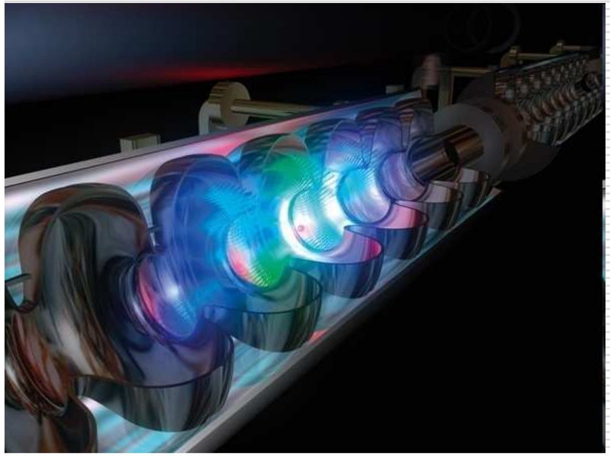
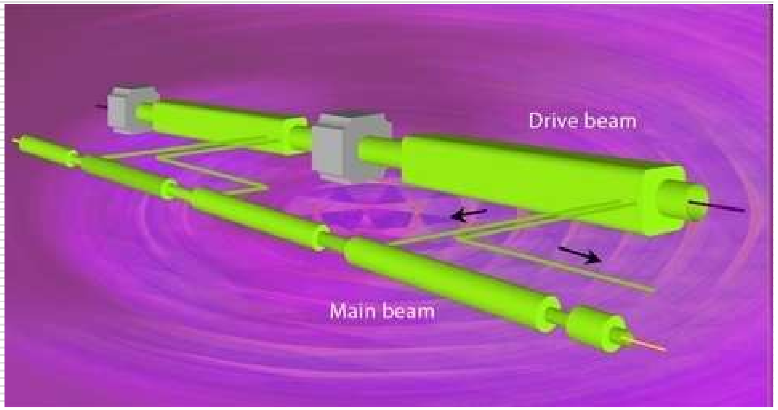
Scenario for a world wide e+e- collider

CIEMAT, Spain, September 24, 2009

F. Richard LAL/Orsay





Outline

- Introduction
- The basic scenario
- Recent evolutions
- Technical challenges for the LC and its detectors
- Alternate physics scenarios
- Summary and conclusions

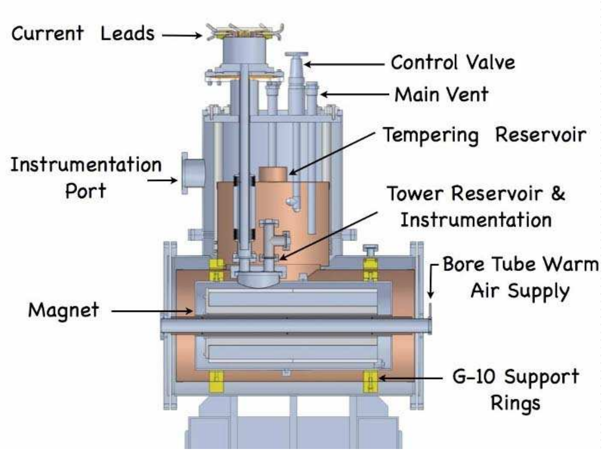
Introduction

- Particle physics requires (very) long term planning
- LHC has taken >20 years (reminder: first workshop on LHC was 1984. . .)
- Satellite expts also very long: Planck Surveyor (CMB), just launched, planned since 1992
- Since 2004 there is an international consensus (OCDE) that the next large HEP machine should be an **e+e- linear collider**
- To reach this goal one should avoid disruptions, conflicts (SSC episode), duplication of efforts
- At the moment there is a clear roadmap to reach this goal

Present worldwide roadmap

- By far the most advanced project is the TeV SC collider called **ILC** which is developed by a worldwide collaboration installed by ICFA
- It aims at a TDR for end of 2012
- **CLIC** for a multi-TeV collider is in an R&D phase and intends to prove its feasibility (CDR) by 2010
- These machines are very challenging projects in comparison to LEP2/SLC
- A muon collider is studied at FNAL
- Even more futuristic R&D is actively performed with laser-plasma and beam-plasma acceleration

The ILC project



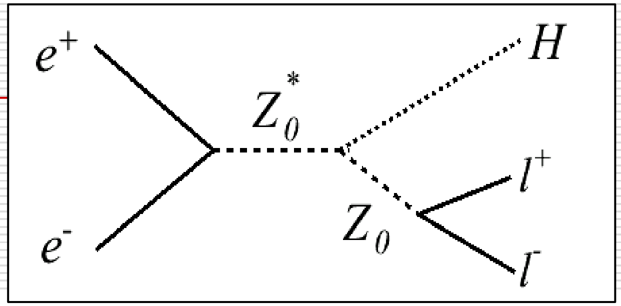
- ILC has a large 5% Linac 'prototype' under construction, the **DESY XFEL**, and intense R&D on critical aspects in Asia, Europe and NA
- Spain (+other Europeans like FR, Ge, IT, UK, CERN) is actively contributing to ILC (e.g. SC test magnet), to XFEL and works on CLIC R&D
- ILC is about to produce an 'almost' ready for construction project to be proposed to governments in 2012
- ILC works with a large community ~1000 physicists and engineers preparing detectors and furbishing solid physics arguments in favor of such a project

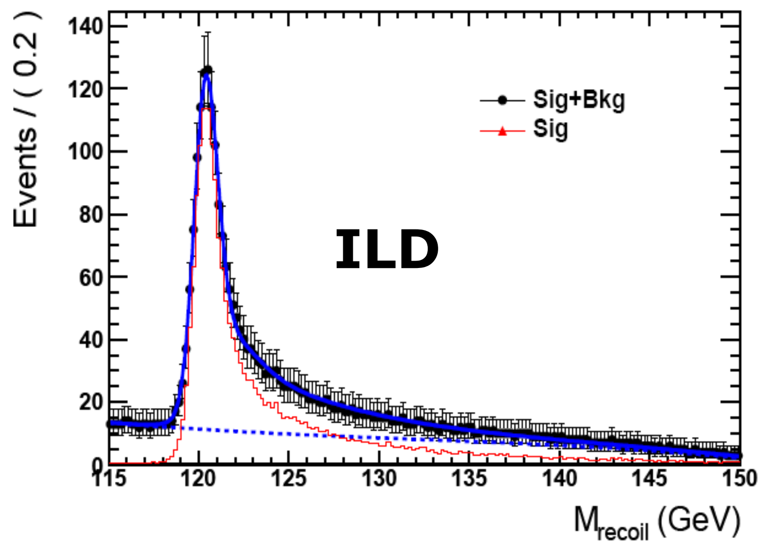
Physics at ILC

- Physics arguments in favor of ILC are solid
- A light Higgs is predicted within SUSY and the SM interpretation of LEP/SLC/TeVatron precision measurements (PM)
- 0.5-1 TeV is an optimal energy to cover Higgs physics and presumably the lightest SUSY particles (CMSSM)
- ILC accuracy needed in the Higgs and SUSY sectors (as illustrated below)
- SC technology is well suited for this energy range but, while not strictly limited to 1 TeV cannot, with present SC materials, go well beyond

ee->Z*->HZ

- The recoil mass technique with Z->μ+μ- gives a very clean signal at √s=MH+110 GeV
- Works even if H decays into invisible or complex modes
- ZZH coupling constant determined to ~1%
- In the SM case most BR ratios known 10 times more precisely than at LHC

