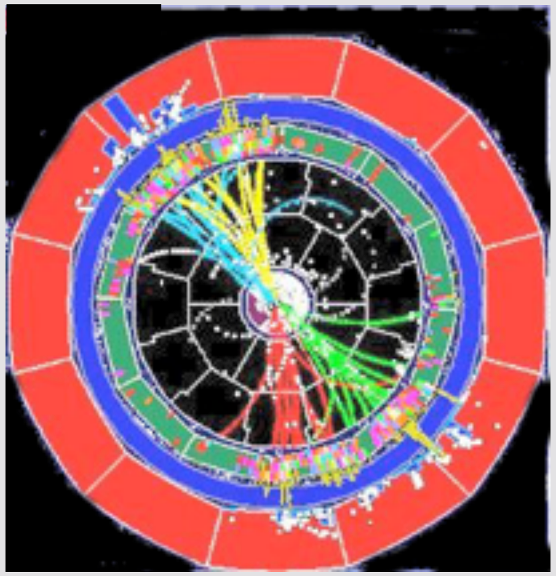
FCC
hh ee he



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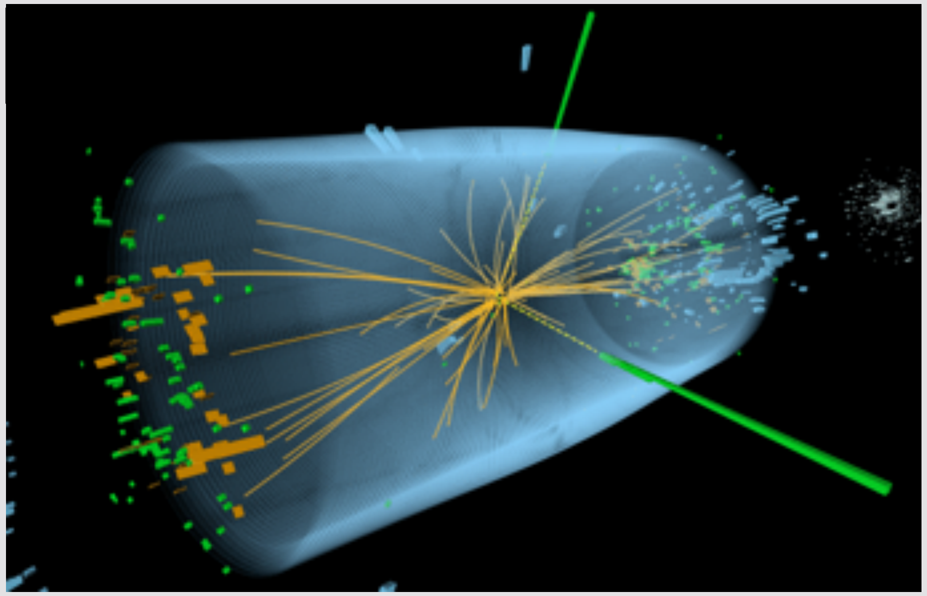

→ ?

credit: A. Cattai for many discussions

Lepton experiments & detectors

Gigi Rolandi - CERN and Scuola Normale

The FCC-ee program

$\sqrt{s}$ (GeV)	<L >(ab-1/year)*	Rate (Hz) ee—>hadrons	Years	Statistics
90	5.6	2 10^4	1	2 10^{11} Z decays
160	1.6	25	1-2	2 10^7 W pairs
240	0.5	3	5	5 10^5 HZ events
350	0.13	1	5	2 10^5 ttbar

* each interaction point

The Physics Case includes

- Precise measurement (0.1% to 1%) of the Higgs Couplings
- Improve precision (statistics x 10^5) on the measurements of the Z parameters [M_Z, Γ_Z , R_ℓ, R_b, R_c, Asymmetries & weak mixing angle]. Z rare decays.
- Scan W threshold (aiming at 0.5 MeV precision). W rear decays
- Scan ttbar threshold (aiming at 10 MeV)

JHEP01(2014)164

Physics Requirements on the detector

Will be eventually set by the Physics Groups: here only few simple observations

All masses measured from a scan of the cross section what matters is energy calibration of the accelerator.

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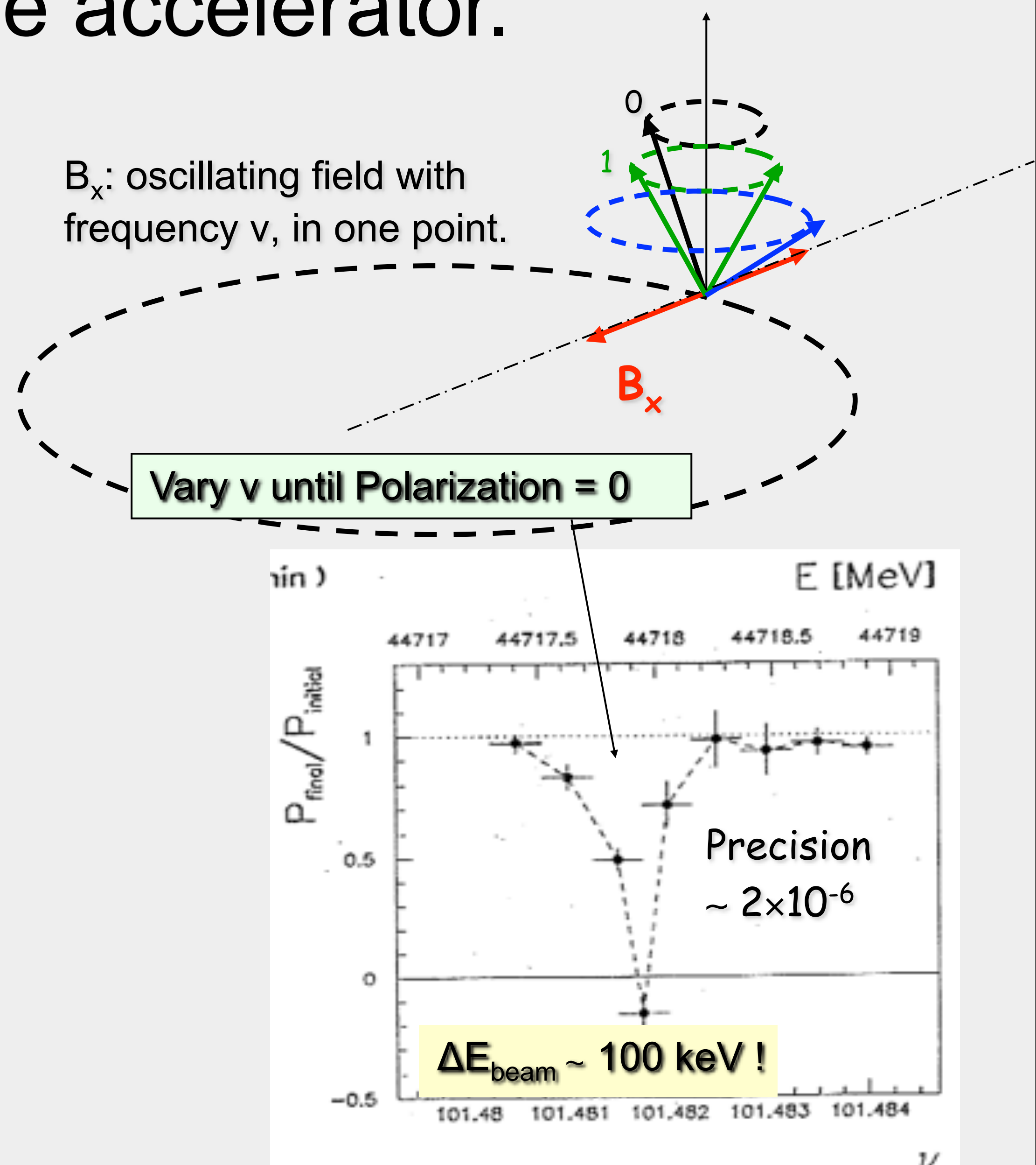
Selective depolarization of few bunches

Beam energy calibrated with resonant depolarization
[Up to > 80 GeV/ beam]



Physics Requirements on the Detector

Will be eventually set by the Physics Groups: here only few simple observations

Very high statistics (2 10^{11} Z—>hadrons , 10^{10} Z—>each lepton pairs) puts high strain on reducing systematic errors

ALEPH syst errors…..

