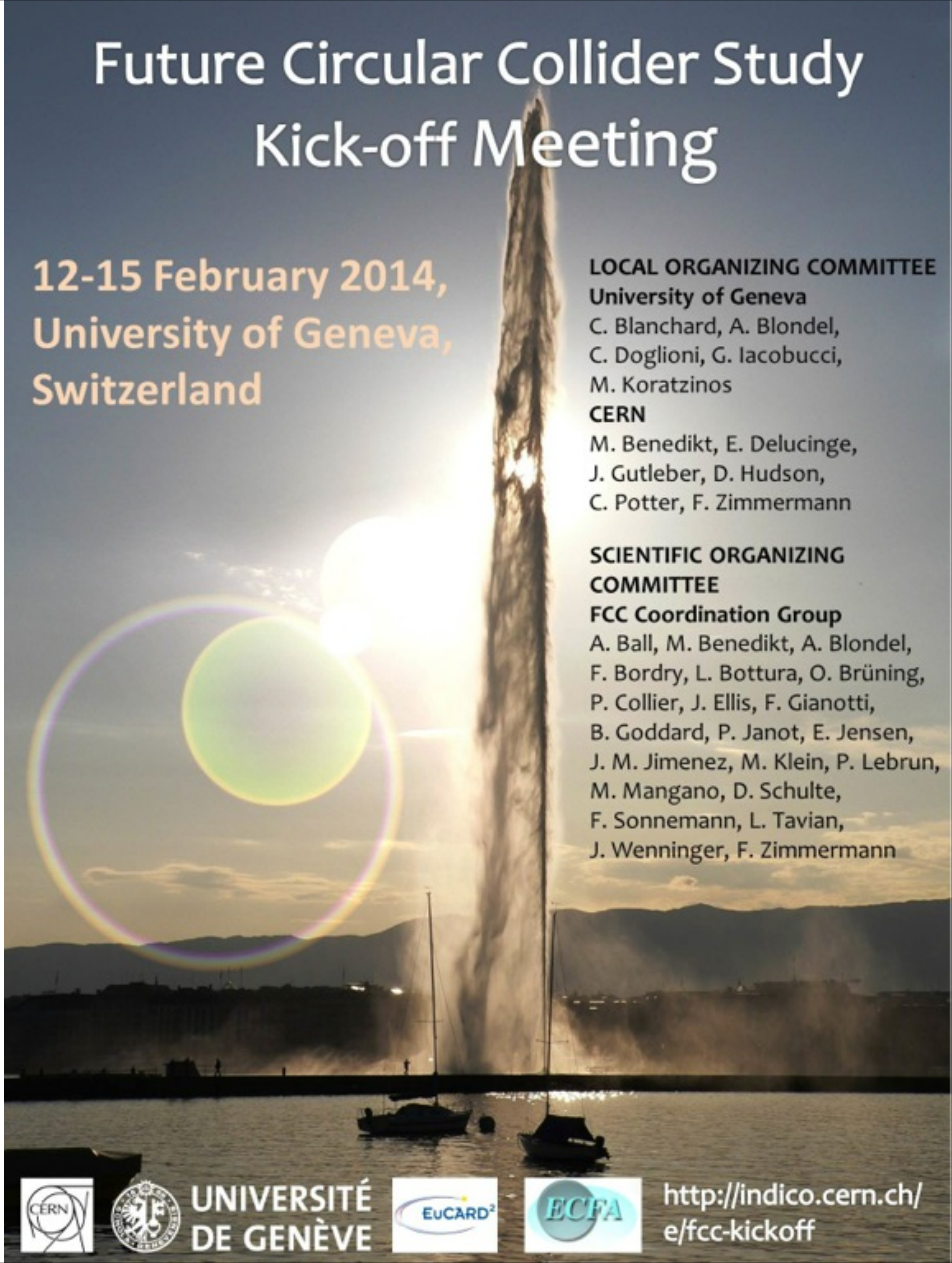
FCC
hh ee he

PHYSICS

Barbara Mele *(INFN Roma1)*

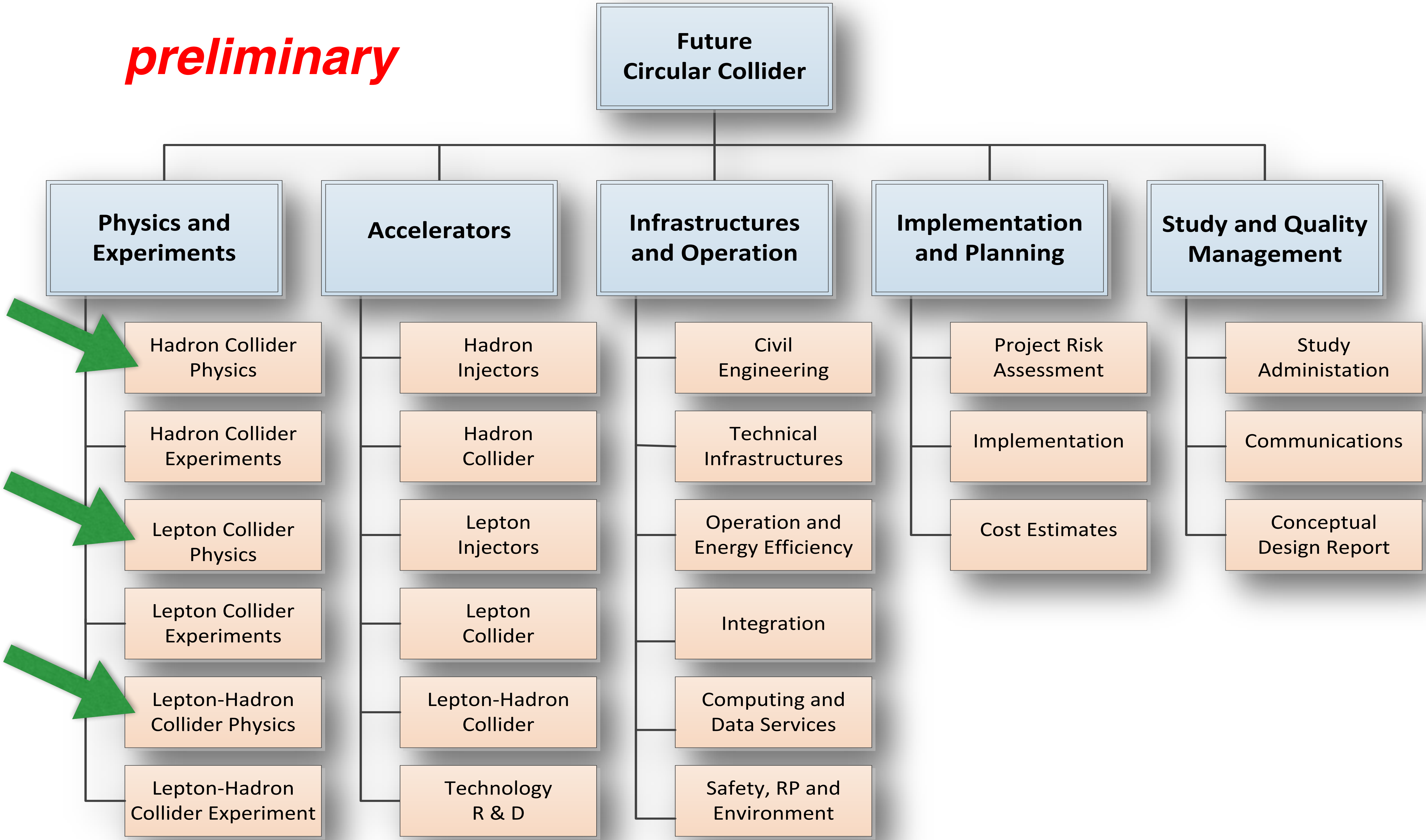
FCC kick-off meeting summary

Rome 27 March 2014



Proposal for FCC WBS top level

preliminary



FCC Kick-Off & Study Preparation Team

Future Circular Colliders - Conceptual Design Study
Study coordination, **M. Benedikt, F. Zimmermann**

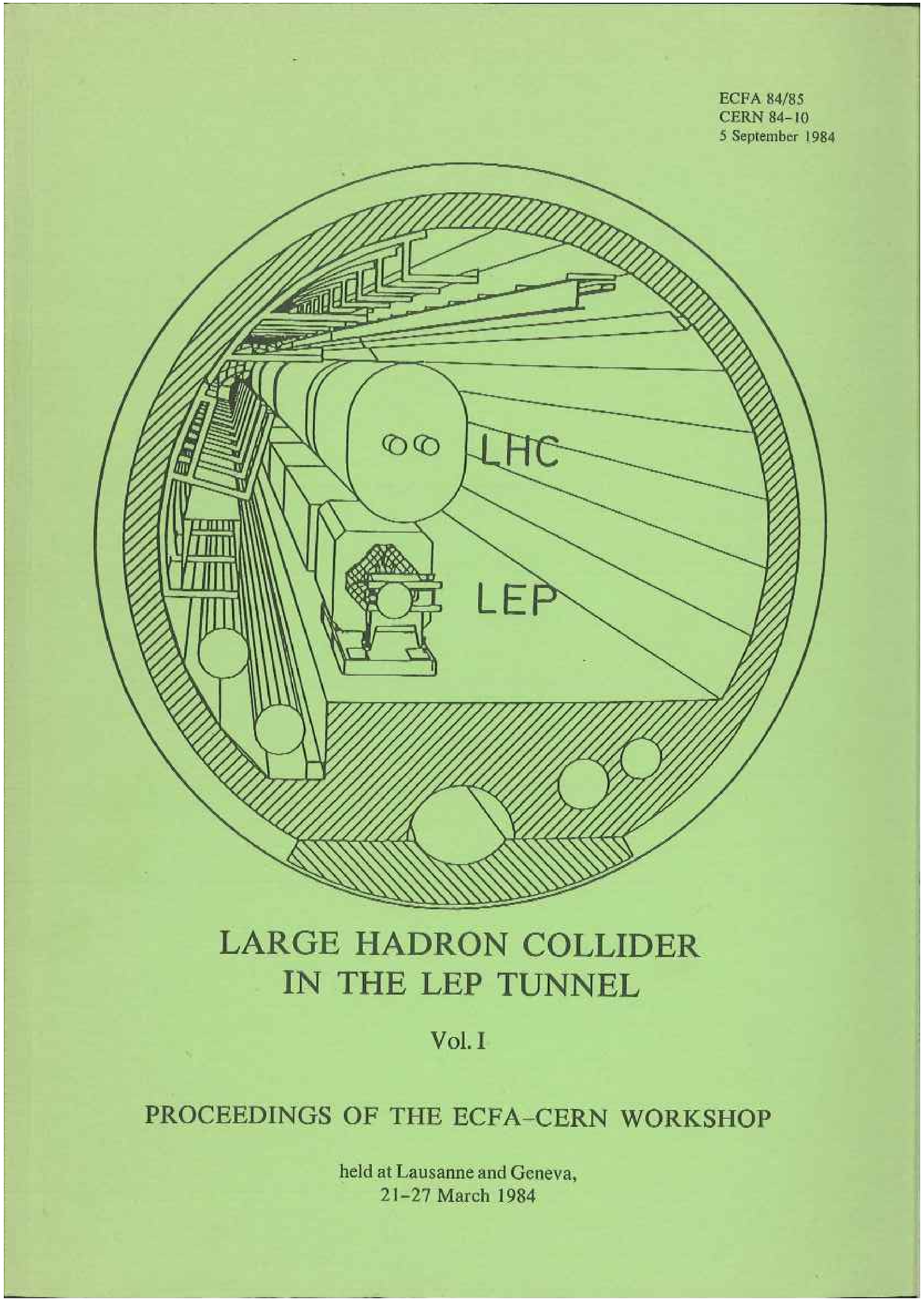
Hadron collider	Hadron injectors	e+ e- collider and injectors	Infrastructure, cost estimates	Technology	Physics and experiments
D. Schulte	**B. Goddard**	**J. Wenninger**	**P. Lebrun**	High Field Magnets **L. Bottura**	Hadrons **A. Ball, F. Gianotti, M. Mangano**
				Supercon-ducting RF **E. Jensen**	e+ e- **A. Blondel J. Ellis, P. Janot**
				Cryogenics **L. Tavian**	e- p **M. Klein**
				Specific Technologies **JM. Jimenez**	

e- p option
Integration aspects **O. Brüning**

Operation aspects,
energy efficiency, safety, environment **P. Collier**

Planning (Implementation roadmap, financial planning, reporting)
F. Sonnemann, J. Gutleber

- **30 years after LHC kick-off meeting (1 year after W discovery)**
- **similar scale of ambition, and readiness to invest in extraordinarily challenging enterprises**
- **maybe easier boundary conditions then : LEP (tunnel) already approved….**



The Physics Case

Wednesday 12 February 2014

Session 1a - Opening (Chaired by Giuseppe IACOBUCCI/Alain BLONDEL - University of Geneva) - MR380 (13:30-15:00)

time	title	presenter
13:30	Welcome	VASSALLI, Jean-Dominique BLONDEL, Alain
13:40	Opening & Introduction	HEUER, Rolf
14:00	Energy frontier after the Higgs discovery	ARKANI-HAMED, Nima
14:30	Precision frontier at high energies	GROJEAN, Christophe

Thursday 13 February 2014

Session 2b - Hadron physics (Chaired by Tejinder VIRDEE - Imperial College) - MR380 (11:00-12:30)

time	title	presenter
11:00	Hadron collider experiments and physics: introduction	GIANOTTI, Fabiola
11:25	Experimental challenges and first ideas about detector layouts	FOURNIER, Daniel
11:50	The physics landscape and opportunities	MANGANO, Michelangelo
12:15	Open discussion	

Friday 14 February 2014

Breakout Sessions

<u>FCCs overall physics and phenomenology</u> - Basement - MS 050 (14:00-18:00)