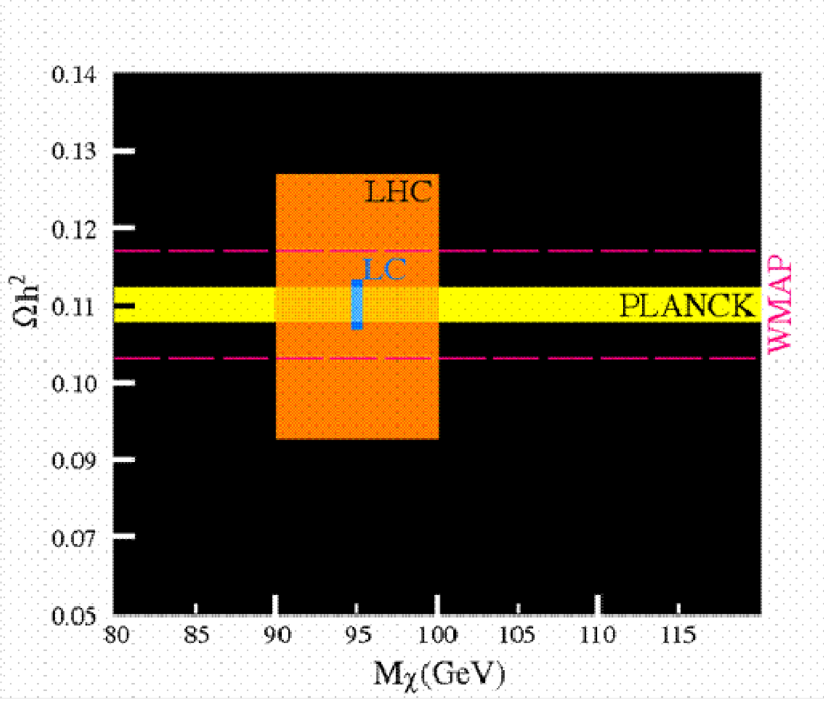




Full Simulation

Dark matter & SUSY

- With LHC+LC it is possible to reach sufficient accuracy on the predicted dark matter to match cosmological observations
- Do they coincide ?



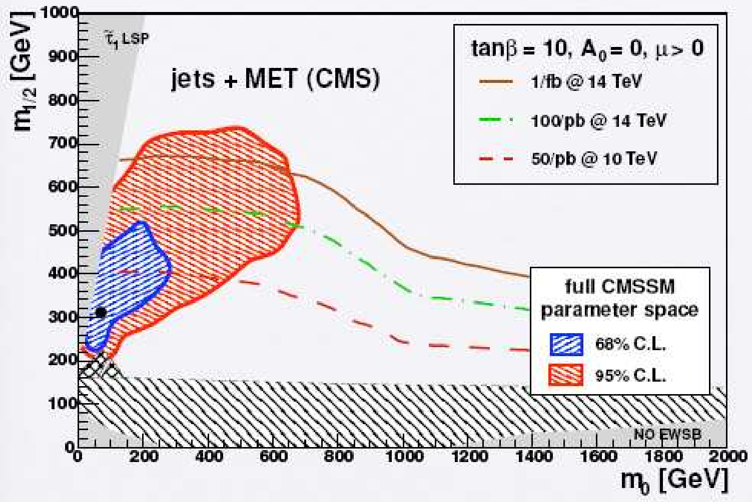
Recent evolutions

- Basic uncertainty: are we certain to observe a light Higgs ?
- One can envisage 3 types of scenarios
- Higgs SM & SUSY which looks promising within CMSSM
- Higgs composite (TC or ~5D) : Higgs couplings and presumably t,b couplings could show anomalies KK bosons (or ~ ρ) particles >2-3 TeV (but KK quarks ~500 GeV)
- Higgless
- Present wisdom is therefore: wait for physics results from LHC (or Tevatron) but work to be ready for a decision by end of 2012 (?)
- This choice is now acceptable given the imminent start of LHC

How soon can LHC give answers?

- Will start will reduced lumi & energy (≤5 TeV/beam) and with few 100 pb-1 not enough to discover the Higgs boson immediately (6-9 months shutdown end 2010 to reach 7 TeV)
- CMSSM could be explored with ~200pb-1 at 5+5 TeV
- Possibly new quarks <500 GeV either from extra dimensions or with a 4th family
- An indication for Z′ in lepton pairs may require >1fb-1

LHC REACH VS CMSSM



ler, Cavanaugh, De Roeck, Ellis, Flacher, Heinemeyer, Isidori, Olive, Paradisi, Ronga, Weiglein

Politics

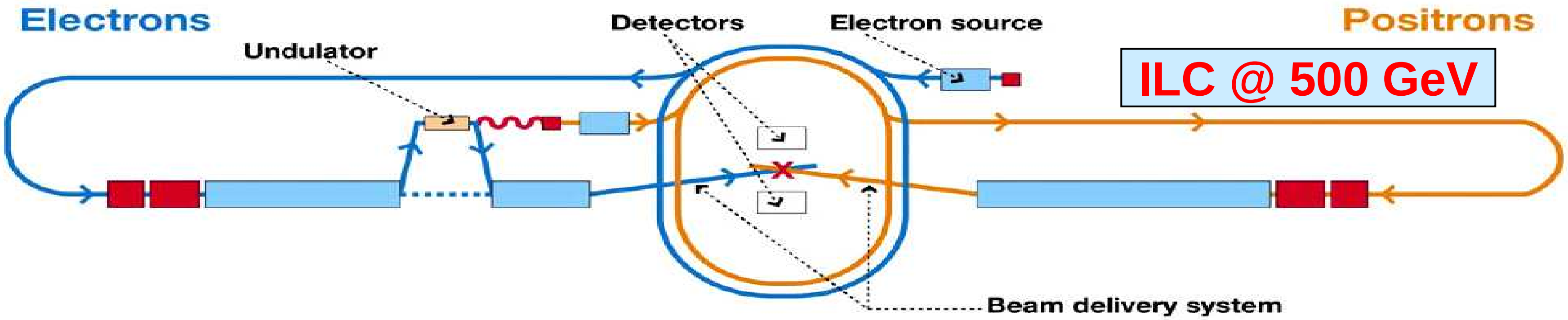
- ILC in the US seems improbable after the pessimistic cost estimate of DOE (3-4 times the 6B$ estimated by ILC) but has good contributions (FNAL, JLAB, Cornell) at ~35M$
- Japanese ambitions (Nobel prize, Political & Industrial lobbying) but they have JPARC + superBelle
- CERN ? LHC first !
- CERN is however preparing (legal aspects: 'Scientific and geographical enlargement of CERN') to become a major partner for a world wide LC even if it not constructed at CERN
- CERN wants CLIC to be kept as an option
- -> Develop a technical collaboration between ILC and CLIC both on machine and detectors
- ->Common effort to promote the need for a LC after LHC

