**Requirements of running at the Z-pole and WW-threshold** 

Gudrid Moortgat-Pick (Uni Hamburg, DESY)

- Status physics and Collider options
- > Impact of precision measurements at Z and WW
- Calibration Issues
- > Technical remarks on the machine
- Conclusions

## Why running at low energies (Z, WW) at ILC?

#### **Clear distinction needed:**

#### A. For calibration purposes

- Parameter group studies this question: dedicated questions to detector groups
- Status: preliminary answer from ILD (not yet official), not yet from SID
- A few remarks on this later, but not topic of this talk!

#### **B.** For physics aspects

- Status of physics case now
- For which cases may running at WW be important?
- For which cases may Z-pole runs be important?

# Status physics

guaranteed physics!

- Current physics case for e+e- (as well known):
  - Higgs precision physics
  - Top precision physics
  - Light electroweak particles/DM searches
  - BSM detection in general, complementary to LHC
- HEP-e+e-: ILC, CLIC or CepC or Fcc-ee



- CLIC: √s=500 GeV,1.5, 3 TeV, 560 MW, 48 km, polarized beams,t≥2035(?)P. Burrows
- CepC: √s=240 GeV, 500 MW, 54 km, polarization unclear, t≥2028

W. Chou, EPS15

well

motivated

- FCC-ee: √s=350 GeV, 500 MW, 100km, no polarization at 350, t≥2035?
- Many ideas, but realistically only one mature project —the ILC—that could start operation before LHC switches off (~2035)
  - very substantial for future development of the field as a whole!

KET Workshop@ Munich, May 2/3 2016

## Current experimental result from LHC (CMS)

Many model beyond the Standard Model on the market: no clear sign!



High mass limits: any alternative to get sensitivity to new physics?
> exploit electroweak precision observables

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*Electroweak precision observables: MW, sin2θeff, MH, (g-2)μ, b physics* 

Comparison of observables with theory

Precision data: MW, sin2θeff, aμ, Mh Theory: SM, SUSY, Z',...

Test of theory at quantum level: senstivity to heavy masses via loops!



SM: limits on MH,

**BSM: limits on MX** 

Very high accuracy of measurements as well as theoretical predictions needed

- > only models 'ready so far: SM, SM-like, SUSY
  - .....still room for improvement from theory
- > in the following —as case study only— SUSY