	Hadronic selection	
	Charged tracks	Calorimeter
Efficiency (%)	97.48	99.07
Background:		
$\tau^+\tau^-$ (%)	0.32	0.44
$\gamma\gamma$ (pb)	78±12	48±9
($\gamma\gamma$ in % of peak cross section)	(0.26)	(0.16)
e^+e^- (pb)	negl.	23 ± 8
(e^+e^- in % of peak cross section)	negl.	(0.08)
$\mu^+\mu^-$	negl.	negl.
Source of systematic uncertainty (%):		
MC simulation of detector response	0.02	0.09
Hadronisation modelling	0.06	0.03
MC statistics	0.02	0.02
Background:		
$\tau^+\tau^-$	0.03	0.05
$\gamma\gamma$	0.04	0.03
e^+e^-	negl.	0.03
Total systematic uncertainty	0.087	0.116
Combined	0.071	

q-qbar selection: 7 10^{-4}

Leptonic selection…..

Source of relative uncertainty (%)	e^+e^-	$\mu^+\mu^-$	$\tau^+\tau^-$
TPC Tracking	0.05	0.03	0.03
$\cos\theta^*$	0.02	0.01	0.01
ISR/FSR sim.	0.03	0.03	0.03
Total acceptance	0.06	0.04	0.04
MC statistics	0.05	0.06	0.07

error on acceptance 4 10^{-4}

$$\varepsilon^{\rm id}_{\mu\mu} = 0.99976 \pm 0.00001$$

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…. how does it reflect on detector requirements ?

Physics Requirements on the detector

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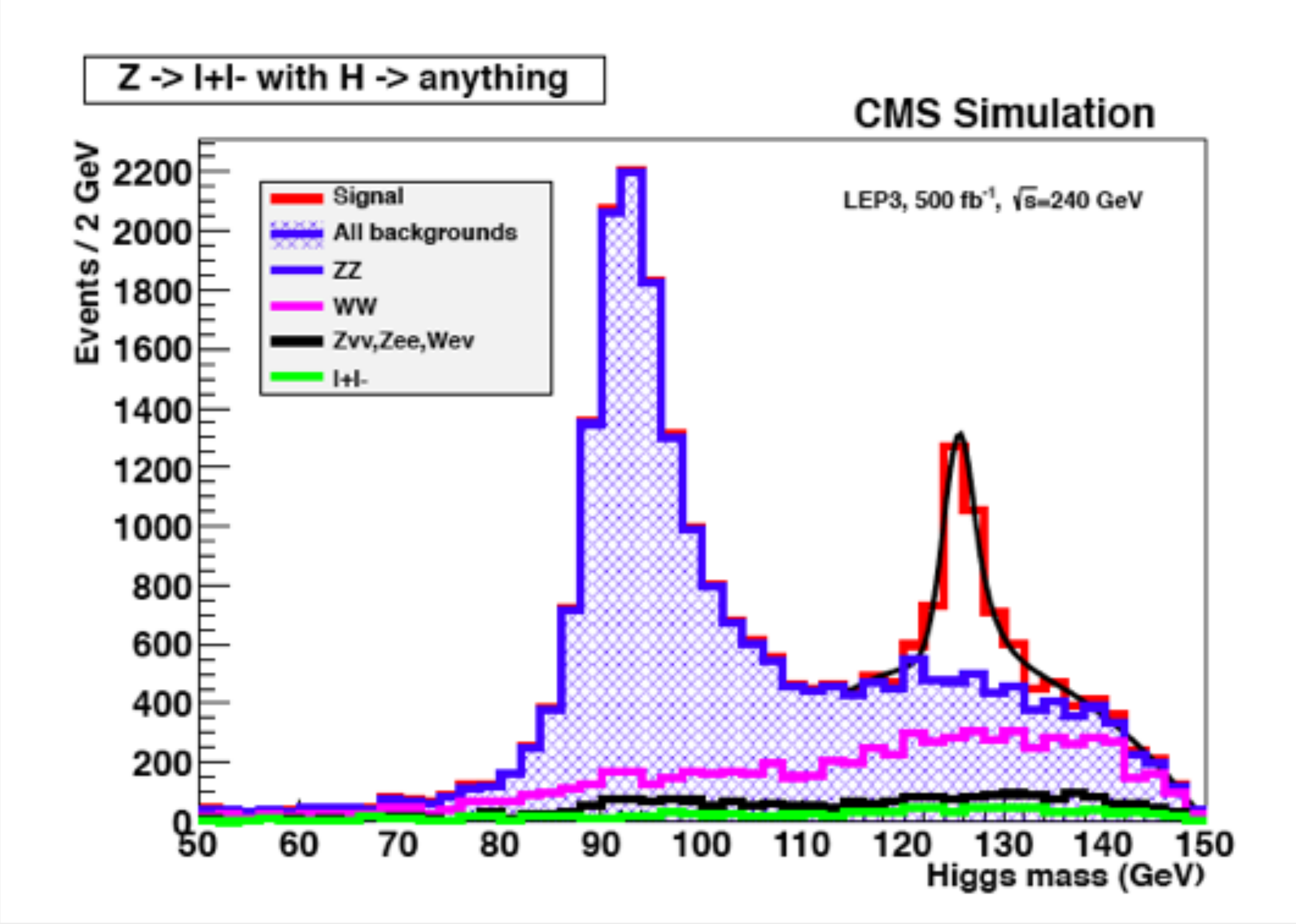
Resolution in measuring leptons is important for narrow resonances recoiling to Z as ZH—> l^+l^- X



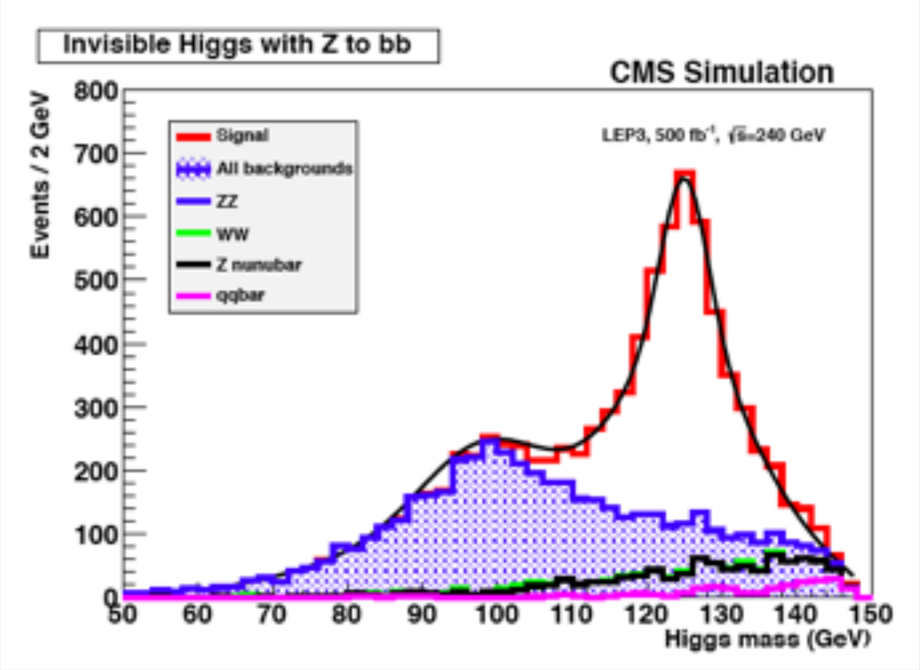
σ_{core} = 1.5 GeV

http://arxiv.org/abs/1208.1662

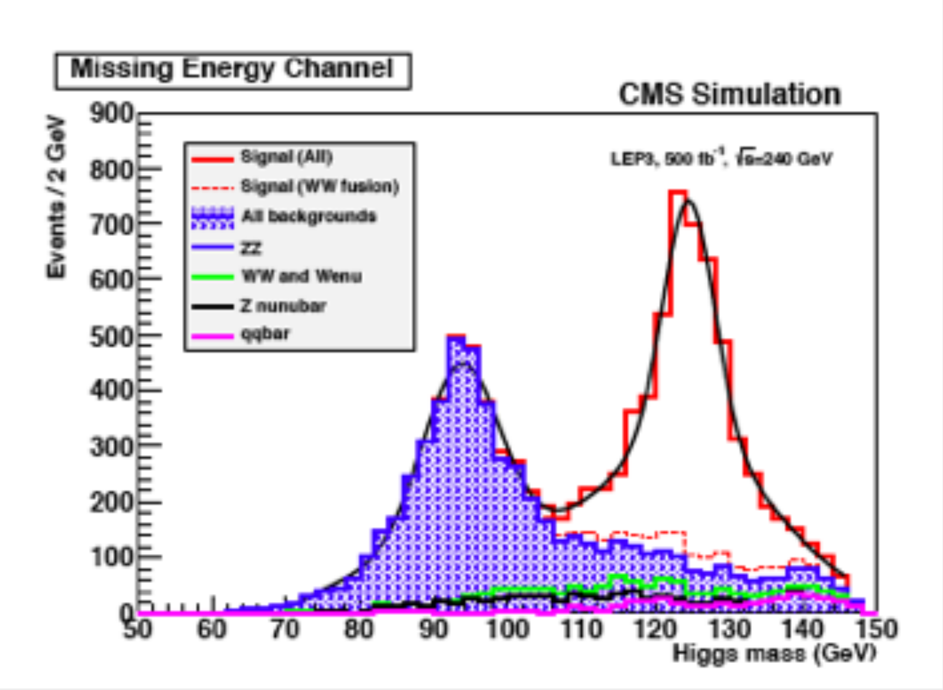
Physics Requirements on the detector

Will be eventually set by the Physics Groups: here only few simple observations

Resolution in measuring jet-jet invariant mass greatly benefits from beam constraints