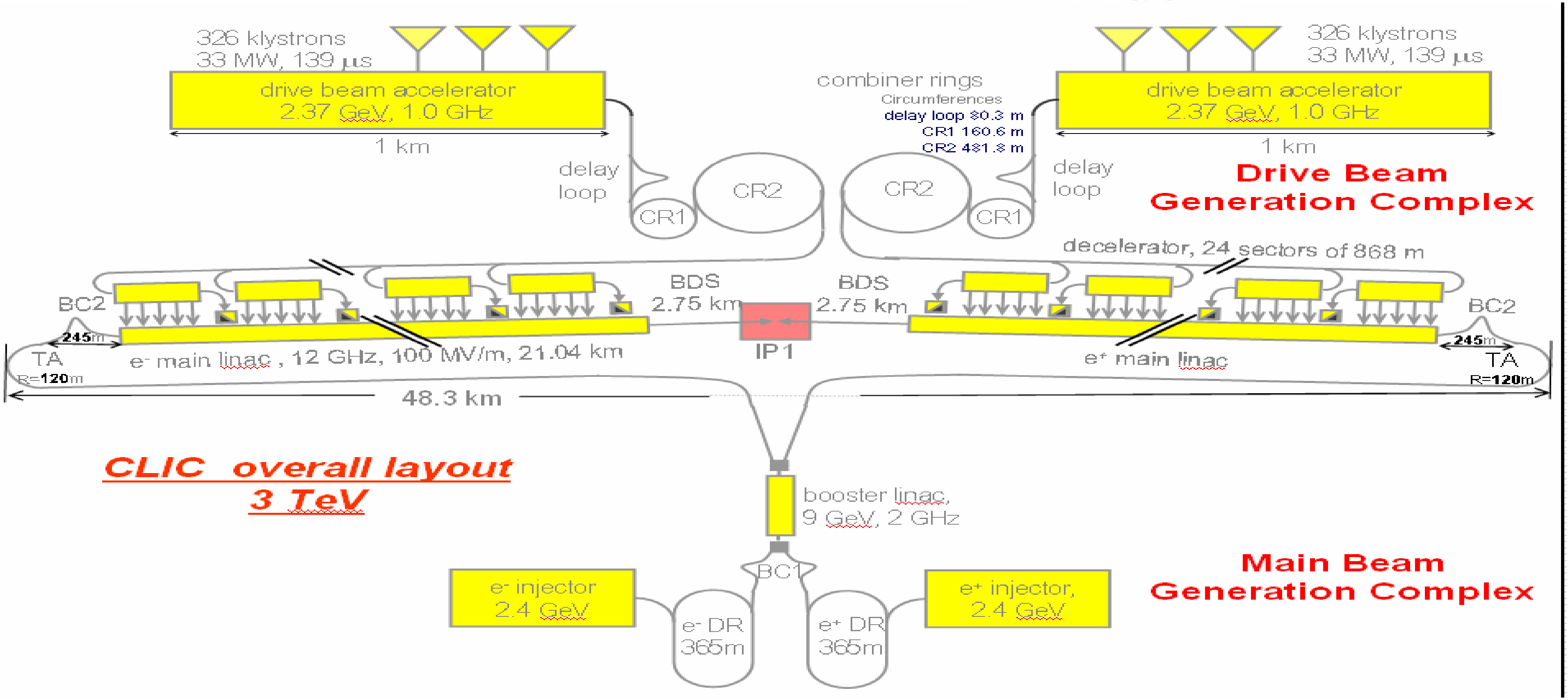
Breaking news

http://www.physorg.com/news172317407.html

- **CERN boss wants to bid for linear collider**
- September 16th, 2009 **CERN's director general Rolf-Dieter Heuer will push for the linear collider, the next big experiment in particle physics after the Large Hadron Collider (LHC), to be built at the Geneva lab. Heuer made his call to situate the linear collider at CERN in an exclusive video interview with *Physicsworld*, which is being relaunched today, Wednesday 16 September.**

CLIC and ILC layouts





Some parameters

$$L \sim \eta \frac{P_{\mathrm{electrical}}}{E_{CM}} \sqrt{\frac{\delta_E}{\varepsilon_{n,y}}} H_D$$

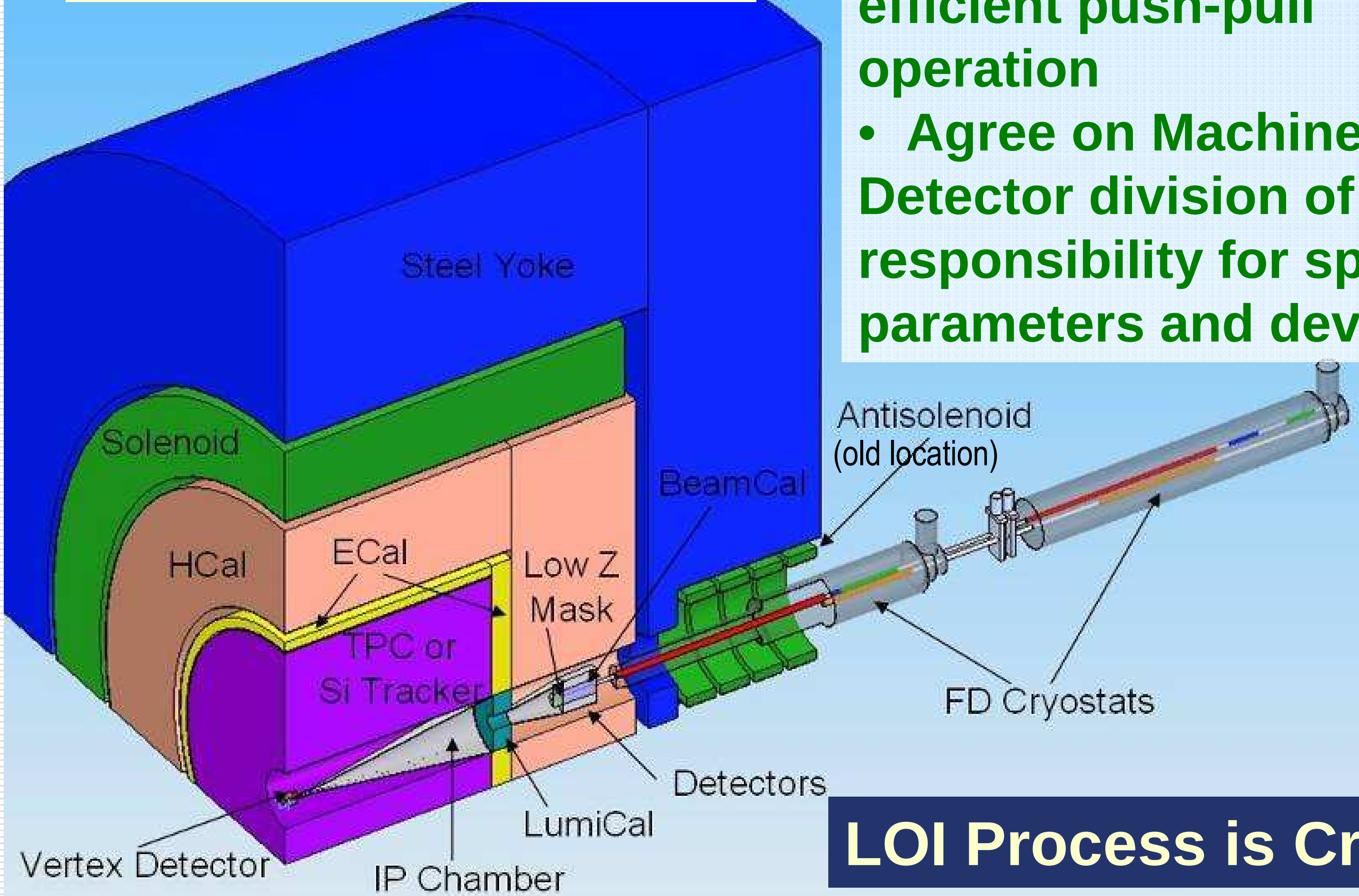
Type	LEP200	SLC100	ILC500	CLIC500
Vertical size nm	4000	700	5.7	2.3
Total P MW	65	50	216	129.4
Wall plug transf % η			9.4	7.4
Luminosity $10^{31}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$	5	0.2	1500	1400
Interval between bunches ns	>>>	>>>	176	0.5
Polarisation %	No	80	>80	>80
Gradient MV/m	8	17	31.5	100

- ILC and CLIC intend to start at 500 GeV
- ILC is upgradable, with present technology, at 1 TeV
- CLIC could reach 3 TeV but with ~constant luminosity (same δ)

Detectors

- They need to be ready end 2012 as for the machine and well integrated to the machine(push pull issue)
- 3 Letters of Intent (1000 P+I) have been examined for validation by peer review (IDAG) during summer
- **SiD ILD** have been validated based on PFLOW ideas
- Important to pursue R&D on the multi-readout technology proposed by the **Fourth** concept
- Challenging detectors quite different from LEP
- CERN has joined this effort and intends to use the same detector concepts for CLIC
- Does it work? Seems OK for WW/ZZ separation but watch for duty cycle effects

