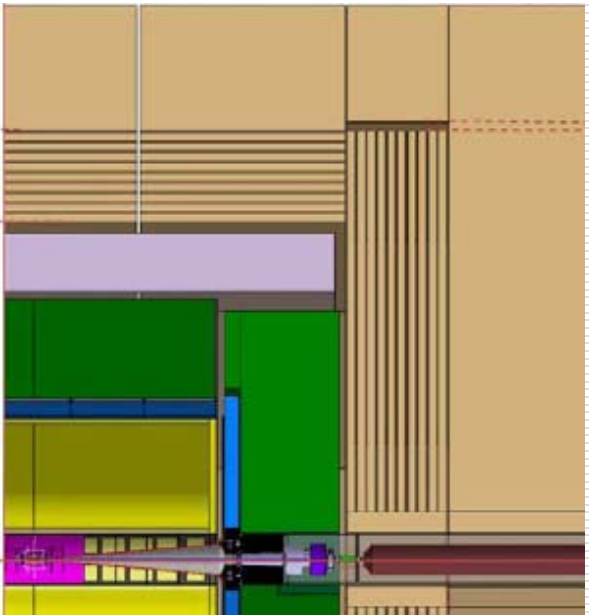
international linear collider

A global project for the future linear collider

LC10 at Frascati

BRUNO TOUSCHEK memorial lectures

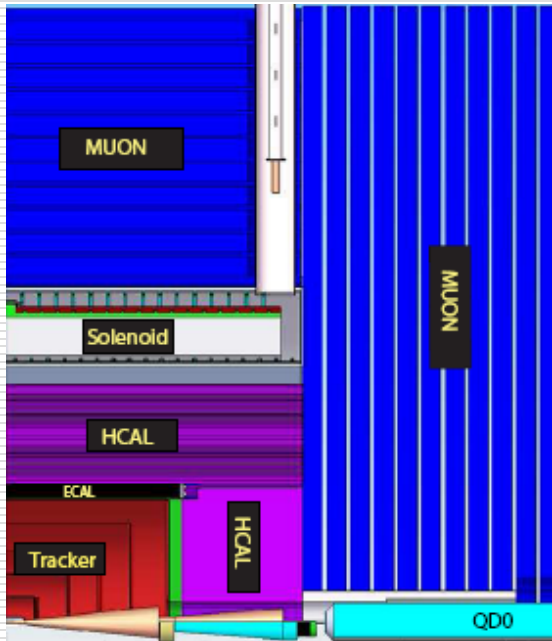
F. Richard
LAL/Orsay



ECFA Study

Physics and Detectors for a Linear Collider

F. Richard 30/11/10



Outline

- Introduction
- IWLC2010, a CLIC-ILC workshop at CERN
- The physics case for a LC
- Expectations from LHC/Tevatron
- Progress on detectors
- Progress on LC technology
- What can happen in 2012 ?
- Conclusions

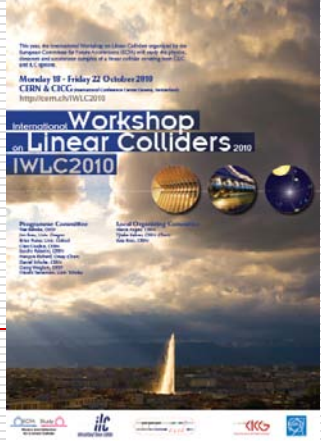
Introduction (1)

- So far ILC has been the global project elected by an international panel for the future LC, which means a project supported by ICFA and monitored by ILCSC
- At the same time CERN has developed an R&D to go beyond 1 TeV with the CLIC project
- In the US, mainly at FNAL, there is a revival of μ-coll studies also aiming energies beyond 1 TeV
- The recent strategy of ILC, encouraged by CERN management, has been to develop a tight collaboration between CLIC and ILC
- IWLC2010, the LC workshop under ECFA, is based on this collaboration
- What is the rational behind this move?

Introduction (2)

- Firstly, the lack of resources requires avoiding duplication of efforts when possible
- Many collaborations on the machine and on detectors (almost identical !) were identified
- The two projects remain in competition but it is well understood that this competition is collaborative
- We can work together in defending an international LC as the next HEP machine
- The final choice should not be based on politics but on physics (keeping in mind technological limitations), in particular LHC results
- At IWLC2010, in his introduction, the CERN DG has strongly encouraged this European approach

The CLIC-ILC workshop



- ~500 attendants ¼ from CERN, ¼ non Europeans
- Active participation of the LC partners: theorists, GDE, CLIC, SiD, ILD, R&D collaborations on detectors
- The plenary and parallel sessions were organized in common by ILC+CLIC representatives (will be the case for LCWS2011 planned in Granada in September 2011)
- The CLIC CDR on detectors, planned for 2011, receives full support from SiD and ILD (>50% of the editors)
- Quoting R. Heuer at LCWS10: **experimental results will be dictating the agenda of the field**
- Therefore a plenary ECFA session organized by theorists on the topic: What can one say (or cannot say!) after a few fb-1 collected at LHC

Physics case for a LC

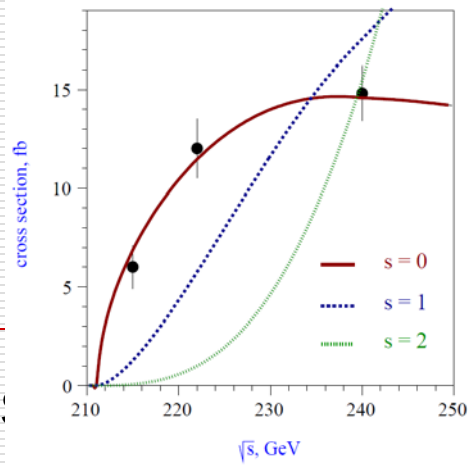
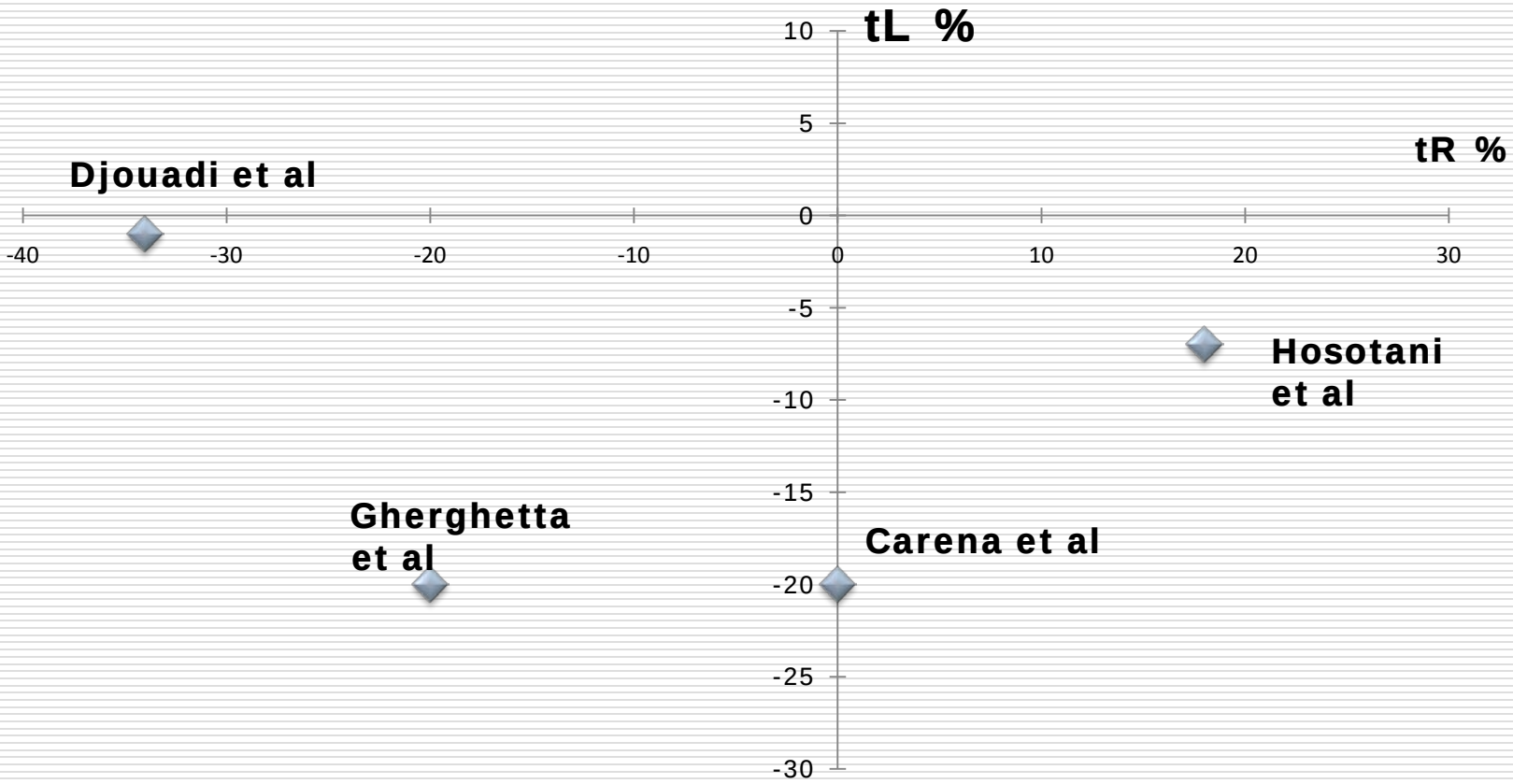


FIGURE 2. The cross sections determined at $\sqrt{s}$ = 215, 222 and 240 GeV (dots predictions for s=0 (full line), s=1 (dashed line) and s=2 (dotted line).