## **Current experimental result from LHC (ATLAS)**

#### ATLAS SUSY Searches\* - 95% CL Lower Limits ATLAS Preliminary $\sqrt{s} = 7, 8, 13 \text{ TeV}$ Status: March 2016 $e, \mu, \tau, \gamma$ Jets $E_{\tau}^{\text{miss}} \int \mathcal{L} dt [\text{fb}^{-1}]$ Model Mass limit $\sqrt{s} = 7, 8 \text{ TeV}$ $\sqrt{s} = 13 \text{ TeV}$ Reference 0-3 c. µ/1-2 r 2-10 jets/3 b Yes MSUGRA/CMSSM 20.3 1.85 TeV m(ij)=m(j) 1507.05525 0 2-6 jets Yes 3.2 980 GeV $m(\tilde{\tilde{x}}_1^0)=0$ GeV, $m(1^{st}$ gen. $\tilde{q})=m(2^{sd}$ gen. $\tilde{q})$ ATLAS-CONF-2015-062 $\tilde{q}\tilde{q}, \tilde{q}\rightarrow q\tilde{t}$ $\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{t}_{1}^{0}$ (compressed) mono-jet 1-3 jets Yes 3.2 610 GeV m(ij)-m(it)/0.5GeV To appear 2 e. µ (off-Z) 2 jets Yes 20.3 m(x1)=0 GeV 1503.03290 $\tilde{q}\tilde{q}, \tilde{q} \rightarrow q(ll/lv/vv)\tilde{t}_{1}$ 820 GeV Search 0 2-6 jets Yes 3.2 m(x1)=0 GeV ATLAS-CONF-2015-062 .52 Te\ 22. 2→qq2 $1 e. \mu$ 2-6 jets Yes 3.3 $m(\tilde{\chi}_{1}^{0}) < 350 \text{ GeV}, m(\tilde{\chi}^{2}) = 0.5(m(\tilde{\chi}_{1}^{0}) + m(\tilde{\chi}))$ ATLAS-CONF-2015-076 $\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq\tilde{\chi}_{1}^{n} \rightarrow qqW^{2}\tilde{\chi}$ 1.6 Te 0-3 jets $\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq(\ell\ell/\ell\gamma/\nu\nu)\tilde{\ell}_1^0$ $2e,\mu$ 20 1501.03555 1.38 TeV m(2)=0 GeV $\tilde{g}\tilde{g}, \tilde{g} \rightarrow qqWZ\tilde{\chi}_{1}^{0}$ 0 7-10 jets Yes 3.2 1.4 TeV m(x<sub>1</sub><sup>0</sup>) =100 GeV 1602.06194 GMSB (( NLSP) 1-2 T + 0-1 l 0-2 jets Yes 20.3 1.63 TeV $\tan\beta > 20$ 1407.0603 GGM (bino NLSP) $2\gamma$ cr(NLSP)<0.1 mm 1507.05493 Yes 20.3 1.34 TeV nol GGM (higgsino-bino NLSP) y 1bYes 20.3 1.37 TeV m(x)<950 GeV, ct(NLSP)<0.1 mm, µ<0 1507.05493 GGM (higgsino-bino NLSP) γ 2 jets Yes 20.3 1.3 TeV m(x2)<850 GeV, cr(NLSP)<0.1 mm, µ>0 1507.05493 GGM (higgsino NLSP) 2 jets m(NLSP)>430 GeV $2 e. \mu (Z)$ 20.3 900 GeV 1503.03290 Yes $m(\tilde{G})>1.8 \times 10^{-4}$ eV, $m(\tilde{g})=m(\tilde{q})=1.5$ TeV Gravitino LSP 0 mono-jet Yes 20.3 865 GeV 1502.01518 22. 2→bb2 0 3b Yes 3.3 1.78 TeV m(it)<800 GeV ATLAS-CONF-2015-067 0-1 e.µ To appear 36 3.3 1.76 TeV $m(\tilde{\chi}_1^0)=0$ GeV $\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\tilde{t}\tilde{X}_{1}$ Yes 0-1 e, µ $\tilde{g}\tilde{g}, \tilde{g} \rightarrow b\tilde{e}\tilde{\chi}_{1}^{*}$ 1407.0600 3 b Yes 20.1 1.37 TeV m(x<sup>0</sup>)<300 GeV $\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{t}_1$ 0 2b Yes 3.2 840 GeV m(x20)<100 GeV ATLAS-CONF-2015-066 2 e, µ (SS) 325-540 GeV $m(\tilde{t}_{1}^{0})=50 \text{ GeV}, m(\tilde{t}_{1}^{+})=m(\tilde{t}_{1}^{0})+100 \text{ GeV}$ 1602.09058 $b_1b_1, b_1 \rightarrow t\hat{\chi}_1$ 0-3 b Yes 3.2 $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow h \tilde{t}_1^{\pm}$ 1-2 e. µ 1-2 b Yes 4.7/20.3 200-500 GeV $m(\hat{\chi}_{1}^{*}) = 2m(\hat{\chi}_{1}^{0}), m(\hat{\chi}_{1}^{0})=55 \text{ GeV}$ 1209.2102, 1407.0583 7,117-170 GeV $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow W b \tilde{\chi}_1^0$ or $t \tilde{\chi}_1^0$ 205-715 GeV 745-785 GeV 0-2 e. µ 0-2 jets/1-2 b Yes 90-198 GeV $m(\tilde{t}_1^0)=1 \text{ GeV}$ 08616, ATLAS-CONF-2016-007 20.3 150 mono-jet/c-tag Yes 90-245 GeV 1407.0608 0 20.3 m(i1)-m(i1)-85 GeV $\tilde{h}_1 \tilde{h}_1, \tilde{h}_1 \rightarrow c \tilde{K}_1$ I<sub>1</sub>I<sub>1</sub>(natural GMSB) m(x1)>150 GeV $2 e. \mu(Z)$ 20.3 1403.5222 1bYes 150-600 GeV $\tilde{t}_2 \tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$ $3 e. \mu(Z)$ 1bYes 20.3 290-610 GeV m(x1)<200 GeV 1403.5222 $\tilde{t}_2 \tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + h$ $1 e, \mu$ 6 jets + 2 b 320-620 GeV Yes 20.3 m(x1)=0 GeV 1506.08616 2 e. µ 20.3 90-335 GeV m(x1)=0 GeV 1403.5294 $l_{LR}l_{LR}, l \rightarrow l_1^{R_1}$ 0 Yes $\hat{\chi}_1^* \hat{\chi}_1^-, \hat{\chi}_1^* \rightarrow \tilde{\ell}_{V}(\ell \bar{\nu})$ 140-475 GeV 1403.5294 2 e. µ 0 Yes 20.3 $m(\hat{t}_{1}^{0})=0$ GeV, $m(\hat{t}, \hat{v})=0.5(m(\hat{t}_{1}^{0})+m(\hat{t}_{1}^{0}))$ $\hat{\chi}_1^* \hat{\chi}_1^-, \hat{\chi}_1^* \rightarrow \tilde{r} \nu(\tau \tilde{r})$ 355 GeV 1407.0350 2 7 Yes 20.3 $m(\hat{\chi}_{1}^{n})=0$ GeV, $m(\hat{\tau}, \hat{\nu})=0.5(m(\hat{\chi}_{1}^{n})+m(\hat{\chi}_{1}^{n}))$ $\begin{array}{l} \hat{\chi}_{1}^{*} \hat{\chi}_{2}^{0} \rightarrow \hat{\ell}_{L} \nu \hat{\ell}_{L} \ell(\tilde{\nu}\nu), \ell \tilde{\nu} \hat{\ell}_{L} \ell(\tilde{\nu}\nu) \\ \hat{\chi}_{1}^{*} \hat{\chi}_{2}^{0} \rightarrow W \hat{\chi}_{1}^{0} Z \hat{\chi}_{1}^{0} \end{array}$ 3 e. µ 0 20.3 1402.7029 Yes 715 GeV $m(\hat{x}_{1}^{n})=m(\hat{x}_{2}^{n}), m(\hat{x}_{1}^{n})=0, m(\hat{t}, \hat{v})=0.5(m(\hat{x}_{1}^{n})+m(\hat{x}_{1}^{n}))$ 2-3 e.µ 0-2 jets 425 GeV $m(\tilde{t}_1^n)=m(\tilde{t}_2^n), m(\tilde{t}_1^n)=0$ , sleptons decoupled 1403.5294, 1402.7029 Yes 20.3 $m(\tilde{\tilde{x}}_{1}^{n})=m(\tilde{\tilde{x}}_{2}^{n}), m(\tilde{\tilde{x}}_{1}^{n})=0$ , sleptons decoupled 1501.07110 $\tilde{\chi}_{1}^{\pm}\tilde{\chi}_{2}^{0} \rightarrow W \tilde{\chi}_{1}^{0} h \tilde{\chi}_{1}^{0}, h \rightarrow b \bar{b} / W W / \tau \tau / \gamma \gamma$ e. µ. y 0-2 b Yes 20.3 270 GeV $\tilde{\chi}_{2}^{0}\tilde{\chi}_{1}^{0}, \tilde{\chi}_{2,1}^{0} \rightarrow \tilde{\ell}_{R}\ell$ $4 e. \mu$ 20.3 $m(\tilde{t}_{2}^{0})=m(\tilde{t}_{2}^{0}), m(\tilde{t}_{1}^{0})=0, m(\tilde{t}, \tilde{v})=0.5(m(\tilde{t}_{2}^{0})+m(\tilde{t}_{1}^{0}))$ 1405.5086 Ő 635 GeV Yes GGM (wino NLSP) weak prod. cr<1mm 20.3 115-370 GeV 1507.05493 $1c.\mu + \gamma$ Yes ŵ Direct $\hat{\chi}_1^* \hat{\chi}_1^-$ prod., long-lived $\hat{\chi}_1^*$ Disapp, trk 1 jet Yes 20.3 270 GeV m(t1)-m(t1)-160 MeV, t(t1)=0.2 ns 1310.3675 Direct $\hat{x}_1 \hat{x}_1$ prod., long-lived $\hat{x}_1^{\pm}$ 1506.05332 dE/dx trk Yes 18.4 495 GeV m(x11)-m(x11)-160 MeV, r(x11)<15 ns Stable, stopped g R-hadron 0 1-5 jets Yes 27.9 850 GeV m(x2)=100 GeV, 10 µs<r(z)<1000 s 1310.6584 Metastable g R-hadron 1.54 TeV dE/dx trk 3.2 m(\$20)=100 GeV, r>10 ns To appear GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau(e, \mu)$ $1-2 \mu$ 19.1 537 GeV 10-ctan/i-c50 1411.6795 $2\gamma$ 20.3 1409.5542 GMSB, $\hat{\chi}_{1}^{0} \rightarrow \gamma \tilde{G}$ , long-lived $\hat{\chi}_{1}^{0}$ Yes 440 GeV 1<r(2)</li> 1504.05162 $\tilde{g}\tilde{g}, \tilde{\chi}_1^0 \rightarrow eev/euv/\mu\mu v$ displ. ee/eµ/µµ 20.3 1.0 TeV 7 <cr(\$2)<740 mm, m(2)=1.3 TeV GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1 \rightarrow Z\tilde{G}$ displ. vtx + jets 20.3 6 <cr(2) < 480 mm, m(2)=1.1 TeV 1504.05162 1.0 TeV LFV $pp \rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e\mu/e\tau/\mu\tau$ еµ,ет,µт 20.3 1.7 TeV Jan =0.11, Jan 2007 1503.04430 Bilinear RPV CMSSM 2 e, µ (SS) 1.45 TeV $m(\tilde{q})=m(\tilde{q}), c\tau_{LSP}<1 mm$ 0-3 b Yes 20.3 1404.2500 $\tilde{\chi}_{1}^{*}\tilde{\chi}_{1}^{-}, \tilde{\chi}_{1}^{*} \rightarrow W \tilde{\chi}_{1}^{0}, \tilde{\chi}_{1}^{0} \rightarrow ce\tilde{\nu}_{\mu}, e\mu\tilde{\nu}_{e}$ 4 e. µ 20.3 760 GeV $m(\hat{x}_{1}^{0})>0.2\times m(\hat{x}_{1}^{0}), \lambda_{121}\neq 0$ 1405.5086 Yes $\tilde{\chi}_{1}^{*}\tilde{\chi}_{1}^{-}, \tilde{\chi}_{1}^{*} \rightarrow W \tilde{\chi}_{1}^{0}, \tilde{\chi}_{1}^{0} \rightarrow \tau \tau \tilde{\nu}_{e}, e \tau \tilde{\nu}_{\tau}$ 3 e. µ + τ Yes 20.3 450 GeV $m(\hat{x}_{1}^{0}) > 0.2 \times m(\hat{x}_{1}^{0}), \lambda_{131} \neq 0$ 1405.5086 6-7 jets BR(r)=BR(h)=BR(c)=0% $\hat{g}\hat{g}, \hat{g} \rightarrow q\bar{q}q$ 0 20.3 1502.05686 917 GeV $\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq\tilde{t}_{1}^{0}, \tilde{t}_{1}^{0} \rightarrow qqq$ $\tilde{g}\tilde{g}, \tilde{g} \rightarrow \tilde{t}_{1}t, \tilde{t}_{1} \rightarrow bs$ 6-7 jets m(x1)=600 GeV 1502.05686 Ö 20.3 980 GeV 2 e, µ (SS) 0-3 b Yes 20.3 880 GeV 1404,2500 $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow bs$ Ô 2 jets + 2 b 20.3 320 GeV 1601.07453 $\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow b\ell$ 2 e. µ 26 20.3 0.4-1.0 TeV BR(i<sub>1</sub>→be/µ)>20% ATLAS-CONF-2015-015 0 20 20.3 510 GeV m(x<sub>1</sub><sup>0</sup>)<200 GeV 1501.01325 Other Scalar charm, $\tilde{c} \rightarrow c \tilde{\tilde{t}}_{1}^{0}$ Yes \*Only a selection of the available mass limits on new 10-1 Mass scale [TeV]

#### states or phenomena is shown.

#### So far: rather heavy SUSY mass limits ....but not exclusively

#### All simplified models!

S. Heinemeyer Talk at MPI Munich, 5/16

Importance of  $M_W$  and mixing angle  $sin^2\theta_{eff}$ 

A. Theoretical prediction for  $M_W$  in terms of  $M_Z$ ,  $\alpha$ ,  $G_{\mu}$ ,  $\Delta r$ :

$$M_W^2 \left( 1 - \frac{M_W^2}{M_Z^2} \right) = \frac{\pi \alpha}{\sqrt{2} G_\mu} \left( 1 + \Delta r \right)$$

loop corrections

#### Evaluate $\Delta r$ from $\mu$ -decay $\Rightarrow M_W$

**One-loop result for M<sub>W</sub> in the SM:** 

$$\Delta r_{1-\text{loop}} = \Delta \alpha - \frac{c_W^2}{s_W^2} \Delta \rho + \Delta r_{\text{rem}}(M_H)$$
$$\sim \log(\frac{M_Z}{m_f}) \sim m_t^2 + \log(M_H/M_W)$$
$$\sim 6\% \sim 3.3\% \sim 1\%$$

#### > Large impact of m<sub>top</sub>, M<sub>H</sub> and M<sub>Z</sub> and their uncertainties!

#### Which precision in M<sub>W</sub> do we need?

- Case study SUSY versus Standard Model
  - > Strong correlation of  $M_W$ ,  $M_t$  and  $M_H$ :



#### Current experimental world average: M<sub>W</sub>=80.385 ±0.015 GeV, M<sub>t</sub>=173.34±0.76 GeV

POSIPOL@ Orsay, September, 14-16, 2016

S. Heinemeyer Talk at MPI Munich, 5/16

## Which precision in M<sub>W</sub> do we need?

Just as case study SUSY: m<sub>stop1</sub>=400±40 GeV, other susy masses>500 GeV

![](_page_8_Figure_3.jpeg)

> precision for  $\Delta M_W$  below/about 5 MeV required in order to be sensitive to heavy susy masses!

## The mass of the W boson

Today: LEP2, Tevatron: MWexp=80.385±0.015 GeV ILC: - polarized threshold scan **G.** Wilson 2013 kinematic reconstruction of WW hadronic mass (single W) ΔM<sub>W</sub><sup>exp,ILC(FCC-ee)</sup><3 (1) MeV (from threshold scans) (but without Theo uncertainties!) Theoretical accuracies: intrinsic today:  $\Delta M_W^{SM,theo} = 4 \text{ MeV} \implies \text{future: } \Delta M_W^{SM,theo} = 1 \text{ MeV}$ parametric uncertainties today: future: from  $\Delta mt = 0.9 \text{GeV} \implies \Delta M_W^{mt} = 5.5 \text{MeV}$  $\Delta mt = 0.05 \text{ GeV} \implies \Delta M_W^{mt} = 0.5 \text{ MeV}$  $\Delta \alpha$ had=5x10-5  $\Rightarrow \Delta M_W^{\alpha had}=1 \text{ MeV}$ from  $\Delta \alpha$  had=10-4  $\Rightarrow \Delta M_W^{\alpha had} = 2 MeV$  $\Delta mZ = 1/0.1 MeV \implies \Delta M_W^{mZ} = 0.2/0.02 MeV$ from  $\Delta mZ=2.1 MeV \implies \Delta Mw^{mZ}=2.5 MeV$ 

**Experimental accuracy:** 

**B.** Effective mixing angle:

$$\sin^2 \theta_{\text{eff}} = \frac{1}{4 \left| Q_f \right|} \left( 1 - \frac{\text{Re} \, g_V^f}{\text{Re} \, g_A^f} \right)$$

**Higher order contributions:** 

$$g_V^f o g_V^f + \Delta g_V^f, \quad g_A^f o g_A^f + \Delta g_A^f$$

also impact of new physics contributions!

![](_page_11_Figure_1.jpeg)

POSIPOL@ Orsay, September, 14-16, 2016

![](_page_12_Figure_1.jpeg)

MSSM band: scan over SUSY masses

overlap: SM is MSSM-like MSSM is SM-like

SM band: variation of  $M_H^{SM}$ 

#### S. Heinemeyer **Impact of the precision of the mixing angle sin**<sup>2</sup> $\theta_{eff}$ Munich, 5/16

- Experimental accuracy:
  - Today: LEP, SLD: sin2θeff=0.23153 ± 0.00016
  - GigaZ/TeraZ: both beams polarized, Blondel scheme

 $\Delta sin 2\theta_{eff}^{exp,ILC(FCC-ee)} = 13/3 \times 10-6$  (but without Theo uncertainties!)

• Theoretical accuracies: [10-6] intrinsic today:  $\Delta sin2\theta_W^{SM,theo} = 47 \Rightarrow future: \Delta M_W^{SM,theo} = 15$ parametric uncertainties today: future: from  $\Delta mt = 0.9 \text{GeV} \Rightarrow \Delta sin2\theta_{eff}^{mt} = 30$ from  $\Delta \alpha had = 10-4 \Rightarrow \Delta sin2\theta^{\alpha had} = 36$ from  $\Delta mZ = 2.1 \text{MeV} \Rightarrow \Delta sin2\theta_{eff}^{mZ} = 14$  $\Delta mZ = 1/0.1 \text{MeV} \Rightarrow \Delta sin2\theta_{eff}^{mZ} = 6.5/0.7$ 

• Last but not least: relevance of both beams polarized:

![](_page_14_Figure_2.jpeg)

Heinemeyer, Weiglein 2005

- > precision on  $sin^2\theta_{eff}$  relies strongly on both beams polarized
- > crucial to reach sensitivity!

POSIPOL@ Orsay, September, 14-16, 2016

## **Remark on running at Z/WW for calibration**

- Calibration needs with Z pole data
  - > referred to in the TDR, but without specific design
  - > promised precision can only be guaranteed if matched by alignment and calibration
  - > not clear whether switching between low and high energy running is critical
  - clear question to the detector groups: how often and which lumi is needed and which detector component does really need Z pole running?

*G. Wilson Talk at DESY Hamburg, 5/16* 

$\sqrt{s}$	$\sigma(\mu\mu)$ (pb)	$\sigma(q\overline{q})$ (pb)	$\rho_Z(\mu\mu)$	$\rho_Z(q\overline{q})$
91.2	1580	30500	1.0	1.0
250	4.99	50.1	316	609
350	2.57	24.8	614	1230
500	1.30	12.6	1210	2420
1000	0.386	3.64	4080	8370

- Assuming γ scaling of lumi: hadronic events are 440 times higher at Z-pole compared to 500 GeV.
- Calibration that may need about a year at 500 can be done in 1 day at Z-pole,...if well mature designed

## **Remark on running at Z/WW for calibration**

#### **Preliminary intermediate results (thanks to Jenny!)**

- So far, ILD tracking systems expects frequent Z calibration runs with 10<sup>32</sup> or 1 pb-1 in few hours
- Calorimetry: absolute scale of ECAL no Z pole running needed
  - > MIP scale calibration requires couple of days Z pole calibration
  - > HCAL: MIP scale most efficiently via Z pole
- Jet Energy scale: no dedicated running at Z or WW

However: still many details under work

- no lumi-issues for positron source
- can be delivered with low intesity source

## Machine issues: options to run at low energies

*N. Walker Talk at DESY Hamburg, 12/15* 

• Luminosity issues: γ scaling may not be appropriate

![](_page_17_Figure_3.jpeg)

also 10 Hz scheme not always applicable if ΔE between pulse too big, e.g.
45 GeV and 150 GeV.....problems with linac dynamics

## Machine issues: options to run at low energies

*N. Walker Talk at DESY Hamburg, 12/15* 

• Further option: split linac !

![](_page_18_Figure_3.jpeg)

#### Major reconfiguration of accelerator

Requires a mini design study

- 3rd beamline in linac tunnel
- additional doglegs, bypasses and possible dumps

• Z and W running conceptually possible at 2-4Å~1033 and 3-6Å~1033 respectively but much more detailed studies required !

## Conclusions

#### Calibration Issues:

- still under work, some detector parts require Z-pole (10^32) (time issues!)
- > crucial information how quickly and how often energy changes are required: stay tuned, under work
- Physics:
  - > Threshold runs at WW needed: mass precision
  - > GigaZ run needed (including polarized beams!): electroweak precision angle
  - > FCC-ee option: can not replace ILC@Z,WW
- Accelerator issues:
  - ➣ in principle no lumi issues but design changes required
  - > Technical solution via split linac
  - > For lumi upgrade still some more work to do (but also for e-driven source unclear)

#### ILC only compatible and complentary to LHC if physics runs with 10<sup>33</sup> at low energy not excluded !

![](_page_20_Picture_0.jpeg)

**Revealing present mysteries** 

![](_page_20_Picture_2.jpeg)

![](_page_20_Picture_3.jpeg)

Feeding future brains