Missing mass recoiling to Z—>bbar [Here h assumed to be invisible]



H—>bbar Z—>vv

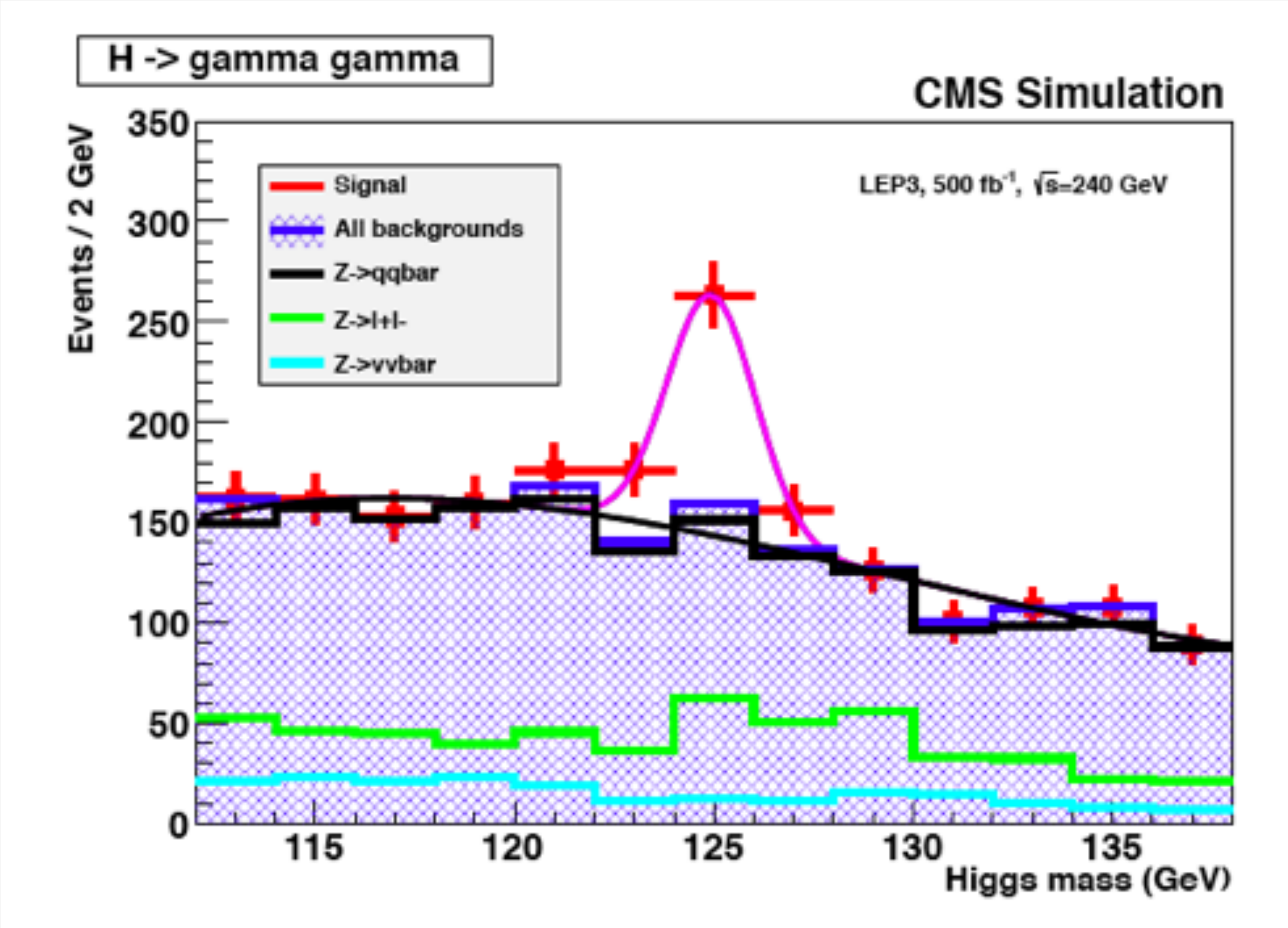
fitting with two gaussians :

σ_1 ~ 3 GeV ; σ_2 ~ 8 GeV

Physics Requirements on the detector

Will be eventually set by the Physics Groups: here only few simple observations

Resolution in measuring photons is important for narrow resonances : H—>gamma gamma



σ = 1 GeV

General Detector Requirement

- Be suitable for high precision measurement
- Large Magnetic Field
- Excellent lepton id and lepton/photon momentum resolution
- Adequate calorimeter granularity [Particle Flow Friendly]
- Precise angular (and energy) jet measurement
- High granularity vertex detector with b and c tagging capabilities
  - .... in a low occupancy environment

Magnet

- Large magnets are used in very few projects and their construction requires a long R&D period to deploy into the industry the technological expertise needed to build them
  - Today would be impossible to re-build the CMS magnet without a long R&D period (P. Fabbricatore)
- A large magnets is a large investment in money and brain power. It can be used by more than one experiment
  - It makes sense to consider the design and construction of a large magnets a common FCC project

Magnet

- Using Nb-Ti superconductor with stabilization in pure aluminum (CMS solenoid) one can reach fields similar to the one in CMS (4 T , 6 m diameter)
- ITER is now building solenoids (smaller size than CMS) with Nb_3Sn superconductor with stabilization in steel. With this more difficult technology its conceivable to build a magnet 7 m diameter and 8-10 T field.
  - Some 10 years of R&D are needed to prepare its construction.

Sub-detectors

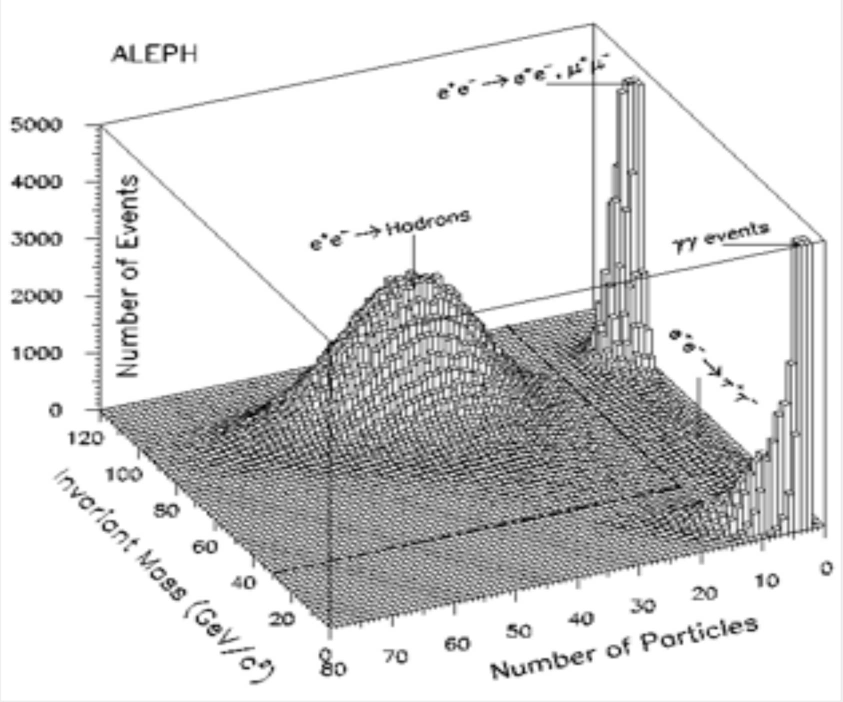
- Will seek synergies with linear collider studies whenever appropriate. A lot of good work on an e+e- detectors in this c.o.m.energy range has been done for ILC.

- Z peak physics poses special requirements for DAQ and for matching the design to the very ambitious precision of 10^{-5} !