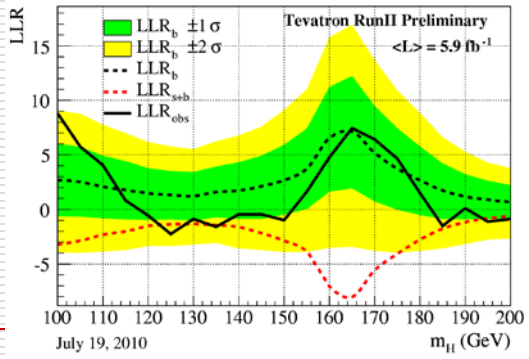
- Overwhelming with a light Higgs which is the SM/MS
- Top physics is a rising star for BSM models RS/Little /Compositeness which predict distinct anomalous couplings
- Many observables: σtot ALR AFB Pt, at the few per mill level allow to extract topL and topR couplings, CPV (dipole moment)
- ttH was revisited: ~10% accuracy on the top Yukawa coupling + CPV in the Higgs sector (threshold dependence)
- ZHH remains very challenging
- CLIC energy most probably needed to produce H/A and the squarks
- Both machines need to be able to perform scans from 200 GeV up to their maximum energy with good luminosity (L~E)
- Could be very time consuming in case of SUSY (Higgs, SUSY threshold scans) if L decreases faster than E

  -> challenging but feasible both for ILC and CLIC

Top anomalous couplings



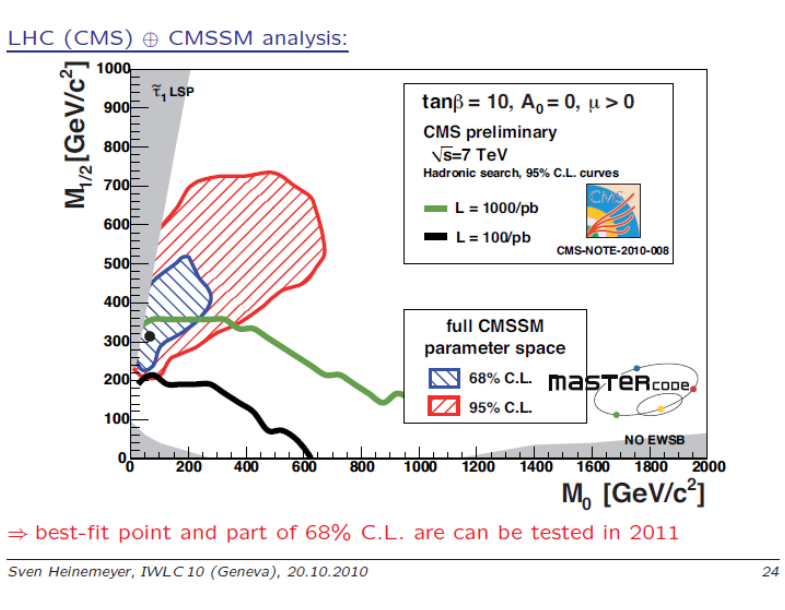
LHC or TeVatron inputs



- Tevatron -> qqbar collider producing HW HZ, giving a unique opportunity to observe (3 sd) or exclude a light Higgs in the near future
- Tevatron+LHC could cover a SM Higgs up to 500 GeV or allow a 3 sd effect for mH 125-500 GeV in 2012
- Present indications of an excess 120-140 GeV prevents exclusion of Tevatron at low masses
- LHC -> gluon-gluon collider already better than Tevatron for $\sqrt{s}$ >500 GeV with 50 pb-1 and therefore effective on gluinos, squarks or 4^{th} generation quarks (unitarity limit mQ<500 GeV)

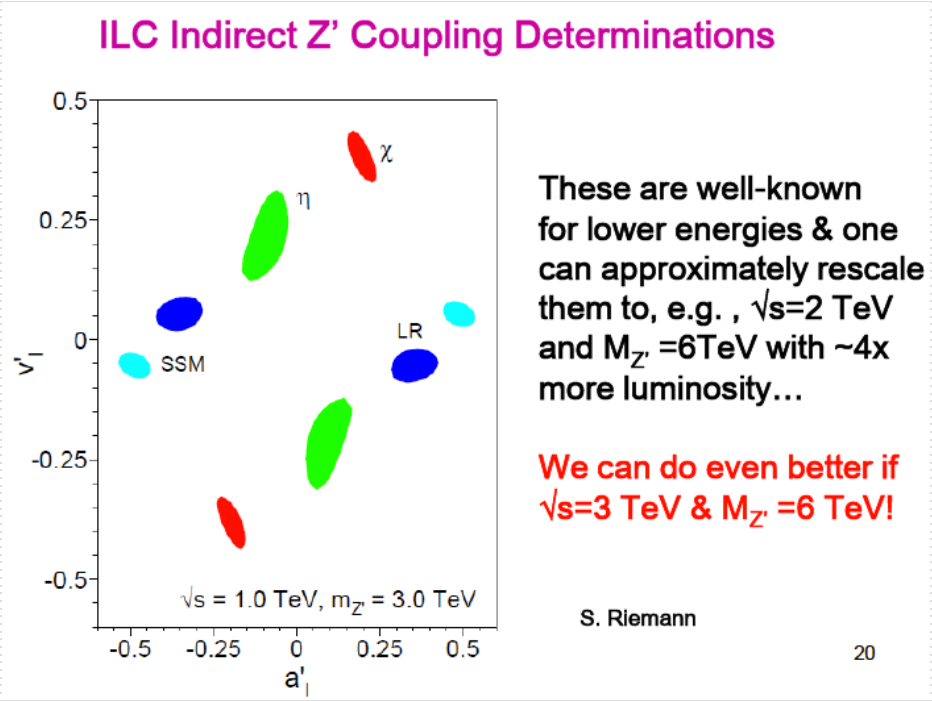
A light SUSY scenario

- Extension of SUSY domain by LHC ~800 GeV for colored particles providing a significant test of CMSSM
- CAVEAT: as pointed out by M. Peskin, non-observation of these particle cannot be translated in a model independent way into limits on gauginos and sleptons relevant for LC
- 3.6 sd on g-2 reported by M. Davier indicates that these particles could be light (~200 GeV for tanβ=10)



The Z' case

- What if we see a Z' at 1.5 TeV or above?
- Common prejudice is that we need to run on the pole
- It has been shown that with high luminosity and polarisation one can learn a great deal on Z' properties at lower energies



