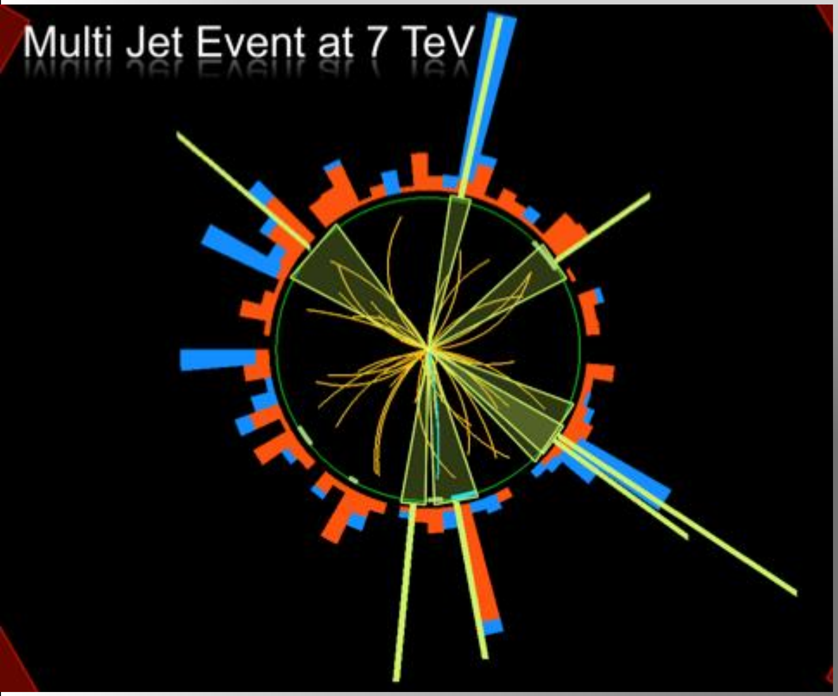
FCC-hh Physics

Albert De Roeck, CERN

FCC Mini-workshop
Istanbul
11-12 March 2016

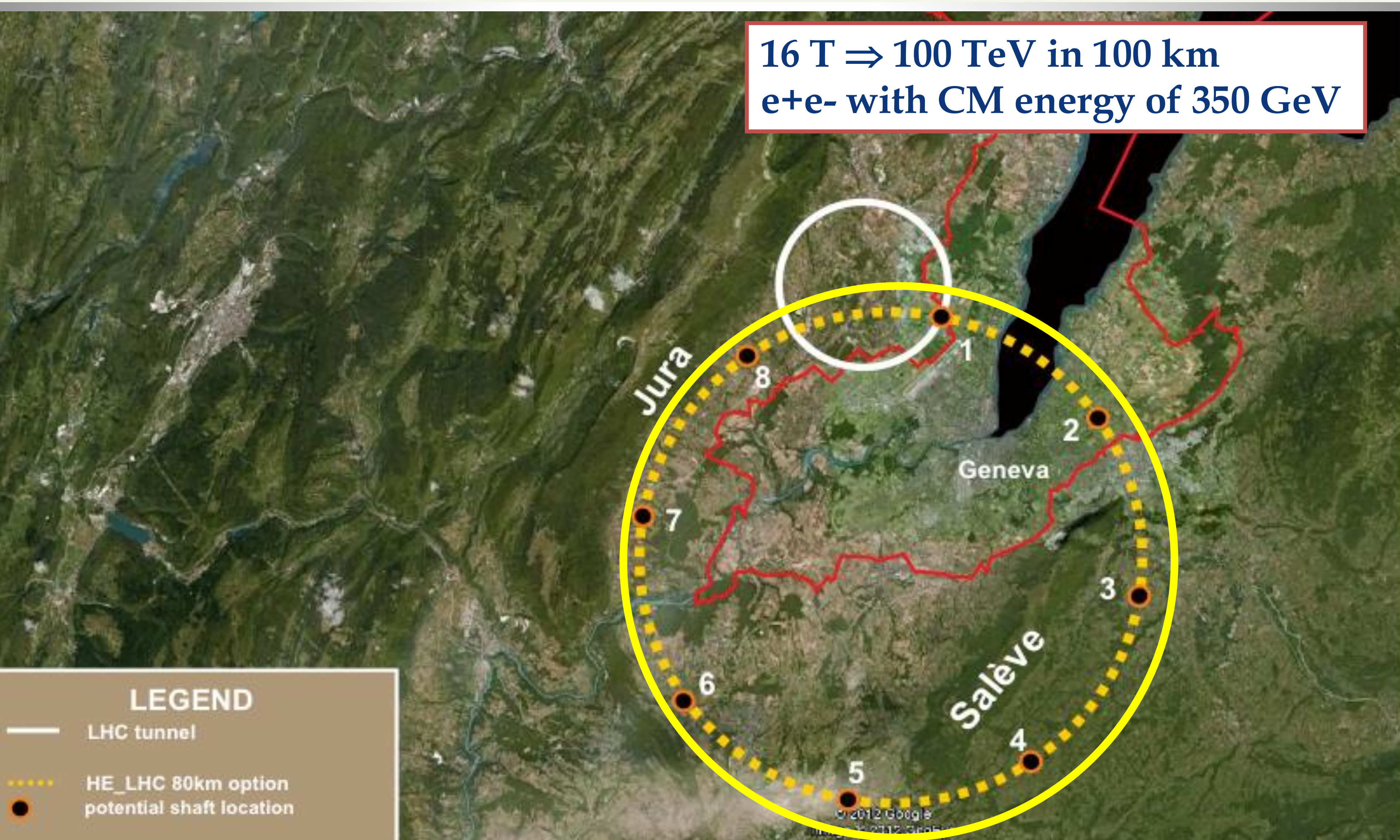


Outline

- Introduction: Experimental conditions at the FCC-hh
- Searches for massive particles
- The Higgs
- Dark Matter
- Precision measurements
- Conclusion

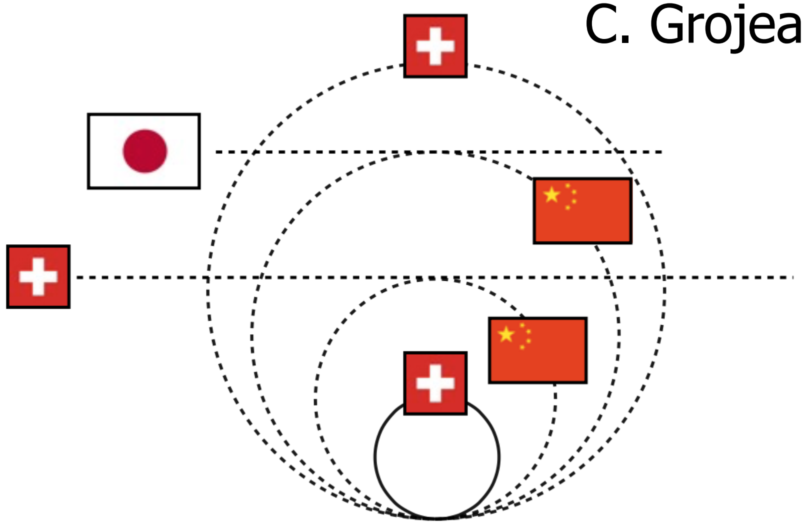
100 km tunnel infrastructure in Geneva area – design driven by pp-collider requirements

with possibility of e^+-e^- and p-e

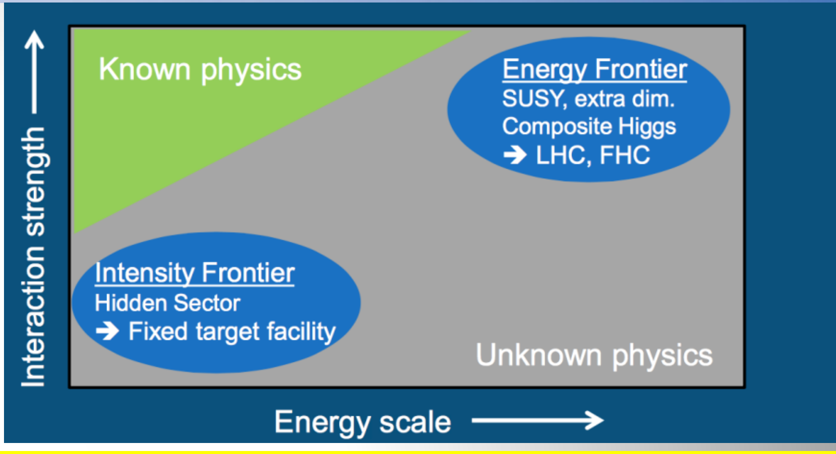


Future Colliders?

C. Grojean



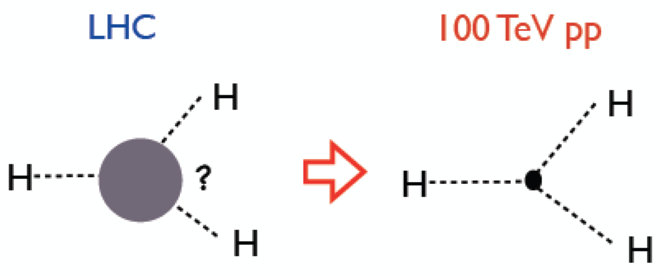
Theorist view on future colliders



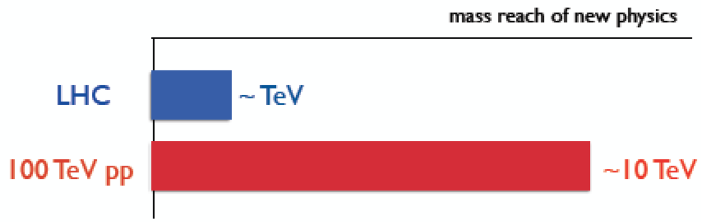
FCC-hh: THE machine for direct search at the higher energy scale.

FCC-hh main themes:

The study of the Higgs Boson(s)



The search for massive new physics



FCC-hh: A New Frontier

- LHC has shown that the hadron colliders can lead to precision measurements despite high pile-up, hadron structure, underlying event, etc.
- FCC-hh will above all be a machine for high event rates and has a high mass reach for searches
- Complementarity with future e+e- machines, circular or linear that may happen before a new hadron collider
- Studies for the physics case for the FCC-hh started in 2014. Mostly theory/phenomenology studies. Lots of room for especially more experimental contributions
- No no-loose theorem as such yet
- Document before the next strategy meeting in 2018-2019

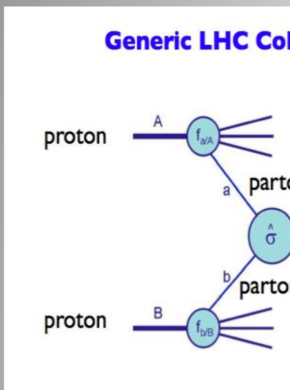
Physics Opportunities of a 100 TeV Proton-Proton Collider

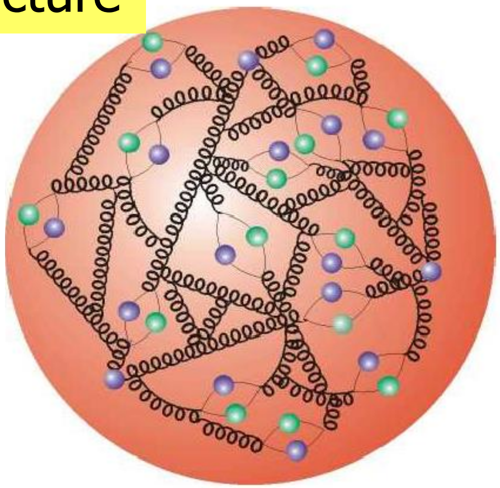
Nima Arkani-Hamed[a], Tao Han[b], Michelangelo Mangano[c], Lian-Tao Wang[d]

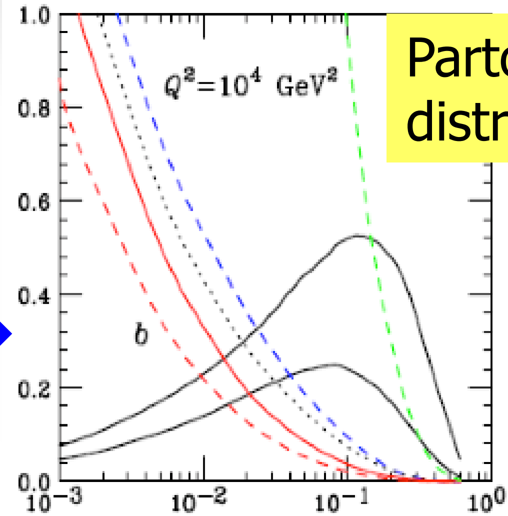
A recent review paper arXiv:1511.06495

pp Collisions : Complications

Protons have structure



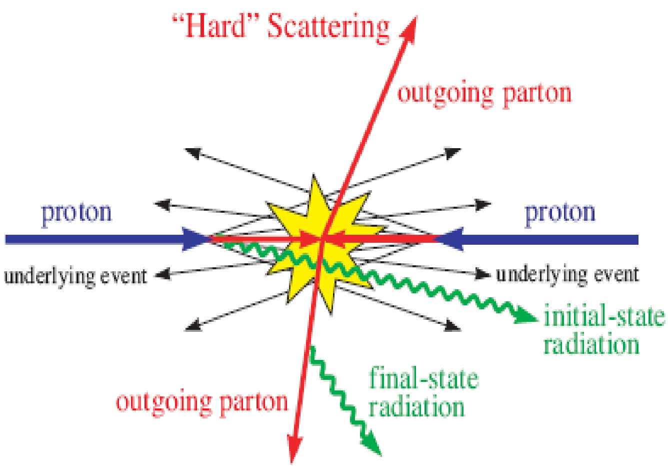




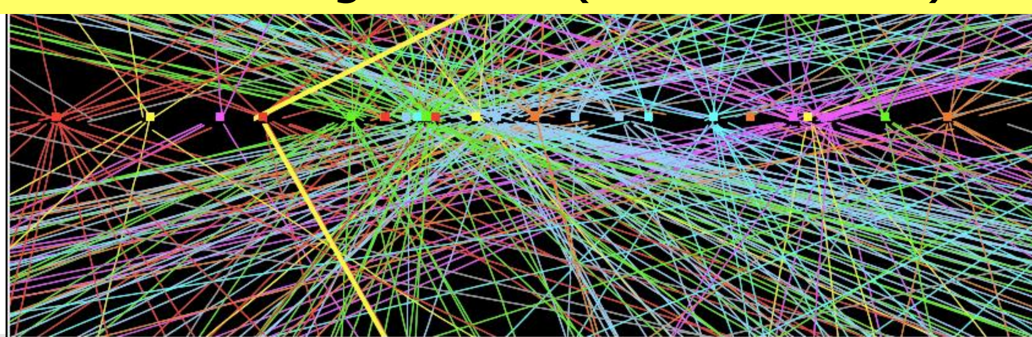
Parton distributions

$$\sigma = \sum_{i,j} \int_0^1 dx_1\, dx_2\, f_i(x_1,\mu)\, f_j(x_2,\mu)\, \hat{\sigma}_{ij}$$

pp collisions have an underlying event

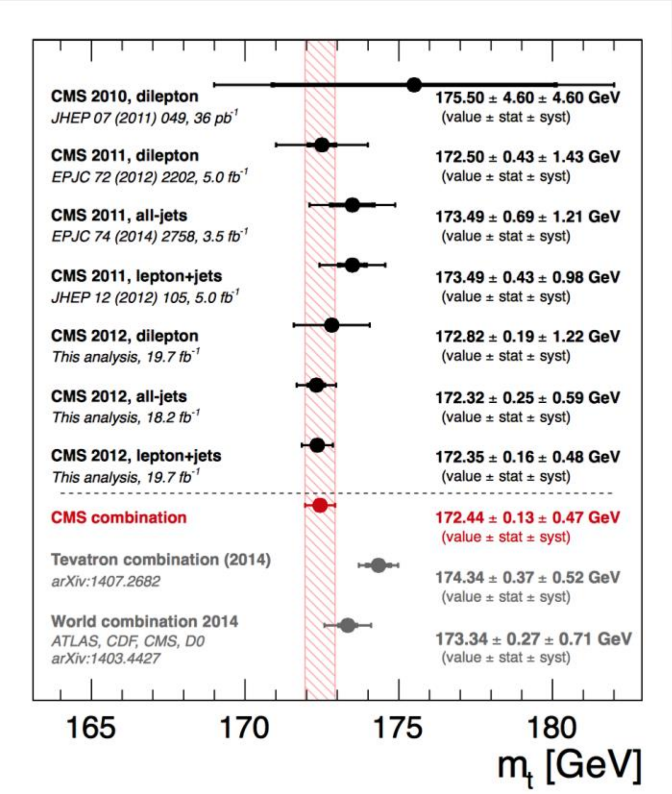


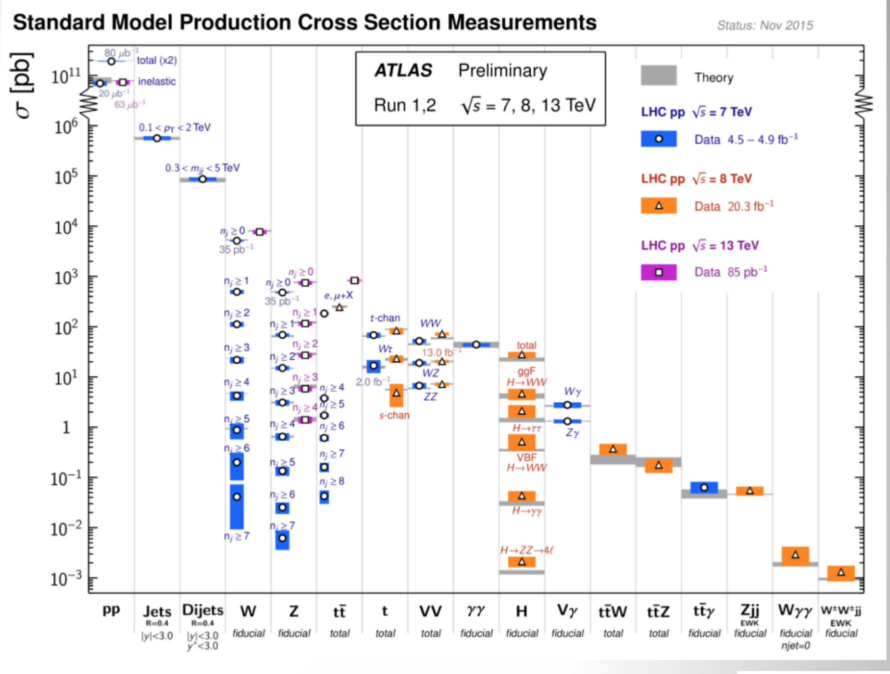
Pile-up@LHC approximate 20 collisions per bunch crossing in 2012 (more in future)

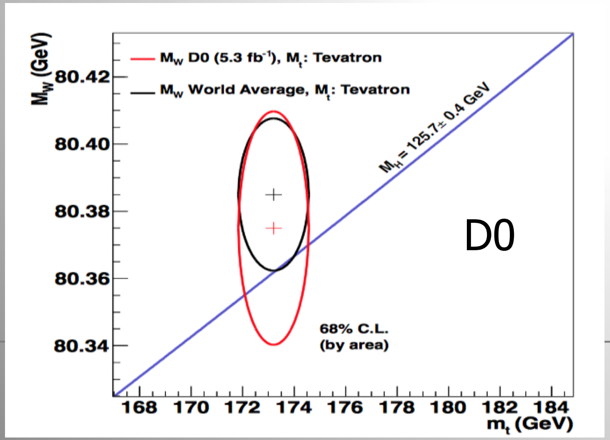


Z→ μμ event with ~20 reconstructed vertices (2012)

LHC & Tevatron: Precision is Possible







CMS/LHCb

$$\mathrm{BR}(B_s \to \mu\mu) = \left(3.0^{+0.9}_{-0.8}\ (\mathrm{stat})^{+0.6}_{-0.4}\ (\mathrm{syst})\right) \times 10^{-9}$$

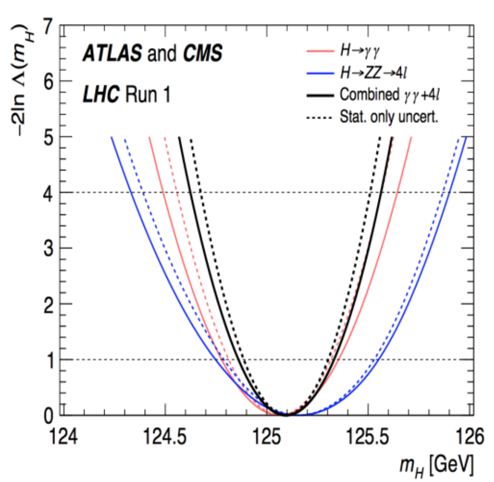
$$\mathrm{BR}(B_d \to \mu\mu) = \left(3.5^{+2.1}_{-1.8}\ (\mathrm{stat{+}syst})\right) \times 10^{-10}$$

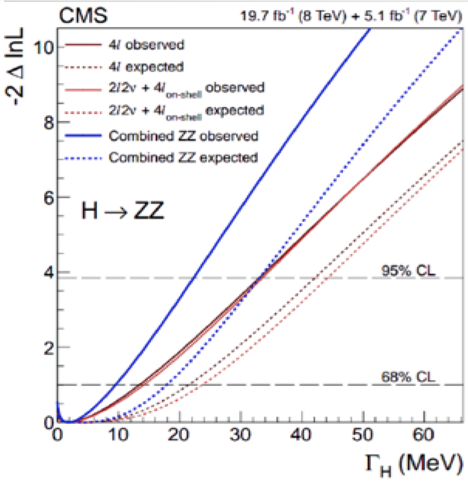
We learned a lot from the Tevatron and in particular from the LHC

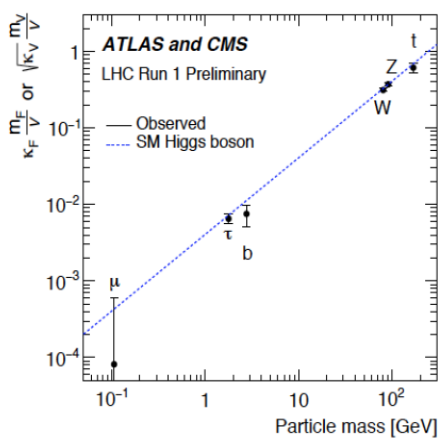
We Found a Higgs Particle @ the LHC

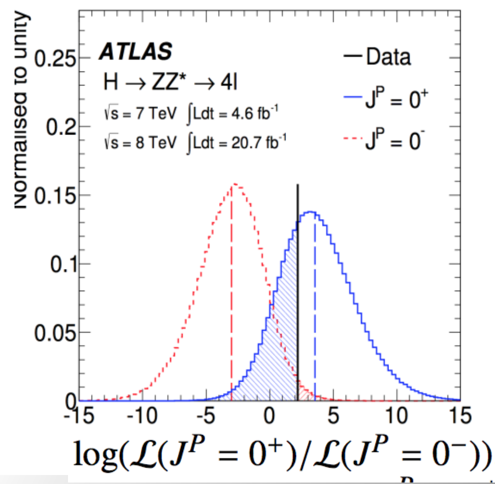
We know already a lot on this Brand New Higgs Particle!!

CMS: PAS-HIG-15-002
ATLAS-CONF-2015-044









Mass = CMS+ATLAS
125.09 ±0.21(stat)
±0.11(syst) GeV

Width =
A: < 24 MeV
C: < 22 MeV
(95%CL)

Couplings are within 15-20% of the SM values

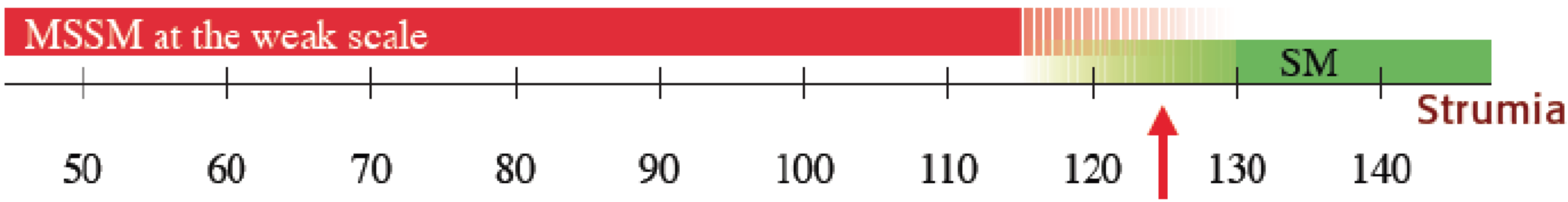
Spin = $0^{+(+)}$ preferred over 0^-,1,2

SM-like behaviour for most properties, but continue to look for anomalies, i.e. unexpected decay modes or couplings, multi-Higgs production…

A Higgs @ 125 GeV…

A malicious choice!

m_H = 125.0 +/- 0.2 GeV



The Higgs: so simple yet so unnatural

Guido Altarelli
1941-2015

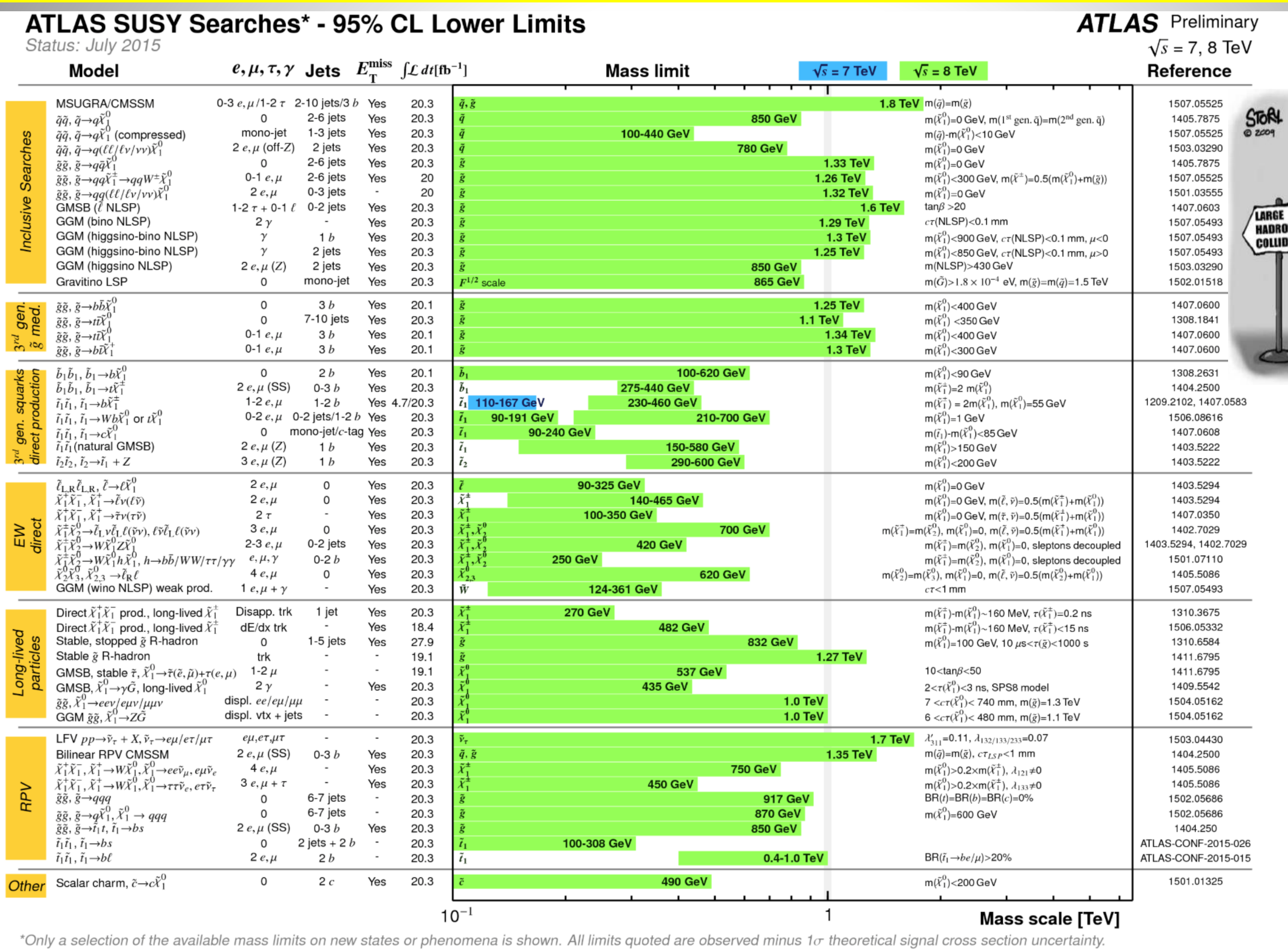
Stockholm Nobel Symposium
May 2013

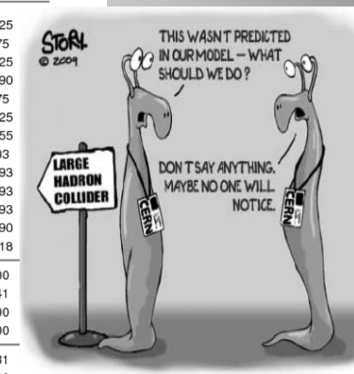
"We do not understand why the mass of the Higgs is 125 GeV
It most likely tells us something on what is Beyond the Standard Model"

A light Higgs is "unnatural" and calls for physics beyond the SM

But where is everybody?

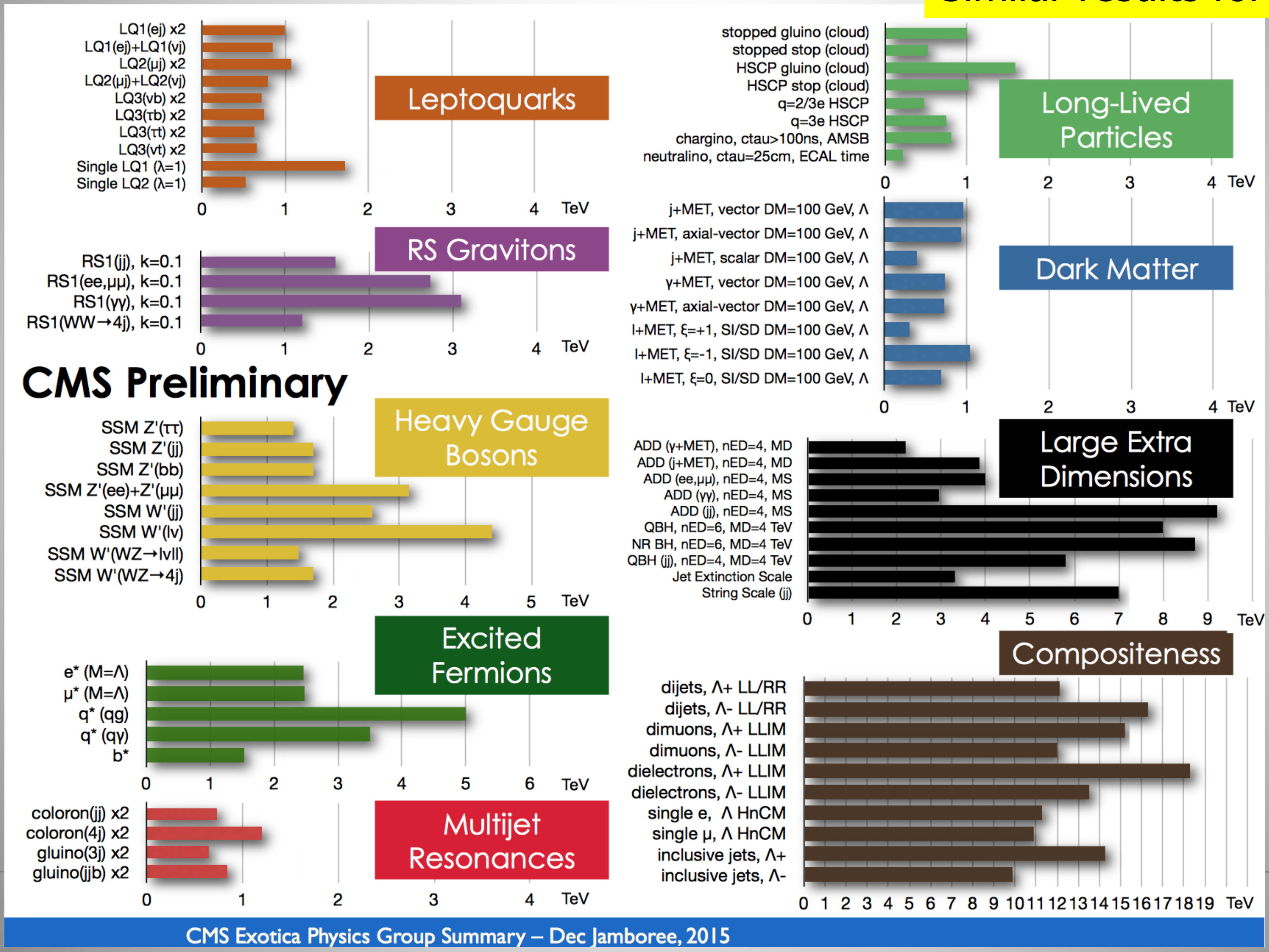
Eg: NO clear sign of SUSY with the data collected in run-I (similar plot for CMS)





Summary of Run-I Exotica Searches

Similar results for ATLAS



Perhaps Something on the Horizon??

New Scientist of 3rd March 2016

New Scientist

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FEATURE 2 March 2016

Bigger than the Higgs, bigger even than gravitational waves…

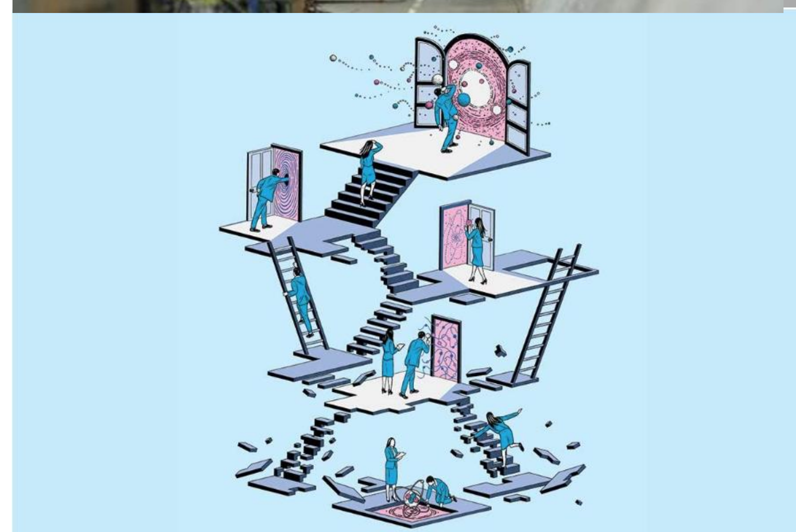
It looks like the LHC may have found a surprise massive particle that gives a glimpse into a better – and entirely unexpected – theory of reality

IF IT is anything, it is what Gian Giudice has been waiting for his entire scientific life. "We are not talking about a confirmation of an established theory, but about opening a door into an unknown and unexplored world," says Giudice, a theoretical particle physicist based at CERN near Geneva, Switzerland.

That's if it turns out to be anything. At the moment, all we have are hints emerging from the debris of collisions within CERN's showpiece particle smasher, the Large Hadron Collider. But if those hints firm up in the course of the coming weeks and months, it could be the big one. Forget the Higgs, forget even gravitational waves: 2016 could go down as the year when a new picture of nature's fundamental workings was unveiled.

The hopes spring from two "bumps" that have appeared independently, in the same place, in the latest data from the LHC's two big detectors, ATLAS and CMS. They point to the existence of a particle that dwarfs even the Higgs boson, the giver-of-mass particle discovered at CERN in July 2012.

The Higgs was a milestone, but ultimately one that marked the end of a road. It was the last particle to be found of those predicted by the standard model of particle physics. This clutch of sophisticated equations matches every experimental result to date with exquisite precision, and explains the workings of three of the fundamental forces of nature: electromagnetism and the weak and strong nuclear forces ...

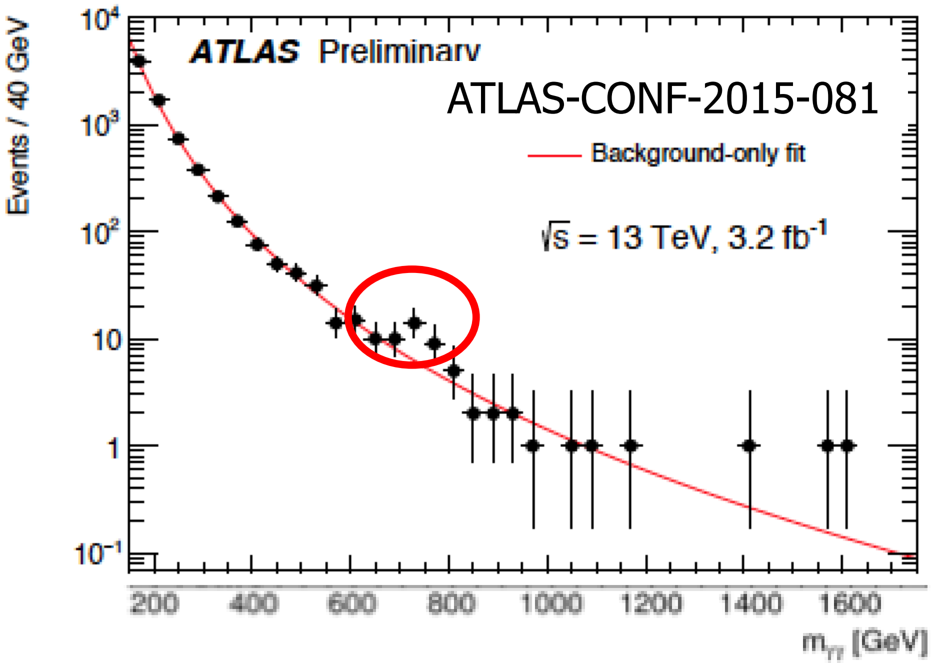


Has the LHC caught a glimpse of a new theory of reality?
Stuart Patience

High Mass Search: $X \rightarrow \gamma\gamma$???

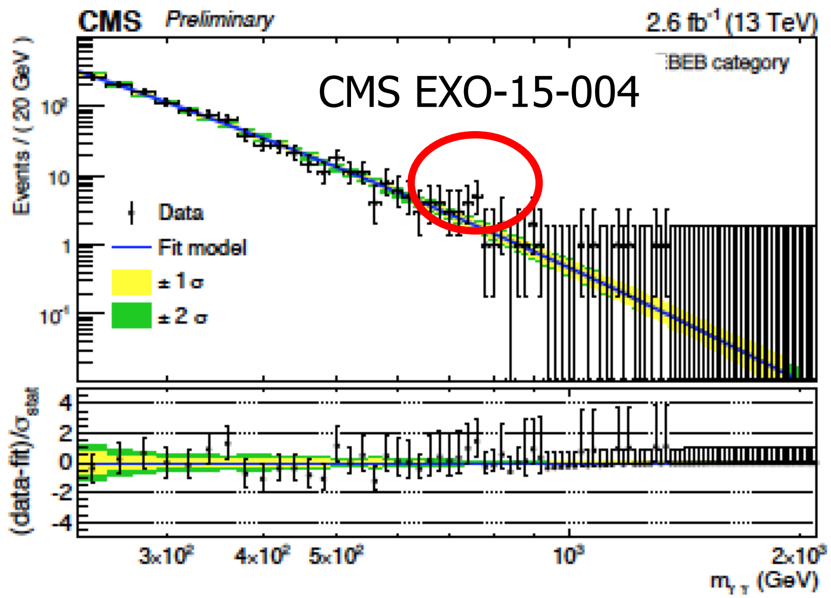
News from the 2015 data run in last December!!!
->Some excitement over and observed excess in both experiments for a di-photon mass of around 750 GeV

3.6σ -> 2.0σ (NWA)
3.9σ -> 2.3σ (Γ=45 GeV)



2.6σ -> $<1.2\sigma$ (1% width)

A totally unexpected new particle???



Statistical fluctuation? A new resonance? See ~ 250 papers from theorists on the arXiv since… Let's see with more data in 2016

The Next Future Facilities

The ultimate goal: answering the *big* open issues

M. Mangano

- **What's the origin of EW symmetry breaking? The solution to the hierarchy problem?**
- **What's the origin of matter/antimatter asymmetry in the universe?**
- **What's the origin of Dark matter / energy ?**
- **What's the origin of neutrino masses?**
- **What's the solution to the strong CP problem?**
- **....**

and continue pursuing the underlying assumptions:

- *are there additional fundamental forces, symmetries?*
- *are the known elementary particles truly elementary?*
  - *compositeness? strings?*
- ....

A 100 TeV pp Collider: Luminosity?

Luminosity goals for a 100-TeV pp collider

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April 24, 2015

Abstract

We consider diverse examples of science goals that provide a framework to assess luminosity goals for a future 100-TeV proton-proton collider.

Important discussion on luminosity: An integrated luminosity goal of 20 ab^{-1} matches very well the

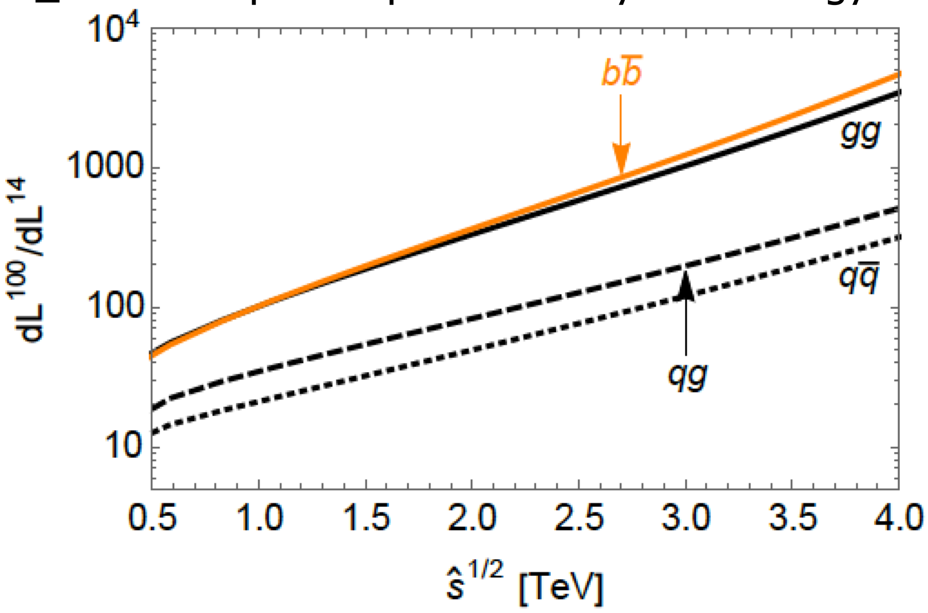
100 TeV C.M. Energy

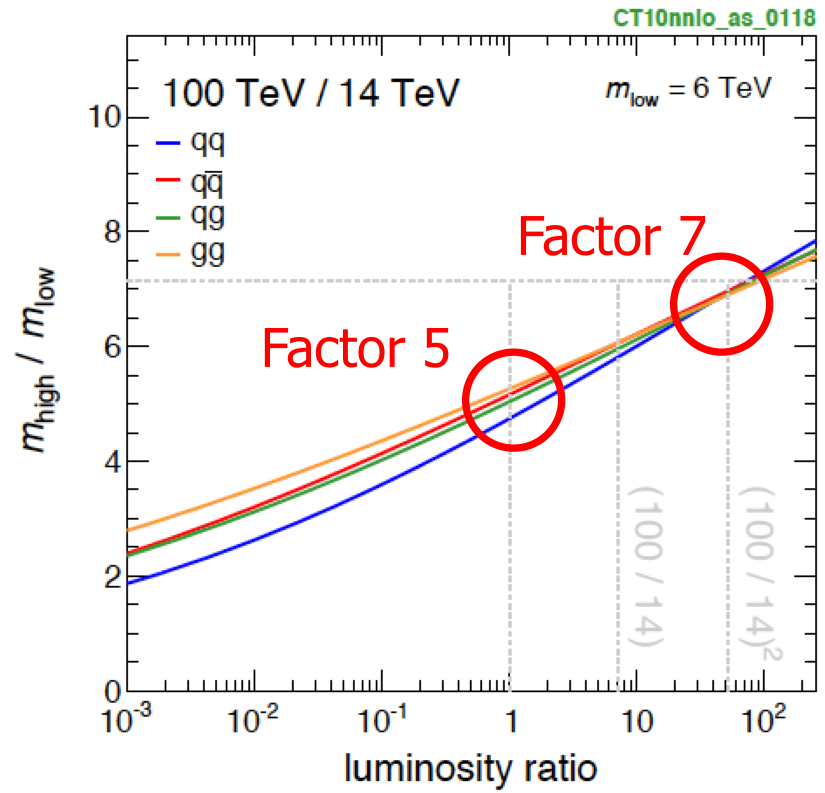
FCC-hh: Parton Luminosities

Parton luminosity ratios between 100 TeV and 14 TeV and the ratio of the reach for new physics scale from the LHC to the 100 TeV collider --compared to a LHC reach limit of 6 TeV-- vs luminosity

Generically about a factor ~5-6 increase in mass-reach w.r.t. HL-LHC

s_hat is the parton-parton CM system energy





http://collider-reach.web.cern.ch/collider-reach/

Luminosity for a Hadron Machine

The present working hypothesis is:

- **peak luminosity baseline: 5×10^{34}**
- **peak luminosity ultimate: $\leq 30\times10^{34}$**

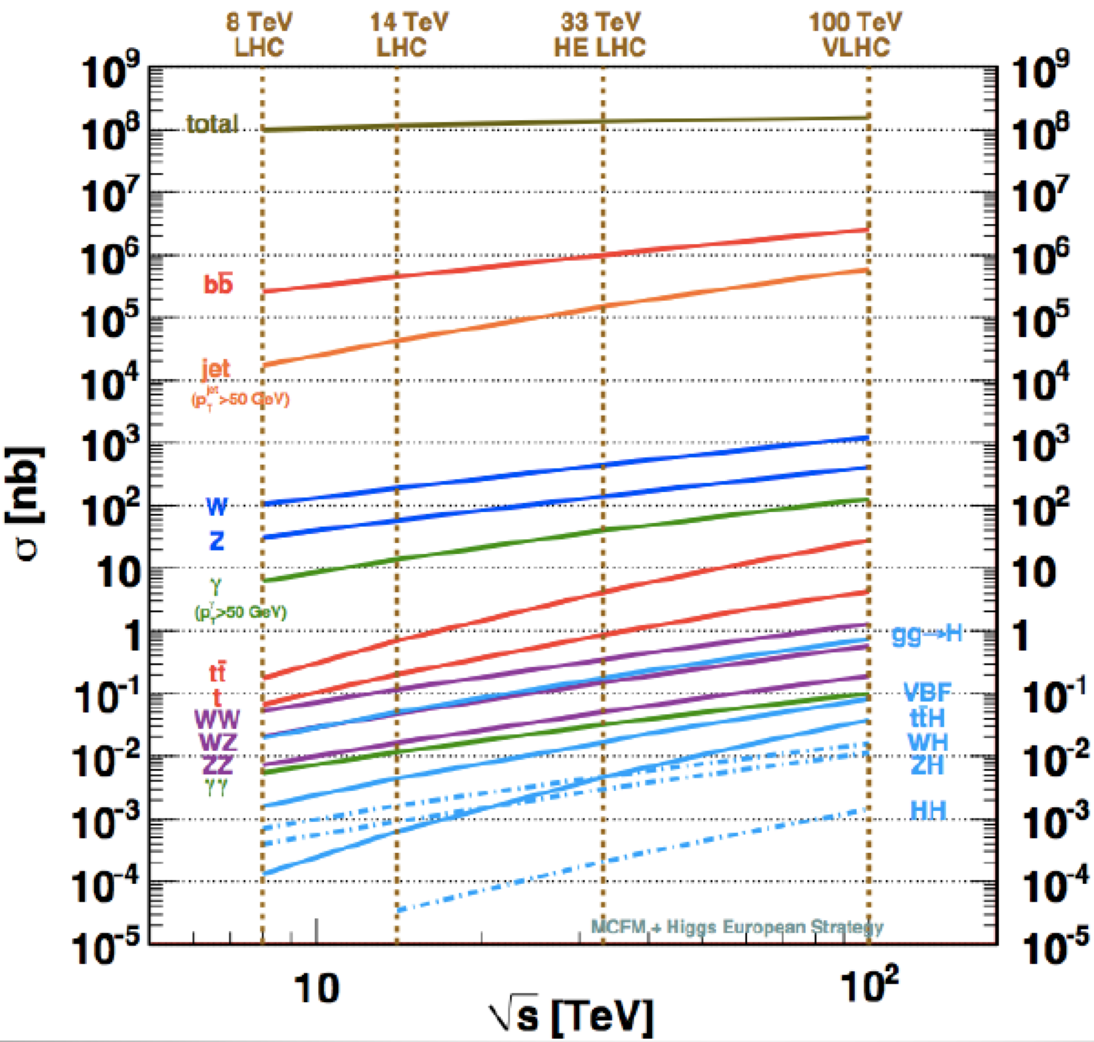
- **integrated luminosity baseline ~250 fb^{-1} (average per year)**
- **integrated luminosity ultimate ~1000 fb^{-1} (average per year)**

An operation scenario with:

- **10 years baseline, leading to 2.5 ab^{-1}**
- **15 years ultimate, leading to 15 ab^{-1}**

would result in a total of O(20) ab^{-1} over 25 years of operation.

Cross Sections/Events at the FCC-hh



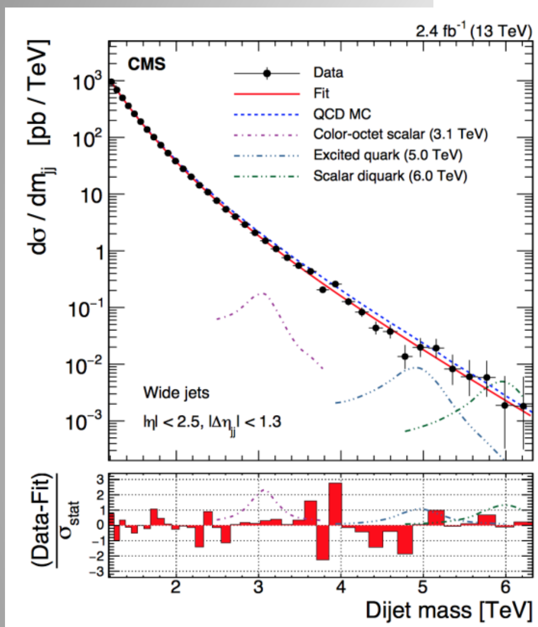
final state	N_{ev}/ $10ab^{-1}$
W	10^{13}
t tbar	3×10^{11}
H	10^{10}
HH	10^{6}
jets (p_T>5 TeV)	10^{6}
jets (p_T>10 TeV)	10^{4}

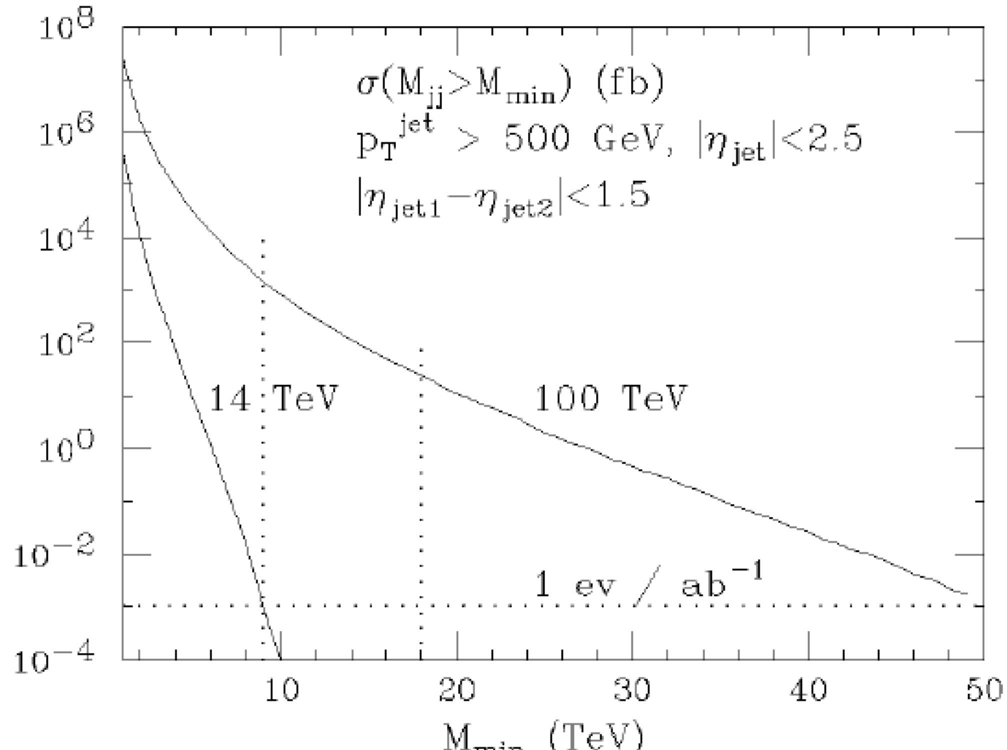
Huge event rates, eg jets with p_T> 10 GeV

New Massive Particles

Searches in Dijet Production

Even with very modest luminosity one quickly bypasses the LHC sensitivity

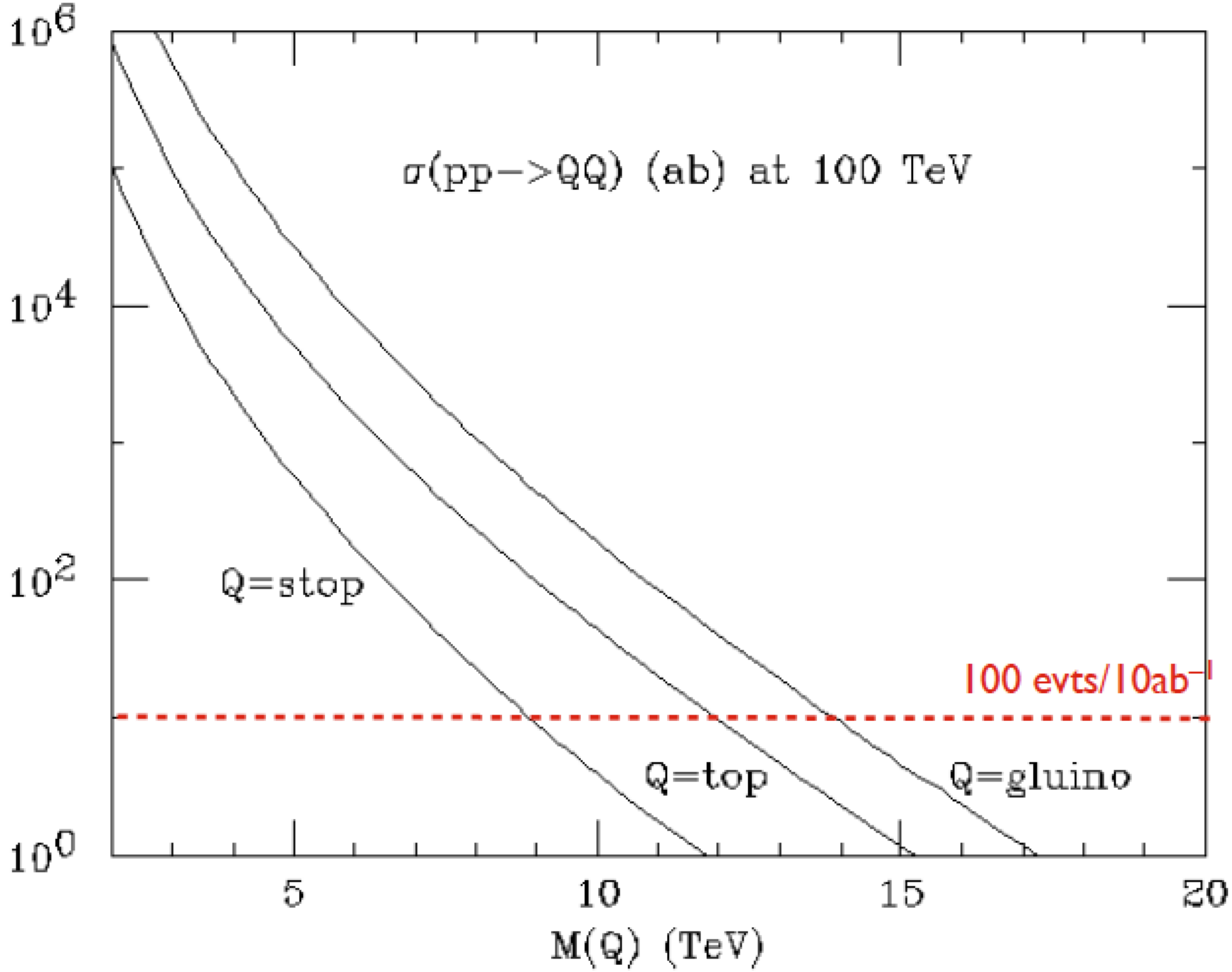




- 1 pb^{-1} to recover sensitivity of HL-LHC ⇒< 1 day @ 10^{32}
- 50pb^{-1} to 2x the sensitivity of HL-LHC ⇒< 1 month @ 10^{32}
- 1fb^{-1} to 3x the sensitivity of HL-LHC ⇒< 1 year @ $2x10^{32}$

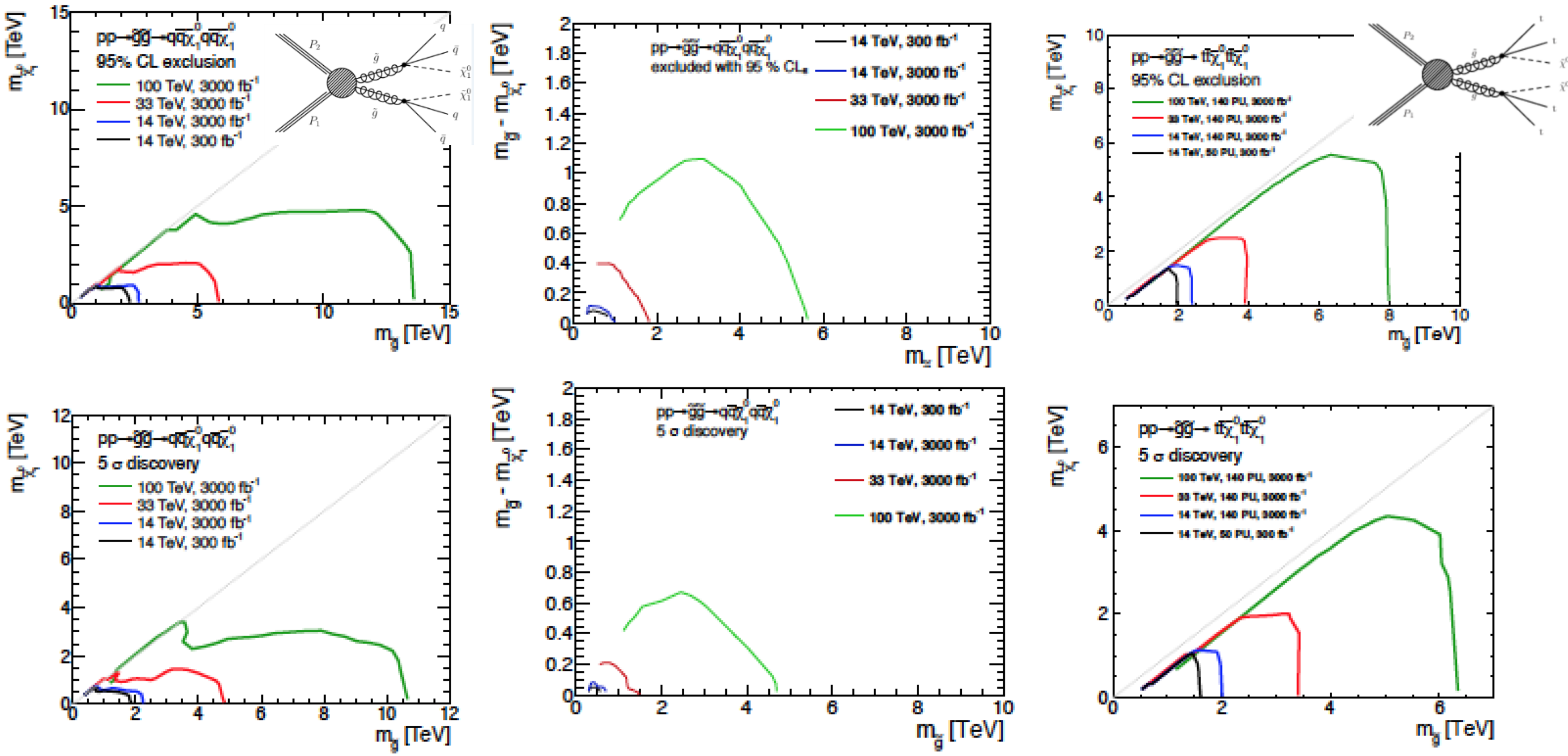
High Mass Discovery Potential

Discovery reach for pair production of strongly-interacting particles



SUSY Sparticle Reaches

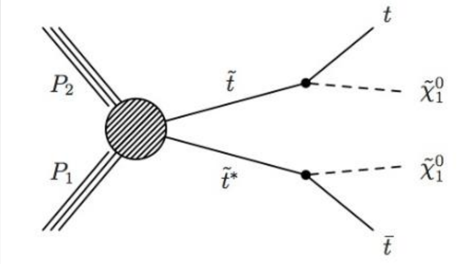
Popular presentation of data: Simplified ModelS (SMS)

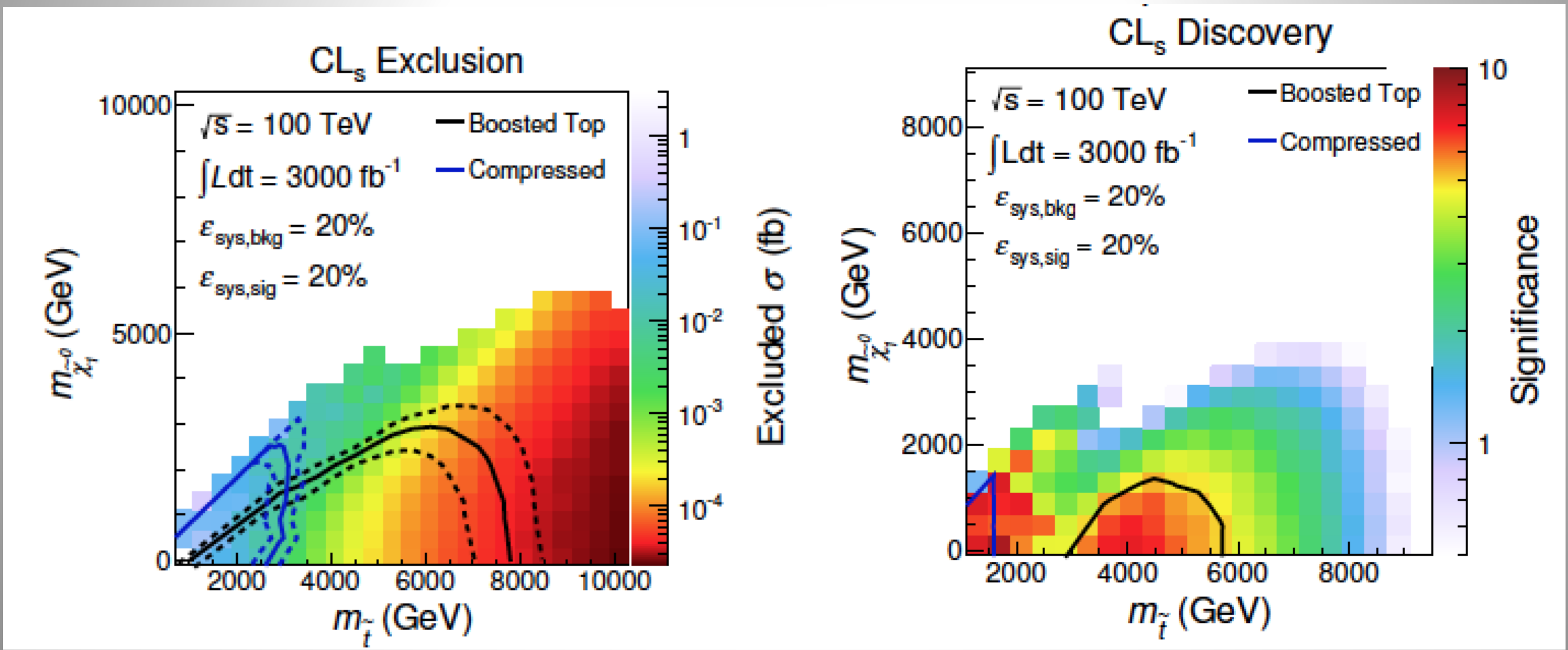


Gluino discovery (exclusion) up to 10 TeV (14 TeV) with 3 ab^{-1}

Stop Production

Popular presentation of data: Simplified ModelS (SMS)

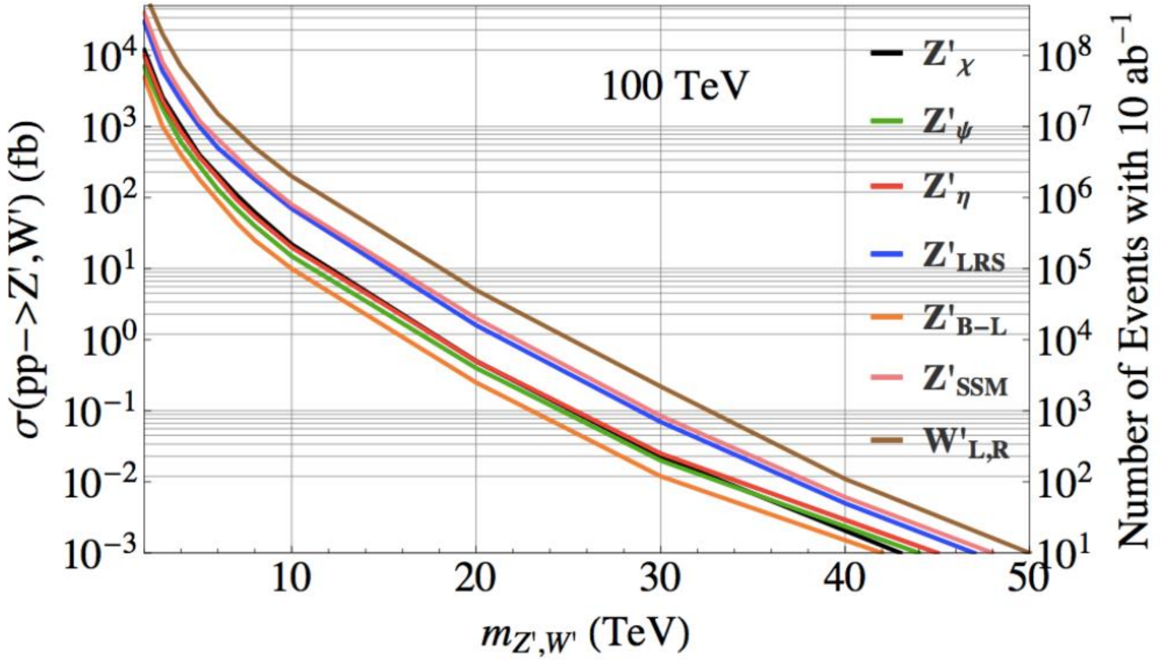




Stop discovery (exclusion) up to 6 TeV (8 TeV) with 3 ab^{-1}

Reach for Z' Searches

New weak gauge interactions



Discovery reach

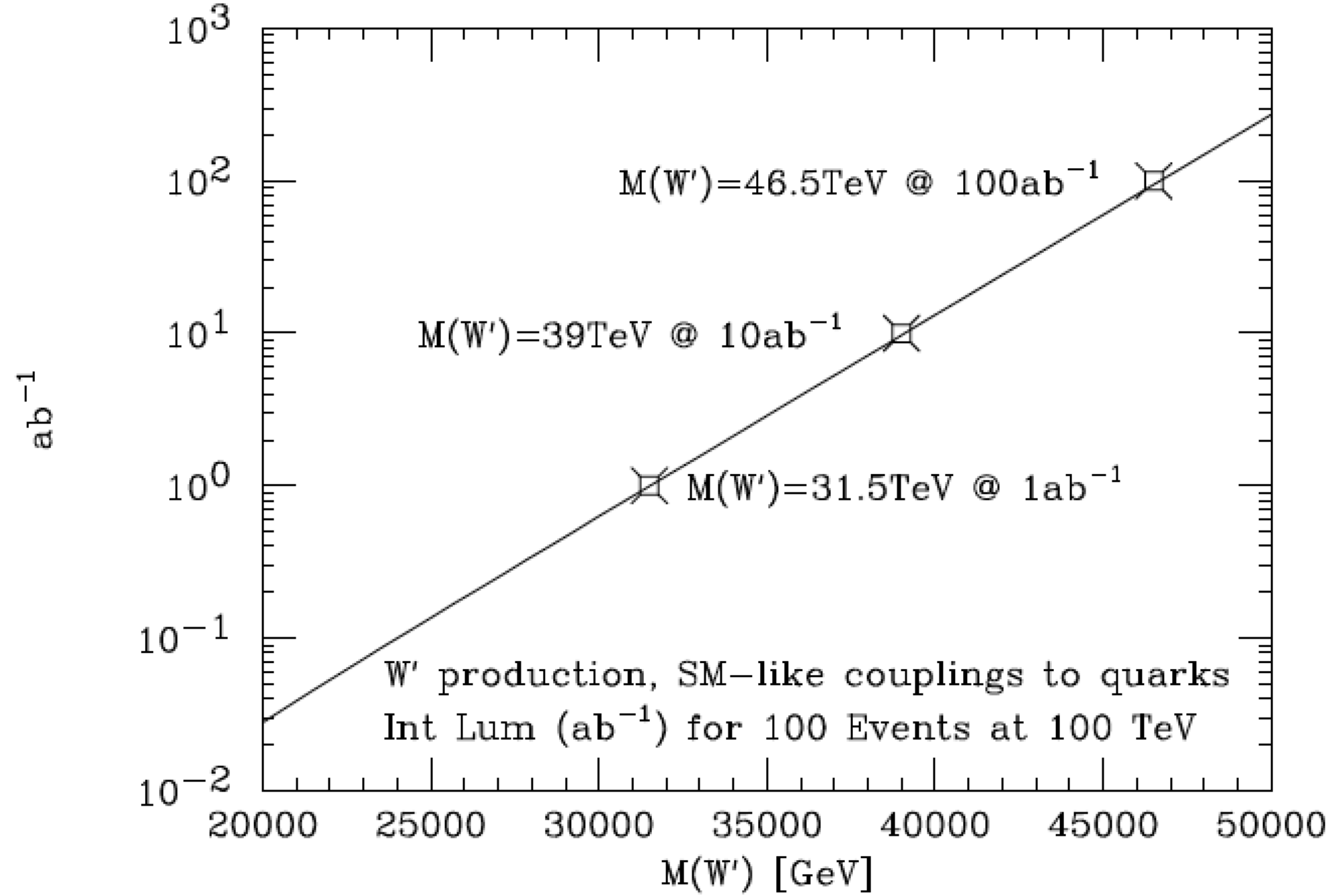
T.Rizzo, arXiv:1403.5465

Model	1 ab^{-1}	10 ab^{-1}	100 ab^{-1}
SSM	23.8	33.3	41.3
LRM	22.6	31.5	39.5
ψ	20.1	29.1	37.2
χ	22.7	30.6	38.2
η	20.3	29.8	38.0
I	22.4	29.2	36.2

New Boson Discovery Reach

Example: **W' with SM-like couplings**

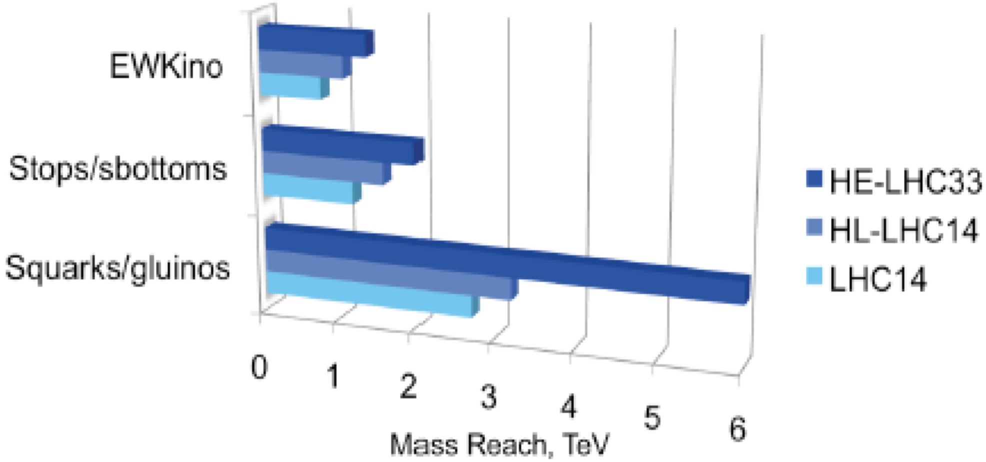
NB For SM-like Z', $\sigma_{Z'}\ BR_{lept} \sim 0.1 \times \sigma_{W'}\ BR_{lept}$, ⇒ rescale lum by ~ 10



At L=O(ab^{-1}), Lum x 10 ⇒ ~ M + 7 TeV

FCC-hh: Searches for New Particles

Searches for pair produced SUSY particles



FCC-hh

- -Reach sparticle masses search up to about 15 TeV for gluinos and 8 TeV for stops for 3 ab^{-1}
- -Excited quarks probe the structure of quarks down to 4×10^{-21} m
- -Discovery of resonances up to masses of about 40-50 TeV

E.g. 2HDM in SUSY

$m_h, m_H, m_A, m_{H^\pm}$ $\tan\beta \equiv \langle\Phi_2\rangle/\langle\Phi_1\rangle$

FIne tuning and naturalness: (N.Craig, BSM@100 Wshop)

$\Delta \approx \sin^2(2\beta)\frac{m_H^2}{m_h^2}$ $\Delta(\tan\beta = 50) \leq 1 \rightarrow m_H \lesssim 3.1\ \text{TeV}$

Extra H can be heavy, well above LHC reach, but cannot be arbitrarily heavy

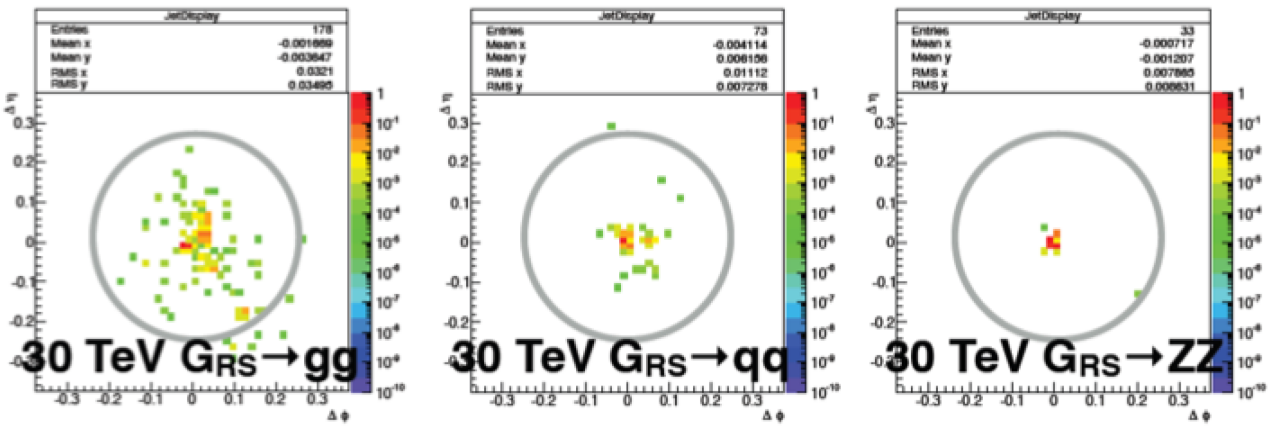
Upper limit for higher Higgs mass in 2HDM models?

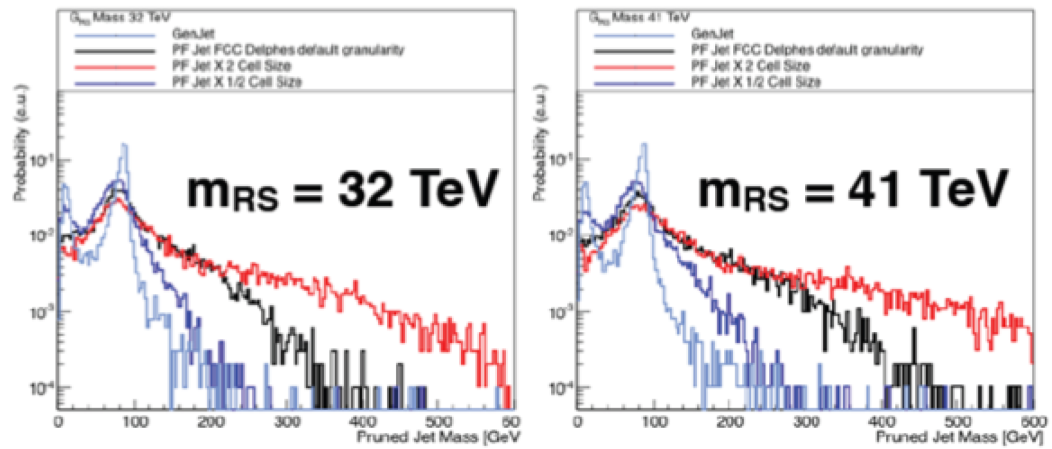
- **Why 100 TeV ?**
  - Need for O(100 TeV) in the cards since the SSC days: fully explore EWSB, probing in particular unitarization of WW scattering at m(WW)> TeV, and explore dynamics well above EWSB

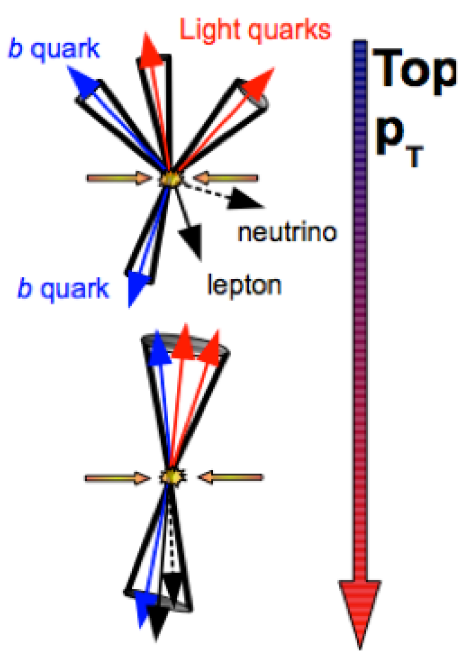
Boosted Objects

Already important at the LHC now!
Will be even more so at a 100 TeV machine !

M.Pierini







Calorimeter granularity important in optimization for boosted objects

Higgs

Higgs Production @ 100 TeV

Rate comparisons at 8, 14, 100 TeV

	N_{100}	N_{100}/N_8	N_{100}/N_{14}
gg→H	16 G	4.2×10^4	110
VBF	1.6 G	5.1×10^4	120
WH	320 M	2.3×10^4	66
ZH	220 M	2.8×10^4	84
ttH	760 M	29×10^4	420
gg→HH	28 M		280

$N_{100} = \sigma_{100\,\mathrm{TeV}} \times 20\ \mathrm{ab}^{-1}$

$N_8 = \sigma_{8\,\mathrm{TeV}} \times 20\ \mathrm{fb}^{-1}$

$N_{14} = \sigma_{14\,\mathrm{TeV}} \times 3\ \mathrm{ab}^{-1}$

Statistical precision:

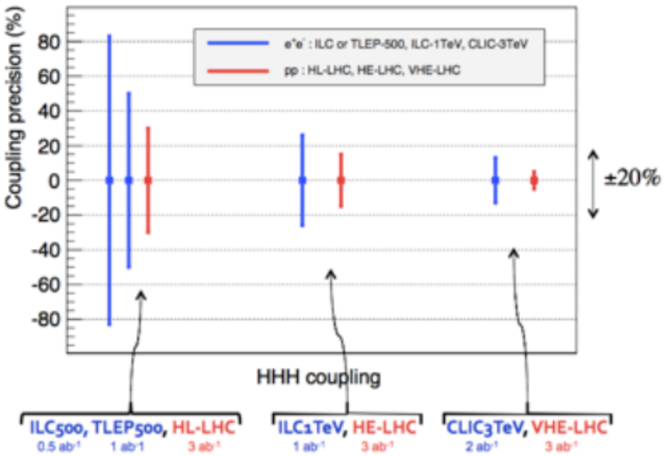
- O(100 - 500) better w.r.t Run I
- O(10 - 20) better w.r.t HL-LHC

FCC-hh Higgs Program

- ➡ Rare SM and non-SM decays
  - $\delta\kappa_\mu \cong 2\%$ (extrapolated from LHC)
- ➡ Higgs self coupling
- ➡ BSM (heavy) Higgs boson production
- ➡ Cascade decays including Higgs bosons
- ➡ Differential cross section measurements
- ➡ … and in general a continuation of the LHC/HL-LHC program

	HL-LHC	HE-LHC	VLHC
$\sqrt{s}$ (TeV)	14	33	100
$\int \mathcal{L}dt$ (fb^{-1})	3000	3000	3000
$\sigma \cdot \text{BR}(pp \to HH \to bb\gamma\gamma)$ (fb)	0.089	0.545	3.73
$S/\sqrt{B}$	2.3	6.2	15.0
λ (stat)	50%	20%	8%

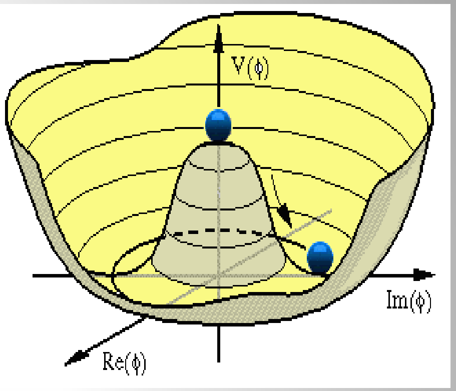
arXiv:1310.8361

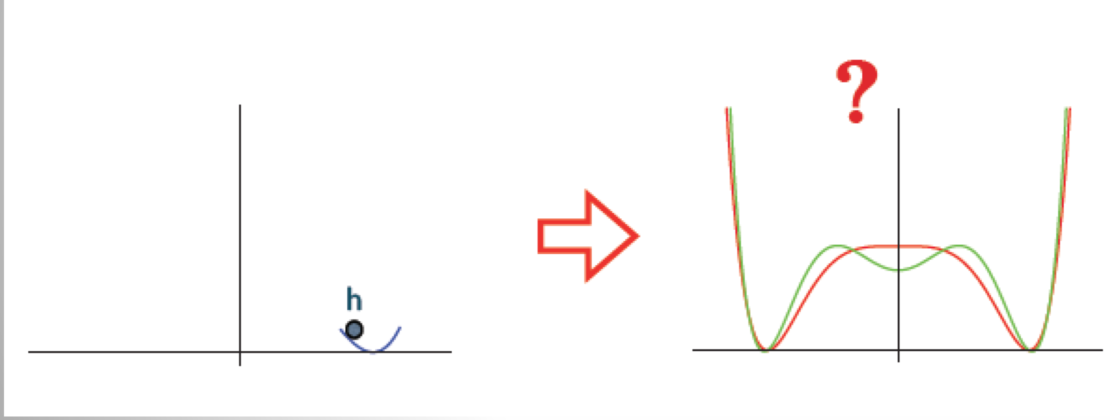


The Higgs Self Coupling!

A key measurement for our understanding of the Higgs field potential!

in pp





Difficult measurements!!:
Evaluation till ongoing
for HL-LHC sensitivity

There are several theoretical ideas to make progress to measure the Higgs potential in detail but more experimental studies are needed to see what realistically can be done at the FCC-hh

HH Production: Prospects

Higgs selfcouplings: pp→HH

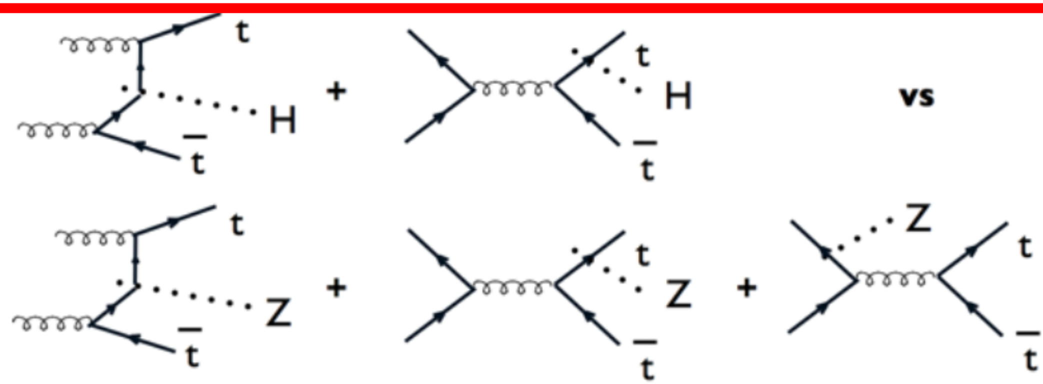
- gg→HH (most promising?) , qq→HHqq (via VBF)
- Reference benchmark process: HH→bb γγ
- Goal: 5% (or better) precision for SM selfcoupling

$HH \to b\bar{b}\gamma\gamma$	Barr,Dolan,Englert,Lima, Spannowsky JHEP 1502 (2015) 016	Contino, Azatov, Panico, Son arXiv:1502.00539	He, Ren Yao arXiv:1506.03302
$FCC_{@100TeV}$ 3/ab	30~40%	30%	15%
$FCC_{@100TeV}$ 30/ab	10%	10%	5%
$S/\sqrt{B}$	8.4	15.2	16.5
Details	✓ λ_{HHH} modification only ✓ $c \to b$ & $j \to \gamma$ included ✓ Background systematics o $b\bar{b}\gamma\gamma$ not matched ✓ $m_{\gamma\gamma} = 125 \pm 1$ GeV	✓ Full EFT approach o No $c \to b$ & $j \to \gamma$ ✓ Marginalized ✓ $b\bar{b}\gamma\gamma$ matched ✓ $m_{\gamma\gamma} = 125 \pm 5$ GeV ✓ Jet /W_{had} veto	✓ λ_{HHH} modification only ✓ $c \to b$ & $j \to \gamma$ included o No marginalization ✓ $b\bar{b}\gamma\gamma$ matched ✓ $m_{\gamma\gamma} = 125 \pm 3$ GeV

Work in progress to compare studies, harmonize performance assumptions, optimize, etc
⇒ ideal benchmarking framework

Study of ttH

ttH / ttZ



➡ Theoretical uncertainties cancel mostly

- PDF (CTEQ 6.6) ± 0.5%
- Missing higher orders ± 1.2%

➡ Complementarity with FCC-ee program

➡ Opens the possibility to measure top-Yukawa coupling with percent level precision

➡ More studies are needed to verify that < 1% level target can be reached

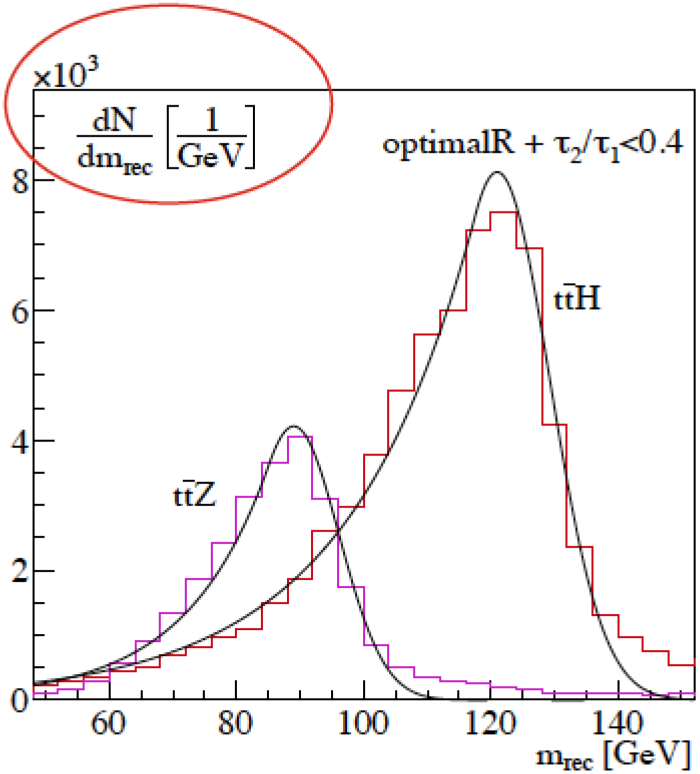
Study of ttH

	$\sigma(t\bar{t}H)$[pb]	$\sigma(t\bar{t}Z)$[pb]	$\frac{\sigma(t\bar{t}H)}{\sigma(t\bar{t}Z)}$
13 TeV	$0.475^{+5.79\%+3.33\%}_{-9.04\%-3.08\%}$	$0.785^{+9.81\%+3.27\%}_{-11.2\%-3.12\%}$	$0.606^{+2.45\%+0.525\%}_{-3.66\%-0.319\%}$
100 TeV	$33.9^{+7.06\%+2.17\%}_{-8.29\%-2.18\%}$	$57.9^{+8.93\%+2.24\%}_{-9.46\%-2.43\%}$	$0.585^{+1.29\%+0.314\%}_{-2.02\%-0.147\%}$

Scale + PDF uncert.