Precision vs material

- There is a believe that TPC is the ideal detector for e+e-. Certainly TPC have been used with success at LEP.
- There are big advancements on silicon detectors and FCC ee has a “radiation friendly” environment . A lot of studies have been done on light and stiff structures
  - Studies should be done on performance vs material to quantify the different physics output as a function of the Inner Tracking material

Calorimeter granularity



- Separating leptonic Z decays at the 10^{-5} is a challenge that requires a complete event reconstruction possible with Particle Flow (PF)
- Measuring well jet angles calls for a PF jet definition.

The granularity of the calorimeters should be adequate for an optimal PF

Broad Brush List of questions to the physics groups

- What is the requirement for jet energy and angular resolution ?
- What are the requirements for systematic 10^{-5} precision on Z peak observables ?
- Which variables are needed for charm tagging ?
- Added value of kaon id ?
- ……….

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Broad Brush List of topics for the Detector Design

- How does jet angular and calorimeter resolutions scale with calorimeter's granularity ?
- Performance (jets, e/gamma) vs tracking material
- Can a TPC work @20kHz hadronic events ?
  - distortions , power consumption
    - see talk by Philippe Schwemling on Friday 5.40 pm
- How light can be a full silicon (pixel ?) detector
  - material, integration time, occupancy
- Beam pipe design vs pixel first layer installation
- Compare tracking/calorimetry w/o kaon id
- How well one can measure luminosity
- Forward detectors and their integration

Time scale

- Some 90 people signed up to the FCC-ee Detector Designs mailing list

- Call for start of activities in the month of March

BACKUP

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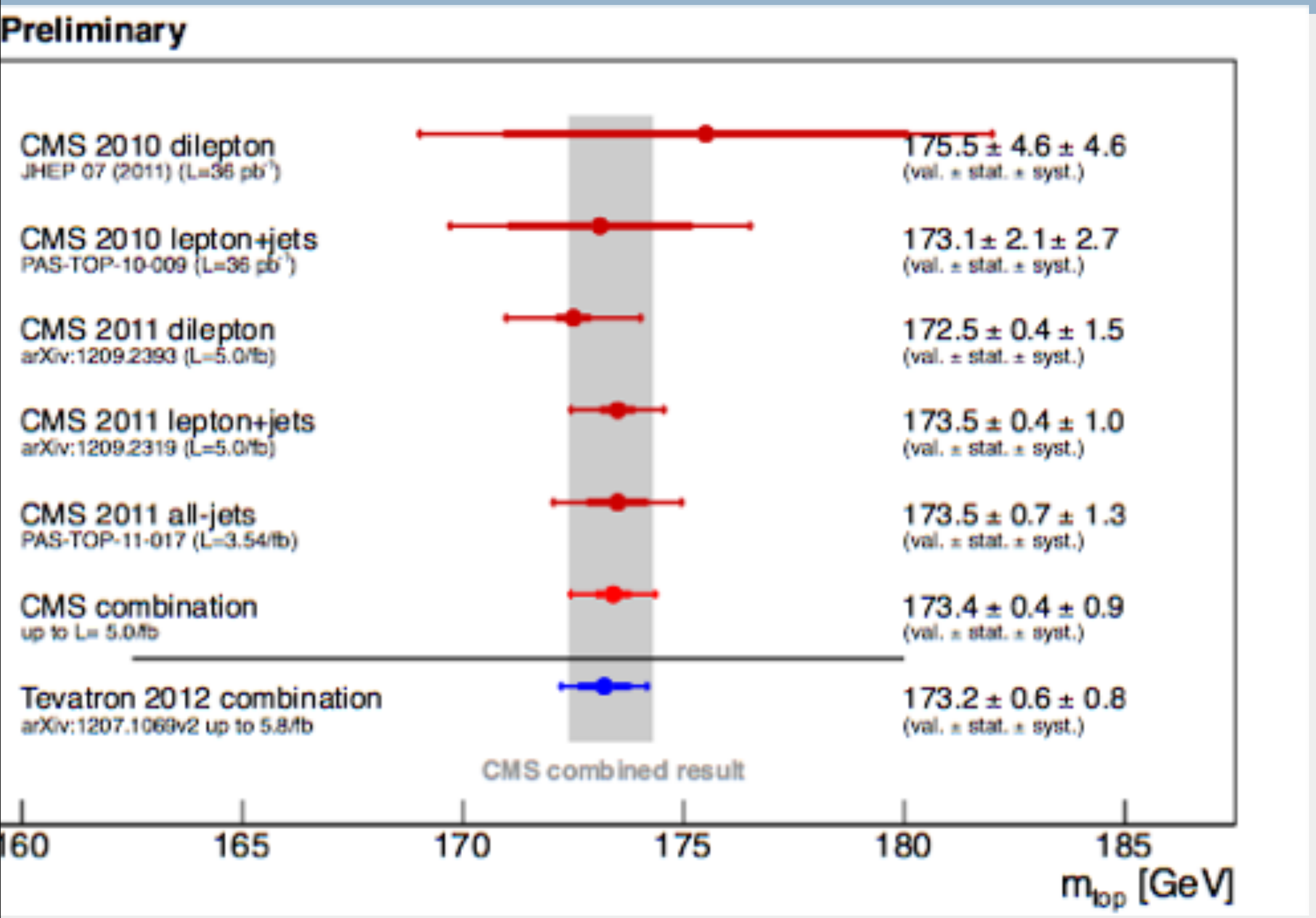
Top mass measurement