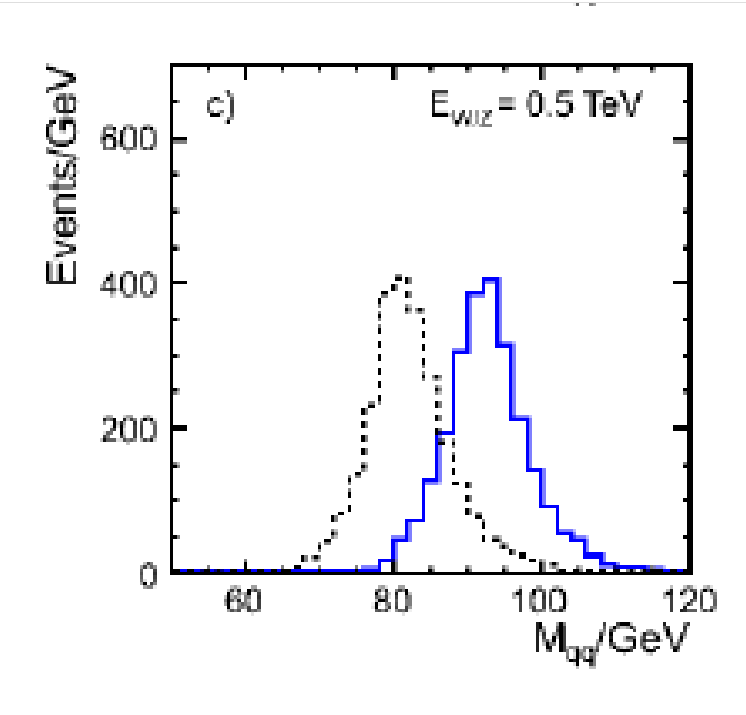
Recent achievements on LC Detectors

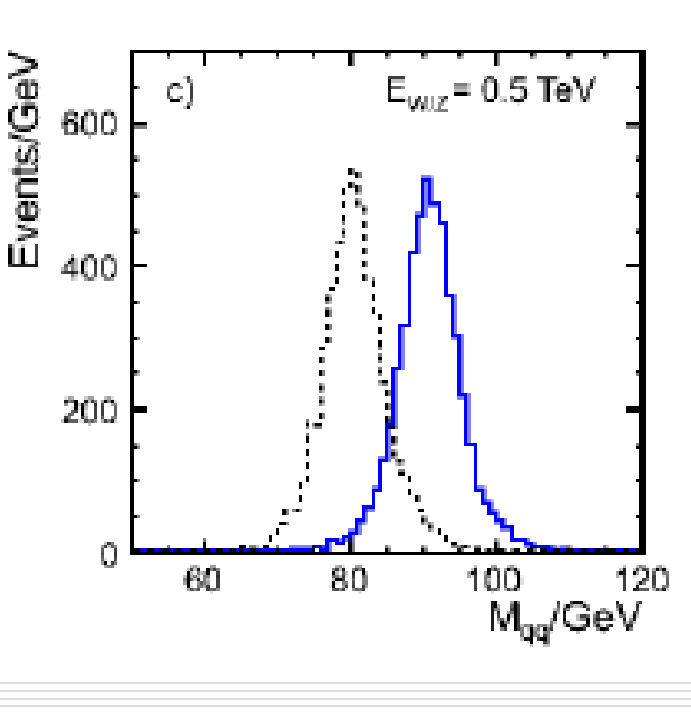
Worldwide Study of the Physics and Detectors for Future Linear $e^+ e^-$ Colliders

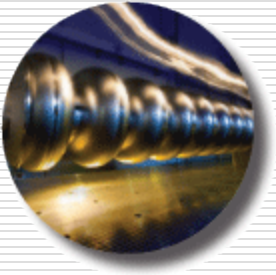
- ILD & SiD concepts developed for ILC can work for CLIC with added capabilities (larger dimensions + tungsten absorber)
- Push/pull scheme is developed for both projects
- PFLOW ideas are now experimentally proven by test beam data
- Improvements under the pressure of CLIC challenges: W/Z separation works up to 500 GeV
- Note that the R&D effort on LC detectors is common with CLIC (EU support with EUDET & AIDA) and has applications in other fields: LHC (3D Si), superB (DEPFET), RHIC mimosa chip for STAR, T2K µmegas TPC, medical applications…
- A Detailed Baseline Design should be ready end of 2012 in conjunction with the TDR of ILC

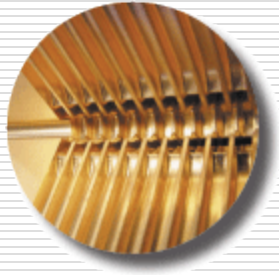
Pflow optimisation at HE

M. Thomson









LC Technology

- ILC will provide a TDR end of 2012
- Various R&D, the most critical is on gradient, with >50% cavities already passing 35 MV/m, while >90% should be reached in 2012
- Constant progress benefitting from a strong boost on SCRF technology: FLASH/XFEL in DESY, Jefferson lab, FNAL with project X, KeK
- First steps towards industrialization (eg Pilot Plant with Japanese industry at KeK)
- CLIC progress is impressive allowing to reach the proof of feasibility with a CDR in 2011
- CERN resources do not allow to set a firm date for a TDR

What happens beyond 2012 ?

- Quoting R. Heuer: 2012 could be a decisive year concerning LC (in time with update of European strategy)
- There is need for a global strategy
- Be ready to build on early discoveries by preparing a scenario allowing an early construction of a LC (nobody looses, CLIC would come after or become the predominant option depending on LHC results)
- CERN ready (new rules adopted by CERN council) to provide the needed support even if this construction is not within the lab
- ICFA/ILCSC has entered in an active phase to give a fully international framework for governance & siting

Possible scenario

- GDE replaced in 2012 by a Multinational Laboratory before a treaty based (~CERN) takes over
- This process would start in 2011
- ILCSC invites the community to read the existing document and provide suggestions
- http://cpdg.kek.jp (cpdg username & password)

Toward 2012 in ILCSC-6

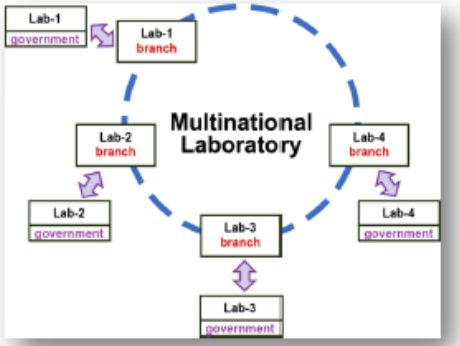
Top-Level Management (IL-1, GD-0)

B. Representative models for the ILC

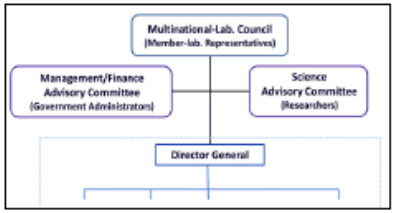
- Model 1: Treaty-based + mostly common-fund (CERN-like model) **working well, but taking a longer time for realization of treaty**
- Model 2: Limited-liability company + mixture of common-fund and in - kind contributions (XFEL-like model) **dual management structure**
- Model 3: Treaty-based + mostly in-kind contributions (ITER-like model)
- Model 4: Lab-agreement-based + mostly in-kind contributions **Pre-ILC Lab.** (Multinational Laboratory Model)
- Model 5: Evolutionary Model : Model 4 to Model 1, or 3

RFC focused on Model 3 and Model 4 for reasons of their nature of "Decentralization and Partnership : Globalization"

GDE governance document



- Each of world HEP-labs, which wishes to participate, sets up its branch within Multinational-Lab. These participating HEP-labs are called member-labs
- This Multinational-Lab is virtually built first in ICFA, and inside the host laboratory after the host-site selection
- The member-labs contribute in sharing the human and financial resources

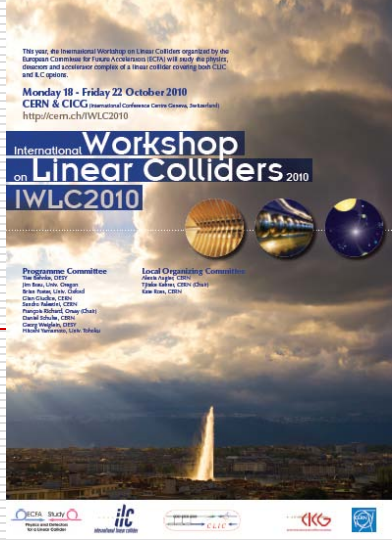


Conclusions

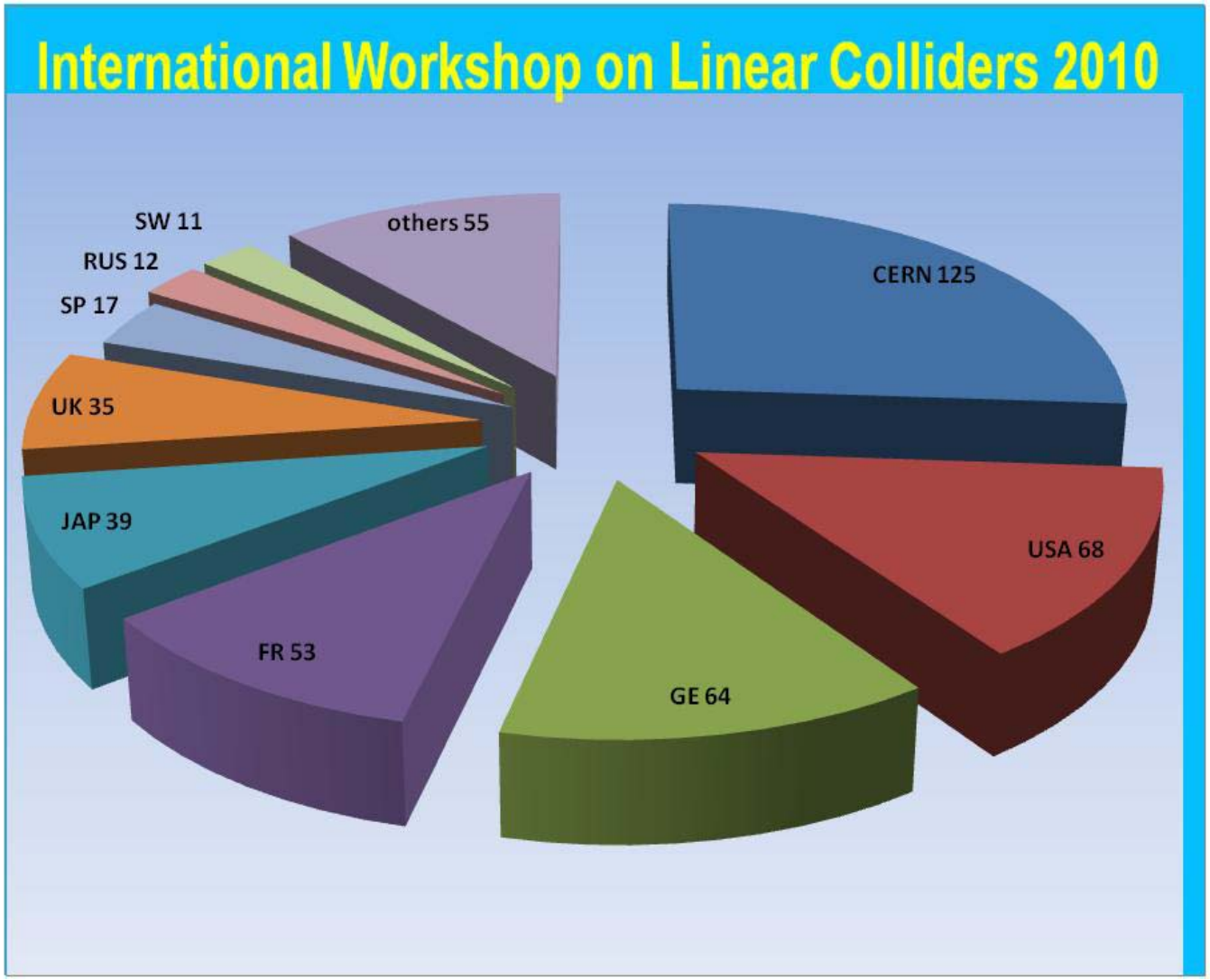
- IWLC2010 has given us the first opportunity to gather the LC effort, CLIC and ILC, in a unified way
- There is good progress on Machine and Detector components and there will be a CLIC CDR in 2011 and an ILC TDR+DBD in 2012
- LHC/Tevatron could provide significant inputs in 2012
- It is very important to prepare for an global organisation allowing an early decision on the future LC
- 2012 could be a decisive year concerning LC (in time with update of European strategy)