N(events) w. 20 ab^{-1}, tt→e/μ + jets

$H \to 4\ell$	$H \to \gamma\gamma$	$H \to 2\ell 2\nu$	$H \to b\bar{b}$
$2.6 \cdot 10^4$	$4.6 \cdot 10^5$	$2.0 \cdot 10^6$	$1.2 \cdot 10^8$



Top fat C/A jet(s) with R = 1.2, |y| < 2.5, and $p_{T,j}$ > 200 GeV

1% precision on y_{top} within reach

(assuming B(H→bb) known)

arXiv:1507.08169

Rare Processes: Higgs to μμ

Example: H→μμ statistical precision vs $p_T^{min}(\mu)$ vs $\Delta m_{\mu\mu}$ resolution (Bkg=off-shell DY)

LO only, no K factors

$\sqrt{B/S}$ for $10ab^{-1}$ — $\Delta m_{\mu\mu} = \pm$ 2.5 GeV

pt mu min	*pt H min* 30	50	100	150	200
20.00	0.141E-01	0.160E-01	0.185E-01	0.197E-01	0.206E-01
30.00	0.149E-01	0.170E-01	0.193E-01	0.201E-01	0.209E-01
40.00	0.165E-01	0.185E-01	0.201E-01	0.206E-01	0.212E-01
50.00	0.194E-01	0.204E-01	0.209E-01	0.213E-01	0.218E-01
75.00	0.235E-01	0.235E-01	0.234E-01	0.232E-01	0.233E-01
100.00	0.254E-01	0.254E-01	0.254E-01	0.254E-01	0.252E-01

$\sqrt{B/S}$ for $10ab^{-1}$ — $\Delta m_{\mu\mu} = \pm$ 1 GeV

pt mu min	*pt H min*				
20.00	0.902E-02	0.102E-01	0.119E-01	0.128E-01	0.135E-01
30.00	0.953E-02	0.109E-01	0.124E-01	0.130E-01	0.137E-01
40.00	0.105E-01	0.119E-01	0.129E-01	0.134E-01	0.139E-01
50.00	0.124E-01	0.131E-01	0.135E-01	0.139E-01	0.143E-01
75.00	0.153E-01	0.153E-01	0.153E-01	0.152E-01	0.153E-01
100.00	0.168E-01	0.168E-01	0.168E-01	0.168E-01	0.167E-01

1 % level measurement of B(H→μμ)/B(H→γγ) ?

Similar numbers for (H→Zγ) ...

Higgs Precision

work to do: complete the table!

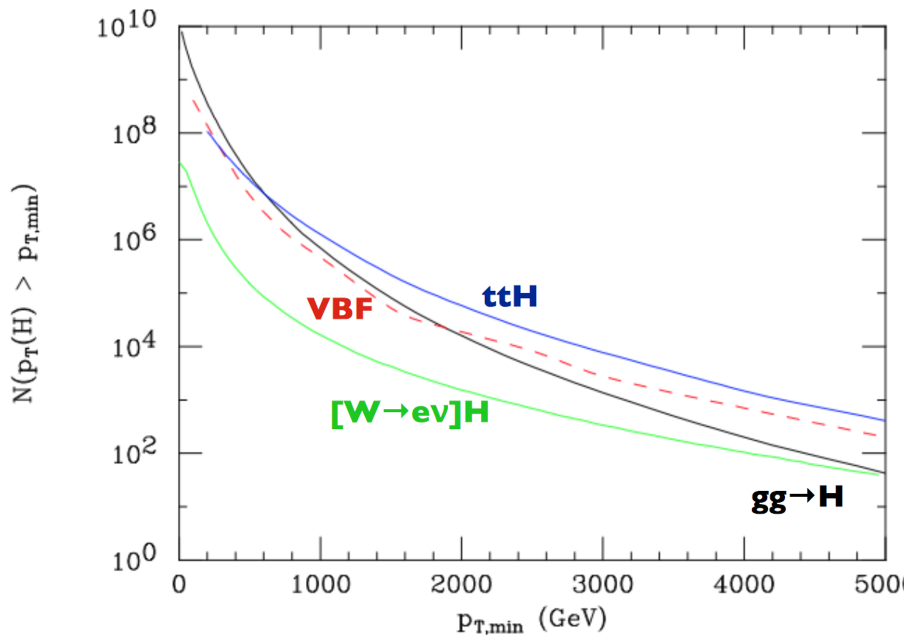
g_{HXY}	FCC-ee	FCC-hh
ZZ	0.15%	?
WW	0.19%	?
γγ	1.5%	<1%?
Zγ		1% ?
tt		1% ?
bb	0.42%	?
ττ	0.54%	?
cc	0.71%	??
ss	H→Vγ, in progr.	???
μμ	6.4%	2% ?
uu,dd	H→Vγ, in progr.	????
ee	e^+e^-→H, in progr.	????
HH		5% ?
BR_{exo}	0.45%	$<10^{-3}$ for specific channels, like H→eμ, ...
Γ_{tot}	1%	?

A lot of room here for experimentalists (and theorists) to help us fill this table in the next 2 years…

Complementarity with the FCC-ee

High P_T Higgs Production

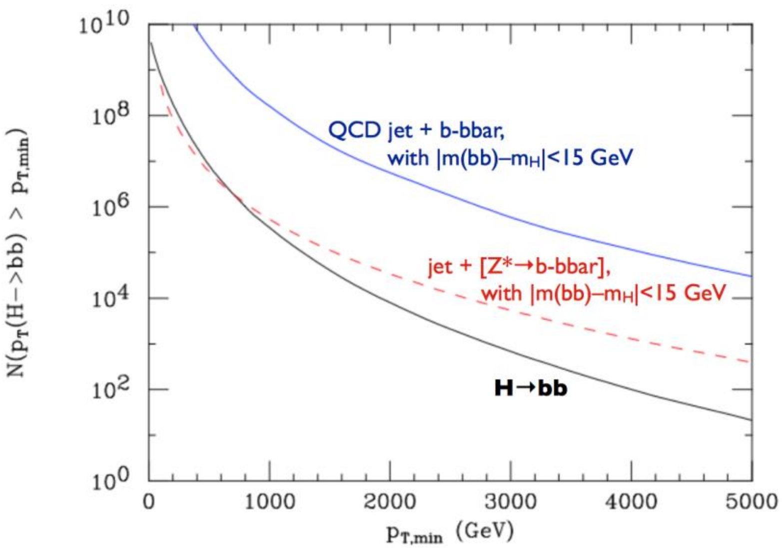
Large rates of high p_T produced Higgses at 100 TeV!



Higgs to bb?

Detailed experimental study needed!

Reach for H→bb at high pT



$S/\sqrt{B}$ ~ 1 at $p_{T\ min}$ ~ 3 TeV, but plenty of room to outsmart the QCD rate ....

Higgs →bb tagging at multi-TeV ?

Dark Matter

Dark Matter

Dark Matter

M. Mangano

For ~complete discussion, see "Dark Matter at a future hadron collider" Workshop, FNAL Dec 4-6, http://indico.cern.ch/event/445743/

- DM could be explained by BSM models that would leave no signature at any future collider (e.g. axions).
- More in general, no experiment can guarantee an answer to the question "what is DM?"
- Scenarios in which DM is a WIMP are however compelling and theoretically justified
- We would like to understand whether a future collider can answer more specific questions, such as:
  - do WIMPS contribute to DM?
  - can WIMPS, detectable in direct and indirect (DM annihilation) experiments, be discovered at future colliders?
  - what are the opportunities w.r.t. new DM scenarios (e.g. interacting DM, asymmetric DM, ...)?

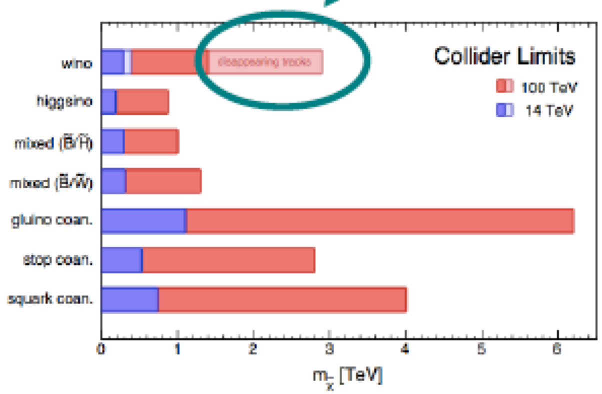
Dark Matter @FCC-hh

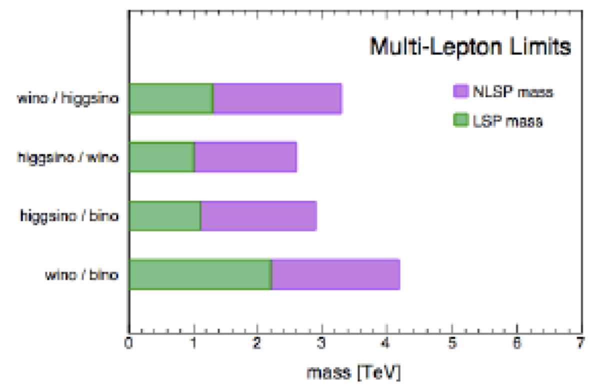
Dark Matter Searches within SUSY Scenarios

WIMP searches at colliders

L.Wang @ FCC week

disappearing tracks





Collider reach for neutralino DM

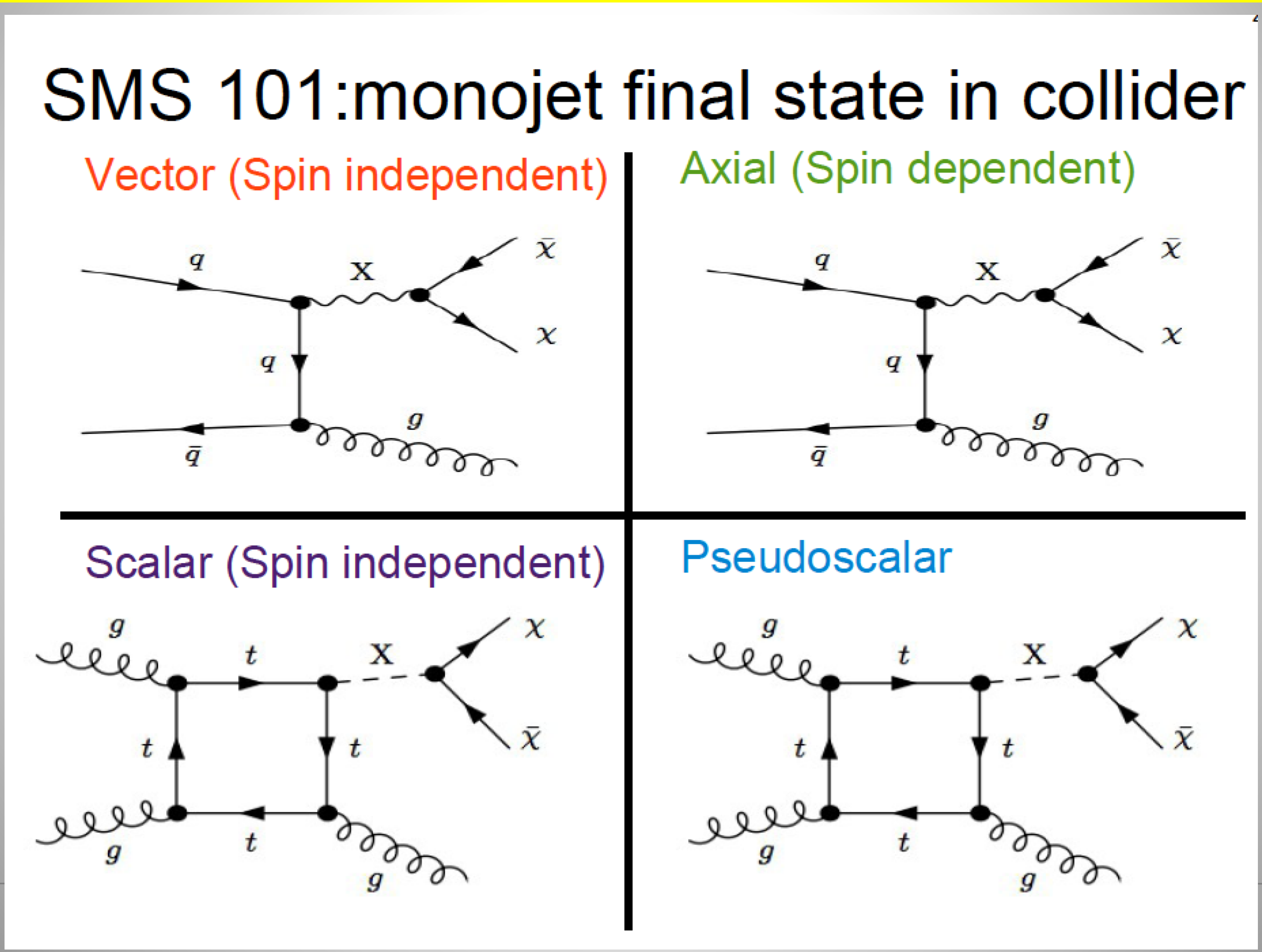
Electroweakino cascades

$$M_{\mathrm{WIMP}} \leq 1.8\ \mathrm{TeV} \left(\frac{g^2}{0.3}\right)$$

100 TeV pp collider will probe TeV WIMP very well.

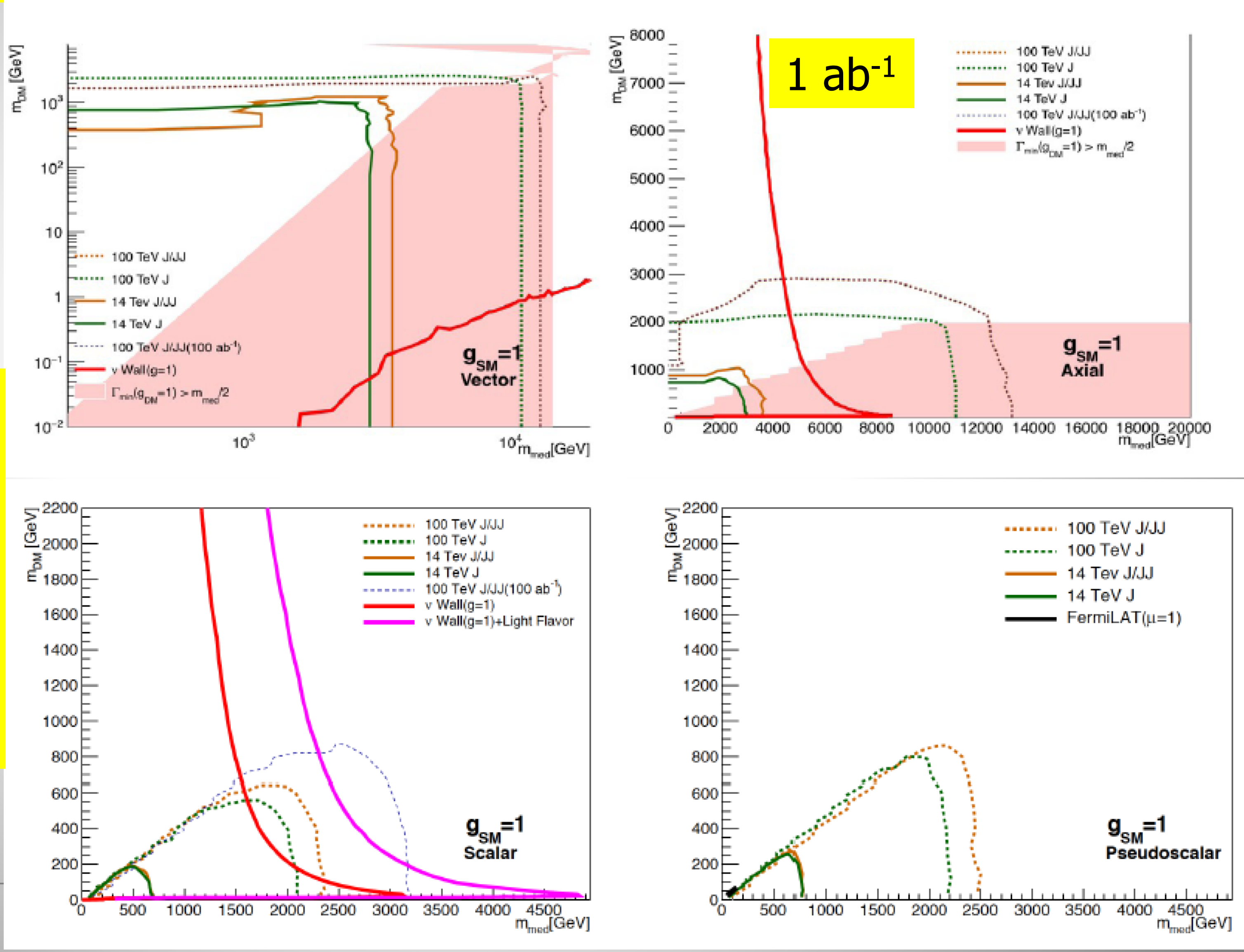
"Modern" Collider Dark Matter Studies

Use simplified models representing DM production via exchanged mediators



Dark Matter Study Results

Results of the monojet (J) and multi-jet(JJ) study: SMS presentation



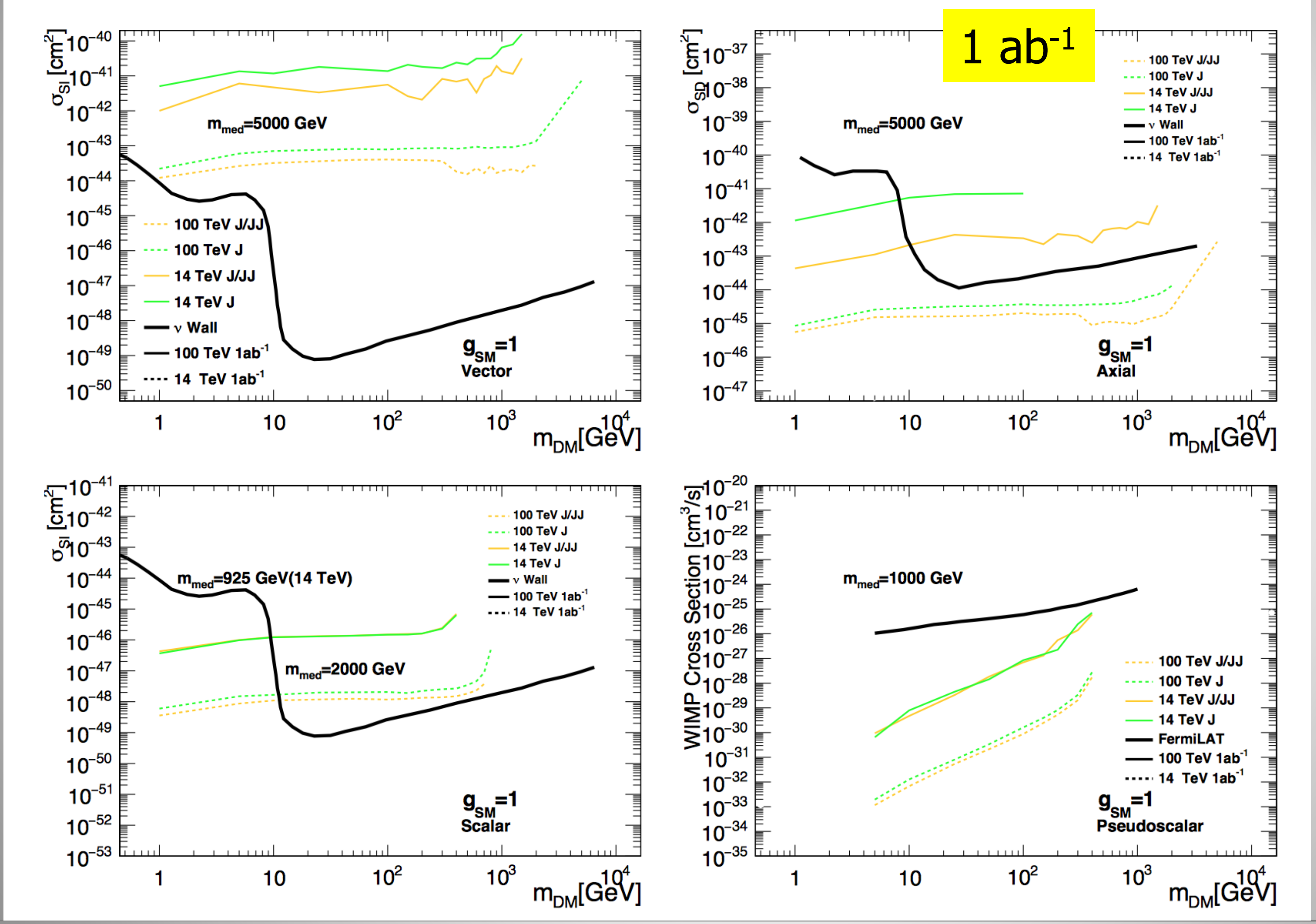
Breaking through the neutrino wall!!'

Going beyond the direct search experimental sensitivity

Dark Matter Study Results

Most elaborate study to date ->arXiv:1509.02904   DM plot presentation

1 ab^{-1}



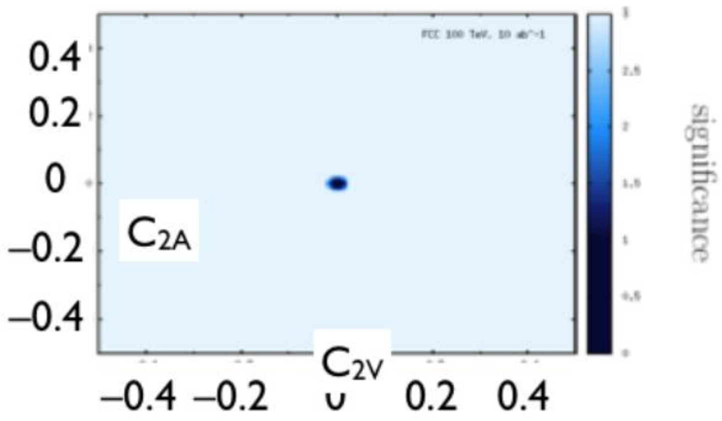
monojet (J) and multi-jet (JJ) analyses combined

Breaking through the neutrino wall!

Precision Measurements Examples

Potential for Top EWK Couplings

Top EW couplings at FCC-hh



Constraints on *top-Z* weak dipole moments

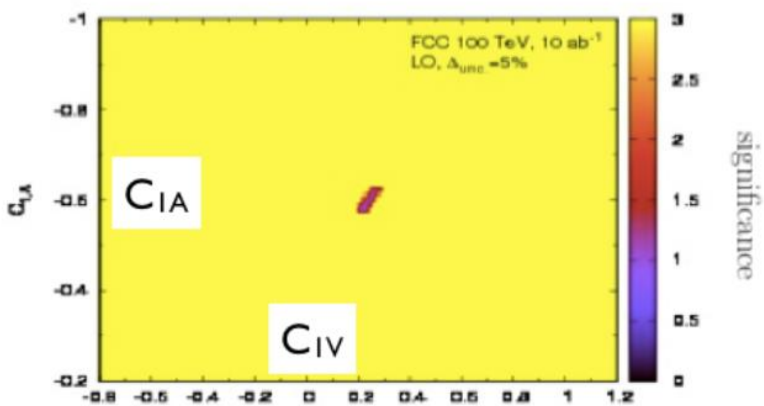
[Röntsch,Schulze]

ttbar + Z

FCC 100 TeV, 10 ab^{-1}

scale+pdfs: ± 5 %

arXiv:1501.05939
arXiv:1404.1005



Constraints on *top-Z* vector and axial couplings

[Röntsch,Schulze]

ttbar + Z

FCC 100 TeV, 10 ab^{-1}

scale+pdfs: ± 5 %

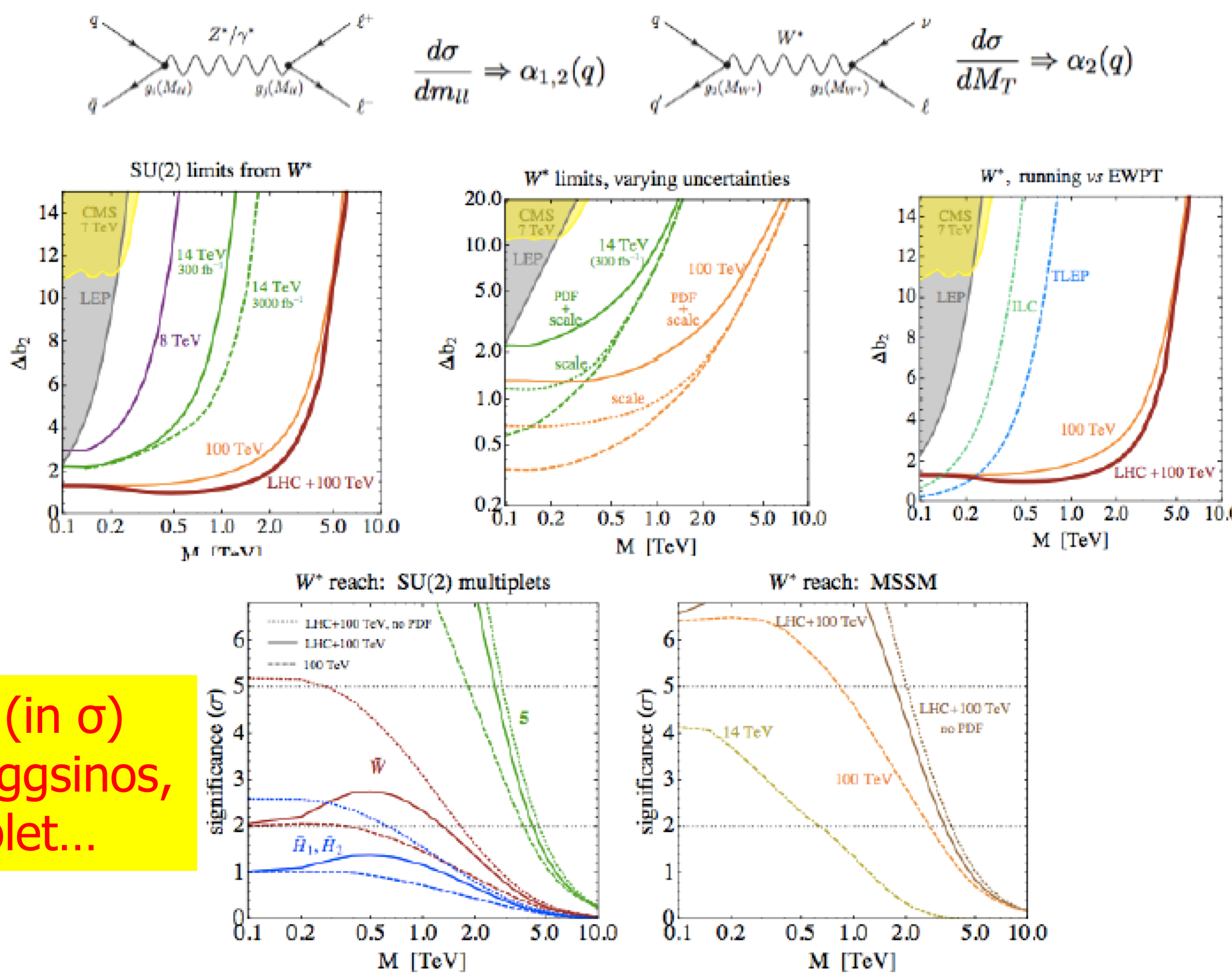
arXiv:1501.05939
arXiv:1404.1005

Precision Probes

Running Electroweak Couplings as a Probe of New Physics

D.Alves, J. Galloway, J.Ruderman, J.Walsh *arXiv:1410.6810*

Percent level measurements of the energy dependence of the EWK running couplings



Expected exclusion (in σ) on winos, pair of higgsinos, SU(2) fermionic 5-plet…

Inclusive Top Quark Production

Inclusive top quark production

- Top quark production $\sigma_{100\,\mathrm{TeV}}$ (tt)~30 nb ~ 30 x $\sigma_{14\,\mathrm{TeV}}$ (tt)

LO (CT14lo): sigma_tot = 21.7 + 4.8 (22 %) - 3.6 (17 %) [nb].
NLO (CT14nlo): sigma_tot = 32.1 + 3.6 (11 %) - 3.3 (10 %) [nb].
NNLO (CT14nnlo): sigma_tot = 34.7 + 1.0 (2.9 %) - 1.6 (4.8 %) [nb].
NNLO (NNPDF30_nnlo_as_0118): sigma_tot = 34.8 + 1.0 (2.9 %) - 1.6 (4.7 %) [nb]. *Mitov et al*

- ⇒ about 10^{12} top quarks produced in 10 ab^{-1}
  - rare and forbidden top decays
  - 10^{12} fully inclusive W decays, triggerable by "the other W"
    - rare and forbidden W decays
    - 3 10^{11} W→charm decays
    - 10^{11} W→tau decays
  - 10^{12} fully charge-tagged b hadrons

Other Topics Under Study

Only a limited number of topics were discussed

- EWK radiation of W's and opportunities
- New high mass scalar resonance sensitivity
- Production of exotic coloured states
- Production of heavy leptons
- Flavor physics opportunities
- Quadruple Higgs production and quartic couplings
- BSM Higgs searches
- EW interactions at multi-TeV (eg WW scattering)
- Coloured and neutral naturalness
- Composite Higgs, twin-Higgs… models
- Precise QCD measurements
- …

Lots of opportunities for studies

Conclusion

- The discovery of a new scalar boson has triggered a concerted effort and study for next accelerators
- A study on the physics potential for a 100 TeV pp accelerator (FCC-hh) is ongoing. More experimental studies would be welcome. Report planned for 2018
- Such a machine will have huge event rate and high mass reach for direct new particle production.
- Detailed Higgs studies can be made eg: HH production, rare Higgs decays, new high mass Higgses, ttH, etc. Complementary to an FCC-ee
- Extend the reach for new particles to ~ 10-50 TeV
- There is lots of room for blue sky thinking/ideas for measurements and experiments at such a machine!!

To follow FCC-hh physics activities

- Register with the FCC-hh mailing list for announcements:
  - http://simba3.web.cern.ch/simba3/SelfSubscription.aspx?groupName=fcc-experiments-hadron
- Check agendas and contents of previous events at the following indico categories:
  - *Informal meetings of all* ***physics*** *subgroups (SM, Higgs, BSM):*
    - https://indico.cern.ch/category/6067/
  - *Workshops*
    - https://indico.cern.ch/category/6071/
  - *Physics with injectors:*
    - https://indico.cern.ch/category/6070/
  - *Heavy ion physics:*
    - https://indico.cern.ch/category/6068/
  - *Detector subgroup:*
    - https://indico.cern.ch/category/6069/
  - *Detector magnets subgroup:*
    - https://indico.cern.ch/category/6244/
  - *Software group (common with FCC-ee and FCC-eh):*
    - https://indico.cern.ch/category/5666/

Backup