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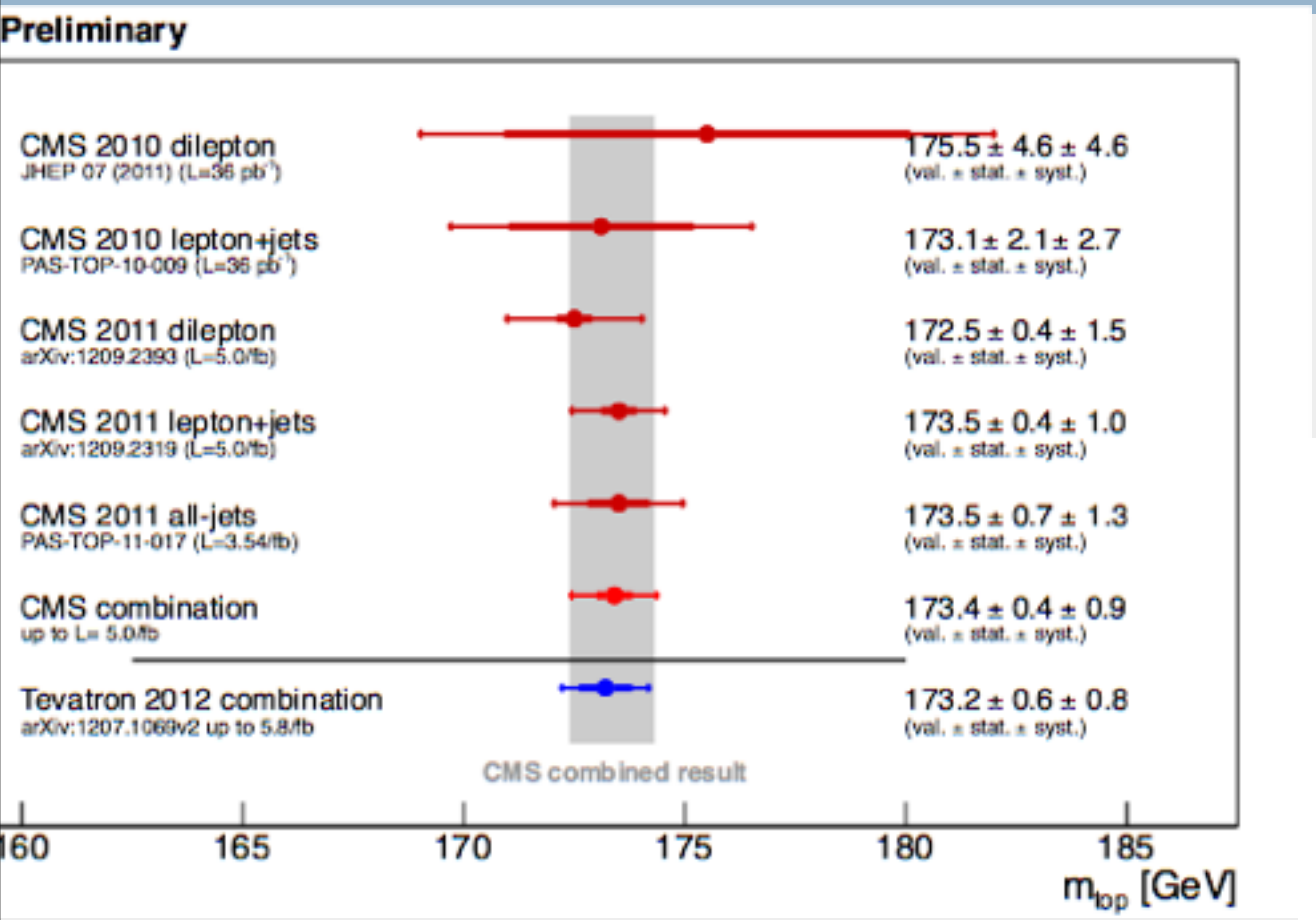
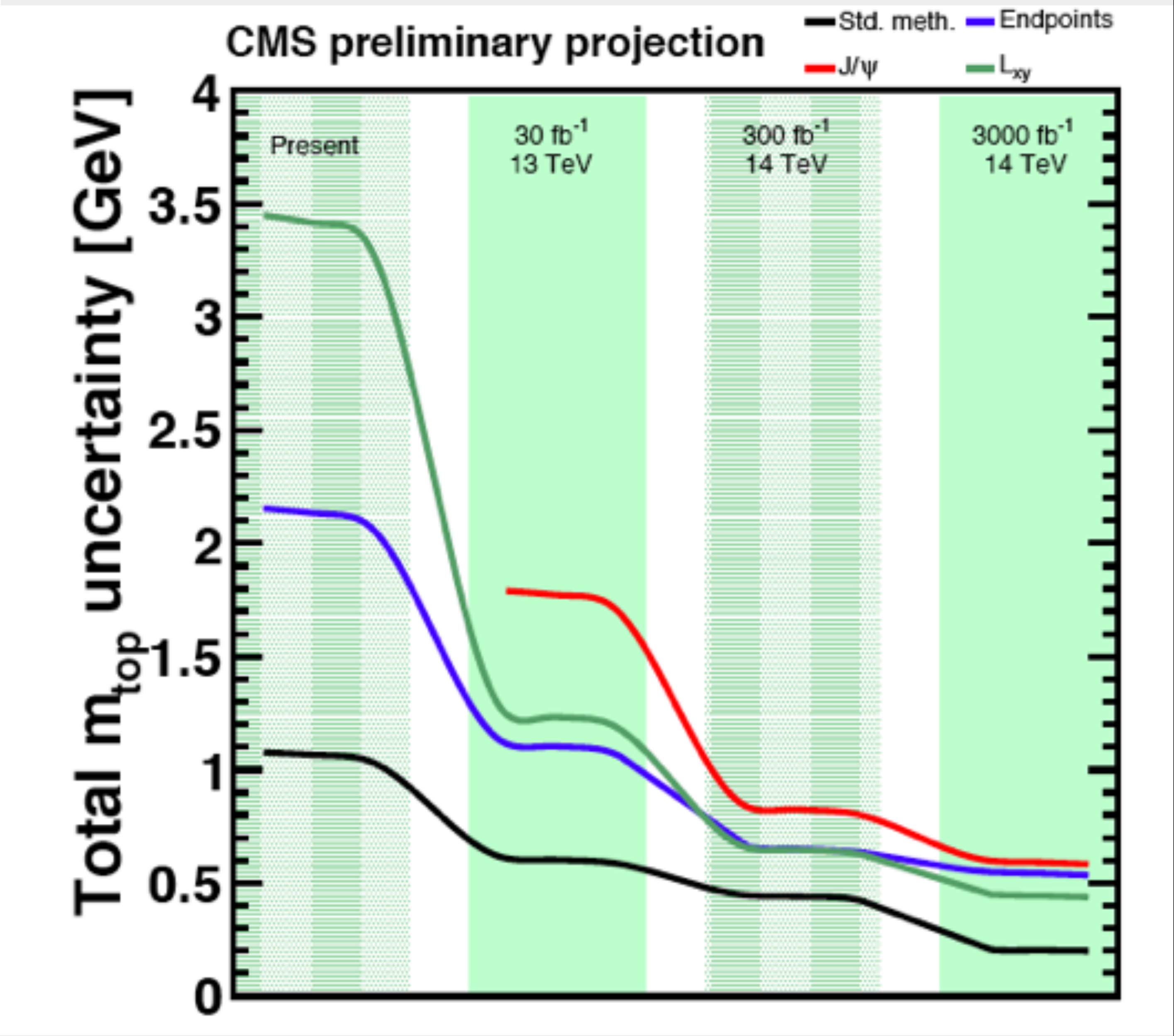
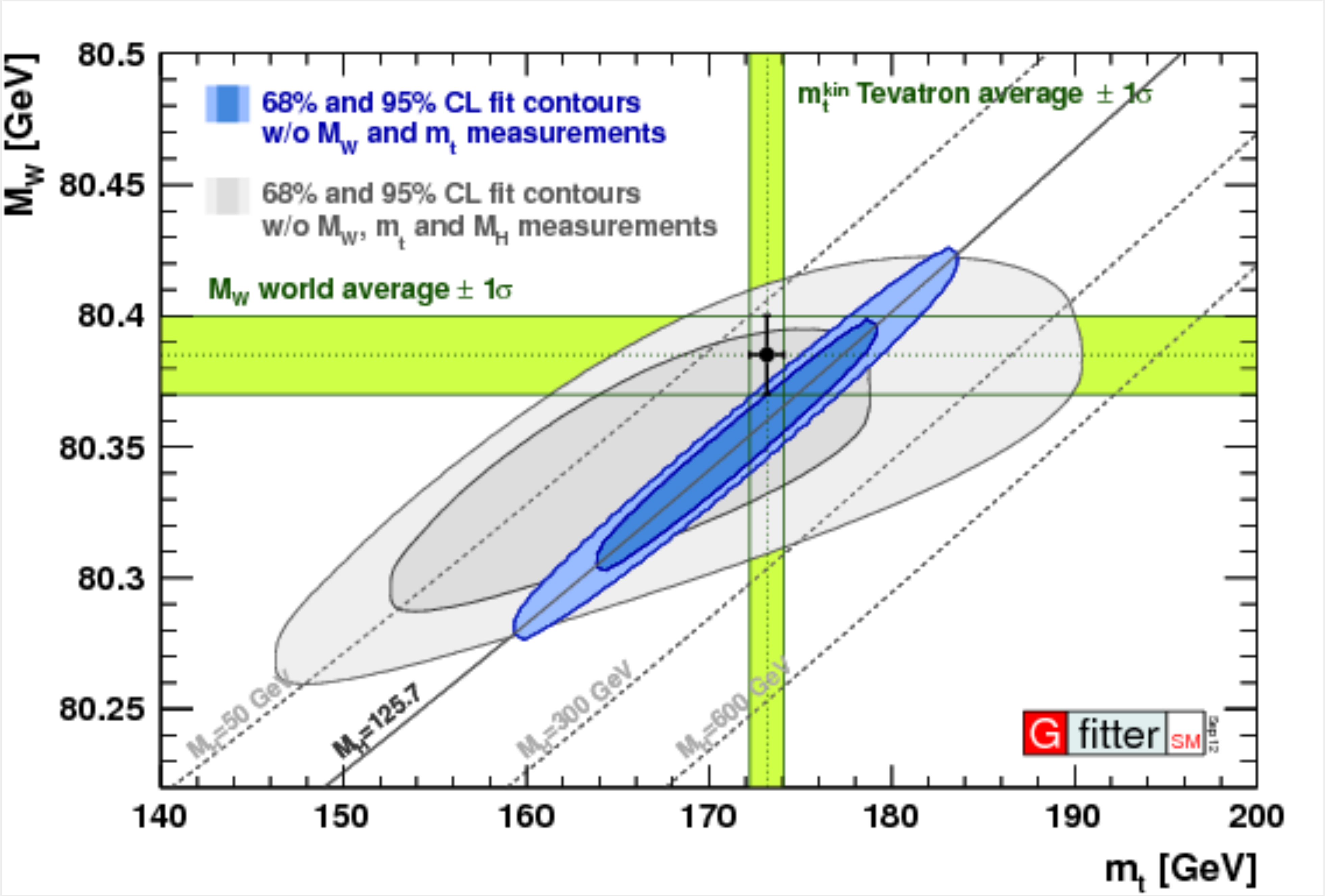
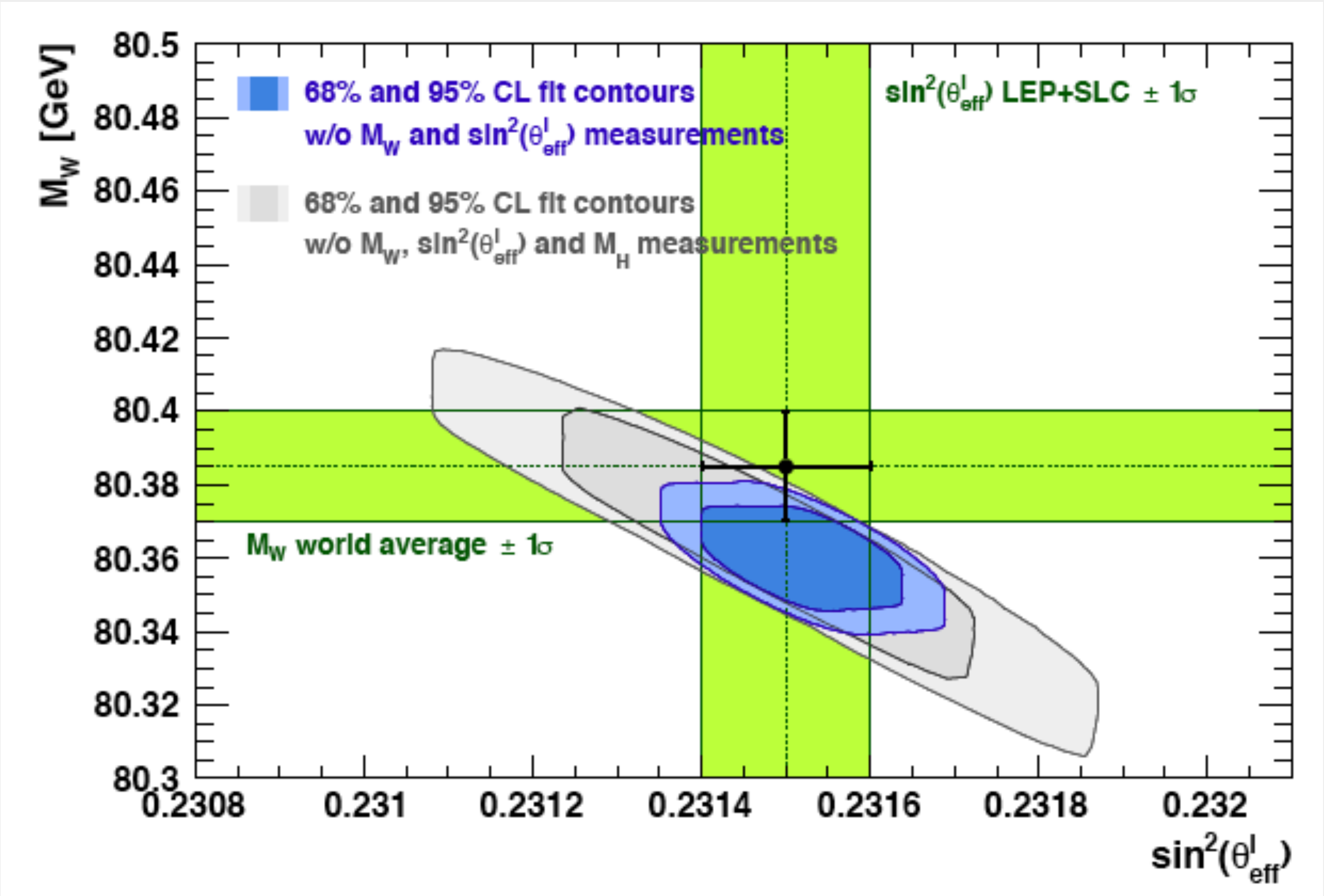




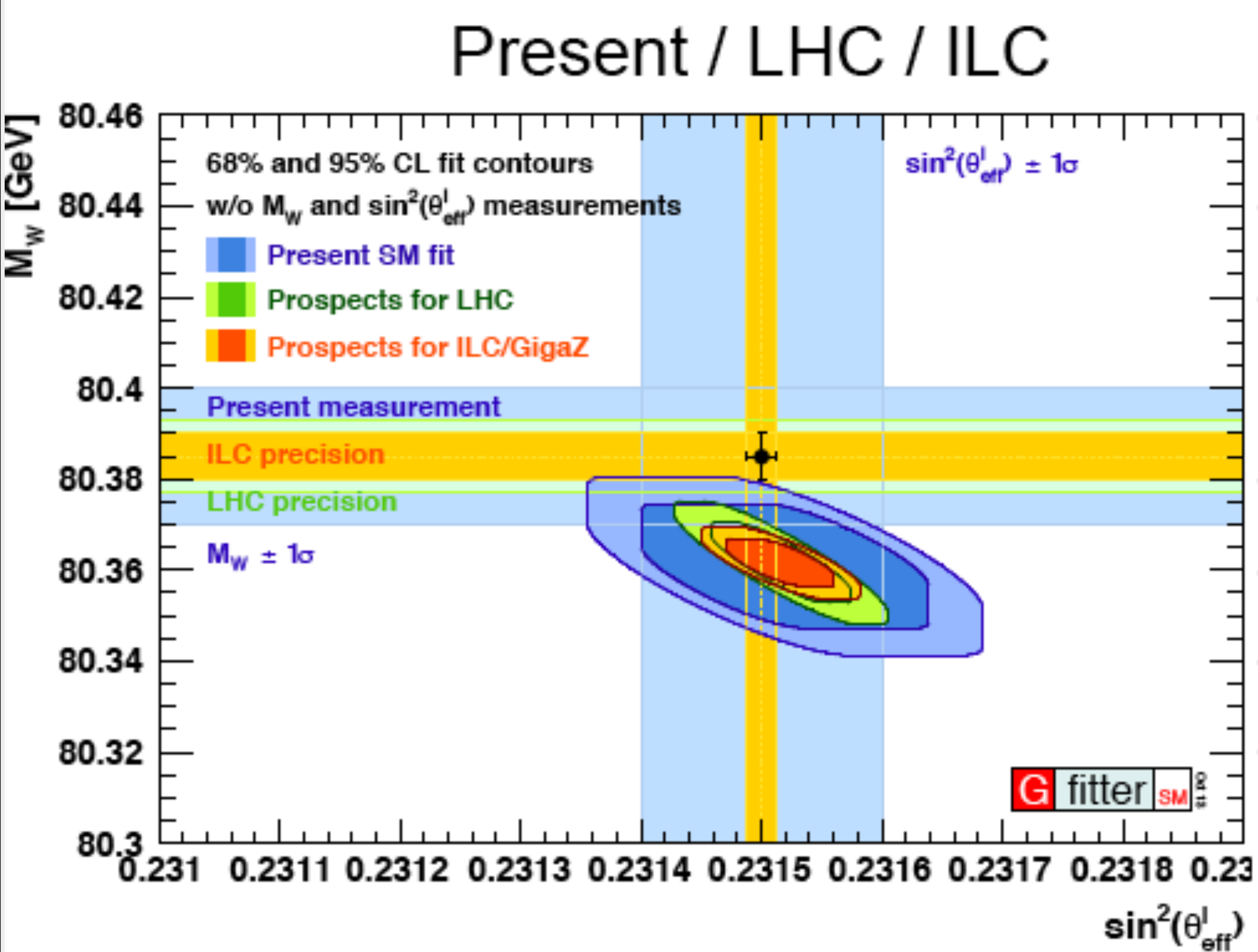
M_W and M_{top} vs prediction

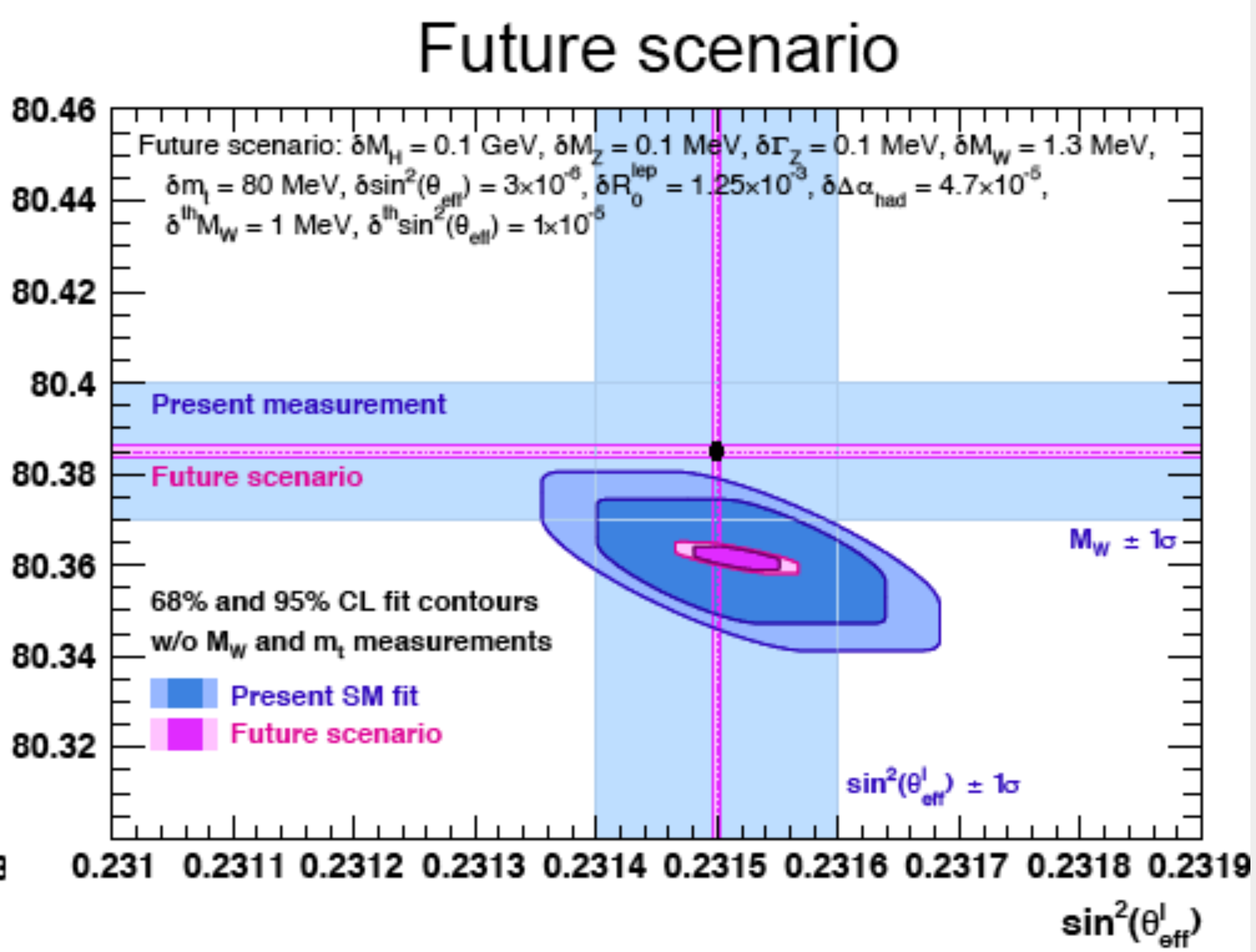


M_W and $\sin^2\theta_{eff}$ vs prediction



Prospects: M_W and $\sin^2\theta_{eff}$ vs prediction





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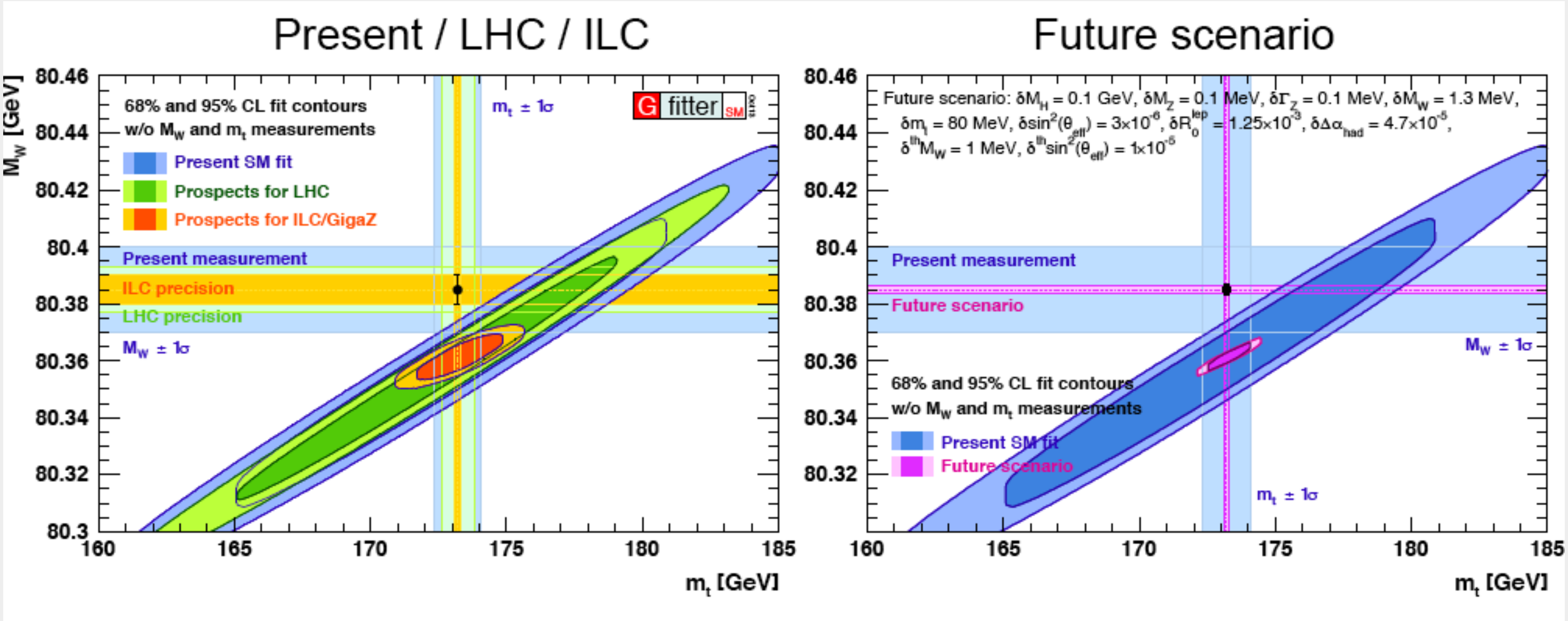
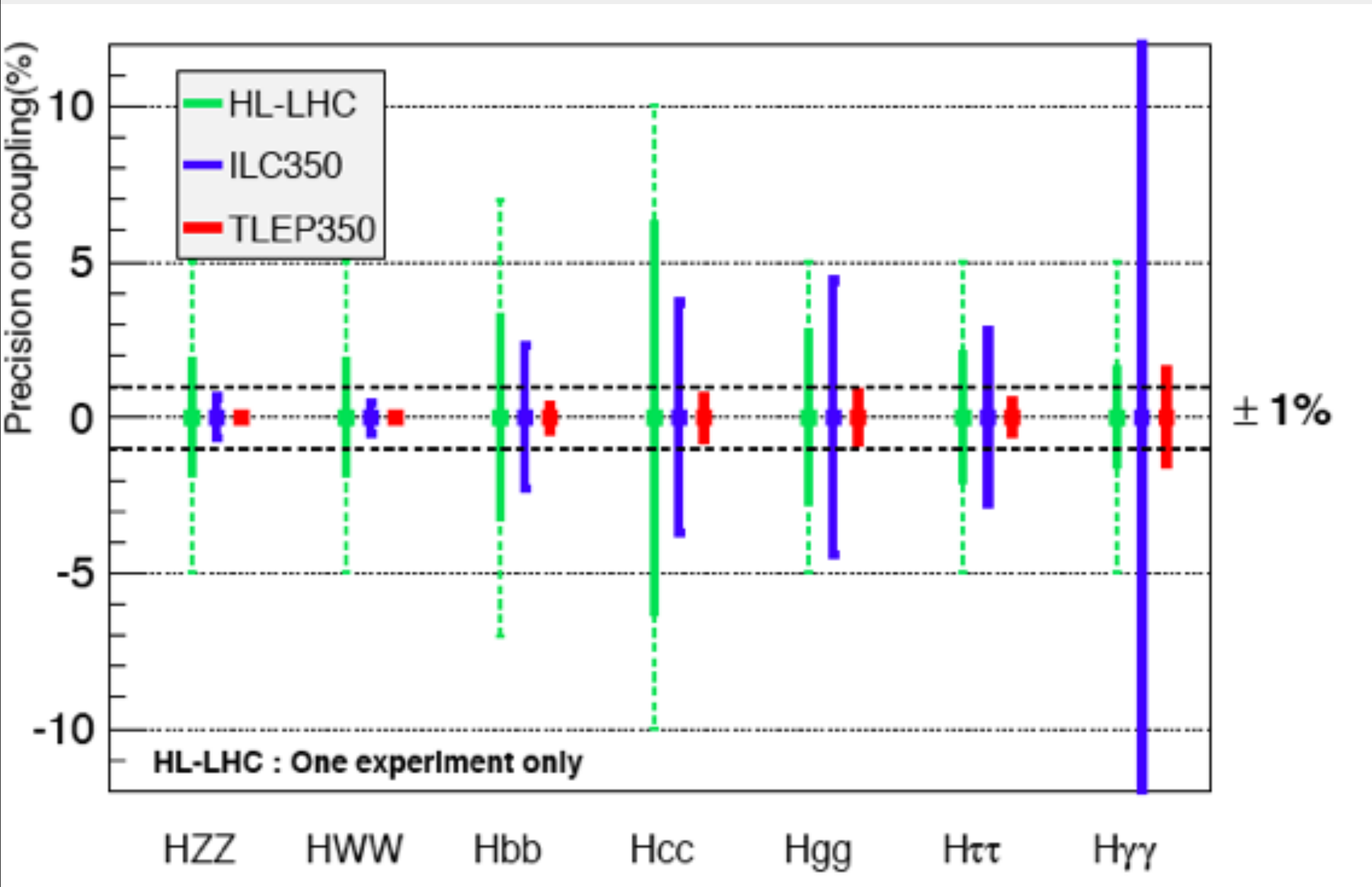


Prospects: Higgs Couplings

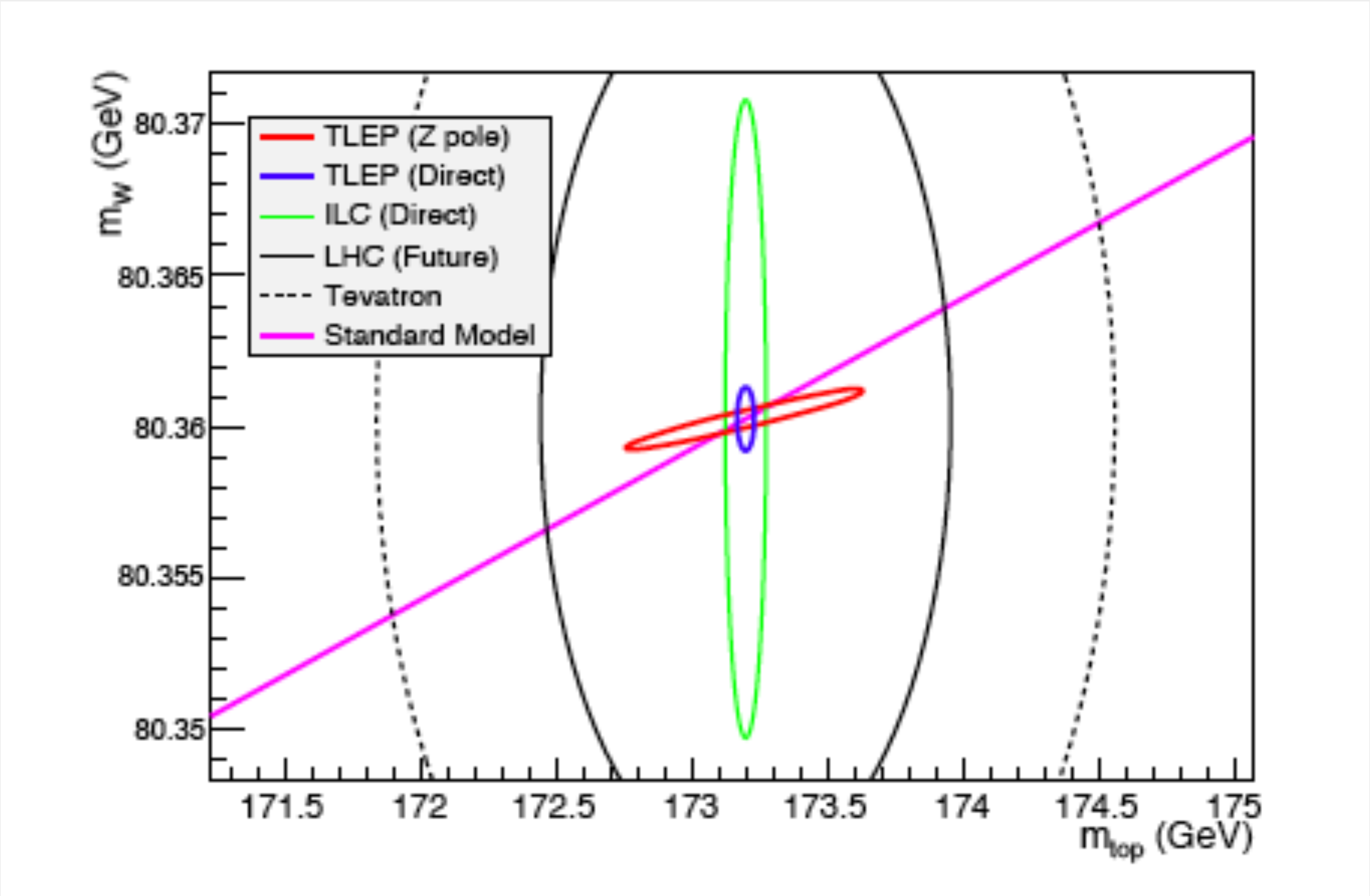


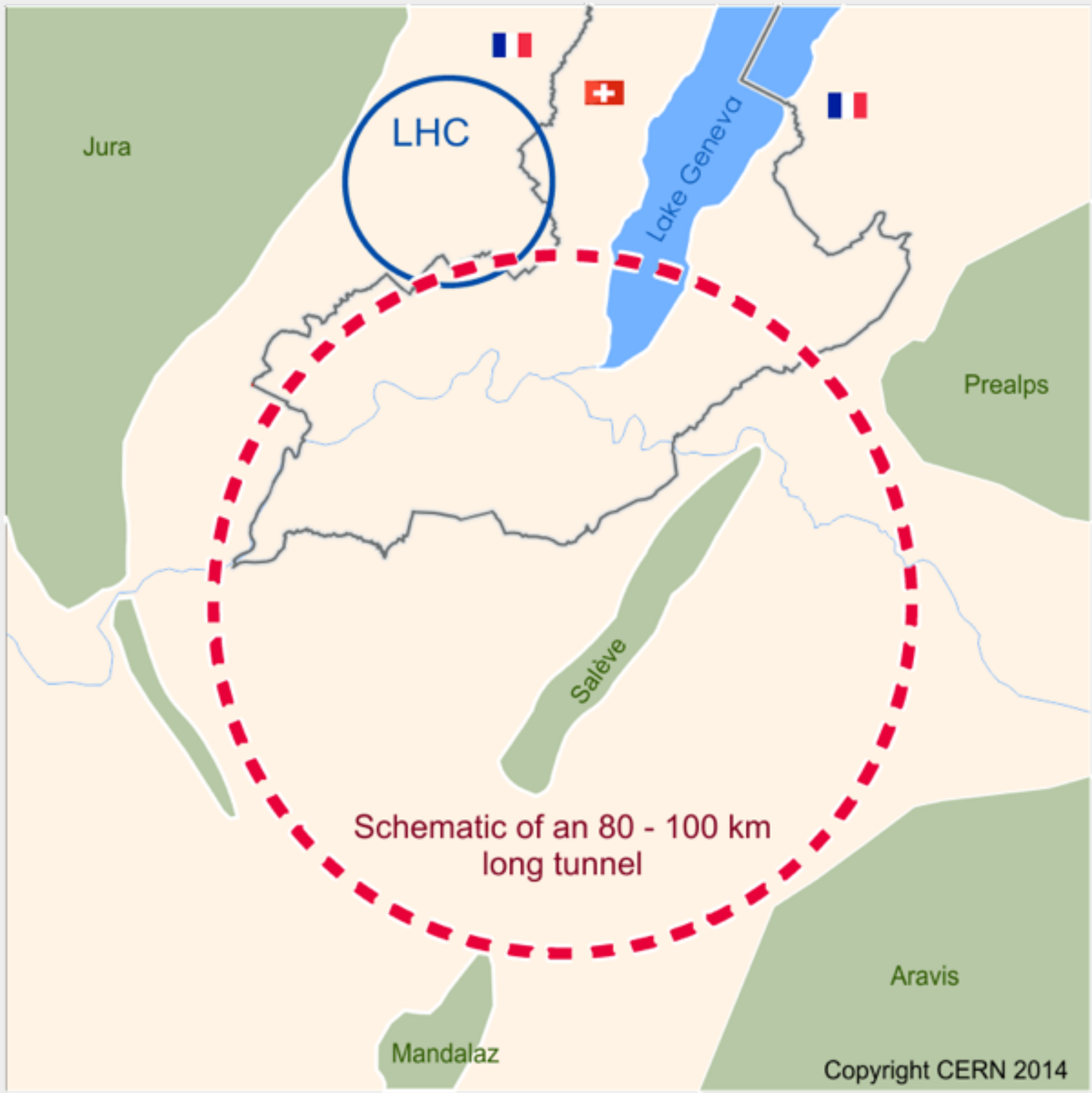
• • • • Systematic errors unchanged

—— Systematic errors 1/sqrt(L) , theory halved

A glance to the future: ILC,TLEP

Bicer et al, TLEP arXiv:1308.6176




LHC
Jura
Lake Geneva
Prealps
Salève
Schematic of an 80 - 100 km
long tunnel
Aravis
Mandalaz
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