- Conveners: Ellis, Jonathan R.; Mangano, Michelangelo

time	title	presenter
14:00	Perspectives at the Energy Frontier	QUIGG, Chris
14:30	Status and plans for the Heavy Ion physics studies	DAINESE, Andrea
15:00	QCD at the FCC: opportunities and challenges	ZANDERIGHI, Giulia
15:30	Coffee break	
16:00	Status and plans for the physics studies of TLEP	ELLIS, Jonathan R.
16:30	FCC-hh: topics and work plan for phenomenology studies	MANGANO, Michelangelo
17:00	Status and prospects of precise Higgs and BSM calculations for the FCC	SPIRA, Michael
17:30	Prospects for Higgs and BSM studies in ep collisions at the FCC	KLEIN, Uta

<u>Lepton collider physics, experiments, detectors</u> - Second floor - M2 193 (14:00-18:20)

- Conveners: Janot, Patrick; Blondel, Alain

time	title	presenter
14:00	Introduction	JANOT, Patrick
14:20	Plans for Working Groups 1 & 2: EW physics at the Z pole, and di-boson physics	TENCHINI, Roberto BLONDEL, Alain
14:40	Plans for Working Group 4: Top quark physics	AZZI, Patrizia
15:00	Plans for Working Group 5: QCD and gamma gamma physics	D'ENTERRIA, David SKANDS, Peter
15:20	Plans for Working Group 6: Flavour Physics	MONTEIL, Stephane
15:45	Coffee break	

Parallel activities in the world

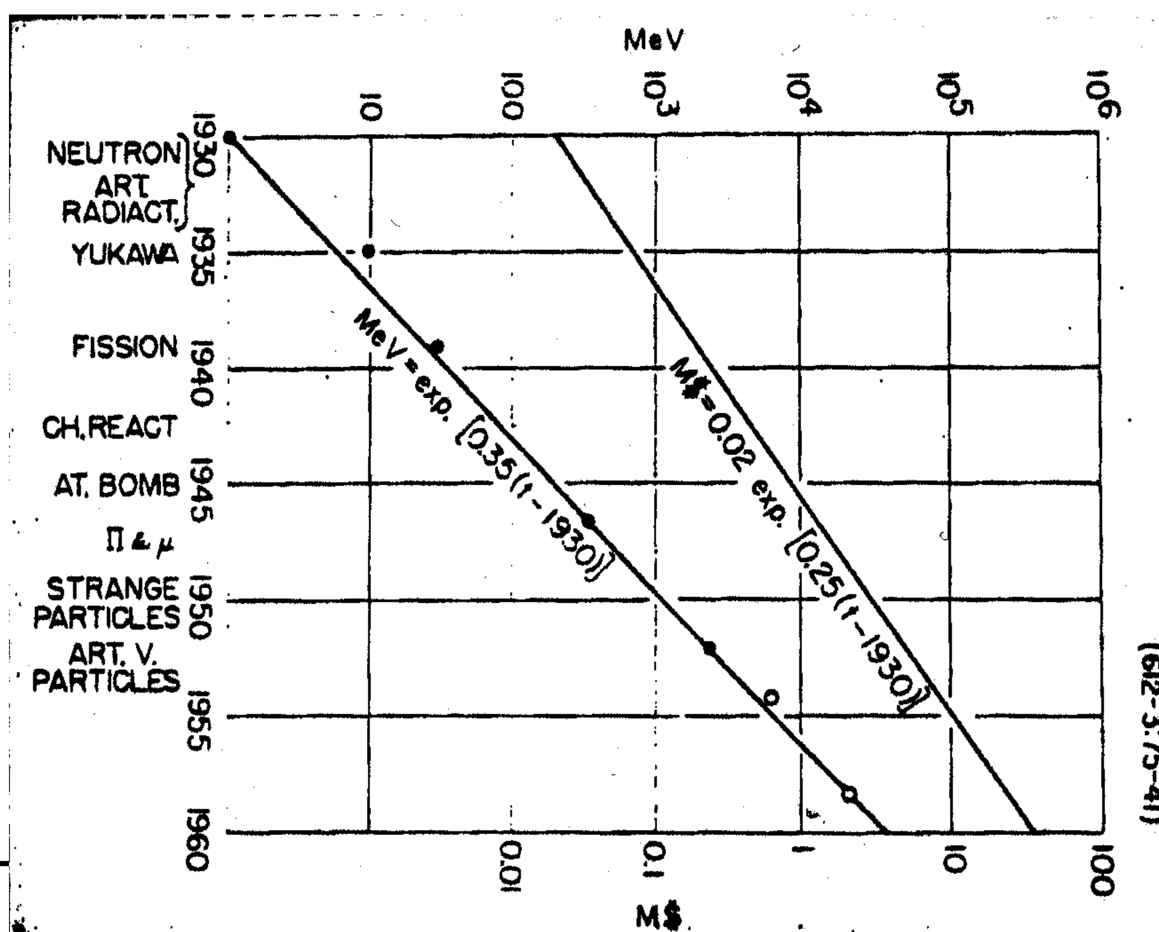
The Physics Case

Gianotti

From E. Fermi, preparatory notes for a talk on
"What can we learn with High Energy Accelerators ? "
given to the American Physical Society, NY, Jan. 29th 1954

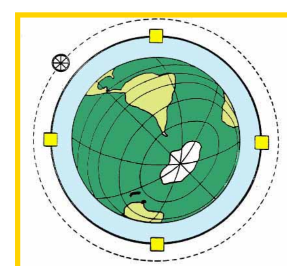
For these reasons....clamoring for higher and higher....
Slide 1 - MeV - M$ versus time.
Extrapolating to 1994...5 hi 9 Mev or hiest cosmic...170 B$....preliminary design....8000 km, 20000 gauss
Slide 2 - 5 hi 15 eV machine.

Whay we can learn impossible to guess....main element surprise....some things look for but see others.....Experiems on pions....sharpening knowledge....~~spin zero and odd symmetry~~.....certainly look for multiple production...



F.

Fermi's extrapolation to year 1994:
2T magnets, R=8000 km (fixed target !),
E_{beam} ~ 5×10^3 TeV → √s ~ 3 TeV
Cost : 170 B$



Was that hopeless ??

NO !

We have found the solution:
we have invented colliders
and superconducting magnets …
and built the Tevatron and the LHC

Motivations

(I) Physics of Unbroken EW symmetry

(II) Ultimate Fate of Naturalness

(III) Robust probe of WIMP DM

(IV) Opportunities from Flavor/CP to Heavy Ions

NATURALNESS, CHIRAL SYMMETRY, AND SPONTANEOUS

CHIRAL SYMMETRY BREAKING

G. 't Hooft

Institute for Theoretical Fysics

Utrecht, The Netherlands

Naturalness is not a recent "fashion": it's a problem almost as old as the SM itself, first raised by one of the fathers of the SM

Aug **1979**. 23 pp.

NATO Adv.Study Inst.Ser.B Phys. 59 (1980) 135

As we will see, naturalness will put the severest restriction on the occurrence of scalar particles in renormalizable theories. In fact we conjecture that this is the reason why light, weakly interacting scalar particles are not seen.

> Pursuing naturalness beyond 1000 GeV will require theories that are immensely complex compared with some of the grand unified schemes.

We're finally there, at 1 TeV, facing the fears about a light SM Higgs anticipated long ago

A remarkable attempt towards a natural theory was made by Dimopoulos and Susskind [2)]. These authors employ various kinds of confining gauge forces to obtain scalar bound states which may substitute the Higgs fields in the conventional schemes. In their model the observed fermions are still considered to be elementary.

Most likely a complete model of this kind has to be constructed step by step. One starts with the experimentally accessible aspects of the Glashow-Weinberg-Salam-Ward model. This model is natural if one restricts oneself to mass-energy scales below 1000 GeV. Beyond 1000 GeV one has to assume, as Dimopoulos and Susskind do, that the Higgs field is actually a fermion-antifermion composite field. Coupling this field to quarks and leptons in order to produce their mass, requires new scalar fields that cause naturalness to break down at 30 TeV or so.

Clearly, how to proceed will depend on first LHC13 results.

But in every scenario I can imagine, we will need the 100 TeV pp machine

* Tuning probe $\propto E_{cm}^{2}$

* Higgs + nothing else @ 100 TeV

$\Rightarrow \sim 10^{-4}$ tuning!!

* Never seen this level of tuning in particle physics.

* Qualitatively new, mortal blow to naturalness

pp at 100 TeV opens three windows:

➥ Access to new particles in the few→30 TeV mass range, beyond LHC reach

➥ Immense rates for phenomena in the sub-TeV mass range ⇒

increased precision w.r.t. LHC

➥ Access to very rare processes in the sub-TeV mass range ⇒

search for stealth phenomena, invisible at the LHC

There is a strong motivation for a fresh look at the possible role of phenomena taking place at the 10 TeV scale

This process is starting now, a lot of work is required, and it premature to draw conclusions now

FCC-hh physics activities documented on:

Mangano

- o http://indico.cern.ch/categoryDisplay.py?categId=5258
- o https://twiki.cern.ch/twiki/bin/view/LHCPhysics/FutureHadroncollider

Mailing list exist (see e.g. header of any of the mtgs in the Indico category above) => register to be kept uptodate

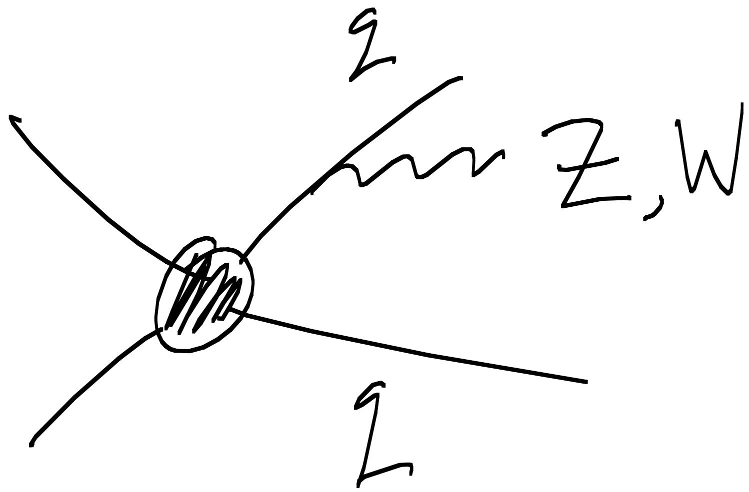
So far:

- 5 preparatory mtgs of the pp WG => *sample results presented in talks in the FCC-hh parallel sessions, Friday*
- 2 preparatory mtgs of the HI subgroup => *sample results presented in talks in the FCC-hh parallel sessions, Friday*
- "BSM opportunities at 100 TeV" Workshop:
  - http://indico.cern.ch/event/284800/

PLAN: prepare a report documenting the physics opportunities at 100 TeV, on the time scale of end-2015, ideally in cooperation with efforts in other regions

Arkani-Hamed

Ewk Radiation

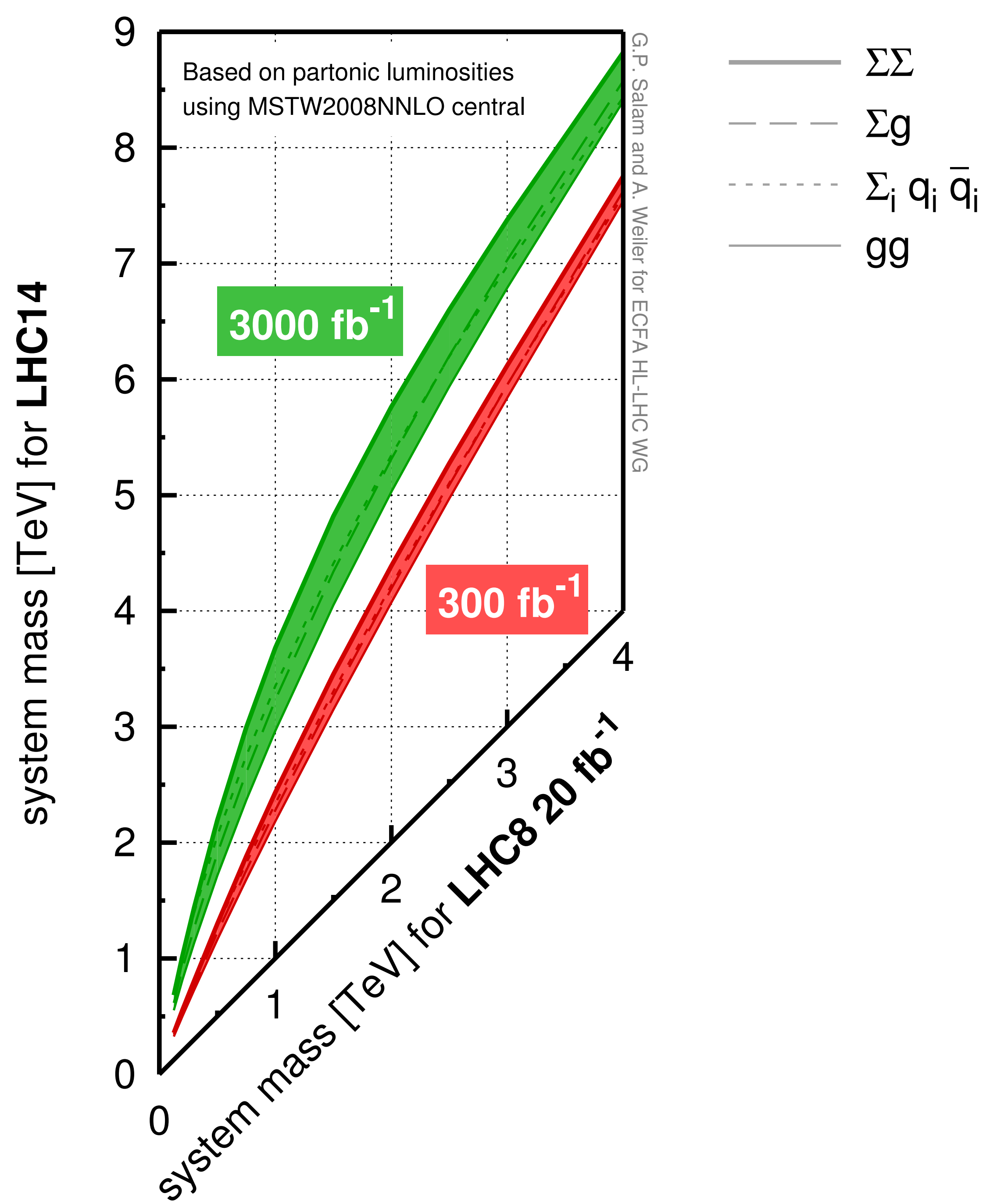


$$\frac{4\alpha_2}{\pi} \log^2\left(\frac{5\,\text{TeV}}{m_Z}\right)$$ not small

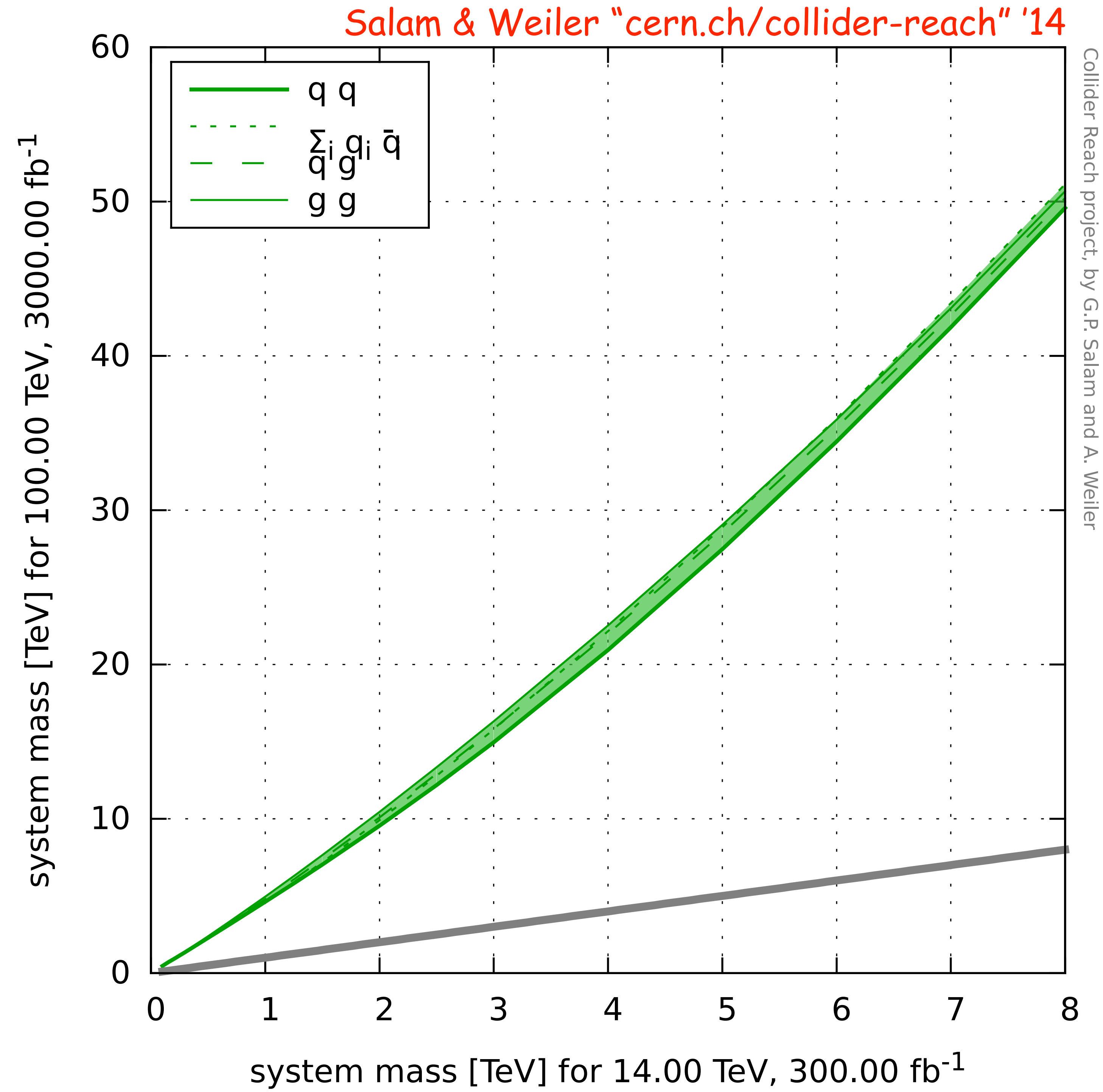
~15% of ~10 TeV jets have a W/Z

The benefit of being energetic

Direct exploration of an unexplored energy territory



LHC14/LHC8:
mass reach x O(2)



VHE-LHC100/LHC14:
mass reach x O(5)

Higgs rates at high energy

NLO rates $\mathbf{R(E)} = \sigma(E\ \text{TeV})/\sigma(14\ \text{TeV})$

	σ(14 TeV)	R(33)	R(40)	R(60)	R(80)	R(100)
ggH	50.4 pb	3.5	4.6	7.8	11.2	14.7
VBF	4.40 pb	3.8	5.2	9.3	13.6	18.6
WH	1.63 pb	2.9	3.6	5.7	7.7	9.7
ZH	0.90 pb	3.3	4.2	6.8	9.6	12.5
ttH	0.62 pb	7.3	11	24	41	61
HH	33.8 fb	6.1	8.8	18	29	42

In several cases, the gains in terms of "useful" rate are much bigger.
E.g. when we are interested in the large-invariant mass behaviour of the final states:
$\sigma(ttH, p_T^{top} > 500\ \text{GeV}) \Rightarrow R(100) = 250$

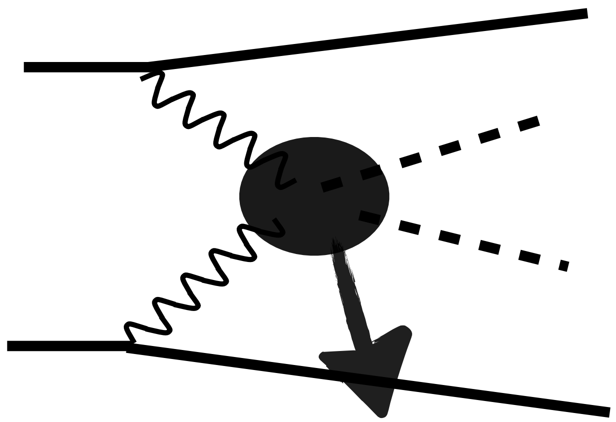
Task: explore new opportunities for measurements, to reduce systematics with independent/complementary kinematics, backgrounds, etc.etc.

Mangano

WW→HH: probing Higgs strong interactions

in the SM, the Higgs is essential to prevent strong interactions in EWSB sector

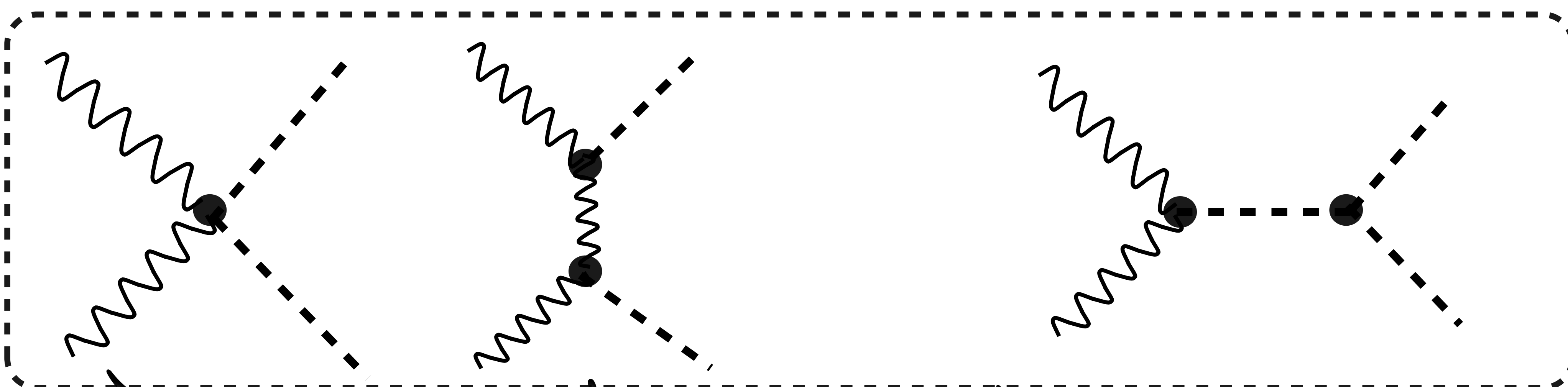
(e.g. WW scattering)



SM: $a=b=d_3=d_4=1$

$$\mathcal{L}_{\rm EWSB} = \frac{v^2}{4}\mathrm{Tr}\left(D_\mu\Sigma^\dagger D_\mu\Sigma\right)\left(1+2a\frac{h}{v}+b\frac{h^2}{v^2}\right)$$

$$V(h) = \frac{1}{2}m_h^2h^2 + d_3\frac{1}{6}\left(\frac{3m_h^2}{v}\right)h^3 + d_4\frac{1}{24}\left(\frac{3m_h^2}{v^2}\right)h^4 + \ldots$$



$$\mathcal{A} \underset{m_{hh}^2 \gg m_W^2}{\sim} \left(b-a^2\right)\frac{4m_{hh}^2}{v^2}$$

asymptotic behavior
sensitive to strong interaction

$$\mathcal{A} \underset{m_{hh}^2 \sim 4m_h^2}{\sim} \mathrm{cst.} + 3ad_3\frac{m_h^2}{v^2}$$

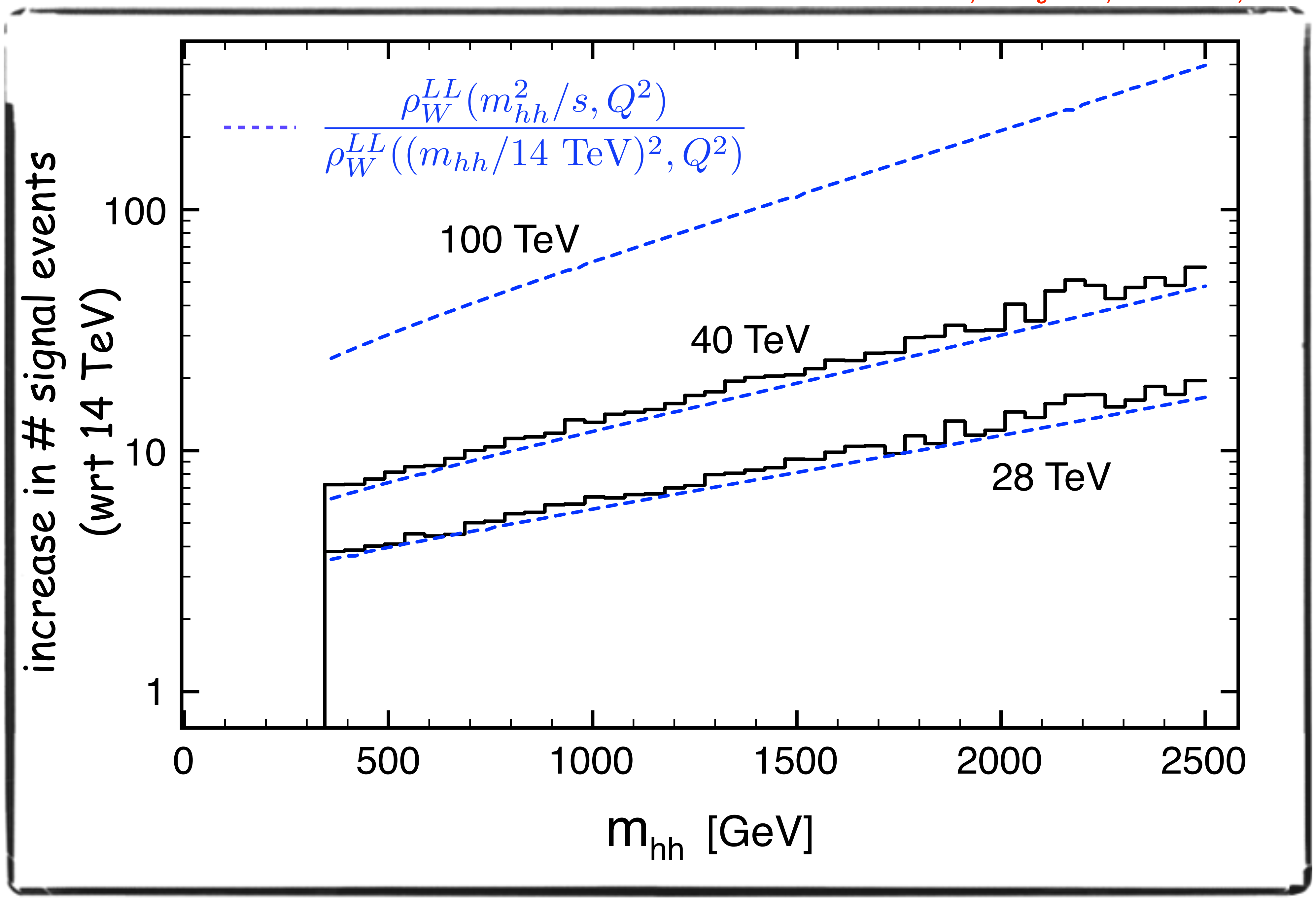
threshold effect
anomalous coupling'

WW→HH: probing Higgs strong interactions

in the SM, the Higgs is essential to prevent strong interactions in EWSB sector

(e.g. WW scattering)

