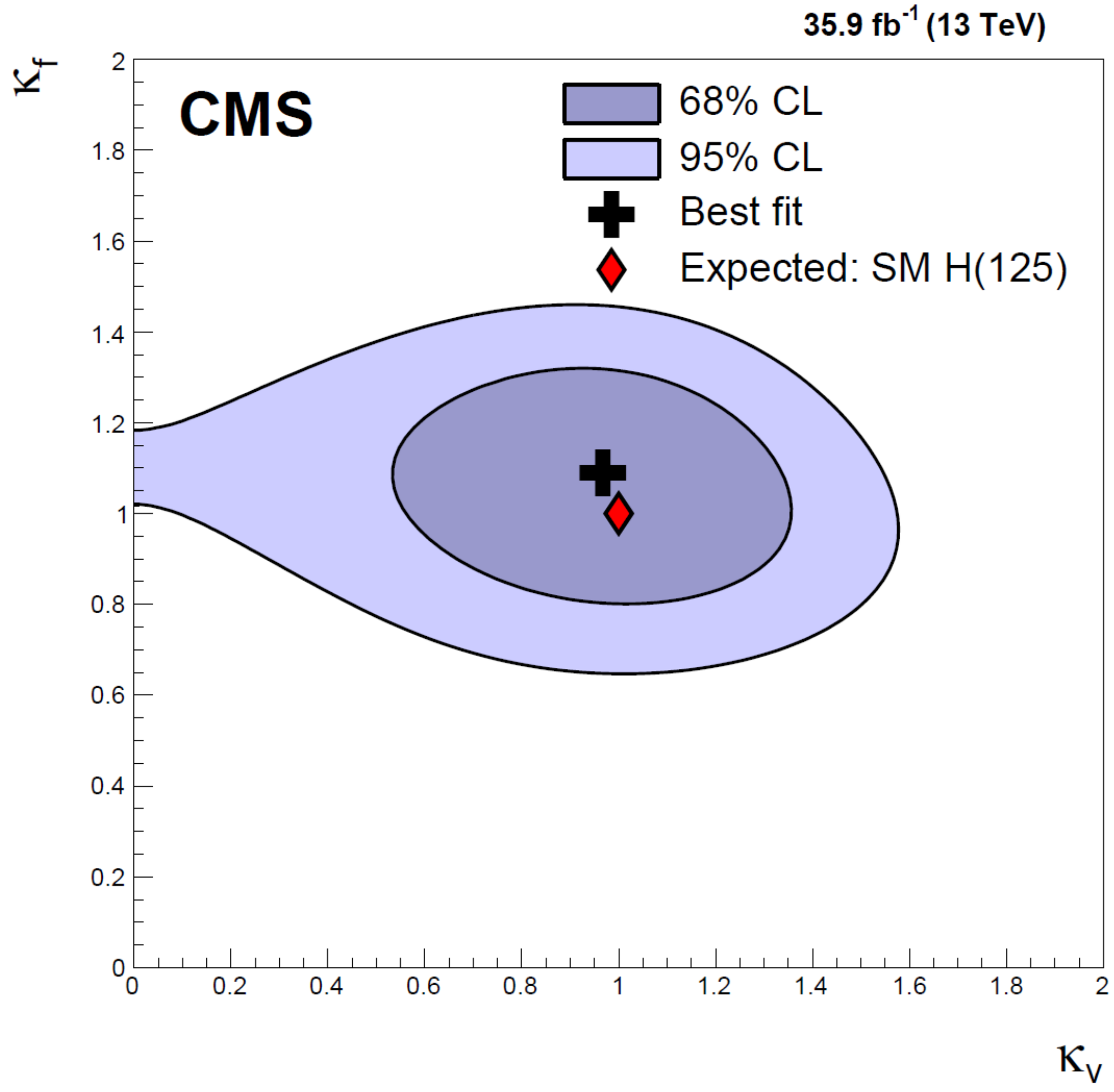
including also the published results at 7 and 8 TeV

μ = 0.98 ± 0.18.

Observed and expected significance:

. σ = 5.9 s.d.

fit of the relative couplings to vector bosons and fermions



Higgs boson at 13 TeV

H → ττ

supplemented analysis. VH (V→ leptons)
e.g.
Z→ ee, μμ, H → $\tau_e\tau_h$, $\tau_\mu\tau_h$, $\tau_h\tau_h$, $\tau_e\tau_\mu$

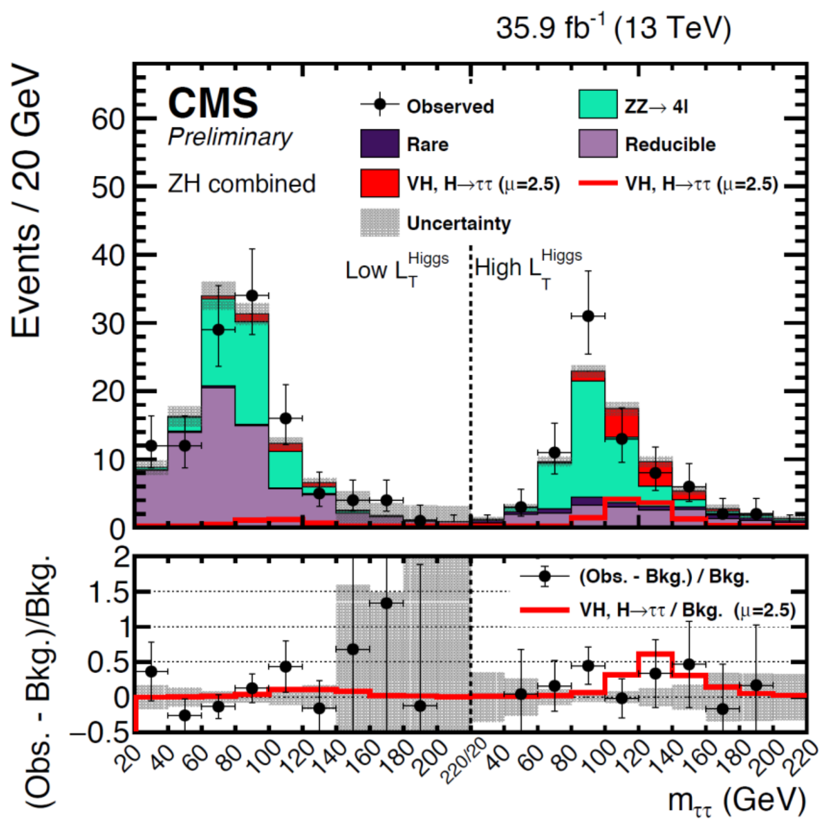
In addition WH

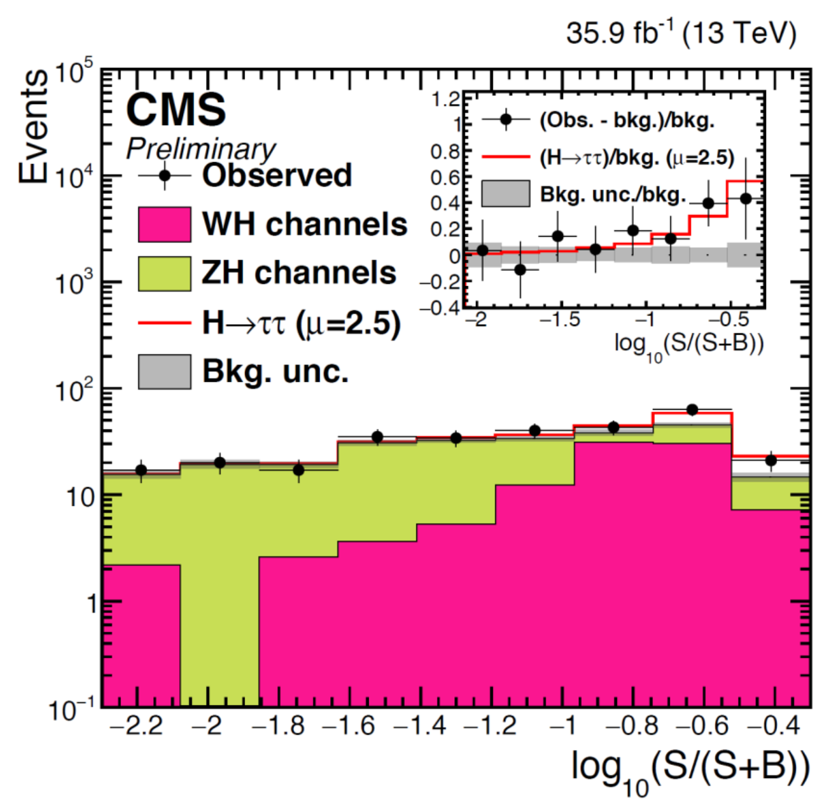
signal strength

$\mu = 2.5 \pm 1.4$

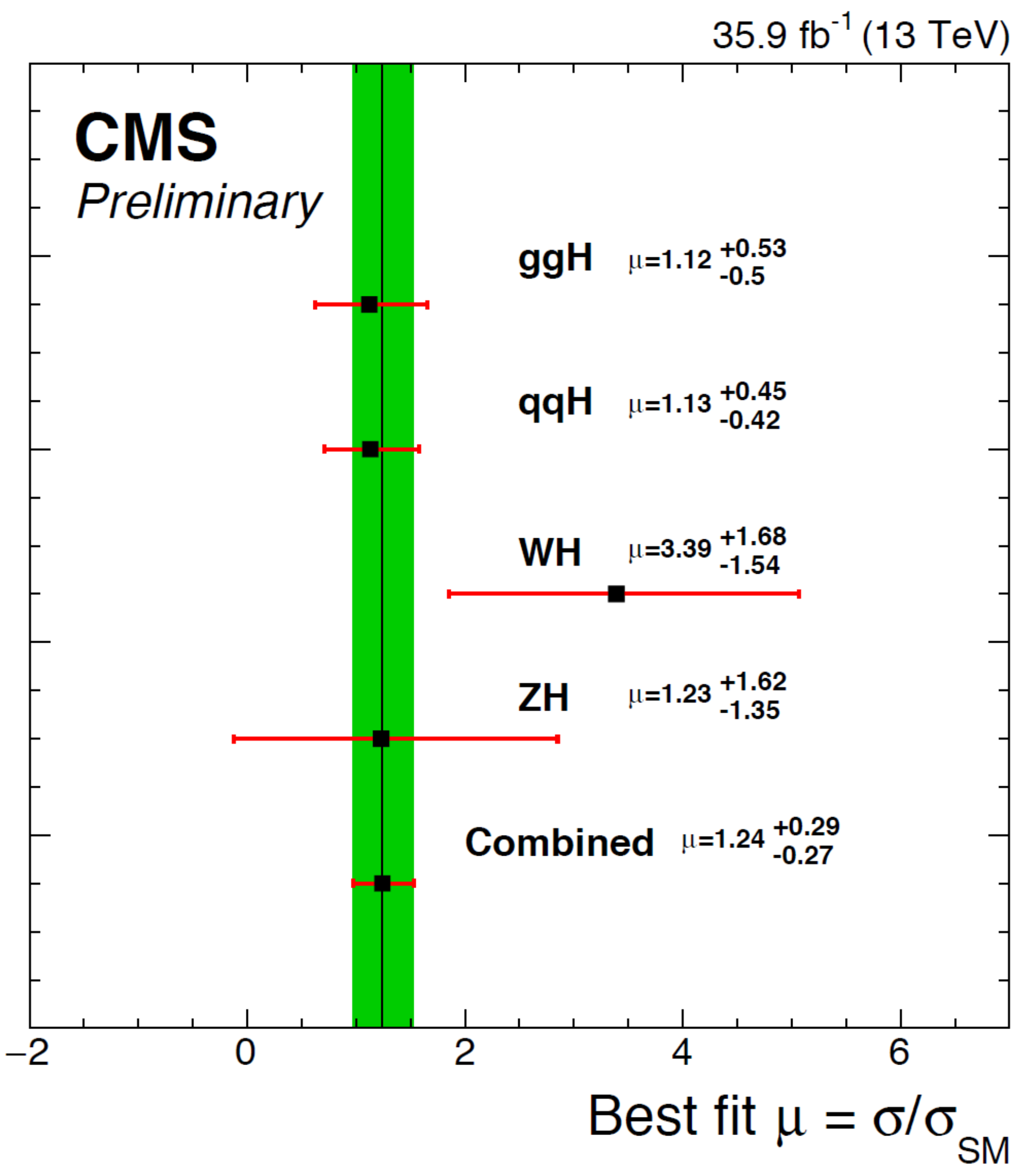
Observed and expected significance:

. σ = 2.3 (1.0) s.d.