IR Integration

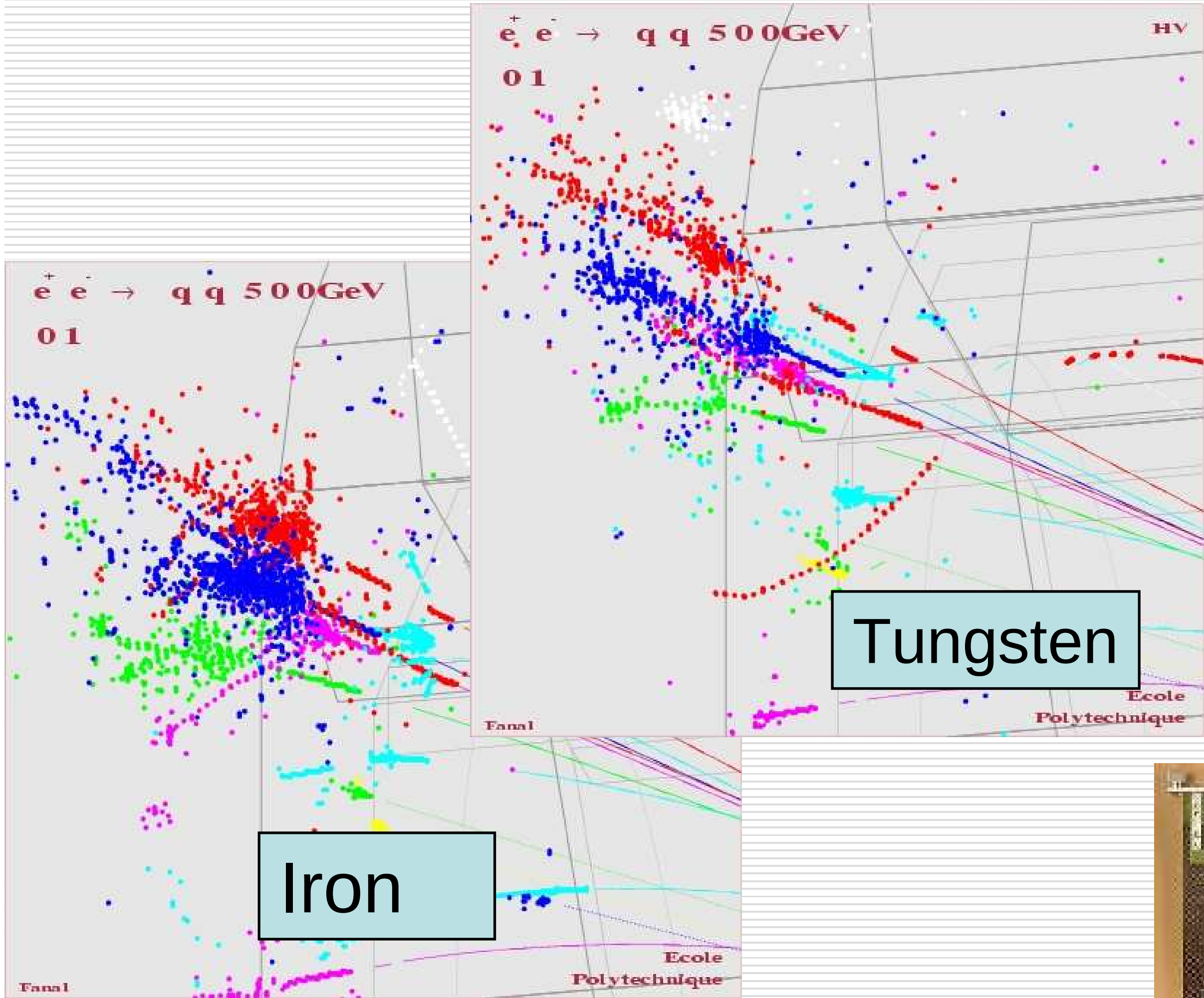


CHALLENGES:

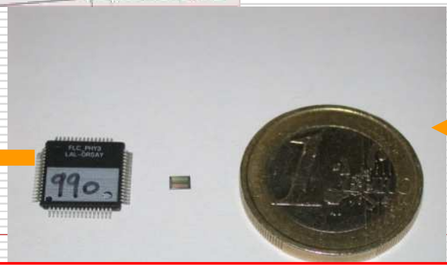
- **Optimize IR and detector design ensuring efficient push-pull operation**
- **Agree on Machine-Detector division of responsibility for space, parameters and devices**

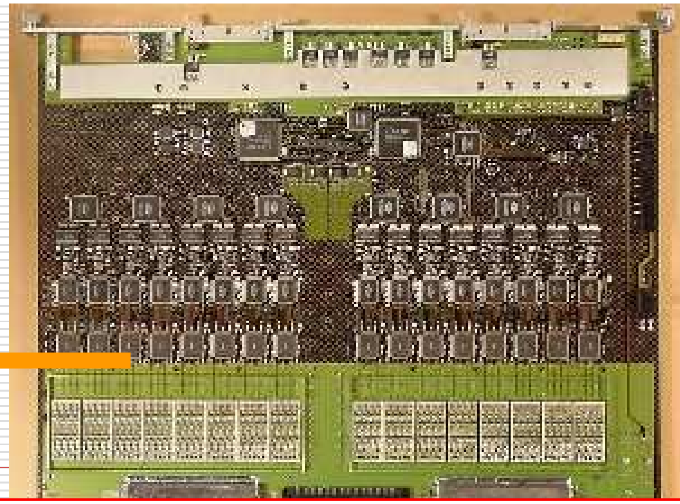
LOI Process is Crucial

JETS



- High granularity+high density (SiW)
- µelectronics integrated inside calorimeters
- Possible with new technology+power pulsing
- Requires R&D





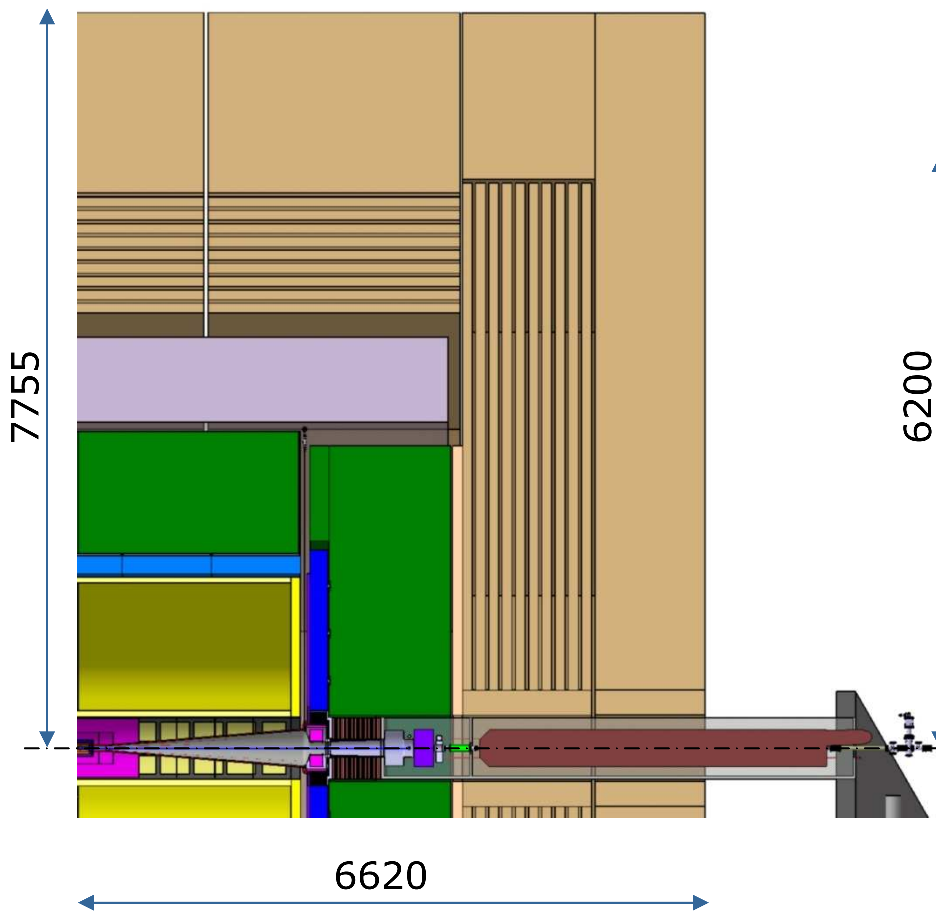
ILC : **100µW/ch**

Physics Proto. 18ch 10*10mm **5mW/ch**

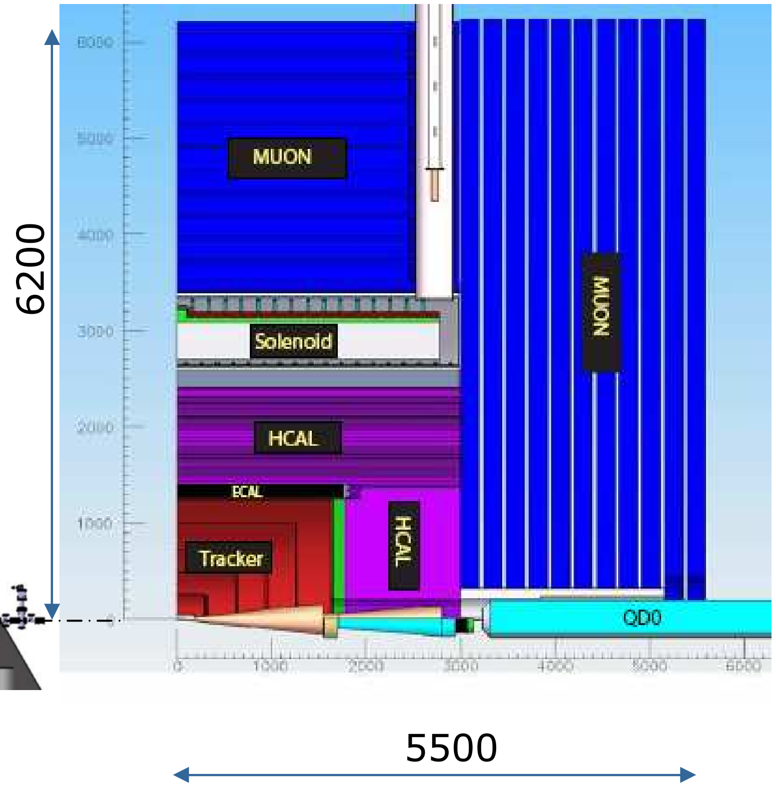
ATLAS LAr FEB 128ch 400*500mm **1 W/ch**

Do they differ ‘enough’ ?

- Similar in calorimetry (but with options e.g. AHCAL & DHCAL)
- This calorimetry is ‘risky’ and it will help to have competition in the framework of the R&D organisation CALICE
- If dual read out is fully proven/affordable there could be an evolution in SiD
- Very distinct trackers : TPC and Si detectors
- SiD significantly smaller and therefore cheaper but more challenging on PFA


7755
6620

ILD


6200
MUON
Solenoid
HCAL
ECAL
Tracker
HCAL
MUON
QD0
5500

SiD

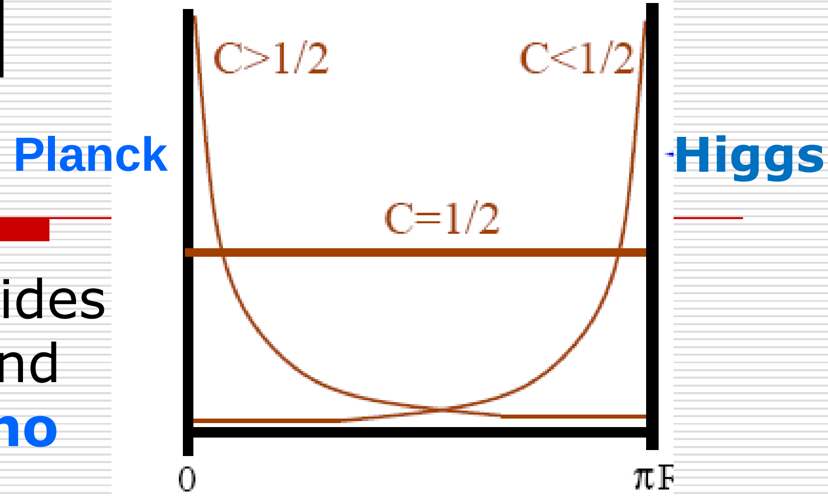
European organization on Detectors

- By far Europe gives the strongest contribution to detector R&D
- There is EU support which helps in this process (EUDET for FP6 and now an initiative for FP7)
- Spain is becoming a strong actor of this effort (SiLC, DHCAL in CALICE, detector alignment…)
- CERN is entering the game through CLIC-ILC collaboration and provides unique expertise on large detector integration

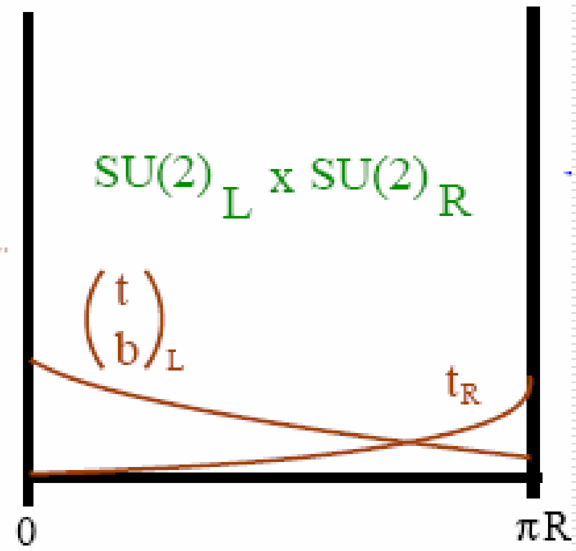
Alternate Physics Scenarios

- What are the alternate physics scenarios, and how can they influence our choices ?
- Most of these scenarios have a hard time to pass PM
- It seems however possible to accommodate a heavy Higgs and even an absence of Higgs
- Examples: strongly coupled field theory (TC) dual to extra dimensions (RS), 4th generation, BESS etc…
- These models provide S,T extra contributions and therefore alter the light Higgs prediction (‘conspiracy’)
- What could a LC observe in such scenarios ?

RS in a nutshell

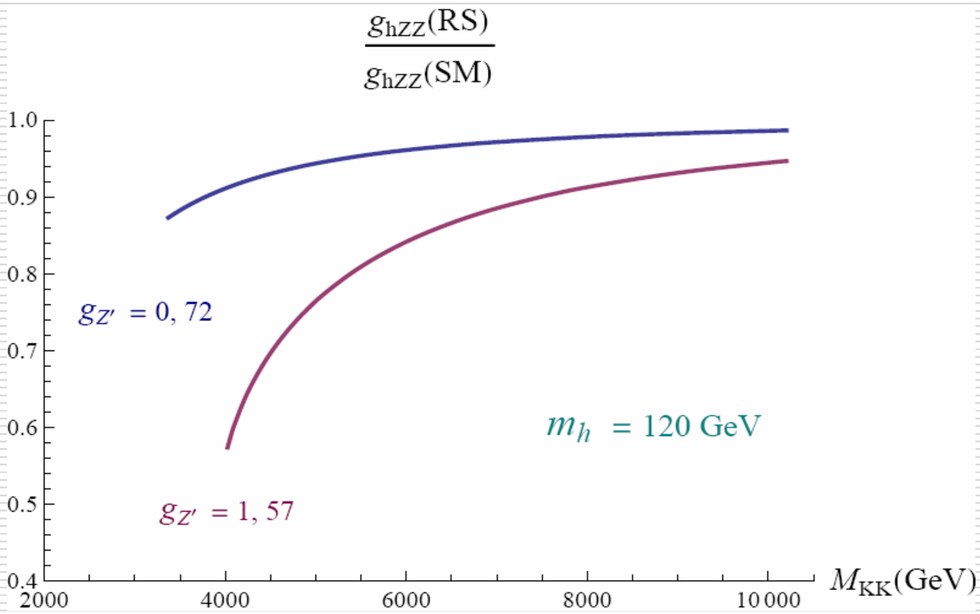


- The Randall Sundrum model provides an interpretation for Planck/EW and fermion masses hierarchies with **no new scale**
- S,T constraints requires extended groups and hence not only KK states but also Z' and 'custodians'
- KK bosons couple preferentially to b and even more to t, most likely tR
- AFBb at LEP1 could be interpreted within RS by Z-Z' mixing in RS
- AFBt indication at Tevatron can be interpreted as Gkk exchange



Example on ZZH

- Reduced ZZH coupling
- Not a problem at ILC (but severe for LEP2)
- Could be the only RS signal if KK are heavy in which case ILC could be sensitive to this new physics well beyond LHC (works up to ~10 TeV)