Contino, Grojean, Moretti, Piccinii, Rattazzi '10



VHE-LHC can probe the high invariant-mass distribution with high statistics

Boosted Higgs

inability to resolve the top loops

- the bearable lightness of the Higgs: rich spectroscopy w/ multiple decays channels
- the unbearable lightness: loops saturate and don't reveal the physics @ energy physics (*)

m_H(GeV)	$\frac{\sigma_{NLO}(m_t)}{\sigma_{NLO}(m_t\to\infty)}$	$\frac{\sigma_{NLO}(m_t,m_b)}{\sigma_{NLO}(m_t\to\infty)}$
125	1.061	0.988
150	1.093	1.028
200	1.185	1.134

e.g. Grazzini, Sargsyan '13

the inclusive rate doesn't "see" the finite mass of the top

(*) unless it doesn't decouple (e.g. 4th generation)

⇛ cannot disentangle
- long distance physics (modified top coupling)
- short distance physics (new particles running in the loop) ⇚

$$\mathcal{L} = \frac{\alpha_s c_g}{12\pi}|H|^2 G_{\mu\nu}^{a\,2} + \frac{\alpha c_\gamma}{2\pi}|H|^2 F_{\mu\nu} + y_t c_t \bar{q}_L \tilde{H} t_R |H|^2$$

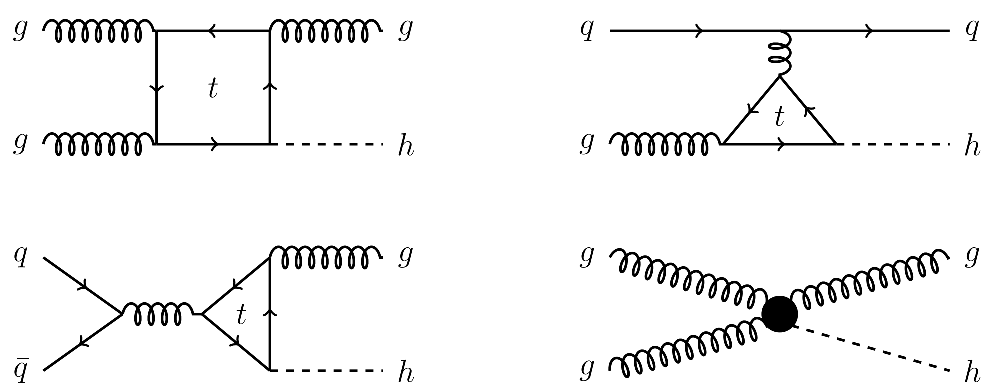
$$\frac{\sigma(gg\to h)}{\text{SM}} = (1+(c_g-c_t)v^2)^2 \qquad \frac{\Gamma(h\to\gamma\gamma)}{\text{SM}} = (1+(c_\gamma-4c_t/9)v^2)^2$$

fermionic top-partners in composite Higgs models exactly lead to $\Delta c_t = \Delta c_g = \frac{9}{4}\Delta c_\gamma$.

having access to $ht\bar{t}$ final state will resolve this degeneracy
but notoriously difficult channel
14%-4% @ LHC^{14}_{300}-LHC^{14}_{3000} vs 10%-4% @ ILC^{500}_{500}-ILC^{1000}_{1000}

Boosted Higgs

Grojean, Salvioni, Schlaffer, Weiler '13



$$\frac{\sigma_{p_T^{\min}}(\kappa_t, \kappa_g)}{\sigma^{\rm SM}_{p_T^{\min}}} = (\kappa_t + \kappa_g)^2 + \delta\, \kappa_t\, \kappa_g + \epsilon\, \kappa_g^2$$

large pT, small rates

need to focus on dominant decay modes

$$h \to b\bar{b}, WW, \tau\tau$$

non-isolated "ditau-jets"

(separation between the 2 tau's: $\Delta R \sim 2 m_h / p_T \lesssim 0.5$)

$$\epsilon_{\rm tot} = {\rm BR}(h \to \tau\tau) \left(\sum_{i = \tau_\ell\tau_\ell,\, \tau_\ell\tau_h,\, \tau_h\tau_h} {\rm BR}(\tau\tau \to i)\, \epsilon_i \right) \simeq 2 \times 10^{-2}$$

$\sqrt{s}$ [TeV]	$p_T^{\min}$ [GeV]	$\sigma^{\rm SM}_{p_T^{\min}}$ [fb]	δ	ϵ	$gg,\, qg$ [%]
14	100	2200	0.016	0.023	67, 31
	150	830	0.069	0.13	66, 32
	200	350	0.20	0.31	65, 34
	250	160	0.39	0.56	63, 36
	300	75	0.61	0.89	61, 38
	350	38	0.86	1.3	58, 41
	400	20	1.1	1.8	56, 43
	450	11	1.4	2.3	54, 45
	500	6.3	1.7	2.9	52, 47
	550	3.7	2.0	3.6	50, 49
	600	2.2	2.3	4.4	48, 51
	650	1.4	2.6	5.2	46, 53
	700	0.87	3.0	6.2	45, 54
	750	0.56	3.3	7.2	43, 56
	800	0.37	3.7	8.4	42, 57
100	500	970	1.8	3.1	72, 28
	2000	1.0	14	78	56, 43

×150 enhancement

VHE-LHC is the machine
to decipher the gg→h process

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Additional Higgs bosons

⇒ commonly present in most SM extensions. E.g. at least 2 H doublets is mandatory in SUSY

⇒ implications for flavour, CPV, ...

Difficult scenarios for searches at LHC:
- suppressed couplings to W/Z
- large masses

⇒ Problems addressed at 100 TeV thanks to higher rates, higher M reach

E.g. 2HDM in SUSY

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

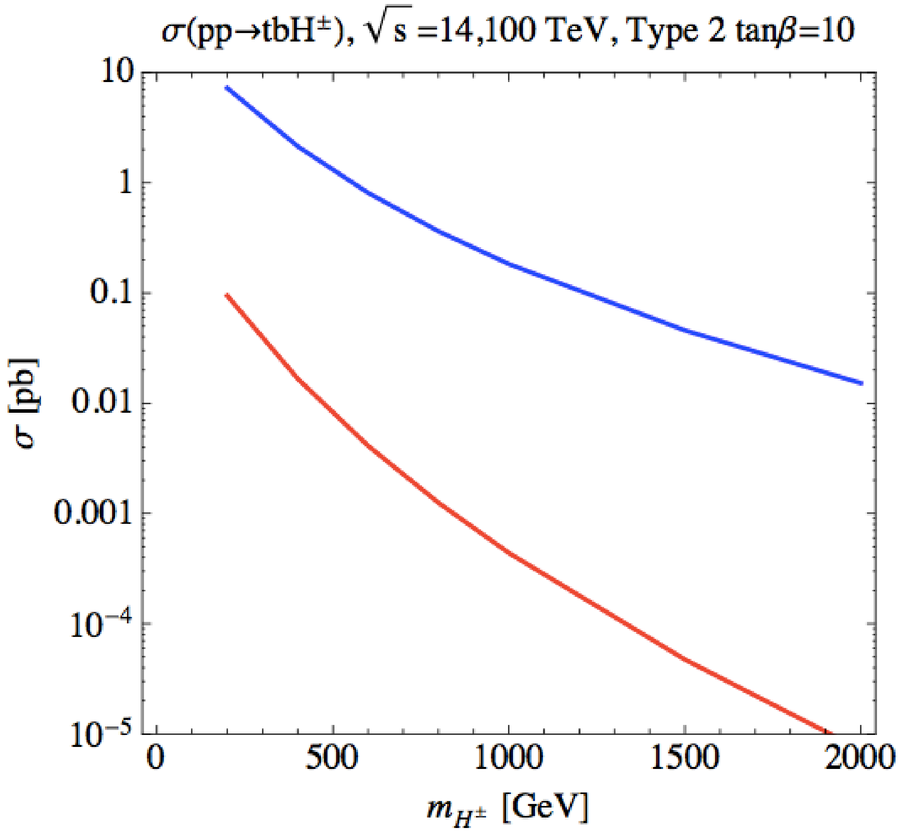
FIne tuning and naturalness: (N.Craig, BSM@100 Wshop)

$$\Delta \approx \sin^2(2\beta)\frac{m_H^2}{m_h^2}$$

$$\Delta(\tan\beta = 50) \leq 1 \rightarrow m_H \lesssim 3.1\ \text{TeV}$$

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

Example: associated $H^{\pm}$ t b production



(N.Craig, BSM@100 Wshop)

Generic features of very heavy H production/decay

Decoupling from W/Z ➡

- "narrow", since $\Gamma \propto m_H$ (cfr $\Gamma \propto m_H^3$ when decaying to W/Z)
- H/A →hh, tt dominate (boosted regime)

⇒ will there be no-lose scenarios ?

⇒ how will, in these scenarios, naturalness constraints from the stop/gluino sectors compare to those from the Higgs sector?

Studies of such questions and of discovery reach just starting.

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10 ab^{-1} at 100 TeV imply:

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10^{10} Higgs bosons => 10^4 x today **Curtin (exotic H decays) BSM@100**

10^{12} top quarks => 5 10^4 x today

=> 10^{12} W bosons from top decays

=> 10^{12} b hadrons from top decays (particle/antiparticle tagged)

=> 10^{11} t → W → taus

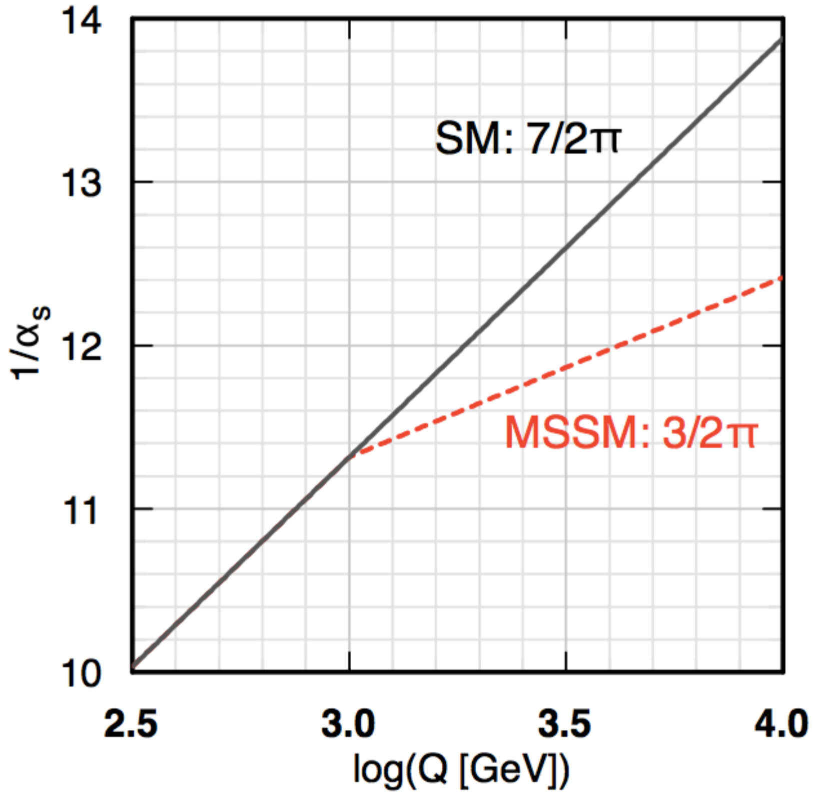
=> few x10^{11} t → W → charm hadrons

Tasks:

o countless list ! .... plus

o examine the possibility of detectors dedicated to final states in the 0.1 - 1 TeV region, with focus on Higgs, DM and weakly interacting new particles, top, W

Quigg @ //



α_s at 100 TeV pp-collider

Zanderighi @ //

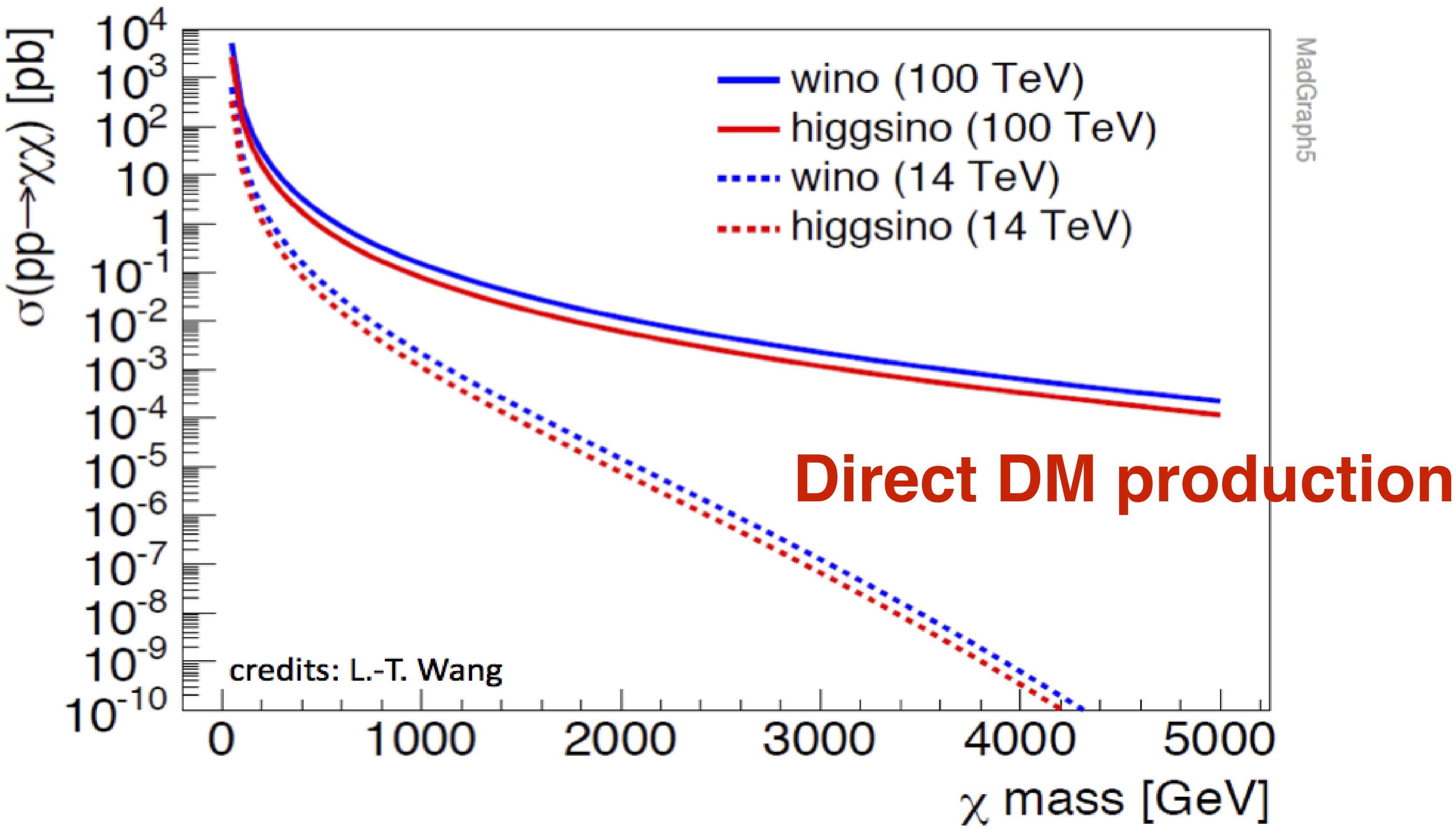
How about measuring α_s from Z+1jet? Could also measure the running nicely over a very large range of p_t values ...

Deviation from QCD running could provide indirect evidence for New Physics

If not Z+1jet, what observable/process would be best...? e.g. ratio of Z+1jet/ZZ ?

Certainly worth exploring the potential of a 100 TeV hadron collider also in this direction

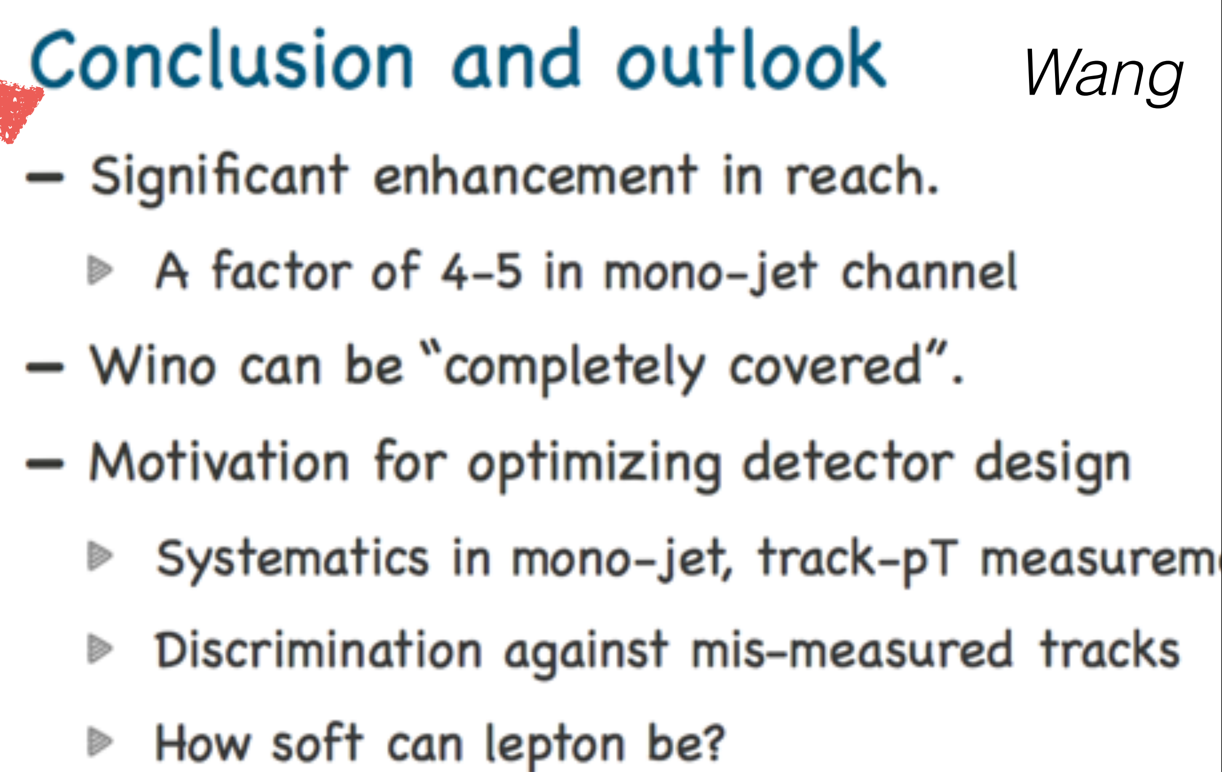
Electroweak SUSY @ 100 TeV



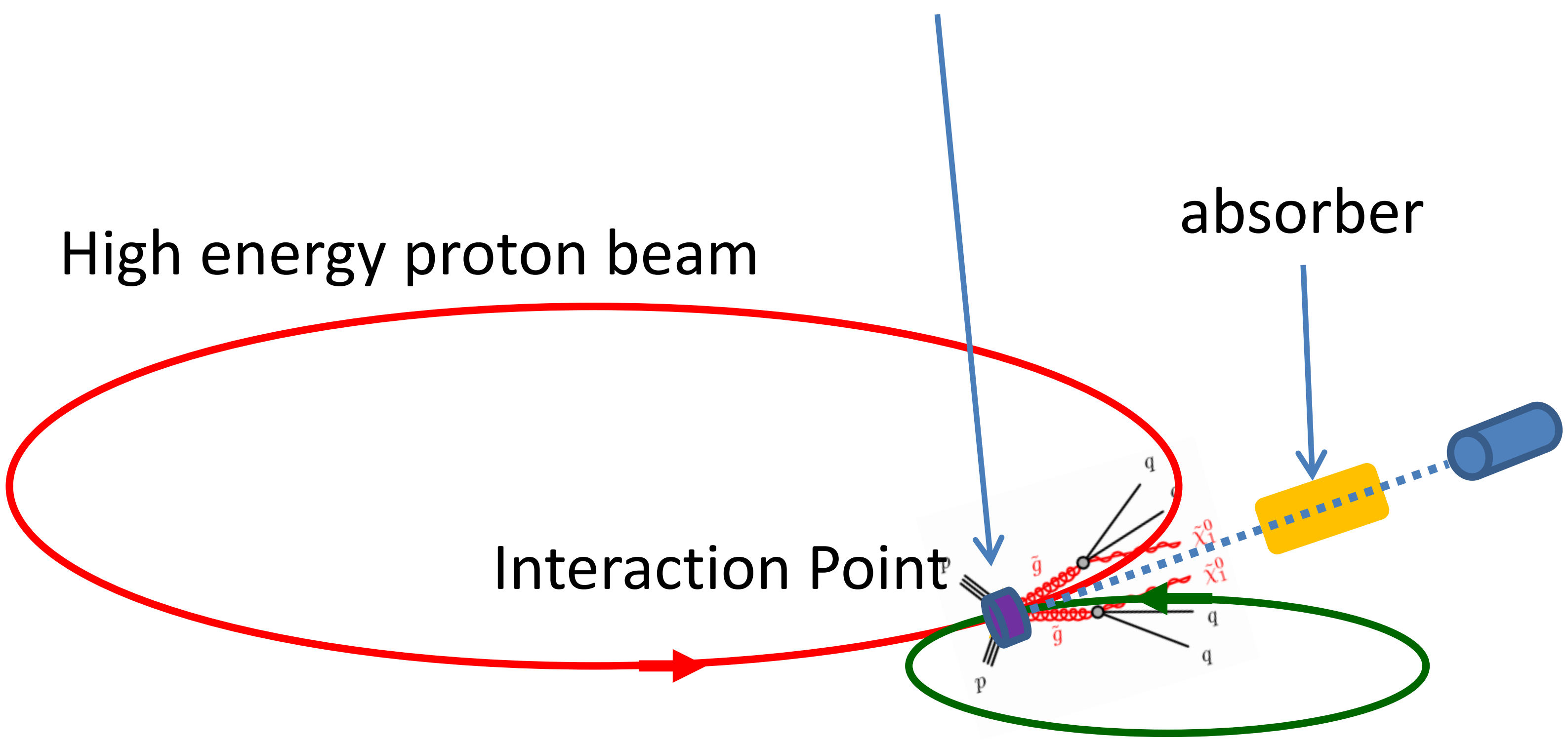
Expecting large improvements!

A few studies already:

- BSM physics opportunities at 100 TeV
- LPC meeting on future 100 TeV proton collider

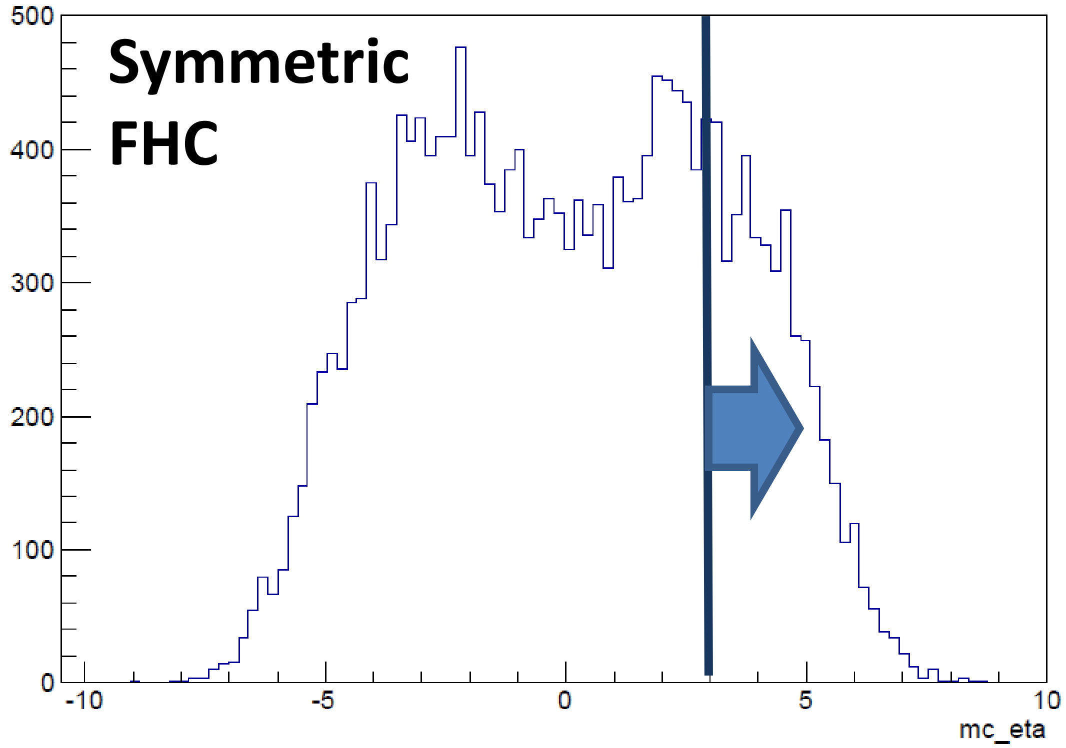


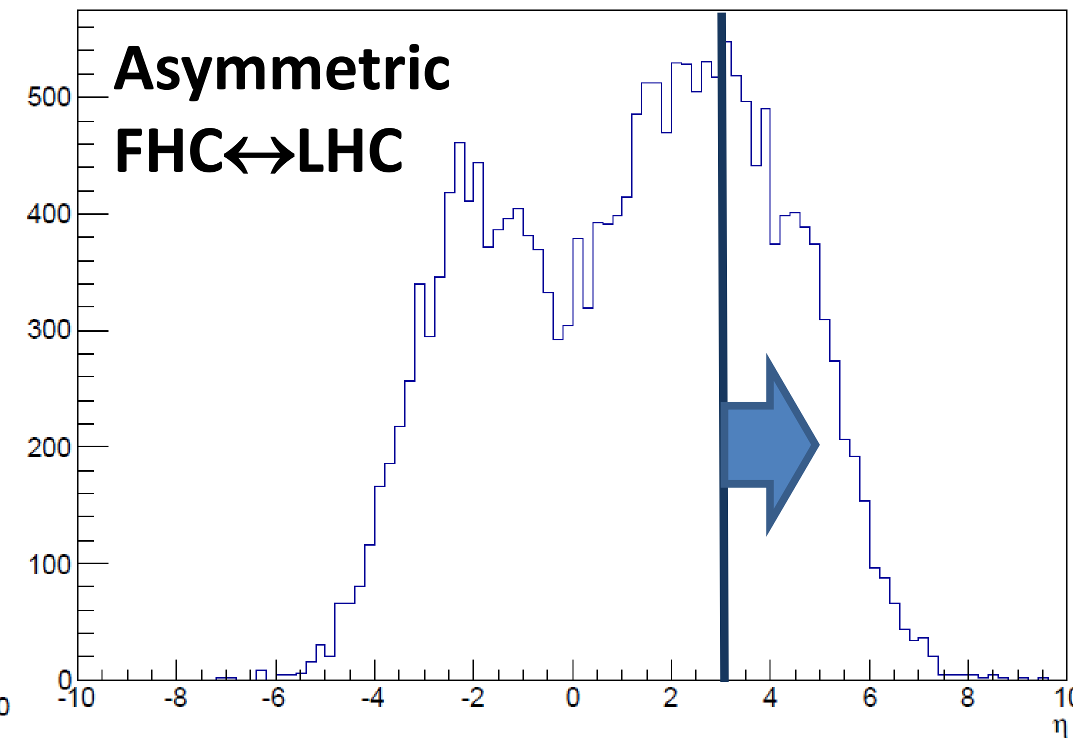
DM Beam from Asymmetric Collider



	E_{high} $[TeV]$	E_{low} $[TeV]$	E_{cm} $[TeV]$	
FHC→Fixed Target	50	0.001	0.3	← insufficient E_{cm}
FHC↔LHC	50	7.000	37.4	promising!
FHC↔Super-SPS	50	3.000	24.5	

Symmetric vs Asymmetric Collider



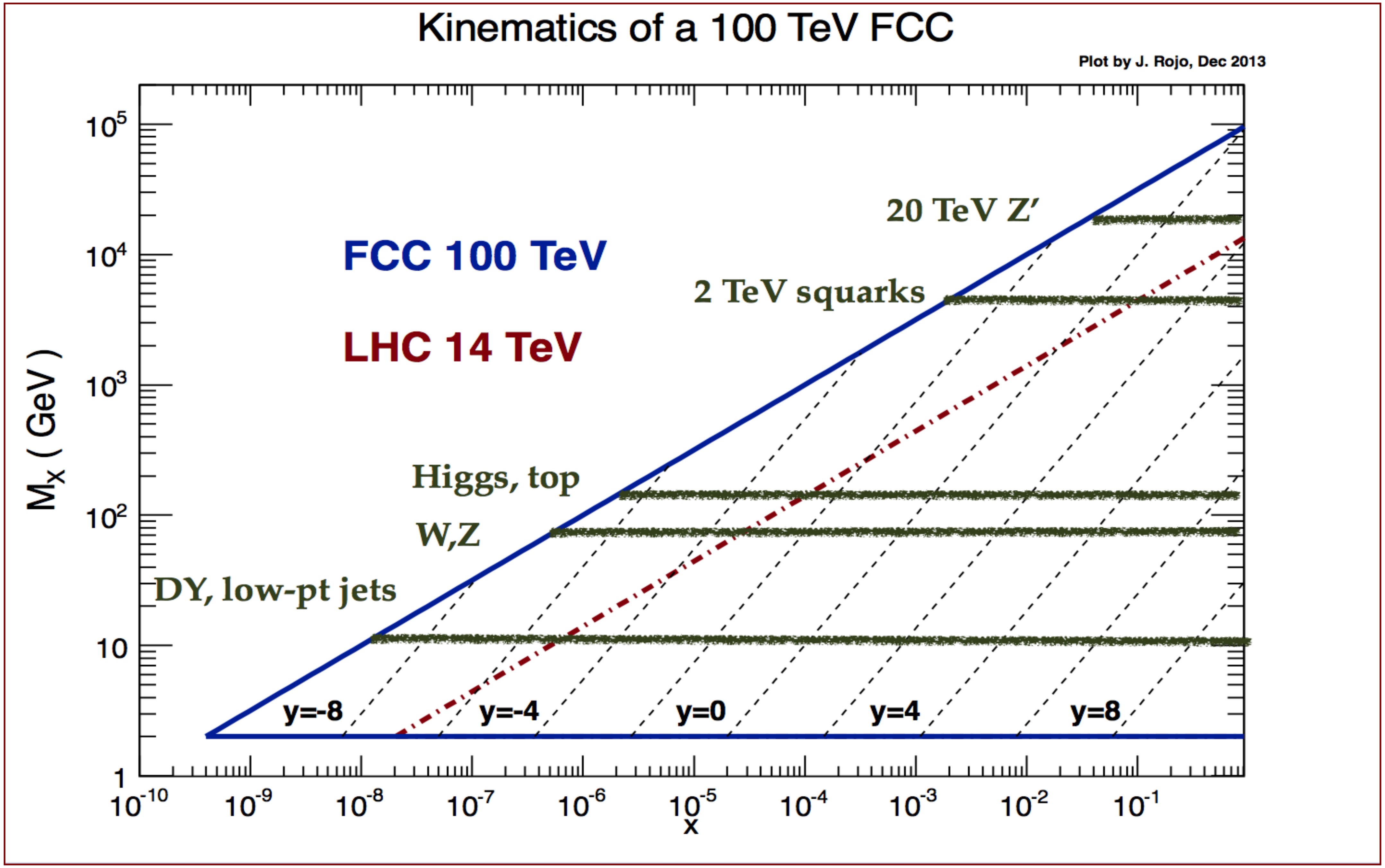


SUSY pMSSM model #9515

	symmetric FHC	asymmetric FHC↔LHC
collider luminosity	10^{36} cm^{-2}s^{-1}	10^{36} cm^{-2}s^{-1}
collider E_{cm}	100 TeV	37.4 TeV
SUSY production cross-section	147 pb	51 pb
detector acceptance (100m)	22%	29%
dark matter energy at detector	~2 TeV	~43 TeV
dark matter cross-section (σ_χ)	10^{-7} pb	23 pb
χ^0_1 in detector (10m copper)	3×10^{-9} signal hit/day	0.3 signal hit/day

unexplored range for PDF's

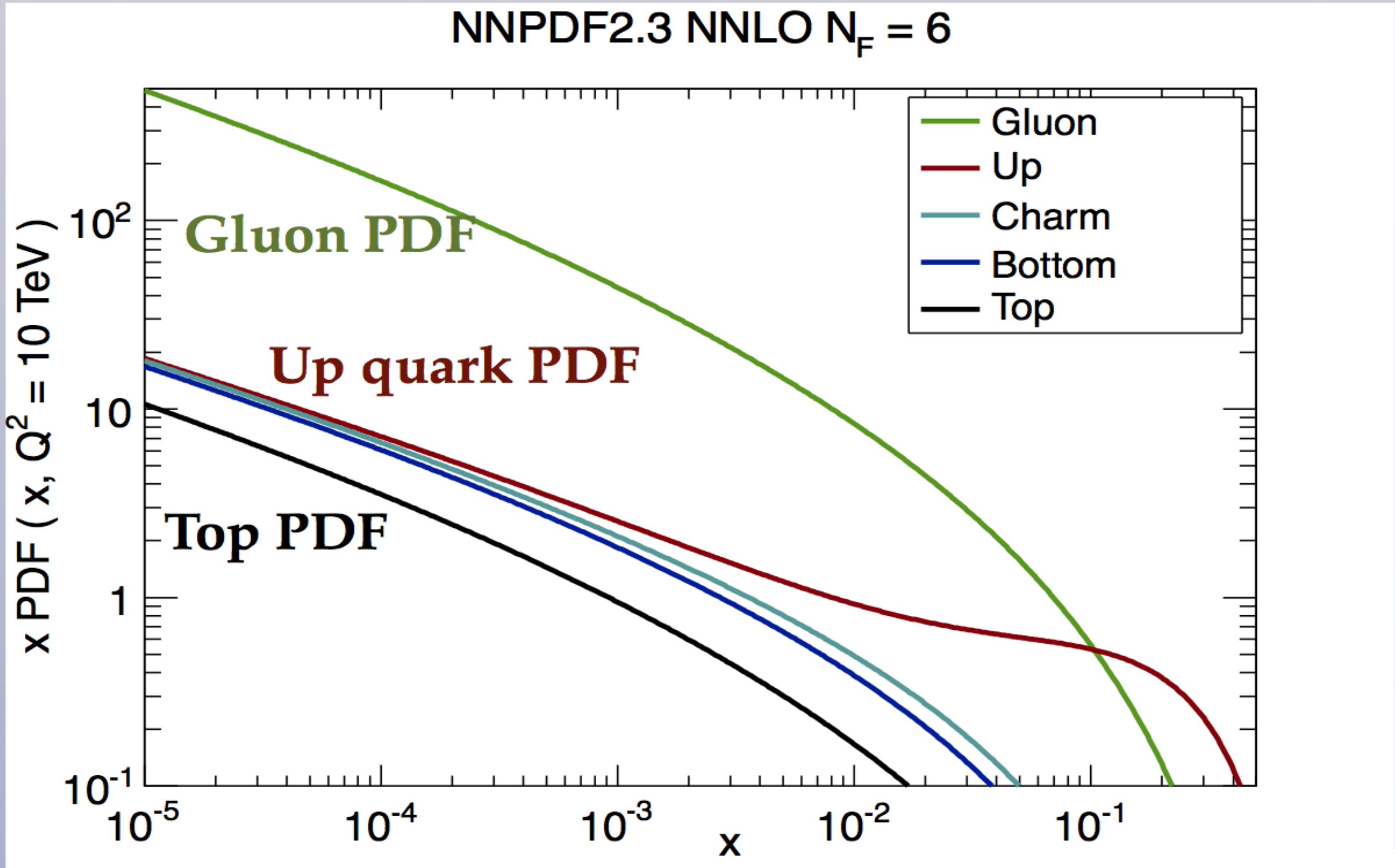
Gianotti

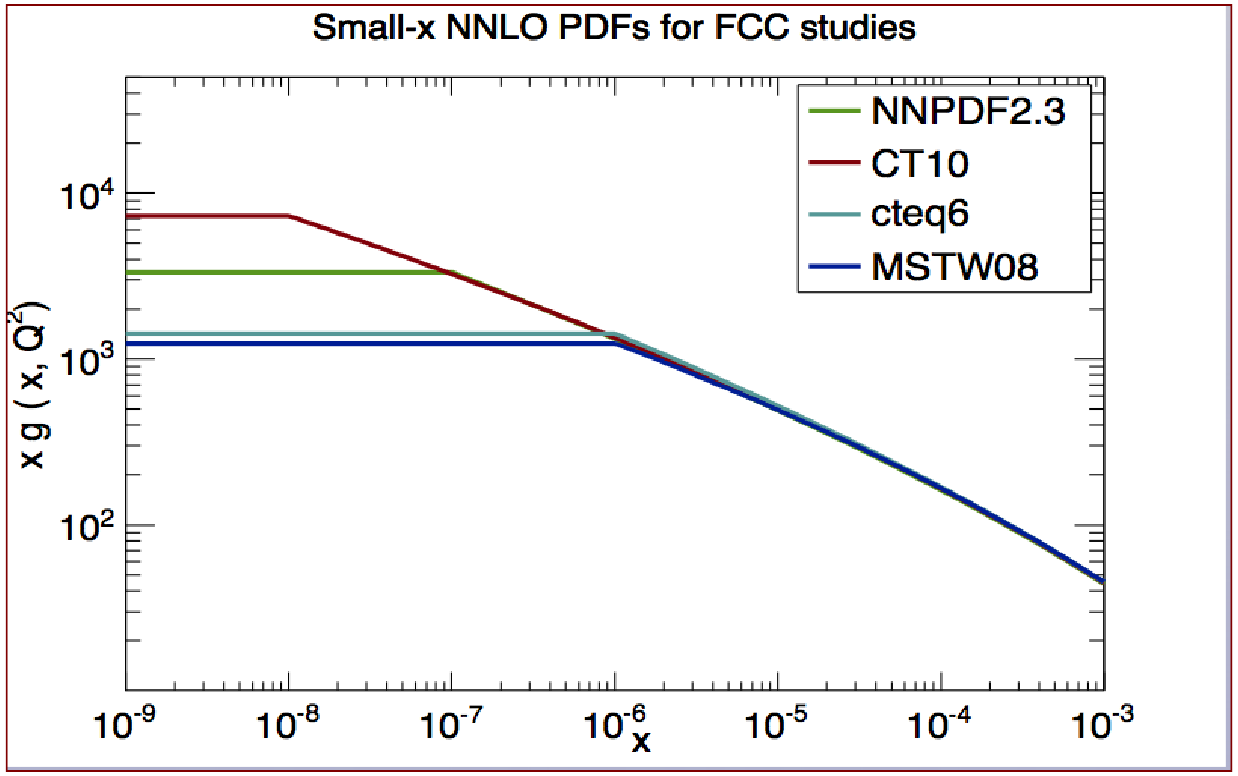


- ❑ Much larger x range (smaller values, down to 10^{-8})
- ❑ Current PDF sets have ~ no constraints below 10^{-4} or for M >> 1 TeV → need QCD evolution (DGLAP equations) to extrapolate (while waiting for more LHC data ..)

Gianotti

✻ At 10 TeV, the top quark PDF **t(x,Q)** is only a **factor 2 smaller that all other quark PDFs** (charm and bottom are very close to light quark PDFs): should be included in theoretical predictions





Some PDF "frozen" below 10^{-6} → not a fundamental problem
→ A group of people will provide a set of PDF for FHC-hh studies

FHC: physics topics list => WG structure (preliminary)

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FHC.1.1 Exploration of EW Symmetry Breaking (EWSB)

FHC.1.1.1 High-mass WW scattering, high mass HH production

FHC.1.1.2 Rare Higgs production/decays and precision studies of Higgs properties

FHC.1.1.3 Additional BSM Higgs bosons: discovery reach and precision physics programme

FHC.1.1.4 New handles on the study of non-SM EWSB dynamics (e.g. dynamical EWSB and composite H, etc)

FHC.1.2 Exploration of BSM phenomena

FHC.1.2.1 discovery reach for various scenarios (SUSY, new gauge interactions, new quark and leptons, compositeness, etc.)

FHC.1.2.2 Theoretical implications of discovery/non-discovery of various BSM scenarios, e.g. address questions such as:

- FHC.1.2.2.1 what remains of Supersymmetry if nothing is seen at the scales accessible at 100 TeV?
- FHC.1.2.2.2 which new opportunities open up at 100 TeV for the detection and study of dark matter?
- FHC.1.2.2.3 which new BSM frameworks, which are totally outside of the HL-LHC reach, become accessible/worth-discussing at 100 TeV ?

FHC.1.3 Continued exploration of SM particles
FHC.1.3.1 Physics of the top quark (rare decays, FCNC, anomalous couplings, ...)
FHC.1.3.2 Physics of the bottom quark (rare decays, CPV, ...)
FHC.1.3.2 Physics of the tau lepton (e.g. tau -> 3 mu, tau -> mu gamma and other LFV decays)
FHC.1.3.2 W/Z physics
FHC.1.3.3 QCD dynamics

FHC.1.4 Opportunities other than pp physics:
FHC.1.4.1 Heavy Ion Collisions
FHC.1.4.2 Fixed target experiments:
FHC.1.4.2.1 "Intensity frontier": kaon physics, mu2e conversions, beam dump experiments and searches for heavy photons, heavy neutrals, and other exotica...
FHC.1.4.2.2 Heavy Ion beams for fixed-target experiments

FHC.1.5 Theoretical tools for the study of 100 TeV collisions
FHC.1.5.1 PDFs
FHC.1.5.2 MC generators
FHC.1.5.3 N^nLO calculations
FHC.1.5.4 EW corrections

The FCC-ee program

√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

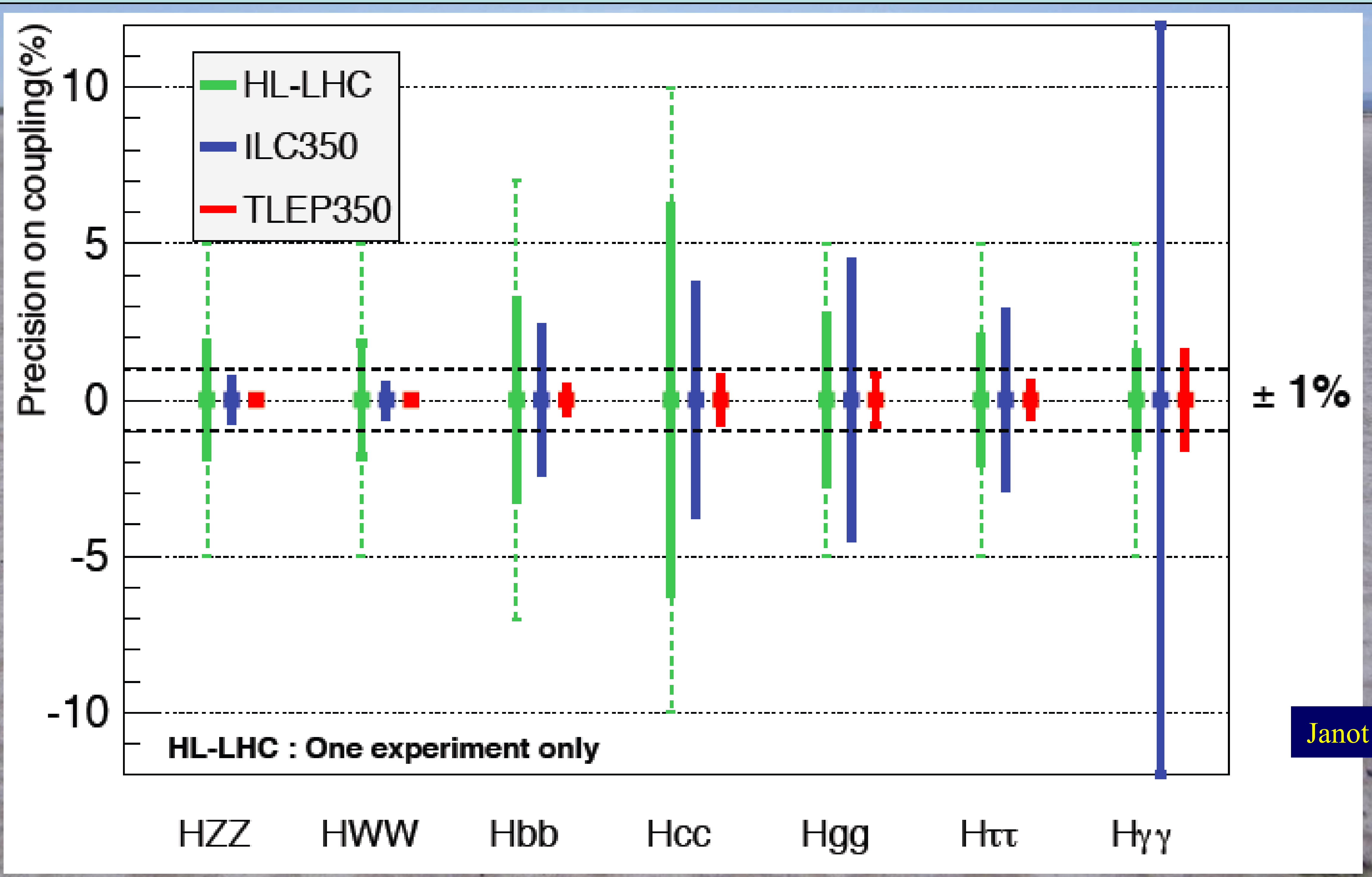
First Look at the Physics Case of TLEP
TLEP Design Study Working Group Collaboration
Published in **JHEP 1401 (2014) 164**

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

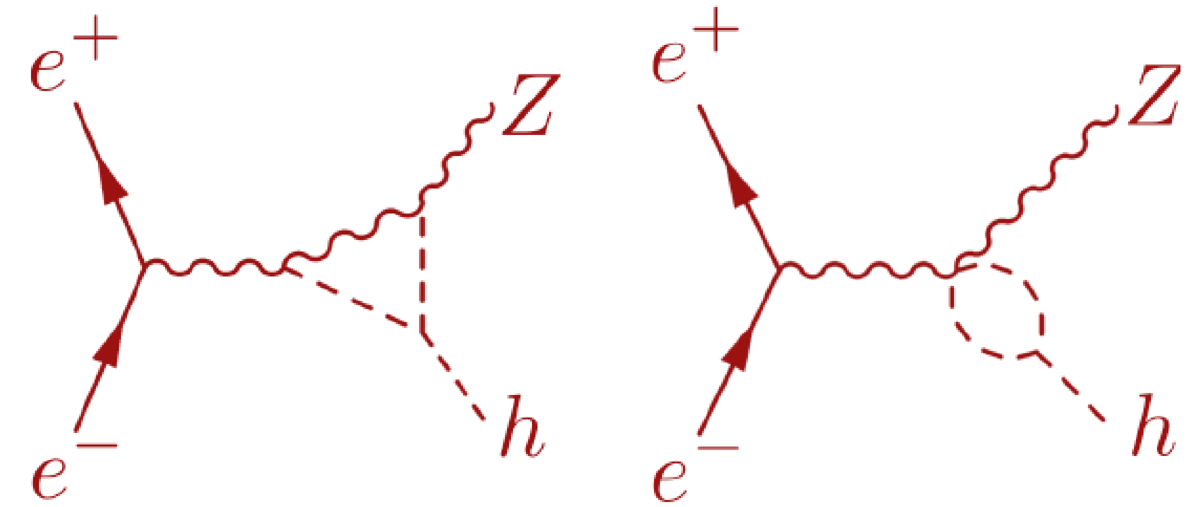
Possible Future Higgs Measurements

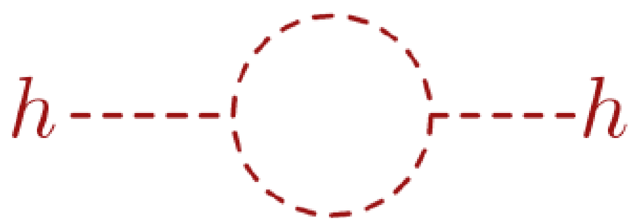


Ellis

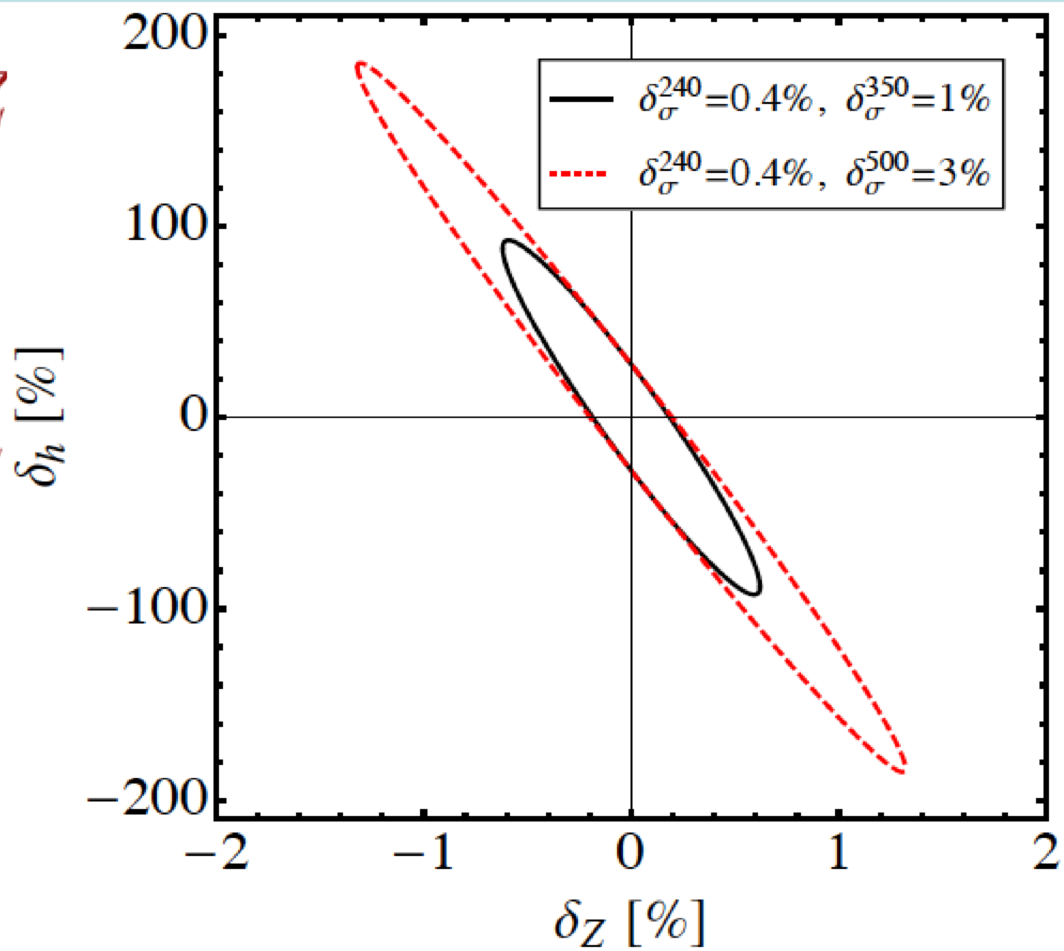
Indirect Sensitivity to 3h Coupling

- Loop corrections to σ(H+Z):



And also: 

$$\delta_\sigma^{240} = 100\,(2\delta_Z + 0.014\delta_h)\,\%$$

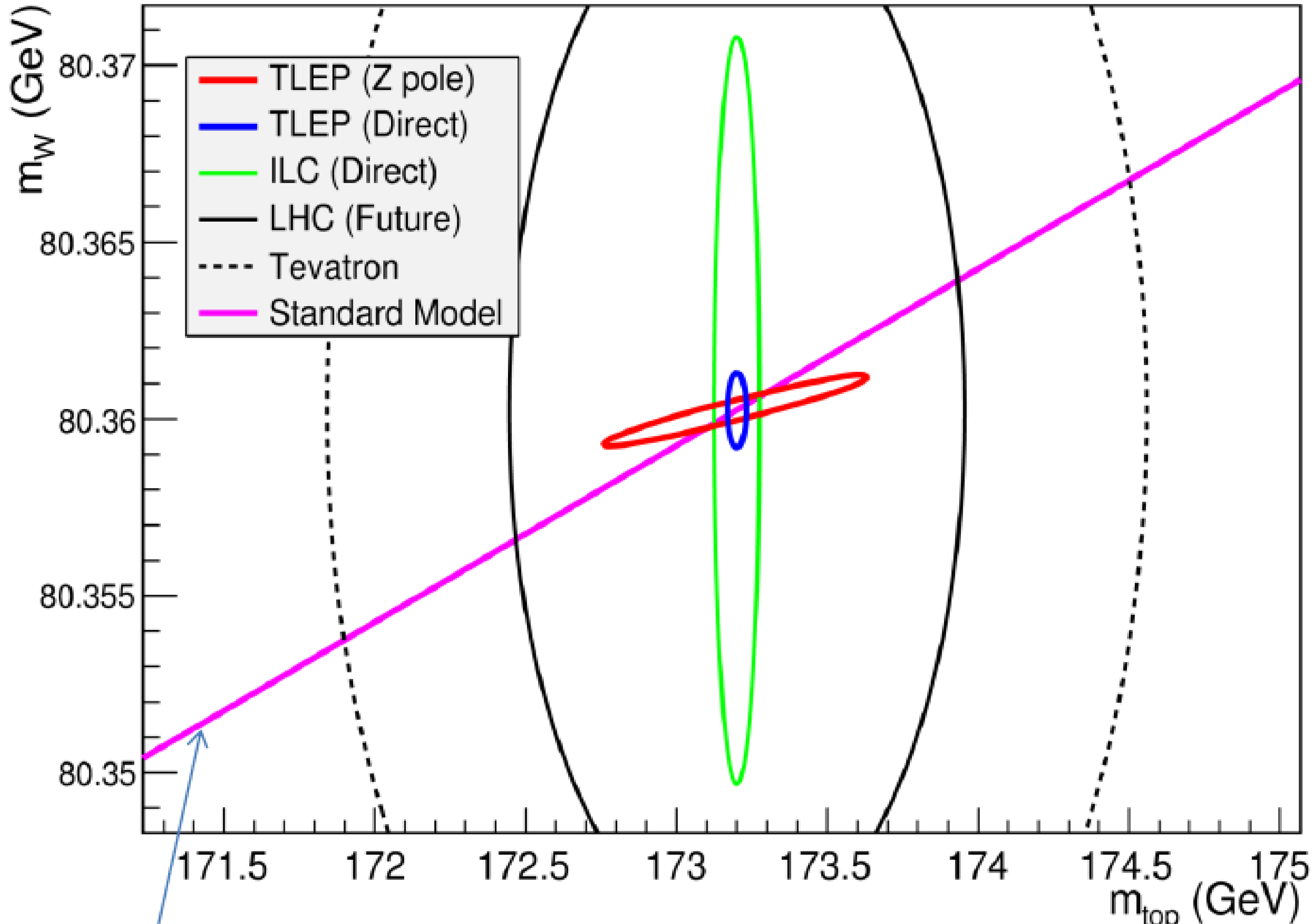


McCullough

- 3h correction δ_h energy-dependent
- δ_Z energy-independent: can distinguish

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_b	δ_b	0.21629 ±0.00066	Z Peak	0.000003	<0.000060	Statistics, small IP	Hemisphere correlations
A_{LR}	**$\Delta\rho, \varepsilon_3, \Delta\alpha$ (T, S)**	0.1514 ±0.0022	Z peak, polarized	0.000015	<0.000015	4 bunch scheme, > 2exp	Design experiment
M_W MeV/c2	**$\Delta\rho, \varepsilon_3, \varepsilon_2, \Delta\alpha$ (T, S, U)**	80385 ± 15	Threshold (161 GeV)	0.3 MeV	<0.5 MeV	E_cal & Statistics	QED corections
m_{top} MeV/c2	**Input**	173200 ± 900	Threshold scan	10 MeV	<10MeV	E_cal & Statistics	Theory interpretation 40 MeV?

TLEP Measurements of m_t & M_W



NB without TLEP the SM line would have a 2.2 MeV width

Experimental Physics WBS (coordinators A. Blondel, P. Janot)

Study the properties of the Higgs and other particles with unprecedented precision

Electroweak Physics at the Z pole	Di-boson Physics m_W measurement	H(126) Properties	Top Quark Physics
R. Tenchini	R. Tenchini	TBA	P. Azzi

QCD and Physics	Flavour Physics	Exp'tal signatures of New Physics
D. d'Enterria	S. Monteil	M. Pierini

Develop the necessary tools

Understand the experimental conditions

Offline Software and Computing	Online Software and Computing	Exp'tal Environment
TBA	C. Leonidopoulos	N. Bacchetta
Synergy with FCC-hh		Synergy with FCC-hh

Set constraints on the possible detector designs to match statistical precision

Detector Designs

G. Rolandi

Synergy with linear collider detectors

conveners jobs is to assemble collaborators and find co-conveners in a global way

Deep Inelastic Scattering at High Energy

Max Klein
University of Liverpool

For the ep/eA study group

FCC Meeting. 14.2.2014
University of Geneva

http://cern.ch/lhec

60 GeV x 7 TeV (LHC)

60 … 175 GeV x 50 TeV (FCC-h)

SM Higgs prospects in DIS

U.Klein @ //

H production

Higgs in e^-p	CC - LHeC ($\sqrt{s}$= 1.3 TeV)	NC - LHeC ($\sqrt{s}$= 1.3 TeV)	CC - FHeC ($\sqrt{s}$= 3.5 TeV)
Polarisation	-0.8	-0.8	-0.8
Luminosity [ab^{-1}]	1	1	5
Cross Section [fb]	196	25	850
Decay BrFraction	N^H_{CC}	N^H_{NC}	N^H_{CC}
$H \to b\bar{b}$ 0.577	113 100	13 900	2 450 000
$H \to c\bar{c}$ 0.029	5 700	700	123 000
$H \to \tau^+\tau^-$ 0.063	12 350	1 600	270 000
$H \to \mu\mu$ 0.00022	50	5	1 000
$H \to 4l$ 0.00013	30	3	550
$H \to 2l2\nu$ 0.0106	2 080	250	45 000
$H \to gg$ 0.086	16 850	2 050	365 000
$H \to WW$ 0.215	42 100	5 150	915 000
$H \to ZZ$ 0.0264	5 200	600	110 000
$H \to \gamma\gamma$ 0.00228	450	60	10 000
$H \to Z\gamma$ 0.00154	300	40	6 500

Uta Klein, Higgs@FCC-he

FFC-he, H→HH cross section ~0.4fb

HH production

Fiducial cross-sections for CC e⁻p DIS : HH->4b (branching ratios included) and *un*polarised electron beam

Processes	E_e (GeV)	σ(fb)	σ_{eff}(fb)
$e^-p \to \nu_e hhj, h \to b\bar{b}$	60	0.04	0.01
	120	0.10	0.024
	150	0.14	0.034

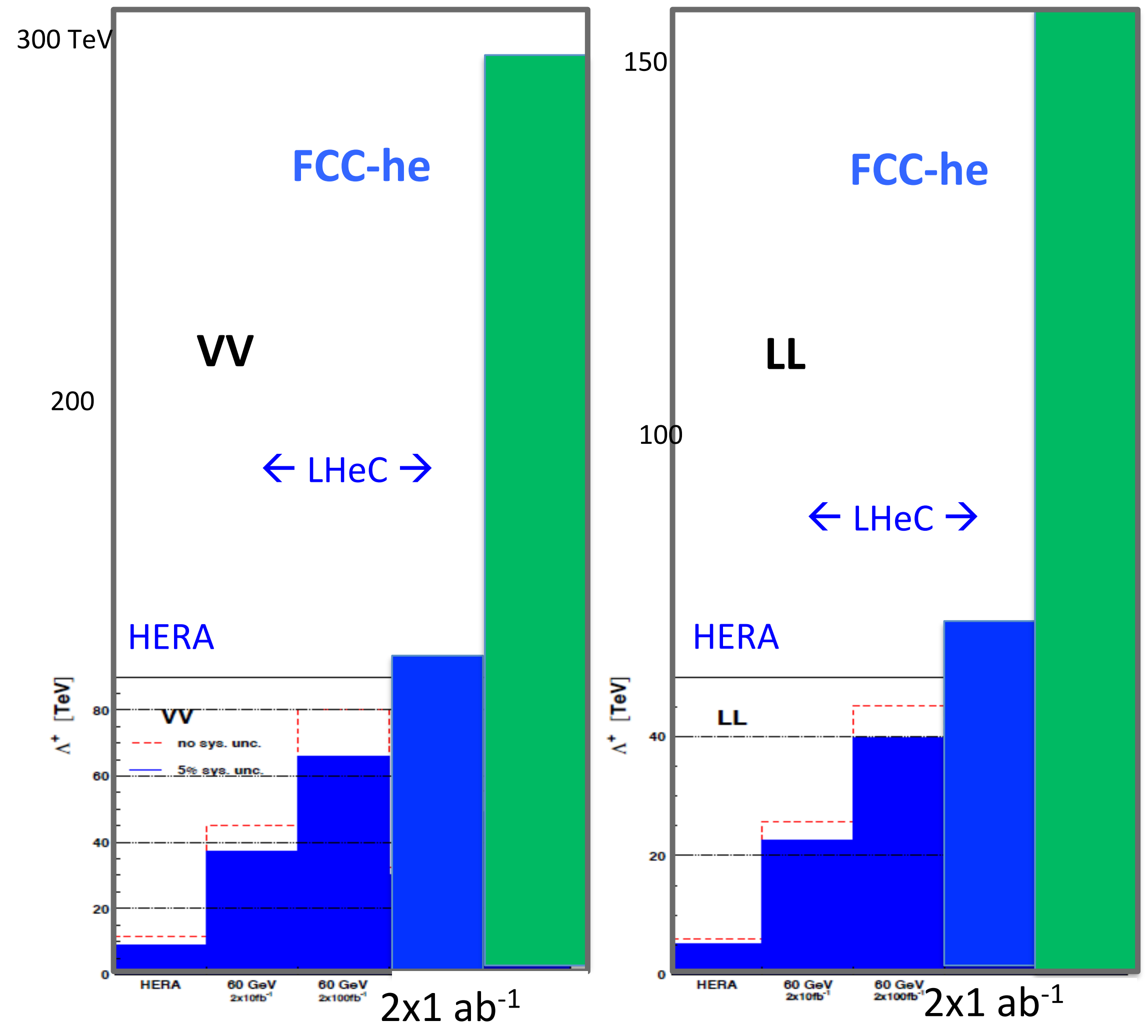
$p_{T_{j,b}} > 20\ GeV$

$\not{E}_T > 25\ GeV$

$|\eta_j| < 5,\ \Delta R = 0.4$

FCC-he

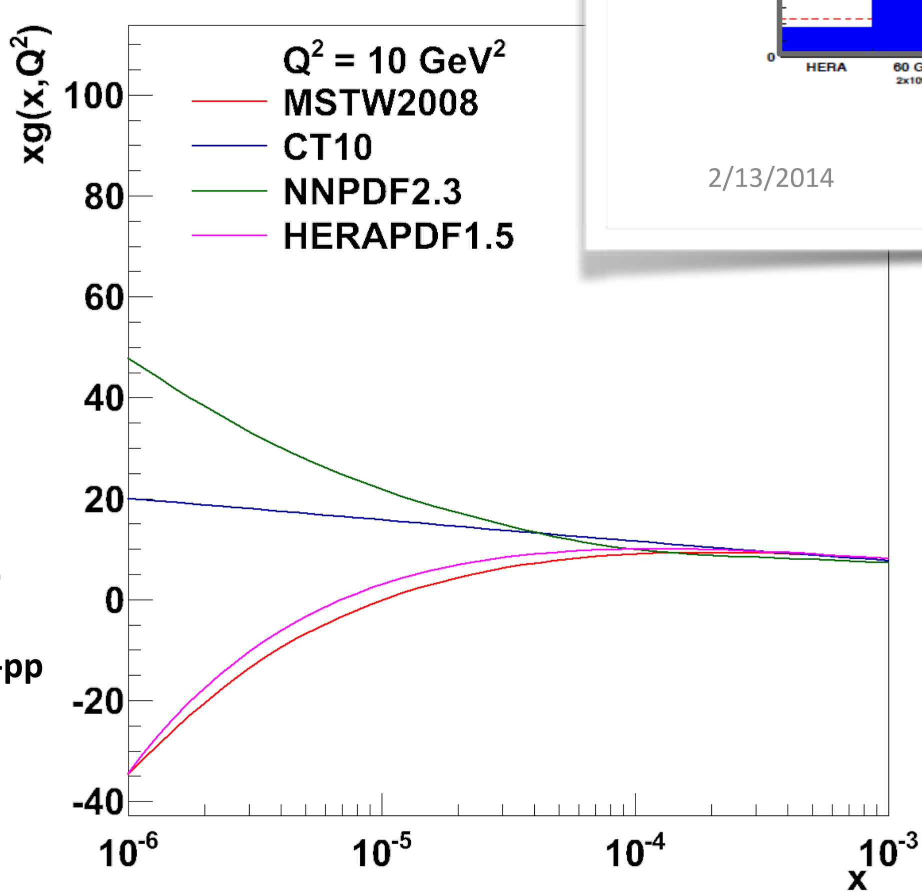
Reach for CI (eeqq) at FCC-he



- Very preliminary scaling from LHeC
- Reach about **O(100) TeV**, expected to be competitive with FHC

2/13/2014 Monica D'Onofrio, FCC Study Kickoff, Geneva 22

xg at low x



No clue about xg for x < 10^{-4}

Evolution law may not be DGLAP

Affects FCC-pp rates because x=M/sqrt(s) exp(+-y)

note x(Higgs) at FCC-pp for y=0 is 10^{-3} ..

Ions at the FCC

- A discussion group on “Ions at the FCC” started: coordinated by A. Dainese, S. Masciocchi, U. Wiedemann
  - sub-group of “FHC Physics, Experiments, Detectors”
- Two meetings up to now, Dec 16-17 and Jan 29
  - https://indico.cern.ch/conferenceDisplay.py?ovw=True&confId=288576
  - https://indico.cern.ch/conferenceDisplay.py?confId=290413
- Participation from CERN accelerator team, theory, ALICE, ATLAS, CMS
- Goal: explore opportunities with heavy ions at the FCC
  - Saturation (contacts: N. Armesto, M. van Leeuwen)
  - Soft physics (contact: U. Wiedemann)
  - Hard probes (contacts: A. Dainese, C. Roland, C. Salgado)
  - UPC (contact: D. d’Enterria)
- Work is in progress! Just few ideas presented here

→ Talk by A. Dainese in Friday parallel session

Next steps (i)

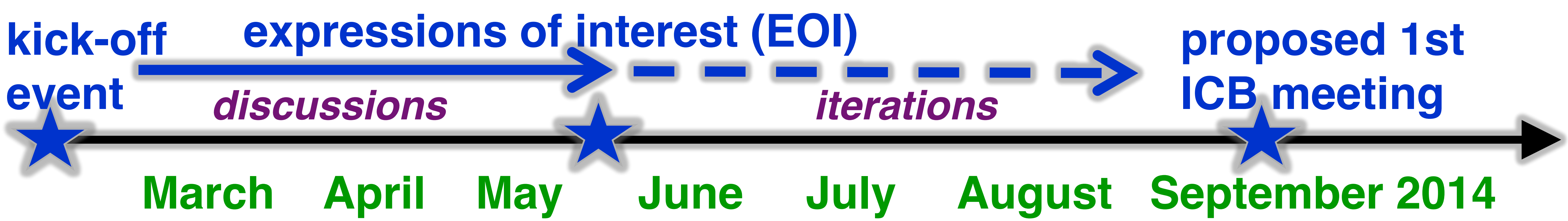
- **Establish an international collaboration:**
- Following very positive reactions and the enthusiasm during the Kick-off meeting:

→ **Formal invitations to institutes to join collaboration**

→ Aiming at **expressions of interest by end May** to form nucleus of collaboration by September

→ Enlargement of the preparation team

→ **First international collaboration board meeting 8-10 September**



Summary

- In line with the **European Strategy**, CERN is launching a **5-year international design study** for Future Circular Colliders (FCC); unique road up to 100 TeV energy scale
- **Worldwide collaboration in all areas** - physics, experiments and accelerators – **is essential** to bring this study to fruition (and to arrive at a CDR by 2018)
- Need to present (additional) **benefits to society** from the very beginning of the study (examples: sc technologies)
- Need to have **excellent communication and outreach** accompanying the study
- Make **efficient use of existing efforts/investments** and interconnect with other projects/studies

Collaboration Dinner at Hotel Kempinski

…still wondering whether dessert was purposely detector-shaped…