Back up slides

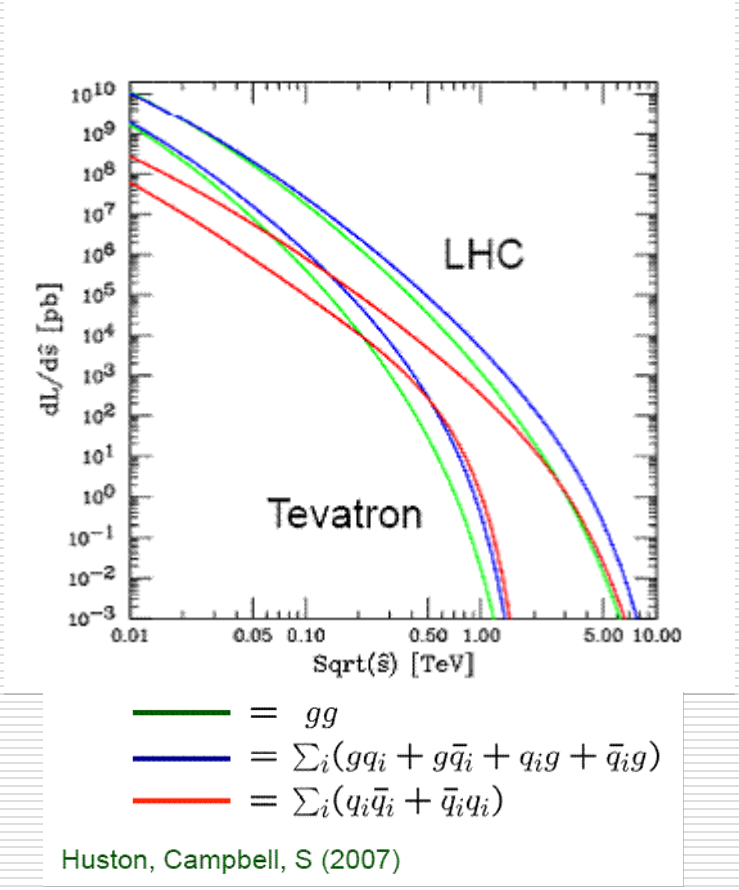
https://espace.cern.ch/LC2010/default.aspx