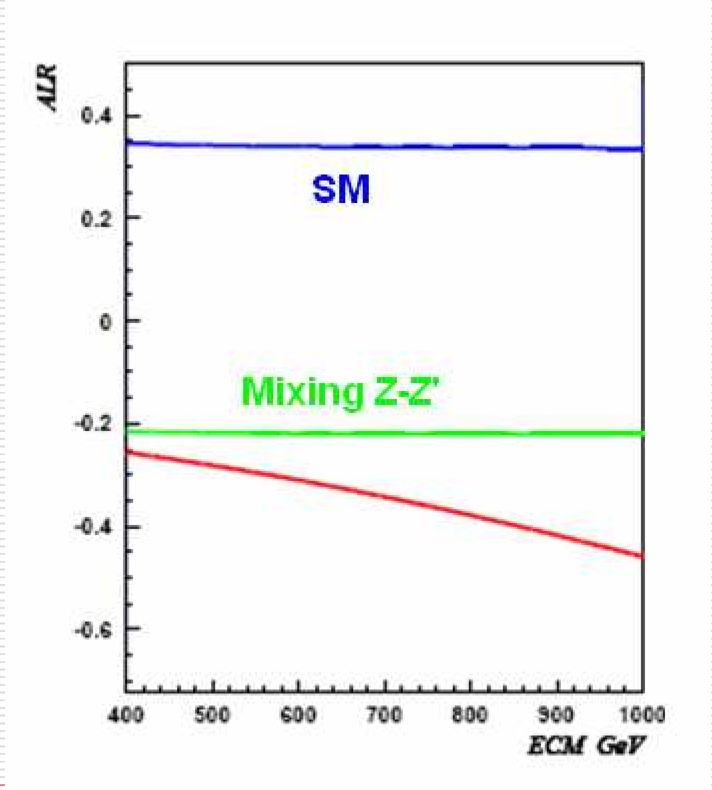
G. Moreau C. Bouchart
LPT-ORSAY-09-70

Giudice et al.
JHEP 0706:045,2007.

Top physics

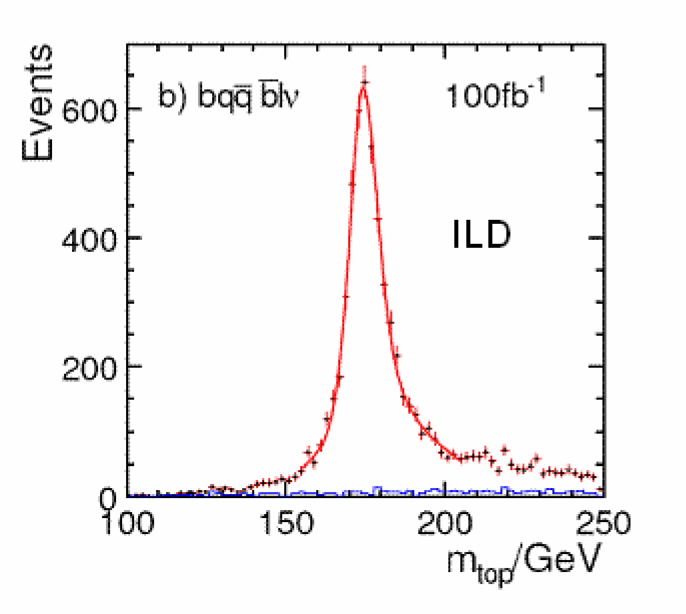
- Plays a very peculiar role in most of these models
- In RS tR couples preferentially to Z′ through Z-Z′ mixing
- Large effect expected from AFBb (MZ′ up to ~10 TeV)

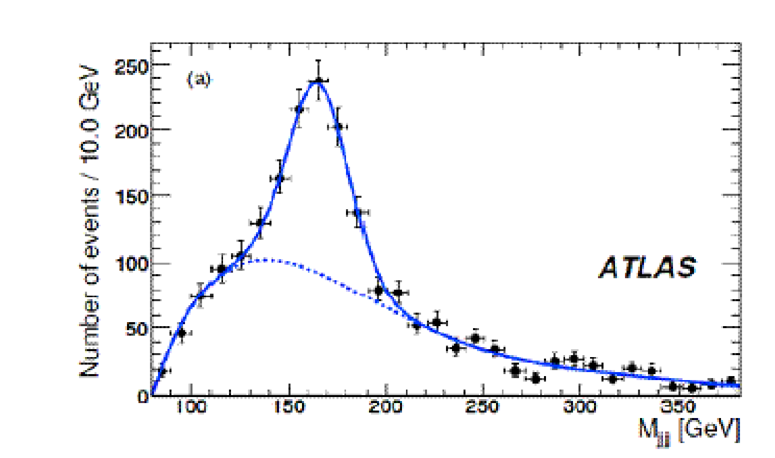
[A. Djouadi](#) et al.
Nucl.Phys.B773:43-64,2007



Top at ILC

- LC 1 pb, LHC 1nb but with larger uncertainties
- Very good s/b at ILC and energy conservation allows to reconstruct modes with a neutrino
- Mt and Γt with 50 MeV error, 0.4% on cross section
- Polarisation allows to separate tR and tL (extra dimensions)





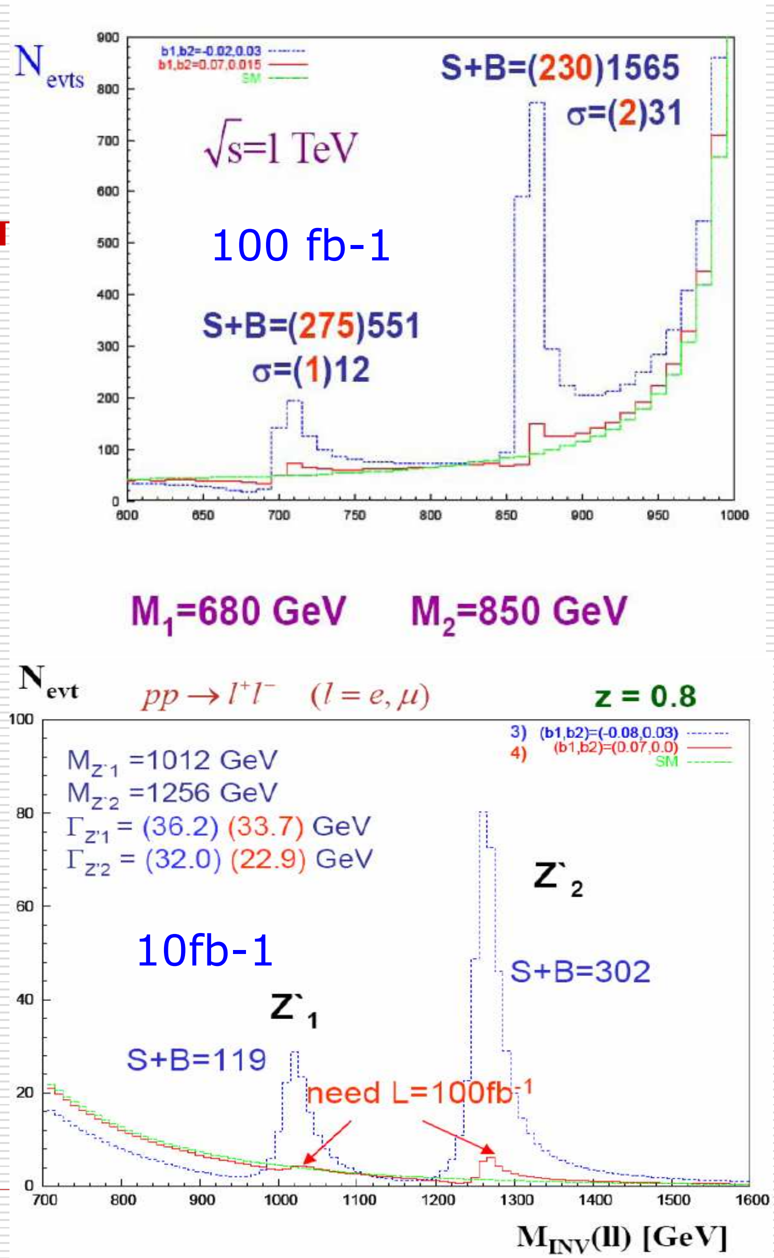
Higgsless scenarios

- Hyp: SM Higgs excluded by TeVatron+LHC
- Truly Higgsless ?
- There is the distinct possibility that a light Higgs was missed even at LEP2 if it cascades to 2 light CP odd Higgs NMSSM
- Would be covered by ILC irrespective of its decay modes (if narrow resonance) and with reduced xsection (RS)
- Without Higgs (RS, TC, BESS) several deviations expected in ee->WW, ZWW, WW$\nu\bar{\nu}$ better observed at CLIC
- Very demanding in luminosity at LHC which would delay any decision to build a LC
- Instead one could observe ~TeV resonances which could be accessible earlier

S. DeCurtis et al.

Higgsless with Z’

- In extra dimension (and ‘deconstructed versions) additional Z required to control unitarity violation in WLWL
- ILC could see a signal but it will require CLIC to see the whole picture
- In some cases very large luminosity is needed both at LC and LHC



HEP strategy

- Connect CLIC and ILC efforts to avoid duplication and potentially damaging competition
- Prepare for major challenges: technical (industrialisation 16000 SC cavities), financial (~6 B$), political with a worldwide machine (LHC different, ~ITER ?) OCDE, ESFRI
- ILC and CLIC projects intend to address these problems
- Present uncertainties justify an open scenario
- However ILC is ready to go while it will take longer to complete the CLIC project

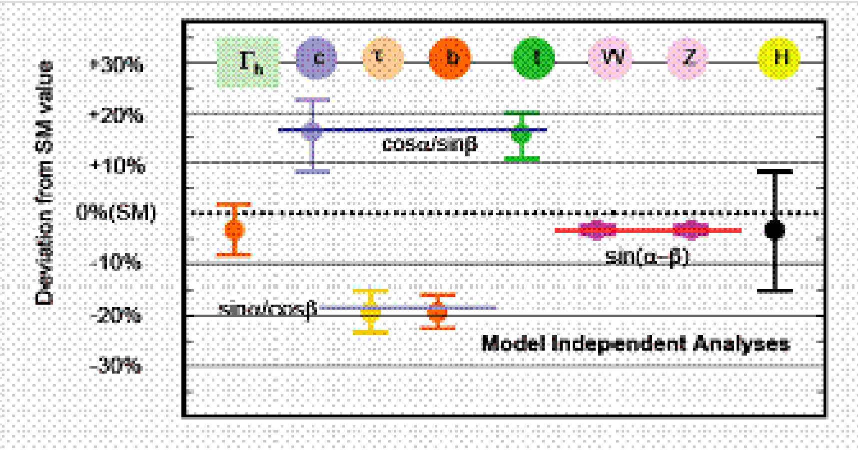
In conclusion

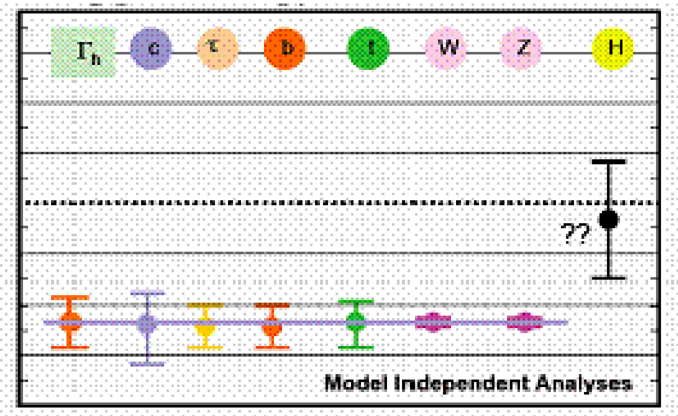
- The HEP community has developped a consistent and worldwide strategy to construct an e+e- LC
- A viable project, ILC, can be presented to the governments end of 2012
- There are encouraging initiatives from Japan and CERN
- A final decision (ILC/CLIC) will depend on the physics results from LHC (or Tevatron)

Why so precise ?

Deviations from SM

(By S. Yamashita)



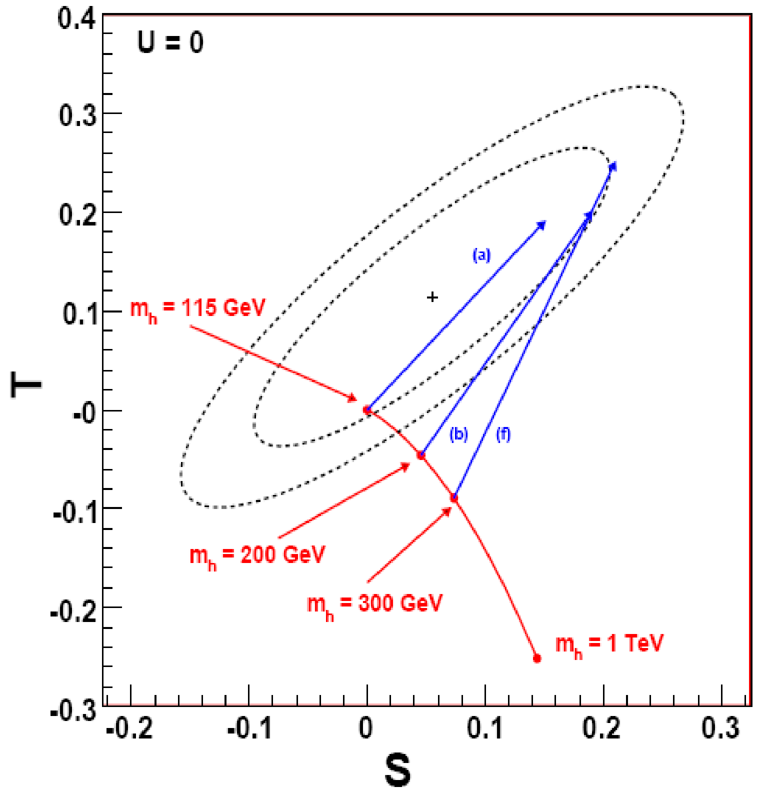


SUSY
(2 Higgs Doublet Model)

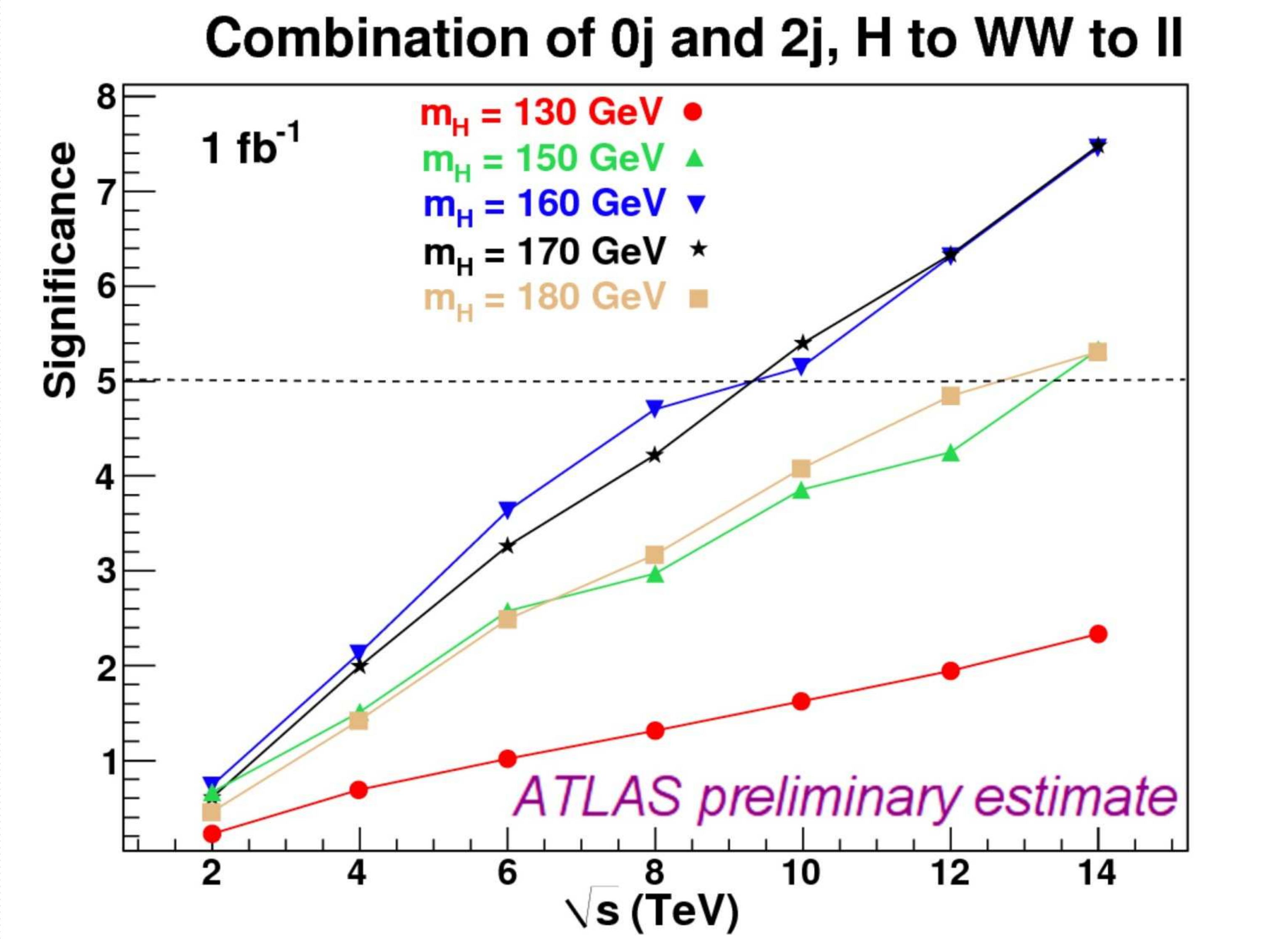
Extra dimension
(Higgs-radion mixing)

An example of 'conspiracy'

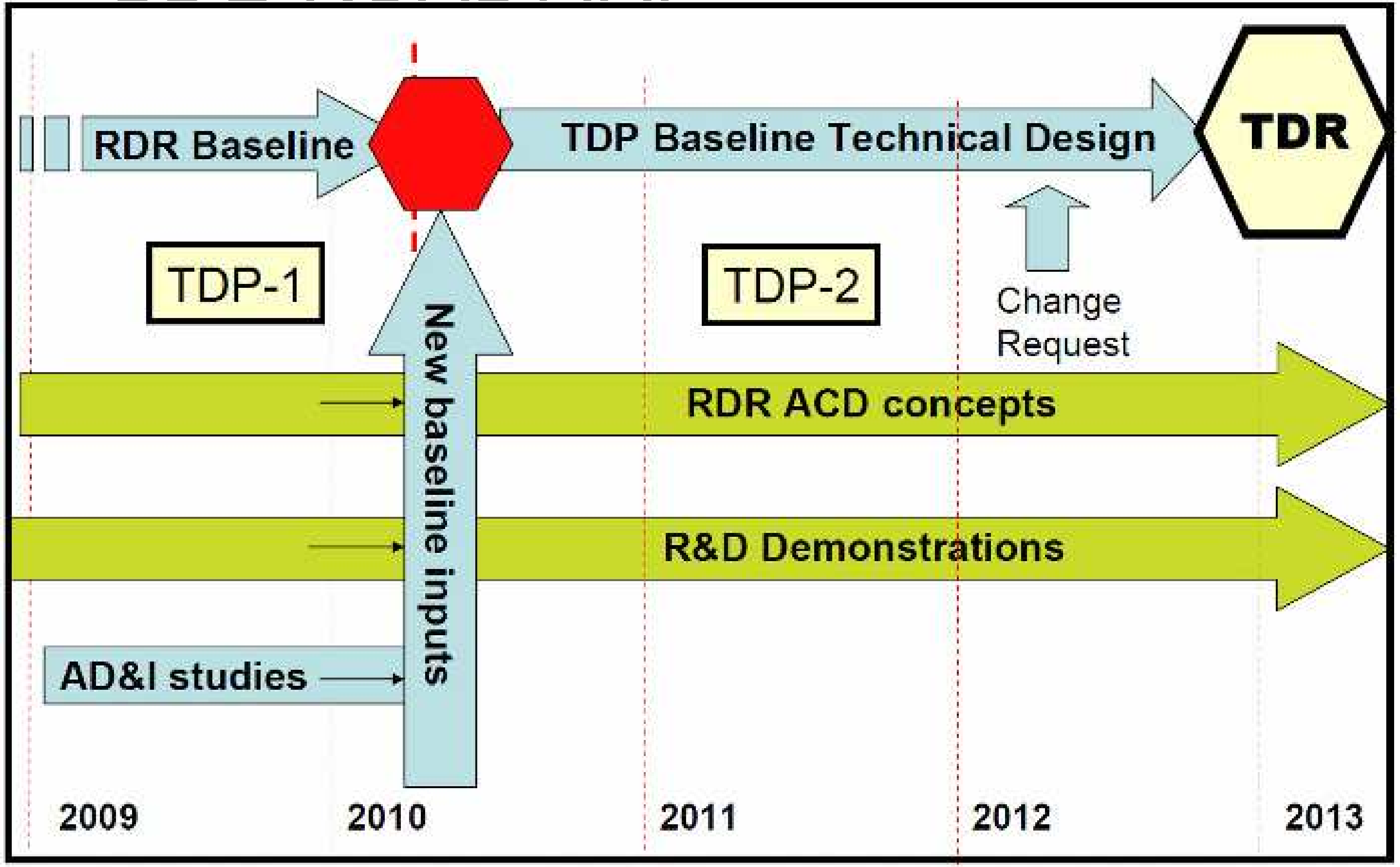
parameter set	m_{u_4}	m_{d_4}	m_H	$\Delta S_{\rm tot}$	$\Delta T_{\rm tot}$
(a)	310	260	115	0.15	0.19
(b)	320	260	200	0.19	0.20
(c)	330	260	300	0.21	0.22
(d)	400	350	115	0.15	0.19
(e)	400	340	200	0.19	0.20
(f)	400	325	300	0.21	0.25



- G. Kribs et al
  http://arxiv.org/abs/0706.3718v
- Heavy Higgs allowed


Combination of 0j and 2j, H to WW to ll
Significance
1 fb-1
mH = 130 GeV
mH = 150 GeV
mH = 160 GeV
mH = 170 GeV
mH = 180 GeV
ATLAS preliminary estimate
√s (TeV)

GDE ROADMAP


RDR Baseline
TDP Baseline Technical Design
TDR
TDP-1
TDP-2
Change Request
New baseline inputs
RDR ACD concepts
R&D Demonstrations
AD&I studies
2009
2010
2011
2012
2013

CLIC 3 TeV main parameters

Center-of-mass energy	CLIC conserv.	CLIC Nominal
Total (Peak 1%) luminosity	$1.5(0.73)10^{34}$	$5.9(2.0)\cdot10^{34}$
Repetition rate (Hz)	50	
Loaded accel. gradient MV/m	100	
Main linac RF frequency GHz	12 (NC)	
Bunch charge10^9	3.72	
Bunch separation ns	0.5	
Beam pulse duration (ns)	156	
Beam power/linac (MWatts)	14	
Hor./vert. norm. emitt ($10^{-6}/10^{-9}$)	3 / 40	2.4 / 25
Hor/Vert FF focusing (mm)	10/0.4	8/0.1
Hor./vert. IP beam size (nm)	83 / 2.0	40 / 1.0
Soft Hadronic event at IP	0.57	2.7
Coherent pairs/crossing at IP	$5\ 10^7$	$3.8\ 10^8$
BDS length (km)	2.75	
Total site length (km)	48.3	
Wall plug to beam transfer eff.	6.8%	
Total power consumption (MW)	415	

LC 500 GeV Main parameters

Center-of-mass energy	ILC	CLIC Conserv.	CLIC Nominal
Total (Peak 1%) luminosity	$2.0(1.5)\cdot10^{34}$	$0.9(0.6)\cdot10^{34}$	$2.3(1.4)\cdot10^{34}$
Repetition rate (Hz)	5	50	
Loaded accel. gradient MV/m	33.5	80	
Main linac RF frequency GHz	1.3 (SC)	12 (NC)	
Bunch charge10^9	20	6.8	
Bunch separation ns	176	0.5	
Beam pulse duration (ns)	1000	177	
Beam power/linac (MWatts)	10.2	4.9	
Hor./vert. norm. emitt ($10^{-6}/10^{-9}$)	10/40	3 / 40	2.4 / 25
Hor/Vert FF focusing (mm)	20/0.4	10/0.4	8/0.1
Hor./vert. IP beam size (nm)	640/5.7	248 / 5.7	202/ 2.3
Soft Hadronic event at IP	0.12	0.07	0.19
Coherent pairs/crossing at IP	10?	10	100
BDS length (km)	2.23 (1 TeV)	1.87	
Total site length (km)	31	13.0	
Wall plug to beam transfer eff.	9.4%	7.5%	
Total power consumption MW	216	129.4	