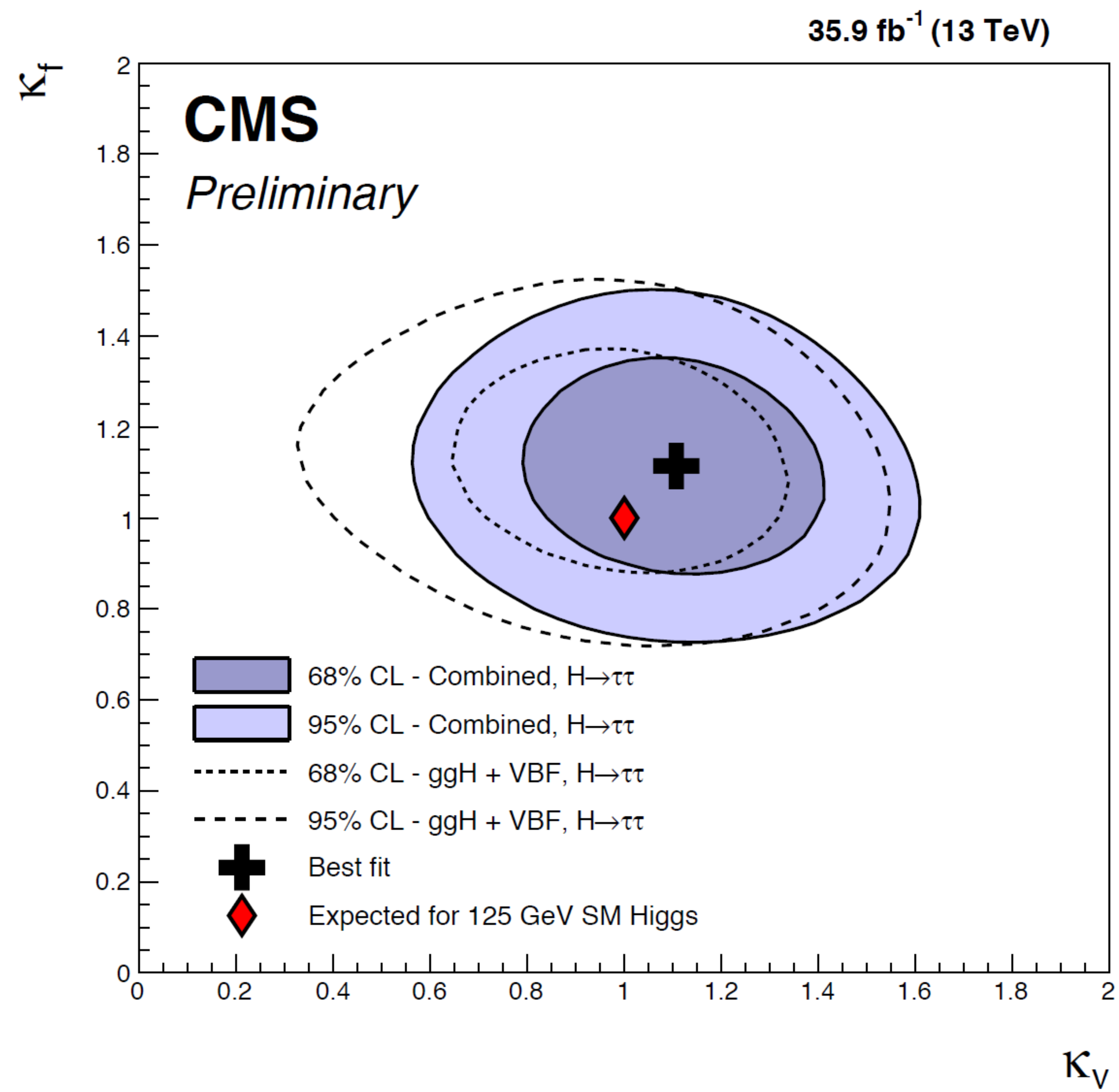




H → ττ



fit of the relative couplings to vector bosons and fermions



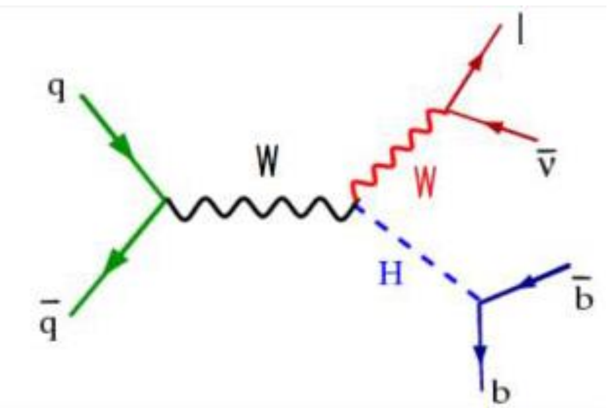
data at 13 TeV

$\mu = 1.24 \pm 0.28$.

Observed and expected significance:

. $\sigma = 5.5\ (4.8)$ s.d.

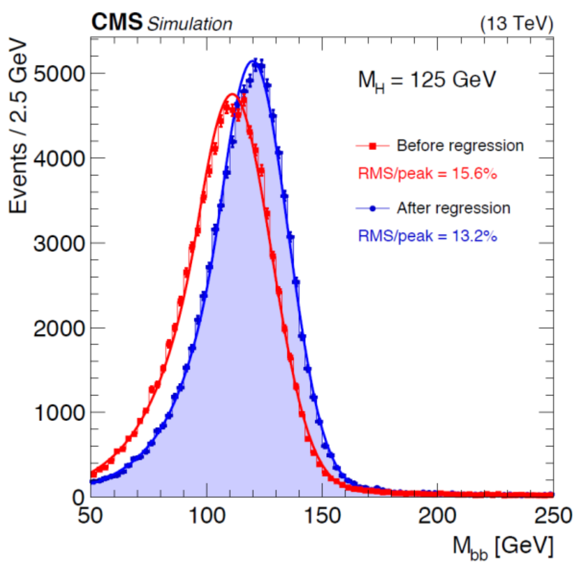
H → bb, large branching fraction, huge background



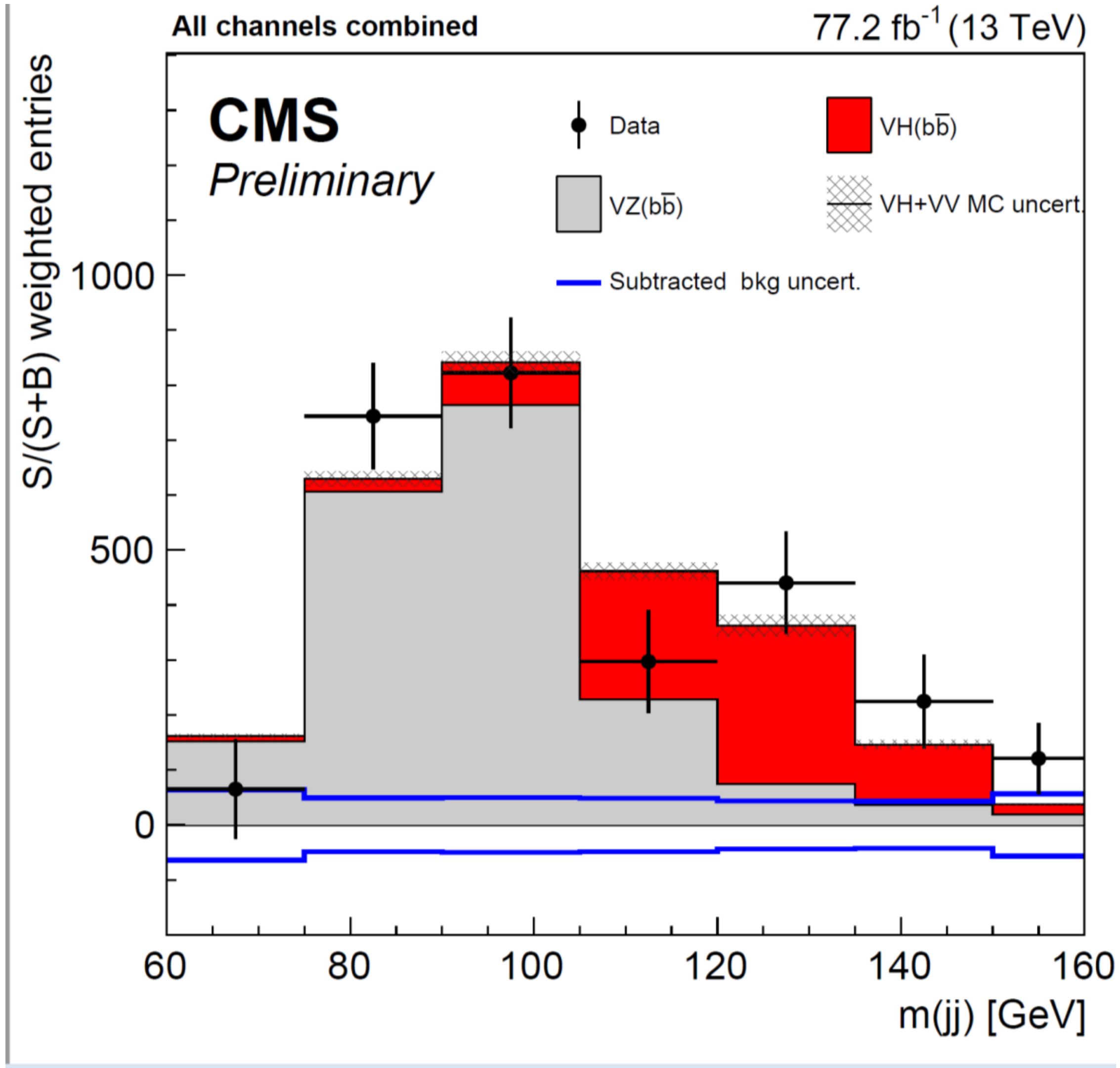
Lcoupling of the Higgs to down-type quark
challenge: tremendous QCD background

golden channel: Higgs-strahlung, VH

Topology: 2 b-tagged jets
- two oppositely charged leptons, (ZH)
- one lepton, missing p_T (WH)
- missing p_T (ZH)



regression technique to improve the bb mass resolution



combination of all production mechanisms

$$\mu = 1.04^{+0.20}_{-0.19}$$

(5.6 st. d. observed, 5.5 st.d. expected)

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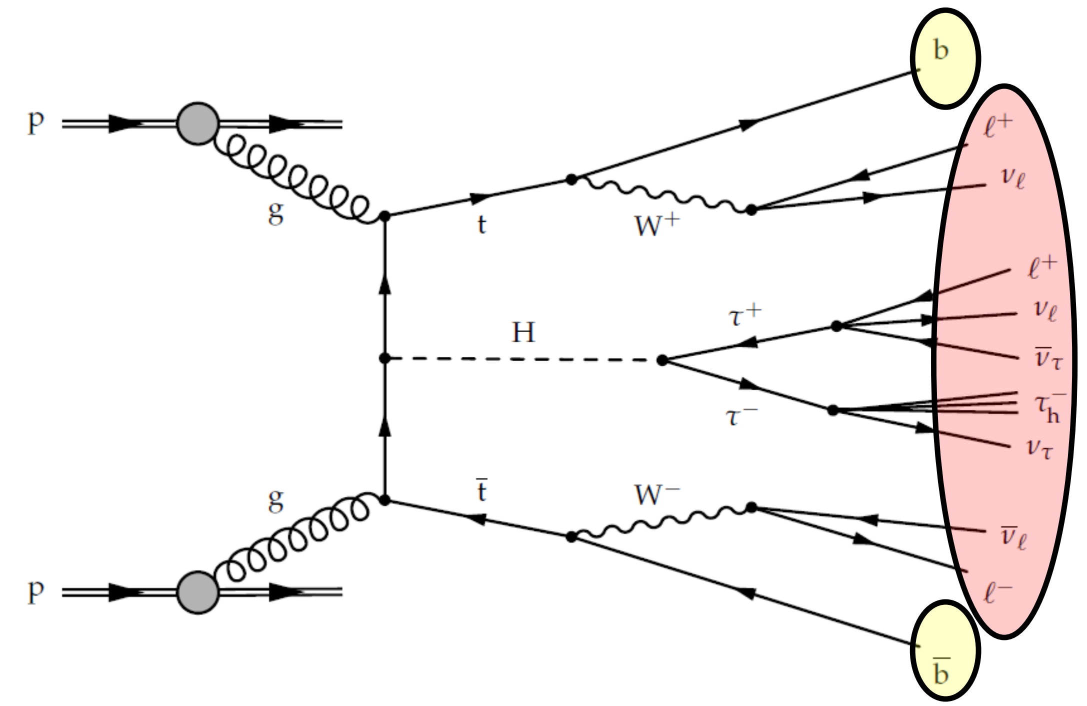
t- h associated production



t-h coupling is expected to be the largest in the SM

Search is performed in multi-lepton final states, comprising
- H → WW
- H → ZZ
- H → ττ

produced together with b-quark jets

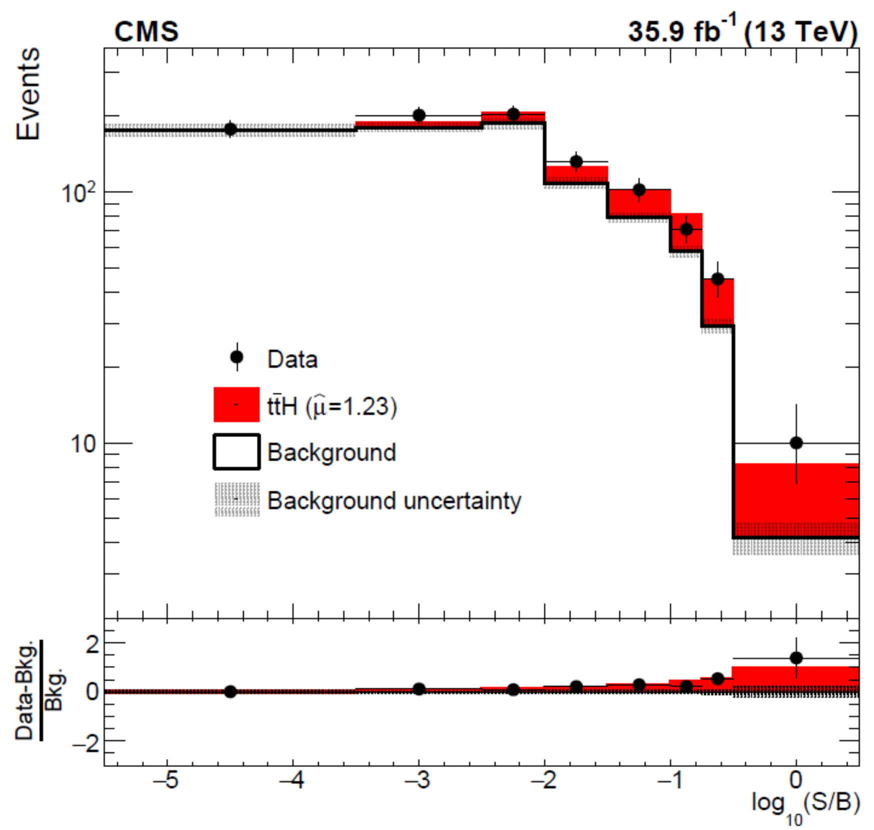
leptons are identified as e, μ or τ_h

six event categories, containing three leptons of different flavour composition or four (e,μ)

main backgrounds: ttW, ttZ and WZ+jets
shape taken from MC and normalised using control samples