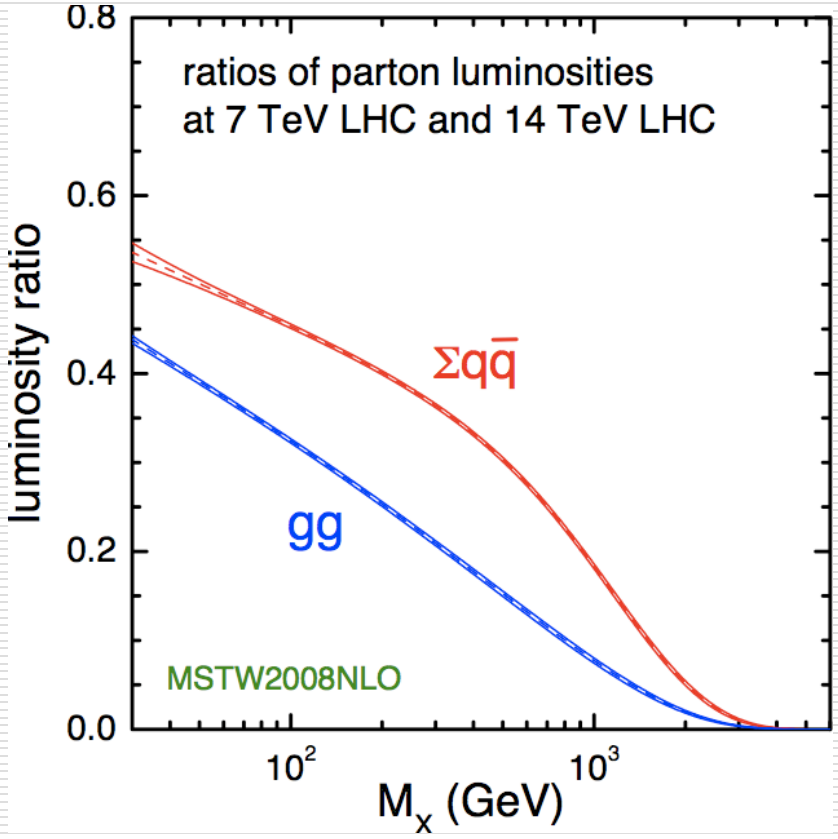


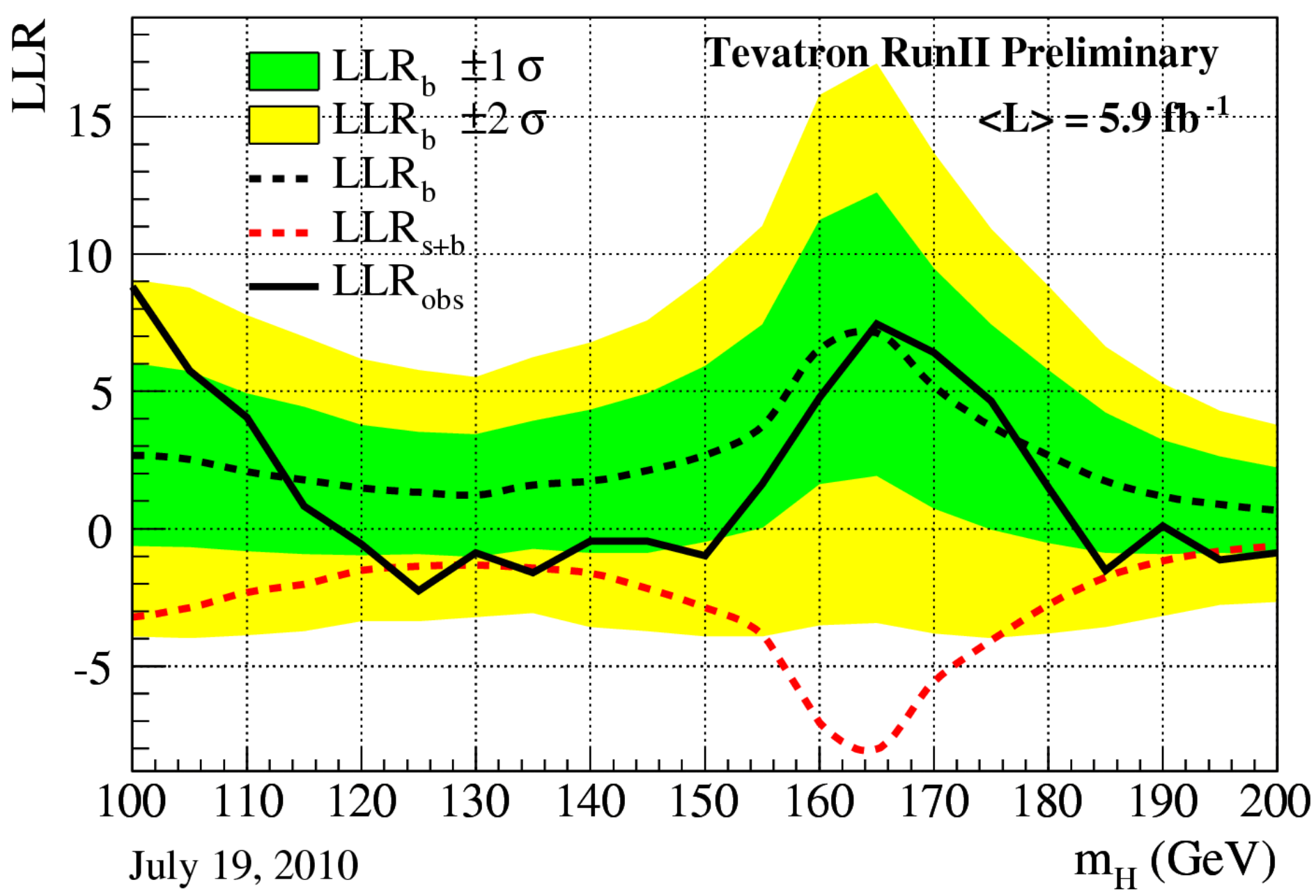
The attendance: 479



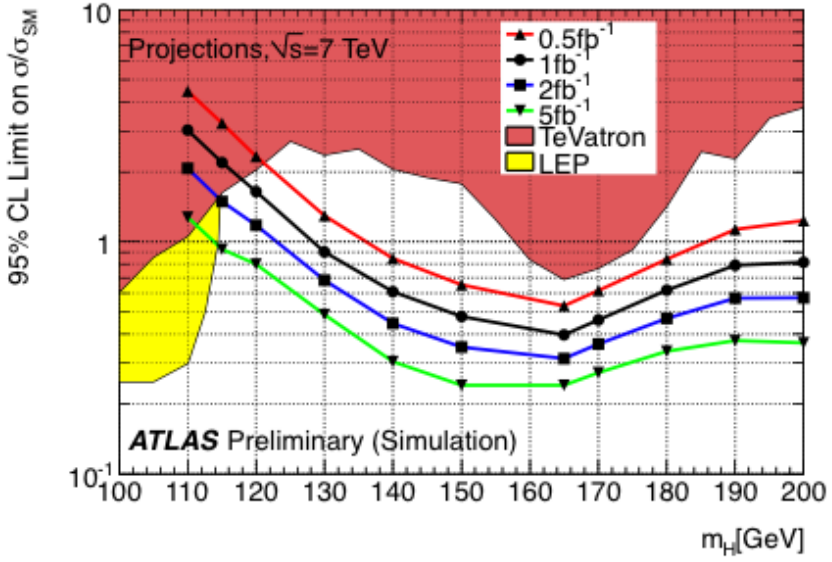
Differential luminosities

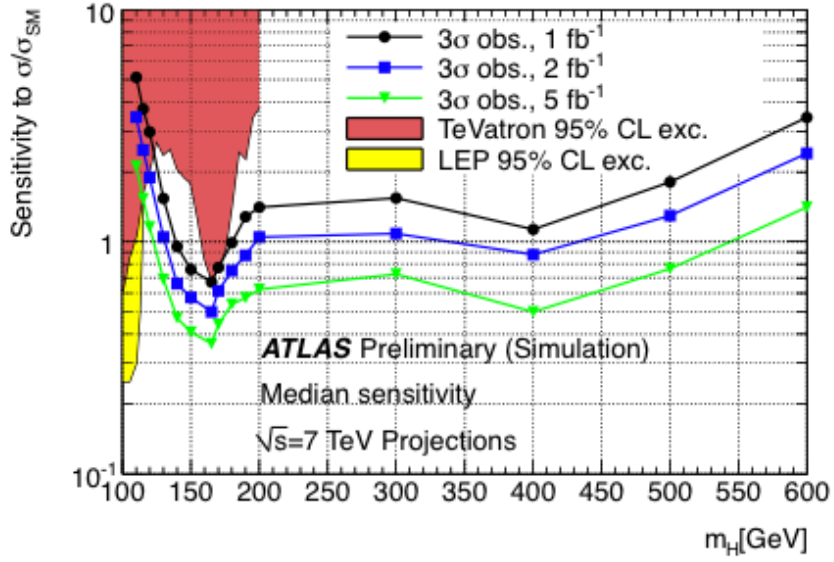


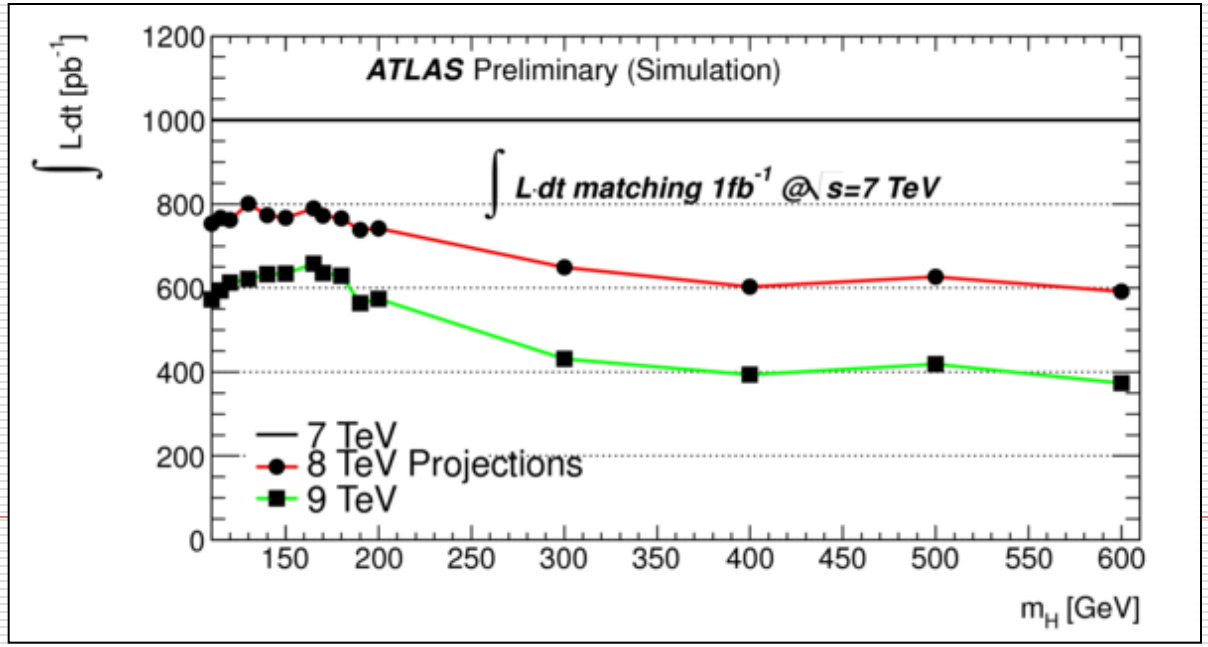



LLR
15
10
5
0
-5
LLR_b ±1 σ
LLR_b ±2 σ
LLR_b
LLR_s+b
LLR_obs
Tevatron RunII Preliminary
<L> = 5.9 fb^-1
100
110
120
130
140
150
160
170
180
190
200
July 19, 2010
m_H (GeV)

