Deep into the future.

Panel discussion at Naturalness 14

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- Tim Cohen

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  (contributed points)

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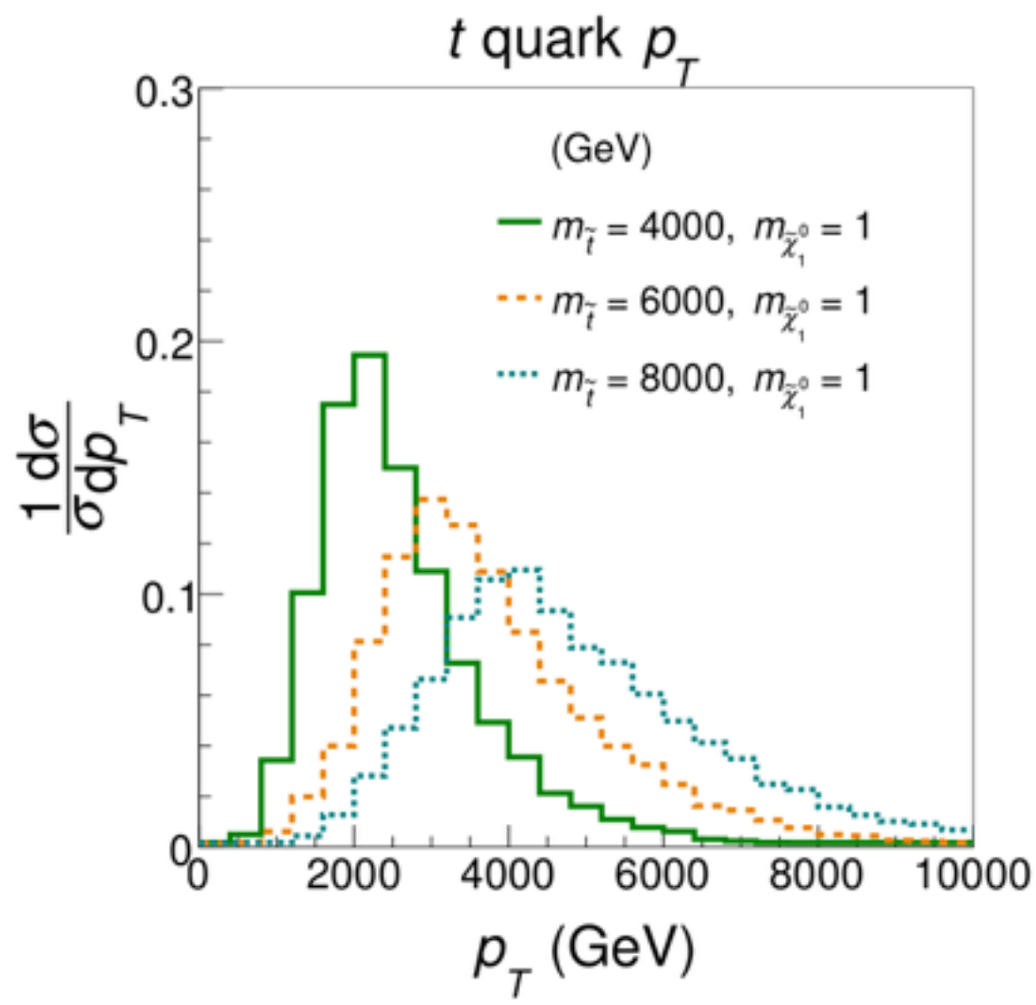
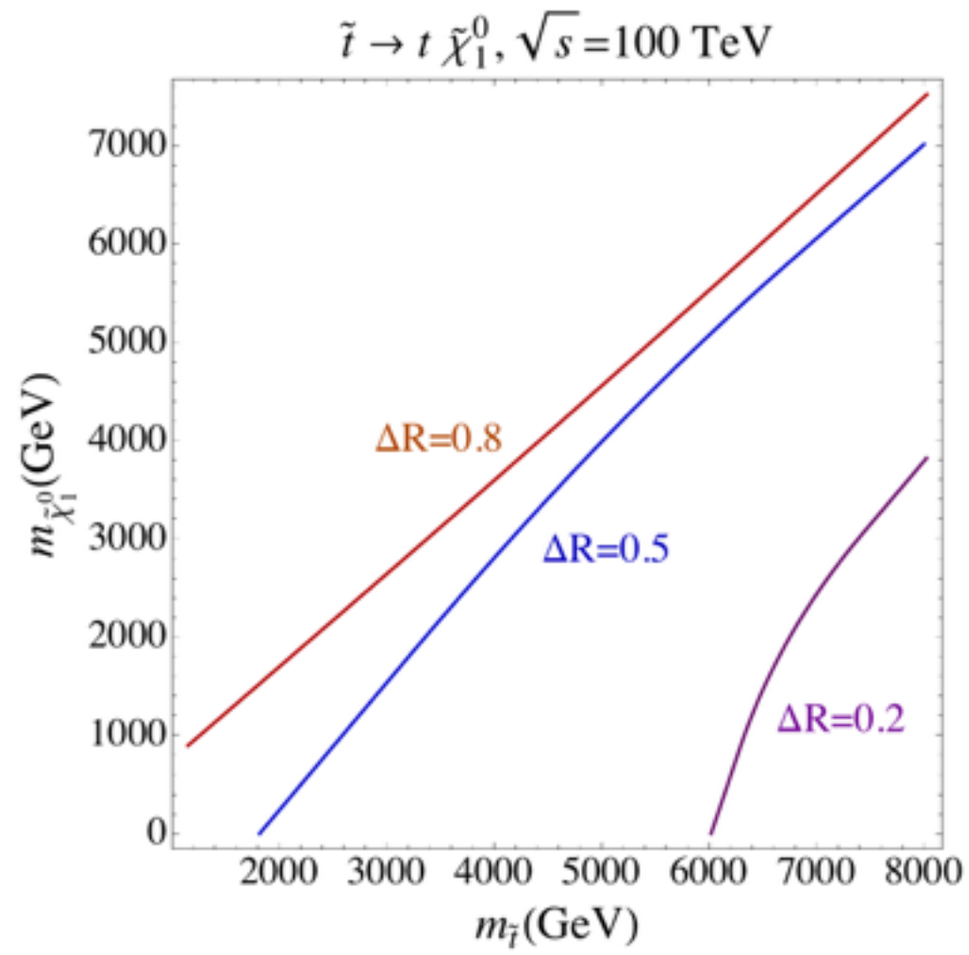
- Tim Cohen
- Andi Weiler
- Pekka Sinervo (contributed points)
- LianTao Wang

4 Messages

1) Want to continue the search for top partners:

heavier masses yield more boosted tops;
new strategies will be required.