BDT used for signal extraction

signal strength: μ = 1.23±0.45.



also studied other Higgs boson decay modes:
H → γγ
H → bb
with slighly less expected significance

7 +8 + 13 TeV data combined:

$\mu = 1.26^{+0.32}_{-0.26}$ (5.2 σ observed, 4.2 σ expected)

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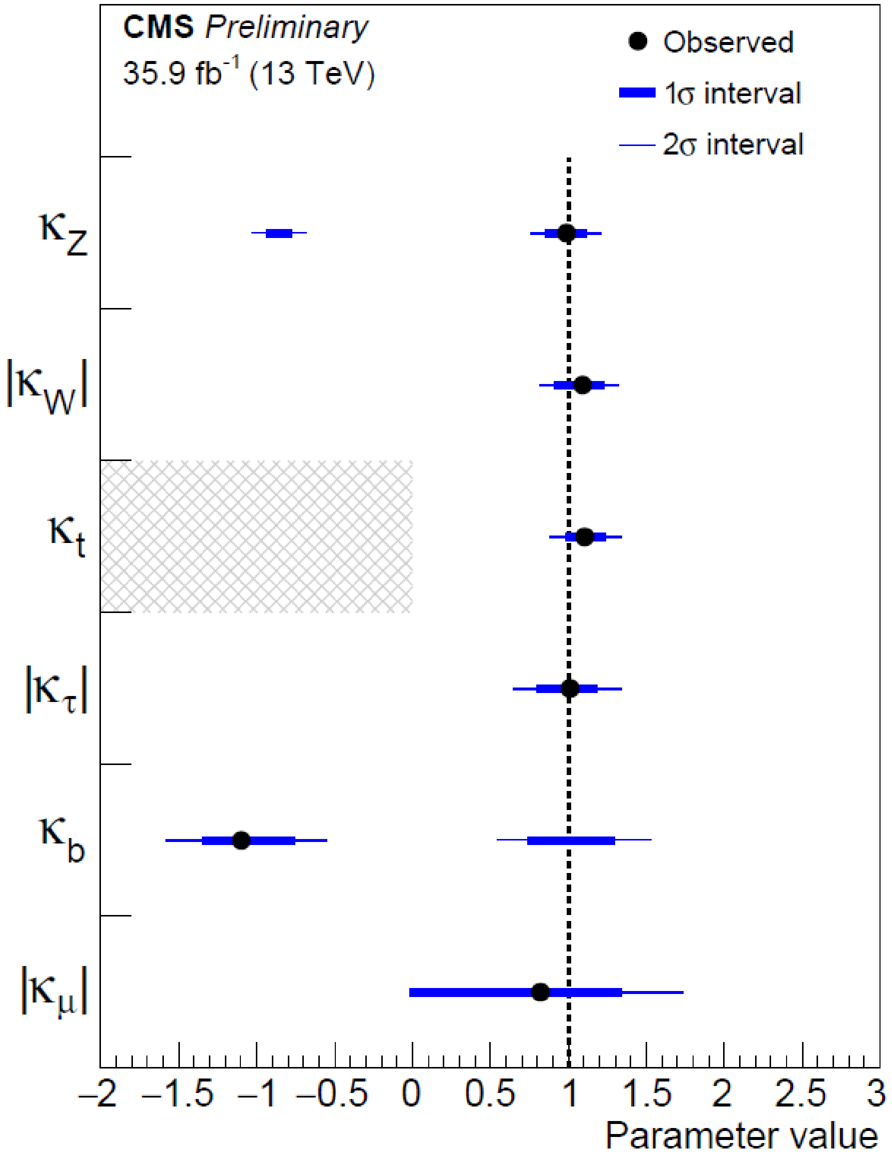
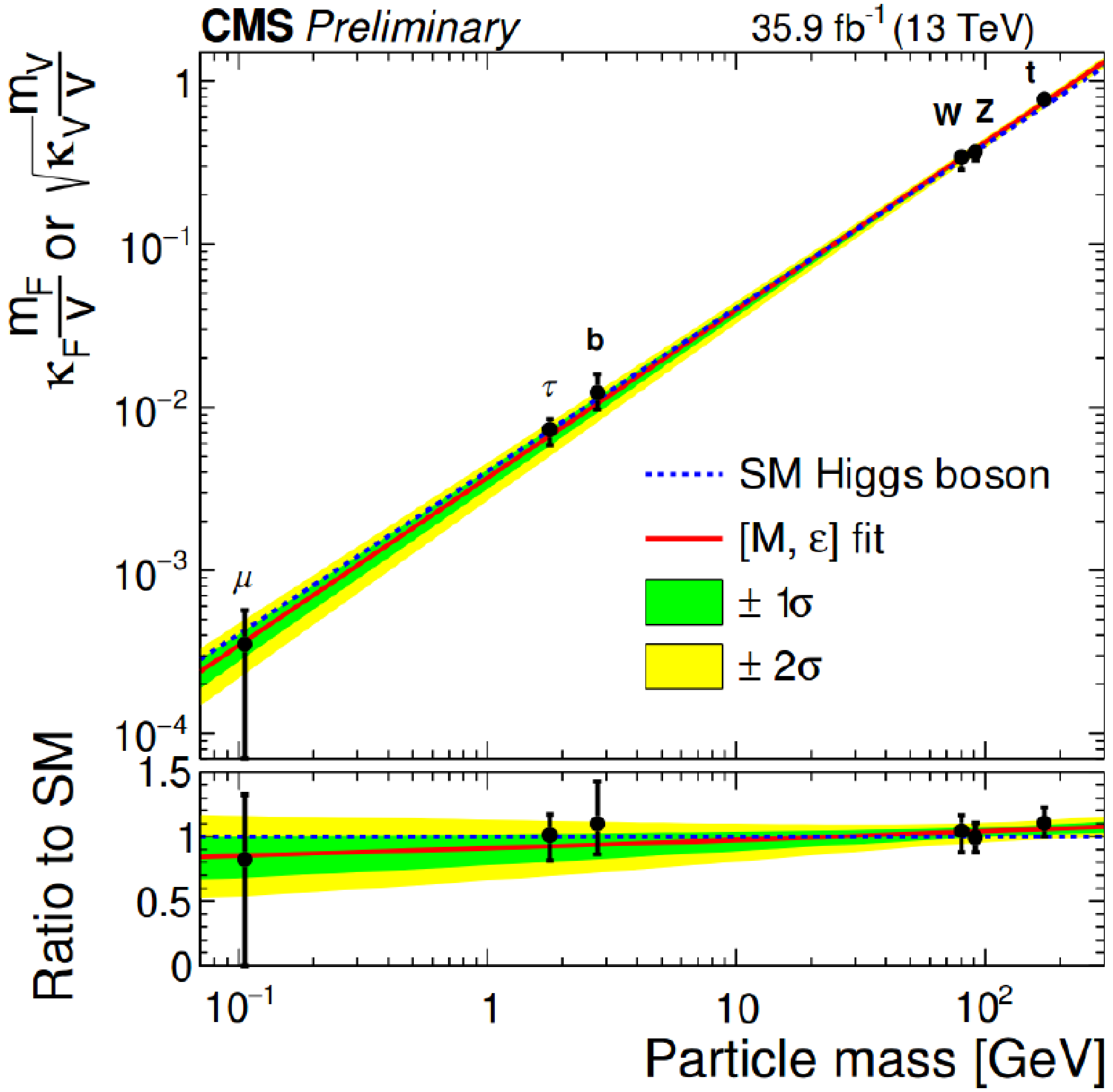
Higgs boson summary





- couplings to the vector bosons measured with 10-20% precision
- observation of the Yukawa coupling to tau leptons
- Observation of Yukawa couplings to b- and top-quarks, τ-leptons
- to be found: Higgs self coupling, to probe the Higgs potential

signal strength: $\mu = 1.17 \pm 0.10$

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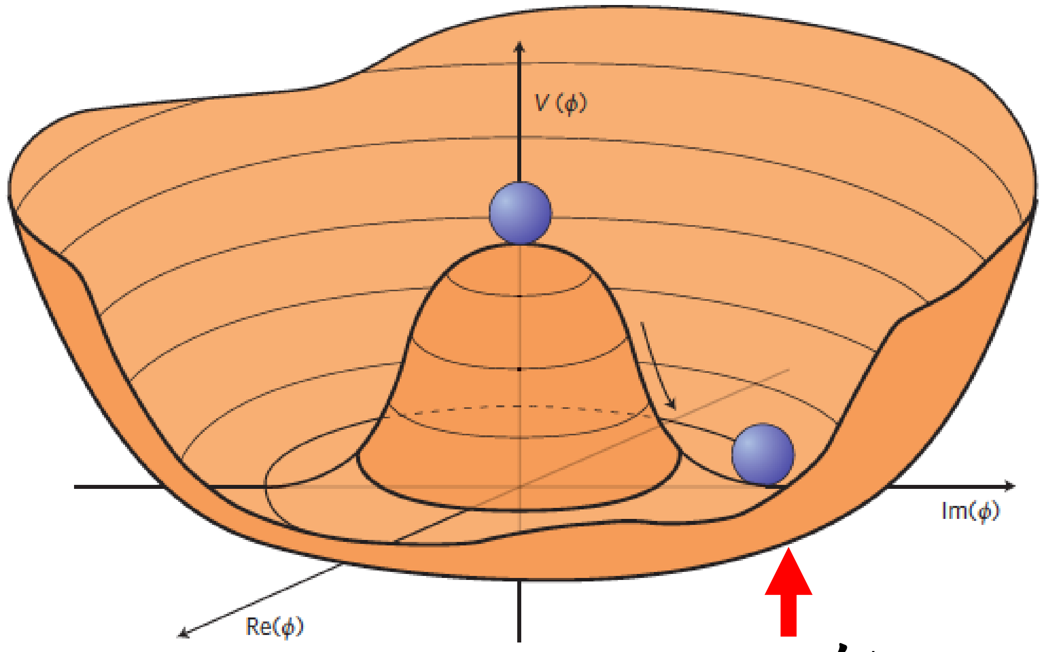
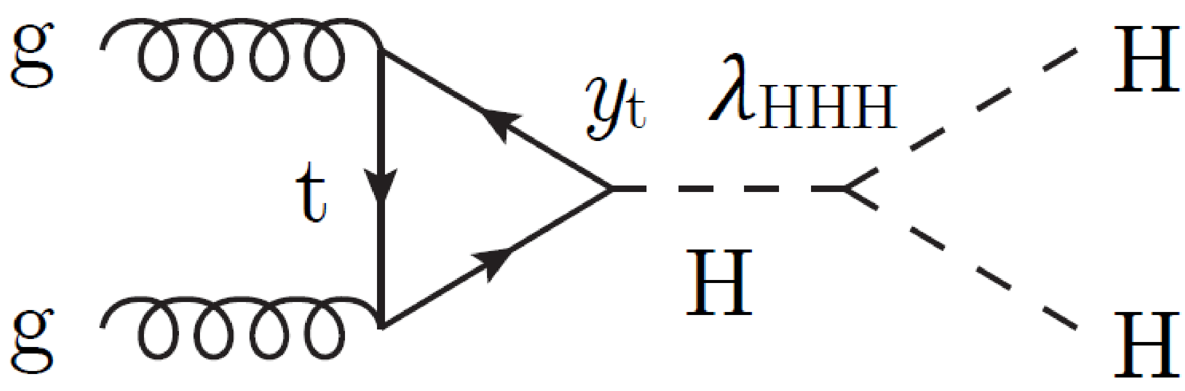
potential in the Higgs Lagrangian

$V(\Phi) = -\mu^2 \Phi\Phi^\dagger + \lambda \; [\Phi\Phi^\dagger]^2$



$m_H = (\sqrt{2\lambda})\, v$ and $v^2 = (\sqrt{2} G_F)^{-1}$

Higgs-boson self-coupling



$\lambda_{HHH} = \lambda \, v$

Question: are the two measurements of λ consisten?

Search for Higgs-boson pair production in pp collisions at 13 TeV (35.9 fb^{-1} 2016 data)

$p\,p \rightarrow H_1 H_2\; X$

Final states: $H_1 \rightarrow bb$ $\quad$ $H_2 \rightarrow bb, \gamma\gamma, \tau^+\tau^-, W^+W^-, ZZ,$

Predicted cross section: σ_{HH} = 33.53 ± (8%) (i.e. with the integrated luminosity given above we have about 1000 events in the detector, but efficiency and acceptance are small),

$H_1H_2 \rightarrow bb\gamma\gamma$: BR = 0.26 %,
two b-tagged jets, two isolated photons, small background. fit performed to m(bb) vs, m($\gamma\gamma$)

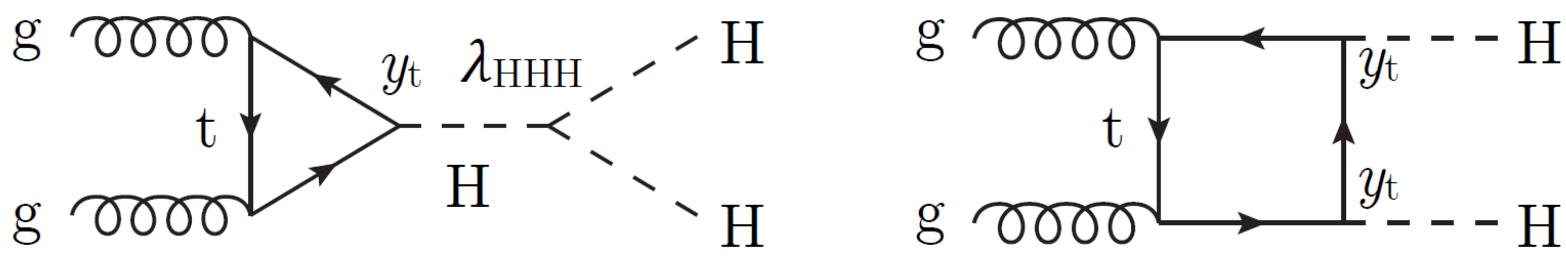
$H_1H_2 \rightarrow bbbb$: four b-tagged jets, BR = 33.6 %, but bery large QCD background

$H_1H_2 \rightarrow bb\tau\tau$: two b-tagged jets, two τ-leptons, BR = 7.3 %, low background

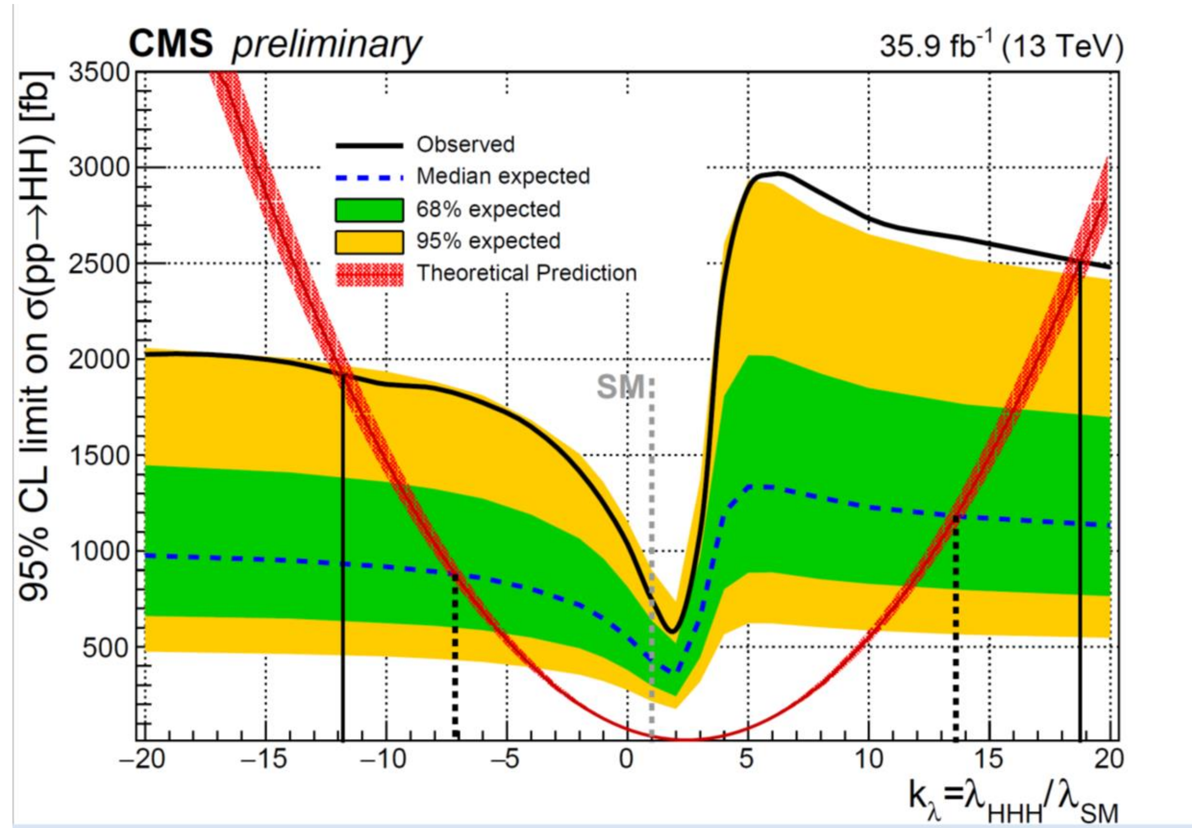
$H_1H_2 \rightarrow bbVV$: two b-tagged jets, two isolated leptons and missing momentum, BR = 2.7 %

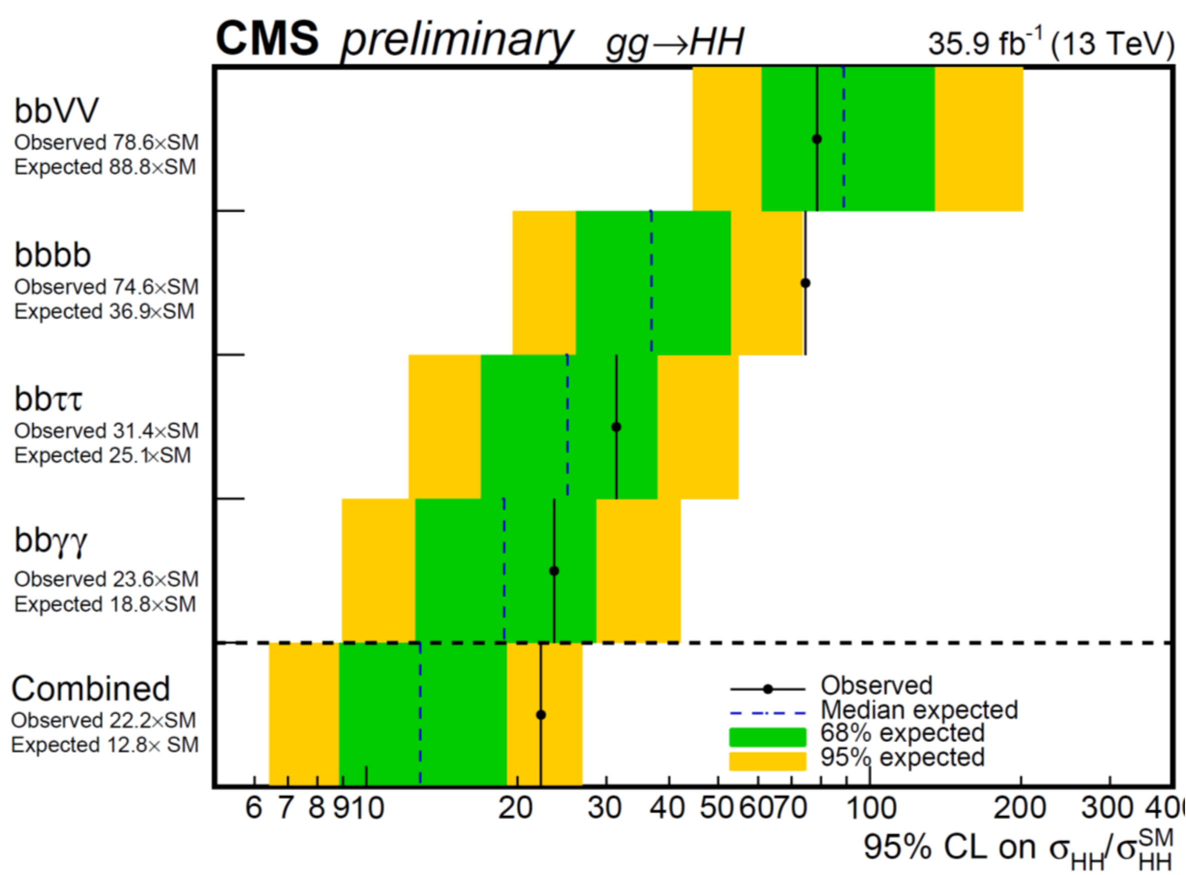
Triple Higgs-boson coupling

predicted cross section (SM)
two Feynman diagrams,
also interference !



$k_t = y_t / y_{sm} = 1$





$k_\lambda = \lambda_{HHH}/\lambda_{SM}$

$$-11.8 < k_\lambda < 18.8 \ (-7.1 < k_\lambda < 13.6) \text{ at the 95\% CL}$$

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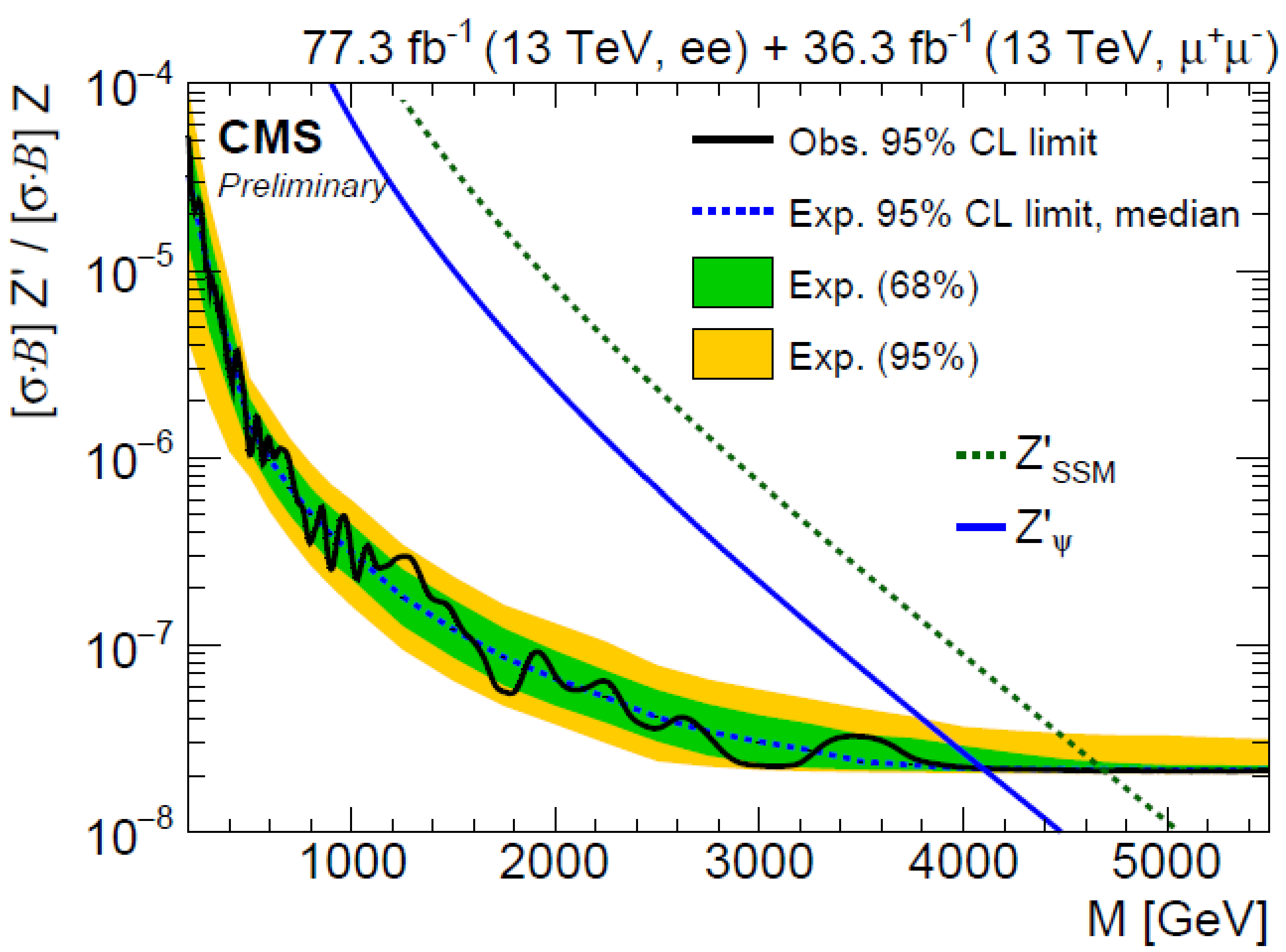
Z‘ → e^+e^-

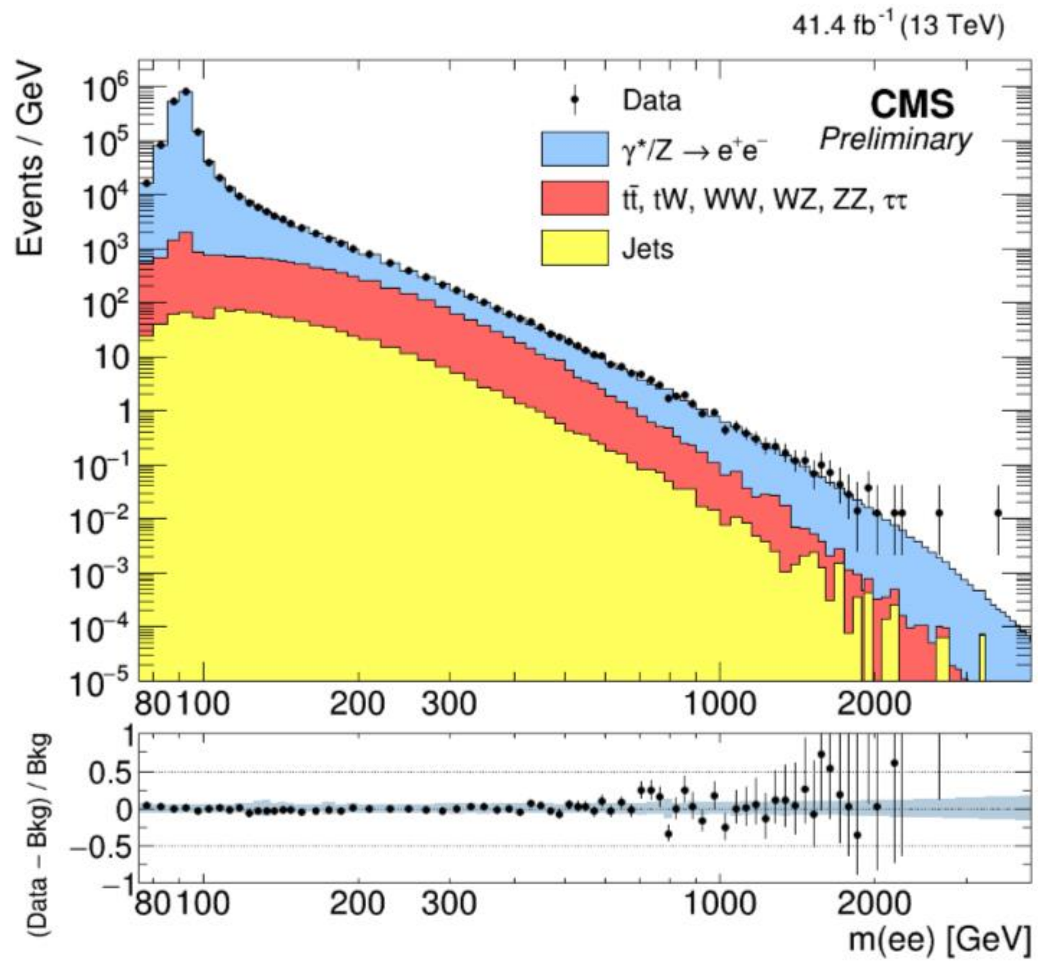
two isolated elecrons, opposite charge, in the barrel or barrel-end-cup e.m. calorimeter

Motivated by U(1) extension of the SM or GUT inspired models based on E6 gauge group

limit on the mass (e^+e^- and $\mu^+\mu^-$ combined)

$m_{Z'} >$ 4.7 TeV

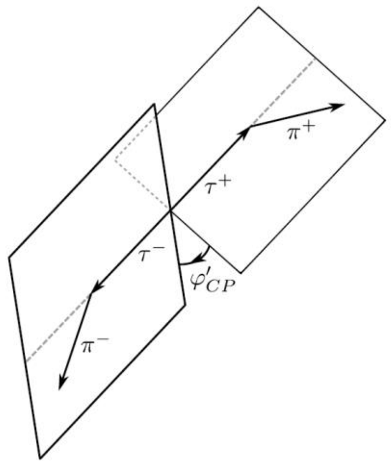


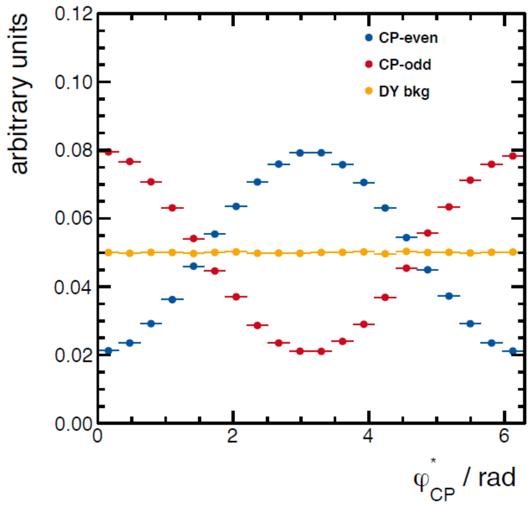


- search for CP mixing in Higgs boson production and decay

$$-\frac{m_f}{v}(\mathrm{a_f}\bar{f}f + \mathrm{b_f}\bar{f}i\gamma_5 f)\,h = -\frac{m_f}{v}\kappa_\mathrm{f}(\cos\alpha_\mathrm{f}\bar{f}f + \sin\alpha_\mathrm{f}\bar{f}i\gamma_5 f)\,h$$

method1: measurment of the angle between the two decay planes of the tau leptons in h → $\tau^+\tau^-$





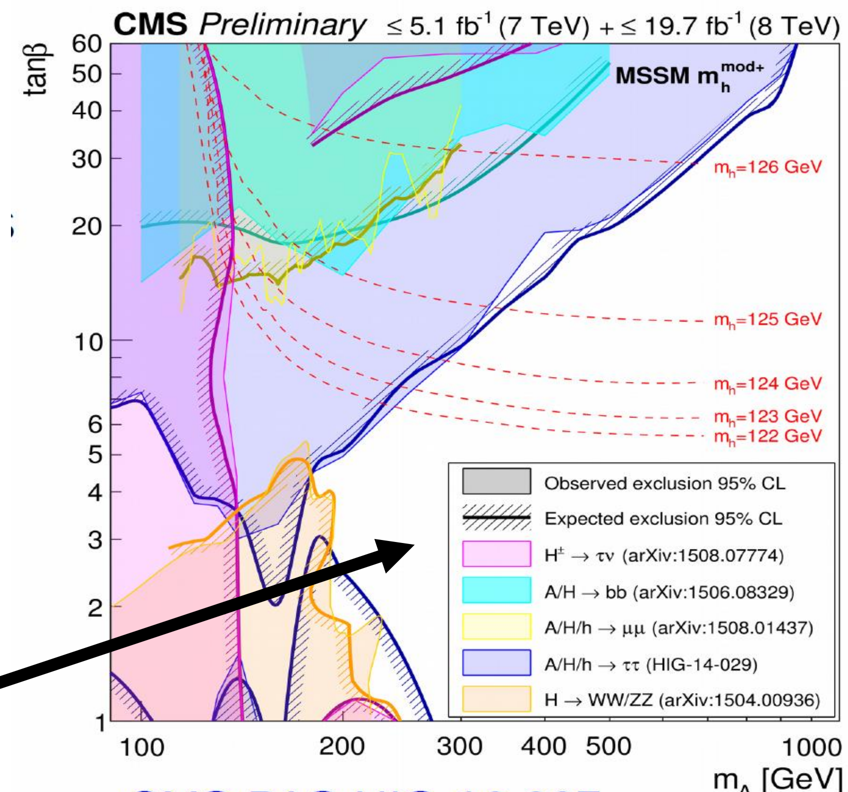
$h \to \tau^-\tau^+ \to \pi^-\pi^+ + 2\nu$

method 2: measurement of the difference in the azimuthal angle in Higgs boson production with two associated jets.

$$\Delta\phi_{jj} = \phi_{y>0} - \phi_{y<0}$$

- search for additional Higgs bosons at higer mass, as predicted in extensions of the SM, e.g. in H → W^+W^- and H → $\tau^+\tau^-$

  . explore low tan β and higher mass



CMS-PAS-HIG-16-007

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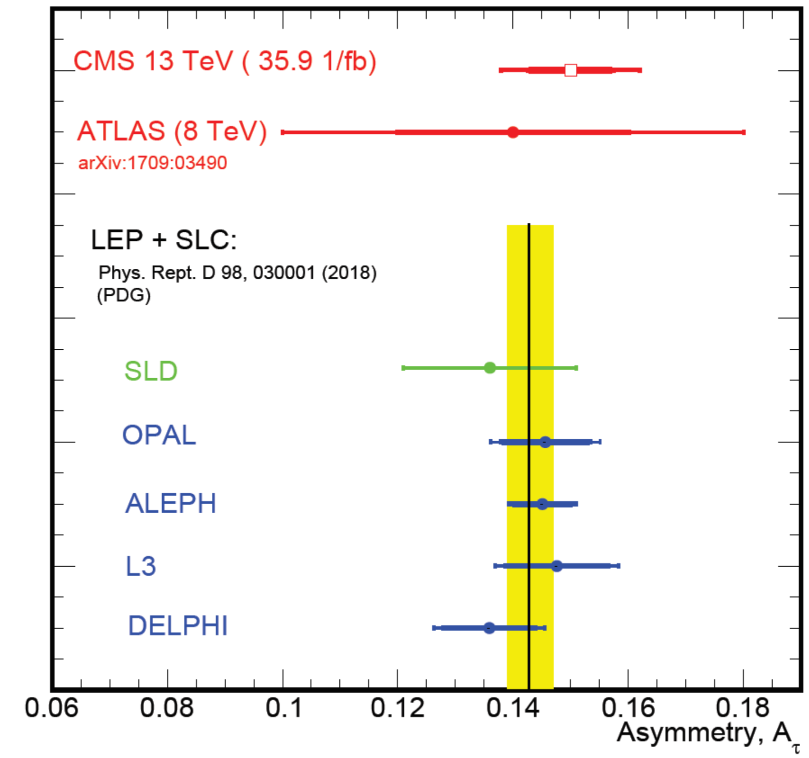
- Measurement of the τ-lepton polarisation in Z→ $\tau^+\tau^-$

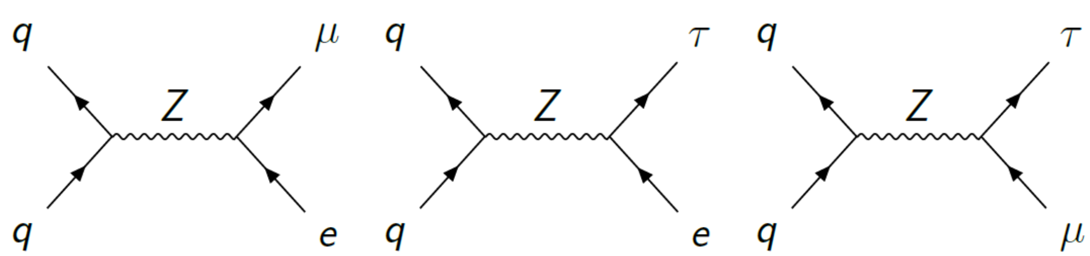
$$\langle P_\tau \rangle = \frac{N(\tau_R^- \tau_L^+) - N(\tau_L^- \tau_R^+)}{N(\tau_R^- \tau_L^+) + N(\tau_L^- \tau_R^+)} \simeq -2(1 - 4\sin^2\theta_{eff})$$

  - precision measurement of the weak mixing angle solely from τ-lepton couplings
  - statistics larger than at LEP
  - challenge: reconstruction of τ-lepton kinematics

CMS expeced precision



- Search for lepton flavour violation in Z decays



Best limits so far:

$$BR(Z \to e\mu) = 7.3 \cdot 10^{-7}$$
$$BR(Z \to e\tau) = 9.8 \cdot 10^{-6}$$
$$BR(Z \to \mu\tau) = 1.2 \cdot 10^{-5}$$

  - number of Z bosons larger than at LEP
  - challenge: precise estimate of background processes

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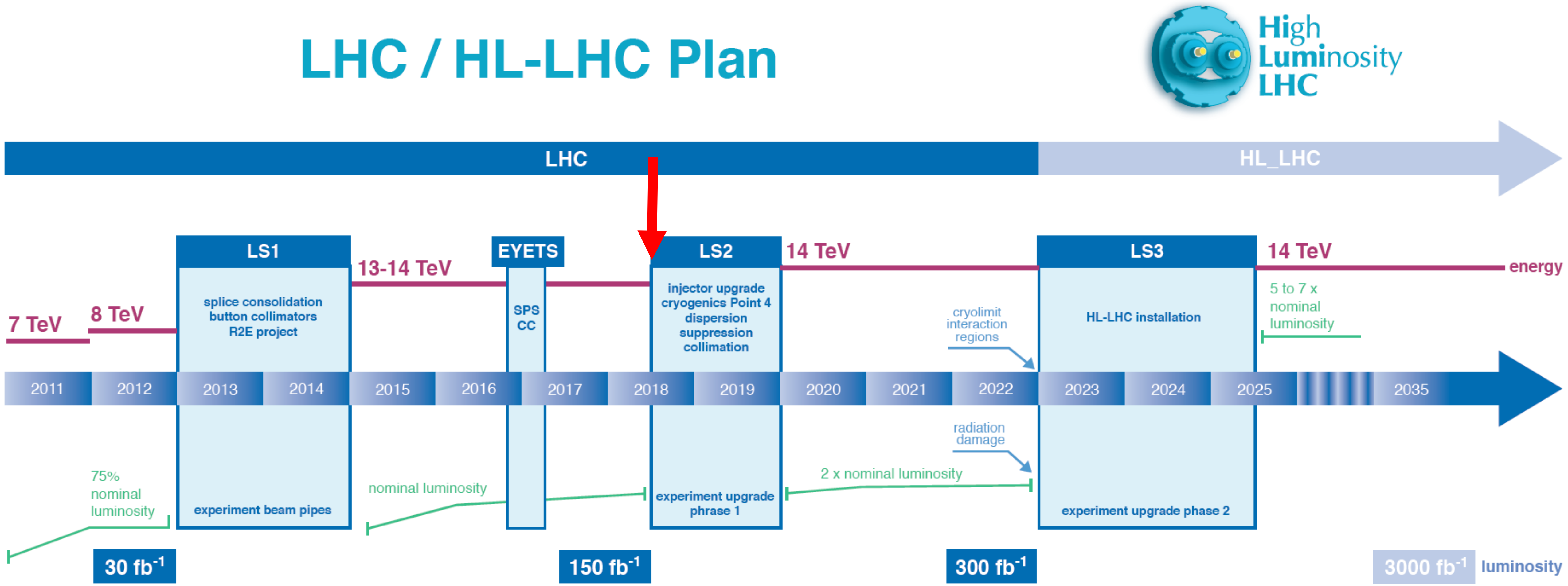

Major CMS upgrades for the HL LHC phase

- new (again full silicon) tracker with larger coverage and higher granularity and L1 trigger capability
- new calorimeter endcaps, fine-grained silicon-tungsten sandwhich electromagnetic calorimeter
- trigger and DAQ
- HCAL and muon
- luminometers

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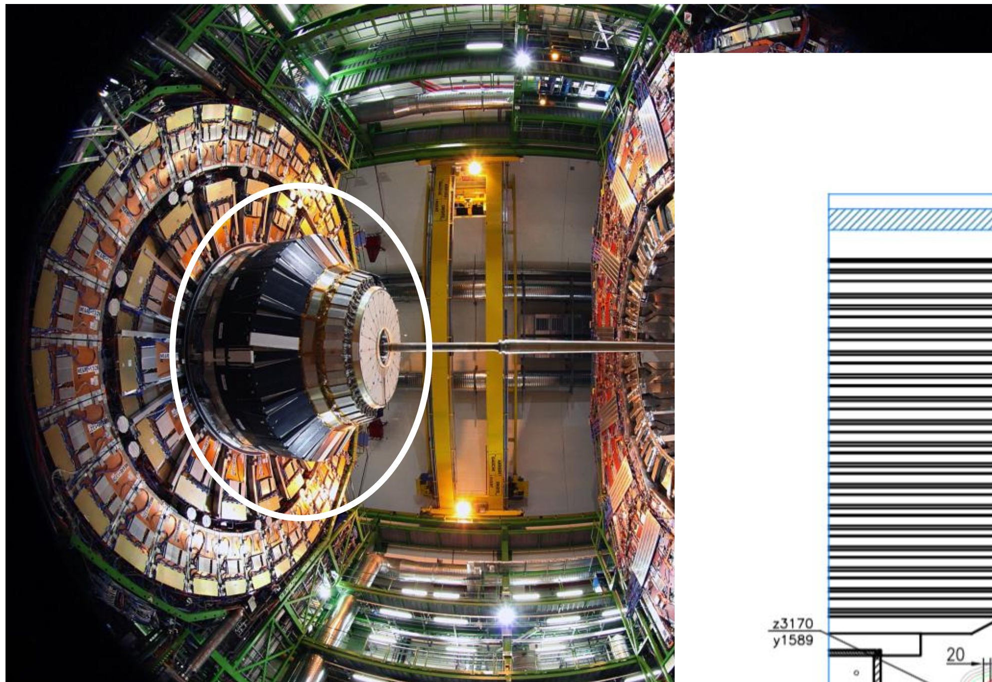
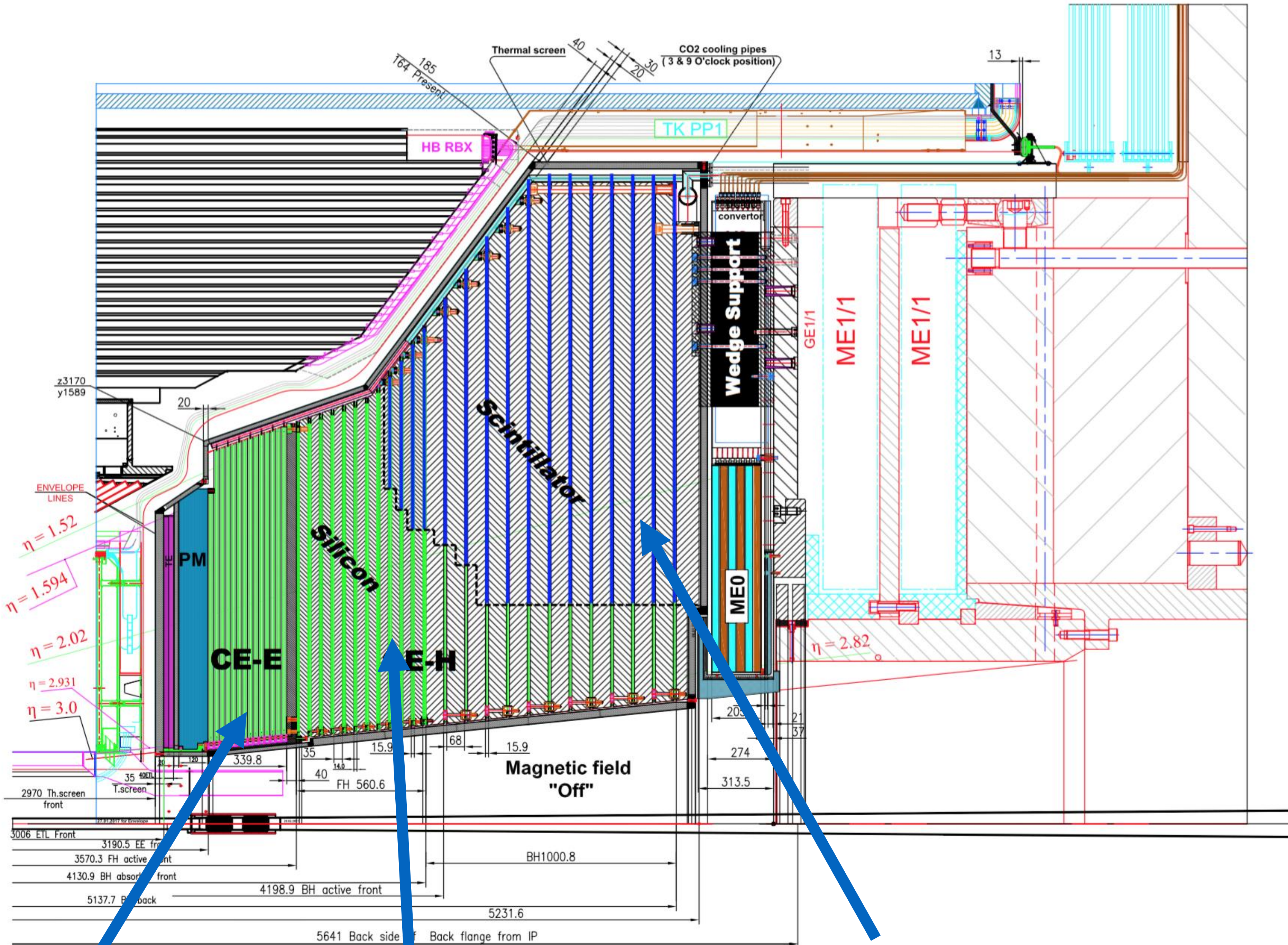


operation at -30^{0}C

Finely segmented Si sensors
~ cm^2 pads

scintillator tiles readout with Si PMs

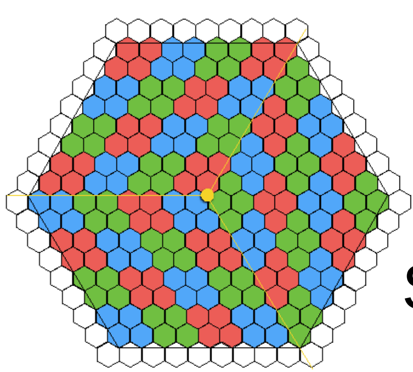
Inpired by the ILC TDR



26 X_0 SiW

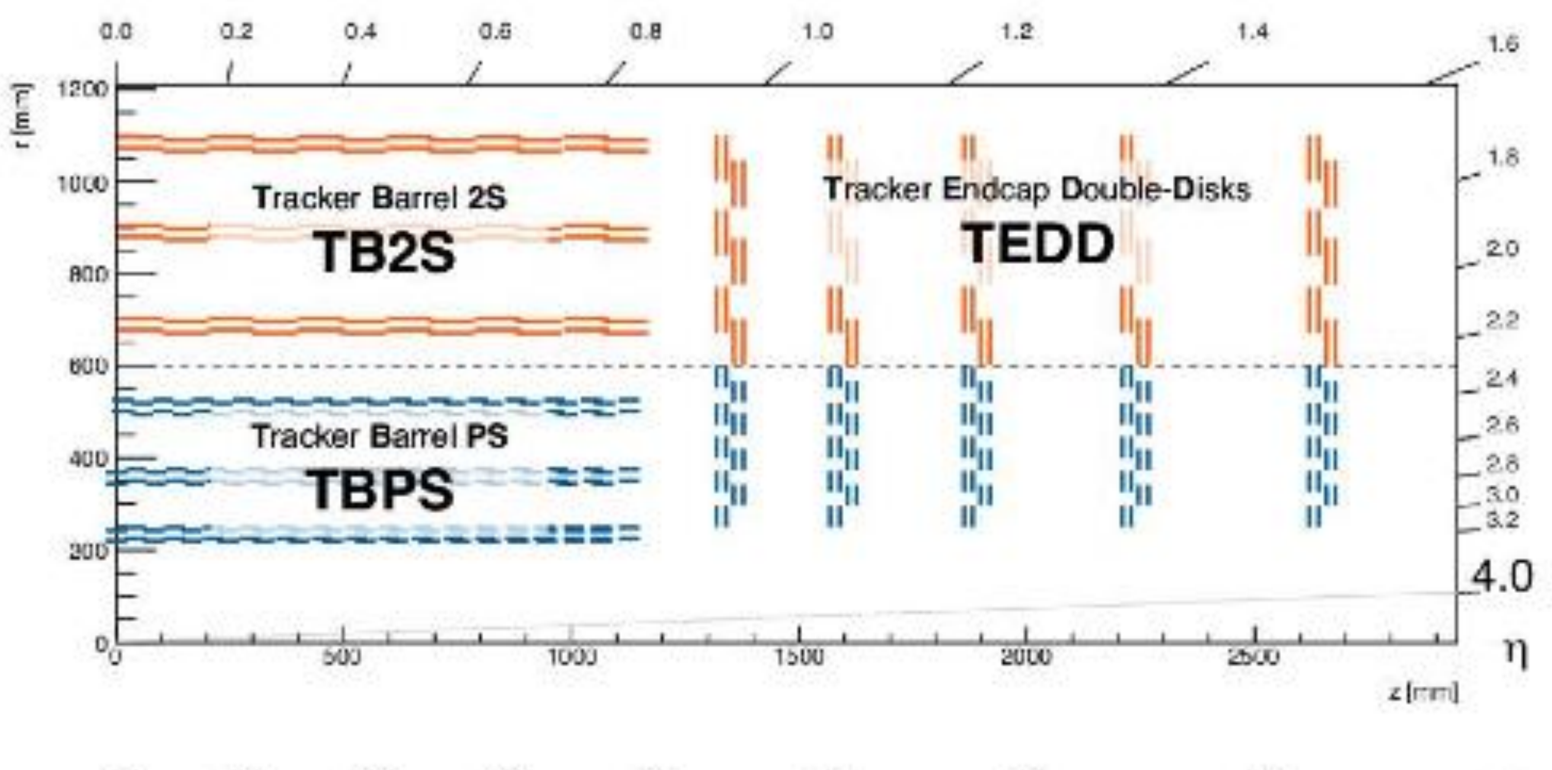
3.6 λ Si/brass

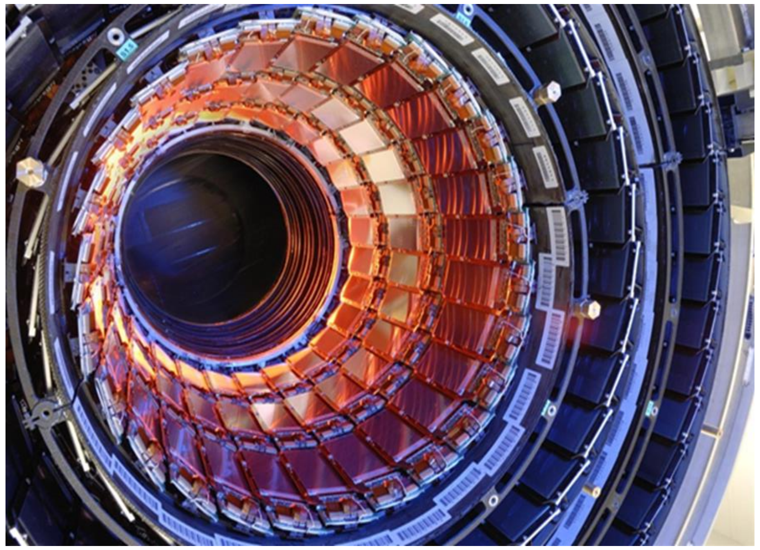
5 λ scintillator/brass



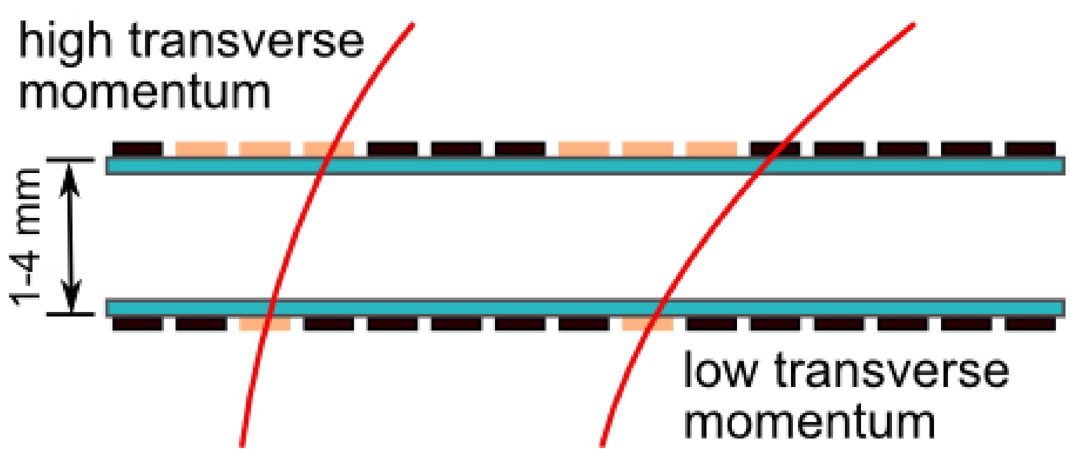
Silicon sensor tile

Upgrade tracker





- 6 barrel layers (**TBPS**, **TB2S**) and 5 end cap double disks (**TEDD**)
- pixelated modules at r < 60 cm (stacks of pixel and strip sensors - **PS**)
- stack of two strip sensors at r > 60 cm (**2S**)



- Modules with on-board p_t discrimination
- Tracker sends „stubs“ with 40 MHz
- „stubs“ used to form track(lets) → 100 kHz readout
- Two different module types **PS** and **2S**

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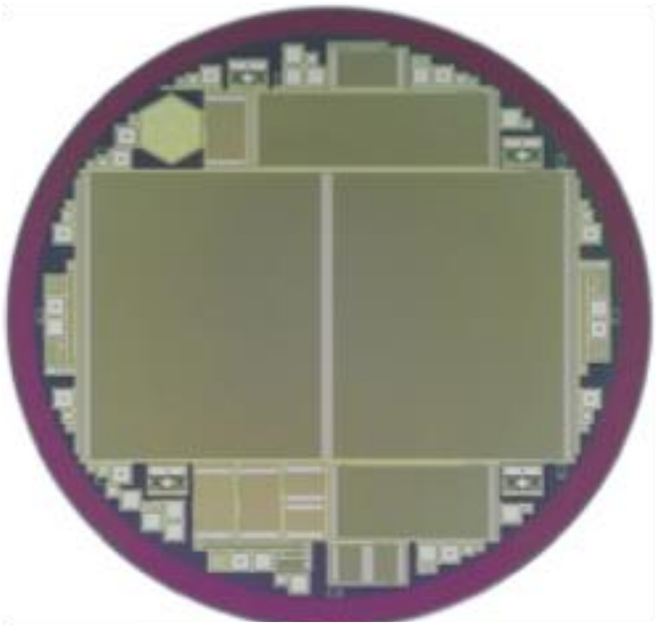
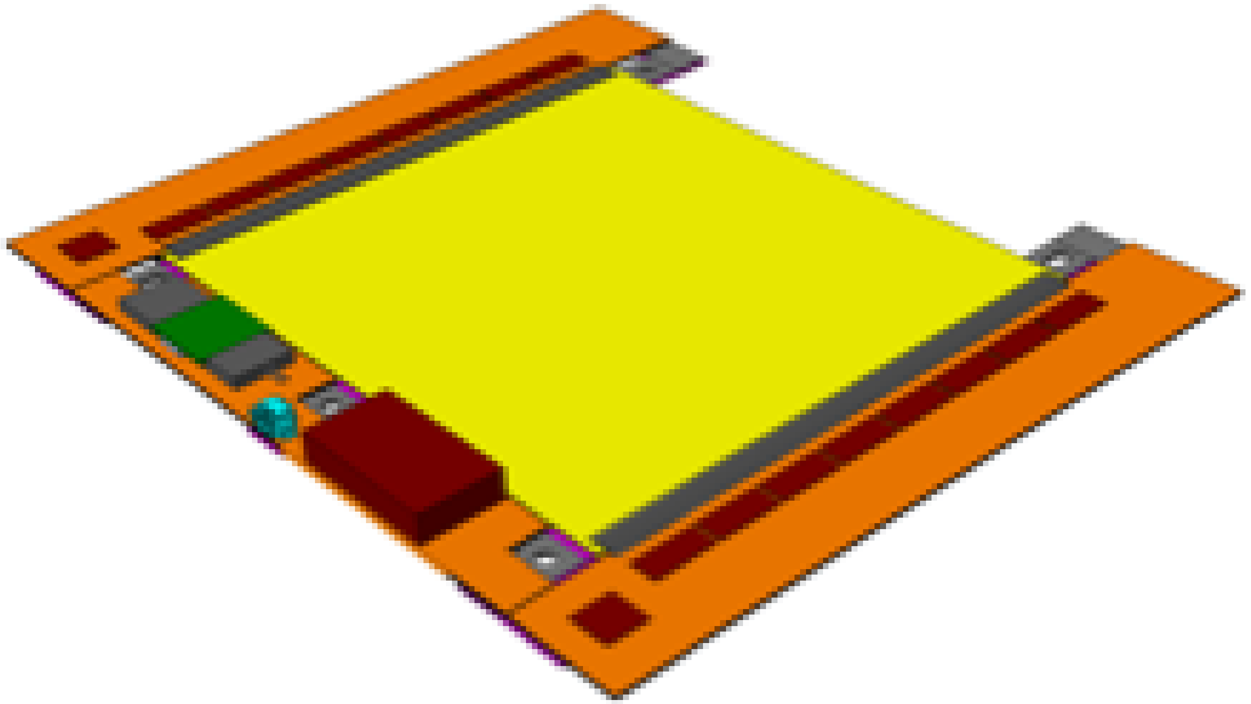


- - designed: Vienna
- - manufactured: Infineon
- - 8 inch p-substrate FZ wafers with 7 kΩ cm
- - 200 μm physical thickness
- - 25 wafers with p-stop and p-spray for strip isolation technique



2 Strip sensors

- produced on 6 inch wafer
- Strips: 5 cm x 90 μm
- Strips: 5 cm x 90 μm
- occupancy < 1%
- P=5.0W
- ~92cm^2 active area

15508 modules (218 m^2 active silicon)
47.8 million strips
218 million macro pixels

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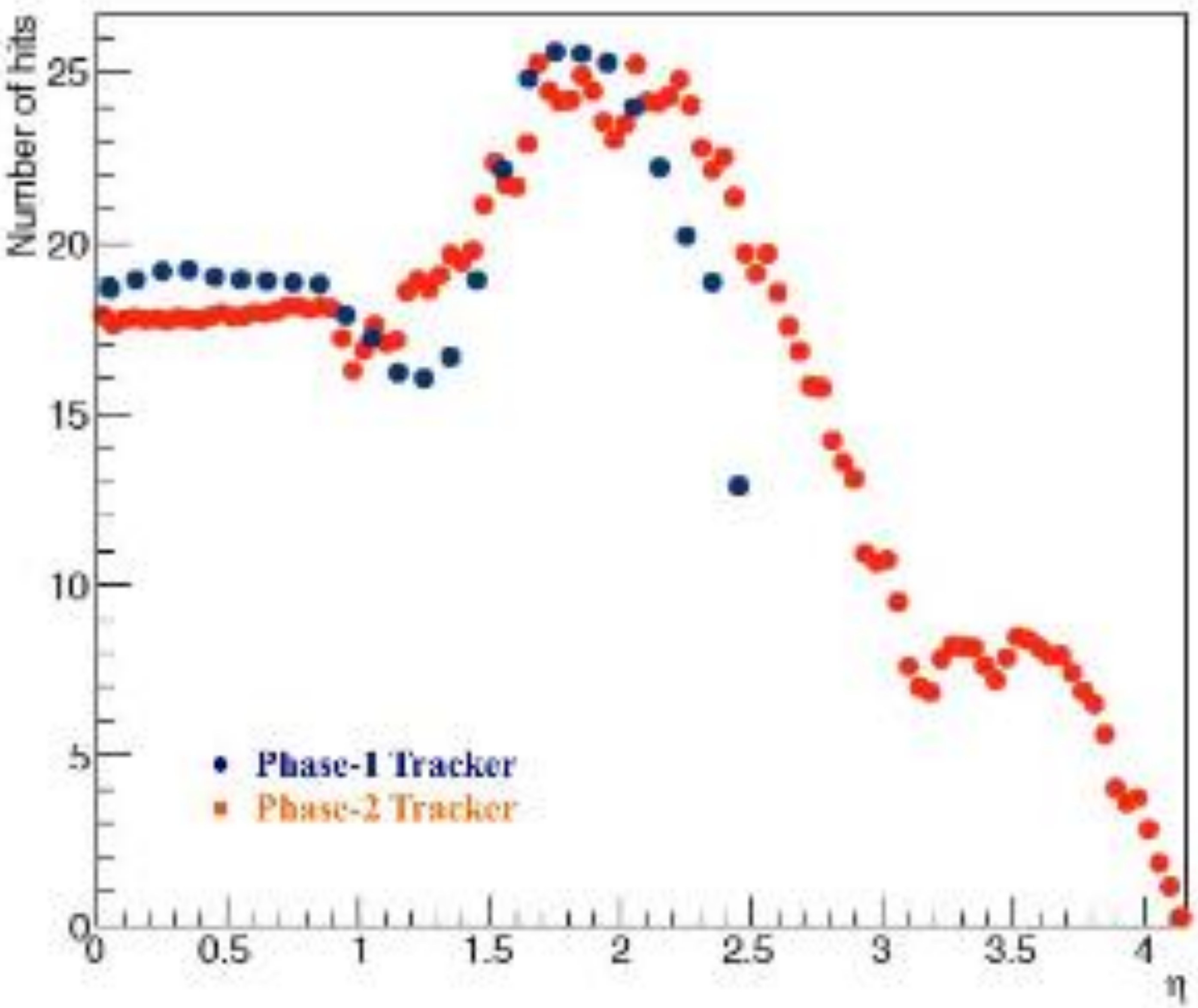
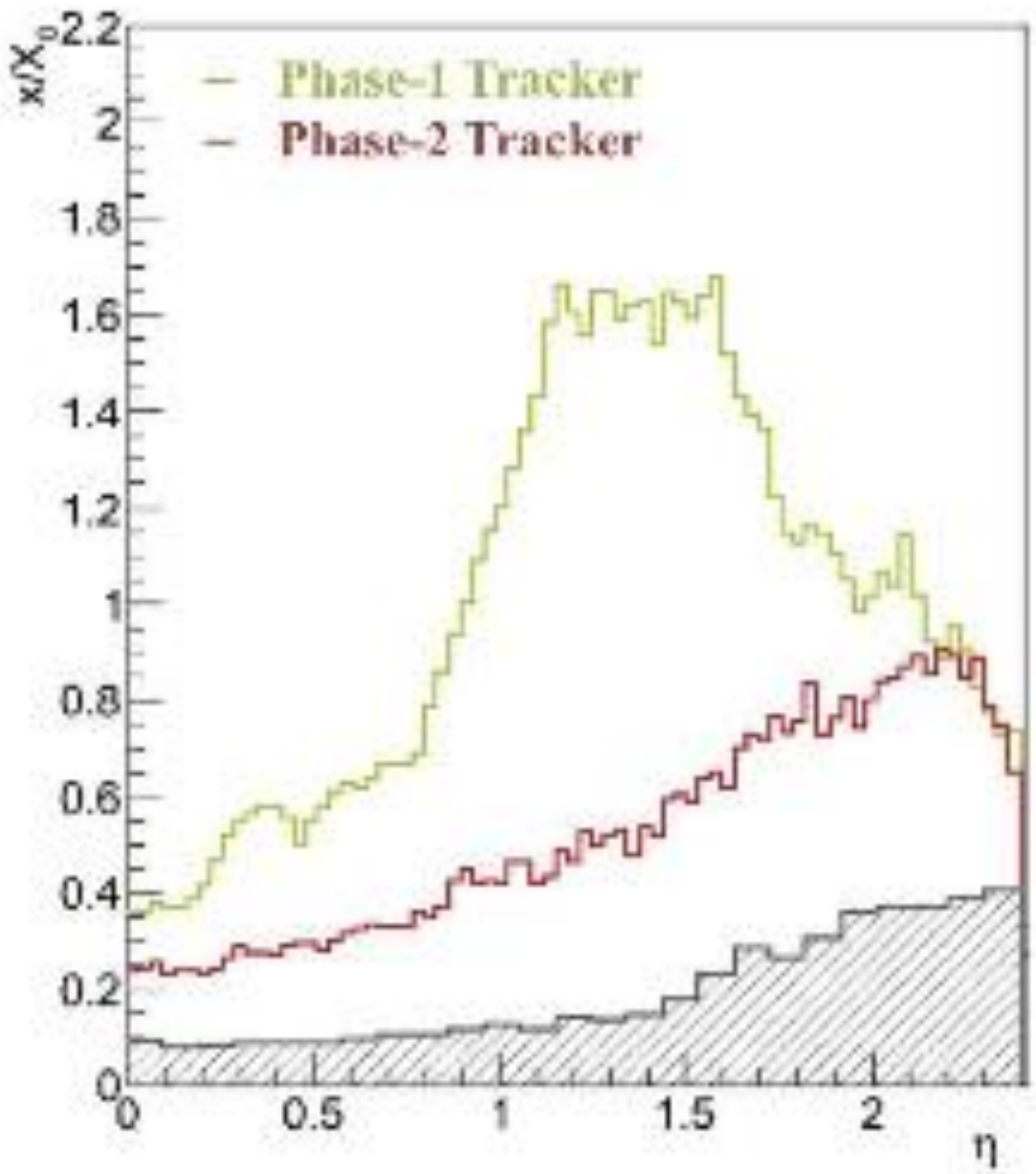
Upgrade tracker performance





III. Physikalisches Institut

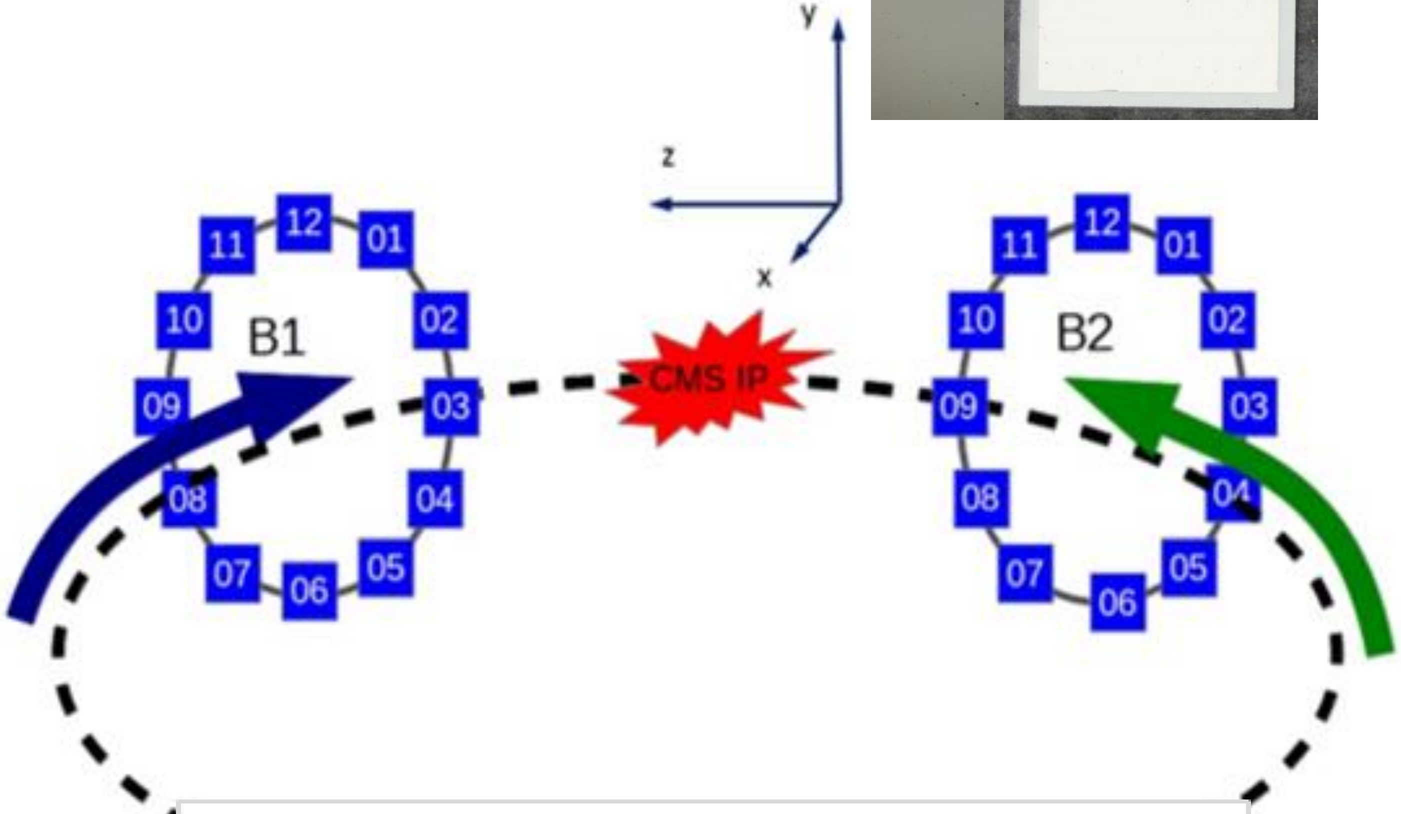
RWTH AACHEN UNIVERSITY

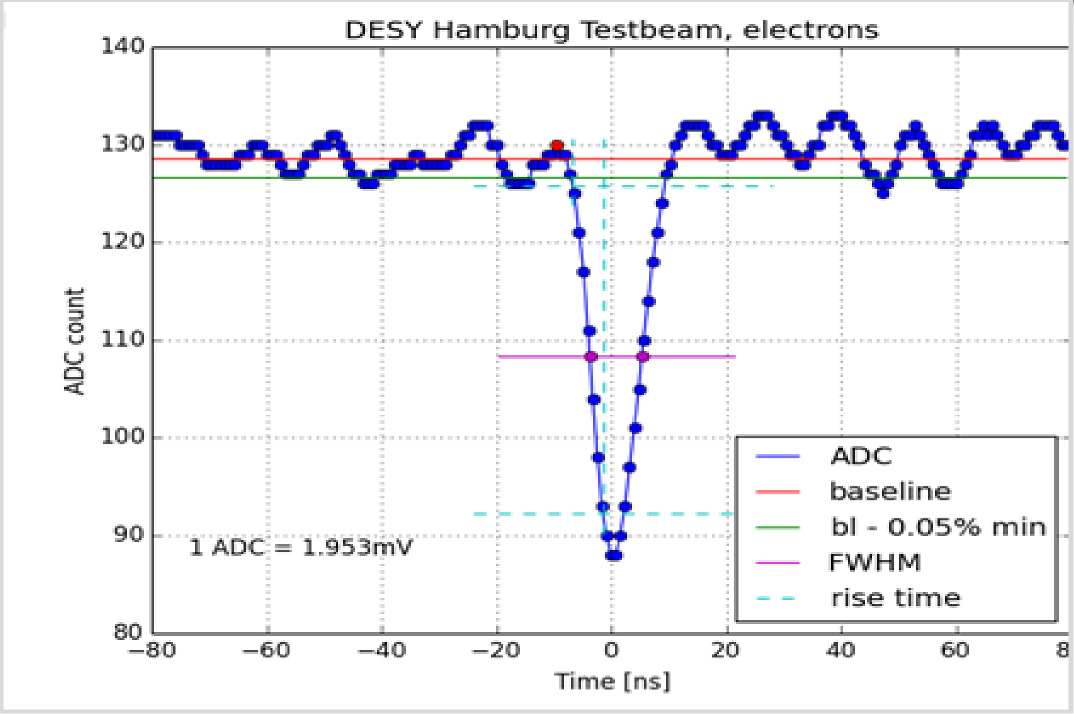
Fast Beam Condition Monitor BCM1F – what I did for CMS

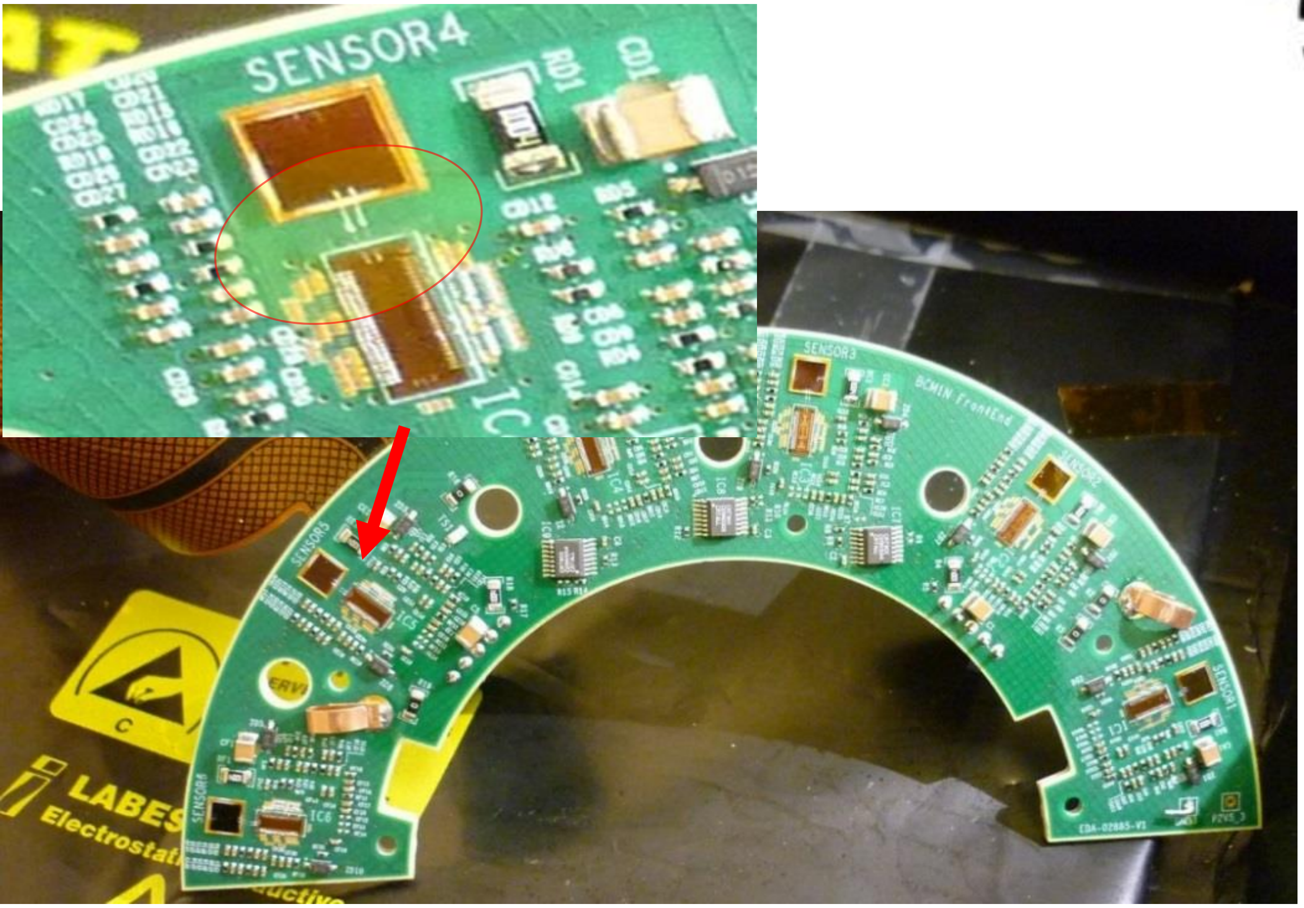
24 Single crystal two pad diamond sensors, 5x5 mm^2, 500mm thick

Surface flattened with reactive ion etching

Metallisation: 100 nm TiW (Princeton)
or 50nm/100nm Cr/Au (GSI)







- precision electroweak measurements at LHC approach LEP/SLD precison even for parameters which are easier accessible in electron-positron annihilations
- top-quark mesurements allow precision tests, both for QCD and electroweak physics
- top-quark studies reached the level of ‚rare processes‘
- probing the Higgs boson shows agreement with SM expectations (10-20% precison)
- SM so far in agreement with all observations
- new physics may appear in meaurements of better precision, to see inconsistencies, or in a dedecated search, or in the unexpected. we have to be patient
- HL-LHC will be a challenge for the detectors. major upgrades in preparation, based on the experience in runs I and II (listen to the talk of Pavel de Barbaro)

In the invitation of the school is written:

LANGUAGE
English is the working language of the School-Conference and publications.

Gomel school 1977:

Chris Quigg
Lectures on Charmed Particles, XIth International School for Young Scientists on High-Energy Physics and Relativistic Nuclear Physics, Gomel, Byelorussia, September, 1977. Five lectures.

Carlo Rubbia
NA4 as a Y factory

A.K. Mann
Neutrino Physics

A.M.Baldin
Commulative quark effects

S.M.Bilenky, B.Ponlecorvo
ON "FAST" AND "SLOW" NEUTRINOS

Proceedings ol the XI International School on High Energy Physics and Relatlvtstlc Nuclear Physics for Young Scientists. Gomel, 1977.

I. Savin
Deep Inelastic Muon Scattering