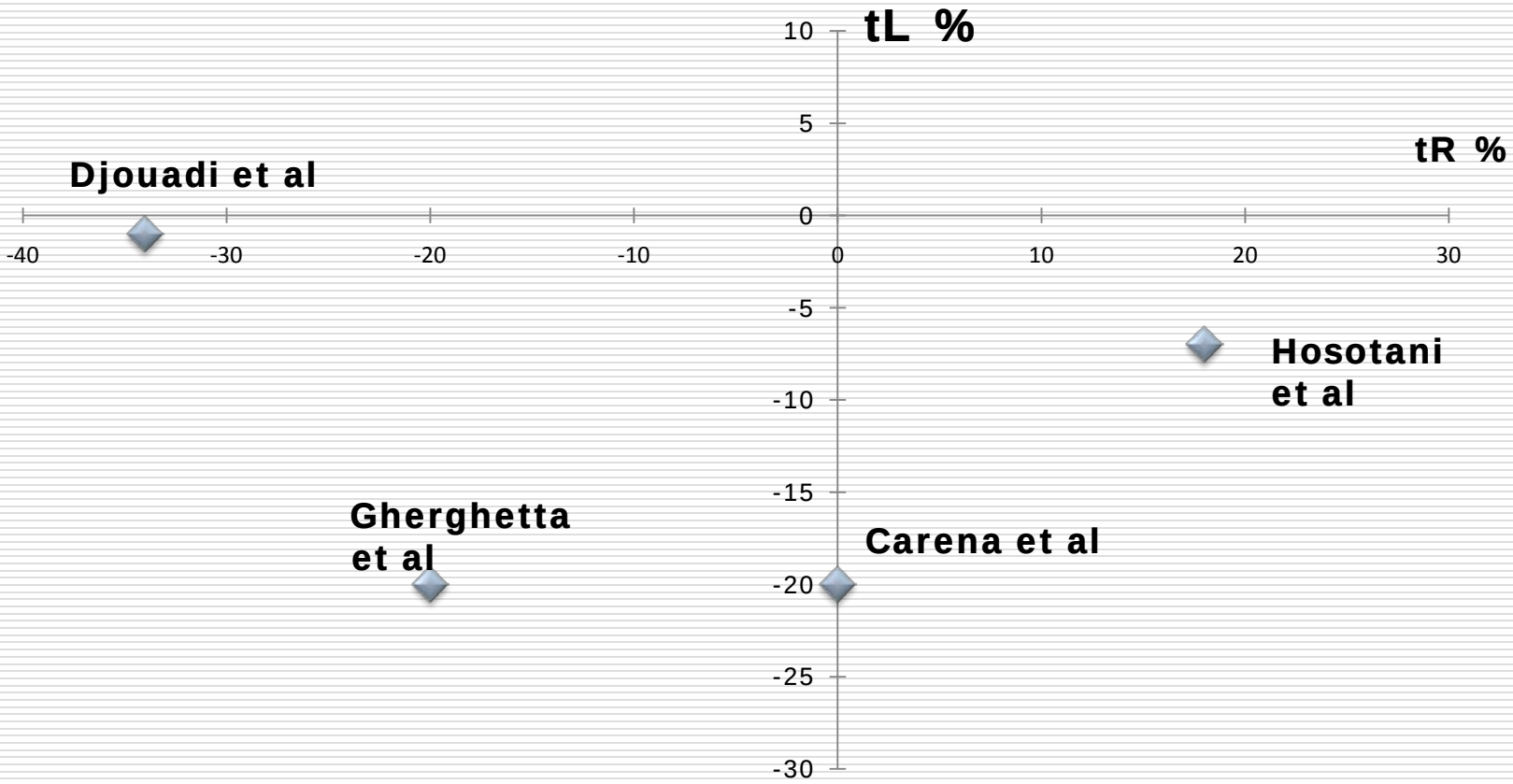
Higgs sensitivities







Top anomalous couplings



ttH and CPV

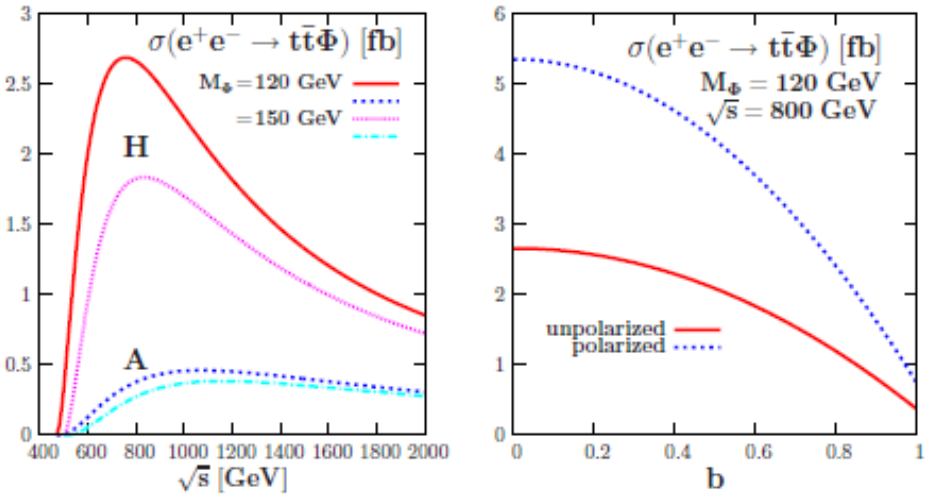


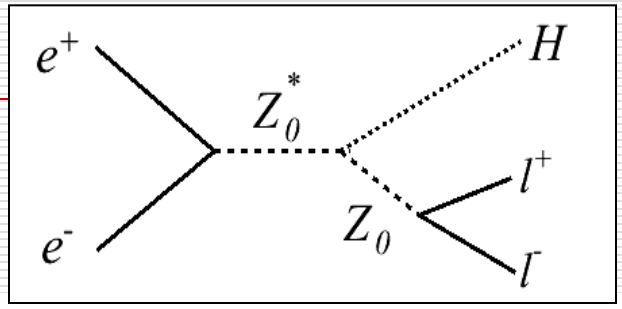
Figure 2: The production cross sections $\sigma(e^+e^- \to t\bar{t}\Phi)$ for a scalar and a pseudoscalar Higgs boson as a function of $\sqrt{s}$ for two masses $M_\Phi = 120$ and 150 GeV (left) and for unpolarized and polarized $e^\pm$ beams as a function of the parameter b at $\sqrt{s} = 800$ GeV with $M_\Phi = 120$ GeV (right).

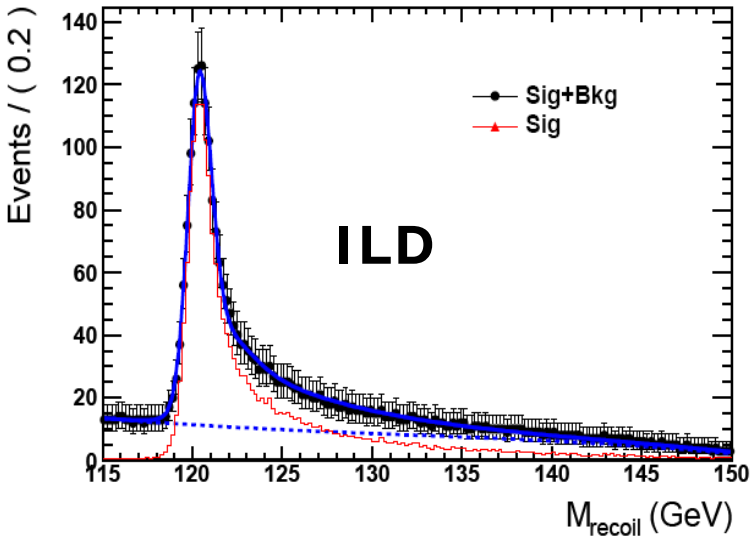
$$g_{\Phi tt} = -i\frac{e}{s_W}\frac{m_t}{2M_W}(a + ib\gamma_5)$$

R. Godbole et al
arXiv:0710.2669

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

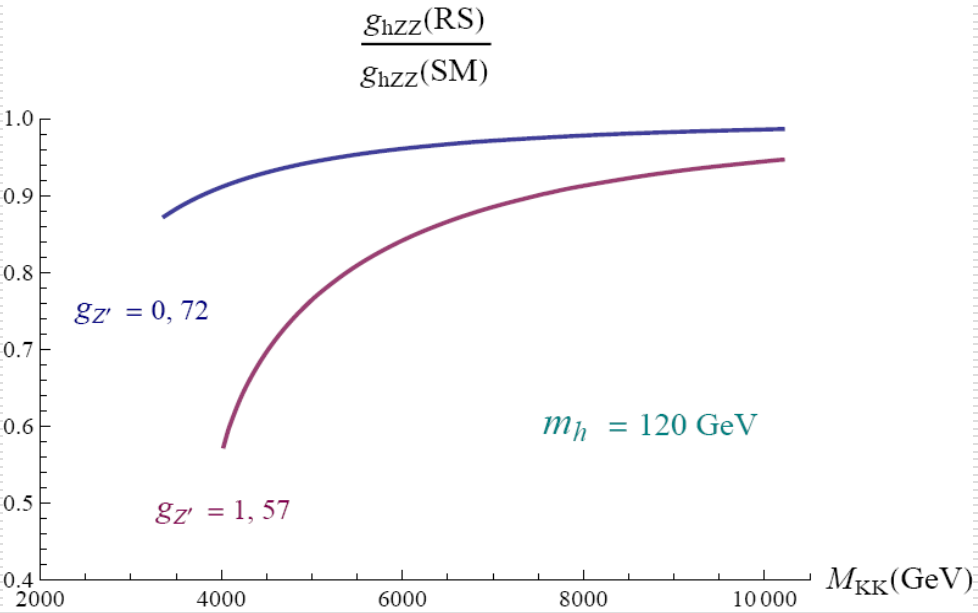




Full Simulation

Example on ZZH

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



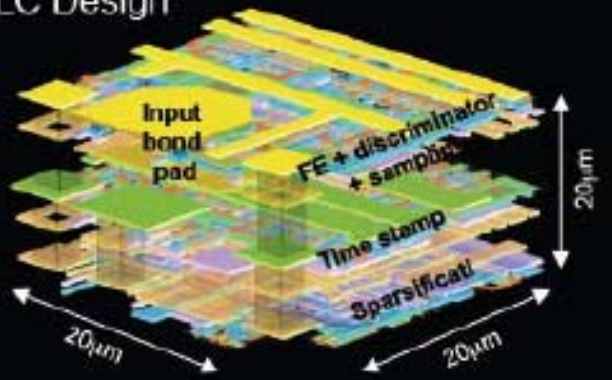
G. Moreau C. Bouchart
LPT-ORSAY-09-70

Giudice et al.
JHEP 0706:045,2007.