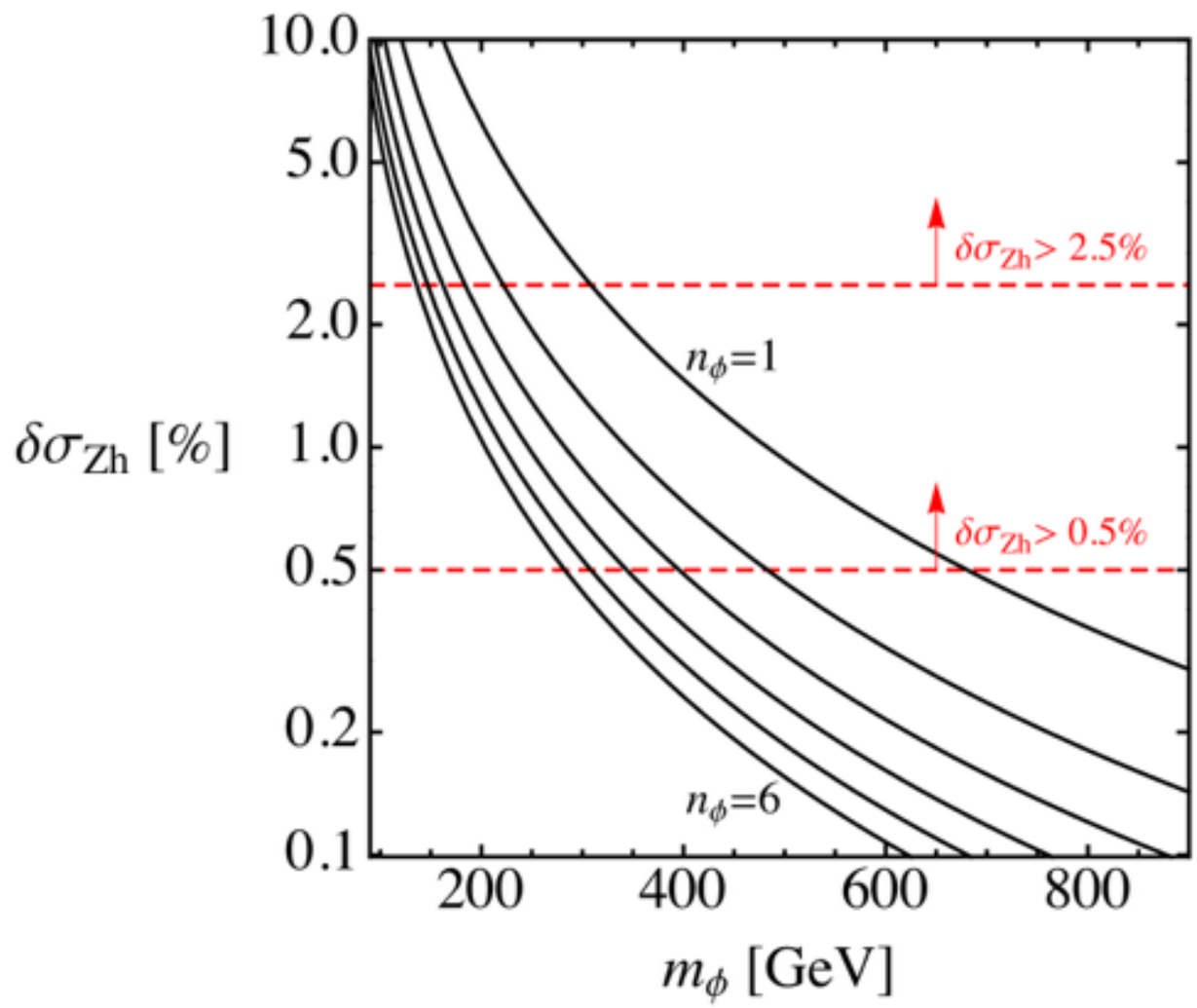




TC, D'Agnolo, Hance, Lou, Wacker [arXiv:1406.4512]

4 Messages

2) Precision Higgs coupling measurements will be critical: *ZZh* coupling probe light states that couple to the Higgs.



Craig, Englert, McCullough [arXiv:1305.5251]

4 Messages

3) Want interplay between pushing mass limits higher and probing difficult signatures which might be more natural (e.g., compressed).

4) Continue theoretical progress

- new naturalness mechanisms
- deeper understanding of the measure
- ...

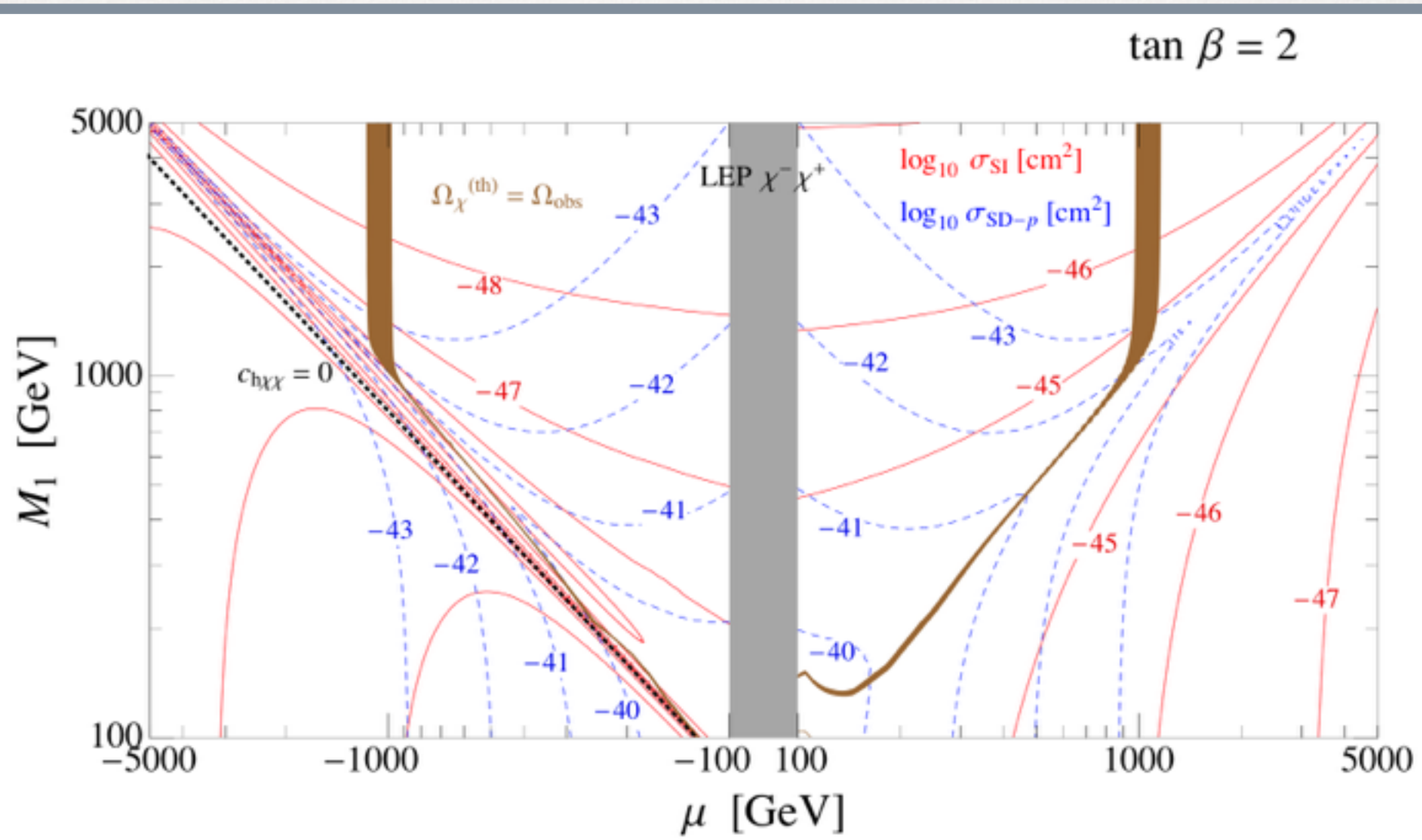
3 Questions

1) What are motivated models which point to scales outside LHC reach?
(e.g., mini-split with 3 TeV Wino and 18 TeV gluino)

2) How do we close all naturalness loopholes?
(e.g., strategies for uncolored top partners)

3 Questions

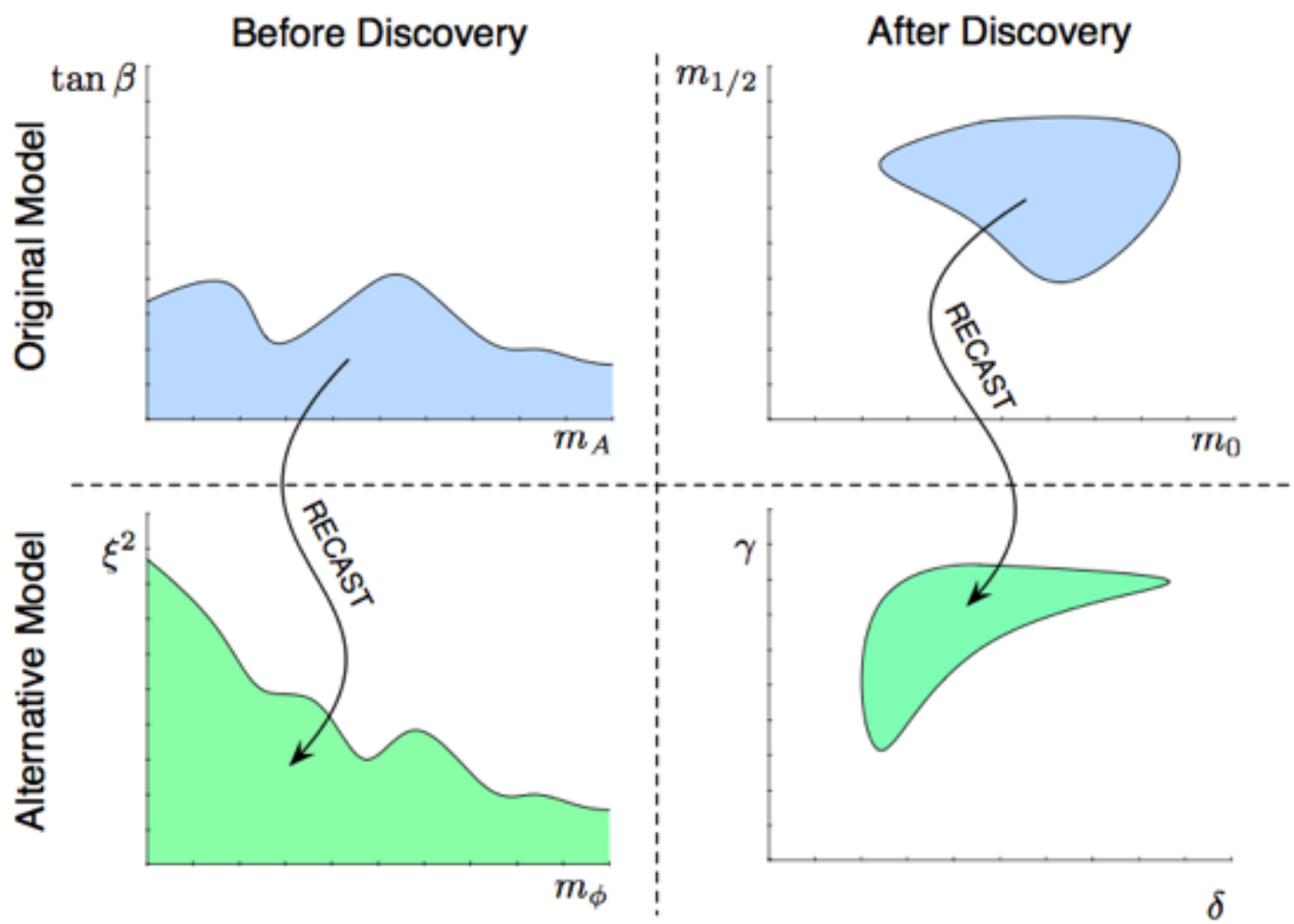
3) Assuming dark matter experiments hit the neutrino floor, how does this impact our feelings about naturalness (e.g., SUSY with light Higgsinos)?



