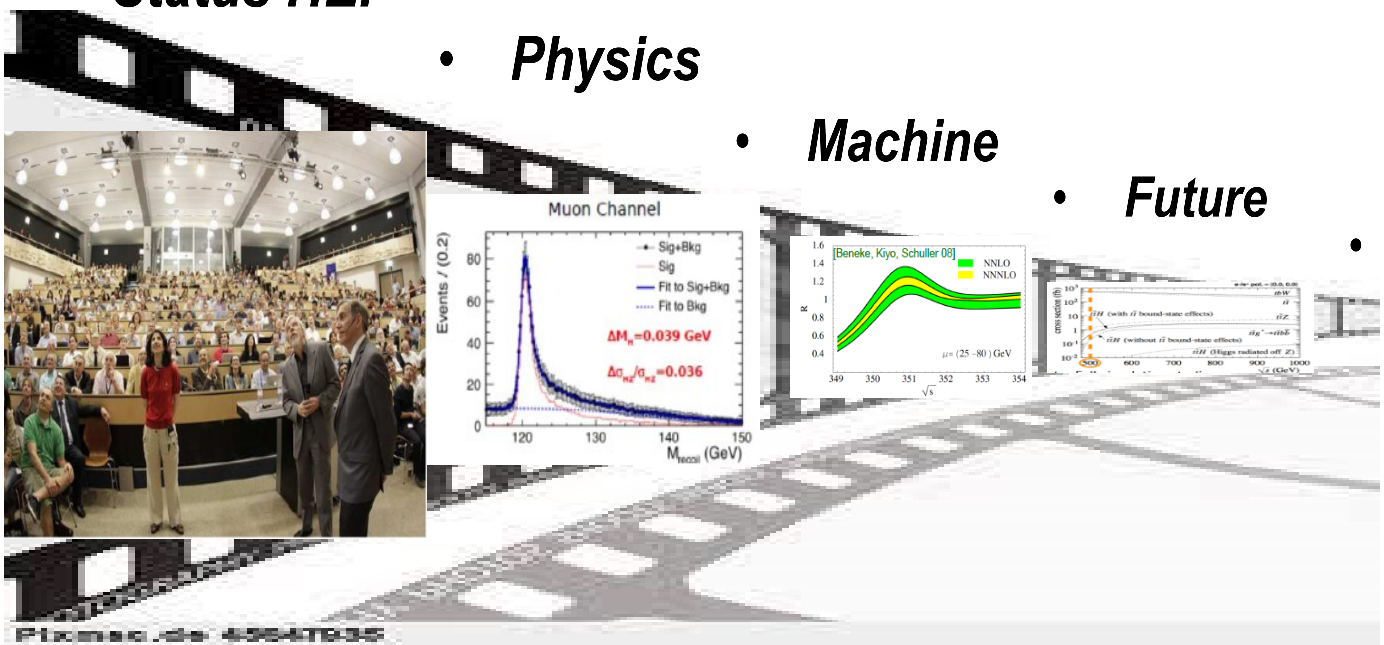
The ILC in the LHC era: goals ,challenges and status

G. Moortgat-Pick (Uni Hamburg/DESY)

- Status HEP
- Physics
- Machine
- Future
- Summary



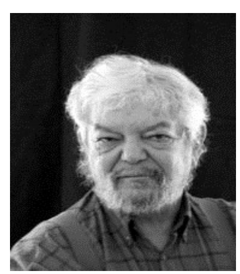
LINEAR COLLIDER COLLABORATION

Physics Nobel price 2013

Francois Englert

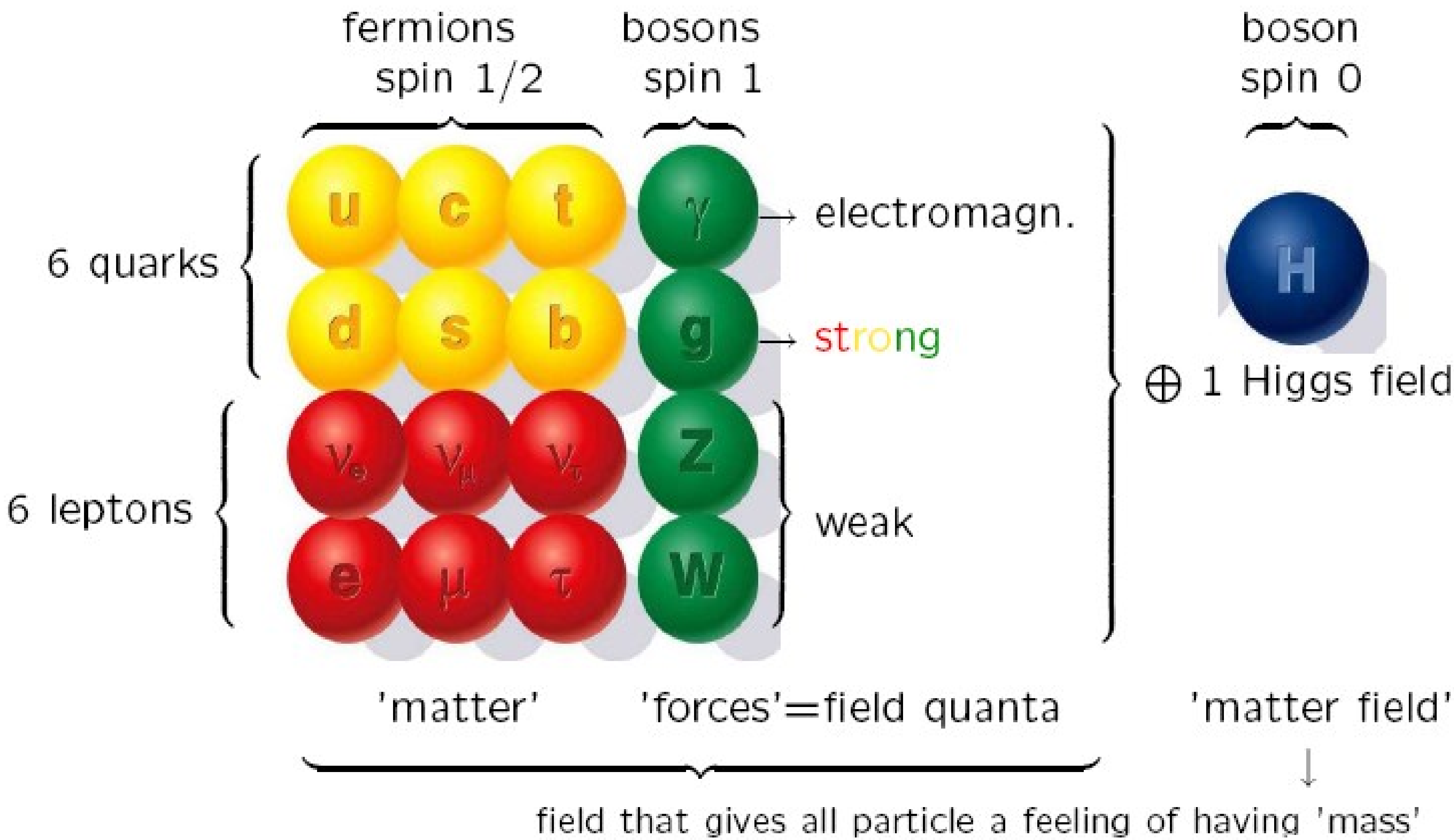
Peter Higgs

Robert Brout († 2011)



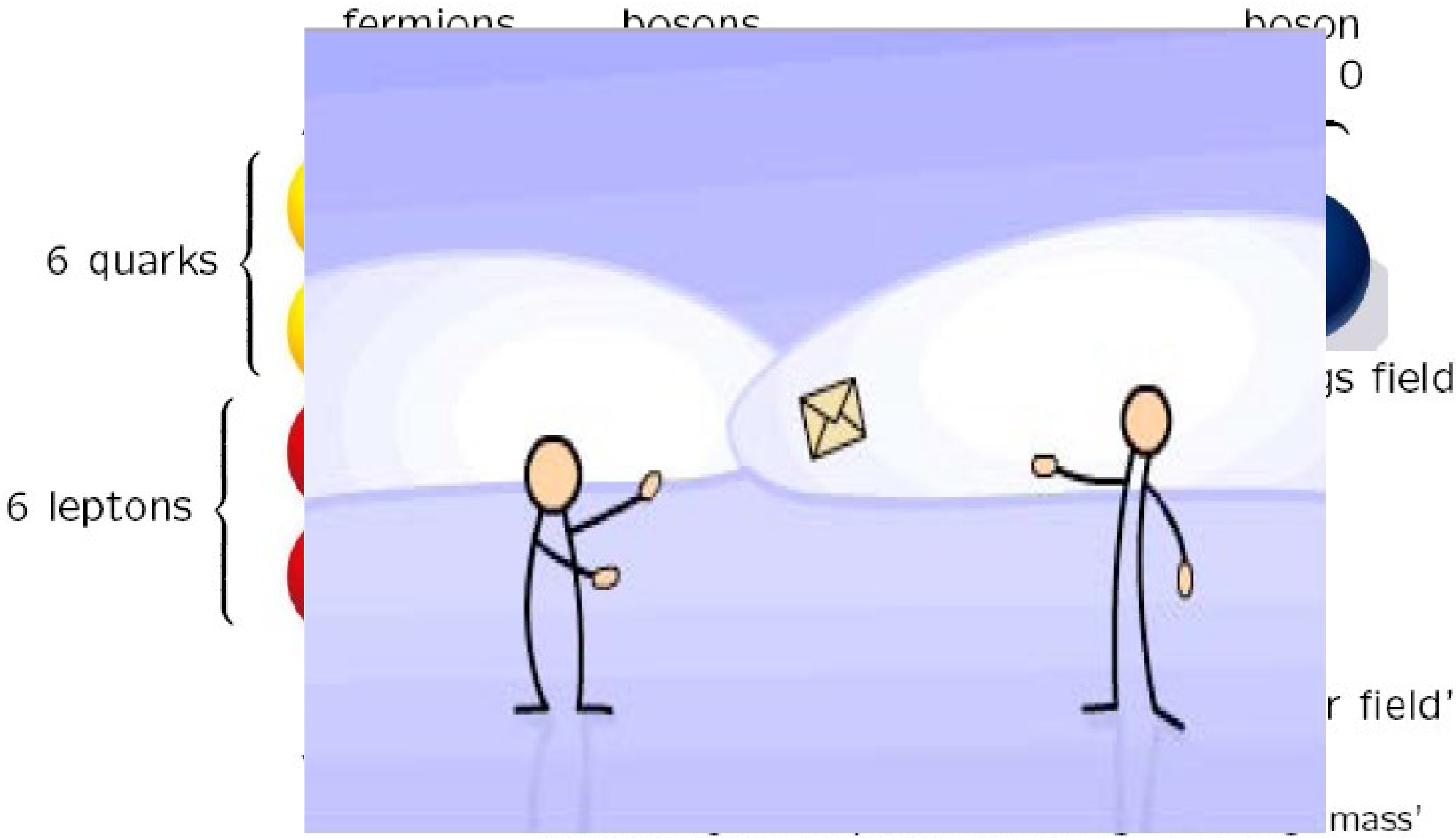
Discovery on 4.July 2012 at LHC

Standard Model of particle physics



In experiment: o.k. o.k. **4.7.2012 !**

Standard Model of particle physics



In experiment: o.k. o.k. **4.7.2012 !**

Higgs 'field ' and Higgs 'boson'

- **Higgs mechanism:** ***particles get their masses via the interaction with the Higgs field***

- **Higgs boson(s):** ***quanta of the Higgs field (analogue photon = quantum of the electromagnetic field)***

- **Decisive:** ***Coupling between Higgs and the particle is proportional to their mass***

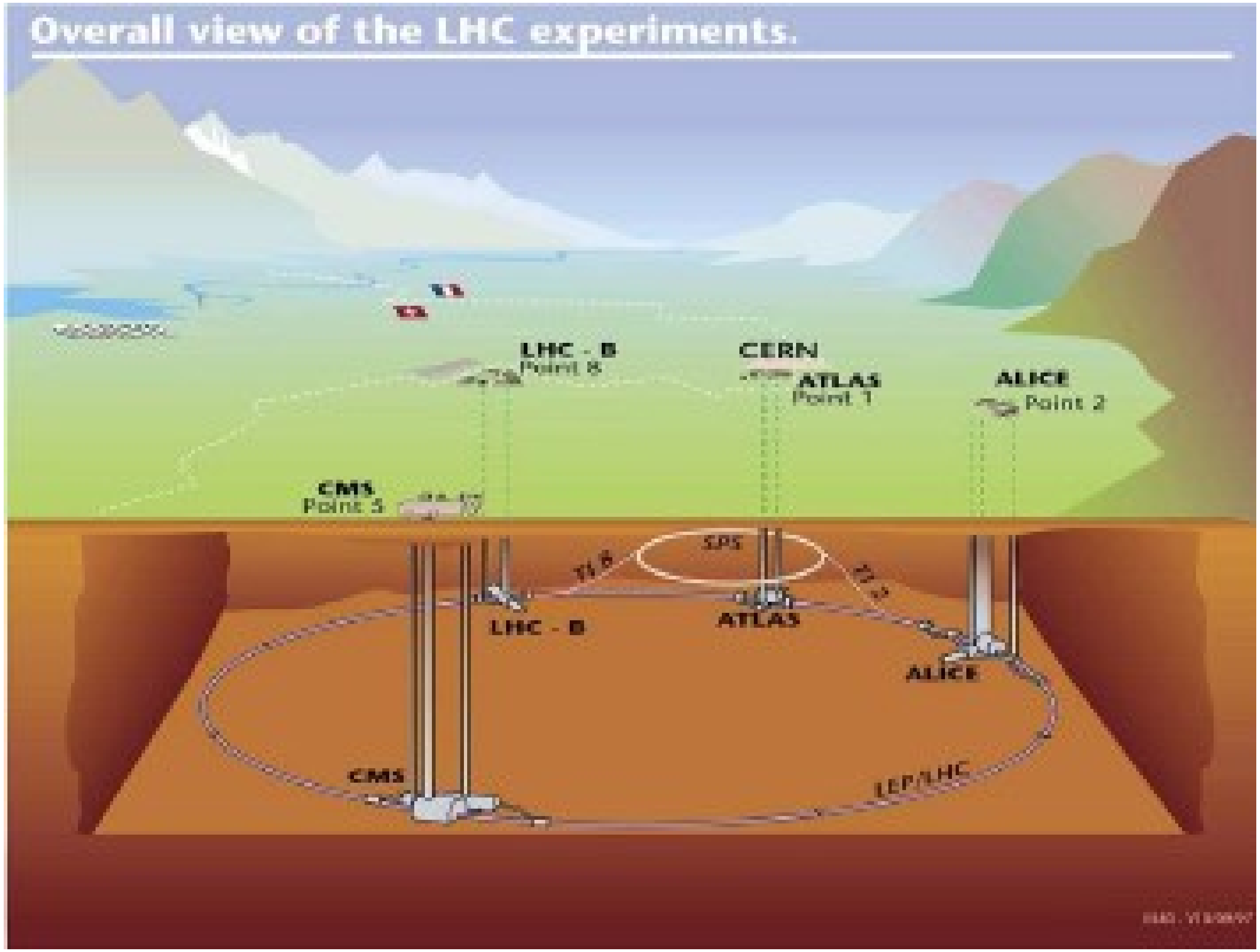
- **Spin*:*** ***postulated Higgs is a scalar particle, i.e. spin 0 !***
  - ***before 4/7/2012 there has never been observed a fundamental scalar particle !***

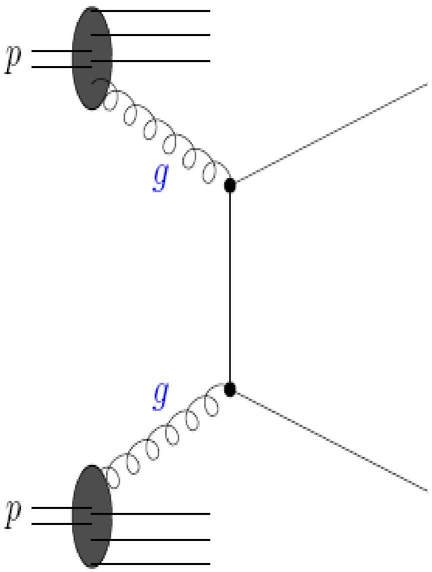
What is so spectacular at the Higgs?

- H is neither „matter“ (spin1/2) nor „;force“ (spin 1) but „spin 0“
- H interacts directly with <u>all</u> particles, that (seems to) carry mass (more strongly if more mass)
- Therefore this particle can only be produced if enough energy is provided
- H is rather short living (10^{-22} s) – it decays fast in pairs of almost all massive particles of the Standard Model.

➢ **The Higgs particle is not only „yet another particle“ but a fundamental new building block of the nature !**

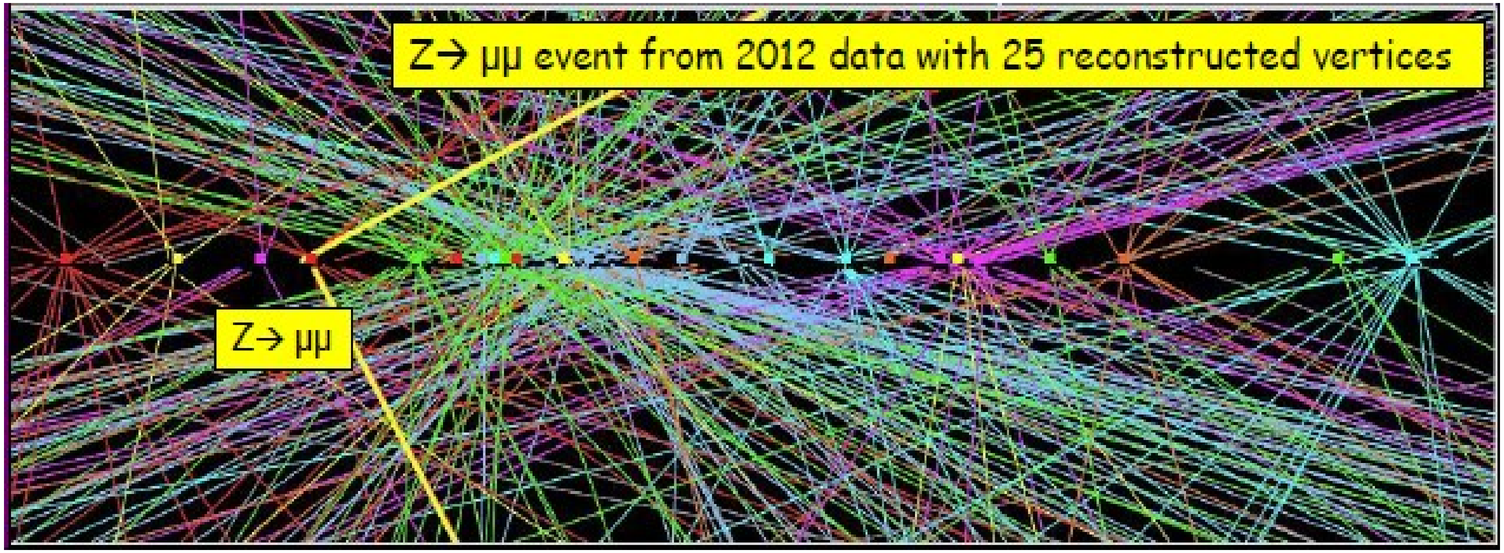
Large Hadron Collider: proton-proton



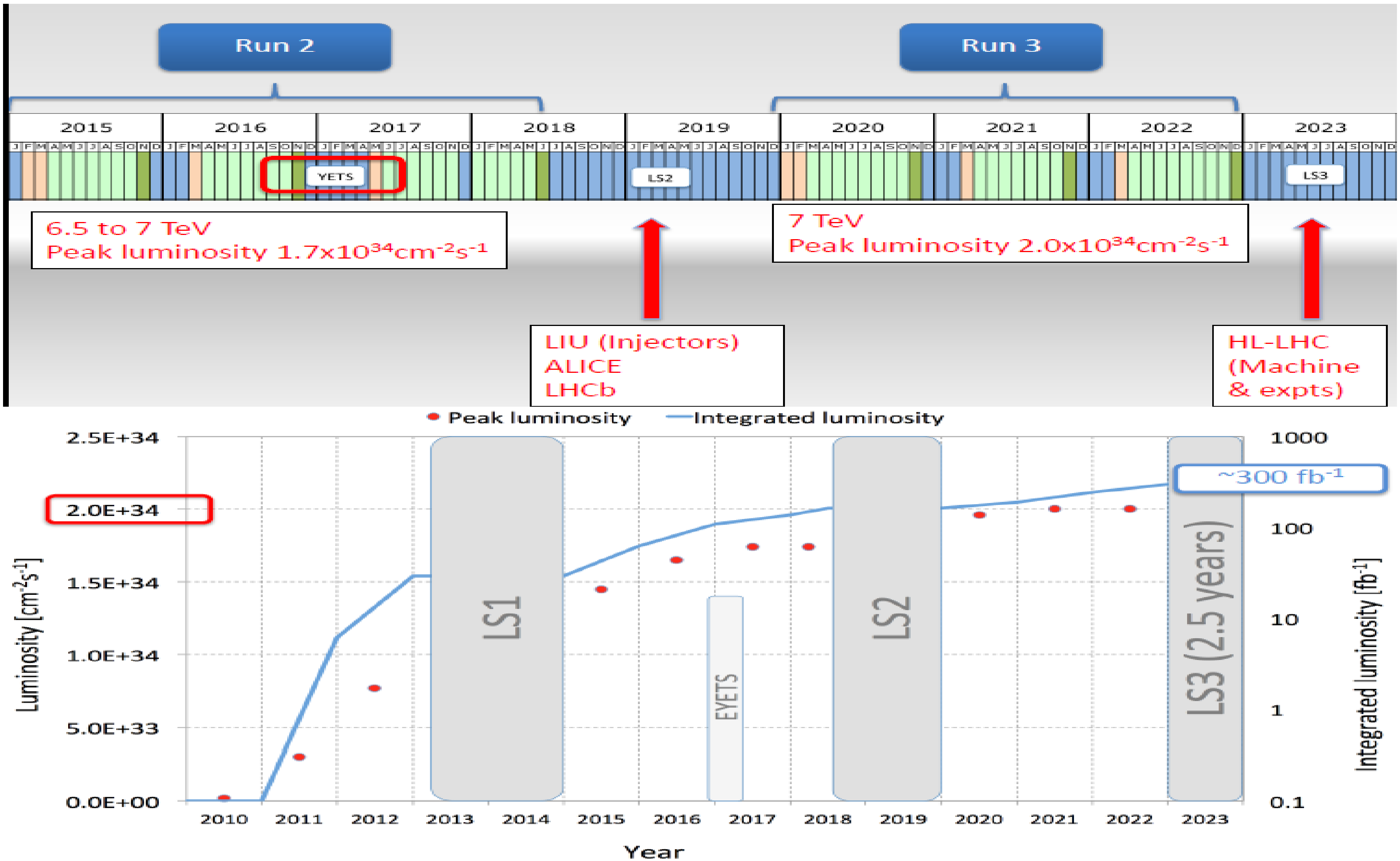


Huge amount of data @ LHC

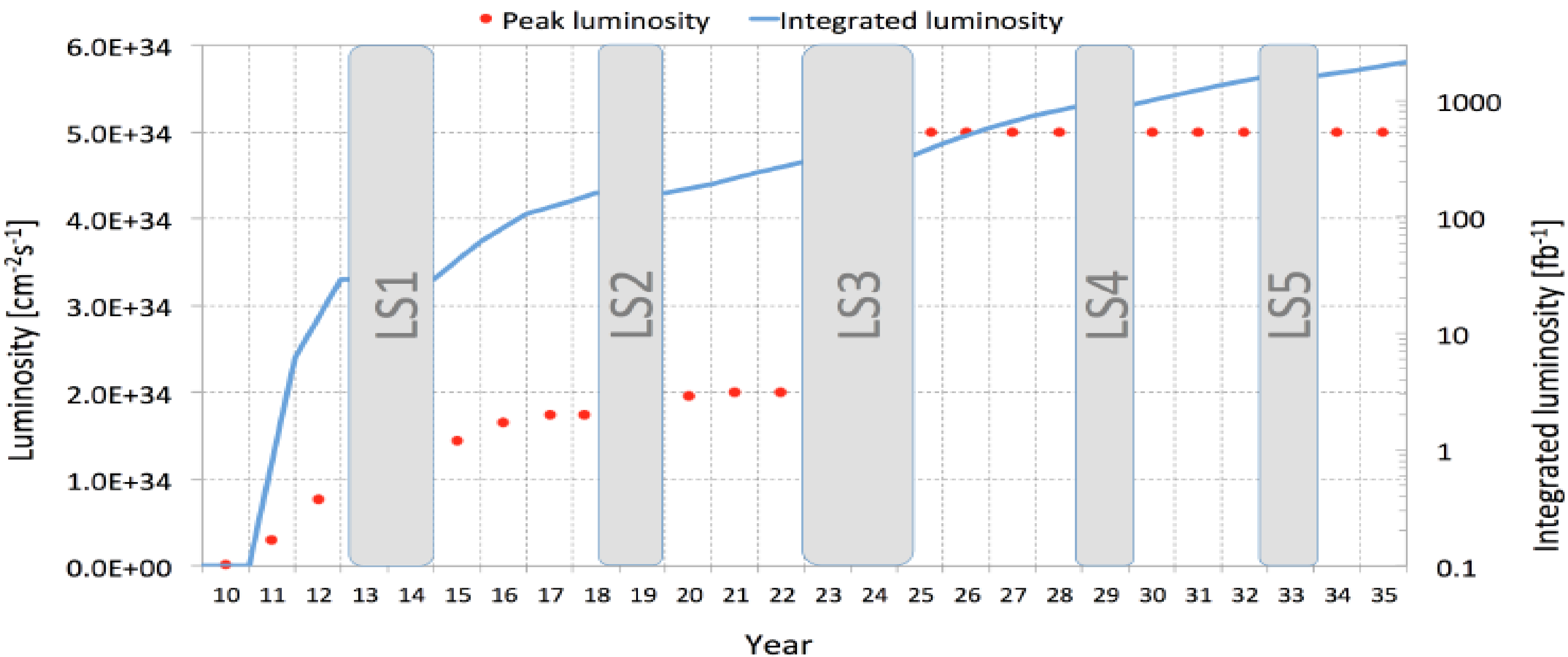
- LHC delivers annually about 15 Petabytes
- Reconstruction of these events is highly non-trivial!



LHC timeline -- next 10 years



LHC timeline -- up to the end in 2035



- **~ 2035: lumi of 3 ab^{-1} expected**
- ***Any physics space left for a Linear Collider?***
- ***At which energy steps?***

Status HEP

- **HEP experiments:**
  - Very successful 1st run at LHC
  - Higgs discovery on July 4th, 2012
  - Excellent data interpretation, but no(t yet) hints for ‘surprises’
  - Standard Model seems to be complete
- **2nd run at $\sqrt{s}$=13-14 TeV starts soon !**
- **LC: 8 billion project – world-wide effort mandatory**
  - Currently very intense activities at Japan towards ILC realization
  - Site selection in Japan
  - Intense contact government, science community, industry

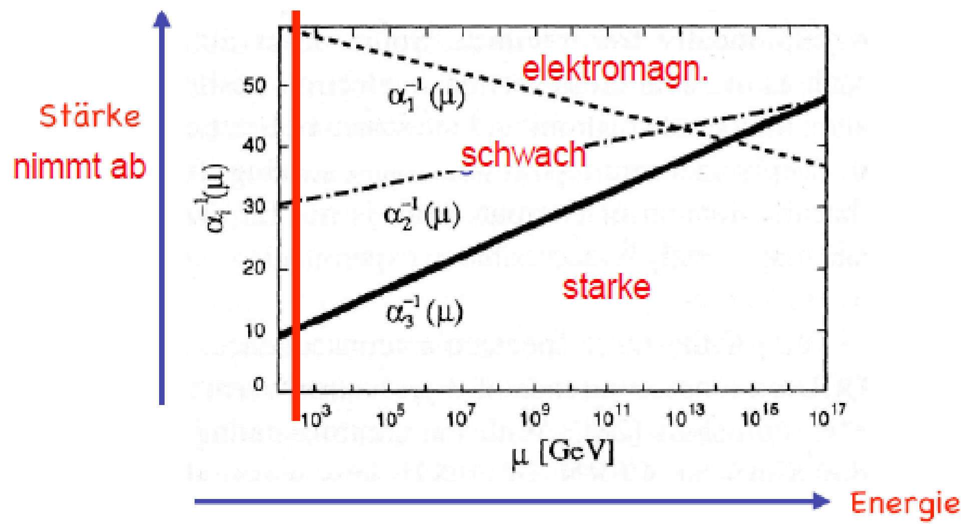
Physics case justified?

Open questions:

- **Particle discovered with m_H=125.5 GeV – Higgs@SM?**
  - The discovered signal is so far compatible with a SM-like Higgs, but a variety of interpretations is possible, corresponding to very different underlying physics
  - Bur we still need spin, couplings, potential, CP properties
- **In addition**

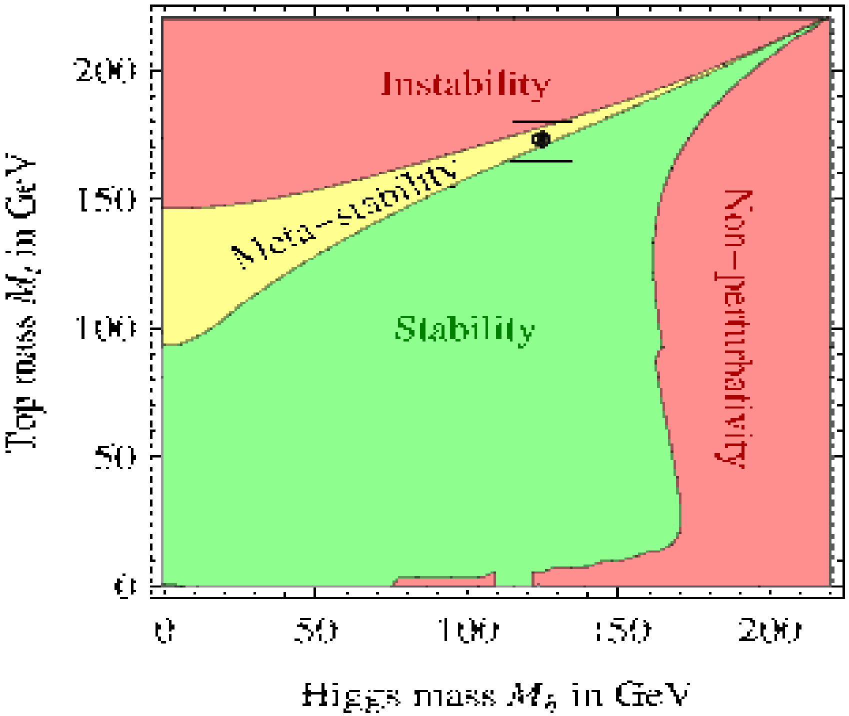
  The SM does not contain
  - Unification
  - Dark matter

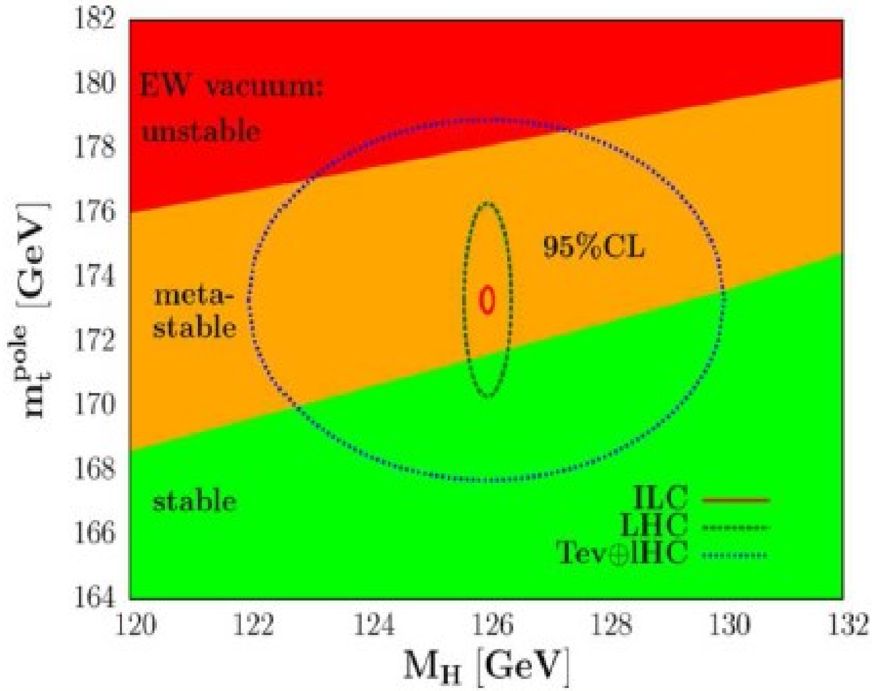
  Cosmo constant
  - Extreme fine tuning



- **Solutions via `Beyond Standard Model' Physics?**

Open question: `stable' Universe?





- **Strong relation between Higgs boson and top quark: m_t~173.3±0.8GeV**
  - **If Higgs boson is too 'light': Universe could be instable**

    (don't panic:... only under the assumption of the pure Standard Model….)
- **Precise measurements of m_t and m_H mandatory!**

Higgs mass: the need for high precision

- Measuring the mass of the discovered signal with high precision is of interest in its own right !
  - Currently m_H~ 125.1±0.2 GeV
- But a high-precision measurement has also direct implications for probing Higgs physics

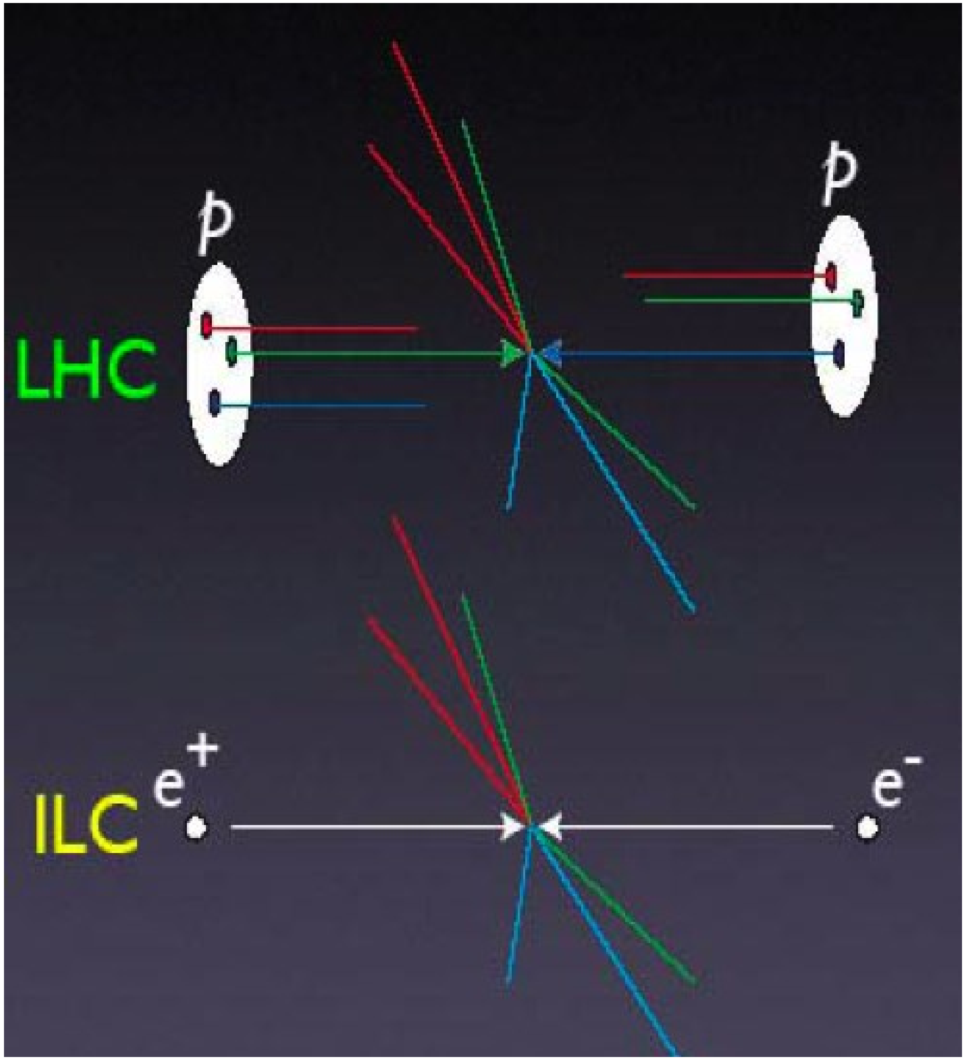
➢ *M_H: crucial input parameter for Higgs physics*

- BR(H → ZZ*), BR(H → WW*): highly sensitive to precise numerical value of M_H
- A change in M_H of 0.2 GeV shifts BR(H → ZZ*) by 2.5%!

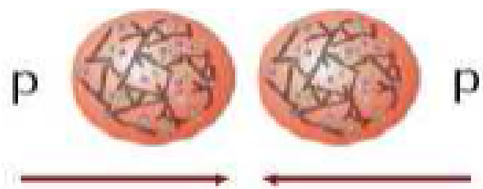
➢ Need high-precision determination of M_H to exploit the sensitivity of BR(H → ZZ*), .etc.. to test BSM physics !

e^+e^- versus pp

- Simple particles
- Well defined:
  energy, angular mom.
- E can be scanned
  precisely
- Particles produced
  ~ democratically
- Final states generally
  fully reconstructable



Comparison: LHC and ILC



Characteristics of pp collider

composite particles collide

E(CM) < 2 E(beam)

strong interaction in initial state

`no' polarization applicable

LHC: $\sqrt{s}$ = 14TeV,

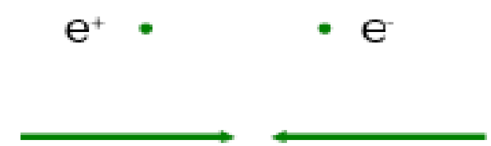
used $\hat{s} = x_1 x_2 s$ few TeV

small fraction of events analyzed

multiple triggers

superposition with spectator jets

Large potential for direct discovery



and of the e +e-(γe, γ γ) collider

Pointlike particles collide

Known E(CM) = 2 E(beam)

well defined initial state

polarized initial e- and e+ beams

ILC: $\sqrt{s}$ = 500 GeV -- 1 TeV, tunable

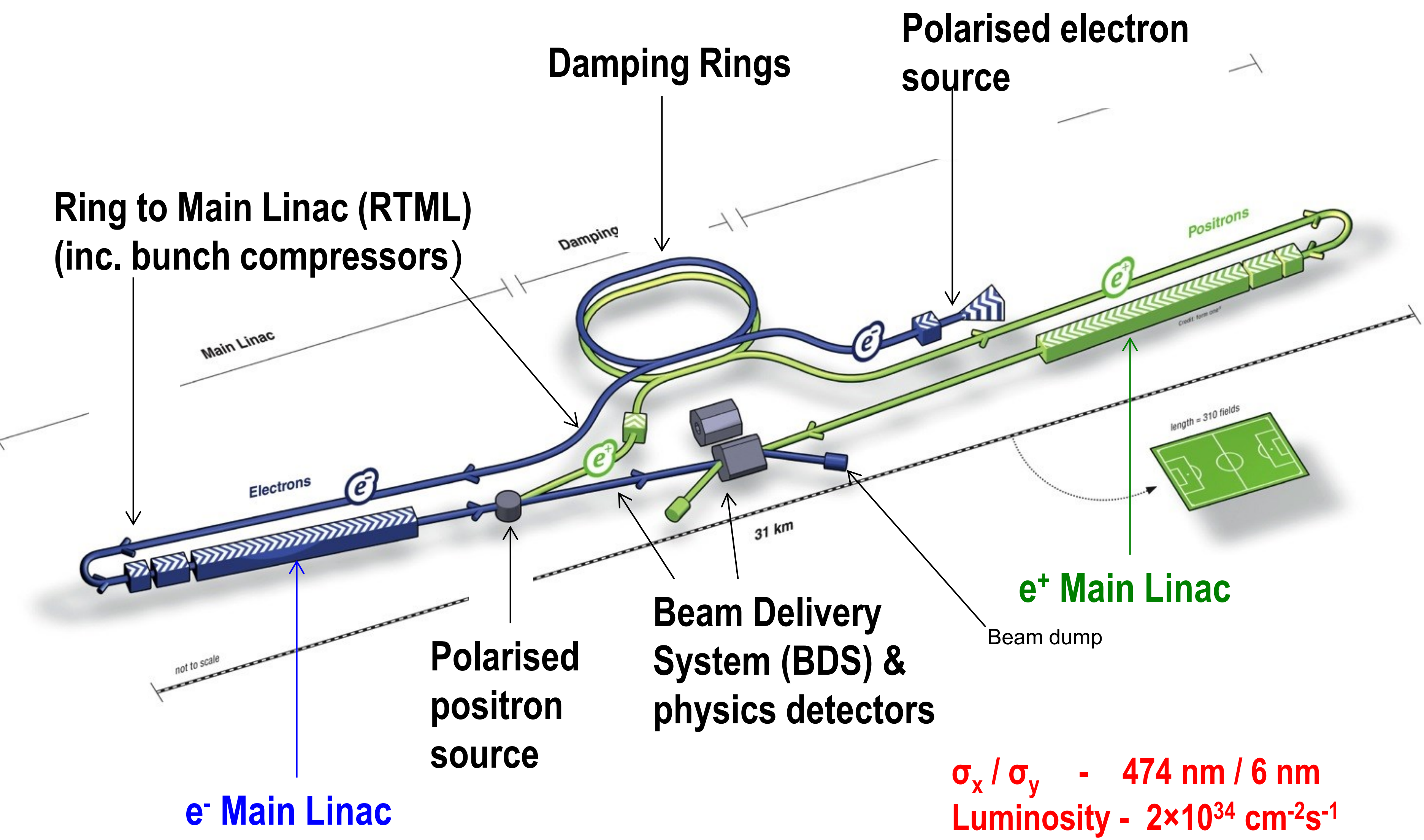
most events in detector analyzed

no triggers required

clean +fully reconstructable events

Large potential for discovery also via high precision

ILC Machine Overview



σ_x / σ_y - 474 nm / 6 nm
Luminosity - 2×10^{34} $cm^{-2}s^{-1}$
Polarisation (e-/e+) - 80% / 30%

ILC Scheme | © www.form-one.de

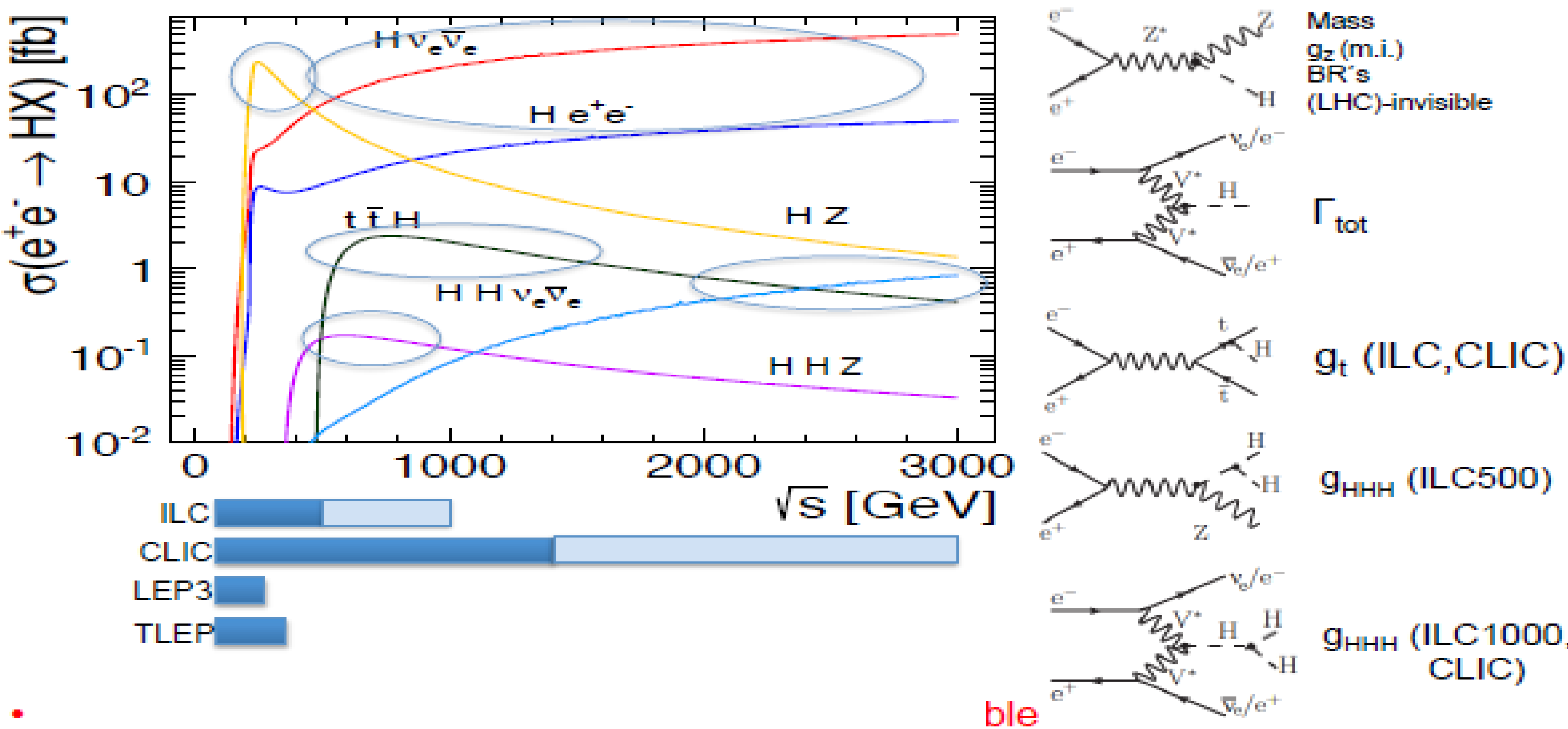
The LC offers and challenges

- Staged energy approach:
  - $\sqrt{s}\sim240$ GeV, `Higgs frontier‘
  - $\sqrt{s}\sim350$ GeV, `Top threshold‘
  - $\sqrt{s}\sim500$ GeV, `Top Yukawa‘
  - ($\sqrt{s}=91$ GeV, `EW Precision frontier‘)
  - $\sqrt{s}\sim1000$ GeV, `Higgs potential‘
- Polarized beams and threshold scans:
  - impact on ‘quality’ (and quantity)
  - Something ‘new’ comp. to LHC analyses
- **Highest precision measurements !**

Why are these features important?

Higgs @ LC

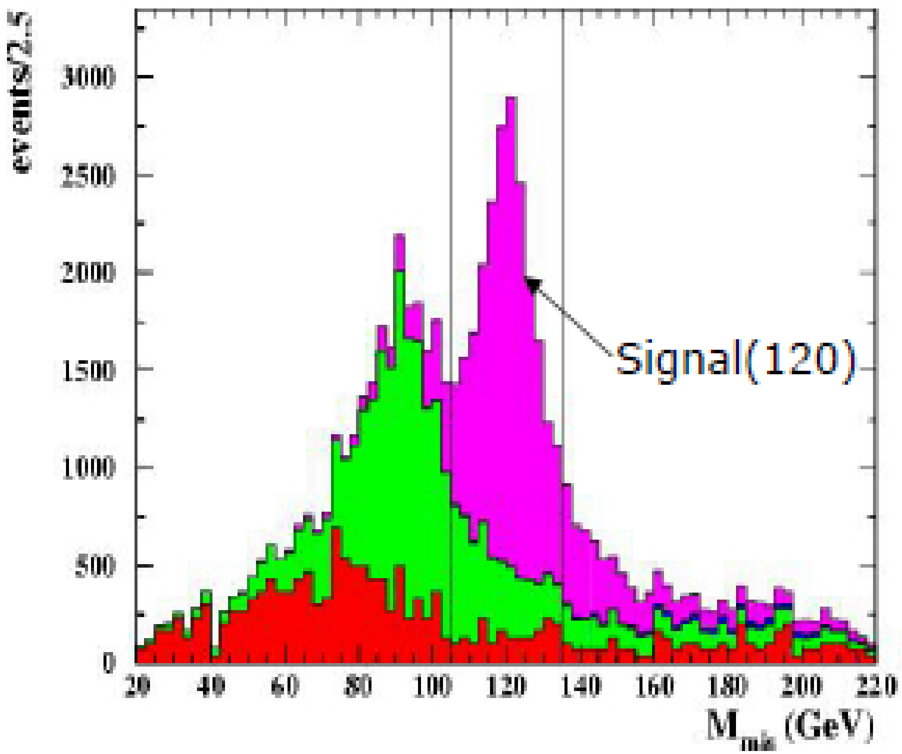
Many processes at different √s needed & accessible

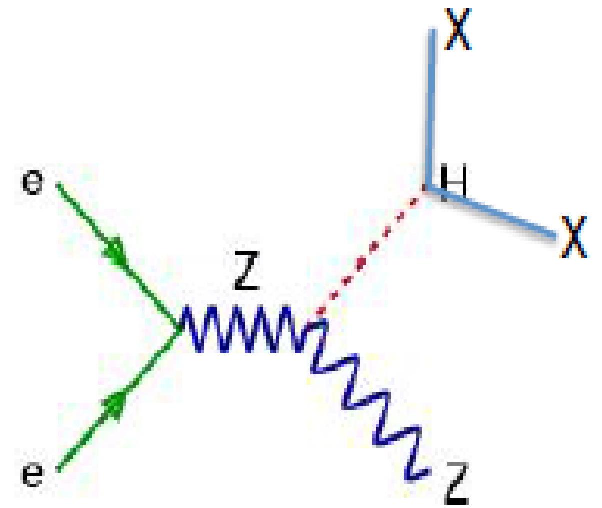


• ble

The Linear Collider is crucial in this regard!

Unique sensitivity at a LC: H→invisible





- ***Recoil method: Unique potential of the LC***
  - *Only measure Z production and decay*
  - *Precise initial state: Higgs reconstruction independ. of decay*

Unique sensitivity at a LC: H→invisible

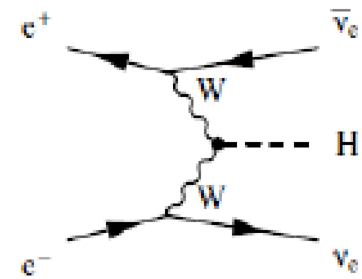
- **Dark matter: sizeable deviation to SM predictions possible, even if couplings to gauge bosons and SM fermions are very close to SM**
  - If dark matter consists of one or more particles with a mass below ~63 GeV, then the decay of the state at 125 GeV into a dark matter pair is kinematically open!

- **Crucial: detection of an invisible decay mode of the 125 GeV-state could be manifestation of BSM physics**
  - Direct search for H $\longrightarrow$ invisible
  - Suppression of all other branching ratios

➢ ***Unique potential: high precision recoil method !***

Crucial: Higgs width at the LC

- **Already at $\sqrt{s}$=350 GeV:**
- Access to Higgs total width :
  - Total width for mH=125 GeV: T_h^{tot} ~4 MeV!
  - Does need WW-fusion in addition to HZ



	$\Delta T_h^{tot} / T_h^{tot}$
250 GeV:	13%
350 GeV:	~7%
500 GeV:	~5-6%
1 TeV:	~ 4%

$$\sigma_{tot} = \sigma_{prod} \times \Gamma_{part}/\Gamma_{tot}$$

- Higgs width crucial for absolute BR's, couplings and model discrimination!

Top Yukawa coupling

- Crucial quantity!
  - Key role in dynamics of ew symmetry breaking
- At $\sqrt{s}$=500 GeV: first measurements of ttH-coupling
  - At this energy: ttH is close to threshold
  - But thanks to threshold effects: σ enhancement by a factor 2!
    - Yukawa couplings $\Delta g_{ttH} / g_{ttH} \sim 10\%$ based on $1ab^{-1}$ and polarized beams (-80%,+30%)

LHC estimates: $\Delta g_{ttH} / g_{ttH} \sim 10\%$ at HL-LHC at 14 TeV and 3000 fb^{-1}

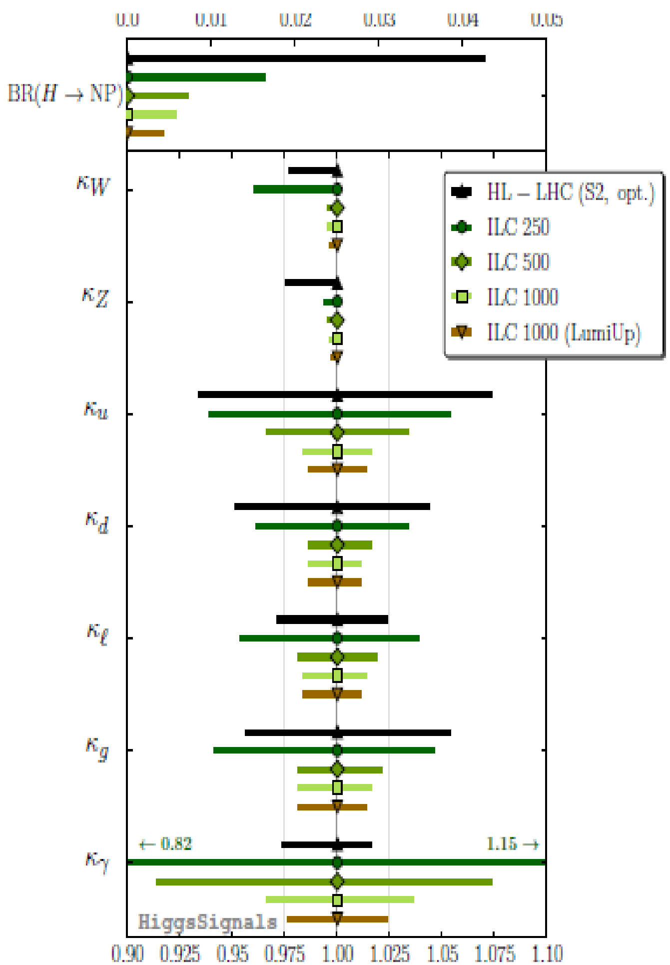
- At $\sqrt{s}$=1 TeV: $\Delta g_{ttH} / g_{ttH} \sim 4.3\%$ based on $1ab^{-1}$ and polarized beams (-80%,+20%)

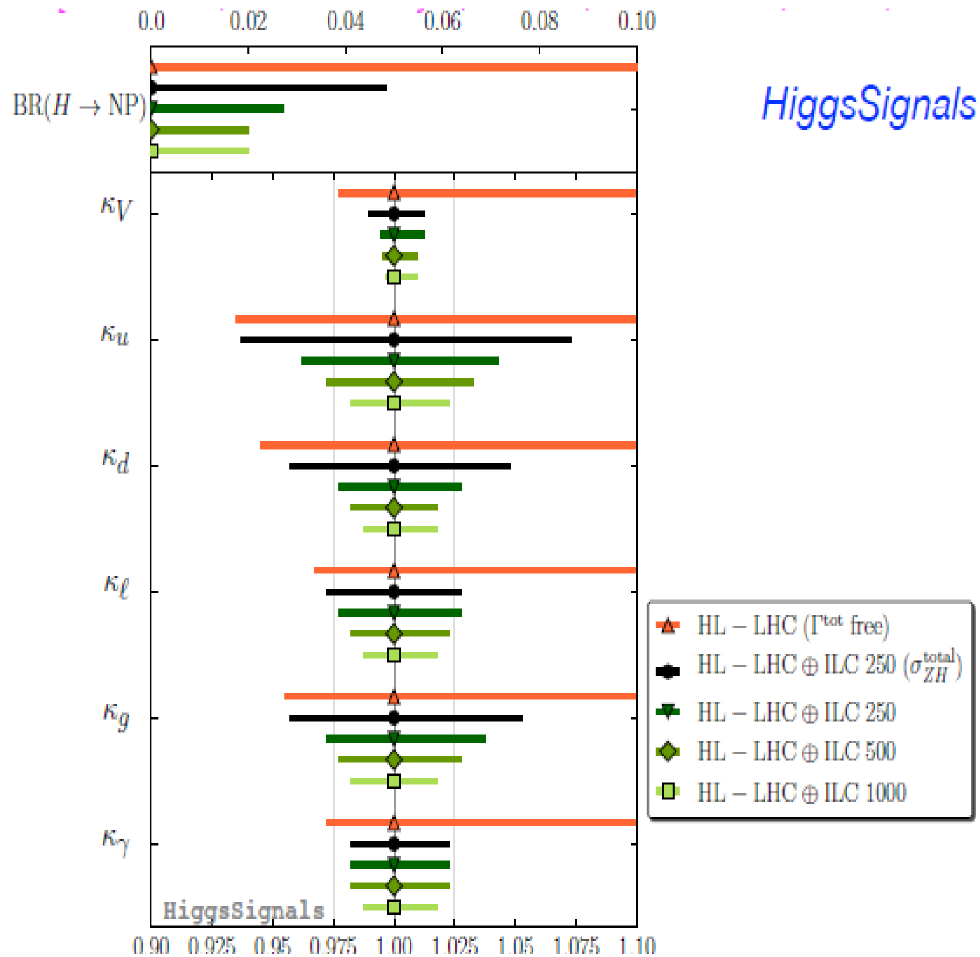
New: Exploiting hadronic+semi-leptonic ttH in decay angle distribution !

Great thanks to LHC+ILC

Somewhen in ~2050 ?!

Assumed: $\kappa_V \leq 1$





HiggsSignals

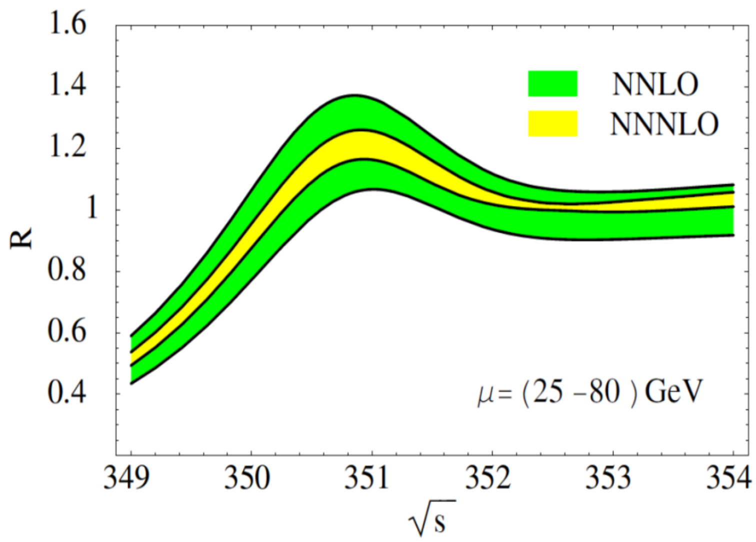
Top production at the LC

- **Top very special role: heaviest fundamental fermion**
  - **most strongly coupled to EWSB sector,**
  - **Intimately related to the dynamics behind the SB mechanism**
  - **M_{top} affects M_H, M_W, M_Z via radiative corrections**
- **At LHC/Tevatron: Δm_{top}~1 GeV**
  - **Crucial: relation between measured mass to a well-defined parameter that is a suitable theoretical input, as $\overline{MS}$ mass**
  - **Relation affected by non-perturbative contr. = limiting factor**
- **At the LC, e+e- -> t t: measure 'threshold mass'**
  - **Relation to well-defined m_{top}, theoret.ically well under control**
  - **Threshold scan: Δm_{top}~100 MeV**

Top mass

$\sqrt{s}$=350 GeV

- **Threshold scan:**



Important shift due to non-logarithmic NNNLO terms

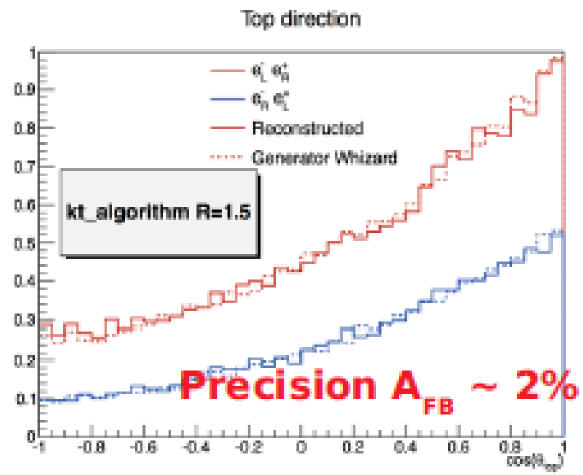
- LC: Peak position remains stable: m_t=100 MeV
- includ. exp uncertainty of ~30 MeV + theo. uncertainty ~70 MeV
- expected accuracy confirmed by full simulation studies!
- Dedicated threshold scan required with about ~100fb^{-1}

Top electroweak coupling

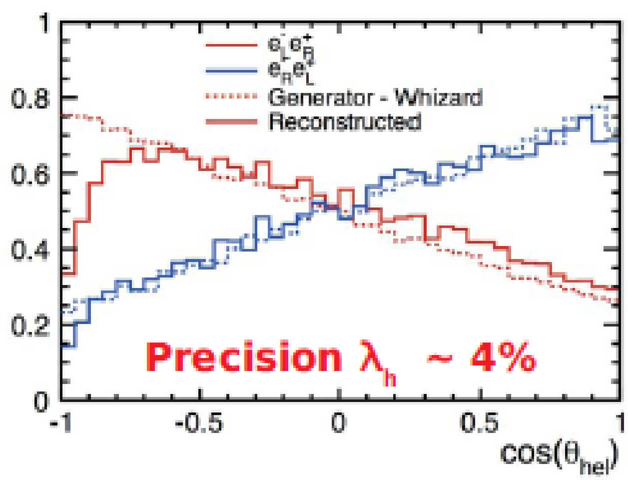
Results of full simulation study for DBD at $\sqrt{s}$ = 500 GeV

LC-REP-2013-007

Precision: x section ~ 0.5%



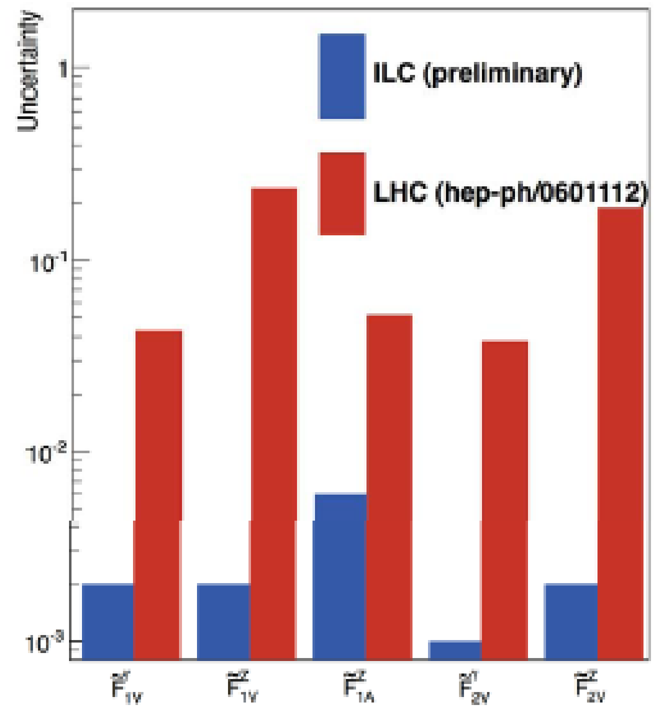
Precision A_{FB} ~ 2%



Precision λ_h ~ 4%

=>

Precision of couplings

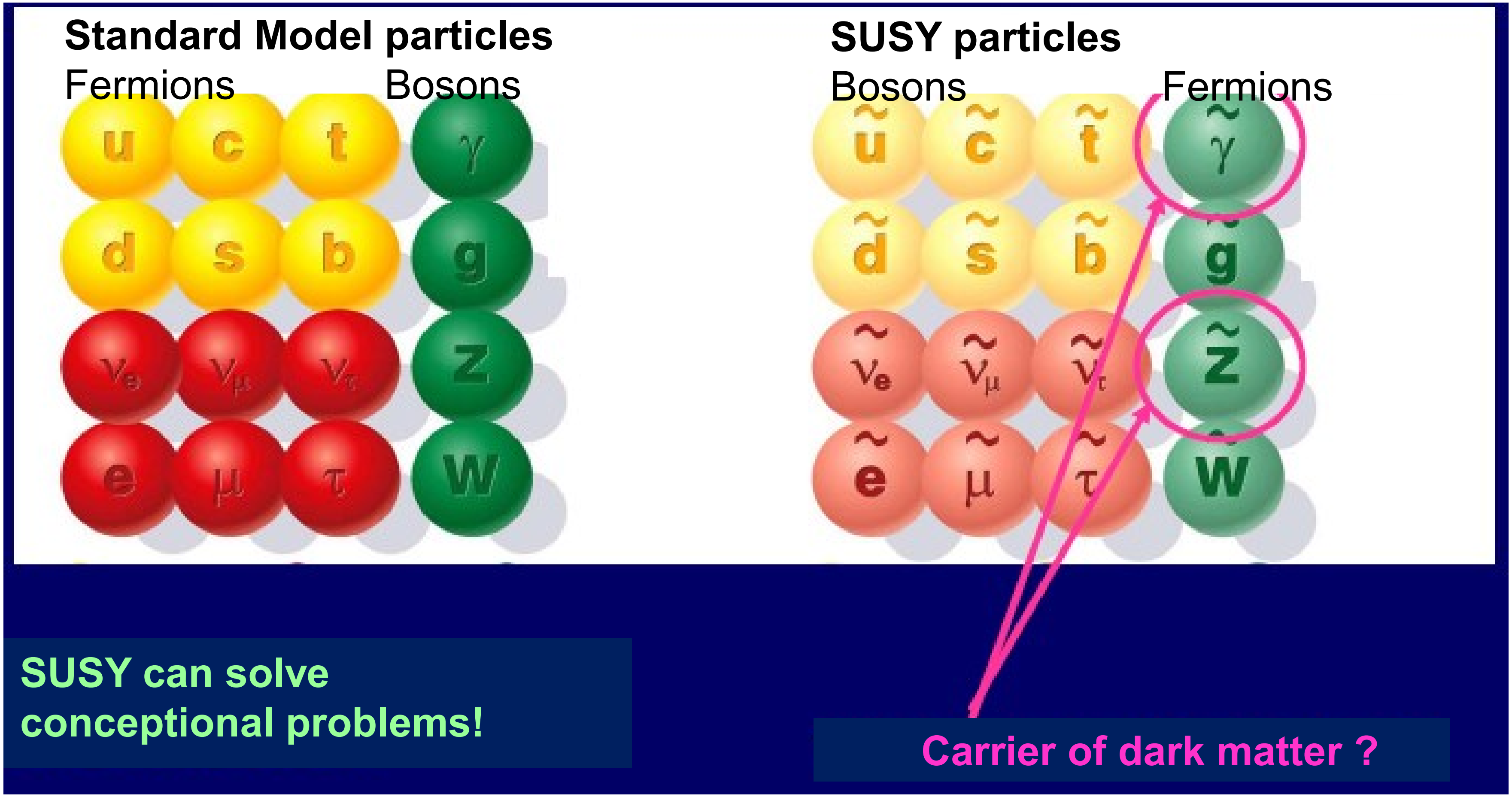


ILC might be up to two orders of magnitude more precise than LHC ($\sqrt{s}$ = 14 TeV, 300 fb^{-1})

15

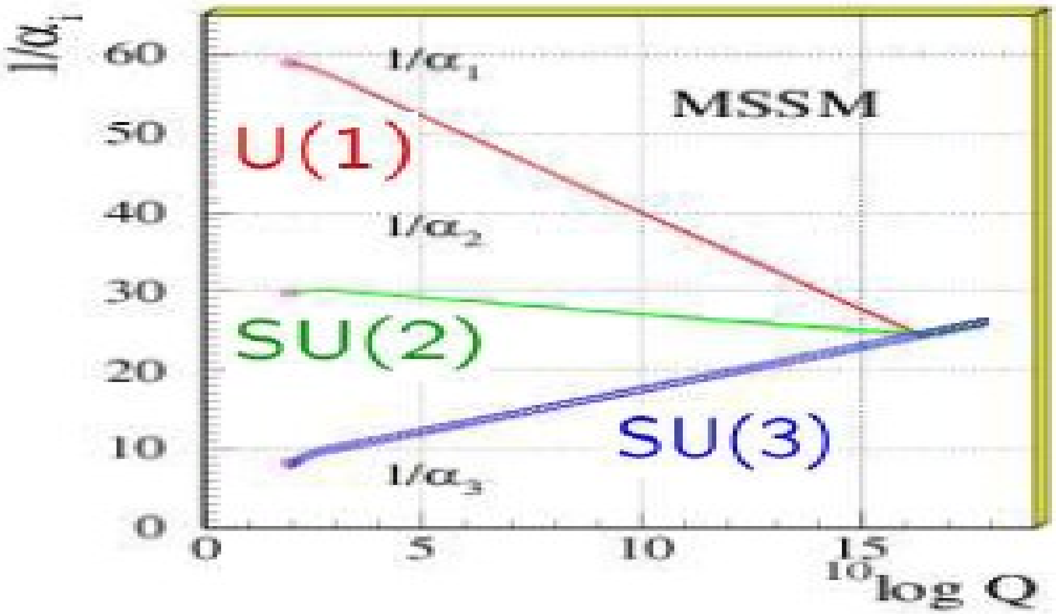
Prospects for BSM at the LC

- **Postulate new kind of symmetry: Supersymmetry**
  - **Symmetry between force and matter particles**



SUSY and unification

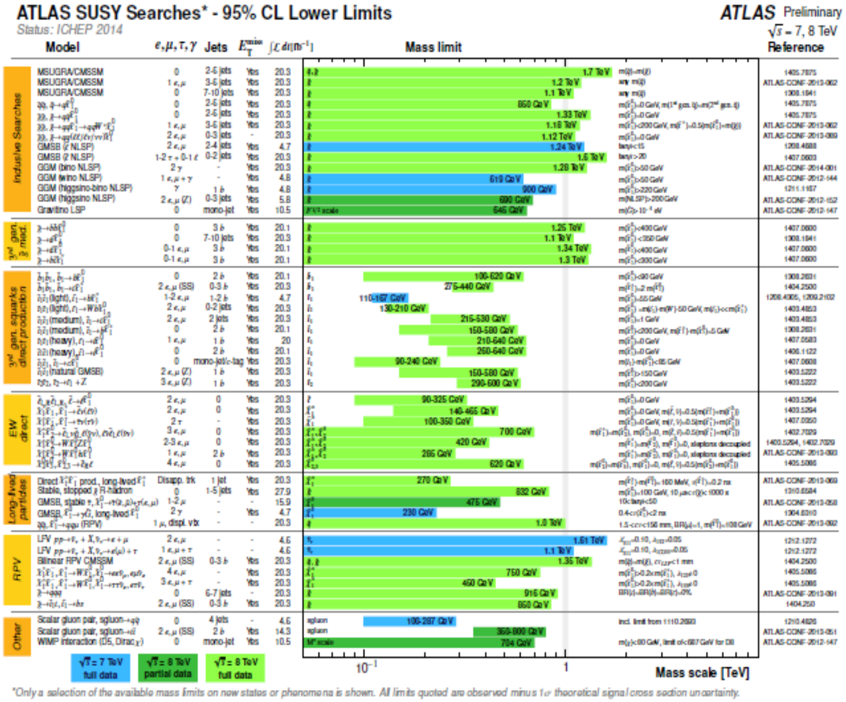
- **Idea:**
  - **New SUSY particles change energy dependence of forces**



- **Unification possible!**
- **SUSY provides candidate for dark matter**
- **SUSY predicts even 5 Higgs particles …… so stay tuned!**

Impact from LHC BSM limits

- **SUSY: still strongly motivated and beautiful, but**
  - so far, no hints of a signal, only rather high exclusion limits in the coloured sector
  - Big worries? No!
  - Minimal SUSY offers 105 new parameters
  - So far only 'constrained' models under tension!
- **Still lots of studies to do!**
- **Further hints from theory?**



Why 'should' light SUSY be preferred?

- **Minimization of 1-loop Higgs Potential:**

$$\frac{M_Z^2}{2} = \frac{m_{H_d}^2 + \Sigma_d^d - (m_{H_u}^2 + \Sigma_u^u)\tan^2\beta}{\tan^2\beta - 1} - \mu^2 \simeq -(m_{H_u}^2 + \Sigma_u^u) - \mu^2$$

- **To keep EWFT ~ 3%:**
  - rather small μ (~200 GeV) required
  - 'naturalness'
  - Several 'natural' scenarios: light stops and light higgsinos,…

Still lots of hopes and expectations !

- **Consistence with results from low energy, $(g\text{-}2)_\mu$**
  - Favours also rather low SUSY masses in electroweak sector

$$\delta a_\mu(\mathrm{N.P.}) = \mathcal{O}(C)\left(\frac{m_\mu}{M}\right)^2, \quad C = \frac{\delta m_\mu(\mathrm{N.P.})}{m_\mu}$$

What if nothing else than H is found now?

The exciting Higgs story has just started….

- **Since m_H is free parameter in SM at tree level**
  - **Crucial relations exist, however, between m_{top}, m_W and $\sin^2\theta_{eff}$**
  - **If nothing else appears in the electroweak sector, these relations have to be urgently checked**
- **Which strategy should one aim?**
  - **exploit precision observables and check whether the measured values fit together at quantum level**
  - **m_Z ,m_W,α_{had}, $\sin^2\theta_{eff}$ und m_{top}**
- **Exploit \`GigaZ' @ILC: high lumi run at $\sqrt{s}$ = 91 GeV**
  - **Pe-=80% and Pe+=60% required !**

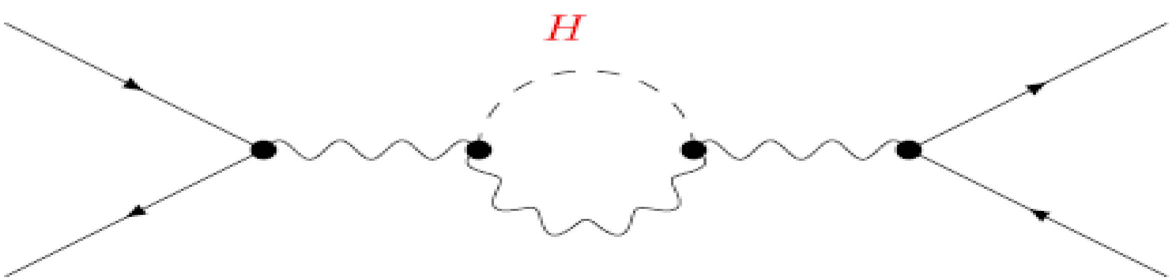
    (If only Pe-=90% : precision ~factor 4 less!)

One more window to new physics

EW precision data: $M_Z, M_W, \sin^2\theta_{\text{eff}}^{\text{lept}}, \ldots$	Theory: SM, MSSM, ...

$\Downarrow$

Test of the theory at Quantum Level

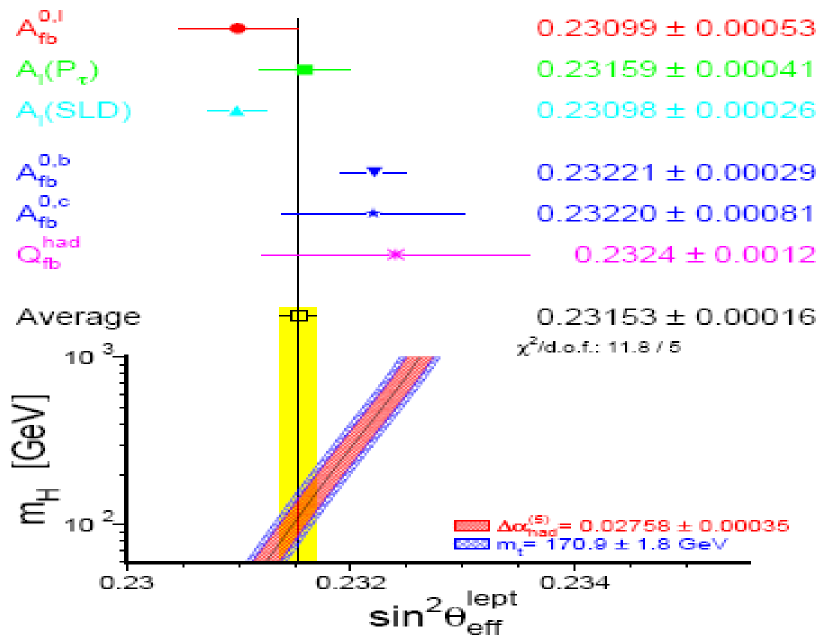


$\Downarrow$

Sensitive to parameters of new physics: Higgs mass etc.

- ➢ Window opens to 'new Physics'!

Higgs story has just started … $\sqrt{s}=91$ GeV



LEP:

$\sin^2\theta_{eff}(A_{FB}^b)$ = 0.23221±0.00029

SLC:

$\sin^2\theta_{eff}(A_{LR})$ = 0.23098±0.00026

World average:

$\sin^2\theta_{eff}$ = 0.23153±0.00016

Goal GigaZ: $\Delta\sin\theta$=1.3 x 10^{-5}

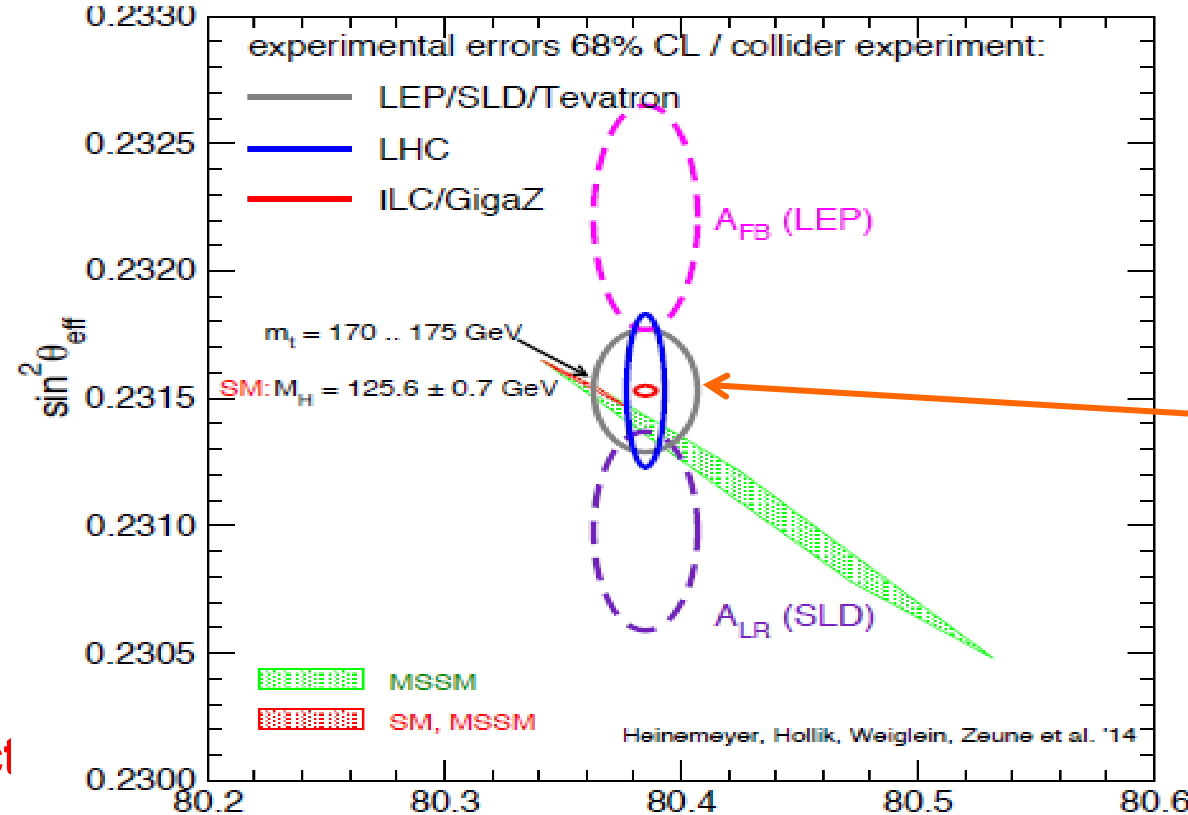
- **Uncertainties from input parameters: Δm_Z, m_{top}, etc. …**
  - Δm_Z=2.1 MeV: $\Delta\sin^2\theta_{eff}^{para}\sim1.4\times10^{-5}$
  - $\Delta m_{top}\sim$1 GeV (Tevatron/LHC): $\Delta\sin^2\theta_{eff}^{para}\sim3\times10^{-5}$
  - $\Delta m_{top}\sim$0.1 GeV (ILC): $\Delta\sin^2\theta_{eff}^{para}\sim0.3\times10^{-5}$

To close the story… GigaZ $\sqrt{s}$=91 GeV

- **Measure $\sin^2\theta_{eff}$ via A_{LR} with high precision: $\Delta\sin\theta$=1.3 10^{-5}**

World average → happy with both!

Central value has large impact !!!



← LEP value disfavours both, SM+MSSM

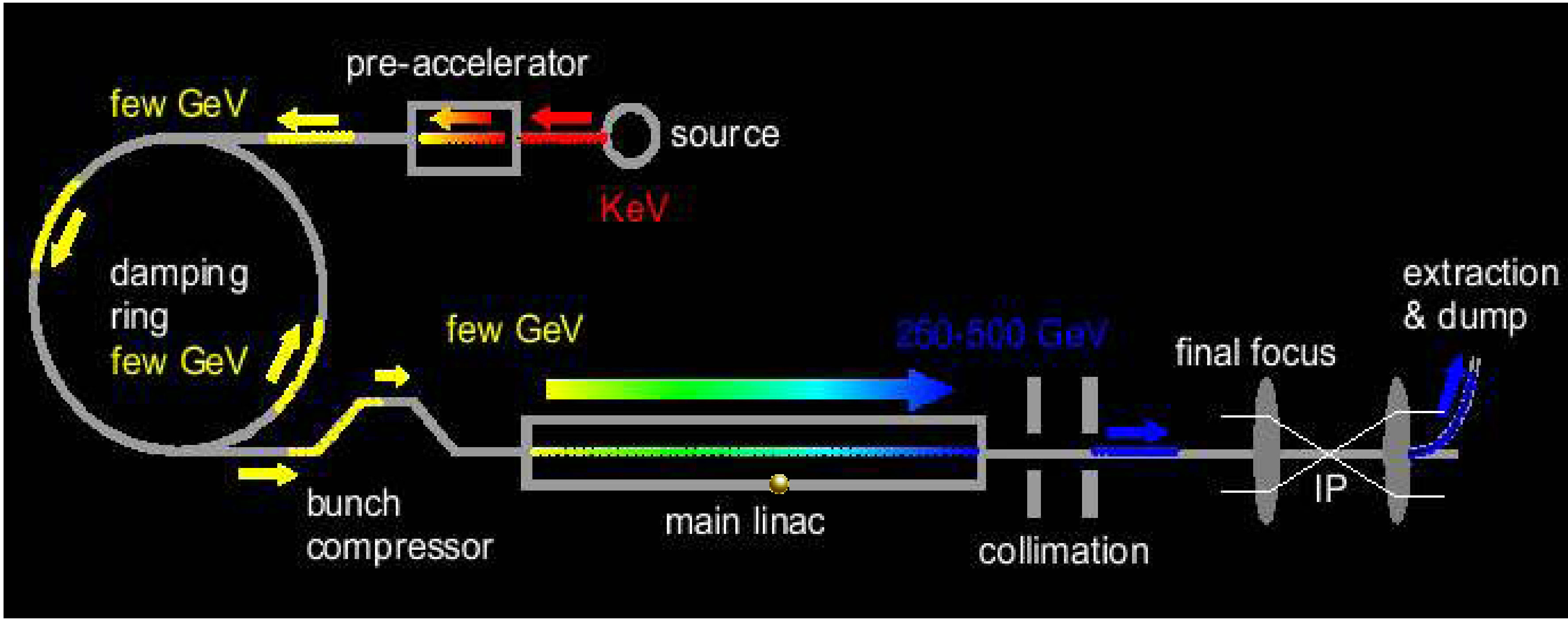
GigaZ precision!

↑ SLD value disfavours SM

Be prepared for the 'Unexpected'…

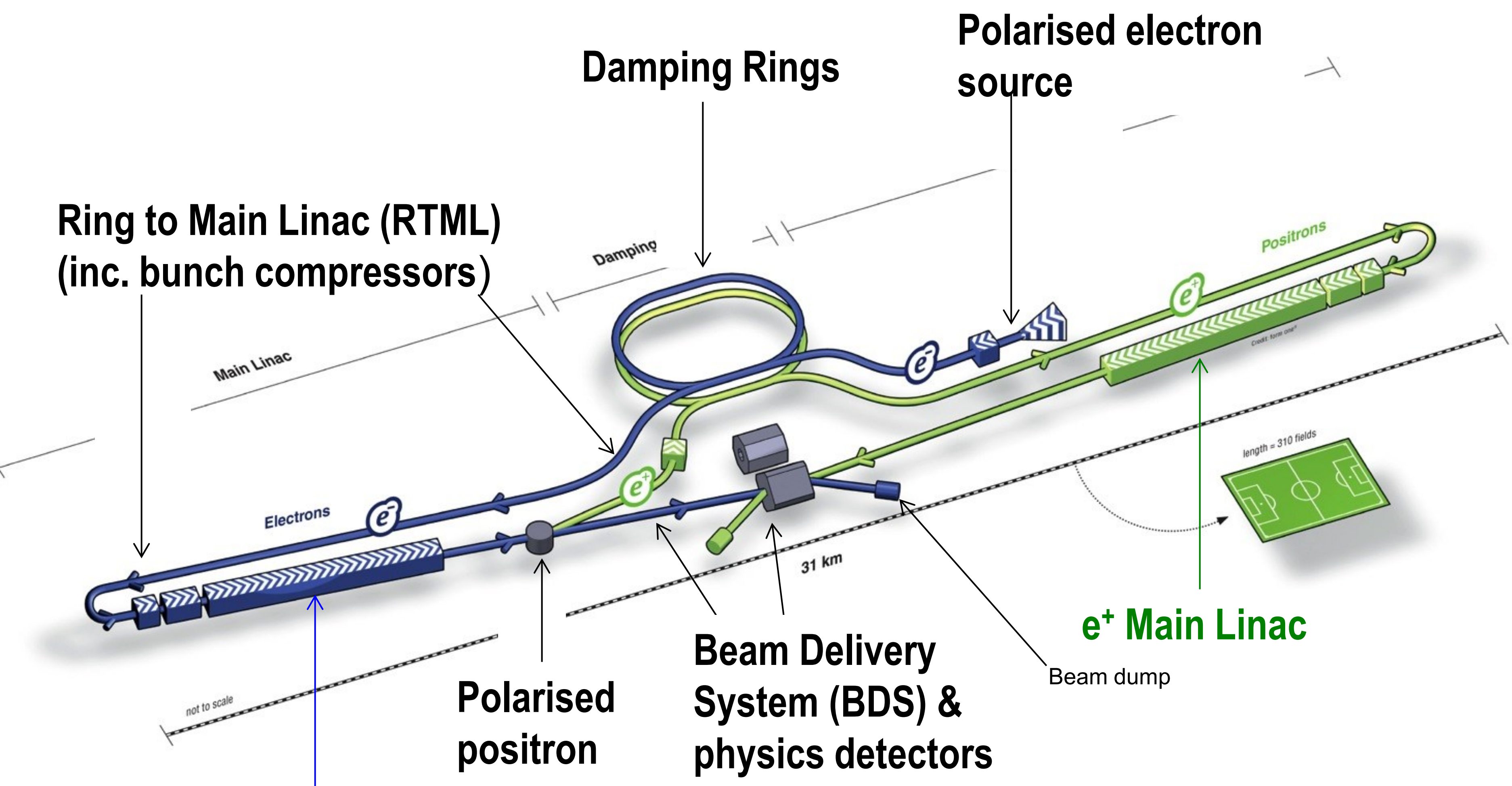
- *the LC +LHC are mandatory………!*

Generic Linear Collider



- *High luminosity:* **ILC beam structure = 3000 bunches per pulse, pulse every 5 Hz and each bunch contains about 10^{10} particles !**
- *Challenge:* **number of $e^{\pm}$ / pulse = factor 1000 higher than at SLC ('88-98) ! (but luminosity even factor 10000!)**

ILC Machine Overview



σ_x / σ_y - 474 nm / 6 nm

Luminosity - 2×10^{34} cm^{-2}s^{-1}

Polarisation (e-/e+) - 80% / 30%

ILC Parameters

Centre-of-mass energy	E_{CM}	GeV	200	230	250	350	500
Luminosity pulse repetition rate		Hz	5	5	5	5	5
Positron production mode			10 Hz	10 Hz	10 Hz	nom.	nom.
Estimated AC power	P_{AC}	MW	114	119	122	121	163
Bunch population	N	$\times 10^{10}$	2	2	2	2	2
Number of bunches	n_b		1312	1312	1312	1312	1312
Linac bunch interval	Δt_b	ns	554	554	554	554	554
RMS bunch length	σ_z	µm	300	300	300	300	300
Normalized horizontal emittance at IP	$\gamma\epsilon_x$	µm	10	10	10	10	10
Normalized vertical emittance at IP	$\gamma\epsilon_y$	nm	35	35	35	35	35
Horizontal beta function at IP	β_x^*	mm	16	14	13	16	11
Vertical beta function at IP	β_y^*	mm	0.34	0.38	0.41	0.34	0.48
RMS horizontal beam size at IP	σ_x^*	nm	904	789	729	684	474
RMS vertical beam size at IP	σ_y^*	nm	7.8	7.7	7.7	5.9	5.9
Vertical disruption parameter	D_y		24.3	24.5	24.5	24.3	24.6
Fractional RMS energy loss to beamstrahlung	δ_{BS}	%	0.65	0.83	0.97	1.9	4.5
Luminosity	L	$\times 10^{34}$ cm^{-2} s^{-1}	0.56	0.67	0.75	1.0	1.8
Fraction of L in top 1% E_{CM}	$L_{0.01}$	%	91	89	87	77	58
Electron polarisation	P_-	%	80	80	80	80	80
Positron polarisation	P_+	%	30	30	30	30	30
Electron relative energy spread at IP	$\Delta p/p$	%	0.20	0.19	0.19	0.16	0.13
Positron relative energy spread at IP	$\Delta p/p$	%	0.19	0.17	0.15	0.10	0.07

SCRF Linac Technology

- solid niobium
- standing wave
- 9 cells
- operated at 2K (Lqd. He)
- 35 MV/m
- $Q_0 \geq 10^{10}$

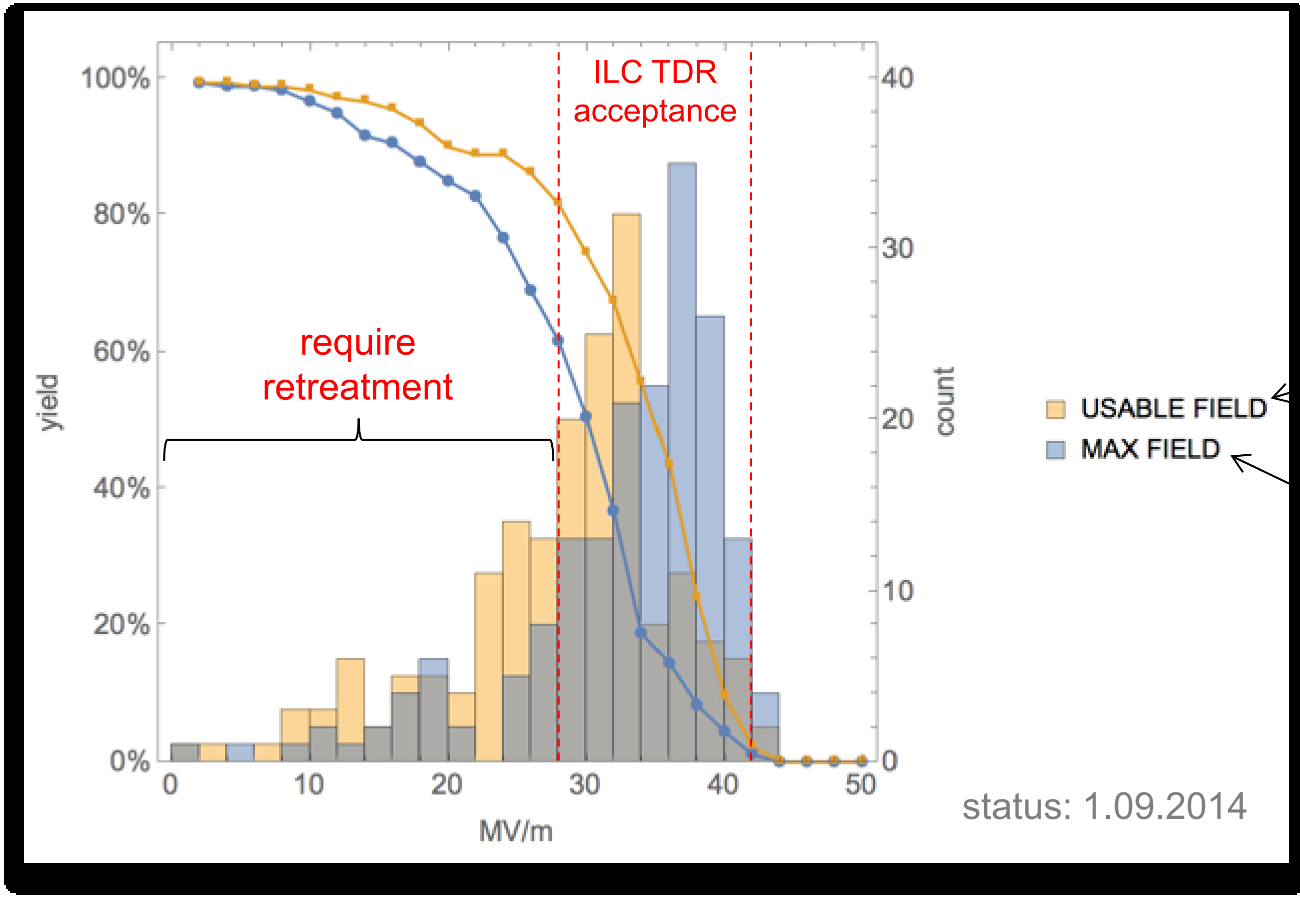
1.3 GHz Nb 9-cell Cavities	16,024
Cryomodules	1,855
SC quadrupole package	673
10 MW MB Klystrons & modulators	436 / 471*

* site dependent

Approximately 20 years of R&D Worldwide → Mature technology

Industrial production - XFEL

Vendor following ILC baseline recipe (4 per week, final total: 400 cavities)



Field emission limit (XFEL spec.)

quench limit

Thanks to Nick Walker and Brian Foster

	Tests	Average	rms	Yield@28	Yield@31.5	Yield@35
Max	148	32.8	7.6	82%	69%	48%
Usable	148	28.6	8.1	63%	41%	18%

Beam polarization at HEP colliders

- *Polarization* = ensemble of particles with definite helicity $\lambda = -\frac{1}{2}$ left- or $+\frac{1}{2}$ right-handed :

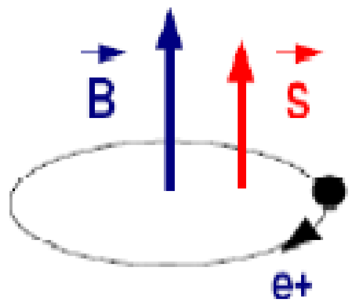
$$\boxed{\mathcal{P} = \frac{\#N_R - \#N_L}{\#N_R + \#N_L}}$$

→ beam polarization gives access to the couplings and unravels the structure of interactions

Polarized beams at circular e^-e^+ colliders:

- Polarization of both beams via Sokolov-Ternov effect

  (= spin-flip effect due to synchrotron radiation)



- At LEP (e+e-): massive depolarization effects; low polarization; not used for physics
- At HERA (ep): excellent e^- / e^+ polarization reached, ~50%-70%; spin rotators used to produce longitudinally polarized beams for physics studies

Beam Polarization at the LC

Polarized beams at linear e^-e^+ colliders:

- synchrotron radiation due to longitudinal acceleration negligible
- beams have to be polarized at the source !

Polarized e^- source:

- at the SLAC Linear Collider (SLC): excellent e^- polarization of about 78%
- led to precision measurement of the weak mixing angle:

  $\sin\theta_{eff} = 0.23098 \pm 0.00026$ (SLD) (LEP: 0.23221 ± 0.00029)

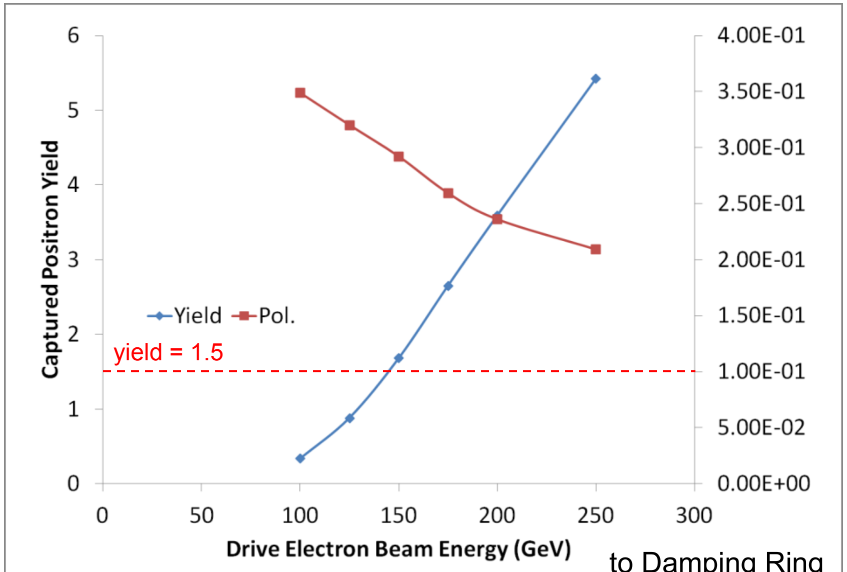
Polarized sources at the ILC/CLIC:

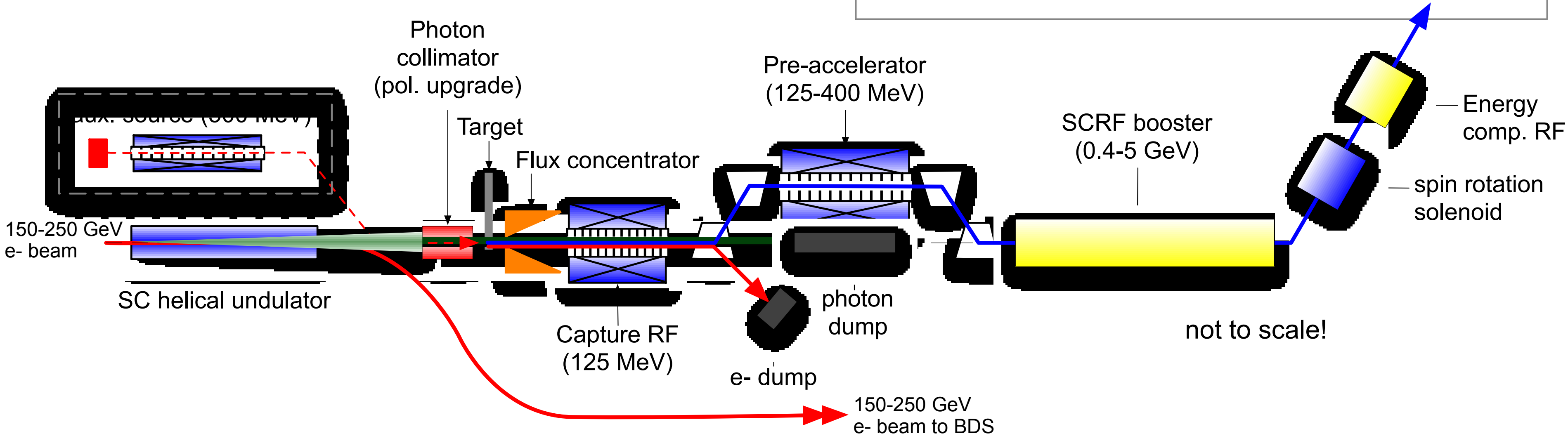
- expected e^- polarization between 80% and 90%

- Polarized e+ source designed, absolute tech. novelty!

Positron source: challenge for all LC!

- located at exit of electron Main Linac
- 147m (up 231m) SC helical undulator
- driven by primary electron beam (150-250 GeV)
- produces ~30 MeV photons
- converted in thin target into e^+e^- pairs





P_{eff} and L_{eff} for the staged approach

- With the listed parameters:

$\sqrt{s}$	$P(e^-)$	$P(e^+)$	$P_{\rm eff}$	$\mathcal{L}_{\rm eff}/L$	$\frac{1}{x}\Delta P_{\rm eff}/P_{\rm eff}$
total range	$\mp 80\%$	0%	$\mp 80\%$	1	1
250 GeV	$\mp 80\%$	$\pm 40\%$	$\mp 91\%$	1.3	0.43
$\geq$350 GeV	$\mp 80\%$	$\pm 55\%$	$\mp 94\%$	1.4	0.30
total range	$\mp 90\%$	0%	$\mp 90\%$	1	1
250 GeV	$\mp 90\%$	$\pm 40\%$	$\mp 96\%$	1.4	0.43
$\geq$350 GeV	$\mp 90\%$	$\pm 55\%$	$\mp 97\%$	1.5	0.29

← No gain!

← No gain!

Gain in polarization! (Almost 100%)

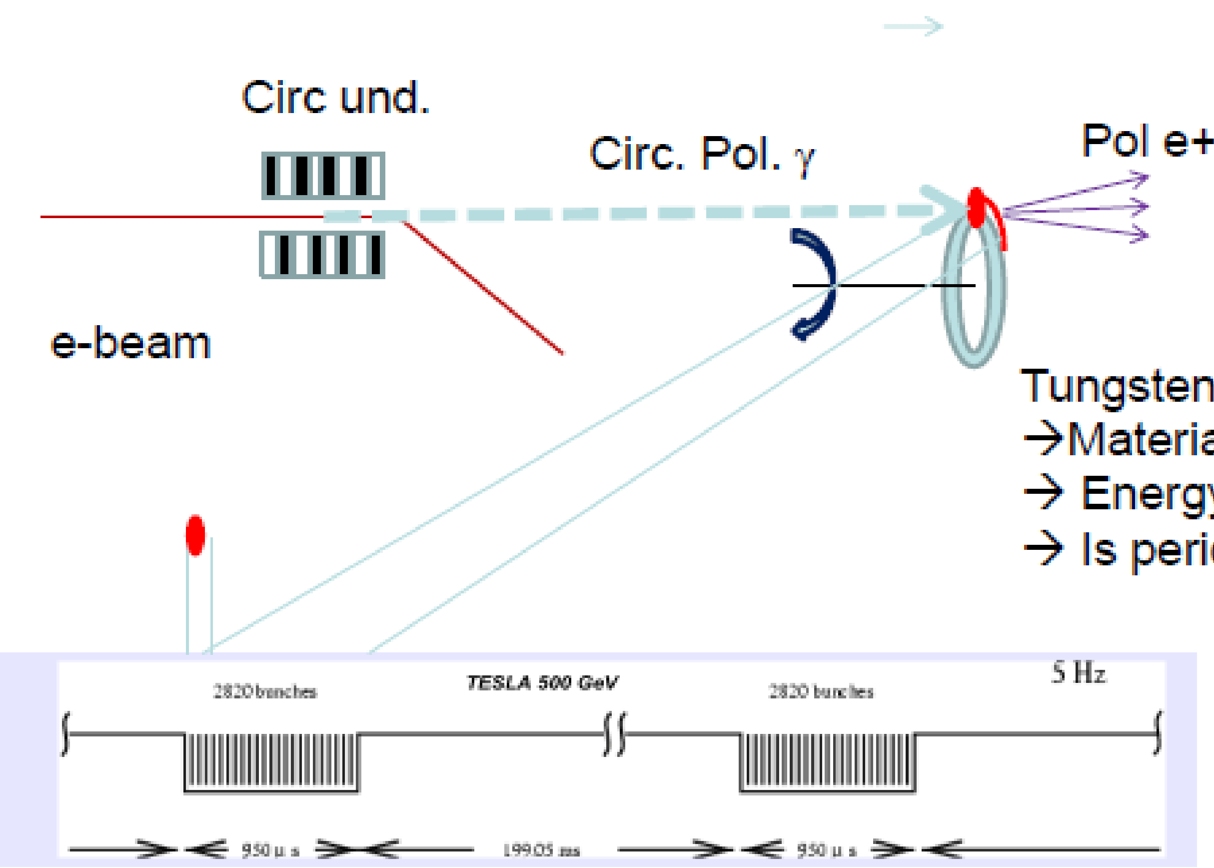
Gain in number of interactions!

Gain in precision by more then a factor 3! (large N)

- Just by switching on P(e+)!

Fatigue limit of ILC e+ targets

Thermischer Stress: Massive Energieeinträge durch den pol. Gammastrahl!

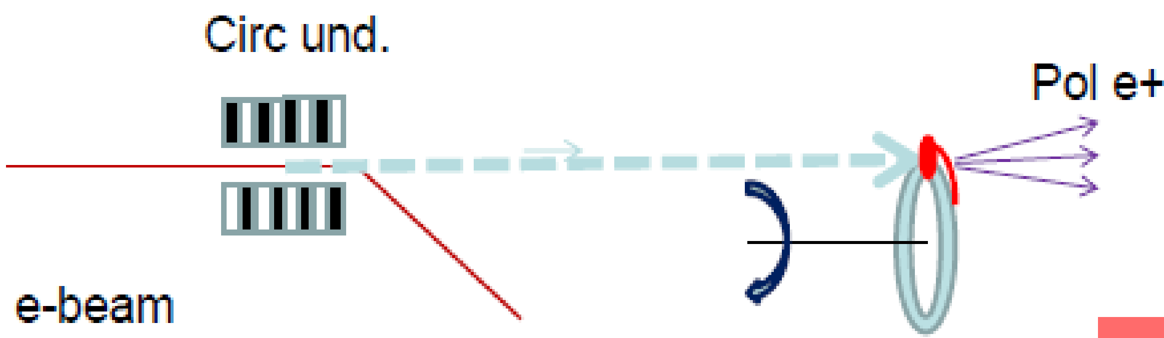


Energy deposition:

- **photon target, Ti wheel, Ø = 1m, 2000rpm**
- **PEDD per bunch train: 67.5 J/g (101.3 J/g h.lumi) ⇔ ΔTmax = 130K (195K)**
- **Energy deposition per bunch: 0.31 … 0.72J ⇔ $\Delta T \approx O(1K)$**
- **Fatigue limit in Ti : $\Delta T \sim 600K$ (340MPa)**

Tungsten Target (v=100m/s)
→Material remains 20μs in γ-beam)
→ Energy deposition (dE/dV~1kJ/cm^3)
→ Is periodically repeated (fatigue?)

Thermic stress studies at MESA and MAMI



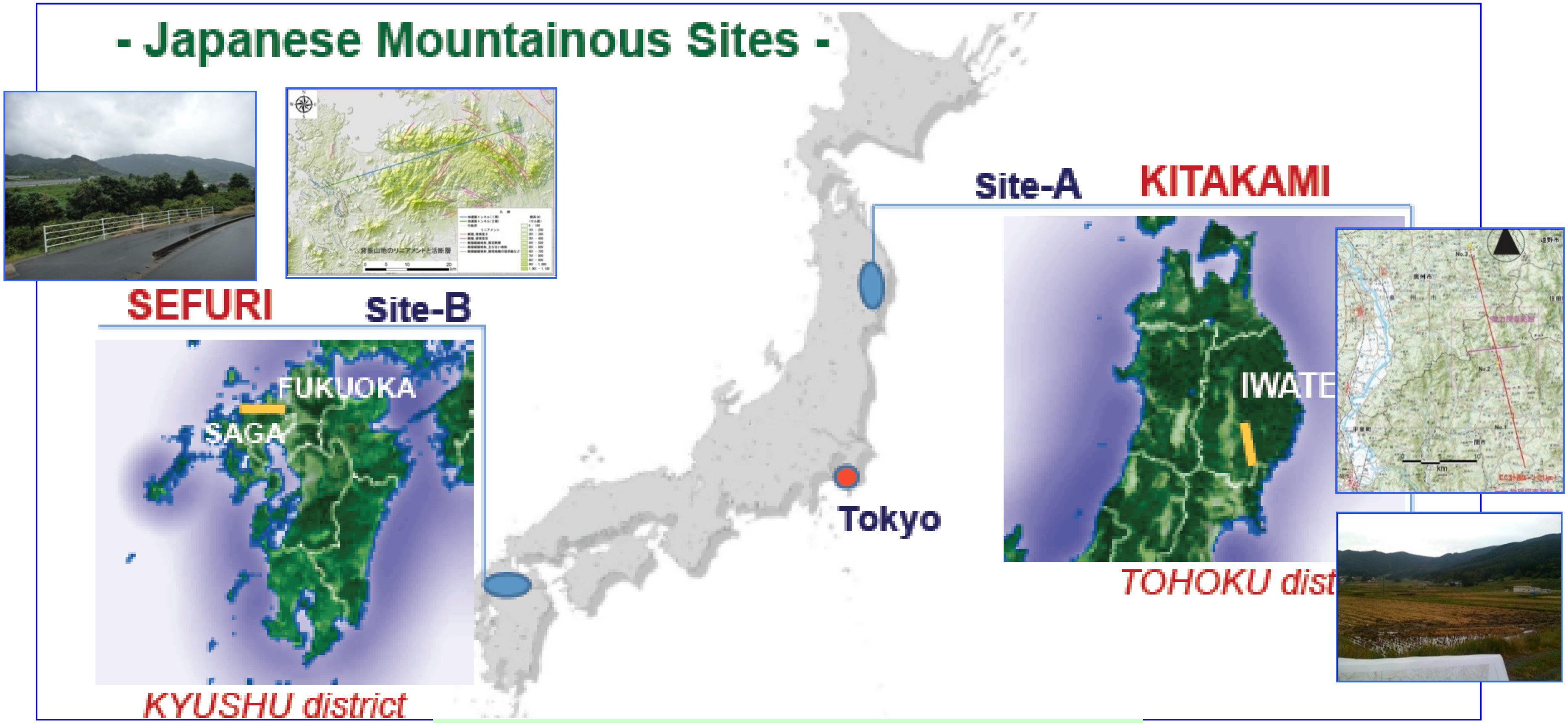
K Aulenbacher
BMBF with UHH
+S Riemann
(Desy Zeuthen)

dE/dV~1kJ/cm^3
in 20 μs

- γ-radiation deposits heat homogenously in Tungsten
- No powerful γ-source available → mimick by 20μs long electron pulses
- Check if (non-moving) material gets destroyed (single pulse+fatigue)
- Electrons mainly ionize the (thin) material if $E_{beam}<E_{krit}$~10MeV.
- Reduce beam size and target thickness until dE/dV is achieved
  for available electron beam
- MAMI c.w. injector: 1mA/3.5MeV
- At MAMI typical beam spot target-thickness length scale is 1/10mm (ILC~mm)
- Due to c.w. capability arbitrary repetition rate possible → „artificial aging"

Japanese Site(s) for the ILC

Brian Foster



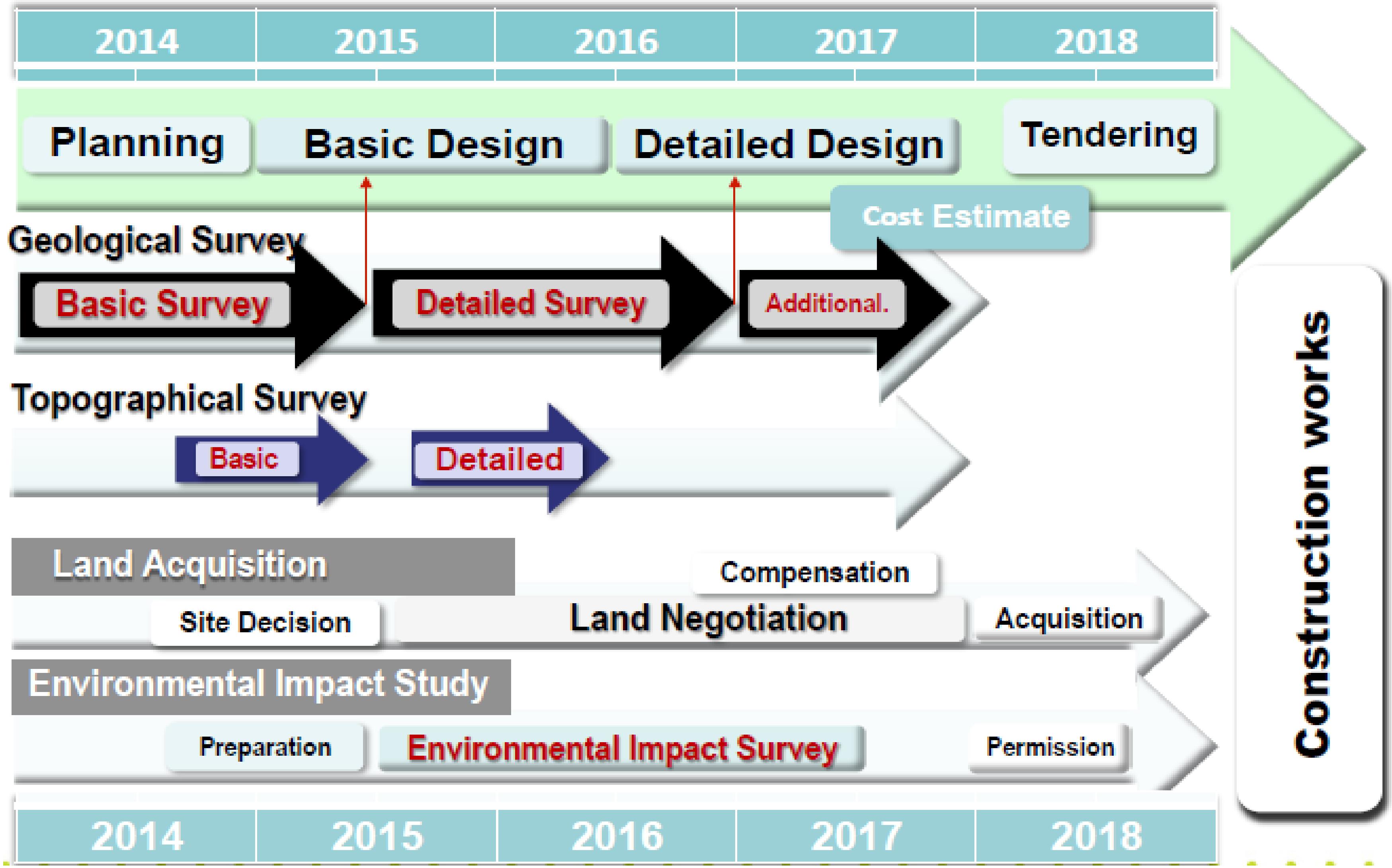
- GDE-CFS group visited two sites, Oct., 2011.
- GDE EC visit in Jan. 2012.

Japanese Site

Brian Foster

Site specific schedule

Brian Foster



Parametric 'value' costing for TeV–class machines (KILCU):*

Brian Foster

- Civil Construction: 35 / m
- Utilities: 5000 / MW
- Superconducting RF 180 / m (inclusive)**
- 'Conventional Acc.' 35 / m

		TLEP-t quantity	MILCU	ILC quantity	MILCU
Civil Construction	km	80	3000	34	1200
Power and cooling	MW	416	2000	162	800
SRF (incl. packing)	km	1.2 / .7	250	22	4000
'Conventional'	km	160	5500 ***	12	800
Installation	km	80	100	34	100
Total			**11000**		**7800****

*** 1 ILCU = USD 01.2012**
**** cryogenics not included – reuse LHC assumed; 900 MILCU included for ILC**
***** Conventional cost – scale reduced 2x for ring**

Institutional Labor is part of the project cost and must also be analyzed.

Power consumption

Brian Foster

ILC and 80 km ring:	ILC -H	ILC-nom	Ring - H	Ring - t
E_cm (GeV)	250	500	240	350
SRF Power to Beam (MW)	5.2	10.5	100	100
Eff. RF Length (m)	7,837	15,674	600	1200
AC to RF efficiency (%)	10	14	45	45
klystron operating margin, HVPS, Klystron Aux and klystron water cooling (%)			20*	20
Cryo (MW)	16	32	20	40
Normal Conducting (exc. Injector complex) (MW)	6	10	120**	120
Injector complex	32	32	16***	16
Conventional (Air, lighting, ..)	6	6****	18	18
Total (exc. detector)	**112**	**153**	**396**	**416**

* 5% for operating margin, 2% for auxiliaries, 3% for HVPS and 10% for water cooling
** assume 1.5 kW / m tunnel inclusive (ILC avg. 3 kW / m)
*** from SSC / Fermilab injector (linac + LEB + MEB)
**** 6 MW for 30 km beam tunnel complex; ~3x more for 80 ring

Cf. Blondel et al. estimated ~ 260 MW

Der Linear Collider: summary

- **Excellent prospects in Higgs, Top and BSM**
- **Machine is ready to be built: tunable energy, polarization etc.**
- **Encouraging activities towards a LC@Japan**

Z-pole
92 GeV

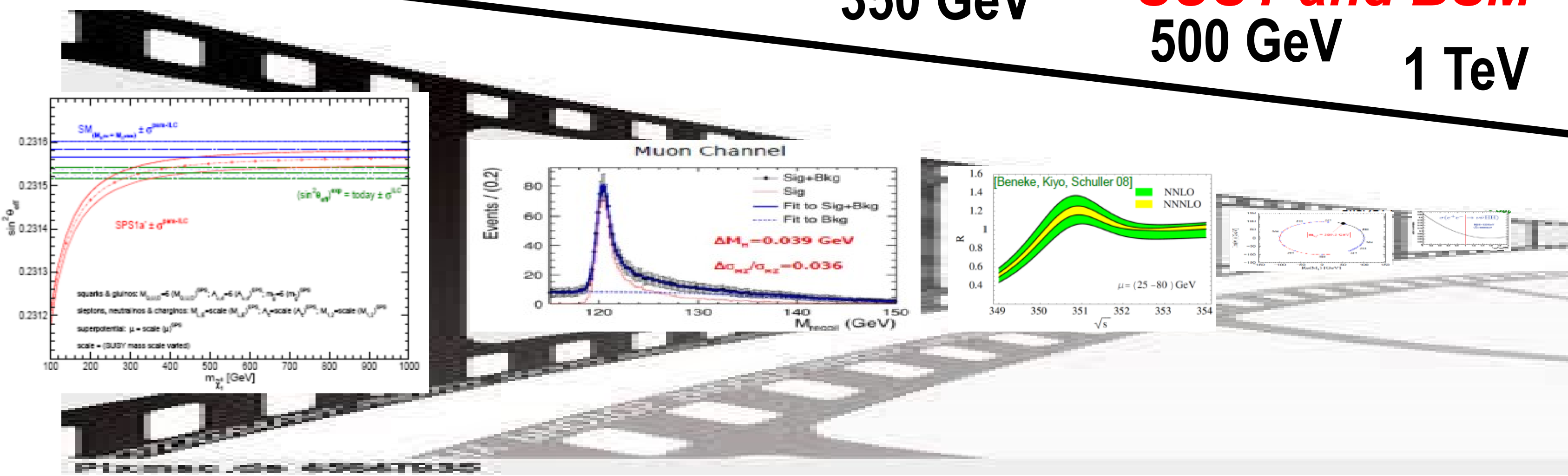
Higgs Physik
250 GeV

Top Physik
350 GeV

Higgs Potential + SUSY and BSM
500 GeV

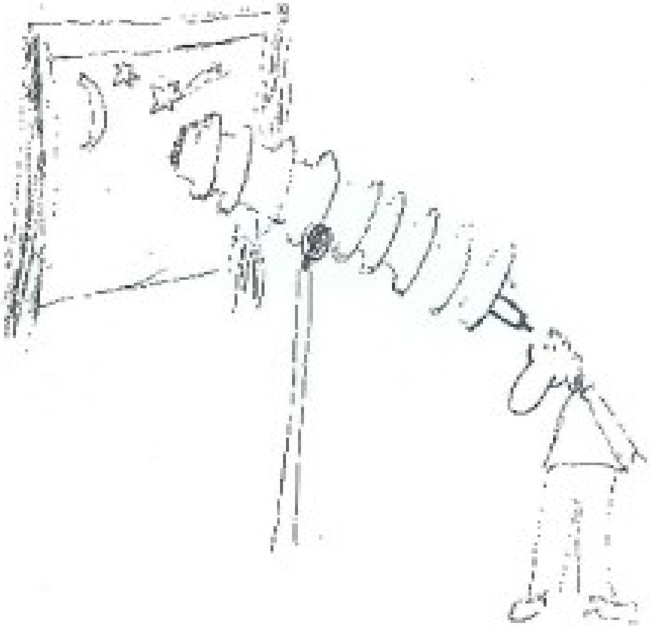
1 TeV

3 TeV

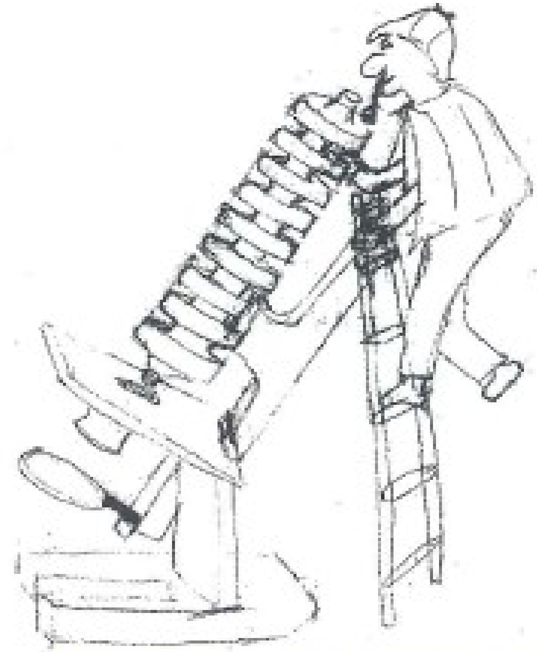


Stay tuned! Now or never….

I Love Cavities



Unraveling the past



Revealing present mysteries

Feeding future brains

THE I L C

Other crucial Higgs quantity: Total Higgs width: recent LHC analyses

- Exploit different dependence of on-peak and off-peak contributions on the total width in Higgs decays to ZZ(*)
- CMS quote upper bound of Γ/Γ_{SM}<5.4 at 95% c.l., where 8.0 was expected, ATLAS: Γ/Γ_{SM}<5.7 at 95% c.l., 8.5 expected

CMS Collaboration '14, ATLAS Collaboration'14

- Problem: assumed equality beyond on-shell and off-shell couplings! Relation can be severely affected by new physics contributions, in particular via threshold effects (note effects of this kind may be needed to give rise to a Higgs-boson width that differs from the SM one by the currently probed amount) C.Englert. Spannowski '14

➢ SM consistency test rather than model-independent bound

Destructive interference between Higgs- and gauge-boson contr. (unitarity cancellations) $\longrightarrow$ difficult to reach Γ/Γ_{SM} ~ 1 even for high statistics

Chiral quantum numbers at LC

- **Unique feature: polarized e- and e+ beams available**

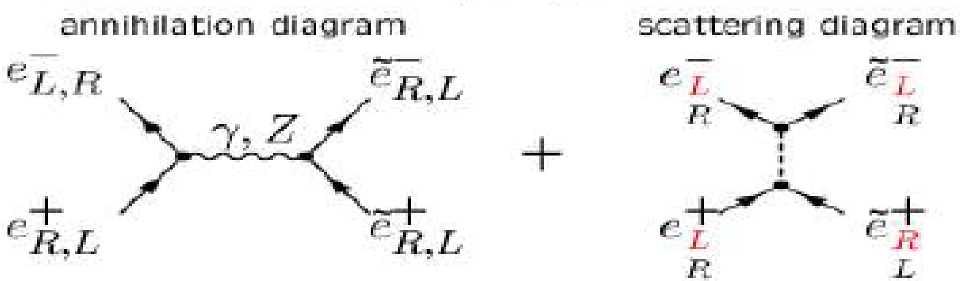
Test of SUSY assumption: SM $\leftrightarrow$ SUSY have same quantum numbers!

$\Rightarrow e^-_{L,R} \leftrightarrow \tilde{e}^-_{L,R}$ and $e^+_{L,R} \leftrightarrow \tilde{e}^+_{R,L}$

Scalar partners $\leftrightarrow$ chiral quantum numbers!

How to test this association?

Strategy: $\sigma(e^+e^- \to \tilde{e}^+_{L,R}\tilde{e}^-_{L,R})$ with polarised beams



$\Rightarrow$ 2nd diagram: unique relation between chiral fermion $\longleftrightarrow$ scalar partner

Use e.g. $e^+_L e^-_L$

$\to$ scattering diagram: $\tilde{e}^+_R \tilde{e}^-_L \longrightarrow \tilde{e}^+_R \leftrightarrow \tilde{e}^-_L$

$\to$ no annihilation diagram

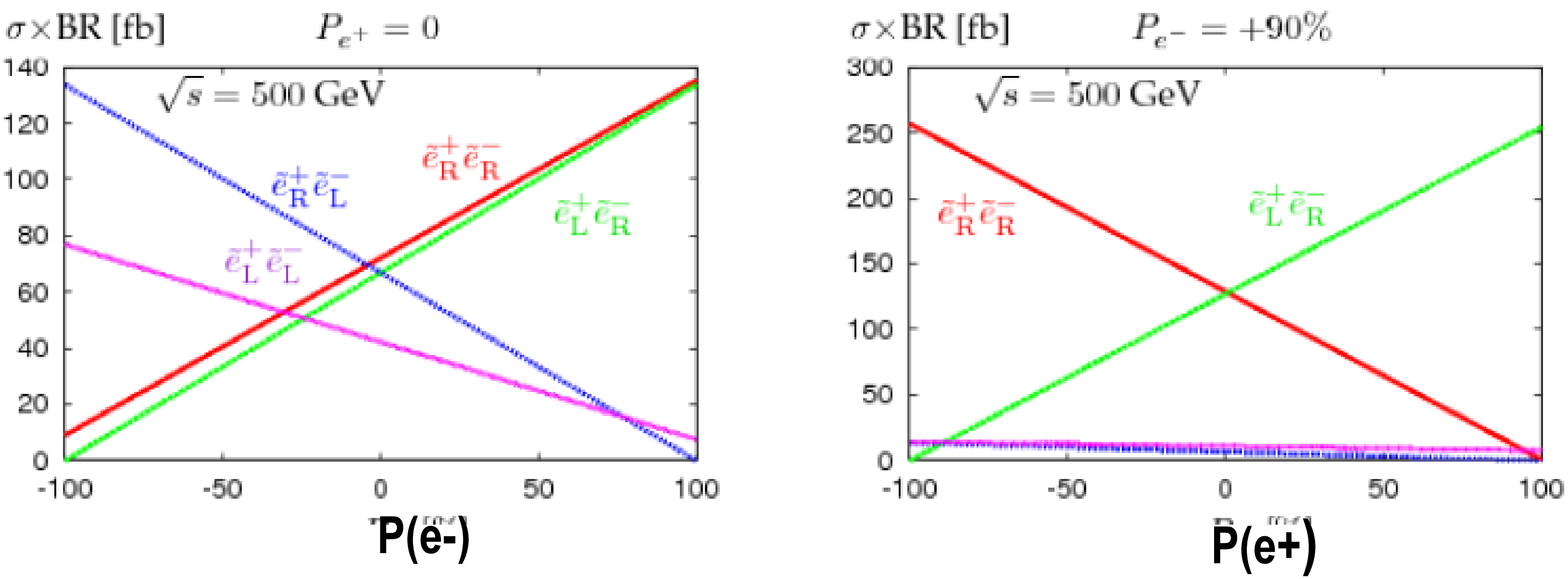
Selectron chiral qu. numbers

Model: SPS1a' like, but:

$M_{\tilde{e}_L}$ = 200 GeV and $M_{\tilde{e}_R}$ = 195 GeV. Both decay 100 % to $\tilde{\chi}^0_1$ e.

Even with $P_{e^-} \geq +90\%$, one can't disentangle the pairs $\tilde{e}^+_L \tilde{e}^-_R$ and $\tilde{e}^+_R \tilde{e}^-_R$': Ratio of the cross sections ≈ constant.

Polarised positrons a must !



'New tools': Qualitative P(e+) effects

- Access to chirality

  In practically all new physics models

  – Chirality of particles/interactions has to be identified

  – Since for E>>m: chirality = helicity = polarization

- Access to specific asymmetries ($\tilde{\nu}$, heavy leptons, ..., see LC notes)

$$\boxed{A_{\mathrm{double}} = \frac{\sigma(P_1,-P_2)+\sigma(-P_1,P_2)-\sigma(P_1,P_2)-\sigma(-P_1,-P_2)}{\sigma(P_1,-P_2)+\sigma(-P_1,P_2)+\sigma(P_1,P_2)+\sigma(-P_1,-P_2)},}$$

- Exploitation of transversely-polarized beams (~ P_{e-} P_{e+})

  – Access to tensor-like interactions (Extra dimensions, etc.)

  – Access to CP-violating phenomena

  – Access to specific triple gauge couplings

  – Optimize top quark polarization