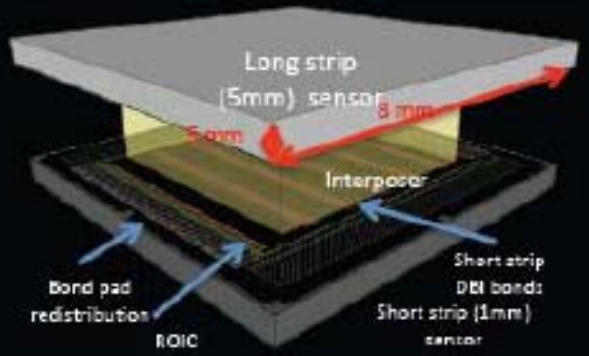
Benefits of ILC Detector Program

- The development of new technologies and the implementation in prototype detectors has been very beneficial to the community at large
  - 3D Silicon

ILC Design



LHC Upgrade

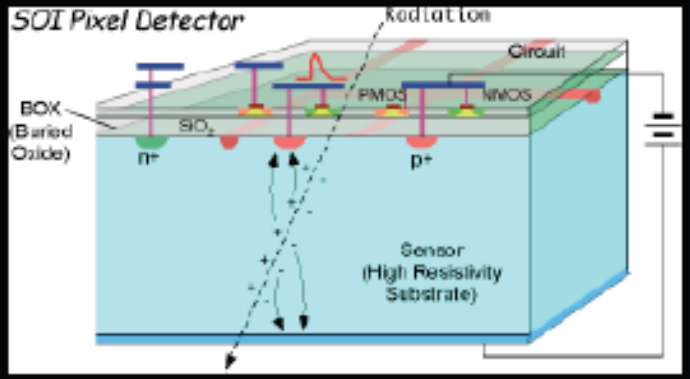


  - Micromegas TPC

T2K TPC

Benefits of ILC Detector Program

- Silicon On Insulator started as purely ILC driven technology

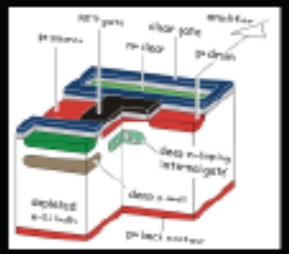


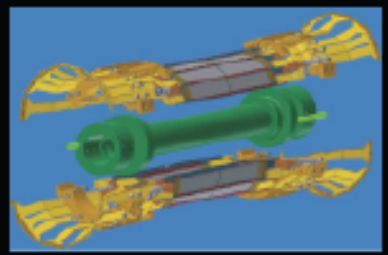
X-ray detection with femtosecond timing (LBNL)

- Mimosa Pixel Chip

Beam test telescope at DESY and CERN

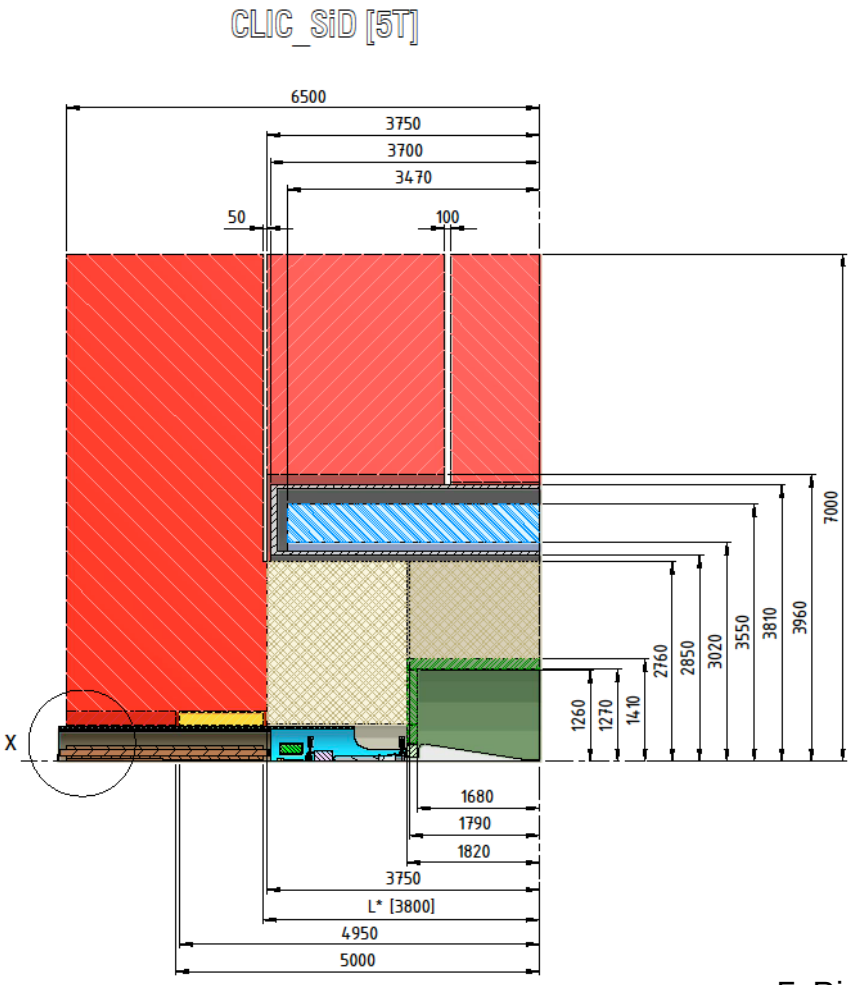
- DEPFET

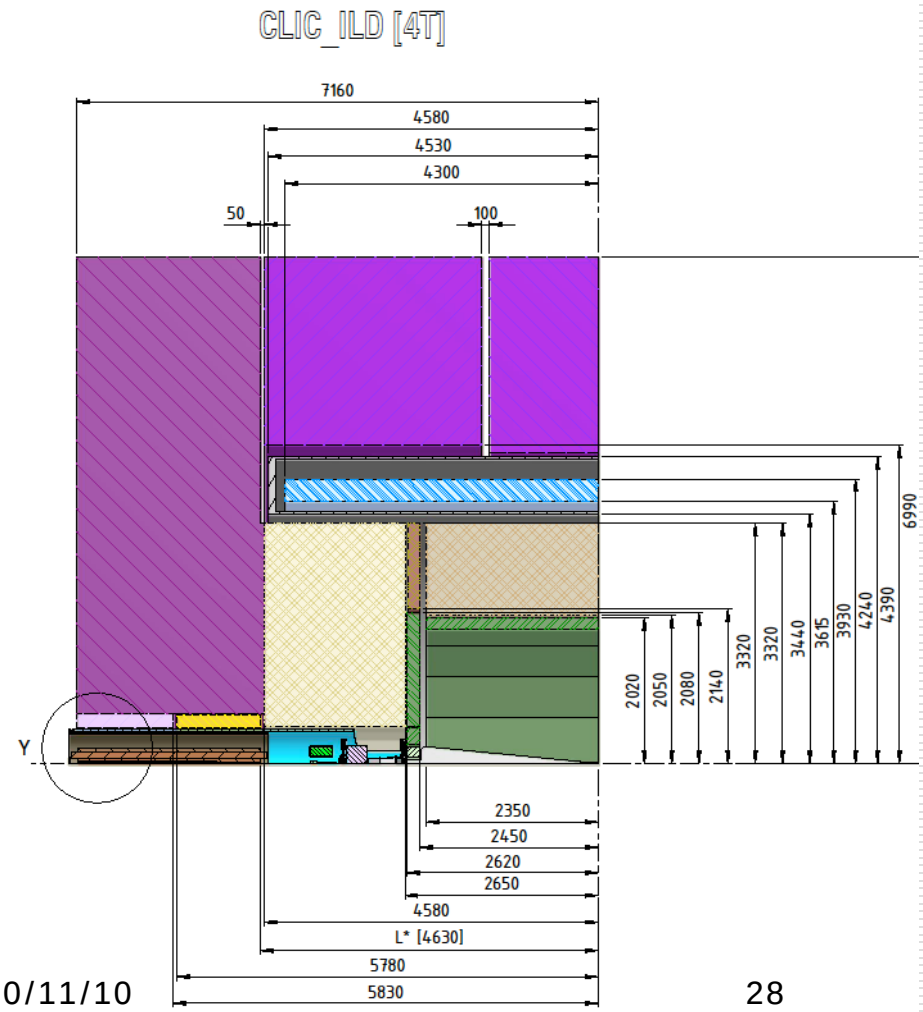




Belle

SiD' & ILD'


CLIC_SiD [5T]
6500
3750
3700
3470
50
100
7000
3960
3810
3550
3020
2850
2760
1410
1270
1260
X
1680
1790
1820
3750
L* [3800]
4950
5000