Cheung, Hall, Pinner, Ruderman [arXiv:1211.4873]

Legacy of the LHC:

We need to make more of the collected data.
Ongoing discussing of presentation of results,
reproducibility to (eventually) sharing of data



plot from arXiv:1010.2506v1

Rules of thumb

1) Increase collider energy by **X**
   & increase luminosity by **X^2**

→ **reach goes up by X**

* for m/√s between 0.15 … 0.6

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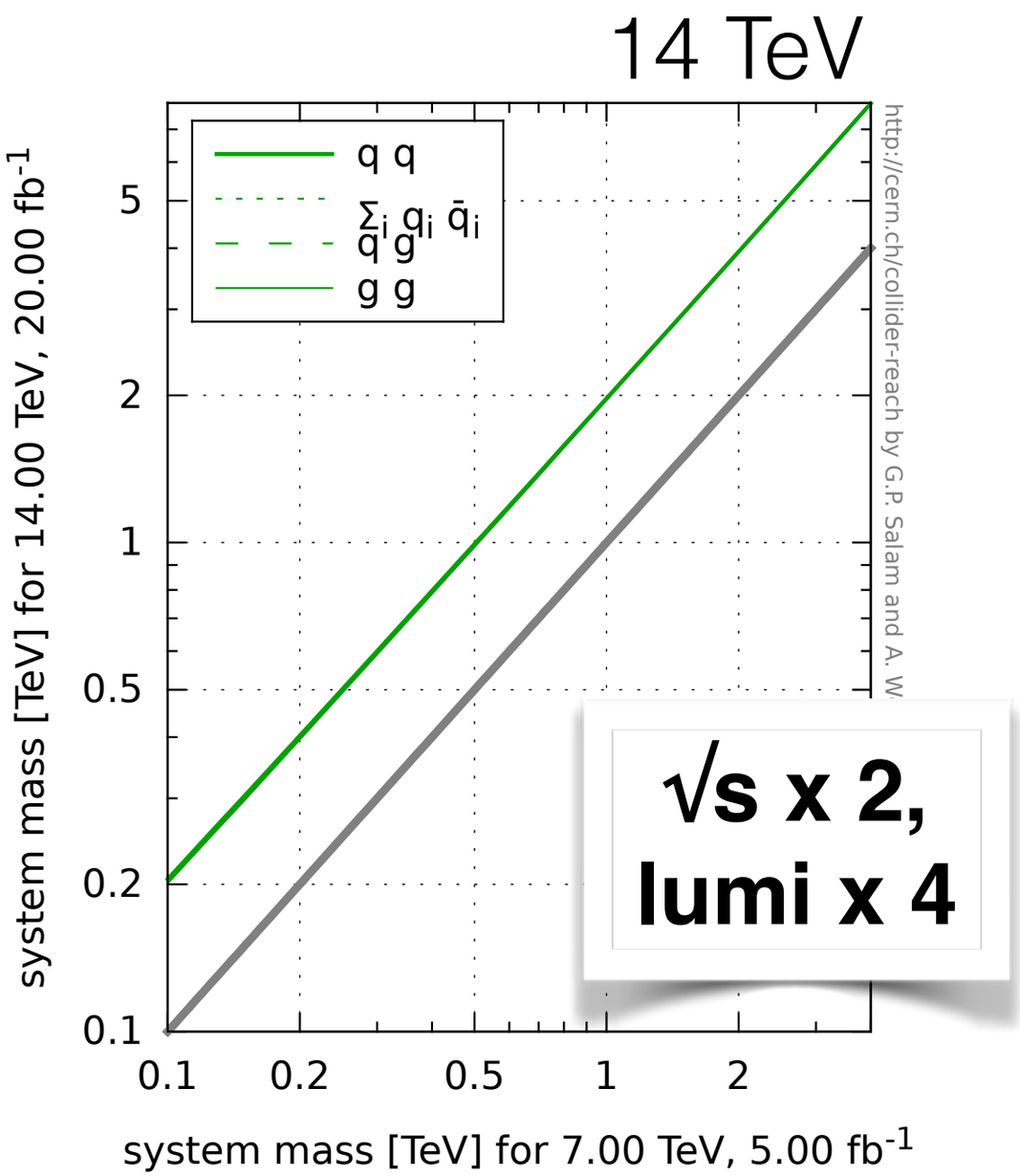

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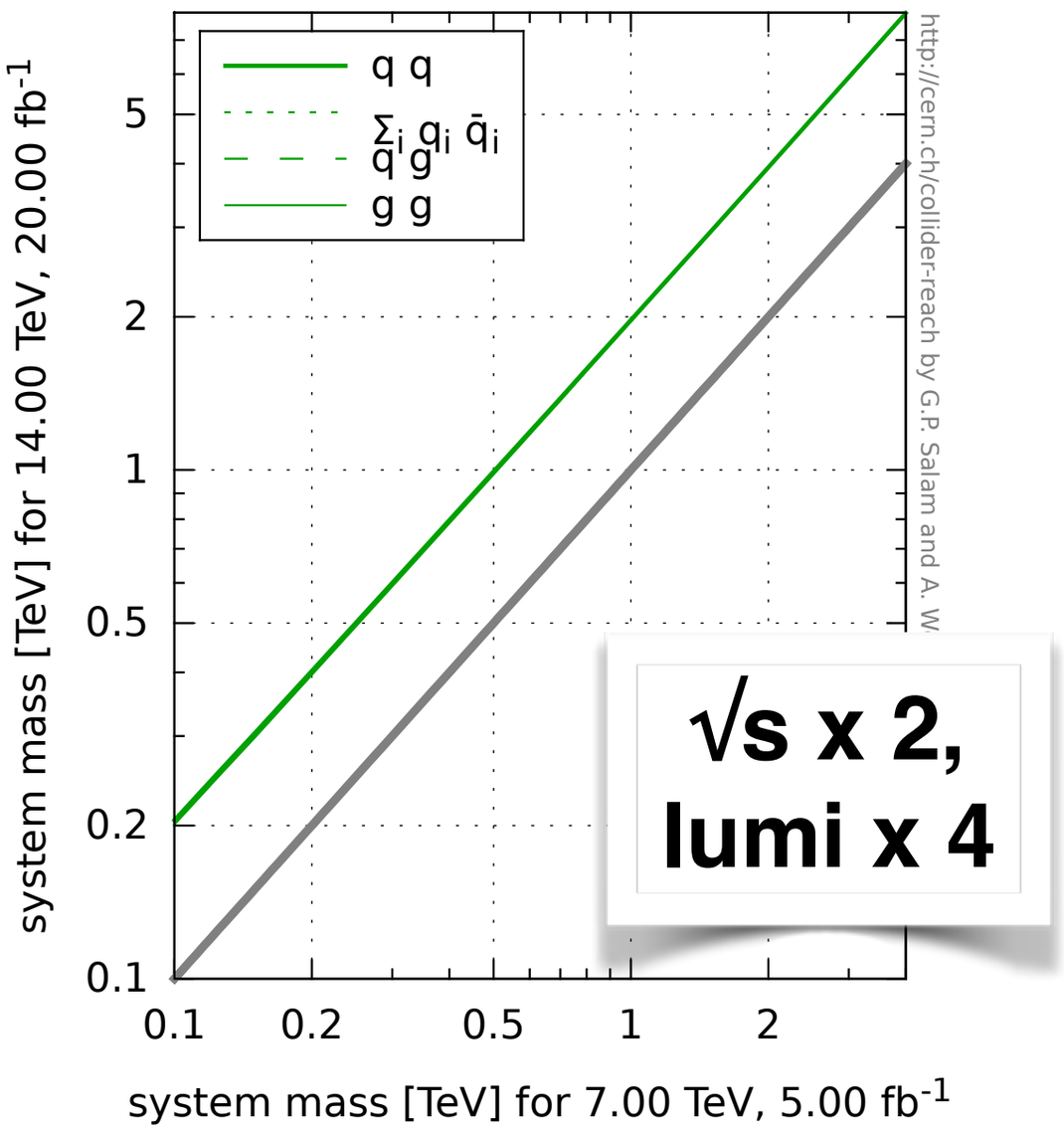
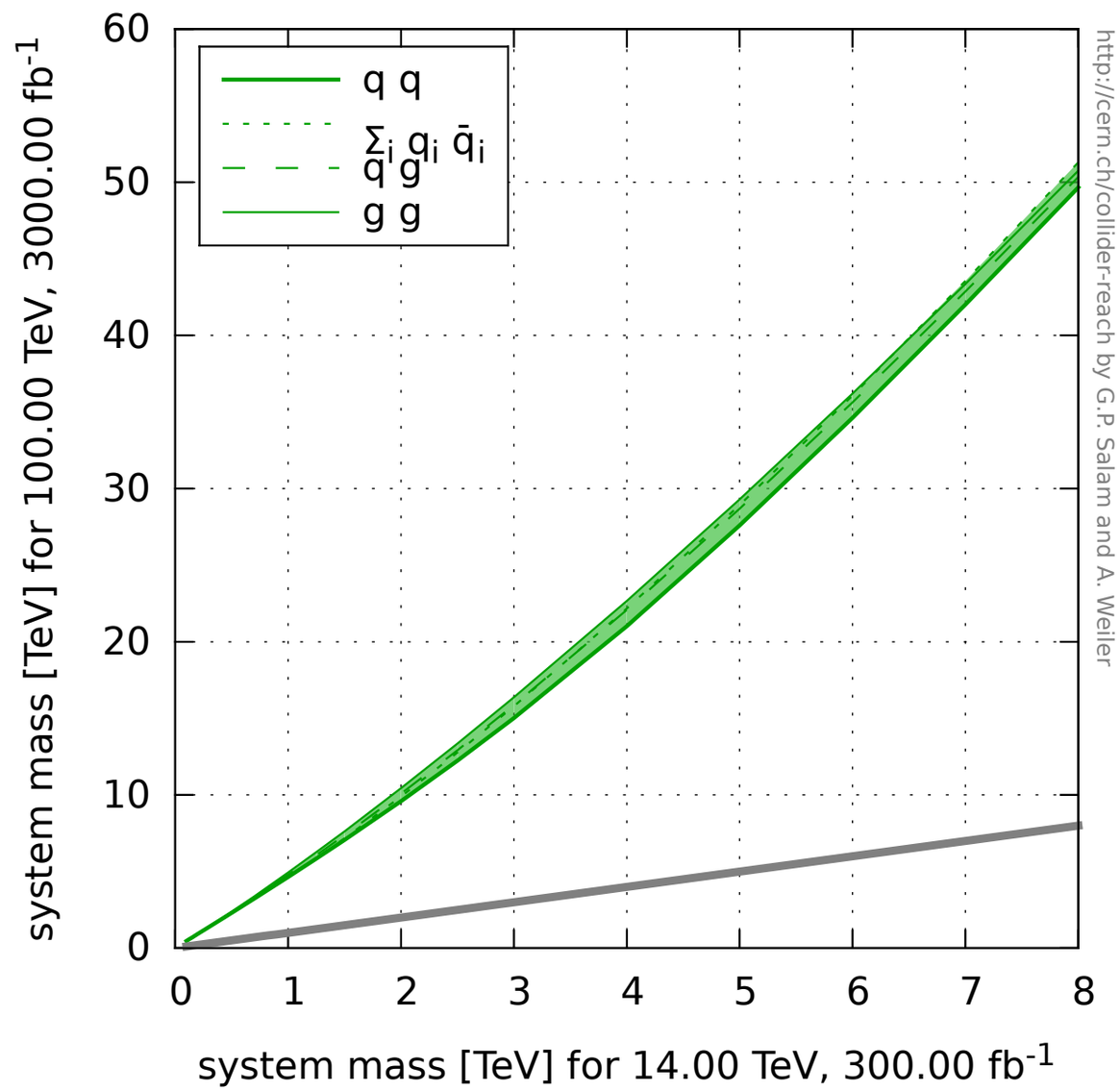
14 TeV



√s x 2, lumi x 4

100 TeV



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→ **reach increases*** **by constant $\Delta m \simeq 0.07\sqrt{s}$**

$\simeq$ 1 TeV_{LHC14}

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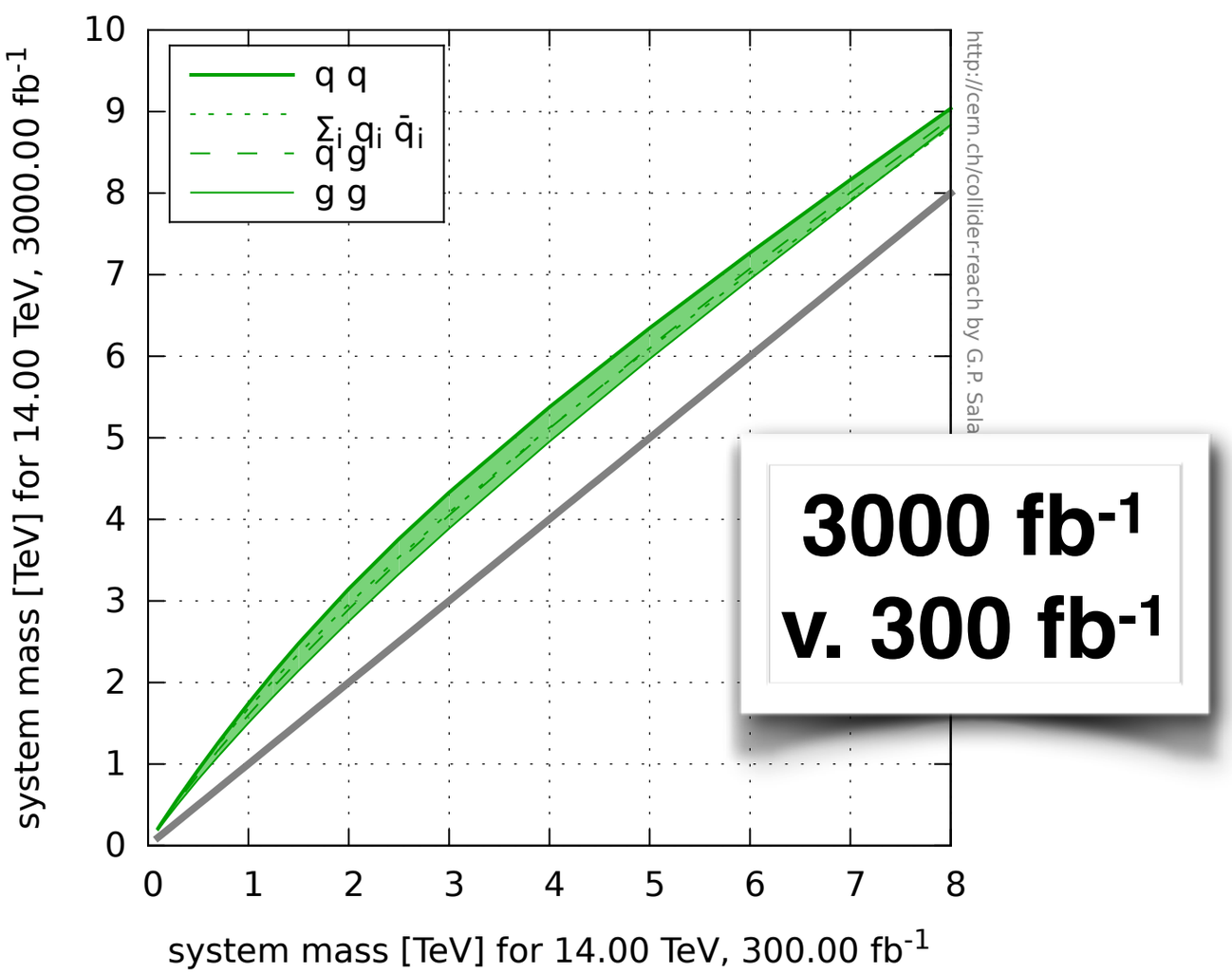


HL - LHC

* for m/√s between 0.15 … 0.6

Design study for Future Circular Colliders

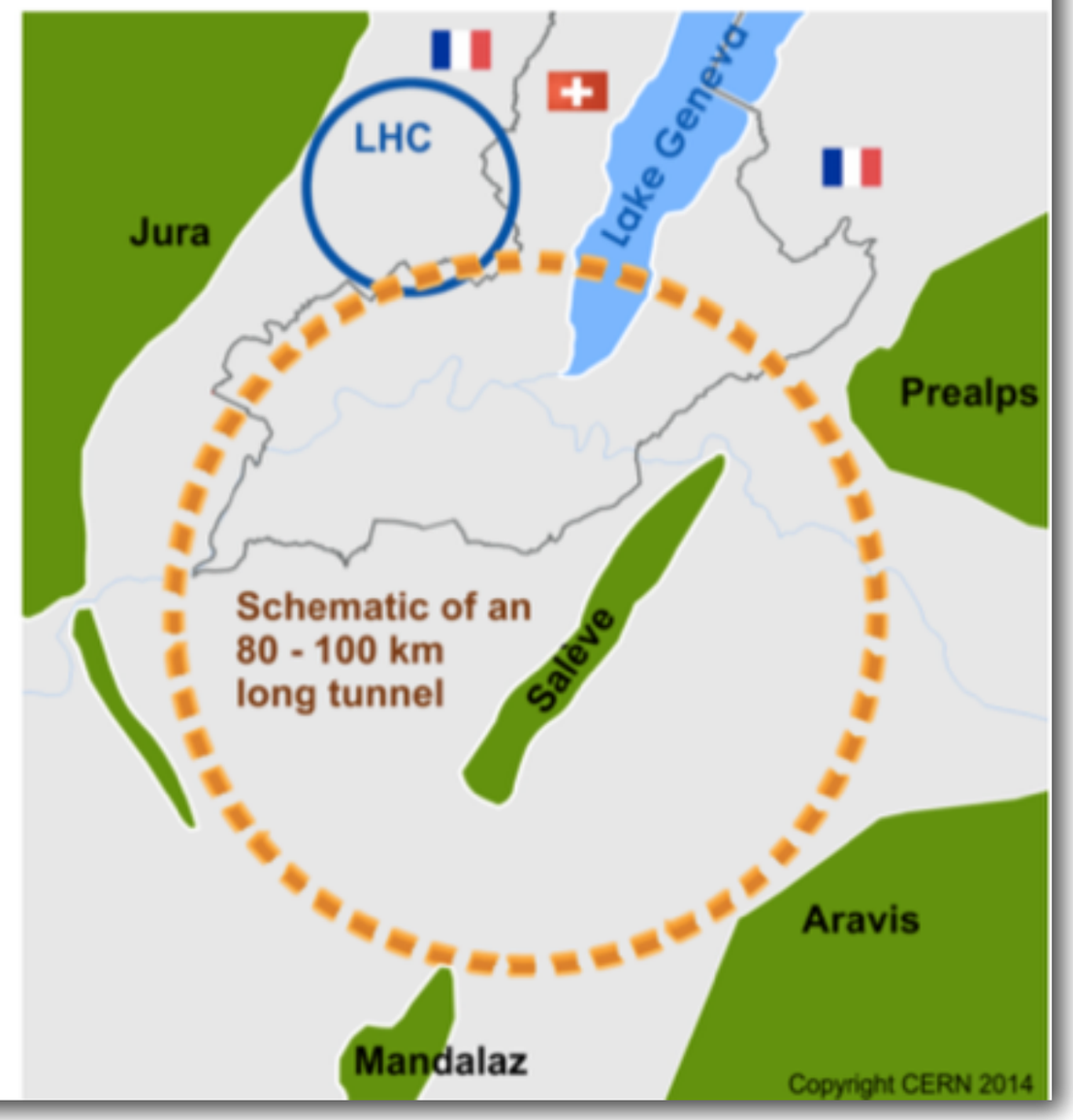
https://espace2013.cern.ch/fcc/

Forming an international collaboration to study:

- ***pp*-collider (*FCC-hh*)**
  → defining infrastructure requirements

  ~16 T ⇒ 100 TeV *pp* in 100 km
  ~20 T ⇒ 100 TeV *pp* in 80 km

- **e^+e^- collider (*FCC-ee*)** as potential intermediate step
- ***p-e* (*FCC-he*) option**
- **80-100 km infrastructure** in Geneva area



M.L.Mangano

Andreas Weiler (CERN/DESY)

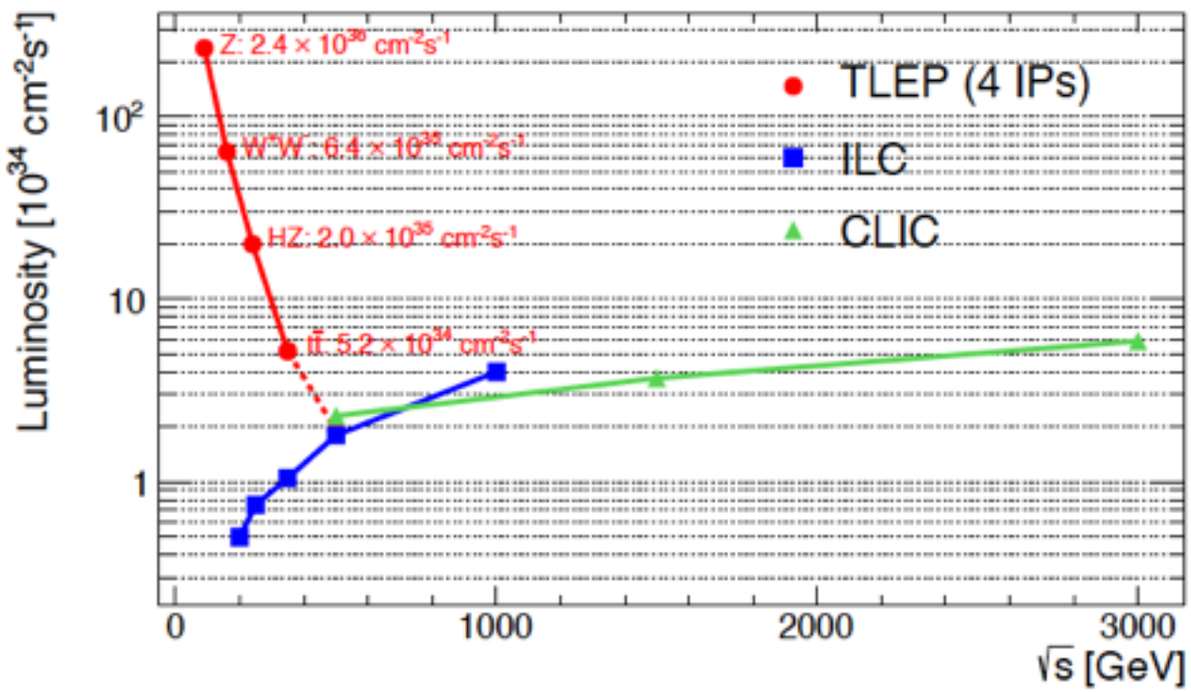
Future Circular Collider at CERN

- **Goal of this effort:** Conceptual design report (CDR) and first cost estimate ready for the next Strategy Group assessment (~2018)
- **Likely next step:** Commission a full technical design report (TDR), ready for the following Strategy Group assessment (~2024)
- **Plausible next step at 2024 Strategy Review:** Review TDR and updated cost estimate, in view of LHC14@300fb^{-1} results and more. Recommend CERN Council to approve, abort, or postpone.

==> we have ~10 years to articulate the physics case, focusing on the physics discussion and on the study of LHC results

M.L.Mangano

FCC-ee



precision & luminosity

Quantity	Physics	Present precision		TLEP Stat errors	Possible TLEP Syst. Errors	TLEP key	Challenge
M_Z (keV)	Input	91187500 ±2100	Z Line shape scan	5 keV	<100 keV	E_cal	QED corrections
Γ_Z (keV)	$\Delta\rho$ (T) (no $\Delta\alpha$!)	2495200 ±2300	Z Line shape scan	8 keV	<100 keV	E_cal	QED corrections
R_ℓ	α_s, δ_b	20.767 ± 0.025	Z Peak	0.0001	<0.001	Statistics	QED corrections
N_ν	PMNS Unitarity sterile ν's	2.984 ±0.008	Z Peak	0.00008	<0.004		Bhabha scat.
N_ν	PMNS Unitarity sterile ν's	2.92 ±0.05	(γ+Z_inv) (γ+Z→ ll)	0.001 (161 GeV)	<0.001	Statistics	
R	δ	0.21629	Z Peak	0.000003	<0.000060	Statistics,	Hemisphere

Andreas Weiler (CERN/DESY)

3 questions

- What can be discovered at HL-LHC which isn't already constrained by $LHC14_{300\ 1/fb}$?
- If we haven’t seen something at 14 TeV, why should it show up at 100 (10^6) TeV? Next no-loose scale?
- Why have I agreed to talk about this?

Points from Pekka Sinervo

We should collectively take at least a "glass half-full" approach to the next decade. Naturalness as a principle is under stress, and the LHC will either find evidence to support it or place even more stress on that principle. This will be progress.

The best part of the Naturalness principle is that it provides a framework to look for new phenomena. I'll be surprised, however, if what we discover has a model built for it. Examples in the past support this: the discovery of charm, the tau lepton, beauty, B oscillations were all serendipity at some level.

One approach we didn't talk about a great deal was to use specific models to motivate more generic, model-independent searches. That may be a more effective way to make progress. Searches require well-posed models, but a single search can be made to work for multiple models (the searches using dijet mass and angular distributions are an example of that).

We do have some more work to do collectively. We should continue to work on developing stronger engagement between theory and experiment. The Higgs discovery and the effective way we have been able to marshall the resources of the field to make very rapid progress on it is reflective of that collaboration. That said, many of us personally know how difficult it is to get meaningful engagement. I believe it will require continued efforts to bring experimentalists and theorists together, in ways that are reflected in Naturalness 2014.

Many thanks to the organizers for a very stimulating, fun workshop.

Messages

Lian Tao Wang, Chicago

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- Naturalness will be with us in the deep future.
  - I hope it will stop at some time, either vindicated by discoveries or we find better topic to work on.

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- LHC run 2 will not be conclusive (assuming no discovery).
- Need to go beyond, and there is hope.
  - Higgs factories (up to TeV(s) NP, cover gaps)
  - 100 TeV pp collider (5-7 increase in mass reach, 2 order of magnitude in tuning)

Main parameters of CEPC at 50km

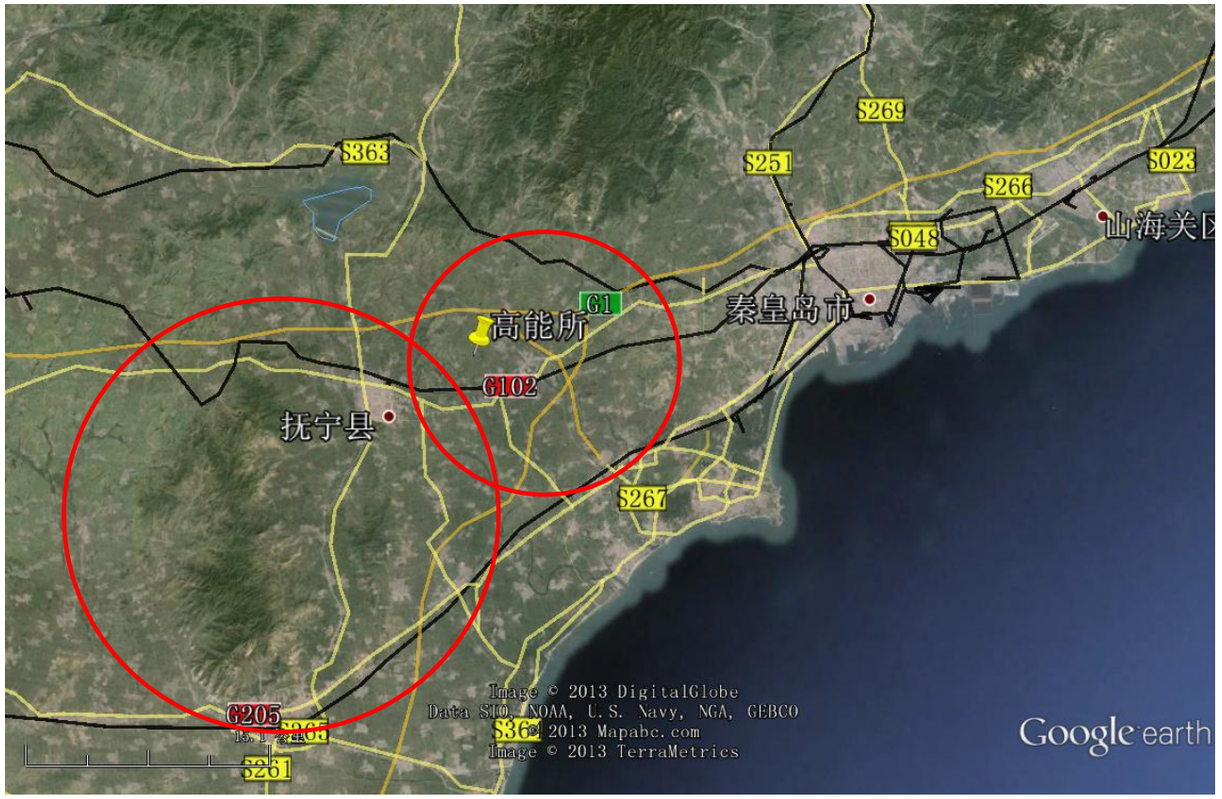
Parameter	Unit	Value	Parameter	Unit	Value
Bean Energy	GeV	120	Circumference	km	50
Number of IP		2	L_0 /IP (10^{34})	$cm^{-2}s^{-1}$	2.62
No. of Higgs/year/IP		1E+05	Power(wall)	MW	200
e+ polarization		0	e- polarization		0
Bending radius	km	6.2	N_e/bunch	1E10	35.2
N_b/beam		50	Beam current	mA	16.9
SR loss	(GeV/turn)	2.96	SR power/beam	MW	50
Critical energy of SR	MeV	0.6	ε_x,n	mm-mrad	1.57E+06
ε_y,n	mm-mrad	7.75E+03	β_{IP} (x/y)	mm	200/1
Trans. size (x/y)	μm	36.6/0.18	Bunch length	mm	3
Energy spread SR	%	0.13	Full crossing angle	mrad	0
Lifetime due to Bhabha	sec	930	Damping part. No. (x/y/z)		1/1/2
b-b tune shift x/y		0.1/0.1	Syn. Osci. tune		0.13
RF voltage V_{rf}	GV	4.2	Mom. compaction	1E-4	0.4
Long. Damping time	turns	40.5	Ave. No. of photons		0.59
dB beam-beam	%	0.014			

LianTao Wang, Chicago

Main Parameters of SppC

Parameter	SppC-1	SppC-2
Beam energy (TeV)	25	45
Circumference (km)	49.78	69.88
Number of IPs	2	2
SR loss/turn (keV)	440	4090
N_p/bunch (10^{11})	1.3	0.98
Bunch number	3000	6000
Beam current (mA)	0.5	0.405
SR power /ring (MW)	0.22	1.66
B_0 (T)	12	19.24
Bending radius (km)	6.9	7.8
Momentum compaction (10^{-4})	3.5	2.5
β_{IP} x/y (m)	0.1/0.1	0.1/0.1
Norm. trans. emit. x/y (μm·rad)	4	3
ξ_y/IP	0.004	0.004
Geo. luminosity reduction factor F	0.8	0.9
Luminosity /IP ($10^{35}cm^{-2}s^{-1}$)	2.15	2.85

The circle is on the map

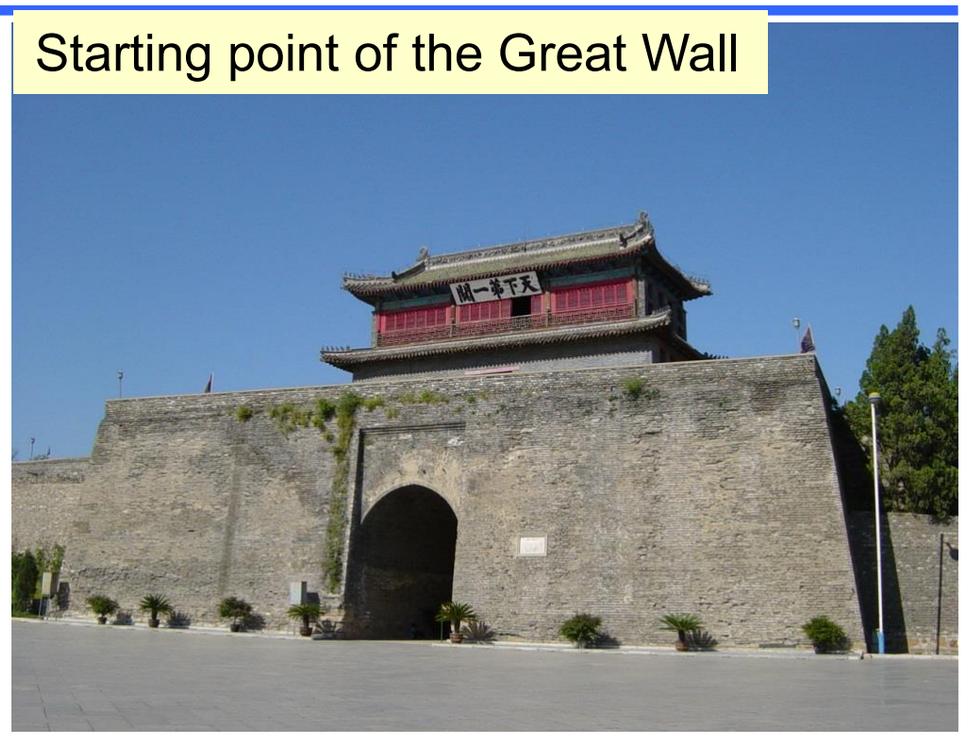


- A likely site: QinHuangDao (秦皇岛), 300 km from Beijing, 1hr by train.
- Good geological condition.
- Strong local support. Thinking about building a science city around it.

Beautiful Place for a Science Center

Best beach & cleanest air
Summer capital of China

Starting point of the Great Wall



Wine yard

LianTao Wang, Chicago

In the last 2 years

- Started "talking about it" in 2012.
- Things are happening fast since then
  - Several meetings, workshops.
  - Working groups, studies being organized in China.
  - Established Center for Future High Energy Physics (CFHEP): international collaboration in the study of physics case.
  - Broad conversation happening within Chinese physics community.
- PreCDR by the end of this year.
- R/D money decision to be made (likely) in 2015.

The Chinese Dream

- **CPEC**
  - Pre-study, R&D and preparation work
    - Pre-study: 2013-15
      - **Pre-CDR by the end of 2014 for R&D funding request**
    - R&D: 2016-2020
    - Engineering Design: 2015-2020
  - Construction: 2021-2027
  - Data taking: 2028-2035
- **SppC**
  - Pre-study, R&D and preparation work
    - Pre-study: 2013-2020
    - R&D: 2020-2030
    - Engineering Design: 2030-2035
  - Construction: 2035-2042
  - Data taking: 2042 -

Yifang Wang at FCC kick off meeting

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  - Tuned but not too tuned? Landscape, selection?

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  - But, it will certainly guide us to think differently.
  - Is this the "ether problem" of our time?

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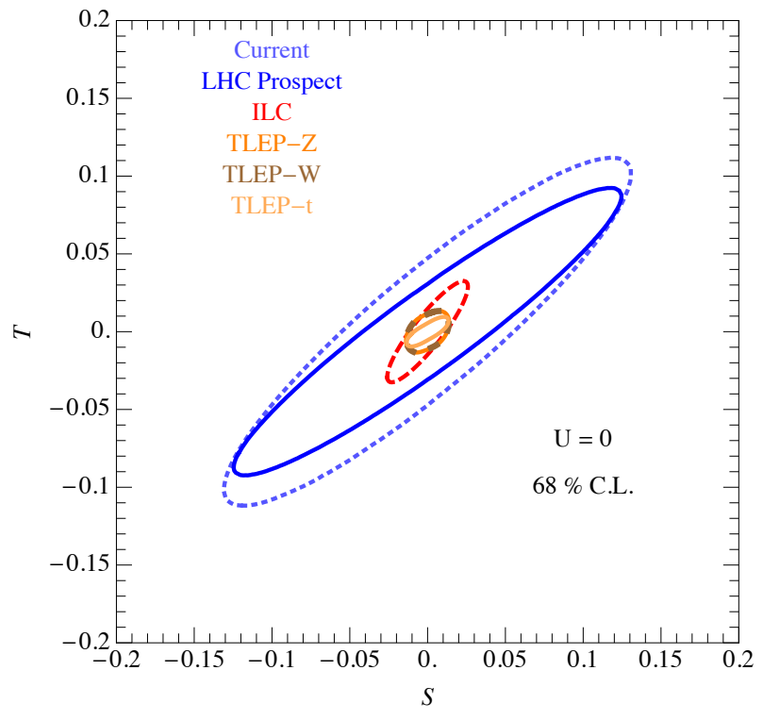
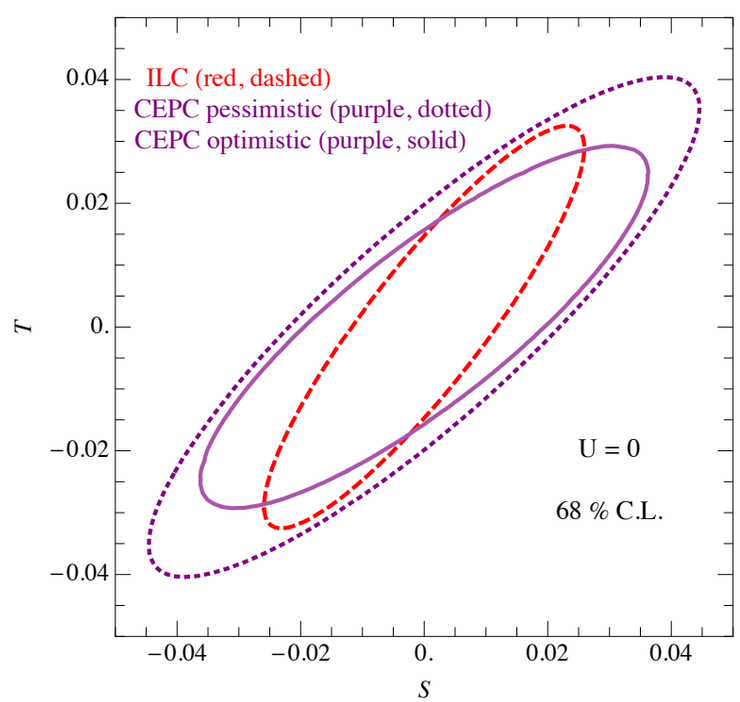
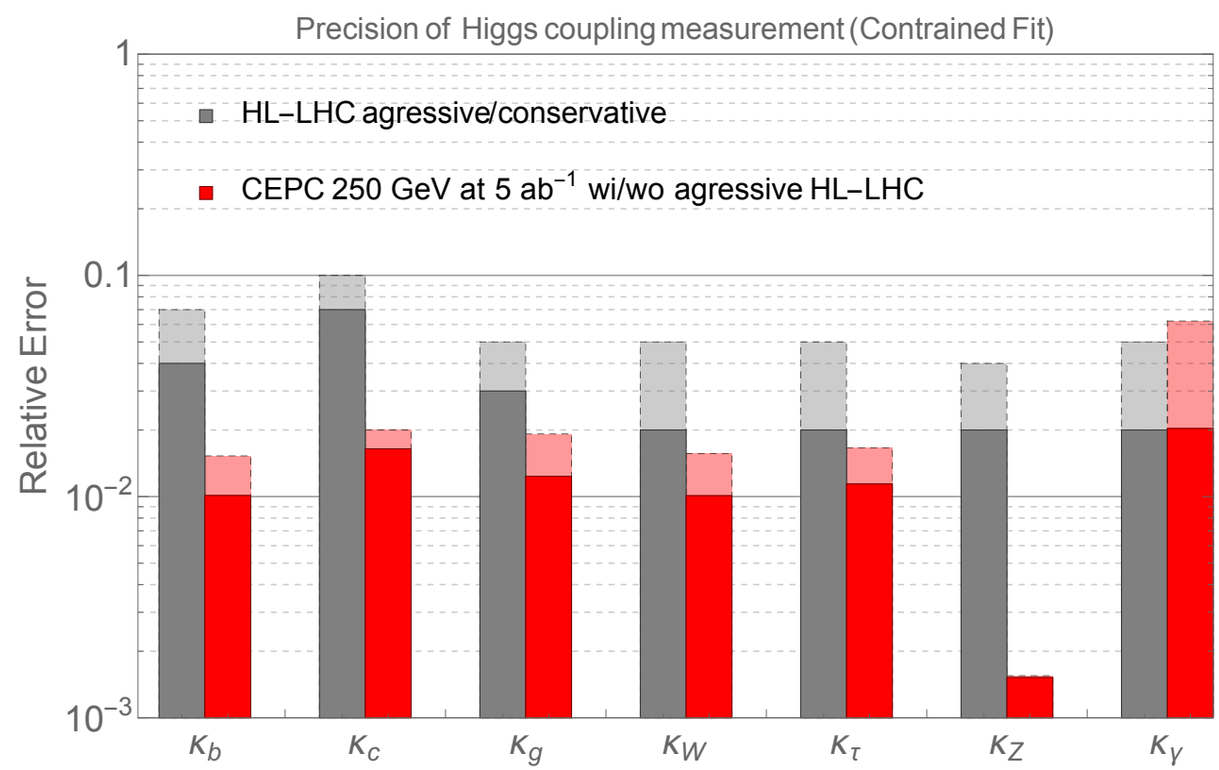
  - But, it will certainly guide us to think differently.
  - Is this the "ether problem" of our time?
- Are we missing some new strategies to experimentally probing naturalness?

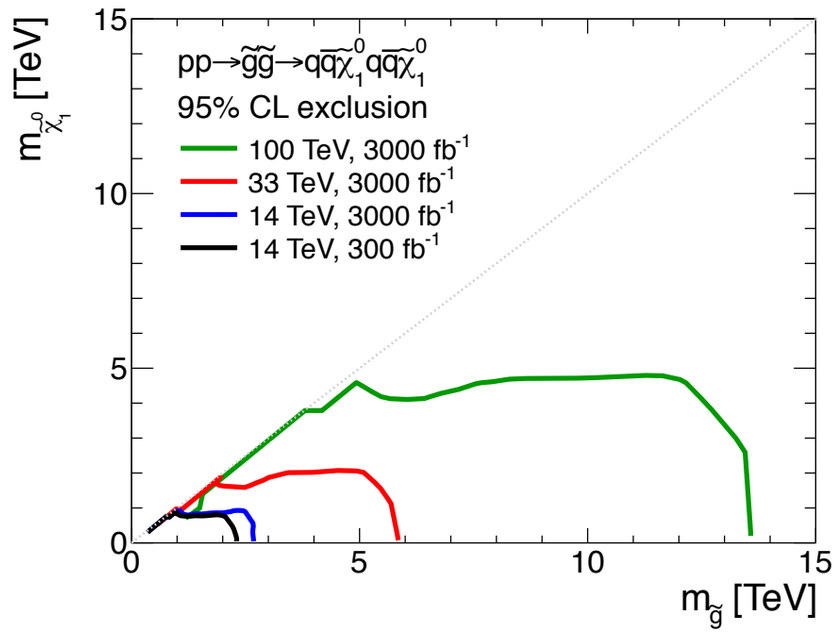
extras


Current
LHC Prospect
ILC
TLEP−Z
TLEP−W
TLEP−t
U = 0
68 % C.L.
T
S

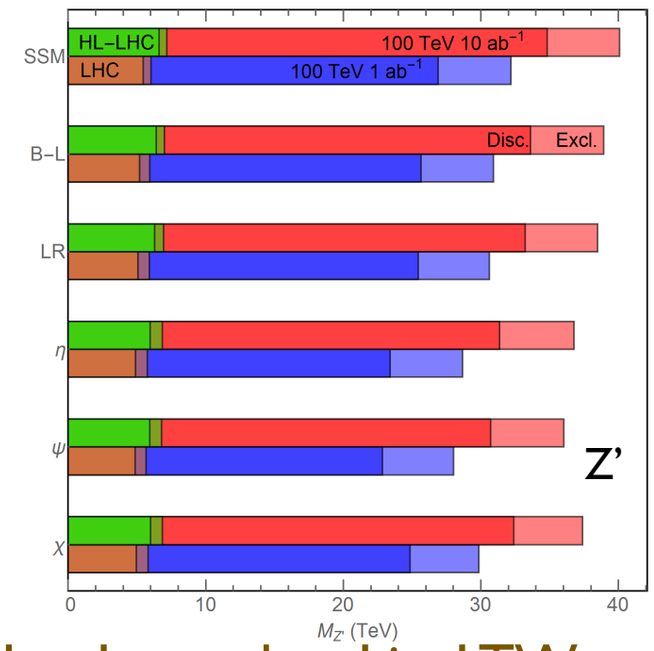

ILC (red, dashed)
CEPC pessimistic (purple, dotted)
CEPC optimistic (purple, solid)
U = 0
68 % C.L.
T
S


Precision of Higgs coupling measurement (Contrained Fit)
HL−LHC agressive/conservative
CEPC 250 GeV at 5 ab^{-1} wi/wo agressive HL−LHC
Relative Error
κ_b
κ_c
κ_g
κ_W
κ_τ
κ_Z
κ_γ

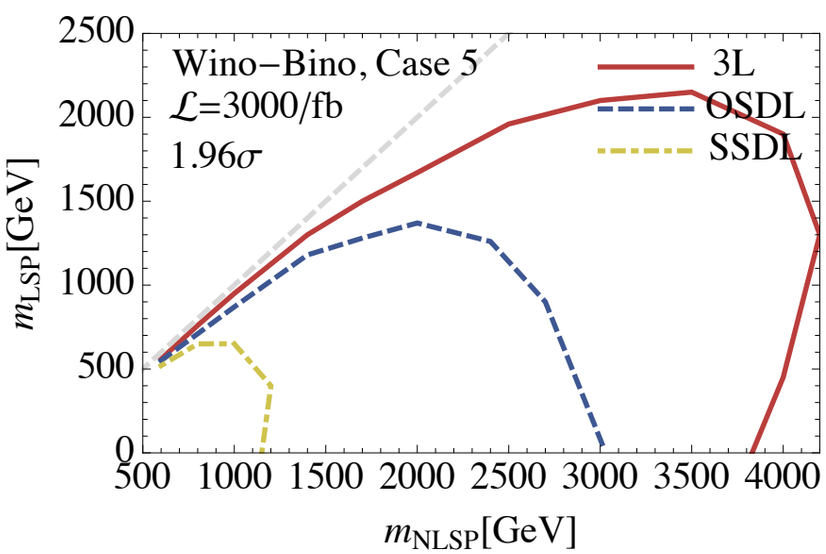
Big step forward



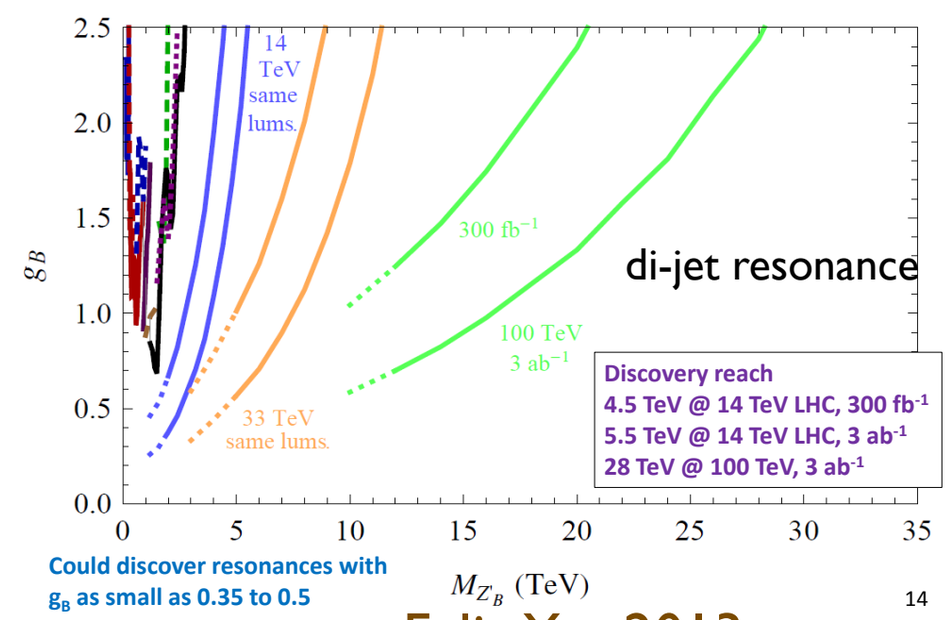
Cohen et al, 2013



Han, Langacker, Liu, LTW, to appear



Gori, Jung, LTW, Wells, 2014



Felix Yu, 2013

cross the board: x 5(more) improvement, into (10)TeV regime