CLIC_ILD [4T]
7160
4580
4530
4300
50
100
6990
4390
4240
3930
3615
3440
3320
3320
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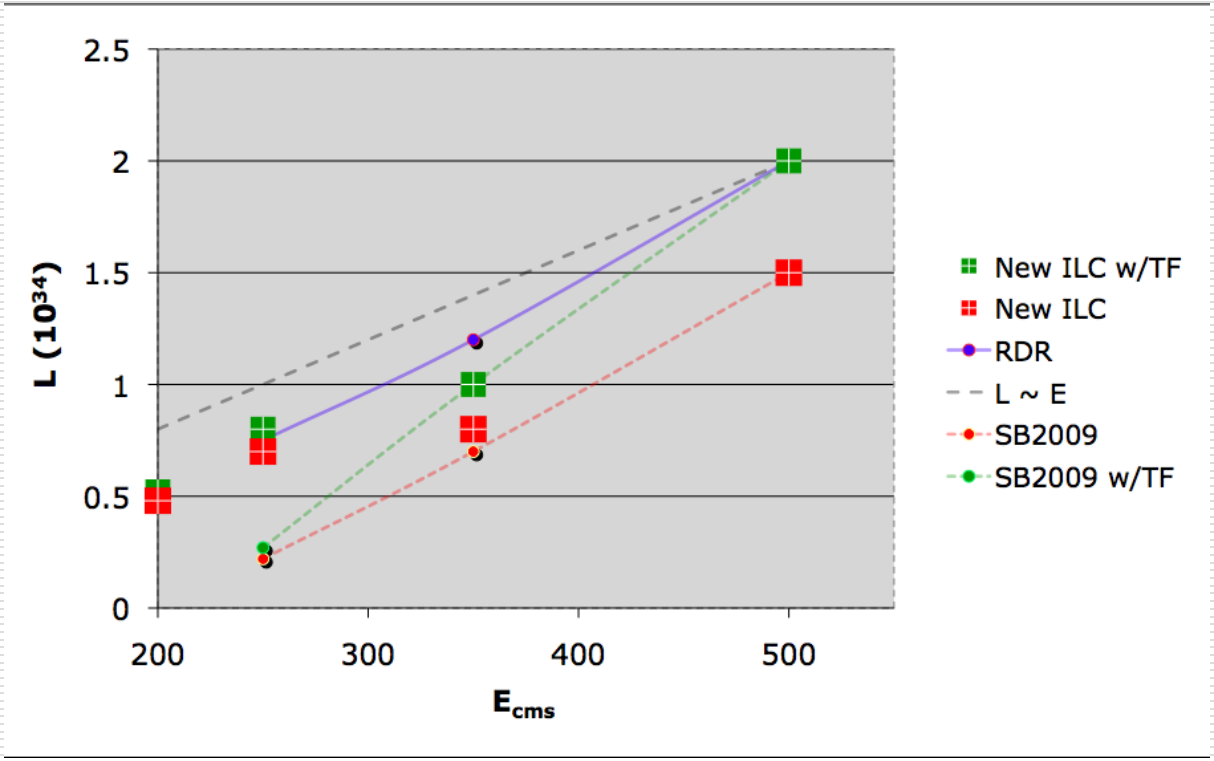
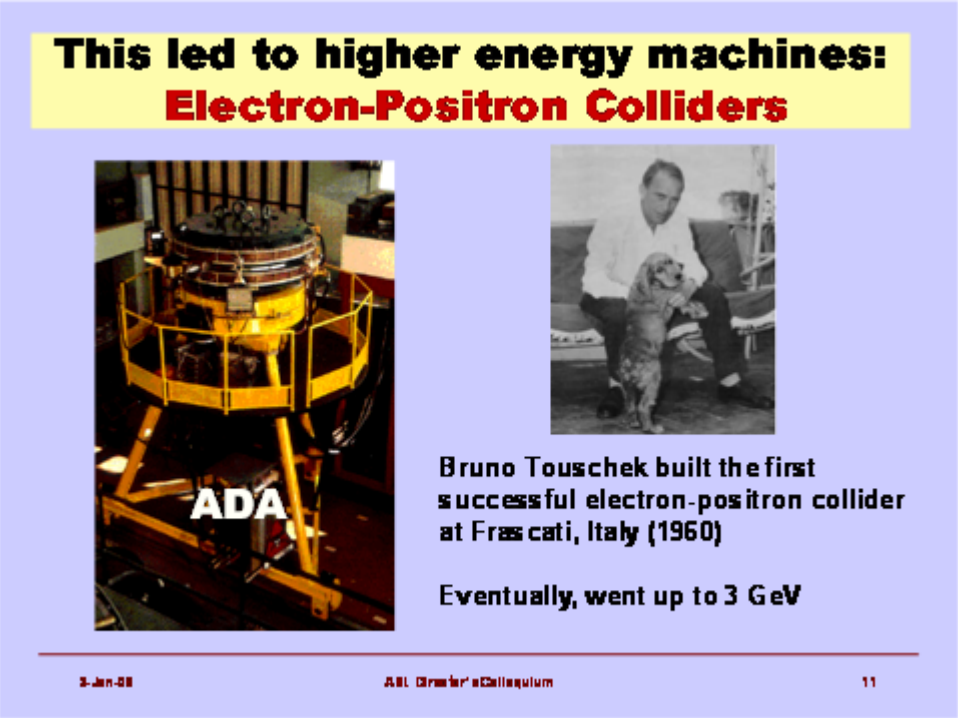
2620
2650
4580
L* [4630]
5780
5830

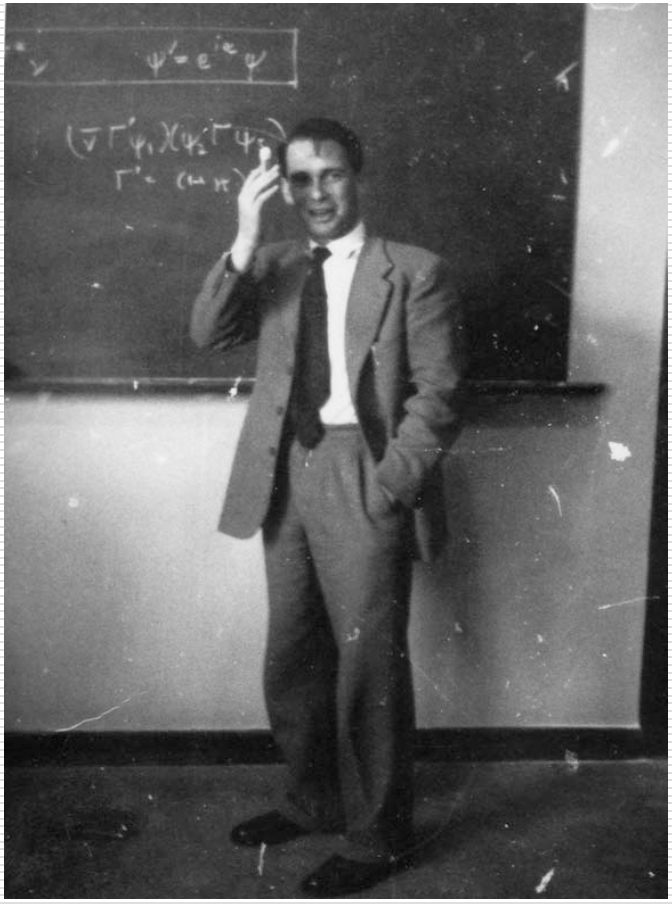

2.5
2
1.5
1
0.5
0
L (10³⁴)
200
300
400
500
E_cms
New ILC w/TF
New ILC
RDR
L ~ E
SB2009
SB2009 w/TF

Remembering Bruno Touschek

- An inspiration to the LC (B. Barish at ANL)



A friend of LAL/Orsay



How to understand RC in e+e-

- I gratefully remember a seminal paper where using a beautiful classical analogy they allow us to understand us intuitively RC, the exponentiation which removes low k divergence

[75] E. Etim, G. Pancheri, and B. Touscheck, "The Infra-Red Radiative Corrections for Colliding Beam (Electrons and Positrons) Experiments", *Nuovo Cimento* 51B (1967) 276.

- Provides a probabilistic interpretation of RC

$$\frac{dP}{du\,d\cos\theta} = u^{b-1} F(\cos\theta_\gamma) \quad b = \int F(\cos\theta_\gamma)\, d\cos\theta_\gamma$$

$$u = \frac{k_\gamma}{E_e} \quad F(\cos\theta_\gamma) = \frac{2\alpha}{\pi} \frac{\sin^2\theta}{(1-\beta_e^2\cos^2\theta_\gamma)^2}$$

- b~.007 at ACO and DAFNE, was called the Bond factor…
- Many applications (neutrino counting using ISR at angle with b'~0.1b, Breit-Wigner modification $\sim(\Gamma/M)^b$, auto-scan…)

Fabulous progress since ADA/ACO

- Determination of Φ properties in 1968 (!) with ~150 evts at ACO
- Now more than one billion Φ (GigaPhi)
- ISR used in DAFNE and Babar for auto-scan to produce very precise determination for σ(ee->had) between threshold and nominal energy
- This gives precise inputs for g-2 and α(Mz)
- Using these inputs one could conceive a 'GigaZ' factory measuring $\sin^2\theta w$ to ± 0.000013

Sense of humour…

- When it came to the designation of the Director of LAL, with an increasing risk for me, I had constantly in mind his cartoon: